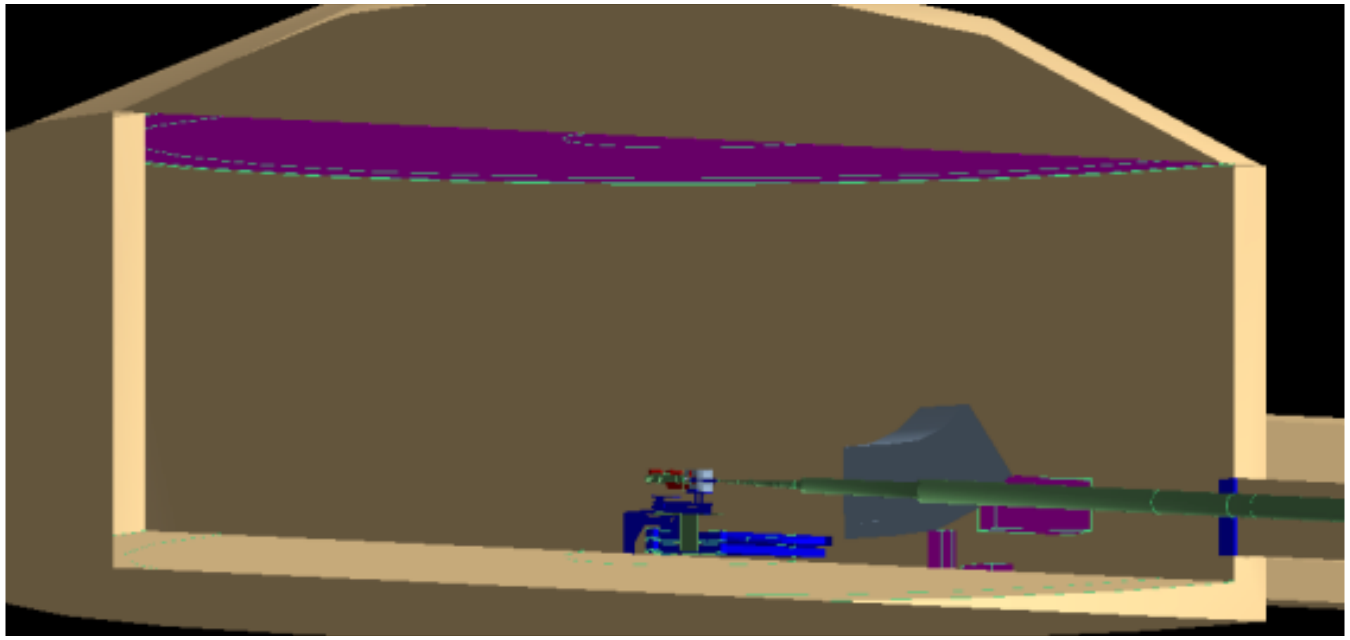
PREX Dump configuration

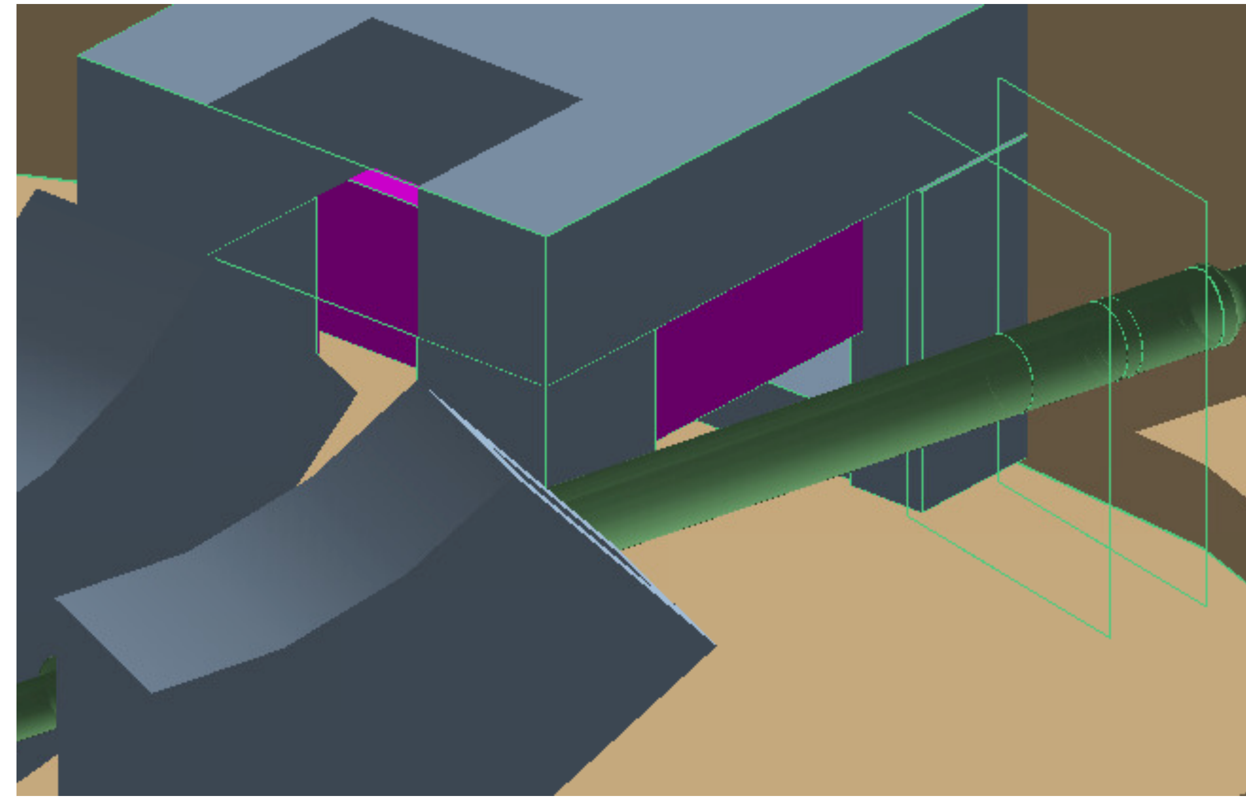
Ciprian Gal
UVa

Simulation updates

ERR



Update

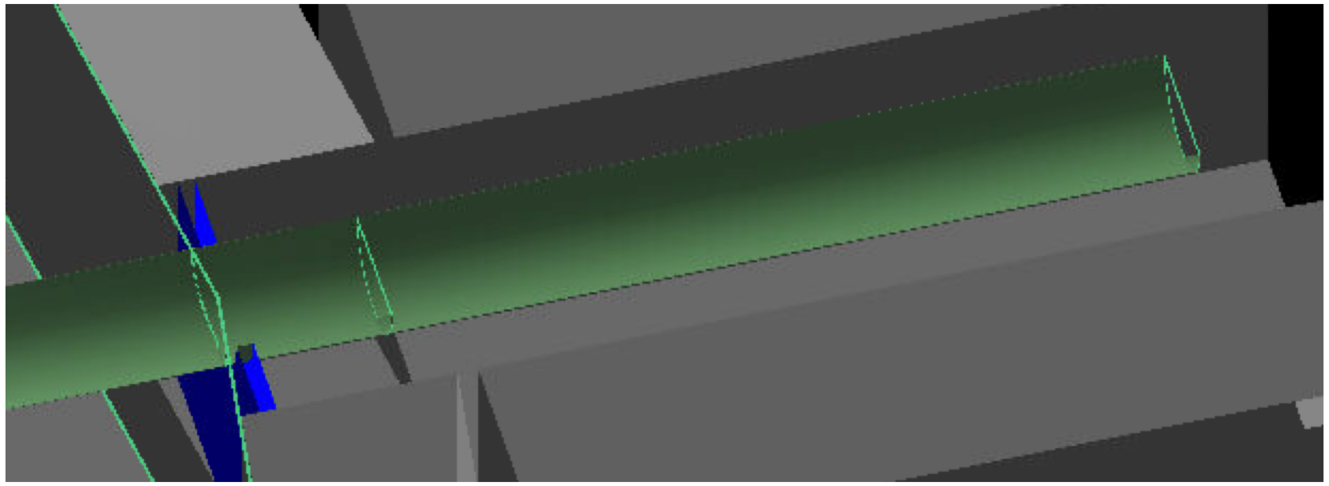


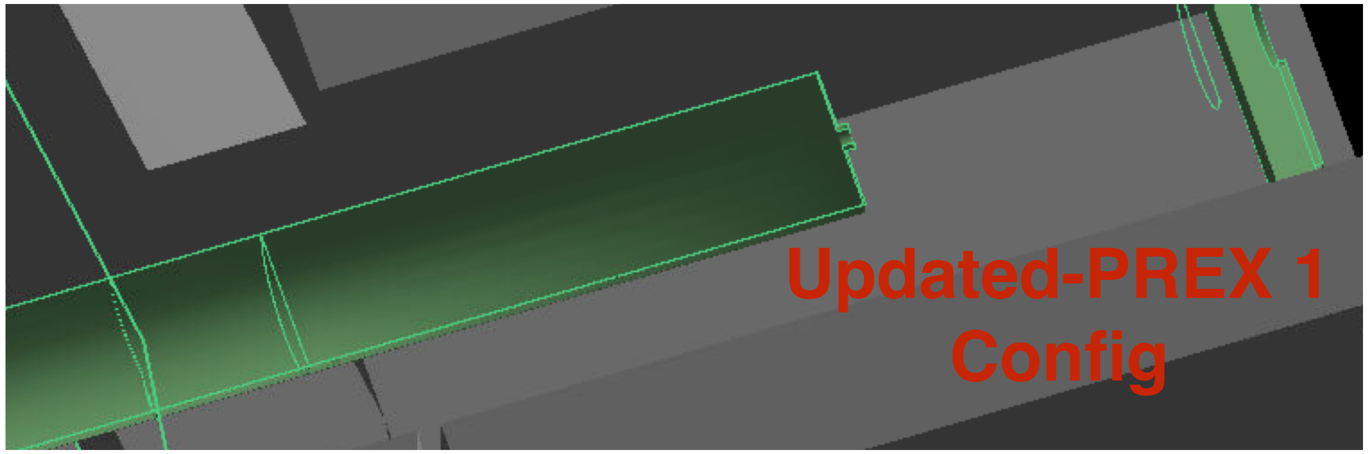
- Since ERR simulation geometry updated:
  - increased the size of the hall to ~26 m (from 25 m) — no visible effect on radiation calculations results
  - use APEX HRS platform geometry to add detail; in particular the legs around the HRS platform electronics
  - measured area where electronics could be placed and placed sensitive detectors to cover the entire area

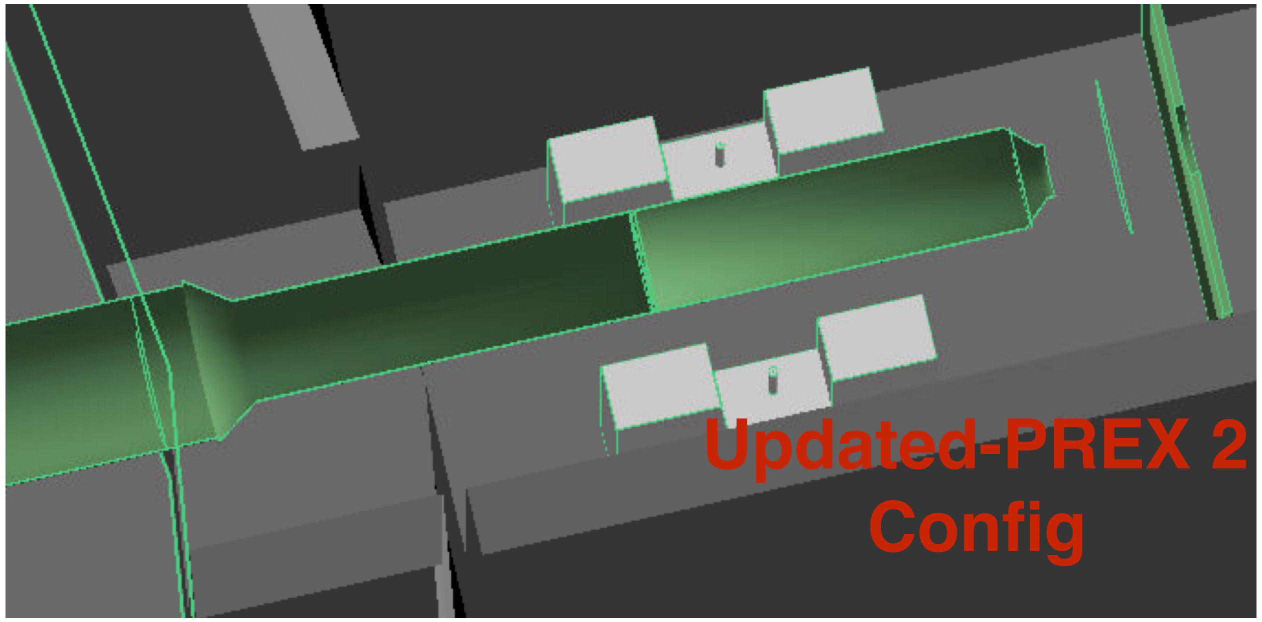
Simulation updates

ERR

Update

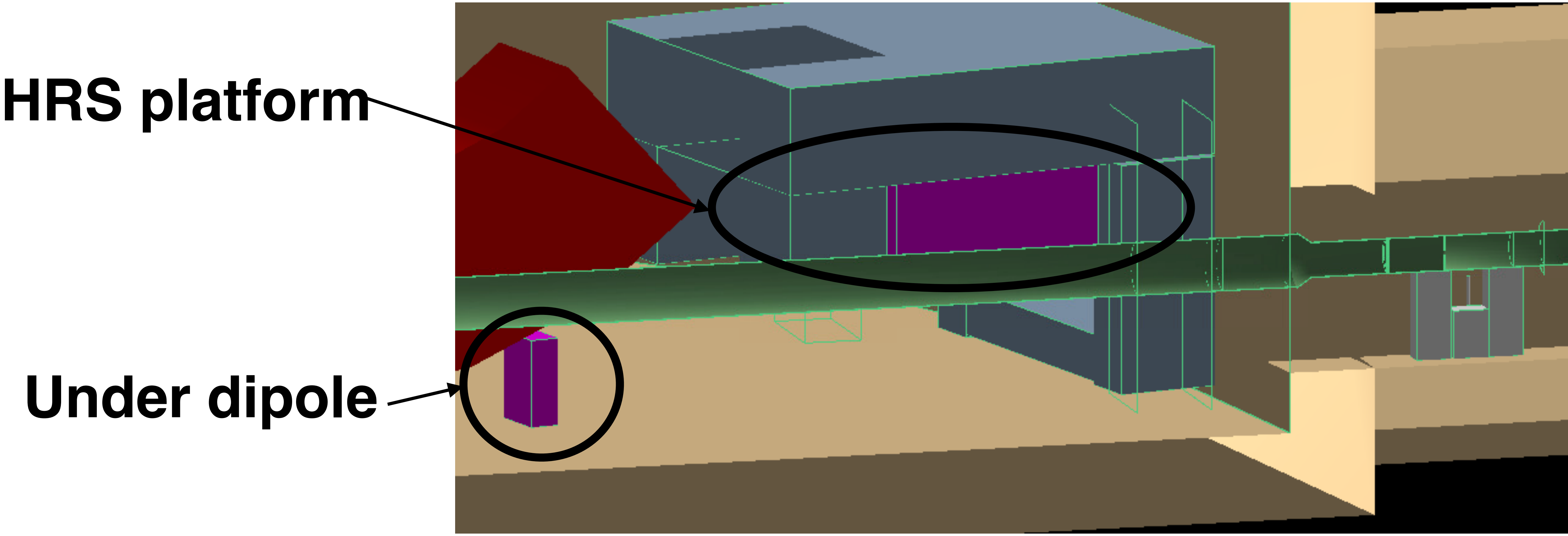






- Dump configuration for ERR:
  - for the ERR we had a thick stainless steel covering the dump entrance to fake splash back from the dump
  - The beam pipe was also open to the back
- Dump configuration update:
  - updated with configurations consistent with JLab Drawings (obtained from Keith Welch) for both PREX1 and PREX2 including the limiting apertures
  - removed stainless steel wall from front and added aluminum wall separating the He region

