LCFIVertex status and plans

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on behalf of the LCFI working group

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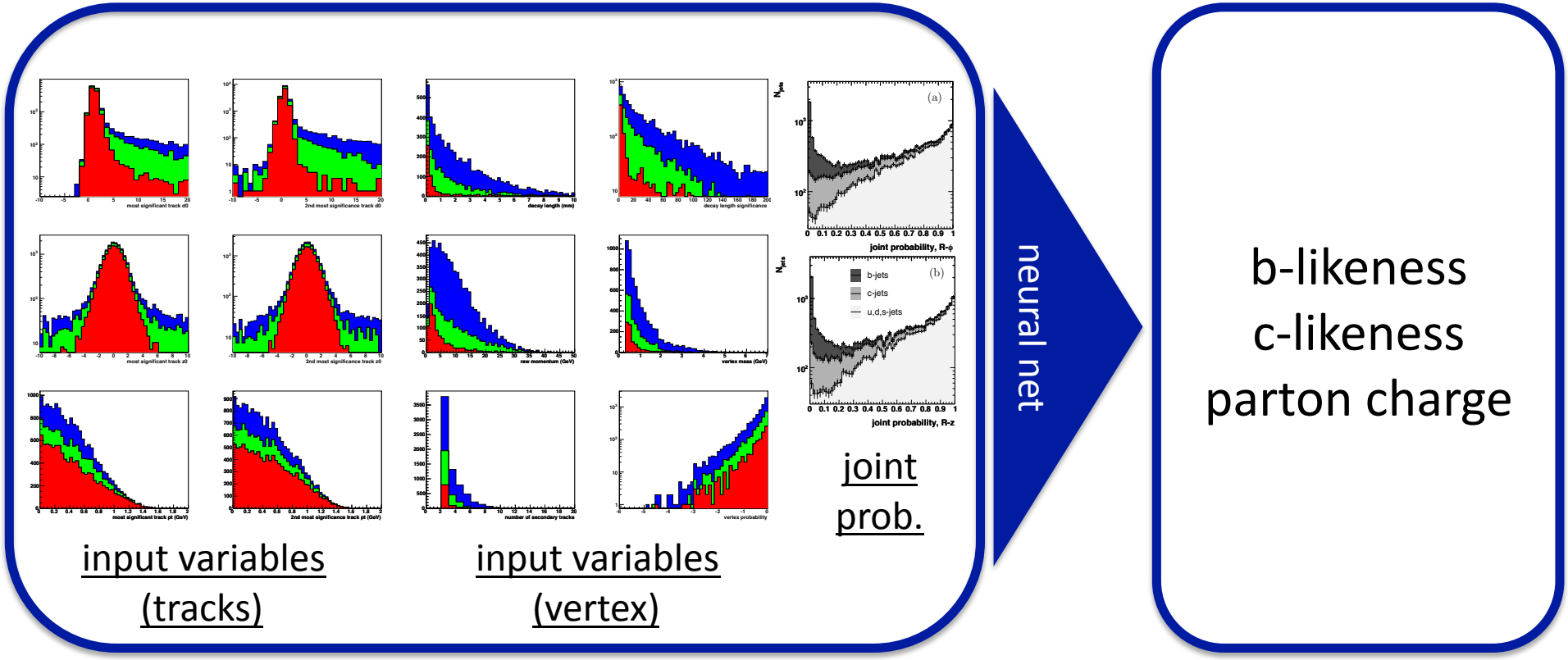
THE UNIVERSITY OF TOKYO

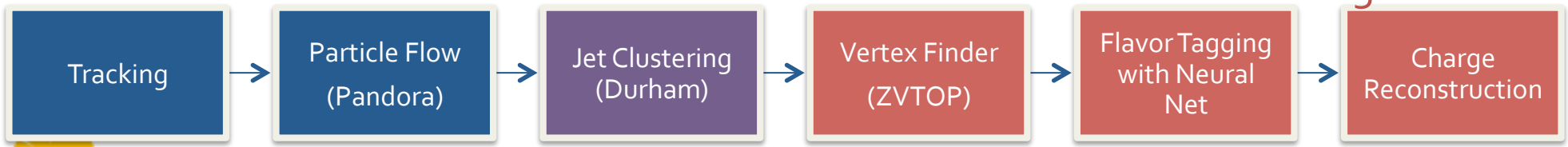
LCFIVertex

LCFIVertex is a collection of algorithms for flavor tagging and parton charge identification.



LCFI collaboration: NIM A 610 (573) [arxiv:0908.3019]

LCFIVertex Package



LCFIVertex activities

two main streams of LCFIVertex activities:

- fundamental improvements of algorithms
  - flavor tagging & jet clustering
  - T. Tanabe, T. Suehara, S. Yamashita (Tokyo)

completion target: 2010 Q4

- complete studies inherited from the original LCFI authors
  - study of parton charge identification (with focus on jets involving neutral B hadrons)
  - T. Saito, Y. Takubo (Tohoku) with C. Damerell (RAL) as liaison to the original LCFI authors
- software maintenance
  - H. Ono (NDU), A. Miyamoto (KEK)

rest of this talk:

flavor tagging

flavor tagging

- physics motivation: need for improved flavor tagging & jet clustering in a multi-jet environment
  - Higgs self coupling (e^+e^- -> ZHH)
  - top Yukawa coupling (e^+e^- -> ttH)

jet multiplicity 4-8 @ m_H = 120 GeV, up to 10 for m_H = 200 GeV

- as the first step:
  - we investigate flavor tagging performance separately from the effect of jet clustering
  - we will use two jet samples at E_{cm} = 91.2 GeV (prepared by R. Walsh for LoI studies, ilcsoft v01-06)
  - event reconstruction using ilcsoft v01-08-01
    - tracking: FullLDCTracking / SiliconTracking (Brahms/DELPHI)

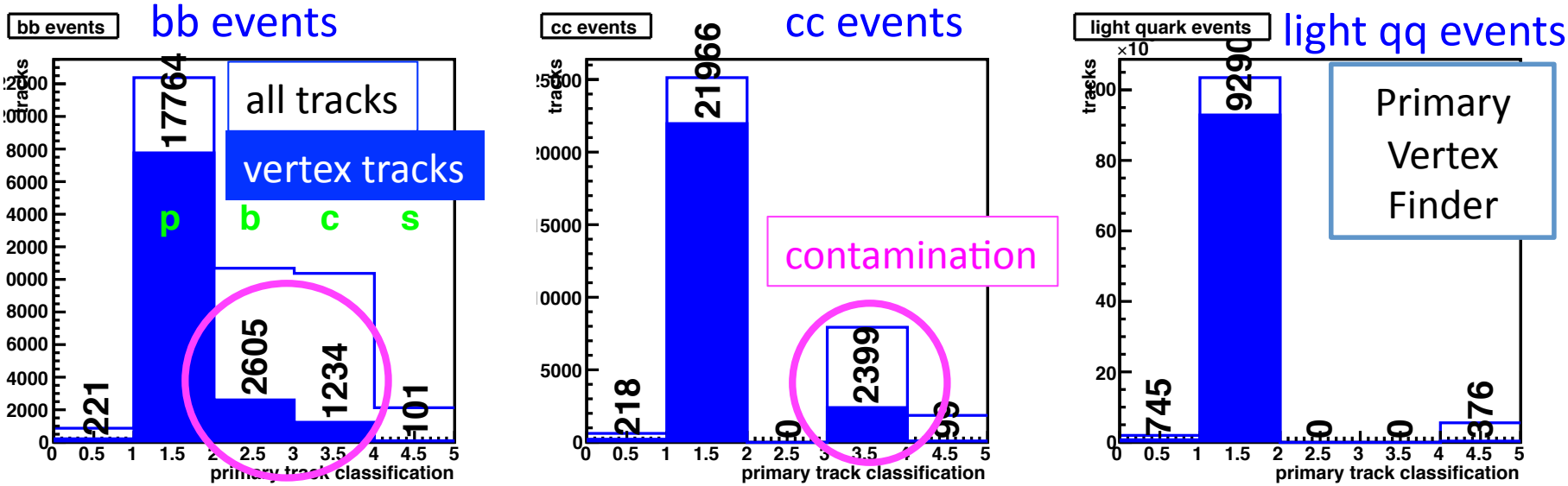
flavor tag optimization strategy

- from basic checks to algorithm tuning
  - ✓ vertex hits
  - ✓ track reconstruction
  - ✓ track residual & track errors
  - ➔ track quality & track selection
    - vertex reconstruction
    - combination of input variables
    - optimization for multi-jet environment

results will be presented in the order they were obtained

primary vertex reconstruction

- we evaluate the performance of the primary vertex finder (LCFI, *teardown*) by looking at the types of tracks used to build the vertex:

