Test of an ATLAS drift tube based Level-1 muon trigger

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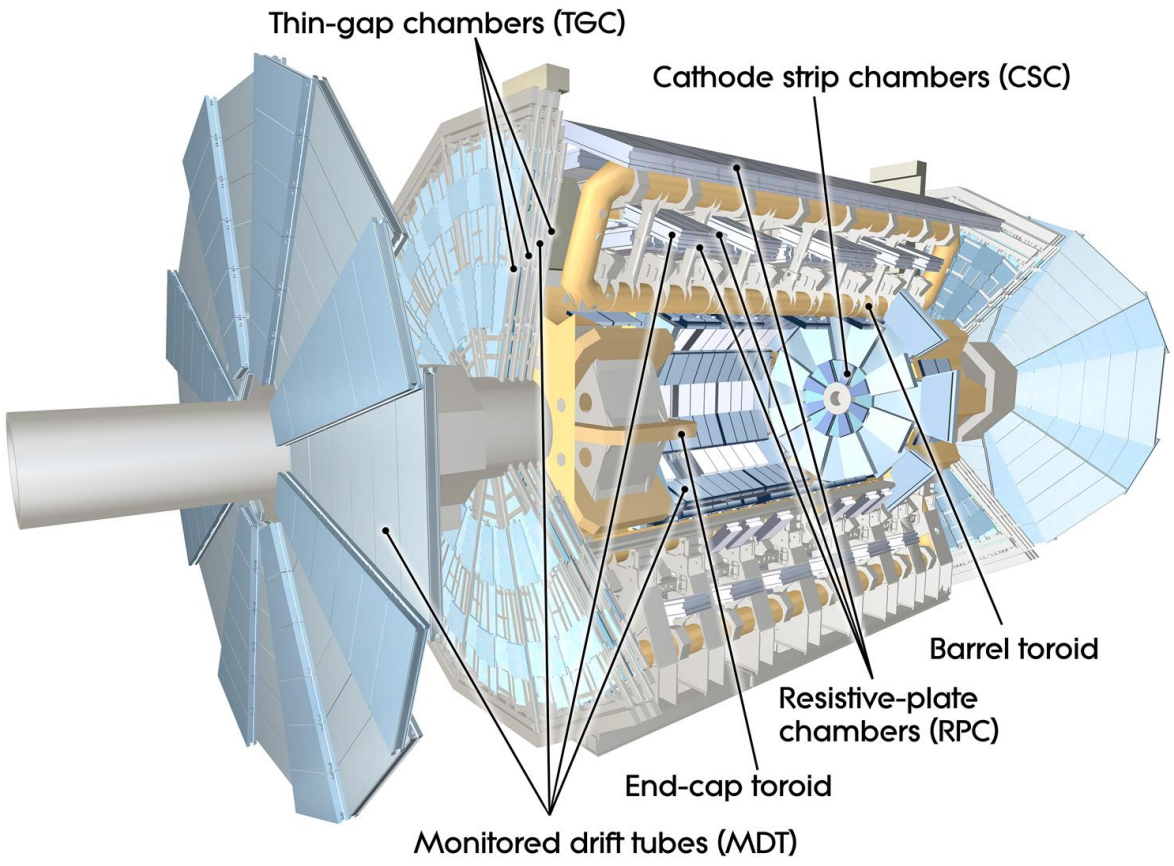
The ATLAS Muon Spectrometer



designed for LHC nominal luminosity:
$\mathcal{L} = 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$

HL-LHC luminosity (planned, 2022):
$\mathcal{L} = 7 * 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$

