Beam Transport Studies

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Beam Transport

- Looking at transport through HRS(QQD_nQ). Septum introduced before first quadrupole. Type equation here.Measurements made at focal plane in HRS. Need a way to link target variables to focal plane variables. Beam transport optics can be studied using matrix formalism.
- First order studies – express focal plane variables as Taylor expansion of target variables to first order (5x5)
- Second order studies – second order Taylor expansion (now 20 x 20)

$$\begin{bmatrix} x_{fp} \\ \theta_{fp} \\ y_{fp} \\ \phi_{fp} \\ \delta_{fp} \end{bmatrix} = T_{fp\leftarrow\ tg} \begin{bmatrix} x_{tg} \\ \theta_{tg} \\ y_{tg} \\ \phi_{tg} \\ \delta \end{bmatrix}$$

5 x 5 matrix to 1st order

Fraction momentum deviation from central trajectory

Exploring 1st Order Effects

First Order Matrix Elements

Heavy coupling between δ and x

Focal Plane Coordinates

$$\begin{bmatrix} x_{fp} \\ \theta_{fp} \\ y_{fp} \\ \phi_{fp} \\ \delta_{fp} \end{bmatrix}$$

-3.1	-0.03	0	0	17.71
-0.3	-0.33	0	0	2.5
0	0	2.51	0.01	-0.57
0	0	1.08	0.4	-0.2
0	0	0	0	1

Target Coordinates

$$\begin{bmatrix} x_{tg} \\ \theta_{tg} \\ y_{tg} \\ \phi_{tg} \\ \delta \end{bmatrix}$$

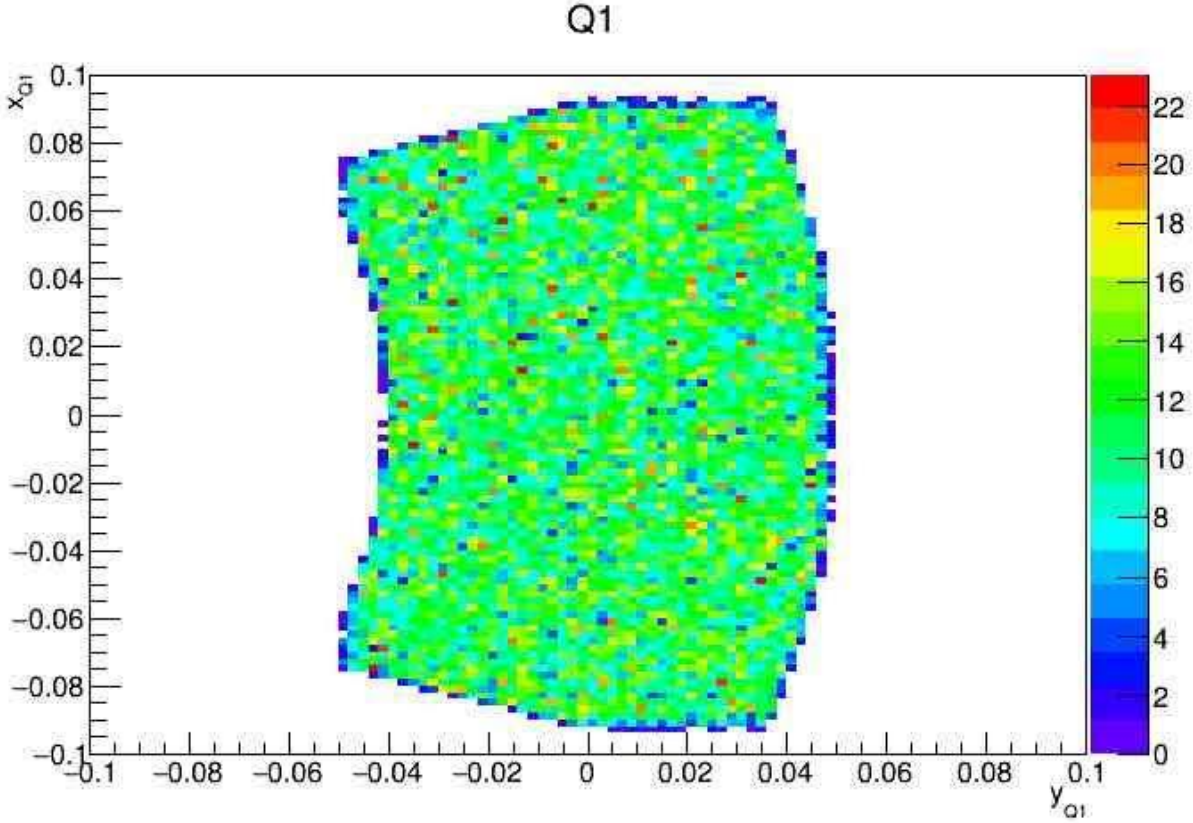
Field values q1 = 0.096255, q2 = -0.131739, q3 = -0.170480

First order studies

- Target variables sampled randomly(expect δ, fixed at 0 i.e., along central ray)
- x,y_{tg} sampling range chosen to be ± 2 mm in each direction – simulates 4mm x 4mm beam raster
- Angular sampling ranges allowed to vary
- Before transport to focal plane, enforced Q1 collimator cut at the Q1 entrance

