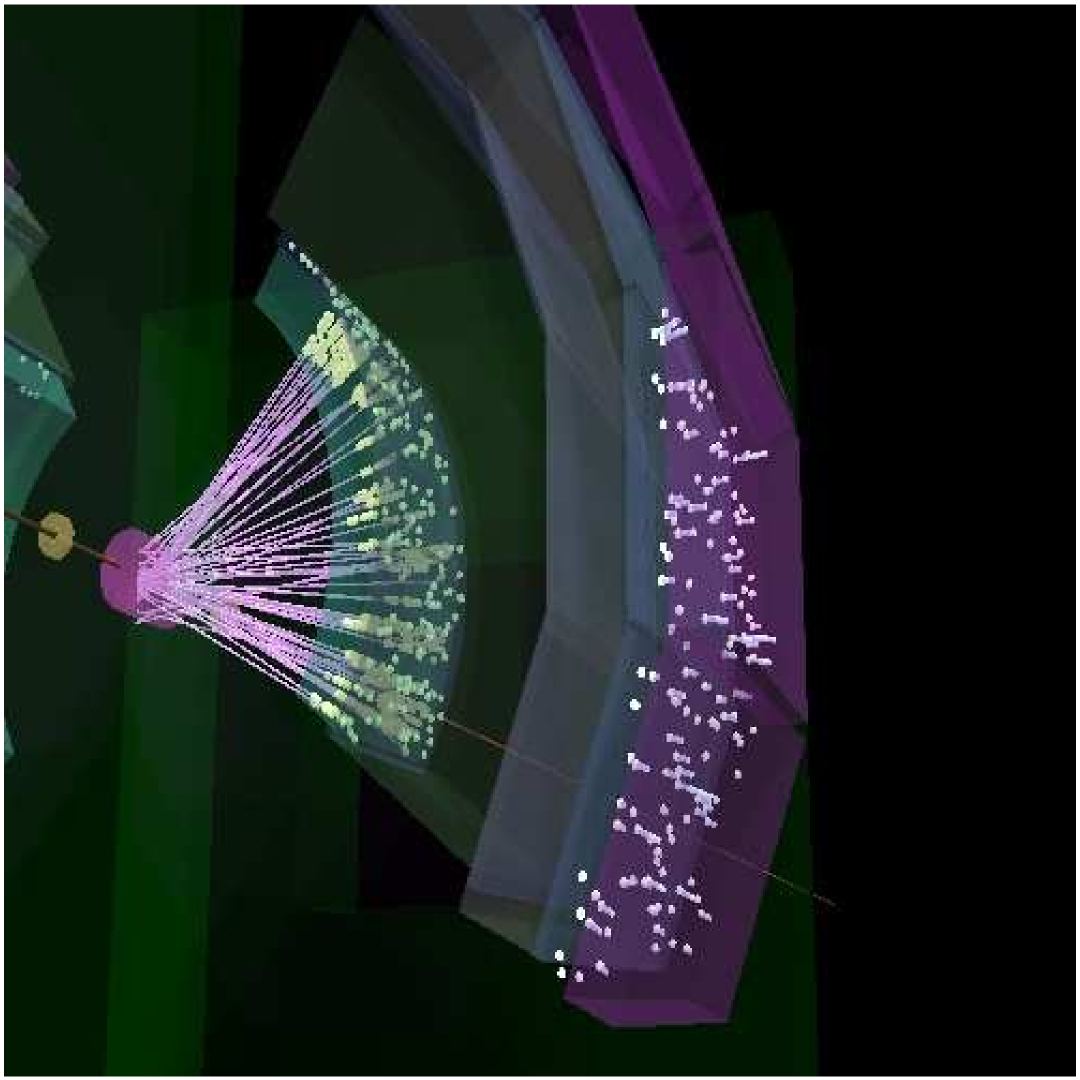
Object-Oriented Track Reconstruction in the PHENIX Detector at RHIC

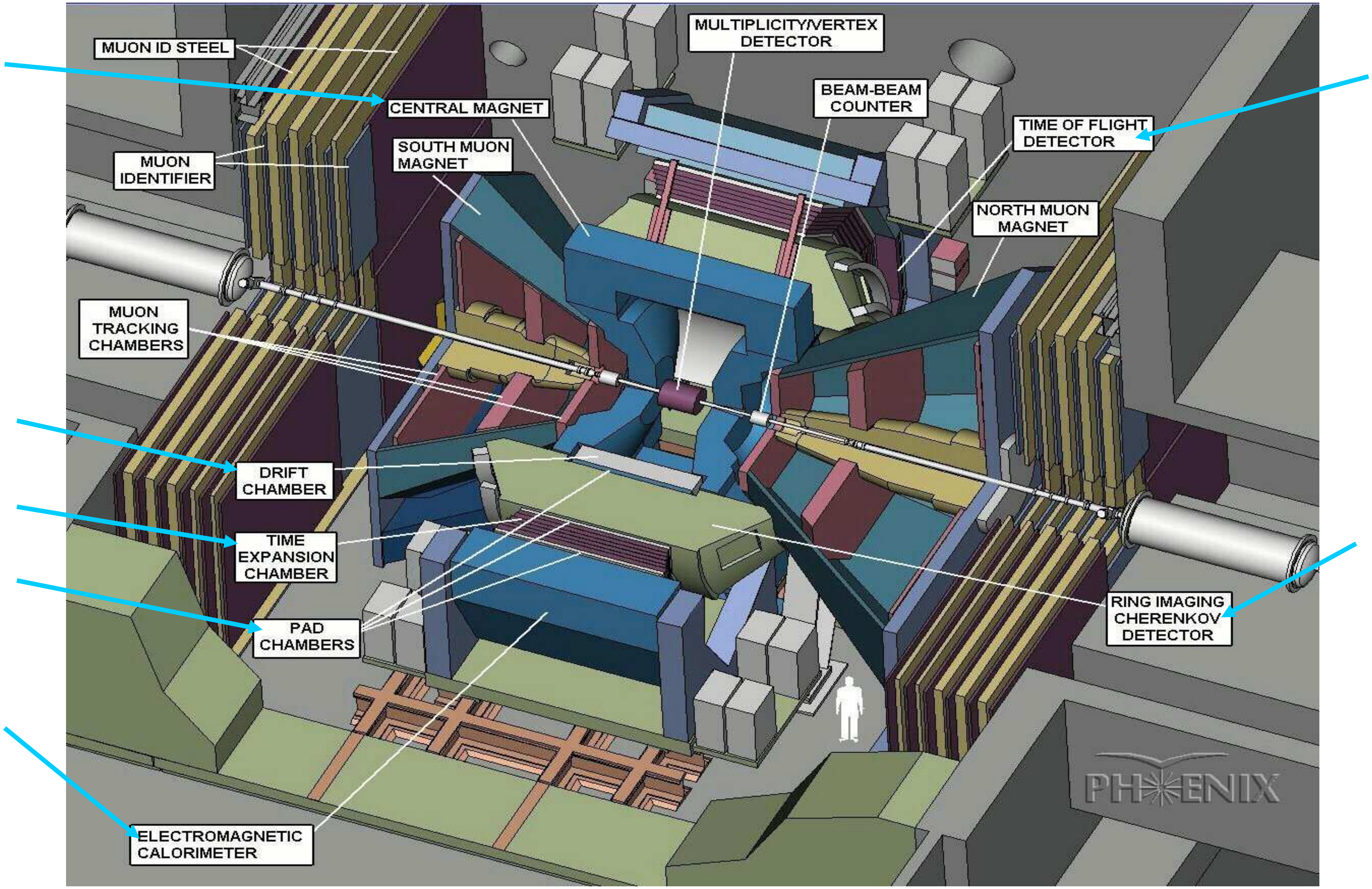
Jeffery T. Mitchell and the PHENIX Collaboration



