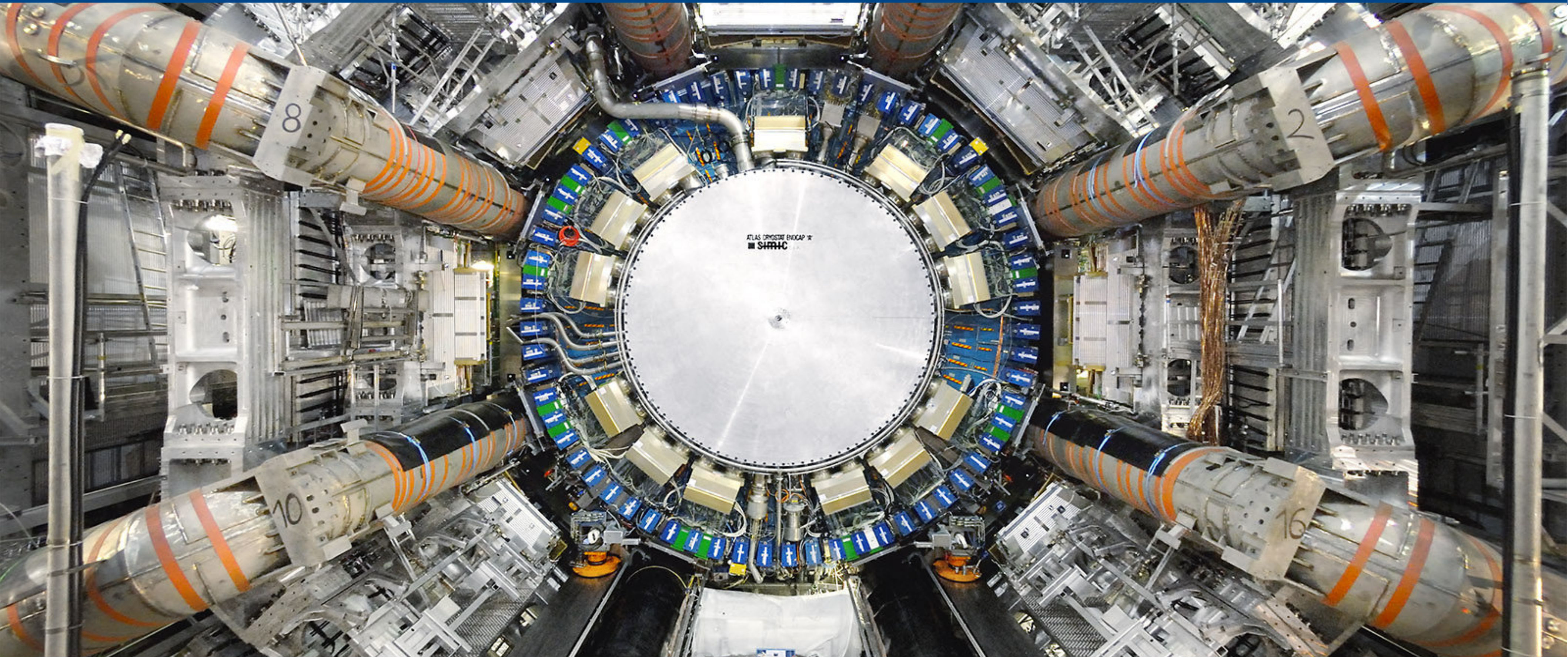
Upgrading ATLAS muon tube readout for high rates

Tests at CERN’s secondary beam facility



Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

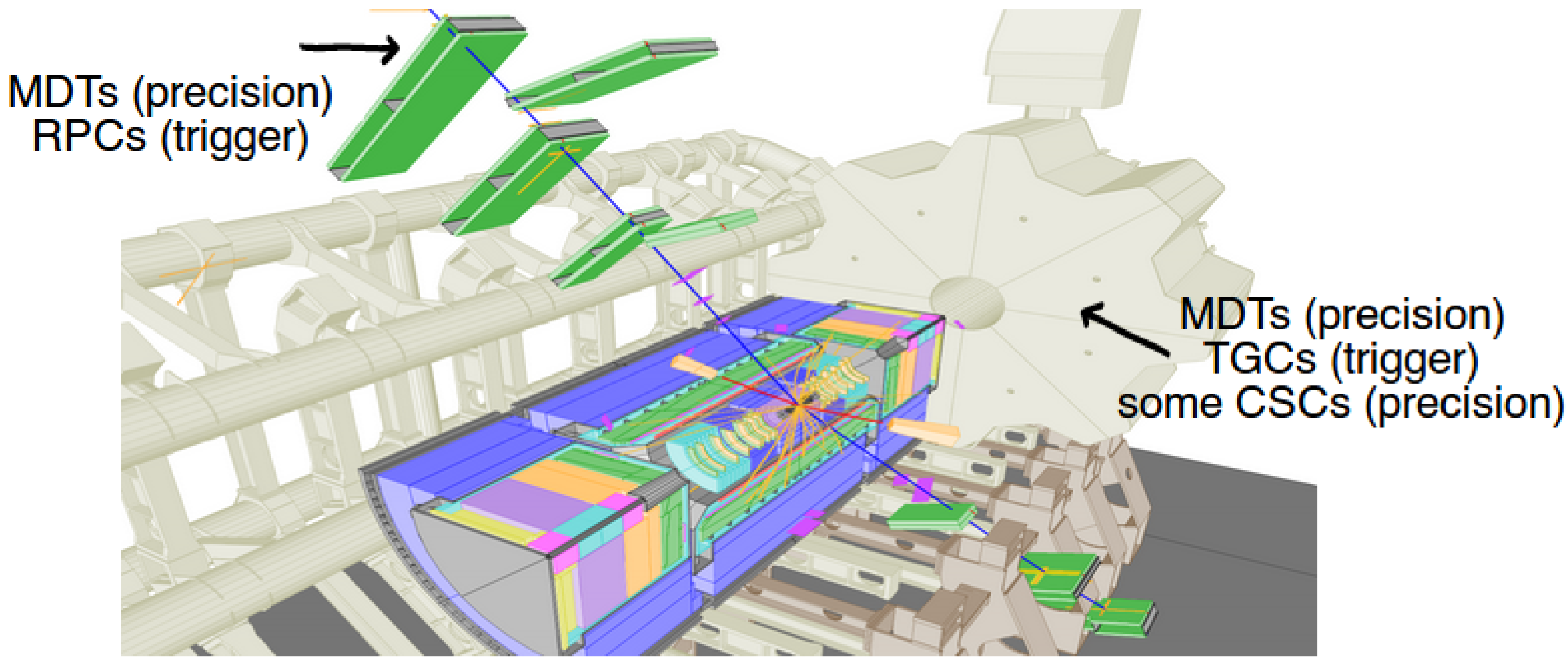
Catriona Bruce

IMPRS Young Scientist Workshop

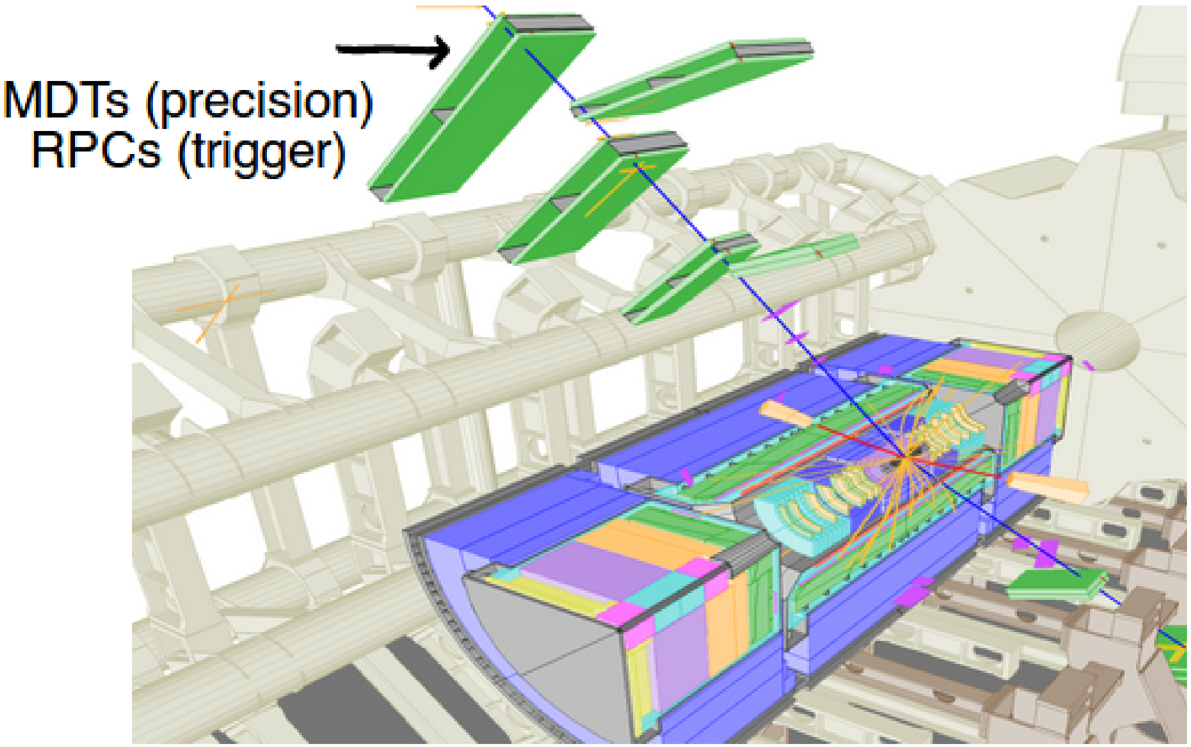
Ringberg, 8.9.2018

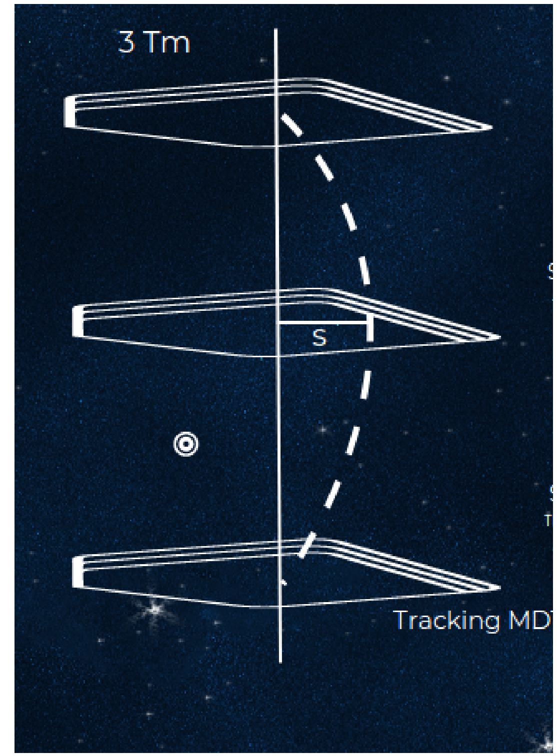
ATLAS EXPERIMENT

Recap: ATLAS muon technologies



Recap: ATLAS muon technologies





e.g. a 1 TeV barrel muon, 0.5 mm sagitta, σ ≤ 50 μm

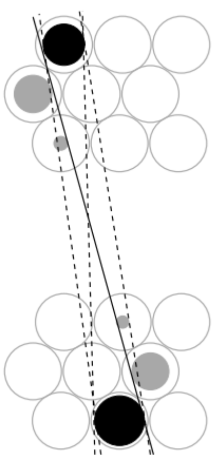
1. Alignment error ~ 30 μm
2. Intrinsic chamber resolution ~ 40-80 μm

