Smearing of Parameters in the Truth Seeding

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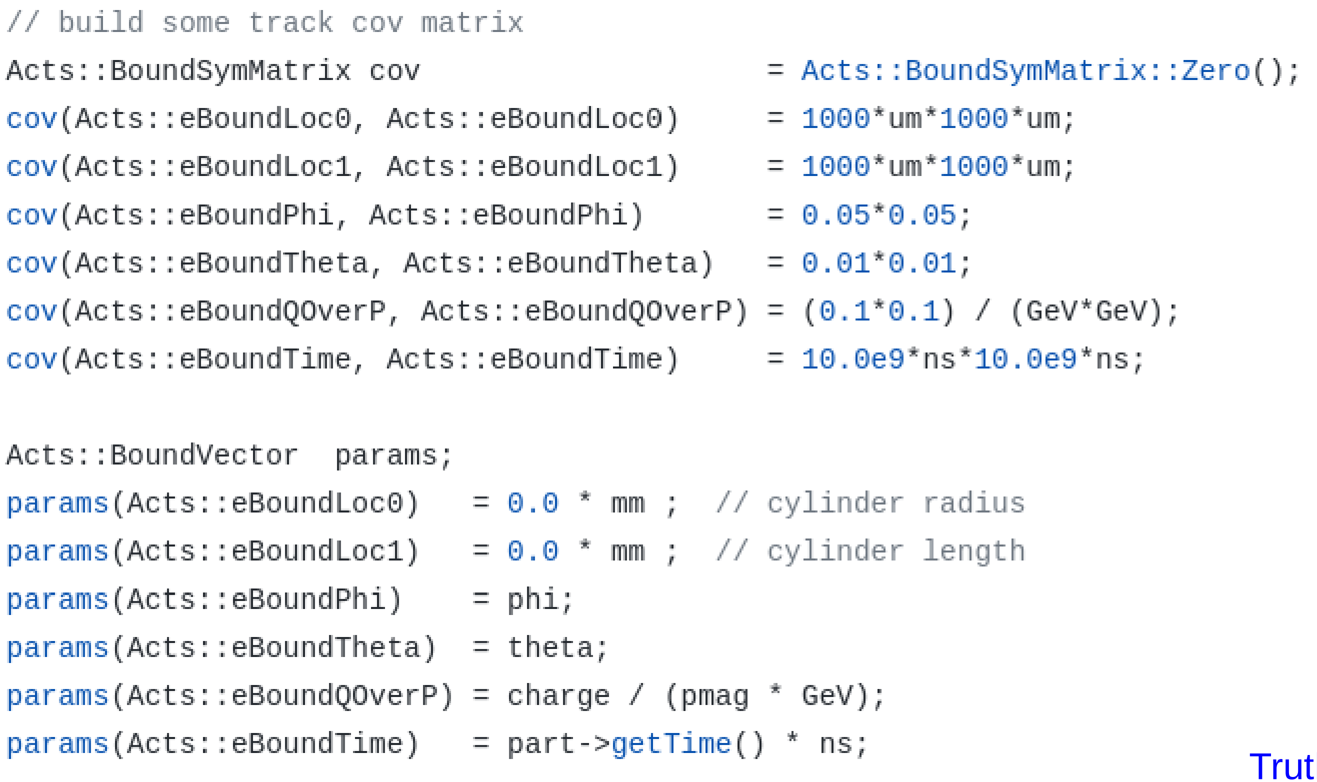
Old Slides

https://indico.bnl.gov/event/18084/contributions/72076/attachments/45516/76791/EPIC_ACTS_Meeting_Shyam12Jan23.pdf

epic_brycecanyon.xml with calorimeters and far forward detectors removed

```
shyam@shyam:~/eic/epic$ git tag -l
22.10.0
22.10_rc1
22.11.0
shyam@shyam:~/eic/epic$ git checkout 22.10.0
shyam@shyam:~/eic/epic$ git pull origin main
```

Truth Parameters in ACTS (Old)



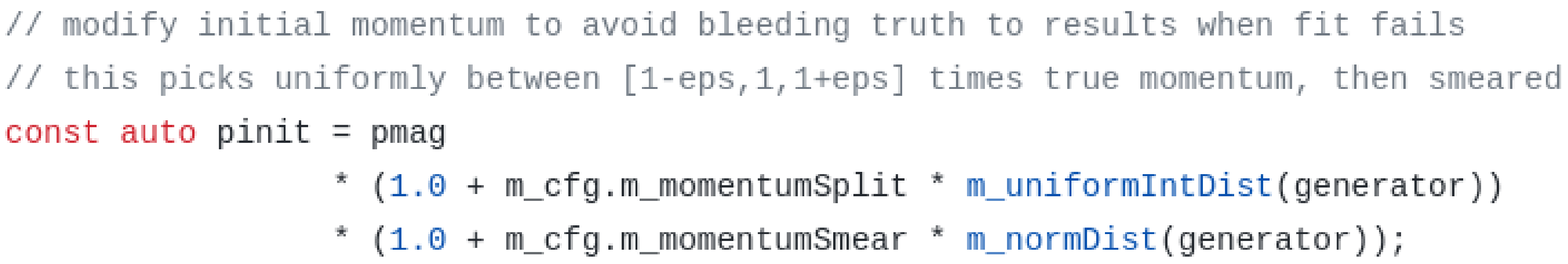
```
// build some track cov matrix
Acts::BoundSymMatrix cov                     = Acts::BoundSymMatrix::Zero();
cov(Acts::eBoundLoc0, Acts::eBoundLoc0)      = 1000*um*1000*um;
cov(Acts::eBoundLoc1, Acts::eBoundLoc1)      = 1000*um*1000*um;
cov(Acts::eBoundPhi, Acts::eBoundPhi)        = 0.05*0.05;
cov(Acts::eBoundTheta, 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;

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 / (pmag * GeV);
params(Acts::eBoundTime)   = part->getTime() * ns;
```

$$\begin{tikzcd}
(l_0, l_1, \theta, \phi, q/p) \arrow[d] \\
(d_0, z_0, \theta, \phi, q/p) \arrow[d, "\text{Extrapolate to Vertex}"] \\
(DCA_{xy}, DCA_z, \theta, \phi, q/p)
\end{tikzcd}$$

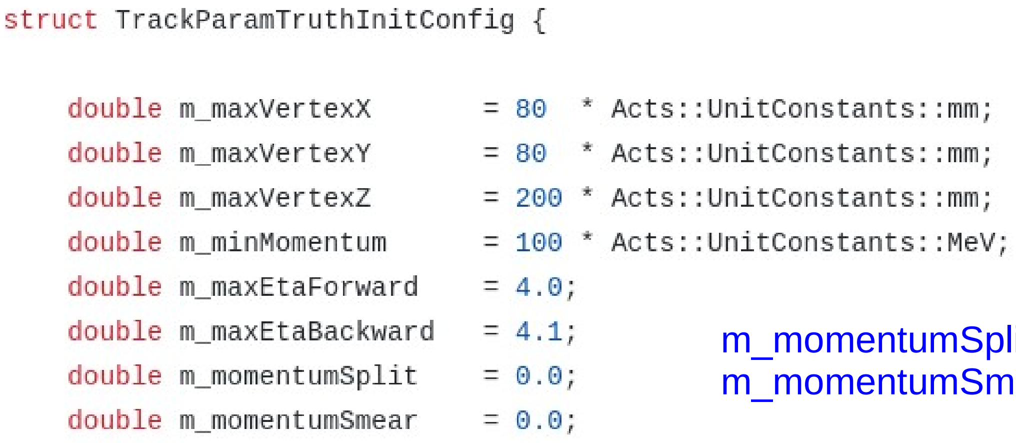
Truth parameters are not smeared !!!

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

Truth Parameters in ACTS (New)



```
// modify initial momentum to avoid bleeding truth to results when fit fails
// this picks uniformly between [1-eps,1,1+eps] times true momentum, then smeared
const auto pinit = pmag
                 * (1.0 + m_cfg.m_momentumSplit * m_uniformIntDist(generator))
                 * (1.0 + m_cfg.m_momentumSmear * m_normDist(generator));
```



```
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_momentumSplit    = 0.0;
    double m_momentumSmear    = 0.0;
```

