Tracking Reconstruction

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What is a track?

- **Ordered association of digits, clusters or hits (finder)**
  - **Digit = data read from a detector channel**
  - **Cluster = collection of digits**
  - **Hit = Cluster (or digit) + calibration + geometry**
    - **Provides a measurement suitable to fit a track**
    - **E.g. a 1D or 2D spatial measurement on a plane**
- **Trajectory through space (fitter)**
  - **Space = 6D track parameter space**
    - **3 position + 2 direction + 1 curvature**
  - **5 parameters and error matrix at any surface**

Requirements

- **Track provides access to ordered**
  - **Hits, their digits and clusters if relevant**
  - **Fits with fit quality (chi-square)**
    - **Fit = surface + 5D track vector + error matrix**
  - **Misses**
    - **Active surface crossed without adding a hit**
    - **Miss probability: individual and/or summary**
  - **Kinks**
    - **Change in direction and/or curvature**

Infrastructure components

- **Hit**
  - **Defined at a surface.**
  - **Provides a measurement and associated error**
  - **Provides a mechanism to predict the measurement from a track fit**
  - **Provides access to underlying cluster and/or digits**

Surfaces

- Surfaces generally correspond to geometric shapes representing detector devices.
- They provide a basis for tracks, and constrain one of the track parameters.
- The track vector at a surface is expressed in parameters which are “natural” for that surface.

Cylinder

- Surface defined coaxial with z, therefore specified by a single parameter r.
- Track Parameters: (ϕ, z, α, tanλ, q/p_T)
- Bounded surface adds z_{min} and z_{max}.
- Supports 1D and 2D hits:
  - 1D Axial: ϕ
  - 1D Stereo: $\phi+\kappa z$
  - 2D Combined: (ϕ, z)

XY Plane

- Surface defined parallel with z, therefore specified by distance u from the z axis and an angle ϕ of the normal with respect to x axis.
- Track Parameters: (v, z, dv/du, dz/du, q/p)
- Bounded surface adds polygonal boundaries.
- Supports 1D and 2D hits:
  - 1D Stereo: $w_v * v + w_z * z$
  - 2D Combined: (v, z)

Z Plane

- Surface defined perpendicular to z, therefore specified by single parameter z.
- Track Parameters: (x, y, dx/dz, dy/dz, q/p)
- Bounded surface adds polygonal boundaries.
- Supports 1D and 2D hits:
  - 1D Stereo: $w_x*x + w_y*y$
  - 2D Combined: (x,y)

Distance of Closest Approach

- **DCA is also a 5D** Surface **in the 6 parameter space of points along a track.**
- **It is** not **a 2D surface in 3D space.**
- **Characterized by the track direction and position in the (x,y) plane being normal; $\alpha=\pi/2$.**
- **Track Parameters: $(r, z, \phi_{dir}, \tan\lambda, q/p_T)$**

Detector

- Using compact.xml to create a tracking Detector composed of surfaces, along with interacting propagators to handle track vector and covariance matrix propogation, as well as energy loss and multiple scattering.
- Converting SimTrackerHits in event into:
  - 1-D phi measurements in Central Tracker Barrel
  - 2-D phi-z measurements in Vertex Barrel
  - 2-D x-y measurements in forward disks
  - Simple smearing being used
    - NO digitization ∴ NO ghosts, NO merging, NO fakes

Track Finding

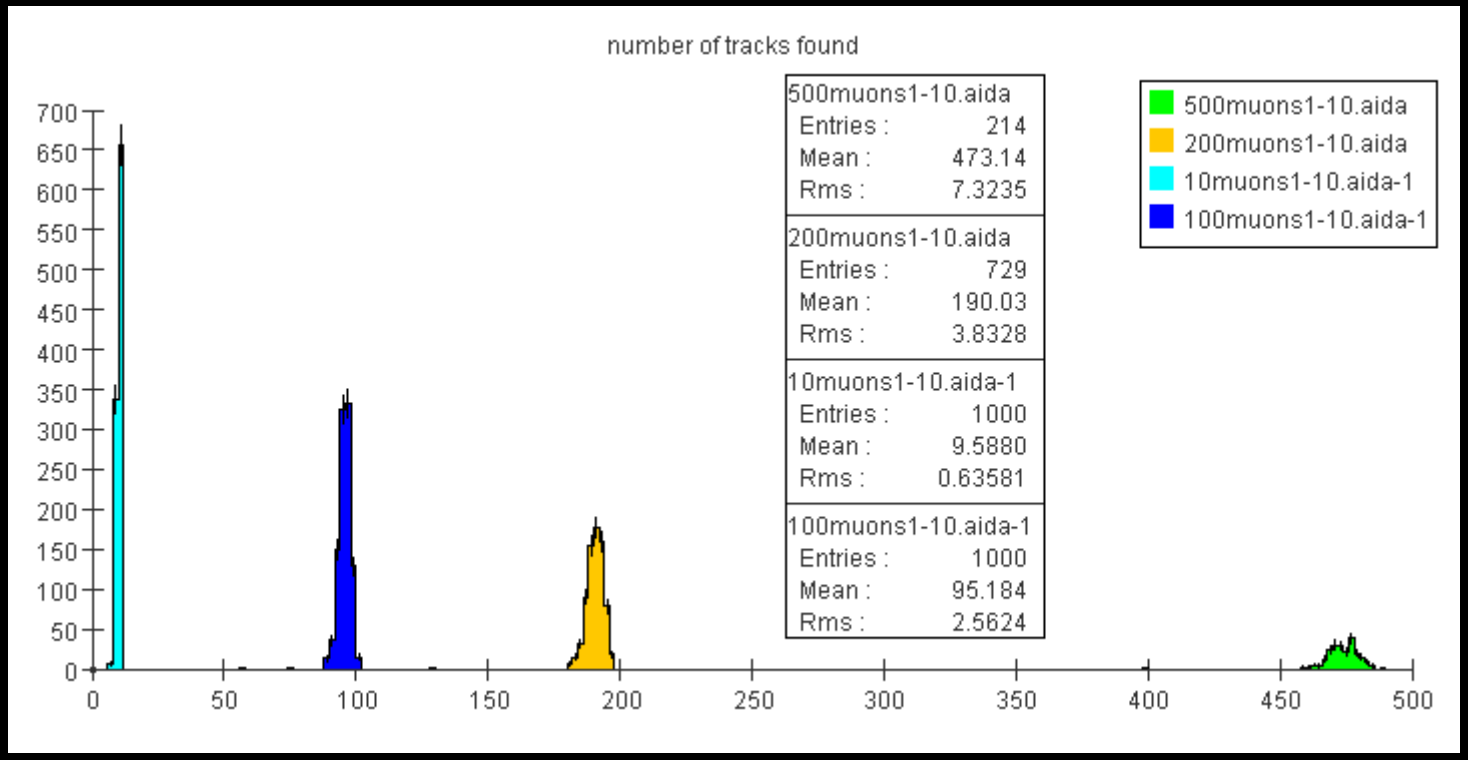
- **Implemented a conformal mapping technique**
  - **Maps curved trajectories onto straight lines**
  - **Simple link-and-tree type of following approach associates hits.**
  - **Once enough hits are linked, do a simple helix fit**
    - **circle in rPhi**
    - **straight line in s-z**
  - **Use track parameters to predict track and pick up hits.**
  - **Currently outside-in, but completely flexible.**
  - **Fit serves as input to final Kalman fitter.**

Data Samples

- **Single muons**
  - simple sanity check
- **Multiple muons**
  - next step in complexity, known momentum, acceptance and number of tracks to find.
- **$t\bar{t} \rightarrow$ six jets**
  - reasonably tough real physics environment. Challenge is to define the denominator, i.e. which tracks should have been found.