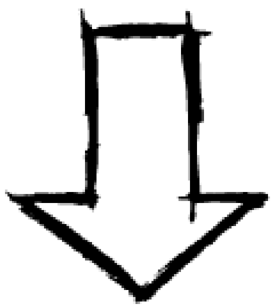
sub-100um precision in 30 mm tube?

How does this work?

Autocalibration

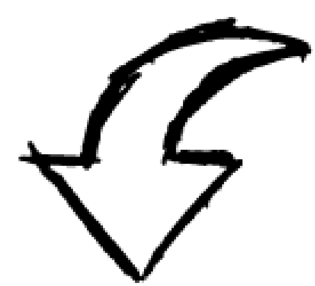
1. Know the shape of a muon trajectory
2. Pick characteristic point in avalanche development $\rightarrow$ rising edge inflection
3. Use the sequence of avalanche inflections to approximate trajectory
4. Iterate!





t

MDT RT relation

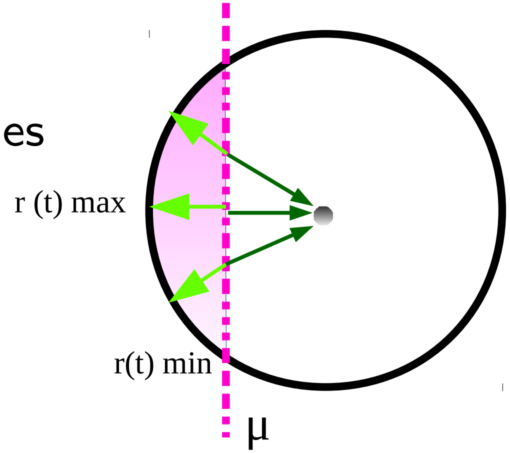


t0

Trigger BC association (LHC clock)

Anatomy of a drift tube current signal

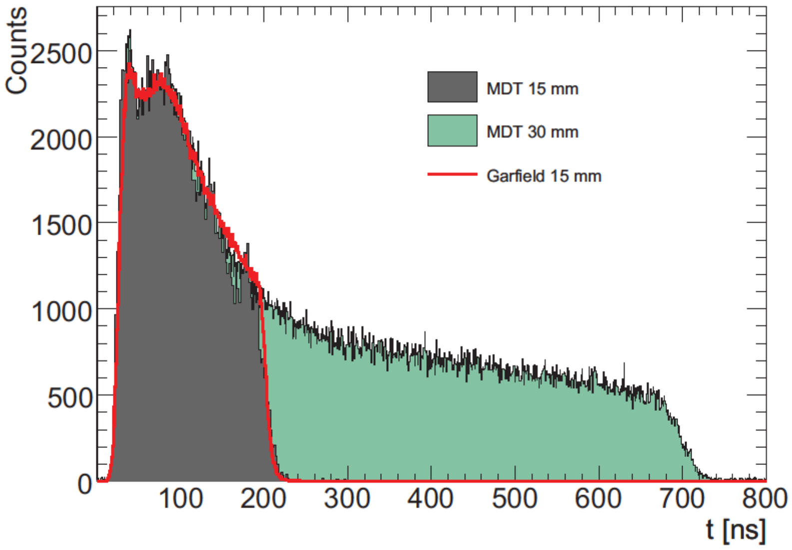
$$I(t) = -\frac{q}{D} v_r(t)$$

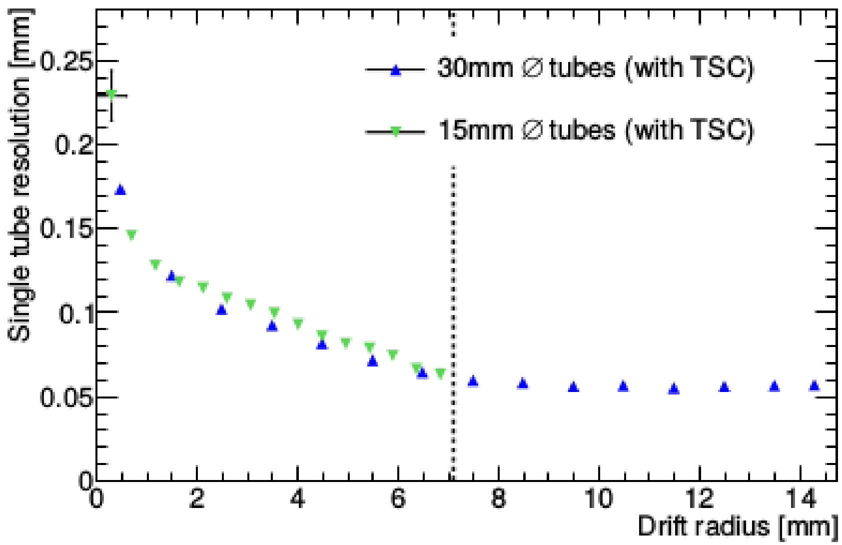


- Differential signal: current pulse due to multiple avalanches

- Convert current pulse to voltage pulse with same shape

- Store rising edge time digitally on buffer



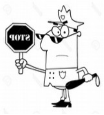


The MDT readout chain

Time stamps stored in a buffer

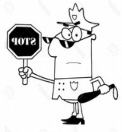
L1 trigger notifies the chamber if it wants the data

Chamber buffer



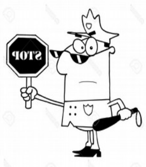
BARREL TRIGGER LOGIC

→ ‘fast’ reconstruction



L1 TRIGGER

→high-level track reconstructions



L2 TRIGGER

→event selection

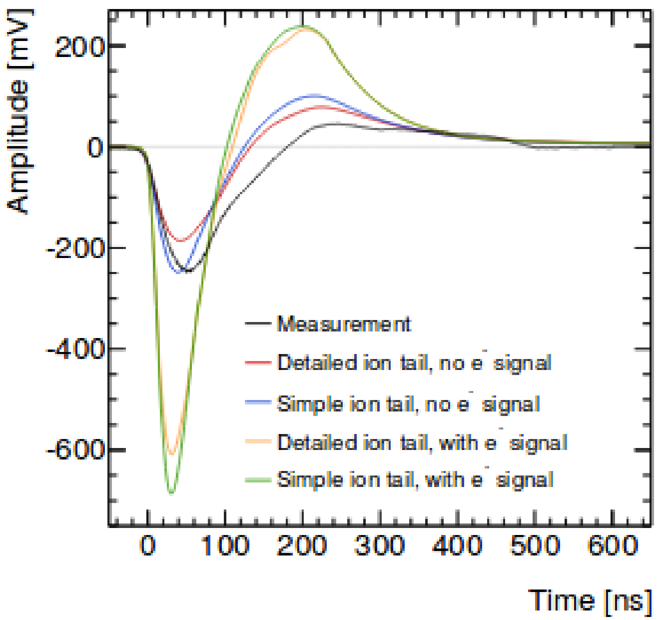
Improving rate capability for HL-LHC

Smaller tubes

- Reduce max drift time (25%)
- Reduce chamber cross section (50%)

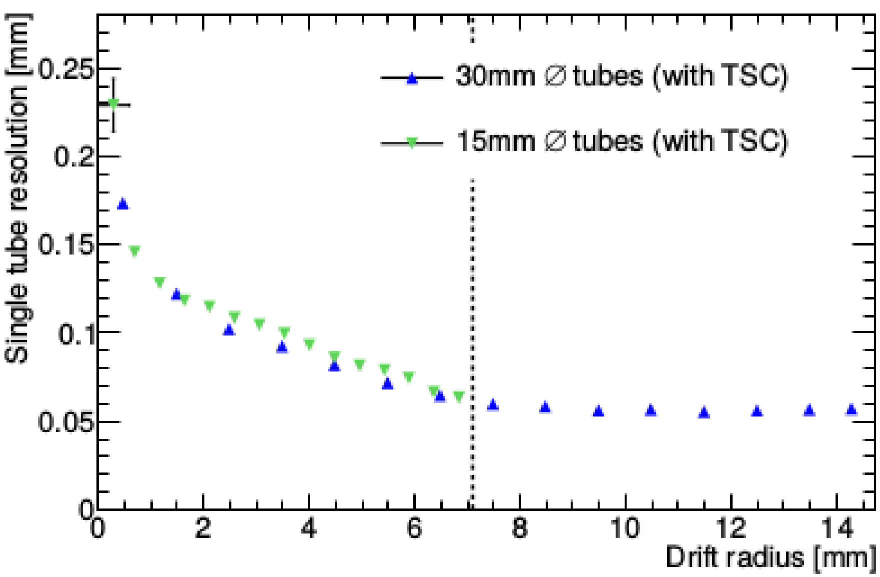
→ chamber occupancy (.125%)

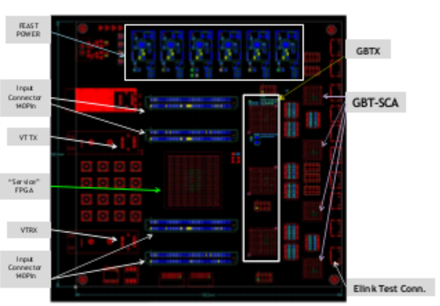
→ shorter dead time (space charge effects)



