

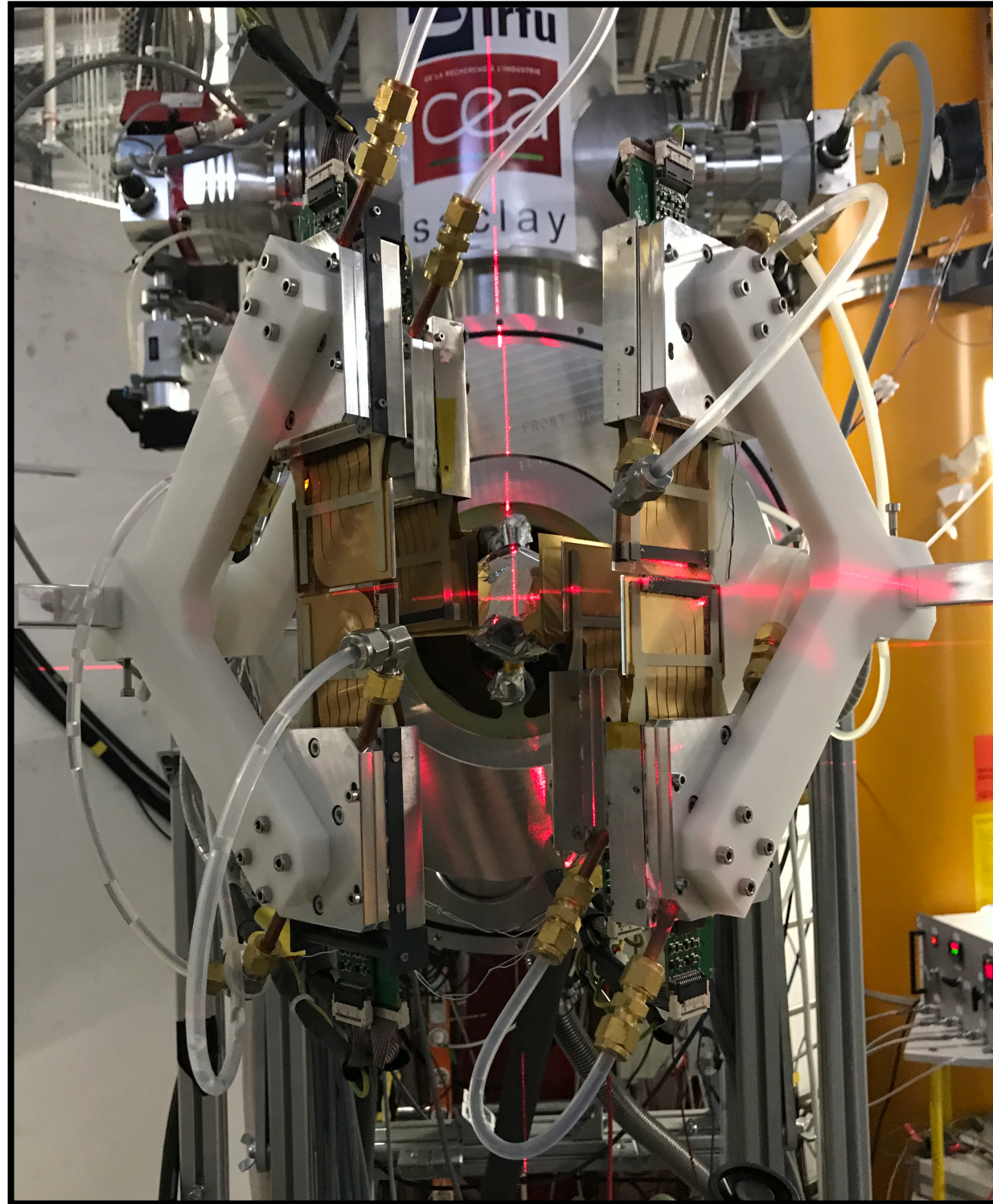
**Development of FOOT detectors:
from Jülich test to the experiments at GSI**

Valerii Panin

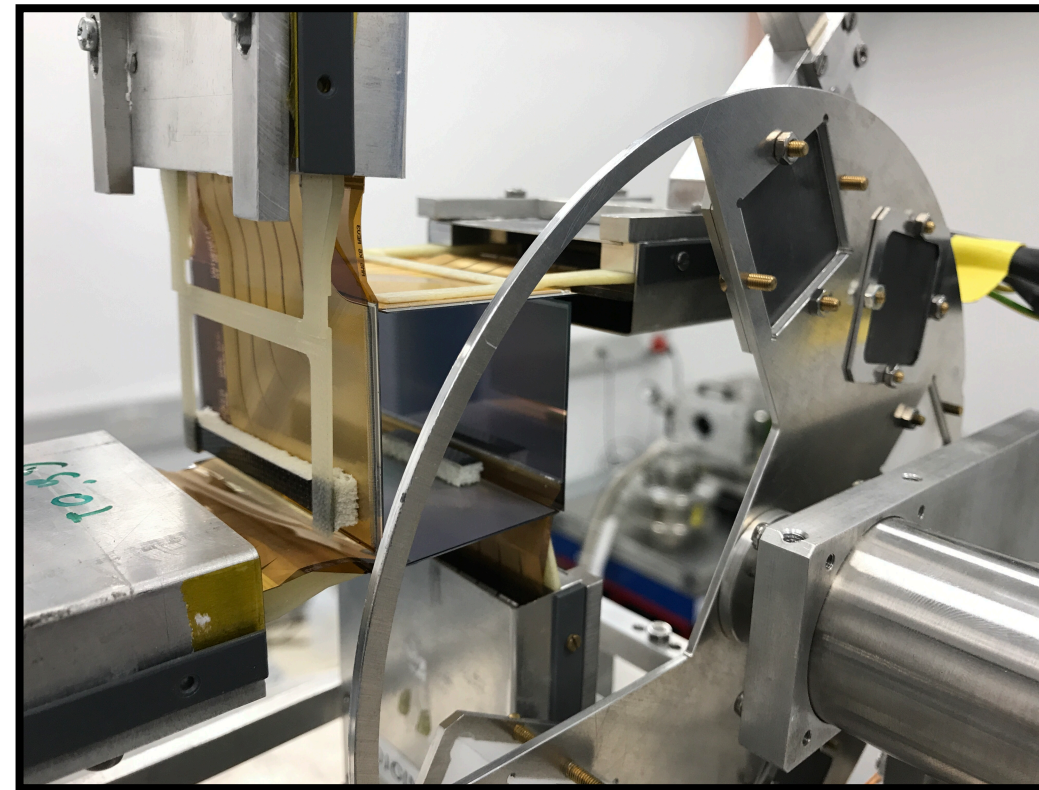
R3B Collaboration Meeting, 7-9 June 2022

Target recoil tracker arrays for R3B experiments

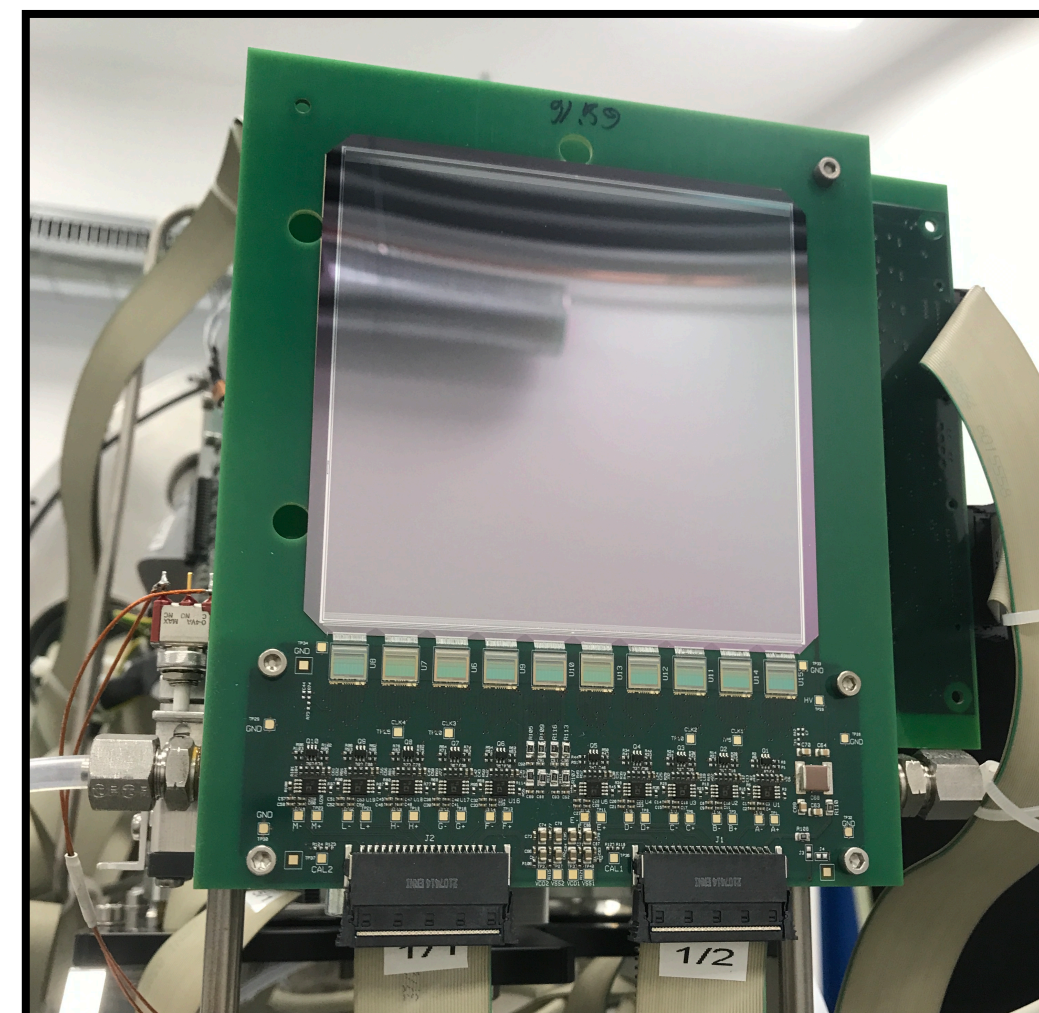
AMS two-arm configuration (s455)



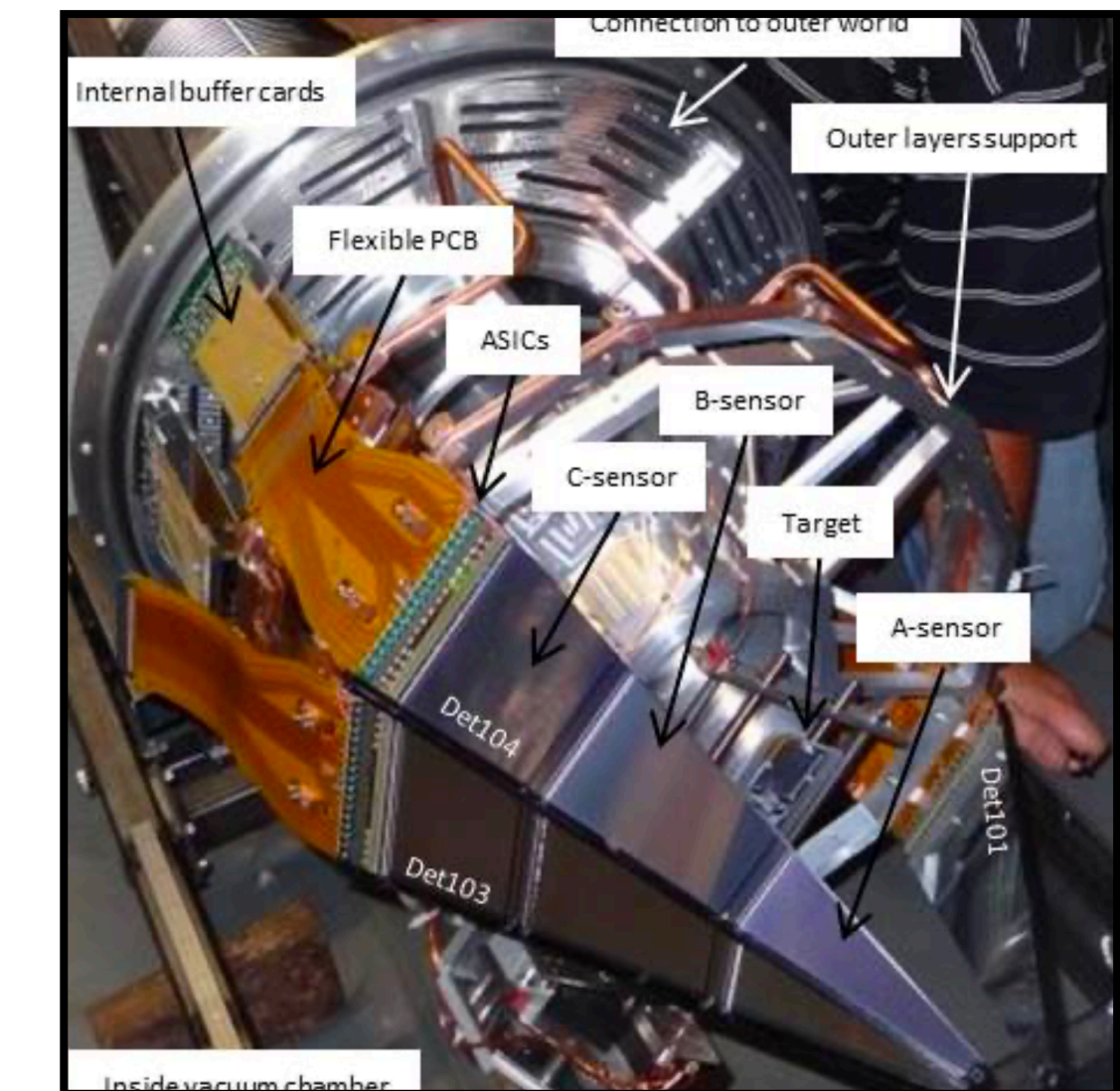
AMS box configuration
(s515 and older experiments)



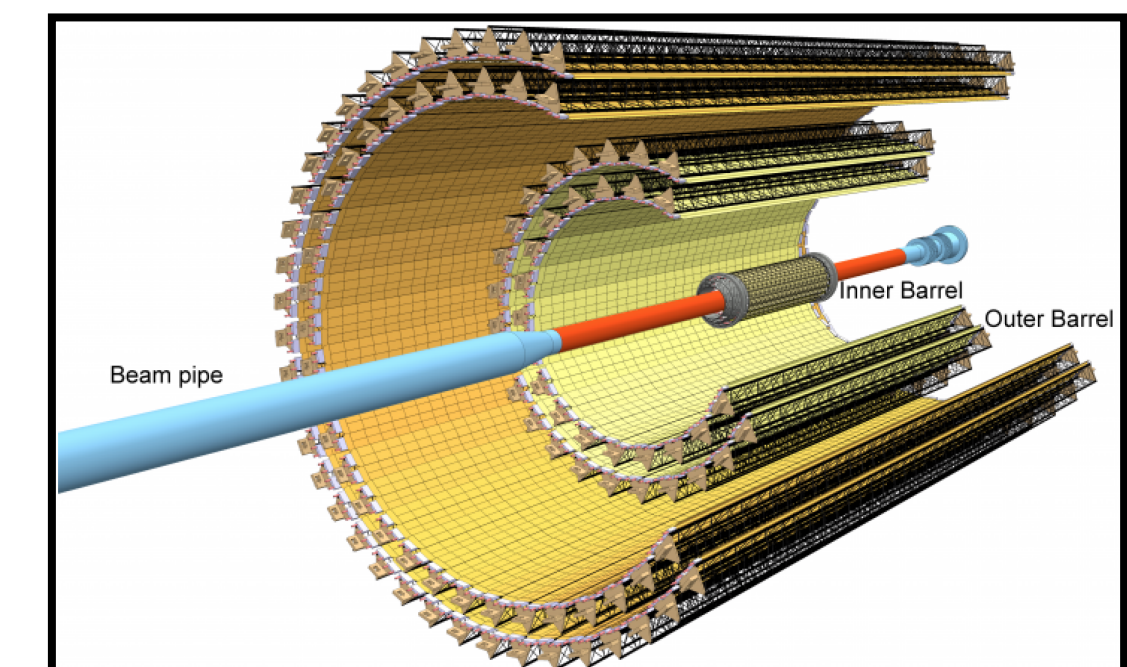
FOOT (2022 experiments)

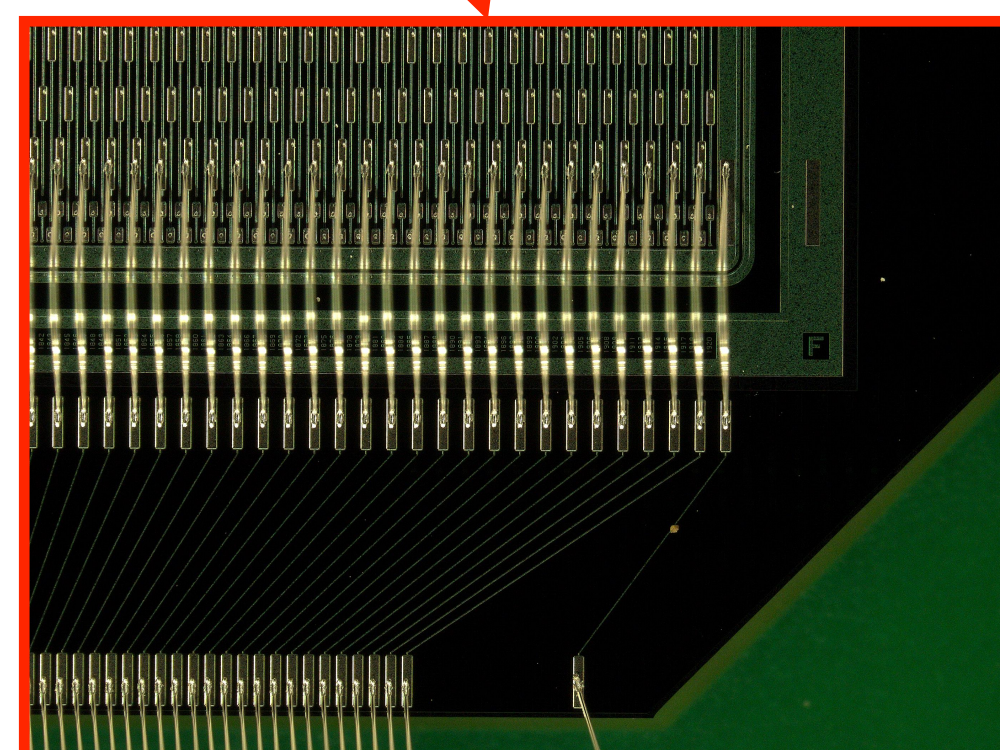
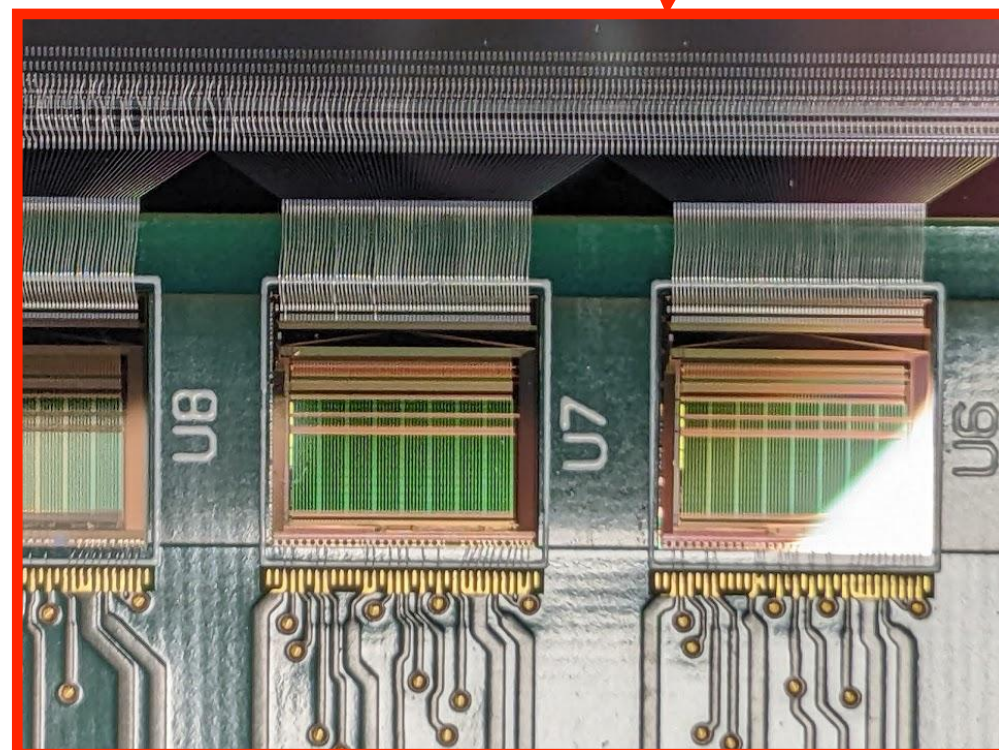
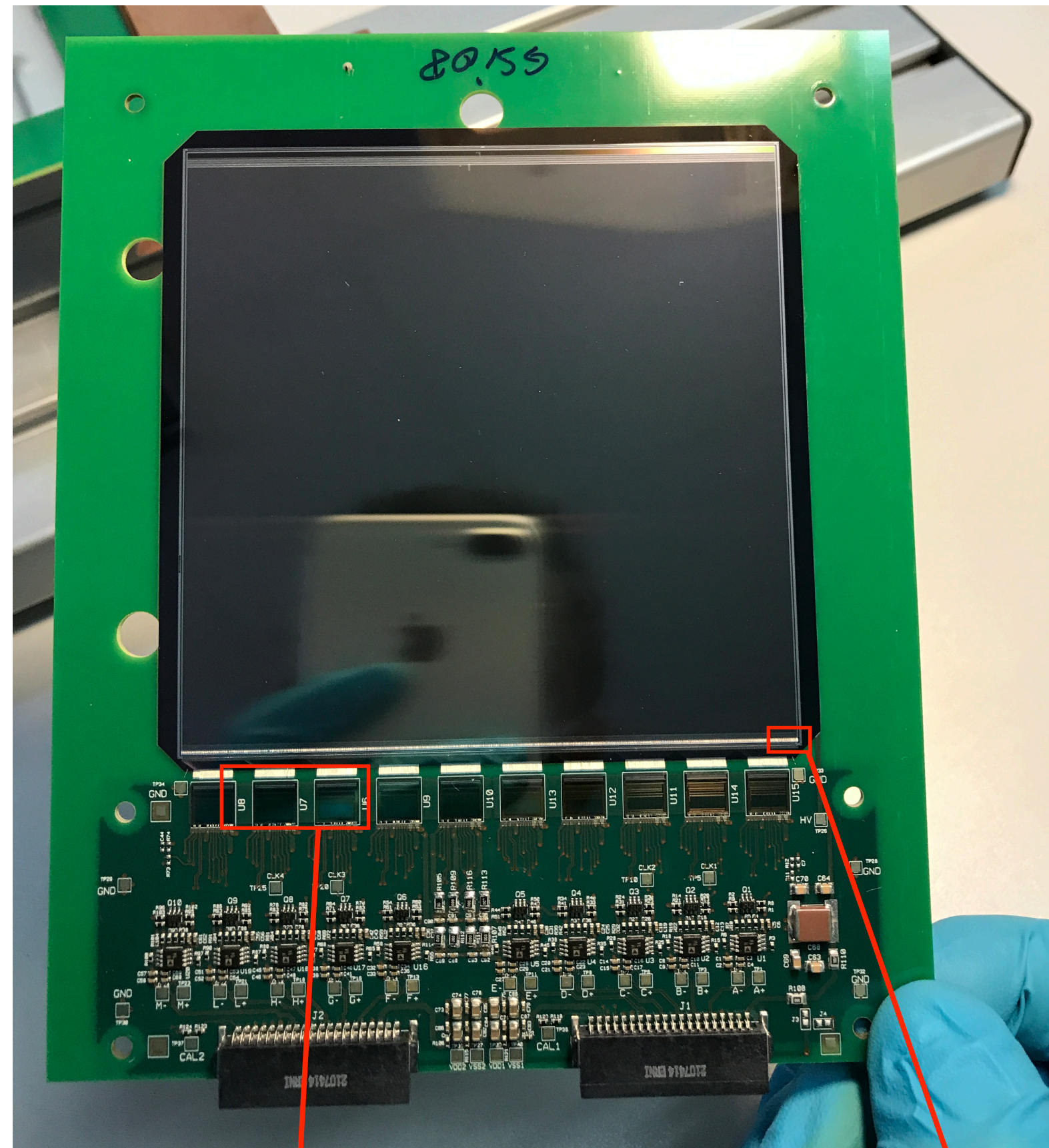


