Updated Roman Pot Study for Ring-Ring: Acceptance, pT reconstruction, and divergence

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eRHIC IR Meeting

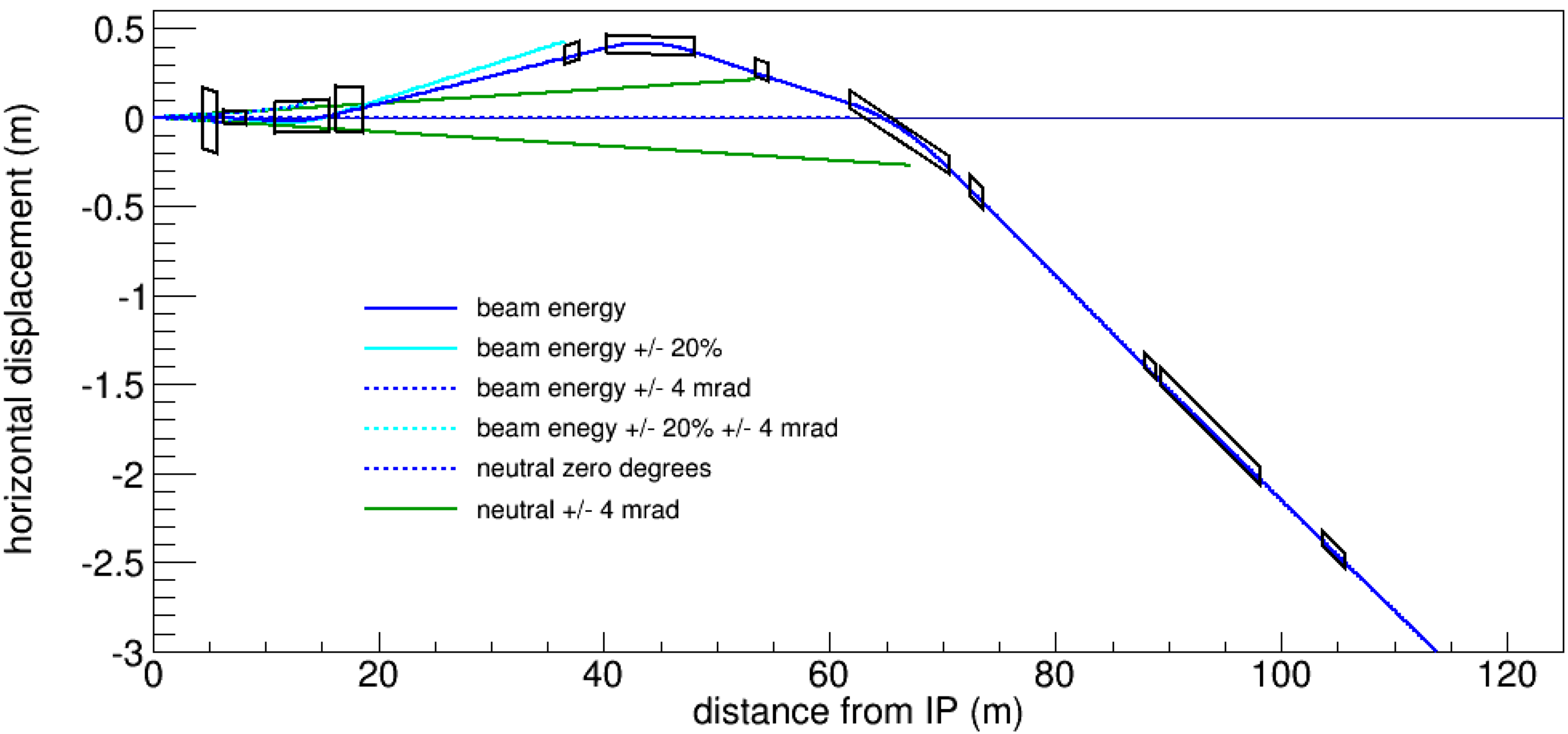
3-3-17

Parameters of the IR

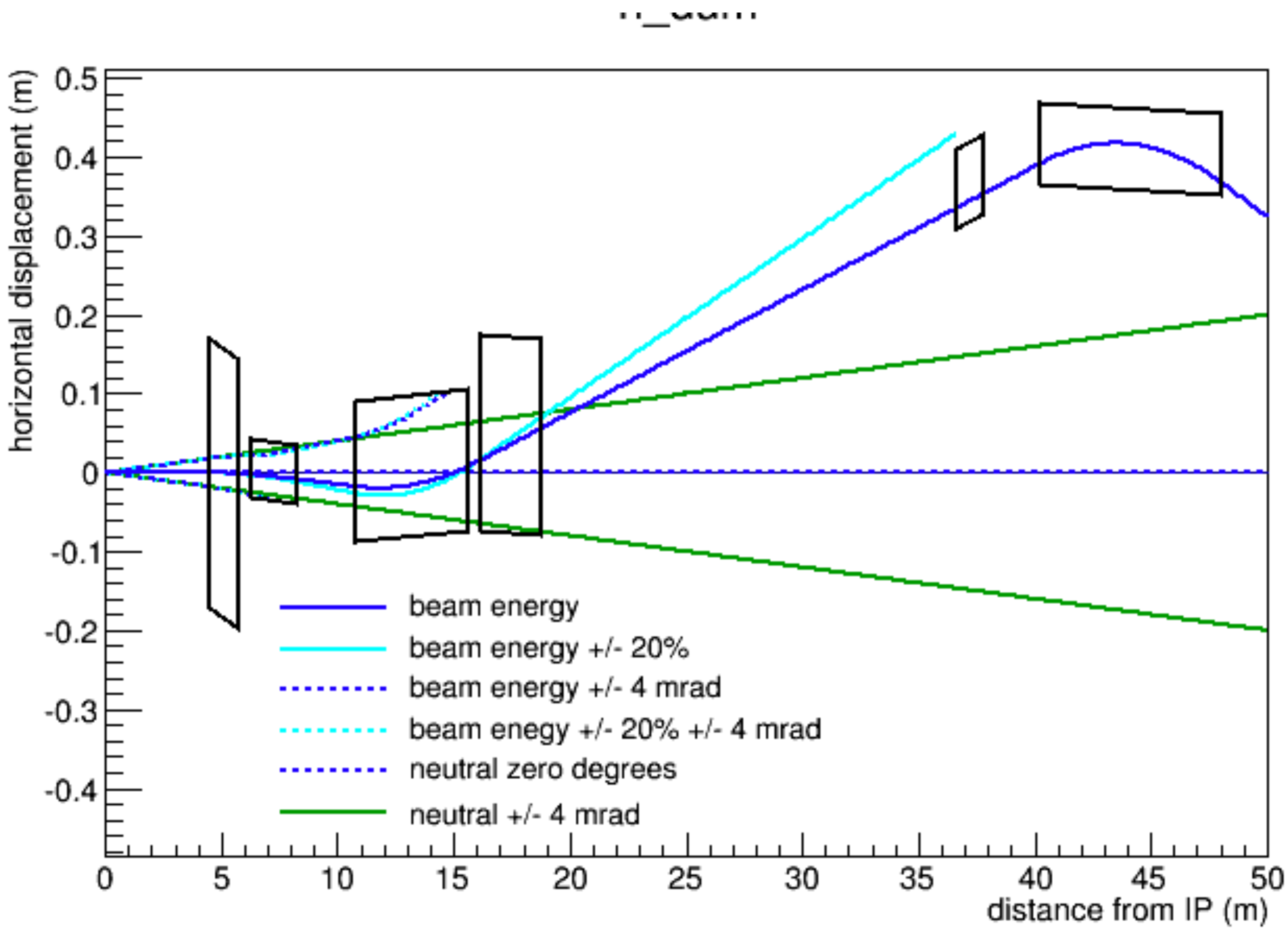
Un-normalized?

```
## 13/2/2017 forward hadrons at 275 GeV/c
## using Palmer's file is beta82cg
## For 'High Luminosity' parameters giving, with electron energy 10.1 GeV, Lum = 2.86 10^33
## Plots and other parameters were distributed on 11/2/2017 in a file 1702-IR Design-v2.pdf
##
## The design reflects Sergei's shift of B3 to the right by 9.4 m
## A new quad NQ was introduced to better control the betas at R3 and R4
##
## Warning:
## This design was simulated by a home made program and may not exactly agree with
## madX and other codes
## The detector solenoid is not included
## ---------------------------------------------------------------
## Initial conditions at IP
##
## beta*_x   beta*_y   g emit_x  g emit_y   angle_x   angle_y
##  [m]        [m]    |  [nm]      [nm]     [mrad]    [mrad]

 0.9440    0.0420    16.1000   6.1000      0        0
## ----------------------------------------------------------------
## magnet parameters
##
##name   center_z center_x center_y radius   length   angle      B      gradient
##           [m]       [m]       [m]      [m]       [m]    [mrad]     [T]      [T/m]
##
  B0pf    5.099  -0.0132    0.00  0.1700    1.200  -22.00    1.700     0.00
  Q1pf    7.289   0.0020    0.00  0.0370    1.981   -4.00    0.000   -91.54
  B1pf   13.198   0.0097    0.00  0.0890    4.800    2.80   3.516     0.00
  Q2pf   17.457   0.0484    0.00  0.1250    2.520   -2.00    0.000    28.41
  Q3pf   37.192   0.3692    0.00  0.0500    1.200   16.20    0.000     0.89
