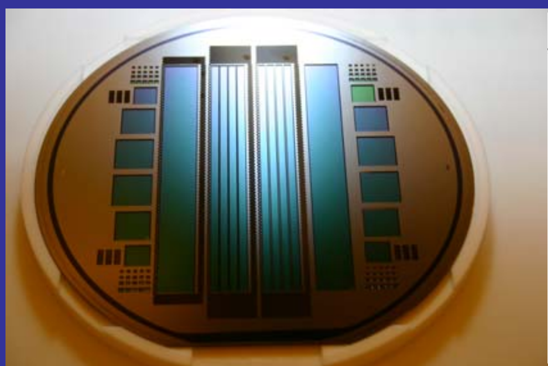
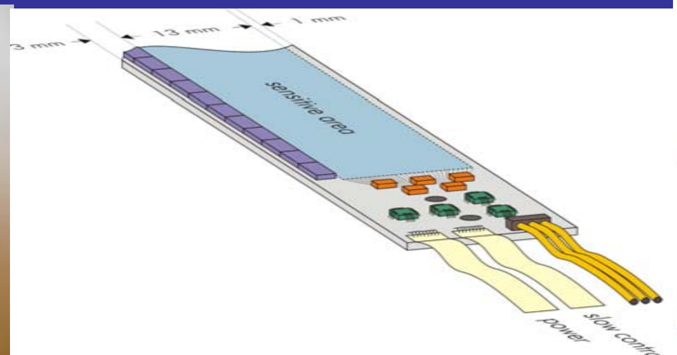
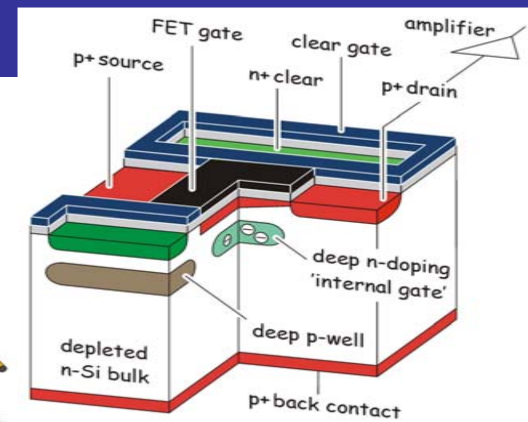
Simulation Studies of a (DEPFET) Vertex Detector for SuperBelle







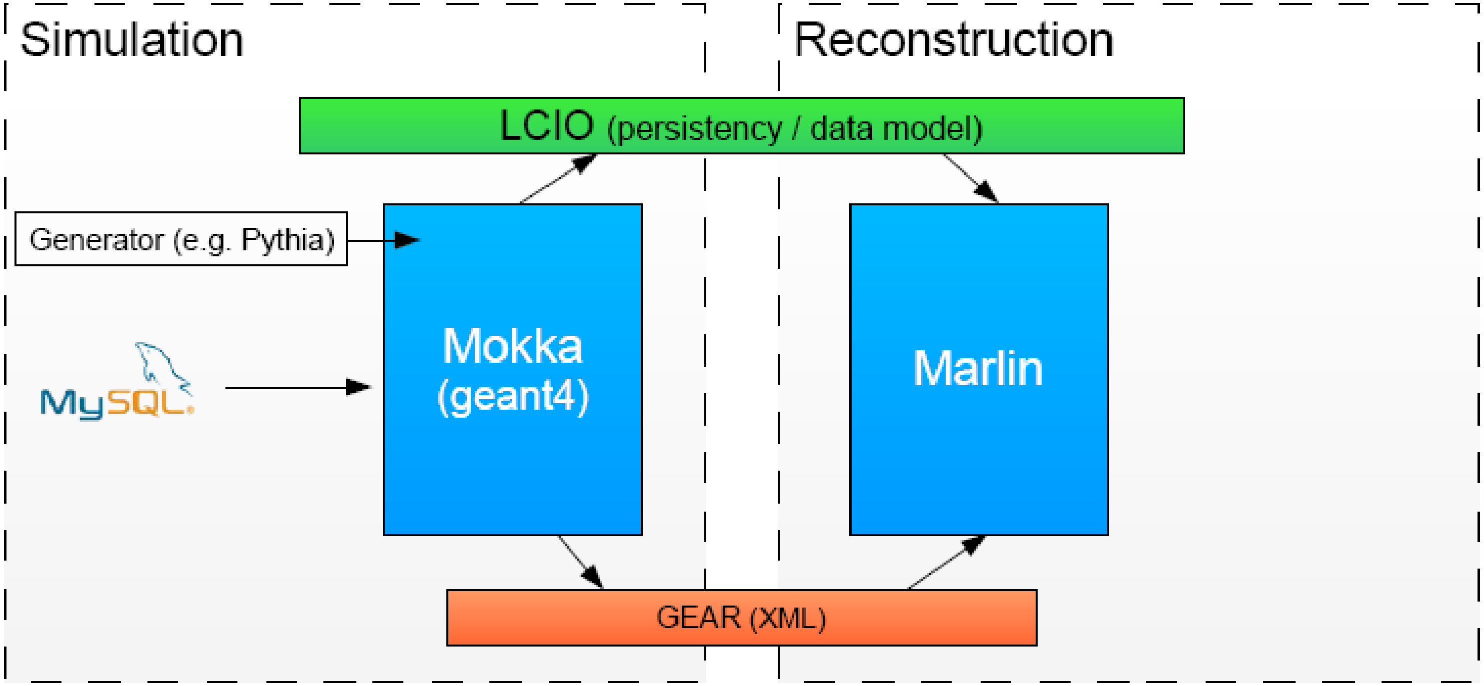
Contents:

- Software framework
- Simulation of the sensor response
- Validation of the simulation with data from beam tests
- Evaluation of the physics performance assuming SBelle geometry

Ariane Frey, Max-Planck-Institut für Physik München

ILC Software Framework

Based on LDC software:



Mokka is geant4 based framework for full detector simulation

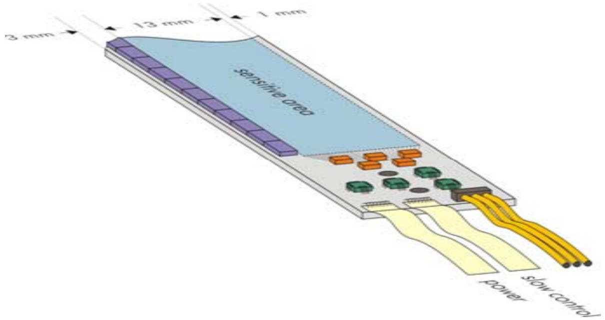
LCIO is a persistency framework that defines a common data model

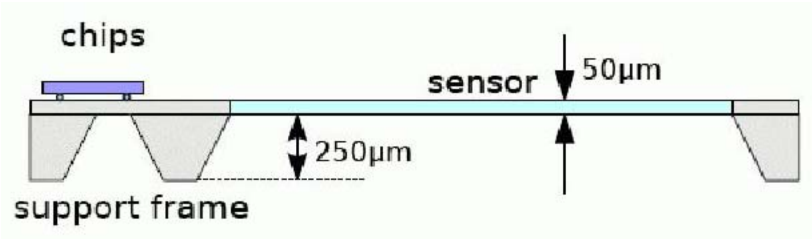
Marlin is modular C++ application framework based on LCIO

GEAR: one source of geometry. Mokka creates geometry xml files used in Marlin

Simulation of the DEPFET VXD geometry

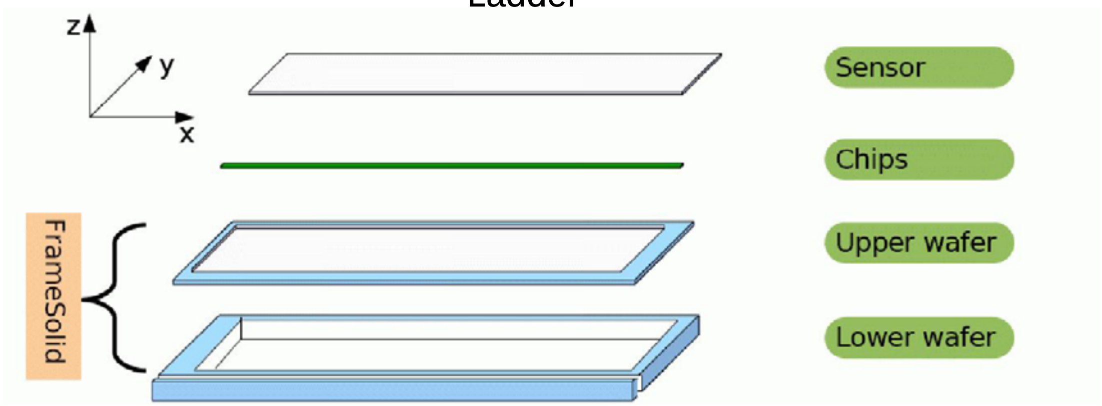
- Realistic description of module design including electronics and support structure



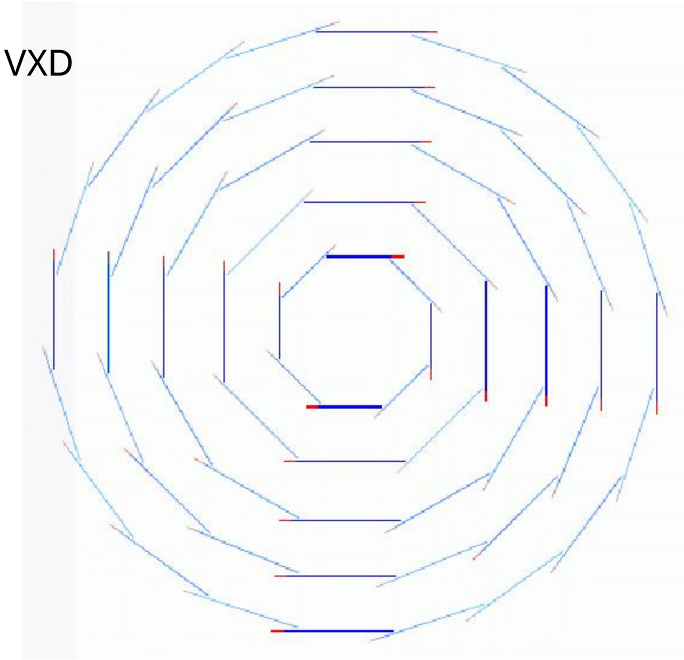


Model in GEANT 4

Ladder

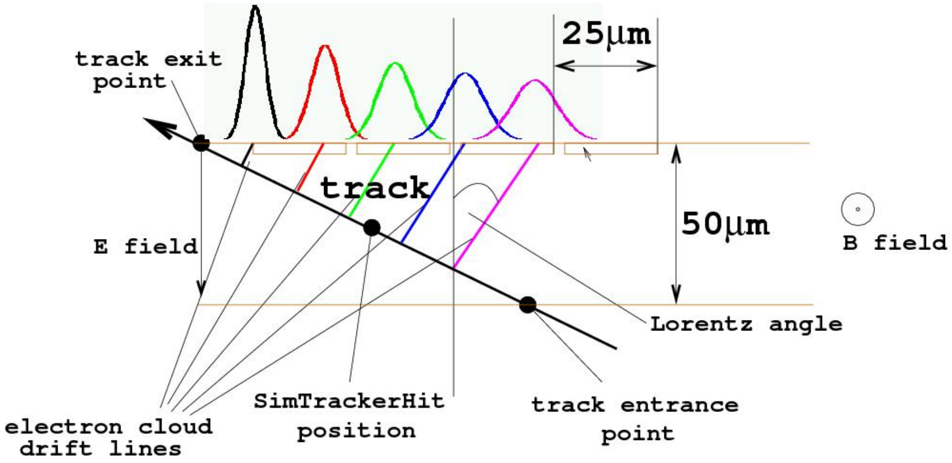


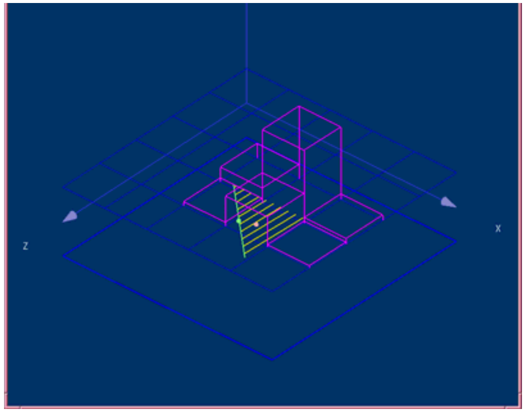
VXD



“outside” support structures simplified and preliminary

Sensor response





- **Digitization** is implemented taking into account

- Landau fluctuations of specific energy loss along track path
- charge transport and sharing between neighboring pixels; diffusion
- Lorentz shift in magnetic field
- electronic noise effects

