Summary of the Hardware and Upgrade Session

Fabian Becherer, Benjamin Schwenker

Deutsches Elektronen Synchrotron, DESY
Belle II Experiment, KEK

September 27, 2023

HELMHOLTZ

Overview

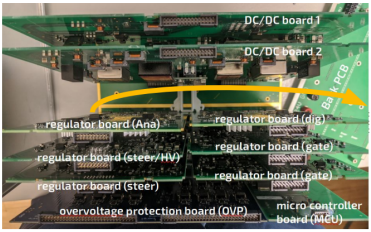
- 9 Talks in total given by master students up to professor
  - Two PXD related talks
  - One about VTX
  - Three about trigger systems
  - One about beam background decomposition
- Fruitful session with a lot of discussion

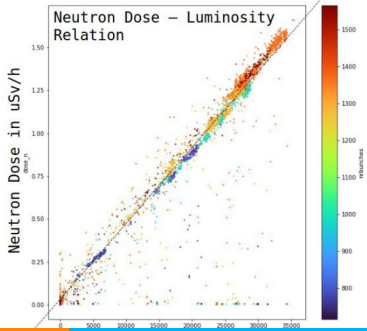
- Detailed talks
- I will just show the main content of the talks
- Please check out the original slides and get in touch with speakers for more information

Upgrade of Belle II Vertex Detector with CMOS Pixel Technology	*Benjamin Schwenker et al.*	
HS229.4	09:00 - 09:20	
Real time decomposition of beam backgrounds at Belle II with neural nets	*Benjamin Schwenker*	
HS229.4	09:25 - 09:45	
Graph Neural Networks for the first Level Trigger at Belle II – A concept study on future hardware upgrades	*Marc Neu*	
HS229.4	09:50 - 10:10	
PXD power supplies	*Jannes Schmitz*	
HS229.4	11:00 - 11:20	
PXD irradiation	*Georgios Giakoustidis*	
HS229.4	11:25 - 11:45	
Status and upgrade of the single track trigger	*Christian Kiesling*	
HS229.4	11:50 - 12:10	
Displaced vertex trigger	*Elia Schmidt*	
HS229.4	12:15 - 12:35	

PXD Power supplies: OVP studies (Jannes Schmitz)

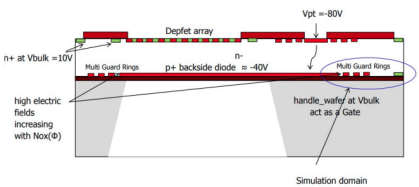
- Complex custom made power supplies
- 23 voltage, ranging from -80V to 20 V
- Currents up to 3A
- Supplied via 15 m long cables
  → 4-wire sensing and stable regulation
- OVP board with protecting circuitry for each channel
- During phase3 fake OVP introduce by neutron radiation
- Reduction by factor 6 with new modification
- Neutron dose will increase linearly with luminosity

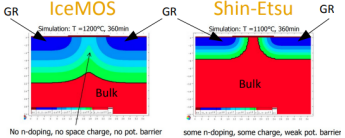


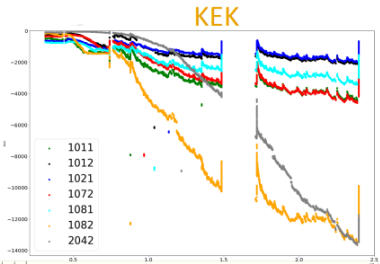


TEST STRUCTURE IRRADIATION (Georgios Giakoustidis)

- High HV currents observed in modules at KEK since spring 2020
- X-ray irradiation campaigns in lab with prototype modules
  - Saturation expected at 1.5 Mrad
  - IceMOS saturation at 7 mA
  - HV current in IceMOS is 10x higher than Shin-Etsu
  - Dose at KEK up to 0.6 Mrad
- High electric fields at shorted guard-ring structures
  $\rightarrow$ Avalanche current multiplication $\rightarrow$ increased currents
- Tests with MOSFET test structure
- Further analysis and interpretations needed

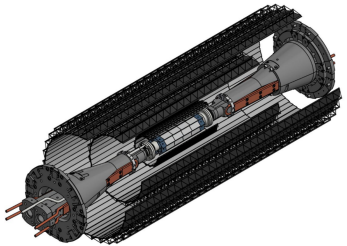


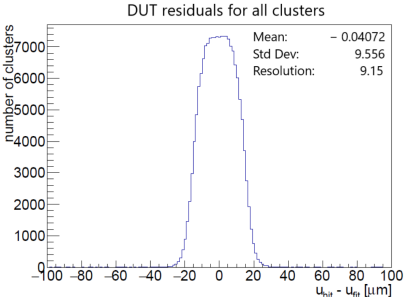




- TJ-Monopix2 sensor tested in test beam (without irradiation)
- Hit efficiency 99.54 at 500e$^-$ threshold
- Cluster position resolution of 9.15μm $\rightarrow$ Next: Irradiation to 10^{14}-10^{15}

