The Muon Spectrometer of the ATLAS Experiment

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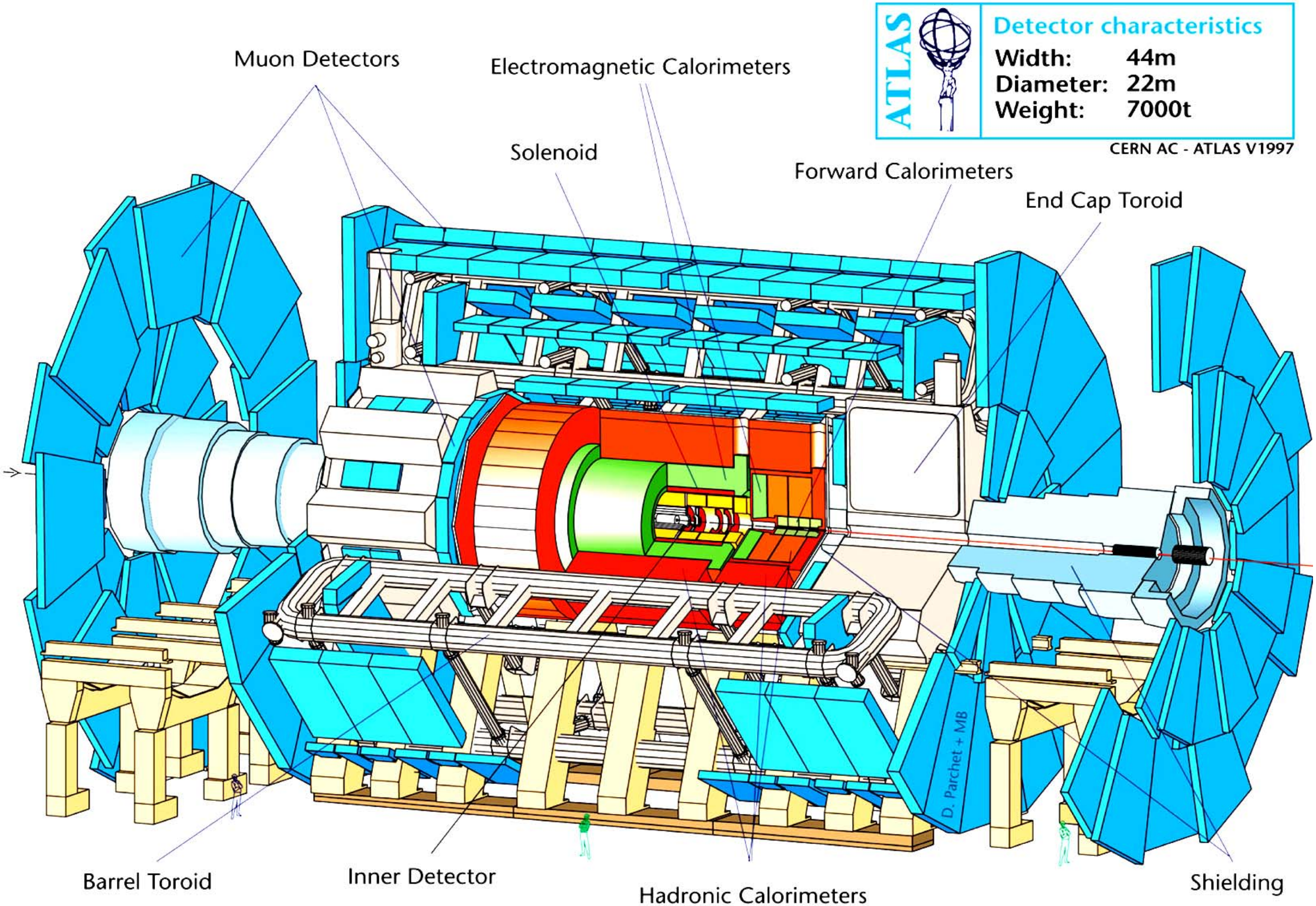
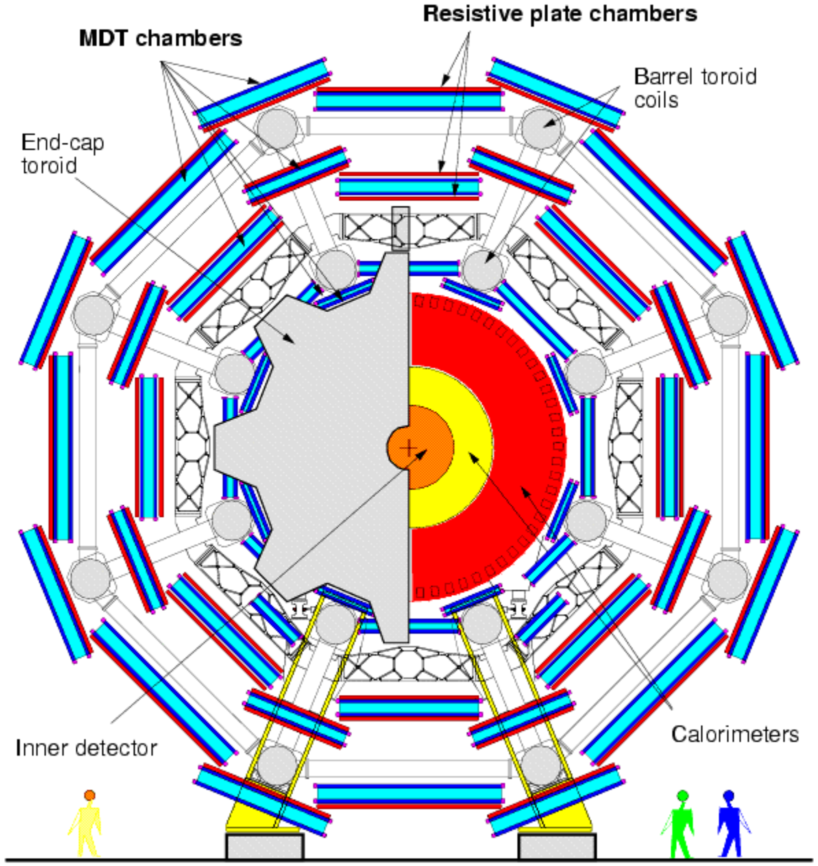
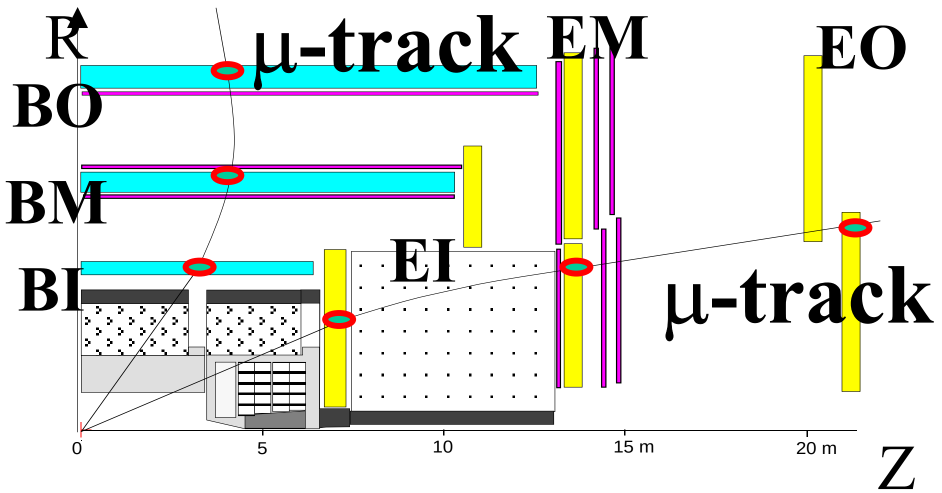
- Spectrometer resolution and impact on Physics

