HRSMC, The Geant4 Simulation of HRS for G2P|GEP

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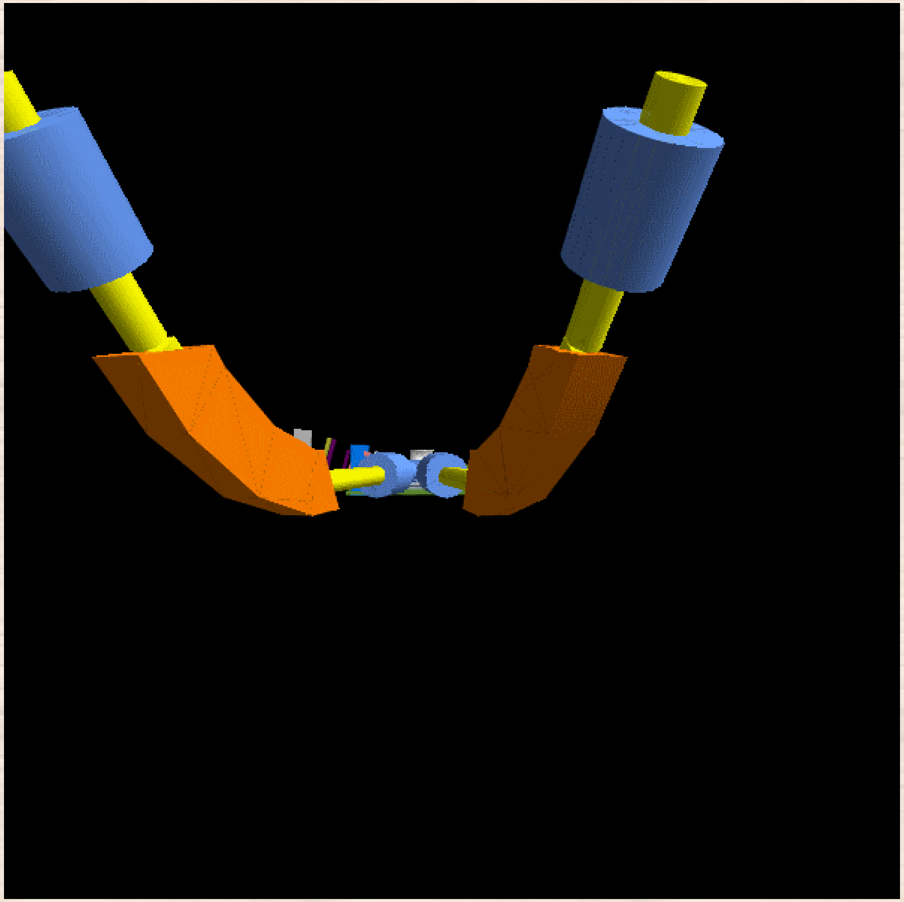
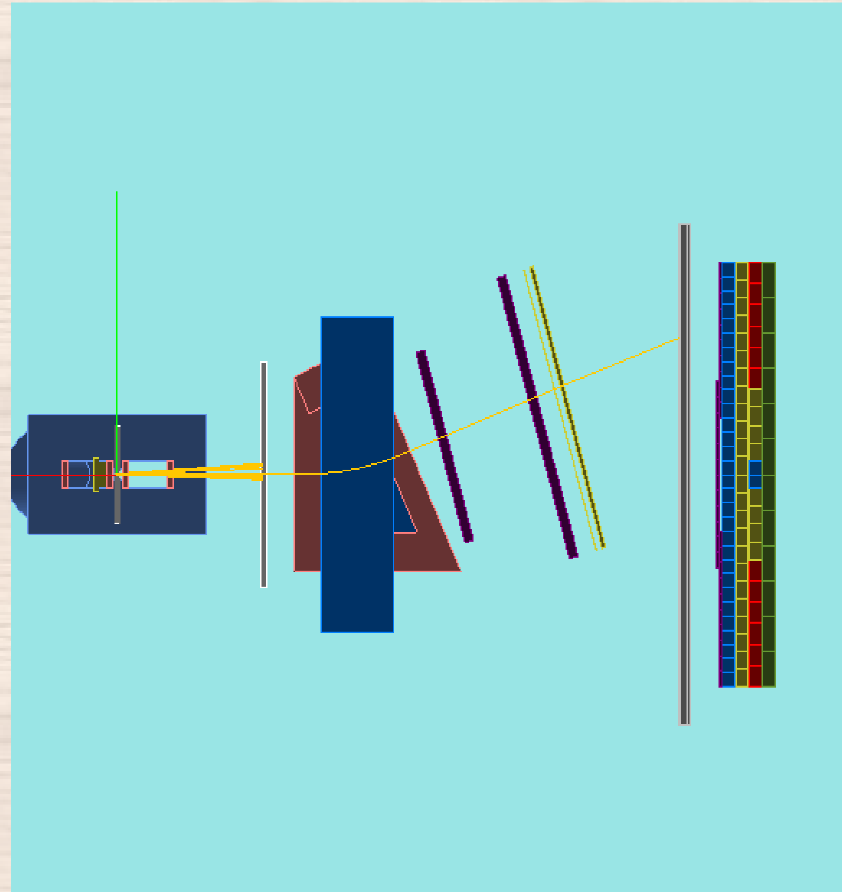
Introduction

- HRSMC is the Geant4 program developed to simulate the physics for HRS, especially for the G2P and GEP experiments. It was designed to support other HRS experiment as well.
- Geometry:
  - Full G2P|GEP geometry: g2p target, target field coil, g2p scattering chamber, local dump, septum, platform itself, 3rd arm
  - HRS QQDQ magnet geometry
  - BigBite, Hall A Neutron Detectors (HAND).
  - CREX: HallA scattering chamber, CREX target.
- Support 5.65 degrees central ray angle(with g2p septum), and also any HRS angle not less than 12.5 degrees (no septum).
- Fields: g2p chicane fields, target field, septum fields, BigBite field. HRS QQDQ fields are not included yet.
- The transportation in HRS are taken care by SNAKE models which came from the program **SNAKE** and **MUDIFI**.

Geometry in HRSMC

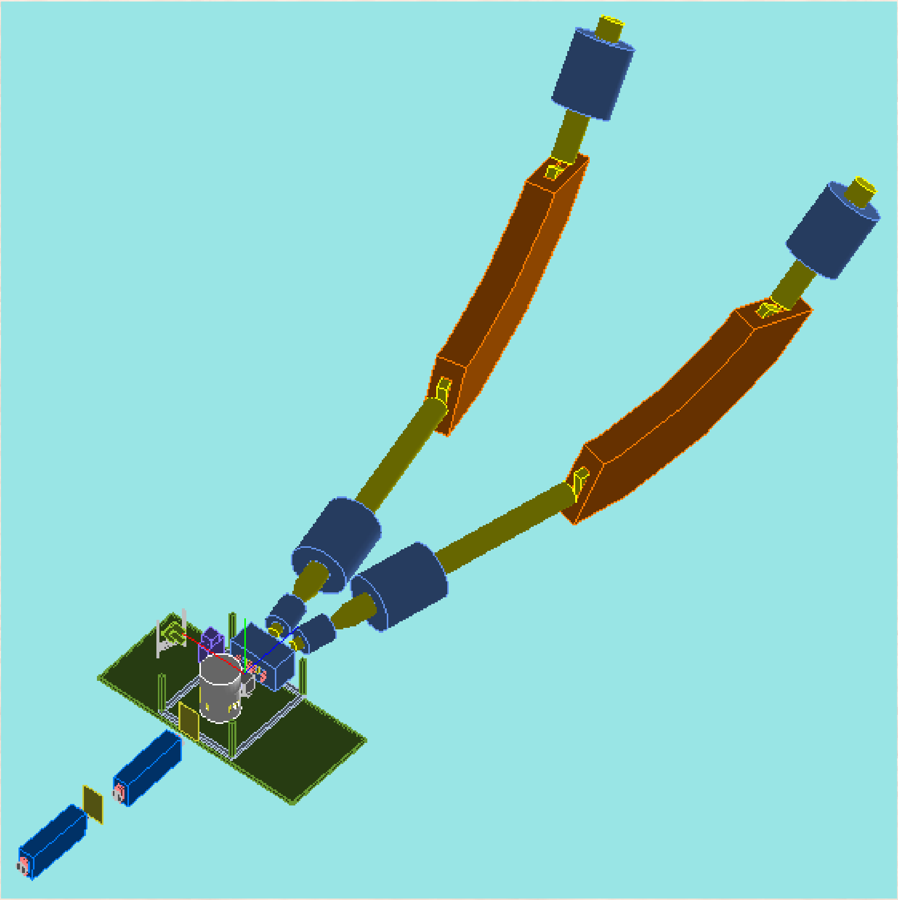


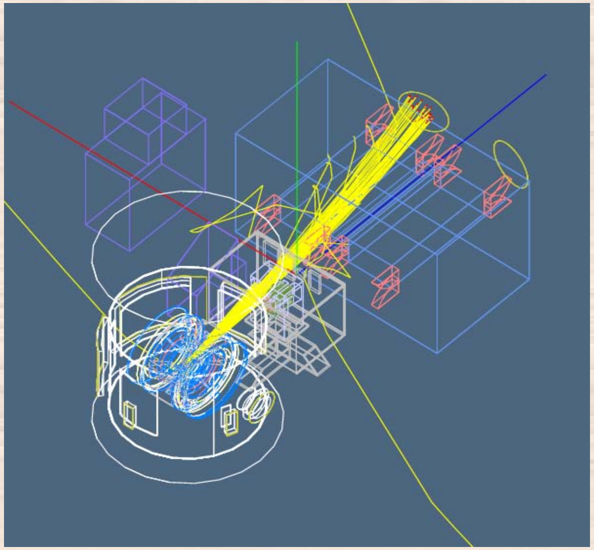


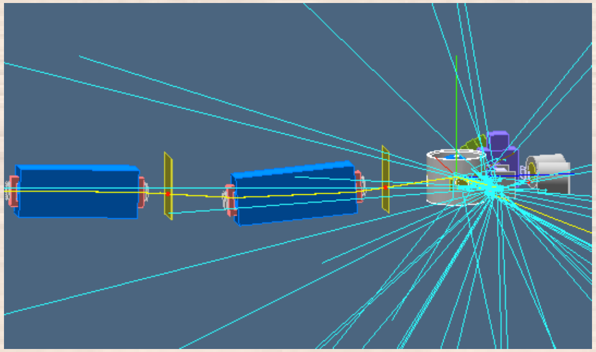
Detectors and fields can be turned on or off in configuration files.

OLD BigBite and HAND geometries are included.

G2P|GEP Geometry







G2P|GEP Geometries include the following: chicane magnet, target platform, scattering chamber, target coil, target nose and the target itself, local dump, sieve slits, septum magnet , plastic shielding blocks, 3rd arm.

Adding New Geometries

HRSMC was designed to support multiple HRS experiments. The geometries of these experiments are usually different only from the target platform.

The geometries of the target platform are hard coded in a Geant4 class from experiment to experiment. Each class is associated with a configuration file to turn each individual component on|off.

