Smearing of Parameters in the Truth Seeding

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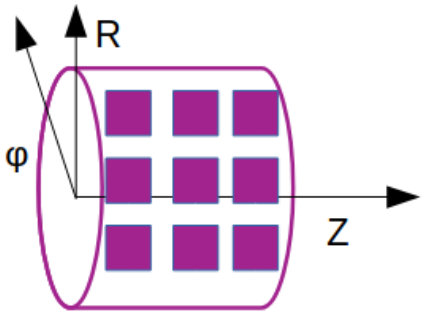
https://github.com/eic/EICrecon/issues/215

Track Parameters (Global to Local)

$\sigma_\varphi = \sigma_z = \text{pixel size}/\sqrt{(12)}$



Cylinder

Global coordinates: (x,y,z,p_x,p_y,p_z)

Track parameters on a surface (l_1,l_2 are local)

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

https://github.com/NicholasLukow/ATHENA_Tracking_GEM/blob/master/Fun4All_G4_Baseline2.C

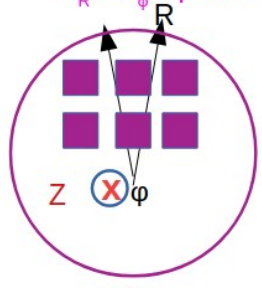
For ACTS see backup

First two local parameters describes the pixel dimensions

Track Parameters in Cylindrical surface:

$$(R\phi, z, \phi, \theta, q/p)$$

$\sigma_R = \sigma_\varphi = \text{pixel size}/\sqrt{(12)}$



Disks

Track Parameters on Disk surface:

$$(R, R\phi, \phi, \theta, q/p)$$

Cylinder (Fun4All)

Class PHG4TrackFastSim

Disks (Fun4All)

```
PHG4TrackFastSim *kalman = new PHG4TrackFastSim("PHG4TrackFastSim");
// add Vertexing Layers
kalman->add_phg4hits(
                "G4HIT_SVTX",
                PHG4TrackFastSim::Cylinder,
                999.,
                pix_size_vtx/10000./sqrt(12.),
                pix_size_vtx/10000./sqrt(12.),
                1,
                0
```

```
// const std::string& phg4hitsNames,

// radial-resolution [cm]
// azimuthal-resolution [cm]
// z-resolution [cm]
// efficiency,
// noise hits
```

```
//  add Disk Layers
kalman->add_phg4hits(
                "G4HIT_FBST",
                PHG4TrackFastSim::Vertical_Plane,
                pix_size_dis/10000./sqrt(12.),
                pix_size_dis/10000./sqrt(12.),
                999.,
                1,
                0
                );
```

```
// const std::string& phg4hitsNames,

// radial-resolution [cm]
// azimuthal-resolution [cm]
// z-resolution [cm]
// efficiency,
// noise hits
```

General equation of a circle

$$(x-x_0)^2+(y-y_0)^2=R^2$$

If circle passed through the vertex (0,0): $x_0^2+y_0^2=R^2$

$$x^2+x_0^2-2xx_0+y^2+y_0^2-2yy_0=R^2$$

using

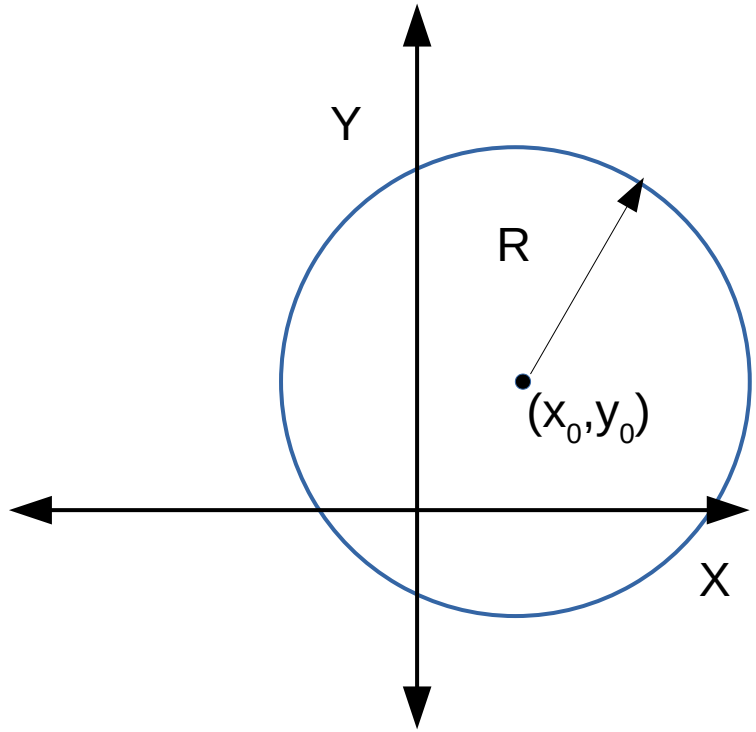
$$u=\frac{x}{x^2+y^2} \qquad v=\frac{y}{x^2+y^2} \qquad x_0^2+y_0^2=R^2$$

