Construction and Test of Muon Drift Tube Chambers for High Counting Rates

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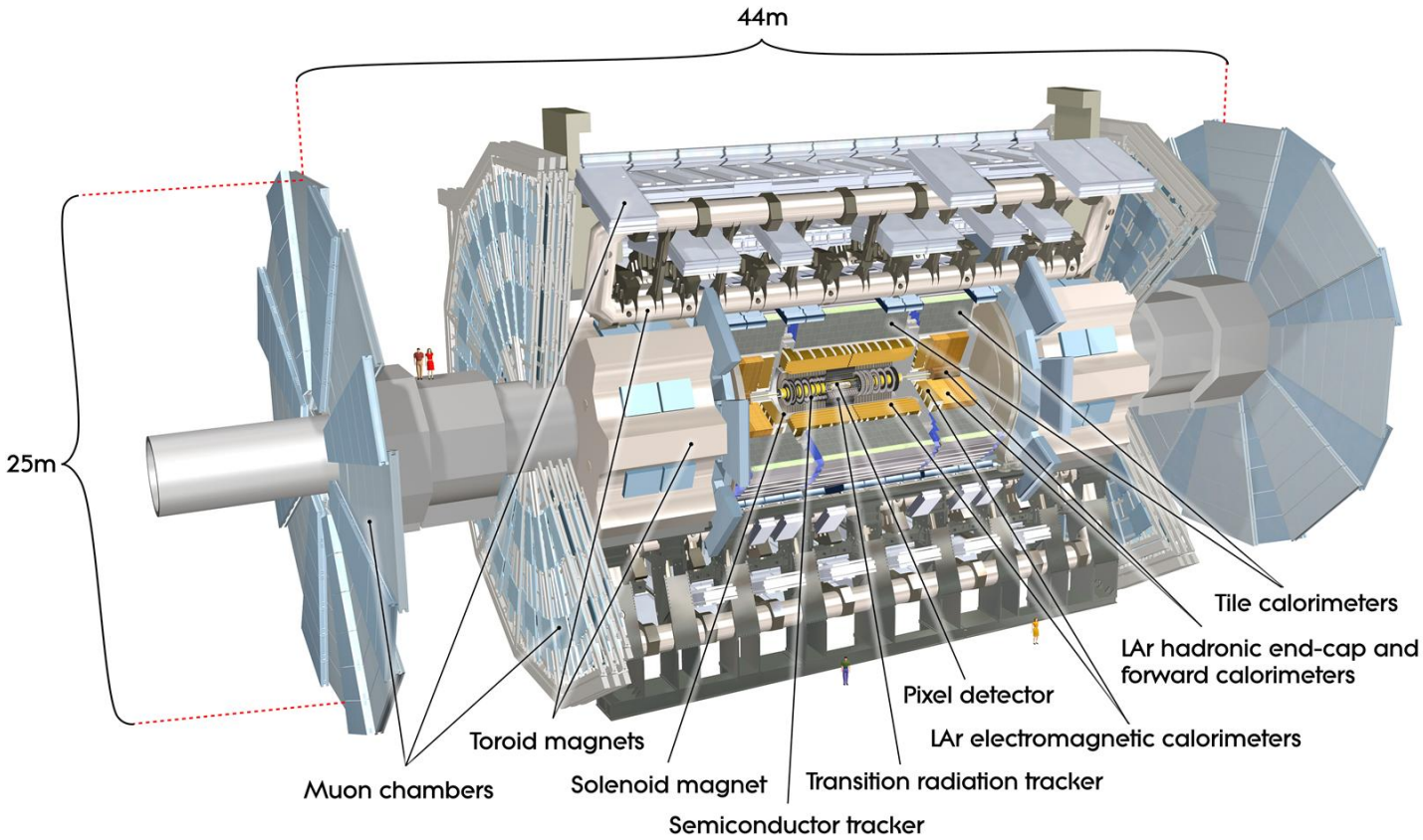
Outline

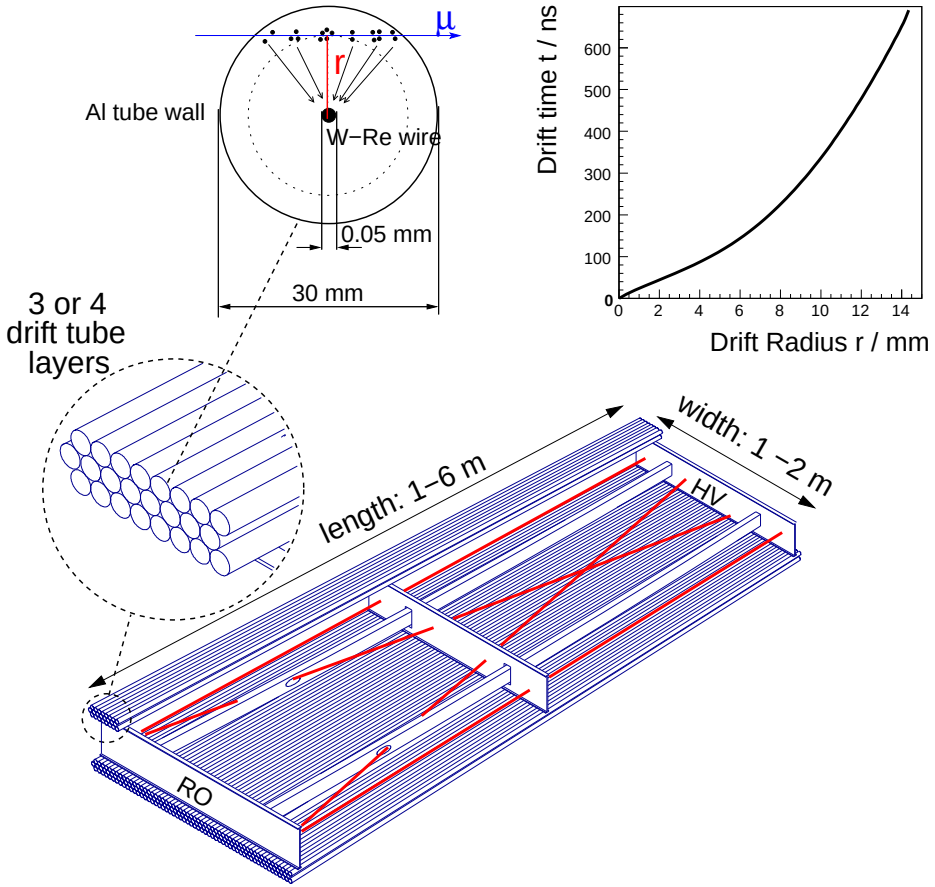
The ATLAS Muon Spectrometer



Demands on the Muon Spectrometer:

- Momentum resolution $\frac{\Delta p_{\mathrm{T}}}{p_{\mathrm{T}}} < 10\,\%$ for muons up to 1 TeV
- Tracking efficiency > 90 %