m_momentumSplit = 0.01, 0.1, 0.2, 0.90
m_momentumSmear = 0.01, 0.1, 0.2, 0.90

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

Spatial Resolution and Multiple Scattering

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

From Fast simulation

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

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

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

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

Curvature

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

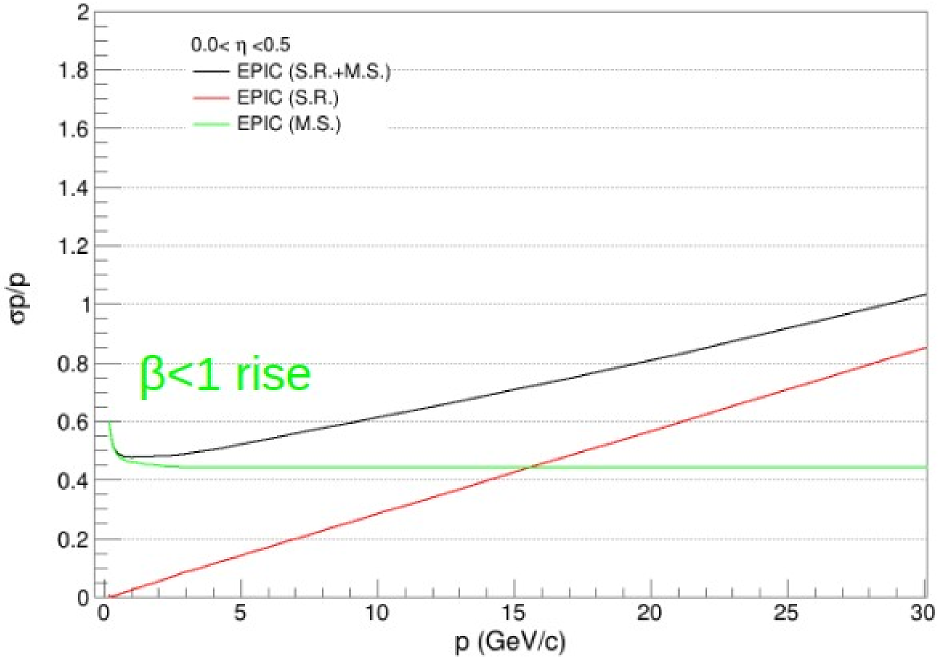
Curvature

Momentum hypothesis

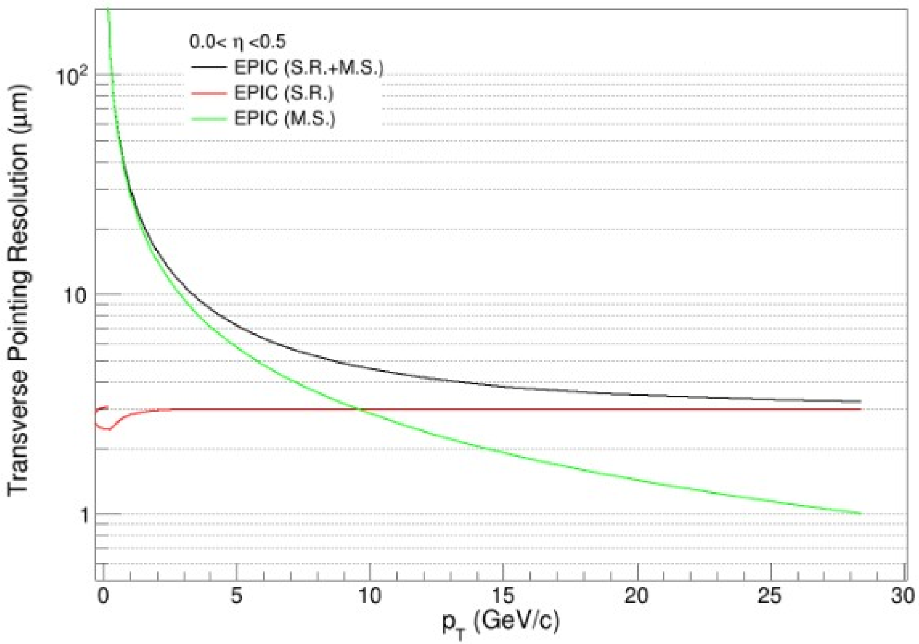
Realistic seeding → Curvature

Momentum hypothesis

Realistic seeding → Curvature



β<1 rise



https://indico.bnl.gov/event/17750/contributions/71187/attachments/44843/75637/EPIC_Tracking_Meeting_Shyam1Dec2022.pdf

Truth Parameters in Fun4All

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

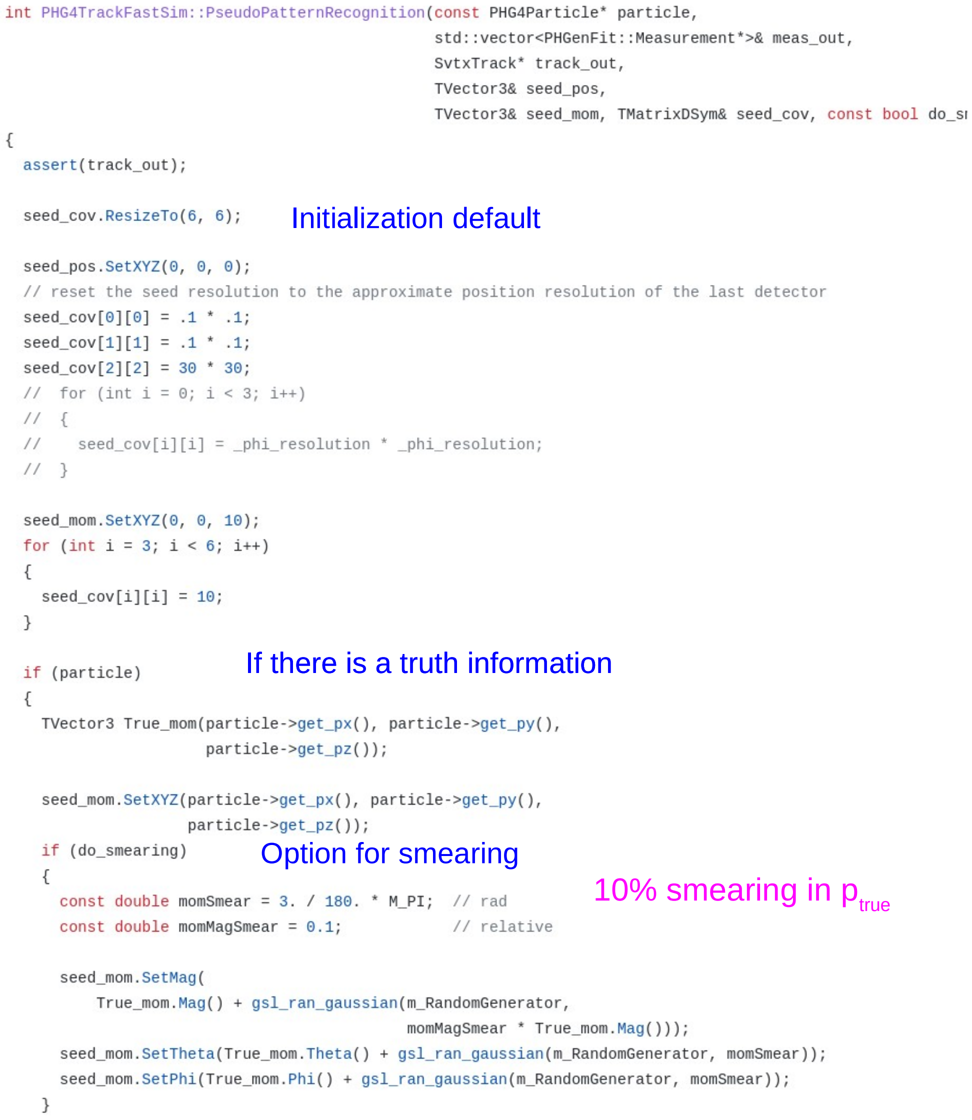
int PseudoPatternRecognition(const PHG4Particle* particle,

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



```
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_sı
{
  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

10% smearing in p_{true}

My Idea on Oct 2022

https://github.com/eic/EICrecon/issues/215

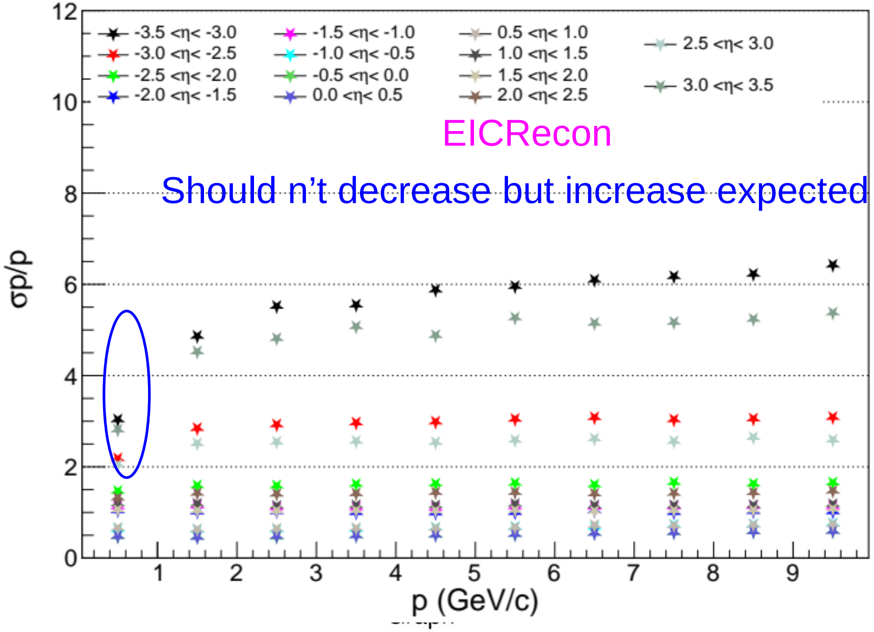
<u>Fun4All also avoid large smearing in momentum but smears theta and phi</u>

