# SiD tracking using VXD as a primary tracking device

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As you can see, my granddaughter, Anastasia Lobanova (age 8 months) is working hard to get ready for ILC. Should not we follow her example ?

Is she too old for ILC ?

*Marthy Breidenbach*

# Topics:

- 1.Existing tracking packages in hep.lcd for full simulation
- 2.Description of VXD based tracking alorithm
- 2.Reconstruction efficiency and what influence it.
- 3.How good are reconstructed tracks ?
- 4.Fake track generation. What are fakes ?
- 5.Fitting puzzle
- 6.Things to do

# Track reconstruction packages in hep.lcd

- The tracking package described below was developed specifically for SiD, and specifically for using VTX Detector as primary tracker. We can call it “tracking from inside to outside”.
- Another algorithm, developed earlier for SD, “combined tracking” could be used for finding tracks from VTX Detector points, however, it uses z positions of the hits in the outer tracker. We should exclude it in the case of SiD.
- Kalman filter algorithm is available for SiD also (package called ftf) It combines fitting with track finding as it propagates track seed from layer to layer. It is not optimized yet for SiD and uses separately compiled C++ code as “native library”. It create some inconvenience for code developers. In general it may be more promising compare to code described here.

# Track reconstruction packages in hep.lcd - continue

- In the addition to “from inside to outside” tracking, there are efforts do develop tracking based on calorimeter “stubs” extrapolated inside tracking volume and with tracking hits attached (Dima Onoprienko). This may be used as addition to any of the above described algorithms for finding tracks of decay products of long lived particles.
- For the very high density of background hits, Hugh transform based tracking was developed and tested. It really reduces CPU time for reconstruction, but has its own limitations. And CPU time reduction is only shows up at hit densities exceeding $10^4$ hits/layer

# Track Reconstruction Algorithm in VXD based tracking

- Initially algorithm developed for BaBar by Henri Videau. Was adapted for JAS by Mike Ronan. I have contributed to Mikes code during 1998-1999 (developed combined track finding, using both TPC and VXD hits), and developed fitting part (based on MOURS Benoit SLD tracks fitter). In 2003 I have developed pure VXD Based track finder.
- Idea: select 3 layers as pattern recognition base, and try all combinations of hit triplets (1 hit from each layer) to see if track traversing these hits may be constructed.
- The huge number of combinations in the case of many tracks in the detector (including backgrounds!) leads to long reconstruction time. It forces us to try to limit number of combinations. Simplest way to do it is to assume that track should originate in the vicinity of IP. That allows not to look at all combinations of hits in 3 layers, but consider only combinations approximately projective from IP (at least in dip angle).

# Track reconstruction Algorithm (continue)

- **Algorithm allows to set dimensions of the area around IP where tracks should originate. The smaller is this area, the faster is reconstruction.**
- **Ideally all possible combinations of 3 layers out of 9 VXD layers (5 barrels and 4 endcap) should be tried. The number of such combinations is 84. In our SiD geometry almost any track will cross 5 layers of VXD. If we assume, that at least 4 layers out of these 5 will see track, we can reduce number of layers combinations to 13.**
- **After 3 points defined parameter of track candidate, additional hits in VXD are attempted to be assigned to such track. If at least one more VXD layer has hit close to such track, candidate is selected for further consideration. Otherwise it is discarded.**
- **Now candidate is extrapolated to first layer of microstrip detectors (either barrel or endcap). Hits in the barrel are attached to track based on Phi of the strip. Z position is only checked to be within strip segment length (10 cm in SiD). In the endcap even layers are supposed to measure only Phi (radial strips) , while odd layers are measuring Radius (phi strips).**

