Detectors

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g–2 Operational Readiness Review

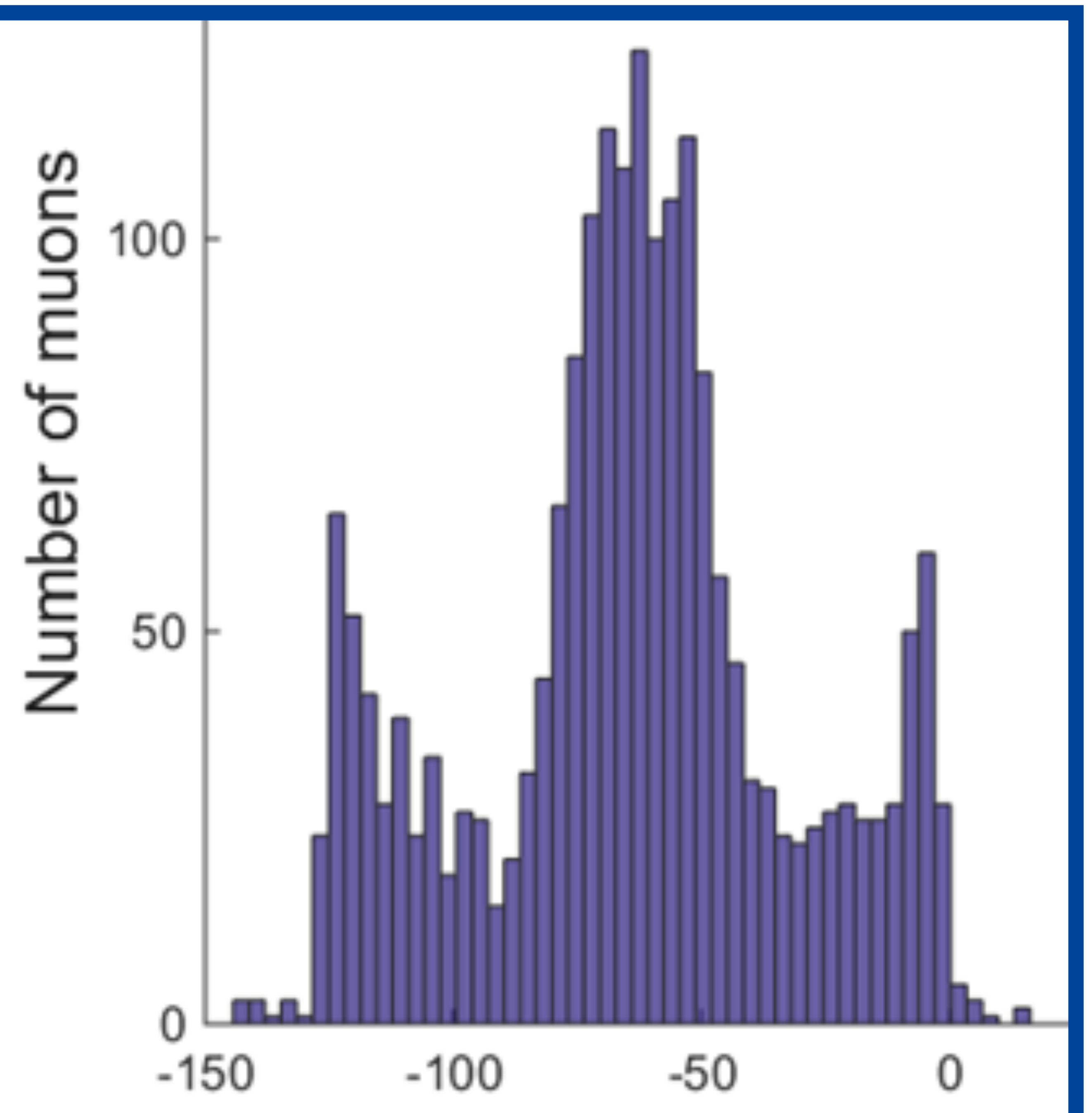
2 October 2017

Outline: a walk through detectors as beam sees them

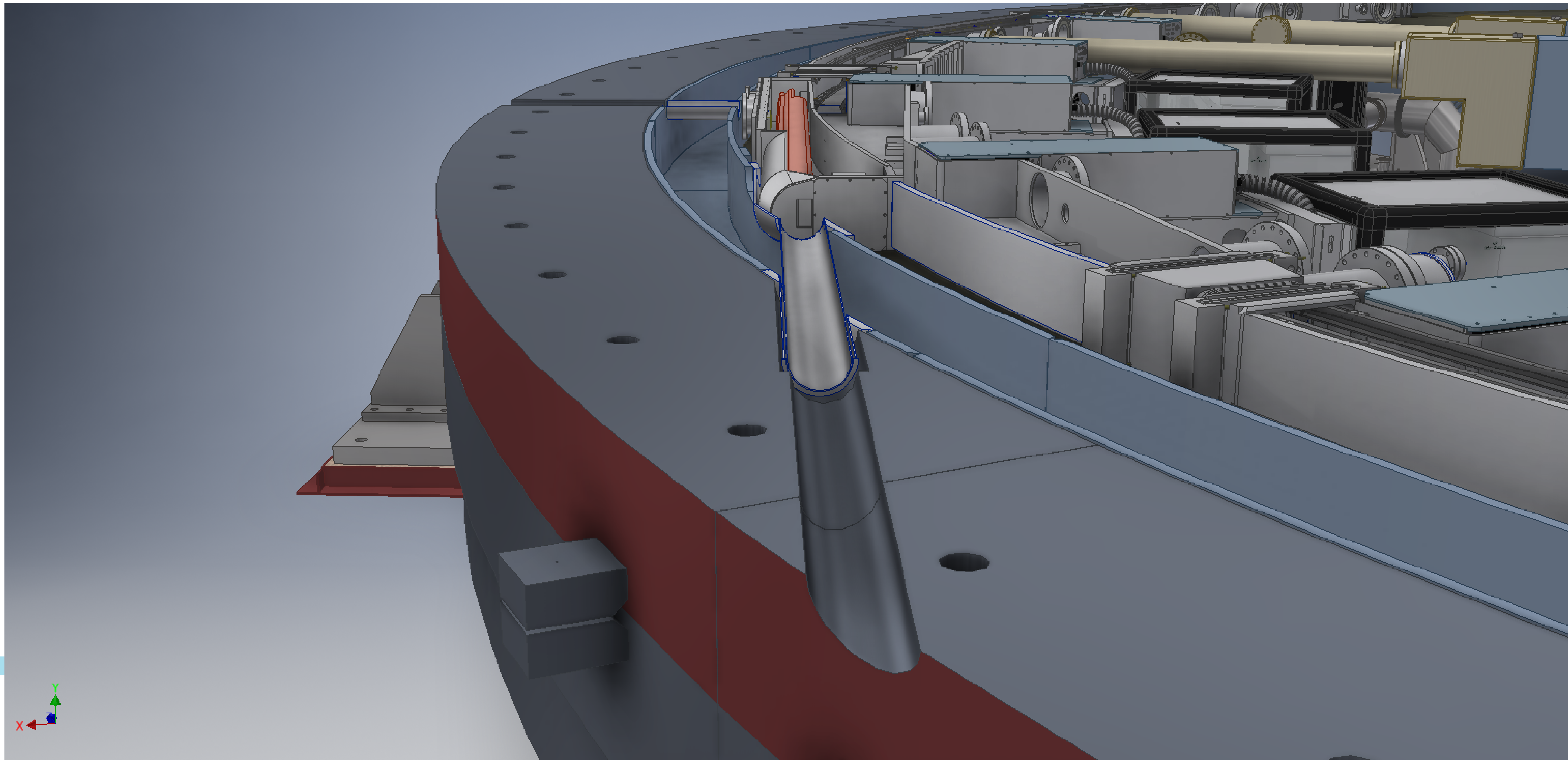
- Entrance counters: T0, IBMS
- Fiber harps
- Trackers
- Calorimeters
- Laser calibration
- Clock, trigger, and blinding
- Aux detectors (Quad, Kicker, trigger)

Beam entrance detectors deliver

1. absolute time when beam enters the storage ring; T0
2. spacial and time profile of the beam
3. synchronization between beam and other detectors
4. absolute count of particles in each fill



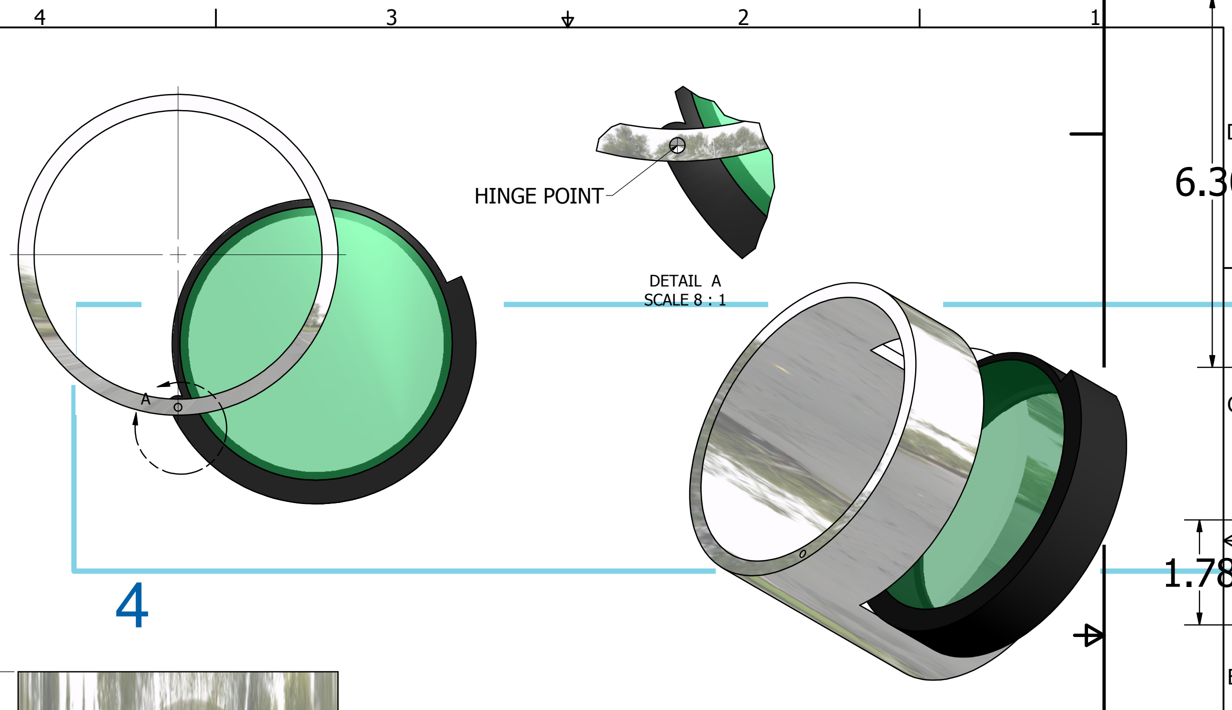
Intensity profile is 120 ns wide with "W" shape

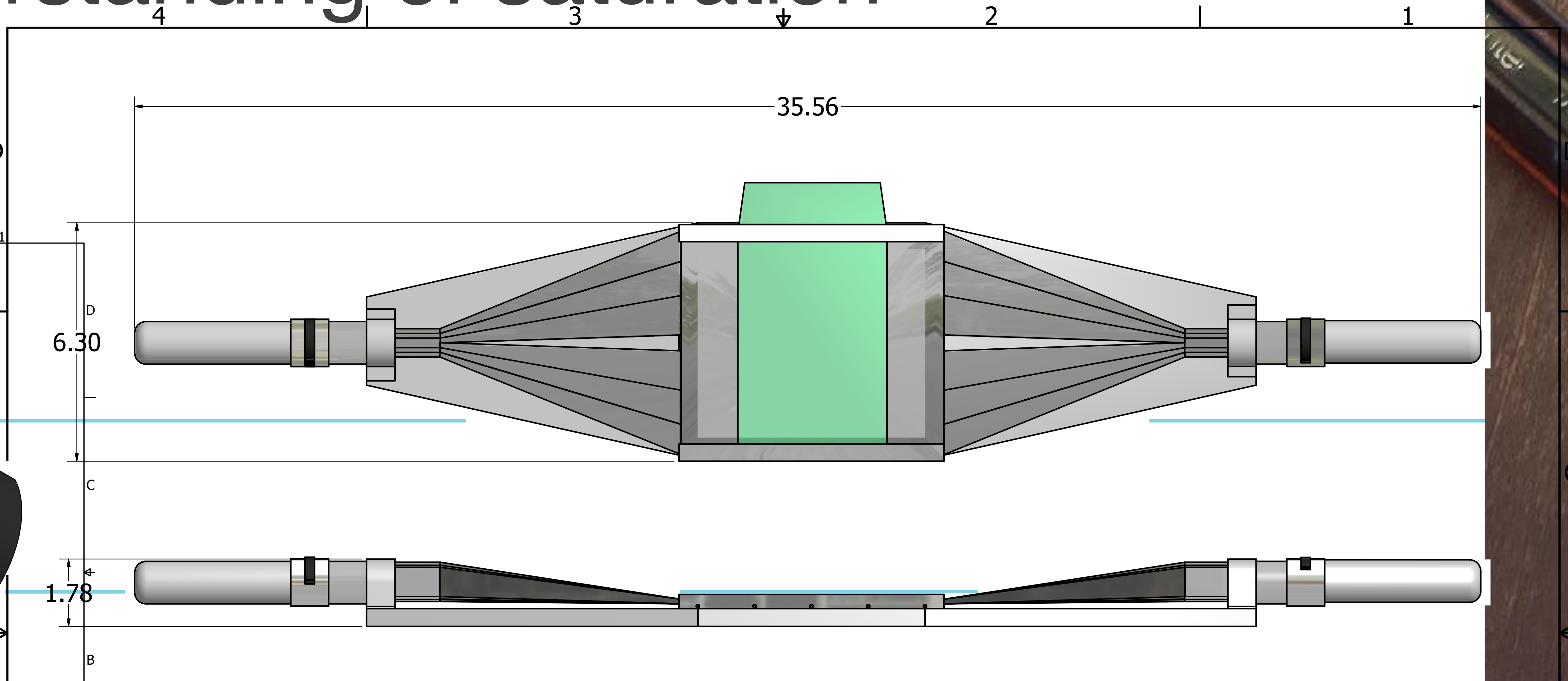


Time Zero counter

1mm thick plastic scintillator
with light mixing guides, and insertable ND filters
readout by 2 PMT’s, and 1 SiPM (single MIP’s)
laser fiber for synchronization

lessons from the engineering run:
wider gain range needed,
and better understanding of saturation





Time Zero redundancy

redundancy to understand saturation:

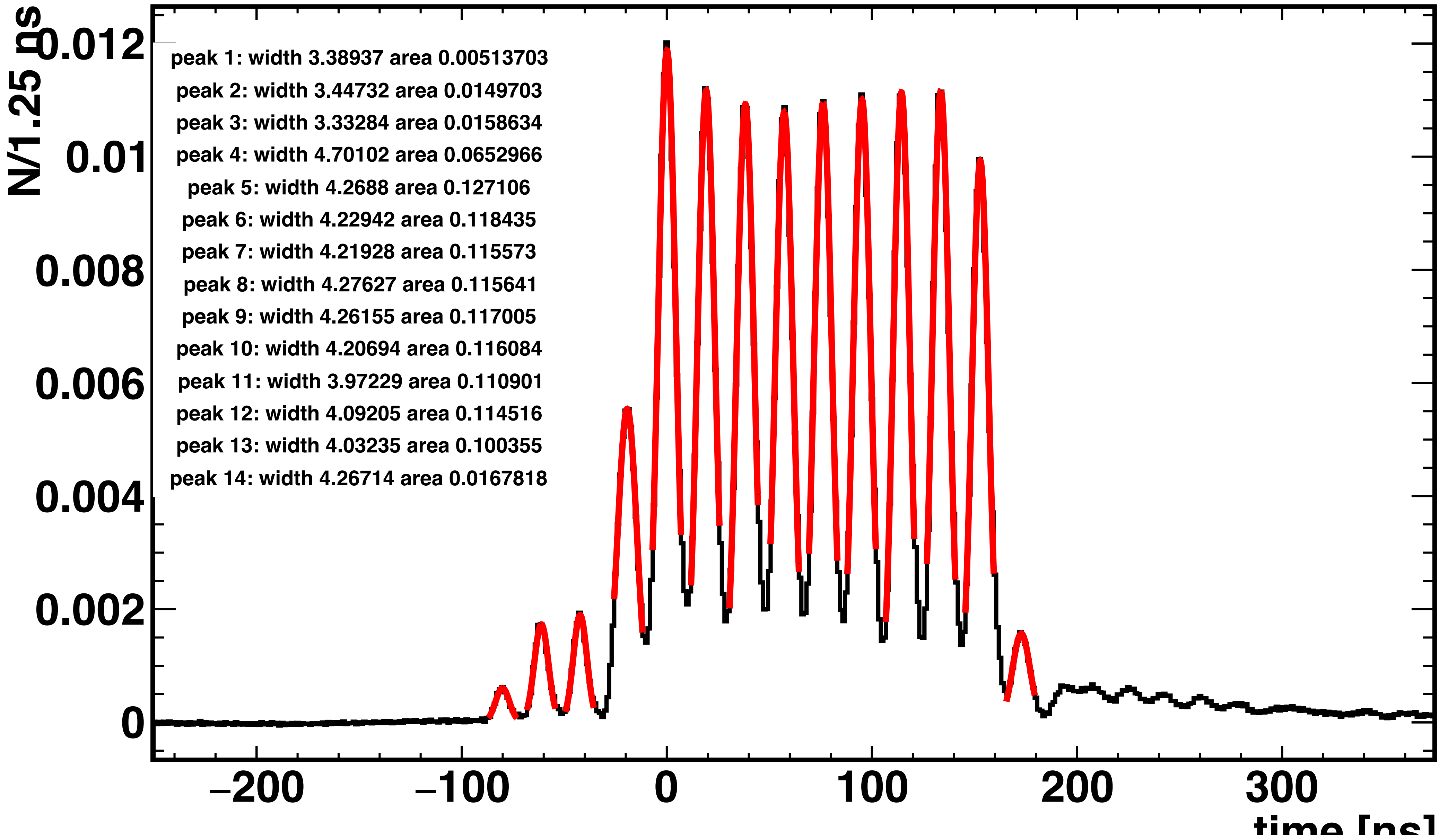
T0, upstream beam monitors Q019, Q020, initial splash in calorimeters

