Transfer matrix for Roman Pot detectors

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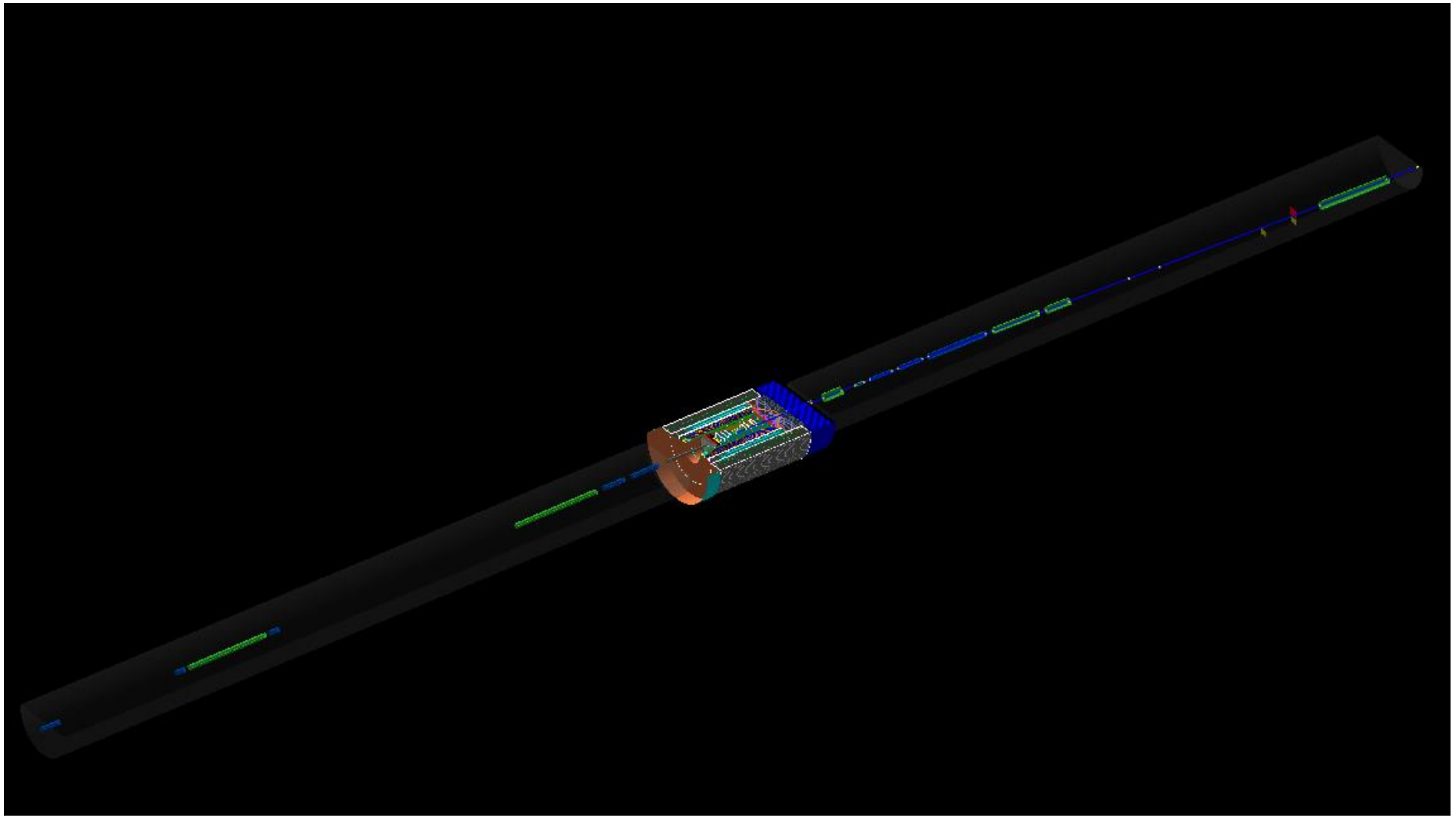
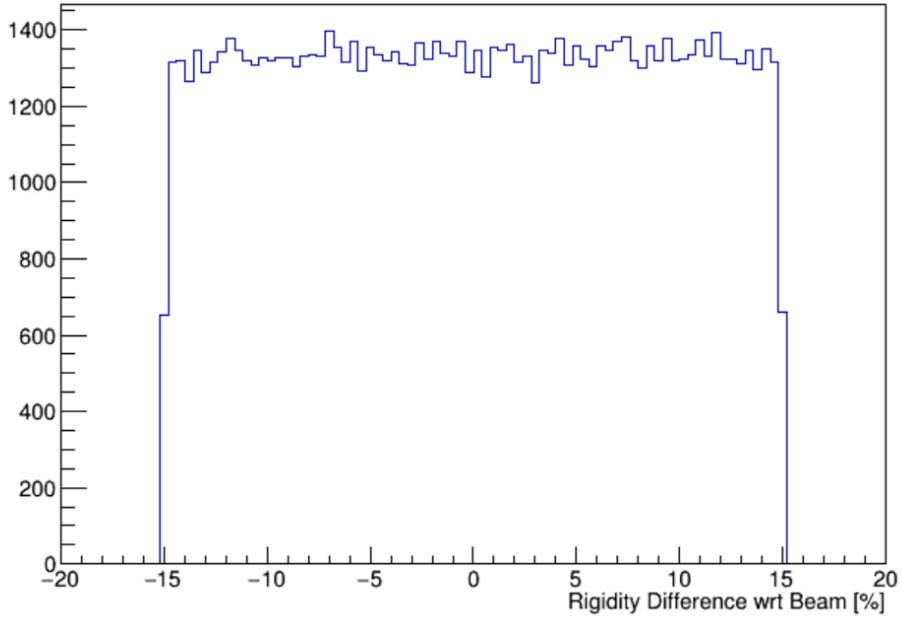
How to calculate 1st order reconstruction matrix

- As one example of analysis in the far-forward region, we want to be able to reconstruct 3 quantities at the interaction point (IP) – the relative rigidity (R_{Rig}) and the scattering angles ($\theta_{x,ip}$, $\theta_{y,ip}$) – as a function of the positions and angles measured at the Roman Pot (RP)
- We use the 275 GeV setting and generate single protons as follows
  1. Fluctuate R_{Rig} with $\theta_{x,ip} = \theta_{y,ip} = 0$
  2. Fluctuate $\theta_{x,ip}$, with $R_{Rig} = \theta_{y,ip} = 0$
  3. Fluctuate $\theta_{y,ip}$, with $R_{Rig} = \theta_{x,ip} = 0$
- We can then calculate the positions (at one of the RPs – we choose the second one) and angles at the RP as function of the IP quantities. Inverting these relations will allow us to determine the reconstruction matrix.