  B2pf   44.091   0.4107    0.00  0.0510    7.800   -1.80   - 4.397     0.00
  Q4pf   53.988   0.2701    0.00  0.0500    1.200  -22.00    0.000    28.96
  B3pf   66.185  -0.0789    0.00  0.0500    8.800  -41.80   -4.400     0.00
  NQpf   72.984  -0.4202    0.00  0.0600    1.200  -63.54    0.000   -52.52
  Q5pf   88.380  -1.3975    0.00  0.0400    1.000  -63.47    0.000    55.00
  H1pf   93.754  -1.7386    0.00  0.0500    8.750  -63.45    0.000     0.00
  Q6pf  104.626  -2.4288    0.00  0.0400    2.000  -63.45    0.000    27.50
## x=0, z=0, y=0 is at the center of the IP
## The z axis is aligned with the inital mean hadron direction
## The apertures of B2 and B3 may be too large requiring changes in settings
## H1 is the spin rotator assumed not to focus or bend
## Q5 and Q6 are place holder for strengths to be set by matching
## --------------------------------------------------------------------------------
##
## parameters at the Roman Pots
##
##loc      Z       beta_x    beta_y    adv_x     adv_y     Disp
##        [m]      [m]       [m]      rad/pi    rad/pi     {m}
##
  R1      31.00    1197.6    195.70    0.476     0.52     0.205
  R2      35.00    1208.2    164.58    0.477     0.53     0.253
  R3      83.55      12.5     12.27    0.597     0.79    -2.051
  R4      86.40       4.4      5.54    0.722     0.90    -2.404

## Phase advance x in R3 should be kept to approx 0.6 and may need tweeking
## beta_y          in R3 should be 12 m or more
##---------------------------------------------------------------------------------
## my next iteration will/may:
## lower beta_x  at B2 and B3 to allow use of RHIC magnets
## require  a new quad between Current Q1 nd B1 for the VHL case
## a lower beta_x at R3 and R4 to maintain acceptances
## This will presumably be for after the March review
```

