A new MDT-based L1 trigger for ATLAS

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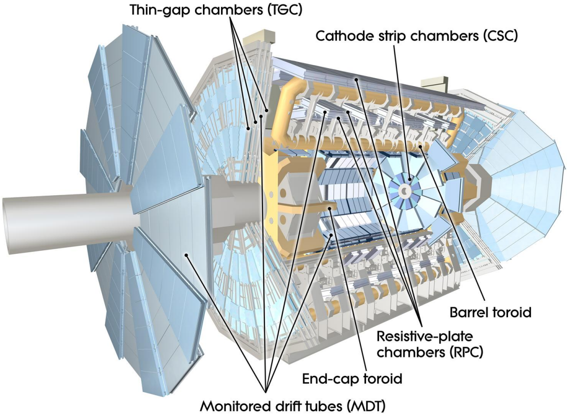
The ATLAS Muon Spectrometer



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

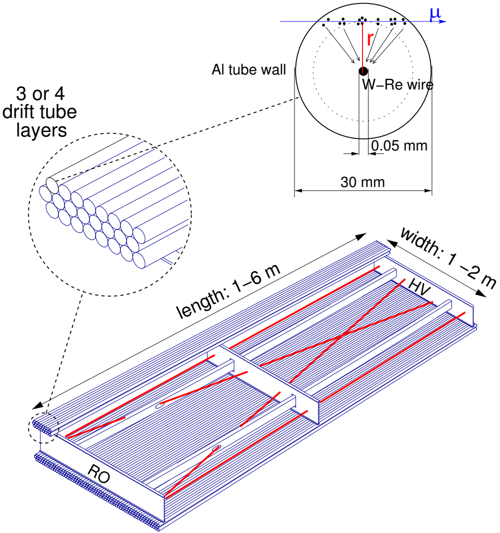
Precision tracking chambers

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

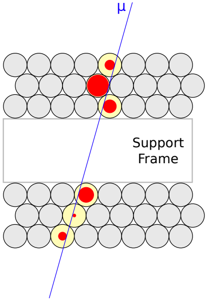
Trigger chambers

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

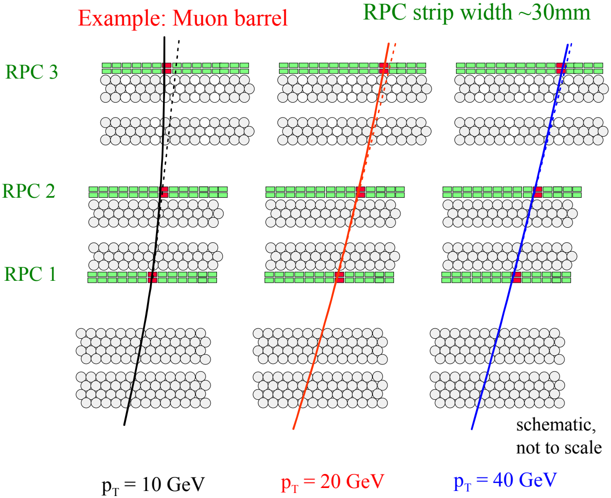
The ATLAS MDT chambers



- 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



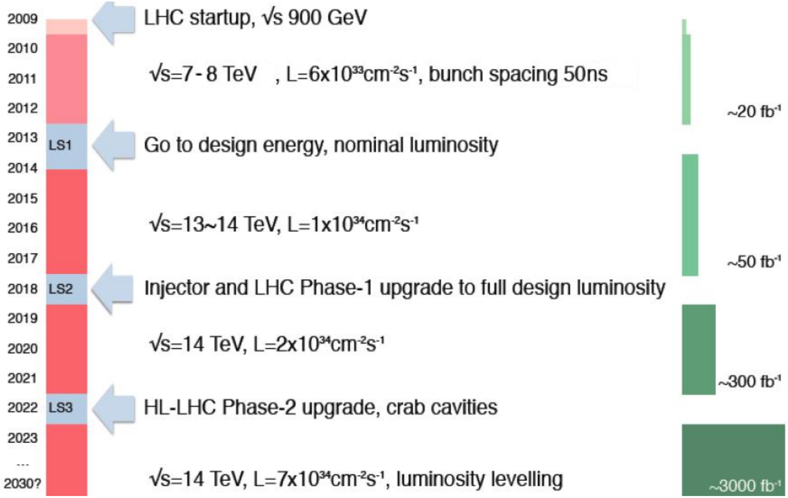