For example:

HRS
Detector.ini

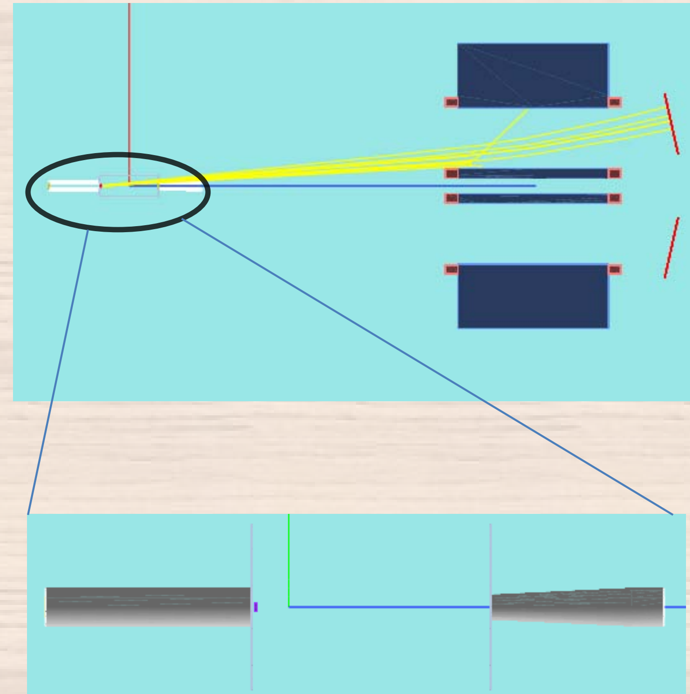
G2P
Detector_G2P.ini

CREX
Detector_CREX.ini

XXX, Future Exp
Detector_XXX.ini

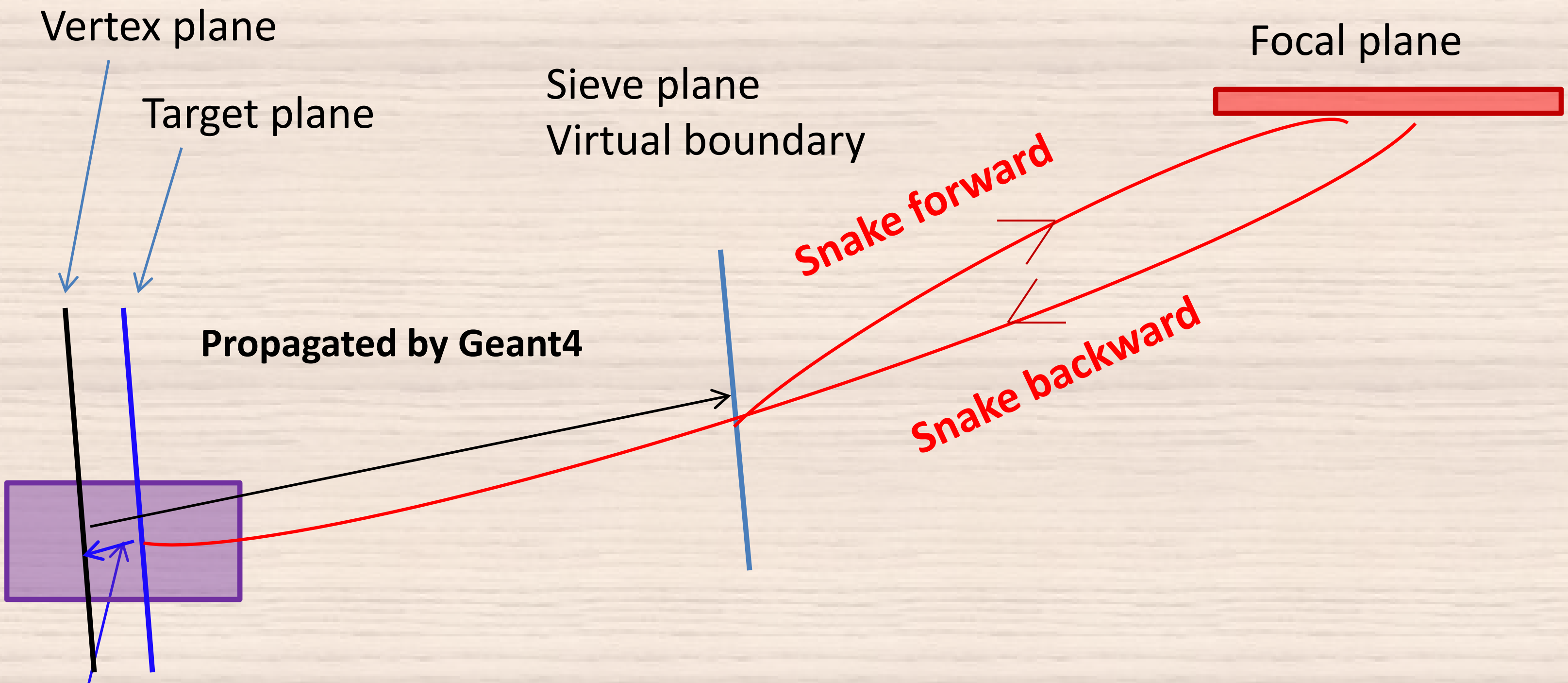
HRSMC can support a new experiment by adding a new Geant4 geometry class.

All sensitive detectors are sharing a standard hit processing but varies in SD_ID. All hits will be recorded automatically.



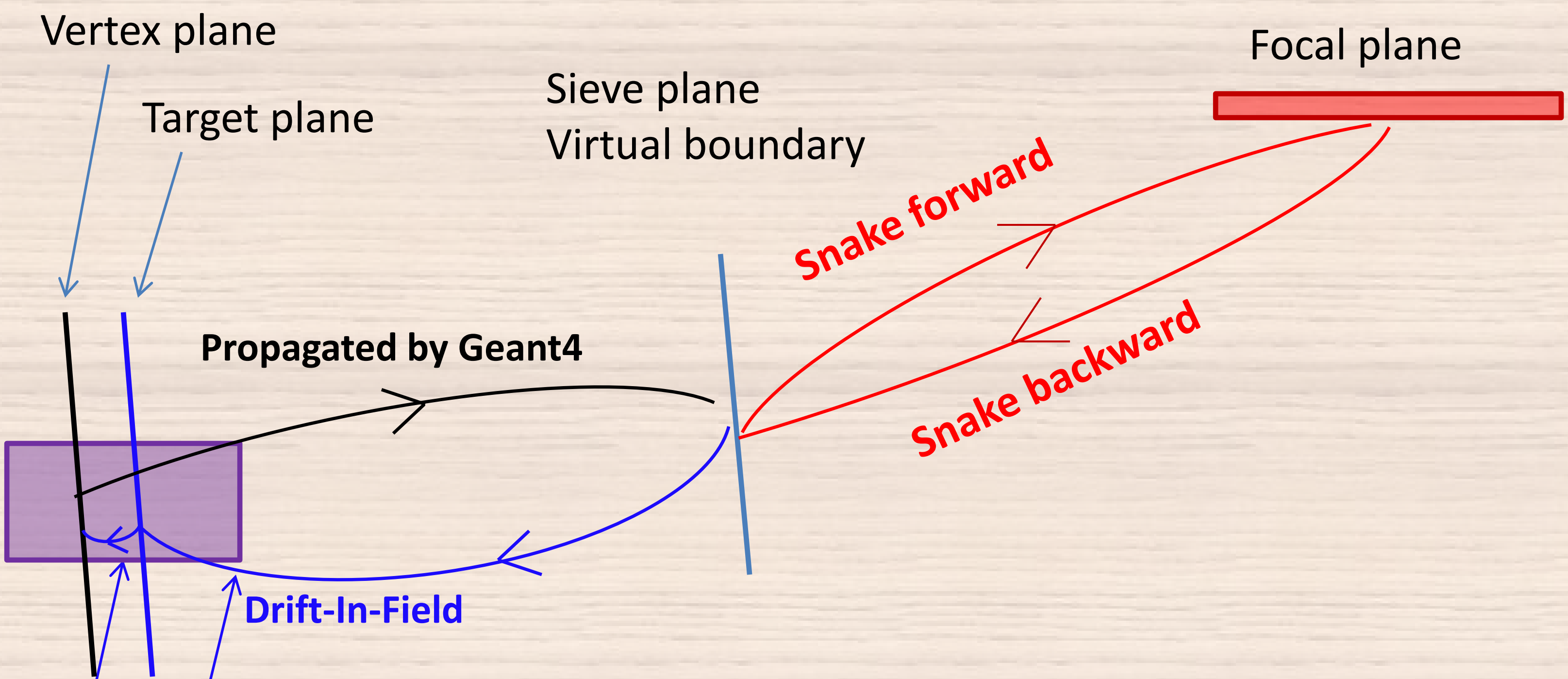
Newly added CREX target and Hall A scattering chamber (not shown in the figure). G2P septum is turned on.

Strategy without Target Field



- **Vertex to Sieve: propagated by Geant4 with a physics model (i.e. MSC, Decay, Ionization, EM physics...)**
- **Sieve to Focal: project sieve to target then using SNAKE forward model, 8-10 software collimator cuts are applied along the trajectory to make sure particle is really hitting the focal plane.**
- **Focal to target: using SNAKE backward model or real optics matrix.**
- **Target to Vertex: linear projection.**

Strategy with Target Field



- Vertex to Sieve: propagated by Geant4 with a physics model
- Sieve to Focal: project sieve to target then using SNAKE forward model, 8-10 software collimator cuts are applied along the trajectory to make sure particle is really hitting the focal plane.
- Focal to Sieve: using SNAKE backward model or real optics matrix from focal to target, then project from target to sieve.
- Sieve to Target: using Drift-In-Field model.
- Target to Vertex: using Drift-In-Field model.

HRS Transportation

- **Sieve2Focal = Sieve2Target (projection) + Target2Focal (SNAKE forward model)**
- **Focal2Sieve = Focal2Target (SNAKE backward model) + Target2Sieve(projection)**
- Focal to target can also be done by REAL optics matrix, the same matrix used in the replay
- Currently the following SNAKE models are already included:
  - Standard HRS, 12.5 degrees, NO septum
  - Two models of 6 degrees HRS with septum for E97-110. One is for larger X0 and the other is for normal X0
  - Several models of 5.65 degrees HRS with septum and 3 cm circular raster for G2P|GEP, varying in the active septum coils in the right septum: 48-48-16 No Shims, 48-48-16, 40-32-16 and 40-00-16
  - Can add more SANKE models, **Min Huang and John are the experts**
- **Will provide some models fitted with g2p real optics data, which will make it possible to match the real data!**
- Switch models in command line:

**HRSMC -Reconstruction <WhereToStopRecon(0)> [SnakeModel(11)] [BPMYRes(1.0)] [BPMXRes(0.5)] **
-UseOpticsDB <UseOpticsDB(1)> [HRSOpticsDBL(db_L.vdc.dat)] [HRSOpticsDBR(db_R.vdc.dat)]

Output

- **Verbose (screen output)**: verbose can be turned on or off using internal command, which can also be written into a macro files.
- **Output files**: 2 types of output are available: ascii file, root ntuple. Can be turn on|off in 'Detector.ini'.

  For the ascii and verbose output, one can choose the following:

  1) keep steps only in the given physical volumes: /stepping/add2PrintList

  2) keep only one track in each event: /tracking/thisTrackOnly

  3) keep only tracks of the given particle: /tracking/particleOnly
- **What is in the ntuple?**

1. Some 1-D or 2-D distribution of the thrown vertex and momentum. Can be use as monitor histogram and as the input for event generator 'RootHisto'
2. Tree "config": record important configuration parameters. Only one event is filled.
3. Tree "track#", where # is 0,1,2...7: contains the vertex plane, target plane, sieve plane, focal plane variables and also the following variable at each step along the particle trajectory: X,Y,Z,L,TL,Ekin,dE,Dsty,Radlen,Bx,By,Bz
4. Tree "D": contains trojectories of all particles and also the detector hit vaiables like: ParicleId,TarckId,ParentTrackId,SD_Id,T(time),X,Y,Z,Edep,Edep_daughter,P,theta,Phi,Pout

See details in file HRS_nt_structure.txt

Advance Features of HRSMC

- Flexible command line, (customize HRSUsage.ini)
- Flexible physics models
- Powerful field interpretor
- Powerful event generator: BdL, Elas, QuasiElas, RootNtuple, RootHisto ...
- Flexible Virtual Detector configured by input file
- Fast option
- XS models: elastic and inelastic(QFS, thanks Chao Gu).
- Various SNAKE models, can easily add new one or be replaced (Thanks Min Huang and John)
- HRS event can be reconstructed by both SNAKE backward and REAL optics matrix

Flexible Command Line

- **HRSMC can take more than 30 options in the command line, each option will have compulsory argument and optinal arguments. Each argument has a default value. The usage looks like:**

  **HRSMC -option1 <argu1(0)> [argu2(0)] ... [argu9(0)] **

  -option2 <argu1(0)> [argu2(0)] ... –optionN

  HRSMC -help : Get all details

  HRSMC -option1 help : Get details only for option1

- **All options, arguments's name, type and their default values and the help menu of these options are defined in 'HRSUsage.ini'.**
- **One can customize HRSUsage.ini' with his own default values to make the command line shorter.**

Geant4 Physics Modules

- The following models are available(default is QGSP_BERT):

  FTFP_BERT, FTFP_BERT_EMV, FTFP_BERT_EMX, FTF_BIC, LHEP, LHEP_EMV, QBBC, QGS_BIC, QGSC_BERT, QGSP, QGSP_BERT, QGSP_BERT_EMV, QGSP_BIC_EMY, QGSP_BERT_EMX, QGSP_BERT_HP, QGSP_BIC, QGSP_BIC_HP

For detials of these model, please refer to

http://geant4.cern.ch/support/proc_mod_catalog/physics_lists/referencePL.shtml

- Jixie's personal Models:

  QGSP_BERT, QGSP_BERT_HP,QGSP_BIC, QGSP_BIC_HP, HRSHadronPhysics

  User-Step-Limit will be invoked for e-, pr, alpha, D2 and He3 in model **HRSHadronPhysics**, allowing various step length in the target nose, scattering chamber, in FZ magnets and the rest of the hall.