Multiple Isotropic Tracks

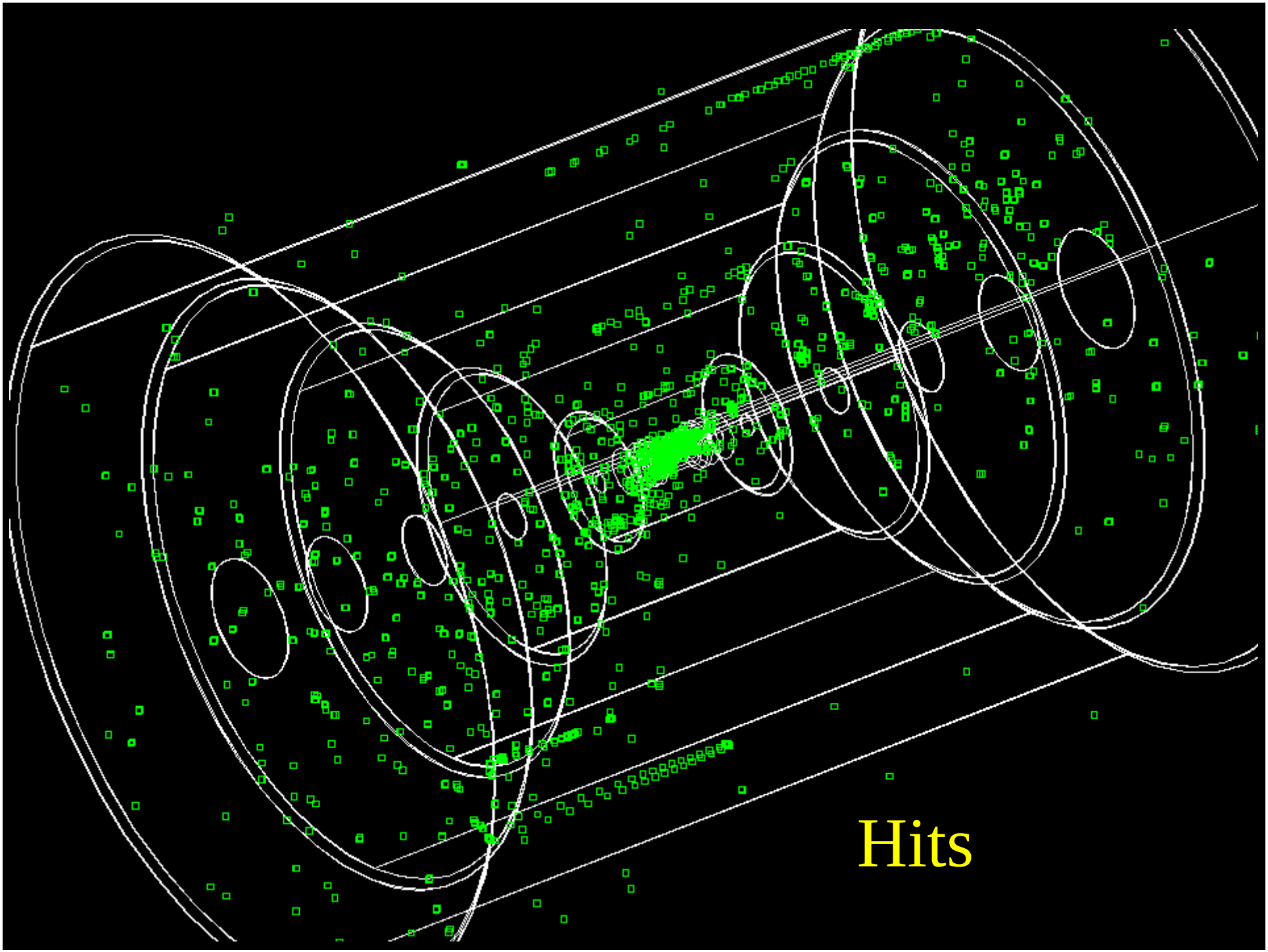
- Generate multiple (10, 100, 200, 500) muons isotropically between 1 and 10 GeV down to 4 degrees of the beam. Find ~95% out of the box.

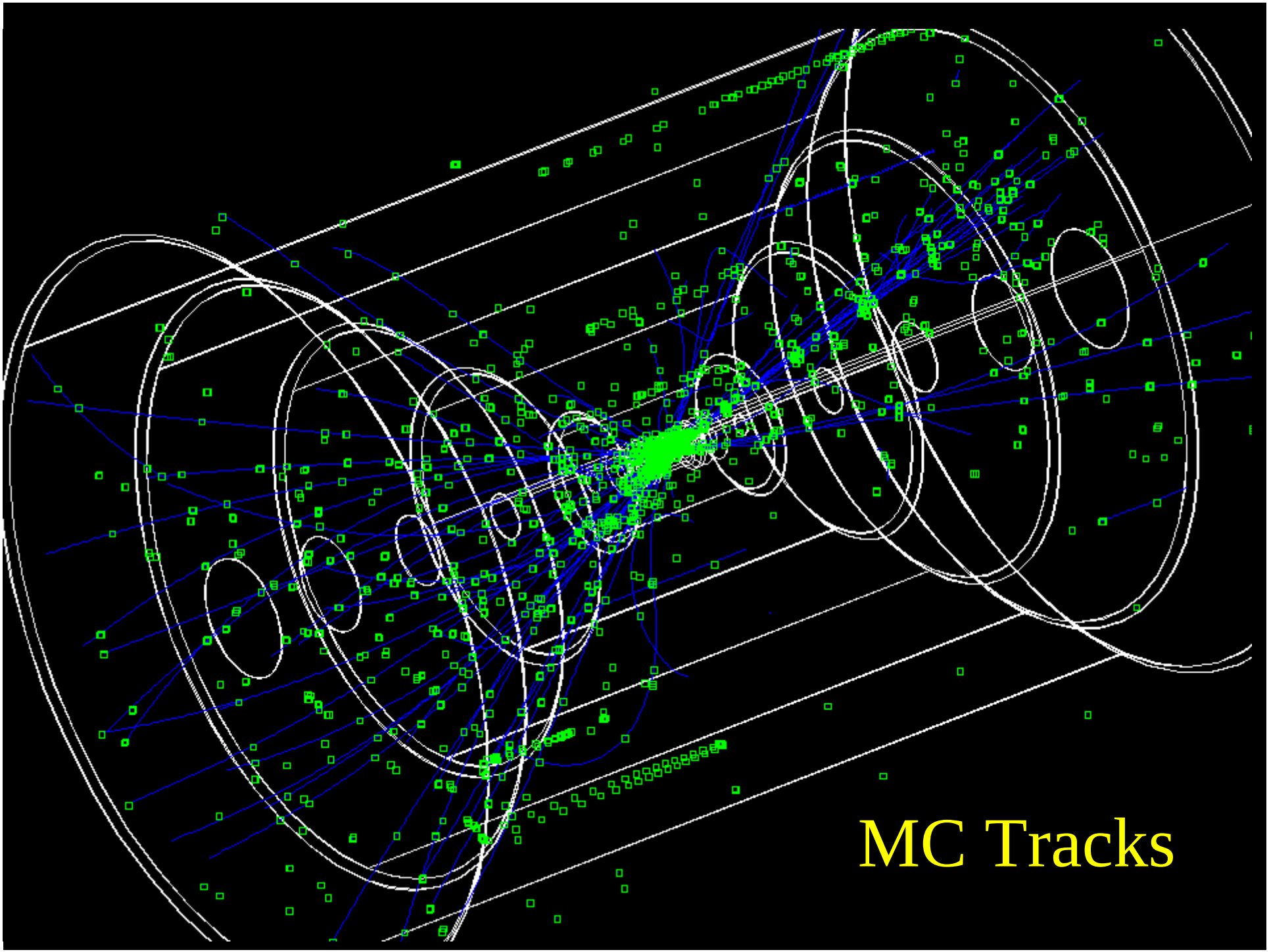


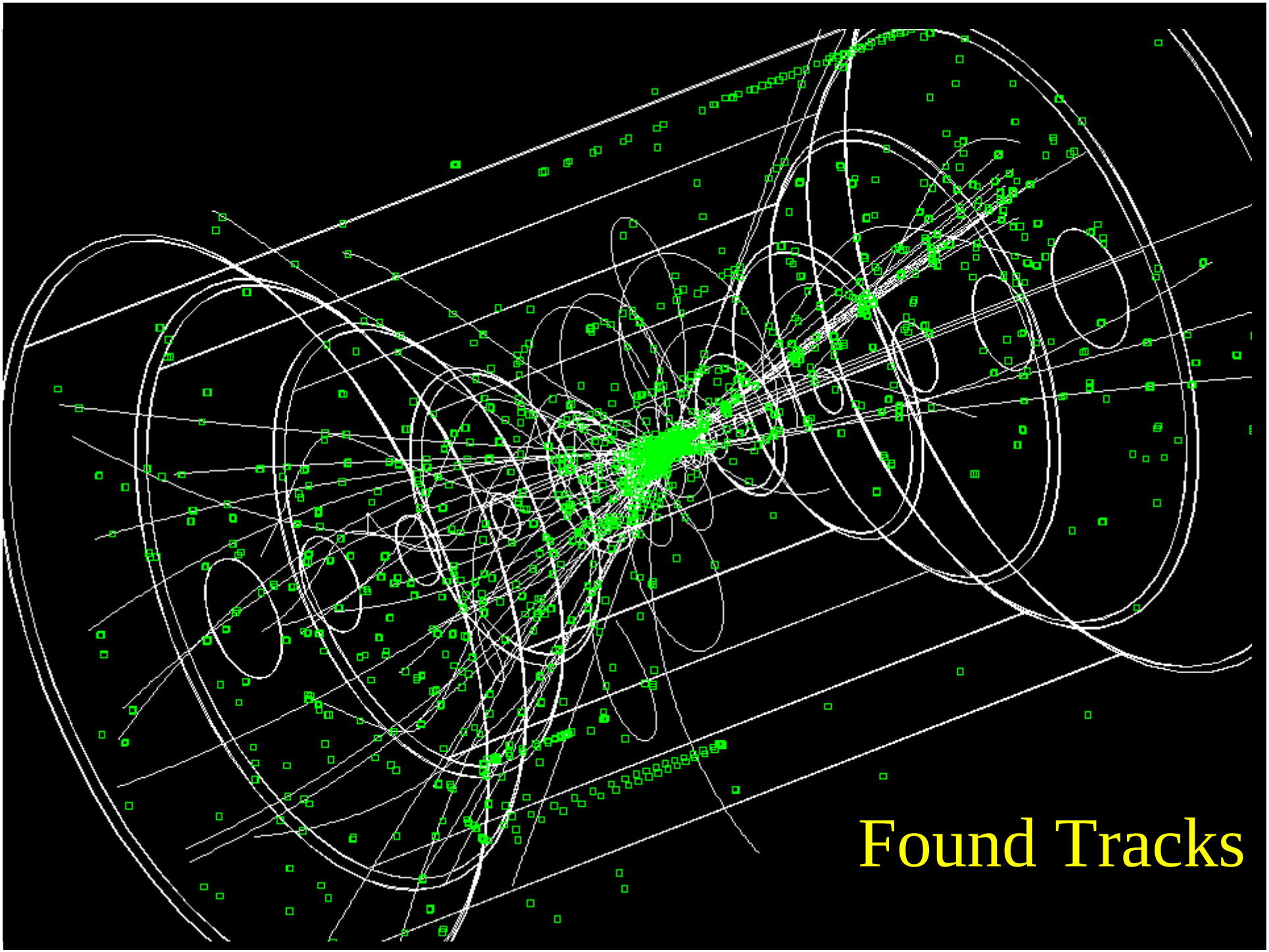
- n.b. some tracks are actually outside tracker acceptance.