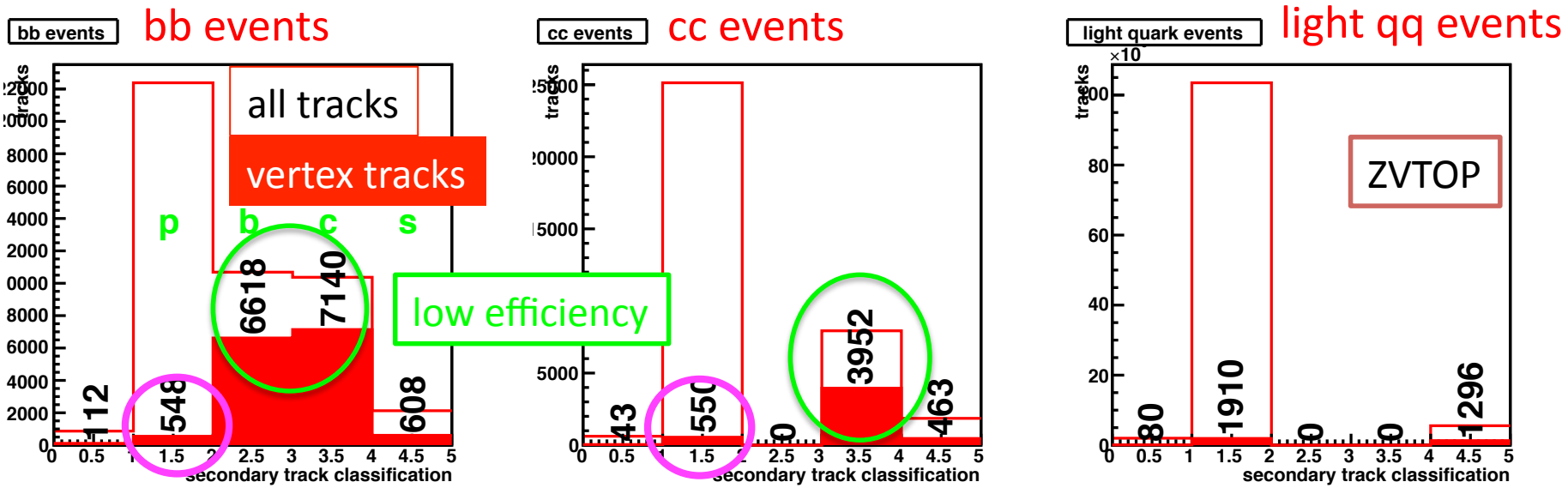


- significant amount of contamination is present
- if this can be cleaned up, they could be set aside during secondary vertex finding which will reduce combinatorial background

E_{cm} = 91.2 GeV
|d0| < 50 mm
|z0| < 50 mm

secondary vertex reconstruction

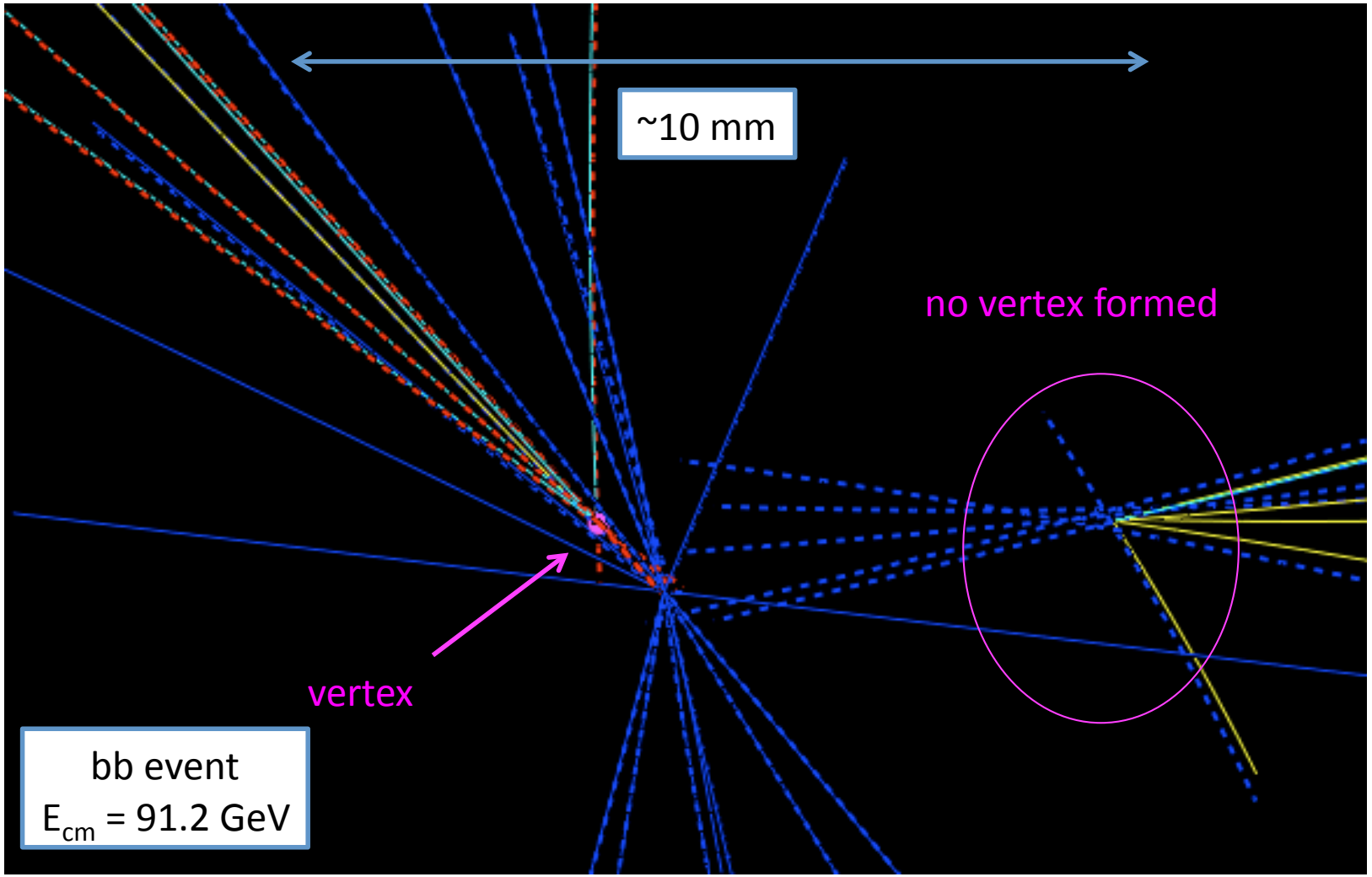
- similar checks were done for secondary vertex reconstruction (LCFI, ZVTOP)



- we would naively expect more efficiency (but we must take into account the fact that a vertex cannot be built from a single track topology e.g. semileptonic decay into neutral hadrons)

E_{cm} = 91.2 GeV
|d0| < 10 mm
d0 error < 0.25 mm
|z0| < 20 mm
Pt > 0.1 GeV
N_{TPC} > 20 or N_{FTD} > 3 or N_{VXD} > 3

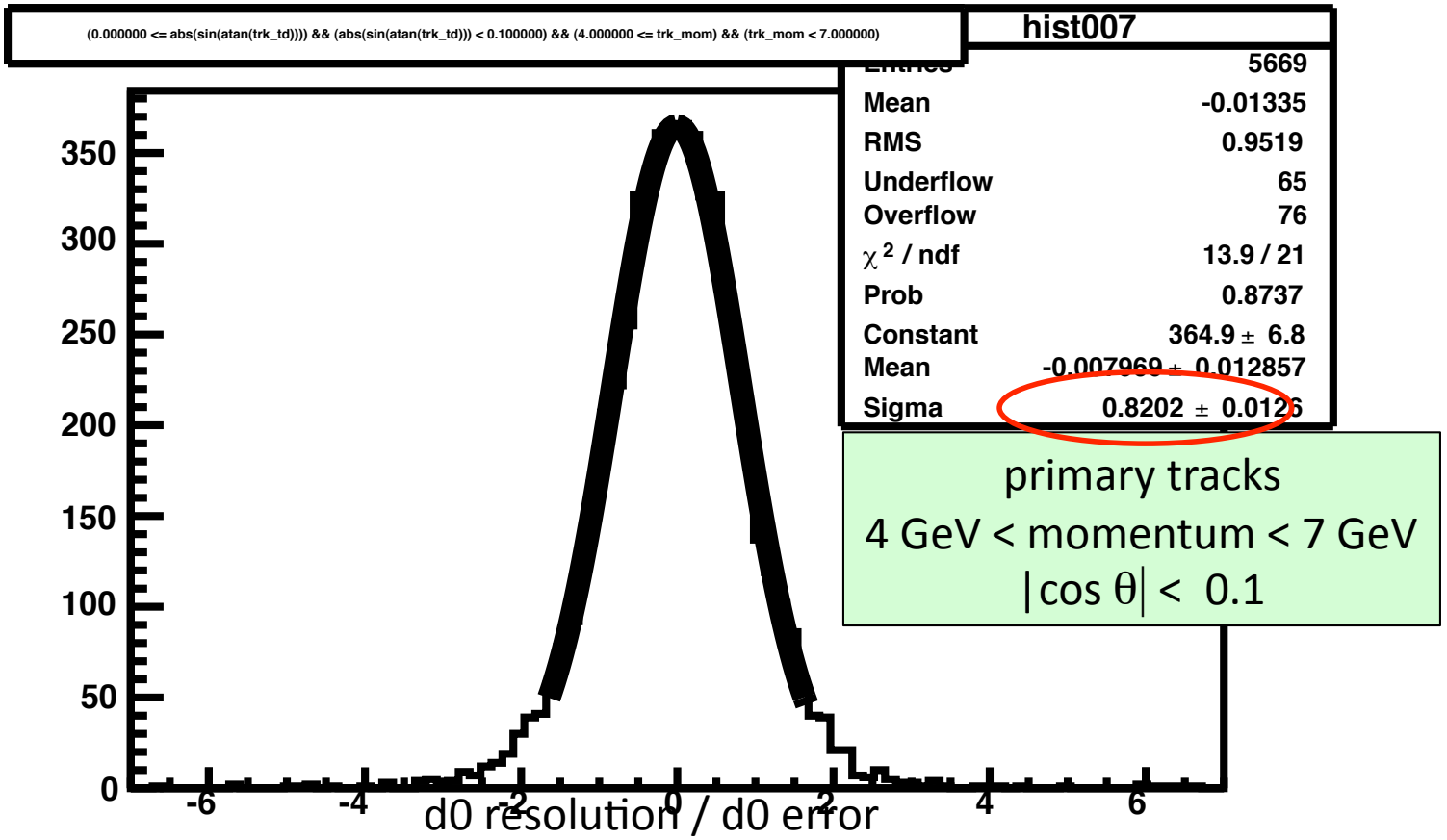
event display



- Checking vertex reconstruction with the event display (dedicated to track + vertex)
- One often finds a cluster of tracks which seem like a perfectly good vertex candidate but the vertexing fails (such as the one shown on the right)