Hall radiation (with update)



- Two regions are of interest where we can have softer electronics
- The HRS platform detector covers all possible areas where sensitive electronics could be placed
- The detector under the dipole iron has flow meters that could be affected by radiation

HRS radiation (with update)

HRS	PREX2 ERR	PREX2 Update	CREX5 ERR	CREX5 Update
HRS rad [NEIL/cm2] (% of PREX1)	4.1E+09 (9)	3.1E+10 (99)	7.4E+09 (16)	2.7E+10 (89)

The updated dump configuration brings the integrated radiation to the HRS platform to be level of PREX1 for the combined PREX2 and CREX run.

- The variable of interest is NEIL (which gives a higher importance to neutrons, as compared to EM radiation)
- Performed two PREX1 estimates: a) one with the old configuration to compare to the ERR results b) with the new configuration to compare to the current configurations
- Comparisons with the open detector put PREX2 and CREX each at the level of PREX1 radiation

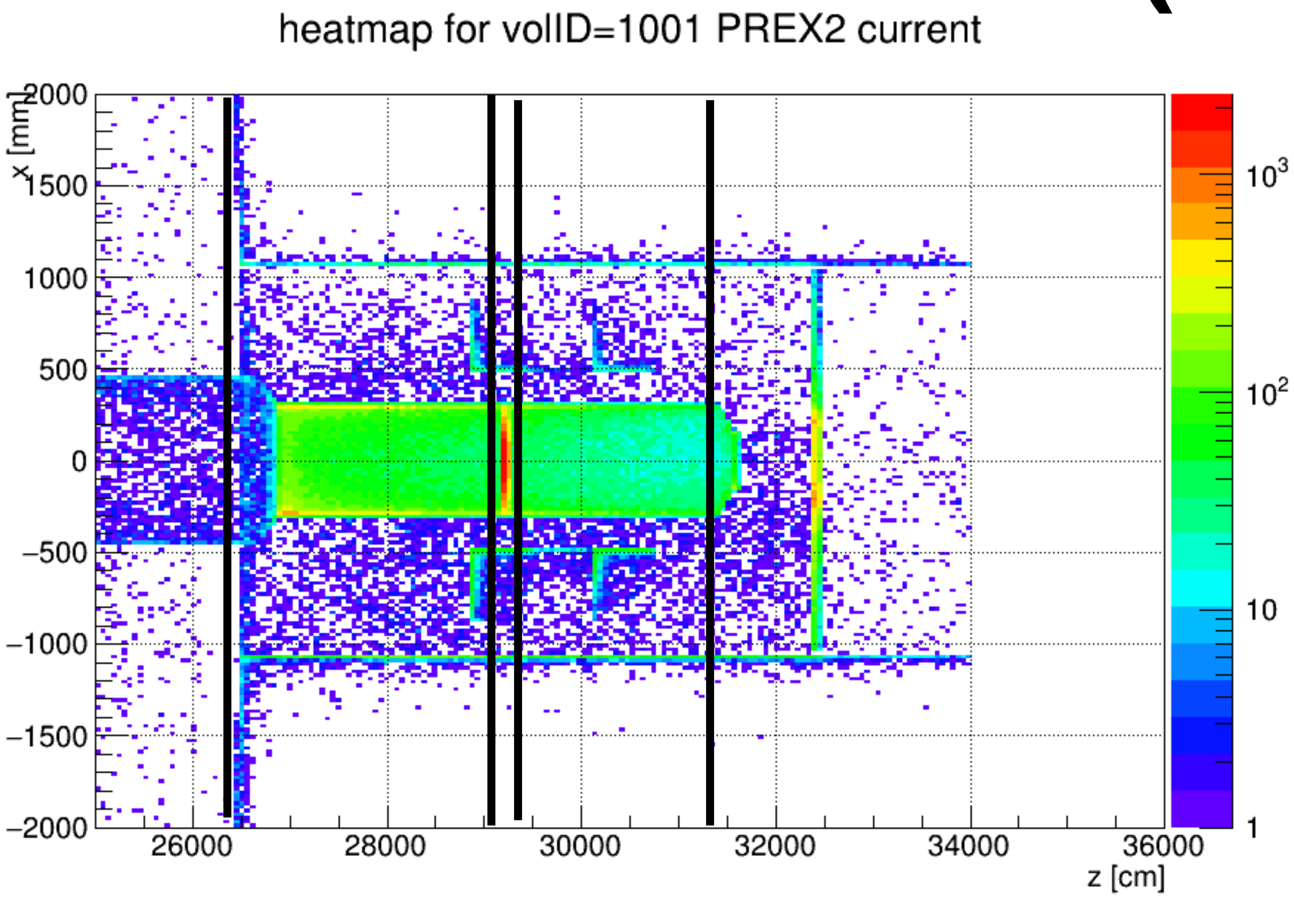
HRS radiation (with update)

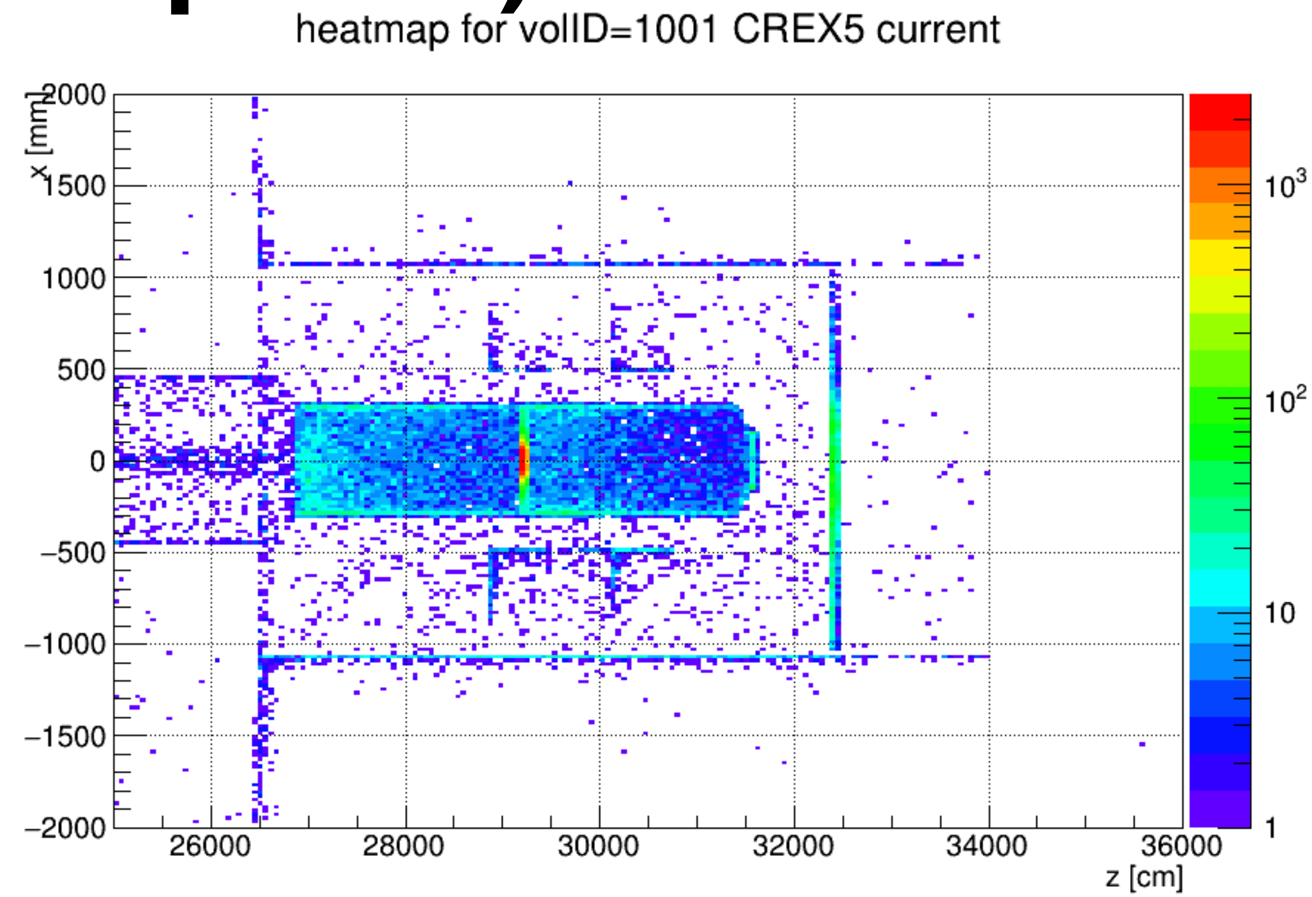
HRS	PREX2 Update	CREX5 Update
HRS rad [NEIL/cm2] (% of PREX1)	3.1E+10 (99)	2.7E+10 (89)
Precent coming from hall	30	29

HRS	PREX2 Update	CREX5 Update
HRS rad [NEIL/cm2] (% of PREX1)	3.1E+10 (99)	2.7E+10 (89)
HRS rad (EM) %of Total	22	13
HRS rad (N) %of Total	78	87

- With the update we can see that about two thirds of the radiation reaching the HRS platform comes from the dump
  - the ERR evaluation was focused on the high radiation load coming from the hall because we were not aware of changes that were made to the beam pipe (for PREX2 and CREX)
- If we look at the particles that produce the radiation at the HRS platform about 80% is caused by neutrons

