Performance of FPCCD vertex detector

T. Nagamine
Tohoku University

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ACFA 9, IHEP ,Beijin

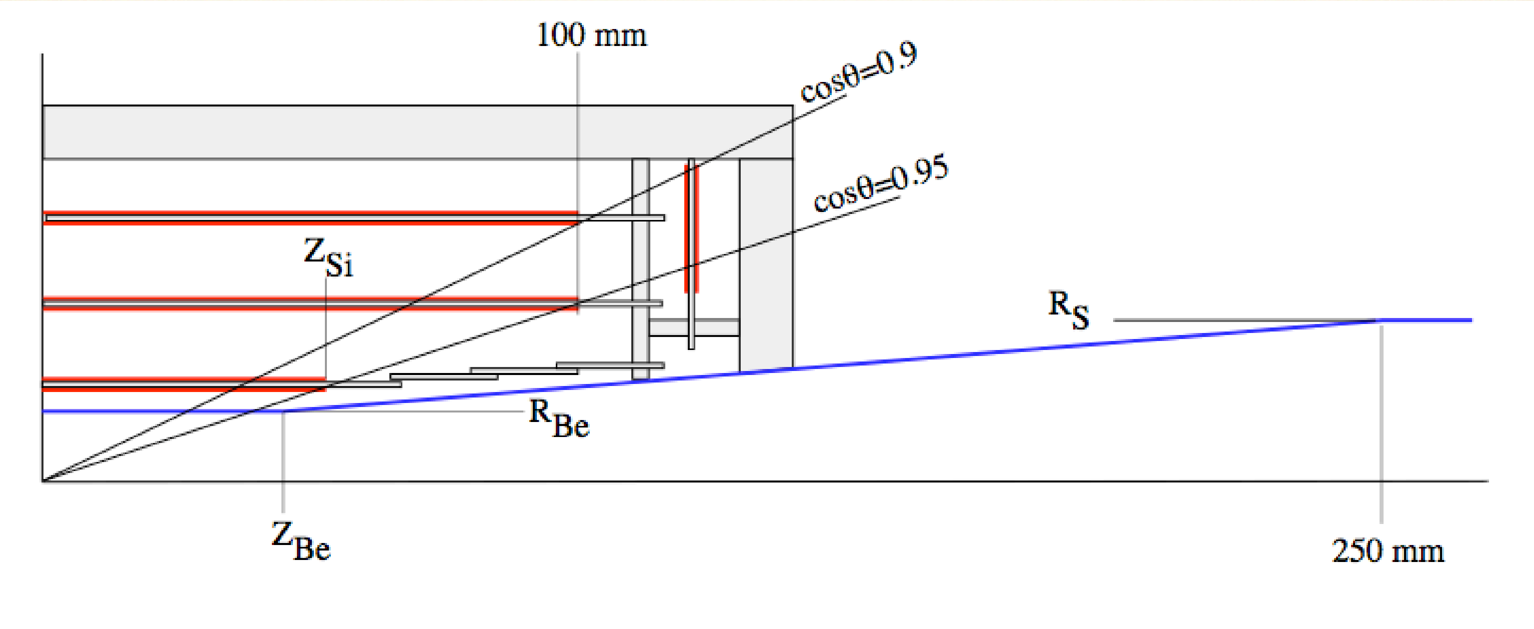
Outline

- FPCCD and Vertex Detector Structure
- Impact Parameter Resolution
- Pair Background in Vertex Detector
- Track finding/fitting in Vertex Detector
- Cluster Shape Analysis
- Energy Loss in Thin Material

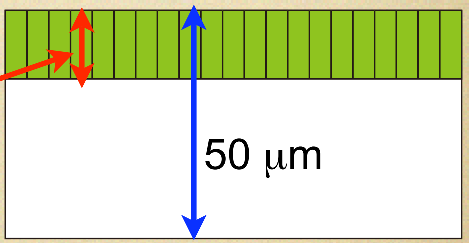
FPCCD features

- Large area device fabrication can be made
  -> small dead area between sensors on ladders
- Fully depleted -> Less smearing
- Very small pixel size
  -> good hit position resolution (~ 2 μm)
  -> Less occupancy
- No charge transfer during a bunch train
  -> Avoid EM noise from beam
- Very thin (a few 10 μm)
  -> Less Multiple scattering, but small signals
- High back ground hit rate accumulated (~ 40 hits/mm^2/train)
  -> Need good background rejection and tracking method

Structure of Vertex Detector

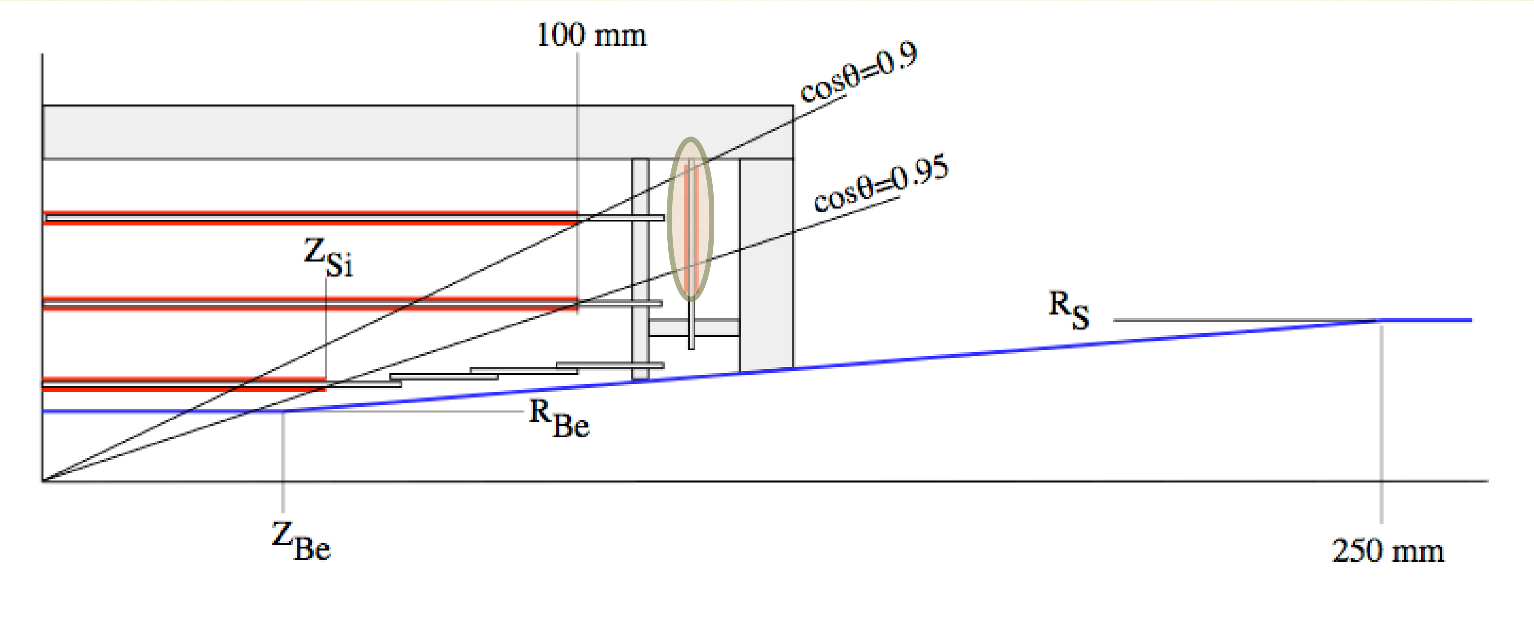


- 3 doublets structure
- Silicon thickness : 50 μm ($0.53 \times 10^{-3} X_0$)
- Depletion layer thickness : 15 μm
- Pixel size : 5x5 μm



CCD Cross Section

Structure of Vertex Detector



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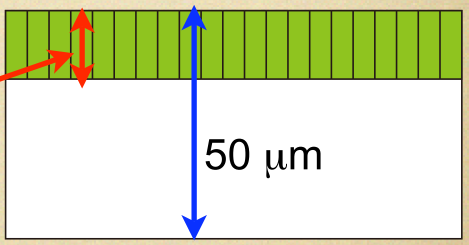

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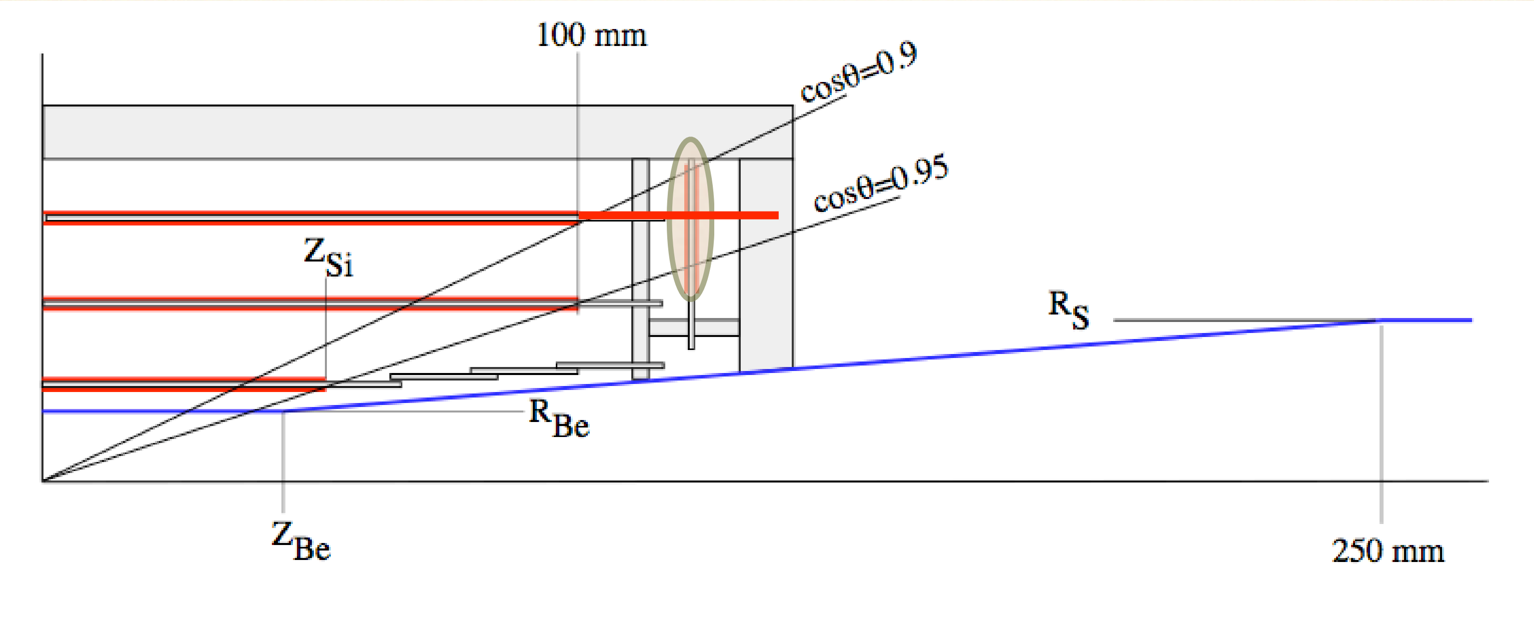