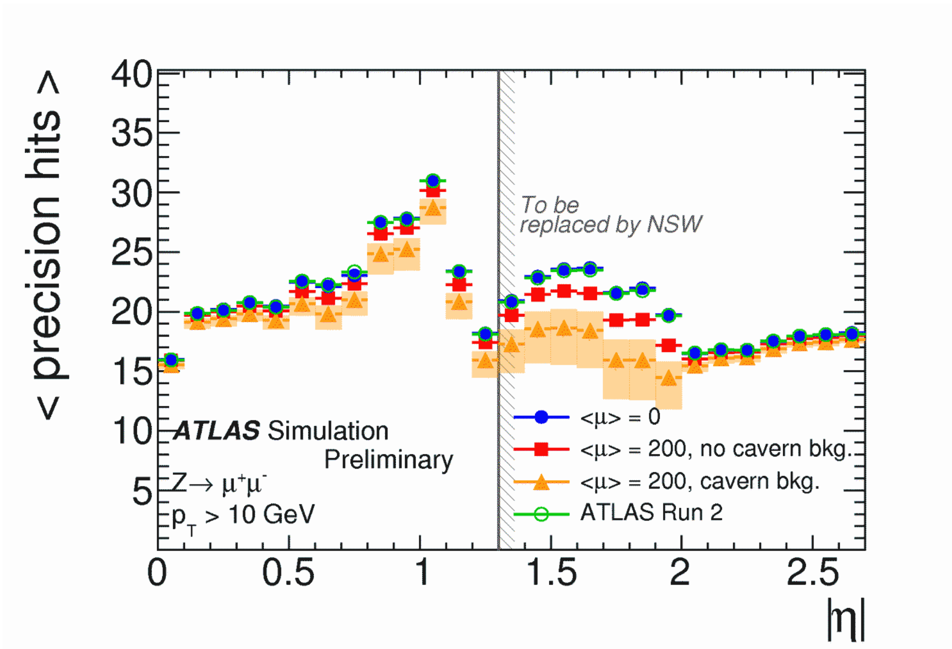
New readout electronics

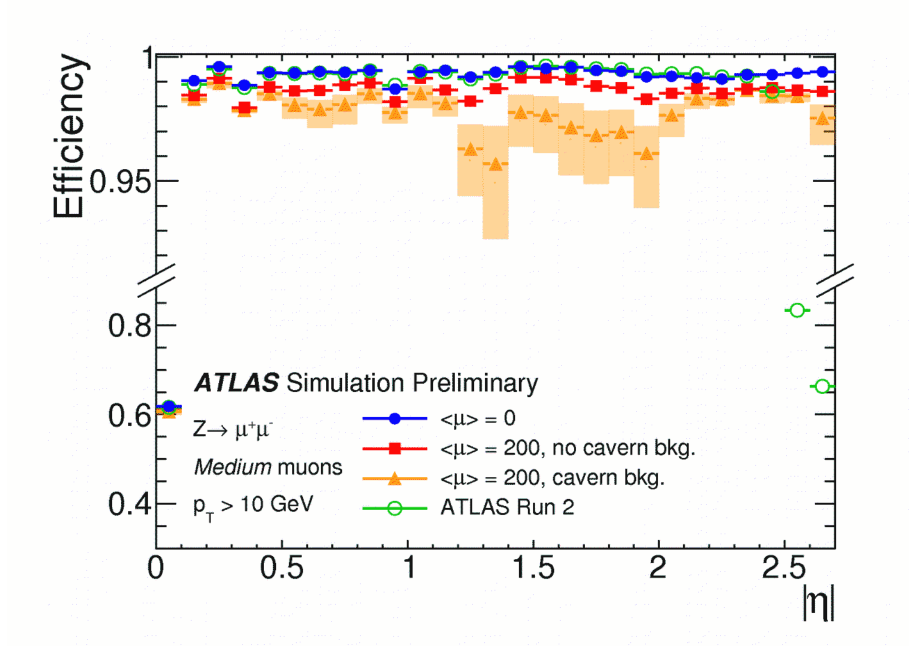
→ Higher TDC bit rate

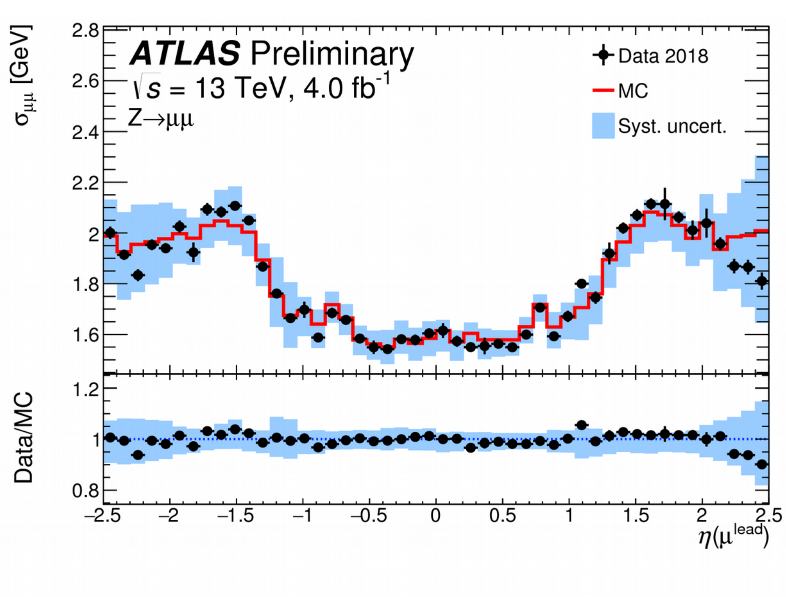




Meanwhile: improving coverage







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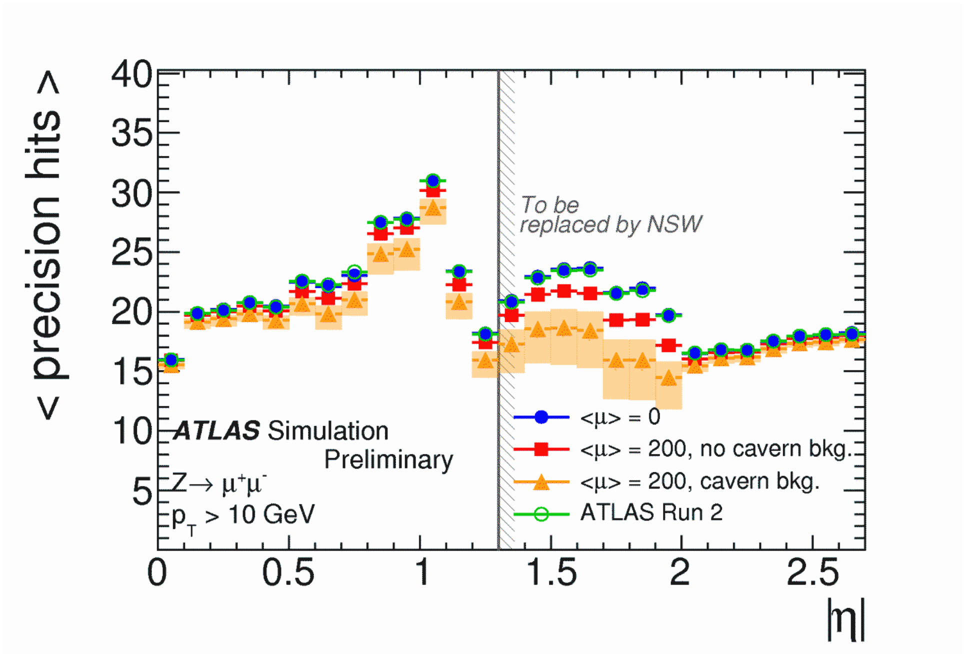
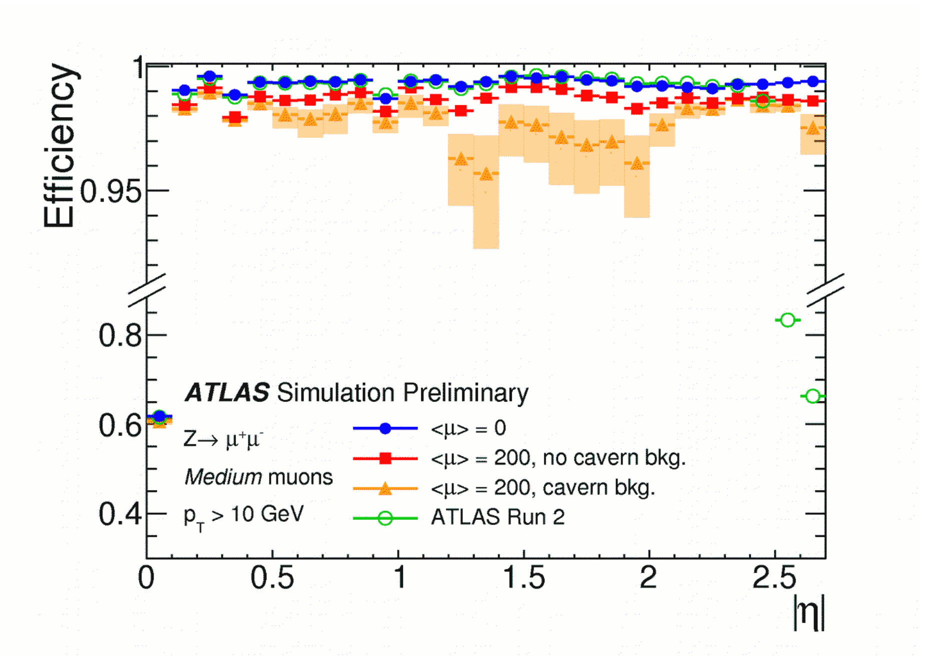
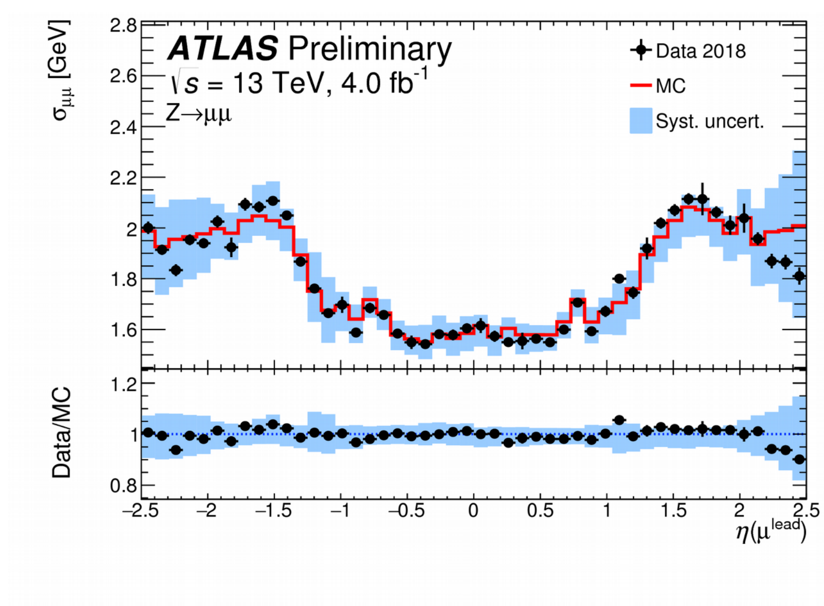
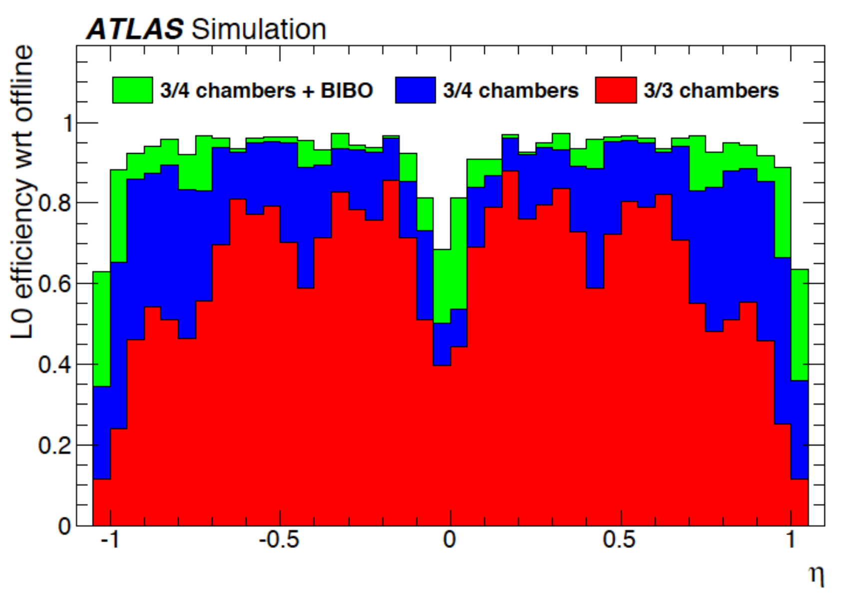






