DEPFET Pixel Detector in the Belle II Experiment

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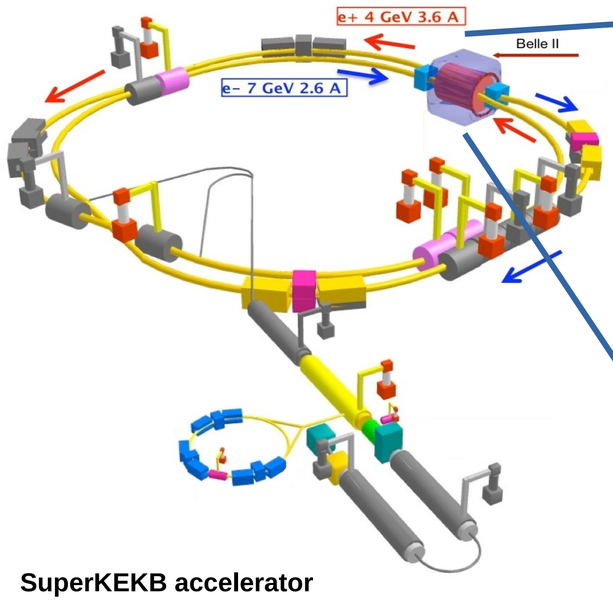
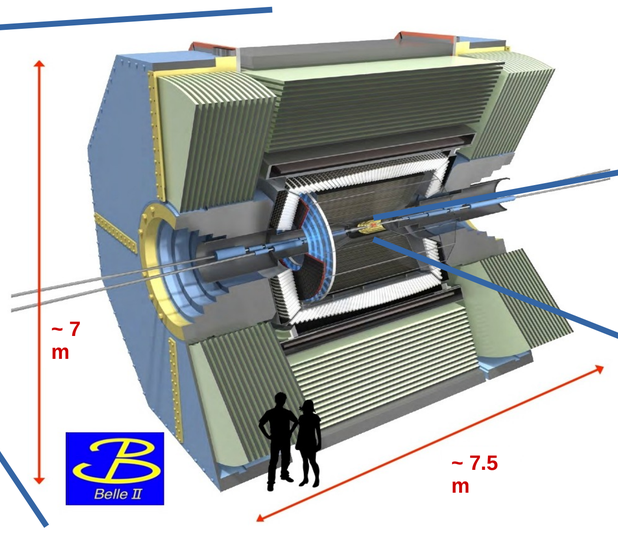
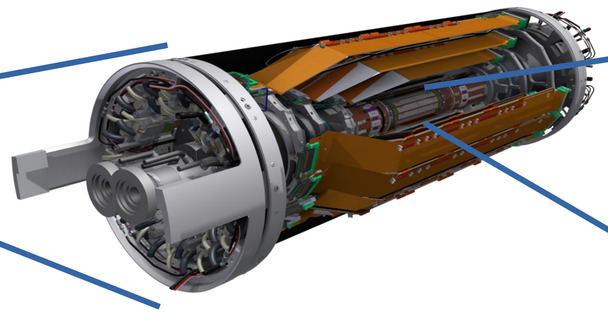
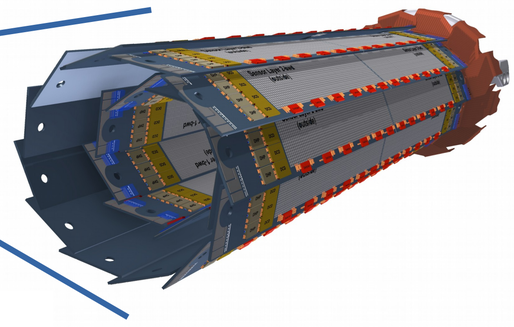
Belle II with a Heart of Silicon









SuperKEKB accelerator

- B-factory with E_{cm} = m(Y(4S)) = 10.58 GeV
- High luminosity (L = 8×10^{35} cm^{-2}s^{-1}: 40x world record)

Belle II Detector

- Complete upgrade of previous Belle detector
- Many new components (e.g. VXD)

Vertex Detector (VXD)

- 4 layers of double-sided silicon strip vertex detector (SVD)
- 2 layers of DEPFET pixel modules (PXD)

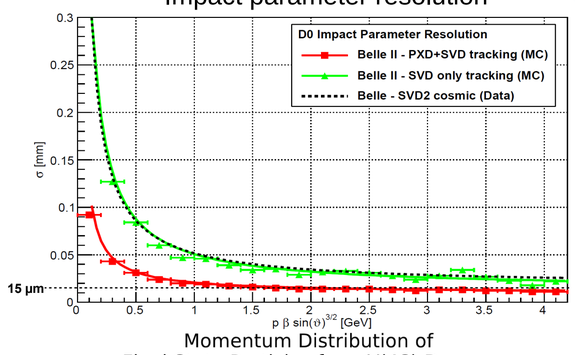
Pixel Detector (PXD)