$$x^2+y^2-2xx_0-2yy_0=0$$

$$1-2\frac{xx_0}{x^2+y^2}-2\frac{yy_0}{x^2+y^2}=0$$

$$2ux_0+2vy_0=1$$

Line in u-v space



Find three hits belong to straight line in u-v space and use them as the seeding, later use combinatorial track finding and fitting using Kalman filter

How are the parameters initialized for fitting?

Truth Parameters in ACTS

```
// 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;
```

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

↓

$(d_0, z_0, \theta, \phi, q/p)$

↓ Extrapolate to Vertex

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

Truth parameters are not smeared !!!

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

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);

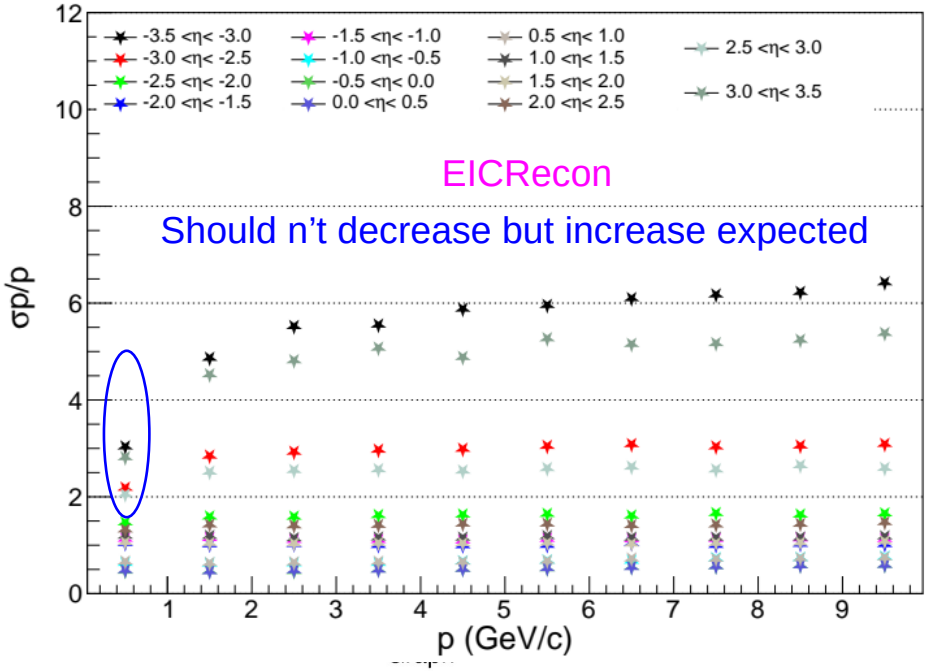
https://github.com/sPHENIX-Collaboration/coresoftware/blob/master/simulation/g4simulation/g4trackfastsim/PHG4TrackFastSim.cc#L734