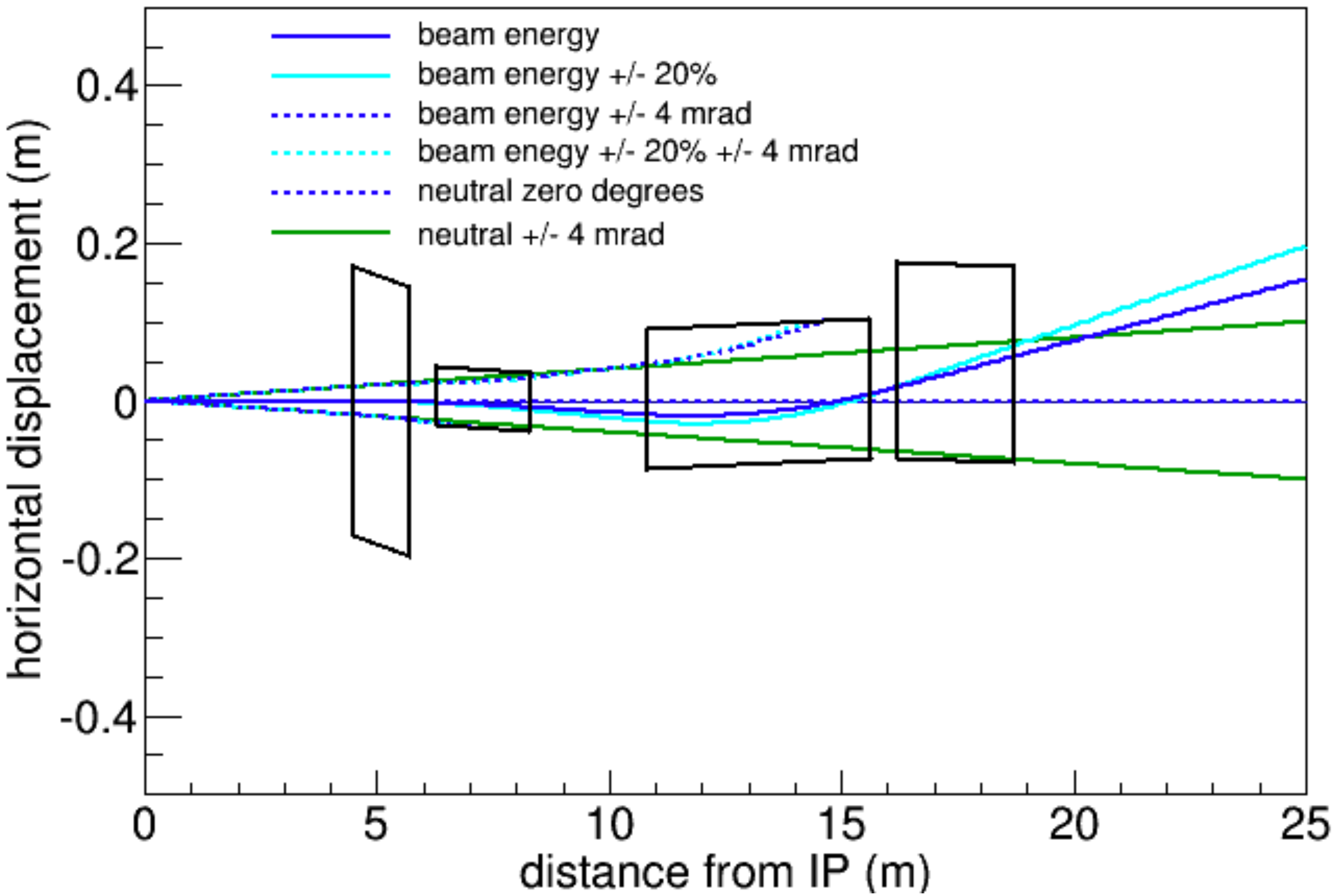
IR layout in EicRoot simulation



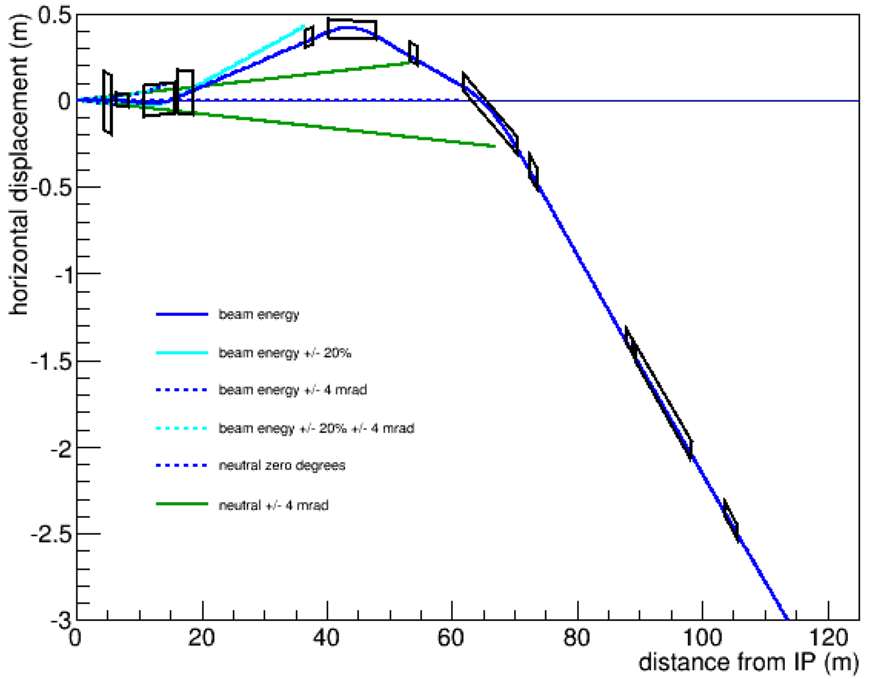
IR Zoom in nearer the IP

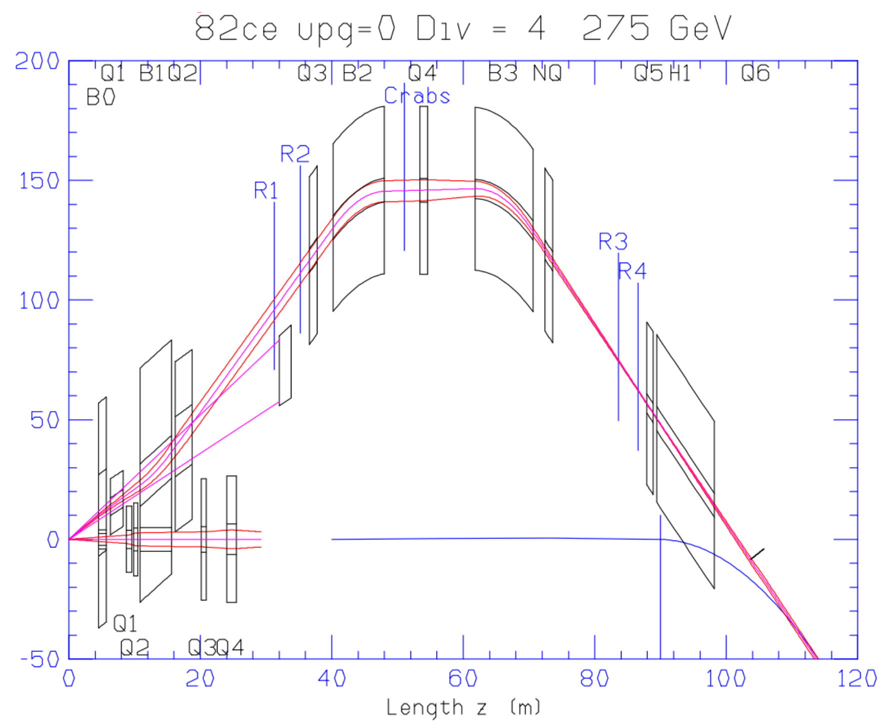


Zoom in even closer



IR layout in EicRoot simulation compared to Bob's picture



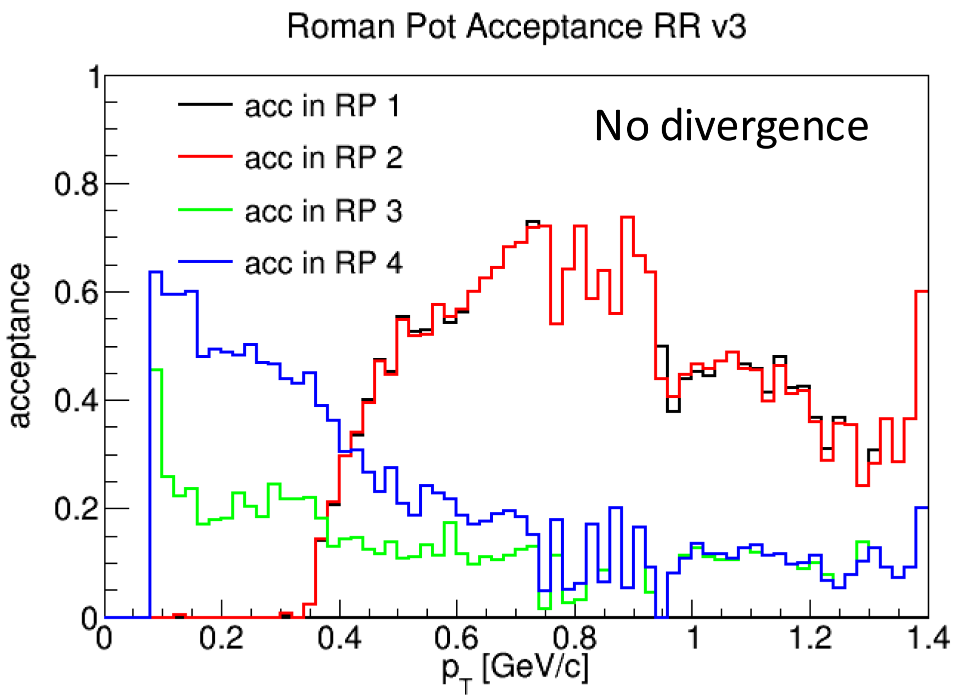


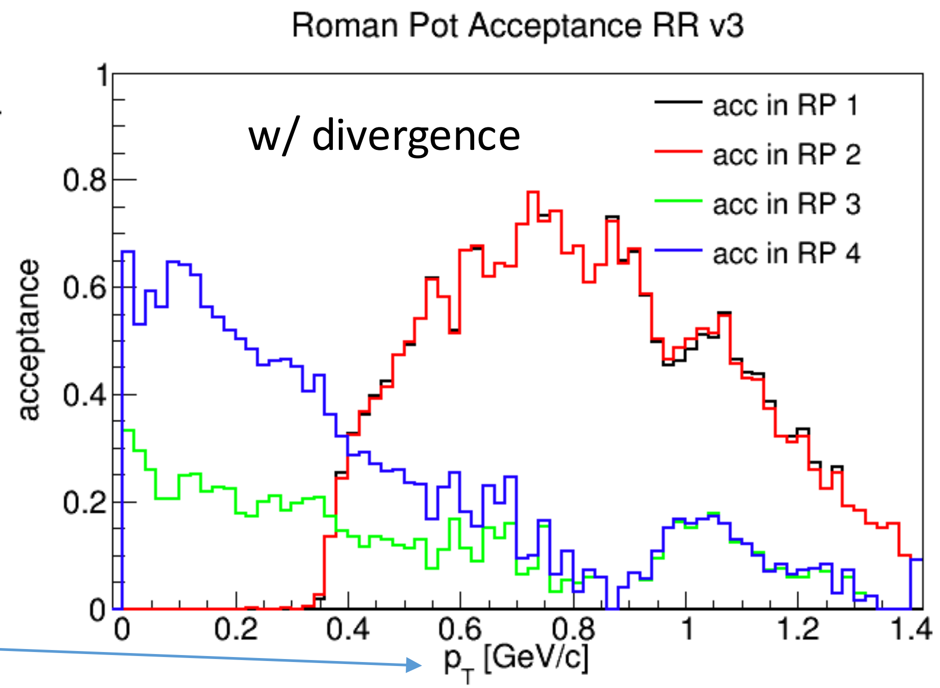
- Note that in my picture, the proton beam is along the z axis, but in Bob's picture, the electron beam is along the z axis

Roman pot details

- 4 silicon trackers per station
  - Each tracker is 10 cm (?) apart
- Pixel size is 20x20 micron
- Each tracker is x cm thick