Current IP6 configuration



First configuration: R_{Rel} generation

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SIMPLE Event FILE
==================
I, ievent, nParticles
=============================================
I  K(I,1)  K(I,2)  K(I,3)  K(I,4)  K(I,5)  P(I,1)  P(I,2)  P(I,3)  P(I,4)  P(I,5)  V(I,1)  V(I,2)  V(I,3)
=============================================
0         0         2
=============================================
1     21     11      0      3      4          0          0        -10            10    0.000511      0      0      0
2     21   2212      0      0      0          0          0        275    275.0016007      0.9383      0      0      0
3     21     22      1      0      0          0          0        -15             5           0      0      0      0
4      1     11      1      0      0          0          0          5             5    0.000511      0      0      0
5      1   2212      0      0      0          0          0    310.857       310.858      0.9383      0      0      0
=============== Event finished ===============
0         1         2
=============================================
1     21     11      0      3      4          0          0        -10            10    0.000511      0      0      0
2     21   2212      0      0      0          0          0        275    275.0016007      0.9383      0      0      0
3     21     22      1      0      0          0          0        -15             5           0      0      0      0
4      1     11      1      0      0          0          0          5             5    0.000511      0      0      0
5      1   2212      0      0      0          0          0    237.759       237.761      0.9383      0      0      0
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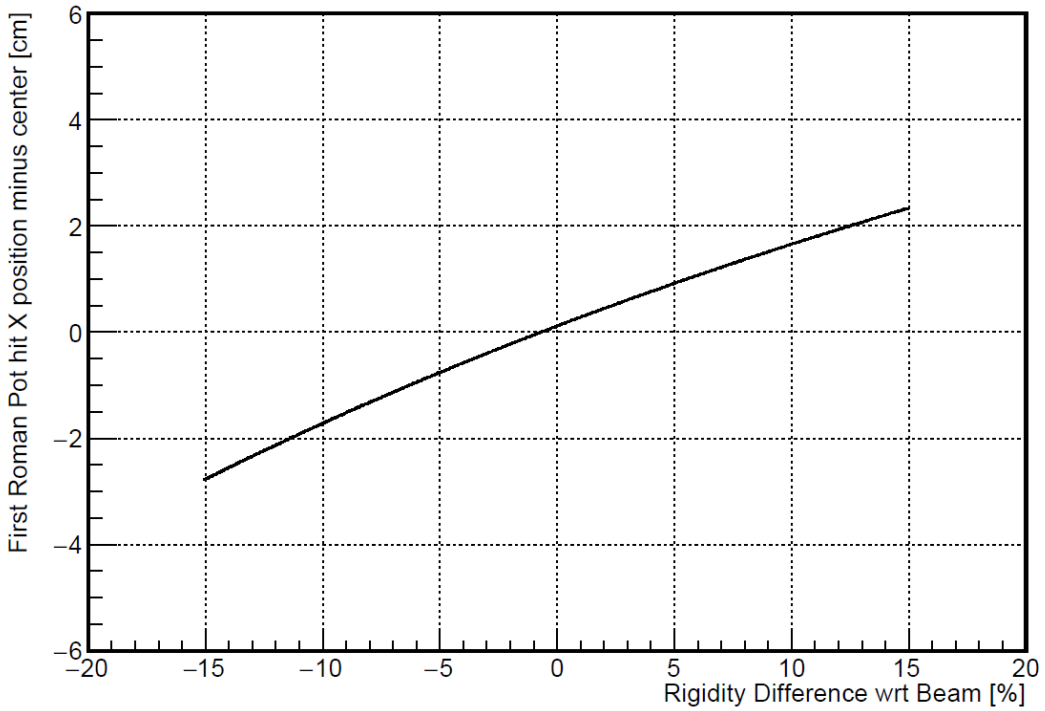
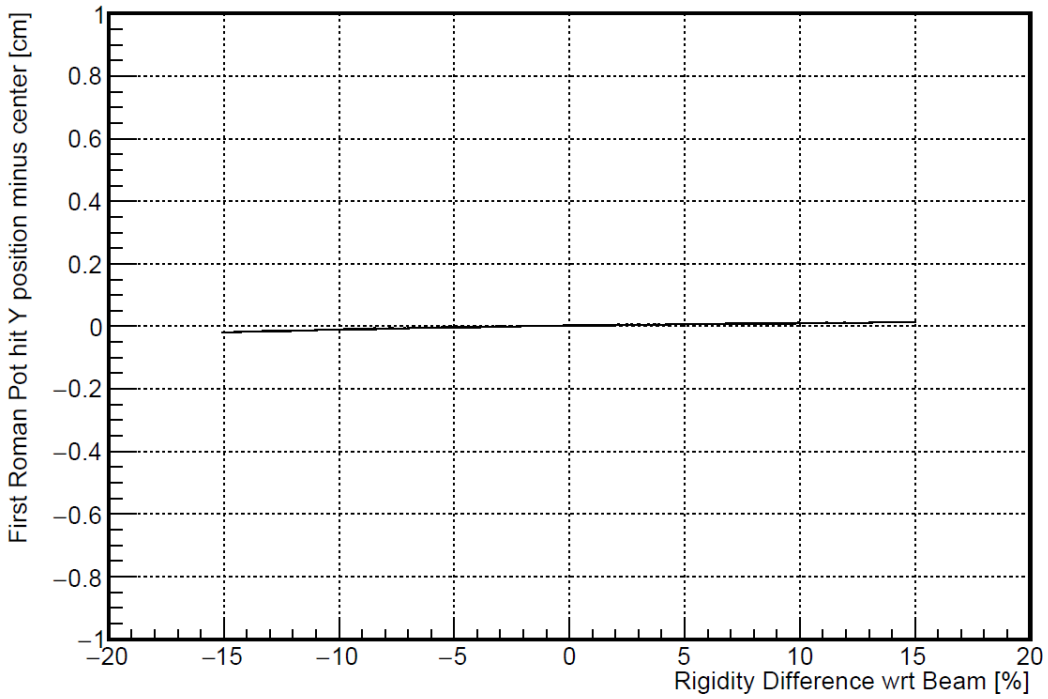
- Forward spectrometer set assuming 275 GeV proton beam.
- Protons are then generated with rigidity difference of [-15%,15%], and no transverse momentum. That is, protons are generated with a momentum (0,0,275*(1+relative rigidity)).
- The *eic-smear* format SIMPLE format is useful for this purpose.
- Next, a minimal (i.e. smallest possible change in energy) Lorentz transformation is applied so that the proton beam goes at 25mRad relative to the z-direction. This causes the generated protons to have some transverse momentum, which is a function of the rigidity difference.

Changes to default simulation

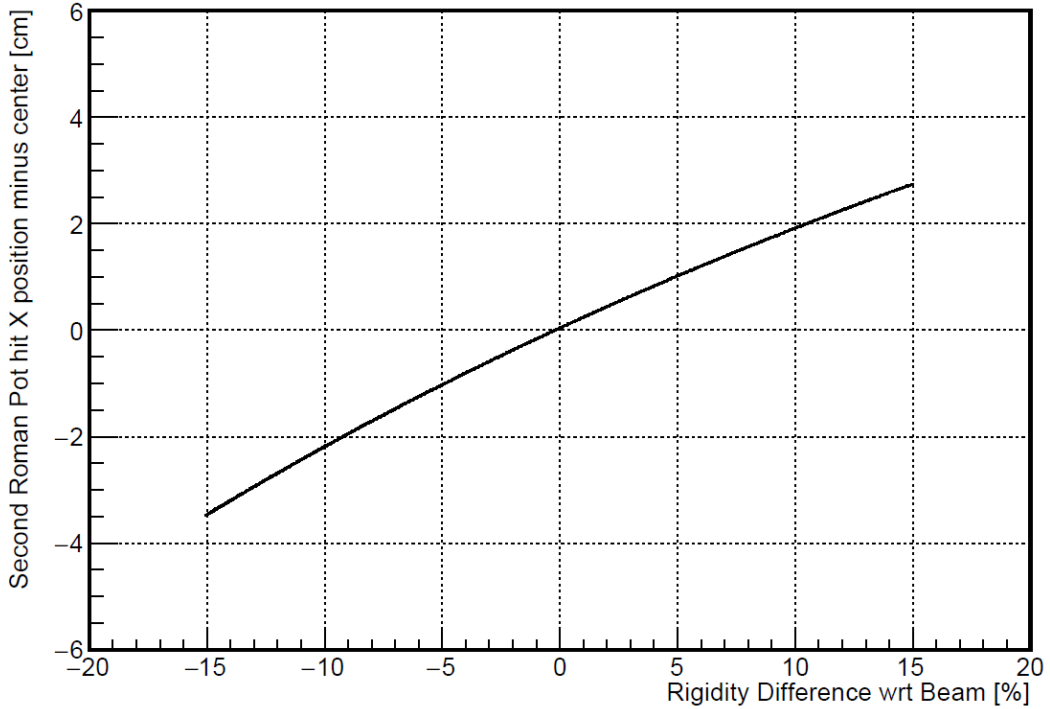
- For these studies, it is simplest to only turn on the far-forward region. Also, we turn off all smearing effects in order to get the 'true' transport matrix.
- Step-by-step, we do the following:
  1. In steering macro, remove central detector and set world volume to **G4_Galactic** and turn off far-forward beam pipes
  2. Use crossing angle in G4_Input.C, but turn off all other beam effects