Include Neutrons, _HP means high precision, covers neutrons below 20 MeV

- Switch physics models in command line:

HRSMC –physicsmodel <PhysicsModel(QGSP_BERT)> [UseJixieModel(0)] [TargetStepLimit(5)] \ [ScatChamberStepLimit(10)] [BStepLimit(500)] [FZBStepLimit(100)]

Fast Option of HRSMC

- Geant4 program can run faster if you understand what you are asking it to do and how it execute your command...

- Some possible actions which can make it run faster:
  - Write a high efficient event generator
  - Disable or minimize verbose (screen printing) using macro files
  - Kill all secondaries if possible
  - Shrink the size of the hall (configure Detector.ini)
  - Place absorber (track got killed when ever hit this object) in anywhere you wish to stop particles
  - Turn off detector resonponse if possible, and do not not store all trajectories into the ntuple
  - Cancel some event actions if possible, for example -CalculateXS 0
- The detail usage for option '-FAST' or '-fast' is: **HRSMC -fast [NoSecondary(1)] [NoDetectorResponse(0)] [StoreSecondary(2)] \ [StoreTrajectory(0)] -CalculateXS [CalculateXS(1)]**

Event Generator Engines

- RootNtuple:
  - Read the given ntuple, which is the output of HRSMC, and use the vertex and momentum
- RootHisto:
  - Read the given ntuple, which is also the output of HRSMC, based on the histogram distribution to throw position and momentum.

Specify event engine in command line using '-engine' and '-mcin#':

**HRSMC -engine <PrimaryEngine1(Uniform)> [PrimaryEngine2(Uniform)]...[PrimaryEngine8(Uniform)] \ -mcin1
<InRootFileName1(InRootFile0.root)> <InRootTreeName1(track0)> [TrigNum1(0)] \ [SkipNum1(0)] ... -mcin8
<InRootFileName8(InRootFile7.root)> <InRootTreeName8(track0)> \ [TrigNum8(0)] [SkipNum8(0)]**

Example:

HRSMC -engine HRSElasEl HRSElasNucleus

HRSMC -engine RootNtuple -micn1 infile.root track0 1000 10

HRSMC -engine RootNtuple RootNtuple -micn1 infile.root track0 -micn2 infile.root track1

Documentation

- Source code is available in SVN: https://jlabsvn.jlab.org/svnroot/halla/groups/g2p/HRSMC/
- Instruction for Geant4 installation, environment setup and update history are available.
- Usage manual will be printed by typing these commands:

  HRSMC -h, HRSMC --h, HRSMC -help, HRSMC --help

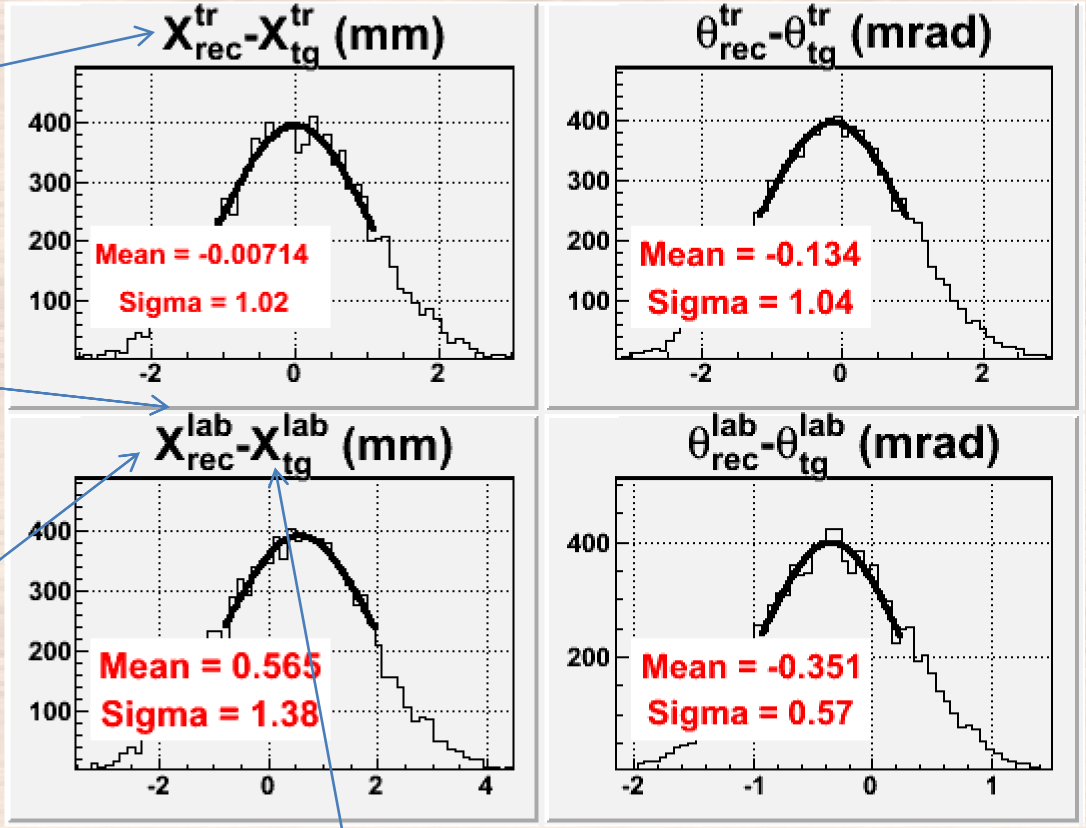
  Usage**: HRSMC [option1 argument_list] [...] [optionN argument_list]**

  To get the detail usage of an option, just type 'help' after it. For example: **HRSMC -physicsmodel help**
- Description for internal commands (html format) are already: https://jlabsvn.jlab.org/svnroot/halla/groups/g2p/HRSMC/Menu/
- Output root ntuple structure description is ready here: https://jlabsvn.jlab.org/svnroot/halla/groups/g2p/HRSMC/HRS_nt_structure.txt
- A lot of macro files and c++ scripts are available: https://jlabsvn.jlab.org/svnroot/halla/groups/g2p/HRSMC/macros

Study The Resolution …

How to read these plots?

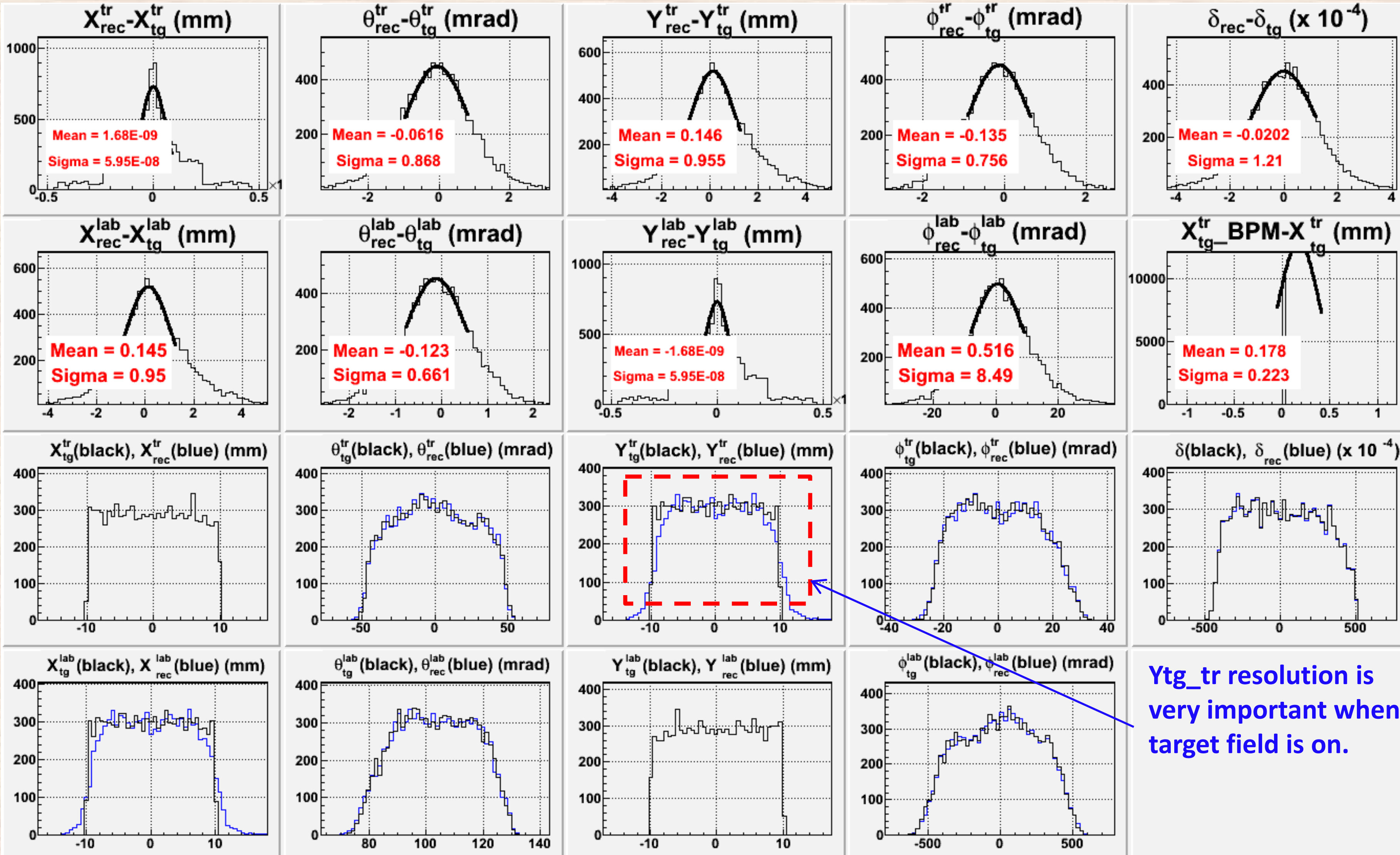
•'tr' means in transport coordinate
•'lab'means in hall coordinate
•'Mean'will be the offset of the reconstruction
•'Sigma'will be the resolution of the reconstruction