- The change in beta function is not accounted for within a station
  - This means that the ”hole” in the trackers is the same for each tracker in the station holding the beta function at the center
- Station is rotated so that beam goes perpendicular to the surface
- The “hole” around the beam accounts for the emittance in the x and y directions (so the “hole” is a rectangle, not a square)

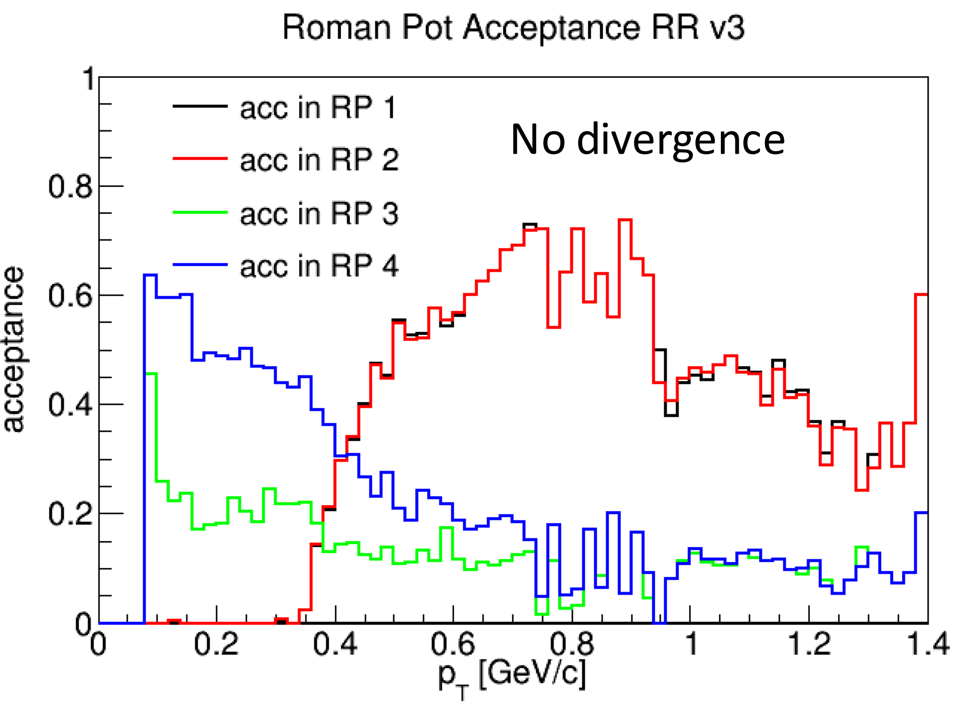
Acceptance (w/ and w/o divergence)

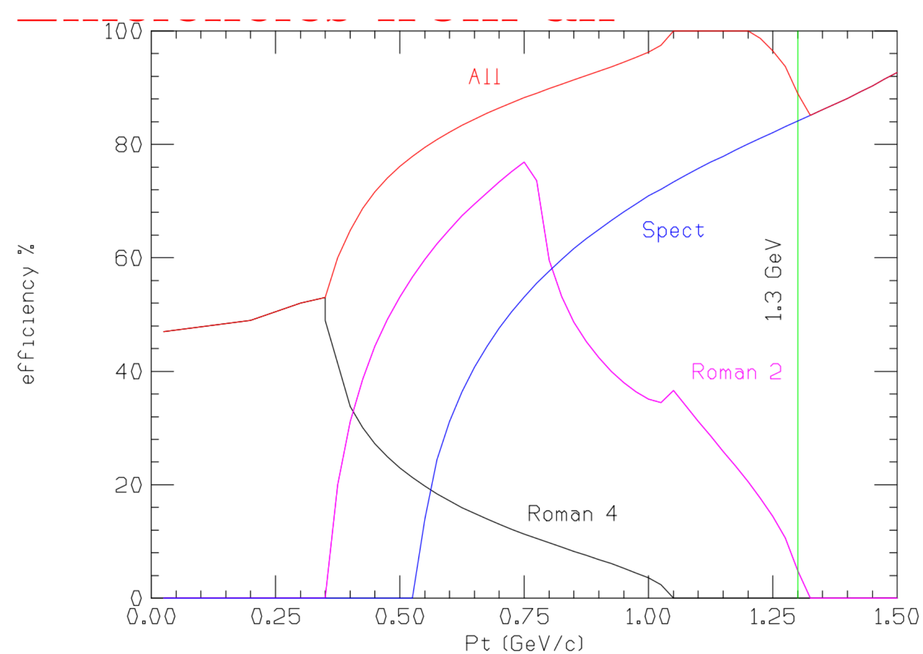




(This is the pT calculated folding in smearing from divergence, not the pT from the physics source purely)

