JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

JENNIFER2 EU grant n.822070

Bundesministerium für Bildung und Forschung

ErUM-FSP T09 Belle II

WP 5: R&D Belle II PXD DAQ

Jens Sören Lange (Justus-Liebig-Universität Giessen)

Jennifer 2 General Meeting, *Prague, 18.11.2022*

WP 5.2

b) Online data acquisition and remote controls

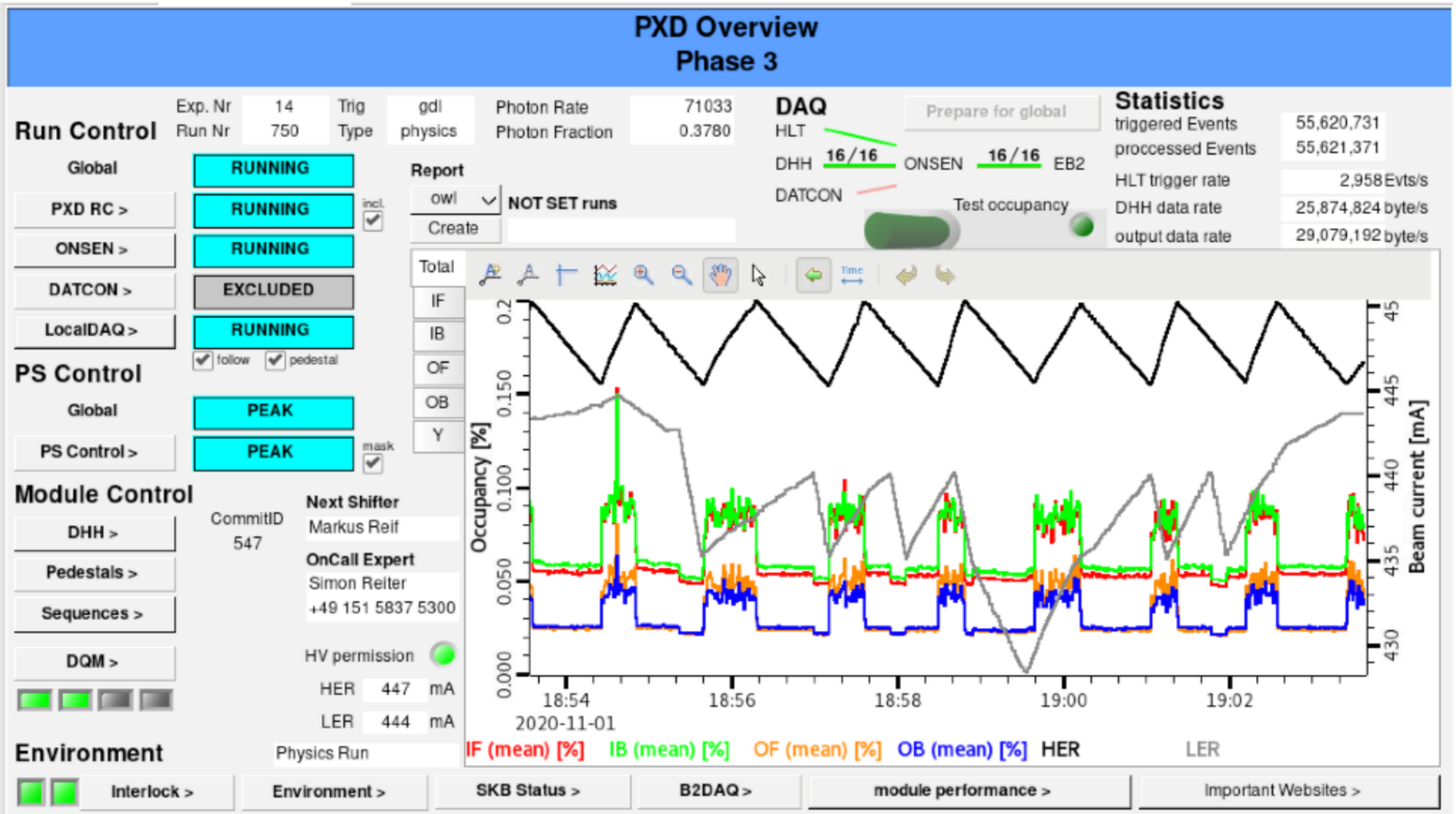
- new hardware technologies for high bandwidth data transfer
  - optical technologies (16.3 Gbps)
  - 10 Gbps ethernet
- precise timing distribution in sub-nanosecond regime
- intelligent realtime algorithms for online data reduction
  - Belle II – background rejection on FPGAs
  - HyperK – vertexing on trigger level ($t < 10$ ns) on GPUs
- novel programming and DAQ software techniques
  - parallelisation on both FPGAs or GPUs
  - methods of artificial intelligence for trigger decisions
  - integrated dynamic service discovery, monitoring, fault tolerance, dynamic routing and remote control.