Reconstructed variables in the target plane

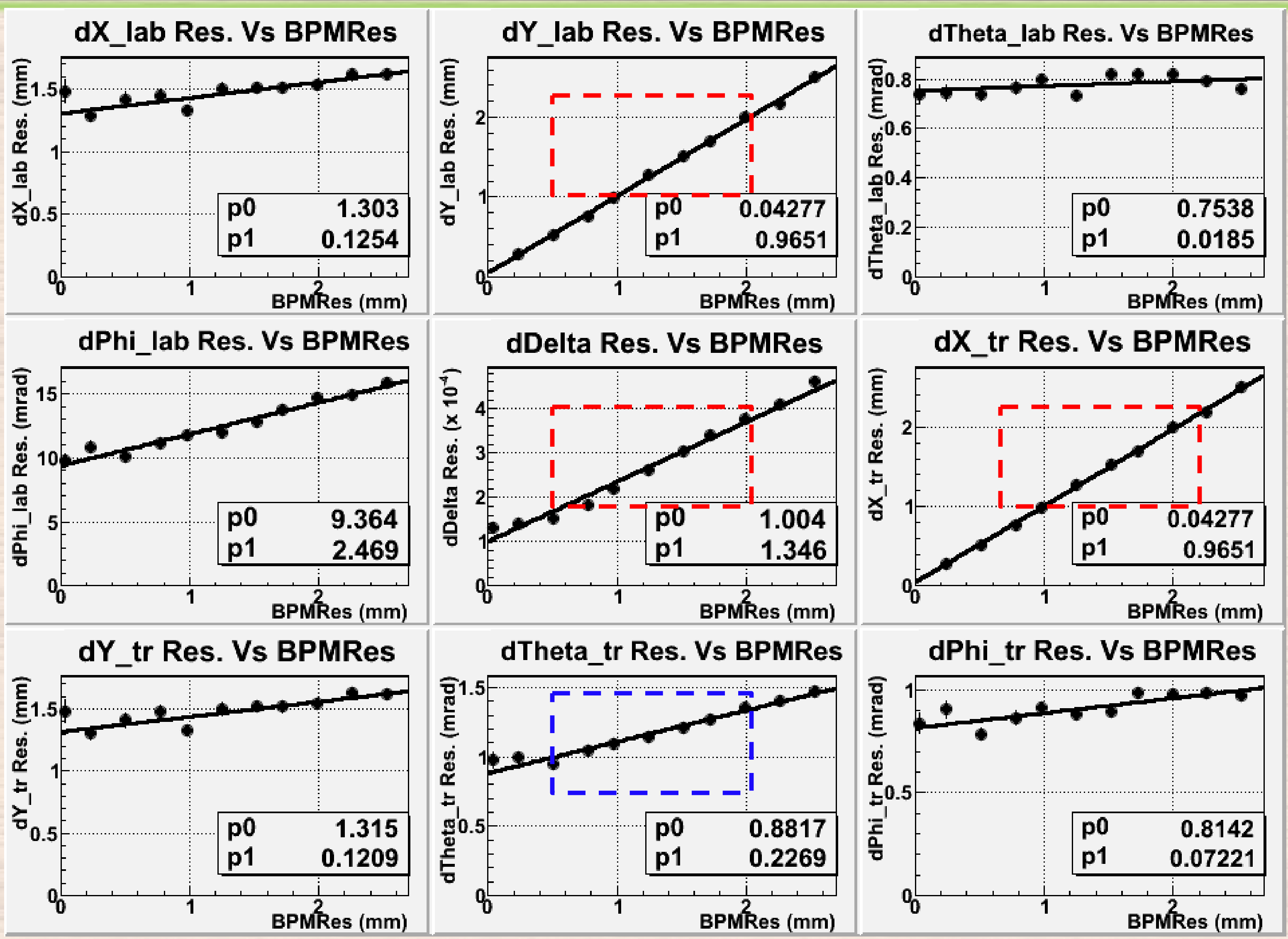
Thrown or effective variables in the target plane

Resolution of SNAKE Model 484816+shim



Normal situation: 2 cm raster, +/-5% delta,full coverage of theta and phi.0 mm BPM vertical resolution.

BPM Dependence of SNAKE Model 484816+shim

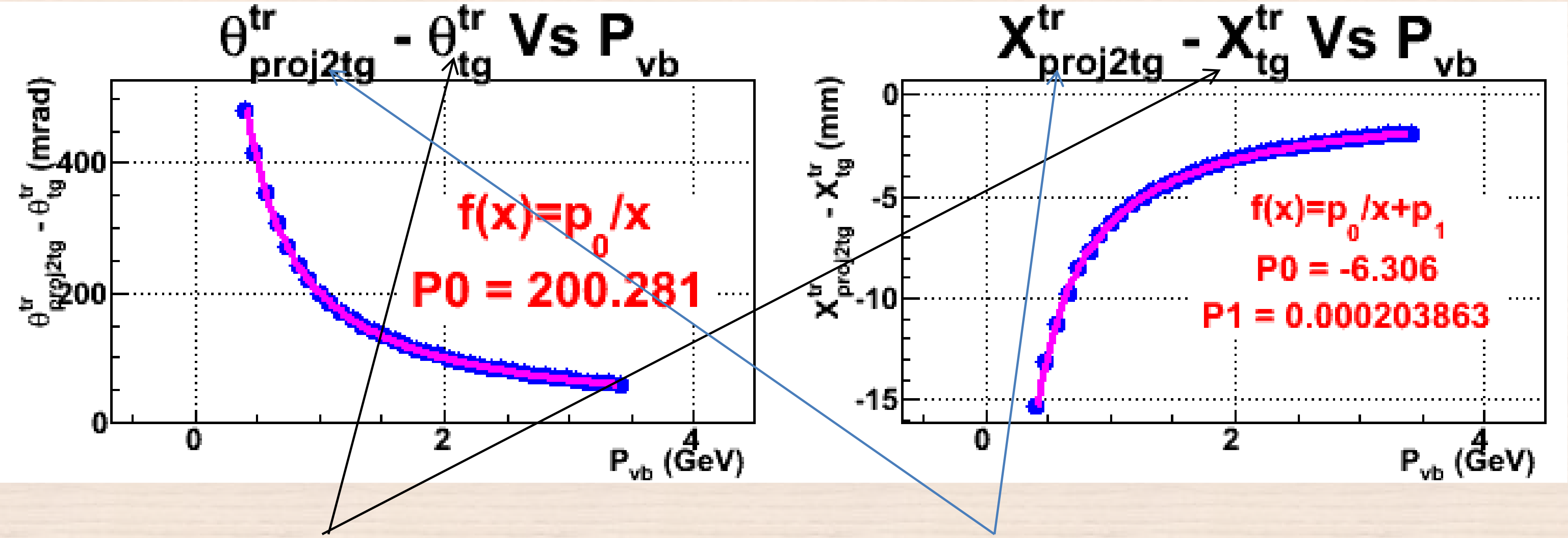


Normal situation: 2 cm raster, +/-5% delta,full coverage of theta and phi.

Delta and X_tr have strong dependence, Theta_tr also has some dependence.

Effective BPM X0_tr and Theta_tr

X0_tr is the BPM vertical measurement, it will be used to reconstruct the focal plane to the target plane. When target field is on, the BPM measurement is no longer the one we should use in the NO target field backward model.