Muon tracks for different momenta



The sagitta in the barrel is
~ 24 mm for p_T = 20 GeV

RPC: Resistive Plate Chamber → Trigger chamber

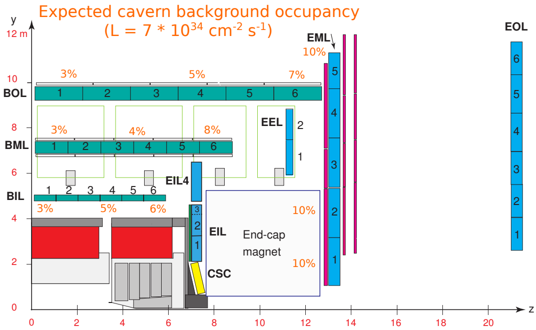
LHC Long Term Schedule



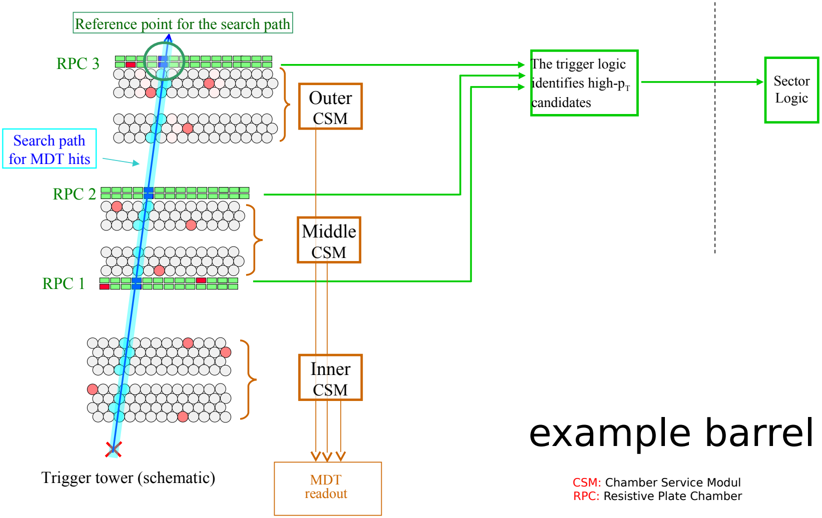
Rates in the ATLAS Muon Spectrometer

- Neutrons, γs and charged hadrons from secondary reactions in detector components and shielding cause high background rates
- Background rate increases proportional with the luminosity

$\Rightarrow$ Rate capability in the *Big Wheels* exceeded



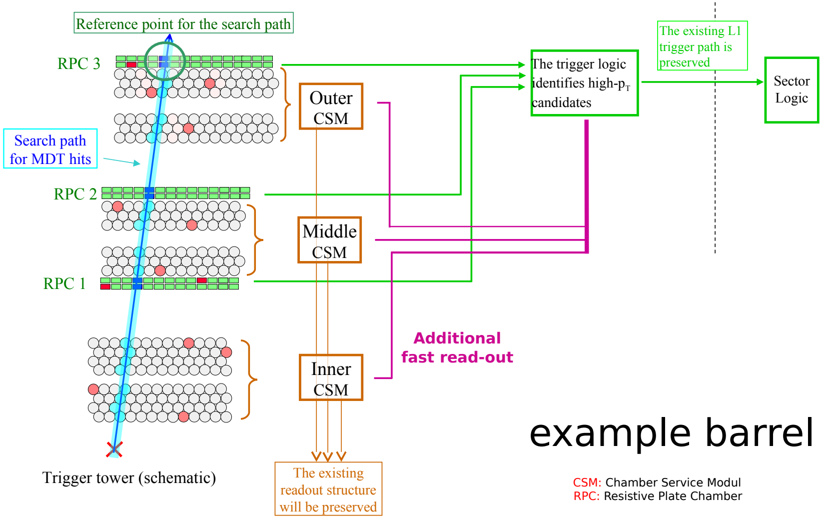
MDT read-out chain (now)



