Pull Distributions with Updated Material Map

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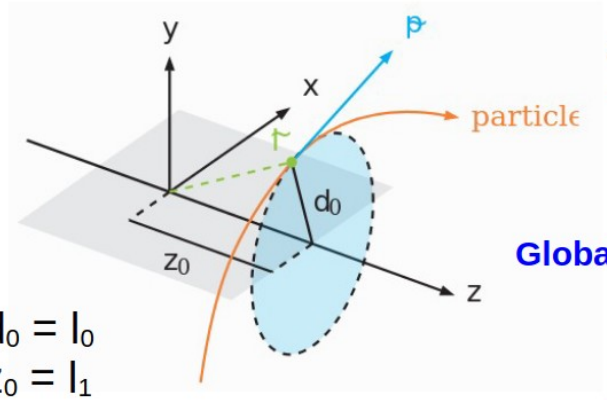
shyam@shyam:~/eic/epic$ git describe --tags --abbrev=0
25.12.0
shyam@shyam:~/eic/EICrecon$ git describe --tags --abbrev=0
v1.32.0

Track Parameters in ACTS

https://indico.bnl.gov/event/28544/contributions/109057/attachments/62799/108633/ePIC_Tracking_Meeting_30June2025_ShyamKumar.pdf

Track Parameters $(l_0, l_1, \phi, \theta, q/p, time)$ If tracking algorithm is working fine Pull must be consistent with unity



$d_0 = l_0$

$z_0 = l_1$

At Point of closest approach

$$(l_0, l_1, \phi, \theta, q/p)$$

Global (Lab frame)

$$(x, y, z, p_x, p_y, p_z, q)$$

$$x = -l_0 \sin\phi, \quad y = l_0 \cos\phi, \quad z = l_1$$

$$p_x = p\cos\phi\sin\theta, \quad p_y = p\sin\phi\sin\theta, \quad p_z = p\cos\theta$$

$$charge = sign(q/p)$$

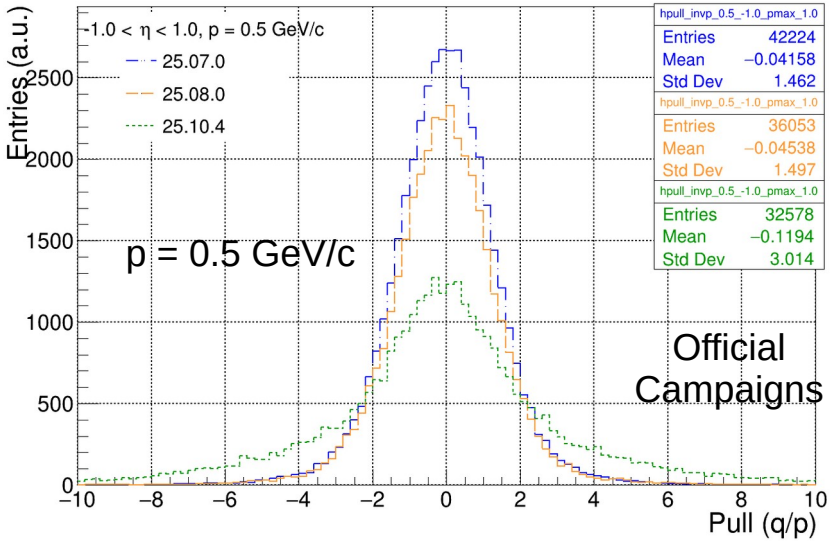
Plan to add it to the benchmarks

$$\text{Pull } l_0 = \frac{(l_{0\,rec} - l_{0\,gen})}{\sigma_{l0}} \qquad \text{Pull } \phi = \frac{(\phi_{rec} - \phi_{gen})}{\sigma_{\phi}} \qquad \text{Pull } q/p = \frac{(q/p_{rec} - q/p_{gen})}{\sigma_{q/p}}$$

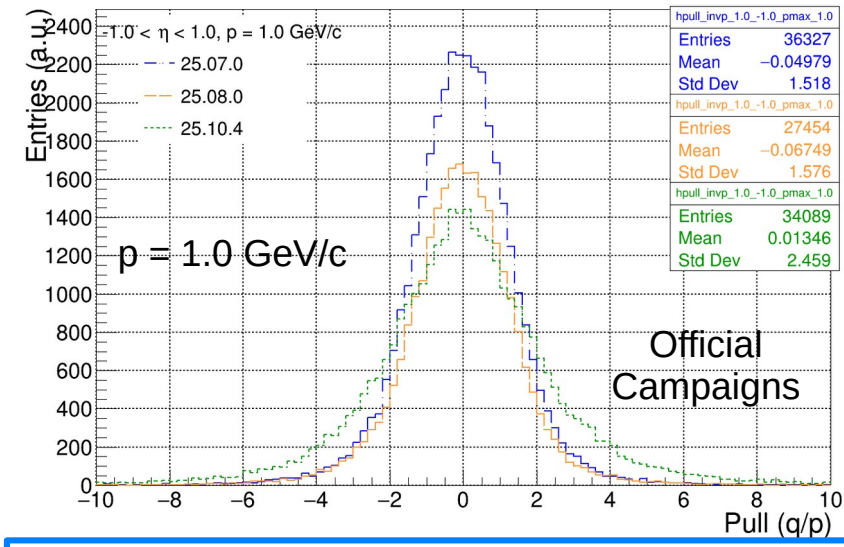
$$\text{Pull } l_1 = \frac{(l_{1\,rec} - l_{1\,gen})}{\sigma_{l1}} \qquad \text{Pull } \theta = \frac{(\theta_{rec} - \theta_{gen})}{\sigma_{\theta}} \qquad \text{Pull } p = \frac{(p_{rec} - p_{gen})}{\sigma_{p}}$$

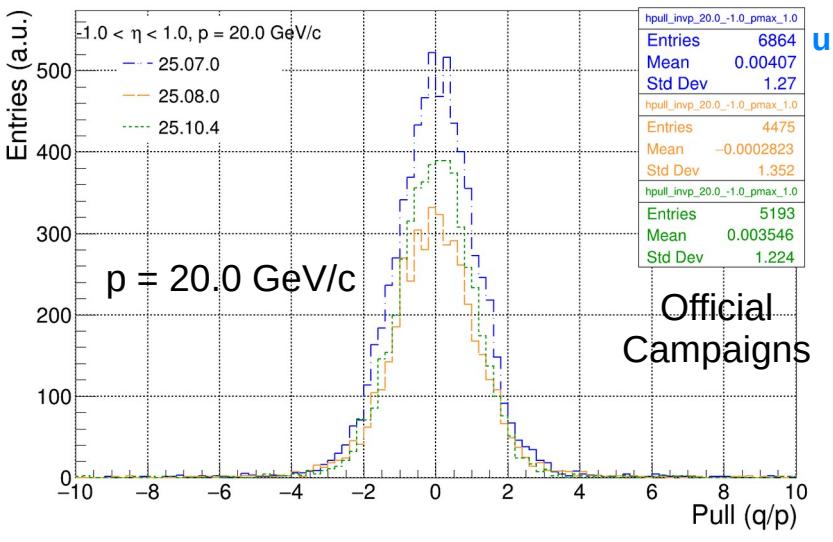
TTreeReaderArray<std::array<float, 21>> rcTrkCov(myReader, "CentralCKFTrackParameters.covariance.covariance[21]"); // **Reading covariance this way works but gives an error message (otherwise change it to vector in data type)**

Comparison of Pull distributions (q/p)