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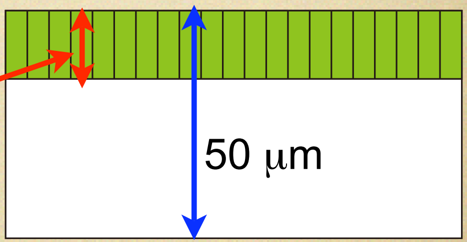
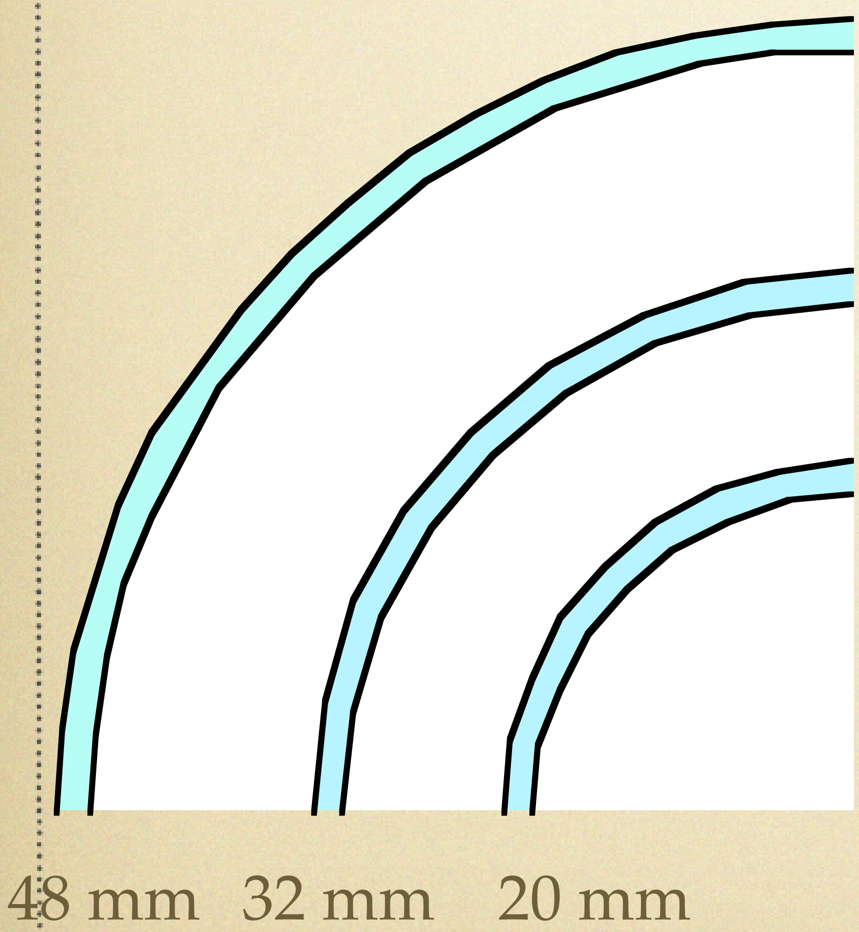


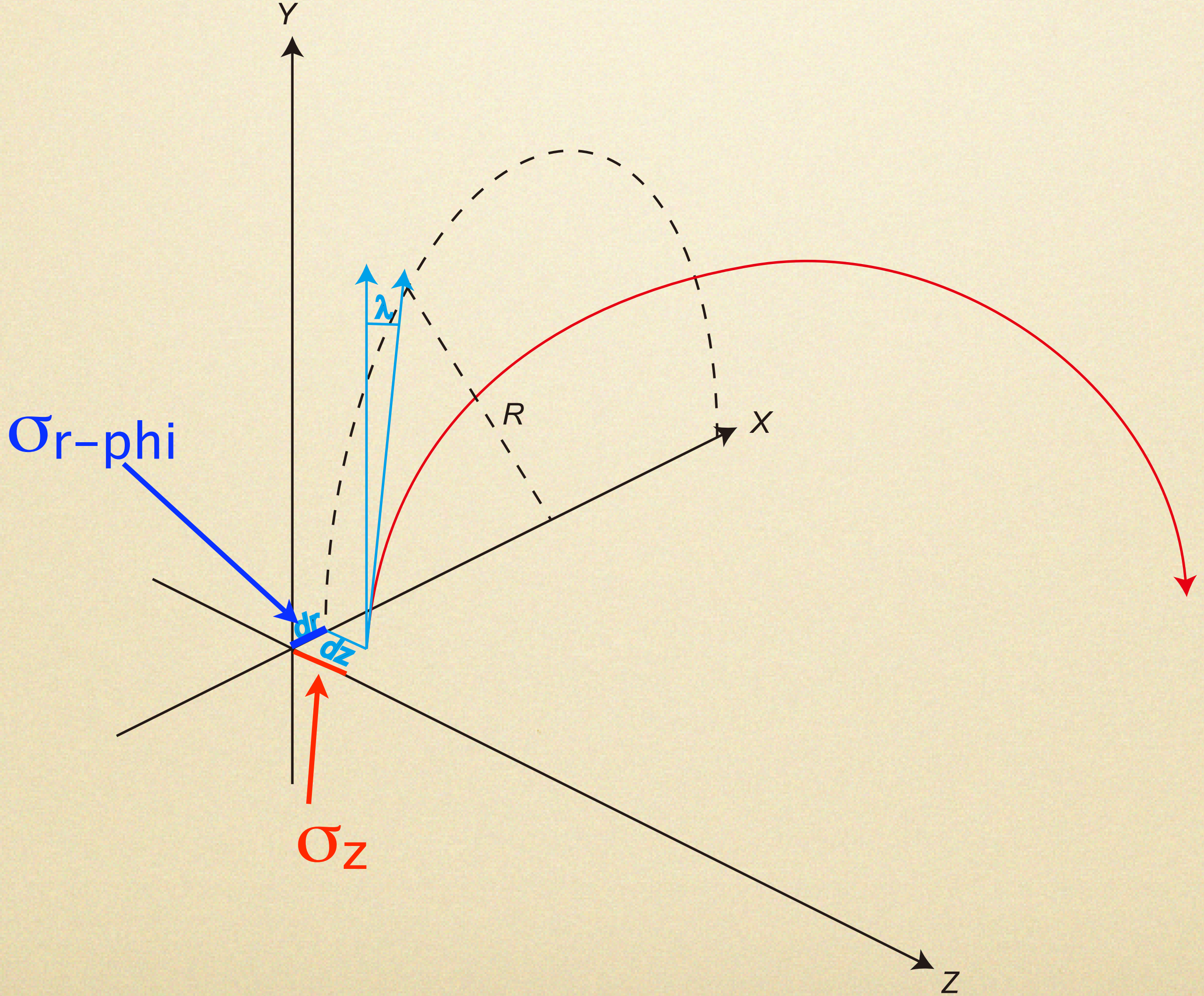
CCD Cross Section

Geometry for Simulation Study

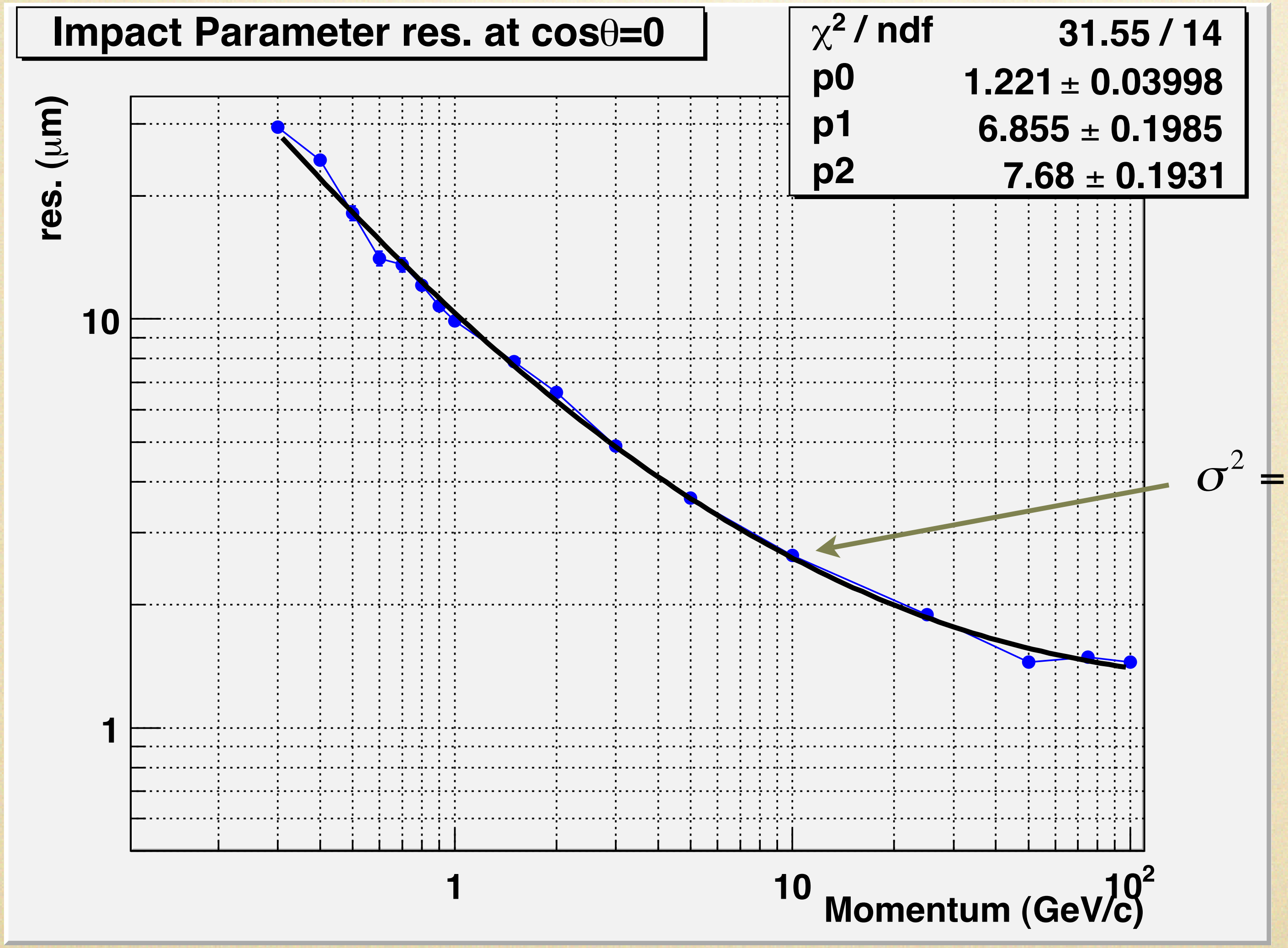


- Tube shape used as each layer
- Layer thickness : 80μm
- 50μm for CCD , 30μm for Support Material, Air used for gaps
- 2 mm separation for each doublet
- 3 configurations are studied
- Doublet 1 : R= 20 mm
- Doublet 2 : R= 32 mm
- Doublet 3 : R= 48 mm
- Hit position resolution: 2μm
- Beam Pipe : Be, t=250μm, R=18mm