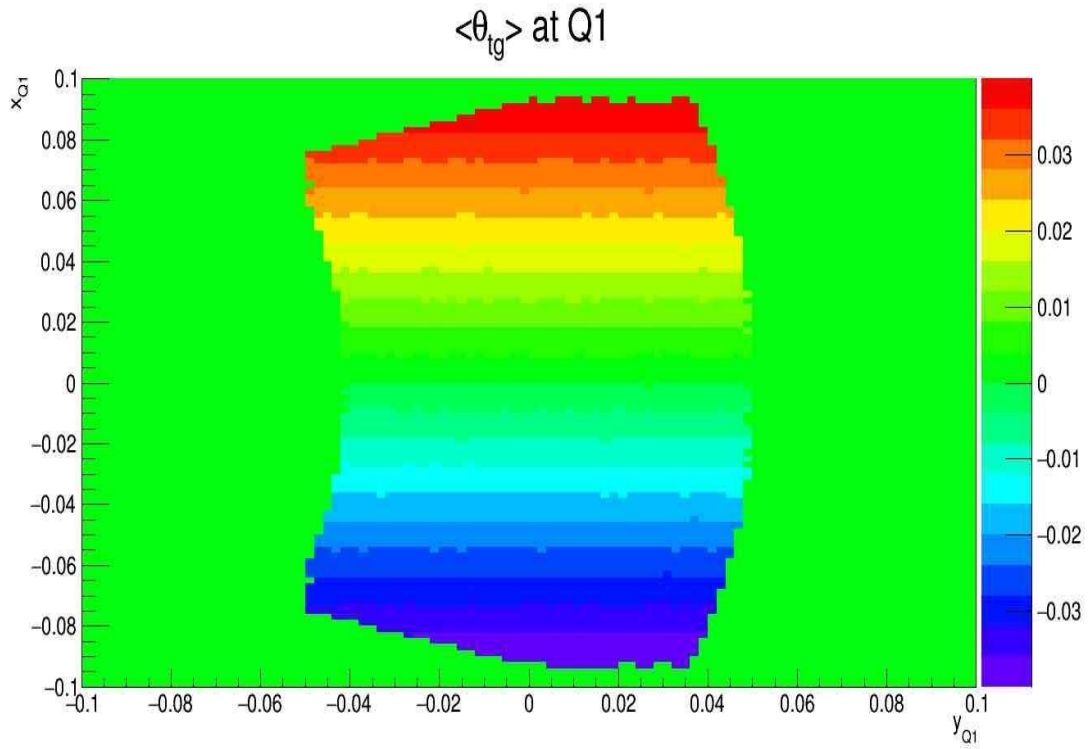
Q1 Collimator Cut

Unweighted histogram x_{Q1} vs y_{Q1}



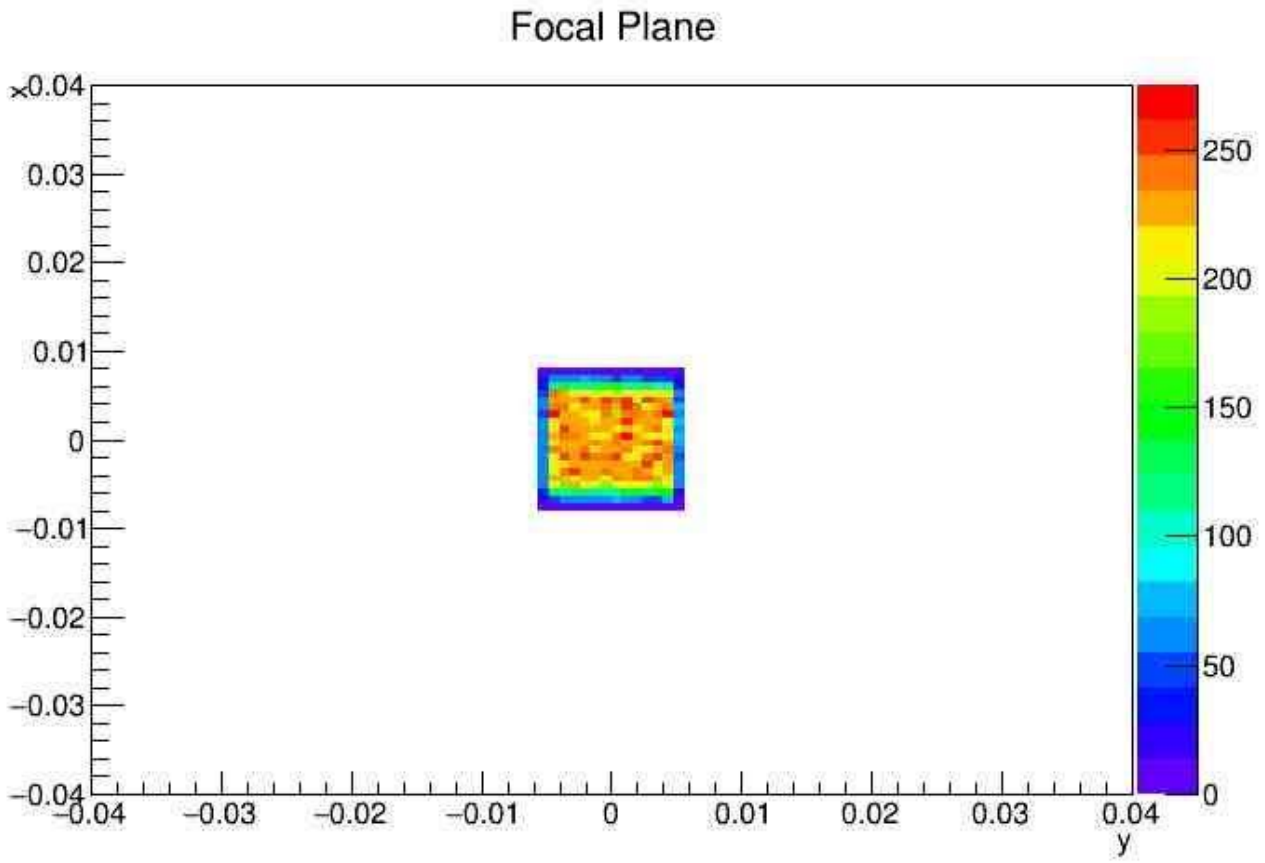
~ 10 % loss of statistics enforcing cut (initially 50,000 events)