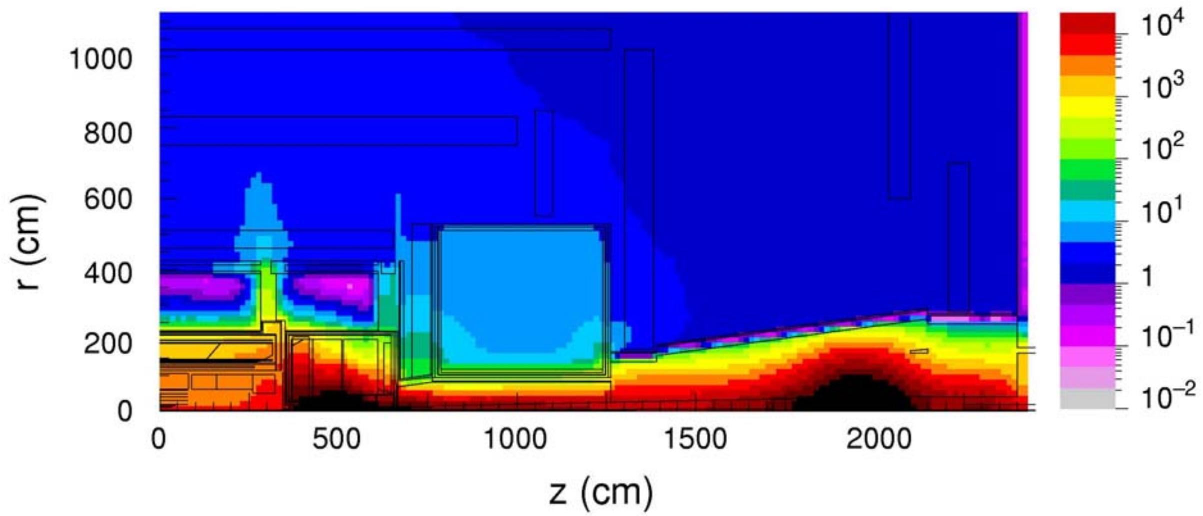

Muon Detectors
Electromagnetic Calorimeters
ATLAS
Detector characteristics
Width: 44m
Diameter: 22m
Weight: 7000t
CERN AC - ATLAS V1997
Solenoid
Forward Calorimeters
End Cap Toroid
D. Parchet + MB
Barrel Toroid
Inner Detector
Hadronic Calorimeters
Shielding

Layout of muon spectrometer

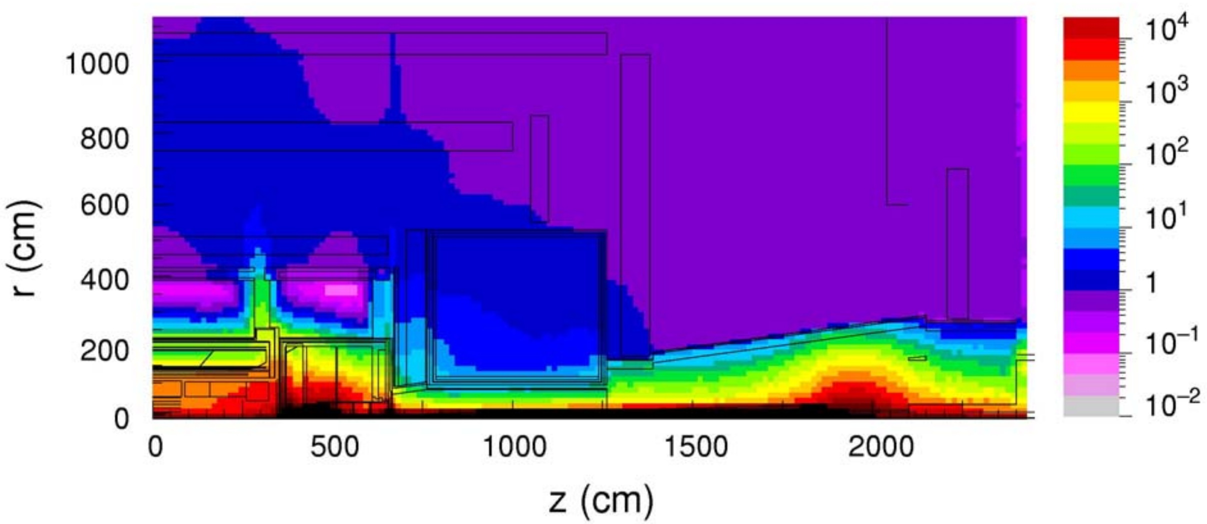




Expected background



Neutron fluence [kHz/cm^2]
Interaction prob ~0.0001-0.001

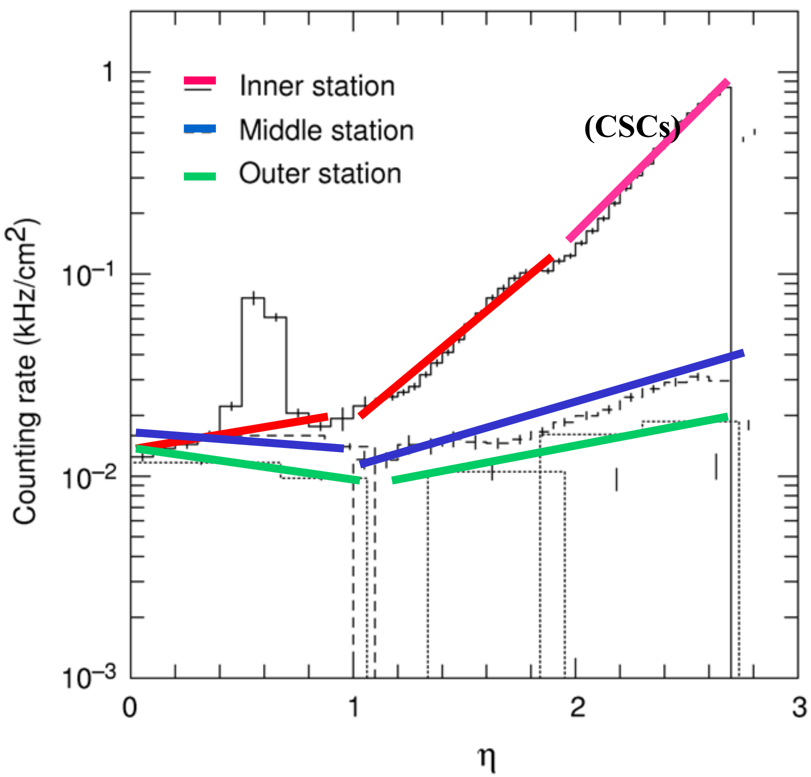


Photon fluence [kHz/cm^2]