Outline

- What has changed in the past 3 years?
- Results on high bandwidth data transfer (Belle II PXD)
- Results on "AI" algorithms and hardware implementation (Belle II PXD)

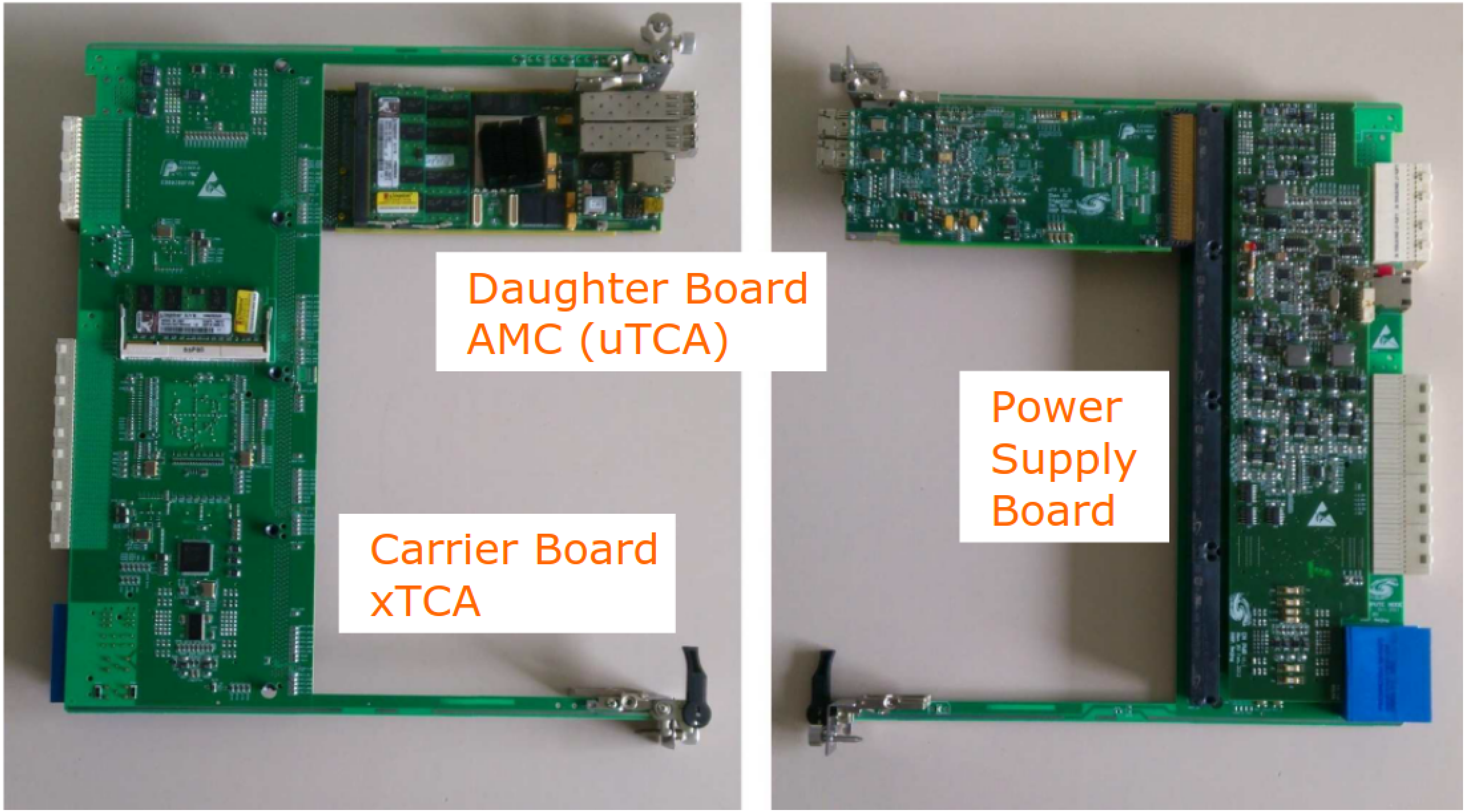
What has changed in the past 3 years?

- Belle II recorded 428 fb^{-1} recorded (comparable to complete BaBar data set)
- PXD DAQ stable, uptime 98.8% (relativ to Belle II DAQ)
- physics results with PXD: lifetime of D^0, D^+, Λ_c^+, Ω_c^0 measured precisely
- PXD decommissioned, work focused on PXD2 installation (long shutdown)



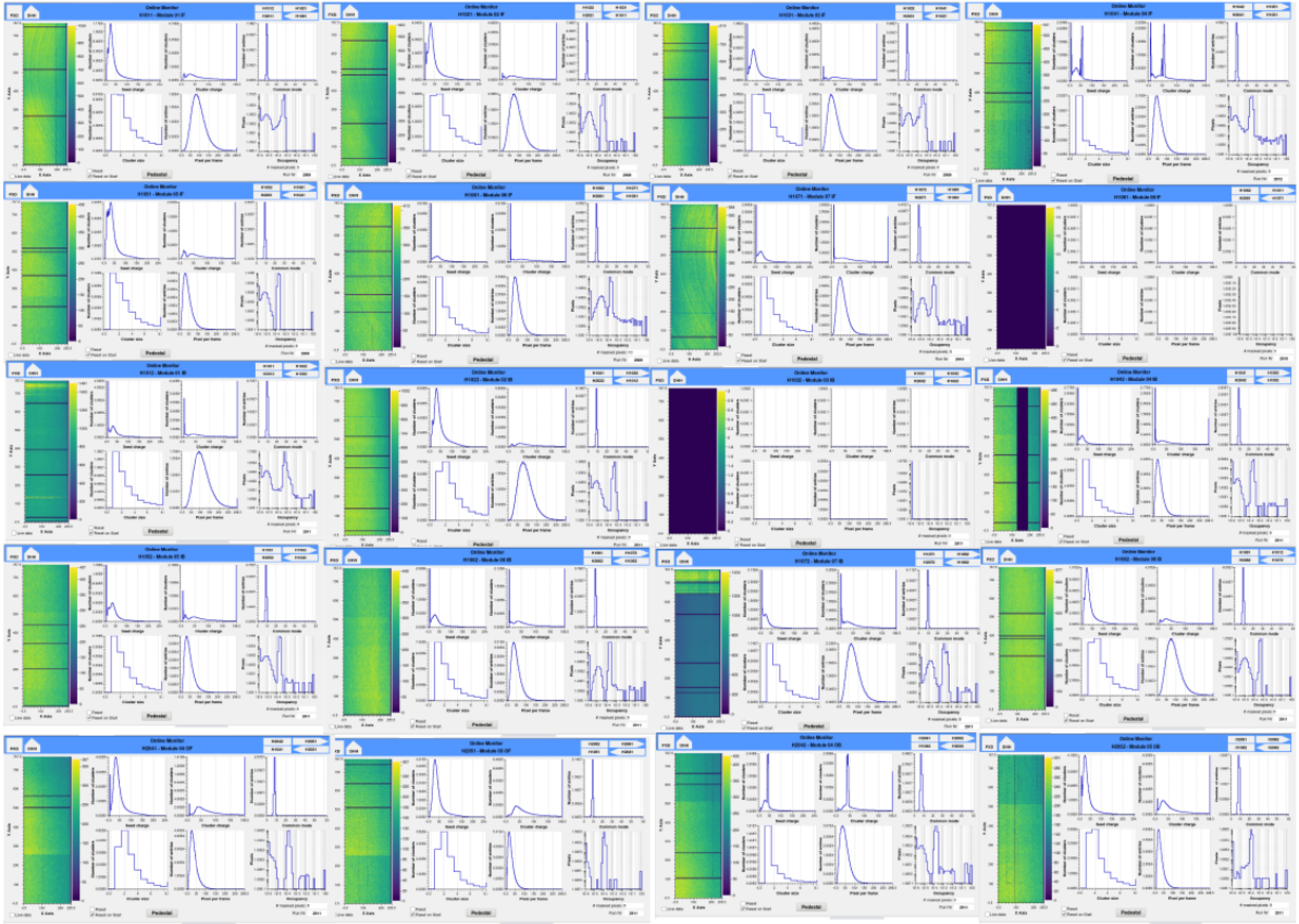
Occupancy calculated online on PXD DAQ (Onsen system)

