Optimization Studies of Pixel Dimensions

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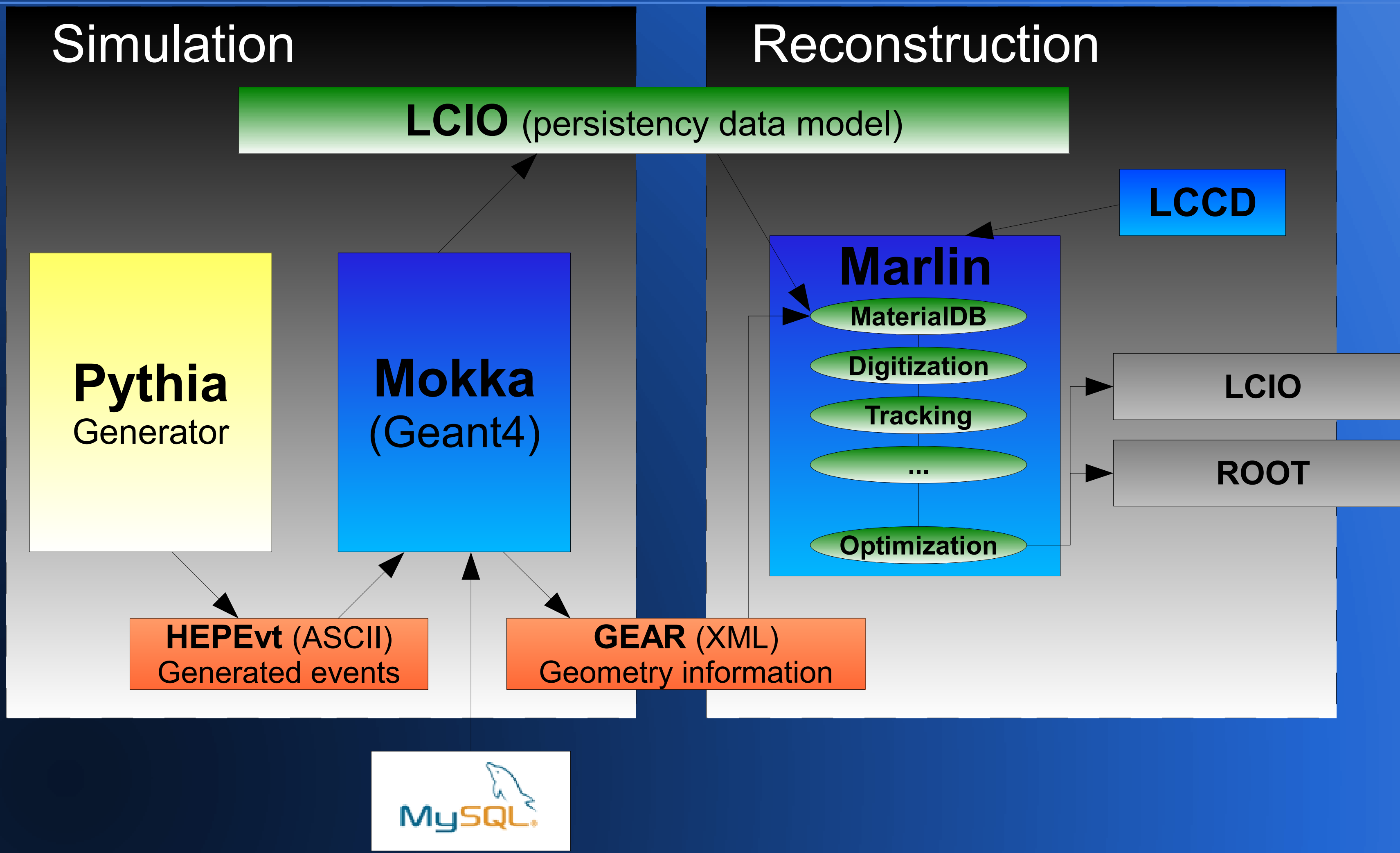
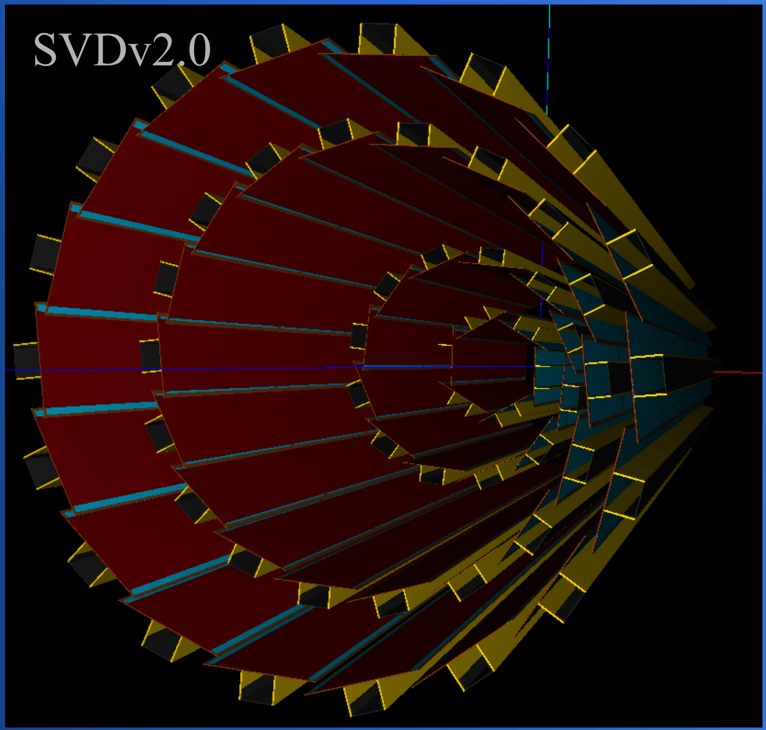
ILC Software for SuperBelle – Scheme



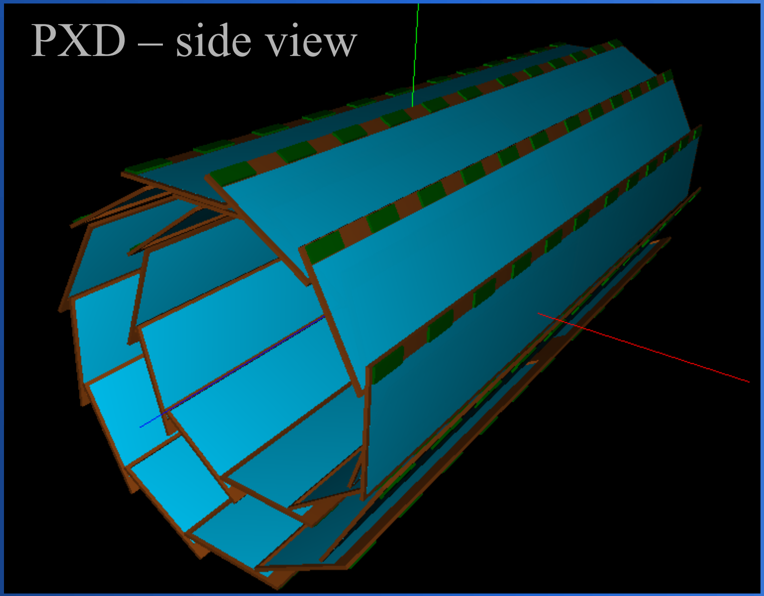
Mokka – Belle Geometry

- Mokka model: ***BelleTracker*** (beam pipe + SVDv2.0 + CDC)
  - ***Beam pipe:*** cylindrical onion-like structure ***(OK)***
    - inner golden layer + inner Be wall + cooling gap (paraffin) + outer Be wall
  - ***SVD:*** 4 layers of Si strip detectors – DSSDs ***(OK)***
    - organized in wind-mill structure
    - active part: layers ⟶ ladders ⟶ Si sensors (300μm)
    - passive part: kaptons (polyimide + Cu) + zylon ribs + CRFP support bridge & rims + Si sensors' rims
  - ***CDC:*** Al cylinder with cone-shaped inner parts
    - active medium: gas He/C_2H_6 (50:50)
- Detailed model ***OK*** to verify simulations