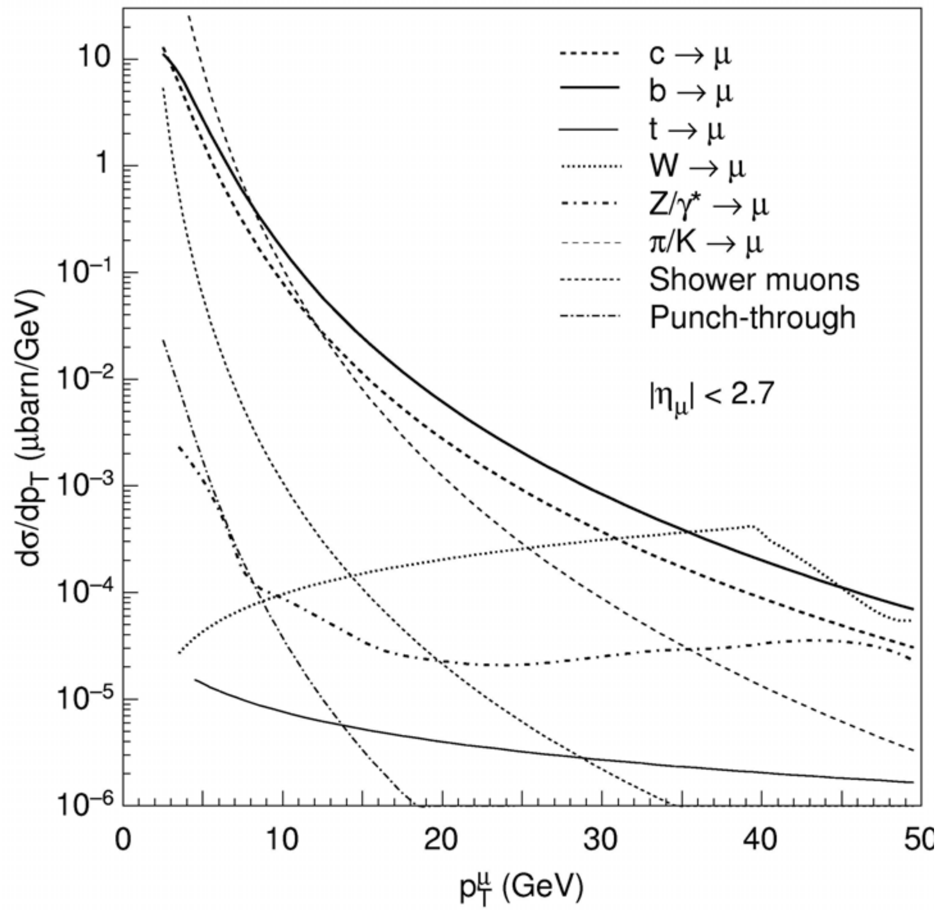
Interaction prob ~0.005-0.01

Rates in muon chambers

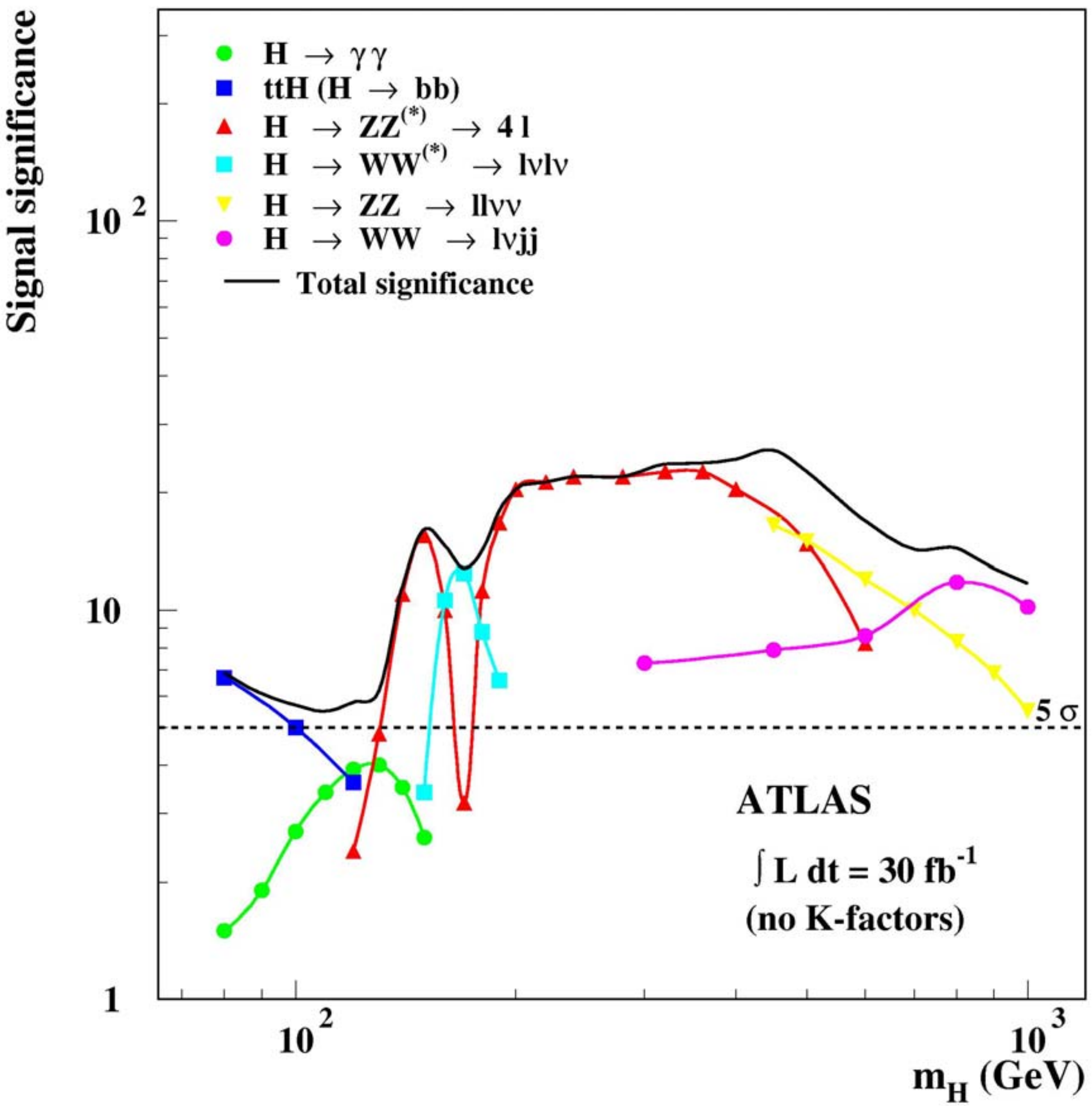
Expected background rate



Muon signal rate



Standard Model Higgs search



Some comments:

M_H<170 GeV

- γγ muons only via associated prod of t, W, Z for triggering purposes. Little relevance however for total significance
- ttH->tt bb muon in triggering and backgr reduction, vertex relevant
- ZZ(*)->4l muons relevant in trigger and ID, resolution not exploited for this mass range
- WW-> lν lν trigger and backgr.
- W*->W(*)H->WWW(*) -> 6 lν as above (not too relevant)

M_H>180 GeV

- ZZ->4l main discovery channel, muons for trigger and mass reolution (MH>200 GeV), low background
- WW->jjlν , ZZ->llνν , ll jj complementary, as above

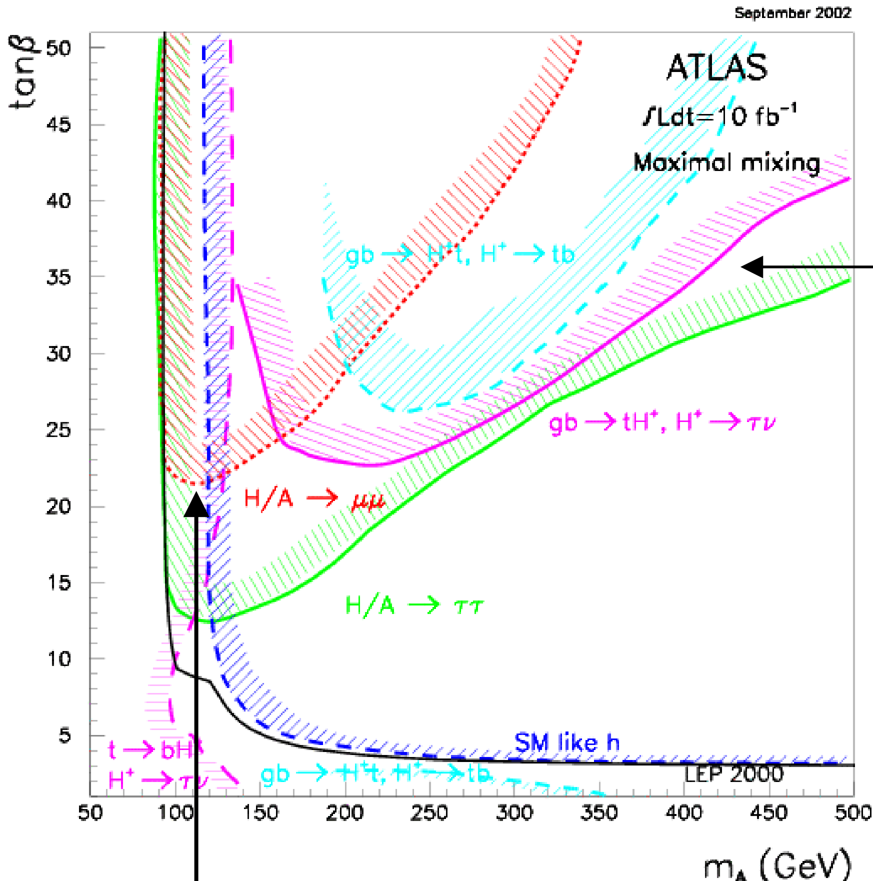
Furthermore:

- qqH→qqττ (M_H=110-130)
- qqH→ qqWW(*) (M_H=130-190)