```
root [0] 3.0/180.*3.1416
(double) 0.052360000
```

0.05236 radian smearing in theta and Phi

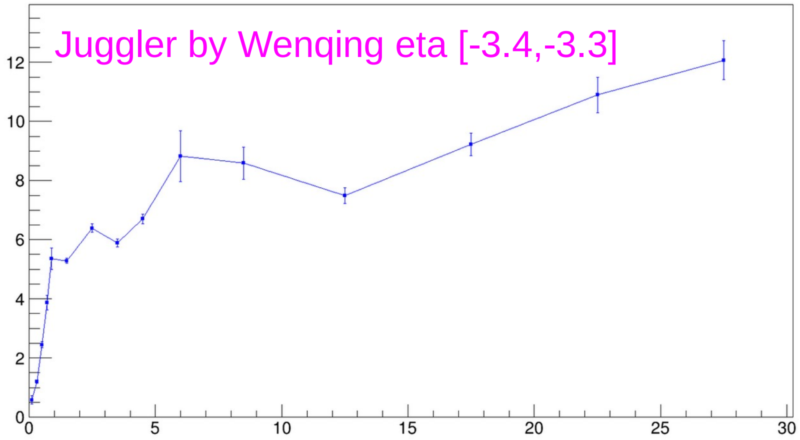
Results

3M pi+ p [0.1,10. GeV/c] and η [-3.5,3.5]



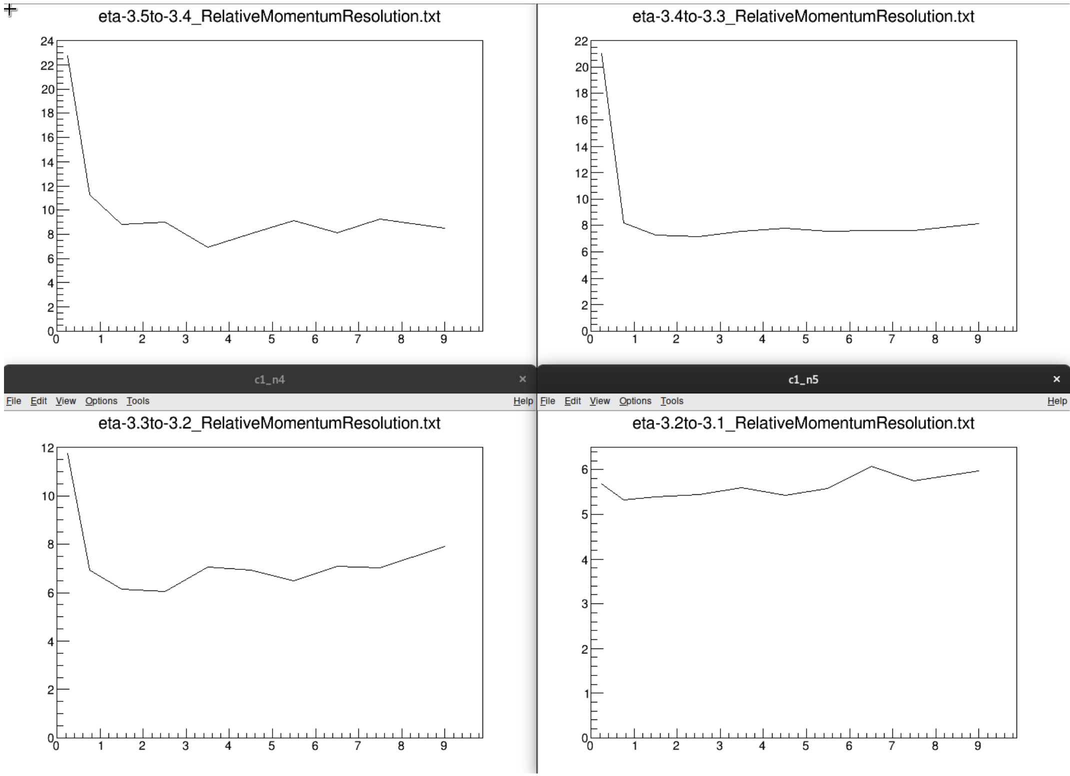
EICRecon

Should n't decrease but increase expected



Juggler by Wenqing eta [-3.4,-3.3]

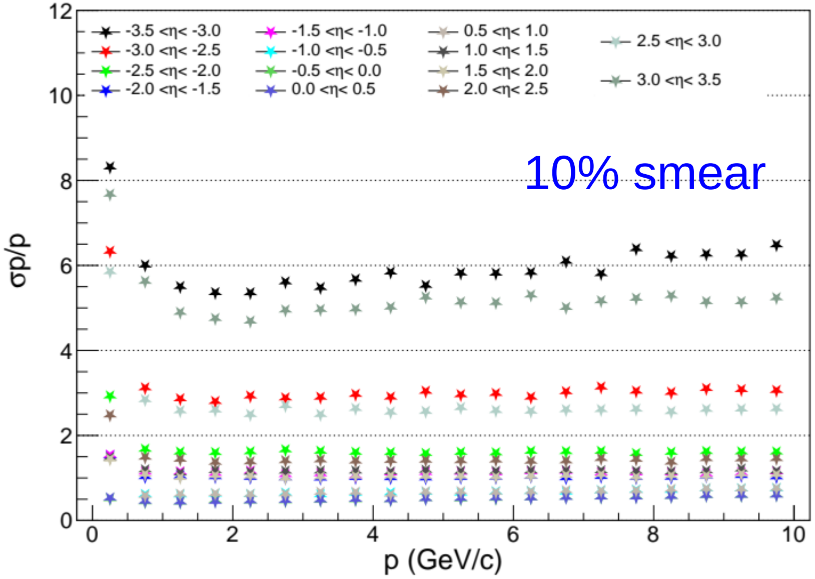
From Stephen using Fun4All (geometry is same)

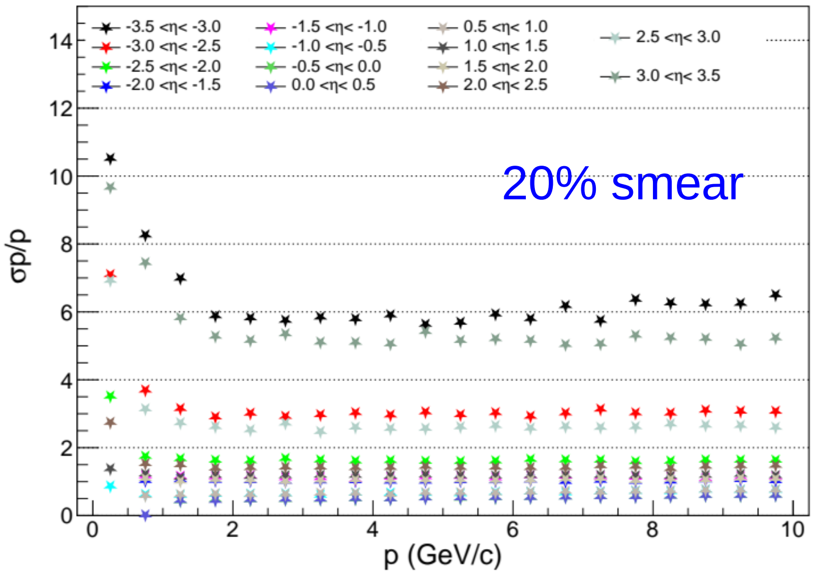


eta-3.5to-3.4_RelativeMomentumResolution.txt
eta-3.4to-3.3_RelativeMomentumResolution.txt
c1_n4
c1_n5
File Edit View Options Tools Help
eta-3.3to-3.2_RelativeMomentumResolution.txt
eta-3.2to-3.1_RelativeMomentumResolution.txt

Fun4All is giving correct trend at low momentum !!

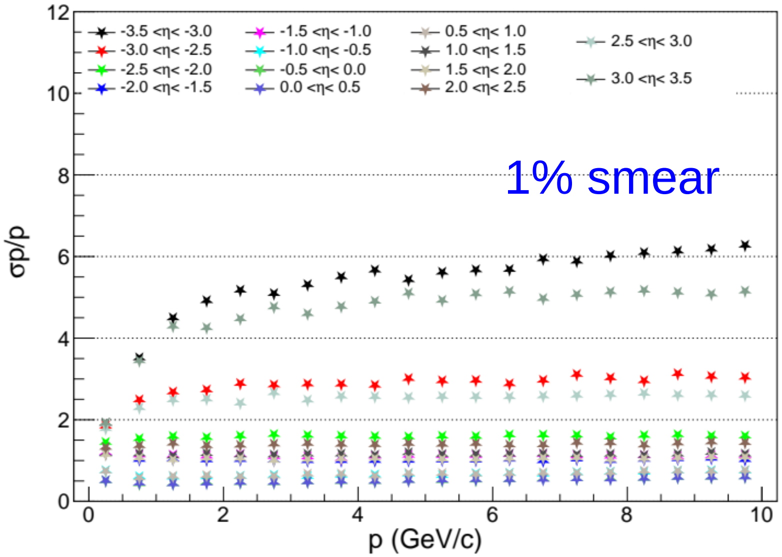
Results (Fine η Bins)





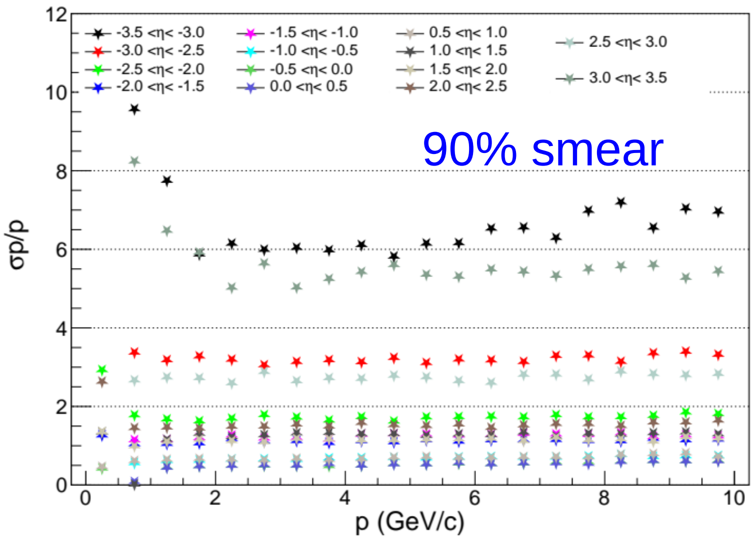
m_momentumSplit