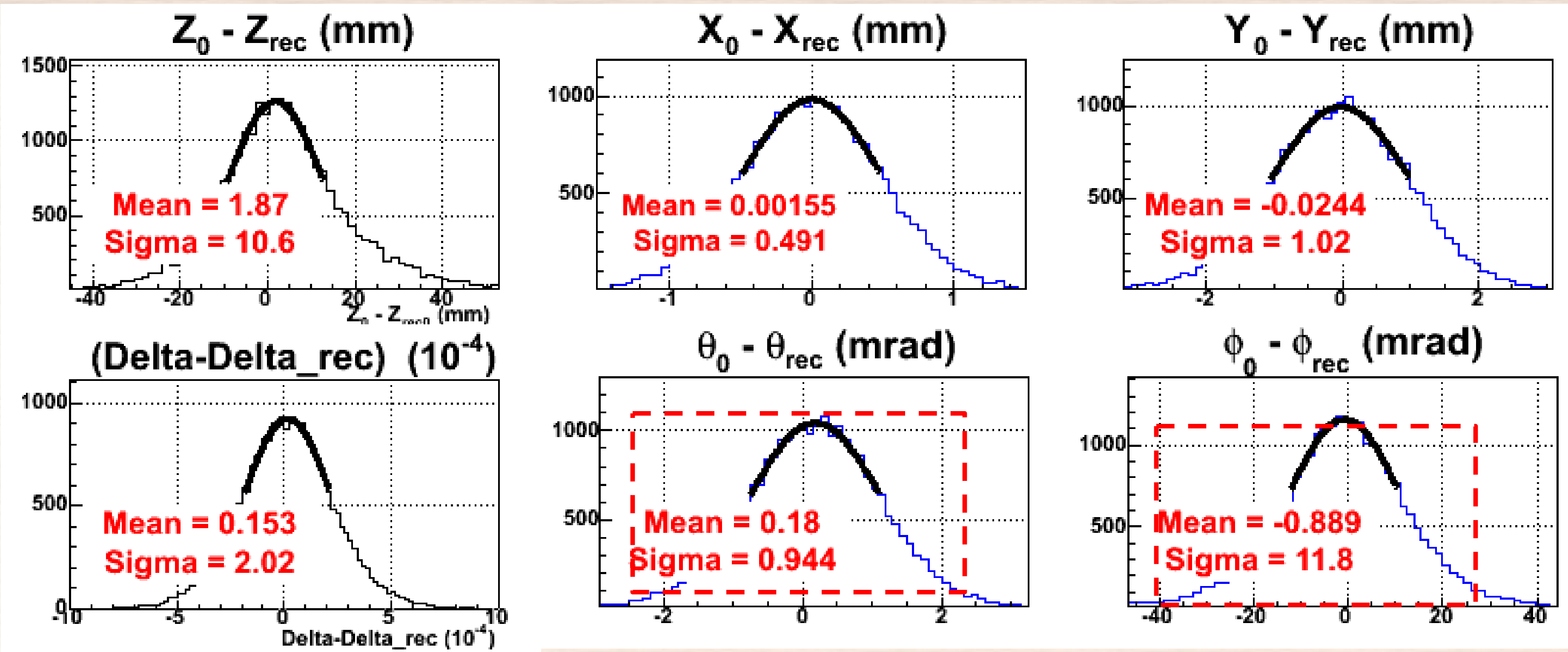


Thrown variable in target plane

Variable in target plane imaged by NO target field SNAKE model

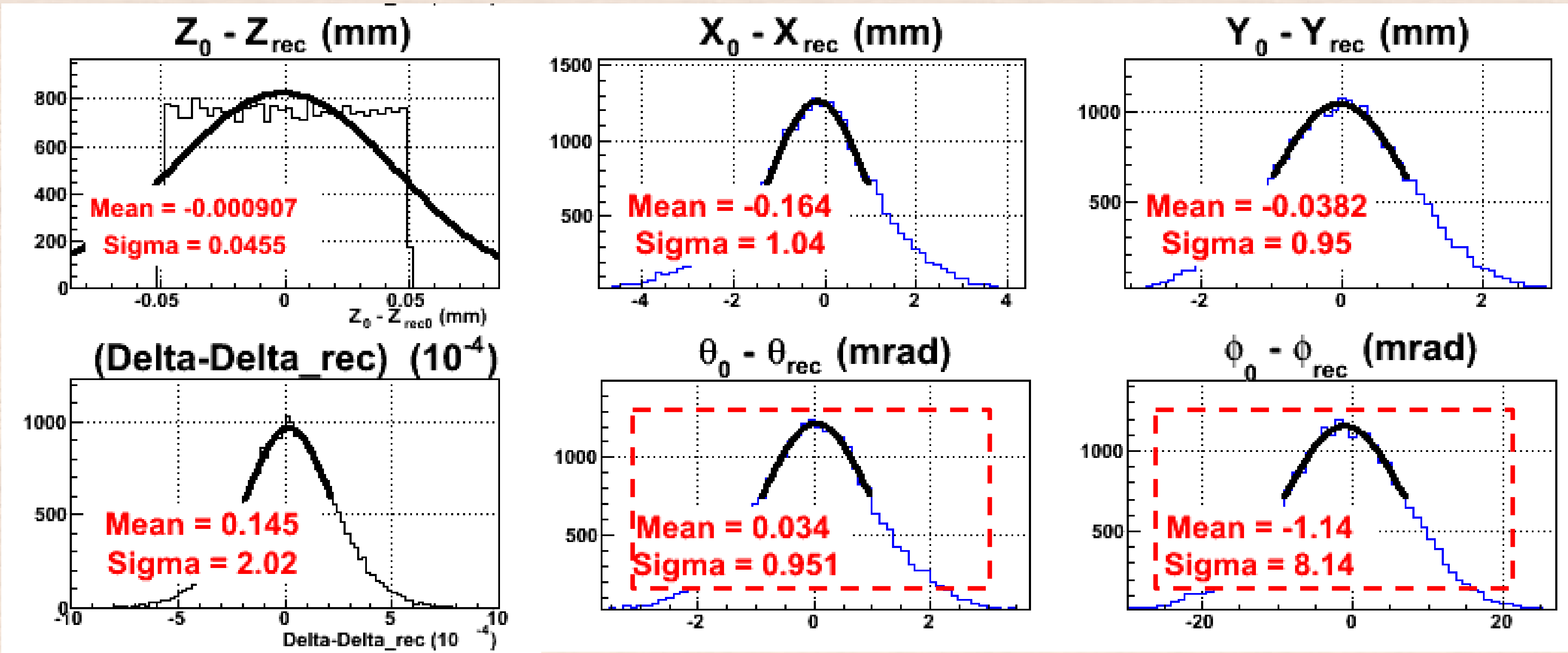
5.0 T target field

Resolution of HRSMC Using SNAKE Model 484816+shim, No Target Field



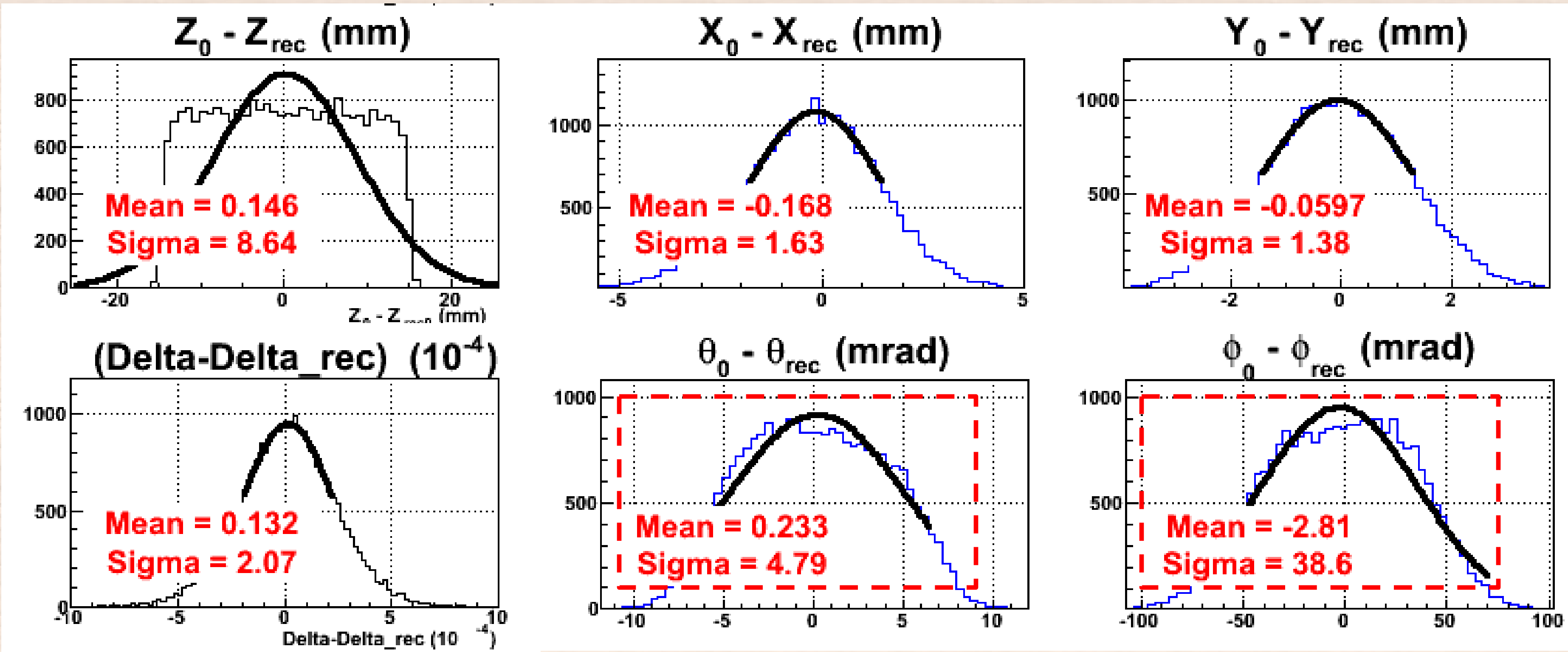
Raster=2.4cm, BPM resolution: 1 mm in vertical, No target field

Resolution of HRSMC Using SNAKE Model 484816+shim, Stop at Exact Z0,5T



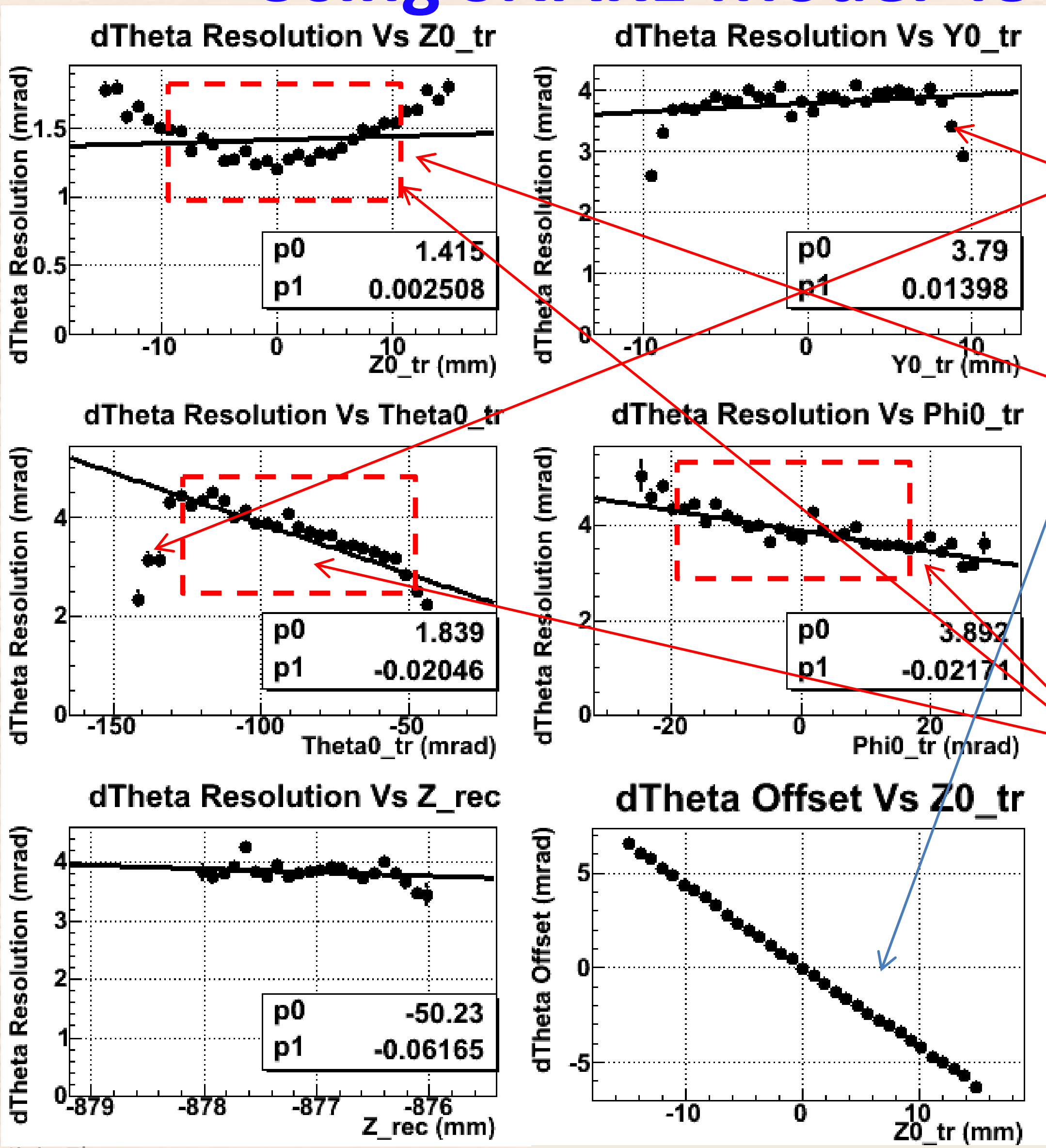
Raster=2.4cm, BPM resolution: 1 mm in vertical, 5.0T target field
Reconstruct to thrown vertex z (perfect Ytg_tr resolution)

Resolution of HRSMC Using SNAKE Model 484816+shim, Stop at Target Plane,5T



Raster=2.4cm, BPM resolution: 1 mm in vertical, 5.0 T target field
Reconstructed to the target center

Dependence of Theta Resolution, Using SNAKE Model 484816+shim,5T



- **Resolution is out of control at the edge of the acceptance**
- **The overall dTheta resolution looks bad, but not too bad if binned in Z0_tr. That indicates it has strong dependence on Z0_tr, or the TRUE vertex z.**
- **dTheta resolution has very strong out-of-plane-angle, in-plane-angle and TRUE vertex z dependence.**
- **In the region |Z0_tr|<10 mm, dTheta resolution satisfies the requirement of g2p. Need to find out a way to select good resolution region.**

Conclusion

- HRSMC is designed for multiple HRS experiment, especially for G2P and GEP. It can be easily modified to support other experiments by adding the geometries.
- HRSMC is ready to use for G2P|GEP.
- Can use real optics matrix to reconstruct simulated focal plane data. In other words, HRSMC can cross check the quality of optics matrix and help to improve it, which is useful for those experiments with large raster. (Beam position scan runs have to be taken in the experiment in order to support large raster...)
- The strategy of the reconstruction with target field is:

  No-Target-Filed-HRS + Drift-Sieve-to-Target-in-field .

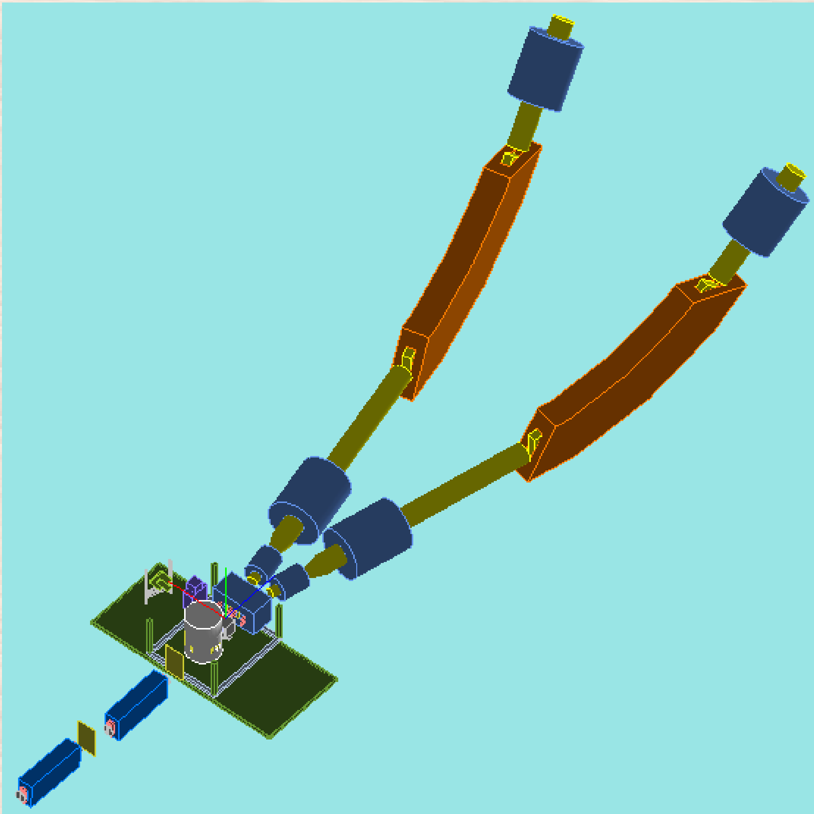
  This requires high Ytg_tr resolution for the reconstruction. If there is no guarantee for Ytg_tr resolution, the target length should be short! The shorter the better.
- A lot advance features are included.
- Need support for SNAKE models. Thanks to Min Huang and John, need their continuous contribution.