# Track reconstruction Algorithm (continue)

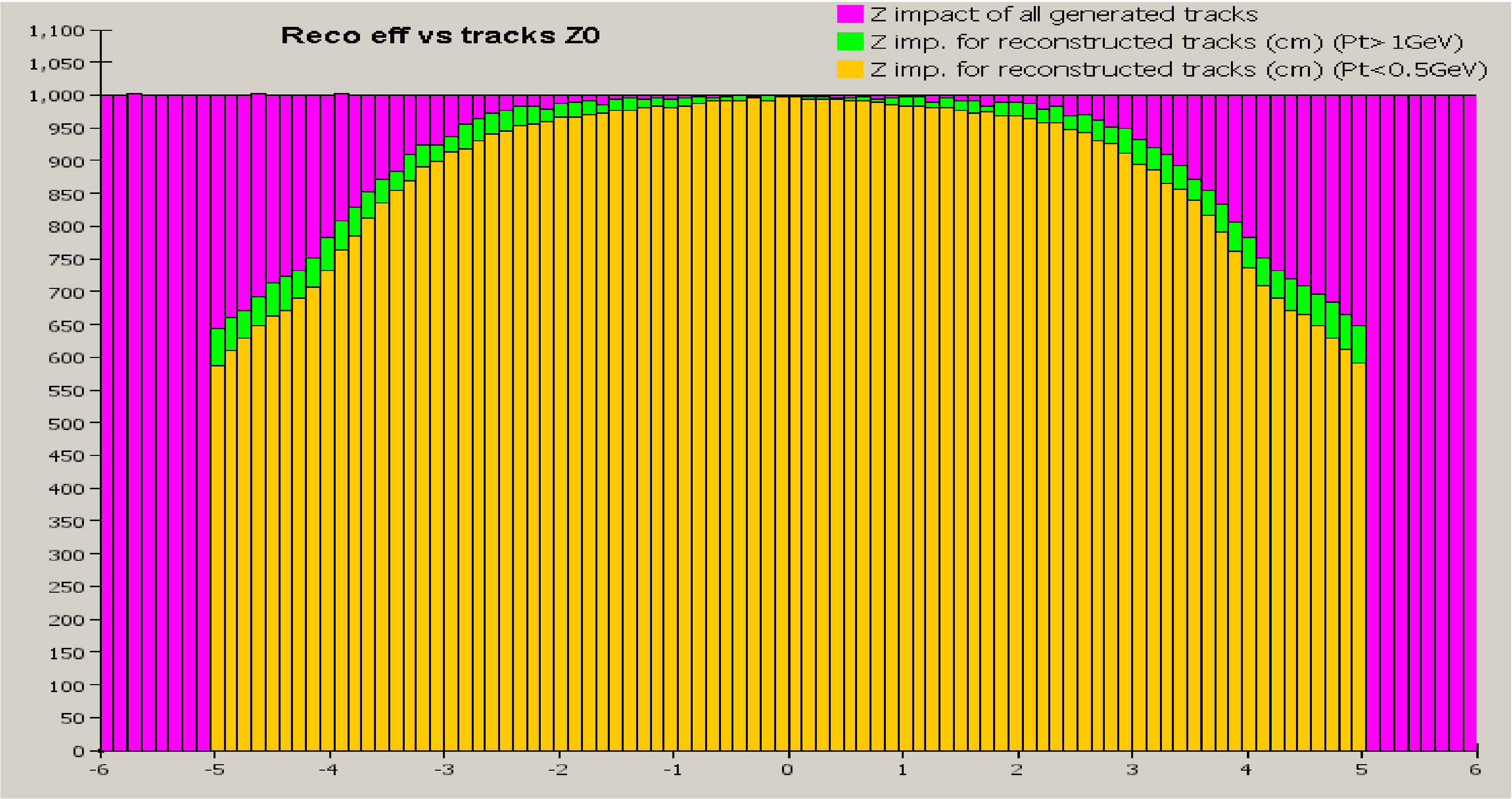
- Because there may be not one, but few hits in first layer of microstrip detector close (within errors) to track extrapolation, few possible continuations of track from VXD are made. Each of such continuations is evaluated for attachment of the hits in following layers. Only one continuation with largest number of attached hits, or with smallest chi squire is selected as final reconstructed track.
- To be finally accepted, such track should satisfy:
  - cut on minimum number of associated hits (total in VXD and microstrips). I usually set this number to 6.
  - Should pass check that it is not a duplicate of track, reconstructed earlier. Only 1 hit is allowed to be shared by 2 tracks in VXD, and one more – in strips. If number of shared hits larger, track is declared duplicate, and comparison with it's counterpart is made. Better (more hits or smaller chi squire) is selected, another is discarded
  - Track should satisfy closest to IP branch of helix criteria. If helix has radius small enough to not hit calorimeter, it may make few turns in tracker. Only closest to IP turn should be used

# Reconstruction controls

- Reconstruction cuts (dimension of track origin area around IP, minimum number of hits on the track, minimum track Pt and so on), selection of layers for pattern recognition and other reconstruction parameters are controlled through "VXDFinderStrategy" object. They are set to some default values, which I would consider reasonable, but user can set them to his/her own taste, if desired. They also may need different setting depending on the reconstruction goal – for example to effectively reconstruct tracks far from IP, or in another case to minimize number of fake tracks.

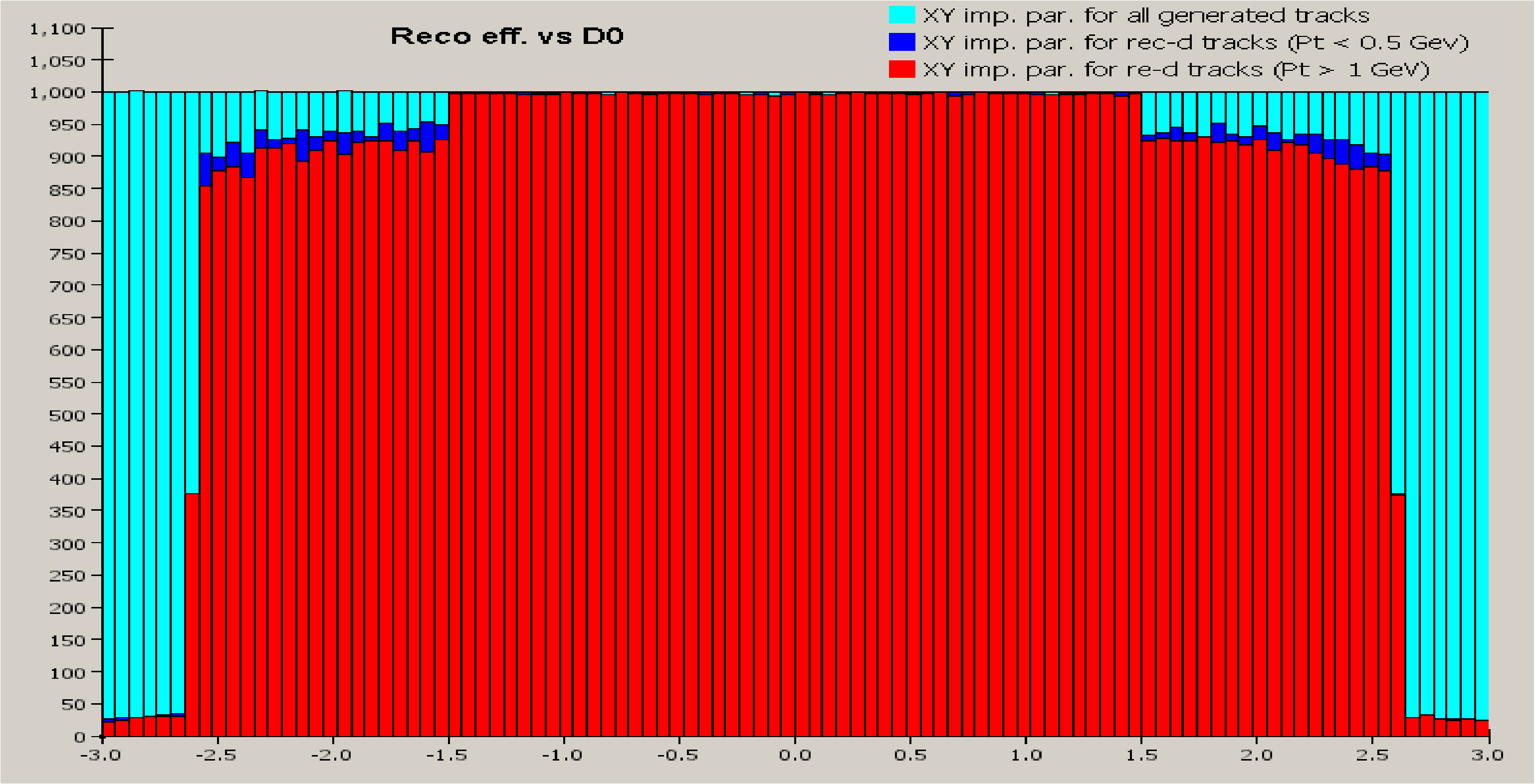
# Reconstruction of tracks originating far from IP in Z

