Simulation des Belle II Pixel Vertex Detektors

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DPG Frühjahrstagung
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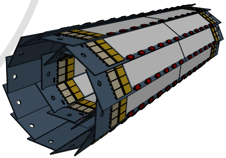
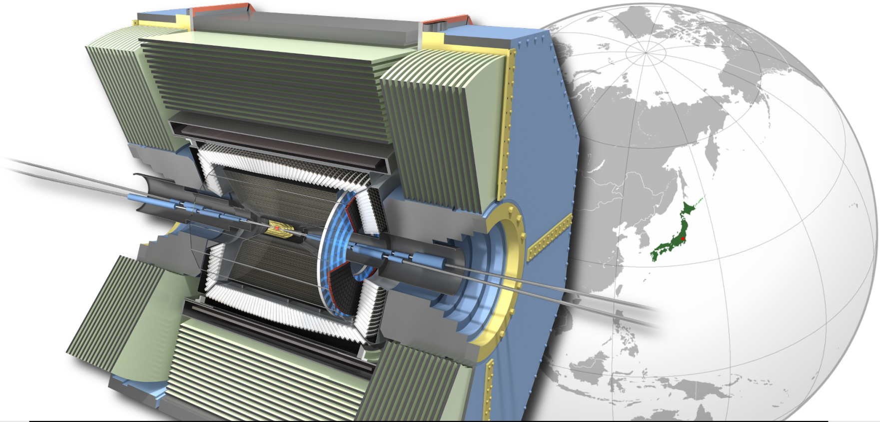
DEPFET
Active Pixel Detector



Belle/Belle II Experiment

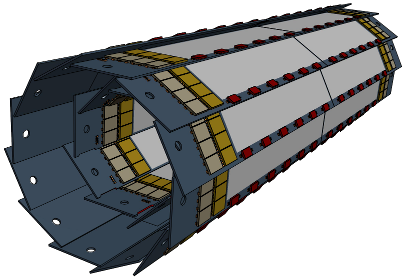
Asymmetric e^+e^- experiment mainly at the $\Upsilon(4S)$ resonance (10.58 GeV)

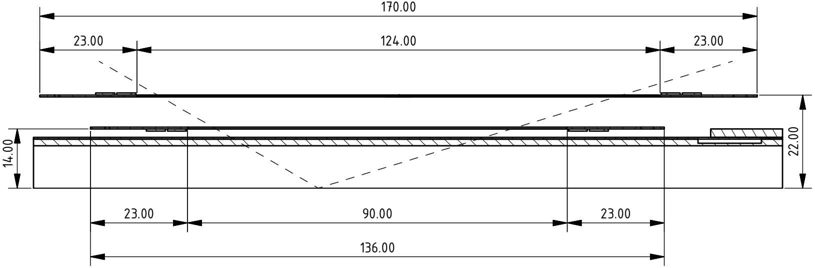


	KEKB/Belle	SuperKEKB/Belle II
operation	1999 – 2010	2014 –
peak luminosity	$2.11 \times 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$	$8 \times 10^{35}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$
integrated luminosity	$1023\,\mathrm{fb}^{-1}$ (772 million $B\overline{B}$ pairs)	$50\,\mathrm{ab}^{-1}$

Pixel Vertex Detector

- innermost part of the detector
- 2 layer pixel detector (8M pixels)
- readout time of 20 ms
- data rate of 240 Gb/s = 30 GB/s
- pixel size of $50 \times 50\ \mu$m and $50 \times 75\ \mu$m
- single track vertex resolution $\mathcal{O}(15 - 30\ \mu\text{m})$





Simulating the PXD

Simulation studies for the PXD strongly depend on accurate simulation of the DEPFET response

Verification of simulation needed

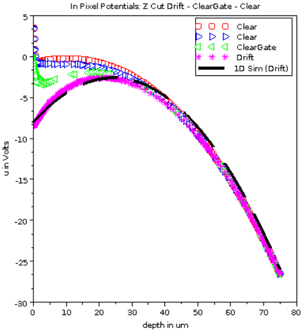
- build simulation based on real device simulations
- use data obtained from testbeam to verify the simulation
- fine tune simulation for results and performance

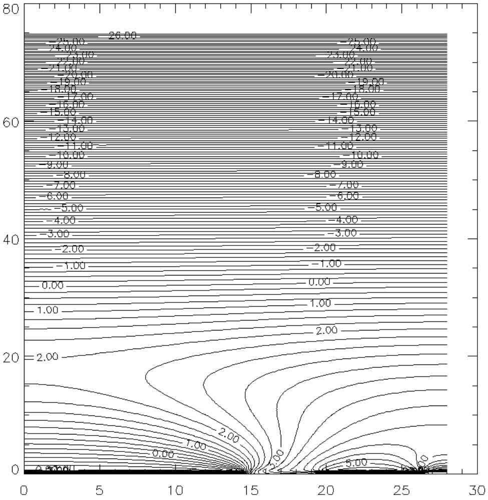
➡ So far, only response to charged particles has been validated