HRS radiation (with update) - counts

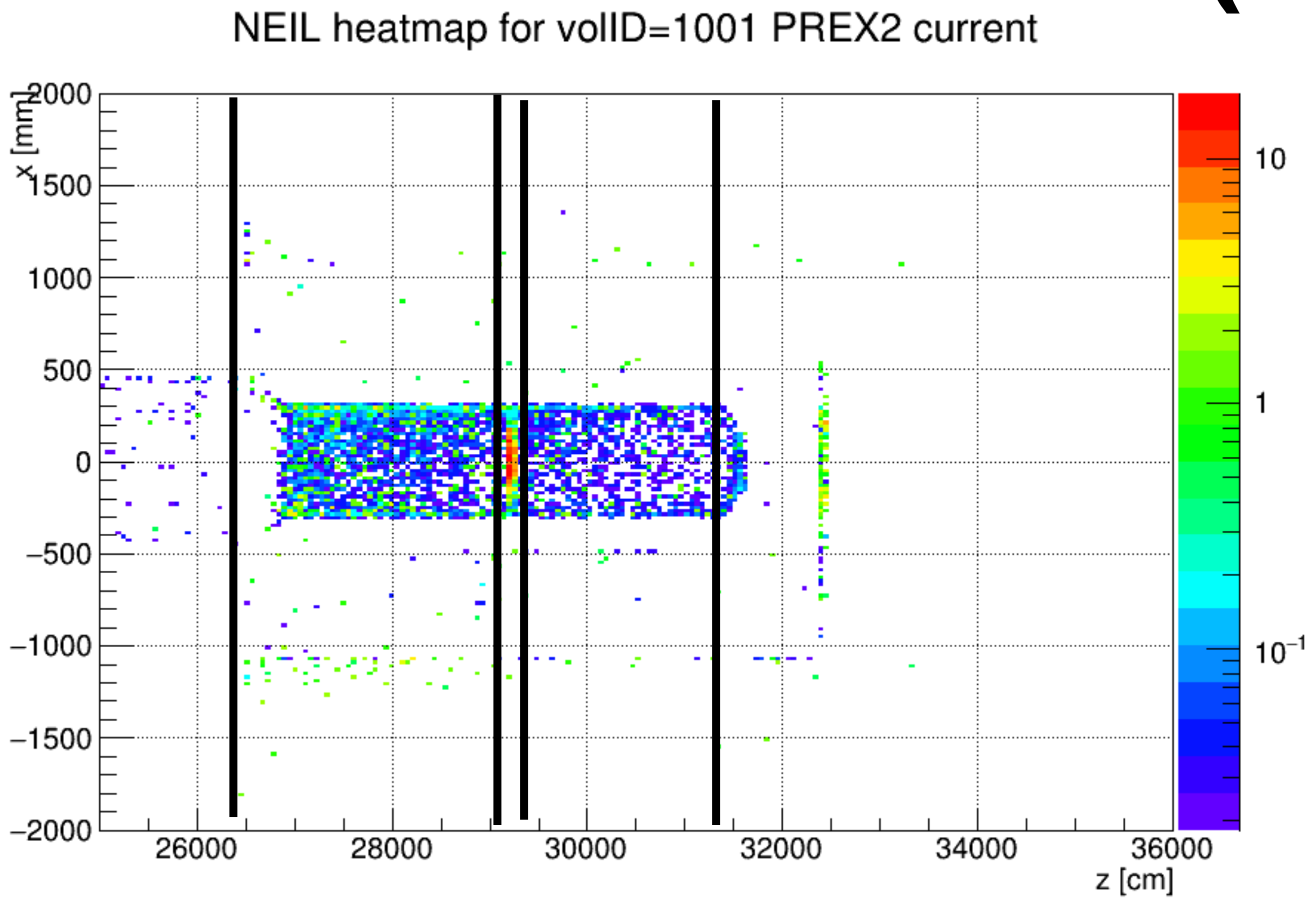


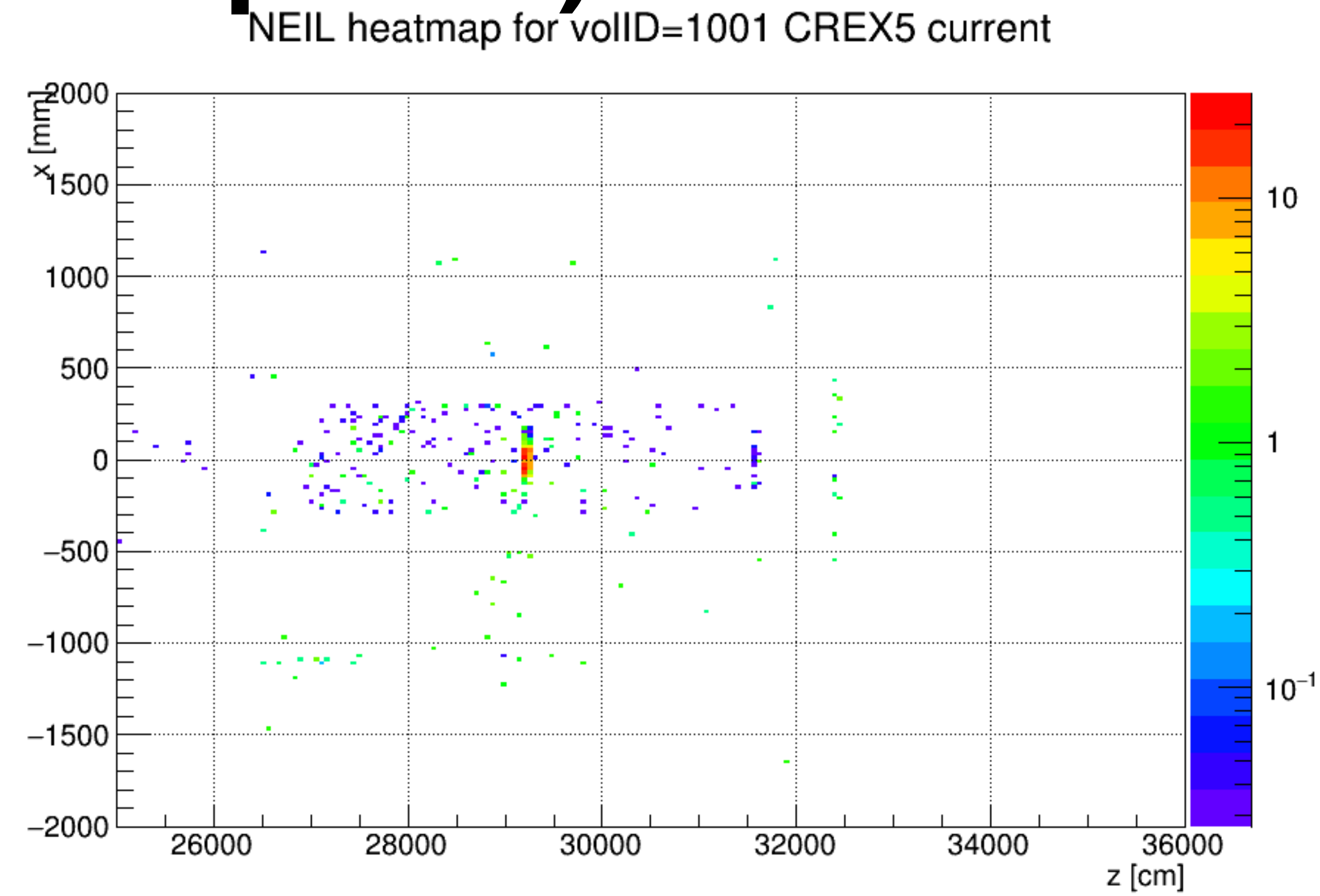


	R1(25 to 26.4)	R2 (26.4 to 29.15)	R3 (29.15 to 29.3)	R4 (29.3 to 31.4)	R5 (31.4 to 36)	Sum
PREX2	2830	126458	54522	53472	35734	273016
CREX	776	12104	25649	8528	5615	52672
PREX2	1%	49%	21%	21%	14%	Ratio
CREX	1%	23%	49%	16%	11%	19%

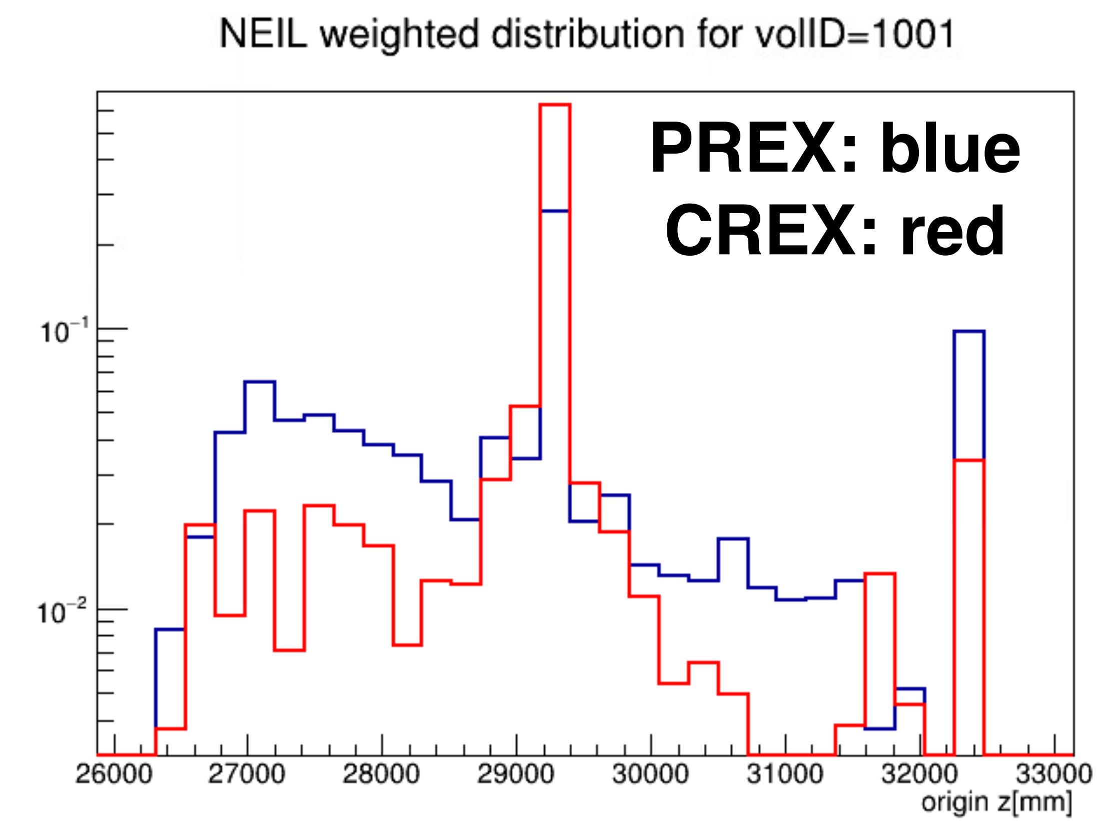
- Total counts for 5e7 electrons on target
- The source counts of (mainly) EM radiation can give us a pretty good estimation of which areas are problematic

HRS radiation (with update) - NEIL





	R1(25 to 26.4)	R2 (26.4 to 29.15)	R3 (29.15 to 29.3)	R4 (29.3 to 31.4)	R5 (31.4 to 36)	Sum
PREX2	13.8906	481.32	272.651	149.928	123.957	1041.7466
CREX	2.83061	78.5768	212.123	27.5833	18.4478	339.56151
PREX2	1%	46%	26%	14%	12%	Ratio
CREX	1%	23%	62%	8%	5%	33%

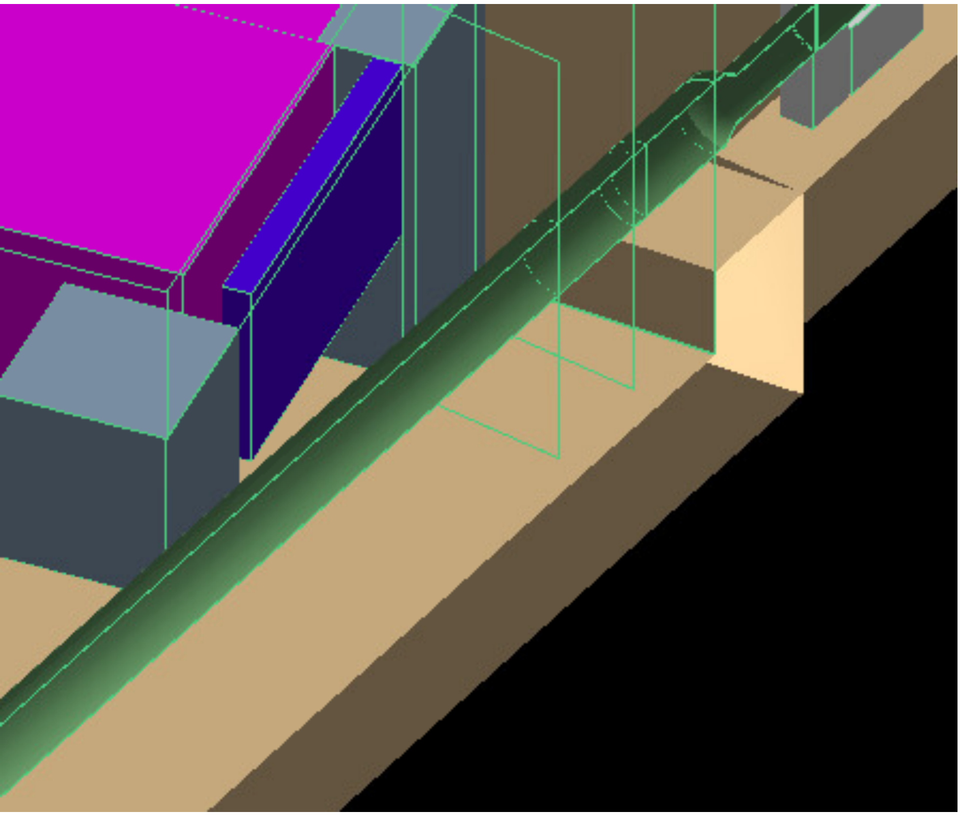


- The conversion to NEIL clarifies the issues we are facing
- While most of the problem for CREX is the donut, for PREX the neck down, the pipe and donut all contribute

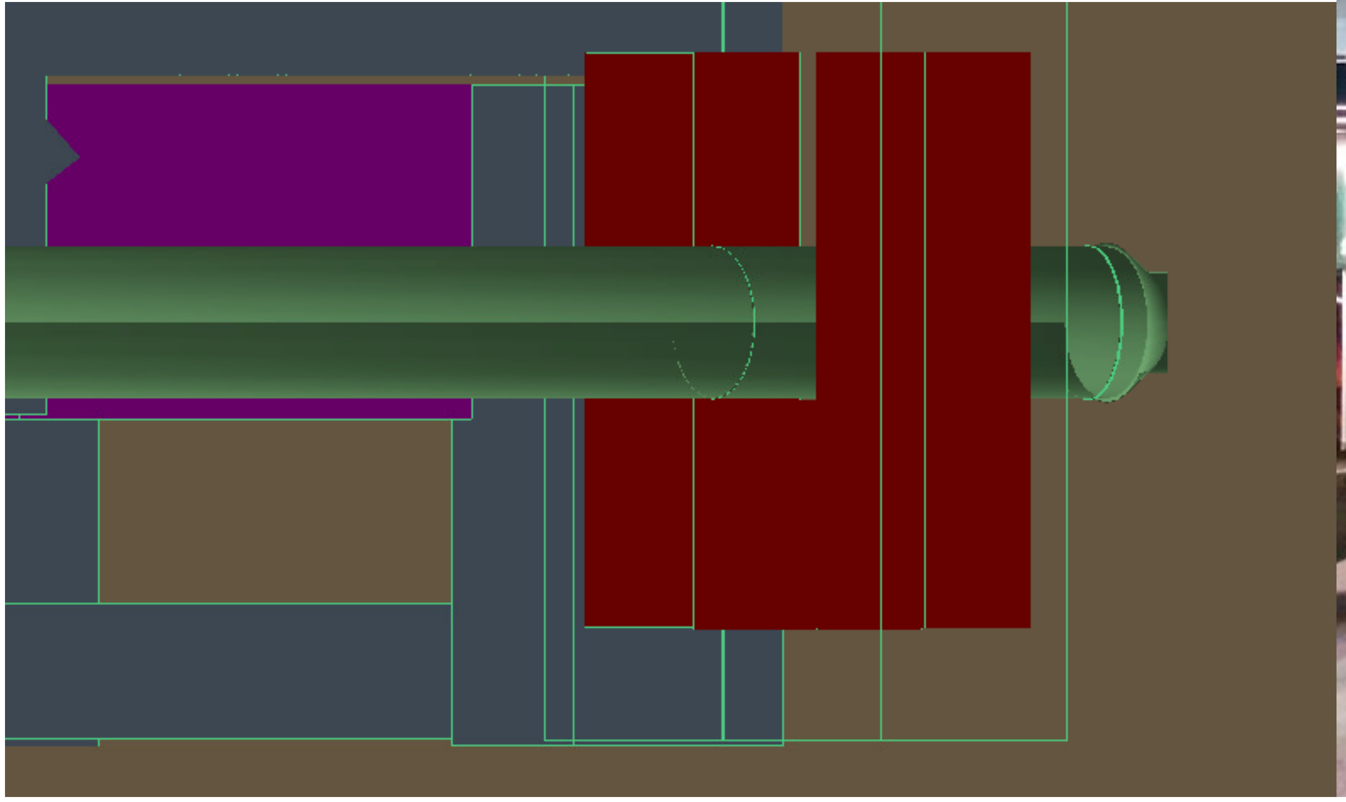
Considered mitigation strategies

- Increasing the size of the donut hole (fixes most of the problems for CREX)
- Replacing the pipe altogether to a PREX1 style pipe and with an end that matches the current connection to the Al wall will fix all issues for both PREX2 and CREX
- Hiding the neck down and/or donut in the shadow of the collimator:
  - to hide the neck down the collimator will have to be able to absorb more than double the power (the donut is more than a factor of 10)
  - the radiation at the HRS platform will increase if we don’t provide additional shielding around the collimator (the area is already pretty much full)
- Shielding the dump/HRS region:
  - we can shield the dump with a wall between the two HRSs
  - we can shield the HRS platform alone with a wall facing the beampipe