Stand alone pattern recognition

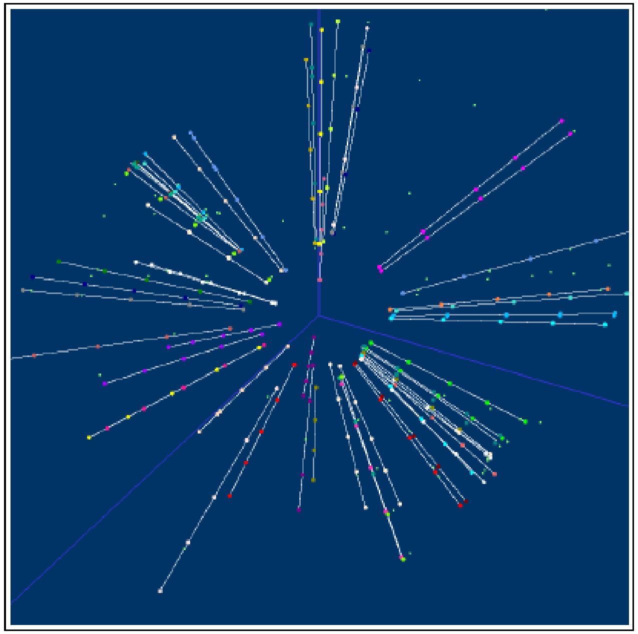
Digitization process:

Digitization

- **SimTrackerHit** from **Mokka** simulation
- physical effects are applied
- → List of **fired cells**
- Hit position reconstruction: **center of gravity** method

Tracking and pattern recognition in the Vertex Detector:

- Starts with finding **triplets** in the outer layers, that are compatible with the **helix hypothesis**
- Inward search for additional hits
- Helix fit of hits → track candidate
- Good χ^2 of helix fit is main criterion to accept track candidates
- Additional loose cuts against fake tracks composed of background hits



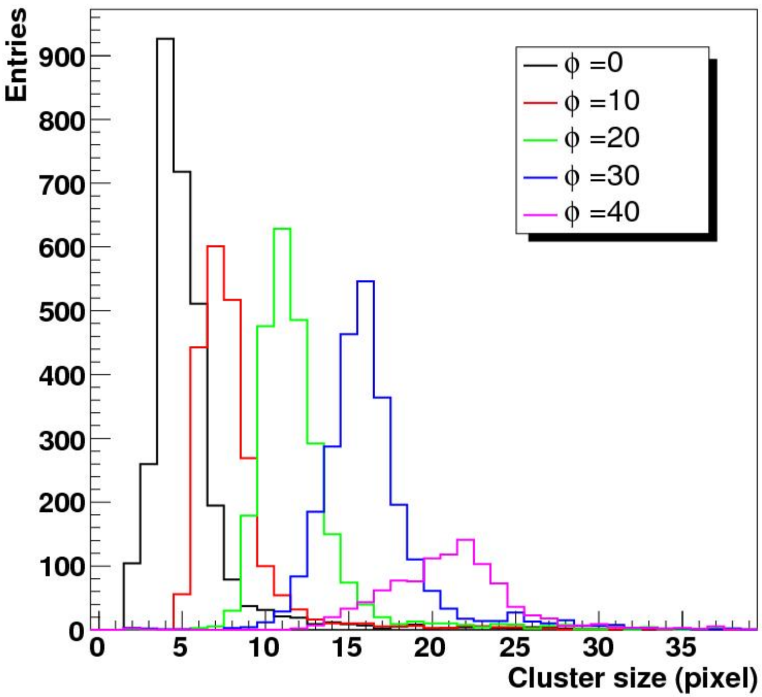
$t\,\bar{t} \rightarrow 6\mathrm{jet}\ event\,,\quad \sqrt{s}=500\,GeV$

Validation with Test Beam Data

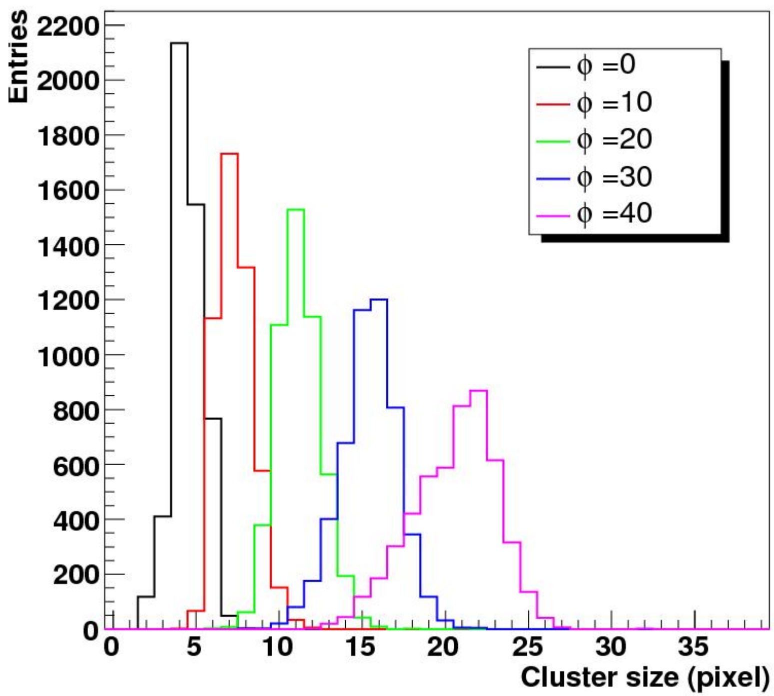
- Comparison with data from DESY 2005 testbeam, 6 GeV electrons
- Thickness 450 μm, pixel size 36 x 22 μm
- no B field, noise set to 300 e^-
- Track incident angles from 0 to 40 degrees

