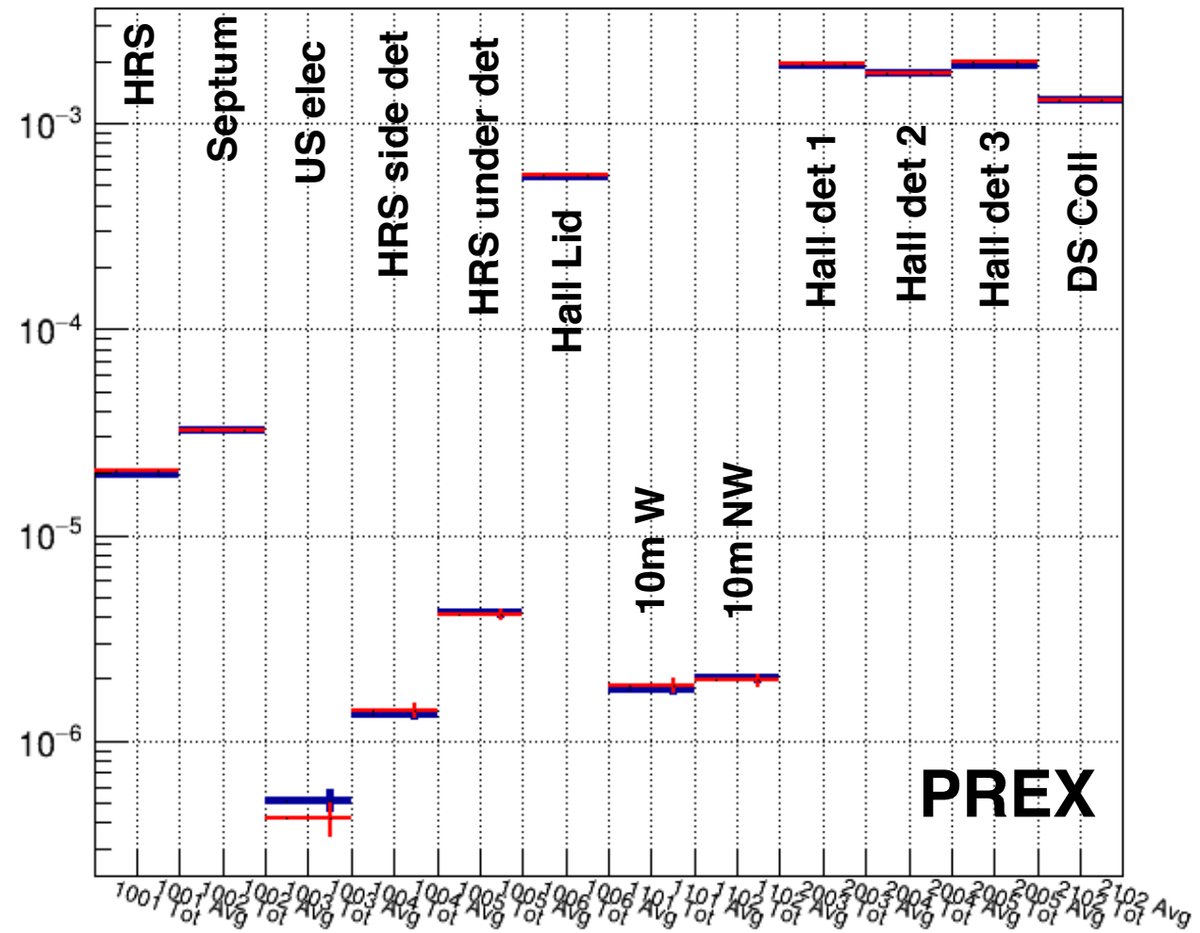
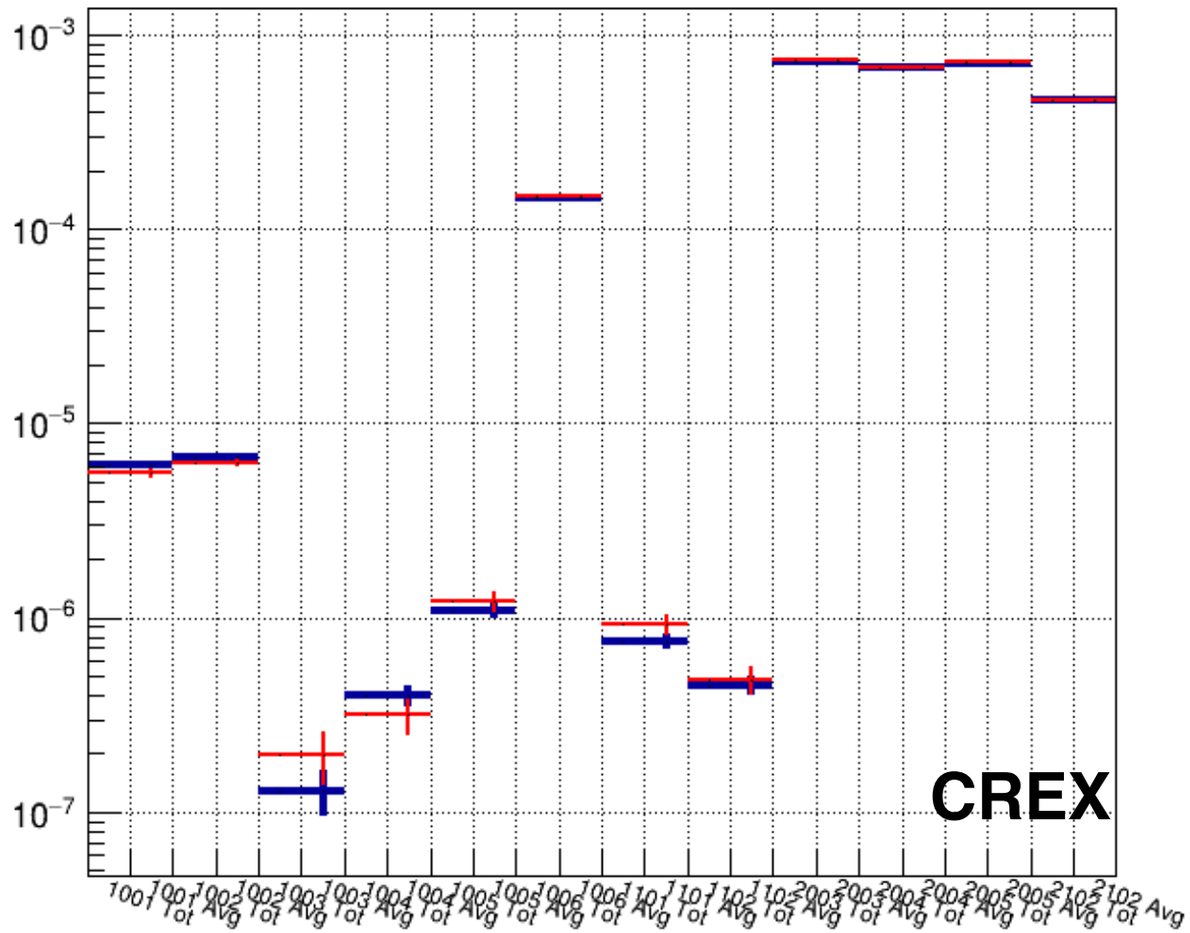
PREX Dump configuration

Ciprian Gal
UVa

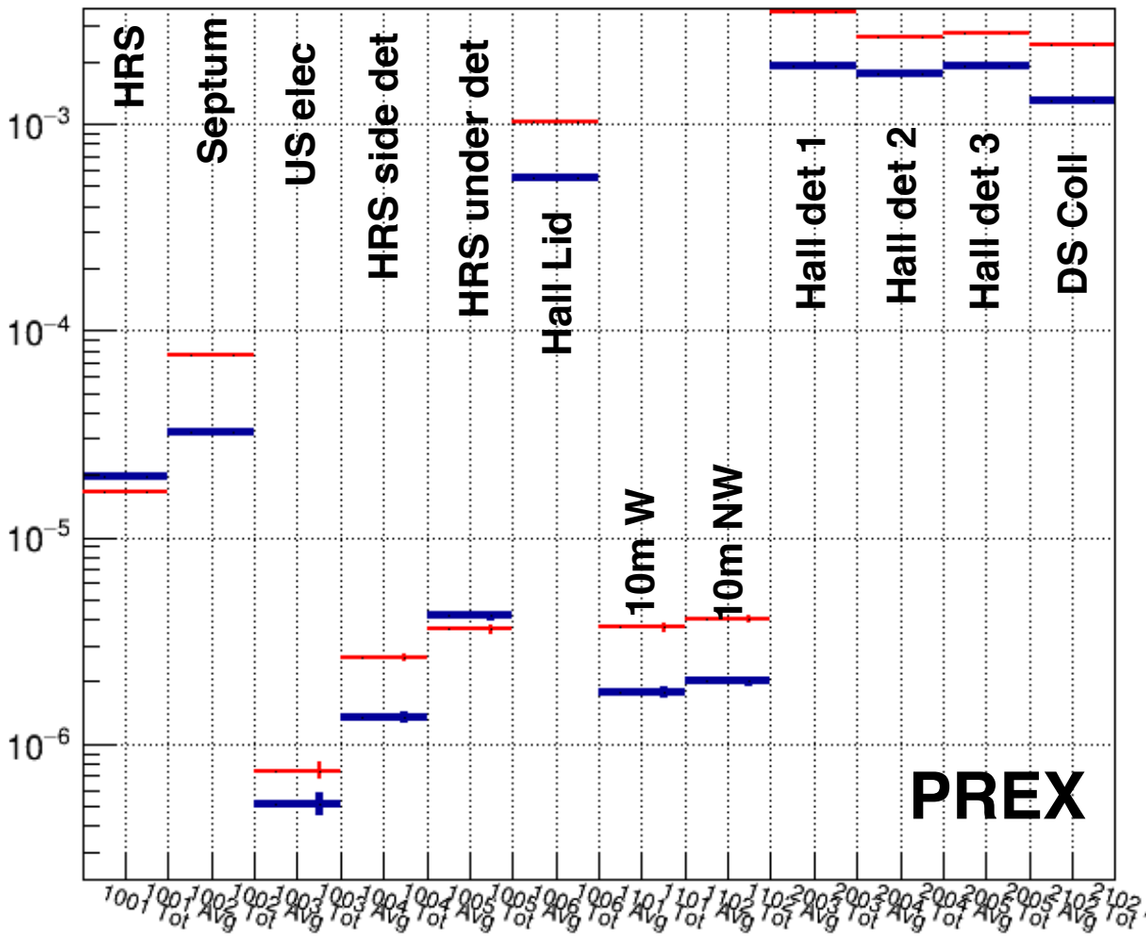
Larger Hall

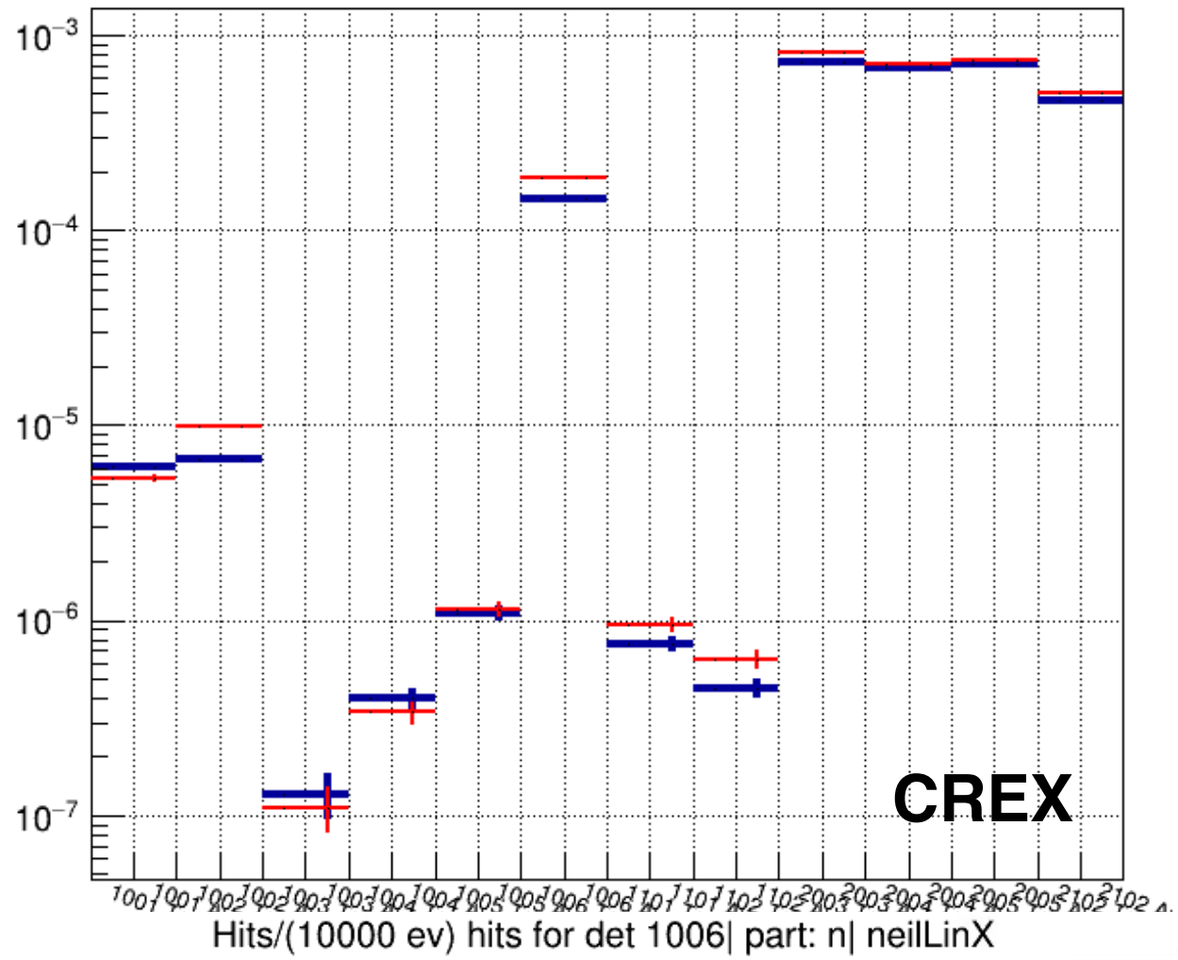




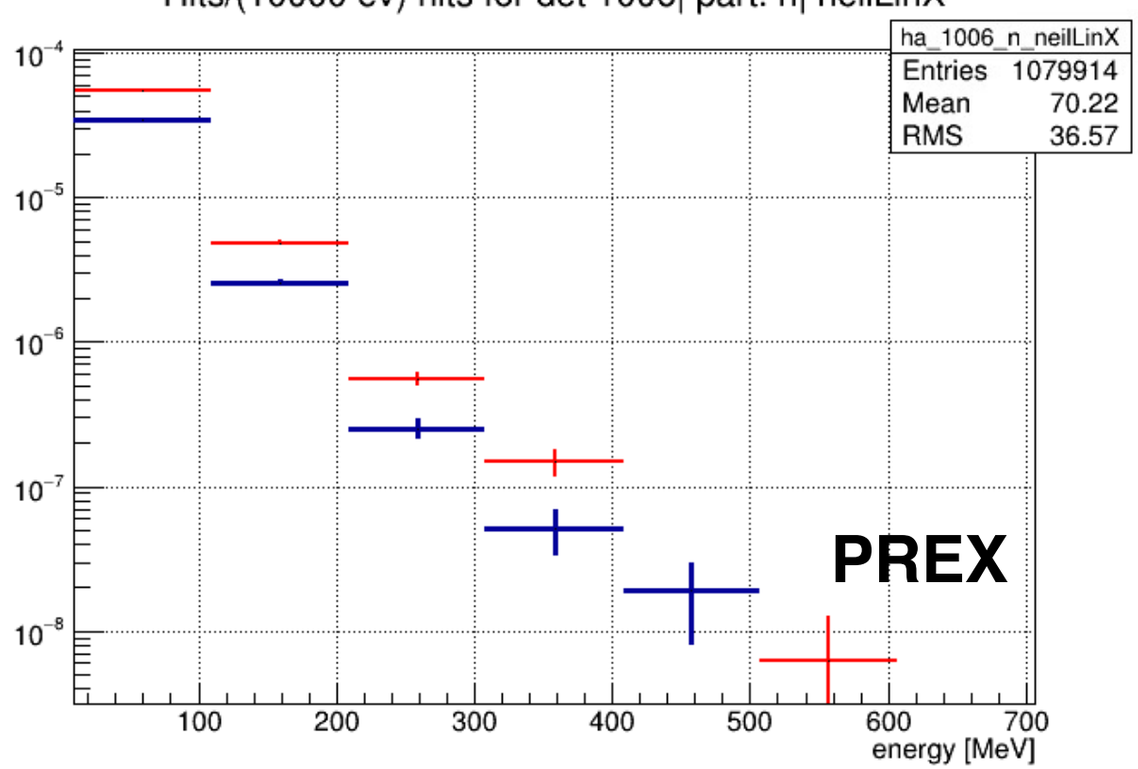
- Current in blue, comparison in red (updated with HRS platform)
- The change in the radius of the hall does not seem to produce significant differences

Tighter collimator (neck Down)

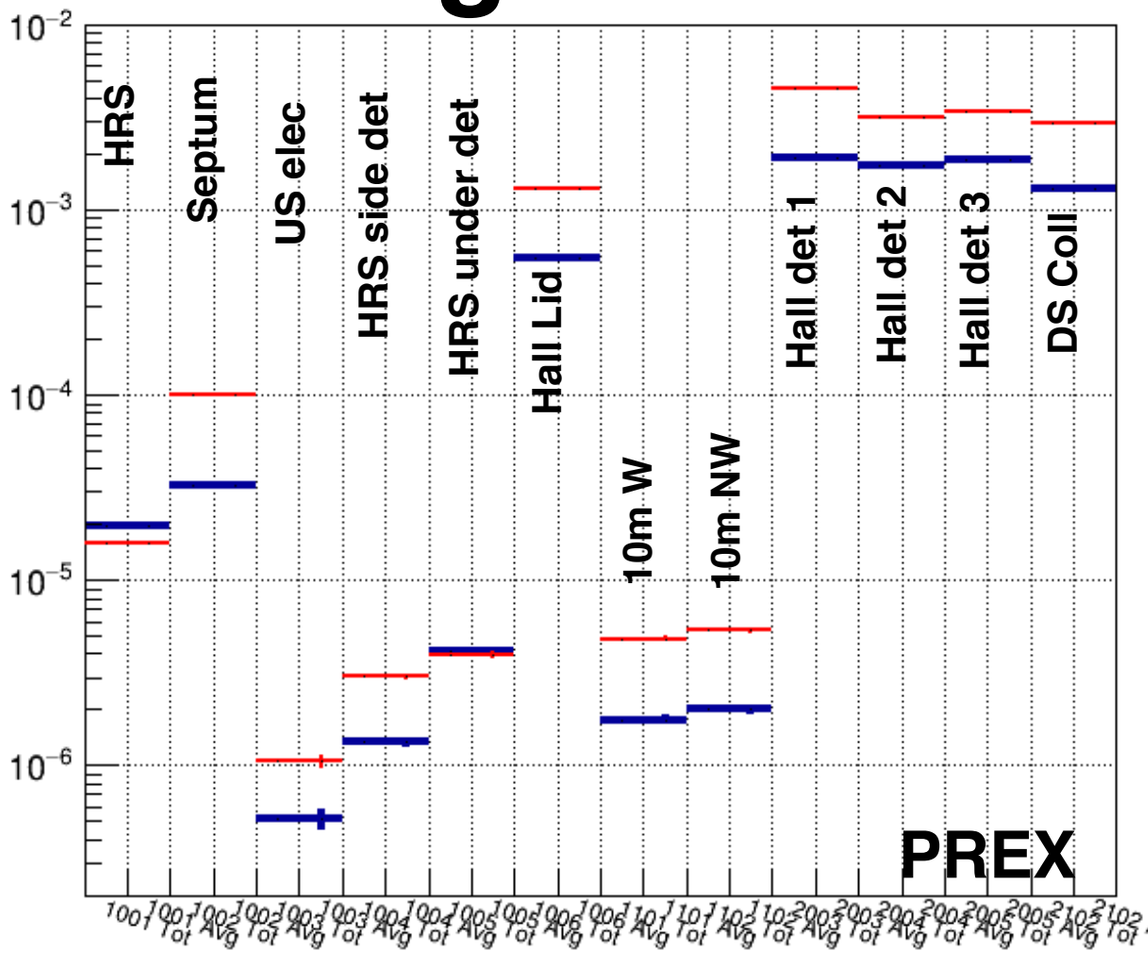


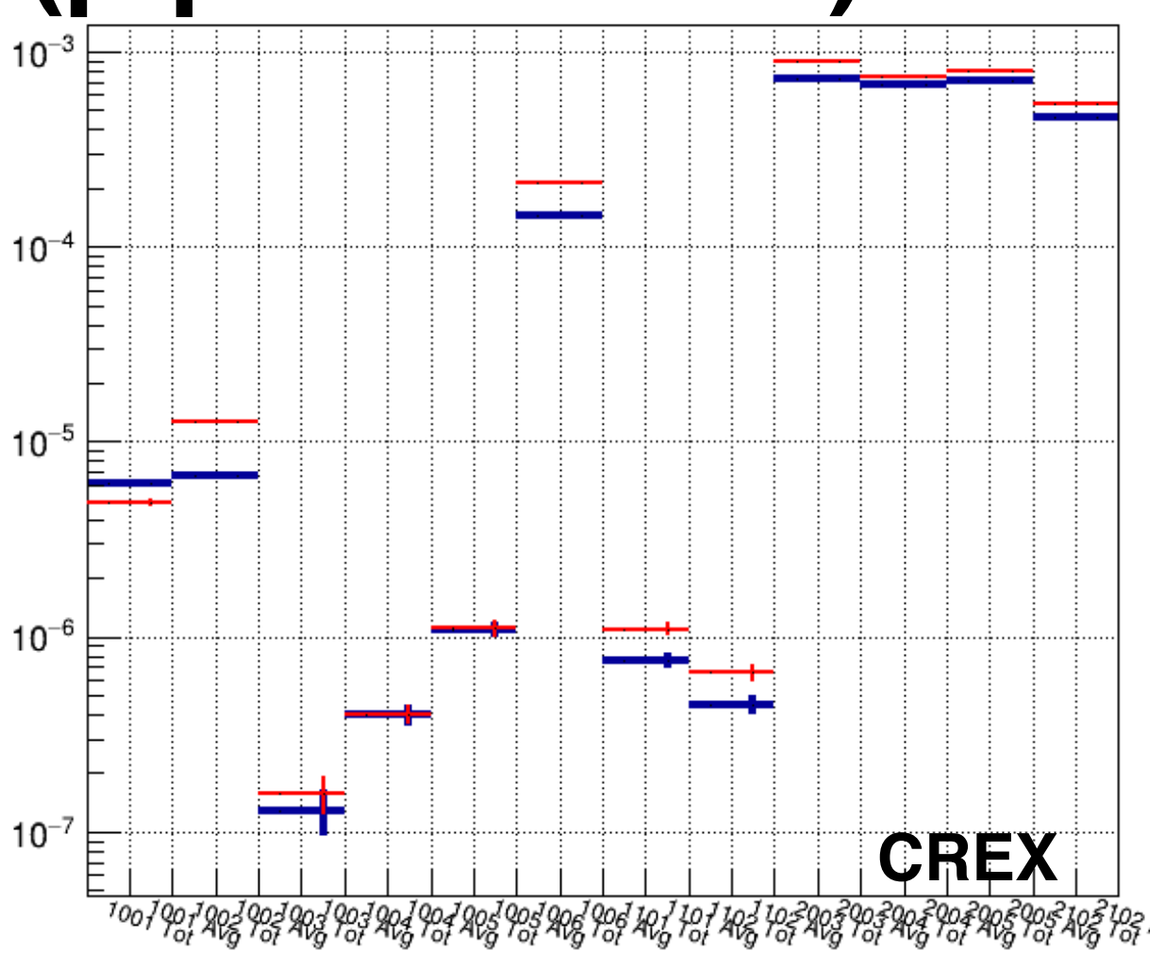


- Current in blue, comparison in red
- Tighter collimator to hide neck down (0.78 deg -> 0.61 deg; US radius: 1.133-> 0.891; DS radius: 1.345->1.058)
- There is a small decrease in the radiation at the HRS platform but the radiation at the hall lid nearly doubles for PREX
- CREX(PREX) sees a 20(65)% increase in number of HE neutrons at the hall lid



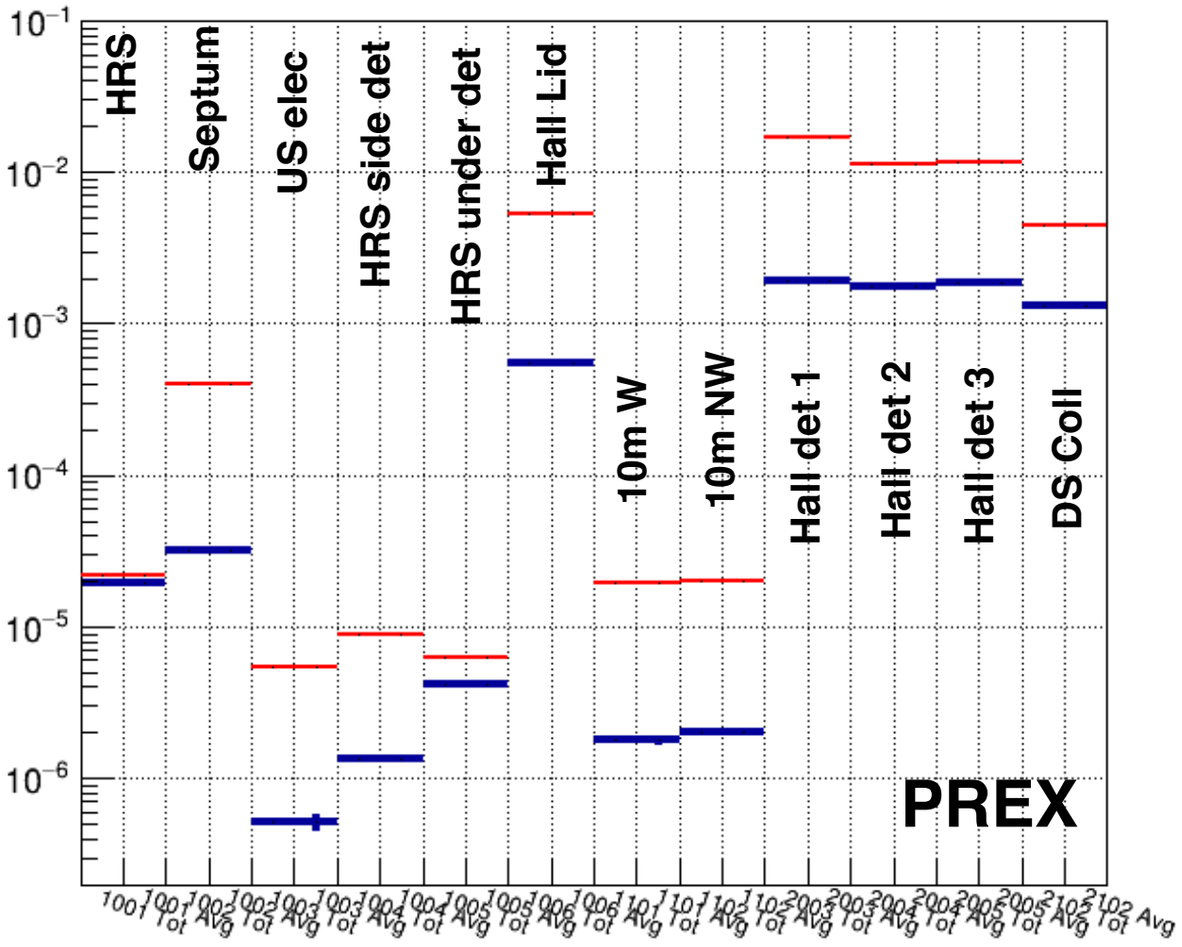
Tighter collimator (pipe to Donut)

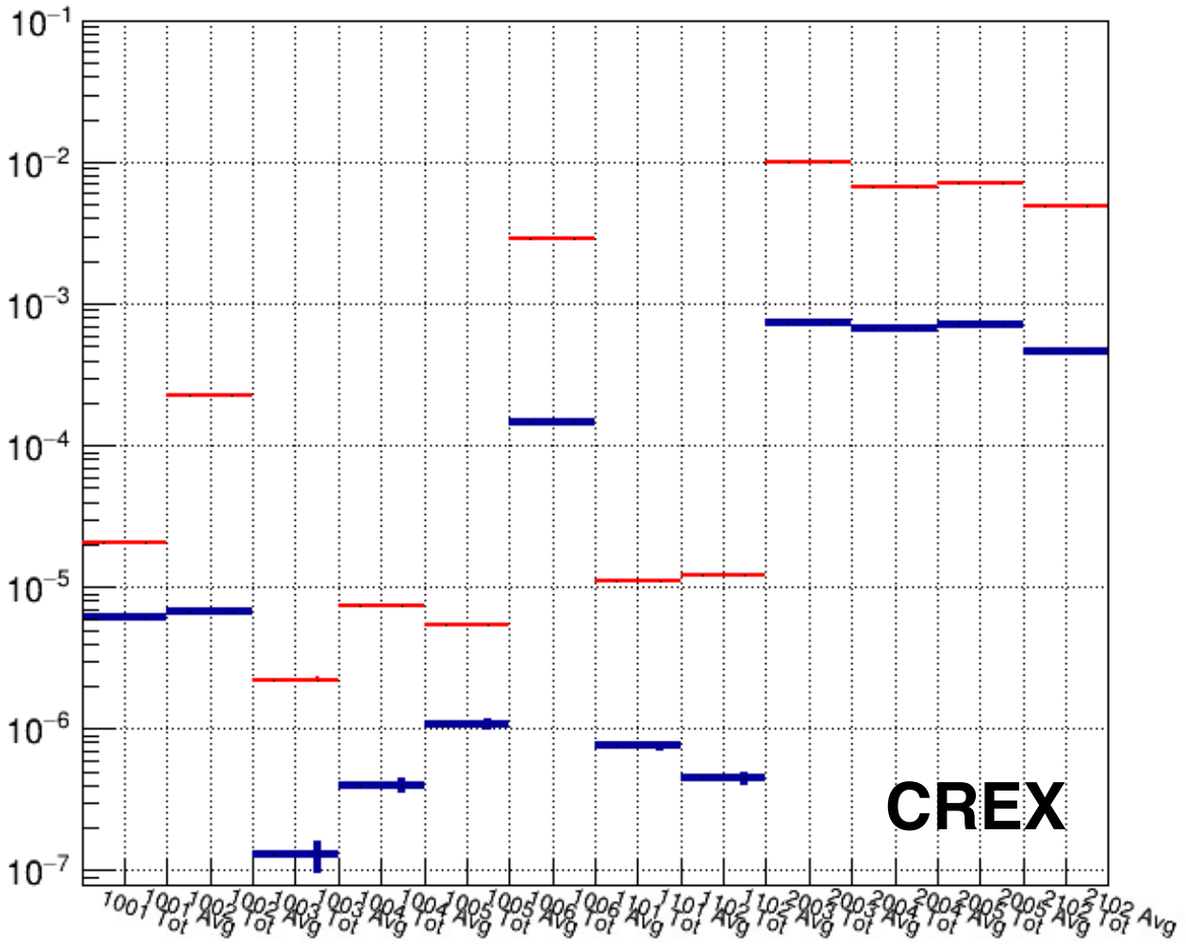




- Current in blue, comparison in red
- Tighter collimator to hide half of donut; covers beam pipe until the donut @2929cm
  - (0.78 deg -> 0.57 deg; US radius: 1.133->0.822; DS radius: 1.345->0.976)
- This is even worse although the HRS seems unaffected (the big dipole iron must be blocking everything)
- CREX(PREX) sees a 30(95)% increase in number of HE neutrons at the hall lid

Tighter collimator (middle of Donut)





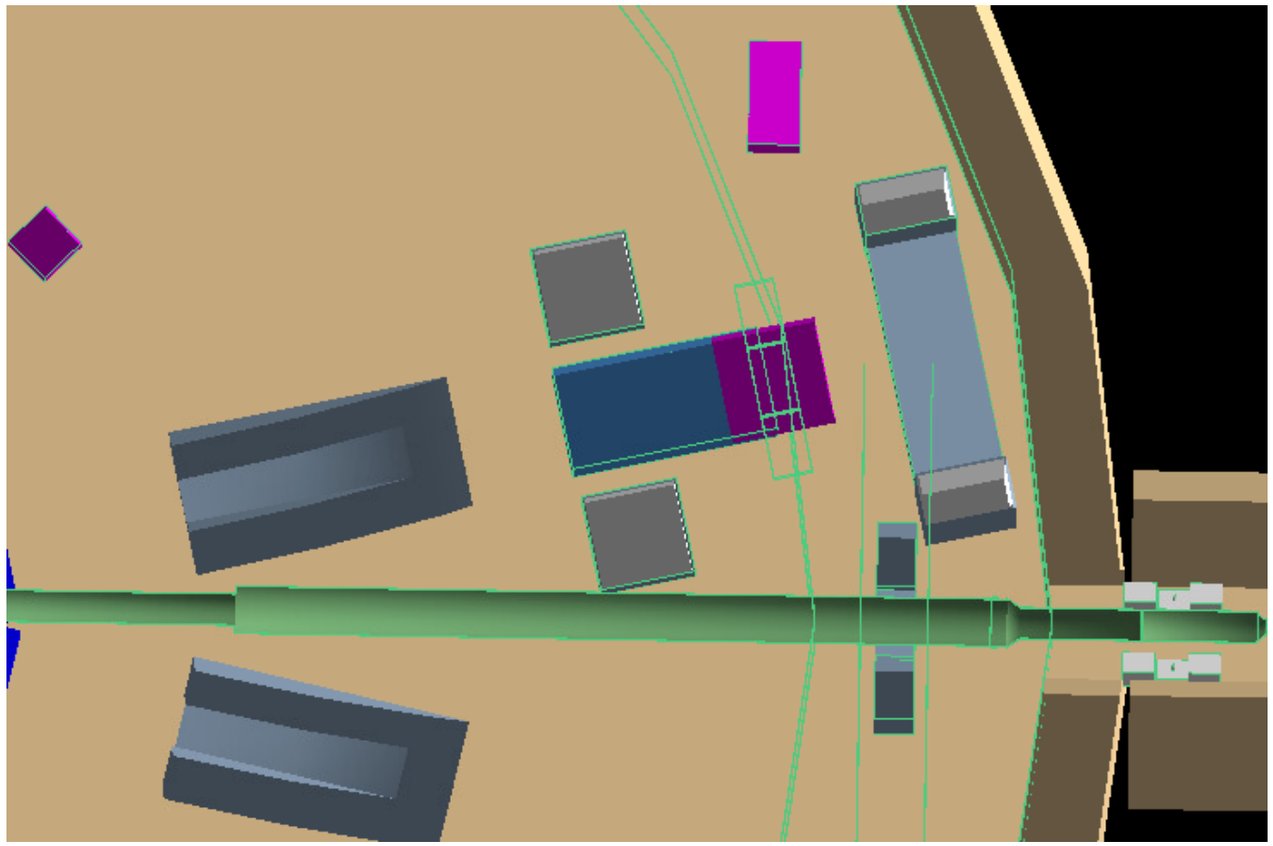
- Current in blue, comparison in red
- Tighter collimator to hide half of donut; to R=15cm @ 2929 cm
  - (0.78 deg -> 0.28 deg; US radius: 1.133->0.412; DS radius: 1.345->0.489)
- CREX(PREX) sees a 1070(816)% increase in number of HE neutrons at the hall lid

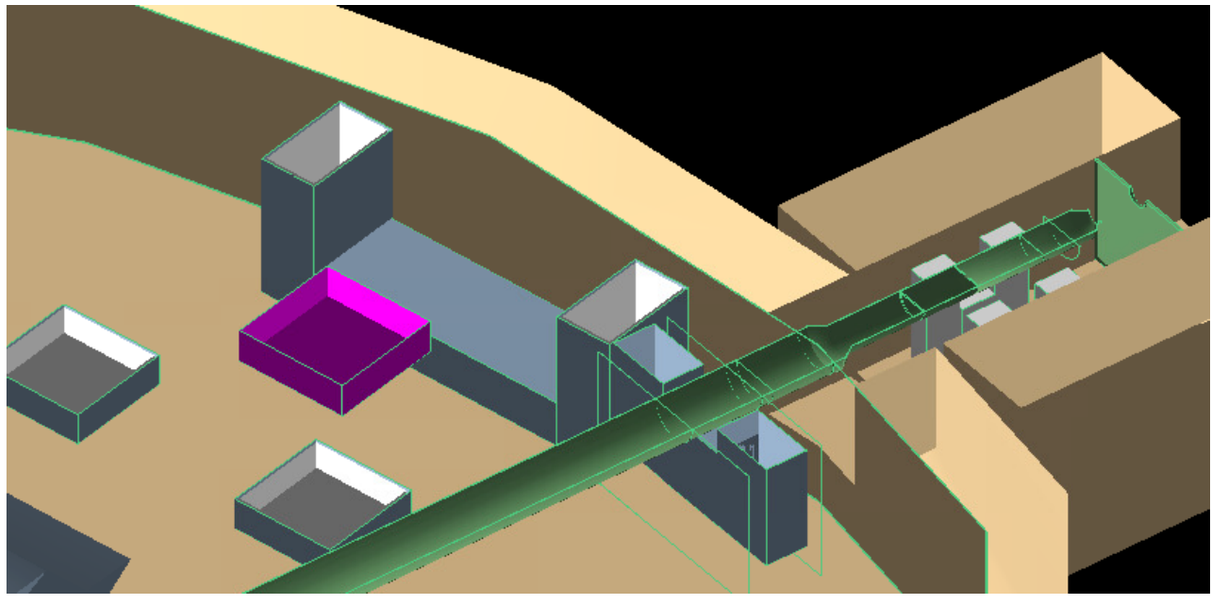
Tighter collimators

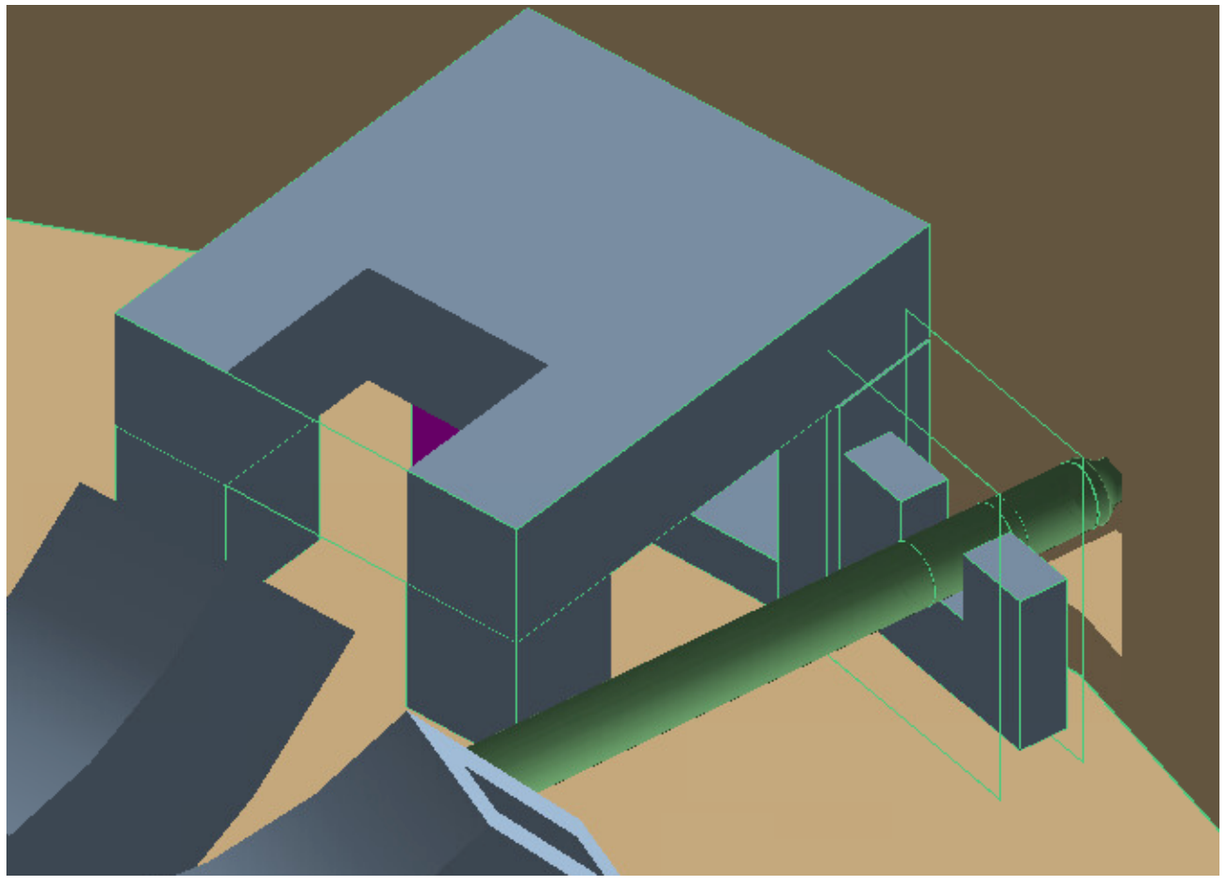
	W/uA			
	PREX	CREX	PREX@70uA [W]	CREX@150uA [W]
current	32	6	2264	833
smaller Coll Neck	74	10	5193	1451
smaller Coll Pipe2Donut	99	12	6965	1805
smaller Coll MidDonut	509	197	35601	29478

- The power deposited in the collimator more than doubles when we cover the neck down

New HRS

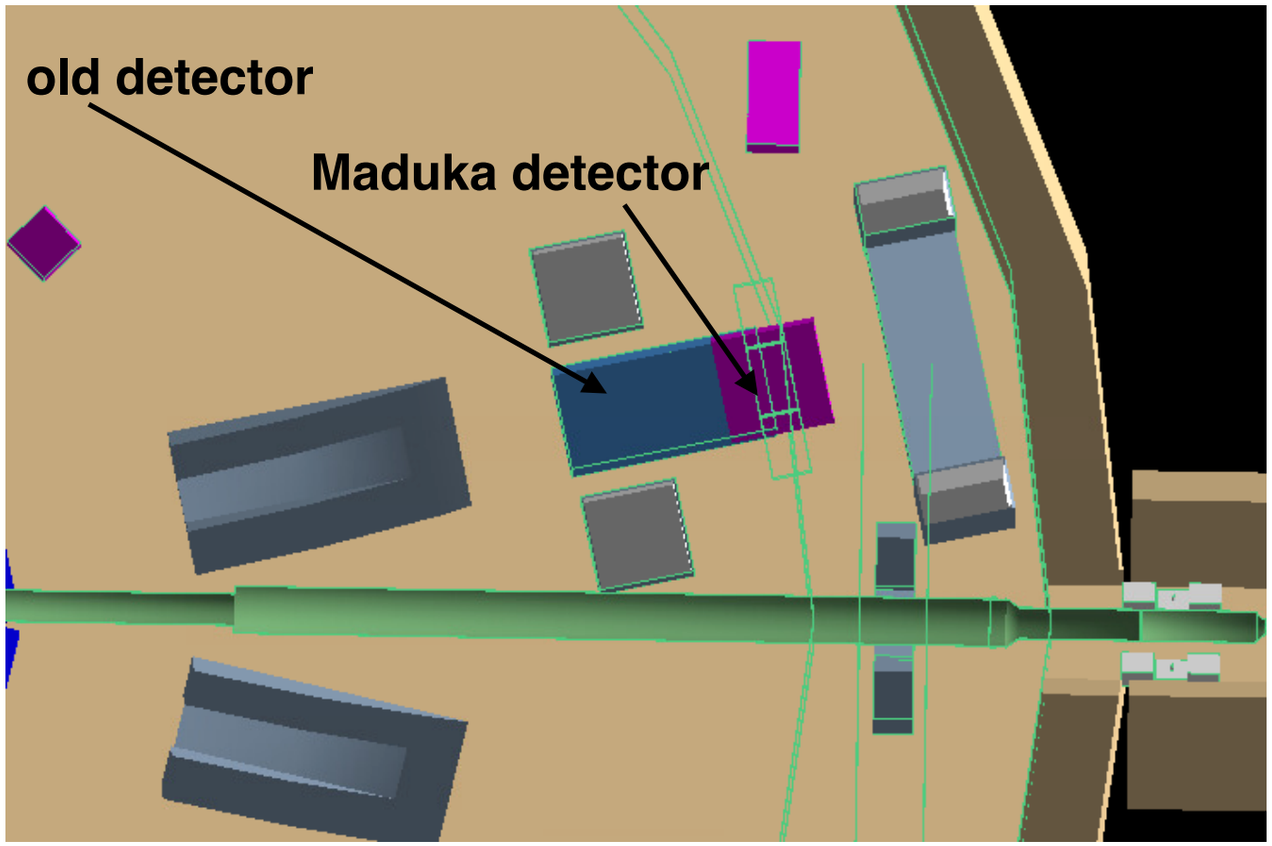




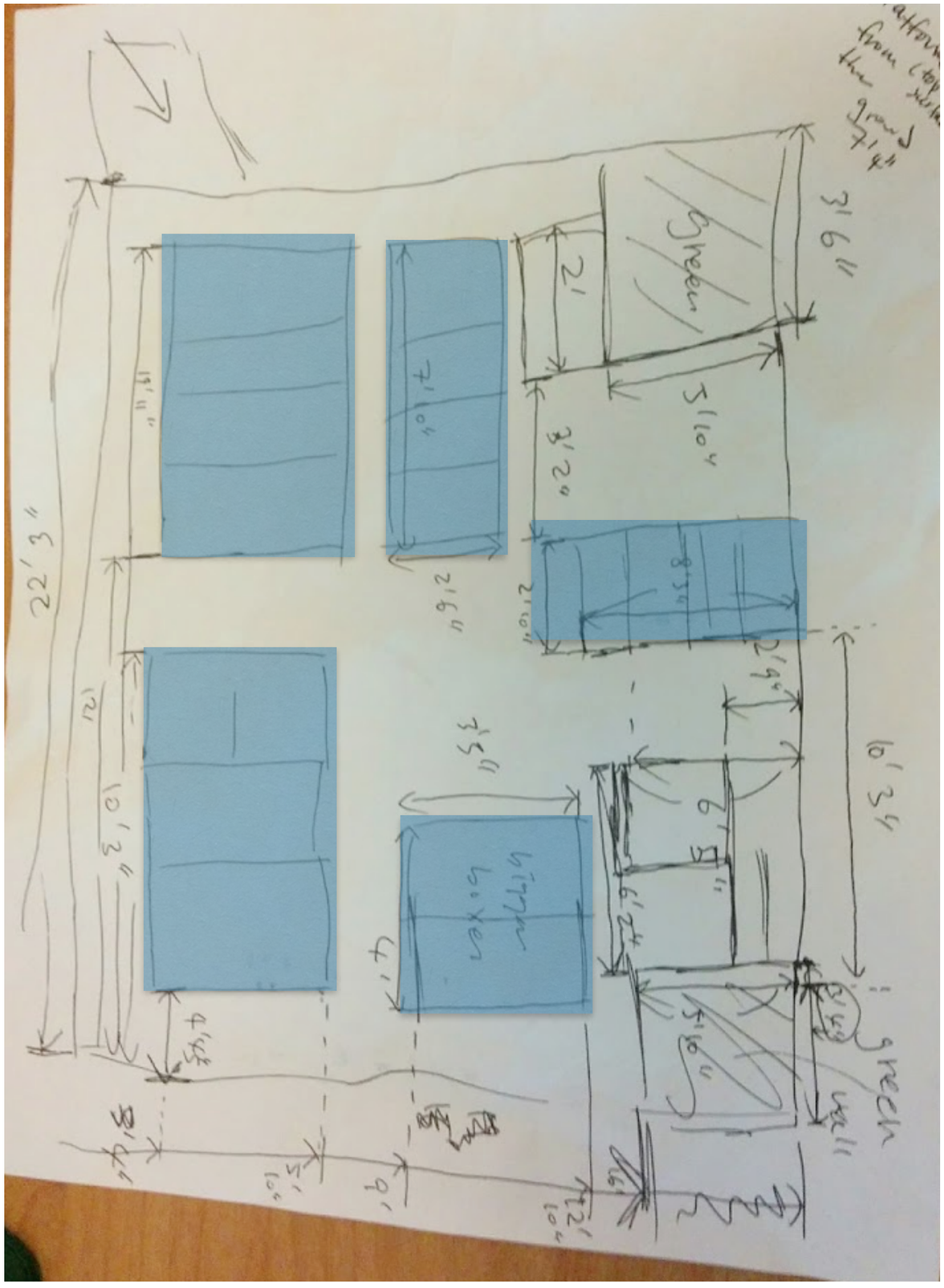


- The detector as implemented by Maduka (pink) sits right at the center of the HRS platform
    - it is significantly smaller than what we had (overlap in blue) and what is on the platform in reality
- plan to increase the size and extend it downstream and to size to make it more accurate
- The support structure is ~5cm thick iron with Air inside

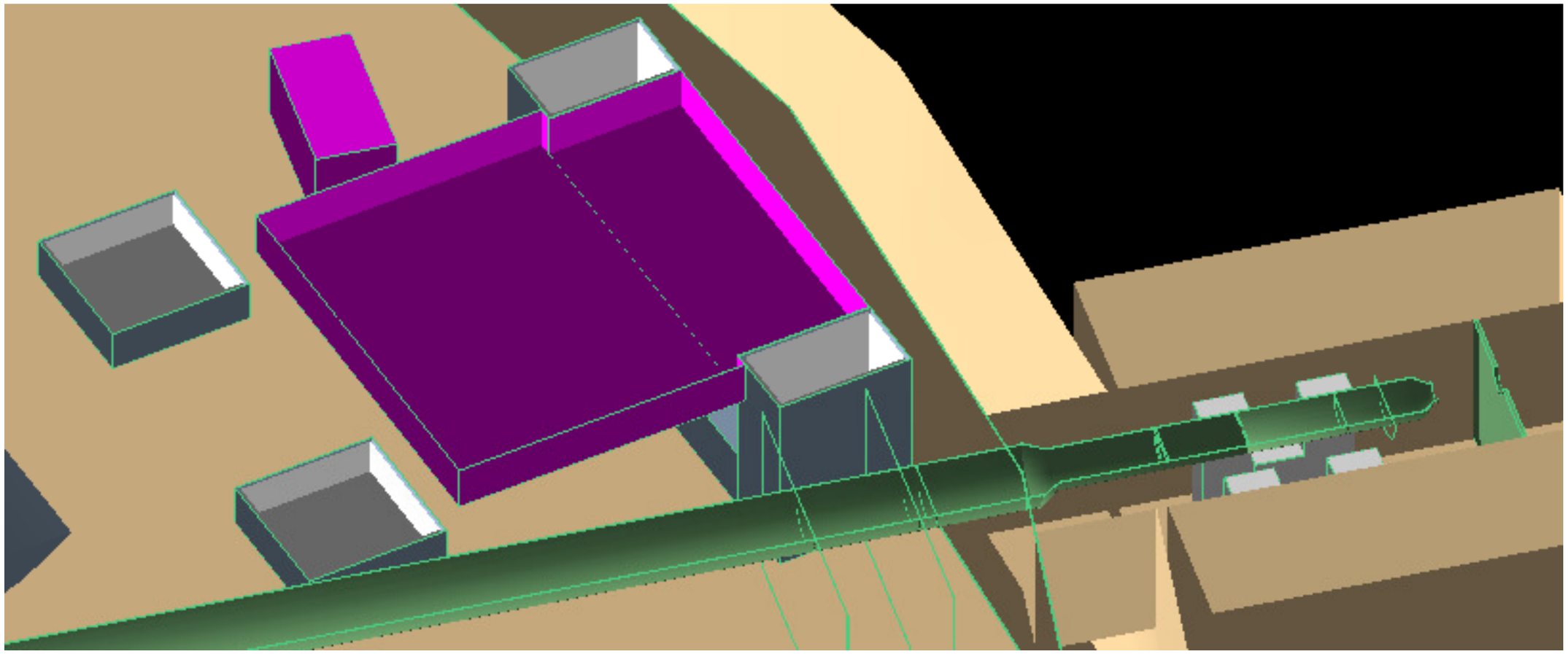
New HRS



- Will need to look at some drawings for the HRS platform dimensions (not urgent)
- The dimensions that Maduka had for the pillars and the total size of the platform is consistent with what Sanghwa and I measured in the hall
- Electronics boxes are spread out over a larger area (highlighted regions on the right drawing) — drawing not to scale



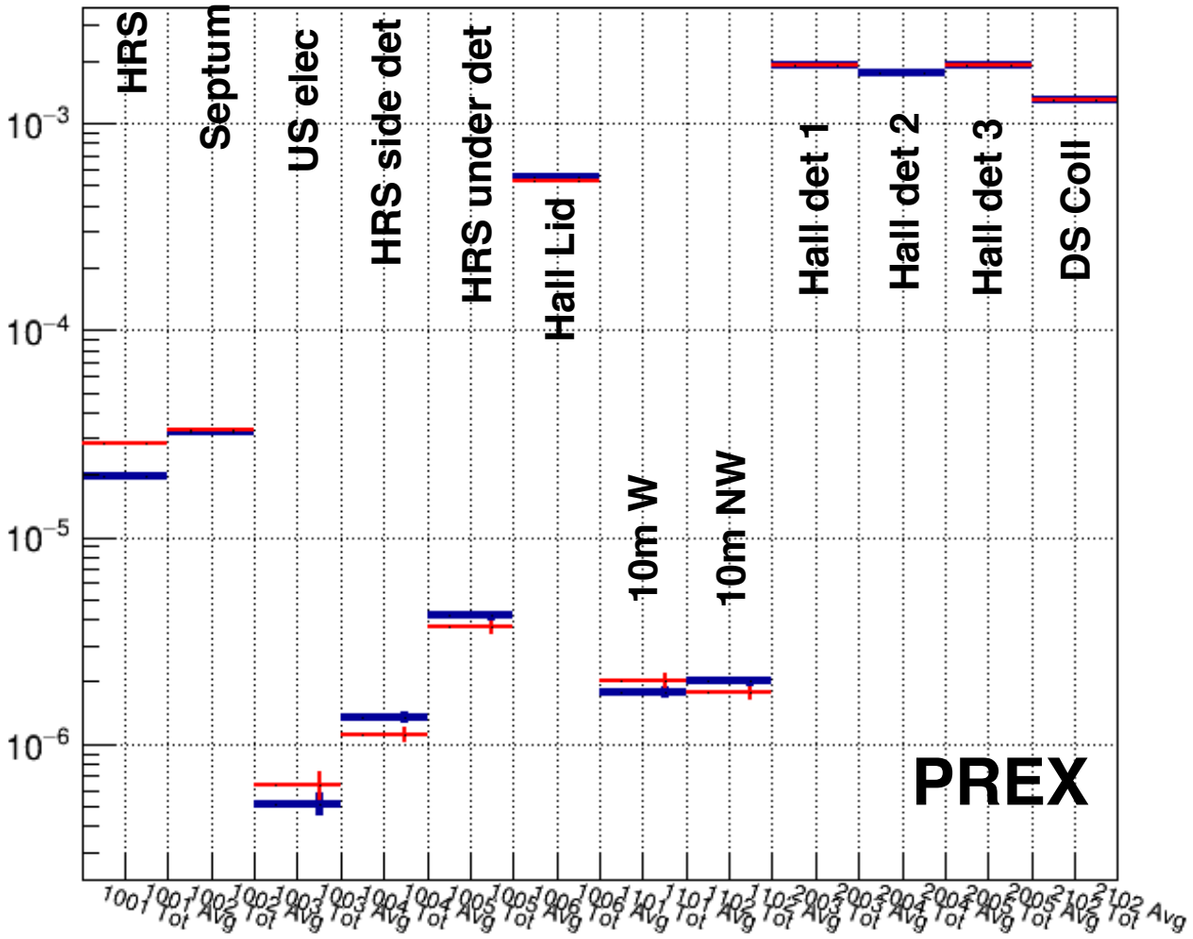
New HRS + new Det

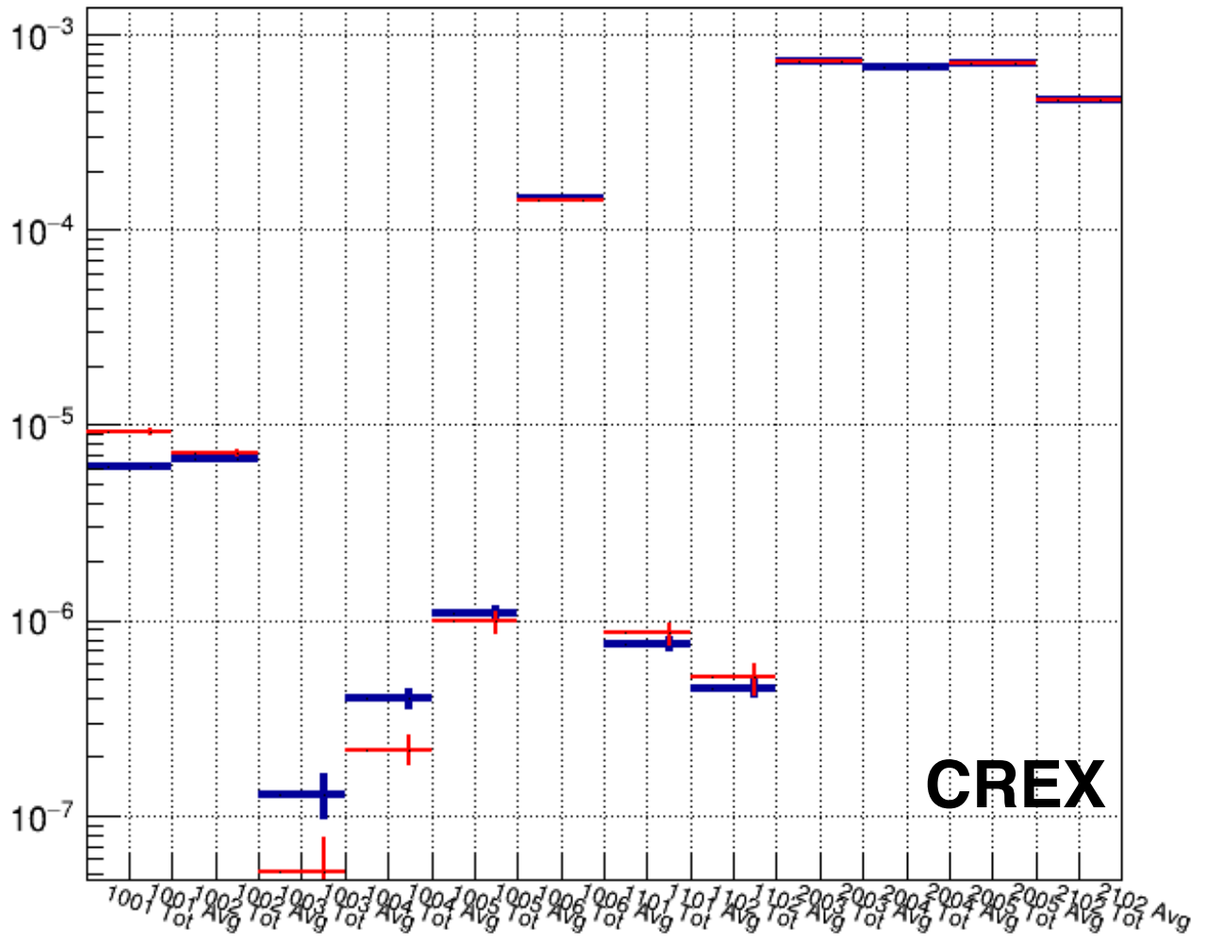


- Increased size of detector to cover any area where electronics could be placed

- This will produce an increase in the radiation per electron since the surface area is increased (400k cm2 to ~987k cm2)

New HRS + newDet

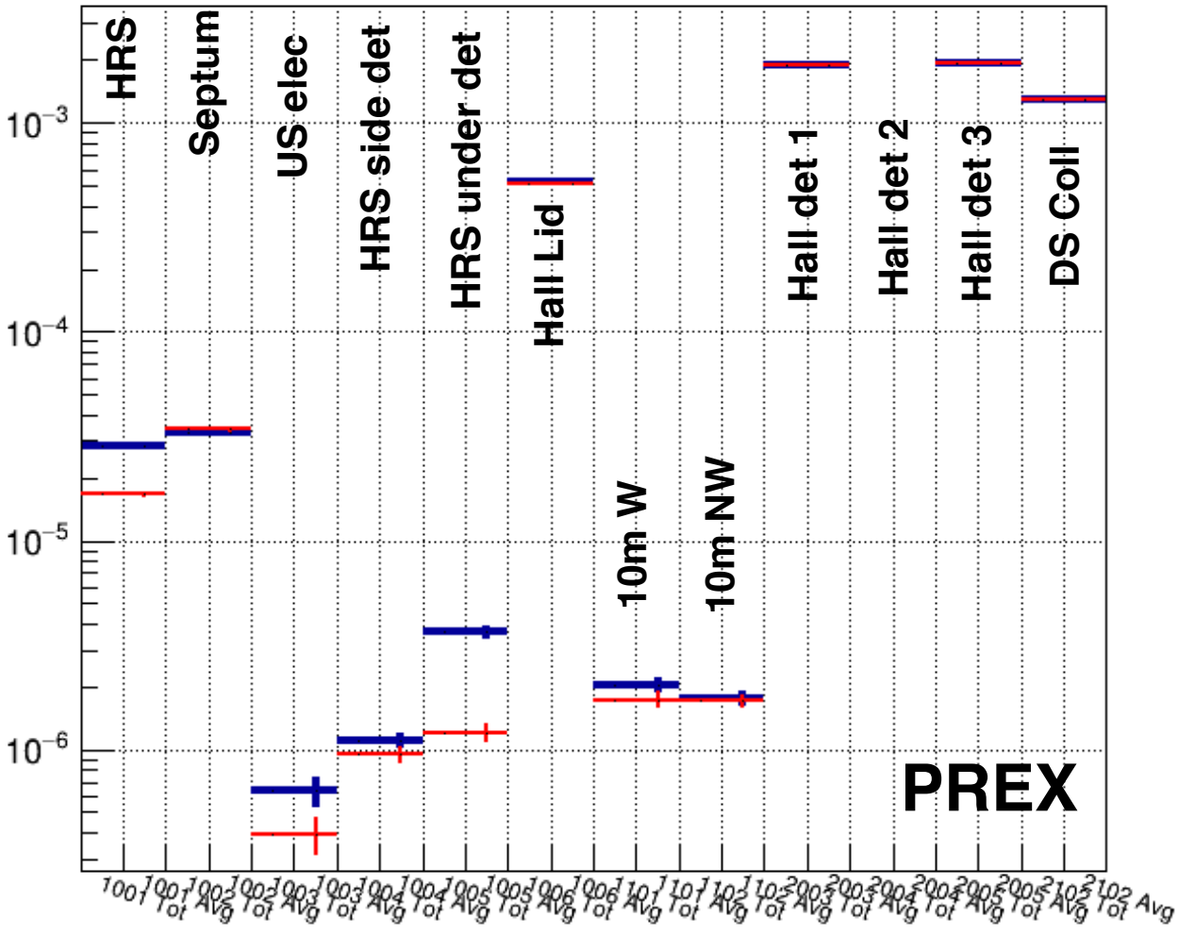


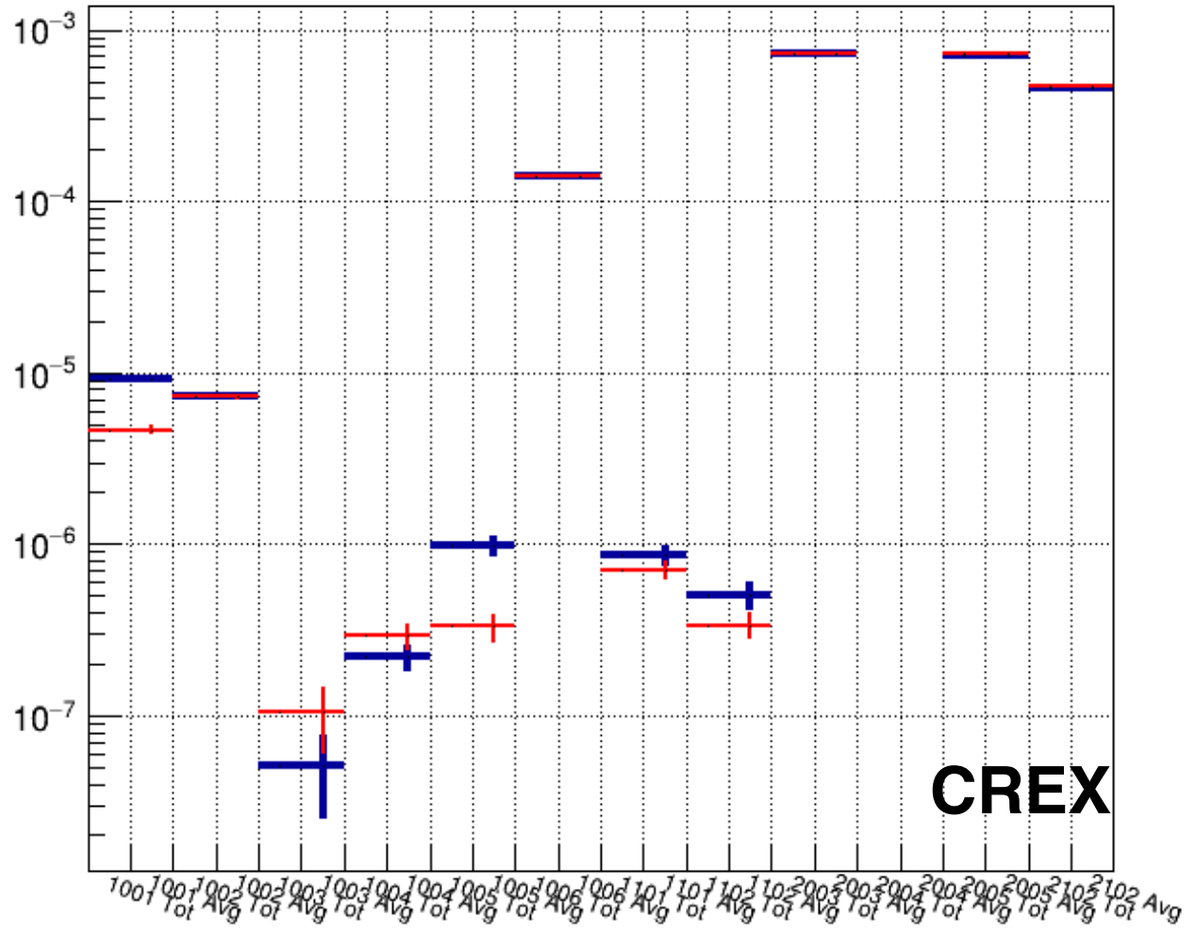


- Blue is current, red is with the new platform (increased hall radius) and new detector

- the increase in instantaneous rate is consistent with a more than doubling of the area of the detector

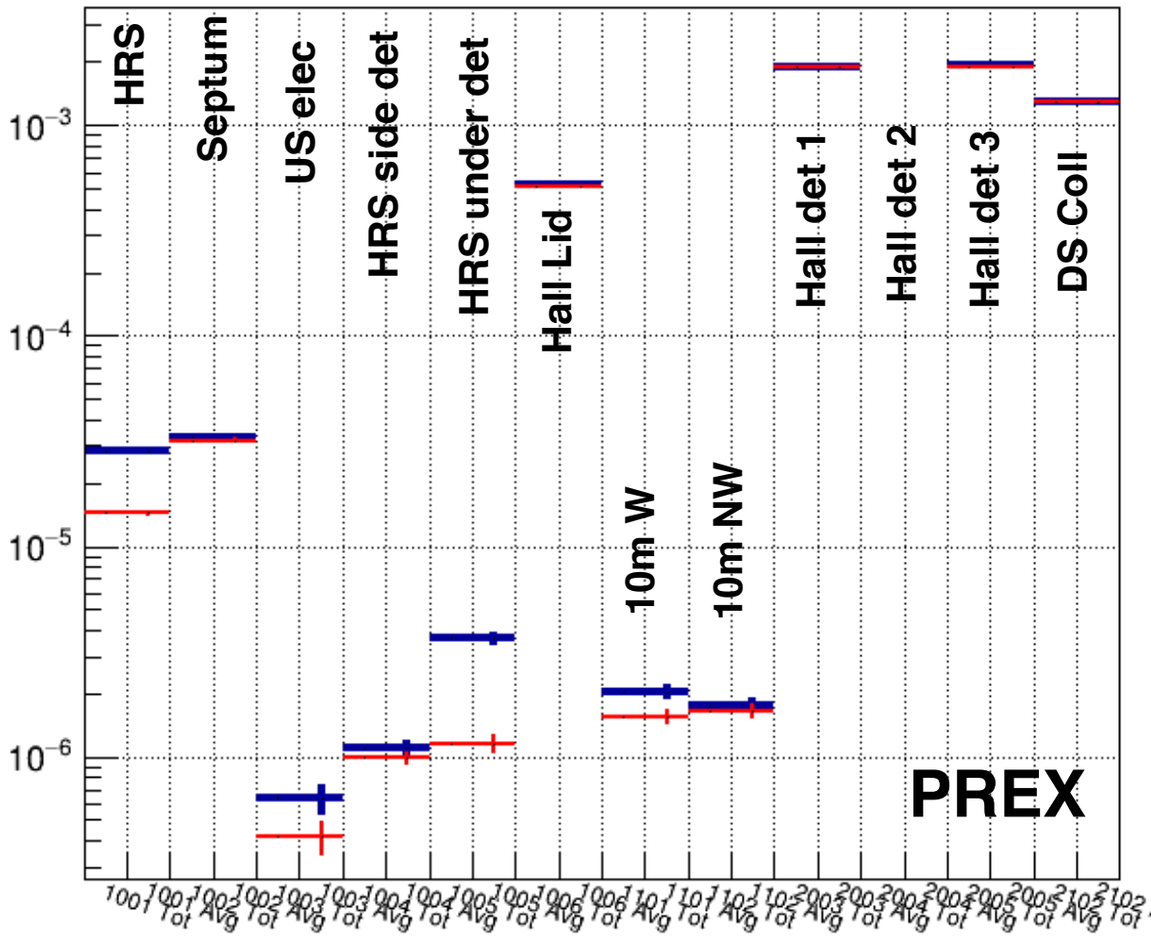
2ft Iron

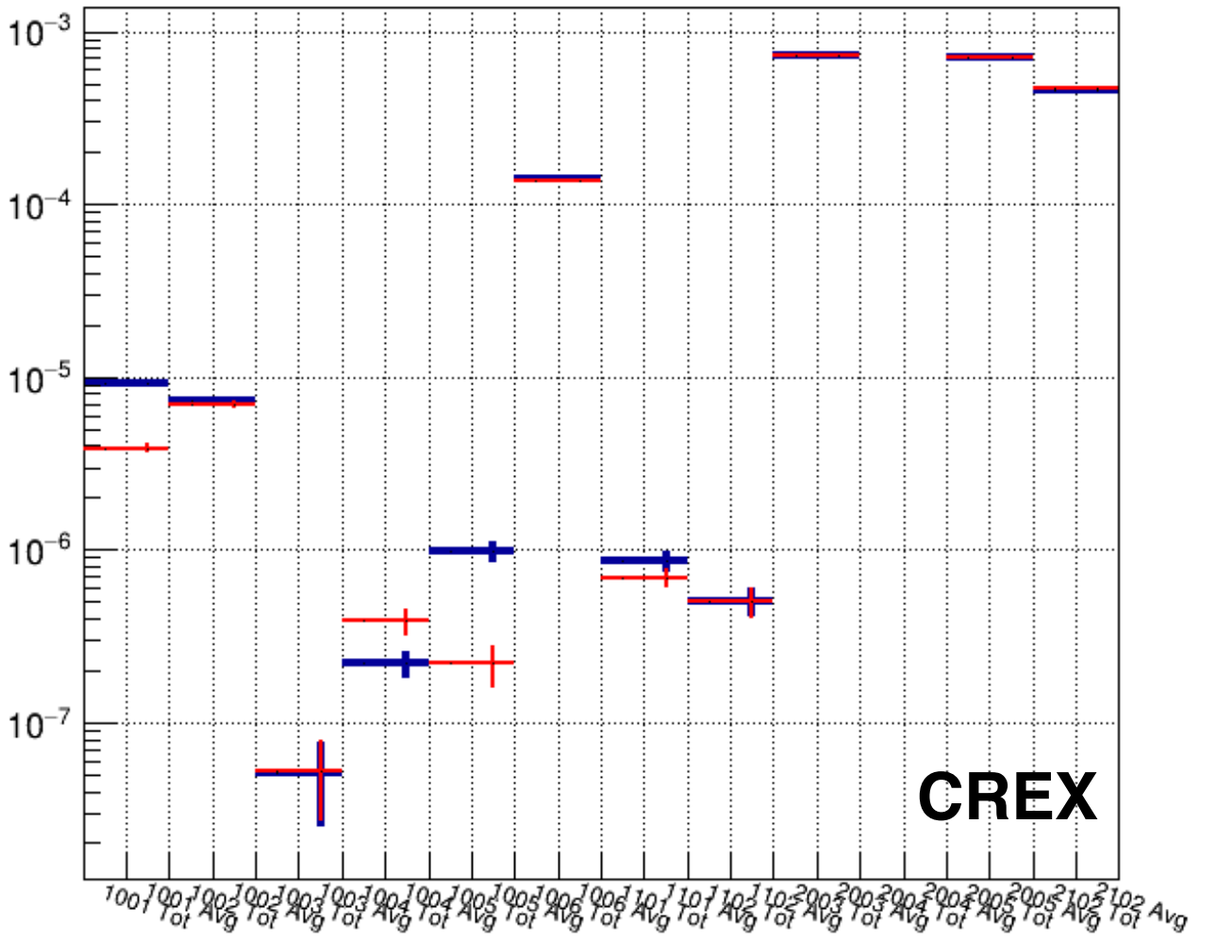




- Blue: is newHRS+newDet; Red is +2ft Iron dump shield

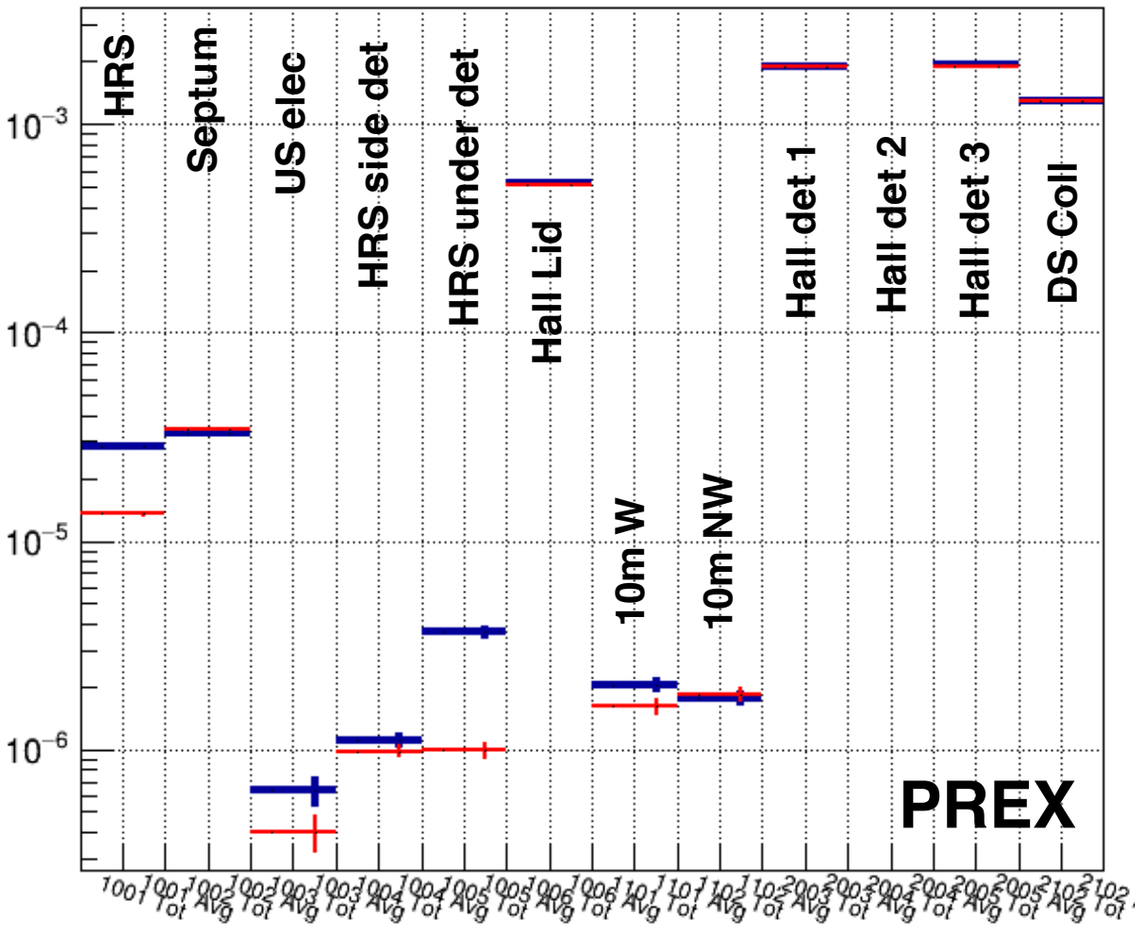
2ft Concrete

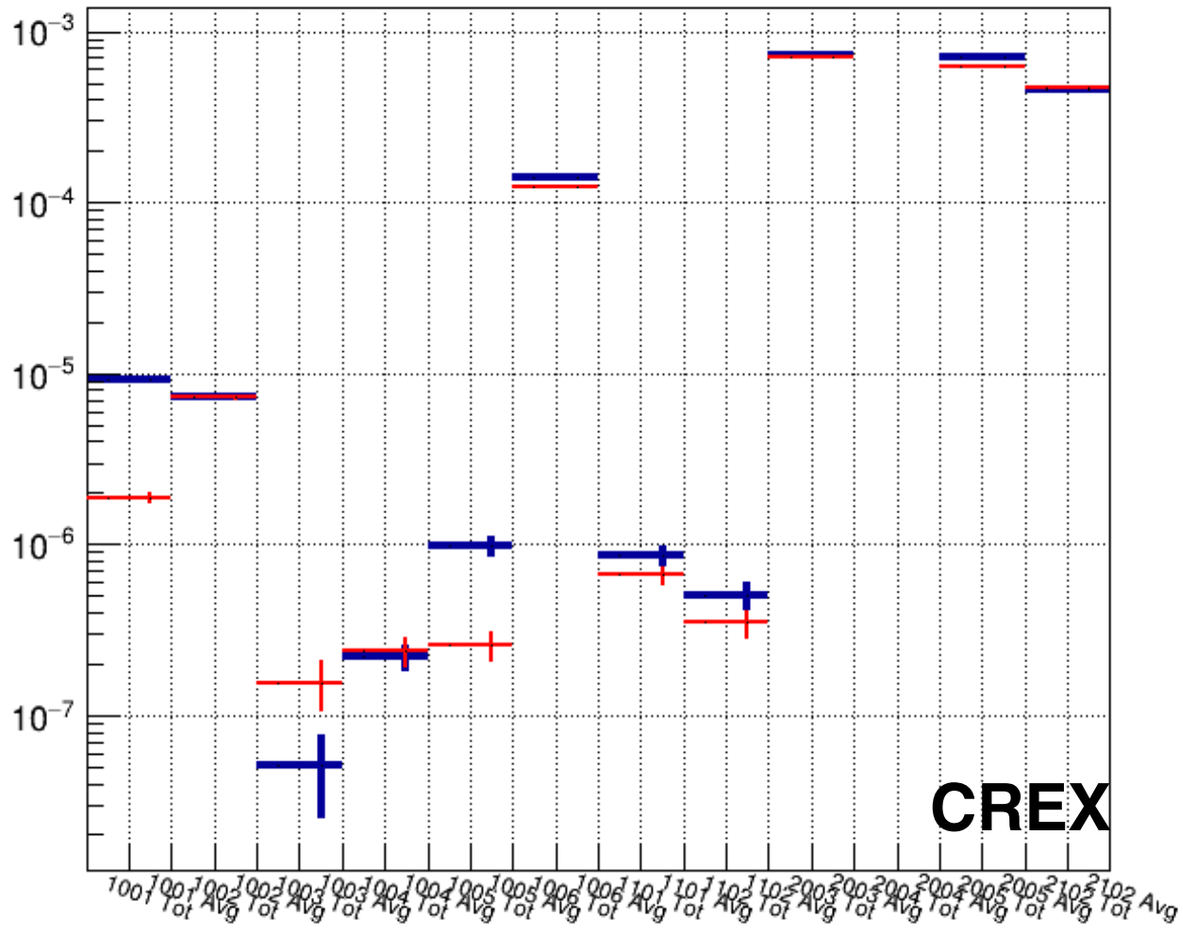




- Blue: is newHRS+newDet; Red is +2ft Concrete dump shield
- Concrete still shows better results compared to iron

1ft concrete+1ft iron+4 in Donut





- Blue: is newHRS+newDet; Red is + 1ft Iron+1ft concrete dump shield + 4in donut
- This is our “maximal shielding” configuration

Summary table

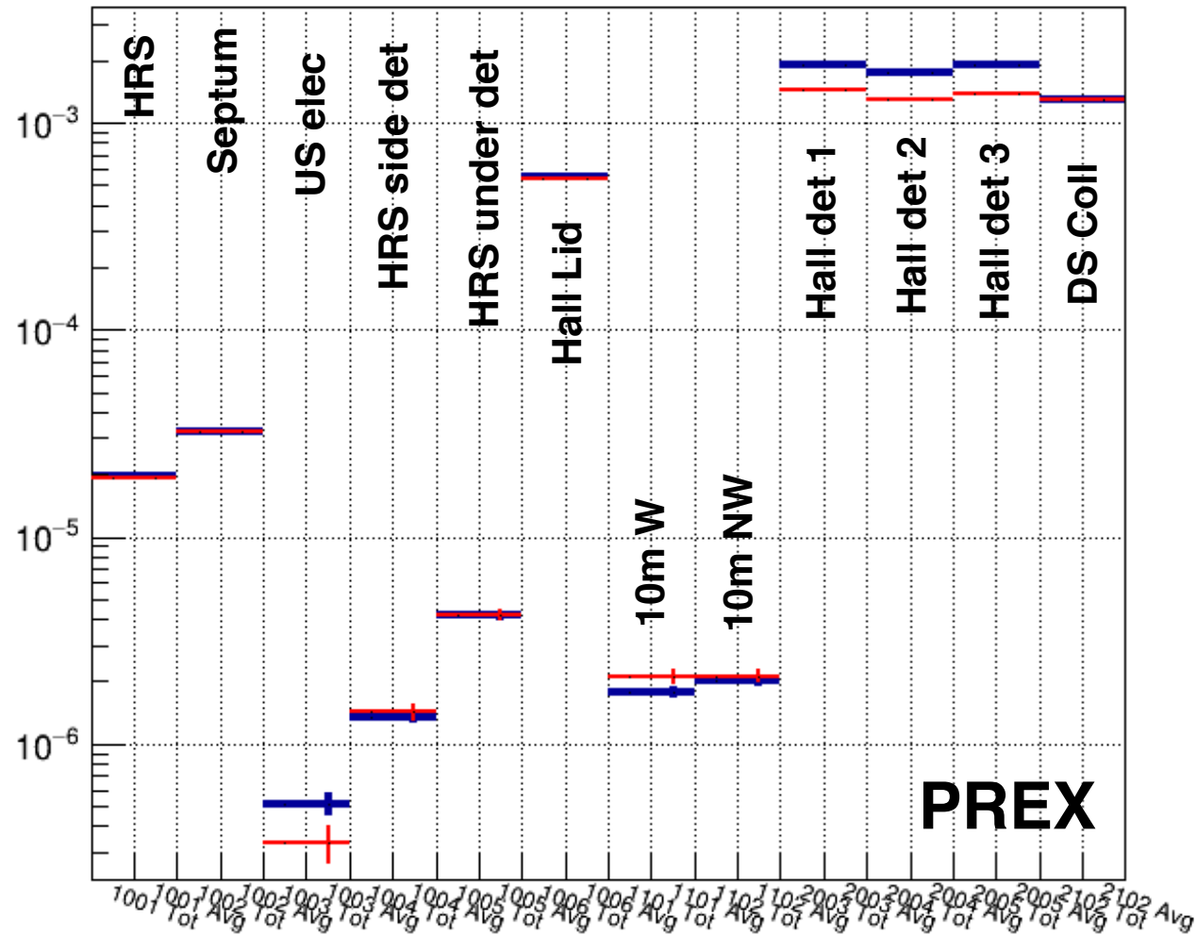
		HRS detector				Under detector			
		Total NEIL/cm2	uncert	Ratio to P1	uncert	Total NEIL/cm2	uncert	Ratio to P1	uncert
	PREX1 (ERR dump)	4.60E+10	1.79E+09	1.00	0.06	7.43E+10	4.92E+09	1.00	0.09
	PREX2 current	5.77E+10	5.69E+09	1.25	0.13	7.60E+10	1.85E+10	1.02	0.26
	C5 current	3.86E+10	7.80E+09	0.84	0.17	4.70E+10	1.96E+10	0.63	0.27
PREX 2	current (farm)	5.23E+10	1.11E+09	1.14	0.05	8.03E+10	3.77E+09	1.08	0.09
	vacuum beamline	5.12E+10	1.55E+09	1.11	0.05	8.06E+10	5.34E+09	1.09	0.10
	no donut	3.90E+10	1.31E+09	0.85	0.04	5.04E+10	3.74E+09	0.68	0.07
	smaller Coll Neck	4.38E+10	1.02E+09	0.95	0.04	6.92E+10	3.19E+09	0.93	0.08
	smaller Coll Pipe2Donut	4.17E+10	9.59E+08	0.91	0.04	7.68E+10	3.29E+09	1.03	0.08
	smaller Coll MidDonut	5.77E+10	9.57E+08	1.25	0.05	1.21E+11	3.50E+09	1.63	0.12
	larger Hall	5.46E+10	1.63E+09	1.19	0.06	8.00E+10	5.32E+09	1.08	0.10
	new HRS	3.00E+10	1.45E+09	0.65	0.04	8.12E+10	5.42E+09	1.09	0.10
	New HRS + 2ft Iron	2.07E+10	1.17E+09	0.45	0.03	2.97E+10	2.81E+09	0.40	0.05
	NewHRSDet	3.05E+10	7.62E+08	0.66	0.03	7.09E+10	4.98E+09	0.95	0.09
	NewHRSDet+2ft Fe	1.79E+10	5.39E+08	0.39	0.02	2.32E+10	2.44E+09	0.31	0.04
	NewHRSDet+2ft Conc	1.55E+10	5.00E+08	0.34	0.02	2.23E+10	2.29E+09	0.30	0.04
	NewHRSDet+1ftConc1ftFe	N/A	N/A	#VALUE!	#VALUE!	N/A	N/A	#VALUE!	#VALUE!
	NewHRSDet+1ftConc1ftFe +4inDonut	1.46E+10	4.81E+08	0.32	0.02	1.91E+10	1.94E+09	0.26	0.03
CREX 5	current (farm)	4.47E+10	1.84E+09	0.97	0.06	5.78E+10	5.41E+09	0.78	0.09
	vacuum beamline	4.01E+10	2.50E+09	0.87	0.06	7.14E+10	8.97E+09	0.96	0.14
	no donut	1.37E+10	1.20E+09	0.30	0.03	2.29E+10	4.73E+09	0.31	0.07
	smaller Coll Neck	3.91E+10	1.77E+09	0.85	0.05	6.03E+10	5.70E+09	0.81	0.09
	smaller Coll Pipe2Donut	3.59E+10	1.65E+09	0.78	0.05	5.86E+10	5.46E+09	0.79	0.09
	smaller Coll MidDonut	1.50E+11	2.53E+09	3.26	0.14	2.84E+11	8.31E+09	3.83	0.28
	larger Hall	4.05E+10	2.53E+09	0.88	0.06	6.48E+10	8.34E+09	0.87	0.13
	new HRS	2.09E+10	2.04E+09	0.45	0.05	5.92E+10	7.85E+09	0.80	0.12
	New HRS + 2ft Iron	1.54E+10	1.76E+09	0.34	0.04	1.42E+10	3.21E+09	0.19	0.05
	NewHRSDet	2.72E+10	1.29E+09	0.59	0.04	5.21E+10	7.38E+09	0.70	0.11
	NewHRSDet+2ft Fe	1.37E+10	8.34E+08	0.30	0.02	1.76E+10	3.37E+09	0.24	0.05
	NewHRSDet+2ft Conc	1.15E+10	7.72E+08	0.25	0.02	1.17E+10	3.24E+09	0.16	0.04
	NewHRSDet+1ftConc1ftFe	N/A	N/A	#VALUE!	#VALUE!	N/A	N/A	#VALUE!	#VALUE!
	NewHRSDet+1ftConc1ftFe +4inDonut	5.57E+09	4.21E+08	0.12	0.01	1.36E+10	2.75E+09	0.18	0.04