= 0.01, 0.1, 0.2, 0.90

m_momentumSmear
= 0.01, 0.1, 0.2, 0.90



If you smear very small fitter is biased

90 % is really bias the result as can be seen in the plot



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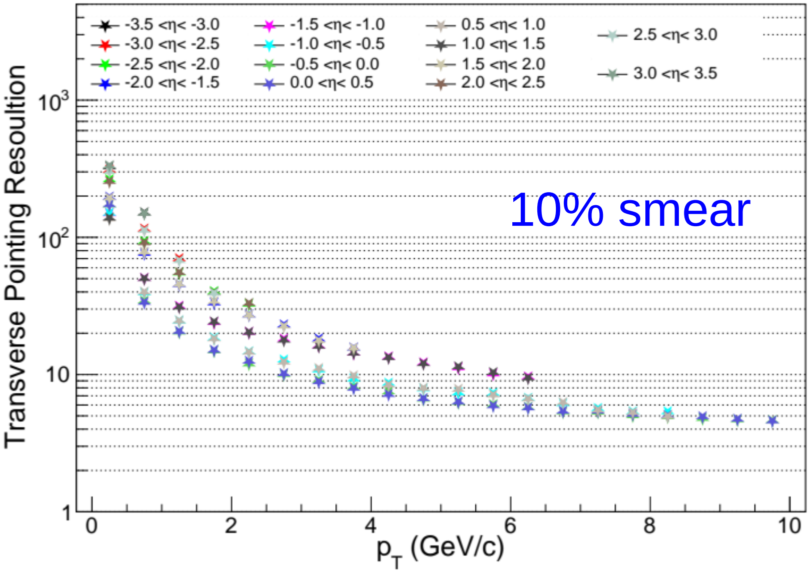

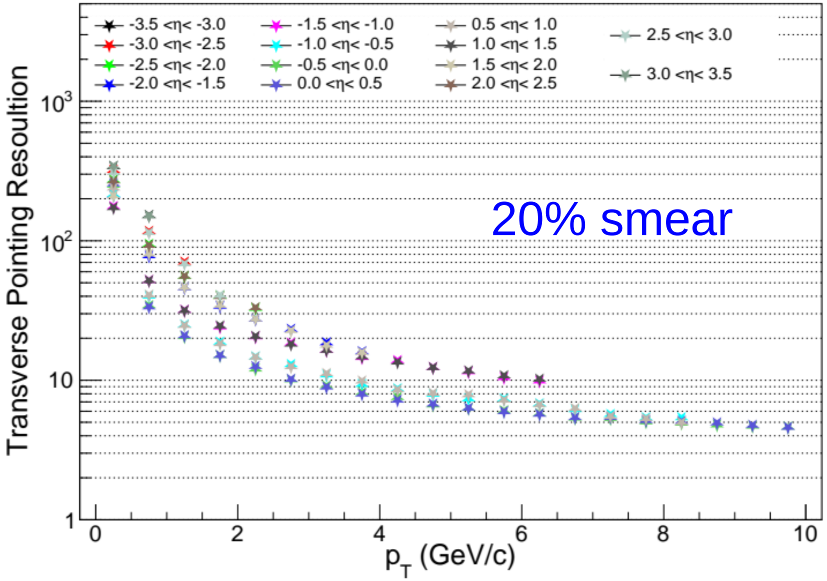

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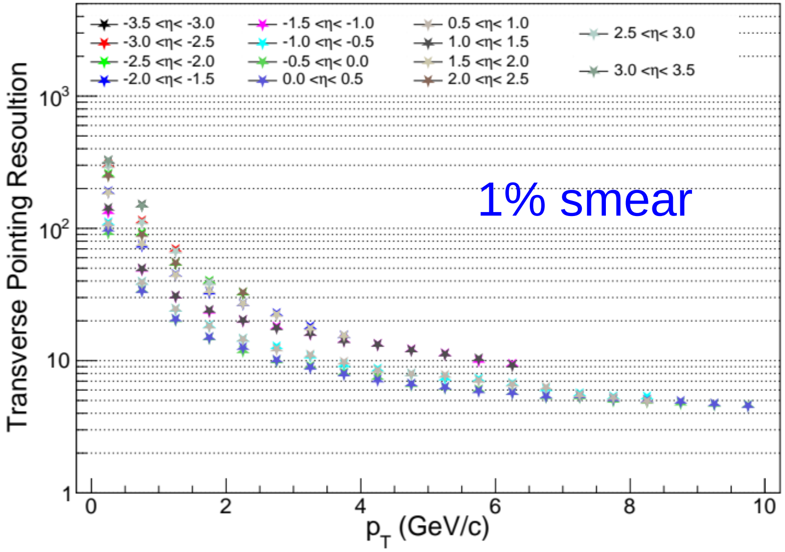

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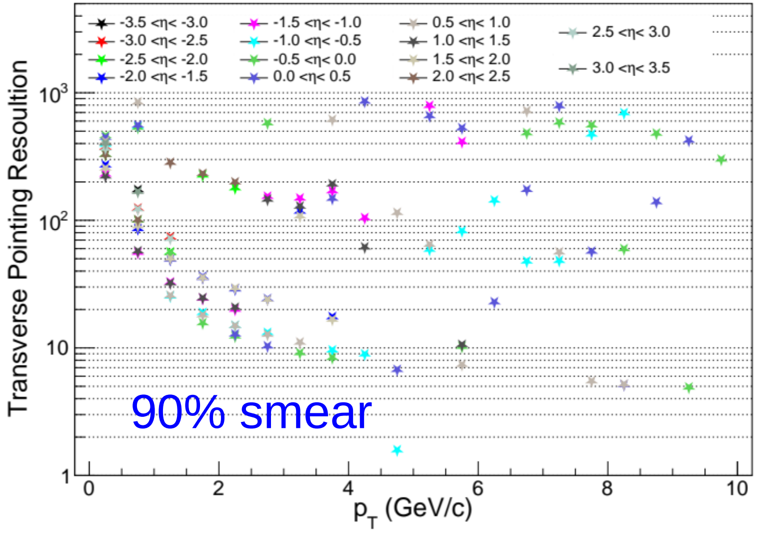
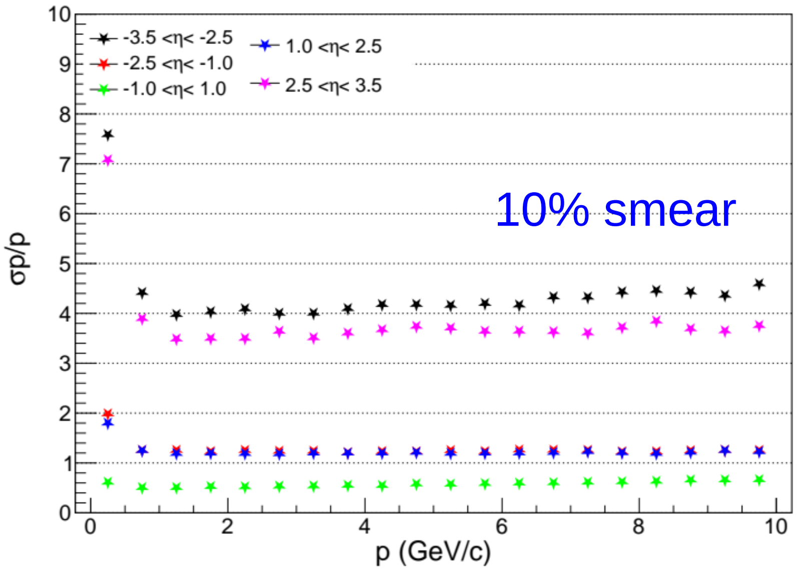


Results (Wide η Bins)



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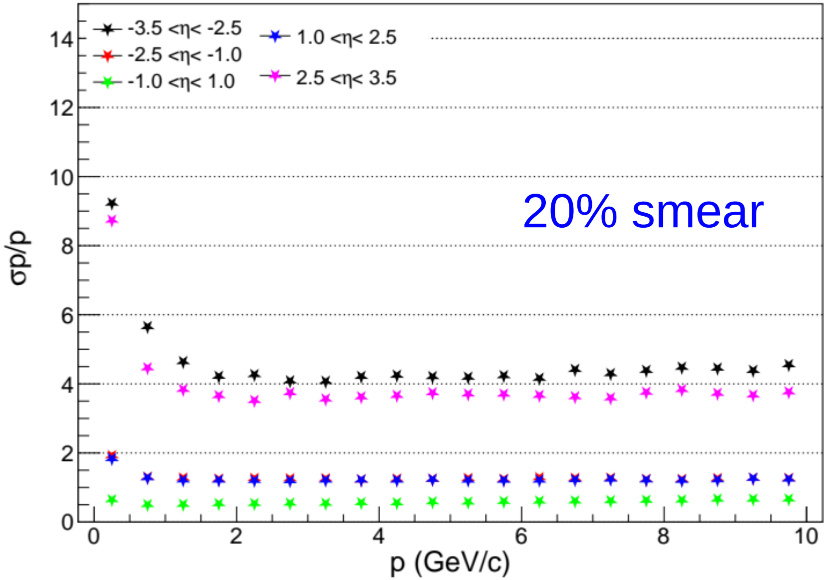
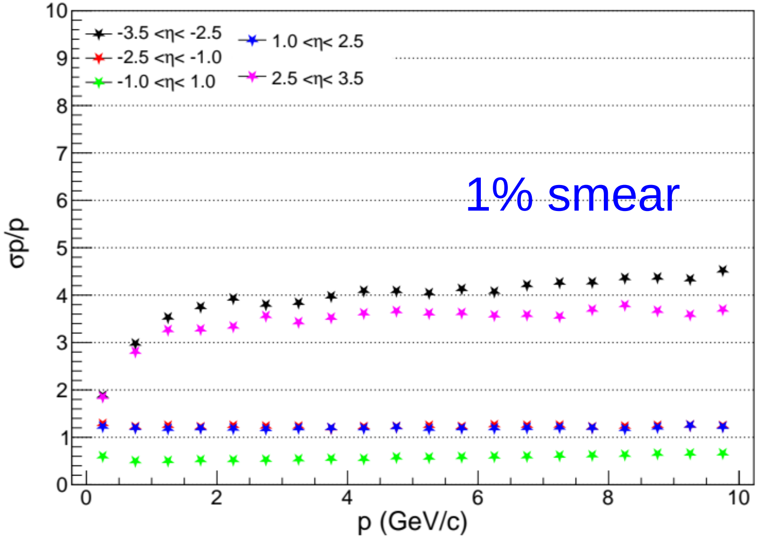
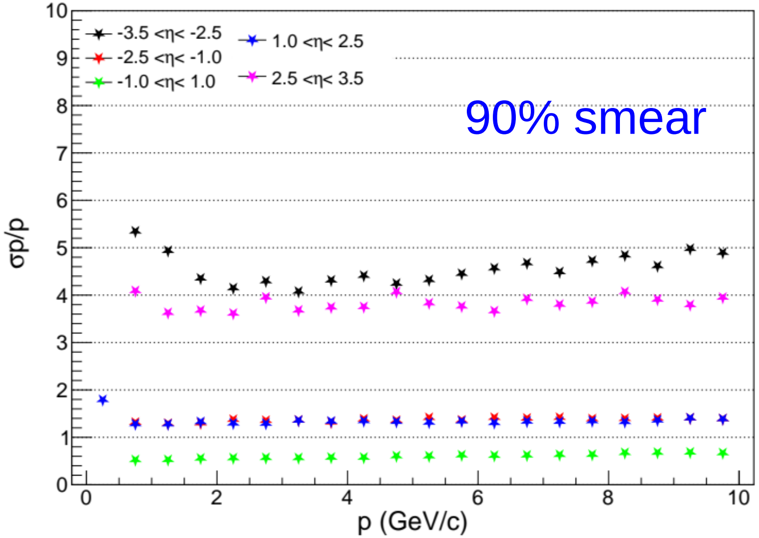
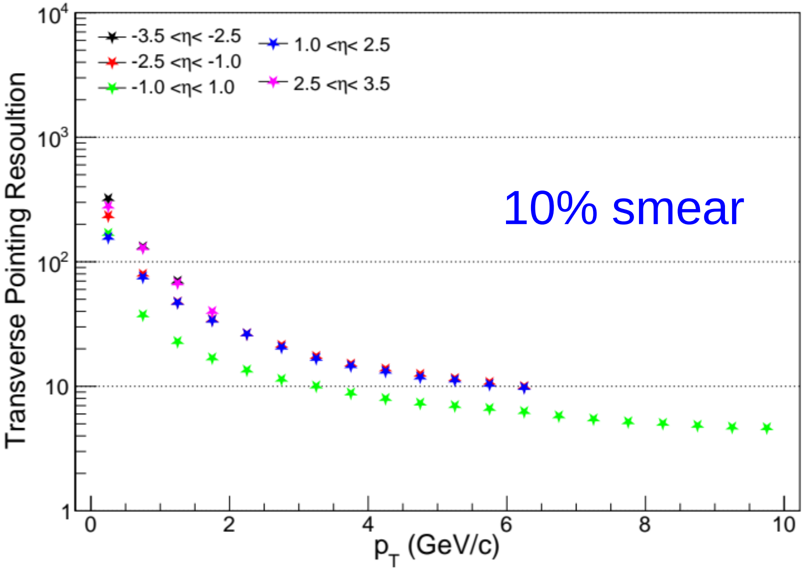






Results (Wide η Bins)