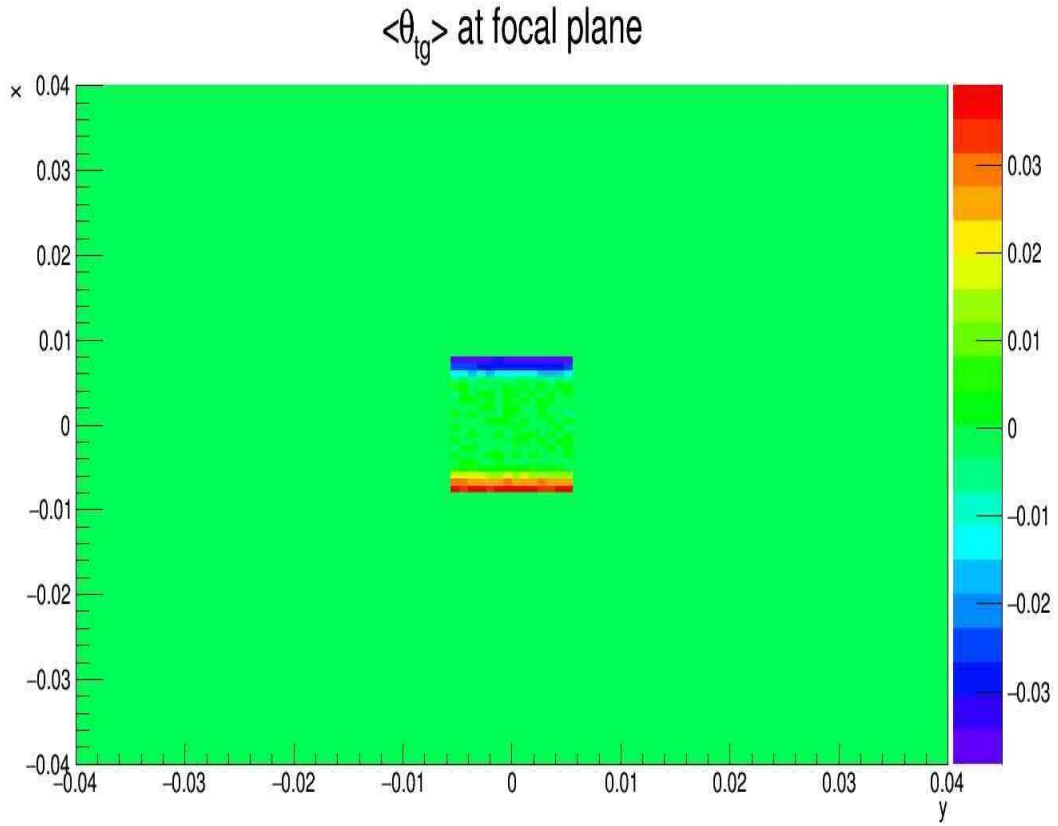
Θ_{tg} weighted histogram at Q1 collimator



Important for A_T systematic studies $A_T \sim \sin \theta_{tg}$. Will require septum mistune

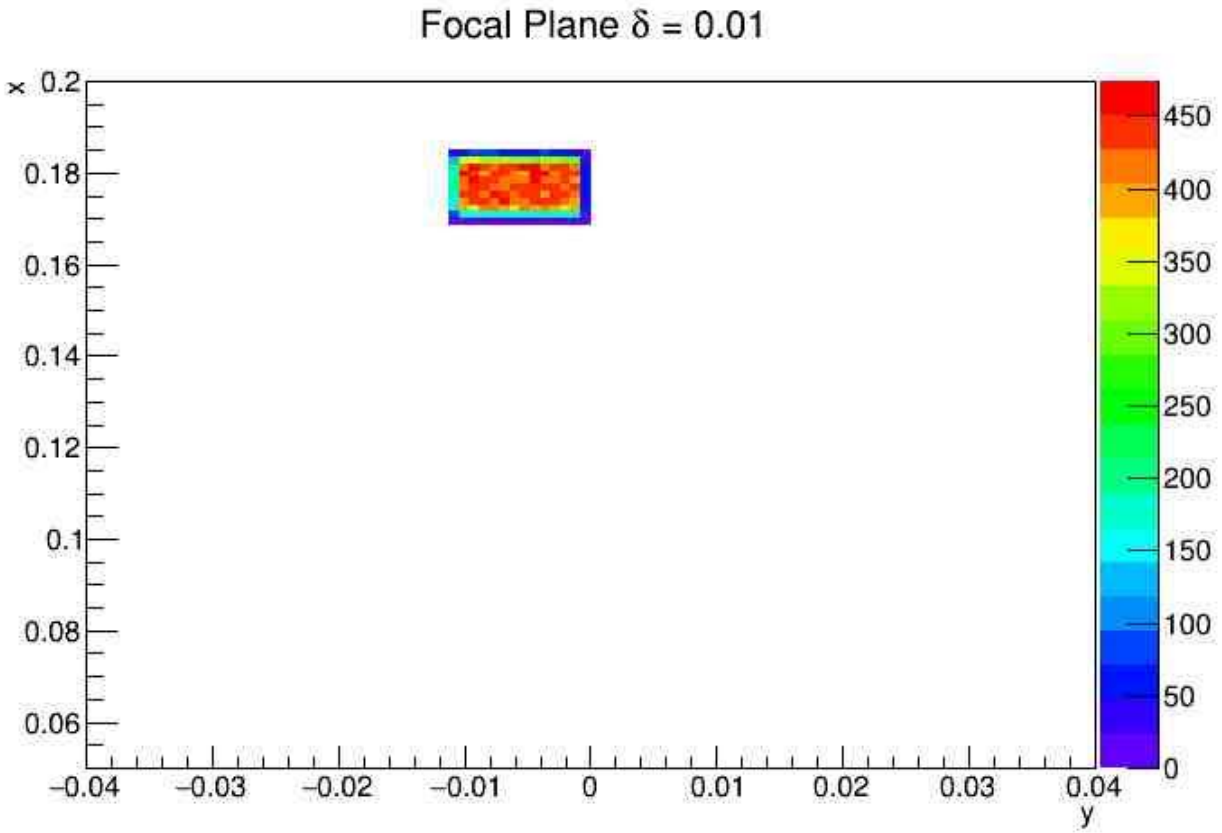
Focal Plane ($\delta = 0$)

