Study of Theta/Phi resolutions with the Smearing of Truth Parameters

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https://indico.bnl.gov/event/17621/contributions/70622/subcontributions/2129/attachments/45442/76674/ePIC_collaboration_meeting_tracking_011023.pdf

Truth Parameters in Fun4All

int PHG4TrackFastSim::process_event(PHCompositeNode* /*topNode*/)

int PseudoPatternRecognition(const PHG4Particle* particle,

std::vector<PHGenFit::Measurement*>& meas_out, SvtxTrack* track_out,

TVector3& seed_pos,

TVector3& seed_mom, TMatrixDSym& seed_cov, const bool do_smearing = true);

https://github.com/sPHENIX-Collaboration/coresoftware/blob/master/simulation/g4simulation/g4trackfastsim/PHG4TrackFastSim.cc#L734

10% smearing in p_{true}

root [0] 3.0/180.*3.1416
(double) 0.052360000
0.05236 radian smearing in theta and Phi

```
int PHG4TrackFastSim::PseudoPatternRecognition(const PHG4Particle* particle,
                                               std::vector<PHGenFit::Measurement*>& meas_out,
                                               SvtxTrack* track_out,
                                               TVector3& seed_pos,
                                               TVector3& seed_mom, TMatrixDSym& seed_cov, const bool do_sm
{
  assert(track_out);

  seed_cov.ResizeTo(6, 6);

  seed_pos.SetXYZ(0, 0, 0);
  // reset the seed resolution to the approximate position resolution of the last detector
  seed_cov[0][0] = .1 * .1;
  seed_cov[1][1] = .1 * .1;
  seed_cov[2][2] = 30 * 30;
  //  for (int i = 0; i < 3; i++)
  //  {
  //    seed_cov[i][i] = _phi_resolution * _phi_resolution;
  //  }

  seed_mom.SetXYZ(0, 0, 10);
  for (int i = 3; i < 6; i++)
  {
    seed_cov[i][i] = 10;
  }

  if (particle)
  {
    TVector3 True_mom(particle->get_px(), particle->get_py(),
                      particle->get_pz());

    seed_mom.SetXYZ(particle->get_px(), particle->get_py(),
                    particle->get_pz());
    if (do_smearing)
    {
      const double momSmear = 3. / 180. * M_PI;  // rad
      const double momMagSmear = 0.1;            // relative

      seed_mom.SetMag(
          True_mom.Mag() + gsl_ran_gaussian(m_RandomGenerator,
                                            momMagSmear * True_mom.Mag()));
      seed_mom.SetTheta(True_mom.Theta() + gsl_ran_gaussian(m_RandomGenerator, momSmear));
      seed_mom.SetPhi(True_mom.Phi() + gsl_ran_gaussian(m_RandomGenerator, momSmear));
    }
  }
```

Initialization default

If there is a truth information

Option for smearing

Truth Parameters in ACTS

```
#pragma once

#include <Acts/Definitions/Units.hpp>

struct TrackParamTruthInitConfig {

    double m_maxVertexX       = 80  * Acts::UnitConstants::mm;
    double m_maxVertexY       = 80  * Acts::UnitConstants::mm;
    double m_maxVertexZ       = 200 * Acts::UnitConstants::mm;
    double m_minMomentum      = 100 * Acts::UnitConstants::MeV;
    double m_maxEtaForward    = 4.0;
    double m_maxEtaBackward   = 4.1;
    double m_momentumSmear    = 0.1;
```

Smearing momentum by 10% (Gaussian)

Track Parameters

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

↓ Extrapolate to Vertex

$(DCA_{xy}, DCA_z, \theta, \phi, q/p)$

Introducing Theta/Phi smearing

```
// modify initial momentum to avoid bleeding truth to results when fit fails
const auto pinit = pmag*(1.0 + m_cfg.m_momentumSmear * m_normDist(generator));
```

```
// build some track cov matrix
Acts::BoundSymMatrix cov                    = Acts::BoundSymMatrix::Zero();
cov(Acts::eBoundLoc0, Acts::eBoundLoc0)     = 1000*um*1000*um;
cov(Acts::eBoundLoc1, Acts::eBoundLoc1)     = 1000*um*1000*um;
cov(Acts::eBoundPhi, Acts::eBoundPhi)       = 0.05*0.05;
cov(Acts::eBoundTheta, Acts::eBoundTheta)   = 0.01*0.01;
cov(Acts::eBoundQOverP, Acts::eBoundQOverP) = (0.1*0.1) / (GeV*GeV);
cov(Acts::eBoundTime, Acts::eBoundTime)     = 10.0e9*ns*10.0e9*ns;
```

Covariance

```
Acts::BoundVector  params;
params(Acts::eBoundLoc0)   = 0.0 * mm ;  // cylinder radius
params(Acts::eBoundLoc1)   = 0.0 * mm ;  // cylinder length
params(Acts::eBoundPhi)    = phi;
params(Acts::eBoundTheta)  = theta;
params(Acts::eBoundQOverP) = charge / (pinit * GeV);
params(Acts::eBoundTime)   = part->getTime() * ns;
```

```
        double m_momentumSmear    = 0.1;
        double m_angleSmear       = 1.0/180.*M_PI; // radian
    }
    return nullptr;
}

// modify initial momentum to avoid bleeding truth to results when fit fails
const auto pinit = pmag*(1.0 + m_cfg.m_momentumSmear * m_normDist(generator));
const auto thetainit = theta + m_cfg.m_angleSmear * m_normDist(generator);
const auto phiinit = phi + m_cfg.m_angleSmear * m_normDist(generator);

Acts::BoundVector  params;
params(Acts::eBoundLoc0)   = 0.0 * mm ;  // cylinder radius
params(Acts::eBoundLoc1)   = 0.0 * mm ;  // cylinder length
params(Acts::eBoundPhi)    = phiinit;
params(Acts::eBoundTheta)  = thetainit;
params(Acts::eBoundQOverP) = charge / (pinit * GeV);
params(Acts::eBoundTime)   = part->getTime() * ns;
```

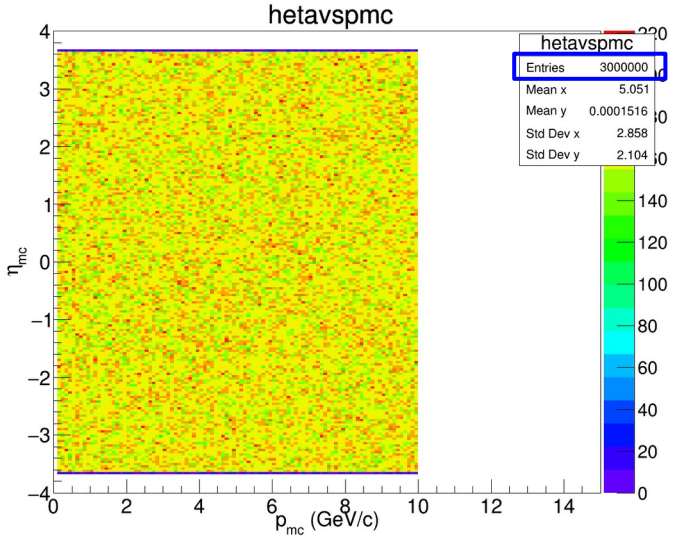
Parameter Initialization

https://github.com/eic/EICrecon/blob/main/src/algorithms/tracking/TrackParamTruthInitConfig.h

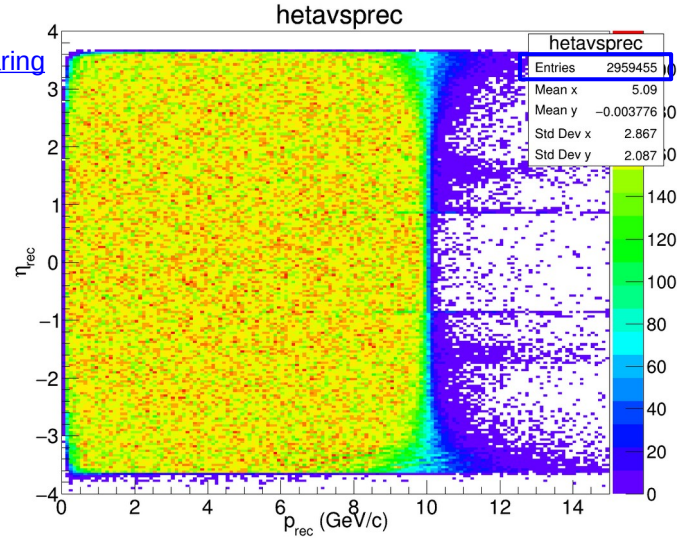
https://github.com/eic/EICrecon/blob/main/src/algorithms/tracking/TrackParamTruthInit.cc

Simulation Details

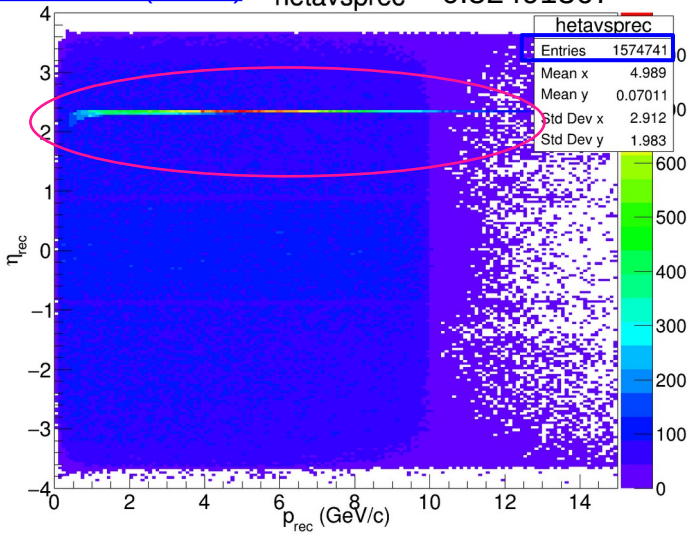
3M Pi+ Simulation with momentum [0.1,10.] GeV/c with epic_brycecanyon geometry with latest epic software



No Theta/Phi Smearing



Smearing = 3.0*Pi/180. (fun4All)