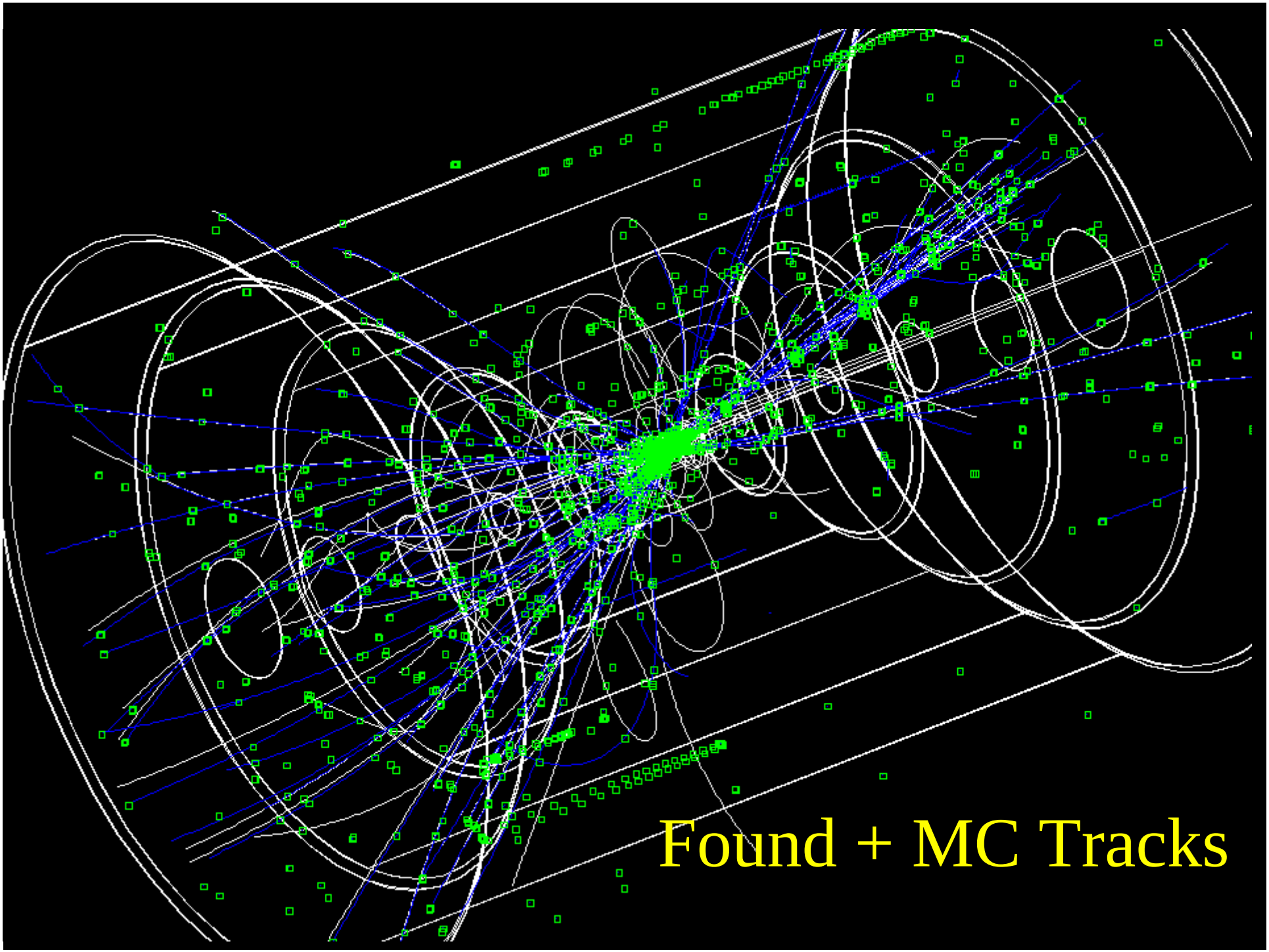
$t\bar{t} \rightarrow$ six jets

- Generate $e^+ e^- \rightarrow t\bar{t}$, $t\bar{t} \rightarrow$ six jets.
- Takes 3min to fully analyze 900 events on 1.7GHz laptop.
  - Open event, read in data.
  - Create tracker hits.
  - Find tracks.
  - Fit tracks.
  - Analyze tracks.
  - Write out histograms.