Mokka – SuperBelle Geometry

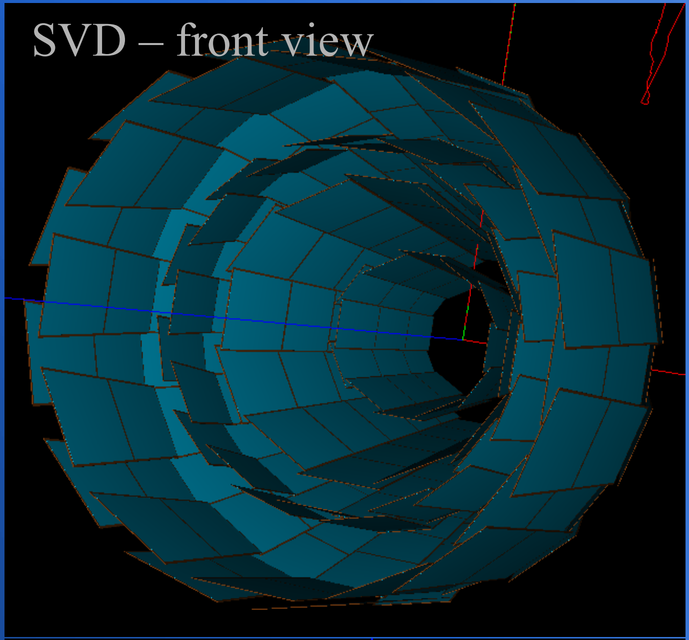
- Mokka model: ***SuperBelleTracker*** (beam pipe + PXD + SVD + CDC)
  - ***Beam pipe:*** cylindrical onion-like structure ***(OK)***
    - inner golden layer + inner Be wall + cooling gap (paraffin) + outer Be wall
  - ***PXD:*** 2 layers of Si pixel detectors – DEPFETs ***(OK)***
    - organized in wind-mill structure
    - active part: layers → ladders → Si sensors (50μm)
    - passive part: Si rims (450μm) + 12 switchers (300μm) + Si support bridge @ 2nd layer (400 μm)
    - option: rotate layers with beam pipe (by 22 mrad)

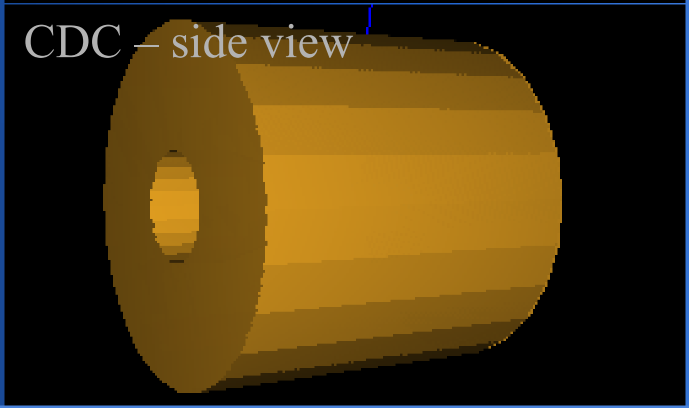


	R [mm]	***# ladders***	***support***
Pxl layer 1	18.00	10	no
Pxl layer 2	22.00	12	yes

Mokka – SuperBelle Geometry cont.

- ***SVD:*** 4 layers of Si strip detectors (DSSDs) in barrel part
  2 layers of Si strip detectors in forward region
  - organized in stagger-like structure
  - active part: layers → ladders → Si sensors (300μm)
  - passive part: Si sensors' rims only
  - missing dead material + design has changed → NEED TO BE IMPLEMENTED!
- ***CDC:*** Al cylinder with cone-shaped inner parts (as Belle)
  - active medium: gas He/C_2H_6 (50:50)
  - used TPC sensitive detector → NEED TO BE CHANGED!
  - design has changed – NEED TO BE IMPLEMENTED!





MarlinReco – Belle & SuperBelle

- Chain of Marlin reconstruction tools:
  - ***MaterialDB:*** (defines all materials – required by Kalman filter in the tracking code)
    - Belle ***(OK)***, SuperBelle ***(OK** for current geometry)*
  - ***MaterialDBView:*** (used in Marlin for visualization of geometry)
  - ***VTXDigitizer:*** (detailed PXD digitizer – both CPS & VPS options possible)
    - SuperBelle ***(OK)***
    - currently used as SVD digitizer for Belle & SuperBelle as well
  - ***SiStripDigi:*** (detailed SVD digitizer – planned to be used for SVD instead of VTXDigi.)
    - finished, under tests
  - ***CDCDigitizer:*** (digitizes data from central drift chamber – simple gaussian smearing)
    - detailed digitizer needed (TPCDigitizer from ILC software fully functional, but doesn't simulate CDC response realistically)

MarlinReco – Belle & SuperBelle cont.

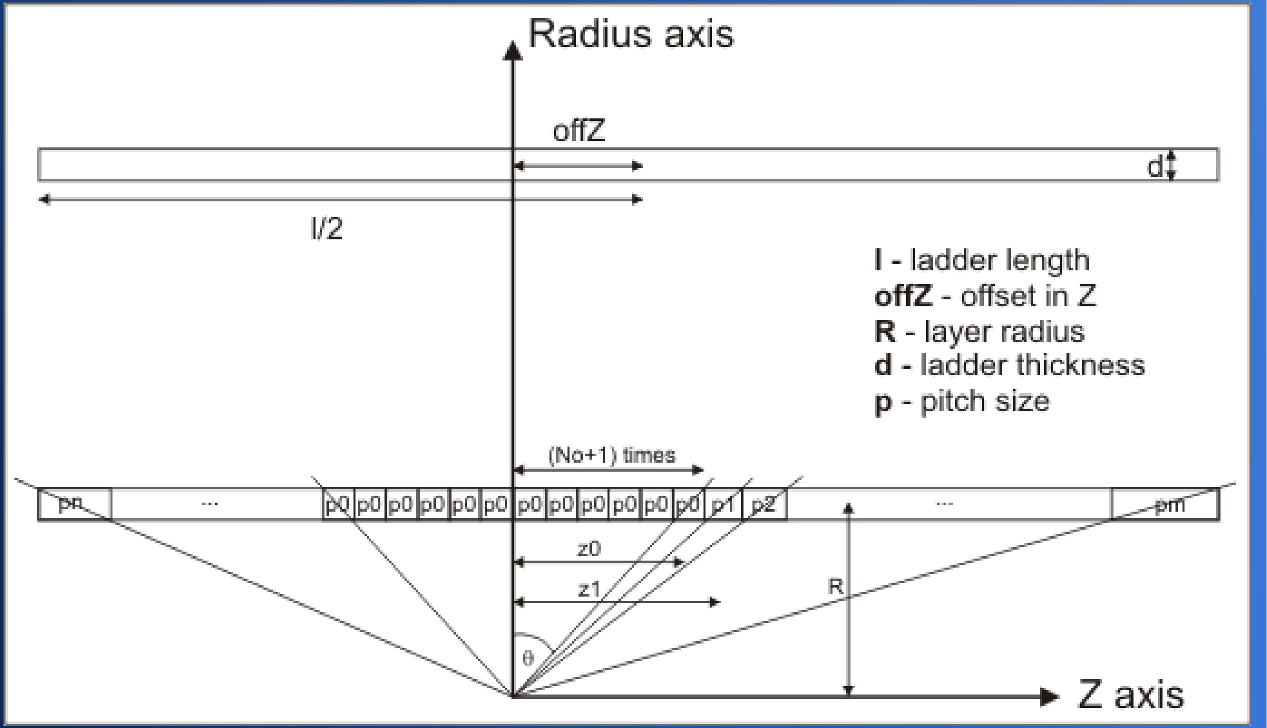
- Chain of Marlin reconstruction tools cont:
  - ***Tracking:***
    - Belle & SuperBelle – adopted & fully functional
    - Outstanding issues (see slides from ILD Software Workshop: April 2009):
      - C++ wrapping for Aleph/Delphi F77 tracking code → hardly managable base
      - error description – impact parameters determined only by Si tracks due to problems with errors for full tracks → currently ONLY PXD AND SVD USED in our simulations!
      - material description
    - Need to work on own tracking code (C++ based only)