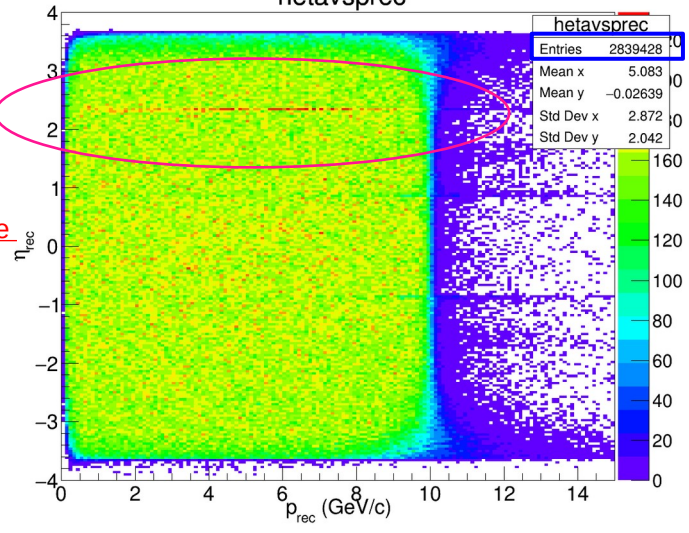
hetavsprec 0.52491367

Structures

Smearing Theta/Phi implies losing efficiency because of track finding

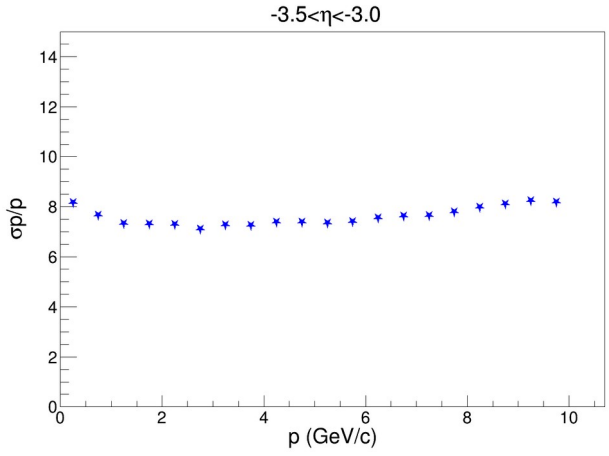
Warning No Tracks found !!

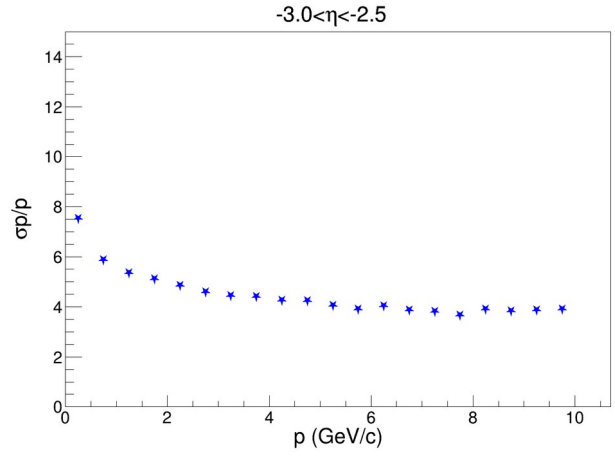
Smearing = 1.0*Pi/180.

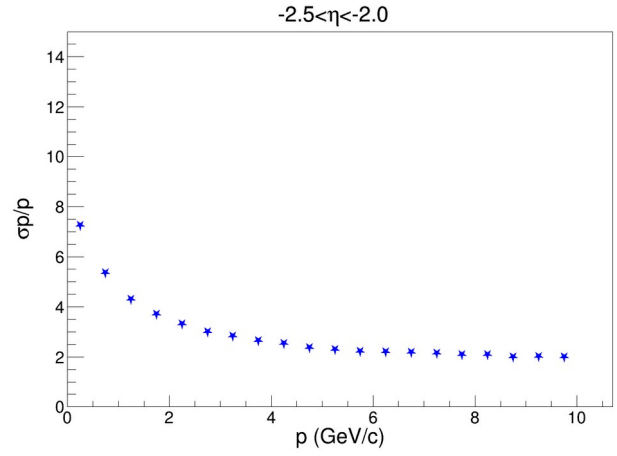


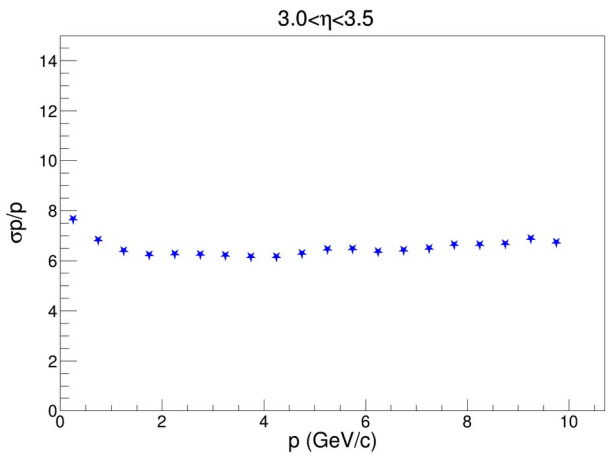
hetavsprec 0.94647600

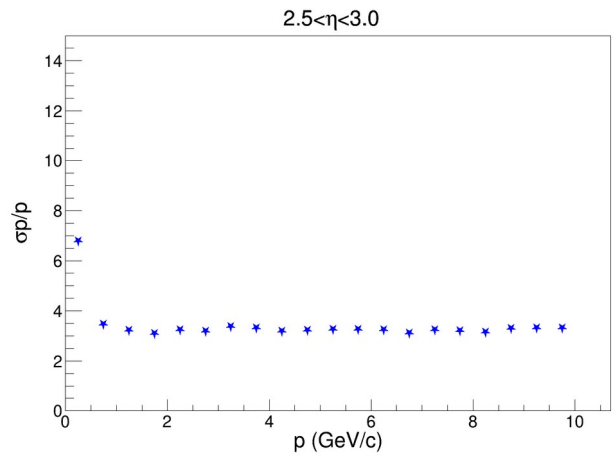
Momentum Resolution (Only Momentum Smearing)

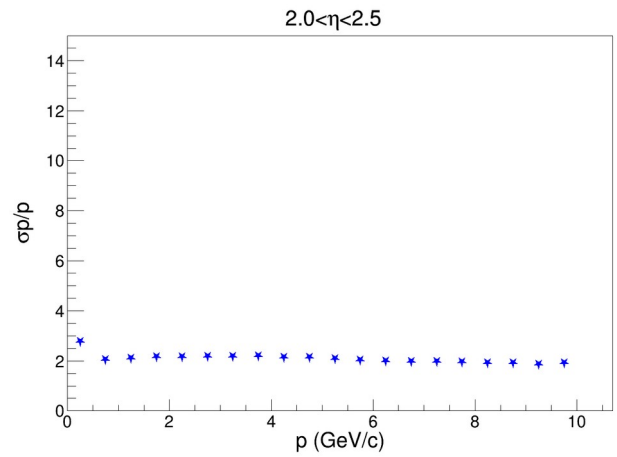












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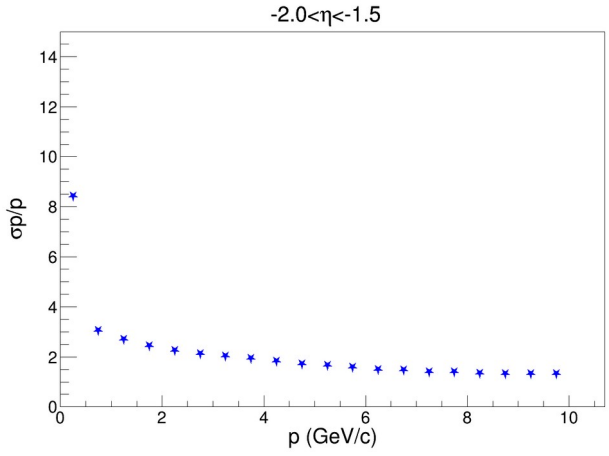
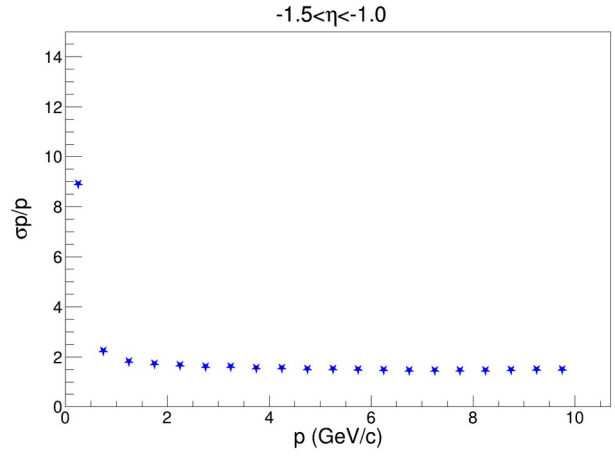
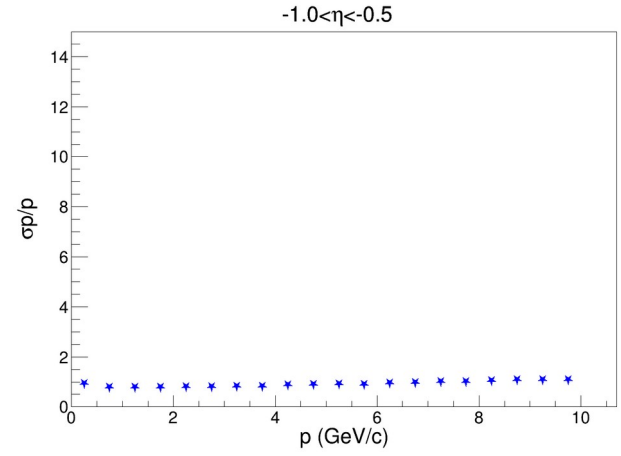
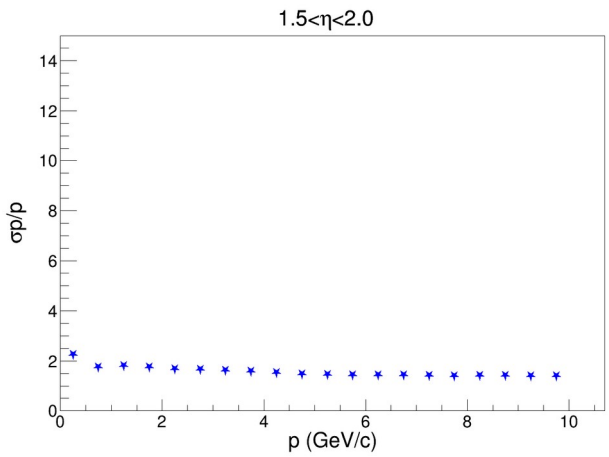
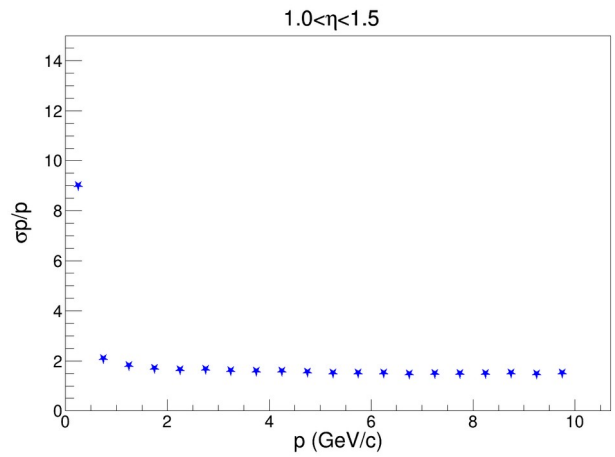
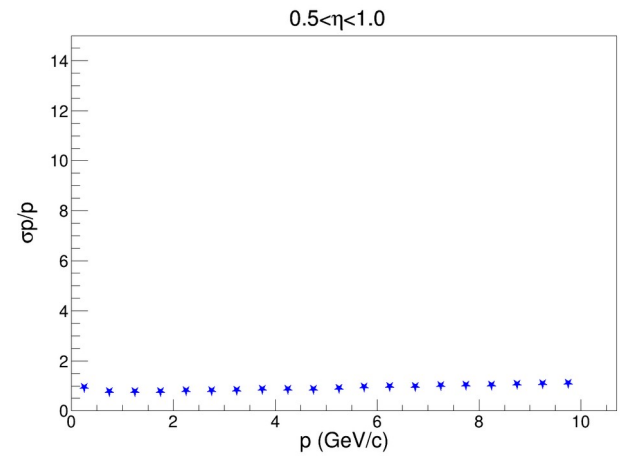