PXD DAQ, ONSEN system hardware




O11S2-IP112
O12S2-IP122
O09S3-IP93
O05S3-IP53
xFP-V4-2-09
xFP-V4-2-22
IHEP
CHINA

PXD online monitor during Belle II physics data taking



HIGH BANDWIDTH DATA TRANSFER

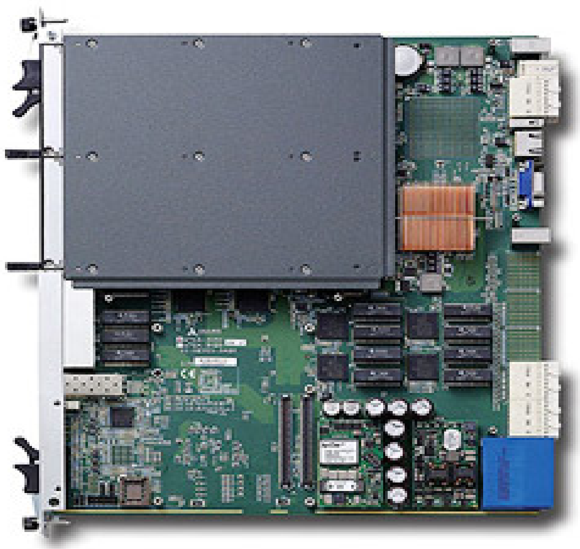
Link bandwidth compared

Wifi (802.11 a/g)	20 Mbps	
4G	20 Mbps (download)	mobile phones
5G	100-300 Mbps (download)	mobile phones
Gigabit Ethernet	1 Gbps	cable (electrical or optical)
ONSEN link	6.125 Gbps	optical
ONSEN link new carrier board	16.3 Gbps	optical
complete PXD	~200 Gbps @ 3% occupancy (5 DVD per 1 second)	
ATCA ADLINK aTCA-3150	10 Gbps (uplink)	
ATCA ADLINK aTCA-3710	40 Gbps (uplink)	

ONSEN system (here: system test at Giessen)