- Reconstruction of secondary vertices and tracking of low-momentum particles
- Close to interaction point: R = 1.4, 2.2 cm, area ~ 0.03 m^2

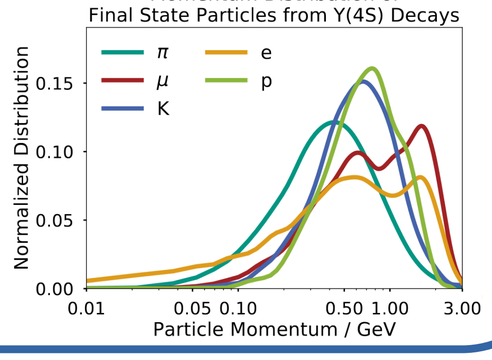
Pixel Detector Specifications

Occupancy	0.4 hits/μm^2/s (< 3%)
Radiation	2 Mrad/year
Frame time	20 μs
Trigger rate	30 kHz
Maximum possible data rate	20 GB/s ≡ ~ 1 MB / event
Data rate (reduced) to storage	< 3 GB/s ≡ < 100 kB / event
Sensor size	44.8 / 61.4 x 12.5 mm^2
Number pixels	768 x 250
Resolution	15 μm (50x75 μm^2)
Acceptance	17°-155°
Material budget	0.2% X_0 per layer
Sensors per layer	16 / 24

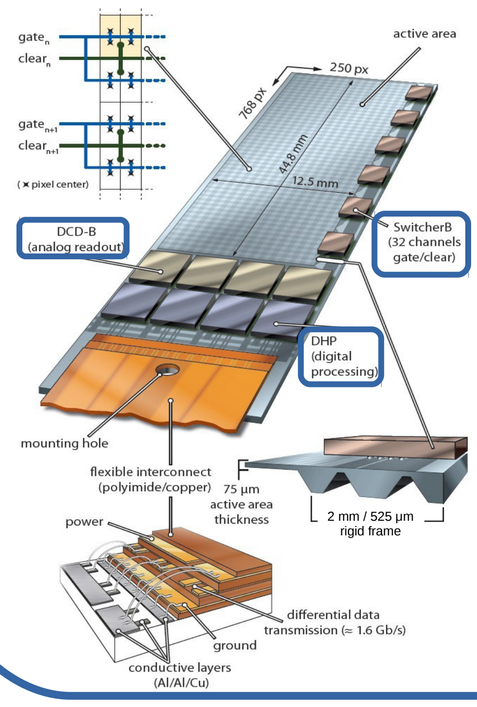
Impact parameter resolution



Momentum Distribution of Final State Particles from Υ(4S) Decays

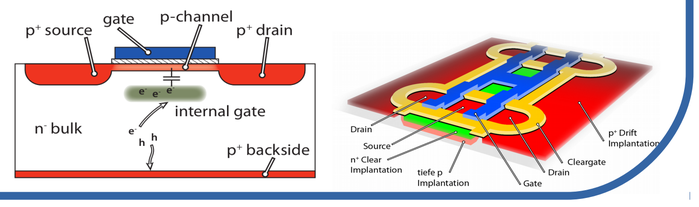


The all-silicon DEPFET module



- High level of integration
- Three regions:
  - Sensor: 768 x 250 pixels, thinned to 75 μm
  - Frame and balcony (525 μm thick + grooves)
  - Self-supporting structure
  - End Of Stave (EOS) outside acceptance
- 3 metal layers for interconnection (2 Al + 1 Cu)
- Three types of ASICs bump-bonded to module
  - 14 chips, ~3000 bumps in total