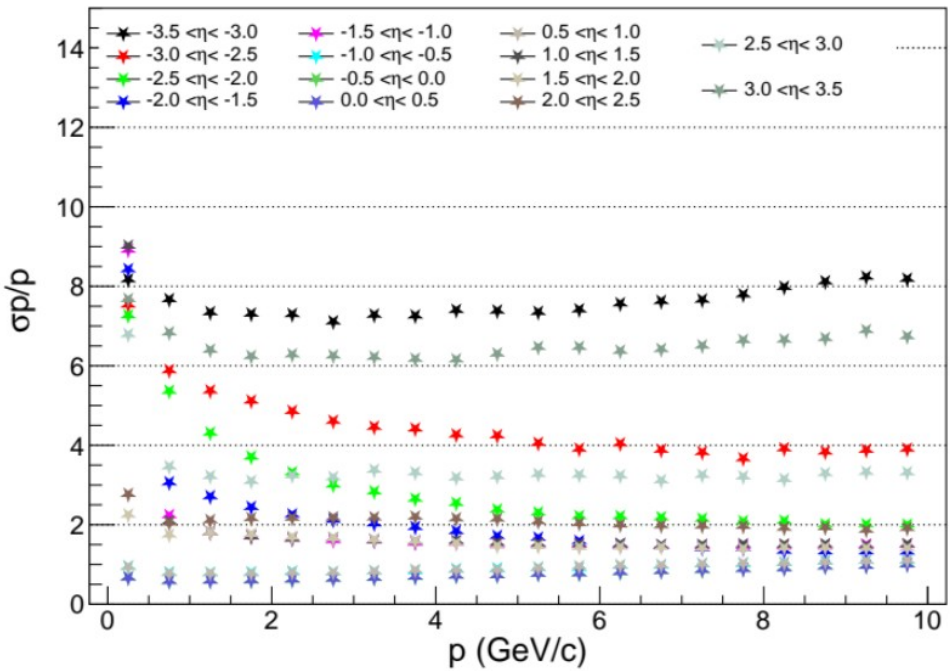


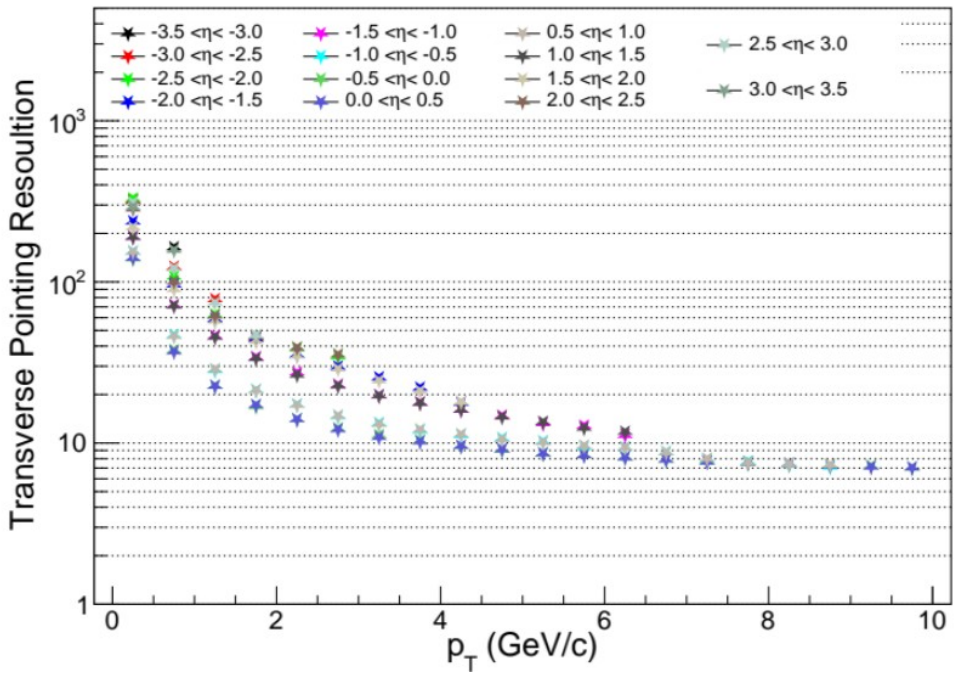




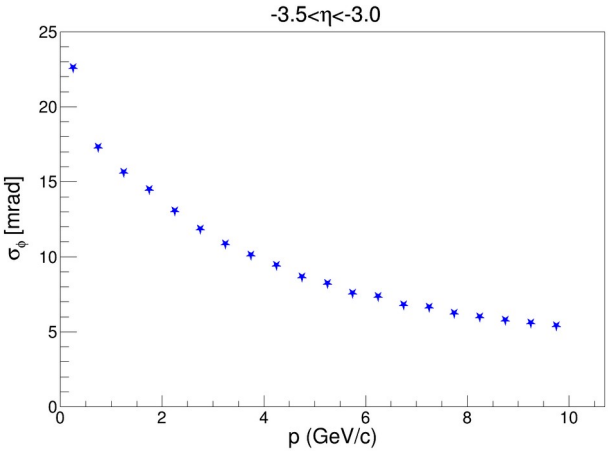
Momentum Resolution (Only Momentum Smearing)

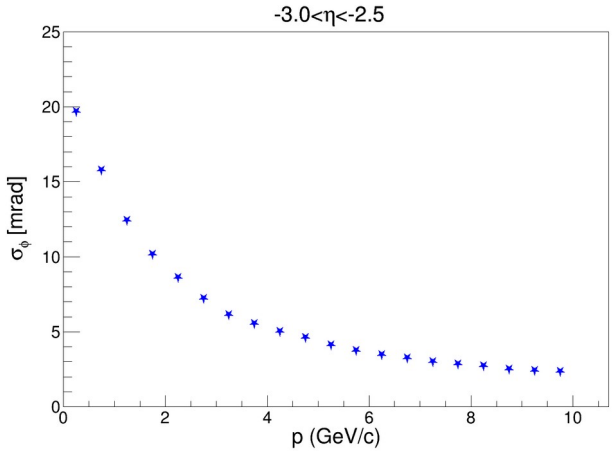
https://indico.bnl.gov/event/18272/contributions/72753/attachments/45921/79986/EPIC_Meeting_Shyam9Feb23.pdf

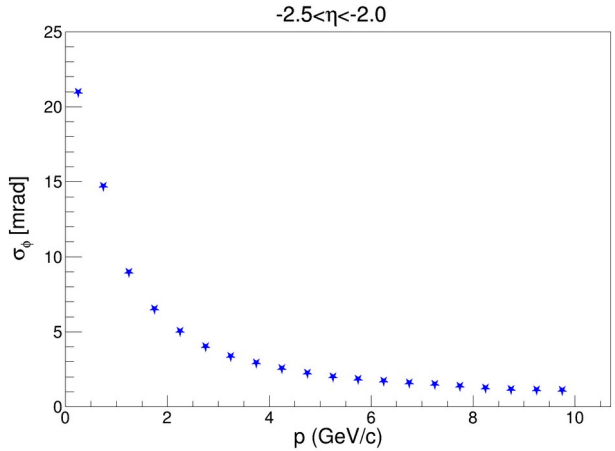


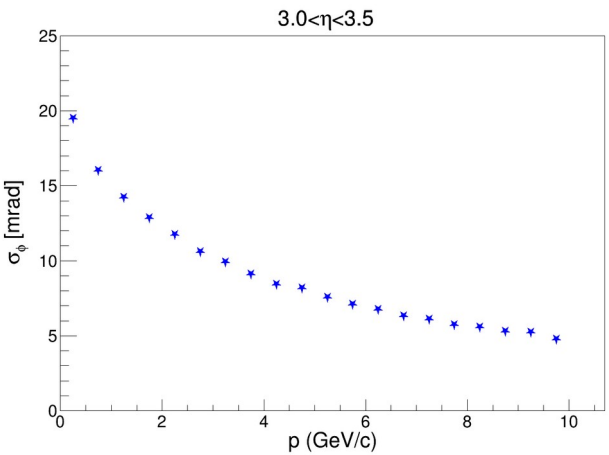


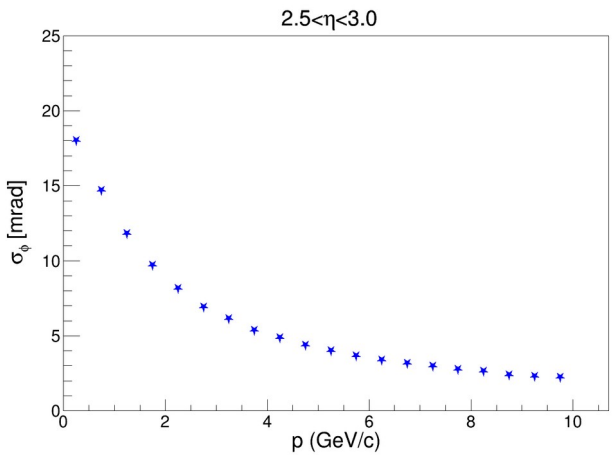
Phi Resolution (Only Momentum Smearing)

