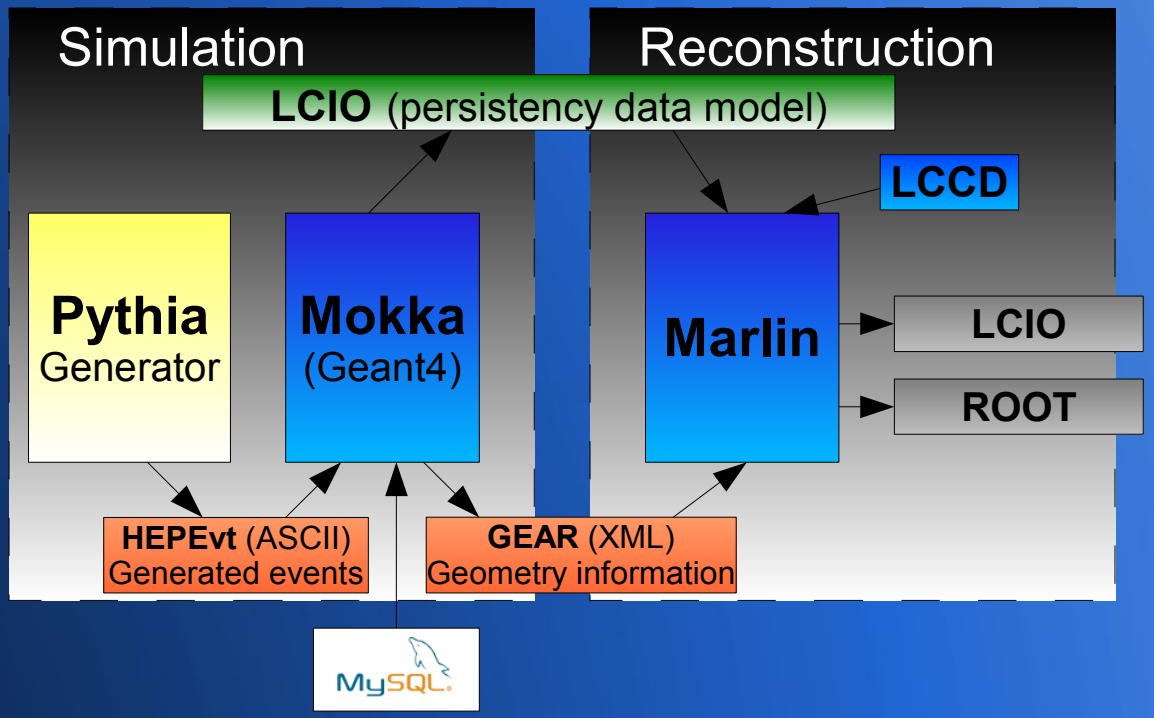
Full Simulation of Belle & Belle II SVD Detector (within ILC Framework)

Z. Drásal

Charles University in Prague

ILC Software Framework – Summary

- ***Mokka***: Geant 4 based, full simulation tool using a realistic detector geometry (accessible via a MySQL database) → output in ***ascii*** or ***lcio*** format
- ***LCIO***: Linear Collider I/O persistency framework, which defines a data model for ILC; data persistency format: Serial Input/Output (**SIO**) → output in ****.slcio*** file
- ***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 recon. code (based on LCIO)
- ***Marlin Reco***: Marlin based toolkit providing reconstruction algorithms for data analysis