- I have used program, generating single tracks with given parameters. Unfortunately it did not accounted for multiple scattering. But all detector resolution parameters were in.



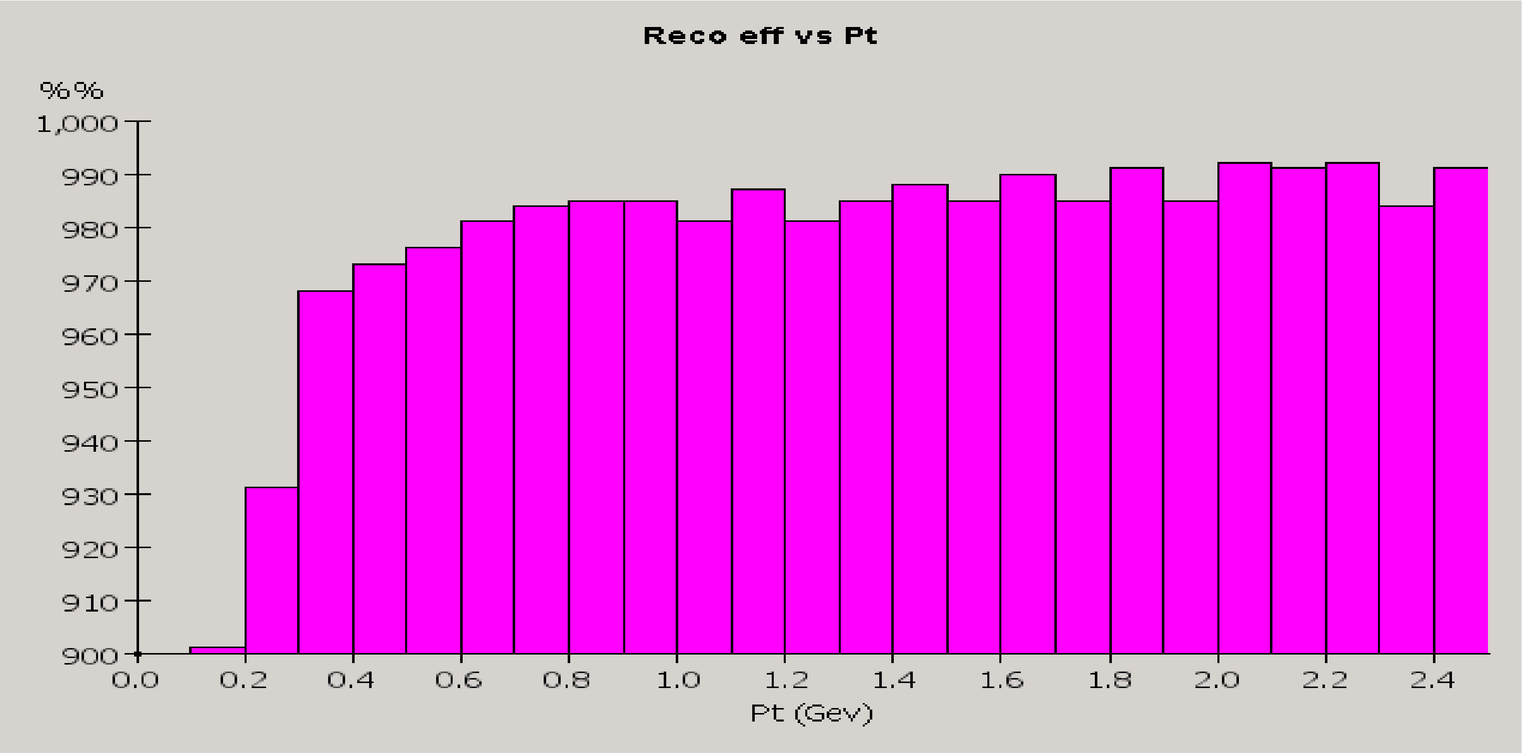
# Reconstruction of tracks originating far from IP in XY

- Interesting to notice, that even some tracks outside second VXD barrels are reconstructed. These are tracks with large cos(theta) – they are hitting endcap VXD and so are reconstructed . Drop between 1.5 and 2.6 due to only 4 VXD layers passed by track.