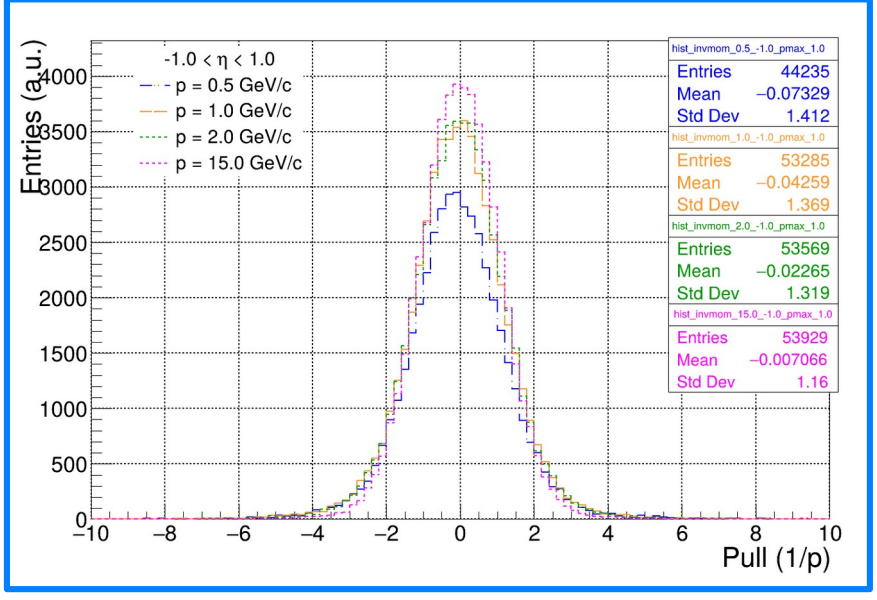


-1< η <1

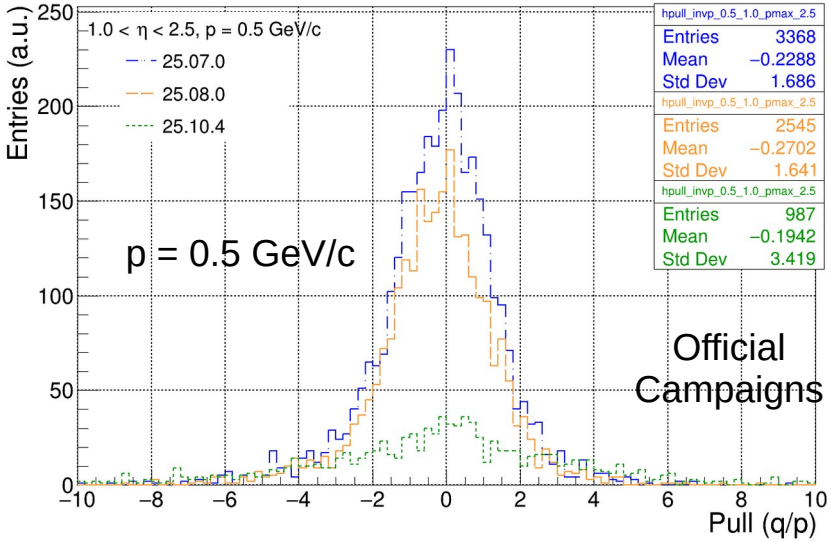




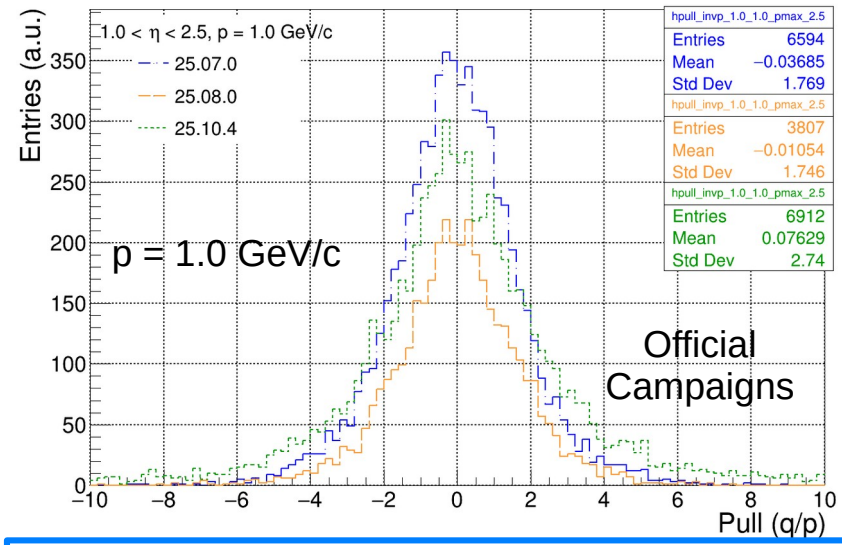
π- sim uniform in η and p with updated material map

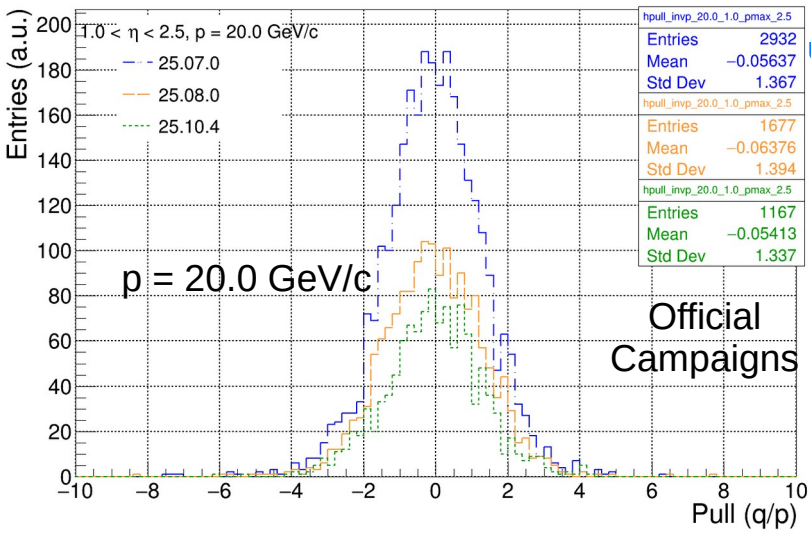


Comparison of Pull distributions (q/p)