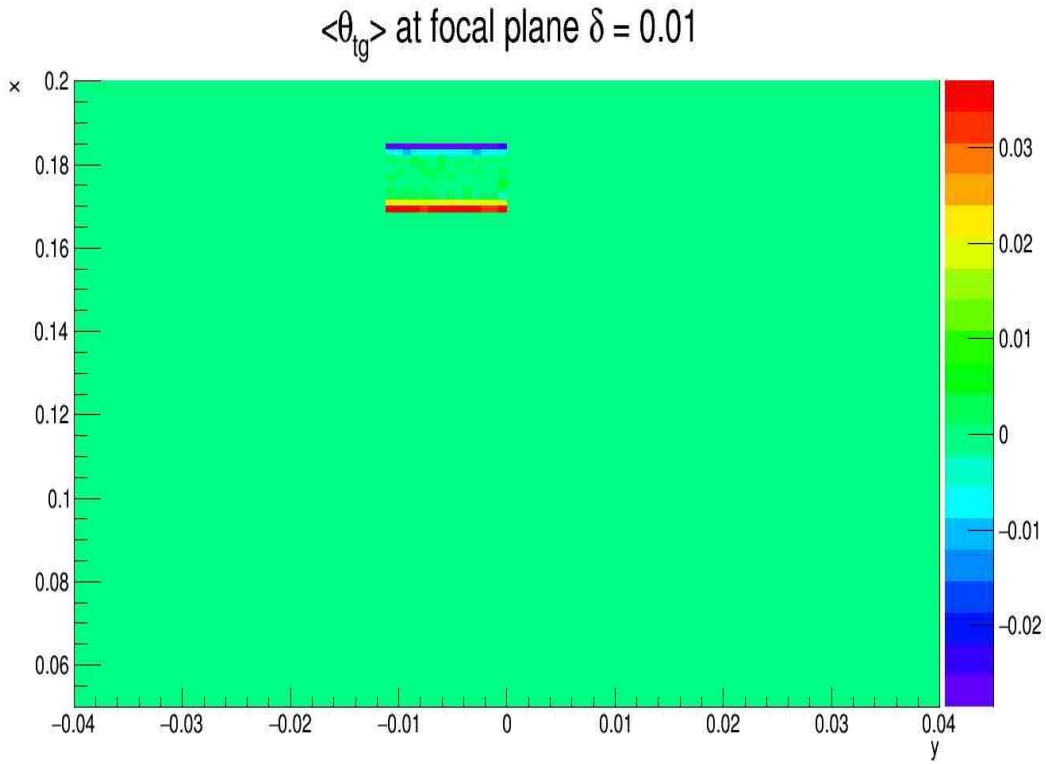




Observe not exactly a point but smearing in the focal plane due to beam raster

Focal Plane ($\delta = 0.01$)





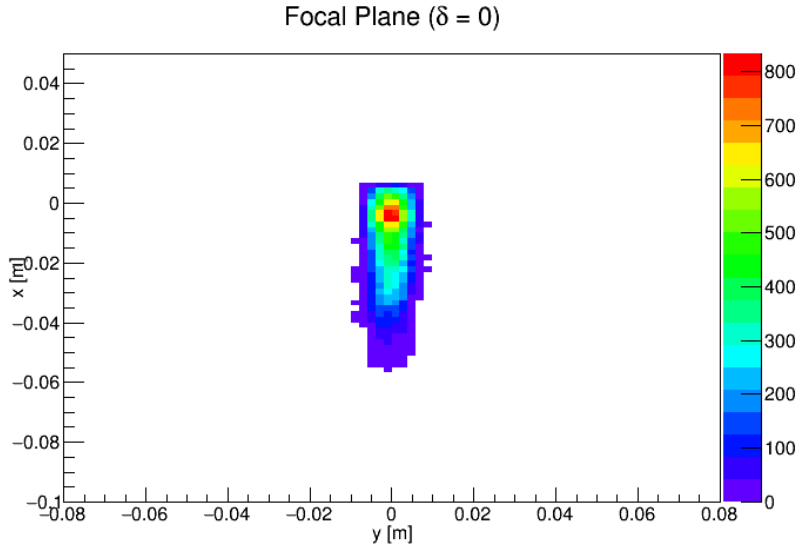
Recall $(x|\delta) = 17.71$ so spot moves in the focal plane. Also see slight shift $(y|\delta) = -0.57$ from the target to focal plane