example barrel

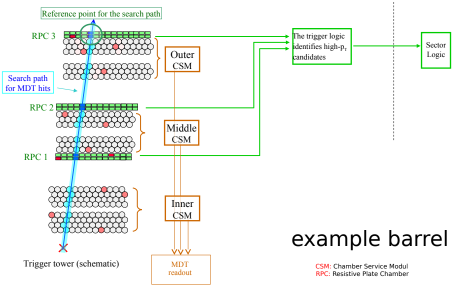
CSM: Chamber Service Modul
RPC: Resistive Plate Chamber

MDT read-out chain (proposed)



Use of more precise MDT information for triggering.

ATLAS Muon Trigger and DAQ System



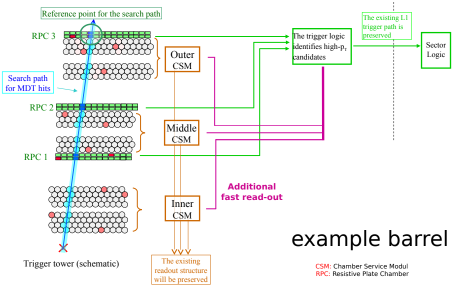
example barrel

CSM: Chamber Service Modul
RPC: Resistive Plate Chamber

Level 1: Trigger chamber
$\rightarrow$ MDT read-out

Level 2: First track reconstruction

ATLAS Muon Trigger and DAQ System



Level 1: Trigger chamber
$\rightarrow$ MDT read-out

Level 2: First track reconstruction

New concept (Upgrade Phase 2):

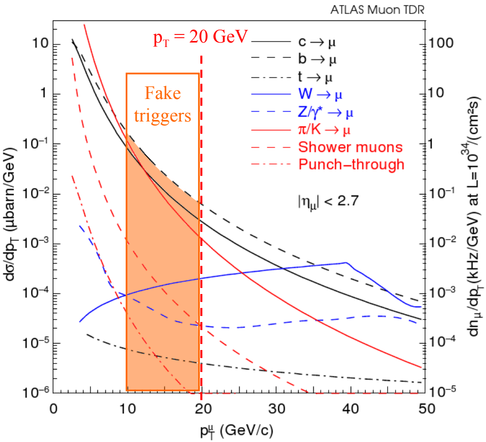
Level 0: Trigger chambers $\rightarrow$ MDT fast read-out

Level 1: MDT chambers fast read-out $\rightarrow$ MDT read-out

Level 2: Track reconstruction

Performance of the existing L1 p_T trigger

Total muon production cross section

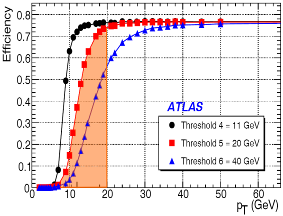


cross section for p_T > 10 GeV: ∼400 nb

cross section for p_T > 20 GeV: ∼47 nb

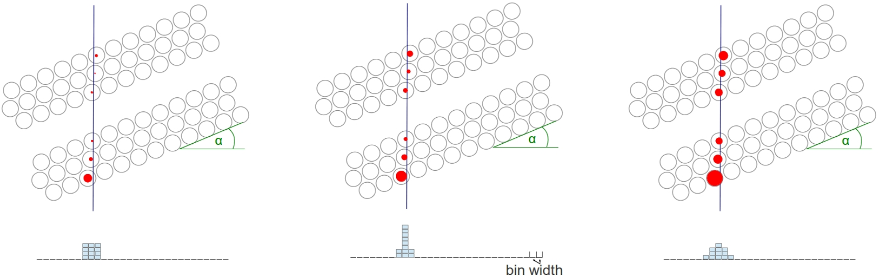
- The interesting physics is mainly at p_T above $\sim$ 20 GeV (see W,Z cross section)
- The slope of the inclusive p_T spectrum is rising very steeply with decreasing p_T $\rightarrow$ threshold definition of the L1 trigger must be sharp to avoid high trigger rates from low p_T muons

