The MDT (Monitored Drift Tube) Chambers of Atlas

SILVIA VENTURA INFN-LNF

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OUTLOOK

- ATLAS physics requirements
- The ATLAS Muon Spectrometer
- MDT:Operating principle and performance
- The alignment system
- Test of the chambers at CERN

ATLAS PHYSICS REQUIREMENTS

The Muon Spectrometer requirements are set by some reactions:

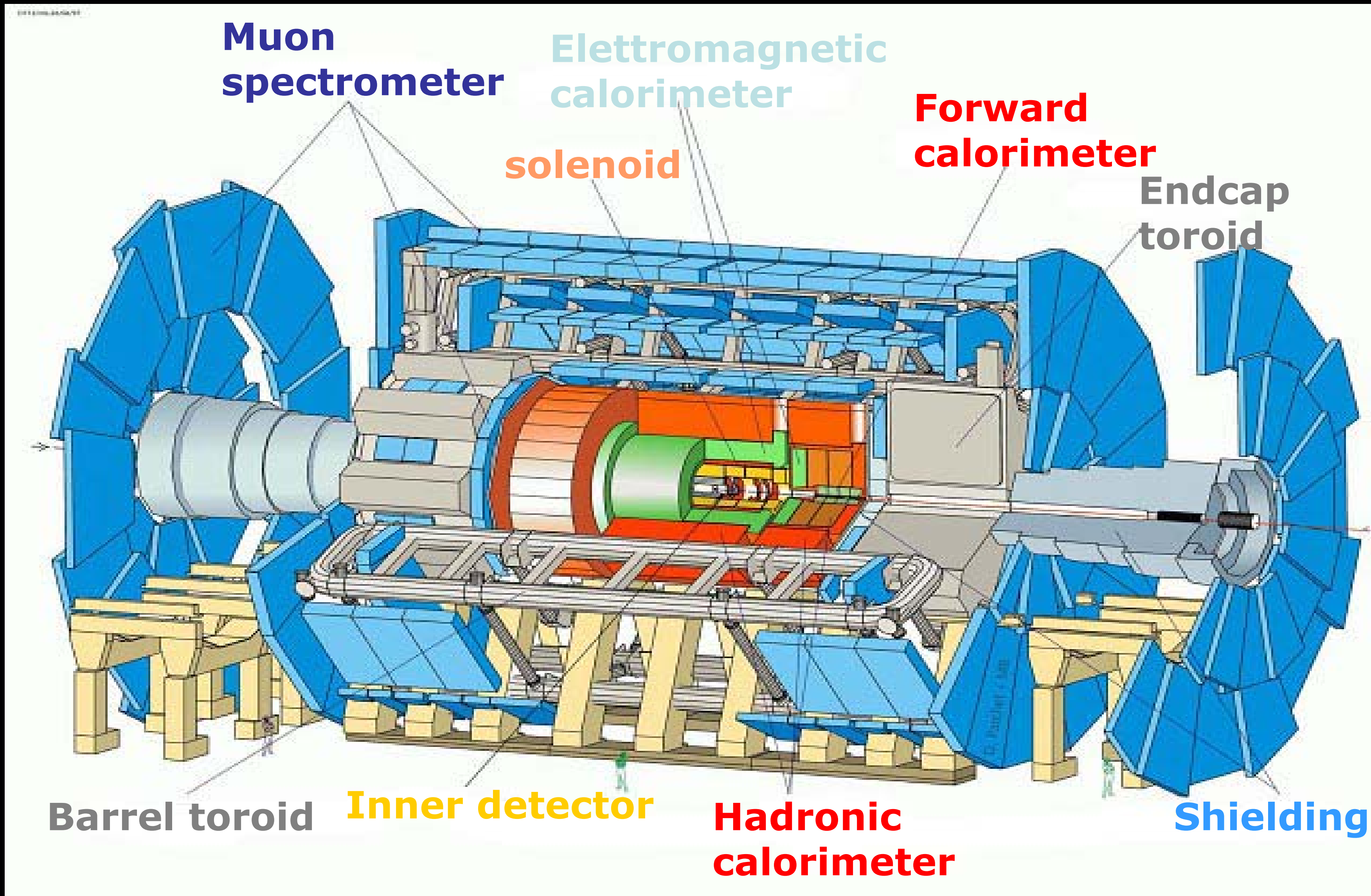
- SM Higgs H → ZZ* → 4μ: discovery channel for the Higgs boson in the mass range from 130 to 170 GeV;
  typical muon momentum range from 5 to 50 GeV;
  the Higgs width in this range is narrow and a mass resolution at the level of 1% is needed;

- MSSM Higgs H/A→ μμ: in the mass range from 180 GeV to $2m_{top}$ similar considerations;

- New Vector Bosons (Z',W'): very high mass range, up to 3 TeV;
  good momentum resolution at very high pt is needed;
  the asymmetry measurement needs a wide rapidity coverage;

- Other physics items: B-physics, top-physics, EW physics…

THE ATLAS DETECTOR



THE ATLAS MUON SPECTROMETER

- Muon momentum measurement with an accuracy of 3 to 10% in the range of 10 to 1000 GeV;

TOROIDAL MAGNETIC FIELD IN AIR
to minimize multiple scattering

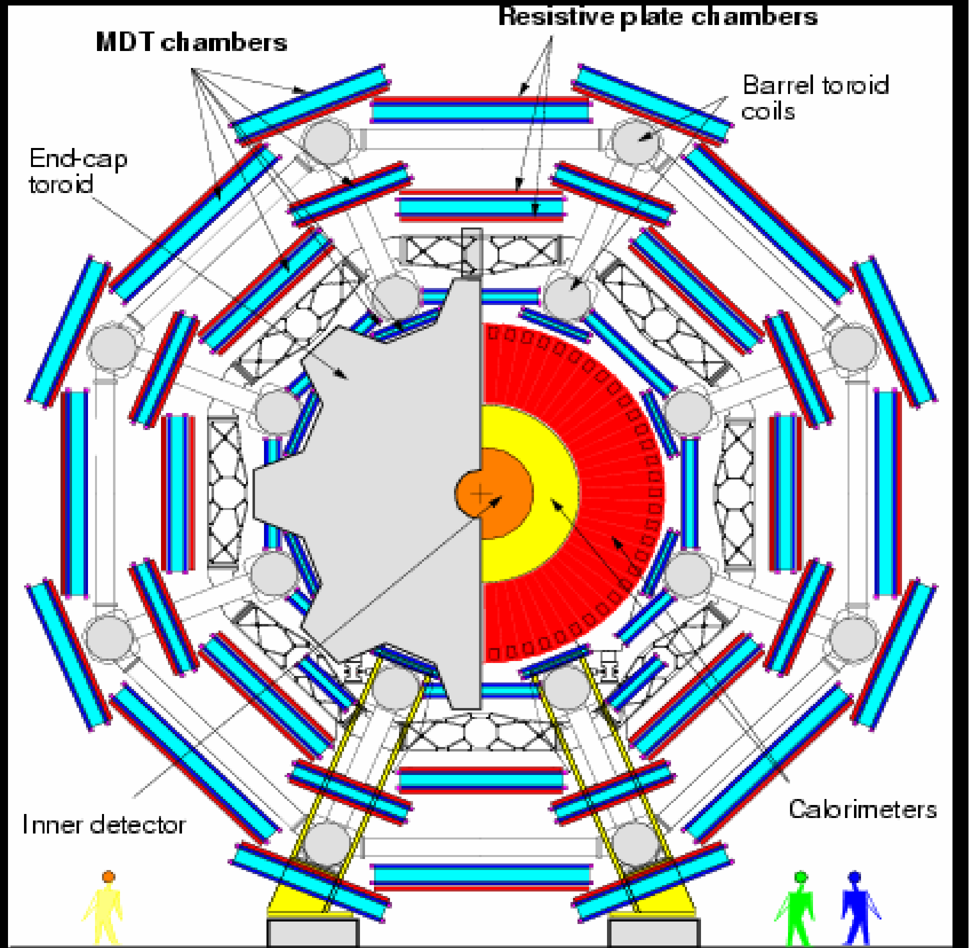
TRACKING DETECTORS (MDT)
high single point resolution
on three stations

