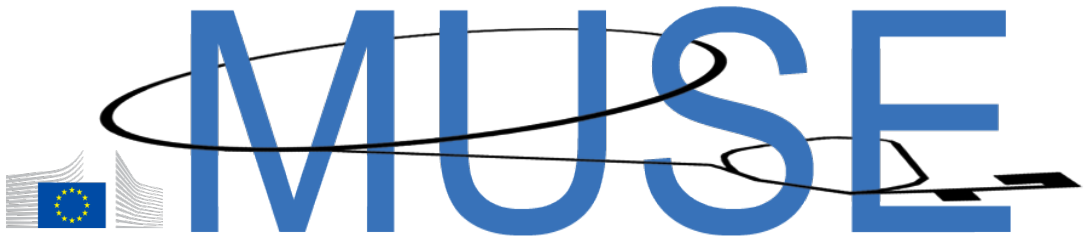


H2020-MSCA-RISE-2015 – Grant Agreement N° 690835

g-2 Tracker

Mark Lancaster (UCL)

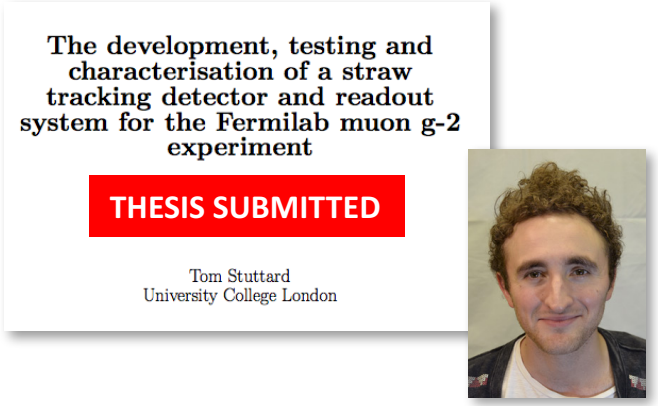
MUSE Mid-Term Meeting
Frascati, 11 May 2017

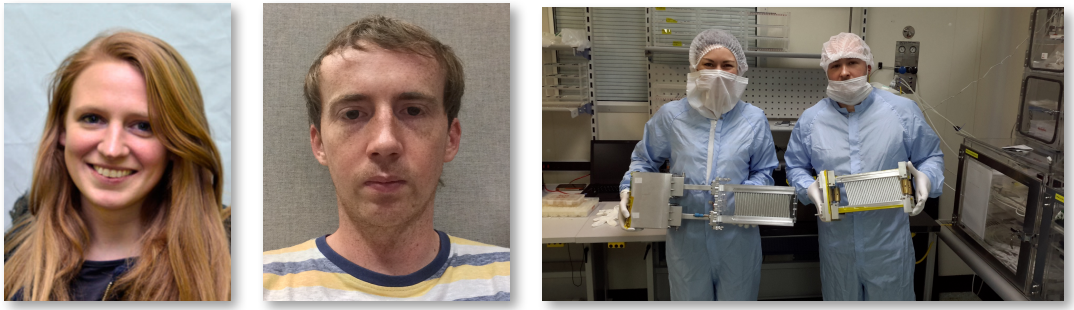
The Team

MUSE has/is/will support the secondment of:

- 8 PhD students
- 2 PostDocs
- 3 Faculty/Academics
- 2 Technicians

to FNAL





Milestones / Deliverables

D1.2 : Installation and initial commissioning of g-2 trackers: 01.01.18

M1 : Tracker DAQ integrated with g-2 DAQ: 01.06.17 (completed 10.04.17) ✓

D3.2 : Software calibration and alignment tools for g-2 straw trackers: 01.07.17

M5: g-2 Calibration system commissioned (tracker & calo): 01.01.19

D4.2: g-2 simulation of 10^{11} μ & stress-testing of analysis framework: 01.01.17 ✓

M6: g-2 offline reconstruction code for analysis of data: 01.01.17 ✓

One deliverable and two milestones already achieved on time
and D1.2 and D3.2 on track.

g-2 Measurement

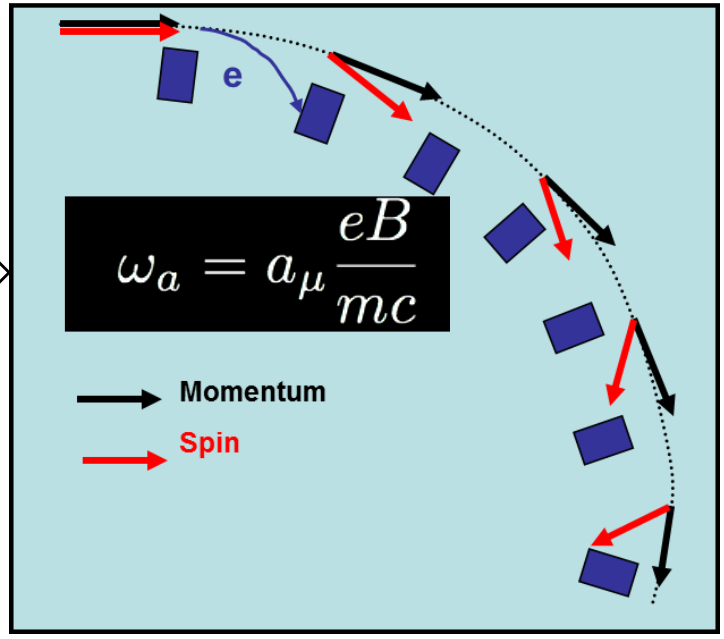
Particle in a circular storage ring (B-field): two frequencies:

$$\omega_S = \frac{geB}{2mc} + (1-\gamma)\frac{eB}{\gamma mc} \qquad \omega_C = \frac{eB}{mc\gamma}$$

Spin vector of muon rotates slightly quicker than Momentum vector.
For a 1.5T field spin rotates in 144ns and momentum in 149ns.

$$\omega_a = \omega_S - \omega_C$$
$$= \left(\frac{g-2}{2}\right)\frac{eB}{mc} = a\frac{eB}{mc}$$

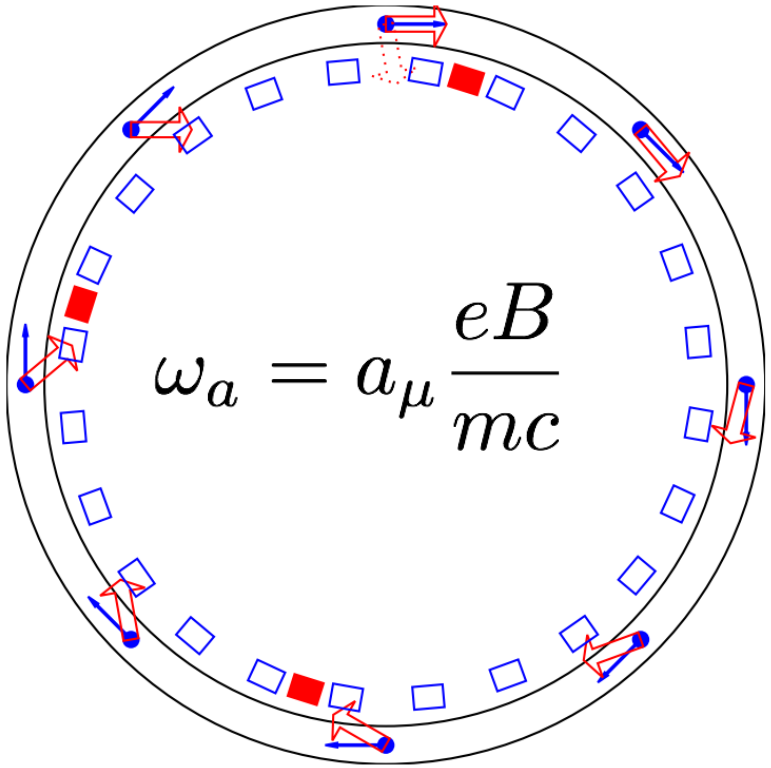
$$f_a = 228 \text{ kHz}$$



g-2 Measurement

Inject 3.09 GeV muons into a storage ring (B = 1.45 T)

Exploit property that direction of e^+ from μ^+ decay is strongly correlated with μ^+ spin for highest energy e^+

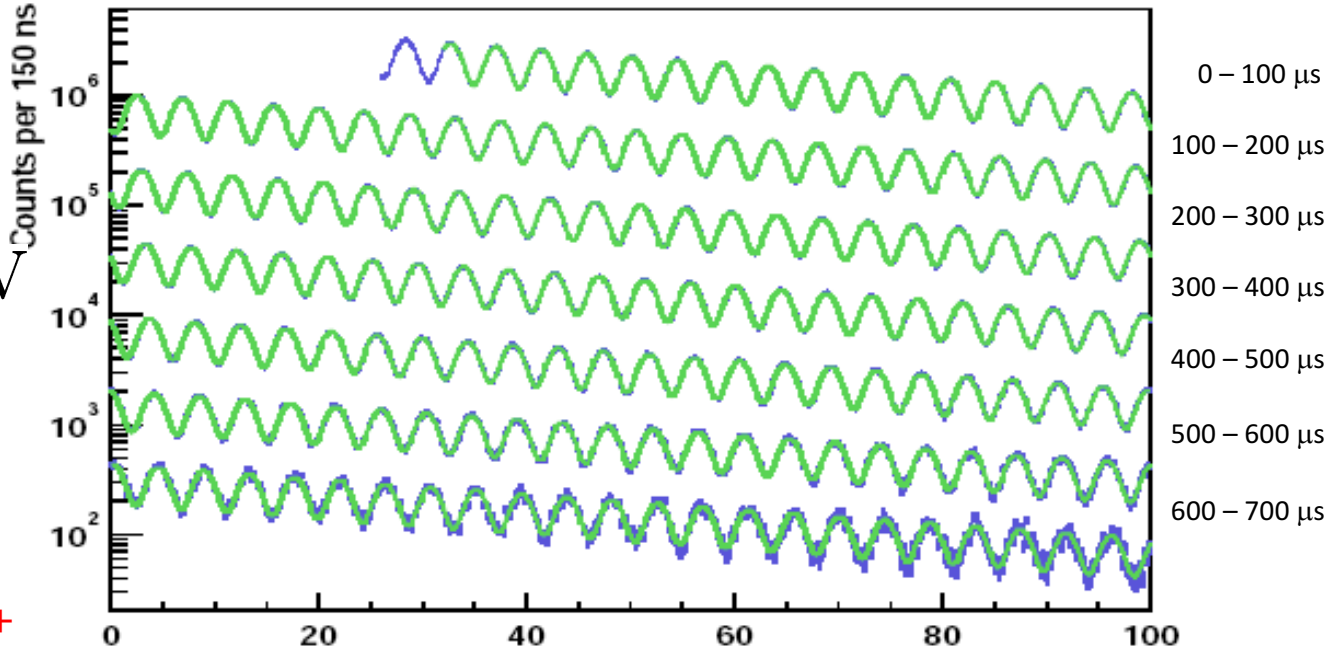


24 calorimeters and 3 straw trackers
Measure e^+ for O(1 ms) for spills separated by 10ms.
16,000 stored 3.09 GeV muons from 10^{12} protons per spill.