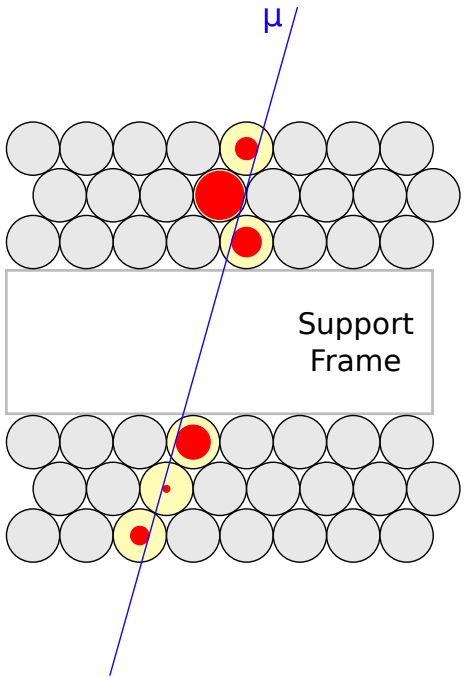
The ATLAS Monitored Drift Tube Chambers



1. charged particle ionizes gas along its path
2. electrons drift in electric field towards the wire
3. avalanche multiplication close to the anode wire ($\approx$ 150 µm)
4. measurement of charge arrival time t at the anode wire
5. determine drift radii $r(t)$ and fit track segment

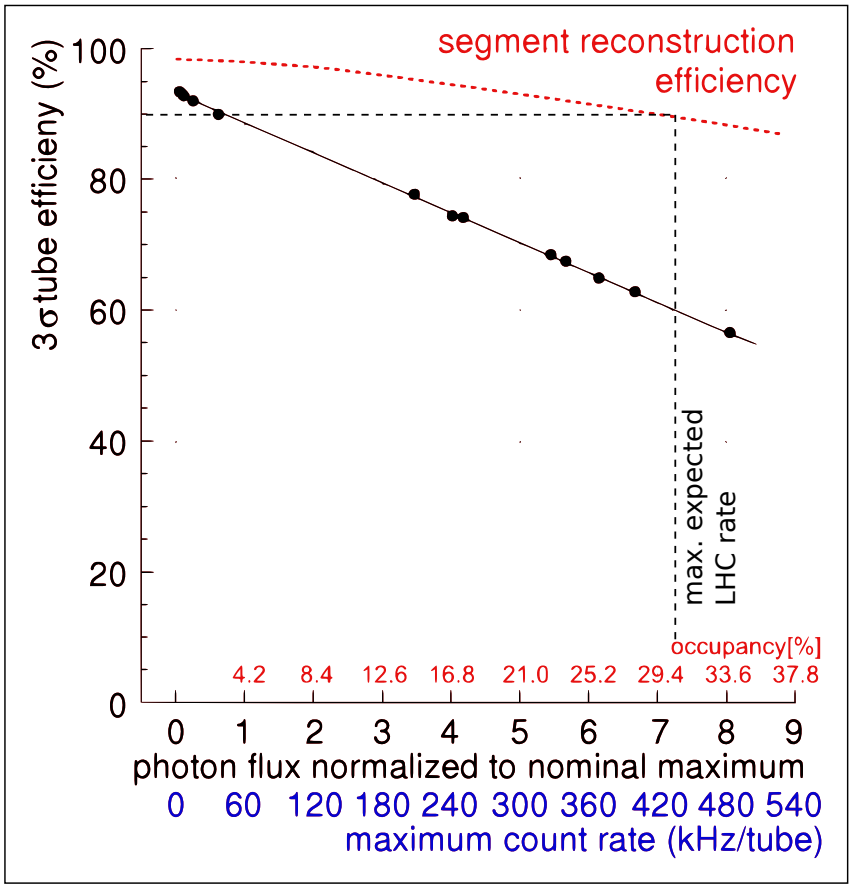
MDT chamber parameters:

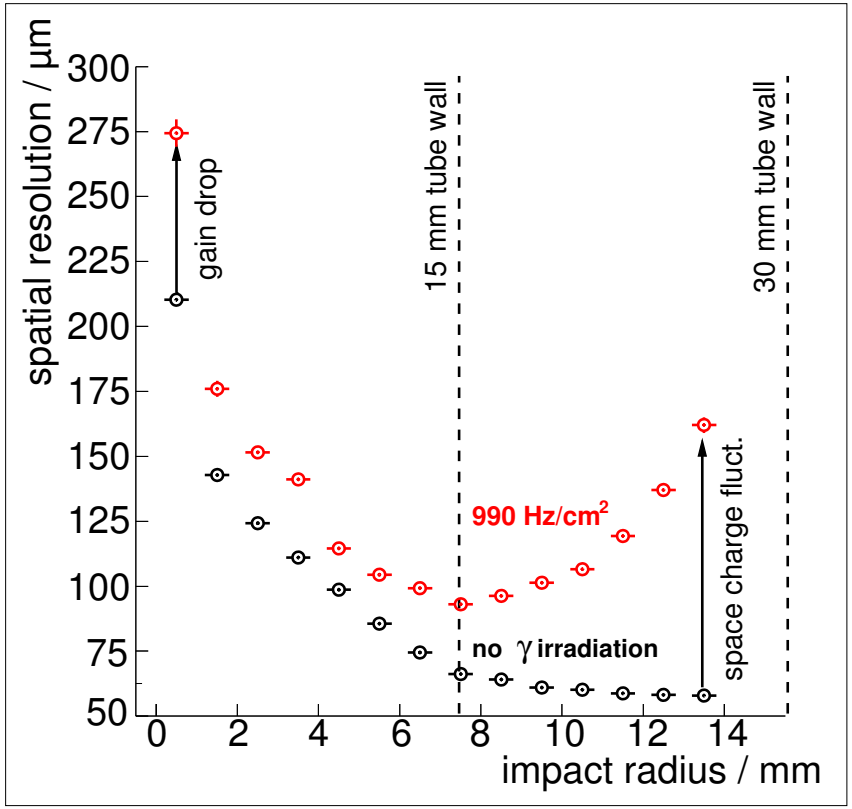
- Gas Mixture: Ar/CO_2 (93/7)
- Max. drift time: $\approx$ 700 ns
- Single-tube resolution: 80 µm
- Track reconstruction accuracy: 35 µm



Problems at High Background Rates

Background neutrons and γ's from secondary reactions in shielding and other detector components cause drop of efficiency and spatial resolution.





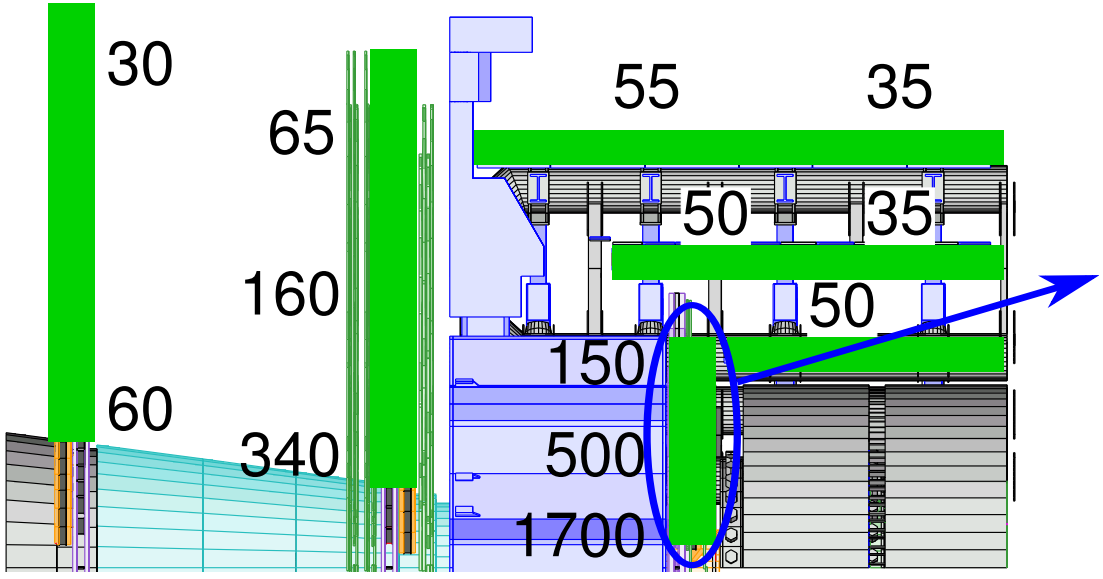
detector occupancy = hit rate × maximum drift time (≈ 700 ns)