- High efficiency single-muon trigger for wide Pt range;

Dedicated TRIGGER chambers:
RPC (Resistive Plate Chambers) in the barrel
TGC (Thin Gap Chambers) in the end-caps.

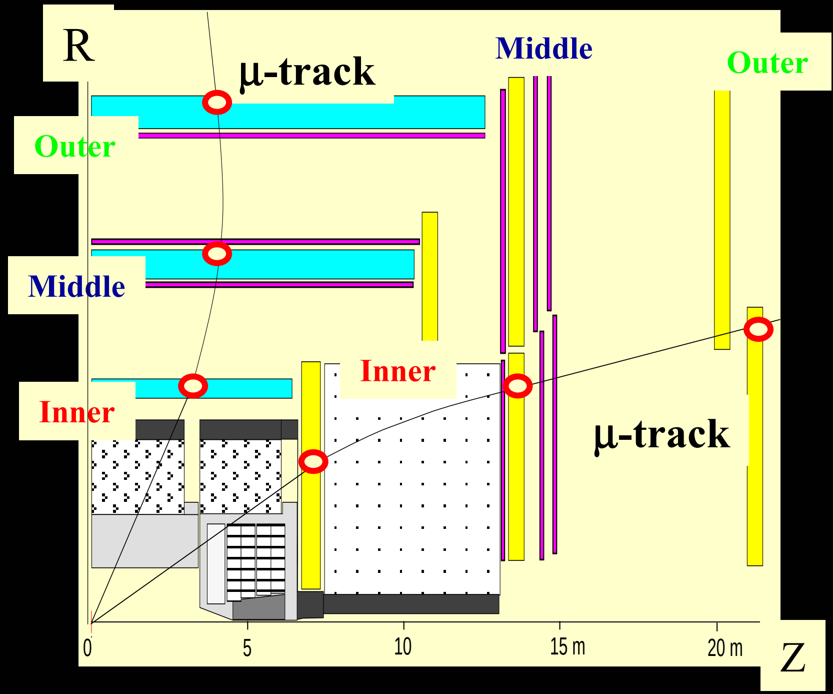
- Stand very high background environment (from 10 Hz/cm^2 for the outer station to 100 Hz/cm^2 for the inner station);

- η coverage up to $|\eta|$~2.7;



THE ATLAS MUON SPECTROMETER

- Pμ: muon curvature in magnetic field from three precision chambers Inner – Middle – Outer
- The detection stations are arranged in cylindrical layers in the central barrel region and in wheel shaped planes in the end-caps.
- Each station provides a measurement along the trajectory with a resolution ~40 μm

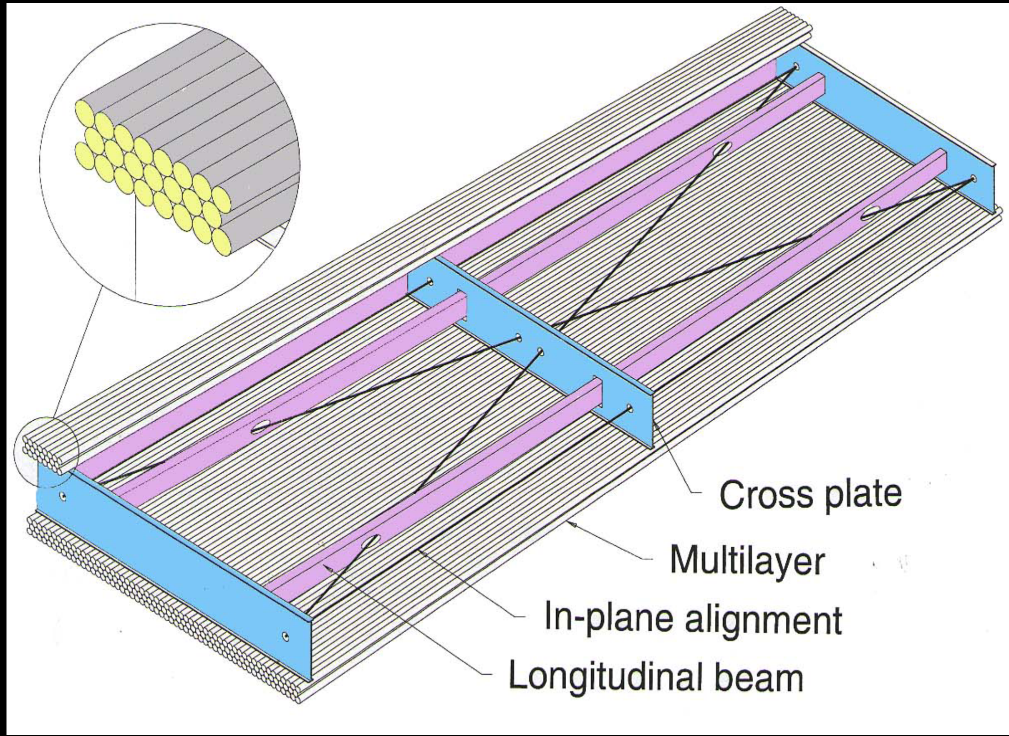


SOME NUMBERS:

Total number of chambers	**1194**
Number of readout channels	**370000**
Gas volume	**800 m^3**
Covered area	**5500 m^2**
Production sites	**13 (in 7 countries)**

MONITORED DRIFT TUBES CHAMBERS

Monitored drift chambers consist of six (eight in the inner stations) layers of drift pressurized tubes.
The layers are organized in two multilayers separated by a space frame.