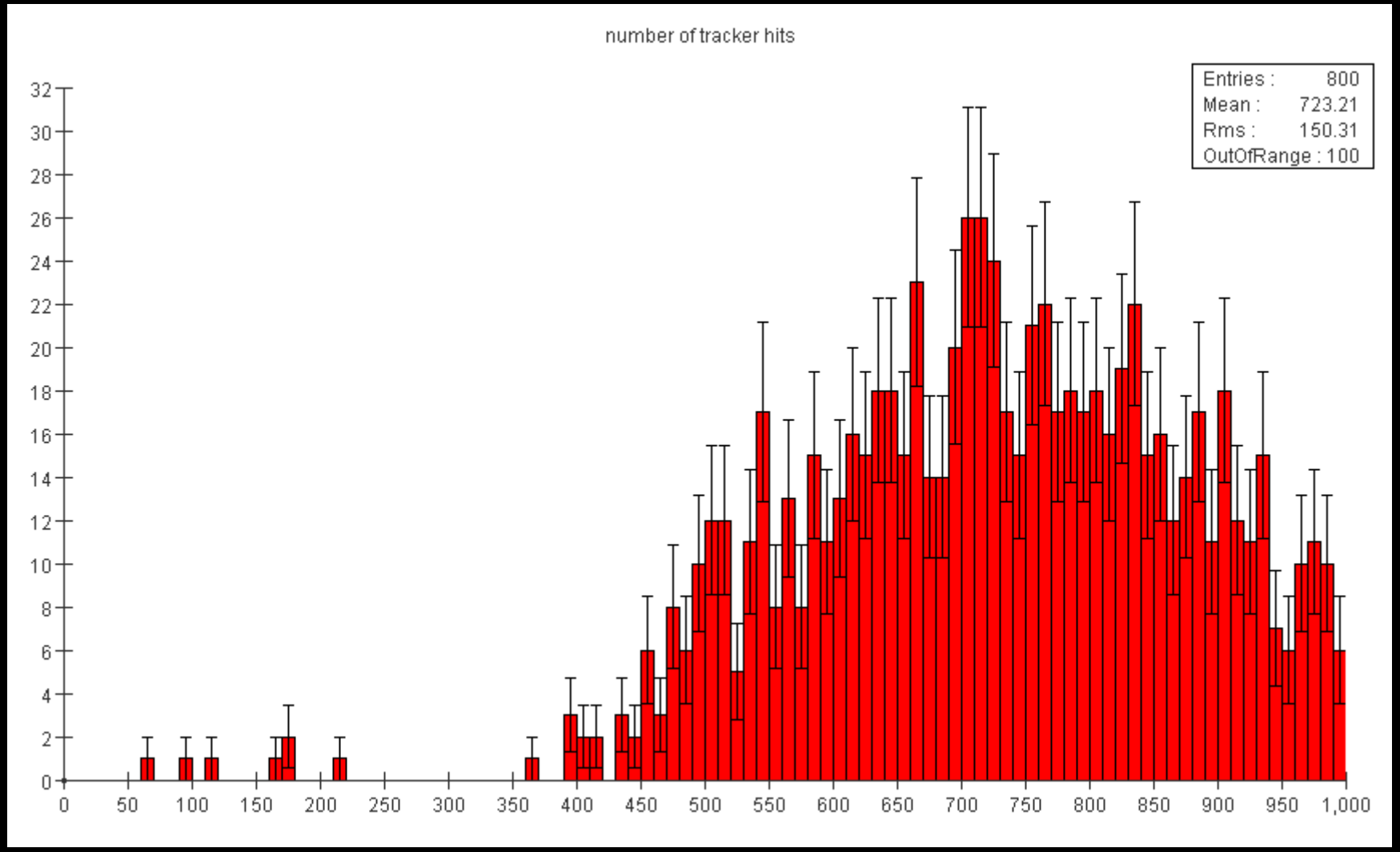

Hits


MC Tracks

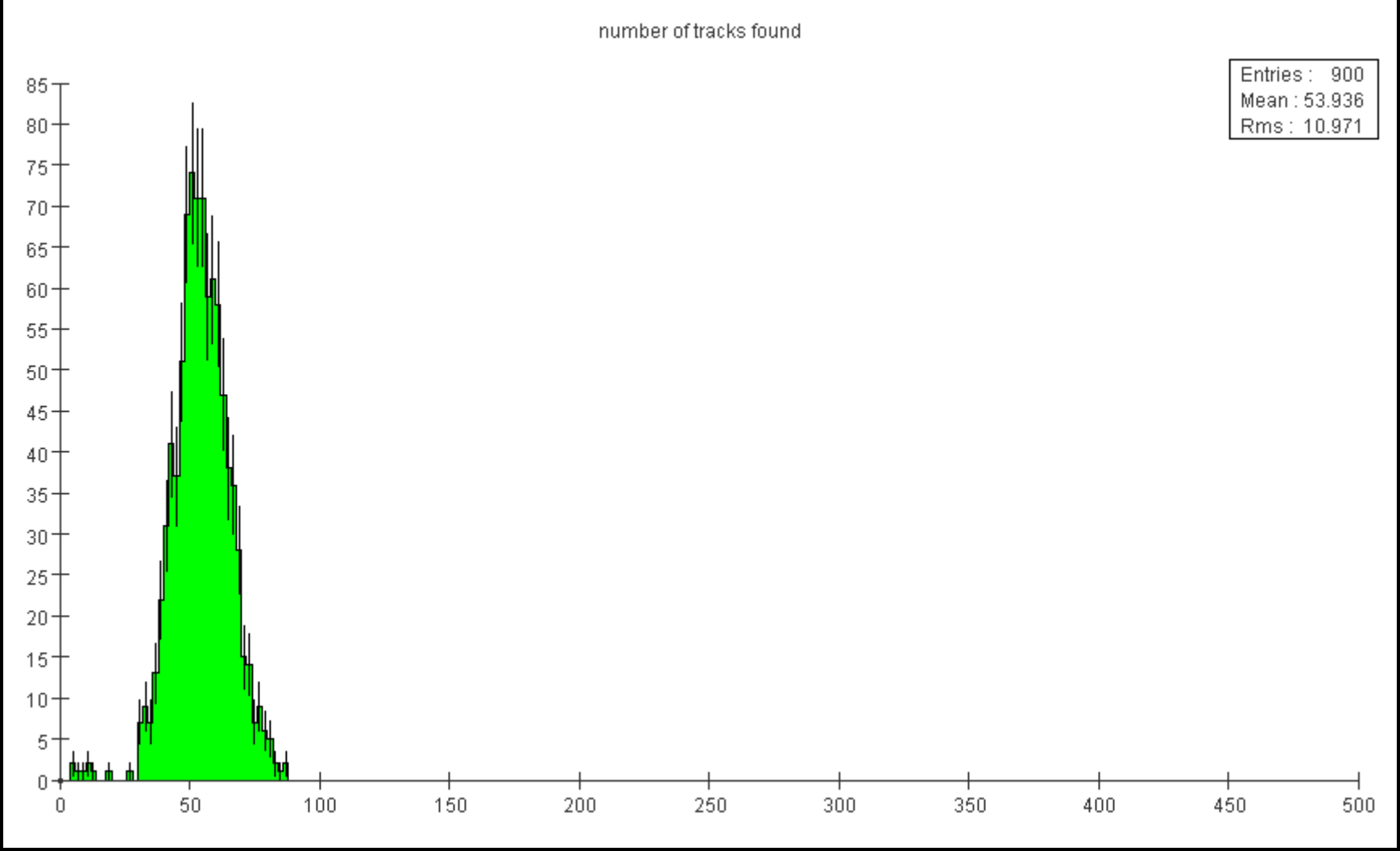

Found Tracks


Found + MC Tracks

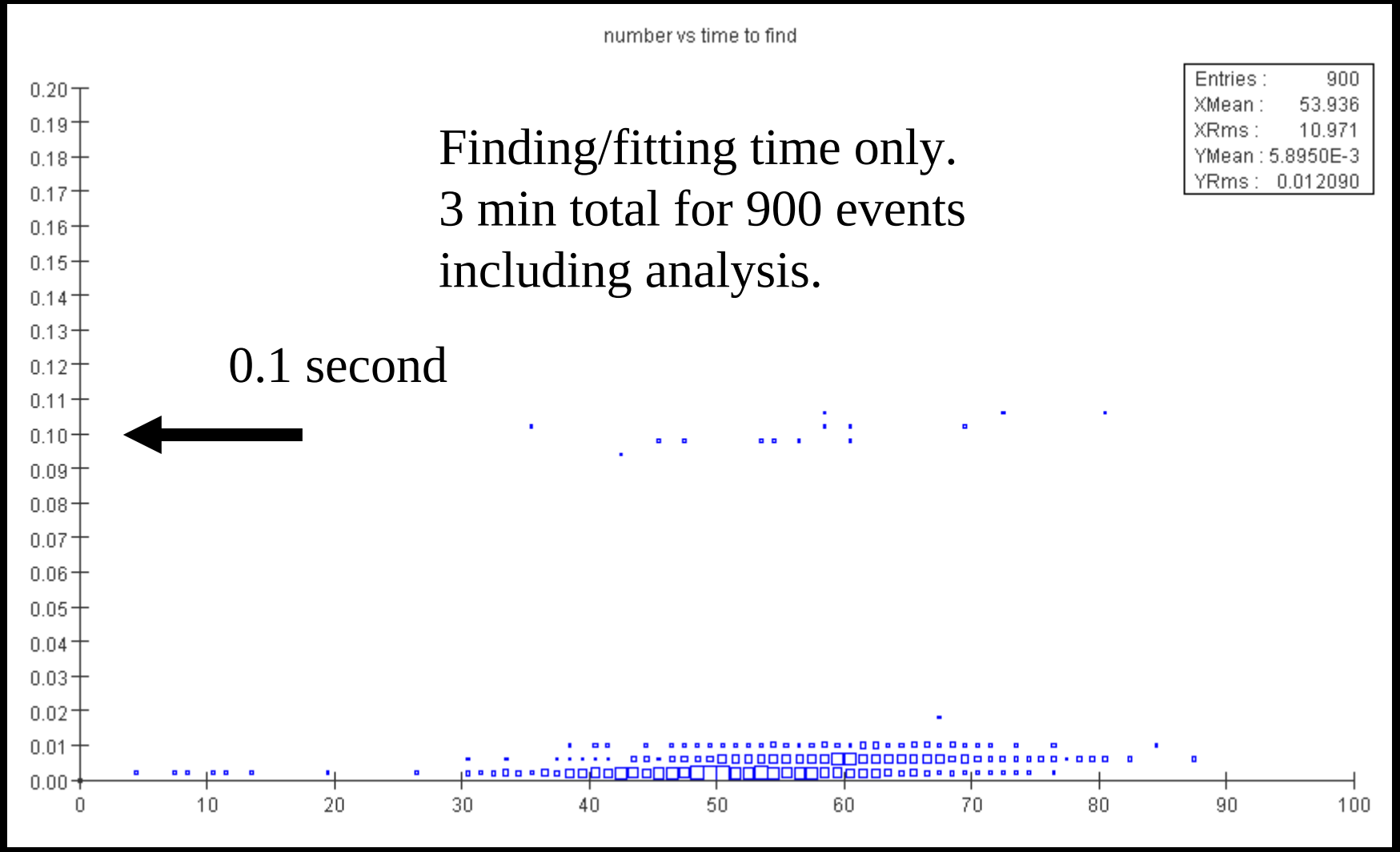
$t\bar{t} \rightarrow$ six jets # of Hits