Shielding

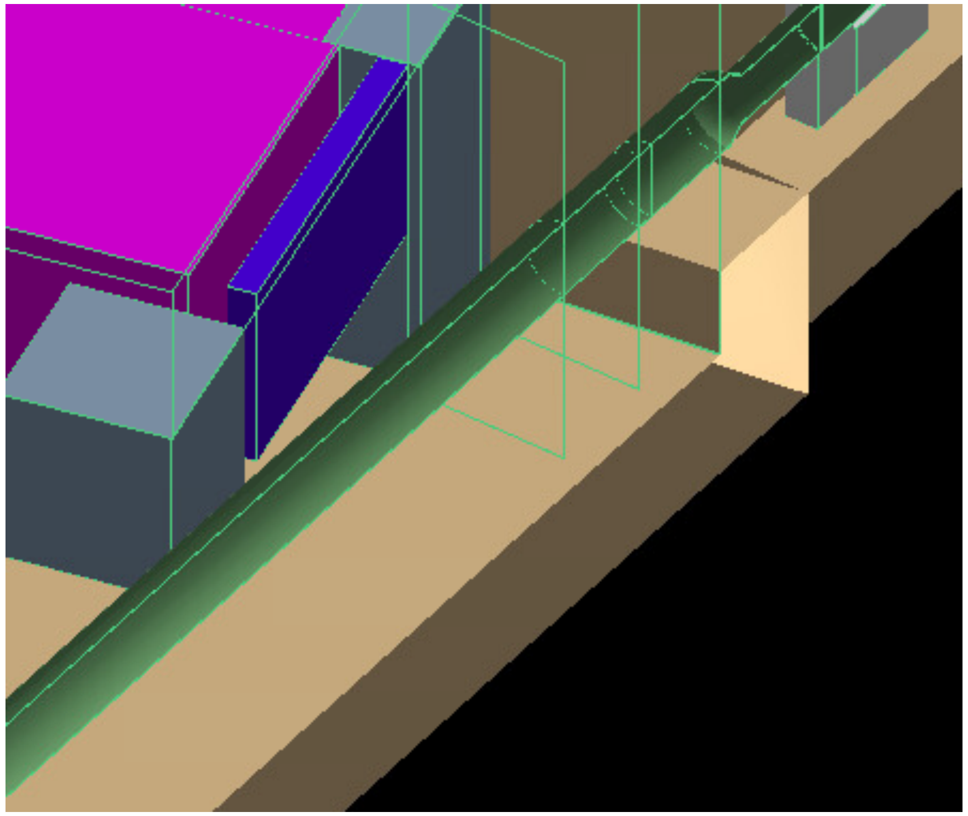


31x210x386 cm3 (5800kg)

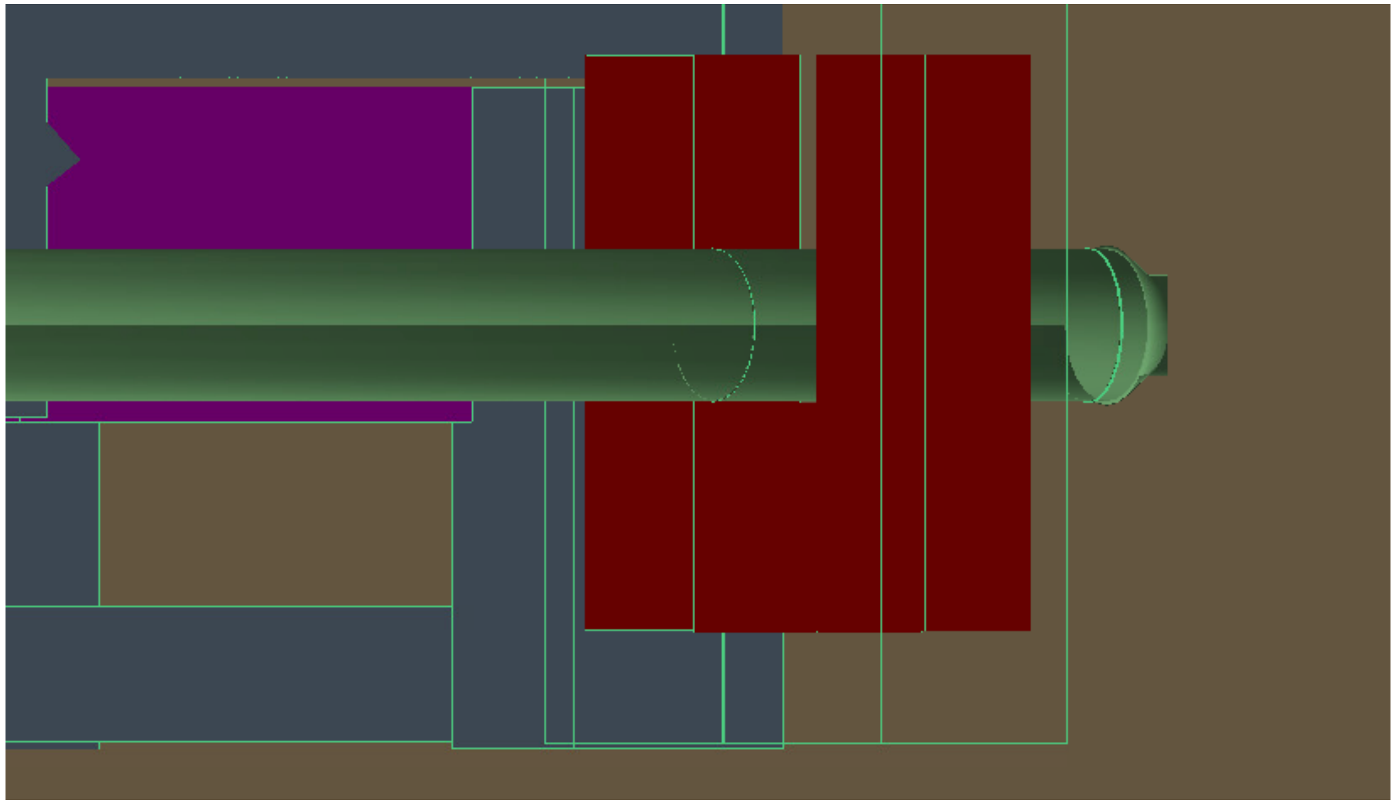


Center: 134x137x45 cm3 (1900 kg)
Sides: 120x344x45 cm3 (4300 kg)

Shielding



31x210x386 cm3 (5800kg)



Center: 134x137x45 cm3 (1900 kg)
Sides: 120x344x45 cm3 (4300 kg)

- Shielding the HRS platform with a 31 cm thick Concrete wall is very effective (for the HRS platform) but leaves the rest of the hall open (for example the flow meters under the dipole iron)
    - it would also be needed to do it on both platforms (two construction regions instead of 1)
- Shielding the dump with about 45 cm thick Concrete is almost as effective for the HRS platform and it provides additional shielding for the rest of the hall

Cumulative Radiation levels

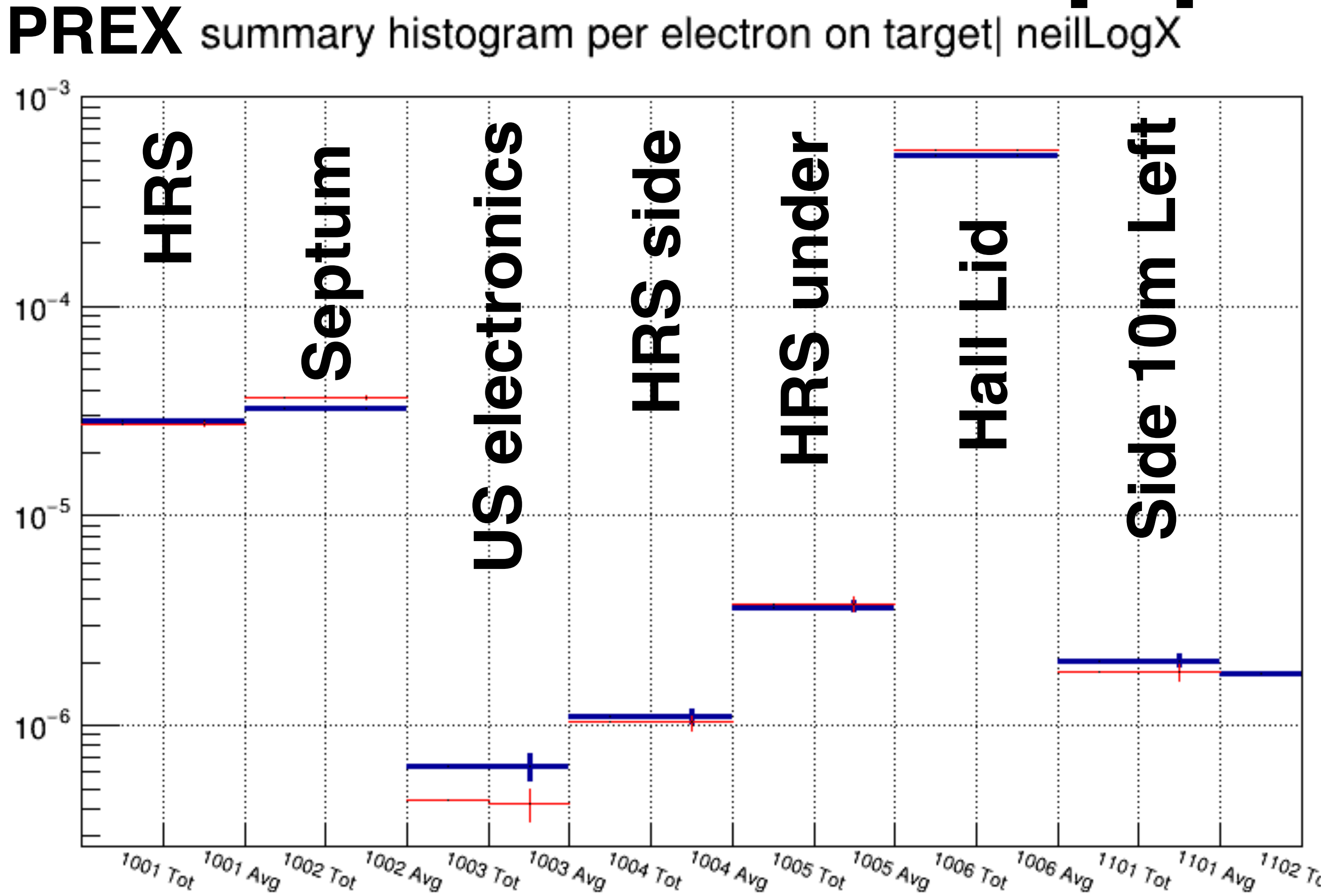
		HRS detector				Under detector			
		Total NEIL/cm2	uncert	Ratio to P1	uncert	Total NEIL/cm2	uncert	Ratio to P1	uncert
	PREX1 (ERR dump)	4.60E+10	1.79E+09	1.00	0.06	7.43E+10	4.92E+09	1.00	0.09
	PREX1 (ERR dump); newHRSDet LargerHall	3.07E+10	4.01E+08	0.67	0.03	9.65E+10	2.68E+09	1.30	0.09
PREX 2	NewHRSDet	3.05E+10	7.62E+08	0.99	0.03	7.09E+10	4.98E+09	0.73	0.06
	newHRSDet+fatPipe+prex2End	7.29E+09	2.88E+08	0.24	0.01	2.18E+10	2.43E+09	0.23	0.03
	newHRS+sideShield(31cmConc) + 4inDonut	9.72E+09	4.36E+08	0.32	0.01	5.90E+10	4.49E+09	0.61	0.05
	newHRS+DSlargeU(30cmConc)+4inDonut	1.35E+10	4.67E+08	0.44	0.02	1.75E+10	2.04E+09	0.18	0.02
	newHRS+DSlargeU(45cmConc)+4inDonut	1.18E+10	4.34E+08	0.38	0.02	2.16E+10	2.29E+09	0.22	0.02
	newHRS+DSlargeU(60cmConc)+4inDonut	1.15E+10	4.18E+08	0.38	0.01	2.39E+10	2.67E+09	0.25	0.03
CREX 5	NewHRSDet	2.72E+10	1.29E+09	0.89	0.04	5.21E+10	7.38E+09	0.54	0.08
	newHRSDet+fatPipe+prex2End	4.06E+09	3.68E+08	0.13	0.01	1.15E+10	2.38E+09	0.12	0.02
	newHRS+sideShield(31cmConc) + 4inDonut	3.15E+09	3.56E+08	0.10	0.01	3.10E+10	5.44E+09	0.32	0.06
	newHRS+DSlargeU(30cmConc)+4inDonut	5.54E+09	4.47E+08	0.18	0.01	1.20E+10	2.67E+09	0.12	0.03
	newHRS+DSlargeU(45cmConc)+4inDonut	5.26E+09	4.35E+08	0.17	0.01	9.55E+09	1.81E+09	0.10	0.02
	newHRS+DSlargeU(60cmConc)+4inDonut	4.80E+09	4.05E+08	0.16	0.01	1.05E+10	1.98E+09	0.11	0.02