impact parameter pull: resolution / error

- if the tracks look good, but vertexing fails, the assigned error must be the culprit (assuming vertex selection cuts are optimized)



if the resolution/error are assigned correctly, the distribution ought to be a unit Gaussian

do residual / error

primary tracks

cos θ bins

<1.5% error on pull values

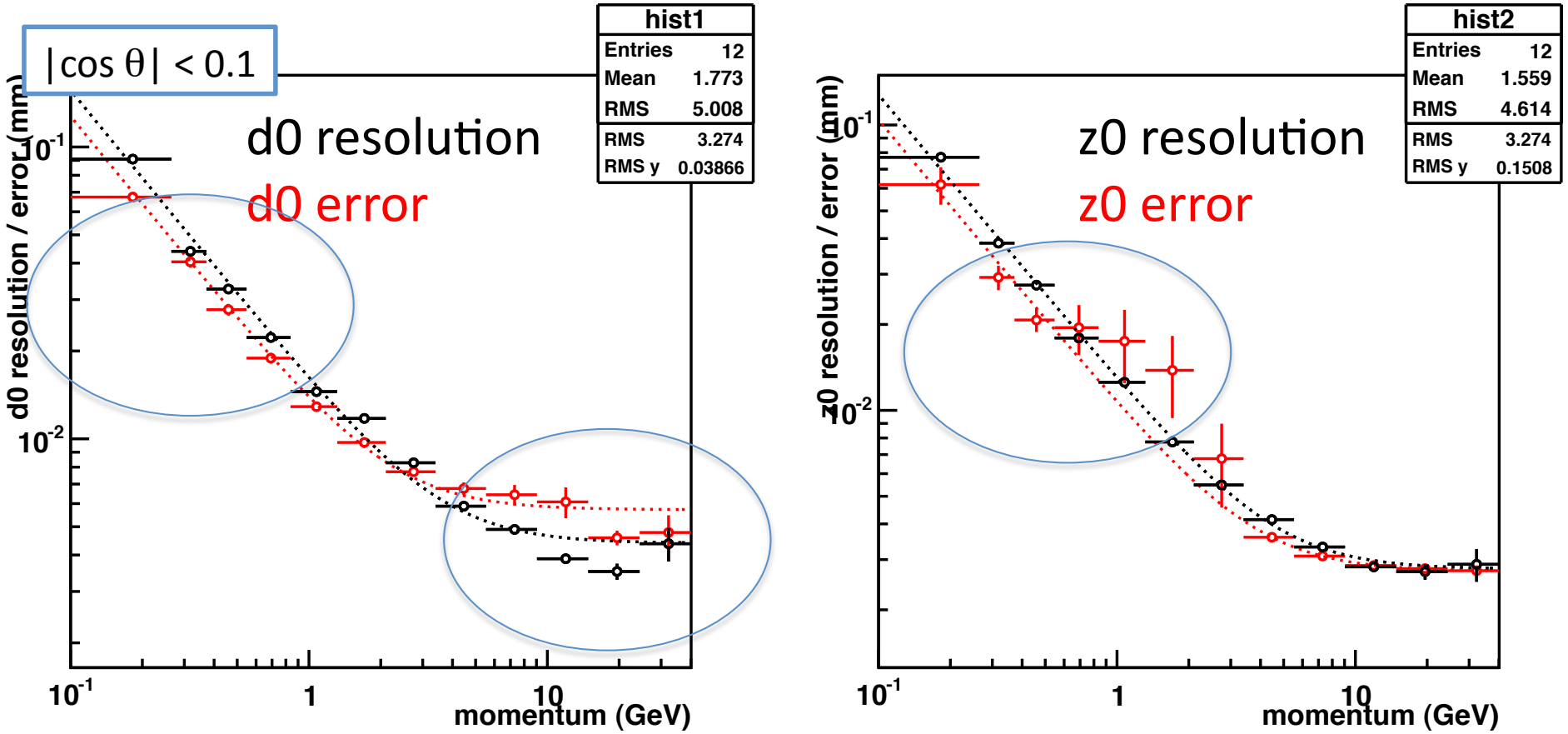
momentum bins

0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	1.0
0.4	1.101	1.191	1.218	1.181	1.183	1.188	1.177	1.161
0.7	1.051	1.070	1.092	1.100	1.119	1.108	1.075	1.122
1.0	1.005	1.063	1.051	1.069	1.063	1.068	1.047	1.122
1.5	1.012	1.022	1.008	0.993	1.020	1.030	0.997	1.119
2.5	0.960	0.944	0.972	0.962	0.962	0.973	0.978	1.124
4.0	0.856	0.873	0.895	0.899	0.889	0.914	0.933	1.106
7.0	0.820	0.820	0.818	0.830	0.834	0.845	0.864	1.076
250	0.736	0.721	0.725	0.727	0.749	0.742	0.766	1.003

The pull distributions are distorted for a wide range of momentum and angle.
The resolution and error must be checked individually.

impact parameter resolution & error

impact parameter resolution: $\sigma = a \oplus \dfrac{b}{p \cdot \sin^{3/2}\theta}$



resolution << error for high momentum region

resolution >> error for low momentum region

must check single hit resolution & amount of material

check VXD digitizer

MarlinReco/TrackDigi/VTXDigi/src/VTXDigiProcessor.cc

single hit resolution

scaled error is used in covariance matrix

```
_pointResoRPhi = _pointResoRPhi_VTX/cos(PhiInLocal);
_pointResoZ    = _pointResoZ_VTX;

//finding the smearing constant
double rSmear  = gsl_ran_gaussian(r,_pointResoRPhi_VTX);

//find smearing for x and y, so that hit is smeared along ladder plane
double xSmear = rSmear * cos(lPhi);
double ySmear = rSmear * sin(lPhi);
                ⋮
float covMat[TRKHITNCOVMATRIX]={0.,0.,_pointResoRPhi*_pointResoRPhi,0.,0.,_pointResoZ*_pointResoZ};
trkHit->setCovMatrix(covMat);
```

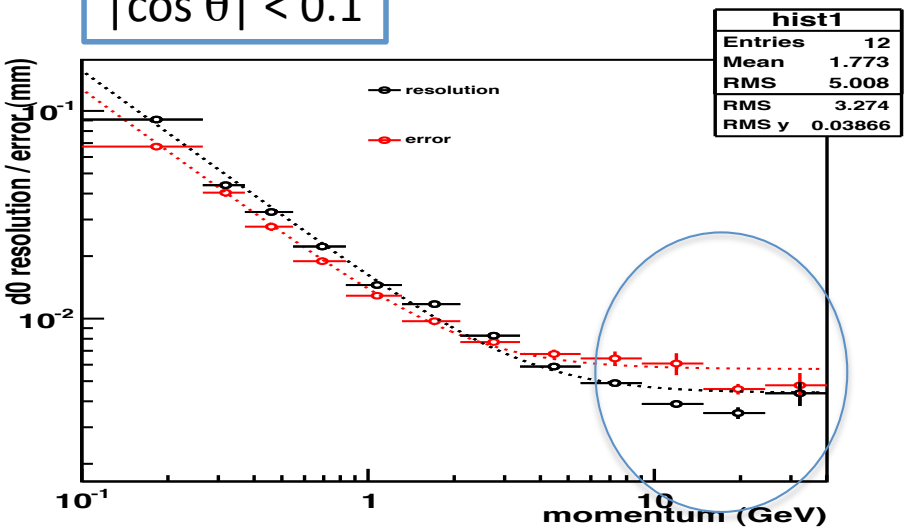
- error(r-ϕ) is scaled by 1/cosϕ factor
  - error(r-ϕ) should scale (naively) as cosϕ (or constant in ϕ?) but not 1/cosϕ
  - tracking code needs to be checked to settle this issue
    - but the Fortran code is too long and complicated

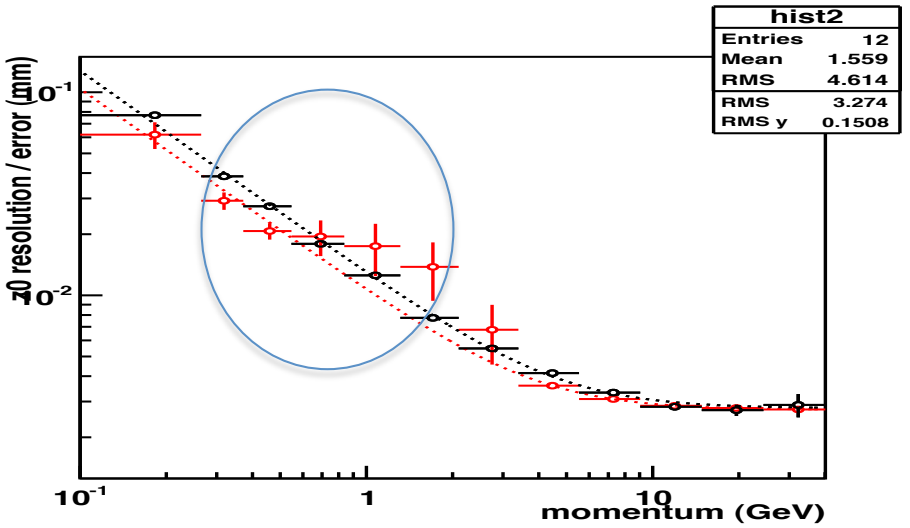
error calibration (1)