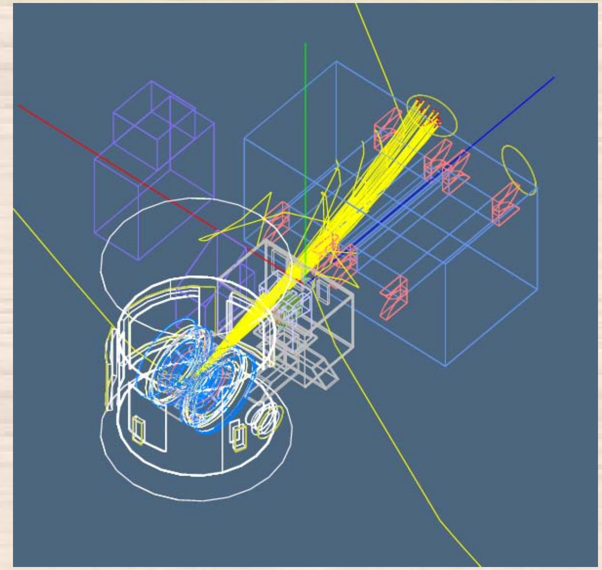
Acknowledgment

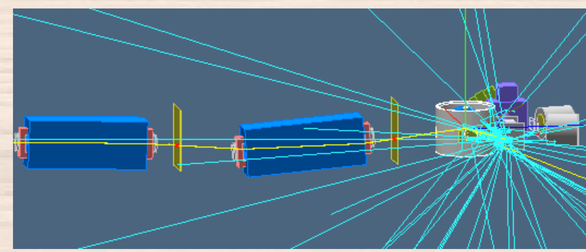
- Thank John LeRose for providing guidance and SNAKE models
- Thank Min Huang for providing SNAKE models and her hard work in optics optimization for real data
- Thank Chao Gu for helping in both simulation and optics optimization
- Thanks to all G2P Collaborators

Back up

Simulation Program is Ready







A geant4 based program,HRSMC, will propagate scattered electron from target to the sieve slit. Then use no target field SNAKE forward model to transport it to the focal plane. The reconstruction is done by no target field SNAKE backwrad model or the no target field REAL optics matrix. When the target field is on, the reconstruction will stop at sieve plane, then drift the electron in magnetic fields back to the target.

Input Files

- **Compulsory input files:**

  Detector.ini: specify hall size, pivot, scattering chamber , target location, HRS angle. Also specify which experiment geometry will be turned on.

  Detector_G2P.ini: Specify how to build G2P geometries

  Detector_CREX.ini: Specify how to build CREX geometries

  Detector_XXX.ini: can be add for any future experiment

  HRSUsage.ini: interpret the command line arguments and provide the usage menu. All default values for the command line arguments are written in'HRSUsage.ini'. One can customize them in this file to avoid typing long command.

  BField_Helm.ini, BField_Septum.ini BField_*.ini: specify the rotation, position and current ratio...etc.

  Field maps: g2p_hallbfield.dat g2p_septumfield_484816.dat ...

- **Macro files:** contains a series of Geant4 commands that one want the program to execute. A lot of files can be found in directory named 'macros'

Vertex Position Generator

- Uniform, support circular, rectangular and elipse shape of rasters.

  /mydet/rasterMode mode, where mode could be 1=circular, 2=rectangular and 3=elipse

  /mydet/gunRHigh Rout unit, (will be the vertical half width if using rectangular raster)

  /mydet/gunRLow Rin unit, (will be the horizontal half width if using rectangular raster)

- Straight beam line with a tilted angle: go through a given point with given slopes:

  /mydet/fixedPointBL3V x0 y0 z0 unit

  /mydet/slopeBL3V dxdz dydz z

- Fixed location

  /mydet/position3V x y z

Momentum Generator Engine(1)

- Uniform:
  - In HCS: Specify the lower and upper limits of Ptot, Theta, and Phi, it will throw them in flat distribution in Hall Coordinate System
  - In TCS: Specify the lower and upper limits of Ptot, in-plane-angle(Theta) and out-plane-anlge(Phi), it will throw them in flat distribution in the Transport Coordinate System
- Gaussian:
  - Specify the mean value of Ptot,Theta and Phi, also given their standard deviations (sigmas), it will thrown them in gaussian distribution in HCS
- BdL:
  - When target field is on, integrate the BdL from the vertex to 1 meter away from the target. Then throw Ptot, based on the BdL to determine the lower and upper limits of the in-plane-angle(Theta) and out-plane-anlge(Phi). Finally throw these 2 angles in TCS.

Momentum Generator Engine(2)

- HRSElasEl(e-N or e-P):
  - Throw the Theta and Phi angle Uniformly, then base on the beam energy and the target mass to calculate the elatic scattering momentum for the scattered electron
- HRSElasNucleus (e-N):
  - Throw the Theta and Phi angle Uniformly, then base on the beam energy and the target mass to calculate the elatic scattering momentum for the scattered electron
  - If shooting both e (1^{st} track)and N (2^{nd} track), it will throw the Theta_el and Phi_el angles Uniformly for the electron, then determine the Ptot_el and Ptot_N, Theta_N, Phi_N
- HRSQuasiElasEl and HRSQuasiElasNucleus:
  - Similar to the elastic generator, but the target mass is proton mass (hard coded)

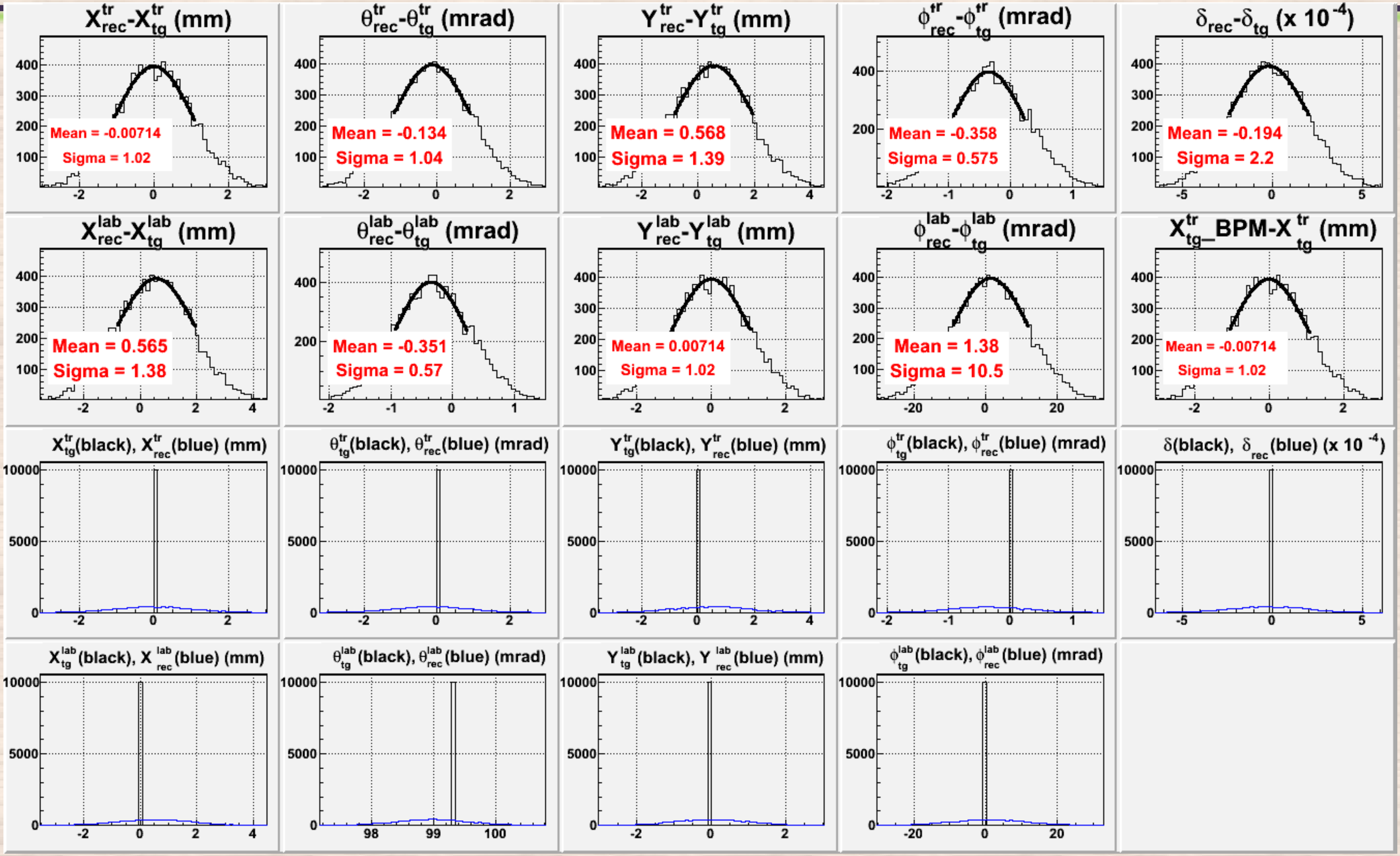
End Planes Propagate procedures and Name Rules for Their Variables

- **Variables**: $={X,Theta,Y,Phi,Delta,(Z,P)}
- Two coordinate systems: Hall coordinate system (HCS) and Transport coordinate system(TCS, variable names always followed by'_tr')
- **Propagate procedures**:
  1. Thrown in vertex plane: $0, $_tr
  2. Images of thrown vertex at target plane: $tg_tr
  3. Sieve plane (Virtual Boundary): $vb, $vb_tr
  4. Projected to target plane: $_proj2tg_tr
  5. Focal plane: $fp_tr
  6. Snake's reconstruction at target plane: $_rec2tg_tr
  7. Project Snake's reconstruction to sieve plane: $_proj2sl_tr
  8. Drift from sieve plane to target plane: $tg_rec_tr
  9. Drift from target plane to vertex plane: $_rec, $rec_tr

$0,$0_tr -> $tg_tr -> $vb,$vb_tr -> $_proj2tg_tr -> $fp_tr -> $_rec2tg_tr -> $_proj2sl_tr -> $tg_rec_tr -> $_rec,$_rec_tr

- BPM resolution of lab Y (vertical) was used in step 5 to go backward
- BPM resolution of lab X (horizontal) was used in step 9 to calculate vertex Z, then determined the vertex plane and do the drift.
- Compare the vaiables between planes: 1 vs 9, 2 vs 8, 4 vs 6

Resolution of SNAKE Model 484816+shim (1)



The best scenerio: x,theta,y,phi,delta are all delta function at the cental values, asumming 1 mm BPM vertical resolution.

Drift-In-Field Module

- **Purpose**: Propagate particle in EM field from one location to the other. In G2P only magnetic field is used.

This module is mainly used to drift electron from sieve plane to target plane or vertex plane (the end plane of the vertex).

- **Input**: 3-vector of initial position and momentum in Hall Coordinate System (HCS), field map, particle's mass and charge.
- **Output**: 3-vector of final position and momentum in HCS
- **Speed**: **12 milisecond to drift 800 mm with 50 um step length.**
- **Other usages**: This module is also used in the following projects:

  1)finding the chicane position and beam pipe angle;

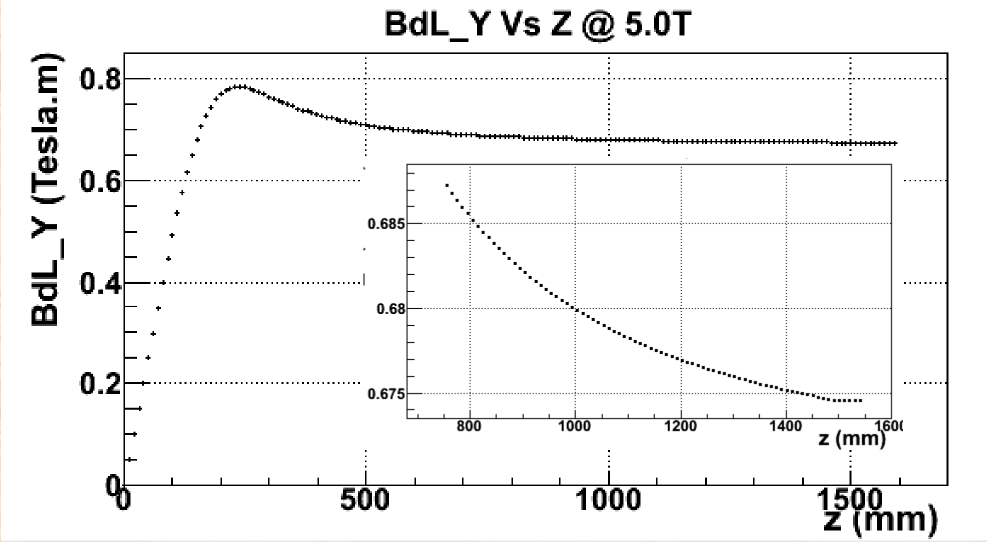
  2)predicting the vertex position at target plane based on BPM A and BPM B measurements;

  3)finding beam titled angle and position offsets at veraious vertex z.

SNAKE Model: Sieve ⟷ Focal

- Snake models are actually fitted between target plane and focal plane.
- All used Snake models are without target field, which means their trajectories in between sieve plane and target plane are **STRAIGHT LINES.**

- Even for 5.0 Tesla target field, the integrated BdL_y from 800 mm to beyond is only 0.01 Tesla.m, about 1.46% of the total. This means the effect from the target field behind the sieve is negligable.