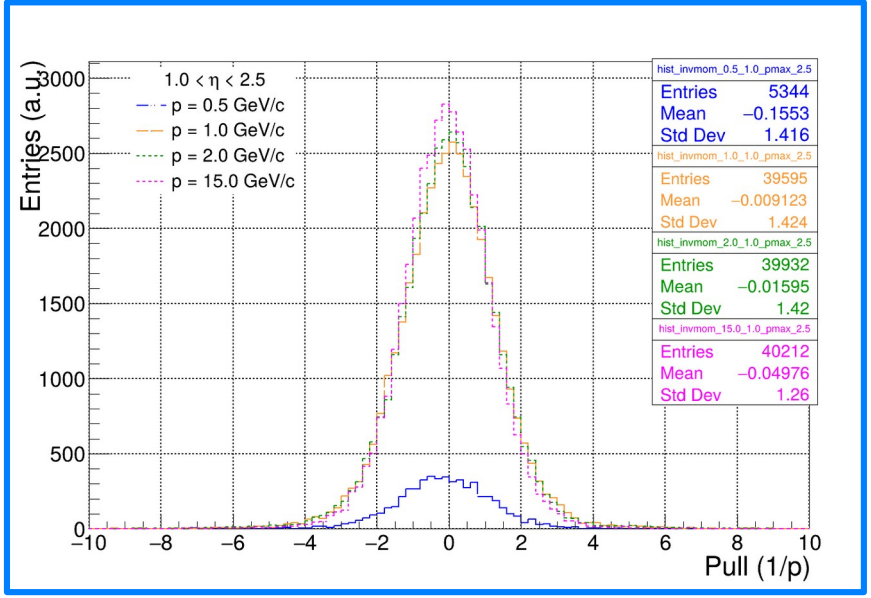


1.0< η <2.5

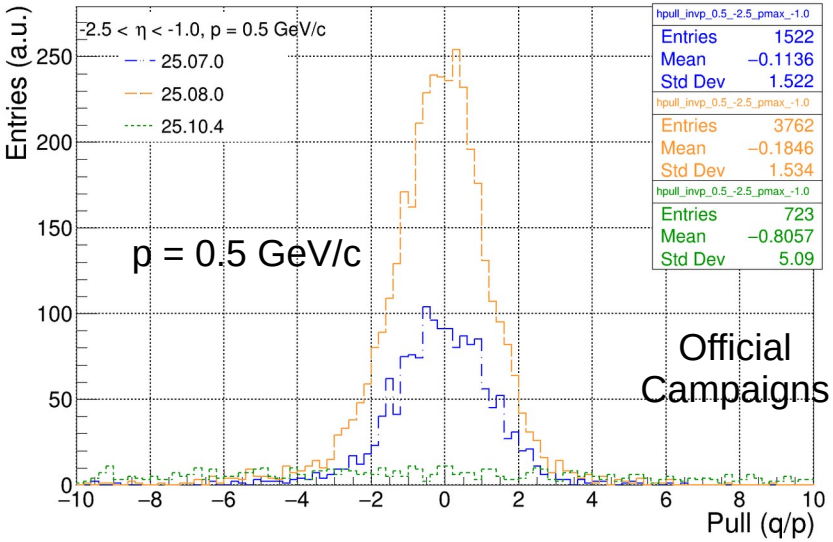




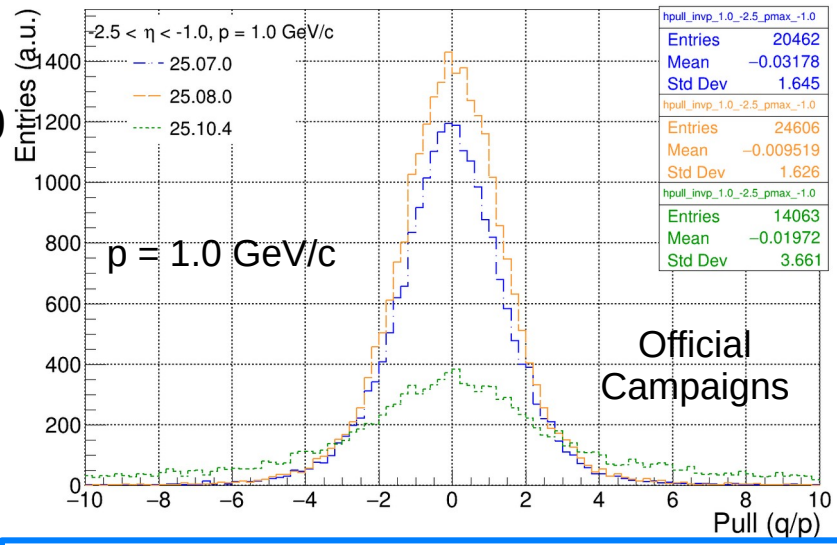
π- sim uniform in η and p with updated material map

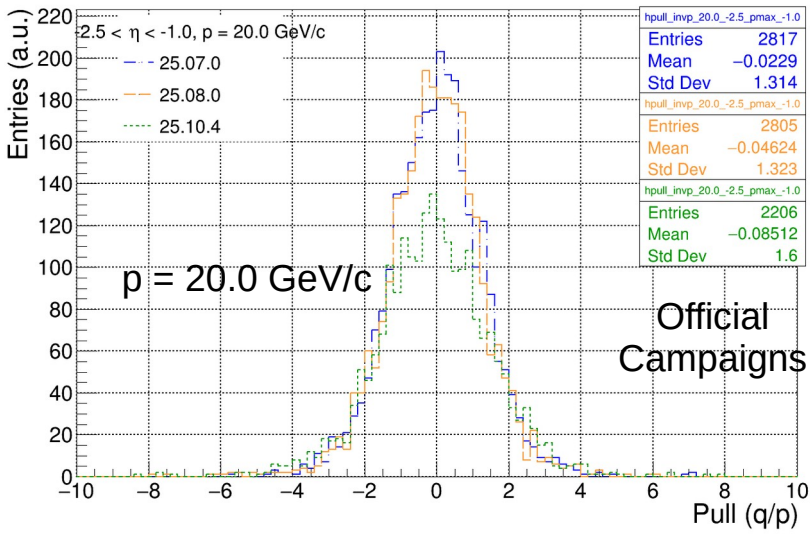


Comparison of Pull distributions (q/p)