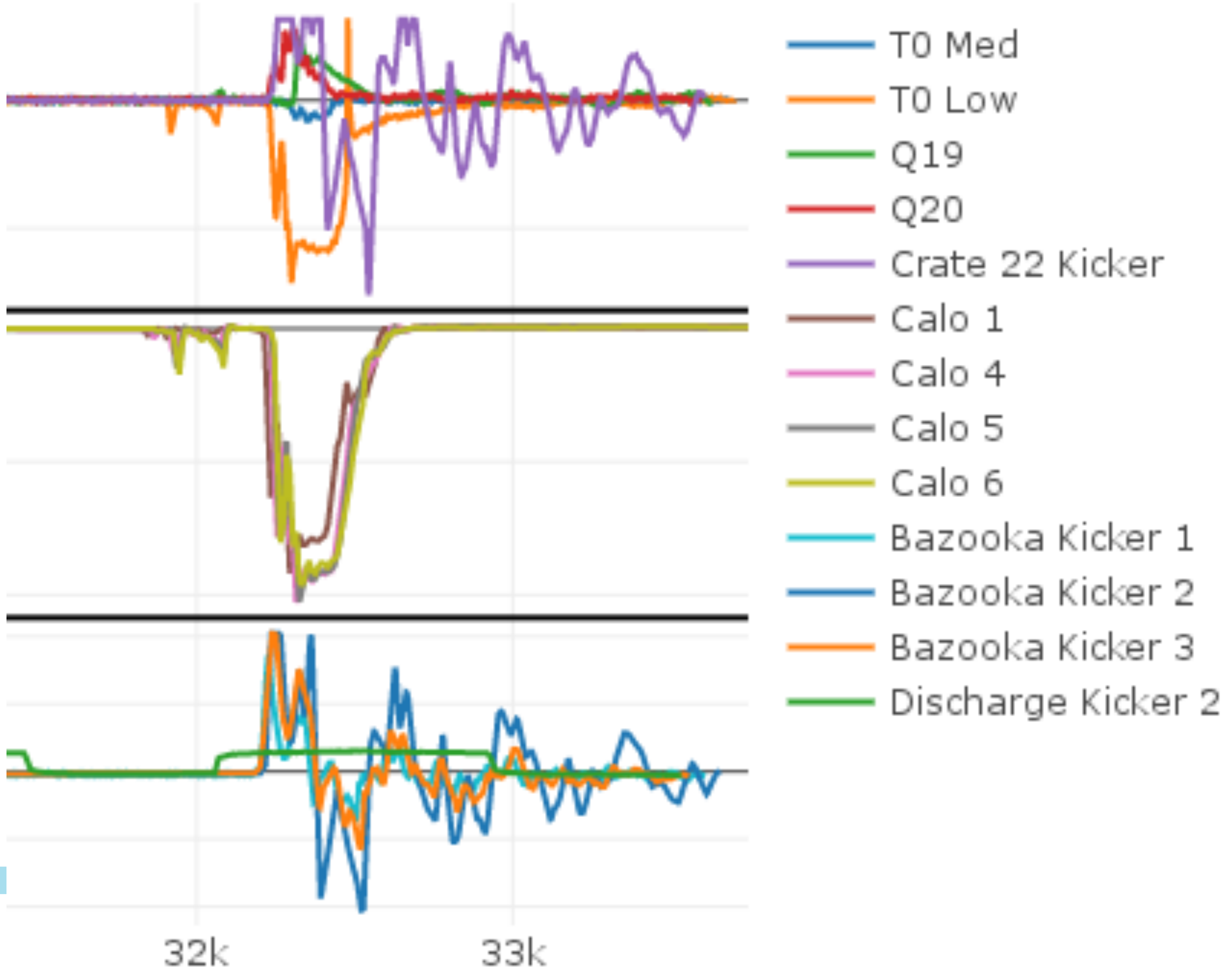
offline analysis: muon+pion and proton ratio

online DQM: kicker timing

work to do:

install the upgraded detector

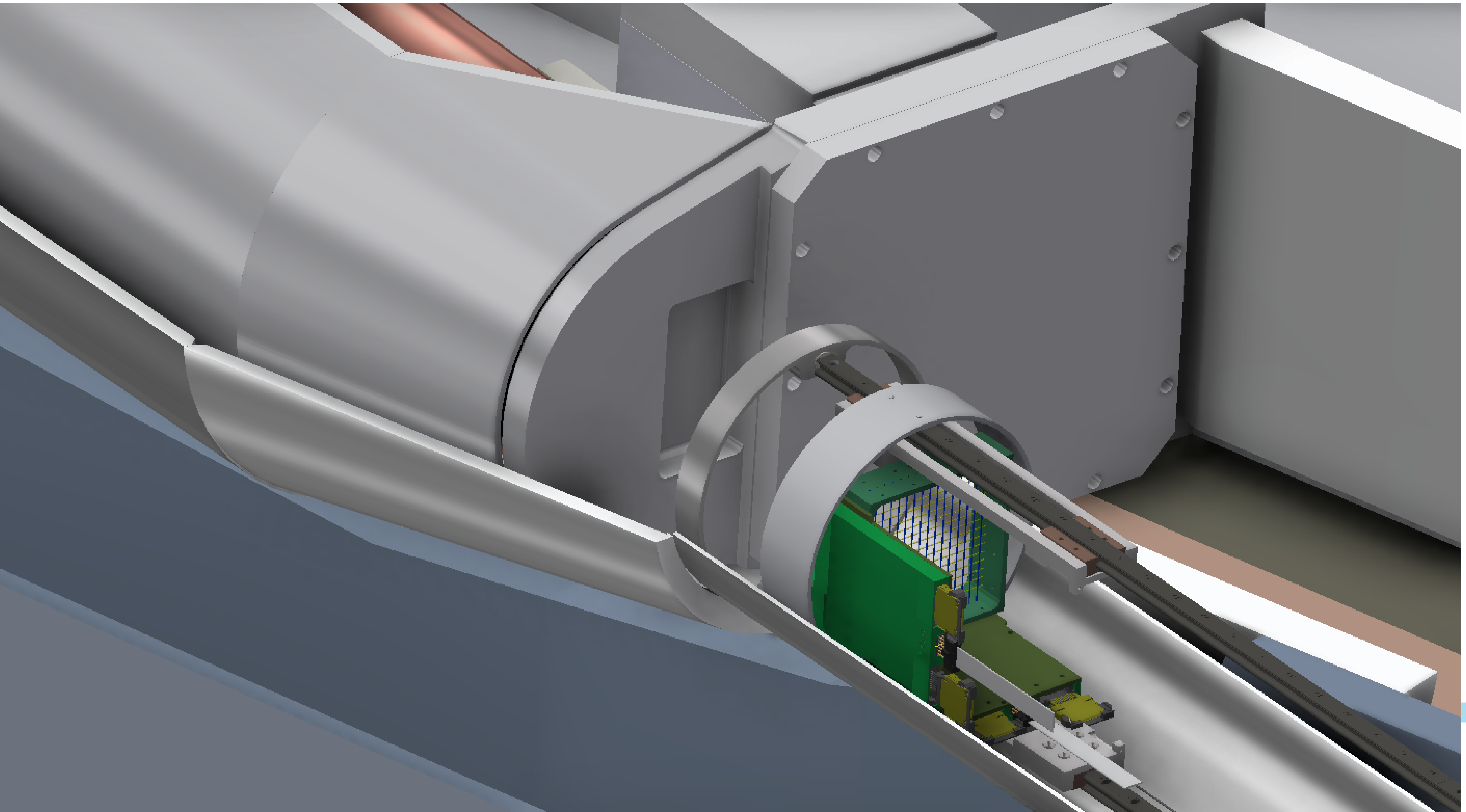


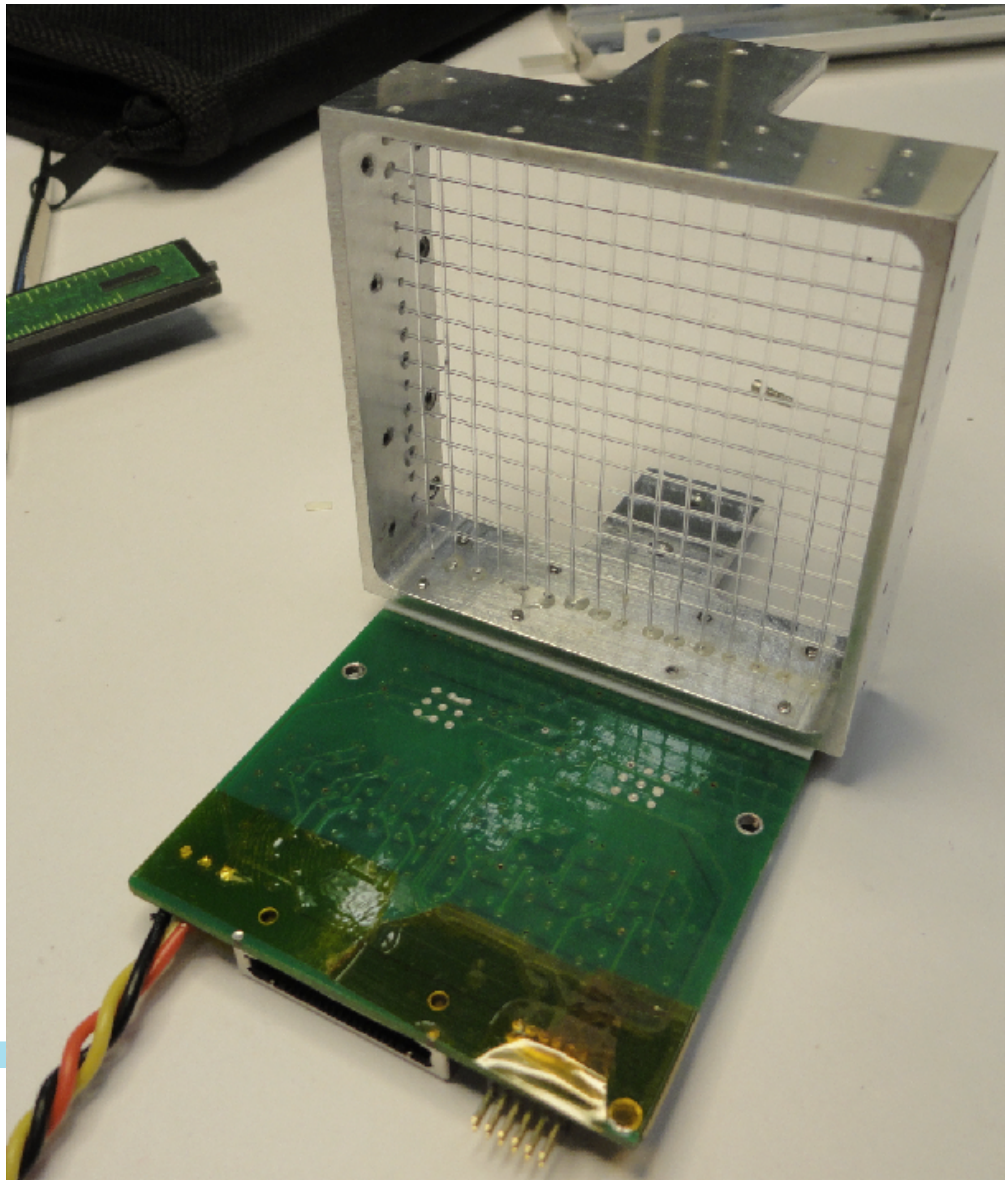


In-beam monitoring system

three grids of scintillating fibers:

1. entrance to the yoke hole (being added during the shutdown)
2. exit of the yoke hole, and entrance window of the inflector (engineering run)
3. exit of the inflector (next shutdown)

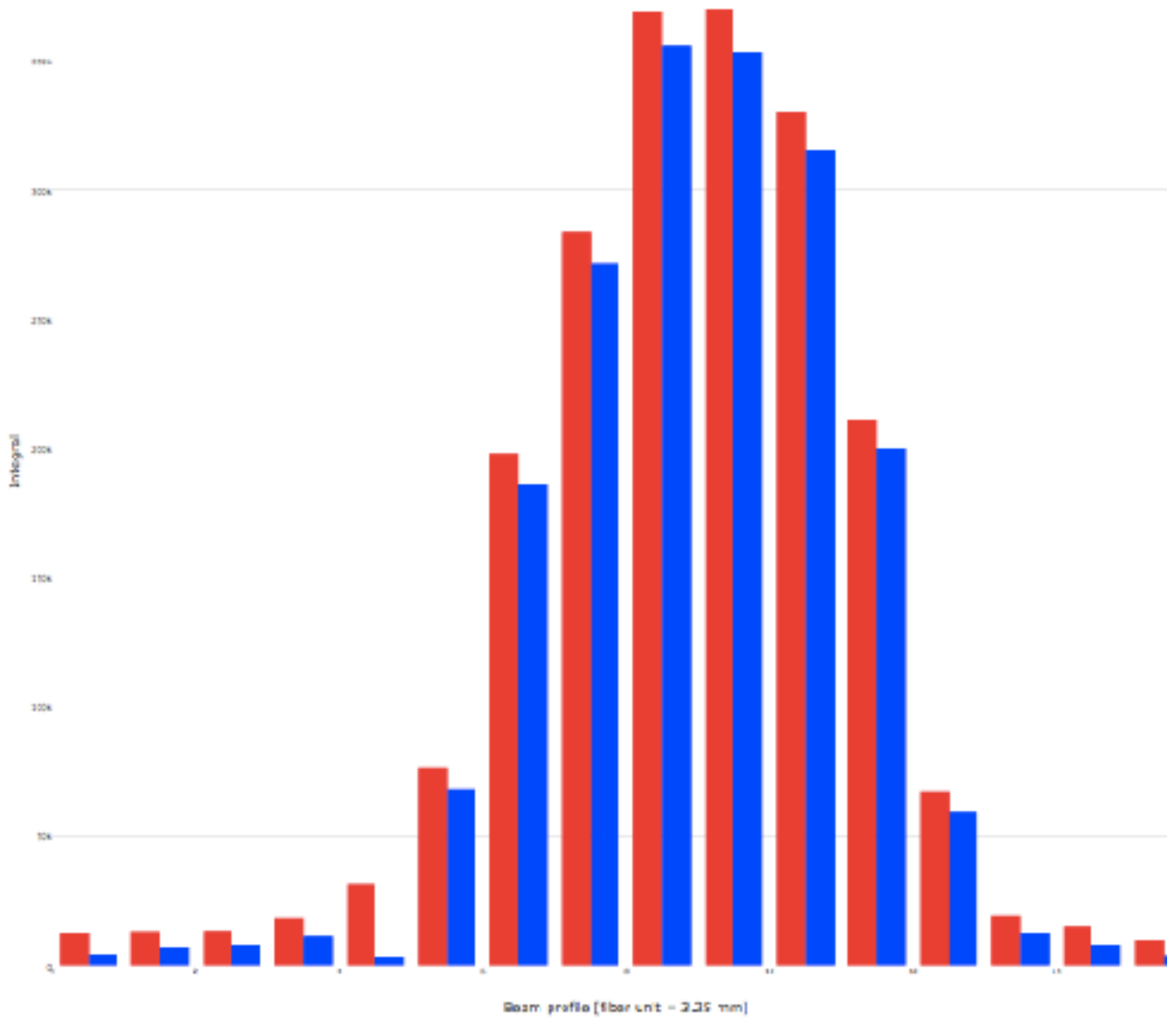


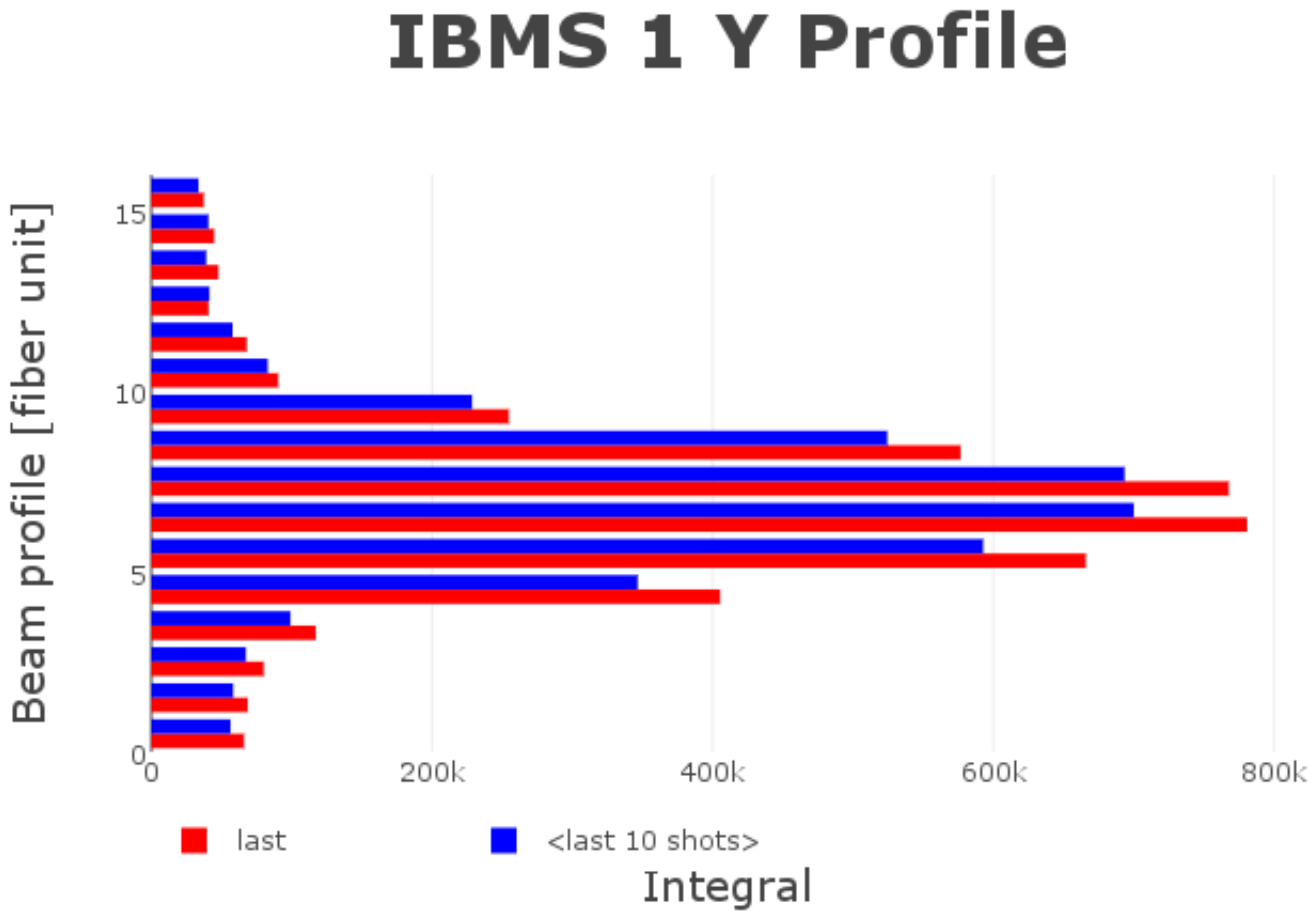


In-beam monitoring system readiness

- new LED calibration system for IBMS2 (gain saturation correction)
- well integrated into online monitoring and offline analysis tools
- IBMS1 and IBMS2 deliver beam position and direction through inflector