Acceptance compared to Bob’s result





- Looks like reasonable agreement between our evaluations

Pt reconstruction details

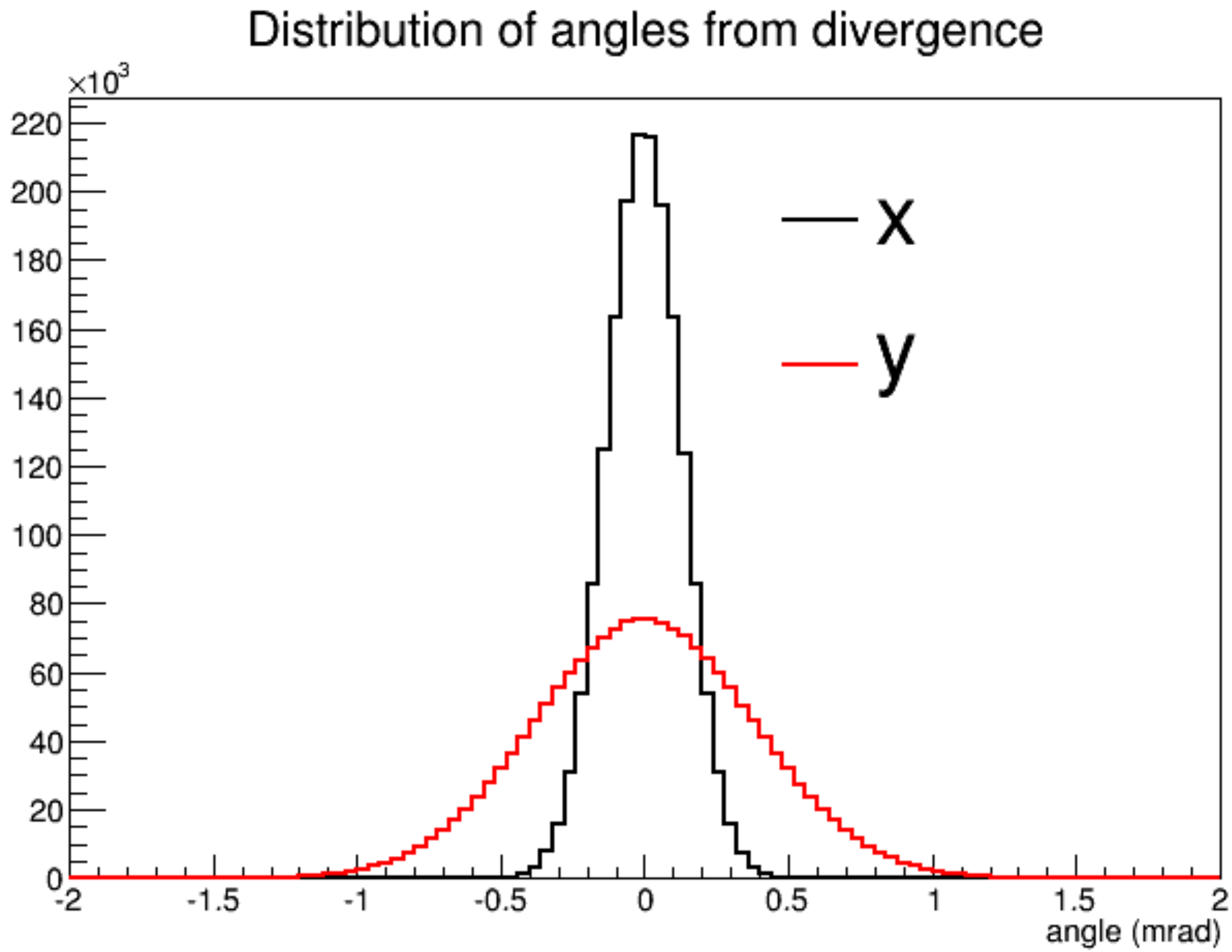
- Use machine learning algorithm to create a “lookup table” mapping input from the detector to the track pt
  - Input is the x, y, z of the first tracker in station hit position and the 3D angle of the track through the tracker
  - Output is the track pt
  - Best results with a support vector machine regression model (straight from scikit-learn in Python)
- A best line fit is found using the hits in the tracker for each station
- The hits are “digitized” to for the 20x20 micron detector
- Consider 3 models:
  - Only using RP1 and RP2
  - Only using RP3 and RP4
  - Only using RP1, RP2, and RP3
- Validate model on set aside data not used for the model training

Handling divergence at the IP

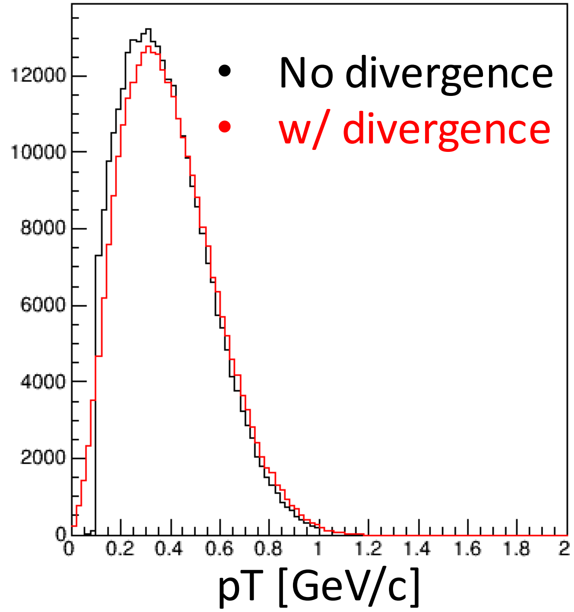
- **The divergence is applied post-collision as a simple rotation to the outgoing momentum vector**
- The divergence is applied with different values in the x and y direction
- An angle in each direction is pulled from a gaussian distribution with a mean of zero and a width equal to the divergence
- The momentum vector of the proton is then rotated about each direction with the angle

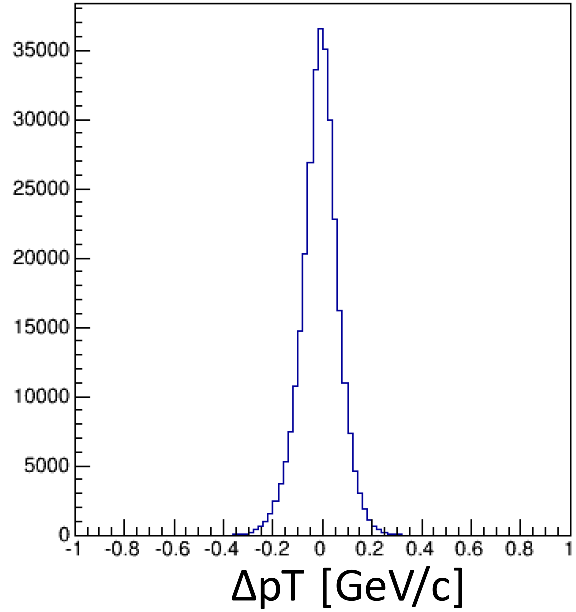
Cross checking the divergence application

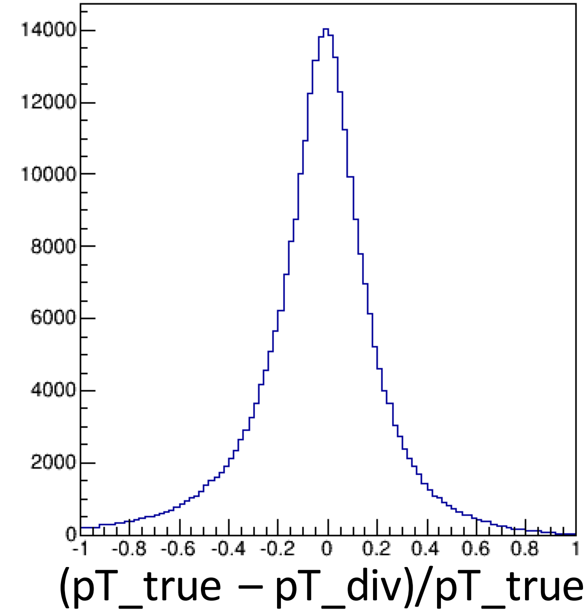
- The distribution of the rotation angles applied as a result of the divergence