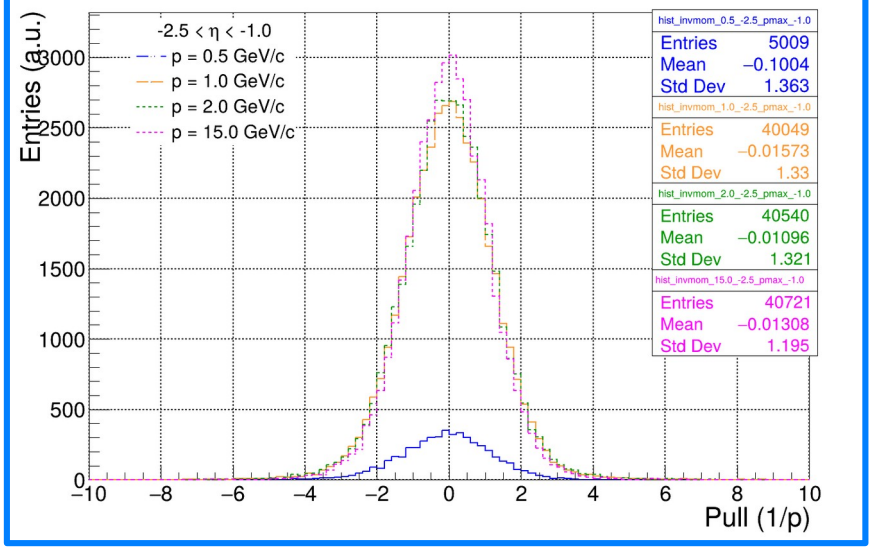


-2.5< η <-1.0

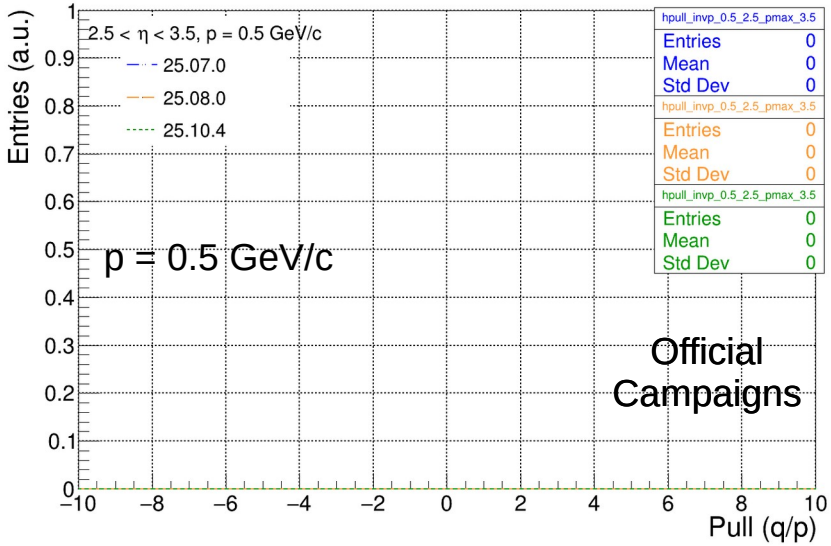




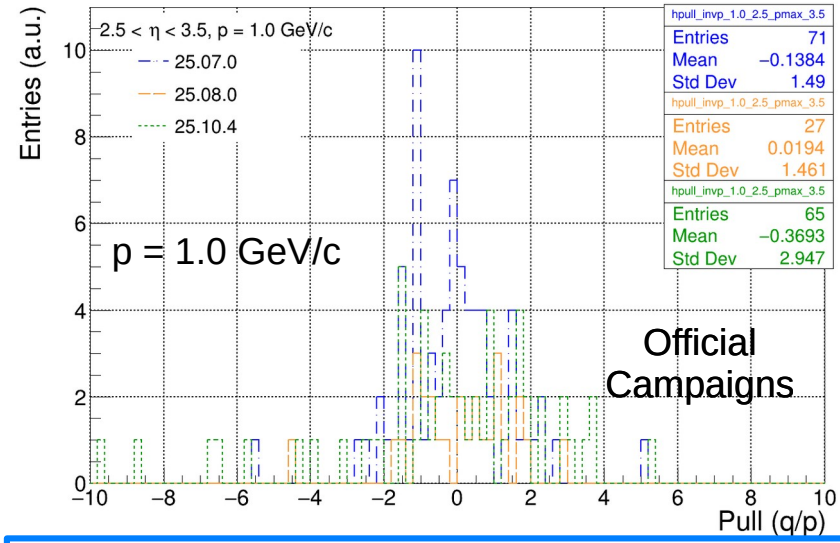
π- sim uniform in η and p with updated material map

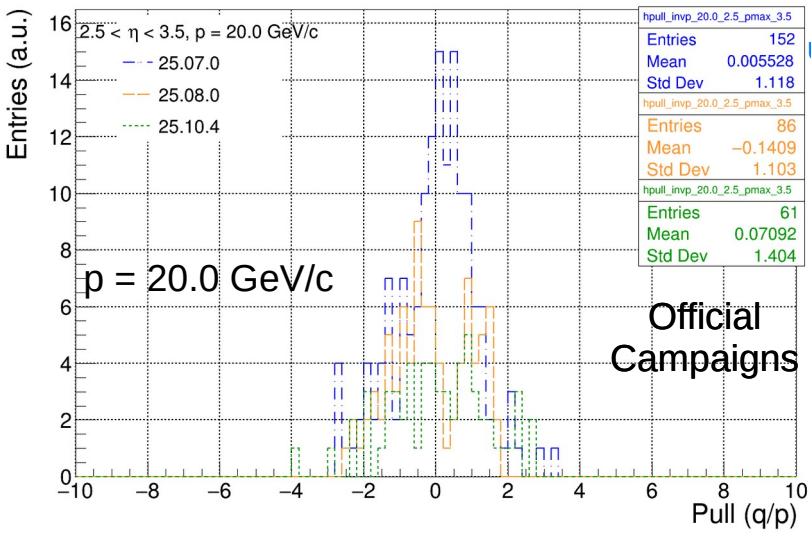


Comparison of Pull distributions (q/p)

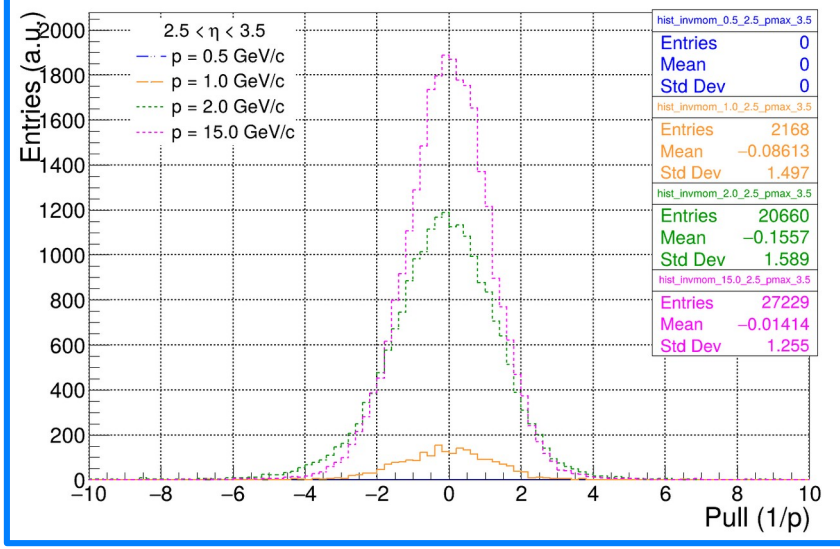


2.5 < η <3.5

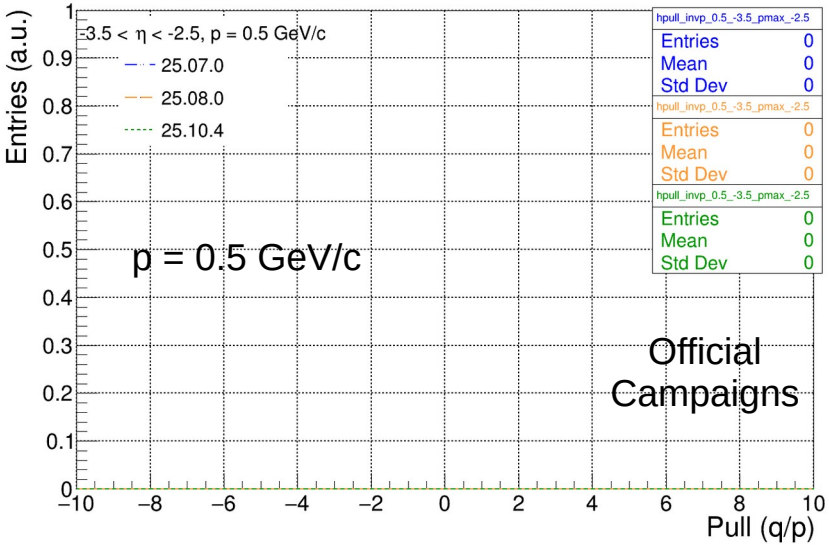




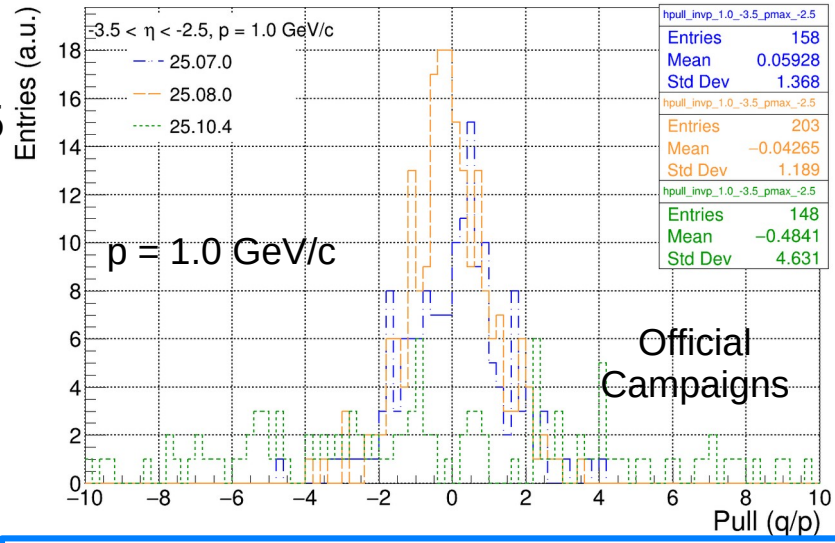
π- sim uniform in η and p with updated material map