- we apply a heuristic "fix" to calibrate the errors
  - we use a cosϕ factor instead of a 1/cosϕ factor for scaling the error in the digitizer
  - we (effectively) increase the amount of material (2x) in the VXD by reducing the radiation length of the material (0.5x)
- we compare the resolution and error before/after this fix

error calibration (2)

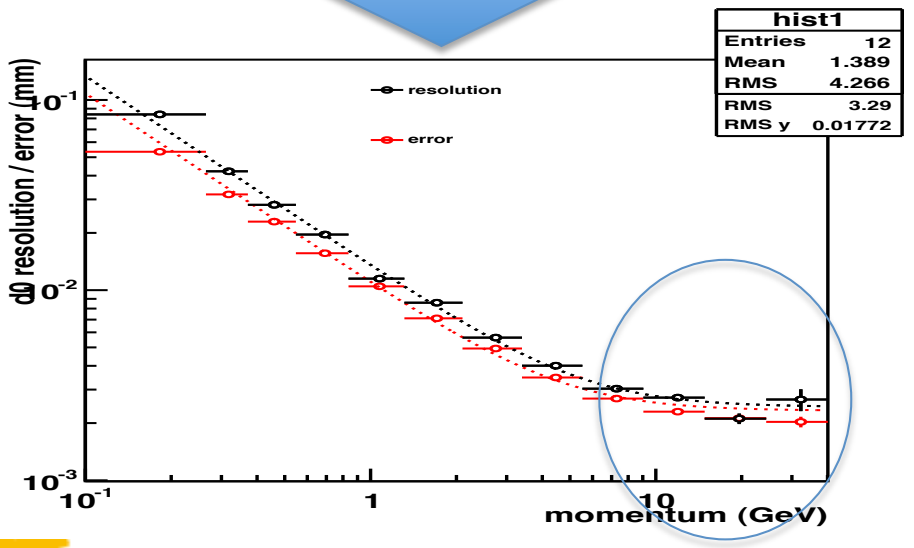
$|\cos\theta| < 0.1$

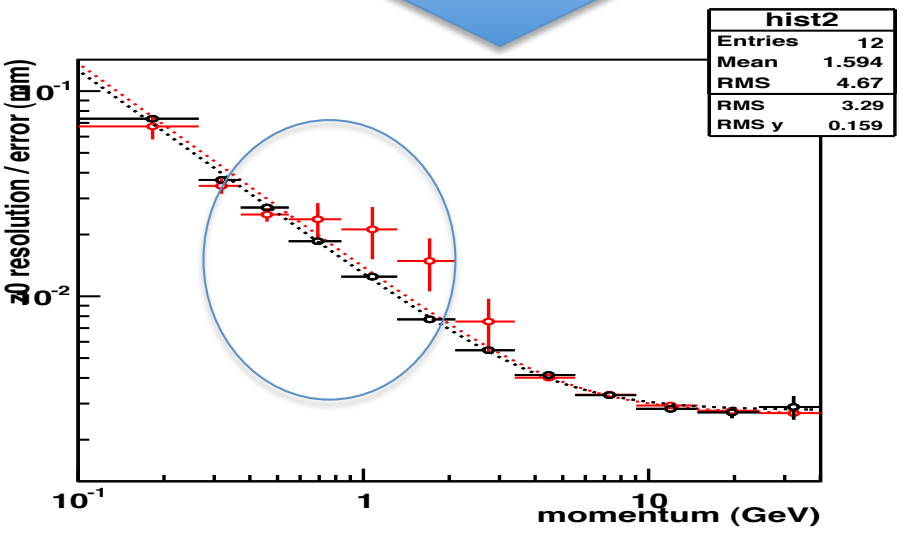




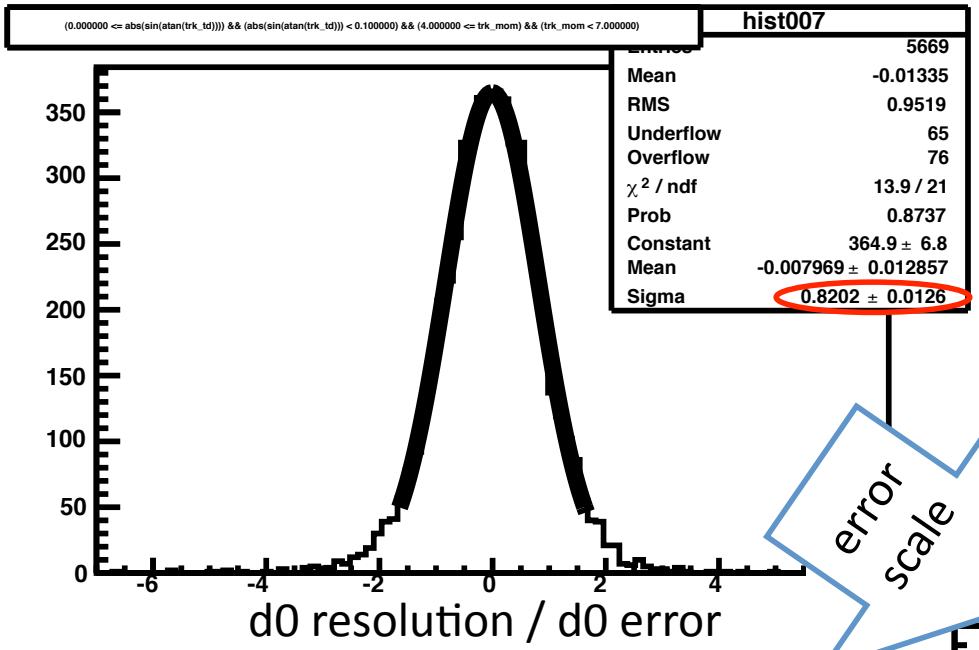
error scale

error scale



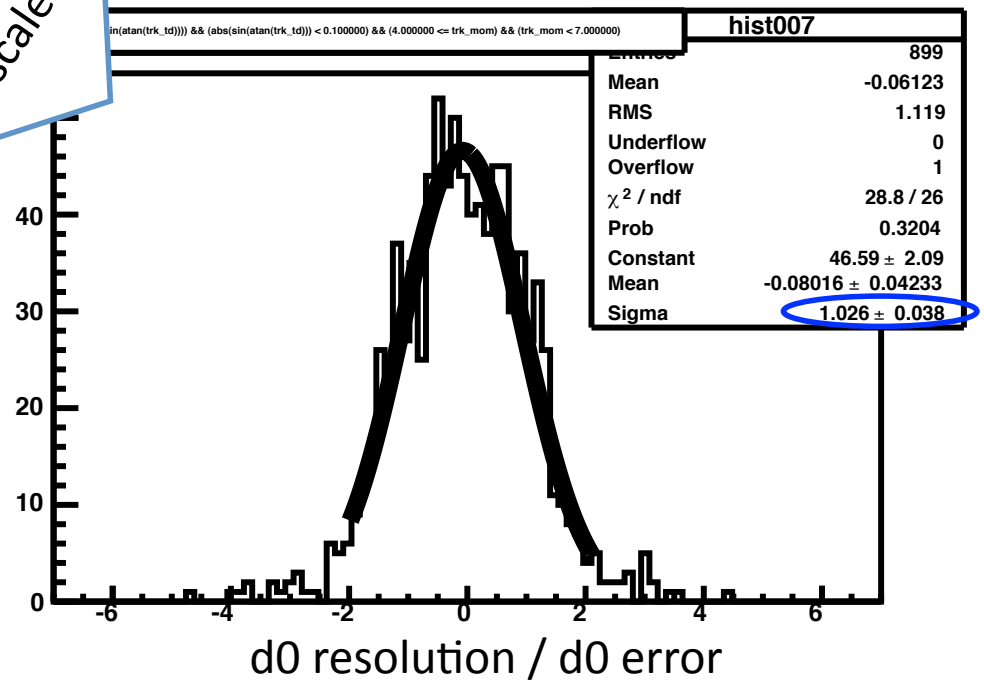


resolution / error (after error scaling)



error scale

primary tracks
4 GeV < momentum < 7 GeV
$|\cos\theta| < 0.1$



do residual / error (after error scaling)

primary tracks, N_{VXD}=6

cos θ bins

approx. 3.0% error on pull values

momentum bins

0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	1.0
0.4	1.098	1.009	0.924	0.959	1.036	0.918	1.026	1.025
0.7	1.081	0.995	0.940	0.995	0.966	0.950	0.991	1.013
1.0	1.072	0.983	1.038	0.985	0.991	0.958	0.990	0.973
1.5	1.152	0.963	1.024	0.956	0.988	0.928	0.956	0.923
2.5	0.988	0.976	1.022	0.961	0.990	0.940	0.988	1.038
4.0	1.110	0.990	1.033	0.969	0.961	0.950	1.011	0.988
7.0	1.090	1.055	0.910	1.018	0.983	0.970	0.998	1.042
250	1.055	0.982	1.027	0.971	0.963	0.925	0.982	0.928

The pull distributions are distorted for a wide range of momentum and angle.
The resolution and error must be checked individually.

zo residual / error (after error scaling)

primary tracks, N_{VXD}=6

cos θ bins

approx. 3.0% error on pull values

momentum bins

0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	1.0
0.4	1.114	0.928	0.980	0.987	0.933	0.969	0.973	0.947
0.7	1.043	1.001	0.908	0.924	0.937	1.011	0.963	1.019
1.0	1.103	0.979	0.932	0.929	0.944	0.959	0.931	0.979
1.5	1.056	0.919	0.950	0.950	0.933	0.963	0.939	1.009
2.5	1.152	0.970	0.954	0.892	0.942	0.943	0.964	0.990
4.0	1.020	1.003	0.968	0.945	0.944	0.969	1.103	1.006
7.0	1.059	1.081	1.030	0.970	0.968	0.960	1.023	1.027
250	1.061	1.031	1.037	1.049	0.989	0.979	1.002	1.166