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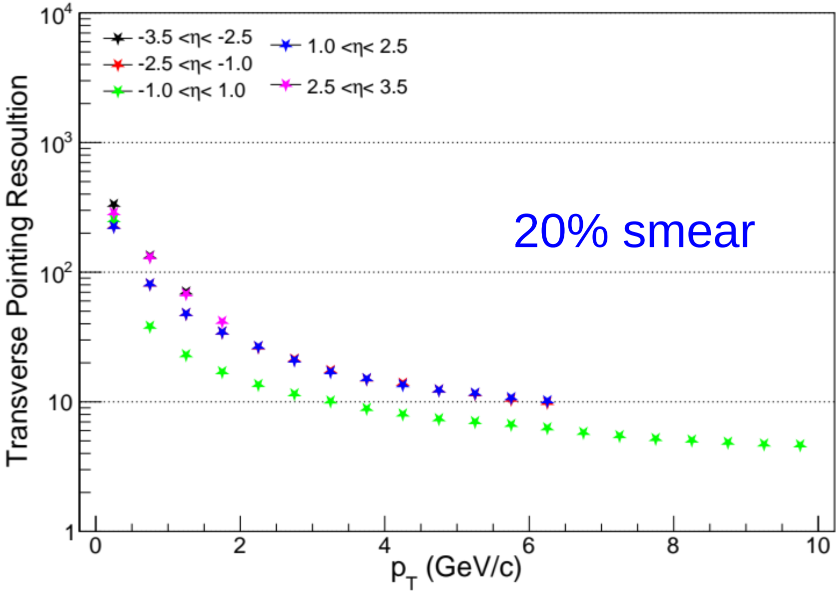
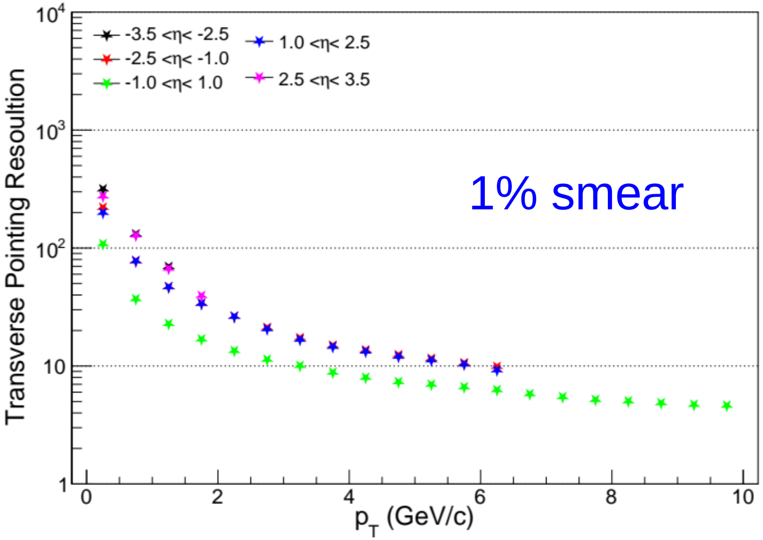
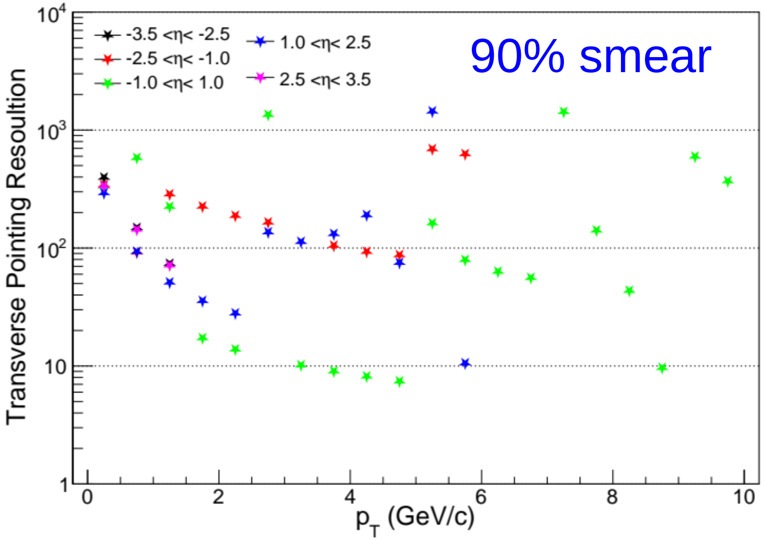
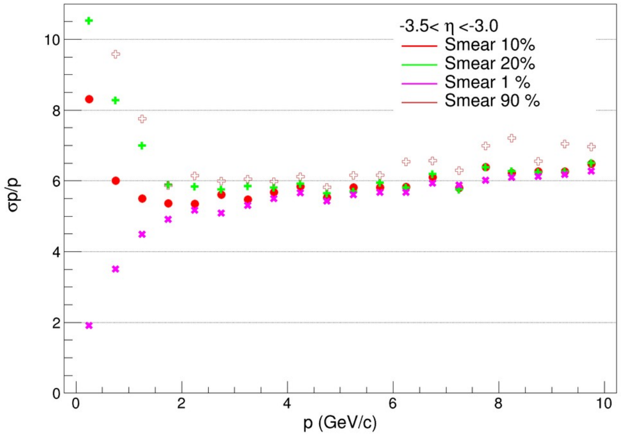
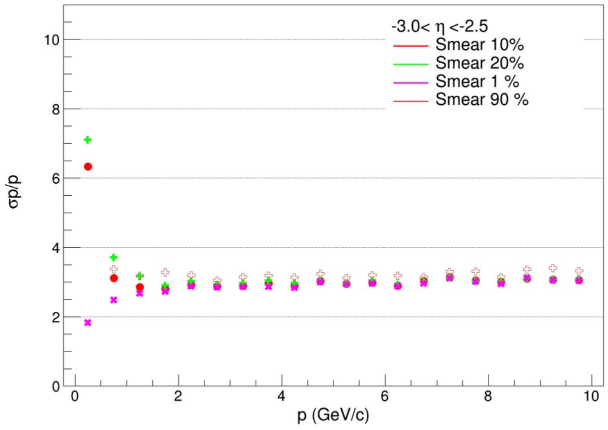


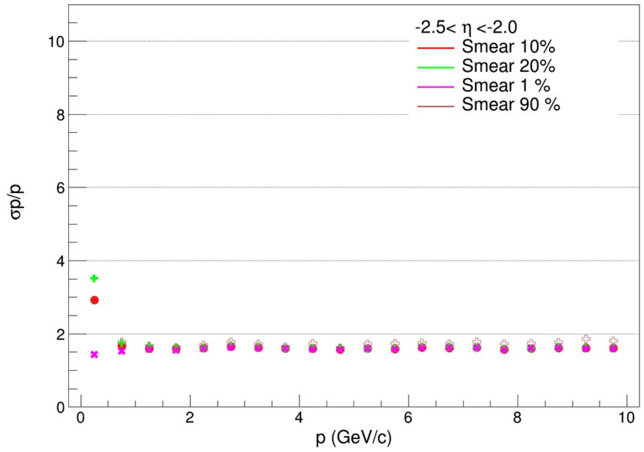


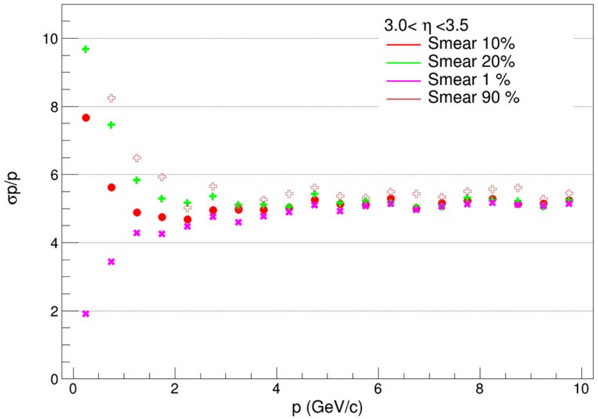


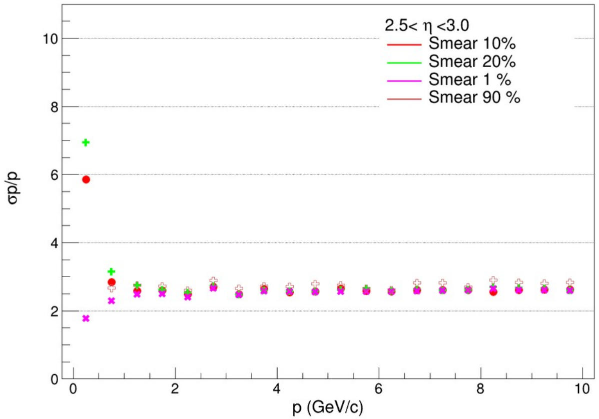
Comparison Momentum Resolution [Fine eta bins]

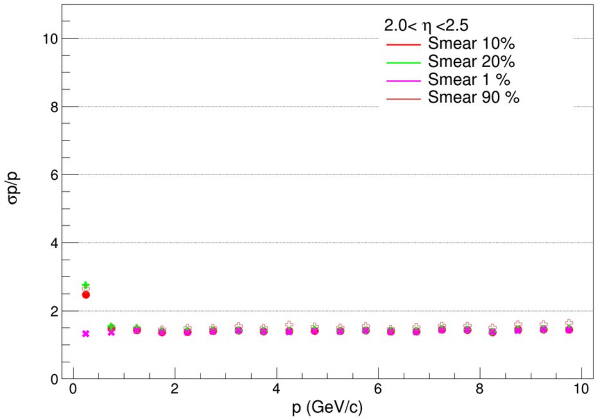












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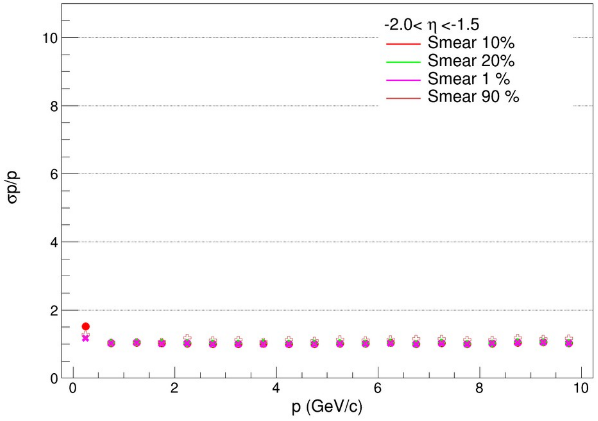
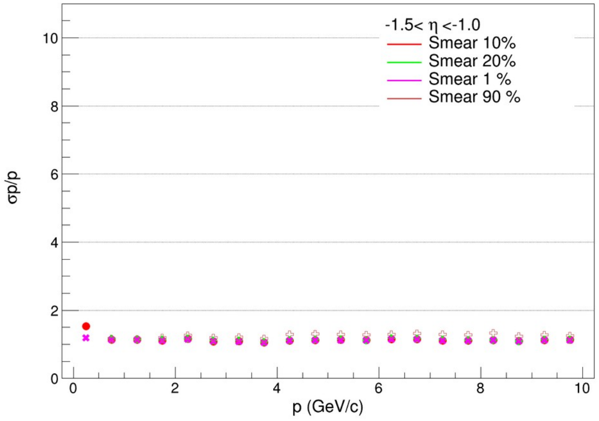
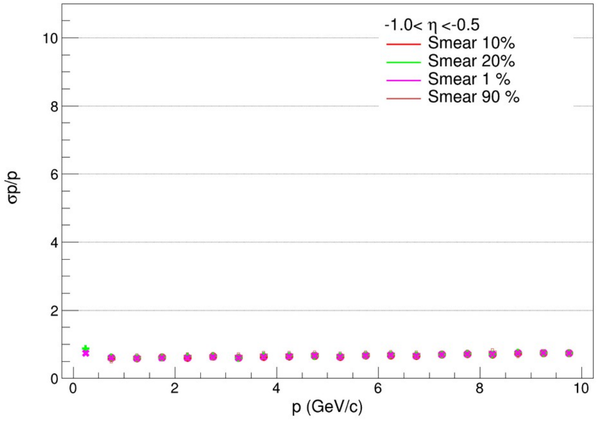
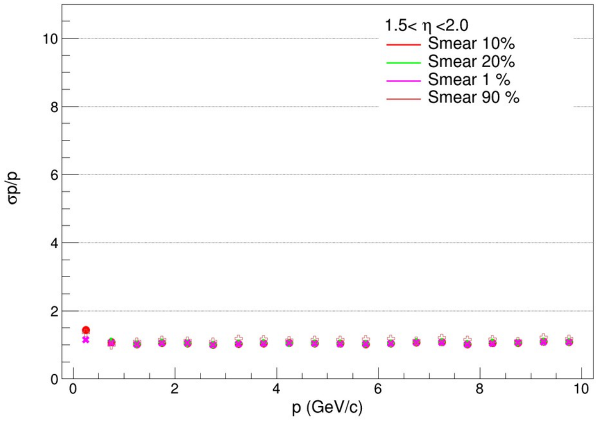
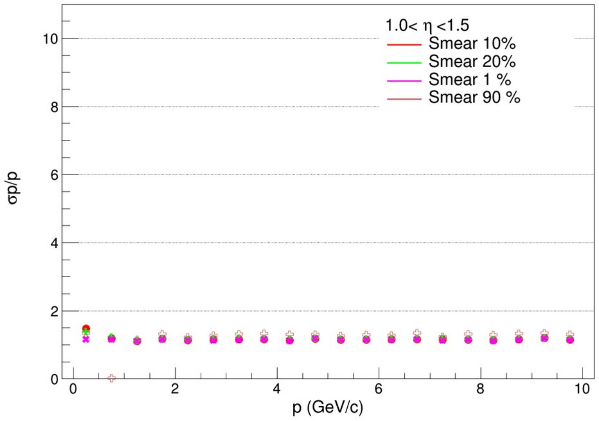
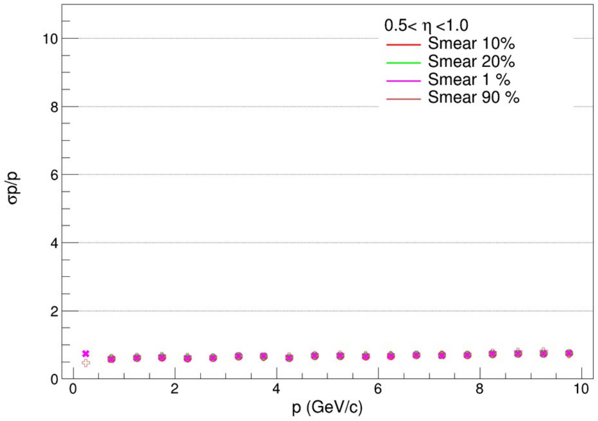




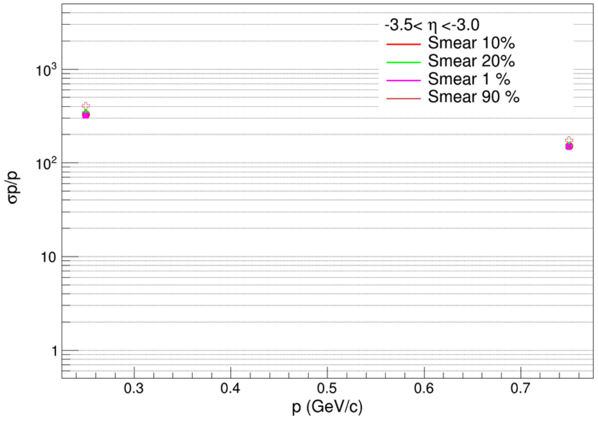


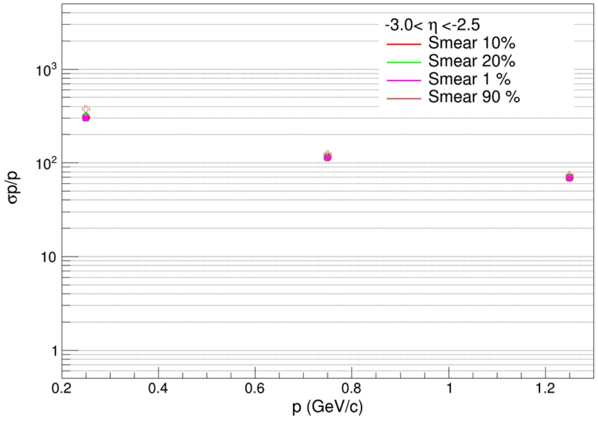