PXD Optimization Studies

- ***PXD Geometry (SuperBelle concept with 2 PXD layers):***
  - Bricked x non-bricked structure in R-Φ (bricked = odd rows are shifted wrt even rows by pitch half)
  - 2^{nd} layer with silicon support structure (5mm x 10mm)
  - Variable pixel size (VPS) x constant pixel size (CPS) along Z axis
  - 800 x 1000 pixels along Z axis, resp. 1600 x 2000 pixels along Z axis (2 x longer read-out time)
- ***Particle muon gun:***
  - Momentum scan: 0.1, 0.2, 0.4, 0.8, 1.5, 2.0 GeV (PXD resolution and cluster size studies performed with 0.5 GeV muons)
  - Polar angle scan: 20, 40, 60, 80 degrees
  - Azimuthal angle: isotropic – uniform smearing

Conception of PXD with VPS

- ***Resolution:*** $\sigma_z \approx$ pitch/(S/N) → idea to keep resolution constant along *Z* axis
- Calculations: requirement for variable pitch in *Z*: $z_0/R = p_0/d$ → $N_0 = R/d - 1/2$
  - $z_0 = p_0(N_0 + 1/2)$
  - $z_1 = p_0(N_0 + 1/2) + p_1/2$
  - $z_2 = p_0(N_0 + 1/2) + p_1 + p_2/2$
  - ...
- Effect of VPS (1st layer) starts at?:
  - 800: theta = 23.1 deg
  - 1000: theta = 29.7 deg
  - 1600: theta = 52.6 deg
  - 2000: theta = 66.3 deg
  - for 2nd layer even worse



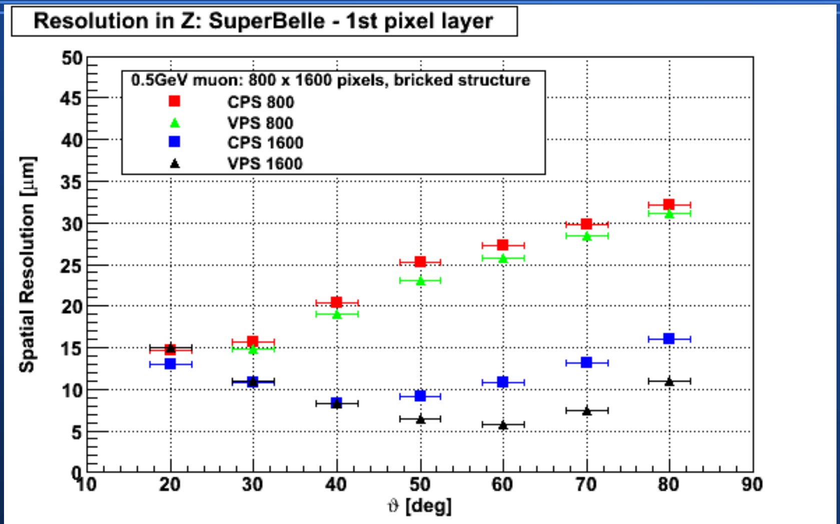
PXD with CPS x VPS – Calculations

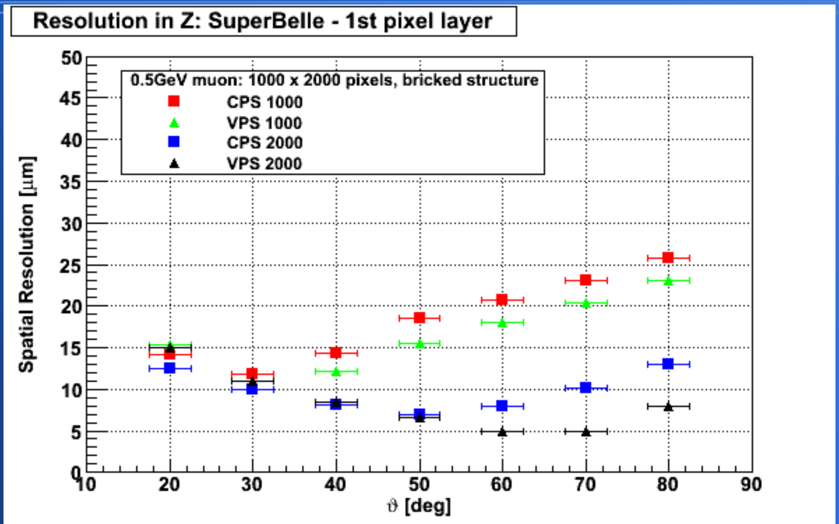
- ***PXD** with two options simulated (in VTXDigitizer):*
  - ***CPS*** **–** constant pixel size along *Z* axis; with bricked structure
  - ***VPS*** – variable pixel size along *Z* axis (see next slide); with bricked structure

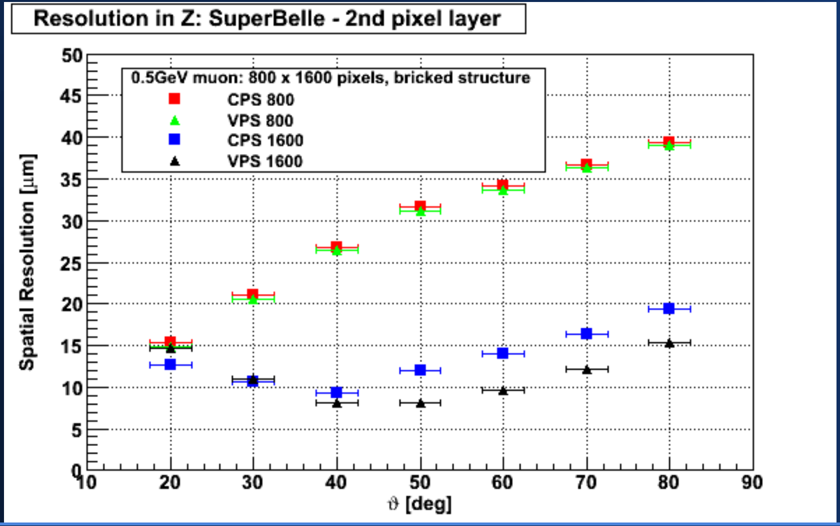
Configuration	R [mm]	l [mm]	N_{pixels}	p_0 [μm]	p_{n} [μm]	p_{m} [μm]
CPS0800_B_layer1	18.0	98.0	800	122.5	122.5	122.5
CPS1000_B_layer1	18.0	98.0	1000	98.0	98.0	98.0
CPS1600_B_layer1	18.0	98.0	1600	61.3	61.3	61.3
CPS2000_B_layer1	18.0	98.0	2000	49.0	49.0	49.0
CPS0800_B_layer2	22.0	117.4	800	146.8	146.8	146.8
CPS1000_B_layer2	22.0	117.4	1000	117.4	117.4	117.4
CPS1600_B_layer2	22.0	117.4	1600	73.4	73.4	73.4
CPS2000_B_layer2	22.0	117.4	2000	58.7	58.7	58.7
VPS0800_B_layer1	18.0	98.0	800	117.1	117.1	177.5
VPS1000_B_layer1	18.0	98.0	1000	87.8	93.9	177.2
VPS1600_B_layer1	18.0	98.0	1600	38.2	93.9	177.2
VPS2000_B_layer1	18.0	98.0	2000	21.9	93.9	177.2
VPS0800_B_layer2	22.0	117.4	800	145.2	145.2	174.2
VPS1000_B_layer2	22.0	117.4	1000	111.6	111.6	174.2
VPS1600_B_layer2	22.0	117.4	1600	56.0	91.9	174.0
VPS2000_B_layer2	22.0	117.4	2000	35.6	91.9	174.0

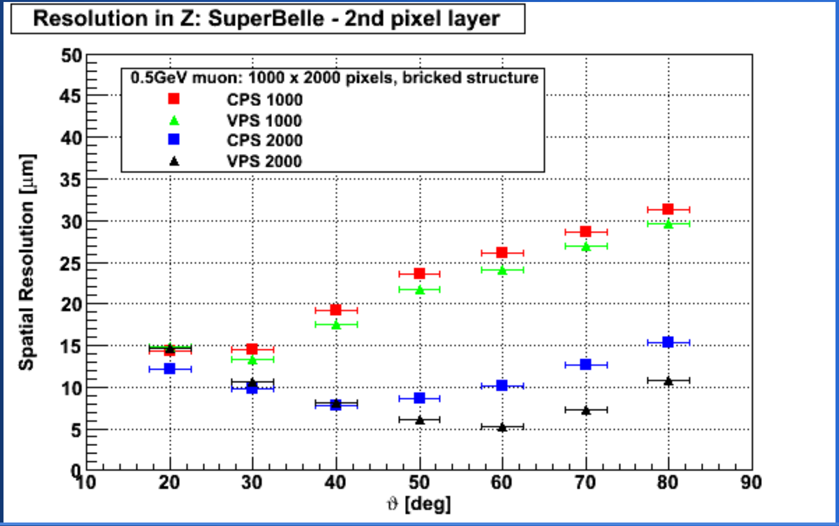
- R = layer radius
- l = ladder length
- p_o = minimal pixel size in Z
- p_n = minimal pixel size in $-Z$
- p_m = minimal pixel size in $+Z$
- for CPS $p_o = p_n = p_m$
- for VPS $p_o \neq p_n \neq p_m$