L3T prototype



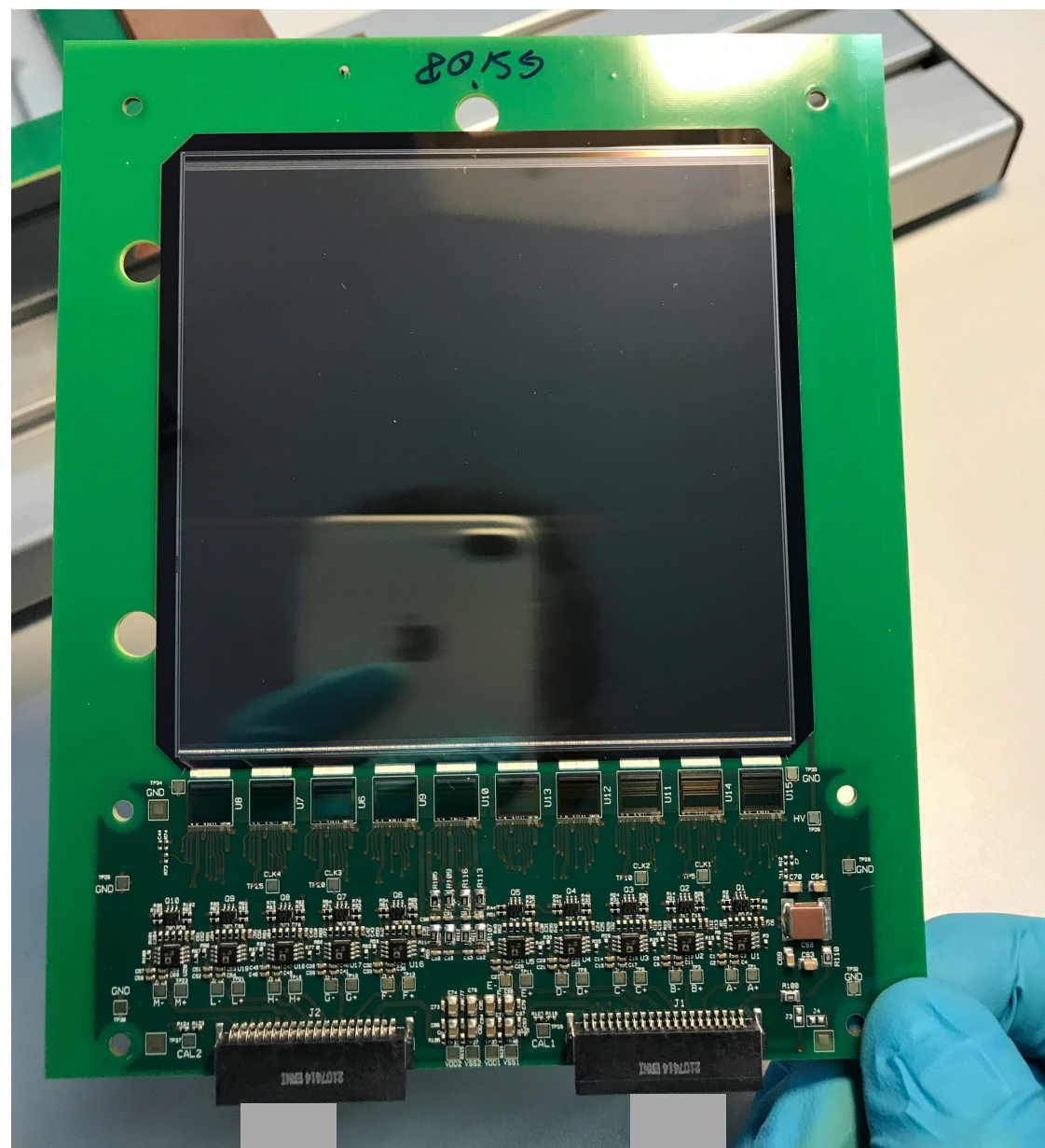
ALPIDE (future tracker)





FOOT (Fragmentati**O**n **O**f **T**arget) - single-sided silicon strip detectors

- HAMAMATSU sensors 150 μm thick
- Physical strip pitch: 50 μm
 - Effective strip pitch size of 150 μm (coupling every 3 strips)
- Number of readout channels: 640
- Active area: 96 x 96 $\text{mm}^2 > (2 \times \text{AMS})$
- Original development of FE and DAQ by INFN group from Perugia
- FE board contains:
 - 10 charge-sensitive ASICs IDE1140 (IDEAS, Norway)
 - AC-coupled, pulse height proportional to the input charge
 - 64 strips bonded to a single ASIC
 - Buffer amplifiers
 - 2 x 40 pin connectors
- First prototypes at GSI: June 2021

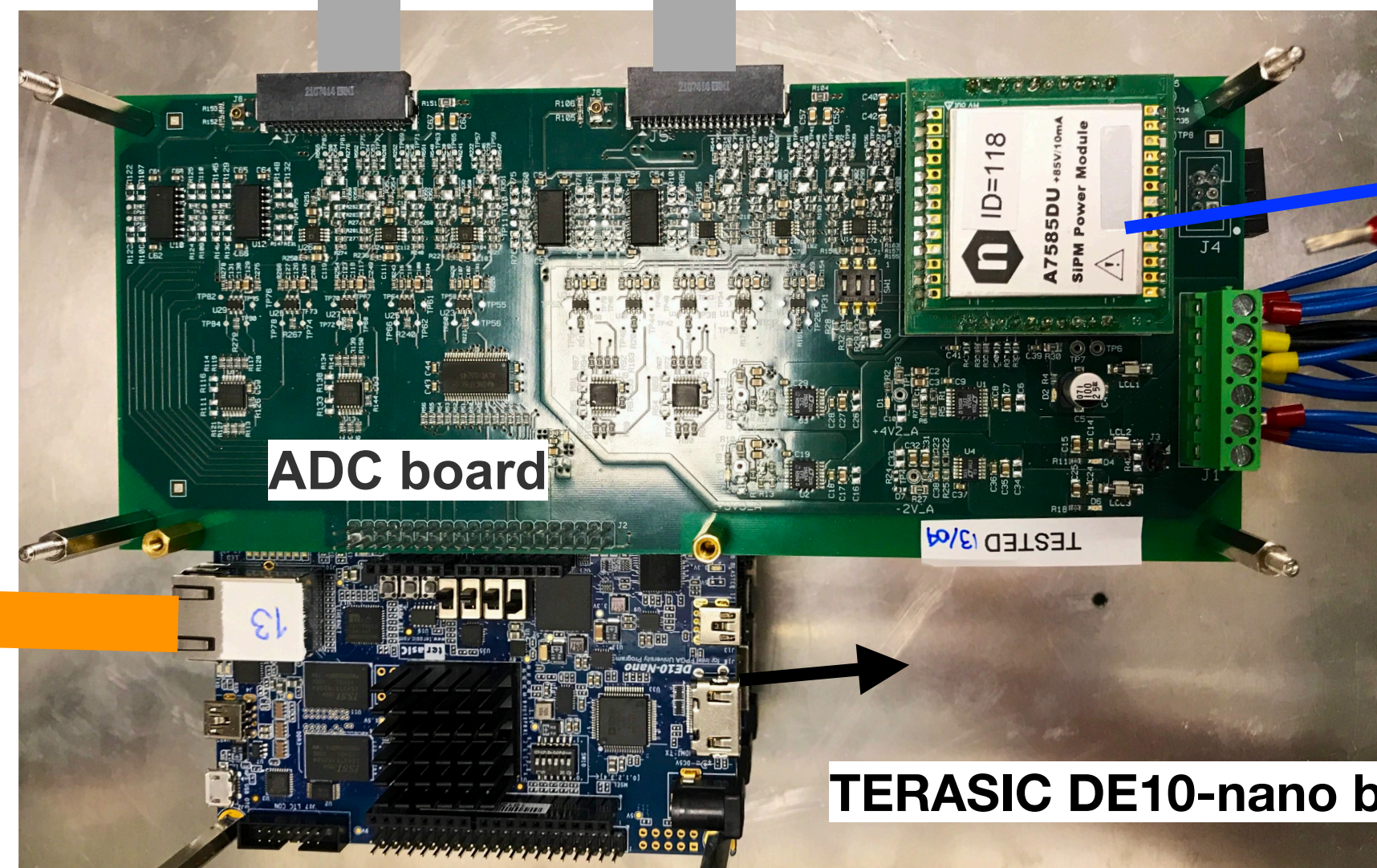


DAQ electronics for a single detector

- Adopting readout solution from Perugia group
- Custom ADC board (provided by Perugia)
 - One ASIC per single 12-bit ADC
- Commercial FPGA: TERASIC DE10-nano with custom-made firmware
 - Steering ADC board and ASICs
 - Communication and readout (drasi)

flat cables

vacuum feed-through



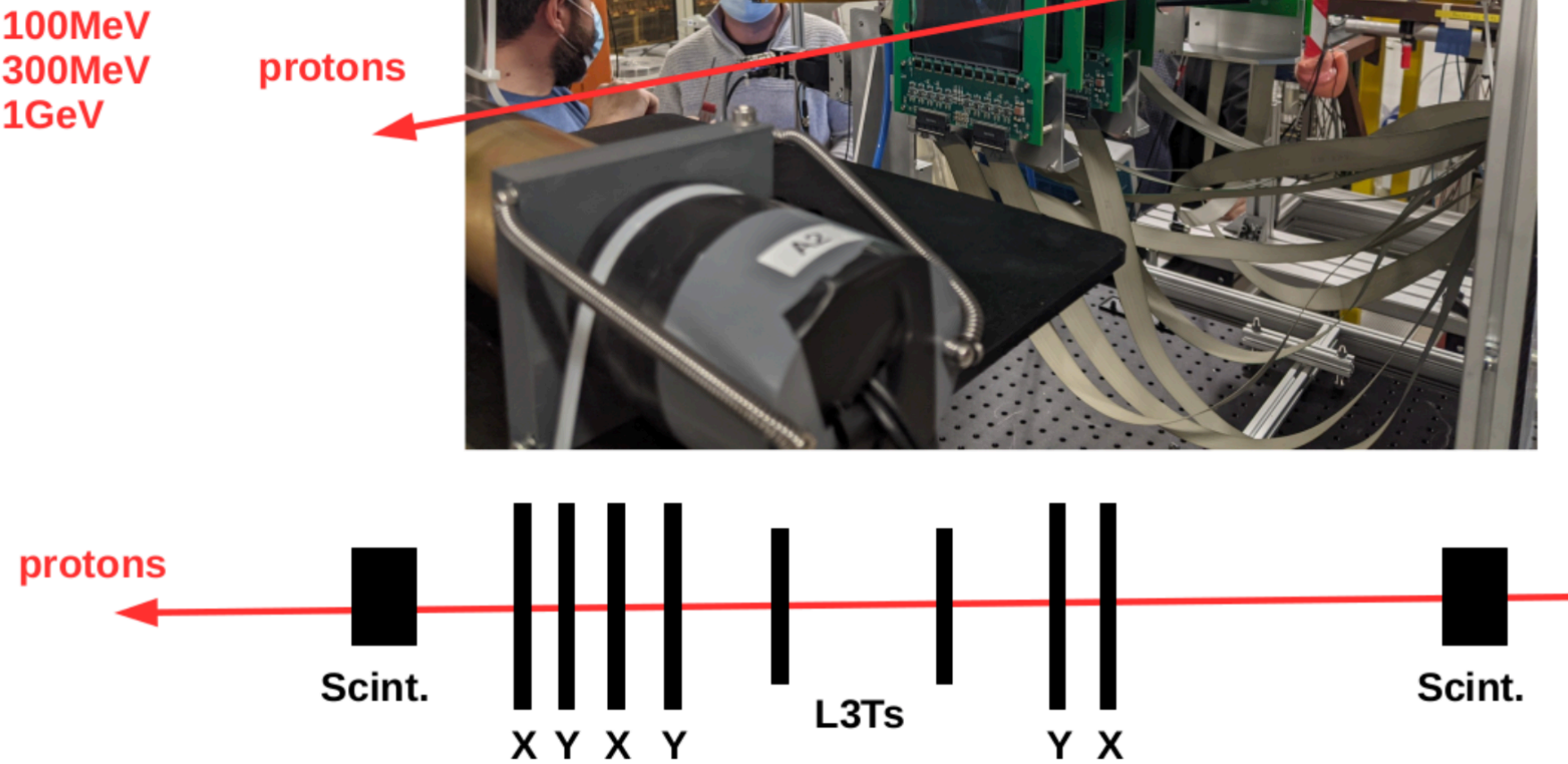
CAEN DC power unit
for silicon bias
(controlled via external
ARDUINO)

Ethernet

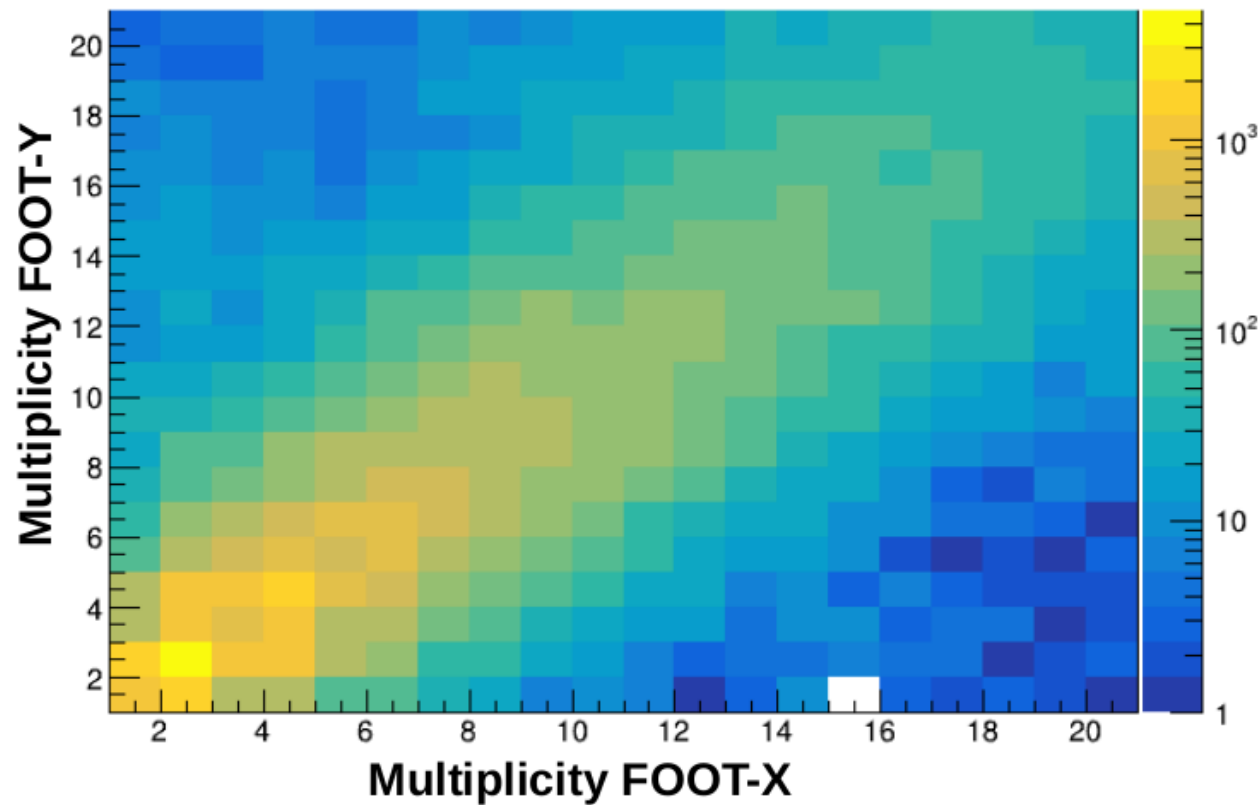
TERASIC DE10-nano board

First test in Jülich (report from Aldric Revel on 14th Dec. 2021)

