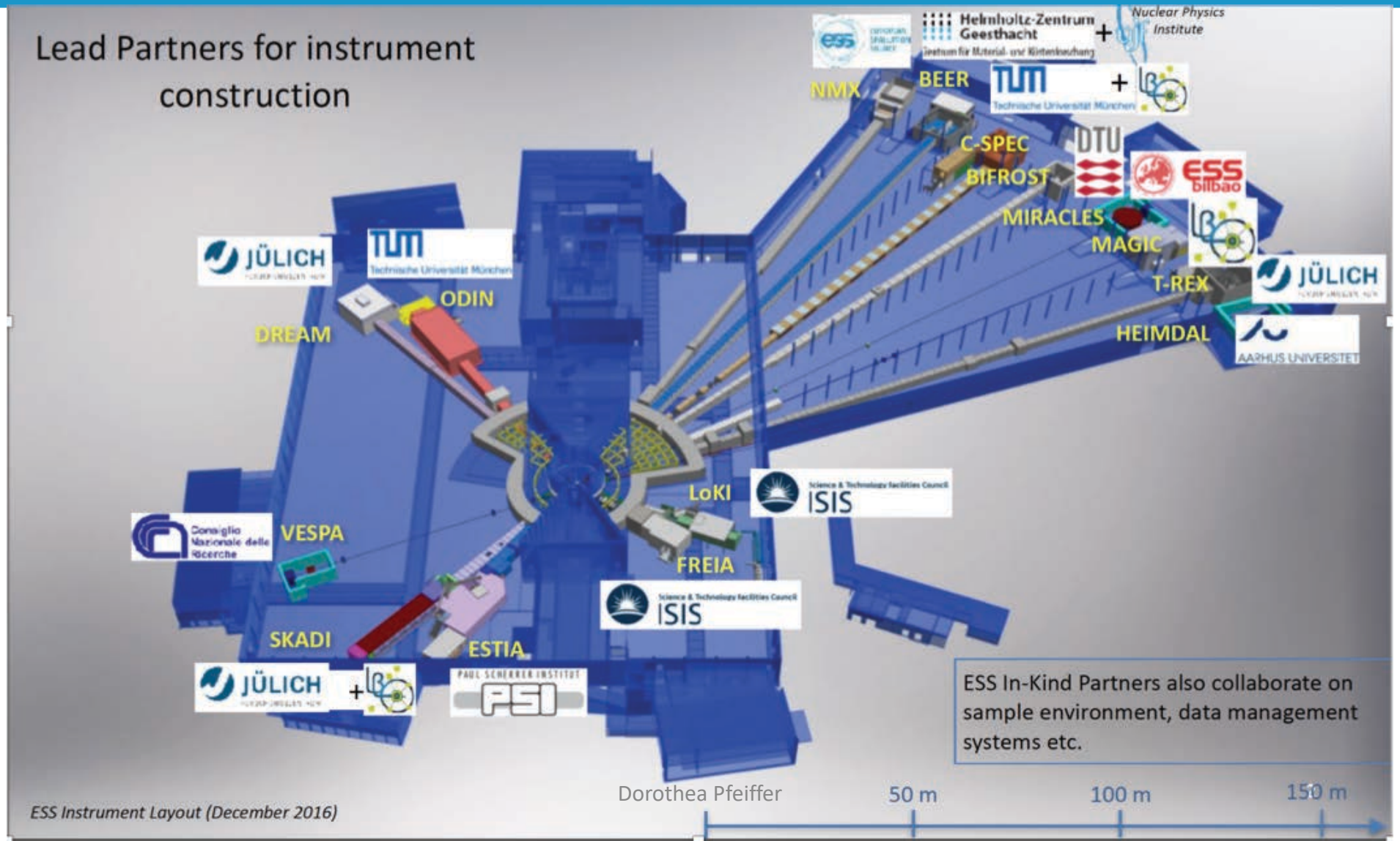
Detectors for NMX. Integration into the EFU

IKON14

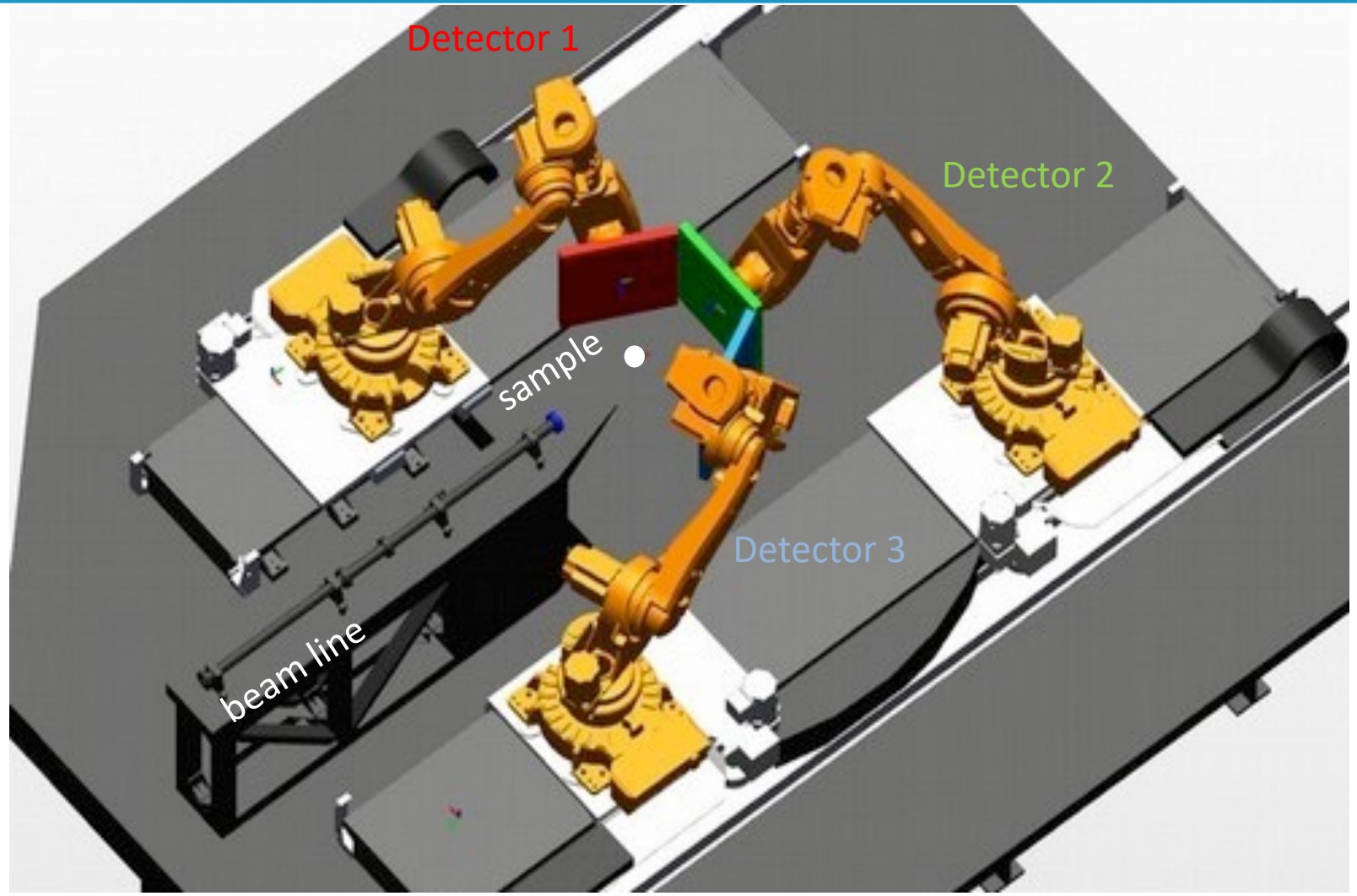
Detectors and Data Acquisition for Instruments Meeting