Test of ATCA switch with 10G uplink

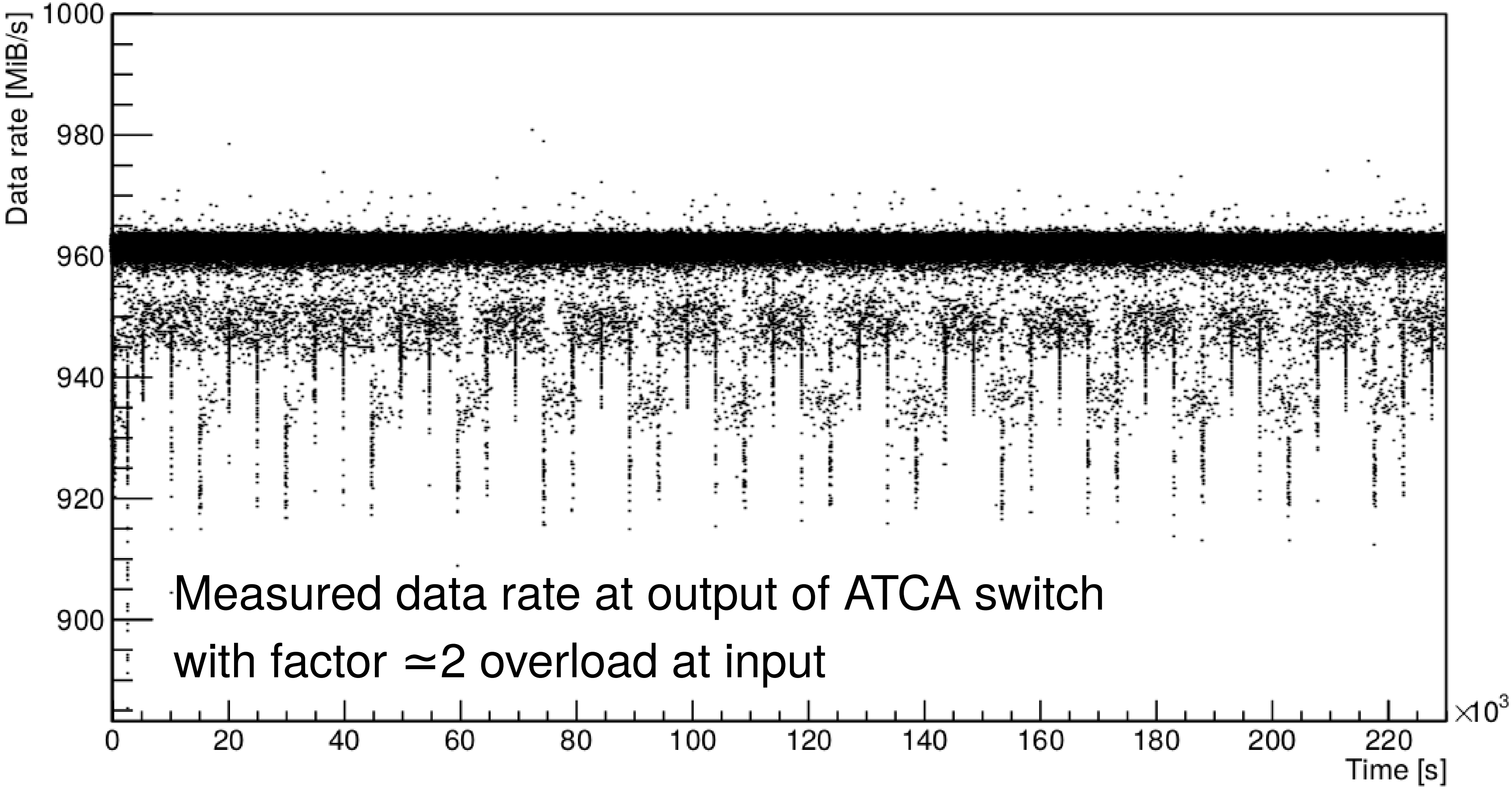
- Output from PXD system to event builder
- Is it possible to reduce 32 cables with 1G by 1 cable with 10G ?
- Does the switch break down?
- Is the buffer large enough?



ATCA ADLINK aTCA-3150
10G Uplink

ATCA ADLINK aTCA-3710
40G Uplink

Test result of ATCA switch with 10G uplink



Klemens Lautenbach, Ph. D. thesis, [link]

New ONSEN hardware

- New generation of ONSEN ATCA carrier board
- past: Xilinx Virtex-5 FX 70T

  future: Xilinx Kintex Ultrascale 060
  - factor 10 more FPGA resources
  - factor ~2.5 higher link bandwidth (16.3 Gbps)
- New firmware developed (master thesis Matthäus Krein):

  link layer protocol changed from Aurora to AXI Stream

AI* METHODS

*better terminology:

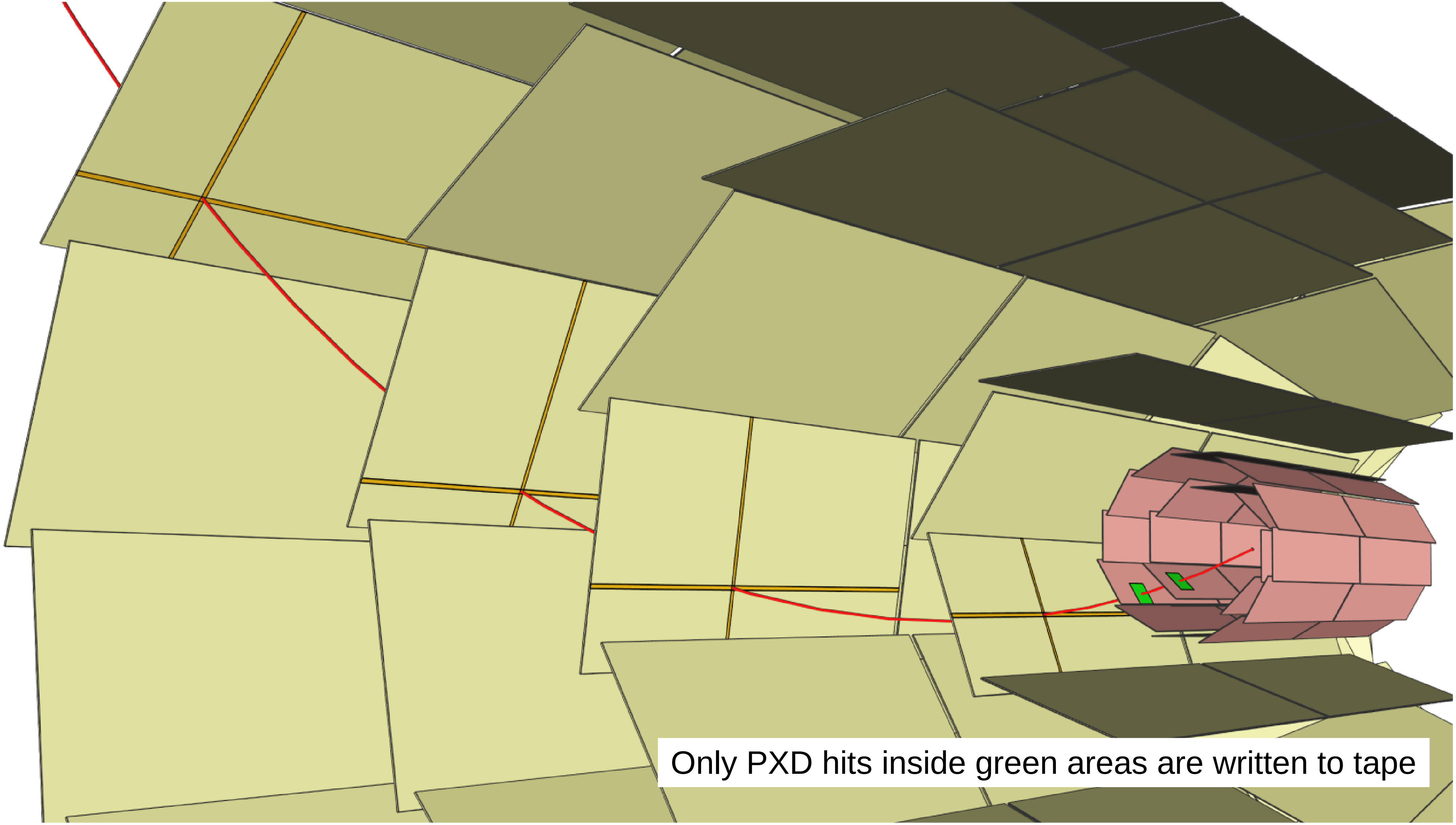
ML METHODS

(machine learning)

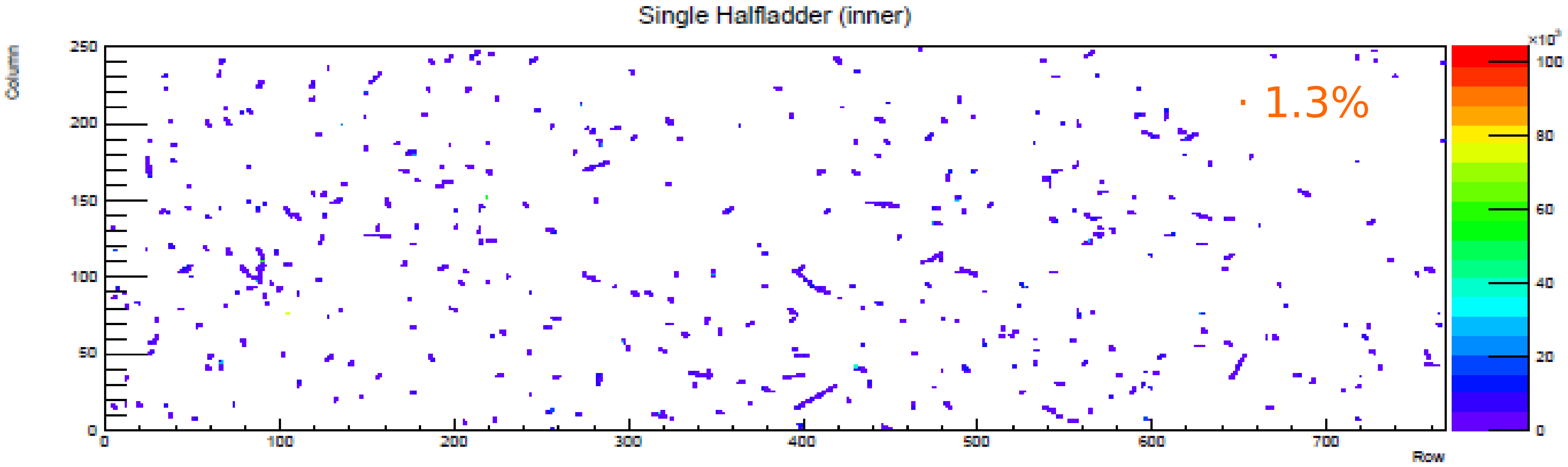
we use

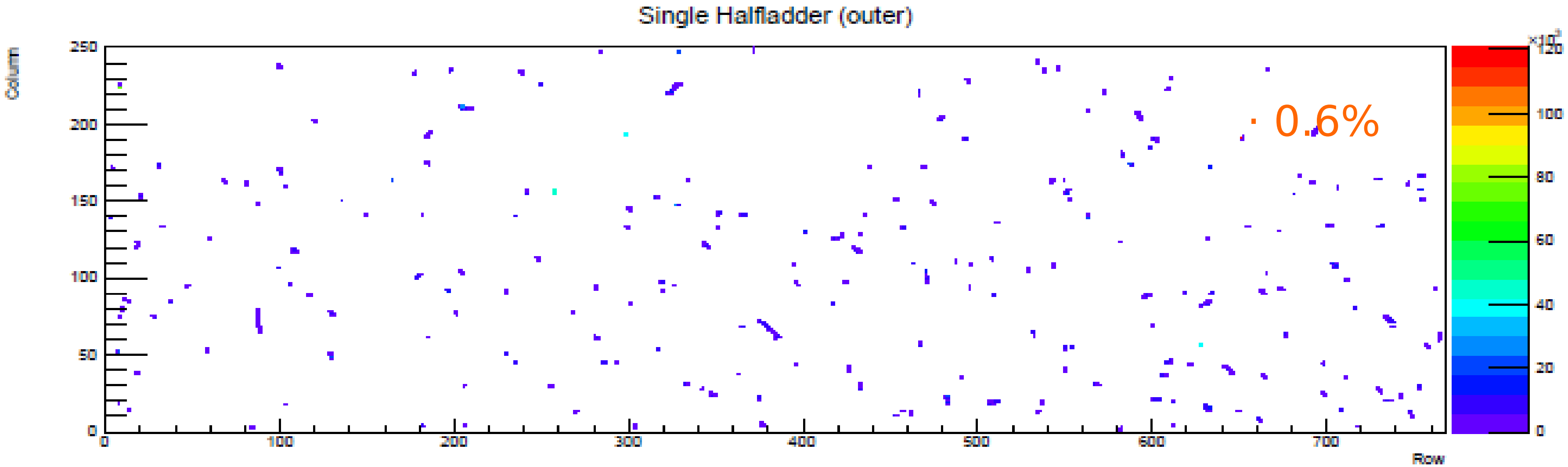
Neural Networks (NN)