Outline

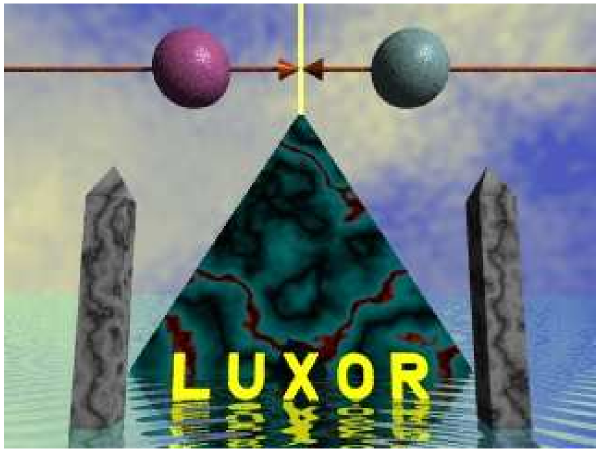
- **The PHENIX Detector**
- **Tracking in PHENIX Overview**
- **Algorithms**
- **Object-Oriented Approach:**
  - ***Track Models***
  - ***Geometry***
  - ***Hit Association***
- **Performance**

The PHENIX Detector At RHIC



Track Reconstruction in PHENIX

• **The PHENIX central arms are optimized for particle identification and produce some of the following tracking challenges:**



- **Very high track multiplicities.**

  (*>300 charged tracks per event possible*)

- **Wide variety of detector types.**

  (*9 subsystems*)

- **Non-symmetric detector configurations.**

  (*the 2 arms are not identical*)

- **Most vector information is obtained from projective measurements.**

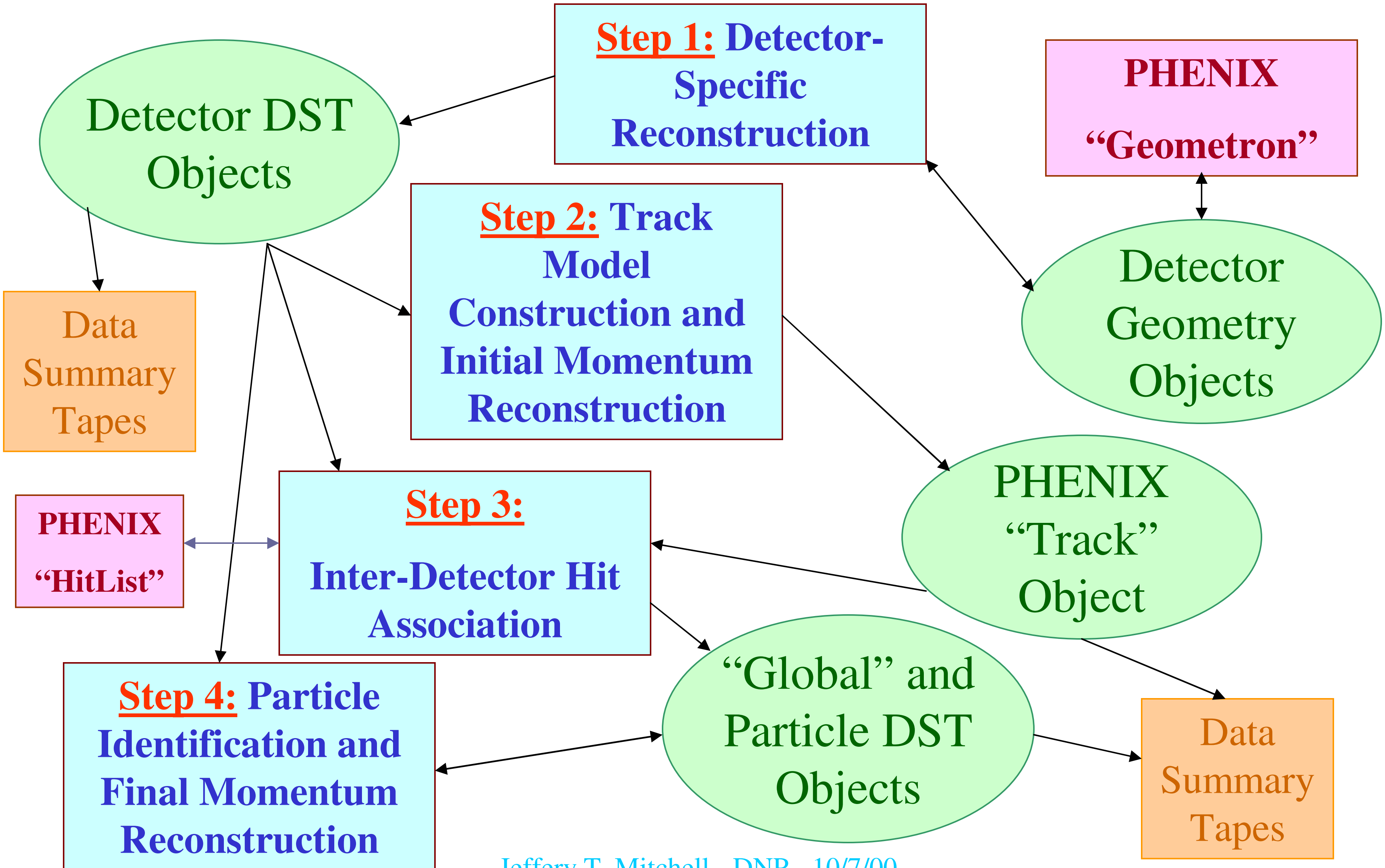
  (*Drift chamber, Time Expansion Chamber*)