- work to do:
  - reinstall IBMS2
  - install & commission IBMS 1

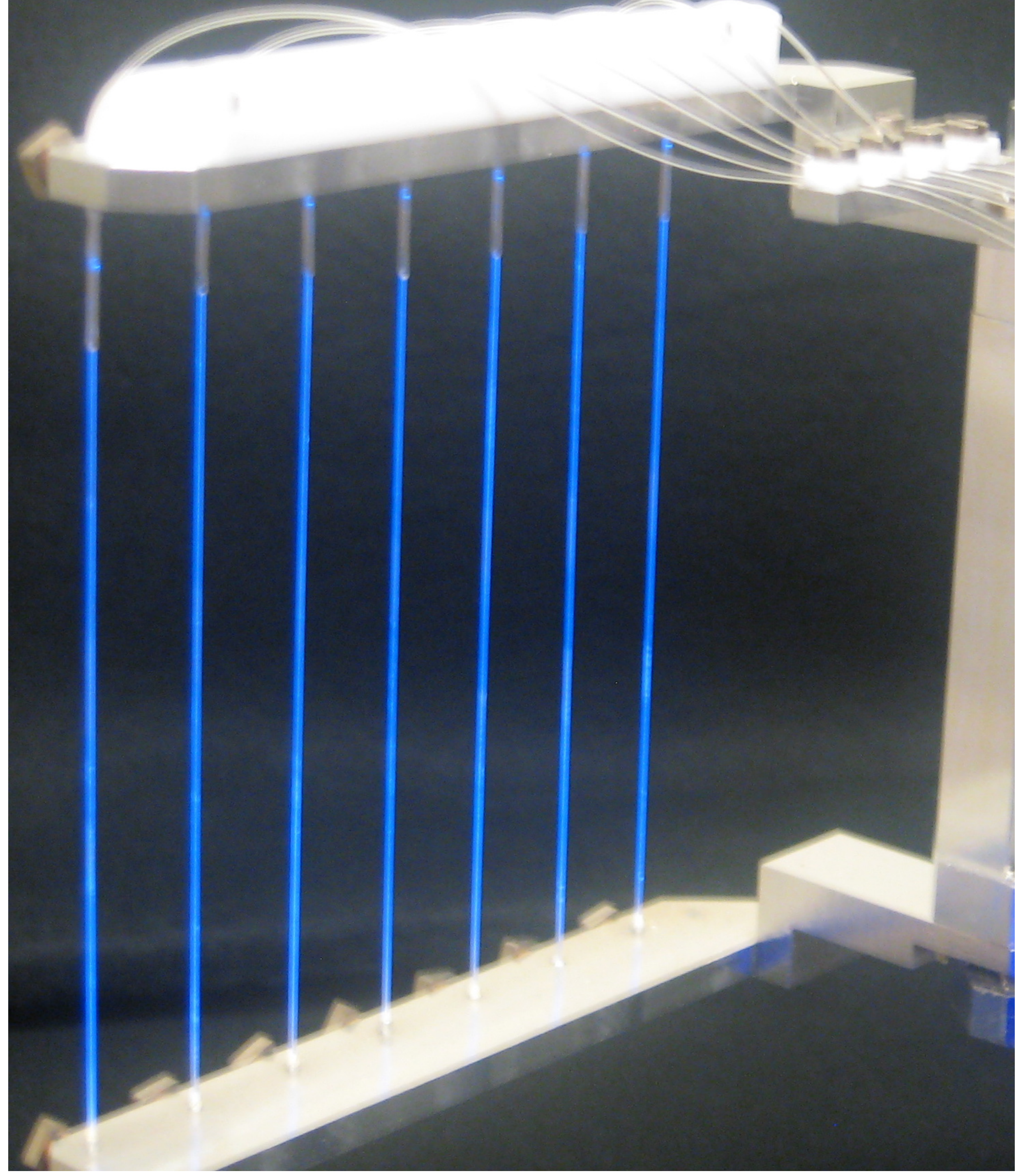


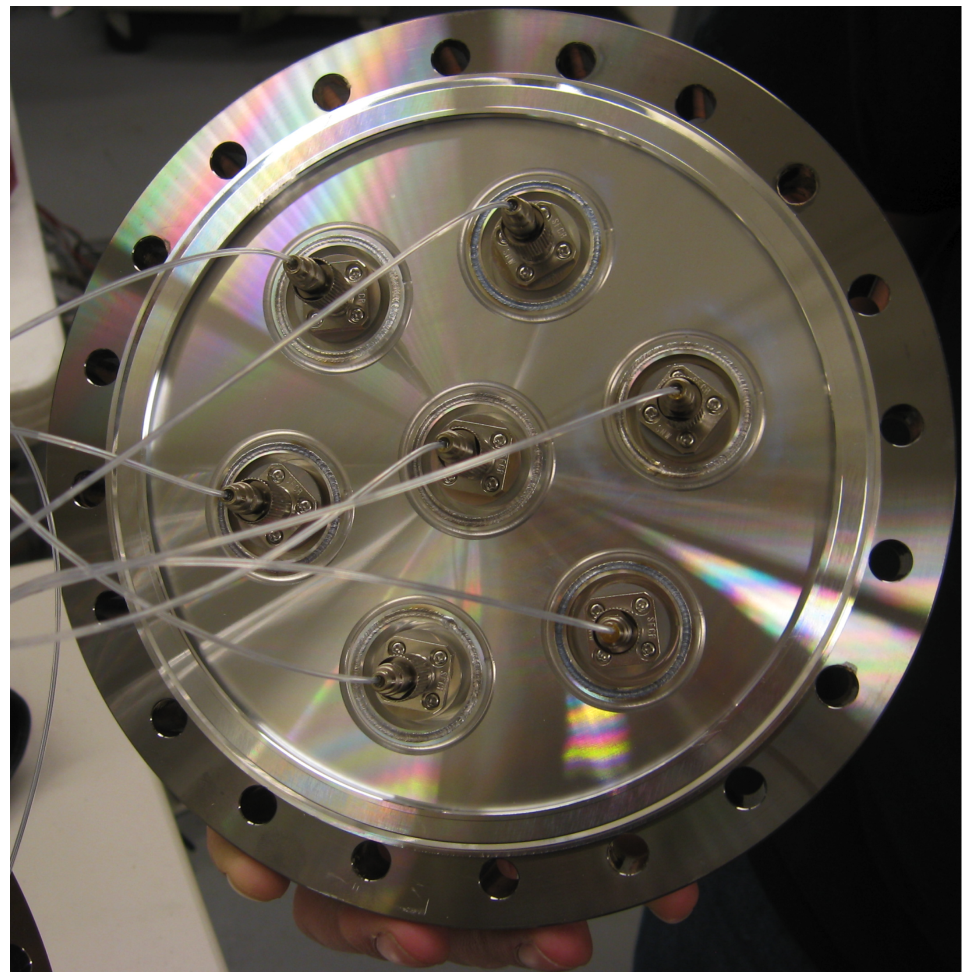


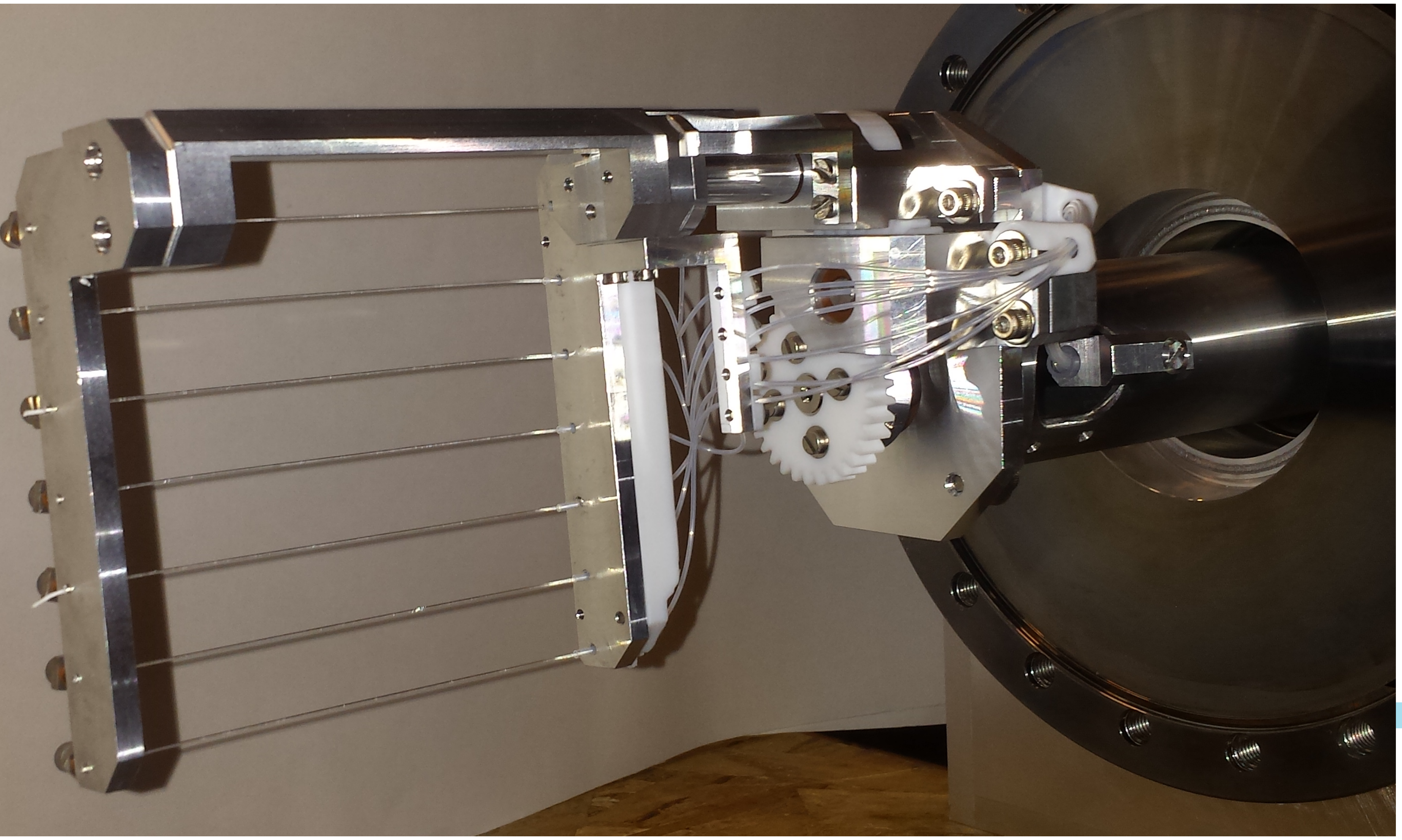
Fiber harps

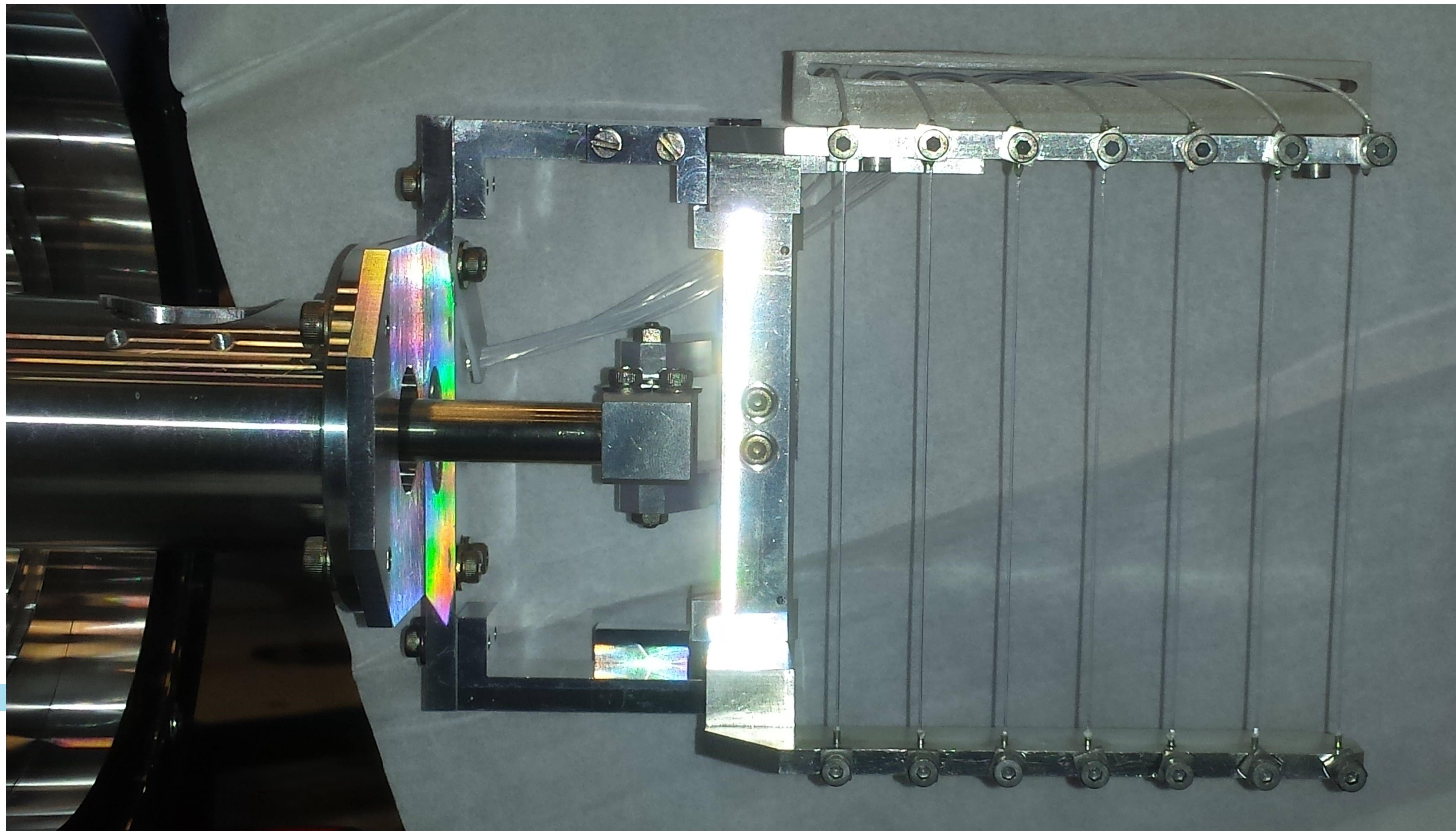
retractable devices that measure ***profiles*** of the stored ***beam***

intrusive way of measurement









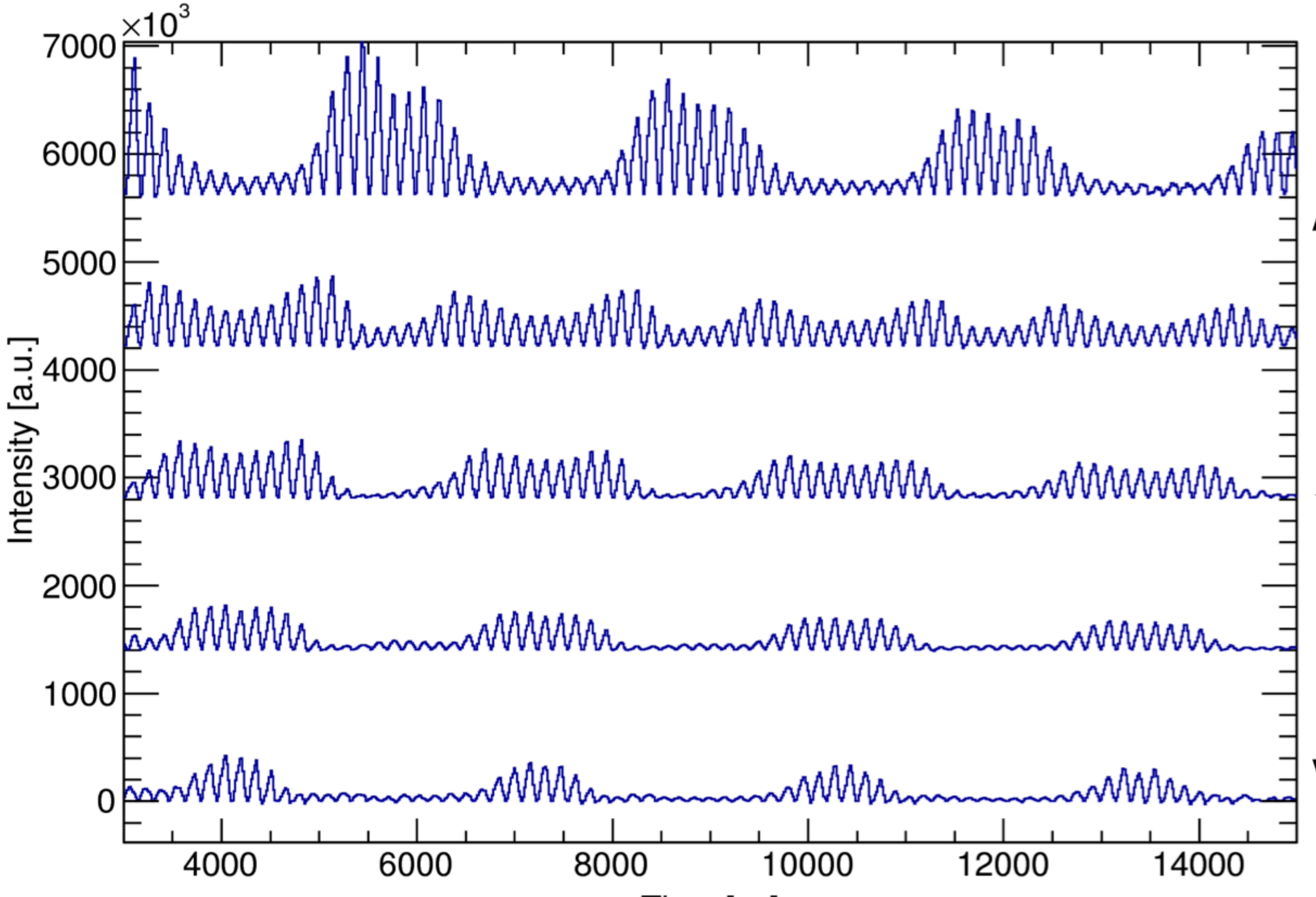
Fiber harp readiness

worked reliably during engineering run

refurbished and recalibrated for the physics run

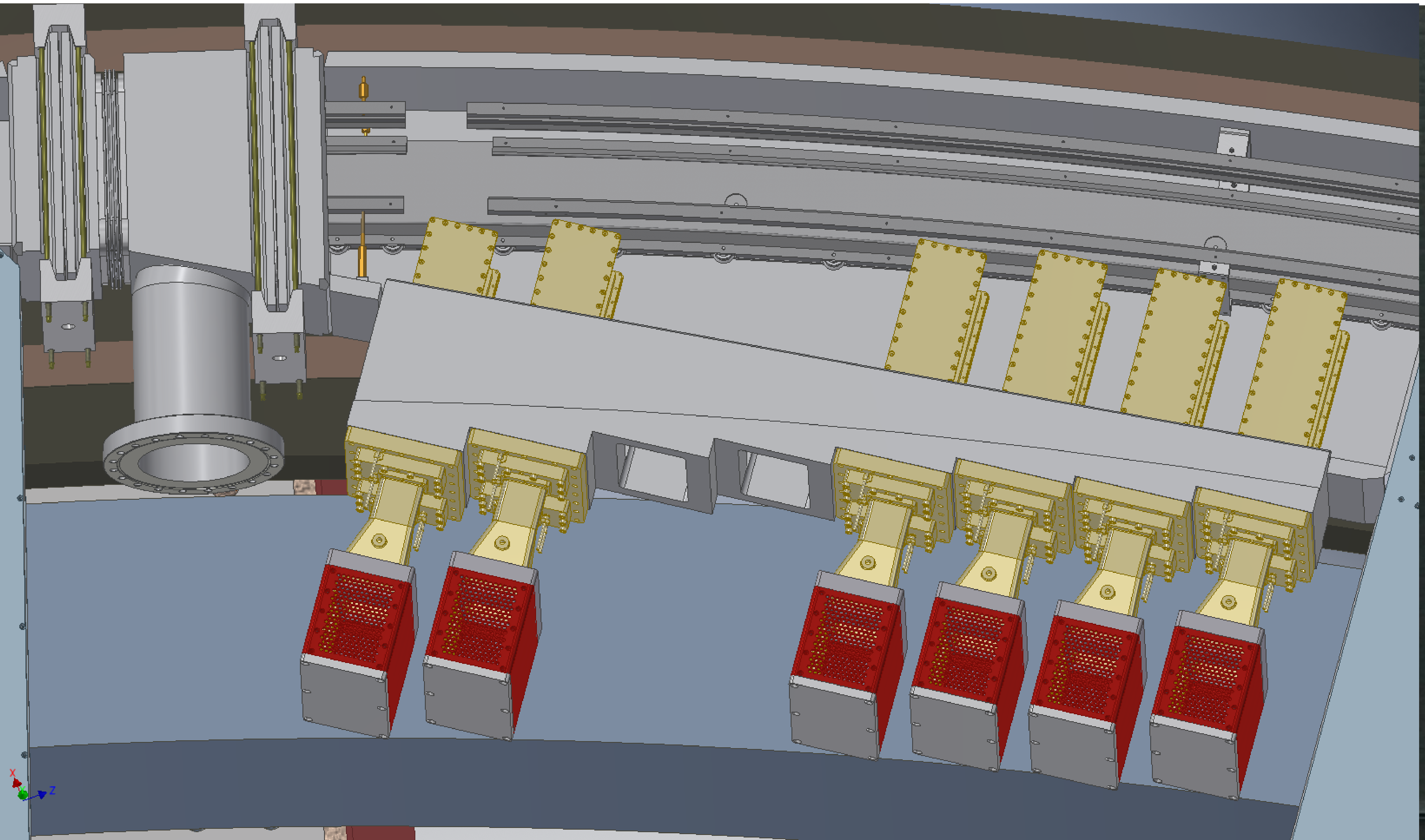
some ***mechanical issues improved*** for increased life time

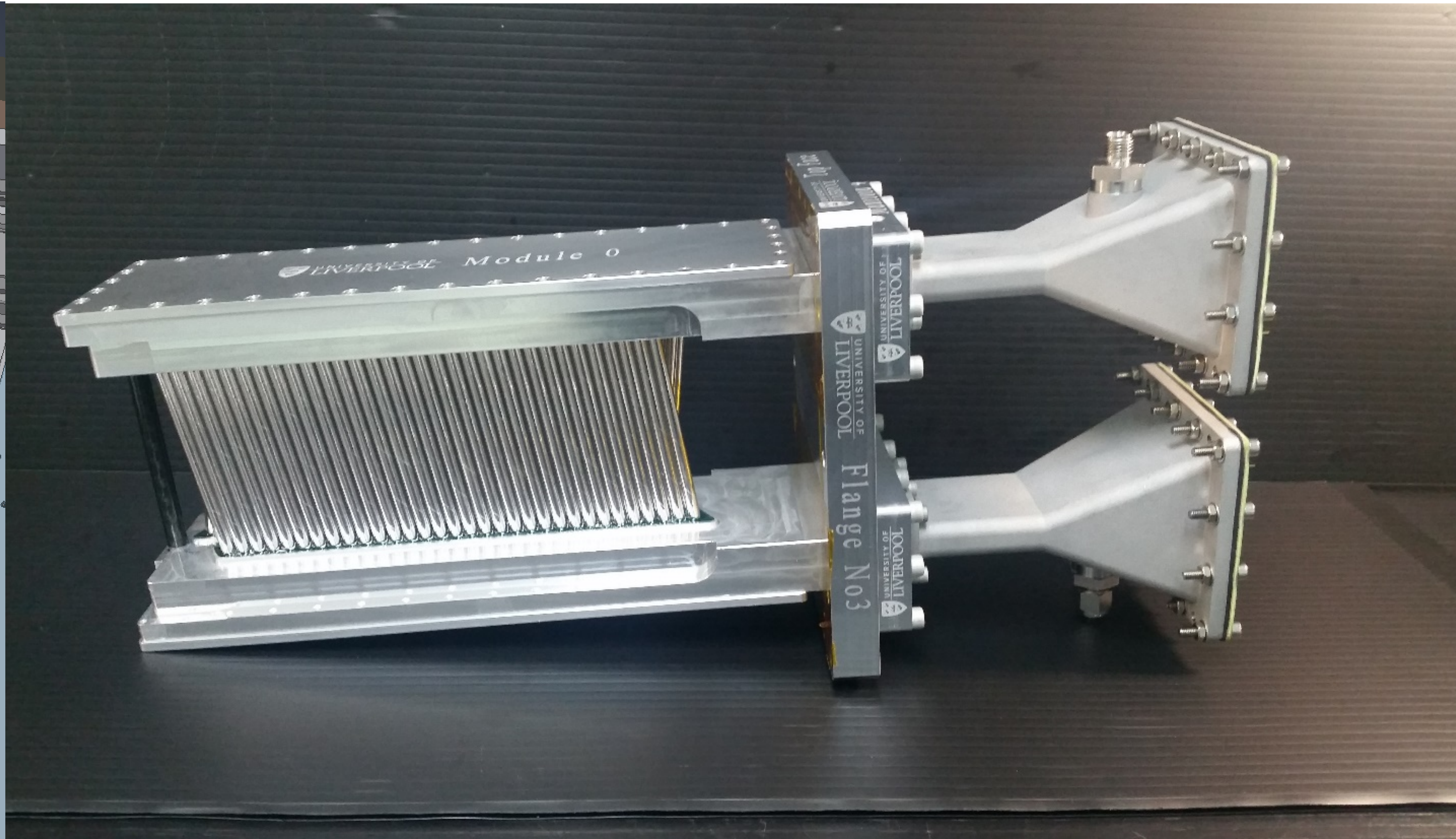
work to do:
reinstall in the ring



Trackers

- At 2 places around ring (1 for eng run, 2nd added during shutdown)
- 8 modules per station
- ***high-gain*** Ar:Ethane (1550V, and 1625V during eng run)
- ***large azimuthal acceptance*** with low material (15μm Mylar)