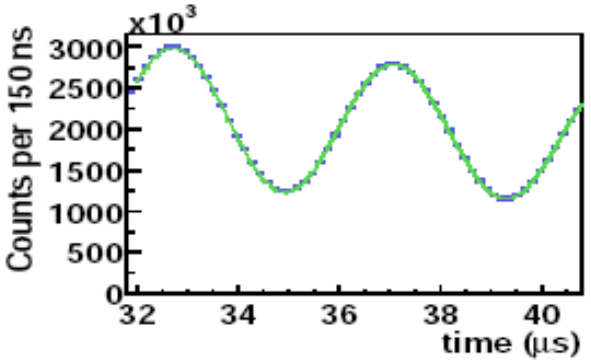
g-2 Measurement

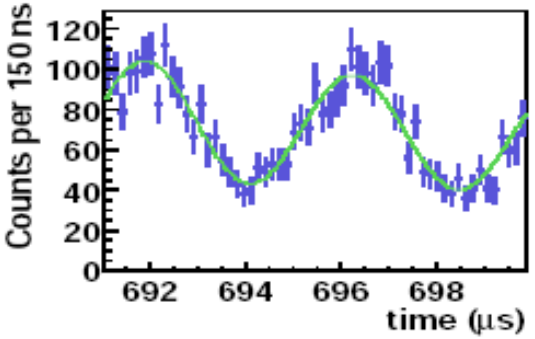
$$N_e(t) \simeq N_0 e^{-\frac{t}{\gamma\tau}} [1 - A\cos(\omega_a t + \phi_a)]$$

$E_{e+} > 1.8$ GeV



Need ~ 10^{11} μ^+

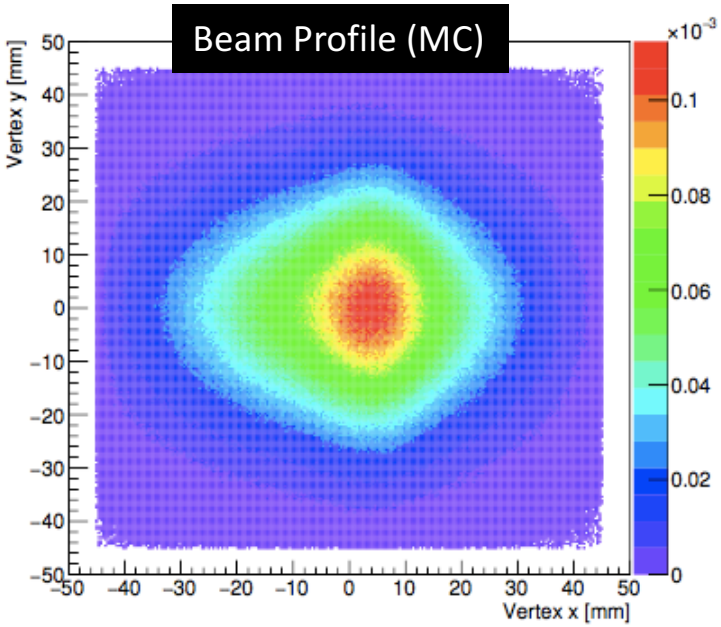


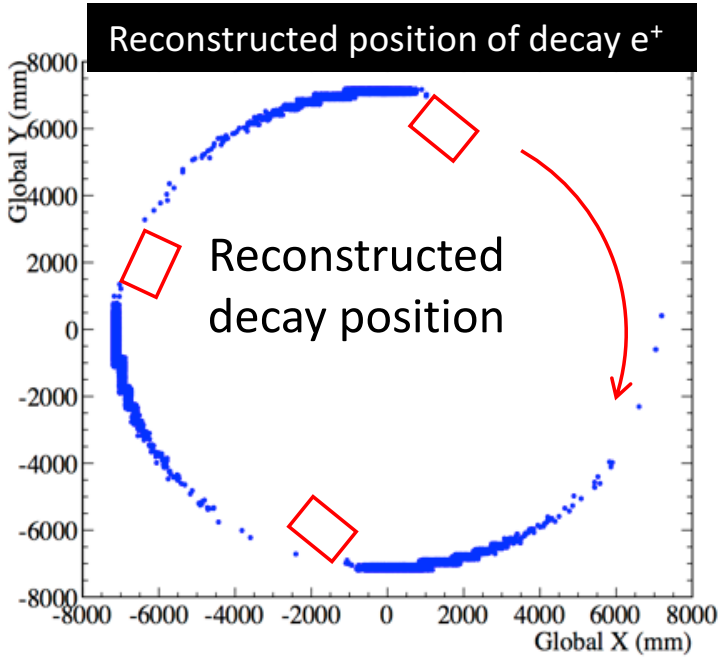


g-2 Straw Trackers : Motivation

1. Measure beam profile
2. Identify pileup & muons lost from beam
3. Measure EDM

Trackers "see" approx 70% of the ring



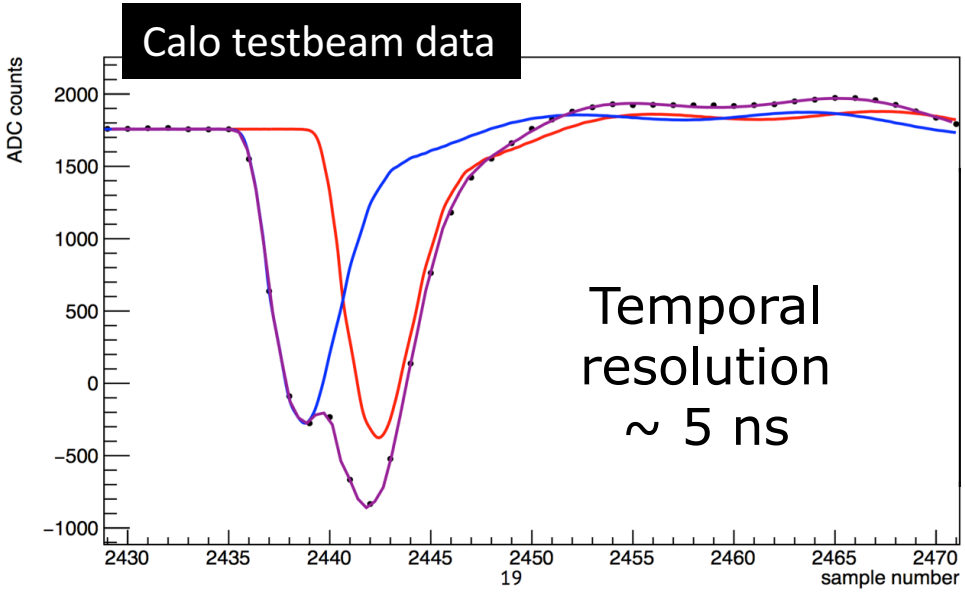


Muons aren't uniformly distributed over storage volume (e.g. due to CBO).

B-field is not uniform over this volume

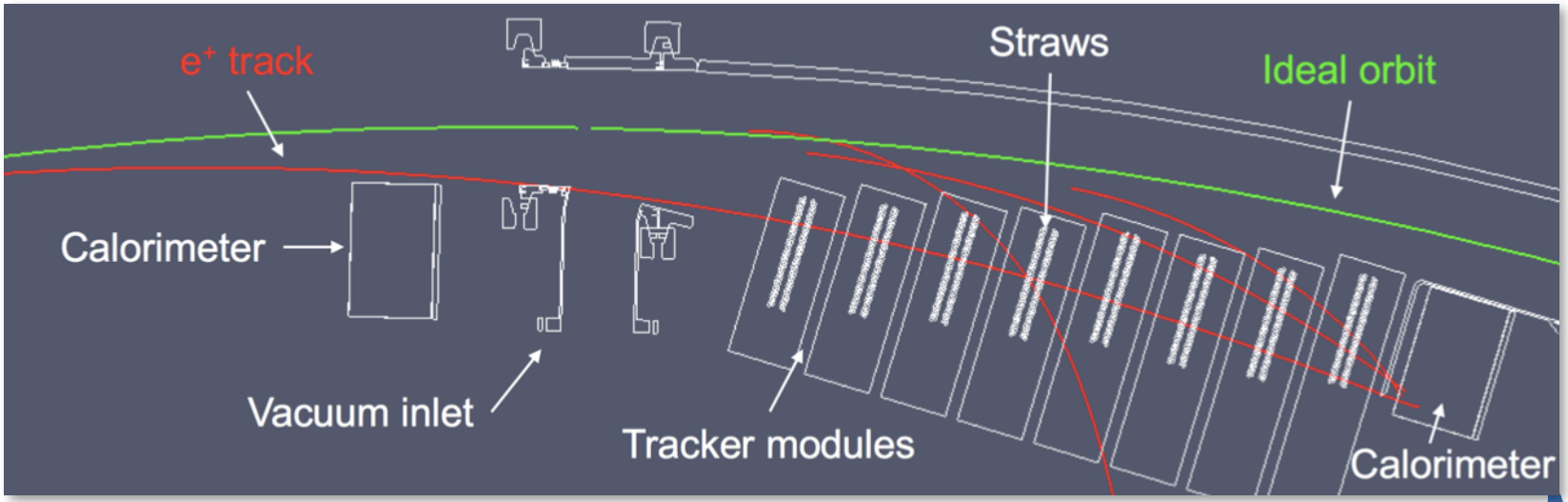
Need to convolute the two.

g-2 Straw Trackers : Calo matching

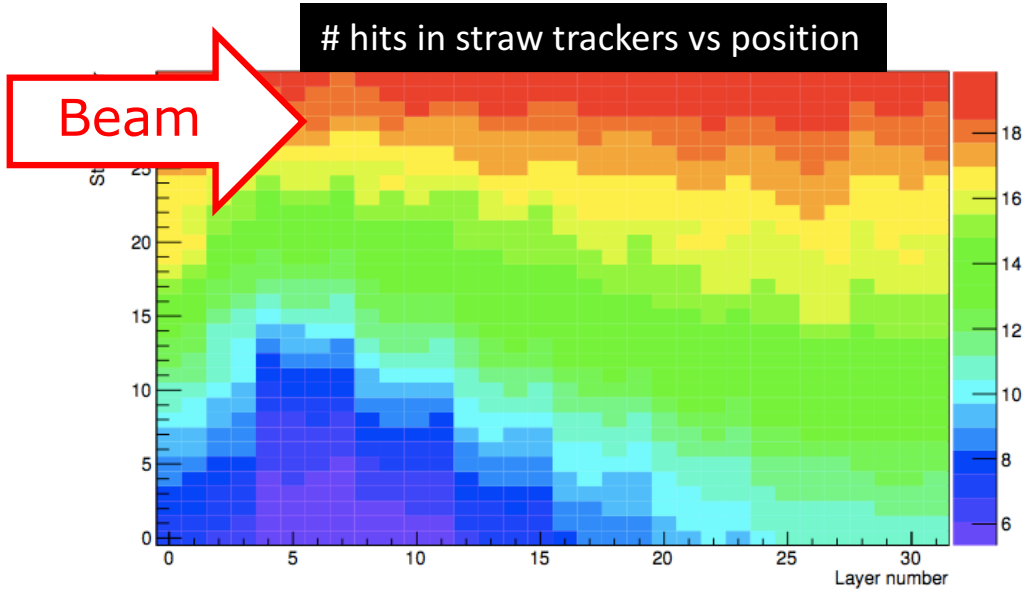


Temporal resolution ~ 5 ns

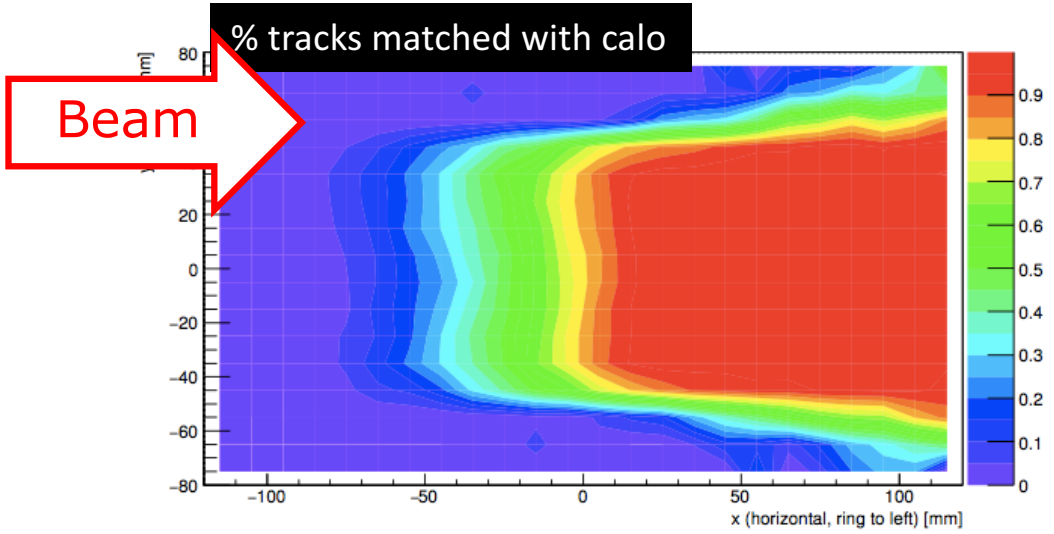
Two low energy e^+ that overlap spatially and temporally in the calo can be counted as a single high energy e^+