Results: PXD Resolution in Z

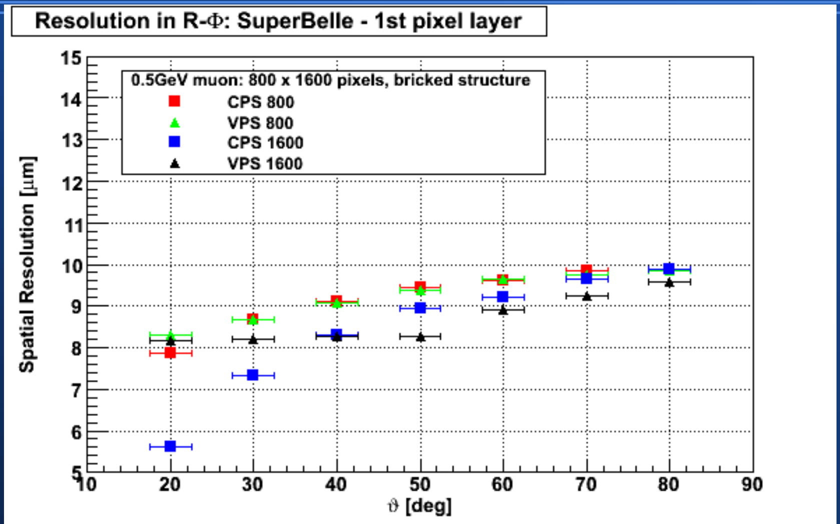


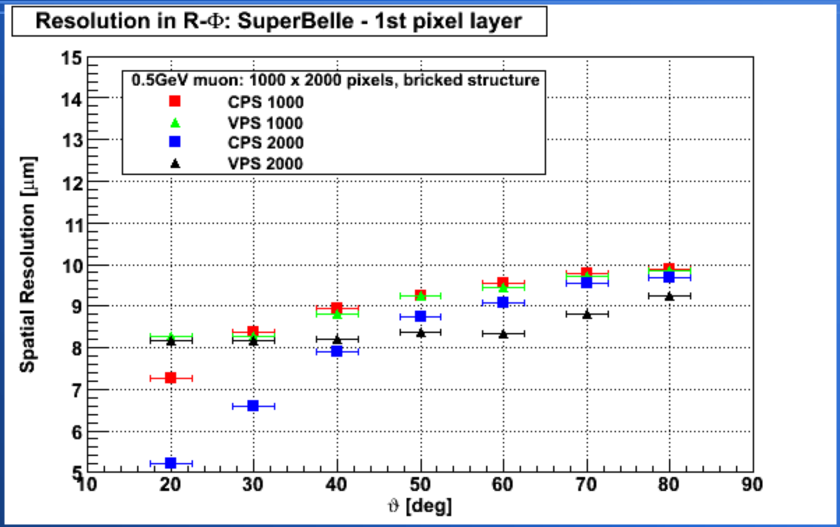


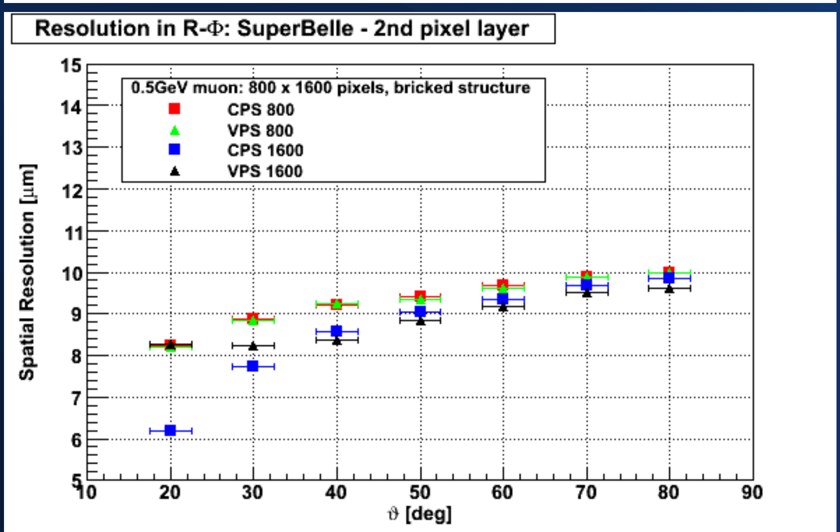


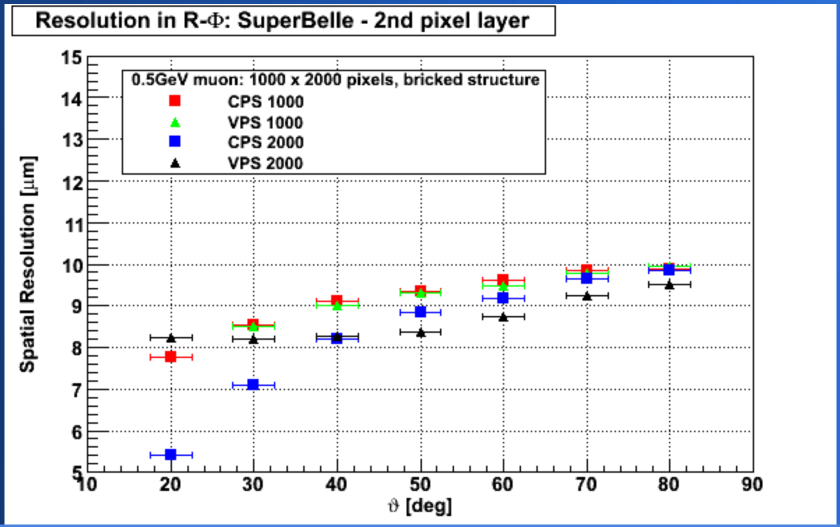


Results: PXD Resolution in *R-Φ*

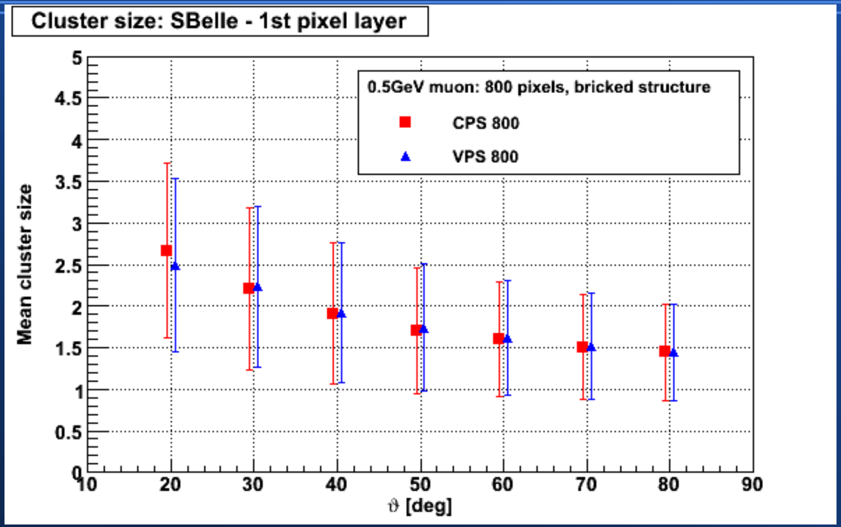


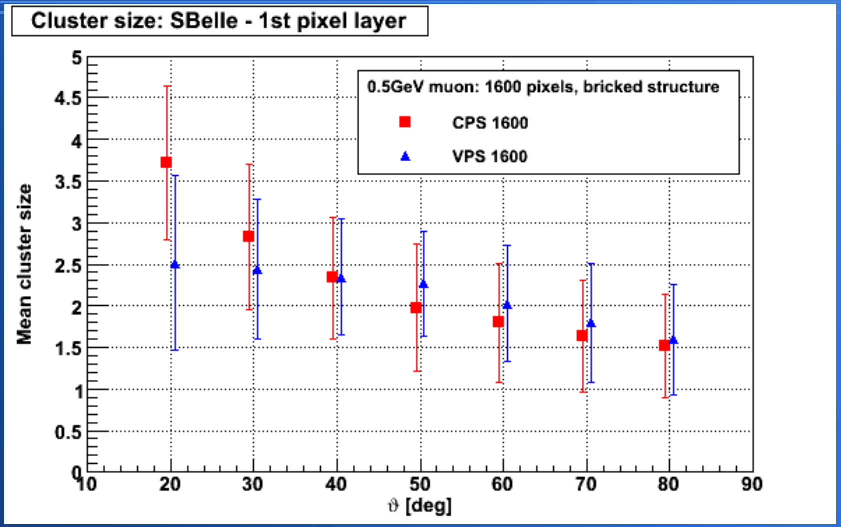


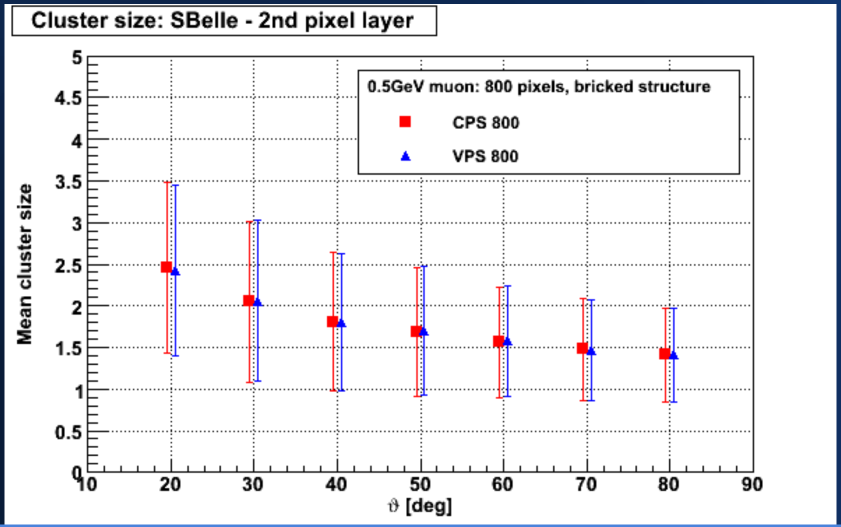


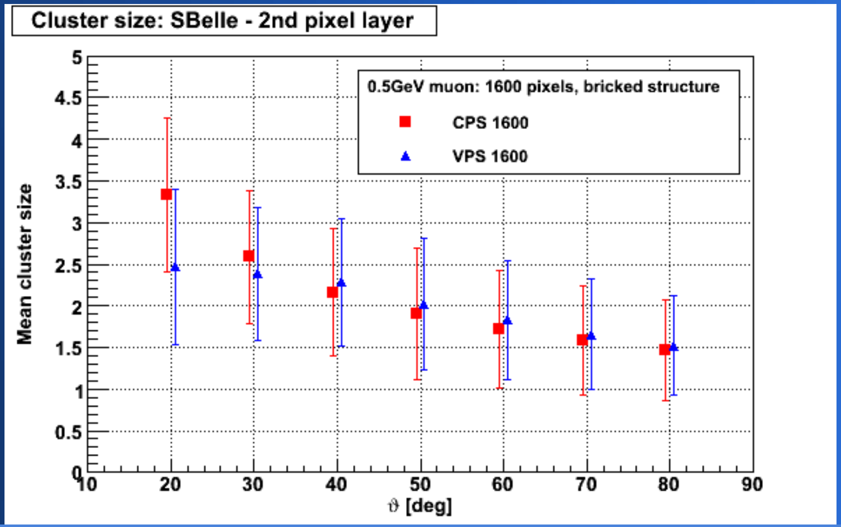


Results: PXD (800 x 1600 pixels) Cluster Size

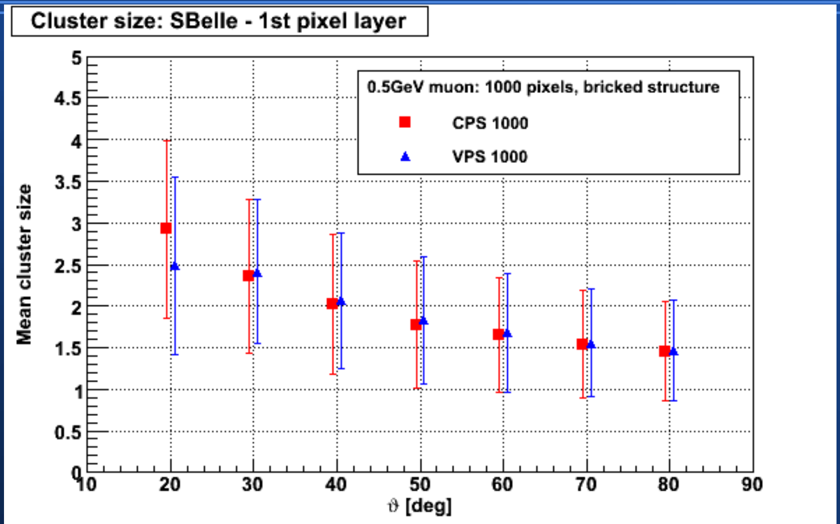


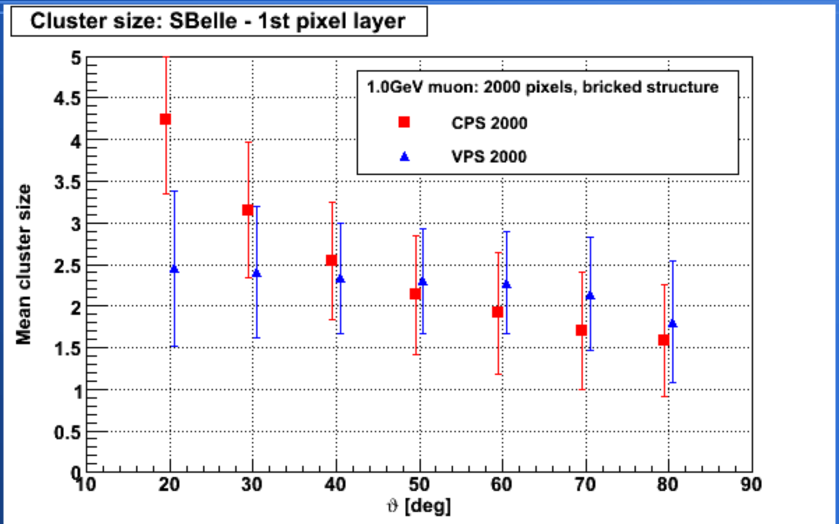


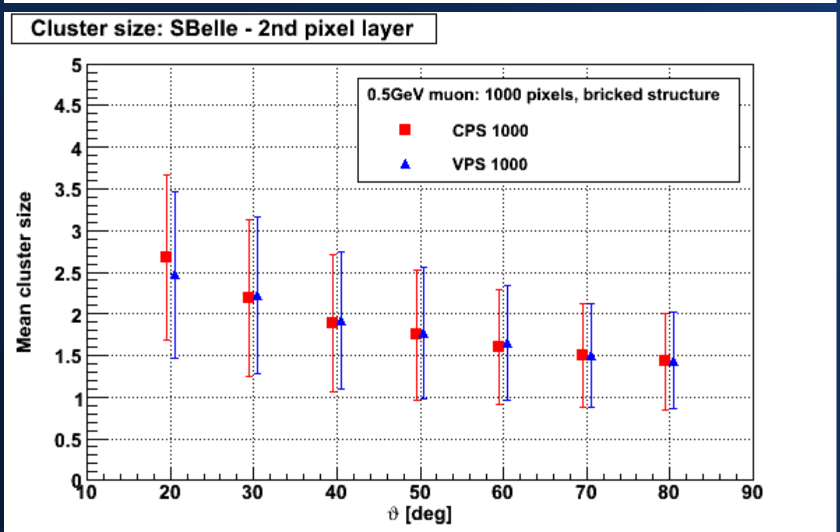


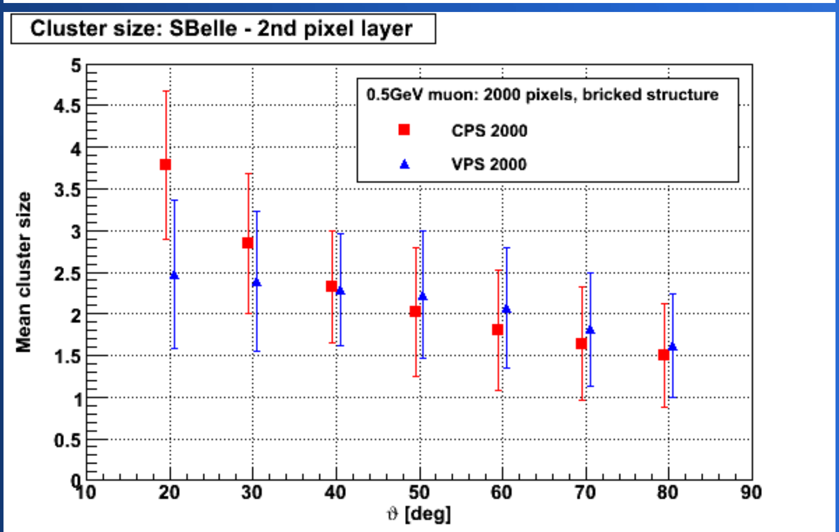


Results: PXD (1000 x 2000 pixels) Cluster Size