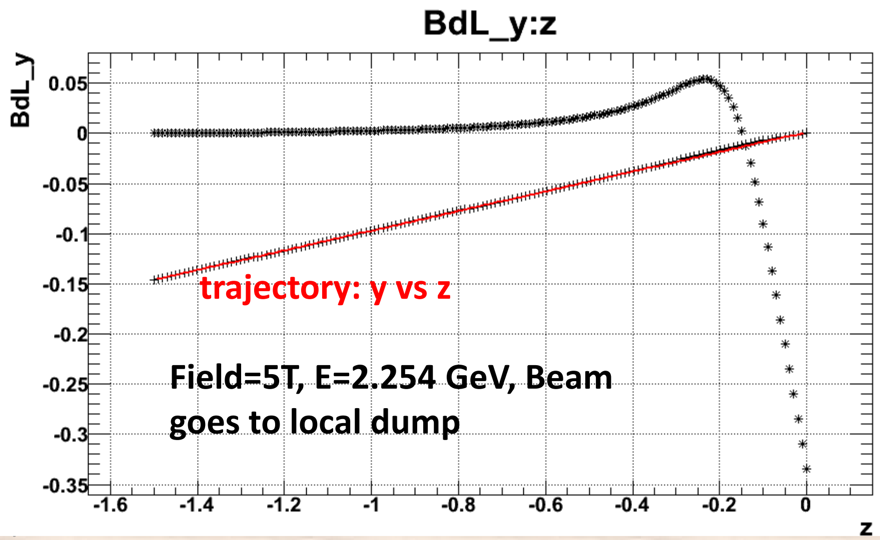
- Therefore:

  Sieve-to-Focal-without-targetfield = Sieve-to-Focal-with-targetfield.
- **Sieve-to-Focal = Target-to-Focal – Target-to-Sieve .**
- **Same for Focal-to-Sieve.**

BPM Resolution

- There are only 4 variables (x, y, theta, phi) in the focal plane, in order to reconstruction back to five variables (x, y, theta, phi, delta) in the target plane, one assumption has to be made. This assumption is that the momentum of the particle (delta) only depends on the VERTICAL displacement and the value of the out-of-plane angle (theta). That said, if the **initial vertical position X0** is known, delta and the other 4 vaiables can all be reconstructed. The initial vertical position X0 usually came from BPM vertical mesurement.
- Two sources: **δX0 = δBPM_Measurement + δVertical_DueToUnknownZ0InField**
- When target field is on, since we do not know the vertex Z0, δZ=15mm, BPM will have large uncertianty in the vertical position. Horizontal is fine.
- δVertical from simulation:

Field(T)	Beam (GeV)	δVertical (mm)
2.5	1.159	1.4
2.5	1.706	0.9
2.5	2.254	0.7
5.0	2.254,3.359	<0.2



Transform Vaiables between Coordinate Systems: TCS and HCS

$$\theta = \arccos(\cos\theta_{\rm tr}\cos(\theta_0+\phi_{\rm tr})) \qquad (1)$$

$$\phi = \arctan\left(-\frac{\tan\theta_{\rm tr}}{\sin(\theta_0+\phi_{\rm tr})}\right) \qquad (2)$$

$$\begin{aligned} d\theta = & \frac{-1}{\sqrt{1-\cos^2\theta_{\rm tr}\cos^2(\theta_0+\phi_{\rm tr})}}(-\sin\theta_{\rm tr})\cos(\theta_0+\phi_{\rm tr})d\theta_{\rm tr} \\ & + \frac{-1}{\sqrt{1-\cos^2\theta_{\rm tr}\cos^2(\theta_0+\phi_{\rm tr})}}\cos\theta_{\rm tr}(-\sin(\theta_0+\phi_{\rm tr}))d\phi_{\rm tr} \qquad (3) \end{aligned}$$

$$\begin{aligned} d\phi = & \frac{1}{1+\left(\frac{-\tan\theta_{\rm tr}}{\sin(\theta_0+\phi_{\rm tr})}\right)^2}\frac{-1}{\sin(\theta_0+\phi_{\rm tr})}\frac{1}{\cos^2\theta_{\rm tr}}d\theta_{\rm tr} \\ & + \frac{1}{1+\left(\frac{-\tan\theta_{\rm tr}}{\sin(\theta_0+\phi_{\rm tr})}\right)^2}(-\tan\theta_{\rm tr})\left(-\frac{1}{\sin^2(\theta_0+\phi_{\rm tr})}\right)\cos(\theta_0+\phi_{\rm tr})\,d\phi_{\rm tr} \ (4) \end{aligned}$$

- TCS = Transport Coordinate System
- HCS = Hall Coordinate System

Curtsey to Chao Gu

Uncertainty Estimation

No field, $<\theta_{tr}> = <\phi_{tr}> = 0$, $\theta_0 \sim 100\,\mathrm{mrad}$

$$(\delta\theta)^2 = \frac{\cos^2\theta_0}{1-\cos^2\theta_0}\tan^2\theta_0(\delta\phi_{tr})^2 = (\delta\phi_{tr})^2$$

$$(\delta\phi)^2 = \frac{1}{\sin^4\theta_0}\sin^2\theta_0(\delta\theta_{tr})^2 = \frac{(\delta\theta_{tr})^2}{\sin^2\theta_0}$$

$$\begin{cases}\delta\theta_{tr} = 1.02 \\ \delta\phi_{tr} = 0.842\end{cases} \Rightarrow \begin{cases}\delta\theta = 0.842 \\ \delta\phi = 10.2\end{cases}$$

$$(\delta\theta)^2 = \frac{\cos^2\theta_0}{1+\cos^2\theta_0}\left((\delta\theta_{tr})^2 + (\delta\phi_{tr})^2\right)$$

$$(\delta\phi)^2 = \left(\frac{1}{1-\cos^4\theta_0}\right)^2 \sin^2\theta_0\left((\delta\theta_{tr})^2 + \cos^4\theta_0(\delta\phi_{tr})^2\right)$$

5.0T, 2.253GeV, $<\theta_{tr}> \sim \theta_0 \sim 100\,\mathrm{mrad}$, $<\phi_{tr}> = 0$

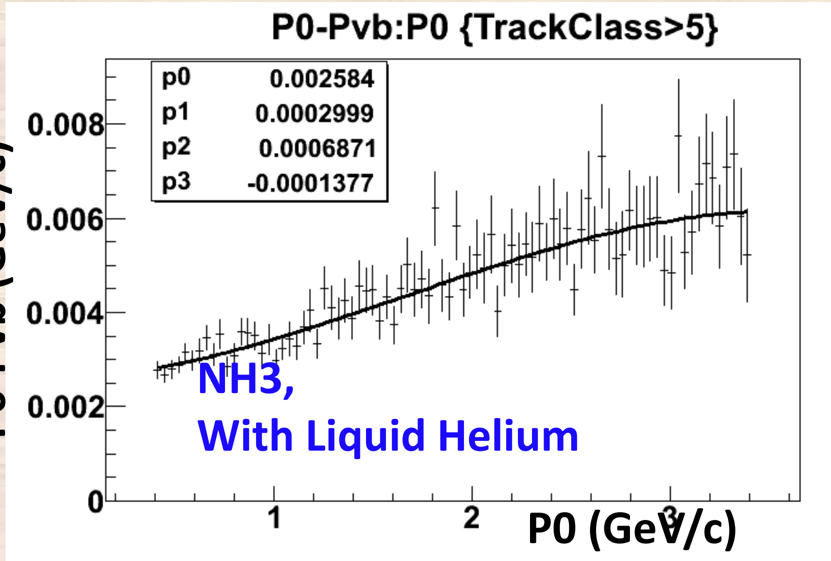
$$\delta\theta = \sqrt{0.497((\delta\theta_{tr})^2 + (\delta\phi_{tr})^2)}$$

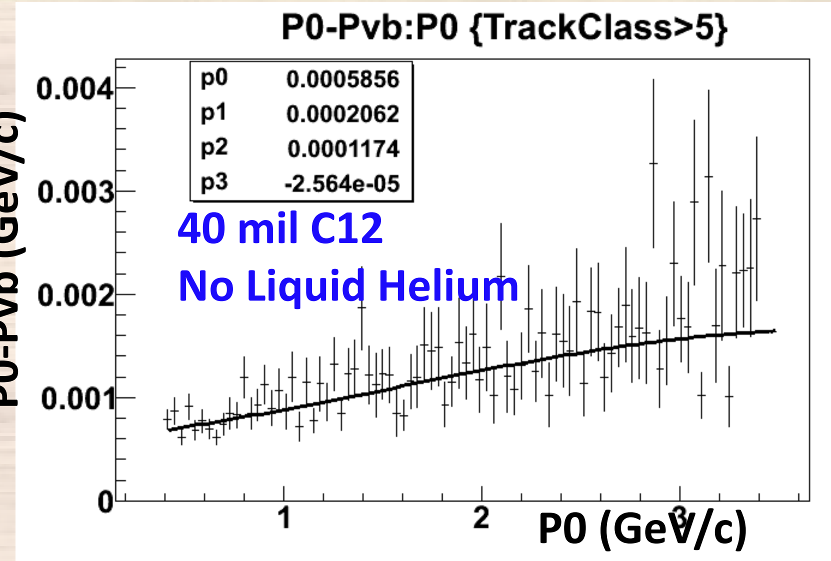
$$\delta\phi = \sqrt{25.3((\delta\theta_{tr})^2 + 0.980(\delta\phi_{tr})^2)}$$

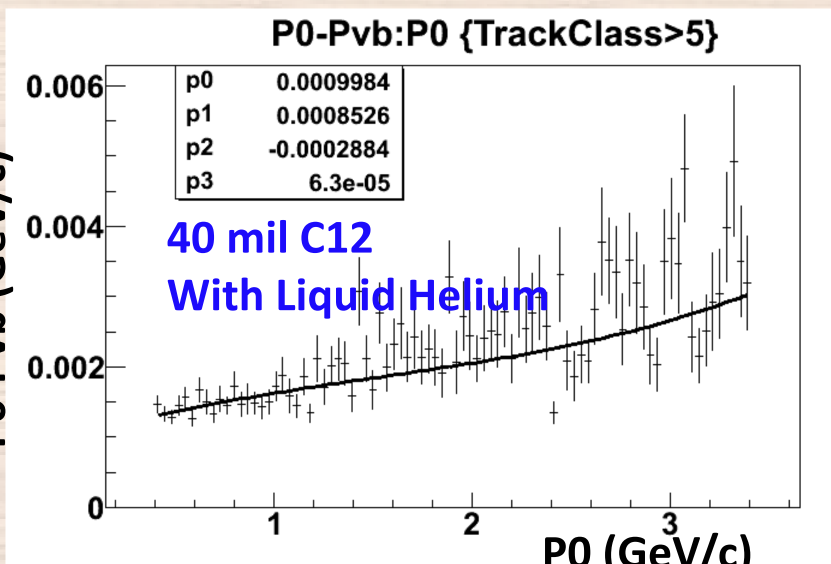
$$\begin{cases}\delta\theta_{tr} = 1.24 \\ \delta\phi_{tr} = 0.868\end{cases} \Rightarrow \begin{cases}\delta\theta = 1.14 \\ \delta\phi = 7.59\end{cases}$$

