SVD validation and calibration

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The validation package

- I have revived the validation package and made it work, see:

  `svn/trunk/software/svd/validation/`

  while the new DQM module is at:

  `svn/trunk/software/svd/modules/svdDQM/`

- The validation plots can be found at:

  `https://belle2.cc.kek.jp/validation/`

  they use 1000 simulated and reconstructed events generated with the EvtGen module

- These plots show some anomalies in the simulation and reconstruction of events (documented in these slides).

The validation module contains:

- Cluster size
- Cluster charge
- Seed charge
- Pull: $(x_{cluster} - x_{hit})/\Delta x_{cluster}$
- Interstrip position: $(x_{cluster} \% p)/p$ (p = pitch)
- Digit charge (digits)
- Signal to noise (digits)
- dE/dx (simhits)
- Lost energy vs Deposited energy (truehits)
- Efficiency (truehits)

Events are divided based on:

- Layer
- Direction
- Sensor type
- Angle

The DQM module

- I have added the Data Quality Monitoring module to the framework
- This monitoring is done online, need to be careful with size :
  - Problems at DESY beam test (total size of $\approx$ 100 MB)
  - Avoid the use of 2D histograms
  - Choose a not-too-fine binning

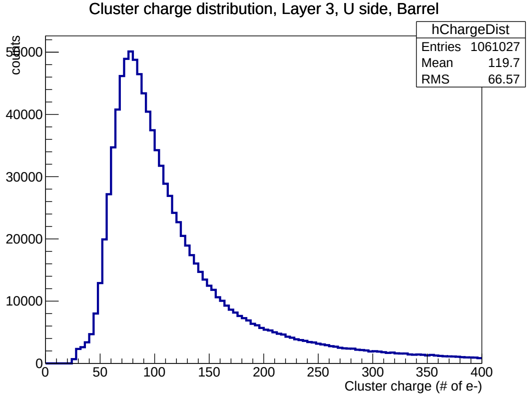
The DQM module contains

- Fired strips per event
- Clusters per event
- Hitmap (u and v, barrel and slanted)
- Digit charge
- Cluster charge
- Seed charge
- Size (u and v)

- Total: 44 histograms
- Only 1D histograms

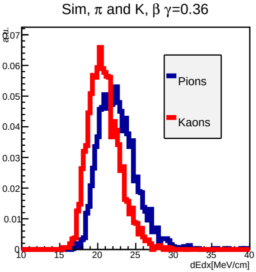
Validation issues - Charge distribution

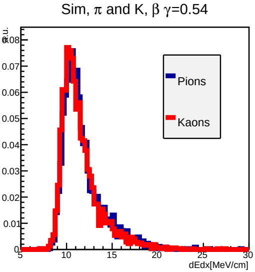
- The collected charge is currently represented by an arbitrary and off scale number (we expect $\sim 25,000$ electron-hole pairs per MIP passing through a 300 μm Si layer):
- (Sensors characterized by different layer number and strip direction show the same pattern).

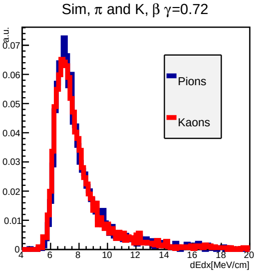


$\beta\gamma$ universality of the energy loss

- When looking at pions and kaons, universality ceases at very low momentum ($p_\pi \sim 50$ MeV), even though:
  - Only looking at first hits (layer 3)
  - Same angular distribution of generated particles with the module
  - No deflection due to magnetic field = simple length calculation
  - Only SVD loaded in simulation geometry - are there other materials that reduce the pions momentum ?