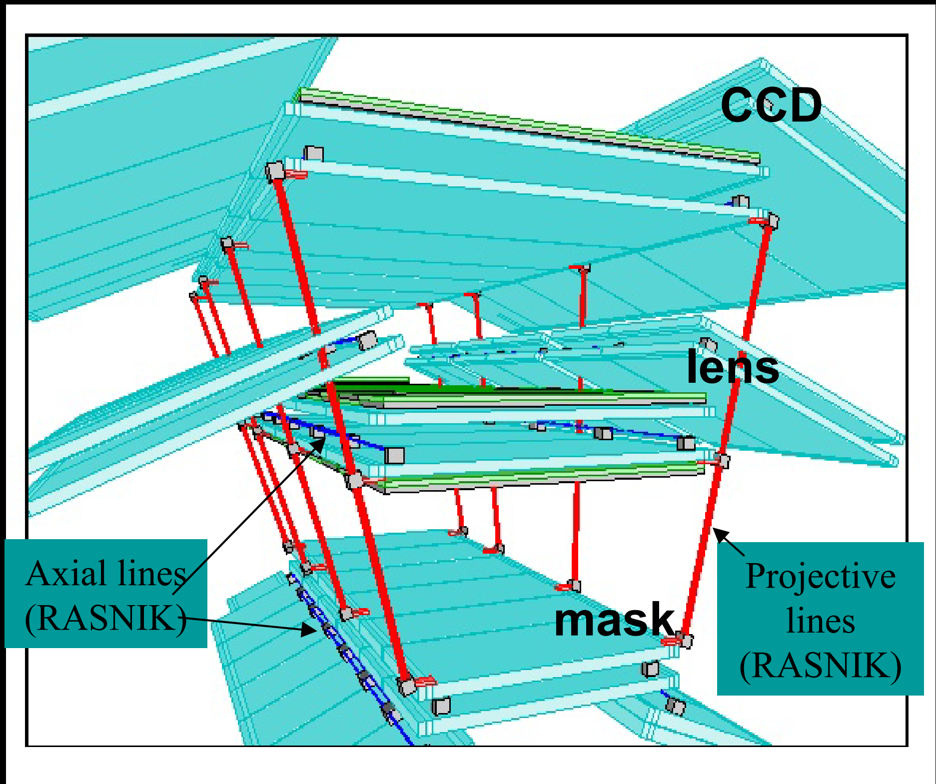


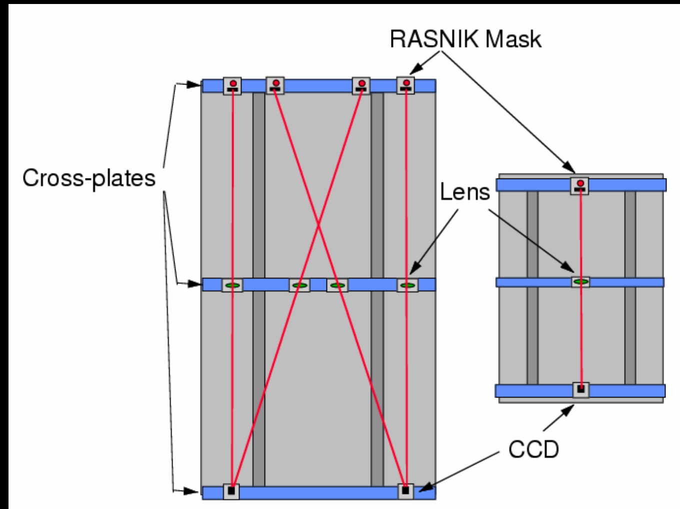
- Diameter: 30 mm
- Thickness:400 μm
- Lenght: da 70 a 630 cm
- Wire thickness: 50 μm
- Gas: Argon 93% CO_2 7%
- HV: 3080 V
- Proportional regime
- Gain: 2×10^4
- Gas pressure: 3 bar

20 μm tolerance on wire position in the chamber

THE ALIGNMENT SYSTEM

An optical system consisting of four RASNIK sensors is incorporated into the chamber structure to monitor the chamber positions in order to correct the track parameters.





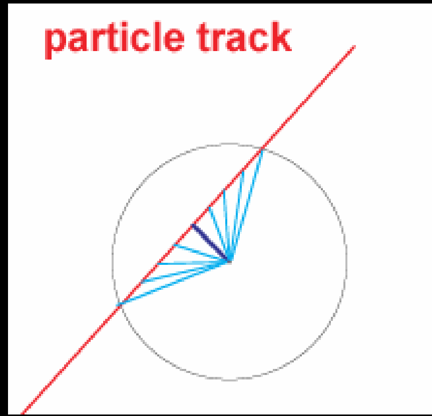
❑RASNIK technology
measure the relative position of a lens between a CCD and a target mask optical line

PERFORMANCE:

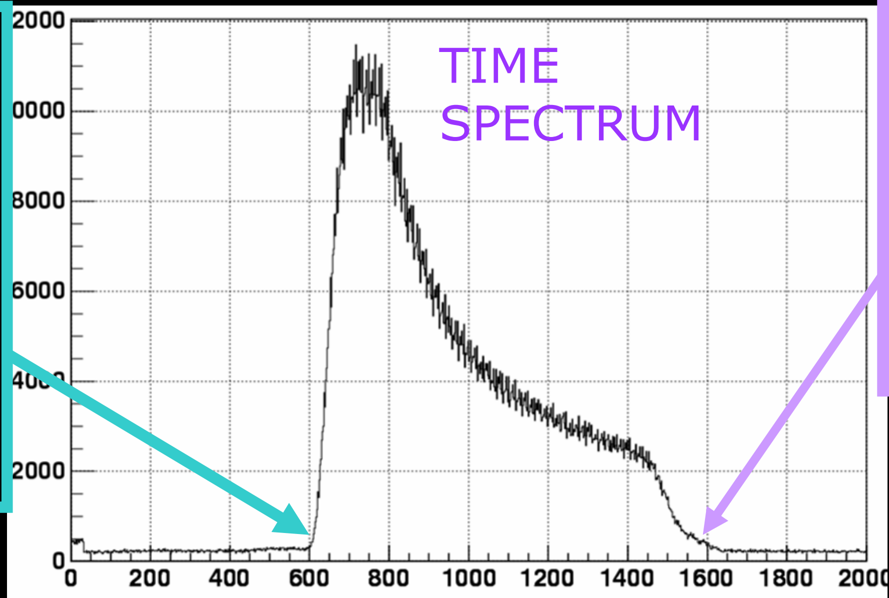
< 40 μm on sagitta error
due to chamber misalignment

SINGLE TUBE PERFORMANCE

Each tube determines the radial distance between a charged particle track and the wire by measuring the arrival time of the ionization electrons.



t_0 → start of the time spectrum.
Does not depend on the drift characteristic of the tube.
It is subtracted to the raw time to determine the drift time.



t_1 → end of the time spectrum.
Depends on drift tube properties.