DEPFET Digitizer

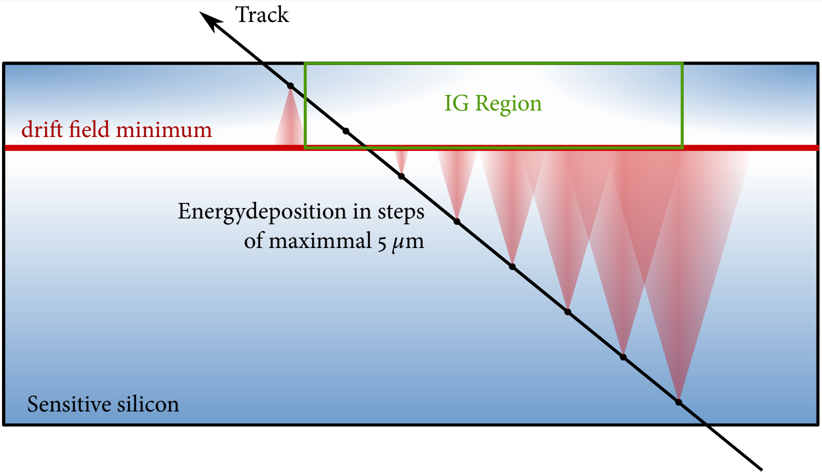
The digitizer is responsible for converting the energy deposition simulated by Geant4 into realistic pixel response

- drift charges inside the silicon
- account for diffusion
- apply noise effects and readout characteristics





Digitization

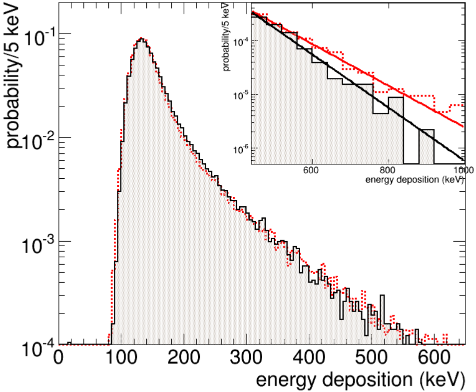


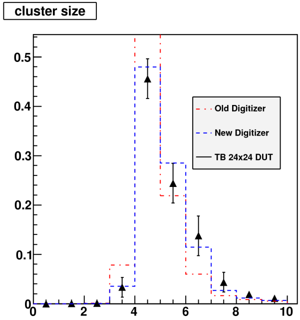
Charge is divided into small electron clouds

- vertical transport to maximum of 1D parabolic potential
- lateral diffusion using random walk until inside IG

Charged particles

Digitizer has been validated for charged particle tracks using DEPFET testbeam data.

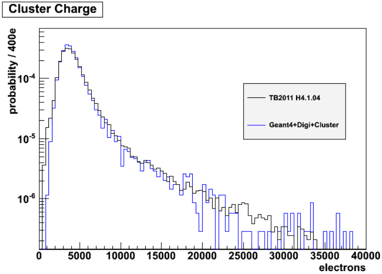


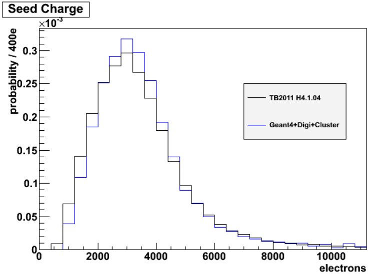


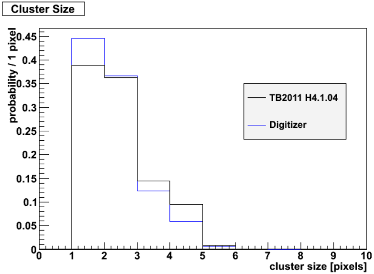
- Results in basf2 should be the same modulo bugs
- Validation using PXD6 Testbeam data already in progress

Thin sensors

First results with the new, thin sensors (50 μm)







- simulation shows very promising results even for thin sensors

Photons

So far, main concern has been pixel response to charged particle tracks

Occupancy is a big challenge for the PXD

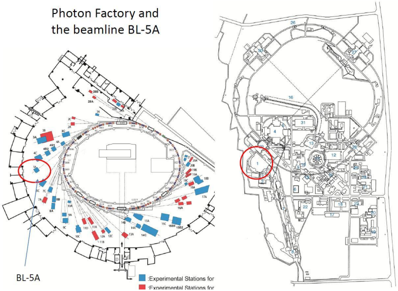
- data rate is extremely large
- maximum amount of data that can be transferred is $\mathcal{O}(3\,\%)$
- maximum amount of data that can be stored is factor 10 less