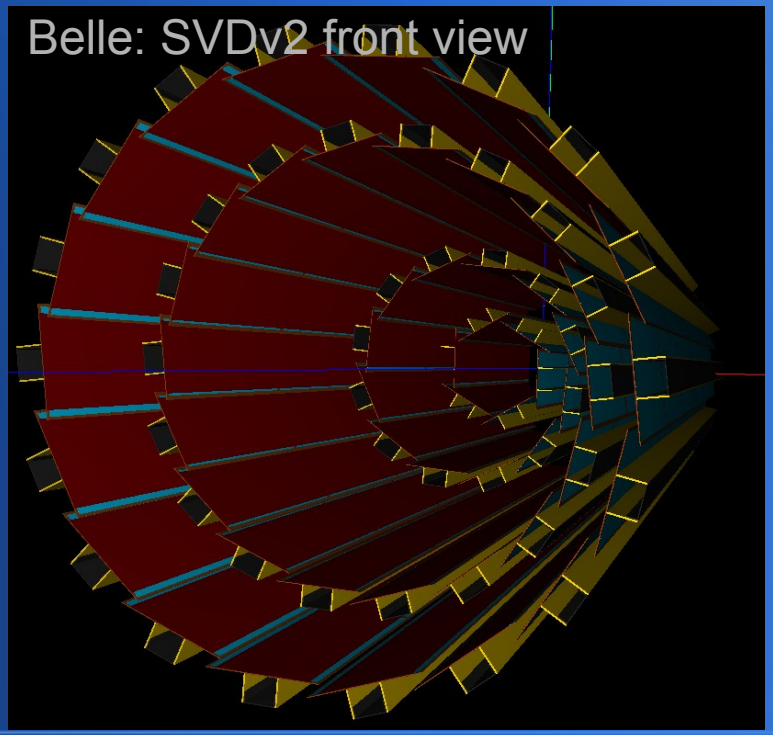
Mokka & Marlin – What's New in SVD Implementation?

- ***Mokka:*** 2 new geom. drivers implemented: SVDBelle (SVDv2), VXDBelleII (PXD+SVD) (new sensitive & hit classes implemented as well ...)
  - ***SVDBelle*** – geom. driver of a current Belle vertex detector – 4 layers of DSSDs
  - ***VXDBelleII*** – geom. driver of a vertex detector intended for Belle II – 2 layers of PXD (pixel-type detectors: DEPFET's) and 4 "barrel-type" layers of SVD & 3 "barrel-slanted-type" layers of SVD (strip-type double sided detectors: DSSDs)
- ***Marlin&MarlinReco:*** new digitizer & clusterizer written, used for very realistic simulation of strip detector response (SimTrackerHit → TrackerPulse → TrackerHit)
  - ***SiStripDigi*** – Marlin processor simulating response of a strip detector; processor digitizes simulated signals and provides electrical pulses on each strip
  - ***SiStripClus*** – Marlin processor calculating clusters from given pulses; processor is trying to find clusters based on seeds, looks for adjacent strips based on threshold cuts, calculates clusters and provides hit position and covariance matrix
  - ***MaterialDB*** – Marlin processor – provides material info for Kalman filter (currently implemented for SVDBelle only, written by Andreas Moll)

Mokka – Belle SVD Geometry

- ***SVDBelle:*** driver used for current Belle vertex detector (SVD version 2)
  - Description: 4 layers in barrel part arranged in wind-mill structure
  - Active part: Si layers → Si ladders → Si sensors - DSSDs (300μm thick)
  - Passive part:
    - Si rims around sensors, i.e. passive Si part (300μm thick)
    - Kaptons (polyimide + copper)
    - Zylon ribs
    - CRFP bridge & rims

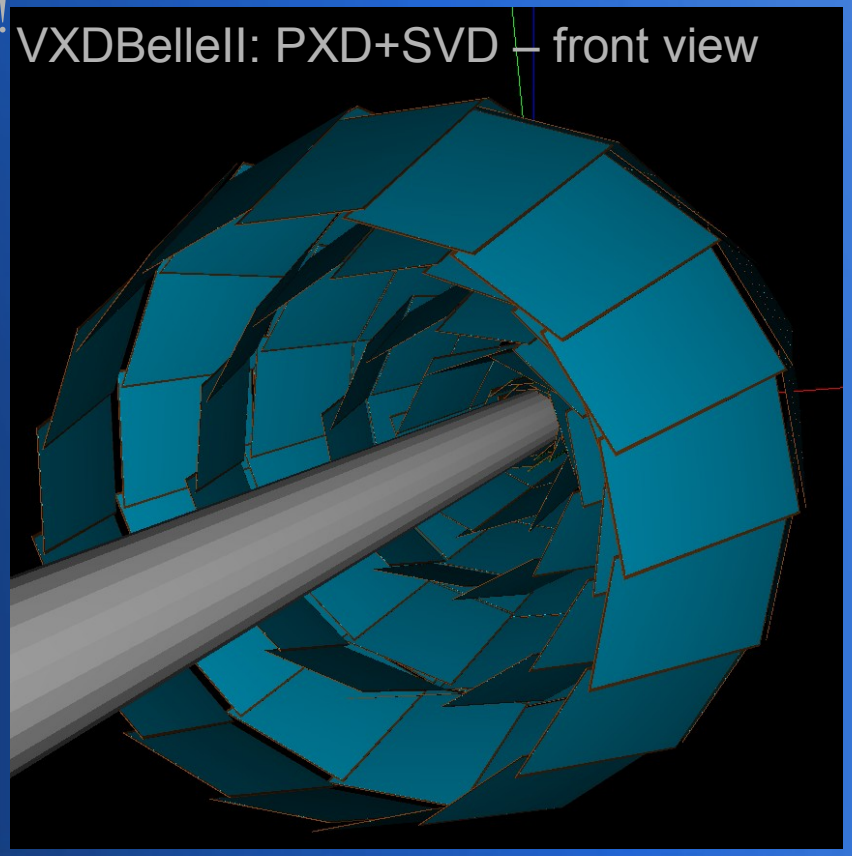
	R [mm]	***# ladders***	***# DSSDs***
Strip layer 1 – barrel	20	6	2
Strip layer 2 – barrel	43.5	12	3
Strip layer 3 – barrel	70	18	5
Strip layer 4 – barrel	88	18	6