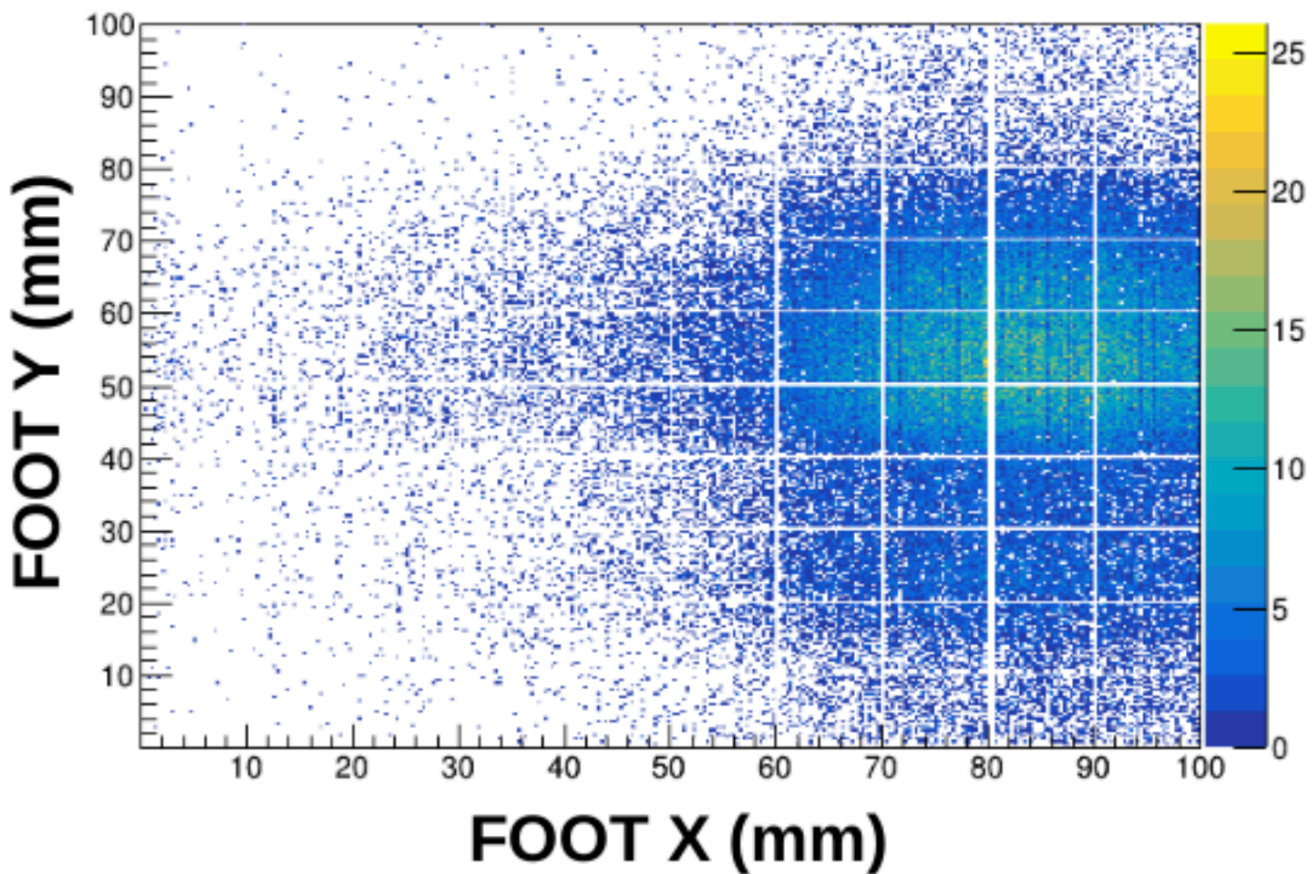
Test setup with 6 FOOT



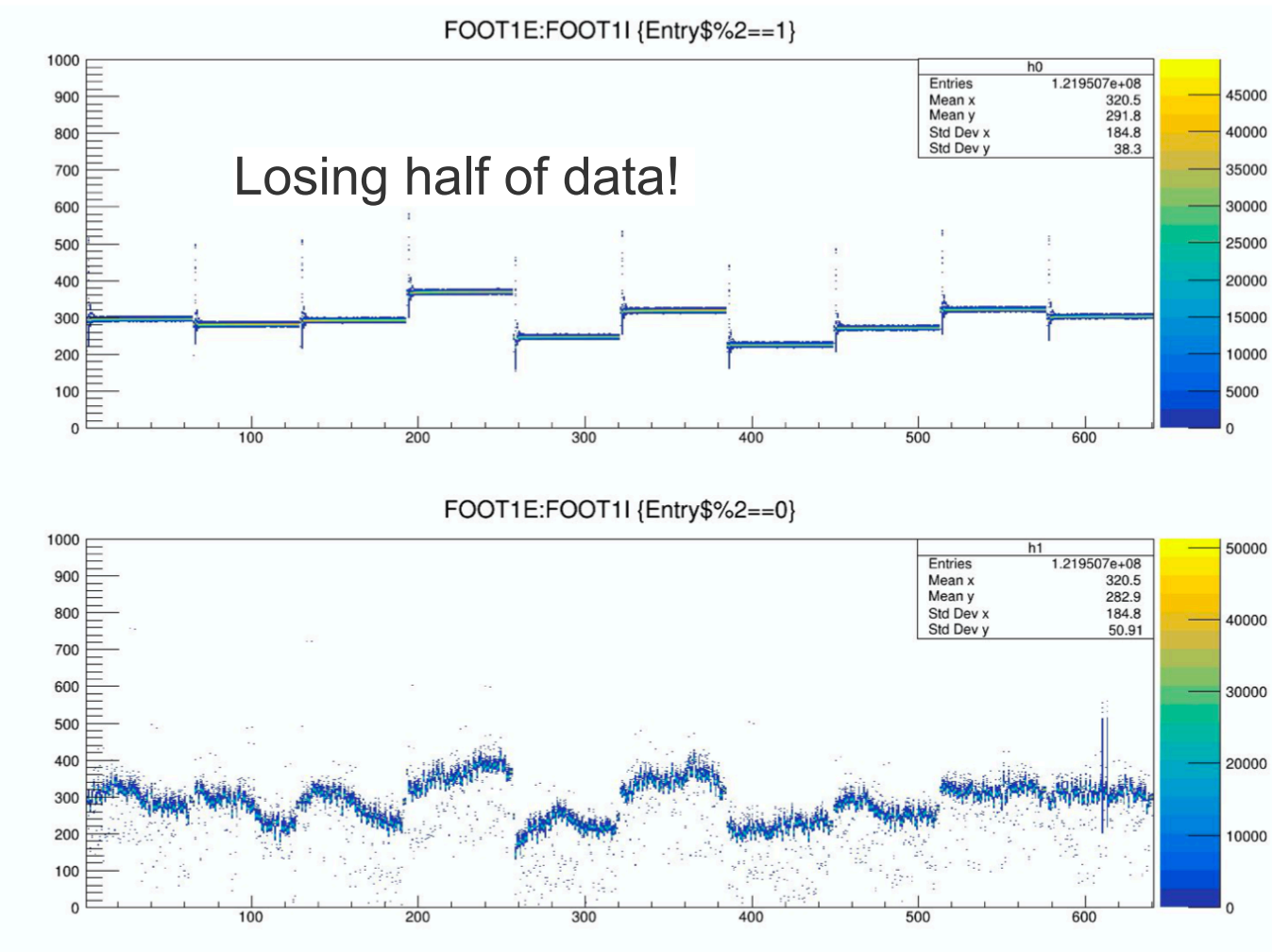
Large hit multiplicities due to poor beam quality



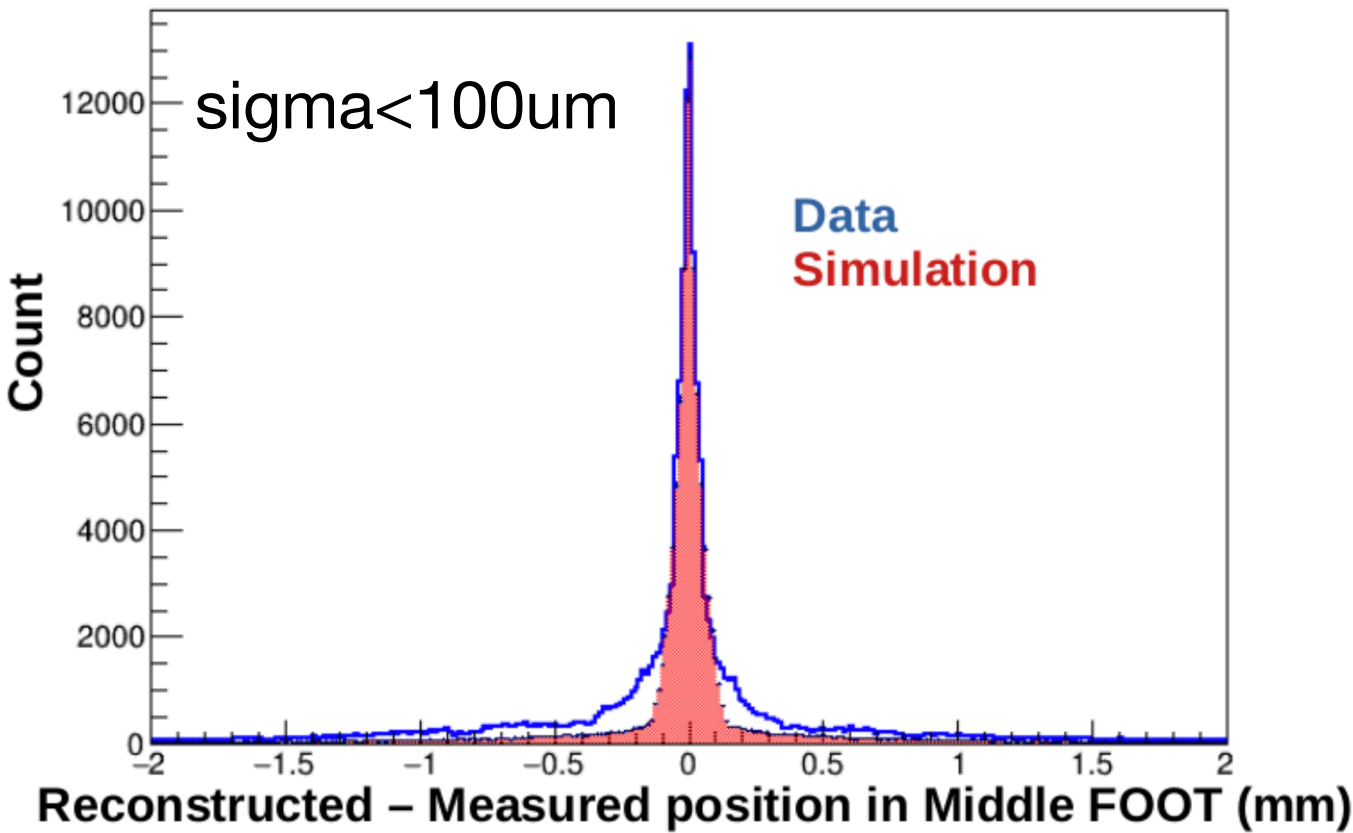
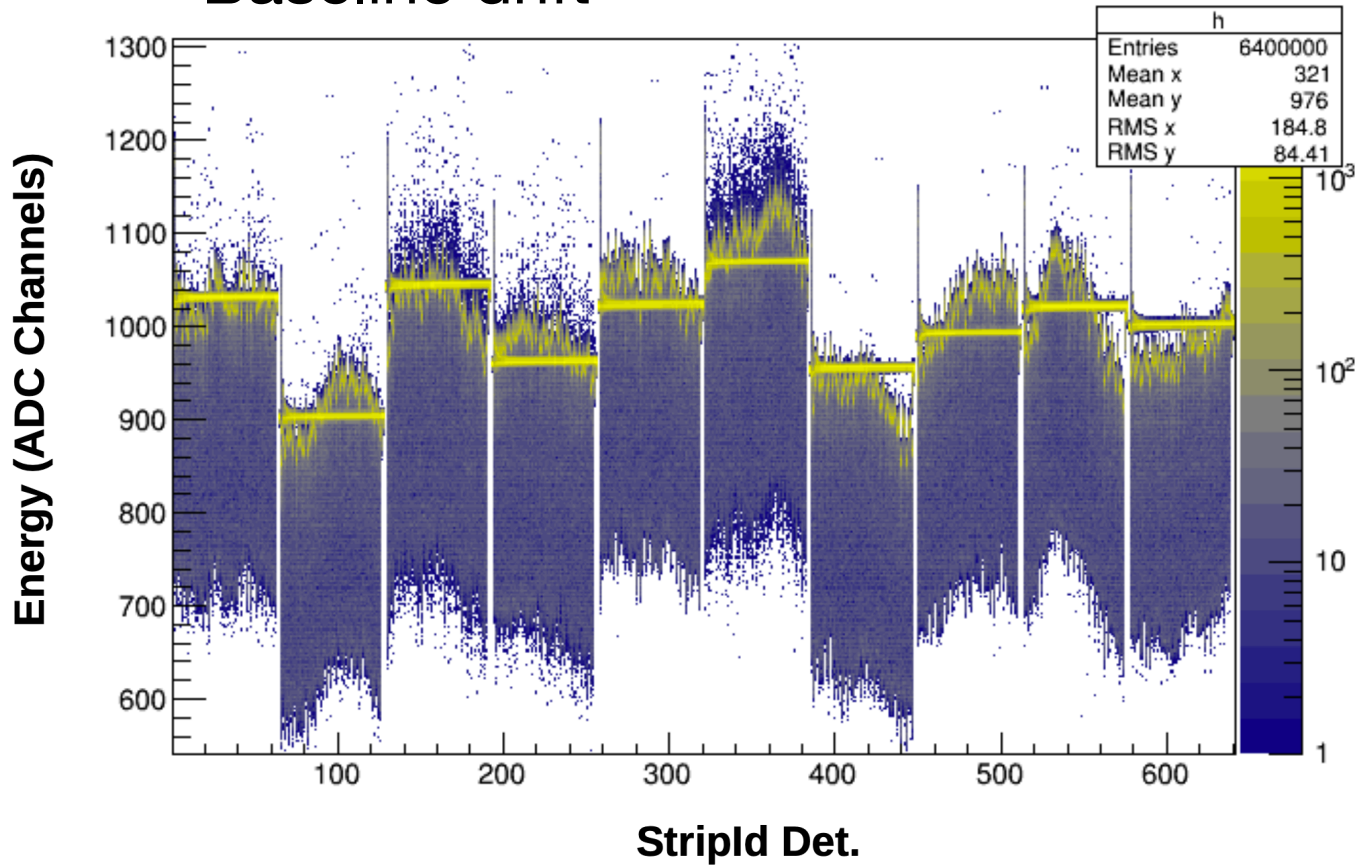
Reconstructed beam profile



Problem with odd-even events



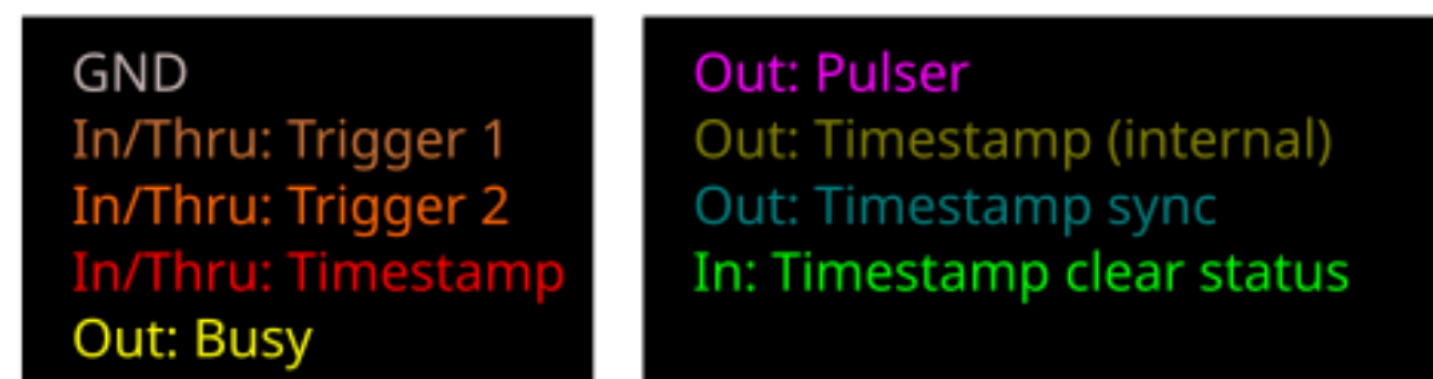
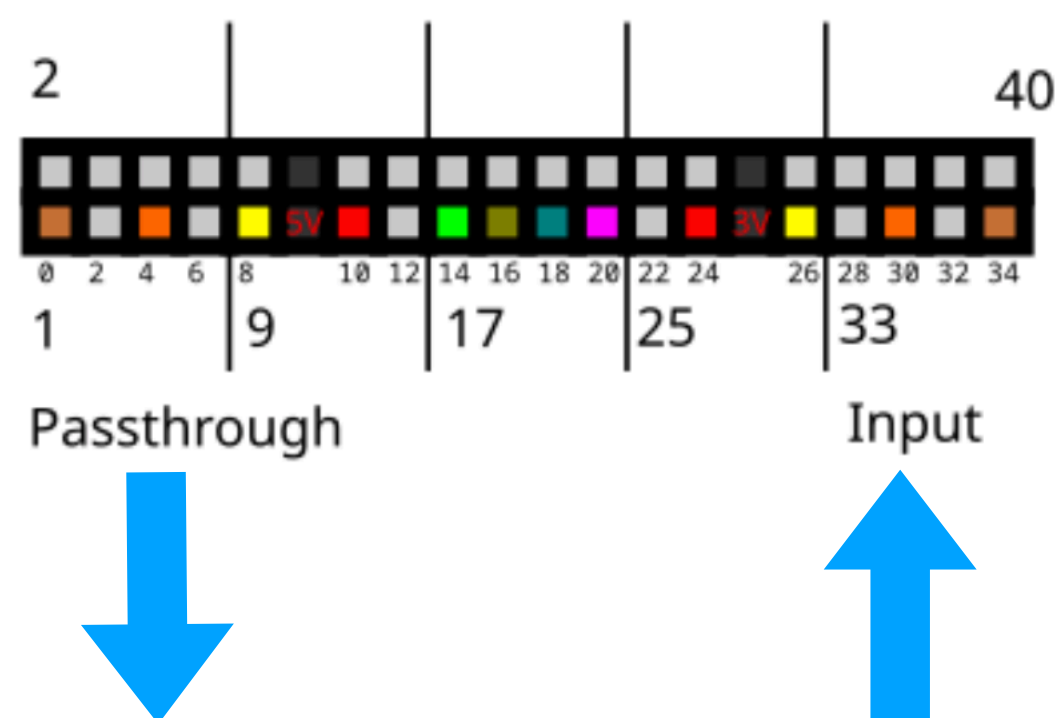
Baseline drift



Electronics tests, software and hardware developments

- Solved difference between odd-even events:
 - Bit registers not resetting in the end of every other readout cycle
 - Forced reset via DRESET pulse in the end of each readout cycle
- Solved baseline drop at small dt between two consecutive triggers ($\approx 1\text{ms}$)
 - Power voltage drop on the preamp at high currents
 - Solved by bridging resistors on the FE (helped by K. Koch)
- Adding internal pulser to FPGA - no external pulser needed
- Implementation of the TS receiver/sender and synchronisation
- Configuring firmware, readout, unpacker etc.