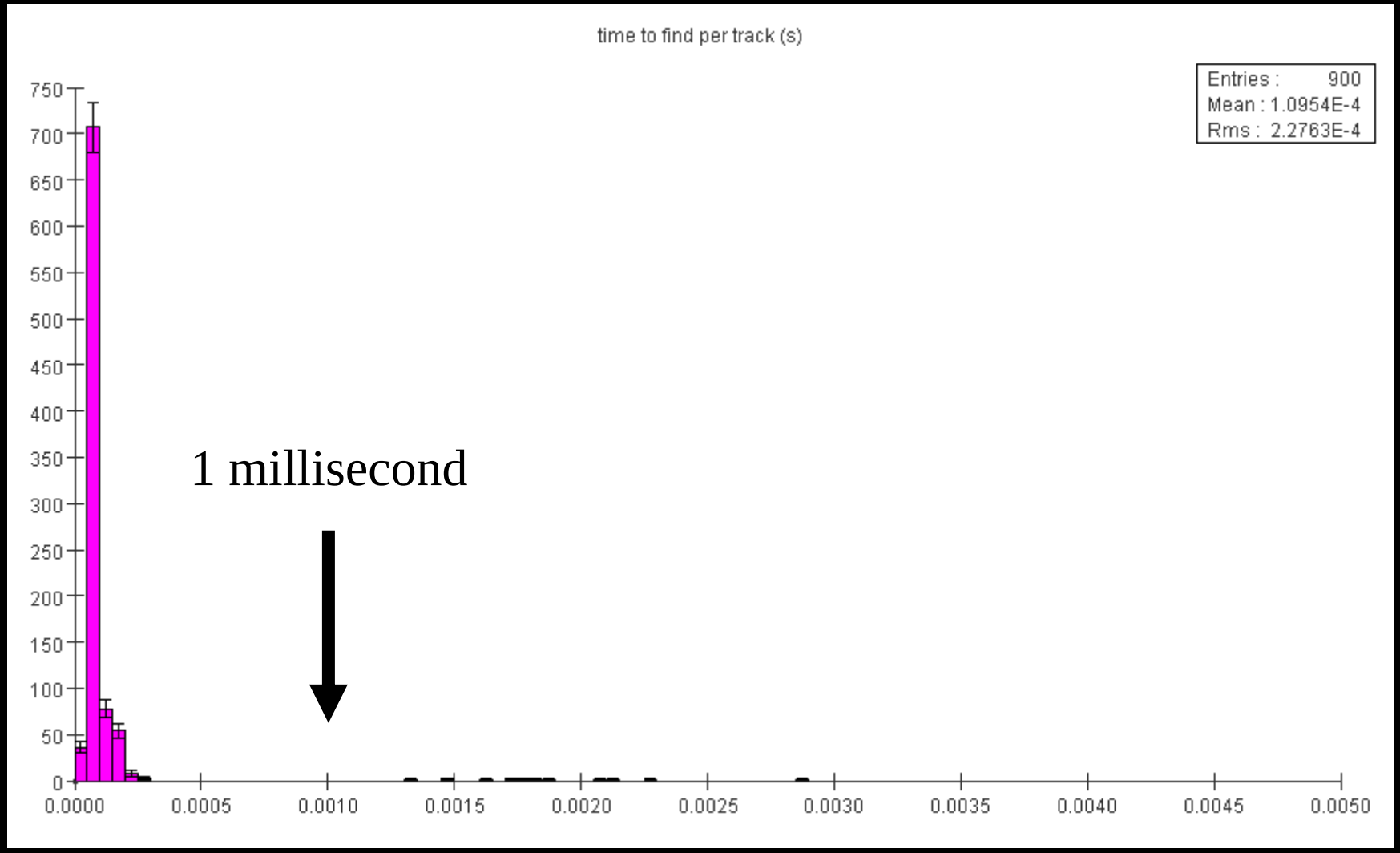
of tracks found



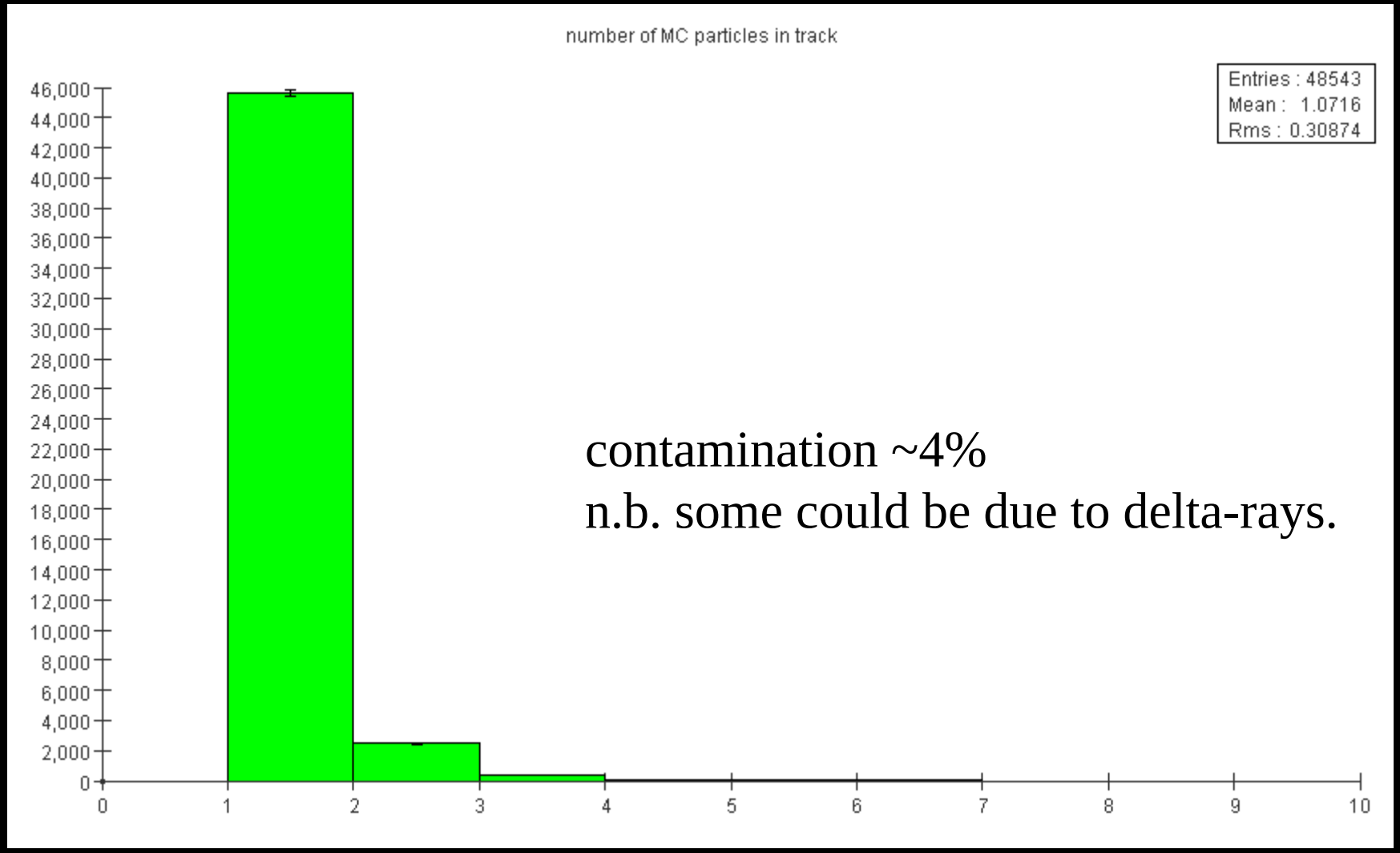
time (s) vs # tracks (1.7GHz)



time(s) per track (1.7GHz)