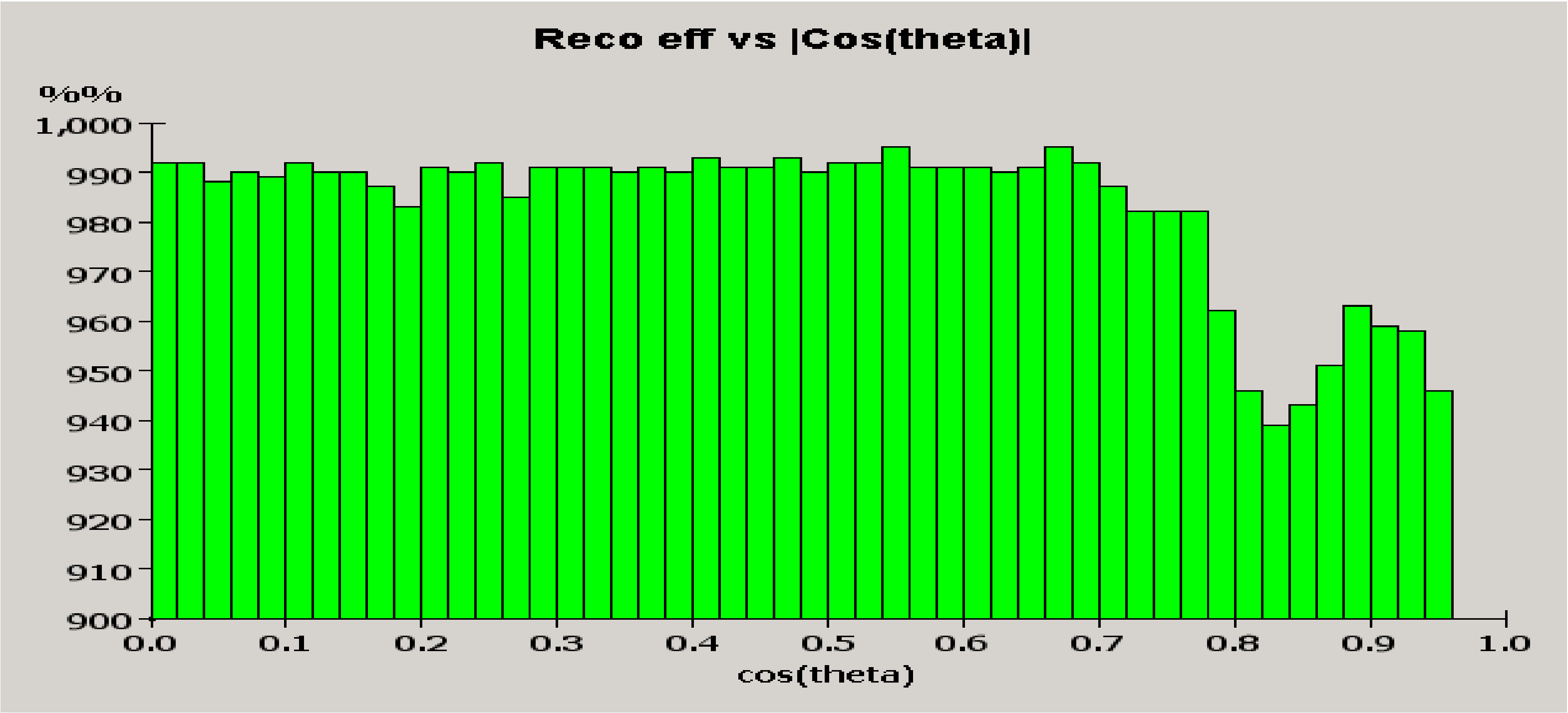
# Reconstruction efficiency vs Pt

- Now I am using physics events. Most of results are obtained using TTbar events, as most challenging (they have largest number of tracks per event) . Also Full CCD simulation was used everywhere.

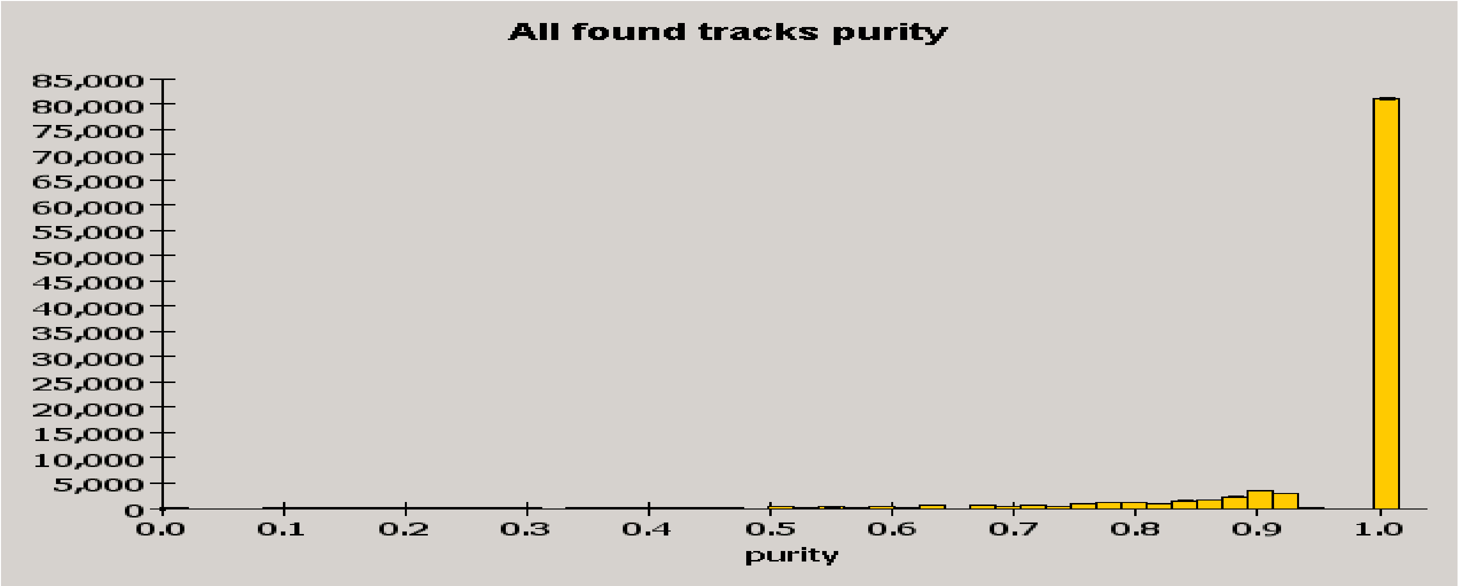


# Reconstruction efficiency vs cos(theta)

- Efficiency in the region cos(theta) > 0.8 may be dropping because of gaps in 5-layer coverage (see slide 8)

