PXD Simulation and Optimisation Studies

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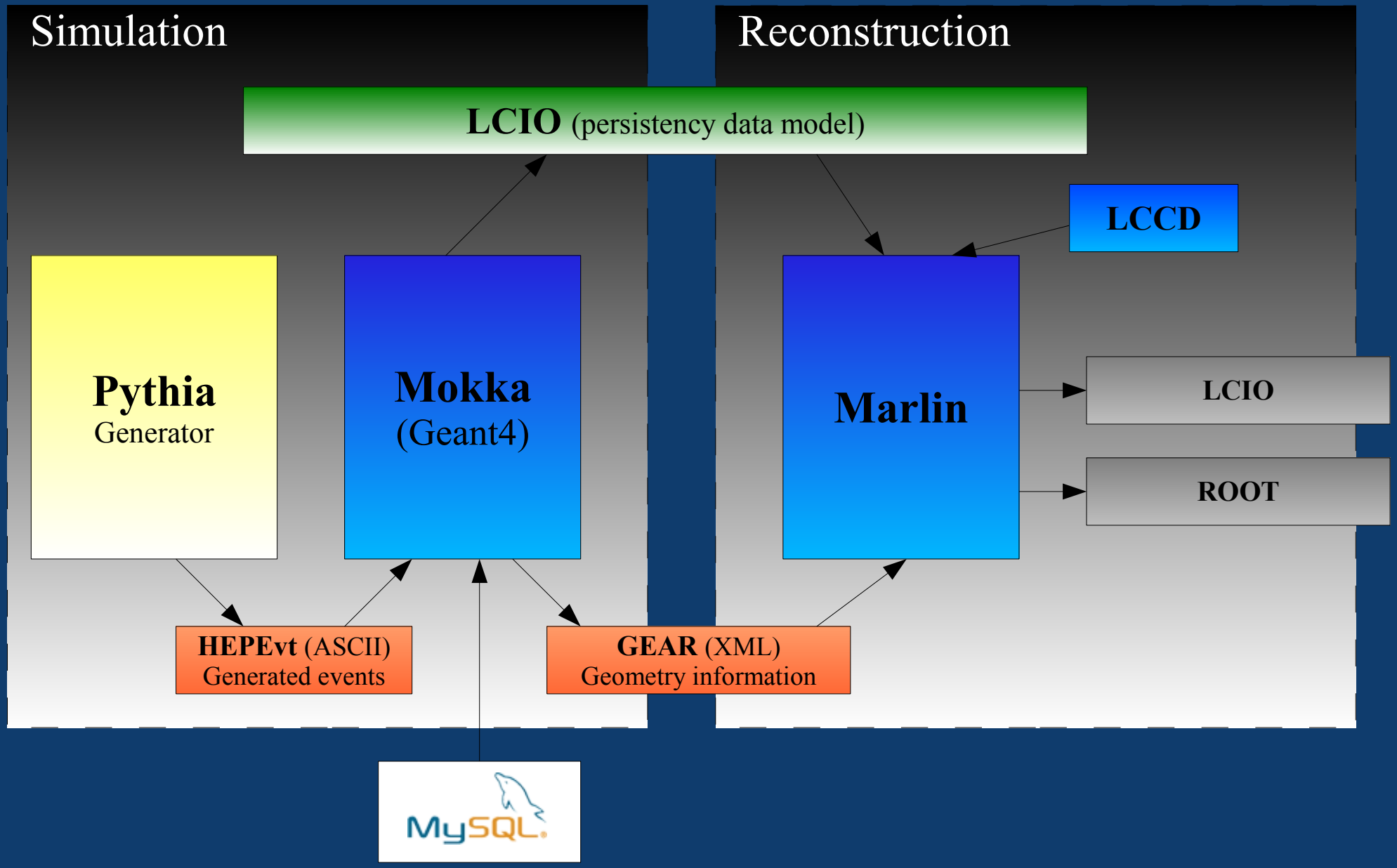
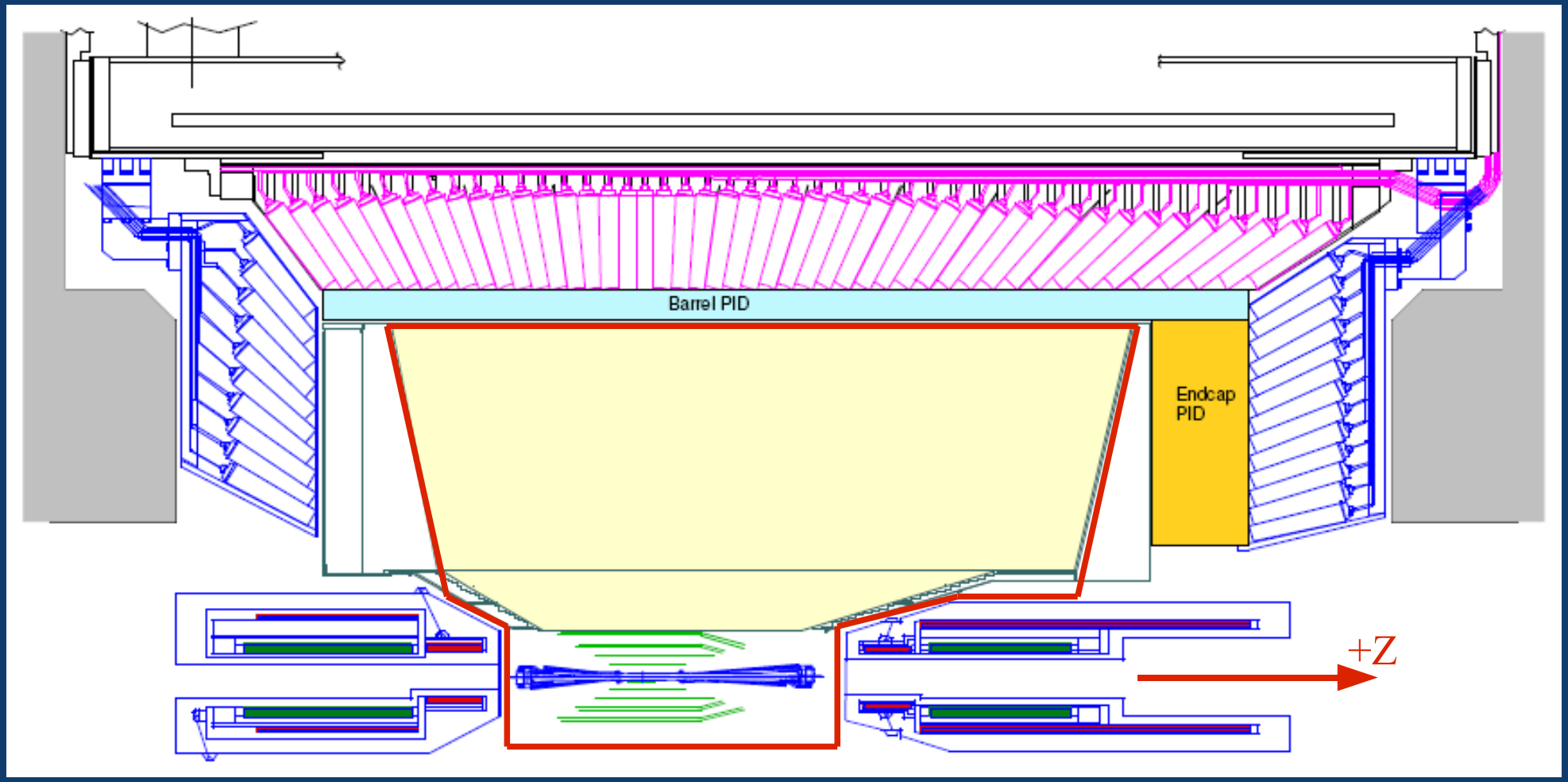
ILC Software Framework – Summary

- ILC software framework:
  - **Mokka:** Geant 4 based, full simulation toolkit using a realistic detector geometry (accessible via a MySQL database) → output in ***ascii*** or ***lcio*** format
  - **LCCD:** Conditions data framework for the ILC
  - **LCIO:** Linear Collider I/O persistency framework, which defines a data model for ILC; concrete data format implementation – Serial Input/Output (**SIO**) → output in ****.slcio***
    - **API:** in Fortran77, C++ and Java
  - **GEAR:** Geometry description toolkit for ILC analysis and reconstruction software → output in ****.xml*** file
  - **Marlin:** ILC Modular C++ Analysis & Reconstruction tool that enables modular approach (using so-called processors) to development of analysis and reconstruction code based on LCIO
  - **Marlin Reco:** Marlin based toolkit providing reconstruction algorithms for detector performance studies

ILC Software Framework – Scheme



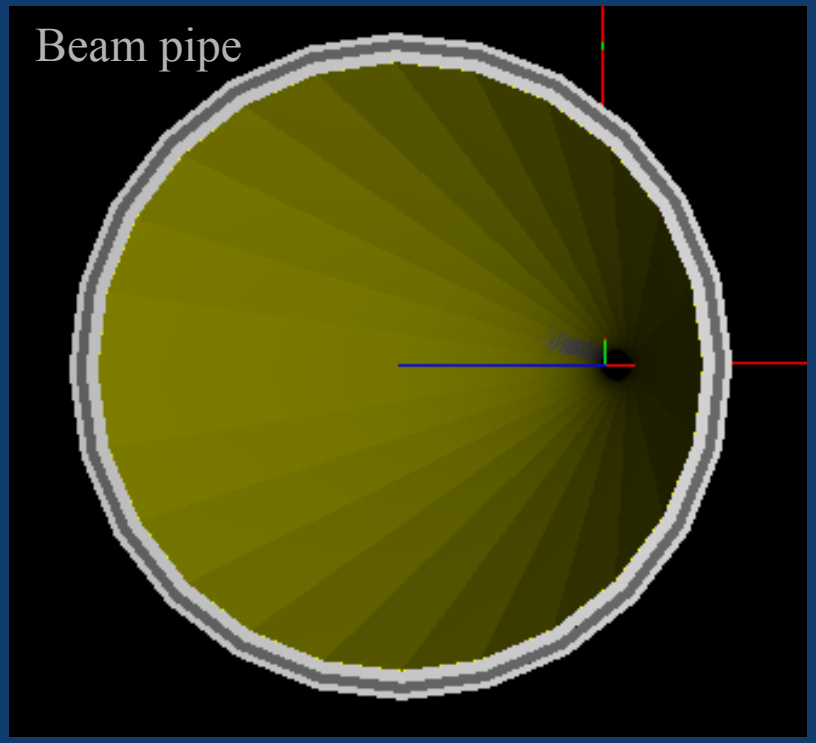
Mokka – Super Belle Detector



- Realistic geometry of: **TUBE** (beam pipe), **VXD** (vertex detector: pixel and strip barrel part and strip "forward" part) and **CDC** (central drift chamber) implemented

Mokka – Beam Pipe Geometry

- **TubeSBelle**: geometry driver that describes a beam pipe for SBelle & SBelle upgrade
  - Cylindrical - onion-like structure - with option to be rotated around Y axis (by 22 mrad):
    - "vacuum"
    - inner gold layer (shielding against soft SR): 10 μm
    - inner beryllium wall: 0.6 mm
    - cooling gap (filled with paraffin): 0.5 mm
    - outer beryllium wall: 0.35 mm

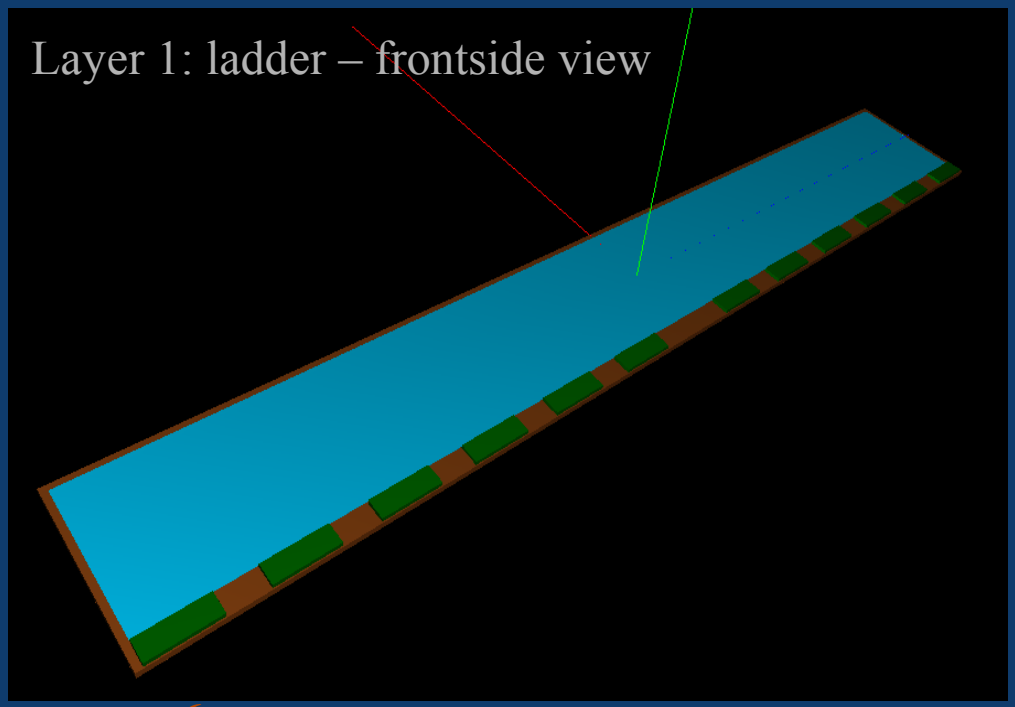


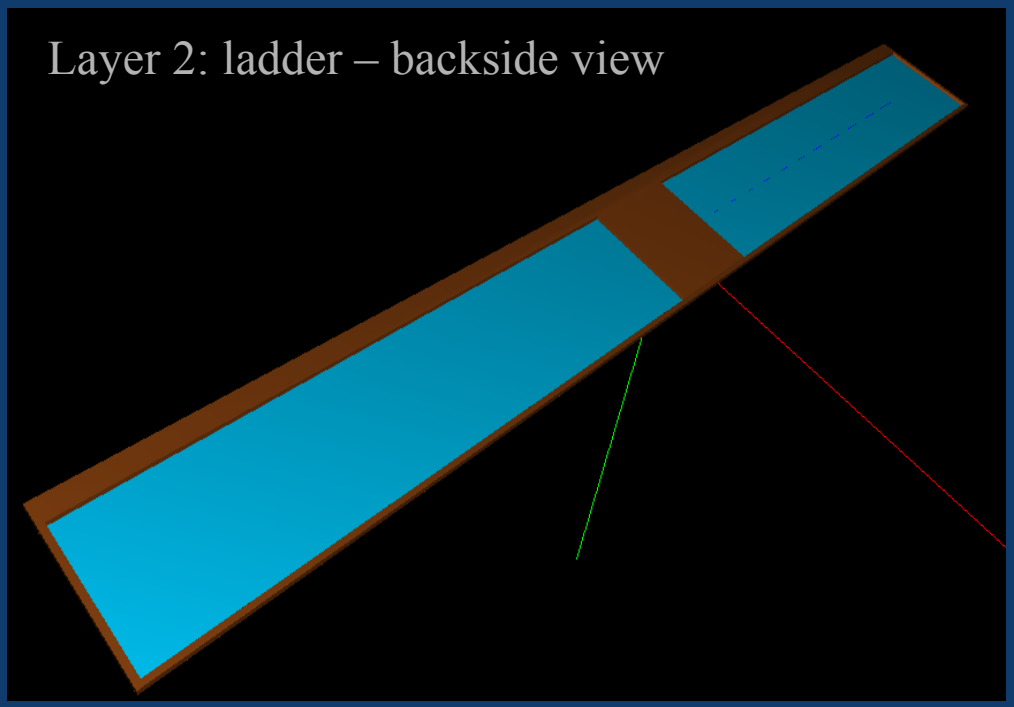
	R_{min} [mm]	R_{max} [mm]
SuperBelle	14.99	16.45
SuperBelleUpgr	8.54	10.00