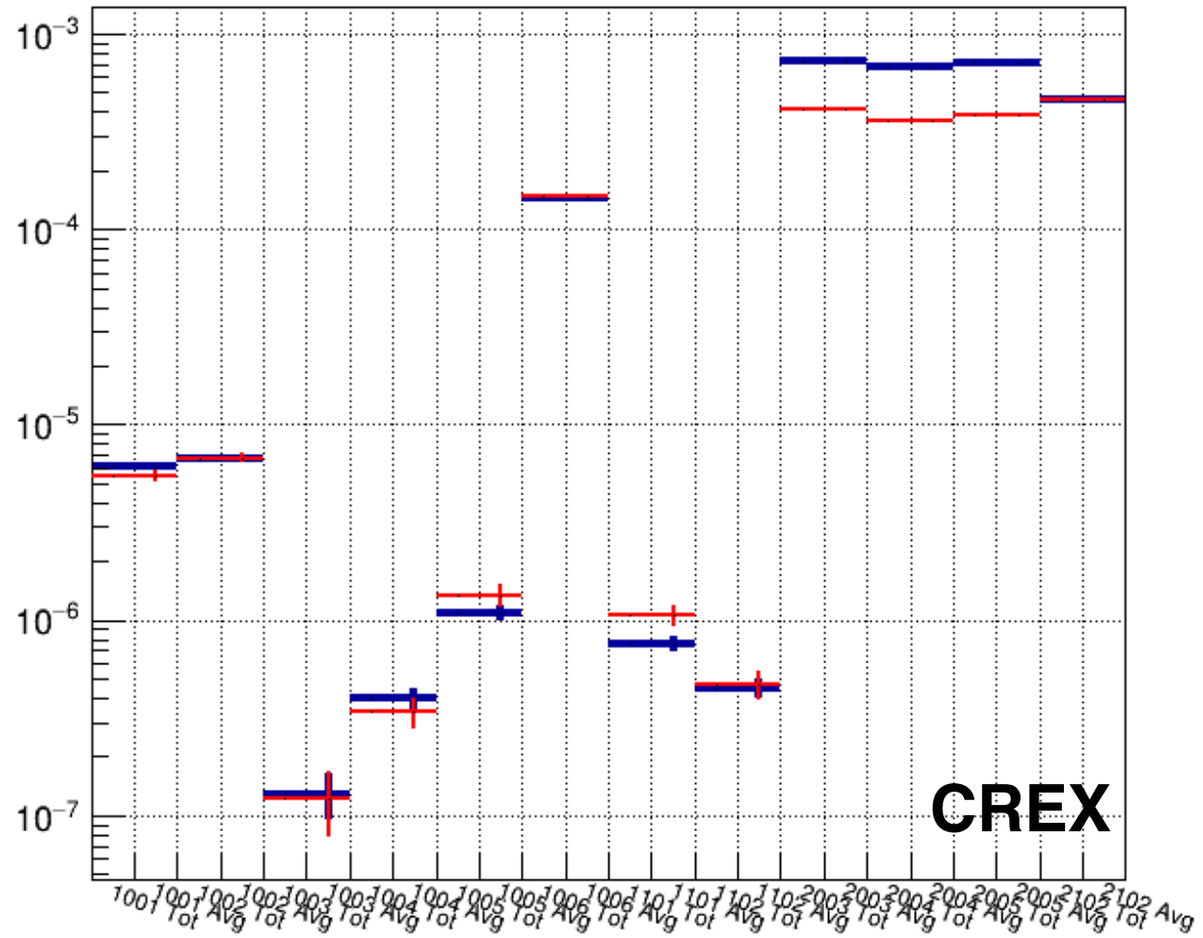
- At best it seems we will get to ~45% of PREX1 for the HRS platform

Todos

- Investigate Iron vs Concrete
- Try 1ft shielding on the platform itself
- Optimize shielding
- Integrate the vacuum pipe and the larger hall into the current(base) configuration
  - Fix detector positions around donut

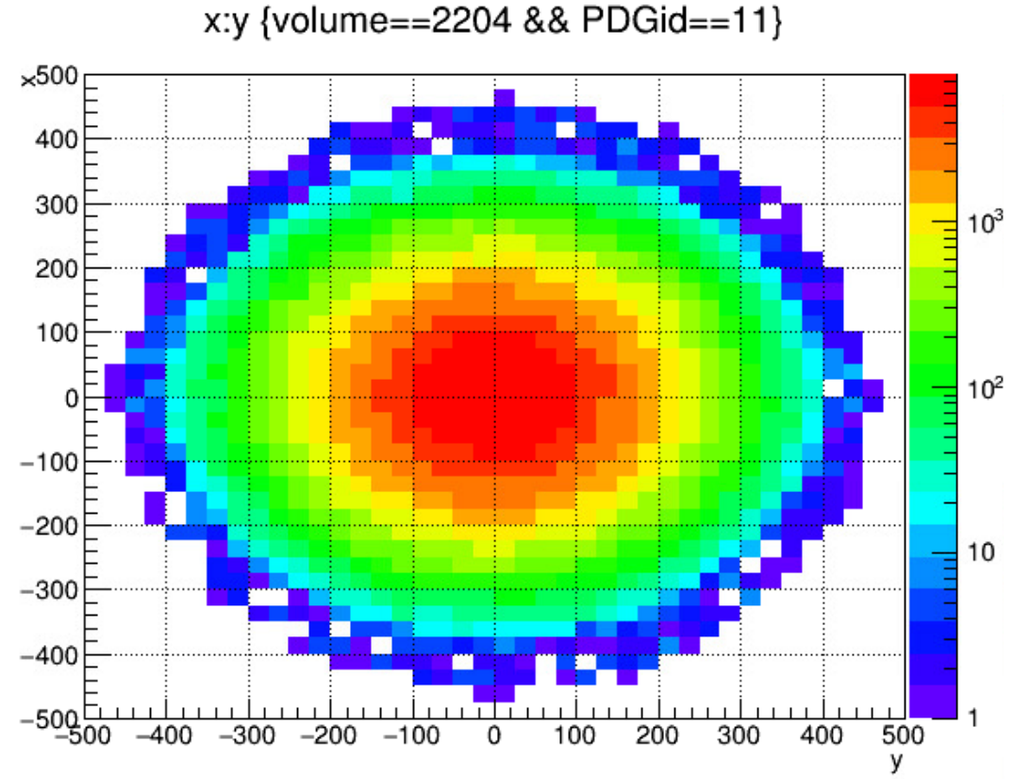
Vacuum in beampipe



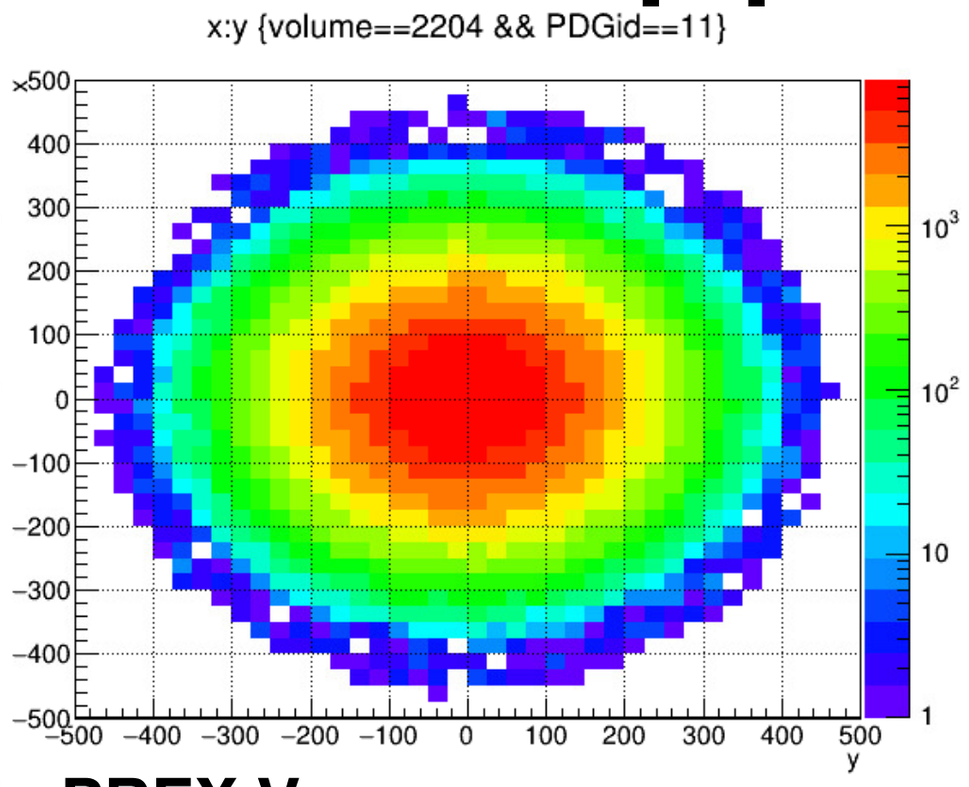


- Current in blue, comparison in red
- When implementing the beam pipe I included only the volumes containing materials
  - since the hall was filled with air otherwise, the hole inside the pipe was effectively air
- There are some small difference in the radiation at different points inside the hall, except for the Hall detectors

Vacuum in beampipe

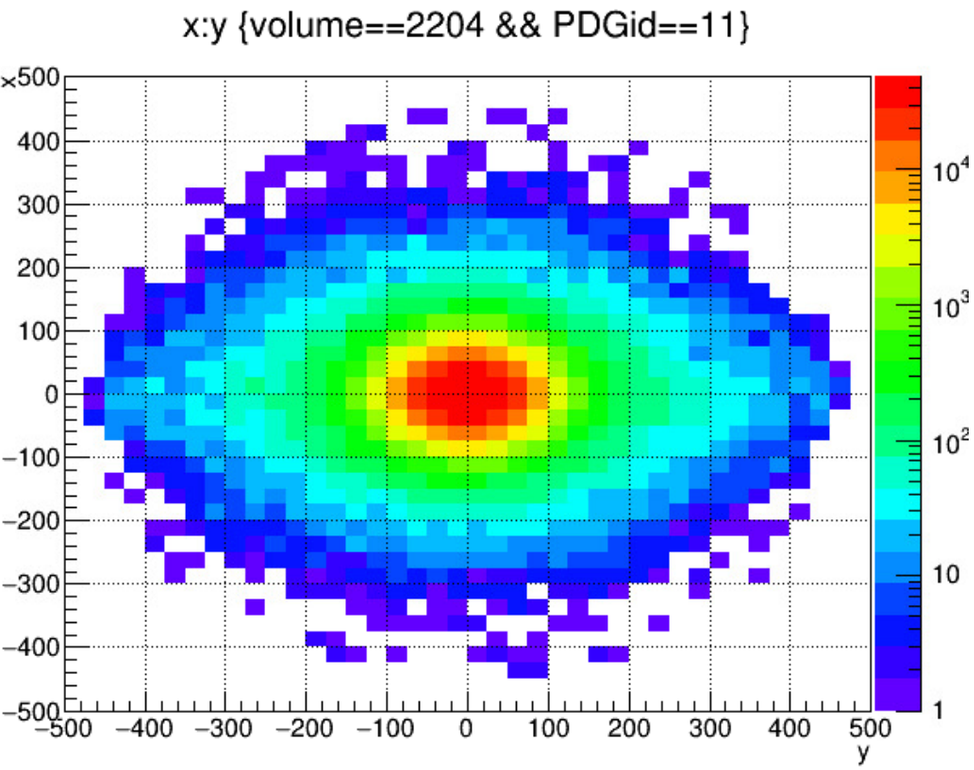


PREX Current

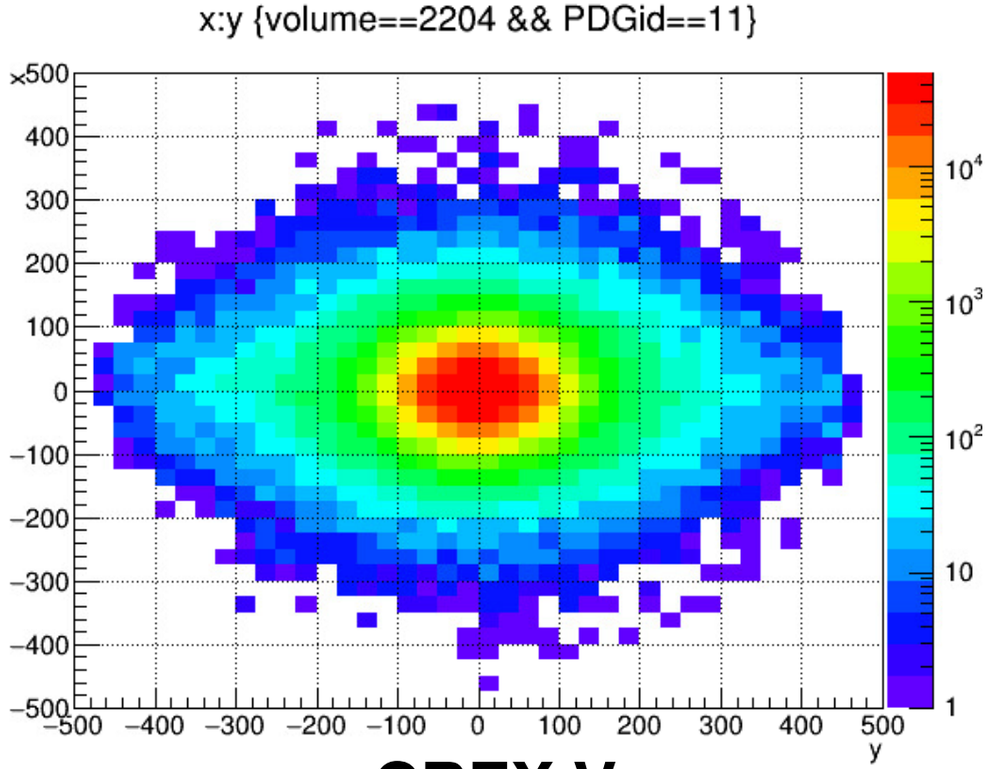


PREX Vacuum

Electrons @ 24m



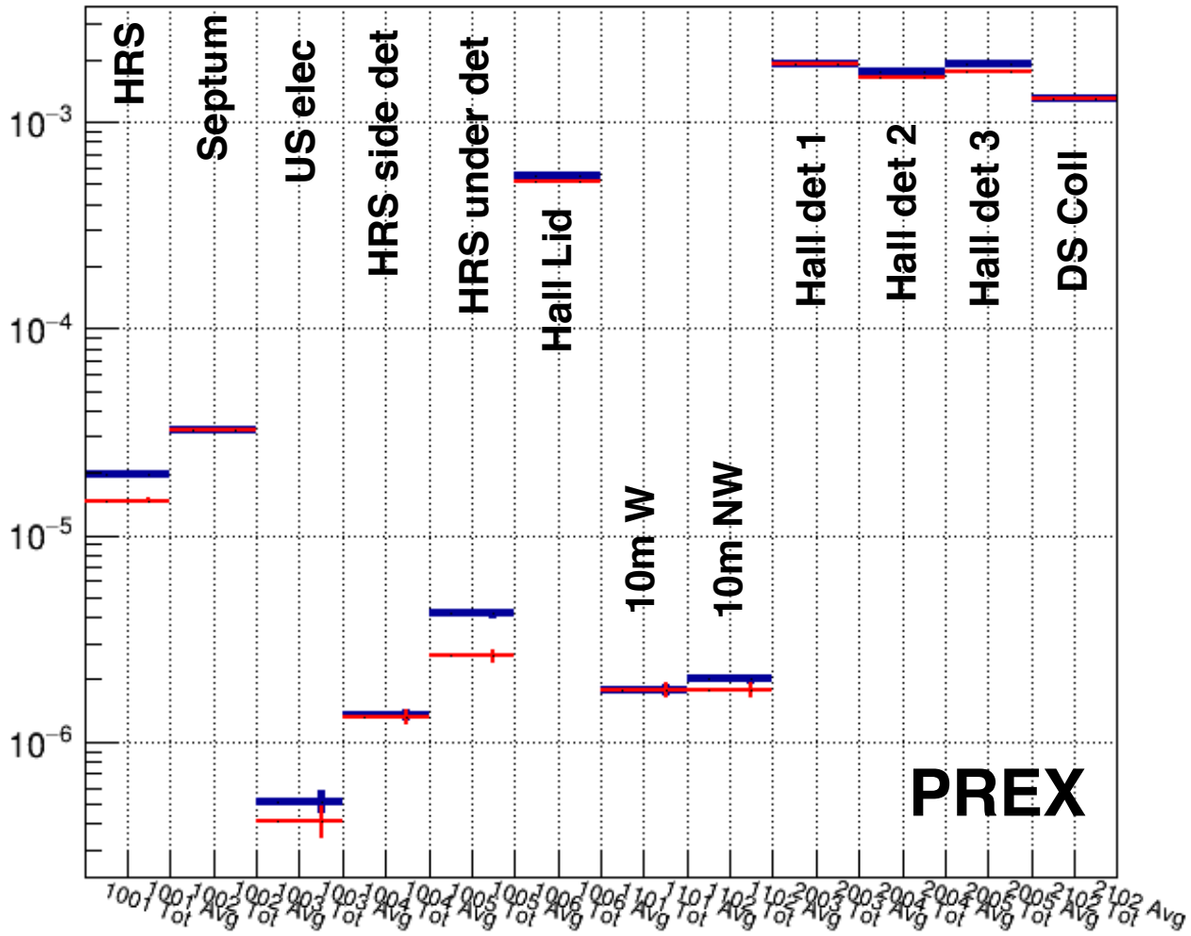
CREX Current

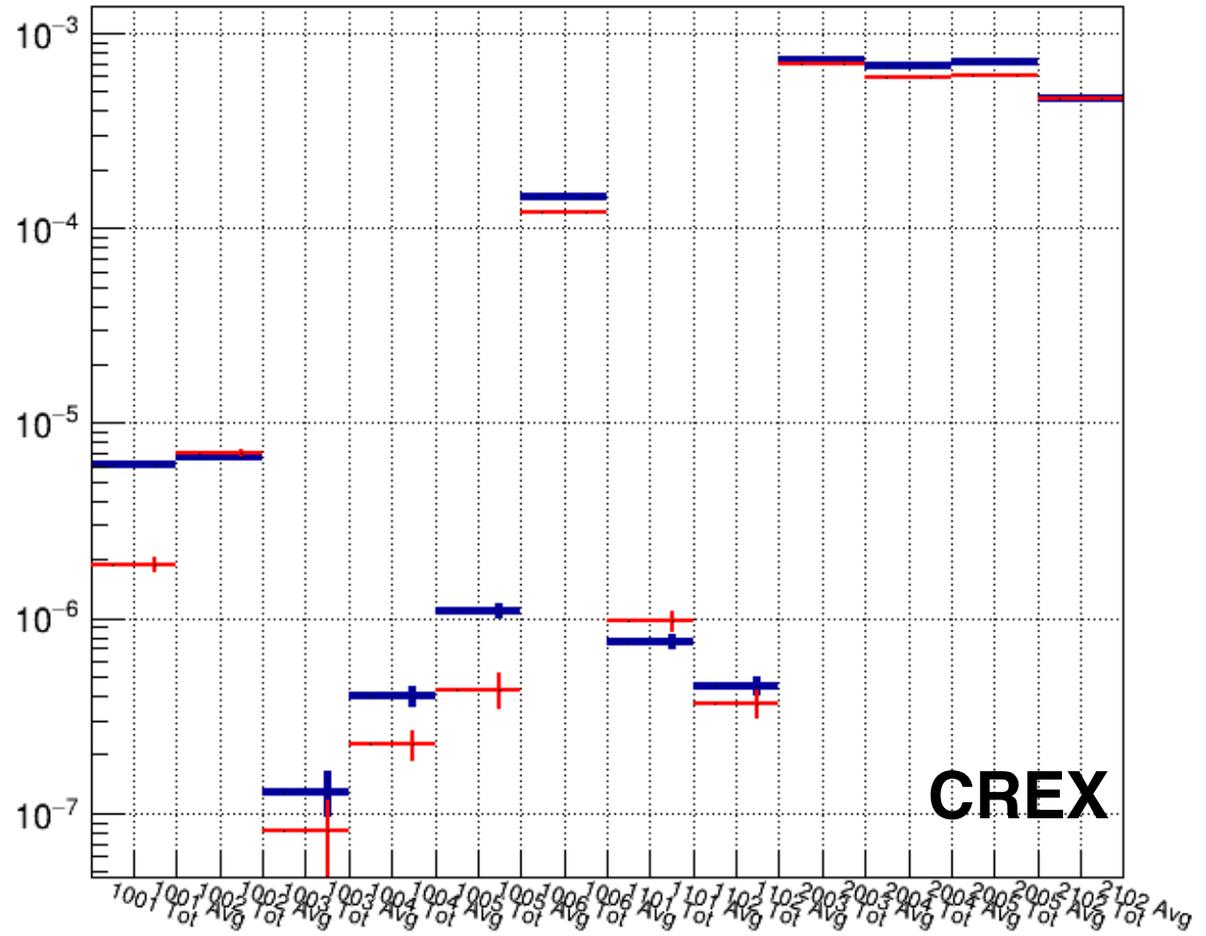


CREX Vacuum

Electrons @ 24m

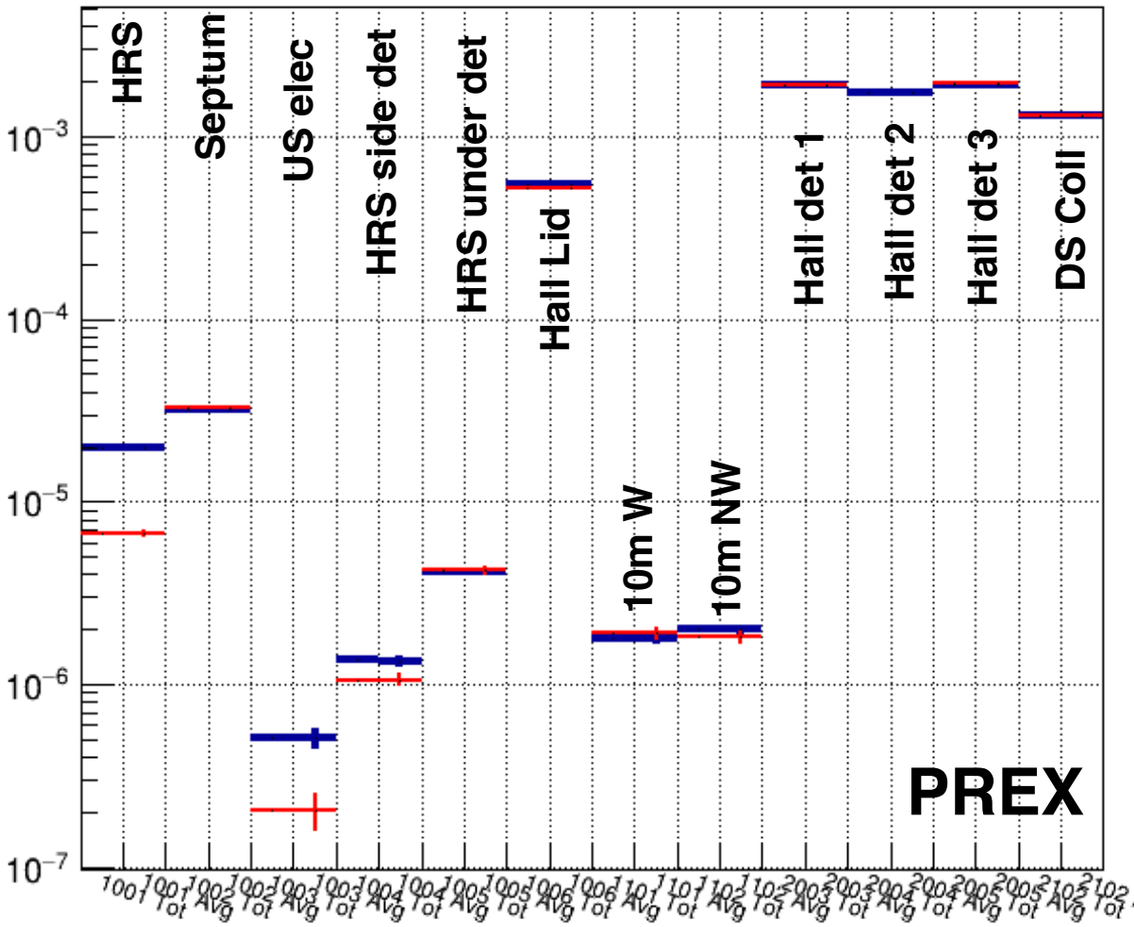
No donut

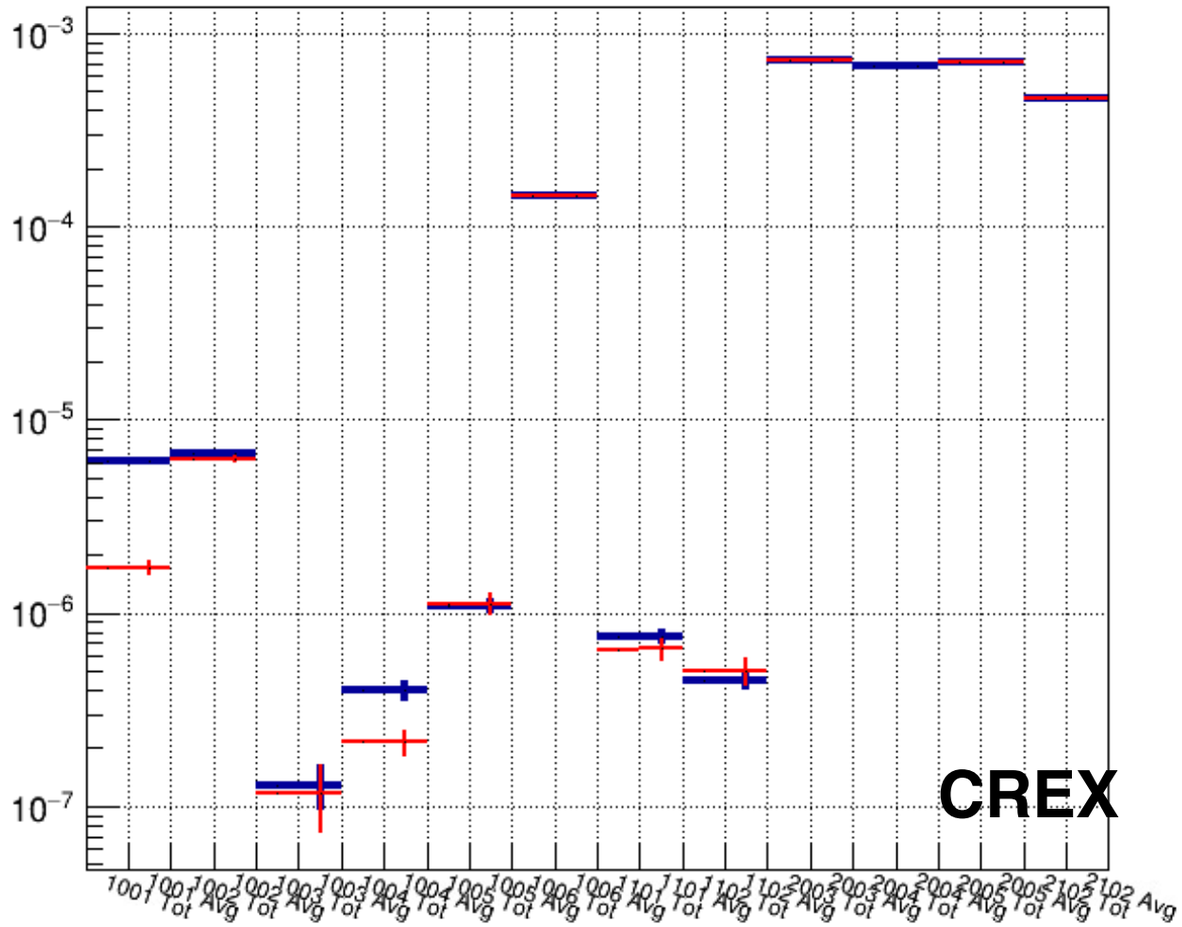




- Current in blue, comparison in red
- As expected this helps CREX quite a bit

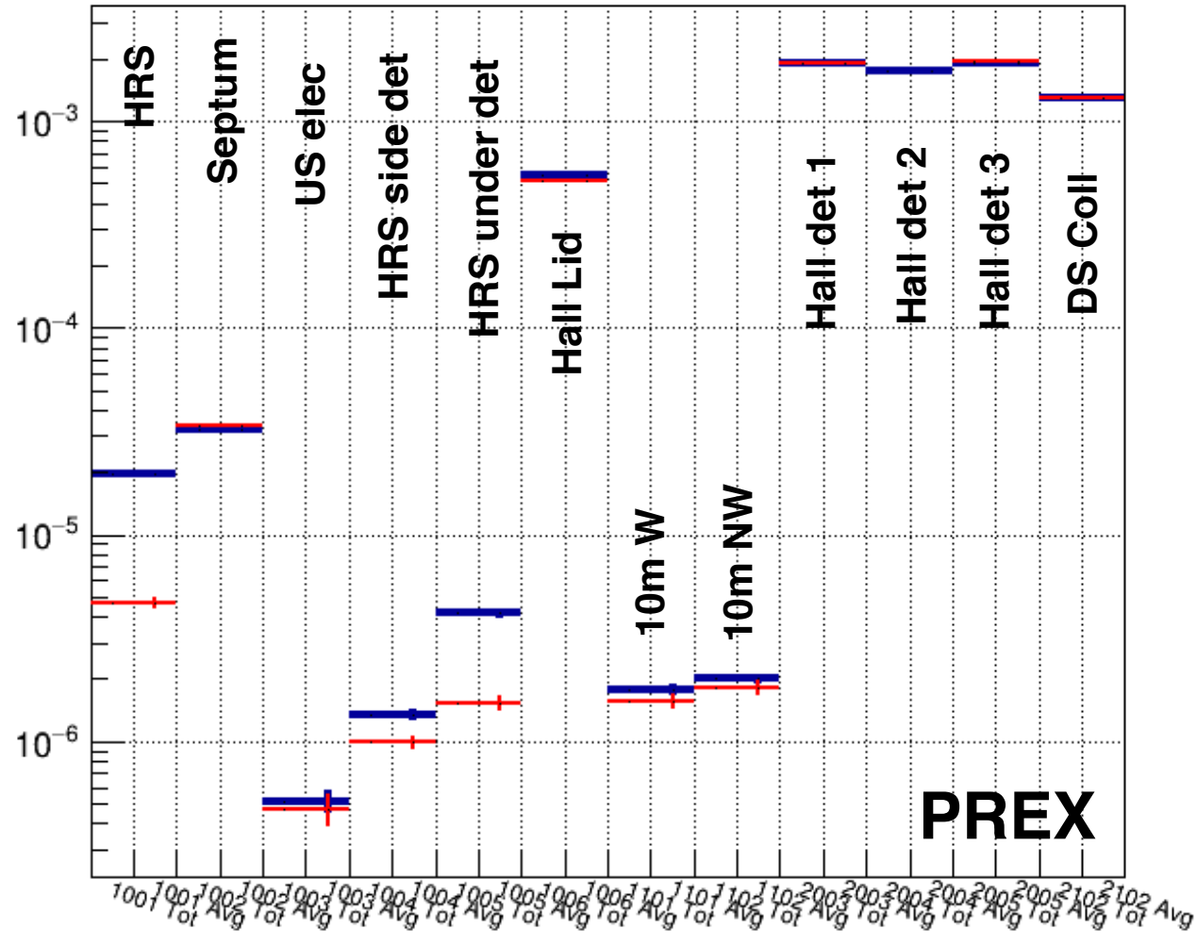
New HRS

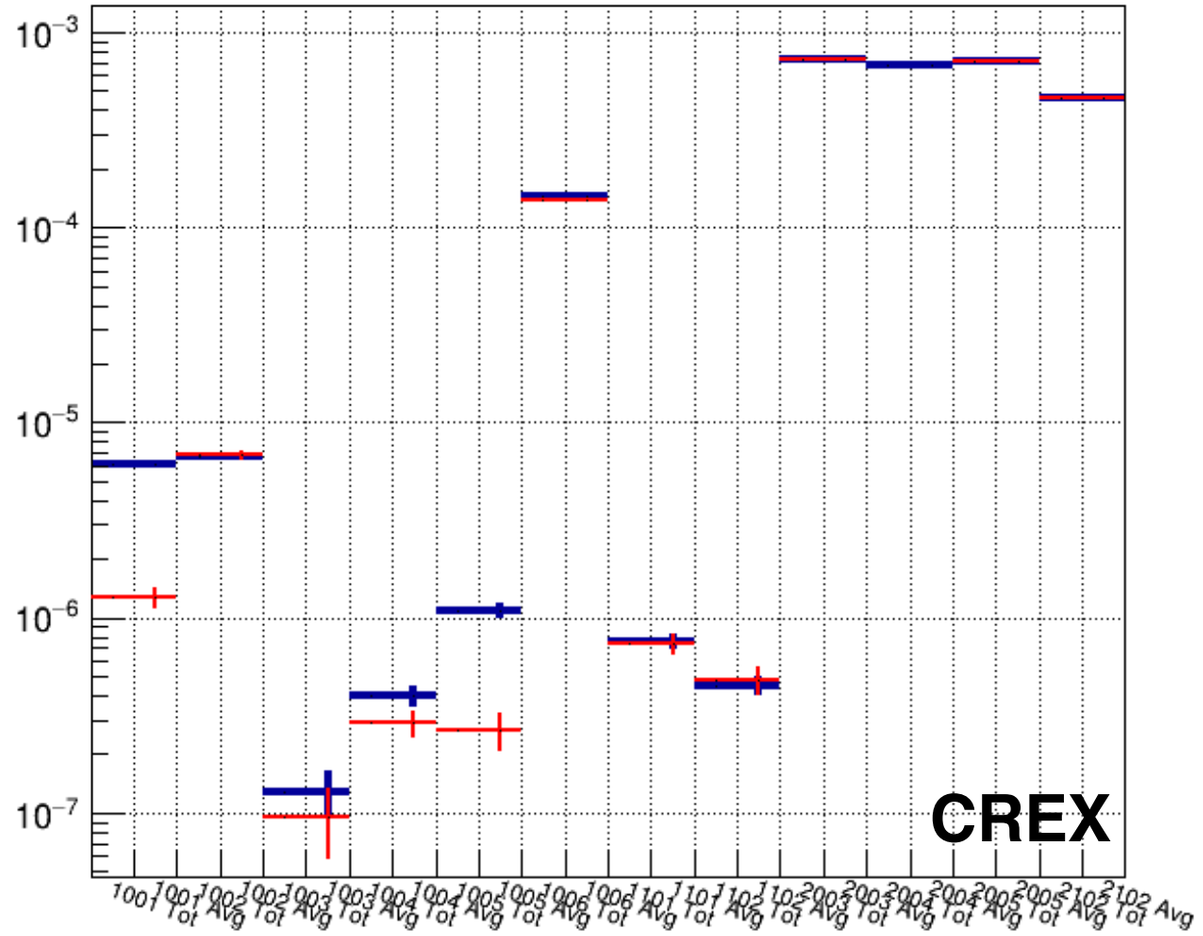




- Current in blue, comparison in red
  - had to remove the hall detector since it was overlapping with the HRS platform
- Because the HRS detector is now in the shadow of the platform legs it shows significantly smaller instantaneous levels of radiation
  - additionally this detector has ~60% of the surface area of the previous detector

New HRS + 2ftIron





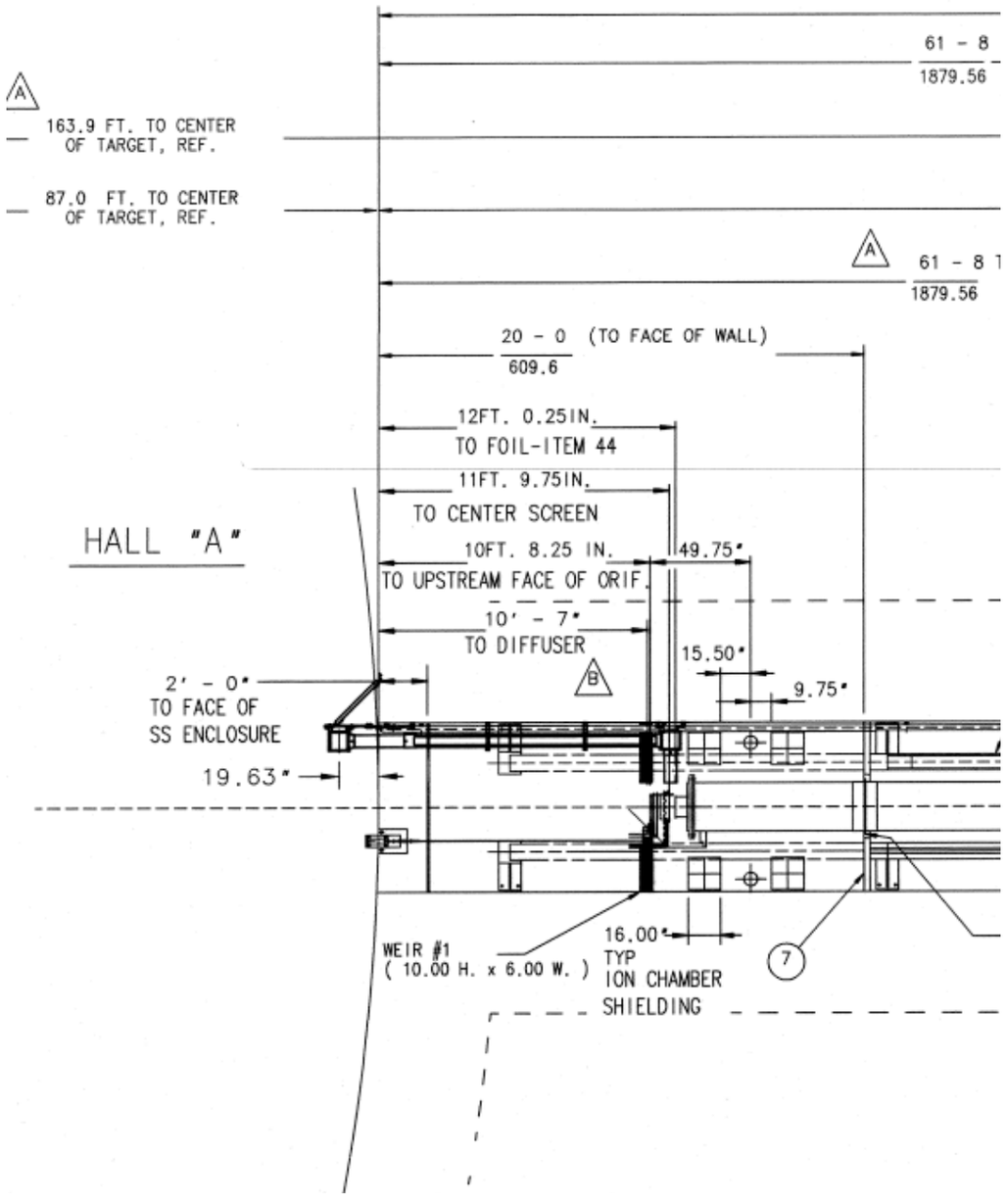
- Current in blue, comparison in red
- As before the 2ft of Iron helps with radiation seen at the platform

Previous Summary table

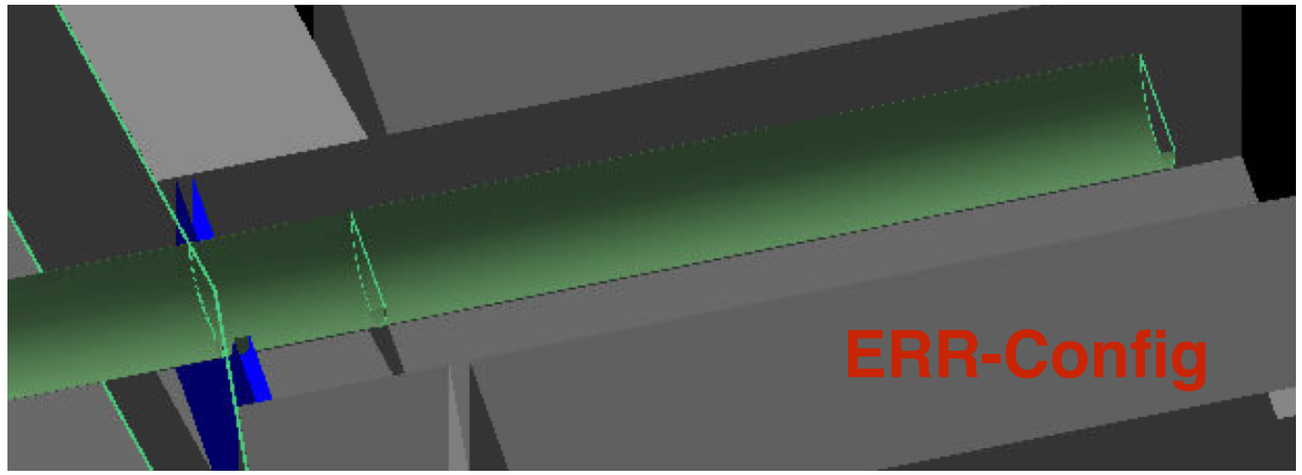
	Total NEIL/cm2	uncert	Ratio to P1	uncert	Total NEIL/cm2	uncert	Ratio to P1	uncert
PREX1 (ERR dump)	4.60E+10	1.79E+09	1.00	0.06	7.43E+10	4.92E+09	1.00	0.09
PREX1 (actual dump)	4.05E+10	1.68E+09	0.88	0.05	7.78E+10	5.39E+09	1.05	0.10
PREX2 ERR	4.96E+09	6.72E+08	0.11	0.02	1.09E+10	2.61E+09	0.15	0.04
PREX2 current	5.77E+10	5.69E+09	1.25	0.13	7.60E+10	1.85E+10	1.02	0.26
P2 with P1pipe	2.12E+10	3.38E+09	0.46	0.08	4.39E+10	1.31E+10	0.59	0.18
P2 current+4in	4.46E+10	4.64E+09	0.97	0.11	6.68E+10	1.45E+10	0.90	0.20
P2 current+Conc	2.38E+10	3.44E+09	0.52	0.08	2.76E+10	1.04E+10	0.37	0.14
P2 current+ (Conc*2)	1.54E+10	1.81E+09	0.33	0.04	1.72E+10	4.07E+09	0.23	0.06
P2 current+ (Conc*0.5)	2.70E+10	2.63E+09	0.59	0.06	2.40E+10	6.13E+09	0.32	0.09
P2 current+Poly	2.19E+10	3.09E+09	0.48	0.07	5.40E+10	1.59E+10	0.73	0.22
P2 current+4in+1ftCont	1.83E+10	2.84E+09	0.40	0.06	2.69E+10	7.95E+09	0.36	0.11
P2 current + donut shield	5.27E+10	5.61E+09	1.15	0.13	8.28E+10	1.98E+10	1.11	0.28
P2+2Pipe+2ftIron	2.30E+10	3.01E+09	0.50	0.07	1.51E+10	6.31E+09	0.20	0.09
P2+2Pipe+2ftIron+Wdonut	2.38E+10	3.10E+09	0.52	0.07	1.68E+10	5.59E+09	0.23	0.08
CREX ERR	6.73E+09	2.05E+09	0.15	0.04	1.31E+10	6.57E+09	0.18	0.09
C5 current	3.86E+10	7.80E+09	0.84	0.17	4.70E+10	1.96E+10	0.63	0.27
C5 current+4in	9.86E+09	2.61E+09	0.21	0.06	3.80E+10	2.11E+10	0.51	0.29
C5 P1pipe	7.31E+10	1.12E+10	1.59	0.25	1.06E+11	3.38E+10	1.43	0.47
C5 current+Conc	2.23E+10	5.78E+09	0.49	0.13	3.21E+10	1.65E+10	0.43	0.22
C5 current+(Conc*2)	1.73E+10	3.23E+09	0.38	0.07	2.68E+10	1.00E+10	0.36	0.14
C5 current+(Conc*0.5)	1.70E+10	3.35E+09	0.37	0.07	1.09E+10	5.20E+09	0.15	0.07
C5 current+Poly	1.86E+10	5.13E+09	0.40	0.11	1.40E+10	1.01E+10	0.19	0.14
C5 current+ 2Pipe septum	3.85E+10	8.70E+09	0.84	0.19	9.65E+10	3.52E+10	1.30	0.48
C5 current+ 4in+1ftConc	1.01E+10	3.28E+09	0.22	0.07	3.85E+10	2.35E+10	0.52	0.32
C5 current+2Pipe+donut shield	4.09E+10	7.86E+09	0.89	0.17	4.73E+10	2.41E+10	0.64	0.33
C5+2Pipe+2ftIron	1.78E+10	5.20E+09	0.39	0.11	1.00E+10	5.61E+09	0.13	0.08
C5+2Pipe+2ftIron+Wdonut	2.35E+10	6.03E+09	0.51	0.13	2.21E+10	1.30E+10	0.30	0.18

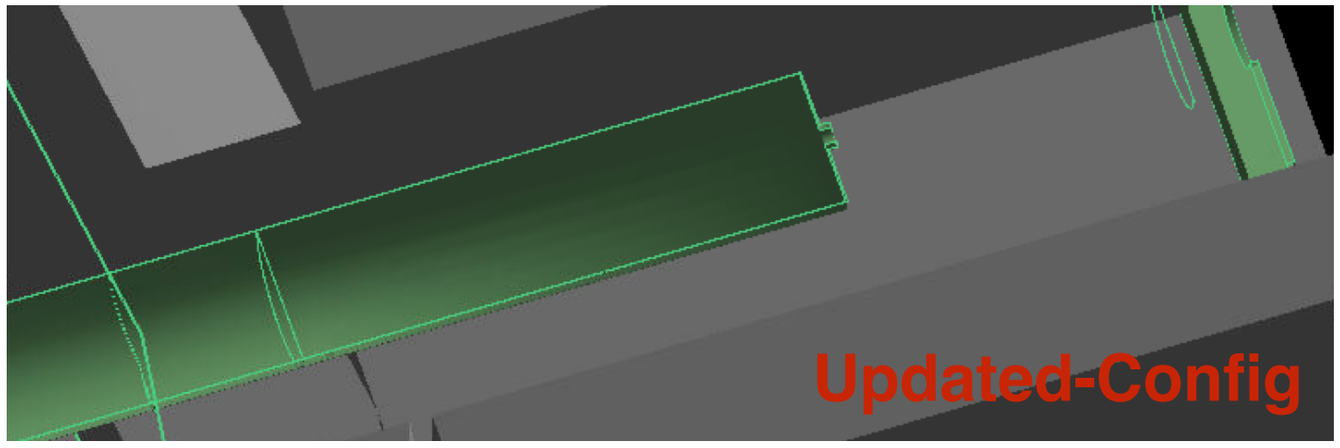
PREX 1 radiation estimation

Hall A dump configuration from Keith W. for 2010:



	ERR	Update
HRS rad [NEIL/cm2]	2.3E+11	2.1E+11





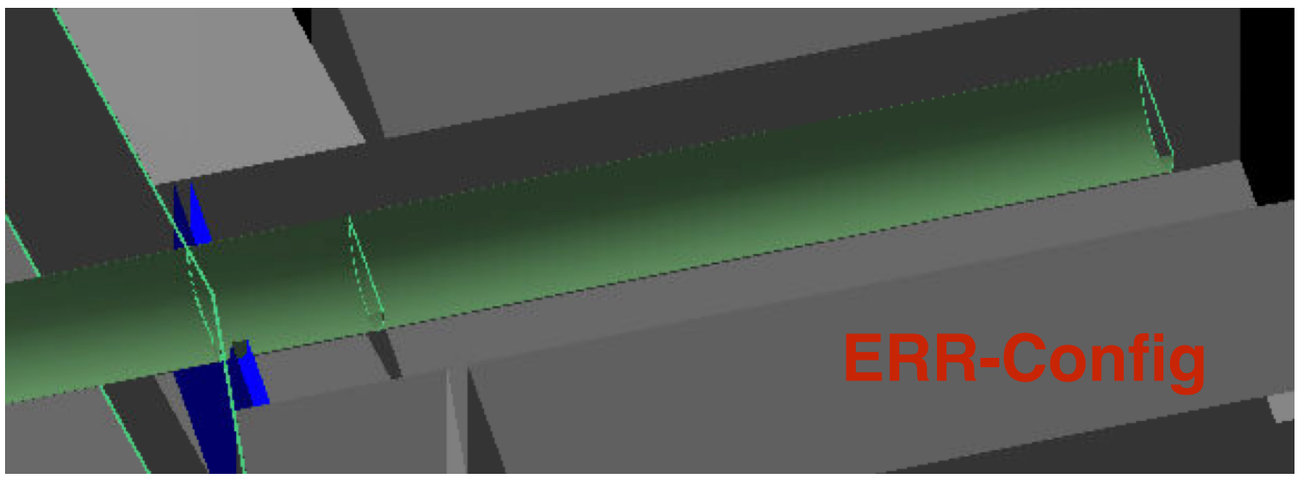
- PREX 1 estimates were done with a rudimentary dump configuration (most of the radiation to electronics came from within the hall proper)
  - The splash back from the dump was simulated by putting a stainless steel wall at the entrance of the dump tunnel
- The updated configuration with 4in aperture and the Al wall produced similar levels of radiation to the HRS platform

ERR estimates

1MeV n_{eq} / cm^2

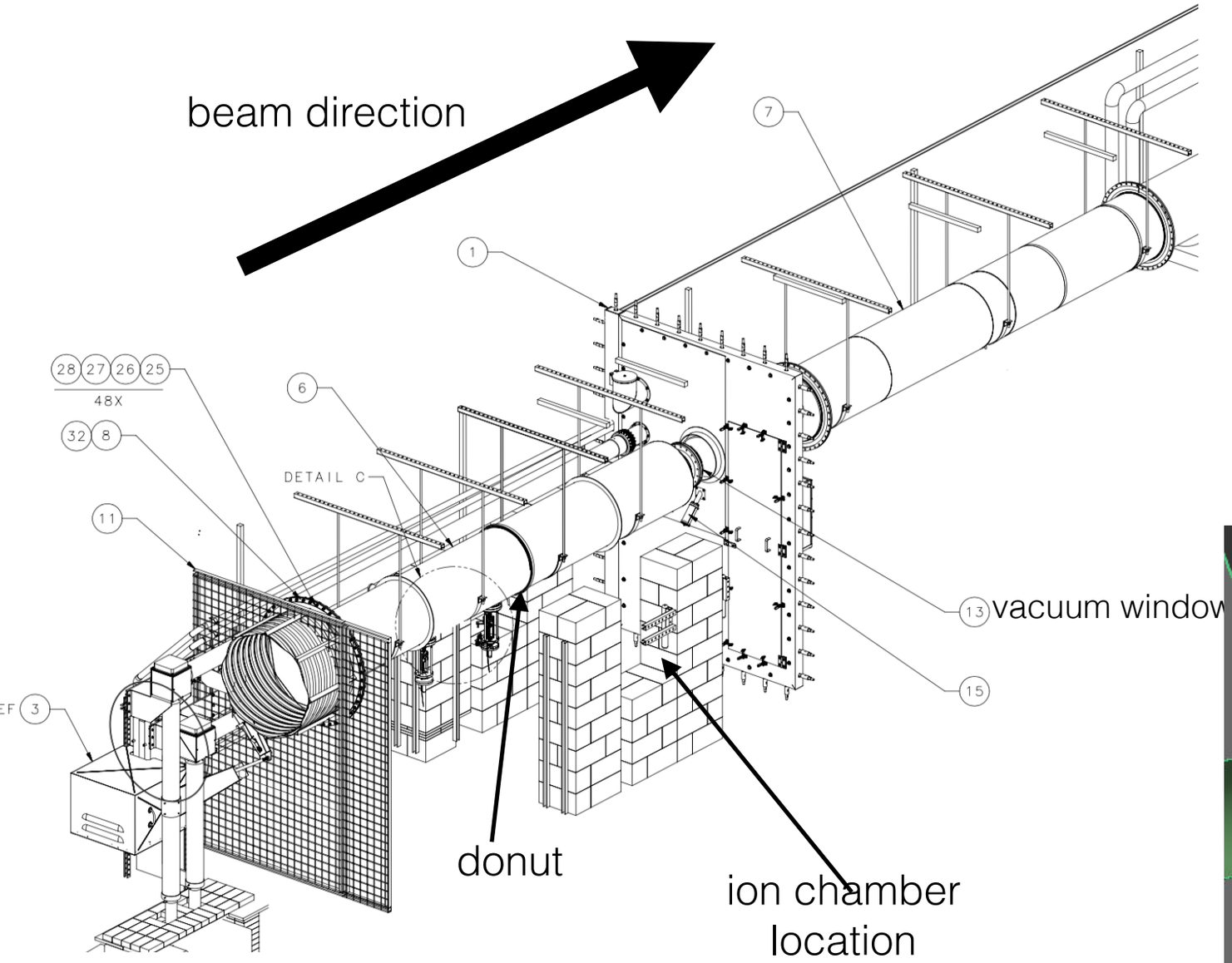
HRS power supply	PREX-I	PREX-II	CREX	P2/P1	CREX/P1	P2/H2	P2/PVDIS
neutron	1.0E+11	7.6E+09	1.5E+10	7%	20%	70%	73%
electron	1.2E+11	1.4E+10	2.1E+10	11%	12%	94%	84%
total	**2.3E+11**	**2.1E+10**	**3.6E+10**	9%	16%	83%	80%

NIEL thresholds: Semiconductor damage ~10^{13}, Optocoupler damage ~10^{11}

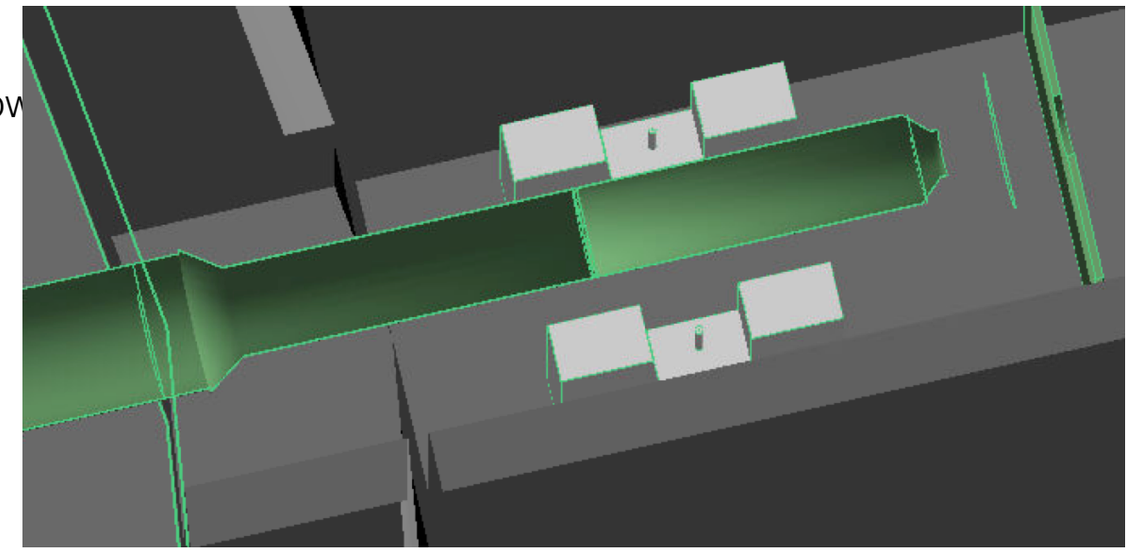


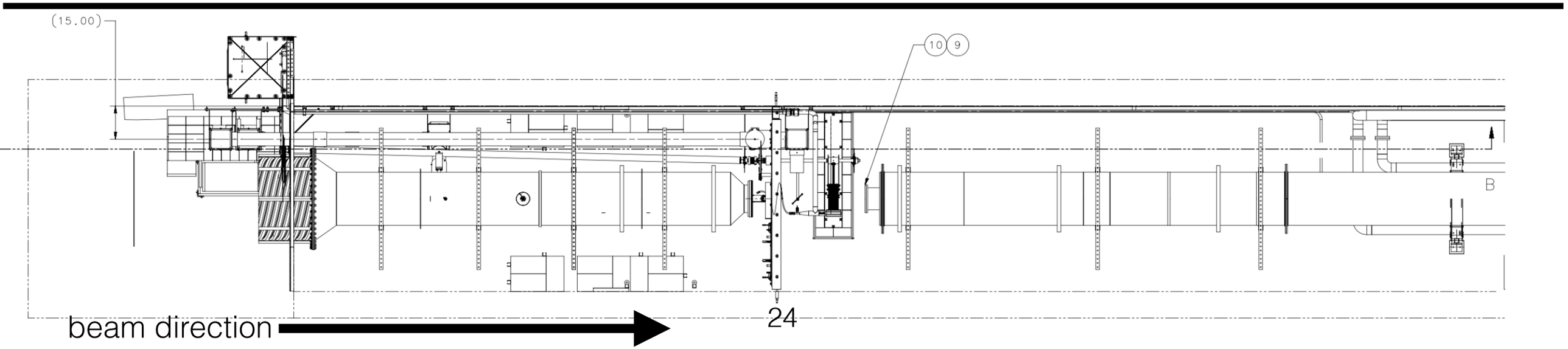
- Focus for design of PREX2 and CREX was successfully cleaning up the radiation from the target and collimator
- We used the same dump configuration for our simulations of PREX2 and CREX
  - We were unaware of changes made to the dump, so we expected our estimate to be reasonable

Current Hall A Dump configuration



- For PREX2/CREX we will not need to use the diffuser
- We implemented the major features of the current design in the simulation
  - including the 4 cm Al aperture at ~midway until the Al door

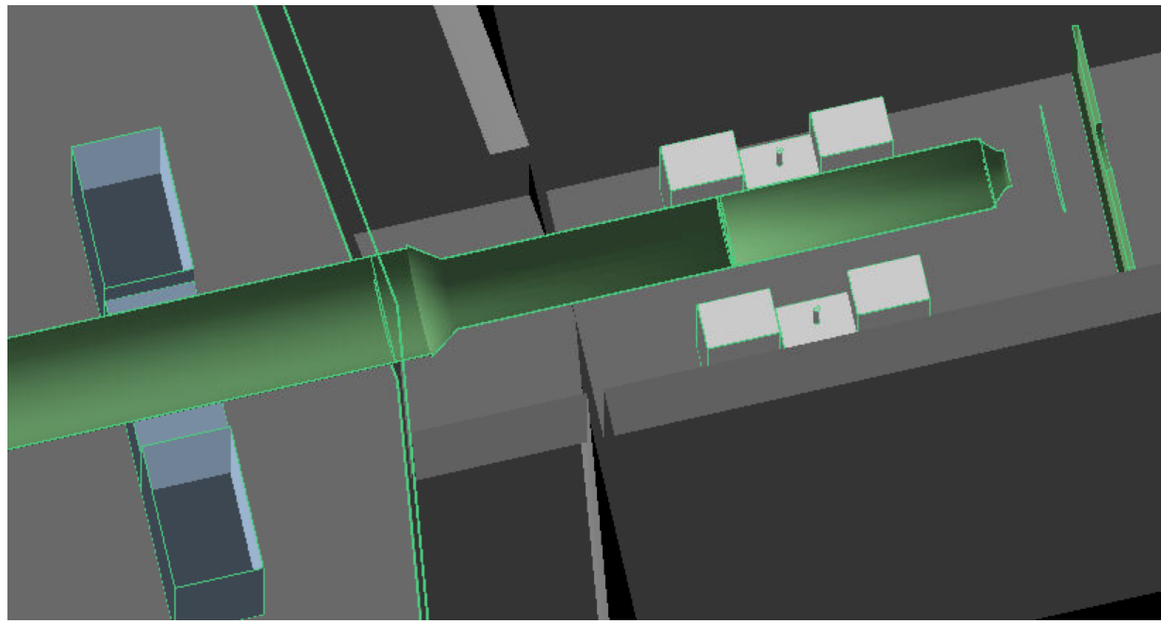


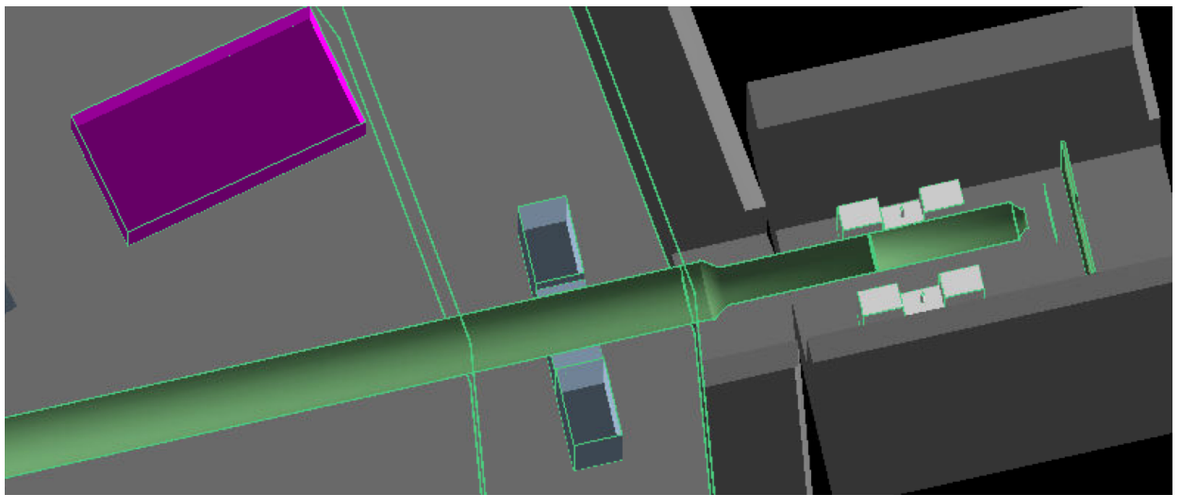


Updated PREX2 and CREX estimates

	P2/P1 (ERR)	C/P1 (ERR)	P2/P1 (now)	C/P1 (now)	C(4in)/ P1	P2(2ft)/ P1
ratio to PREX 1	0.09	0.16	1.25	0.84	0.20	0.33

- The current dump configuration presents 2 problems:
  - the neck down intercepts scattered electrons (this is a problem for PREX2)
  - the aperture intercepts significantly more electrons than in the previous configuration (part of the problem for PREX2, the big issue for CREX)
- Increasing the aperture by ~6 cm (to the old 4in level) the CREX problem is basically solved
- Adding 2 feet of concrete to block the entire line of sight to the HRS detector reduces the PREX2 dose significantly
  - This base shielding design would be possible within the geometrical constraints inside the hall @12.5 deg





Conclusions and optimization plans

- The current dump configuration has the potential to produce significant radiation doses to the HRS electronics platform

- We have identified a 0th order mitigation scheme

  - optimization will follow (material, position, size)

- We plan to add the rest of the dump in the simulation to ensure nothing else could cause an issue

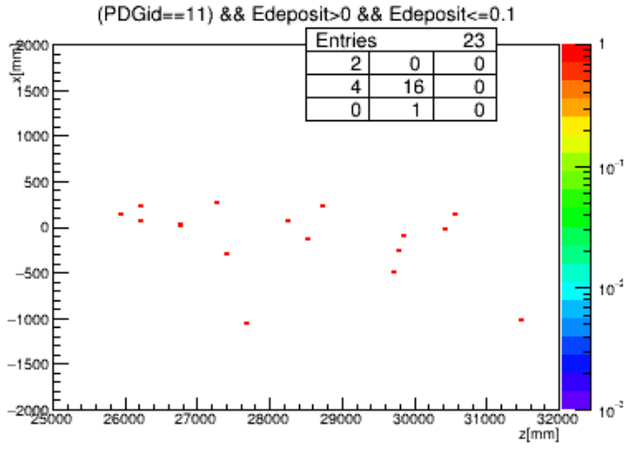
Radiation - entire run values

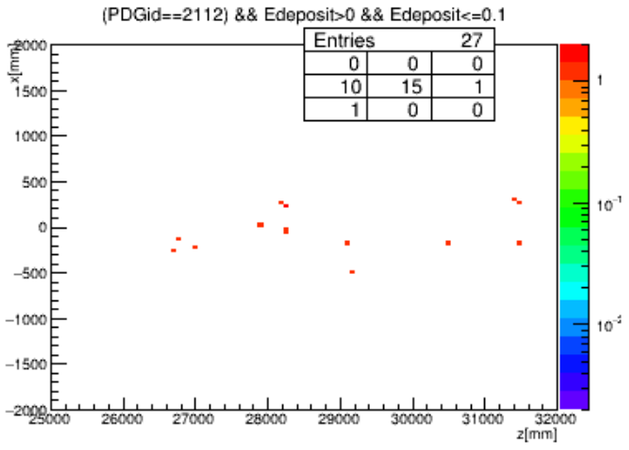
	HRS detector				Under detector			
	Total NEIL/cm2	uncert	Ratio to P1	uncert	Total NEIL/cm2	uncert	Ratio to P1	uncert
PREX1 (ERR dump)	4.60E+10	1.79E+09	1.00	0.06	7.43E+10	4.92E+09	1.00	0.09
PREX1 (actual dump)	4.05E+10	1.68E+09	0.88	0.05	7.78E+10	5.39E+09	1.05	0.10
PREX2 ERR	4.96E+09	6.72E+08	0.11	0.02	1.09E+10	2.61E+09	0.15	0.04
PREX2 current	5.77E+10	5.69E+09	1.25	0.13	7.60E+10	1.85E+10	1.02	0.26
P2 with P1pipe	2.12E+10	3.38E+09	0.46	0.08	4.39E+10	1.31E+10	0.59	0.18
P2 current+4in	4.46E+10	4.64E+09	0.97	0.11	6.68E+10	1.45E+10	0.90	0.20
P2 current+Conc	2.38E+10	3.44E+09	0.52	0.08	2.76E+10	1.04E+10	0.37	0.14
P2 current+ (Conc*2)	1.54E+10	1.81E+09	0.33	0.04	1.72E+10	4.07E+09	0.23	0.06
P2 current+ (Conc*0.5)	2.70E+10	2.63E+09	0.59	0.06	2.40E+10	6.13E+09	0.32	0.09
P2 current+Poly	2.19E+10	3.09E+09	0.48	0.07	5.40E+10	1.59E+10	0.73	0.22
P2 current+4in+1ftCont	1.83E+10	2.84E+09	0.40	0.06	2.69E+10	7.95E+09	0.36	0.11
P2 current + donut shield	5.27E+10	5.61E+09	1.15	0.13	8.28E+10	1.98E+10	1.11	0.28
CREX ERR	6.73E+09	2.05E+09	0.15	0.04	1.31E+10	6.57E+09	0.18	0.09
C5 current	3.86E+10	7.80E+09	0.84	0.17	4.70E+10	1.96E+10	0.63	0.27
C5 current+4in	9.86E+09	2.61E+09	0.21	0.06	3.80E+10	2.11E+10	0.51	0.29
C5 P1pipe	7.31E+10	1.12E+10	1.59	0.25	1.06E+11	3.38E+10	1.43	0.47
C5 current+Conc	2.23E+10	5.78E+09	0.49	0.13	3.21E+10	1.65E+10	0.43	0.22
C5 current+(Conc*2)	1.73E+10	3.23E+09	0.38	0.07	2.68E+10	1.00E+10	0.36	0.14
C5 current+(Conc*0.5)	1.70E+10	3.35E+09	0.37	0.07	1.09E+10	5.20E+09	0.15	0.07
C5 current+Poly	1.86E+10	5.13E+09	0.40	0.11	1.40E+10	1.01E+10	0.19	0.14
C5 current+ 2Pipe septum	3.85E+10	8.70E+09	0.84	0.19	9.65E+10	3.52E+10	1.30	0.48
C5 current+ 4in+1ftConc	1.01E+10	3.28E+09	0.22	0.07	3.85E+10	2.35E+10	0.52	0.32
C5 current+2Pipe+donut shield	4.09E+10	7.86E+09	0.89	0.17	4.73E+10	2.41E+10	0.64	0.33

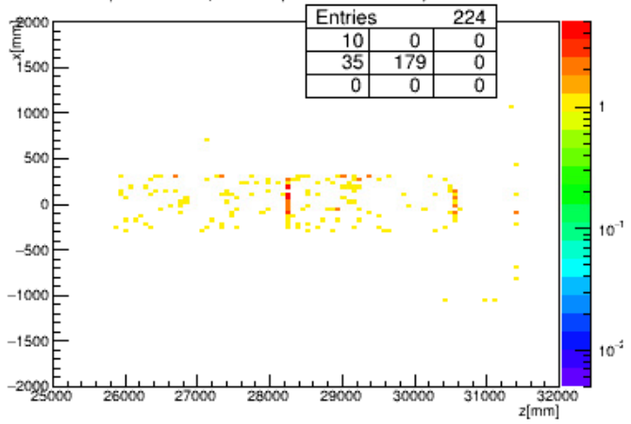
Area for HRS det: 4e5 cm^2
Area for Under det: 6e4 cm^2