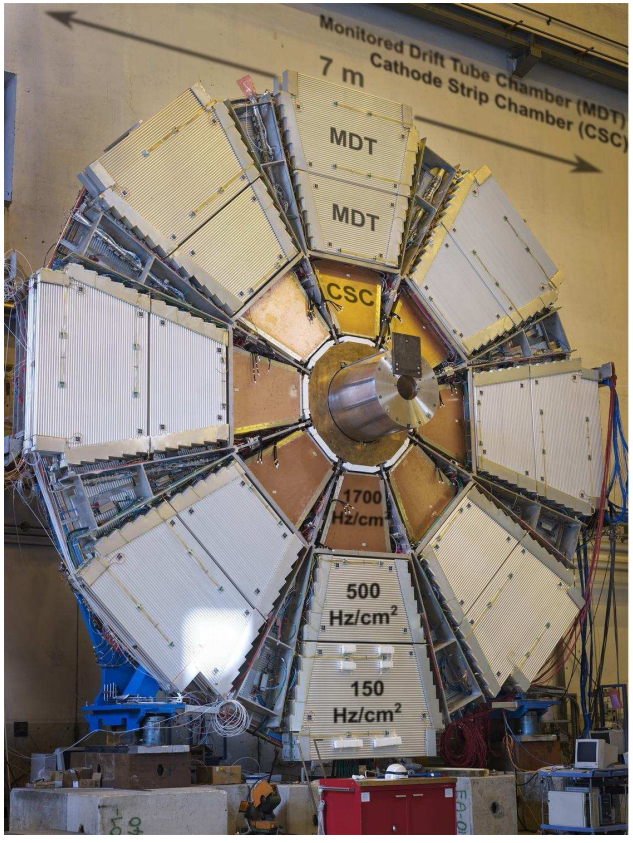
LHC Luminosity Upgrade Plan

- Upgrade of the LHC luminosity over the coming decade to $5\times$ nominal luminosity: $\mathcal{L} = 5 \cdot 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$
- Background rate expected to increase proportional to luminosity increase

$\Rightarrow$ Background rate capability exceeded in the inner forward region (*Small Wheel*) of the muon spectrometer

Expected rate in $\mathrm{Hz}/\mathrm{cm}^2$ at nominal LHC luminosity:





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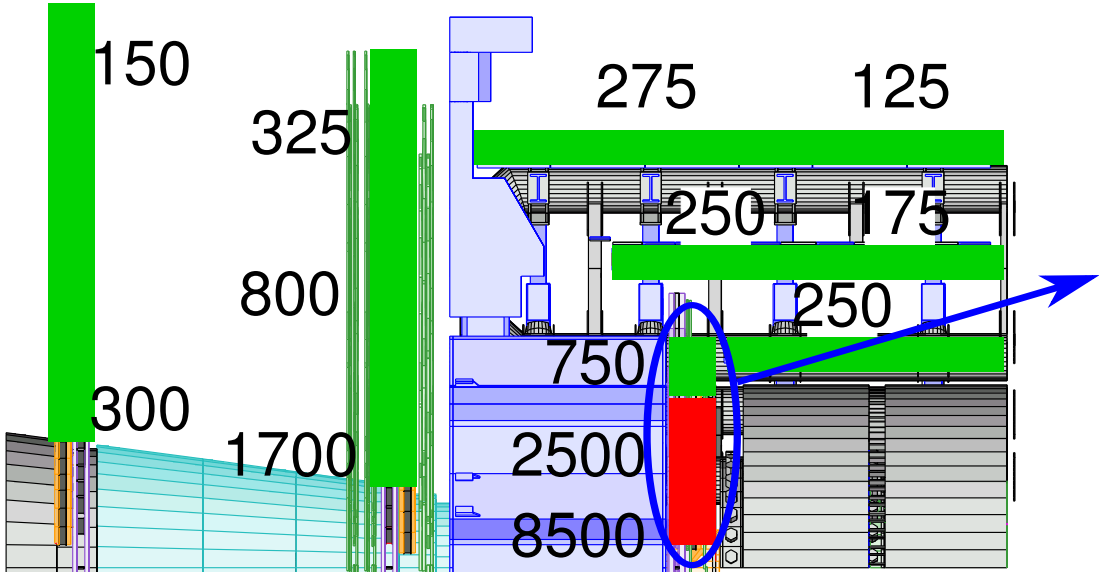
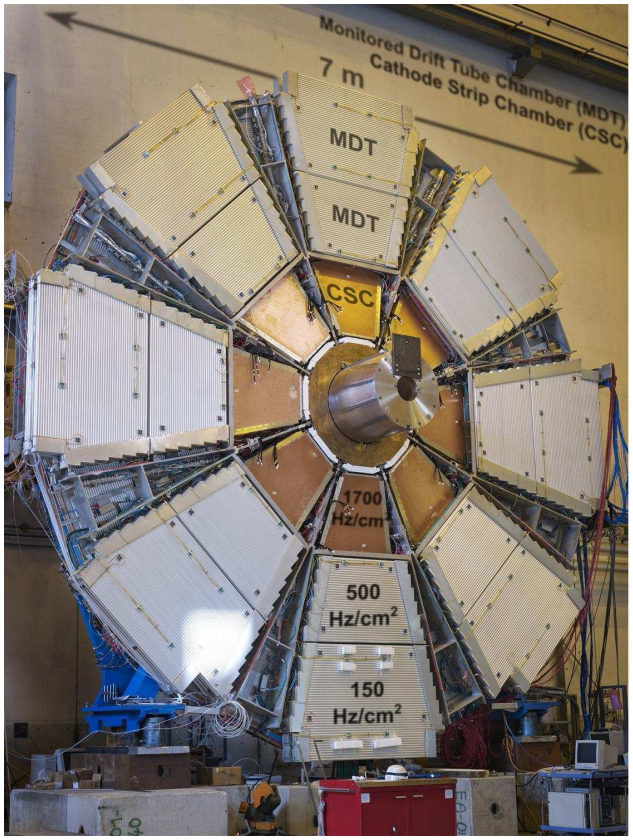
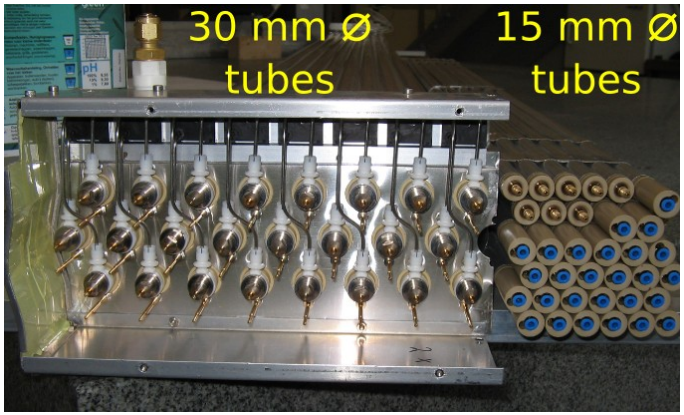
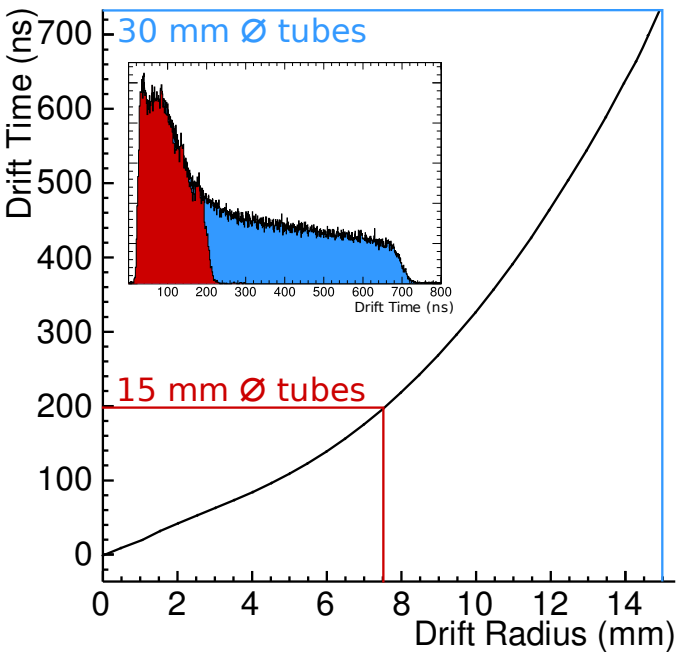