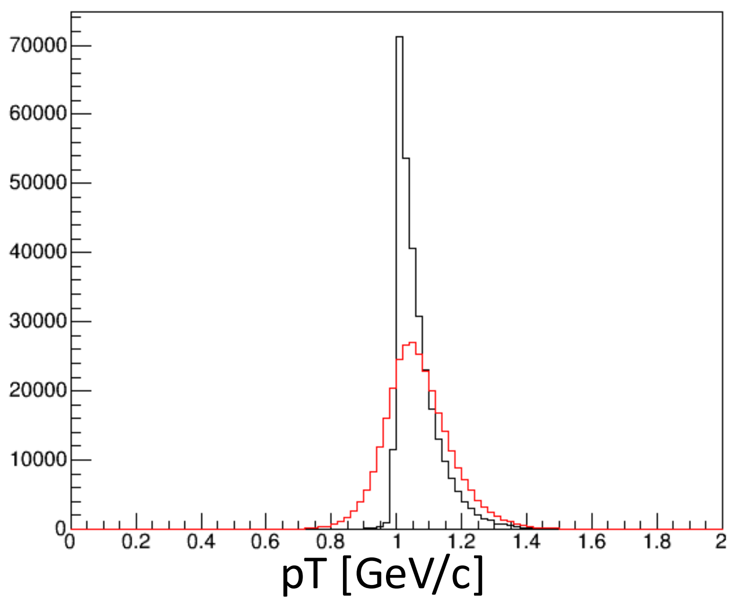


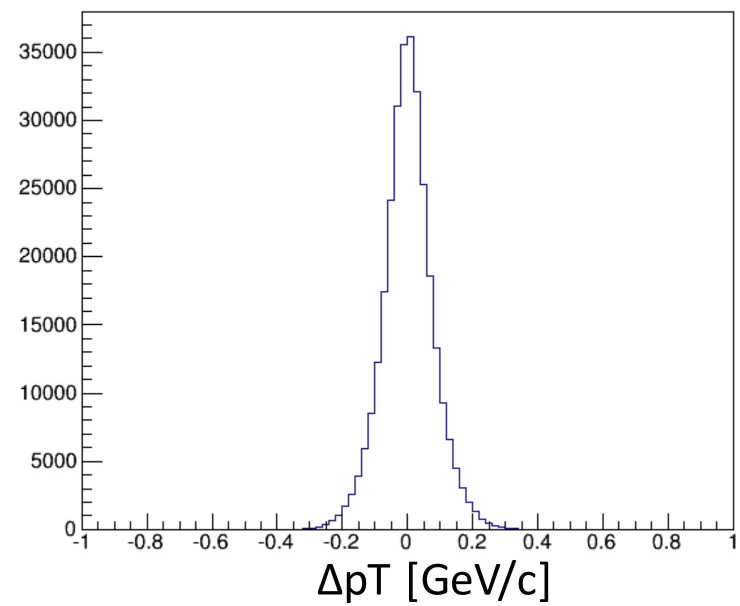
Cross checking the divergence application









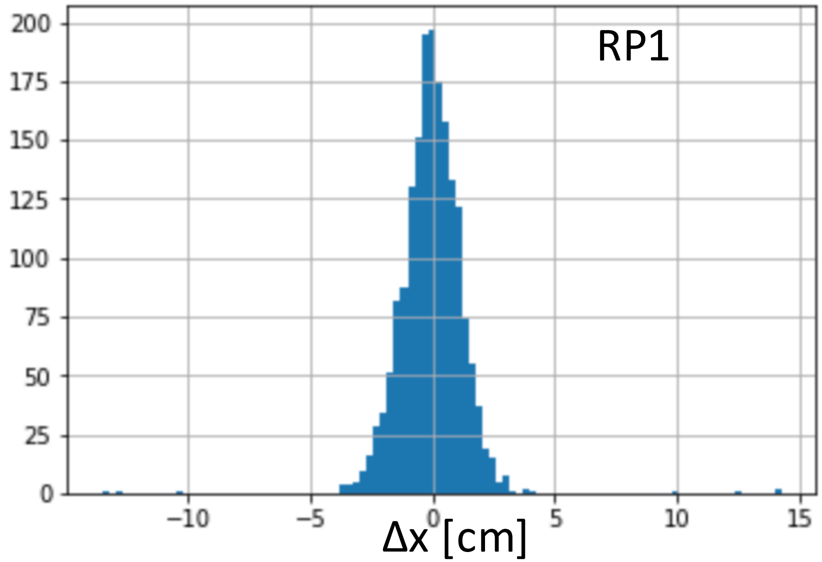


Difference in hit position in pot due to divergence

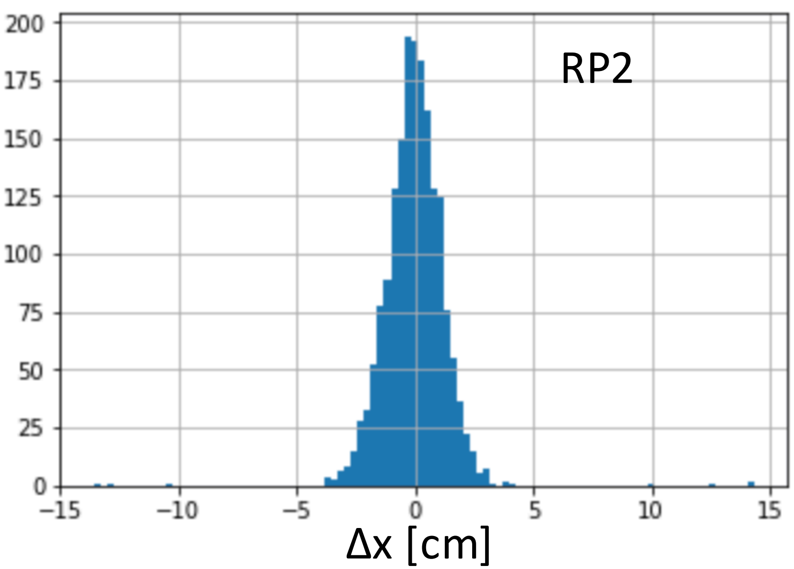
- Use the power of Pandas
  - Load text files into a dataframe
  - Colmuns = x1, y1, z1, tx1, ty1, tz1, x2, y2, z2, tx2 ,ty2 ,tz2, pt
- Merge data for the roman pot reconstruction before and after application of divergence
  - Both files record the original proton pT from the collision
  - Join the two files on the pT and only keep entries where the pT is the same
    - Two files are not the same row by row because divergence will cause some protons to come in or out of acceptance