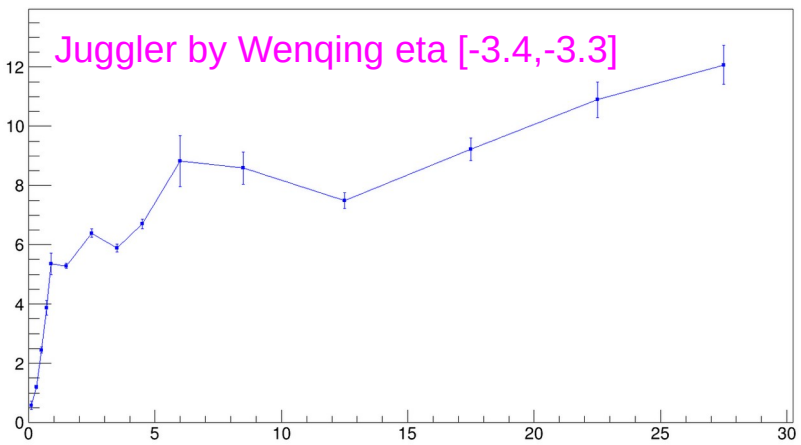
10% smearing in p_{true}

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

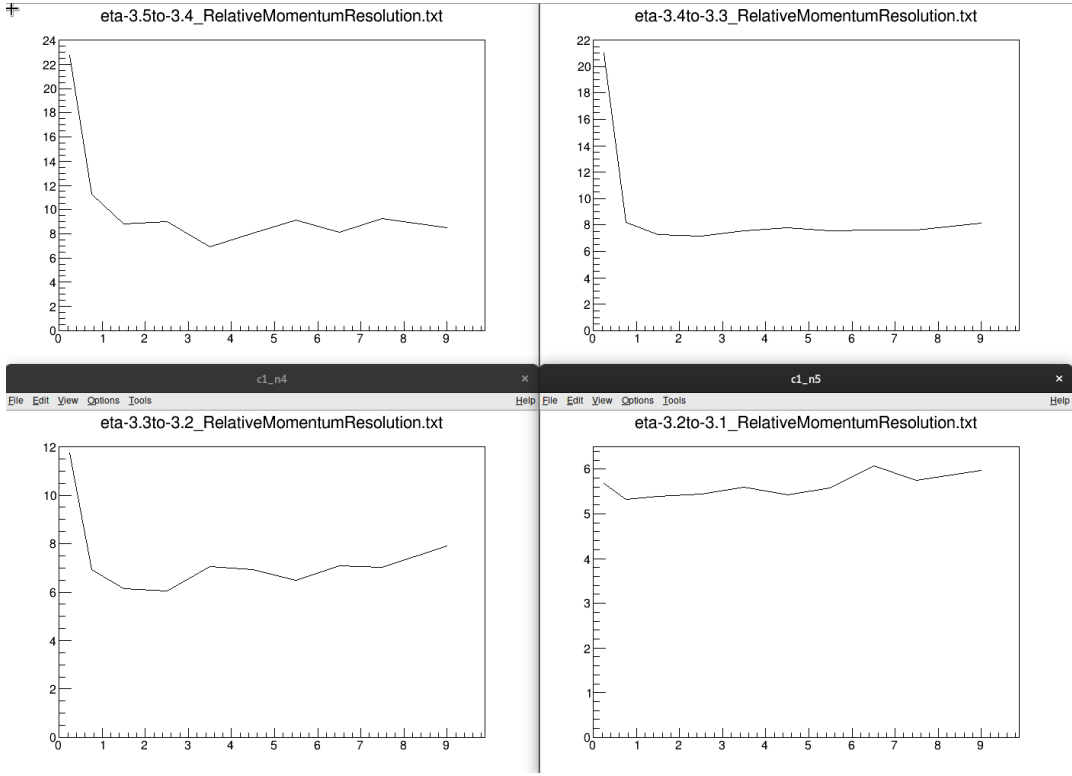
```
int PHG4TrackFastSim::PseudoPatternRecognition(const PHG4Particle* particle,
                                               std::vector<PHGenFit::Measurement*>& meas_out,
                                               SvtxTrack* track_out,
                                               TVector3&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

  seed_cov.ResizeTo(6, 6);        Initialization default

  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)                   If there is a truth information
  {
    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)              Option for 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));
    }
  }
```

Results





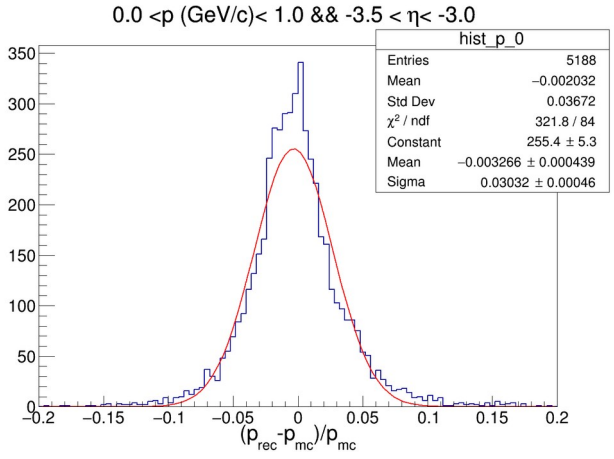
From Stephen using Fun4All (geometry is same)