The pull distributions are distorted for a wide range of momentum and angle.
The resolution and error must be checked individually.

summary and plans

- we performed basic investigations of the track issues in the context of flavor tagging
- track errors were found to be inaccurate
  - we addressed this issue by scaling the errors
  - but a true solution must be provided by understanding and/or rewriting the tracking code
- we are now ready to move to the next step…

summary and plans

- from basic checks to algorithm tuning
  - ✓ vertex hits
  - ✓ track reconstruction
  - ✓ track residual & track errors

  April – June 2010 ✓

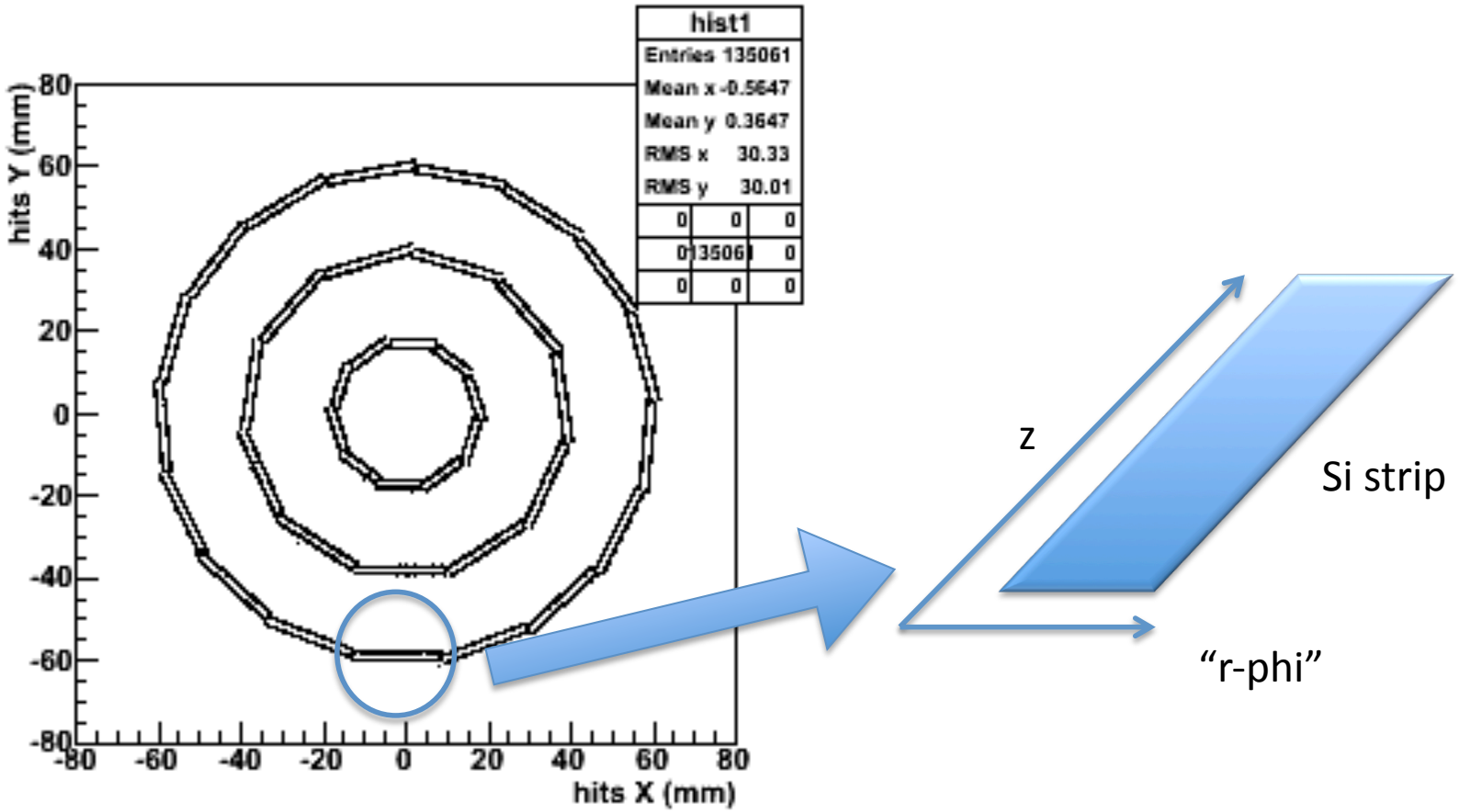
  - ➔ track quality & track selection
    - vertex reconstruction
    - combination of input variables
    - optimization for multi-jet environment

  July – September 2010

  to be completed by ECFA

back up

definitions

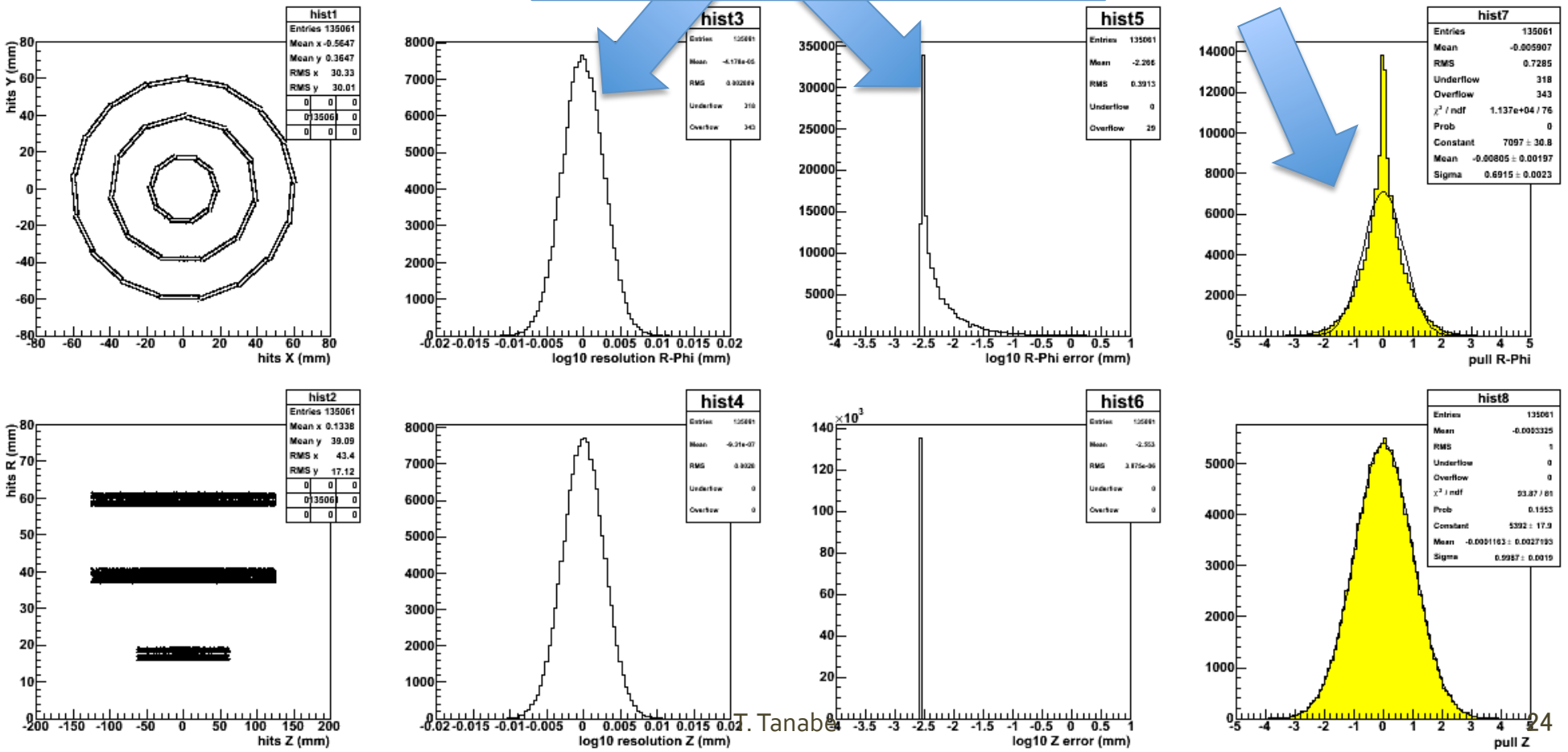


VXD hits

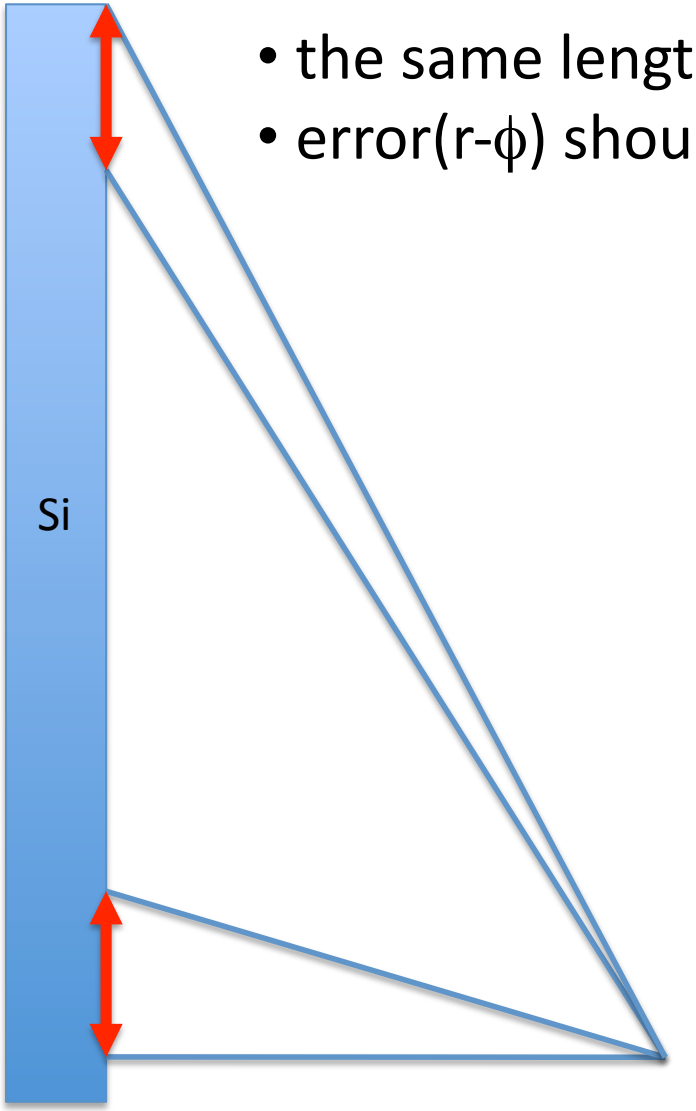
X-Y hit position	R-Phi resolution	R-Phi error	R-Phi pull
R-Z hit position	Z resolution	Z error	Z pull

digitization smearing & error assignment are inconsistent

pull not gaussian!