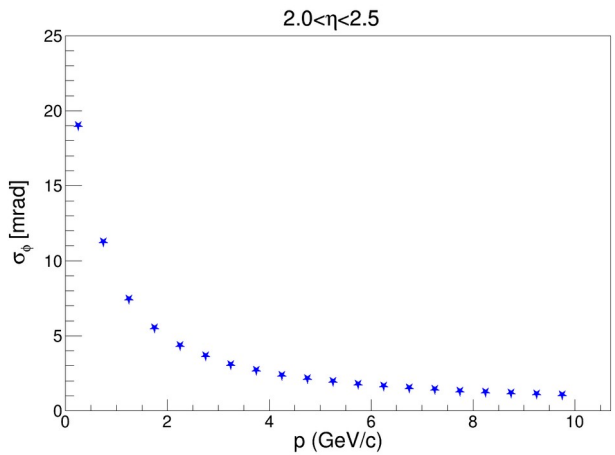












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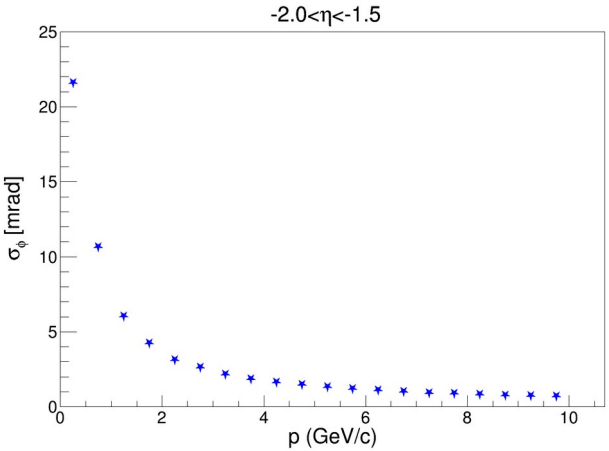
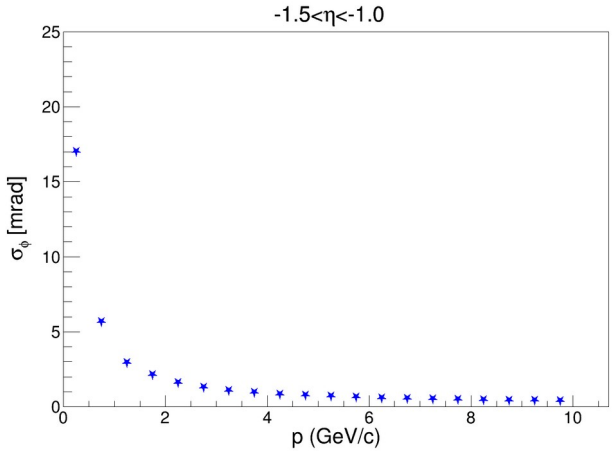
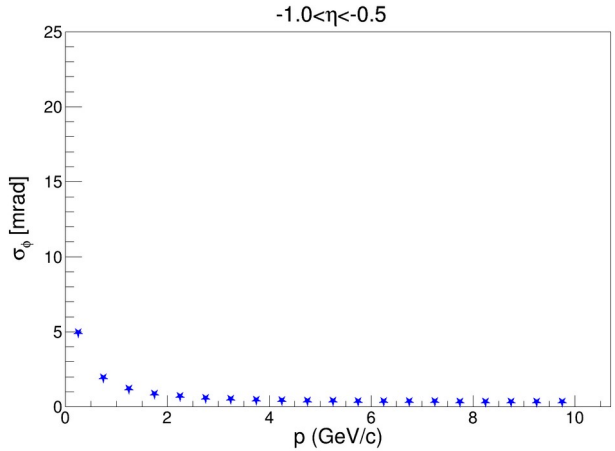
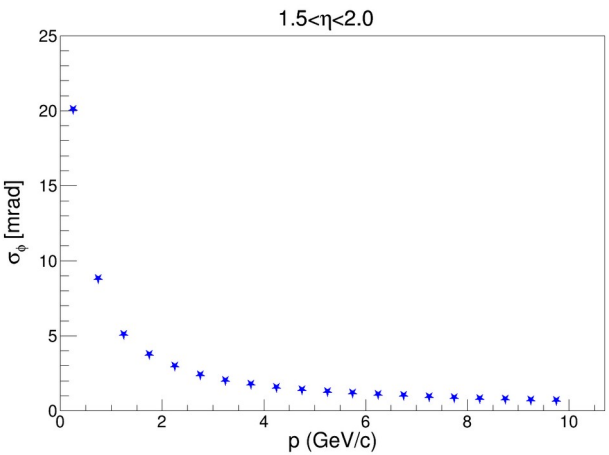
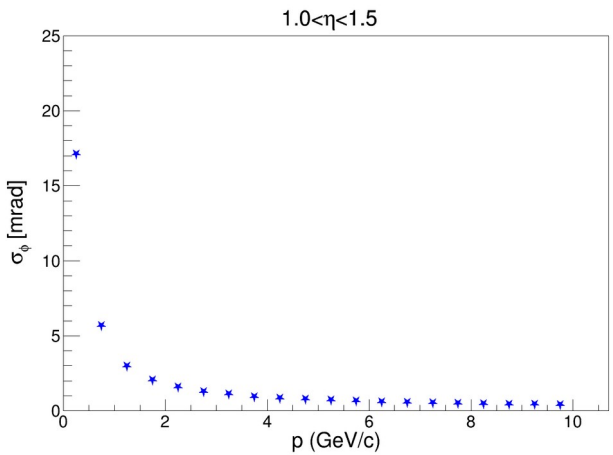
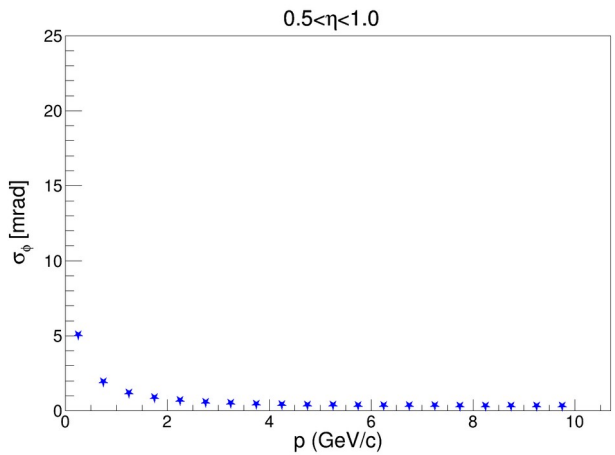