in standard conditions (P=3 bar,T=293 K) $t_{max} = t_1 - t_0 \sim 700$ ns

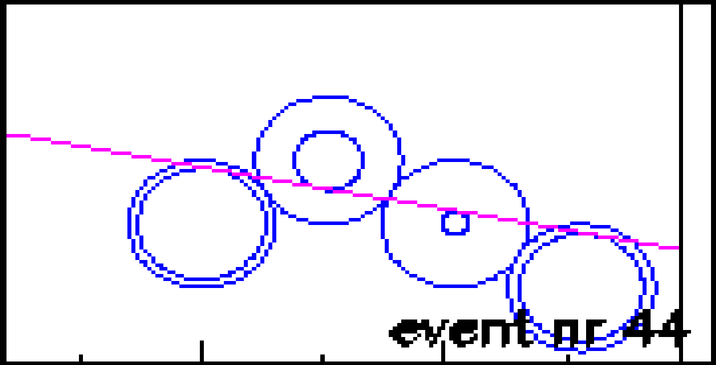
R(t) DETERMINATION

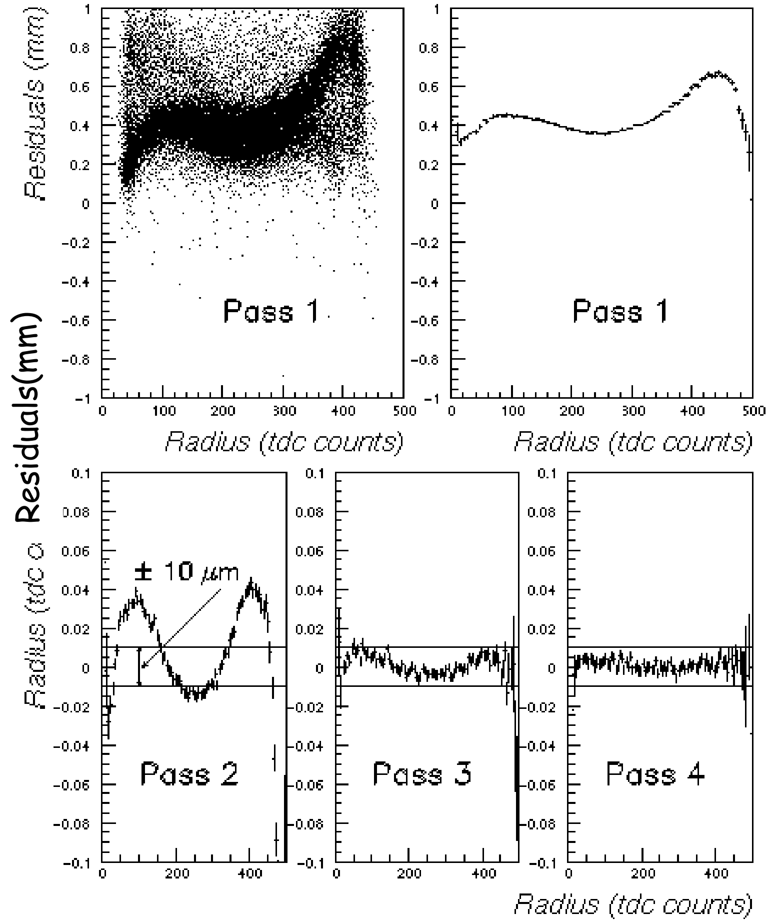
❑Iterative procedure based on track segments residual minimization (in single multilayer):

✓drift time measurement
✓use a starting r(t), determined from simulation, to compute r
✓best track fit
✓use residuals ($\Delta r(t)=r_{fit}-r_{meas}$) to correct r(t)
✓use the new r(t) to compute new r
✓best track fit
✓…new residuals…
✓…new corrections…

❑Procedure stopped when the average residuals are below the required accuracy ~(10-20)μm

❑Statistics needed ~10k tracks per multilayer



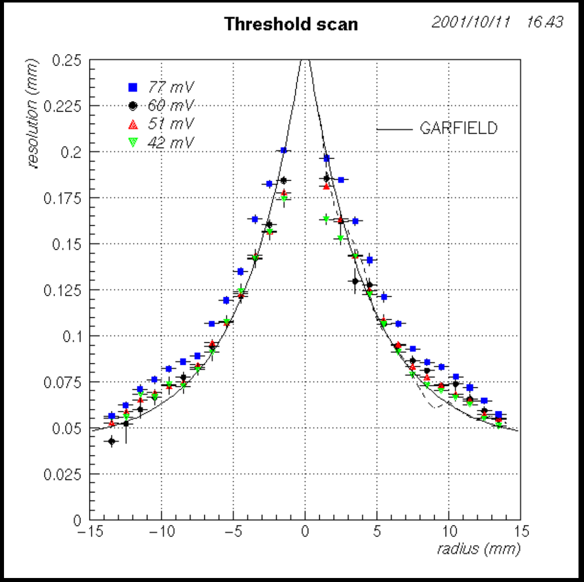


TUBE SPATIAL RESOLUTION

The required chamber resolution of 40 μm corresponds to a single-tube resolution of about 80 μm.

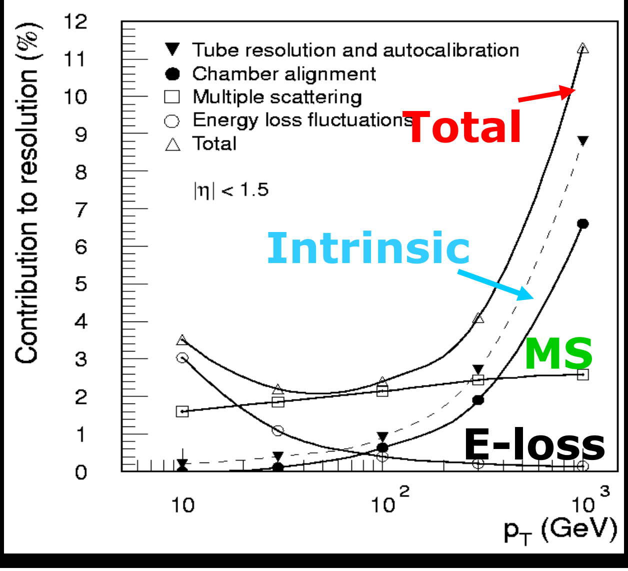
Main contributions to the single tube resolution:

1. discret nature of primary ionization (near the wire)
2. diffusion (near the tube walls)
3. gas gain fluctuations
4. electronic noise