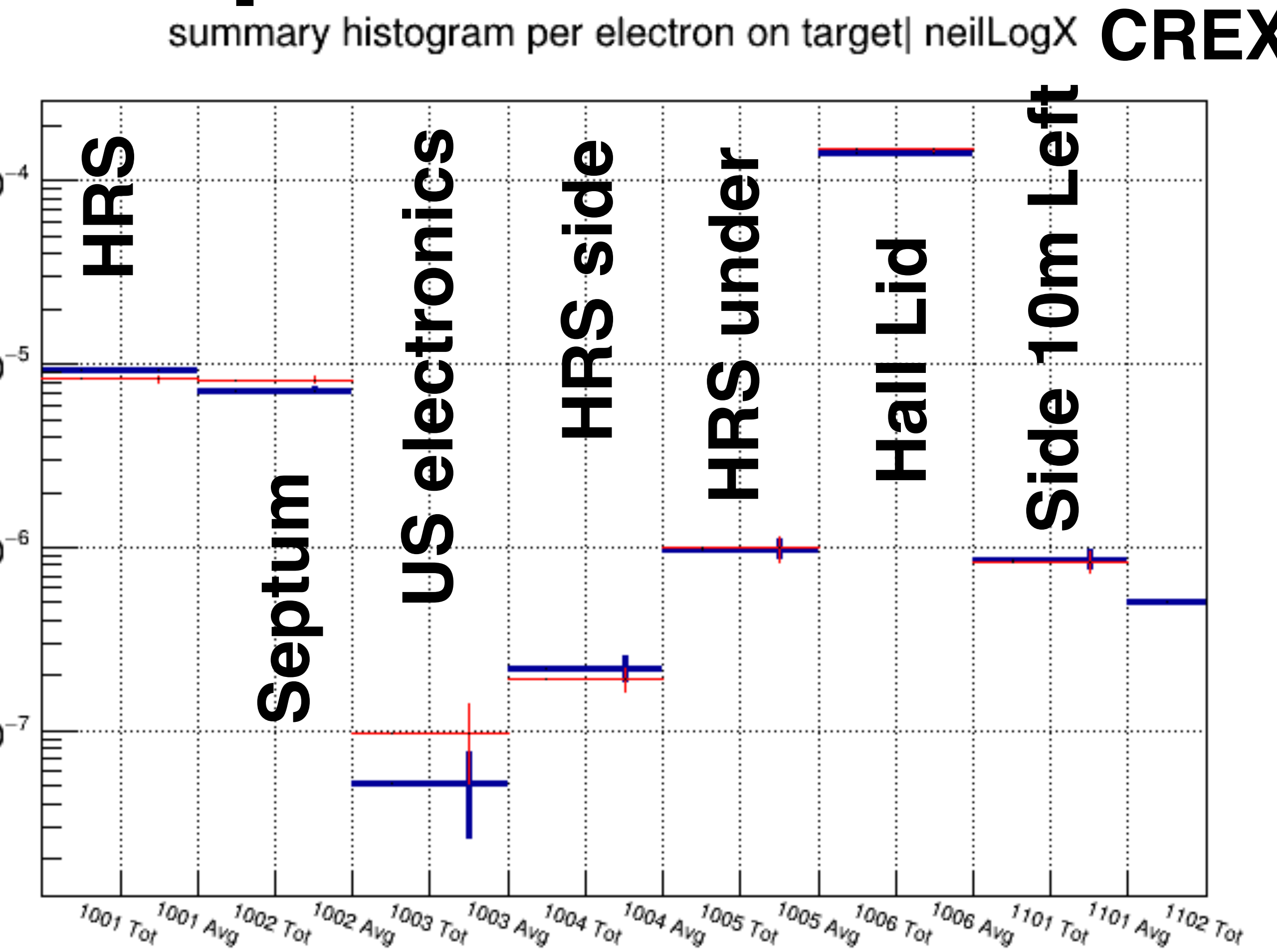
- Shielding the HRS alone produces the best results when we consider both PREX and CREX
    - however if we look at the flow meter detector we can see that it could still use local shielding itself
- Increasing the donut hole to 4in (10.13 cm) solves most of the problems we see during CREX
- The 45 cm U shaped dump shielding can bring us to an overall (PREX2 + CREX) radiation level of 45% of PREX1 (in the ERR we promised 25% of PREX 1)

Conclusions

- The detailed dump simulation indicates that we will have (before mitigation) a slightly higher radiation level inside the hall compared with what was presented at the ERR
  - To fix most of the radiation issue for CREX we propose and increase the donut hole to at least 4 in (10.13 cm)
  - For PREX additional shielding is needed and we determined that a 45 cm thick U shaped wall around the beam pipe, approximately 2 meters in front of the dump is our most efficient configuration (after looking at different configurations and shielding materials)
  - This shielding will weight approximately 8-11 tonnes (considering a density of 1750-2400 kg/m3 for concrete)

Q1 steel pipe comparison

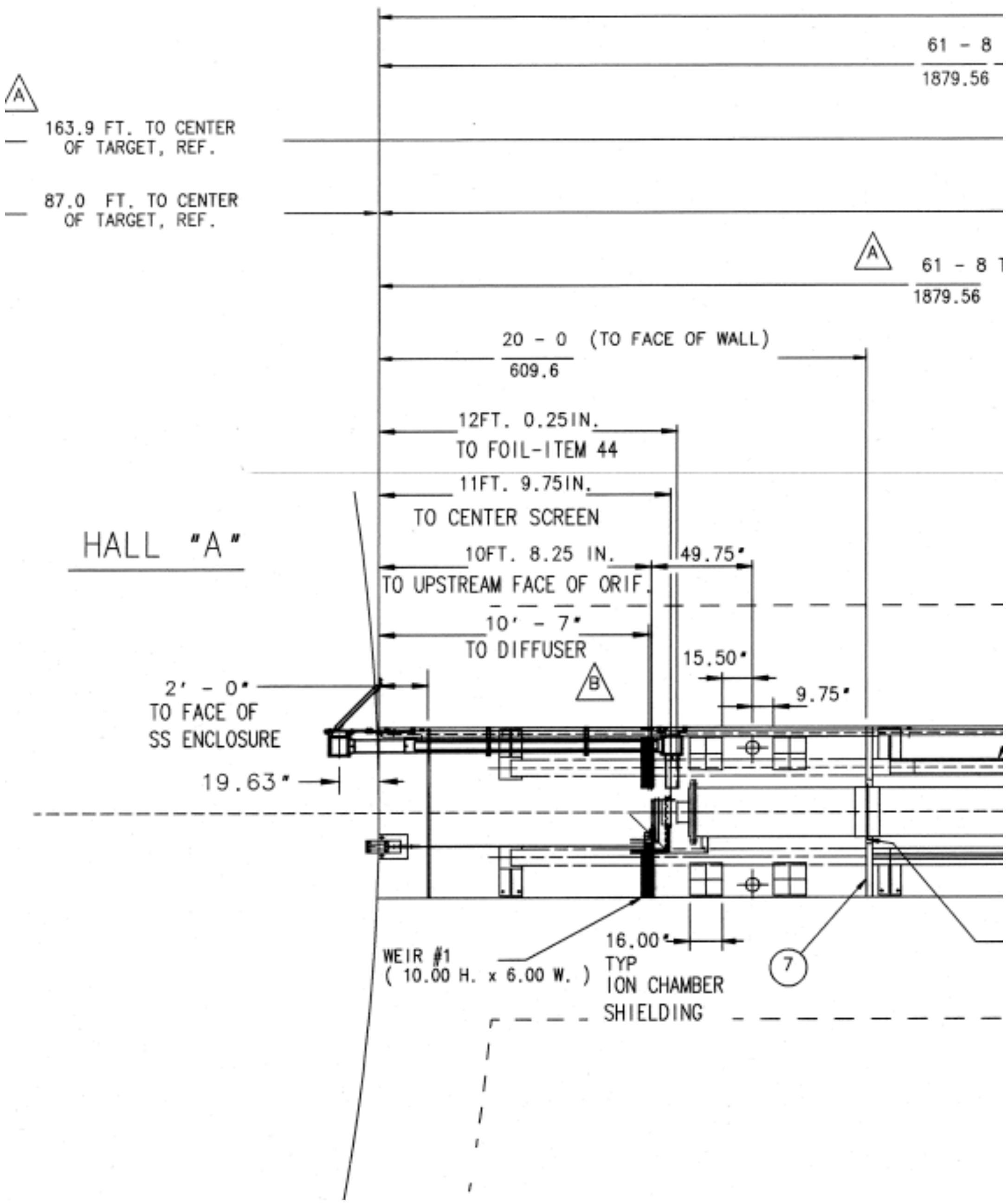


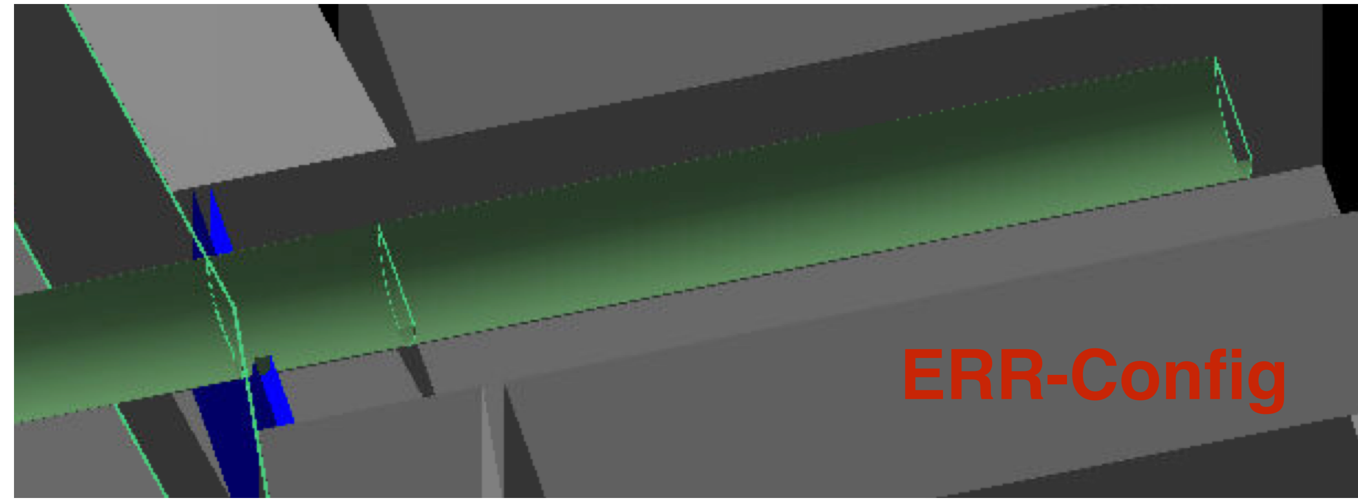


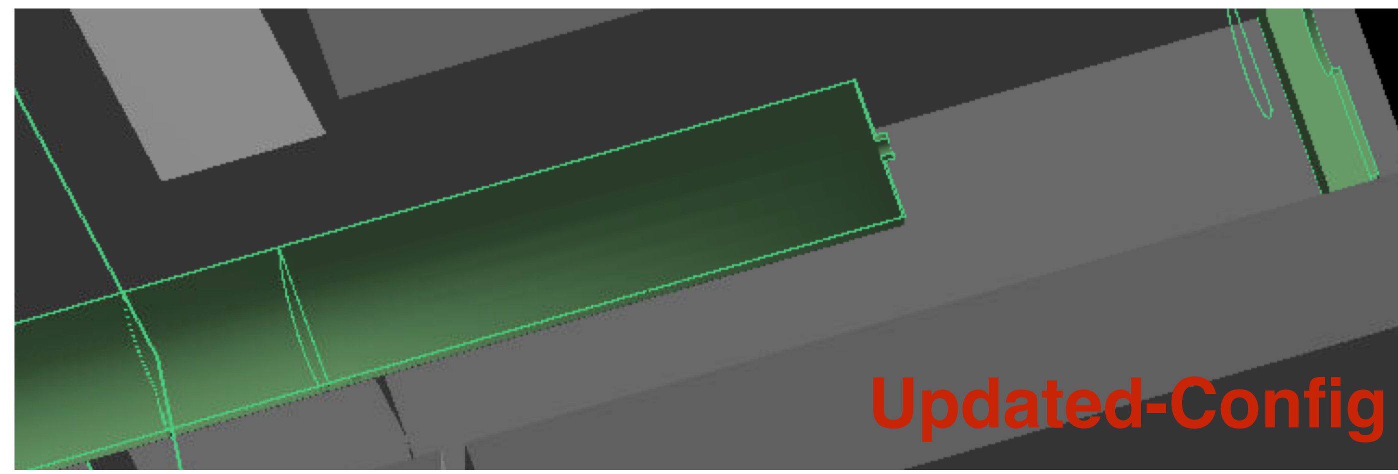
- We replaced the Al telescoping pipe (the part until the 8in gate valve) with stainless steel (the difference to carbon-steel should be minimal in terms to radiation)
- We took a look at the important detectors inside the simulation and calculate the NEIL value per electron on target for each
- We conclude that there is only a minimal increase in radiation close to septum (~10% for both PREX and CREX), while the rest of the detectors don't see statistically relevant increases

PREX 1 radiation estimation

Hall A dump configuration from Keith W. for 2010:



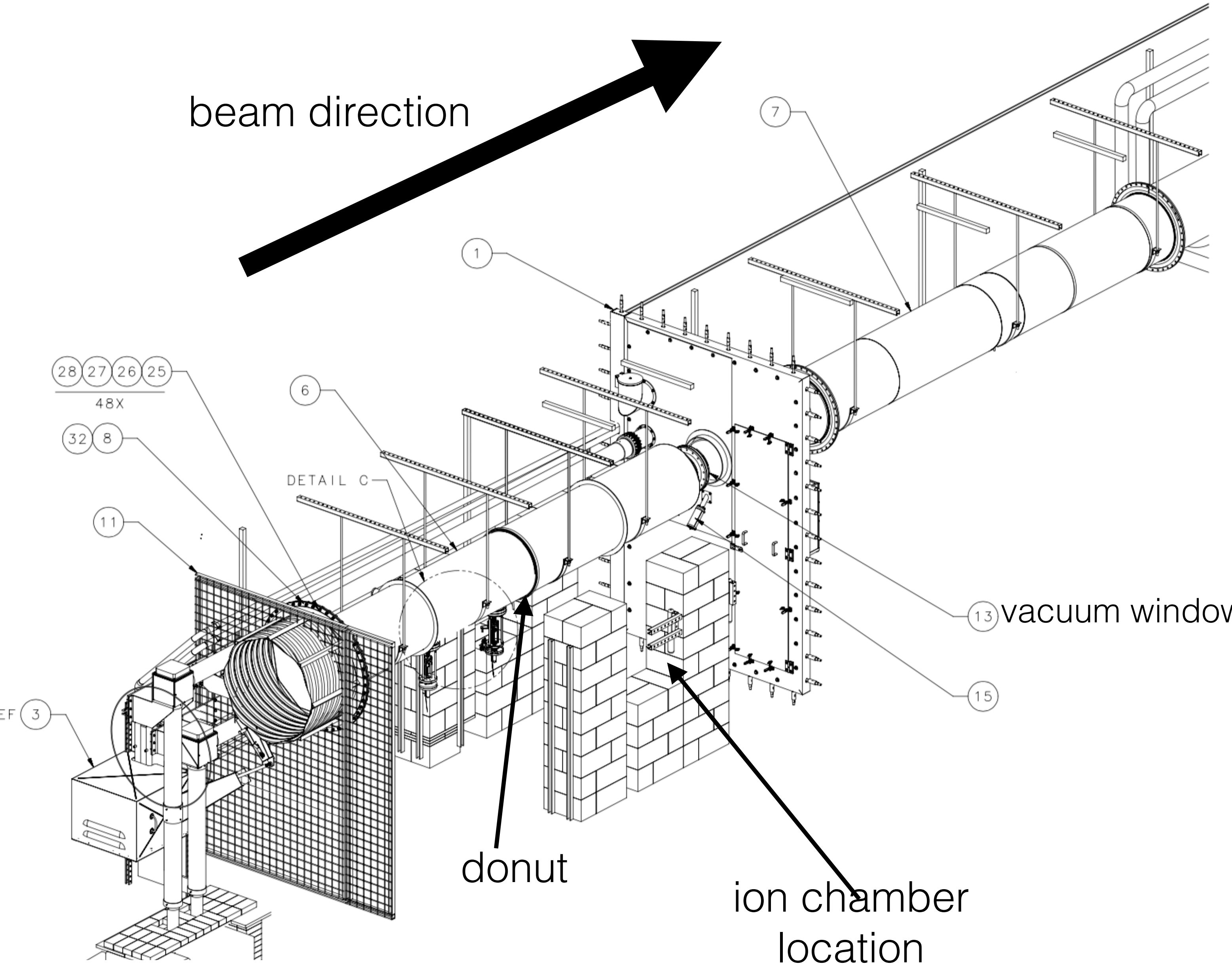




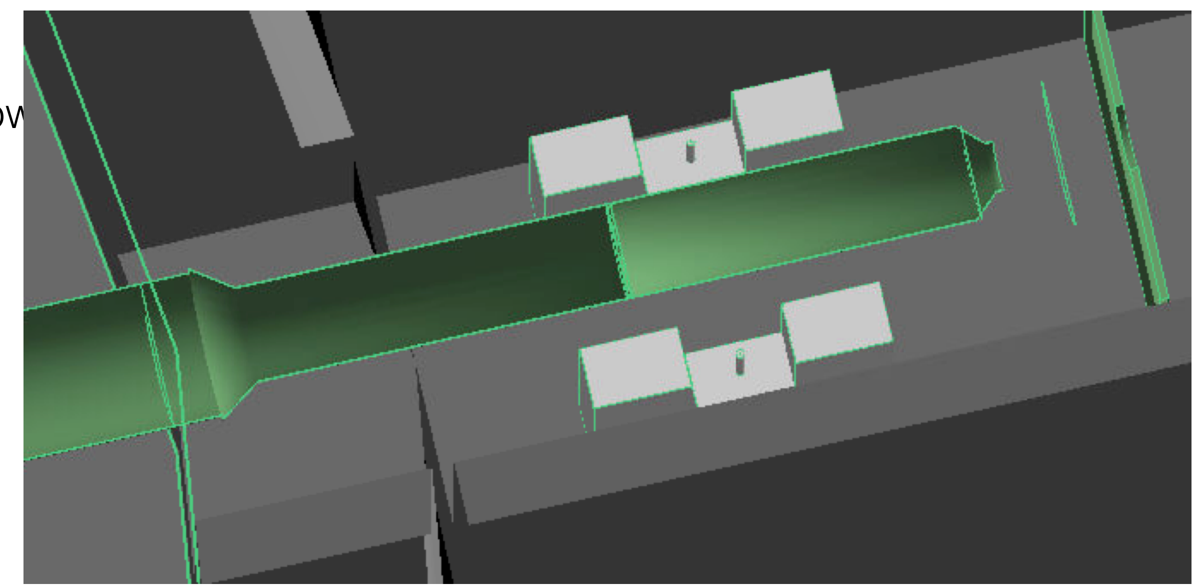
	ERR	**Update**
HRS rad [NEIL/cm2]	2.3E+11	2.1E+11

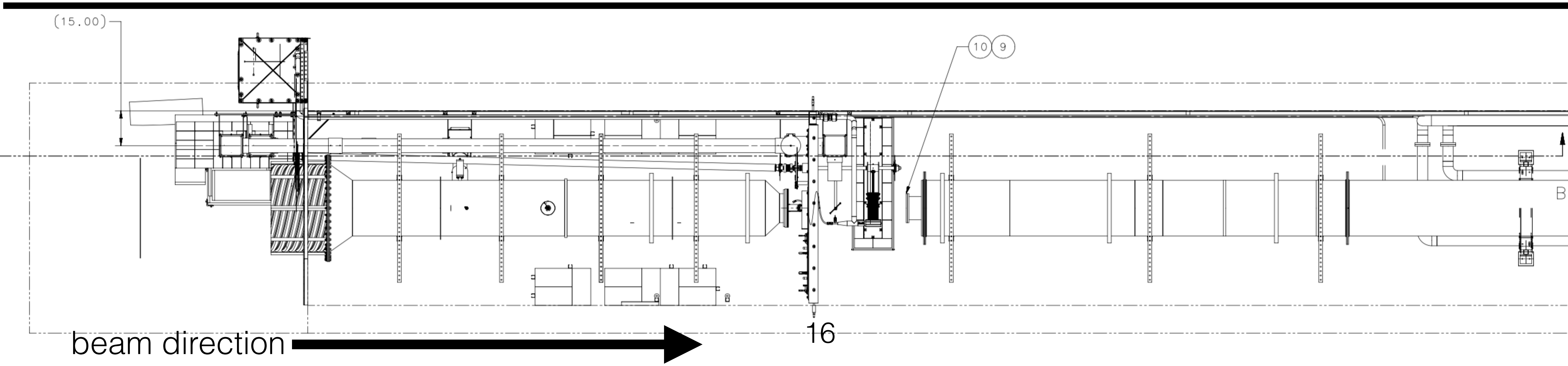
- PREX 1 estimates were done with a rudimentary dump configuration (most of the radiation to electronics came from within the hall proper)
  - The splash back from the dump was simulated by putting a stainless steel wall at the entrance of the dump tunnel
- The updated configuration with 2in aperture and the Al wall produced similar levels of radiation to the HRS platform

Current Hall A Dump configuration



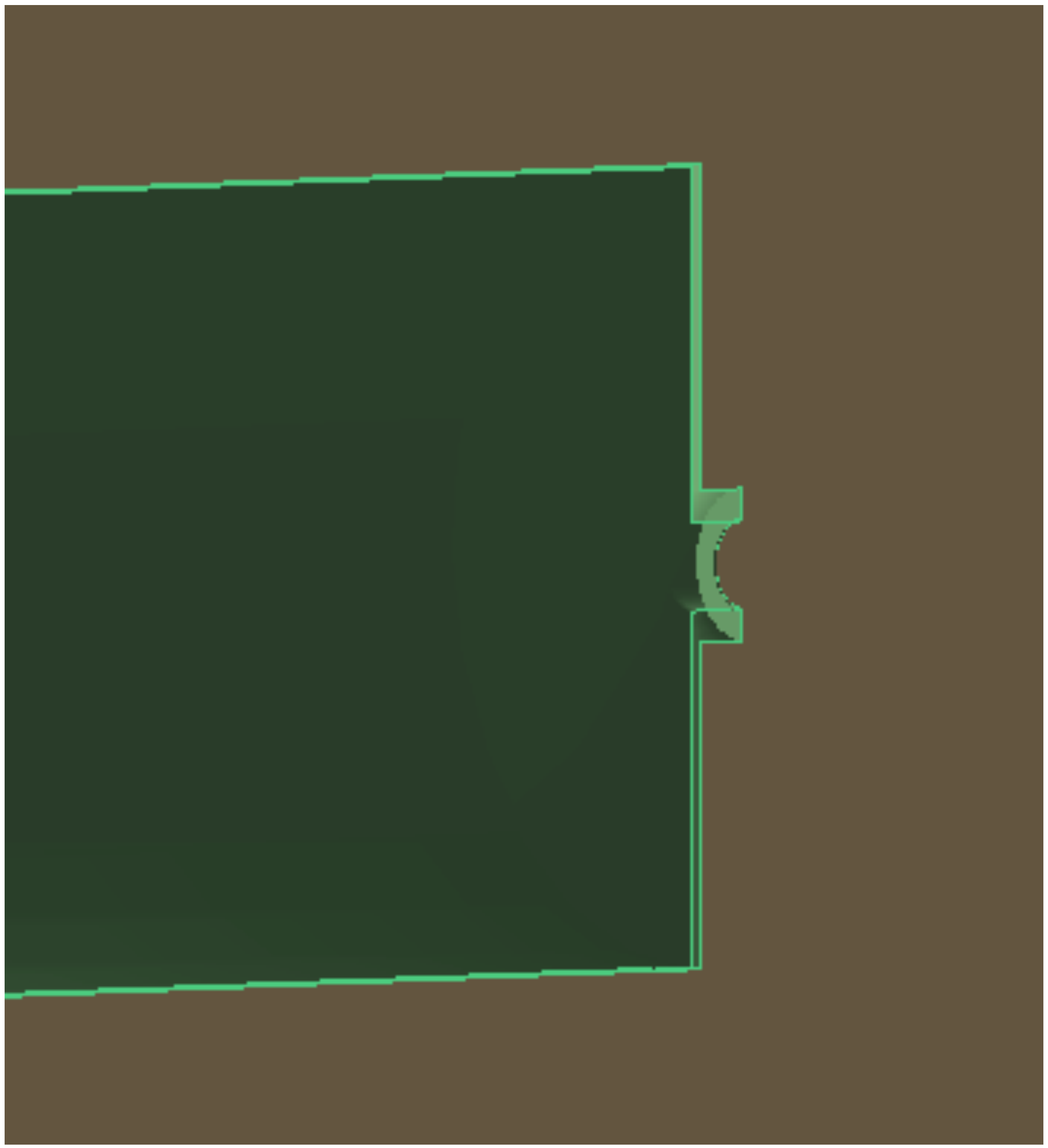
- For PREX2/CREX we will not need to use the diffuser
- We implemented the major features of the current design in the simulation
  - including the 4 cm Al aperture at ~midway until the Al door



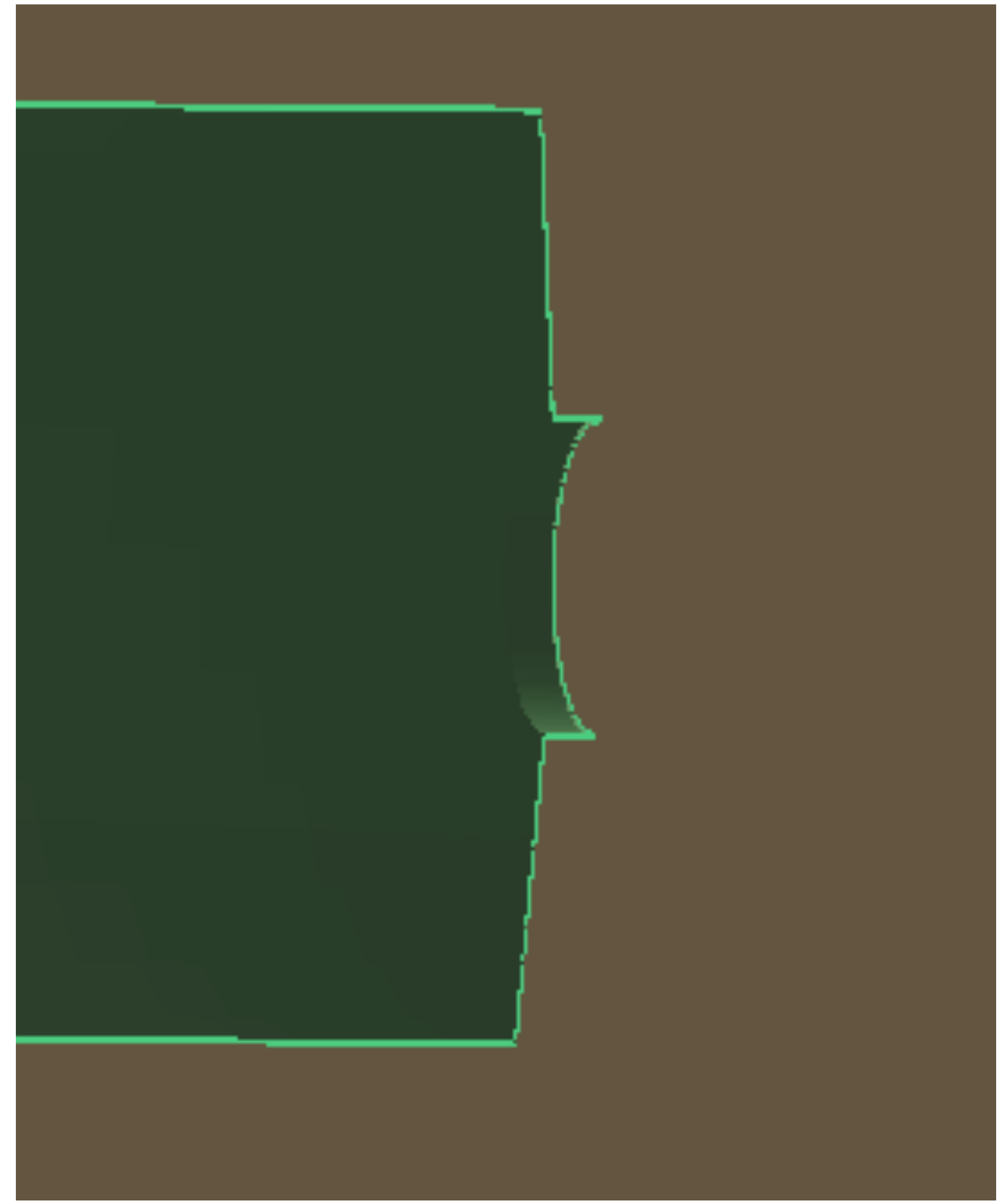


PREX2 fat pipe

PREX1 style pipe end



PREX2 style pipe end



PREX target thickness

	HRS detector				Under detector			
	Total NEIL/cm2	uncert	Ratio to P1	uncert	Total NEIL/cm2	uncert	Ratio to P1	uncert
newHRS+halfLead target+4inDonut	1.91E+10	8.60E+08	0.41	0.02	3.53E+10	4.72E+09	0.48	0.07
newHRSDet+fullLead+4inDonut	2.88E+10	7.36E+08	0.63	0.03	7.50E+10	5.14E+09	1.01	0.10
newHRSDet+fullLead	3.08E+10	7.62E+08	0.67	0.03	6.88E+10	4.84E+09	0.93	0.09
newHRSDet+75%Lead	2.67E+10	8.38E+08	0.58	0.03	5.65E+10	5.00E+09	0.76	0.08
newHRS+halfLead target	2.64E+10	1.03E+09	0.57	0.03	6.30E+10	6.87E+09	0.85	0.11
newHRS+DSlargeU(45cmH2O)+4inDonut	1.08E+10	4.04E+08	0.23	0.01	2.22E+10	2.47E+09	0.30	0.04