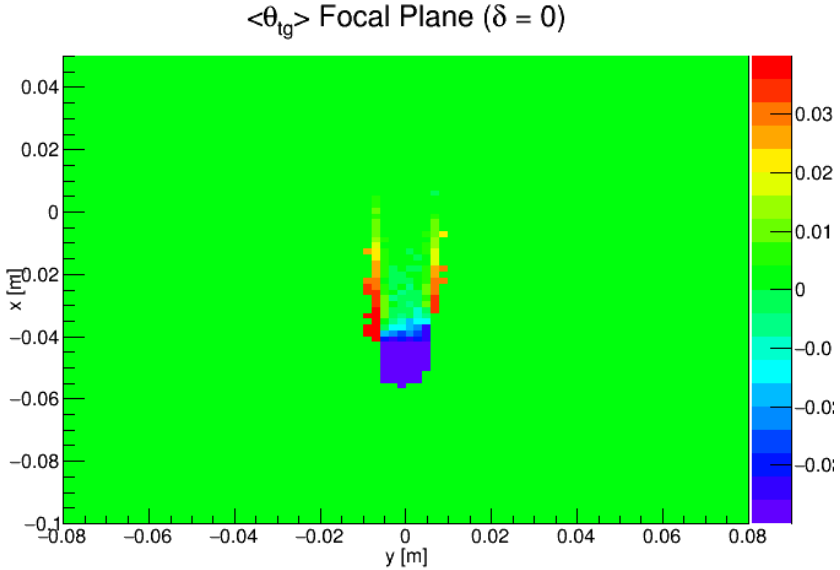
Exploring 2nd Order Effects

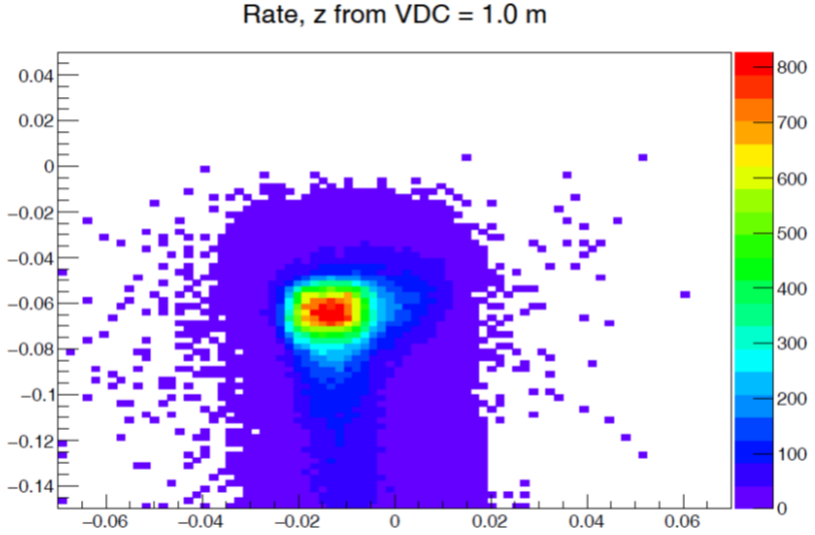
Second Order Effects

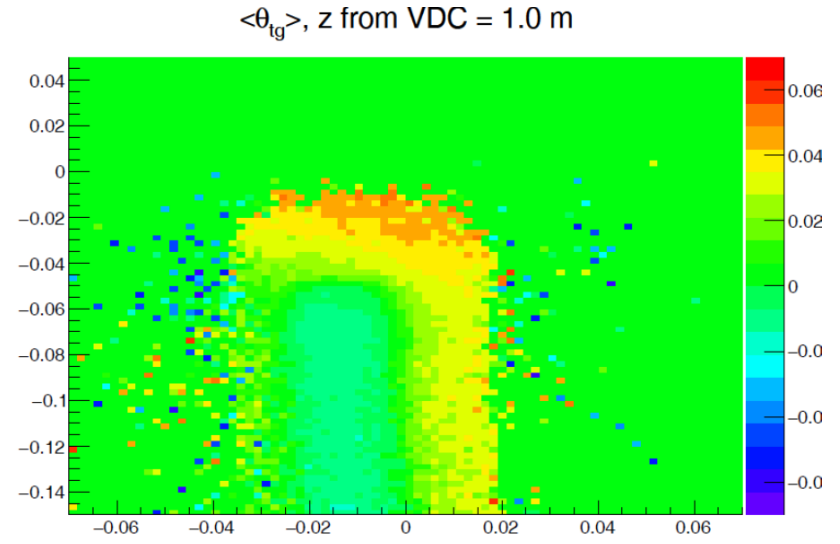
- Second order effects include cross terms for target variables e.g., x^2, $x\theta$, $x\delta$, etc.
- Matrix is now 20 x 20 matrix no longer 5 x 5 matrix
- Looking at $\delta = 0$

Focal Plane

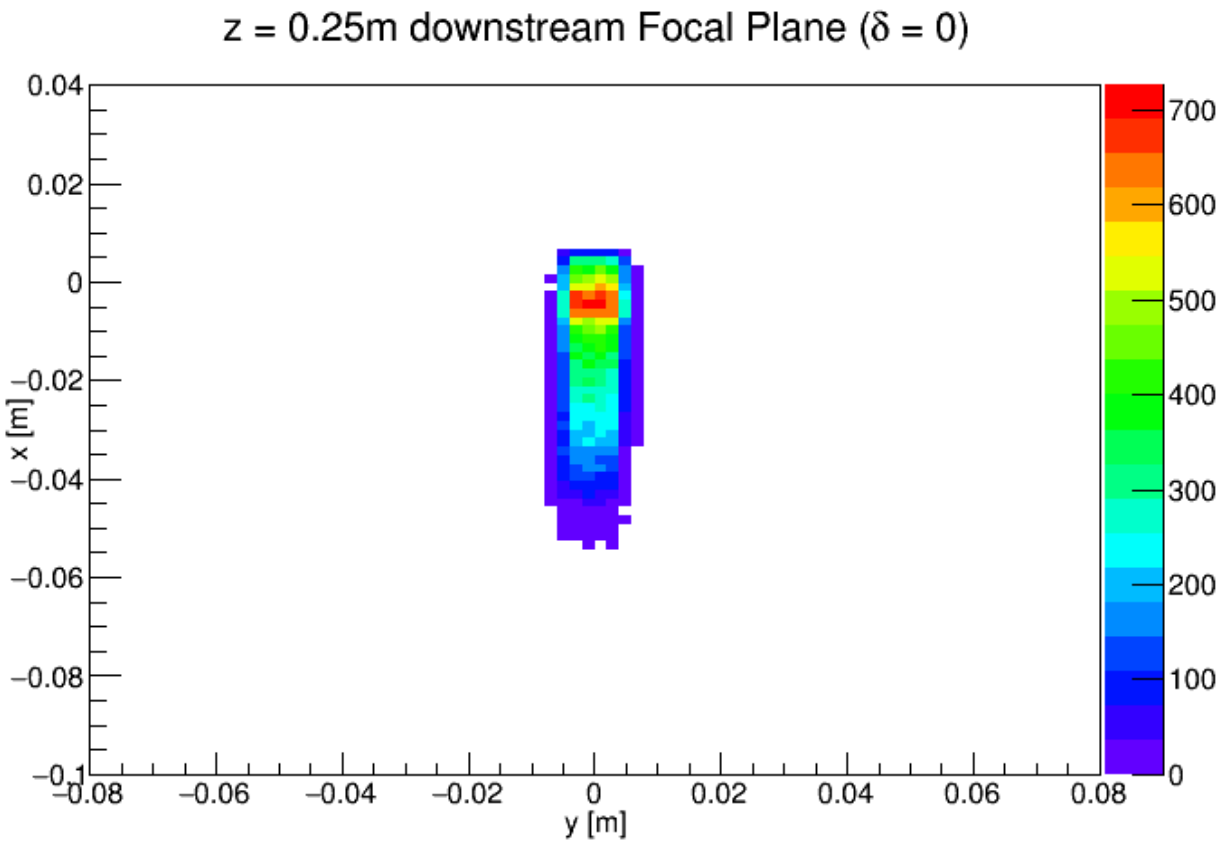

Focal Plane (δ = 0)
x [m]
y [m]