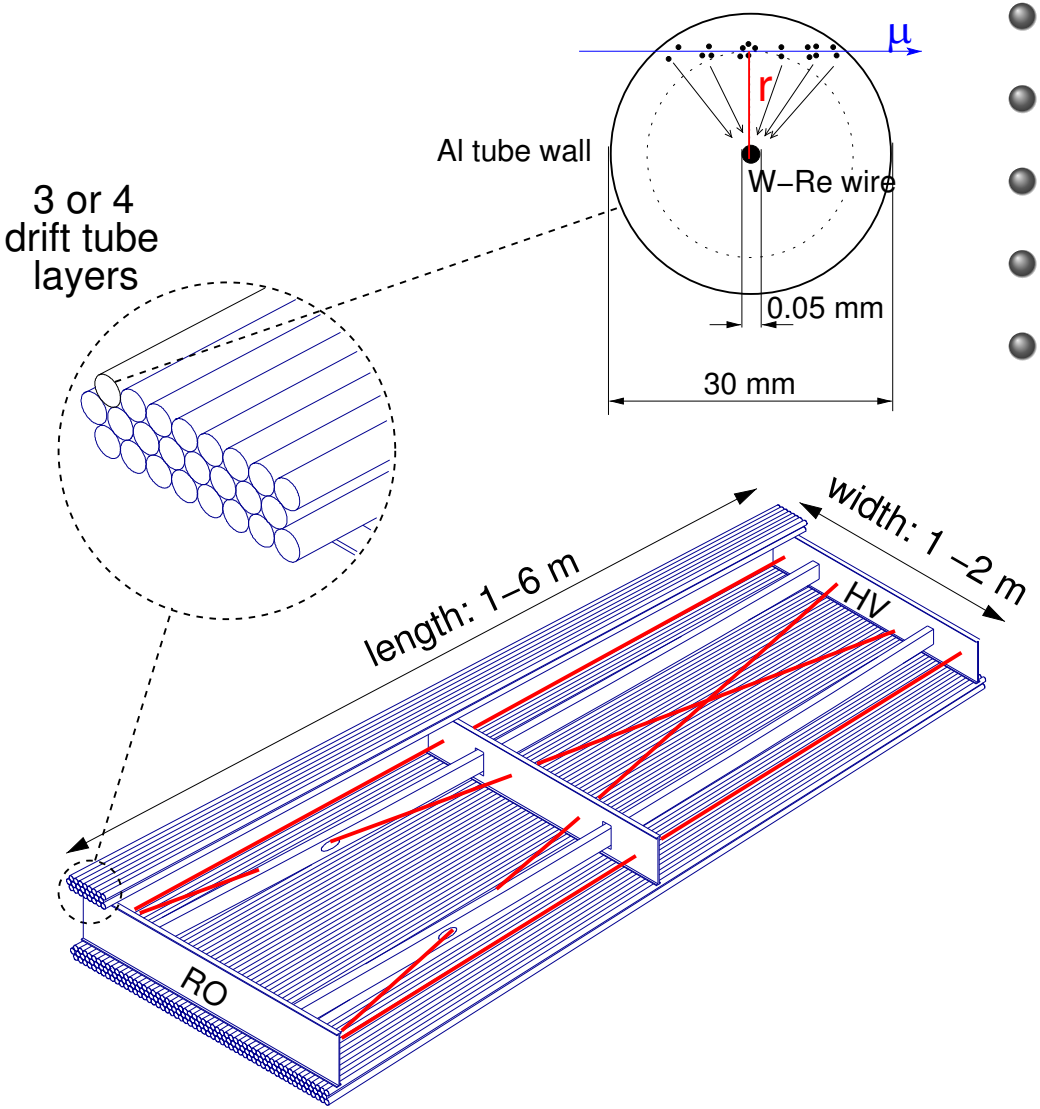
Precision tracking chambers

1150 Monitored Drift Tube Chambers (MDT)
32 Cathode Strip Chambers (CSC)

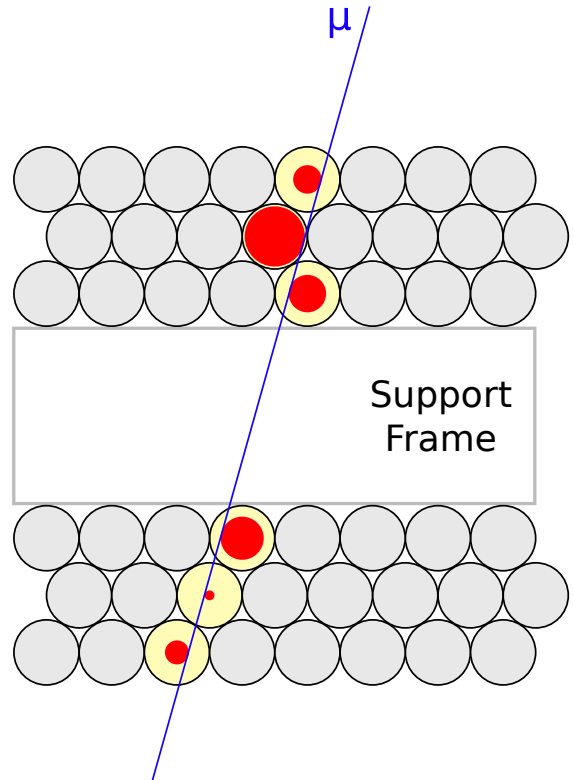
Level-1 trigger chambers

606 Resistive Plate Chambers (RPC)
3588 Thin Gap Chambers (TGC)

The ATLAS MDT chambers

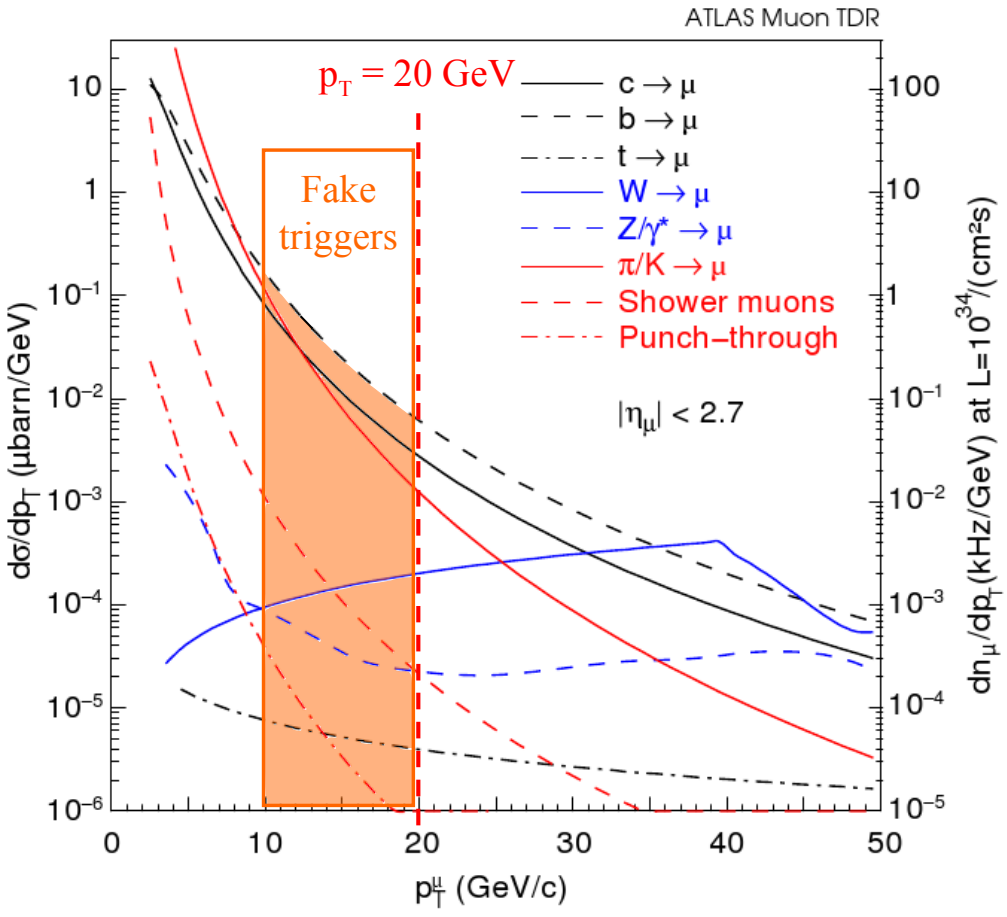


- Gas mixture: Ar/CO_2 (93/7)
- 3 bar absolute pressure
- Max. drift time: $\approx$ 700 ns
- Single tube resolution: 80 µm
- Wire positioning accuracy: $\approx$ 20 µm
- Chamber tracking resolution: $\approx$ 40 µm