Mokka – VXD Geometry – Pixel Ladders

- **VXDSBelle**: realistic geometry driver for SBelle & SBelle upgrade – VXD
  - Description: 2 layers (3 layers for upgrade) → ladders → Si sensors (50 μm) + rims (450 μm) + support (400 μm) + 12 switchers

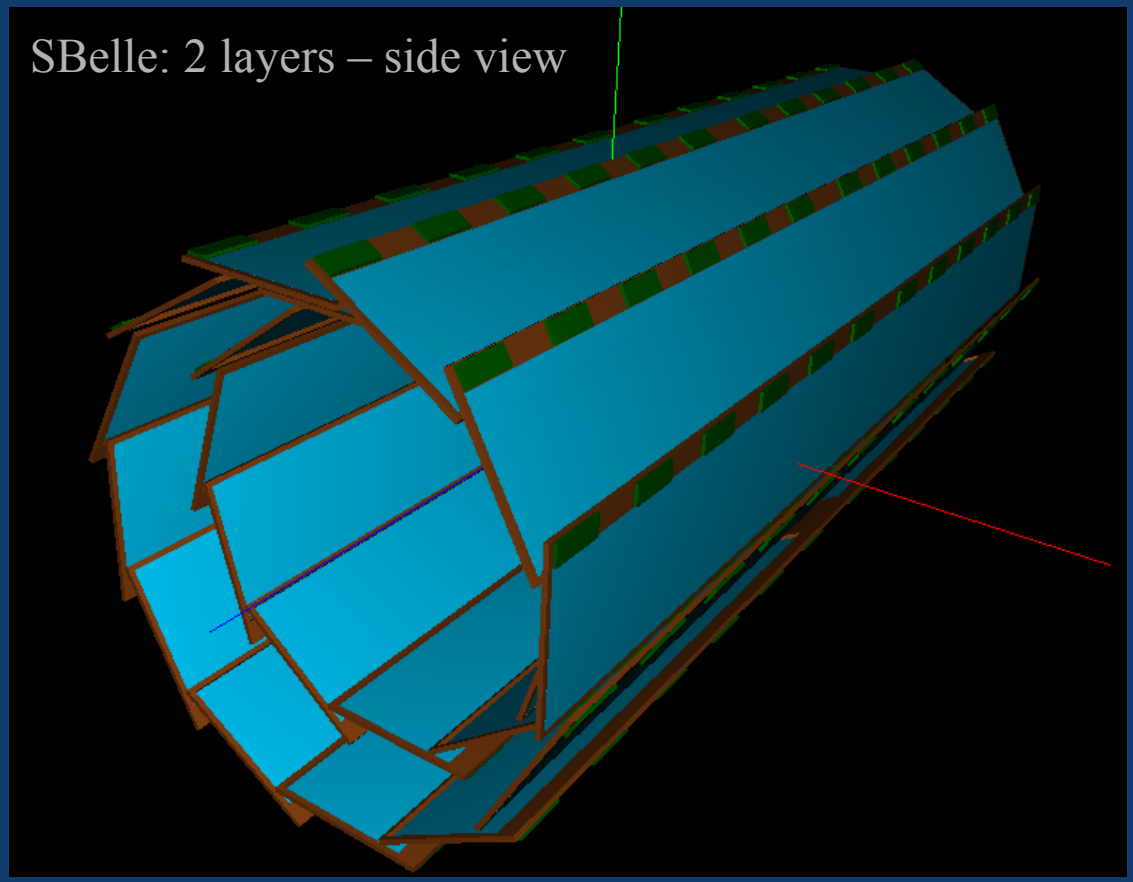
	R [mm]	***# ladders***	***support***
Pxl layer 0	13.00	8	no
Pxl layer 1	18.00	10	no
Pxl layer 2	22.00	12	yes

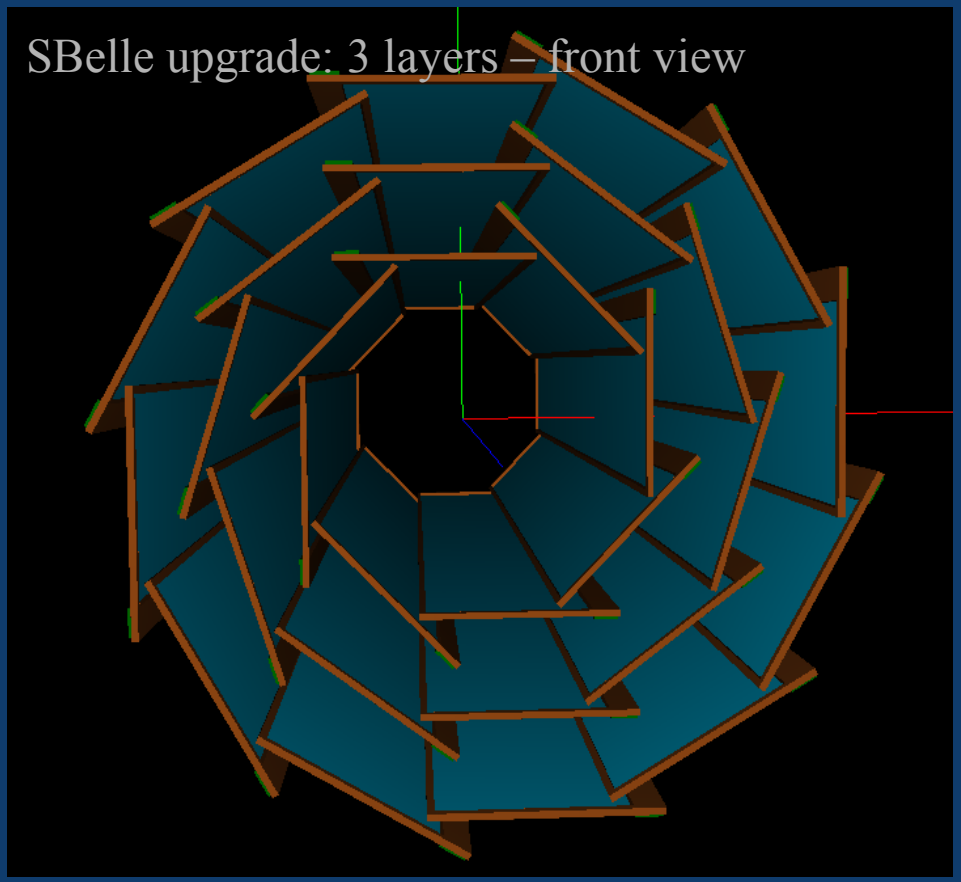




Mokka – VXD Geometry – Pixel Layers

- **VXDSBelle**: detail of pixel part for SBelle & SBelle upgrade
  - Layers with wind-mill structure
  - Option: rotate pixel layers with beam pipe (by 22 mrad)

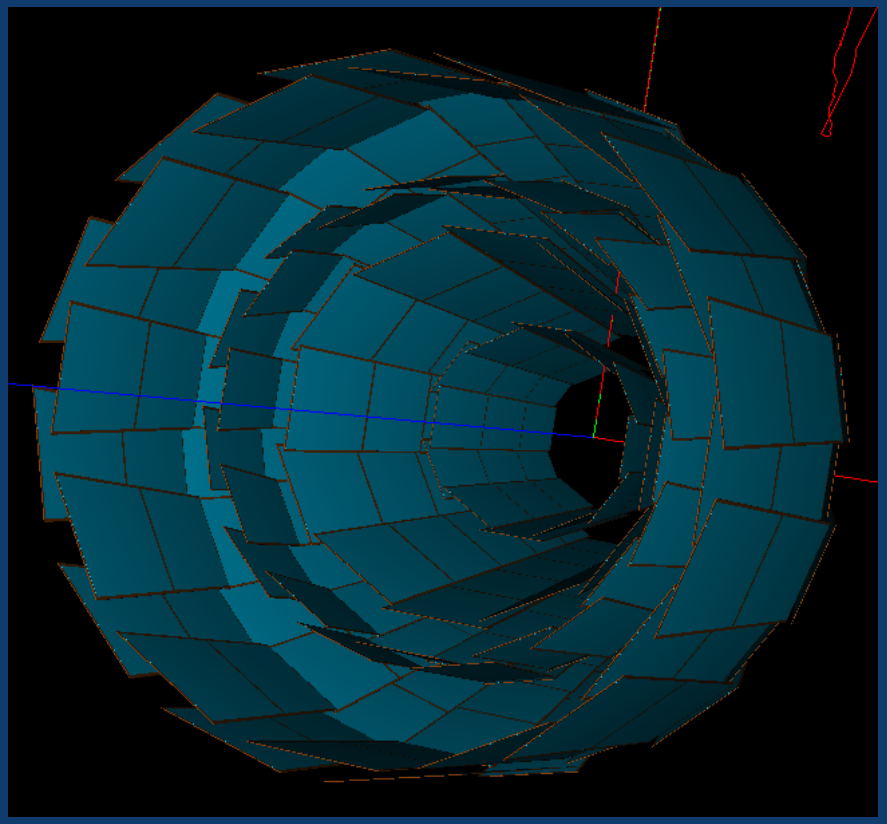




Mokka – VXD Geometry – Strip Layers

- **VXDSBelle:** driver used as well for strip part of VXD of SBelle & SBelle upgrade
  - Description: 4 layers in barrel part + 2 layers in "forward" region - (stagger-like structure) → ladders → Si sensors (active part - 300μm) + Si rims (pasive part - 300μm)

	R [mm]	***# ladders***	***# DSSDs***
Strip layer 31 – barrel	45.15	6	3
Strip layer 32 – barrel	48.15	6	3
Strip layer 41 – barrel	70.15	6	5
Strip layer 42 – barrel	73.15	6	5
Strip layer 51 – barrel	100.15	12	5
Strip layer 52 – barrel-slanted	89.15	12	1
Strip layer 53 – barrel	103.15	12	5
Strip layer 54 – barrel-slanted	92.15	12	1
Strip layer 61 – barrel	137.15	12	6
Strip layer 62 – barrel-slanted	117.65	12	2
Strip layer 63 – barrel	140.15	12	6
Strip layer 64 – barrel-slanted	120.65	12	2

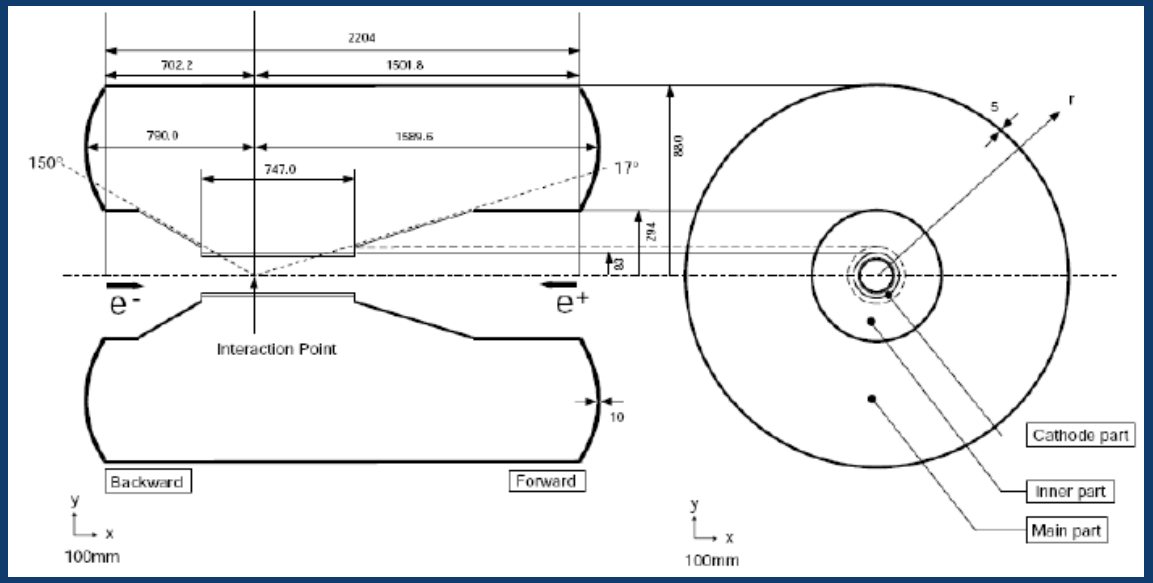


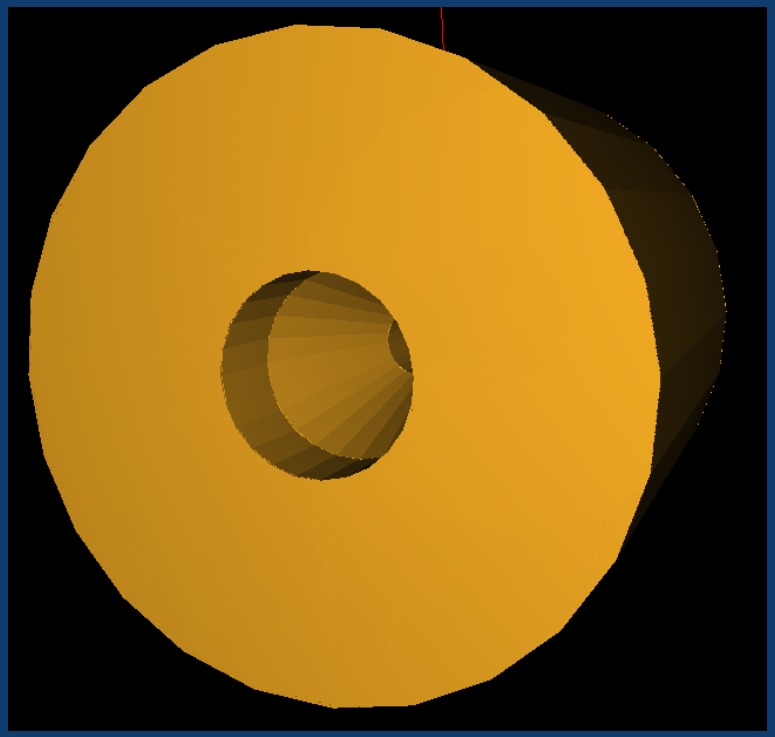
SBelle: strip layers – front view

Mokka – CDC Geometry

- **CDCSBelle:** realistic geometry driver (by P. Vanhoefer) describing central drift chamber for SBelle
  - Aluminium cylinder with cone-shaped inner parts filled with gas He/C_2H_6 (50:50)

Radius – inner boundary	361 mm
Radius – inner-middle boundary	150 mm
Radius – outer boundary	1150 mm
Radius – innermost sens. wire	172 mm
Radius – outermost sens. wire	1120 mm
Number of sensitive layers	58