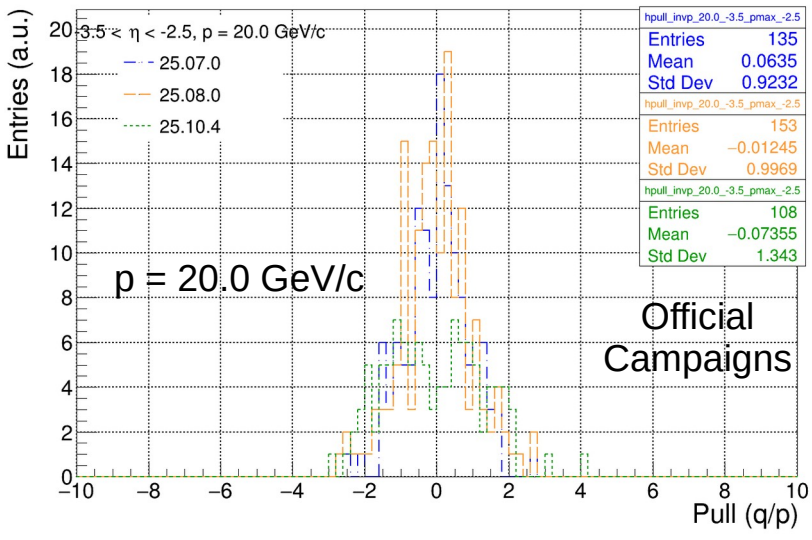


Comparison of Pull distributions (q/p)

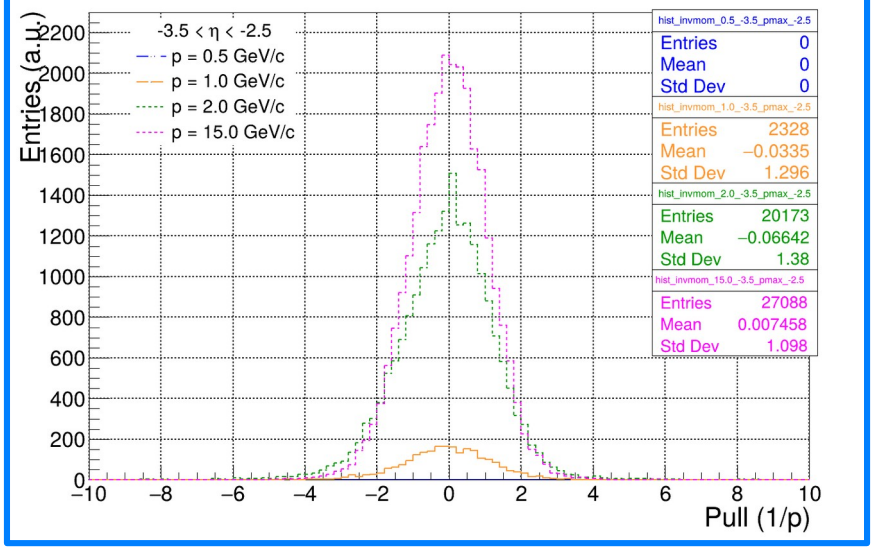


-3.5 < η <-2.5



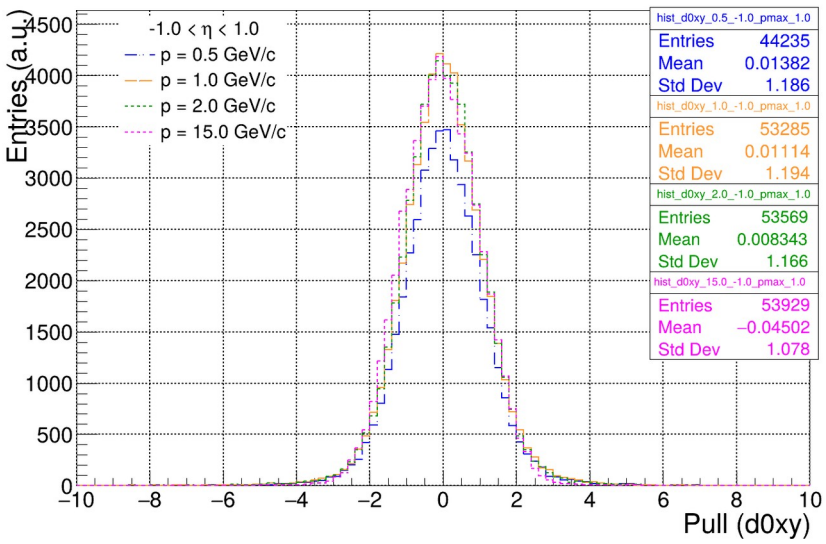


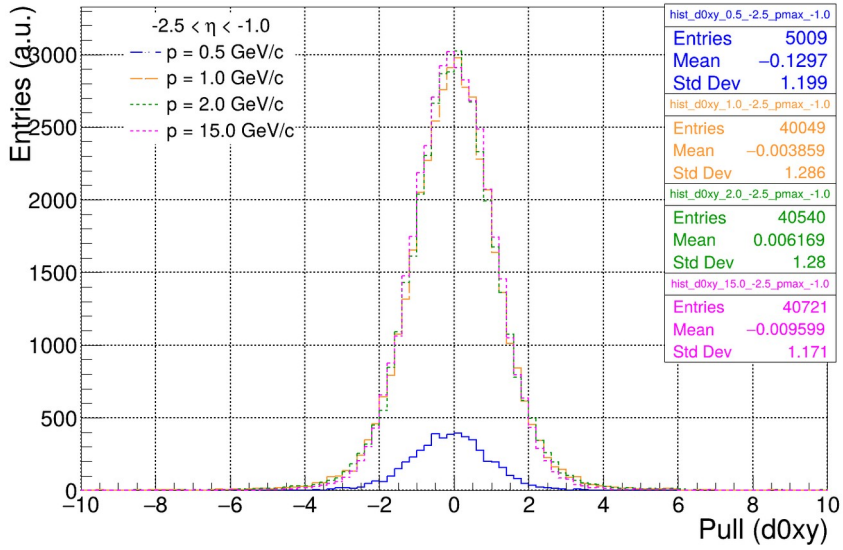
π- sim uniform in η and p with updated material map

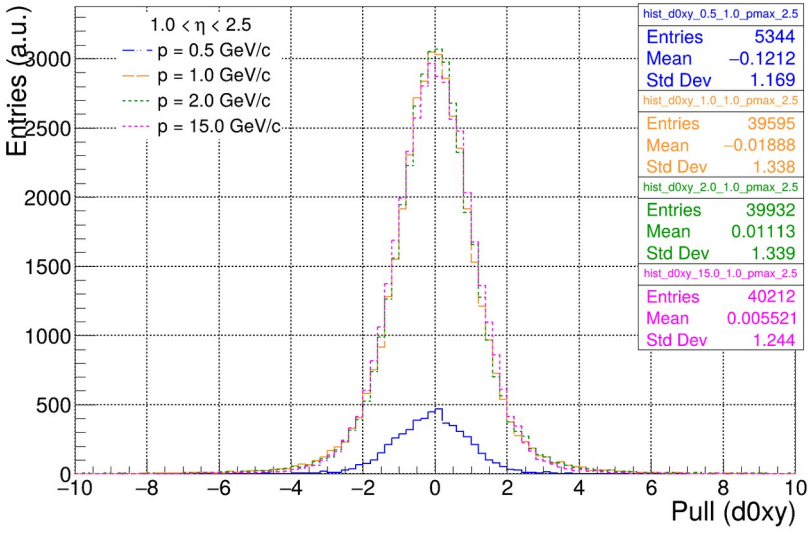


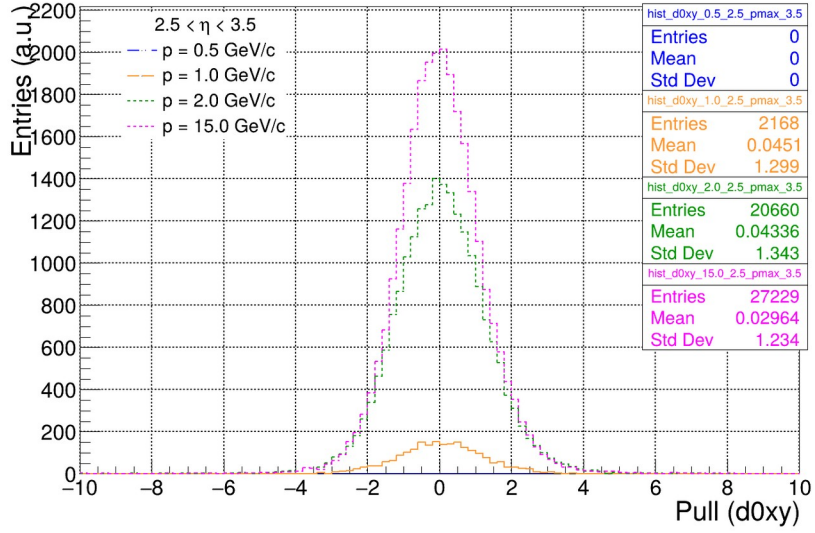
Pull distributions (d_{0xy}) with updated Material Map