Dorothea Pfeiffer
Patrik Thuiner
Michael Lupberger

NMX within the ESS Instrument Suite



NMX Instrument – no fixed detector geometry



Detector Positioning System for ESS NMX, Final Design Report, J.-L. Ferrer

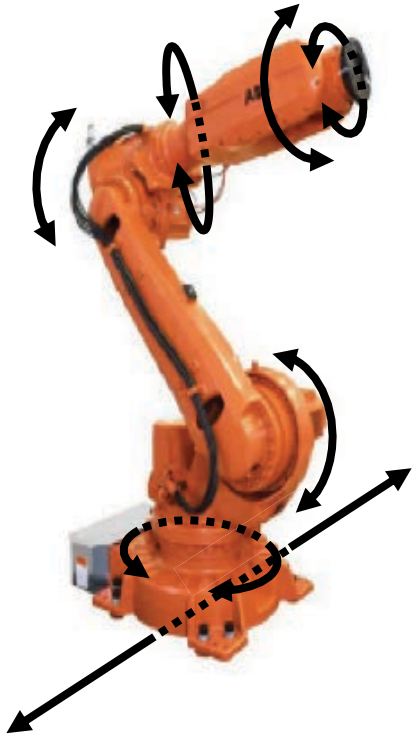
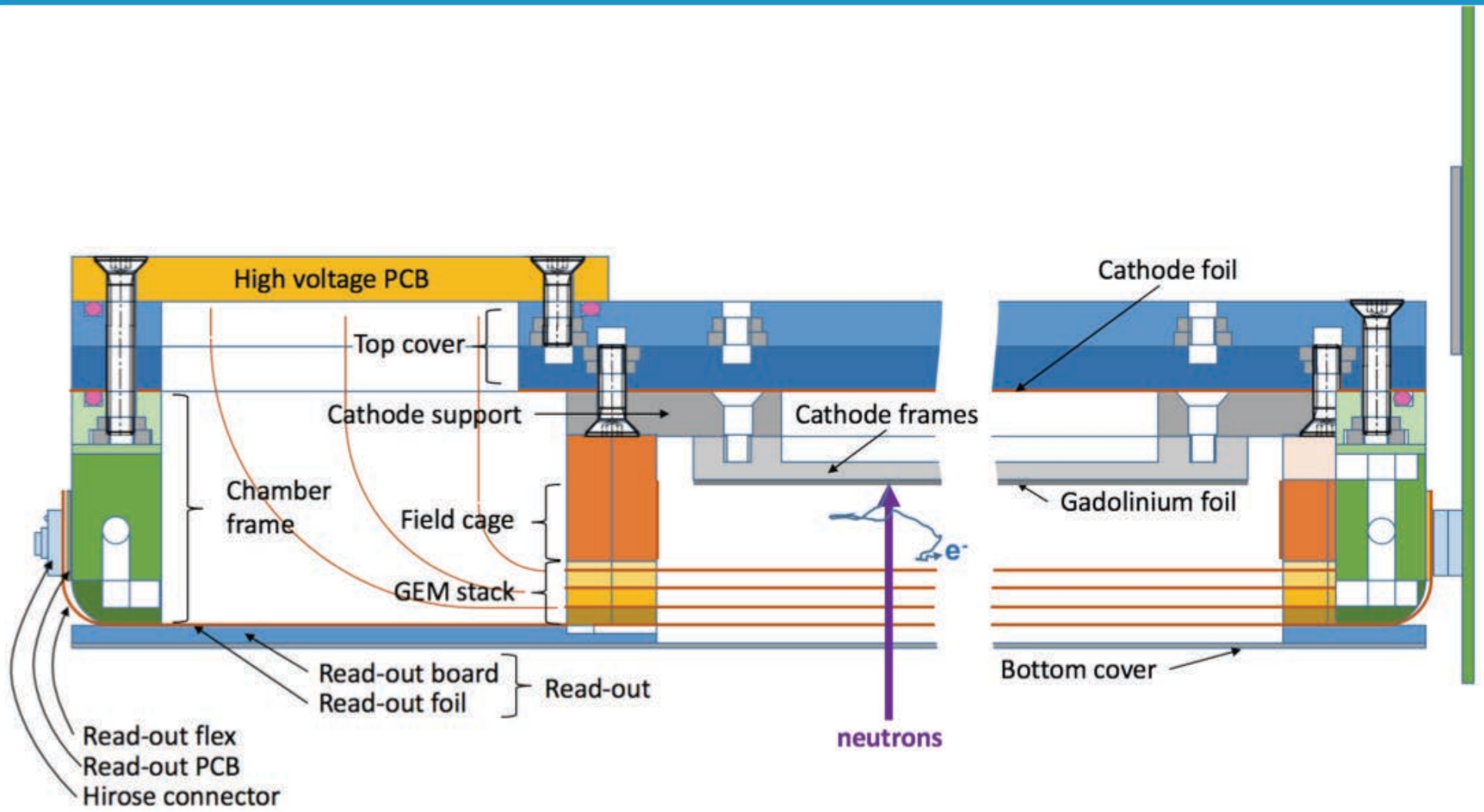


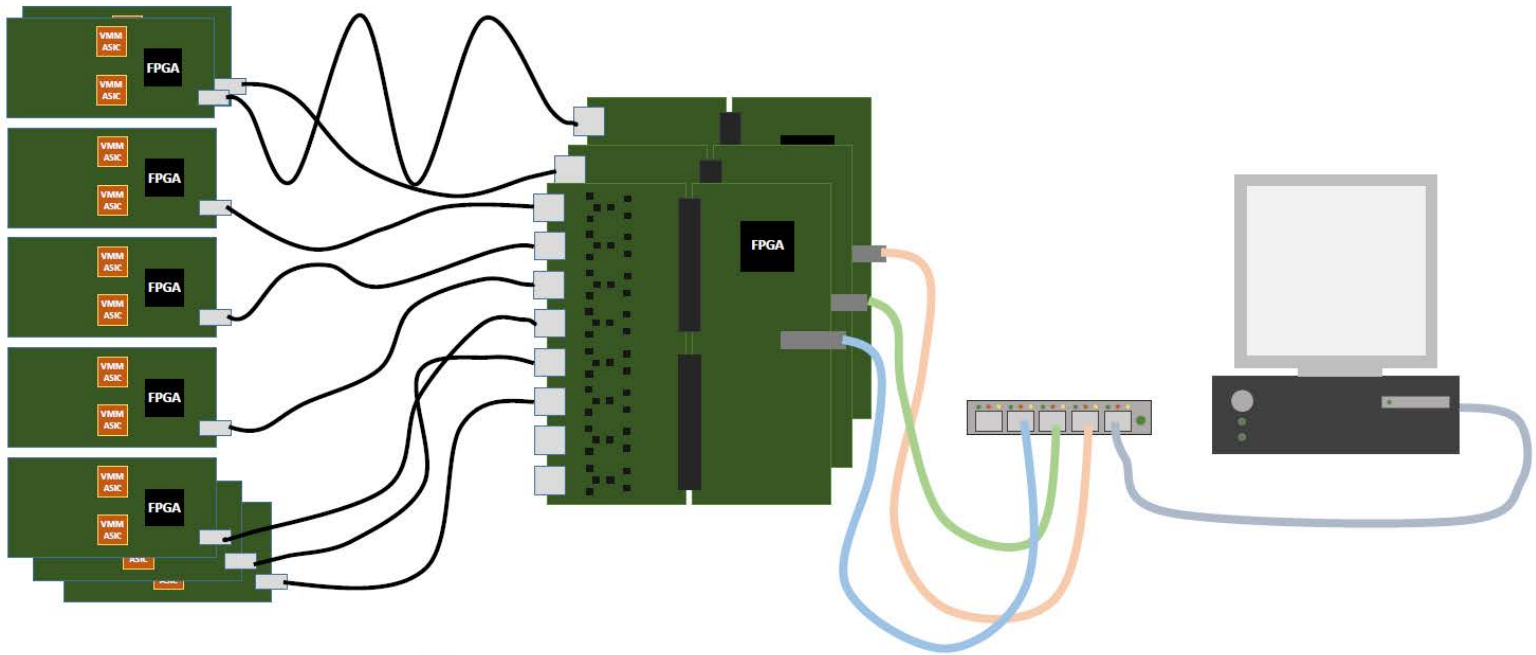
ABB IRB 6620
6 axes, 2.2 m reach
robotic arms on rails

BrightnESS NMX Detector Prototype



NMX Detector Readout (at present: VMM3+SRS)

- New hybrid and adapter card, FPGA firmware, and PC software has been designed to implement VMM in RD51 Scalable Readout System (SRS)
- Scalability: up to 8 VMM hybrids/FEC, many FECs/PC
- For NMX: 3 detectors with 40 VMM3 hybrids