Performance of the existing L1 muon trigger

Total muon production cross section

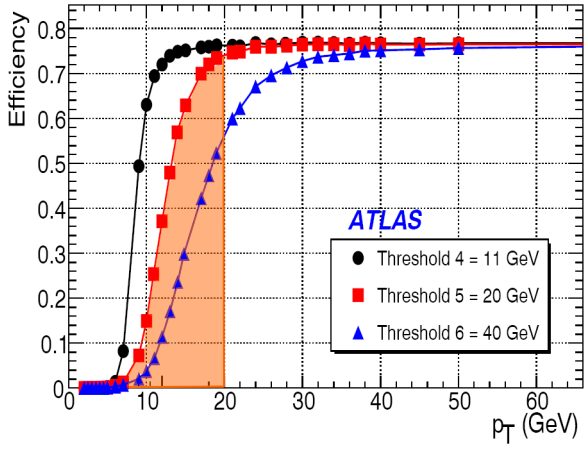


cross section for p_T > 10 GeV: ∼400 nb

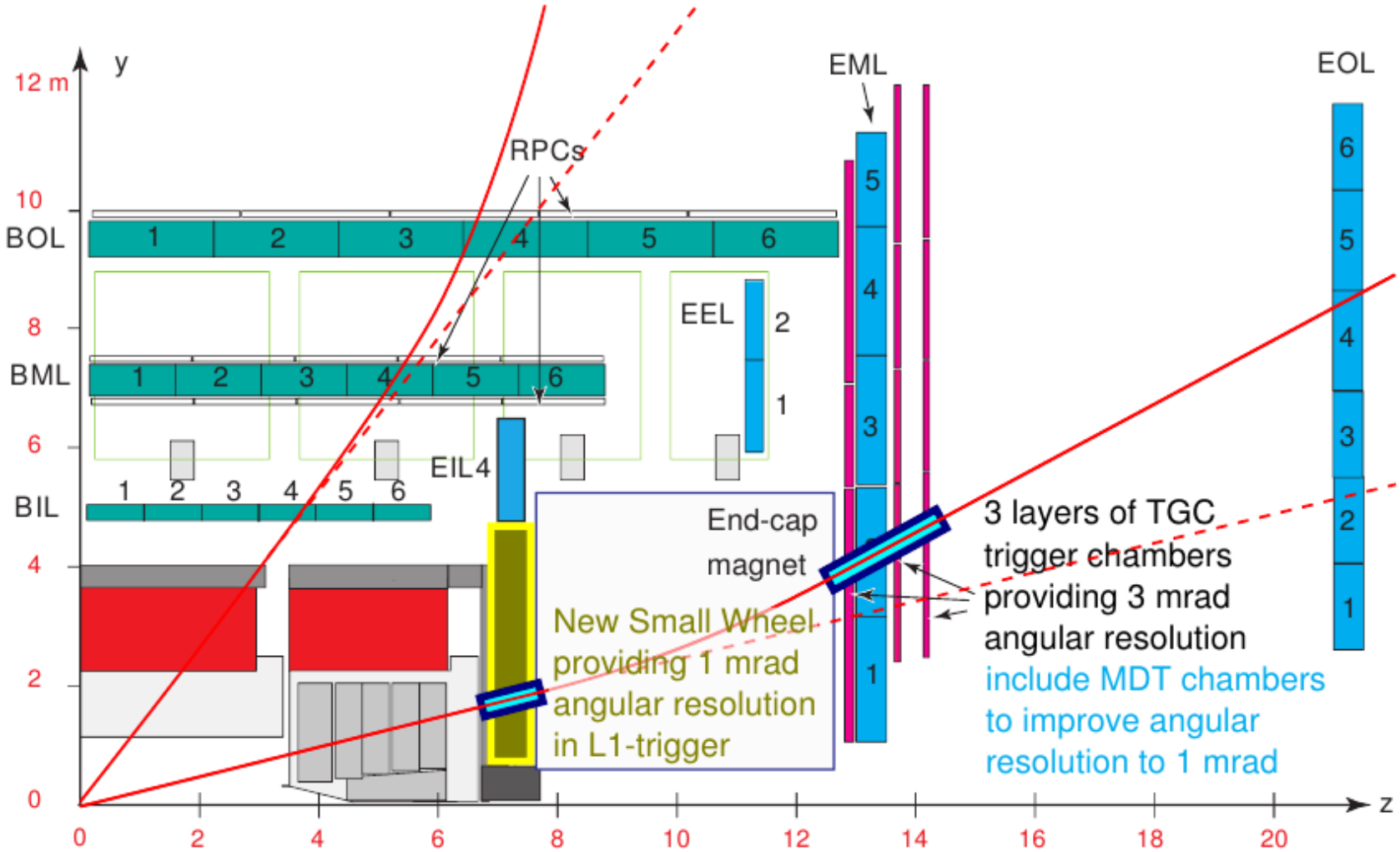
cross section for p_T > 20 GeV: ∼47 nb

- The interesting physics is mainly at p_T above ∼ 20 GeV (see W,Z cross section)