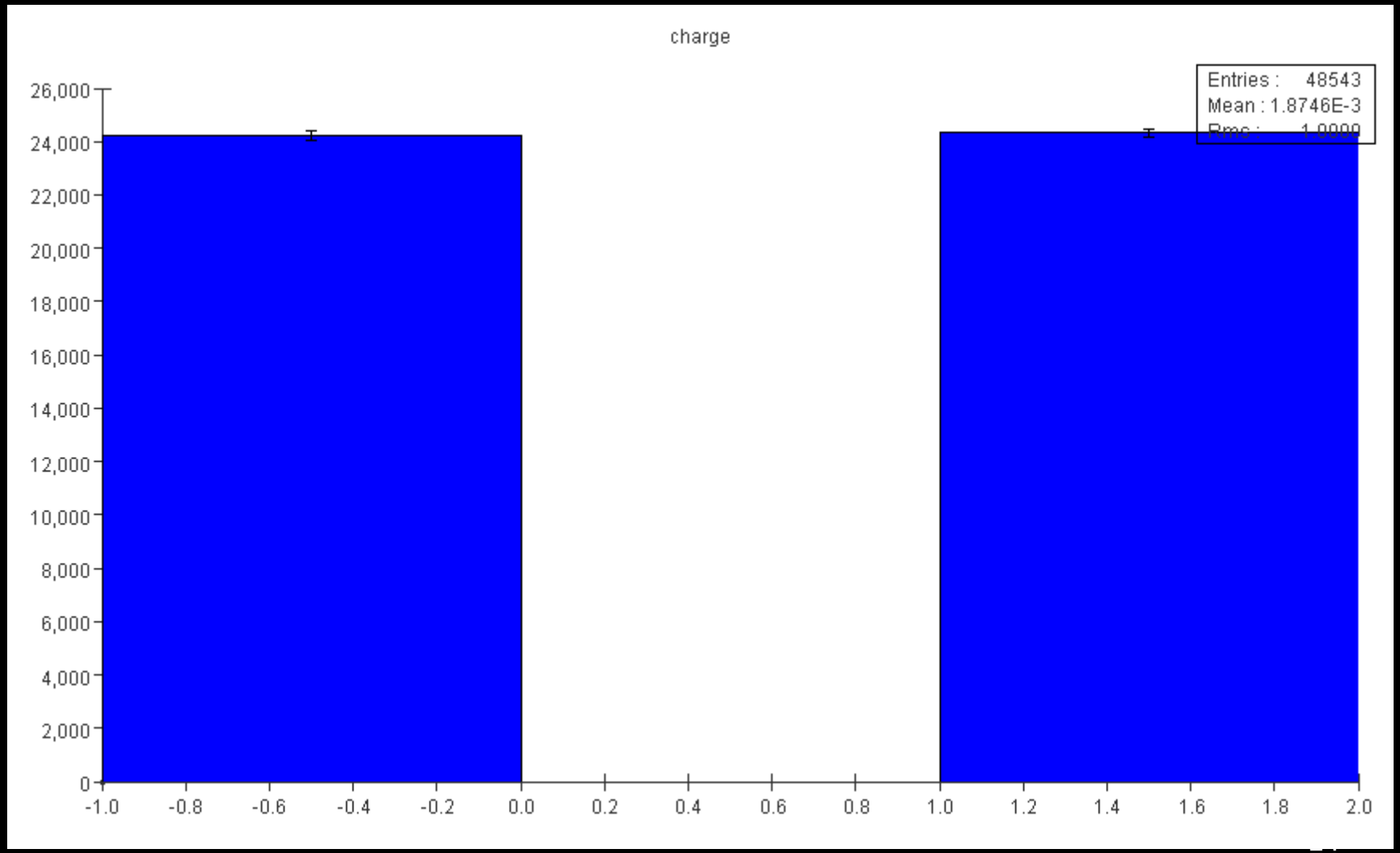


of MCParticles/track

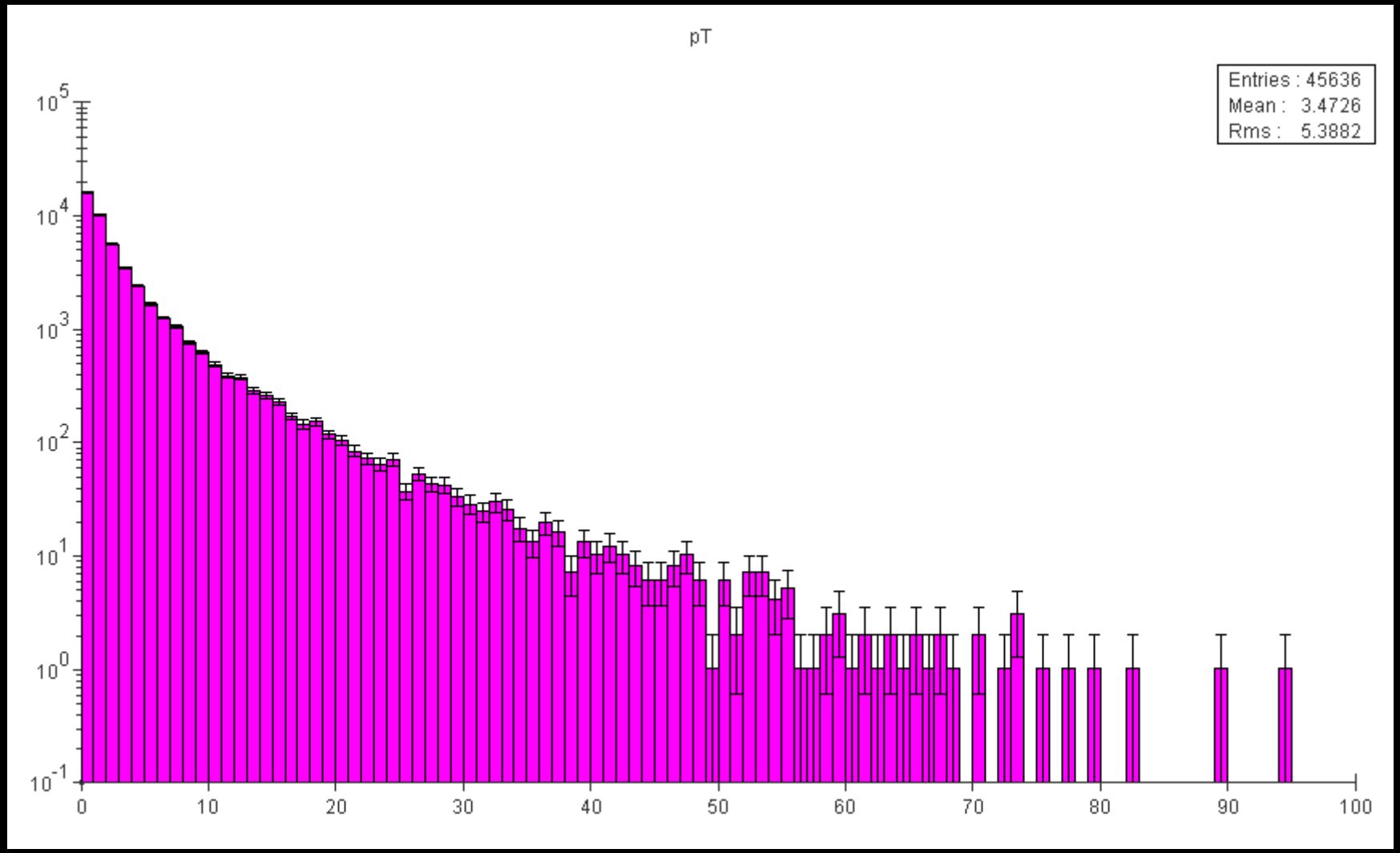


contamination ~4%
n.b. some could be due to delta-rays.

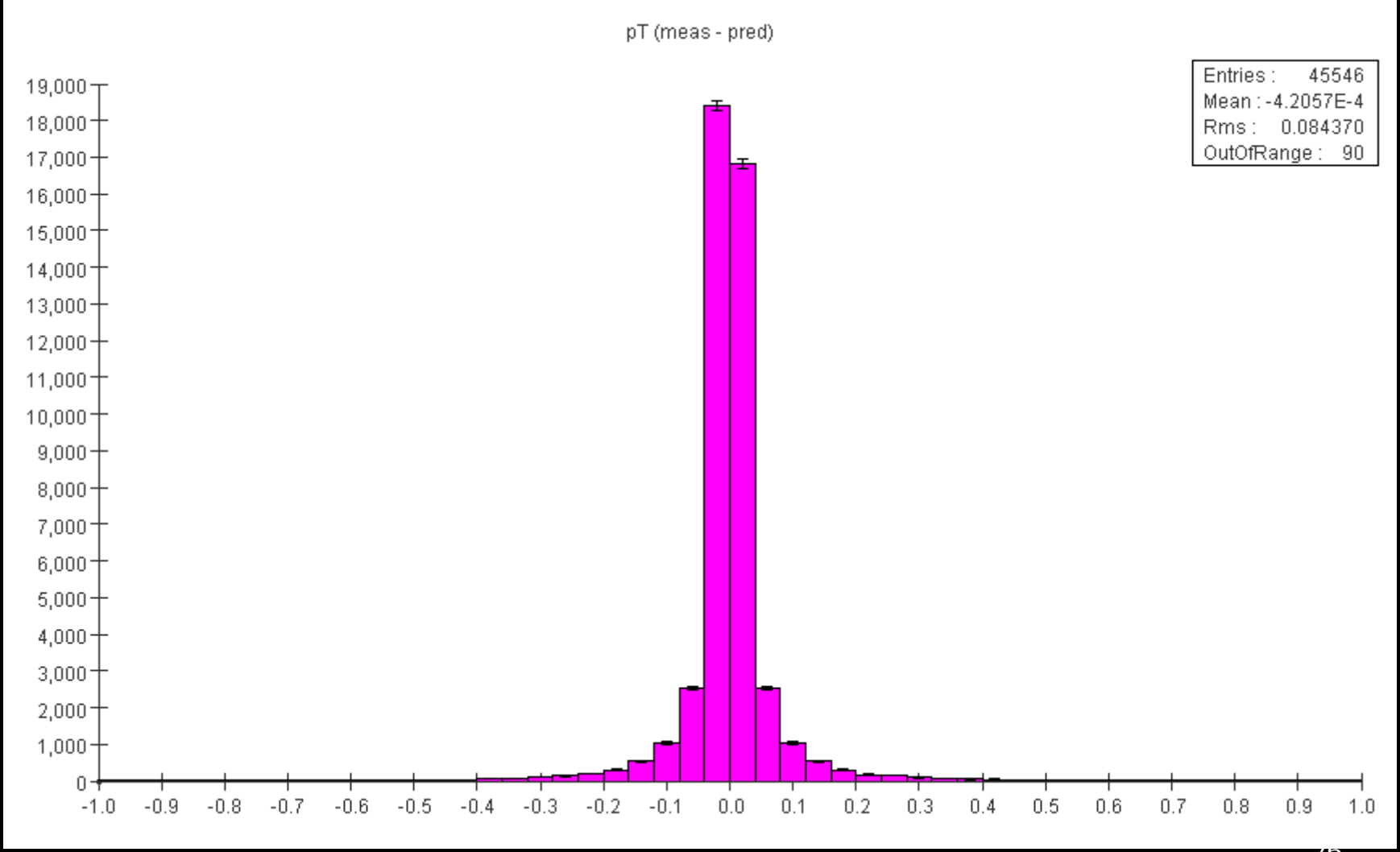
charge


charge
Entries : 48543
Mean : 1.8746E-3
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0