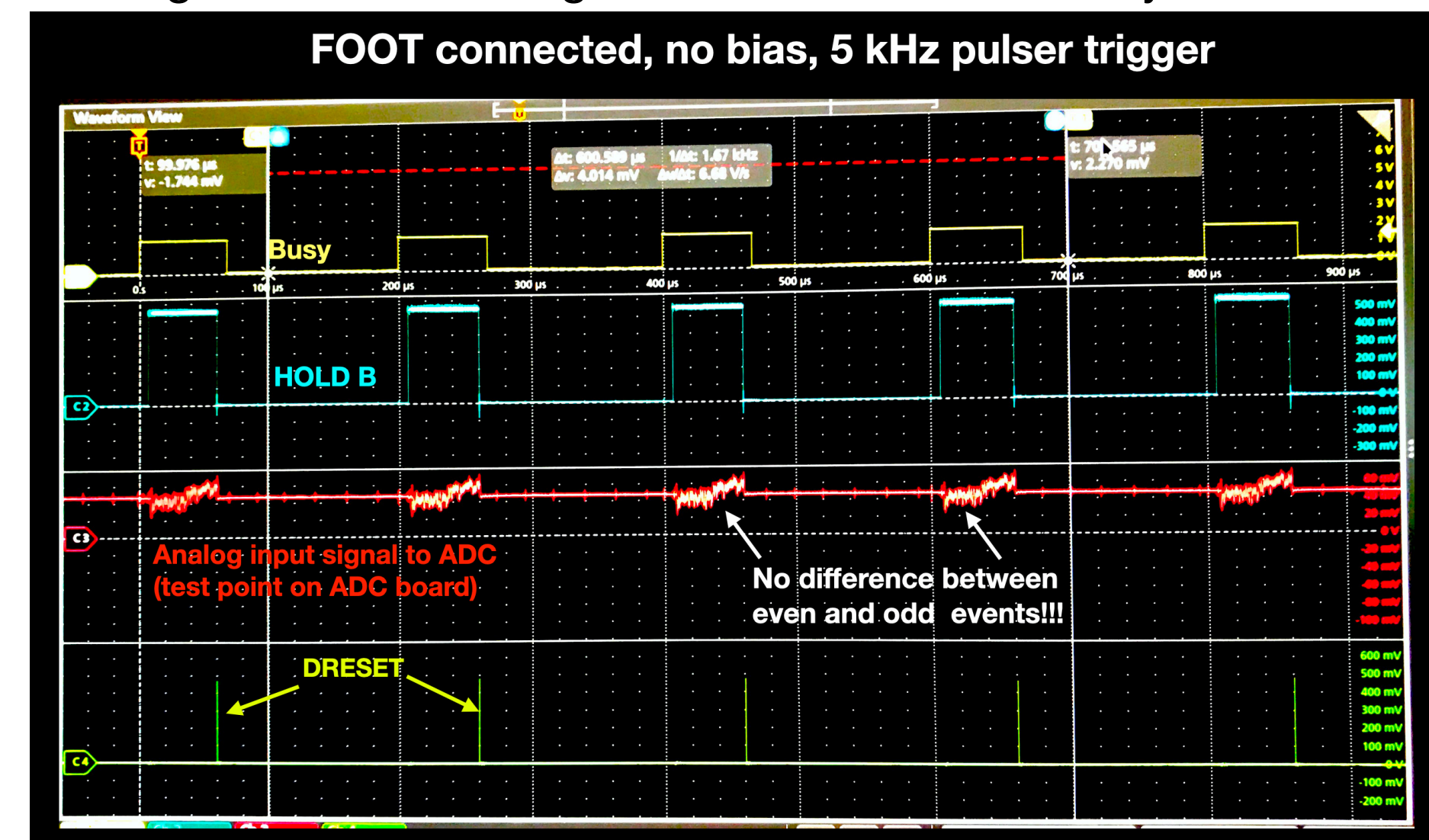
Improved GPIO pinout on FPGA



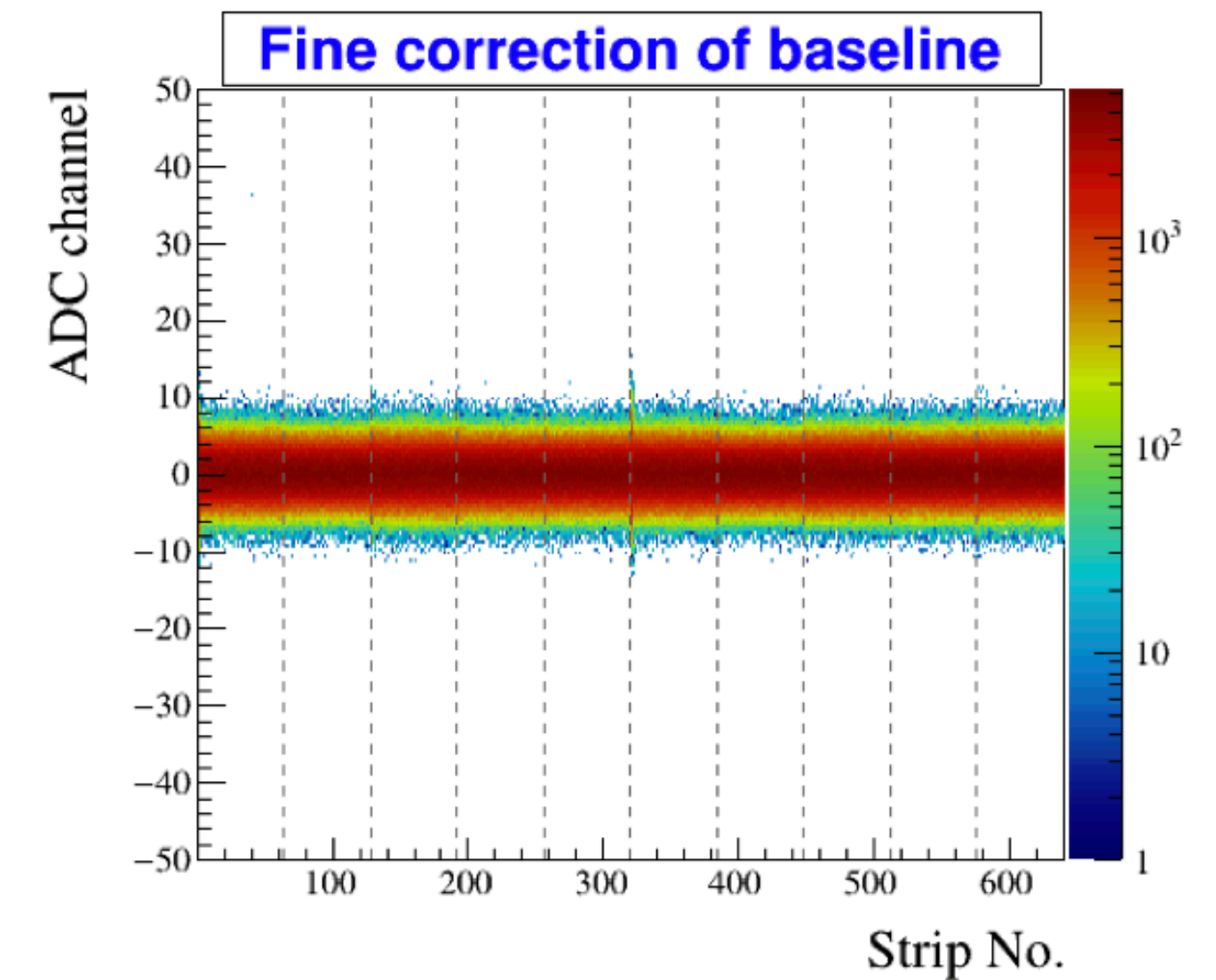
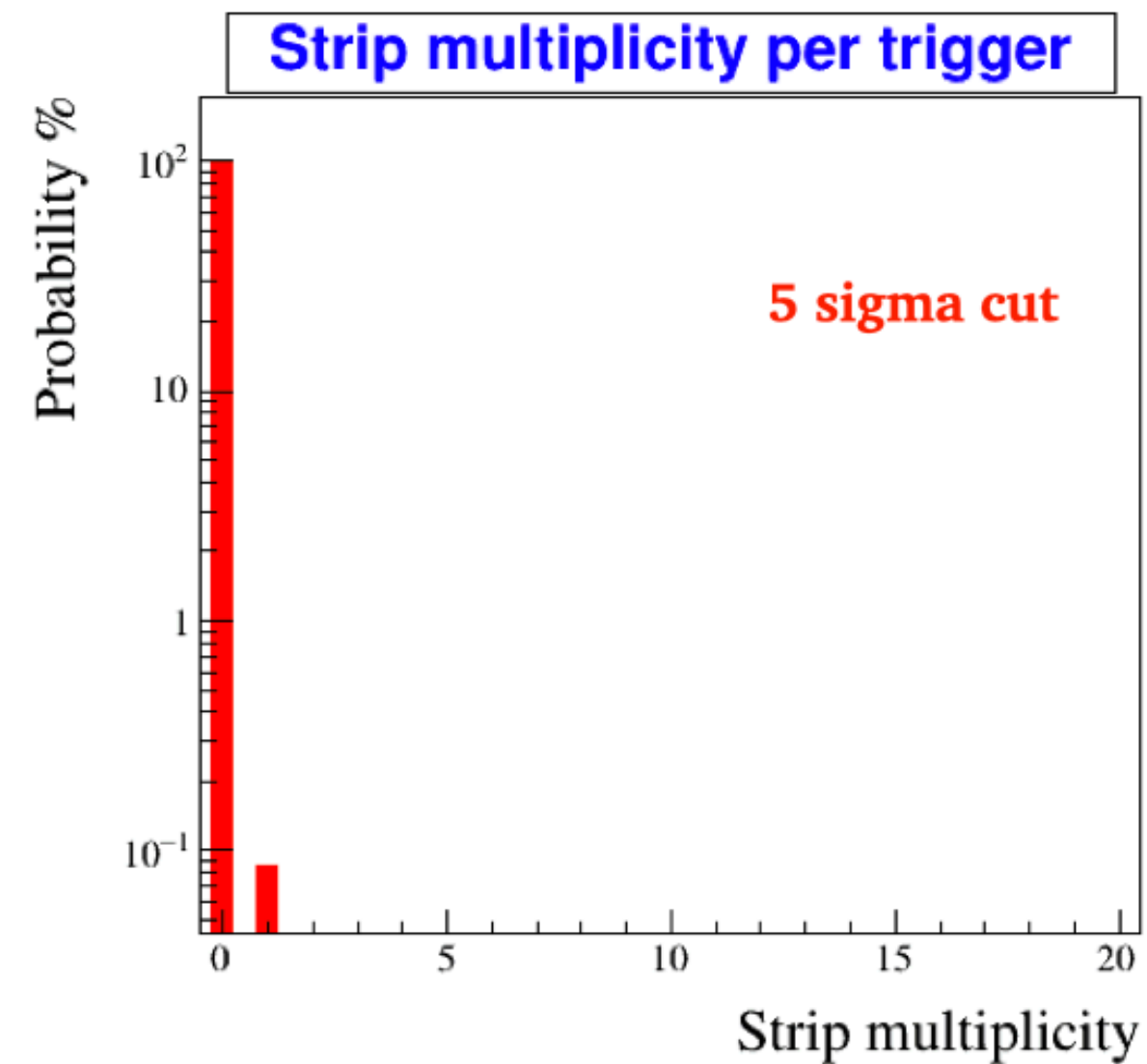
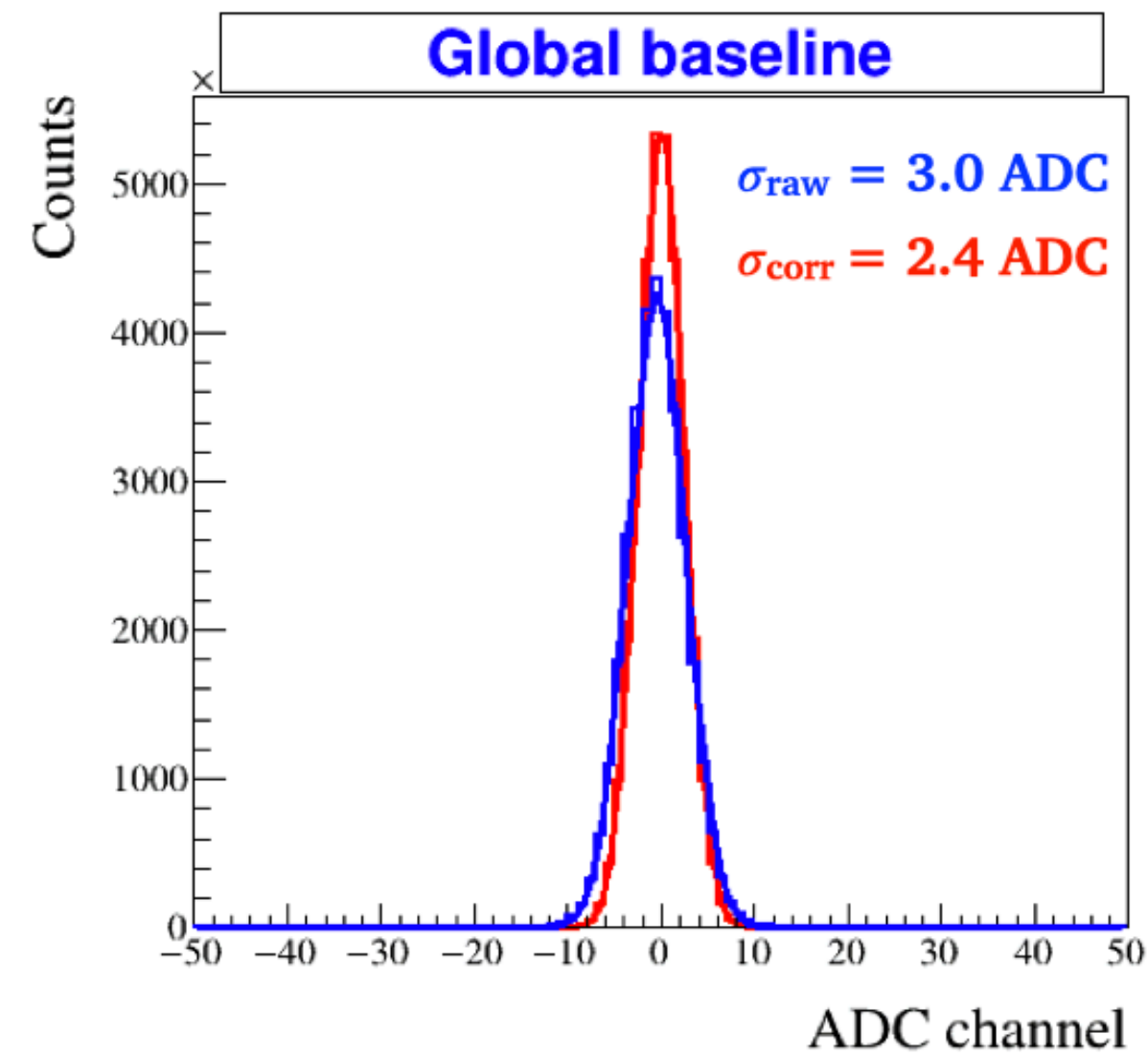
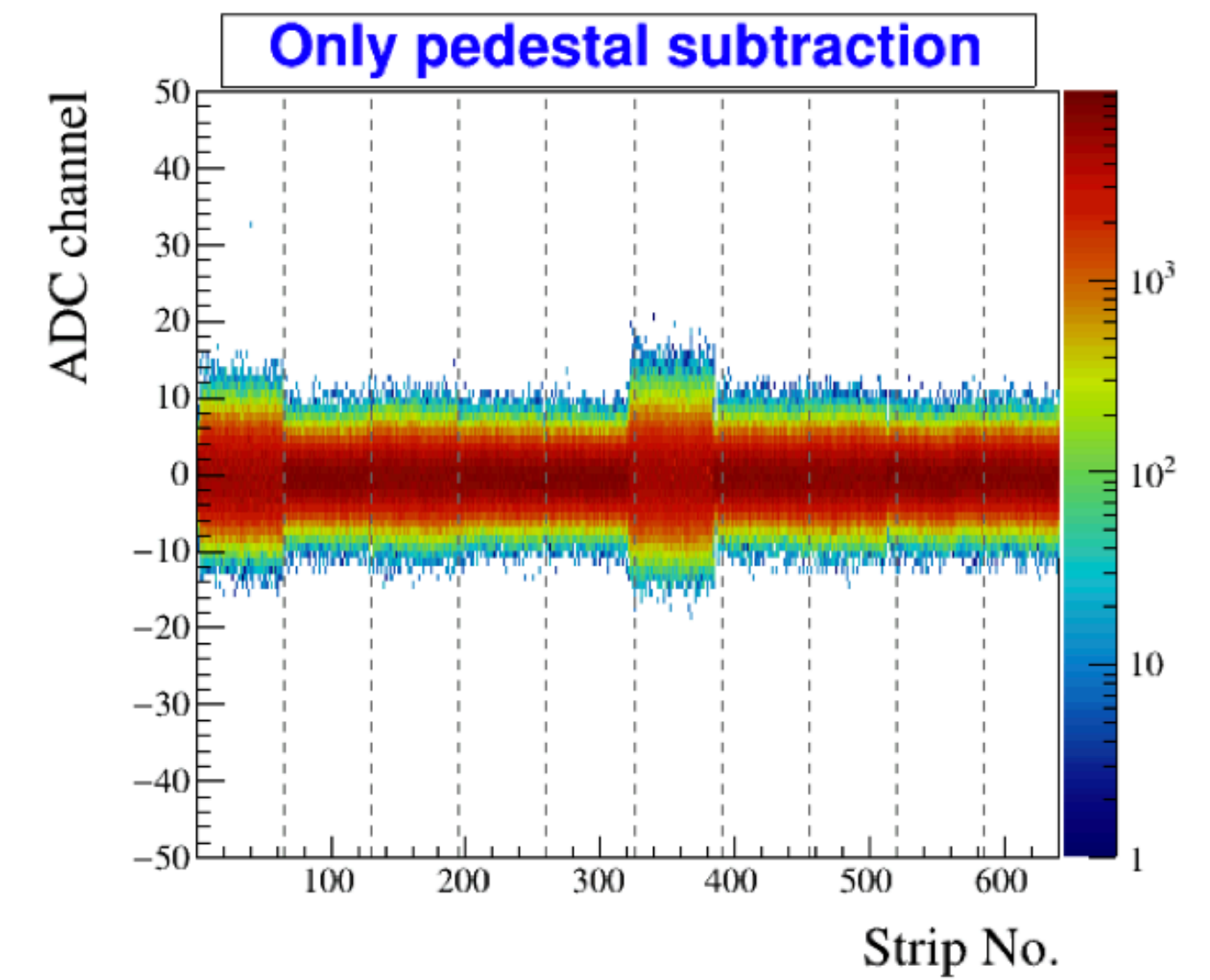
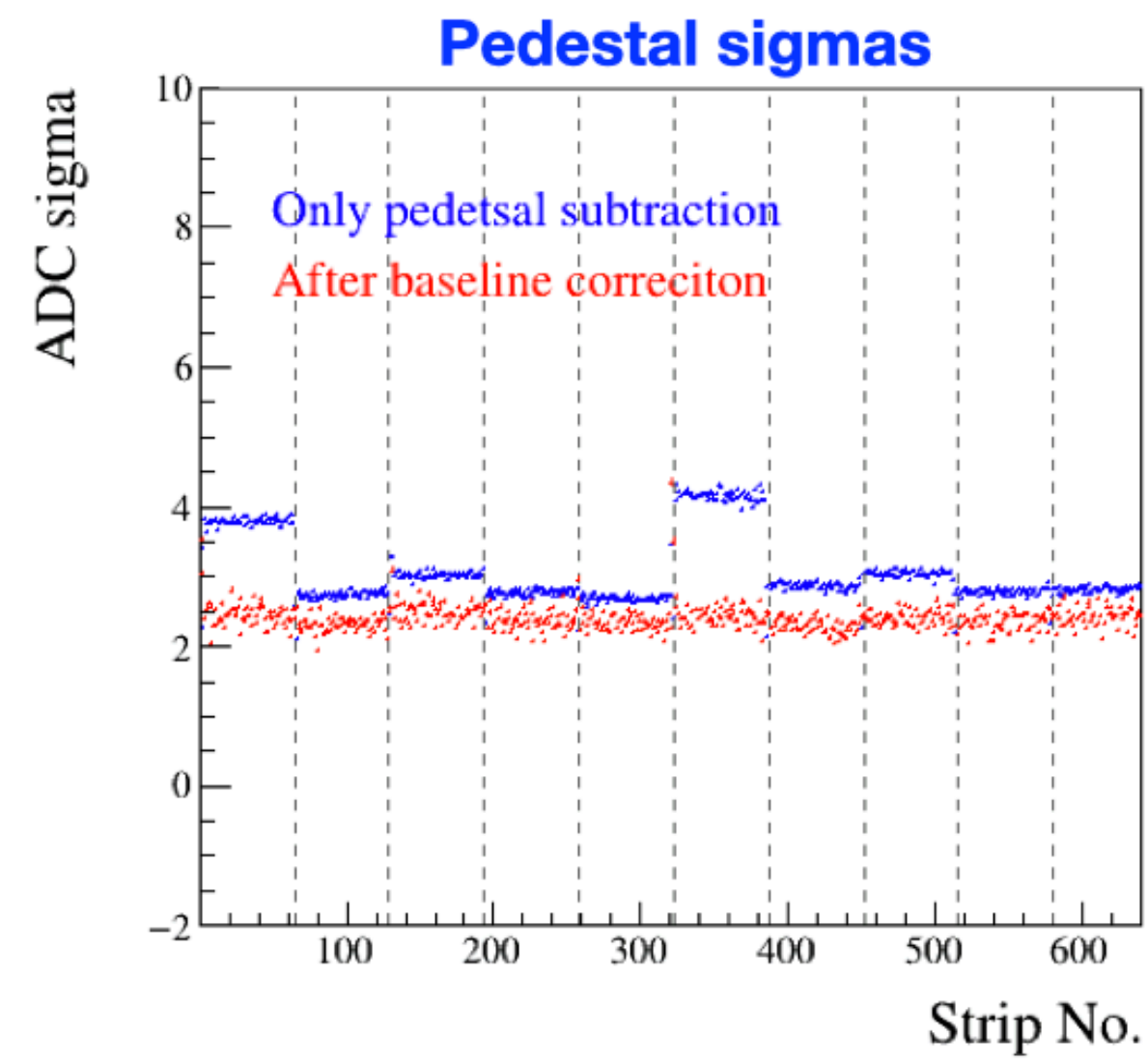
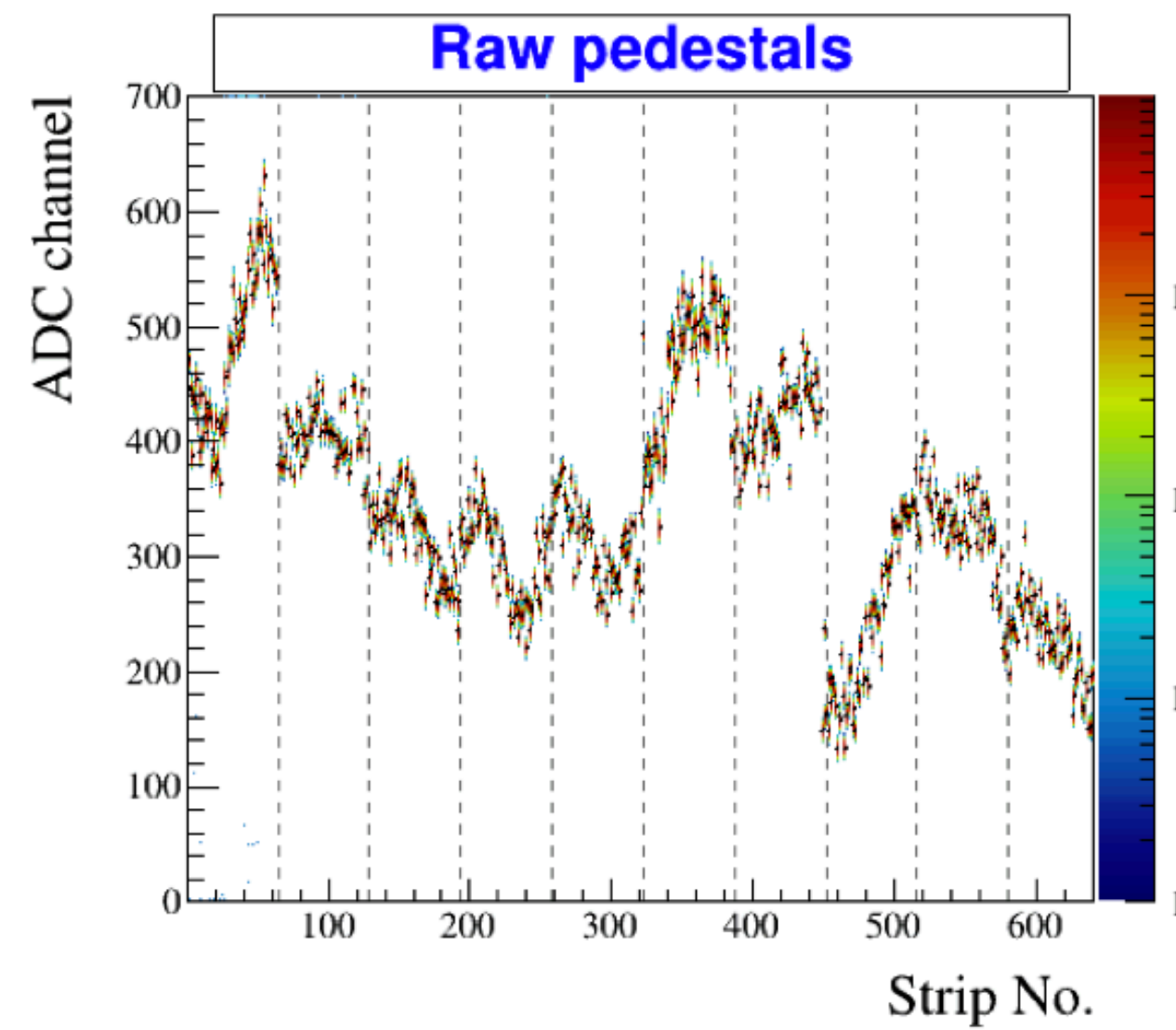
Odd-even event difference on the scope