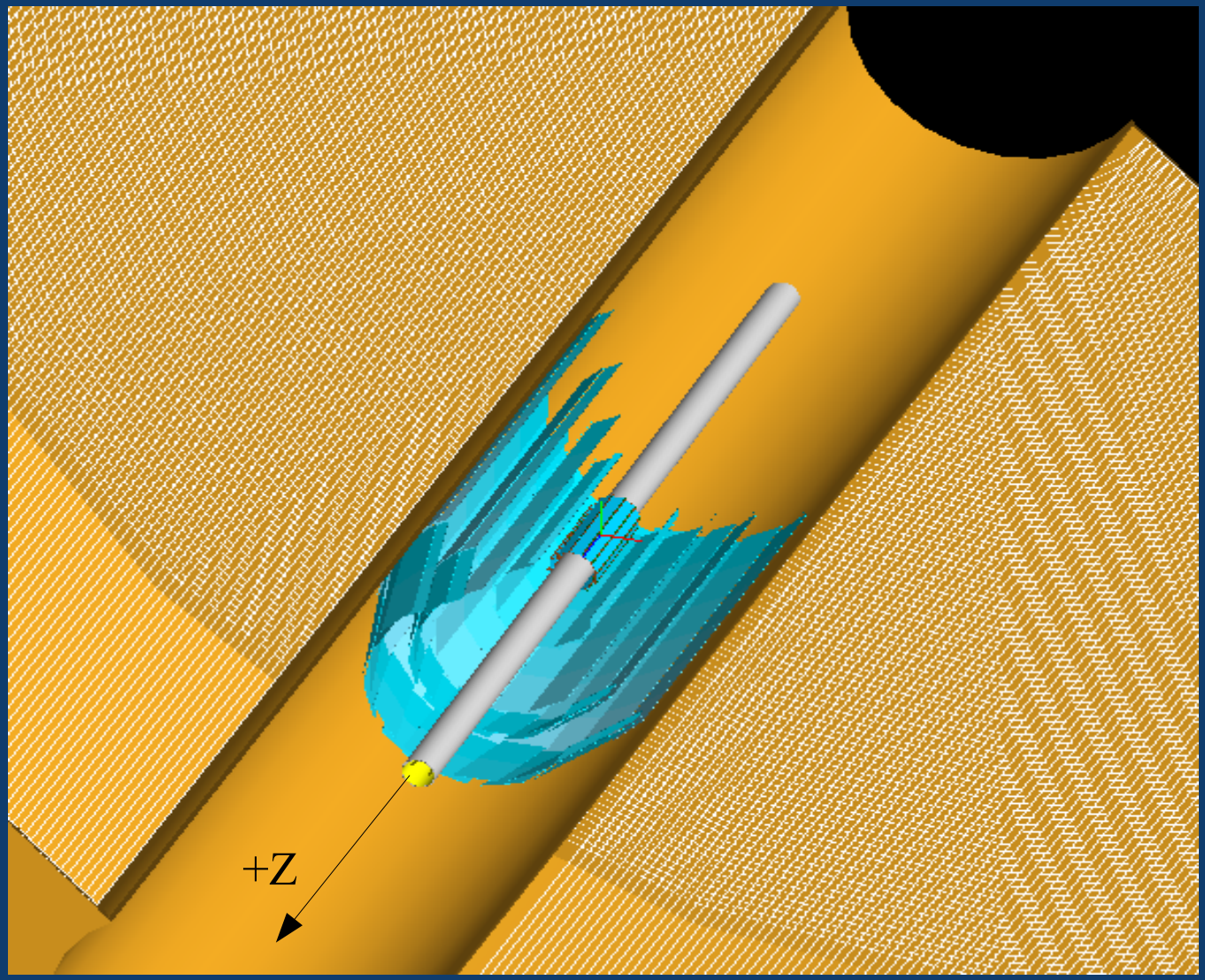




SBelle: CDC – front view

Mokka – Tracker Geometry

- Implemented tracker:
  - Pixel layers (VXD)
  - Strip layers (VXD)
  - CDC

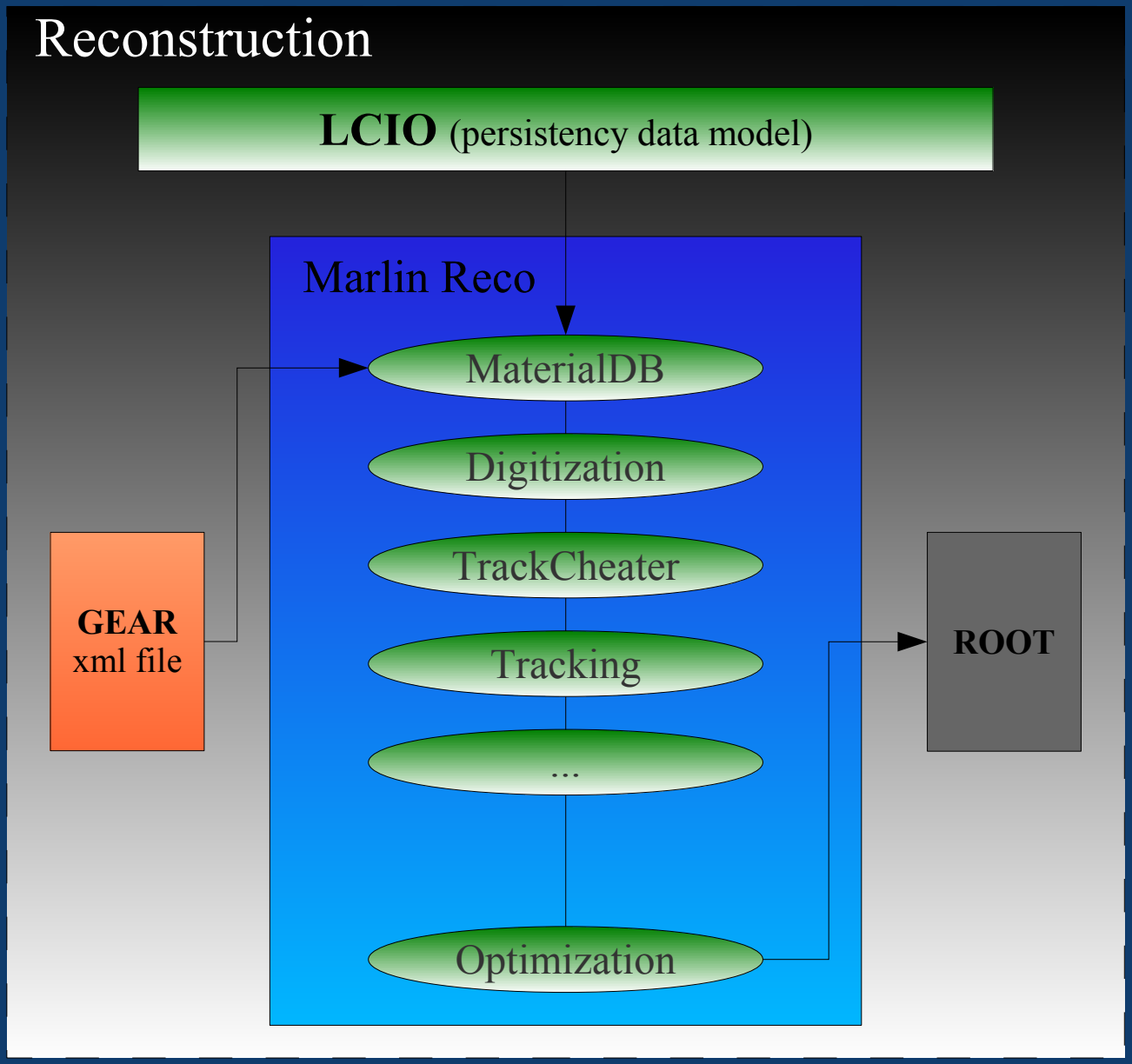


Optimisation studies

- **Geometry:**
  - 3 versions of detectors: Belle (SVD2), SuperBelle, SuperBelle upgrade
  - Pixel detector geometry with:
    - bricked (B) or non-bricked (U) structure in R-Φ (250 pixels)
    - 2nd layer with silicon support structure (0.5 cm or 1 cm)
    - variable pixel size (VPS) or constant pixel size (CPS) along z axis
    - 1000 or 800 pixels along z axis @ integration time 10 μs
    - 2000 or 1600 pixels along z axis @ integration time 20 μs
- **Particle muon gun:**
  - Momentum scan: 0.1, 0.2, 0.3, 0.4, 0.6, 0.8, 1.0, 1.5, 2.0 GeV
  - Polar angle scan: 20, 40, 60, 80 degrees
  - Azimuthal angle: isotropic – uniform smearing
- **Pythia generator:**
  - $J/\Psi \rightarrow \mu^- \mu^+$
  - B decays
- **Optimization studies ongoing – preliminary results presented here ...**

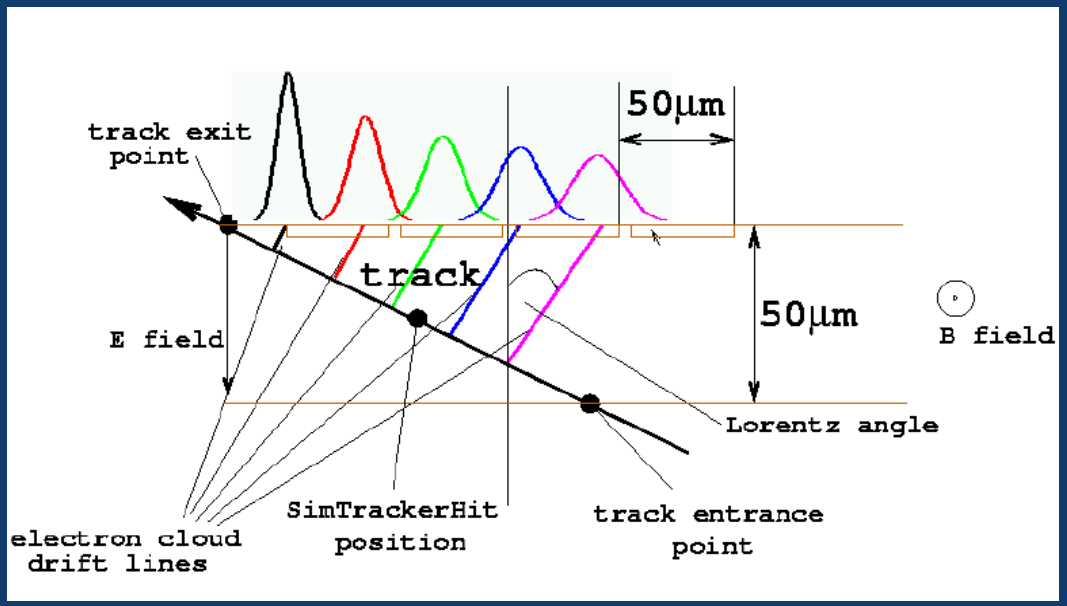
Marlin & MarlinReco

- MarlinReco used – ILC software reconstruction package adapted for SBelle experiment



Marlin – SVD Digitization

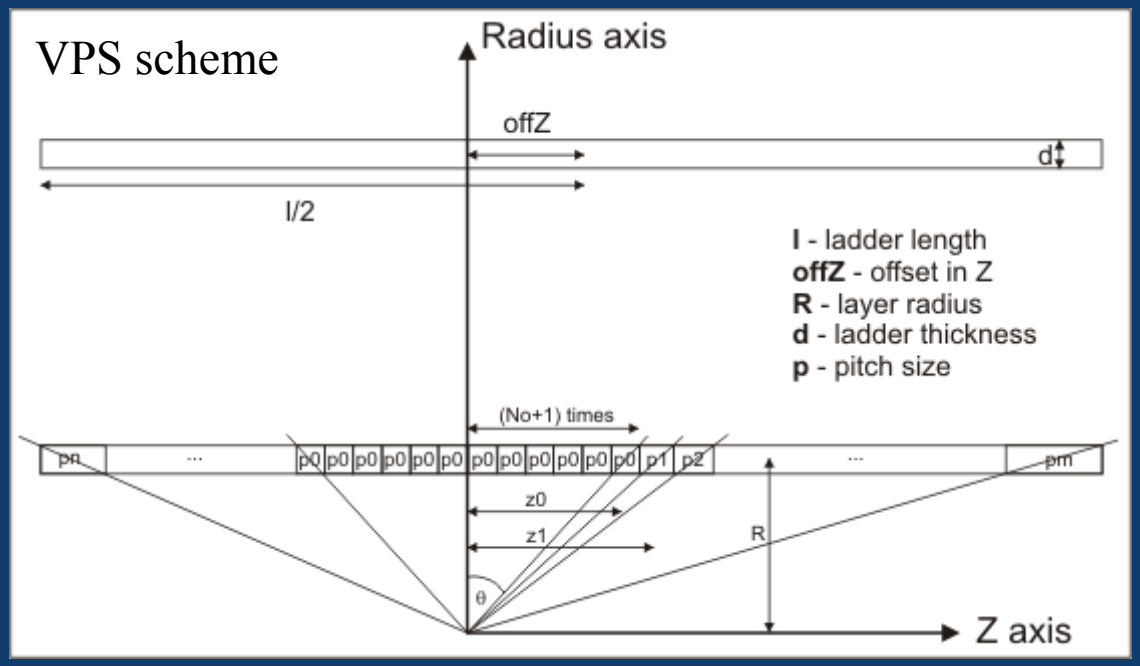
- **VTXDigitizer:** MarlinReco pixel digitizer – adapted A. Raspereza's VTXDigitizer
  - used for both pixel and strip sensors; no dedicated strip detector digitizer – ghost hits are not simulated (plan to implement standalone strip digitizer)
  - Input: LCIO SimTrackerHits → Output: LCIO TrackerHits
  - Processes:
    - Global to local ref. system transformation
    - Ionisation points generated: energy loss fluctuation added → e-h pairs along the path created
    - Signal points generated: e^- drift performed → e^- Lorentz shift in mag. field of 1.5 T calculated → e^- diffusion calculated
    - Digits produced: pixels with signal bigger than threshold (2 x noise) found
      - noise for pixels set = 100 e
      - noise for strips set = 1200 e
    - Local to global ref. system transformation
    - Hits produced – clustering performed
    - Resolution calculated
    - Background generated (see next slide)



Constant x Variable Pixel Size in Z

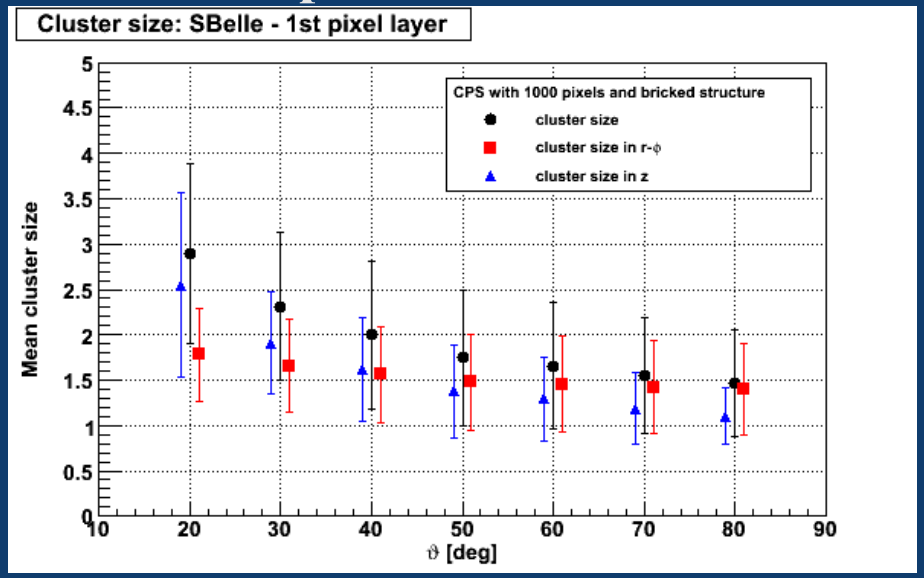
- **Constant pixel size** (CPS) in Z → increasing resolution σ_z
- **Variable pixel size** (VPS) in Z → resolution $\sigma_z \approx$ pitch/(S/N) roughly constant
- Calculations: requirement for variable pad size in Z: zo/R = po/d → No = R/d -1/2
  - zo = po(No + 1/2)
  - z1 = po(No + 1/2) + p_1/2 ...
- "Sensors asymmetric" – the same number of pixel rows on each side required

N = 1000	*po* [μm]	p_n [μm]	p_m [μm]
Pxl layer 0	55.66	101.31	190.87
Pxl layer 1	87.81	93.86	177.16
Pxl layer 2	111.6	n = 0	174.15
N = 800			
Pxl layer 0	81.71	101.31	190.87
Pxl layer 1	117.1	n = 0	177.5
Pxl layer 2	145.2	n = 0	174.15