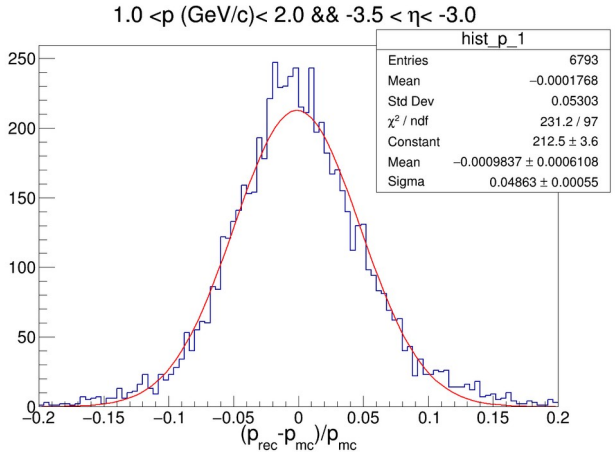


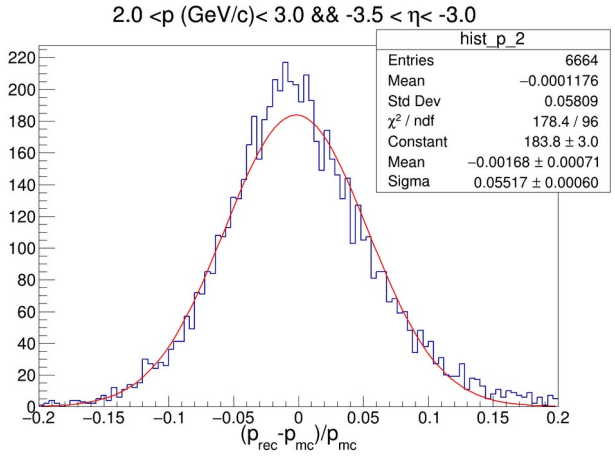
Fun4All is giving correct results at low momentum !!

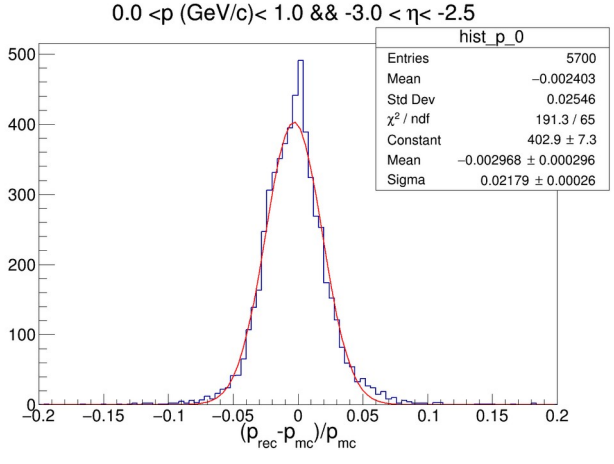
Few Debug Plots

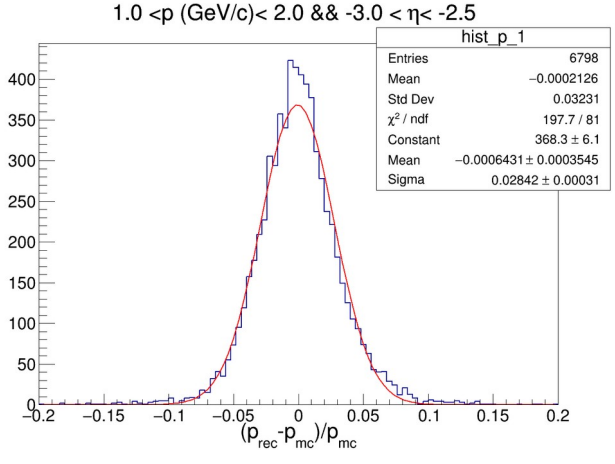
At the very low momentum peak structure can be seen

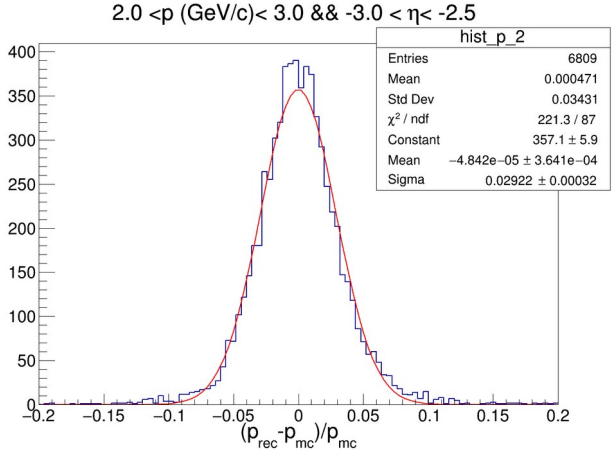












Summary and Future Plan

- Origin of decrease of Momentum resolution at low momentum and higher eta is understood
- We need to come with proper smearing solution
- Need to cross check with smearing and realistic seeding the momentum resolution should increase at low momentum