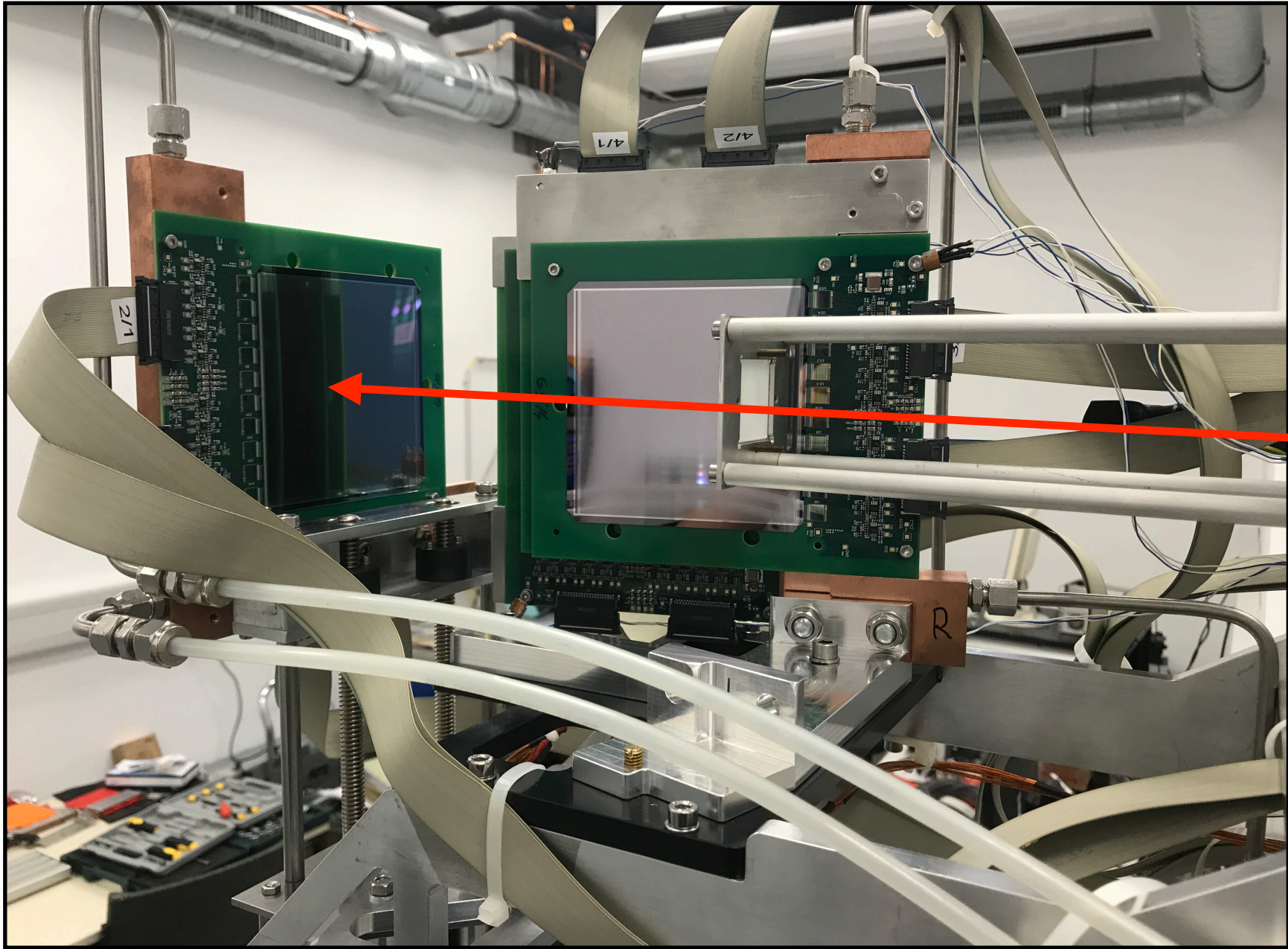
Adding to FW a reset signal in the end of a read cycle



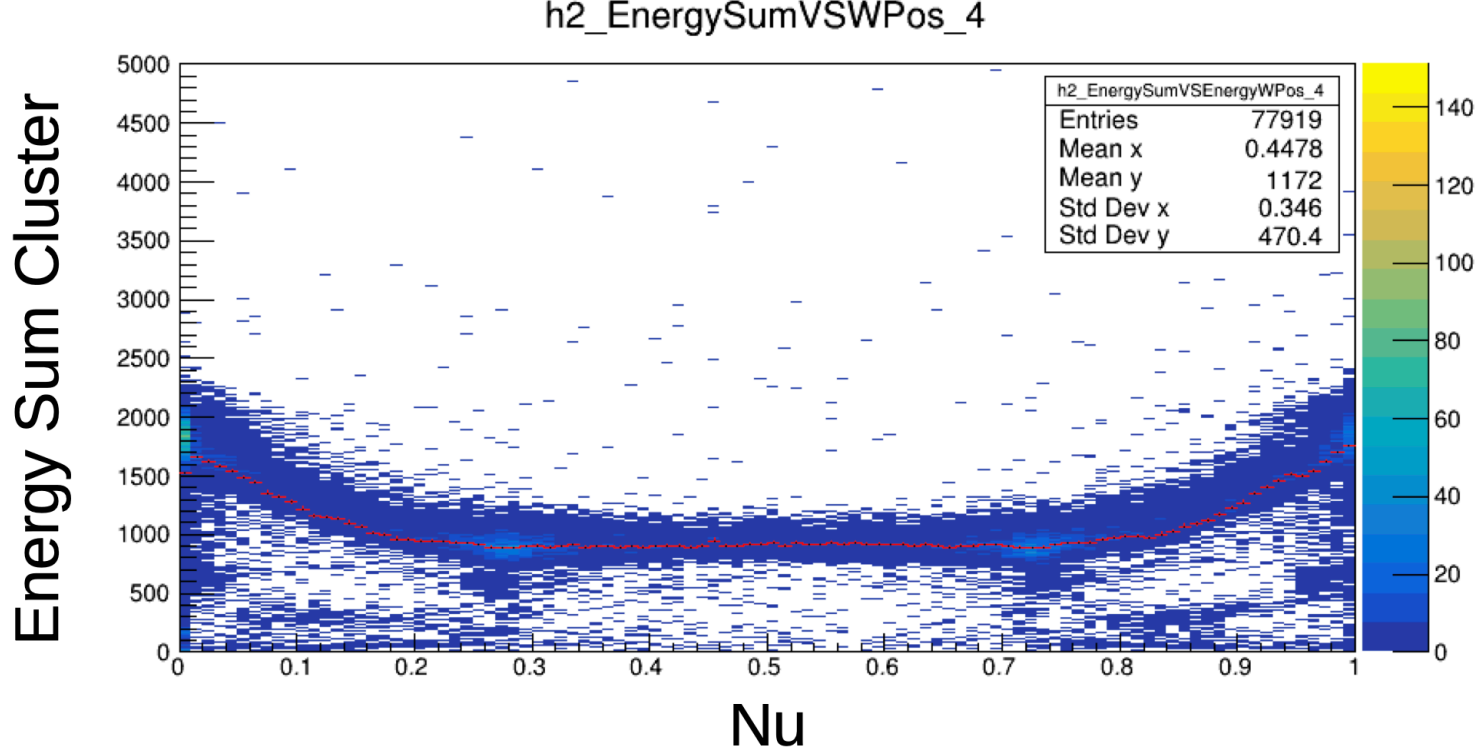
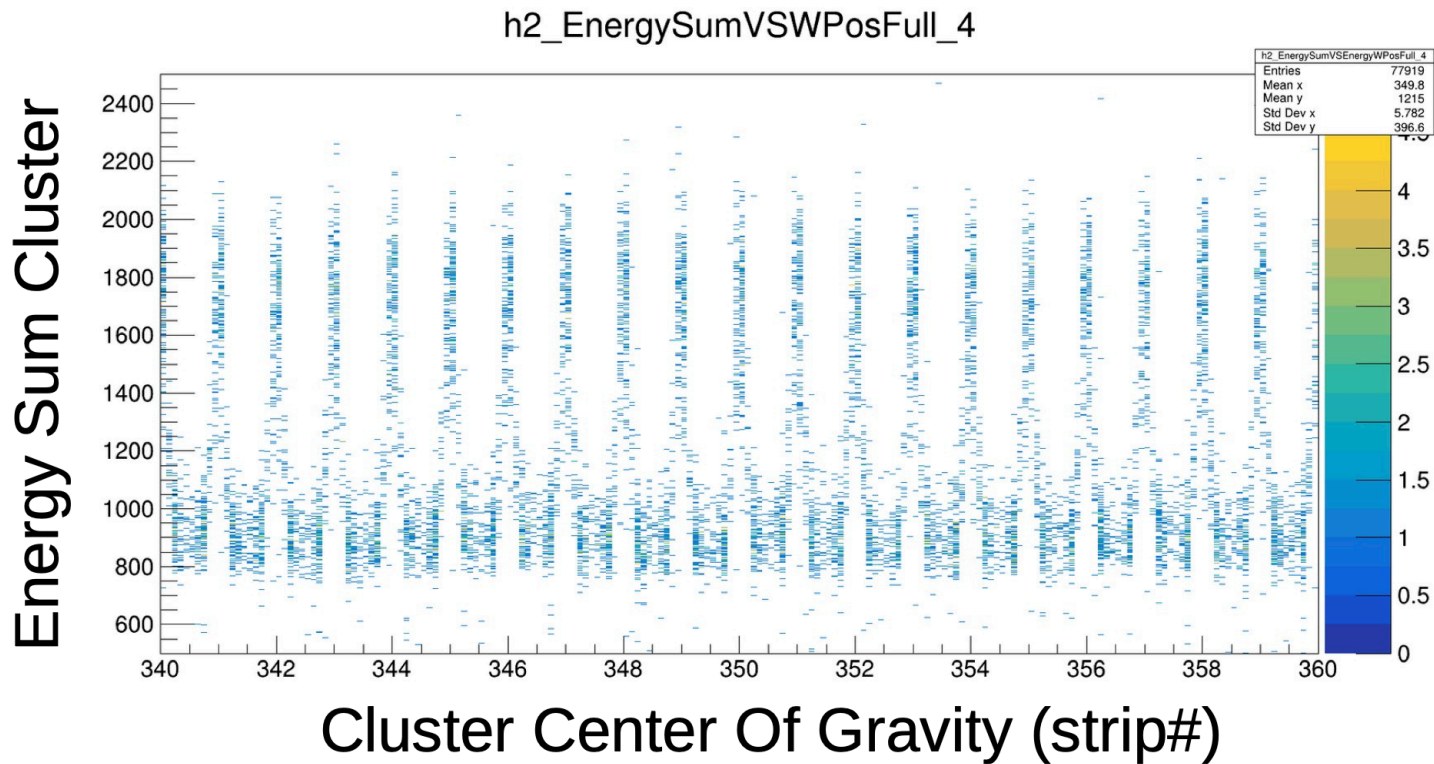
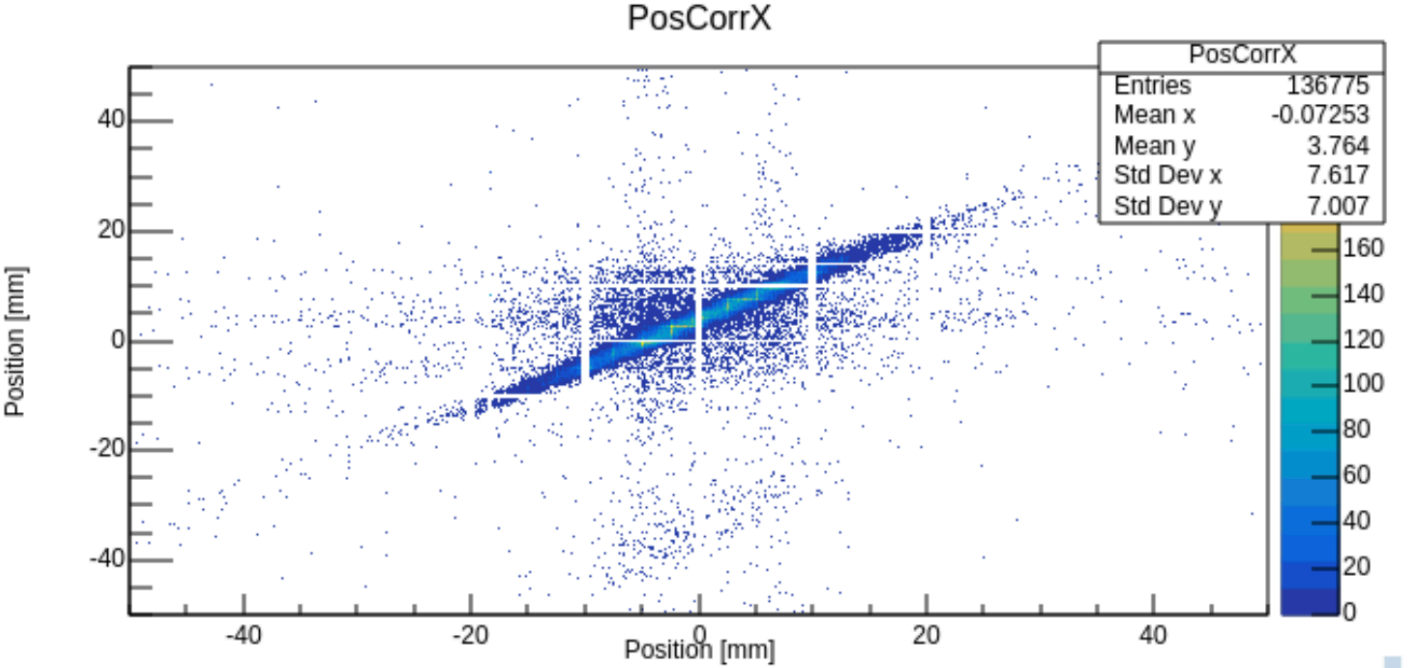
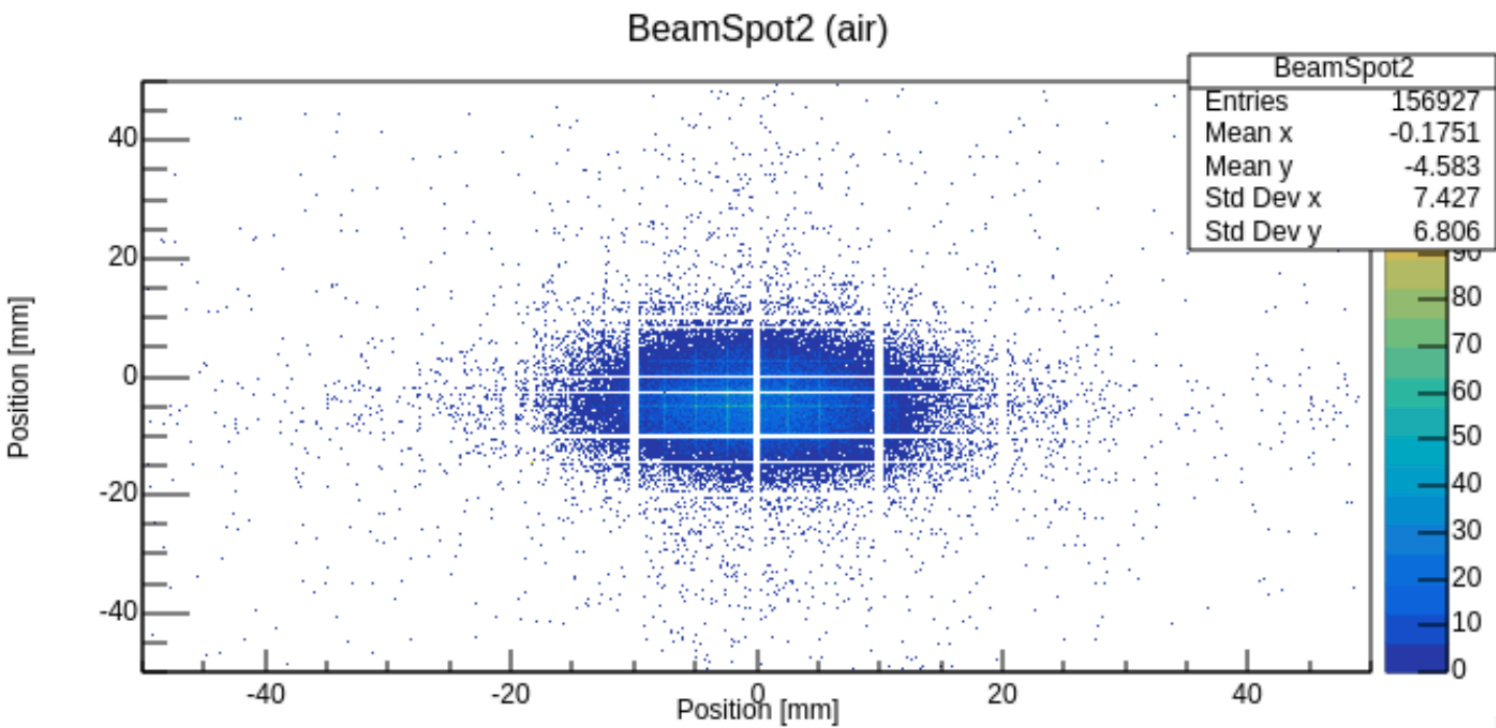
Performance of a single FOOT detector (GSI12) after all modifications