g-2 Straw Trackers : Calo matching



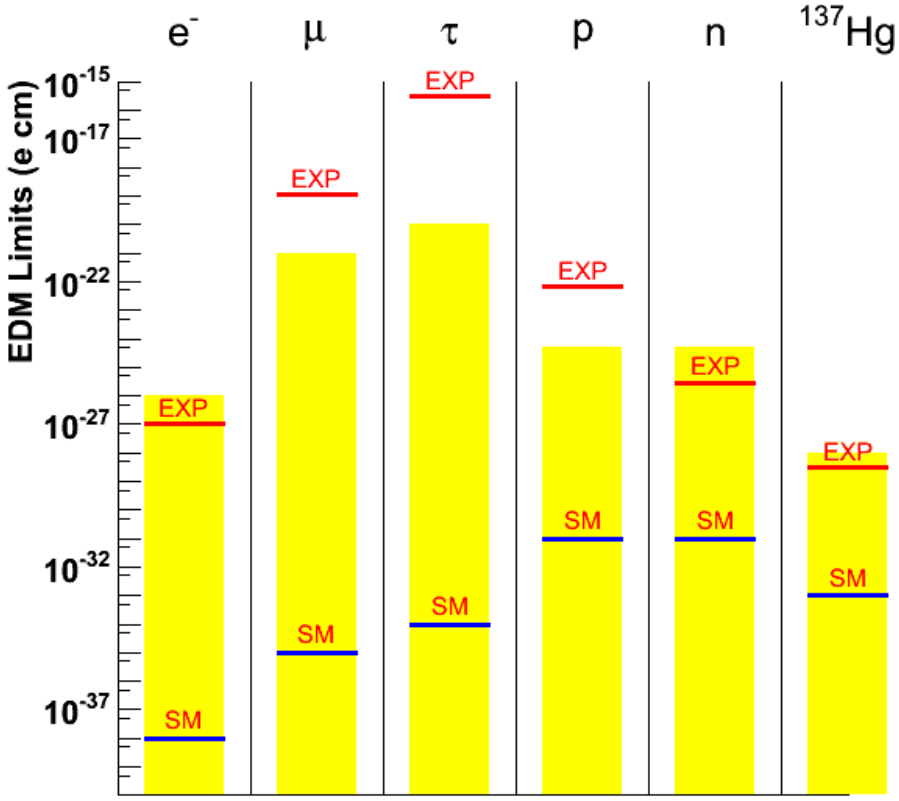
Majority of hits on innermost straws



Match ~ 90% of tracks for crystals furthest from ring

g-2 Straw Trackers : Muon EDM

Essentially zero in SM : any observation is new physics

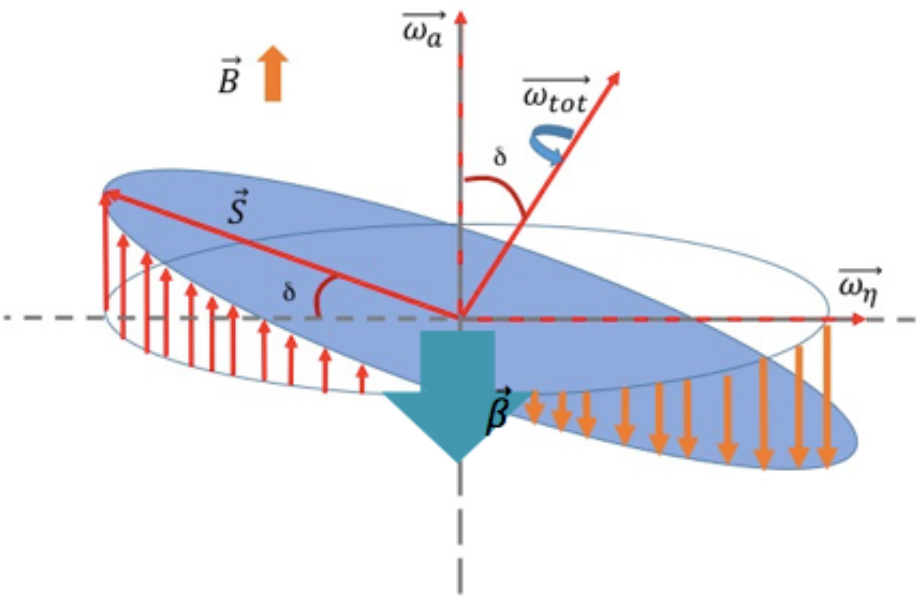


EDM would increase precession frequency and tilt precession plane giving vertical asymmetry in the muon distribution

Trackers have resolution to measure vertical asymmetry

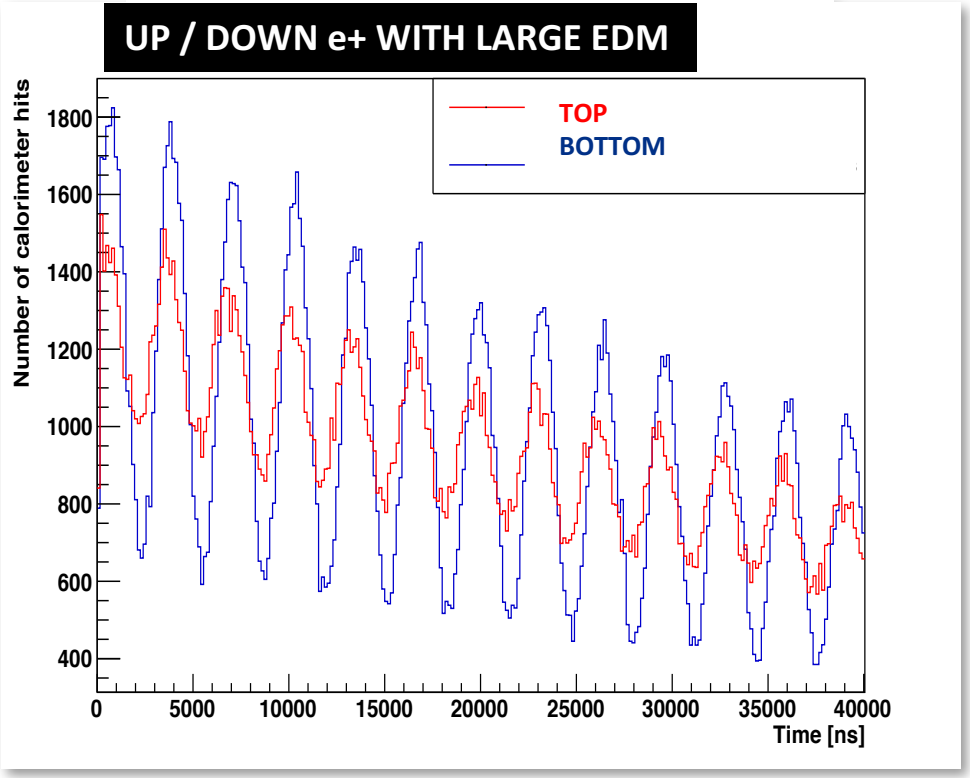
New trackers have larger acceptance, live-time vs BNL trackers

g-2 Straw Trackers : Muon EDM



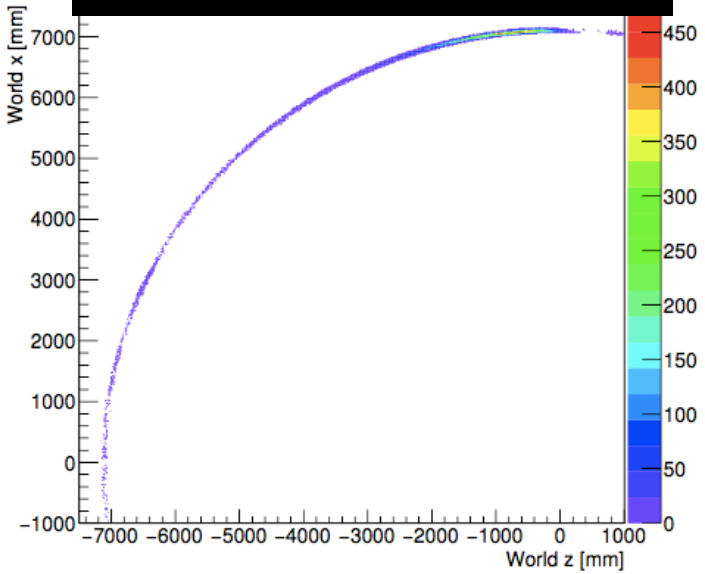
$$\omega_{tot} = \sqrt{{\omega_a}^2 + {\omega_\eta}^2}$$

Expect several billion events in the trackers and so reach sensitivity of 10^{-21} vs 2×10^{-19} at BNL

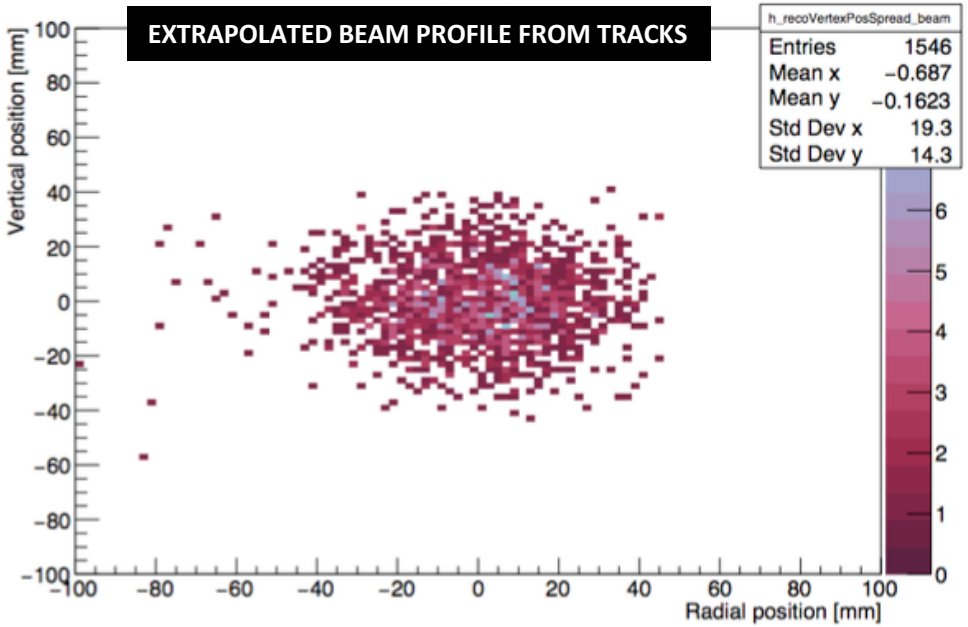


g-2 Straw Trackers : Tracking Code

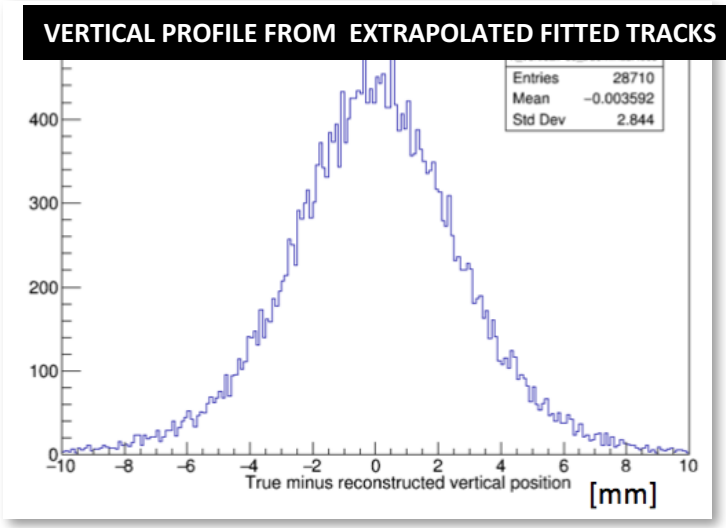
ORIGIN OF e^+ HITTING ONE OF THE 3 TRACKERS