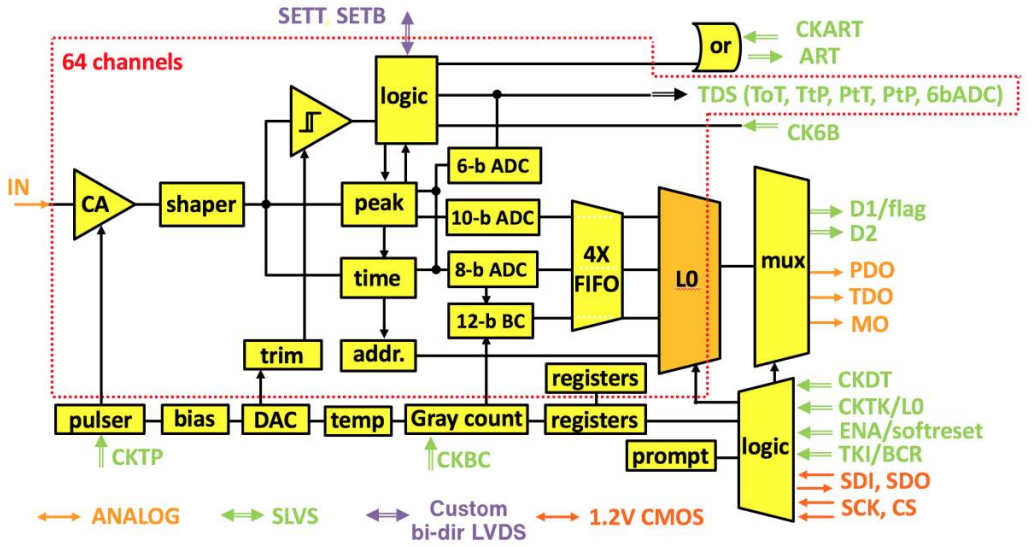
VMM Hybrid → HDMI cable → Adapter card + FEC → Ethernet → Switch →Ethernet → PC

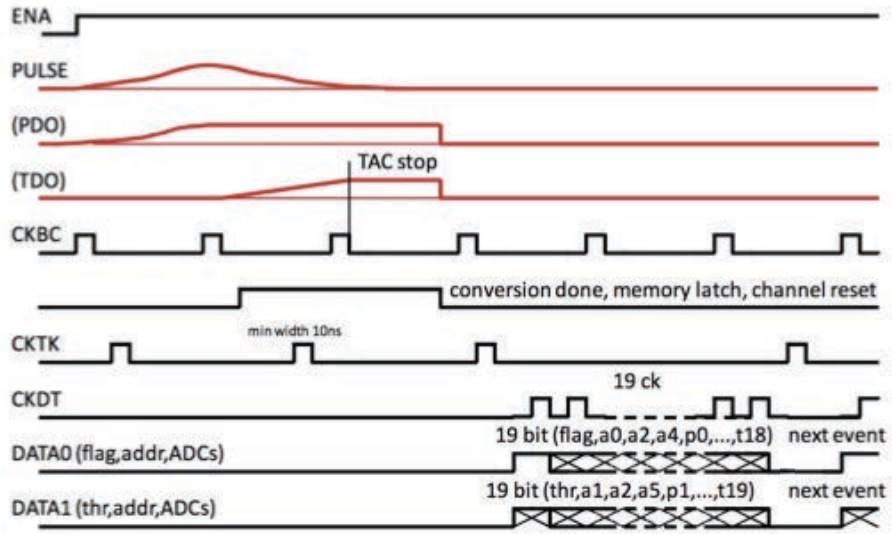
VMM hybrid

SRS FEC and adapter card for VMMs

VMM3 Specification

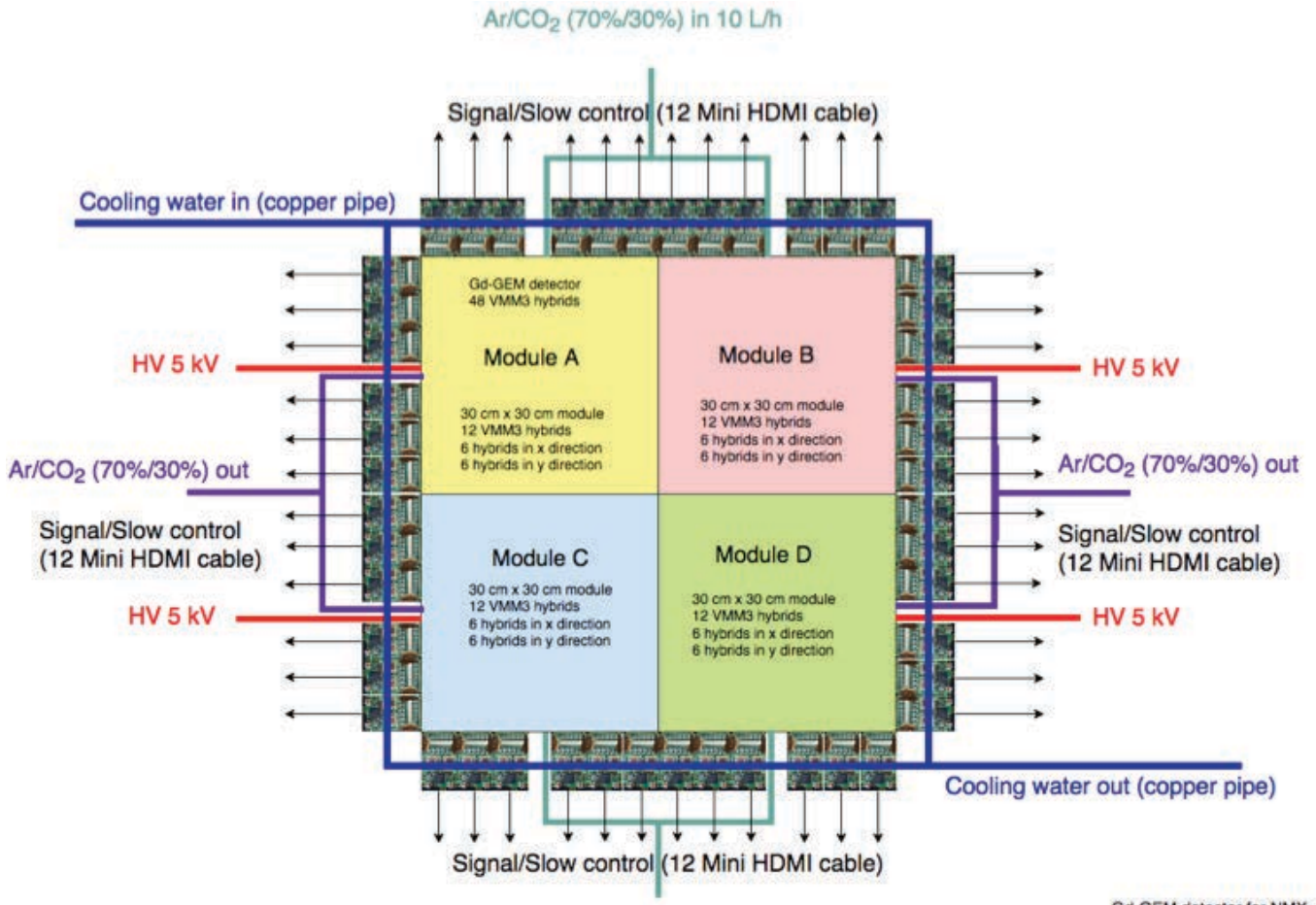
- 64 input channels, self triggered
- Pos. & neg. polarity sensitive
- Adjustable gain 0.5 – 16 mV/fC
- Adjustable shaping time from 25 ns – 200 ns
- Input capacitance from few pF – 1 nF
- **38 bit per hit (if input charge goes over threshold)**
  1. **Event flag (1 bit)**
  2. **Over threshold flag (1 bit)**
  3. **Channel number (6 bit)**
  4. **Signal amplitude (10 bit)**
  5. **Arrival time (20 bit)**





NMX – Logical geometry of detector

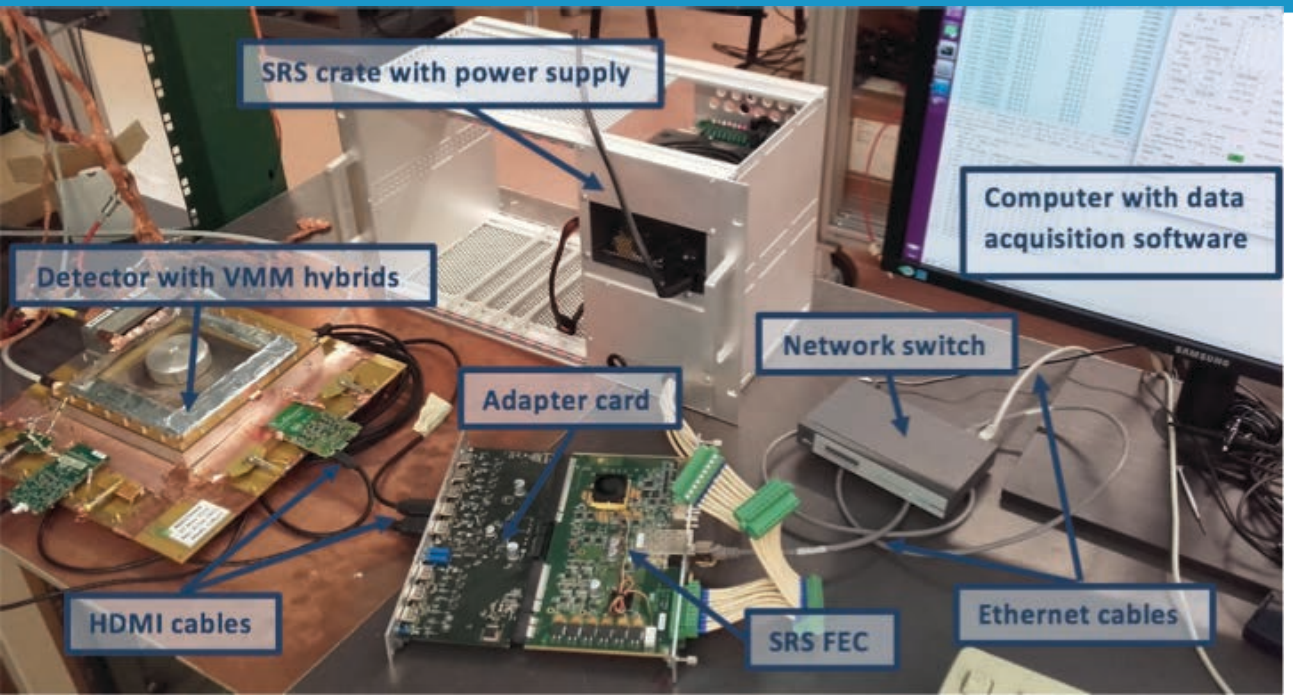
- Readout partitioned into 4 quarters to reduce capacitance and multiplicity of hits
- 5 VMM3 hybrids in x and y each per module
- 40 VMM3 in total
- One VMM3 covers 5.12 cm of readout
- VMM3 chip-ID matched to physical position