- **Non-uniform, focussing magnetic field to optimize acceptance.**

- **No tracking on the interior where the magnetic field is the highest.**

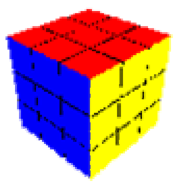
- **Large gap (~1 meter) without tracking where the RICH sits that must be bridged for successful particle Identification.**

Schematic Diagram of the PHENIX Object-Oriented Track Reconstruction Design



Algorithms Applied in PHENIX Track Reconstruction

- **Below is an outline of the various algorithms applied by necessity in PHENIX track reconstruction.**
- **The software is *modular* and *interchangeable* in design.**
- **Algorithms include:**
  - **Combinatorial tracking algorithms for MVD vertex and multiplicity reconstruction, and PC1/PC3 multiplicity analyses.**
  - **Pattern matching algorithms for Pad Chamber cluster reconstruction and Calorimeter cluster reconstruction.**
  - **Local Hough Transform algorithms for Drift Chamber and Time Expansion Chamber track reconstruction.**
  - **Road algorithms for global track hit association.**
  - **Look-up table algorithms for momentum reconstruction and track model calculations.**



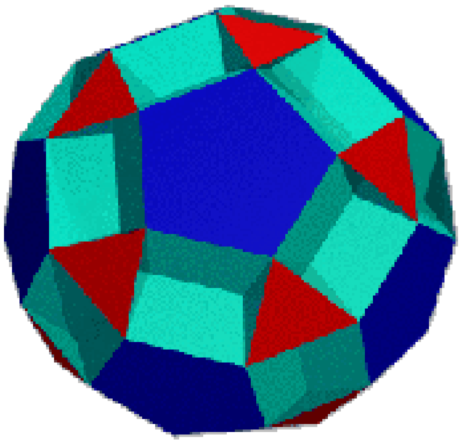
PHENIX Track Models and Track Objects

- **The anchor of our object-oriented approach is the track object, named *PHTrack*.**
- **A track object is simply defined as the shape of the track in space.**
- **With the *PHTrack* base class, we can easily "plug and play" various track shape predictions created in varying conditions via <u>track model classes</u> that inherit from *PHTrack*.**
- **A track model class creates one instance of the *PHTrack* object for each reconstructed track. These can be constructed from any subset of available detectors.**
- **Once a *PHTrack* object is created, it can easily be intersected with any geometrical object that we define.**
- **In addition, a *PHTrack's* path length can be calculated for time-of-flight calculations. Most track models can predict the momentum, also.**

- **We are using one linear track model for magnetic-field-off runs and have evaluated four magnetic-field-on track models for our current data analysis.**

PHENIX Geometry Objects

- **PHENIX has developed a set of classes that define various geometrical quantities necessary for track reconstruction.**
- **Included in the PHENIX Geometry Package are the following quantities:**
  - **Points and Vectors**
  - **Lines and Line Segments**
  - **Planes and Bounded planes (Panels)**
  - **Cylinders and Cylindrical Sections**
  - **Spheres**
  - **Reference Frames**
  - **Angles in the PHENIX Coordinate System**
  - **Polylines for event displays and track shape definition** ← **PHTrack**
  - **Matrices for coordinate transformations**

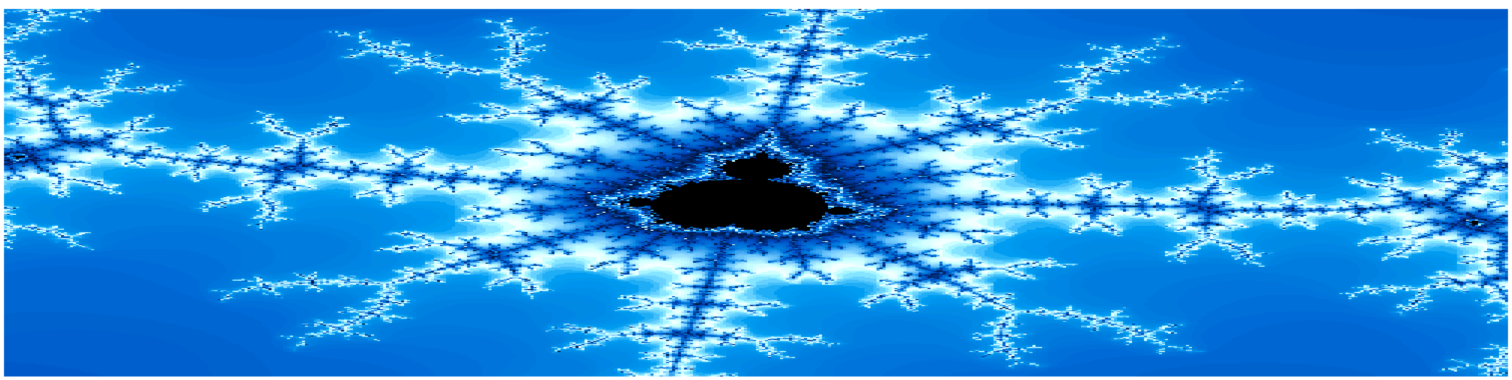


- **The detector geometry is described in terms of these objects, which are then utilized throughout the entire reconstruction chain.**
- **PHENIX geometry objects can be stored in the Objectivity (Object-Oriented) Database, or drawn in an event display.**
- **The alignment software interacts directly with these geometry objects.**