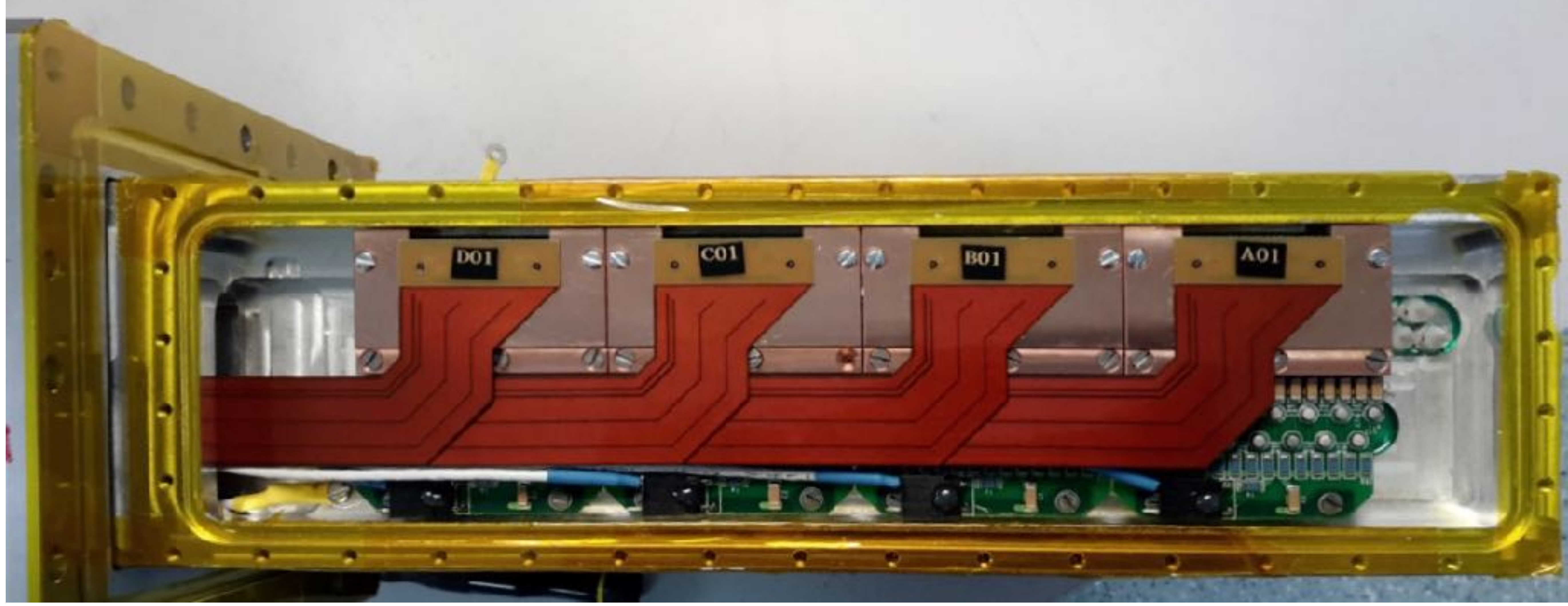


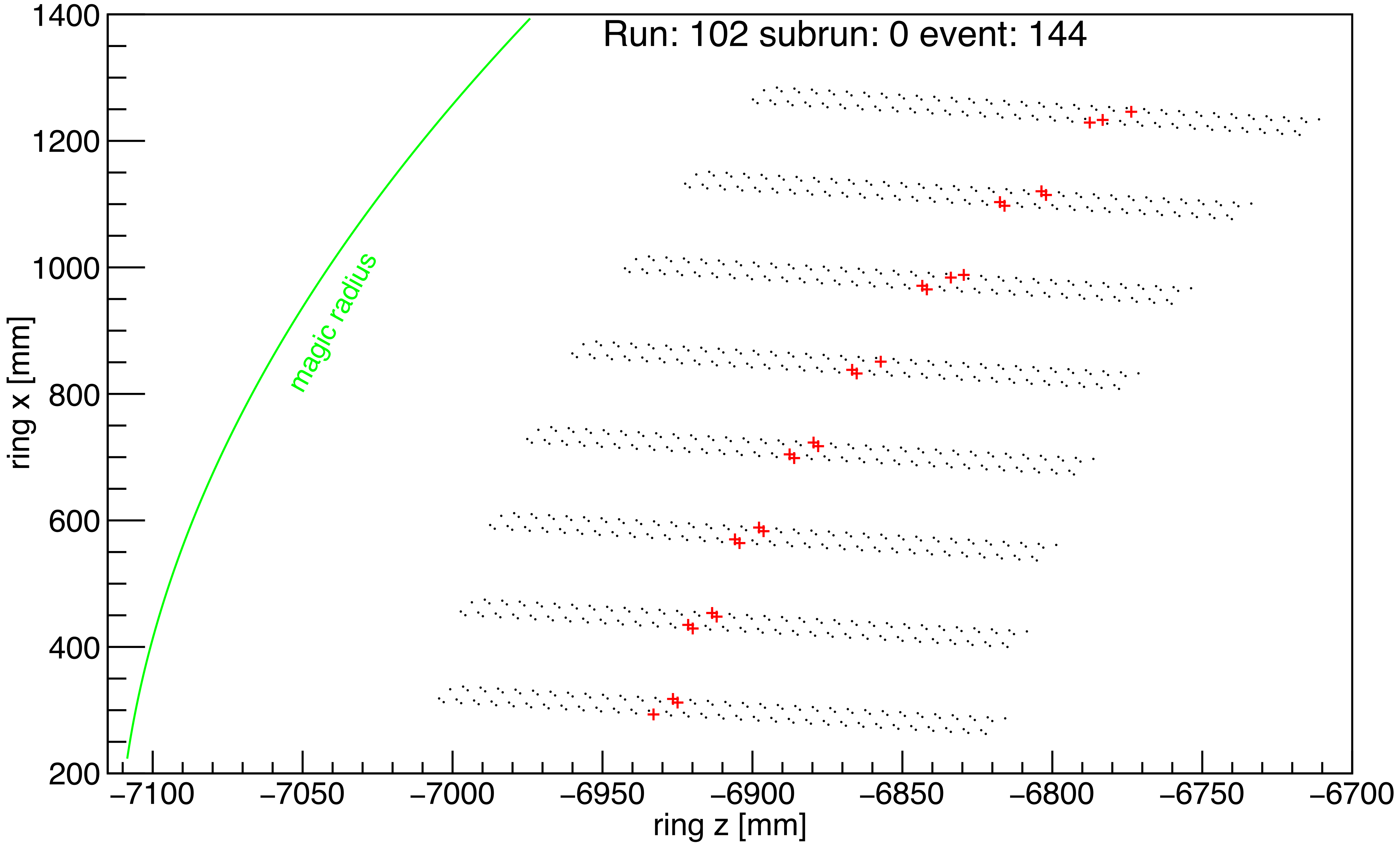
Swiss knife of the experiment

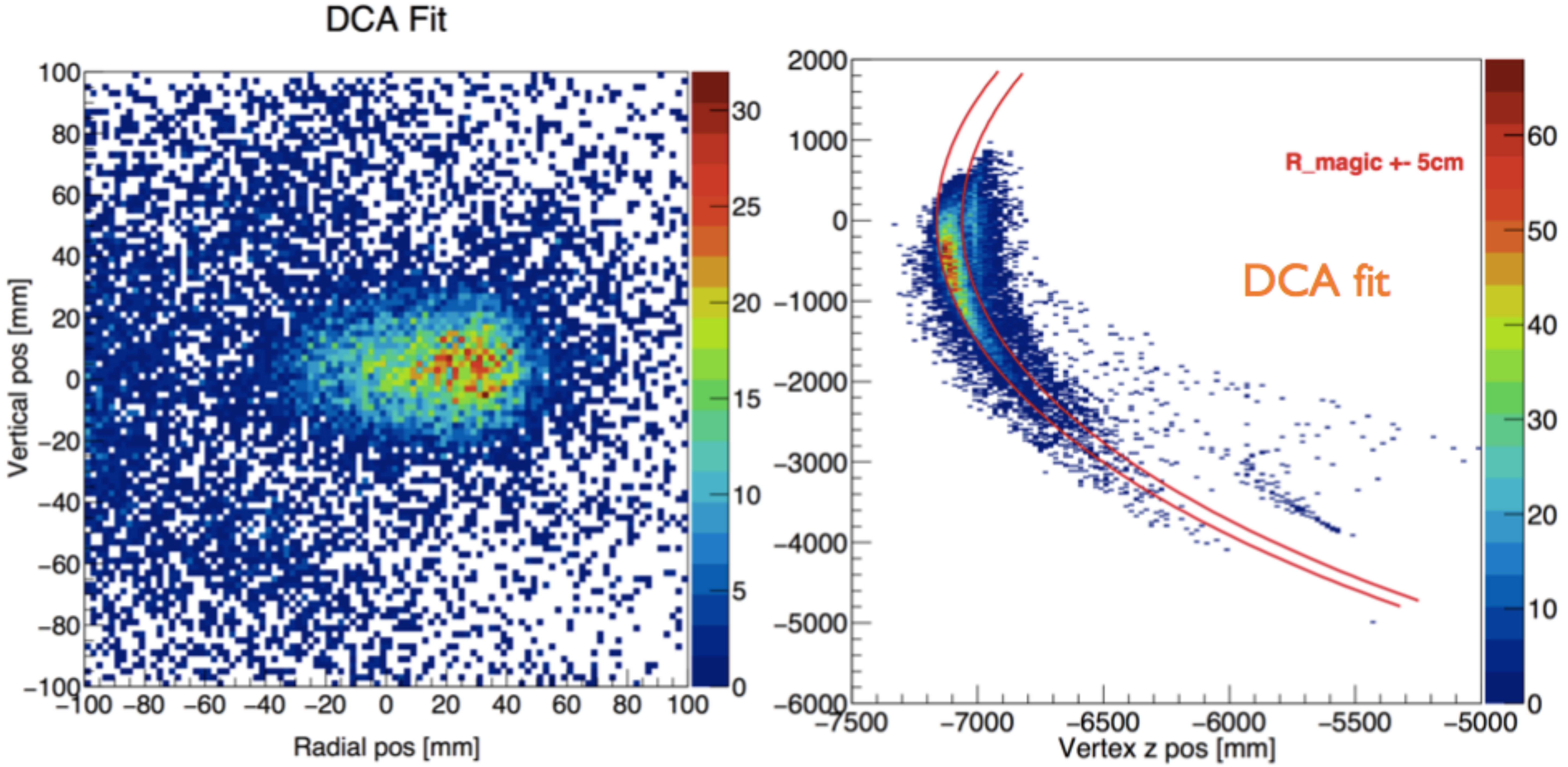
- Measures stored ***muon profile*** and its time evolution.
- Addresses ***pile-up*** systematics, measure positron momentum.
- Detects ***lost muons*** escaping storage region.
- Measures ***vertical pitch*** of decay positrons → EDM measurement.
- Determines area of ***magnetic field map*** seen by the muons
- Limits the size or ***radial and longitudinal*** magnetic ***fields***
- Makes an independent measurement of ***positron momentum***.

Eng run tracks

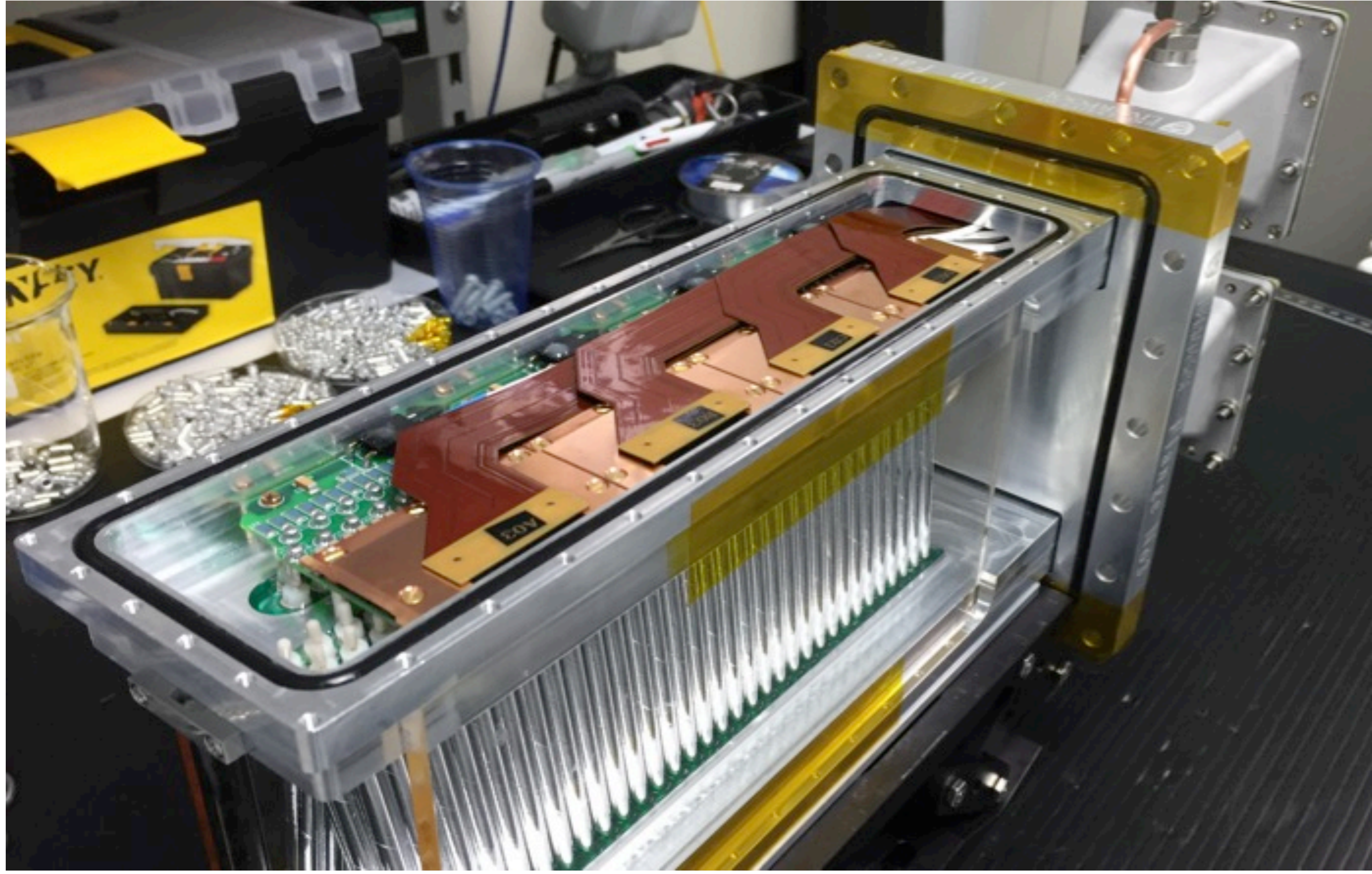
- worked well from day 1
- worked well during the initial splash







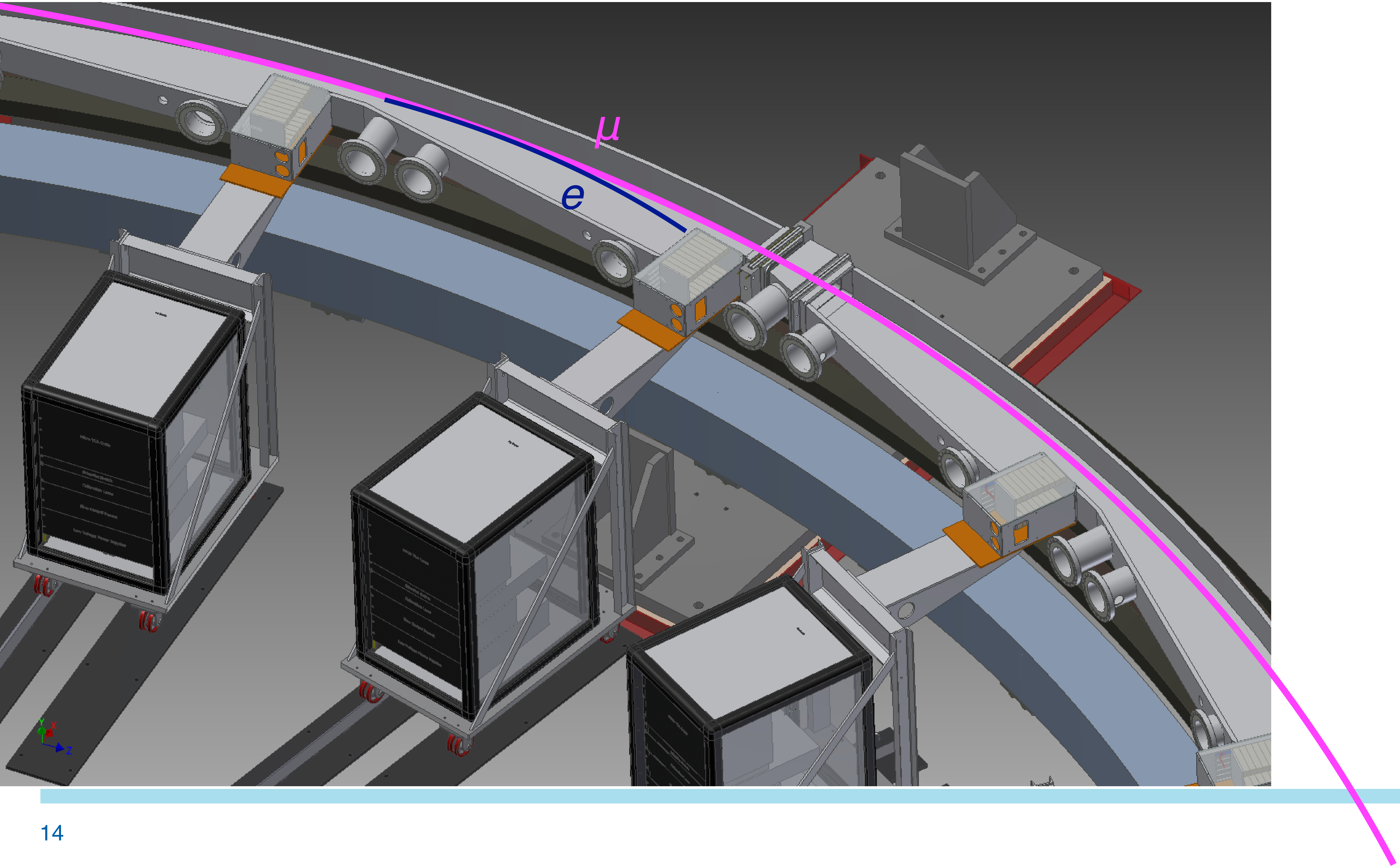
Tracker readiness, and shut down achievements



- 8 more modules ready to install at ***2nd tracker station***
- ***Addressing*** water outgassing; ***vacuum load***
- Updates to DAQ to reach nominal data and trigger rates

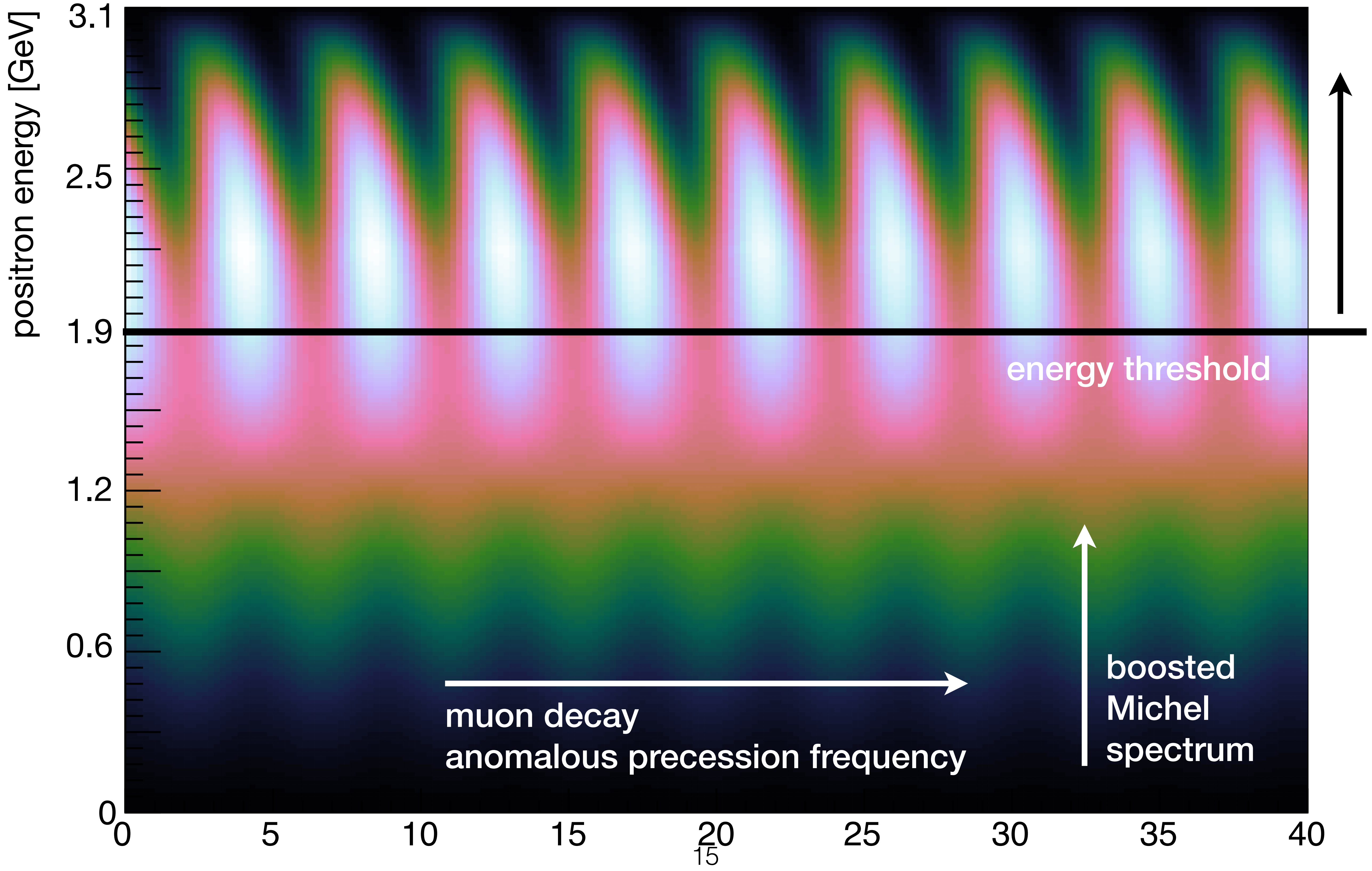
- work to do:
  - reinstall tracker station 1
  - install and commission tracker station 2