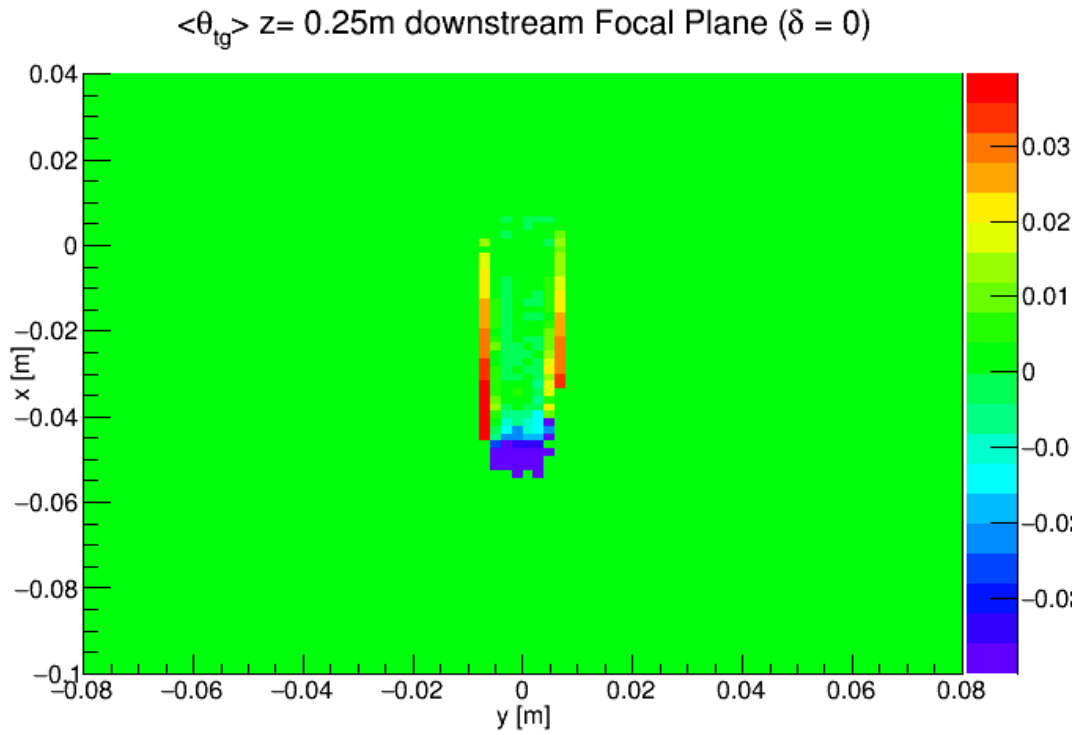

⟨θtg⟩ Focal Plane (δ = 0)
x [m]
y [m]


Rate, z from VDC = 1.0 m

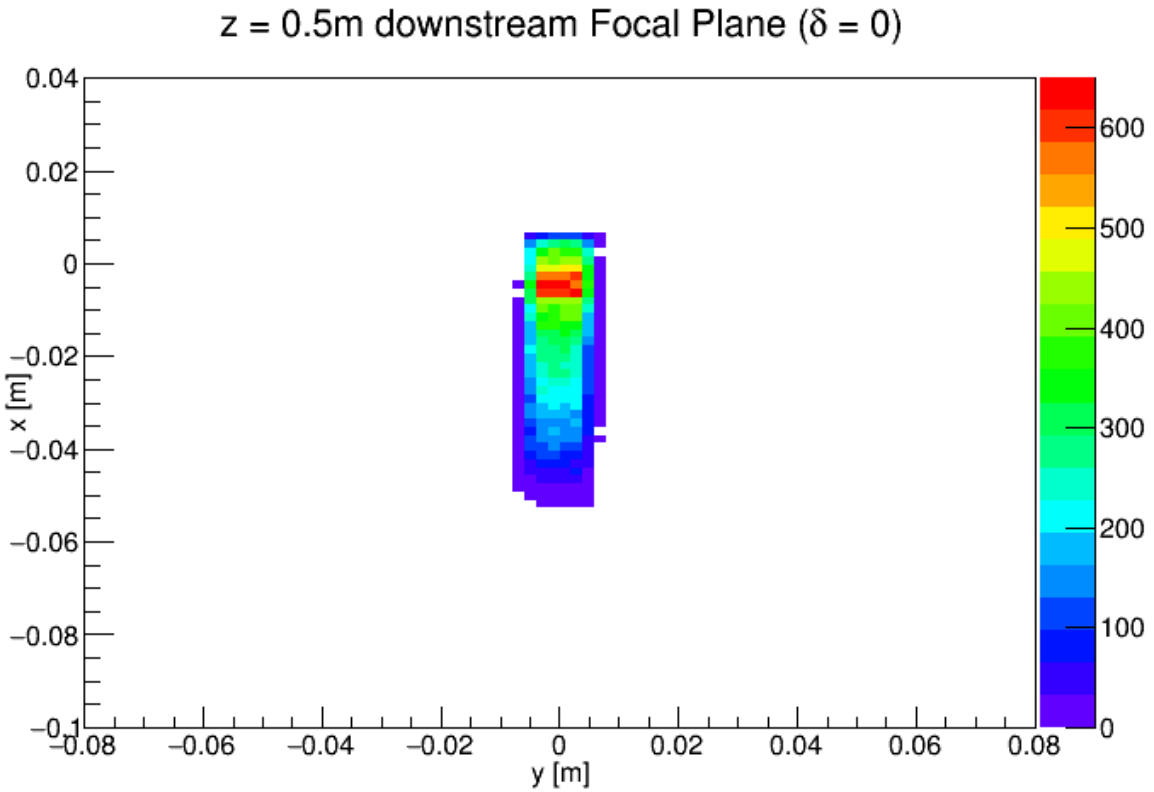

⟨θtg⟩, z from VDC = 1.0 m

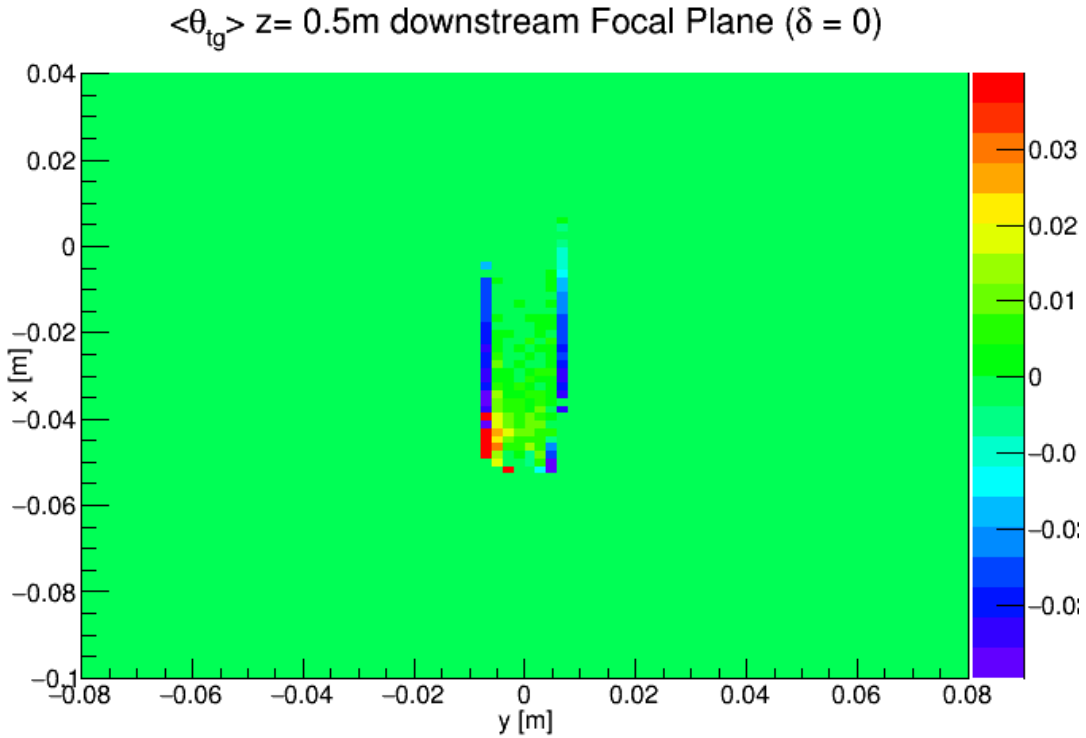
z Progression (0.25m down Focal Plane)