- ***NOTE: The CLHEP libraries were considered but not used due mostly to concerns about support on our short time scale.***

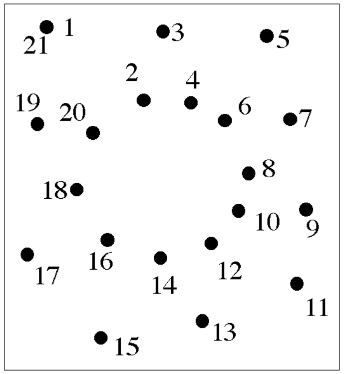
The PHENIX "Geometron"

- **All interactions between PHENIX geometry objects of different types are handled with a *singleton* called the "Geometron".**
- **Included in the Geometron are the following types of methods:**
  - **Intersections between geometrical objects (including *PHTrack* Polylines and Detector geometry objects)**
  - **Transformations of an object from one reference frame to another**
  - **Coordinate system transformations**
  - **Distance of closest approach between geometrical objects**
  - **Vector operations**
  - **Matrix operations**



Inter-Detector Hit Association

- **The most effective algorithm to date is a simple object-oriented road algorithm.**
- **The work-horse for *global* hit association is the PHENIX *HitList* class.**
- **The *HitList* class includes the following methods:**
  - **Constructors for each detector in each arm.**
  - **Sort hits in phi angle or in the z coordinate.**
  - **Return all detector hits in a given coordinate range.**
  - **Return the closest detector hit to a given coordinate.**
- **The *HitList* methods are used in conjunction with the *PHTrack*-to-detector intersections to determine the detector hits to associate.**
- **All association and kinematics results are stored in a Data Summary Tape (DST) file.**



PHENIX Tracking Performance Evaluations

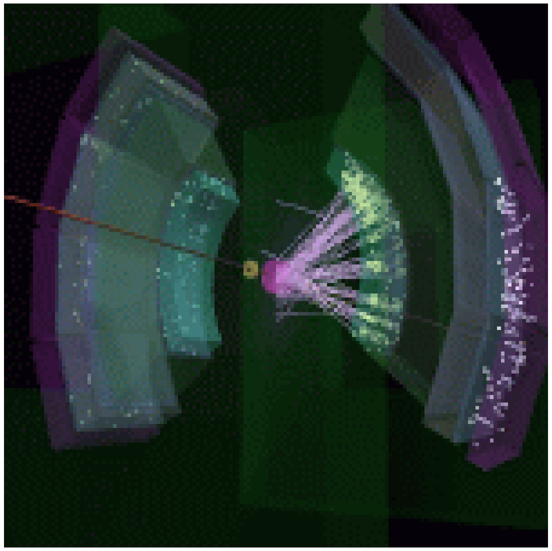
1. Simulate RHIC central Au+Au events using the HIJING event generator.

2. Process the events in the PHENIX GEANT simulation with all physics processes on.

3. Apply the detector response to the GEANT output.

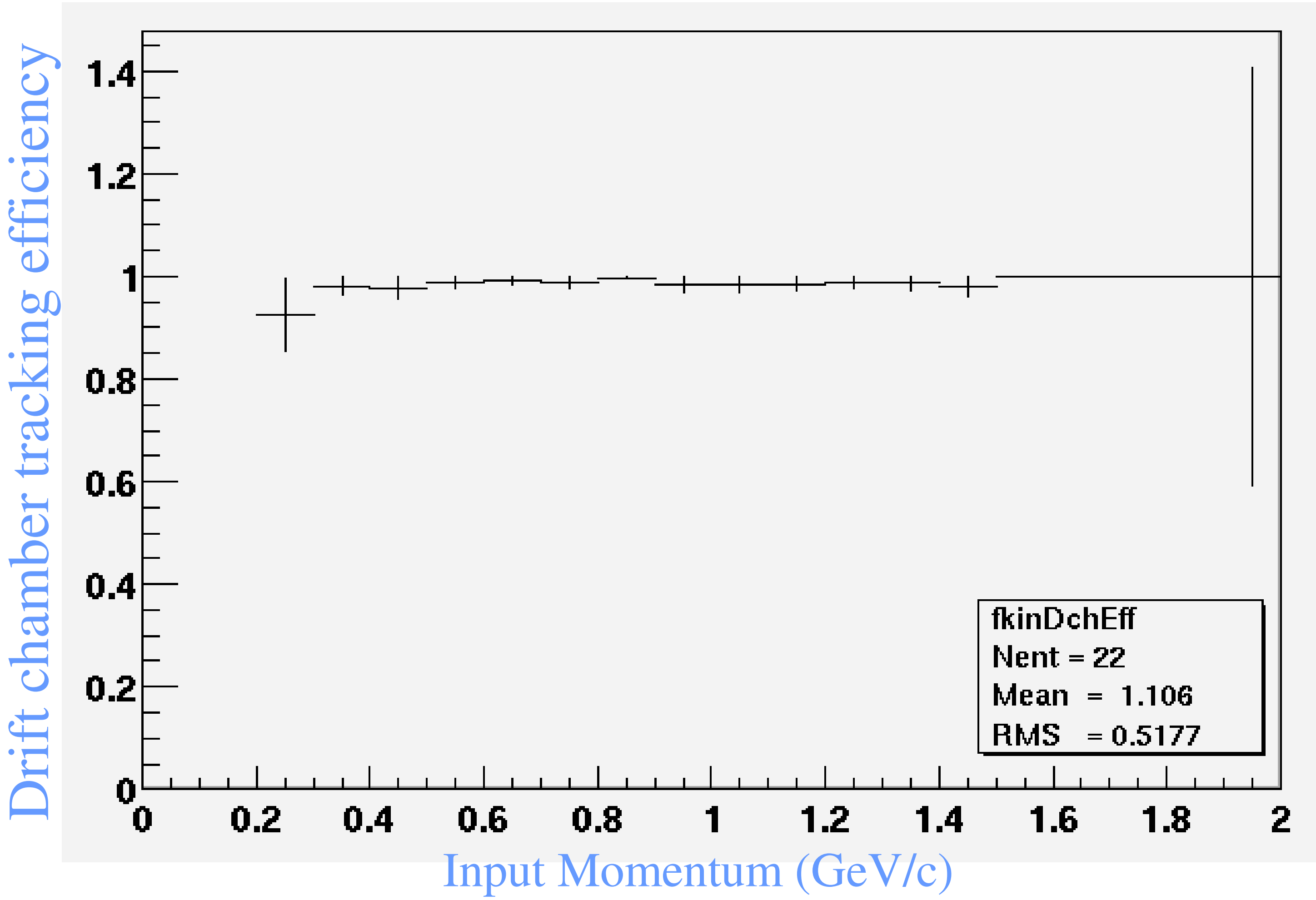
4. Reconstruct the simulated event in the same manner as real data.