- The slope of the inclusive p_T spectrum is rising very steeply with decreasing p_T
  → threshold definition of the L1 trigger must be sharp to avoid high trigger rates from low p_T muons

ATLAS Level-1 muon trigger efficiency

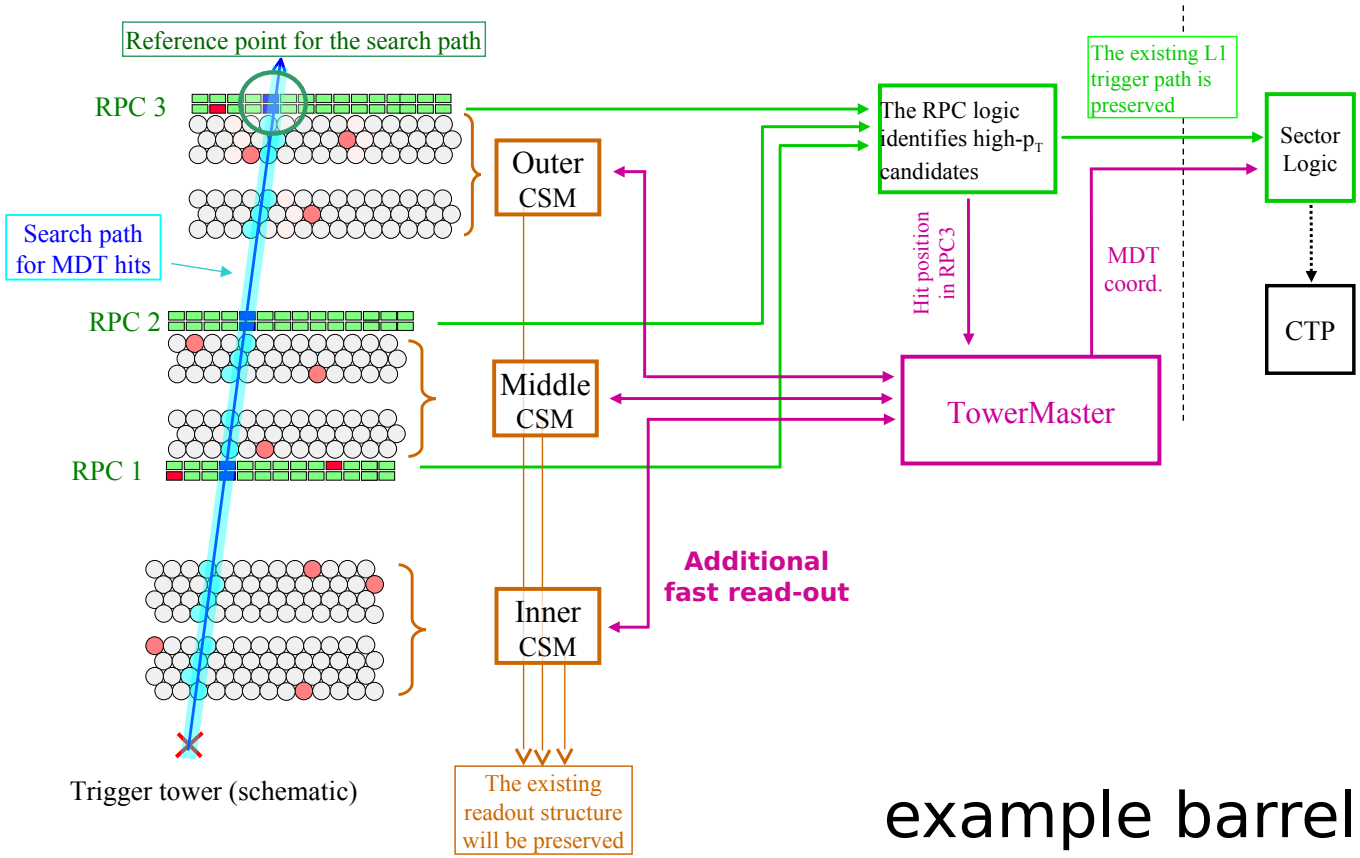


Level-1 muon trigger (HL-LHC)