Schematic drawing (Old design):

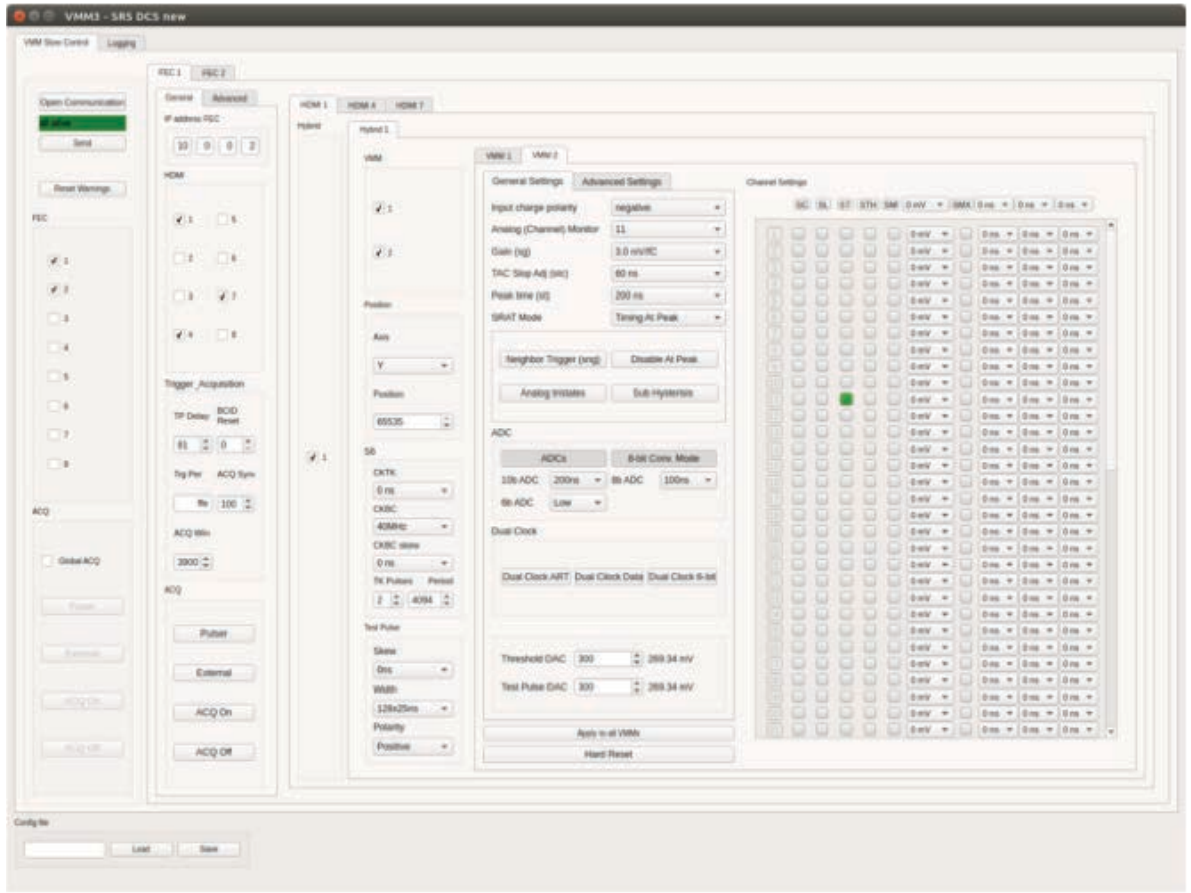
- Now 5 VMM3 instead of 6 per coordinate per module
- Passive cooling instead of water cooling

Detector Readout (at present VMM3+SRS)



Readout chain

VMM3 Slow control



CERN Summer student project of Manuel Guth

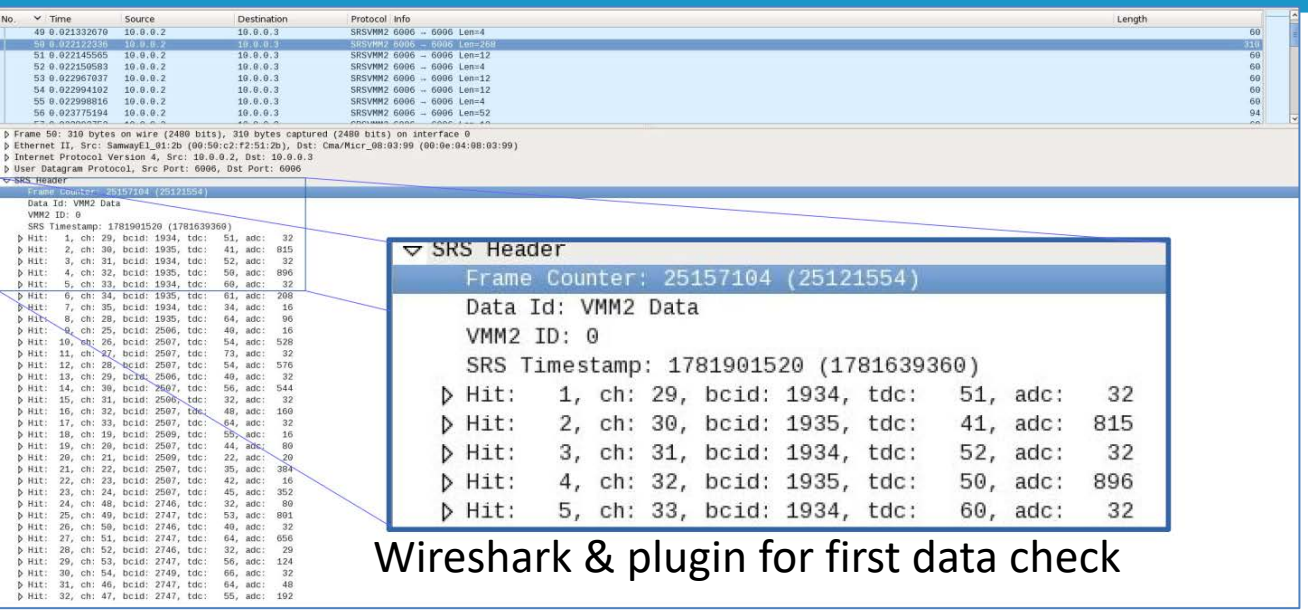
How we read the detector data before the DMSC..