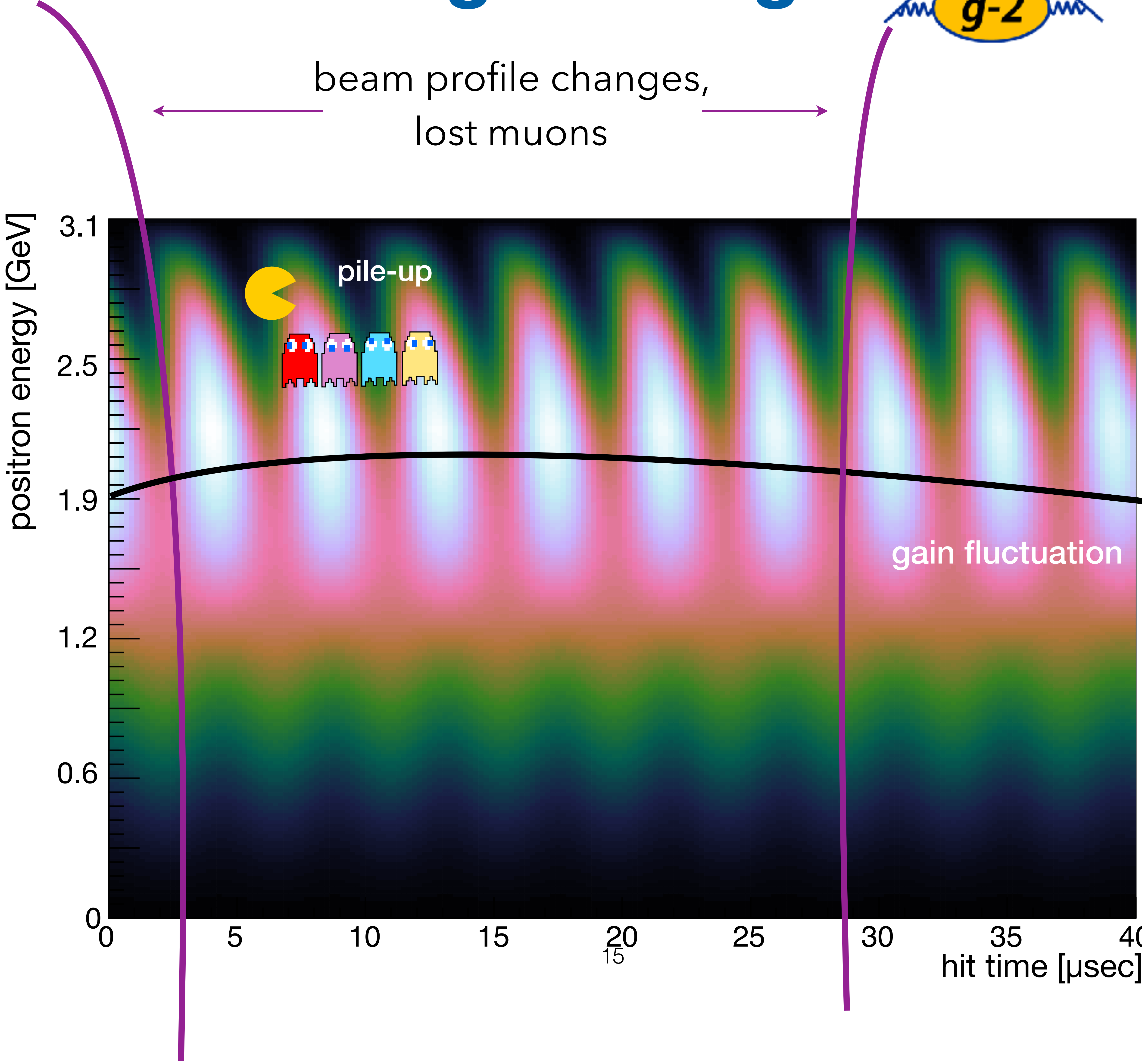
Calorimeters



Fermilab

what does a calorimeter see, and what can go wrong





Calorimeter design goals

1. Positron hit time measurement with accuracy of (100 psec above 100 MeV)
2. Deposited energy measurement with resolution better than 5 % at 2 GeV
3. Energy scale (gain) stability in 1e–3 range, over the course of 700 μsec fill where rate varies by 1e4.
4. 100 % pile-up separation above 5 nsec, and 66 % below 5 nsec.

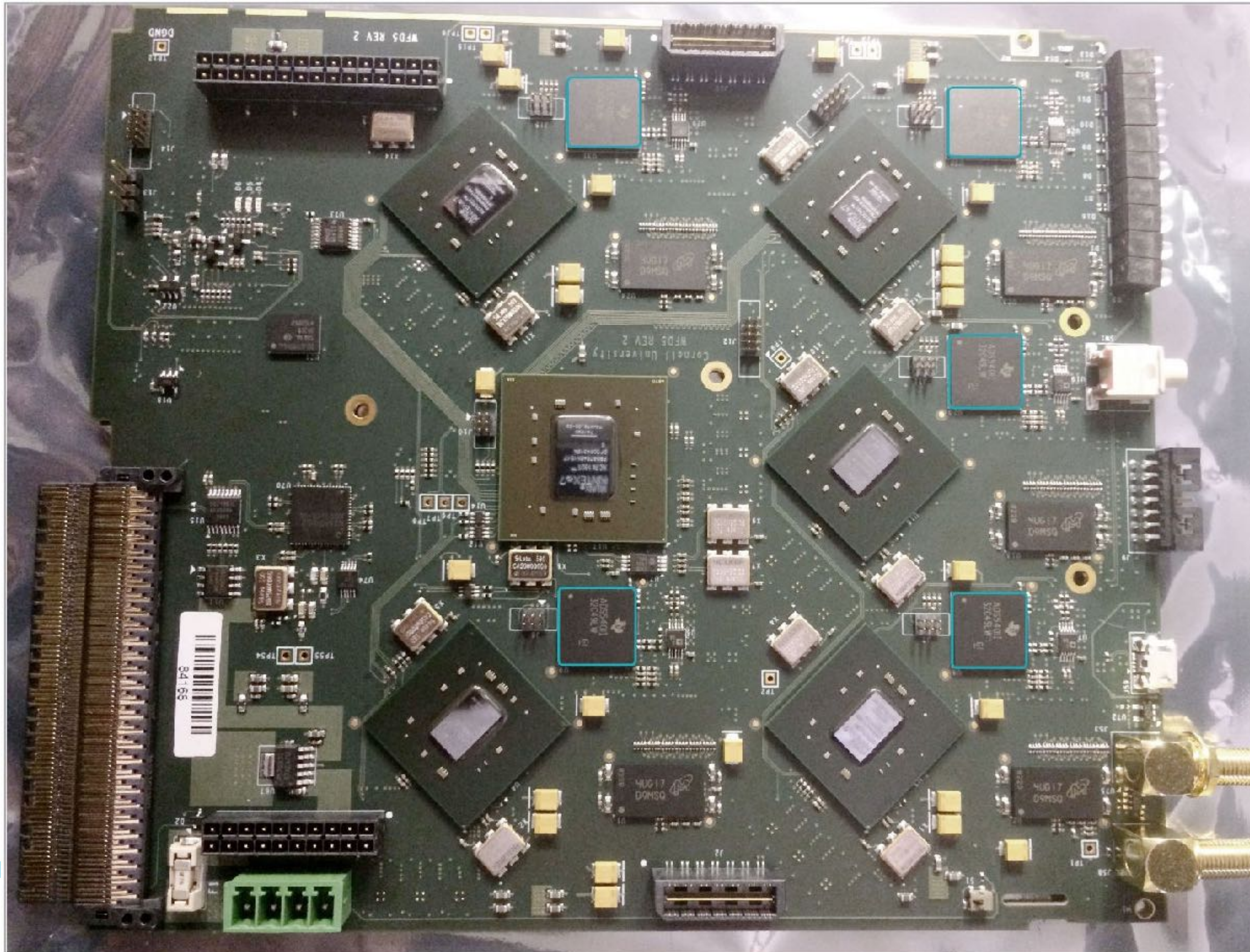

SiPMs
lead fluoride crystals
laser light calibration
system


PEARSTONE
51

Custom made digitizers

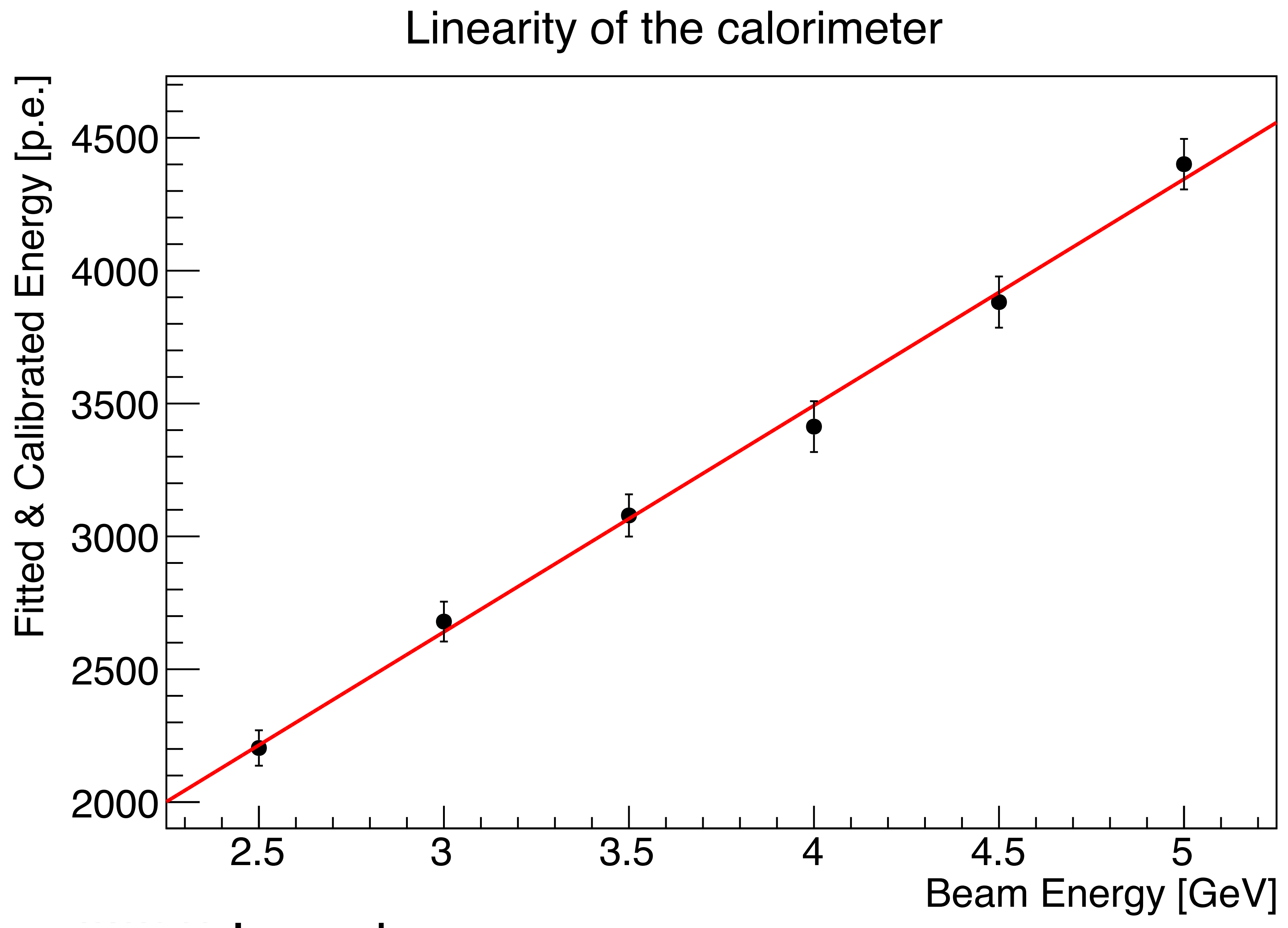
- 5ch, 800 MSpS
- 12 bit, TI ADS5401
- 1 V dynamic range
- <1 mV noise
- μTCA format

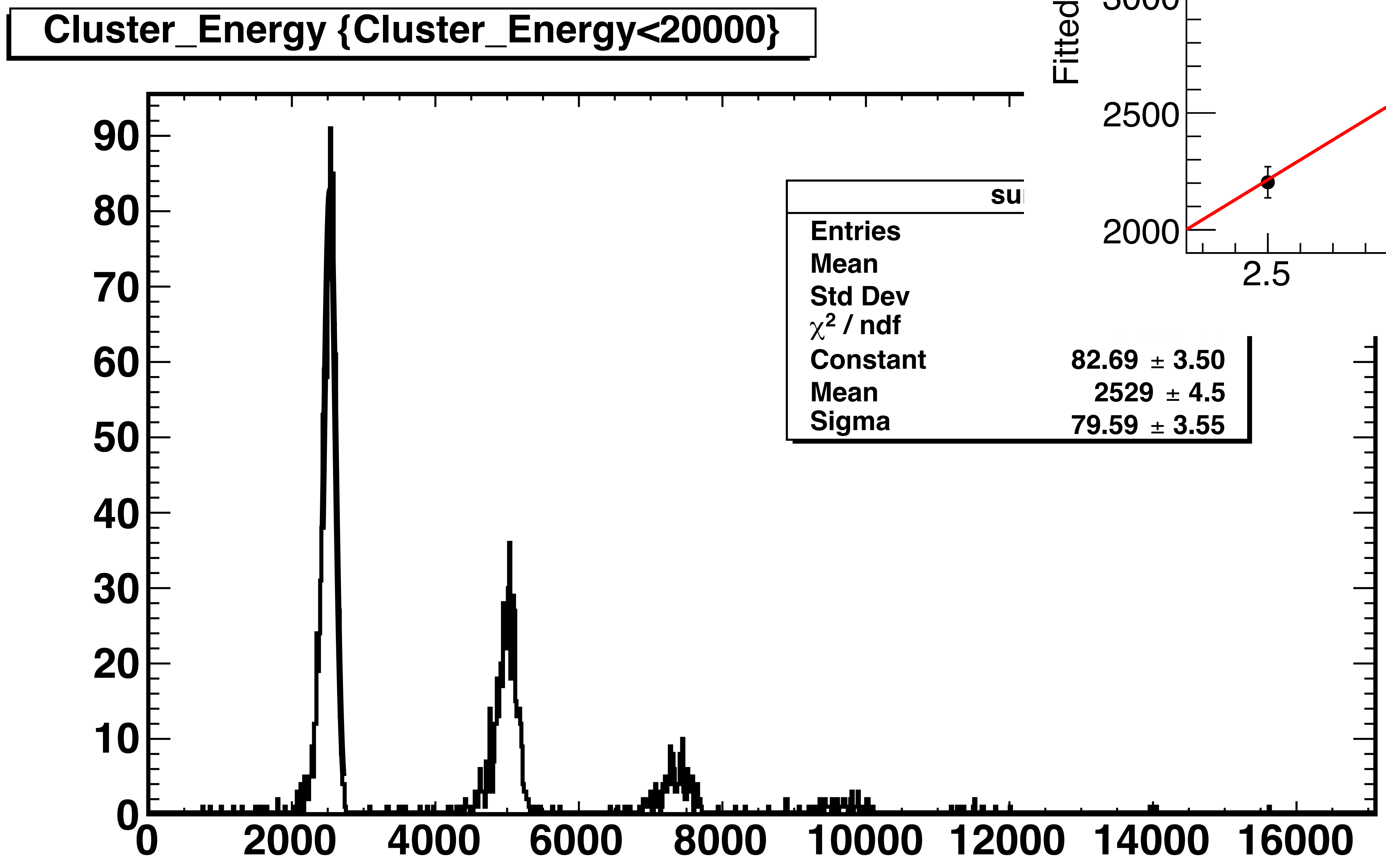
- continuous digitization in fill
- asynchronous mode kicker pulses, Am/NaI

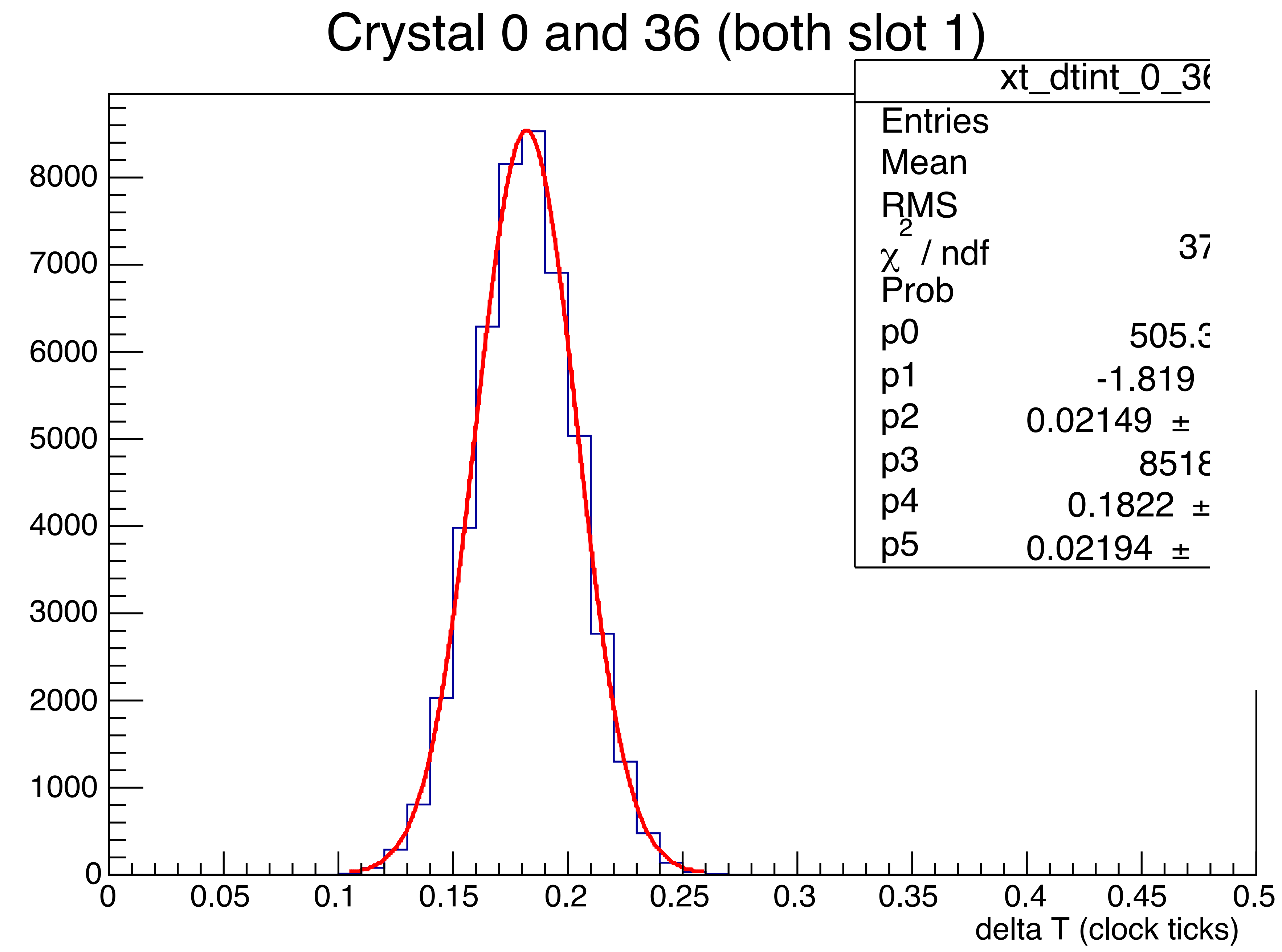


Calorimeter timing and eng resolution meet specs

1. Timing resolution measured as 25 ps above 100 MeV
2. Deposited energy resolution measured as 4 % at 2 GeV

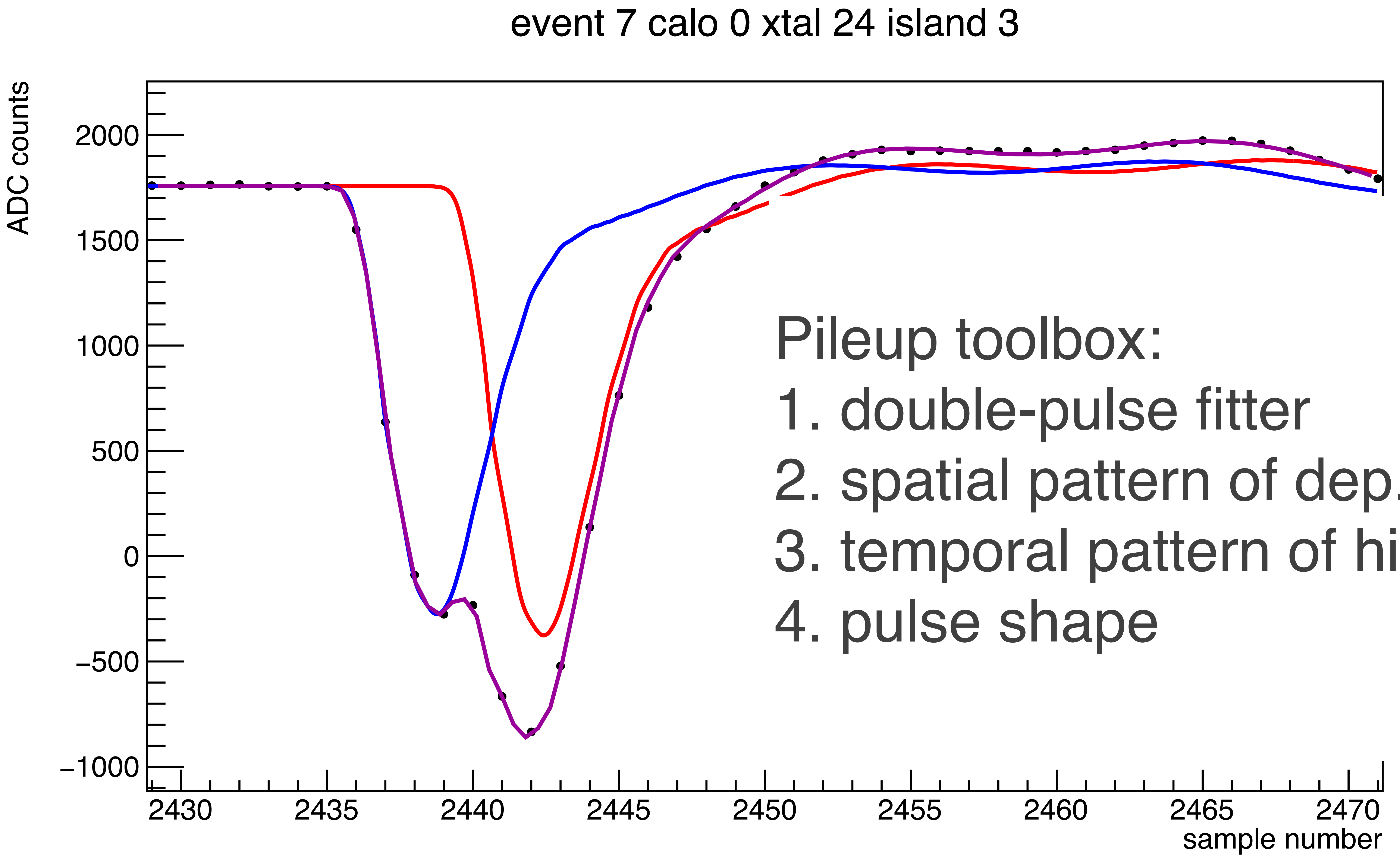






Fermilab

Calorimeter pileup separation



Pileup toolbox:

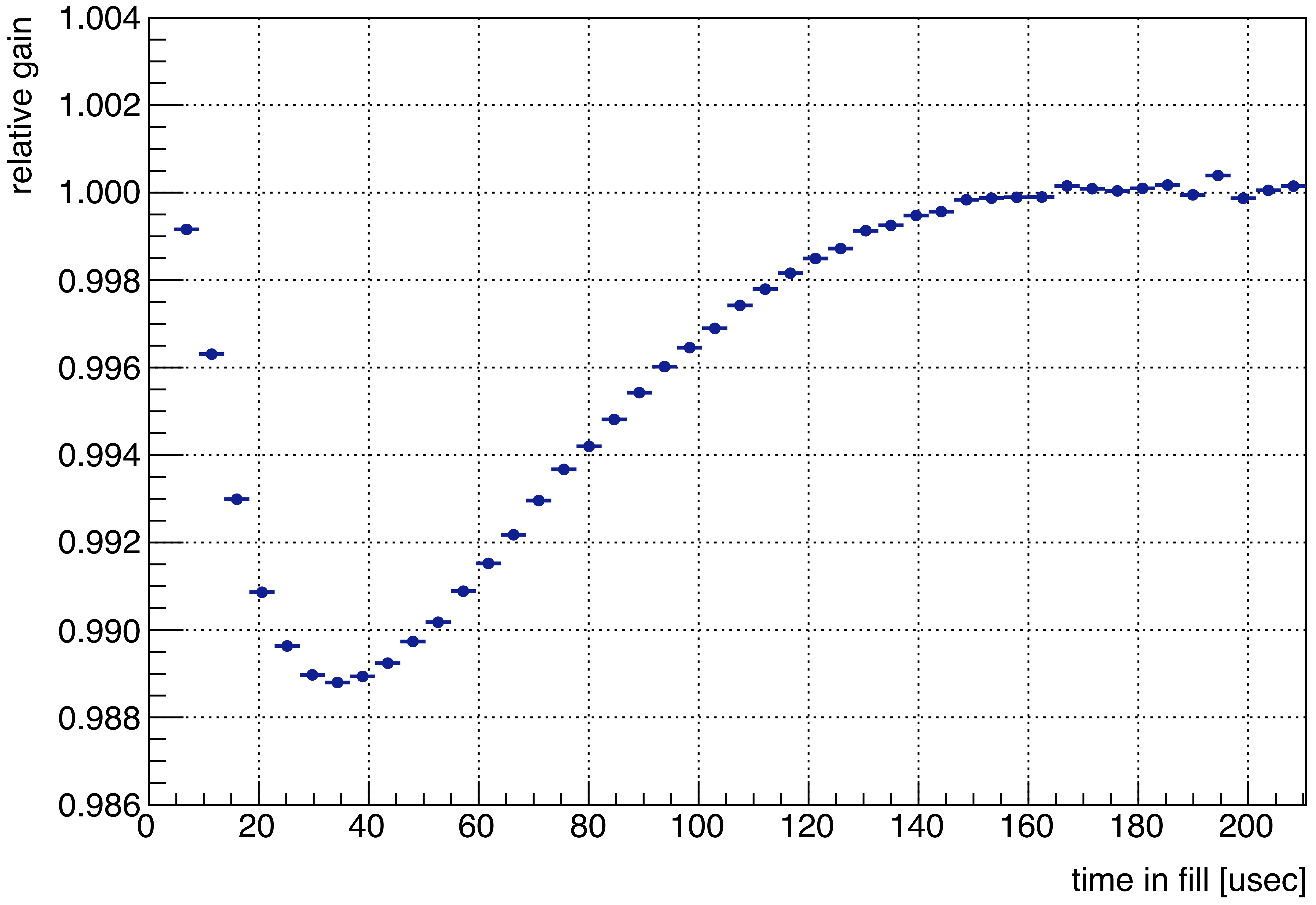
1. double-pulse fitter
2. spatial pattern of dep. energy
3. temporal pattern of hit times
4. pulse shape

Calorimeter gain stability, calibration, and monitoring

Three different timescales:

1. months,
2. muon fill of 700 μsec,
3. pileup ~10 nsec

laser calibration system is the tool



Calorimeter lessons from eng run, shutdown achievements, and readiness

energy scale ***calibration at 1e-4 level***

- number of laser pulses limited by ethernet & DAQ stability
- (ethernet timeouts limited SC, too)

gain uniformity

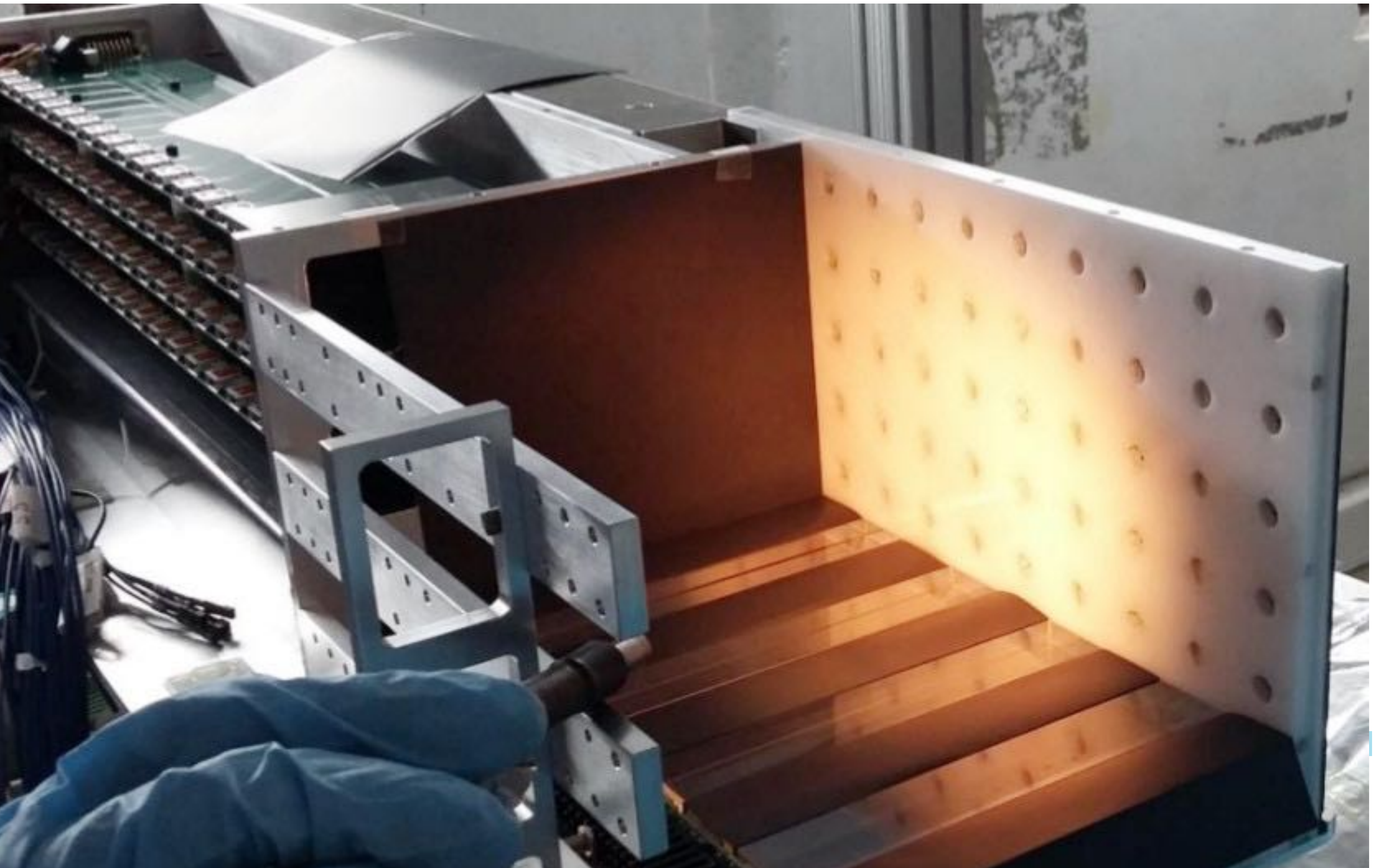
- bias voltage connections to be rearranged for a couple SiPMs

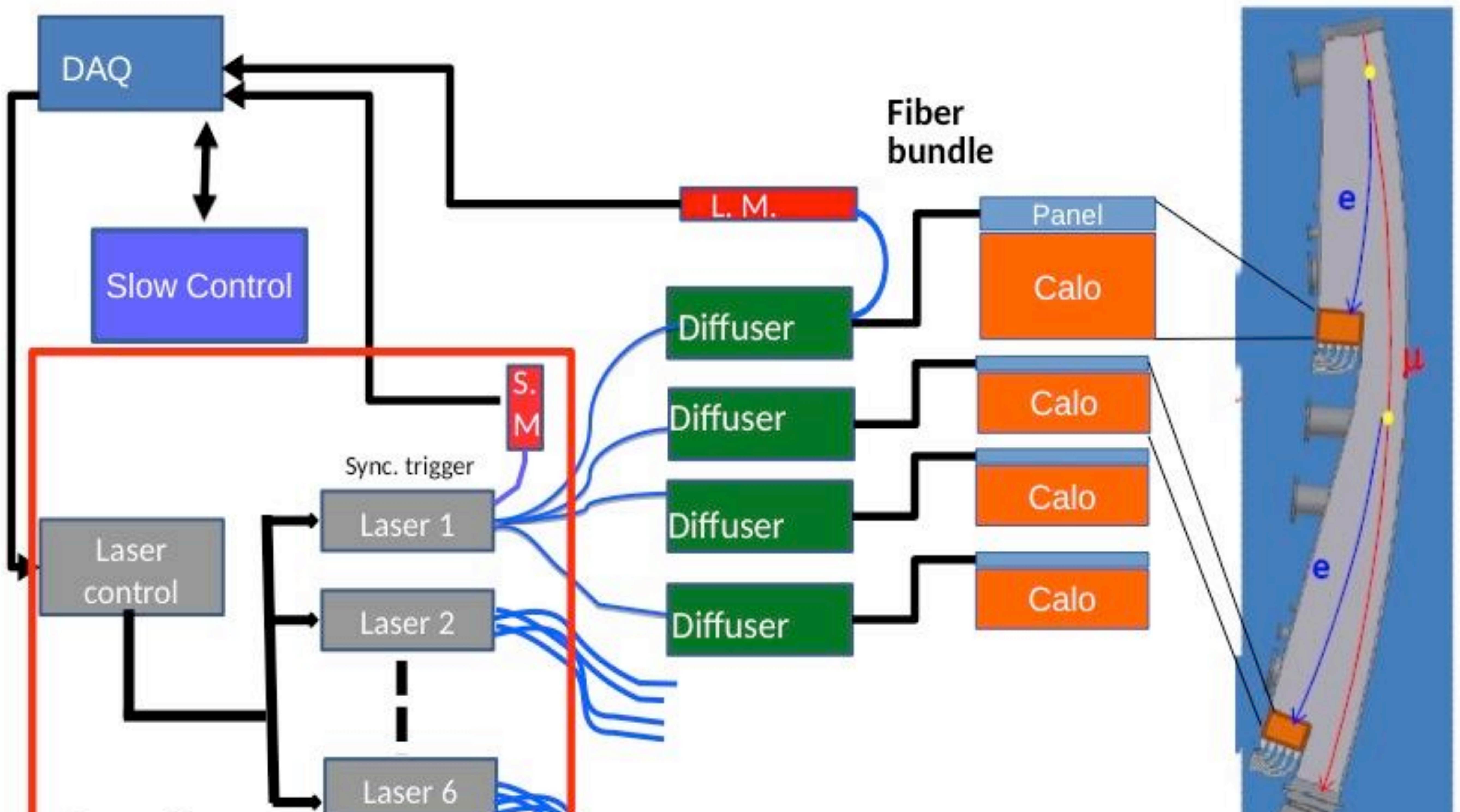
energy threshold of 30 MeV

- grounding and noise issues
- disconnected shield of the signal cables

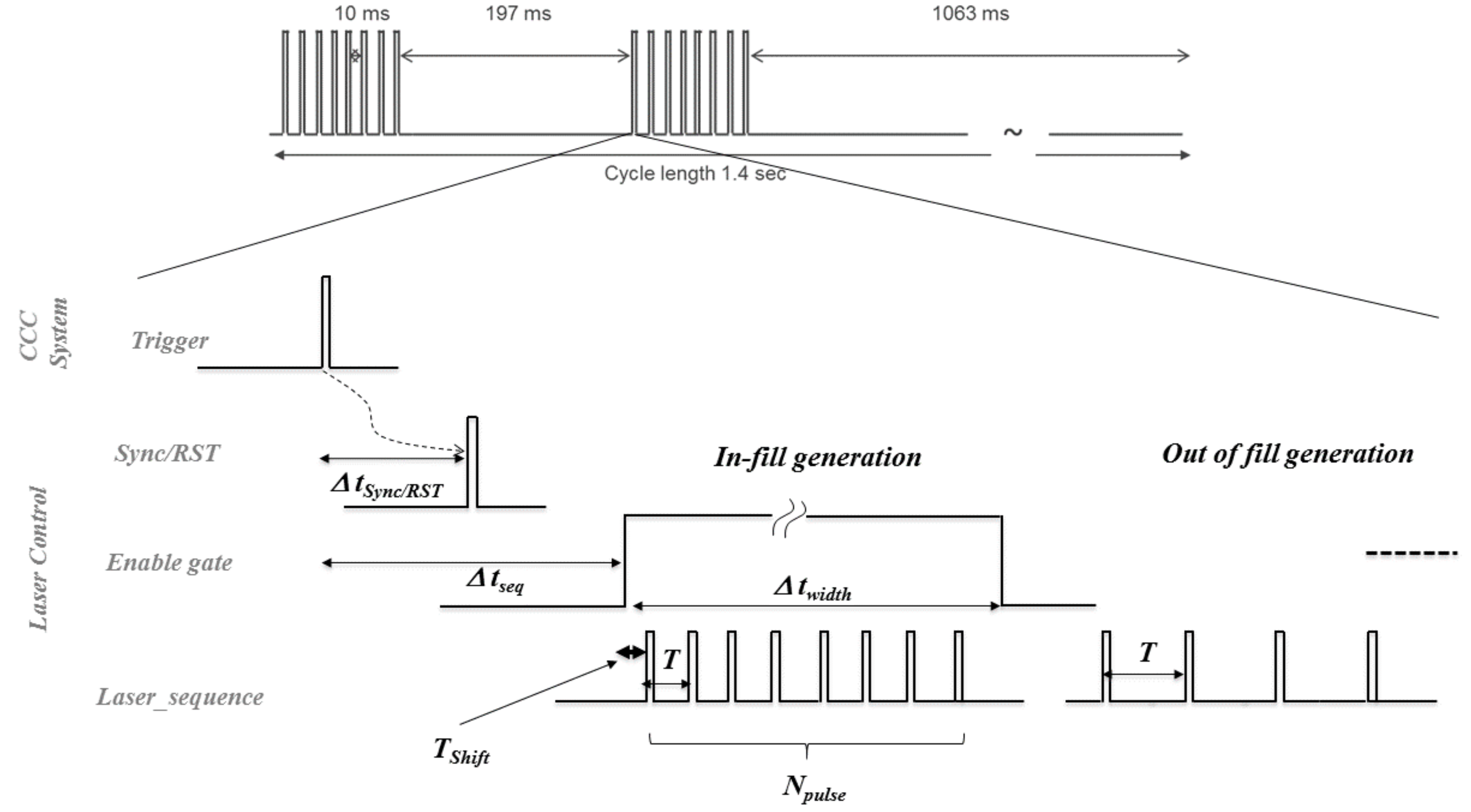
Laser calibration

- gain stability of 0.04% in “offline” mode,
- 405 nm, same pulse shape and path as physics,
- laser monitors with Am/NaI reference,
- and local calorimeter monitors