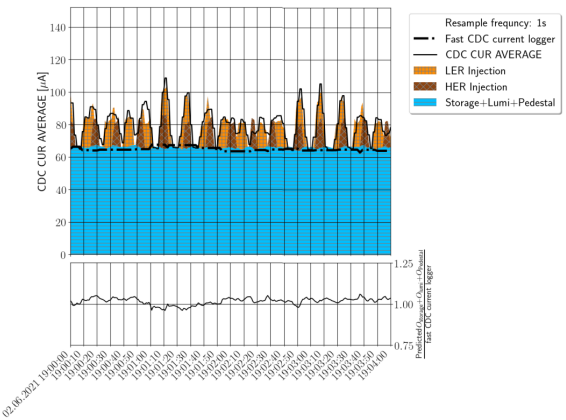
- TJ-Monopix2 matrix design will be carried over to OBELIX
- Main performance figures of non-irradiated sensor matches requirements
- Analysis of test beam with irradiated sensors in July 2023
- OBELIX design, targeting submission in autumn 2023
- Finalization of VTX conceptual design report





Real time decomp. of beam bkg at Belle II with NN (Benjamin Schwenker)

- Explore possible insights into the background composition BGNet can provide
- A NN for the decomposition of beam backgrounds was implemented BGNet Paper
- Model based on heuristic scaling laws
- Feature attribution methods can be used to identify important variables+
- Setup currently being installed and integrated at KEK



GNN for the first Level Trigger at Belle II (Marc Neu)

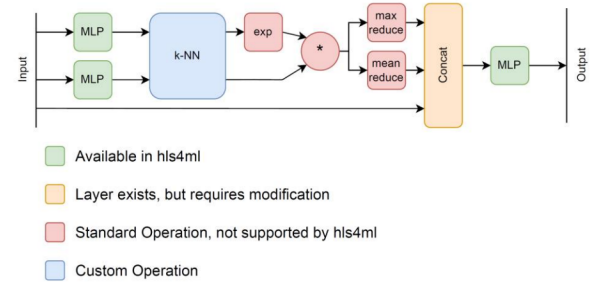
- GNNs have shown promising performance in a wide range of applications
- Proof of concepts presented at CERN
- Possible applications within Belle II: CDC and Calorimeter
- Quantitative numbers on performance improvements and hardware feasibility are required
- Several limitations
  - hls4ml is a very popular tool for automatic conversion of NN
  - However, only 33% of layers in GravNet are supported
  - Currently, discussions with hls4ml ongoing
  - Investigation into alternative frameworks
- First results expected in Q4 2023
- A new hardware platform is required to fully utilize the full potential of GNN-based triggers

Central Drift Chamber

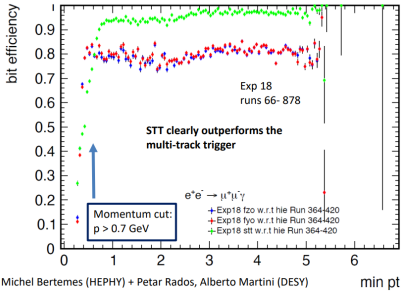
- Latency
  $1\ us\ to\ 2\ us$
- Trigger Data Input Rate
  $II = 32\ MHz$
- Worst Case Graph Size
  - $|V| = 14336$
  - $|E| \approx 80.000$

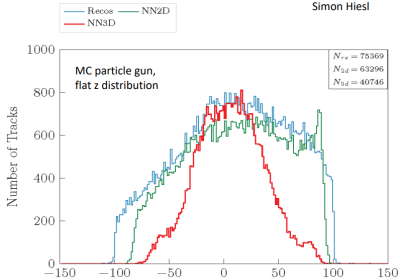
Electromagnetic Calorimeter

- Latency
  $L = \approx 3.2\ us$
- Trigger Data Input Rate
  $II = 8\ MHz$
- Worst Case Graph Size
  - $|V| = 576\ (x4)$
  - $|E| \approx 9216\ (x4)$



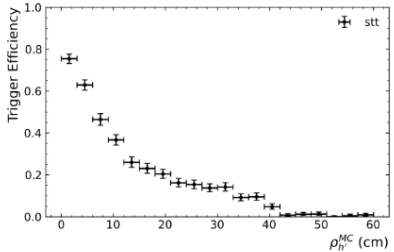
- Minimum Bias Single Track Trigger (STT) outperforms multi-track trigger
- One challenge of STT is "Feed-Down"
- Physics goal: low charged multiplicity
- Future goal: keep efficiency & low trigger rate with rising luminosity
- Improve track finding with 3D Hough space
- Enhance network architecture: "deep-learning"
- New concept shows promising results
- Implement new concept on FPGA





Status of the Displaced Vertex Trigger (Elia Schmidt)

- Development using simulated data (Patrick Ecker, KIT)
- Long lived neutral particle (dark Higgs) [0.5-4.0] GeV
- Decay to muons $e^+e^- \to A(h \to \mu^+\mu^-)$
- First network trained (very limited dataset and no optimization at all)
- Stronger in rejection than old algorithm (due to fewer MacroCells)
- Need to determine precise rejection constraint
- Vertex resolution is satisfactory for an L1 trigger



STT efficiency vs. vertex displacement
[credit: Patrick Ecker, KIT]