5. An object-oriented evaluation class compares the GEANT input to the reconstructed output and calculates reconstruction and association efficiencies.



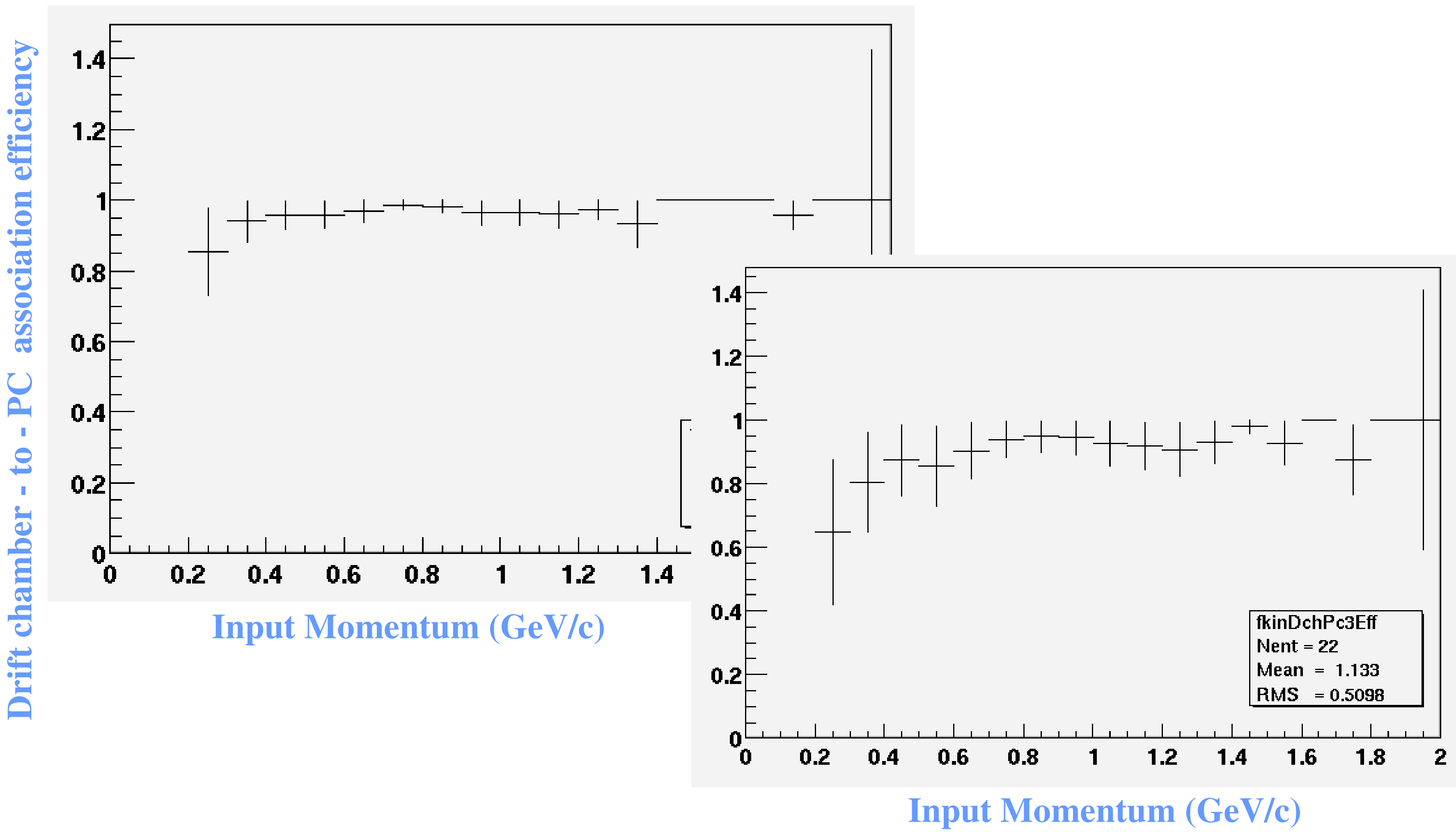
Drift Chamber Tracking Efficiency

For primary tracks within the drift chamber. Reconstructed tracks have a majority of the GEANT input hits associated.