Cluster Size

Data

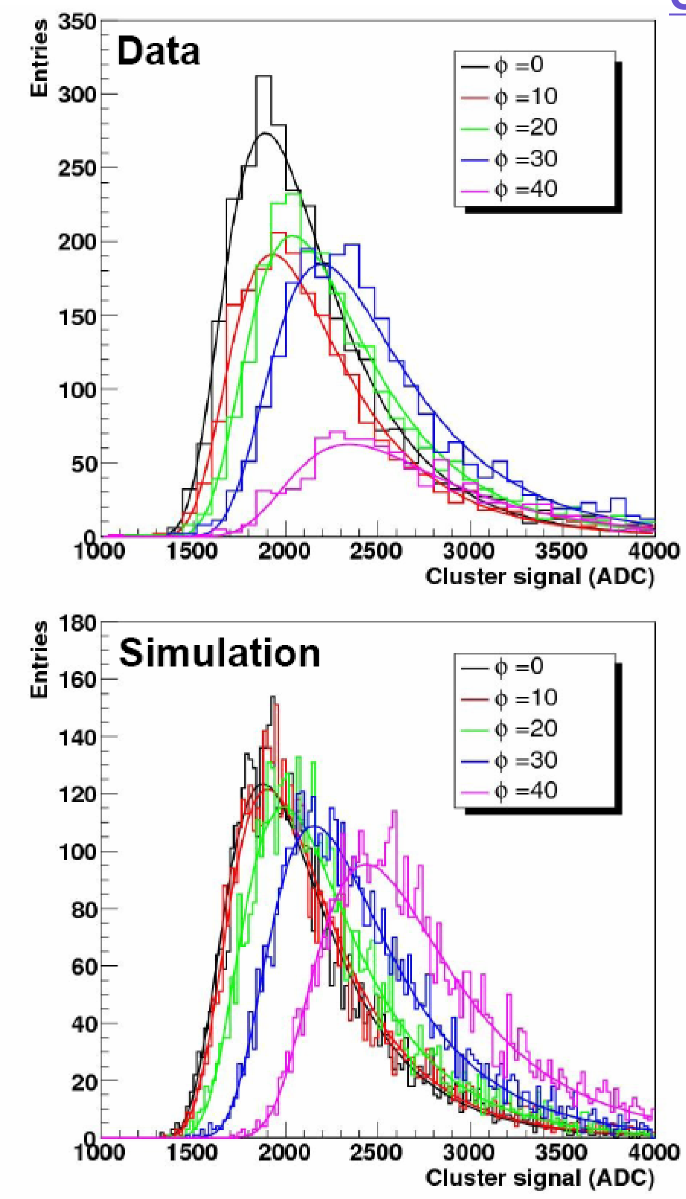


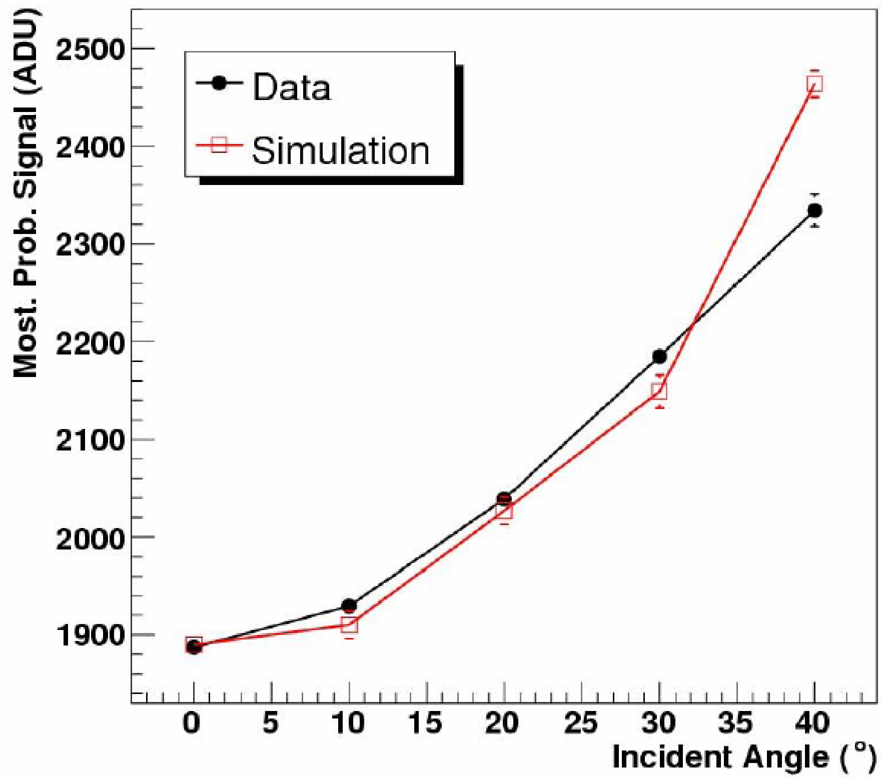
MC



Validation with Test Beam Data

Cluster Signal





Good agreement of test beam data and simulation

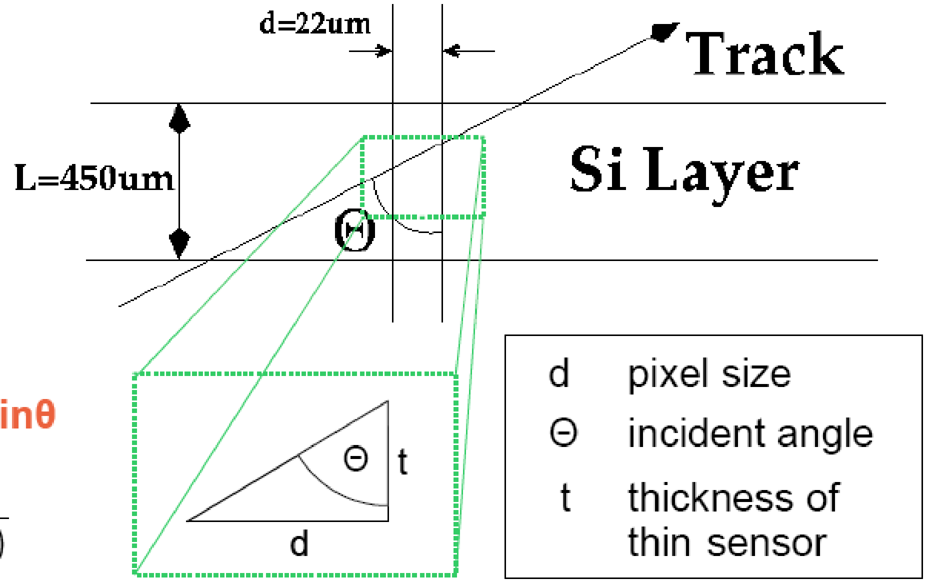
Thin sensors

Validate the simulation of energy loss in **thin sensors** (50 μm)

Use test beam data at **inclined angles** to probe straggling functions at short flight distances

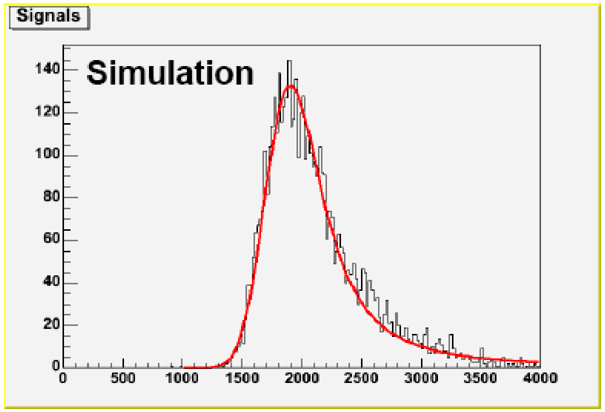
Simulation can be probed @ scales **≈ d/sinθ**

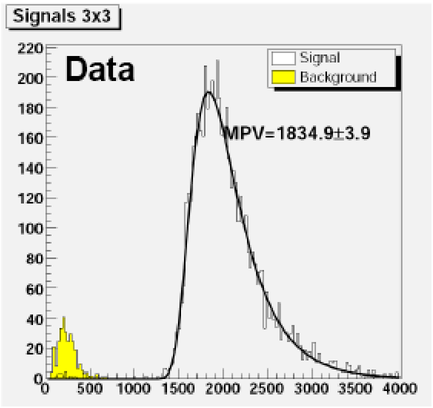
Expected signal $A_{row,column} \approx A_0 \frac{d_{x,y}}{L\cdot\sin(\theta,\phi)}$



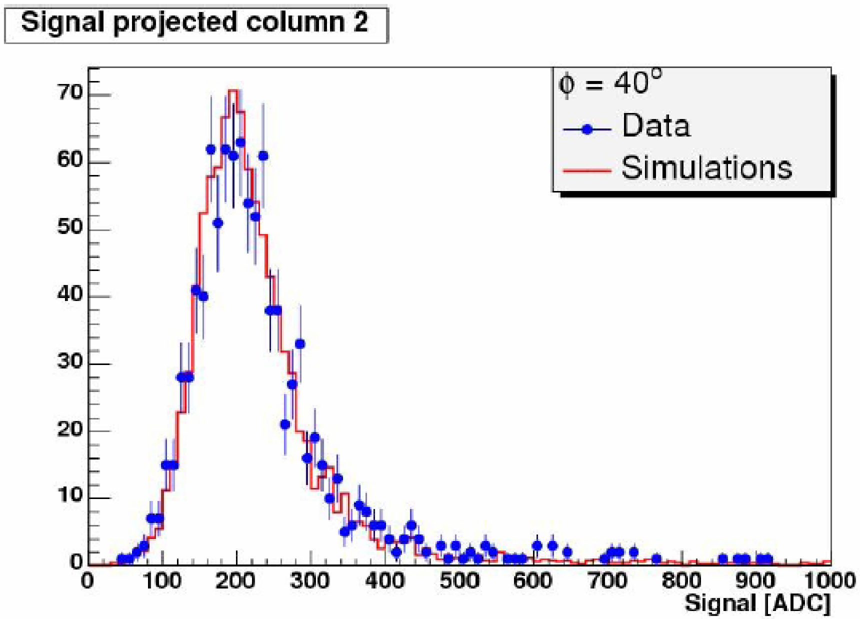
Data collected at normal incidence is used to find the **conversion**

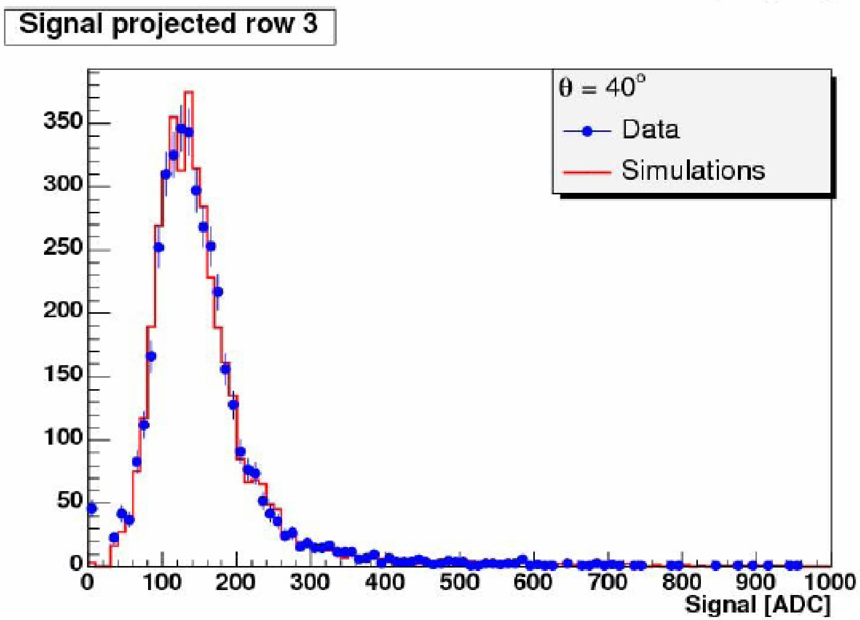
$E_{loss} \leftrightarrow$ ADC counts

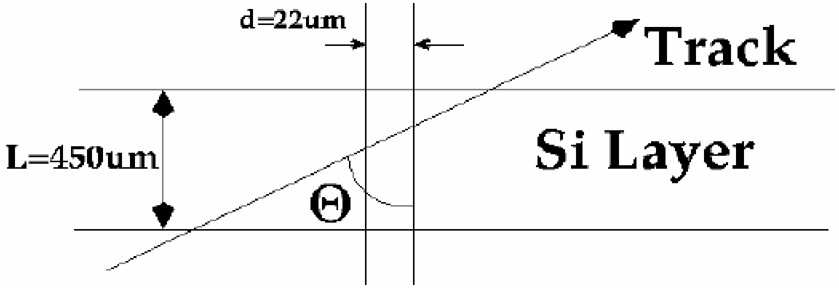




Thin sensors



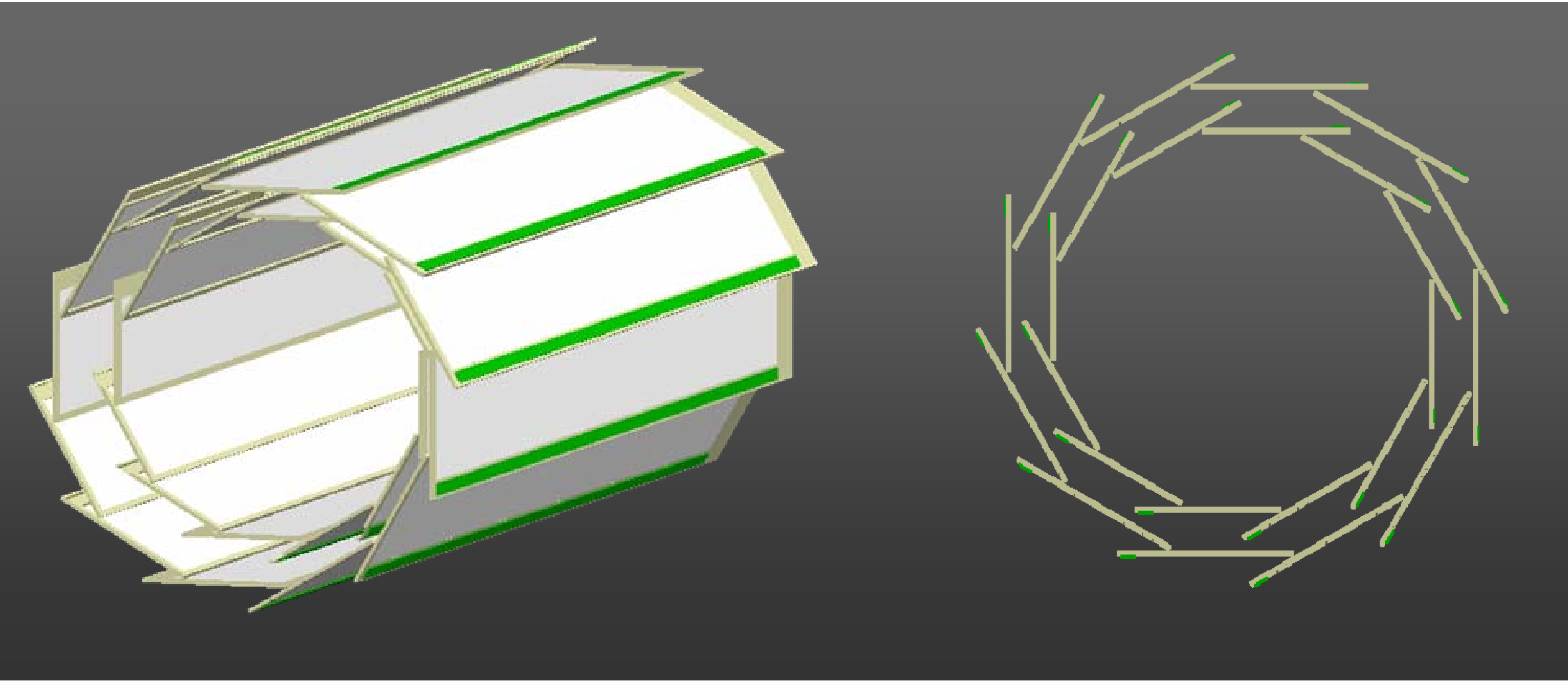




d	pixel size
Θ	incident angle

Simulation yields correct results also for thin sensors.