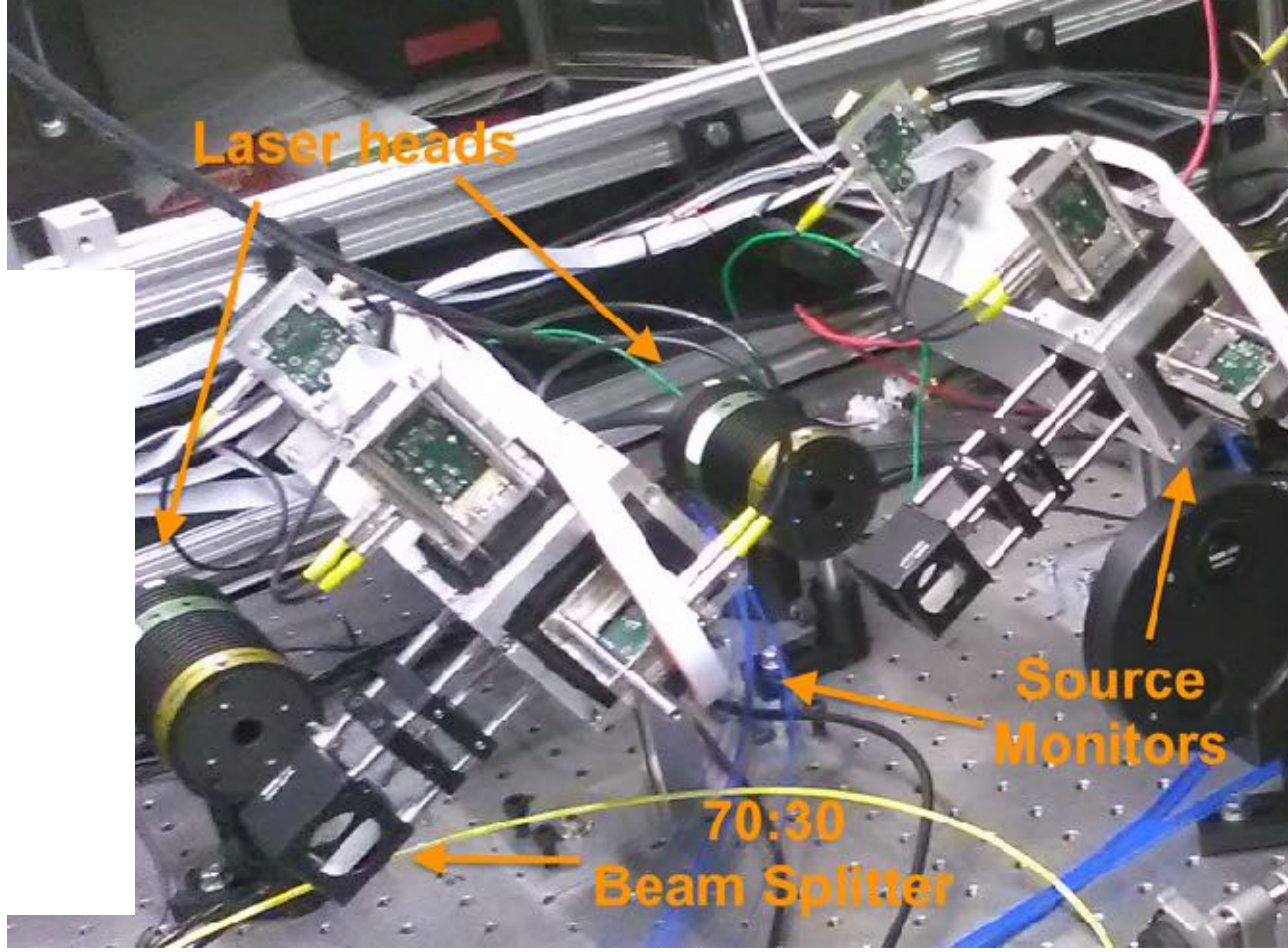


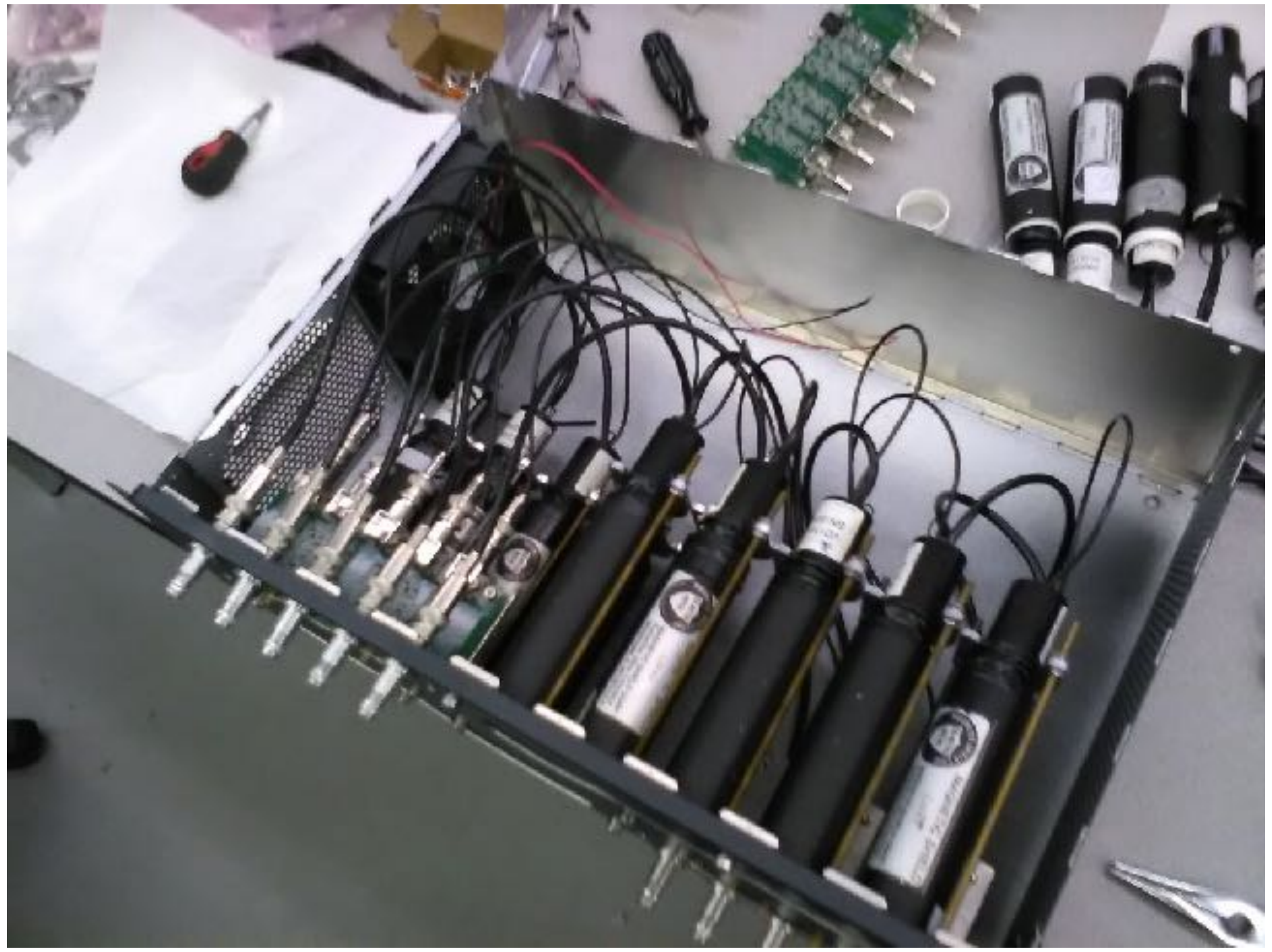
Timing synchronization, gain stability, and calibration

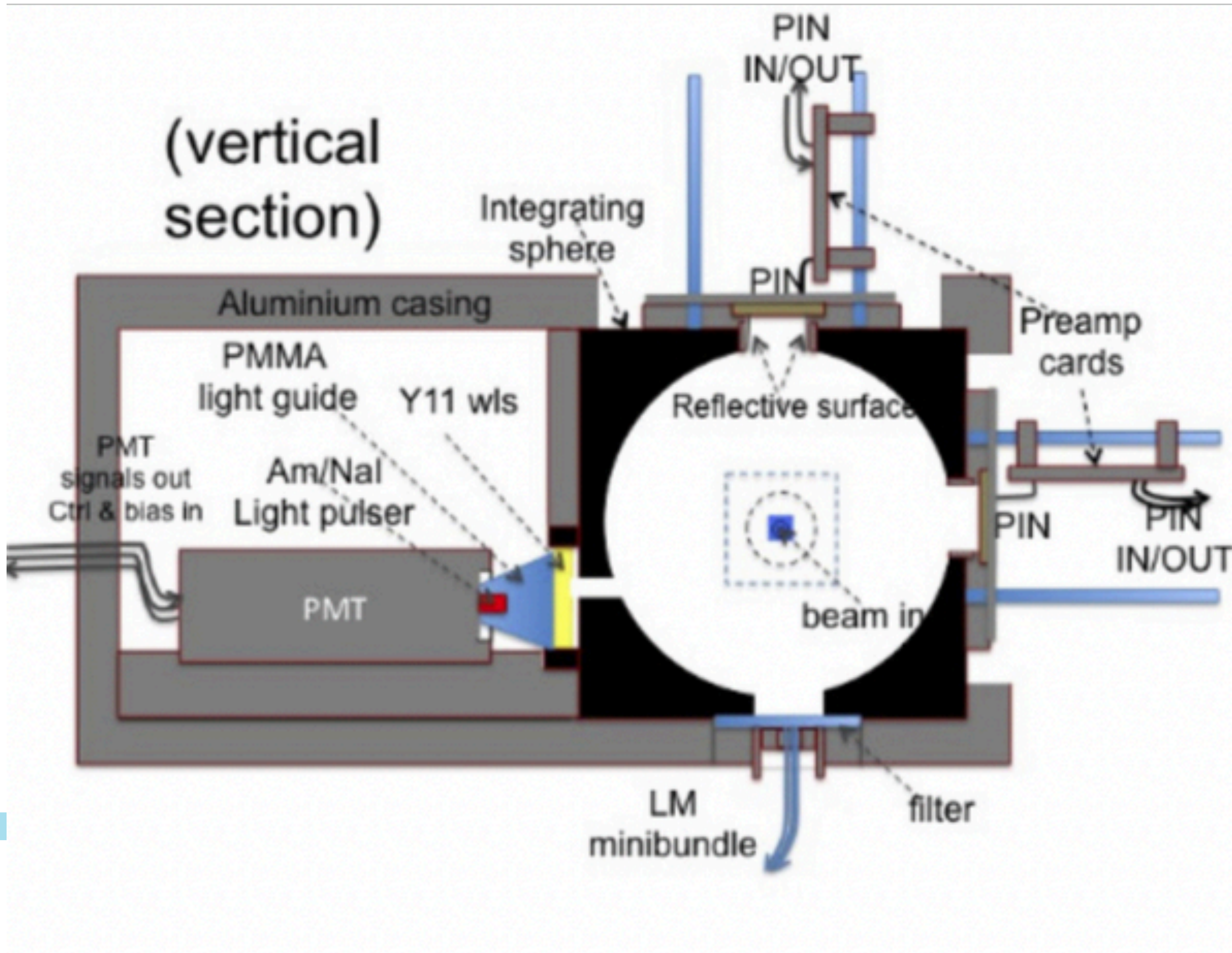


Energy scale monitoring

- source and local monitors for 1e-3 range
- Am/NaI reference local for 1e-4 range
- non-intrusive, out of muon fill

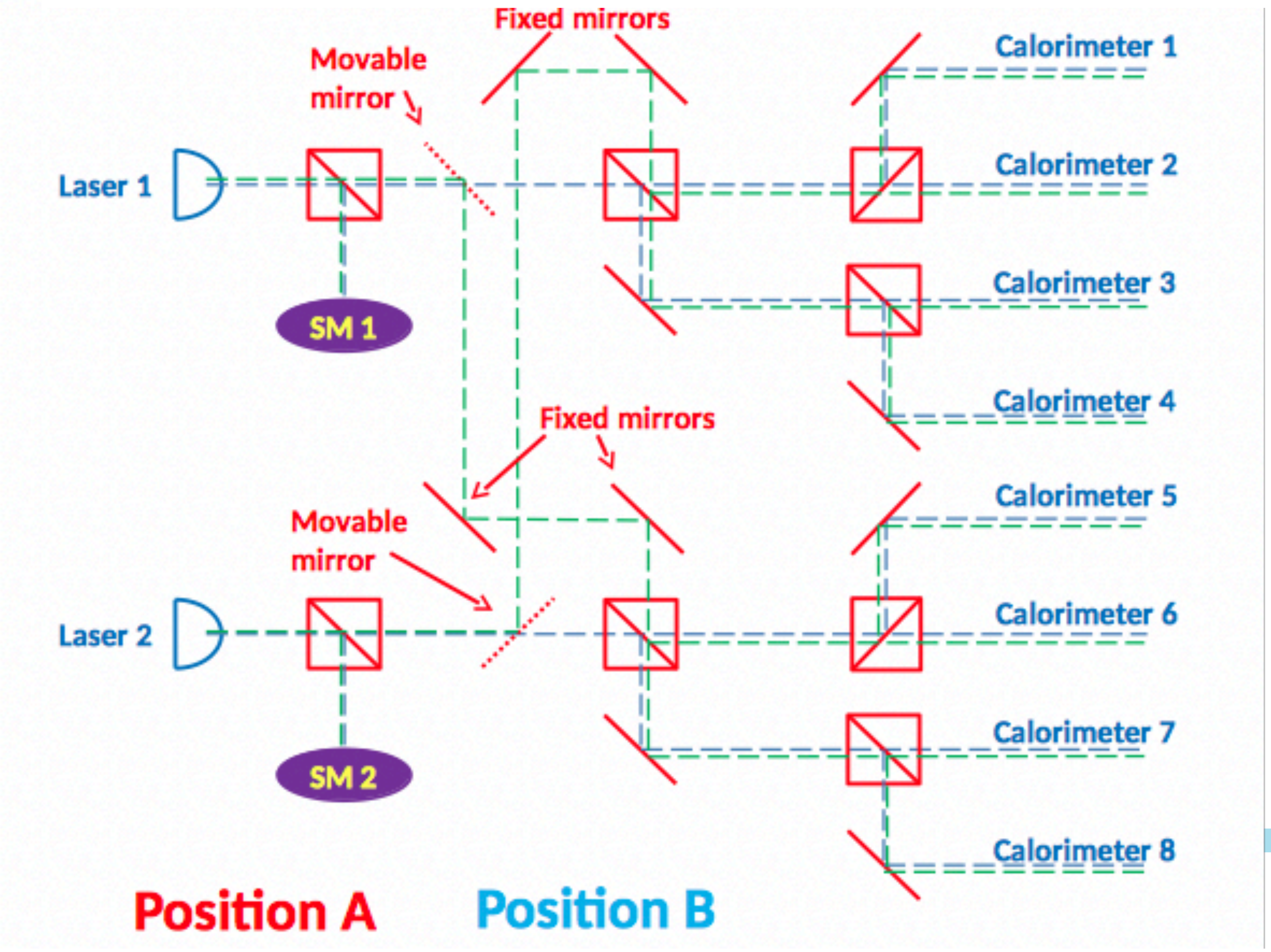


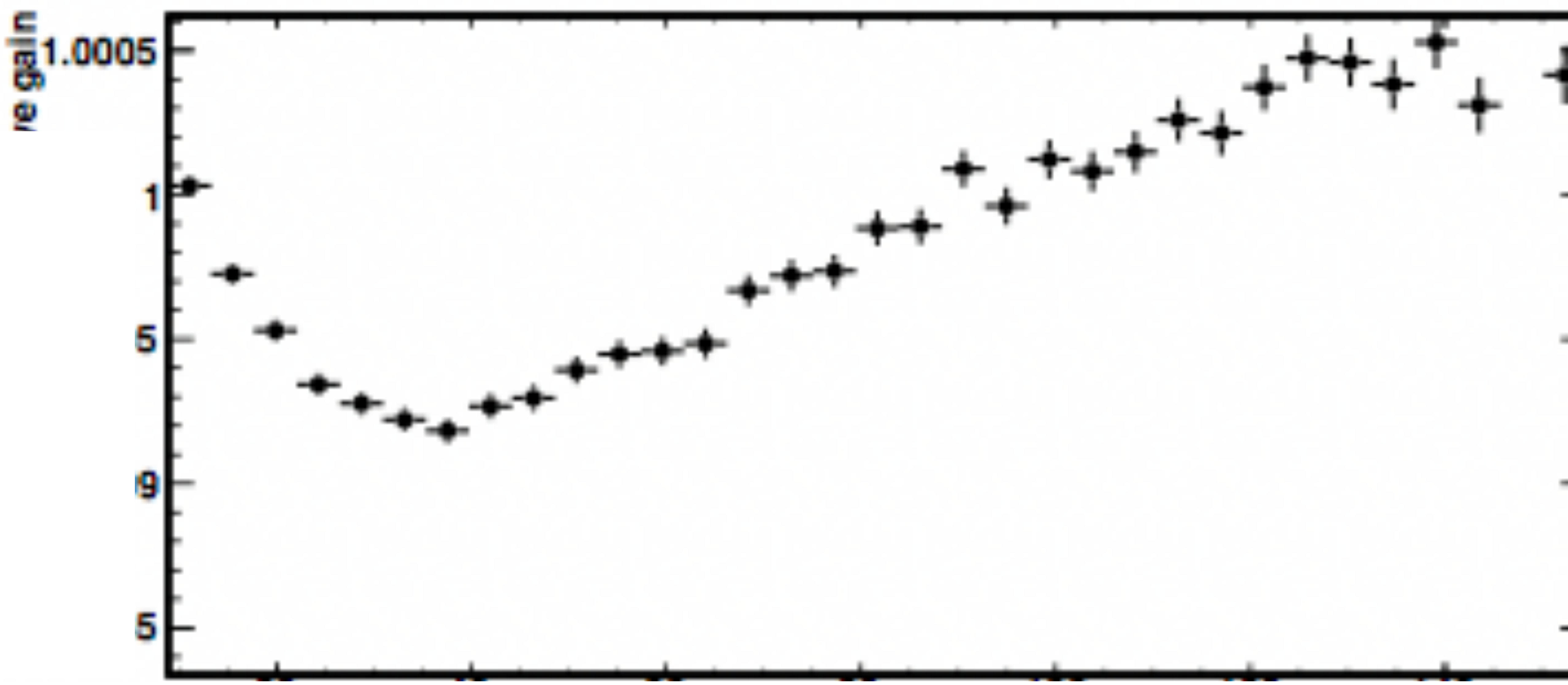


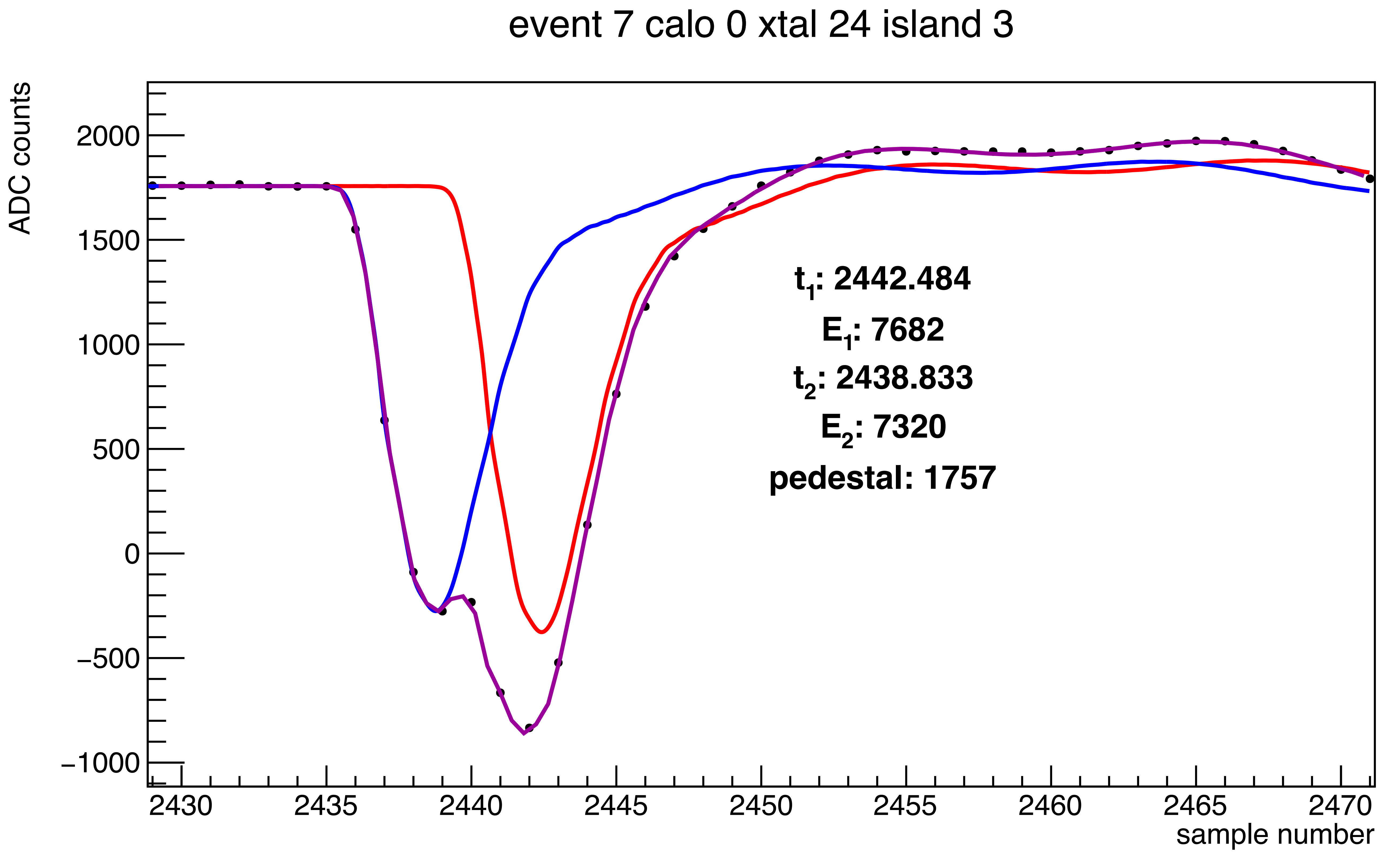


Double pulsing mode

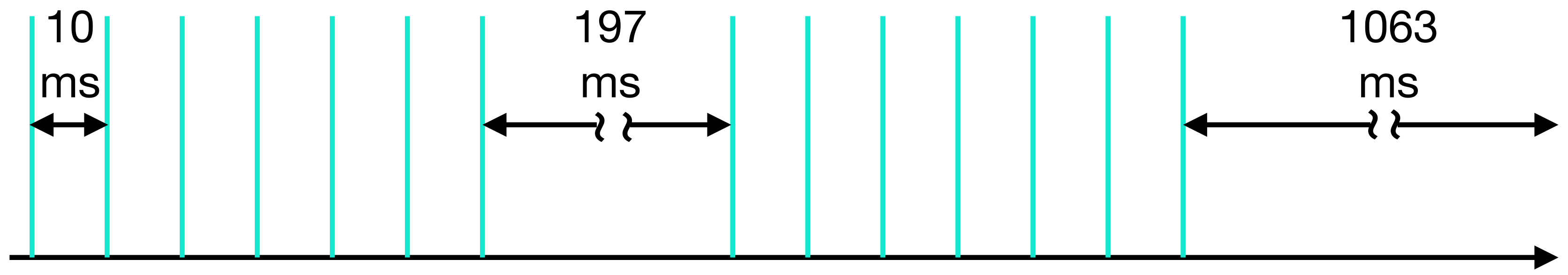
- added during shutdown
- gain calibration
- two different time-scales
- automated, remotely controlled