EXTRAPOLATED BEAM PROFILE FROM TRACKS

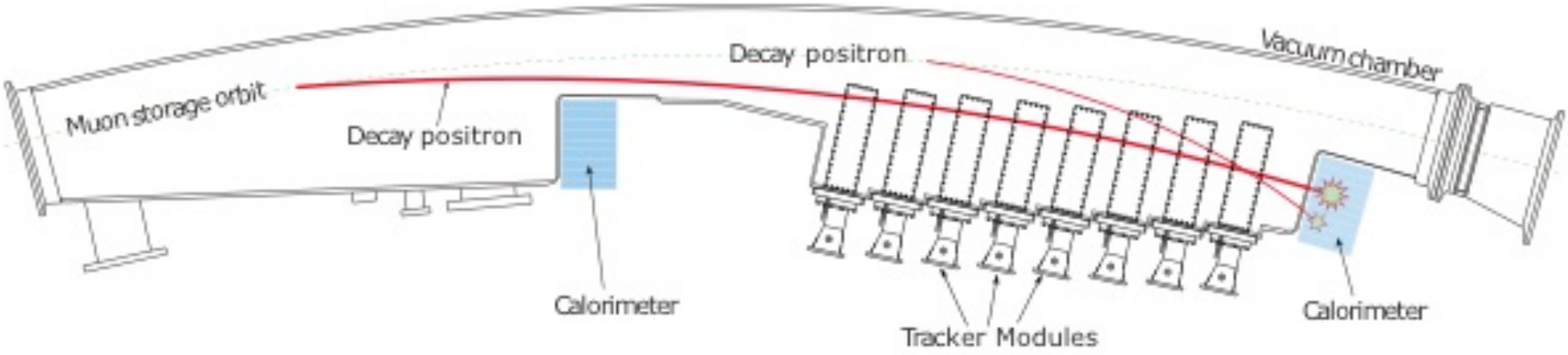


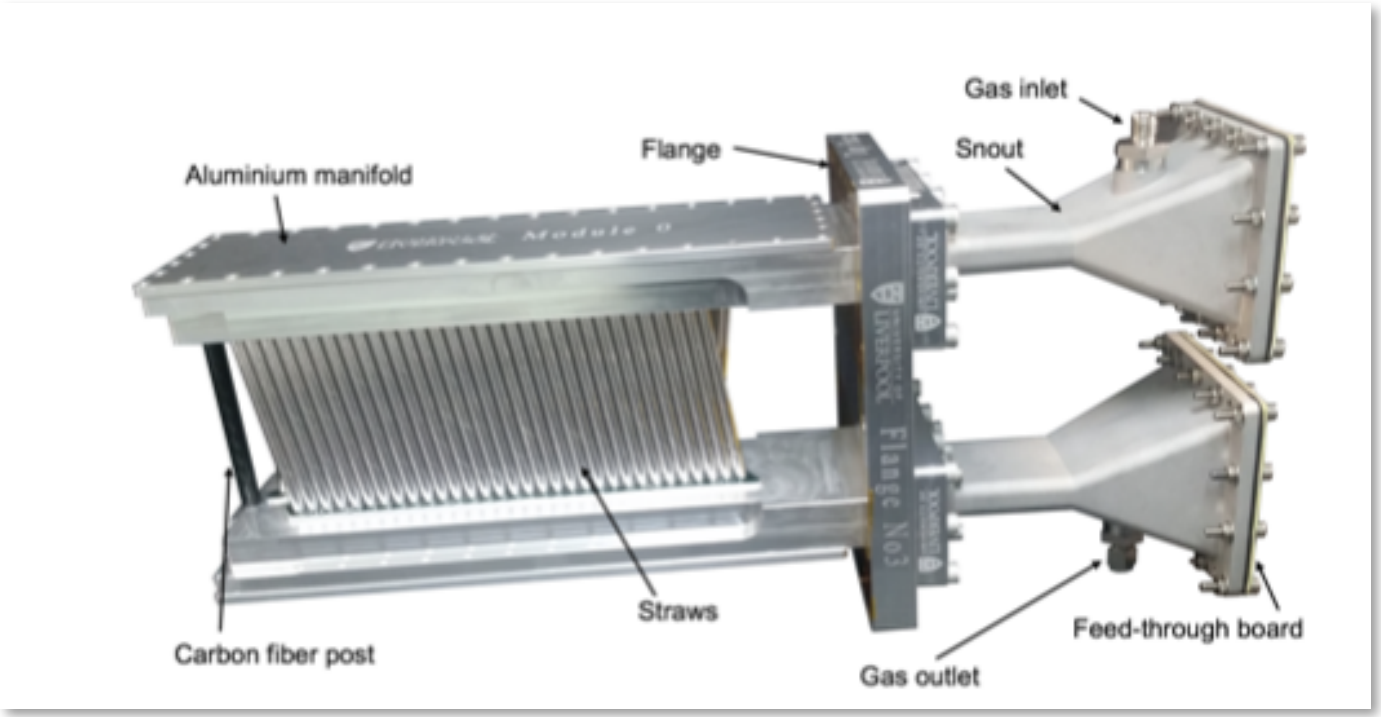
VERTICAL PROFILE FROM EXTRAPOLATED FITTED TRACKS



Inputs into E-field and pitch corrections to a_μ

g-2 Straw Trackers



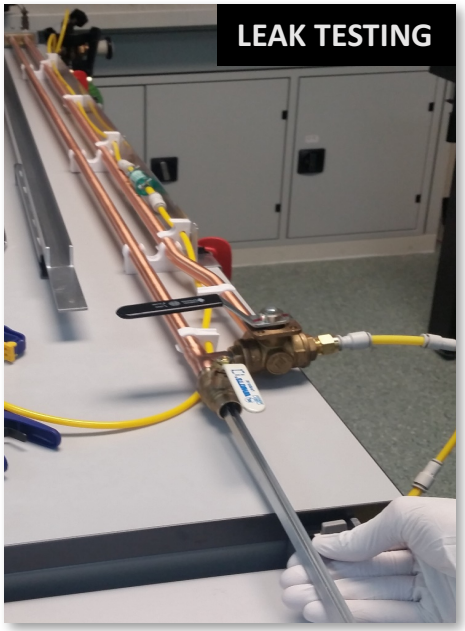


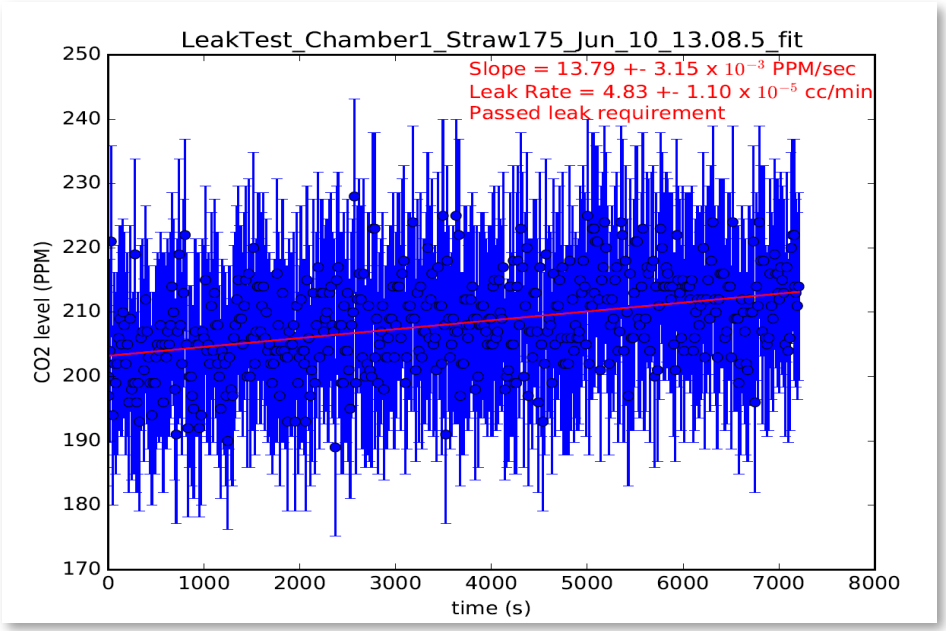
8 modules per tracker

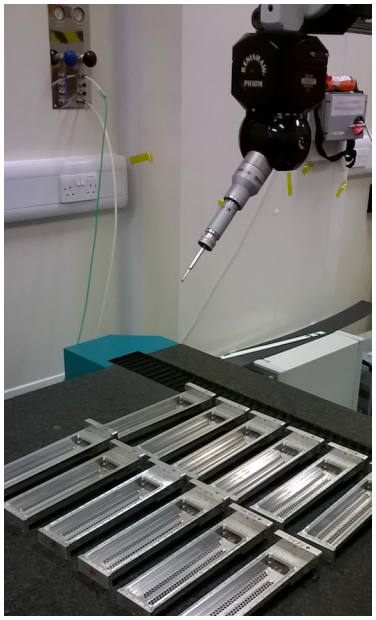
Built in Liverpool
and shipped to FNAL

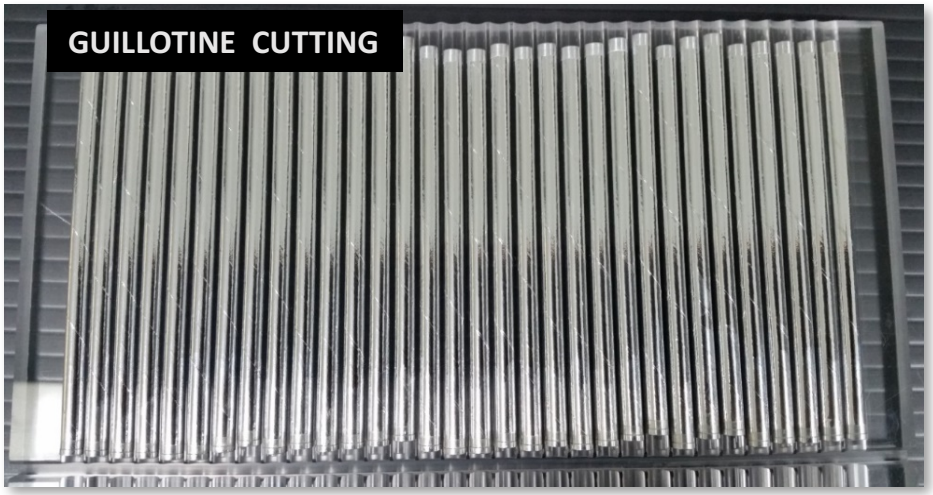
Off detector electronics
& DAQ from UCL