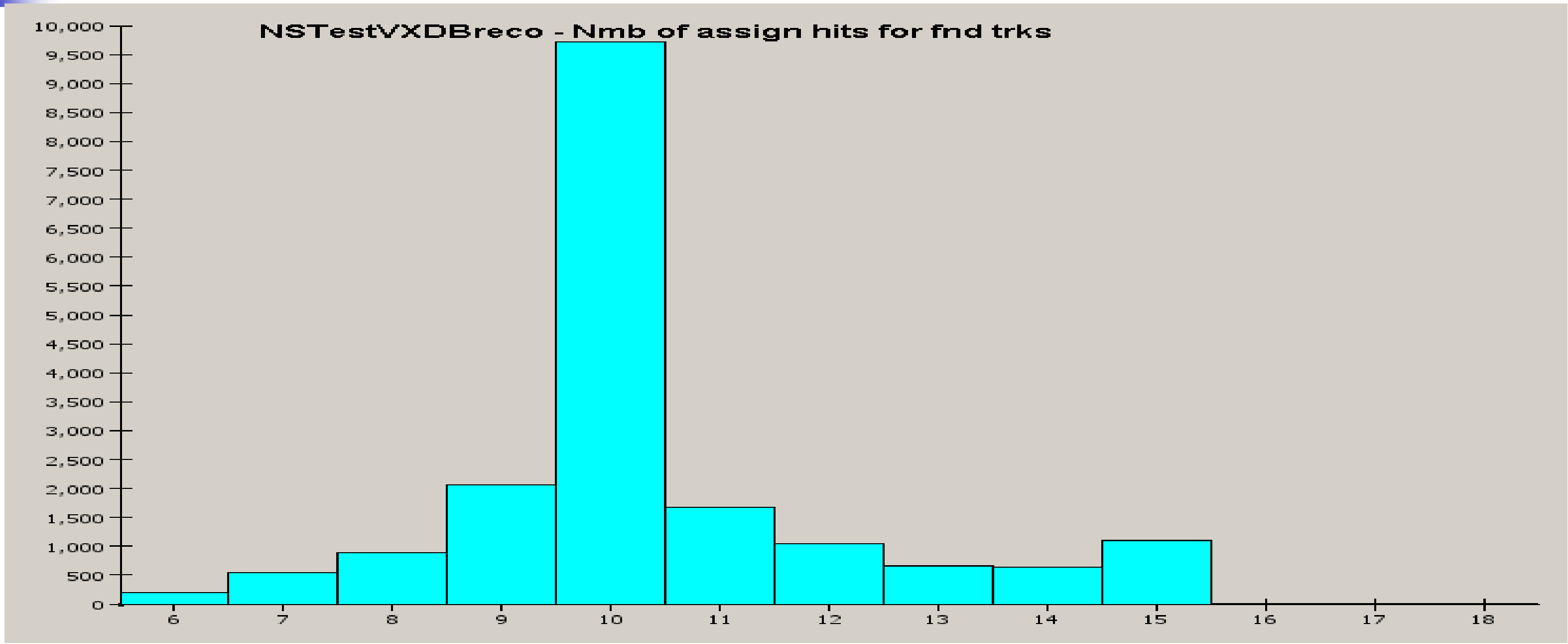


# How good are reconstructed tracks? - track purity



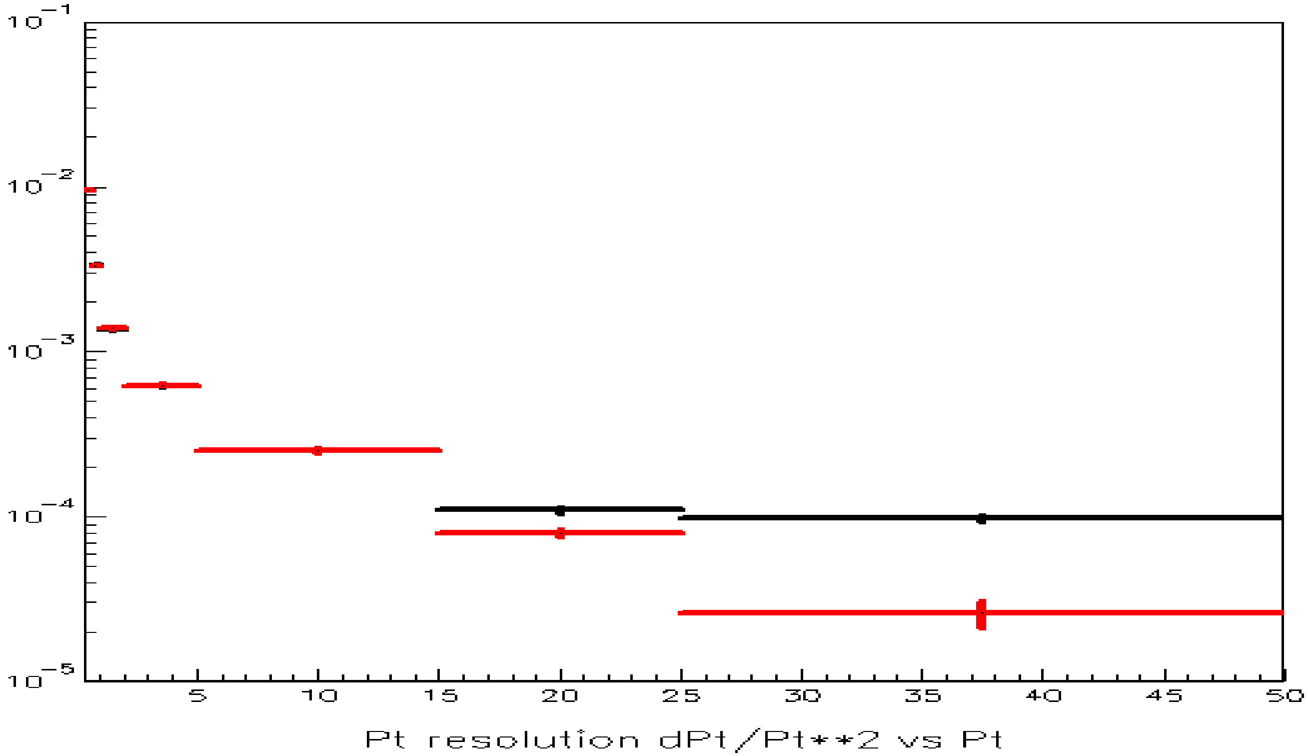

- Purity is defined as fraction of hits having same MC parent among hits attached to track. Here is distribution of purity for reconstructed tracks, matching “reconstructable” MC charge particle track – which is, originated close to IP and seen at least in first layer of microstrip detectors (either barrel or endcap).