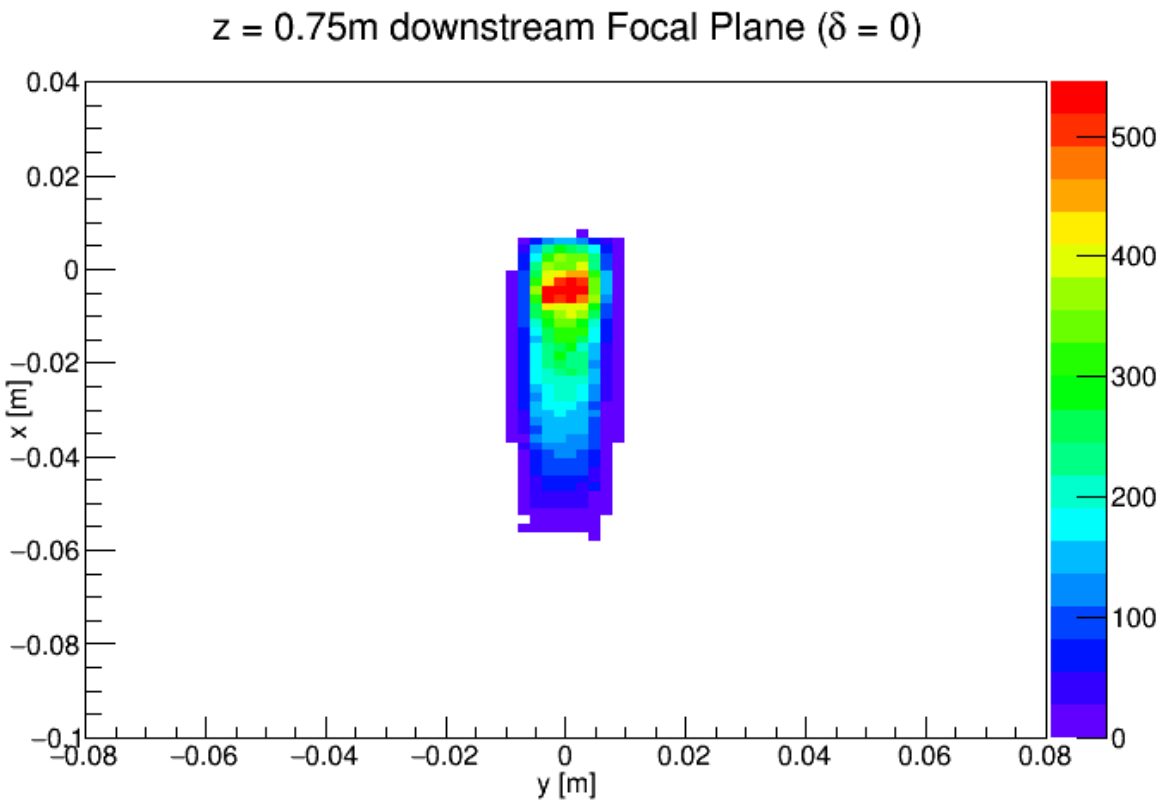


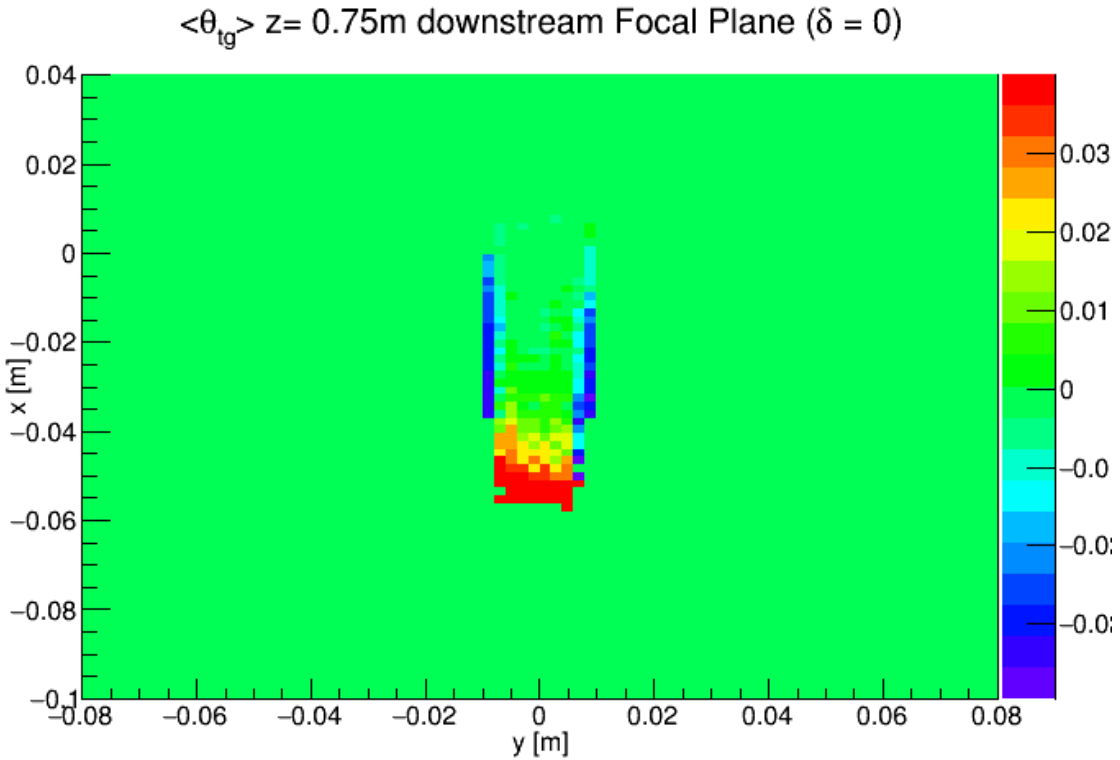
z Progression (0.5m down Focal Plane)