Impact Parameter Study and Helix Parameter

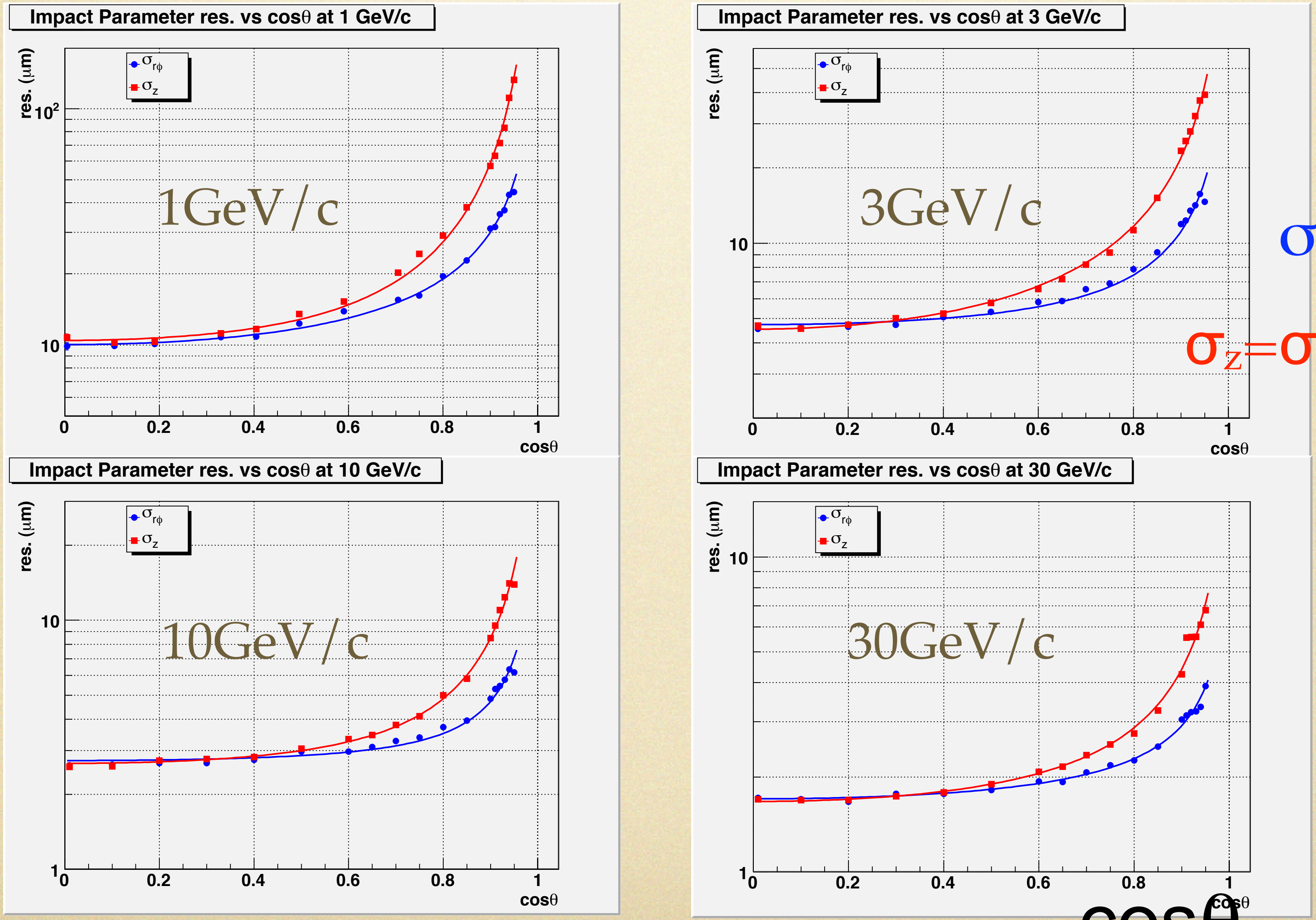


Impact Parameter Resolution σ_{r-phi} Momentum Dependence



$$\sigma^2 = \sigma_0^2 + \frac{\sigma_1^2}{p} + \frac{\sigma_2^2}{p^2}$$

Impact Parameter Resolution
cosθ dependence at 1,3,10 and 30 GeV/c

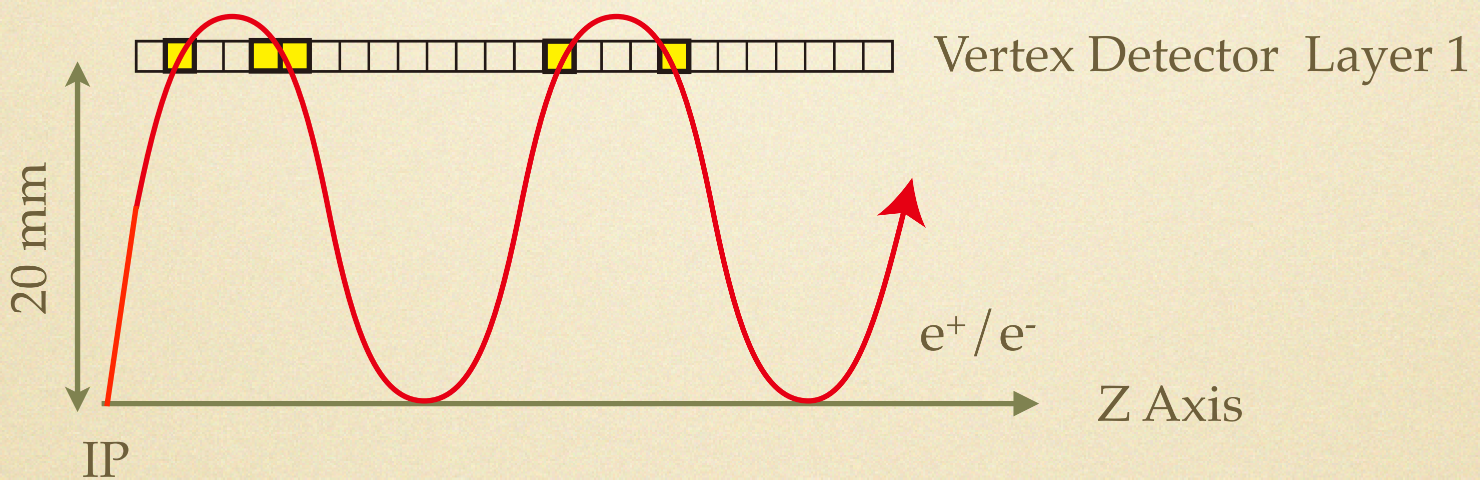


σ_{r-phi}

$\sigma_z = \sigma_{r\text{-}z} / \sin\theta$

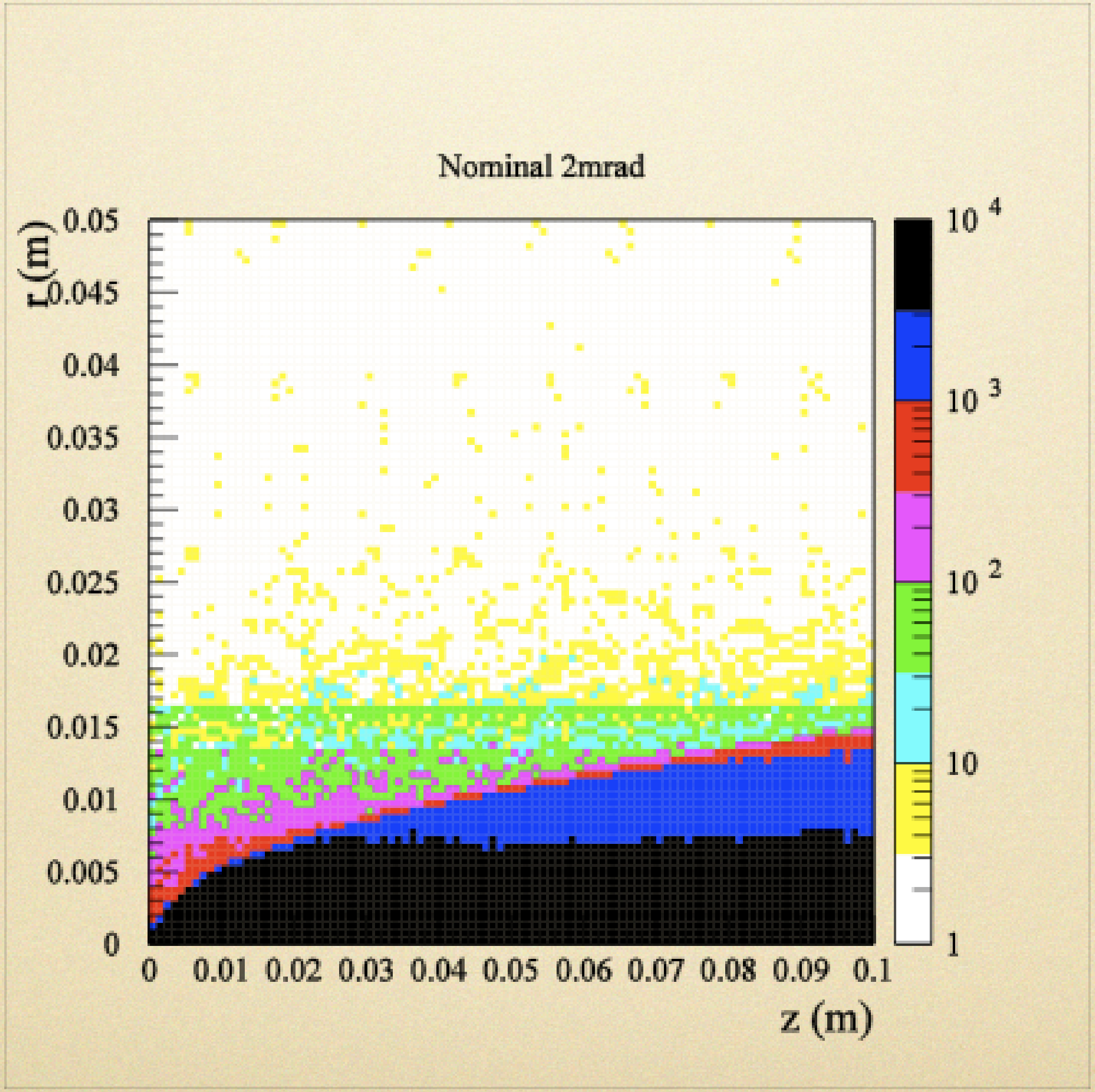
cosθ

Pair BackGround Trajectory



- Pair Background(e+/e-) have low-Pt
- Their Radii are small
- They hit the vertex detector many times

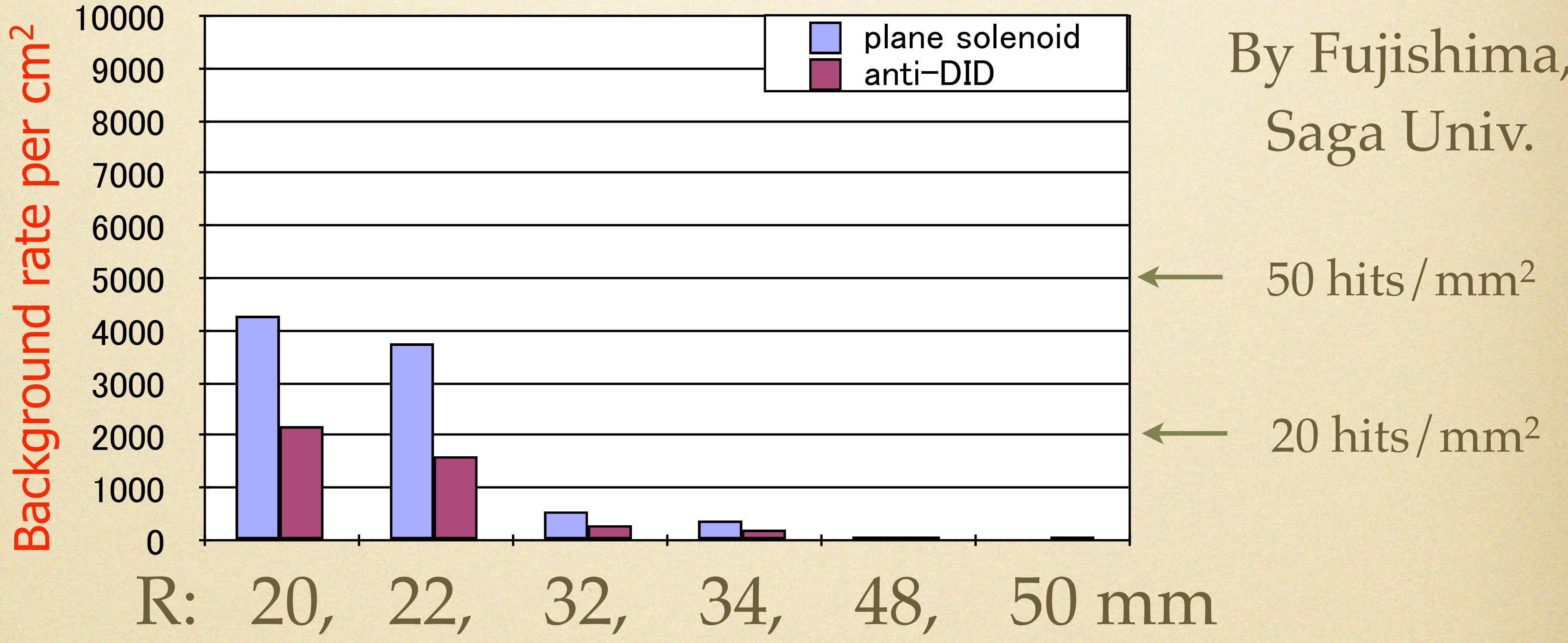
Distribution of Pair Background in Vertex Region