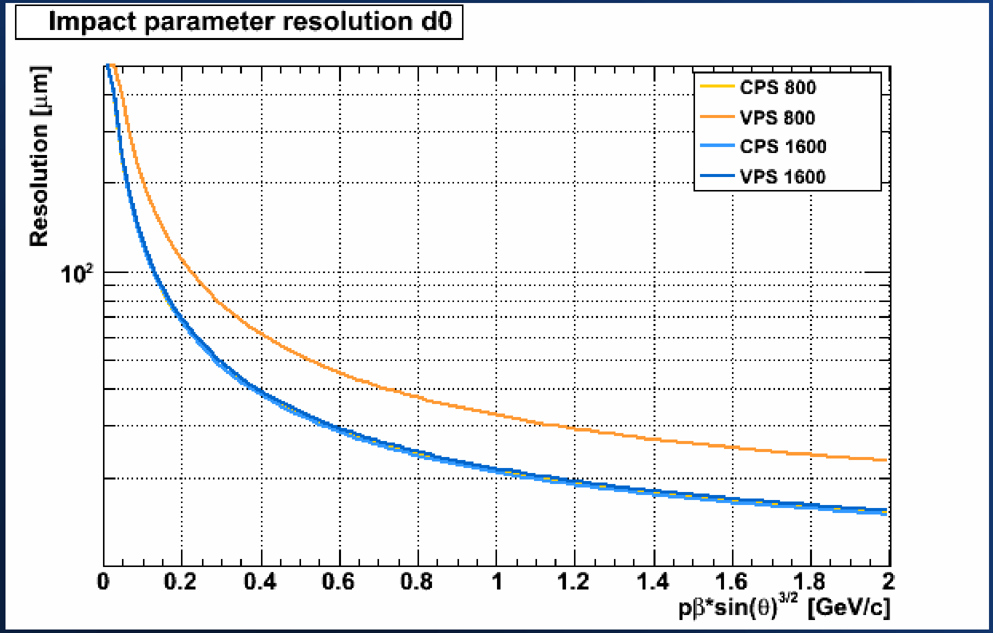


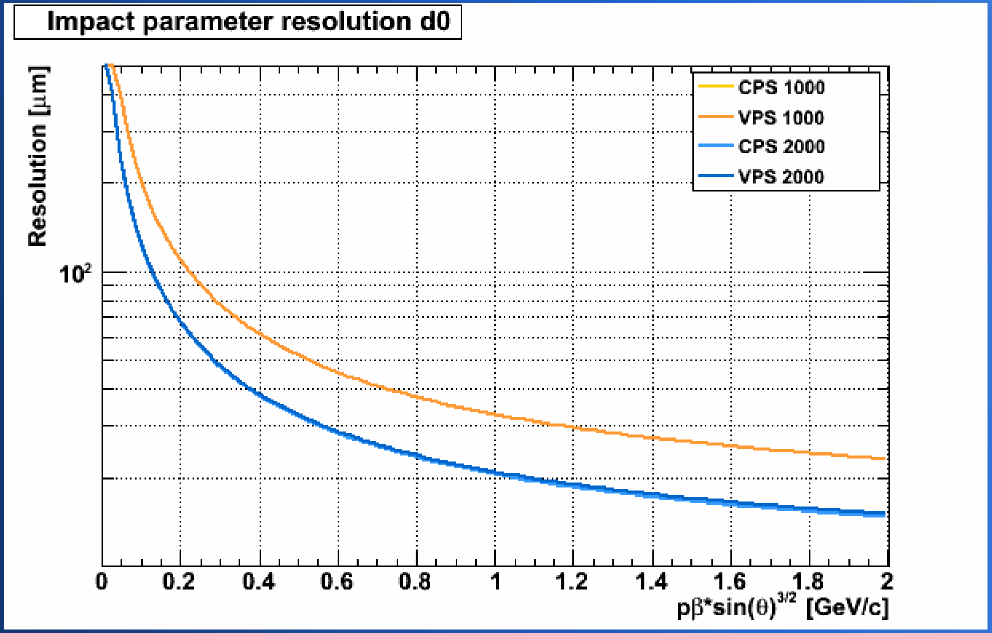
PXD Resolution & Cluster Size: Conclusions

- ***Effects of VPS wrt CPS:***
  - VPS cluster size: constant along *Z* axis until the critical angle achieved (critical angle is defined as: $\tan(\pi/2 - \vartheta) = p_0/d$)) → for higher angles one can expect improvement for VPS spatial resolution by several microns (along *Z* axis)
  - Bricked structure improves PXD resolution in *R*-*Φ* for CPS only (20 – 40 degrees)
  - Generally: effect negligible for PXD with small number of pixels, i.e. 800, 1000 pixels
  - Important effects on PXD with 1600, resp. 2000 pixels; need to prove that overall performance won't degrade