Initial Study of SBelle LoI Layout with DEPFETs



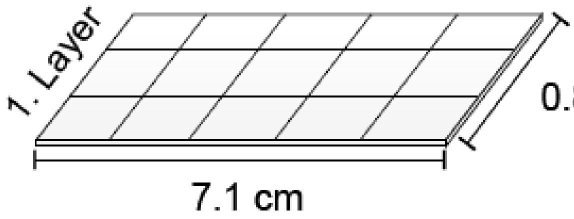
done by **Alexei Raspereza**

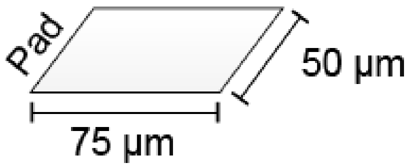
Initial Study of SBelle LoI Layout with DEPFETs

Mokka implementation of SuperBelle Vertex Detector

- New **database** (subdectector) in local MySQL was added.
- New **geometry driver** was written.

Beampipe: r=1cm (Be with 10µm Au layer)



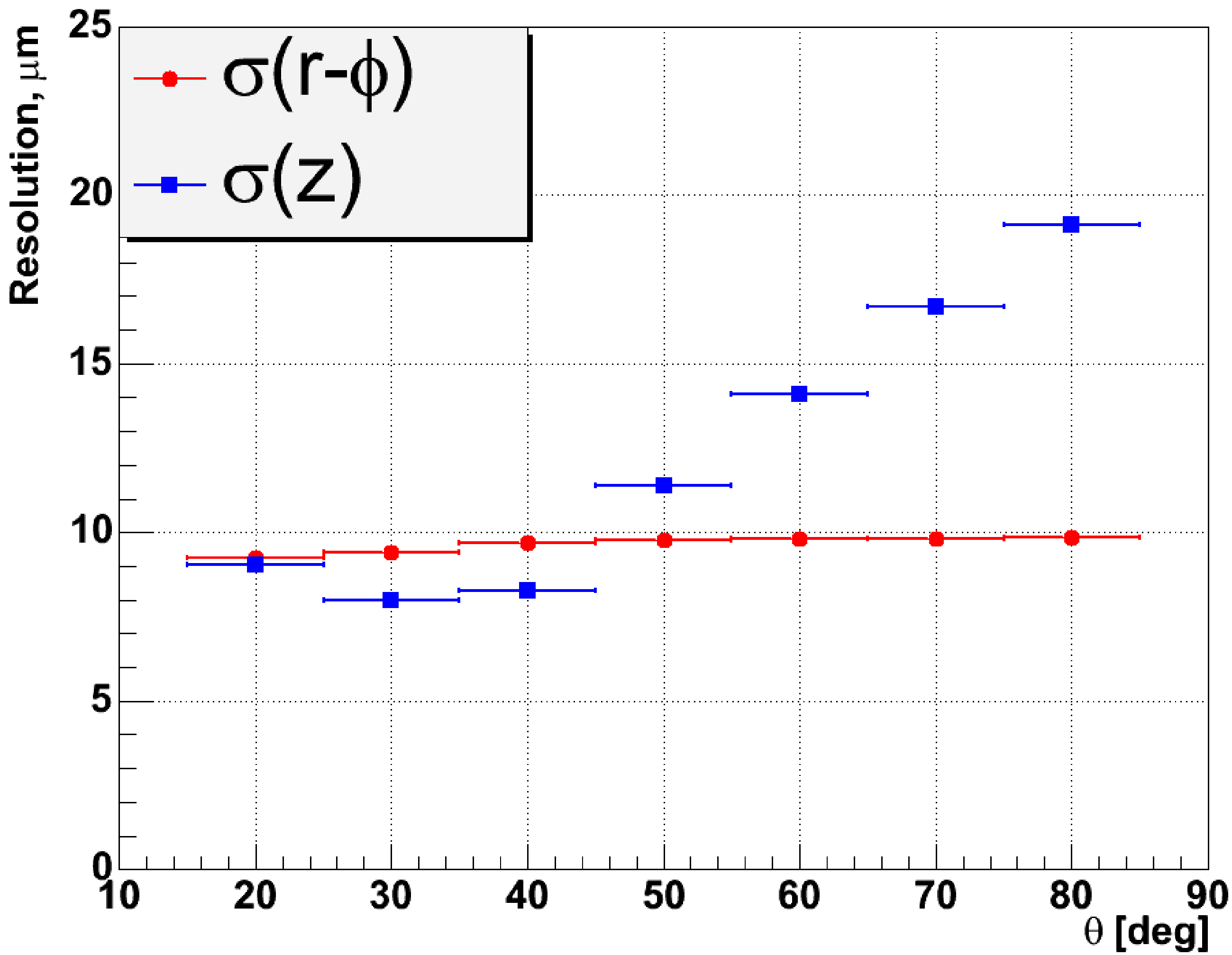


Used values:

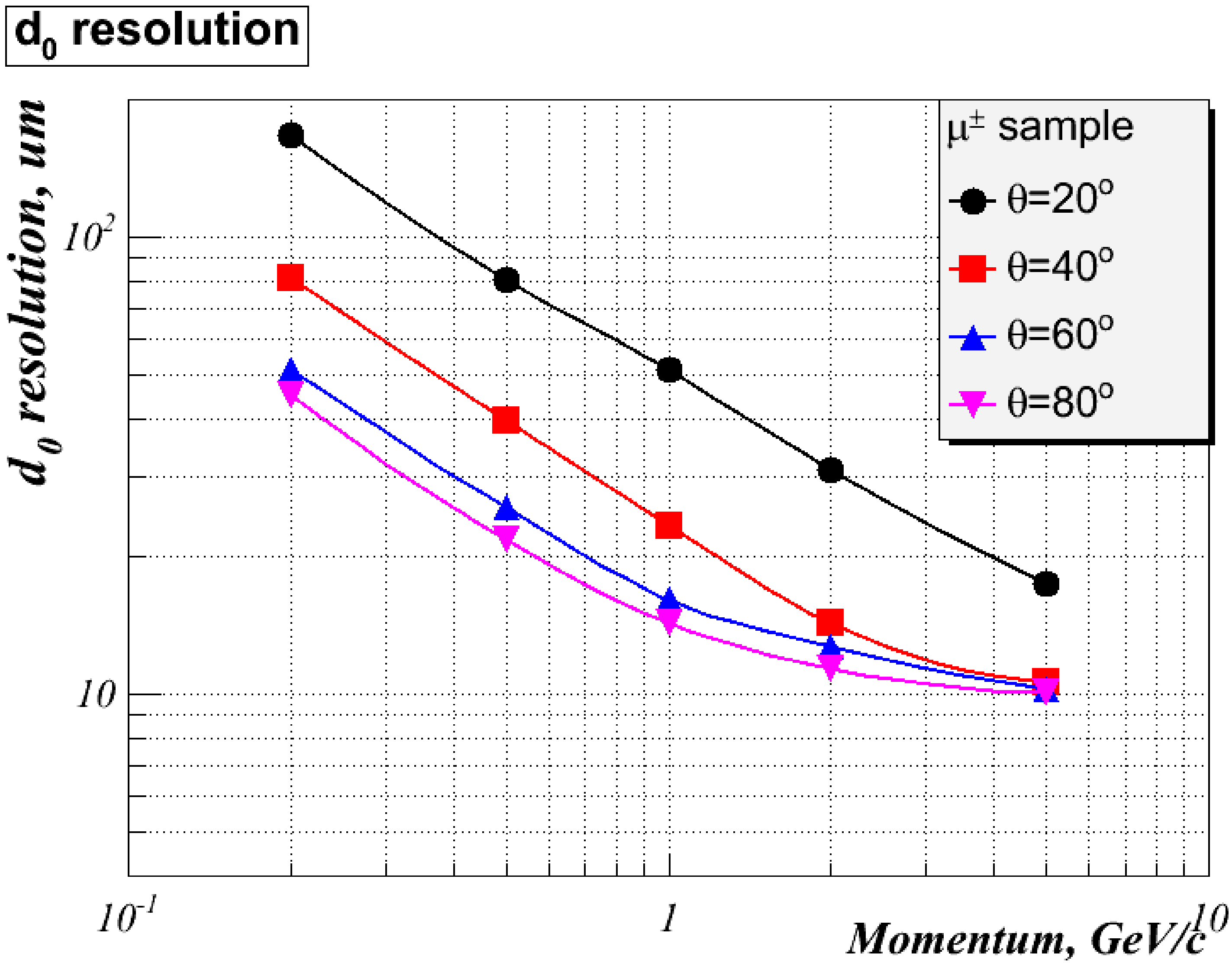
	#	r *(cm)*	sensor *(cmxcm)*	# sensor *in z*	#ladders *(around phi)*	thickness *(µm)*	noise
Pixel	1	1.3	7.1x0.8	1	12	50	100 e-
Pixel	2	1.6	8.4x1.0	1	12	50	
Strips	3	4.5	8.0x2.8	3	12	300	1600 e-
Strips	4	7.0	7.6x4.0	5	12	300	
Strips	5	10.0	9.0x2.8	5	24	300	
Strips	6	13.8	7.6x4.0	6	24	300	