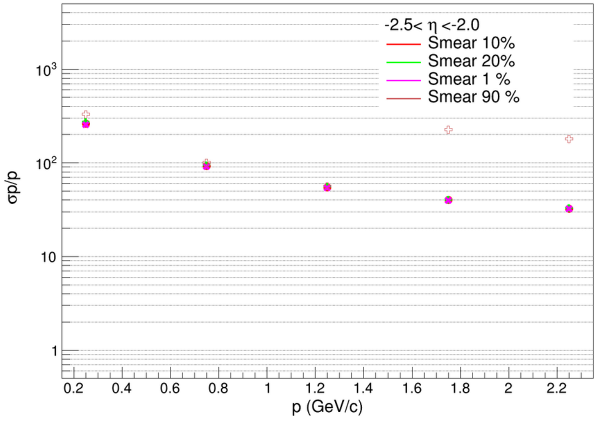


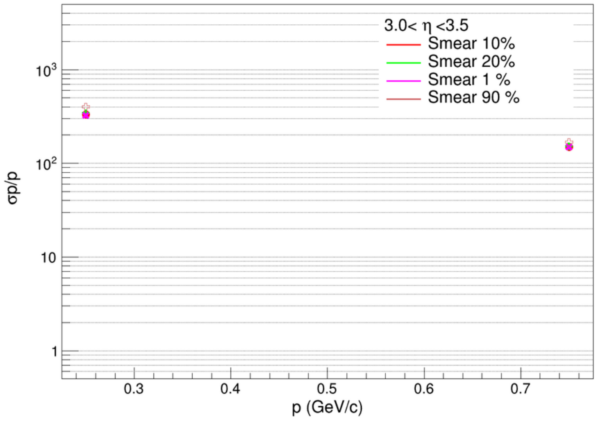


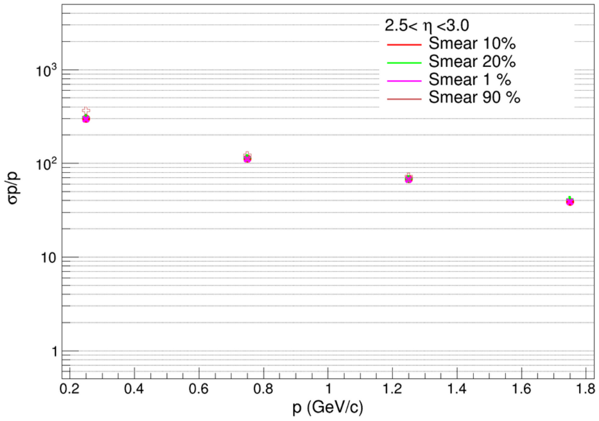
Comparison DCA_{xy} Resolution [Fine eta bins]

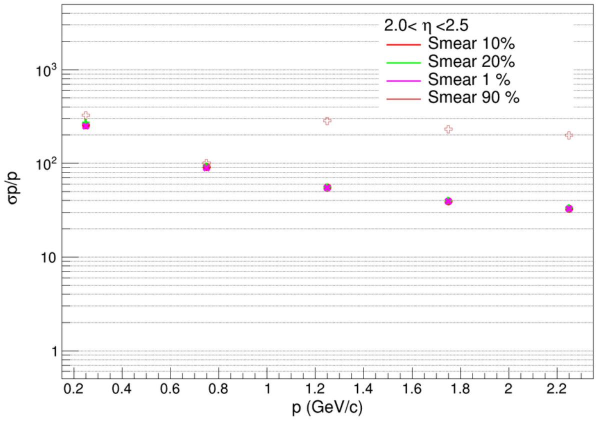




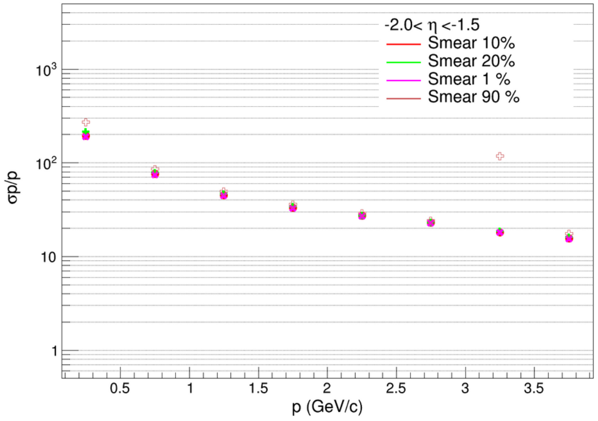


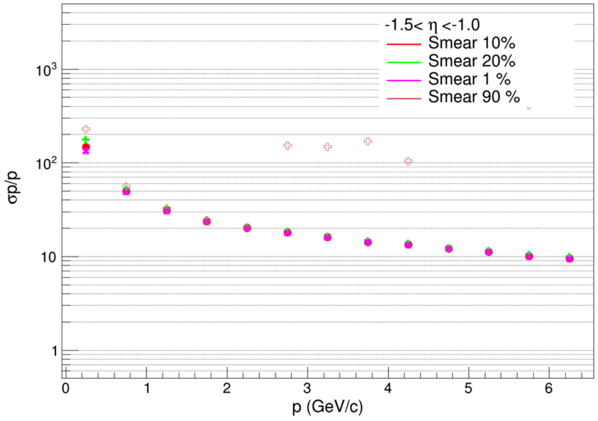


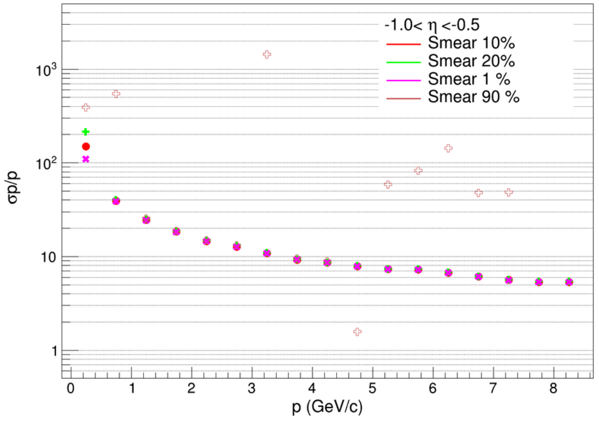


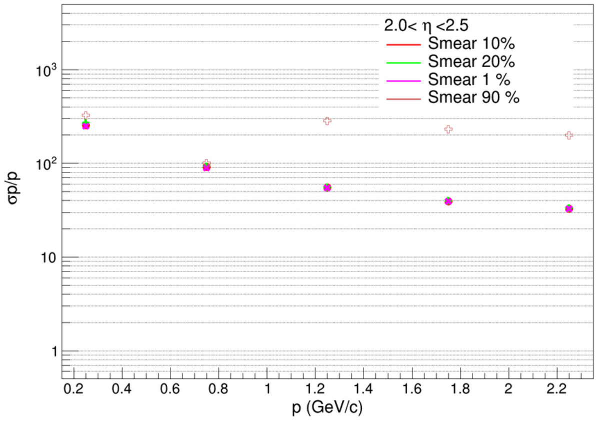


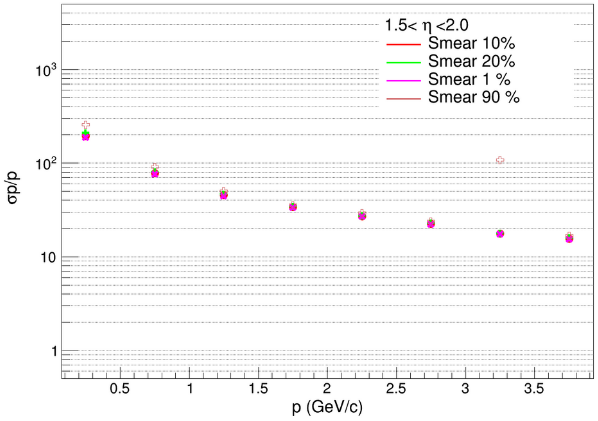
Comparison DCA$_{xy}$ Resolution [Fine eta bins]

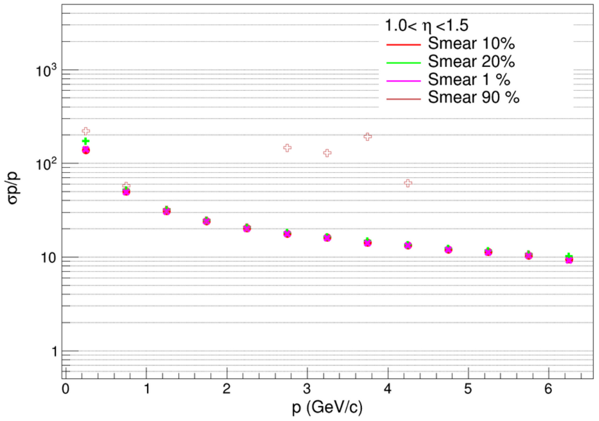




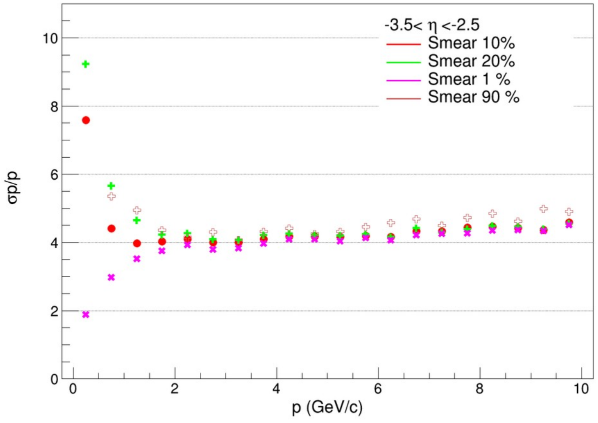


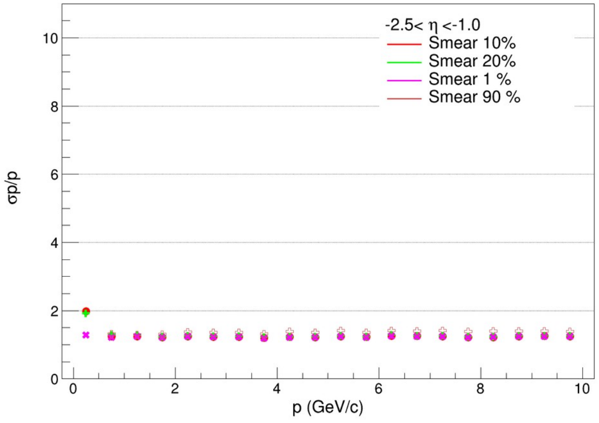


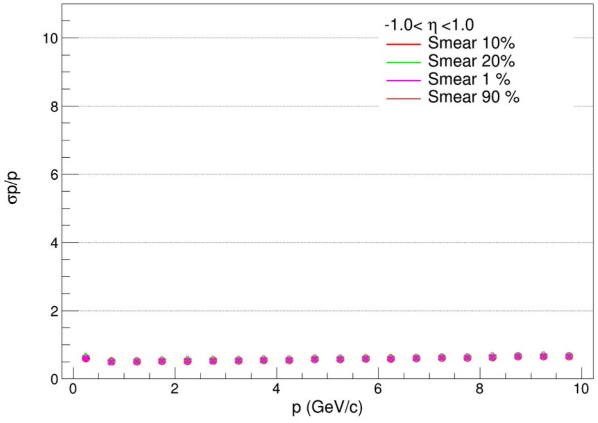


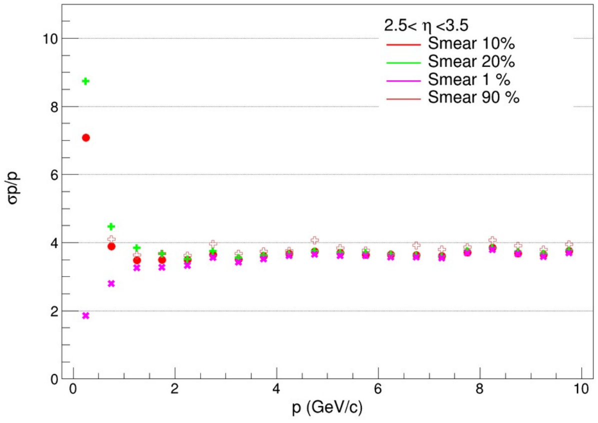


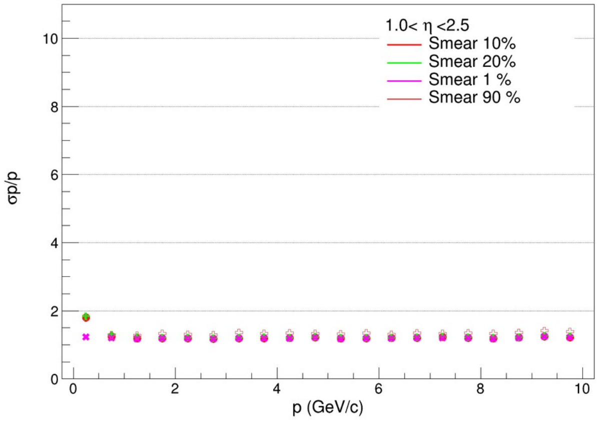
Comparison Momentum Resolution [Wide eta bins]



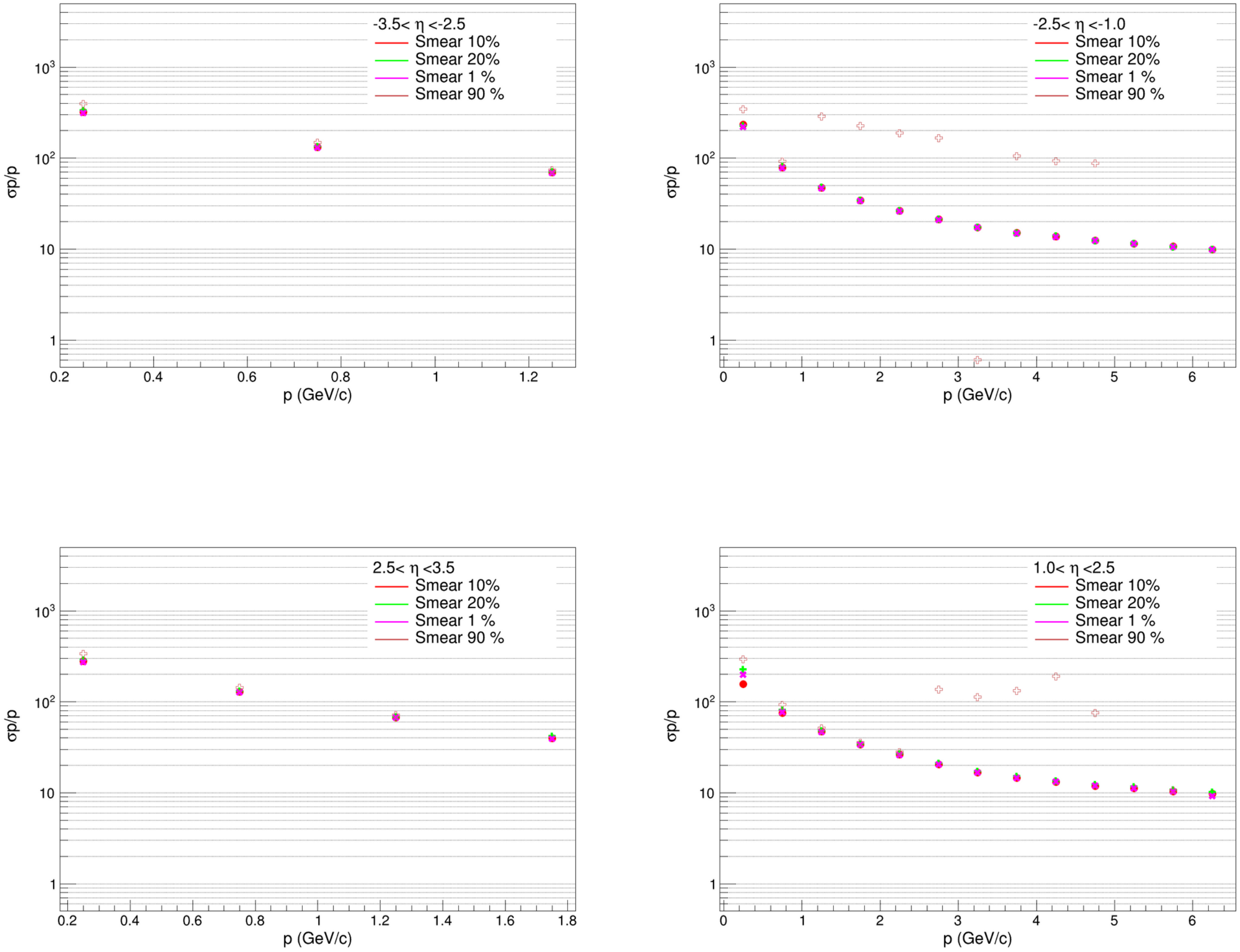








Comparison DCA$_{xy}$ Resolution [Wide eta bins]