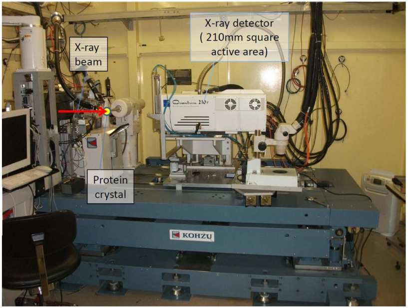
⇨ For Belle II background studies/data reduction, accurate response to photons is also needed

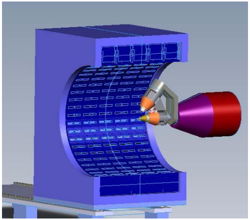
We mainly expect low energy photons (5 to 20 keV) from synchrotron radiation:

- lower energies will be shielded by the beampipe very effectively
- silicon becomes more and more transparent with higher energies

KEK Photon Factory



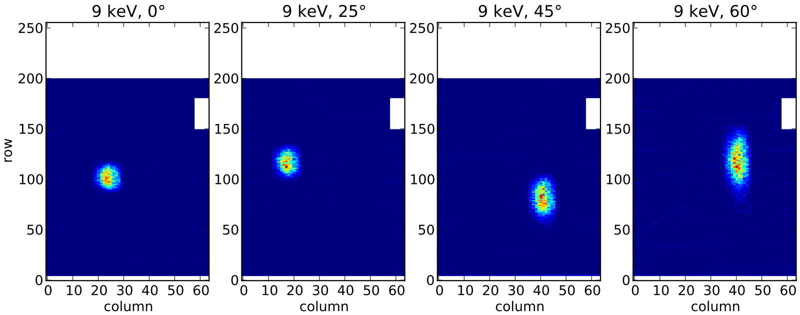




KEK Photon Factory is very interested in DEPFET detectors for their protein structure research

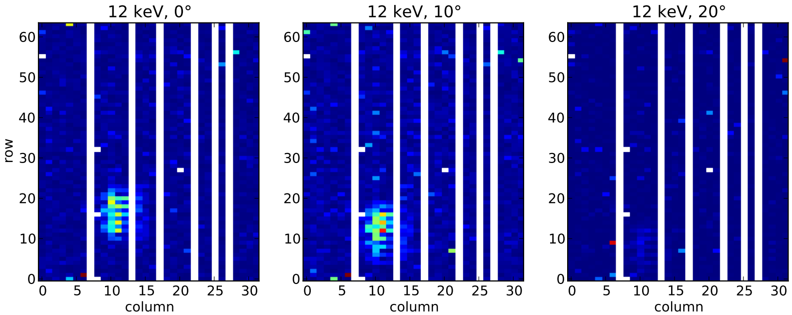
- possibility to expose DEPFET to well defined synchrotron radiation
- first testbeam end of last year
- exposed thick and thin sensors
- energies between 7 and 16 keV
- angles from 0° to 60°

PXD5 (thick sensor)



- S3B System (2.3 ms readout time and 150 Hz DAQ rate)
- ILC type matrix H3.0.23 ($32 \times 24\,\mu$m, 450 μm thick)
- Intensity varies for different energies (finite number of different absorber plates)
- calibration from Testbeam 2009:
  $Q = 7.7\,\text{nA}/g_q \times \text{signal} \qquad g_q = 0.4\,\text{nA}/e^-$

PXD6 (thin sensor)



- DCDB System (5 μs readout time and 150 Hz DAQ rate)
- Belle type matrix H4.1.04 (50 × 50 μm, 50 μm thick)
- calibration and Pedestal/Noise calculation still to be improved

- Due to short integration time, most frames seem to be empty
- There is no coincidence or trigger for photons which makes selection of non-empty frames more difficult

Plans and next steps

- calibration and masking of data has to be improved
- simulation parameters have to be checked
- study different DEPFET data sets
- improve digitizer (3D field simulations now available)

Photon Factory Test

Data from recent photon testbeam will be very useful for digitizer validation and Belle IIbackground studies

- different data sets with well defined energies between 4 keV and 17 keV
- different incident angles (depending on sensor position)

We have a new testbeam scheduled in march to test the thin sensors with longer integration time

⇨ we will start to look into this data to validate the digitizer

Conclusions

Digitizer working in two steps

- Vertical drift along 1D parabolic potential
- Lateral movement dominated by diffusion in potential minimum

Charged particles

- real data from testbeam available
- simulation is able to reproduce data with high accuracy

Photon response

- started to validate simulation with photon data
- still in early phase

Thank you
for your attention