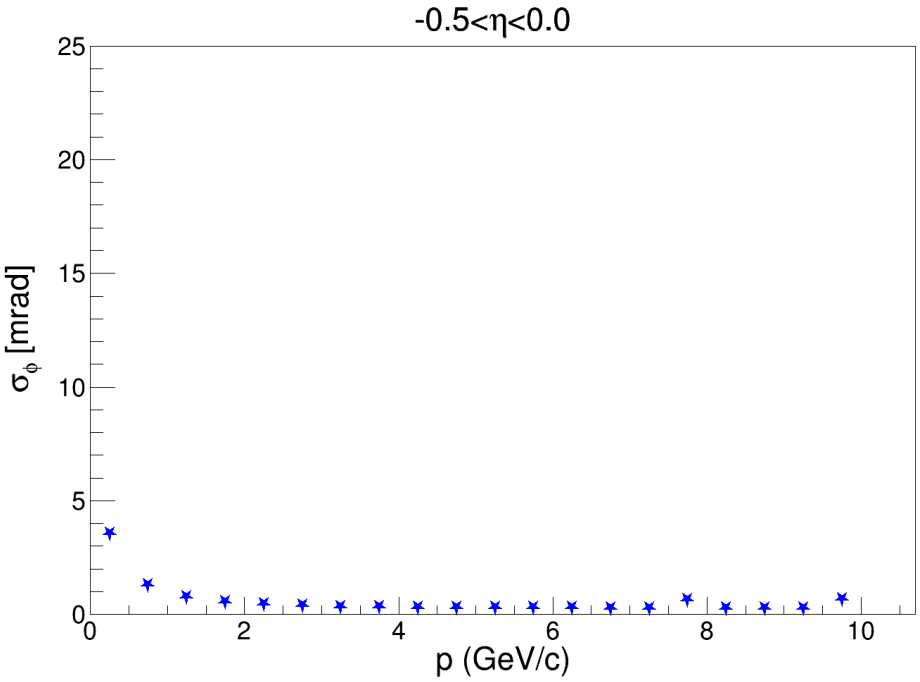


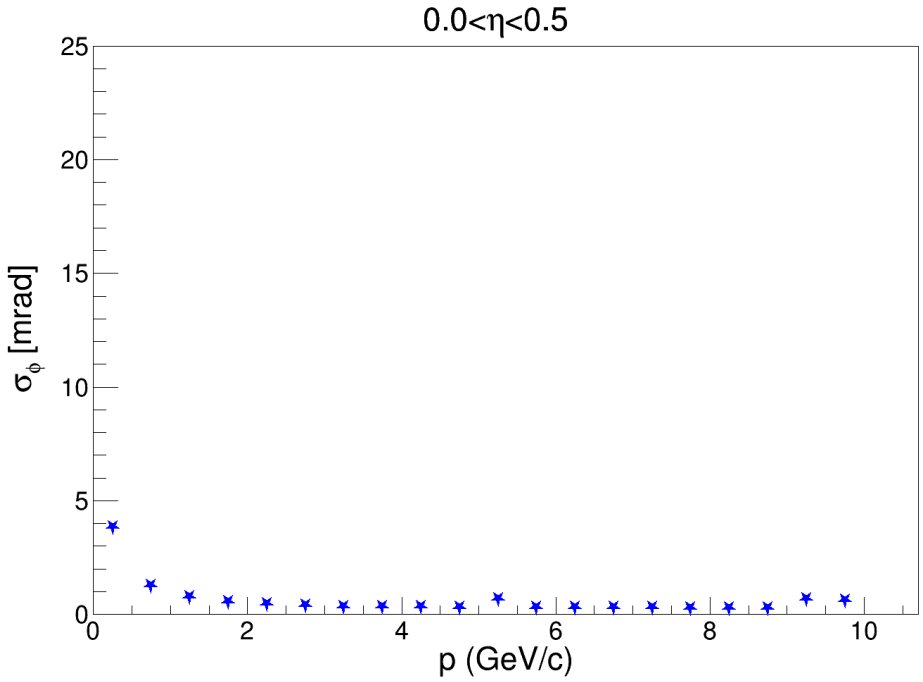




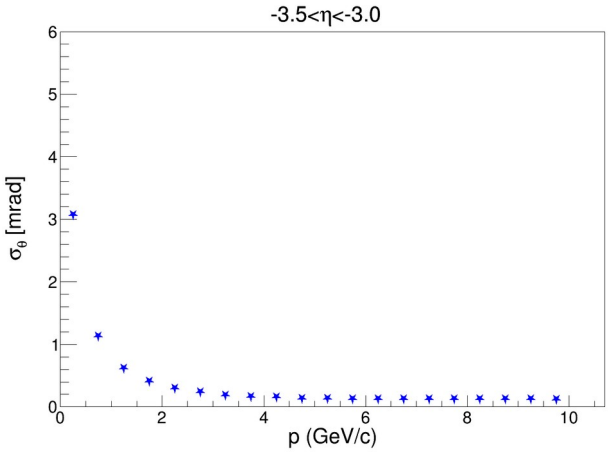


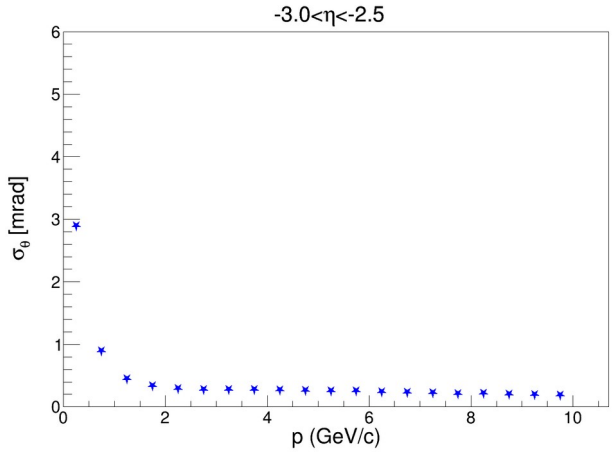
Phi Resolution (Only Momentum Smearing)

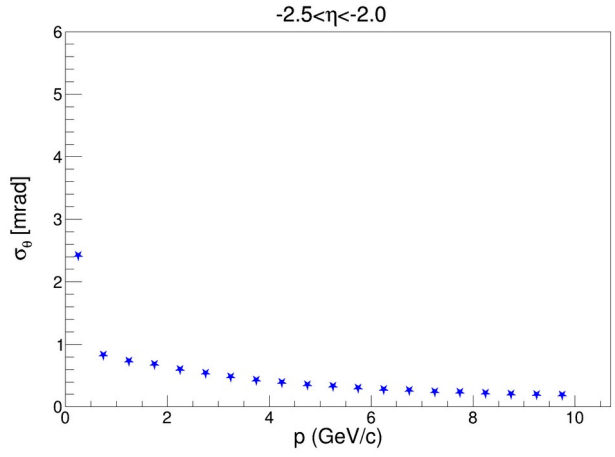


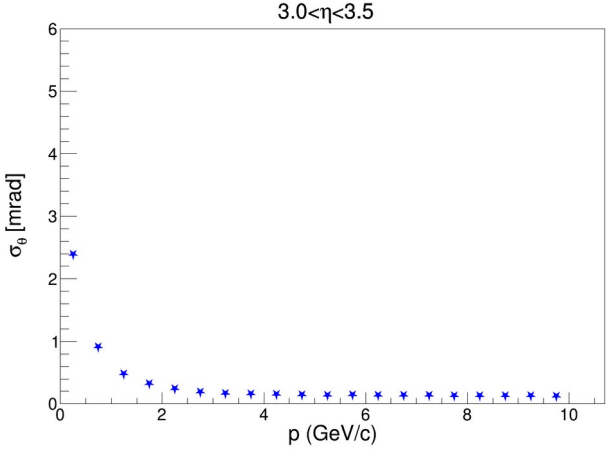


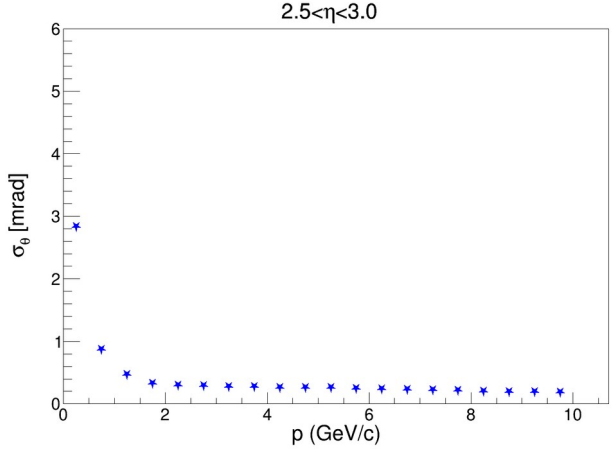
Theta Resolution (Only Momentum Smearing)

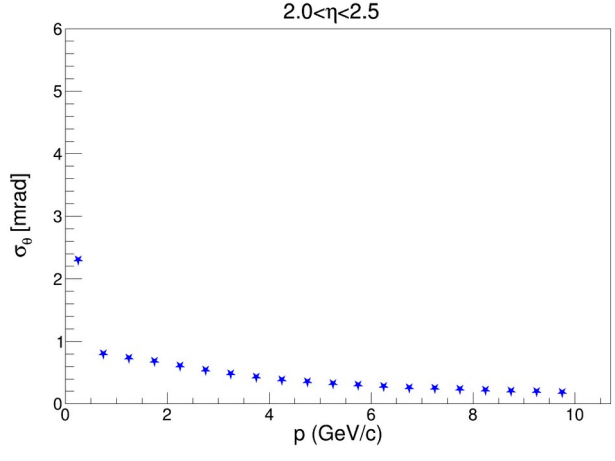




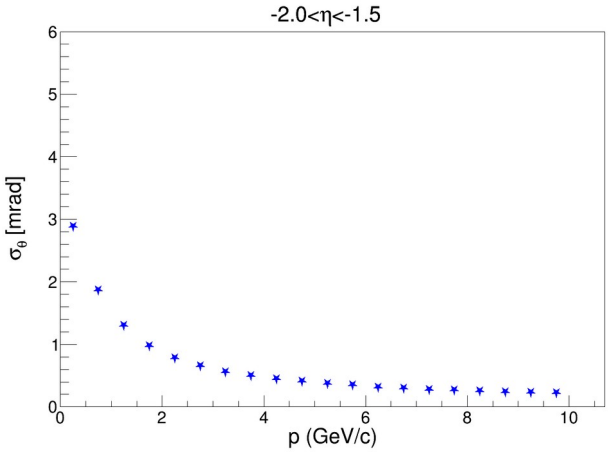


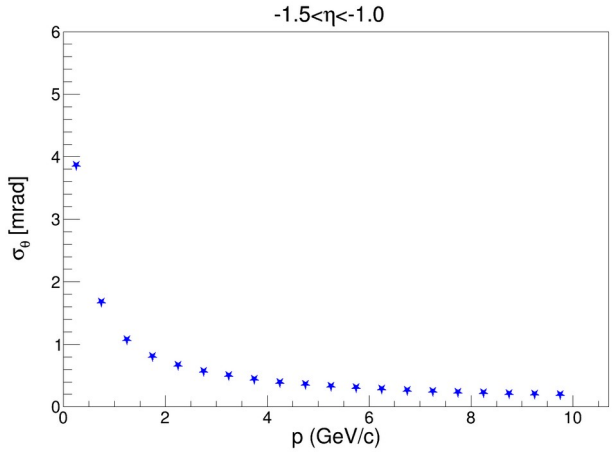


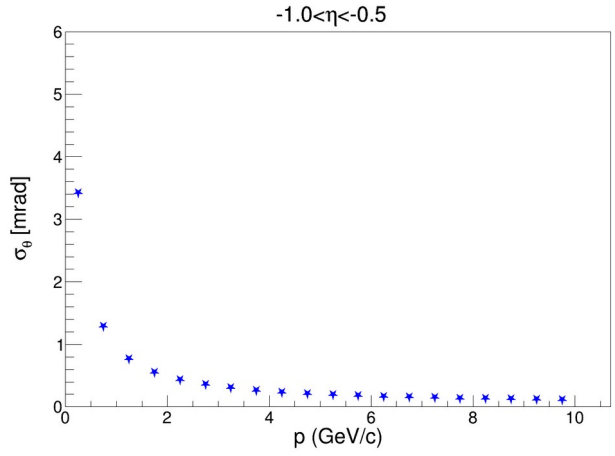


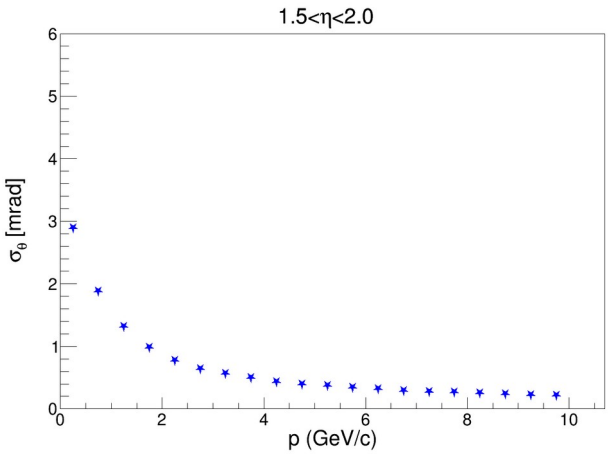


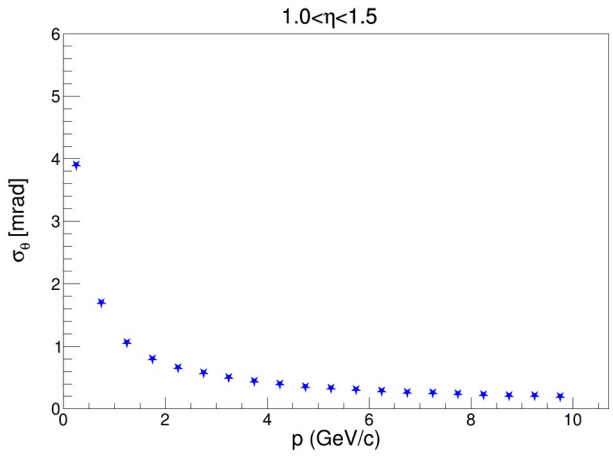
Theta Resolution (Only Momentum Smearing)