Difference in hit position in pot due to divergence

- First hit in each RP station in x



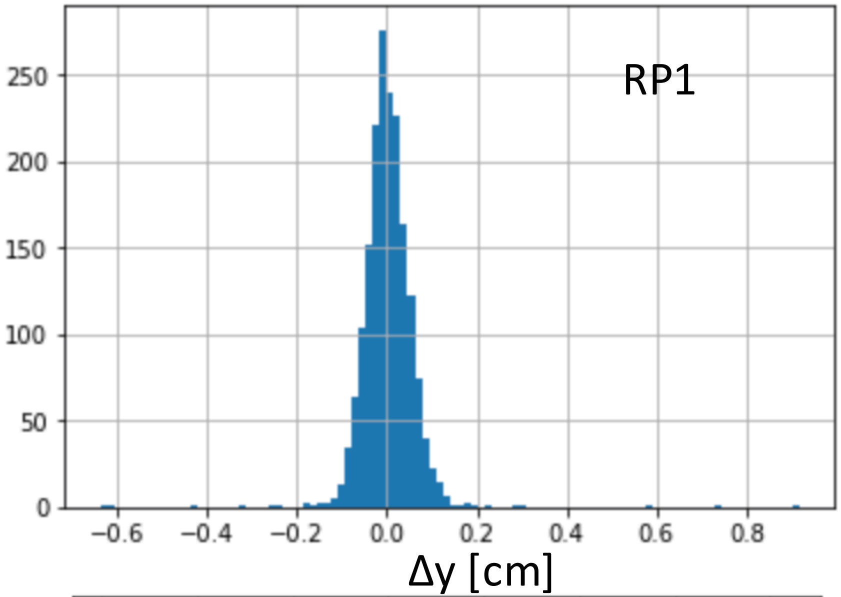
Mean = -0.028 cm
Std = 1.360 cm



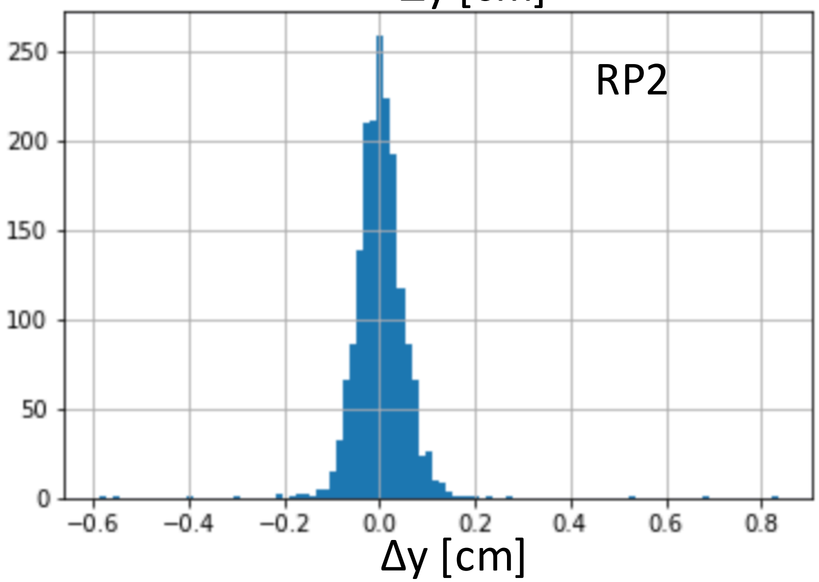
Mean = -0.028 cm
Std = 1.366 cm

Difference in hit position in pot due to divergence

- First hit in each RP station in y

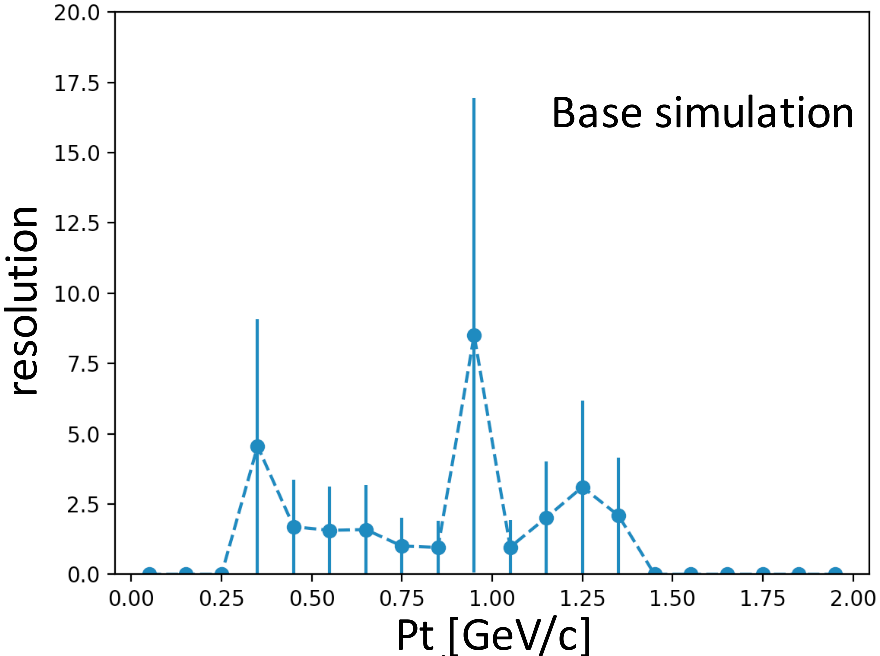


Mean = 0.0028 cm
Std = 0.0615cm

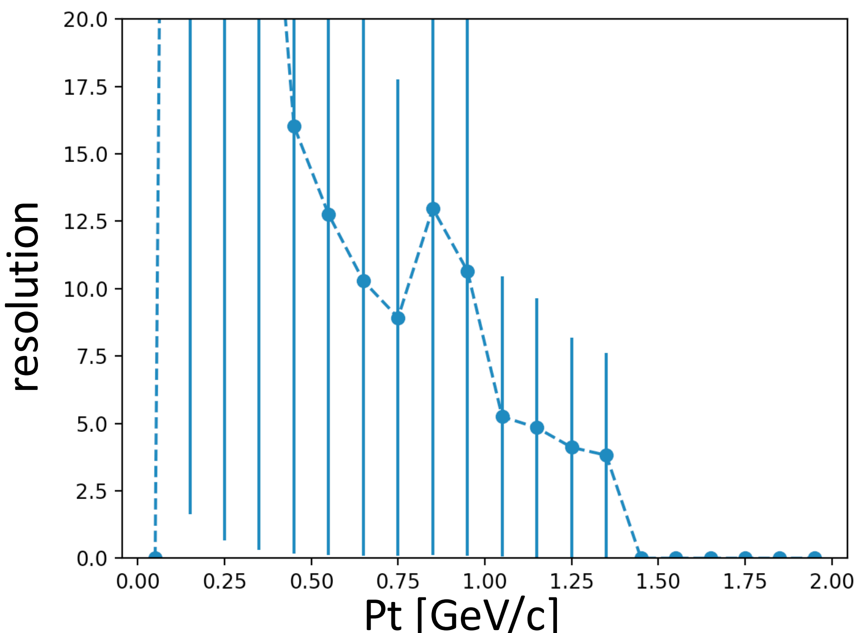


Mean = 0.0027 cm
Std = 0.0587 cm

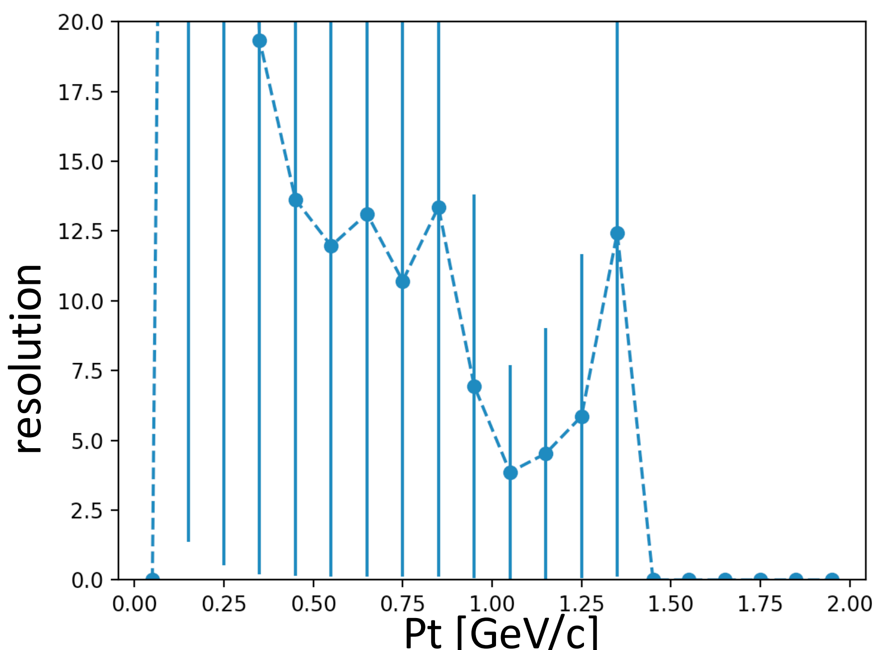
Pt reconstruction results (RP1 and RP2 only)