Mokka – Belle II SVD Geometry

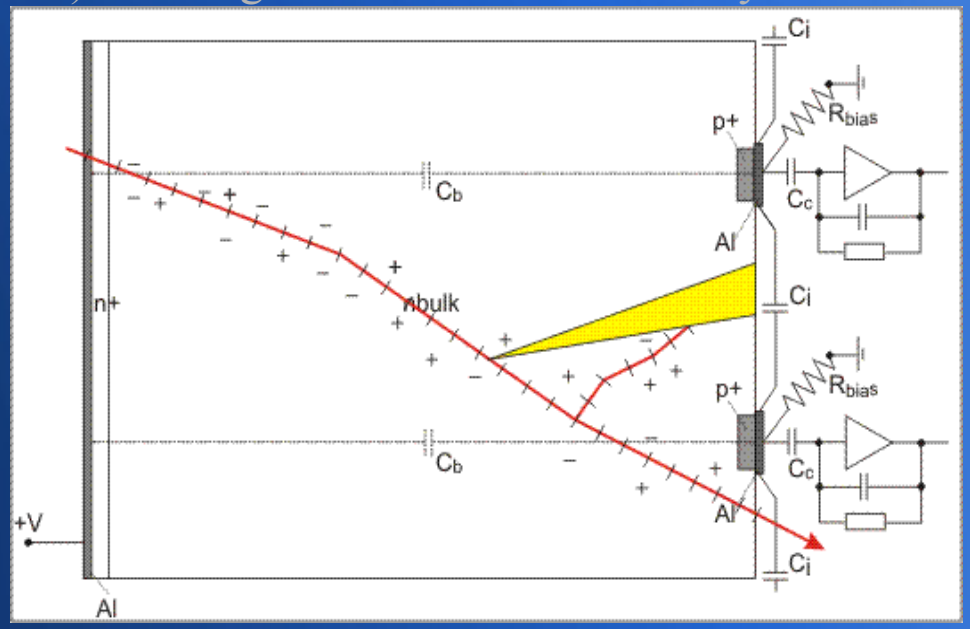
- ***VXDBelleII:*** driver used for VXD of Belle II (pixel part: PXD & strip part: SVD)
  - Description of SVD: 4 layers in barrel part + 3 layers in "forward" region; all arranged in wind-mill structure; only silicon implemented now!
    - Active part: Si layers → Si ladders → Si sensors – DSSDs (300μm thick)
    - Passive part: Si rims around sensors (300μm thick)

	R [mm]	***# ladders***	***# DSSDs***
Strip layer 31 – barrel	38	8	2
Strip layer 41 – barrel	80	10	2
Strip layer 42 – barrel-slanted	66	14	3
Strip layer 51 – barrel	115	17	4
Strip layer 52 – barrel-slanted	95.5	10	1
Strip layer 61 – barrel	140	14	1
Strip layer 62 – barrel-slanted	114	17	1