Reducing the Tube Diameter





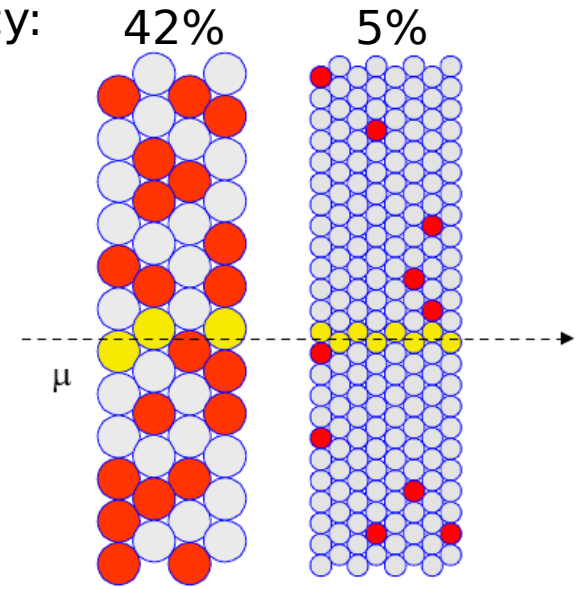
Drift gas: Ar/CO_2 (93:7), 3 bar

Reducing the tube diameter from 30 to 15 mm:

- 7× lower occupancy due to
  - shorter maximum drift time (factor 3.5)
  - smaller tube diameter (factor 2)
- More tube layers in the same volume ⇒ better tracking efficiency

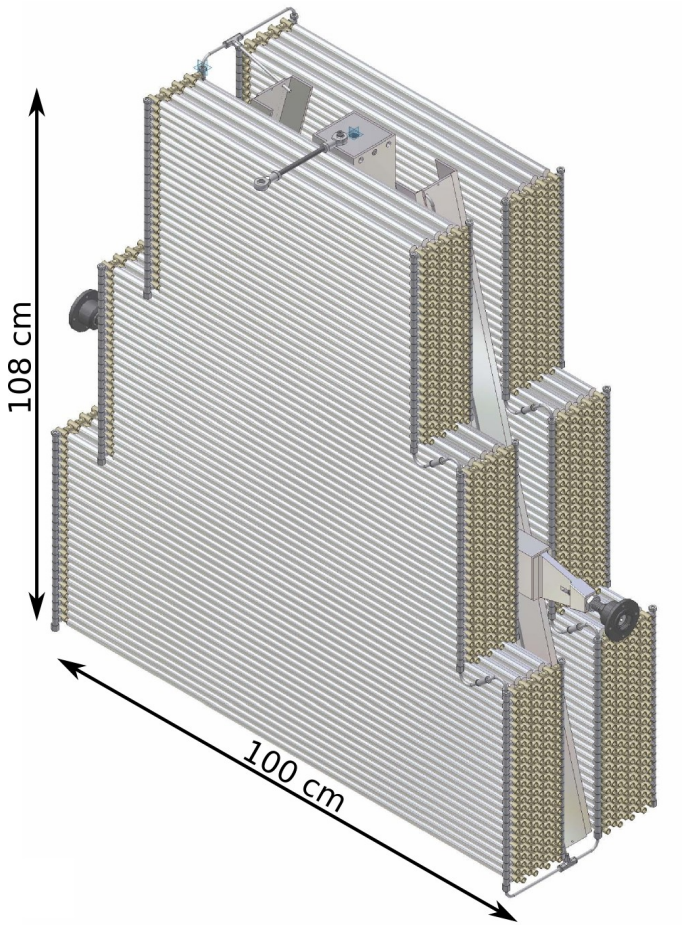
rate: ~3 kHz / cm²

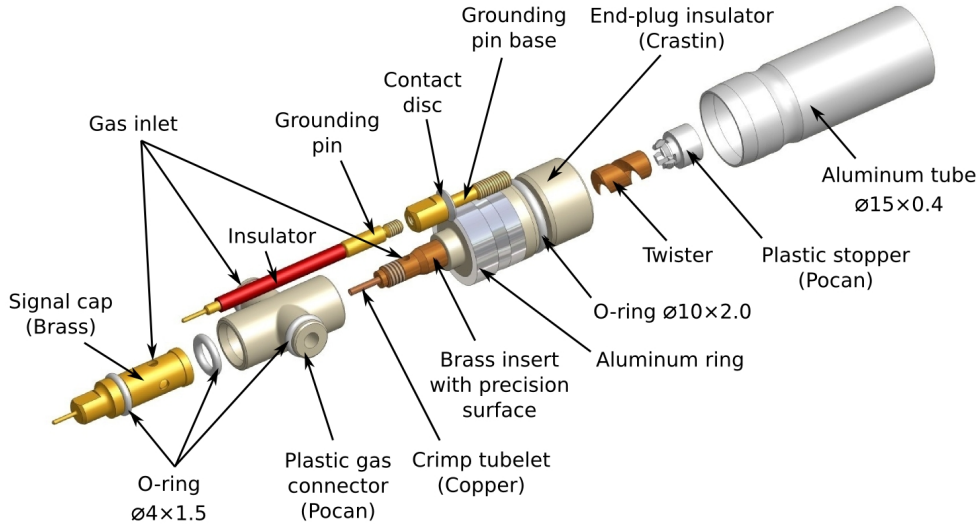
occupancy:

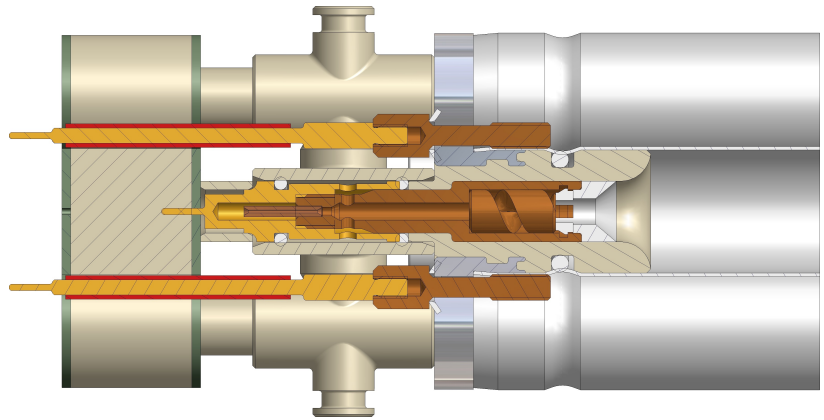


New Drift Tube Chamber Design

- trapezoidal shape
- 3 different tube lengths
- 2×8 tube layers
- 1152 tubes in total



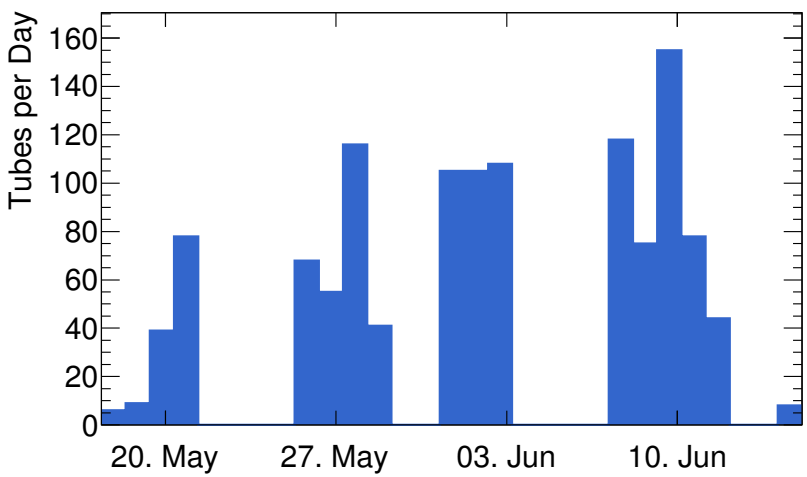




Construction of a Full Scale Prototype Chamber

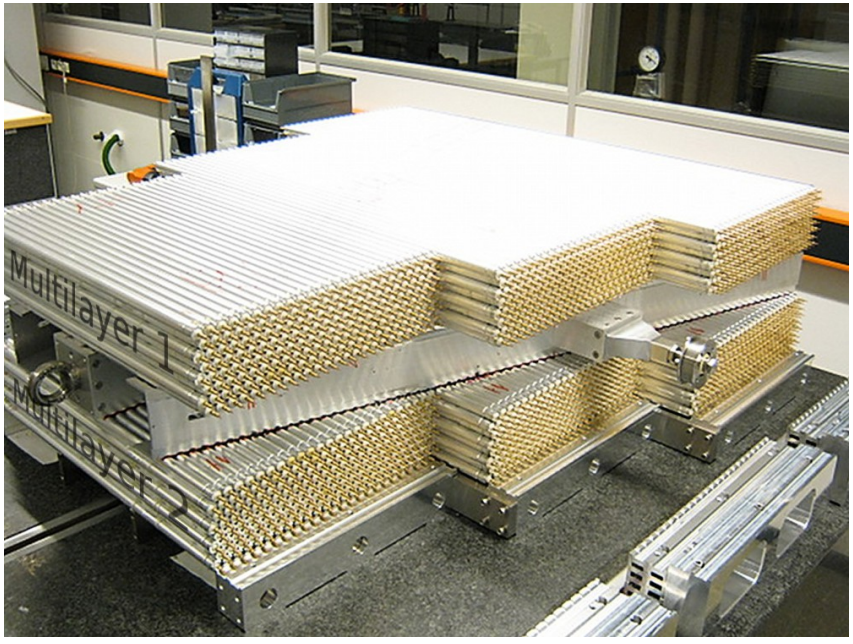
Drift Tube Production and Tests

- Assembly in clean room
- 1200 tubes produced in 3 weeks, manpower 3 people
- Tubes tested for correct wire tension, gas tightness and sustaining high-voltage
- Overall failure rate ≈7 % — decreased to ≈1 % later