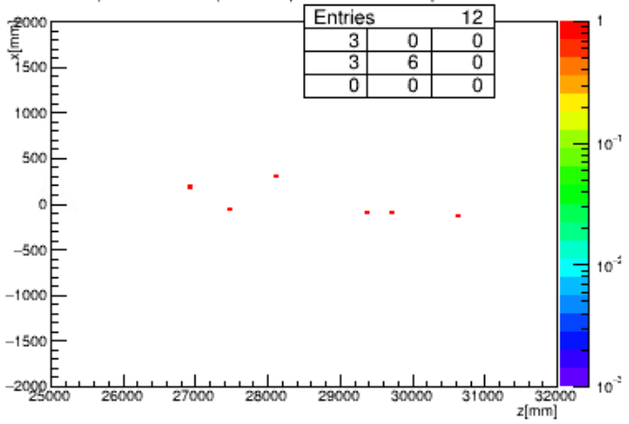
PREX2 - Under HRS detector

current setup

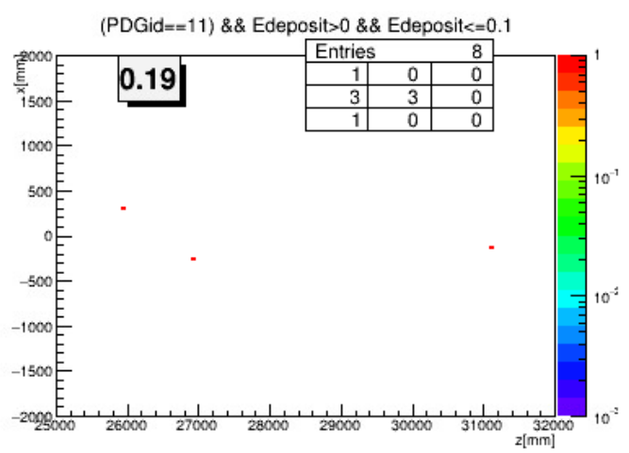


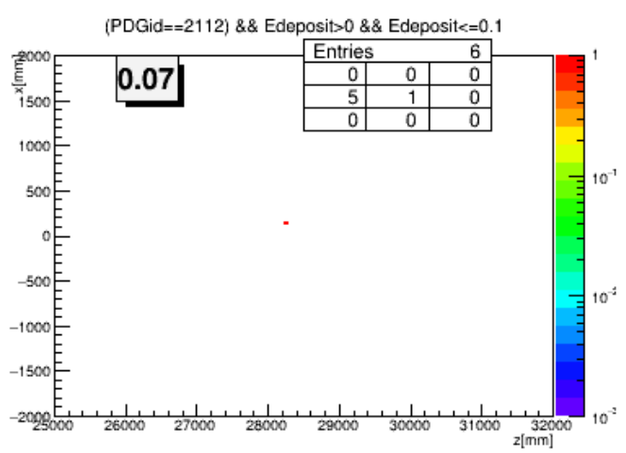


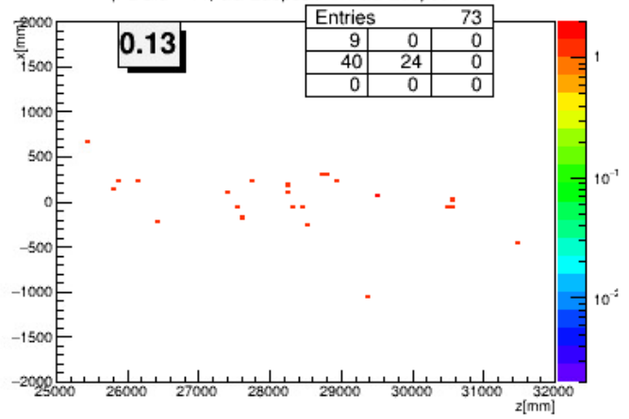


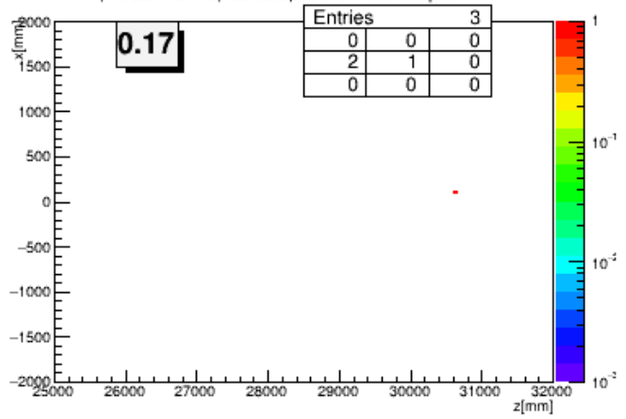


current setup + 1 ft Concrete



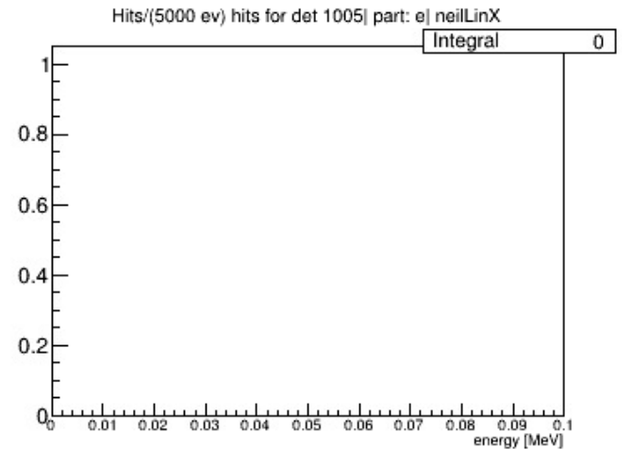


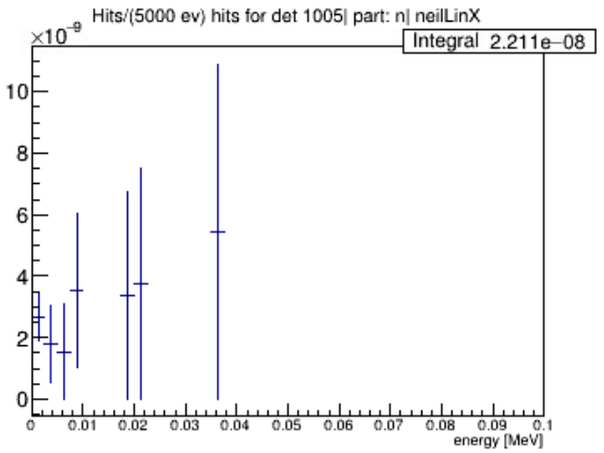


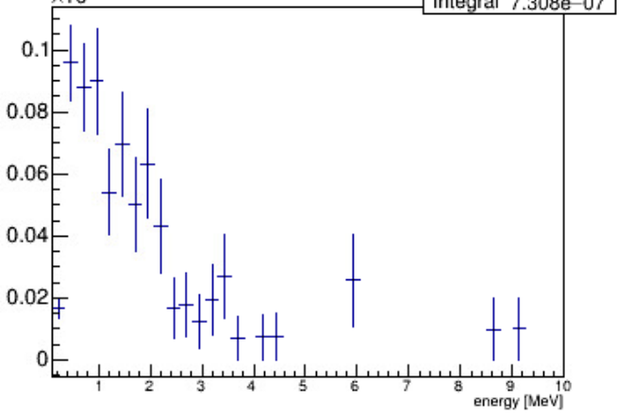


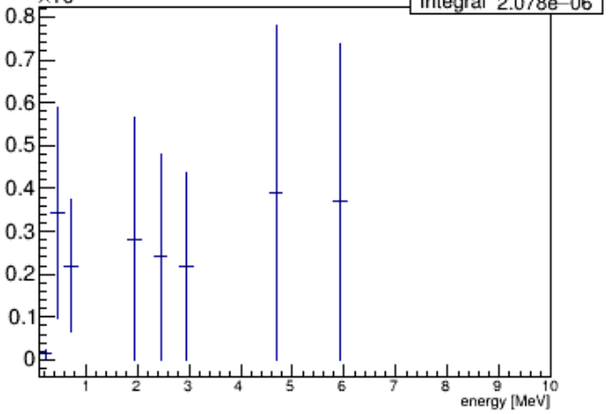
PREX2 - Under HRS detector

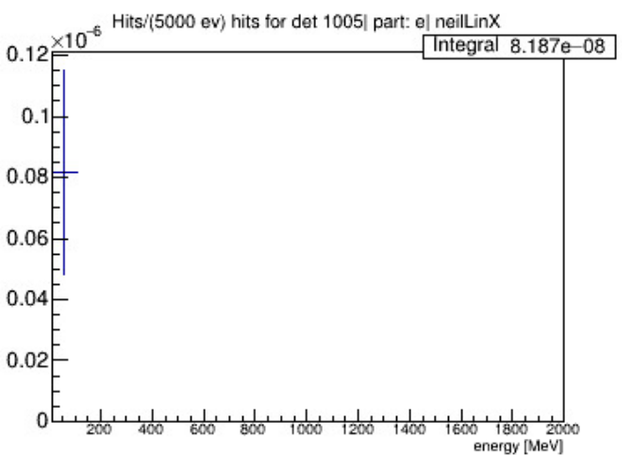
current setup

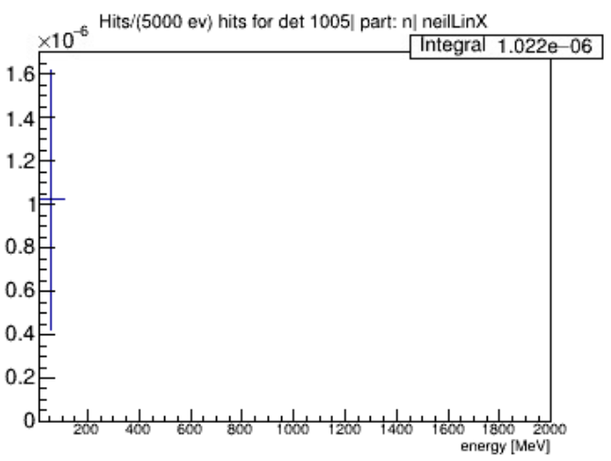




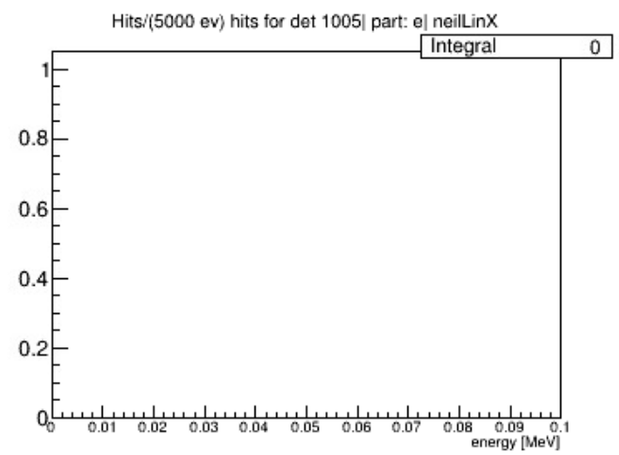


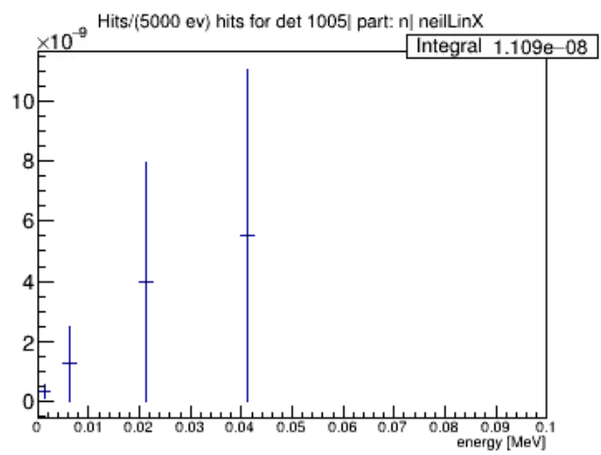


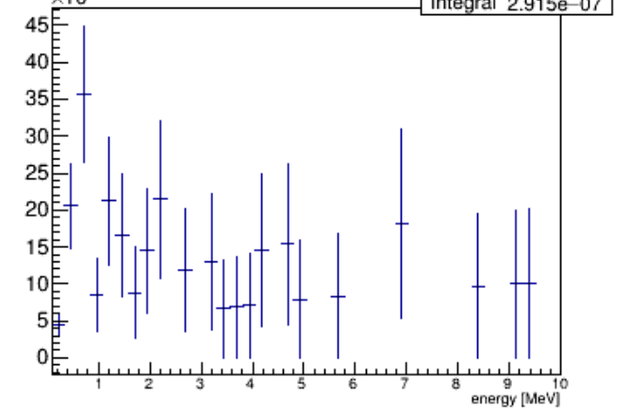


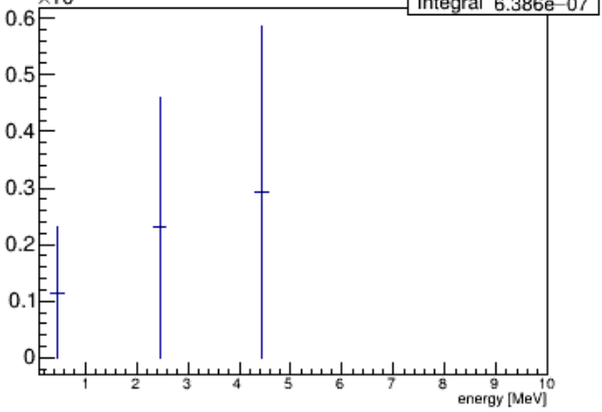


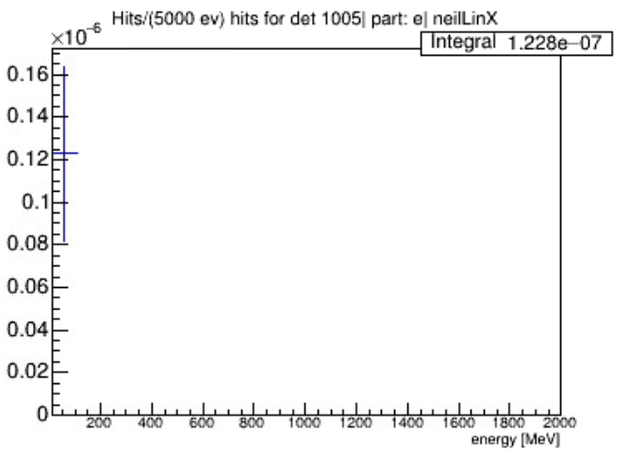
current setup + 1 ft Concrete

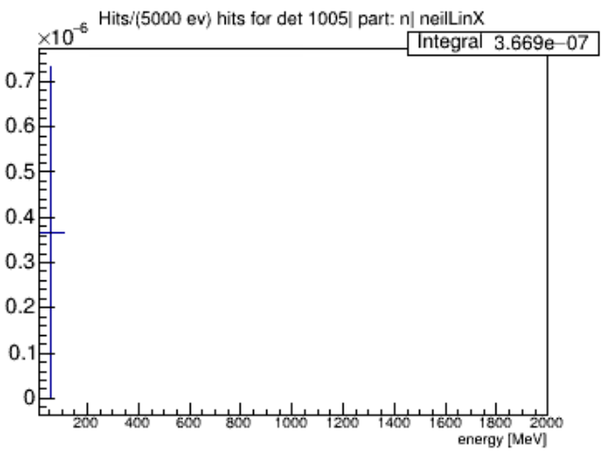






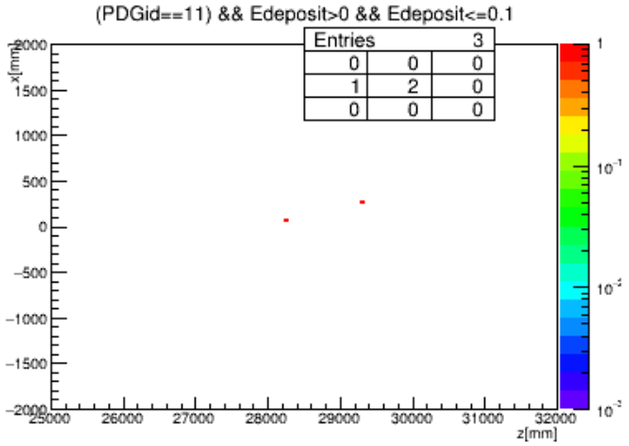


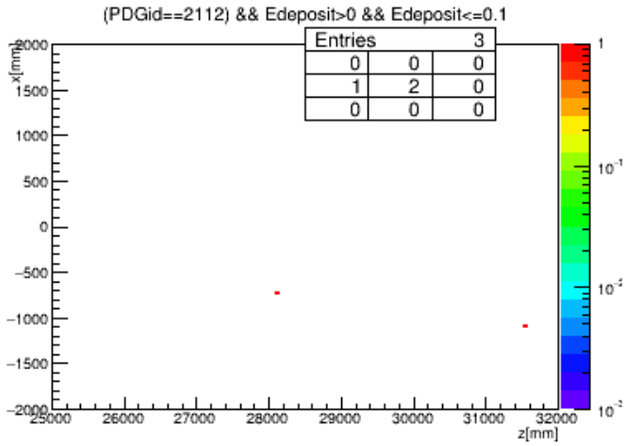


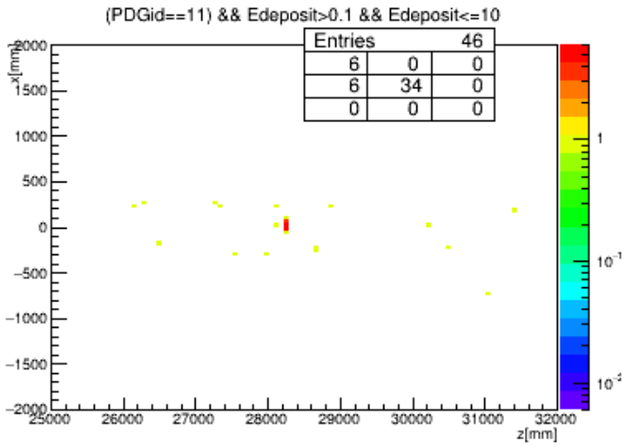


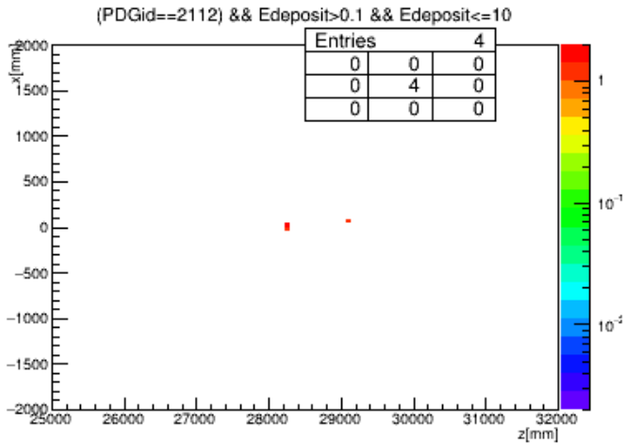
CREX - Under HRS detector

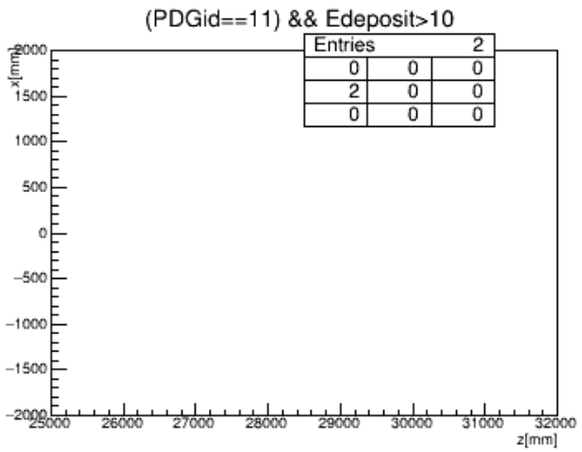
current setup

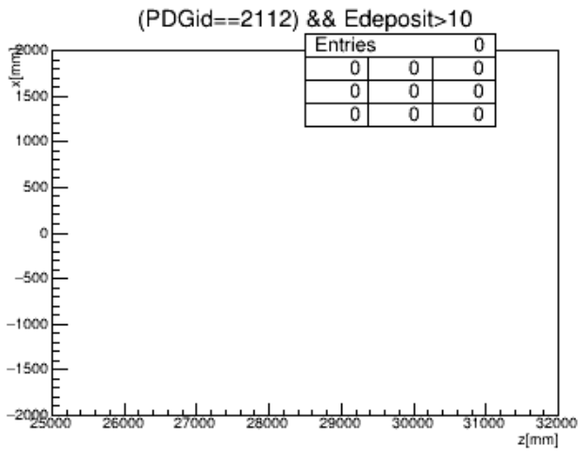




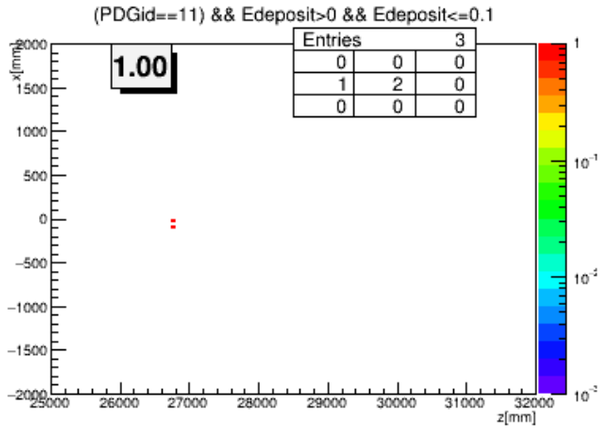


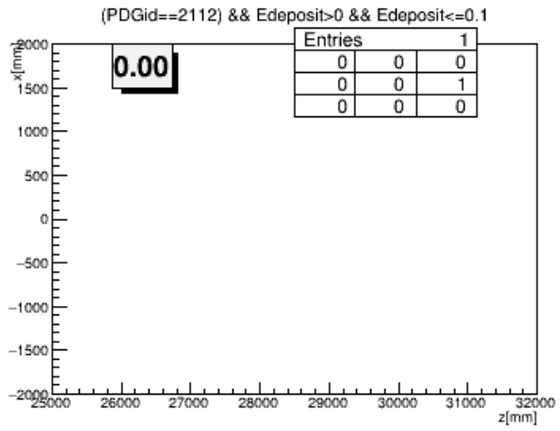


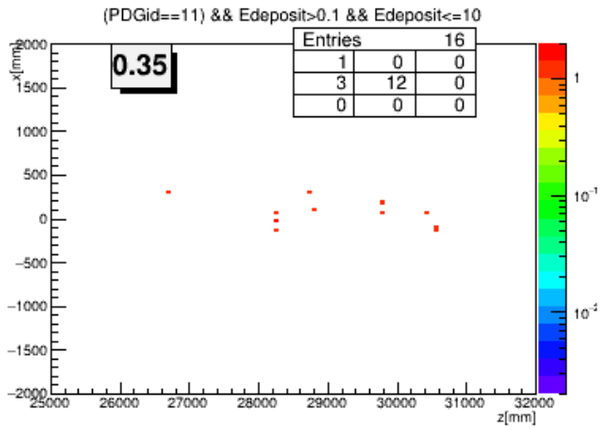


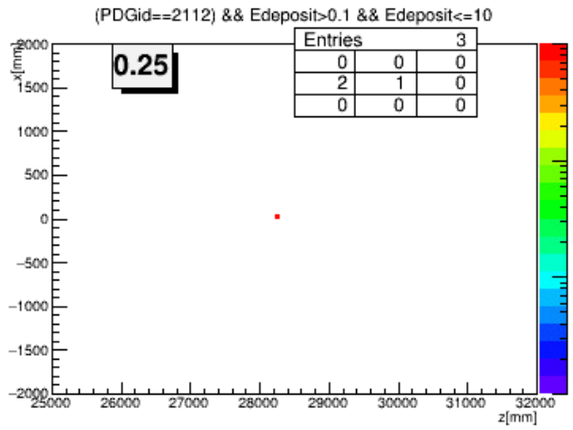


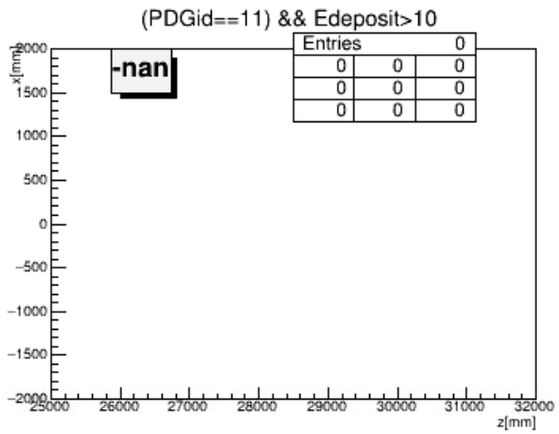
current setup + 1 ft Concrete

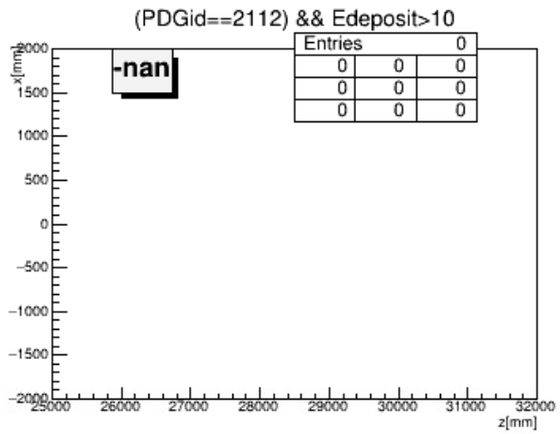






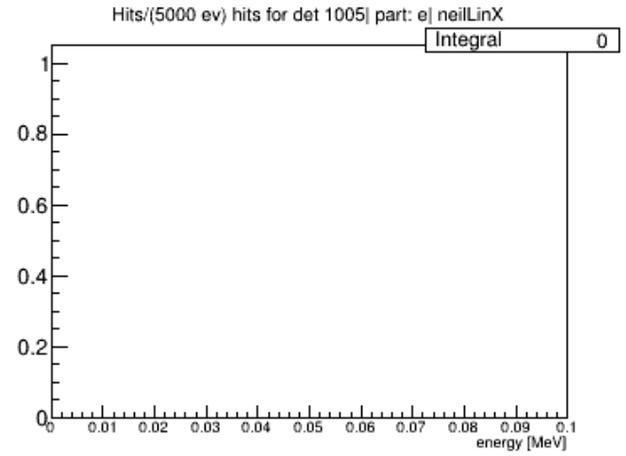


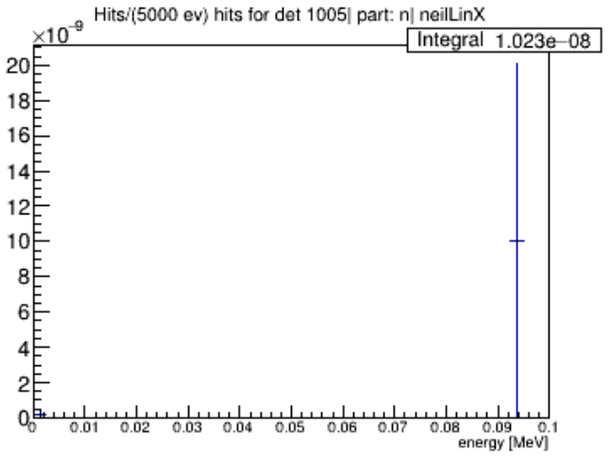


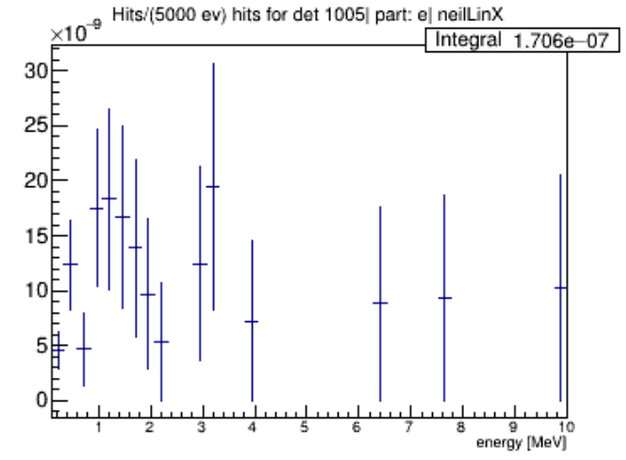


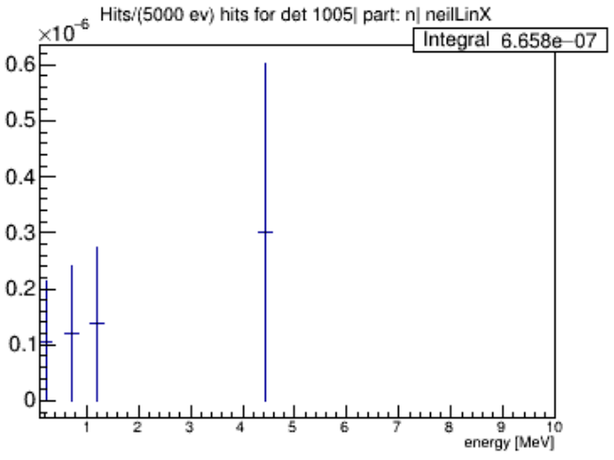
CREX - Under HRS detector

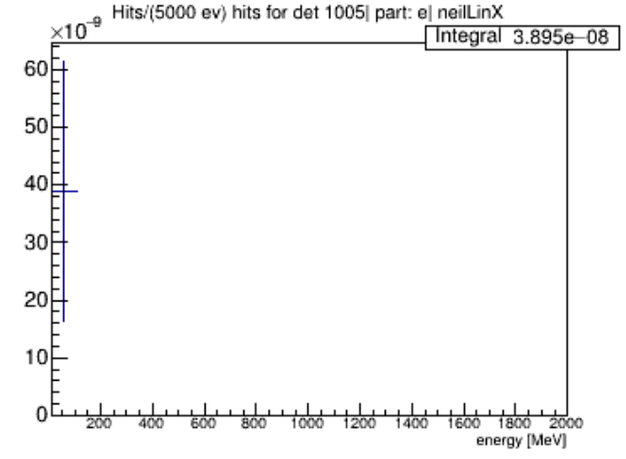
current setup

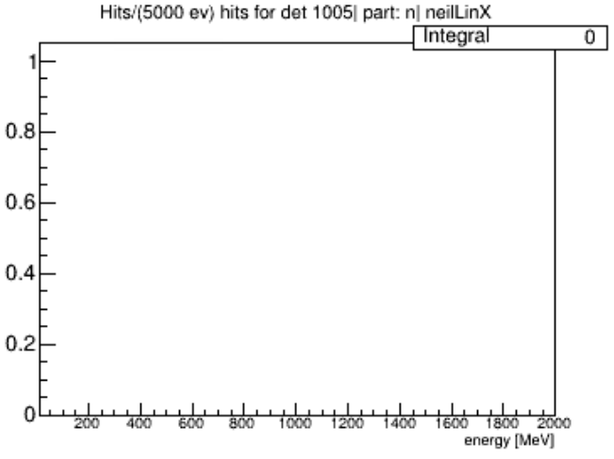




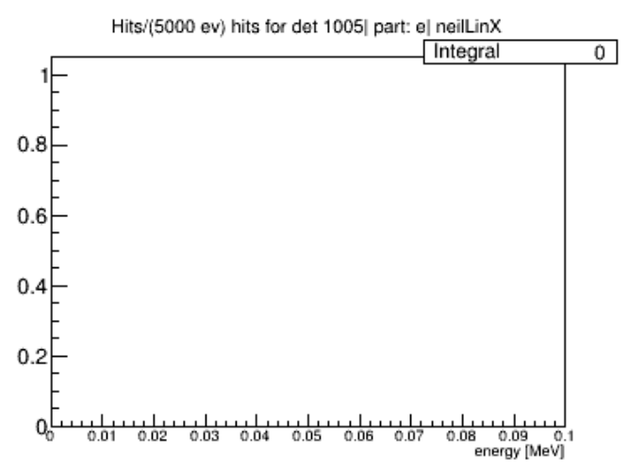


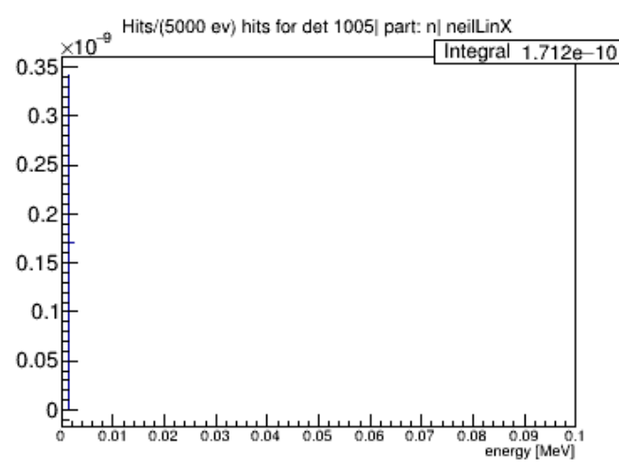


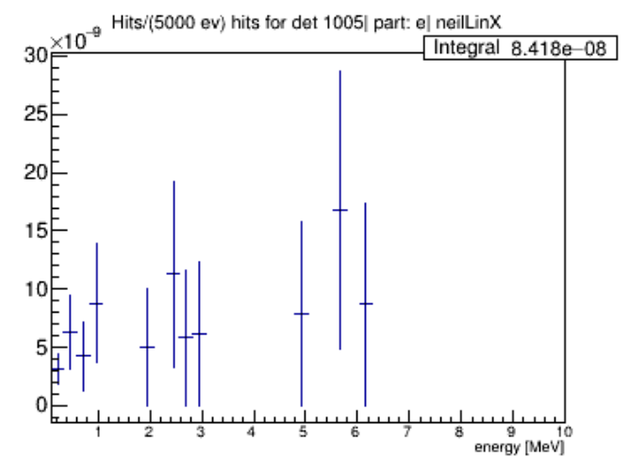


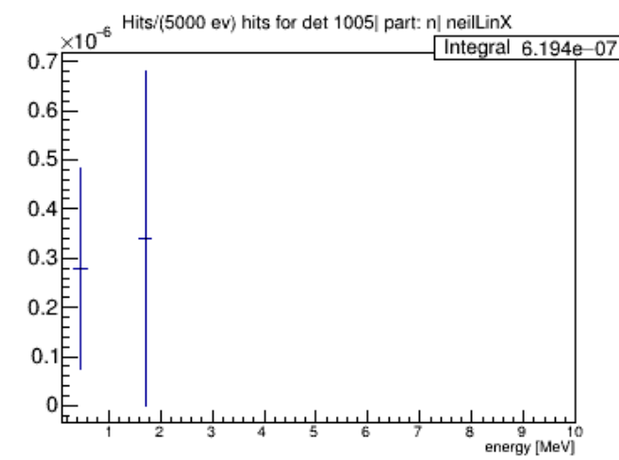


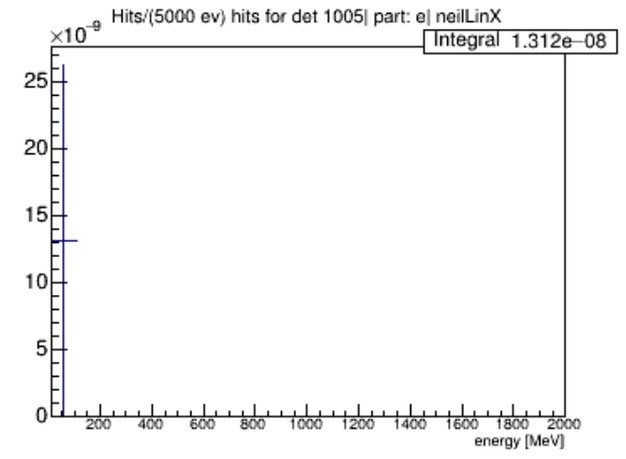
current setup + 4 in donut

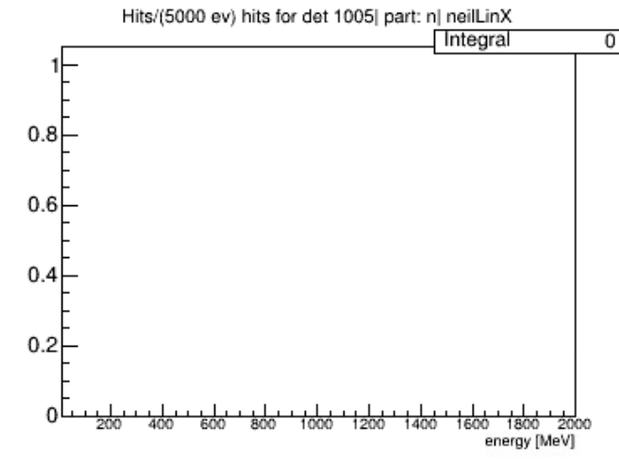






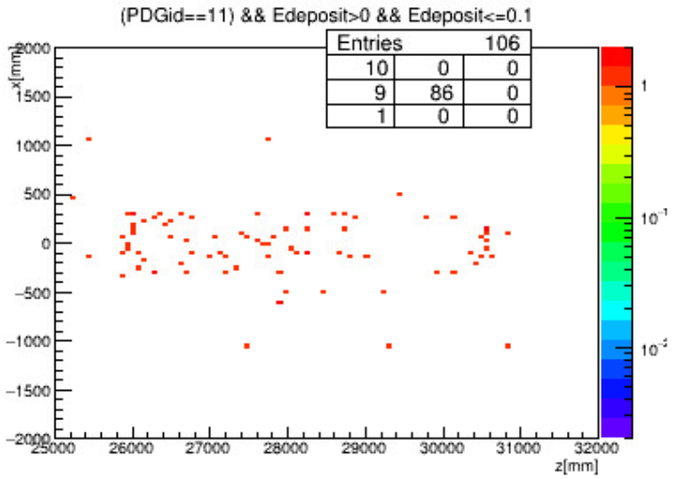




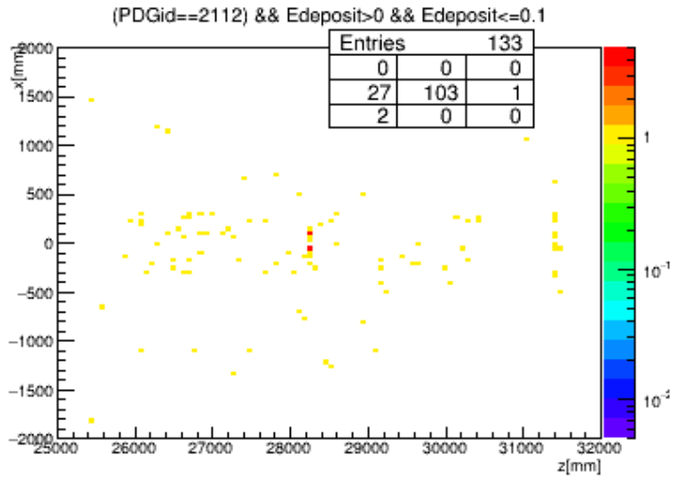


PREX2 - current dump

electrons



neutrons



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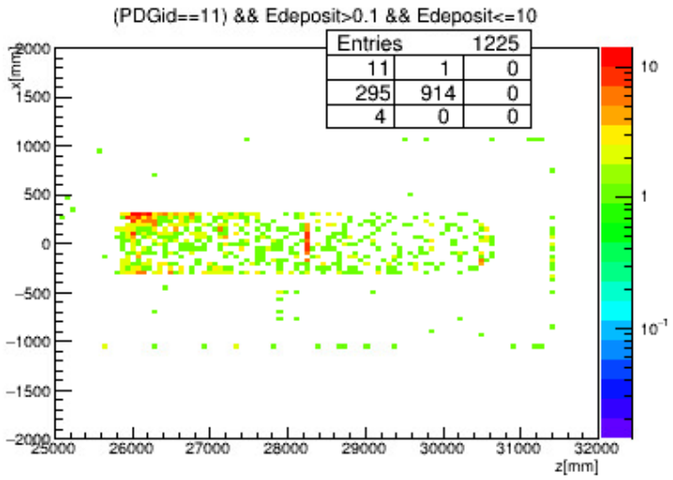

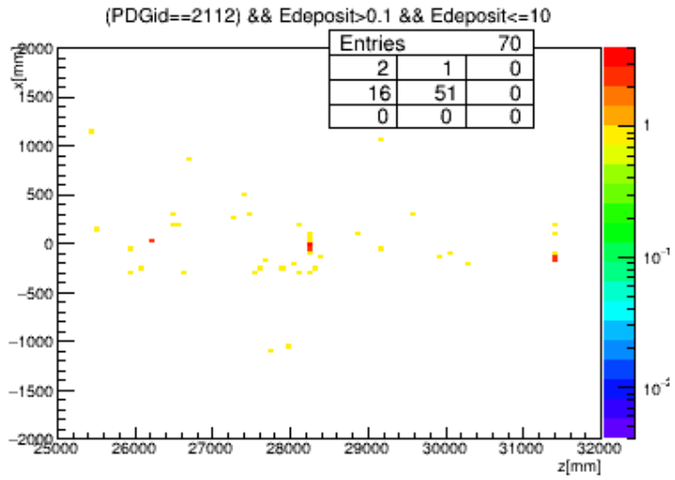

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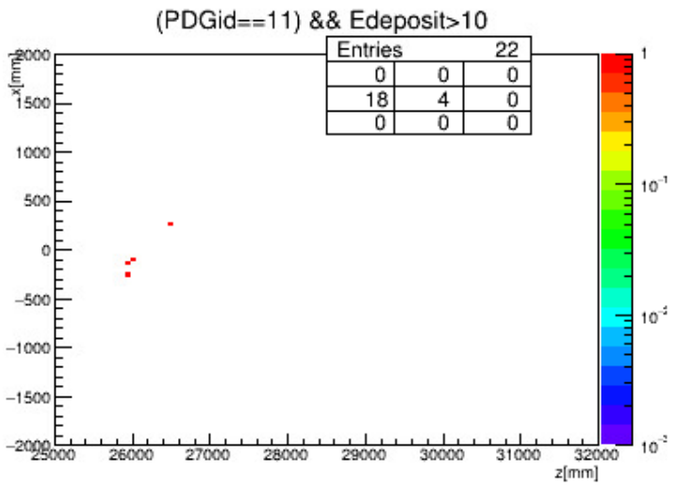
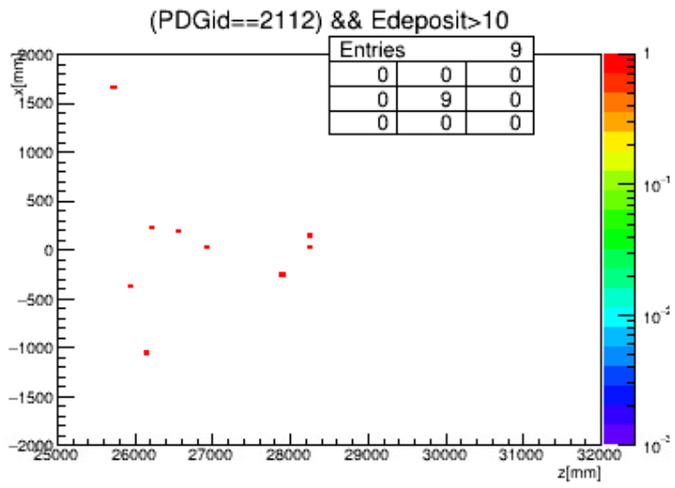
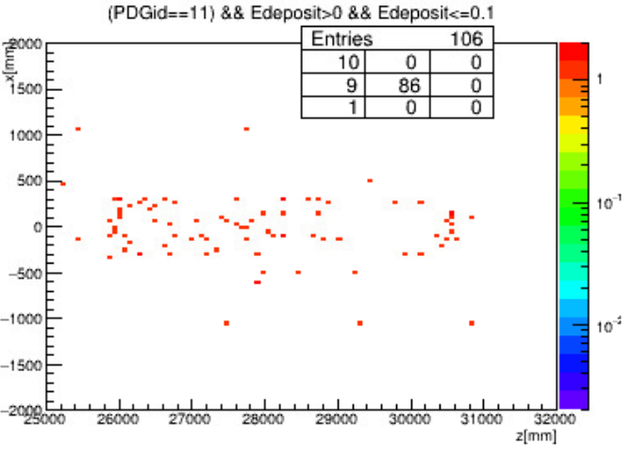


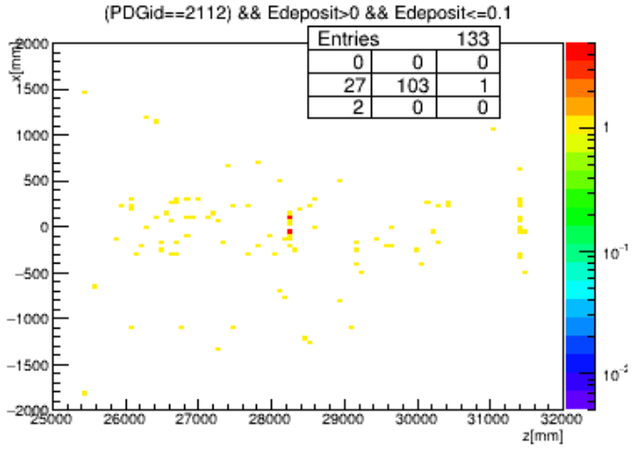


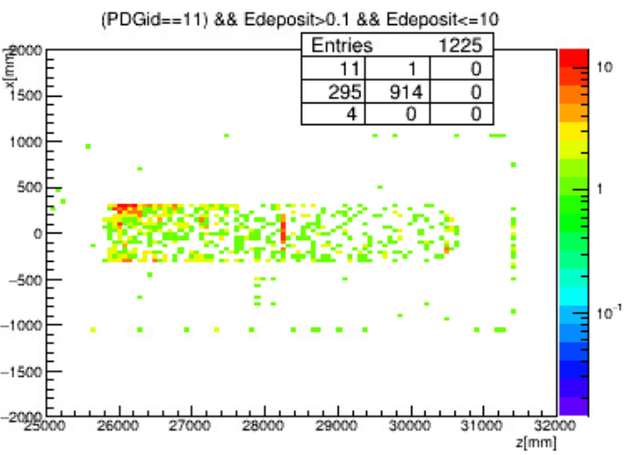
10<E MeV

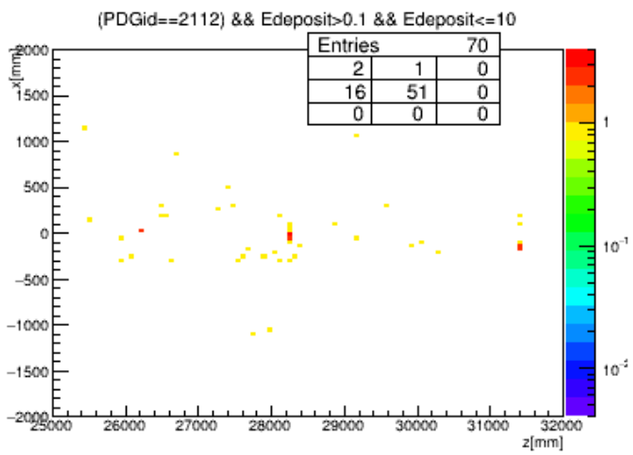
PREX2 - comparison

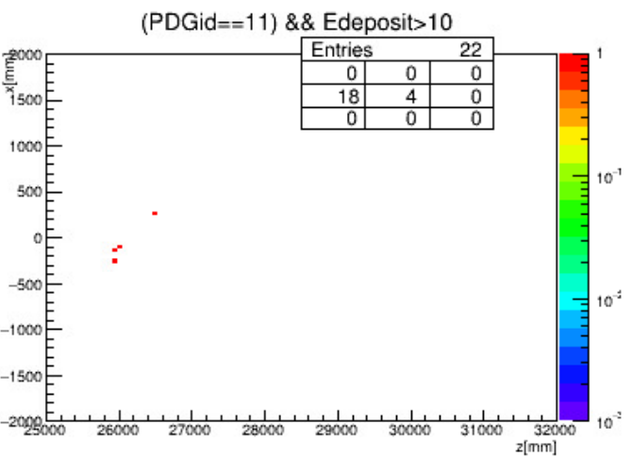
current setup

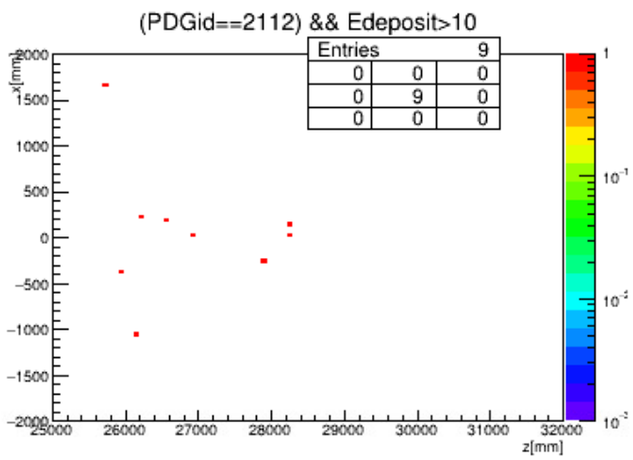




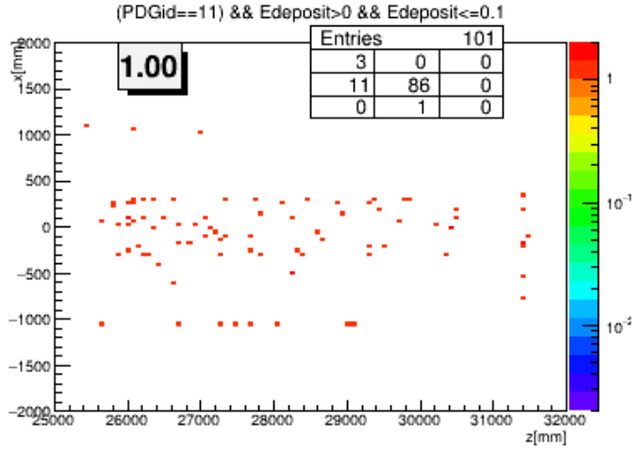


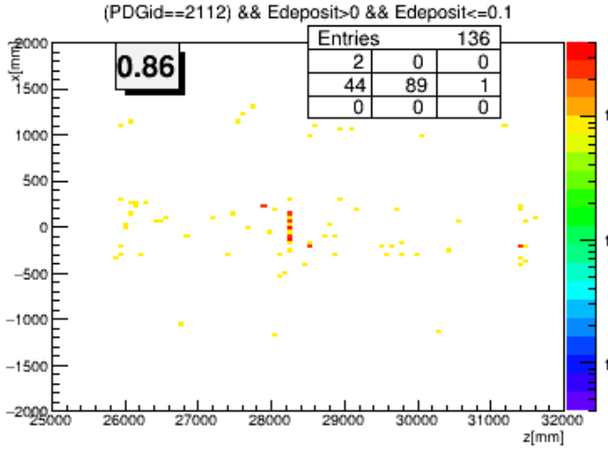


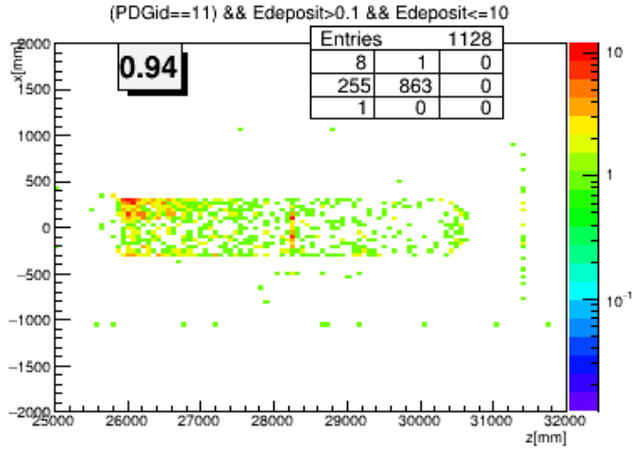


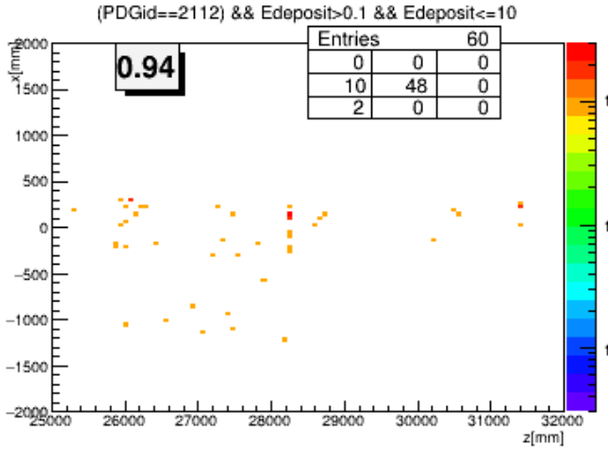


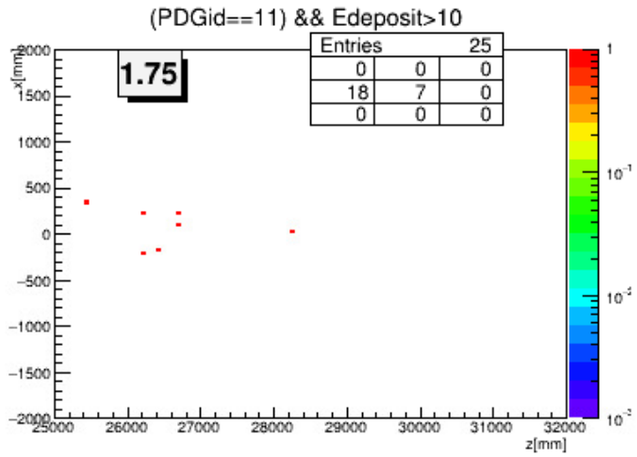
current setup + 4 in donut

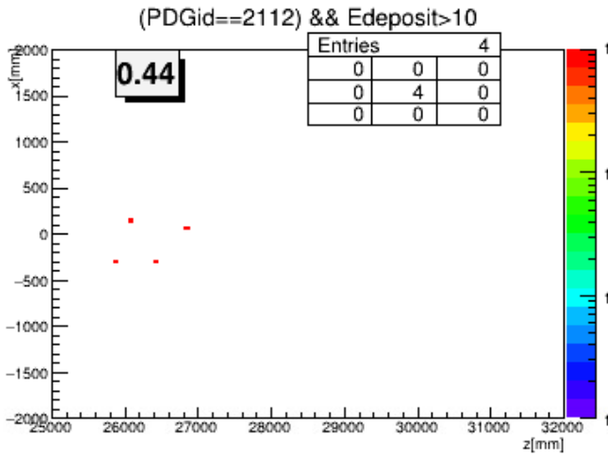






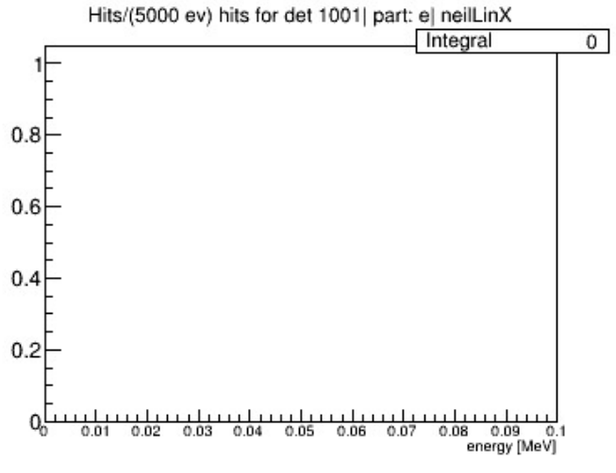


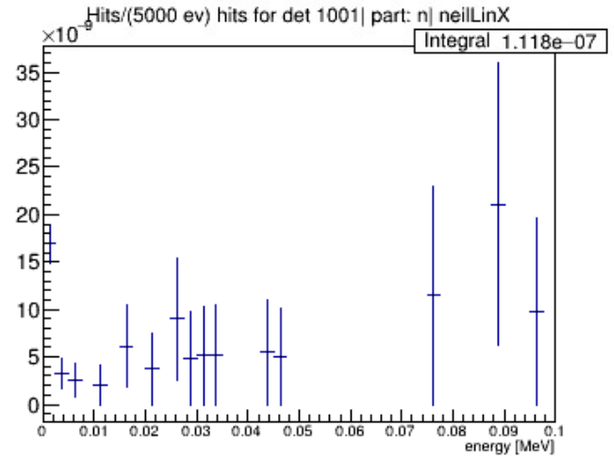


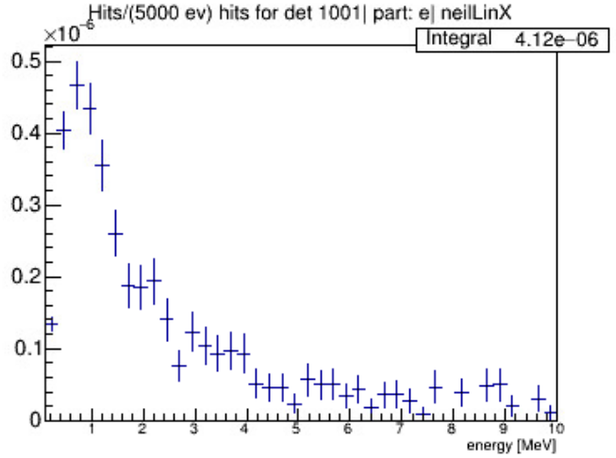


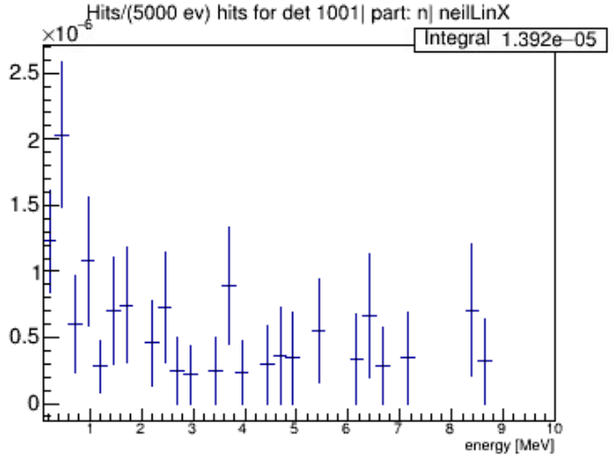
PREX2 - comparison

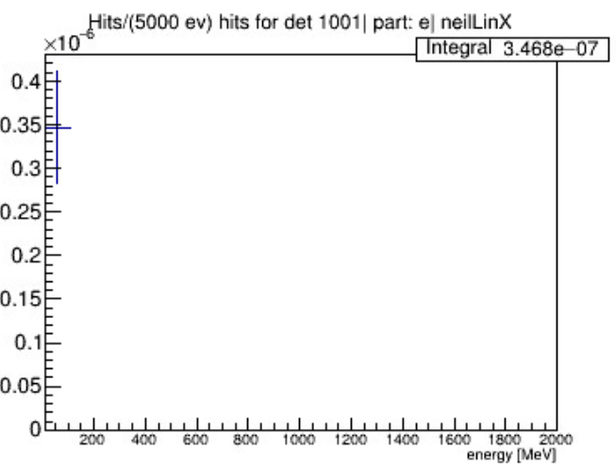
current setup

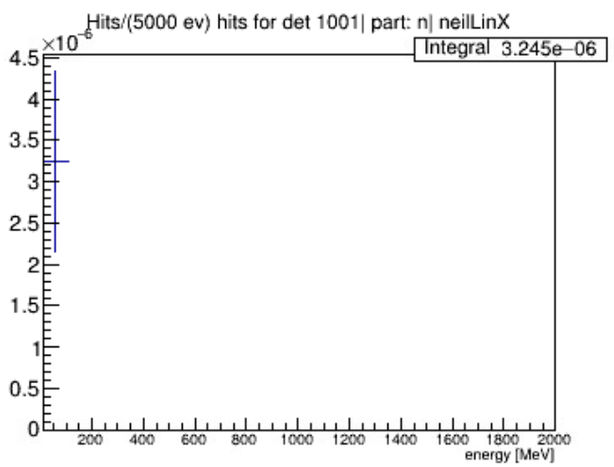




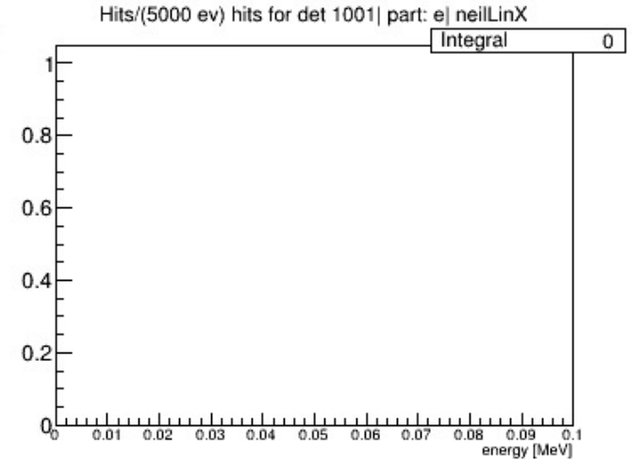


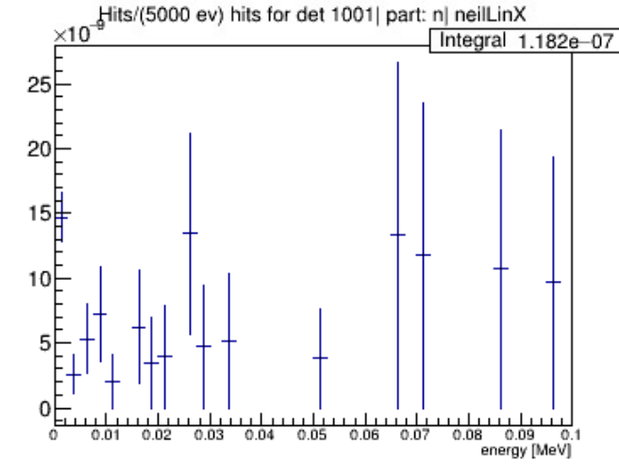


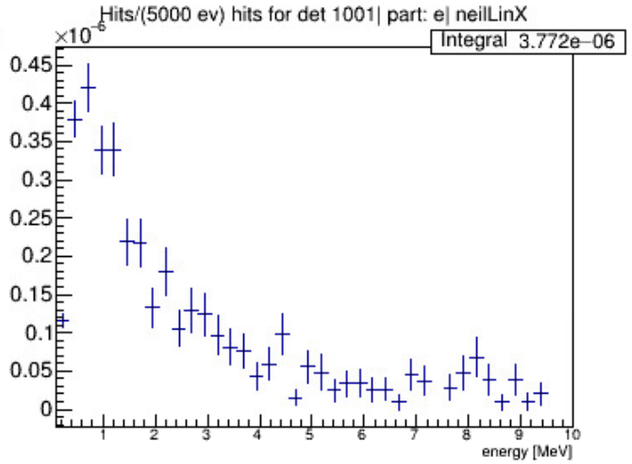


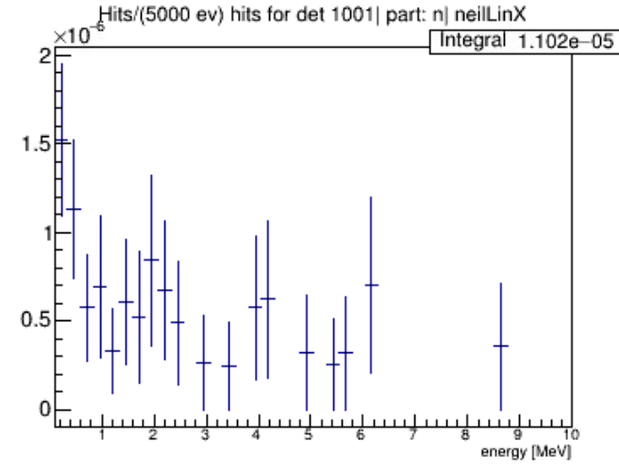


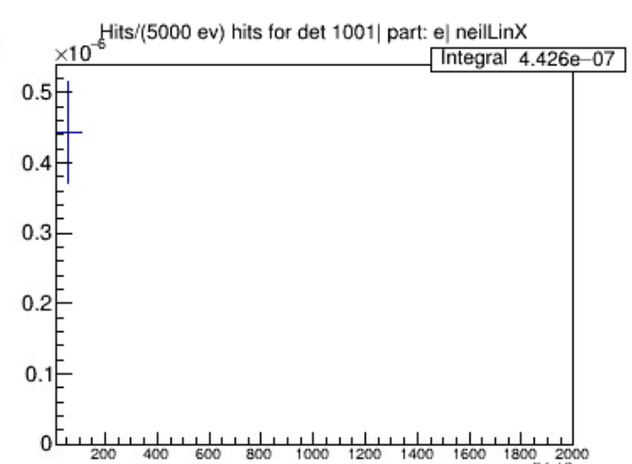
current setup + 4 in Donut

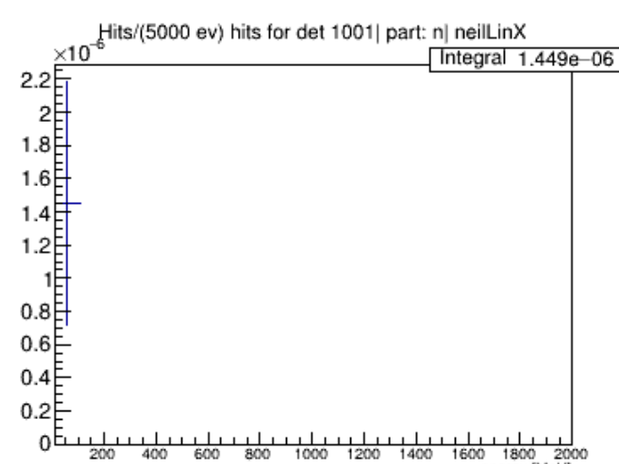






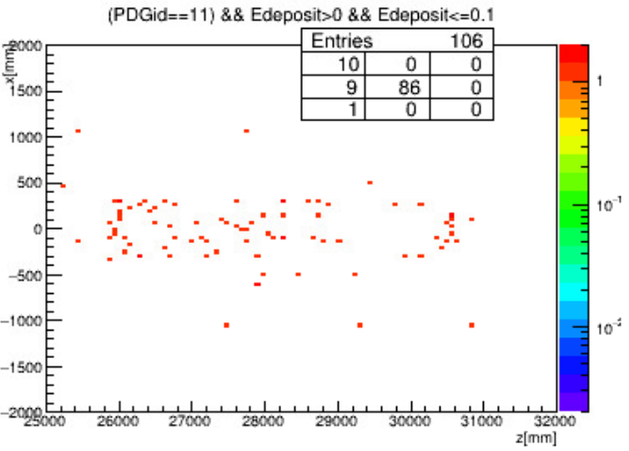


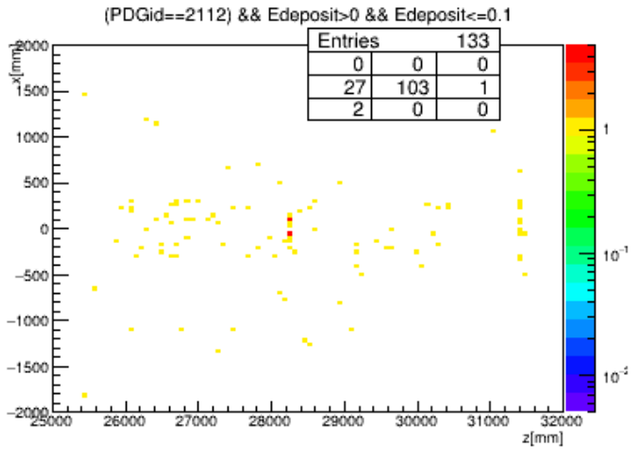


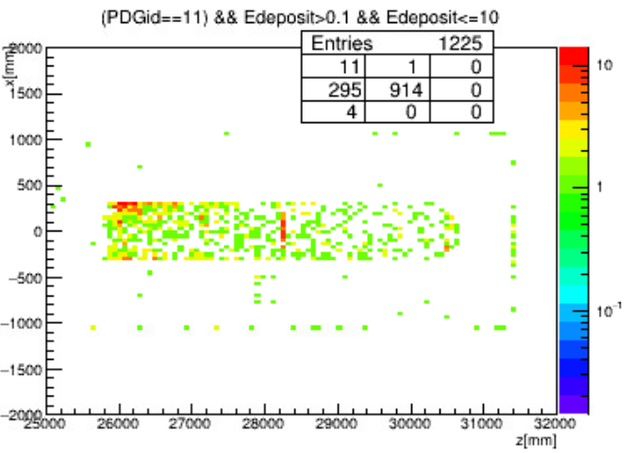


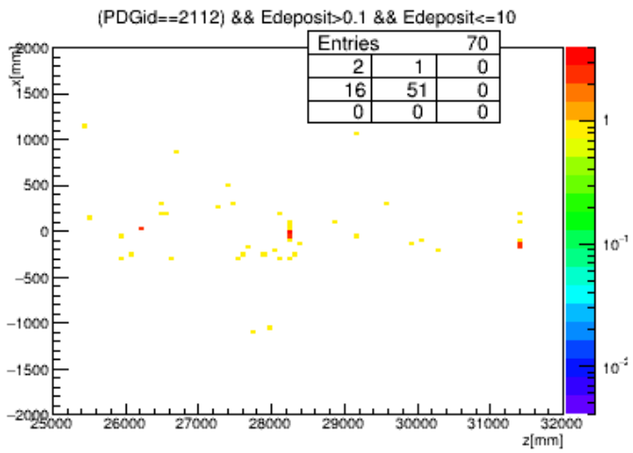
PREX2 - comparison

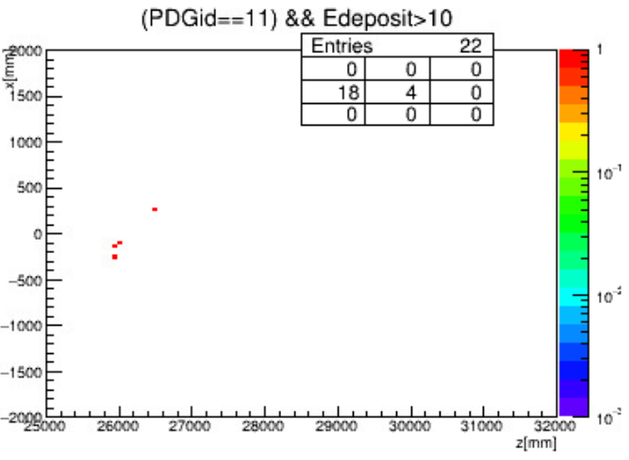
current setup

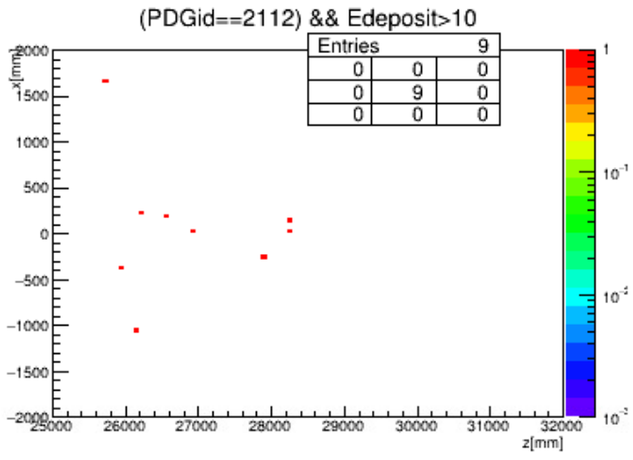




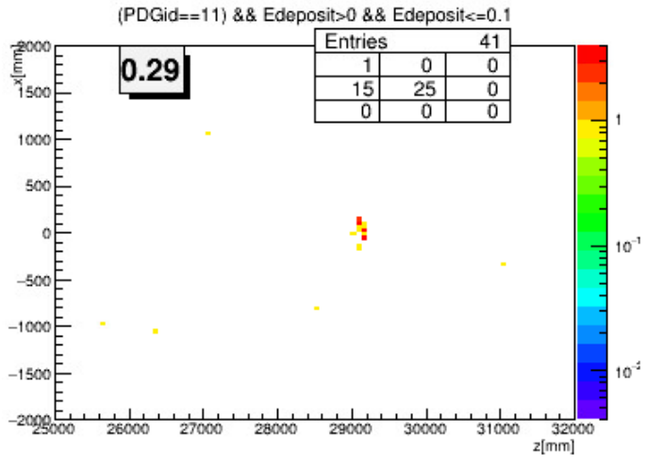


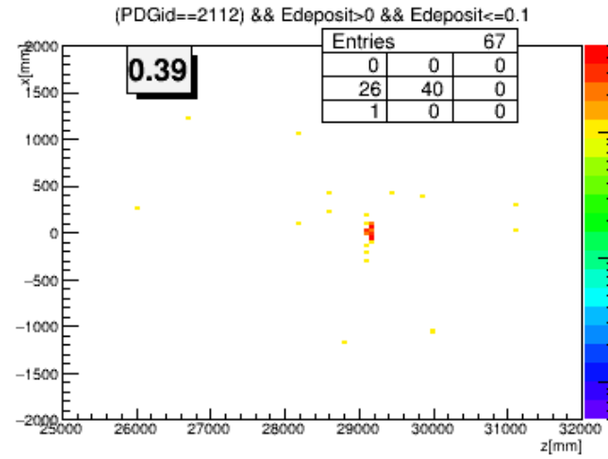


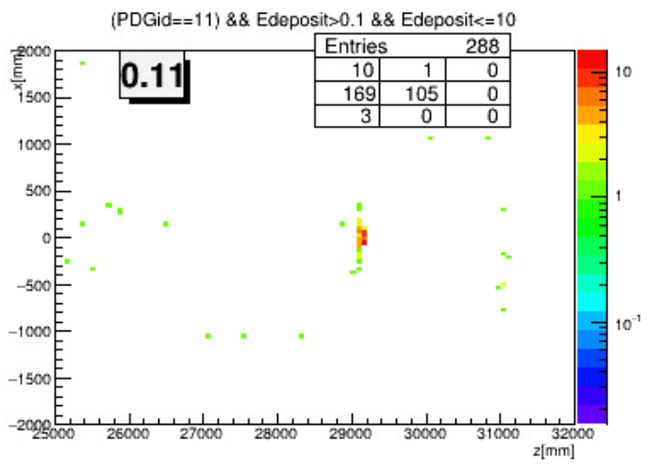


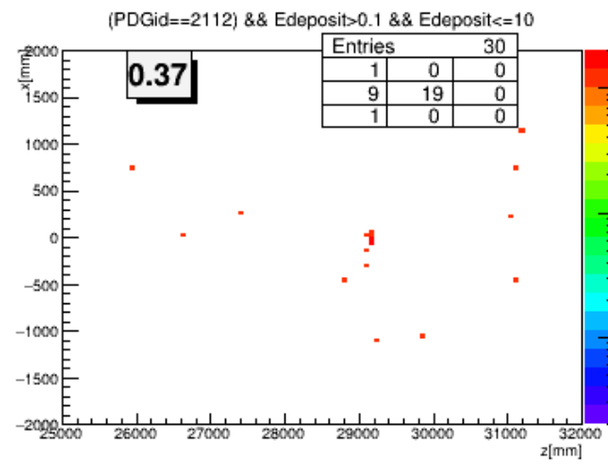


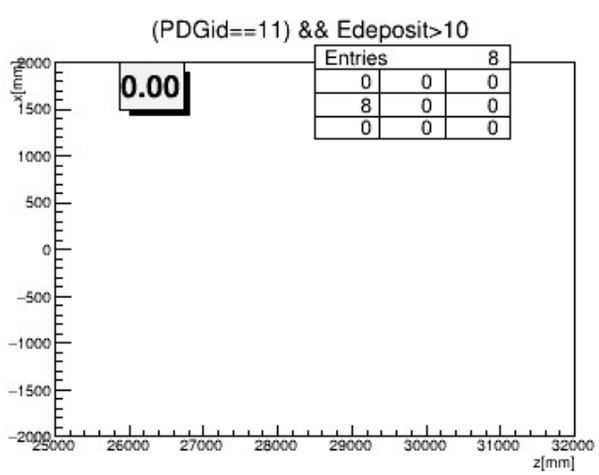
PREX1 dump configuration

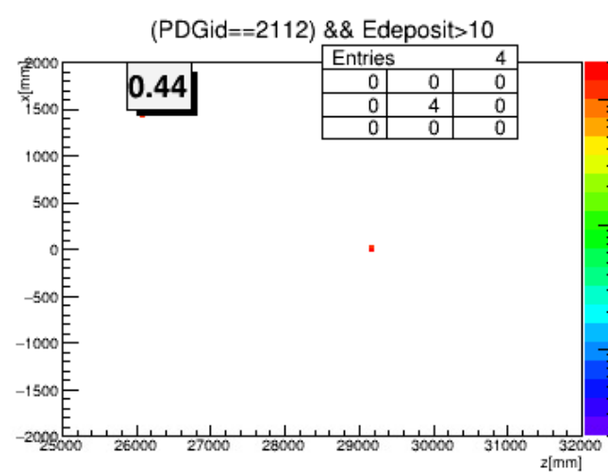






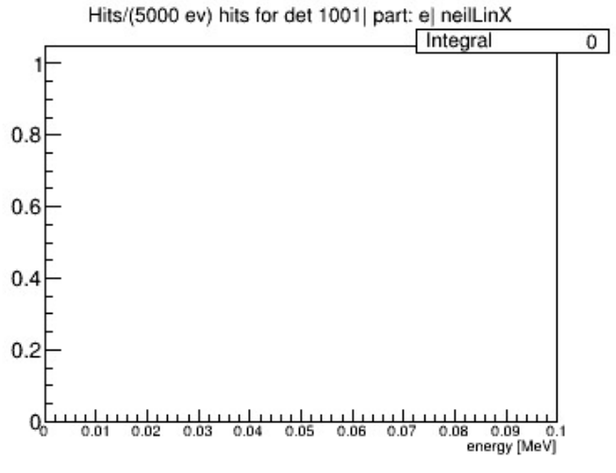


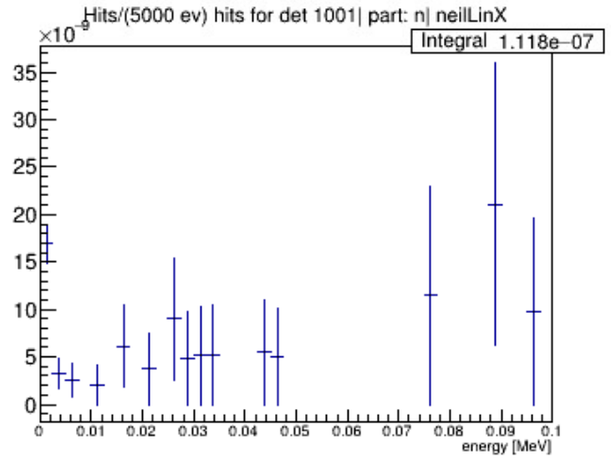


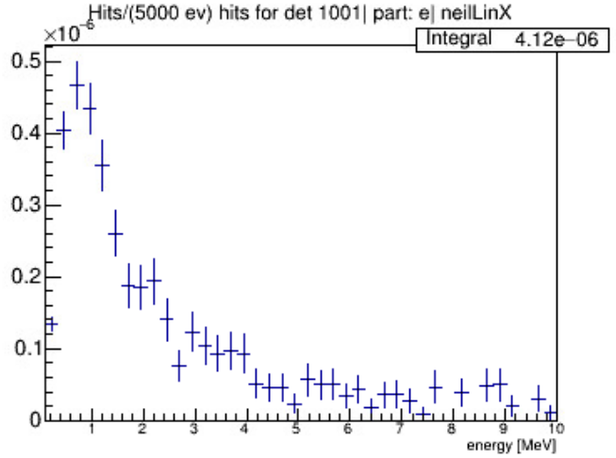


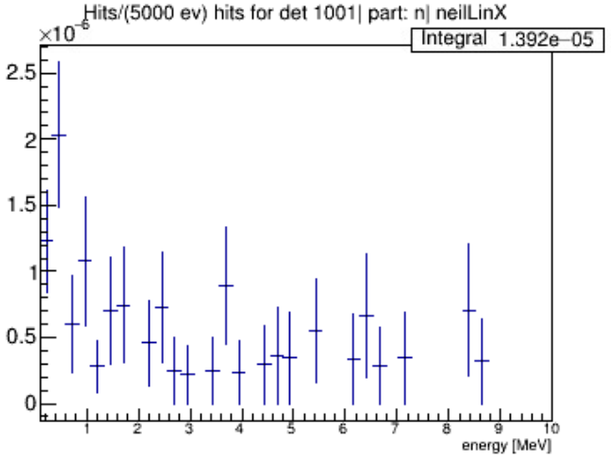
PREX2 - comparison

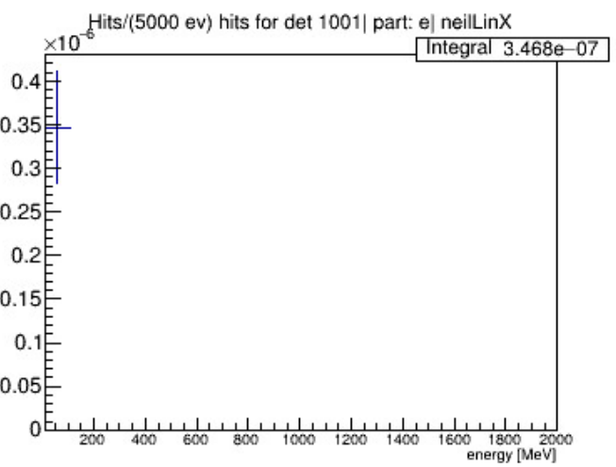
current setup

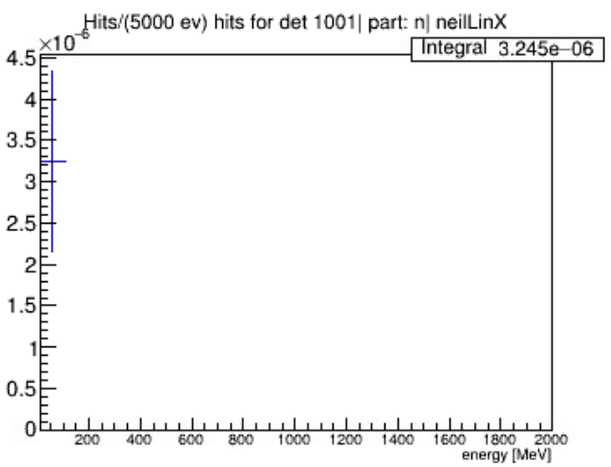




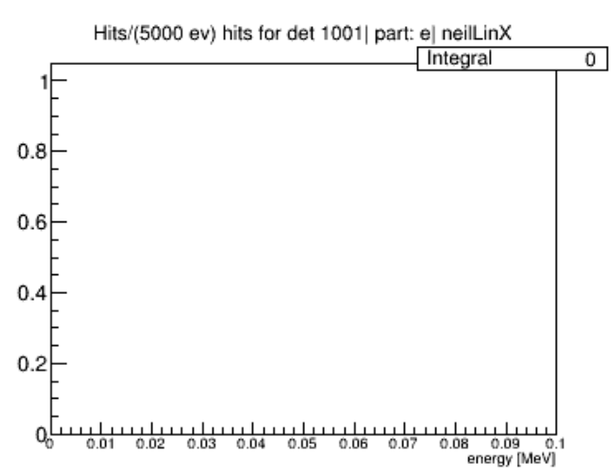


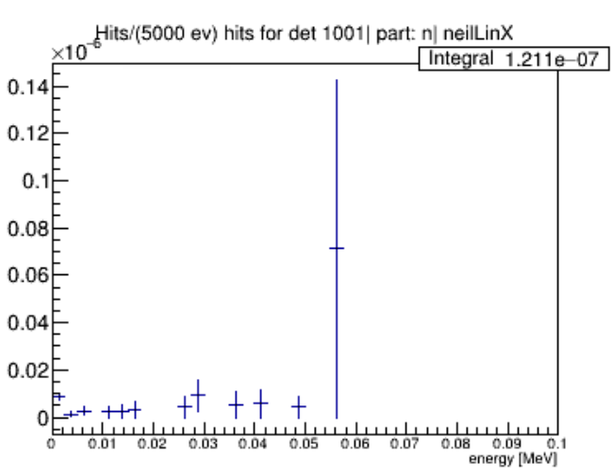


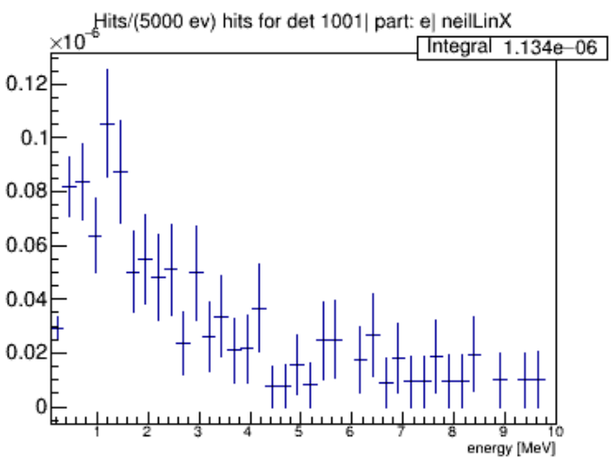


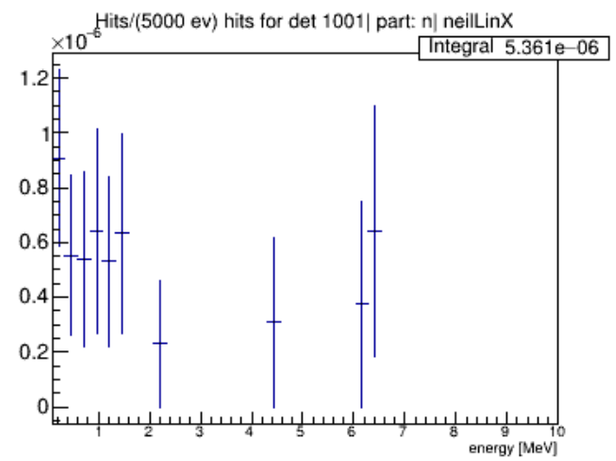


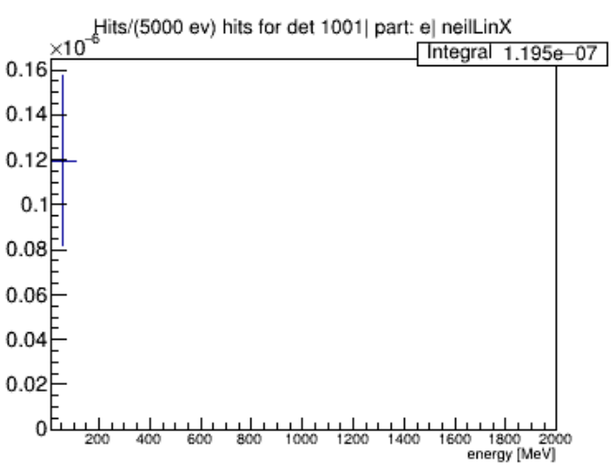
PREX1 dump configuration

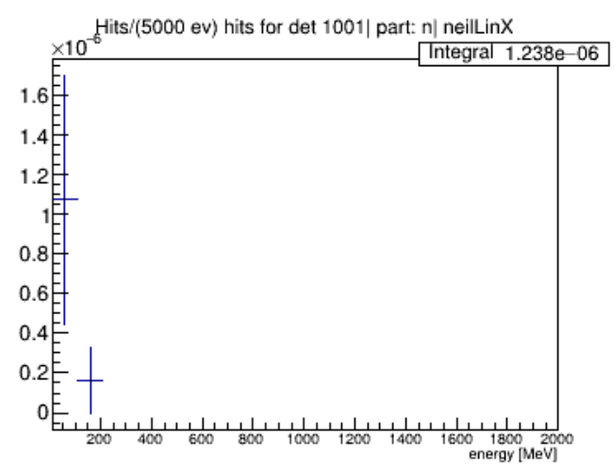






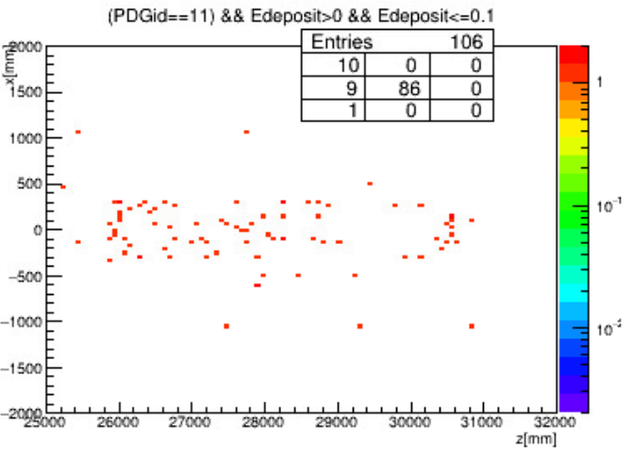


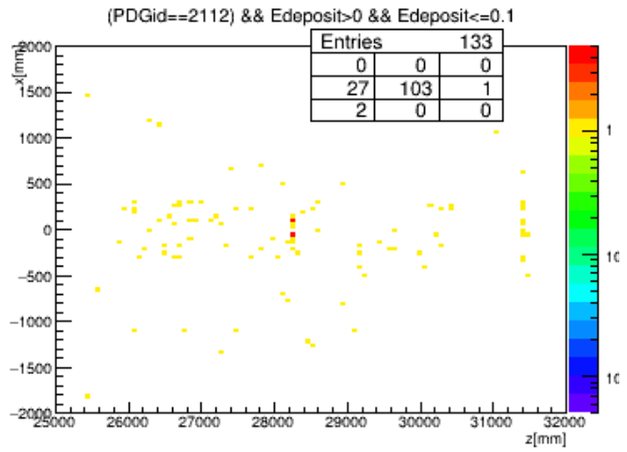


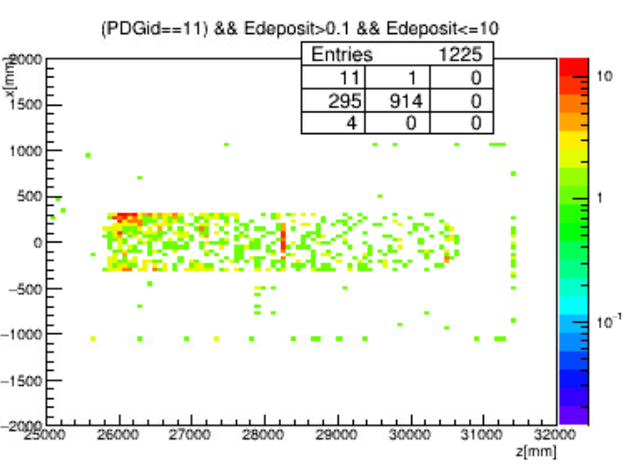


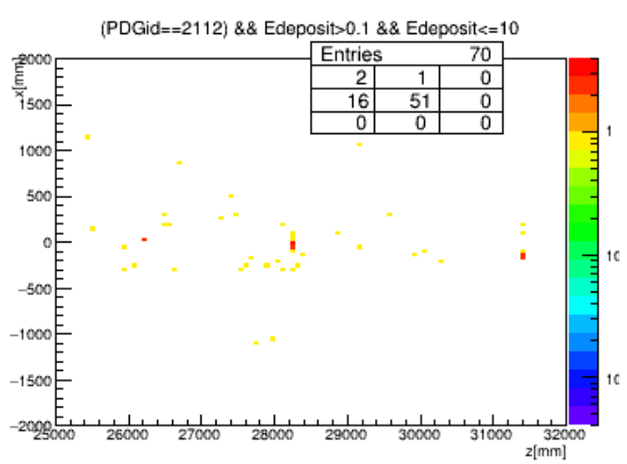
PREX2 - comparison

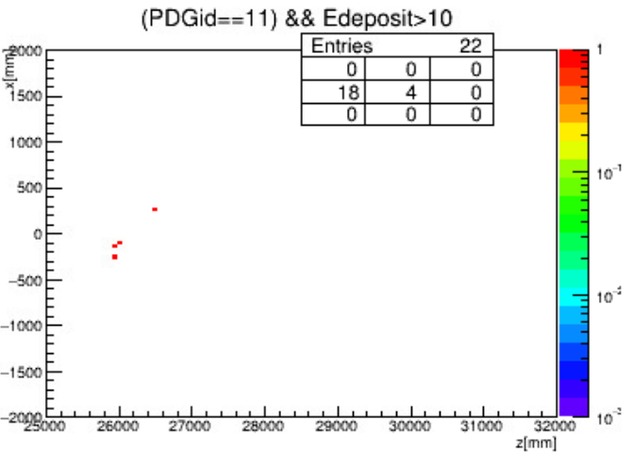
current setup

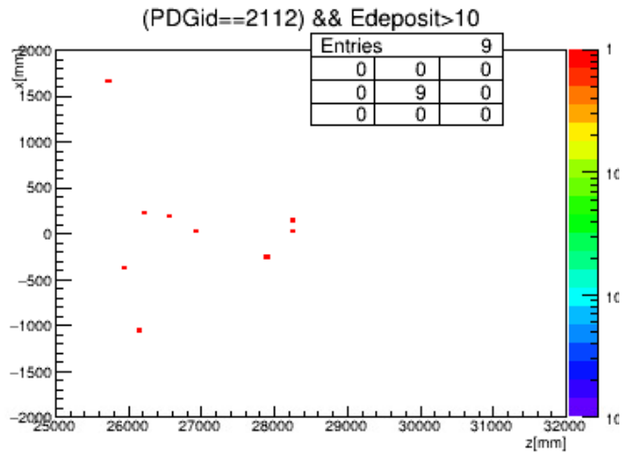




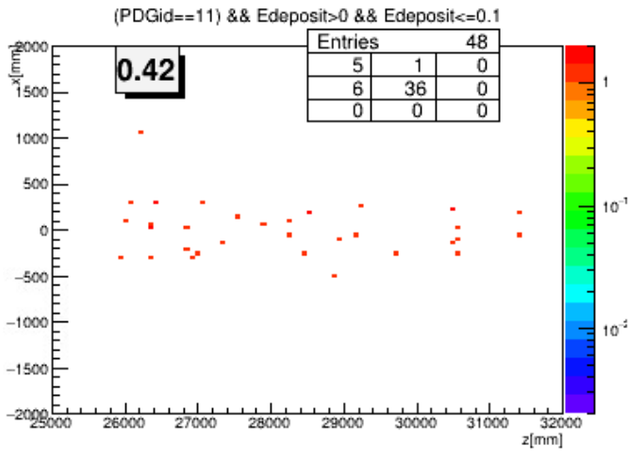


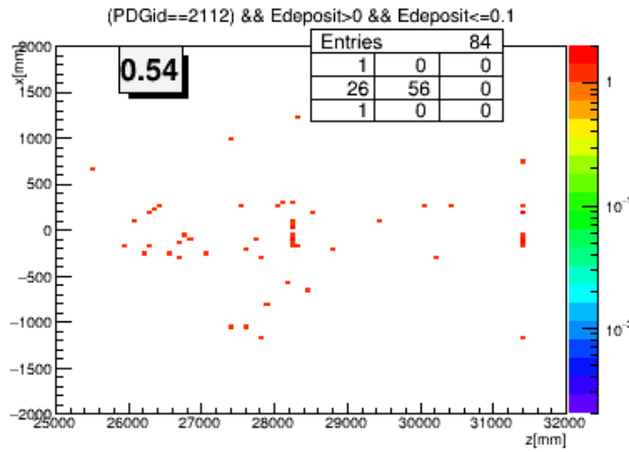


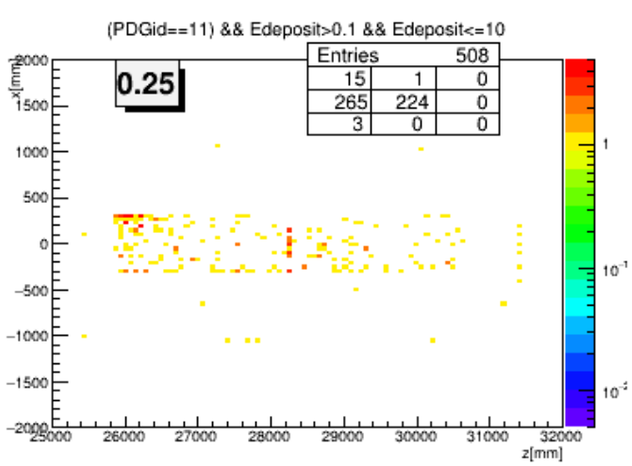


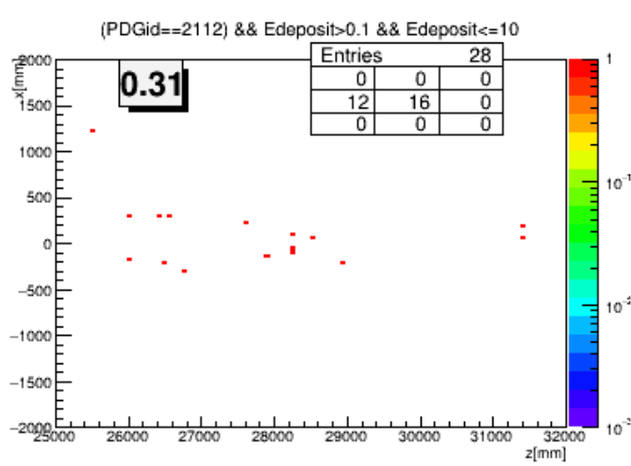


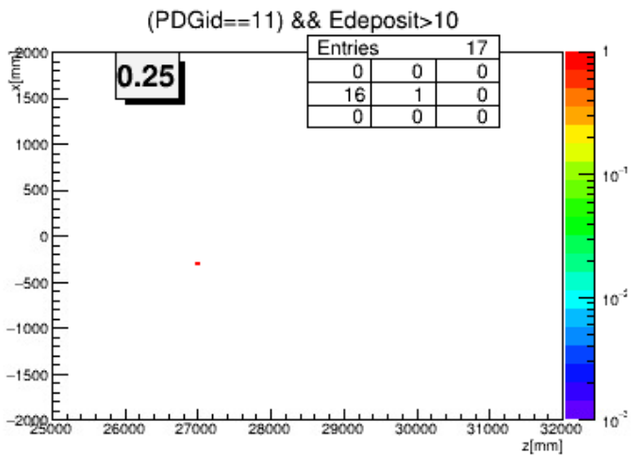
current setup + 1 ft concrete shield

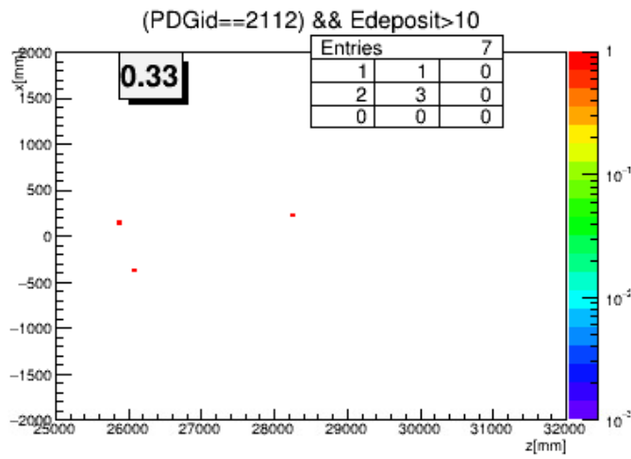






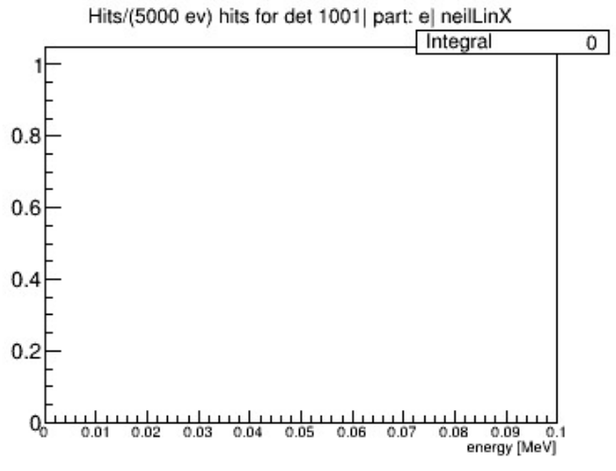


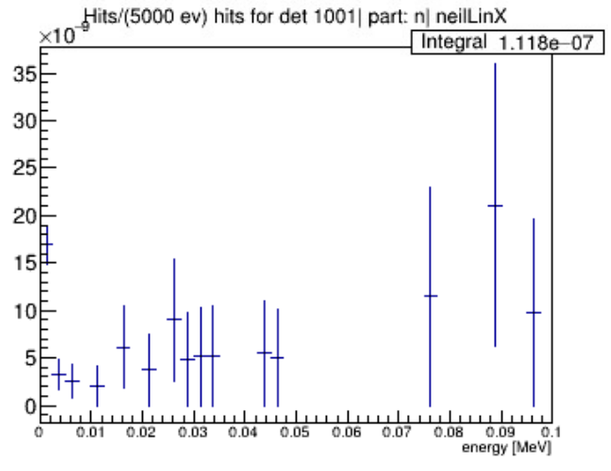


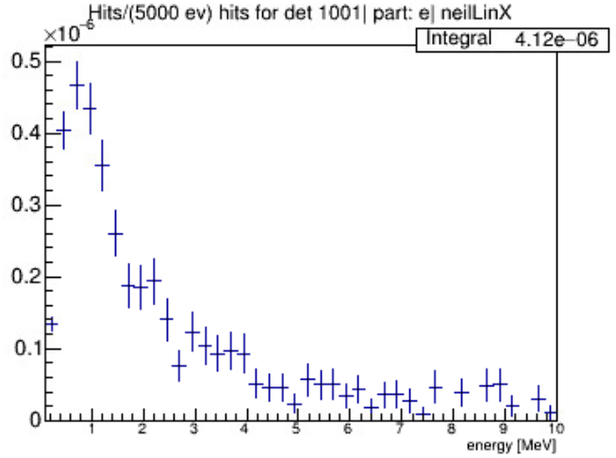


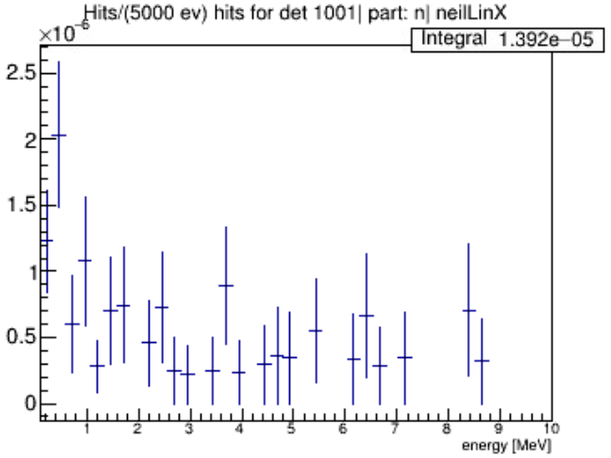
PREX2 - comparison

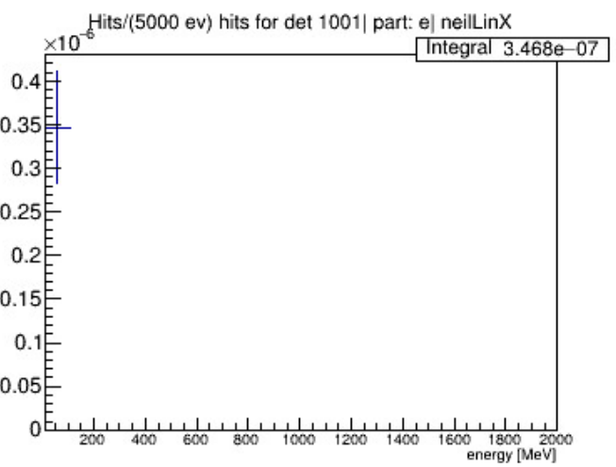
current setup

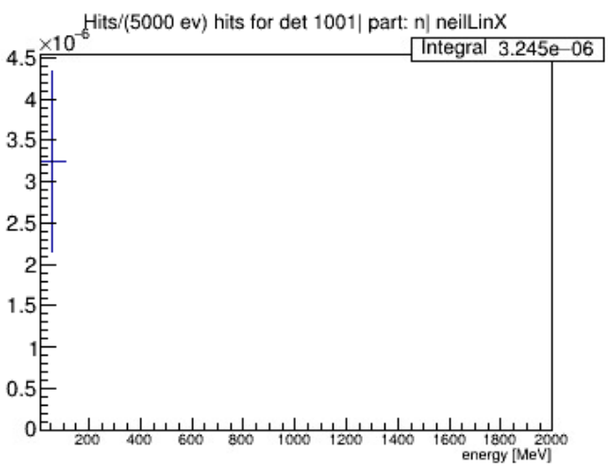




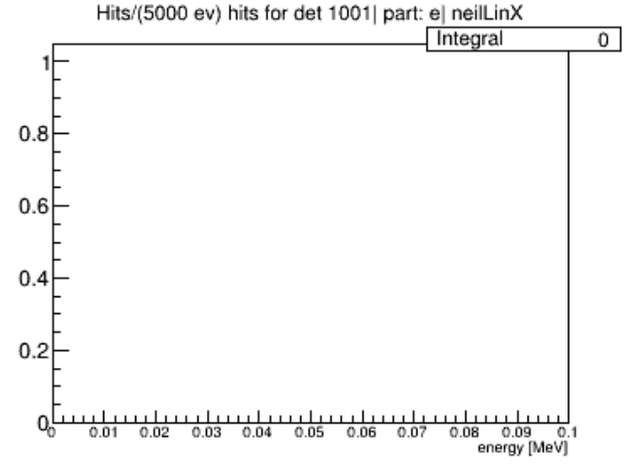


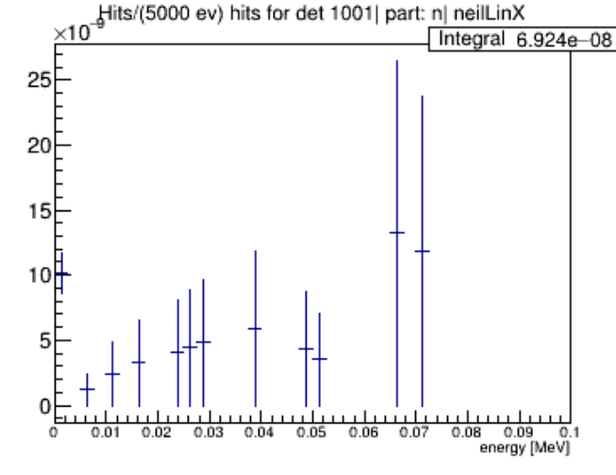


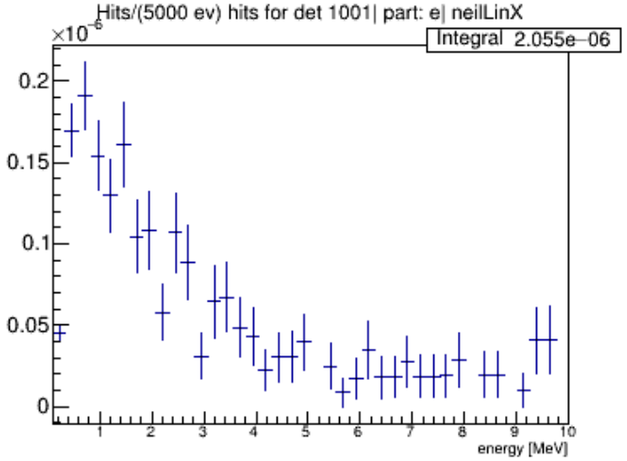


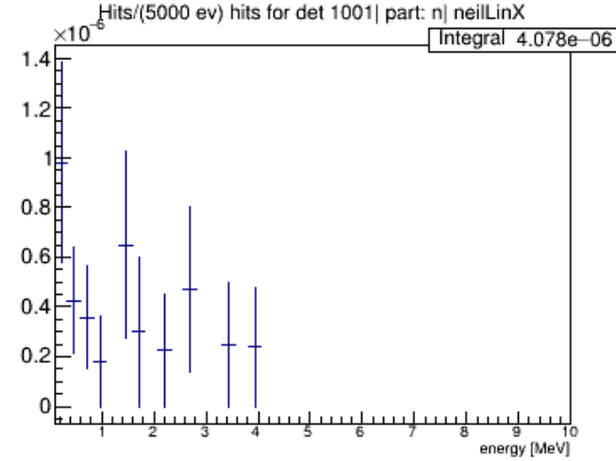


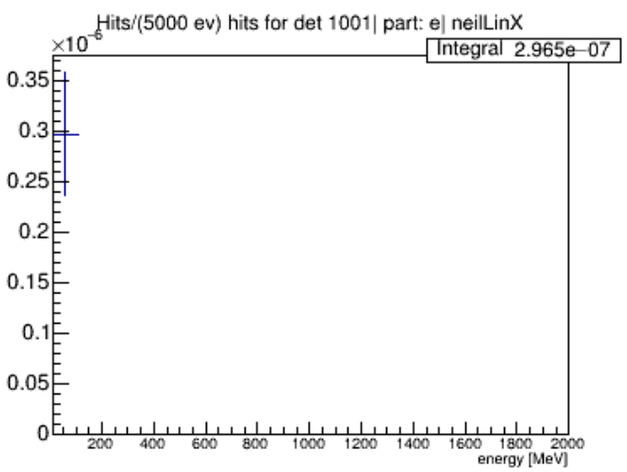
current setup + 1 ft concrete shield

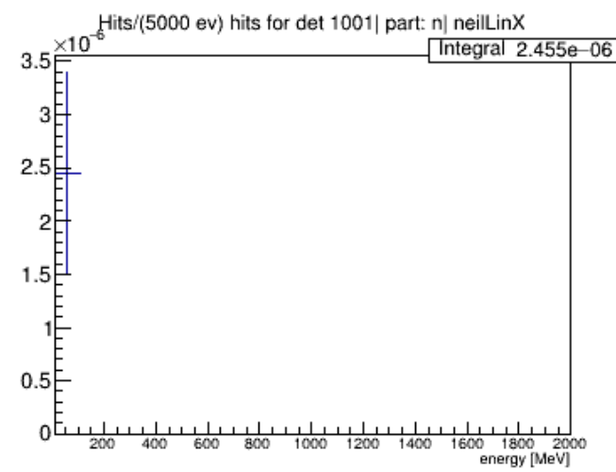






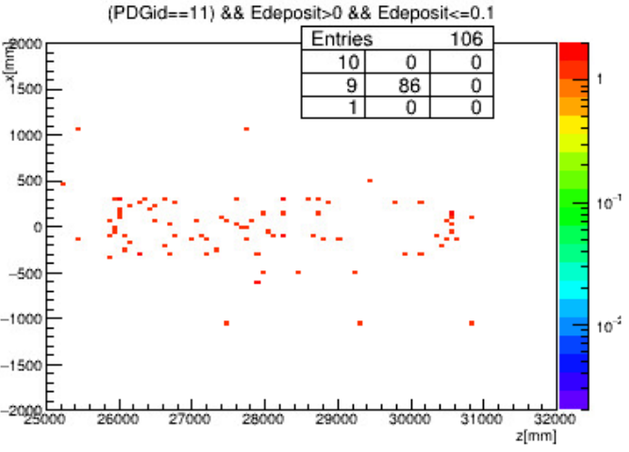


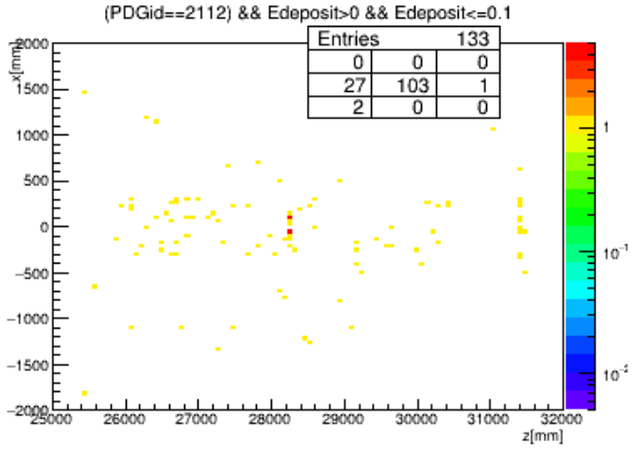


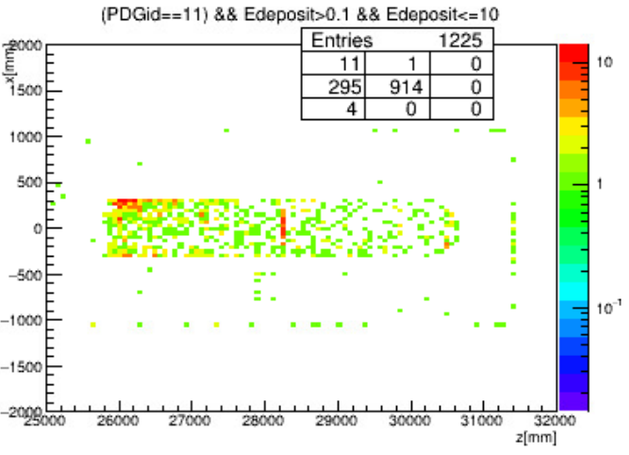


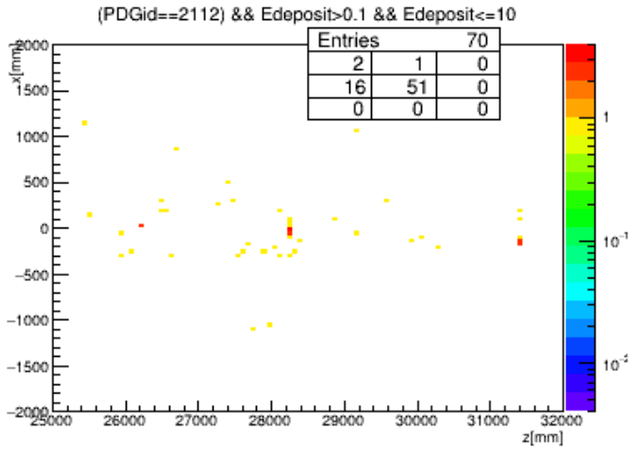
PREX2 - comparison

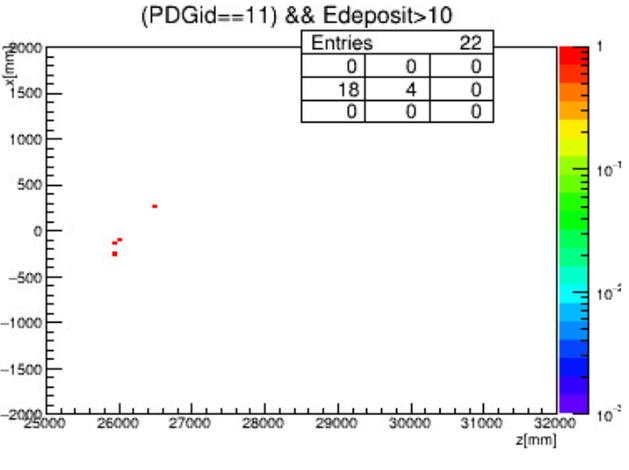
current setup

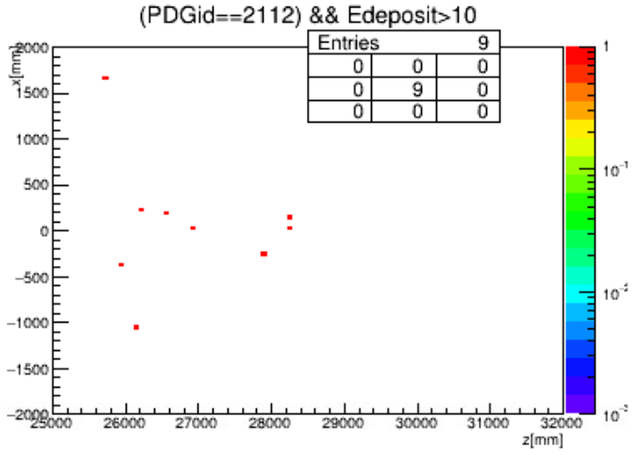




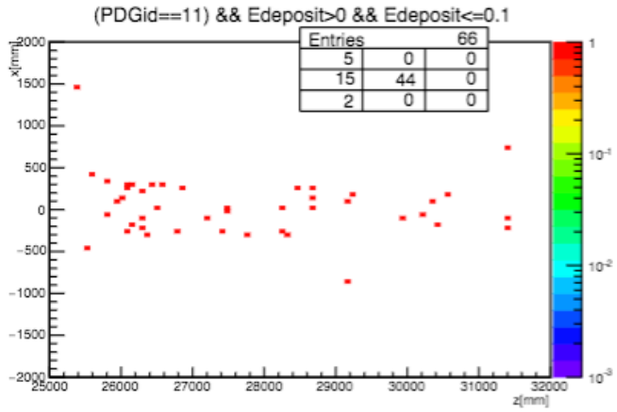


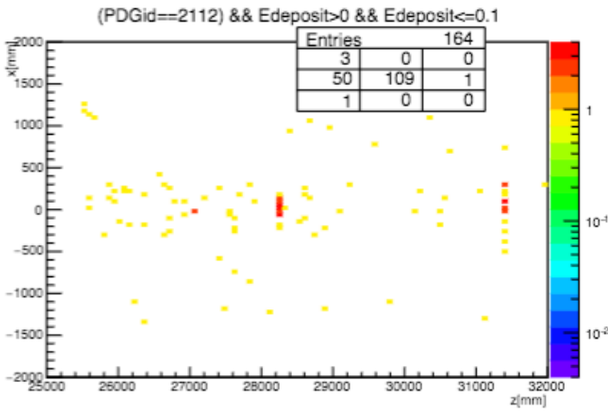


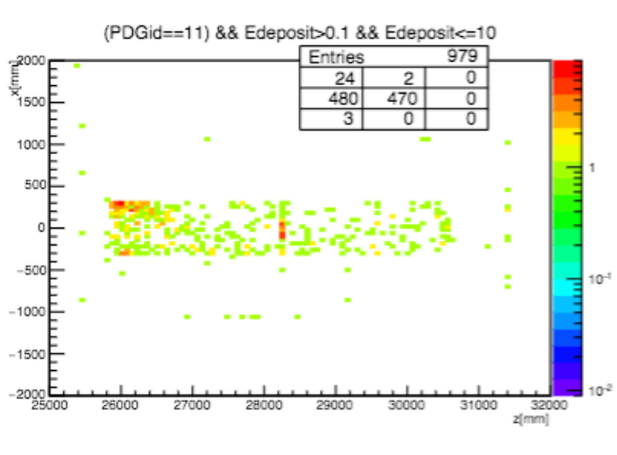


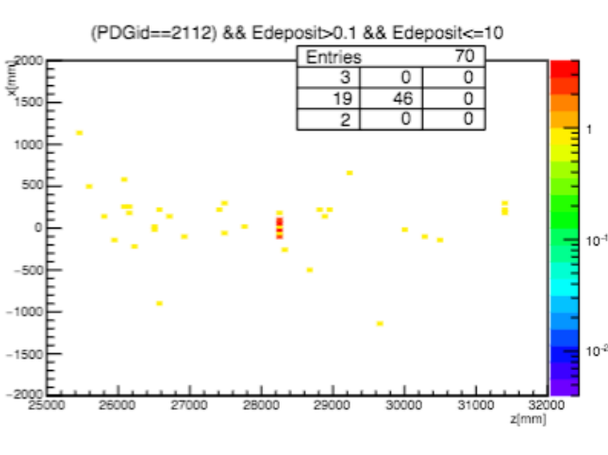


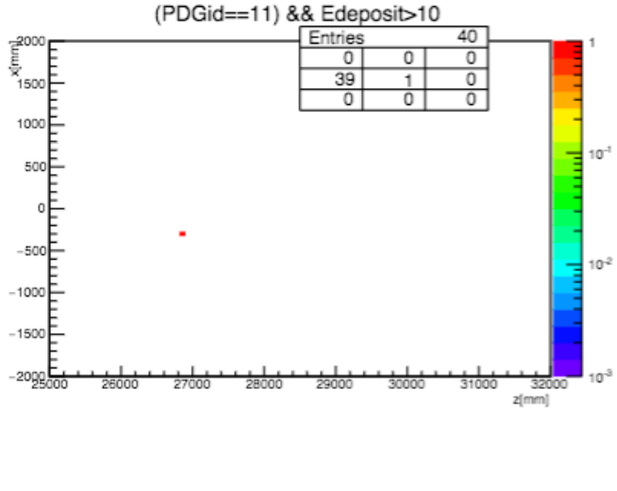
current setup + 0.5 ft concrete shield (2x stat)