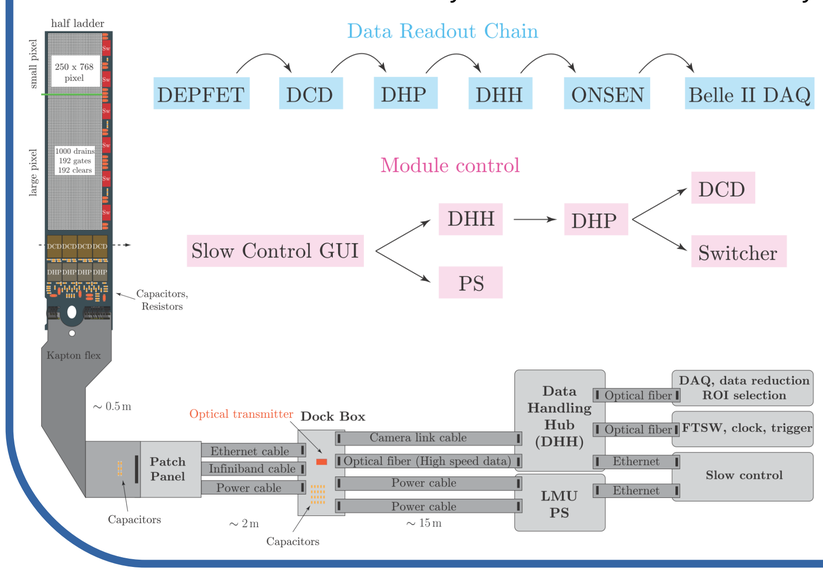
DEpleted **P**-channel **F**ield **E**ffect **T**ransistor (**DEPFET**)



PXD DAQ and DQM

PXD provides at maximum 20 GB/s of data

- Mostly background hits
- On average only 11 charged tracks per BB̄ event ≡ 22 cluster on PXD
- Remove background hits to reduce data
- Goal: online data reduction by factor of 10 for final luminosity



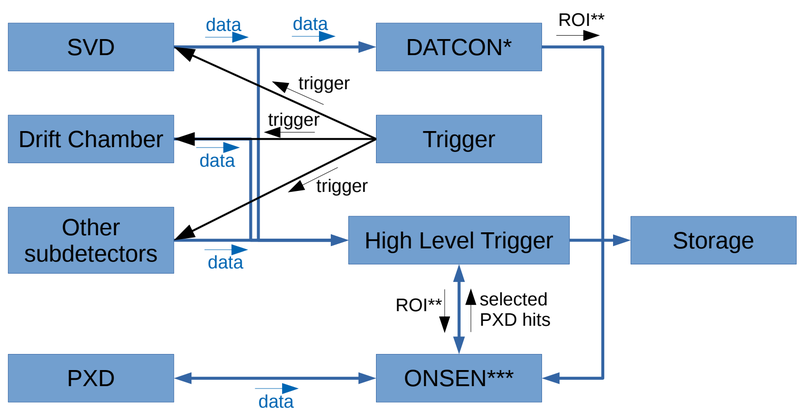
Data Readout Chain

DEPFET → DCD → DHP → DHH → ONSEN → Belle II DAQ

Module control

Slow Control GUI → DHH → DHP → DCD, Switcher; DHH → PS

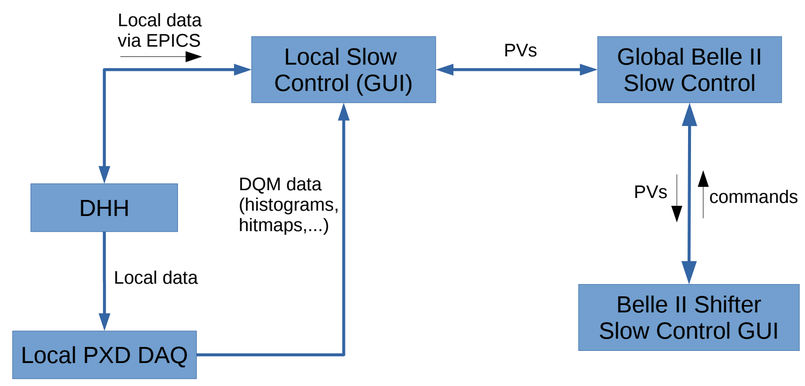
PXD data reduction scheme



- HLT and DATCON perform track reconstruction and calculate ROI
- The ROI are sent to ONSEN
- ONSEN merges the ROI and selects PXD hits inside
- Additional cluster rescue on hardware for particles with high energy loss / very low p_T
- Hits are sent to HLT and afterwards to storage

* Data Acquisition Tracking Concentrator Online Node
** Region Of Interest, *** Online Selector Node