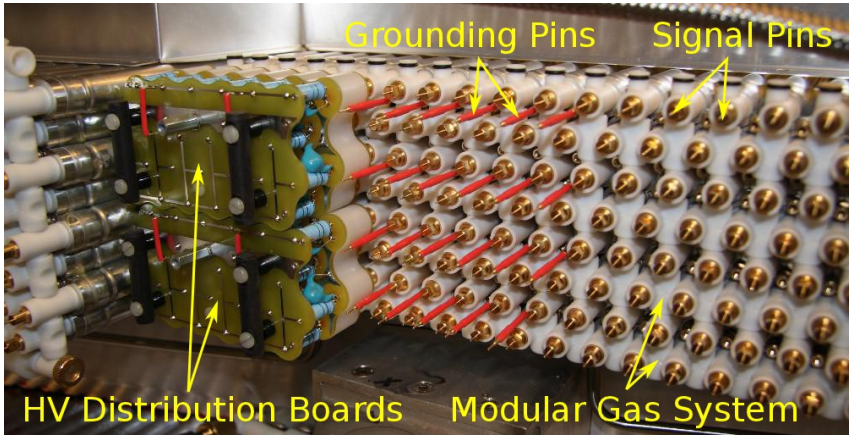


Construction of a Full Scale Prototype Chamber

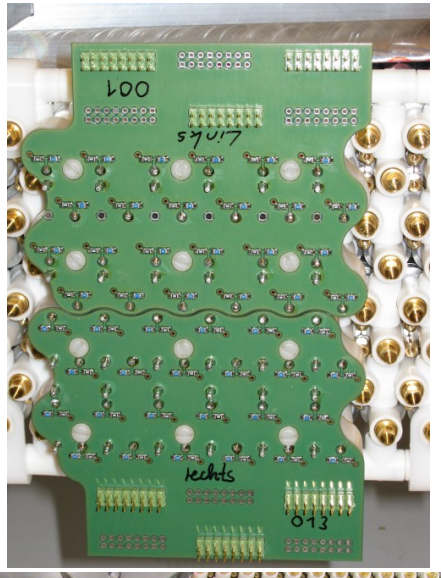
glued multilayers of drift tubes

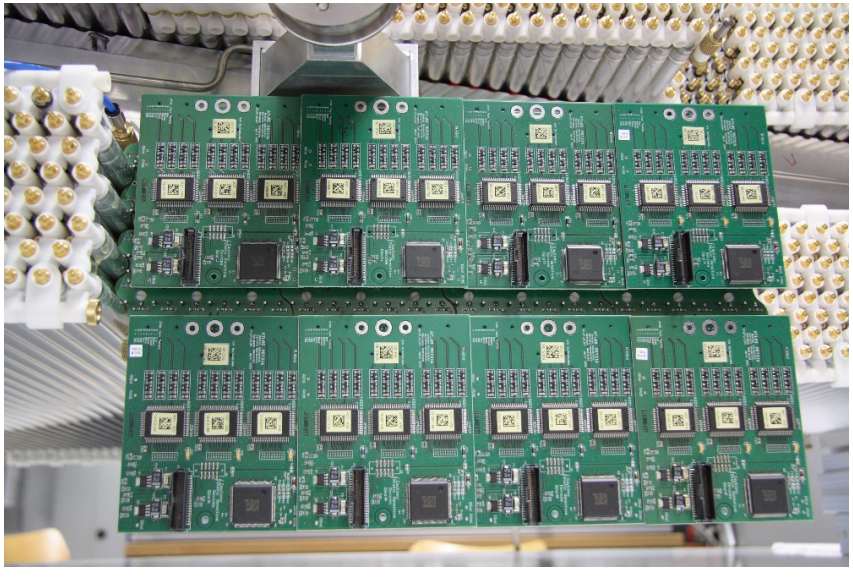


high-voltage distribution boards



front-end read-out electronics



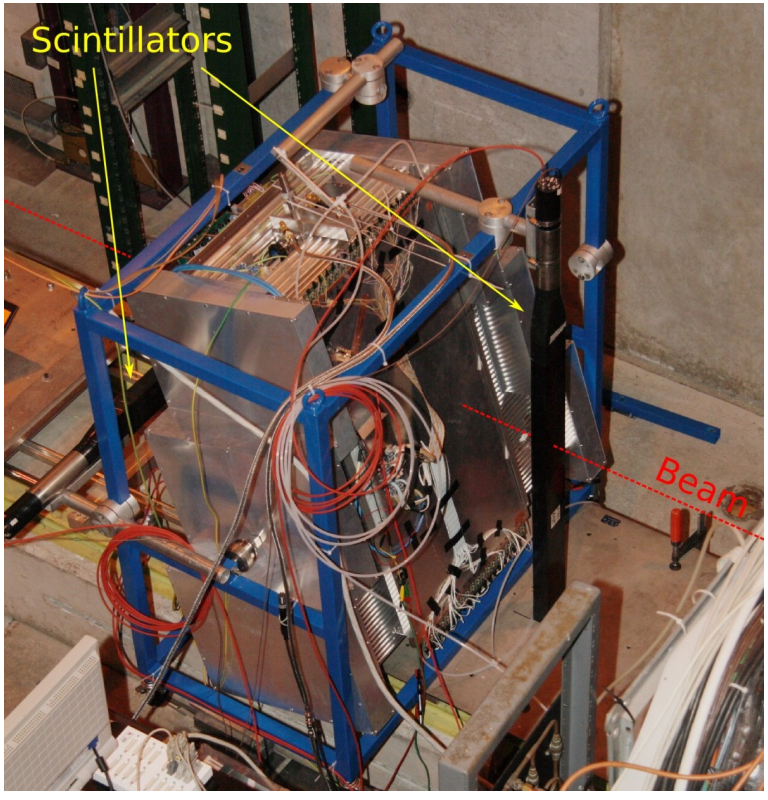


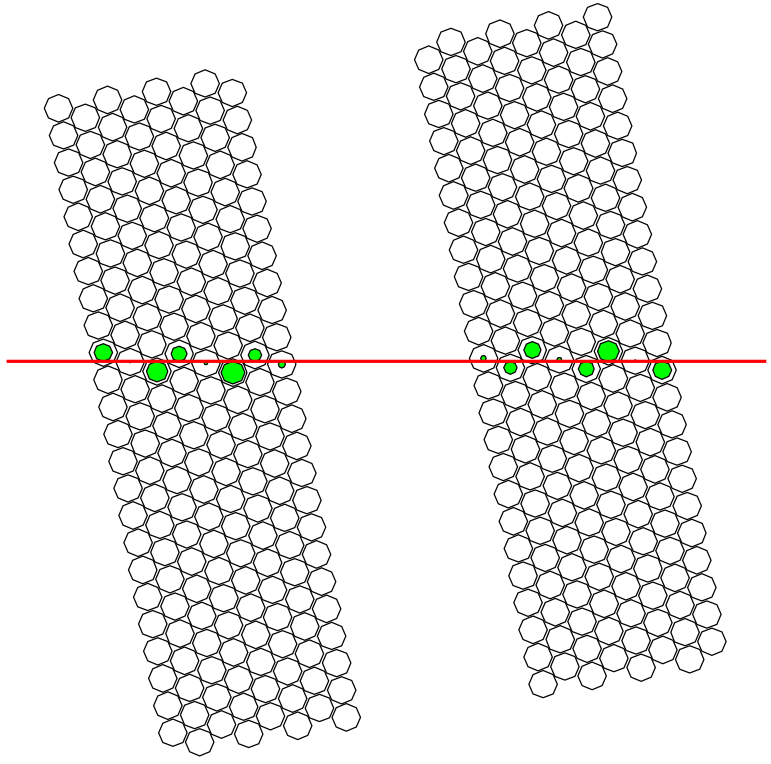
Test Beam Measurements

180 GeV Muon Beam at CERN

Goals:

- First operation of the prototype chamber
- Optimization of the operating parameters
- Measurement of the spatial resolution and the efficiency without background radiation





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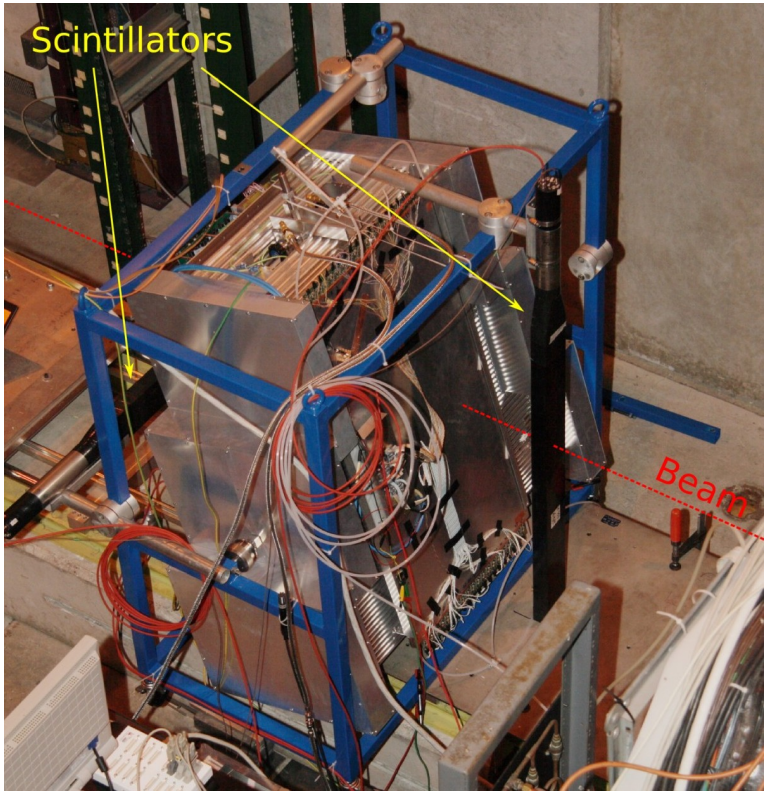
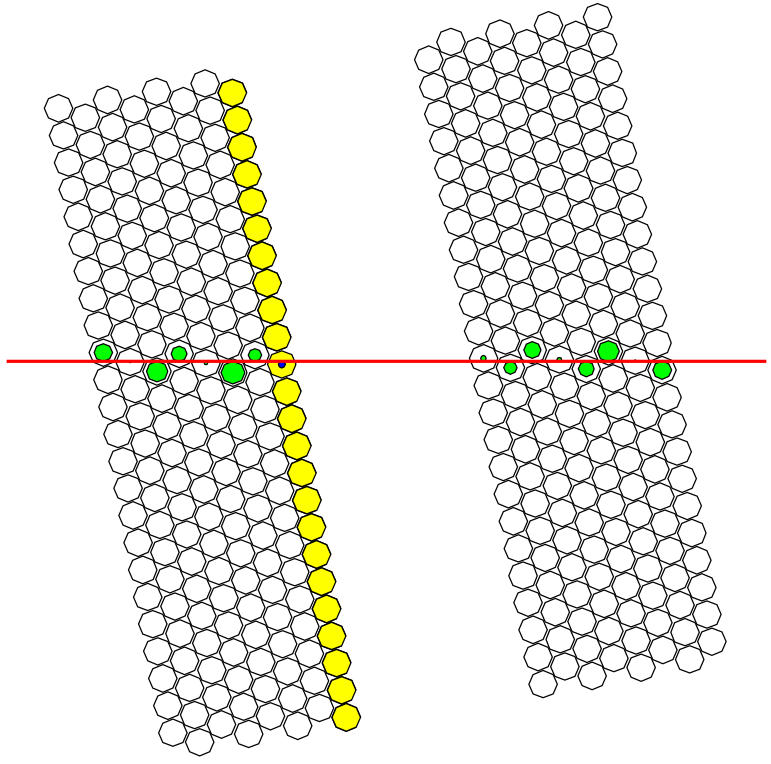