π- sim uniform in η and p with updated material map



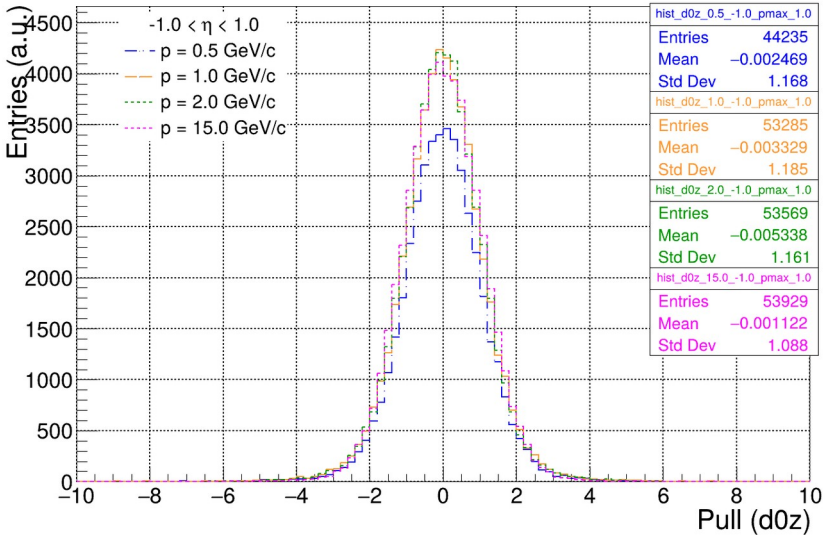


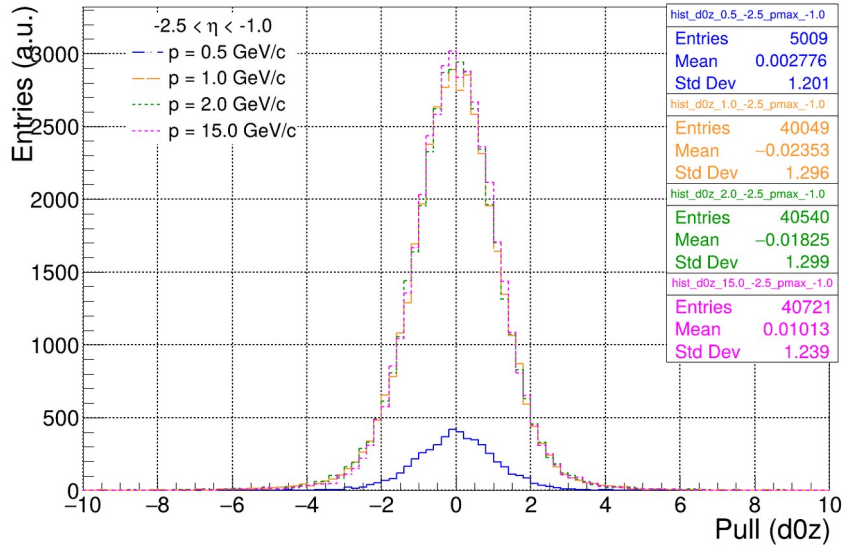


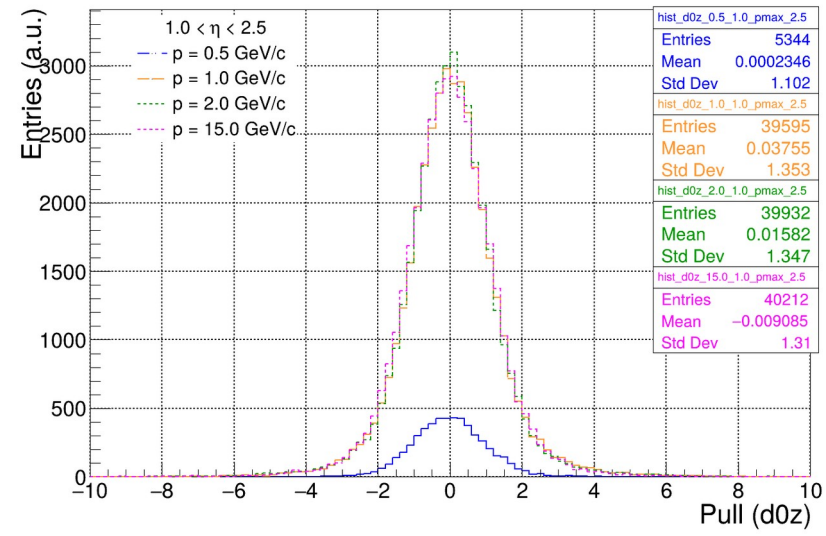


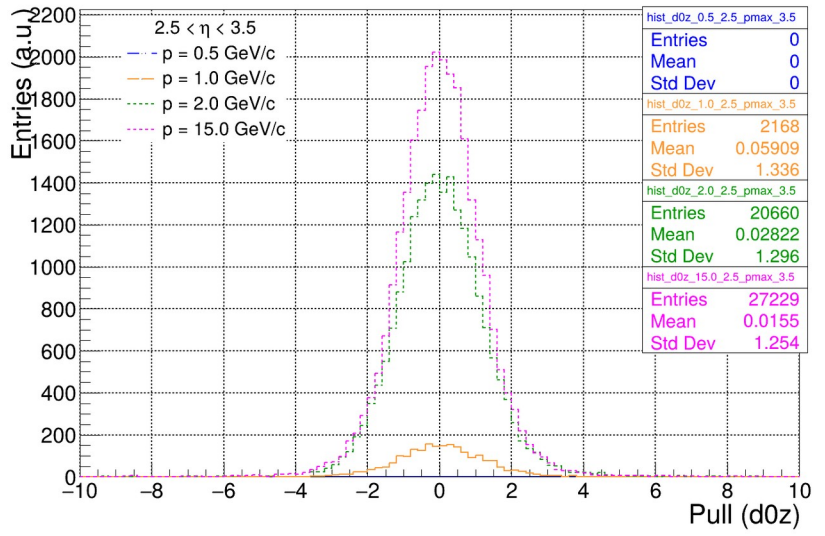
Pull distributions (d_{0z}) with updated Material Map