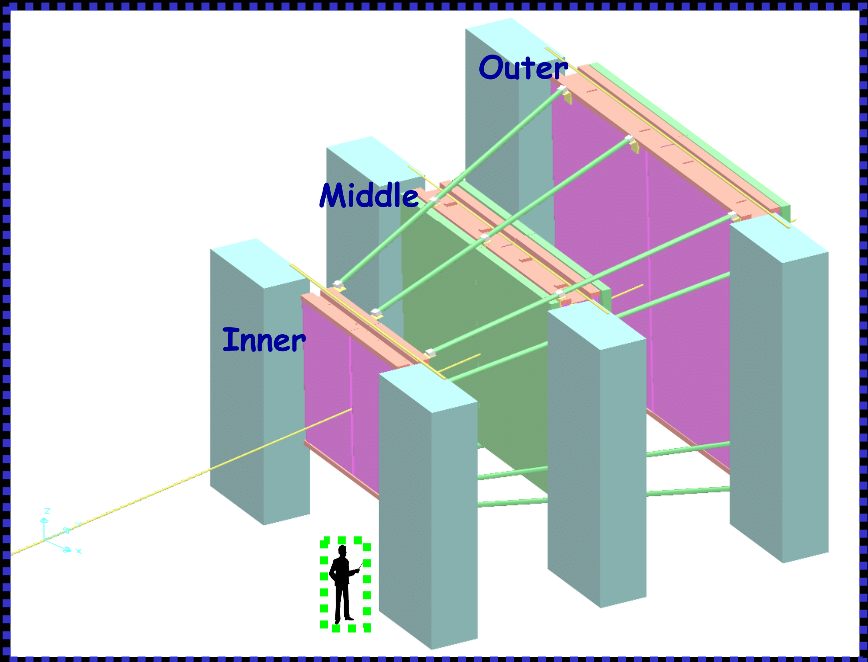
SPECTROMETER MOMENTUM RESOLUTION

1. Statistical fluctuations of energy loss (p_t<20GeV)
2. Multiple scattering in magnet and chambers structure (20 GeV<p_t<300 GeV)
3. Single point resolution, calibration, alignment (p_t>300 GeV)

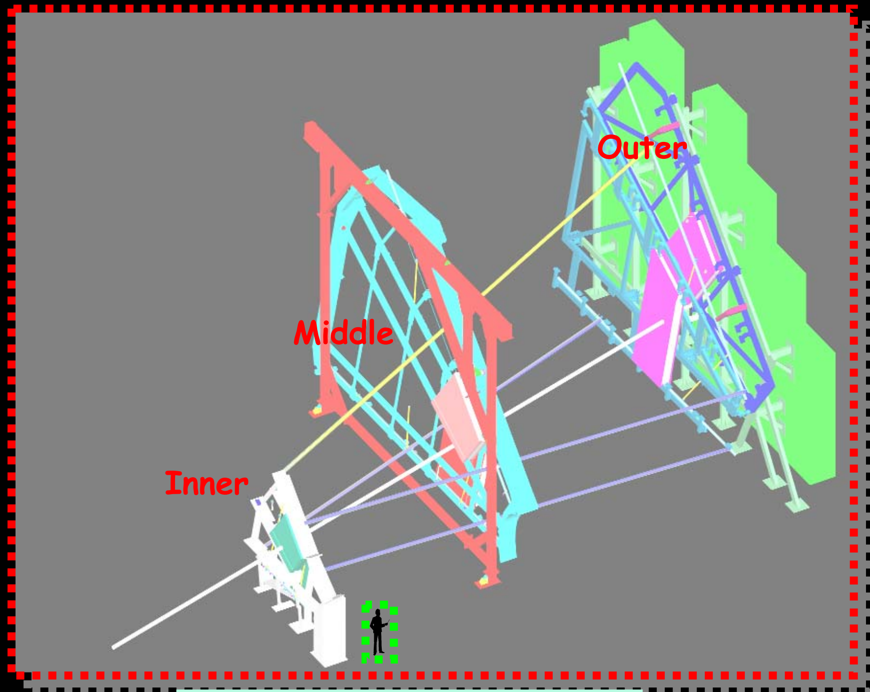


THE H8 TEST BEAM AREA AT CERN

- **Real size test started on the H8 beam line at CERN since year 2000**
- Barrel: 6 MDT chambers 2 Inner, 2 Middle and 2 Outer fully equipped with alignment system (Middle and Outer also equipped with RPC trigger chambers), corresponding to two ATLAS barrel towers.
- End-Cap: one sector with 2 Inner, 2 Middle and 2 Outer MDT chambers with alignment system (also TGC trigger chambers installed in 2003)

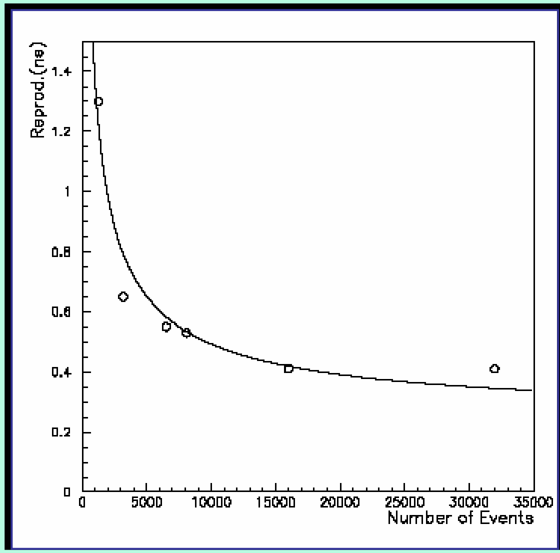


Barrel tower



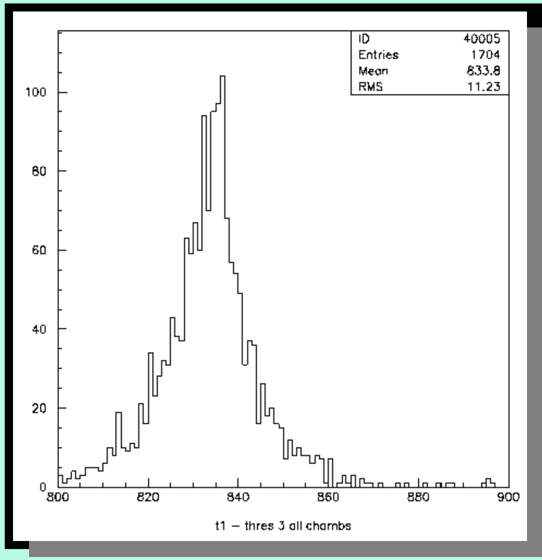
EC sector

H8: CALIBRATION STUDIES t_0,t_{max} & r-t relation



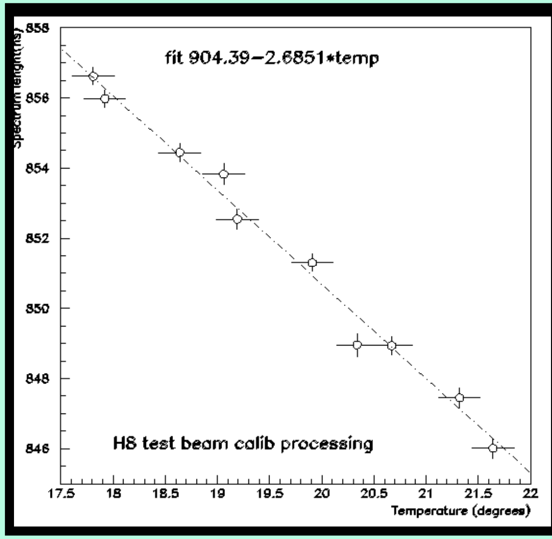
σ(t_o)(ns)
accuracy in t_0 as a function of number of hits per tube:

0.4 ns needs ~ 10^4 hits/tube

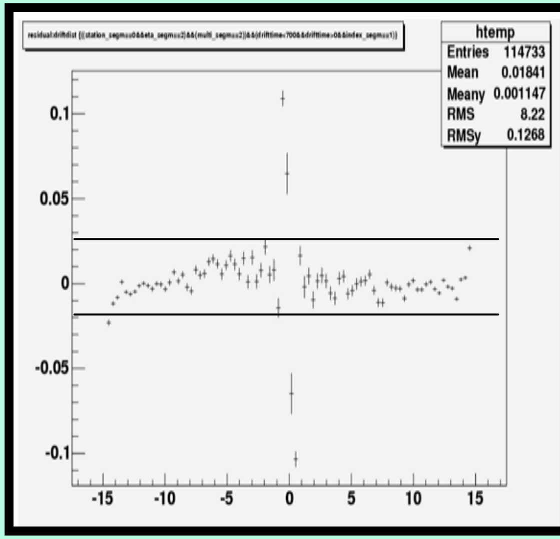


t_{max} distribution for all the barrel chambers

HWHM:
less than 5 ns

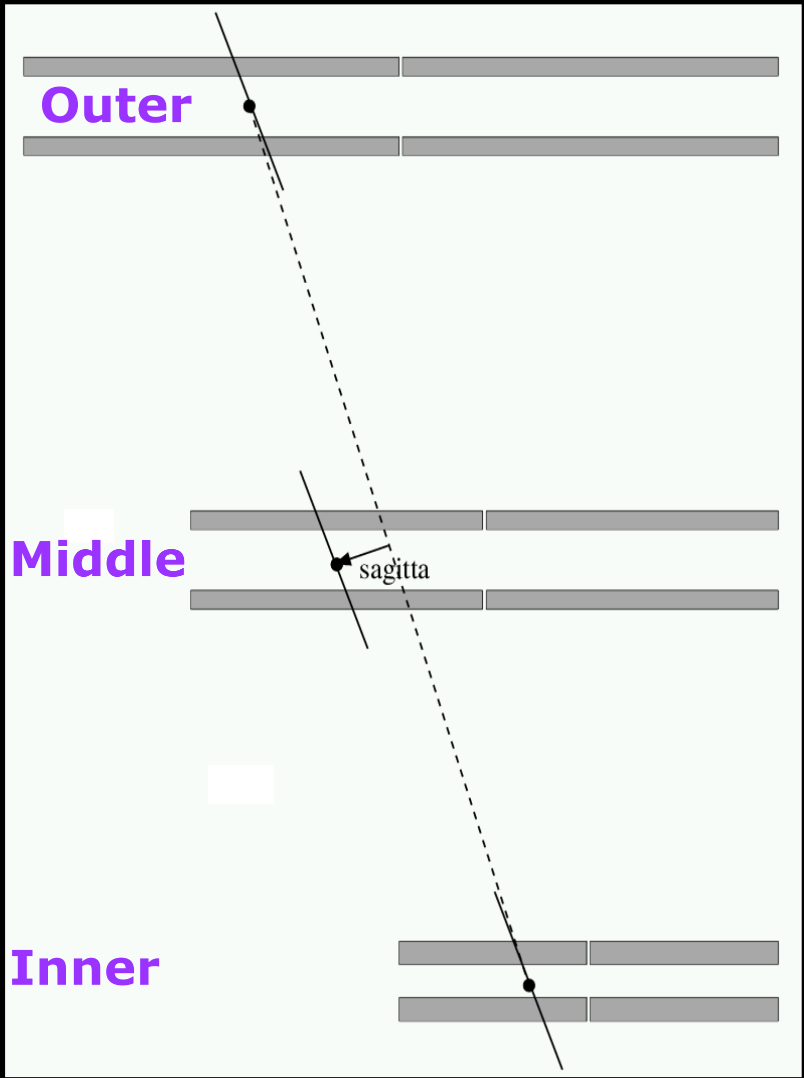


t_{max} dependence on temperature -2.7 ns/K slope.
Temperature needs to be monitored
r-t relation is also temperature dependent.



Residuals as a function of drift distance for a ML of a BIL chamber: within 20 μm for r>1mm