Curtsey to Chao Gu

Energy Loss Correction for Electron



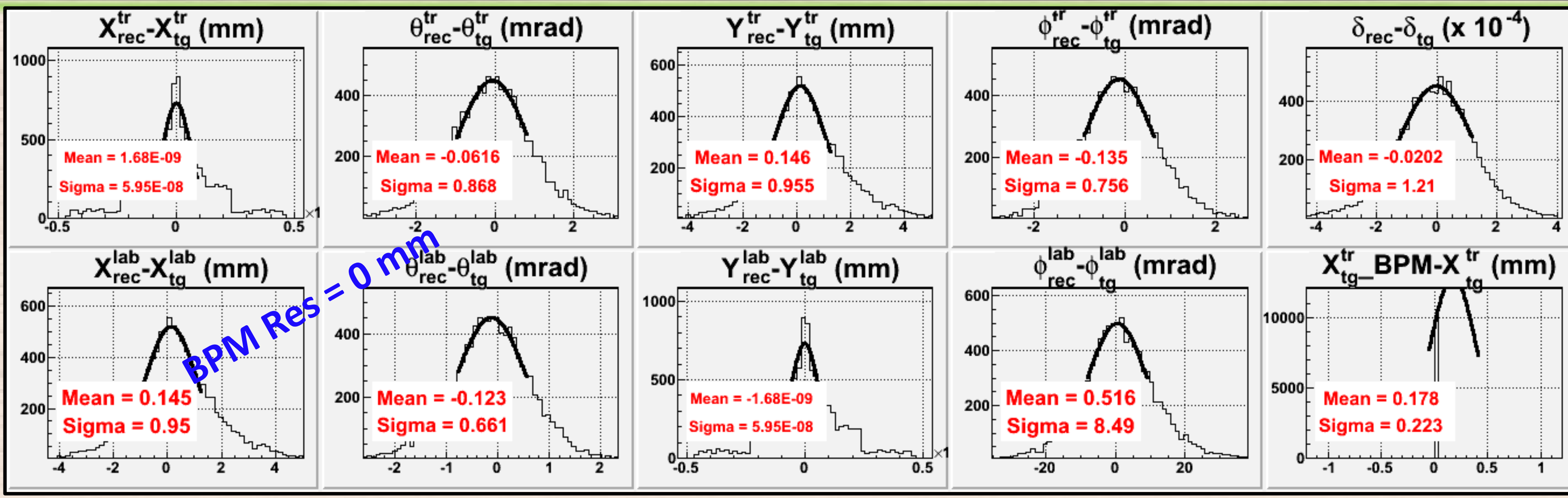


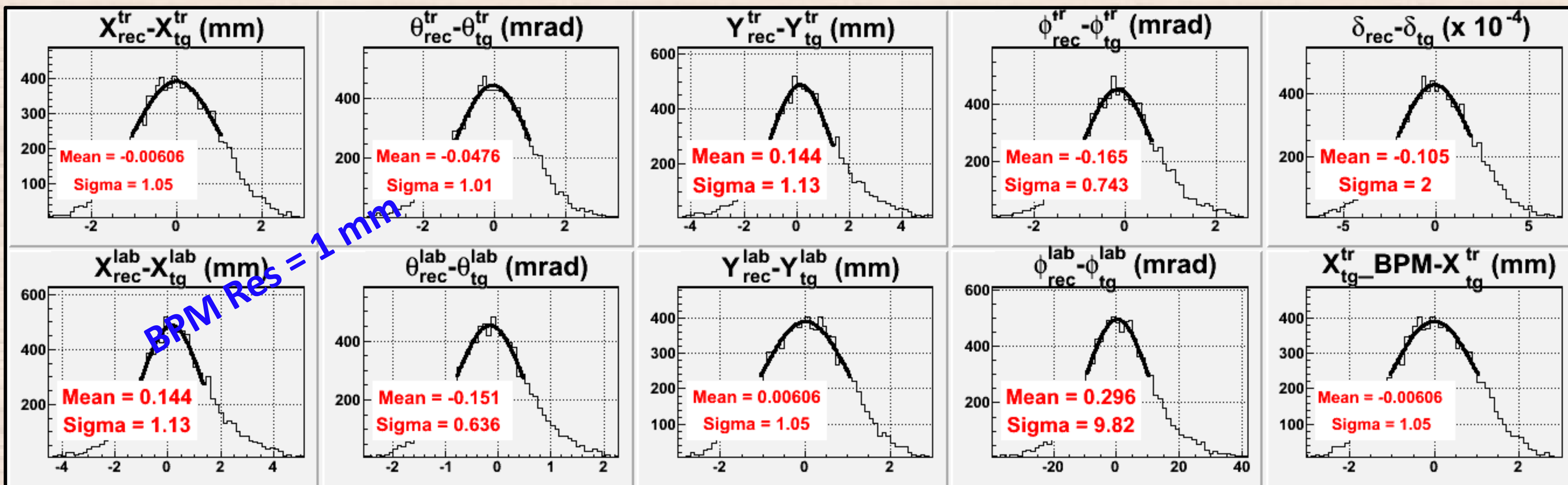


Fit 'pol3' to dp Vs. P0:

$$f(x)= p_0 + p_1*x + p_2*x^2 + p_3*x^3$$

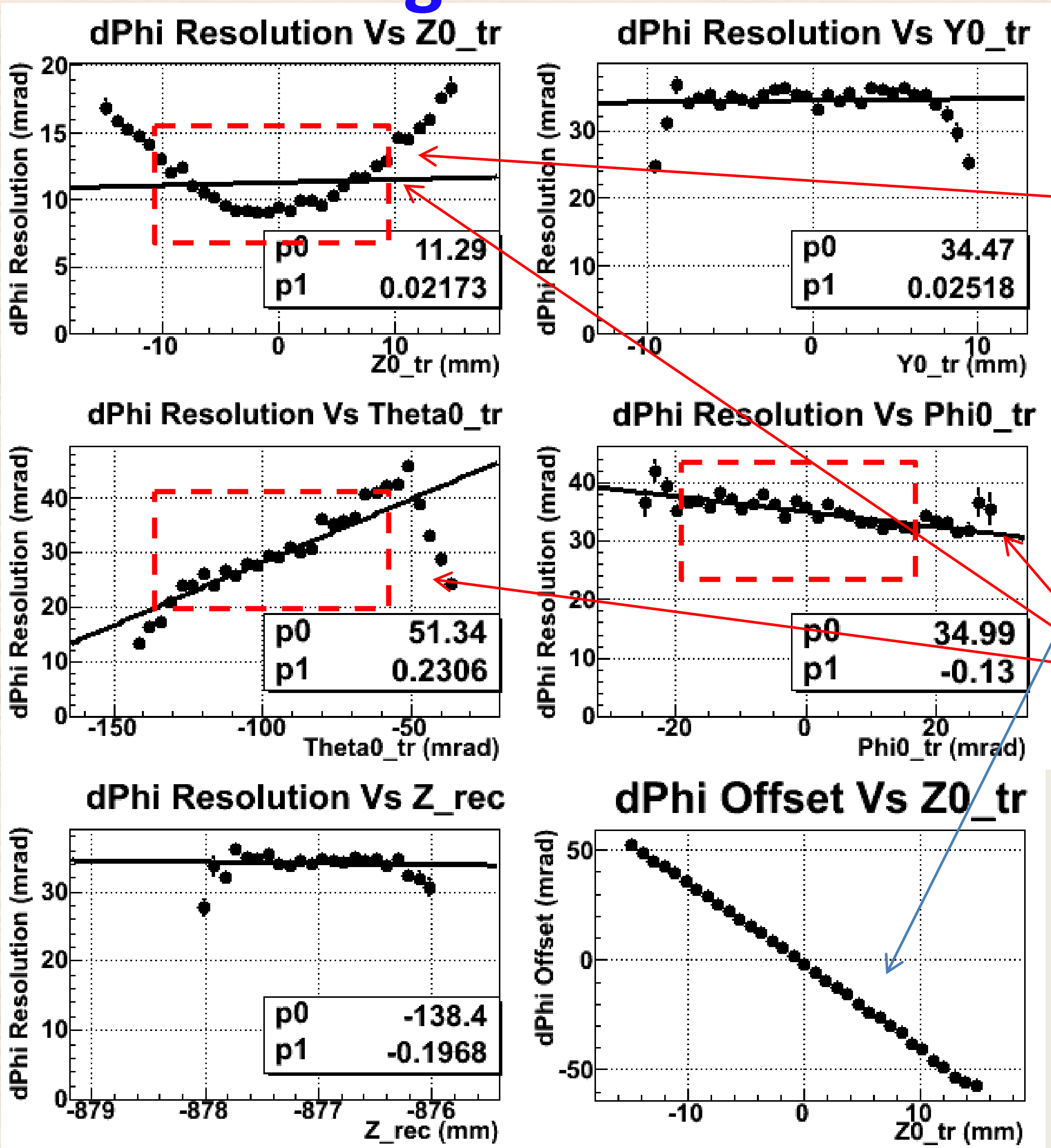
Contribution of BPM Vertical Resolution





Normal situation: 2 cm raster, +/-5% delta,full coverage of theta and phi.

Dependence of Phi Resolution, Using SNAKE Model 484816+shim,5T

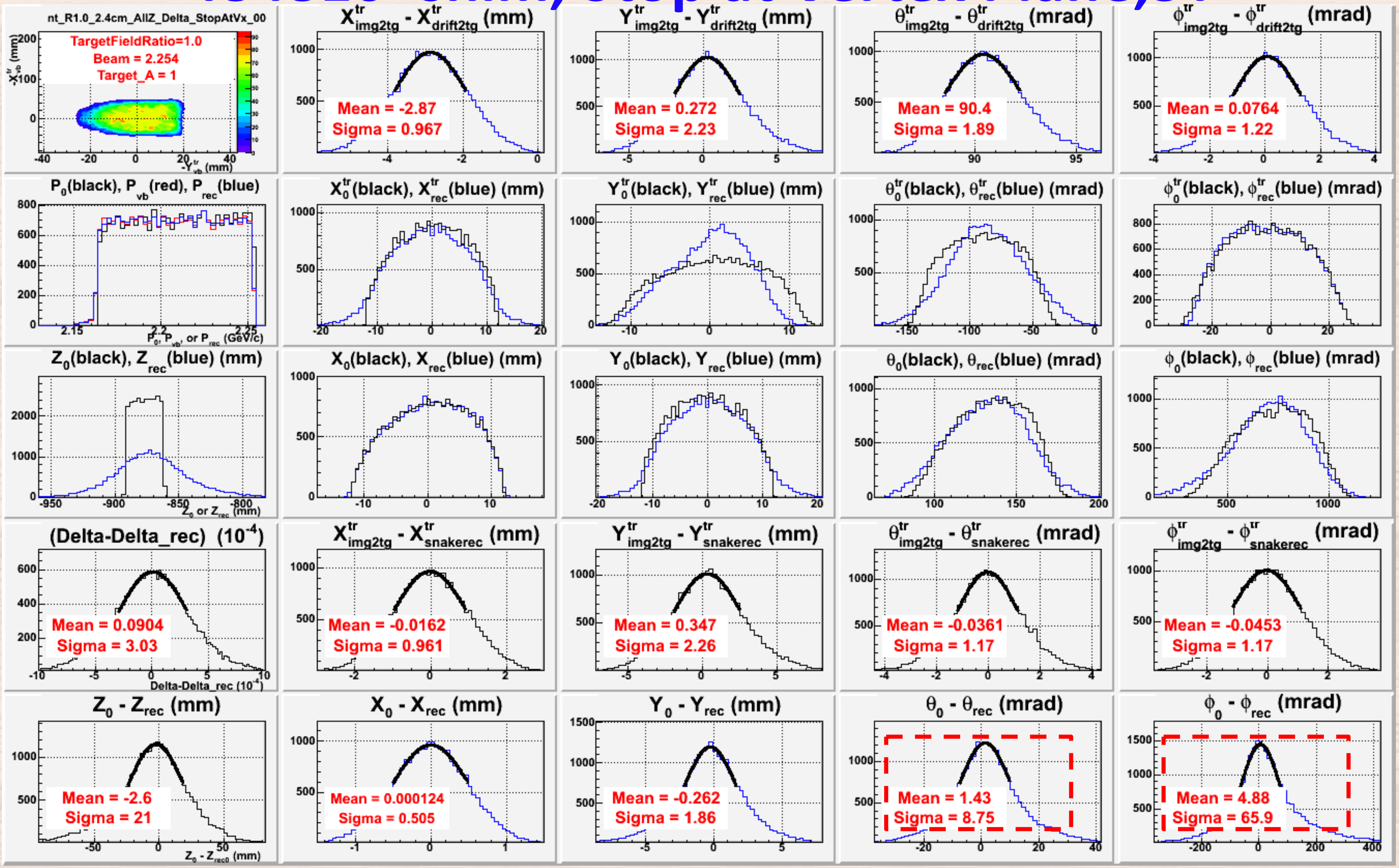


The overall dPhi resolution looks bad, but not too bad if binned in Z0_tr. That indicates it has strong dependence on Z0_tr, or the TRUE vertex z.

dPhi resolution has very strong out-of-plane-angle, in-plane-angle and TRUE vertex z denpendence.

Resolution of HRSMC Using SNAKE Model

484816+shim, Stop at Vertex Plane,5T



Raster=2.4cm, BPM resolution: 0.5mm in horizontal and 1 mm in vertical