B=3T

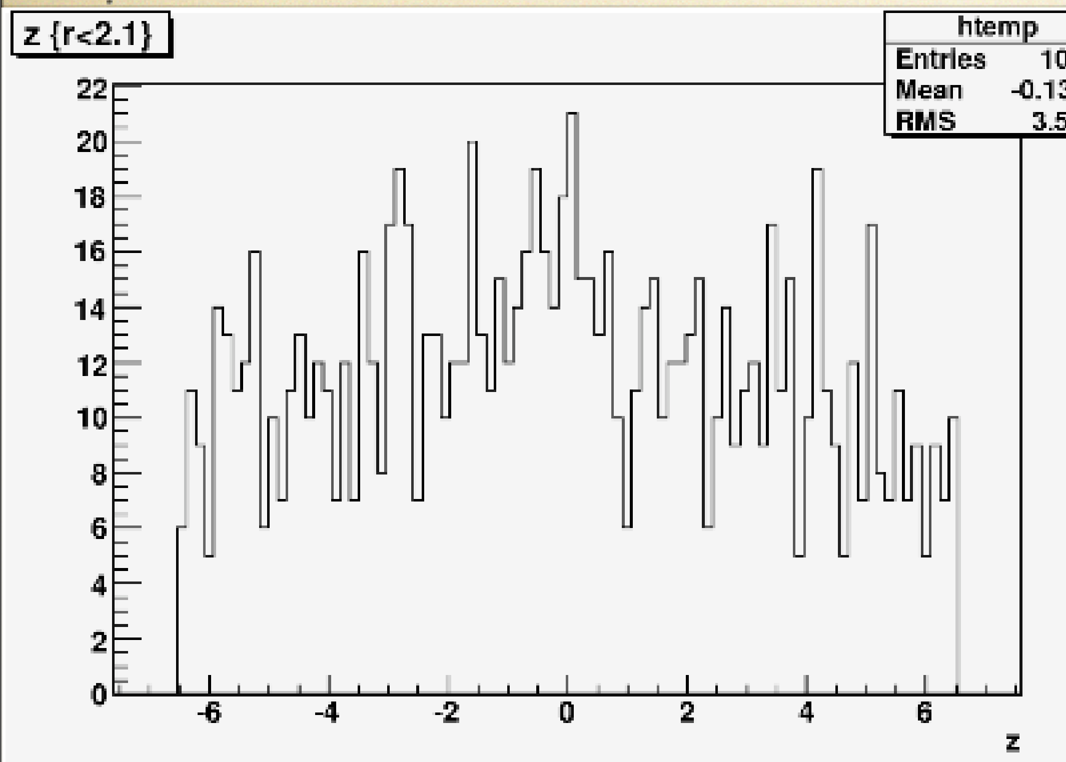
By Sugimoto

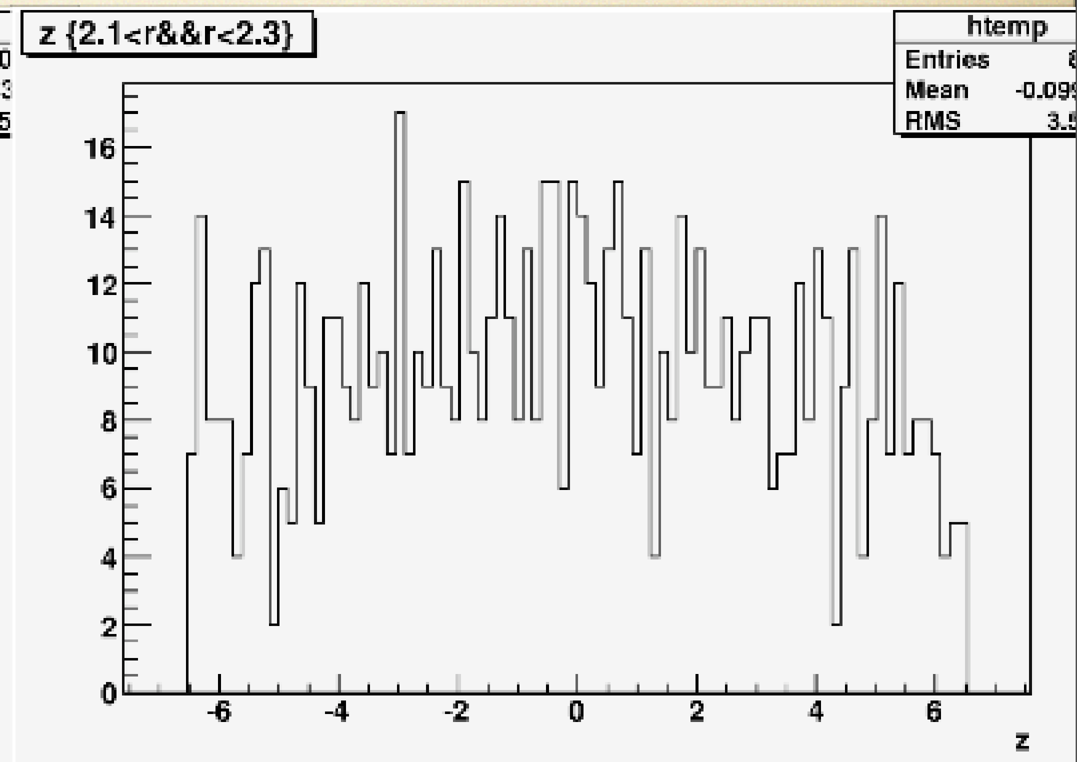
Background rate
Plain vs. anti-DID in VTX



- CAIN/Jupiter/Geant4 results
- Beam Parameter: nominal 500GeV, 14mrad
- Background rate is reduced to 1/2 with ANTI-DID Field

z distribution of VTX hits





Layer 1 **Layer 2**

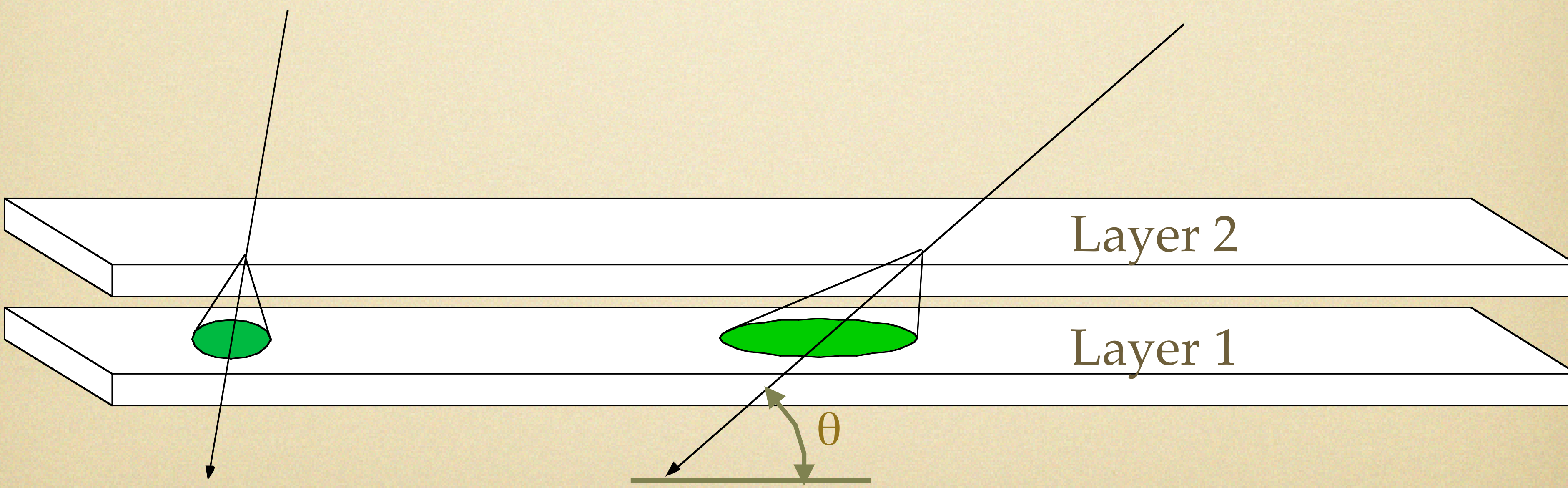
Small Z dependence

By Fujishima

Track Finding

- Track Finder is under development in SimTools!
- Efficiency depends on hit probability in track finding window.

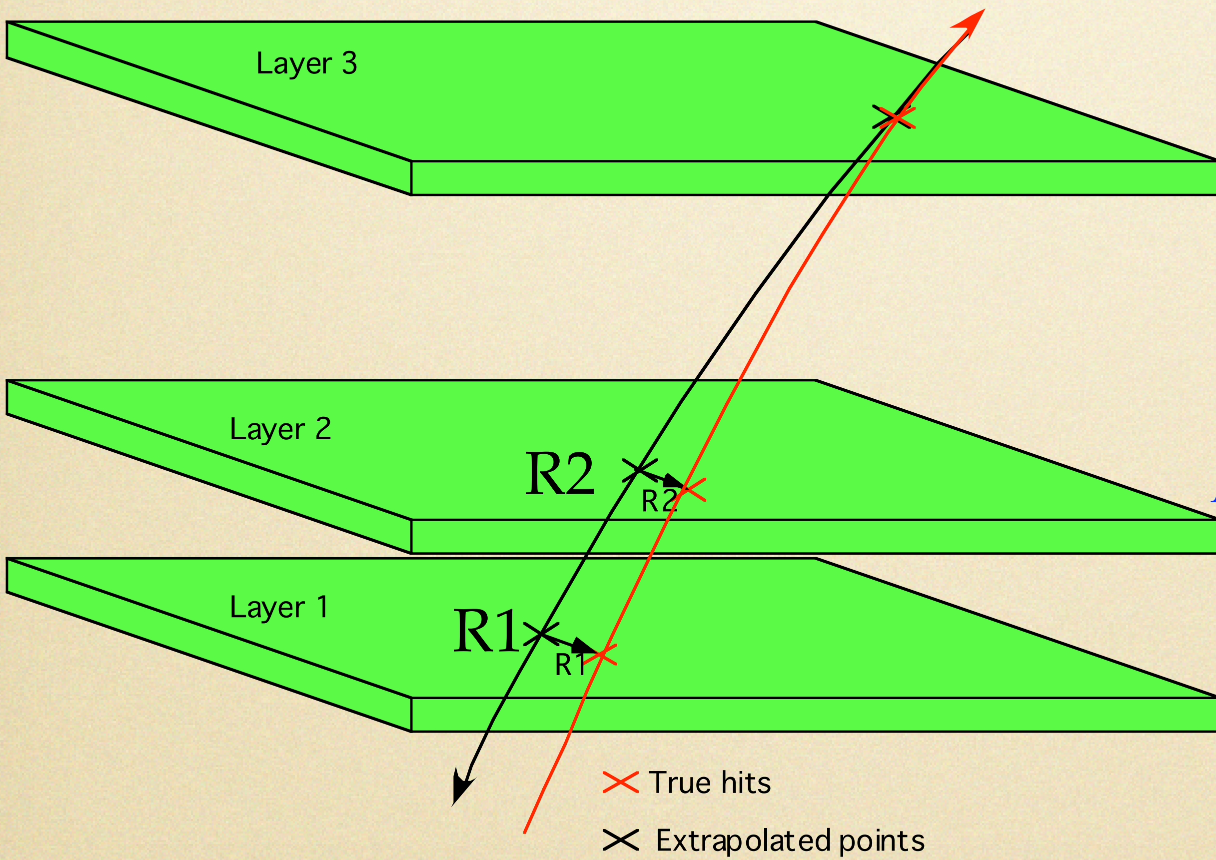
- Track finding window(area) from impact parameter resolution at the layer
- Area depends on polar angle of track as $1/\sin^4\theta$



Effect of Background on Track Finding

- Estimate track-hit matching efficiency using Toy MC
- Generate a true hit around a track with distribution functions obtained by Full MC
- Generate Background hits randomly around the track ; 50, 100 and 200 hits/mm^2
- Accept the true hit closer to the track than background hits
- Ignoring finite pixel and cluster sizes