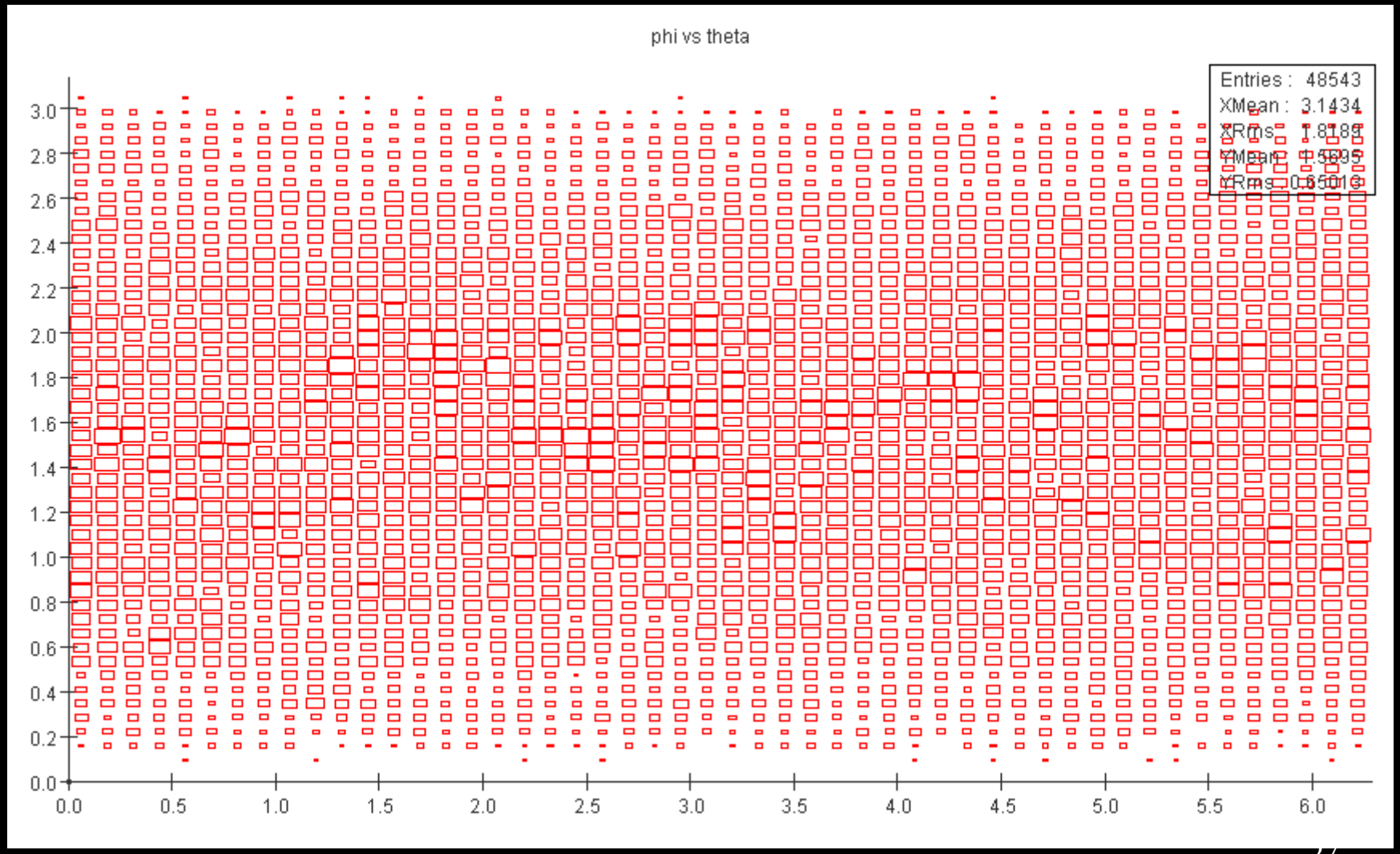
$t\bar{t} \rightarrow$ six jets pT



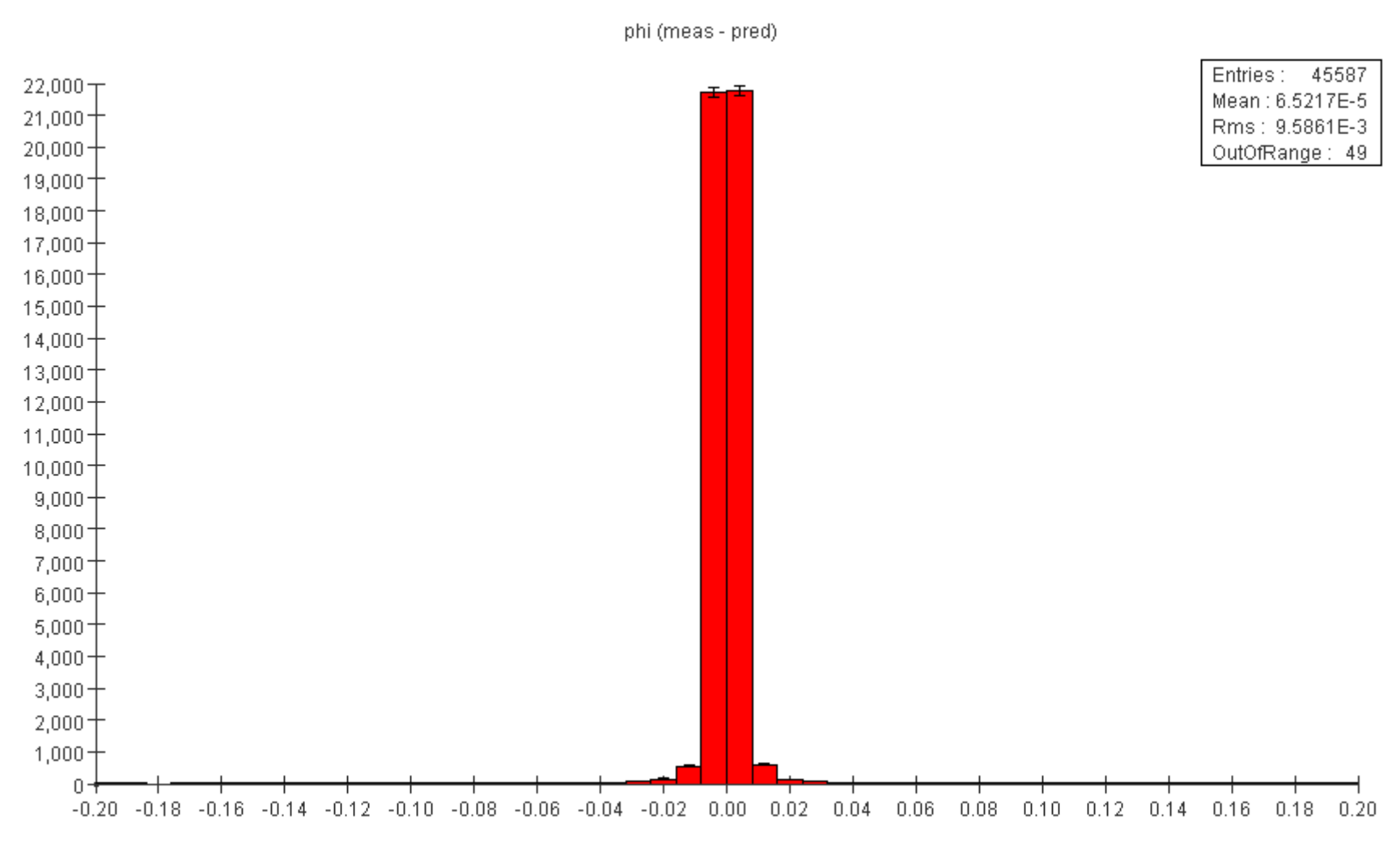
pT (meas-pred)


pT (meas - pred)
Entries : 45546
Mean : -4.2057E-4
Rms : 0.084370
OutOfRange : 90
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
-1.0
-0.9
-0.8
-0.7
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