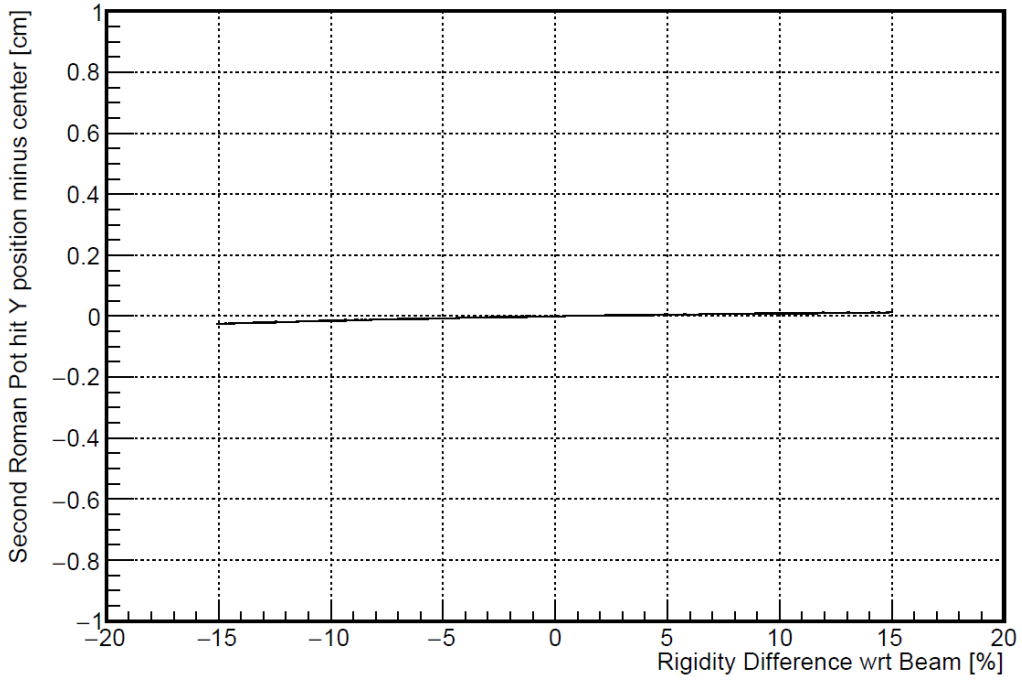
Dependence on R_{Rel} – I



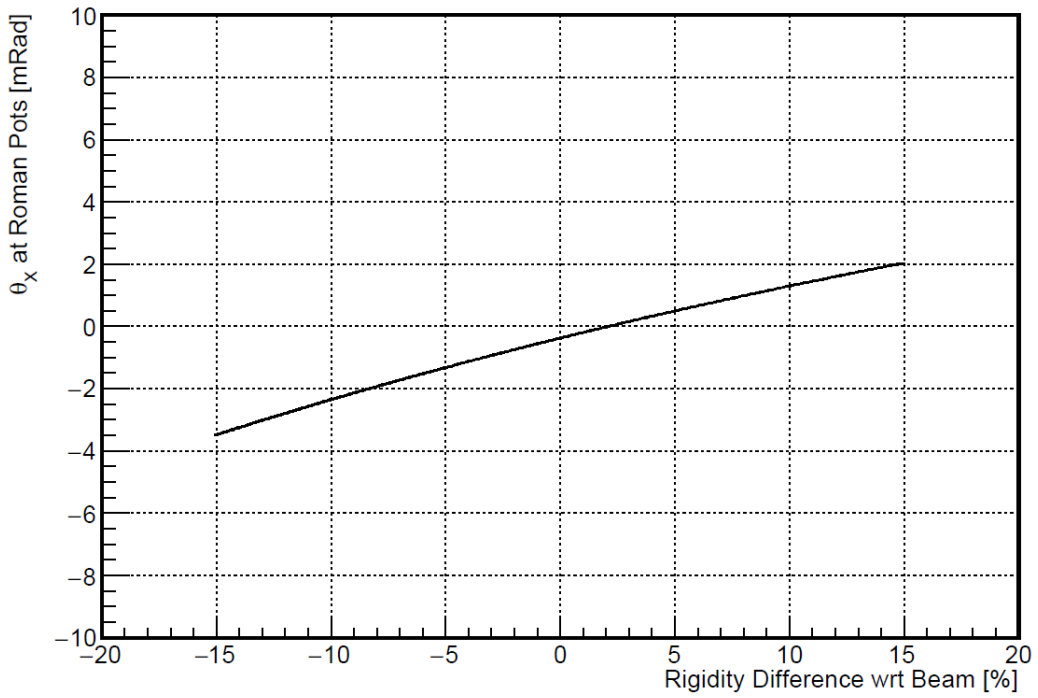


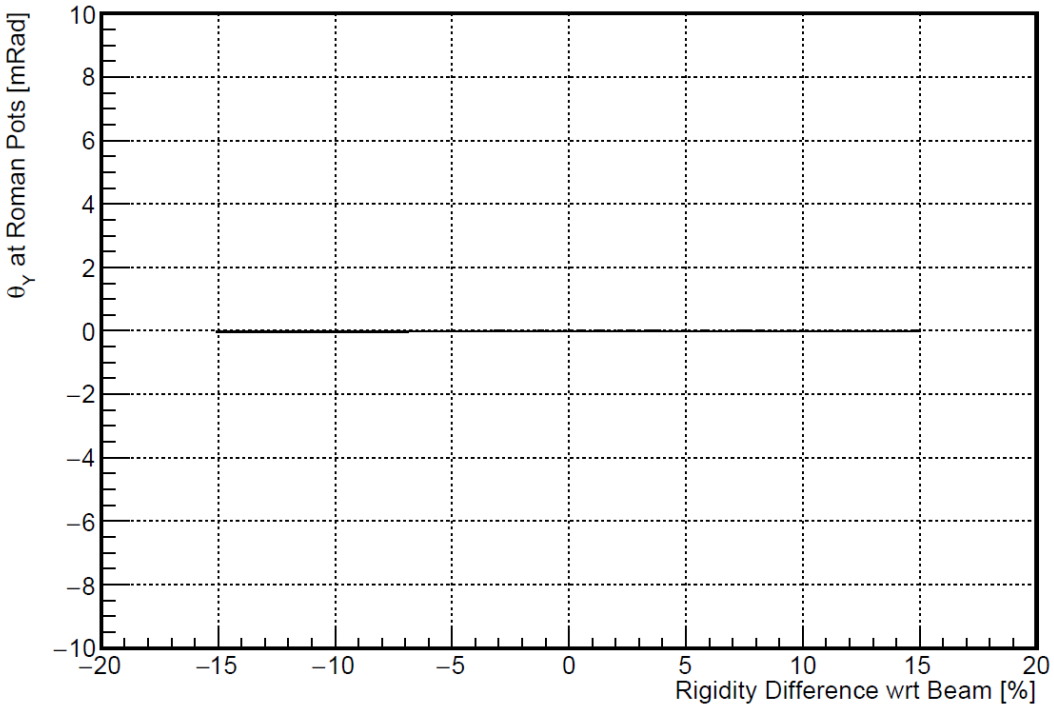
Dependence on R_{Rel} – II



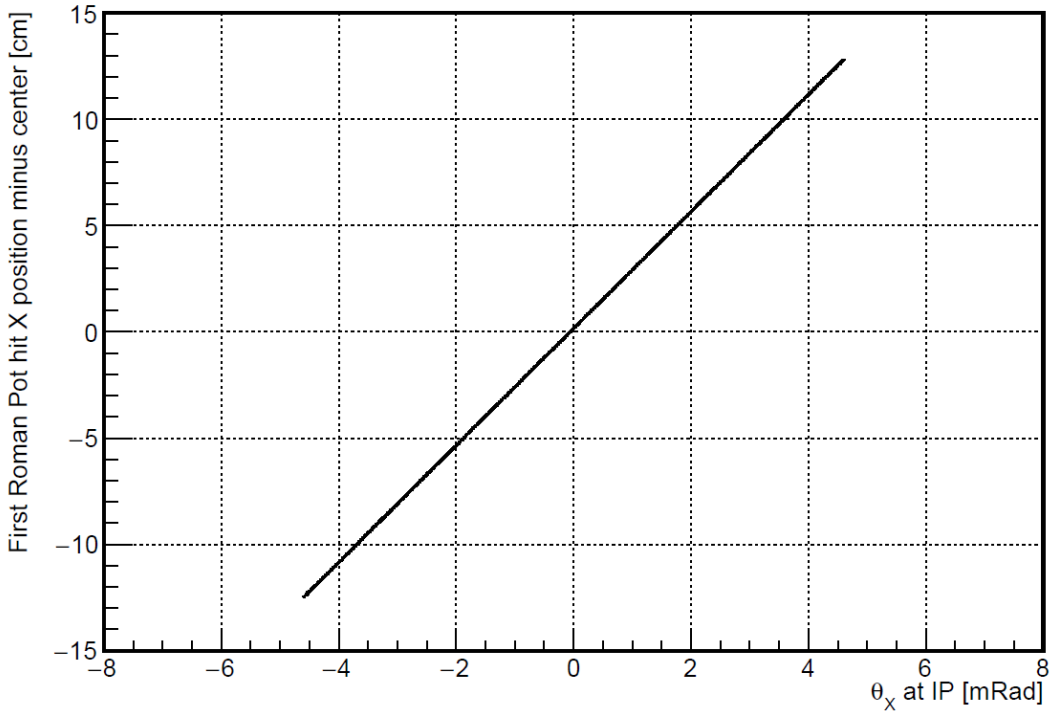


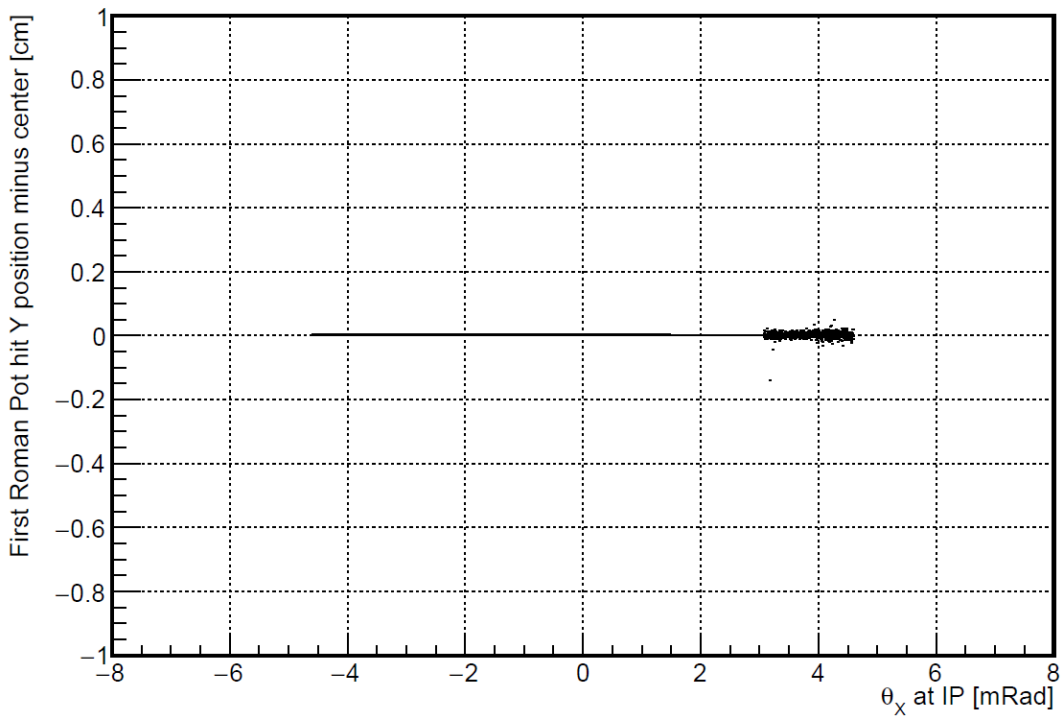