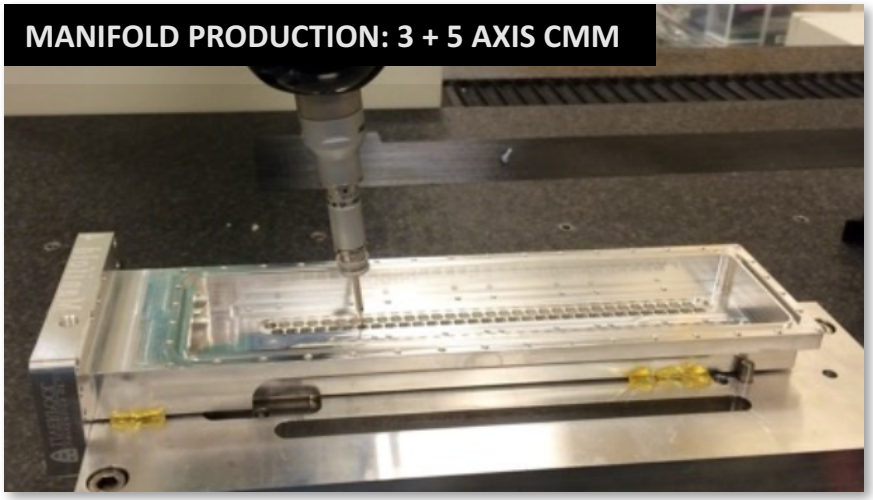
g-2 Straw Trackers : Construction





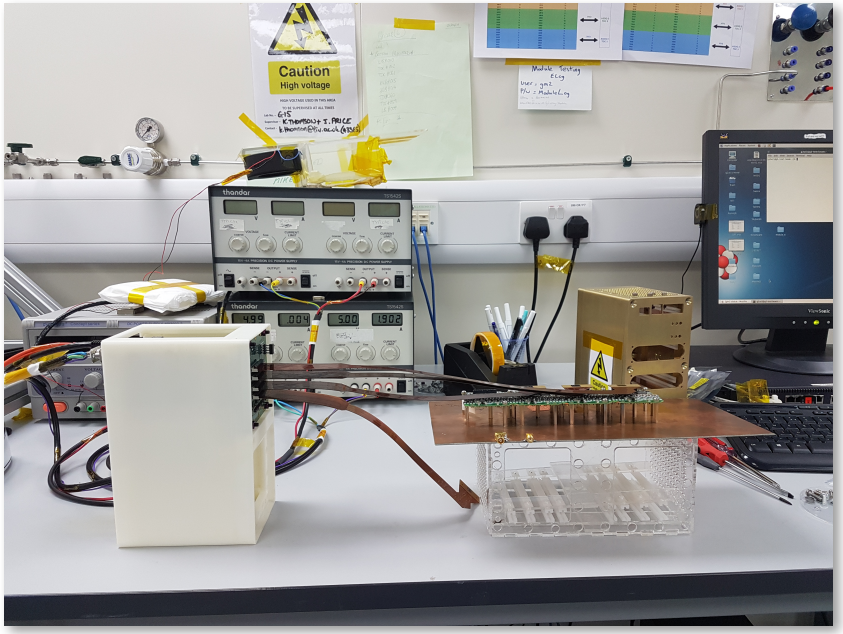




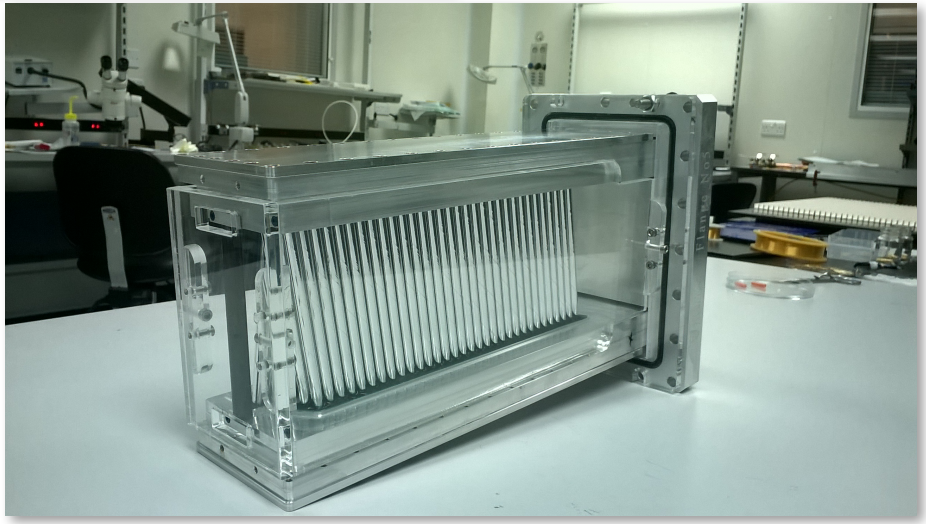


g-2 Straw Trackers : QA

Prisma Electronics SA

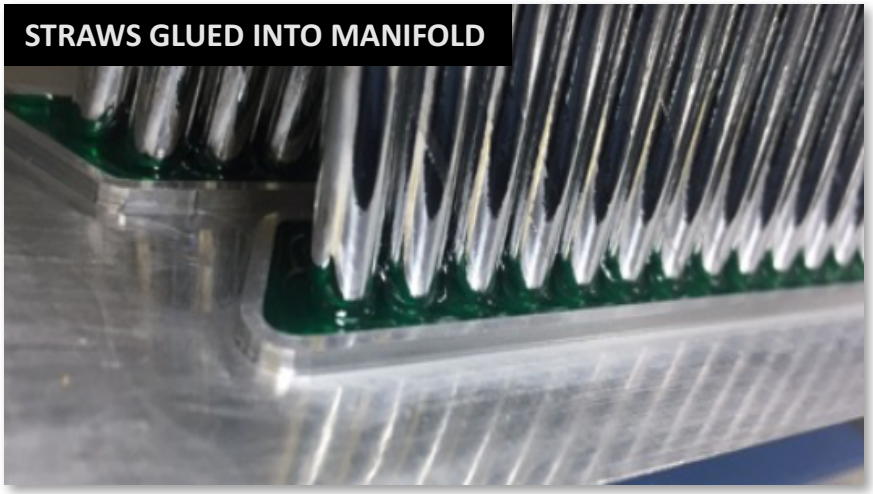


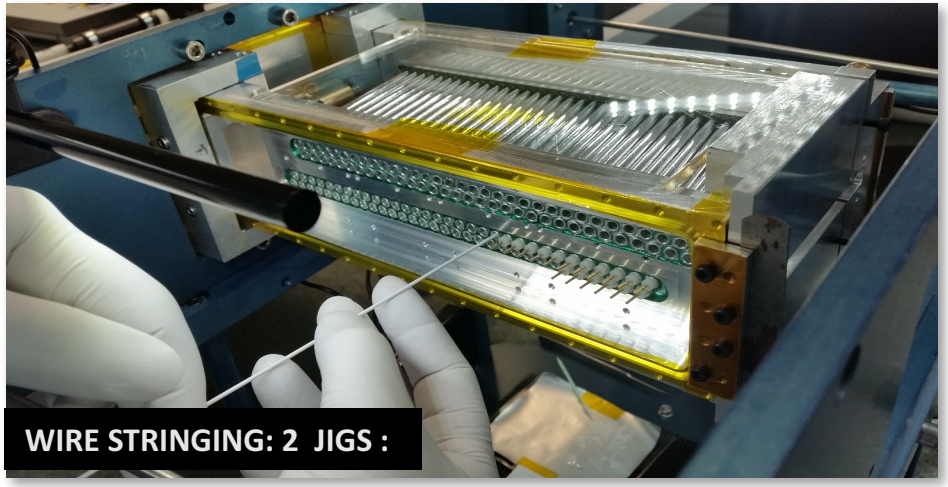
Help from PRISMA in QA
- grounding / HV
- leak testing : straw QA



g-2 Straw Trackers : Construction

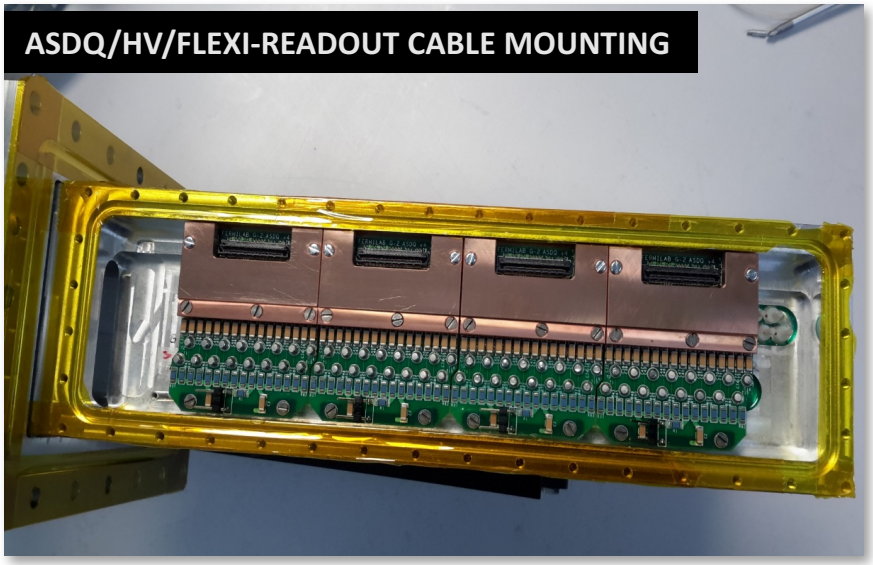
STRAWS GLUED INTO MANIFOLD



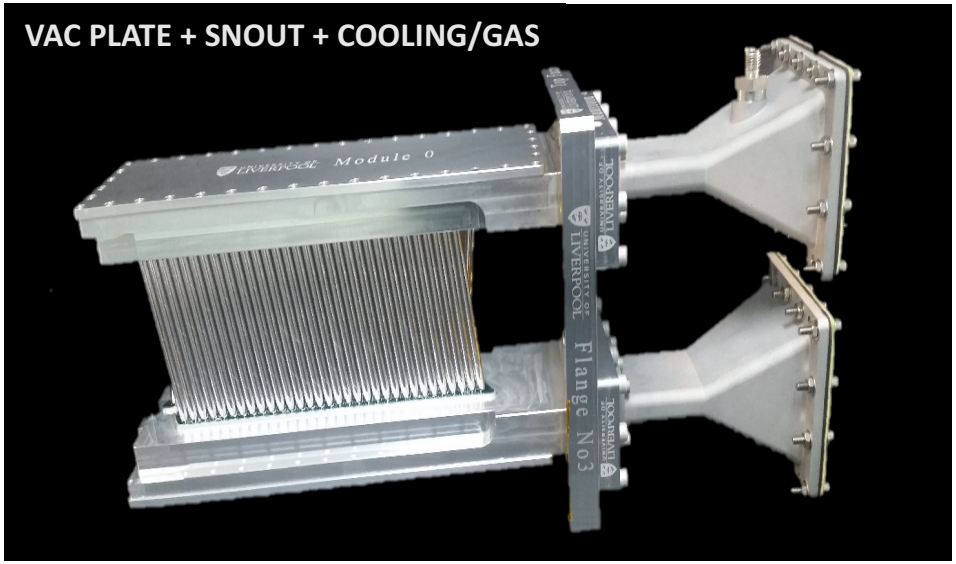


WIRE STRINGING: 2 JIGS :