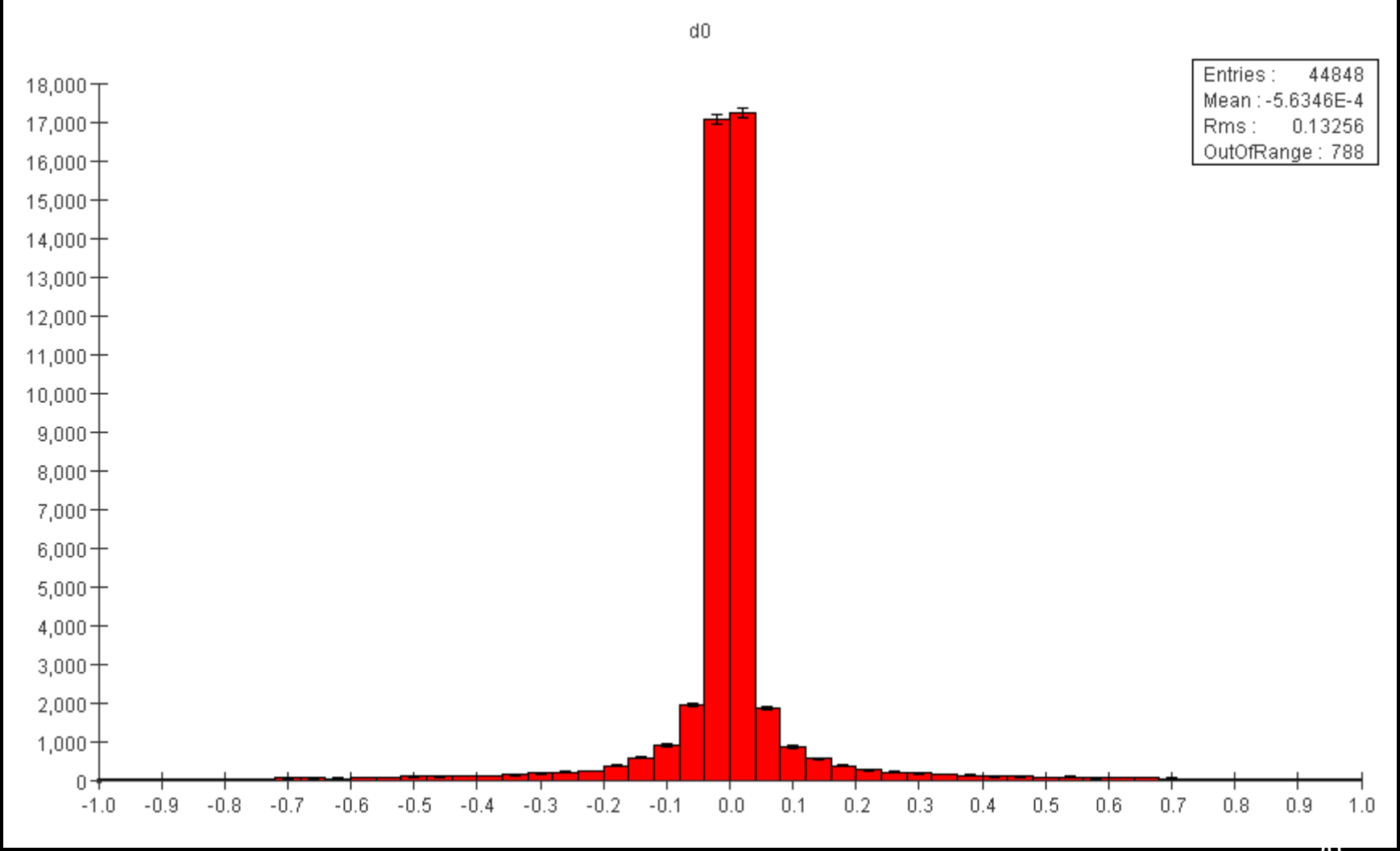
φ vs θ


phi vs theta
Entries : 48543
XMean : 3.1434
YMean : 1.5695
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0

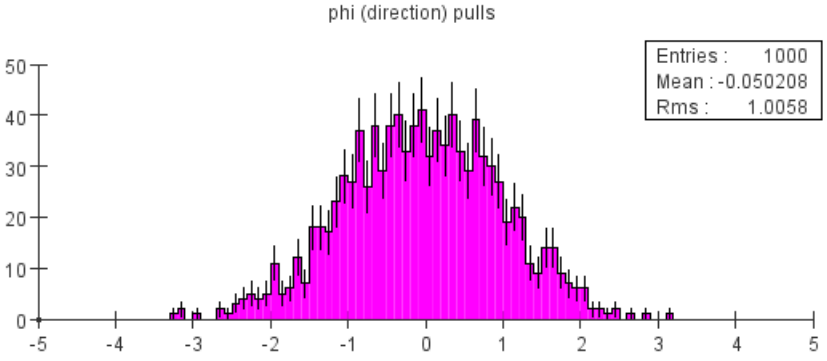
phi (meas – pred)

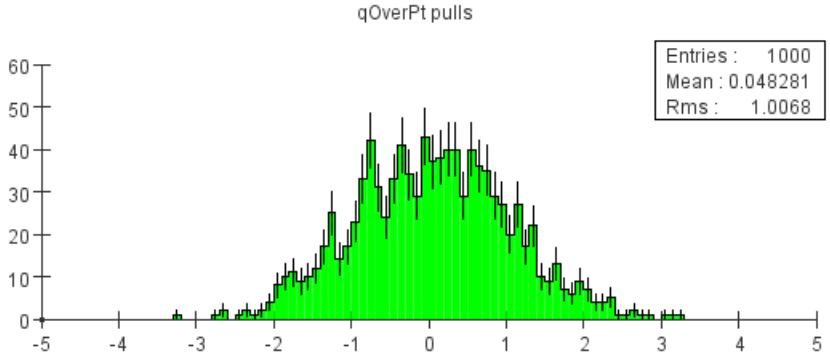


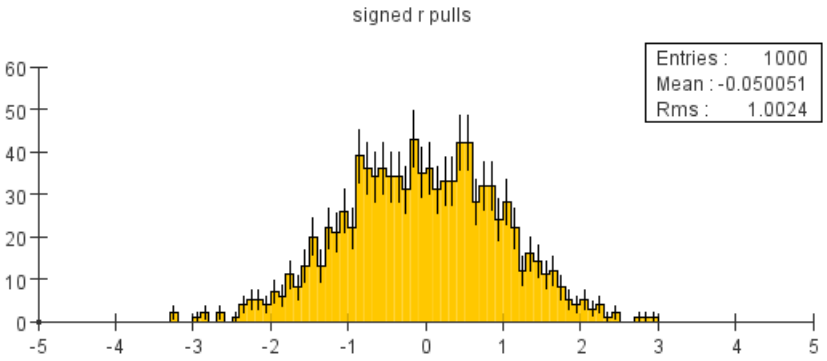
impact parameter

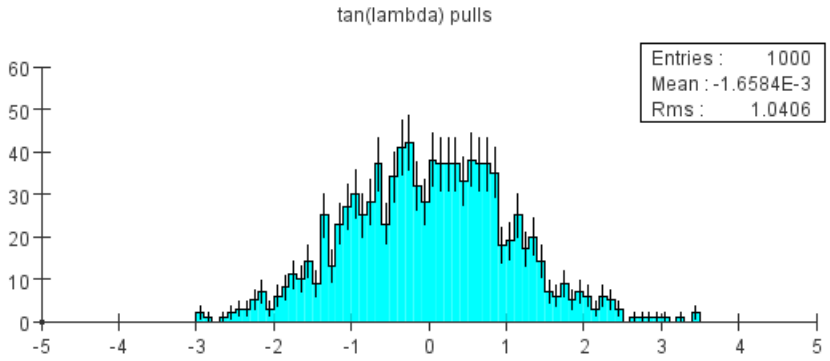


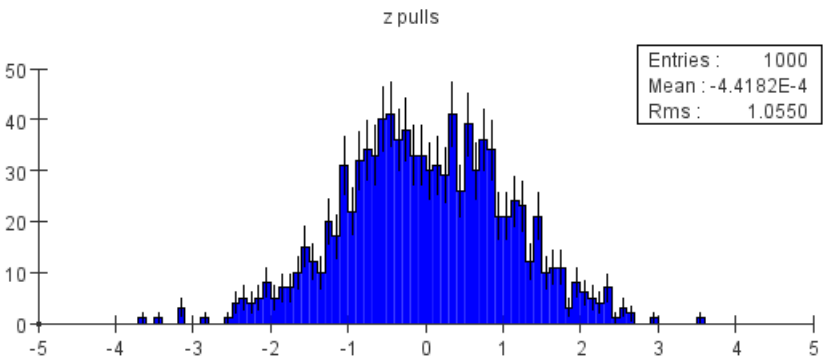
Full Kalman Fit pulls











Single 10GeV muons in central region (5 2D + 5 1D pts).

Test Detector w/ELoss and MCS

Summary

- Improvements are being considered for the tracker hit and track infrastructure.
- Pattern recognition based on 2-D measurements on surfaces is implemented.
- Fast, with high efficiency (# to be determined).
- Extrapolation into outer tracker and fitting with full Kalman filter begun.
  - Working on generic interface between compact detector description and tracking Detector.
  - Lot of effort being devoted to “smart” propagator.
- Lots of work ahead to characterize and improve.