hit error and angular dependence

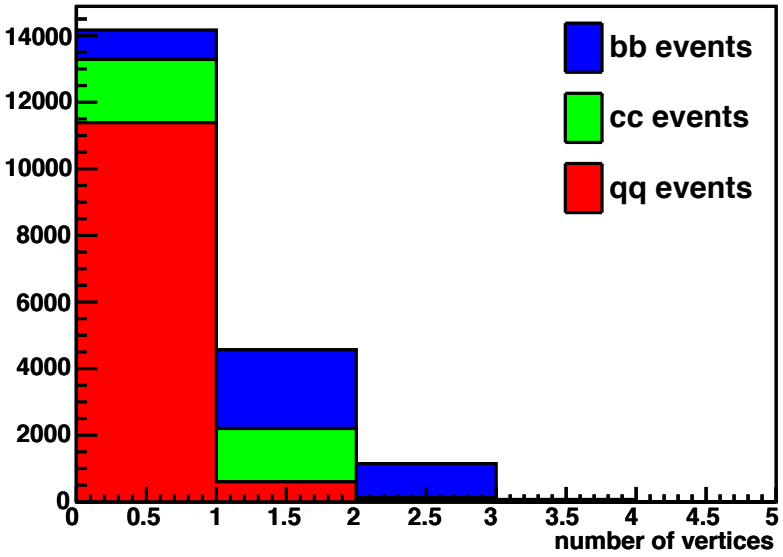


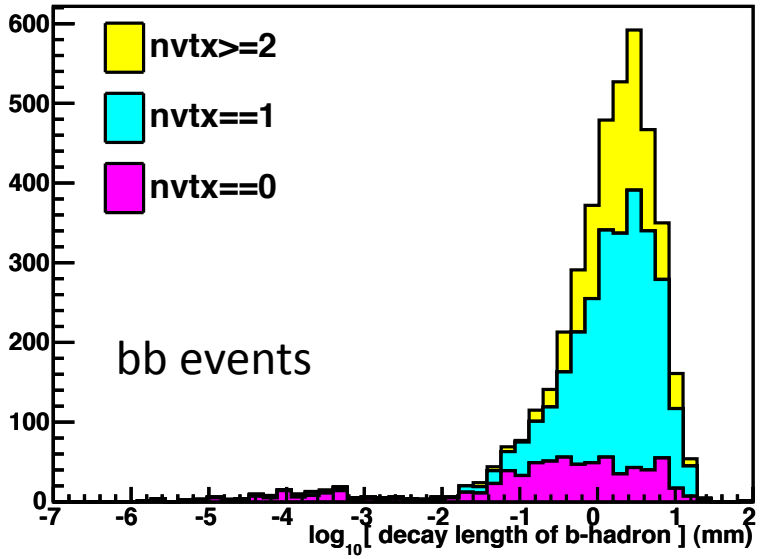
- the same length of silicon can resolve a smaller angle
- error(r-ϕ) should scale as cosϕ and not 1/cosϕ

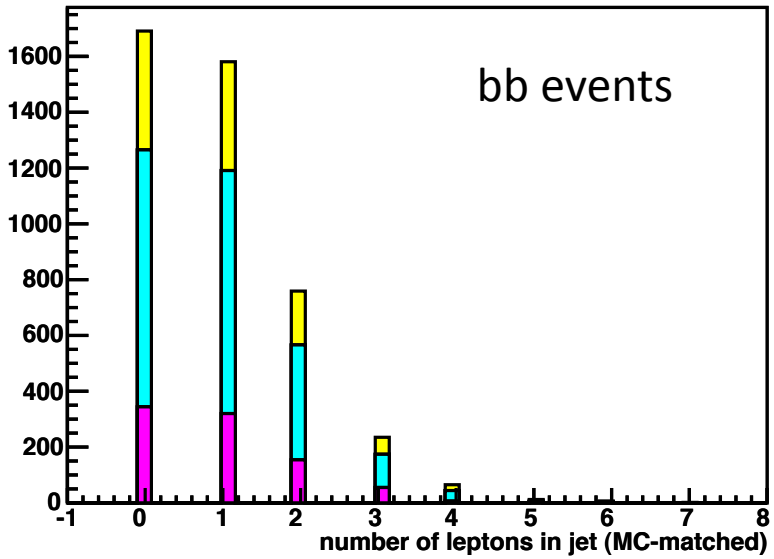
MC studies of jet topologies

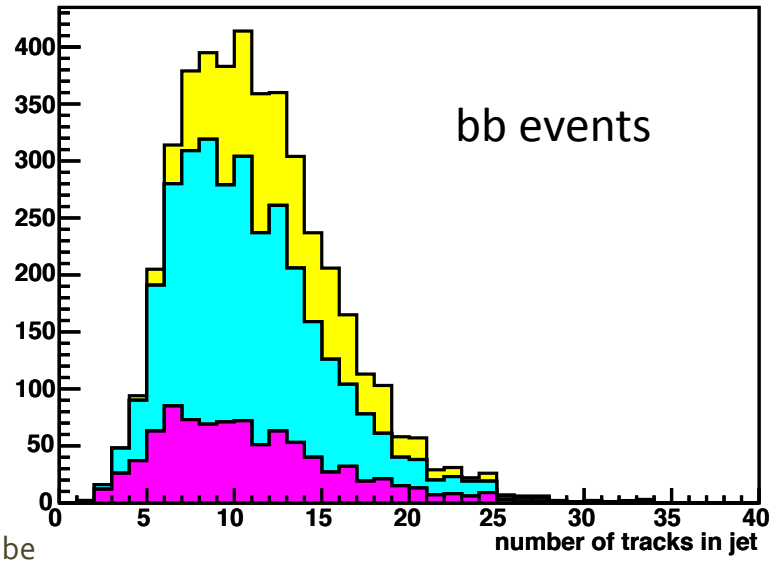
- the purpose here is to evaluate the performance of the vertex finding algorithms.
- for every track found to form a vertex, find its most immediate semi-stable parent (via MC information)
- the following particles have been classified as semi-stable:
  - b-hadrons: B^0, B^+, B_s^0, B_c^0, (Λ_b^0, Ξ_b^-, Ξ_b^0), Ω_b^-
  - c-hadrons: D^0, D^+, D_s^+, Λ_c^+, Ξ_c^0, Ξ_c^+, Ω_c^0
  - s-hadorns: K^0, K^+, Λ, Σ^+, Σ^0, Σ^-, Ξ^0, Ξ^-, Ω^-