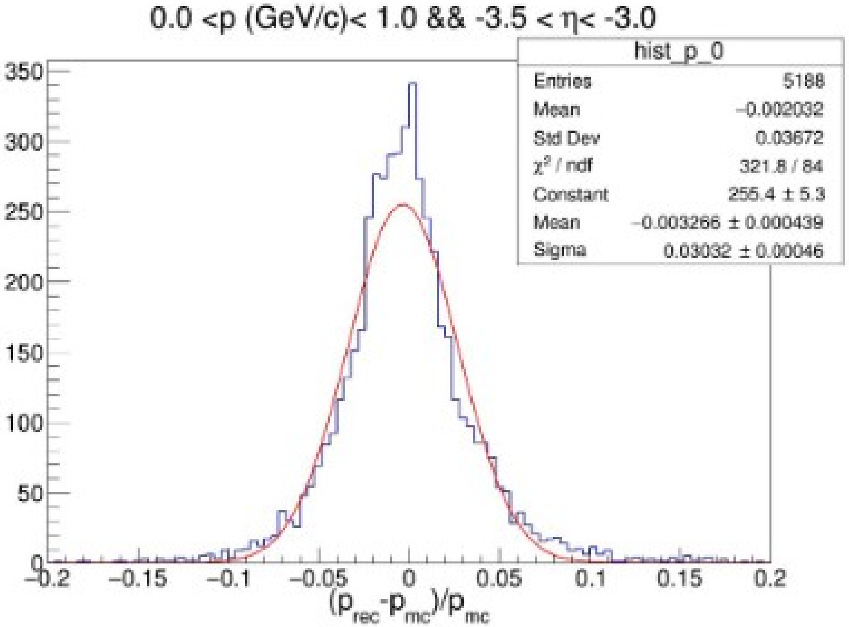
Summary and Future Plan

- Origin of decrease of Momentum resolution at low momentum and higher eta is understood
- Large smearing in momentum can bias results due to underestimation/overestimation of energy loss and multiple scattering
- May be we can try to adopt fun4All solution smear momentum small and also smear other parameters theta, phi which doesn’t effect multiple scattering and energy loss
- We need to come with proper smearing solution (using Chi2 information once there)
- Need to cross check with smearing and realistic seeding the momentum resolution should increase at low momentum

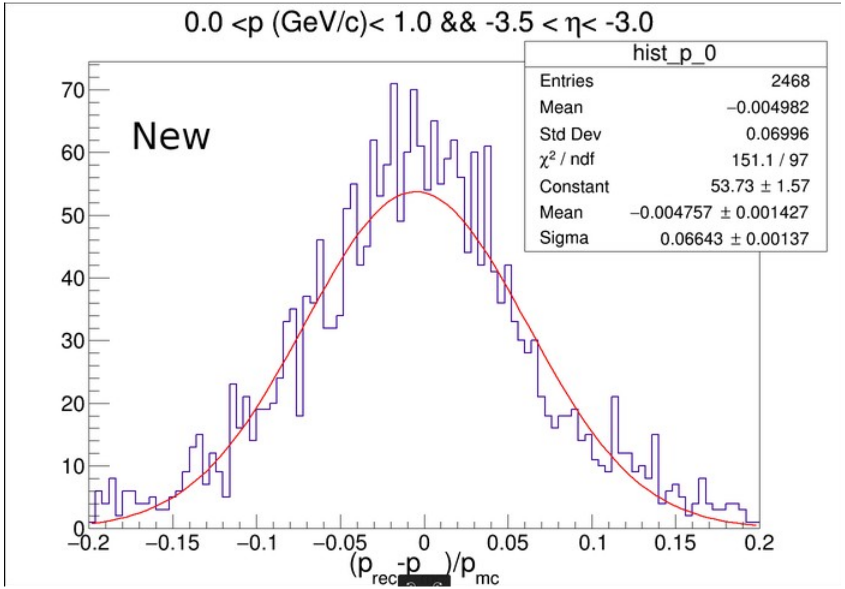
Thank You

Momentum Resolution

Without smearing true parameters

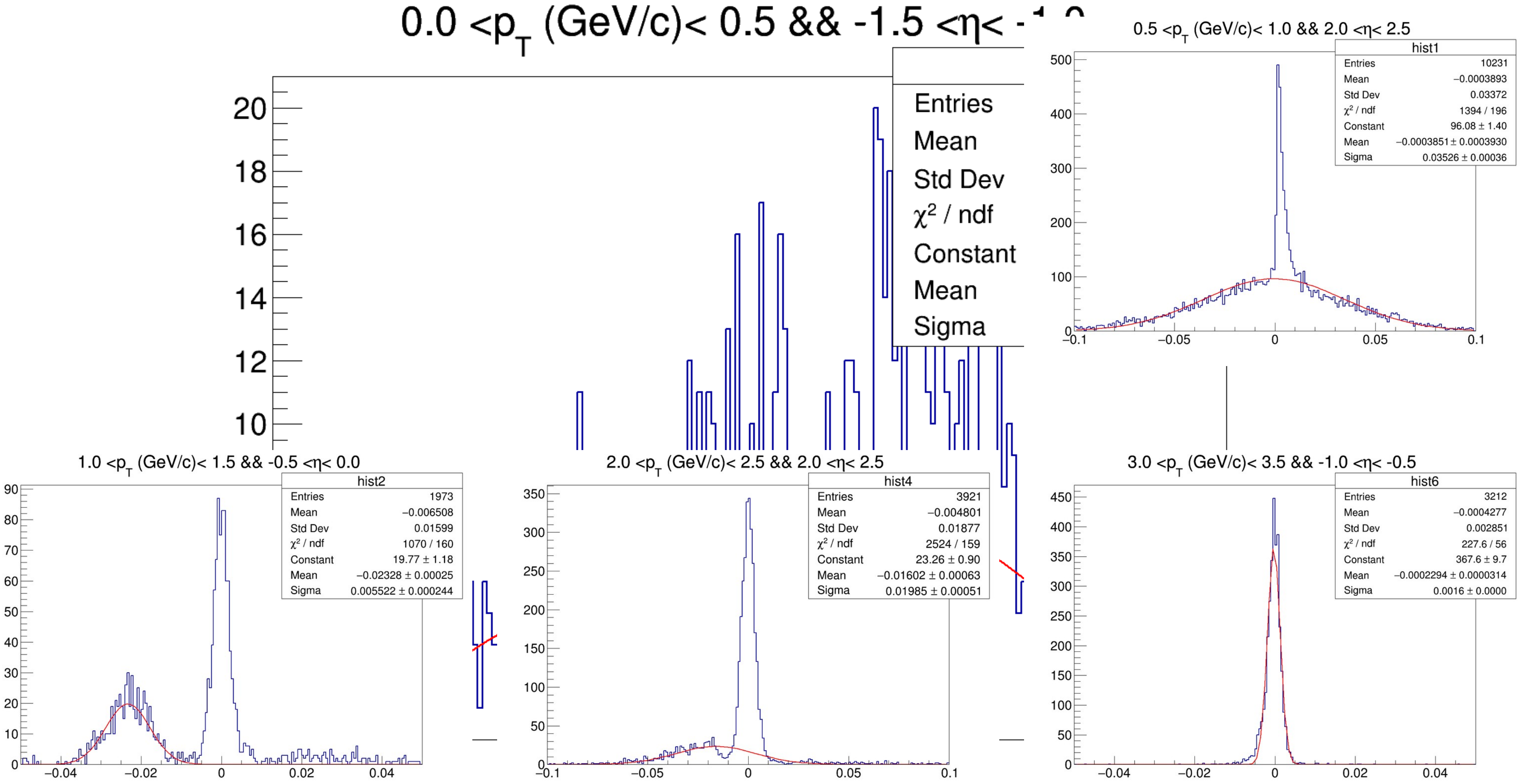


Smearing true parameters by 10%