Performance: Spatial resolution

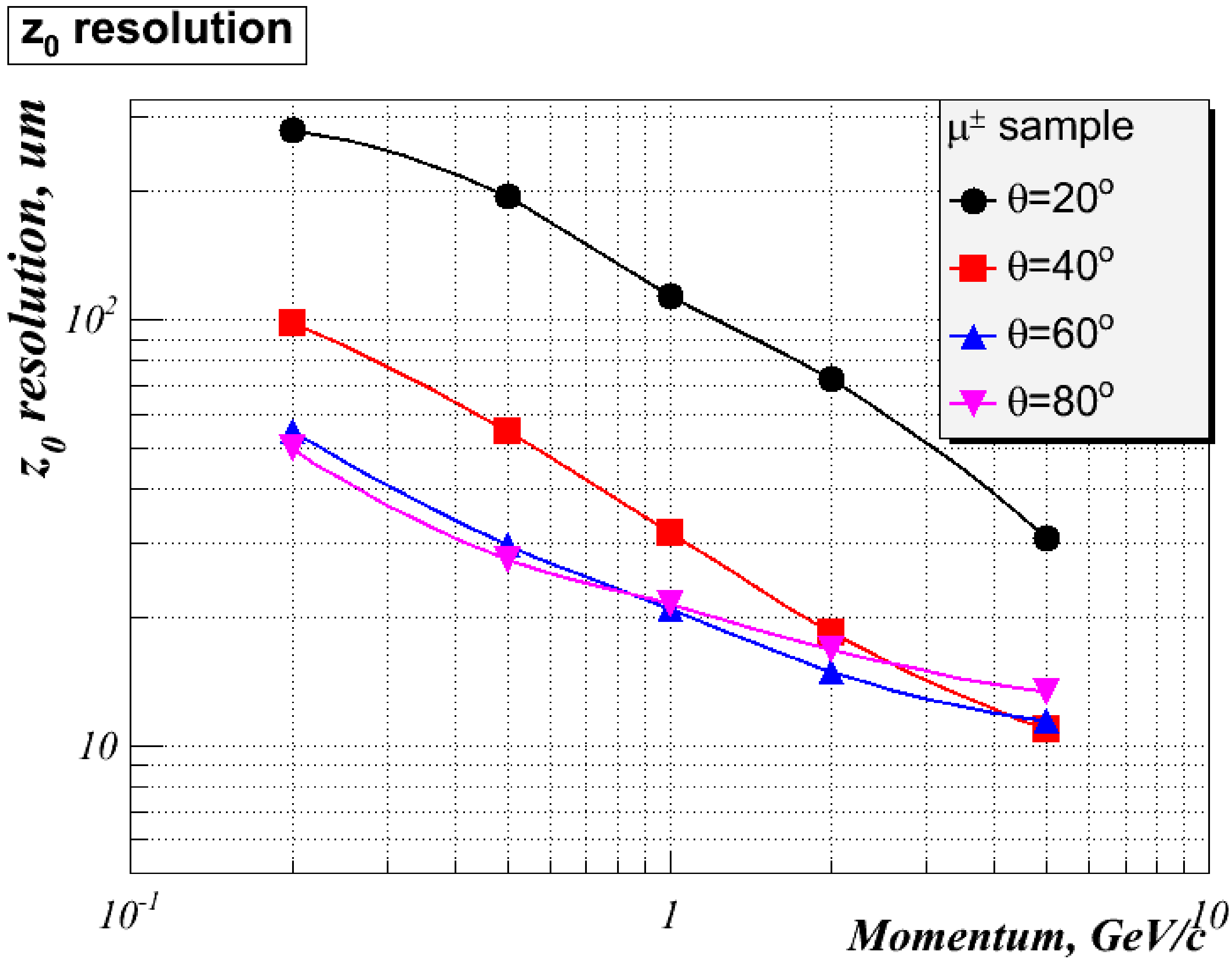
Single muon tracks with 5 GeV/c



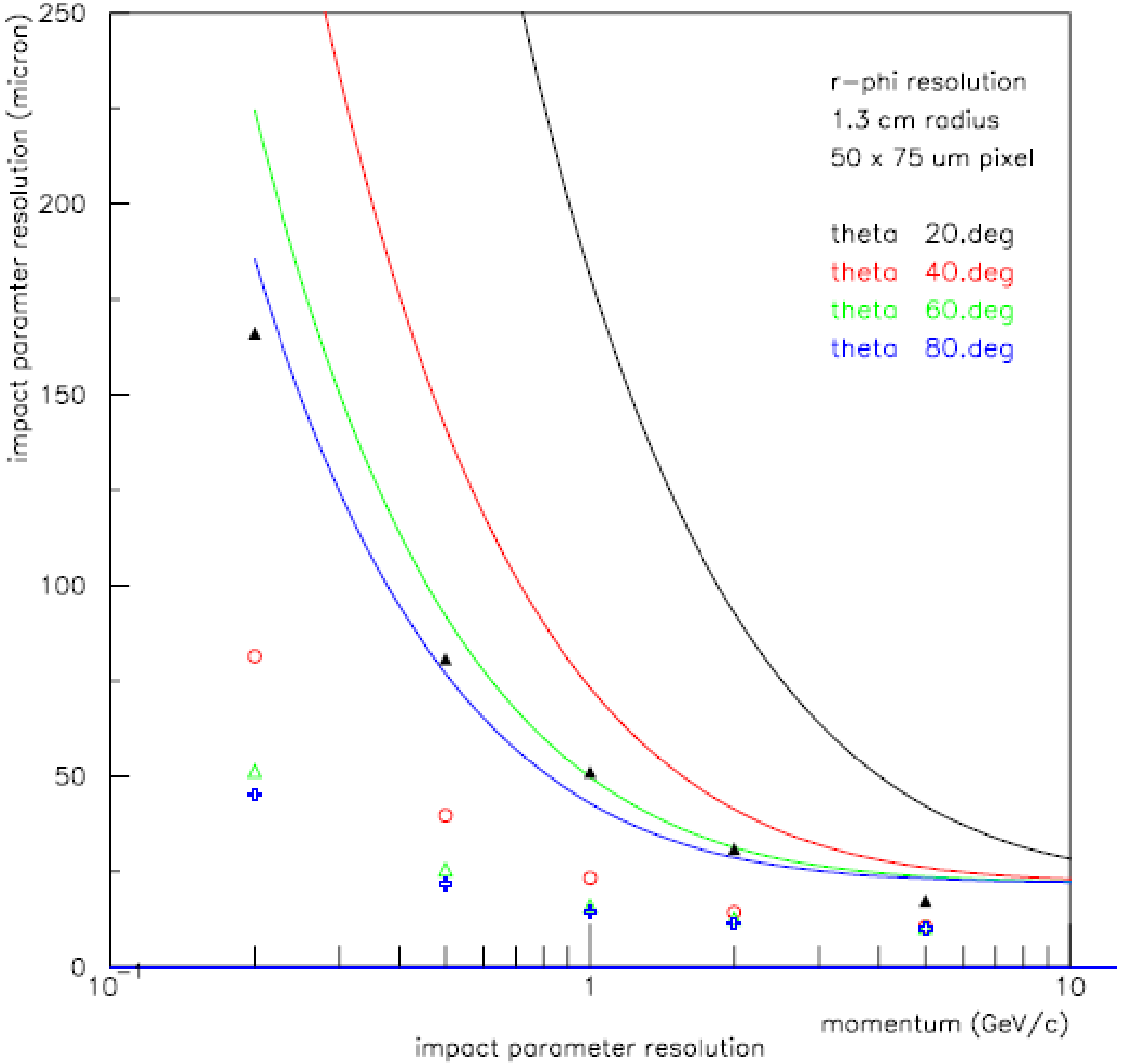
Performance: Impact parameter resolution



Performance: Impact parameter resolution



Performance: Impact parameter resolution



Solid lines: Belles SVD2, symbols: DEPFET sBelle

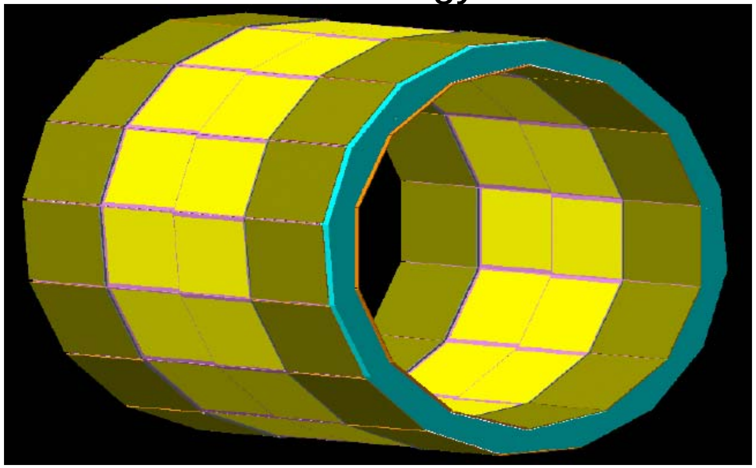
Summary

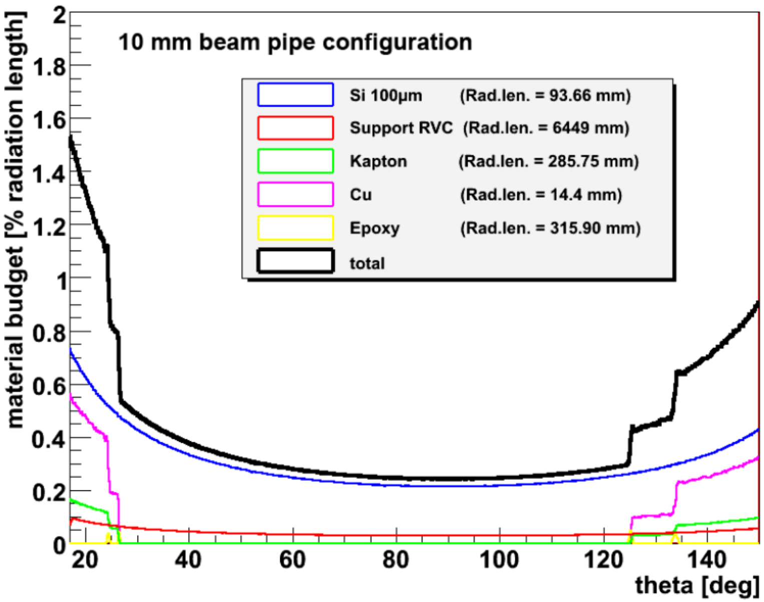
- We used the ILC software framework for SuperBelle Vertex Detector performance studies
- ILC software can be easily adopted to other detector geometries
- Digitization, Tracking and Pattern recognition in VXD detector developed at MPI
- Software has been validated by test beam data
- Optimization studies on-going.
- We need background samples to estimate occupancy, fake track rates
- Outer layers simulated as pixels, need to implement realistic strip detector design.