secondary vertex

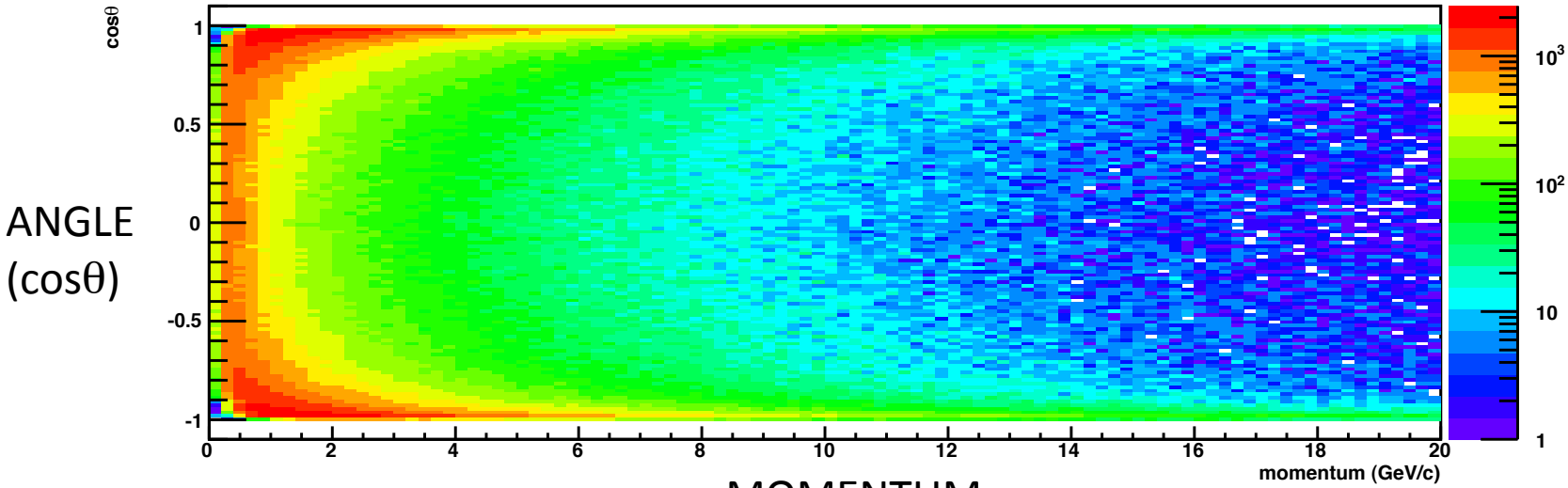


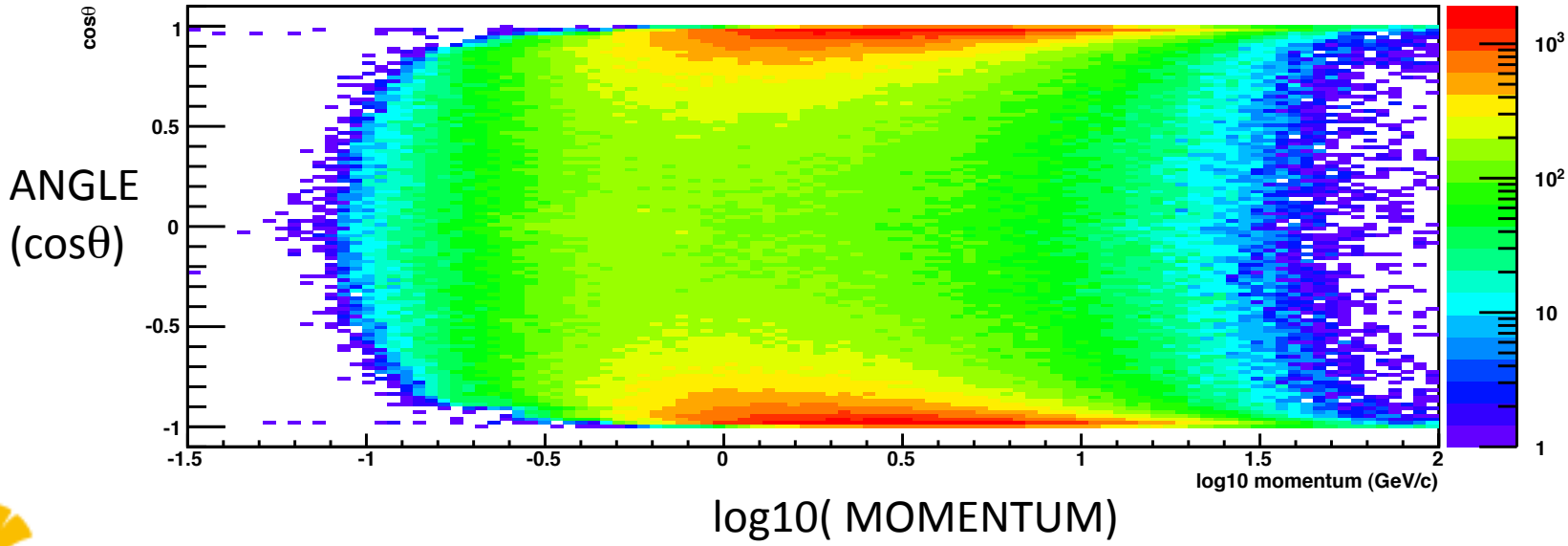






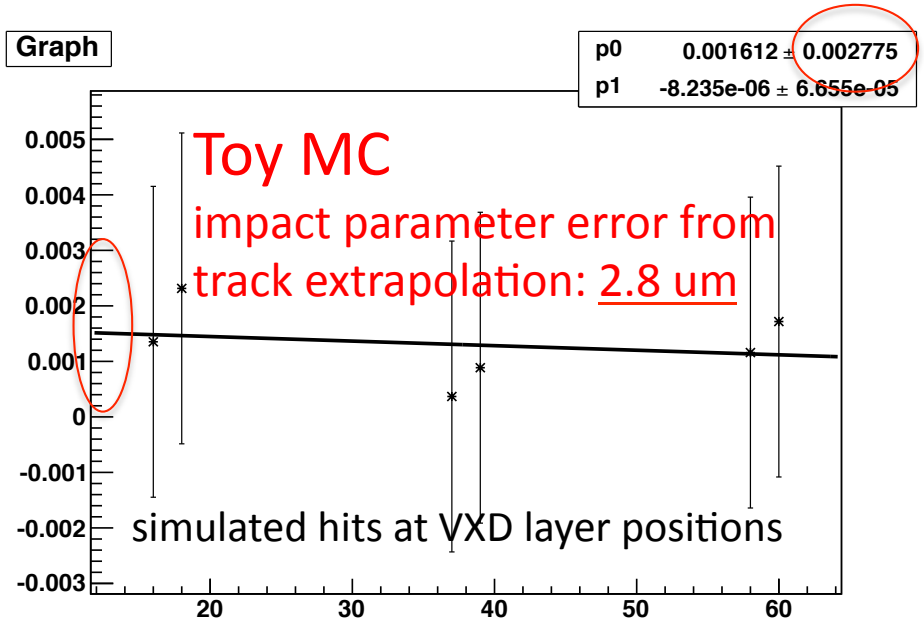
2d distribution

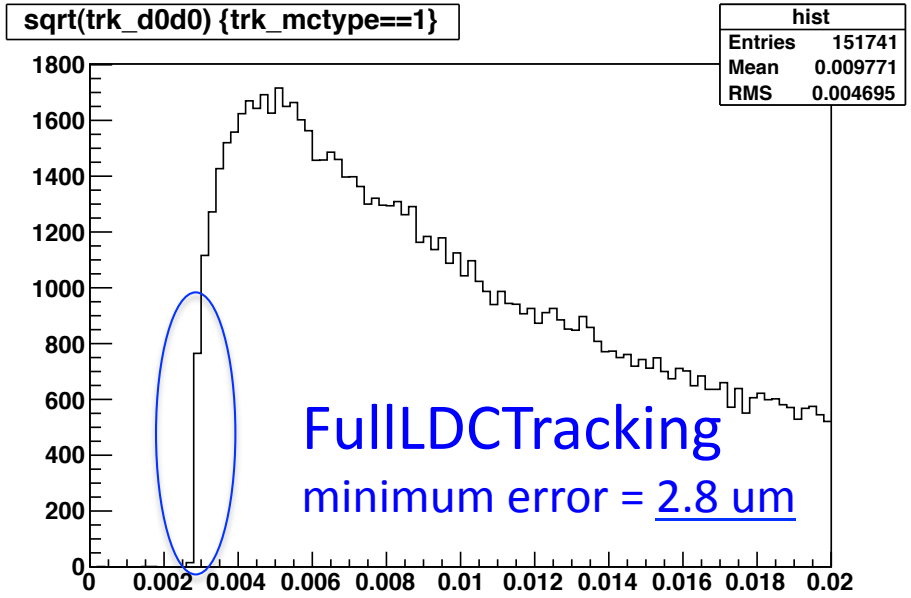




zpole sample + bb sample combined

check track extrapolation

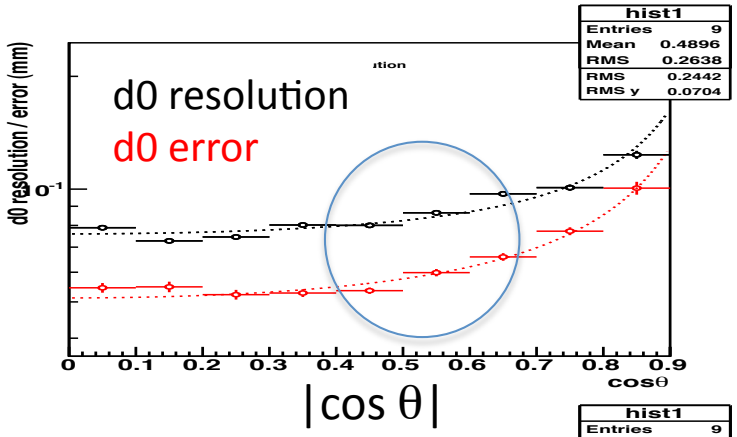


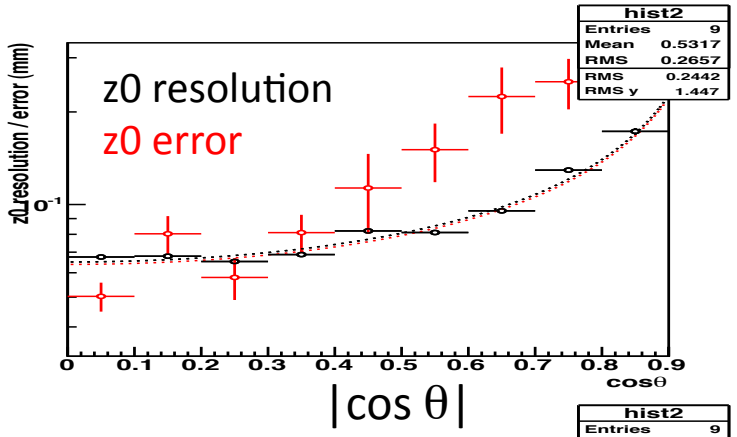


- minimum track errors from FullLDCTracking are consistent with toy MC
  - straight line fit -> corresponds to high momentum track with $|\cos\theta| = 0$
- must check momentum and angle dependence