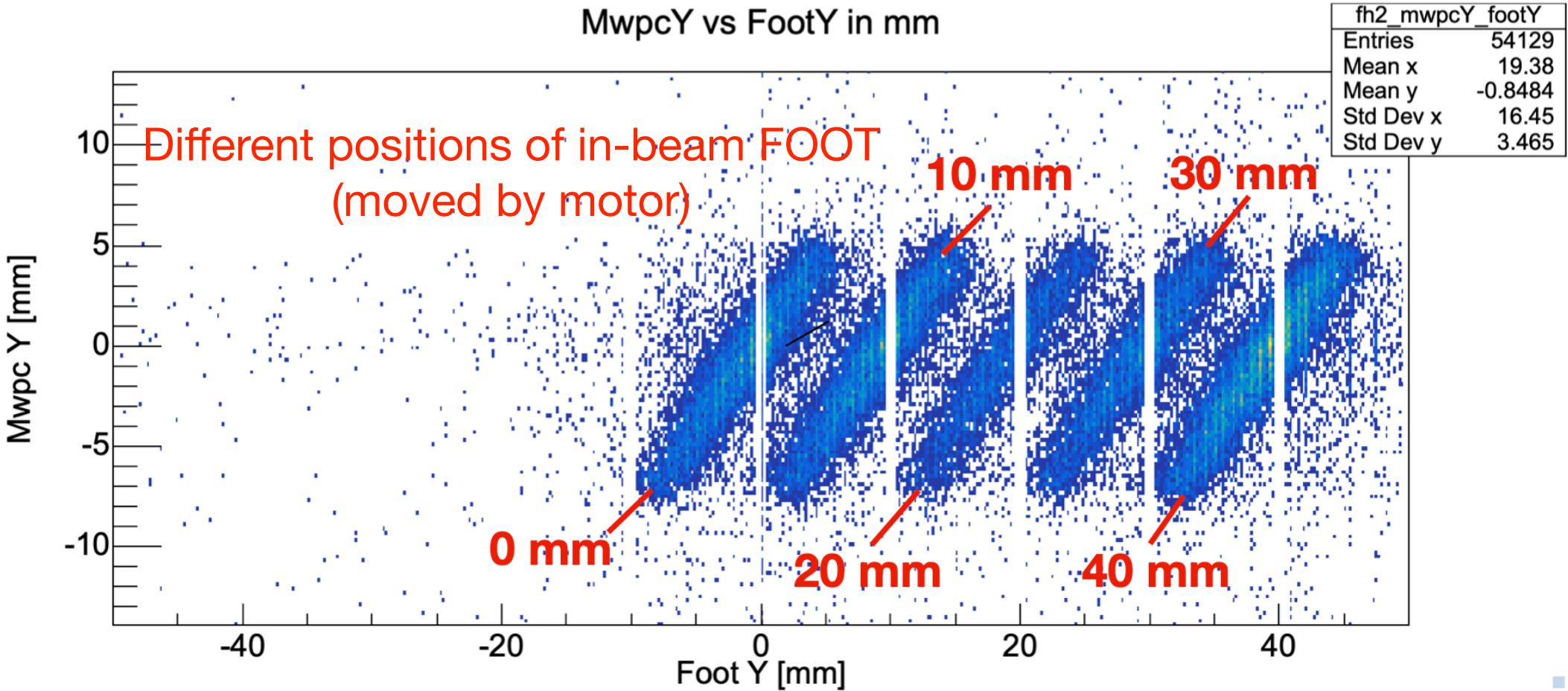
Beam test in Cave C, March 2022



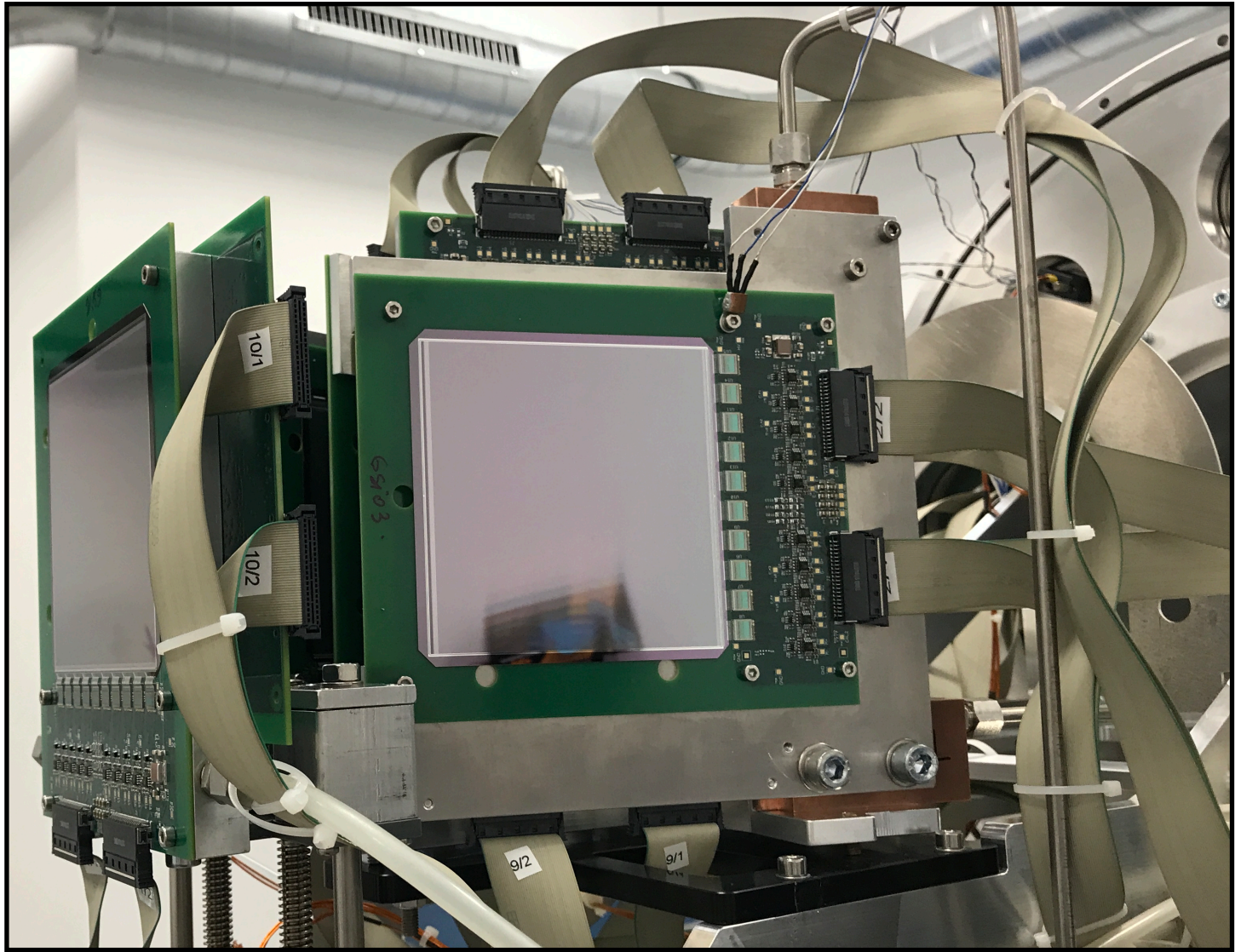
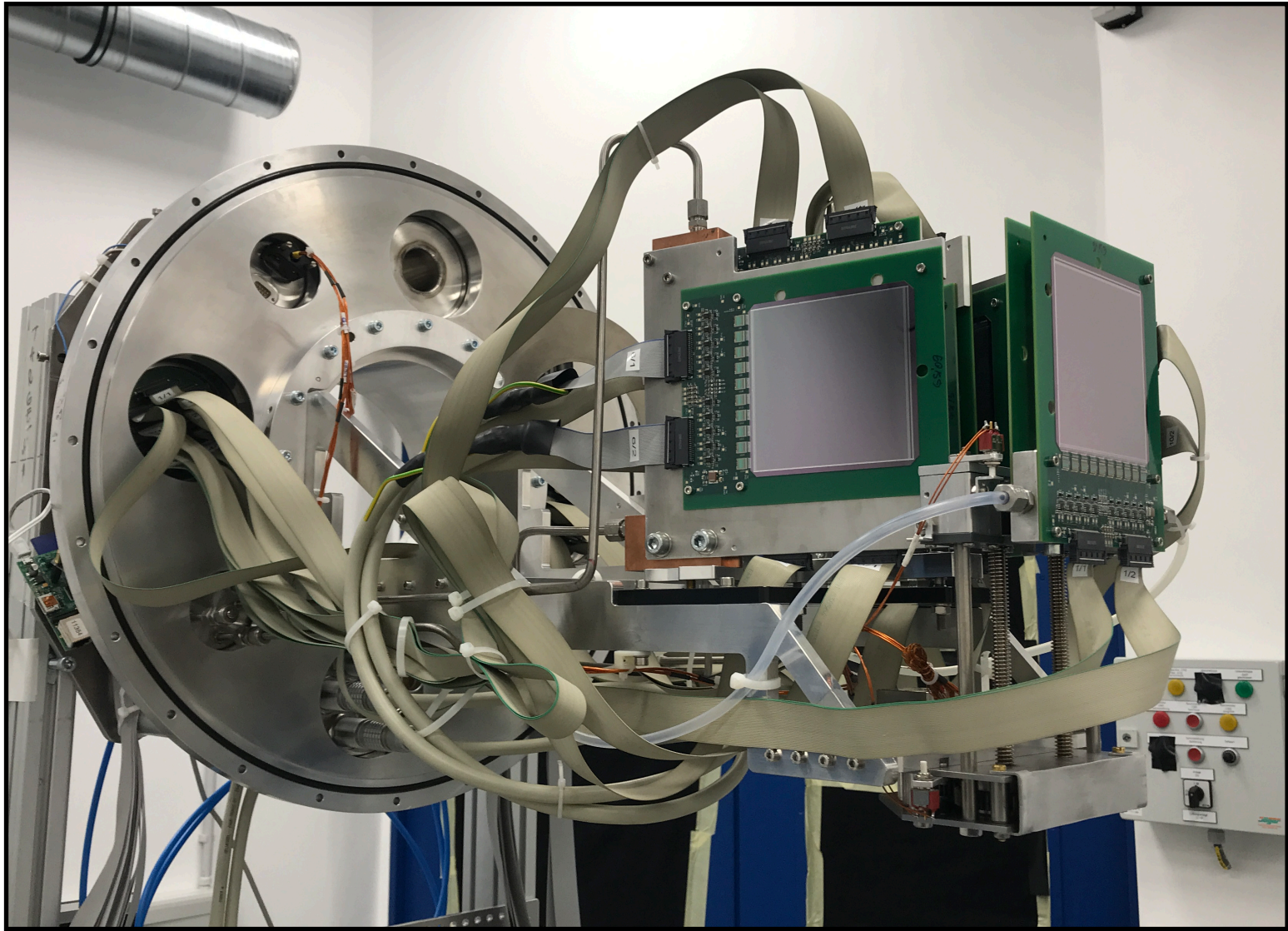
beam



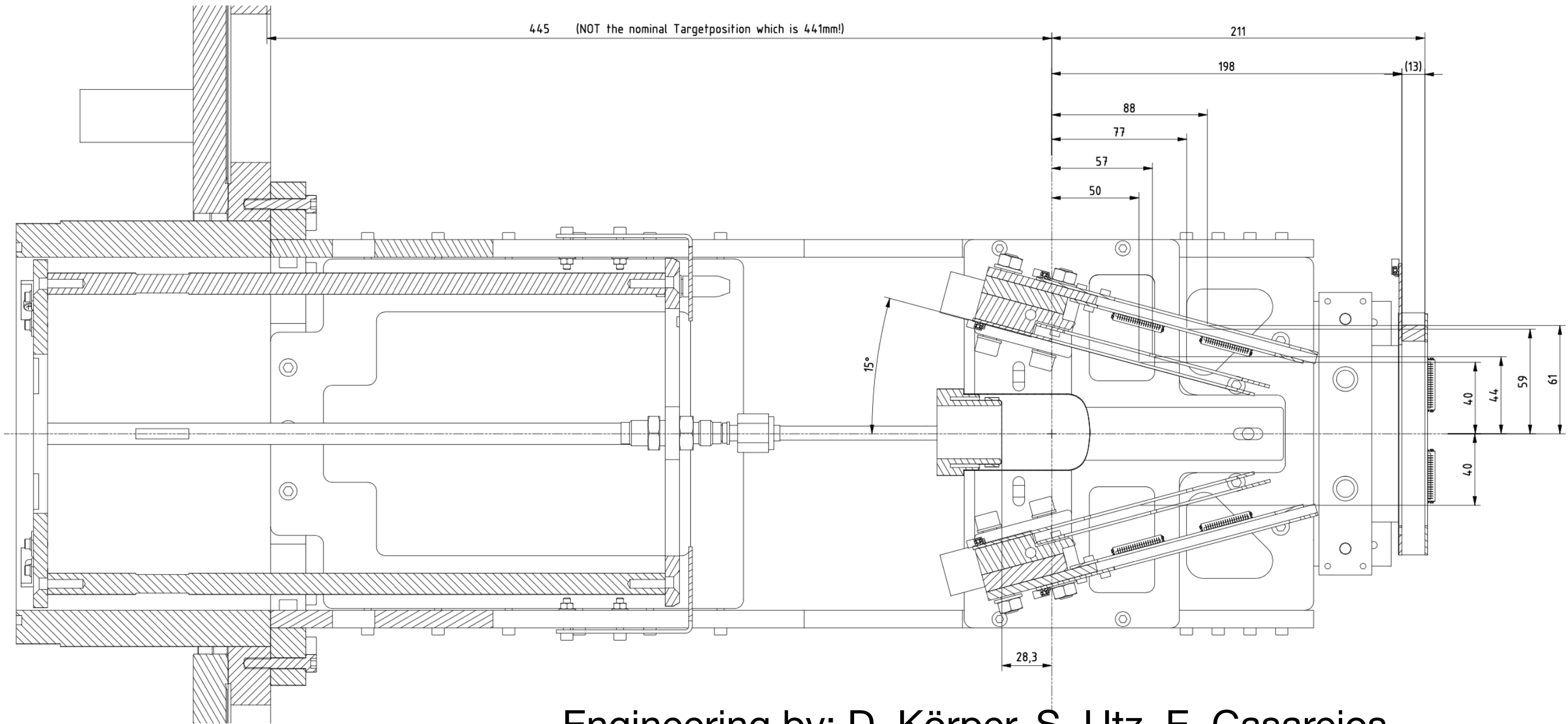
- Single-arm configuration for FOOT
- ^{12}C beam at various energies on CH2 target
- Additional pair of (modified) detectors in air



Final two-arm configuration in 2022 experiments:
10+2 FOOT detectors, 50 mm LH₂ target (COCOTIER)



50 mm LH₂ target

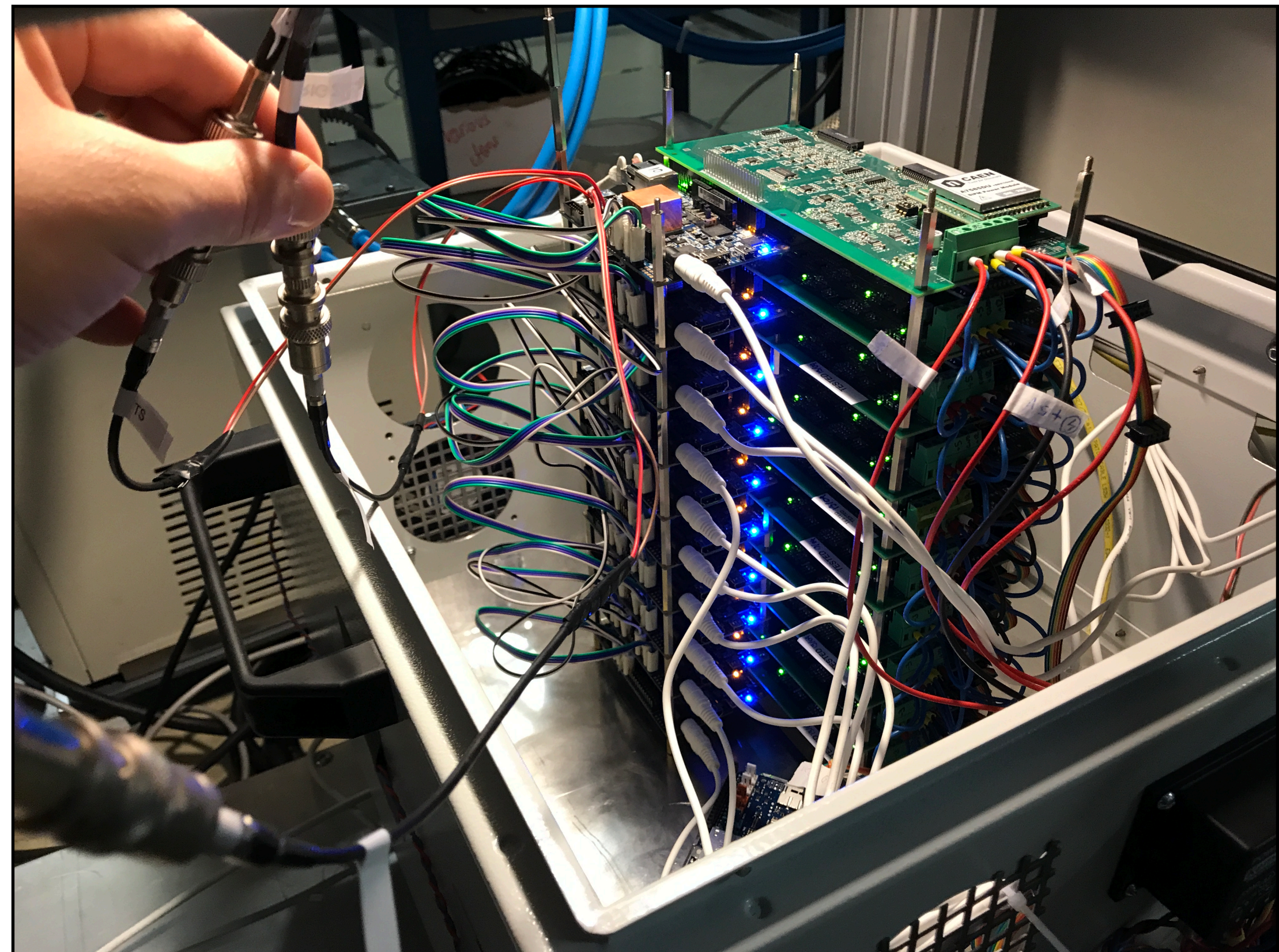
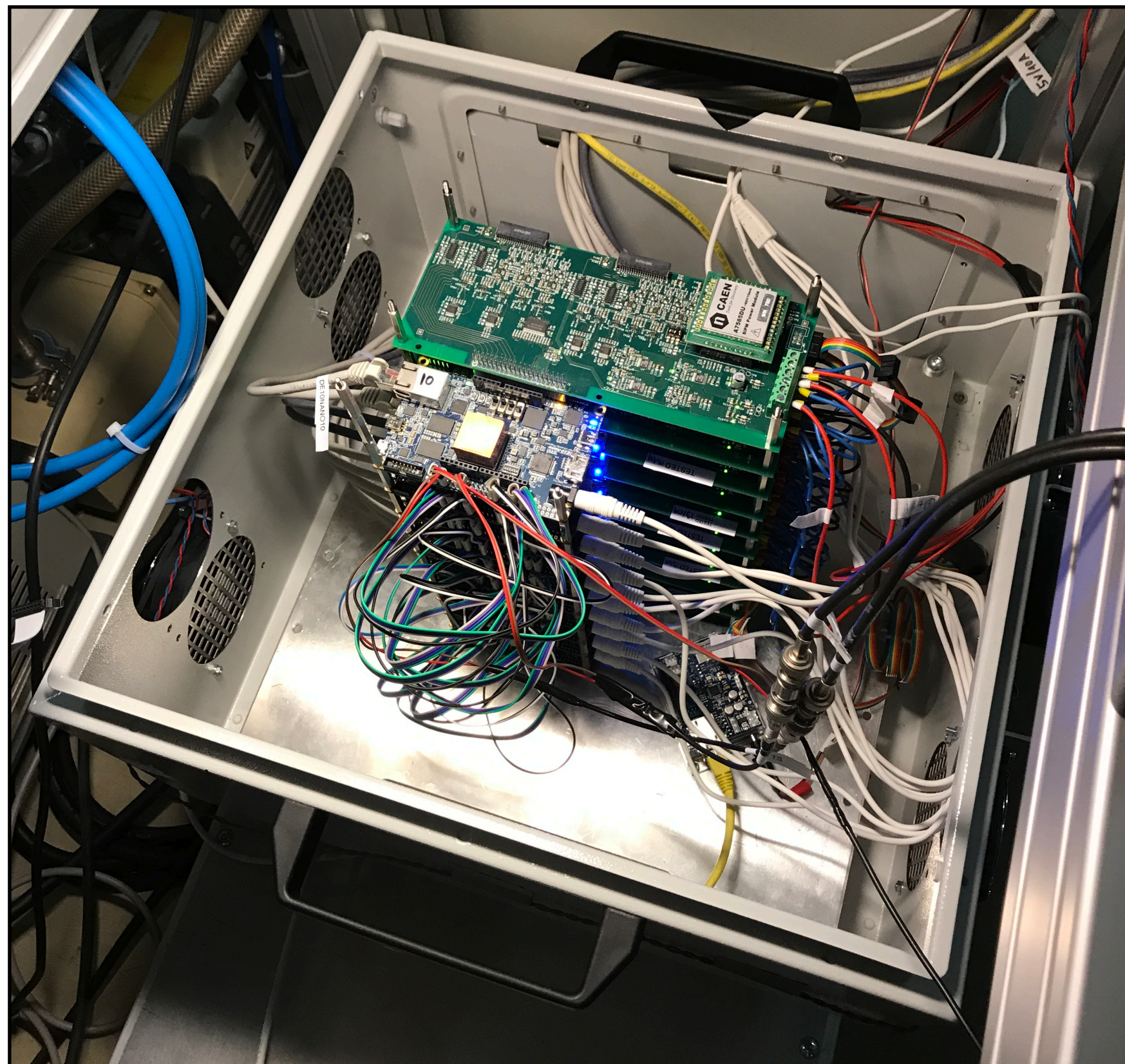