in the presence of background (read-out time is 2x longer) → impact parameter resolution studies required
- The simulated resolution & cluster size serve:
  - as an input for tracking & Kalman filter (as hit position covariance matrix)
  - as an input to estimate background rate @ PXD layers

Results: D0 Impact Parameter Resolution of PXD + SVD (Fit)

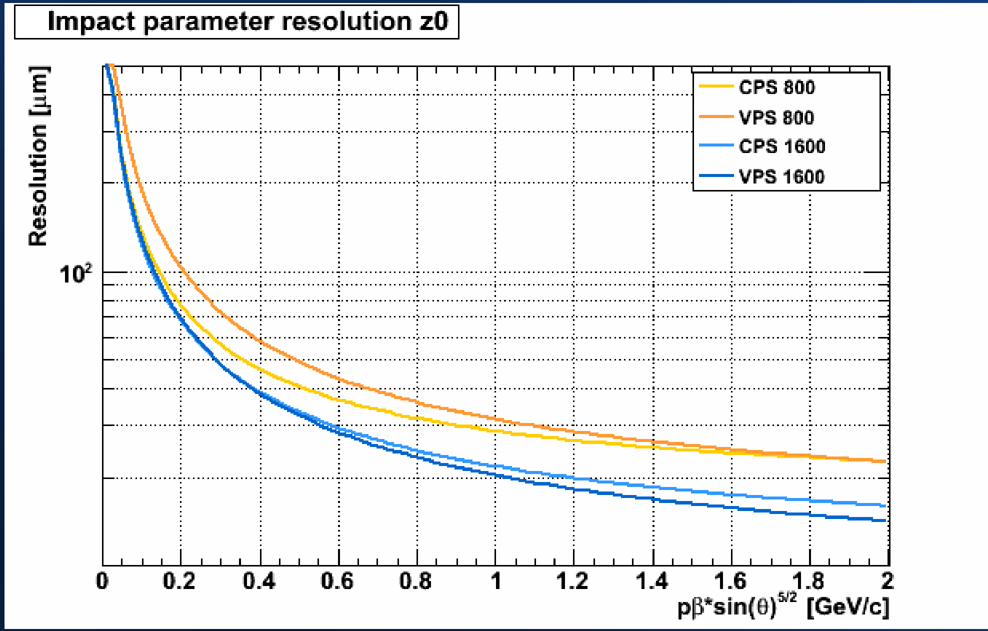
- ***Model: TrackerSuperBelle (2 PXD layers + 4 SVD layers, no CDC)***
  - compared fit functions for different options – CPS x VPS (800, 1600, 1000, 2000 pixels)
  - VPS x CPS → no difference in R-ϕ
  - due to tracking problems – results are subject to further investigations (PRELIMINARY RESULTS)!