# How good are reconstructed tracks ? - number of hits assigned to track




- We should expect 10 hits for high Pt low cos(theta) tracks and 15 hits for low Pt high cos(theta) (traversing all 10 endcap silicon strip layers). Very small amount of tracks with more than 15 hits is due to tracks hitting most of barrel layers, and traversing almos all endcaps – this is possible for narrow region of phase space)

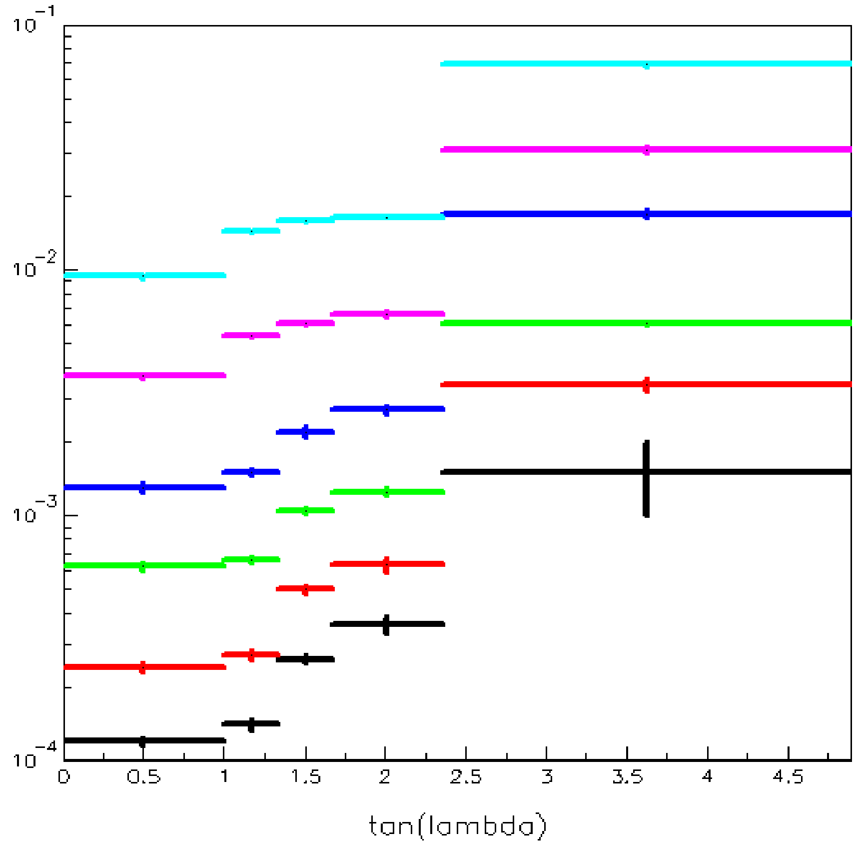
# How good are reconstructed tracks ? - Pt resolution (central region)




- **Fitting is not currently implemented for endcap tracks. I need to work on it. So this picture includes only tracks hitting barrel tracker. Black points are for reconstructed tracks without fitting, red – with.**

# Pt resolution as function of track deep angle

- **Pt resolution for different values of Pt (without fitting, as I don't have fitting for endcaps implemented yet ) as $\delta Pt / Pt^2$ .**
- **1 - 0.3<Pt<0.6 GeV**
- **2 - 0.6<Pt<1.0 GeV**
- **3 – 1.0<Pt<2.0 GeV**
- **4 – 2.0<Pt<5.0 GeV**
- **5 – 5.0< Pt<15.0 GeV**
- **6 – Pt > 15.0 GeV**