Simulation work at U Hawaii

H. Hoedelmoser et al.

Based on SOI technology





Stand-alone Geant4 Simulation of a Pixel Detector for the SuperKEKB Vertex Detector

H. Hoedlmoser, G. Varner, M. Rosen

University of Hawaii at Manoa

SuperBelle Note sBN/0006

June 20, 2008

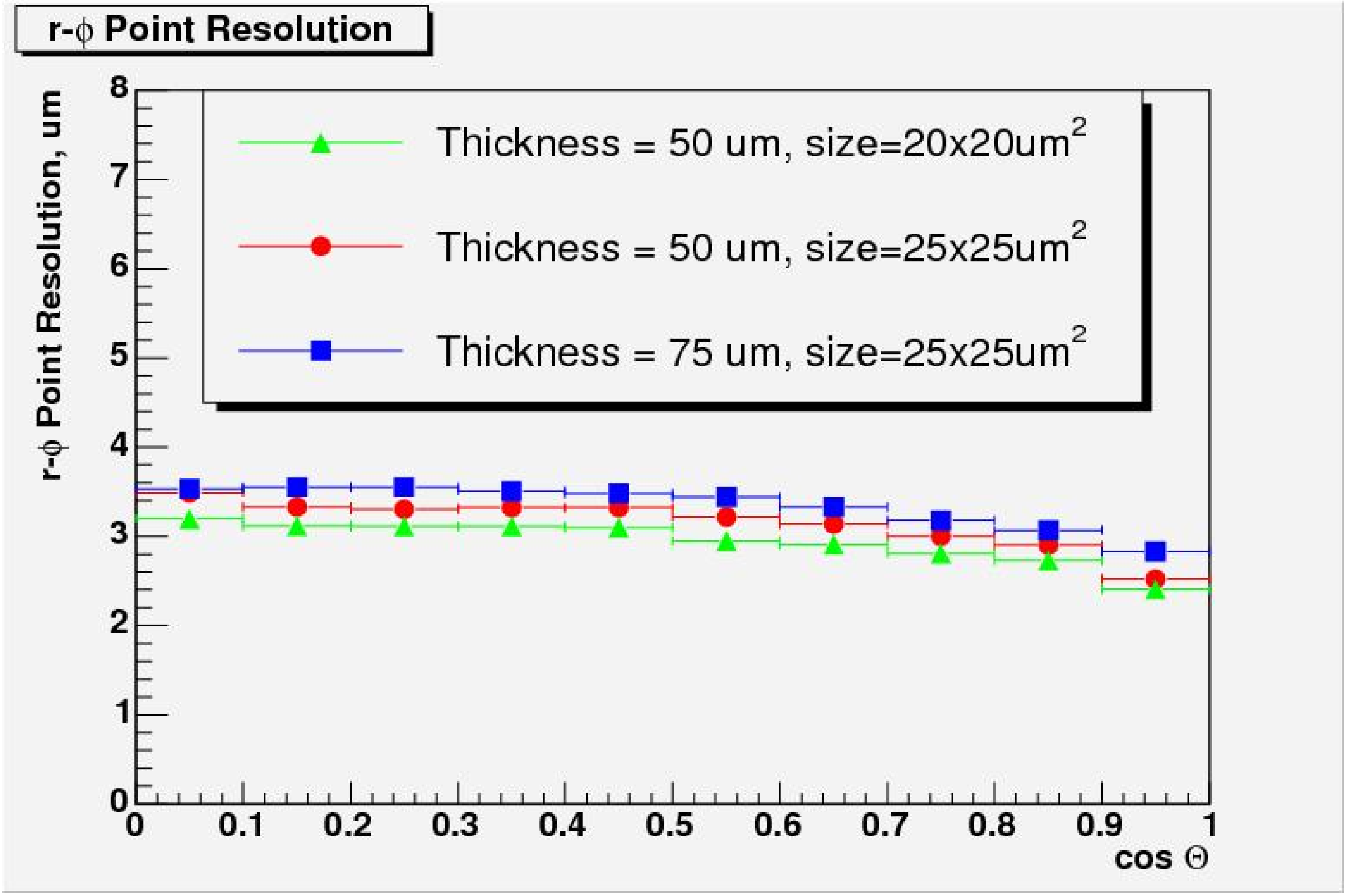
Abstract

This note is the documentation of a stand-alone Geant4 simulation of a double layer of pixel detectors for the vertex detector of SuperKEKB. The model for the pixel detector was based on a binary SOI pixel detector, which is one of the candidate technologies for the pixel detector of an upgraded vertex detector. The model includes the pixel dies with sensitive and insensitive volumes, a support structure and cabling, all in two different configurations corresponding to two different beam-pipe radii. In the first part of the document all the relevant parts of the simulation from material and geometry definitions to digitization and event clustering are described. In the final part of the note results from the simulation are given, including material budget, cluster size distributions, layer efficiencies and intrinsic resolution.

Studies of 15mm and 10 mm beam pipe radius configuration

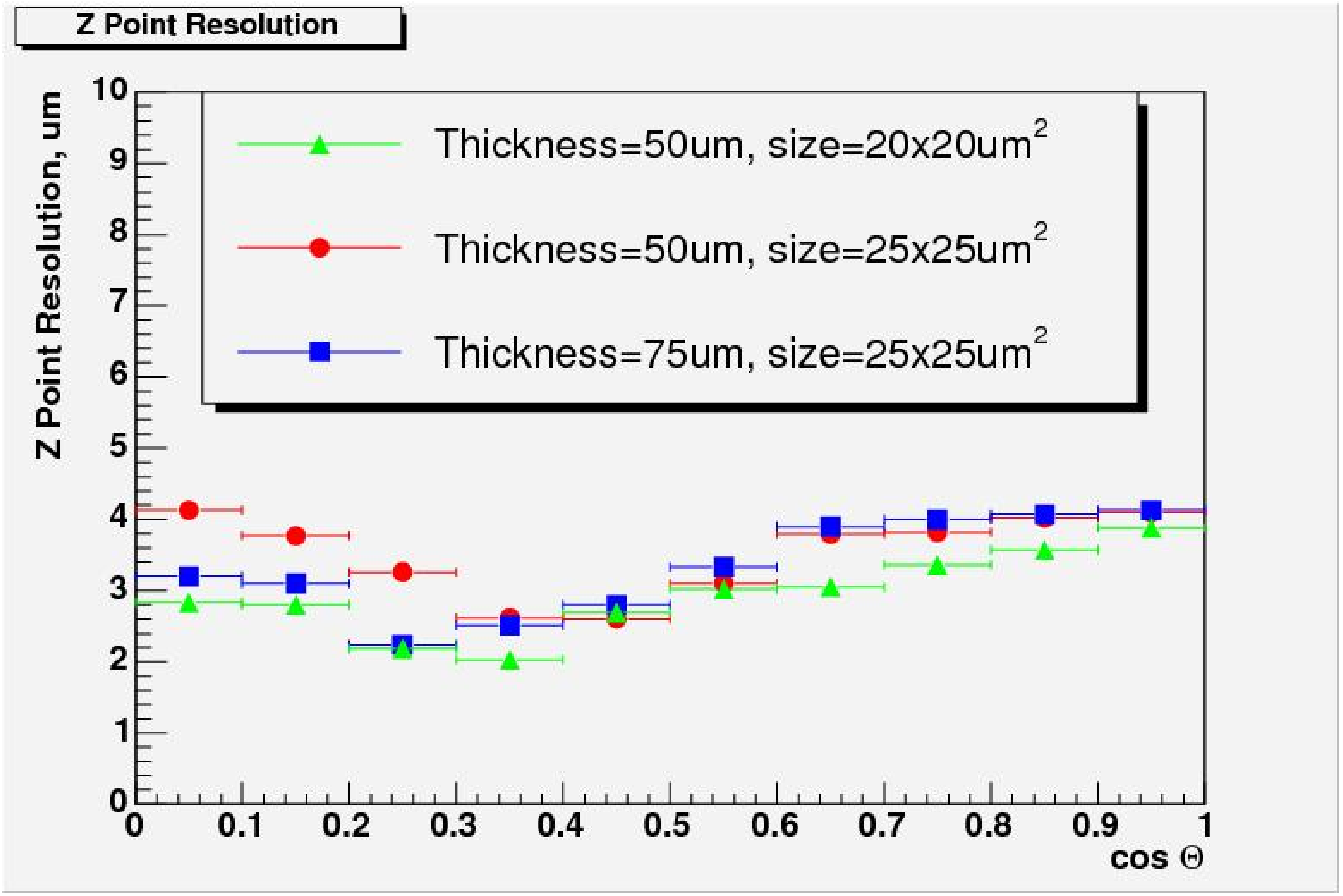
VXD performance: Spatial point resolution

Perpendicular to the B field



VXD performance: Spatial point resolution

Along the B field

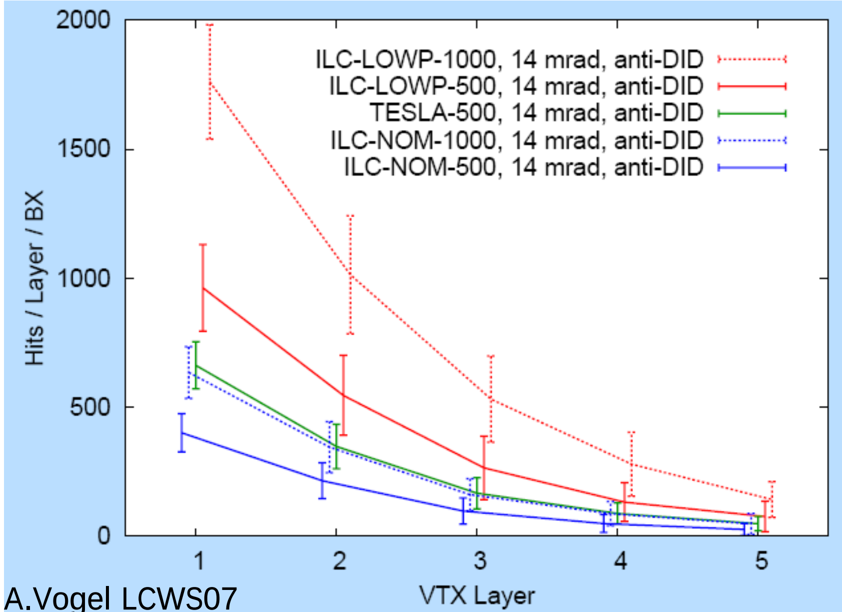


DEPFET VXD in the ILC environment

- Stand-alone tracking
- Able to operate with beam background
- Impact parameter resolution

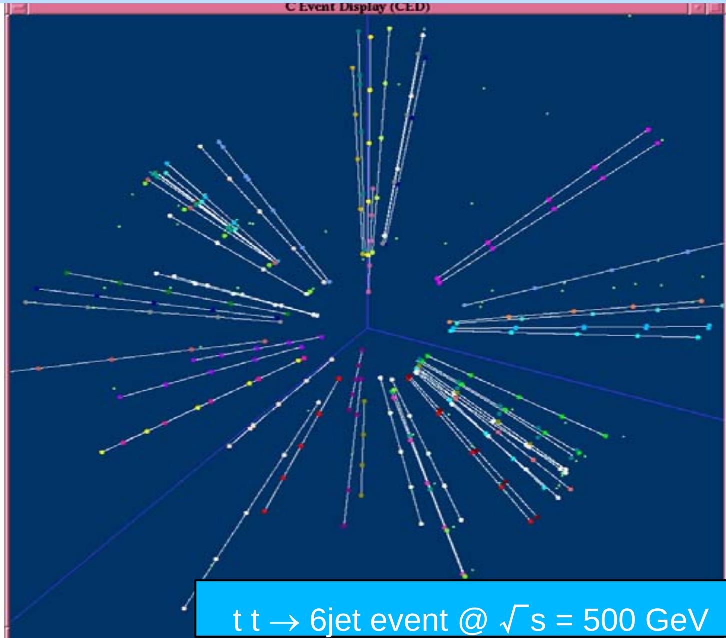
$$\sigma = \sqrt{a^2 + \left(\frac{b}{p\sin^{\frac{3}{2}}\theta}\right)^2}$$

- Req: a < 5 μ m (point precision)
- b < 10 μ m (mult. scattering)