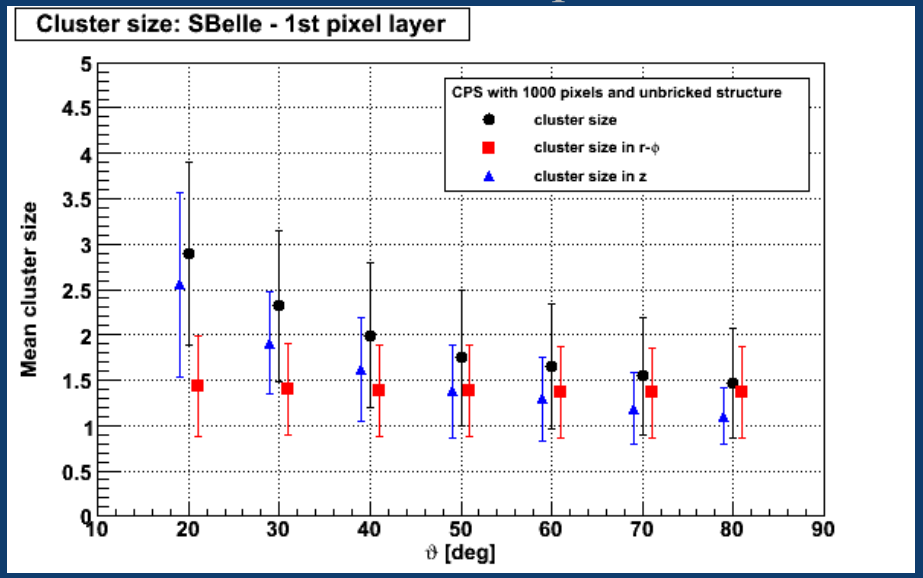


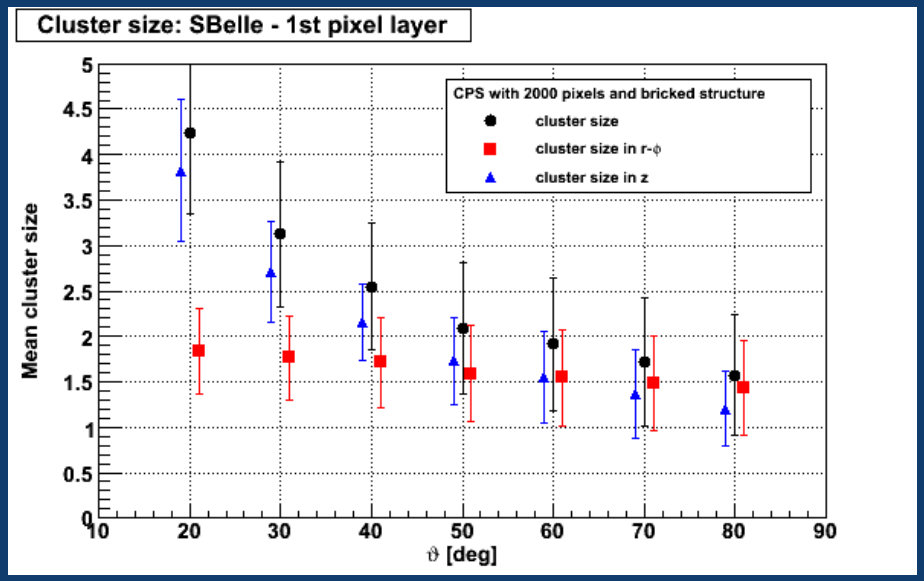
Results: CPS - Cluster Size for 1st Layer

- **Constant pixel size:** bricked versus unbricked structure for **1000** or **2000** pixels, 1GeV μ^-

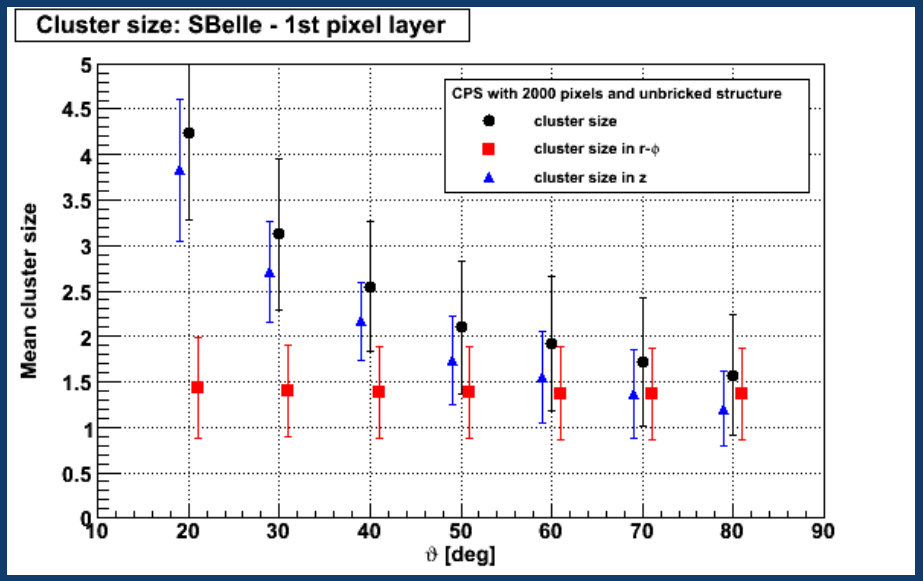


1000
B x U



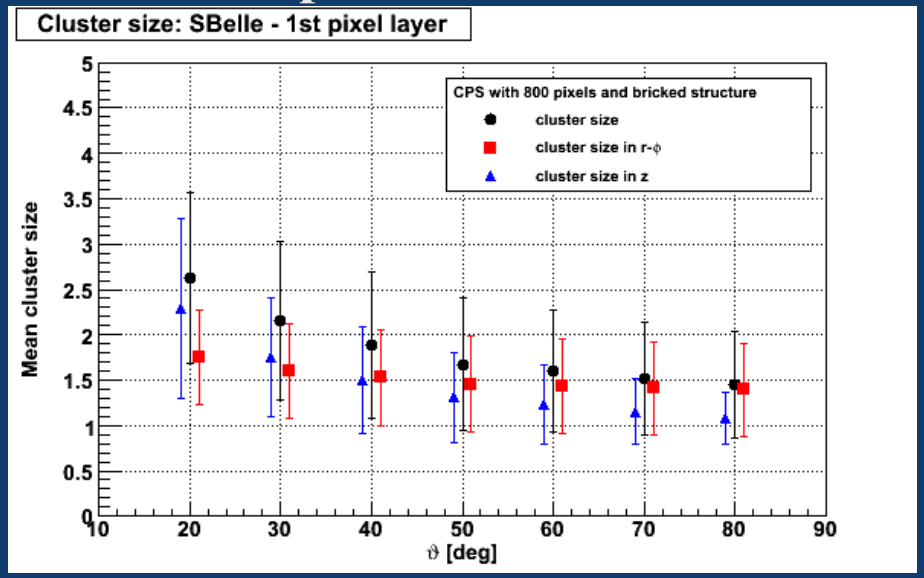


2000
B x U

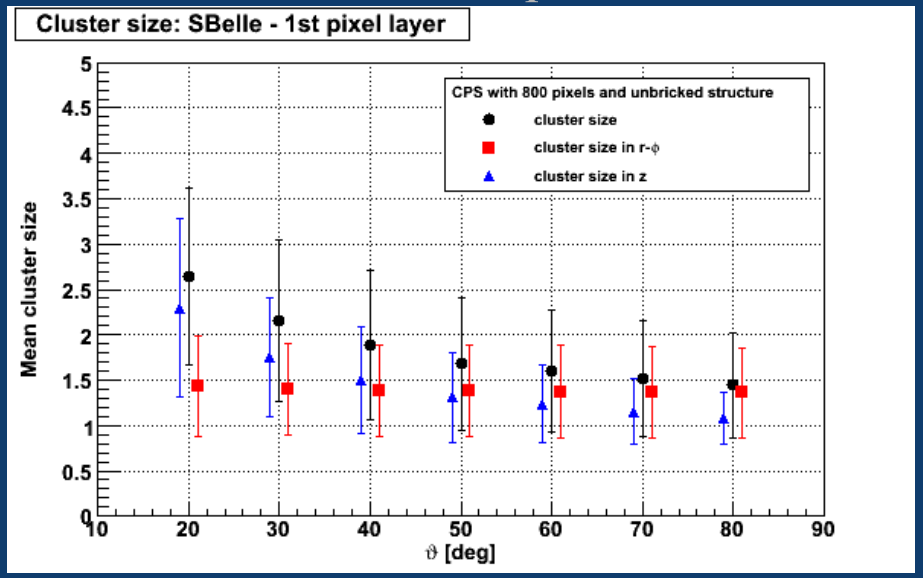


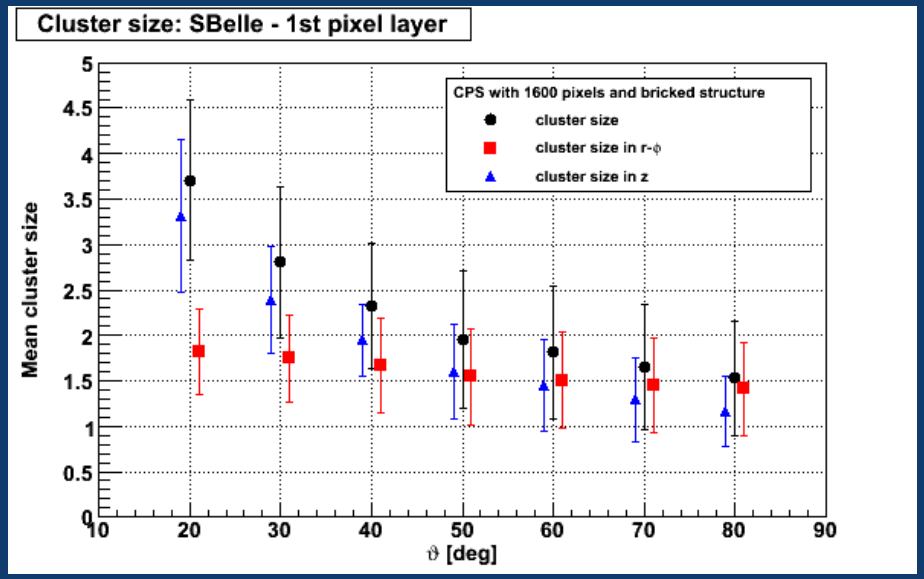
Results: CPS - Cluster Size for 1st Layer

- **Constant pixel size:** bricked versus unbricked structure for **800** or **1600** pixels, 1GeV μ^-

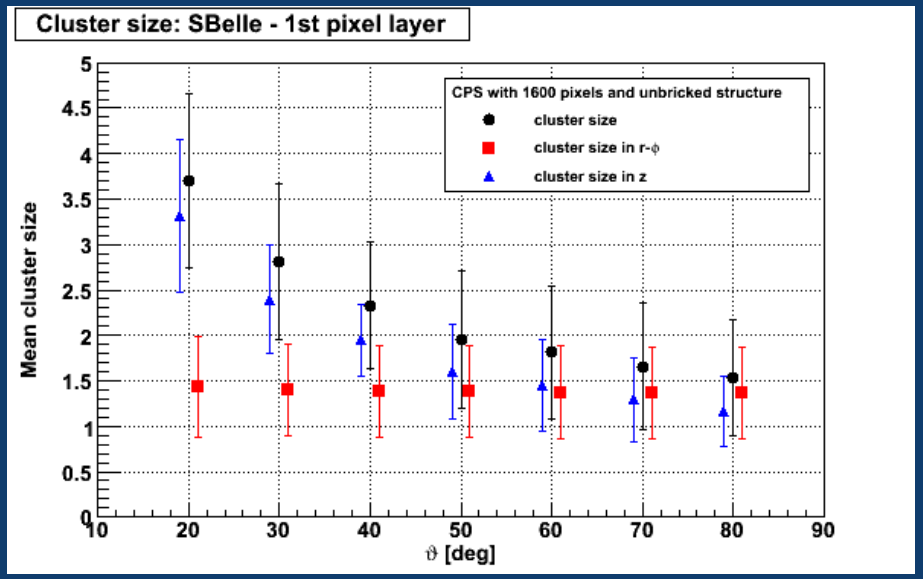


800
B x U



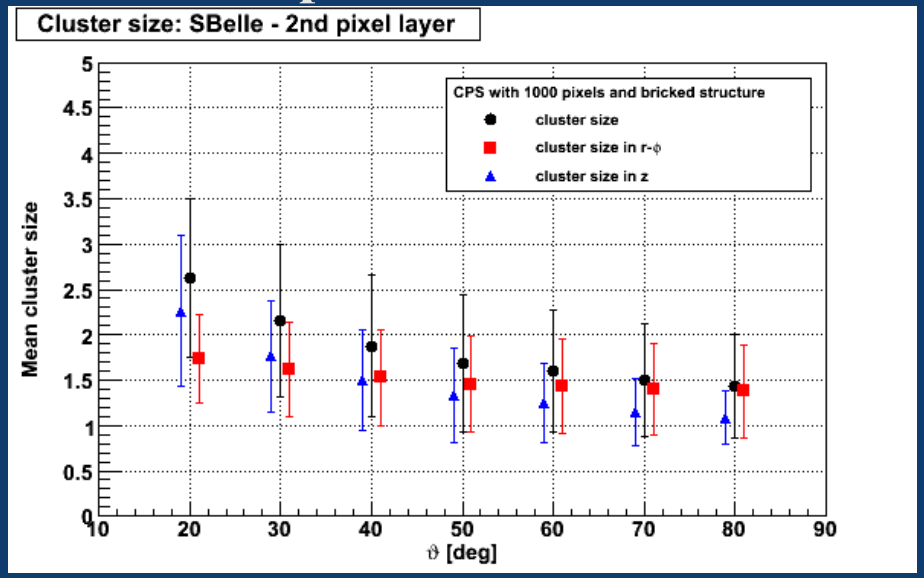


1600
B x U

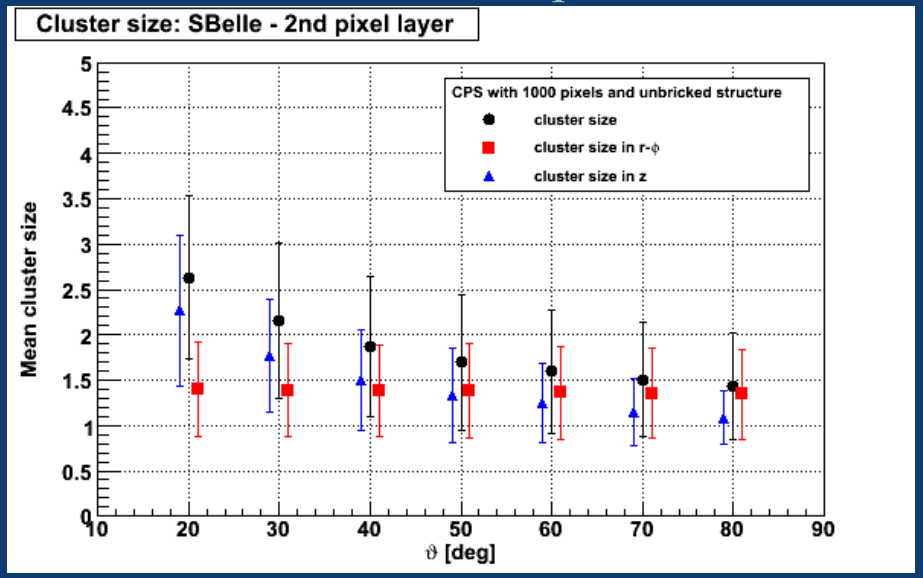


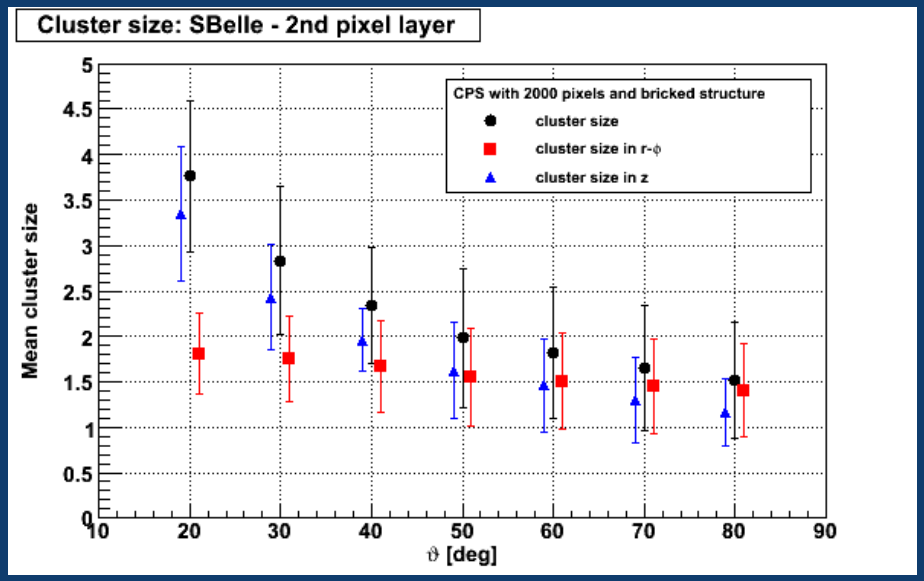
Results: CPS - Cluster Size for 2nd Layer