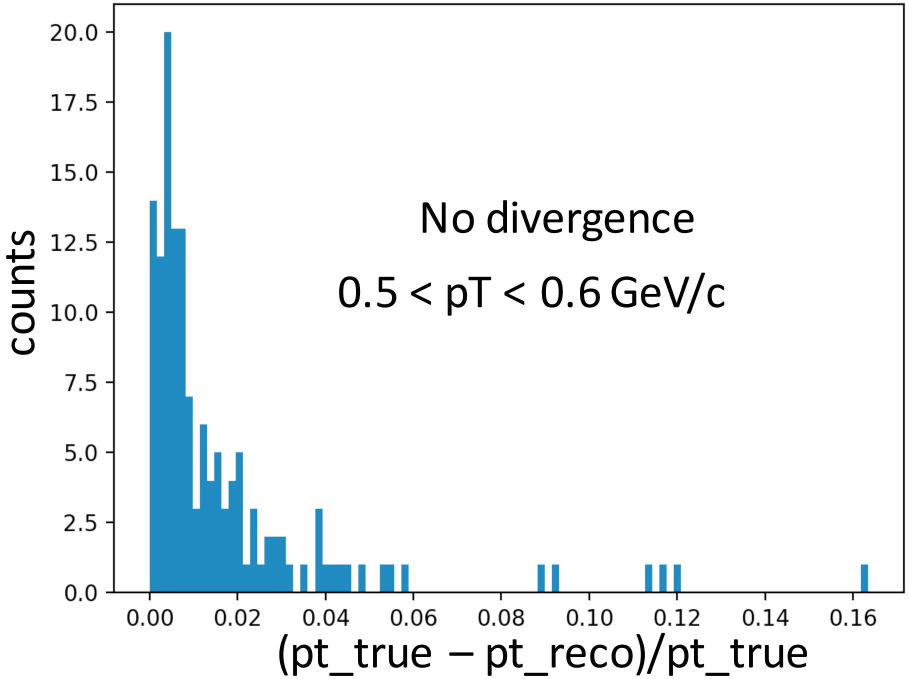
- Add in divergence (but do not retrain model)
- Evaluate on true pt from physics

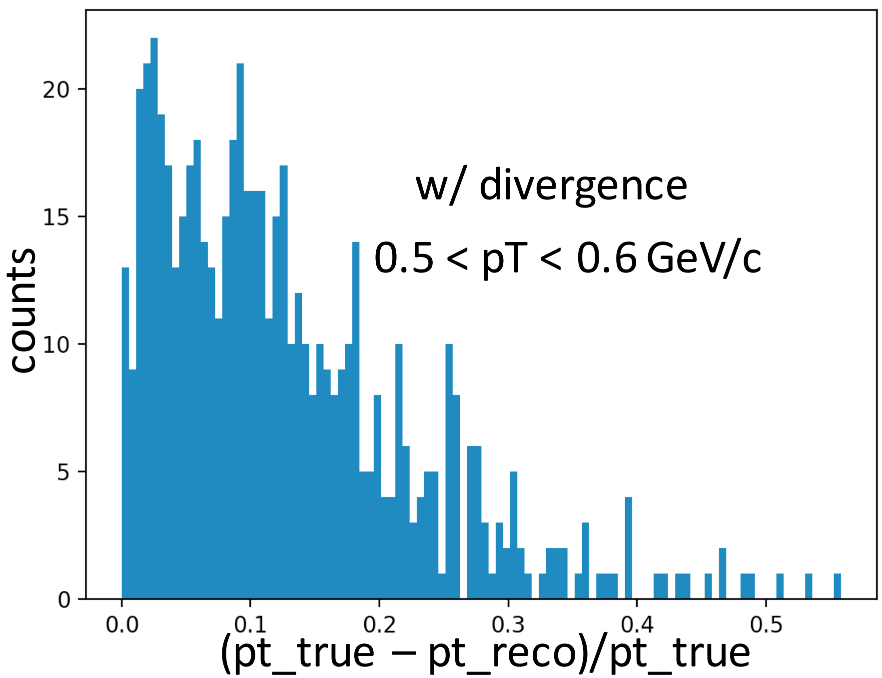


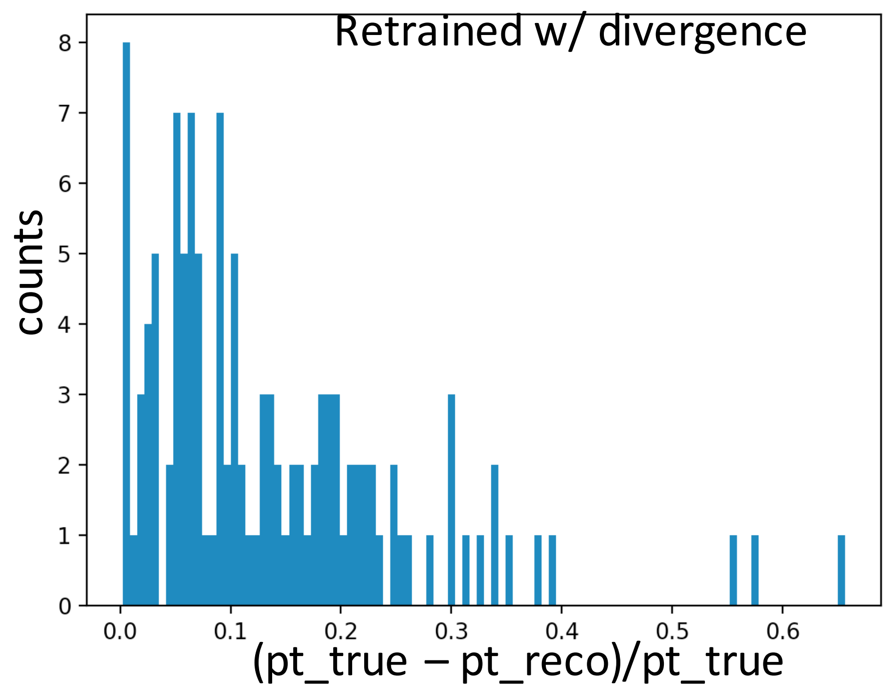
- Add in divergence (and retrain model)
- Evaluate on true pt from physics



Distribution of the pt deviation in a pT bin







Need more stats for further analysis at other stations

- Condor jobs will be launched soon to scale this analysis