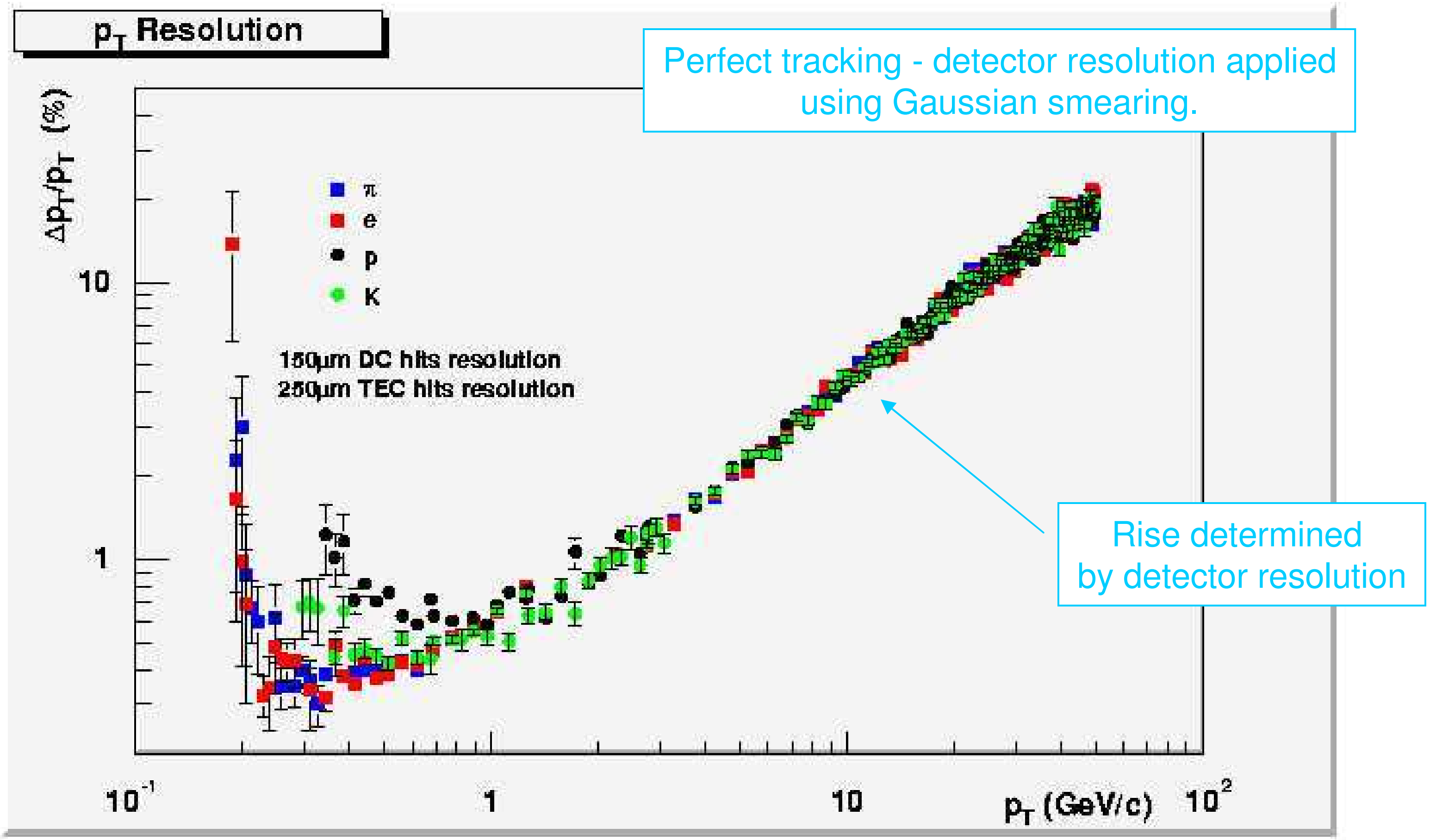


Drift Chamber - to - Pad Chamber Association Efficiency

For primary tracks within the drift chamber and pad chamber.
Successful association requires that the GEANT inputs match.