π- sim uniform in η and p with updated material map



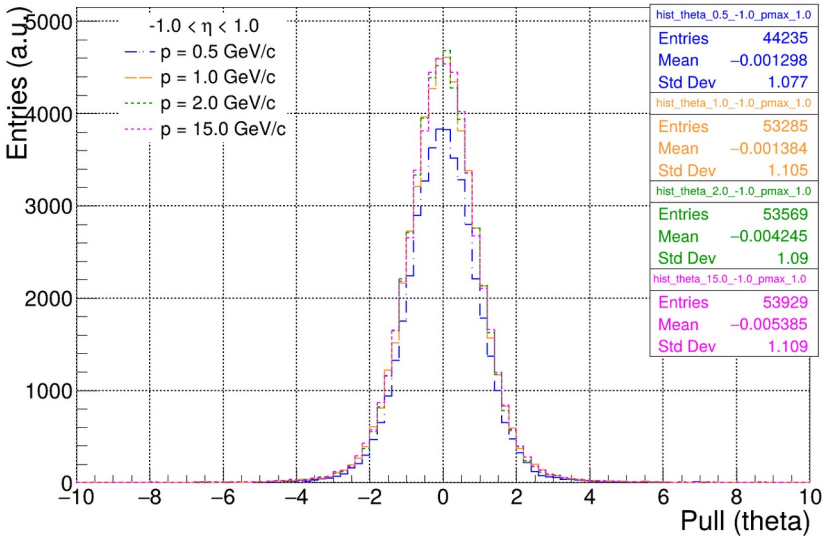


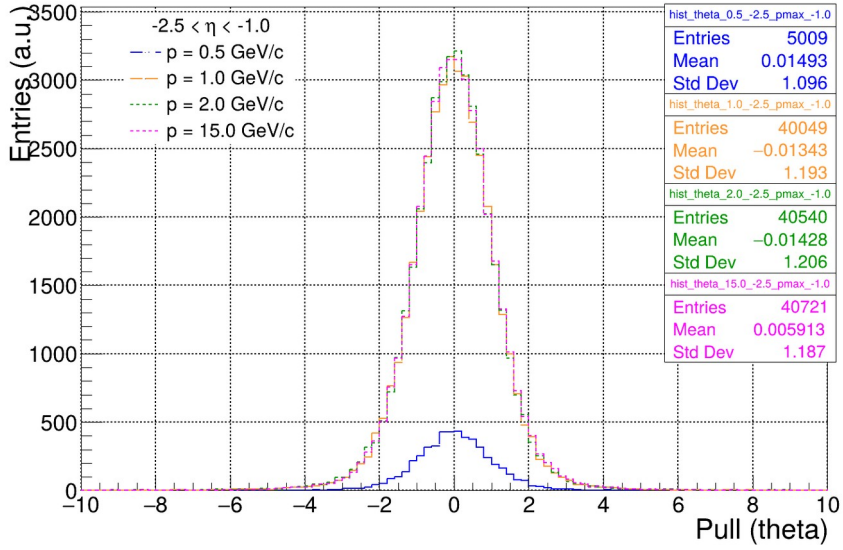


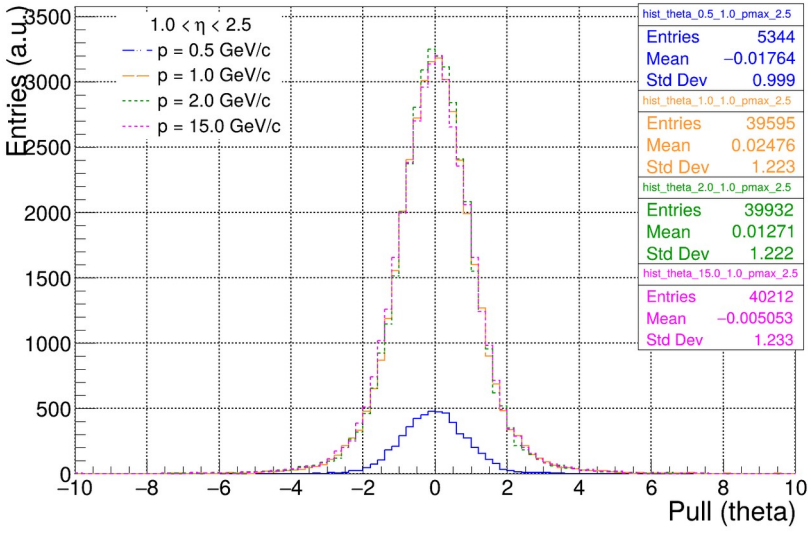


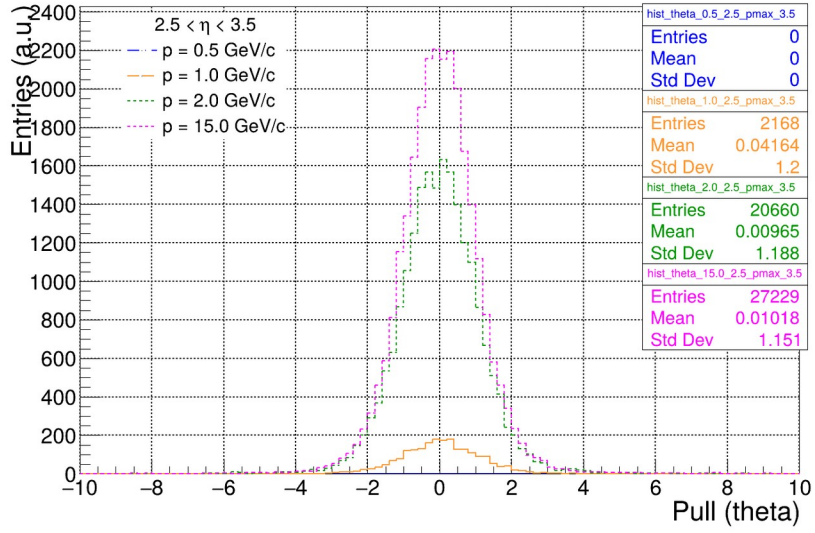
Pull distributions (θ) with updated Material Map