PXD and Belle II Slow Control and DQM scheme

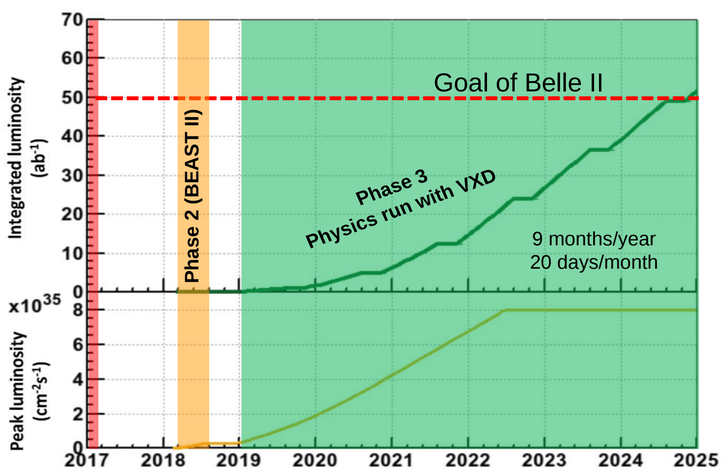


- Slow Control (SC) GUI created in CSS
- Process Variables (PVs) are distributed via EPICS
- Steering of PXD is mainly done via the PXD local SC
- PXD calibration data are evaluated and stored on BonnDAQ
- PXD expert GUI shows cluster size, hitmap, charge distribution, ...
- DQM histograms are sent from BonnDAQ to the PXD SC GUI and to central Belle II shifter DQM screen
- Central Belle II shifter sees PXD status and readiness
- Future plan: Central shifter can steer PXD without PXD expert

Detector Integration and Commissioning

Belle II schedule

- Phase 1: Accelerator commissioning
- Phase 2: BEAST and partial Belle II commissioning
- Phase 3: Full Belle II detector

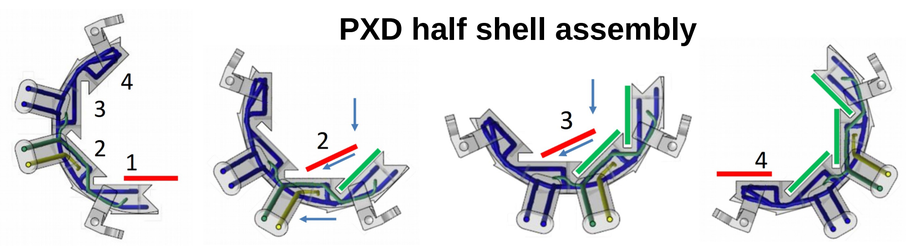


Module testing and final assembly

	REQ	G99	G98	G95	M99	M98	M95
Inner Forward	8	17	3	0	1	0	0
Outer Forward	12	26	6	2	3	1	0
Outer Backward	12	22	3	1	4	0	0
Inner Backward	8	13	3	0	3	1	0

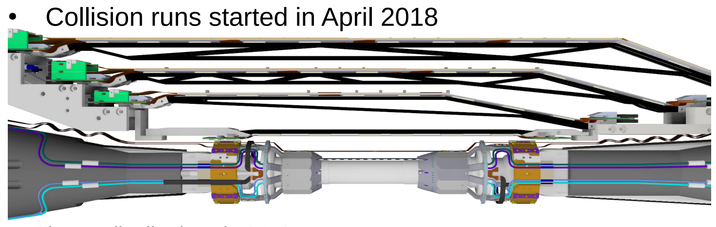
- Final PXD modules for phase 3, cooling blocks and all services tested
- All modules for phase 3 plus contingency have been assembled
- Currently half shell assembly at DESY for layer 1
- Beginning of June: Transport of all phase 3 hardware to KEK
- Afterwards installation of full VXD in fall 2018

PXD half shell assembly

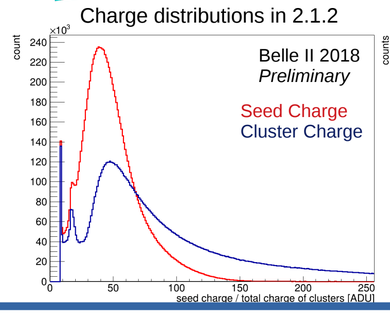


The BEAST II experiment

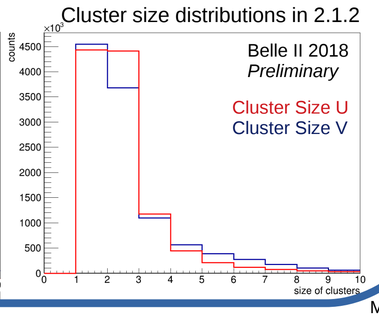
- Accelerator commissioning experiment
- 1 slice of “final VXD”: 4 SVD + 2 PXD layers
- Several additional dedicated beam monitoring detectors
- First integration of real VXD parts into Belle II
- Collision runs started in April 2018



Charge distributions in 2.1.2



Cluster size distributions in 2.1.2



May 2018