MSSM Higgs bosons h, H, A, $H^{\pm}$

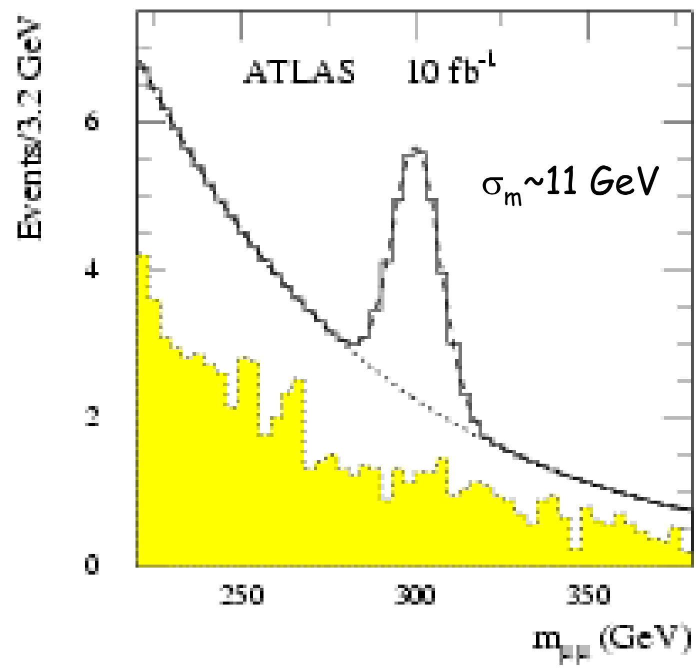
m_h < 135 GeV
$m_A \approx m_H \approx m_{H\pm}$ at large m_A

5σ discovery curves



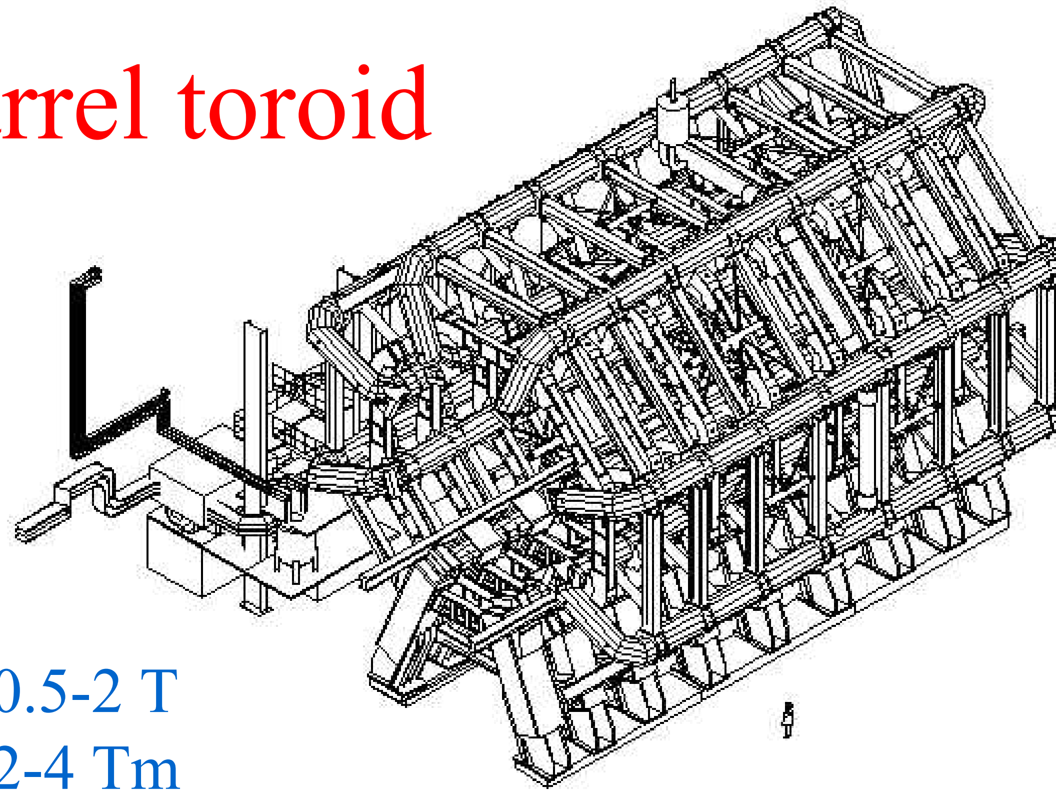
A, H, $H^{\pm}$ cross-section ~ $tg^2\beta$
Best sensitivity from A/H → ττ, $H^{\pm}$ → τν

A/H → μμ, tg β = 38



bbA/H → μμ :
-- covers good part of region not excluded by LEP
-- experimentally easier than A/H → ττ
-- crucial detector : Muon Spectrometer
(high-p_T muons from narrow resonance)