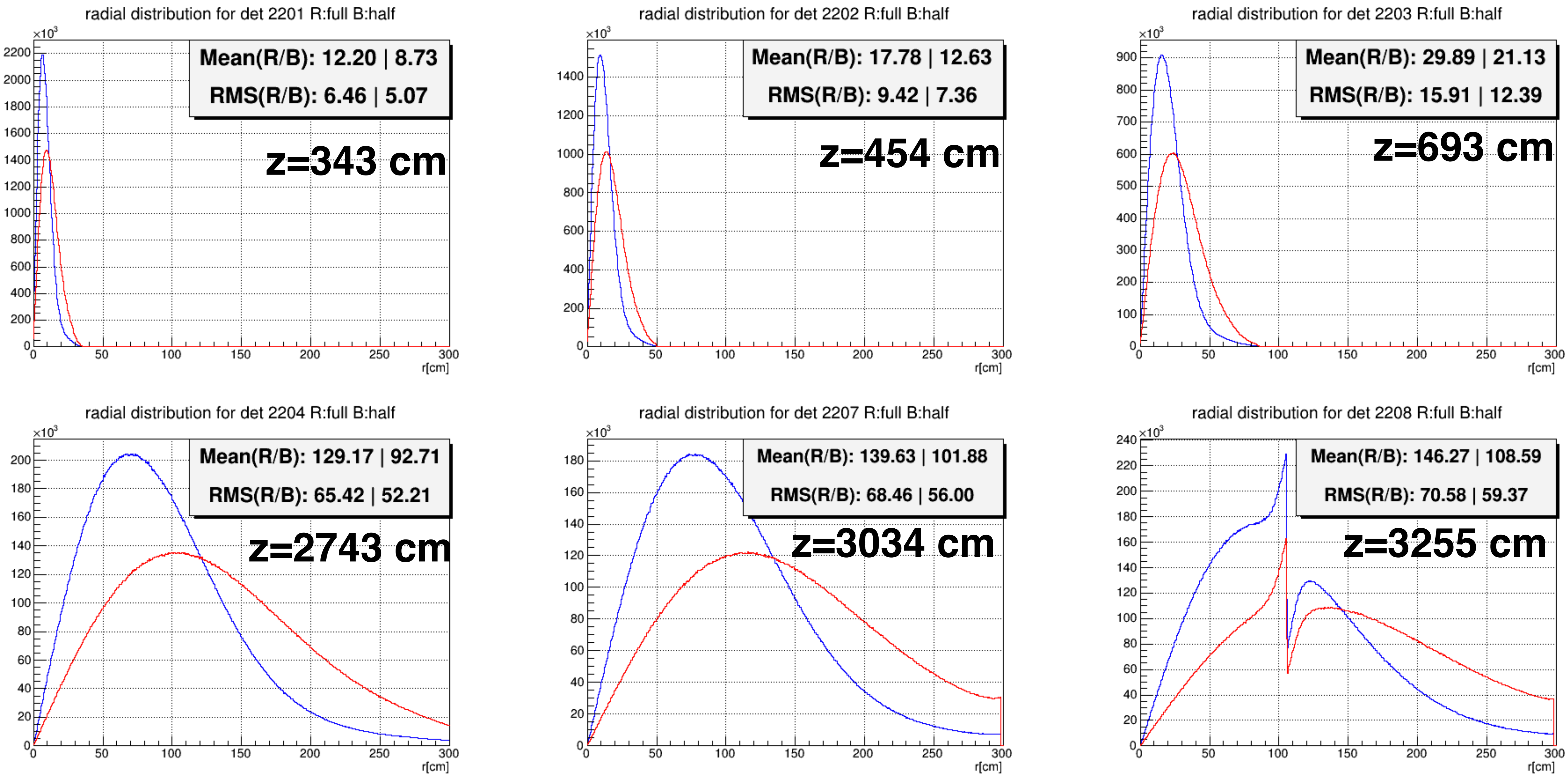
- Scaled each simulation with (1/targetThickness)

- The reduction in radiation due to target thickness is not as effective as shielding

- I am investigating the large difference between halfTarget and halfTarge+4inDonut

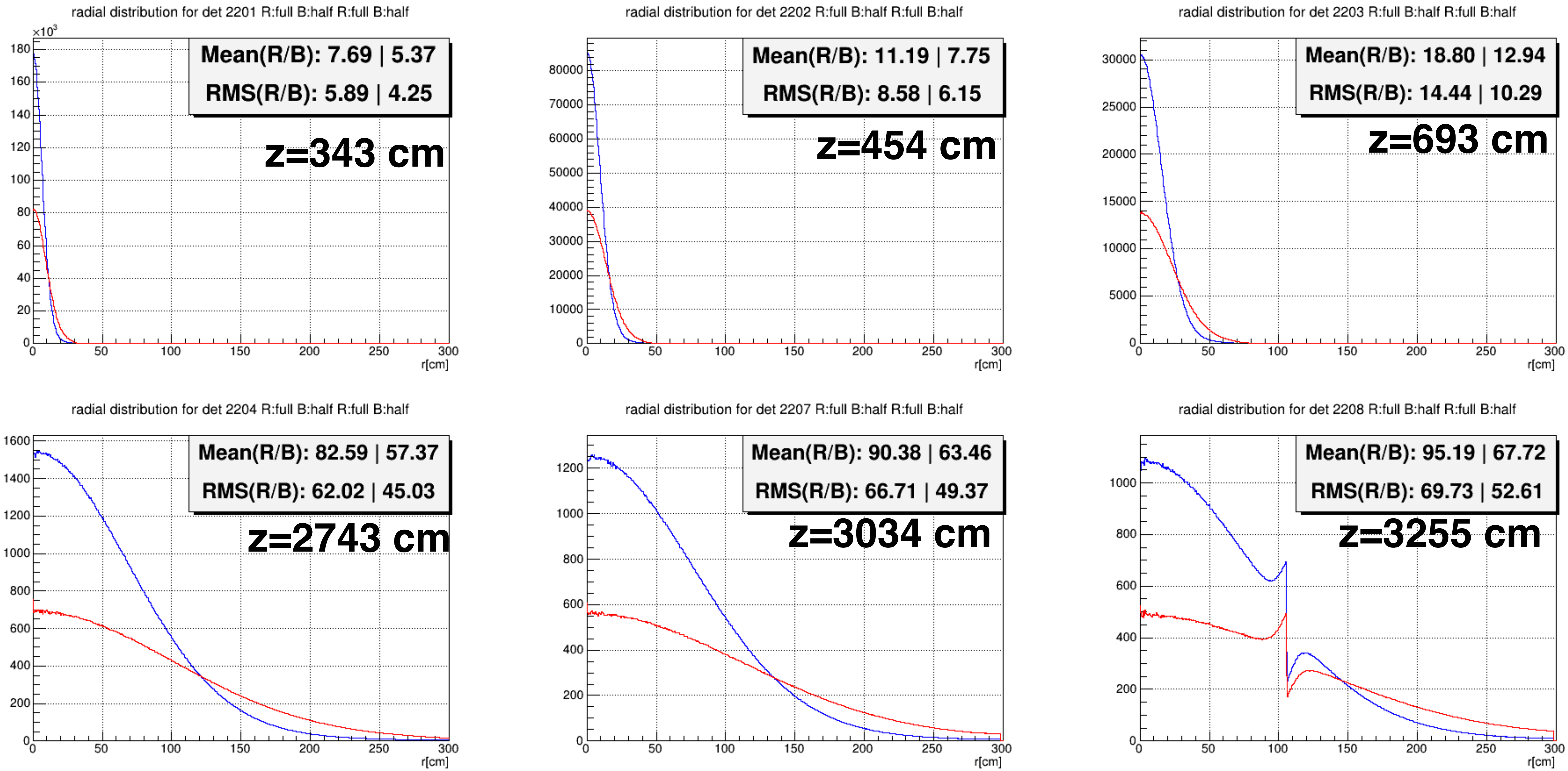
  - it would seem that we get some benefit from going to 75% but it levels off and we get the same benefit for going to 50%

Half target analysis - radial distributions



- Radial distributions of primary electrons as they pass vacuum detector at different z positions away from the target

Half target analysis - radial distributions



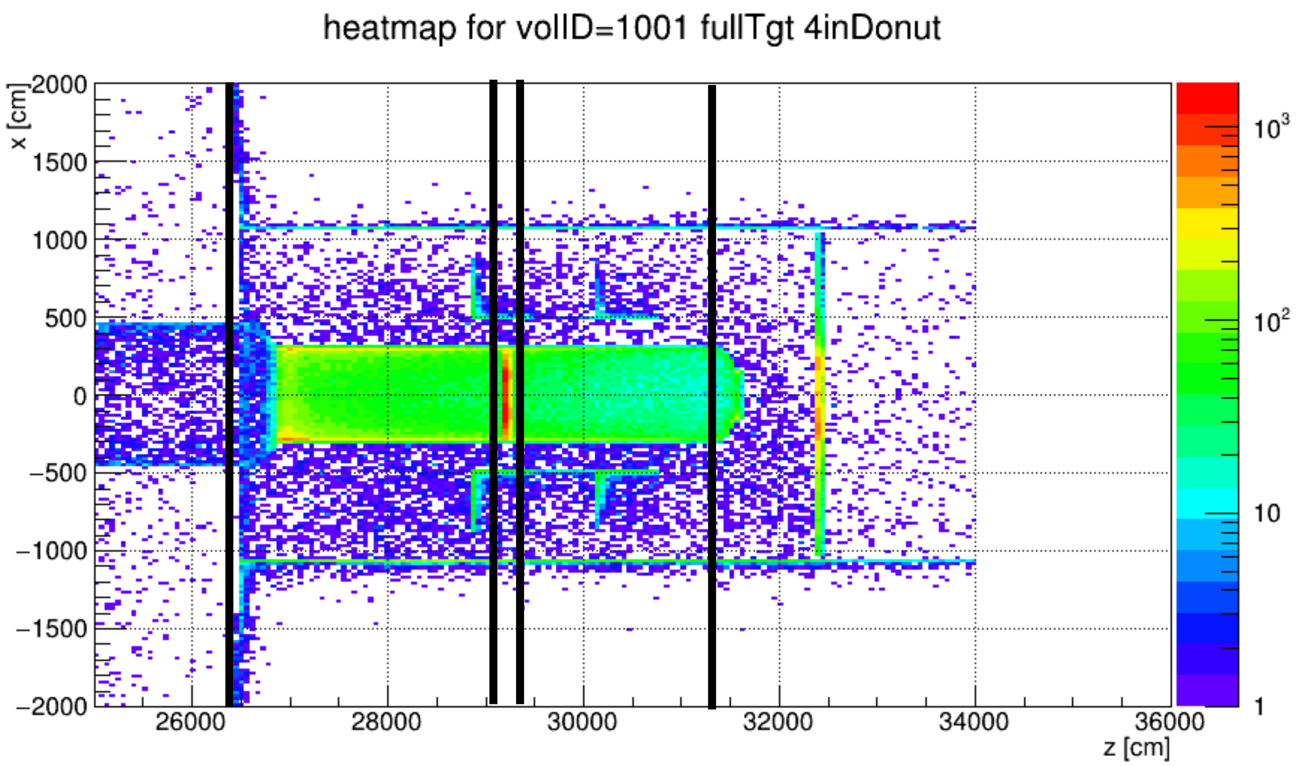
- Radial distributions of primary electrons as they pass vacuum detector at different z positions away from the target (with area taken out)