- Once upon a time, before the DMSC got involved, data taking was tedious
- Data was taken in binary format by a CERN DAQ software, that is very well adapted to the needs at LHC, but not for us
- For each quick check, the binary data file had to be first analyzed, then the analyzed data plotted
- No sanity checks
- No online monitoring
- No clustering

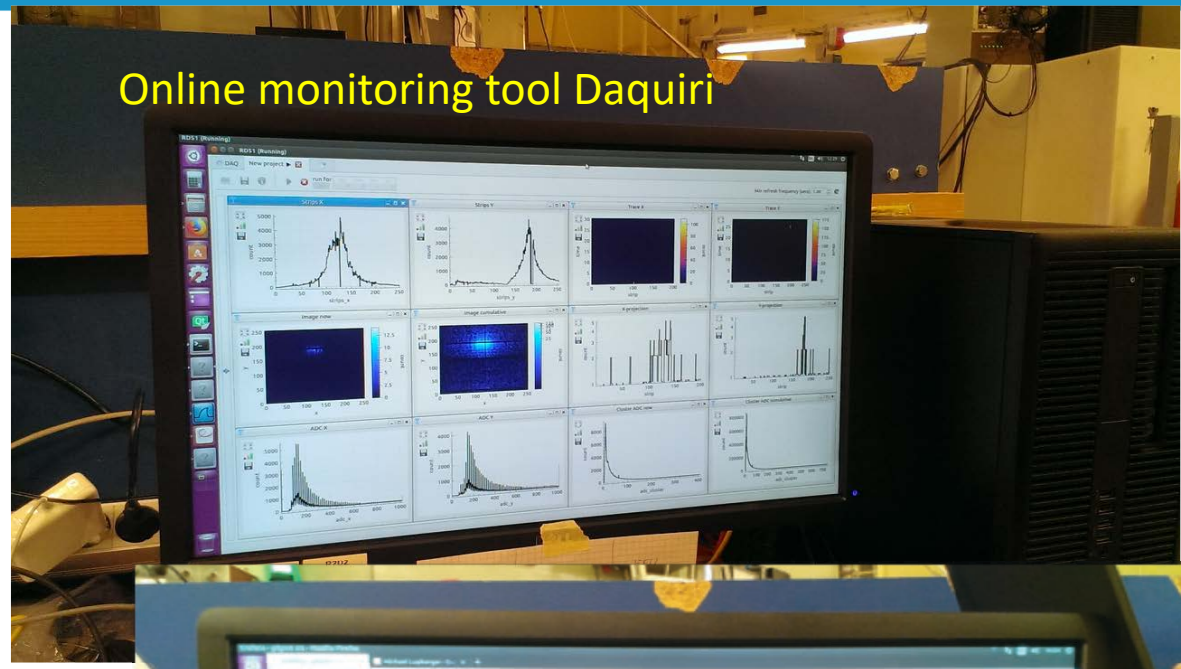
And then the DMSC got involved..

- Collaboration with DMSC and ITU in the framework of BrightnESS work package 5.1
- Morten and Martin (DMSC) work closely together with Michael and me (CERN, ESS DG)
- Key: Understand which type of data NMX produces, how it can be read out, analyzed, clustered and finally the pixel ID calculated

DMSC tools, that help to understand the data

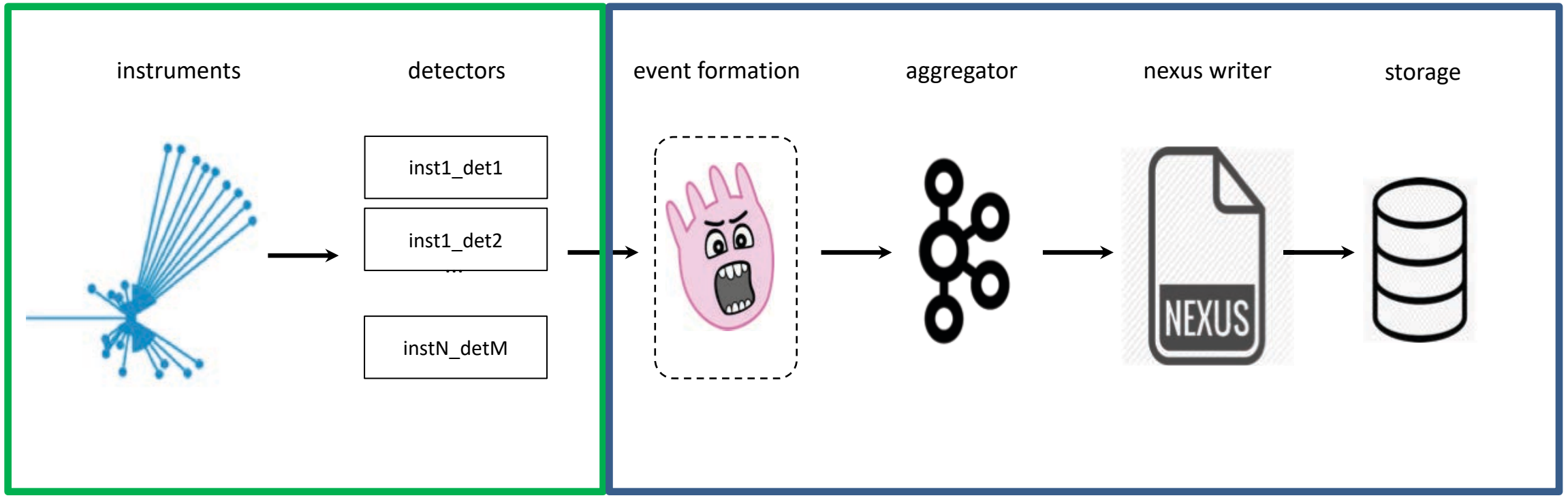


Wireshark & plugin for first data check



- Compared to the productive system, during detector R&D and commissioning, more and different tools are needed
- Tools shown here developed/implemented by DMSC as helper tools during the work on EFU

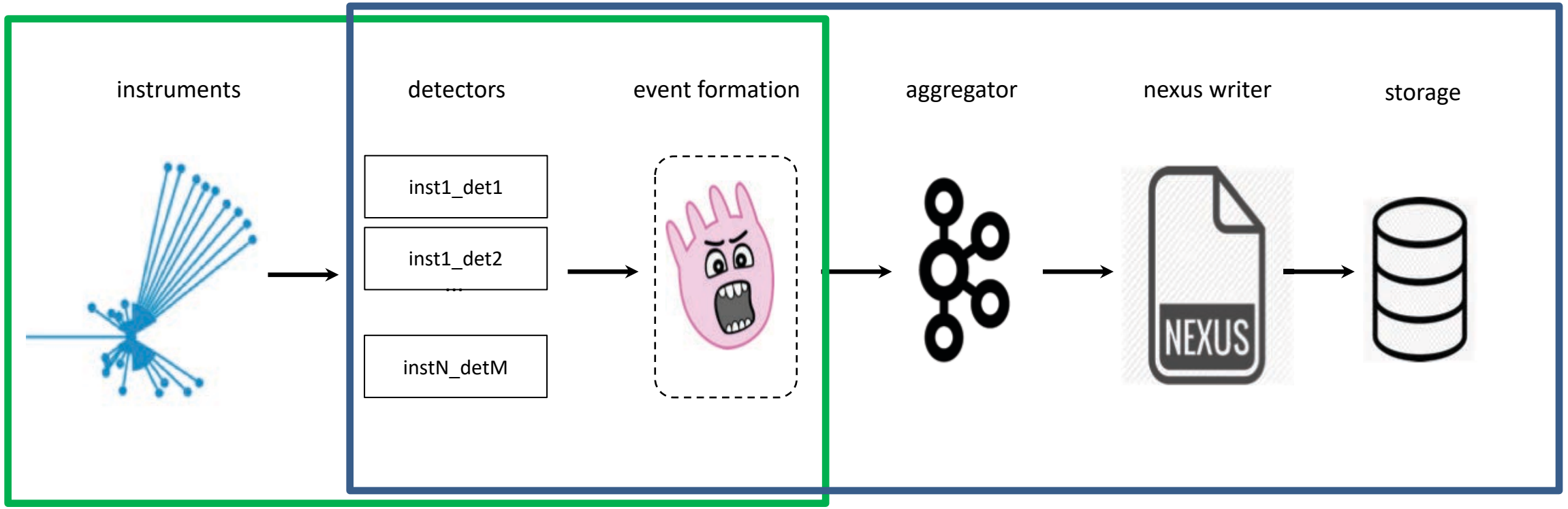
Two worlds apart?