Region-of-Interest (ROI) Selection
based upon track finding on High Level Trigger (HLT)



PXD clusters



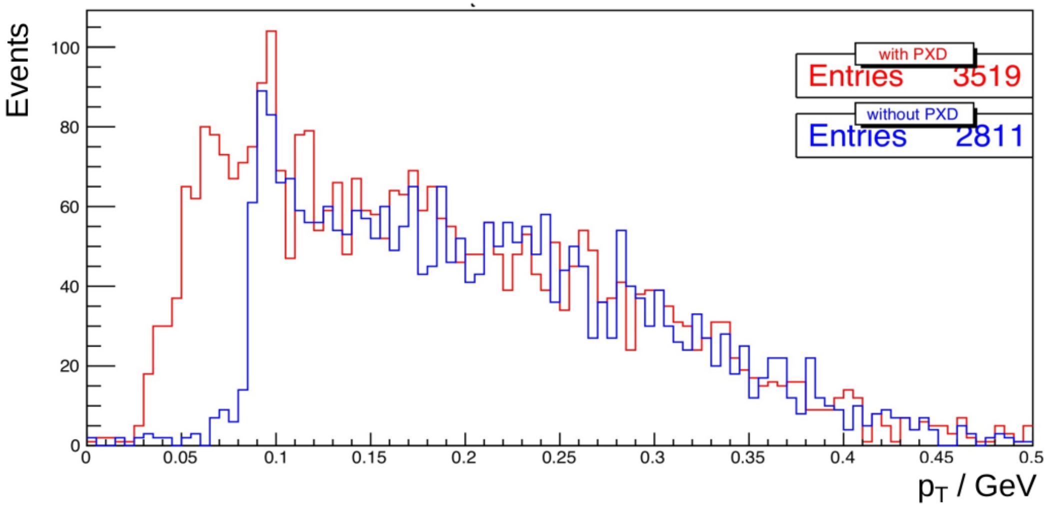


MC, Andreas Moll (MPI)

Ansatz

- Problem:
  - slow pions have high dE/dx and don't reach outer detectors (SVD, CDC)
  - no HLT track
  - no region-of-interest (ROI) in ONSEN system
  - PXD hits are deleted online (before data reach the tape)
- Giessen ML approach:
  - "cluster rescue"
  - image processing
  - 9x9 pixel images and global (x,y,z) position are input to Neural network (NN), ADC value is greyscale
- Ansatz applies to all highly ionizing particles: slow pions, antideuterons, magnetic monopoles, ...

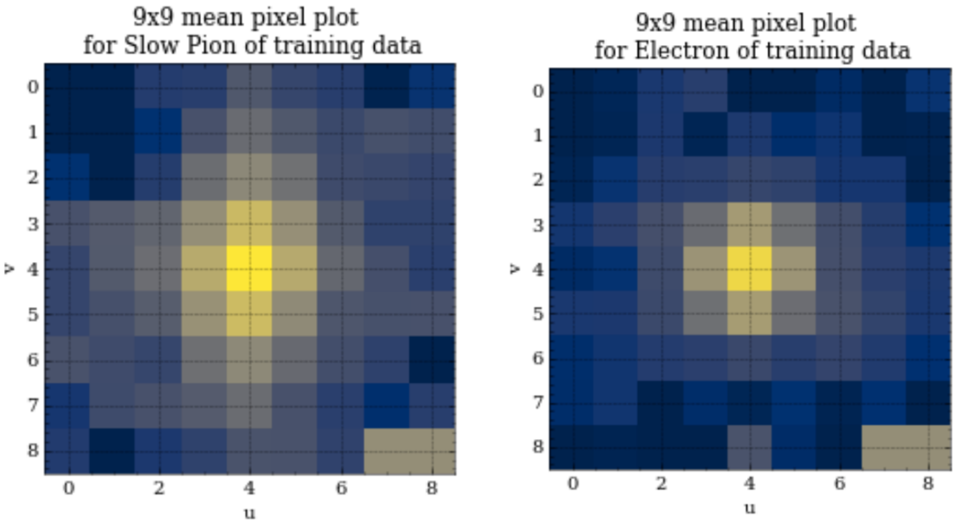
Example: slow π^- from D^{*-}
in decay of a charged Z state (exotic hadron)