Marlin – SVD Digitizer & Clusterizer

- ***SiStripDigi + SiStripClus:*** MarlinReco strip digitizer & clusterizer
  - Input: LCIO SimTrackerHits → LCIO Tracker pulses → Output: LCIO TrackerHits + relations to MC particles & MC weights (more than 1 particle may contribute to the recon. signal)
  - Geometry: Mokka hits transformation (using Gear info) – from global to local reference system
  - Physical processes:
    - Generation of e-h pairs along the path (3.65 eV)
    - Drift of e-h pairs in electric field
    - Diffusion of e-h pairs due to multiple collisions
    - Lorentz shift of e-h pairs in magnetic field
    - Calculation of mutual microstrip cross talk
    - Generation of noise: sensor, electronics …
  - Clustering: (based on COG algorithm)
    - Cluster finding (seed strips + their neighbours) → R-Phi & Z clusters combined into 2D clusters
    - Transformation of 2D clusters' position + cov. matrix back to global ref. system → TrackerHits

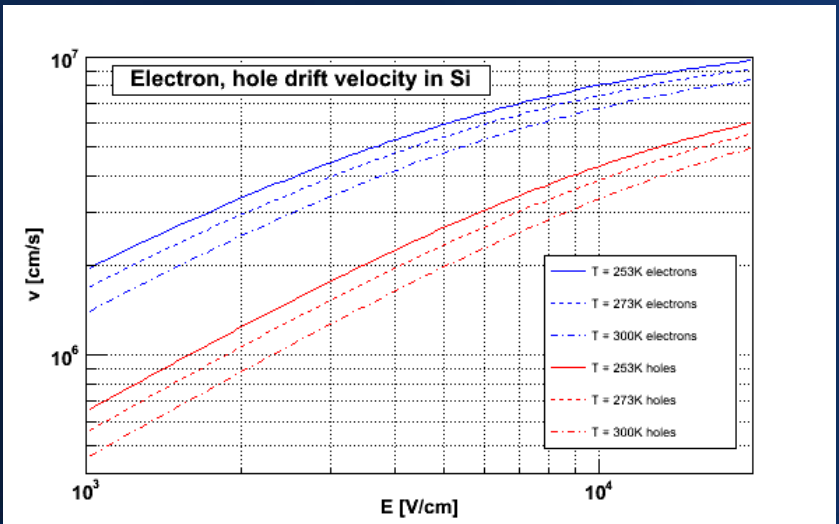


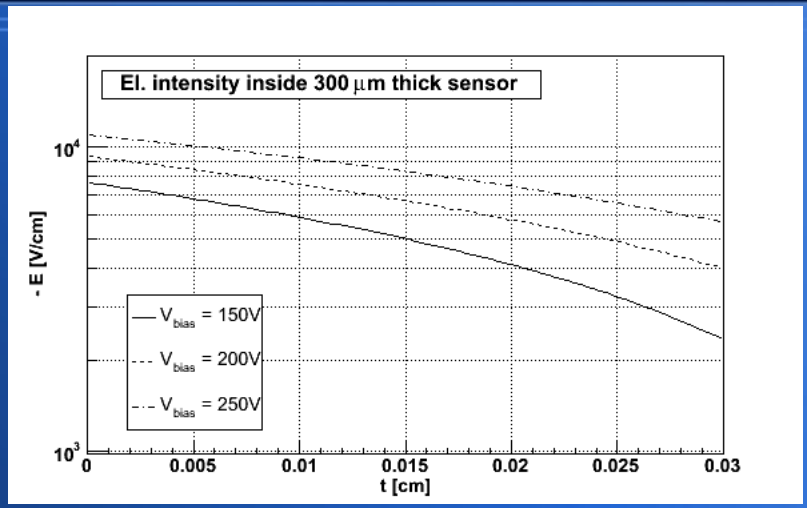
SVD Digitizer Details – El. Field & Drift

- ***Electric field of abrupt p-n junction:***
  - Instead of areas around the strips, the analytically expressible field of p-n junction:

$$E(z) = -\left(\frac{V + V_{dep}}{d} - \frac{2z}{d^2} V_{dep} \right)$$

    is used, it's very similar to what one obtains when solving exact Poisson equation;
  - Parameters: V_{dep} = 60V, V_{bias} = 150, 200, 250V





- ***Drift of e-h pairs:***
  - Represented by the eq. of motion (1st order ODE):

$$v(z) = \mu(E(z), T).E(z)$$

  - The mobility depends on elec. field and sensor temperature:

$$\mu(E(z), T) = \left(\frac{\mu_s / E_c}{(1 + (E(z)/E_c)^{\beta})^{1/\beta}} \right)$$

  - Mobility parameters: μ_s(T,e,h), E_c(T,e,h), β(T,e,h)
  - ODE integrated numerically using Romberg meth.