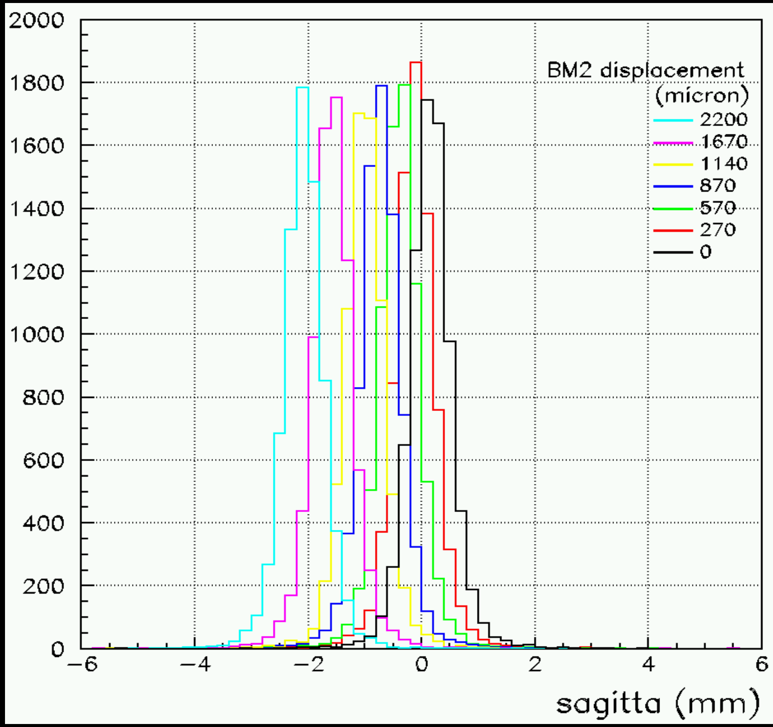
H8: SAGITTA MEASUREMENT



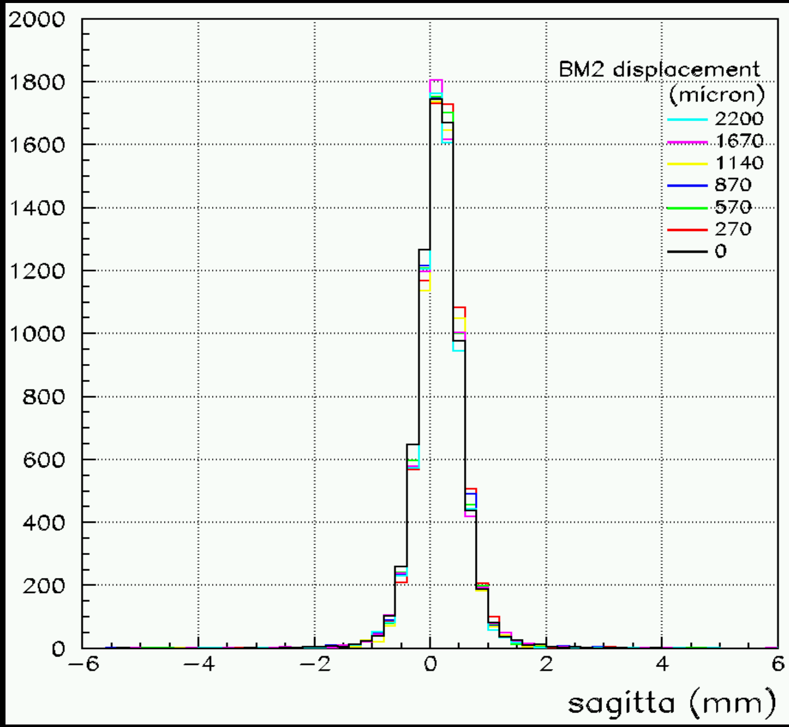
The sagitta is defined as the distance between the track reconstructed from the segments in the outer and inner stations and the segment reconstructed in the middle station.

H8: TEST OF THE ALIGNMENT SYSTEM

Tests of the relative alignment system: perform chambers controlled movements and correct using the information from the optical alignment system – many tests successfully performed during 2004 test beam

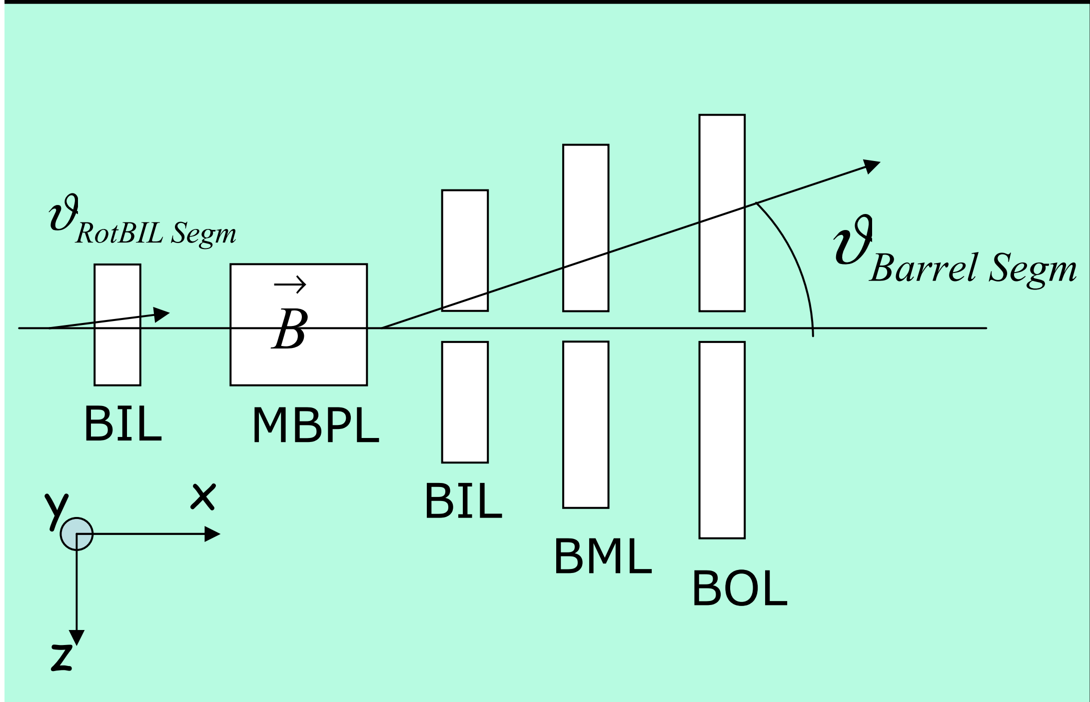


Sagitta before alignment corrections



Sagitta after alignment corrections

H8: BEAM MOMENTUM MEASURAMENT

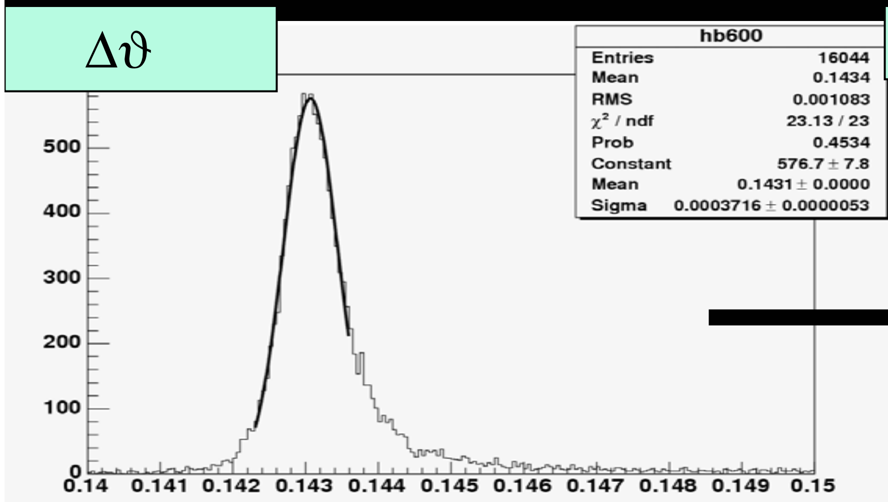


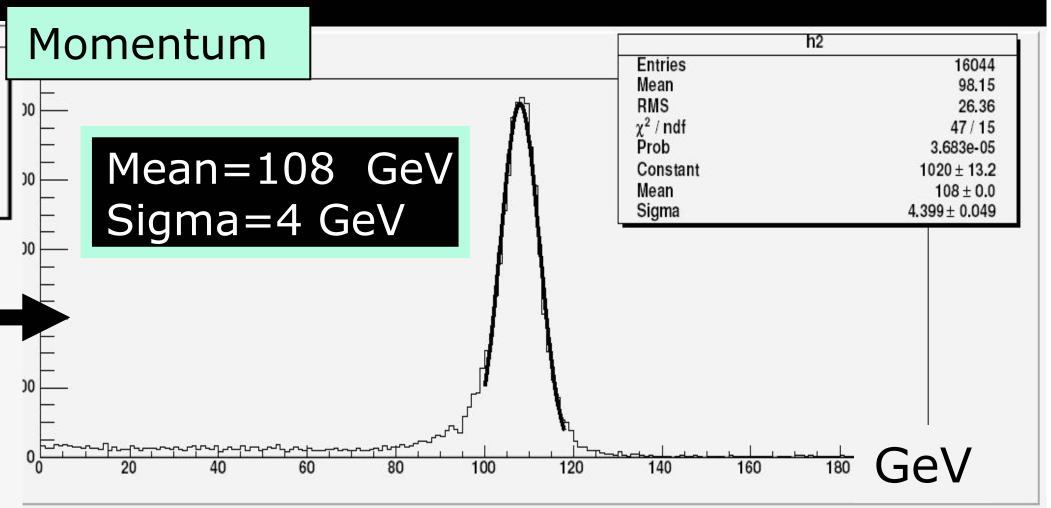
- Exploit the bending in MBPL magnet upstream of barrel stand