Track-Hit Matching Efficiency



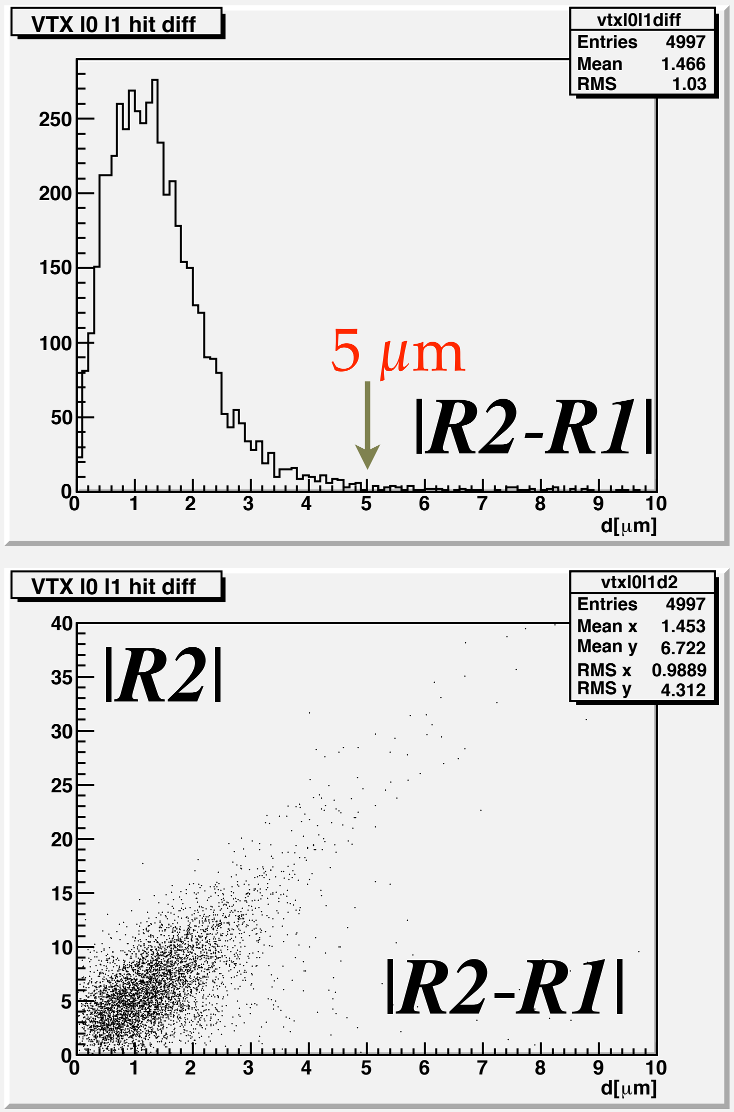
Doublet 2

Track is Fitted using TPC, SIT and Outer Layers of Vertex

Layer 1&2 Hits is not used

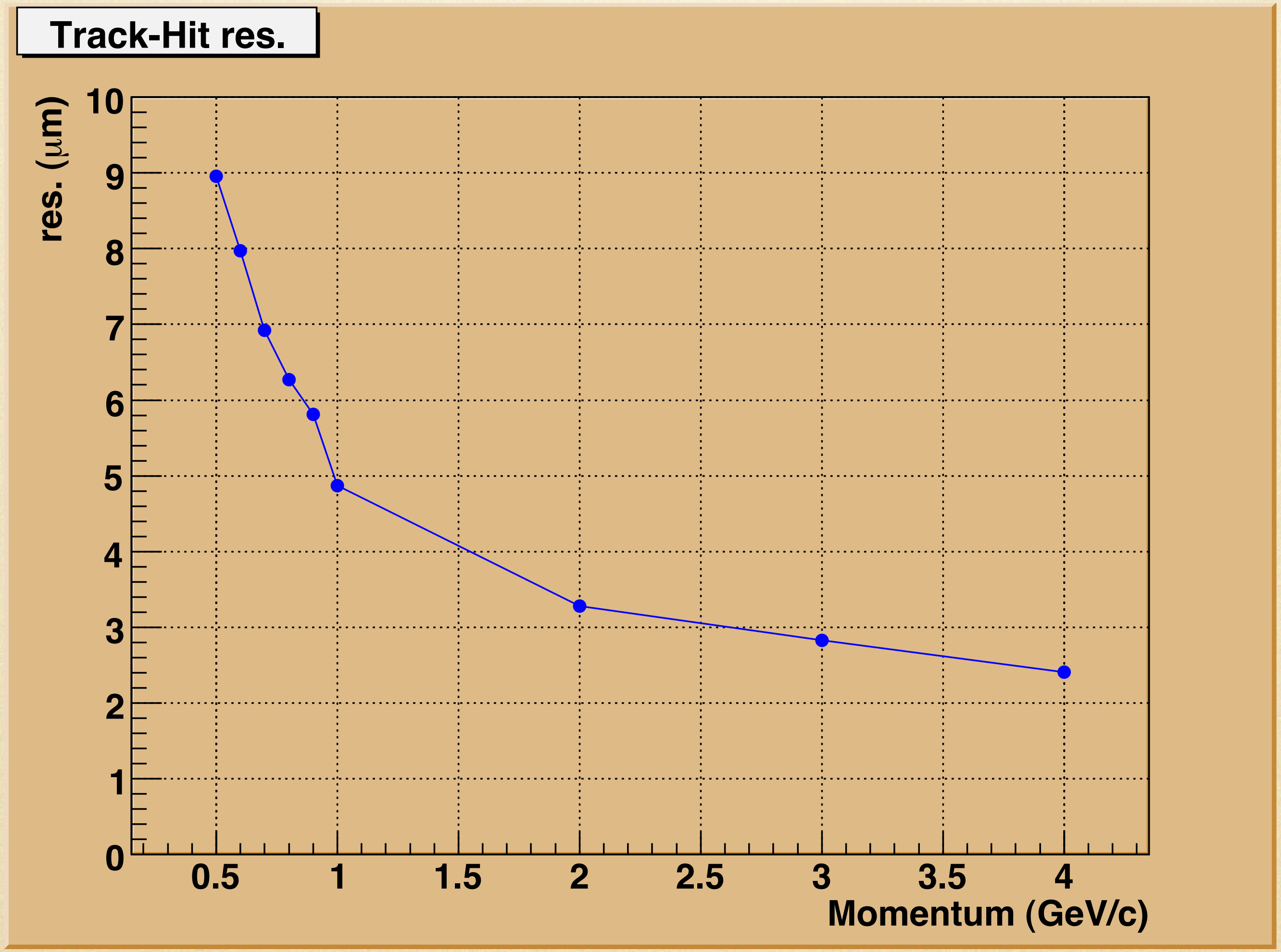
Doublet 1

Track-Hit differences distributions



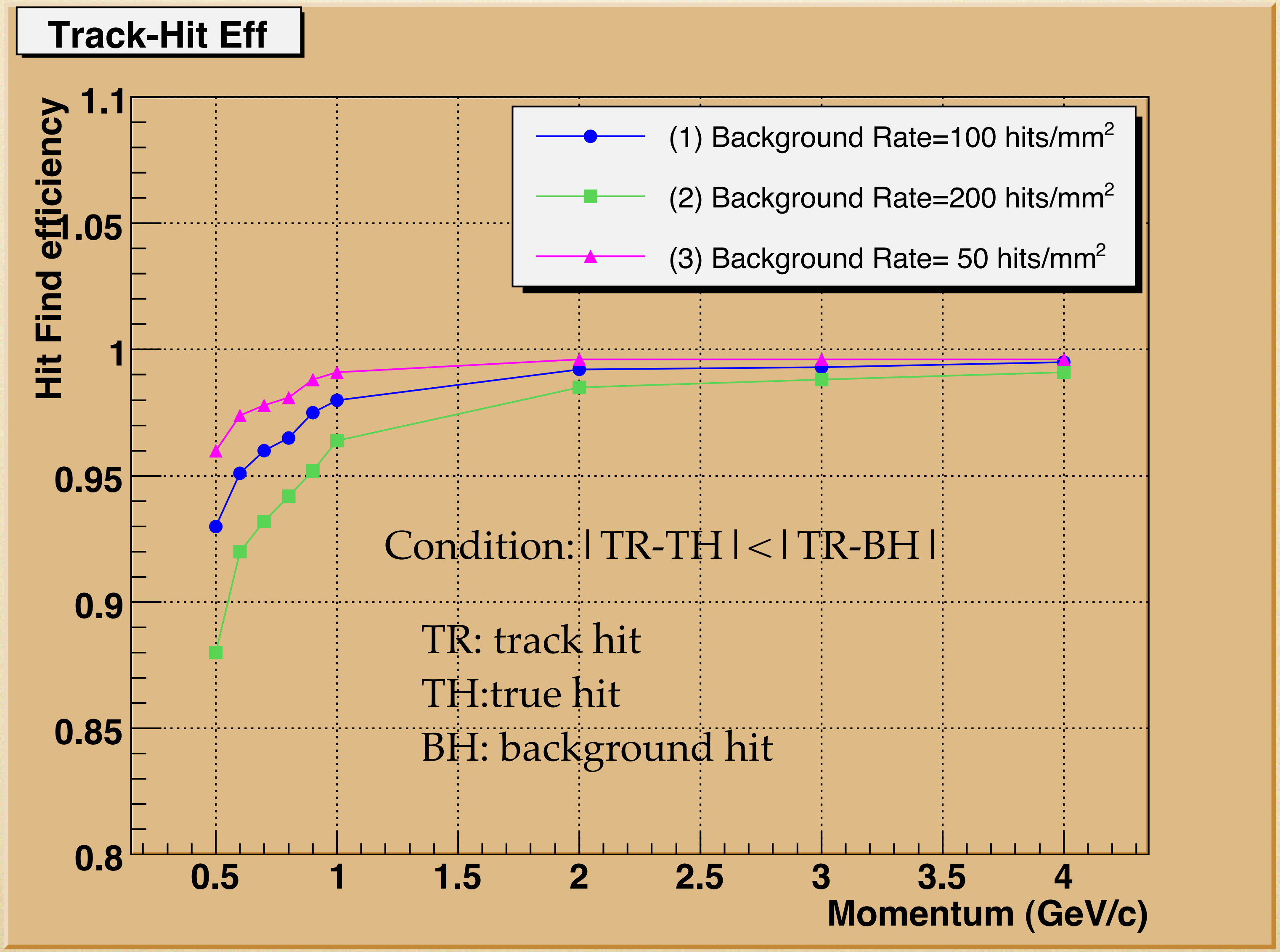
Muon
1 GeV/c
COSθ=0.05

|***R2***| resolution v.s. Momentum



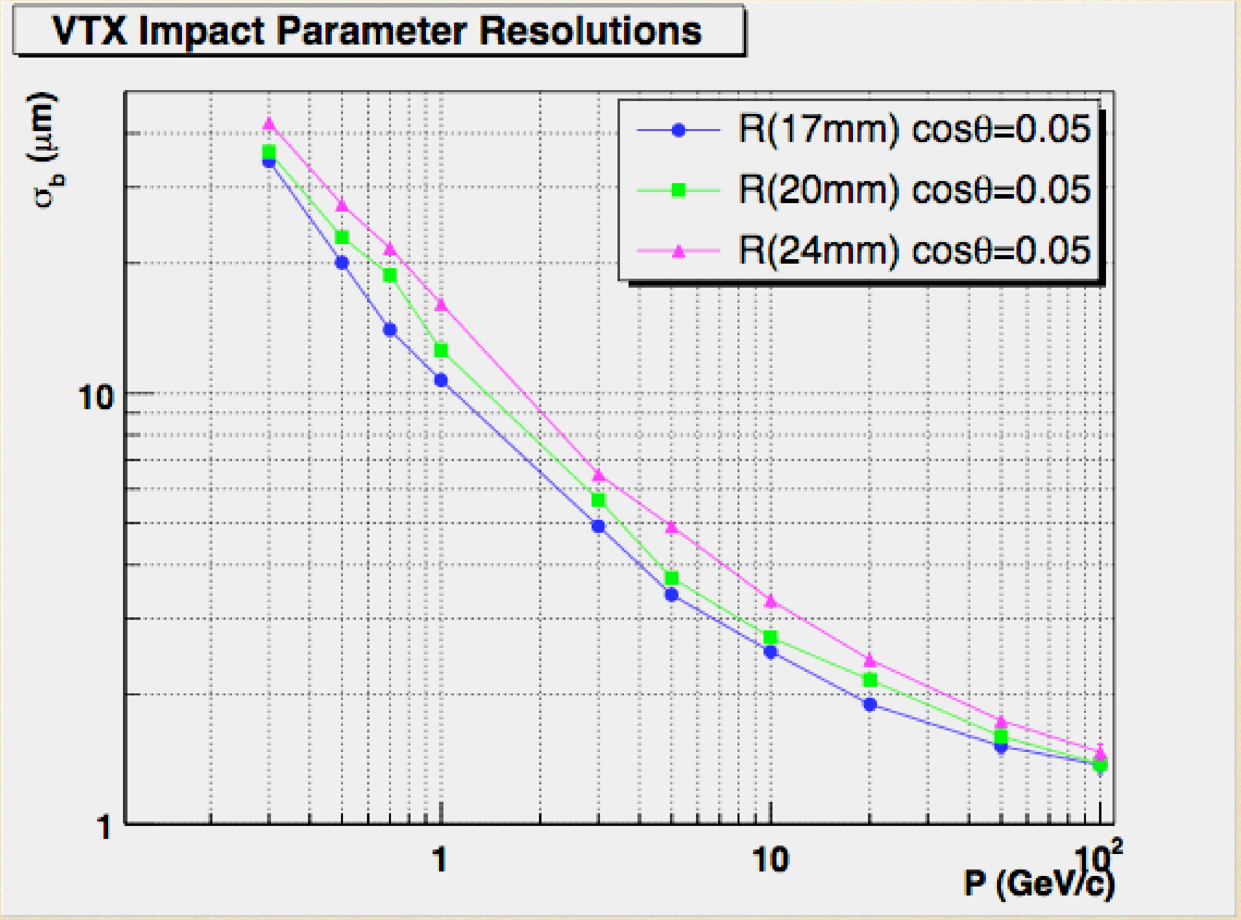
~ 1/3 of Impact Parameter Resolution at IP

Efficiencies for different hit rates



- FPCCD based Vertex Detector can work under hit rate up to 50 $/mm^2$
- The reasons:
  - Good Outer Tracking detector - SIT and TPC
  - Vertex has 6 Layer - 4 layer can use for extrapolate to inner most layer
  - Vertex detector layers are very thin
  - Small pixel size which matches to the resolution