- 50 kHz trigger rate for trigger chambers
- Additional rate reduction to 20-30 kHz by use of 1 mrad precision of the track slope measurement by the MDT chambers at level 1

New trigger implementation based on MDT



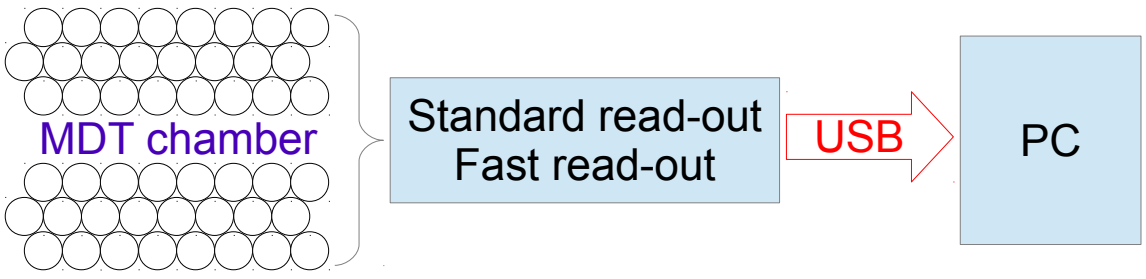
- Additional fast MDT read-out necessary (existing read-out takes too long)
- Fast read-out is triggered by RPC/TGC
  $\rightarrow$ Bunch crossing ID and muon incidence angle are known
- Trigger latency increases (2.5 μs to 20 μs)

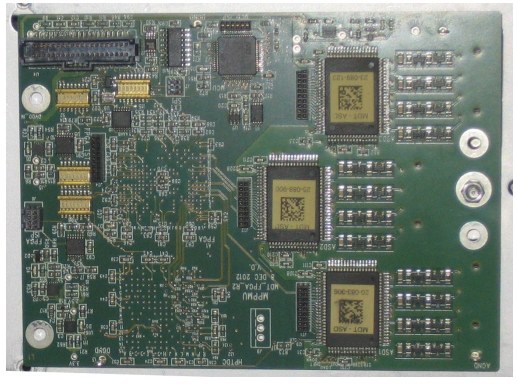
Demonstrator setup for fast MDT read-out

For first studies with real data a demonstrator setup has been designed

Properties:

- Fast read-out is implemented as second TDC (40 MHz clock)
  $\rightarrow$ resolution: $\frac{25}{\sqrt{12}} = 7.22$ ns $\rightarrow$ 229 μm
- Fast read-out and normal read-out are used in parallel
- Fast read-out data has to be analyzed offline
- Fast read-out deadtime: 2500 ns