- **Constant pixel size:** bricked versus unbricked structure for **1000** or **2000** pixels, 1GeV μ^-

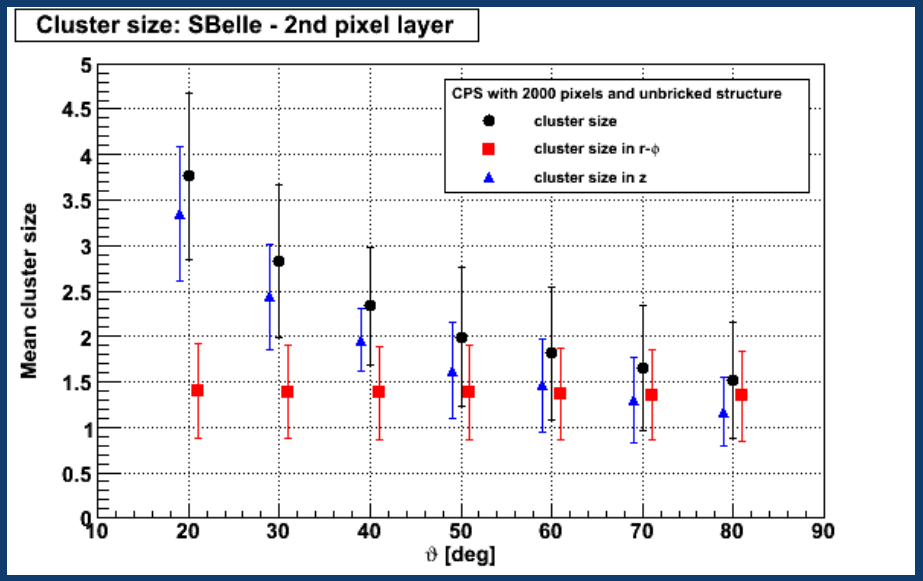


1000
B x U



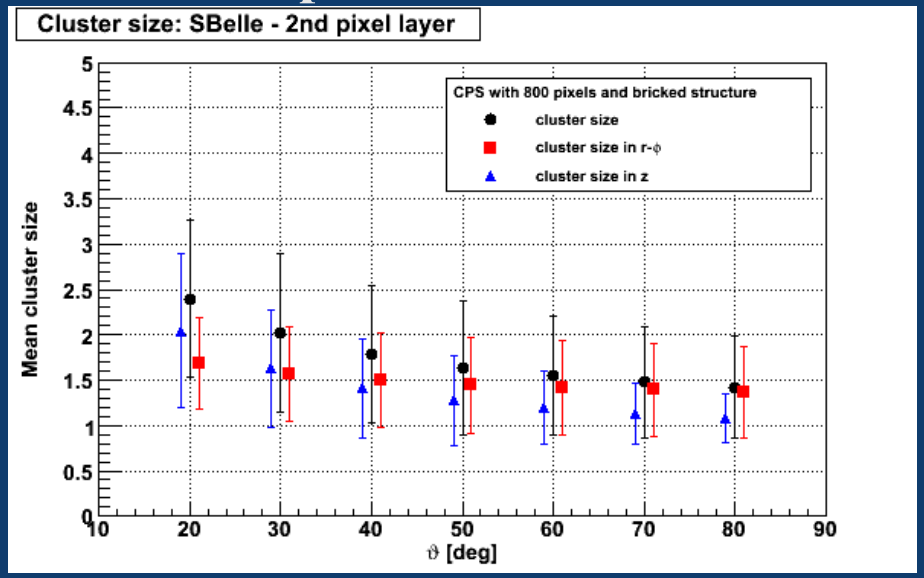


2000
B x U

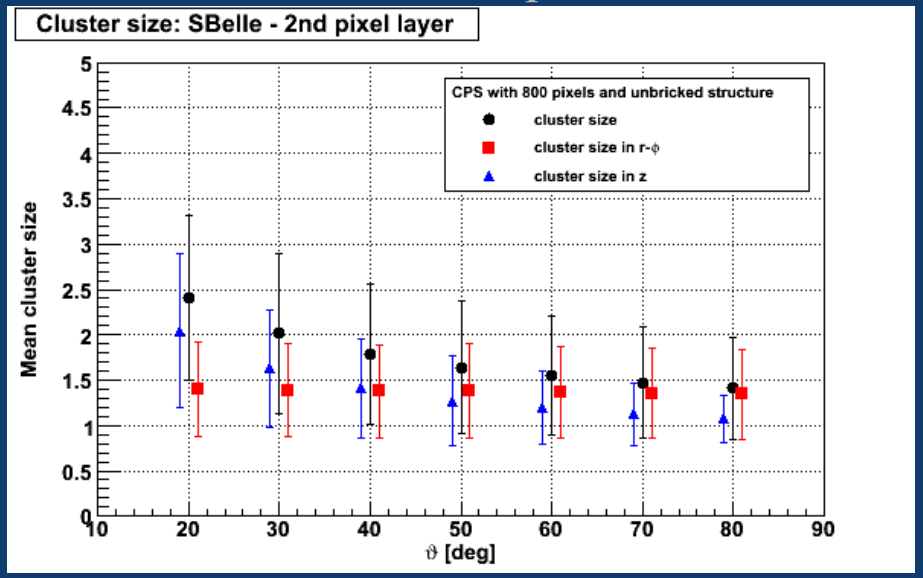


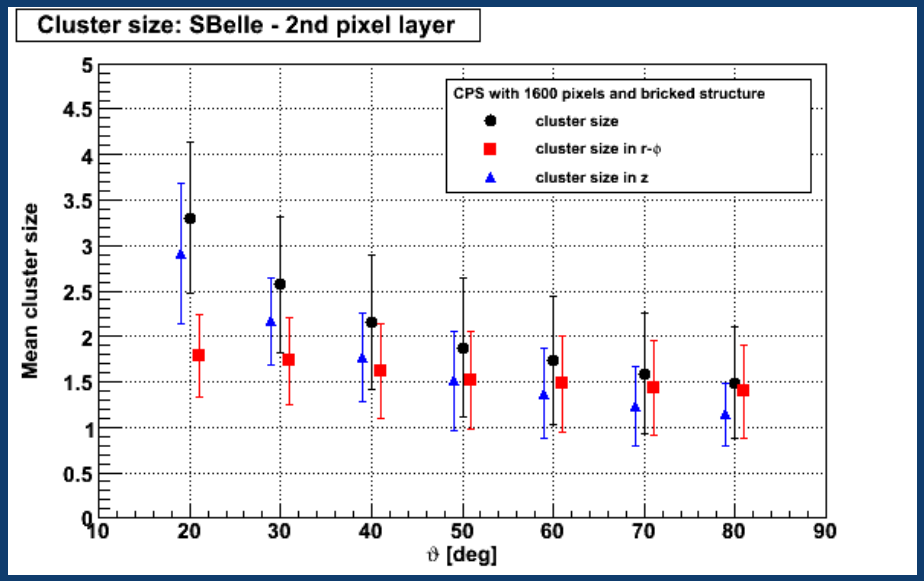
Results: CPS - Cluster Size for 2nd Layer

- **Constant pixel size:** bricked versus unbricked structure for **800** or **1600** pixels, 1GeV μ^-

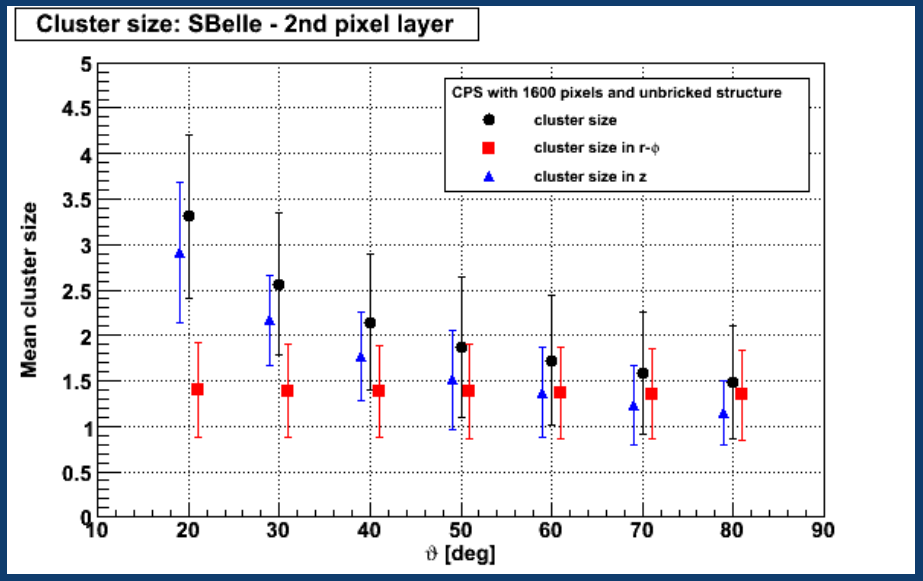


800
B x U



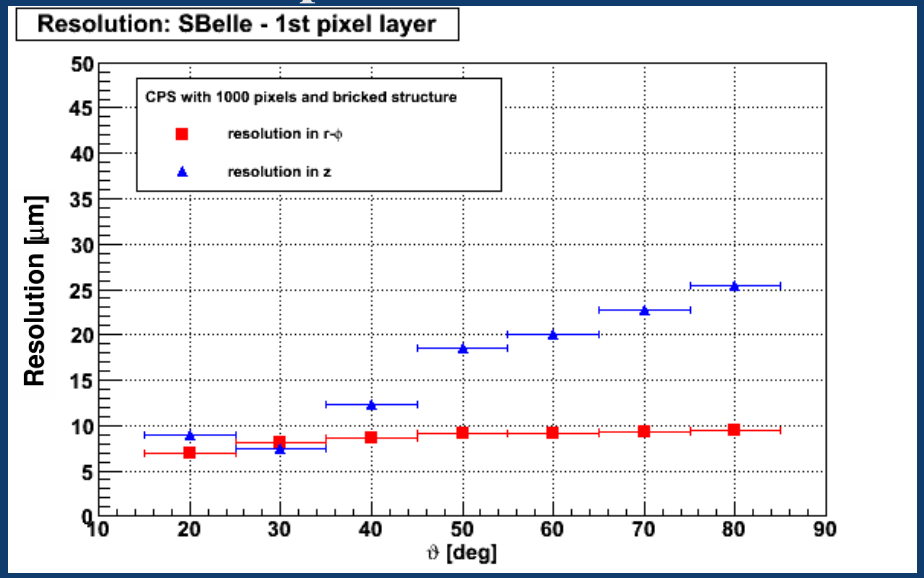


1600
B x U

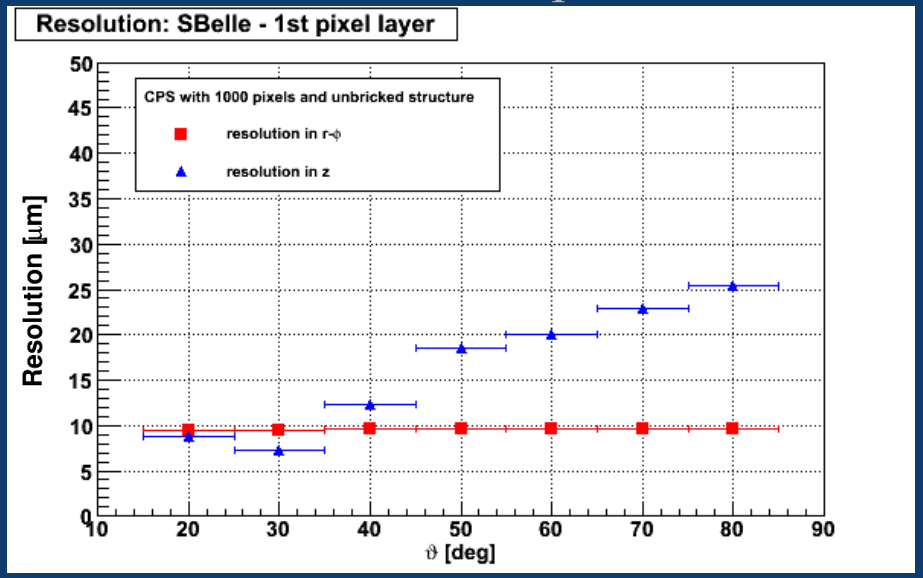


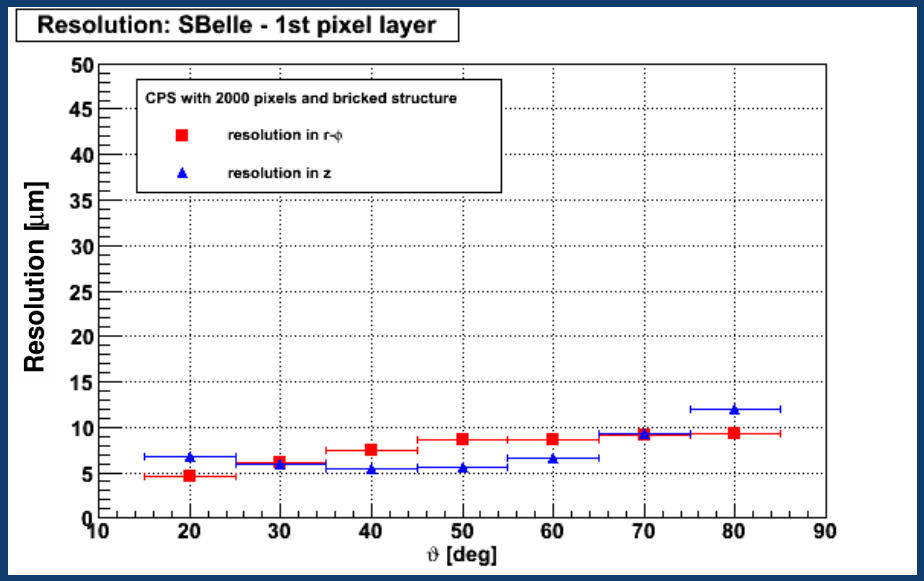
Results: CPS – Resolution for 1st Layer

- **Constant pixel size:** bricked versus unbricked structure for **1000** or **2000** pixels, 1GeV μ^-