Dependence on R_{Rel} – III



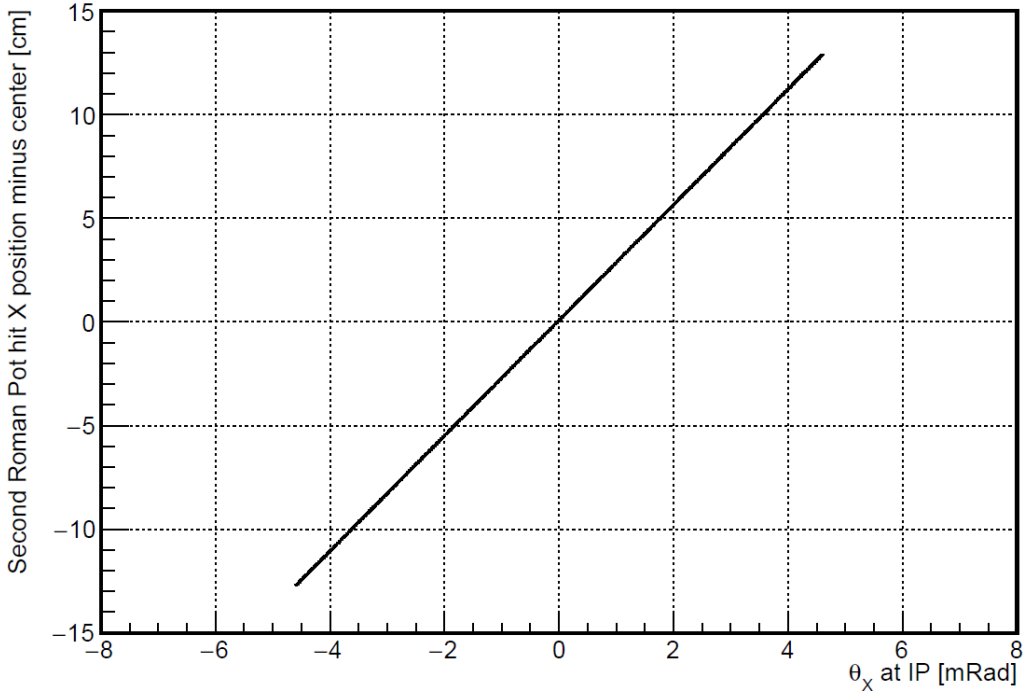


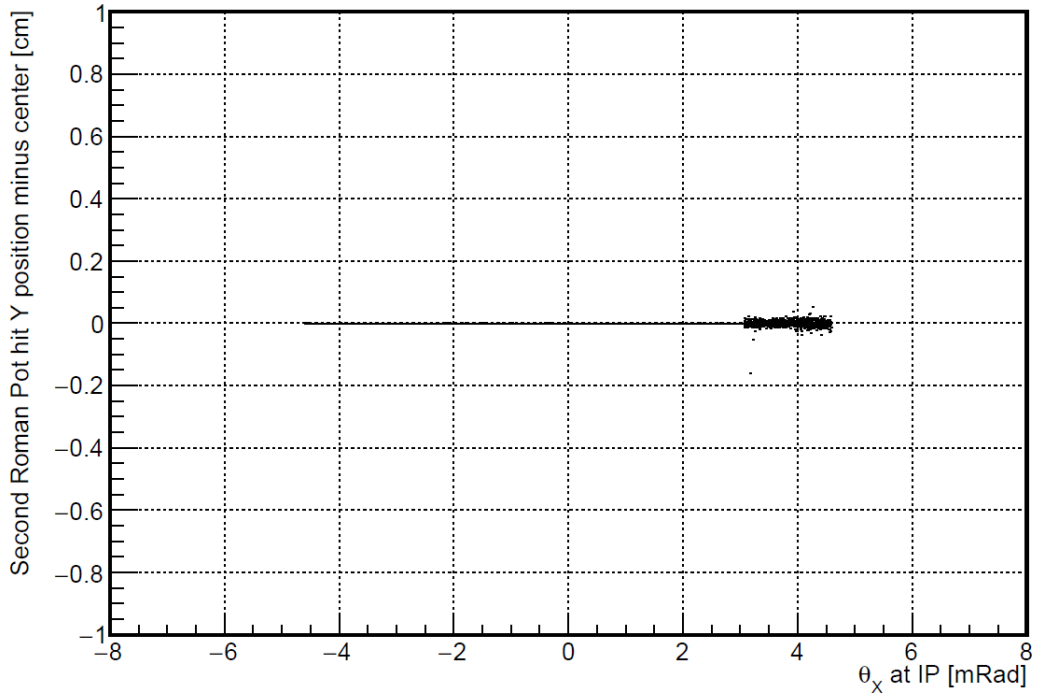
Dependence on $\theta_{X,ip}$ – I



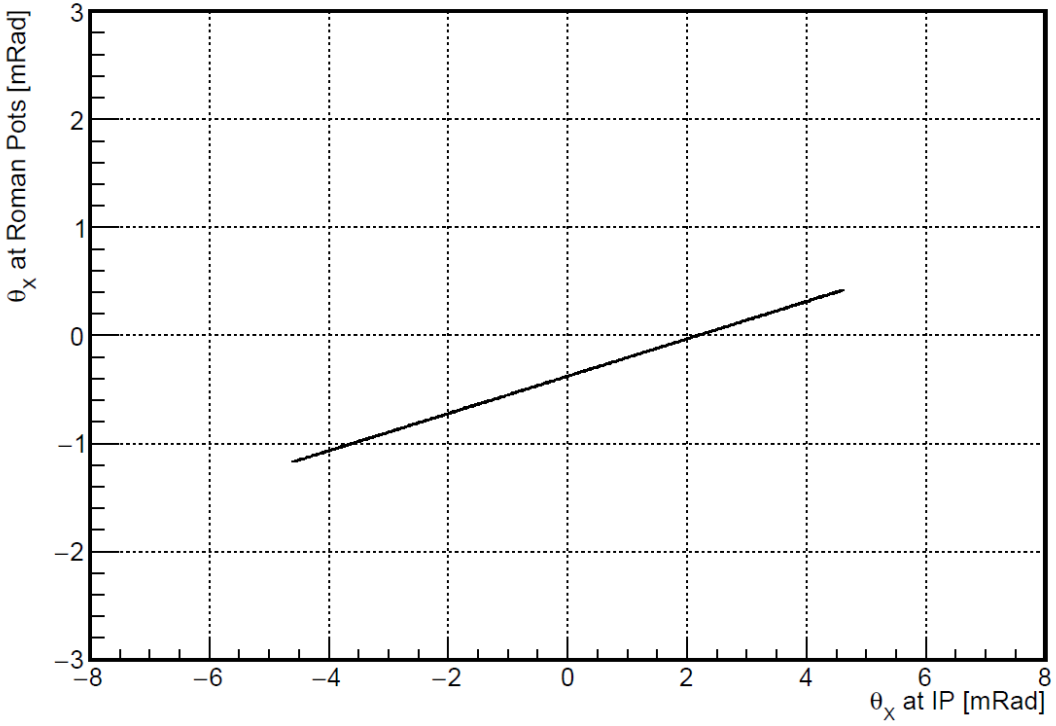


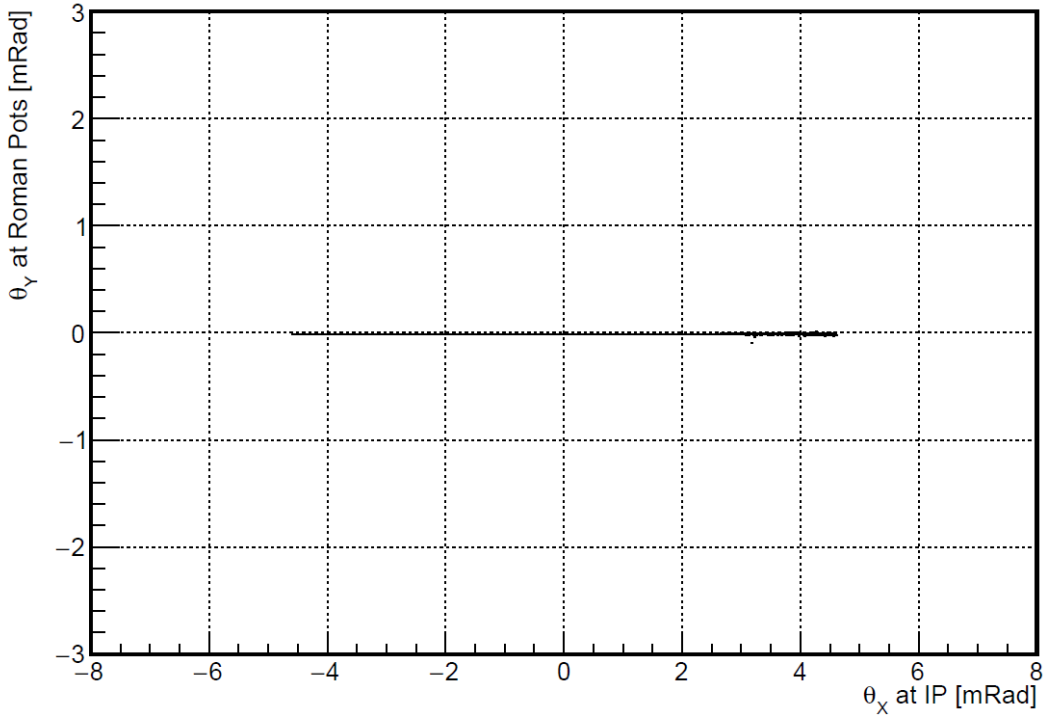
Dependence on $\theta_{X,ip}$ – II