Instrument Scientist
and Detector Scientist

DMSC

Closely connected:
Detectors and Event Formation



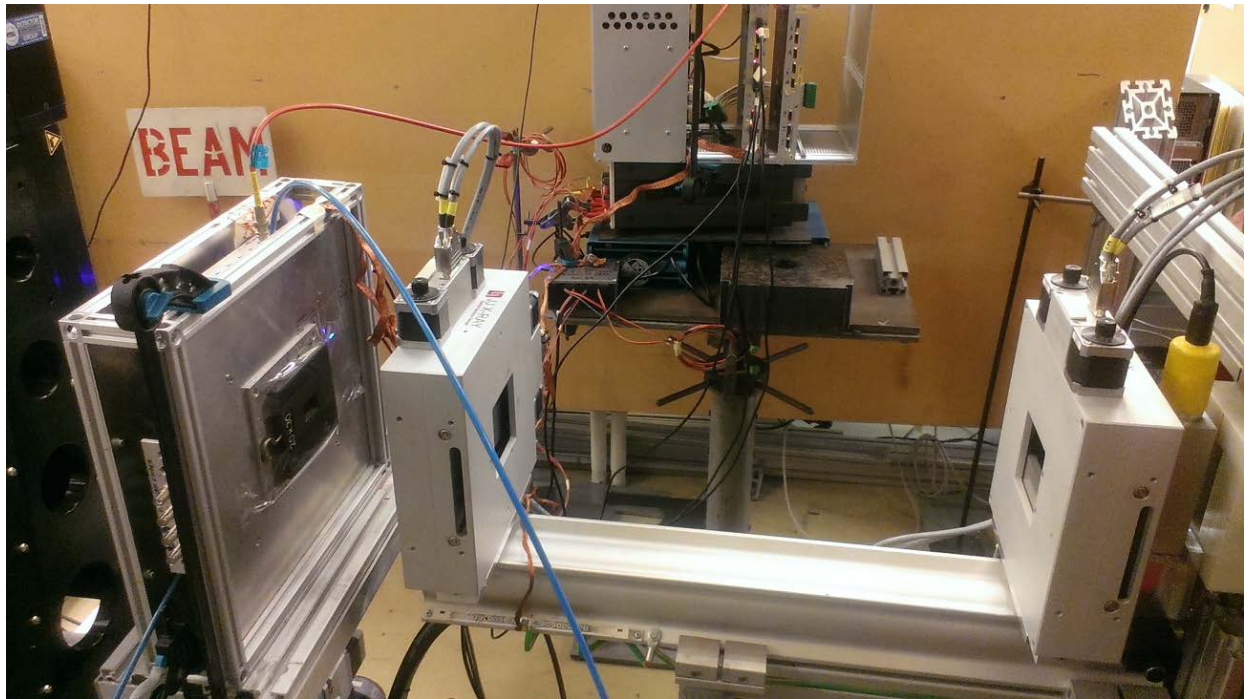
Instrument Scientist
and Detector Scientist

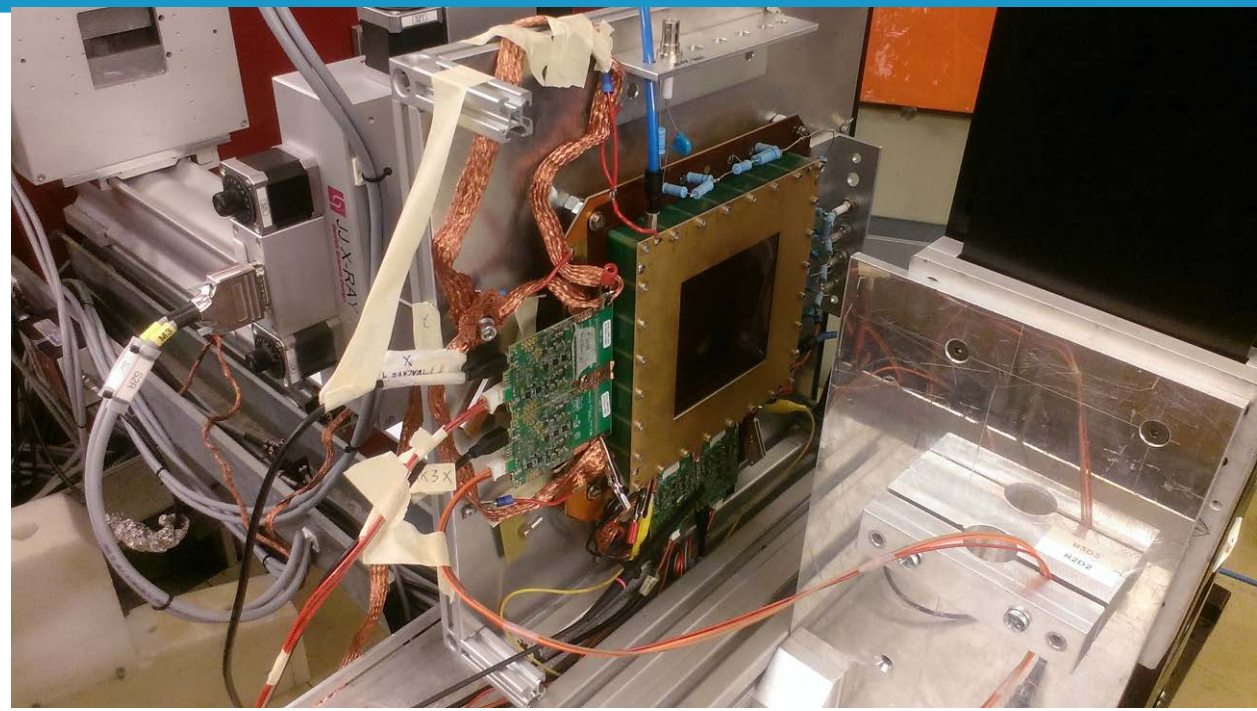
DMSC

Communication between groups crucial for implementation of detector plugin for EFU !

Common ESS DG and DMSC Testbeam at IFE in Kjeller/Norway (December 2017)

- Standard Triple-GEM detector with 10 mm drift
- Gd cathode with copper tape
- 4 VMM3 readout with SRS
- Neutron beam of 1.54 – 2.4 A



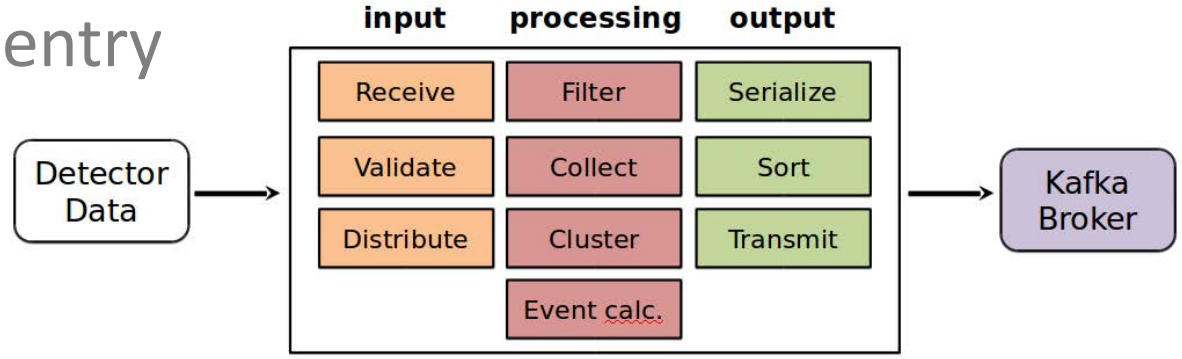


- Large progress being made while running the whole chain from detector over the readout to the EFU

NMX Event Building in EFU

Per one detected neutron (efficiency 15%-30% at 1.8 A depending on Gd isotope) on the detector

- On average 20 strips/channels hit (in x and y)
- Per hit: VMM3 gives channel, pulse height and time
- 1. Reconstruct event data, based on SRS timestamp and BC
- 2. Cluster separately each dimension (x,y) per event
- 3. Match clusters in x and y based on time and charge
- 4. Determine pixel-id from x and y entry positions and time



Event formation unit

Workflow of EFU Integration

- Detector and electronics R&D done by ESS DG group
- To study behaviour of detecor and readout chips, analysis software is written (Mercurial repository dg_epool)
- The core functionalities of this analysis software are implemented within the EFU as detector plugin (https://github.com/ess-dmsc/event-formation-unit/tree/master/prototype2/gdgem/dg_impl)
- DMSC team helps and advises, implements unit tests and benchmarks
- Common effort to find the most efficient algorithms
- Parallelization foreseen