ATLAS Level-1 muon trigger efficiency



Histogram based track finding algorithm

for an additional MDT fast read-out



preceding bunch crossing	correct bunch crossing	following bunch crossing
$t = -1$	$t = 0$	$t = +1$

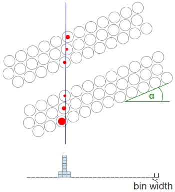
Bunch crossing: Time of muon production

Simulation framework

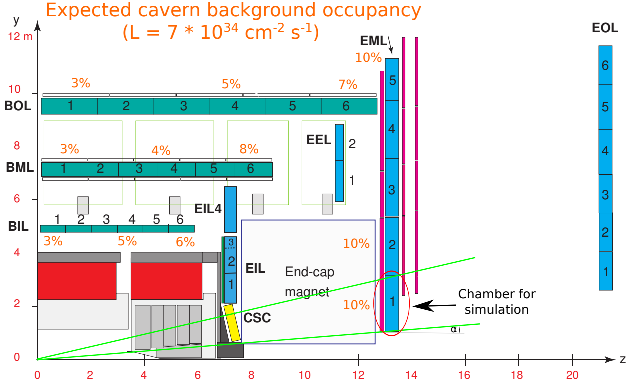
- Stand-alone Monte Carlo simulation
- Adjustable parameters:
  - Drift tube chamber geometry
  - Angle of incidence of the muon and spread of the angle
  - Rate of non-correlated background
  - Effect of δ-rays
- Inefficient regions (tube walls, glue gaps) are included
- Real r-t relation (implemented as look-up table)

Performance studied as a function of the background rate with and without spread of the incident muon angle

Parameters used for all simulation



Drift time resolution	25 ns ($\sim$ 0.5 mm)
Algorithm bin width	2 mm
Angle of incidence (EML1)	$0.123 < \alpha < 0.238$ [rad]
Worst case scenario: EML1	



Definitions for simulation results

Efficiency:

- Calculated track is within 2 mm region (bin width) of real track

Fake probability without ROI (Region Of Interest):

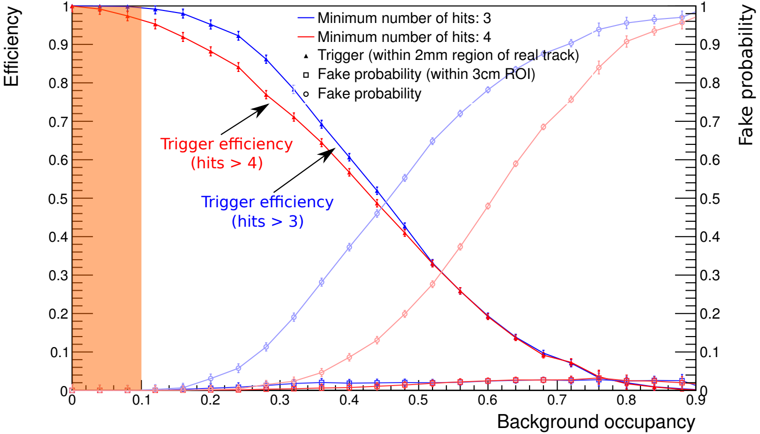
- Calculated track is outside 2 mm region of real track
- The track fitting is not based on trigger chambers information

Fake probability with ROI:

- Calculated track is within 3 cm ROI and outside 2 mm region of real track
- The track fitting is based on trigger chambers information