ASDQ/HV/FLEXI-READOUT CABLE MOUNTING

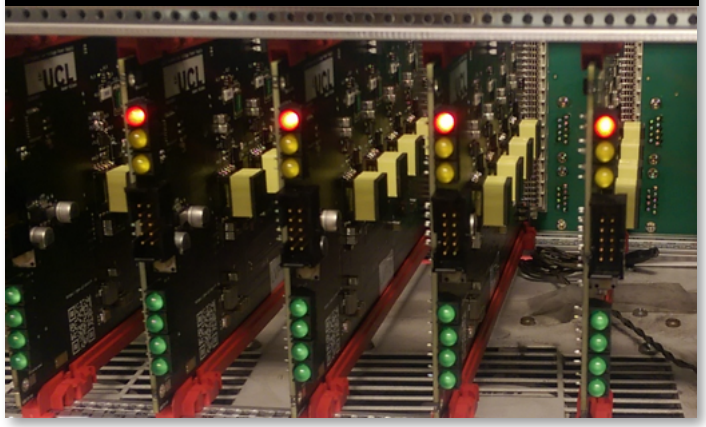


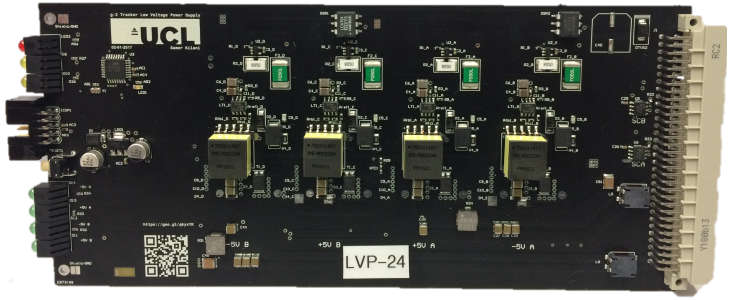
VAC PLATE + SNOUT + COOLING/GAS



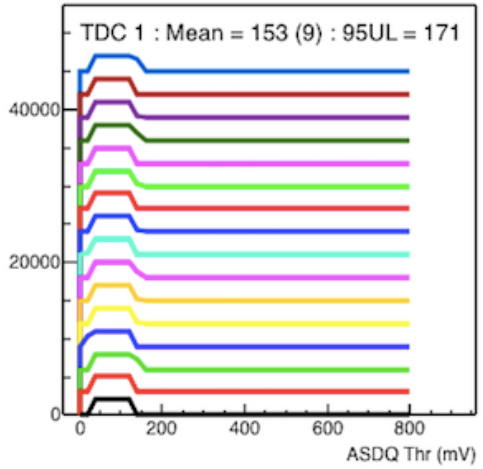
g-2 Straw Trackers : LV/Readout

Bespoke LV + Slow-Control boards

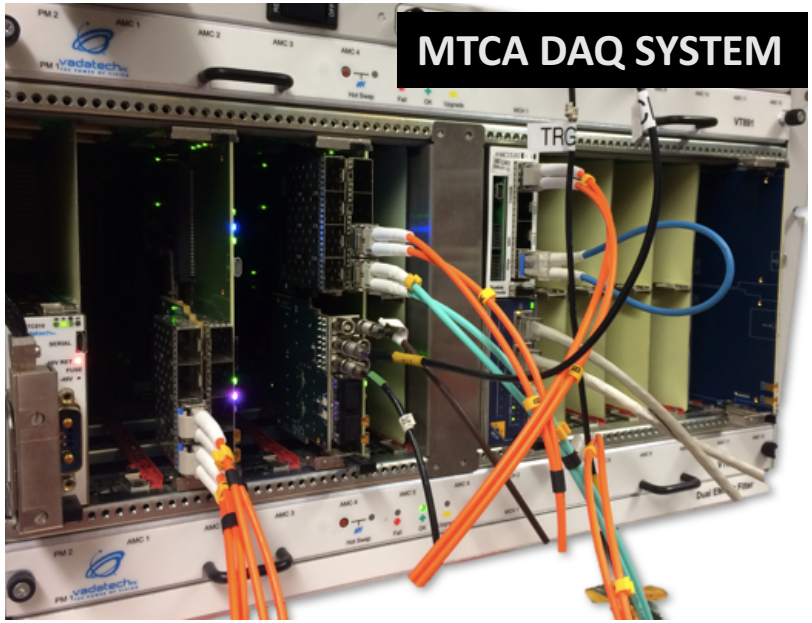




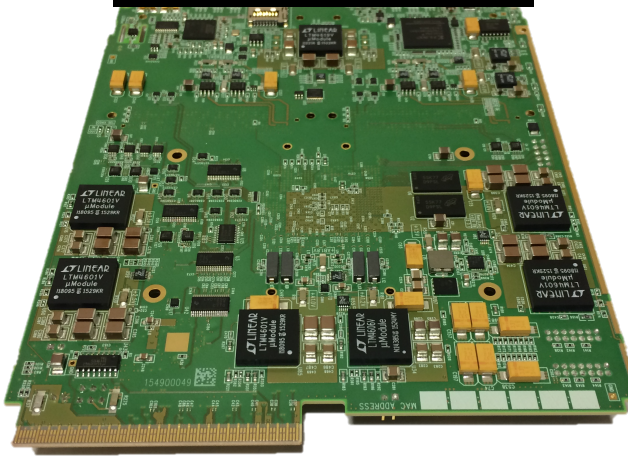
NOISE PERFORMANCE

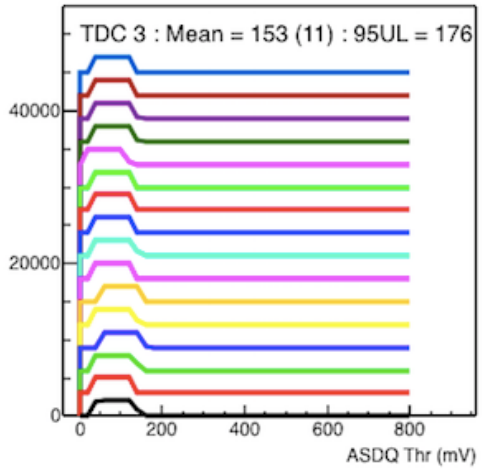


MTCA DAQ SYSTEM

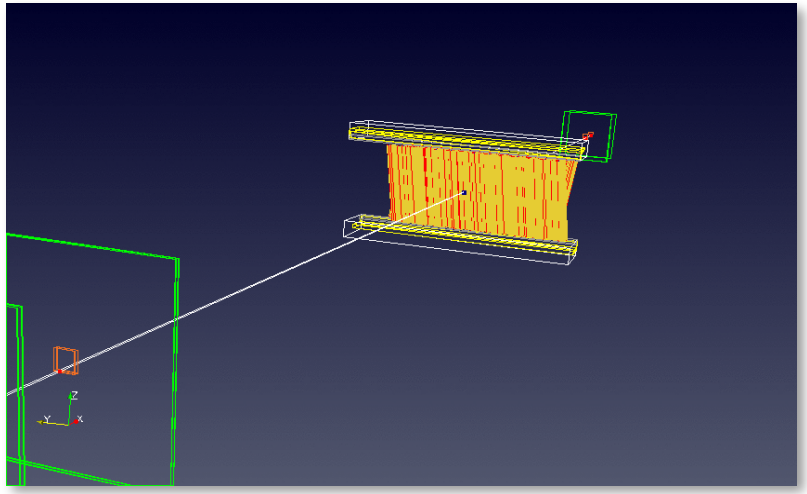


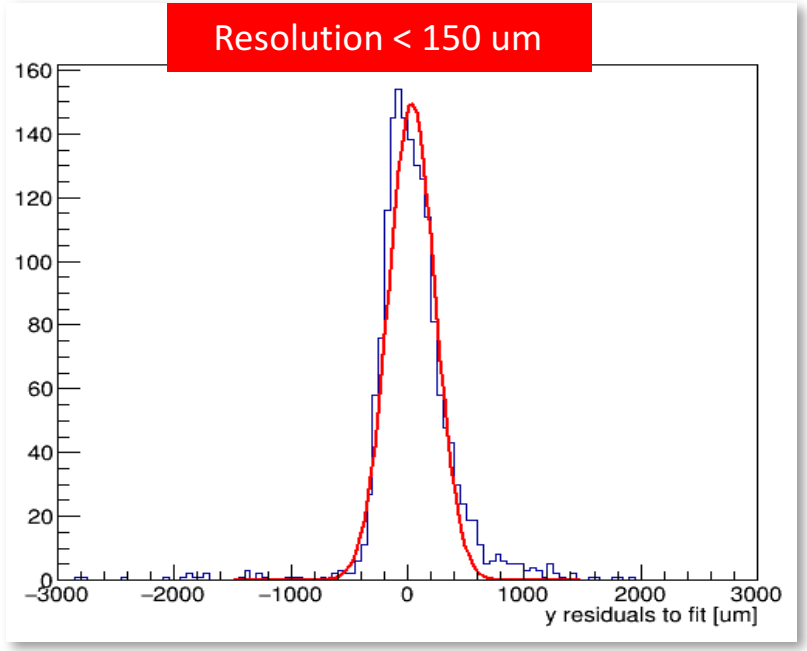
FPGA FC7 FIBER READOUT

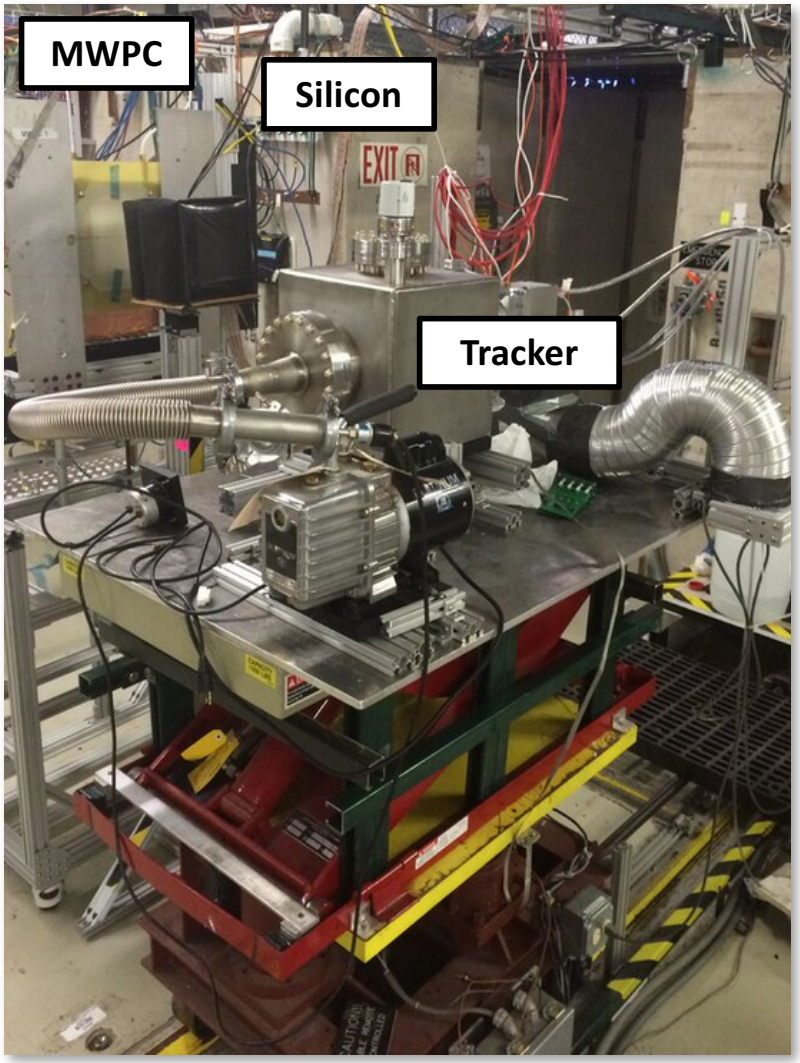




g-2 Straw Trackers : 3 testbeams



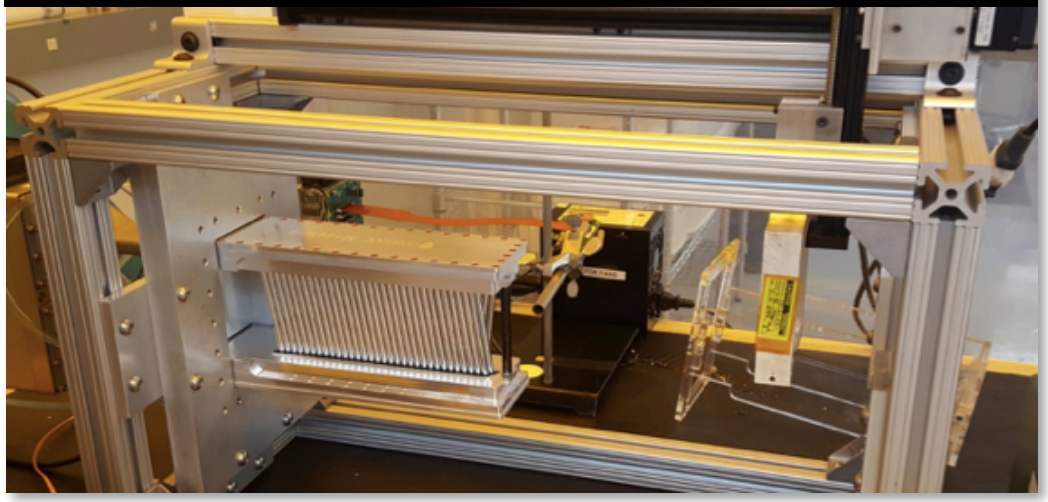


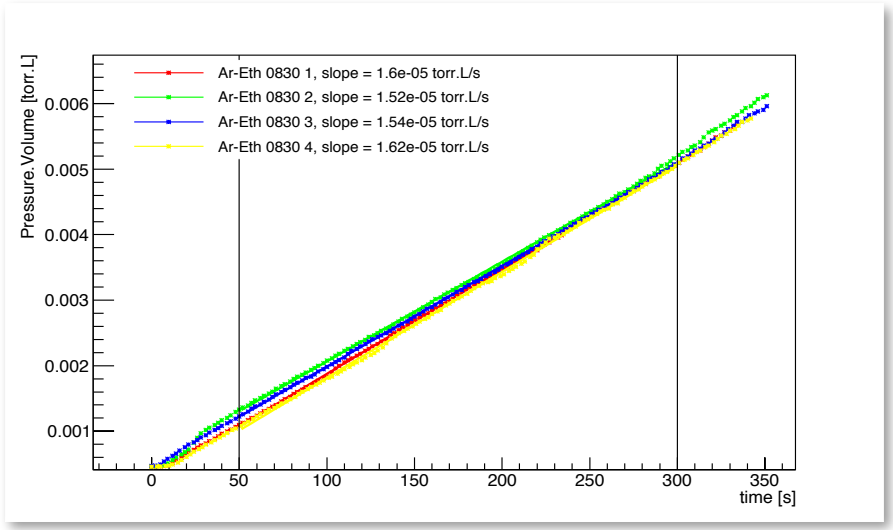


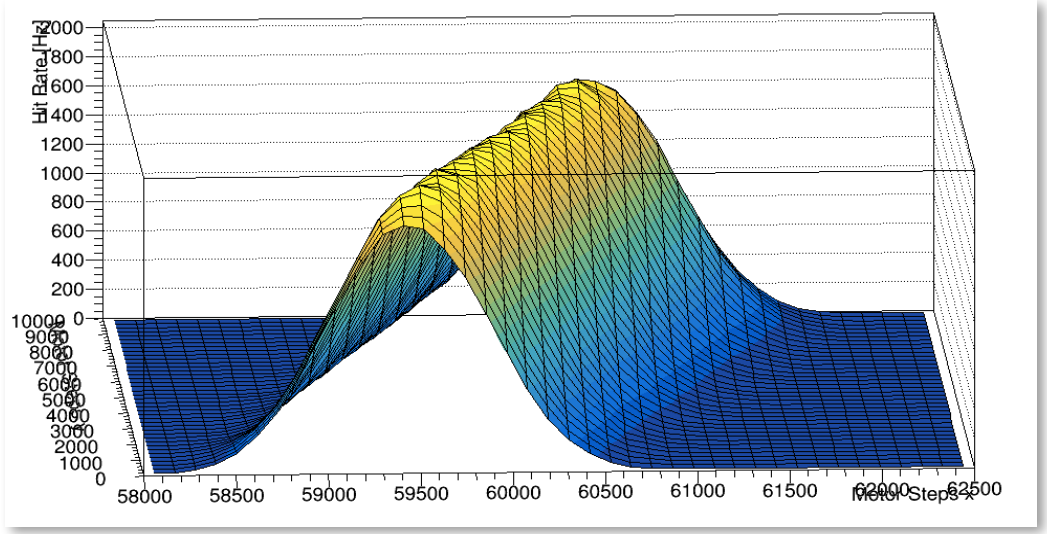
g-2 Straw Tracker: Commissioning

VAC STAND : LEAK TESTING

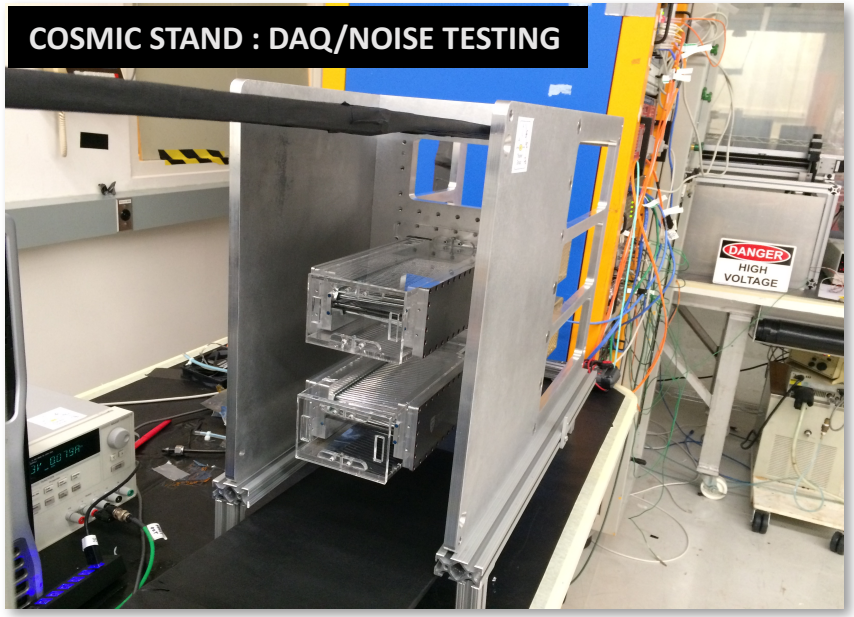
SOURCE STAND : GAIN MEASUREMENTS, X-T CALIBRATION (with NIU)