Example of benchmark and unit test

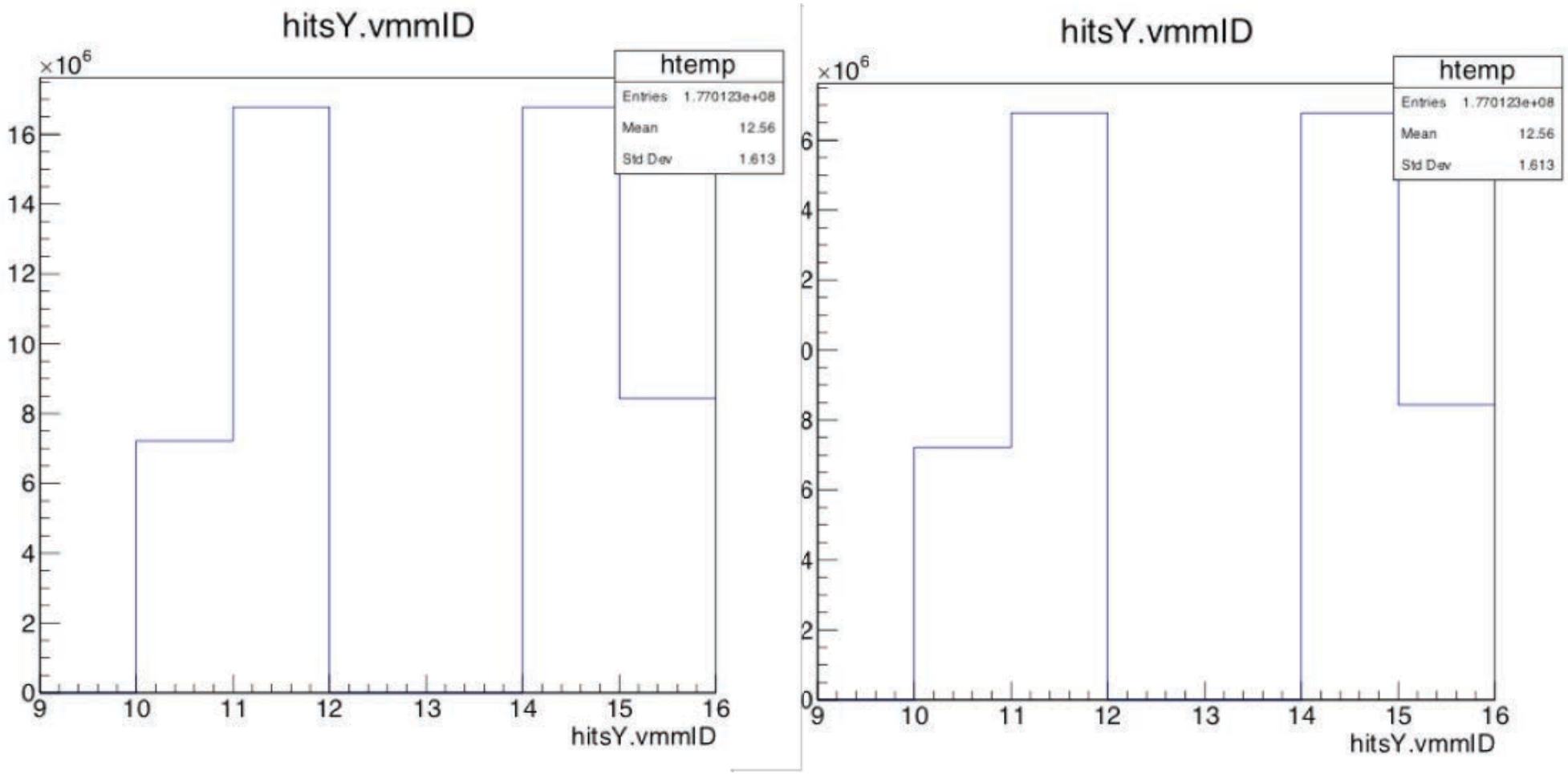
```
daq@essenixsrs6:~/essproj/event-formation-unit/build/unit_tests$ ./NMXClustererTest
[==========] Running 1 test from 1 test case.
[----------] Global test environment set-up.
[----------] 1 test from NMXClustererTest
[ RUN      ] NMXClustererTest.Run16_line_110168_110323
[       OK ] NMXClustererTest.Run16_line_110168_110323 (0 ms)
[----------] 1 test from NMXClustererTest (0 ms total)

[----------] Global test environment tear-down
[==========] 1 test from 1 test case ran. (0 ms total)
[  PASSED  ] 1 test.
daq@essenixsrs6:~/essproj/event-formation-unit/build/unit_tests$
```

With a speed of 16 M/hits per second, the clustering is not the bottleneck, but the file I/O slows things down.

```
daq@essenixsrs6:~/essproj/event-formation-unit/build/benchmarks$ ./NMXClustererBenchmarkTest
2018-02-12 04:04:26
Run on (4 X 3600 MHz CPU s)
CPU Caches:
  L1 Data 32K (x4)
  L1 Instruction 32K (x4)
  L2 Unified 256K (x4)
  L3 Unified 6144K (x1)
***WARNING*** CPU scaling is enabled, the benchmark real time measurements may be noisy and will incur extra overhead.
------------------------------------------------
Benchmark              Time           CPU Iterations
------------------------------------------------
Doit                8828 ns       8828 ns      76834   16.8518M items/s
daq@essenixsrs6:~/essproj/event-formation-unit/build/benchmarks$
```

Run 25: No data loss at high neutron rates (December 2017)

Same amount of hits
per hybrid
(beam in detector center)

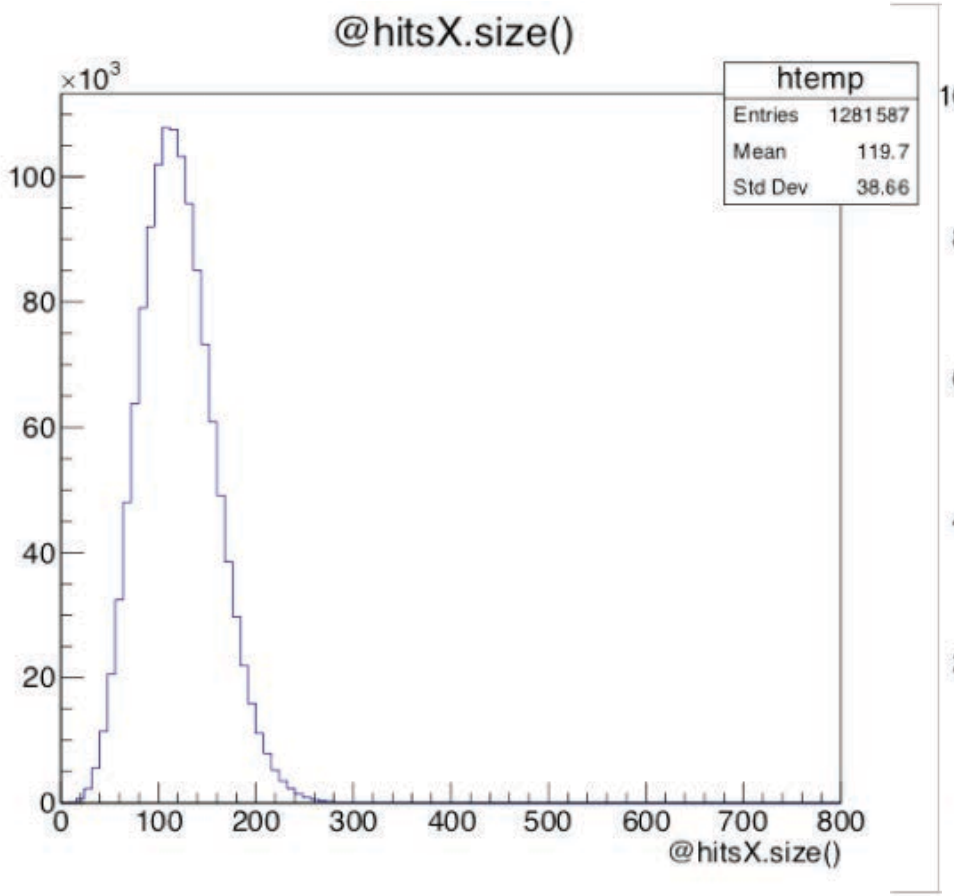


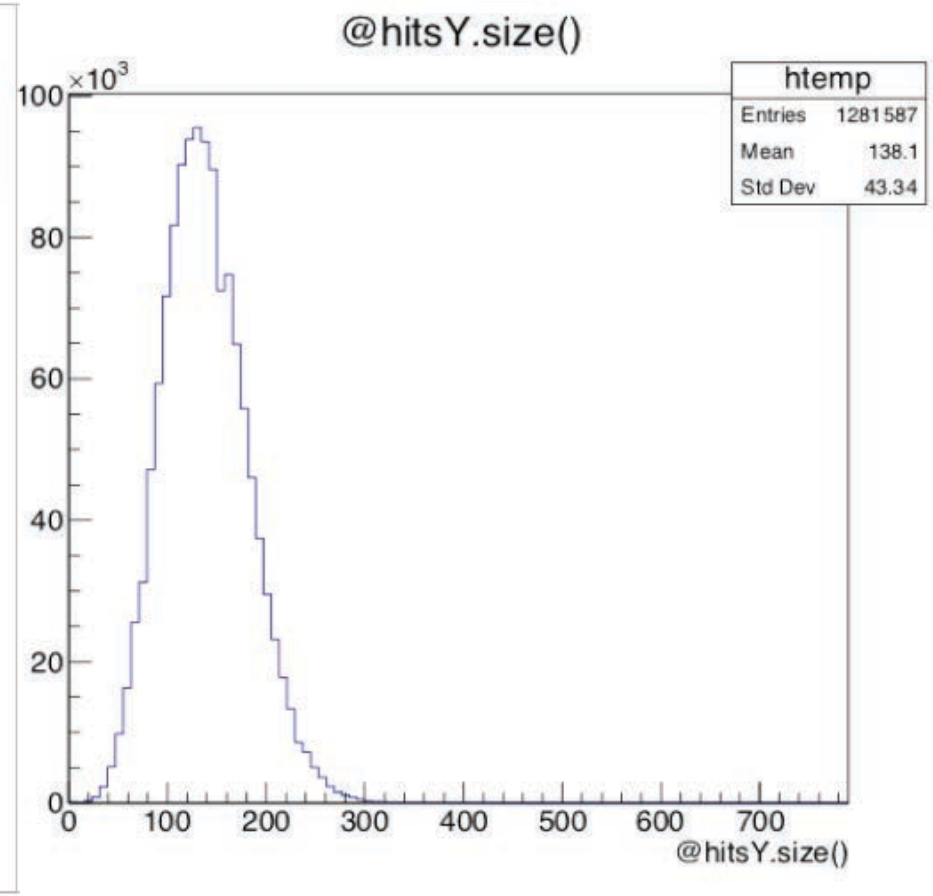
Data written to disk!