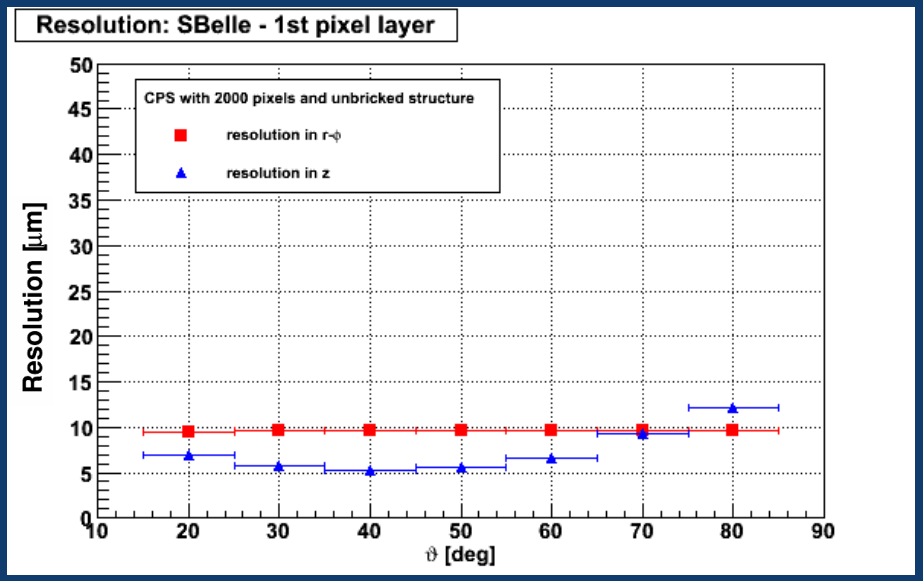


1000
B x U



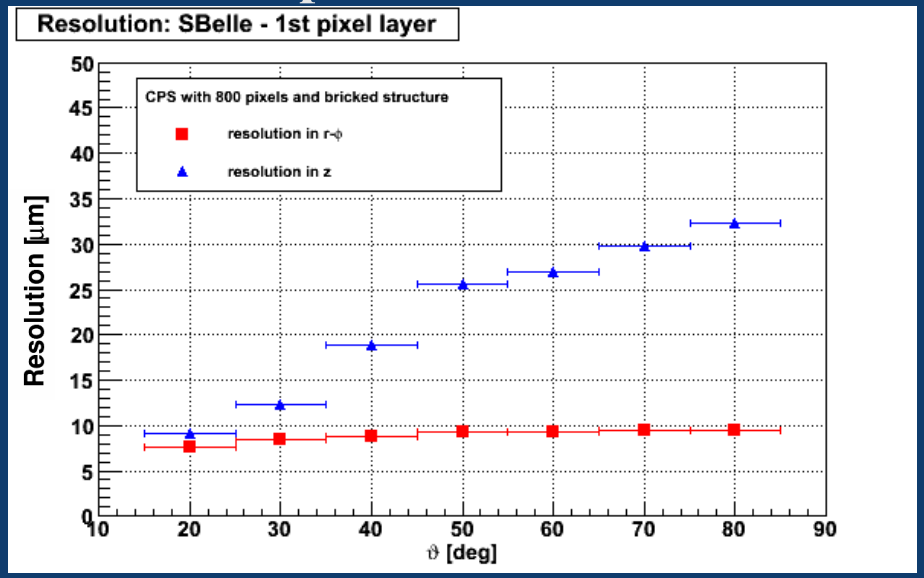


2000
B x U

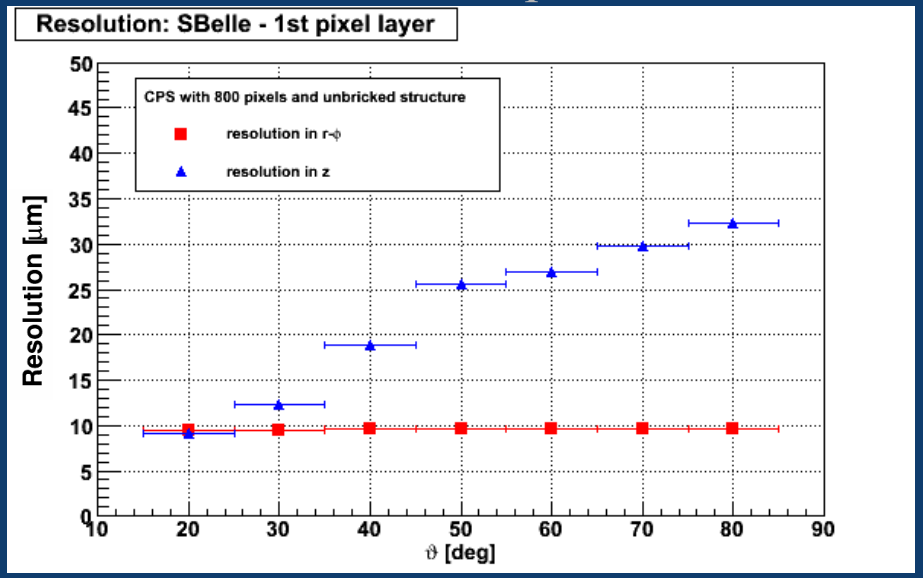


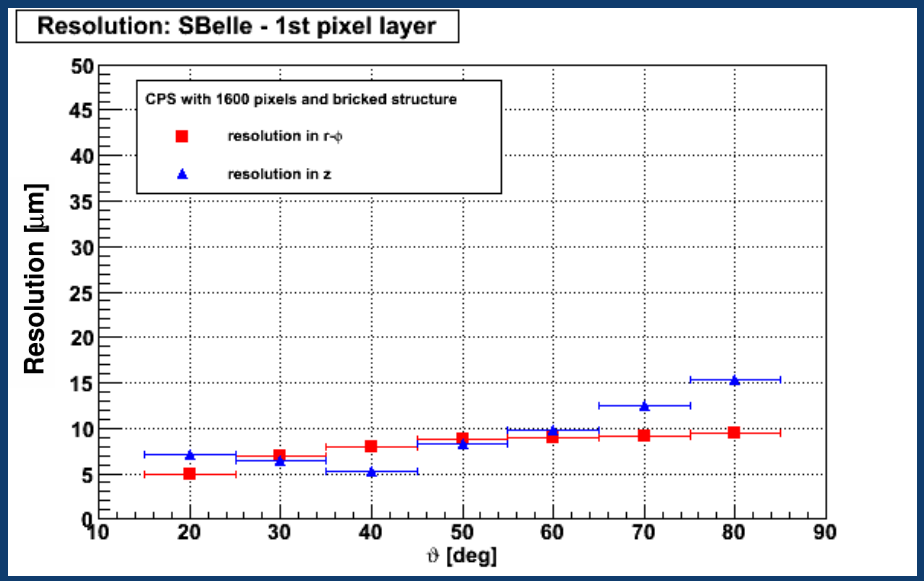
Results: CPS – Resolution for 1st Layer

- **Constant pixel size:** bricked versus unbricked structure for 800 or 1600 pixels, 1GeV μ^-

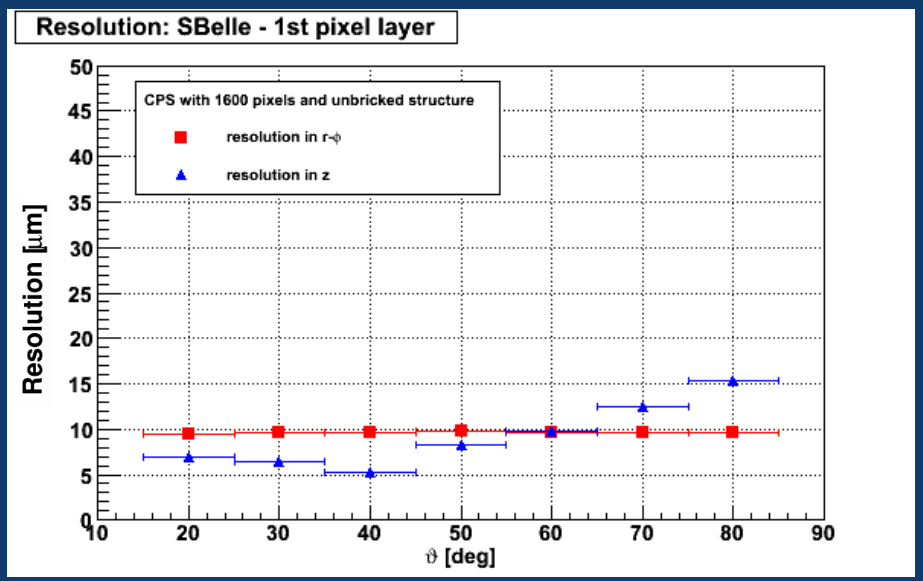


800
B x U



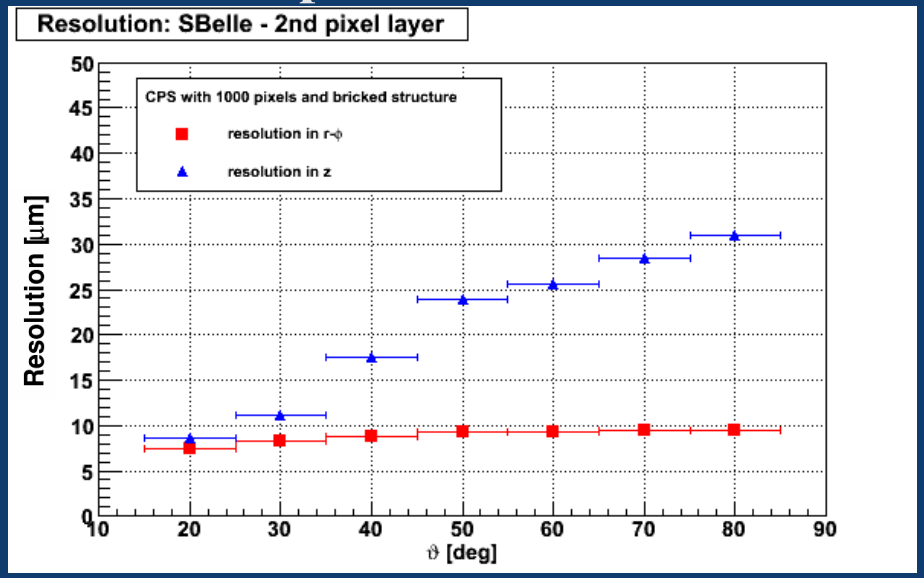


1600
B x U

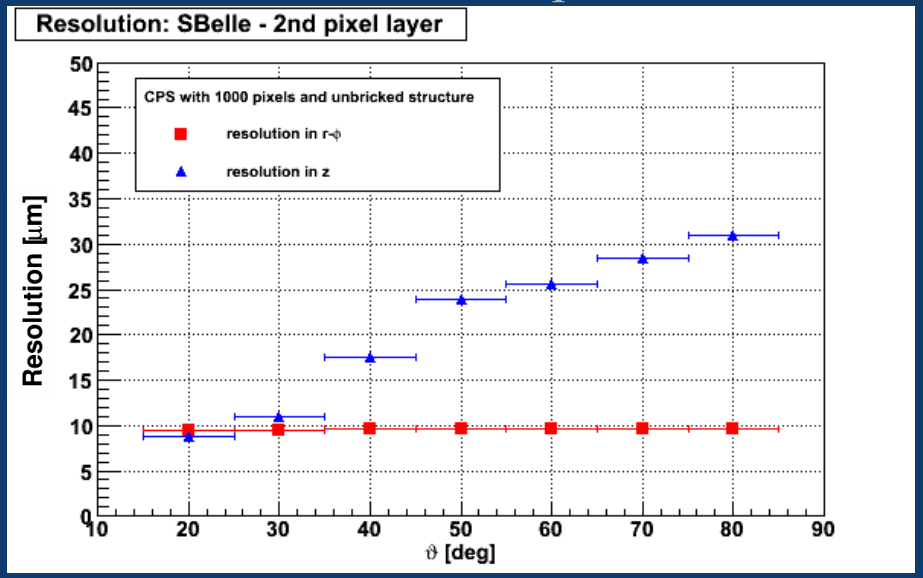


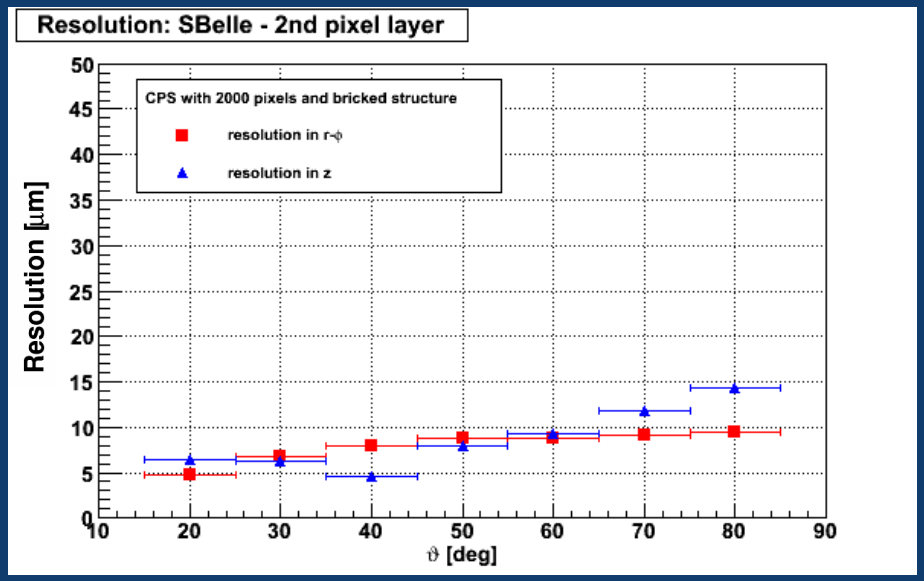
Results: CPS – Resolution for 2nd Layer

- **Constant pixel size:** bricked versus unbricked structure for **1000** or **2000** pixels, 1GeV μ^-