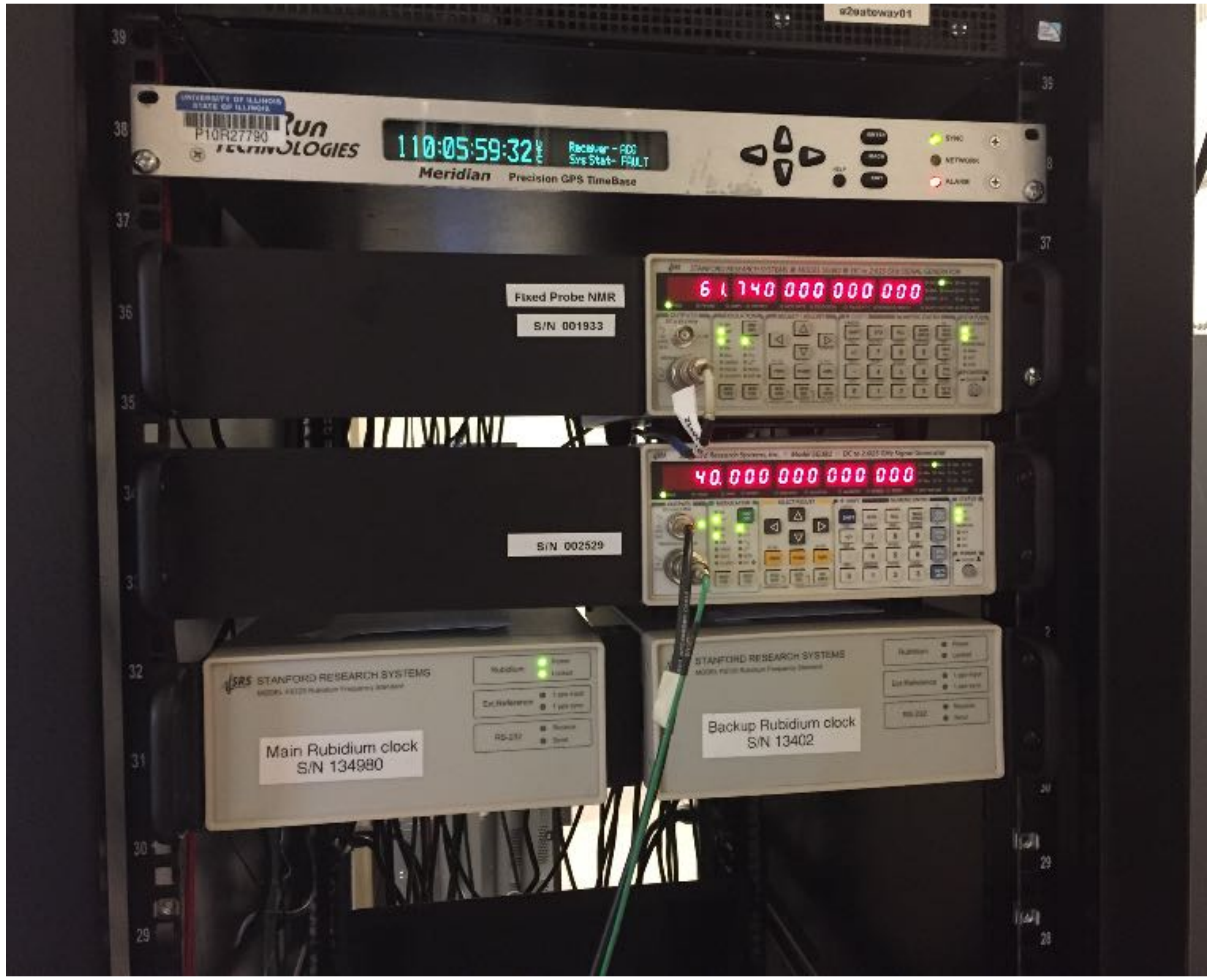




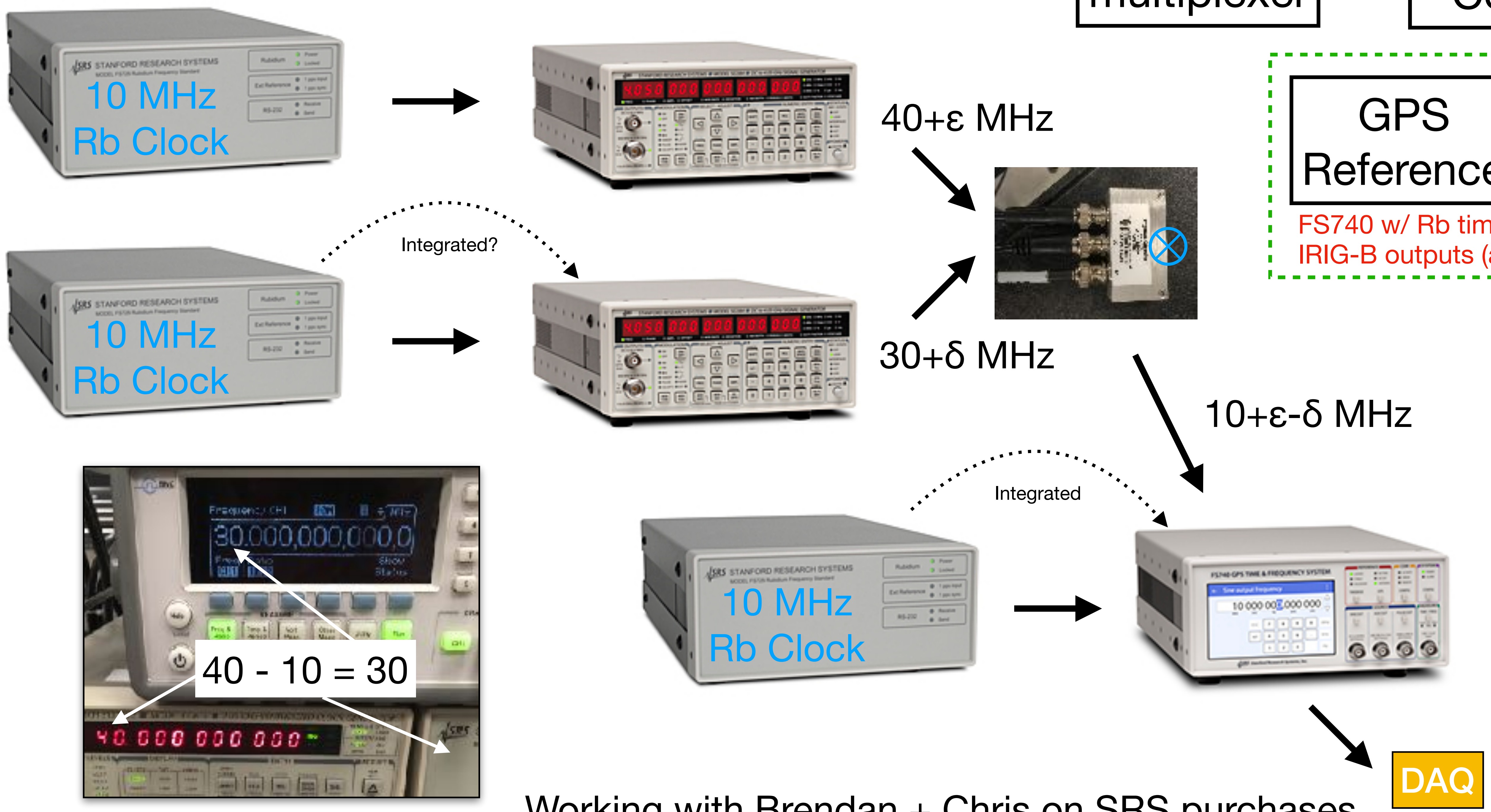
Clock, trigger, and blinding



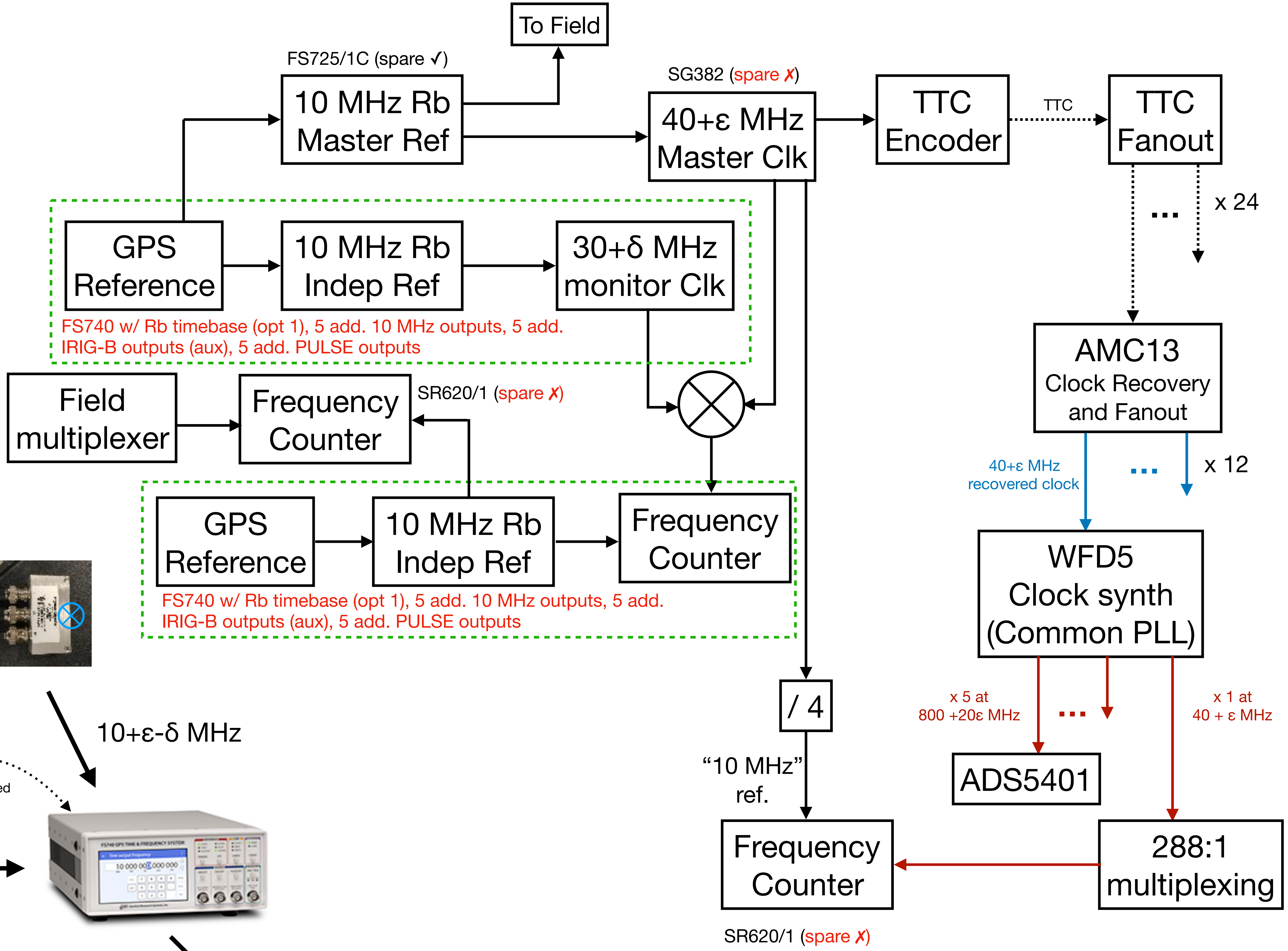
- ***Encodes*** synchronous ***TTC protocol***
  - Combines master 40 MHz clock + accelerator beam triggers ($A6)
  - flexible output ***triggering sequences***, configurable via DAQ
- Distributes TTC signal to μTCA , and ***analog triggers*** to some clients with 2 nsec jitter
- ***Monitors*** μTCA client ***status*** via TTS protocol, and throttles trigger rate if needed



Data blinding in HW

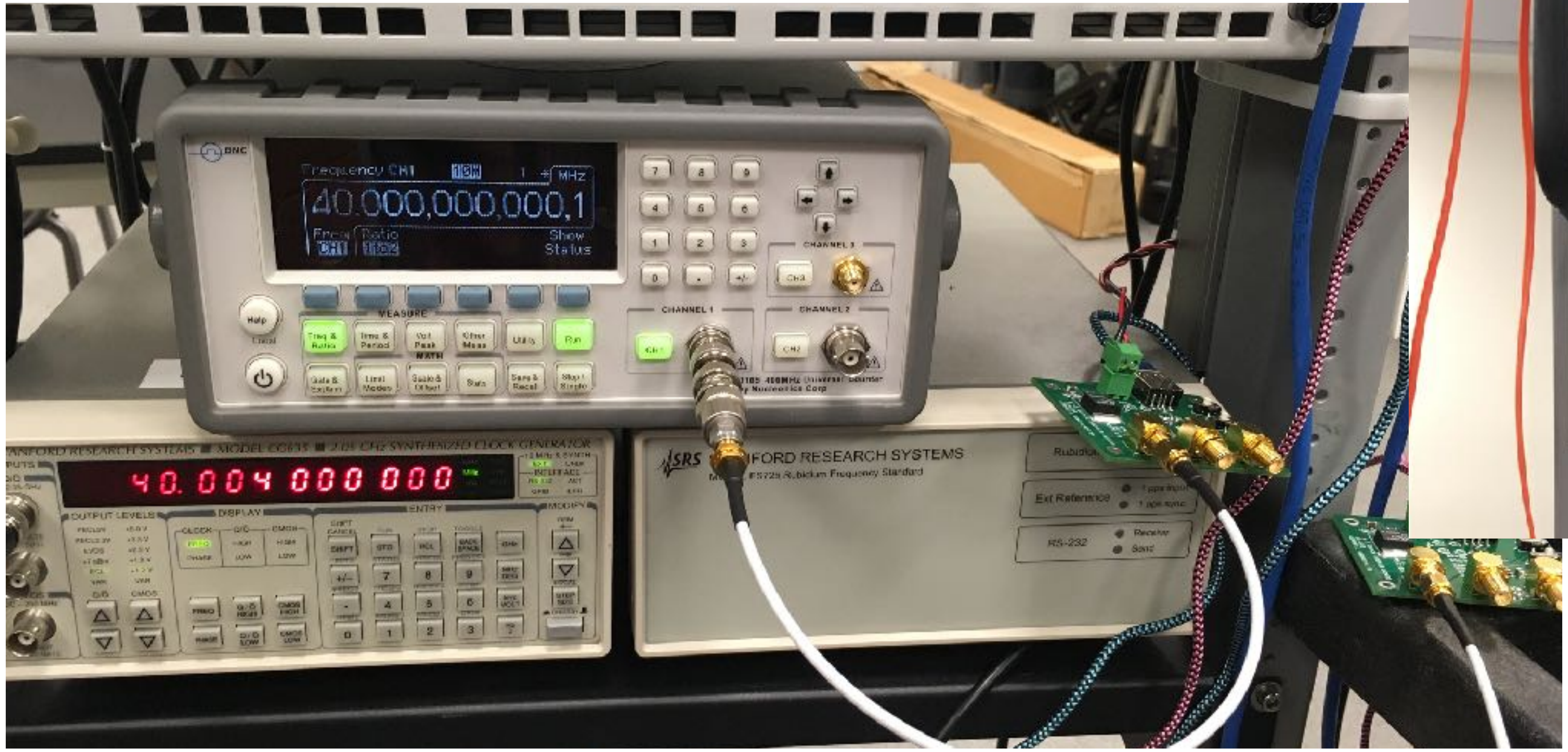


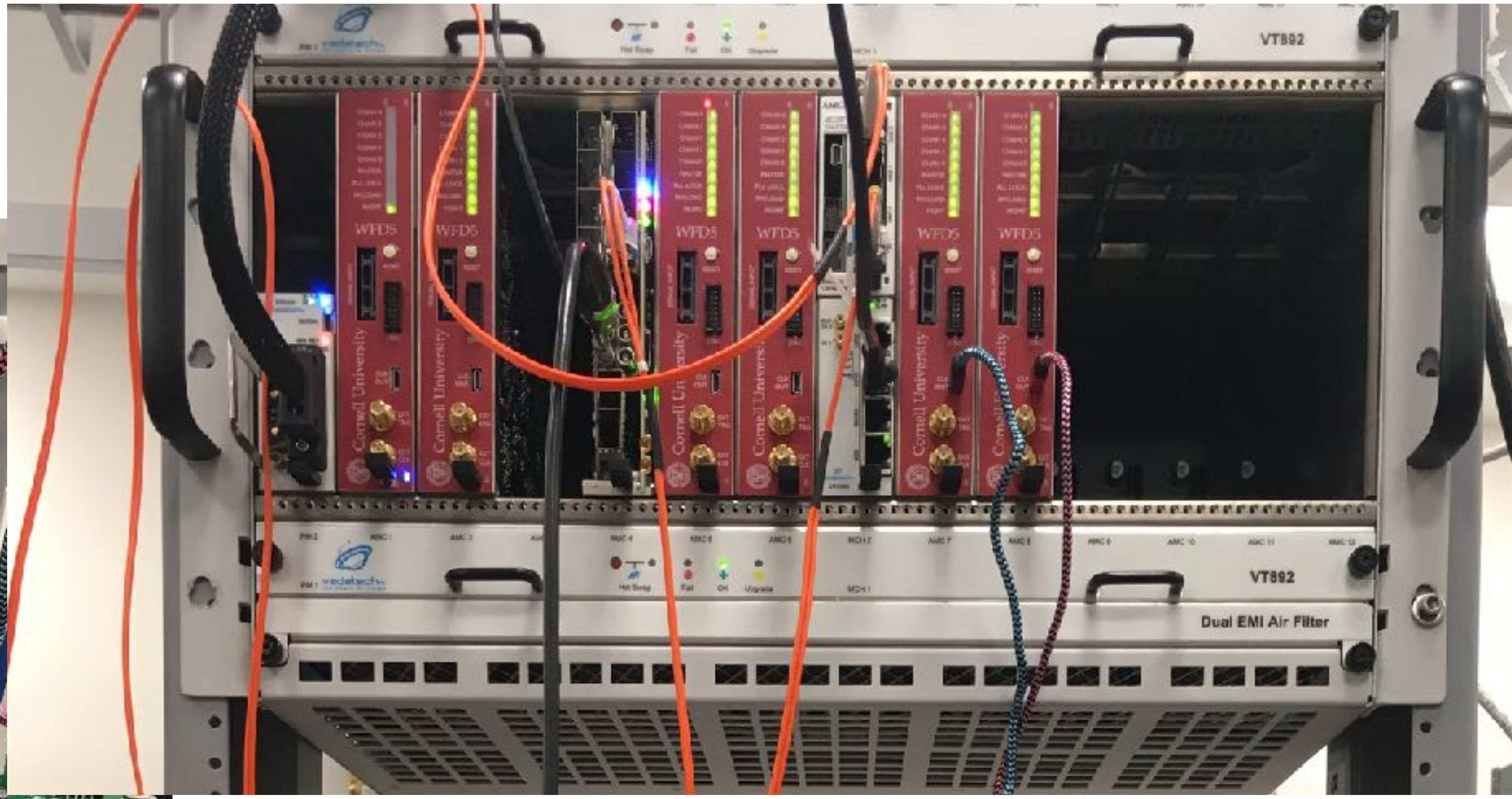
Working with Brendan + Chris on SRS purchases



Fermilab

Blind clock monitoring for stability





Monitored 40+ε MHz

(ε = 4 kHz)

reads: 40 MHz

Reference frequency f_{ref} =

(40+ε) / 4 MHz

to freq. counter

Aux detectors

- ***HV*** applied to ***quads***
- ***Kicker*** pulses (kicker plates, blumleins, and thyratrons)
- machine, and detector triggers
- …

Detector readiness: ready when needed

	built	commissioned	shutdown act	online DQM	offline
entrance	75%	50%	50%	75%	100%
fiber harp	100%	100%	75%	100%	90%
trackers	100%	75%	50%	100%	90%
calorimeters	100%	100%	90%	100%	100%
laser system	100%	100%	90%	90%	90%
clock, trigger	90%	50%	75%	90%	100%
aux	90%	80%	75%	80%	90%

Detector experts

- **Run Coordinators**
  Kiburg (FNAL), Kaspar (UW)
  - **Ring Ops**
    Nguyen (FNAL)
    Crnkovic (BNL)
    - **Magnet**
      Allspach (FNAL)
    - **Inflector**
      Nguyen (FNAL)
    - **Kicker**
      Stoughton (FNAL)
    - **Quads**
      Crnkovic (BNL)
  - **Field Ops**
    Flay (UMass)
    Hong (ANL)
    - **Trolley**
      Hong (ANL)
    - **Plunging probe**
      Flay (UMass)
    - **Fixed probes**
      George (UT)
    - **Surface Coils**
      Osofsky (UW)
    - **Flux gate**
      Tewsley-Booth (UMich)
    - **Calib. Probes**
      Flay (UMass)
  - **Detector Ops**
    Price (Liverpool)
    Mott (BU)
    - **Calorimeters**
      Hempstead (UW)
    - **WFD5 & CCC**
      Sweigart (Cornell)
    - **Laser**
      Marco Incagli (INFN)
    - **Trackers**
      Price (Liverpool)
    - **Aux Detectors**
      Gray (Regis)
    - **Slow Controls**
      Eads (NIU)
  - **DAQ/Online Ops**
    Gohn (UKy)
    Chislett (UCL)
    - **Fast DAQ**
      Gohn (UKy)
    - **DQM**
      Fienberg (UW)
    - **Field DAQ**
      Hong (ANL)
    - **Tracker DAQ**
      Chislett (UCL)
    - **Laser Hut DAQ**
      Driutti (INFN)

Summary: well integrated detector ready for physics

- ***detector ready*** for physics data and trigger rates
- ***detector state*** is ***reproducible***; based on redundant pieces of information
- online ***data quality*** monitoring ready, and the ***infrastructure tested***
- offline (and nearline) infrastructure tested
- ***sufficient pool of spare parts***
- well defined ownership, experts, and onsite personal