Run25, neutrons, BC clock 20 MHz, TAC slope 60 ns, acquisition window 4000

Run 25: No data loss at high neutron rates (December 2017)

- Same amount of hit per dimension
- About 260 hits per SRS trigger of 5 khz
- Rate of 1.3 Mhits/s or 83 Mbit/s written to disk



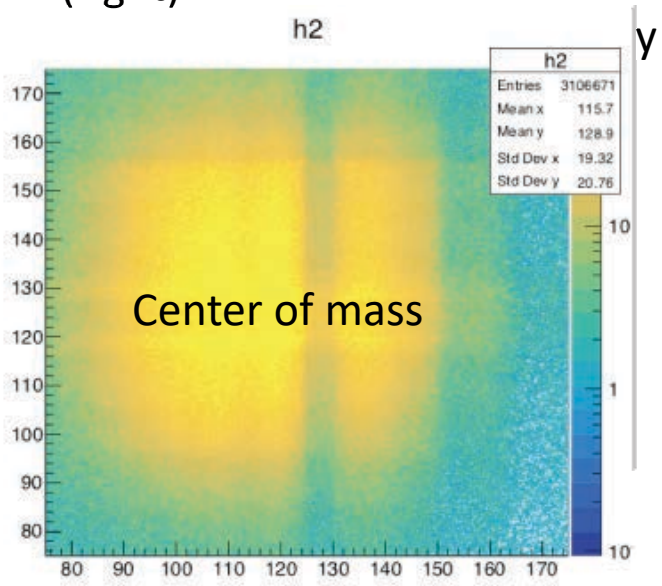


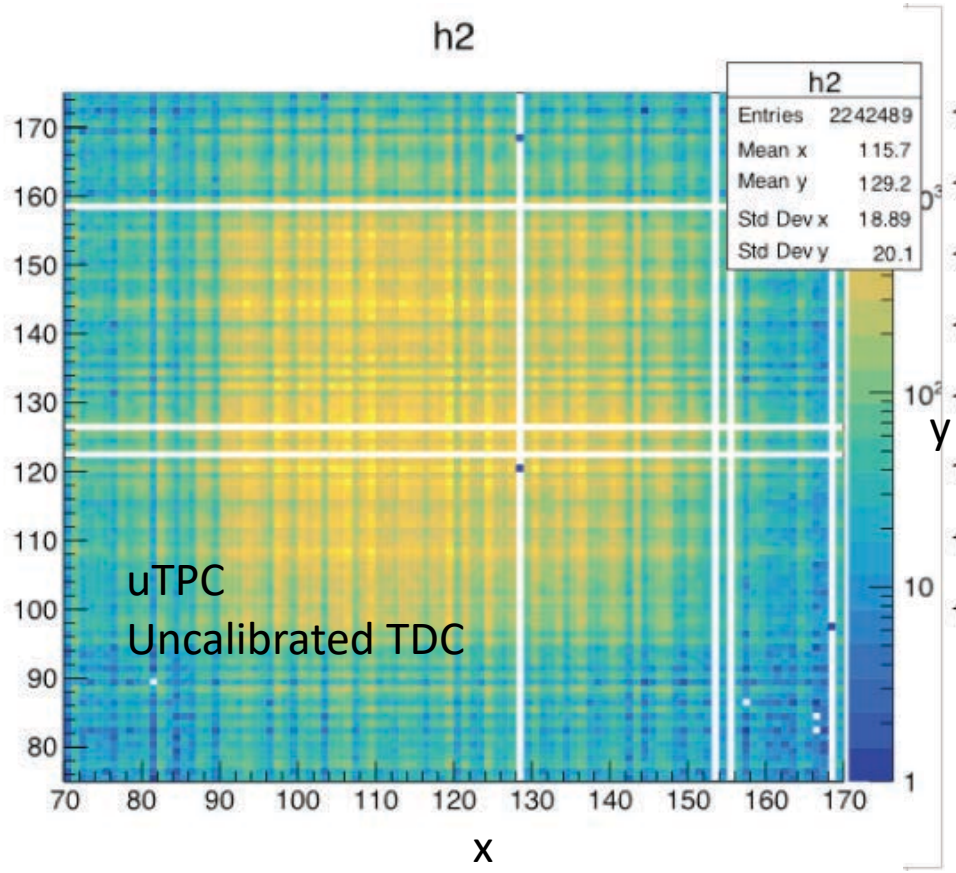
Data written to disk!

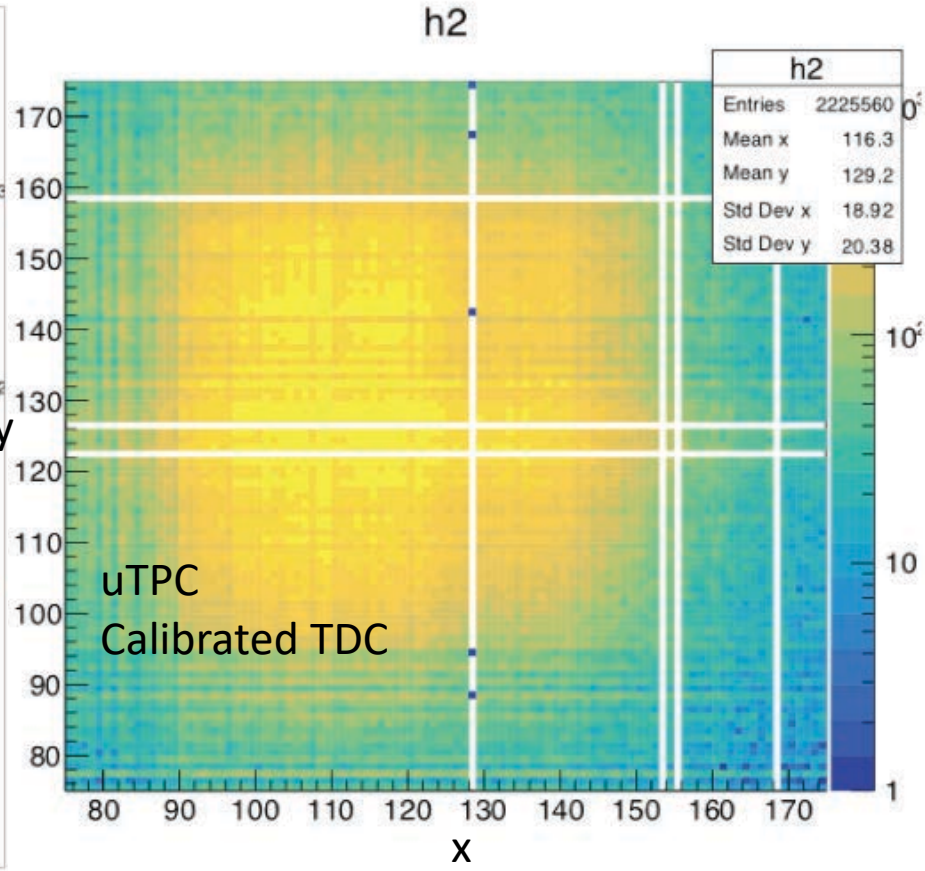
Run25, neutrons, BC clock 20 MHz, TAC slope 60 ns, acquisition window 4000

Run 25: Reconstruction of beam image (December 2017)

- Clustering with uTPC method difficult due to non-calibrated TDC (left)
- Clustering improved after test pulse calibration of the TDC (right)







Run25, neutrons, BC clock 20 MHz, TAC slope 60 ns, acquisition window 4000

Conclusion and Outlook

- The collaboration with the DMSC is very successful
- The whole readout chain from detector over the readout to the DAQ is operational
- The EFU contains a working clustering algorithm
- Code will be adapted to the features of the new VMM3a
- Bottlenecks in the readout chain will be studied
- Code in detector plugin code in EFU will be parallelized to improve performance