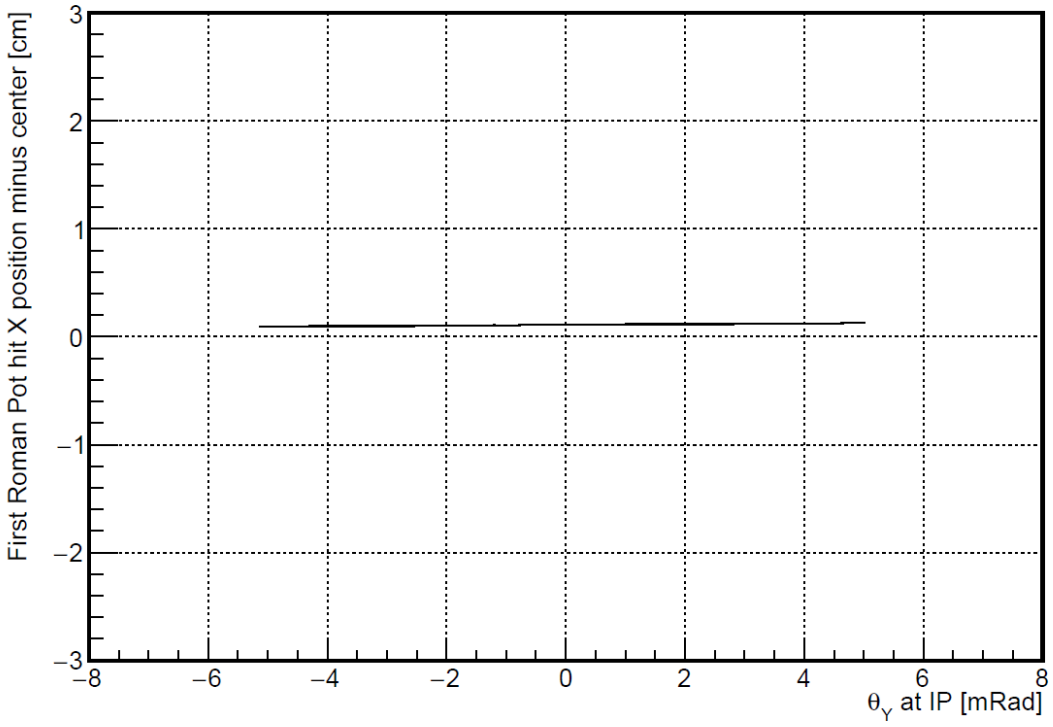


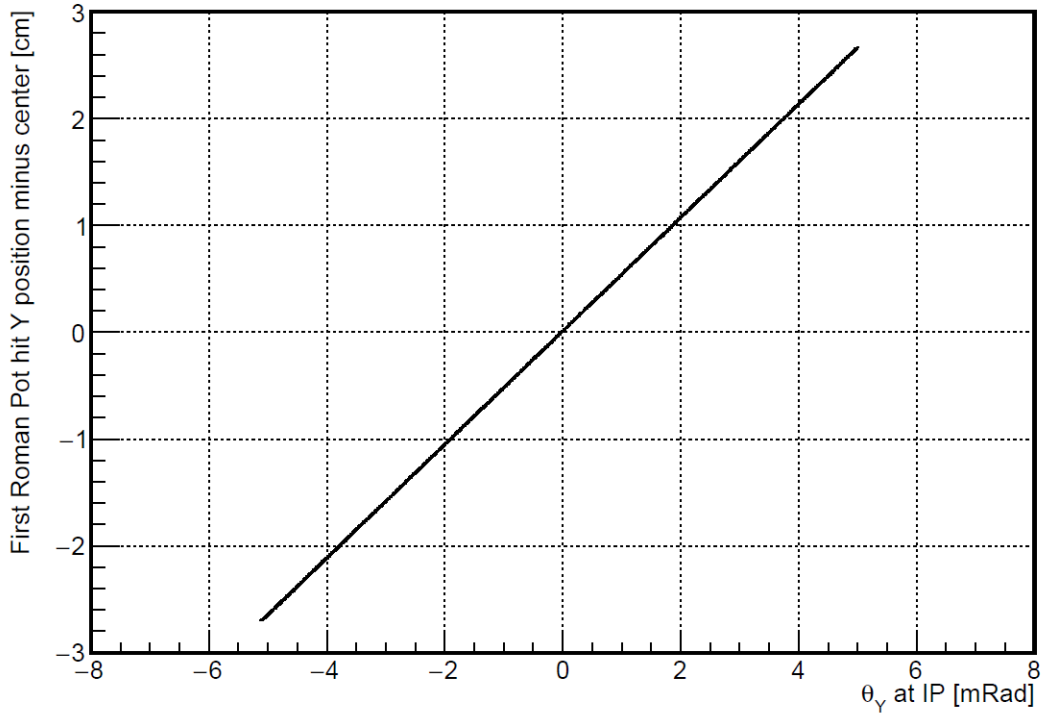
Dependence on $\theta_{X,ip}$ – III



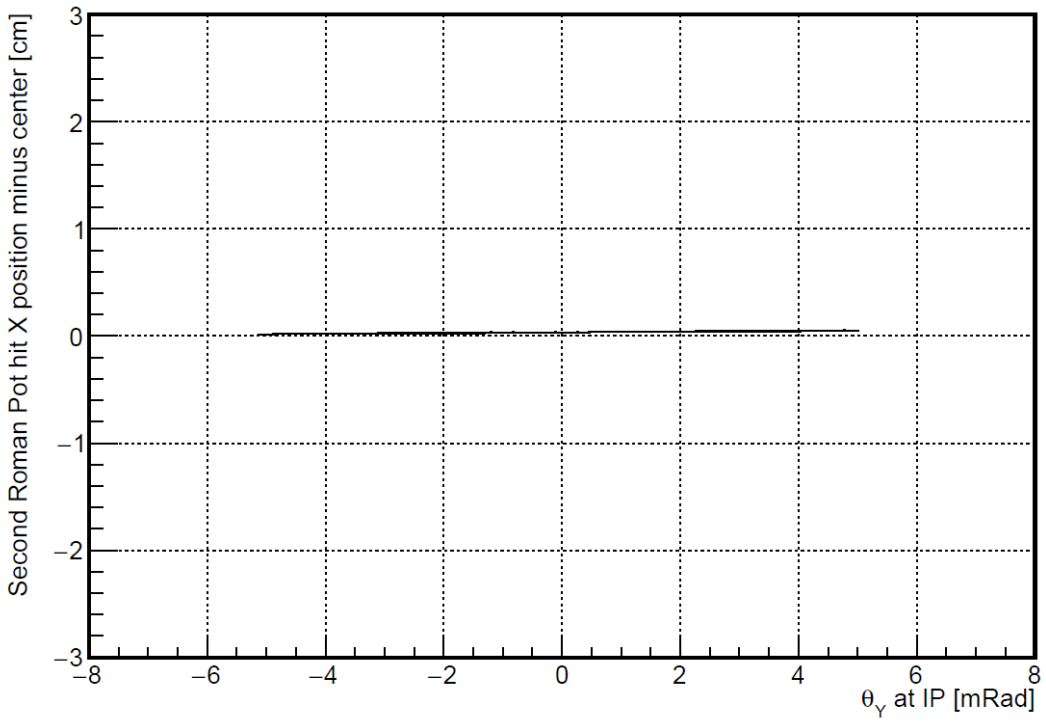


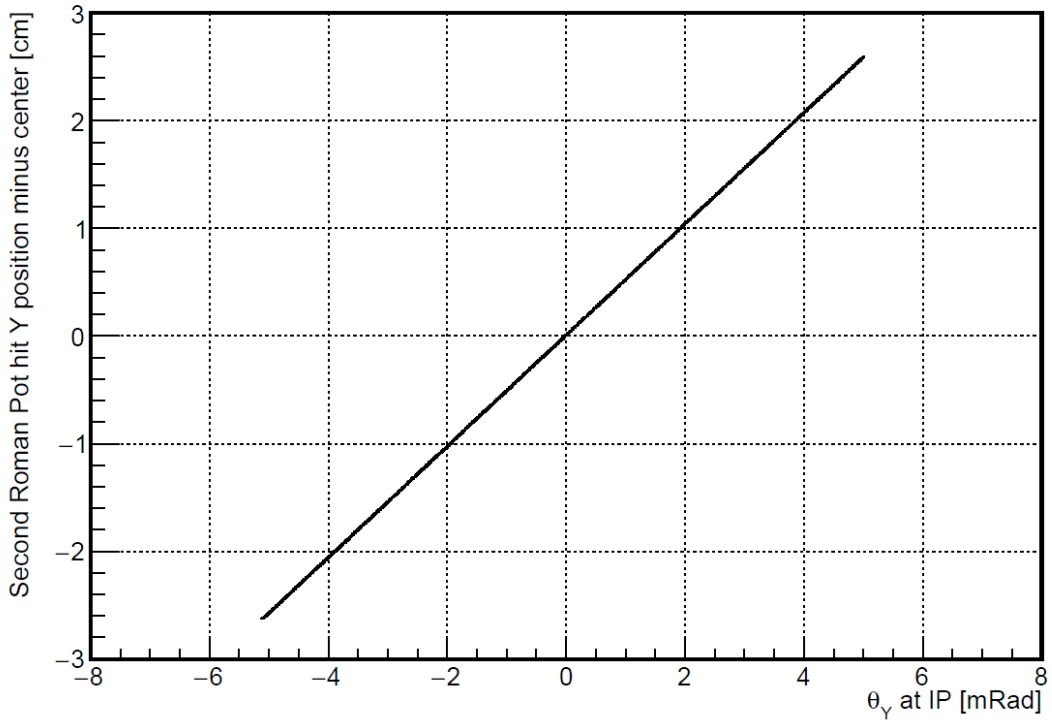
Dependence on $\theta_{Y,ip}$ – I