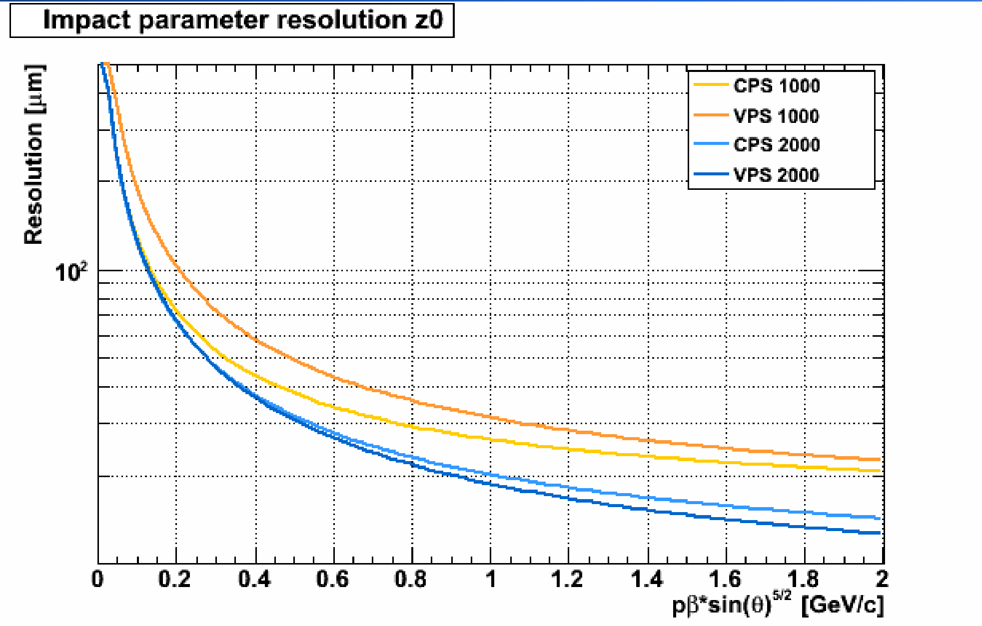




Results: Z0 Impact Parameter Resolution of PXD + SVD (Fit)

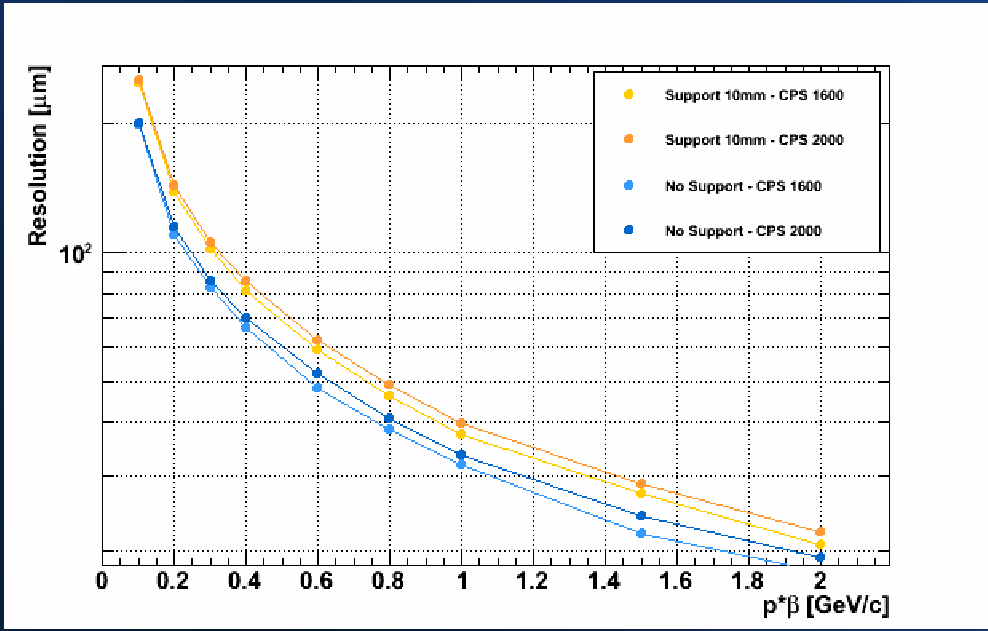
- ***Model: TrackerSuperBelle (2 PXD layers + 4 SVD layers, no CDC)***
  - compared fit functions for different options – CPS x VPS (800, 1600, 1000, 2000 pixels)
  - VPS x CPS → improvement for 1600 & 2000 pixels; degradation for 800 & 1000 pixels
  - due to tracking problems – results are subject to further investigations (PRELIMINARY RESULTS)!

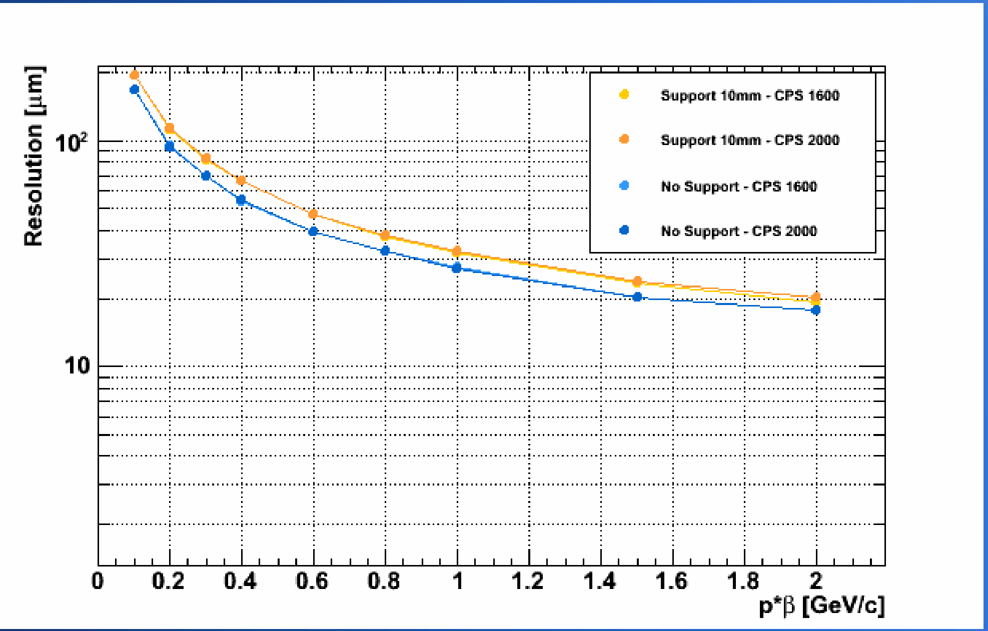




Results: Effect of Support Structure

- ***Z0 (left) x D0 (right) resolution w/o support structure @ 2nd layer***
  - results for muons passing through the support structure only (~ 50 – 70 degrees for VPS, ~ 50 for CPS geometry)
  - roughly factor of 2 degradation (SVD without dead material → won't have such a strong effect after full implementation of SVD ...)





