

The Belle-II DEPFET Pixel Detector: A step forward in vertexing in the SuperKEKB Flavour Factory

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On behalf of the DEPFET Collaboration (<u>www.depfet.org</u>)





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SuperKEKB

- -KEKB machine upgrade
- -Belle-II (PXD)

<u>DEPFET</u>

-Fundamentals-System elements

 PXD (Pixel Detector) -Ladder characteristics -Mechanical design -Thermal studies







Belle-II requirements



	Belle-II	
Occupancy	0.4 hits/µm²/s **	
Radiation	> 1Mrad/year	
Frame time	20 μs (continuous r.o. mode)	
Momentum range	Low momentum (< 1 GeV)	
Acceptance	17º-155º	



- > Required spatial resolution (~10µm) → Moderate pixel size (50 x 50 µm²)
- > Few 100 MeV momenta \rightarrow Lowest possible material budget (0.19% X₀/layer)

 \rightarrow The DEPFET technology can cope with this challenging requirements

** Occupancy for the obsolete High-current option. Chosen Nano-beam is under study!

DEPFET – DEpleted P-channel Field Effect Transistor

Each pixel is a p-channel FET on a completely depleted bulk (sideward depletion). Charge is collected by drift

> A deep n-implant creates a potential minimum for electrons under the gate (internal gate)

> Signal electrons accumulate in the internal gate and modulate the transistor current $(g_q \approx 400 \text{ pA/e}^-)$

Accumulated charge can be removed by a clear contact

> Internal amplification

Low power consumption: Readout on demand (Sensitive all the time, even in OFF state)



o Small pixel size

o Intrinsic Noise≈40e⁻ at high bandwith→Small capacitance and first inpixel amplification

 \circ Thin Detectors≈50µm

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Realistic module (dummy chips) was assembled successfully at home (Heidelberg)







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ASICs are bump bonded only



In-module signal flow

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- This technology has been extensively tested with great results!
- Successful program for several years:
 - SNR>100
 - Position resolution 1.2 μm
 - \bullet However: slow readout, thick sensors (450 μm), old readout chips











→ Test beam period with a close to final design system is planned for November

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	Inner layer	Outer layer
# ladders	8	12
Radius	1.4 cm	2.2 cm
Pixel size	50x50 μm ²	50x75 μm ²
# pixels	1600(z)x250(R-ф)	1600(z)x250(R-φ)
Thickness	75 µm	75 µm

Frame time: 20 µs





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- Implement the full Belle-II ladder geometry in f.e- software
- Apply the loads to the different elements (DCD,DHP,SW,Sensor)
- Find an optimal cooling solution (find T_{env} and T_{cb}) for the current upper limits on the temperatures:
 - \succ T_{max} (Sensor)<30°C
 - ➤ T_{max} (Chips)<60°C</p>

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□ The new super flavour factory (SuperKEKB) is under construction and will be ready by the fall of 2013

- The new machine will deliver a luminosity 40 times the present world record
- The Belle detector will be upgraded to exploit the increased statistics and perform precision measurements

□ To perform precision measurements, the innermost subsystem will consist of two layers of pixels, based on the DEPFET technology

- Low power consumption
- Low material budget
- High resolution
- Well defined ladder geometry (detailed simulation)
- System elements close to the final production(expected performance)





Backup slides



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•Hybrid Board

- DEPFET 64x256 matrix
- Readout chip (CURO)
- Steering chips (Switchers)

•S3b Readout Board

- ADCs \rightarrow Digitization
- FPGA \rightarrow Chip config. and synchronization during DAQ
- RAM \rightarrow Data storage

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• USB 2.0 board \rightarrow PC comm.









MPV~3100 ADC counts

 $g_q \sim 650 pA/e^-$ (2x previous g_q , as expected)

Internal Amplification

The internal amplification measures the change in drain current in the presence of charge "Pixel Difference" (Pixel Difference) in the internal gate:

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$$g_q = \frac{dI_{ds}}{dQ_{int}} \sim \frac{\sqrt{I_{ds}}}{\sqrt{W}L^{\frac{3}{2}}}$$

- \checkmark Increasing g_a increases SNR
- ✓ Playing with channel length we can achieve up to $g_a \sim 1 \text{ nA/e}^-$
- ✓ PXD4 has L=6µm, some matrices in PXD5 have now L=4µm \rightarrow Expect factor 2 better S/N