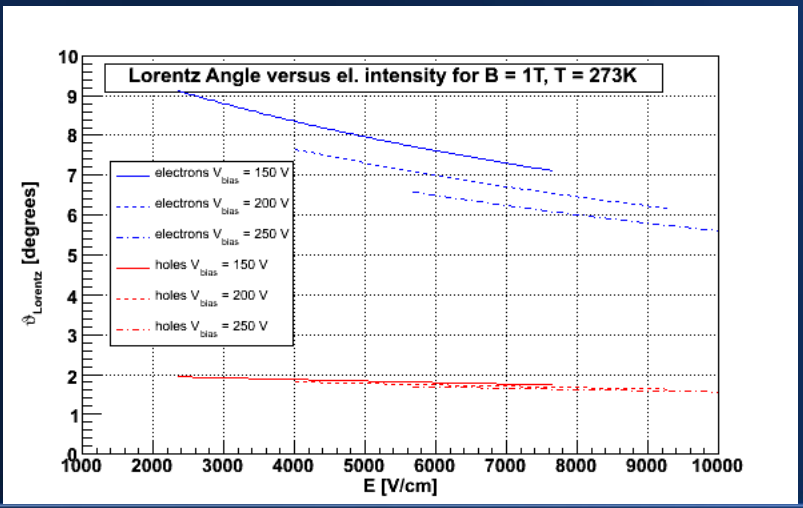
SVD Digitizer Details – Diffusion & Lorentz shift

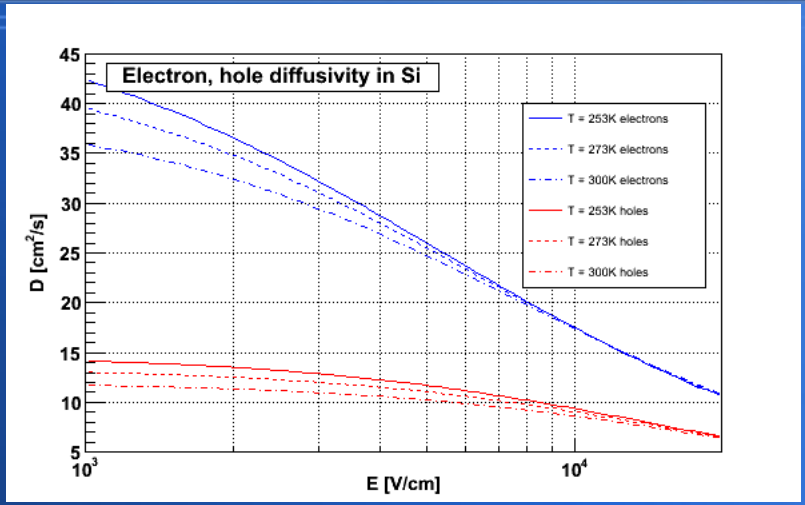
- ***Diffusion of e-h pairs:***
  - ***e,*** resp. ***h***, are during the drift diffused by multiple collisions, given by Gaussian law:

$$dN = \frac{N}{\sqrt{4\pi D t(\vec{r})}} \exp\left(-\frac{\vec{r}^2}{4Dt(\vec{r})}\right) d\vec{r}$$

$$D = \left(\frac{kT}{q}\mu(E,T)\right)$$

  - where ***D*** denotes diffusivity given by Einstein relation and ***t*** the drift time





- ***Lorentz shift of e-h pairs due to mag. field:***
  - ***e***, resp. ***h***, are during the drift deflected in magnetic field (Lorentz shift of charge carriers)