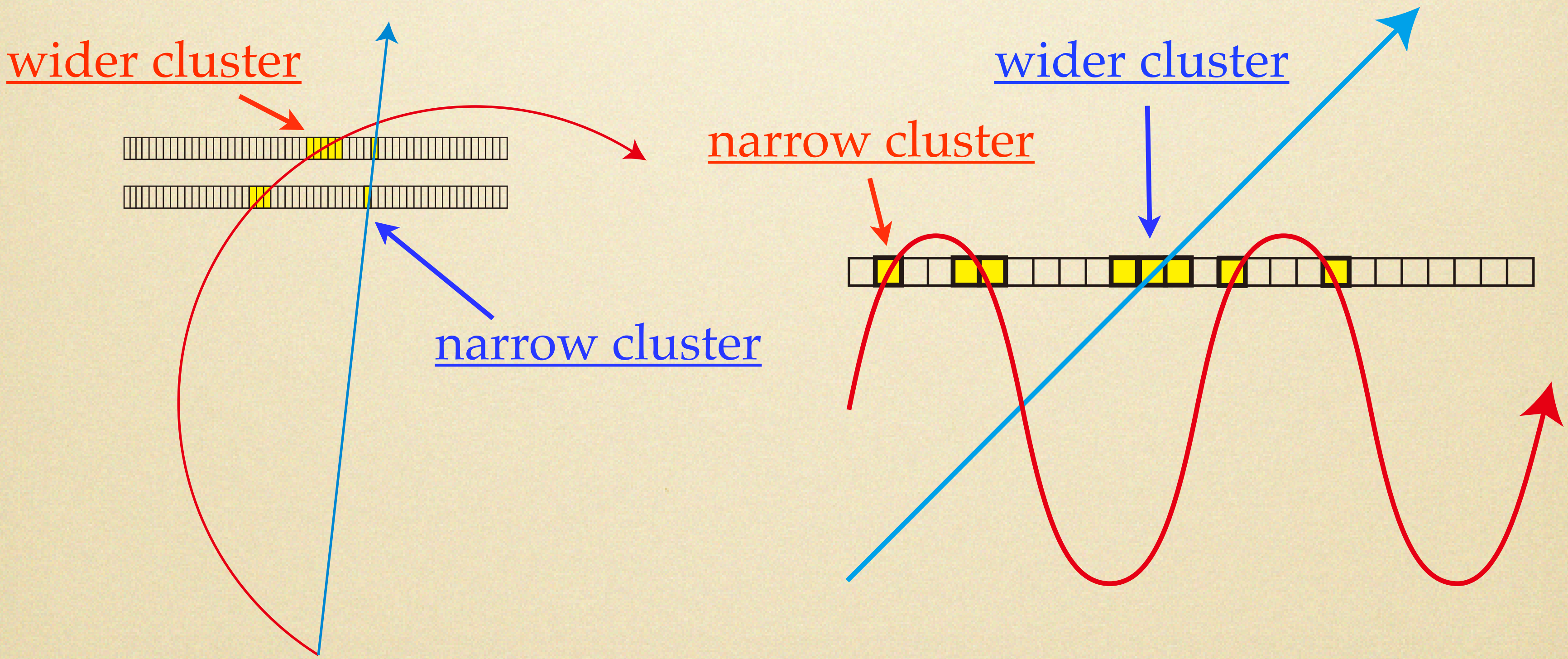
Impact Parameter Resolution R dependence (OLD Geometry)



- Impact Parameter Resolution(R-phi plane) v.s. Momentum
- μ^- at cos(θ)=0.05
- Impact Parameter Resolution increases as radius increases

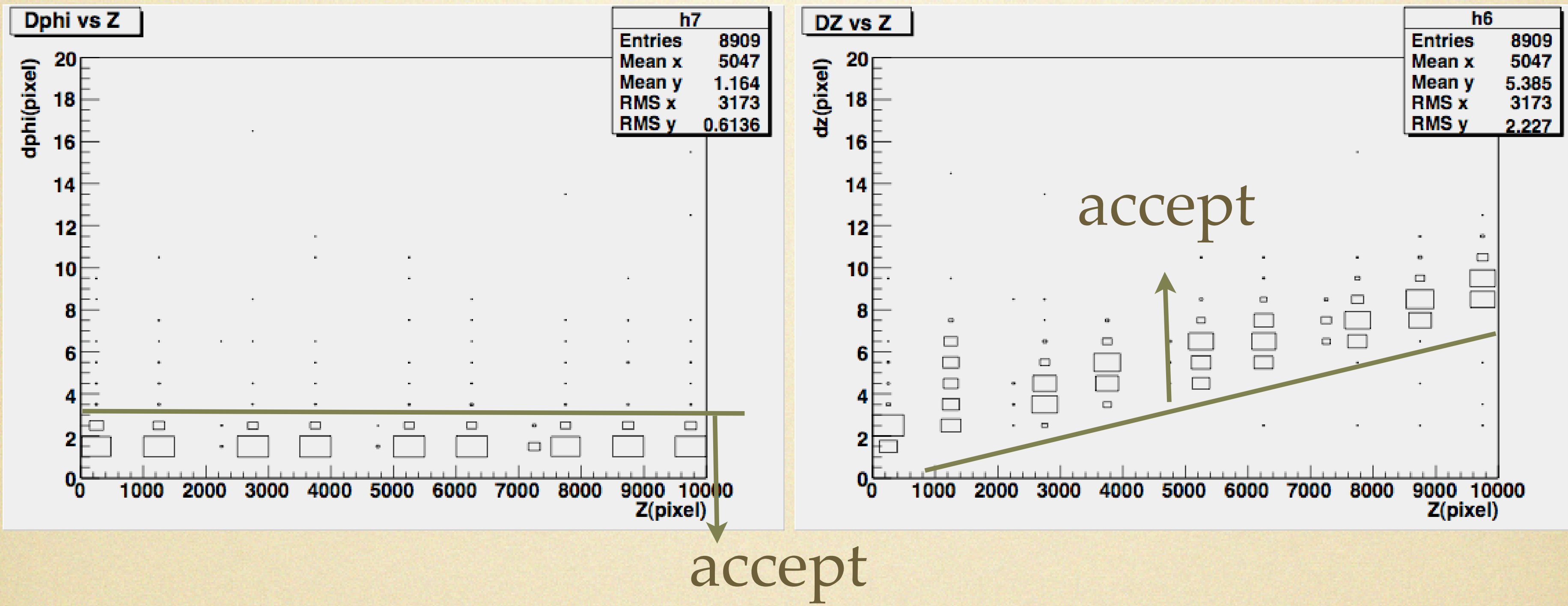
Cluster Shapes for Low-Pt and High-Pt tracks

RED: Low-Pt Track (Pair Background)
BLUE: High-Pt Track



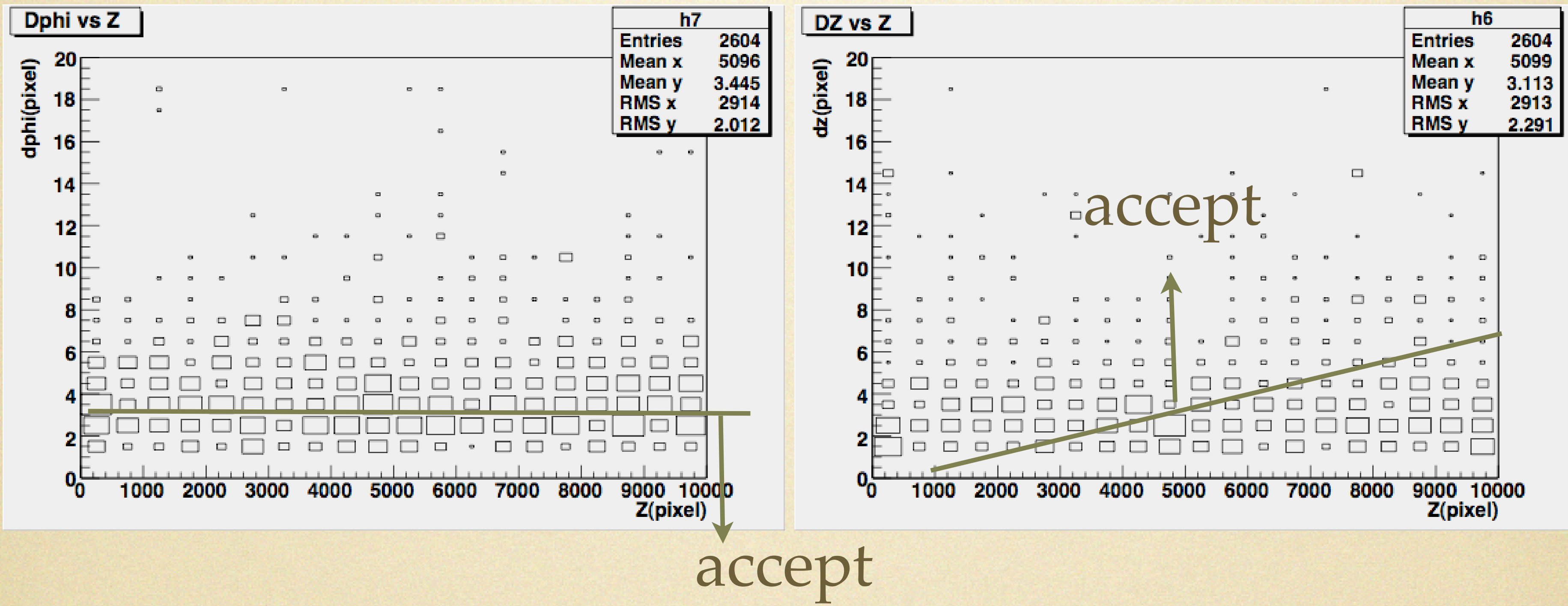
R-Phi Plain R-Z Plain

Distributions of Cluster Width v.s. Z for Muon Tracks



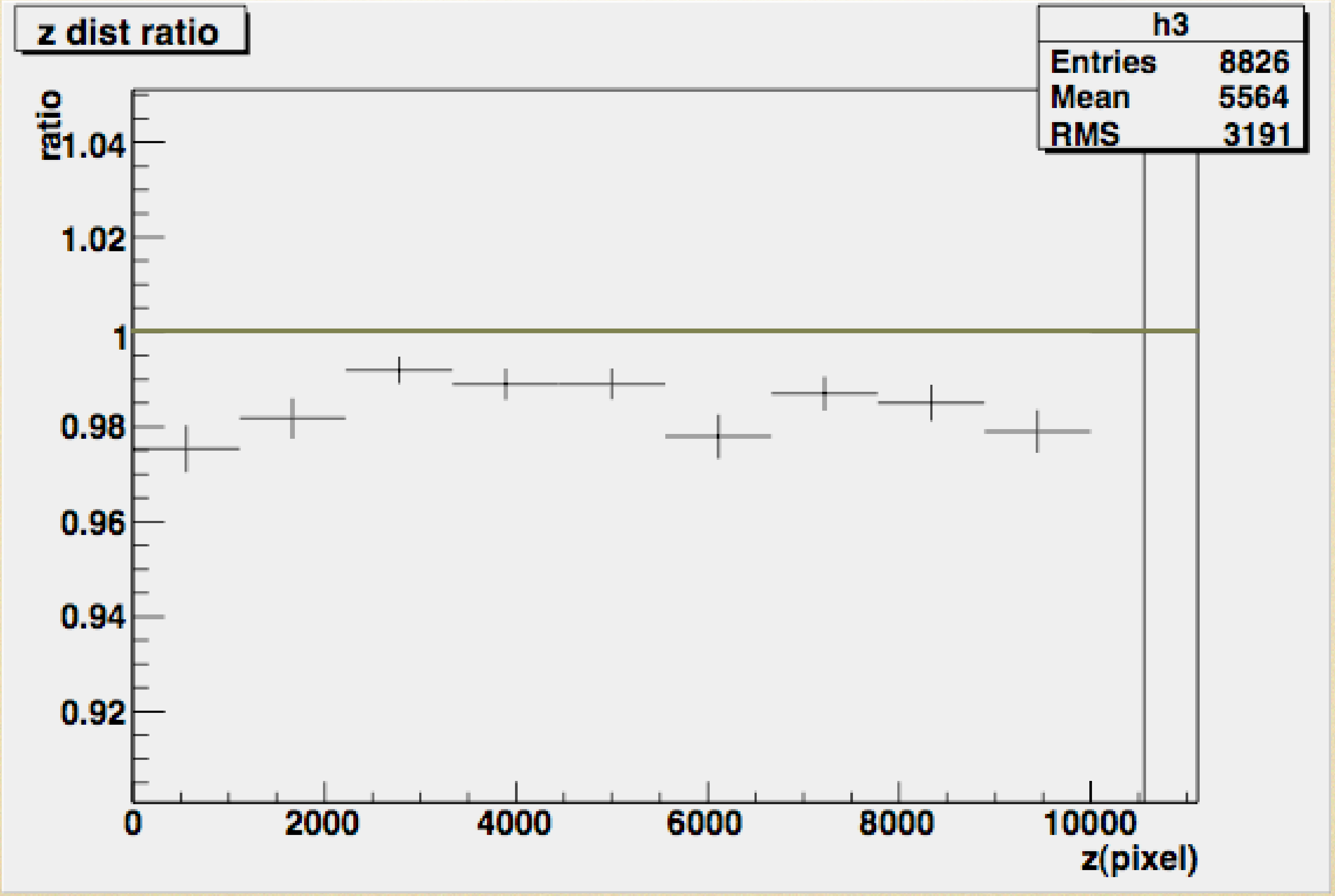
- 1 GeV/c μ^-
- Left: R-Phi, Right: R-Z
- Clear Z dependence of Cluster Width in R-Z