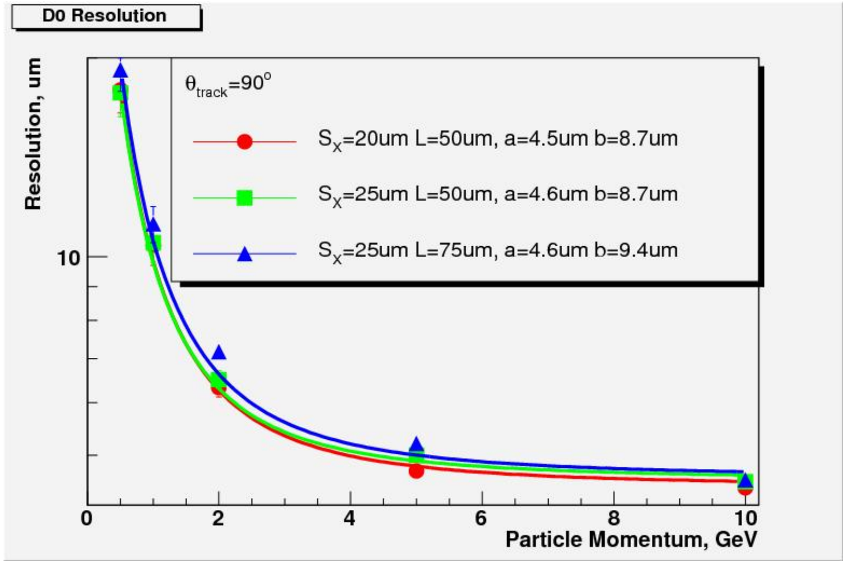


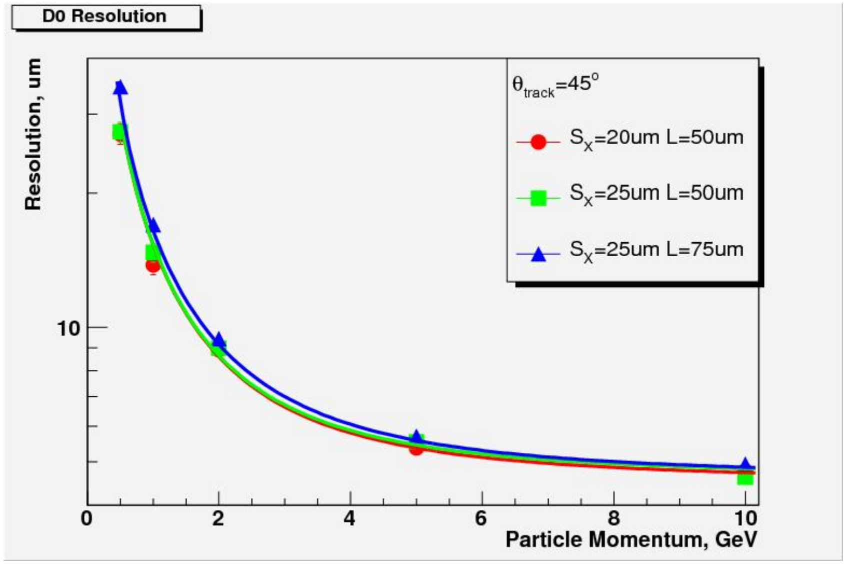
A.Vogel LCWS07

- Developed pattern recognition and Vtx tracking code
- Algorithm features:
  - Starts with finding triplets in the outer layers
  - Inward search for additional hits
  - Good χ^2 of helix fit – main criterion to accept track candidates
  - Additional loose cuts against fake tracks composed of background hits



Performance

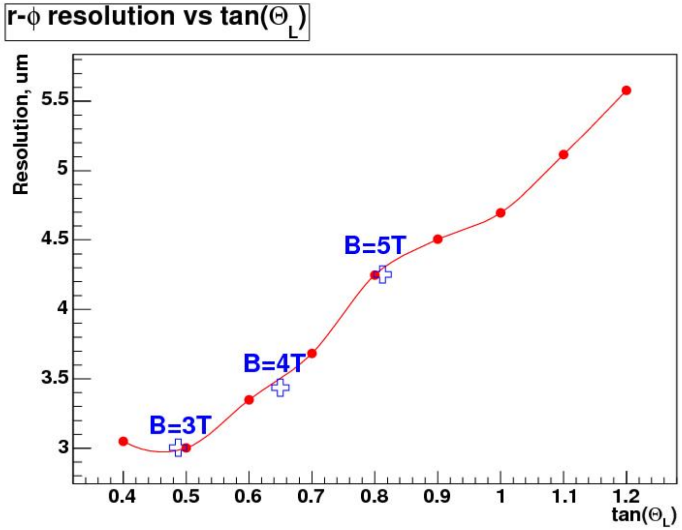




$\sigma = a \oplus b / (p \cdot \sin^{3/2} \theta)$

<u>Result:</u> a = 4.6 μm < 5 μm

b = 8.7 μm < 10 μm



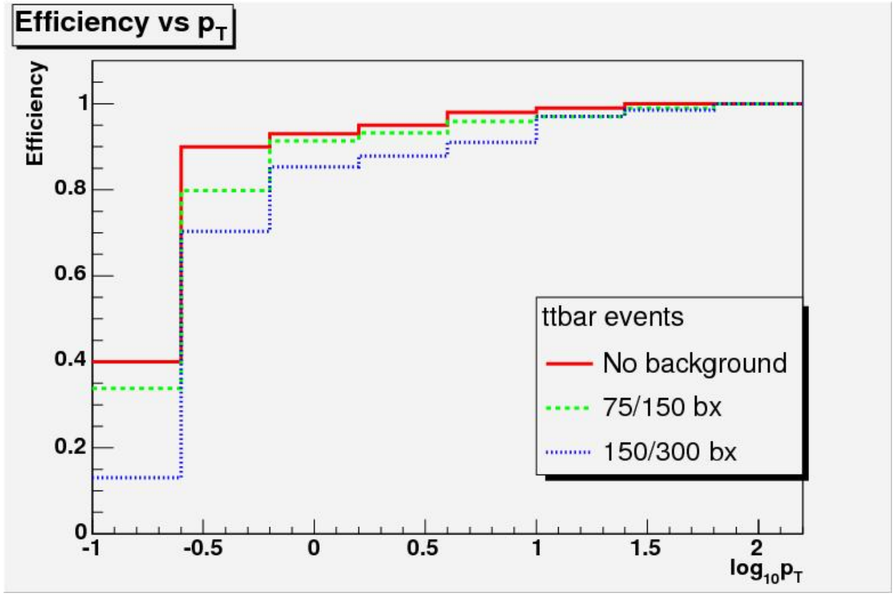
Spatial resolution as a function of B field

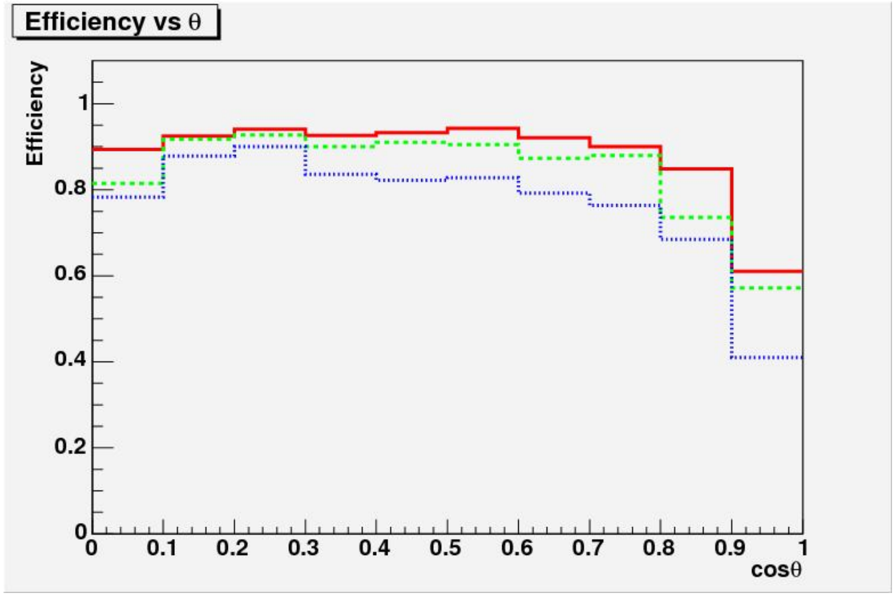
⇒ Performance ok for B = 3-5 T

With background: Tracking efficiency, fake tracks

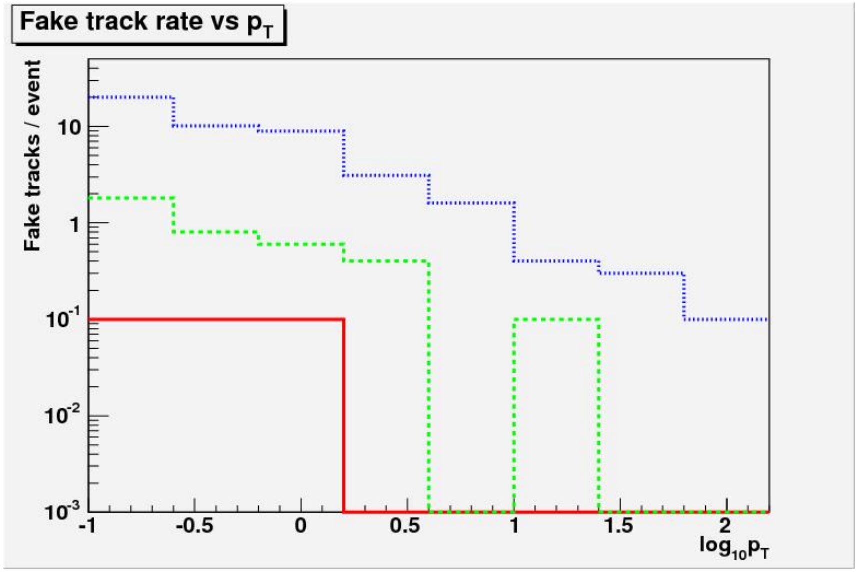
Studied 3 scenarios:

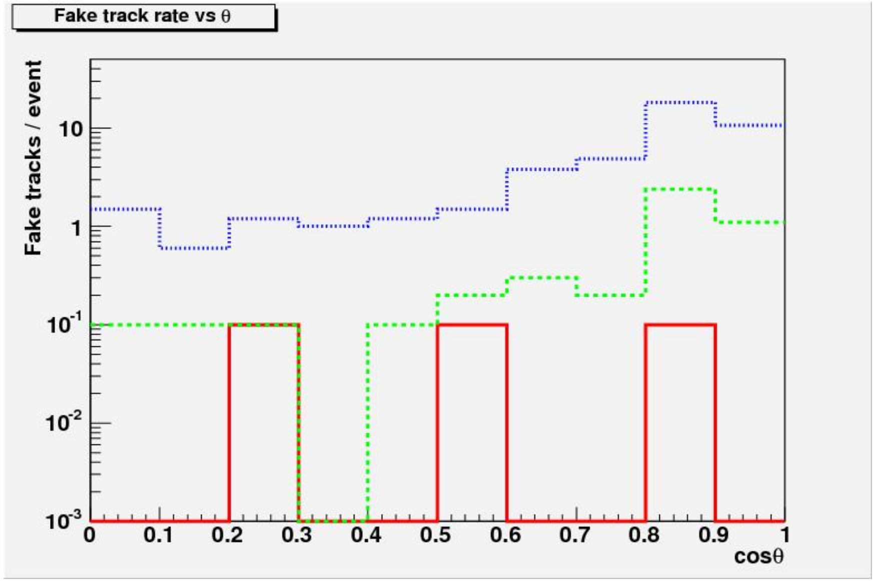
- no background ⇒ 400 hits in layer1
- Integration time of 25 μs(50 μs) in layer1(outer) ⇒ ∫ 75(150) BX, 30k hits in layer1
- Integration time of 50 μs(100 μs) in layer1(outer) ⇒ ∫150(300) BX