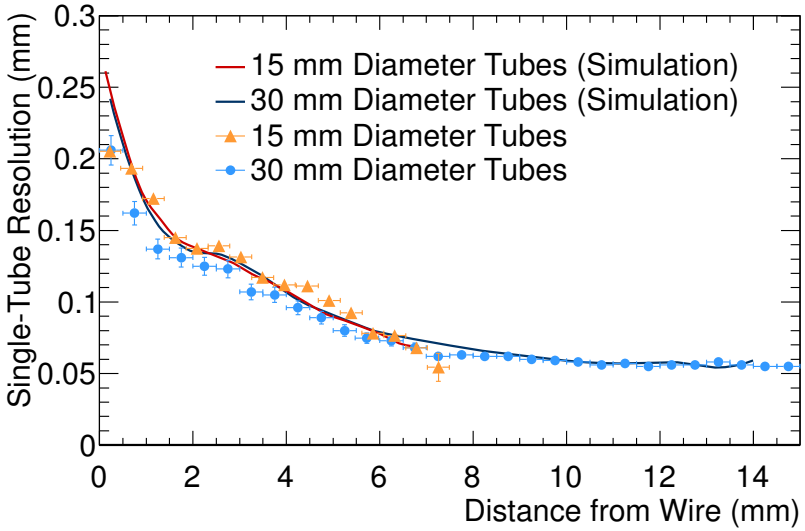


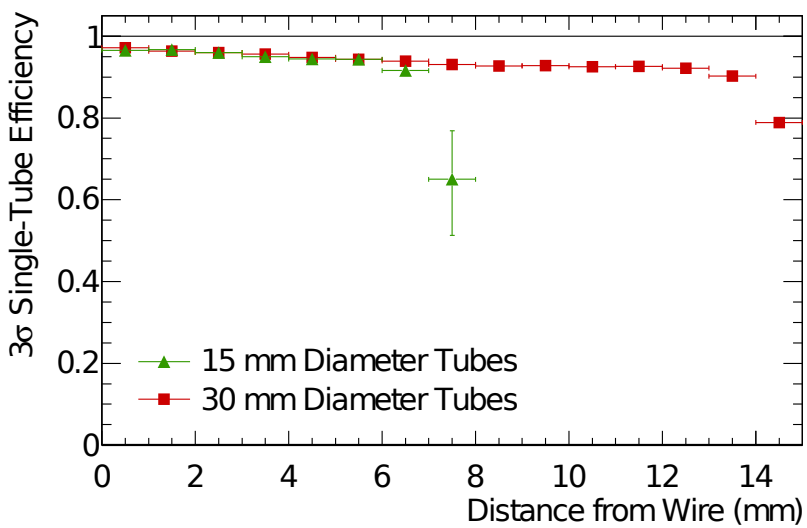
Test Beam Measurements

Results

Stable operation of the prototype chamber in the test beam for one week:

- More than 30 million events recorded
- No high-voltage or electronic noise problems

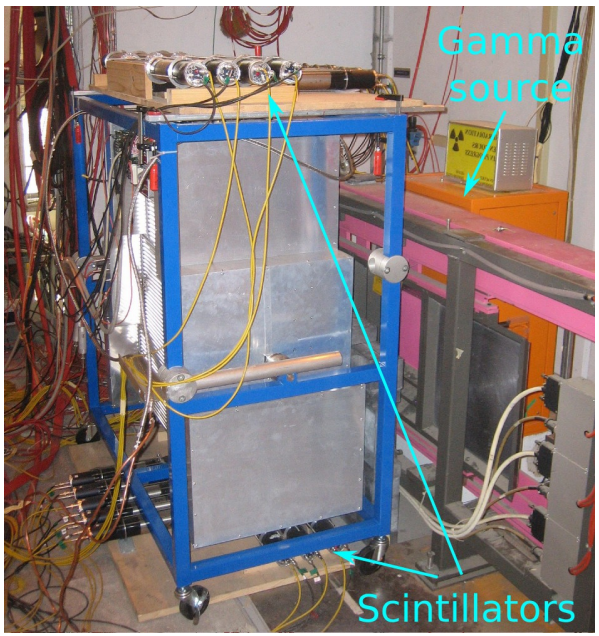


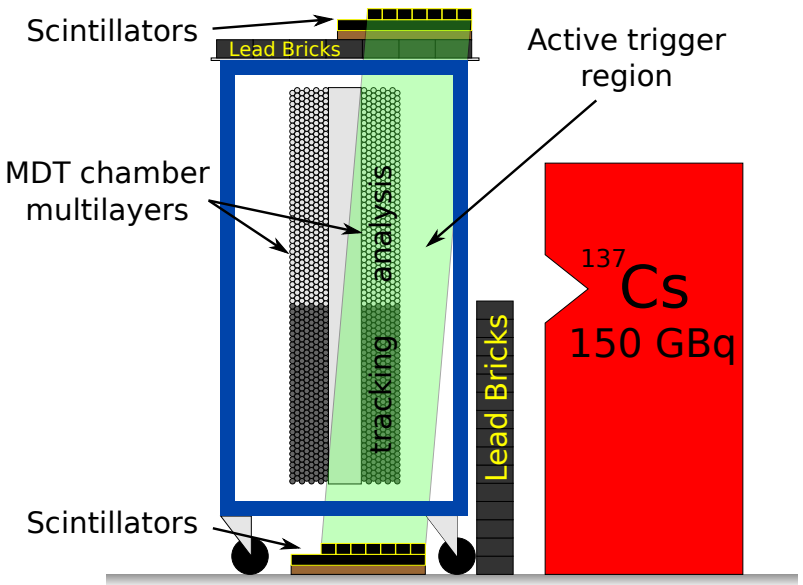


High-Rate Tests

CERN Gamma Irradiation Facility (GIF)

Goal: Measurement of spatial resolution and efficiency as a function of the background counting rate.