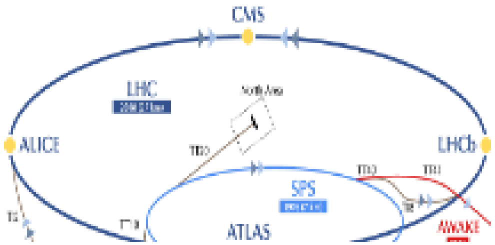


PART II: CERN secondary beam area

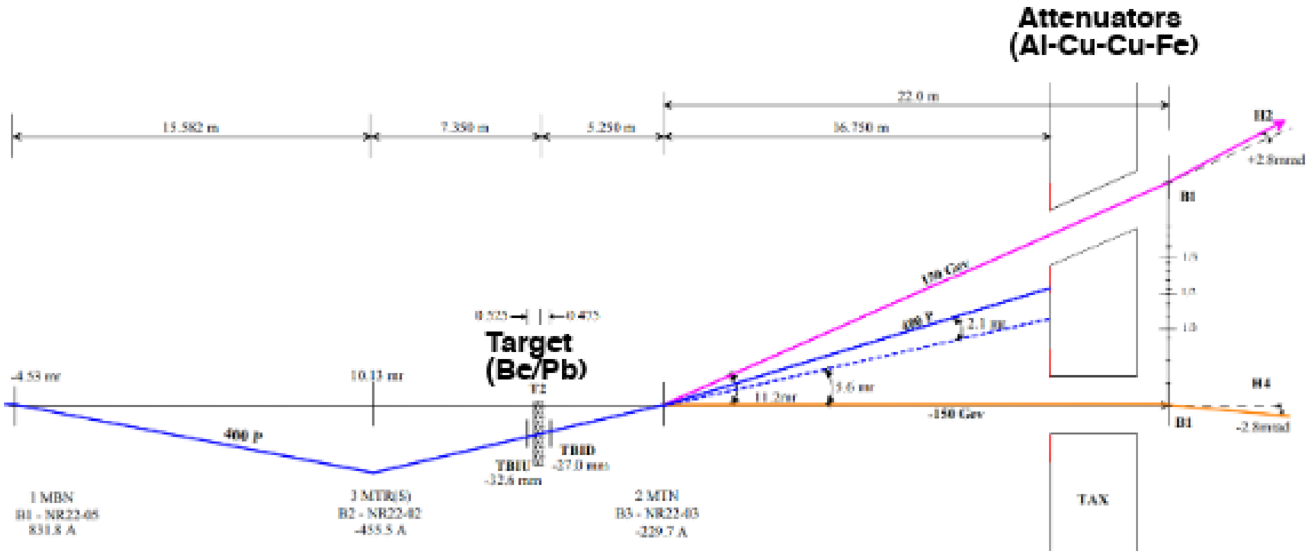
662 keV gamma
14 TBq 137-Cs

CERN secondary beam area

Muon spills up to 100 GeV from SPS protons



- T2 target and Wobbling station -> periodic spills into H2, H4
- Collimators to control particle selection

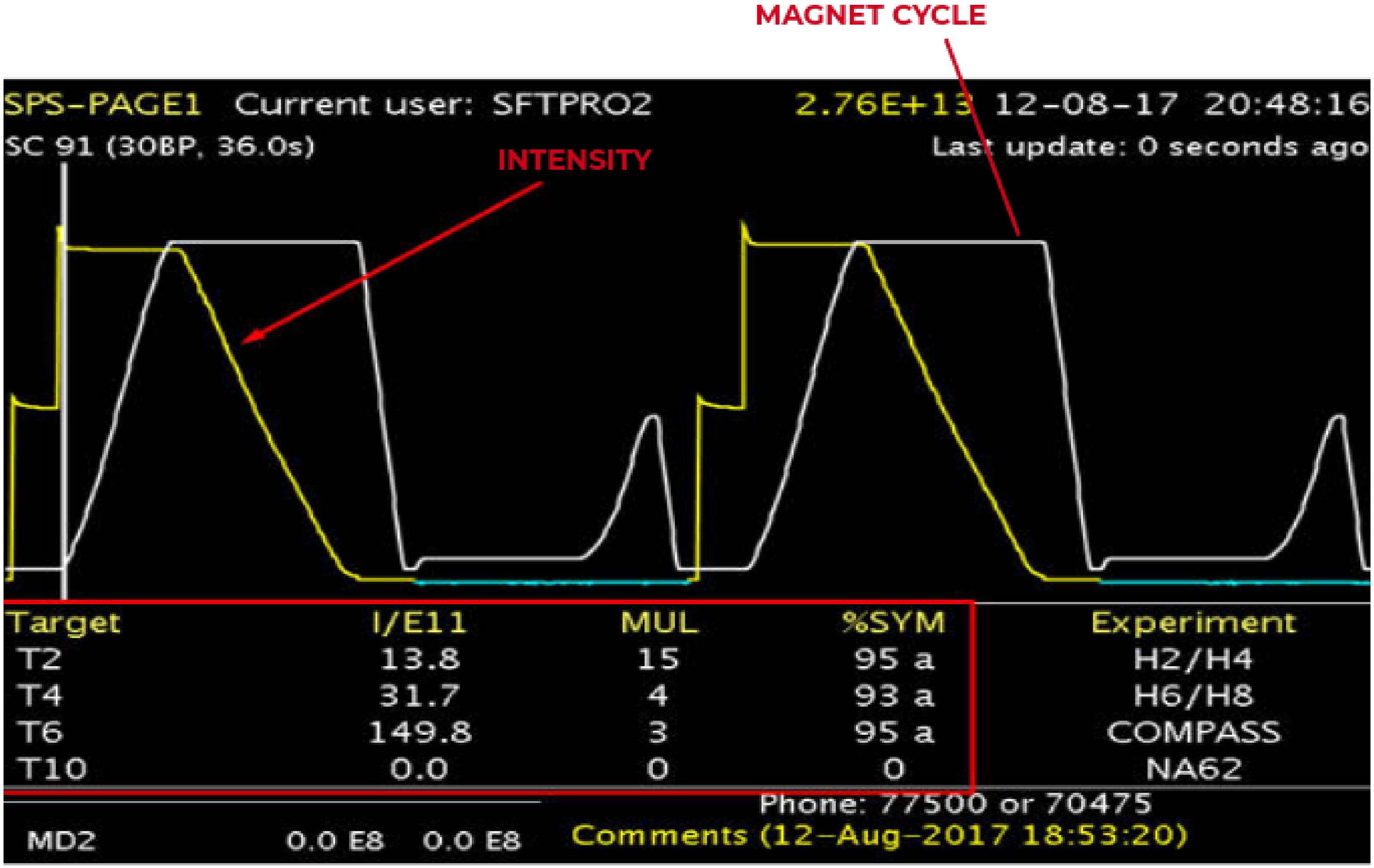


~1% of secondary particle flux makes it through GIF++ scintillator (0.01m2), another