Cases of 90% smearing (DCA_{xy})

Worst case of smearing


0.0 <p_T (GeV/c)< 0.5 && -1.5 <η< -1.0
Entries
Mean
Std Dev
χ² / ndf
Constant
Mean
Sigma
0.5 <p_T (GeV/c)< 1.0 && 2.0 <η< 2.5
hist1
Entries 10231
Mean −0.0003893
Std Dev 0.03372
χ² / ndf 1394 / 196
Constant 96.08 ± 1.40
Mean −0.0003851 ± 0.0003930
Sigma 0.03526 ± 0.00036
1.0 <p_T (GeV/c)< 1.5 && -0.5 <η< 0.0
hist2
Entries 1973
Mean −0.006508
Std Dev 0.01599
χ² / ndf 1070 / 160
Constant 19.77 ± 1.18
Mean −0.02328 ± 0.00025
Sigma 0.005522 ± 0.000244
2.0 <p_T (GeV/c)< 2.5 && 2.0 <η< 2.5
hist4
Entries 3921
Mean −0.004801
Std Dev 0.01877
χ² / ndf 2524 / 159
Constant 23.26 ± 0.90
Mean −0.01602 ± 0.00063
Sigma 0.01985 ± 0.00051
3.0 <p_T (GeV/c)< 3.5 && -1.0 <η< -0.5
hist6
Entries 3212
Mean −0.0004277
Std Dev 0.002851
χ² / ndf 227.6 / 56
Constant 367.6 ± 9.7
Mean −0.0002294 ± 0.0000314
Sigma 0.0016 ± 0.0000