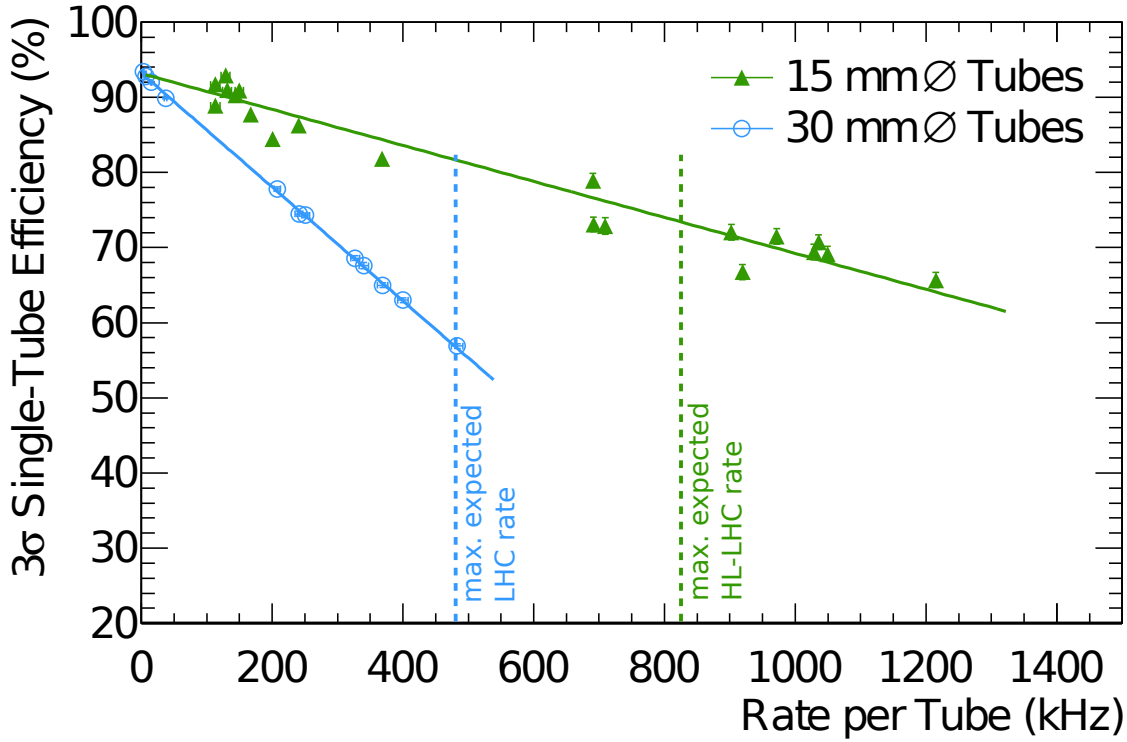


Challenges:

- No muon beam in the GIF $\rightarrow$ have to use cosmic muons
- Spatial resolution dominated by multiple scattering and track extrapolation uncertainties

High-Rate Tests

Results



- Efficiency measurement shows good agreement with expectancy
- Resolution measurement not yet possible, need better trigger acceptance and better tracking

Summary and Conclusions

- Inner forward regions of ATLAS muon spectrometer have to be replaced for high luminosity upgrades of the LHC
- Monitored Drift Tubes are proven and well tested technology for high counting rates
- Successful construction and operation of a full-scale prototype chamber with 15 mm diameter drift tubes
- Efficiency measurements with and without background radiation as expected
- Spatial resolution without background radiation as expected
- 15 mm diameter drift tubes are good candidates for an upgrade of the *Small Wheel*

Outlook

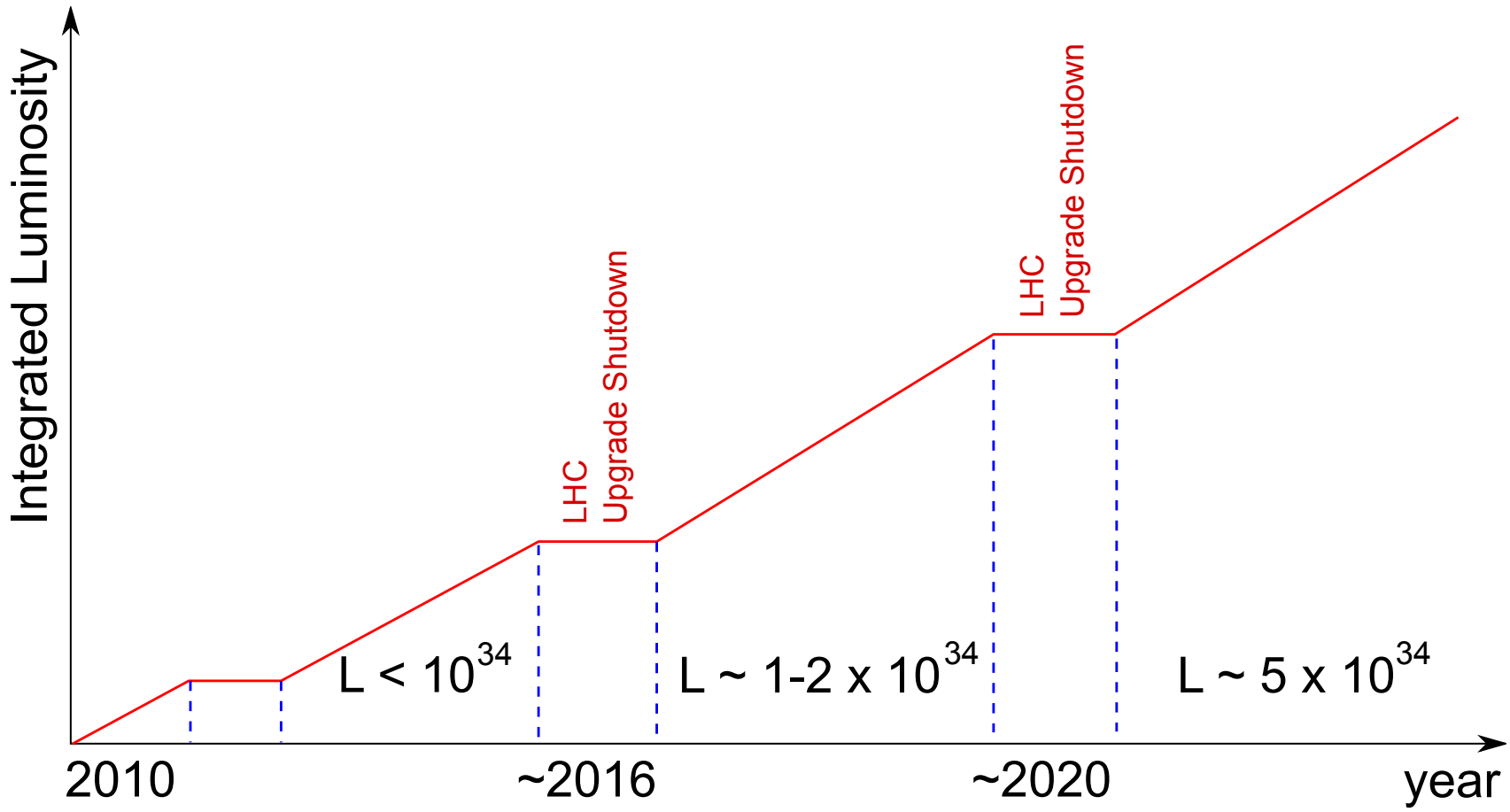
This Year

- Measurement of spatial resolution with background radiation
- Construction of four MDT chambers with 15 mm diameter drift tubes for ATLAS

Questions!?

Backup

A Rough LHC Luminosity Upgrade Outlook



Backup

Spatial Resolution vs. Rate