~1% in a 1m2 cone around beam axis

GIF++ sees 10^4 muons/spill and 2 spills/minute

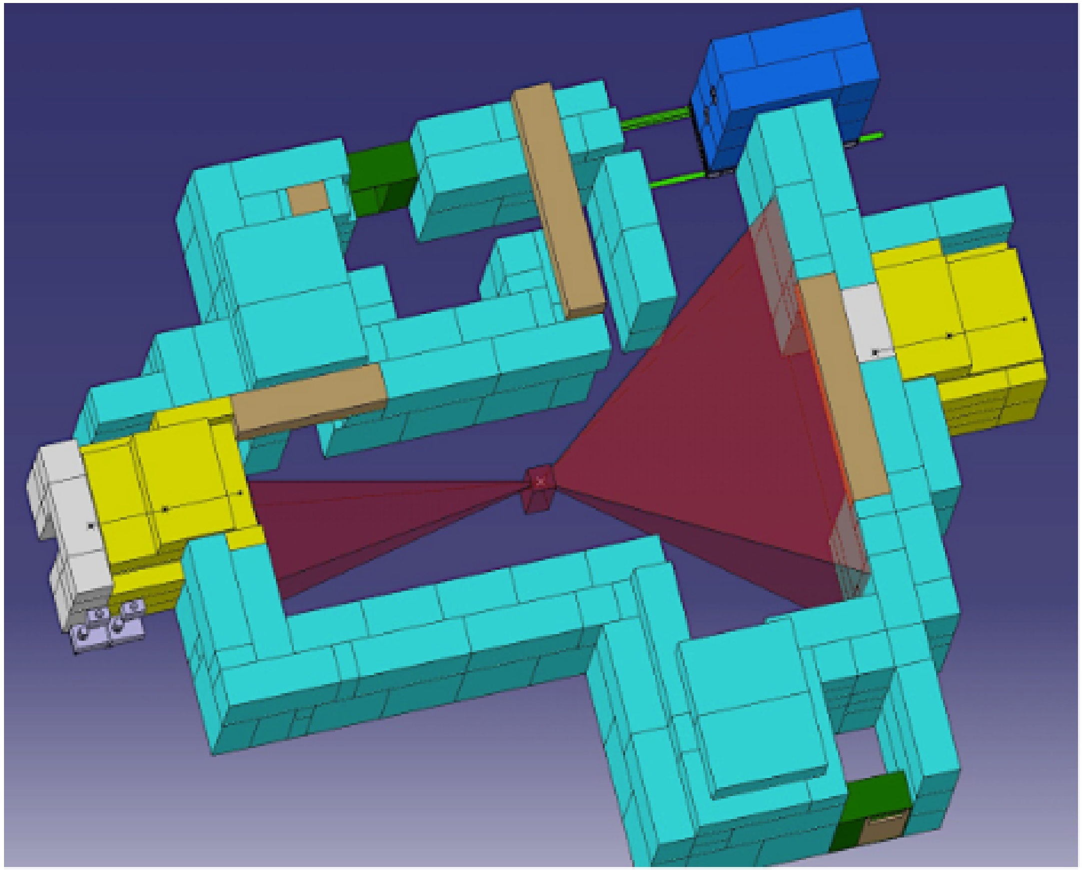
Muon spills up to 100 GeV from SPS protons