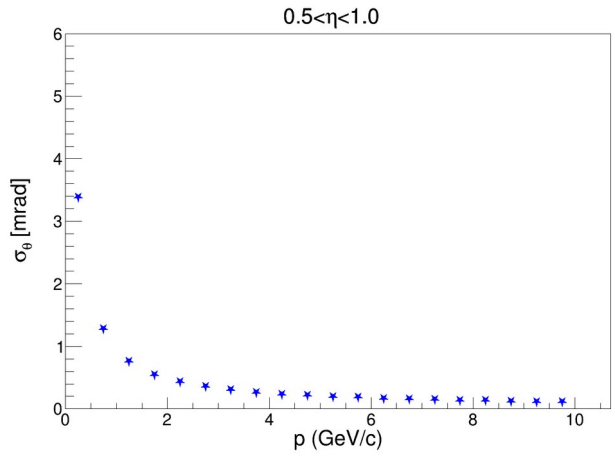




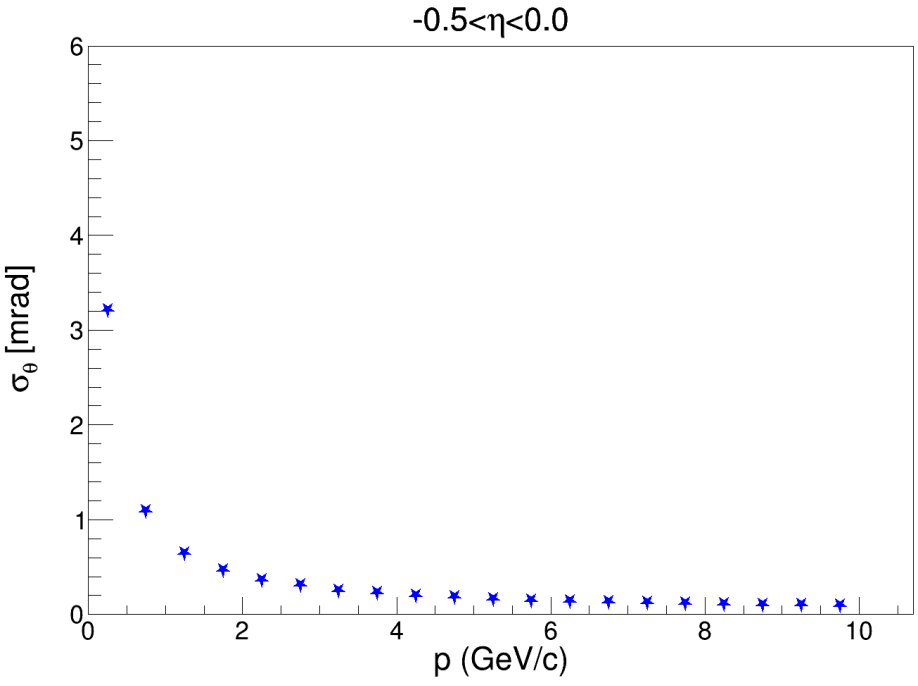


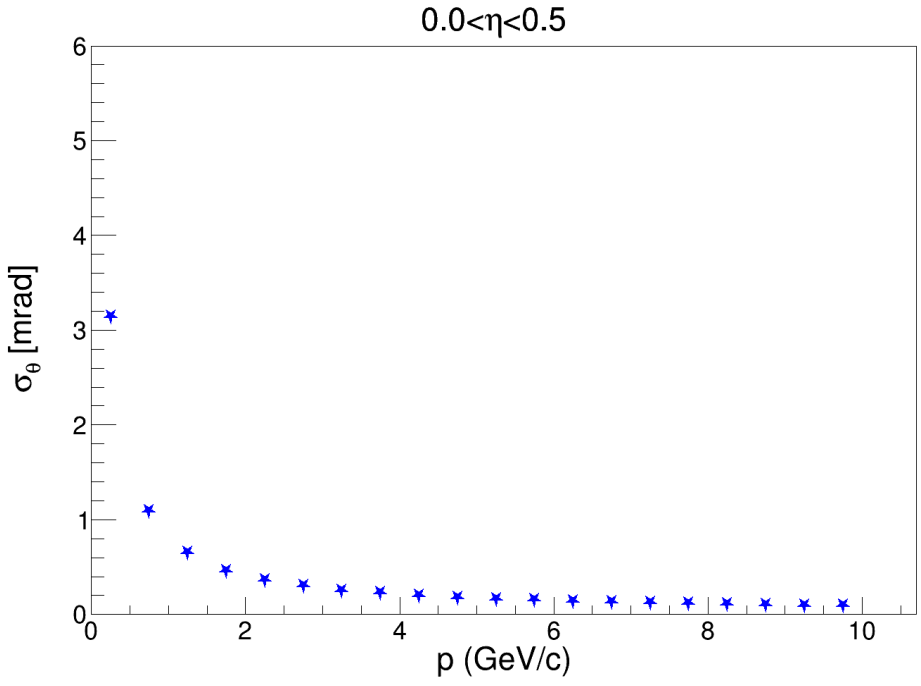






Theta Resolution (Only Momentum Smearing)

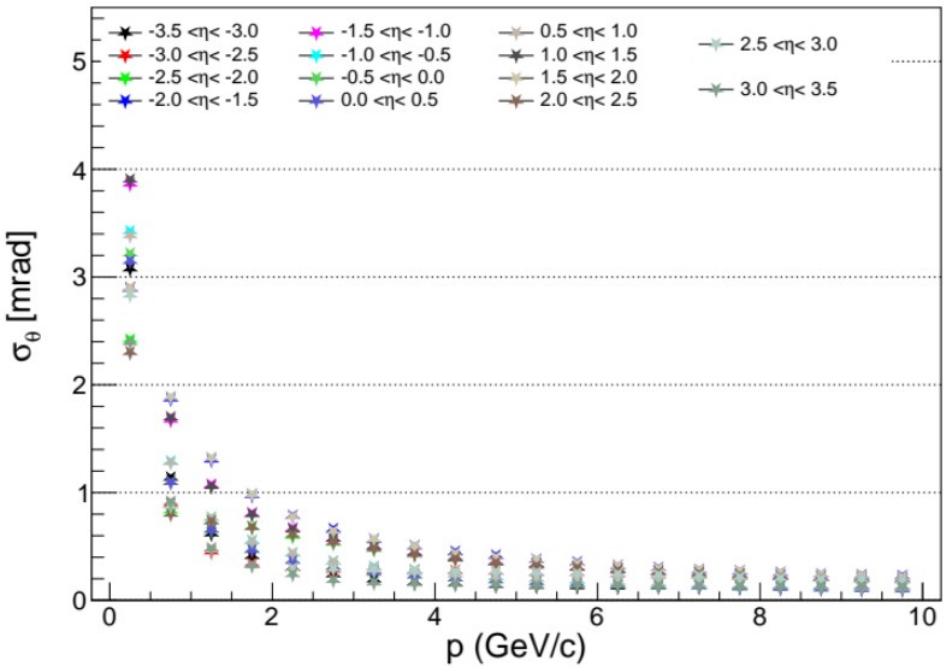


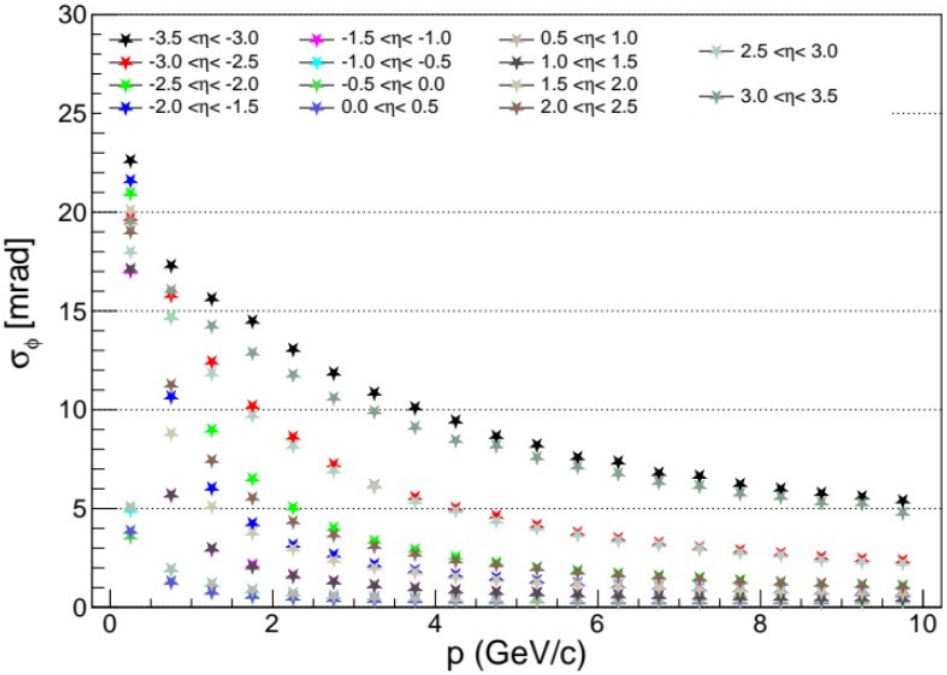


Results (Only Momentum Smearing)

```
mom_Mc.SetXYZ(px_mc[j],py_mc[j],pz_mc[j]);
Double_t theta_mc = mom_Mc.Theta(); Double_t phi_mc = mom_Mc.Phi();
mom_Rec.SetXYZ(px_rec[j],py_rec[j],pz_rec[j]);
Double_t theta_rec = mom_Rec.Theta(); Double_t phi_rec = mom_Rec.Phi();
```

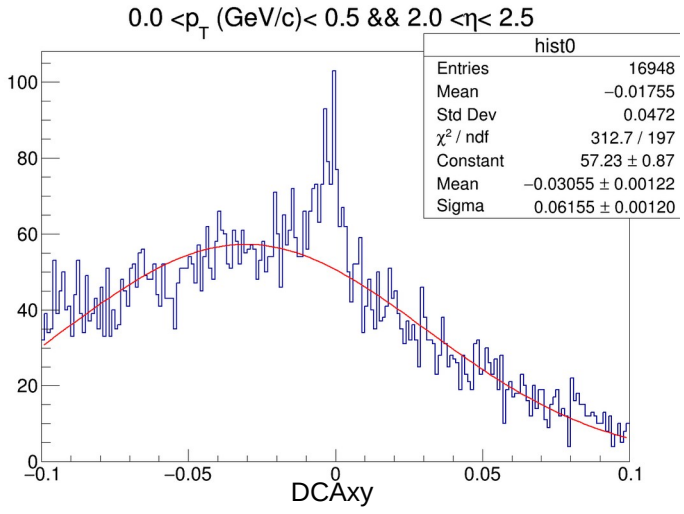
```
Double_t theta_resol = theta_rec-theta_mc;
Double_t phi_resol = phi_rec-phi_mc;
```