$$P(GeV) = \frac{0.3BL(Tm)}{\Delta\vartheta}$$

- Compare track angles in BIL upstream of MBPL and full barrel

$$\Delta\theta = \theta_{BarrelSegm} - \theta_{RotBilSegm}$$





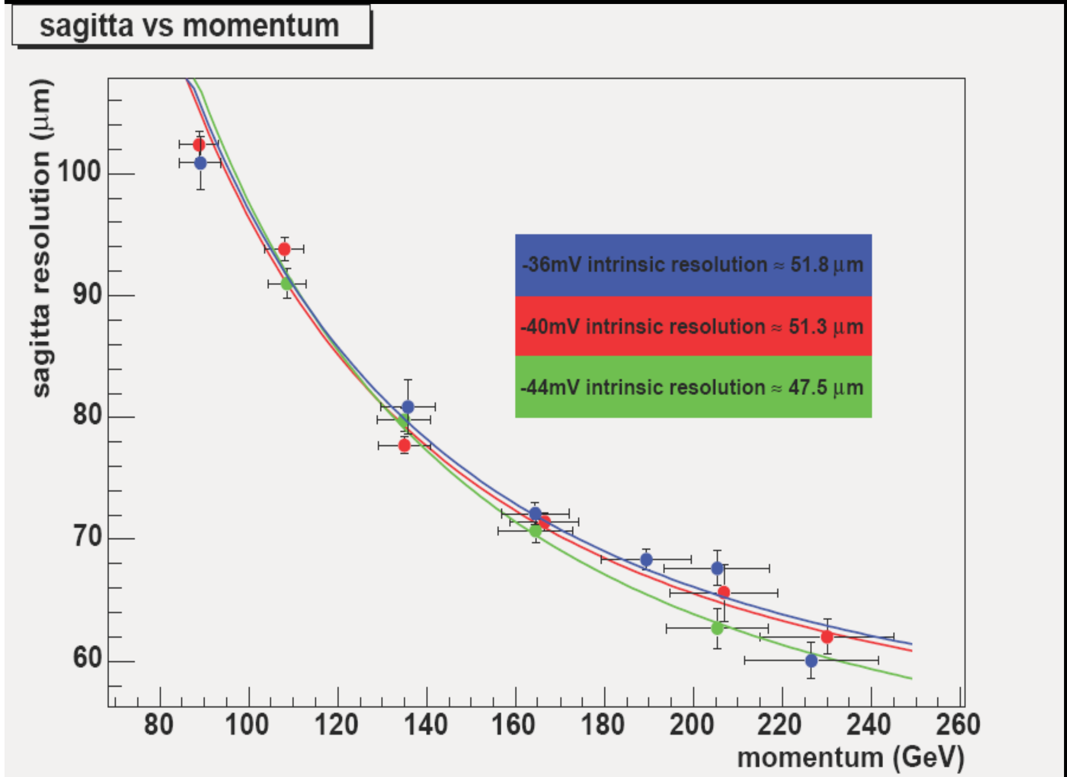
SAGITTA RESOLUTION VS MOMENTUM

$\sigma(s) = \sigma(s)_{Intrinsic} \oplus \sigma(s)_{MS}$

Fitting with : $\sigma_{meas} = \sqrt{K_1^{\,2} + (K_2 / P_{meas})^2}$

K_1 is the intrinsic resolution term to sagitta resolution

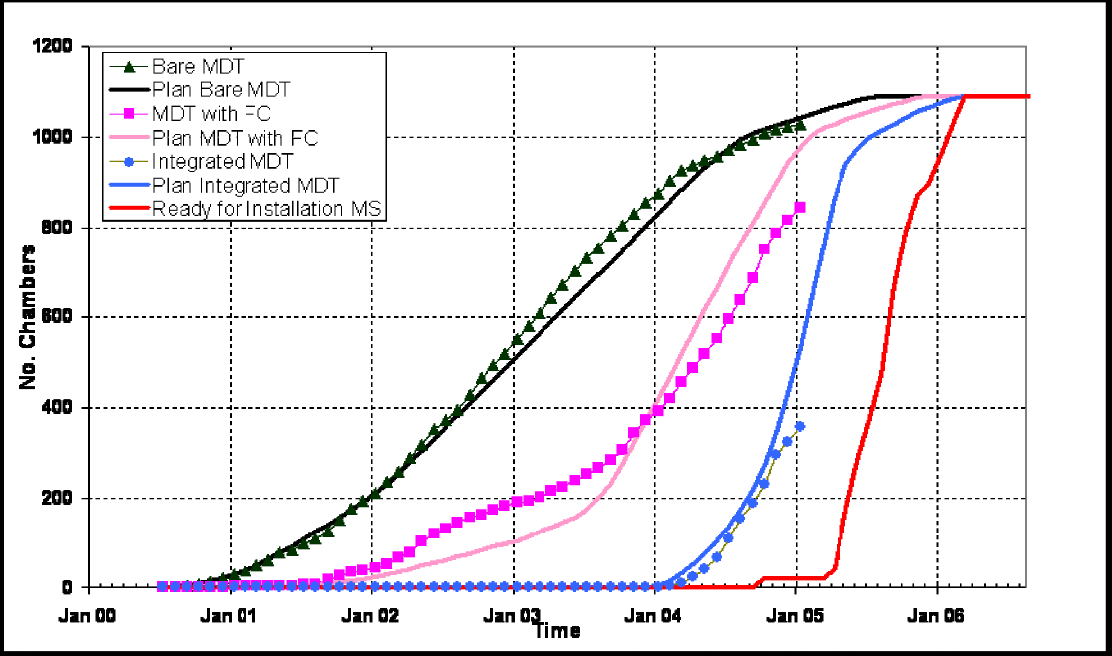
K_2 related to multiple scattering term : $\frac{x}{X_0} = \left(6.84647 \cdot 10^{-5} \cdot K_2\right)^2$



- The intrinsic resolution terms are compatibles within 5µm for the three MDT thresholds
- **Mean intrinsic resolution 50 µm**

CONCLUSIONS

- The ATLAS Muon Spectrometer provides a very high pt resolution in a wide pt range (less than 10% up to 1 TeV);
- MDT (Monitored Drift Tube) Chambers as precision tracking detector: resolution on sagitta measurement of 50 μm;
- MDT performances tested at H8 test beam area at CERN since 2000;



Still 31 january 2005

1027 produced chambers

357 full integrated MDT chambers

12 chambers installed in Atlas.

NOW:
Production completed
22 chambers installed in Atlas