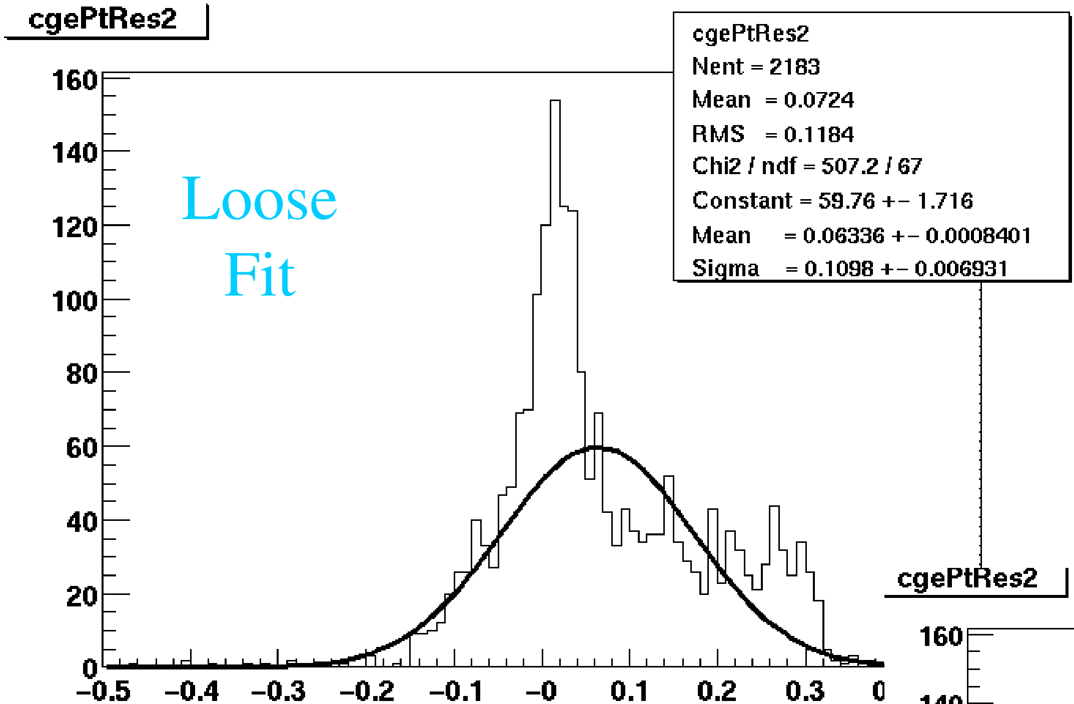


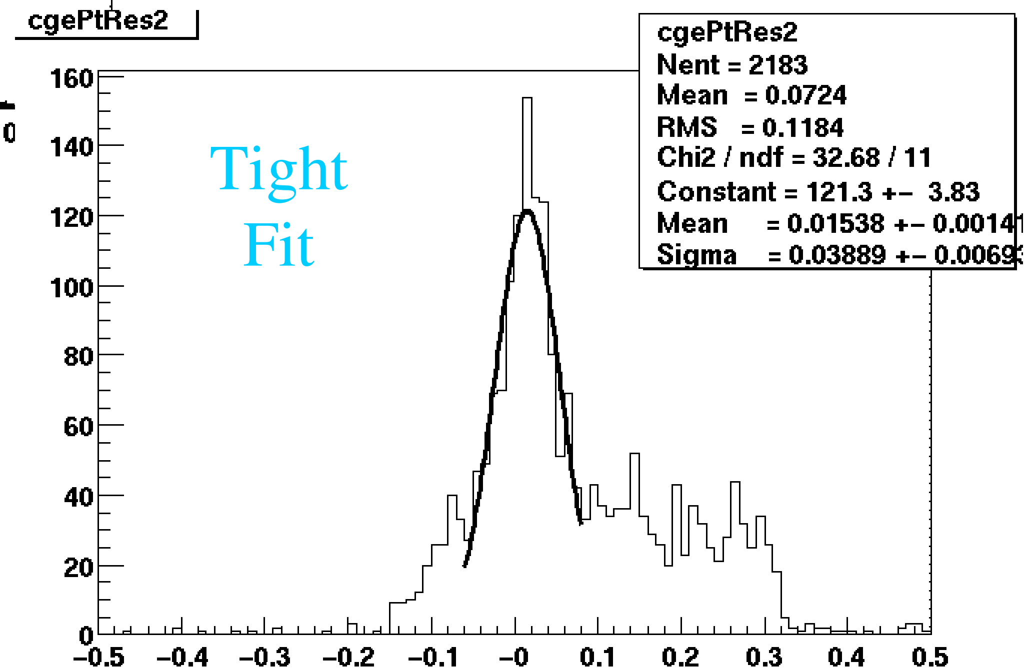
Intrinsic Performance - p_T (west arm)



Summary

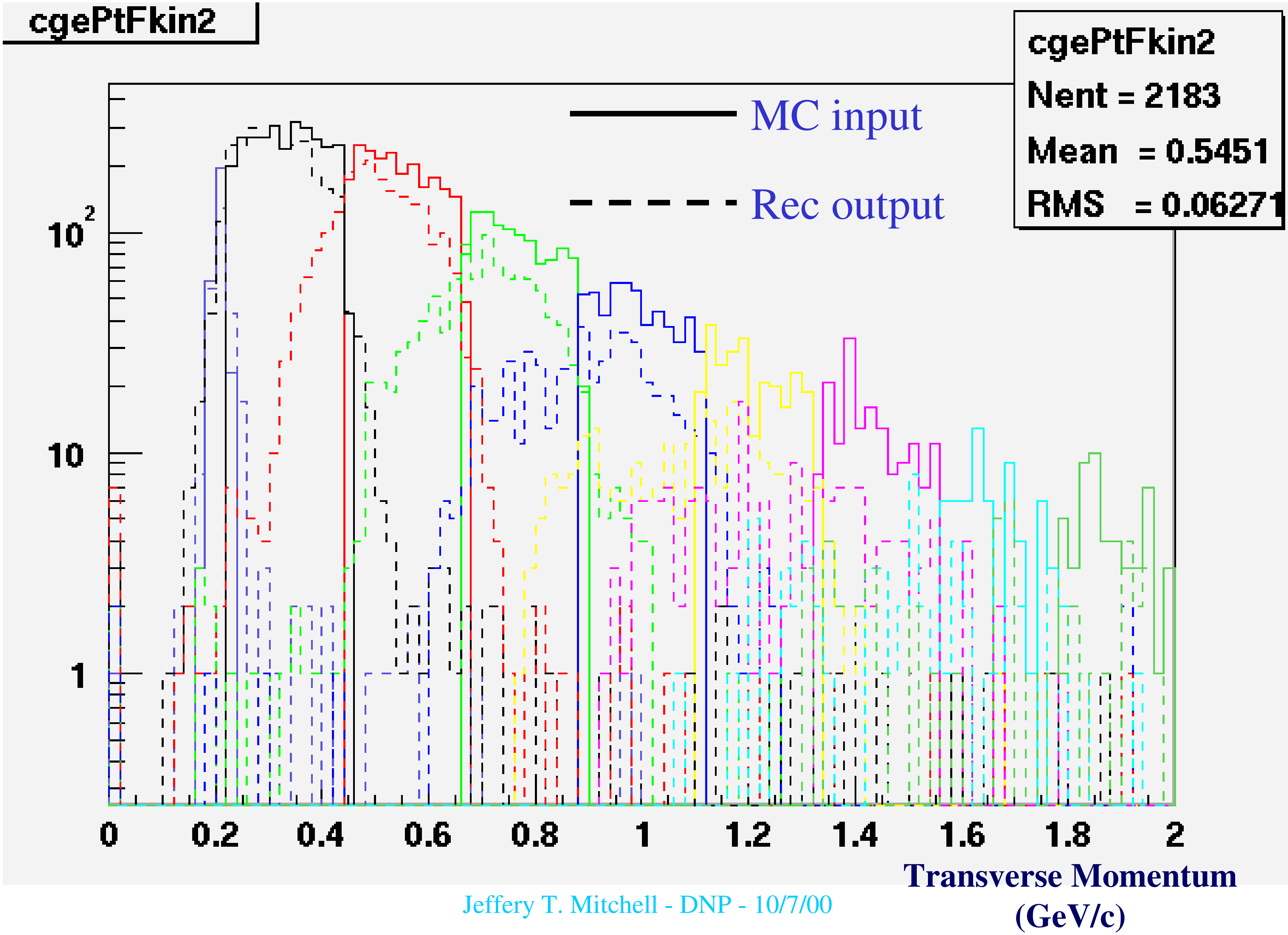
- **An object-oriented approach to the design of the PHENIX track reconstruction software has seamlessly dealt with the diversity of the PHENIX central arm design.**
- **The object-oriented approach has made it easy for us to:**
  - **Define the interfaces between inter-subsystem and intra-subsystem software.**
  - **Provide uniform implementation of common utilities such as geometry, evaluation, hit manipulation, and more.**
  - **Allowed us to quickly integrate and test new ideas.**
- **Object-oriented software is being used to produce many PHENIX results shown at this conference!**