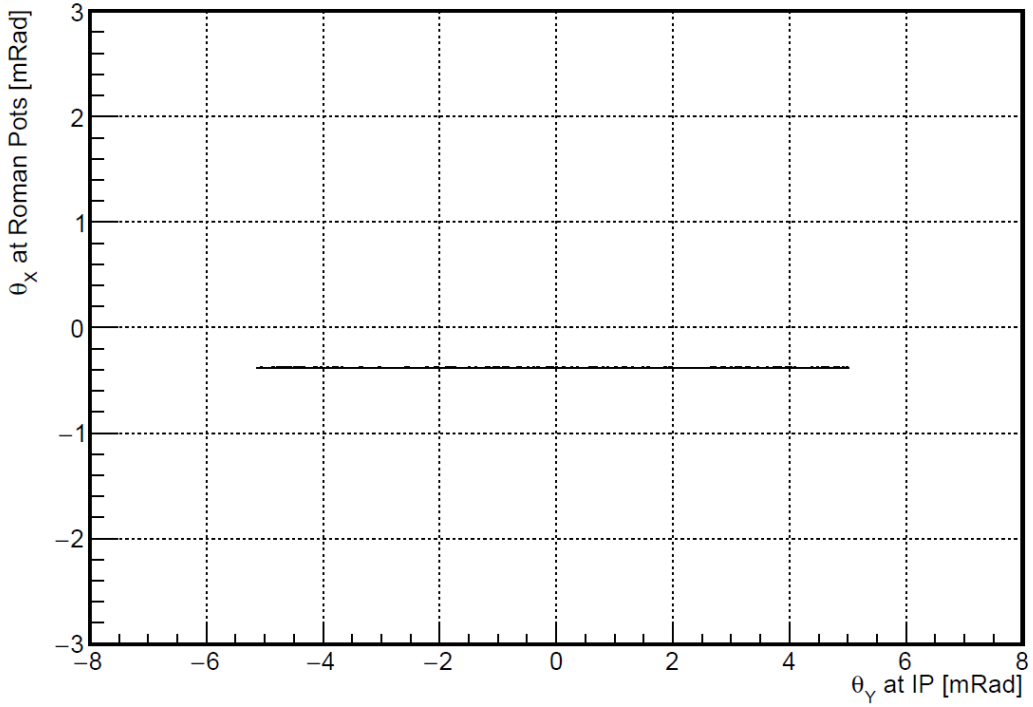


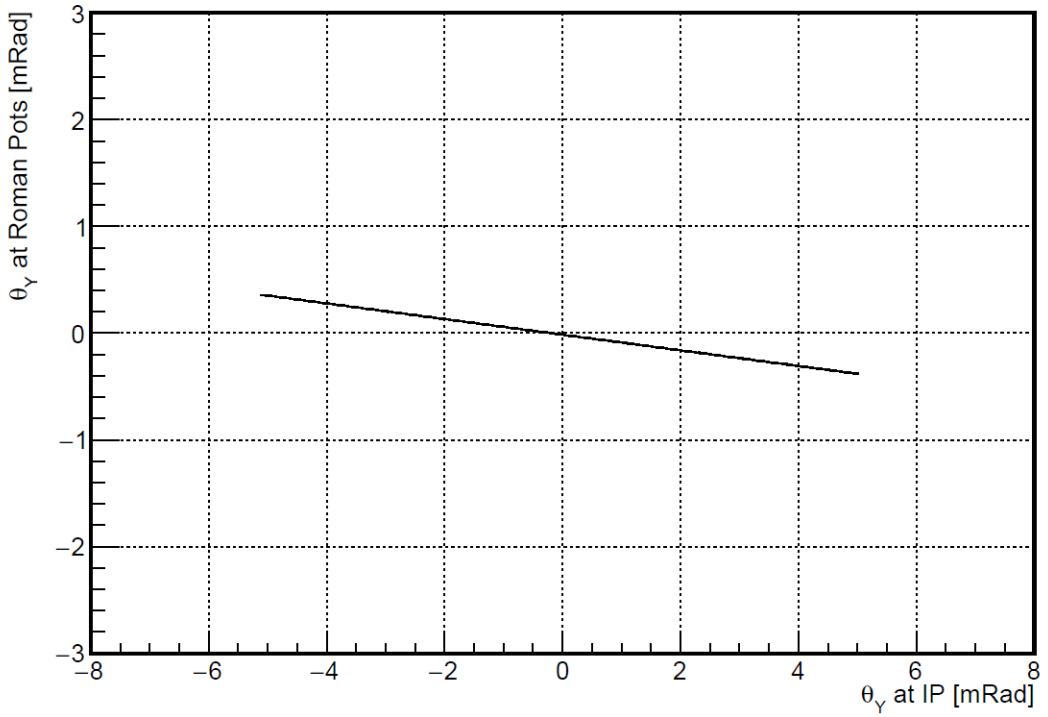
Dependence on $\theta_{Y,ip}$ – II





Dependence on $\theta_{Y,ip}$ – III





Calculated reconstruction matrix

$$\begin{bmatrix} x_{rp2} \\ \theta_{x,rp} \\ y_{rp2} \\ \theta_{y,rp} \end{bmatrix} = \begin{bmatrix} 2.77 & 0 & 0.201 \\ 0.169 & 0 & 0.182 \\ 0 & 0.513 & 0 \\ 0 & -0.072 & 0 \end{bmatrix} \begin{bmatrix} \theta_{x,ip} \\ \theta_{y,ip} \\ R_{Rel} \end{bmatrix} + \begin{bmatrix} 0.027 \\ -0.418 \\ -0.007 \\ -0.007 \end{bmatrix}$$