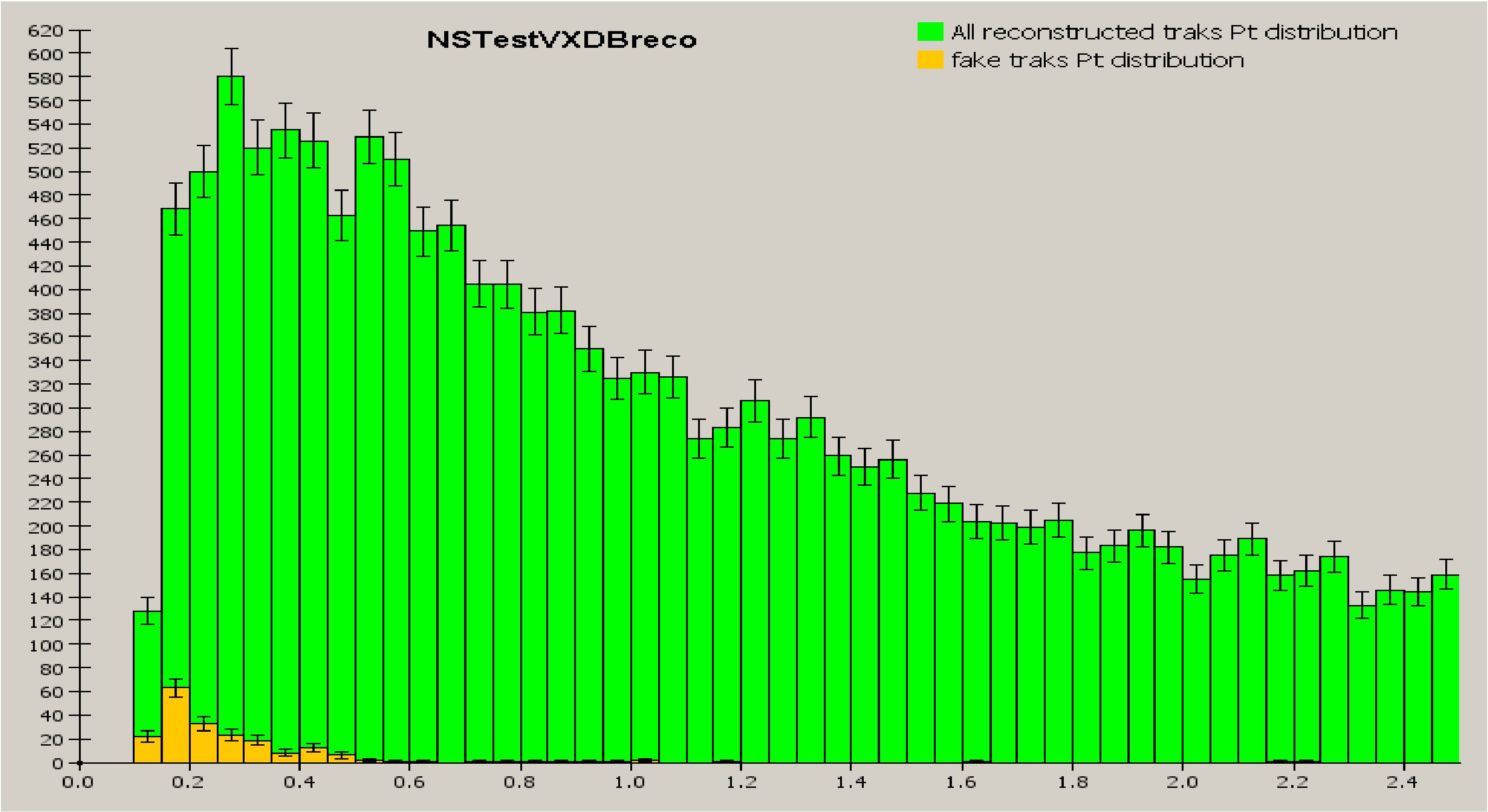
# Impact parameter resolution

- I did not have time to include plots, but here are some numbers:
  - Very high Pt (mu pairs) impact parameter resolution without fitting – 5.0 $\mu$, fitted – 2.5 $\mu$
  - Pt around 10 GeV – without fitting 5.4 $\mu$ fitted – 3.9 $\mu$
  - Pt around 0.5 GeV –without fitting 35.8 $\mu$ fitted – 25.2 $\mu$