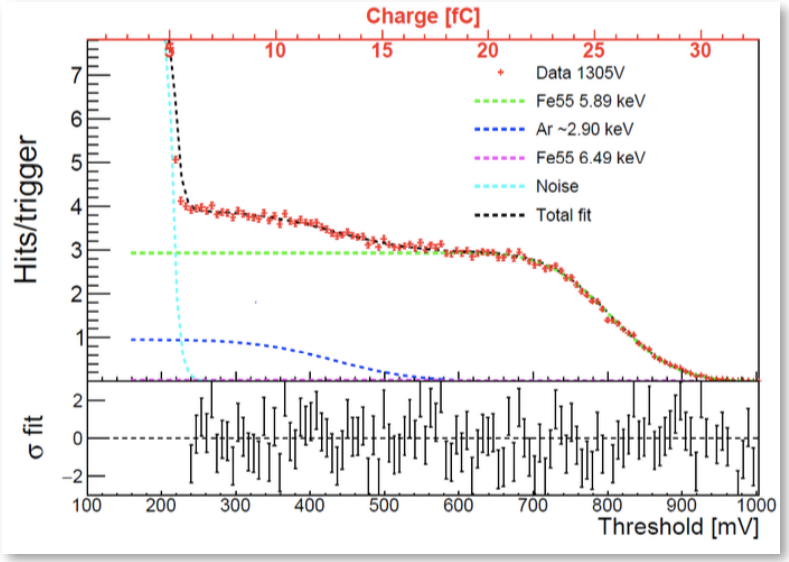


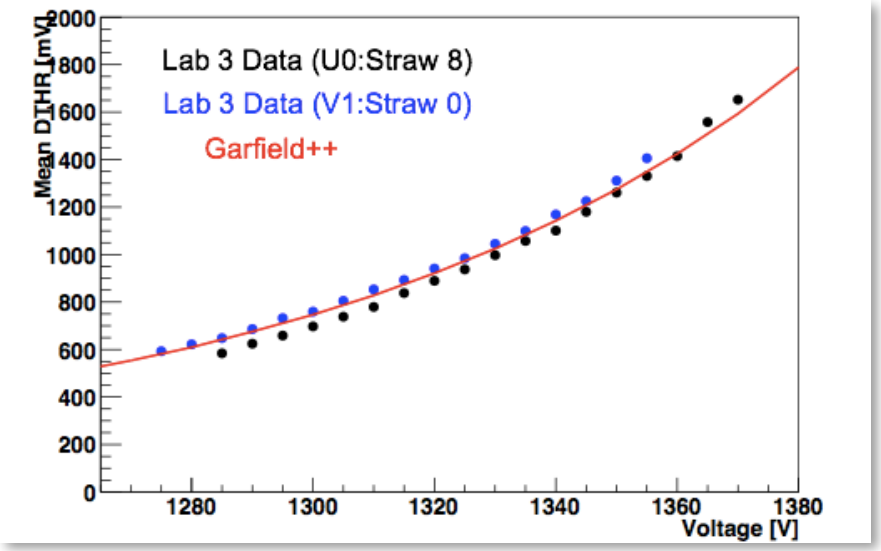




g-2 Straw Tracker : Teststands @ FNAL

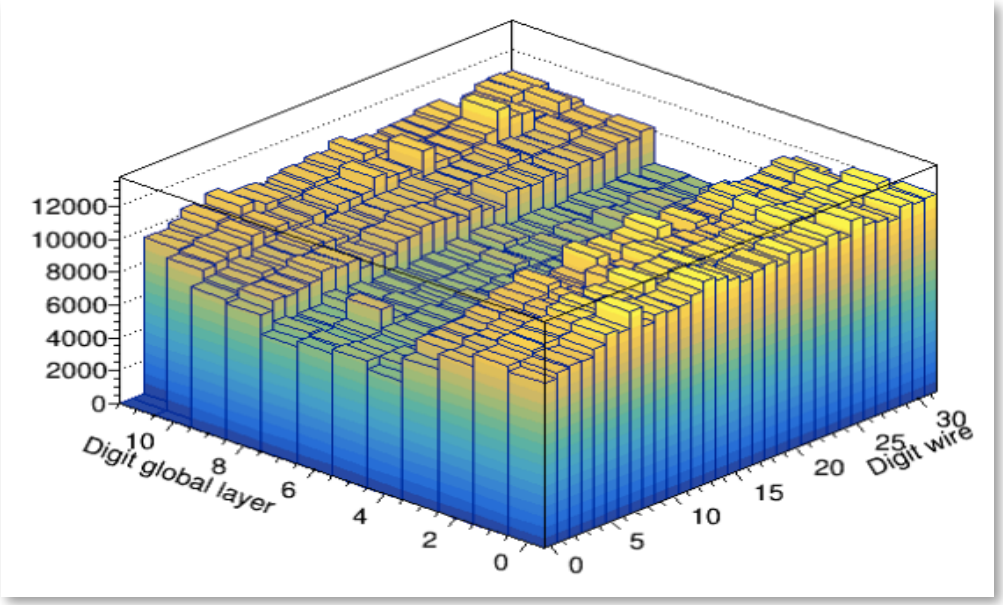


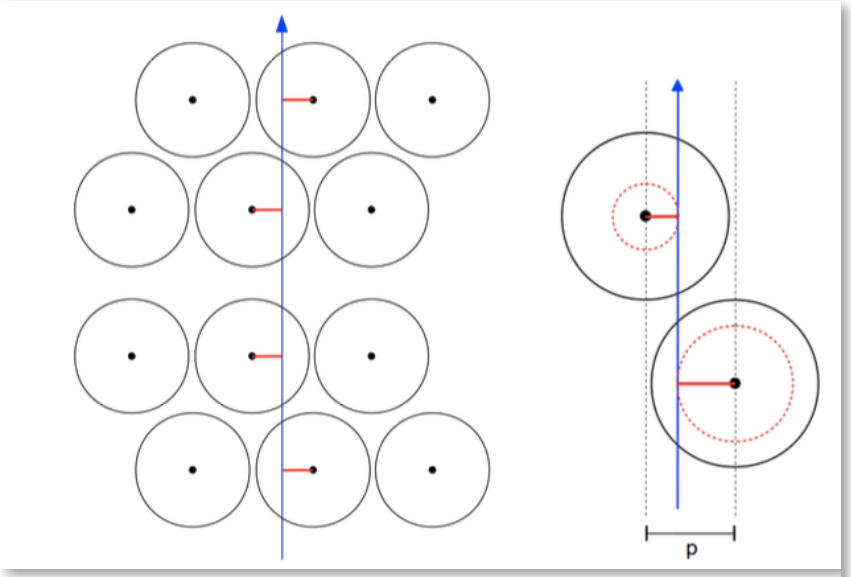


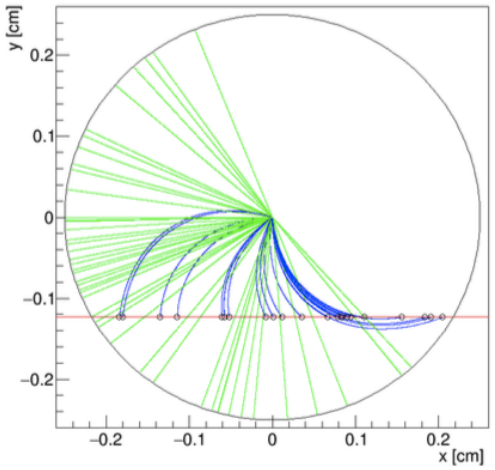


Gain calibration using sources
Time to distance calibration using cosmics

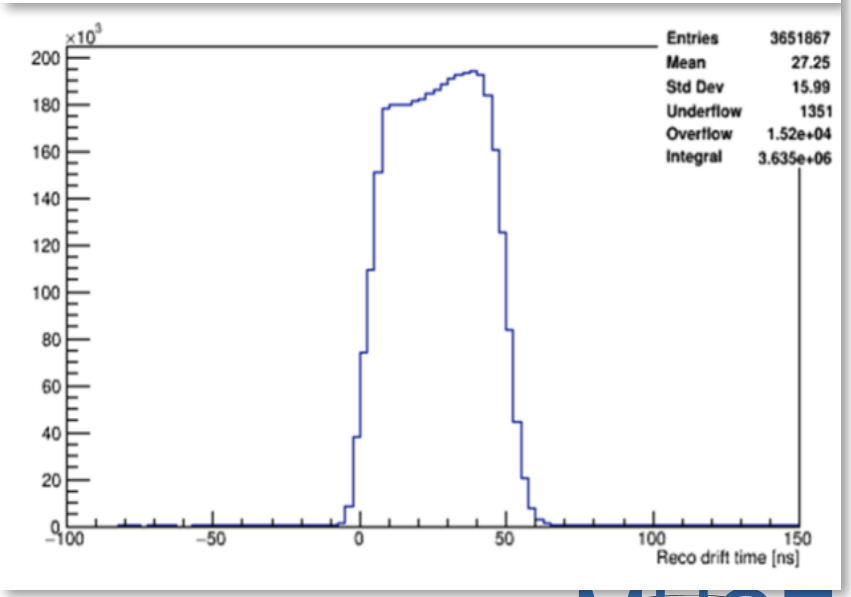
g-2 Straw Tracker : Teststands @ FNAL



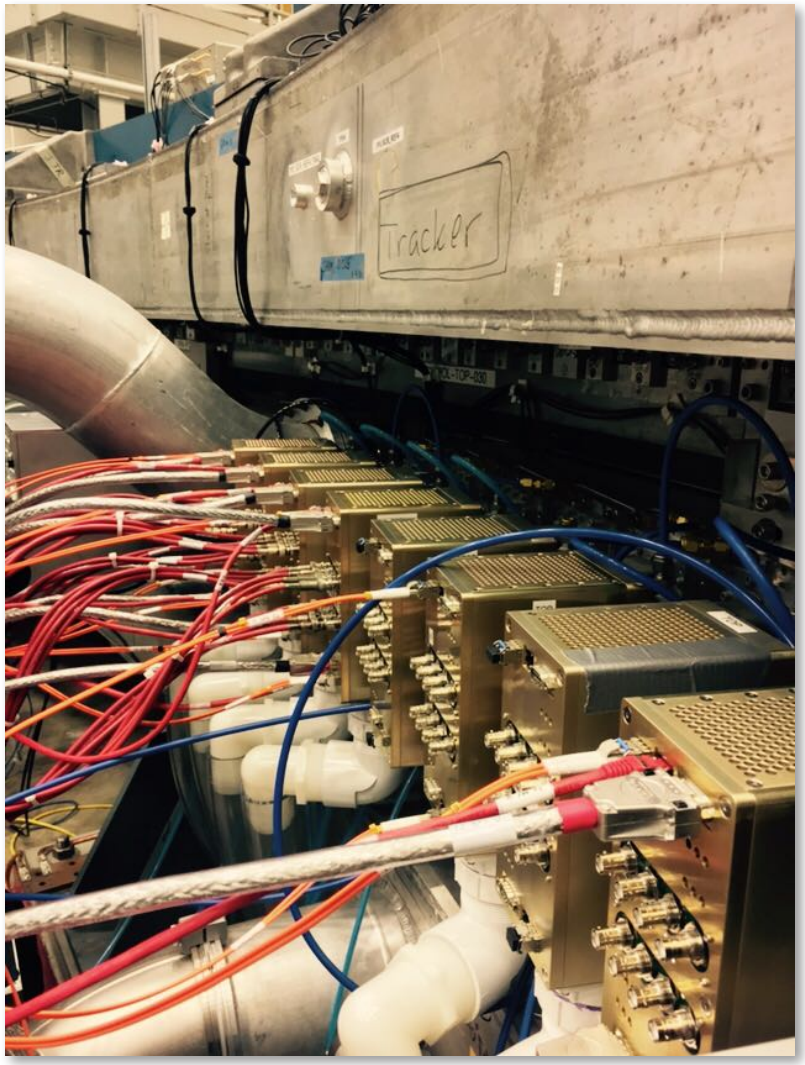




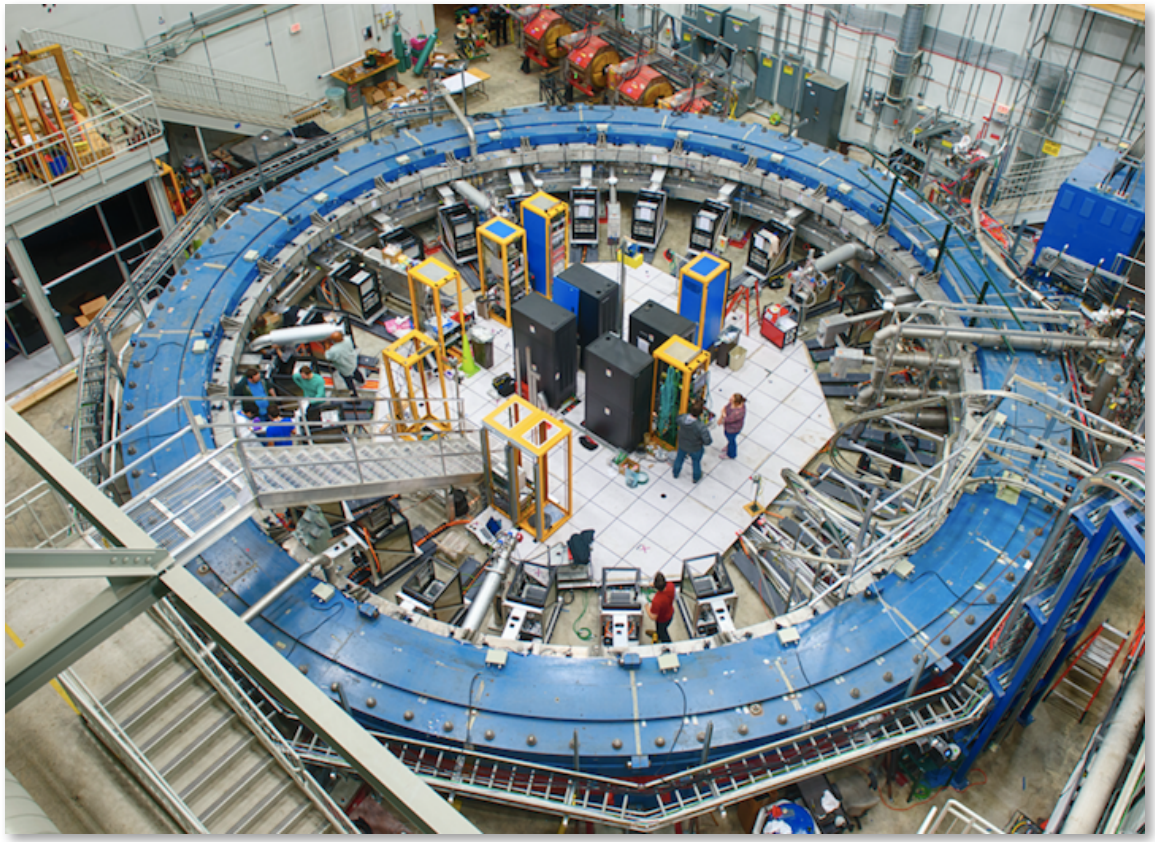
Calibrating the time to distance relation



g-2 Straw Trackers : Installation



g-2 Straw Trackers : DAQ

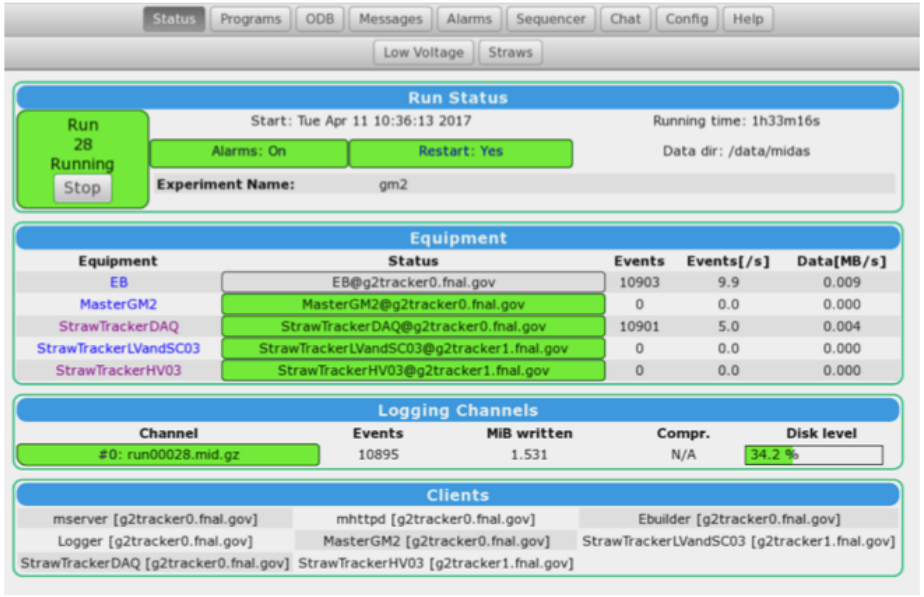


Completed integration with experiment in April

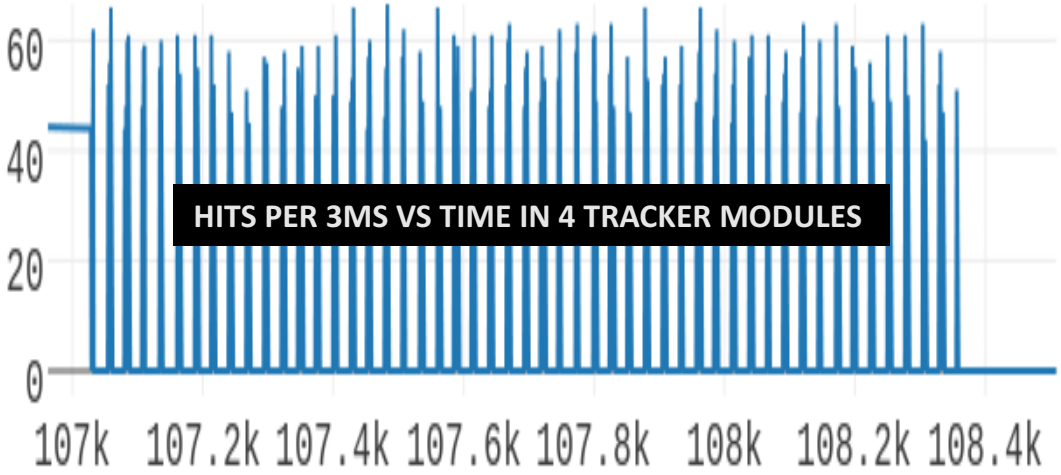
Now running mock-data shifts

g-2 : Data from Ring

TRACKER MIDAS DAQ



TRACKER DQM



HITS PER 3MS VS TIME IN 4 TRACKER MODULES

Hits recorded in trackers while the quads are ramping.

g-2 Straw Trackers : Summary

One of the 3 deliverables already completed on-time.

Remaining two (01.07.17, 01.01.18) are on schedule.

One complete tracker station is now ready for beam and the associated DAQ/readout has been ready for a while.

Tracker source+cosmic+leak stands setup in Lab-3 and MTEST at FNAL to commission/calibrate new modules as they arrive.

The MUSE budget has been absolutely vital in having people at FNAL to commission and install the straw trackers and to bring the detectors to FNAL.

And for the students and postdocs to receive valuable hands-on hardware training.