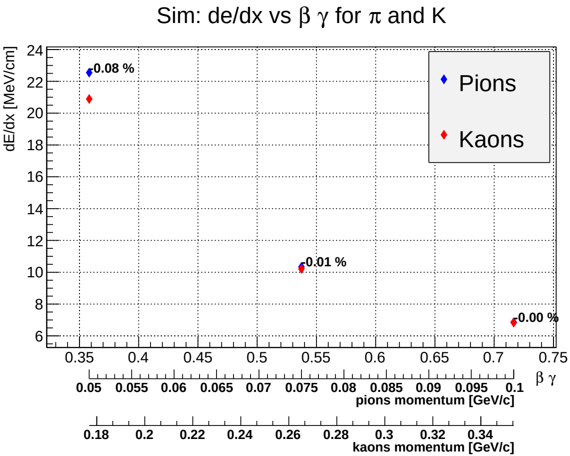






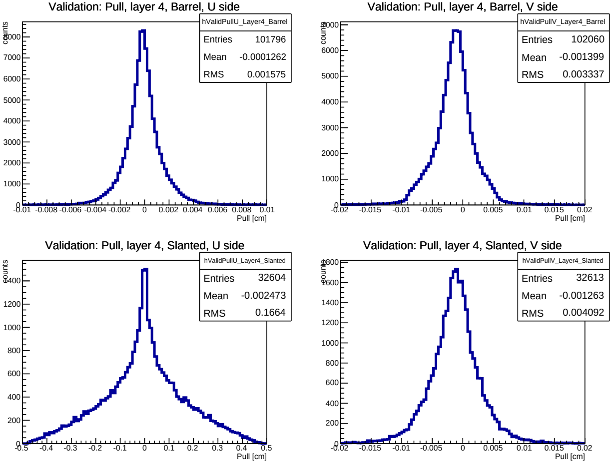
$\beta\gamma$ universality of the energy loss

The quantitative difference between MPVs at very low momentum can be seen in this graph:



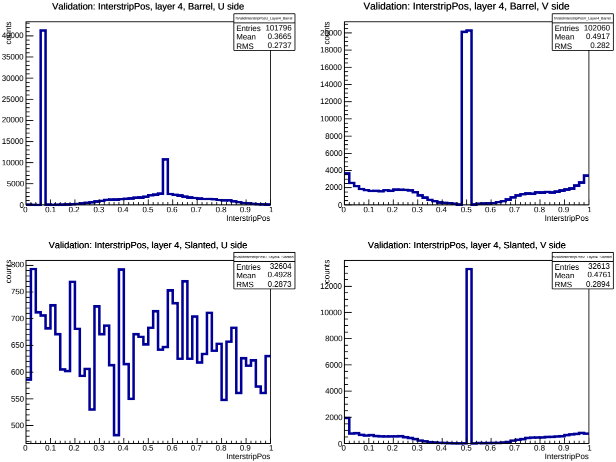
Pull distribution and spatial resolution

- The pull distribution is not symmetrical with respect to zero.
- (Sensors characterized by different layer number show the same patterns).



Interstrip position

- The ~~eta~~ interstrip position distribution shows several "prefered positions"
- (Sensors characterized by different layer number show the same patterns).



Calibration topics and tentative plans

- Following up the validation work I've started to look into the calibration topics
- I will summarize several calibration techniques and their tentative implementation in the Belle II framework, regarding:
  - Charge calibration
  - Cross-talk calibration
  - Lorentz angle calibration
- Also code for the routine calibrations have to be designed (noise, pedestal levels)

Charge calibration

- Important for
  - Signal to noise optimization
  - Coherent dE/dx measurements

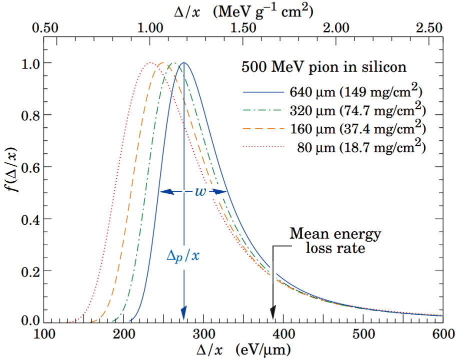
- Signal formation in the sensor involves two steps:

  1) The production of electron/hole pairs through the interaction of the charged particle passing through (Si layer specific)

  2) The reading and amplification of the collected charge (APV specific)
  - the calibration of this step can be done via on-chip calibration circuitry of APV chips
  - or using the APV tickmark (175,000 e^-)

Absolute calibration

- Calibrates also the non-uniformities in the sensors
- It can be done using cosmic muons:
  - Get ADC signal and traversed length
  - Normalize to ADC counts/unit length
  - Fit to Landau-Vavilov-Bichsel distr. to find MPV
  - Test using simulation data

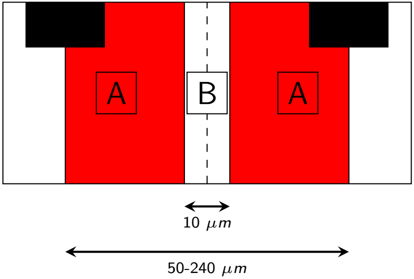


J. Beringer et al. (Particle Data Group), Phys. Rev. D86, 010001 (2012-2013)]

Eta variable

$$\eta = \frac{Q_L}{Q_L + Q_R}$$

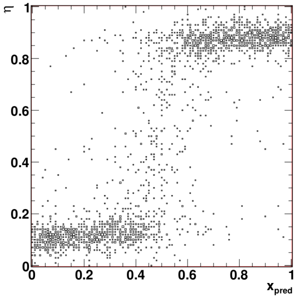
- The cross-talk happens because of capacitative coupling between strips