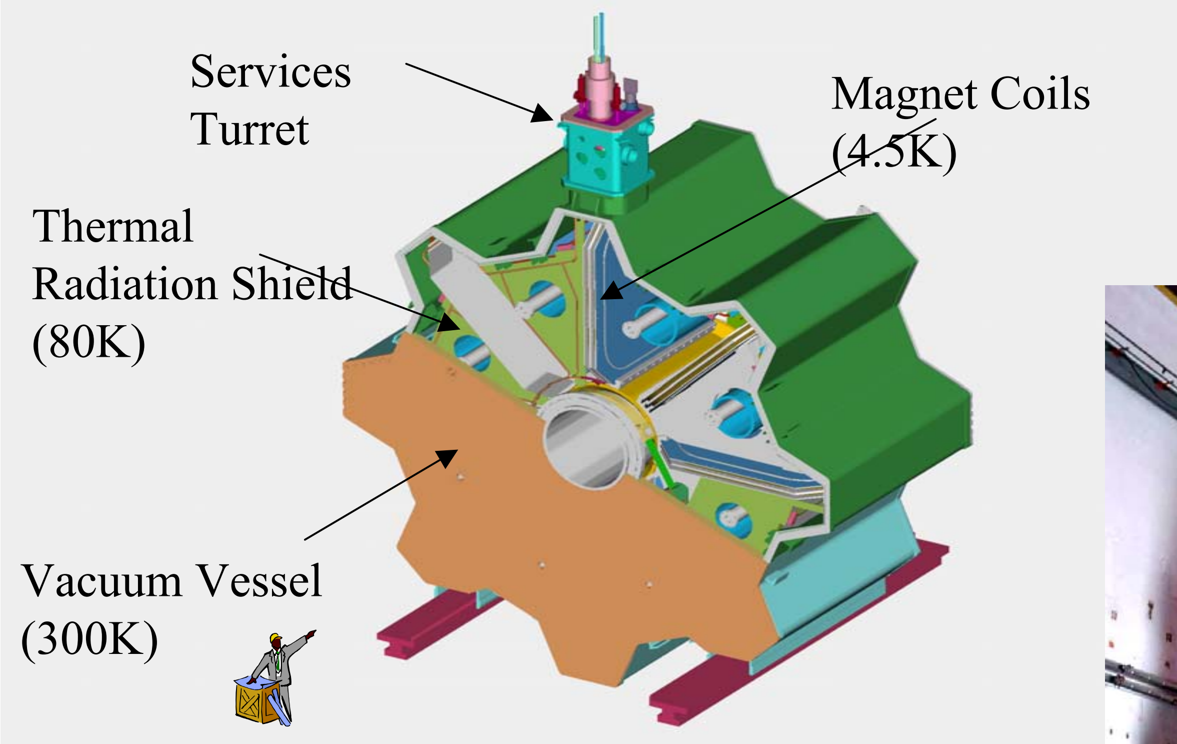
Barrel toroid



0.5-2 T
2-4 Tm

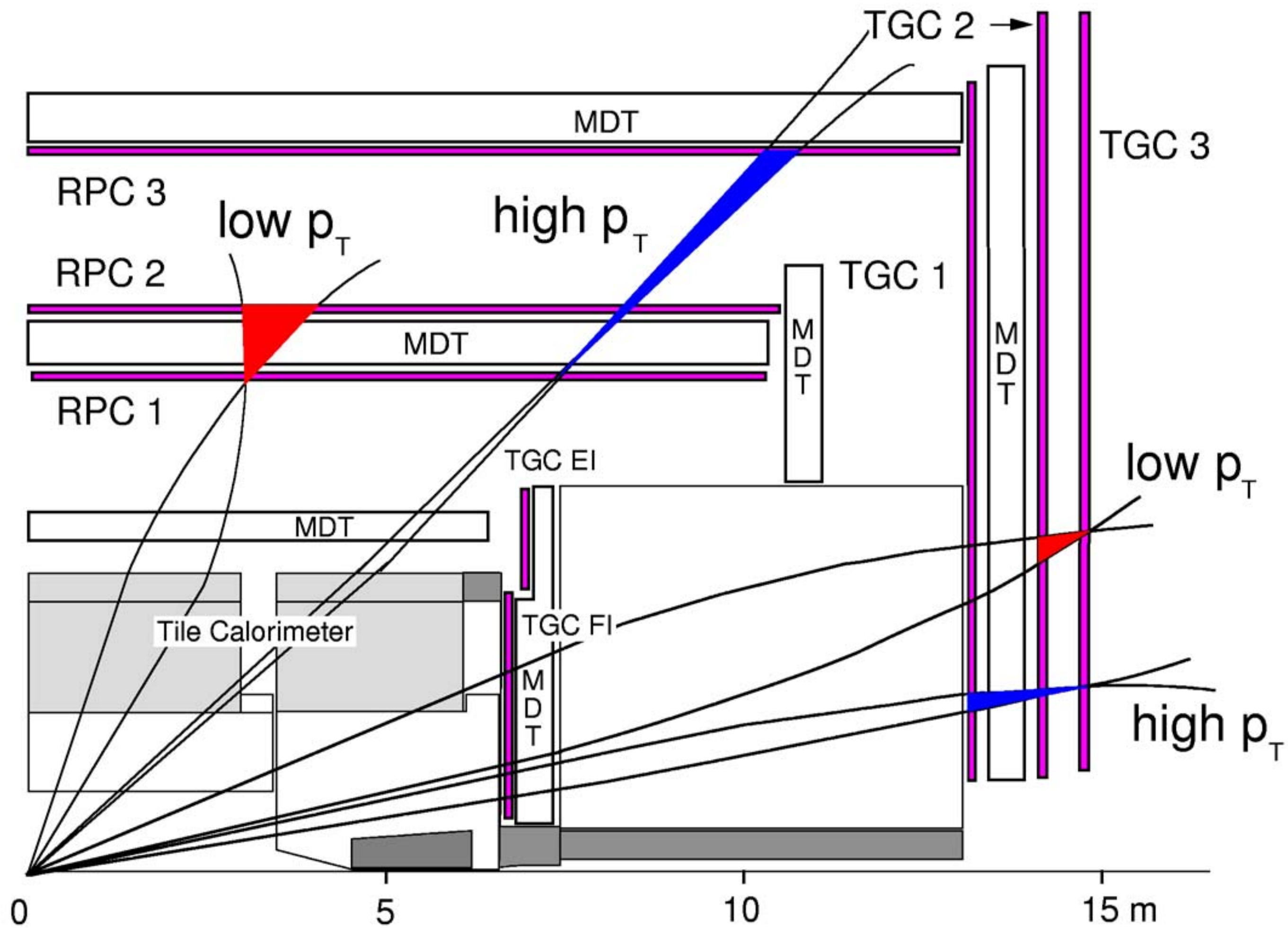
- Components manufacturing
  - Superconductor: completed
  - Pancake coils: 13/16
  - Coil casings: 4/8
  - Vacuum vessels: 4/8
  - Tie rods 8/64
  - Stops 64/256
  - Superinsulation 2/8
  - Shield 0/8