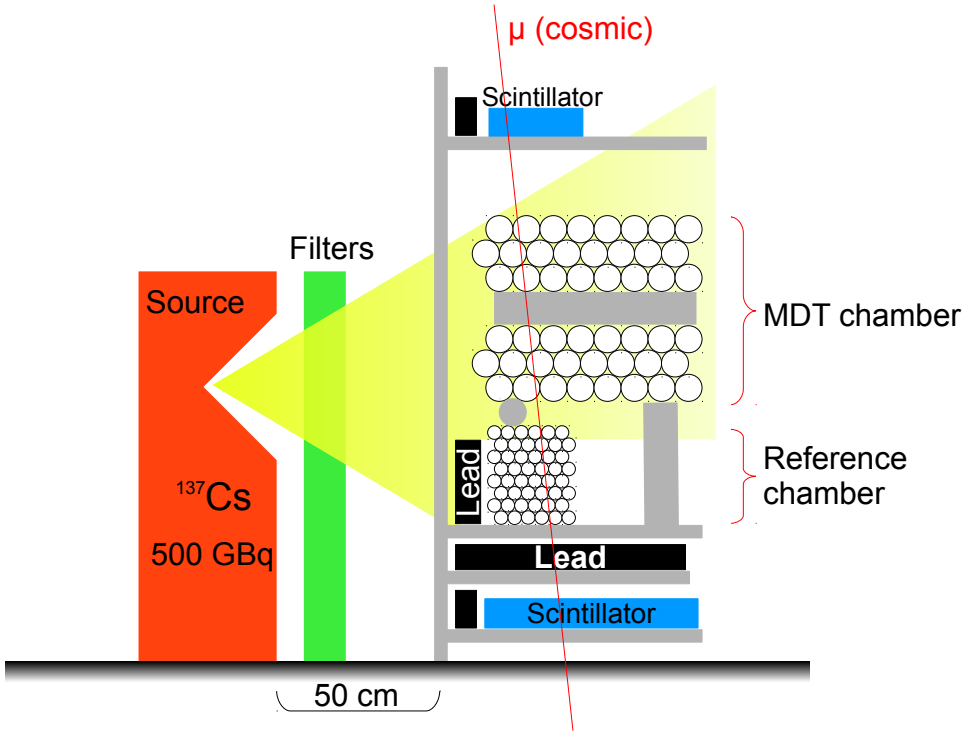


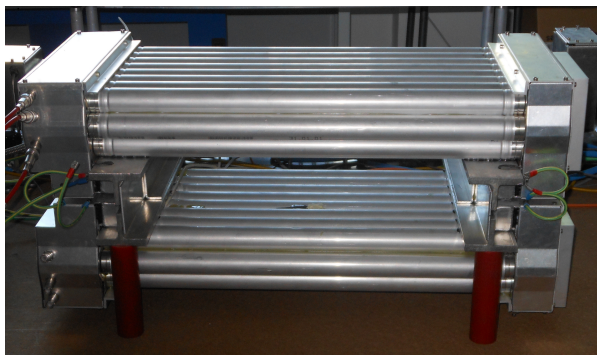


Test of new hardware and fast tracking algorithm

CERN Gamma Irradiation Facility (GIF) - 2013/2014

Goal: Measurement of efficiency and resolution



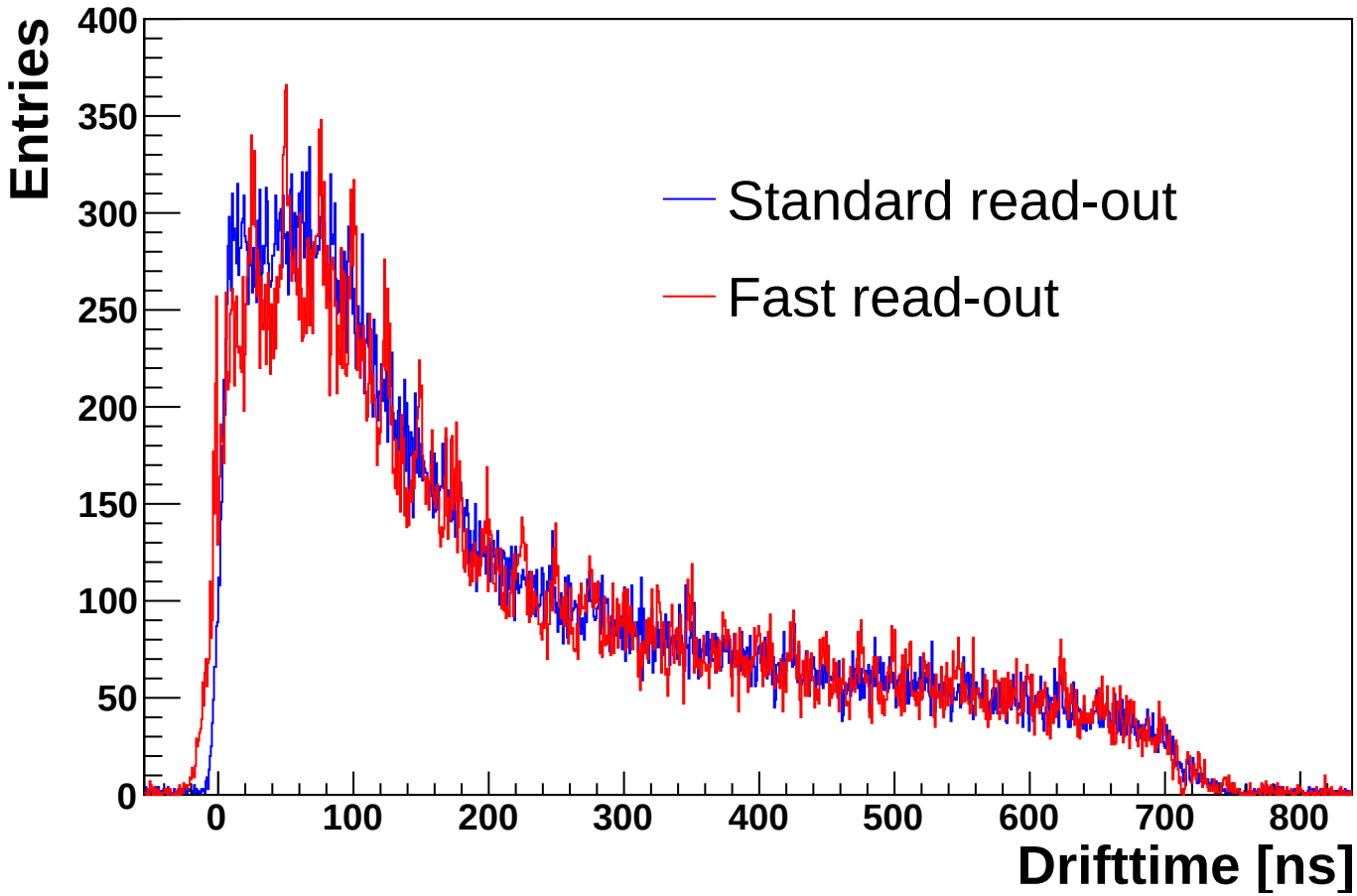


MDT chamber used for test
6 tube layers, 50 cm length

- No muon beam in the GIF $\rightarrow$ use cosmic muons
- Fast read-out and normal read-out are triggered by scintillators
- Angle seed according to reference chamber: 4.7 mrad