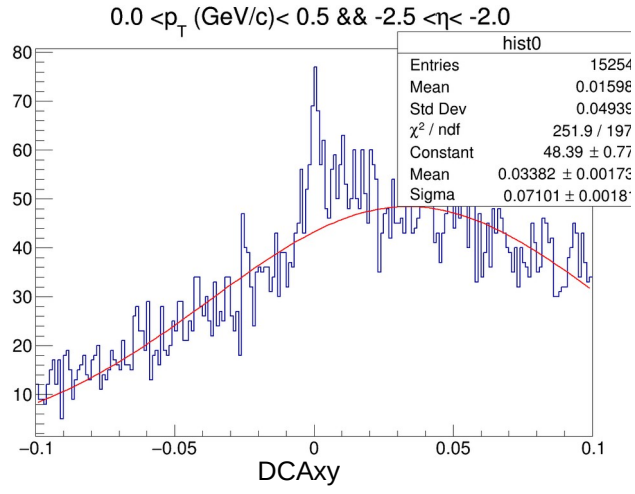


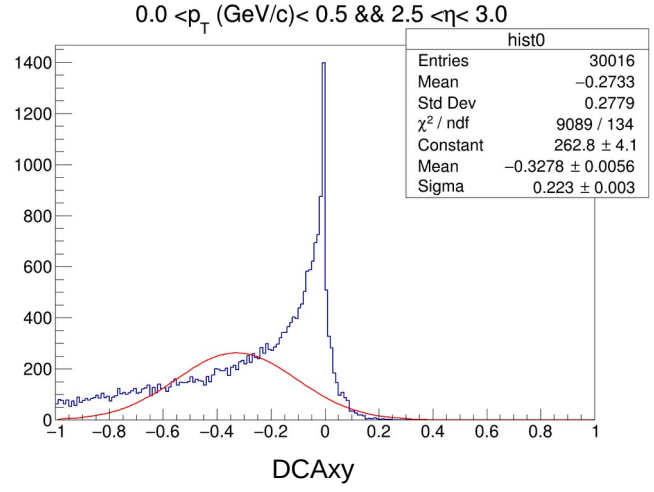


DCAxy Distributions

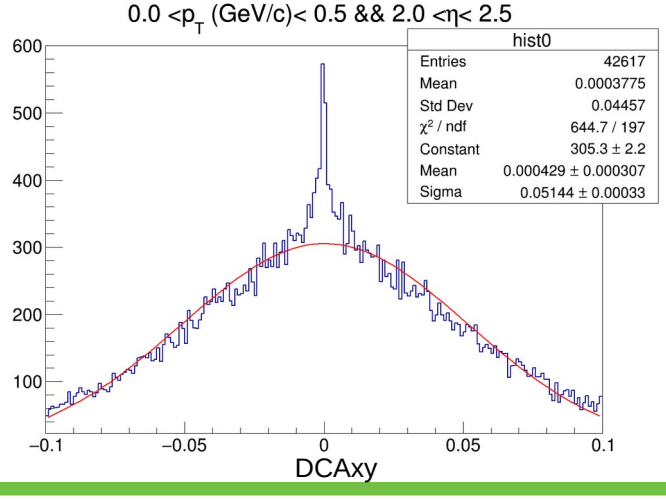
Smearing by 3 deg Theta/Phi (Disturbed DCAxy distribution not a suitable choice)

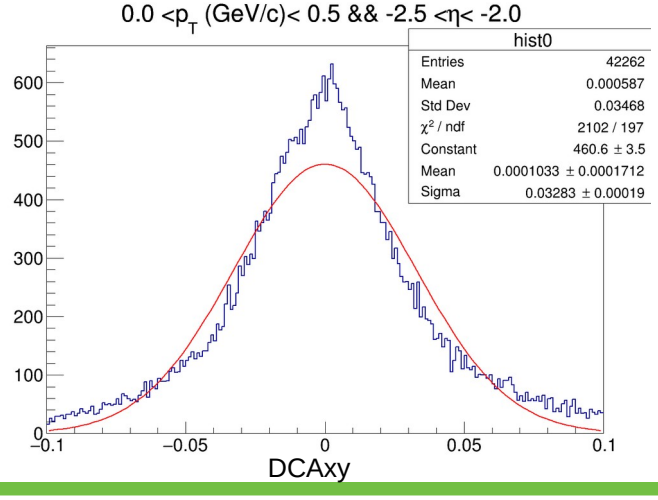


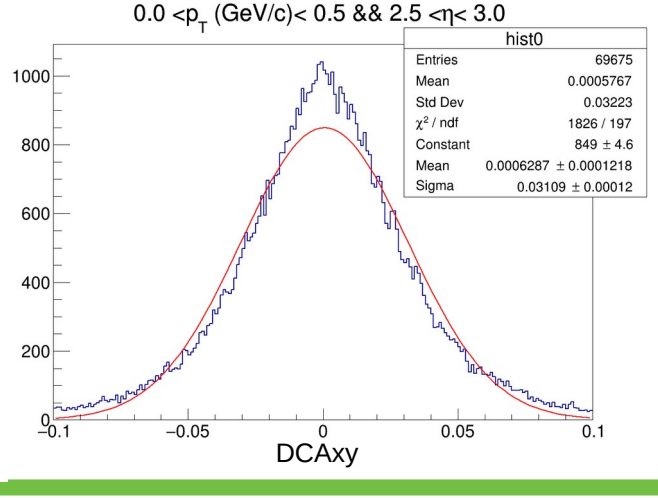




Only Momentum Smearing

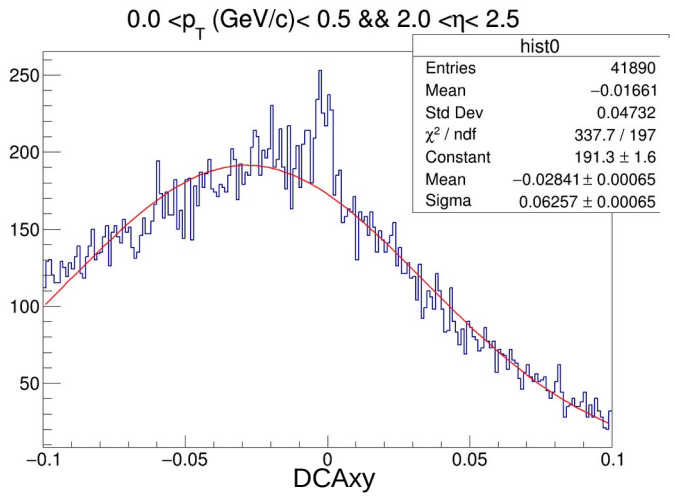


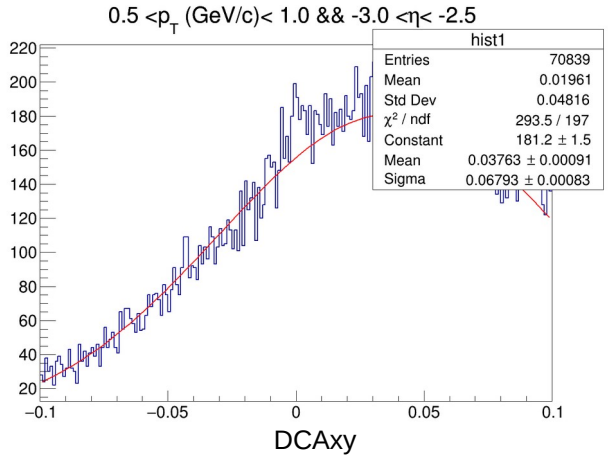


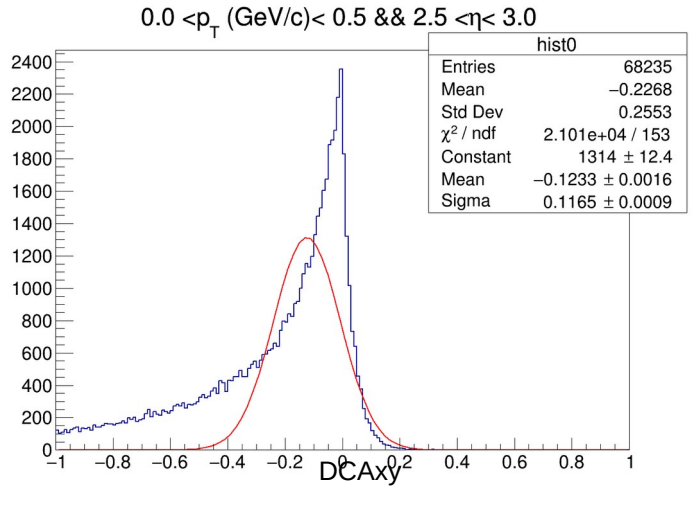


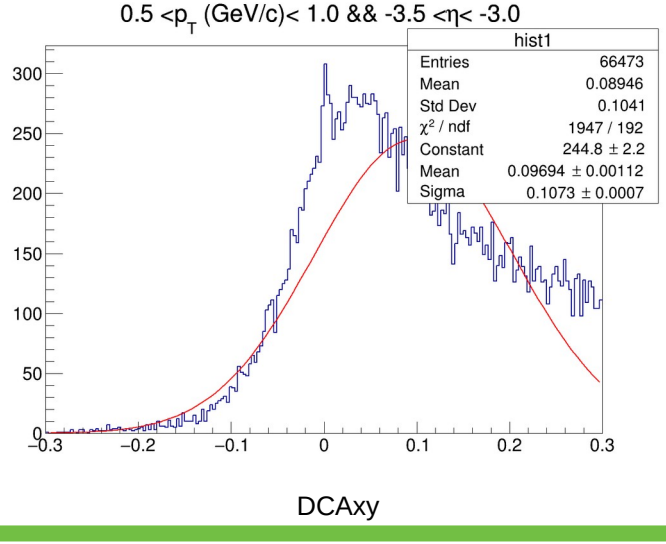
DCAxy Distributions

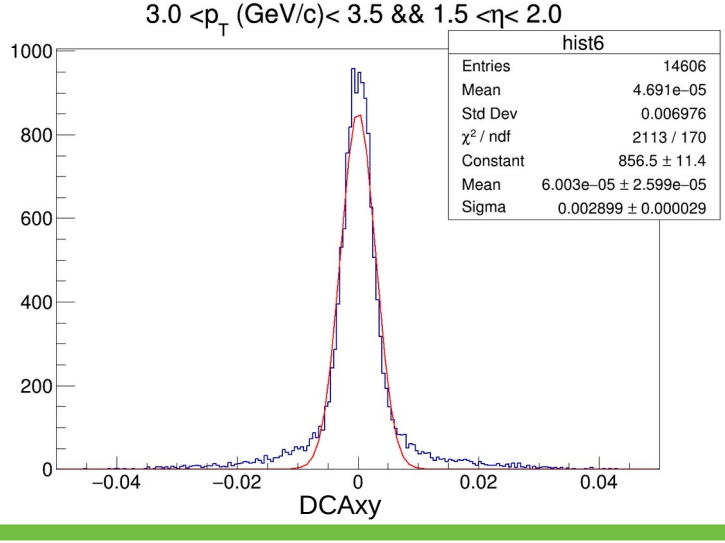
Smearing by 1 deg Theta/Phi (Disturbed DCAxy distribution not a suitable choice)