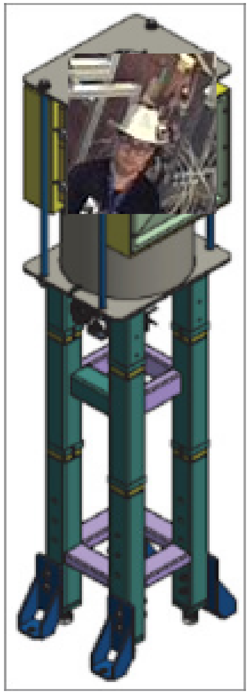


Gamma Irradiation Facility

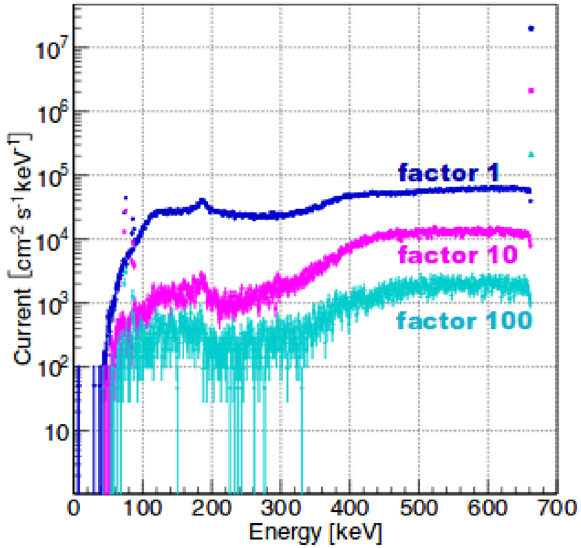
Quickly accumulate HL-LHC doses

14 TBq 137-Cs, 662 keV γ

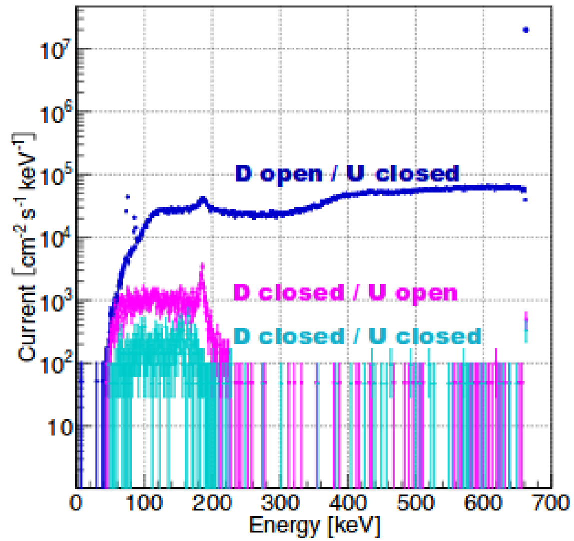




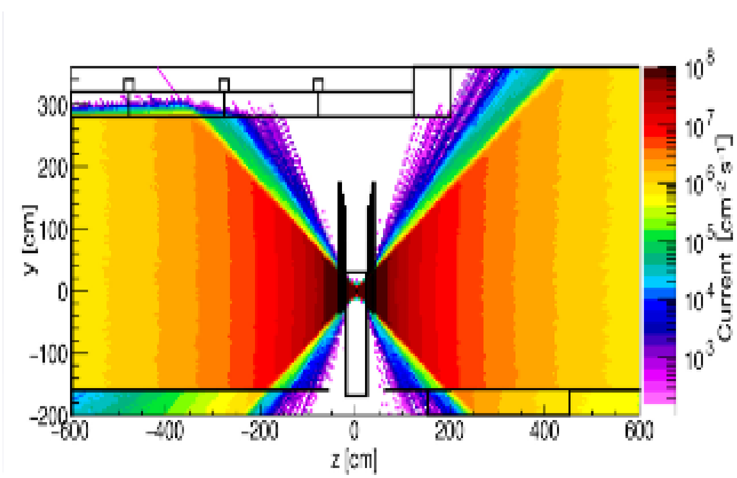
Gamma Irradiation Facility

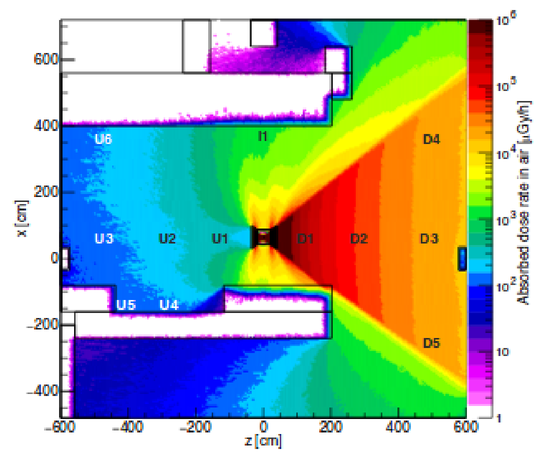


(a) Attenuation factors 1, 10 and 100

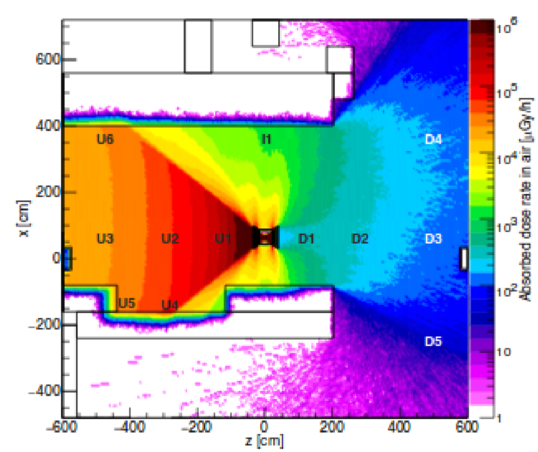


(b) Crosstalk between D and U





(a) D open/U closed

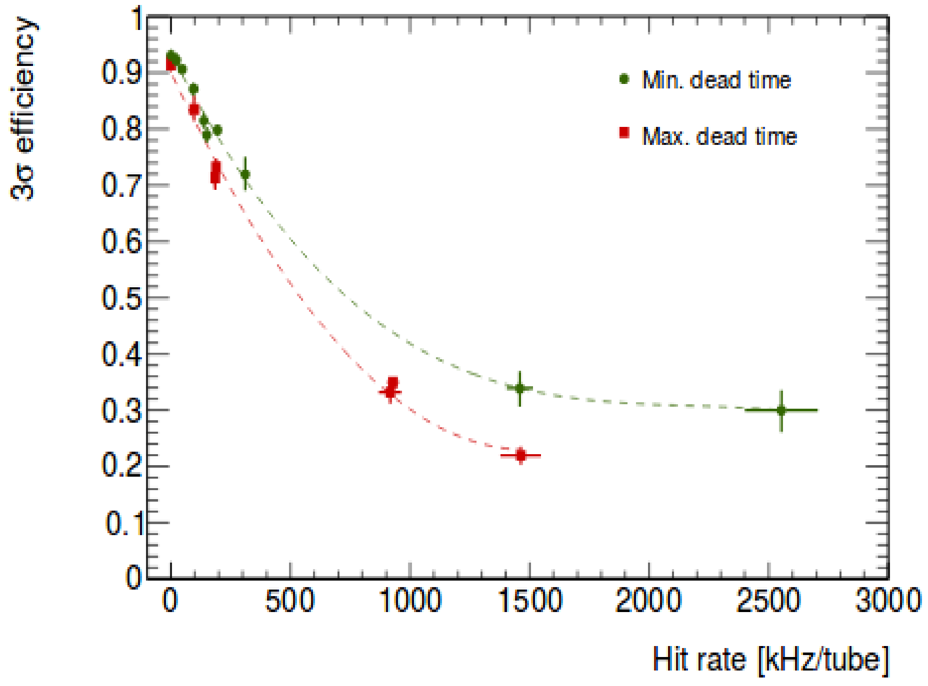


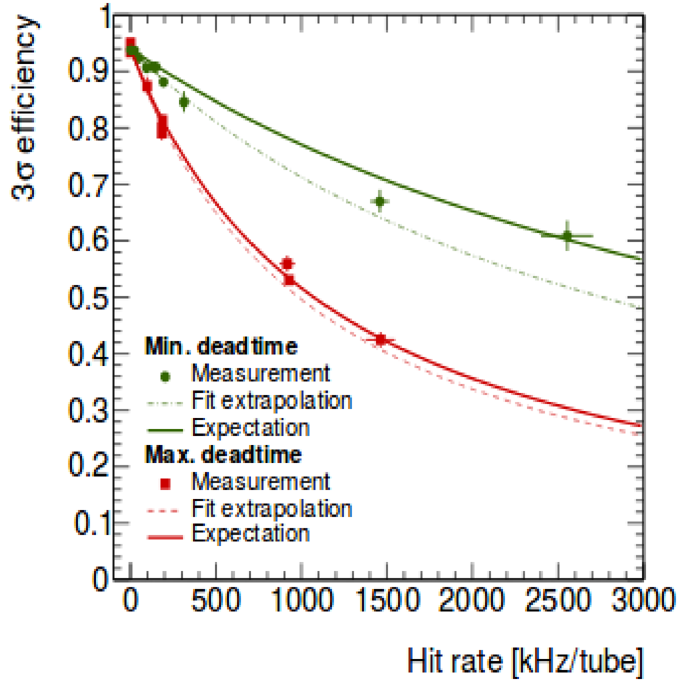
(b) D closed/U open

Efficiency dependence on hit rate

- Remove data point from autocalibration

- See if data point still lies on track





Gamma Irradiation Facility

Stability and quality of front-end signal processing

Parametric performance e.g. applied voltage

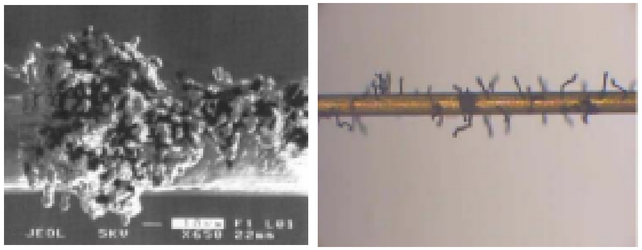
Variability with ambient conditions

Spatial or temporal resolution

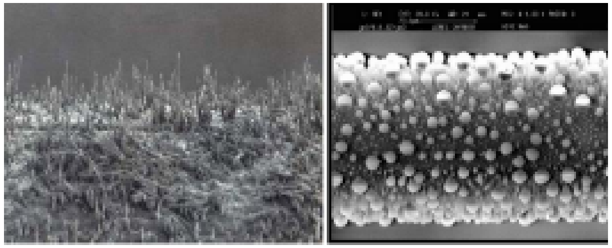
Aging

Anything that needs
high statistics

Aging problem highly material dependent



Ar/CF4/CH4



Silicon

MDTs with CH4: exponential decrease in lifetime with voltage

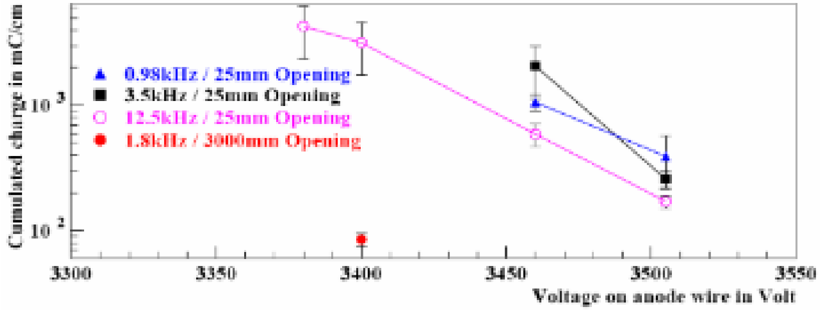
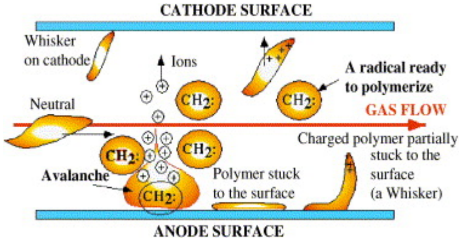


Figure 5. Dependence of lifetime of ATLAS muon drift tubes irradiated in $Ar/CH_4/N_2/CO_2$ (94:3:2:1) as a function of high voltage for different particle fluxes [56].