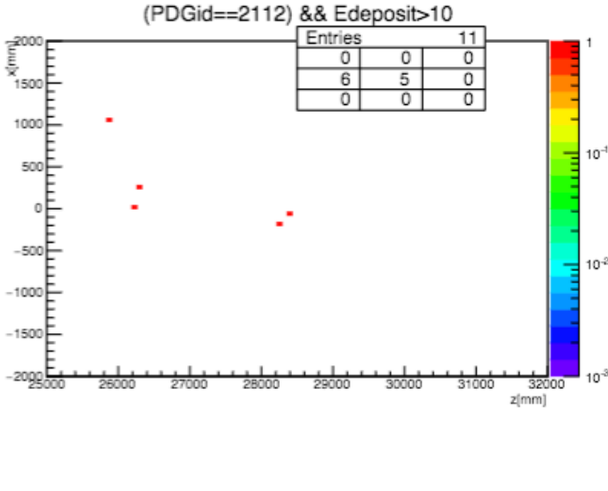






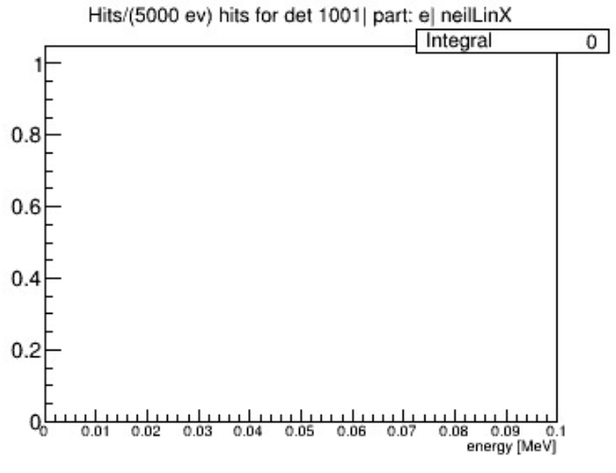


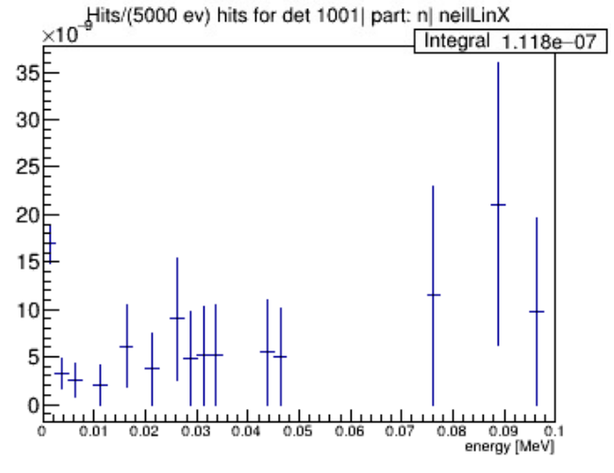


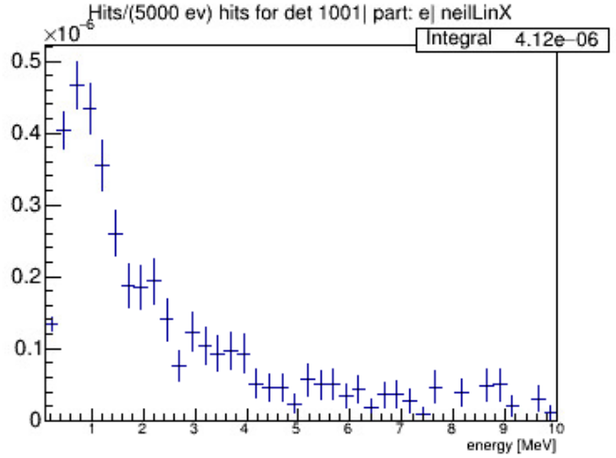


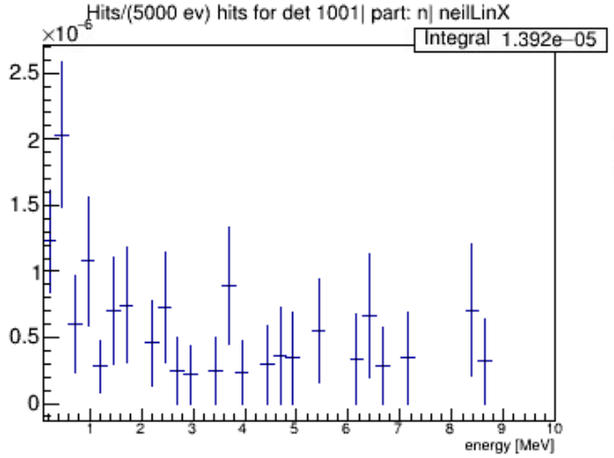
PREX2 - comparison

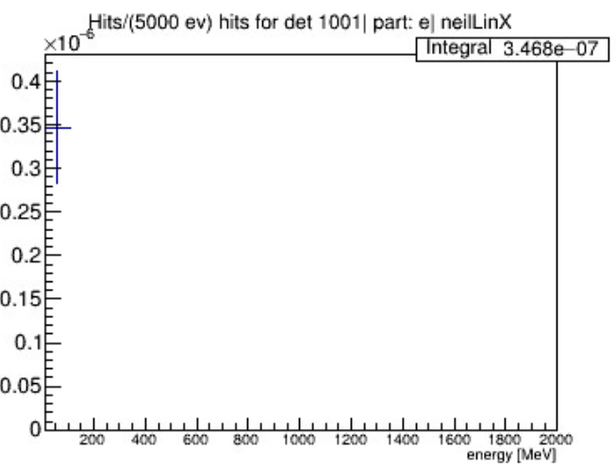
current setup

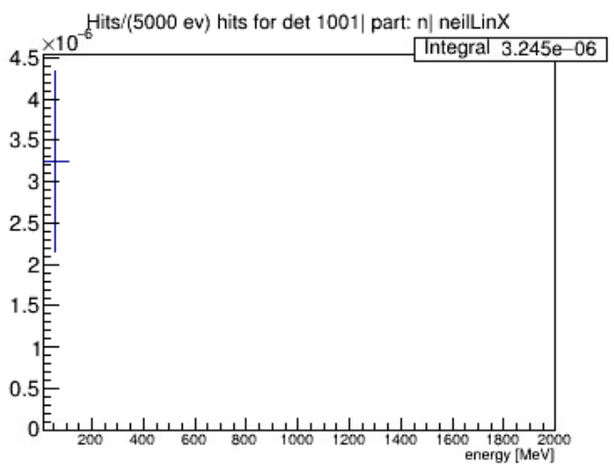




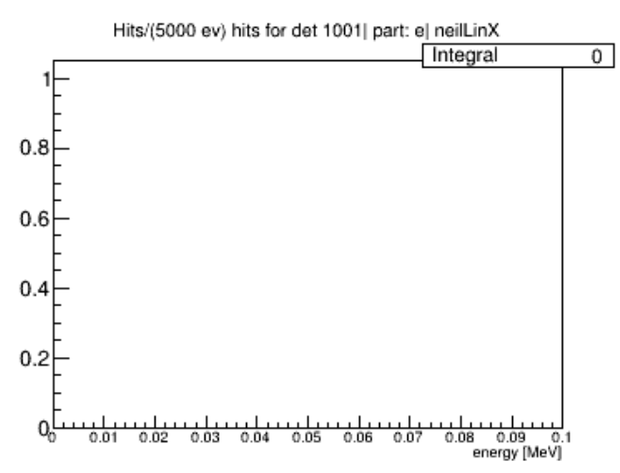


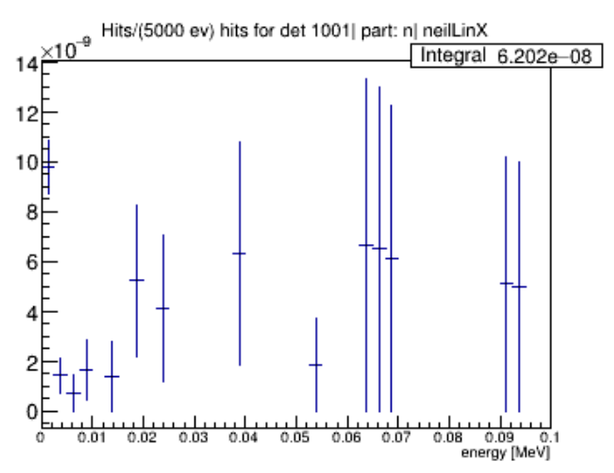


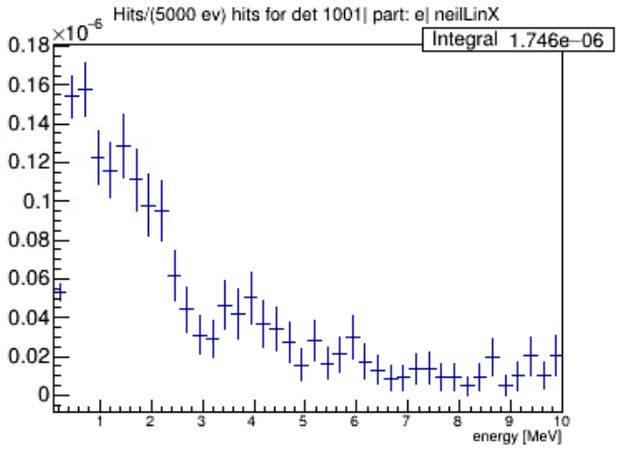


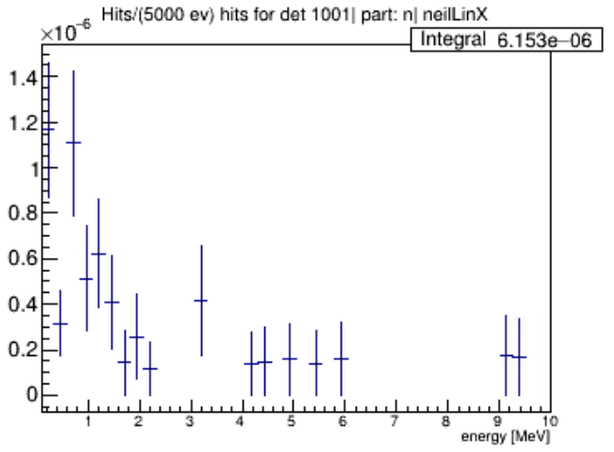


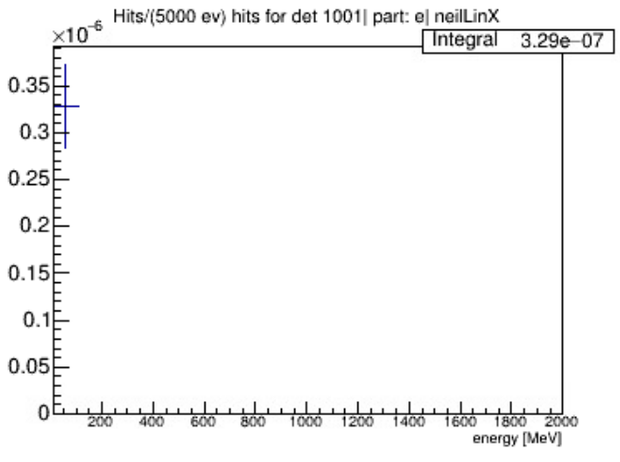
current setup + 0.5 ft concrete shield

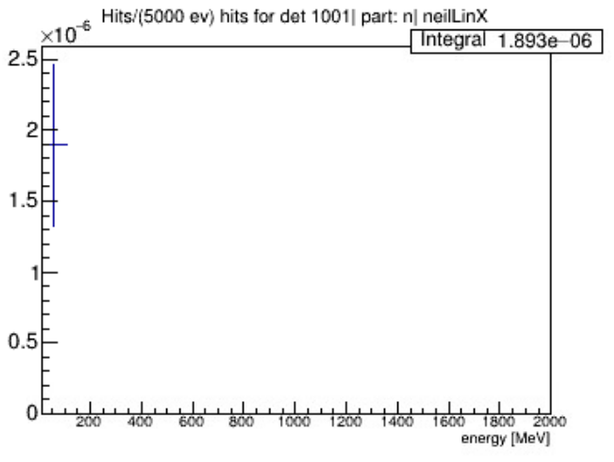






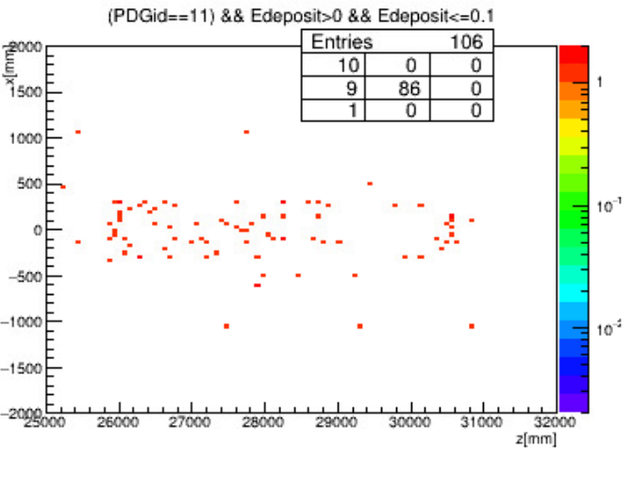


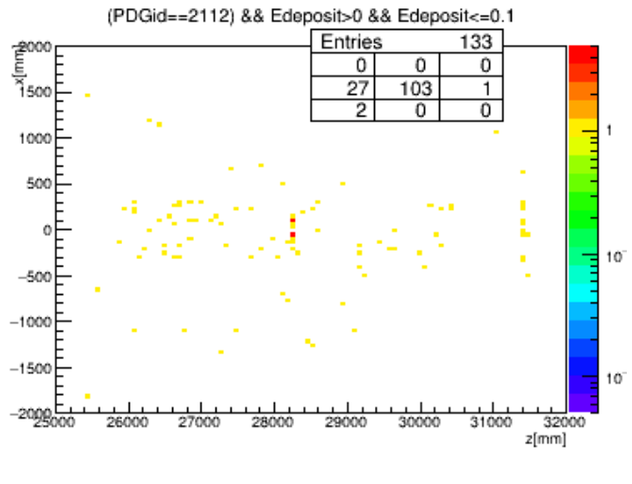


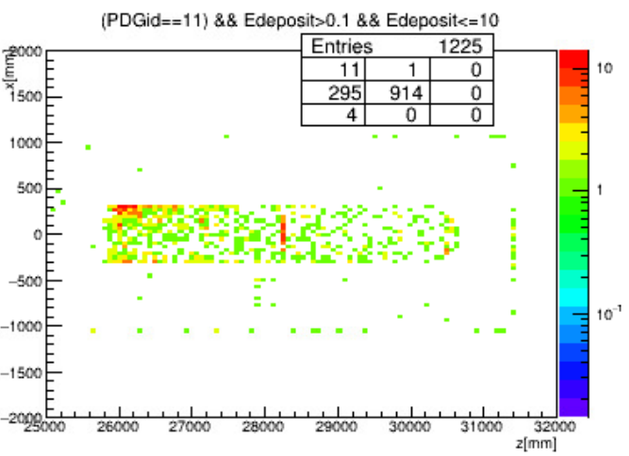


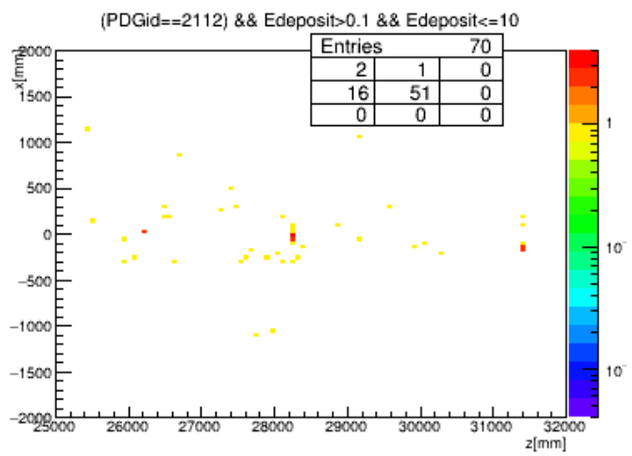
PREX2 - comparison

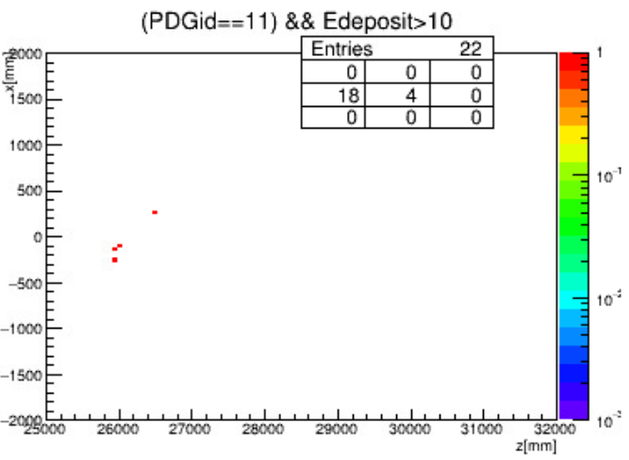
current setup

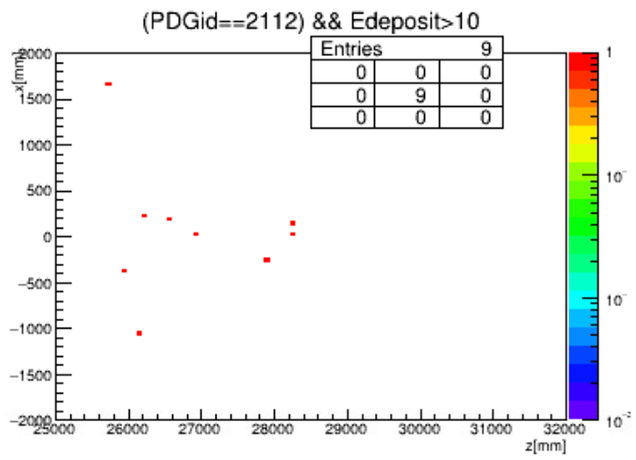




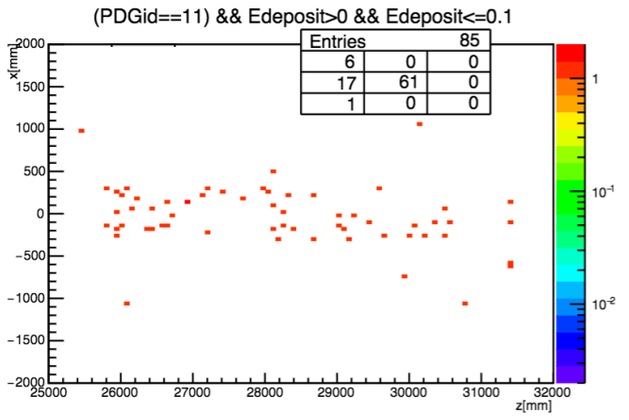


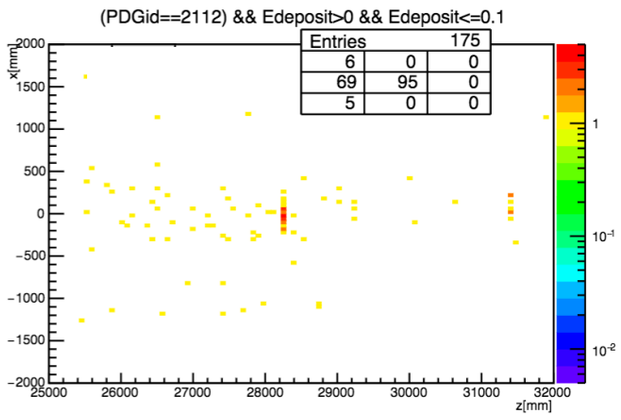


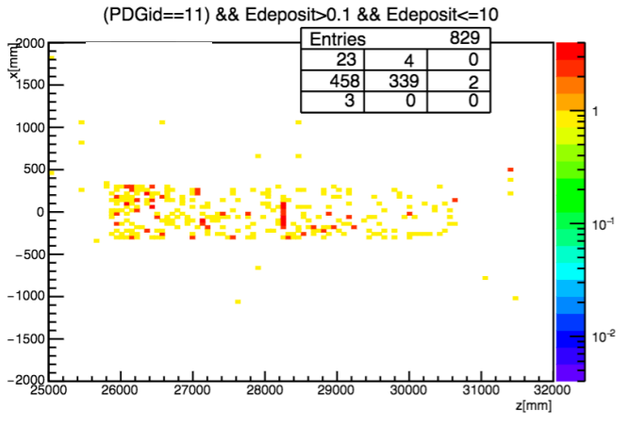


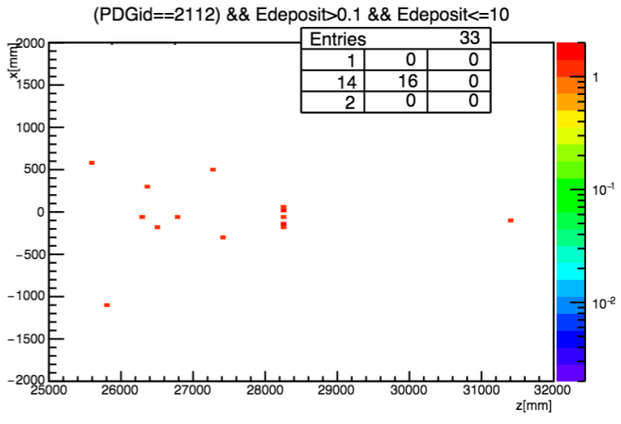


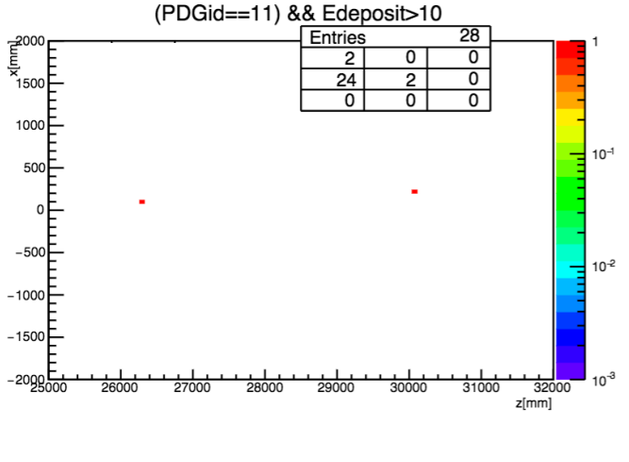
current setup + 2 ft concrete shield (2x stat)

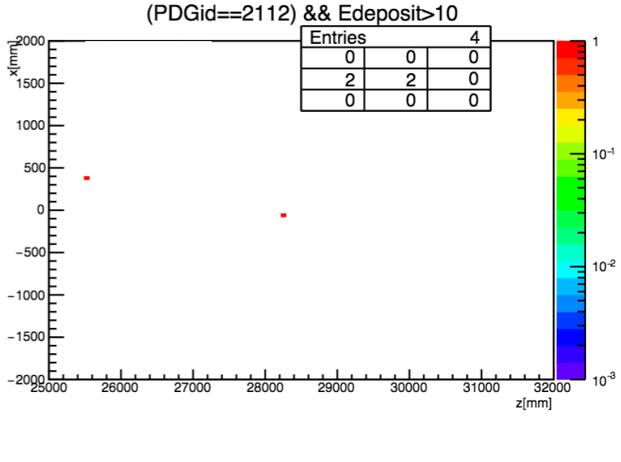






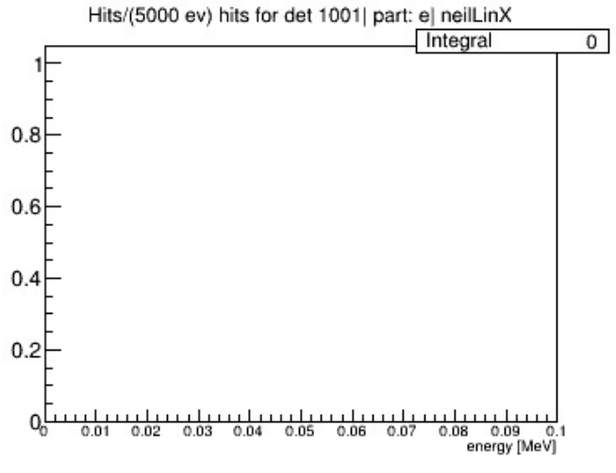


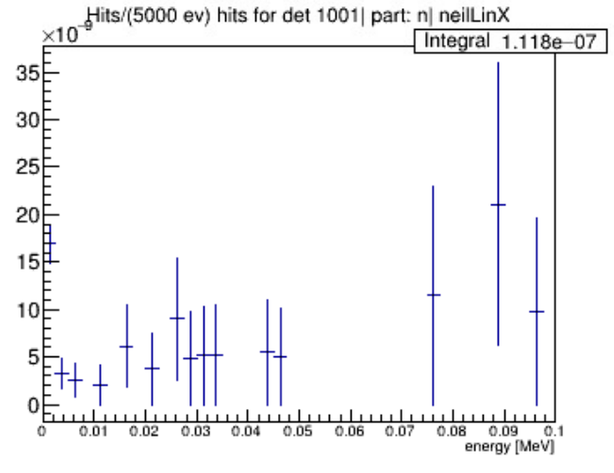


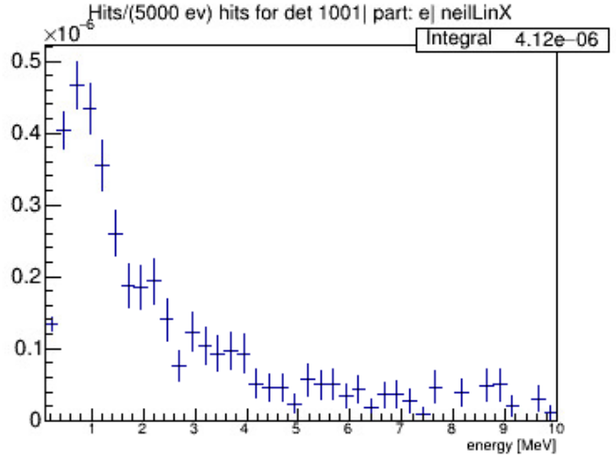


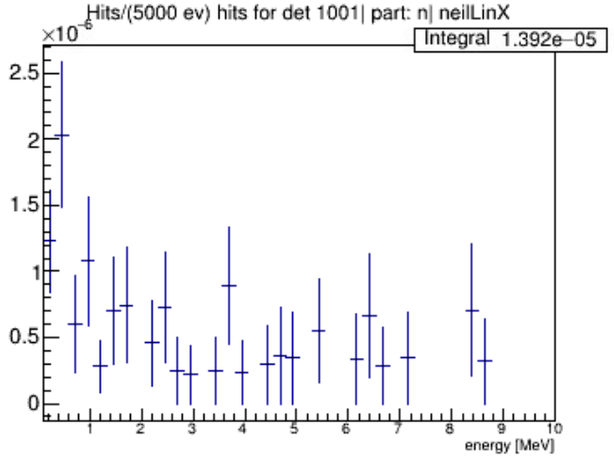
PREX2 - comparison

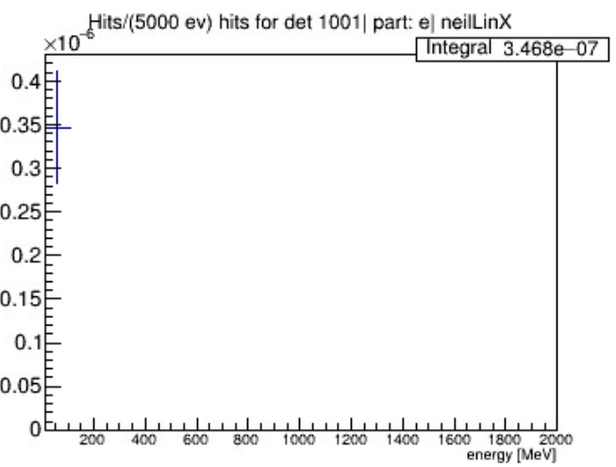
current setup

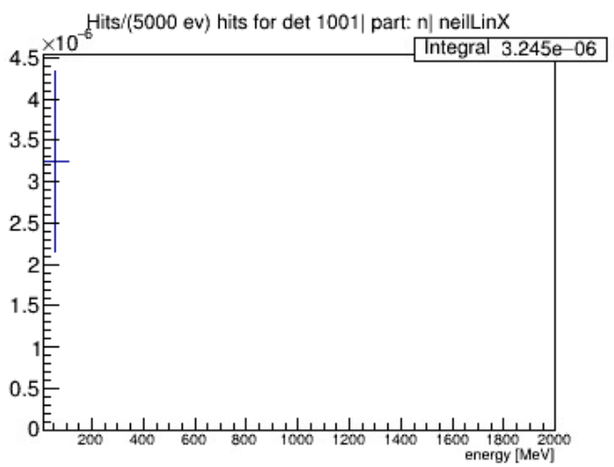




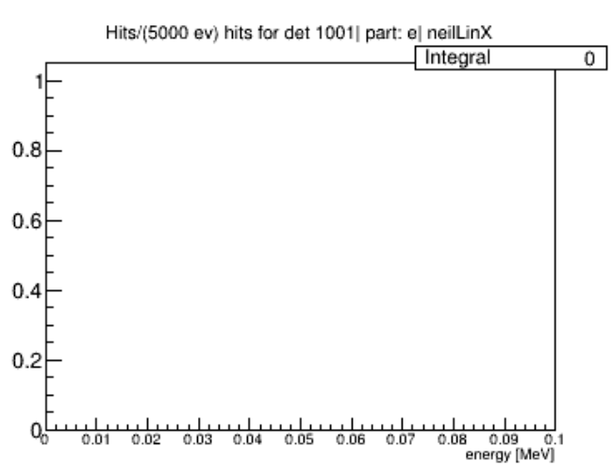


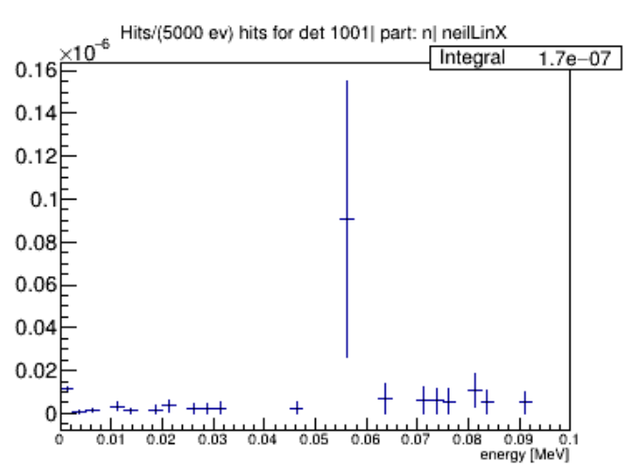


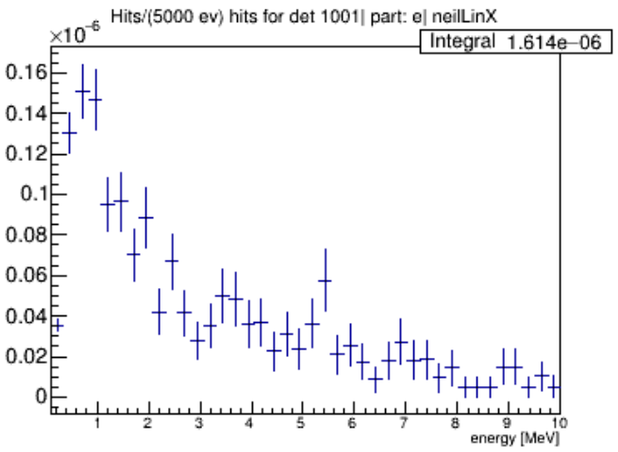


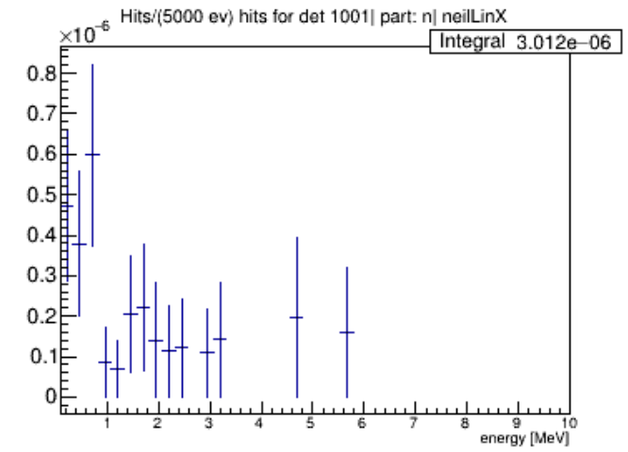


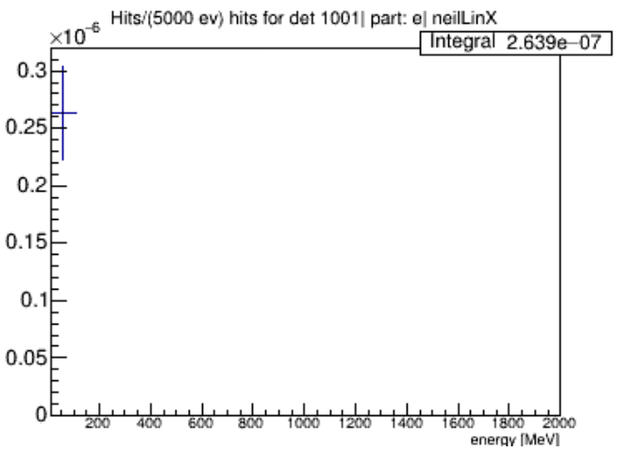
current setup + 2 ft concrete shield

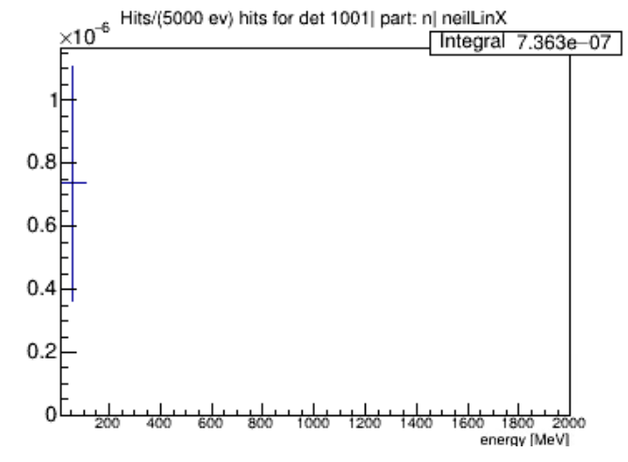






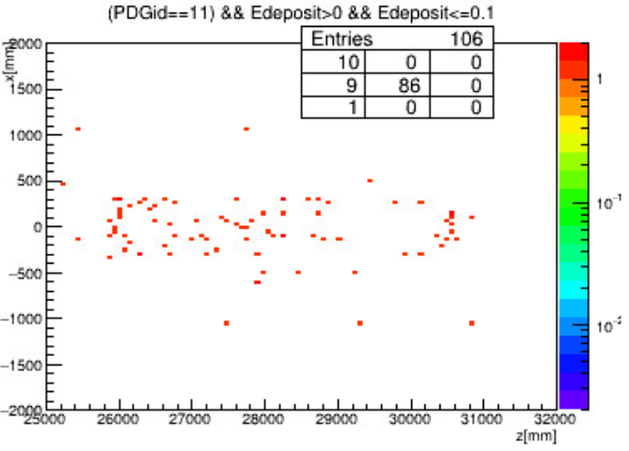


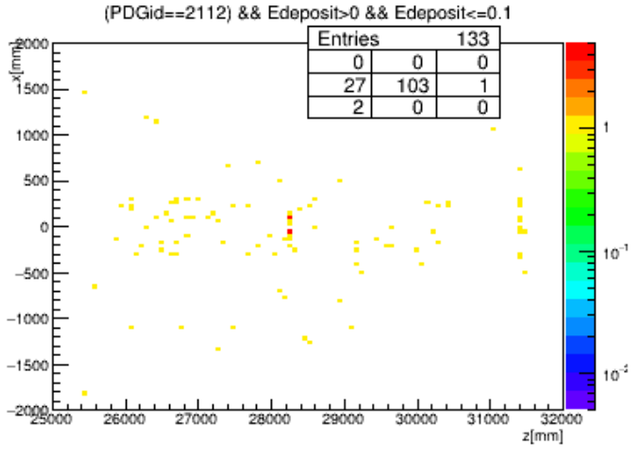


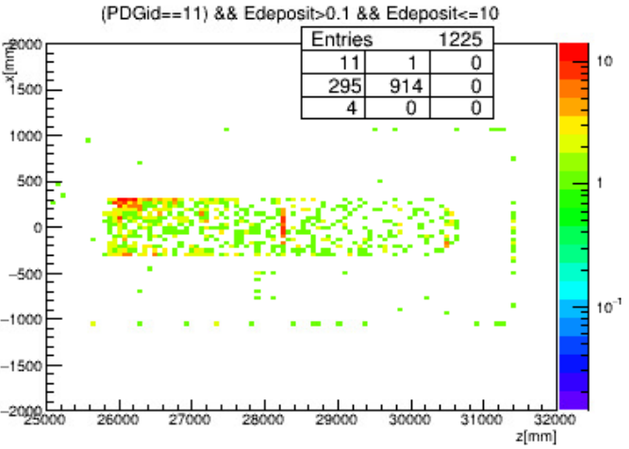


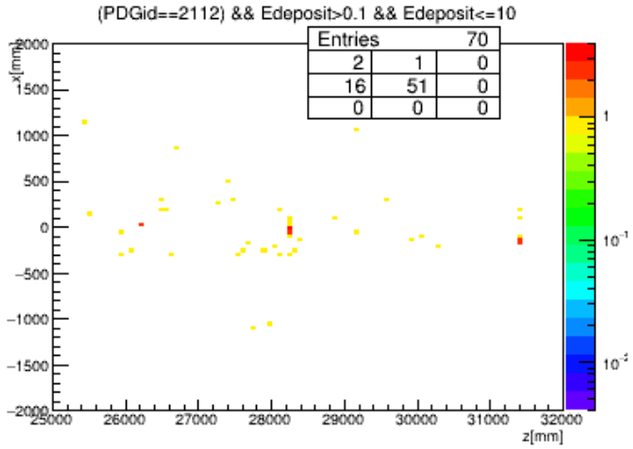
PREX2 - comparison

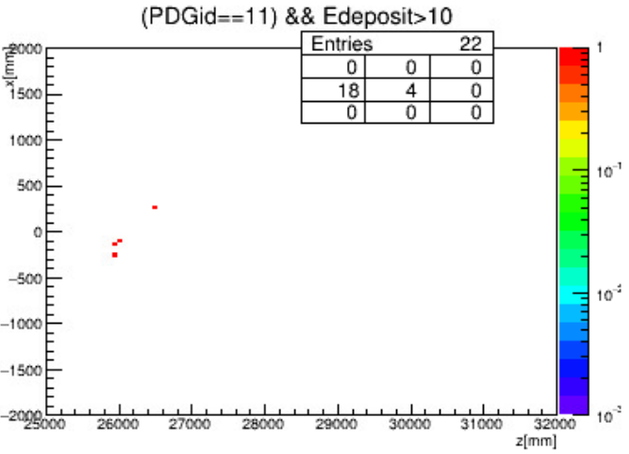
current setup

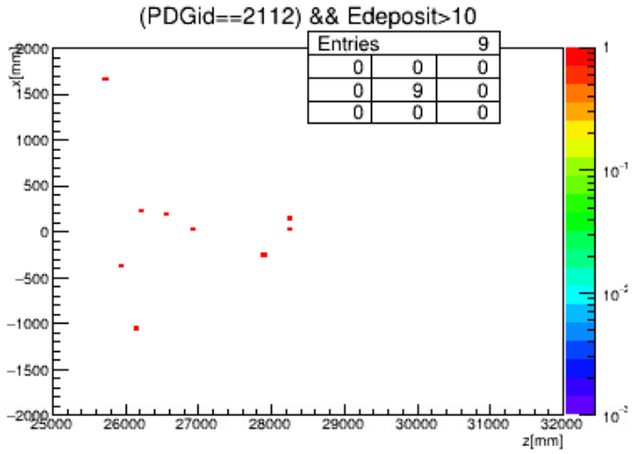




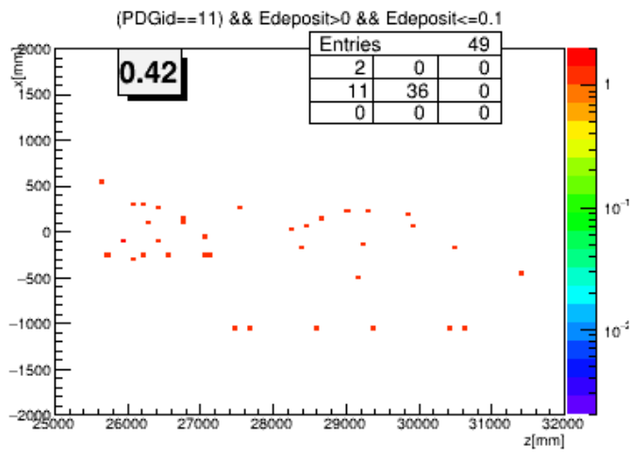


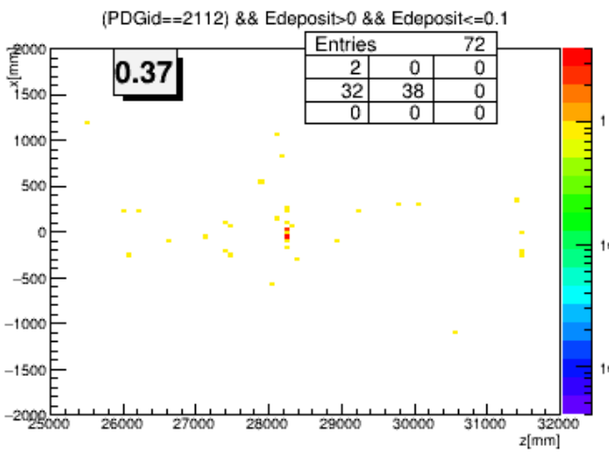


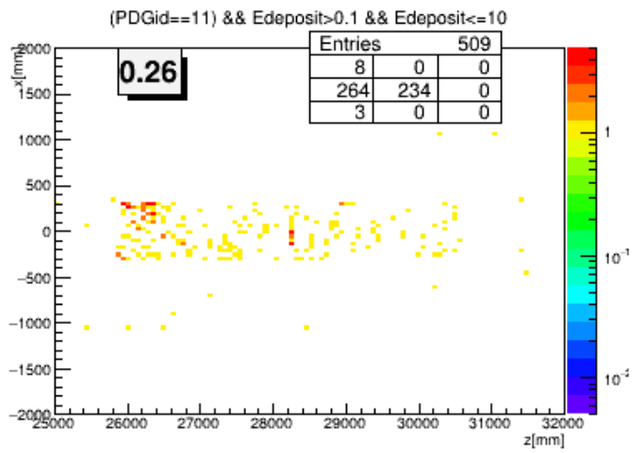


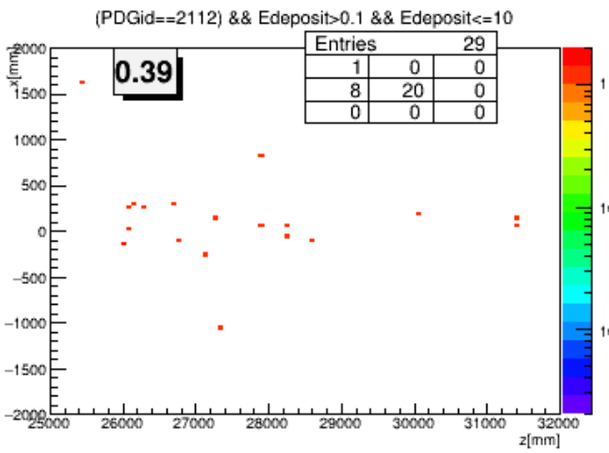


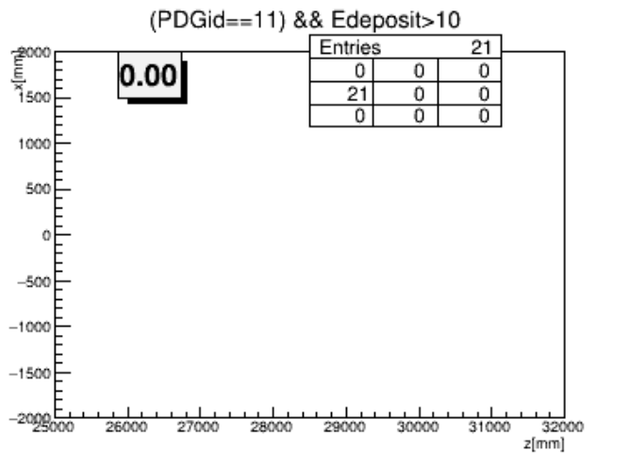
current setup + 1 ft Poly shield

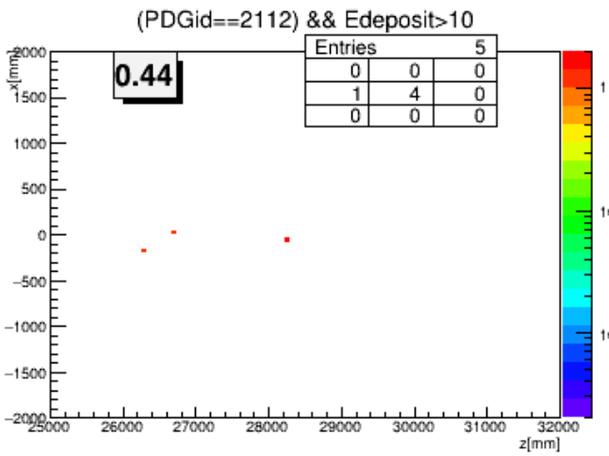






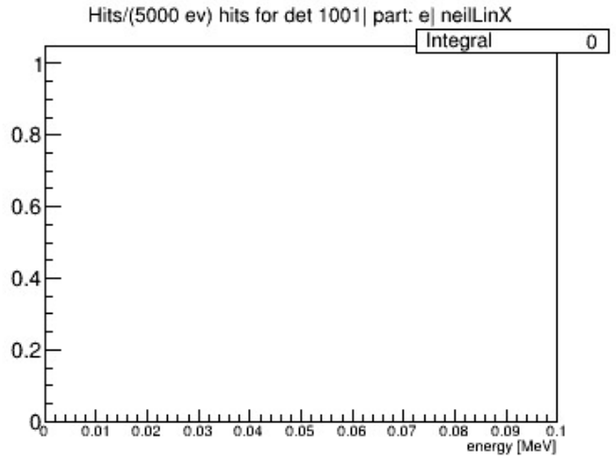


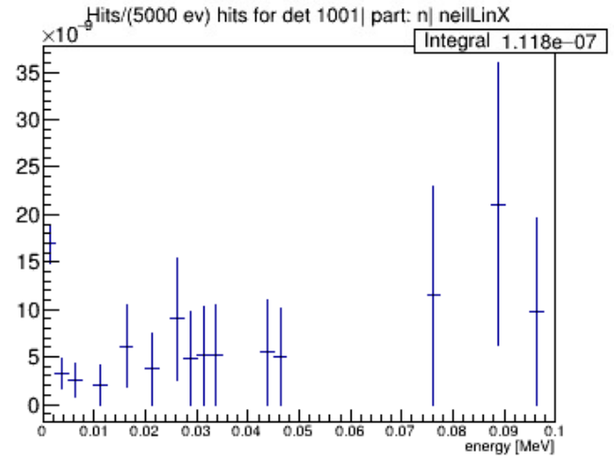


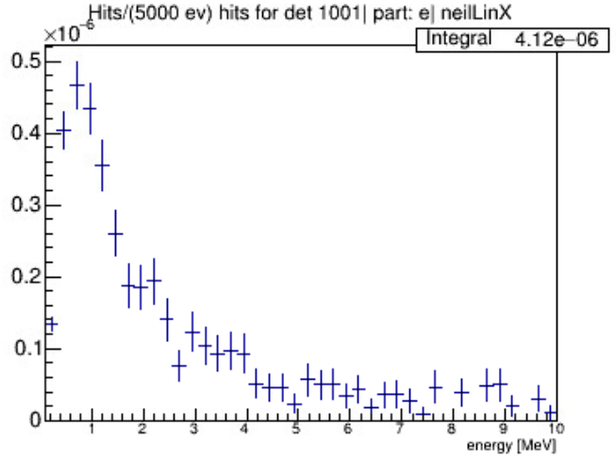


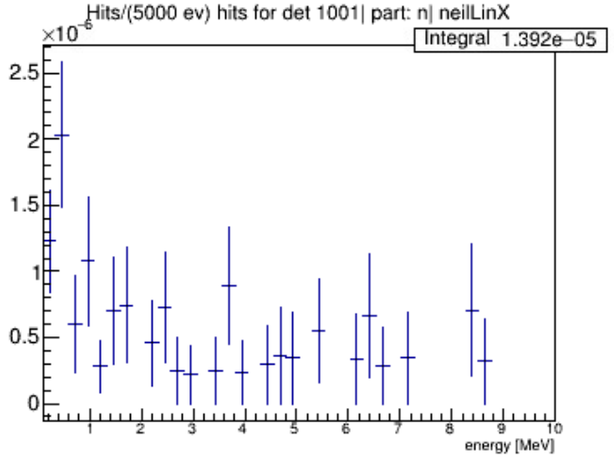
PREX2 - comparison

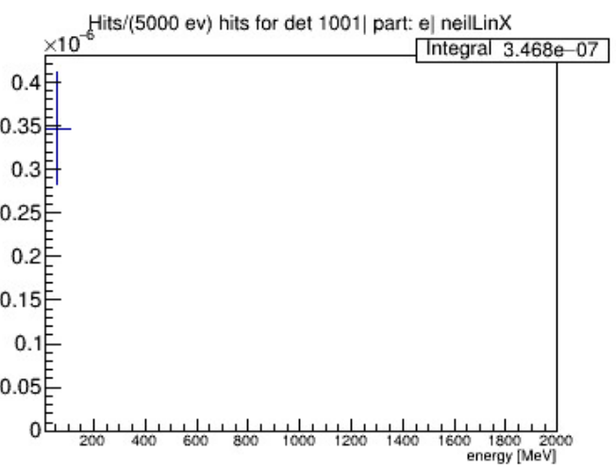
current setup

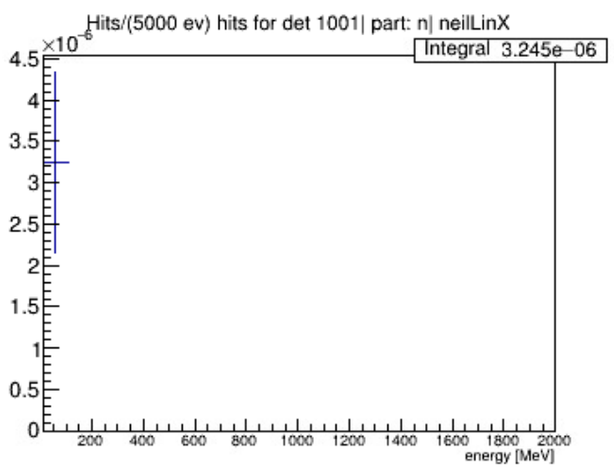




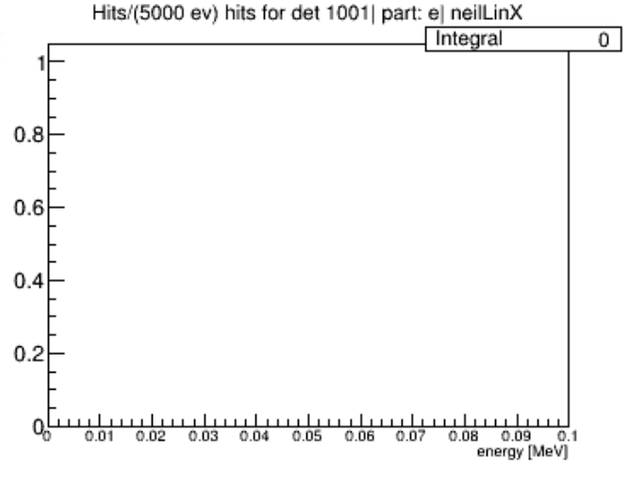


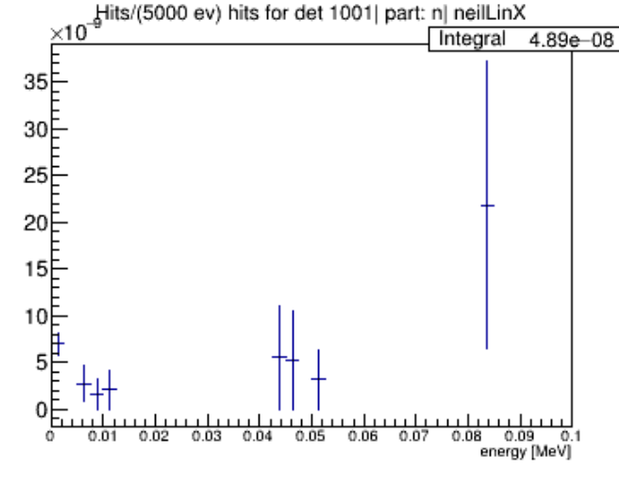


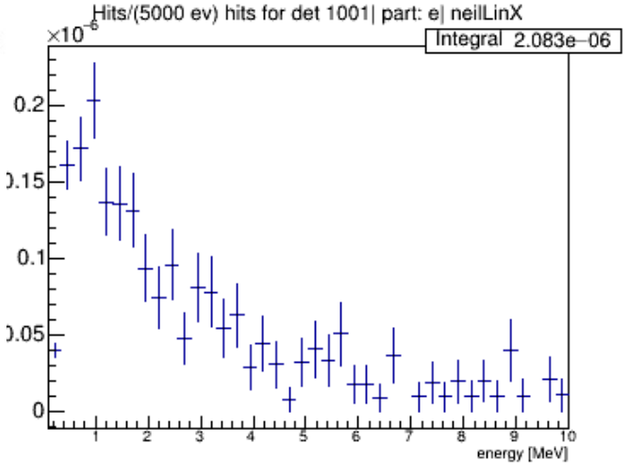


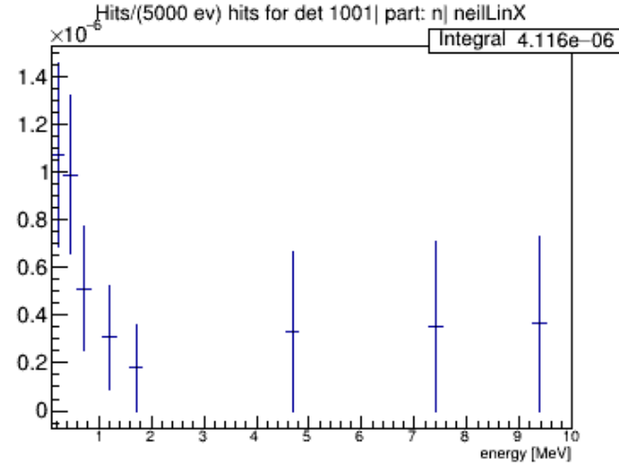


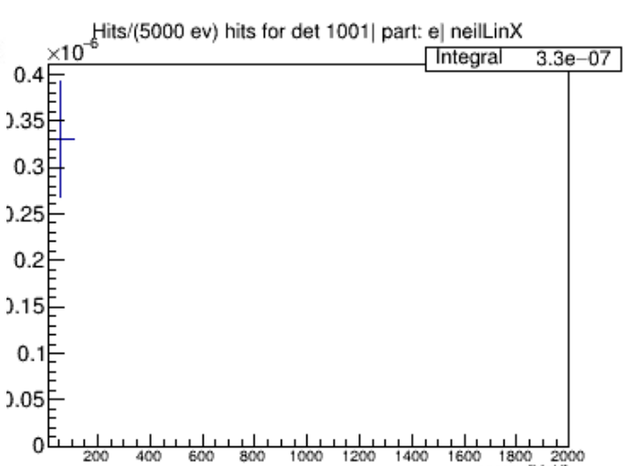
current setup + 1 ft Poly shield

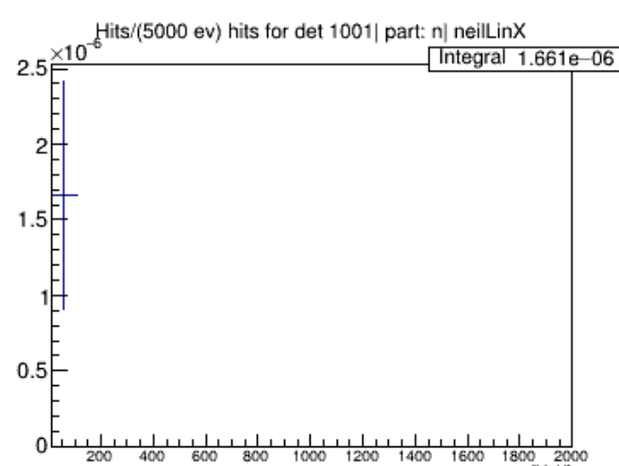






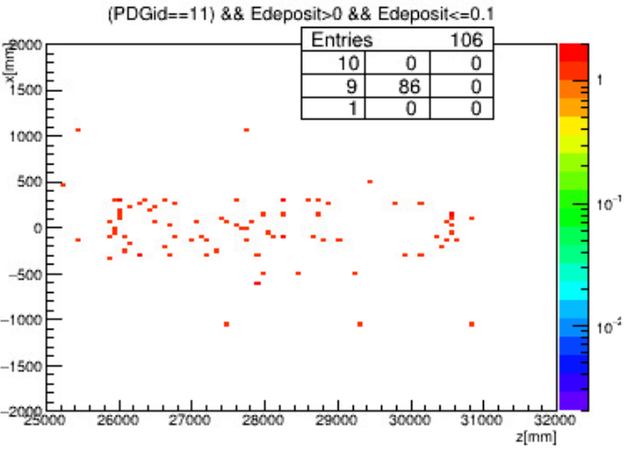


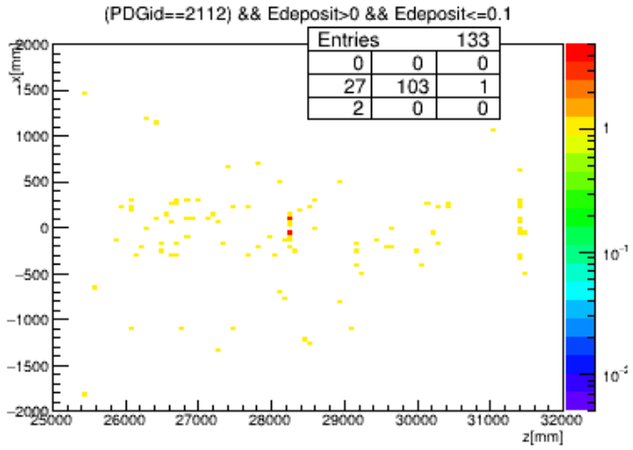


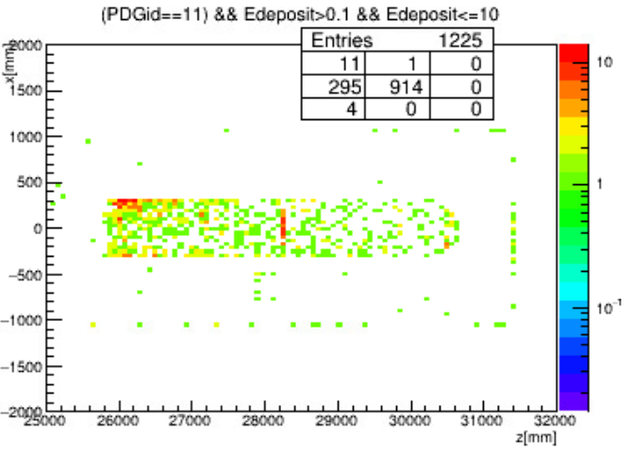


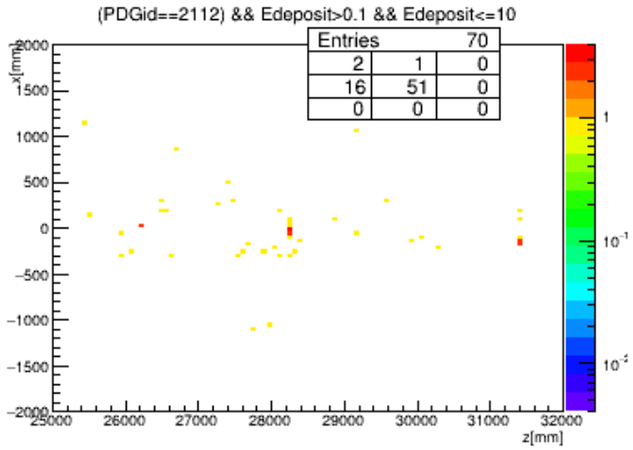
PREX2 - comparison

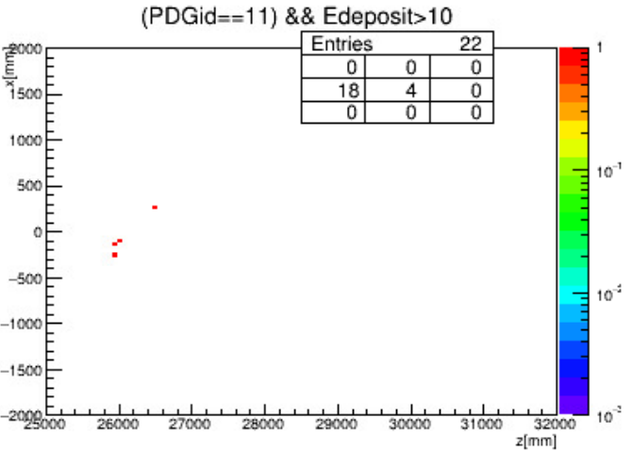
current setup

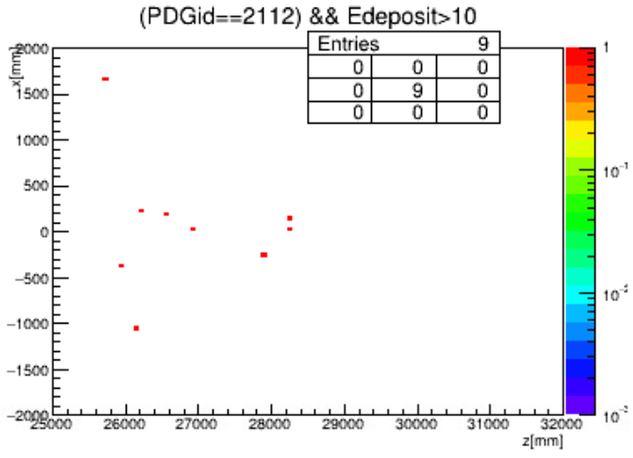




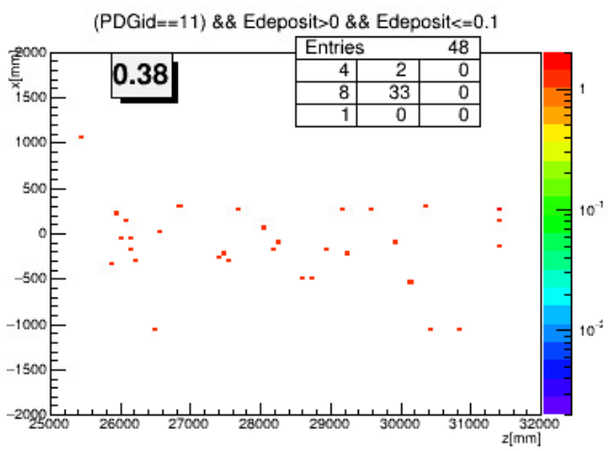


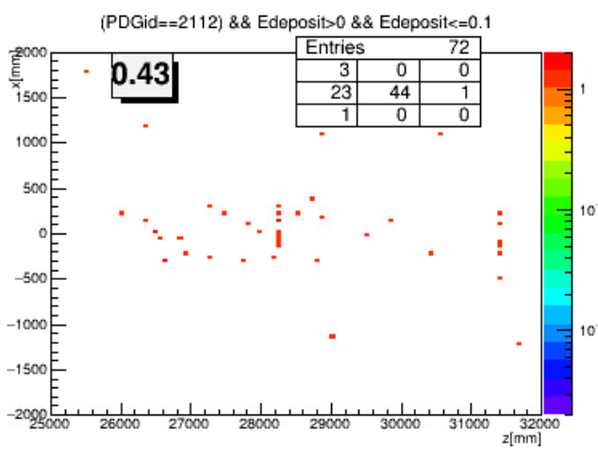


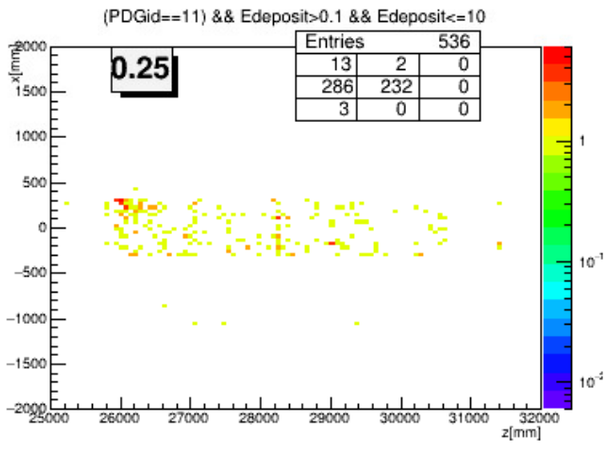


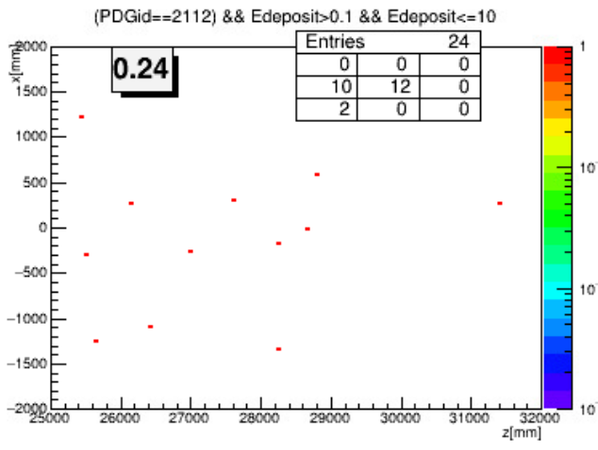


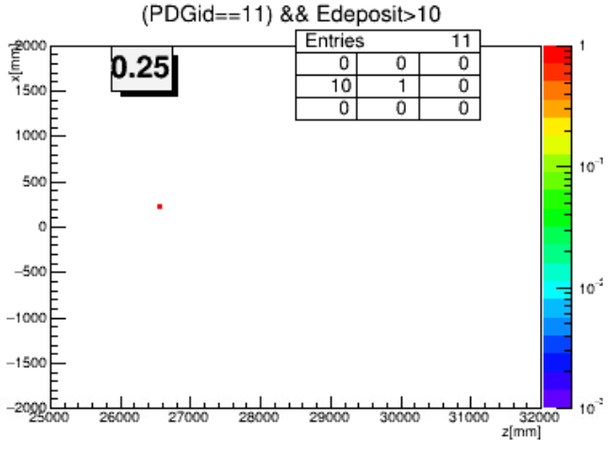
current setup + 4 in Donut+ 1 ft concrete shield

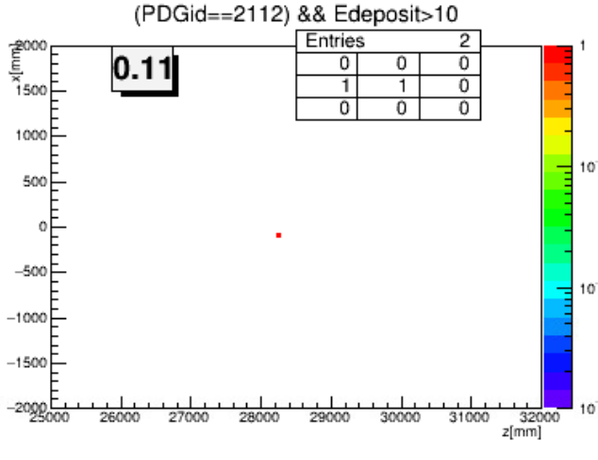






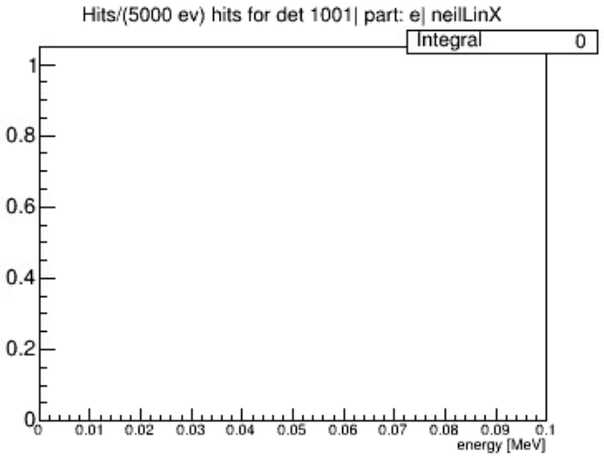


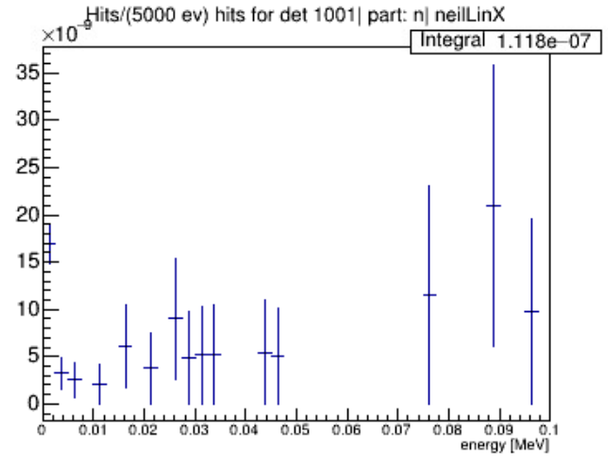


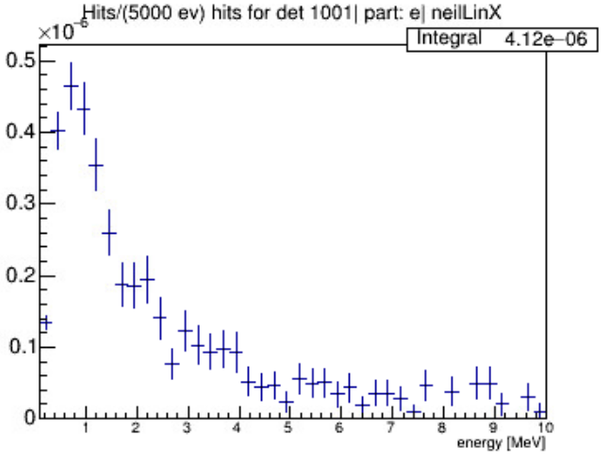


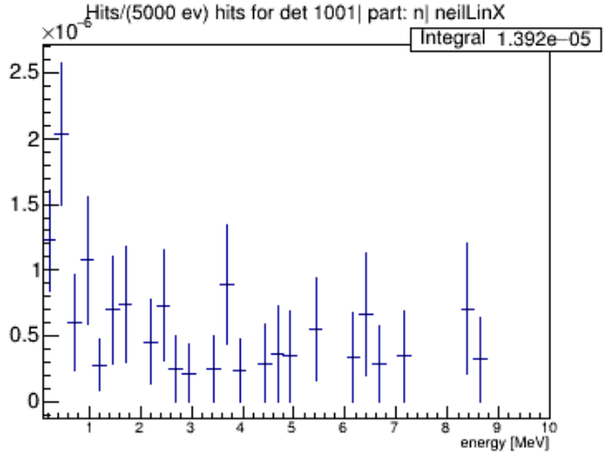
PREX2 - comparison

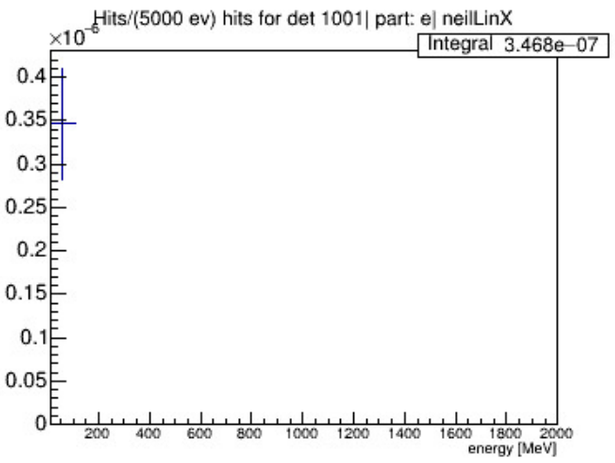
current setup

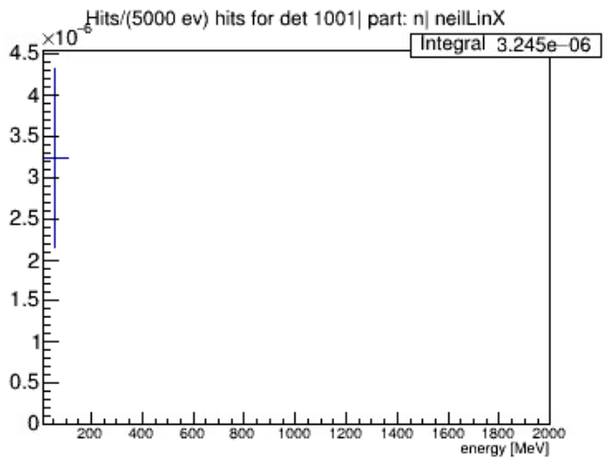




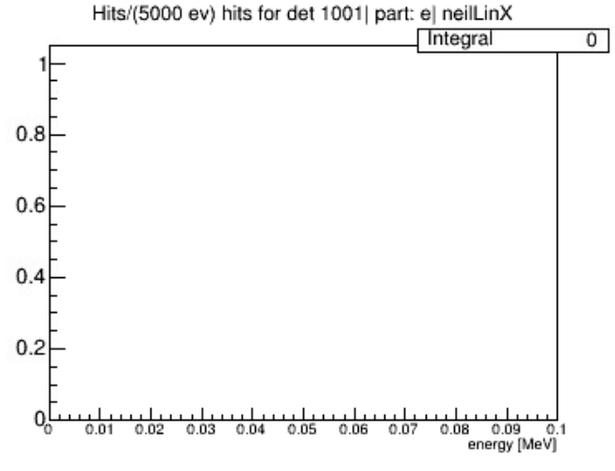


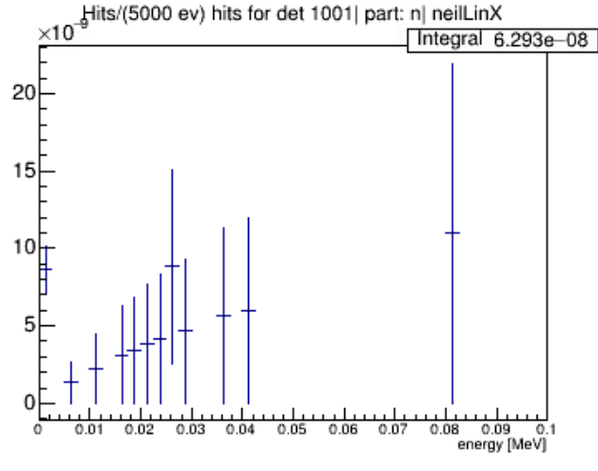


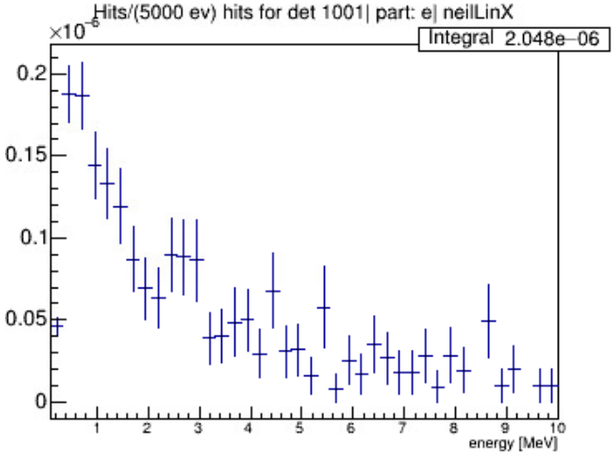


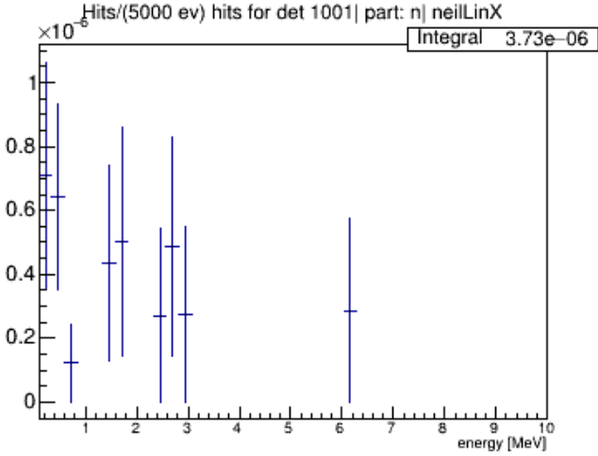


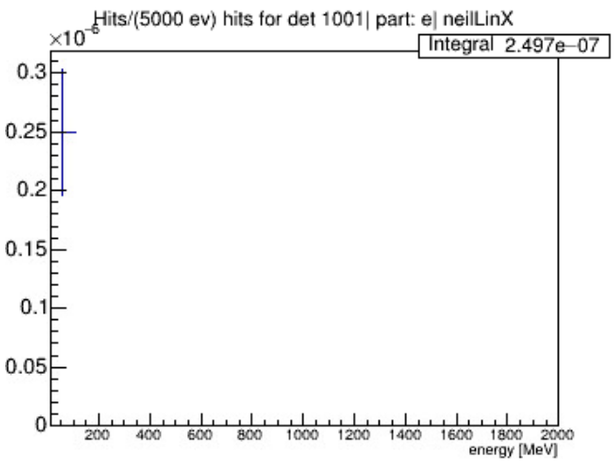
current setup + 4 in Donut+ 1 ft concrete shield

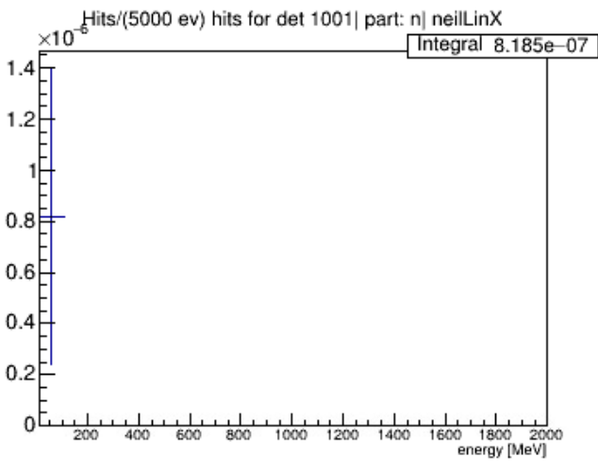








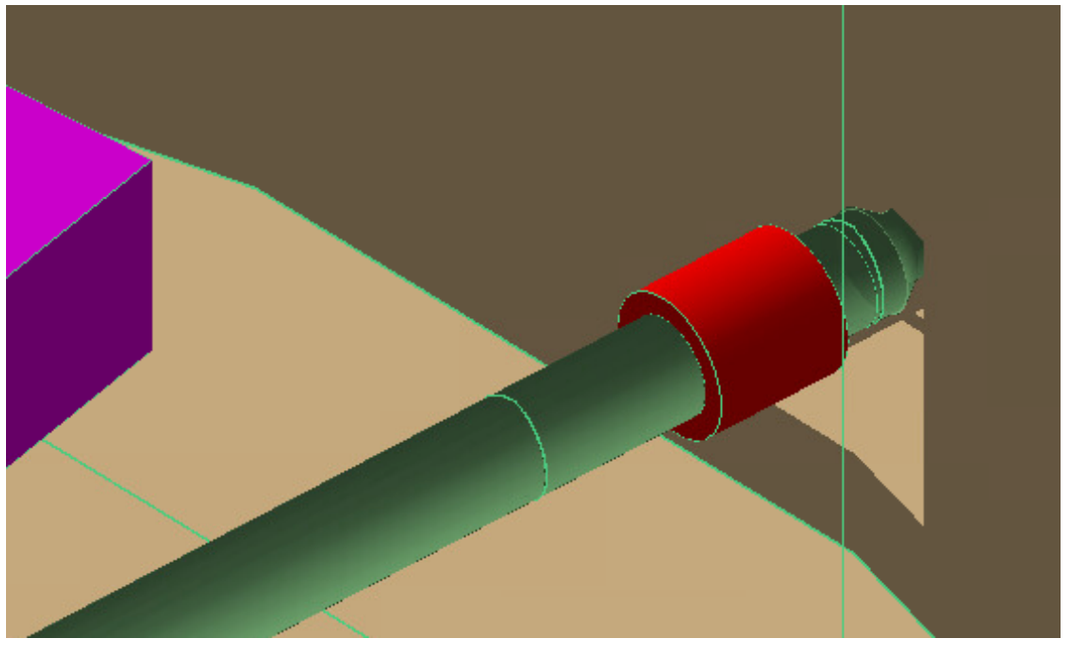


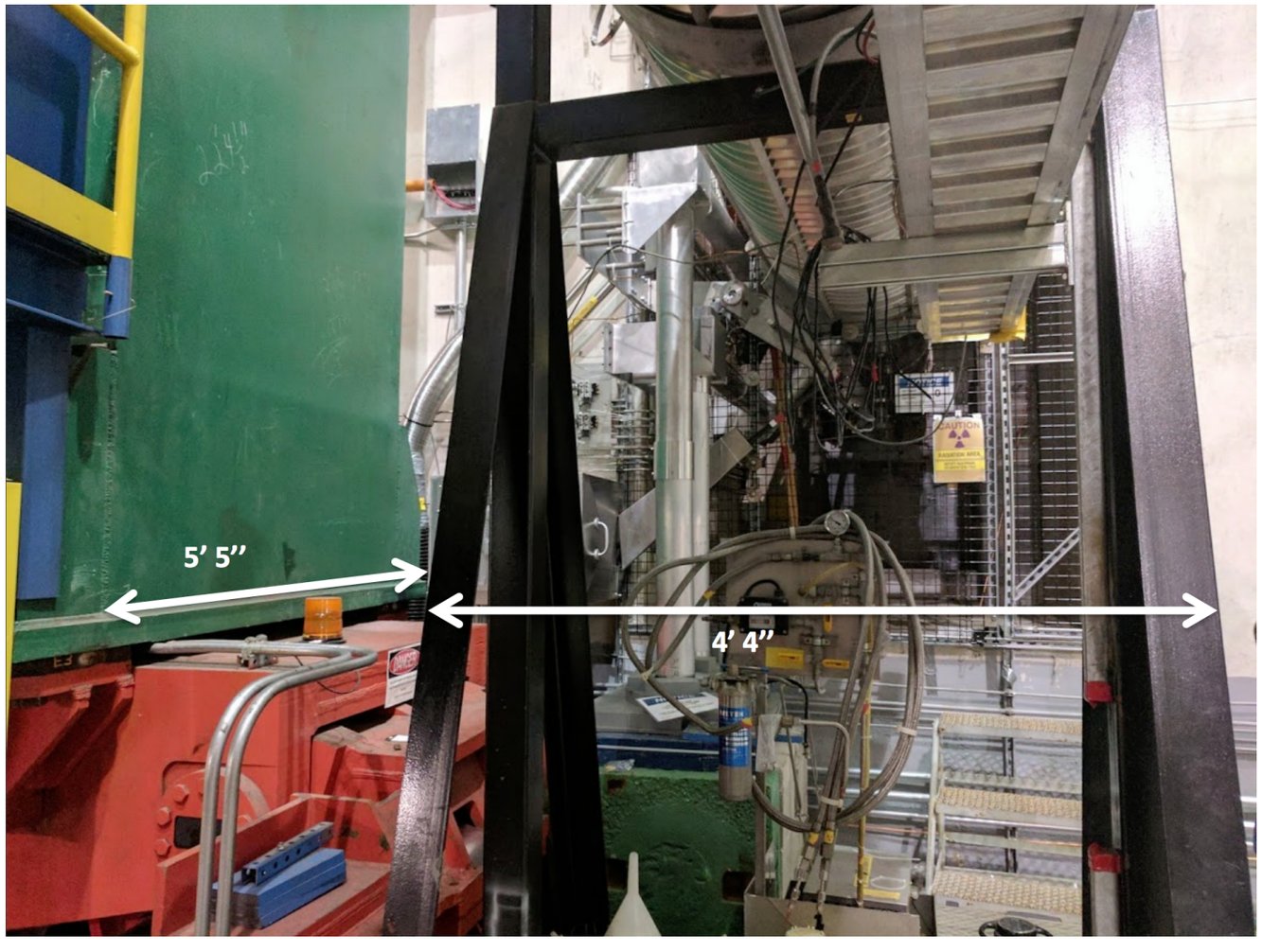


PREX2 - comparison

current setup + donut shield:

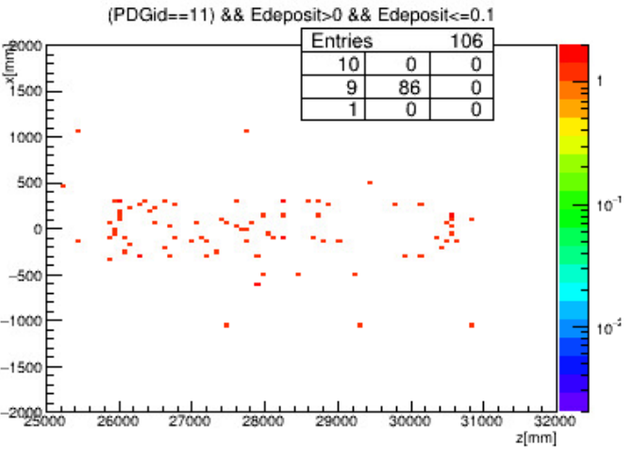
* 131 cm in z
* 20 cm in r (46 to 66 cm)
* DS edge ~50 cm from the edge of the hall (would require some refinement to fit in)

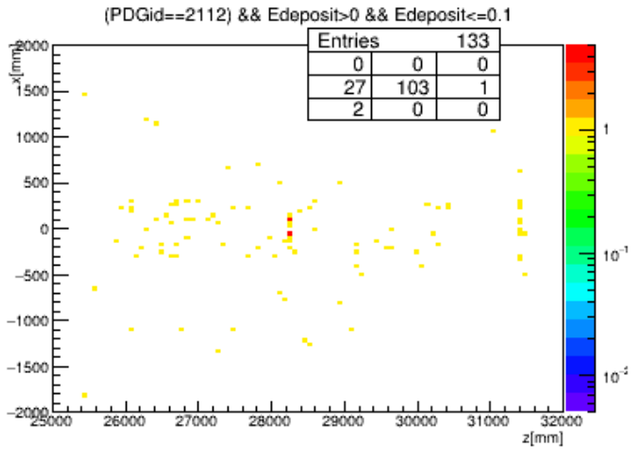


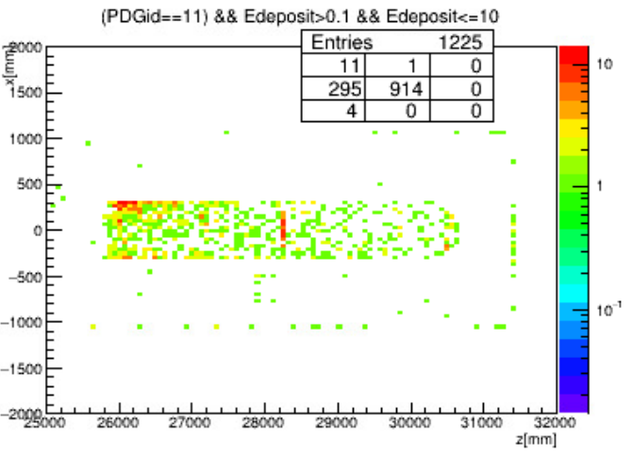


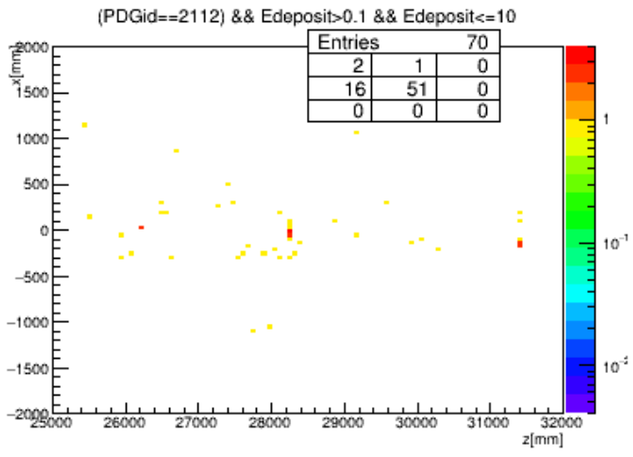
PREX2 - comparison

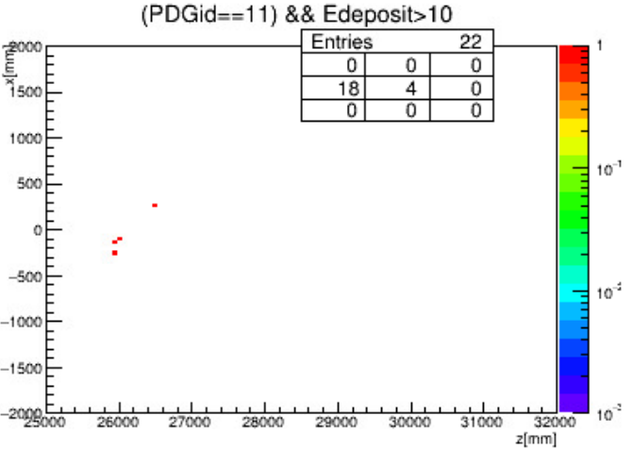
current setup

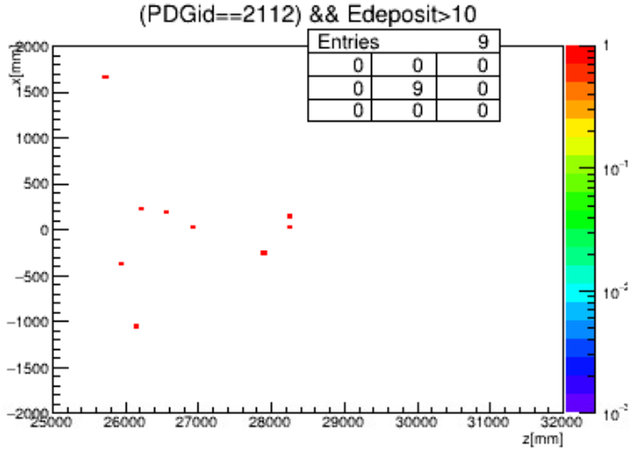




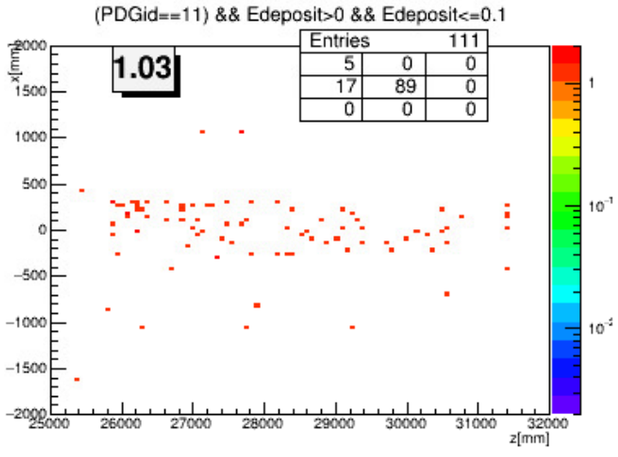


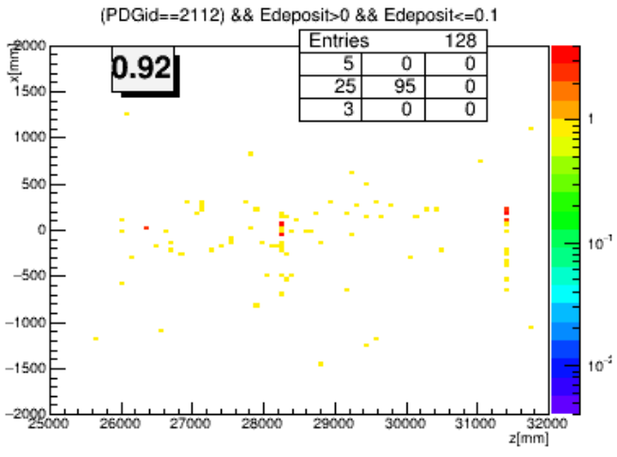


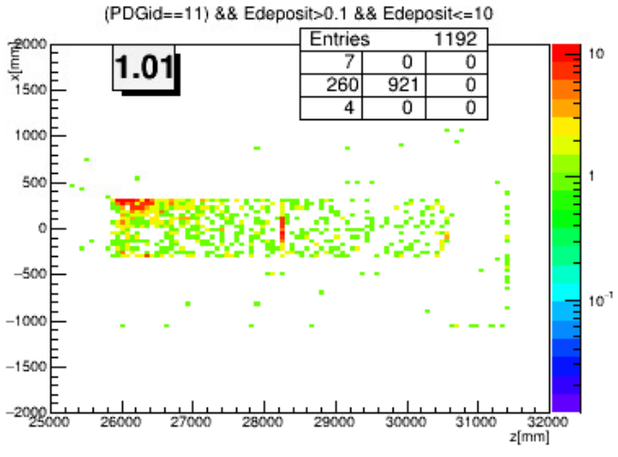


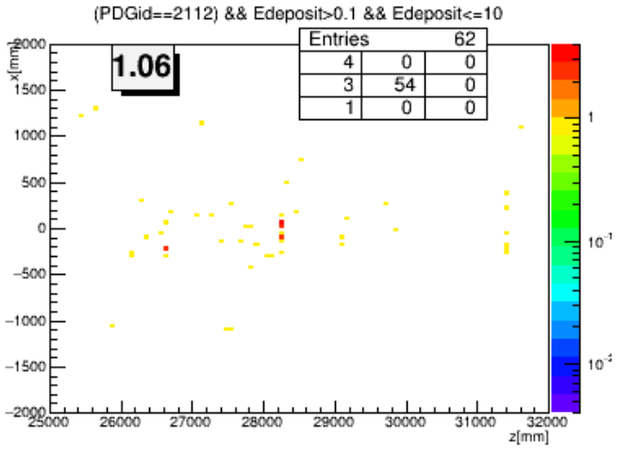


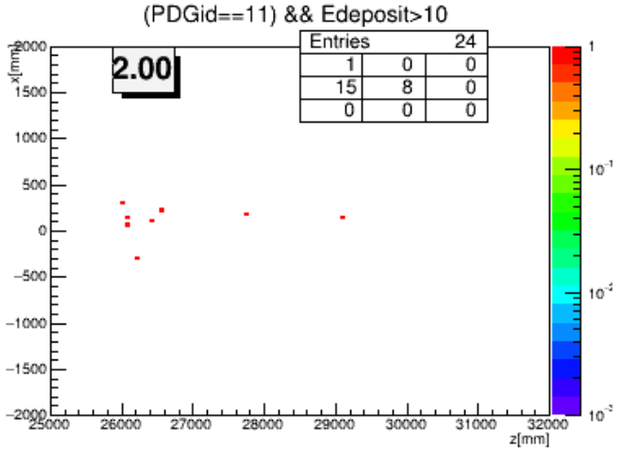
current setup + donut shield

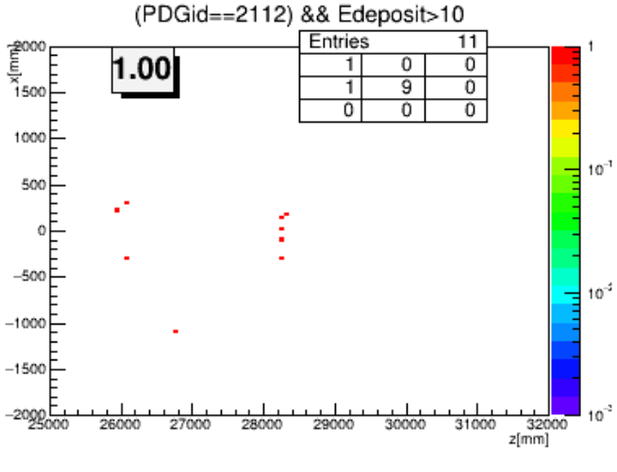






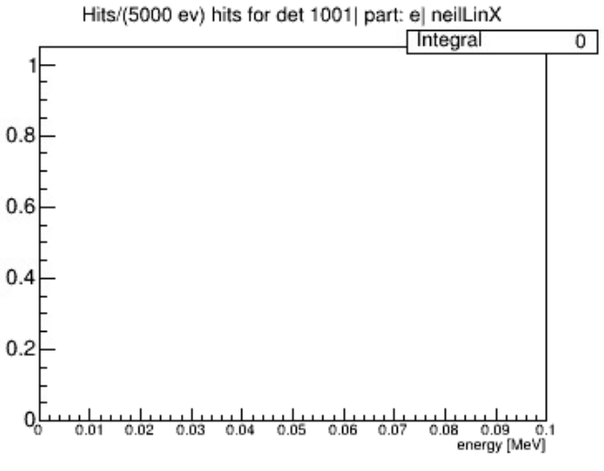


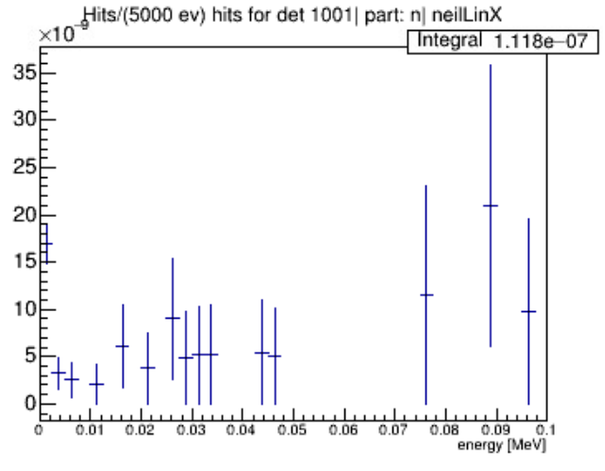


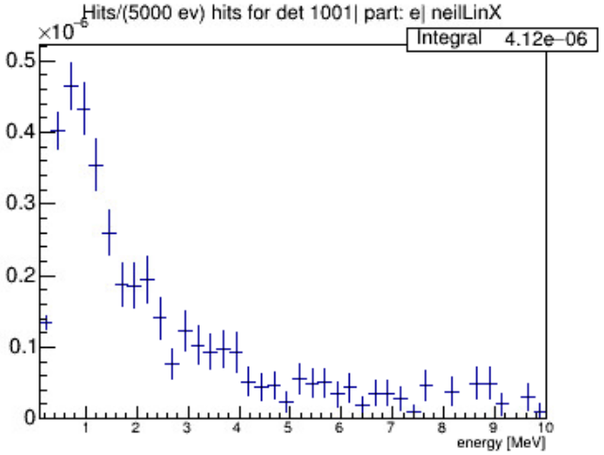


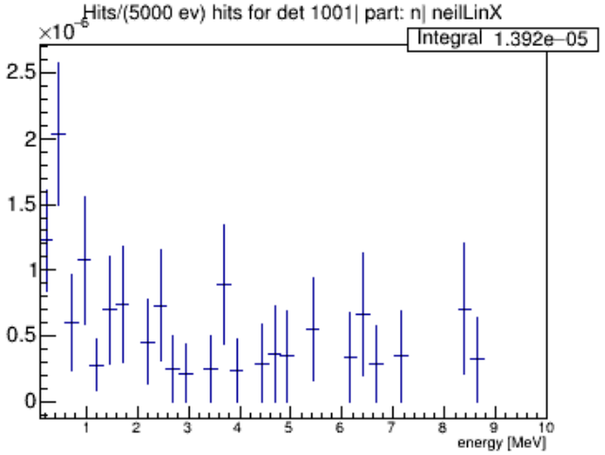
PREX2 - comparison

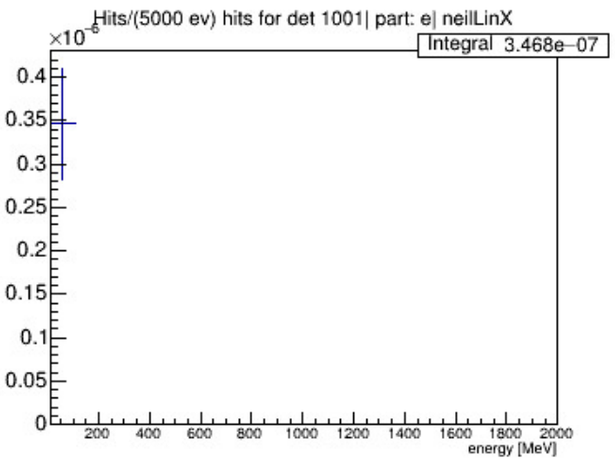
current setup

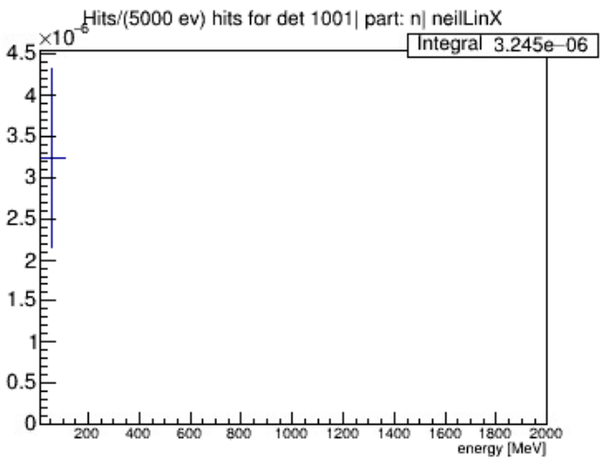




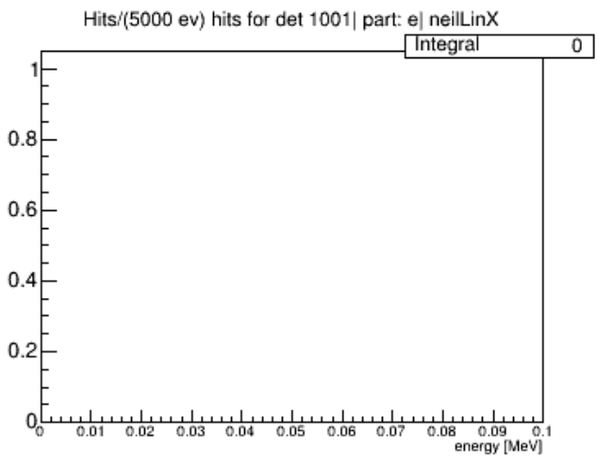


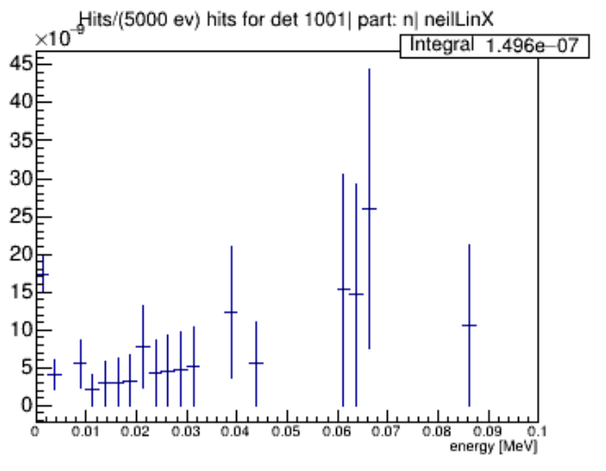


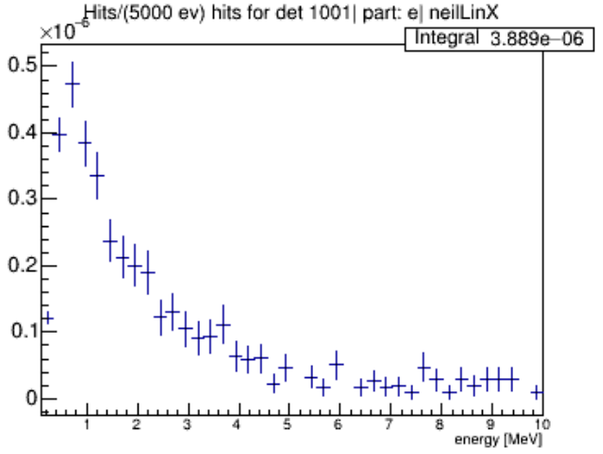


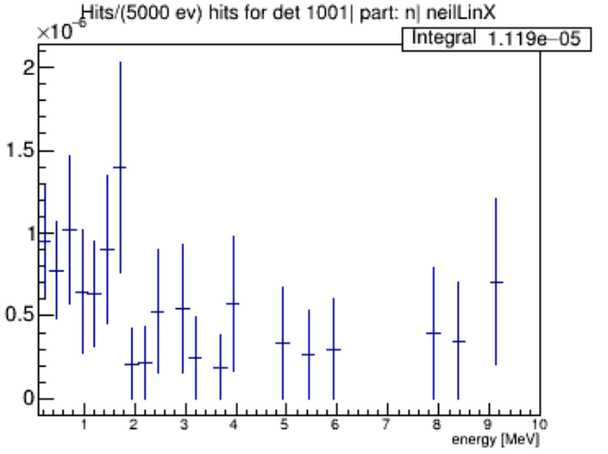


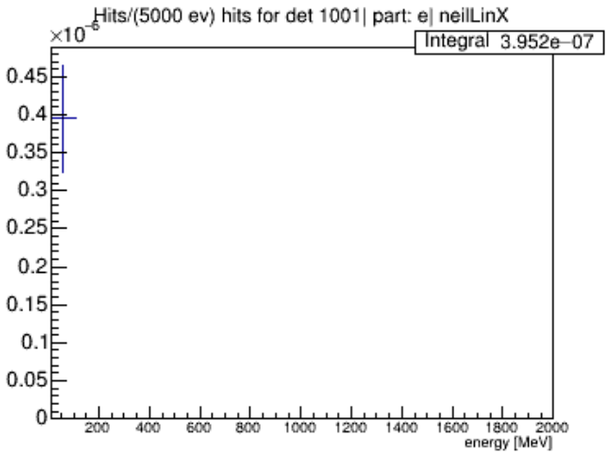
current setup + donut shield

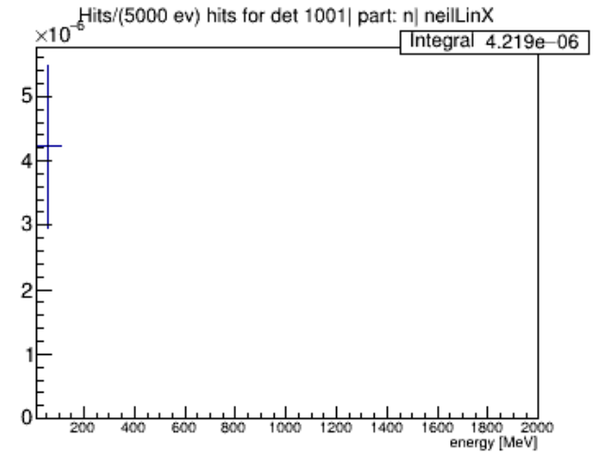






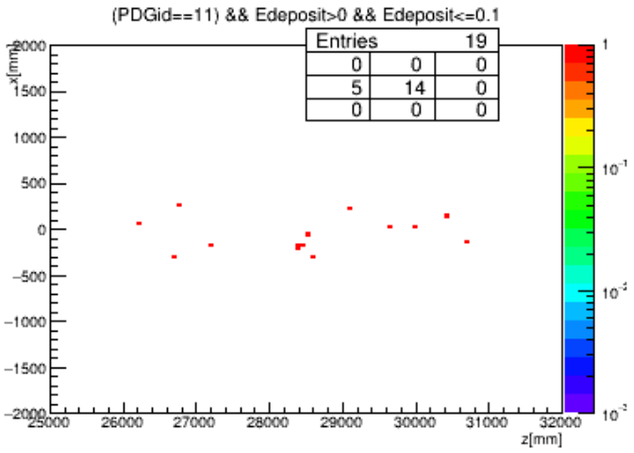


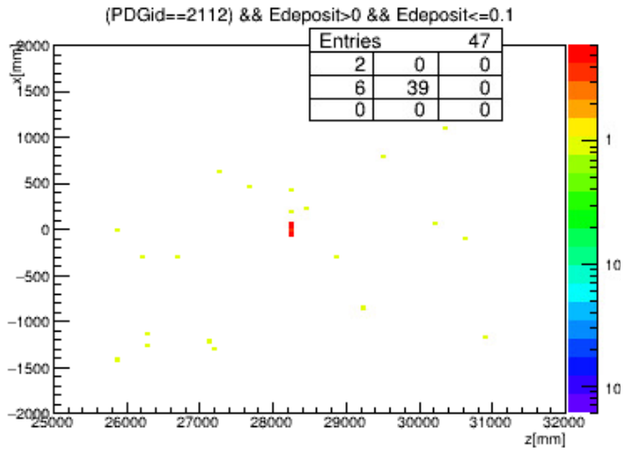


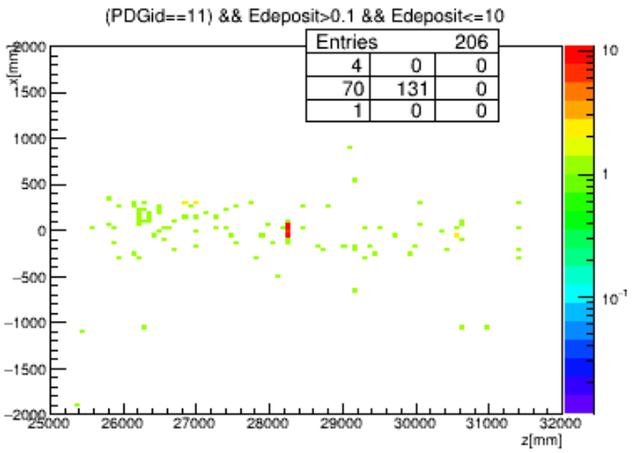


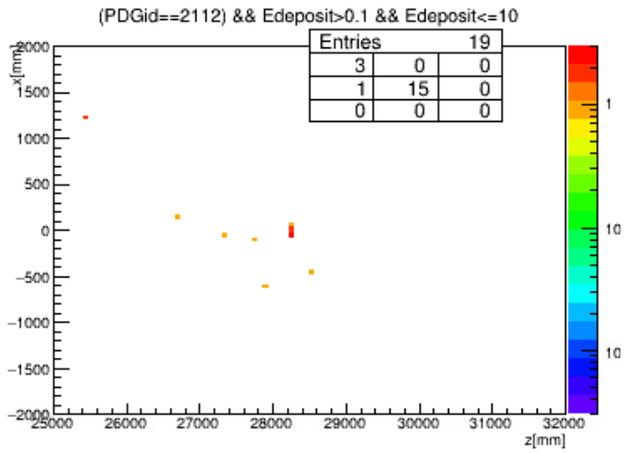
CREX - comparison

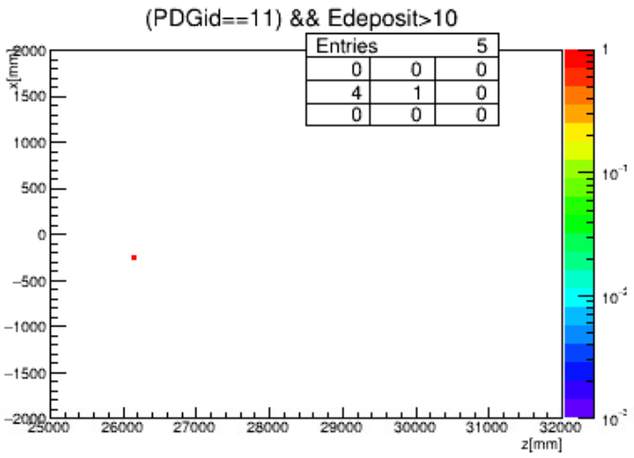
current setup

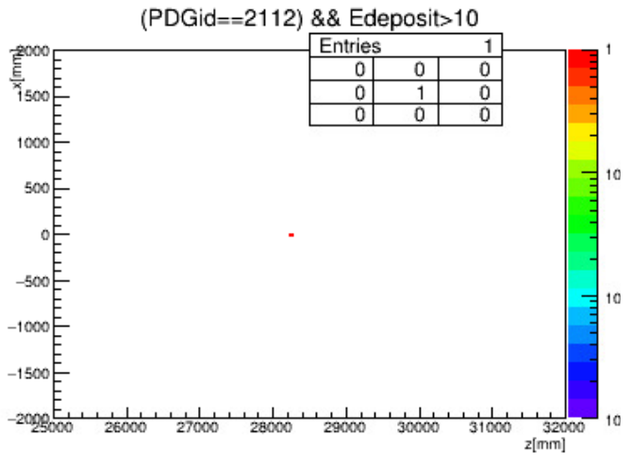




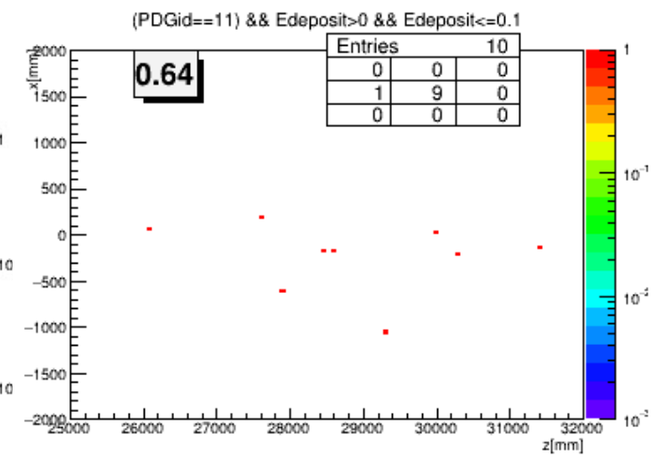


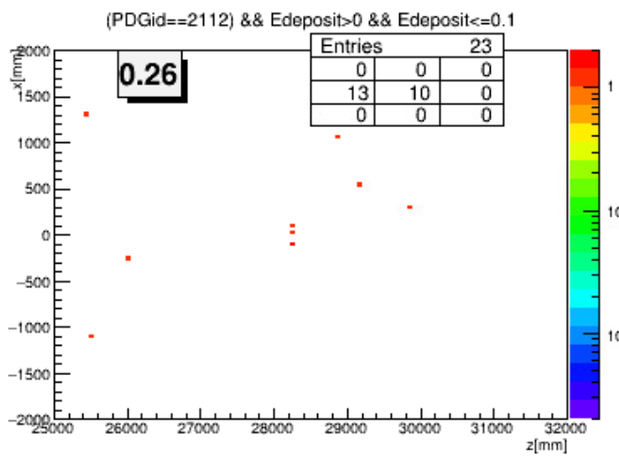


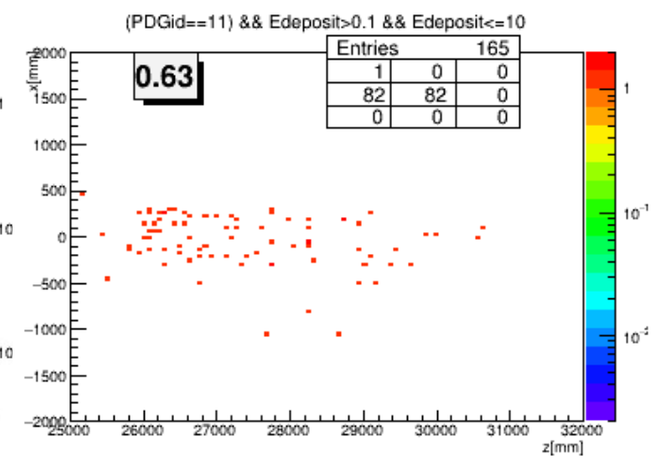


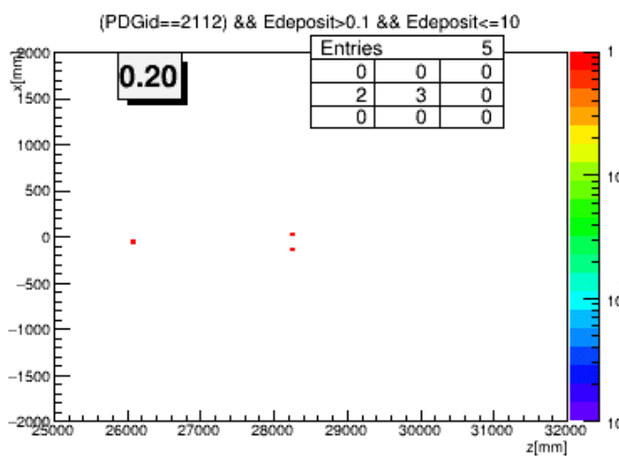


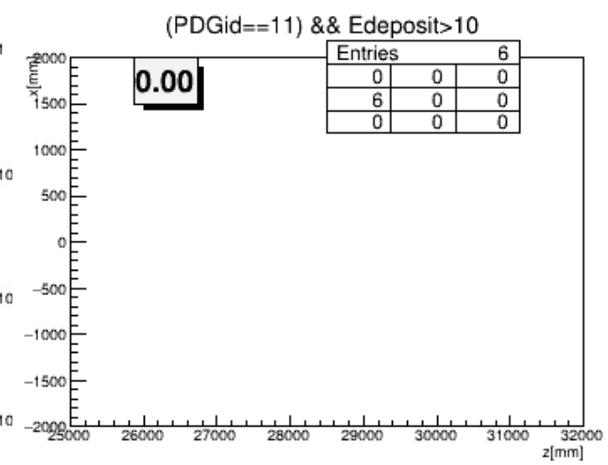
current setup + 4 in donut

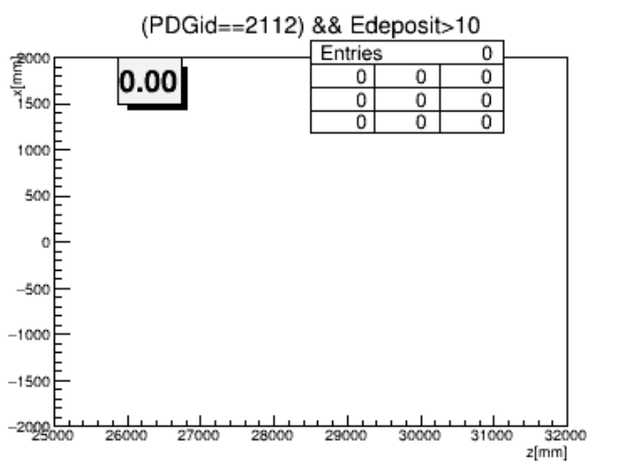






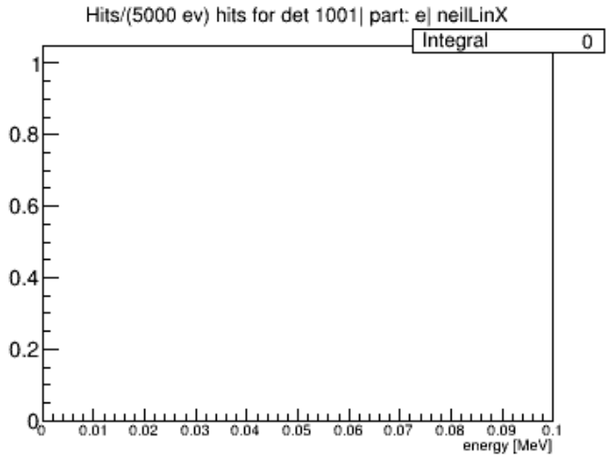


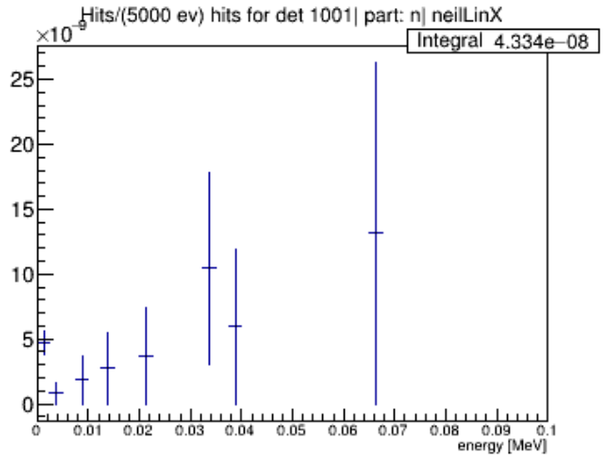


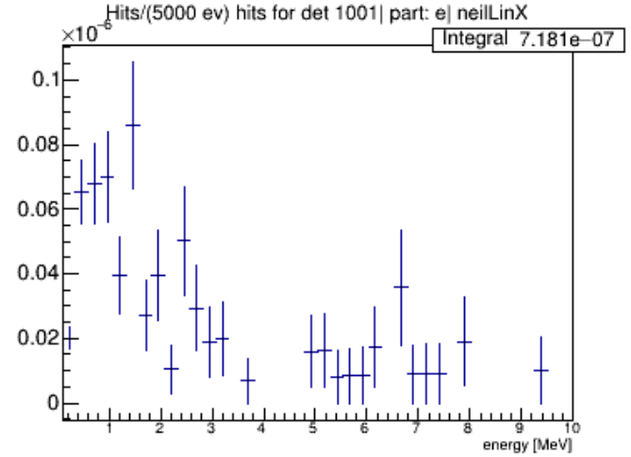


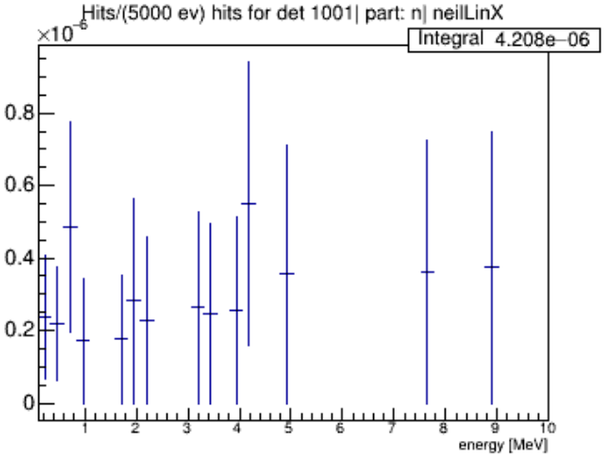
CREX - comparison

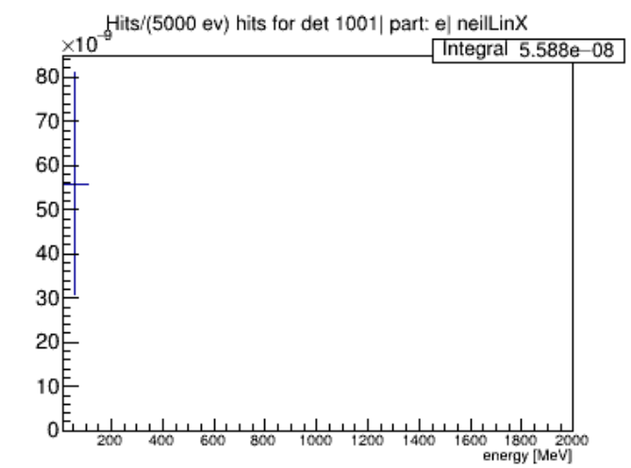
current setup

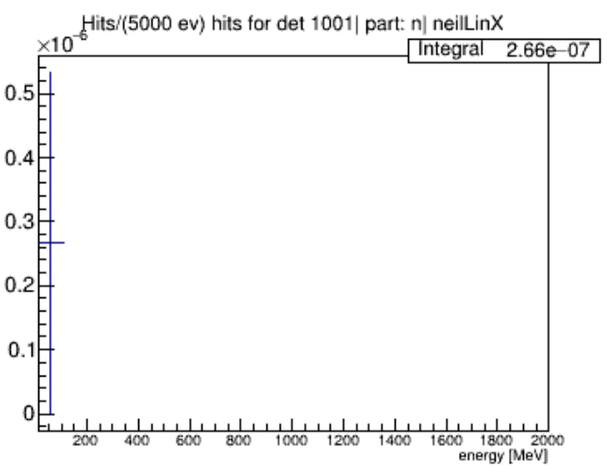




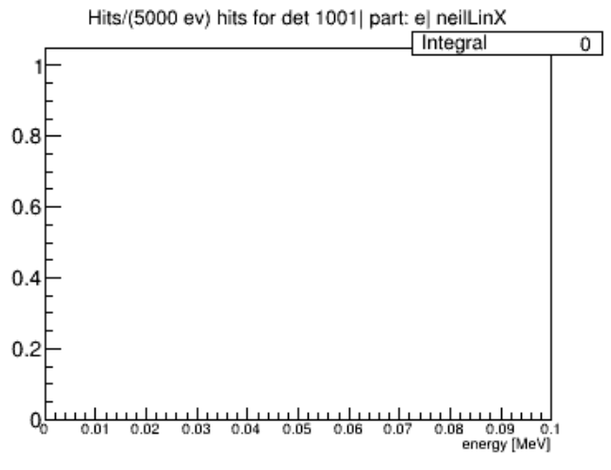


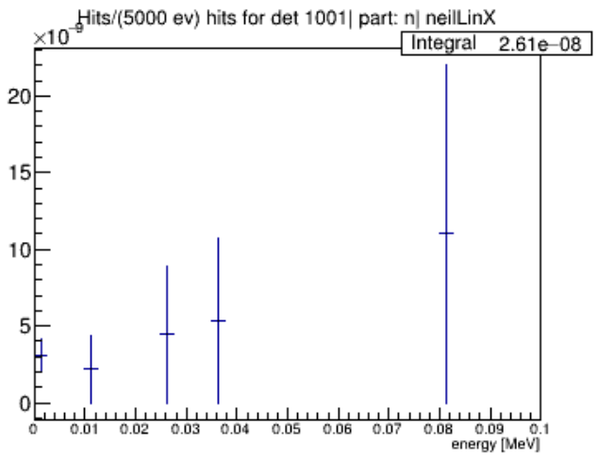


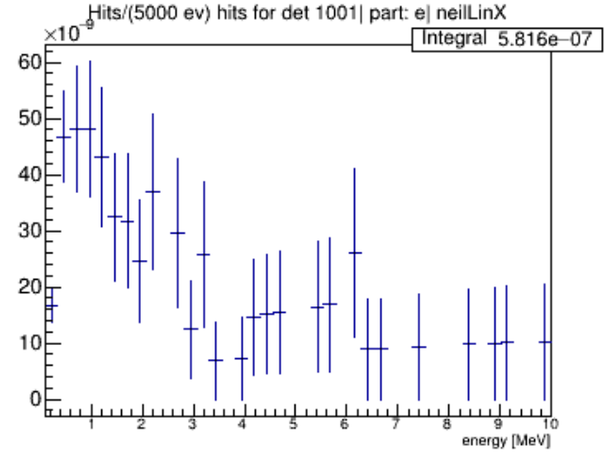


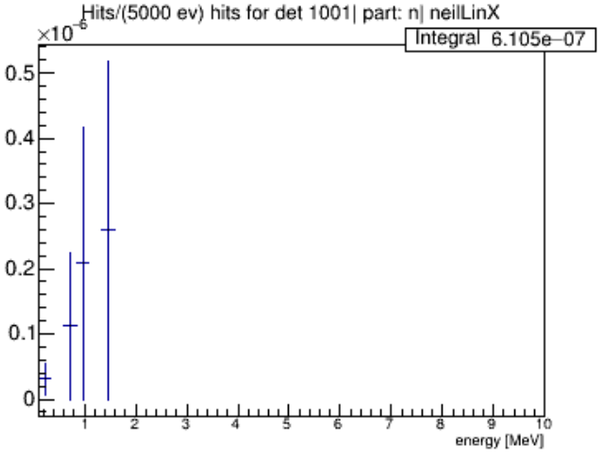


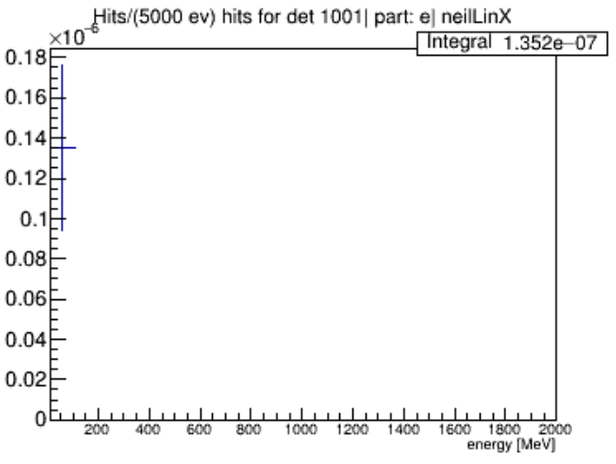
current setup + 4 in donut

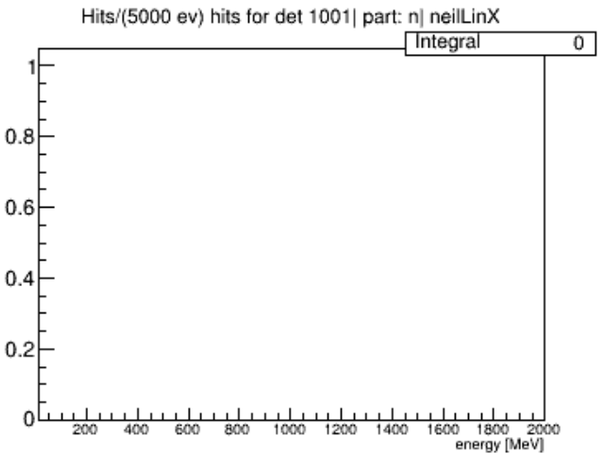








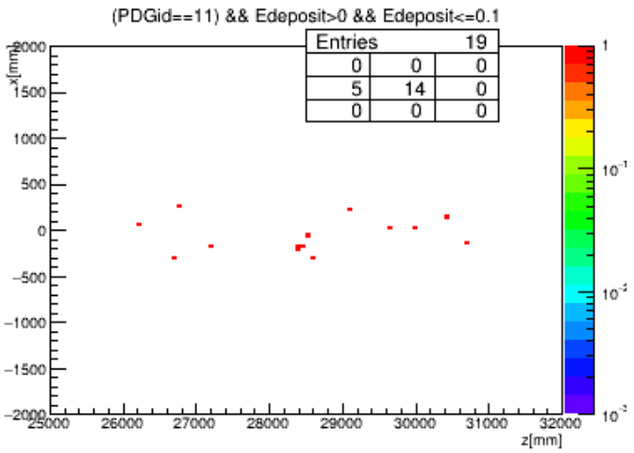


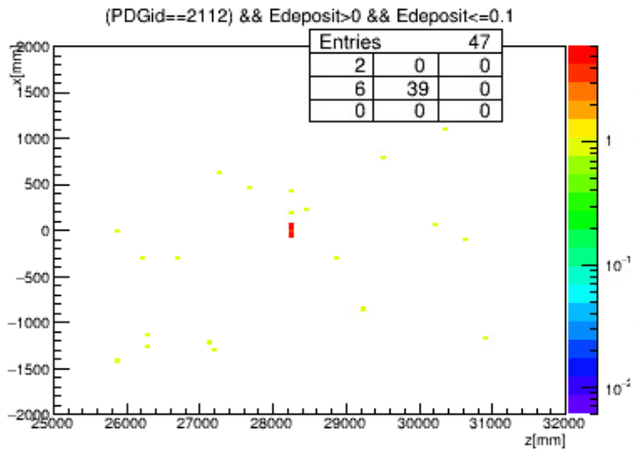


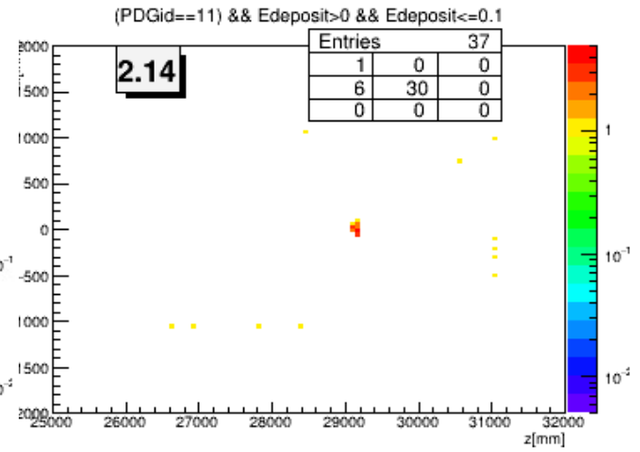
CREX - comparison

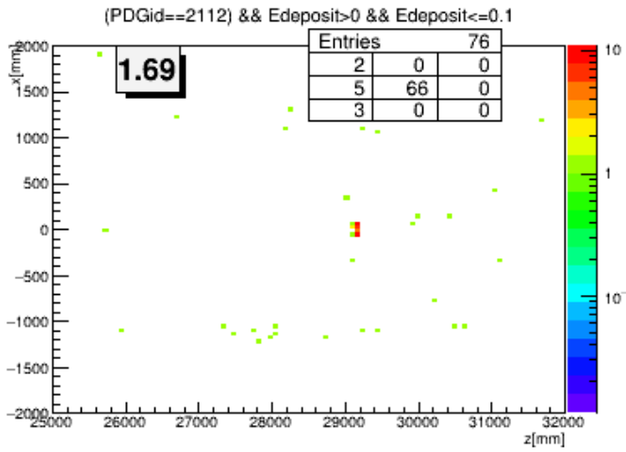
current setup

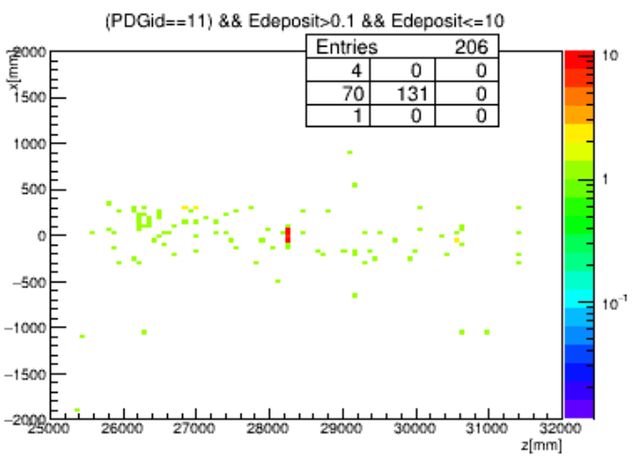
PREX1 dump setup

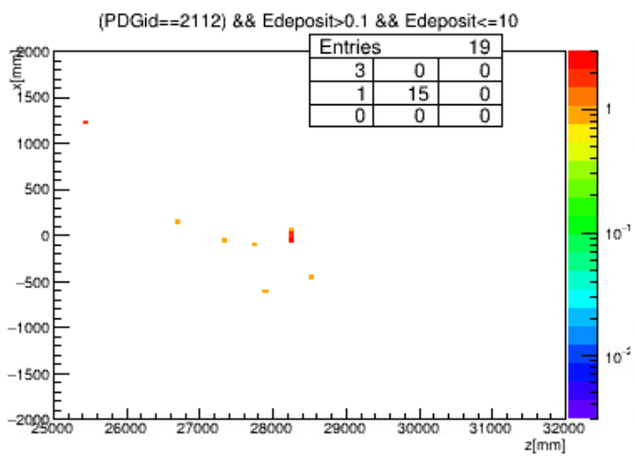


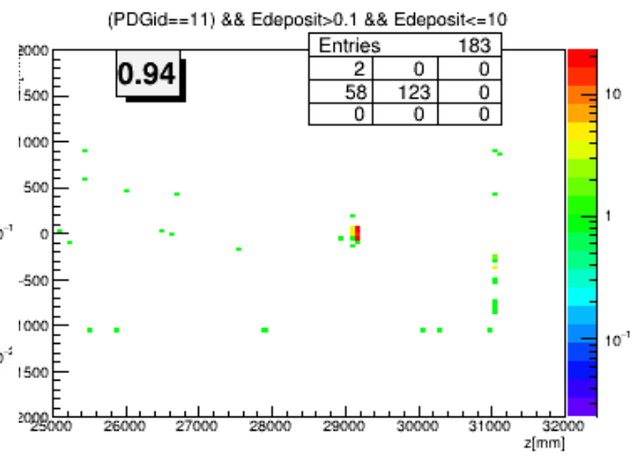


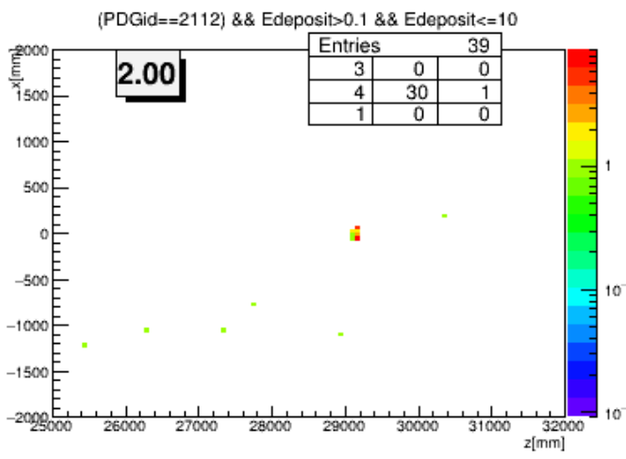


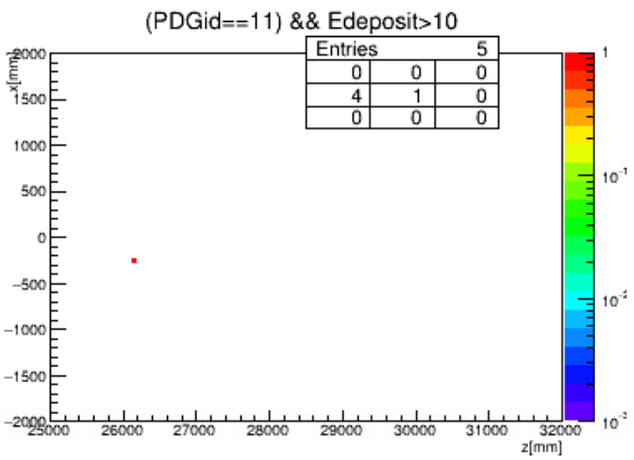


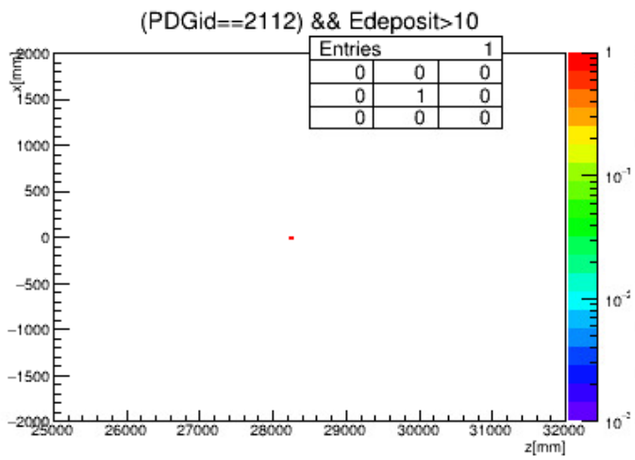


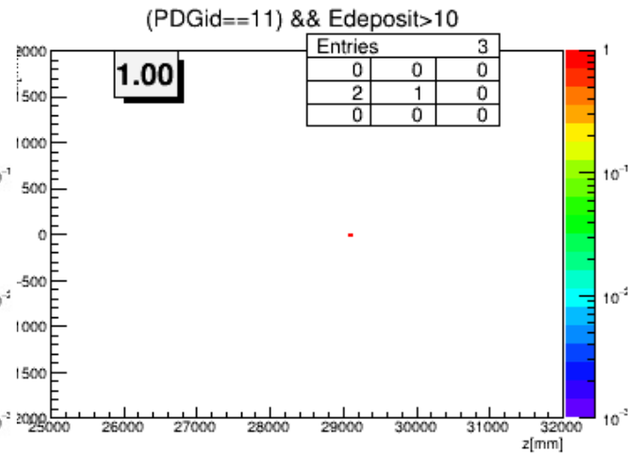


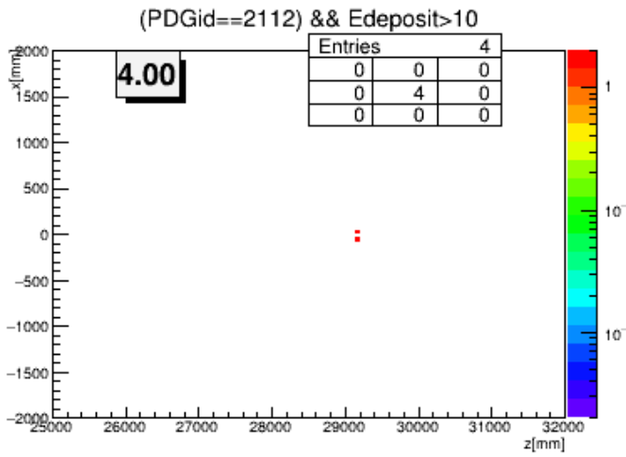






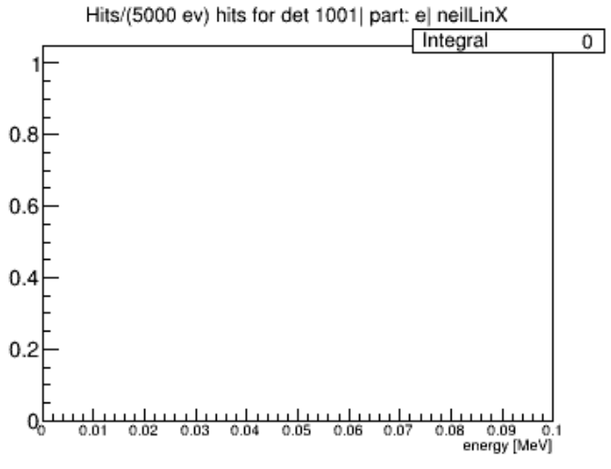


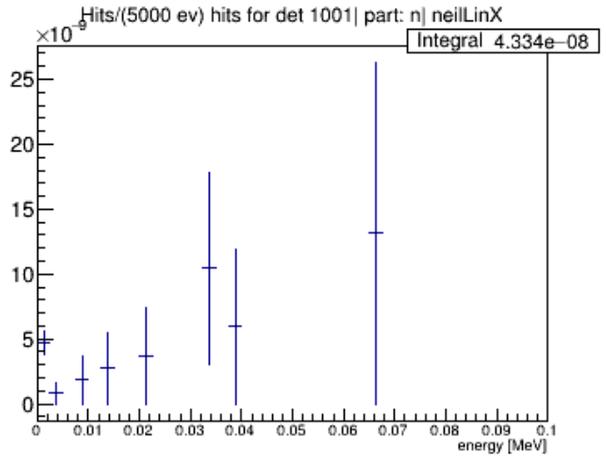


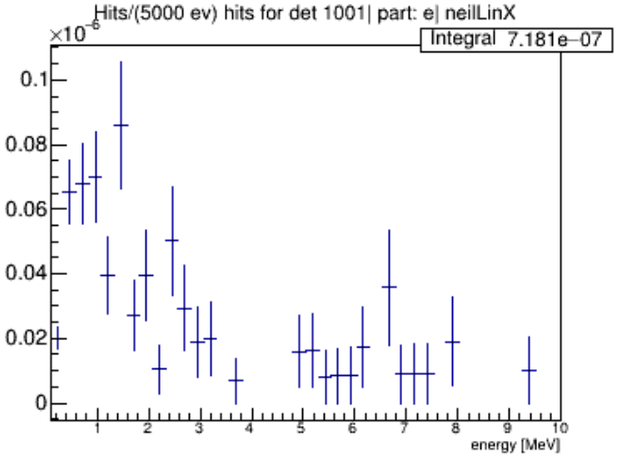


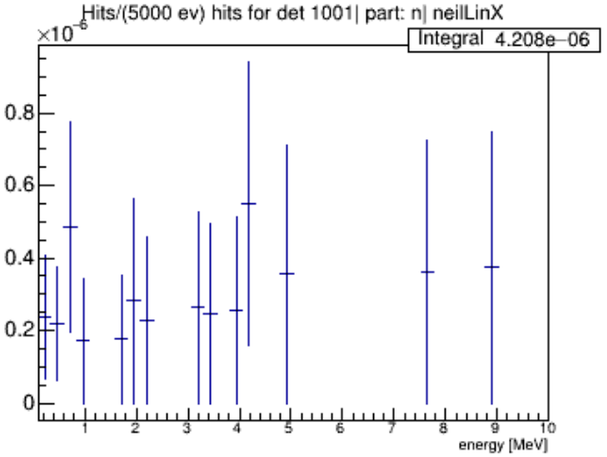
CREX - comparison

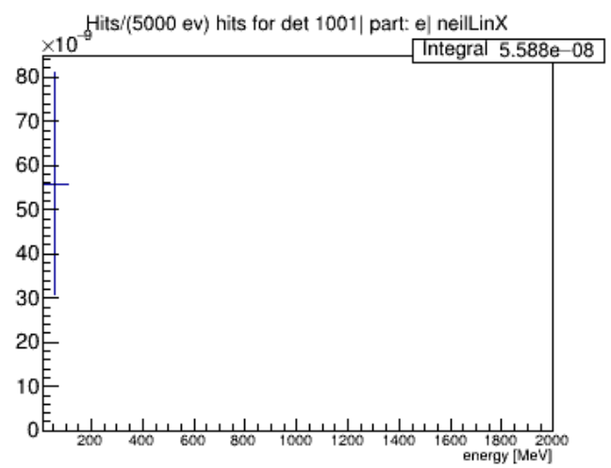
current setup

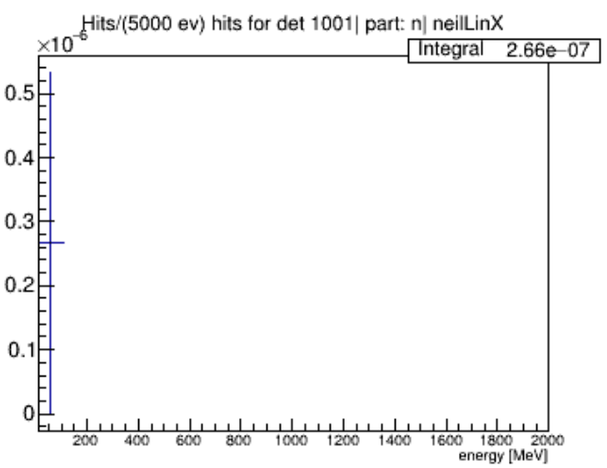




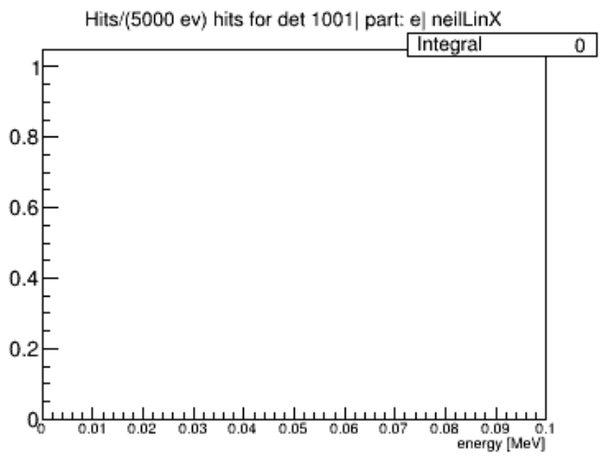


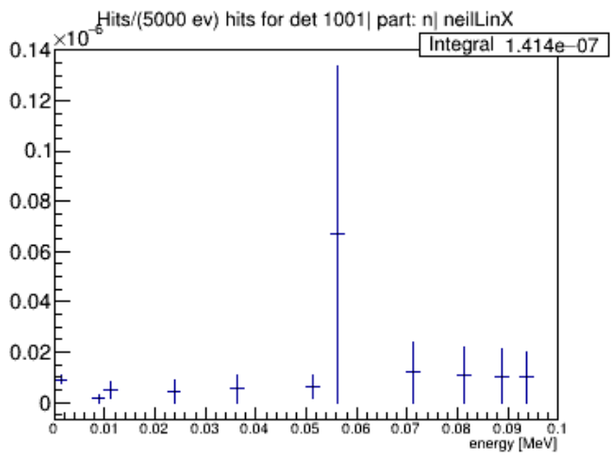


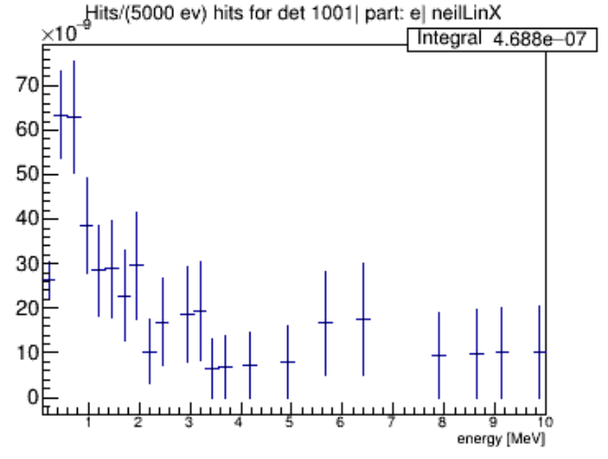


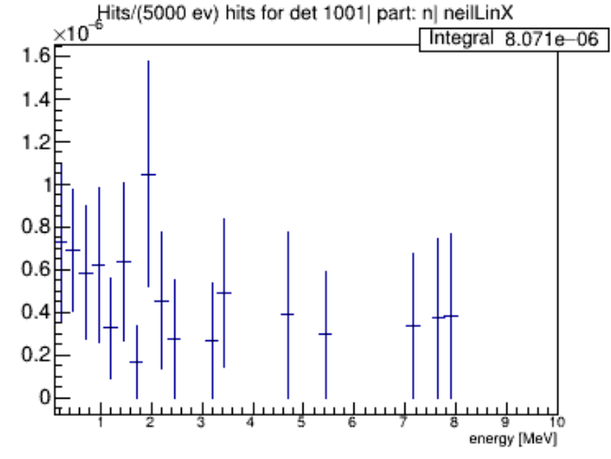


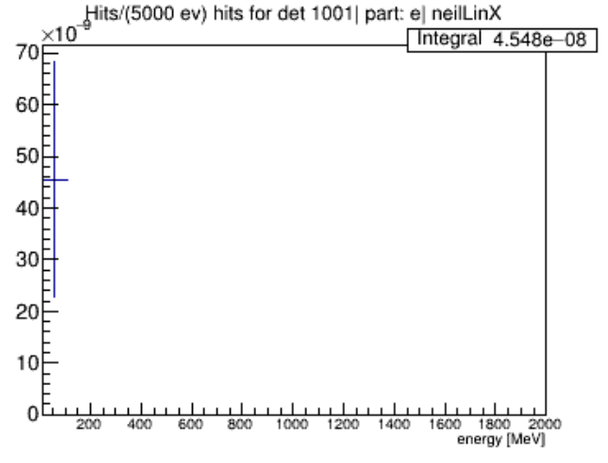
PREX1 dump setup

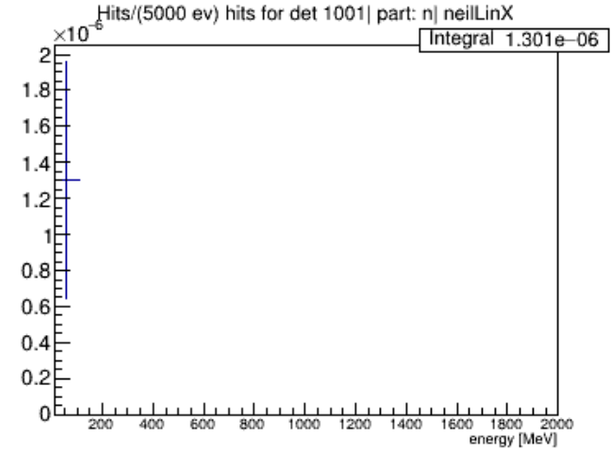






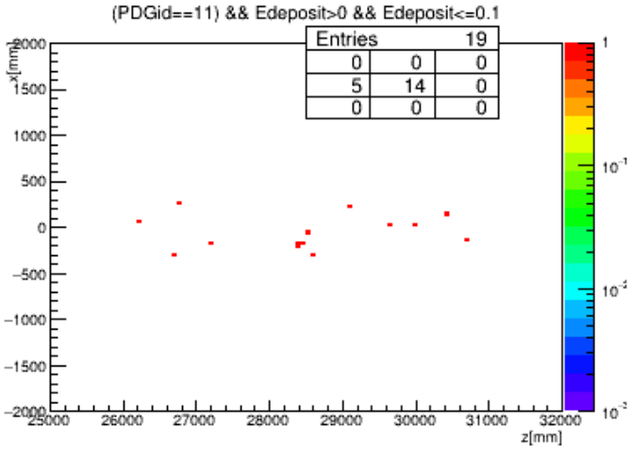


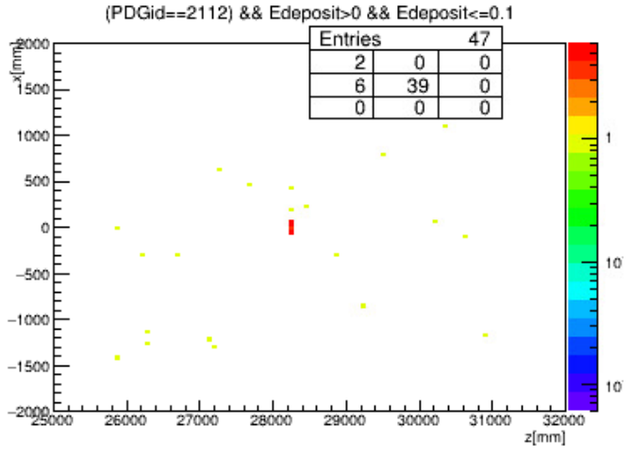


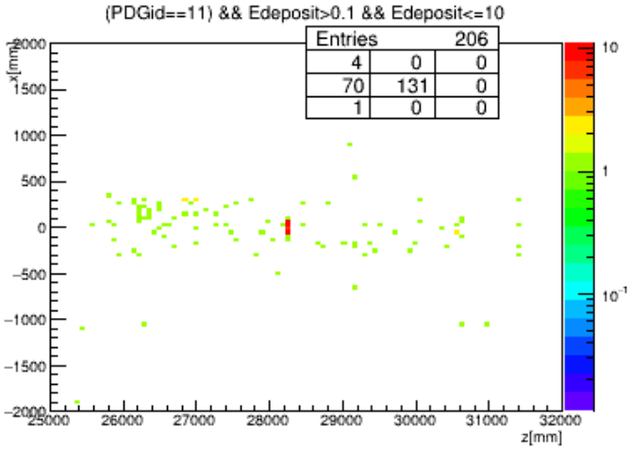


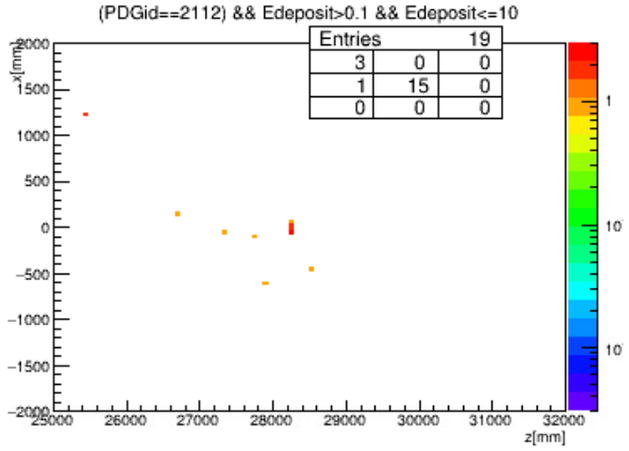
CREX - comparison

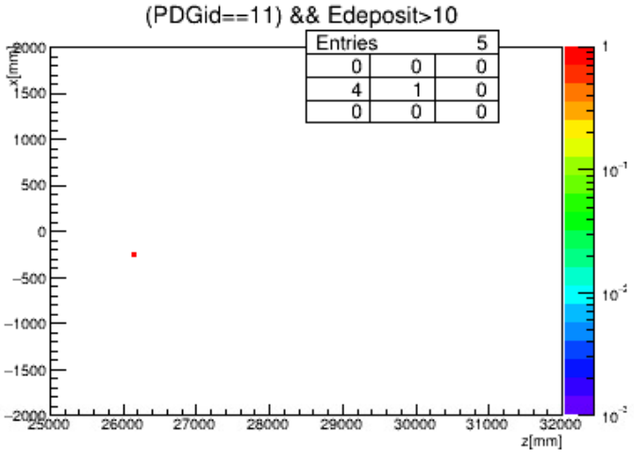
current setup

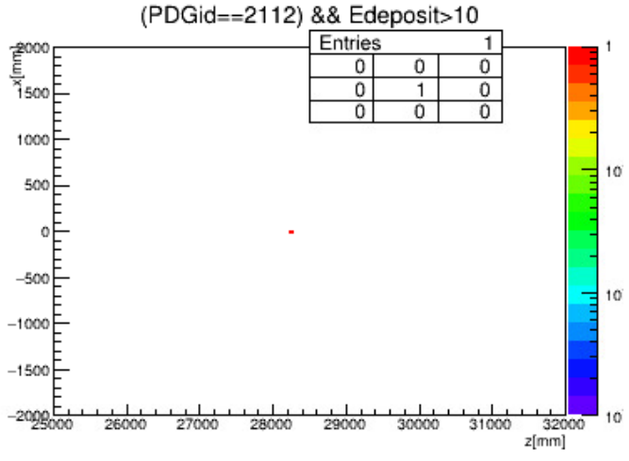




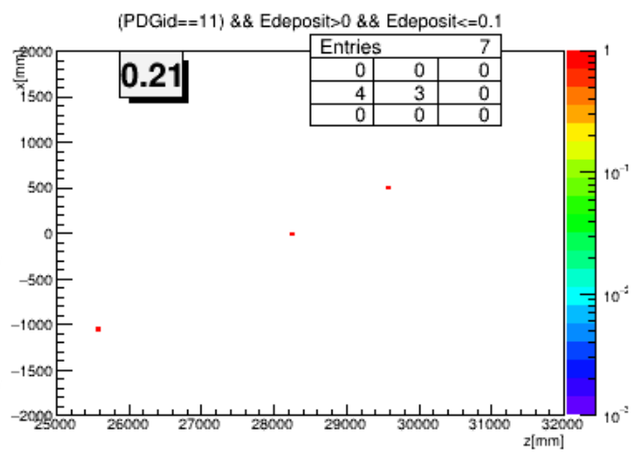


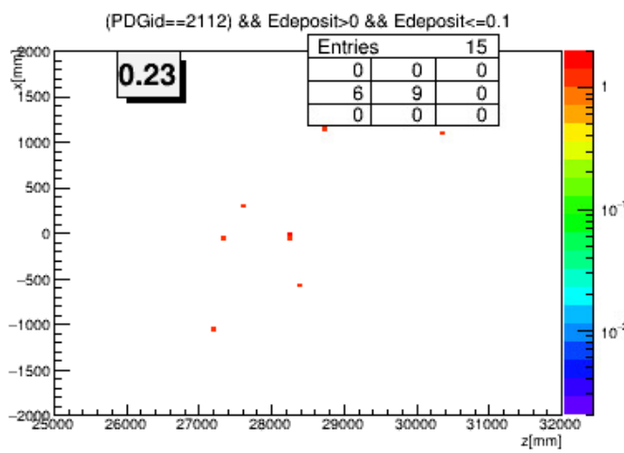


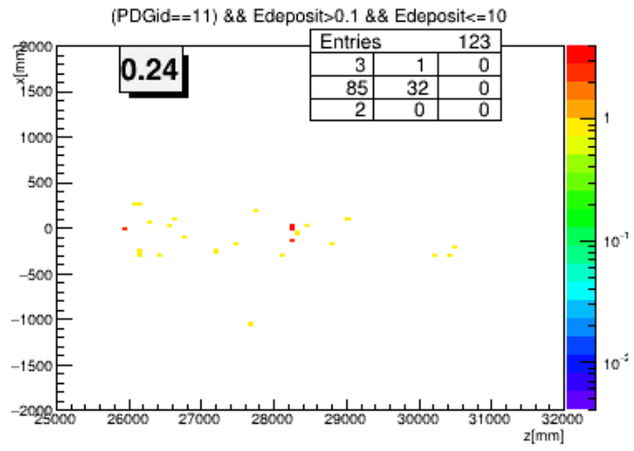


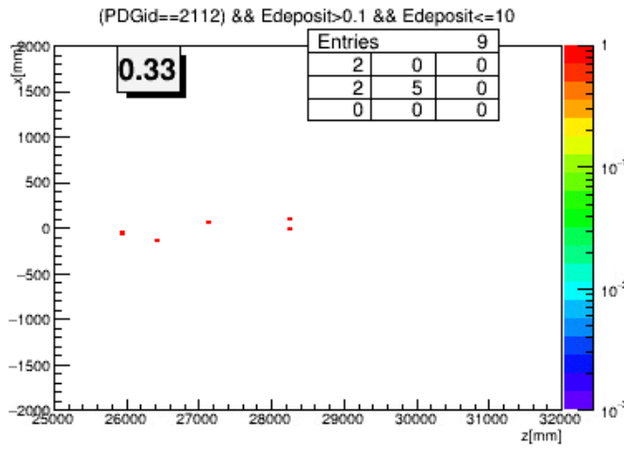


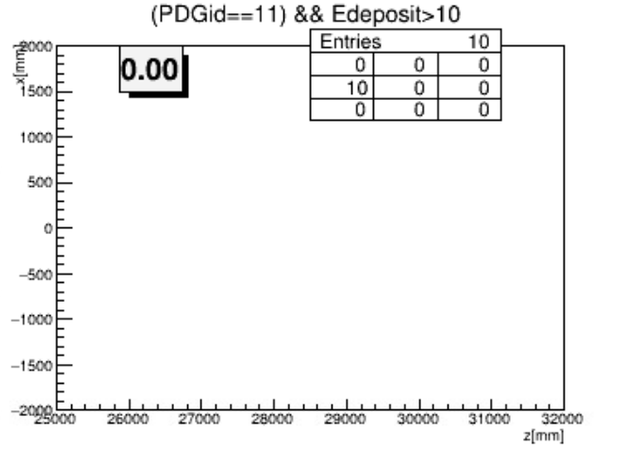
current setup + 1 ft concrete shield

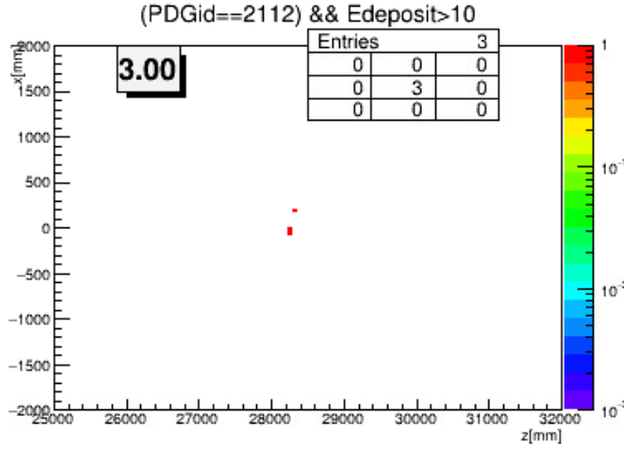






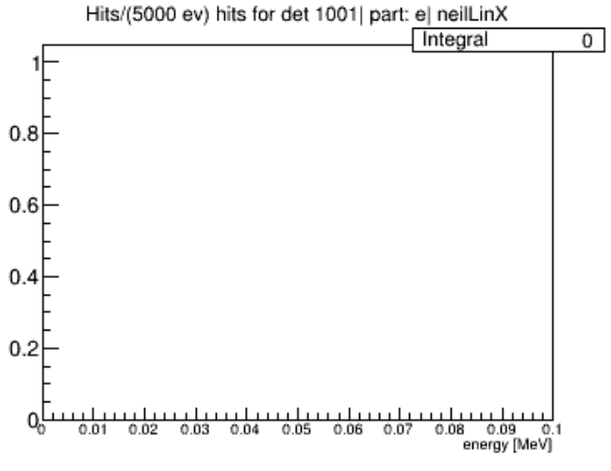


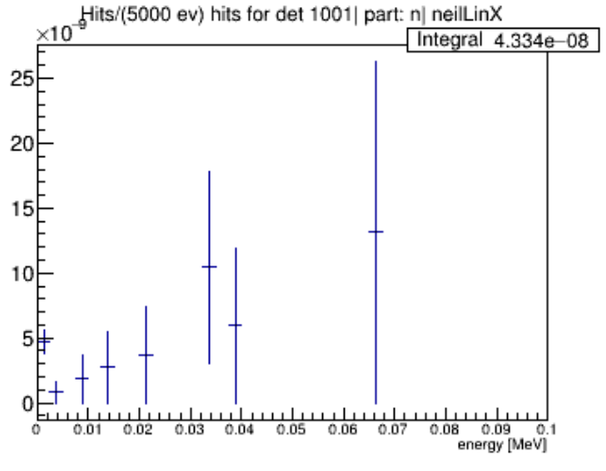


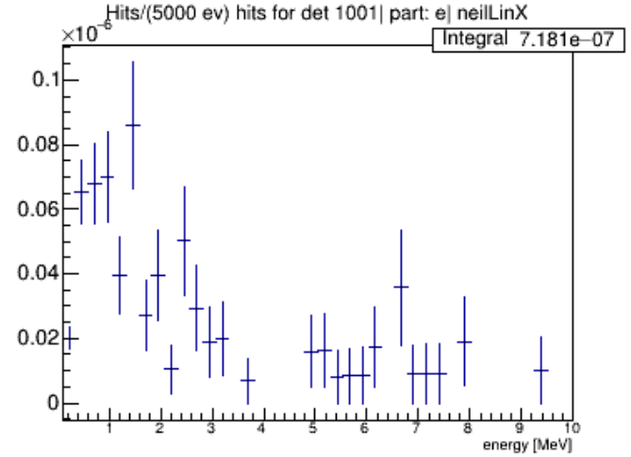


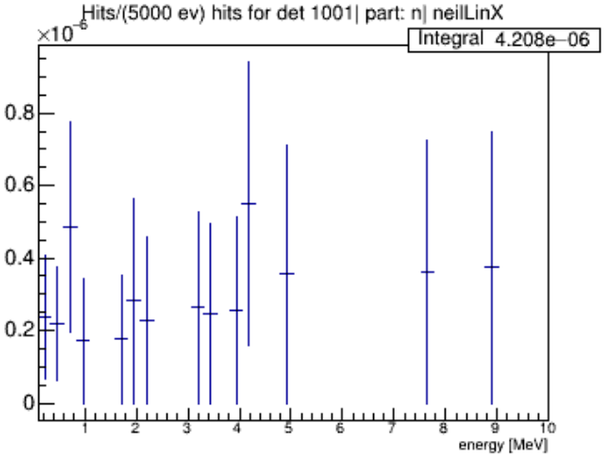
CREX - comparison

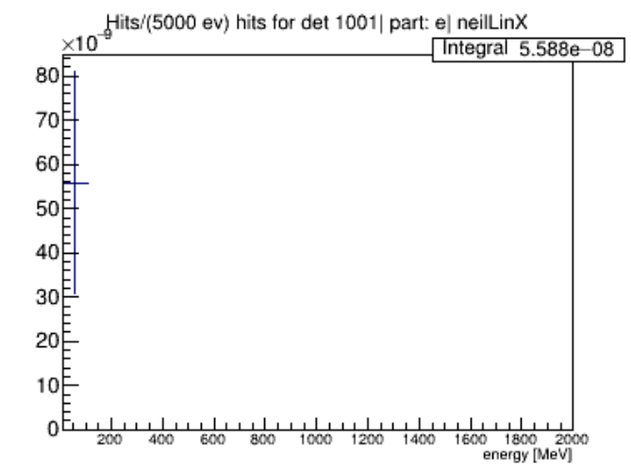
current setup

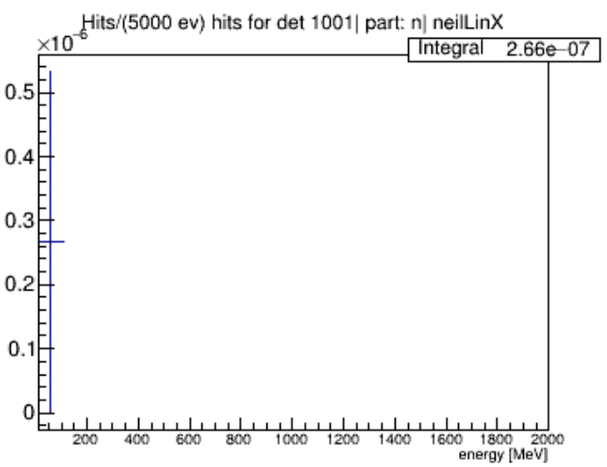




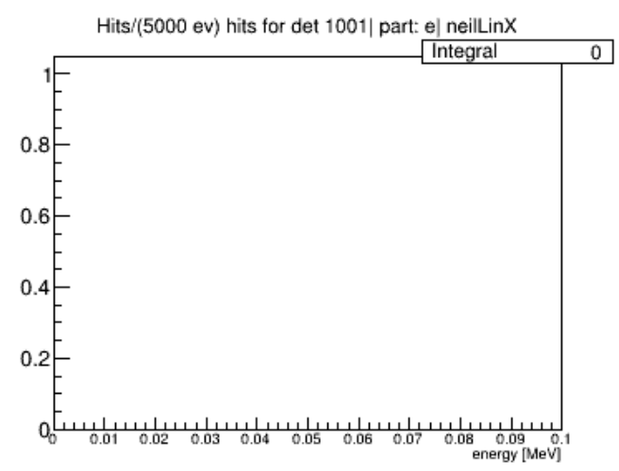


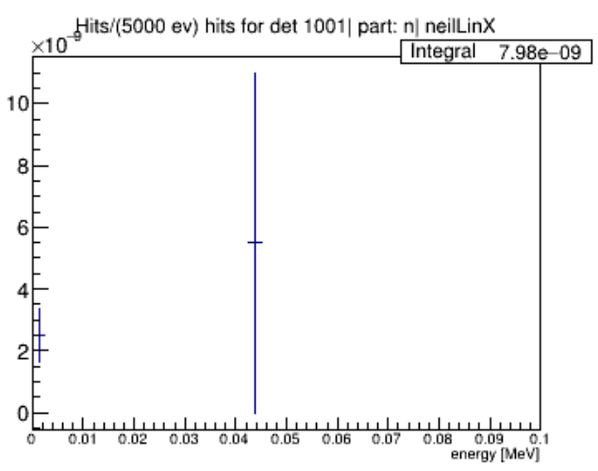


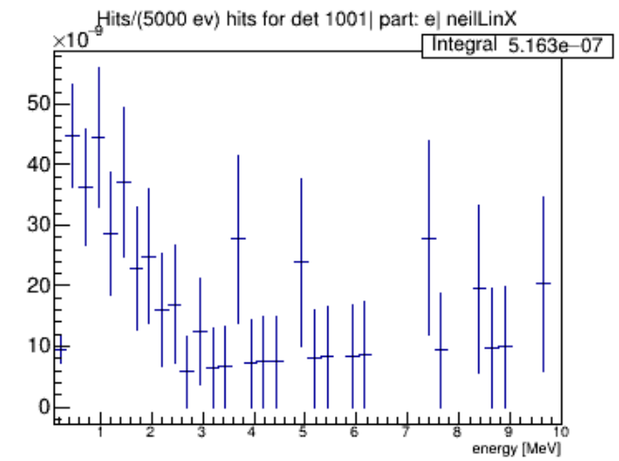


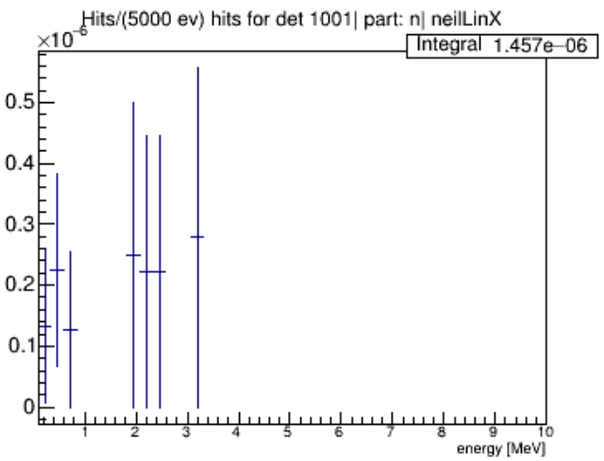


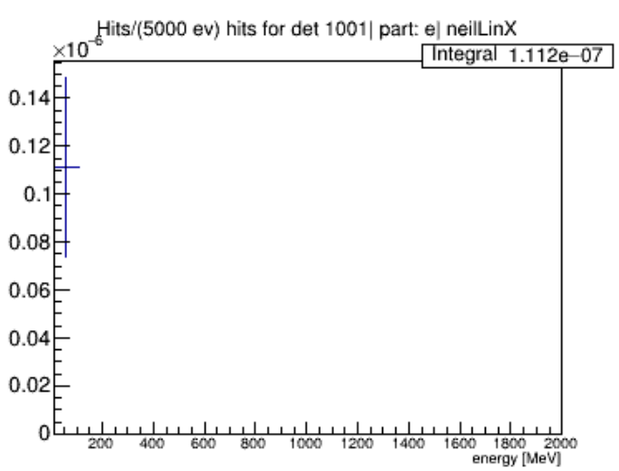
current setup + 1 ft concrete shield

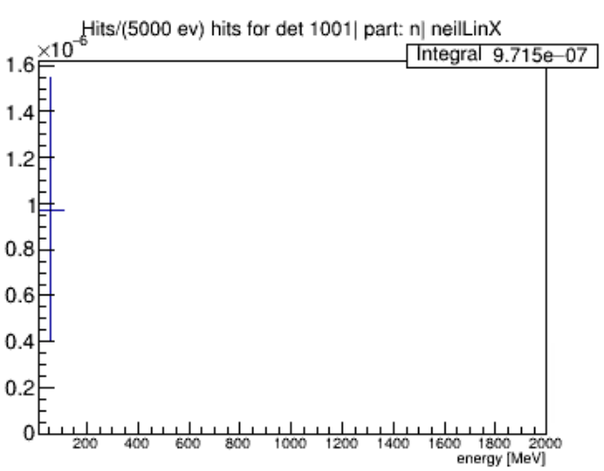






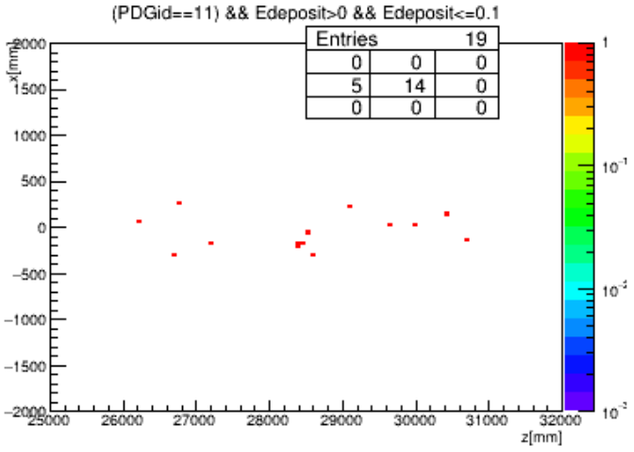


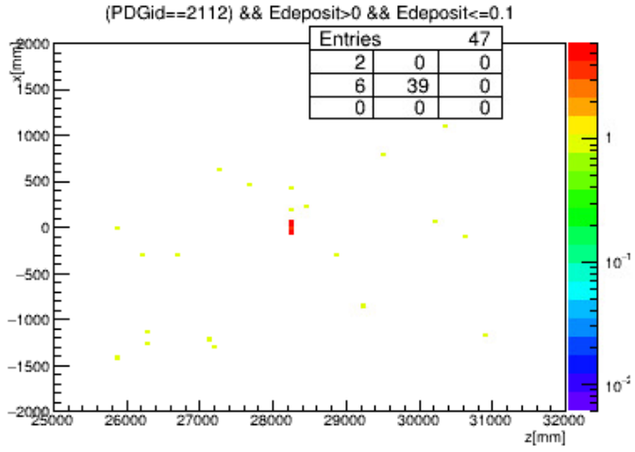


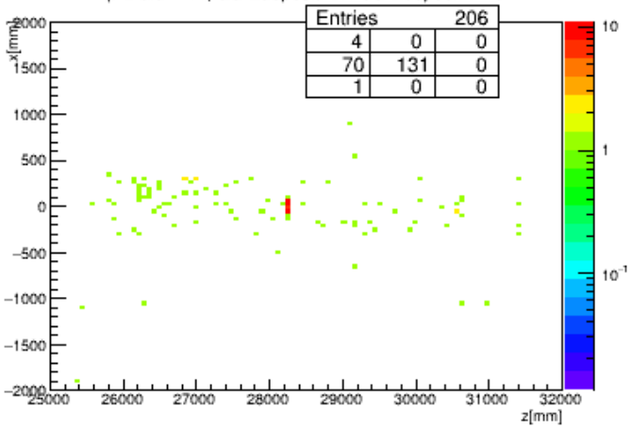


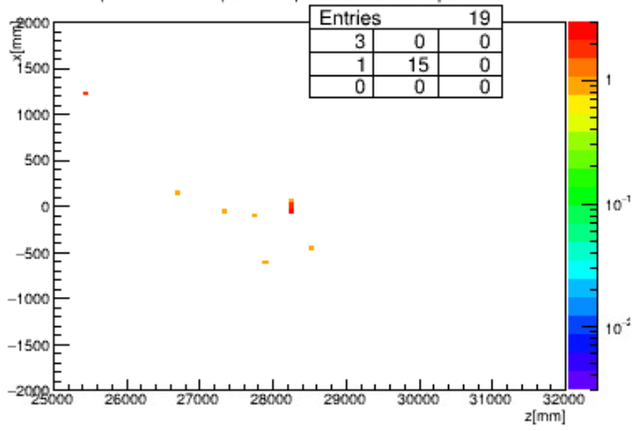
CREX - comparison

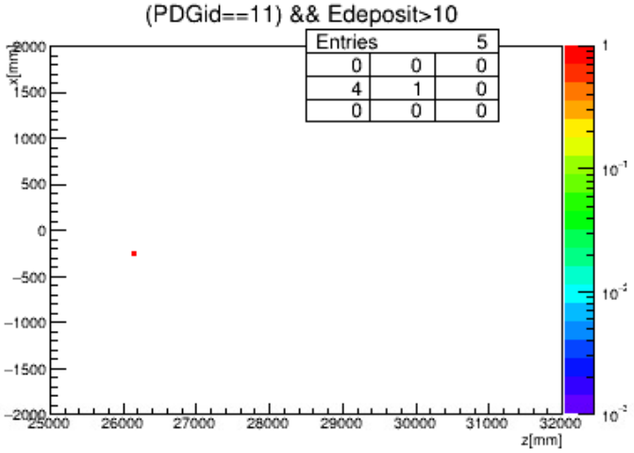
current setup

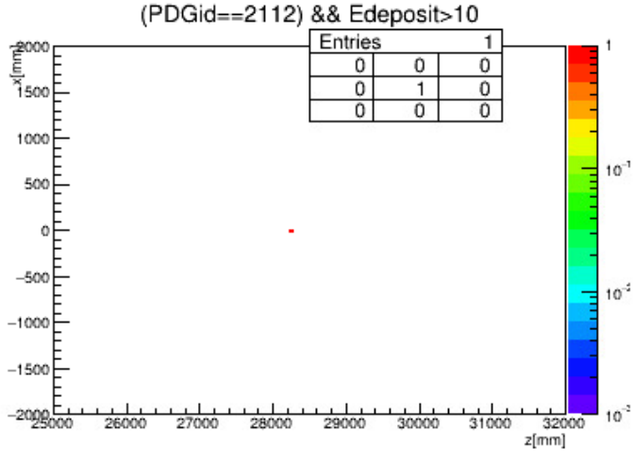




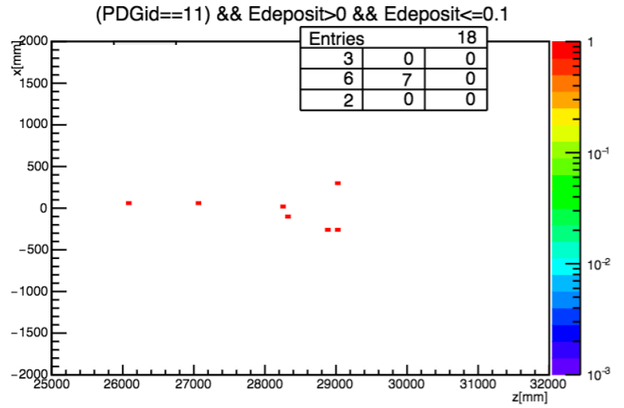


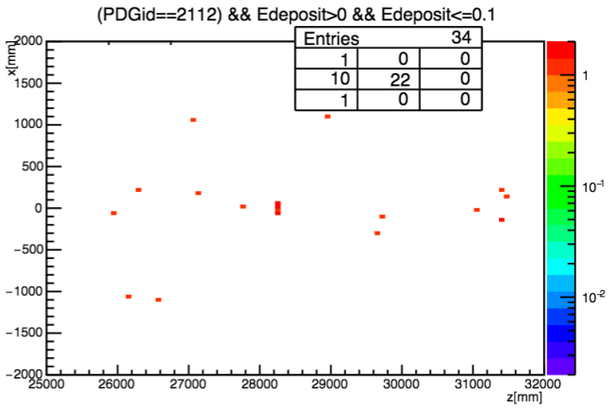


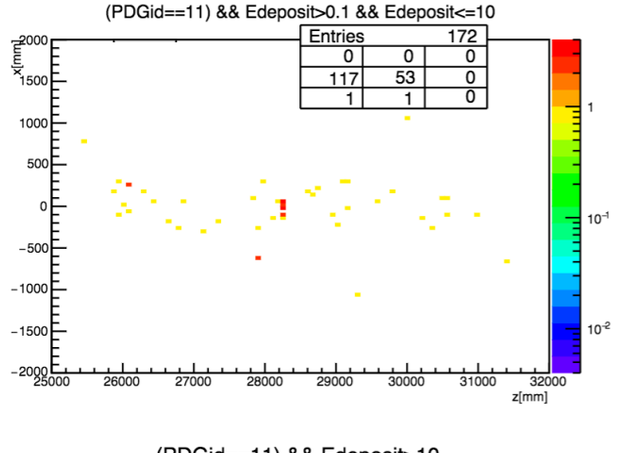


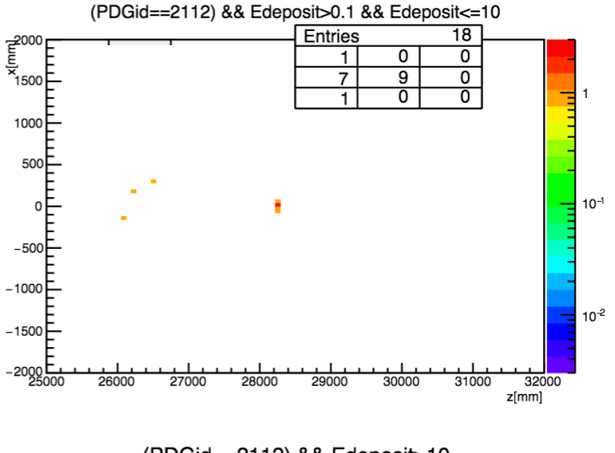


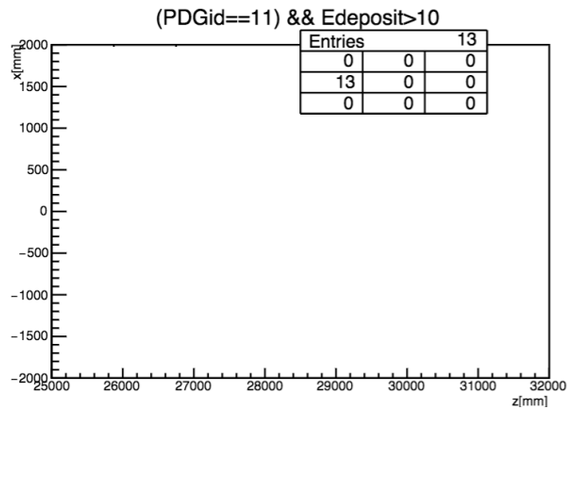
current setup + 2 ft concrete shield (2x stat)