MDT Level-1 muon trigger simulation for EML1

- No incidence angle spread
- With δ-rays

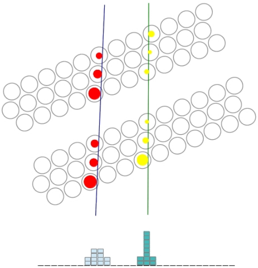


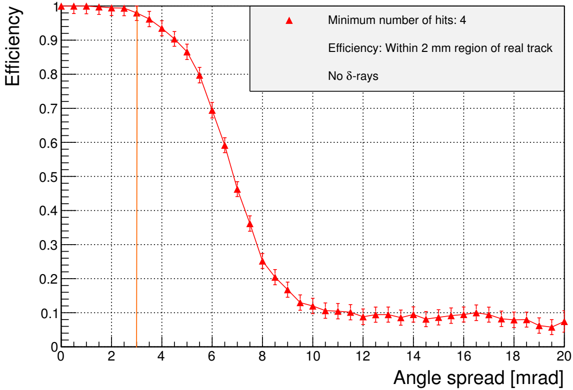
10% Occupancy (3 hits required):

- Efficiency: 98.5%
- Fake probability with ROI: 0.2%
- Fake probability without ROI: 0.5%

Incidence angle spread

- Angle: α = 0.123 rad





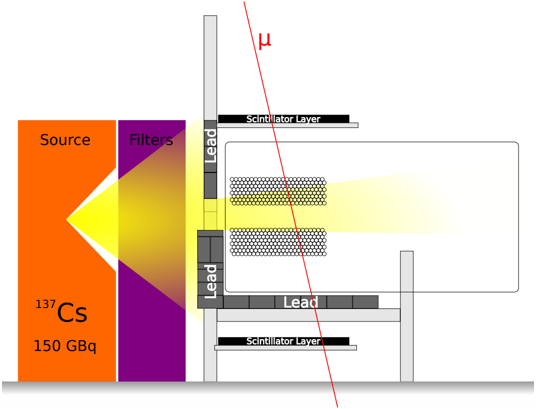
Expected incidence angle spread for EML (p_T = 32 GeV):

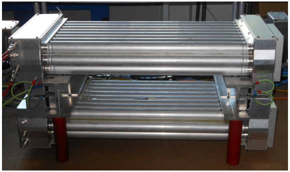
Trigger chamber information not available	20 mrad	algorithm inefficient
Trigger chamber information available	3 mrad	minor degradation

Test of new read-out hardware (planned)

CERN Gamma Irradiation Facility (GIF)

Goal: Measurement of efficiency and resolution of additional fast read-out





- No muon beam in the GIF → use (low energy) cosmic muons
- Fast read-out and normal read-out are triggered by scintillators

⇒ Trigger chambers information is calculated out of muon tracks

Summary and Outlook

- HL-LHC luminosities lead to ATLAS muon spectrometer trigger rate problem

→ Proposal of an MDT-based additional trigger

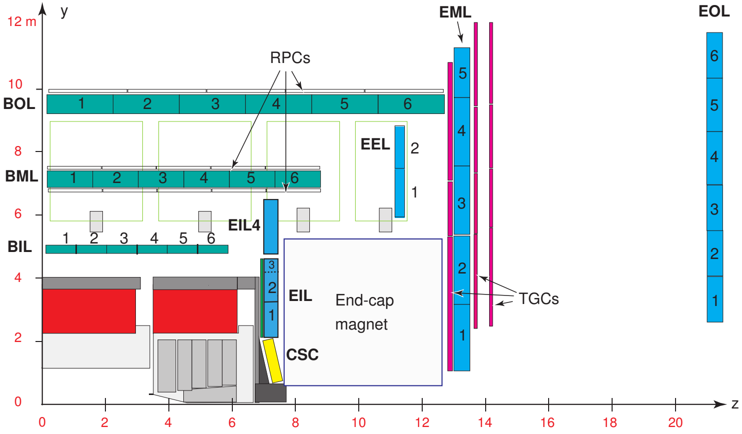
- Simulation results for most difficult region (occupancy 10%):
  - Efficiency: 98.5%
  - Fake probability: 0.5%

- Hardware test setup in development
- First test planned in autumn 2013

New trigger implementation based on MDT

Angular resolution of trigger chambers: 3.0 mrad
Necessary angular resolution: 1.0 mrad
Fast MDT read-out resolution:

25 ns / 12.5 ns $\rightarrow$ 0.5 / 0.26 [mm] $\rightarrow$ 1.7 / 0.9 [mrad]



Hardware implementation