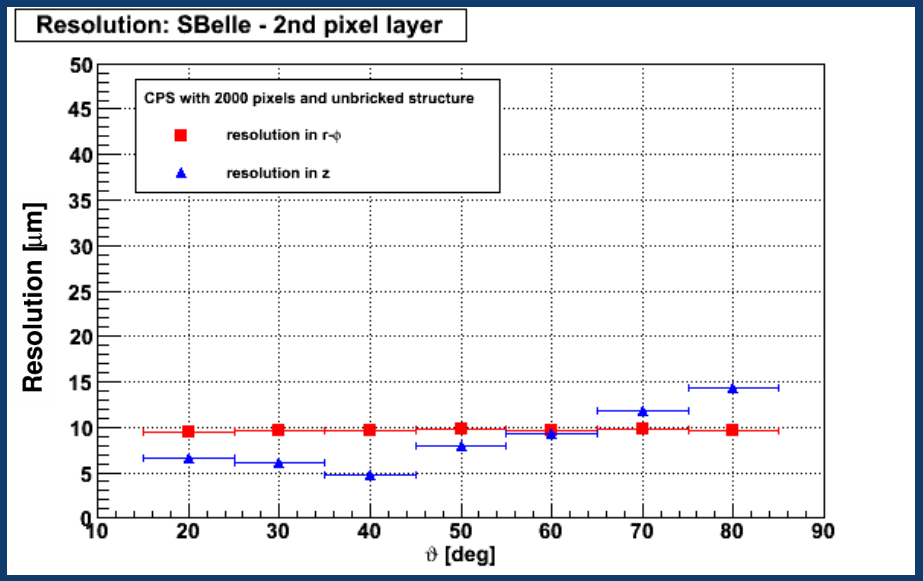


1000
B x U



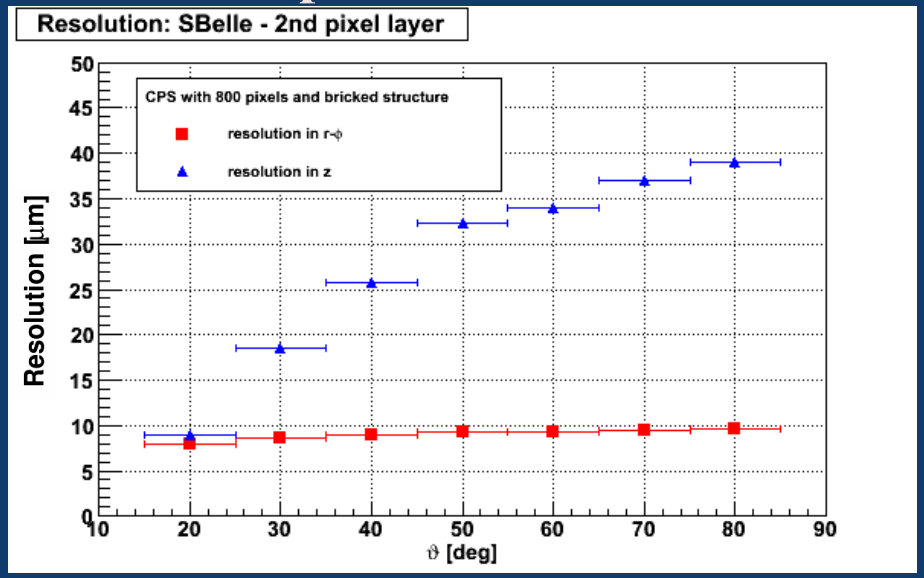


2000
B x U

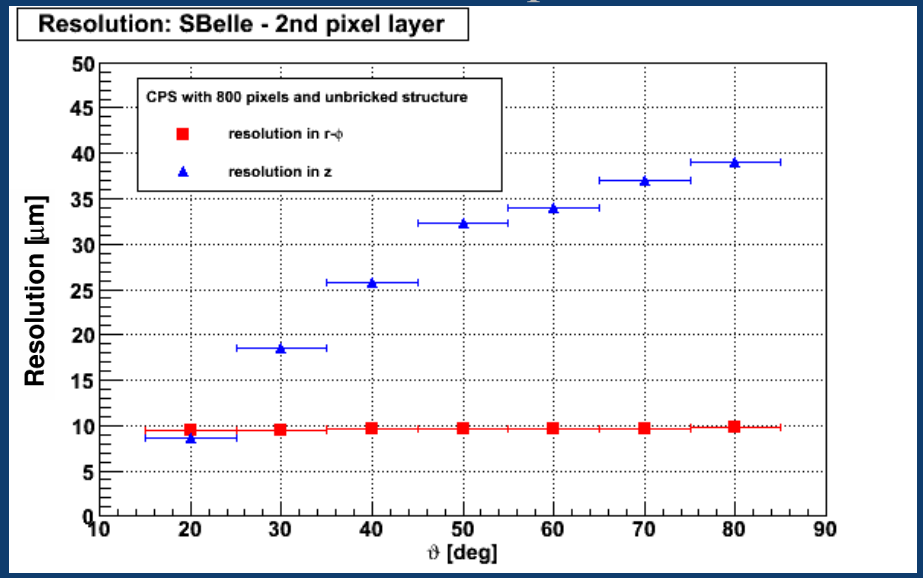


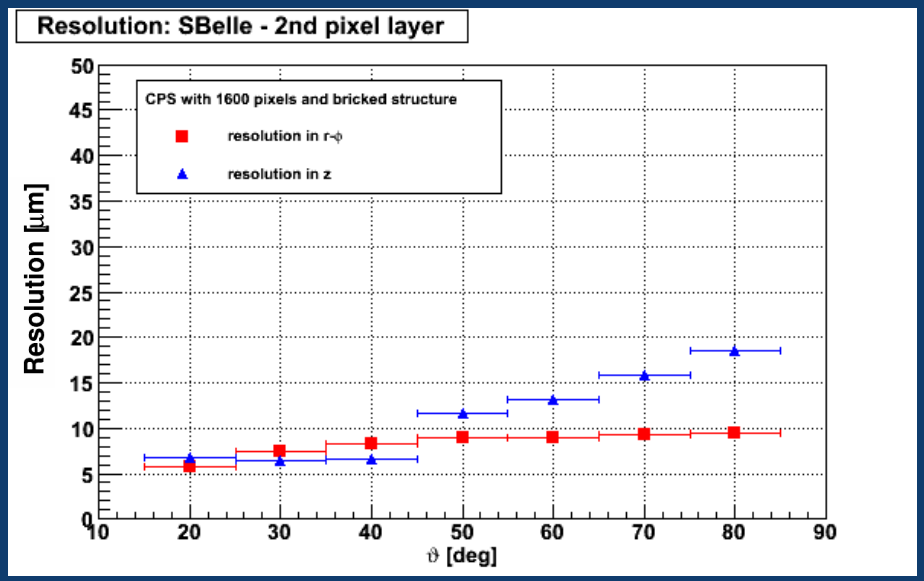
Results: CPS – Resolution for 2nd Layer

- **Constant pixel size:** bricked versus unbricked structure for 800 or 1600 pixels, 1GeV μ^-

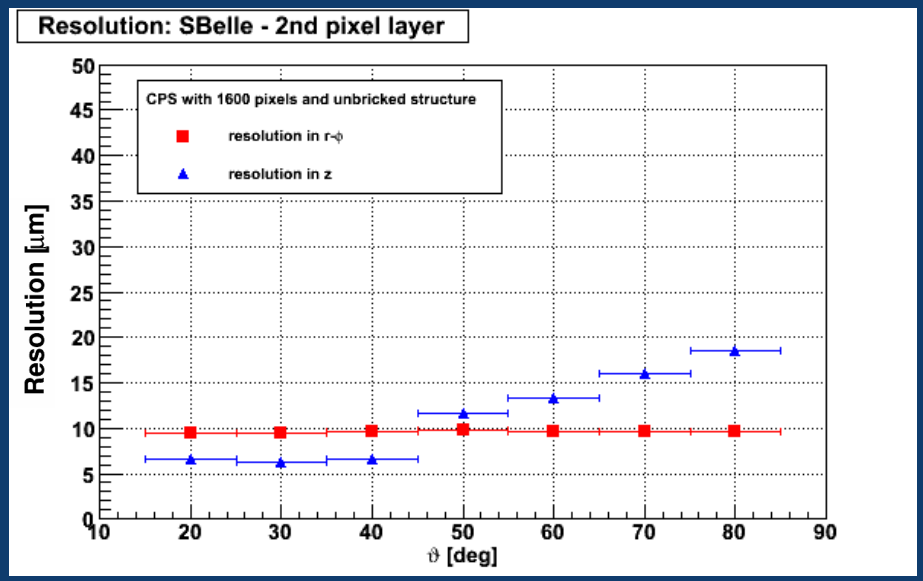


800
B x U





1600
B x U



Background at Belle & SuperBelle

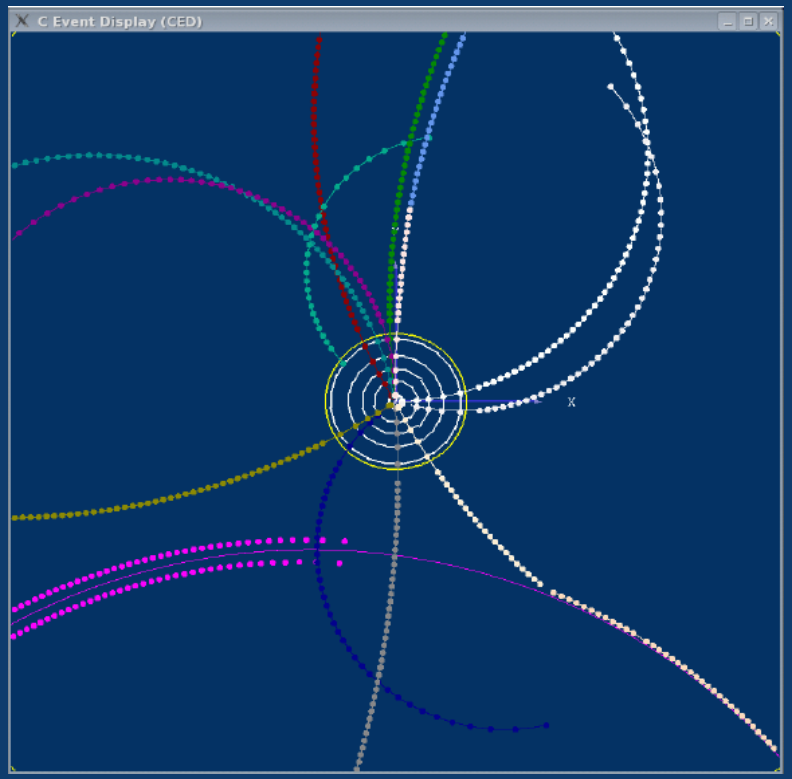
- Main sources of background:
  - Synchrotron radiation background:
    - Soft SR ~ keV
    - Hard SR ~ 40 keV
  - Particle background:
    - Brehmsstrahlung
    - Coulomb scattering with residual gas
    - Intra beam scattering (Touschek effect)
- Background rate estimate for Belle SVD2 inner layer (@ 20 mm) ≈ 23500 $s^{-1}mm^{-2}$
- Increase by factor of 6 expected at SuperBelle (initial phase)
- $1/R^2$ dependence of background rate
  - occupancy = rate · <cluster_size> · pixel_size · integration_time

	R [mm]	***rate*** [$s^{-1}mm^{-2}$]	***Occupancy CPS 2000***	***Occupancy CPS 1600***	***Occupancy CPS 1000***	***Occupancy CPS 800***
Pxl layer 0	13.00	340000				
Pxl layer 1	18.00	180000	2.2%	2.4%	1.7%	2.0%
Pxl layer 2	22.00	120000	1.6%	1.9%	1.3%	1.5%

Marlin – Tracking & Pattern Recognition

- **Chain of MarlinReco Tracking processors** (for more details ask A. Raspereza)**:**
  - TrackCheater – tracking based on MC information
  - MaterialDB – defines material for Kalman filter
  - LEPTracking → SiliconTracking → FullLDCTracking

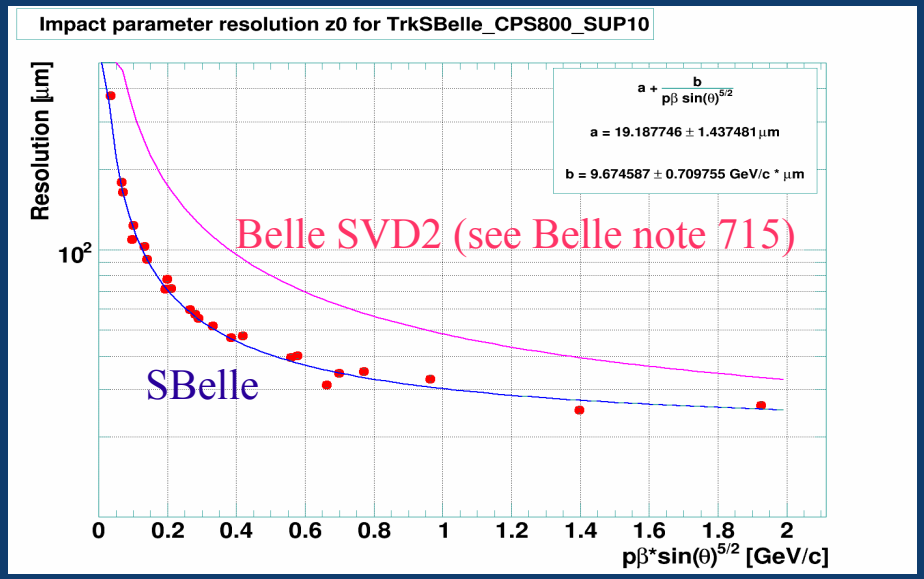
- Pattern recognition in CDC performed: inward search for continuous hit patterns compatible with helix hypothesis (DELPHI code)
- Fit CDC tracks with Kalman filter
- Perform separate pattern recognition in SVD
- Combine SVD tracks and CDC tracks
- Extrapolate track back to the PXD area
- Assign hits on backward helical road
- Refit track after inclusion of new hits using Kalman filtering



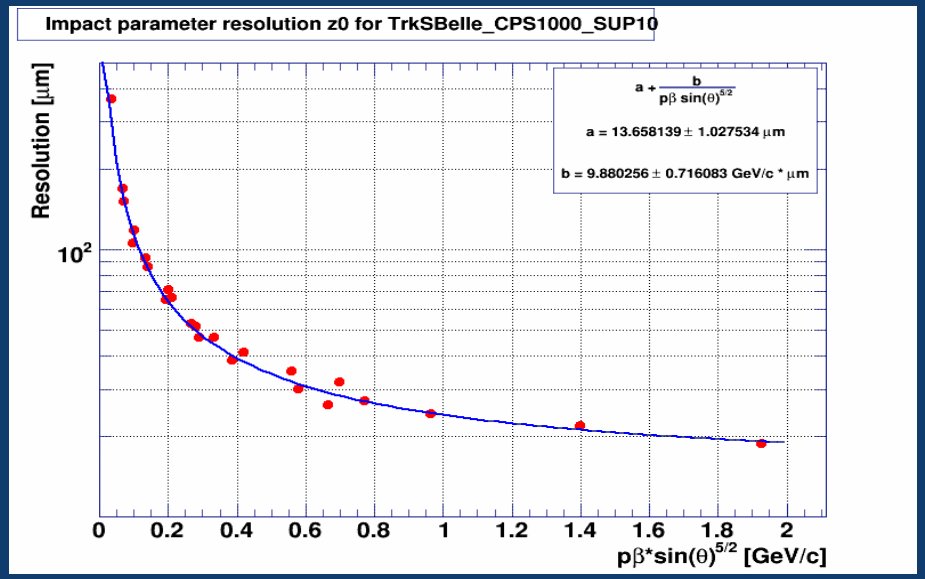
SBelle: A.Raspereza's simulation of $e^-e^+ \rightarrow B^-B^+$ event

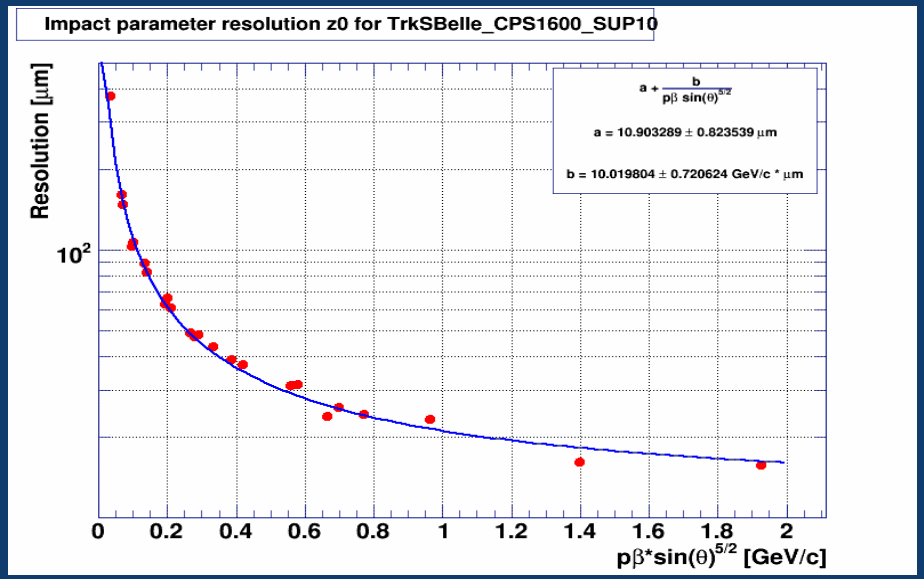
Results: Z0 Impact Param. Resolution Fit: SBelle – 2 Layer PXD

- CPS, bricked structure in R-Φ, 2nd layer – 10 mm support bridge, **no background**