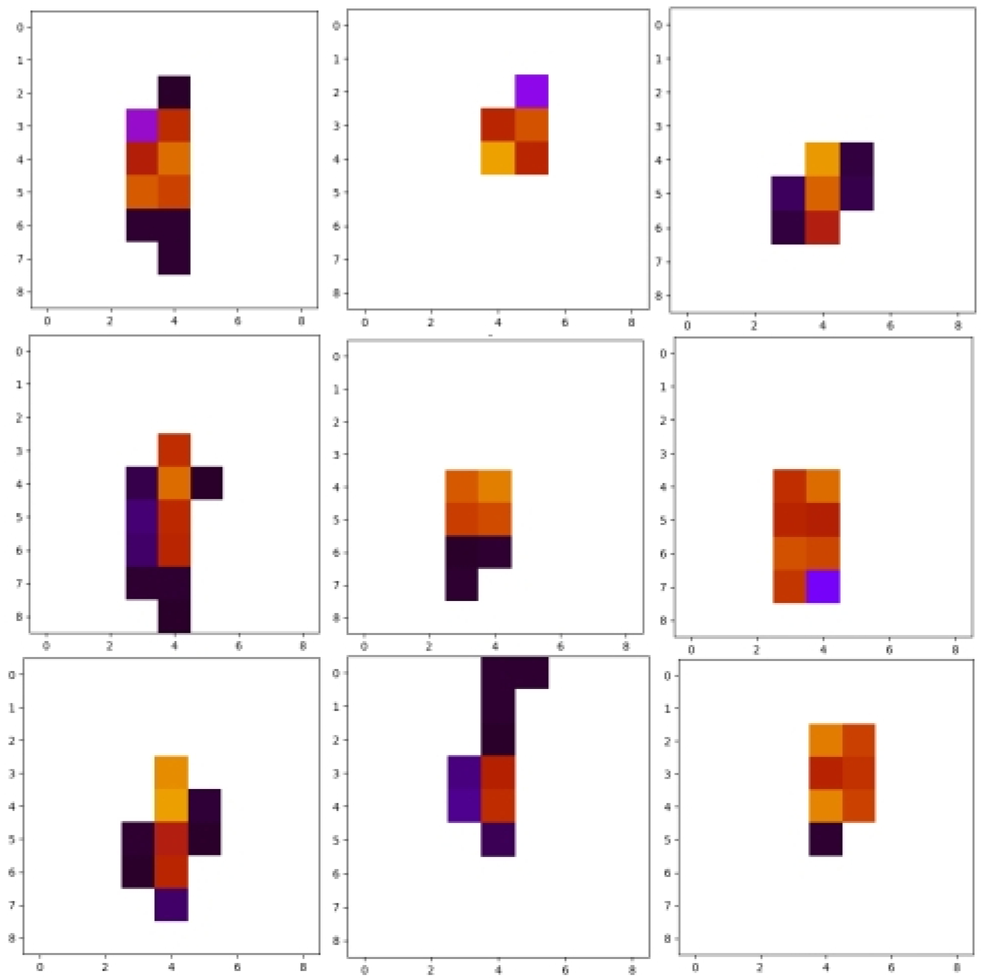
9x9 pixel matrix

Center of the matrix is the seed pixel (= pixel with max. charge)

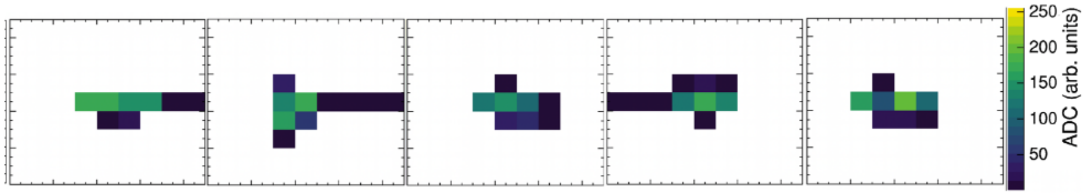
QED background



Beam background



Magnetic monopoles



Reminder: Jennifer WP5, "background rejection"
– Beam background
– QED background (electrons)

NN projects, algorithms

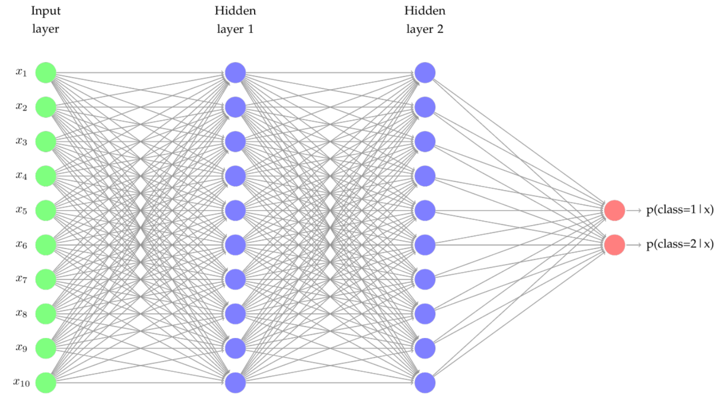
Multilayer perceptron	Katharina Dort
Self-Organizing Map	Katharina Dort, Stephanie Käs
Hopfield NN	Irina Heinz
n-dim voxels	Johannes Bilk, Johannes Budak
Decision trees	Stephanie Käs
Convolutional NN	Johannes Bilk
Support Vector Machines	Timo Schellhaas
Autoencoder	Katharina Dort
Statistical methods (PCA, LDA)	Stephanie Käs
Graph NN	Martin Beyer

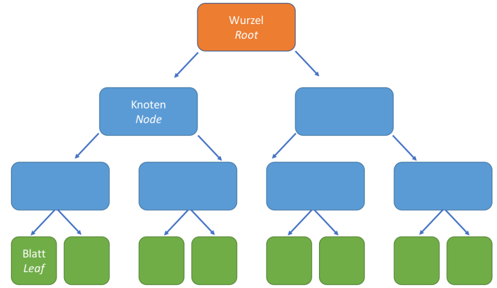
- Results: slow pions can be classified with efficiency ≥80% and purity ≥80%

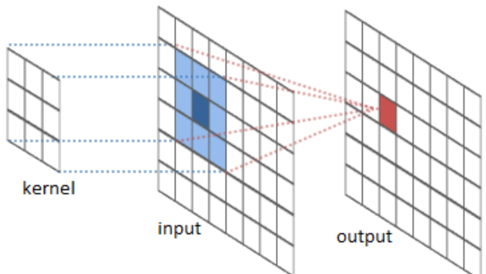
  (only based upon images of PXD clusters, no particle tracks!)
- Results published for magnetic monopoles