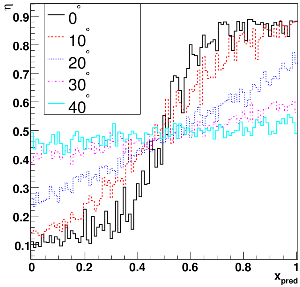


Adapted from R. Turchetta, *Spatial Resolution of Silicon Microstrip Detectors*, Nucl. Instr. Meth. A335 (1993)

Eta variable vs interstrip position

Plotting η vs interstrip position helps to visualize effects of cross-talk





Butz E., Ph.D thesis, *Calibration, Alignment and Long-Term Performance of the CMS Silicon Tracking Detector*, 2009

Similar variables that take into account both strips close to the seed strip can be investigated:

$$\zeta = \frac{Q_L + Q_R}{Q_L + Q_{seed} + Q_R} \qquad \Sigma = \frac{Q_L + Q_R}{2Q_{seed}}$$

Cross talk measurement

- A tentative plan:
- Parametrizing the η distribution helps to measure the cross-talk:

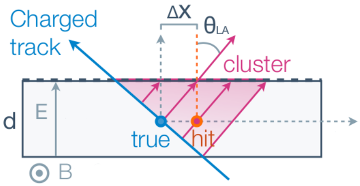
$$Q_{seed} = (1-2k)Q_{seed}^{raw} \qquad Q_L = Q_R = kQ_{seed}^{raw}$$

$$\eta = \frac{Q_L}{Q_L + Q_R} = \frac{k}{1-2k+k} = \frac{k}{1-k}$$

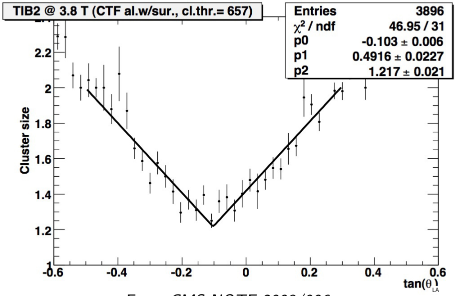
- To implement the eta variable in the framework:
  - Store right and left strips charge and position in the SVDCluster class
  - Plot eta vs interstrip position
  - Extract k parameter for each strip

Lorentz angle measurement

- Magnetic field stretches the length of a cluster and introduces a shift of the cluster center
- Methods for measuring the Lorentz angle:
  - Find the incident angle θ that give the smallest number of strips in cluster, $\theta = \theta_{LA}$
  - Use laser to produce charges on one side of the Si layer and measure the angle of their drifting to the other side
  - Alignment setup can measure hit and cluster deposition positions



Bartosik N., *Simultaneous alignment and Lorentz angle calibration in the CMS silicon tracker using Millepede II*, EPS HEP 2013



From *CMS NOTE-2008/006*

Lorentz angle measurement implementation

- A tentative plan:
- Find average cluster size for different angles
- Plot cluster size vs angle
- Fit to find intersection between two segments
- Test using simulation data

Cluster position algorithms

- Important for spatial resolution of hits
- See R. Turchetta, *Spatial Resolution of Silicon Microstrip Detectors*, Nucl. Instr. Meth. A335 (1993) 4458 [106]
- Several methods are available:
  - Eta algorithm (at small angles, i.e. small number of strips in cluster)
  - Center Of Gravity (at intermediate angles)
  - Analog Head-Tail (at large angles)

$$\frac{x_{AHT}}{p} = \frac{x_h + x_t}{2 \cdot p} + \frac{S_h - S_t}{2 \cdot S_c}$$

  - 1 sided A.H.T. (at very large angles)

Position resolution algorithms

- The resolution on the hit position has a fundamental importance for the precision of the vertex reconstruction. It needs to be estimated what resolution is needed.
- What method yields the best resolution ?
  - Currently only C.O.G. and A.H.T. (size > 2) algorithms are used
  - Try the different algorithms, keeping in mind that each of them applies to a specific range of entrance angle/cluster size

Conclusion

- Validation and DQM have been written and added to the framework
- Reconstruction of energy and position of hits needs to be improved through calibrations
- I will be working on calibration algorithms for the framework
- I have surveyed a set of corrections based on previous experiments
- A tentative plan involves simulation data and then (comparison with) testbeam data

Thanks for your attention !

Any questions and/or comments ?