EndCap toroids

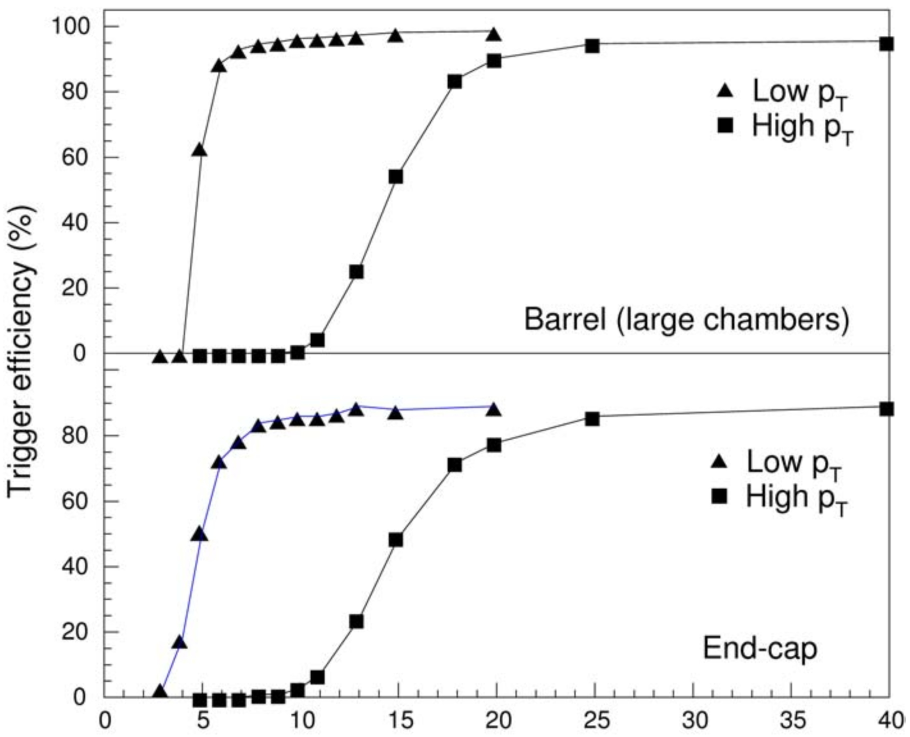


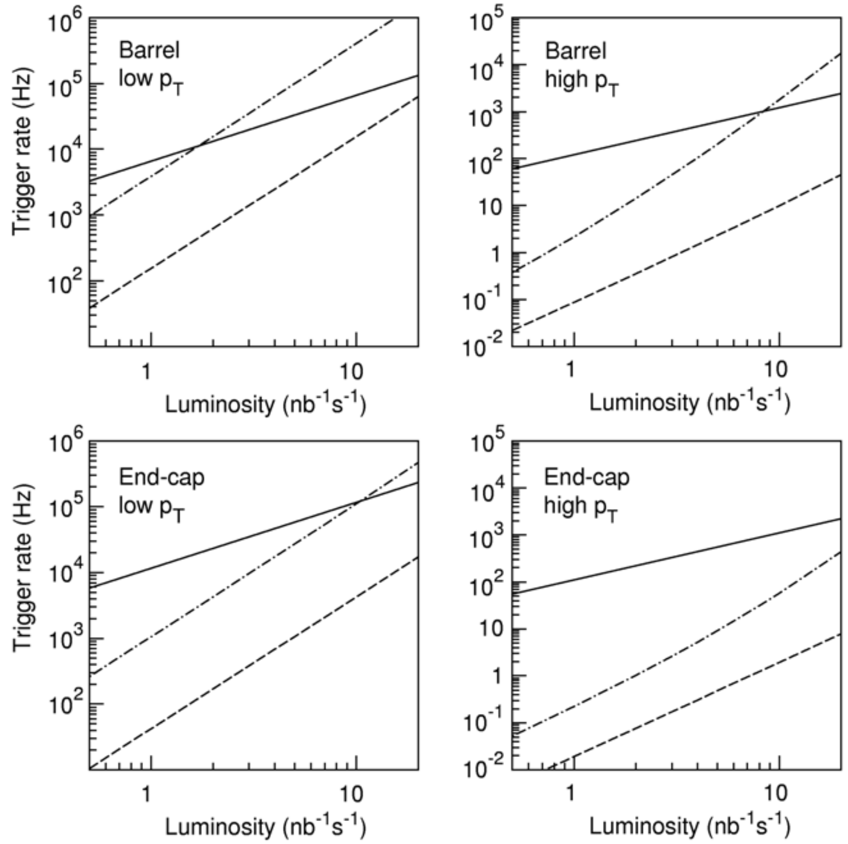
1-2 T ,   3-8 Tm

First level trigger in Muon Chambers



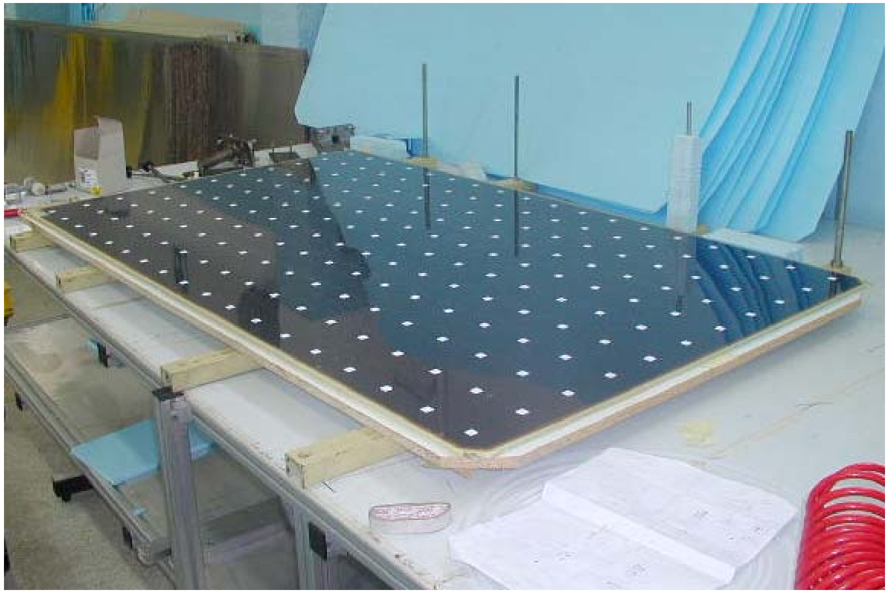
Trigger efficiency and rates

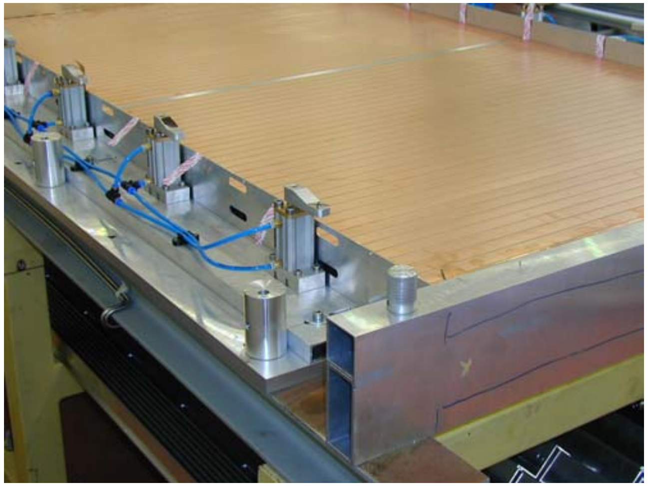


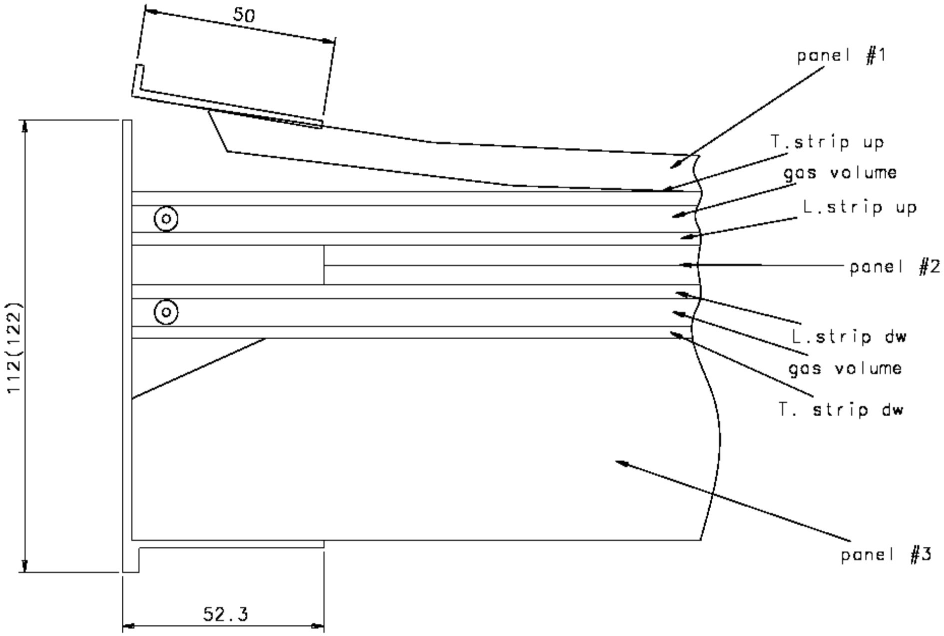


Trigger chambers In Barrel:

Resistive
Plate
Chambers



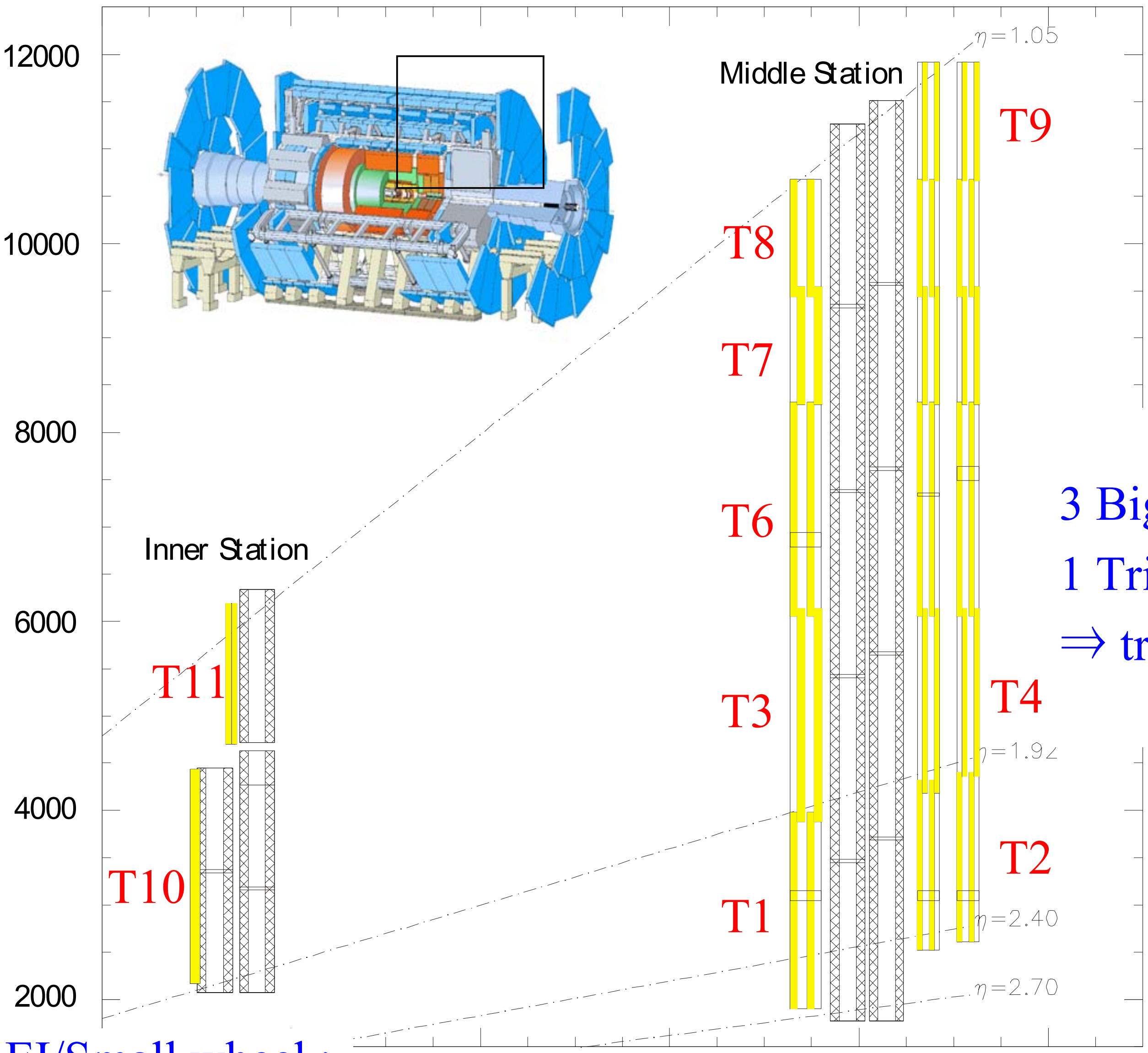




RPC production

- gas volumes produced by industry
- other components, assembly and test in collaborating institutes
- about 25% of gas volumes produced so far
- additional tests in high radiation background started recently (together with CMS etc.):
  - check production line chambers for aging,
  - develop **gas purification** procedure in order to use **gas recirculation**