No known mechanism for aging of Ar/CO2 chambers

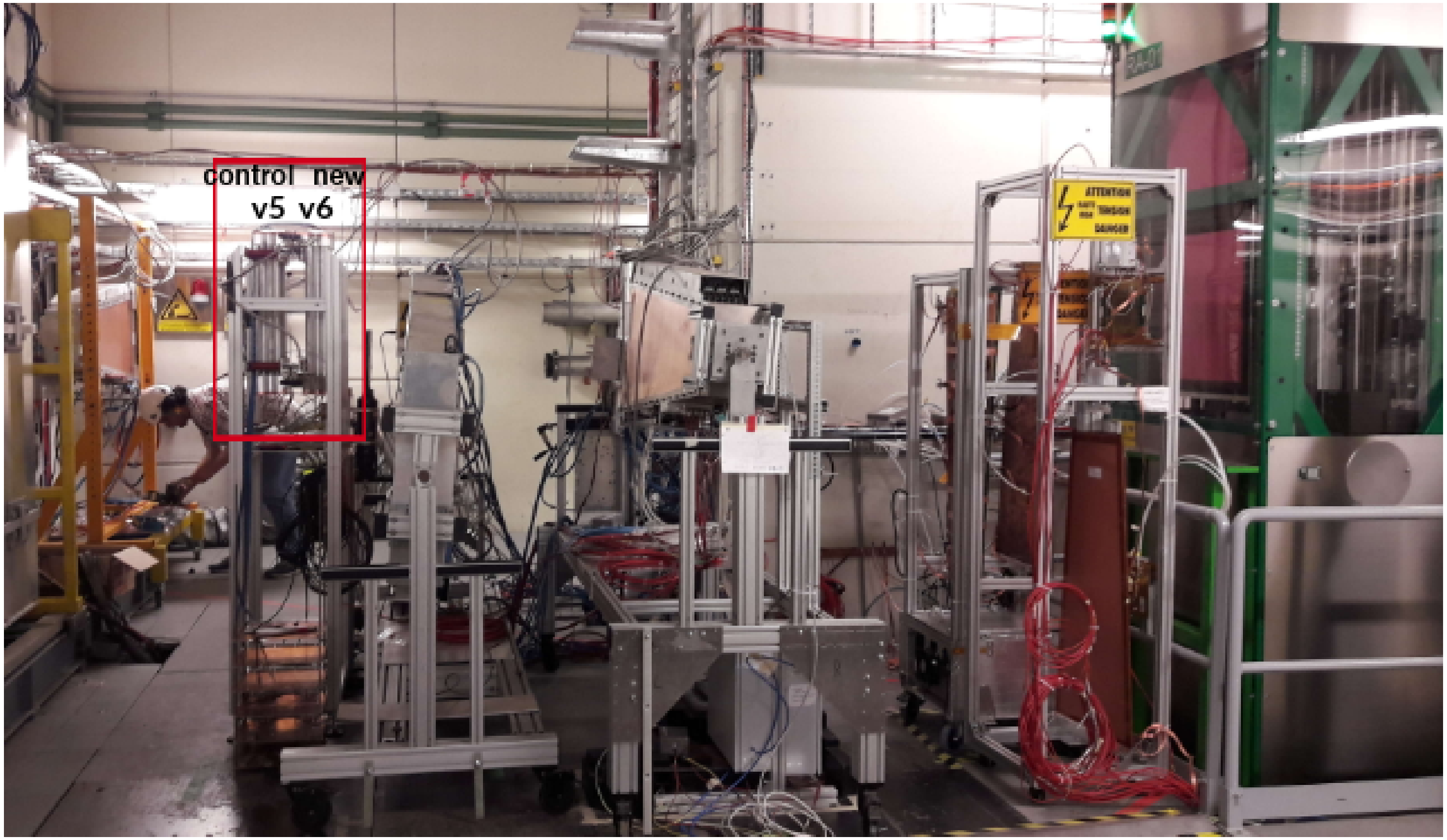


Test of new ASD chip for MDT front end

up to 2.5 MHz
662 keV

4 m

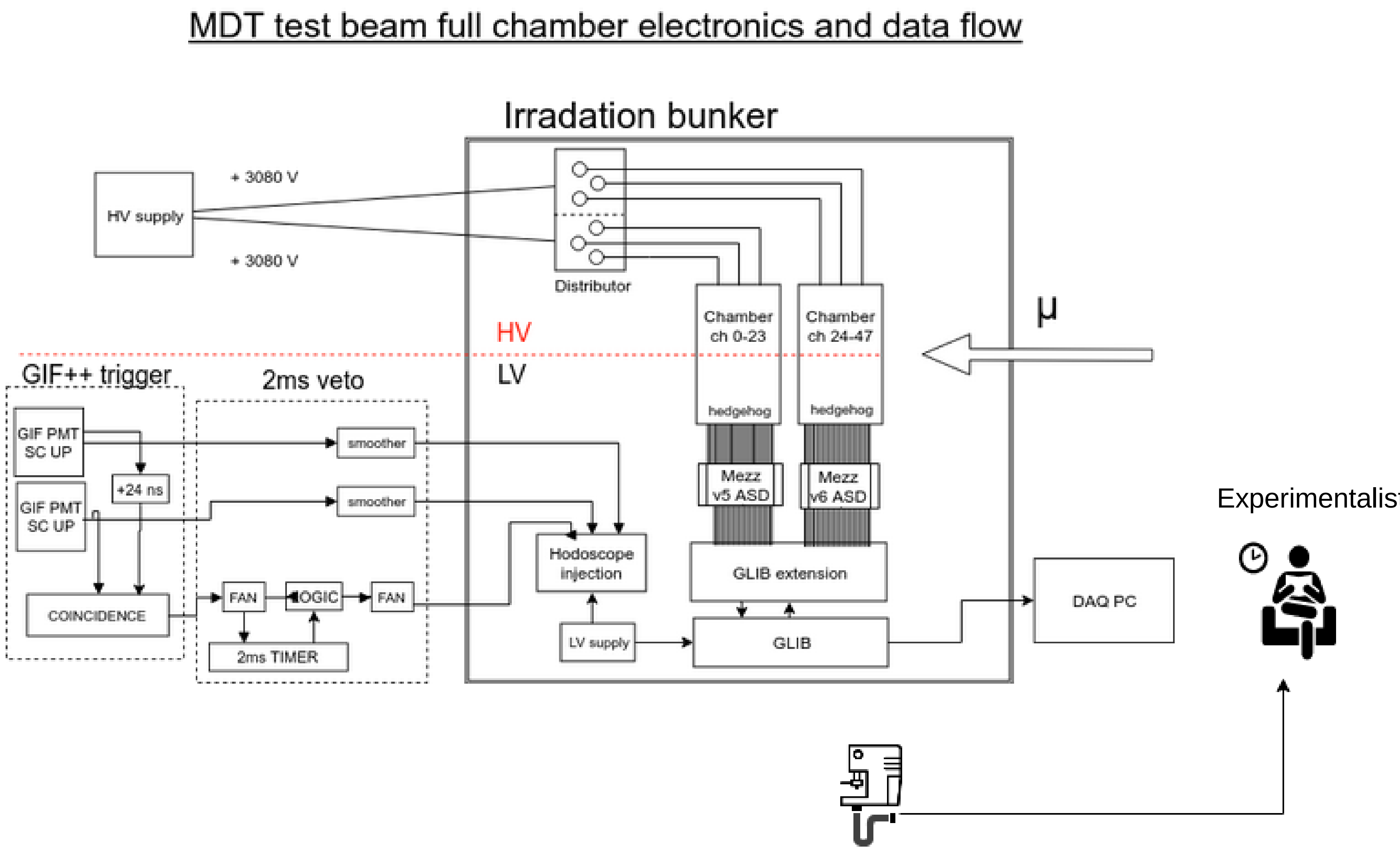
14 TBq
137-Cs



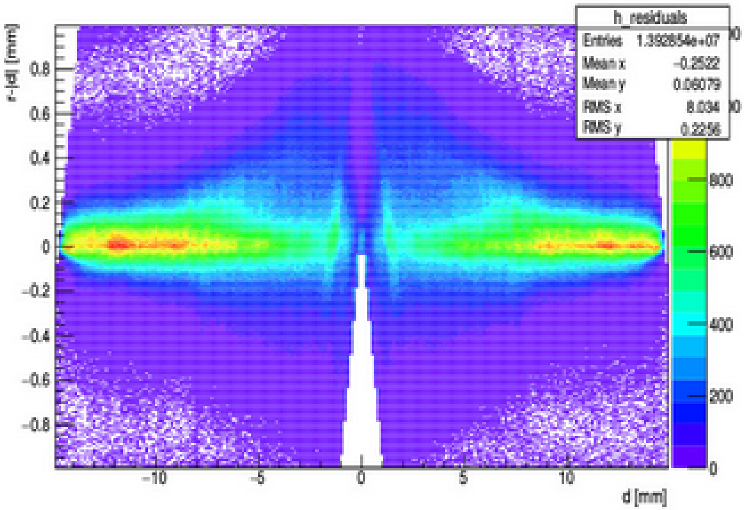
μ

H4
≤ 300 Hz
100 GeV

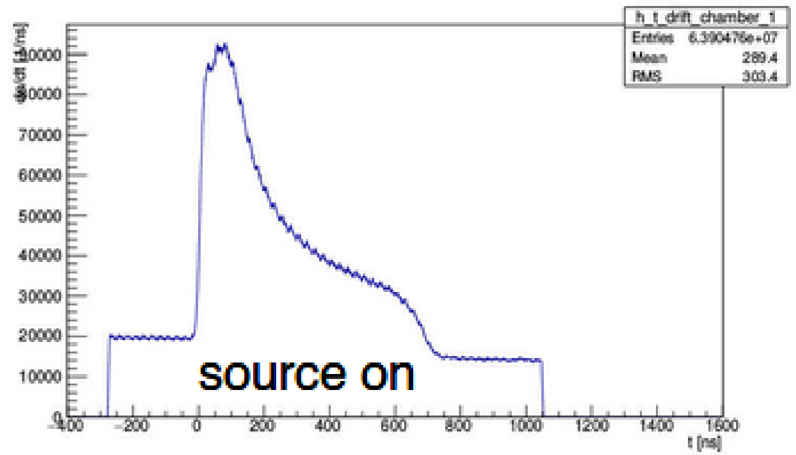
Stripped-down track reconstruction and trigger

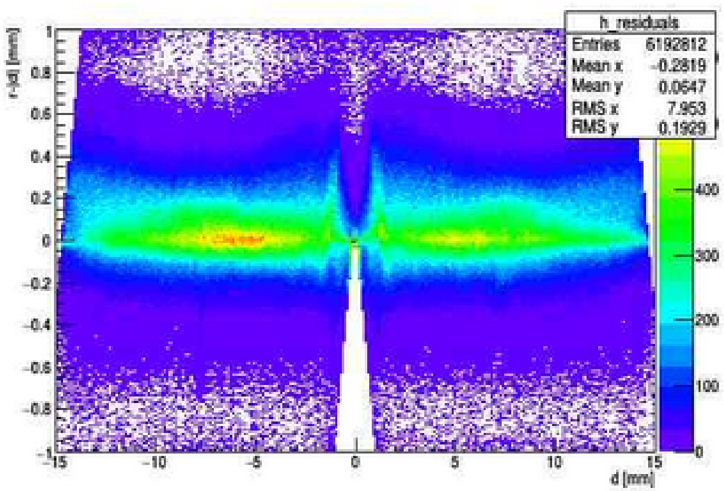


Track-fit residuals (left), drift time spectra (right)

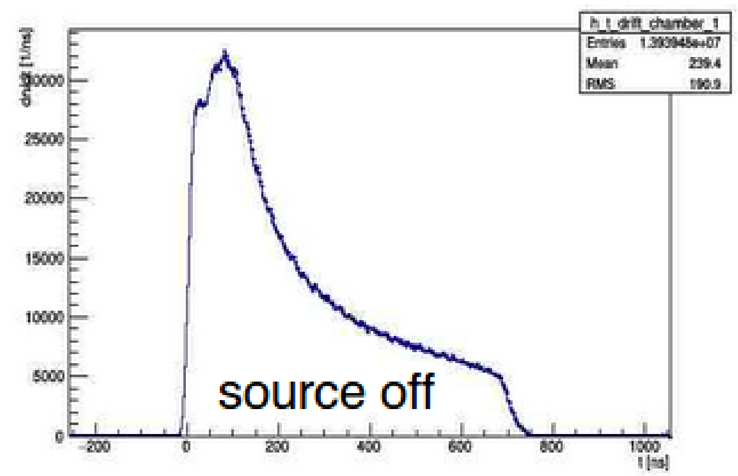


source on

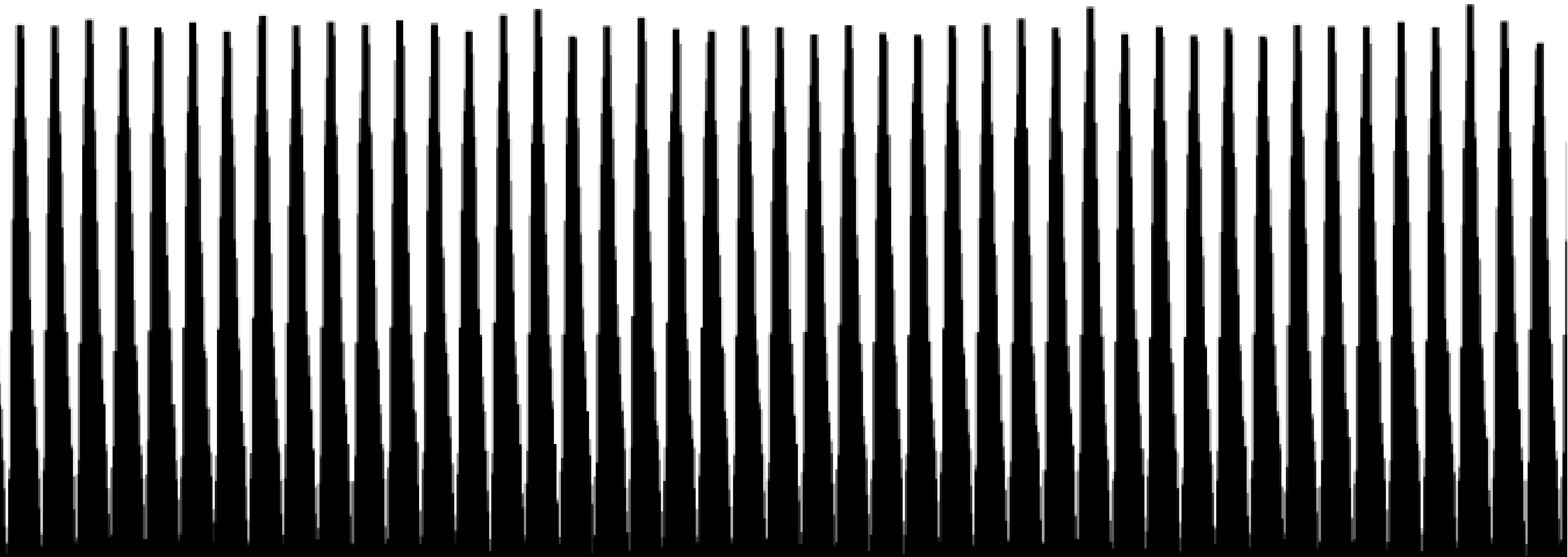




source off



Conclusion and outlook



MDT precision chambers
- extract position from the spreads of avalanche signals across the MS