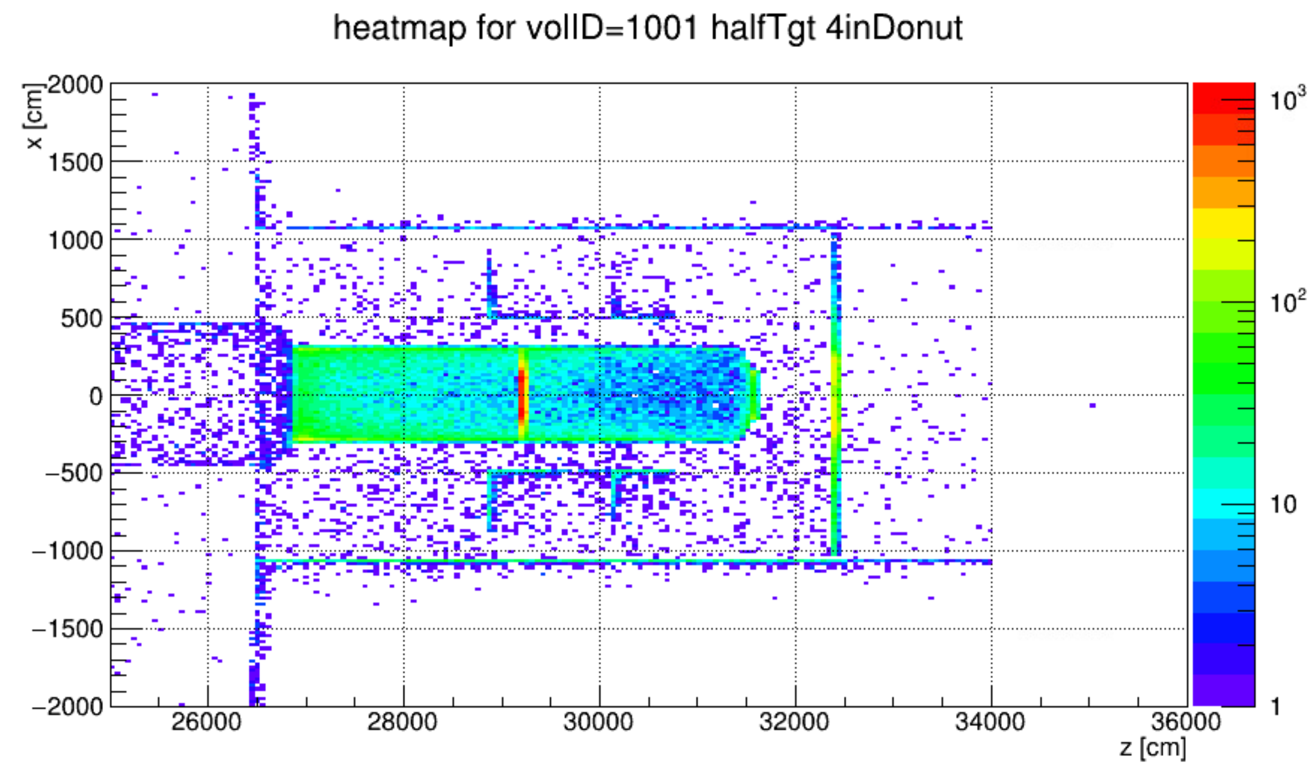
Half target analysis - radial distributions

z position [cm]	full tgt (half width mm)	half tgt (half width mm)	full tgt (rad)	half tgt (rad)	full tgt (deg)	half tgt (deg)
343	5.89	4.25	0.00343	0.00248	0.20	0.14
454	8.58	6.15	0.00378	0.00271	0.22	0.16
693	14.44	10.29	0.00417	0.00297	0.24	0.17
2743	62.02	45.03	0.00452	0.00328	0.26	0.19
3034	66.71	48.37	0.00440	0.00319	0.25	0.18
			MSc width (rad)	MSc width (deg)		
		5%	0.00269	0.15440		
		10%	0.00392	0.22485		

- Taking the widths from the previous slide and looking at the Molliere multiple scattering formula we can see that (at least for the first few detectors) the angular deviations seem to be well described

Half target analysis - counts

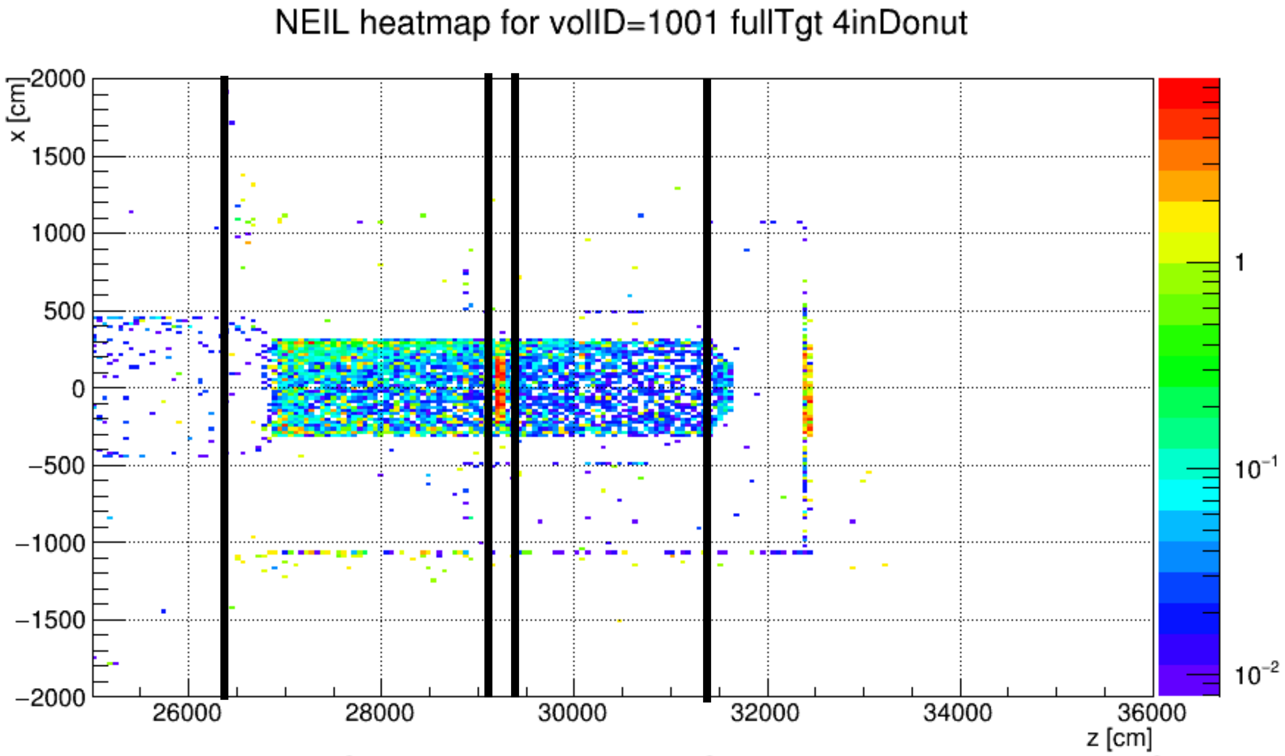


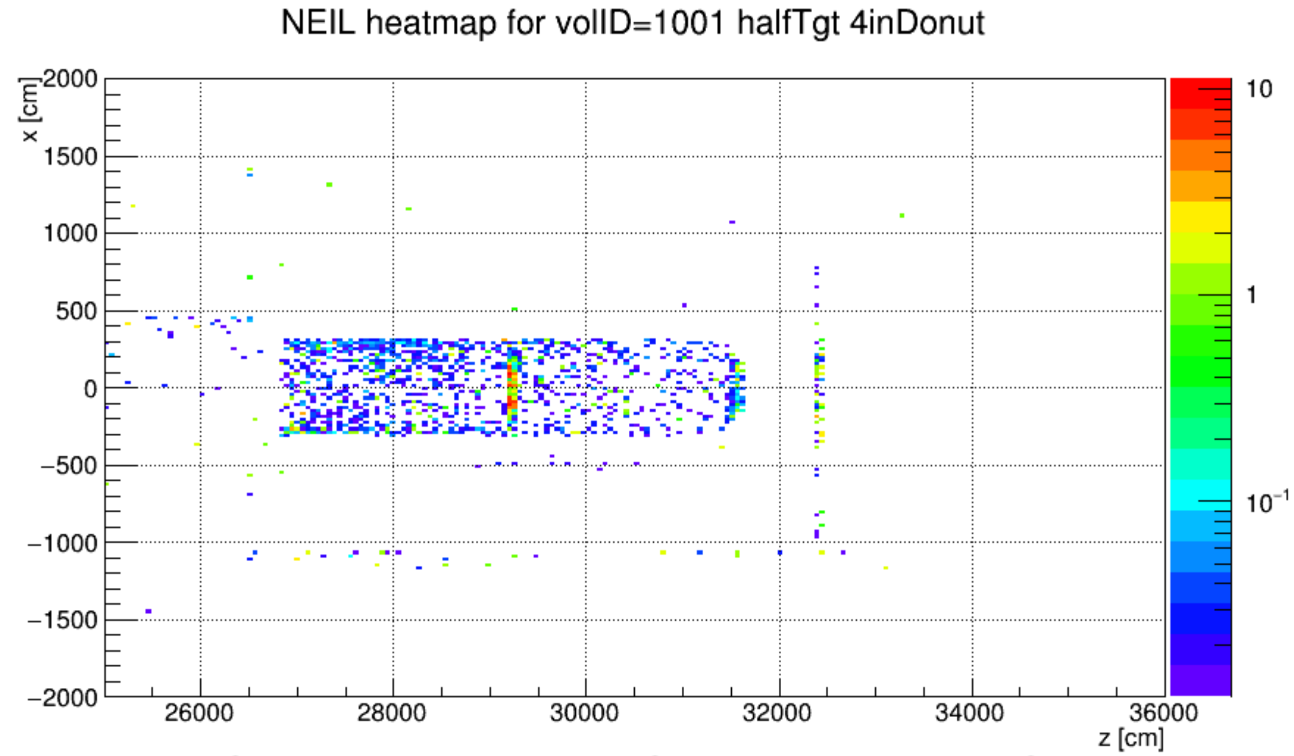


	R1(25 to 26.4)	R2 (26.4 to 29.15)	R3 (29.15 to 29.3)	R4 (29.3 to 31.4)	R5 (31.4 to 36)	Sum
full tgt	2801	126190	42991	51490	34609	258081
half tgt	804	29822	21462	14135	13117	79340
full tgt	1%	49%	17%	20%	13%	Ratio
half tgt	1%	38%	27%	18%	17%	31%

- Look at events from 5e7 electrons on target
- Counts are energies larger 0.1 MeV

Half target analysis - NEIL





	R1(25 to 26.4)	R2 (26.4 to 29.15)	R3 (29.15 to 29.3)	R4 (29.3 to 31.4)	R5 (31.4 to 36)	Sum
full tgt	21.9978	471.863	192.761	160.339	141.427	988.3878
half tgt	8.91172	107.461	132.21	44.2156	57.0149	349.81322
full tgt	2%	48%	20%	16%	14%	Ratio
half tgt	3%	31%	38%	13%	16%	35%

- Look at events from 5e7 electrons on target
- Counts are energies larger 0.1 MeV
- Most of the NEIL is reduces in the beam pipe before the donut

PREX radiation all studies

		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	6.79E+09	1.95E+09	0.15	0.04	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
	newHRSDet+fat Pipe	1.07E+10	4.10E+08	0.23	0.01	3.23E+10	3.18E+09	0.43	0.05
	newHRSDet+fatPipe+prex2End	7.29E+09	2.88E+08	0.16	0.01	2.18E+10	2.43E+09	0.29	0.04
	newHRSDet+sideShield (1ftConc)	9.81E+09	4.33E+08	0.21	0.01	6.66E+10	4.75E+09	0.90	0.09
	newHRS+sideShield(31cmConc) + 4inDonut	9.72E+09	4.36E+08	0.21	0.01	5.90E+10	4.49E+09	0.79	0.08
	newHRS+DStopCover(75cmConc)+4inDonut	1.03E+10	3.80E+08	0.22	0.01	1.88E+10	2.13E+09	0.25	0.03
	newHRS+DSlargeU(75cmConc)+4inDonut	1.11E+10	4.14E+08	0.24	0.01	2.20E+10	2.42E+09	0.30	0.04
	newHRS+DSlargeU(30cmConc)+4inDonut	1.35E+10	4.67E+08	0.29	0.02	1.75E+10	2.04E+09	0.24	0.03
	newHRS+DSlargeU(45cmConc)+4inDonut	1.18E+10	4.34E+08	0.26	0.01	2.16E+10	2.29E+09	0.29	0.04
	newHRS+DSlargeU(60cmConc)+4inDonut	1.15E+10	4.18E+08	0.25	0.01	2.39E+10	2.67E+09	0.32	0.04
	newHRS+halfLead target+4inDonut	9.54E+09	4.30E+08	0.21	0.01	1.76E+10	2.36E+09	0.24	0.04
	newHRS+DSlargeU(45cmH2O)+4inDonut	1.08E+10	4.04E+08	0.23	0.01	2.22E+10	2.47E+09	0.30	0.04
	newHRS+sideShield(31cmConc) + 4inDonut == Hall Only	5.12E+09	3.03E+08	0.11	0.01	1.39E+10	1.58E+09	0.19	0.02
	newHRS+DStopCover(75cmConc)+4inDonut == Hall only	7.20E+09	2.96E+08	0.16	0.01	1.46E+10	1.71E+09	0.20	0.03
	newHRS+DSlargeU(75cmConc)+4inDonut == Hall only	7.30E+09	3.10E+08	0.16	0.01	1.33E+10	1.39E+09	0.18	0.02

CREX radiation all studies

		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
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	5.86E+09	2.46E+09	0.13	0.05	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
	newHRSDet+fat Pipe	2.70E+10	1.26E+09	0.59	0.04	9.70E+10	1.08E+10	1.31	0.17
	newHRSDet+fatPipe+prex2End	4.06E+09	3.68E+08	0.09	0.01	1.15E+10	2.38E+09	0.15	0.03
	newHRSDet+sideShield (1ftConc)	6.96E+09	6.19E+08	0.15	0.01	4.39E+10	6.83E+09	0.59	0.10
	newHRS+sideShield(31cmConc) + 4inDonut	3.15E+09	3.56E+08	0.07	0.01	3.10E+10	5.44E+09	0.42	0.08
	newHRS+DStopCover(75cmConc)+4inDonut	5.51E+09	4.62E+08	0.12	0.01	1.20E+10	2.28E+09	0.16	0.03
	newHRS+DSlargeU(75cmConc)+4inDonut	6.04E+09	4.72E+08	0.13	0.01	1.07E+10	2.18E+09	0.14	0.03
	newHRS+DSlargeU(30cmConc)+4inDonut	5.54E+09	4.47E+08	0.12	0.01	1.20E+10	2.67E+09	0.16	0.04
	newHRS+DSlargeU(45cmConc)+4inDonut	5.26E+09	4.35E+08	0.11	0.01	9.55E+09	1.81E+09	0.13	0.03
	newHRS+DSlargeU(60cmConc)+4inDonut	4.80E+09	4.05E+08	0.10	0.01	1.05E+10	1.98E+09	0.14	0.03
	newHRS+DSlargeU(45cmH2O)+4inDonut	4.36E+09	3.44E+08	0.09	0.01	1.11E+10	2.11E+09	0.15	0.03
	newHRS+sideShield(31cmConc) + 4inDonut == Hall Only	2.13E+09	2.65E+08	0.05	0.01	1.10E+10	2.43E+09	0.15	0.03
	newHRS+DStopCover(75cmConc)+4inDonut == Hall only	3.85E+09	3.18E+08	0.08	0.01	1.17E+10	2.28E+09	0.16	0.03
	newHRS+DSlargeU(75cmConc)+4inDonut == Hall only	4.57E+09	3.82E+08	0.10	0.01	1.05E+10	2.18E+09	0.14	0.03