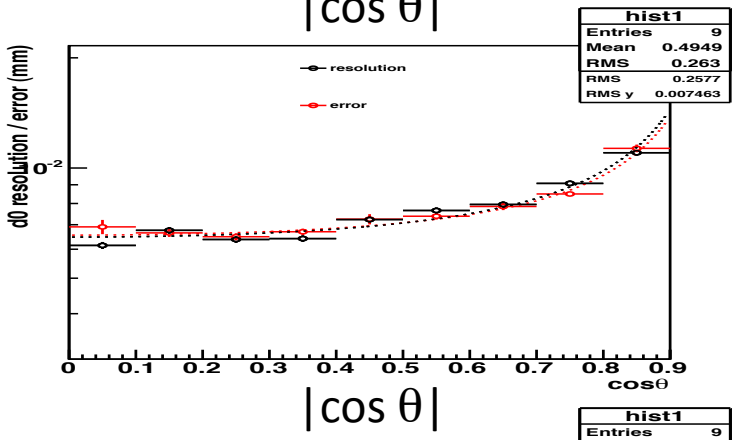
impact parameter: momentum dependence

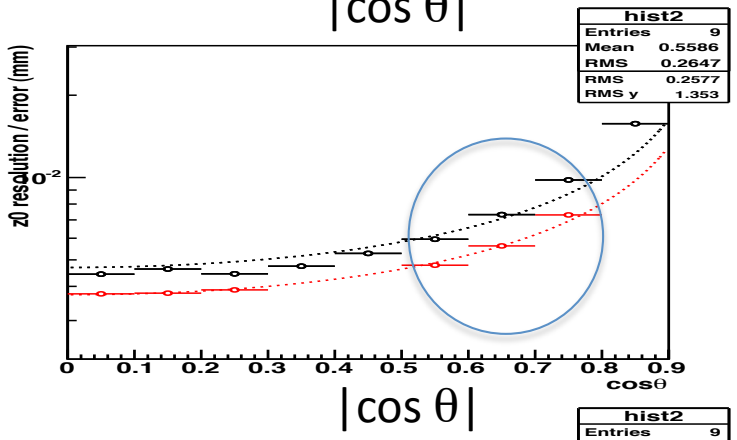
0.1 < p < 0.4 GeV



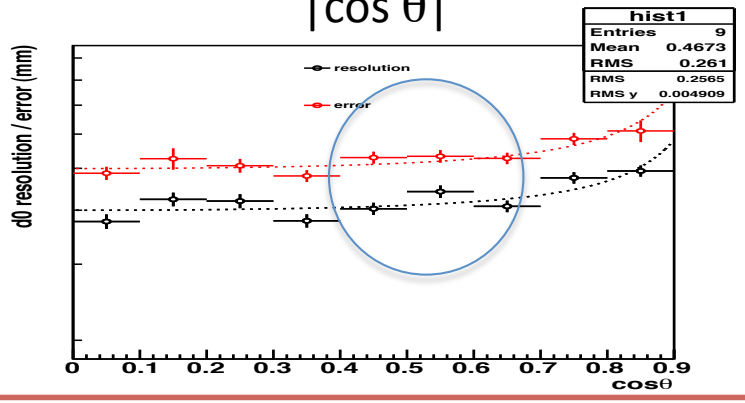


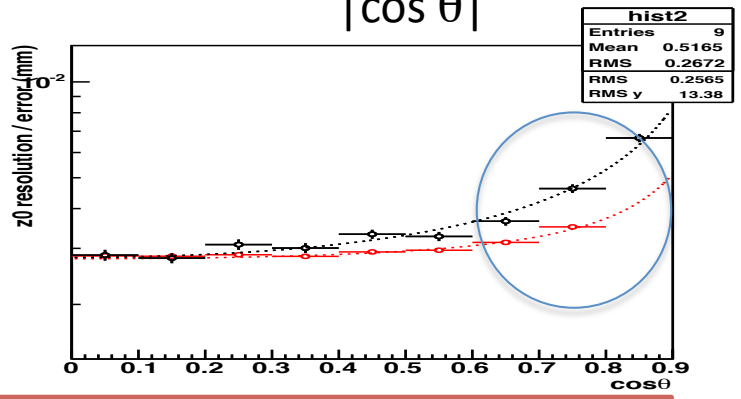
3 < p < 5 GeV





10 < p < 20 GeV

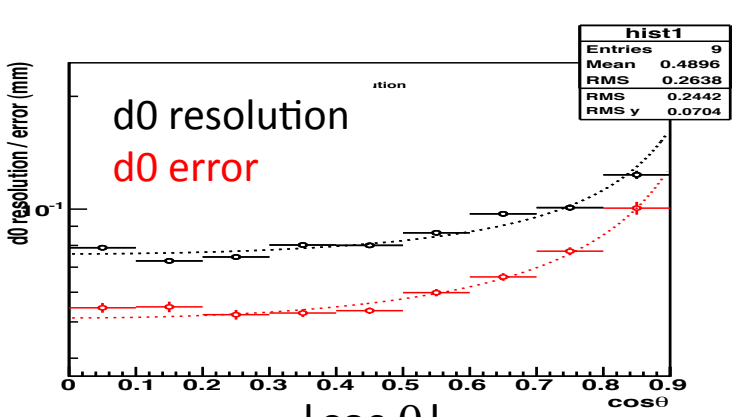


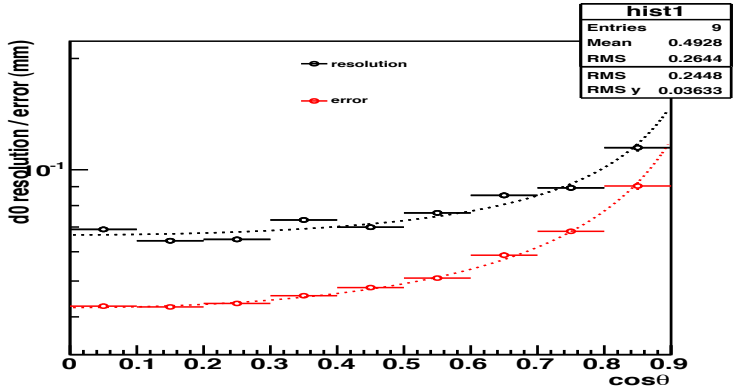


momentum dependence hints at inaccurate estimate of multiple scattering

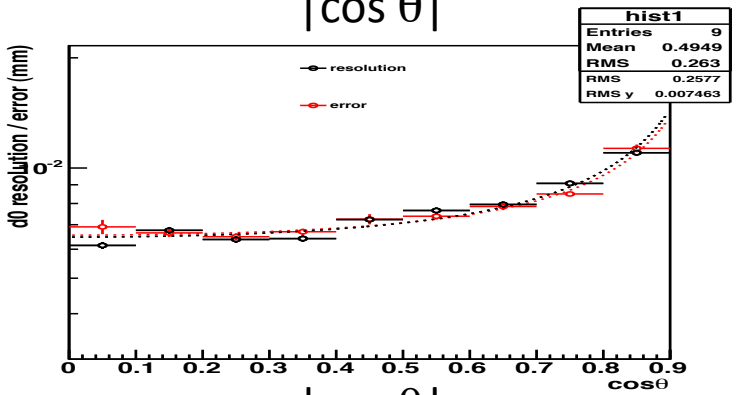
error calibration (3)

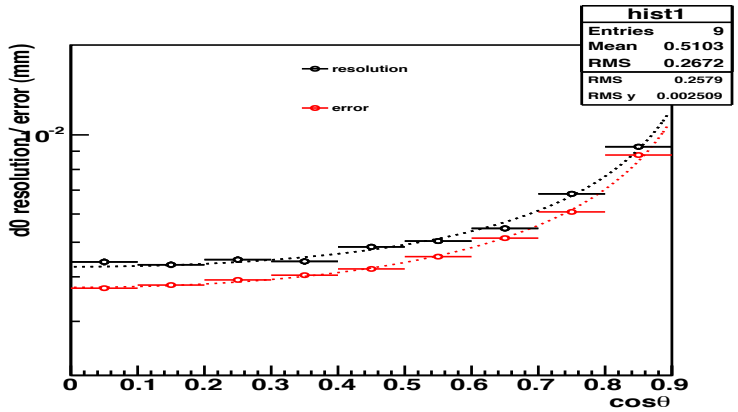
0.1 < p < 0.4 GeV



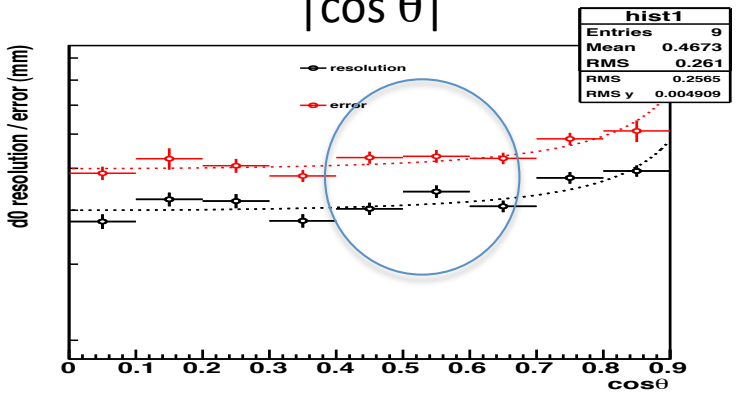


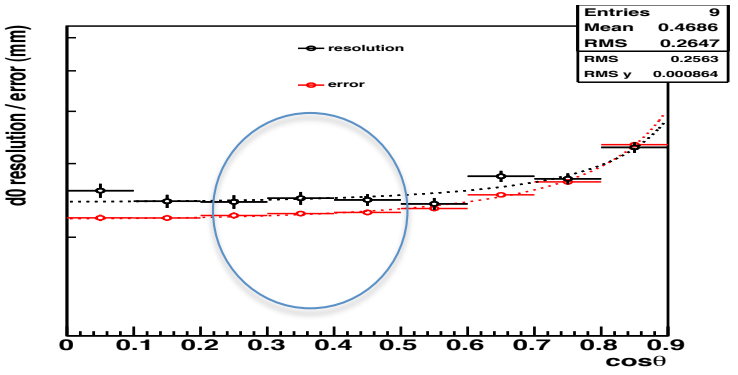
3 < p < 5 GeV





10 < p < 20 GeV





momentum dependence hints at inaccurate estimate of multiple scattering