Engineering by: D. Körper, S. Utz, E. Casarejos

From R3BRoot simulations by A. Revel

Acc. (p,2p)	20%
Res. Theta	2mrad
Res. Vertex_Z	0,17mm
Res. MissM (p,2p)	4,5MeV
Acc. (p,2pn) t,u>0.5GeV/c2	35%
Res. MissP (p,2pn)	3,8MeV

Electronics stack for 10 FOOT detectors

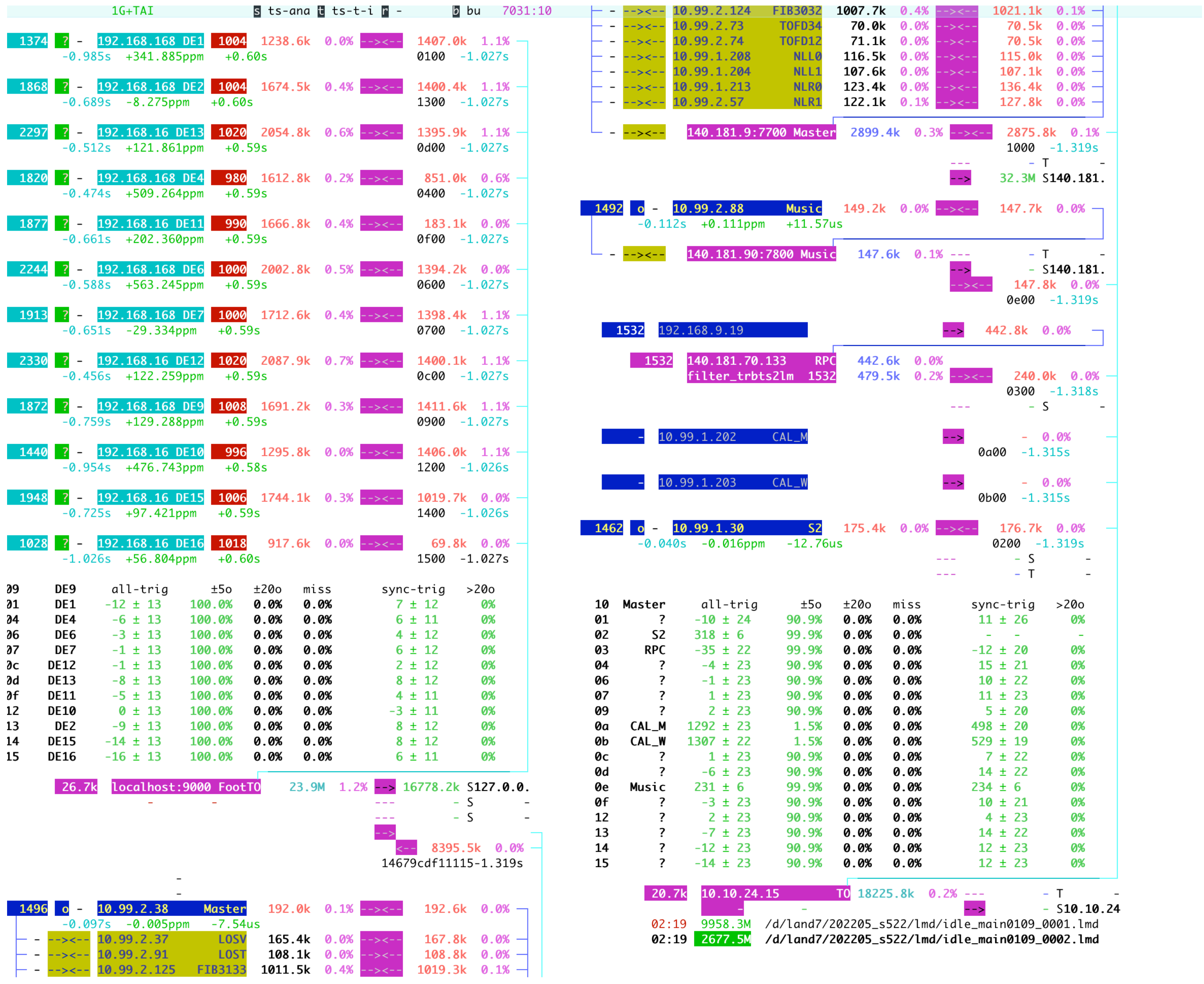


Electronics arrangement near the beam line (s522/s509)

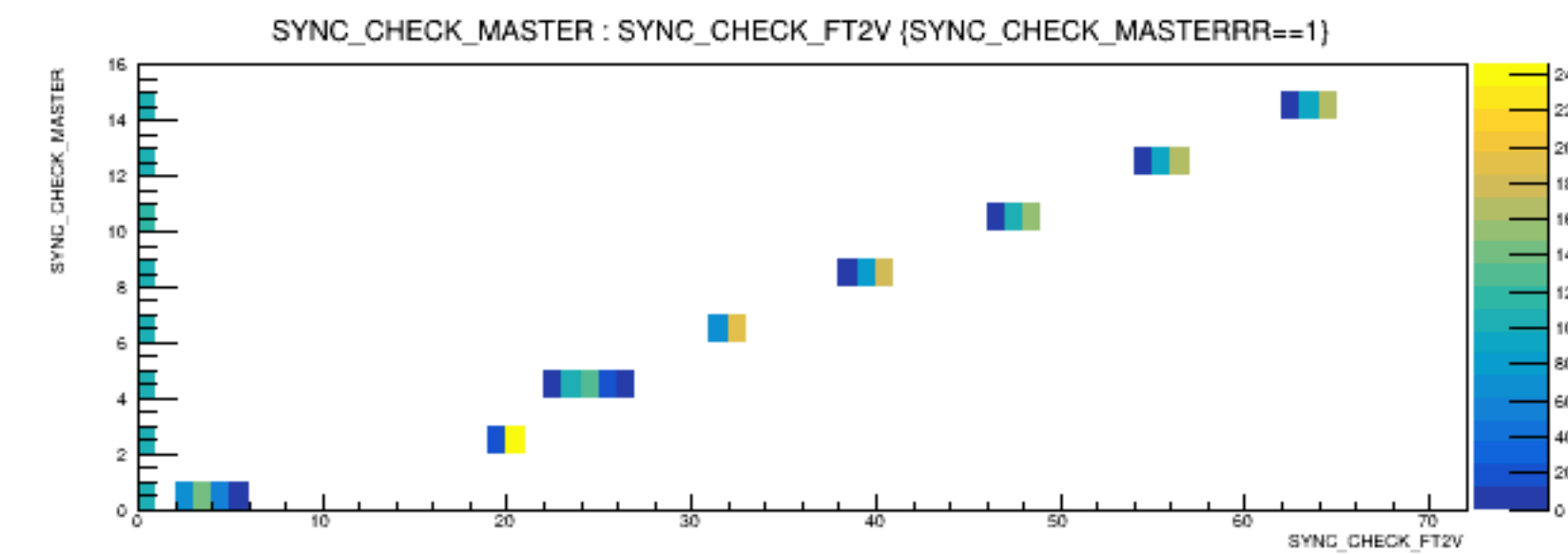
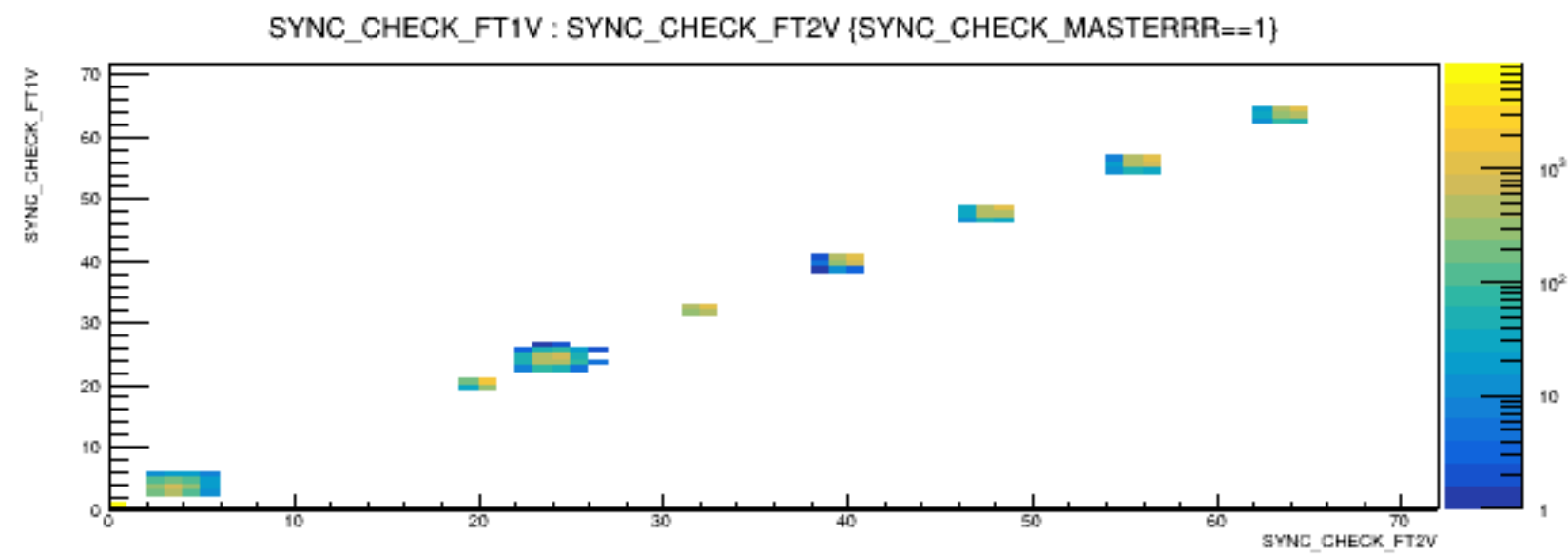
Additional box for two external FOOTs mounted on the air side



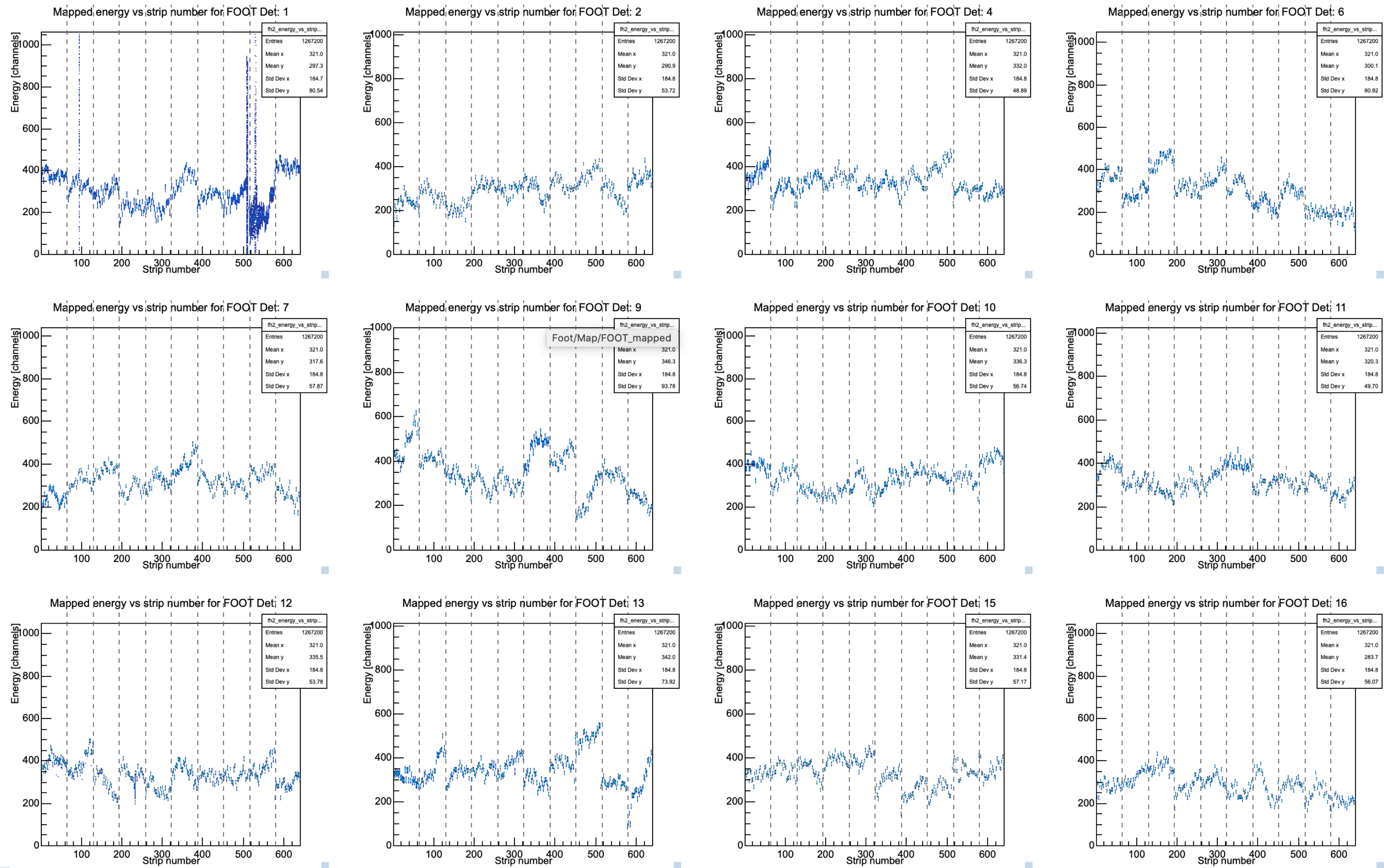
DAQ tree viewer with 12 FOOT



- Running DAQ with 12 FOOT detectors
 - 12 x 640 = 7680 readout channels
- TS synchronisation between different DAQ nodes
- Synchronisation and stable operation within main DAQ
- Main trigger (#1) and sync trigger from main DAQ
- Deadtime ~150 us in s522/s509