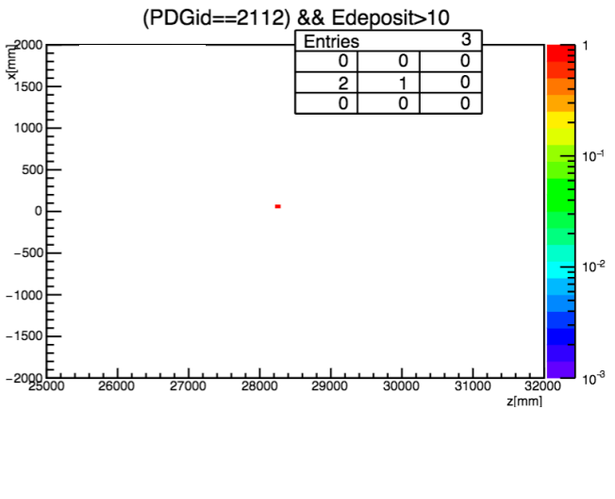






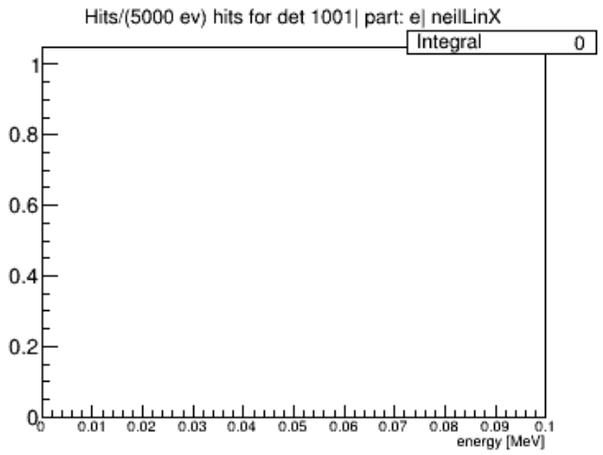


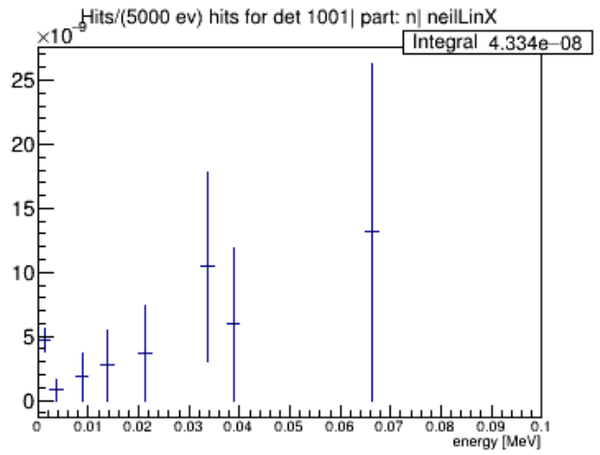


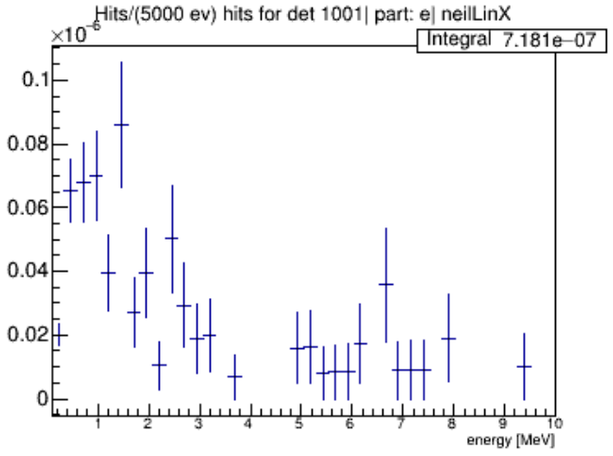


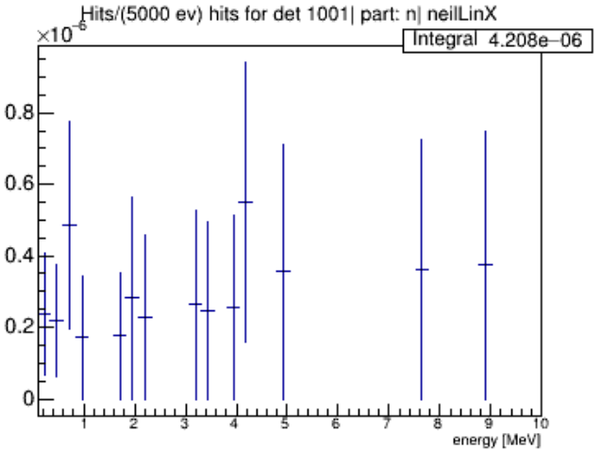
CREX - comparison

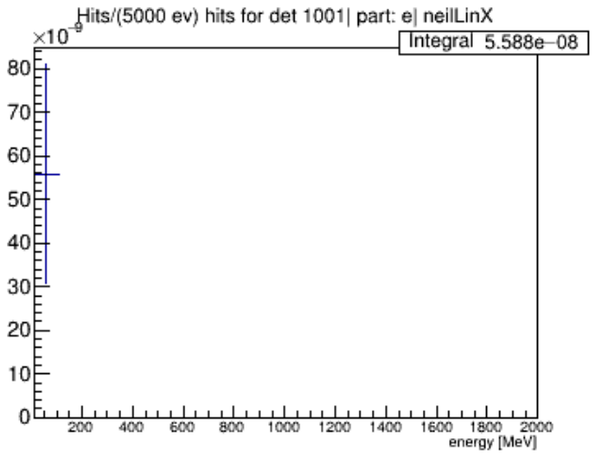
current setup

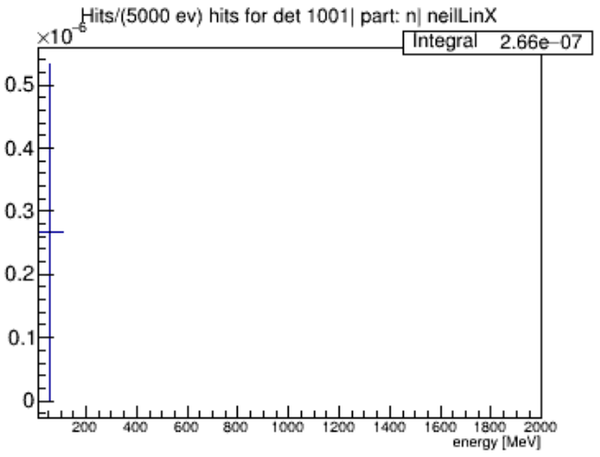




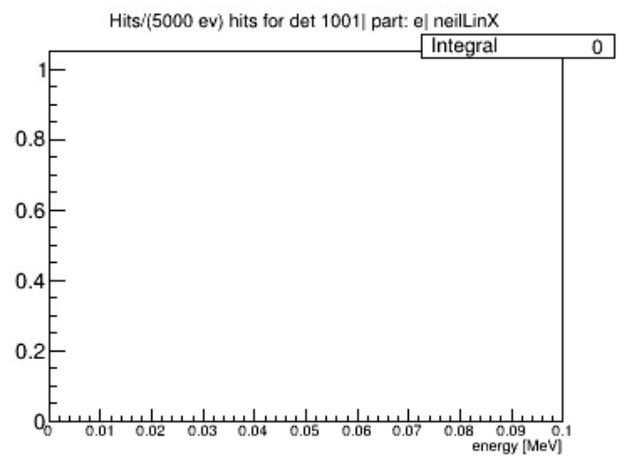


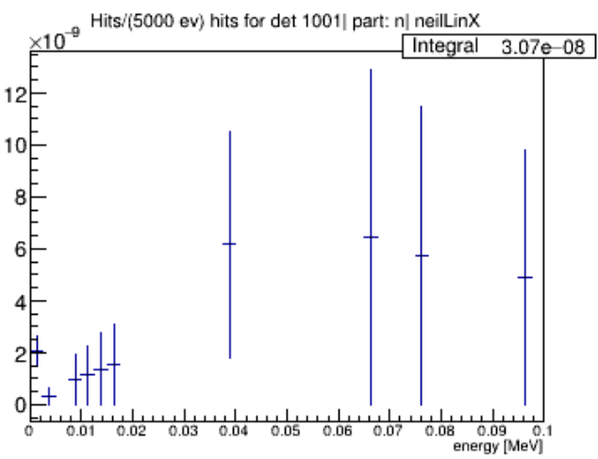


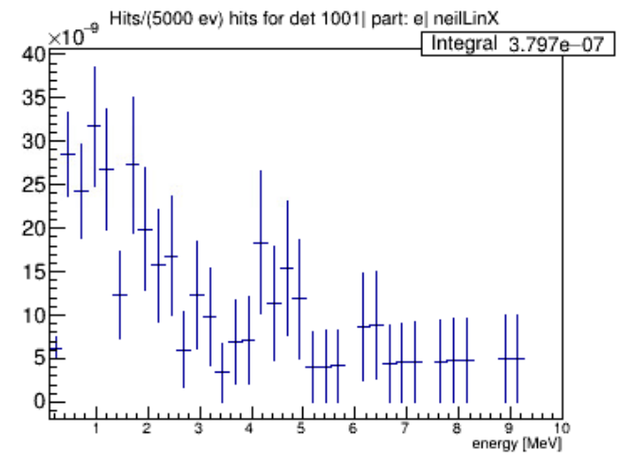


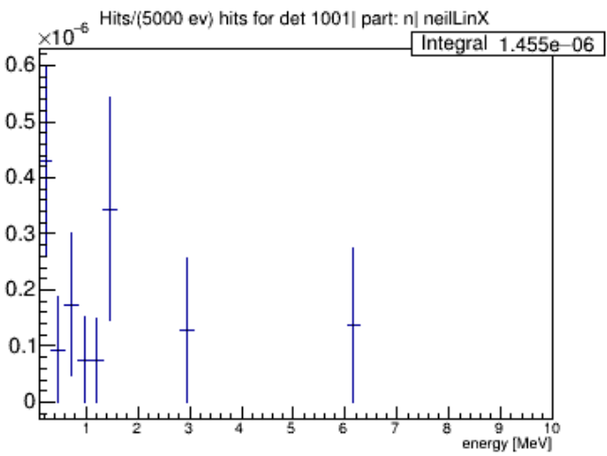


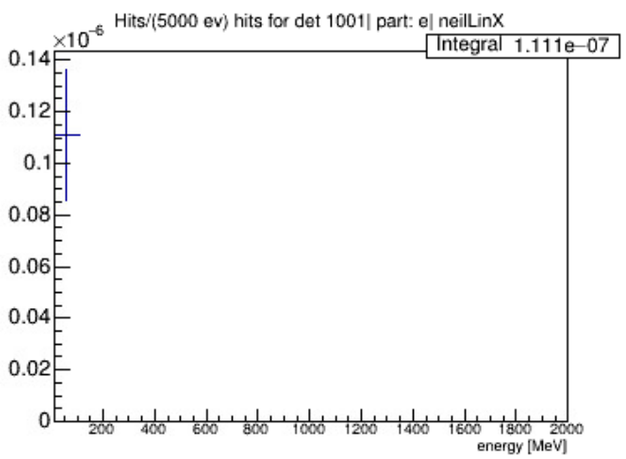
current setup + 2 ft concrete shield

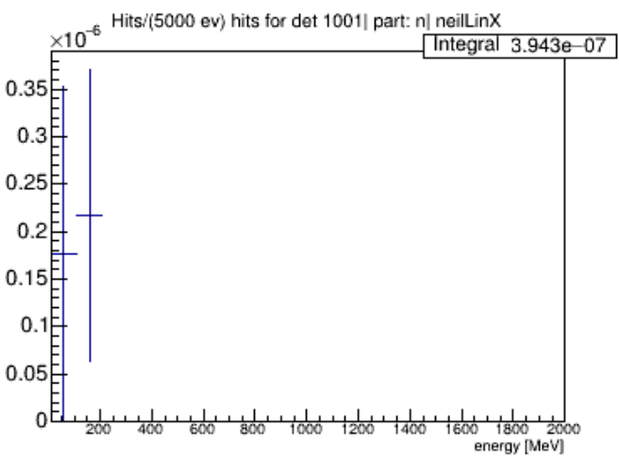






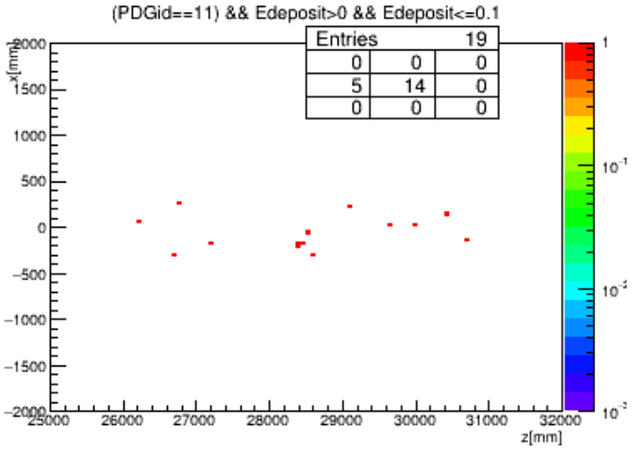


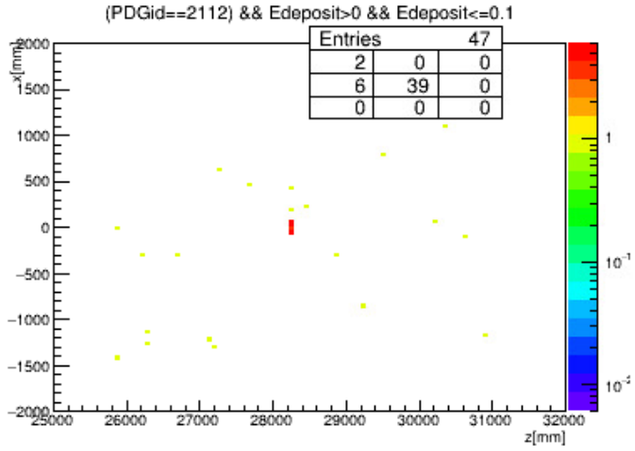


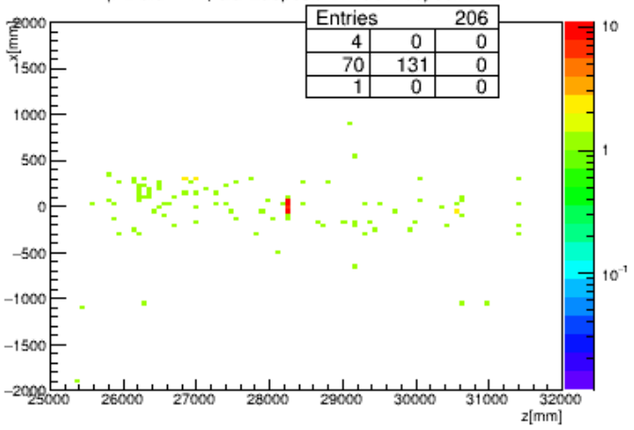


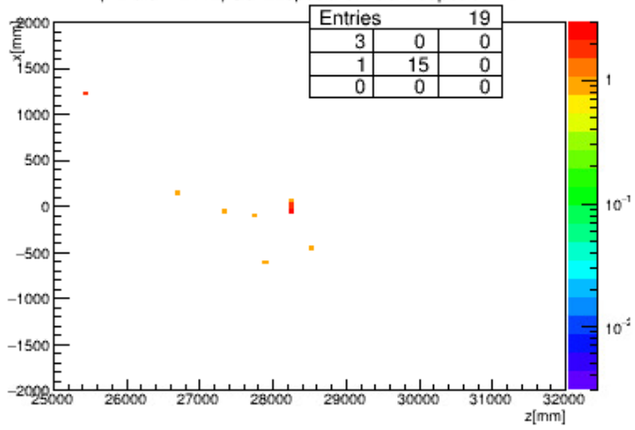
CREX - comparison

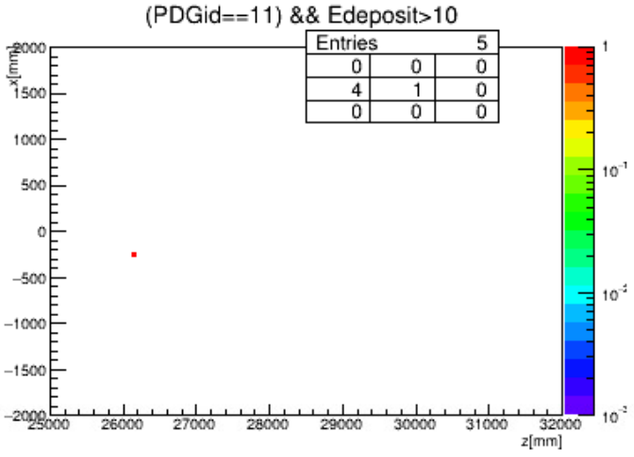
current setup

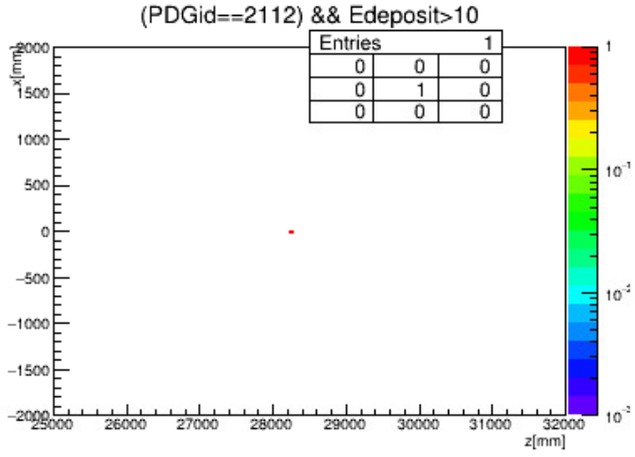




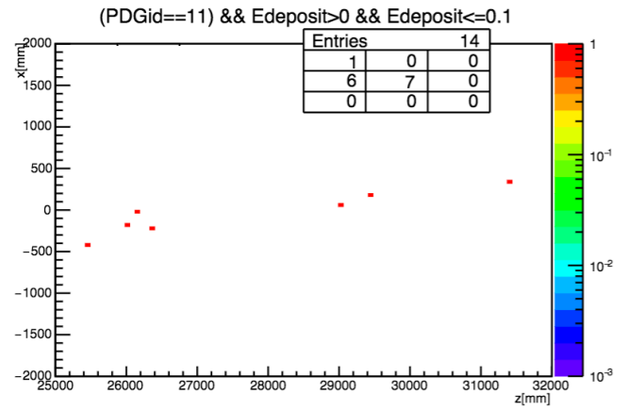


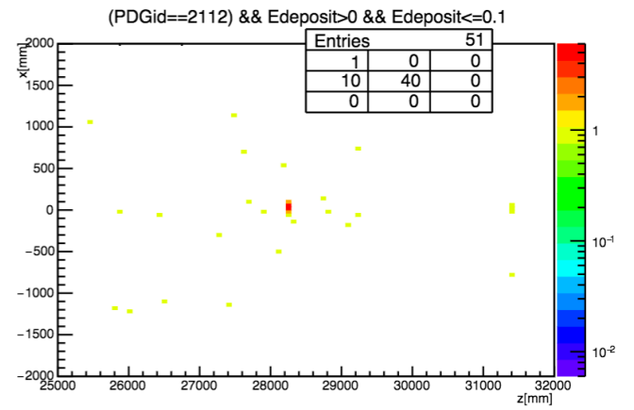


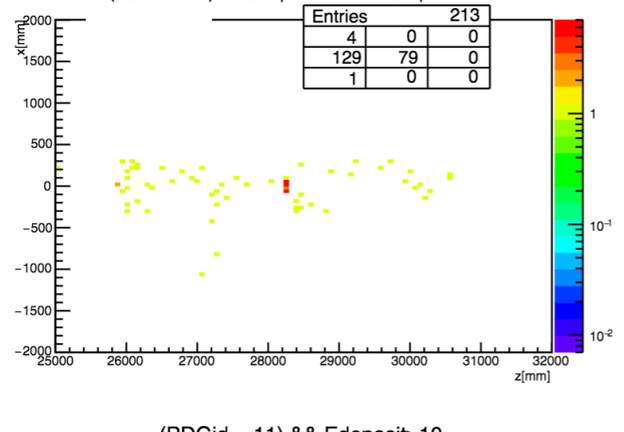


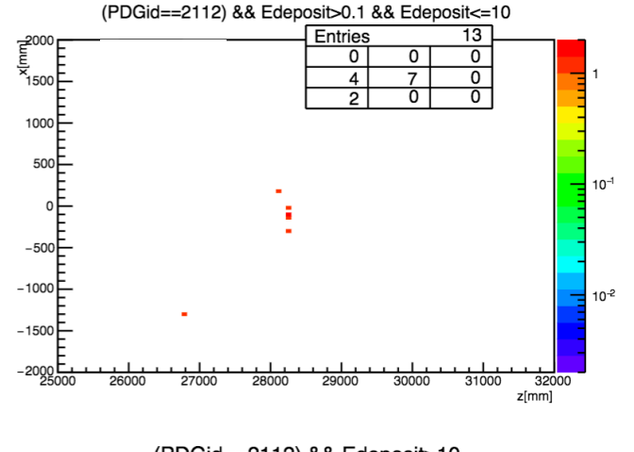


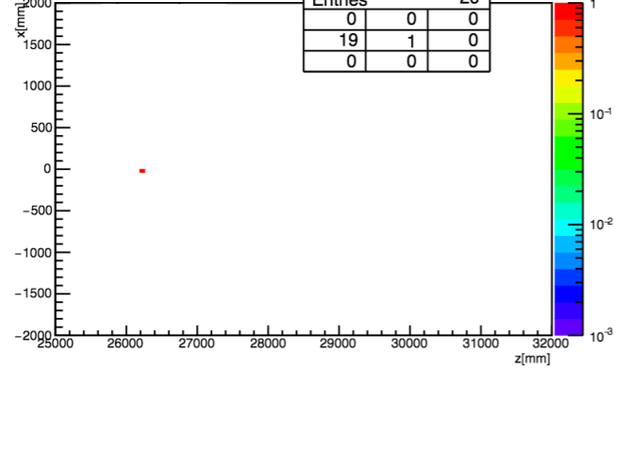
current setup + 0.5 ft concrete shield (2x stat)

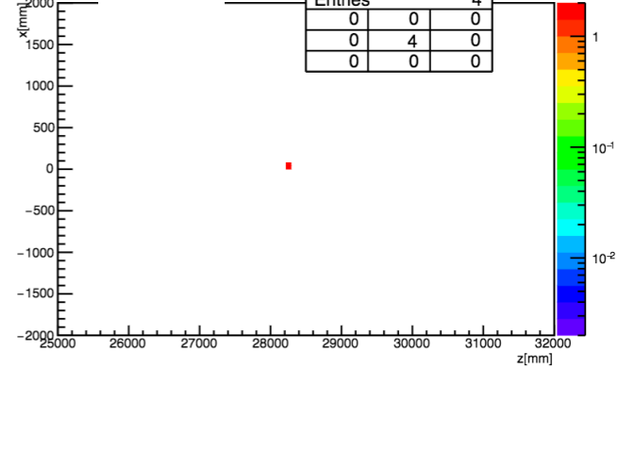






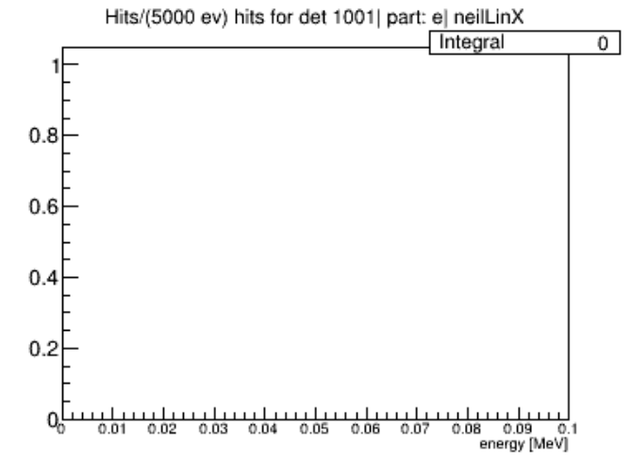


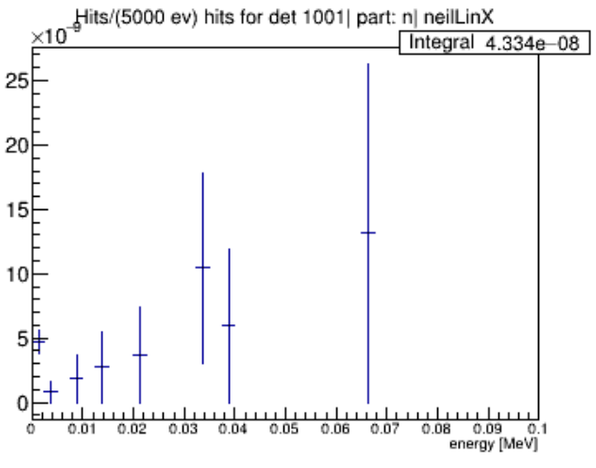


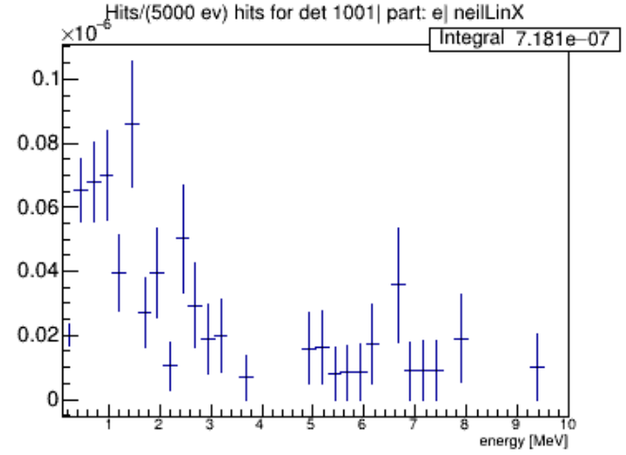


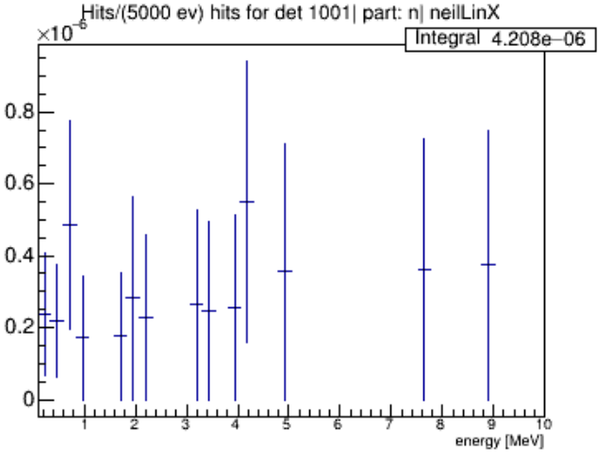
CREX - comparison

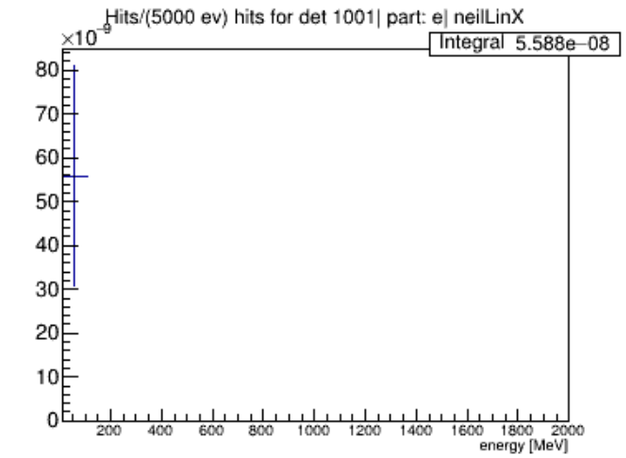
current setup

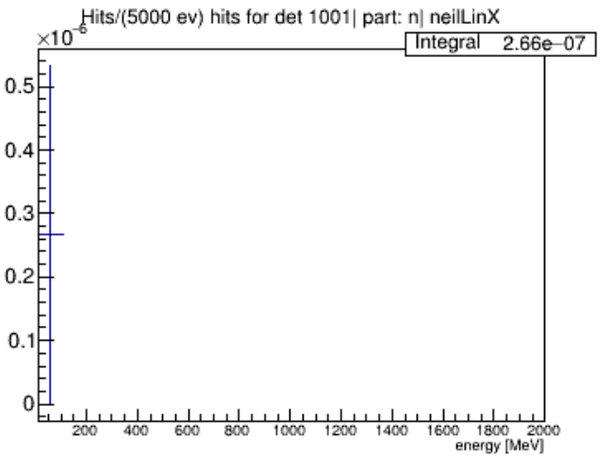




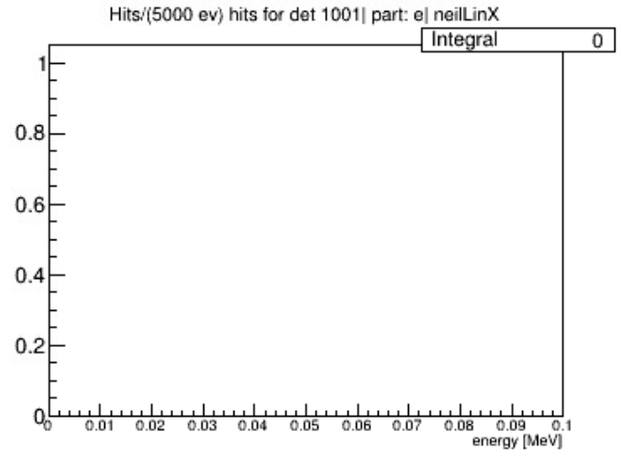


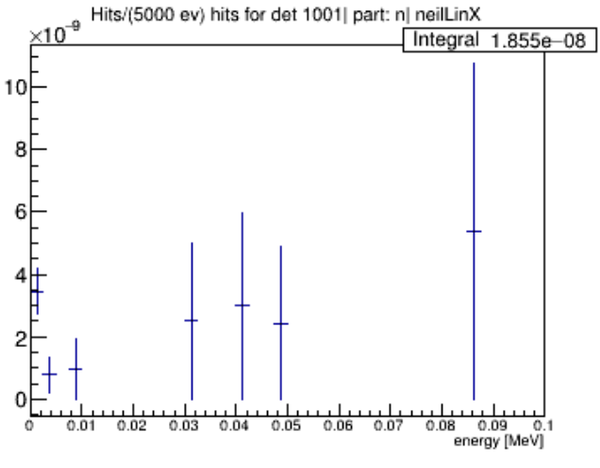


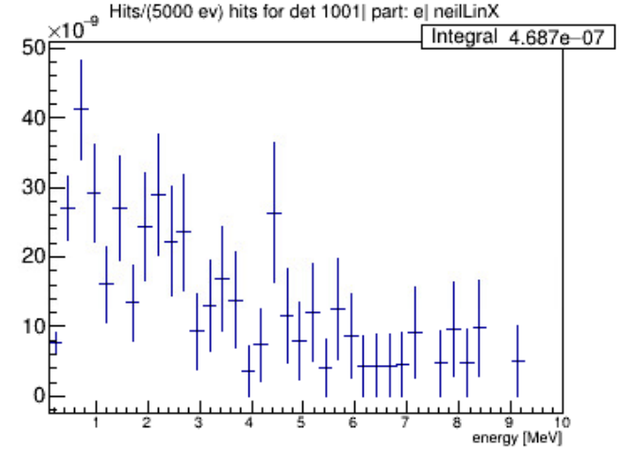


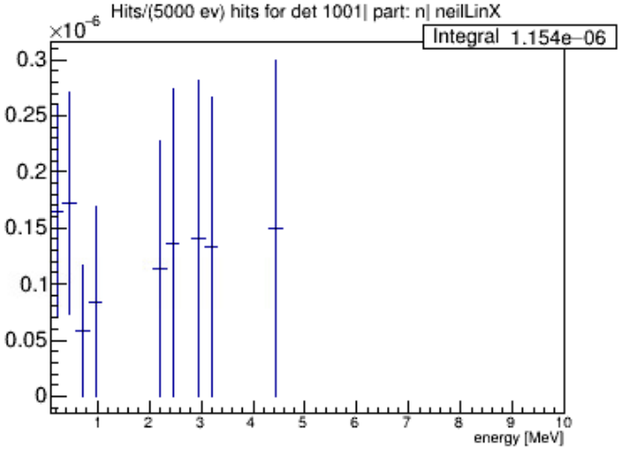


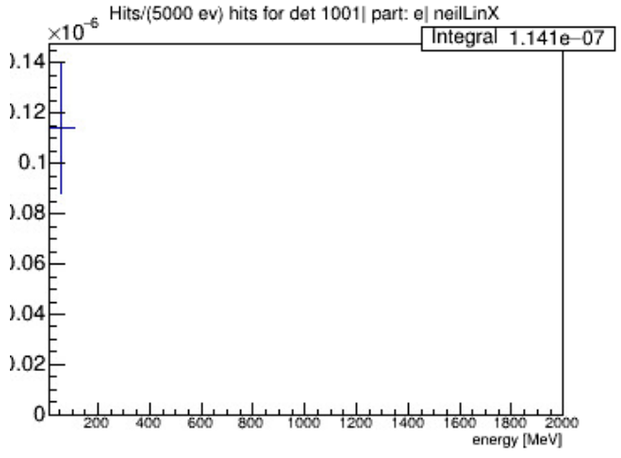
current setup + 0.5 ft concrete shield

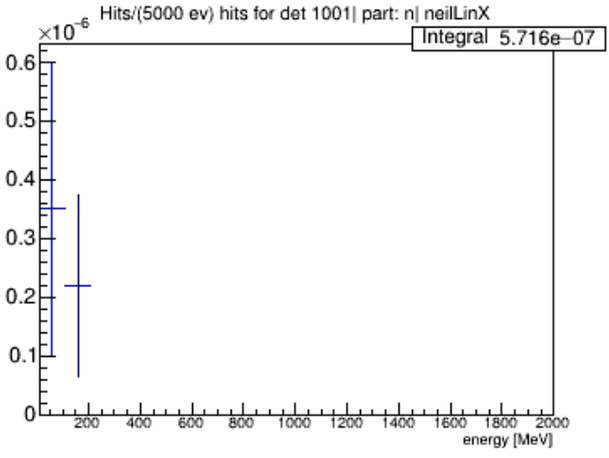






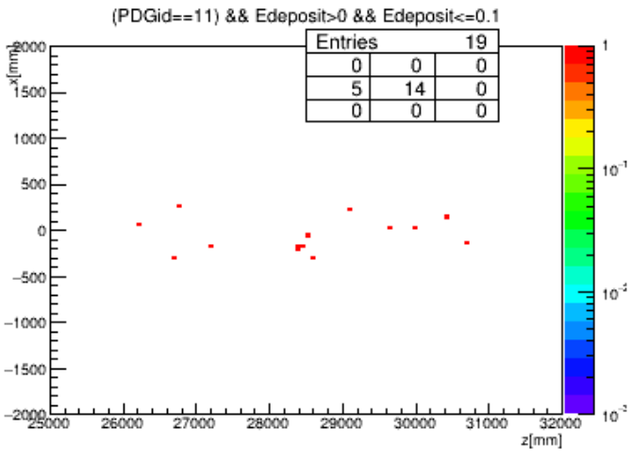


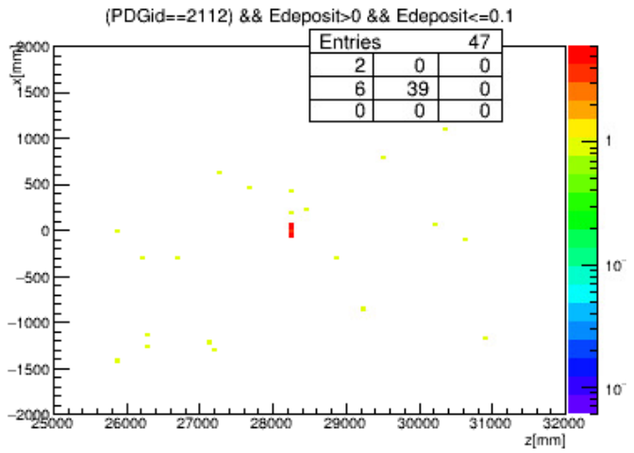


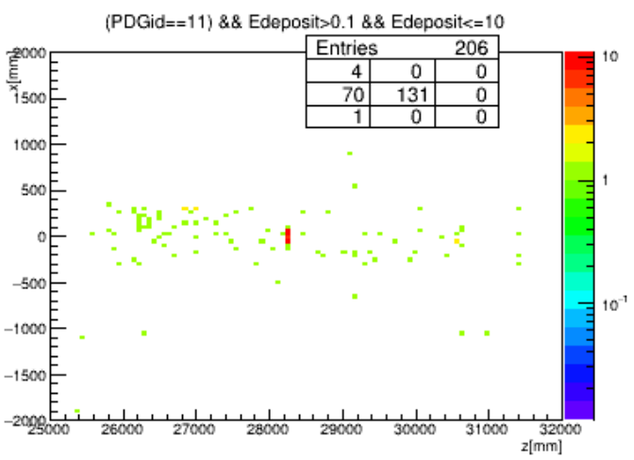


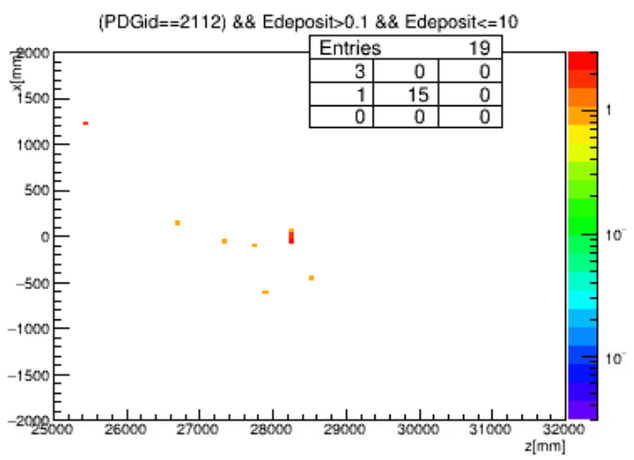
CREX - comparison

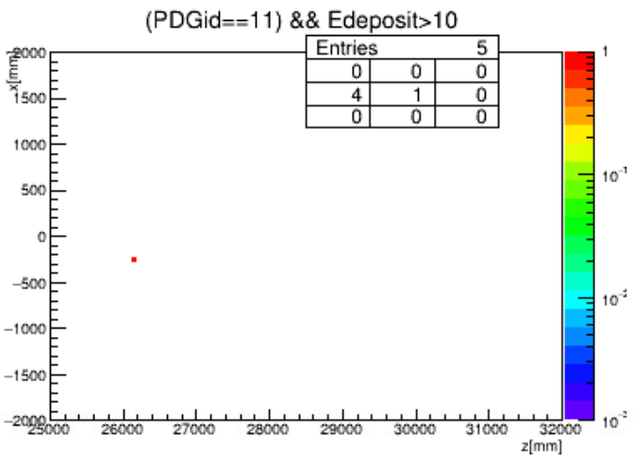
current setup

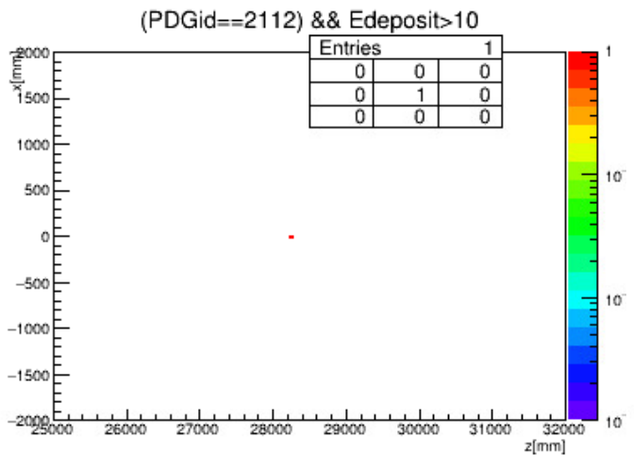




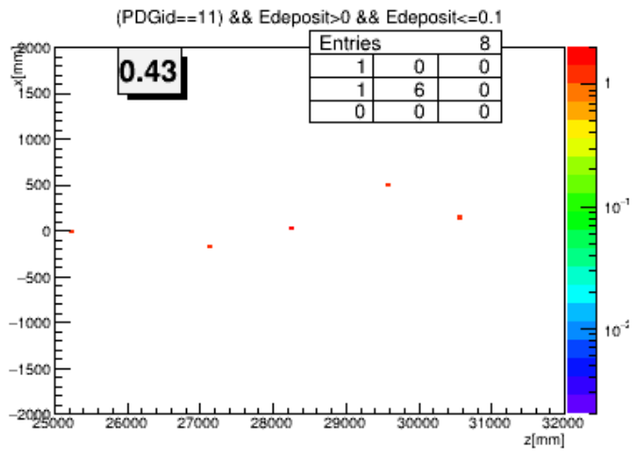


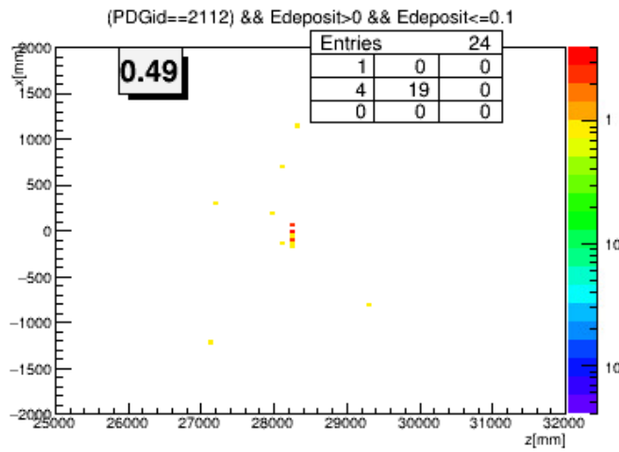


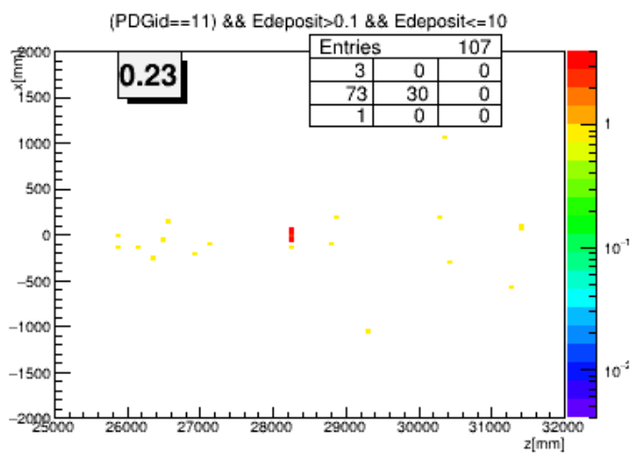


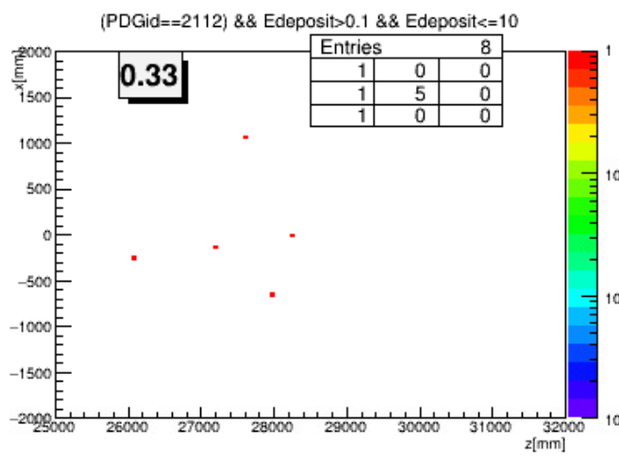


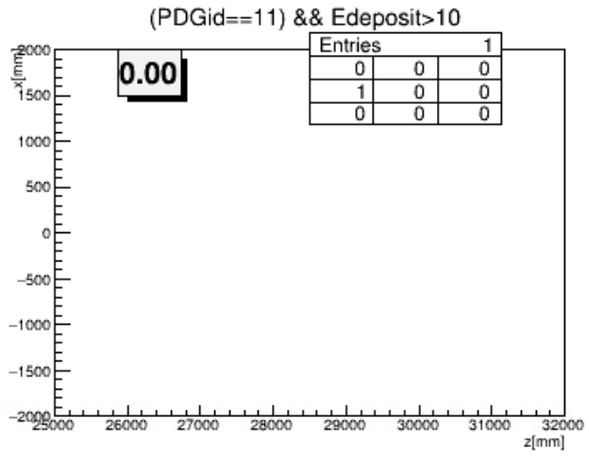
current setup + 1 ft Poly shield

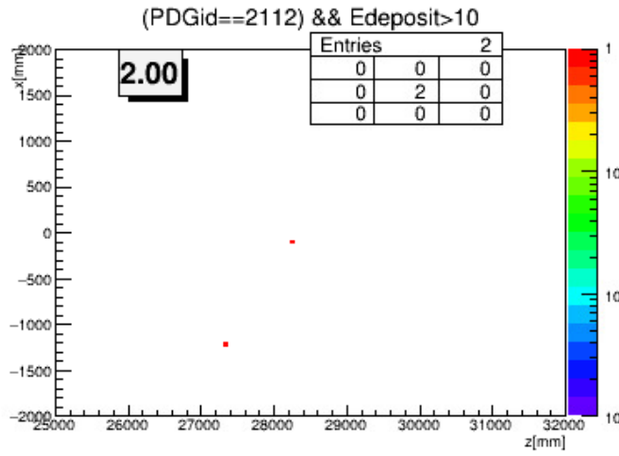






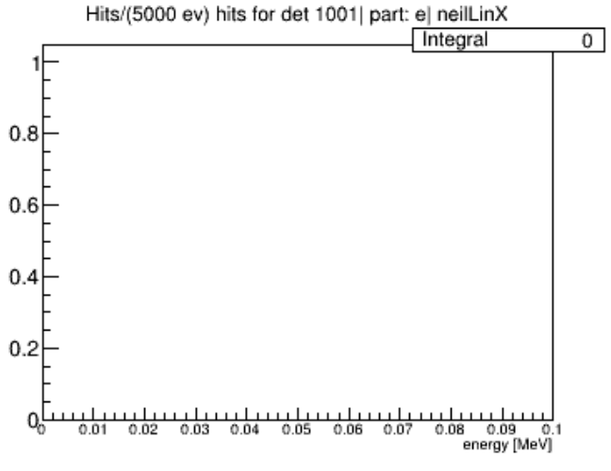


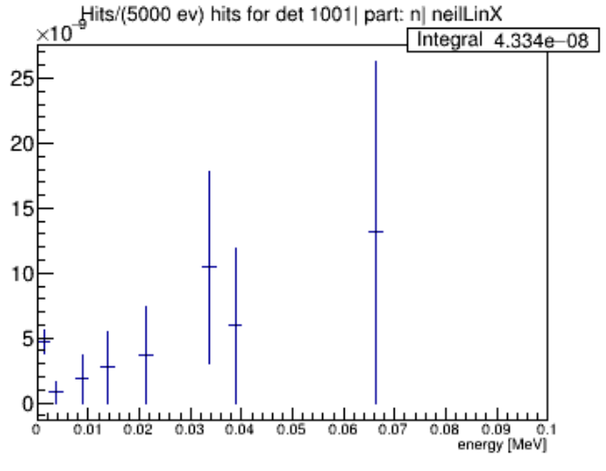


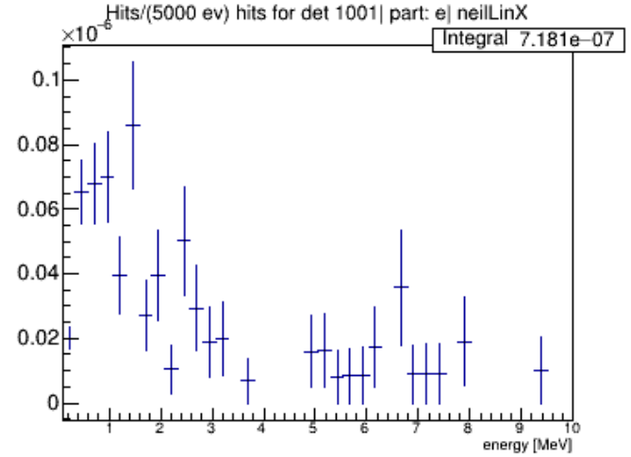


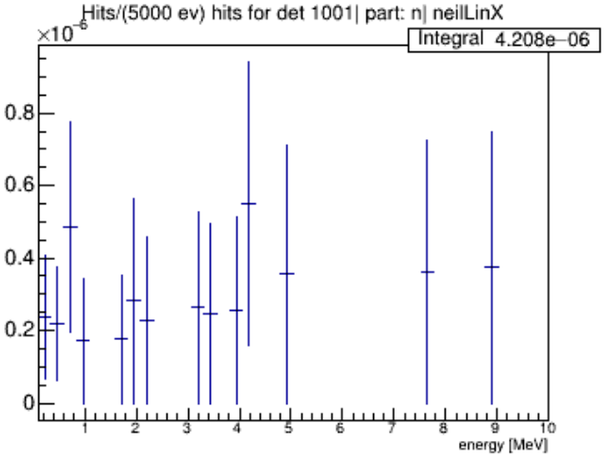
CREX - comparison

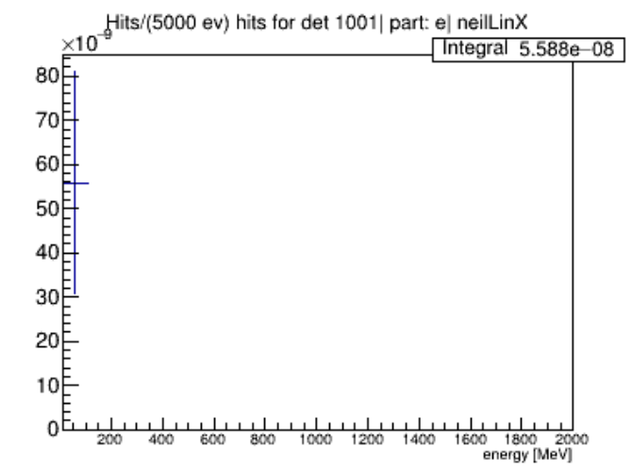
current setup

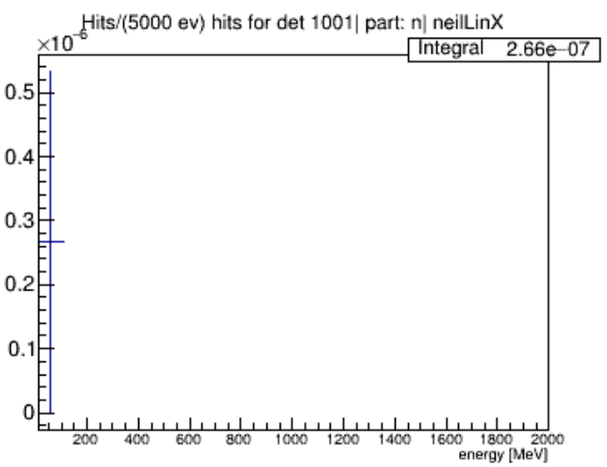




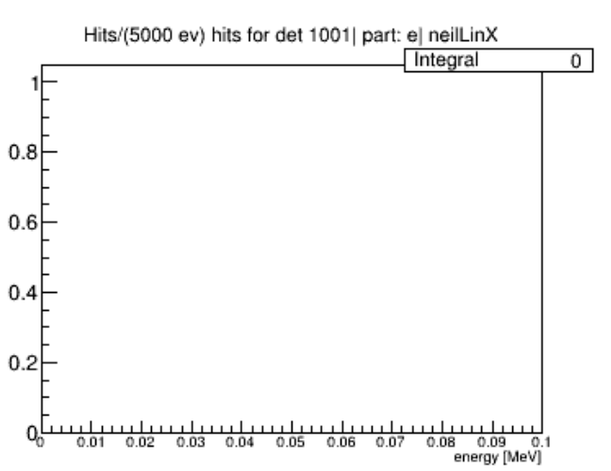


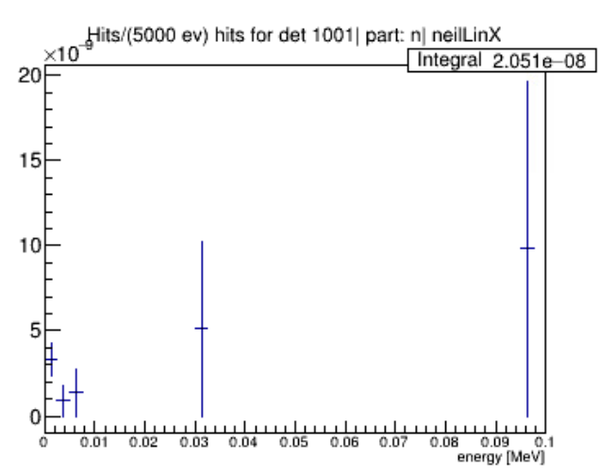


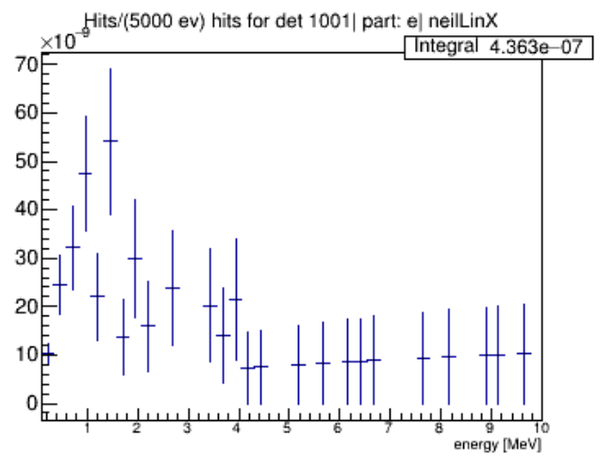


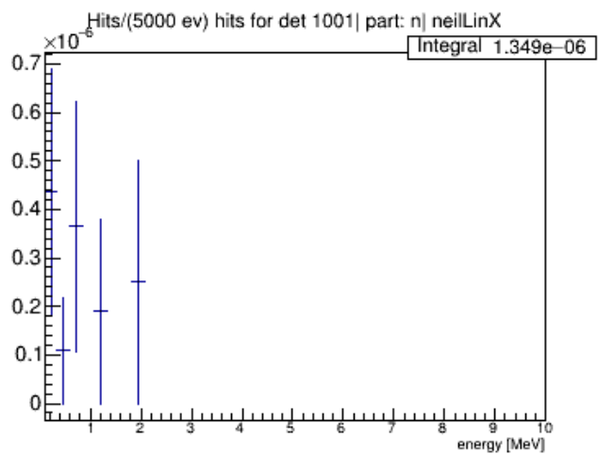


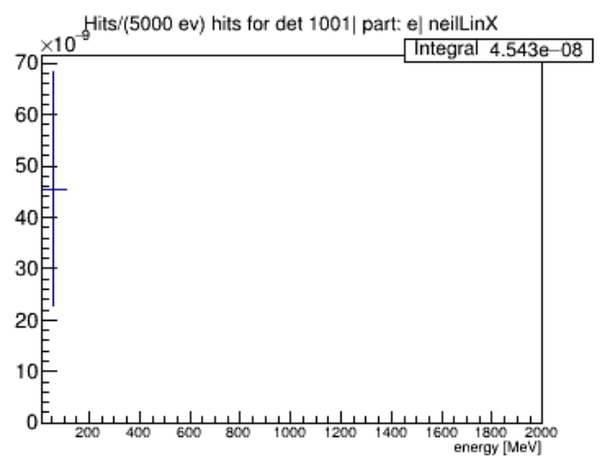
current setup + 1 ft Poly shield

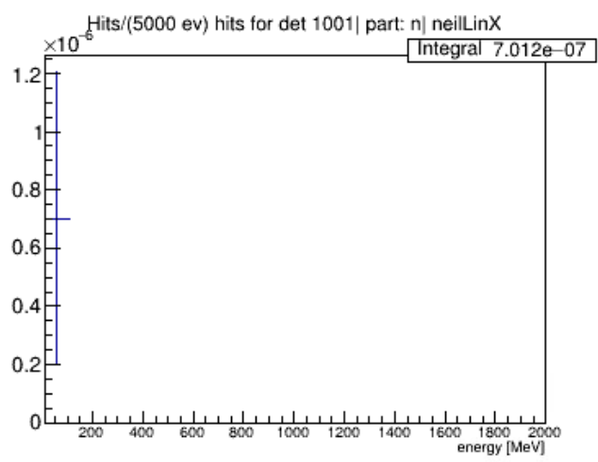






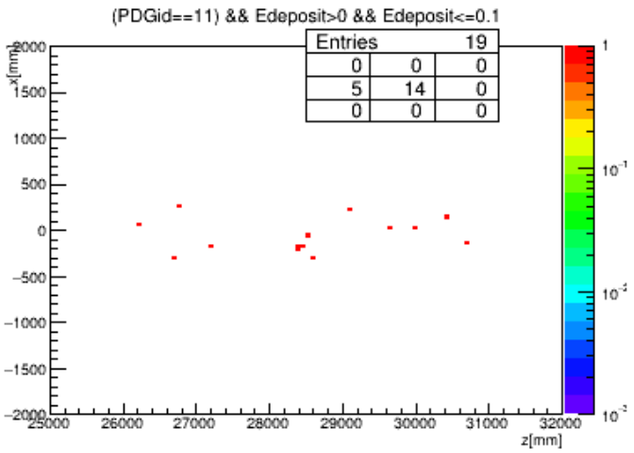


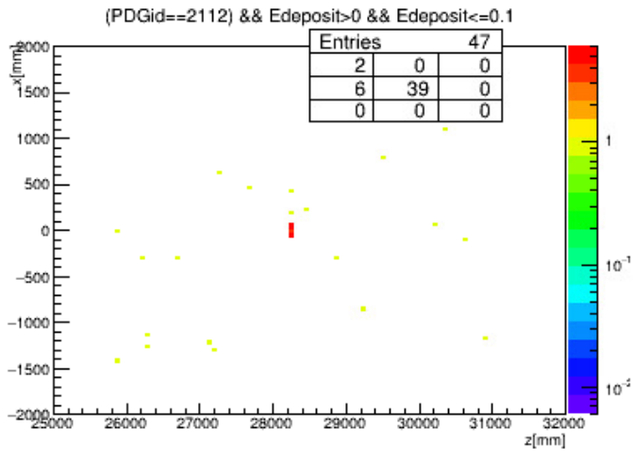


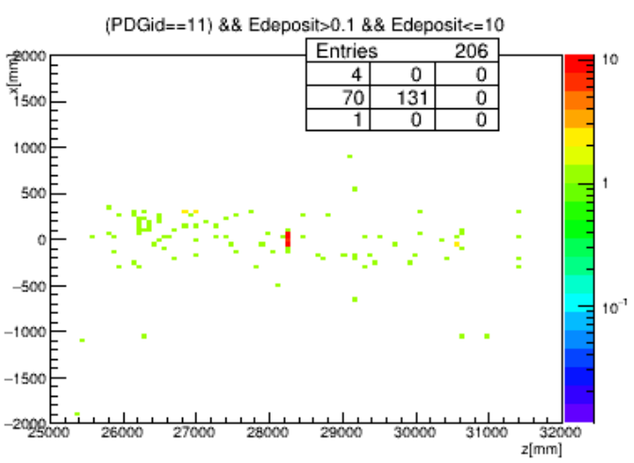


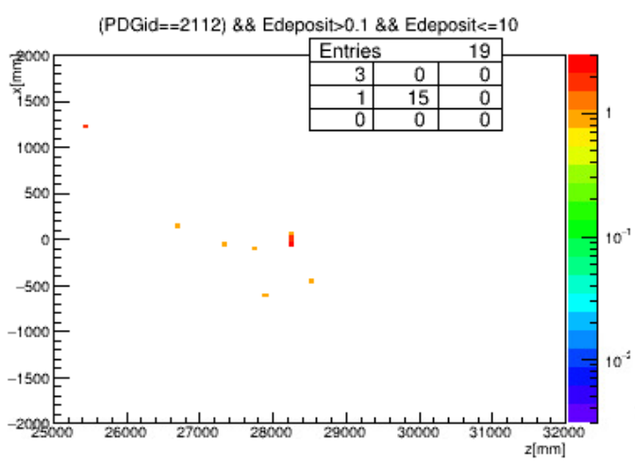
CREX - comparison

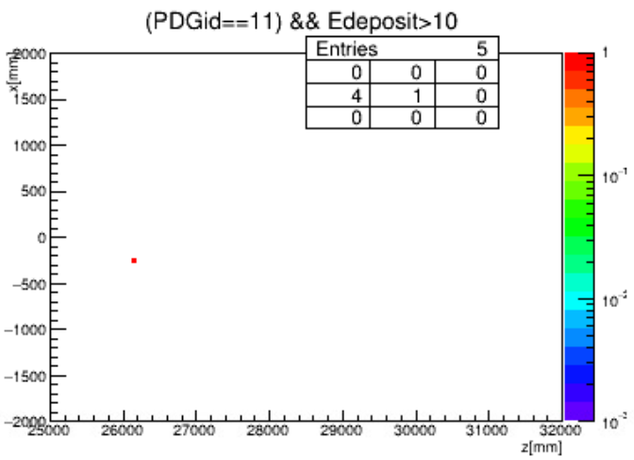
current setup

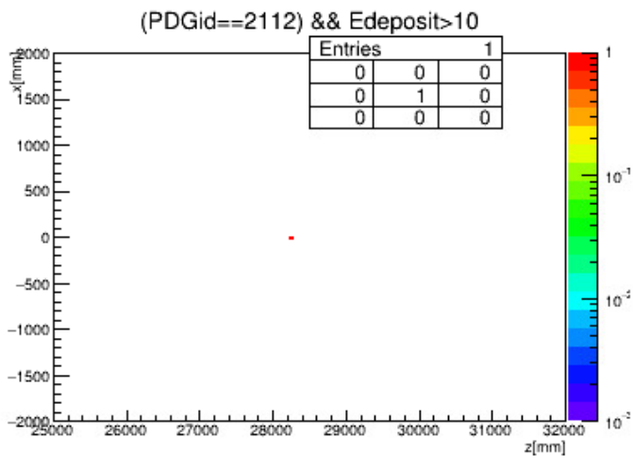




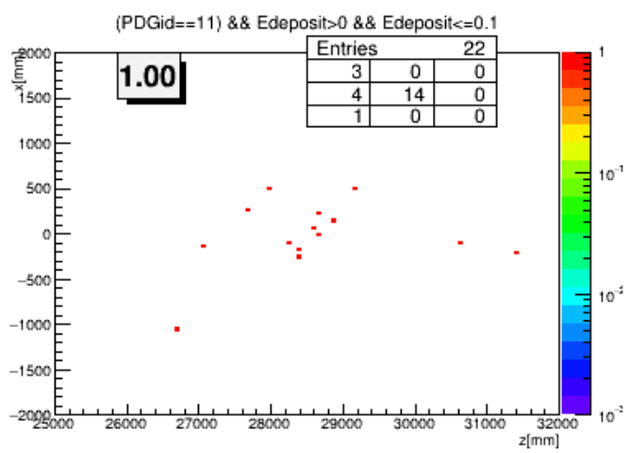


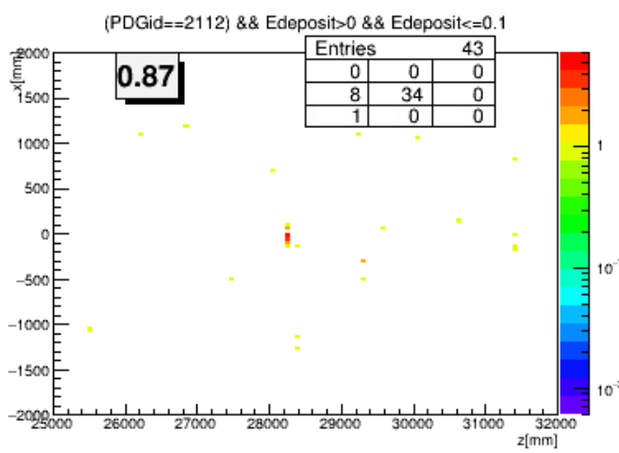


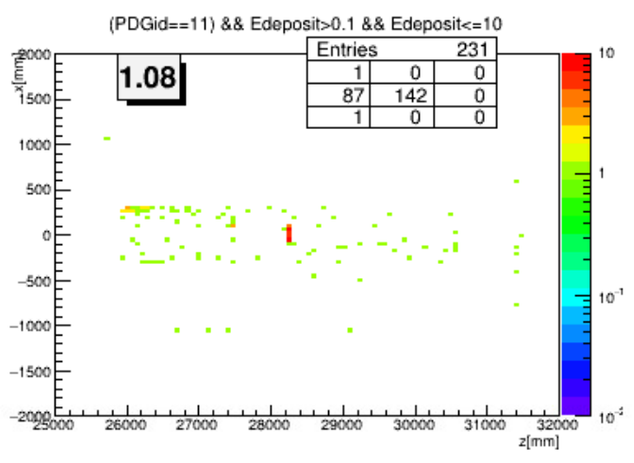


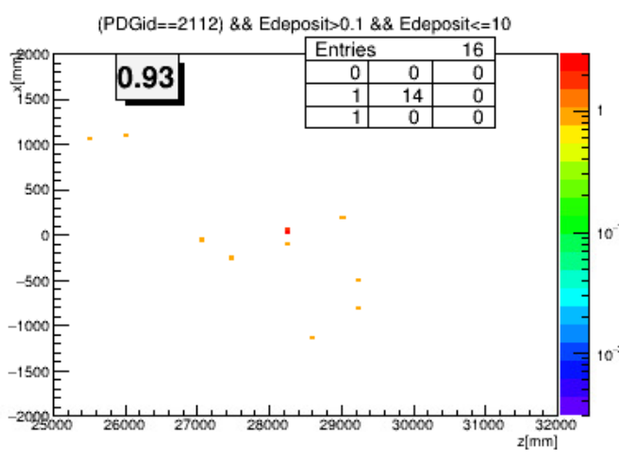


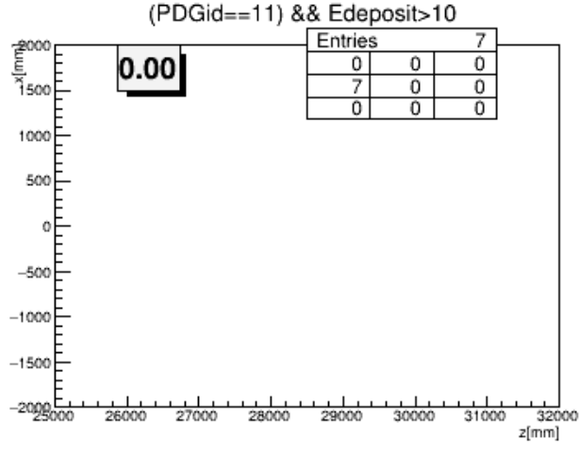
current setup + 2PipeSeptum

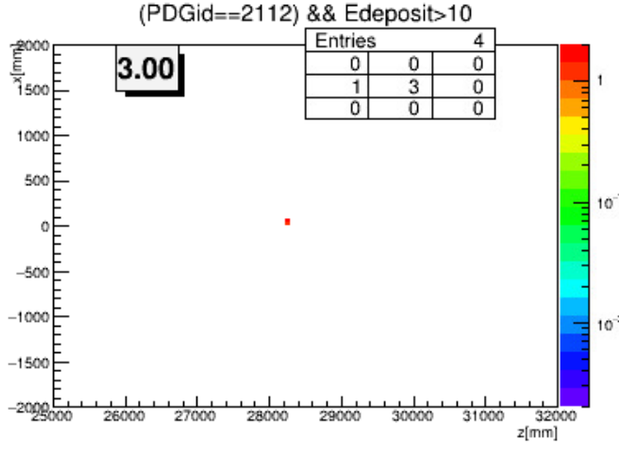






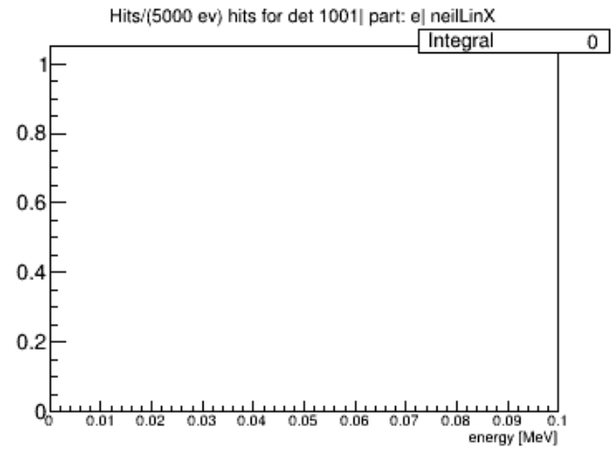


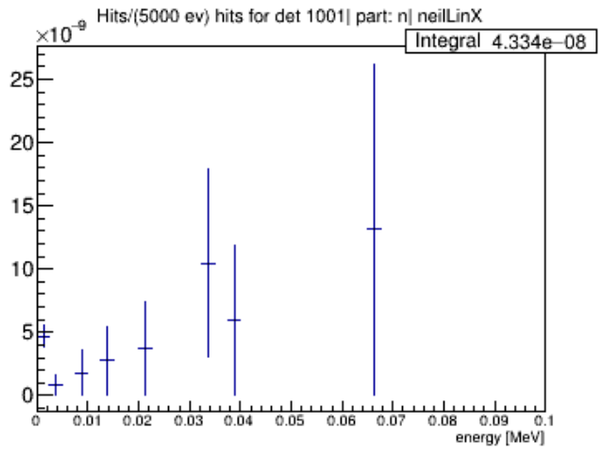


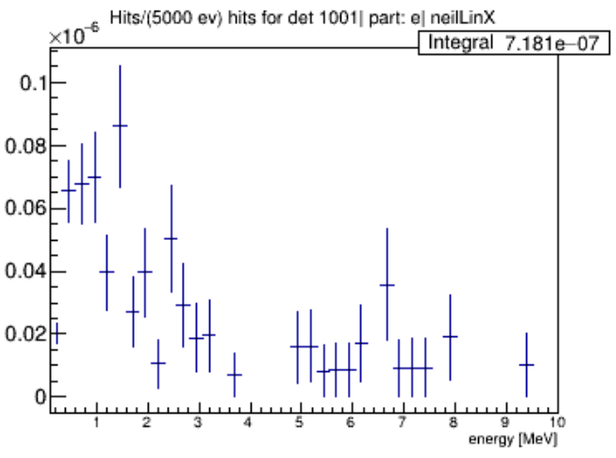


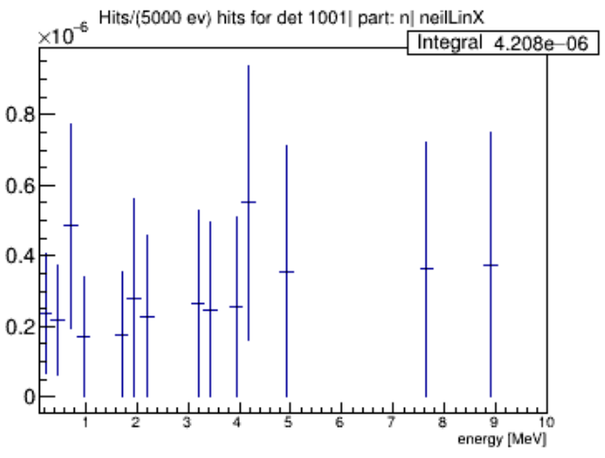
CREX - comparison

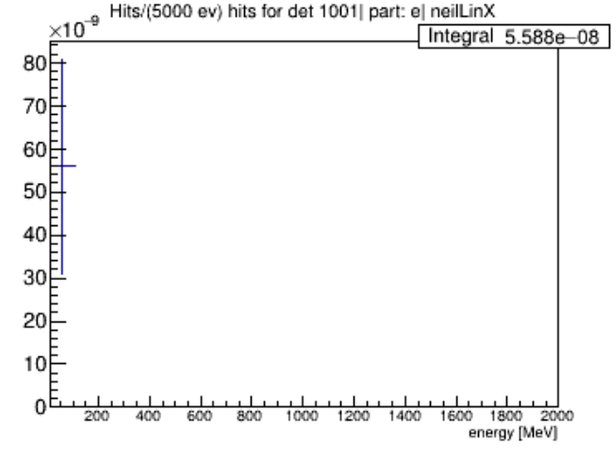
current setup

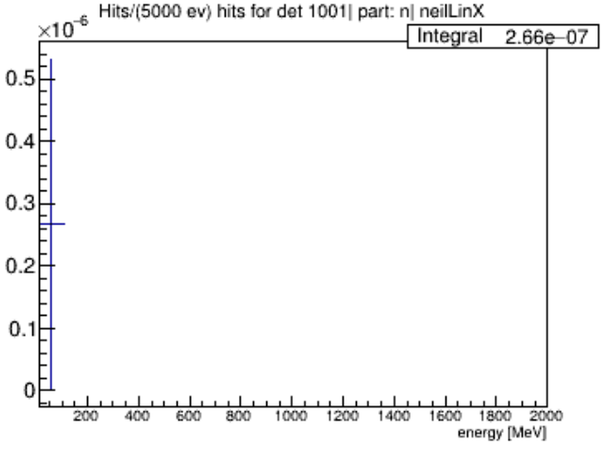




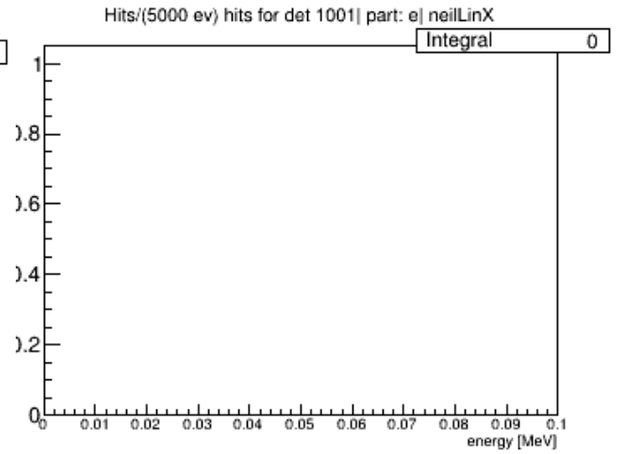


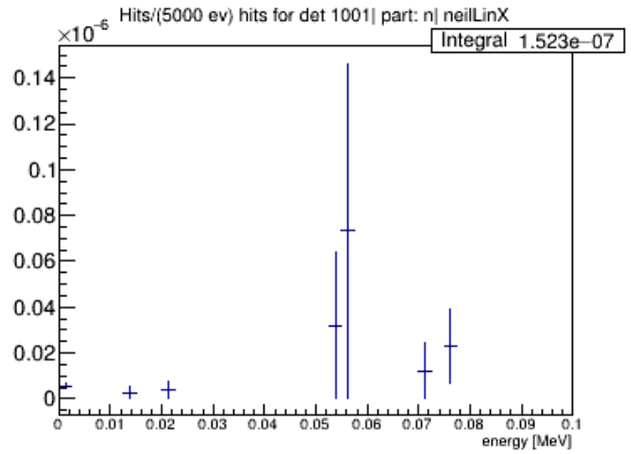


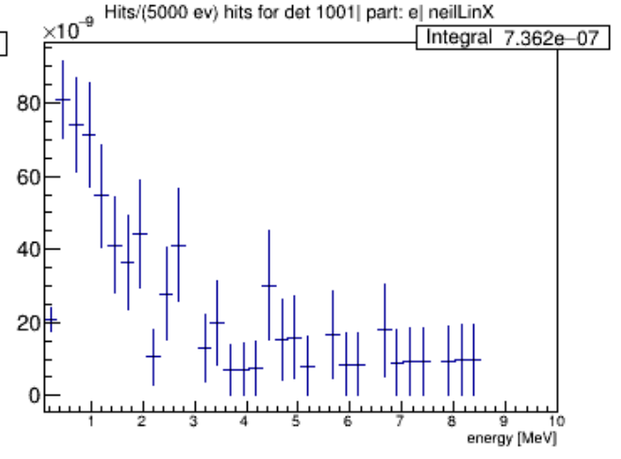


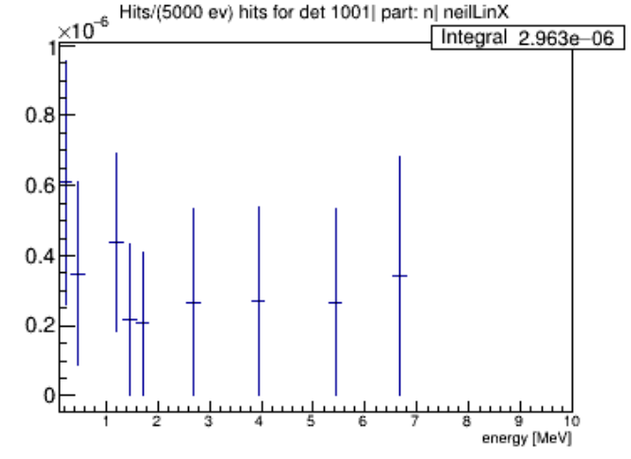


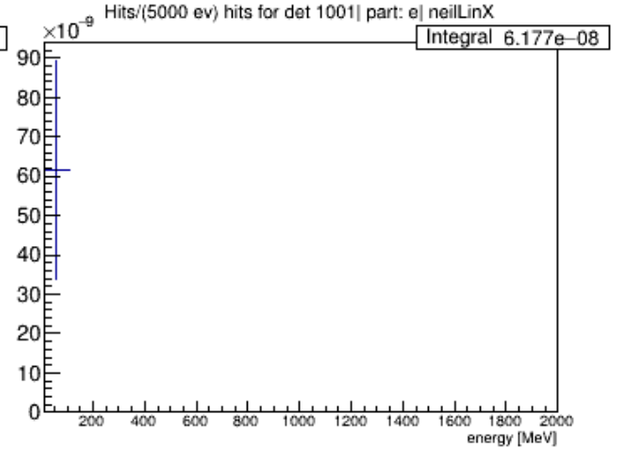
current setup + 2PipeSeptum

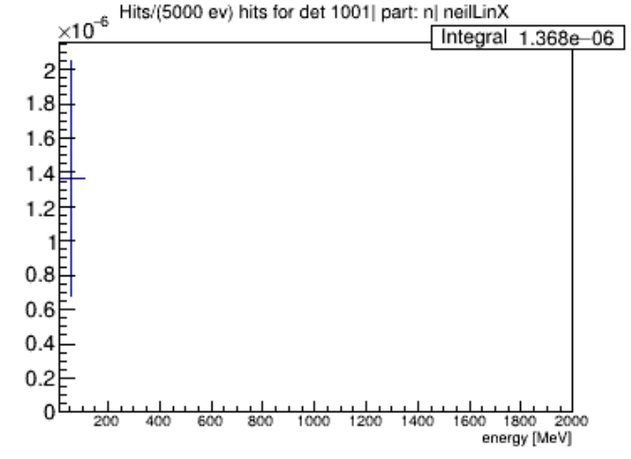






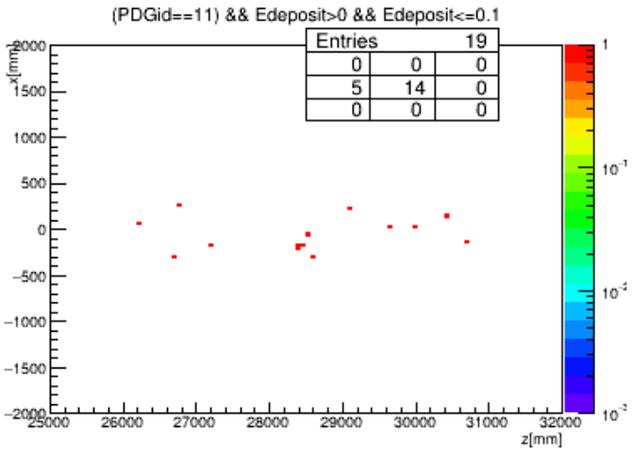


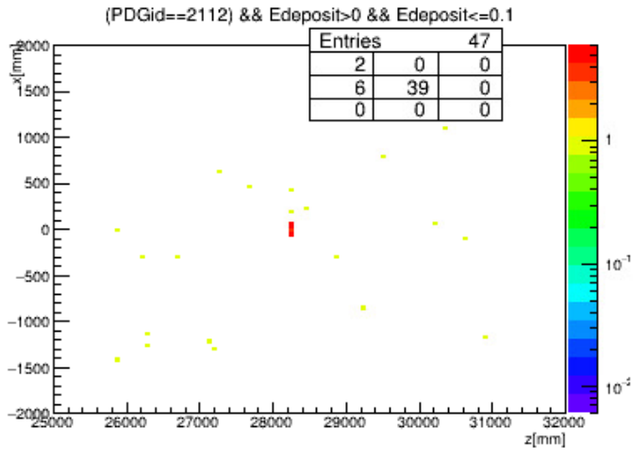


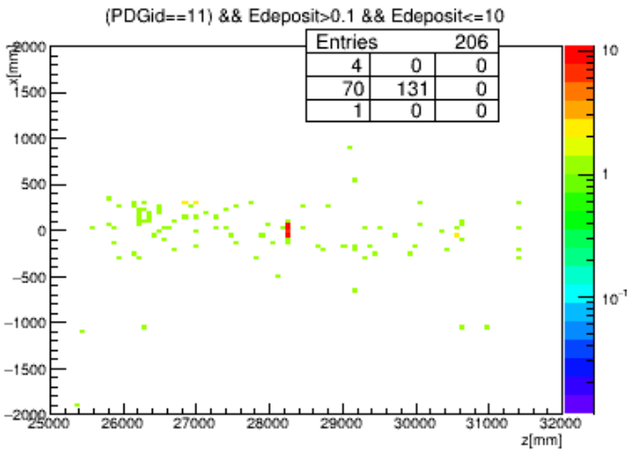


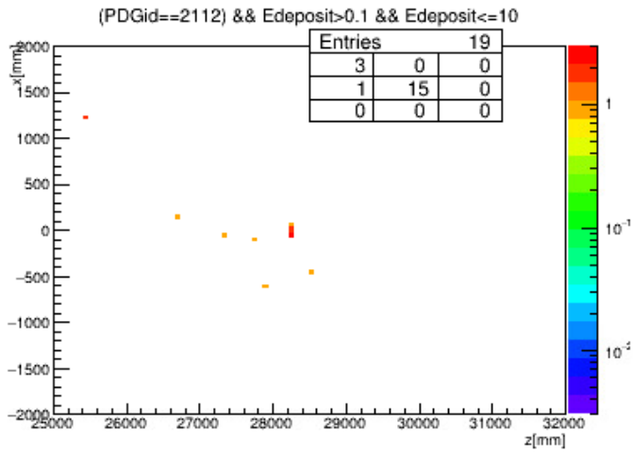
CREX - comparison

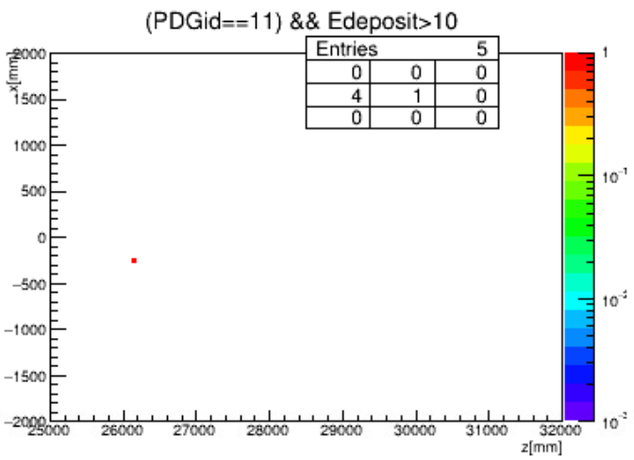
current setup

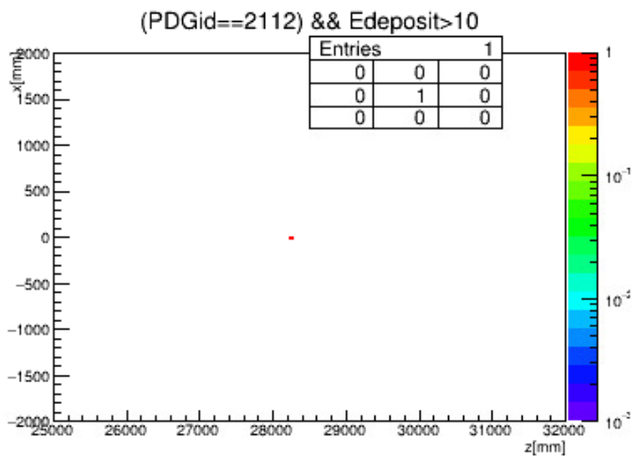




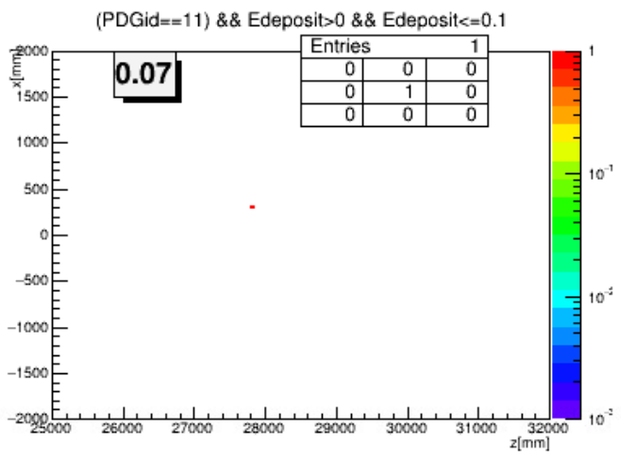


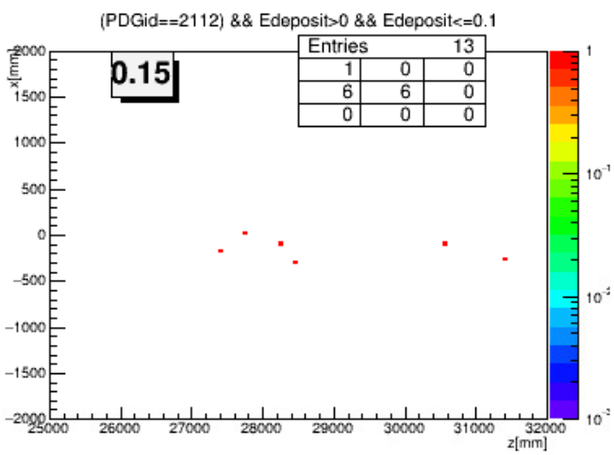


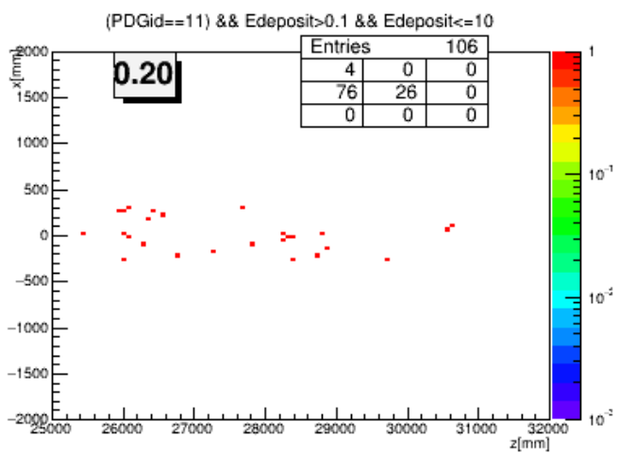


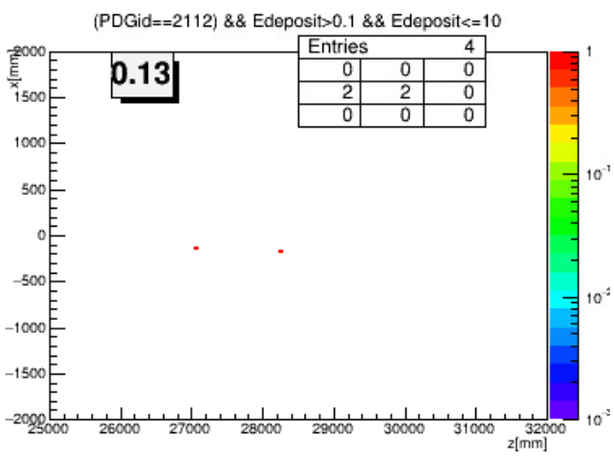


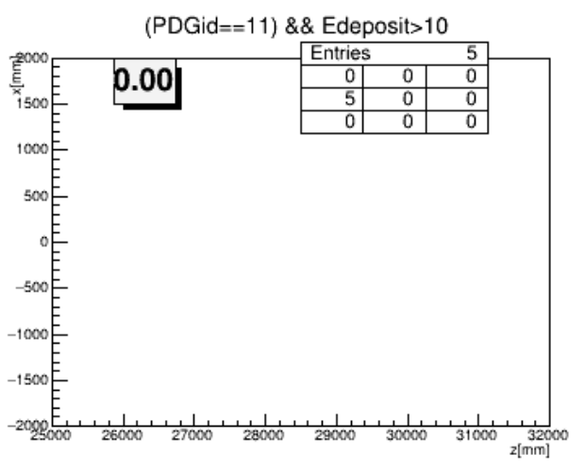
current setup + 4 in Donut+ 1 ft concrete shield