Drift time spectra of new fast read-out

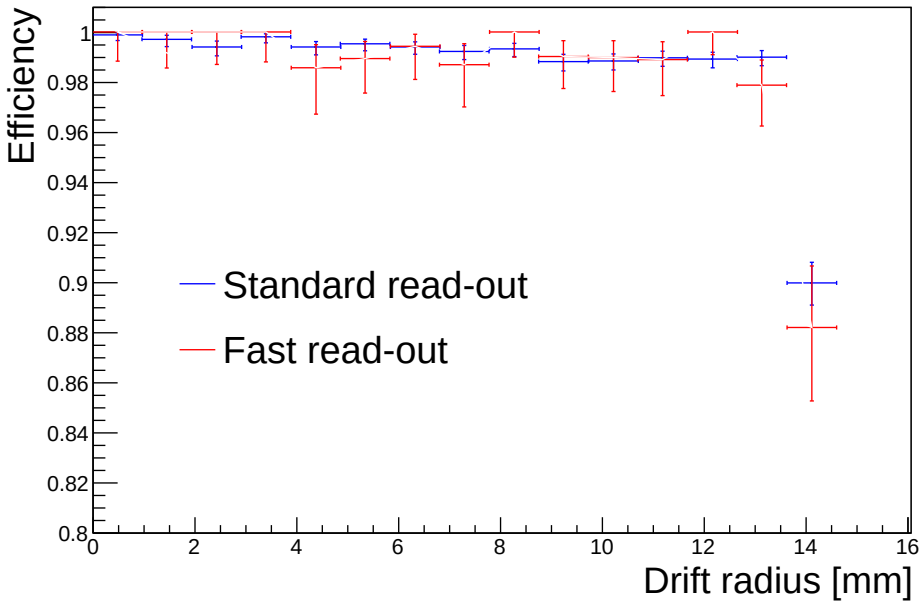
Data taken at CERN in 2014, no background radiation

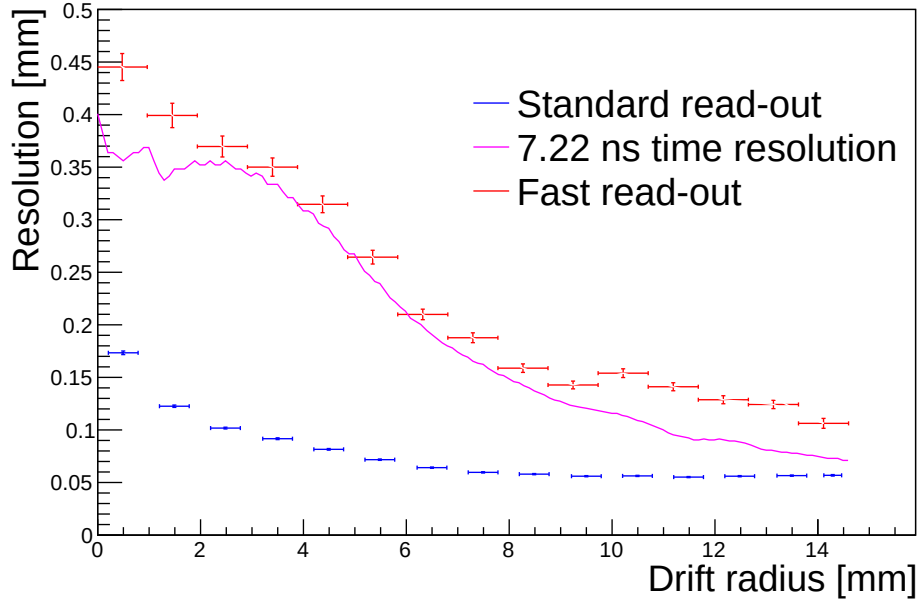


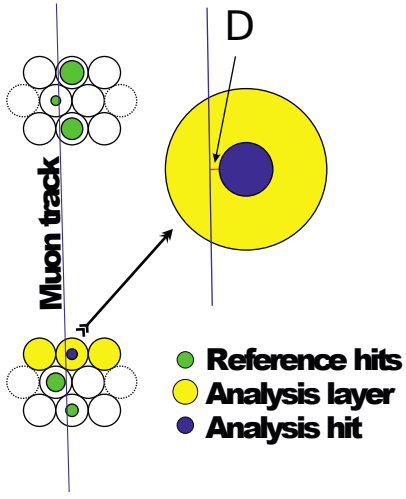
- Spikes in fast read-out data are caused by 25 ns TDC time resolution
- Data is modified with correct trigger time (spikes are smeared out)

Resolution and efficiency of new fast read-out

Data taken at CERN in 2014, no background radiation





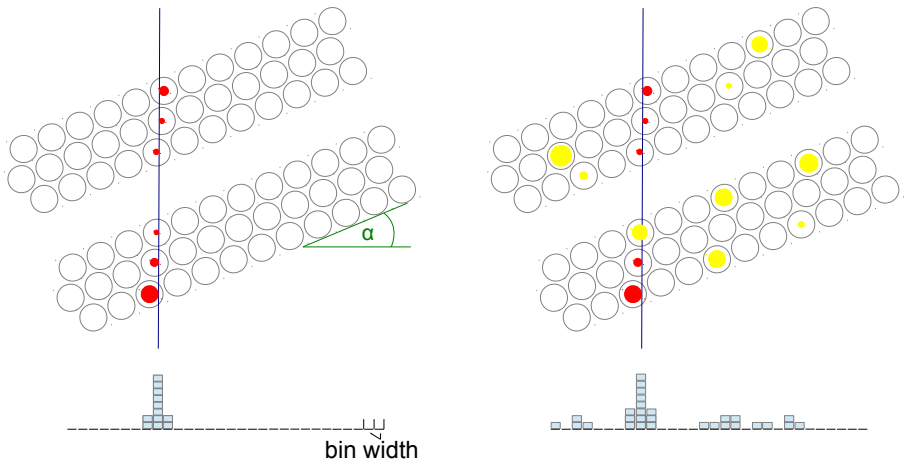


Resolution:

- Use 5 out of 6 layers for track fitting
- Calculate distance between track and hit
- Correct this value with track resolution

Fast track finding algorithm

- Histogram based track pattern recognition



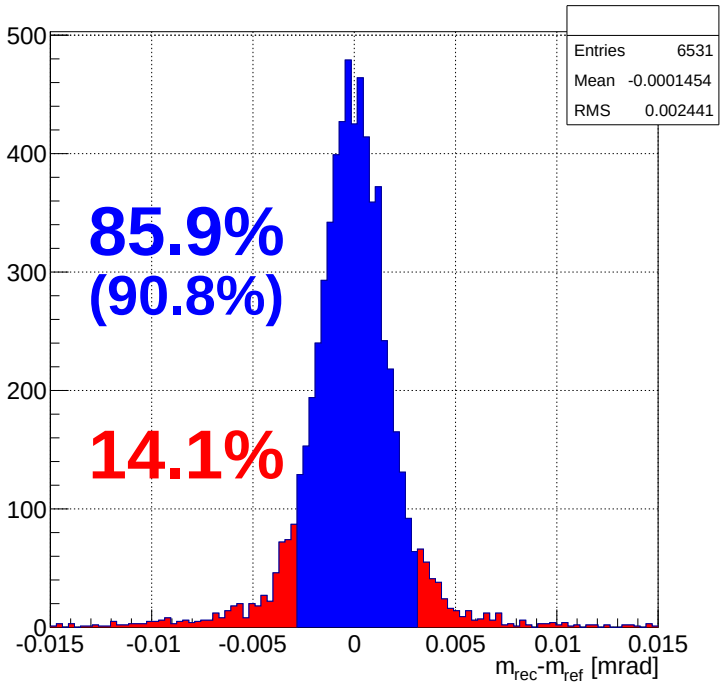
without background with background

- Muons incidence angle α is used as seed
- Project hits in plane perpendicular to the approximate track and fill into histogram
- **Parameter:**
  2 mm bin width of the hit histogram
  At least 4 hits to set trigger

- The tracks angle is finally reconstructed using linear regression

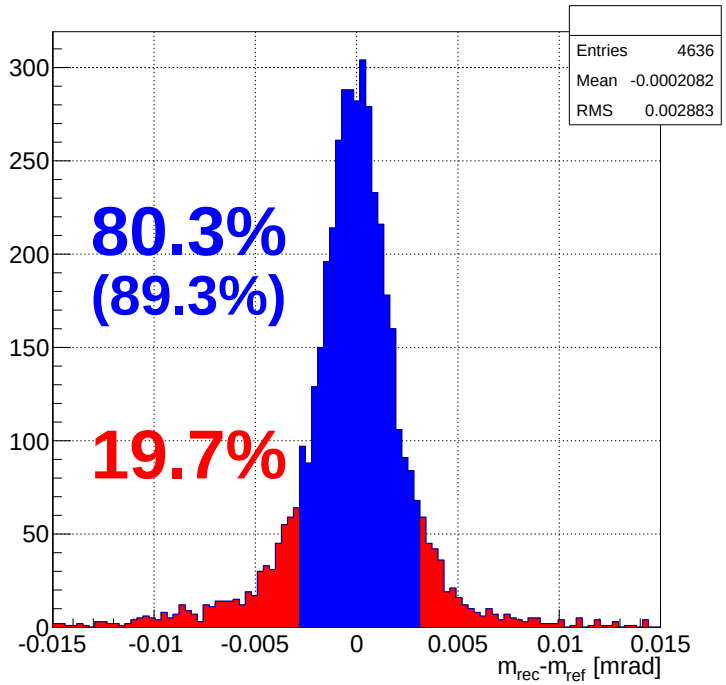
First fast track fitting results

Shielded chamber is used as reference (seed angle resolution of 4.7 mrad)



No background occupancy

Pattern recognition efficiency: 93.4%



10% background occupancy

Pattern recognition efficiency: 74.3%

Two categories:

- Good: $|m_{rec} - m_{ref}| < 3$ mrad (simulated value in brackets)
- Poor: $|m_{rec} - m_{ref}| \geq 3$ mrad

Summary and Outlook

- Improvement of the ATLAS muon trigger by use of MDT based Level-1 trigger
- Demonstrator setup with additional fast MDT read-out has been designed
- Fast read-out shows expected resolution and efficiency
- Future developments
  - Upgrade from prototype to a production version (80 MHz clock, avoiding dead time by use of FIFO)
  - Implementation of fast tracking algorithm in hardware (FPGA)

Hardware implementation