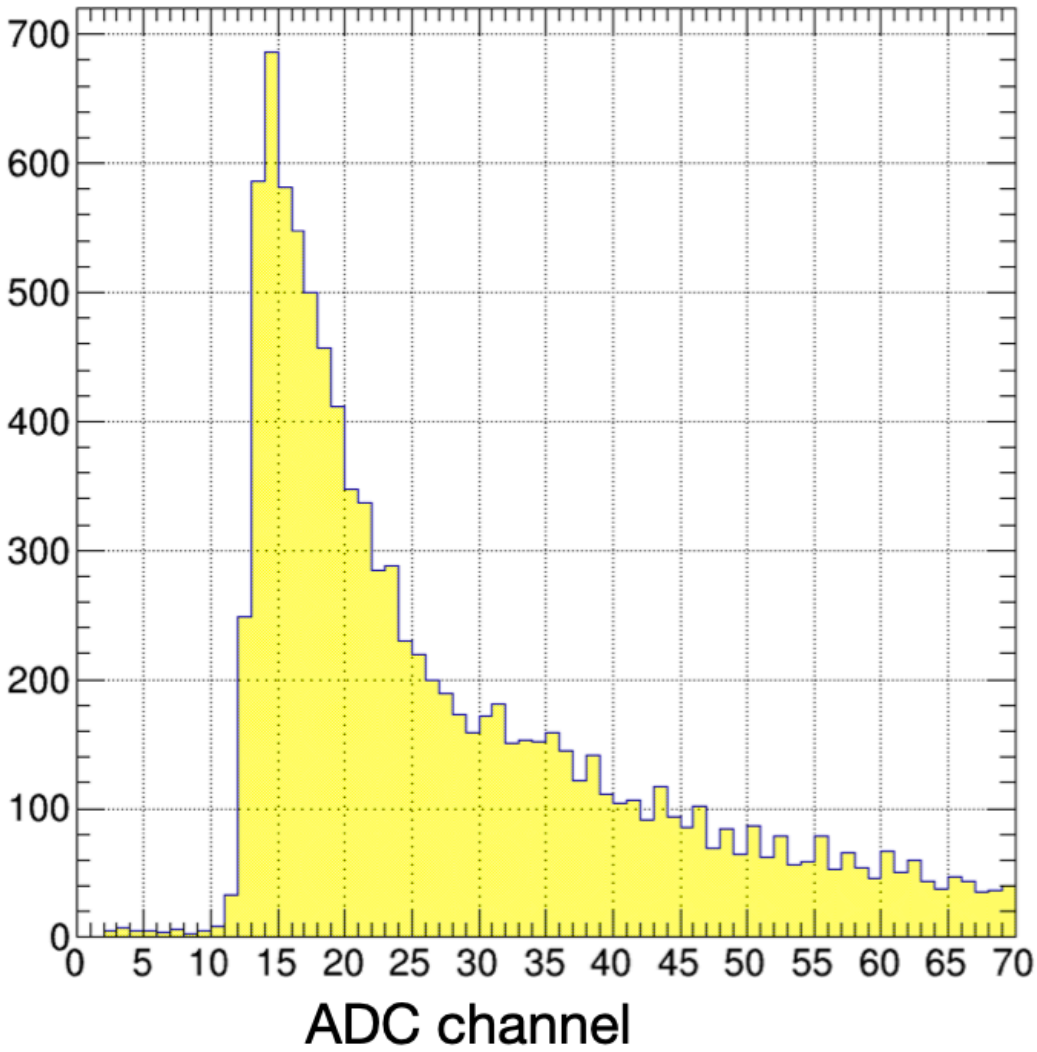


Raw pedestal data from 12 FOOT detectors in the final configuration

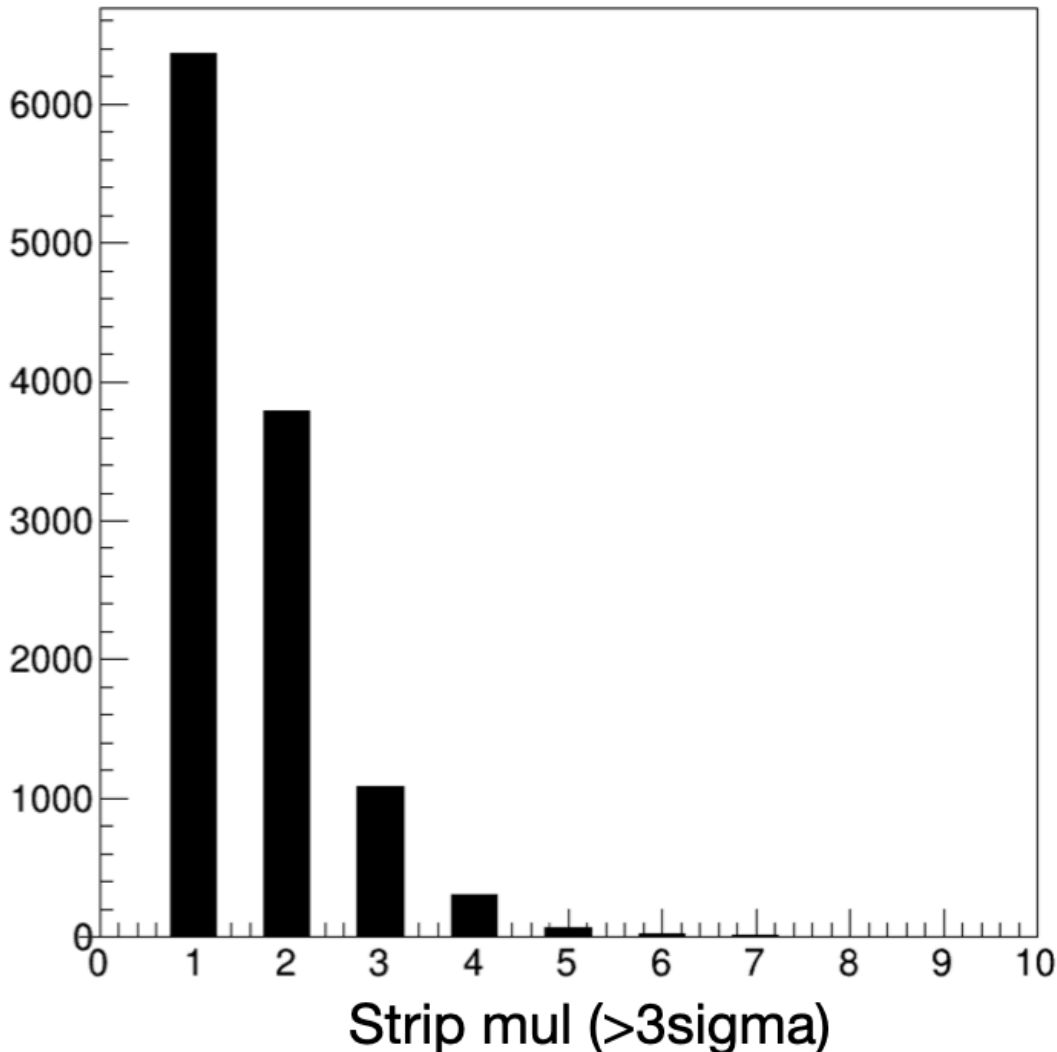


Proton signal in one arm detector

Total signal in one ASIC

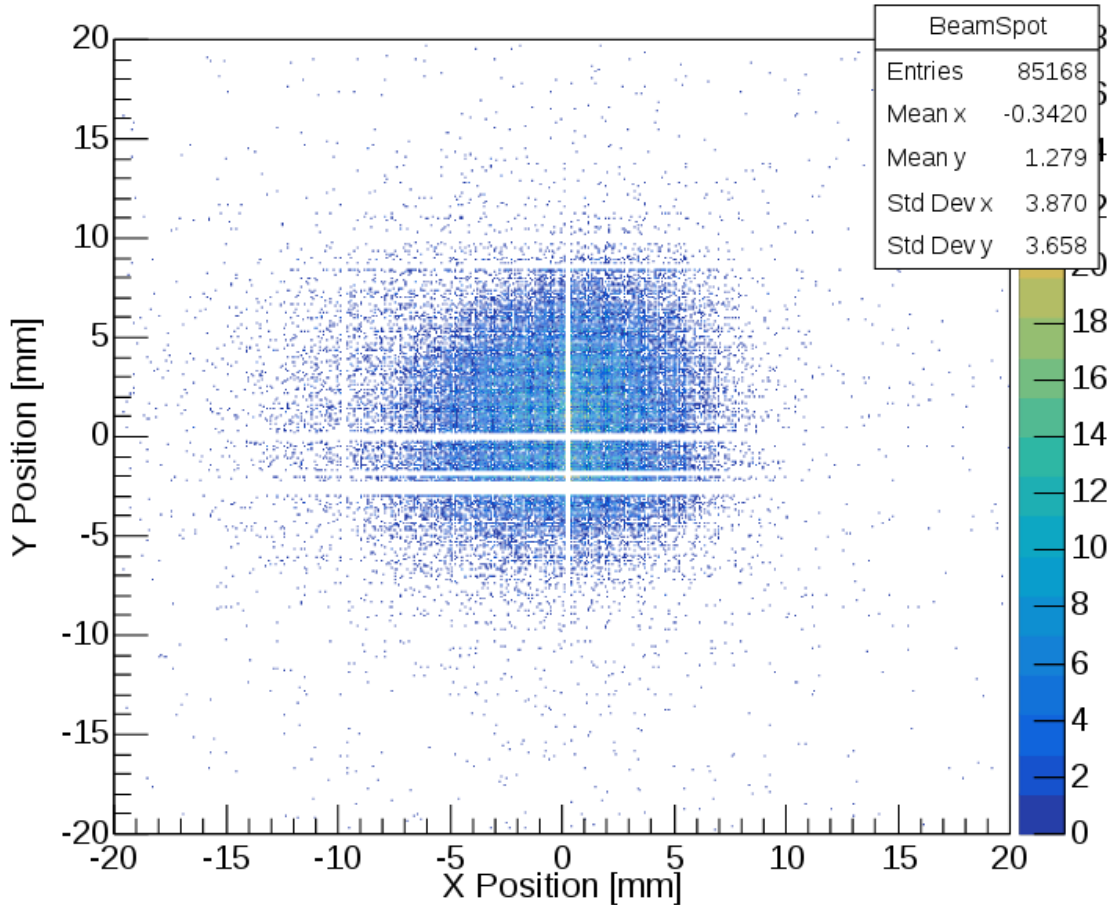


asic_strip_mul

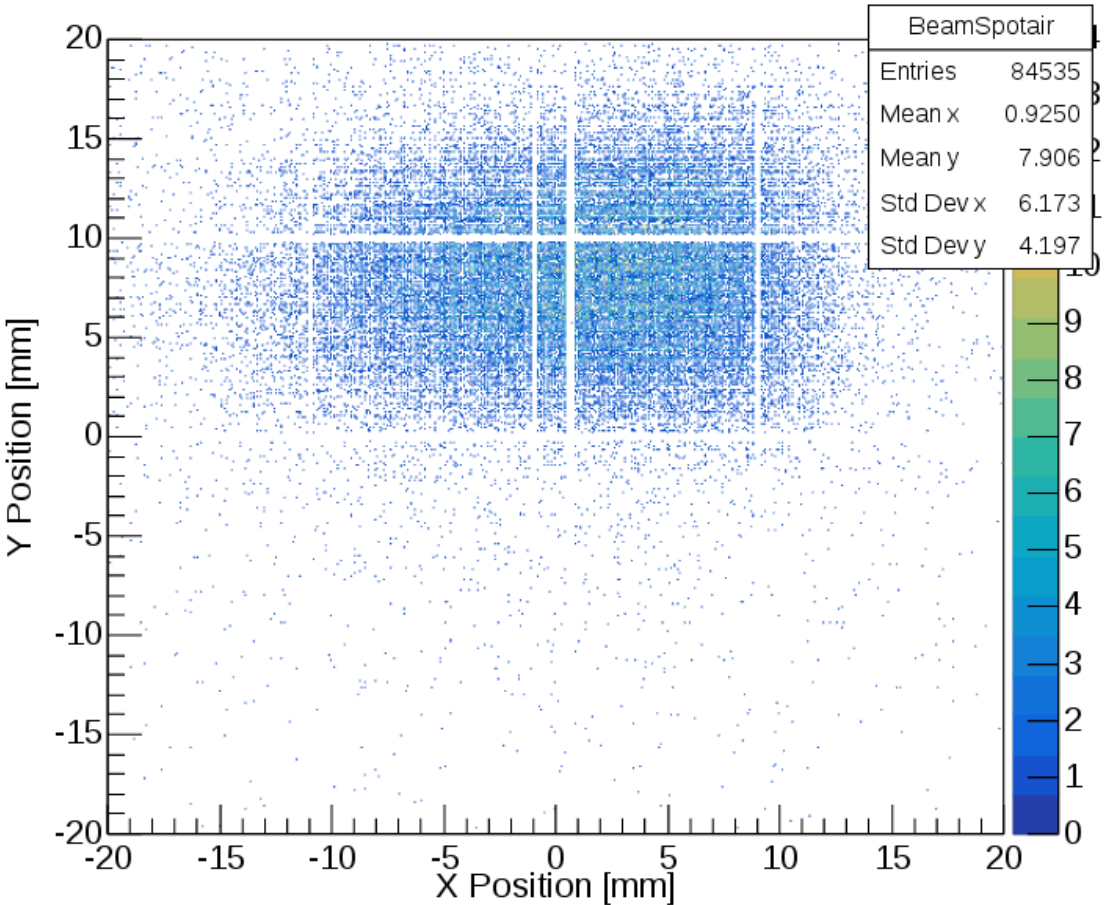


In-beam detectors

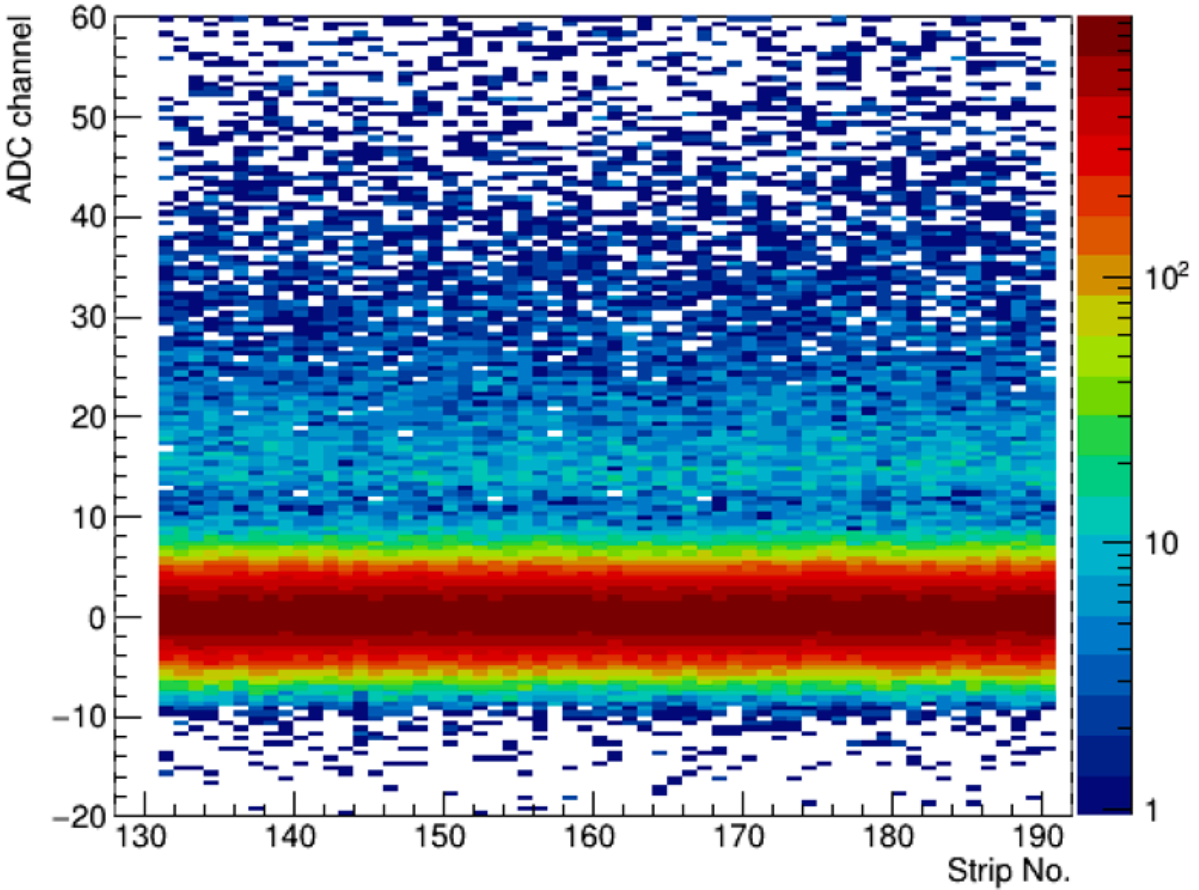
BeamSpot



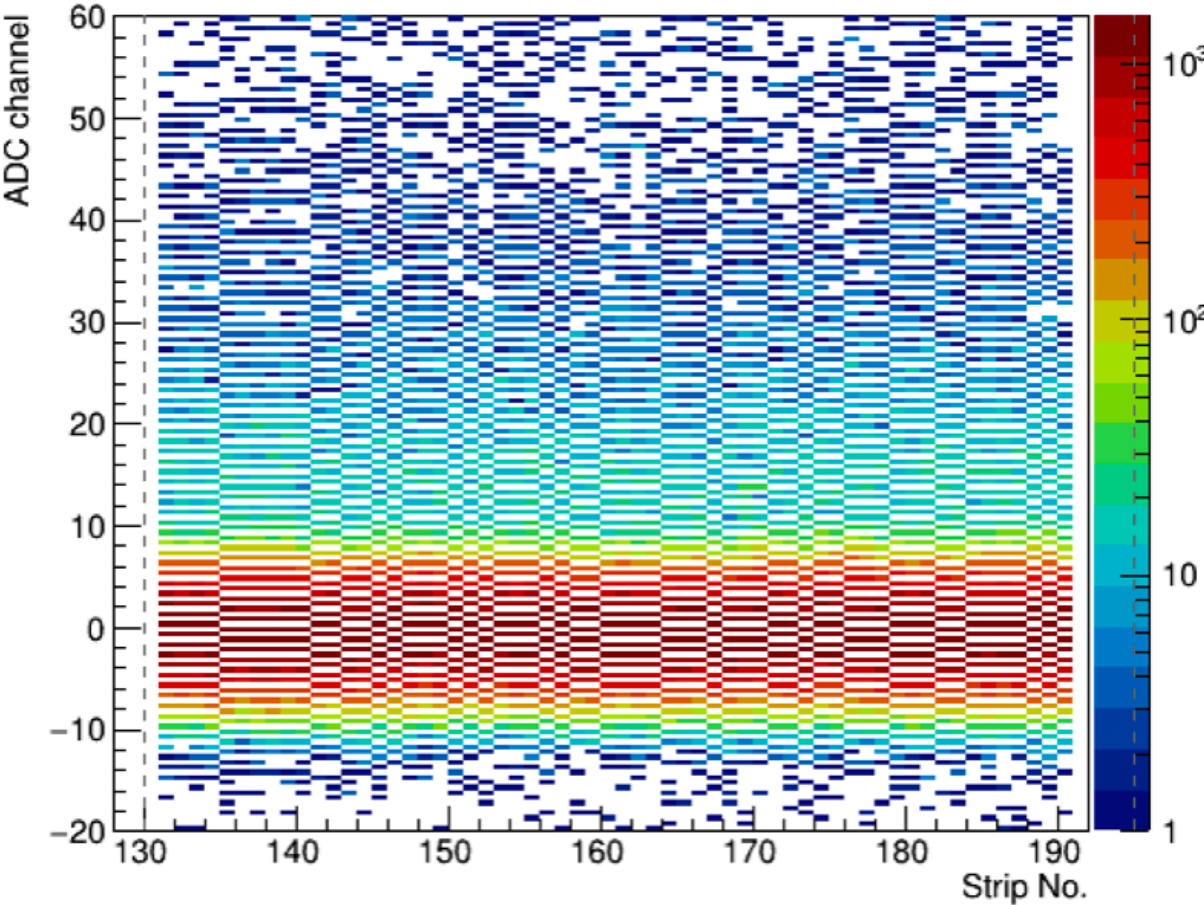
BeamSpot Air FOOT



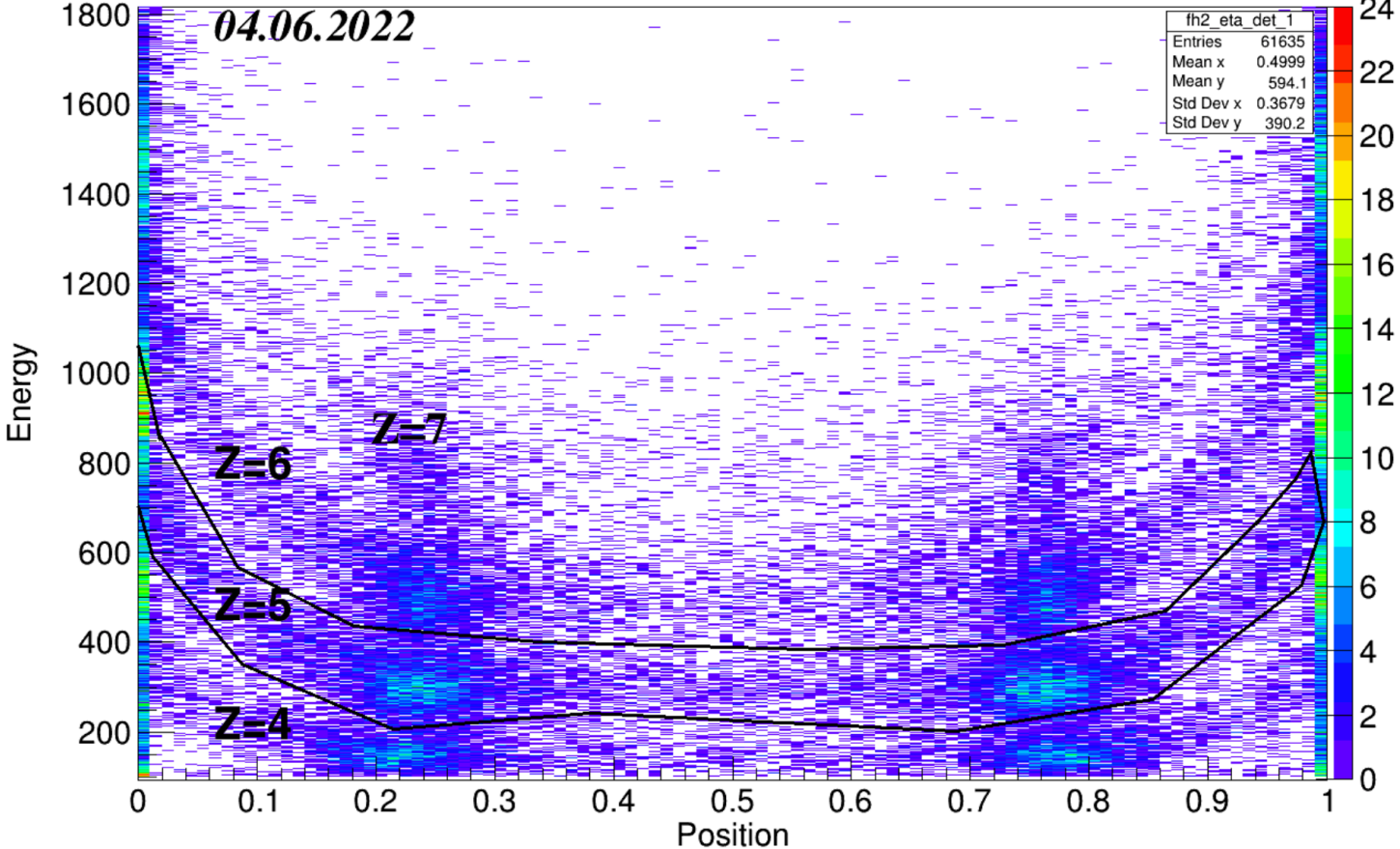
Fine correction of baseline



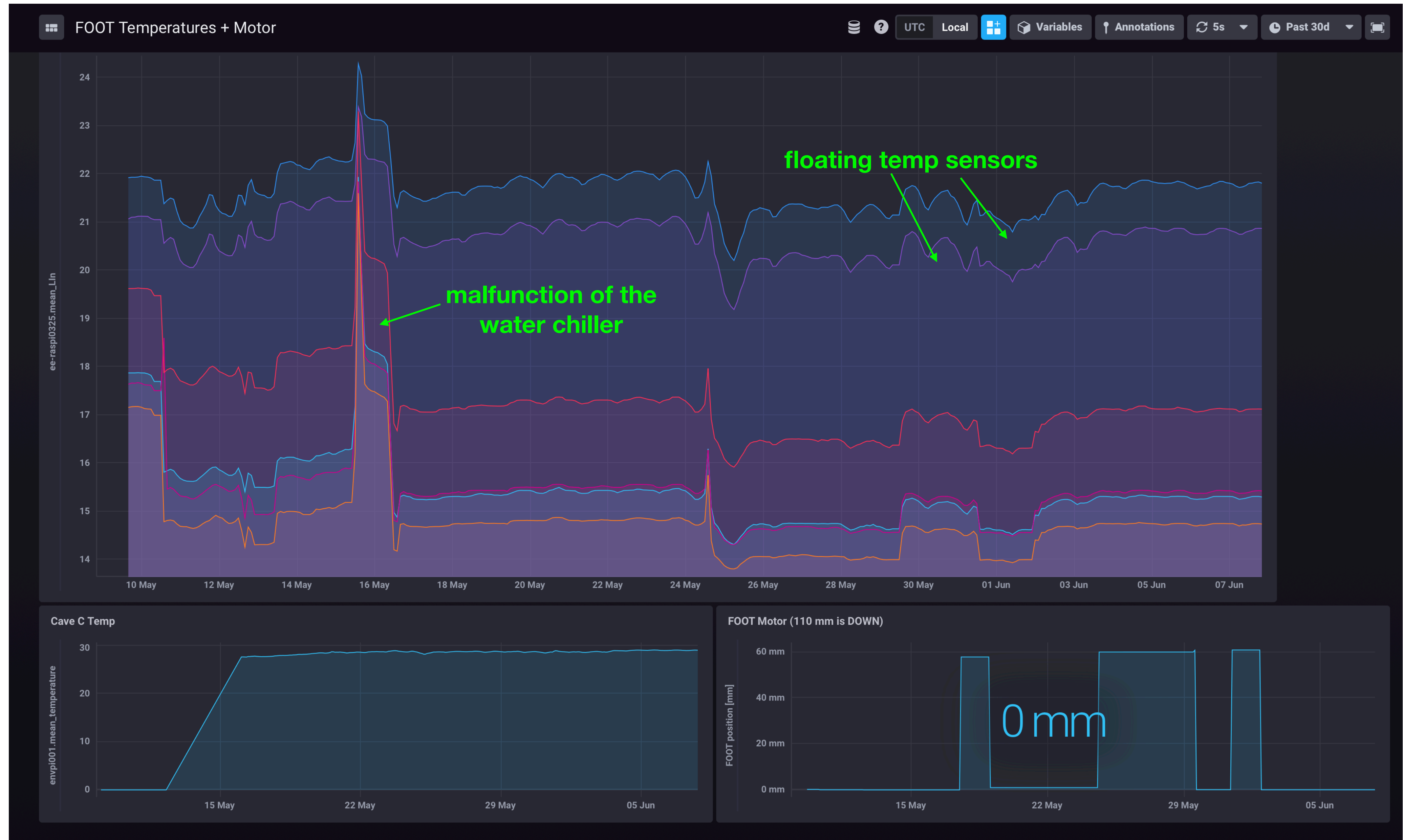
Only pedestal subtraction



Cluster eta function for FOOT1 x det in-beam



Snapshot of 30-days chronograph data



FOOT people

Bastian Löher, Hans Törnqvist, Martin Bajzek, Alexandra & Ionut Stefanescu, Aldric Revel, Andrea Lagni, Antoine Barrière, Alexander Knyazev, Karsten Koch, Kei Kokubun, Aaron Stott, Daneil Körper, Sergei Utz, Anna Corsi, Andrea Jedele, Luke Rose, Eleonora Kudaibergenova, Valerii Panin, Emmanuel Pollaco and many others

Thank you!