Distributions of Cluster width v.s. Z for Pair Background



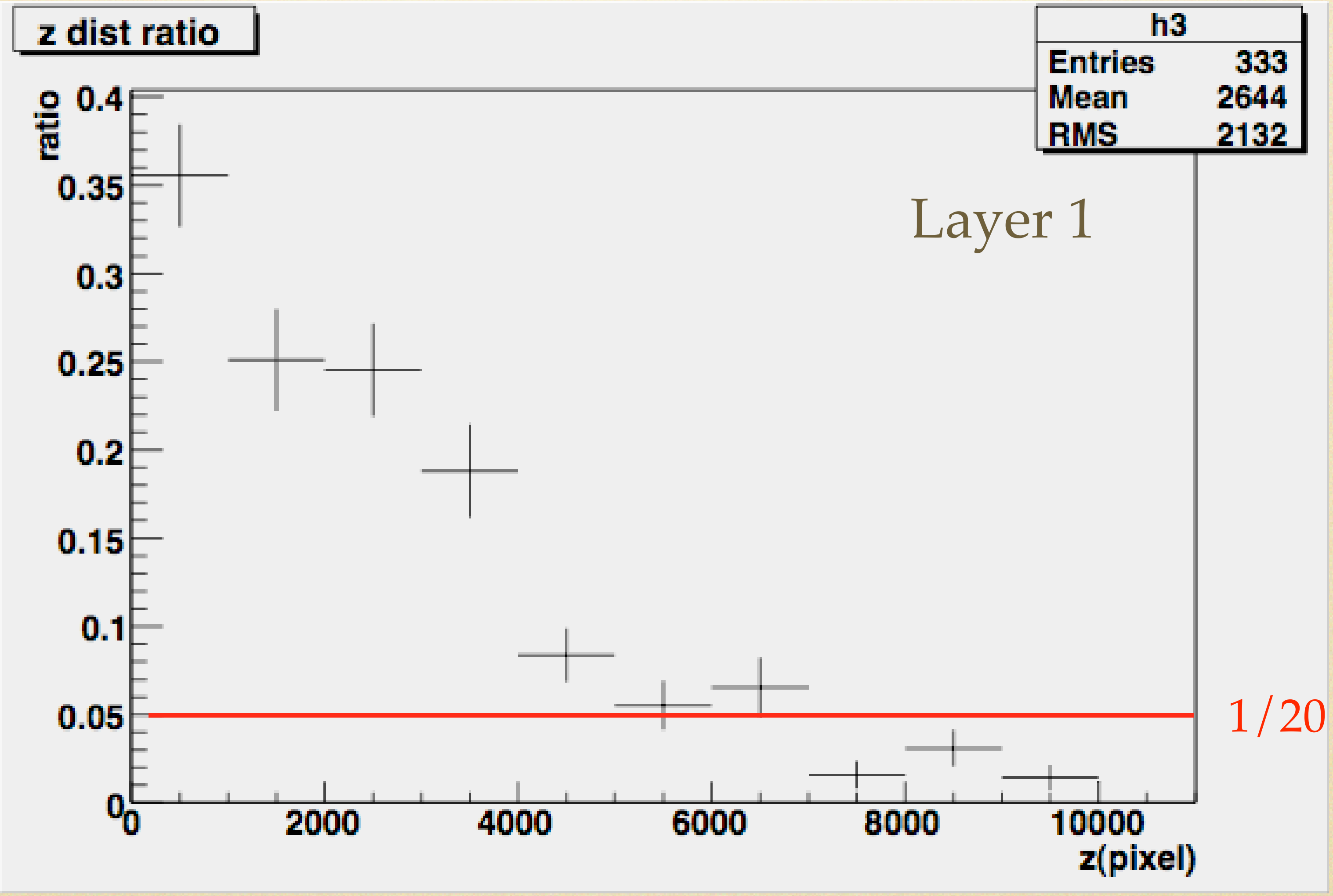
- Pair background
- Left: R-Phi, Right: R-Z
- No Z dependence in both R-Phi and R-Z

Efficiency for Muon track



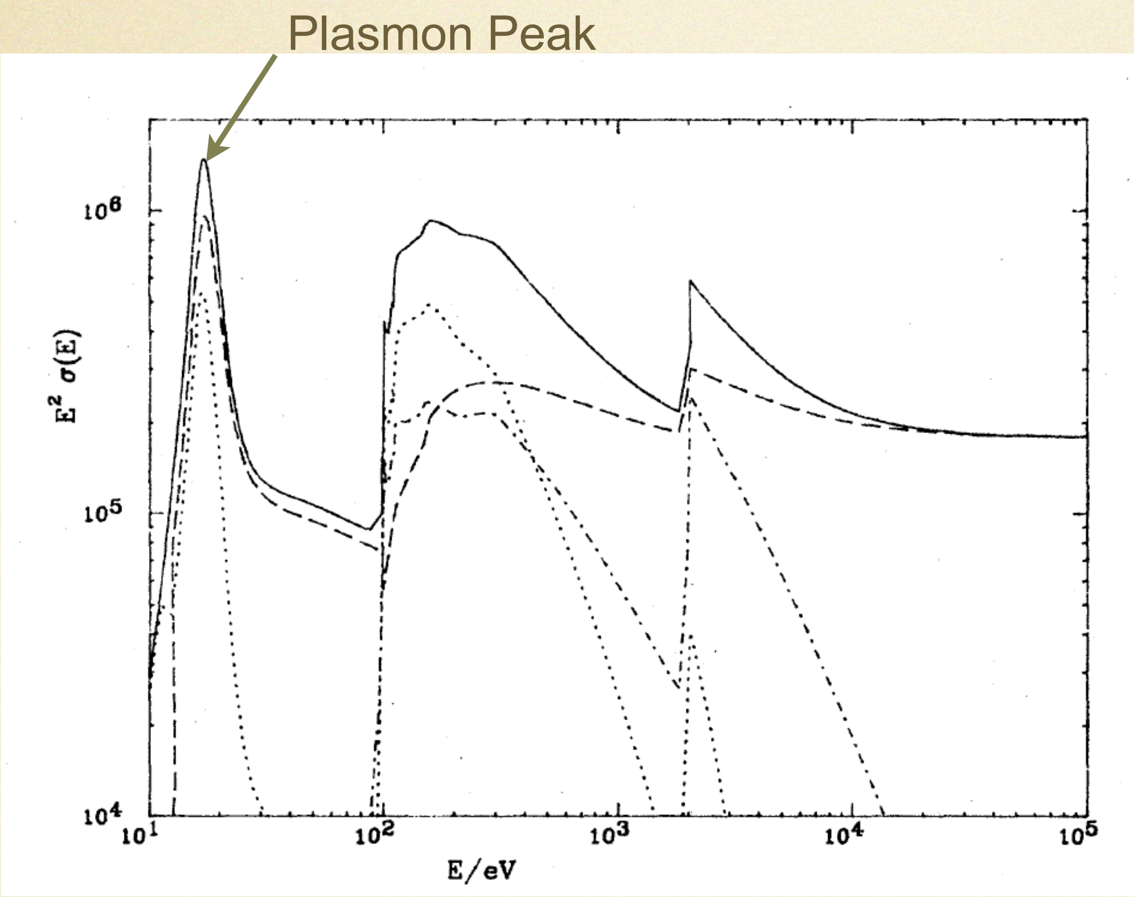
- 1GeV/c μ^-

Efficiency for Pair Background



- Rejection factor is 1/2 ~ 1/20 depend on Z

Energy Deposit in Thin material



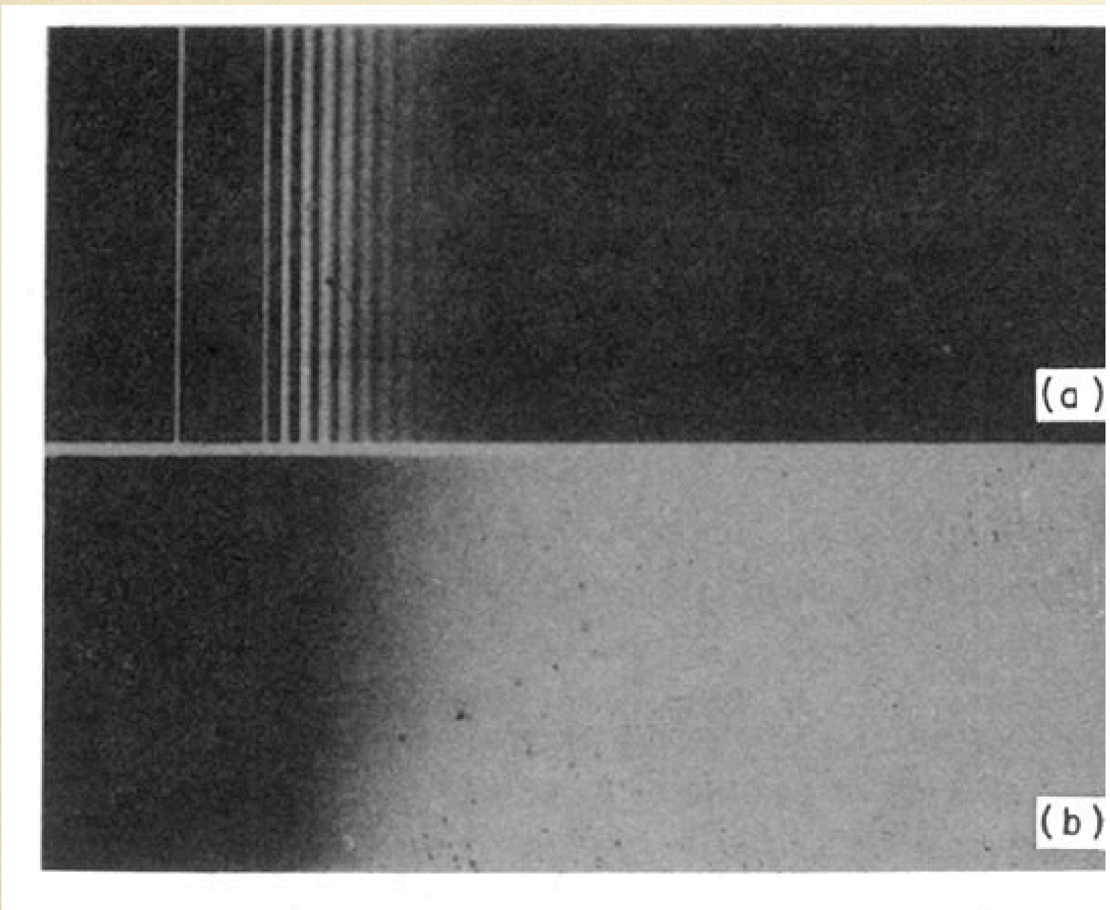
differential collision cross section in Silicon