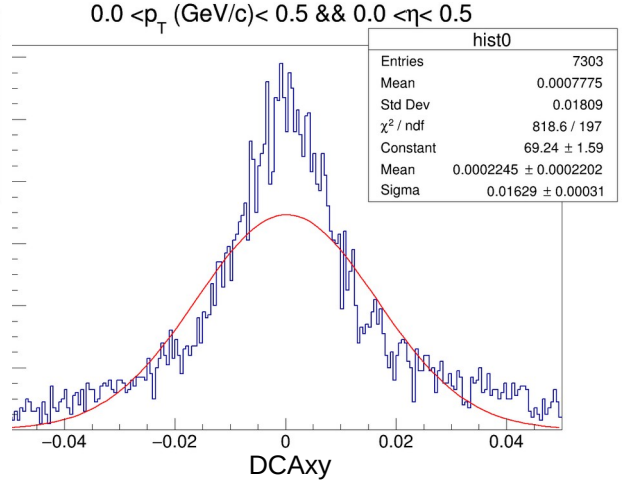




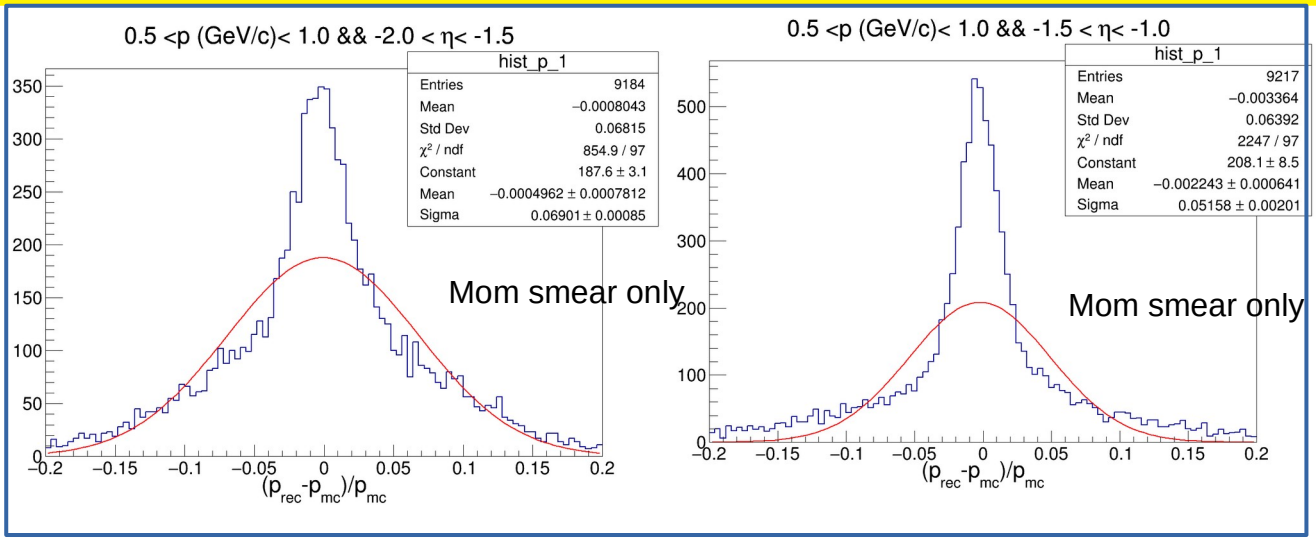


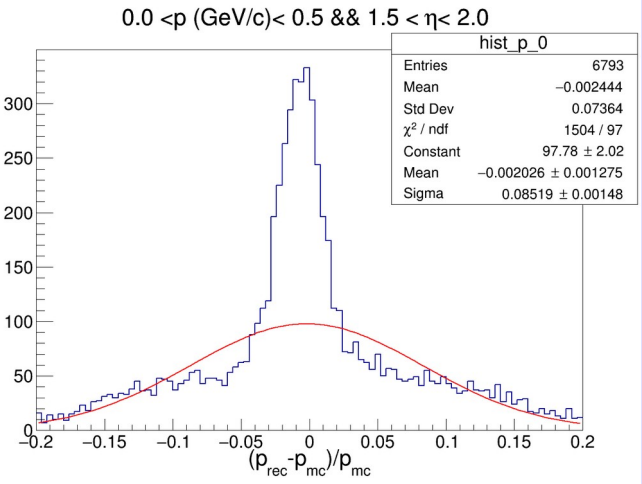


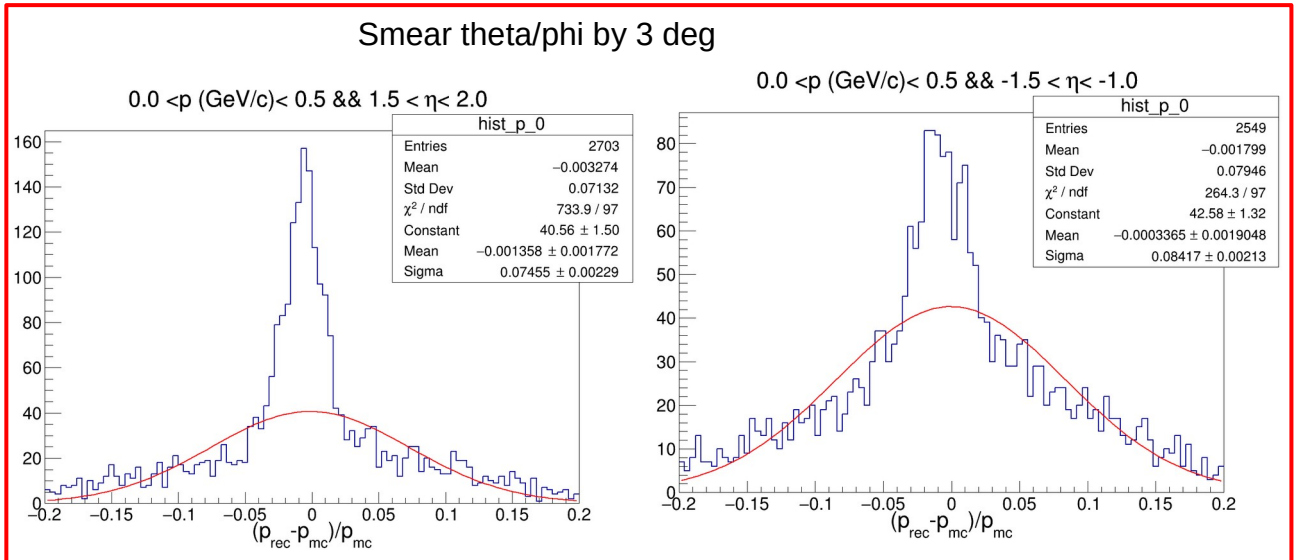


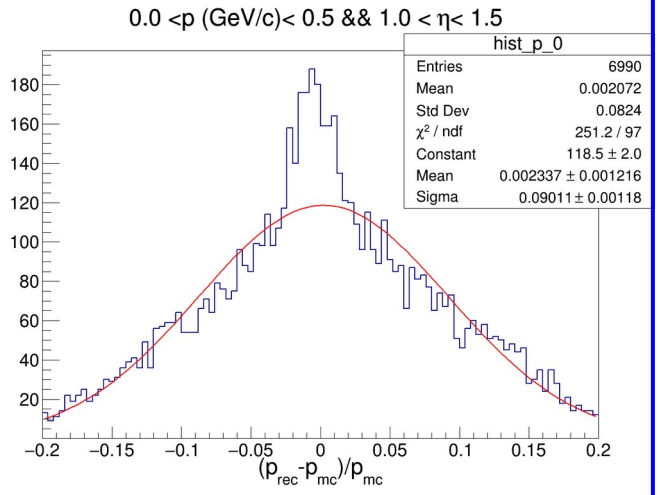


Momentum Resolution (Long tailed distribution)









Summary & Future Plan

- Smearing in Theta and Phi creates the problem in efficiency, also DCAxy distributions are affected
- I don’t see the decreasing trend in Theta/Phi resolution (Momenum smearing already there)
- There is an issue of long tail in the momentum resolution

$$\frac{\sigma_{pT}}{p_T} = \sqrt{\left(\frac{\sigma_{pT_{SR}}}{p_T}\right)^2 + \left(\frac{\sigma_{pT_{MS}}}{p_T}\right)^2}$$

$$\sigma_{d_0} = \sqrt{\sigma_{d0_{SR}}^{\ 2} + \sigma_{d0_{MS}}^{\ 2}}$$

$$\Delta d_0|_{res.} \approx \frac{3\sigma_{r\phi}}{\sqrt{N+5}}\sqrt{1 + \frac{8r_0}{L_0} + \frac{28r_0^2}{L_0^2} + \frac{40r_0^3}{L_0^3} + \frac{20r_0^4}{L_0^4}}$$

$$\sigma_{pT_{SR}} \propto \sigma_{r\phi} p$$

$$\sigma_{pT_{MS}} \propto \frac{1}{\beta p} p = \text{const}/\beta$$

$$\Delta d_0|_{m.s.} \approx \frac{0.0136\,\text{GeV/c}}{\beta p_T} r_0 \sqrt{\frac{d}{X_0 \sin\theta}} \sqrt{1 + \frac{1}{2}\left(\frac{r_0}{L_0}\right) + \frac{N}{4}\left(\frac{r_0}{L_0}\right)^2}$$

Curvature