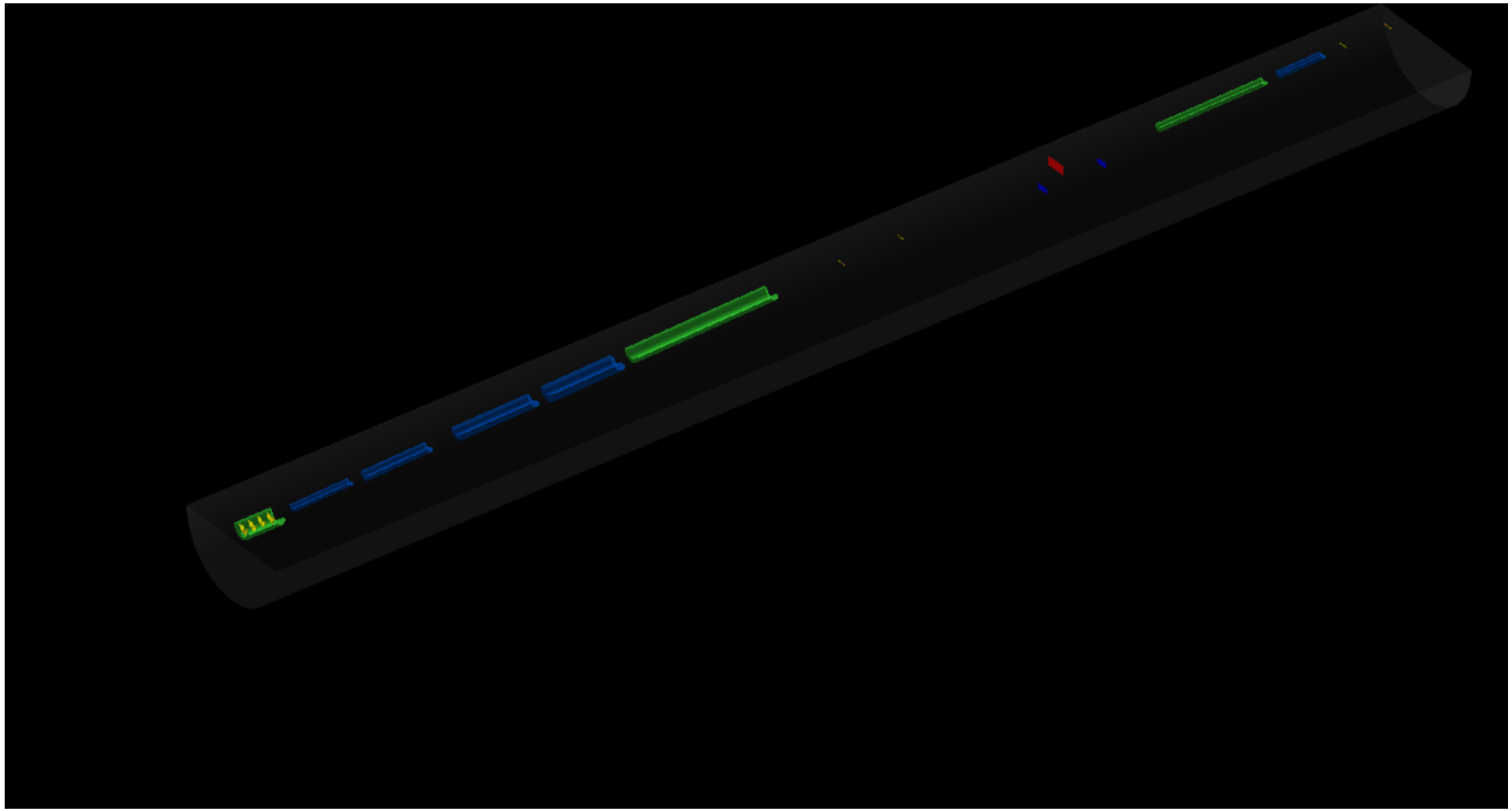
Positions in cm
Angles in mRad
Rigidity in %

$$\begin{bmatrix} x_{rp2} \\ \theta_{x,rp} \\ y_{rp2} \\ \theta_{y,rp} \end{bmatrix}_{corr} = \begin{bmatrix} x_{rp2} \\ \theta_{x,rp} \\ y_{rp2} \\ \theta_{y,rp} \end{bmatrix} - \begin{bmatrix} 0.027 \\ -0.418 \\ -0.007 \\ -0.007 \end{bmatrix}$$

$$\begin{bmatrix} \theta_{x,ip} \\ \theta_{y,ip} \\ R_{Rel} \end{bmatrix} = \begin{bmatrix} 0.387 & -0.428 & 0 \\ 0 & 0 & 1.95 \\ -0.359 & 5.89 & 0 \end{bmatrix} \begin{bmatrix} x_{rp2} \\ \theta_{x,rp} \\ y_{rp2} \end{bmatrix}_{corr}$$

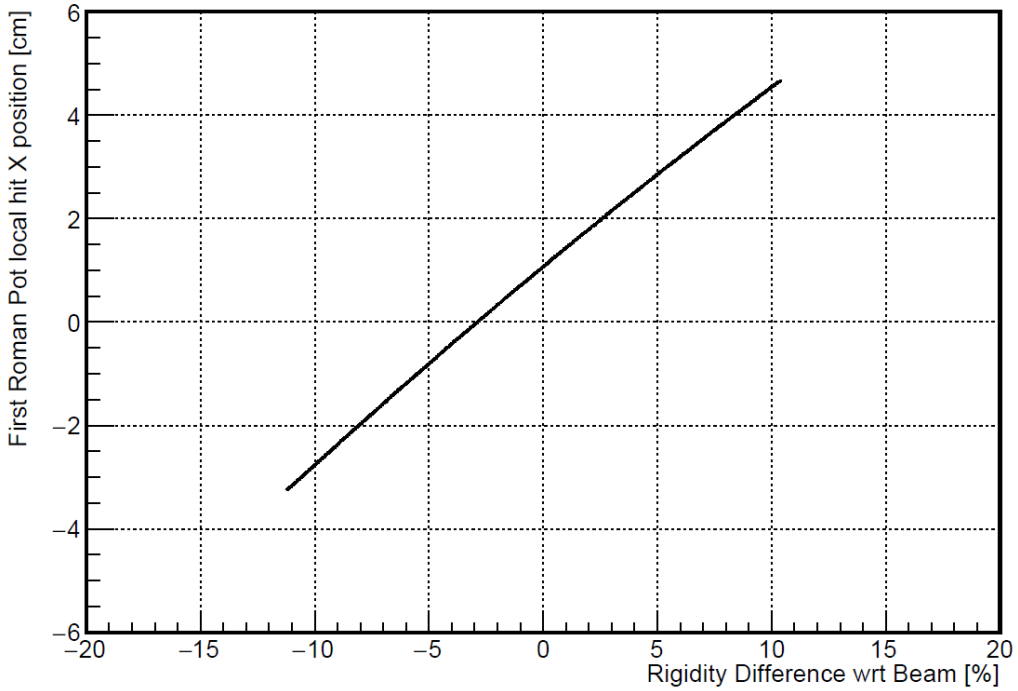
Can use either y_{rp2} or $\theta_{Y,rp}$

Current IP8 configuration

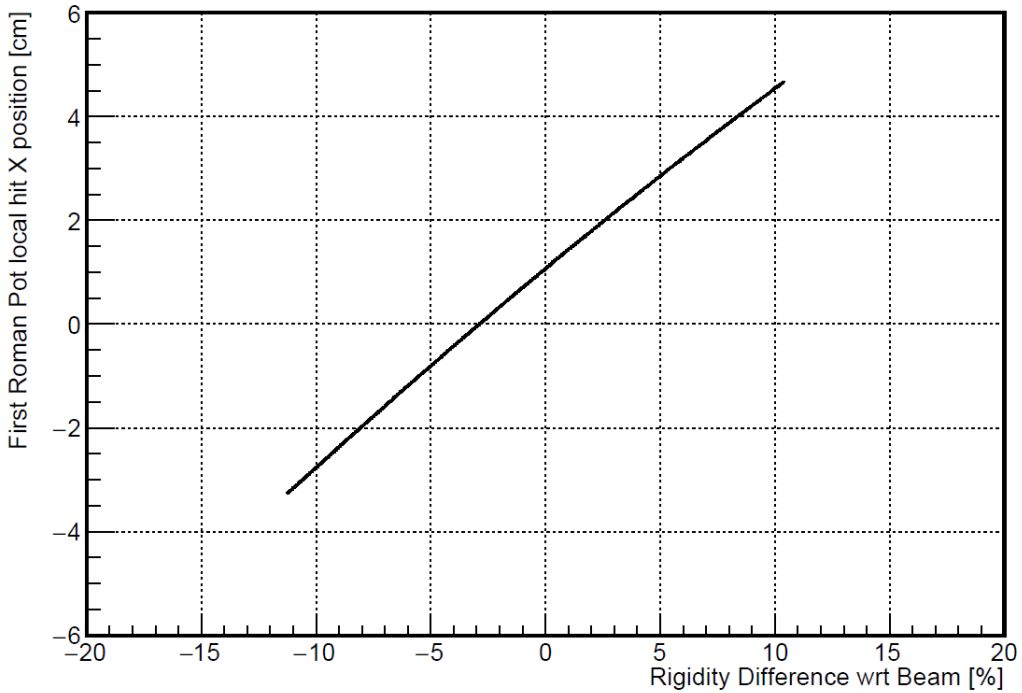


IR8 RP1 (in second set of RPs) x position vs. R_{Rel}

100 GeV Results



275 GeV Results



- **Good linear dependence**
- **Independent of beam energy**
- **Large offset from zero**
- **Acceptance cut off at large $|R_{Rel}|$**