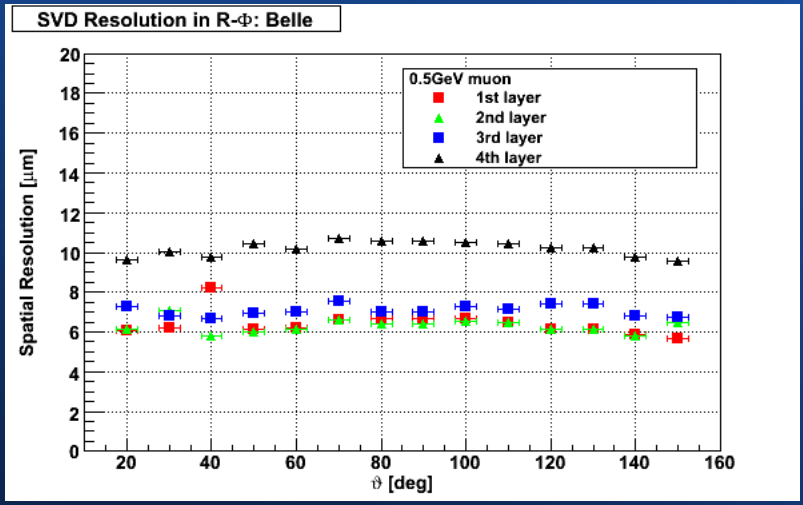
$$\tan(\vartheta_L) = \frac{\int_z^d \mu(E(z)) r B \, dz}{\int_z^d dz}$$

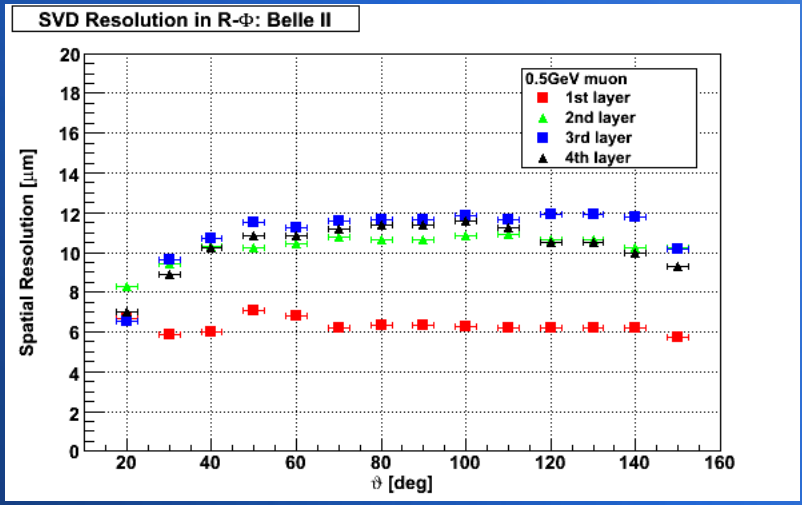
  - wher ***r*** denotes so-called Hall factor, ***r***(T,e,h)
  - ODE integrated numerically using Romberg. meth.