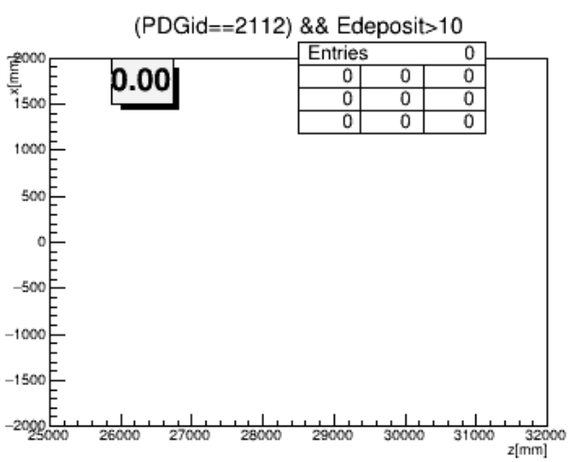






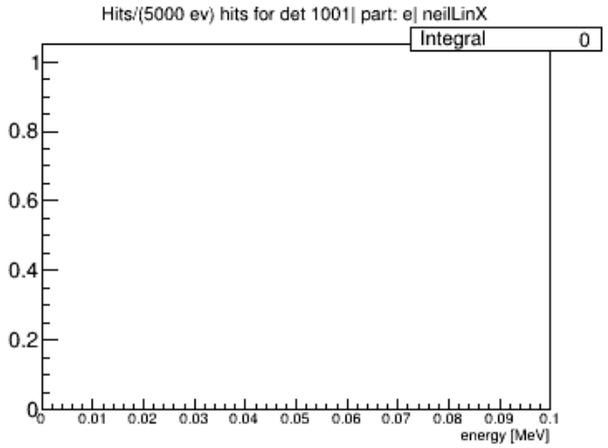


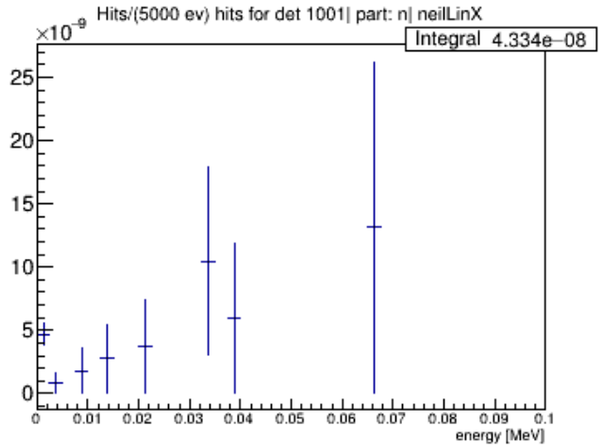


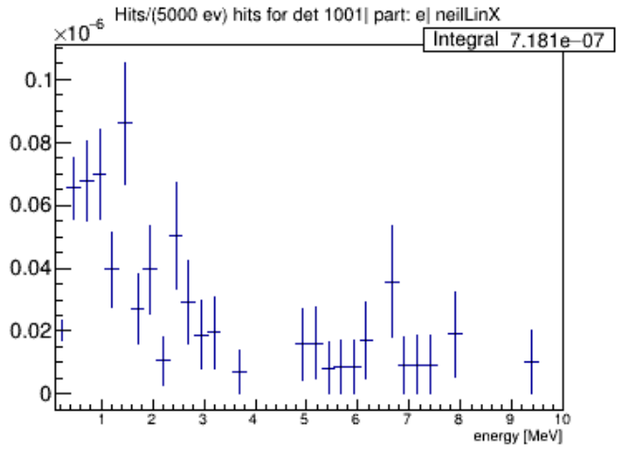


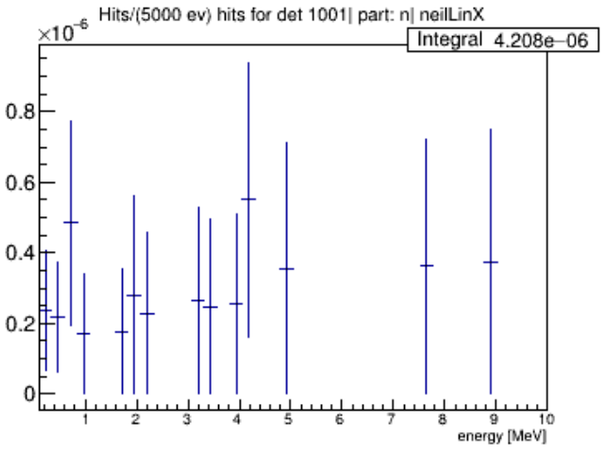
CREX - comparison

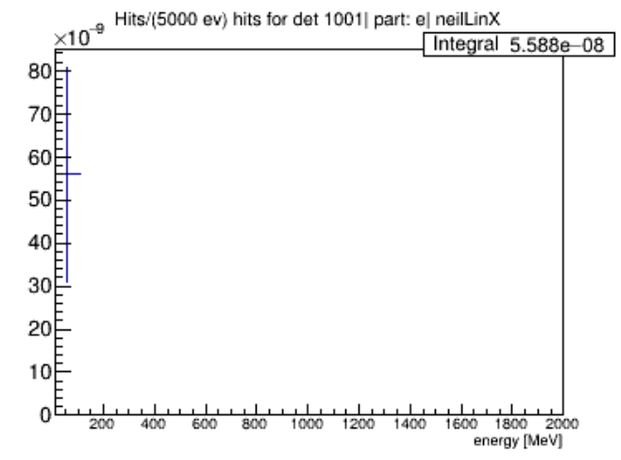
current setup

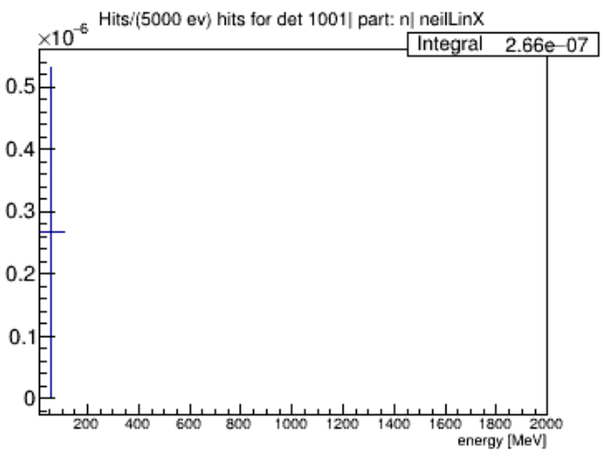




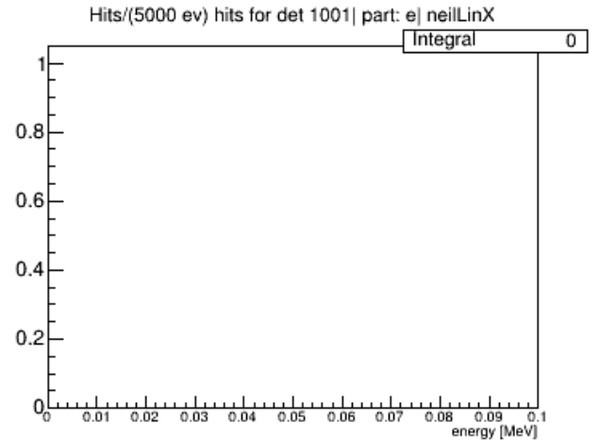


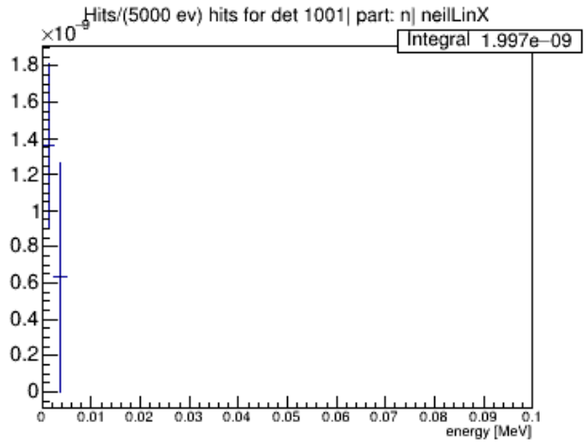


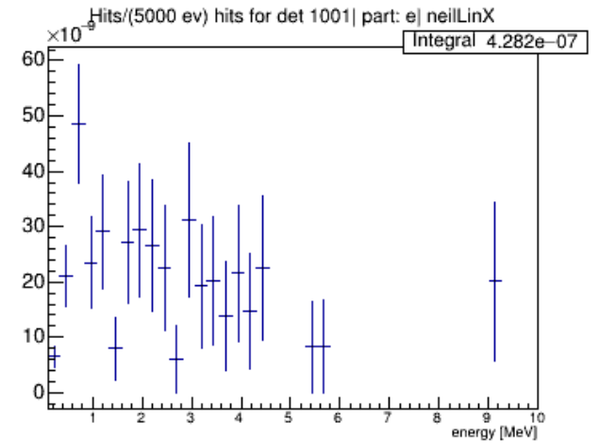


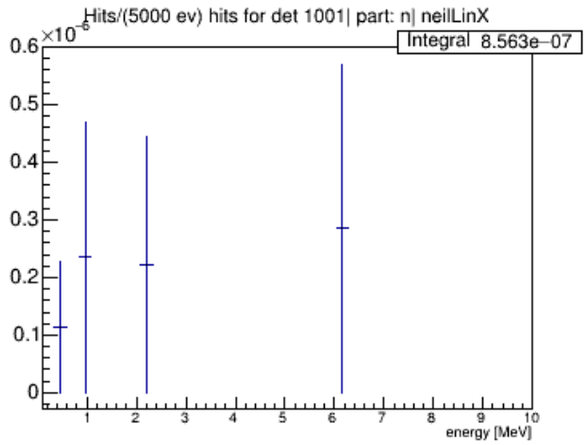


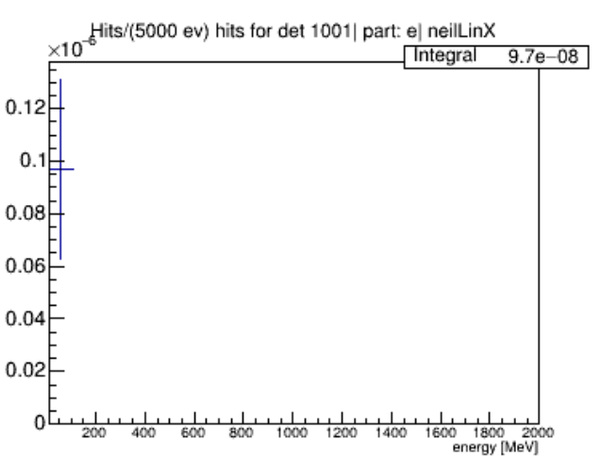
current setup + 4 in Donut+ 1 ft concrete shield

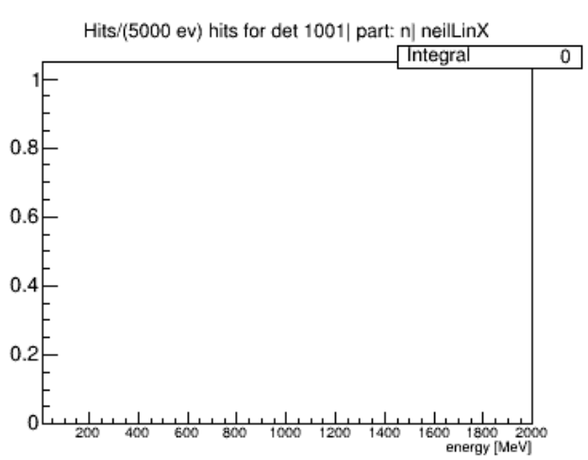






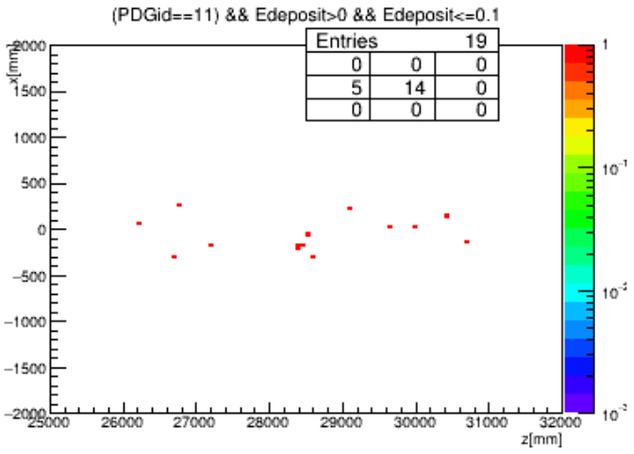


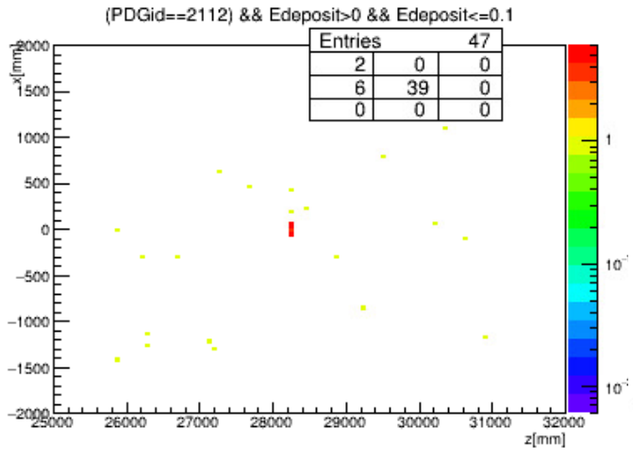


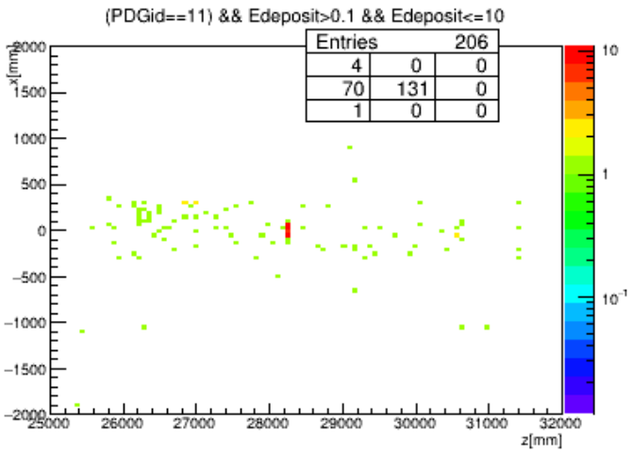


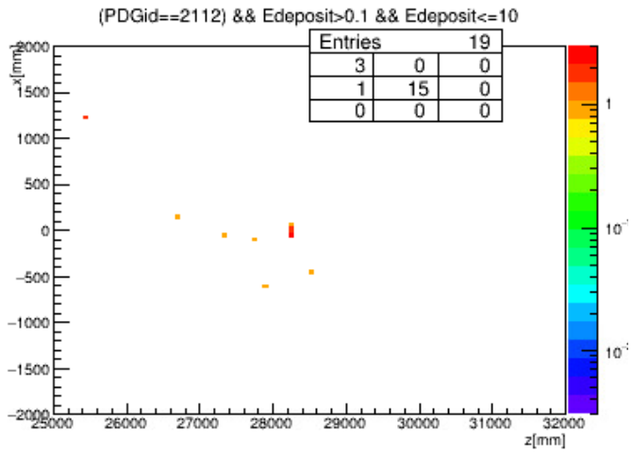
CREX - comparison

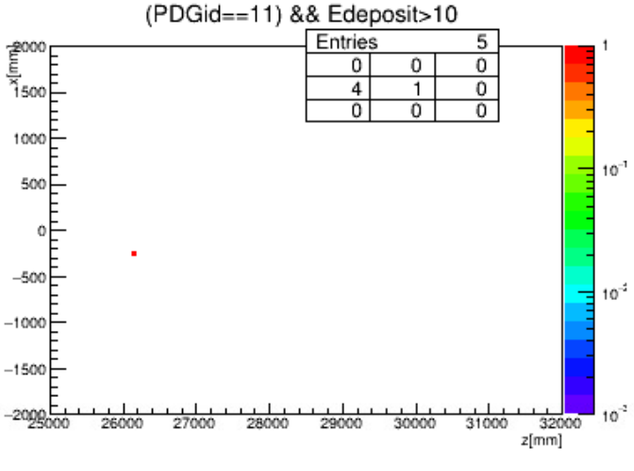
current setup

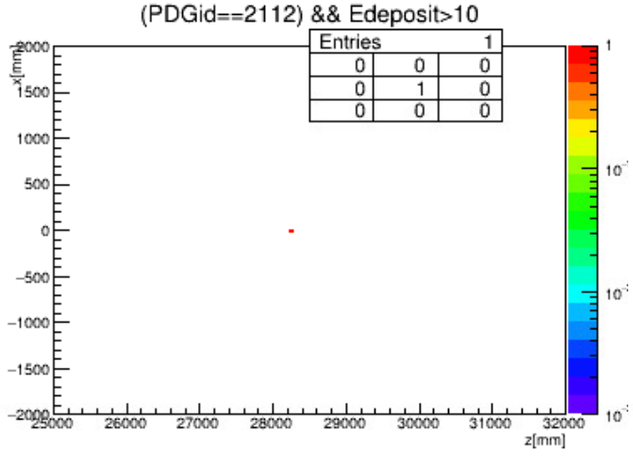




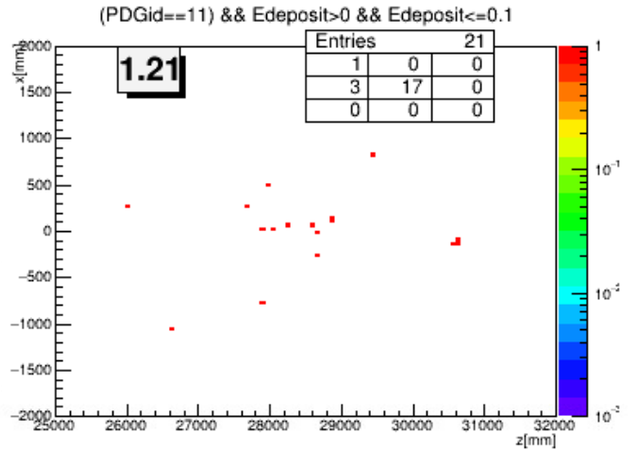


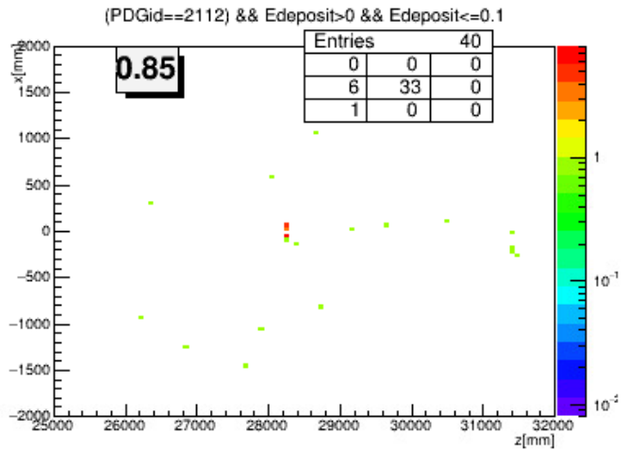


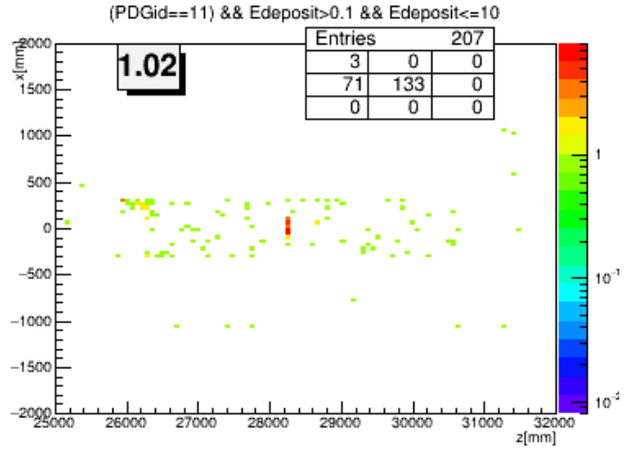


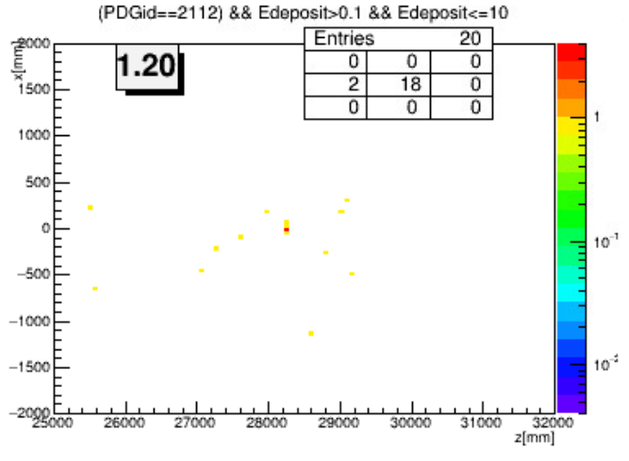


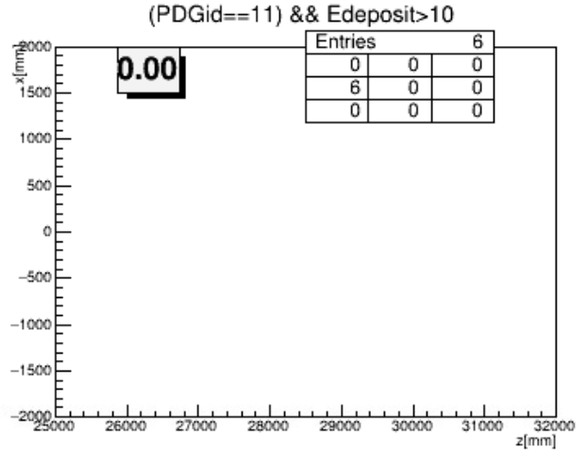
current setup + 2PipeSeptum+donut shield

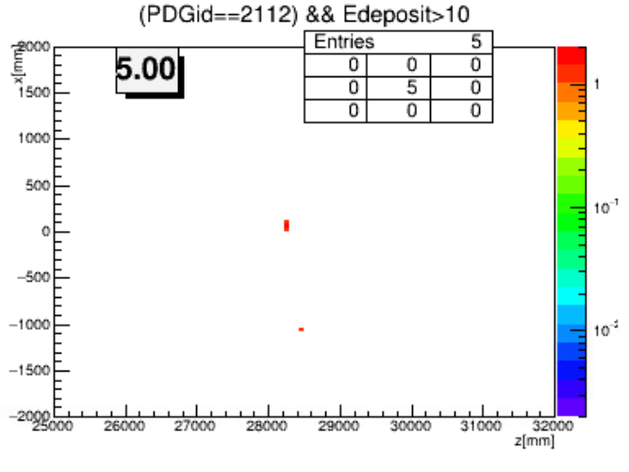






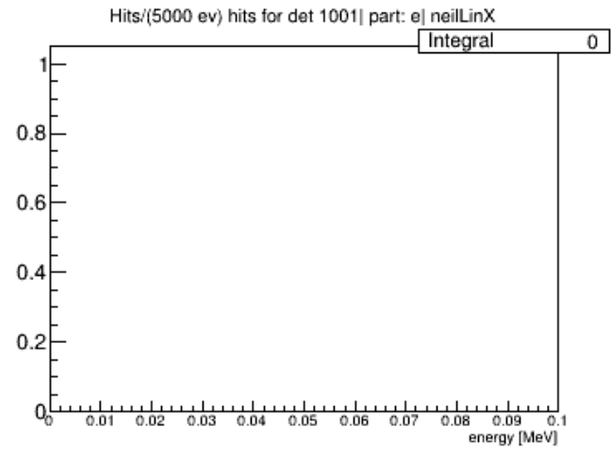


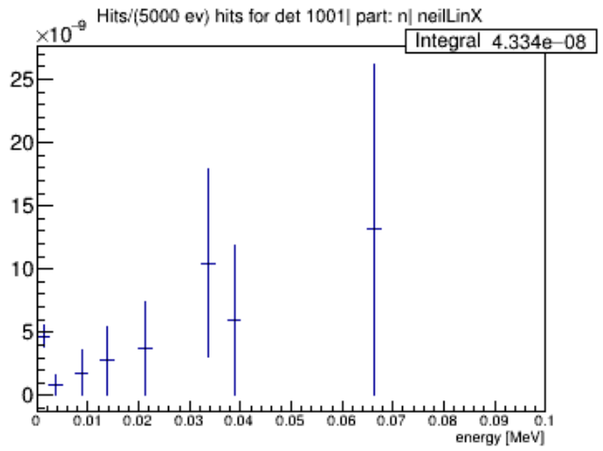




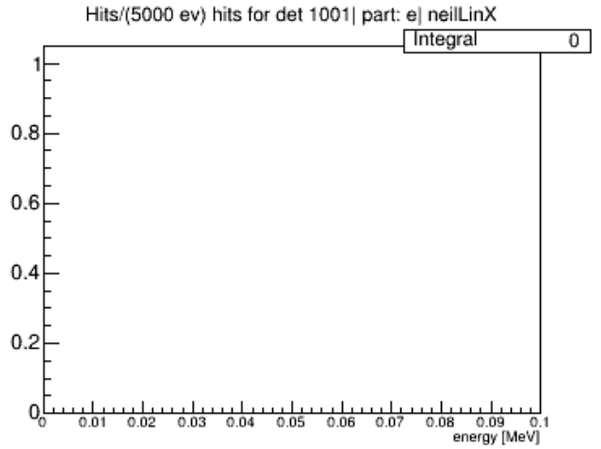
CREX - comparison

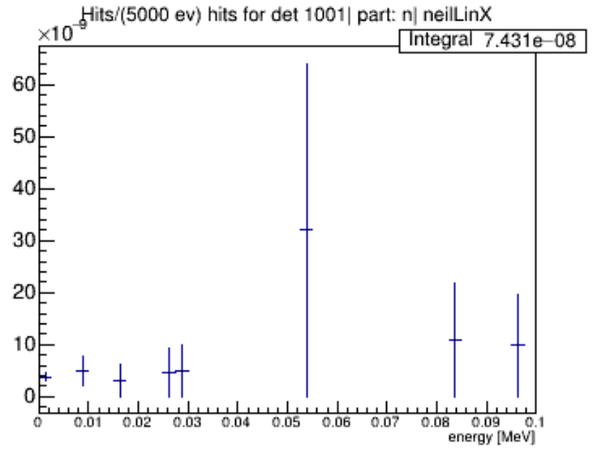
current setup



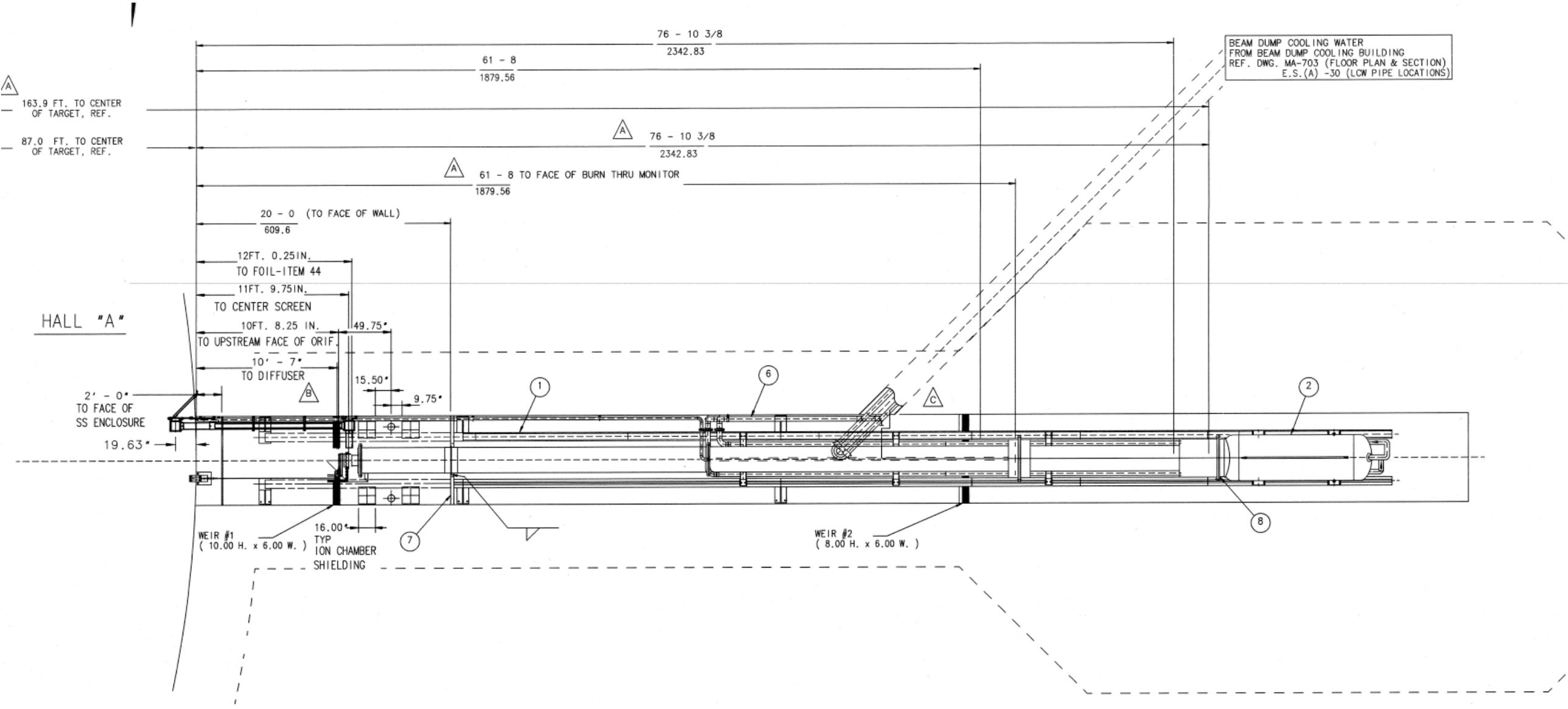


current setup + 2PipeSeptum+donut shield





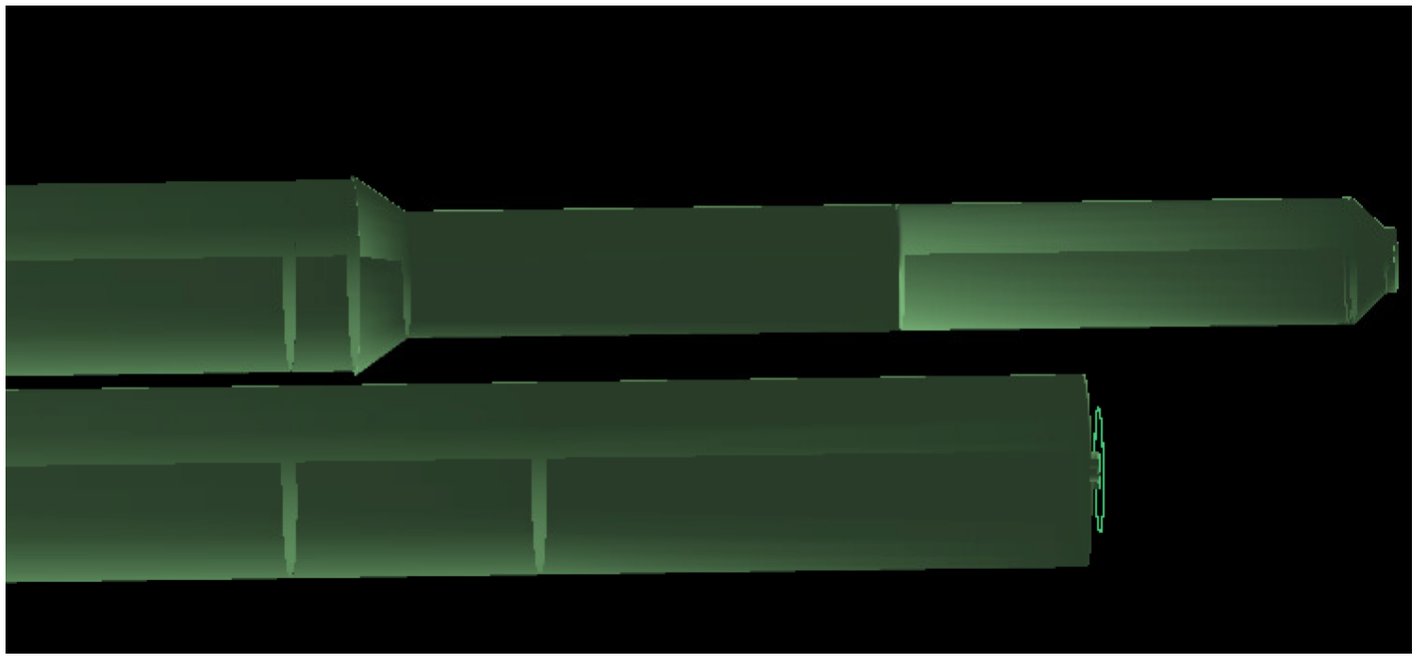
PREX 1 dump configuration

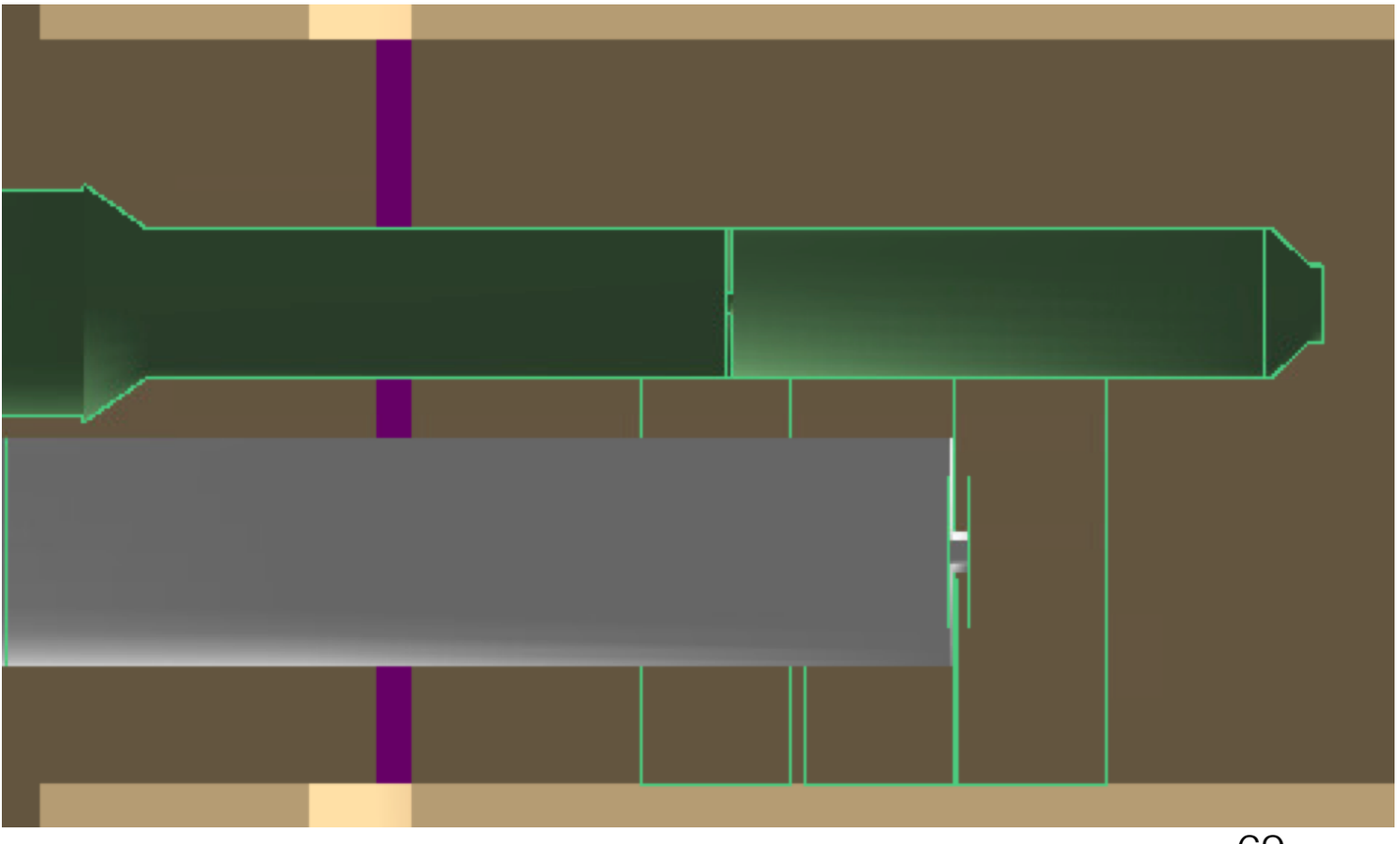


- Dump configuration was different than what we had in the simulation

- The beam pipe has an Aluminum aperture that is about 4in in diameter in about the same location as the donut is now

GDML implementation

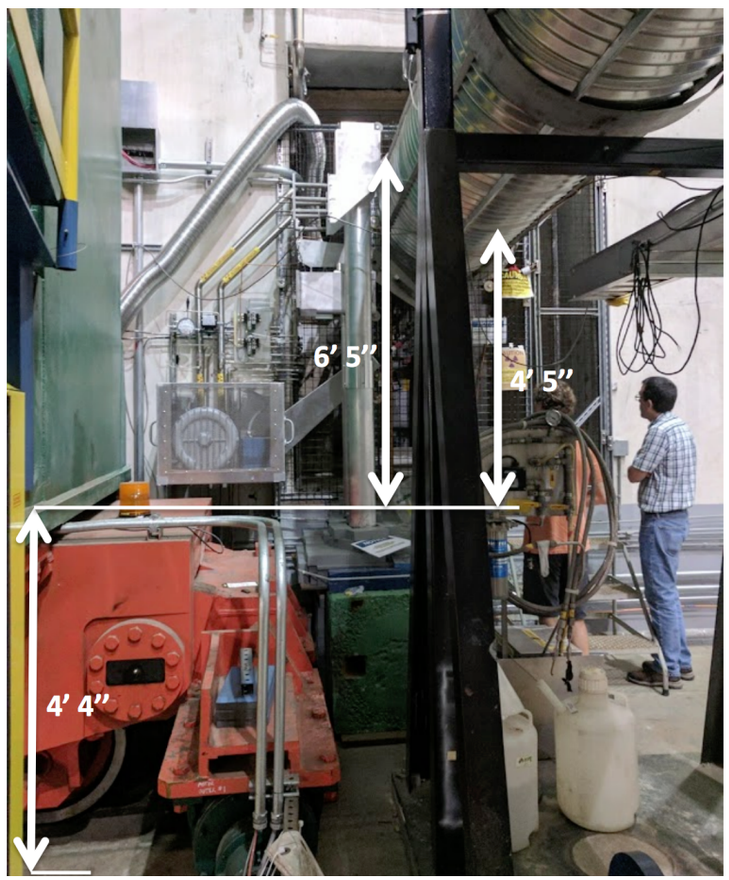




- Furthermore Kent noticed that the neck down in my configuration didn't match the drawing (or reality)

- now the neck-down is right after the wall similarly to what we have in the hall

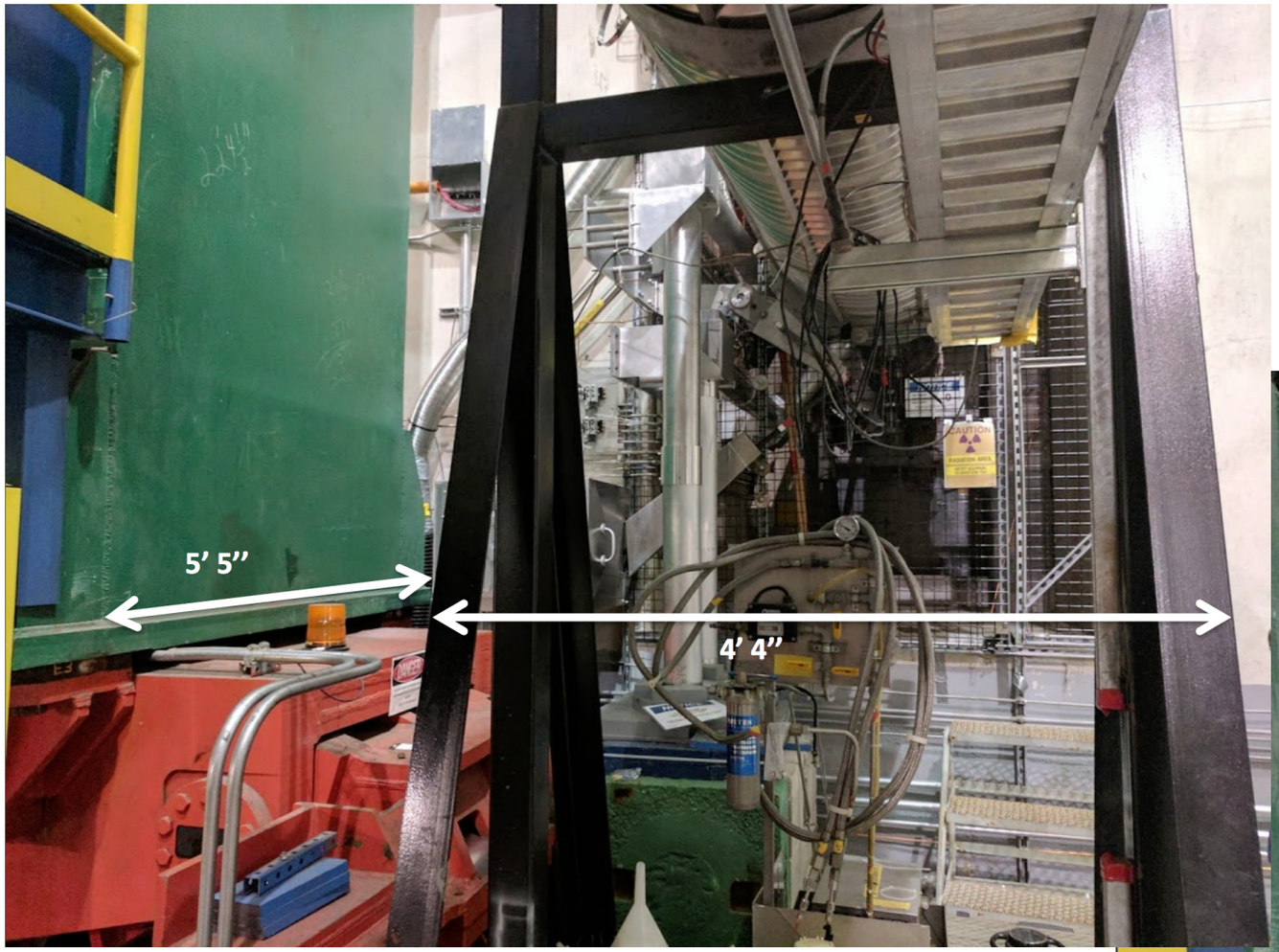
Shielding concept

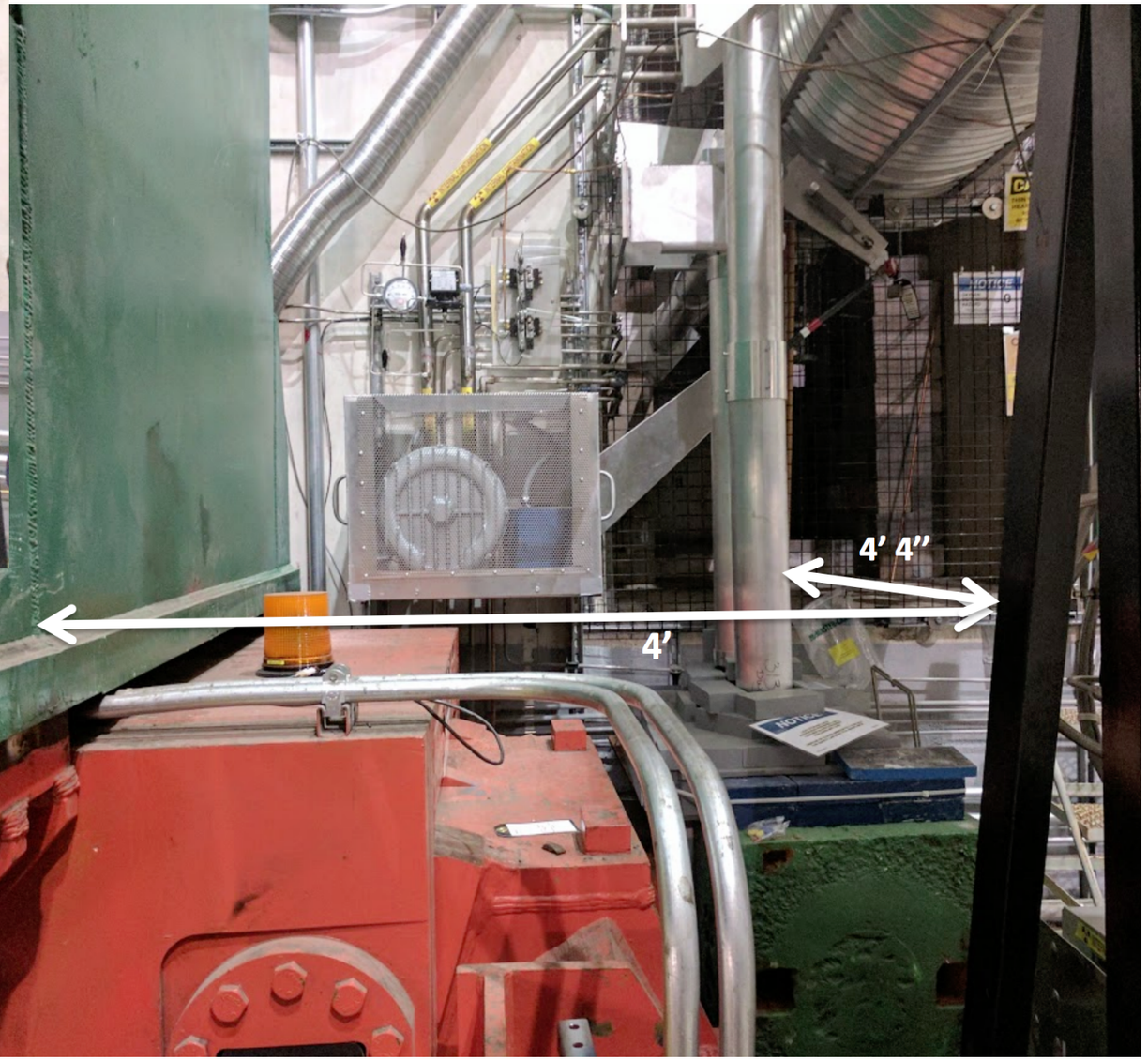


- Sanghwa, Dave and I went over to the hall and we made some measurement of the space available to us with the HRS parked in the 12.5 deg position

- I implemented 3 simple 1 foot thick shielding blocks in the simulation (ran for both concrete and Polyethylene)

Hall Configuration

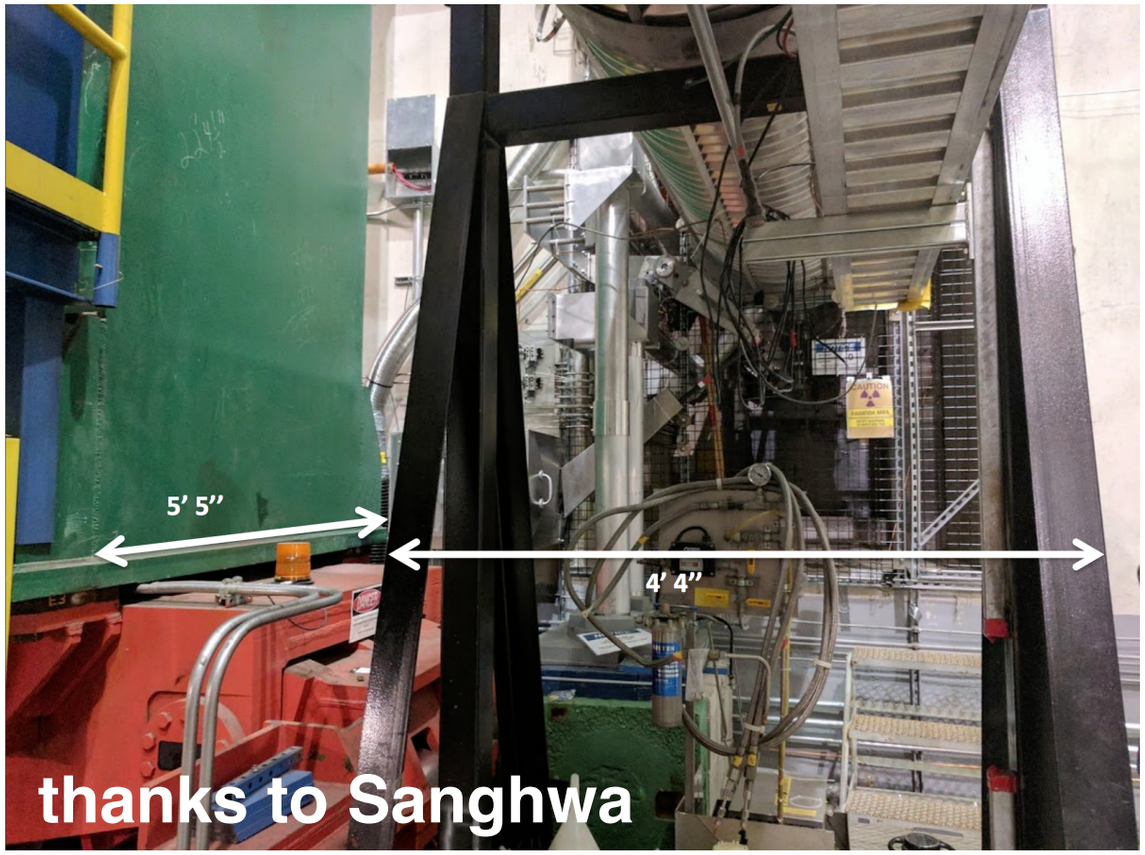


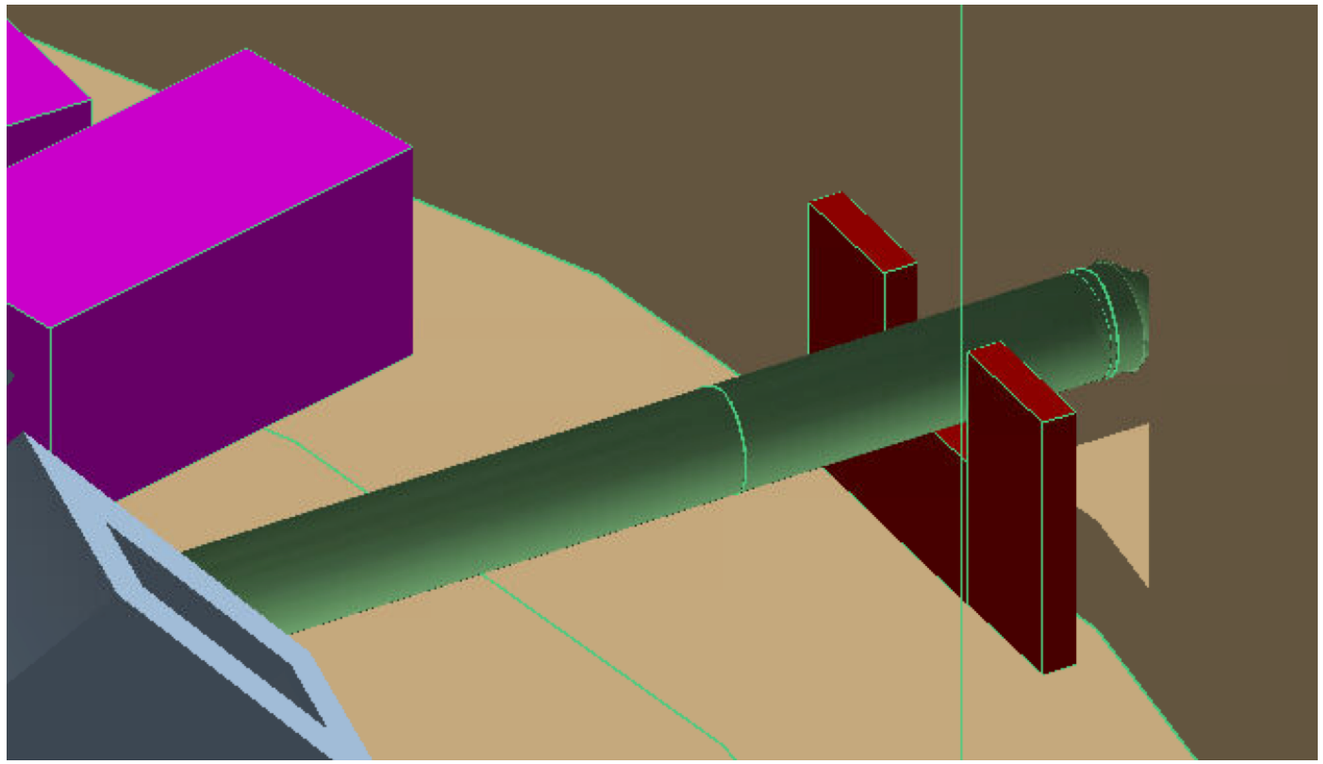


- 10 cm thick Steel wall (in green) is not present in our simulation

thanks to Sanghwa

Hall Configuration

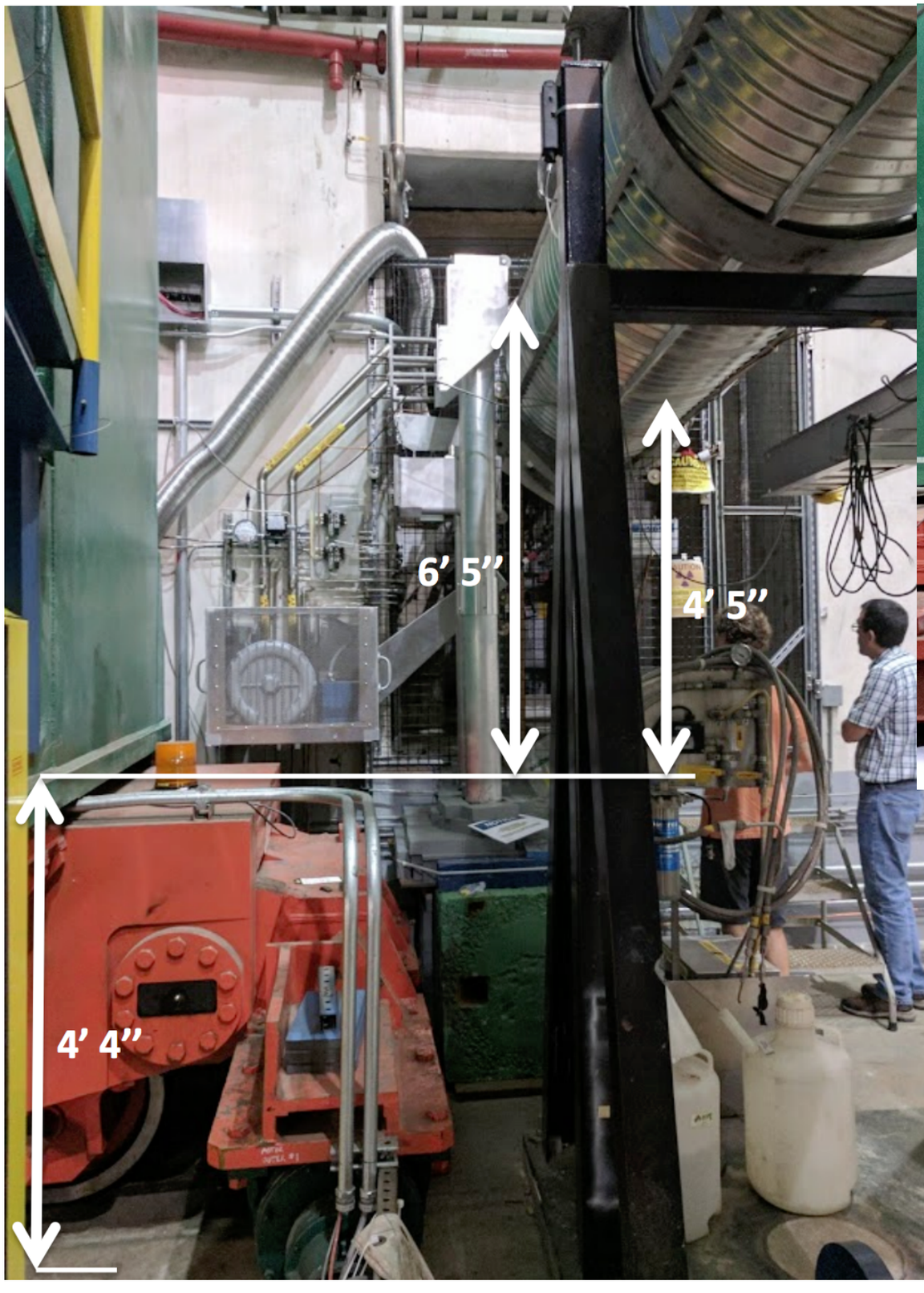


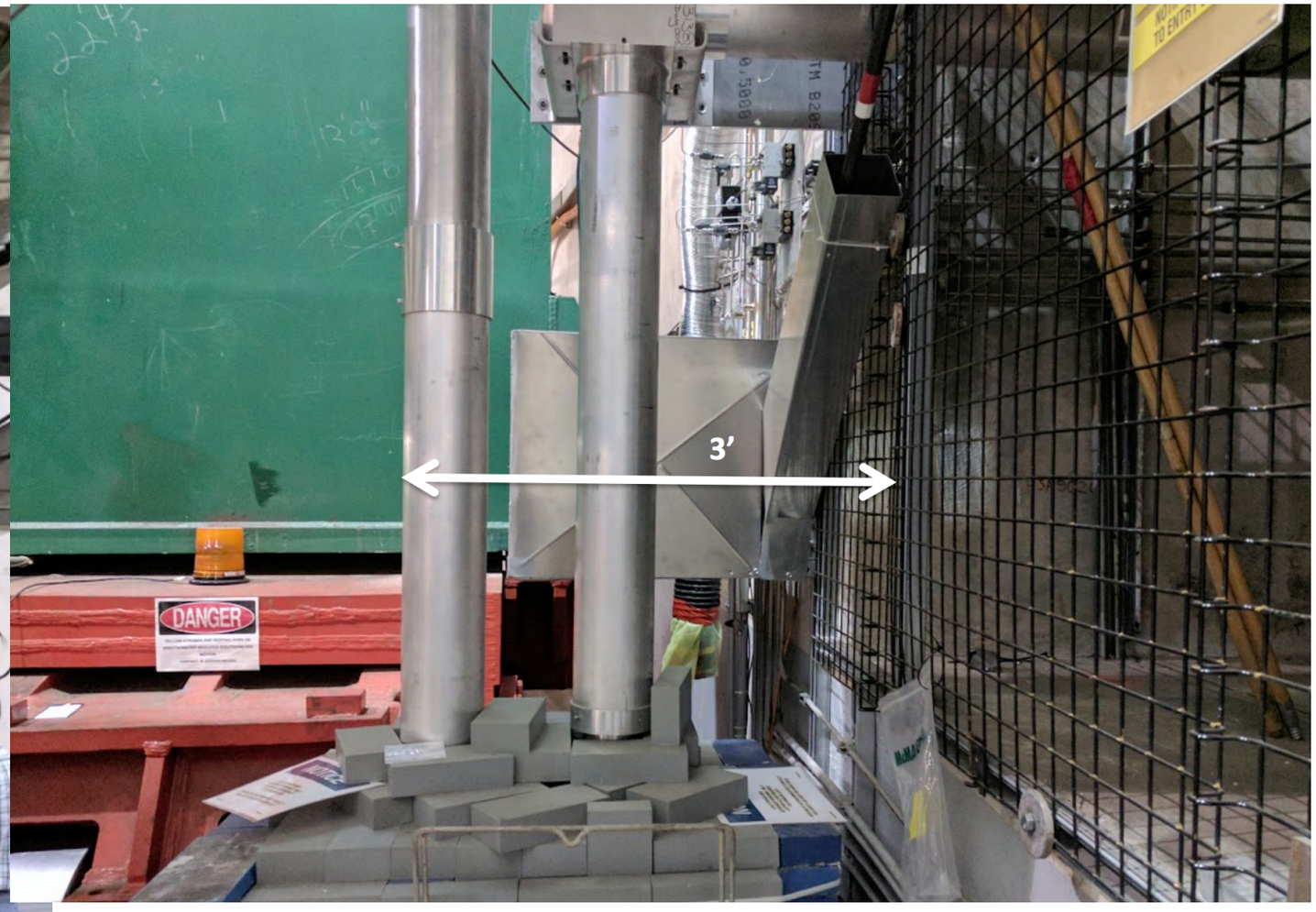


- 10 cm thick Steel wall (in green) is not present in our simulation

- moreover, the hrs “electronics box” we have now doesn’t cover the whole area where electronics exist and may be too forward

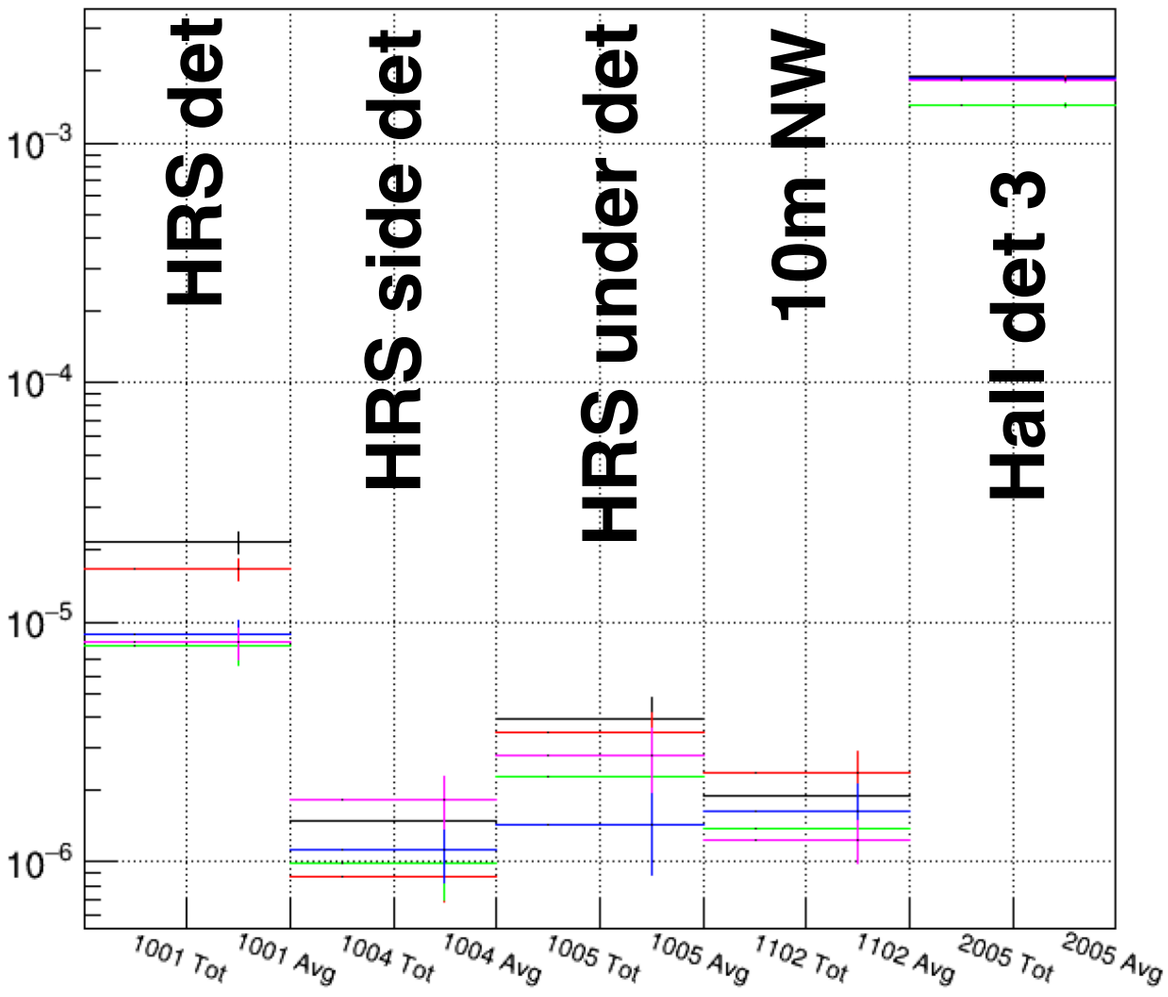
Hall Configuration



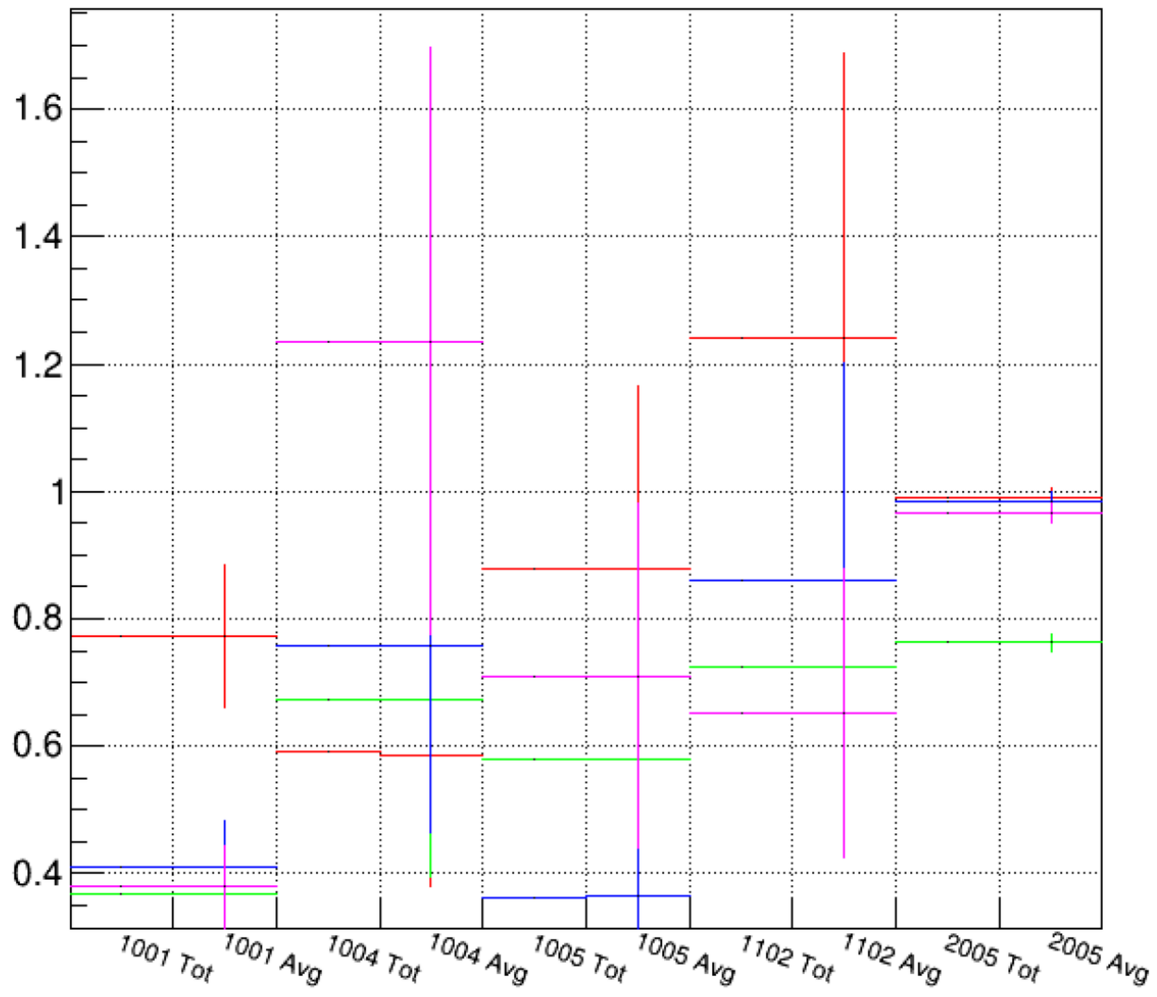


thanks to Sanghwa

PREX2 - HRS rad damage

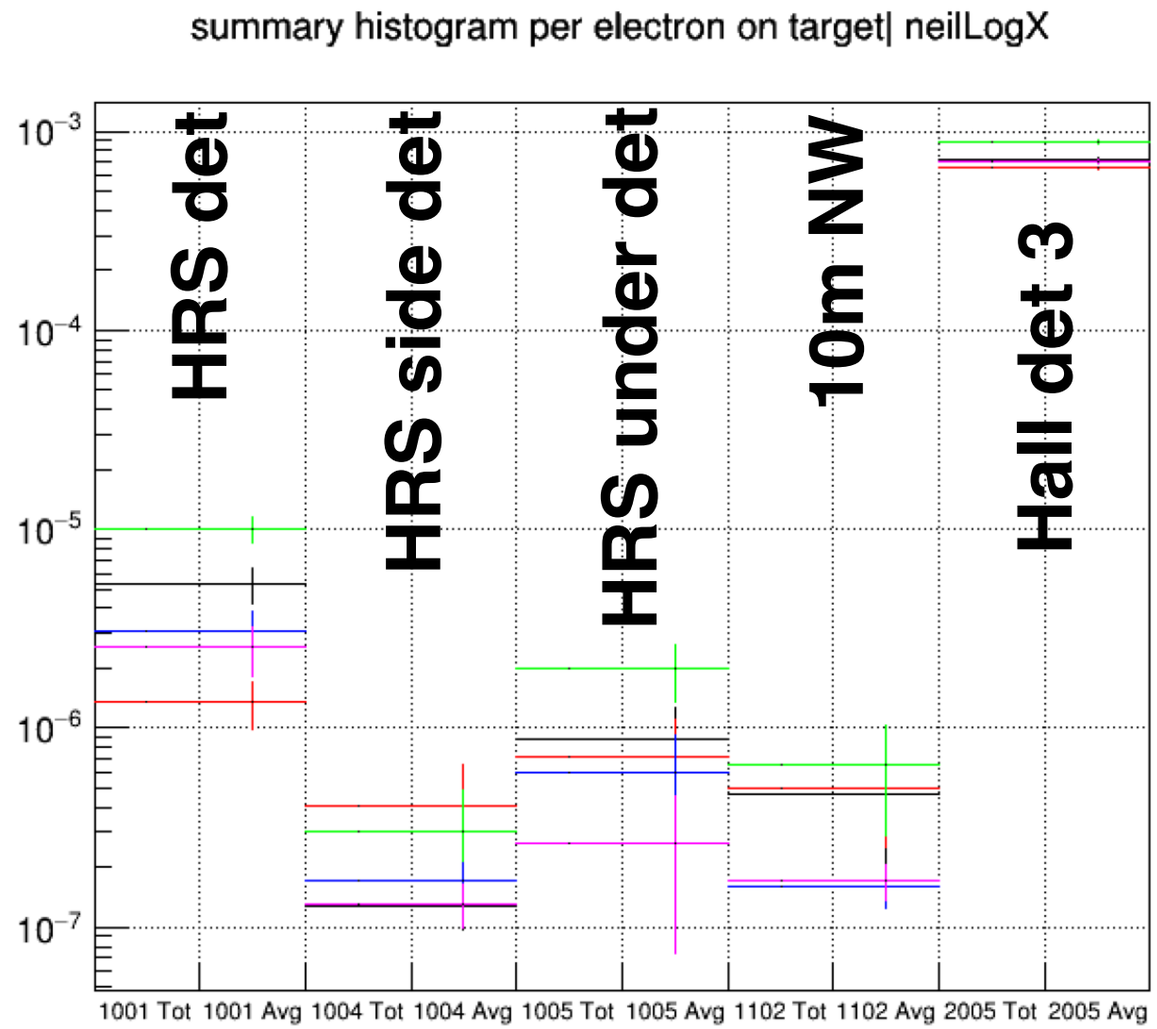


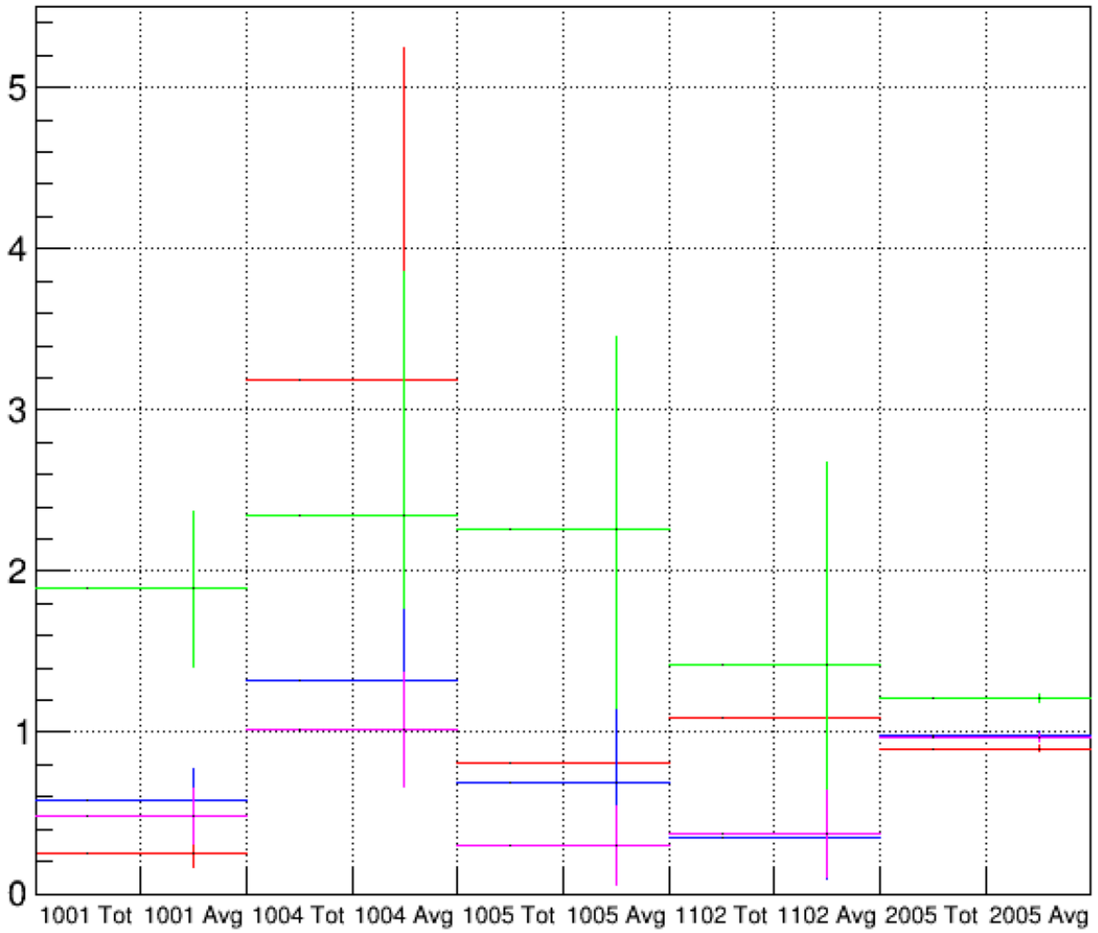
Black: current setup
Red: current setup + 4 in donut
Green: PREX 1 dump
Blue: current setup + concrete Shield
Magenta: current setup + Poly Shield



- Best configuration seems to be the PREX1 beam pipe, followed closely by the current pipe with shielding

CREX - HRS rad damage





Black: current setup
Red: current setup + 4 in donut
Green: PREX 1 dump
Blue: current setup + concrete Shield
Magenta: current setup + Poly Shield

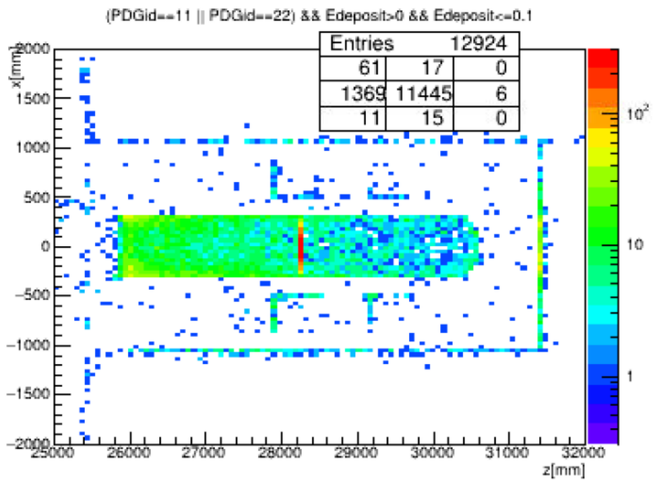
- For CREX having a large aperture can provide significant improvement