π- sim uniform in η and p with updated material map



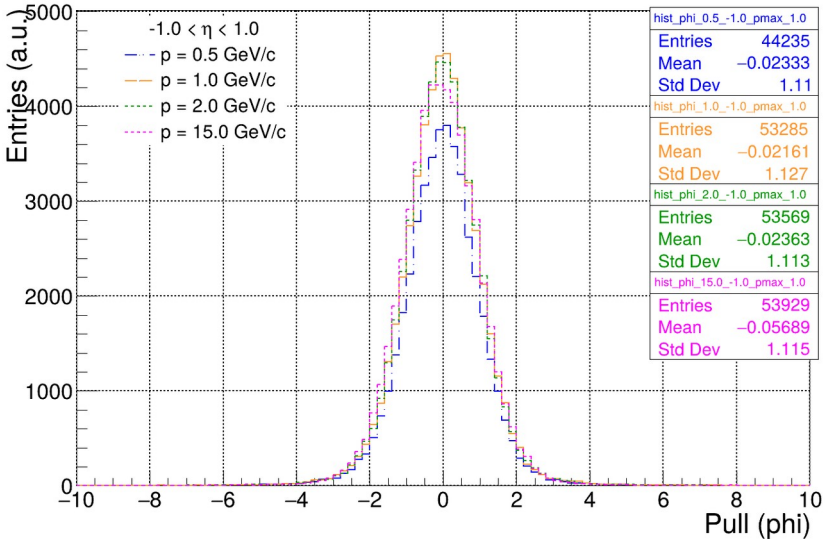


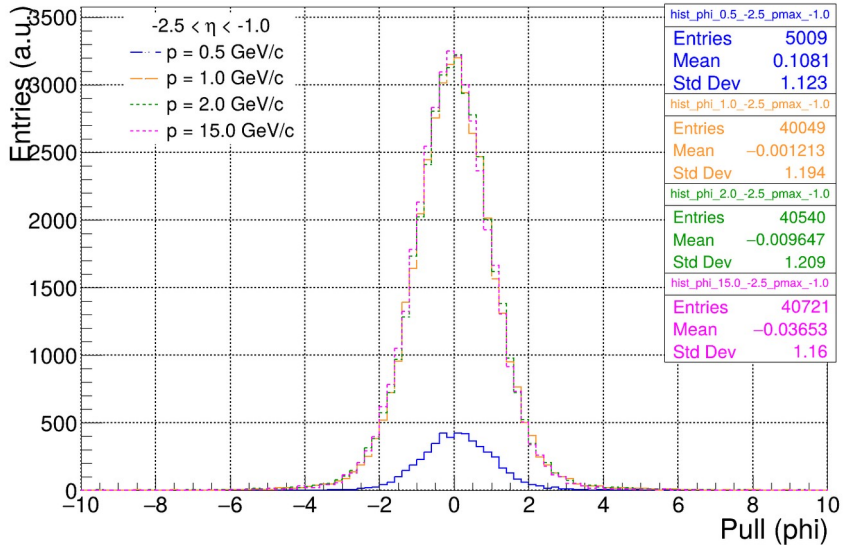


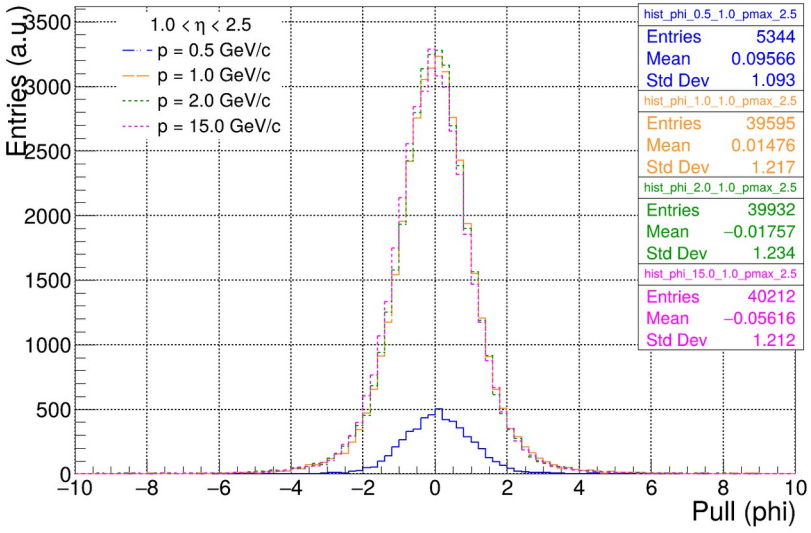


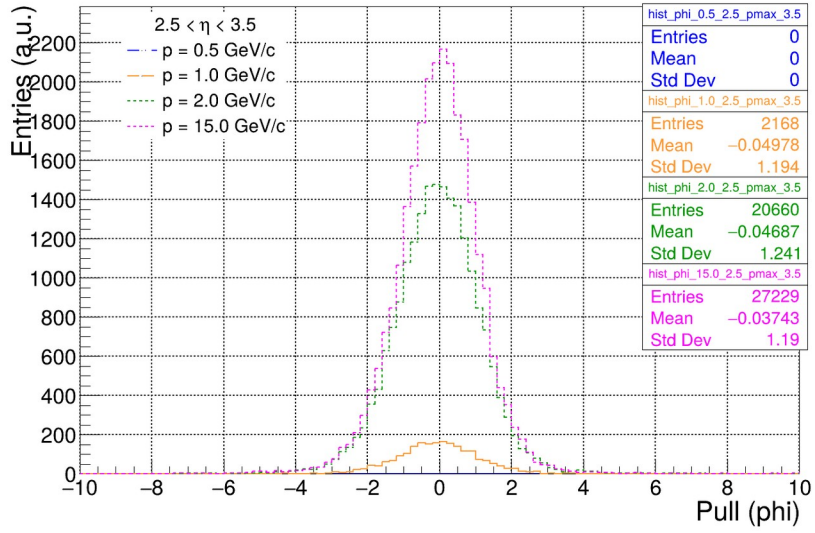
Pull distributions (φ) with updated Material Map

π- sim uniform in η and p with updated material map









Summary

- There were many changes in the detector geometry during the October campaign
- The pulls for momentum were significantly degraded but fixed with the new material map
- I already added the momentum pulls to official benchmark tests
- Please check them after each commit (consider ~5% variations acceptable)
- If possible, please look at all track parameters; otherwise, checking the pull of 1/p is also fine

Thank you for your attention!

Covariance Matrix in ACTS

Track Parameters $(l_0, l_1, \phi, \theta, q/p, time)$

For each fitted track we get track parameters and covariance matrix

$$\begin{array}{c} \\ l_0 \\ l_1 \\ \phi \\ \theta \\ q/p \\ time \end{array} \begin{array}{c} \begin{array}{cccccc} l_0 & l_1 & \phi & \theta & q/p & time \end{array} \\ \begin{bmatrix} \sigma^2(l_0) & \mathrm{cov}(l_0,l_1) & \mathrm{cov}(l_0,\phi) & \mathrm{cov}(l_0,\theta) & \mathrm{cov}(l_0,q/p) & \mathrm{cov}(l_0,t) \\ . & \sigma^2(l_1) & \mathrm{cov}(l_1,\phi) & \mathrm{cov}(l_1,\theta) & \mathrm{cov}(l_1,q/p) & \mathrm{cov}(l_1,t) \\ . & . & \sigma^2(\phi) & \mathrm{cov}(\phi,\theta) & \mathrm{cov}(\phi,q/p) & \mathrm{cov}(\phi,t) \\ . & . & . & \sigma^2(\theta) & \mathrm{cov}(\theta,q/p) & \mathrm{cov}(\theta,t) \\ . & . & . & . & \sigma^2(q/p) & \mathrm{cov}(q/p,t) \\ . & . & . & . & . & \sigma^2(t) \end{bmatrix} \end{array}$$

Symmetric matrix: Independent entries = n(n+1)/2 = 6*7/2 = 21

```
Processing ReadCovarianceArray_new.C...
Event 0, number of tracks: 8
  Track 0 covariance:
    cov[0] = 0.0104456
    cov[1] = 2.366e-06
    cov[2] = 0.0103324
    cov[3] = -0.000289634
    cov[4] = 7.52669e-07
    cov[5] = 8.04972e-06
    cov[6] = -8.12589e-07
    cov[7] = 0.000284166
    cov[8] = 4.50984e-08
    cov[9] = 7.82997e-06
    cov[10] = 0.000153944
    cov[11] = 7.02629e-07
    cov[12] = -4.94218e-06
    cov[13] = 5.14138e-09
    cov[14] = 0.00011838
    cov[15] = -1.41347e-06
    cov[16] = -3.20263e-06
    cov[17] = 3.89044e-08
    cov[18] = -8.82041e-08
    cov[19] = 2.242e-09
    cov[20] = 0.000333566
```

Cov[0] = cov(l0, l0)
Cov[1] = cov(l0, l1)
Cov[2] = cov(l1, l1)
Cov[3] = cov(l0, φ)
cov[4] = cov(l1, φ)
cov[5] = cov(φ, φ)
cov[6] = cov(l0, θ)
cov[7] = cov(l1, θ)
cov[8] = cov(φ, θ)
cov[9] = cov(θ, θ)
cov[10] = cov(l0, q/p)

Cov[11] = cov(l1, q/p)
Cov[12] = cov(φ, q/p)
Cov[13] = cov(θ, q/p)
Cov[14] = cov(q/p, q/p)
Cov[15] = cov(l0, time)
Cov[16] = cov(l1, time)
Cov[17] = cov(φ, time)
Cov[18] = cov(θ, time)
Cov[19] = cov(q/p, time)
Cov[20] = cov(time, time)

$\sigma_{l0} = \sqrt{(Cov[0])}$ $\sigma_{l1} = \sqrt{(Cov[2])}$

$\sigma_{\phi} = \sqrt{(Cov[5])}$ $\sigma_{\theta} = \sqrt{(Cov[9])}$

$\sigma_q/p = \sqrt{(Cov[14])}$