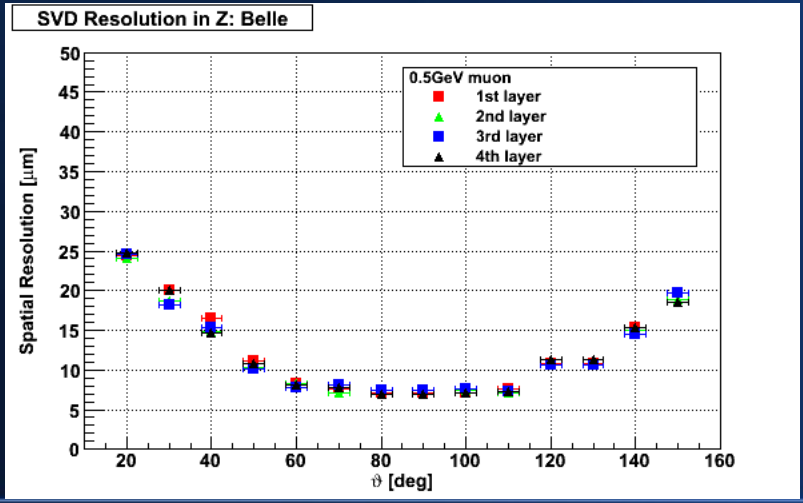
Simulation Studies

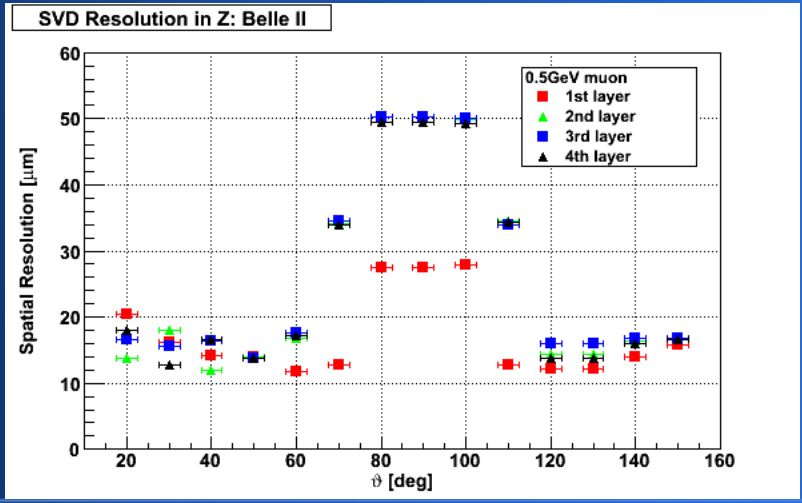
- ***Geometry:*** Belle VXD versus Belle II VXD
- ***Particle muon gun used:***
  - Particle momentum: 0.5 GeV muons
  - Polar angle scan: in whole acceptance range, i.e. 20 – 150 degrees
  - Azimuthal angle: isotropic – uniform smearing
- ***Digitizer settings:***
  - Deplet. voltage = 60 V, bias voltage = 150 V, temperature = 300 K
  - AC coupling = 120 pF, interstrip coupling = 6 pF, noise = 1000 e
- ***Method:***
  - Resolution: calculated as RMS from obtained residuals (residual = reconstructed hits – MC generated hits)
  - Cluster size: calculated as a number of strips above threshold set (seed ~ 5 x noise, neighbours ~ 2 x noise, total signal ~ 7 x noise)