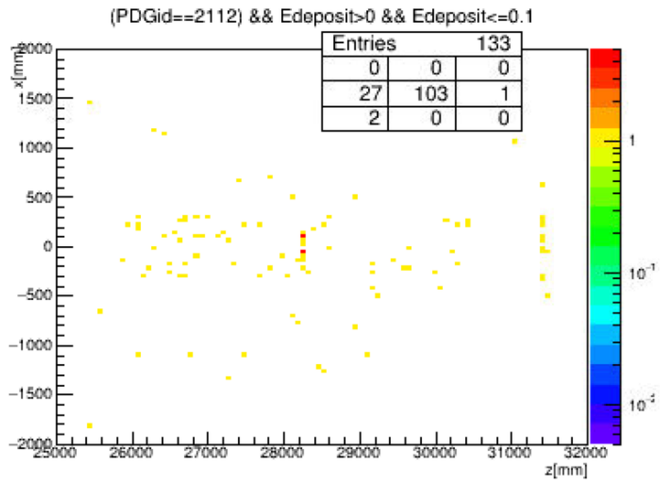
Plots with electrons plus gammas

PREX2 - current dump

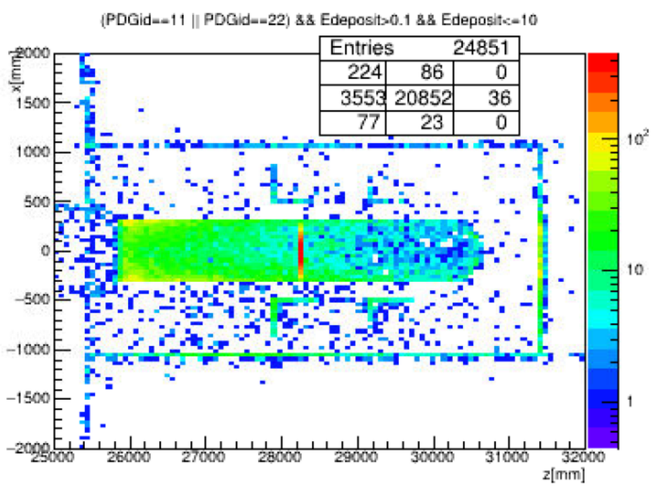
electrons+photons

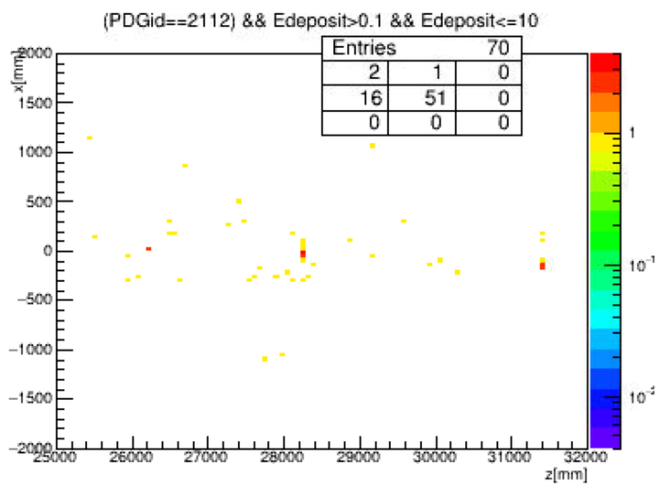
neutrons



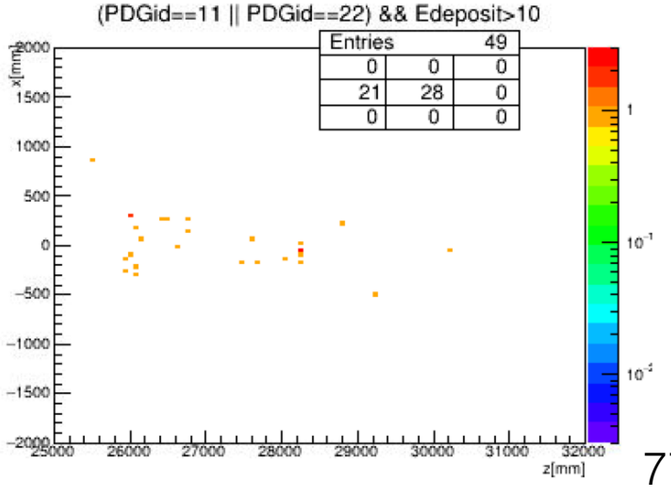


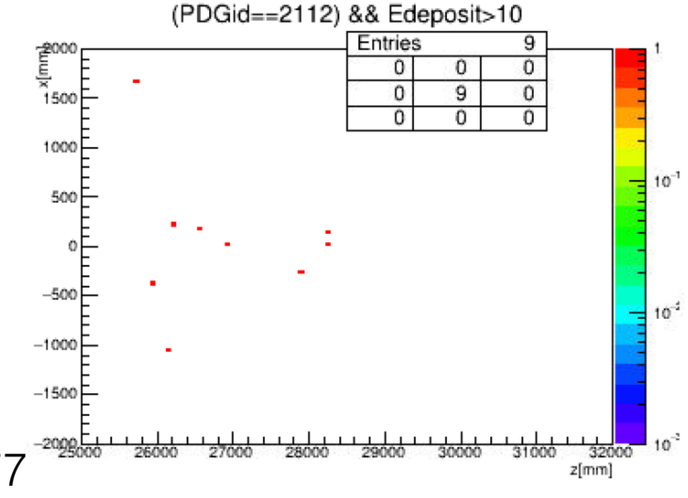
0<E<=0.1 MeV





0.1<E<=10 MeV

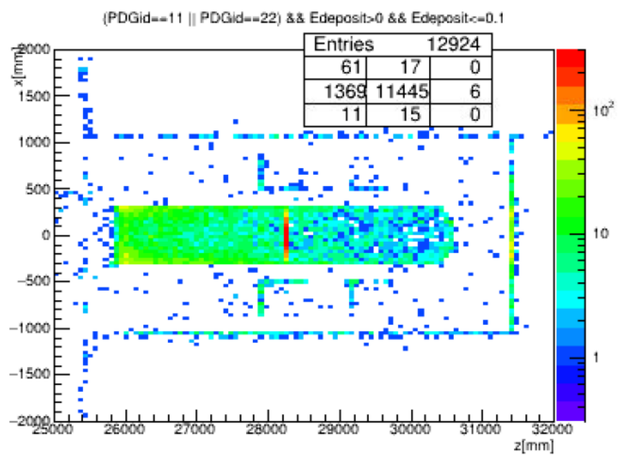


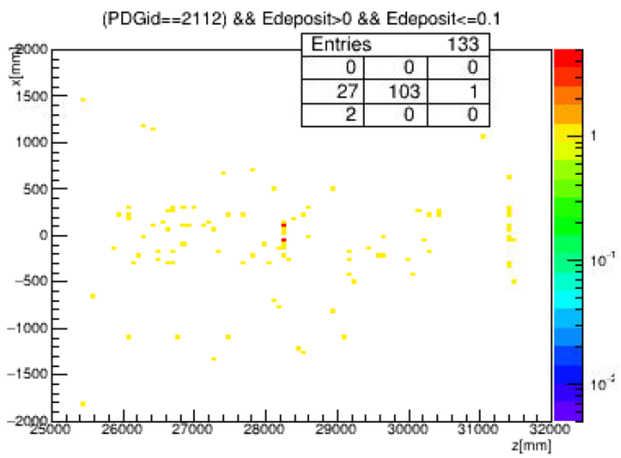


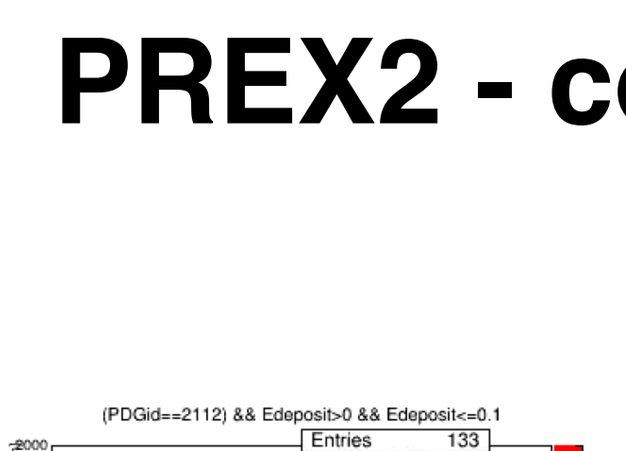
10<E MeV

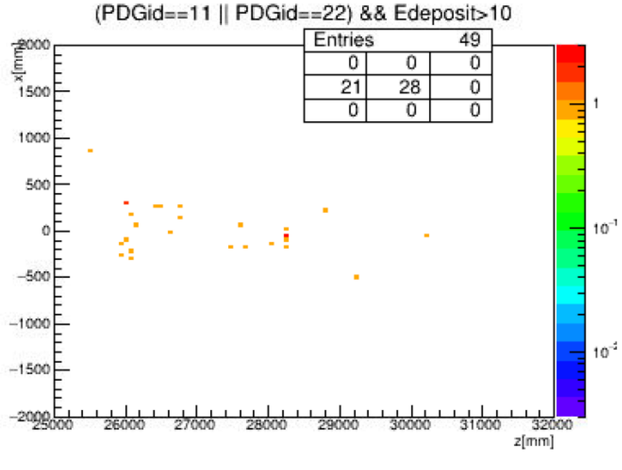
PREX2 - comparison

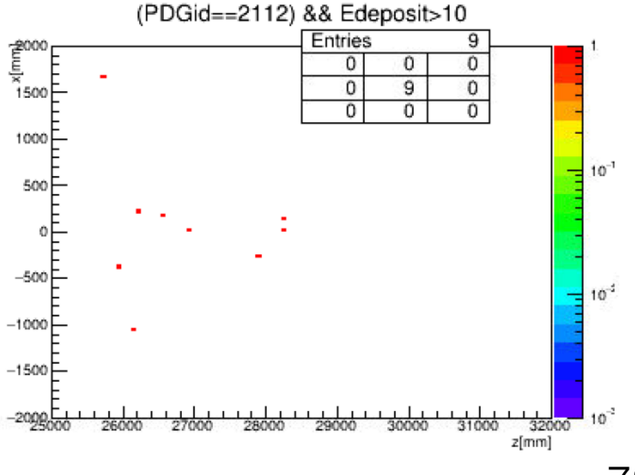
current setup



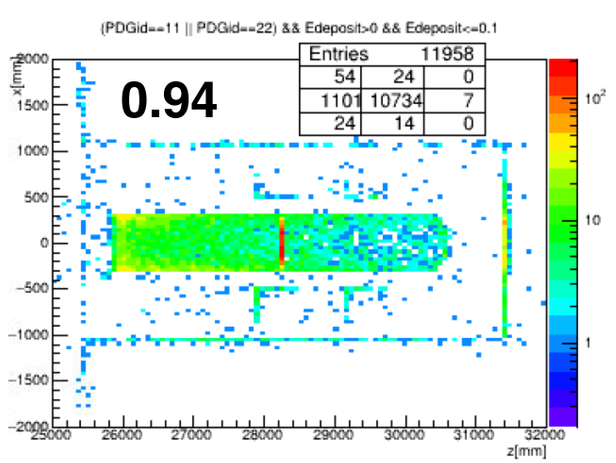


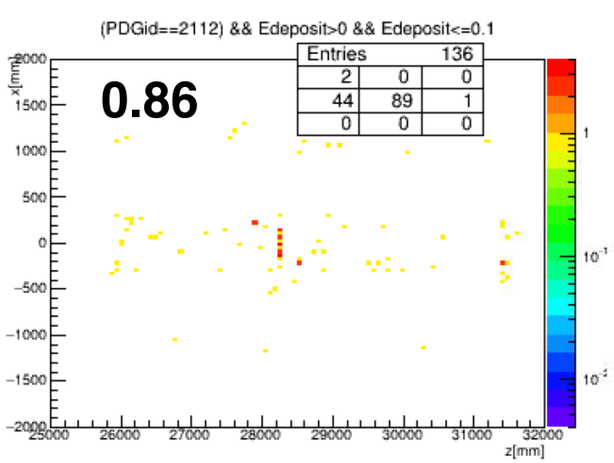


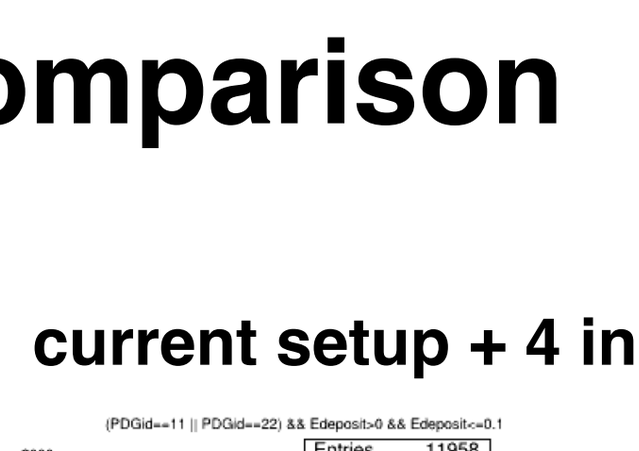


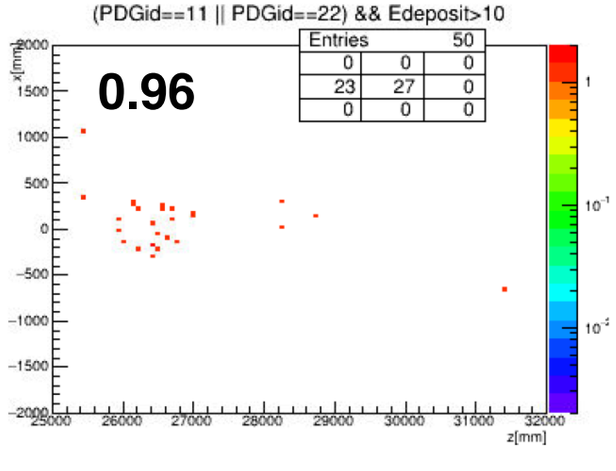


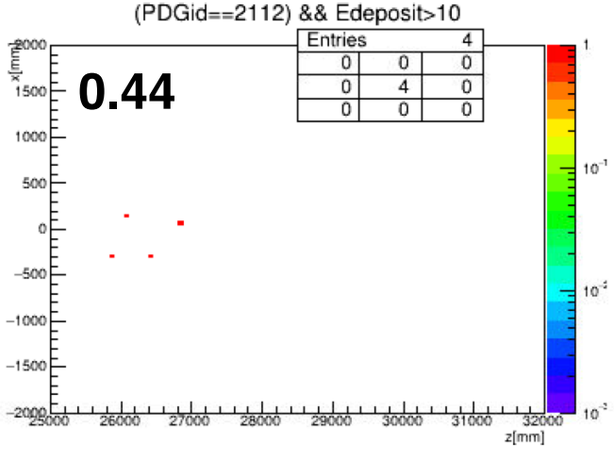
current setup + 4 in donut





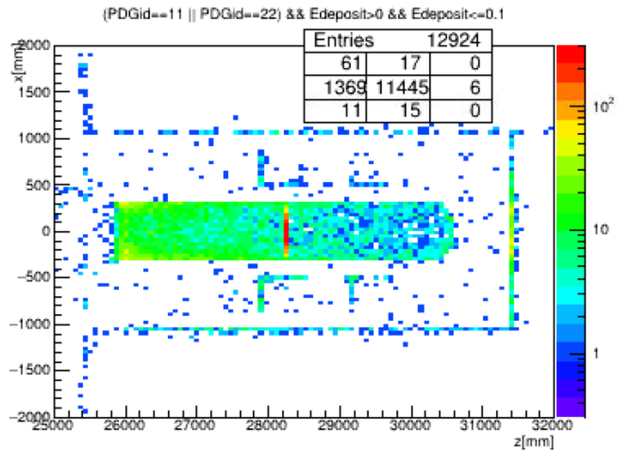


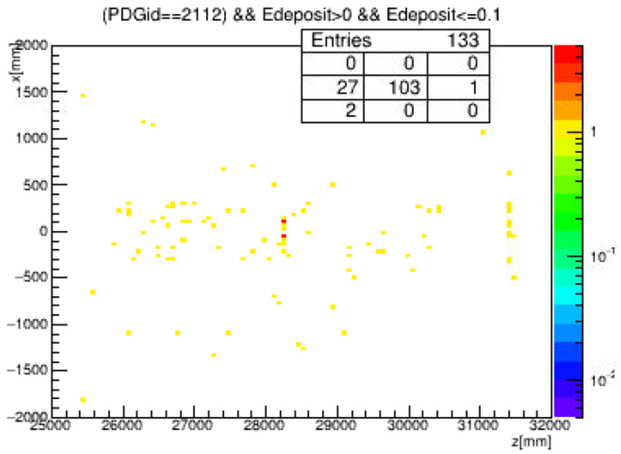


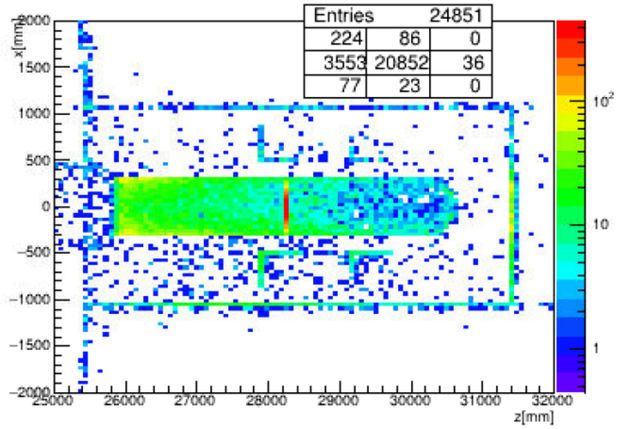


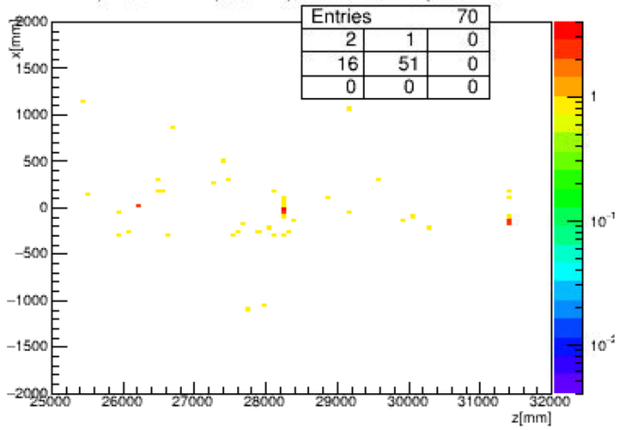
PREX2 - comparison

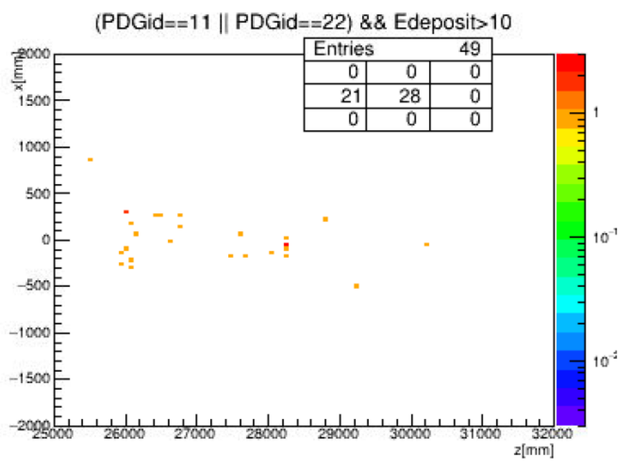
current setup

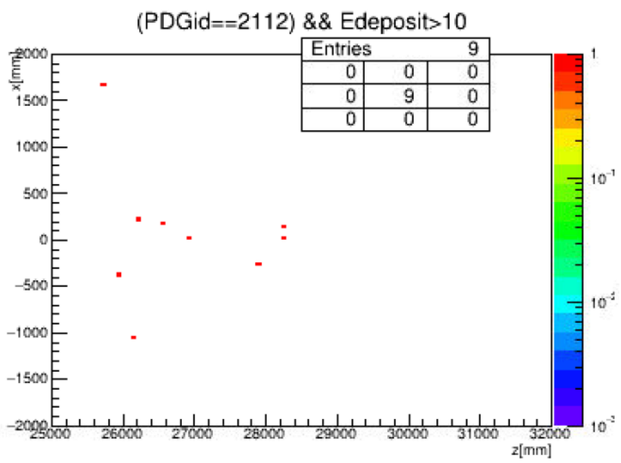




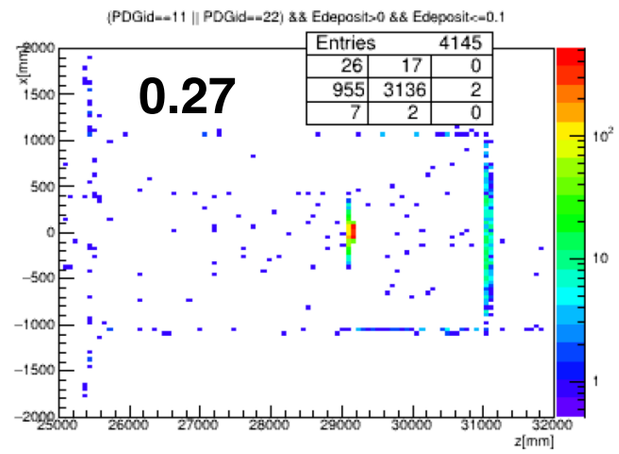


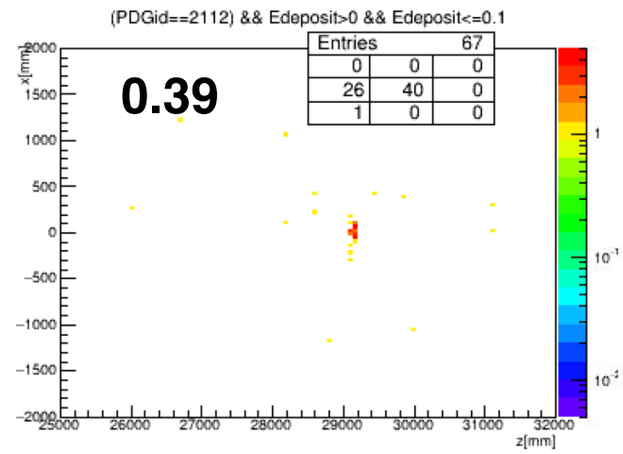


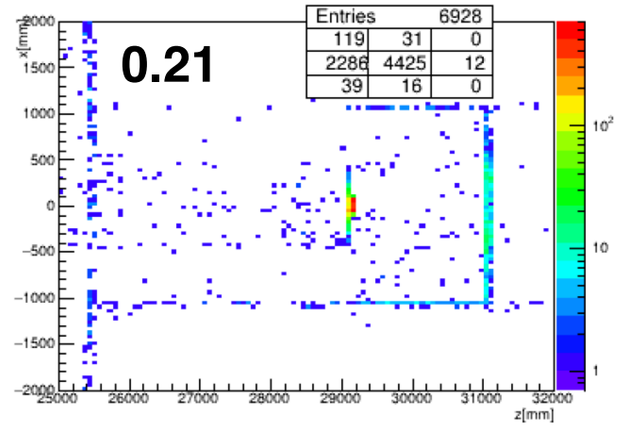


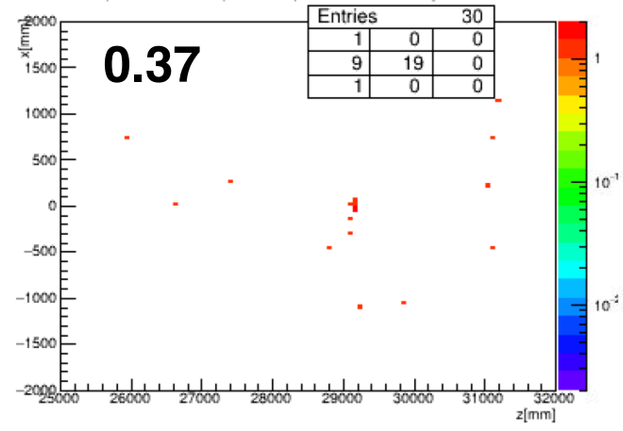


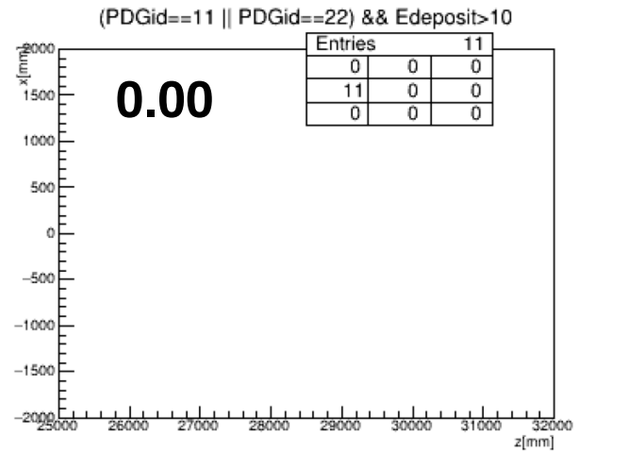
PREX1 dump configuration

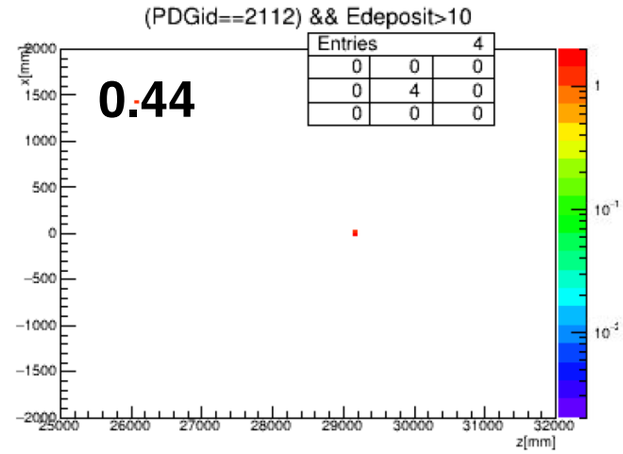






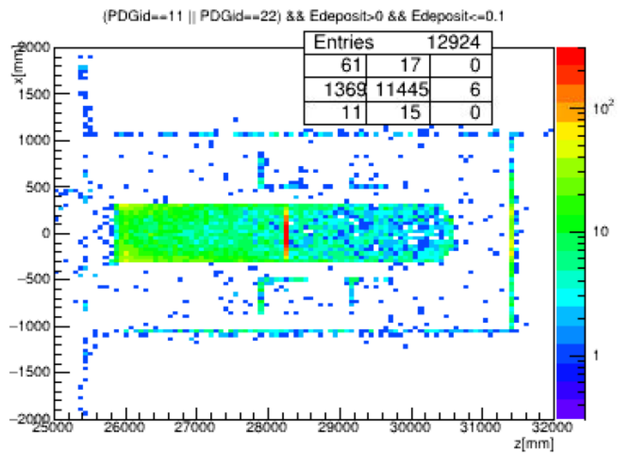


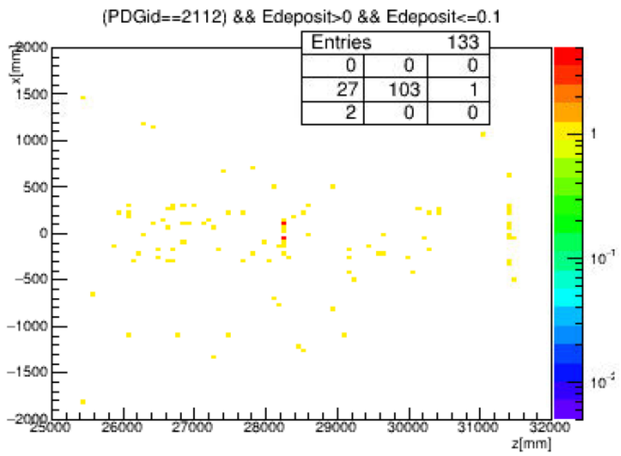


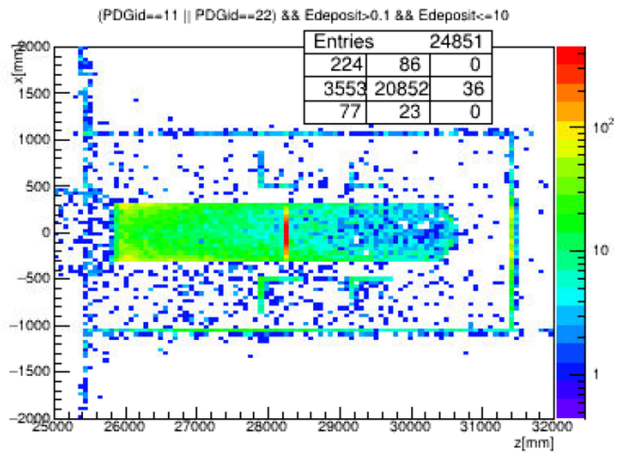


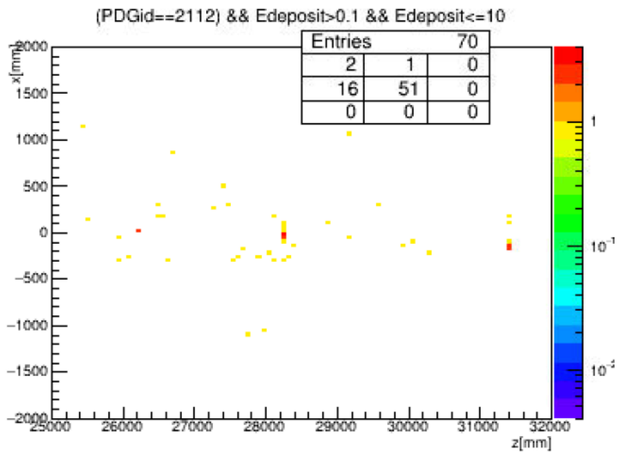
PREX2 - comparison

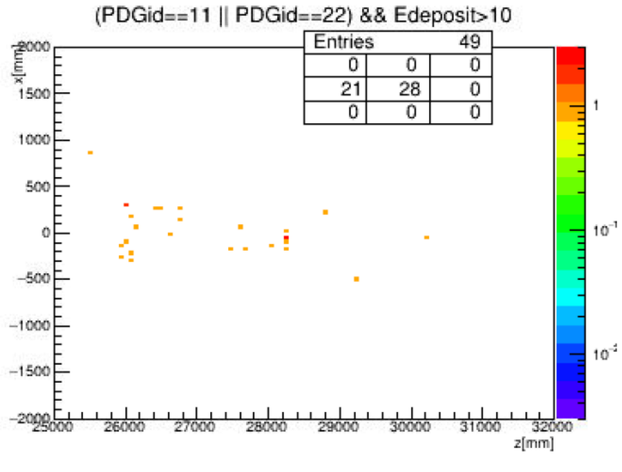
current setup

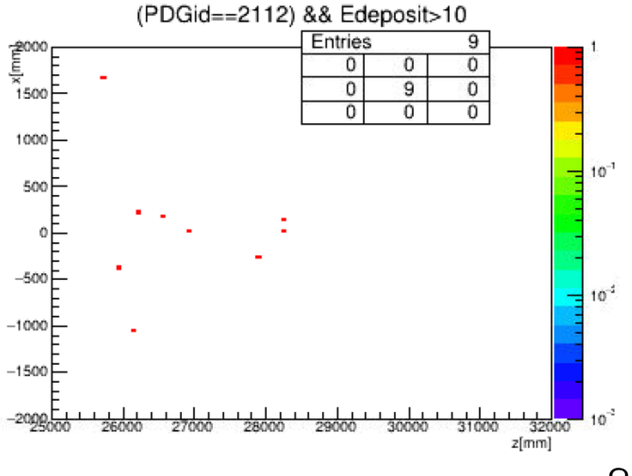




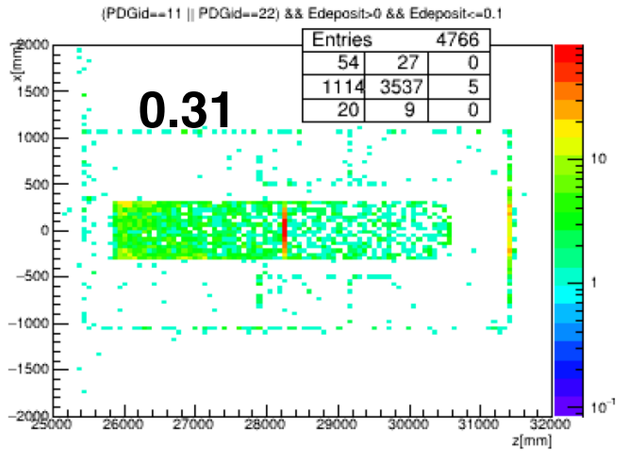


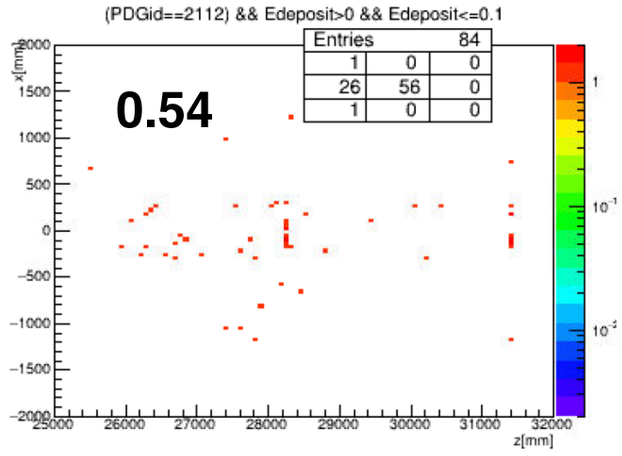


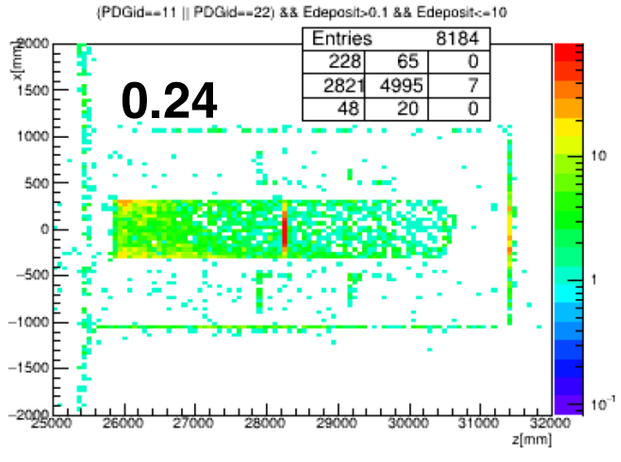


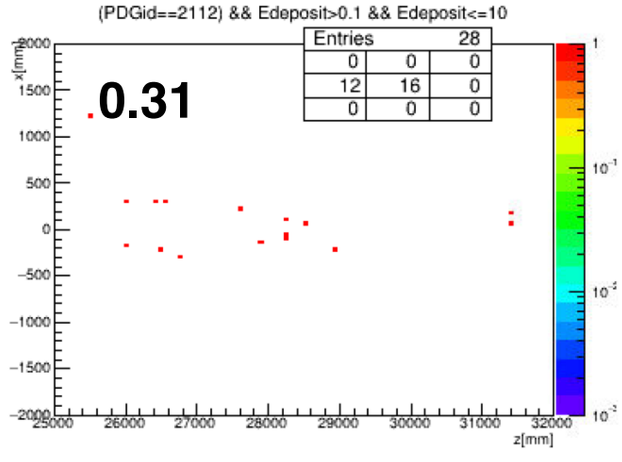


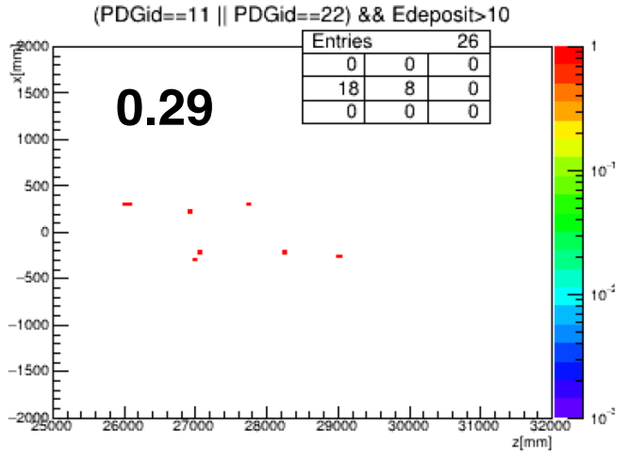
current setup + 1 ft concrete shield

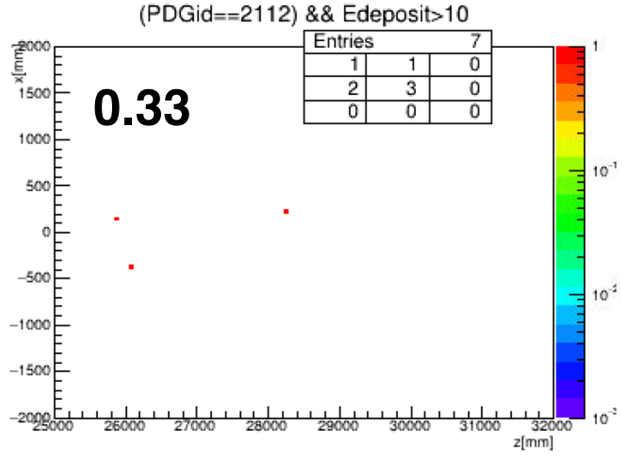






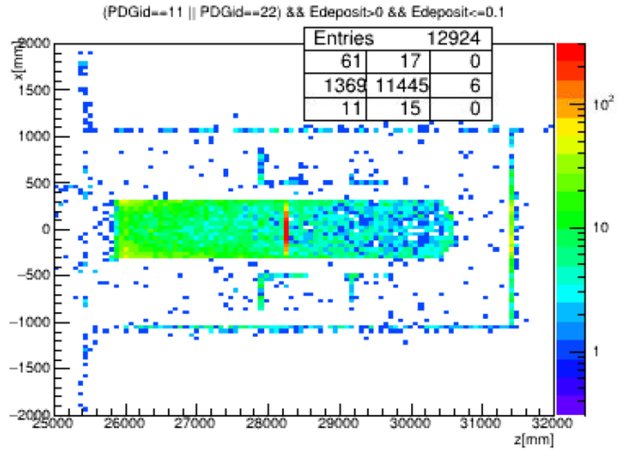


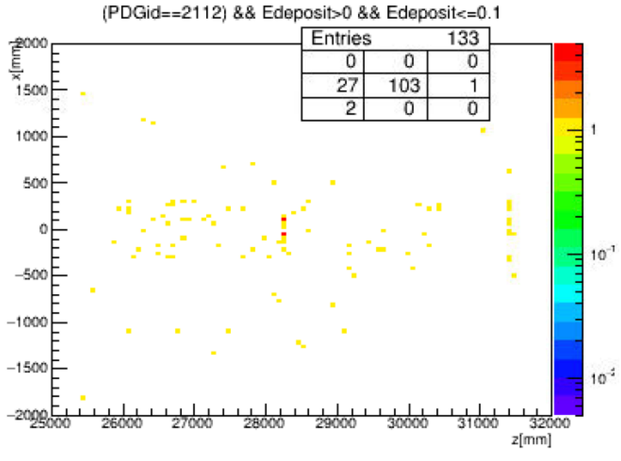


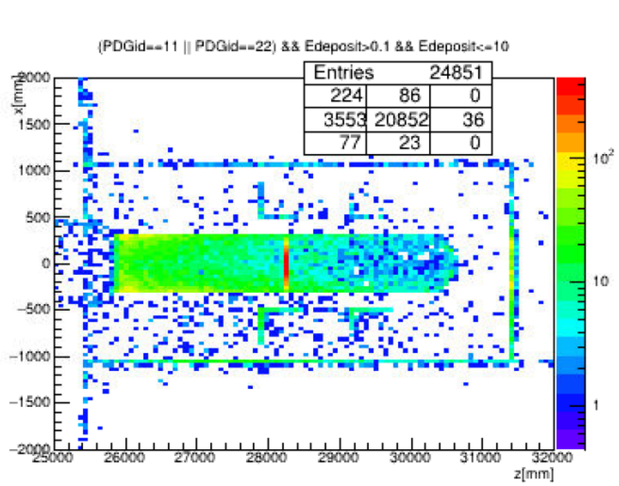


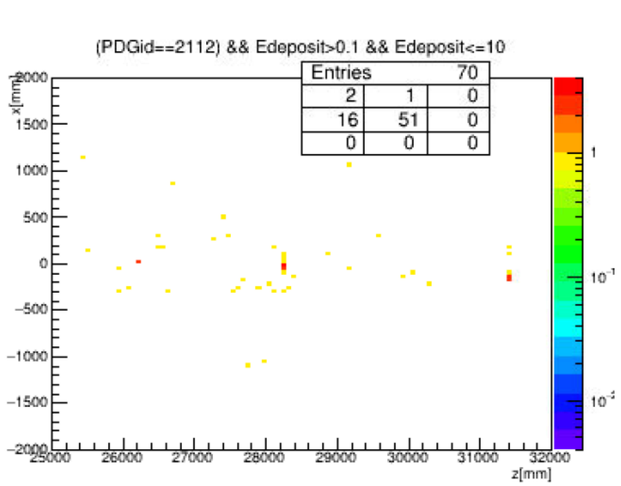
PREX2 - comparison

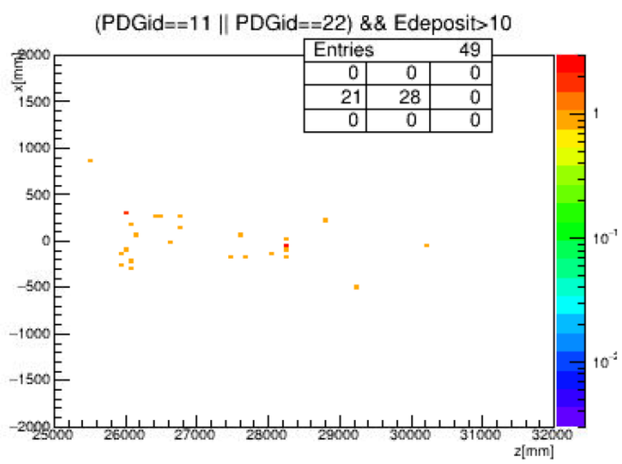
current setup

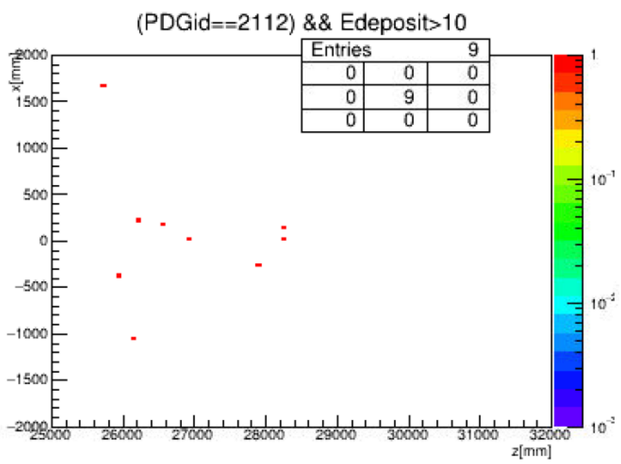




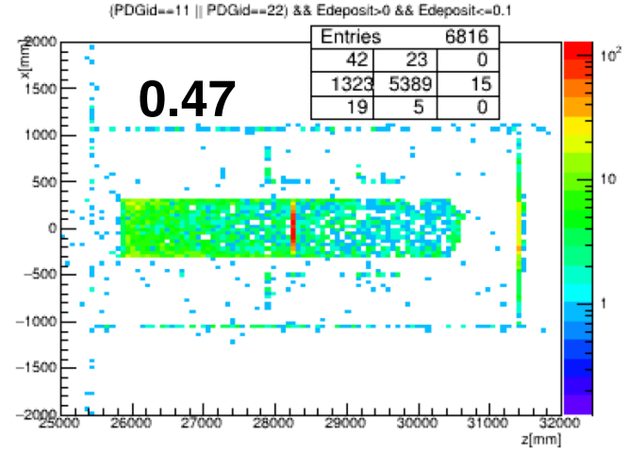


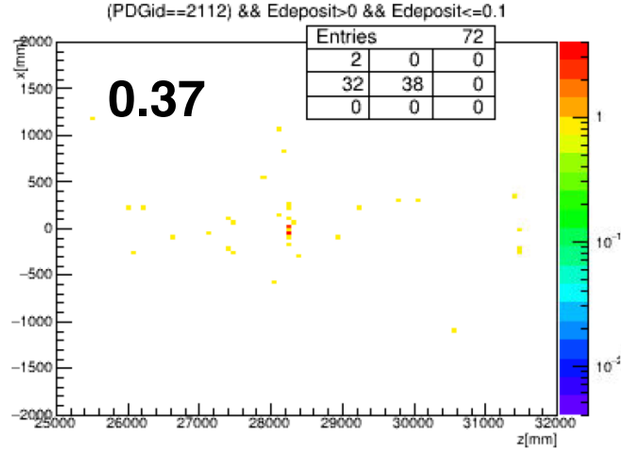


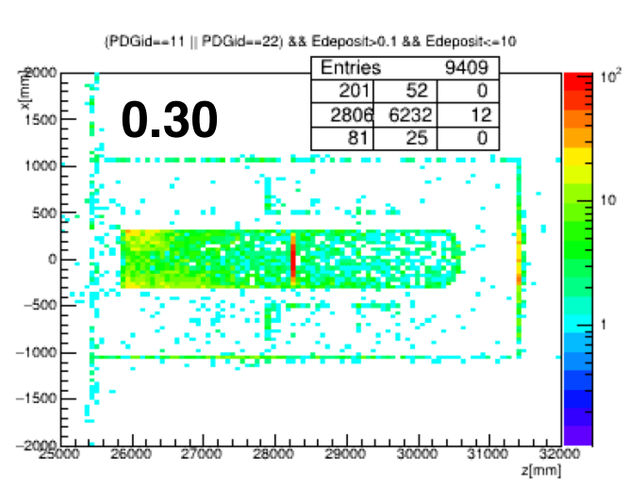


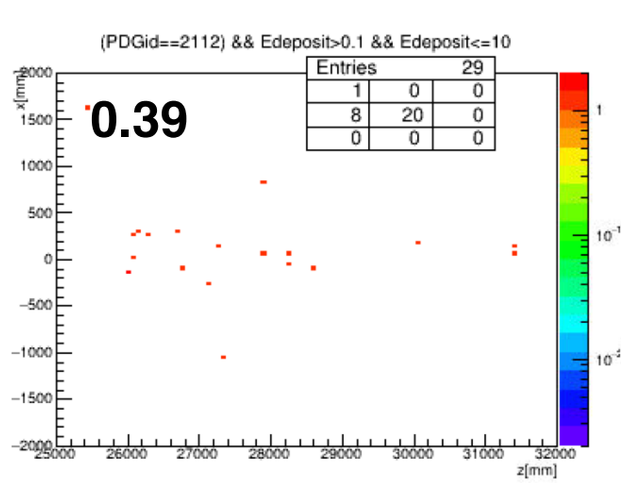


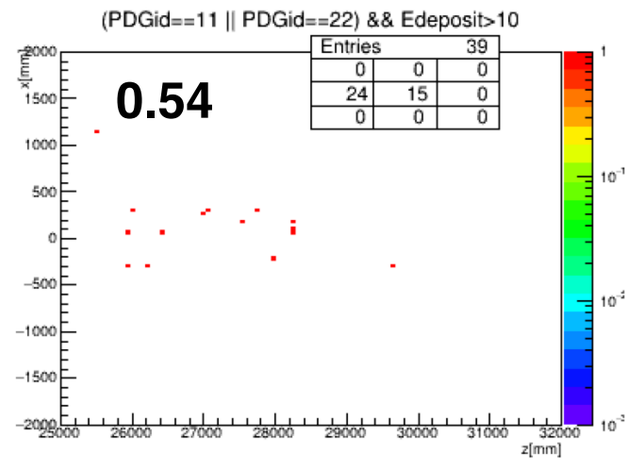
current setup + 1 ft Poly shield

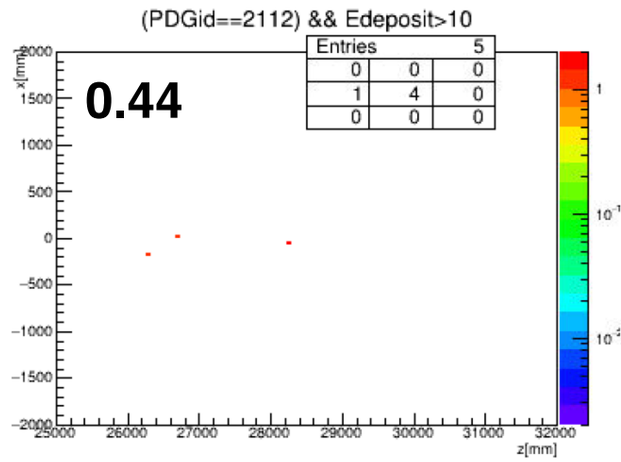






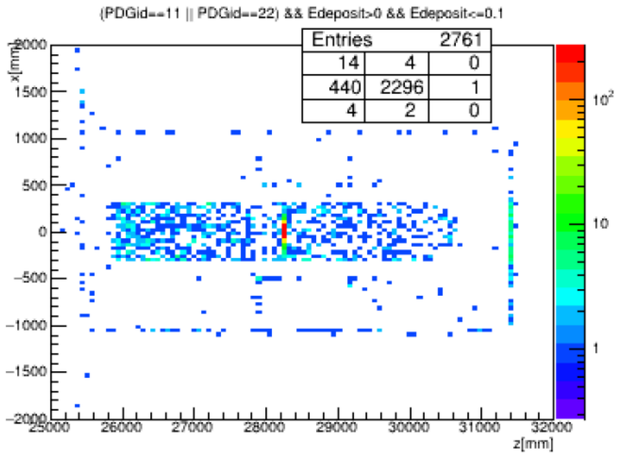


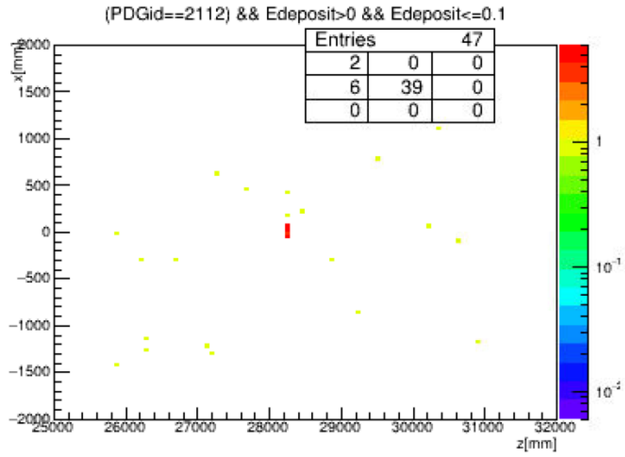


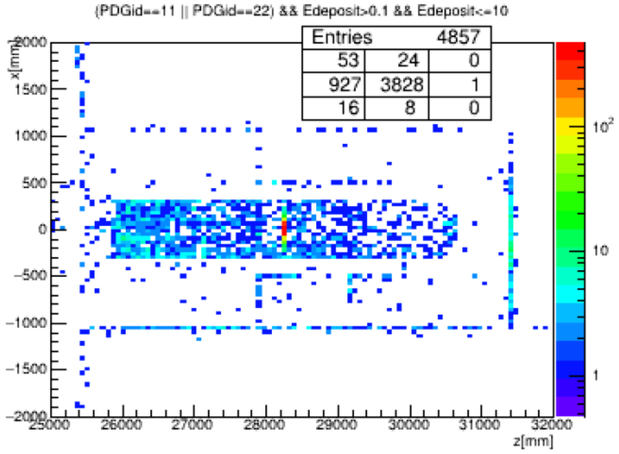


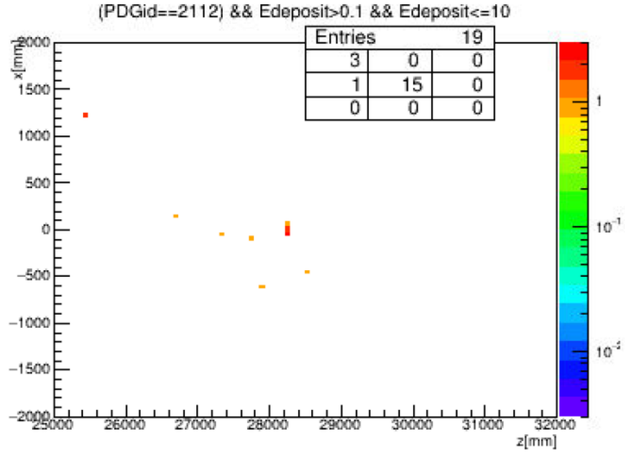
CREX - comparison

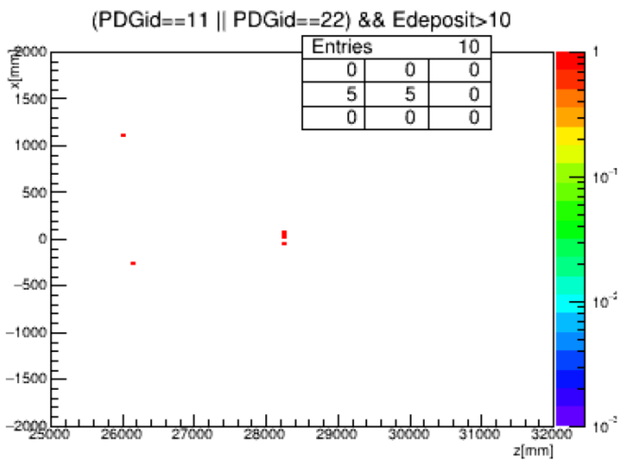
current setup

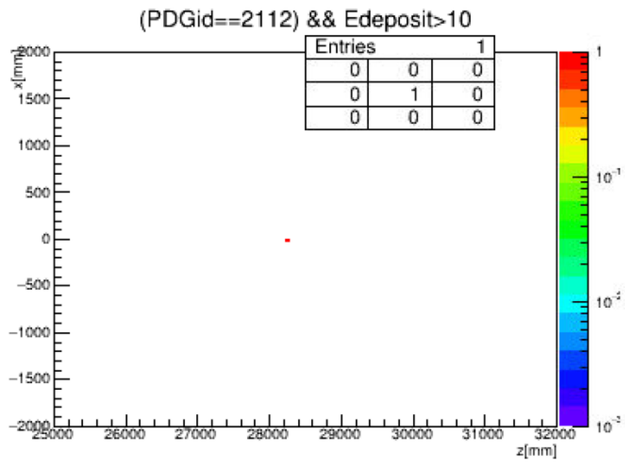




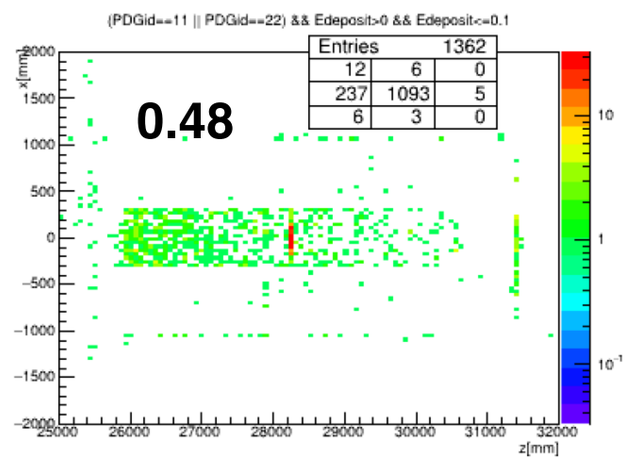


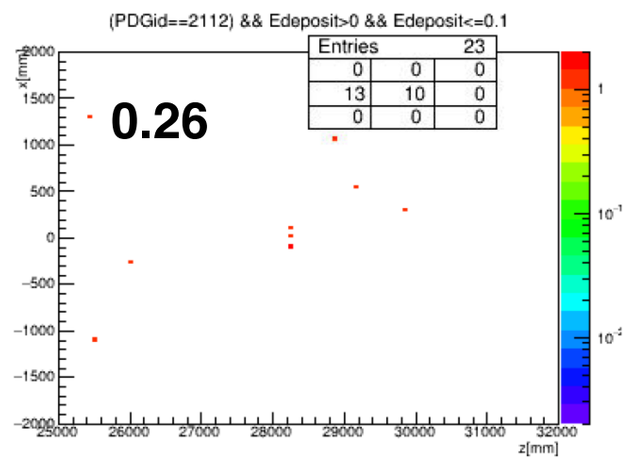


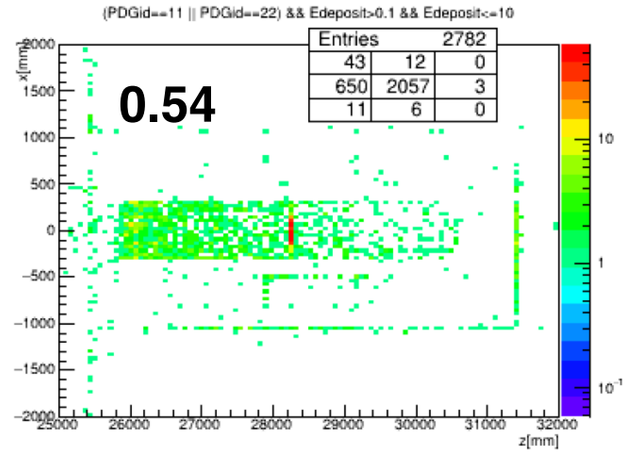


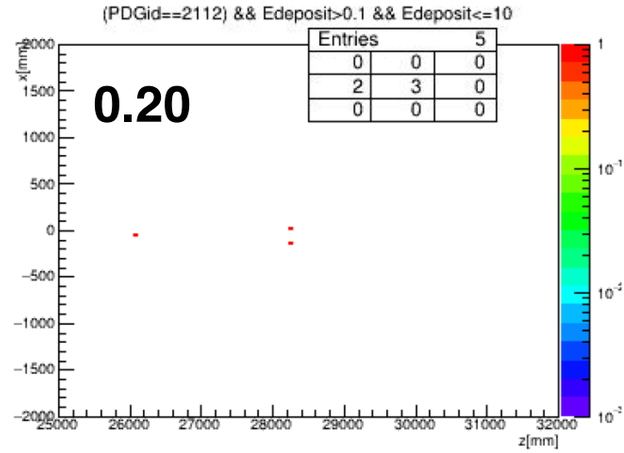


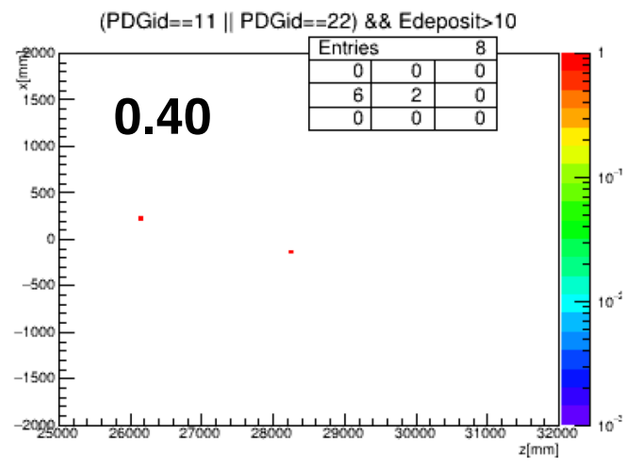
current setup + 4 in donut

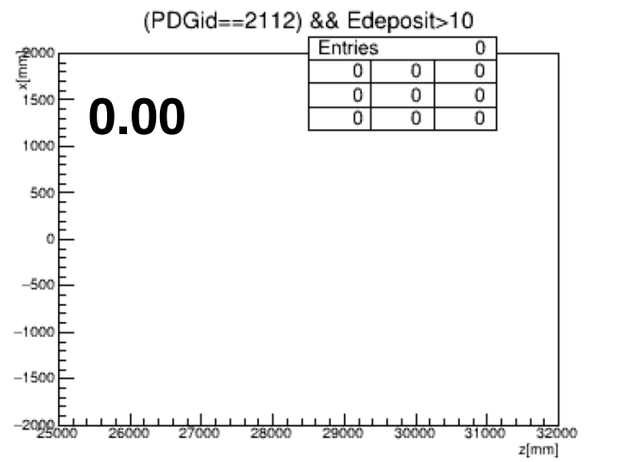






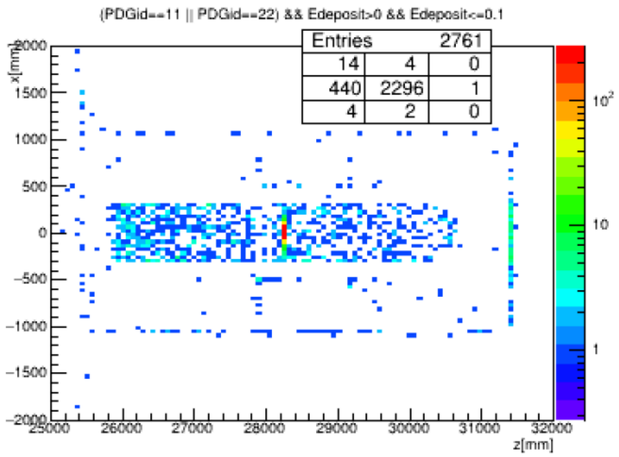


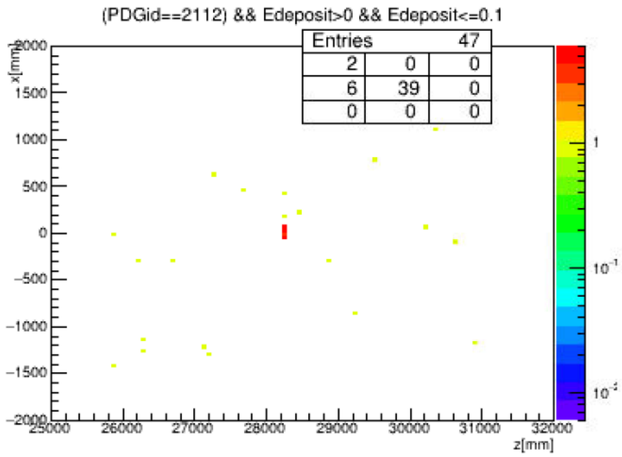


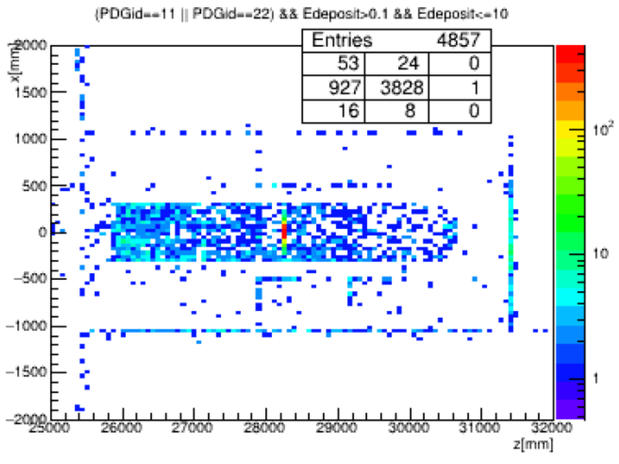


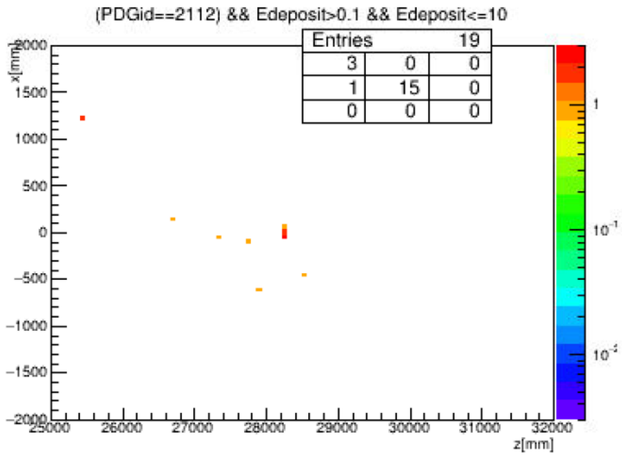
CREX - comparison

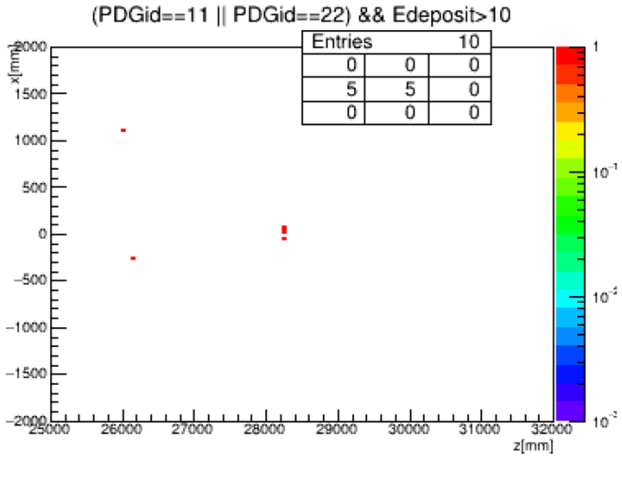
current setup

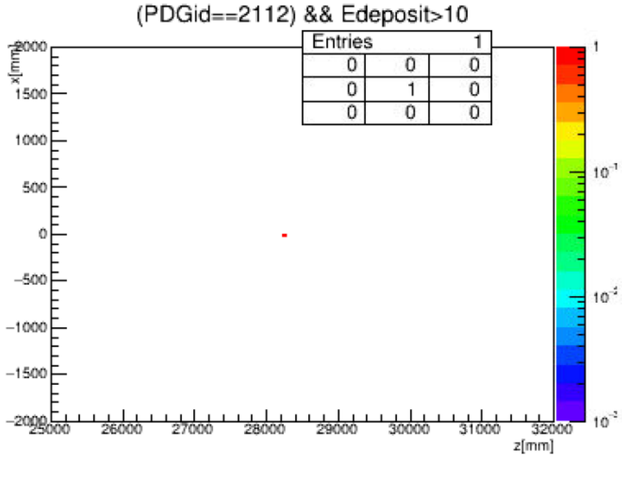




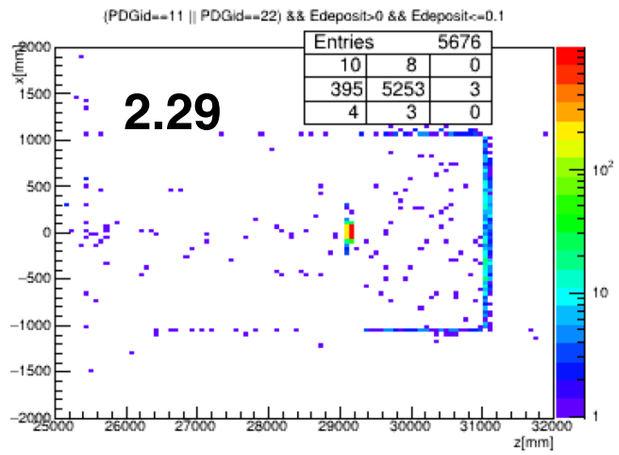


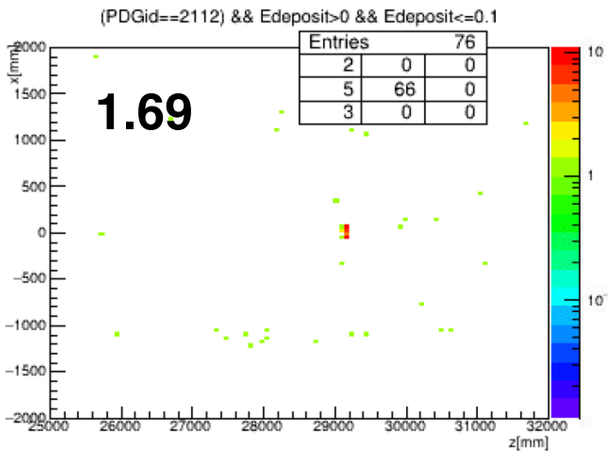


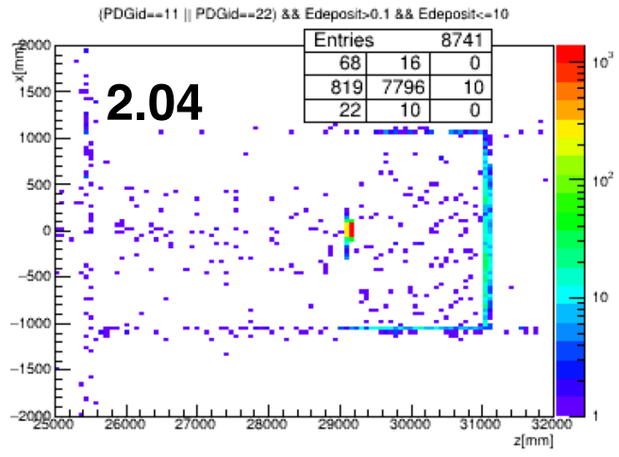


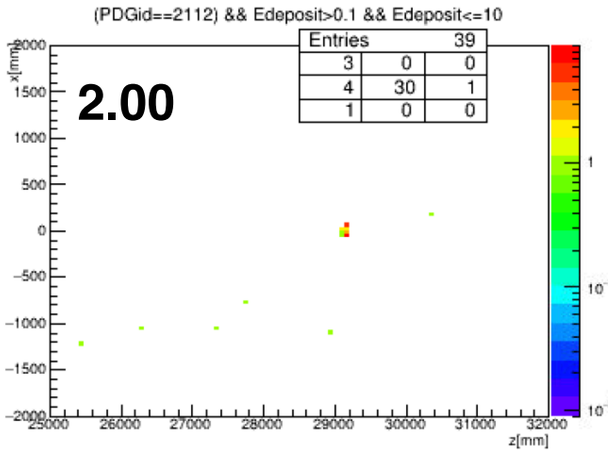


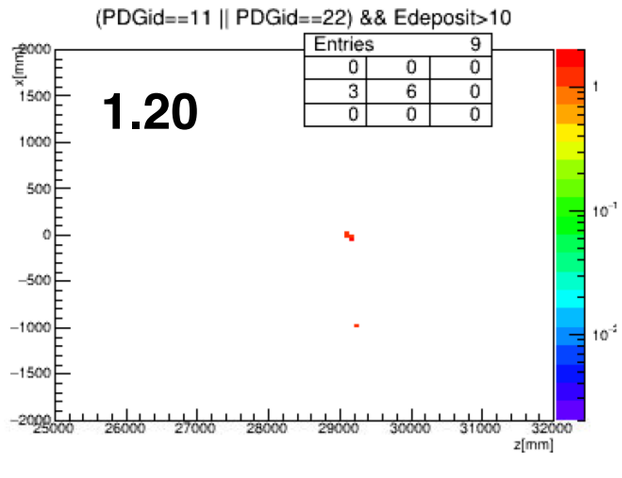
PREX1 dump setup

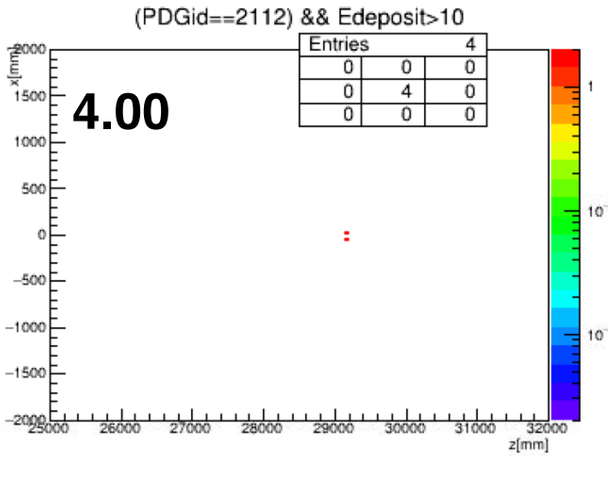






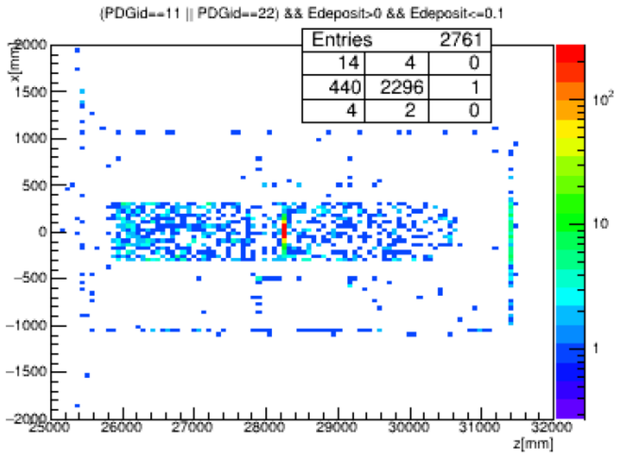


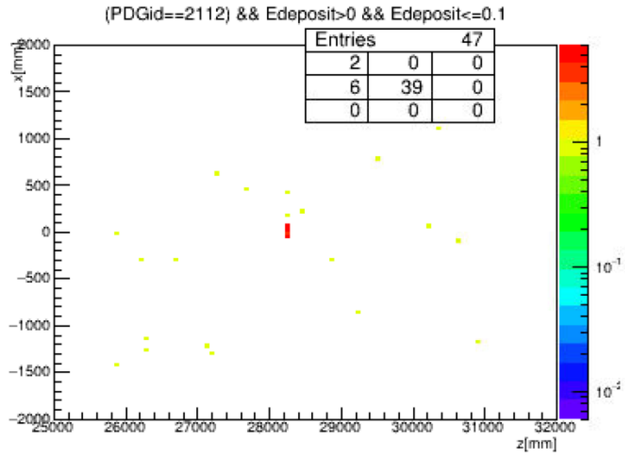


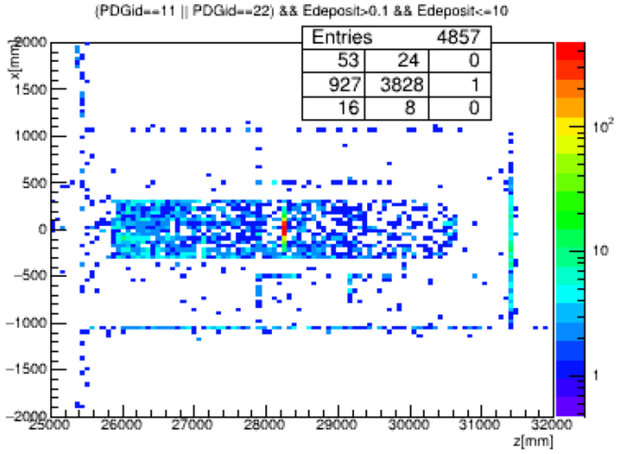


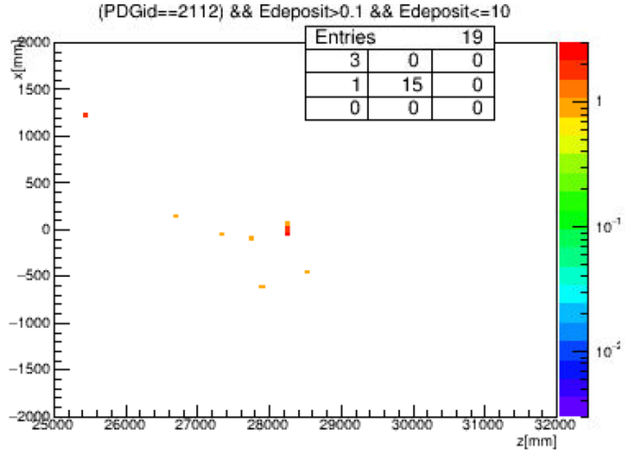
CREX - comparison

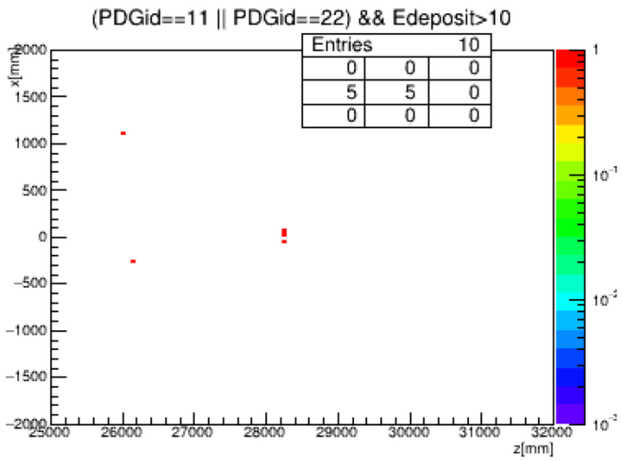
current setup

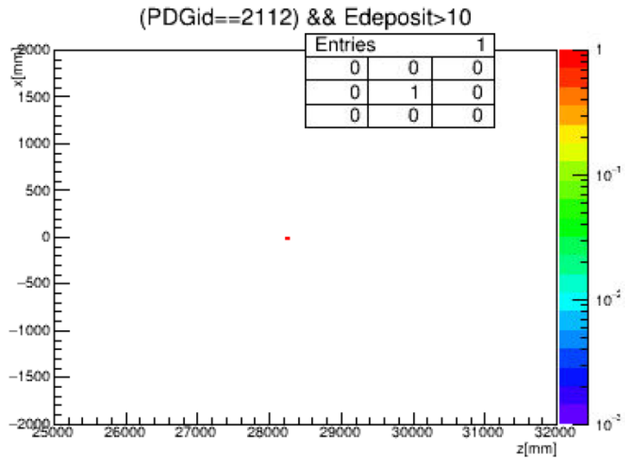




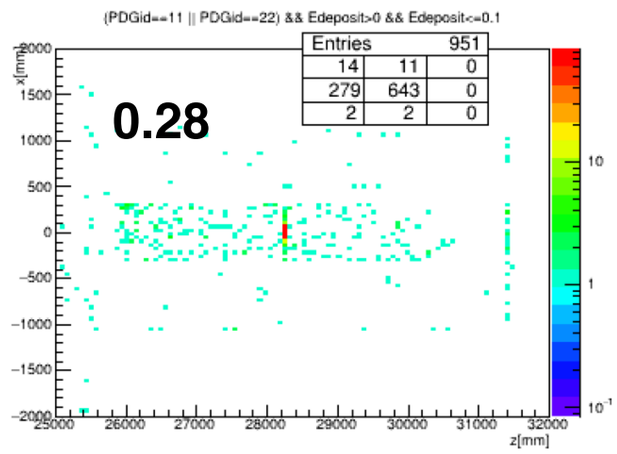


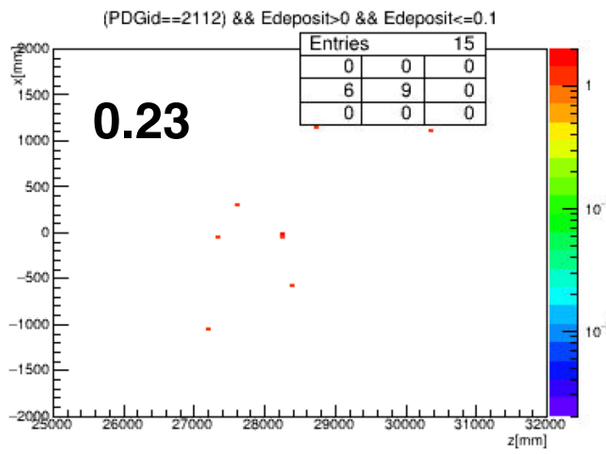


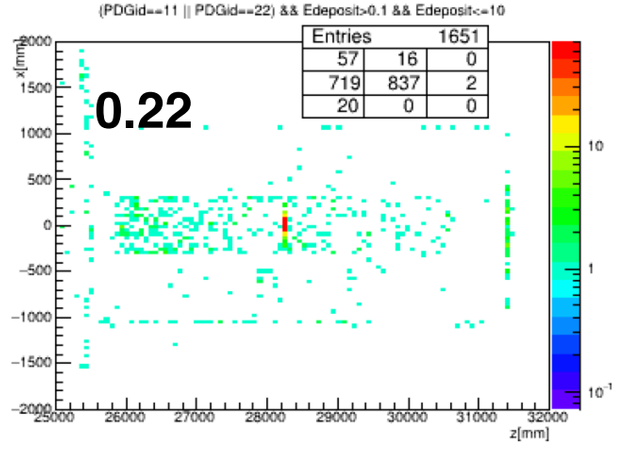


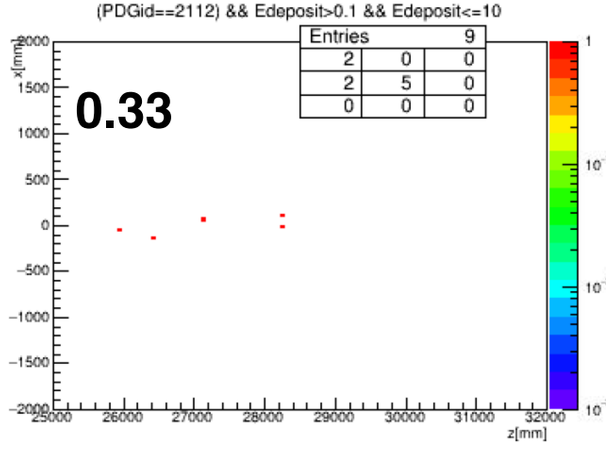


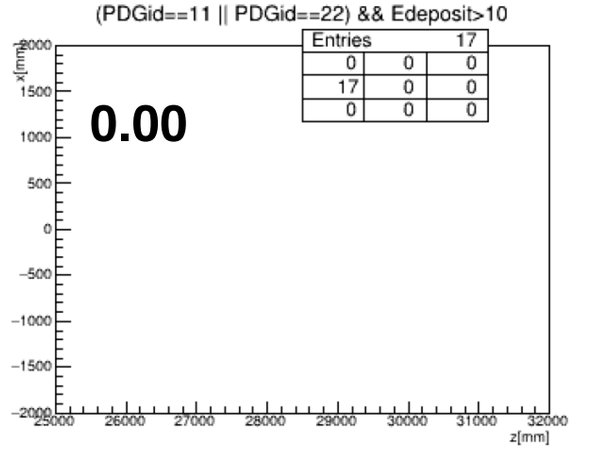
current setup + 1 ft concrete shield

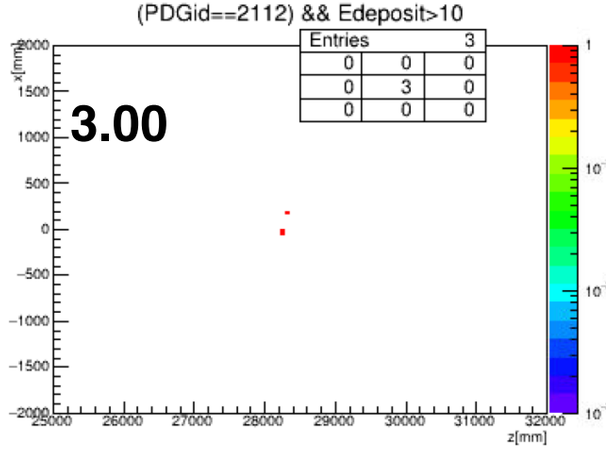






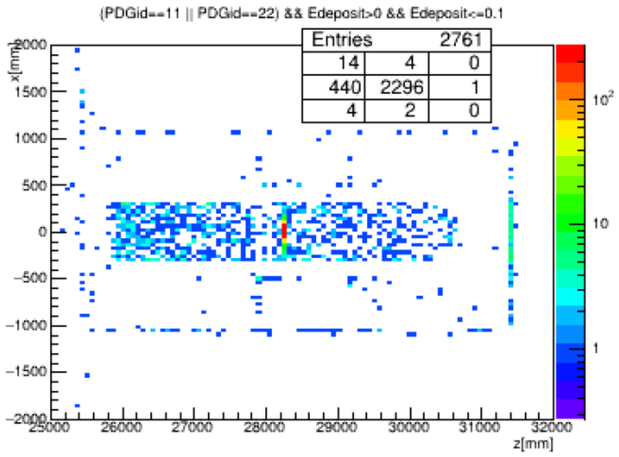


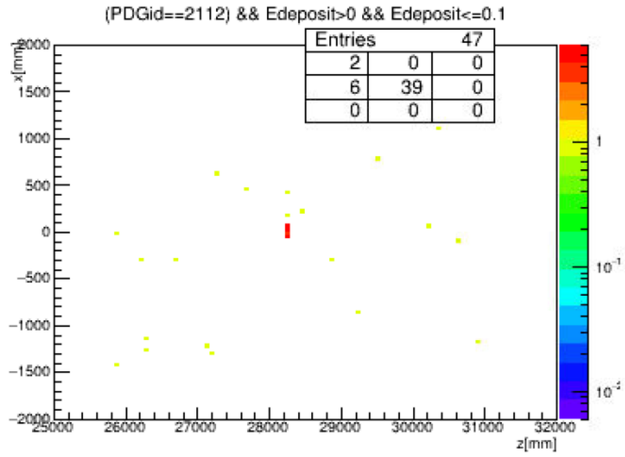


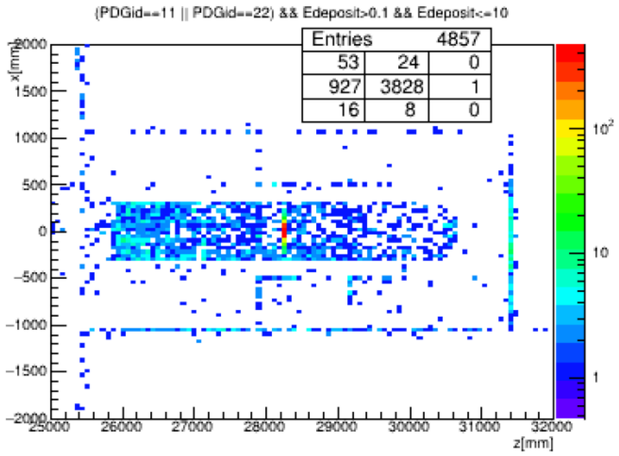


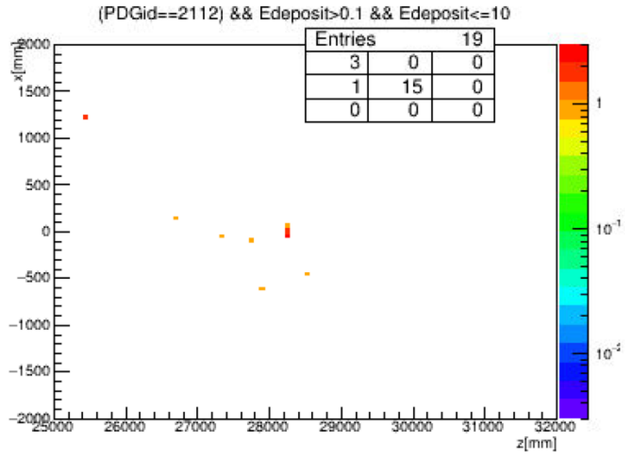
CREX - comparison

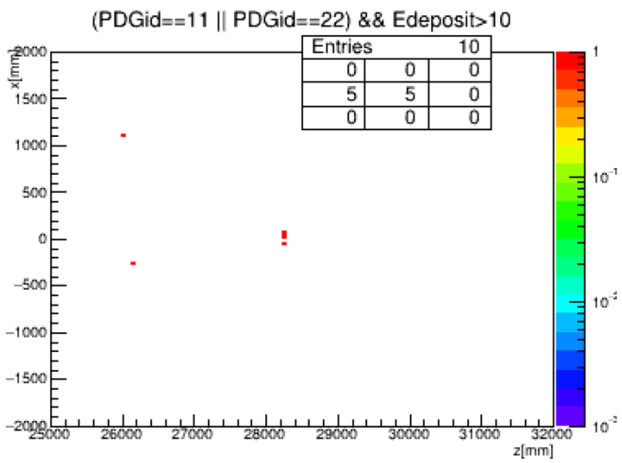
current setup

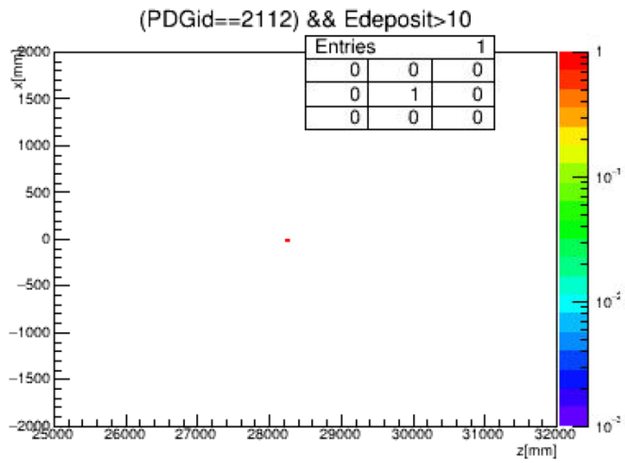
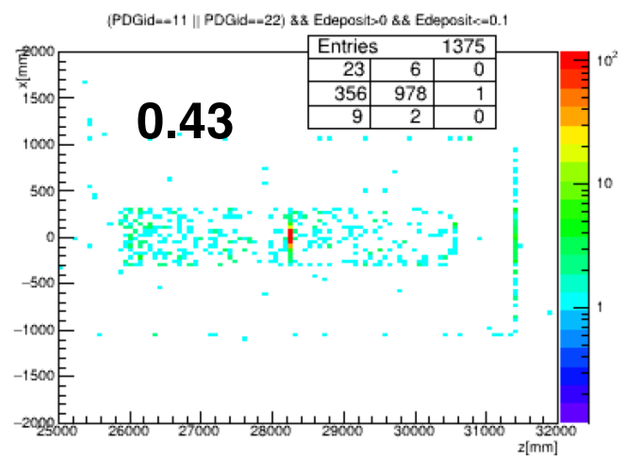
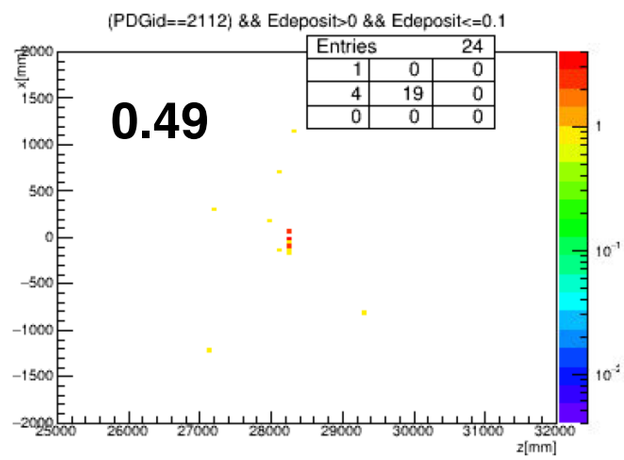
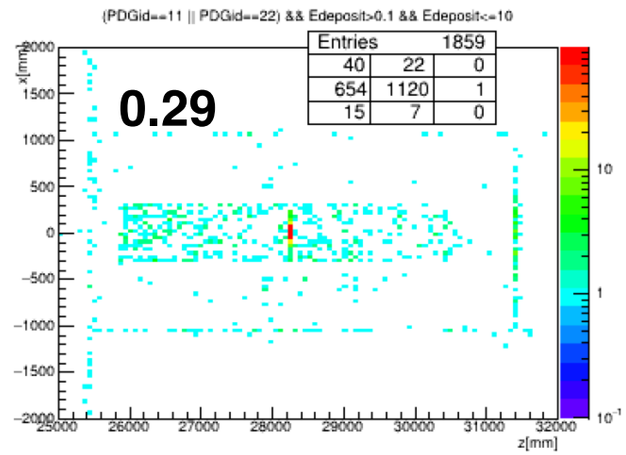
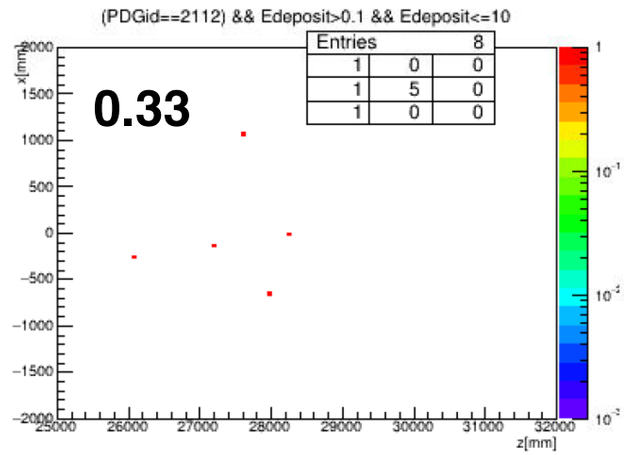
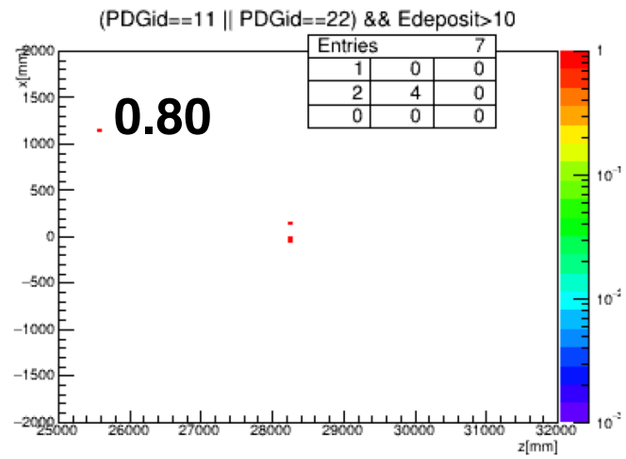
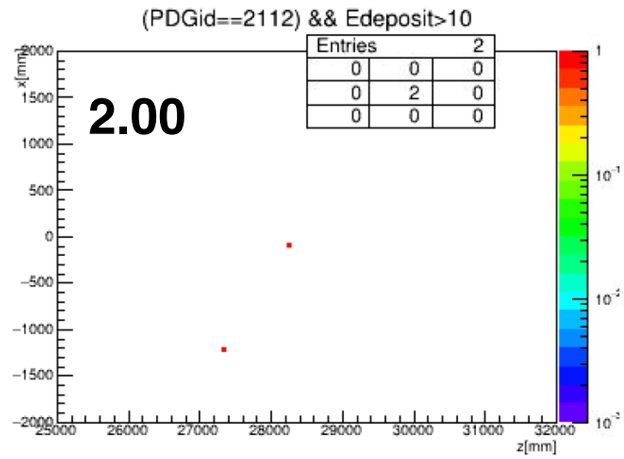












current setup + 1 ft Poly shield