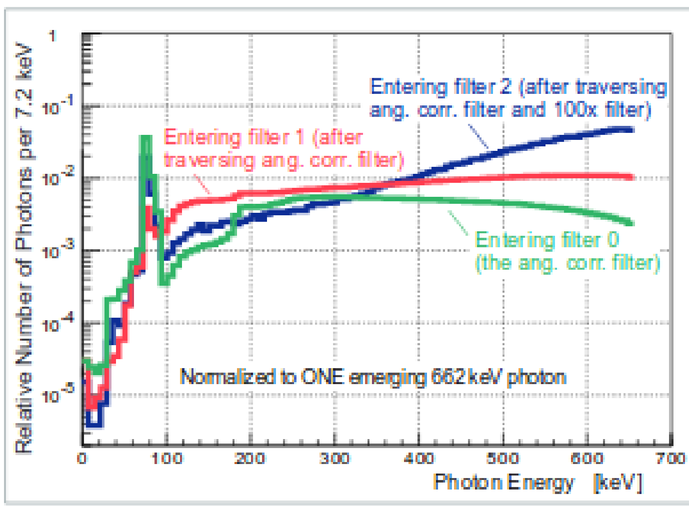
Improvements for HL-LHC
- rate and coverage

CERN secondary beam facilities
- Gamma irradiation
- μ and π beams
- Shared resources between many groups

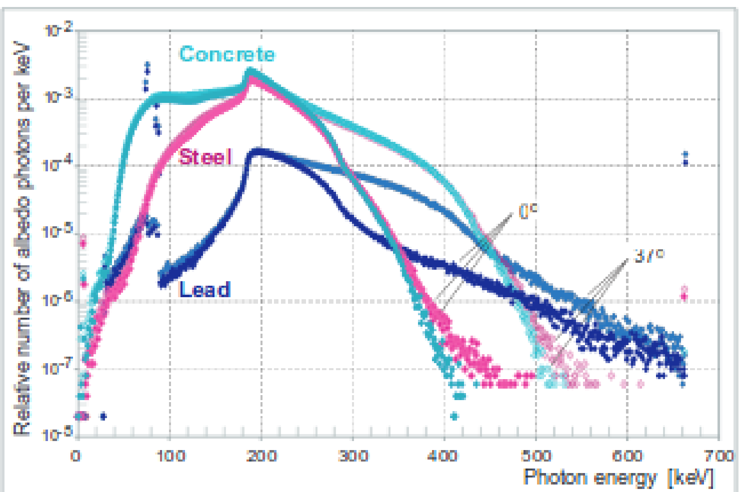
2 test periods so far this year
- proper analysis still underway

Quickly accumulate HL-LHC doses

14 TBq 137-Cs, 662 keV γ



(a) Degraded photons from the irradiator



(b) Albedo photons from a wall

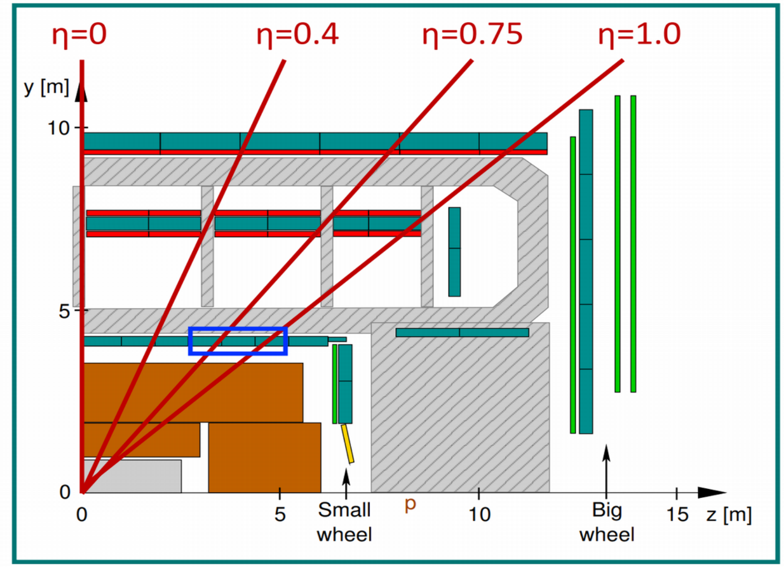
56% expected to be degraded Compton scattered photons

Muon trigger for HL-LHC

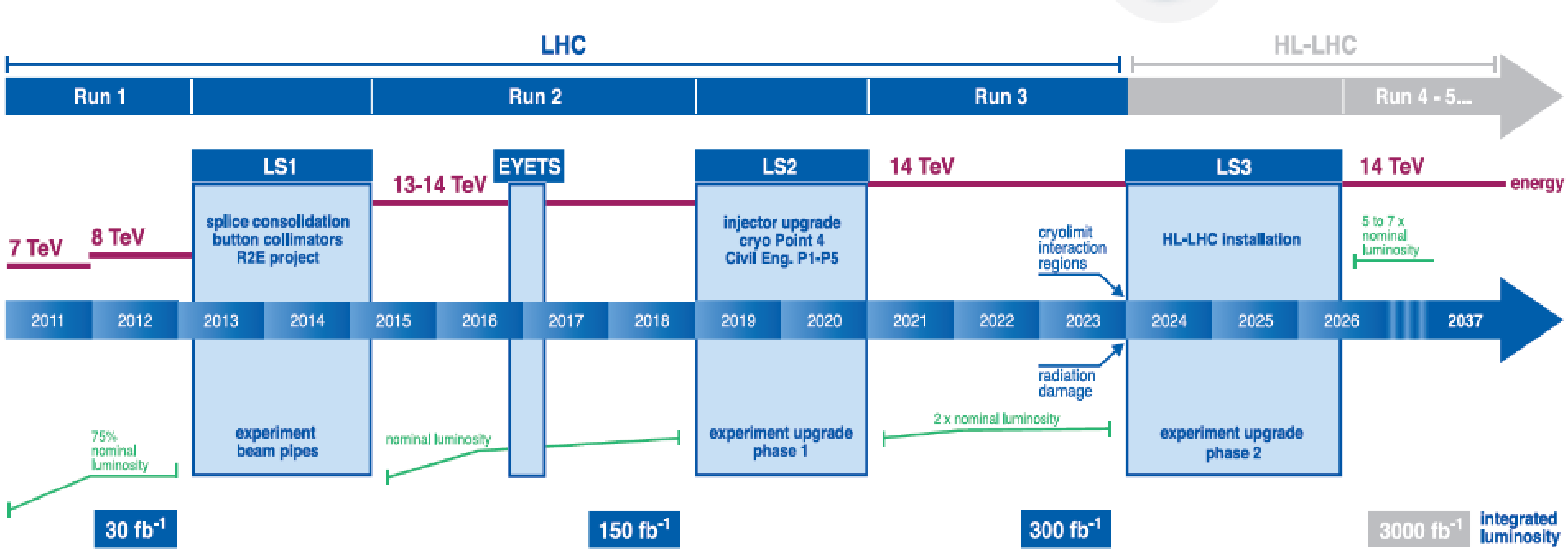
- Eventually, will need to replace current detectors...
  - Lifetime 100kHz/cm^2 for 10 years
  - Rates in HL-LHC will increase sevenfold

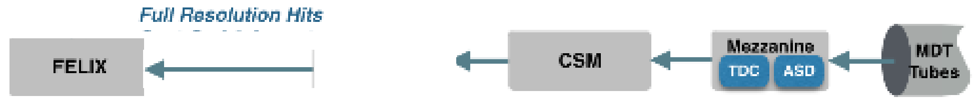
- In the meantime, we can extend their lifespan...
  - Increase number of layers, each detector has less work
  - Fill the blind spots
  - New coincidence requirements

… And improve performance.



2019/20: 16 new sMDT-RPC chambers in BI
We may then require only 2/4 layer coincidence from BM chambers

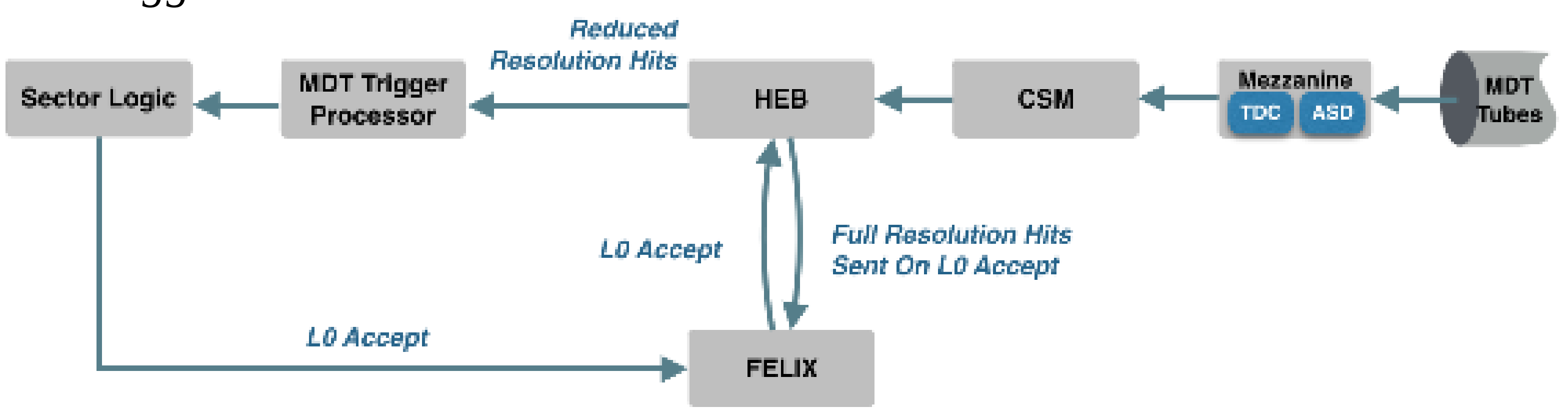




RPC trigger processor

Cavern buffer → ‘fast’ reconstruction → high-level track reconstructions → event selection

MDT-based trigger?



Monitoring: track effect of ambient conditions

•Temperature:
lowered drift velocity as temperature increases. For Tmax, ~1.5 ns K^{-1}.

•Gas pressure (density):
ionisation charge density and the gas amplification.

•Humidity:
increases leakage currents in the high-voltage distribution.

Dark current was also monitored: ~10-50 nA

t0 calibration

Calibrating the scintillation counter times with respect to the minimum drift times (t0) ofthe drift tubes, two time jitter contributions are corrected for at the same time: propagation timevariations both in the scintillation counters and along the drift tubes. First, the drift tubet0-valuesare determined as described in section 4.3.1 ignoring the trigger time offset (ttrigger0=0). The drift

Dark current was also monitored: ~10-50 nA