  Anomaly detection

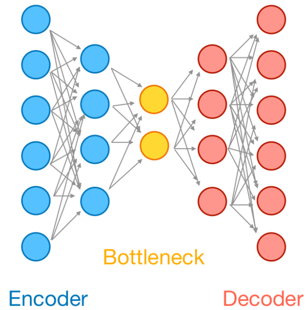
  K. Dort et al., Eur. Phys. J. C 82 (2022) 7, 587, [link]

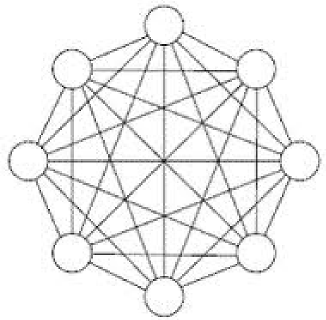


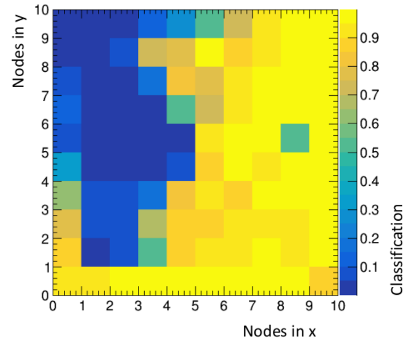




http://colah.github.io/posts/2014-07-Understanding-Convolutions/

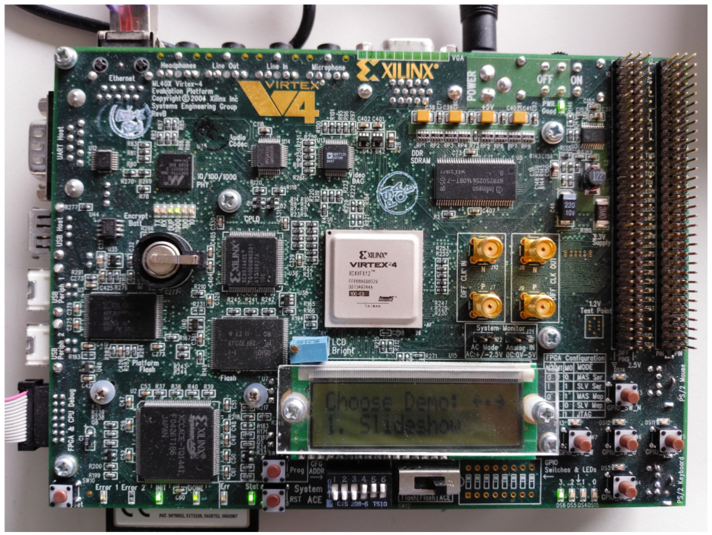






NN projects, hardware implementation

- Tests at Giessen
  - GPU (Marvin Peter, Kim Giebenhain), nVidia QUADRO GPU
  - FINN Framework (Peter Lehnhardt), Xilinx Zync FPGA
  - DSP slices on FPGA (Falk Zorn), Xilinx Virtex FPGA (test of 4x4 matrix multiplication)
- Side remark: Belle II has a Neurotrigger in operation (KIT, TUM, BMBF project)



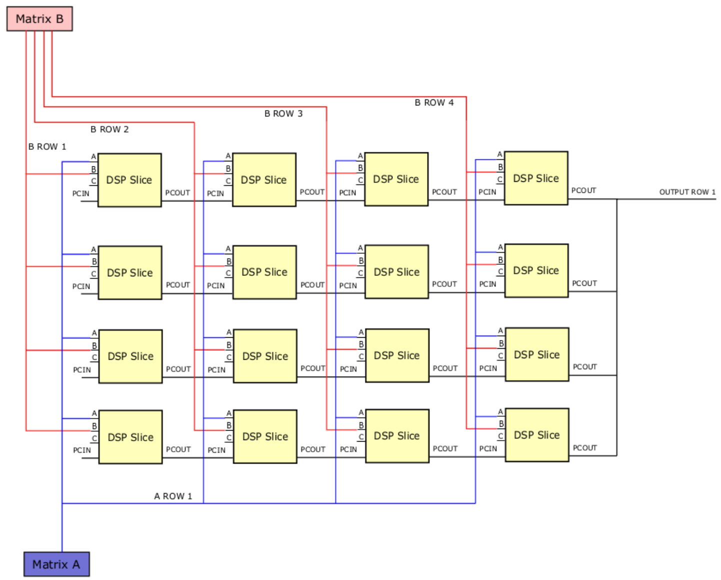


Figure 3: Schematic for DSP slice arrangement for the first calculation step.

Plan

- upcoming 5 secondments for Giessen available
- Planning for 2023 started, 1st secondment in February
- Tasks will be defined, some preparation required.

Task	Secondment sub-task	Remark
high bandwidth data transfer	new carrier board	requires extra hardware at KEK
"AI"	focus on beam background rejection	
sub-nanosecond timing	(not needed for PXD)	not discussed today
parallelisation	TODO	not discussed today

- reminder: PXD is decommissioned, work will focus on PXD2 installation
- some synergy with EURIZON project
  (next generation e+e– colliders):
  Jennifer2: DAQ with large events (0.5 MB), high bandwidth
  EURIZON: DAQ with small events, but very high trigger rates (400 kHz)

Conclusion

- New situation: several subtasks related to WP 5.2 have been worked on in the past 3 years, funded by other sources.
- Future focus will be on PXD2
- Secondments can start in spring 2023,
  sub-tasks to be adapted
- Reminder: WP has only one deliverable
  D5.2 (was due by month 36 in past timetable)
  "REAL TIME WORKSHOP"
  jointly on Belle II (PXD) and Hyper-K DAQ technologies

BACKUP