H. Bichsel, Rev. Mod. Phys. 60, p663

- Effect of statistical fluctuation of collision
- Effect of Plasmon Excitation

Plasmon Spectrum Measurement by Electron Spectrometer

J. Perez, et al, PR A16, p1061



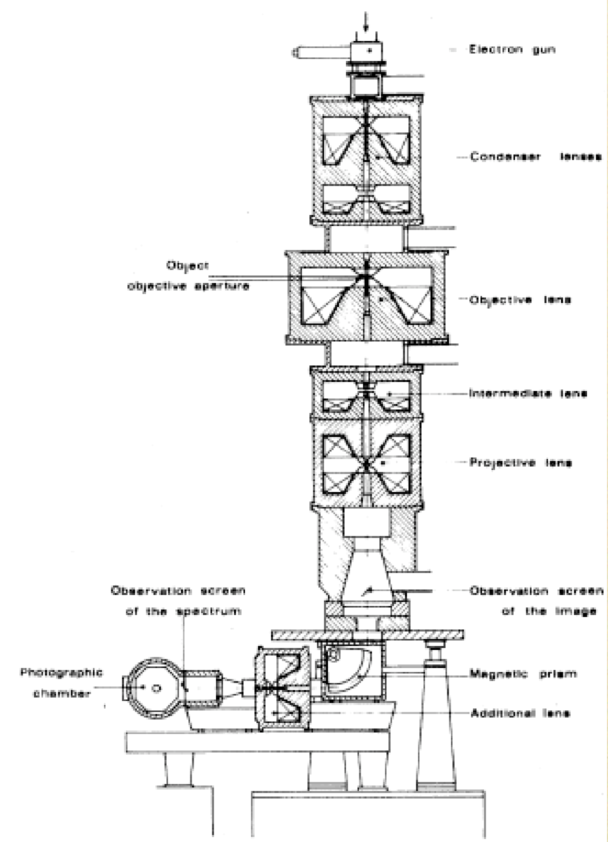
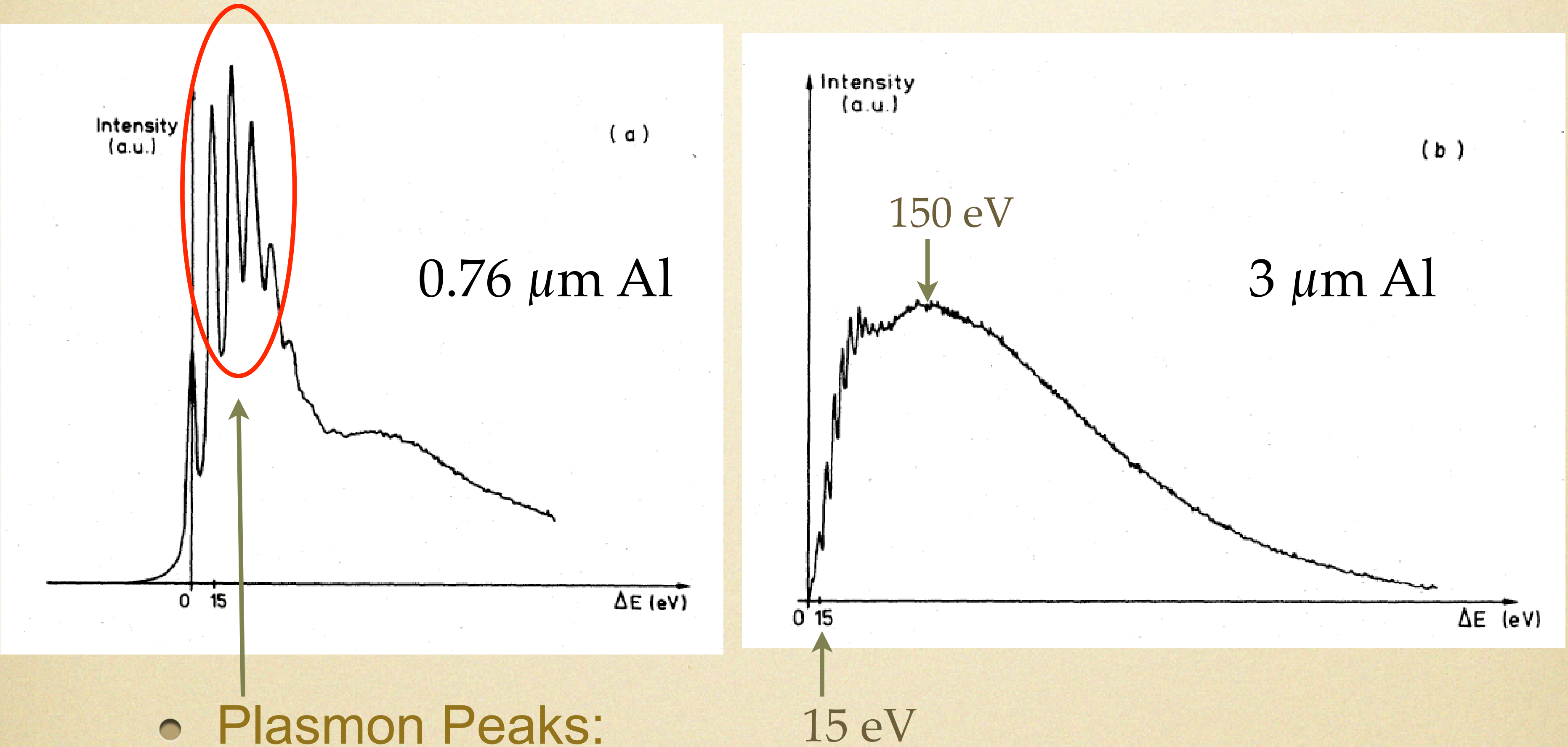


FIG. 1. Cross section of the high-voltage electron analyzer.

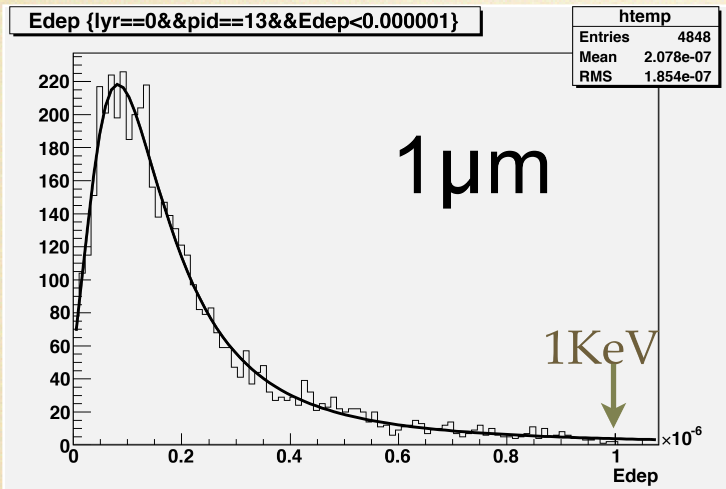
Electron Energy Loss
0.76 and 3 μm Al, T=1.0 MeV

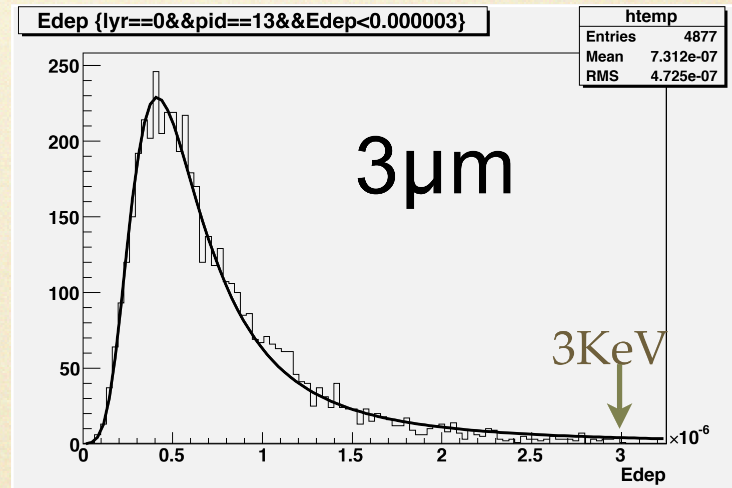


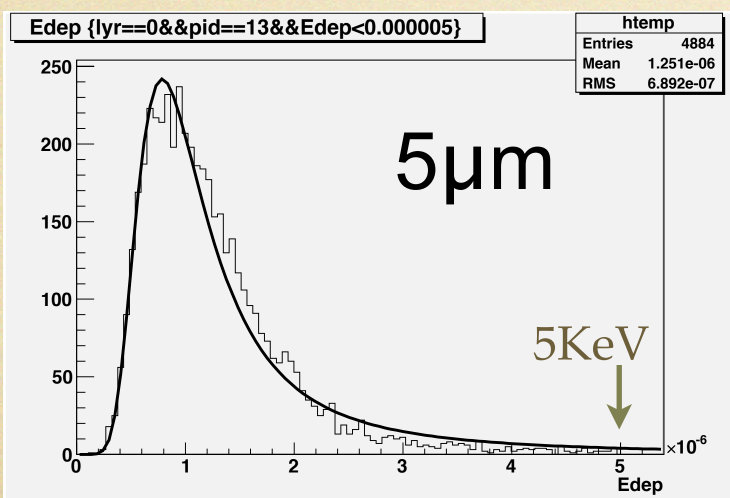
- Plasmon Peaks: 15eV separation

J. Perez, et al, PR A16, p1061

Energy deposit of t=1,3,5μm Si
Geant4 Simulation



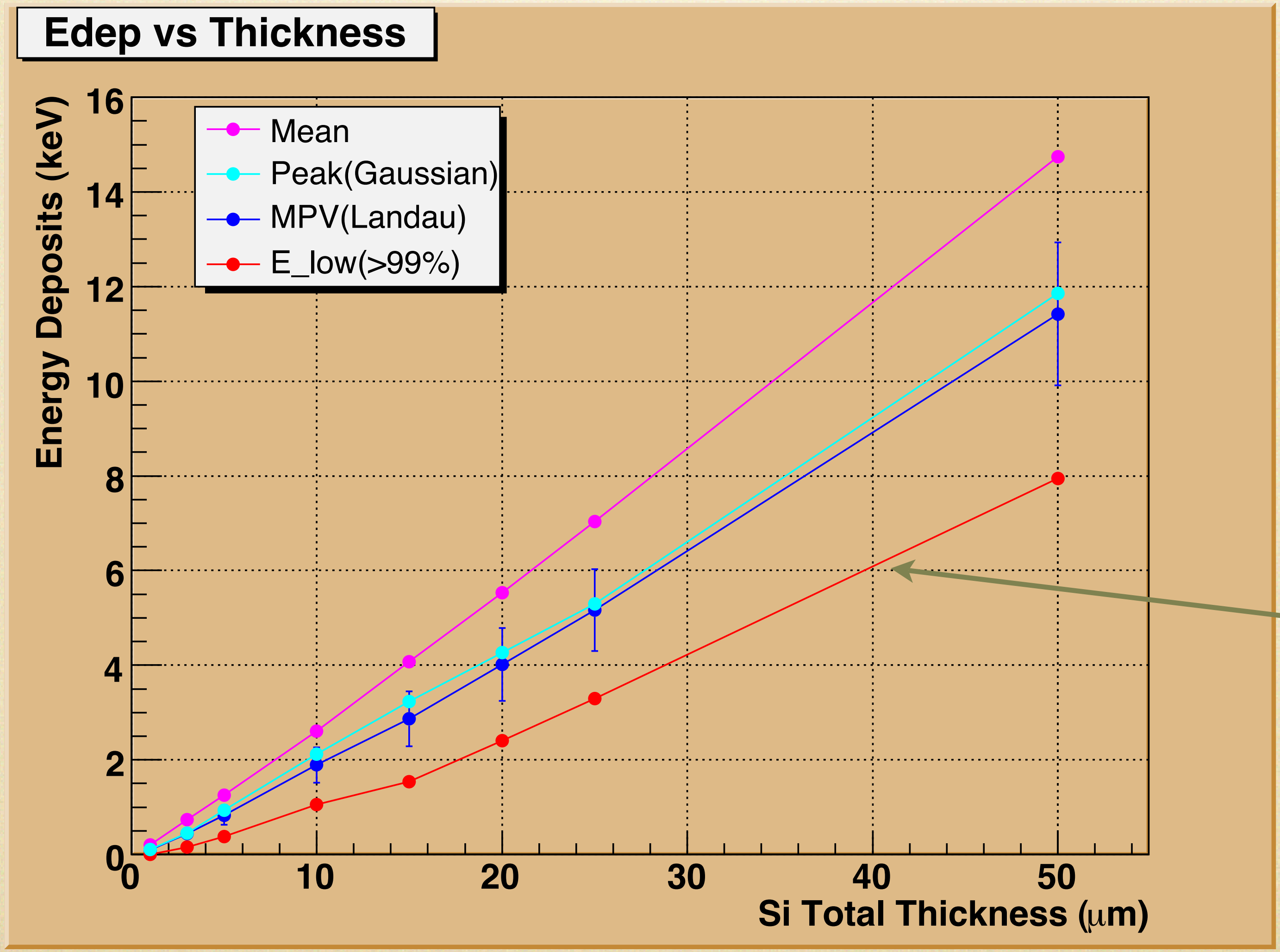




1 GeV/c Muon

No Plasmon Peaks seen

MPV and E_{low}(>99%)



E_{low}(>99%)

Summary

- Current design of FPCCD base Vertex detector has good Impact Parameter Resolution
- Good tracking efficiency can be expected under high background rate (100 hits/mm^2) for higher momentum region, and up to 50 hits/mm^2 for lower momentum region
- Good Pair Background rejection can be expected by Cluster shape (rejection factor = 1/2~1/20)
- Need more study for Energy deposit in thin Si
- Need to study b,c and tau tagging in physics events(Z, ZH, etc)