Thin Gap Chambers



3 Big Wheels :

1 Triplet+2Doublets (7 layers)

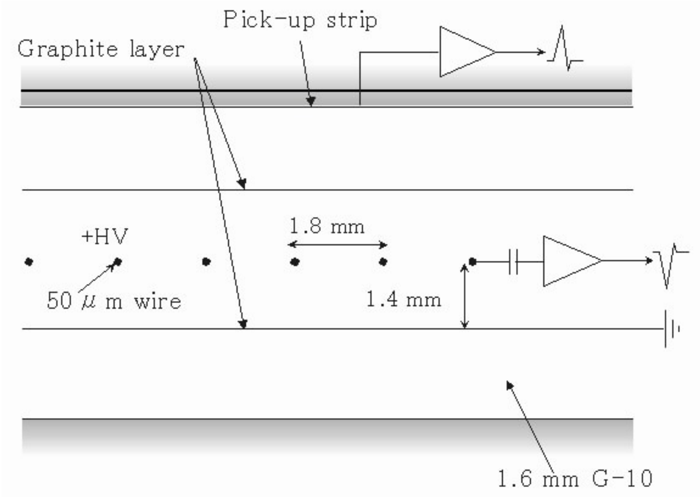
⇒ trigger + 2nd coordinate

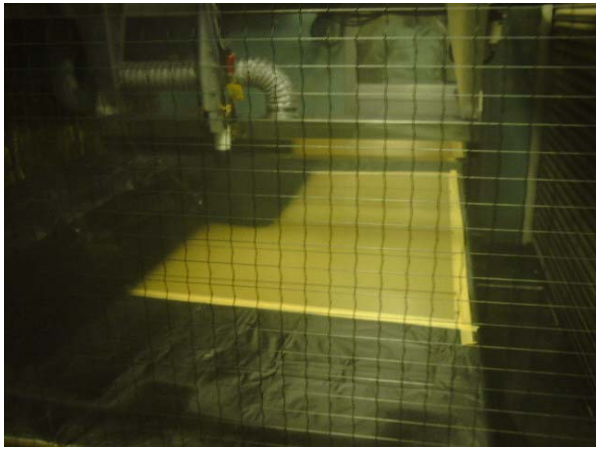
EI/Small wheel :

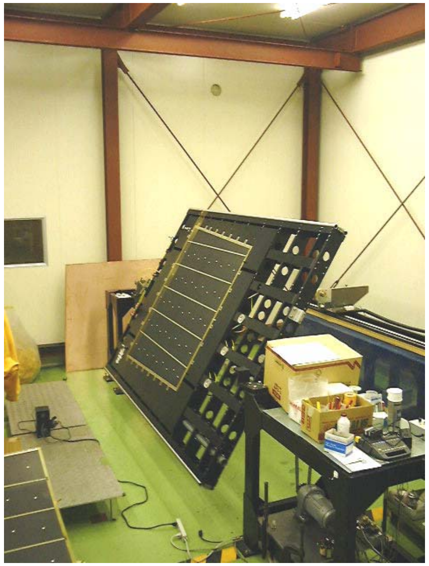
2nd coordinate

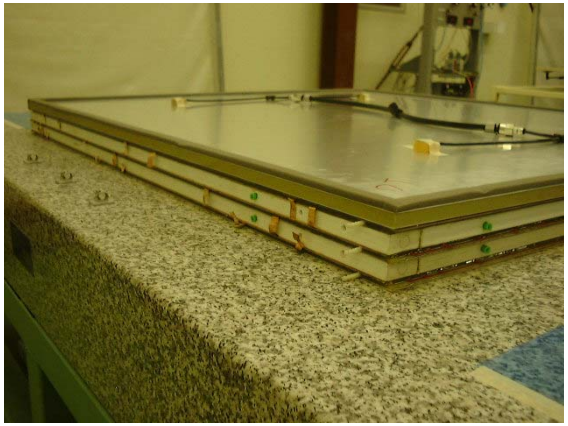
TGC construction

carbon spray (for cathode plane)
parts gluing (for gas volume)
wire winding
TGC closing
unit gluing
readout assembly (HV test incl.)





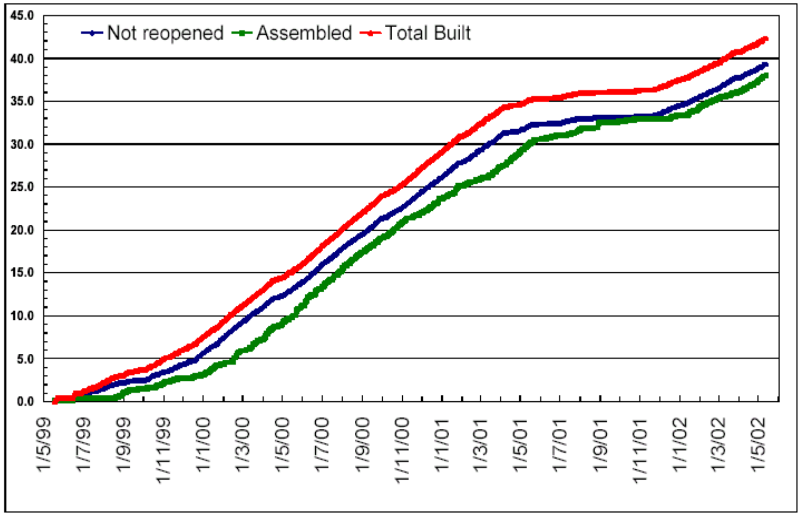




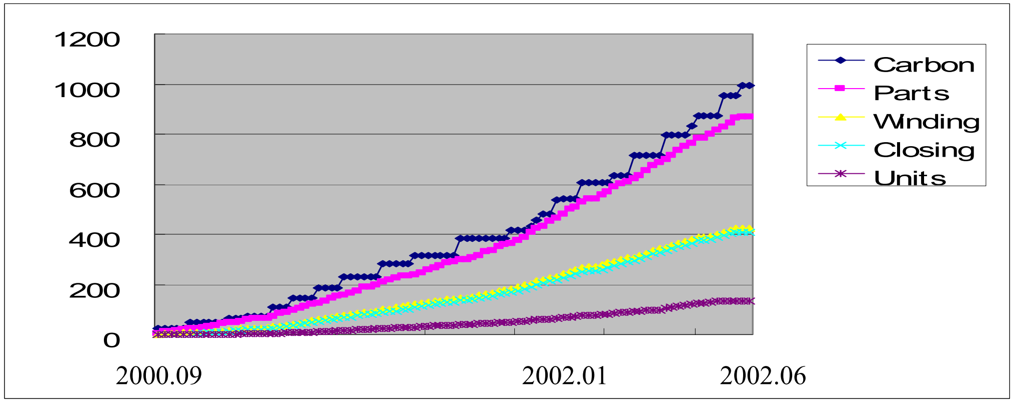
TGC production status

- Israel (Weizmann): 30% built, out of 60% planned
- Japan (KEK): 15% built, out of 30% planned
- China (Shandong), production of planned 10% just started