With background: Tracking efficiency, fake tracks





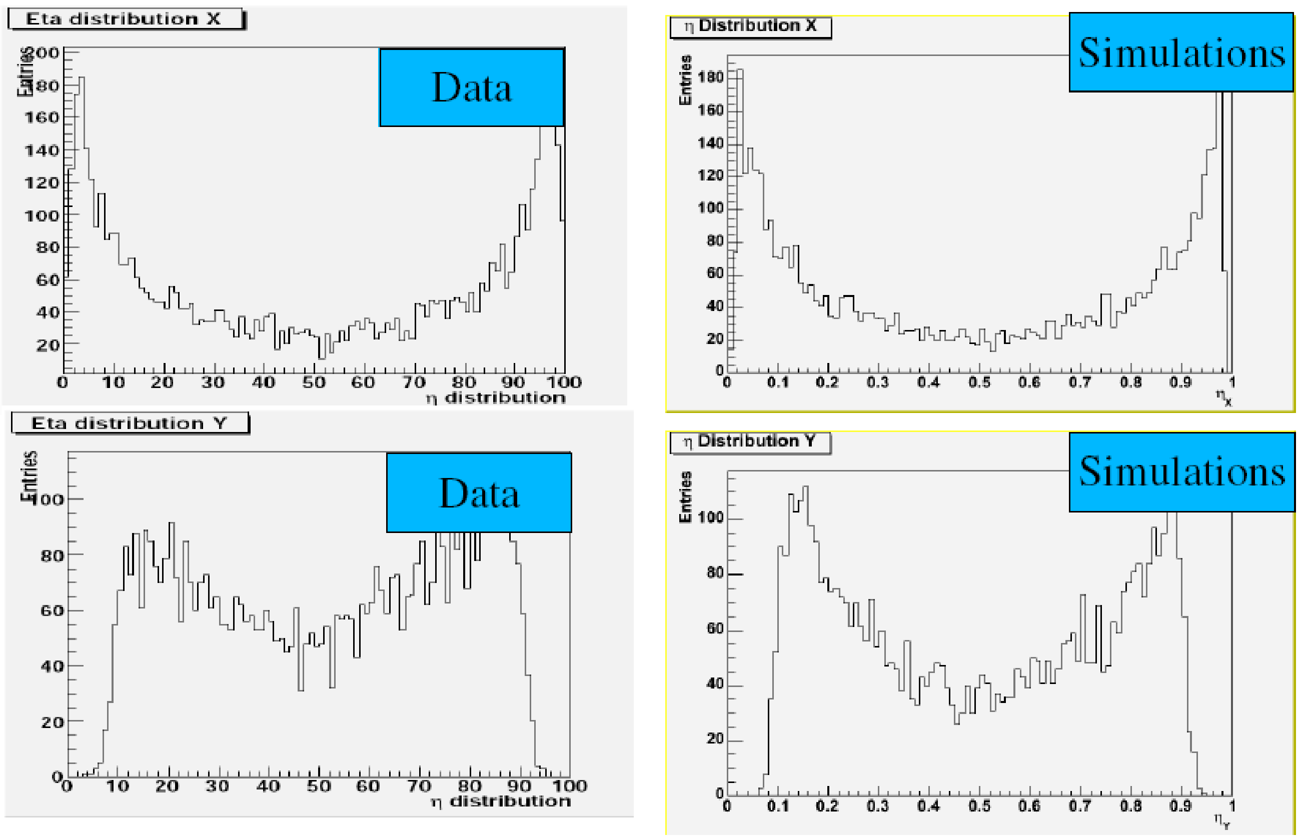
Scenario	Fakes per event	Track finding efficiency, %	
		$p_T > 0.1\text{GeV}$	$p_T > 0.5\text{GeV}$
1	0.3	88	94
2	4.2	84	91
3	45	79	86

$\Rightarrow$ Fast read-out is vital !

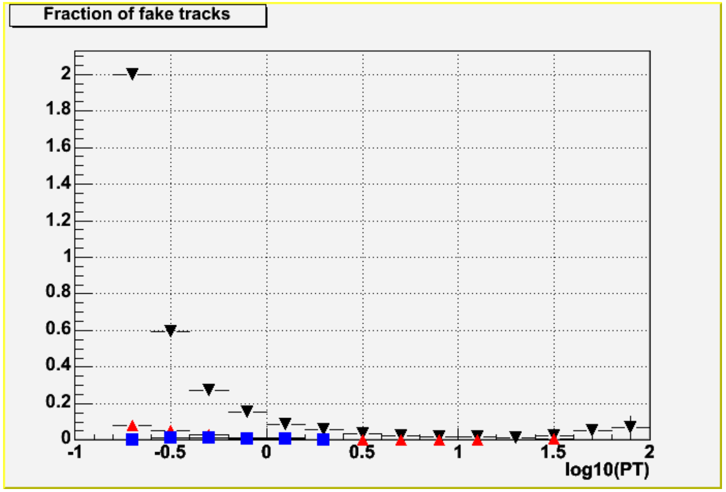
Backup

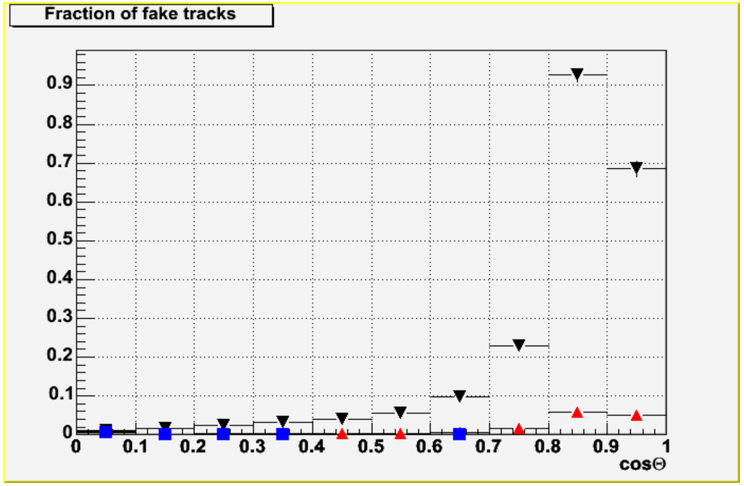
Validation with Test Beam Data

η-Distributions :
Testbeam Data vs. Simulations

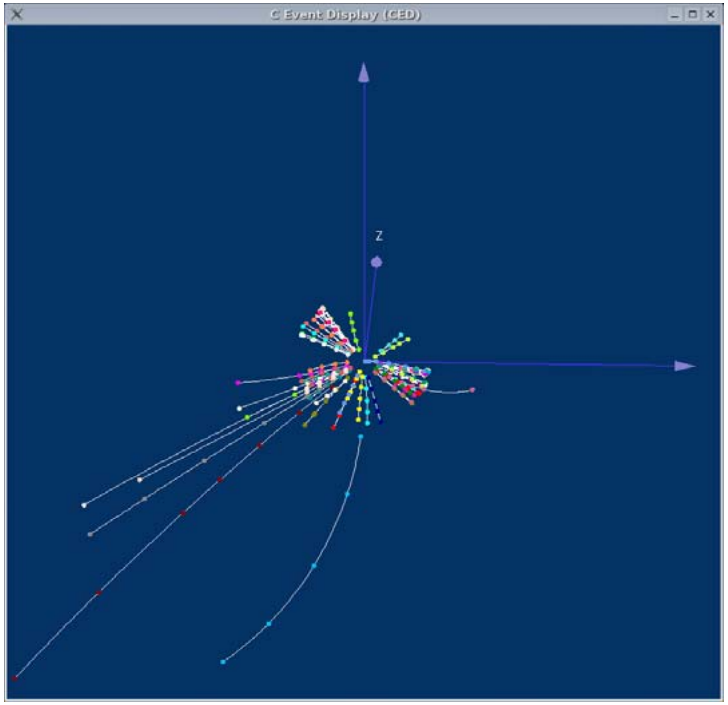


Fake tracks

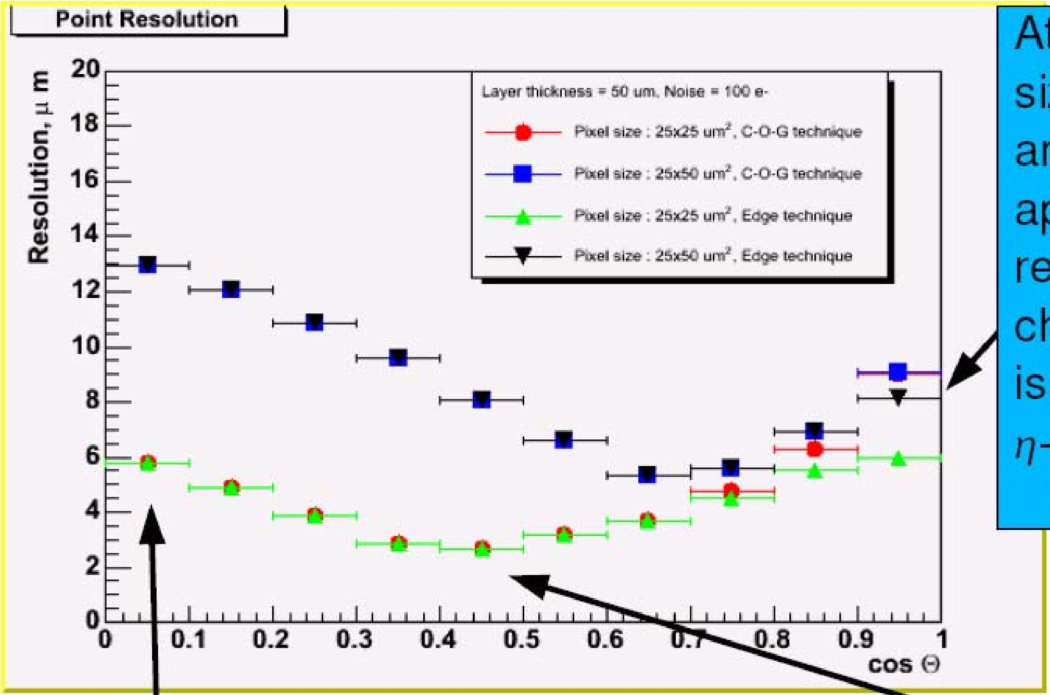




Inclusion of forward tracking helps in discarding fake tracks



Point Resolution in Z



At shallow angles cluster size gets extremely large and simple centre-of-gravity approach yeilds poor resolution due to inter-pixel charge fluctuations. Resolution is improved by means of η-algorithm (edge-technique)

In many cases at normal incidence only one row is fired :
resolution is limited by pixel size

When track is inclined more than one row is fired -> resolution gets better