Background at SuperBelle

- Main sources of background:
  - Synchrotron radiation background: Soft SR ~ keV + Hard SR ~ 40 keV
  - Particle background: Brehmsstrahlung + Coulomb scattering with residual gas + Touschek effect
- Estimation:
  - 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
  - Integration time: 10 μs, resp. 20 μs
  - Occupancy = rate · <cluster_size> · <pixel_area> · integration_time

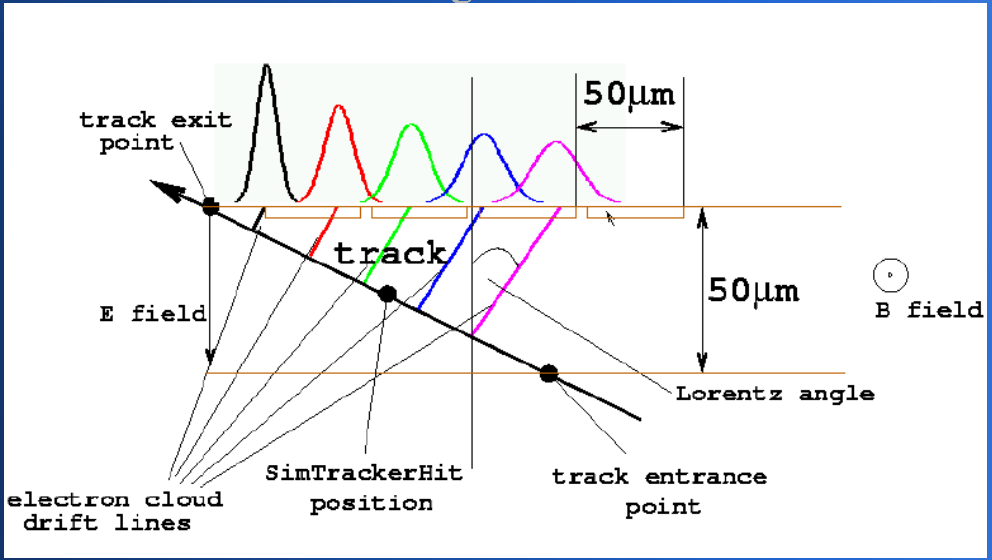
	R [mm]	***rate*** [$s^{-1}mm^{-2}$]	***Occupancy CPS/VPS 2000***	***Occupancy CPS/VPS 1600***	***Occupancy CPS/VPS 1000***	***Occupancy CPS/VPS 800***
Pxl layer 1	18.00	180000	2.2/2.0 %	2.5/2.3 %	1.7/1.6 %	2.1 %
Pxl layer 2	22.00	120000	1.6/1.5 %	1.9/1.8 %	1.3 %	1.6 %

Summary

- ***Simulation software status:***
  - Mokka: all geometry models prepared – need to implement full geometry of SVD (with dead material) and new design of CDC (with appropriate sensitive detector)
  - MarlinReco:
    - digitize SVD with StripDigitizer
    - write appropriate digitizer for CDC and use it for digitization
    - use CDC in tracking
- ***CPS x VPS studies:***
  - resolution studies performed & compared
  - cluster size studies performed & compared
  - D0 & Z0 impact parameter studies done (without background & without CDC) → plans to use full tracking code (after problems with errors fixed by ILC soft. developers) → verify with Belle performance → make full simulations in the presence of background

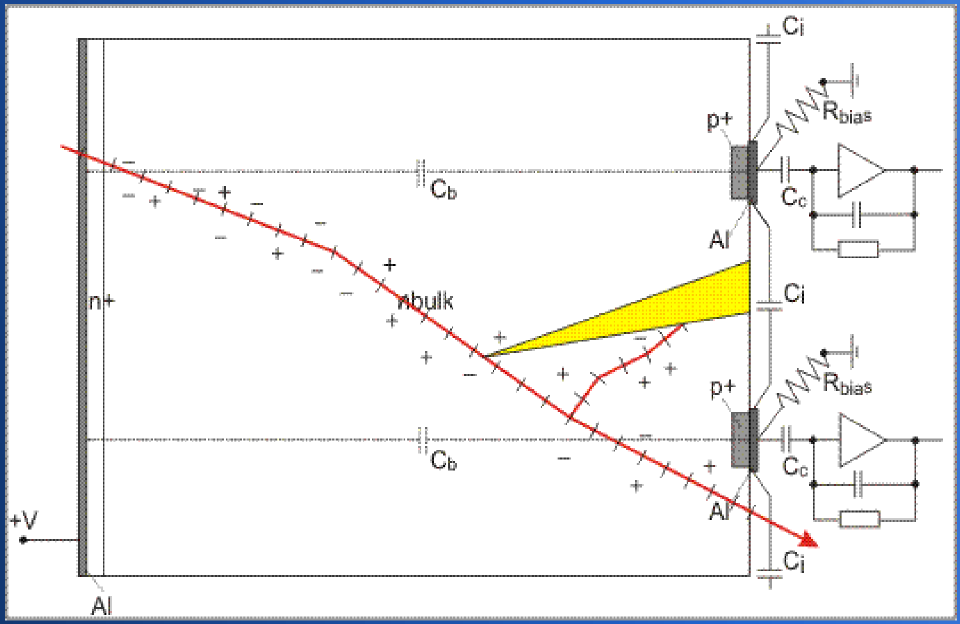
Backup – PXD Digitizer

- ***VTXDigitizer:*** MarlinReco pixel digitizer – adapted A. Raspereza's VTXDigitizer
  - Input: LCIO SimTrackerHits → Output: LCIO TrackerHits
  - Processes:
    - Global to local ref. system transformation
    - Ionization 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 + resolution calculated
    - Background generated



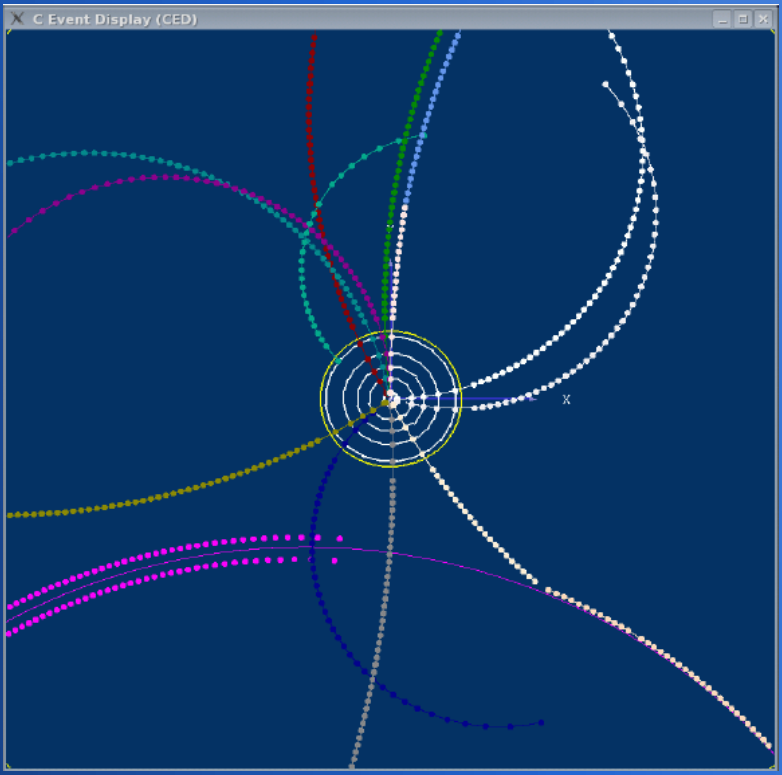
Backup – SVD Digitizer

- ***SiStripDigi:*** MarlinReco strip digitizer
  - Input: LCIO SimTrackerHits → Output: LCIO TrackerHits
  - Geometry: Mokka hits transformation – from global to local reference system
  - Physical processes:
    - Generation of e-h pairs (E_{eh}=3.65 eV)
    - Drift of e-h pairs in electric field
    - Diffusion of e-h due to multiple collisions
    - Lorentz shift of e-h pairs in magnetic field
    - Mutual microstrip cross talks (wrt. AC or DC)
    - Noise: sensor, electronics ...
  - Clustering: (based on COG algorithm)
    - Cluster finding (seed strips + their neighbours)
    - Cluster transformation back to global ref. s.



Backup – Tracking & Pattern Recogn.

- ***Chain of Tracking processors*** *(for more details see http://ilcsoft.desy.de/portal):*
  - LEPTracking → SiliconTracking → FullLDCTracking
  - TrackCheater – tracking based on MC information
- 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 filter



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

Backup – Z0 Impact Parameter Resolution In Numbers