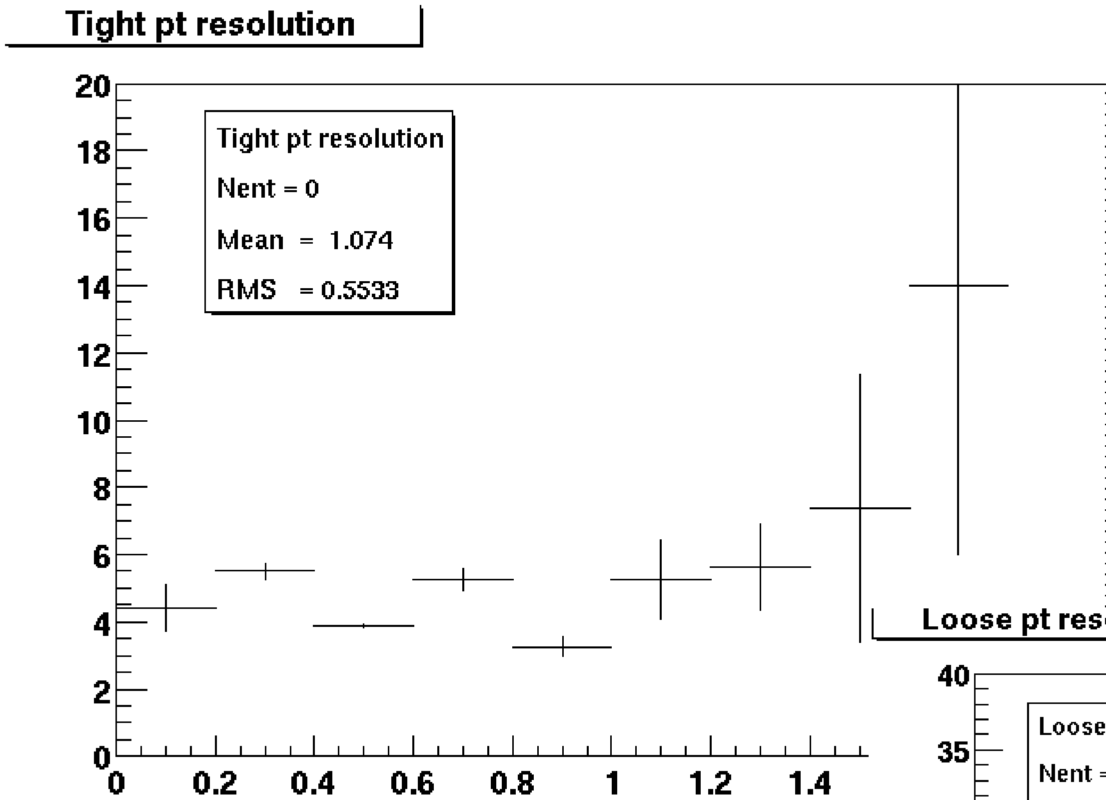


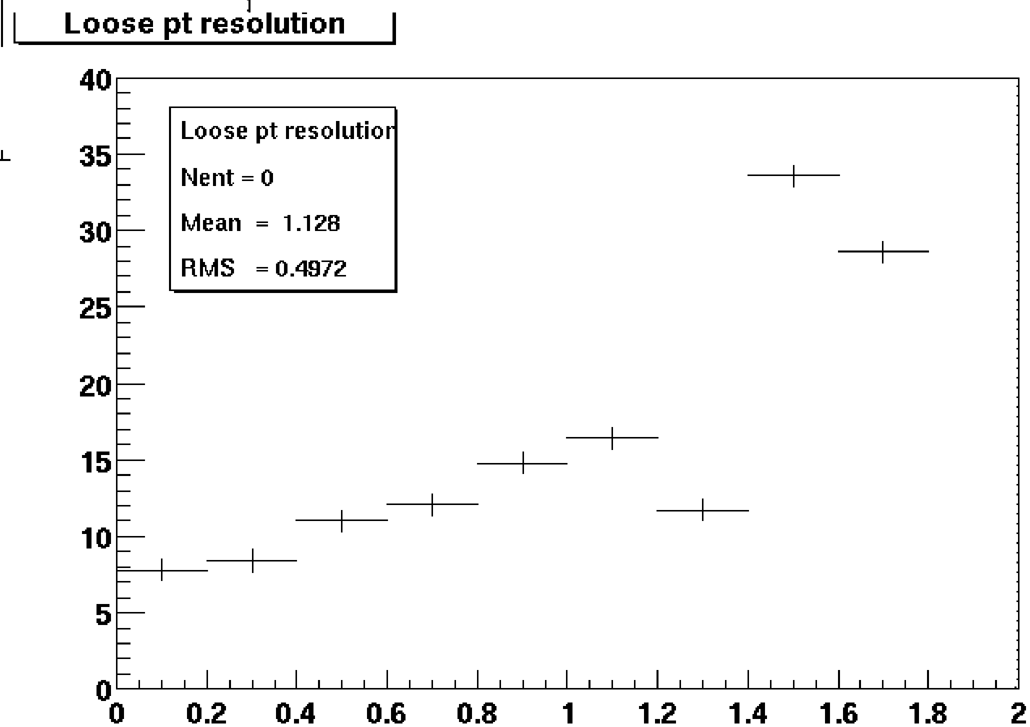


[pt (MC) - pt (Rec)]/pt(MC)

Pt = [400 - 600 MeV/c]


cgePtFkin2
MC input
Rec output
cgePtFkin2
Nent = 2183
Mean = 0.5451
RMS = 0.06271
1
10
10^2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Transverse Momentum (GeV/c)


Tight pt resolution
Tight pt resolution
Nent = 0
Mean = 1.074
RMS = 0.5533
20
18
16
14
12
10
8
6
4
2
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4


Loose pt resolution
Loose pt resolution
Nent = 0
Mean = 1.128
RMS = 0.4972
40
35
30
25
20
15
10
5
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2