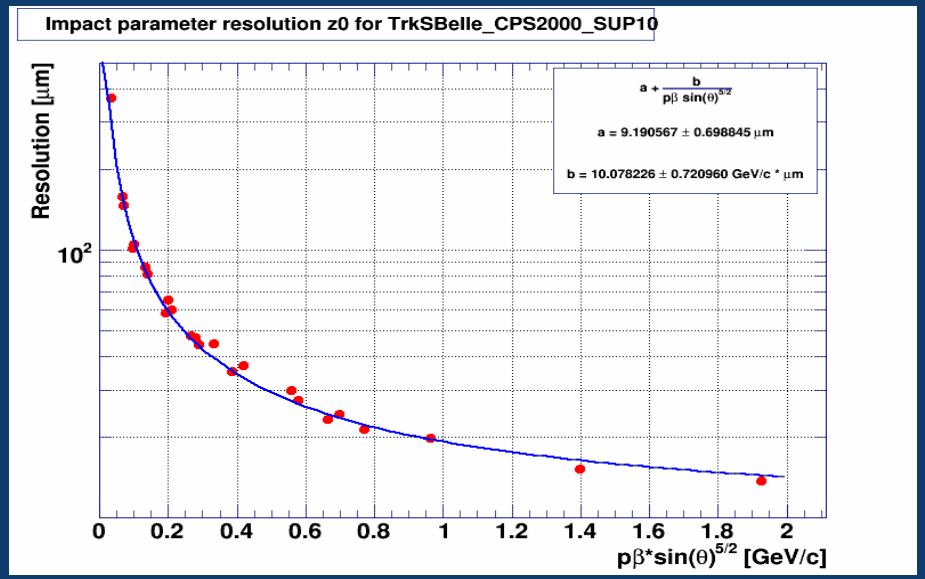


800 x 1000



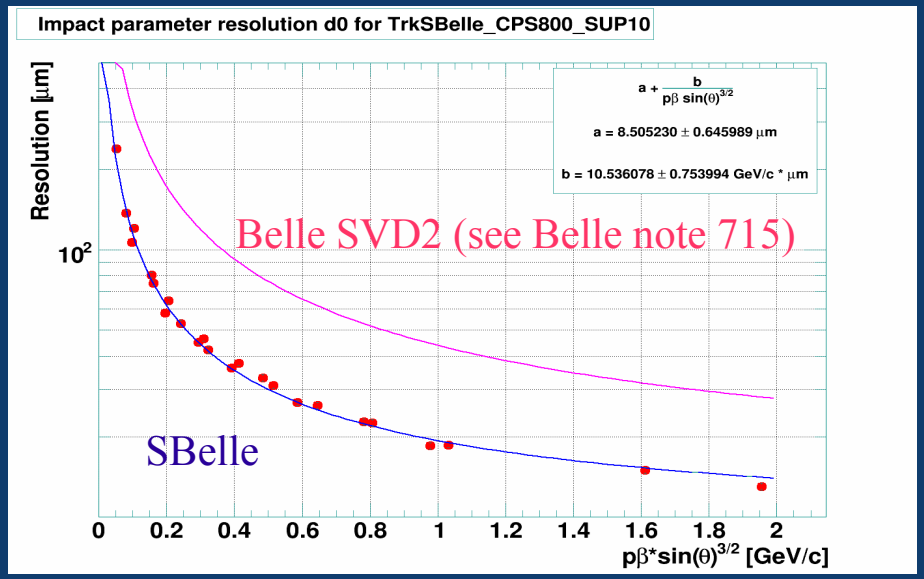


1600 x 2000

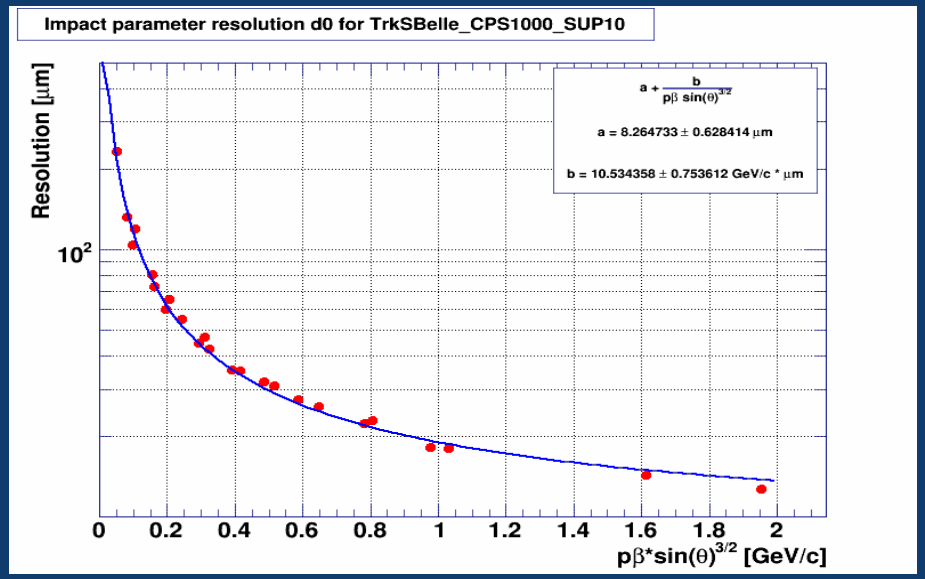


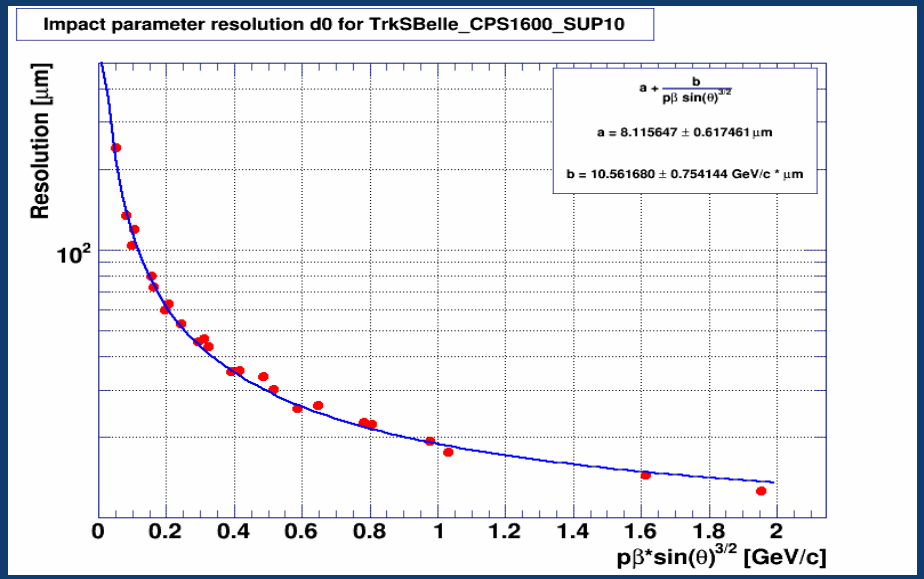
Results: D0 Impact Param. Resolution Fit: SBelle – 2 Layer PXD

- CPS, bricked structure in R-Φ, 2nd layer – 10 mm support bridge, **no background**

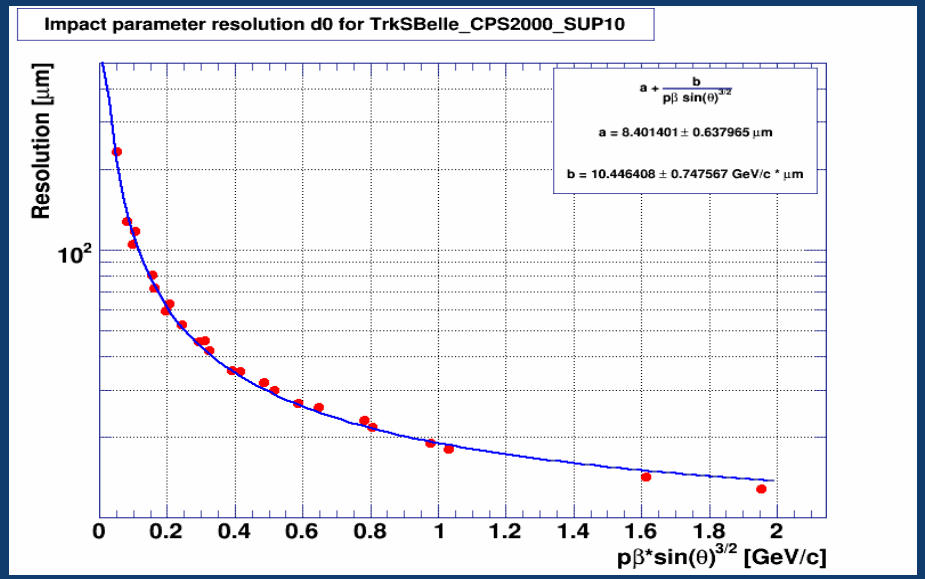


800 x 1000



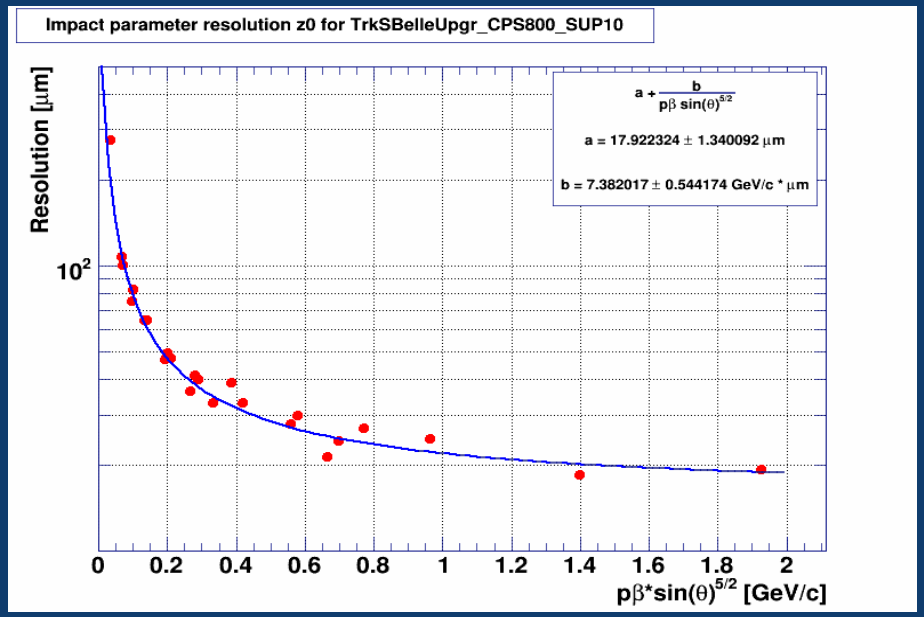


1600 x 2000

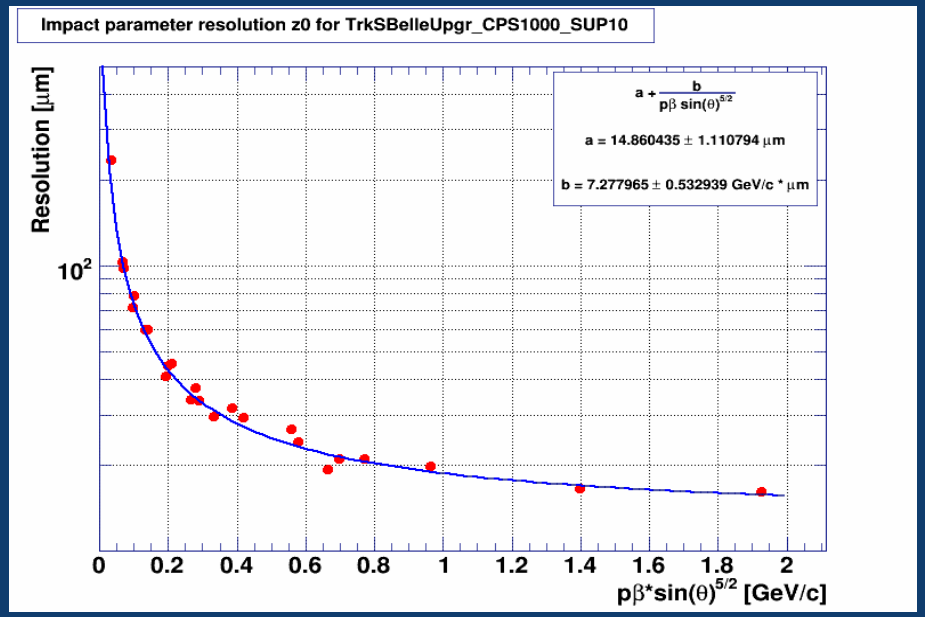


Results: Z0 Impact Param. Resolutions SBelle – 3 Layer PXD

- CPS, bricked structure in R-Φ, 2nd layer – 10 mm support bridge, **no background**

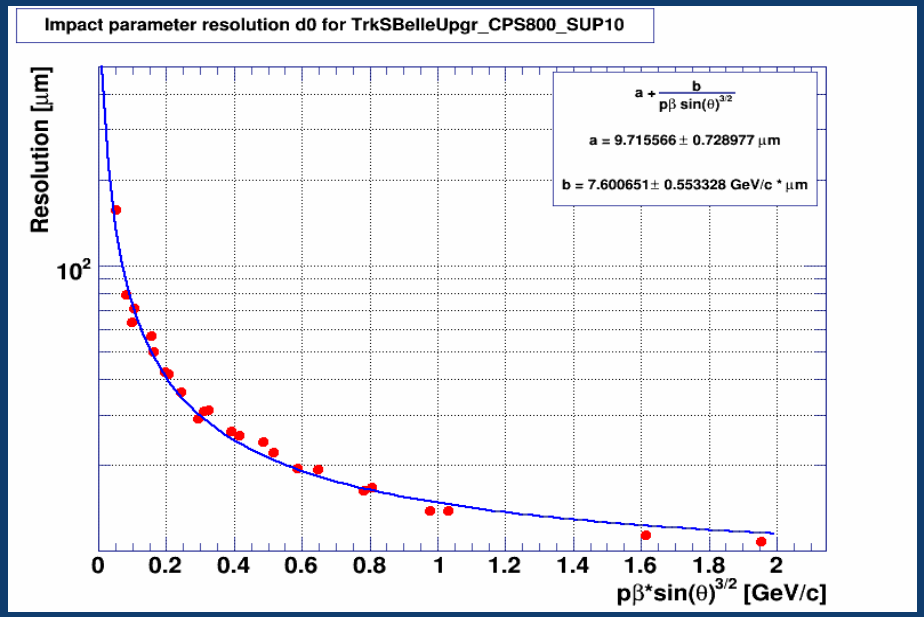


800
x
1000

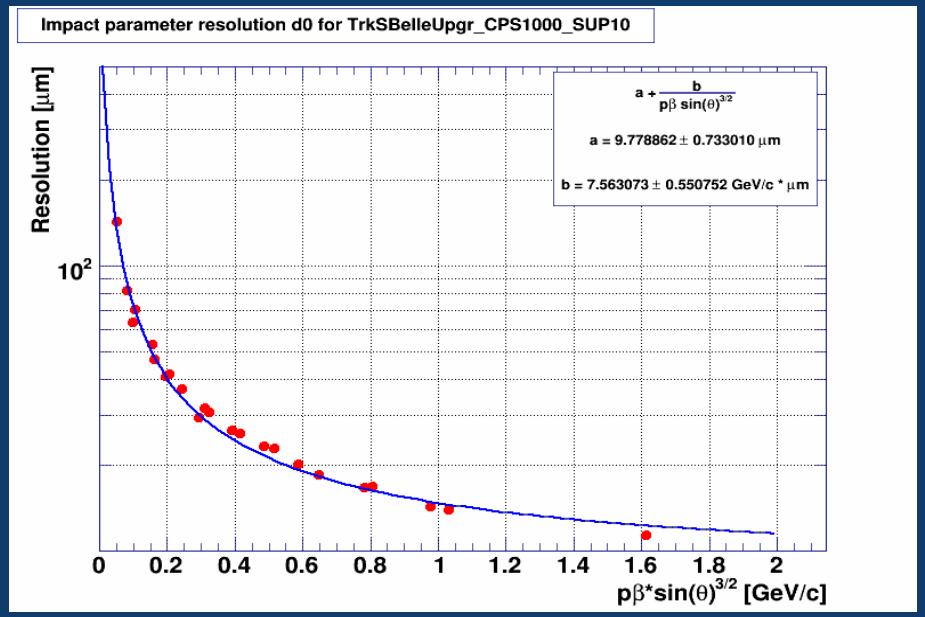


Results: D0 Impact Param. Resolution SBelle – 3 Layer PXD

- CPS, bricked structure in R-Φ, 2nd layer – 10 mm support bridge, **no background**



800
x
1000



Summary

- **Particle generator:**
  - MC generator conversion from BASF (Belle AnalysiS Software) to HepEvt files prepared
- **Mokka:**
  - Realistic geometry of Tube (beam pipe), SVD (pixel + strip detectors) and CDC (central drift chamber) implemented – for both SuperBelle & SuperBelle upgrade
  - Sensitive detector classes adapted
  - Geometry parameters defined inMySQL database (all optimization options prepared)
- **Marlin:**
  - MaterialDB processor adapted to new geometry
  - VTXDigitizer adapted to new geometry
  - Tracking code adapted to new geometry
- **Optimisation studies ongoing …**
  - Mass production @ Garching computing farm started
    - Resolution and cluster size studies performed (for different geometry options)
    - Impact parameter resolutions studied for Super Belle & Super Belle upgrade geometry
    - **Plans:** To perform studies for all possible geometry options with (and without) background to find out the optimal one ...