Preliminary Results: Belle x Belle II SVD Resolution

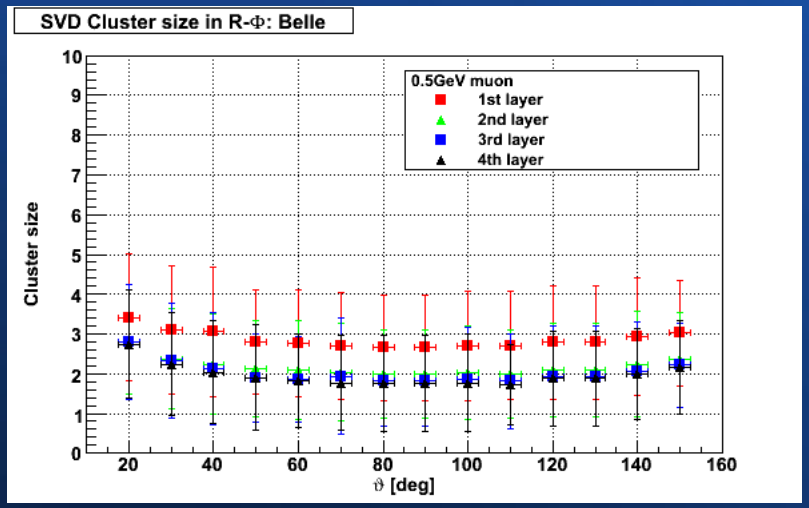


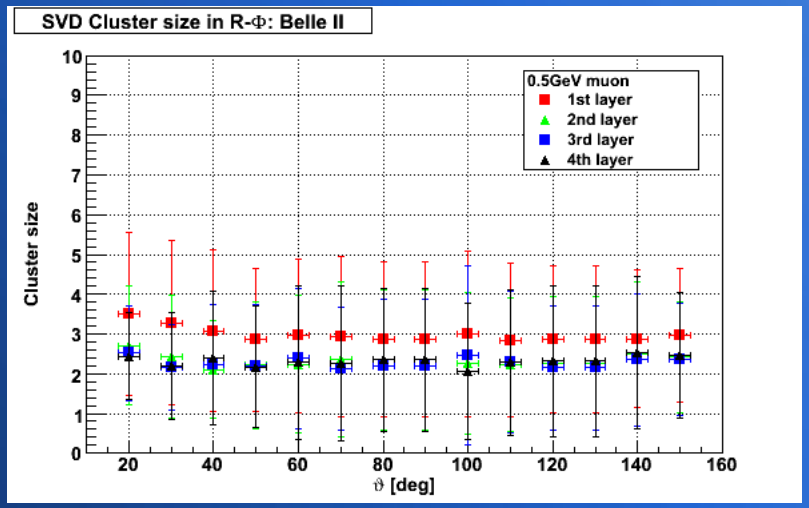


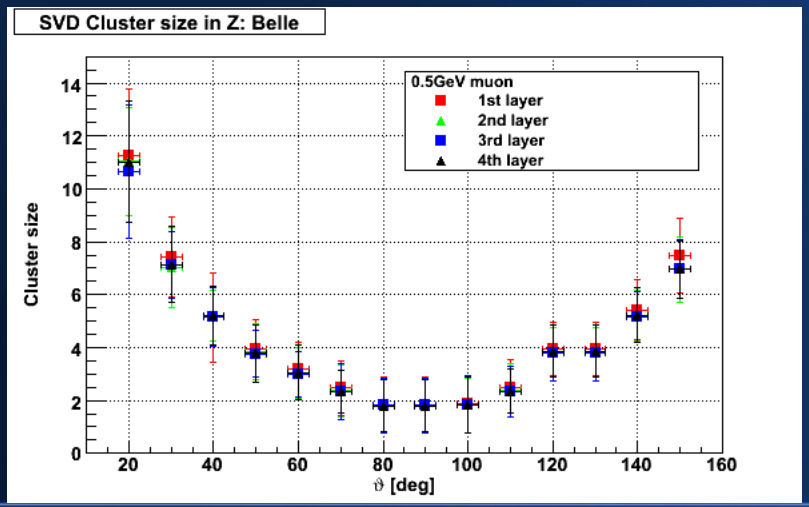


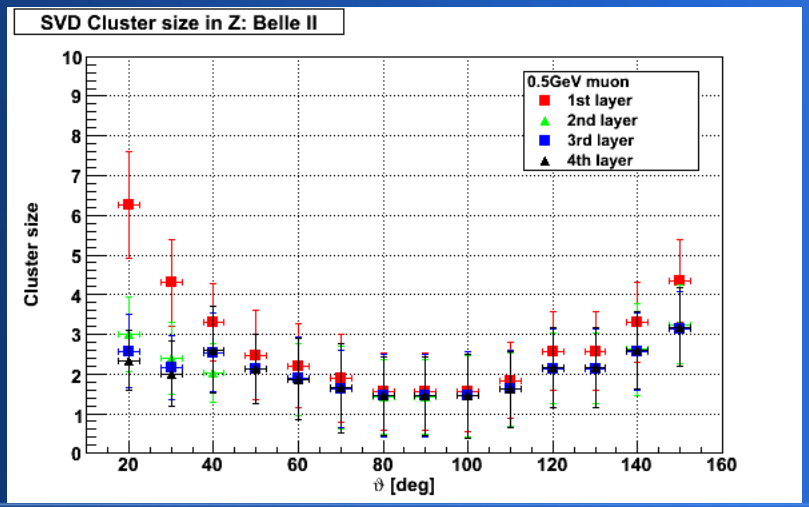


Preliminary Results: Belle x Belle II SVD Cluster Size









Summary & Future Plans

- ***Simulation software status:***
  - ***Mokka:***
    - SVDBelle – realistic geometry model of current Belle SVD prepared in Geant4 ***(OK)***
    - VXDBelleII – realistic geometry model of Belle II VXD (PXD+SVD) prepared in Geant4 – still missing implem. of "dead" material in SVD ***(OK, plan to implement SVD "dead" material)***
  - ***MarlinReco:***
    - SiStripDigi – realistic strip detector digitizer providing full simulation of DSSDs response ***(OK)***
    - SiStripClus – clusterizer providing 2D hits (based on COG algorithm) ***(OK)***
    - MaterialDB for Belle – processor providing material info for tracking code (Kalman filter) ***(OK)***
    - MaterialDB for BelleII – not implemented yet ***(plan to implement)***
    - Tracking code ***(OK, except for SVD slanted parts, no plans currently)***
- ***Simulation studies:***
  - First resolution studies performed & compared Belle wrt Belle II → optimisation studies?
  - First cluster size studies performed & compared Belle wrt Belle II → optimisation studies?