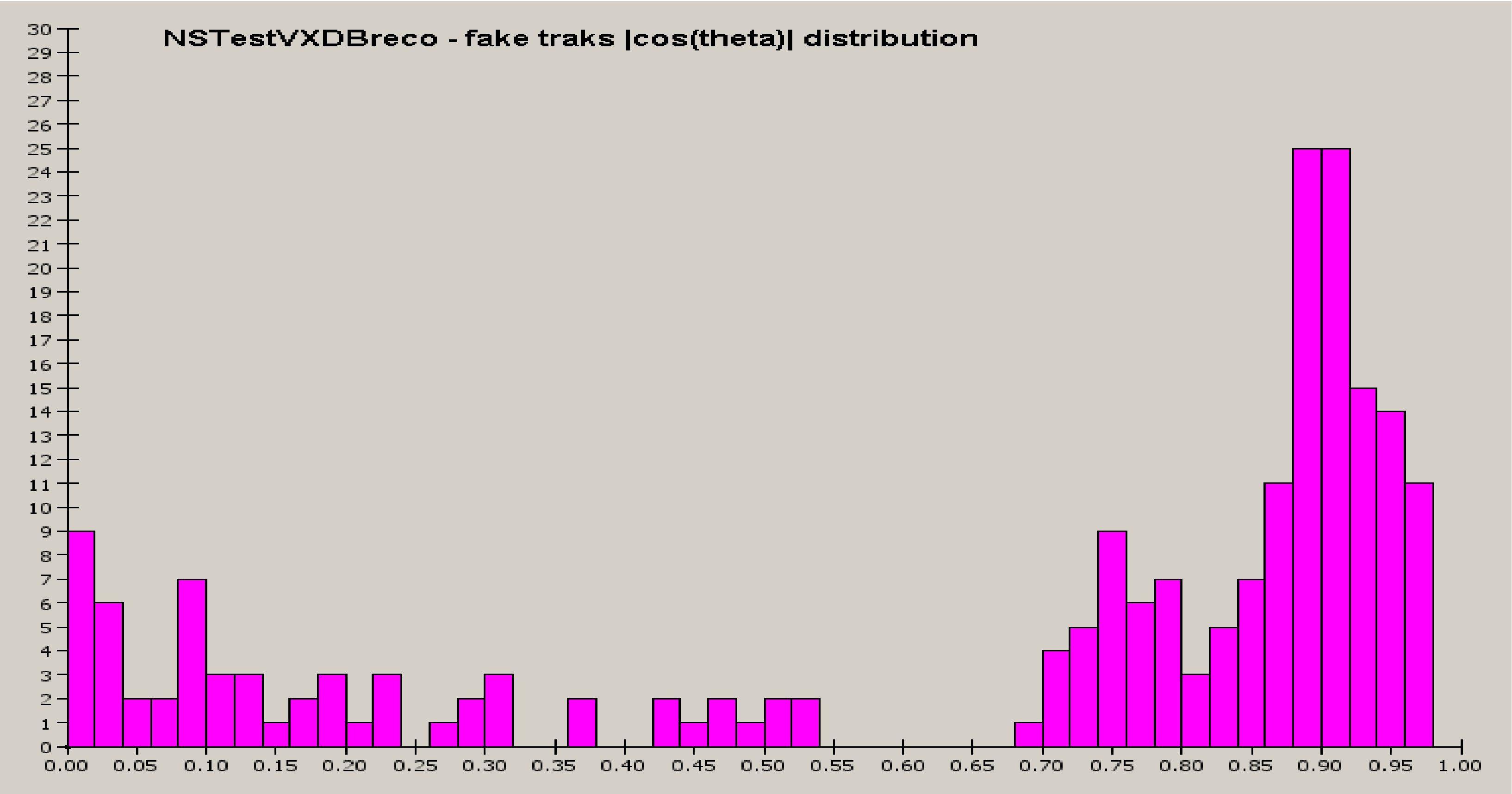
# The problem of fake tracks

- Some tracks reconstructed by described algorithm can't be associated with MC particle – for example, 2 tracks are declaring same MC particle as their "parent". It may happened if hits from the same MC parent were used in both reconstructions. They should form majority in composition of each track, and this is possible if one of the tracks is made from hits belonging to many parent (more than 2). Such track will have purity less than 0.5 . So we choose following criteria to declare reconstructed track fake:
  - It points to MC parent already declared as parent by another track
  - And it's purity is less than 50%

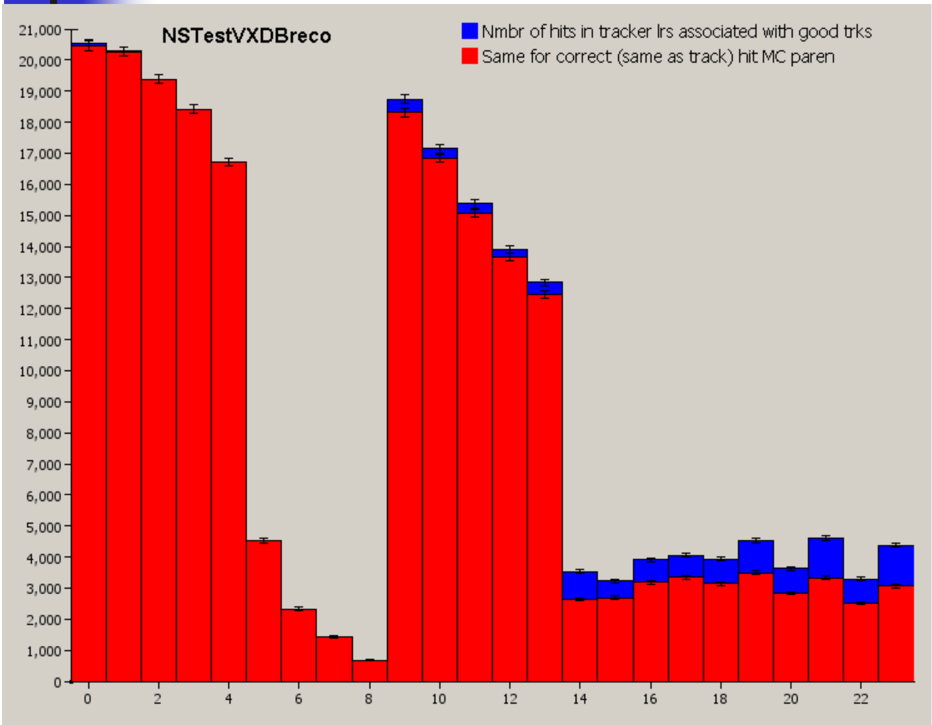
# Characteristics of fake tracks: Pt distribution

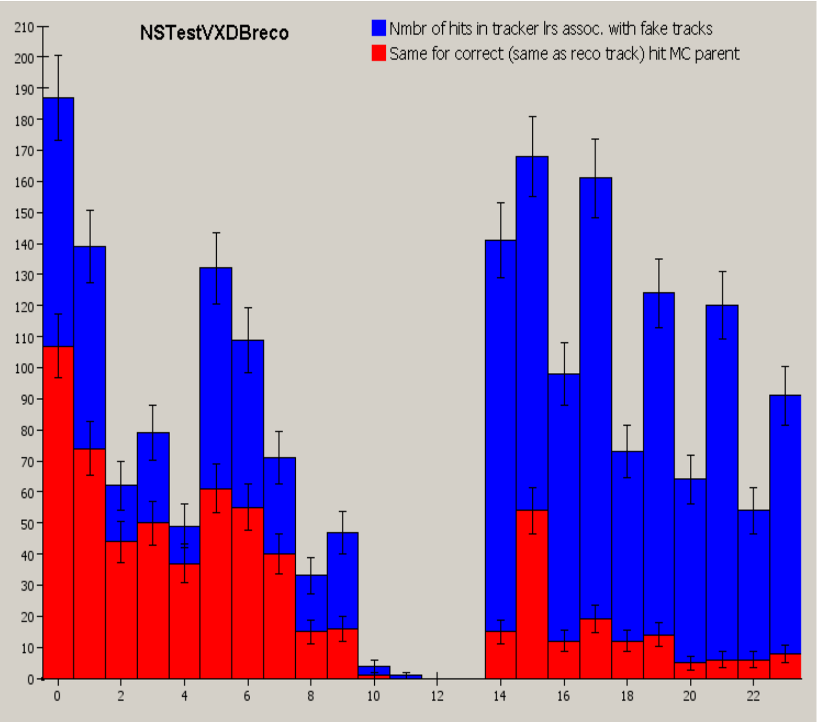


# Characteristics of fake tracks: cos(theta) distribution



# Characteristics of fake tracks: correctness of hits assignment




- Number of correctly assigned hits for different tracker layers (0-4 barrel VXD, 5-9 – endcap VXD, 10-14 – barrel silicon, 15-24 – endcap silicon layers)

# Future plans

- It looks like track finder is free of major bugs now. We can play with it:
  - The main thing is to add backgrounds and see how performance will change
  - We need to look into reconstruction in the dense jets. Though I tried to see change in efficiency for close tracks, and did not find any. But this requires more thorough investigation
- Fitter need to be extended to include endcap layers.
- Software need to be ported into LCSIM environment