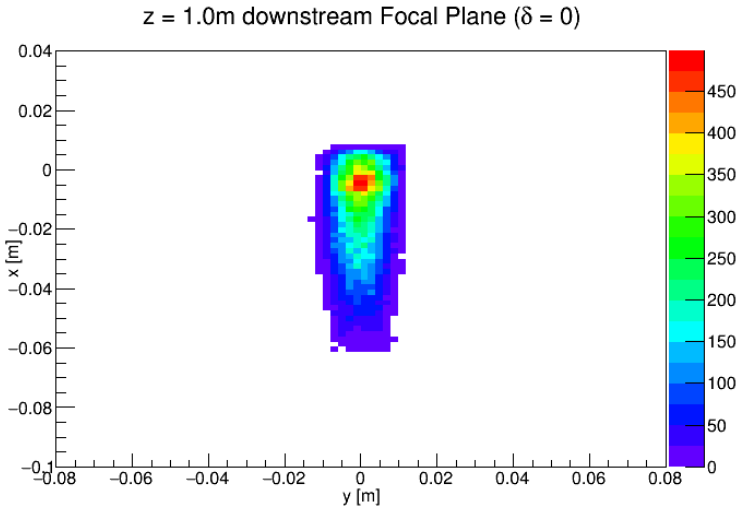


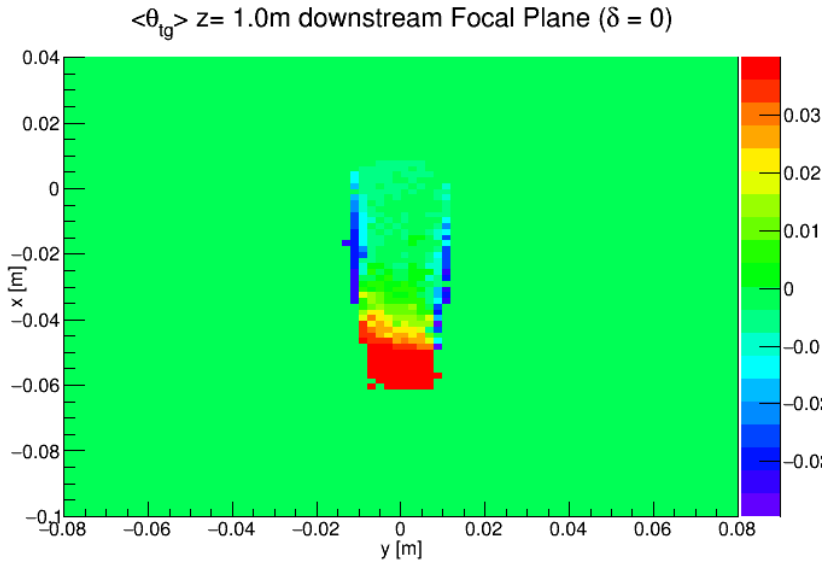
z Progression (0.75m downstream)

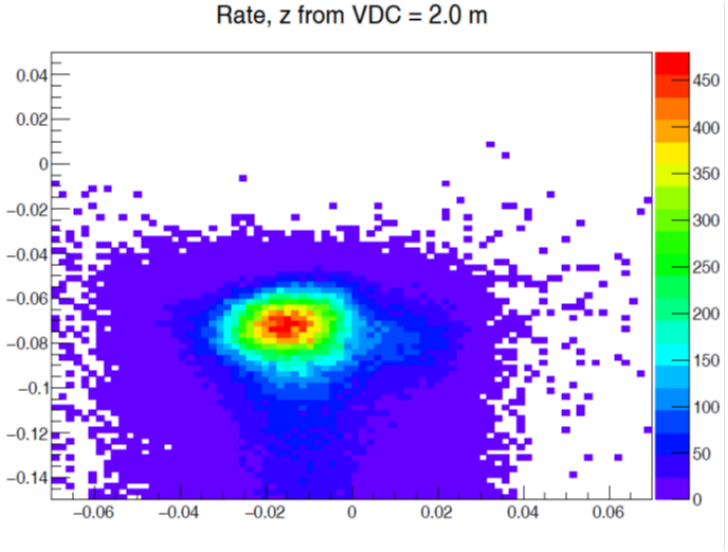


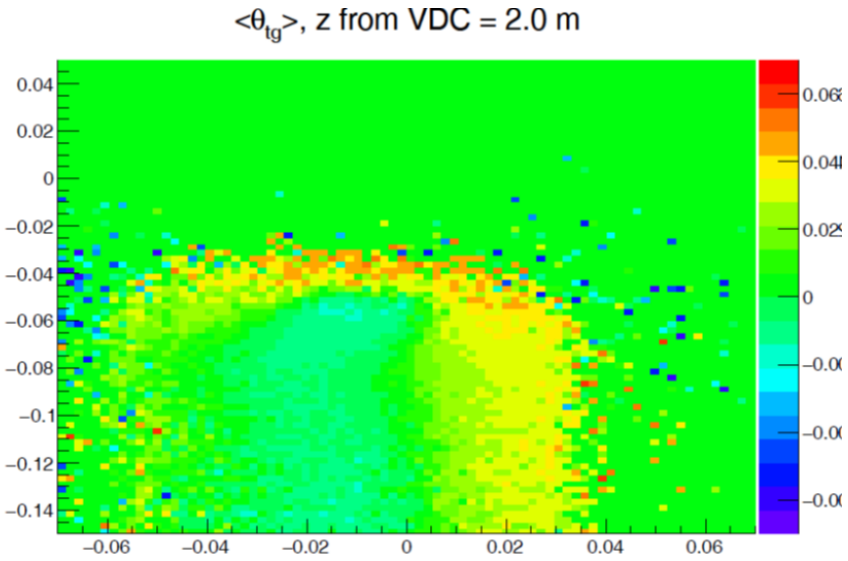


z Progression (1m down Focal Plane)









Summary

- Began exploring first and second order beam transport from the target

- Need to mistune septum for A_T studies and compare results with existing data.