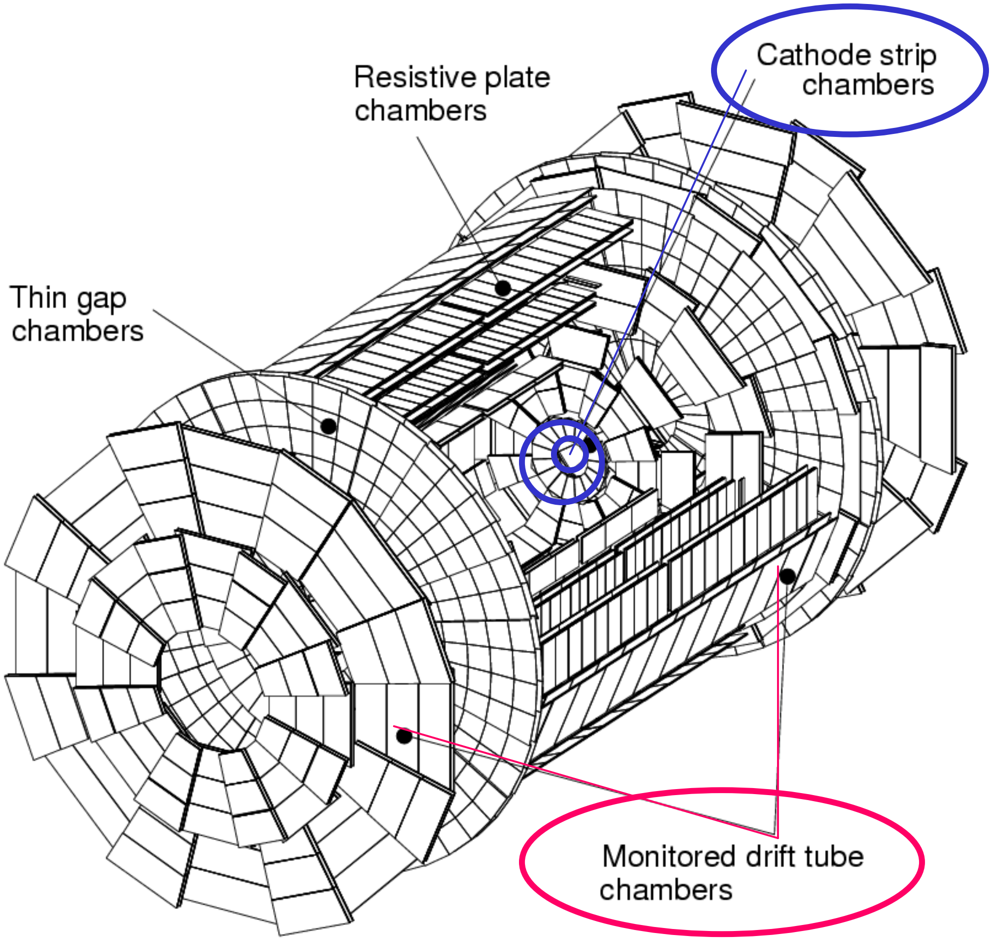
ISRAEL



JAPAN



Precision Chambers



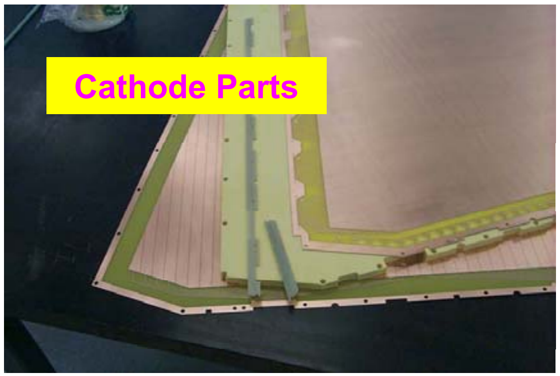
MDTs:

- **Barrel |η| <1**
- **End-cap 1< |η| <2.7**
- **1163 chambers**
- **~370000 channels**
- **5500 m^2**

CSCs:

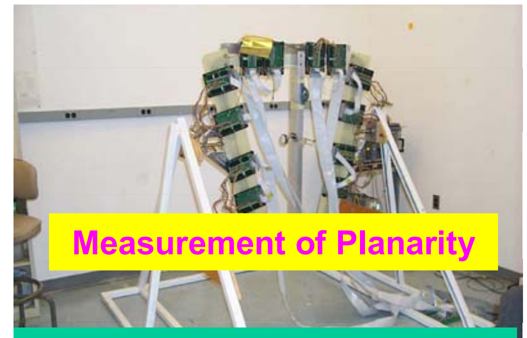
- **2< | η | <2.7 (inner station)**
- **32 chambers**
- **~ 67000 channels**
- **27 m^2**

CSC chambers



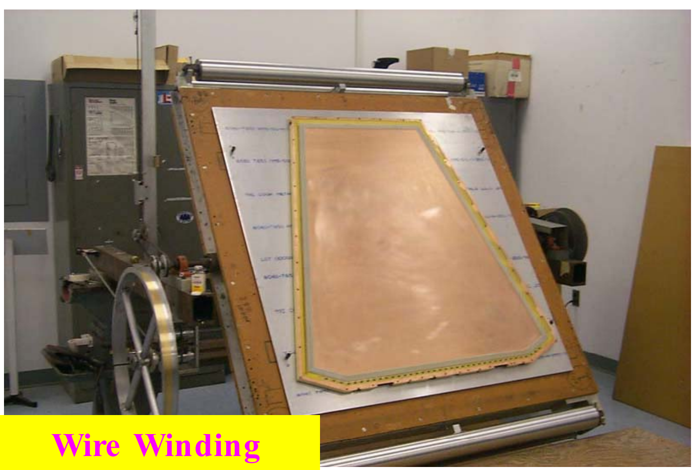
Cathode Parts

Cathode Panel Lamination



Measurement of Planarity

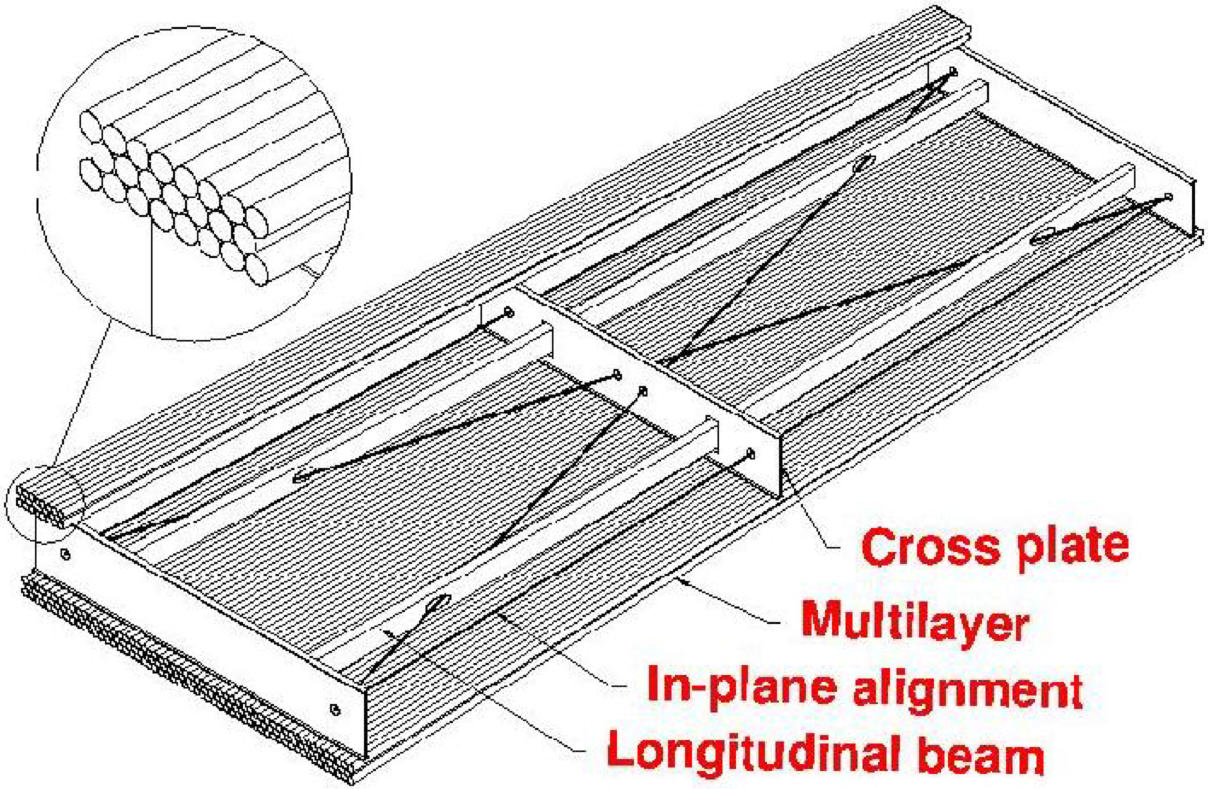
Estimated Production Rate ~ 3 ch. / mo.

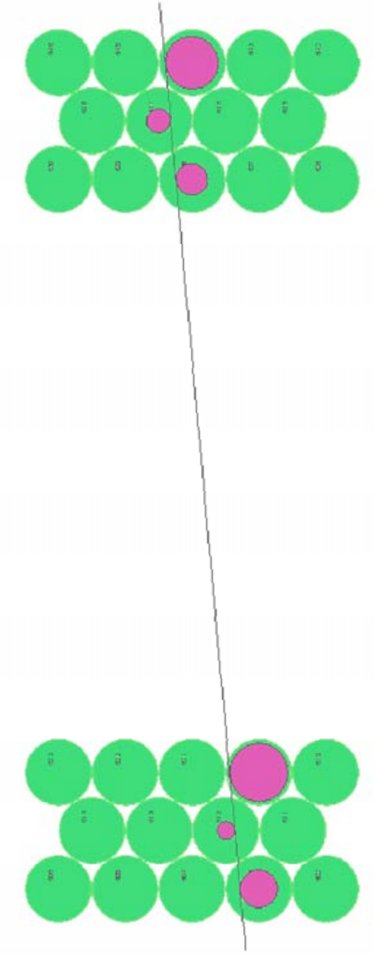


Wire Winding

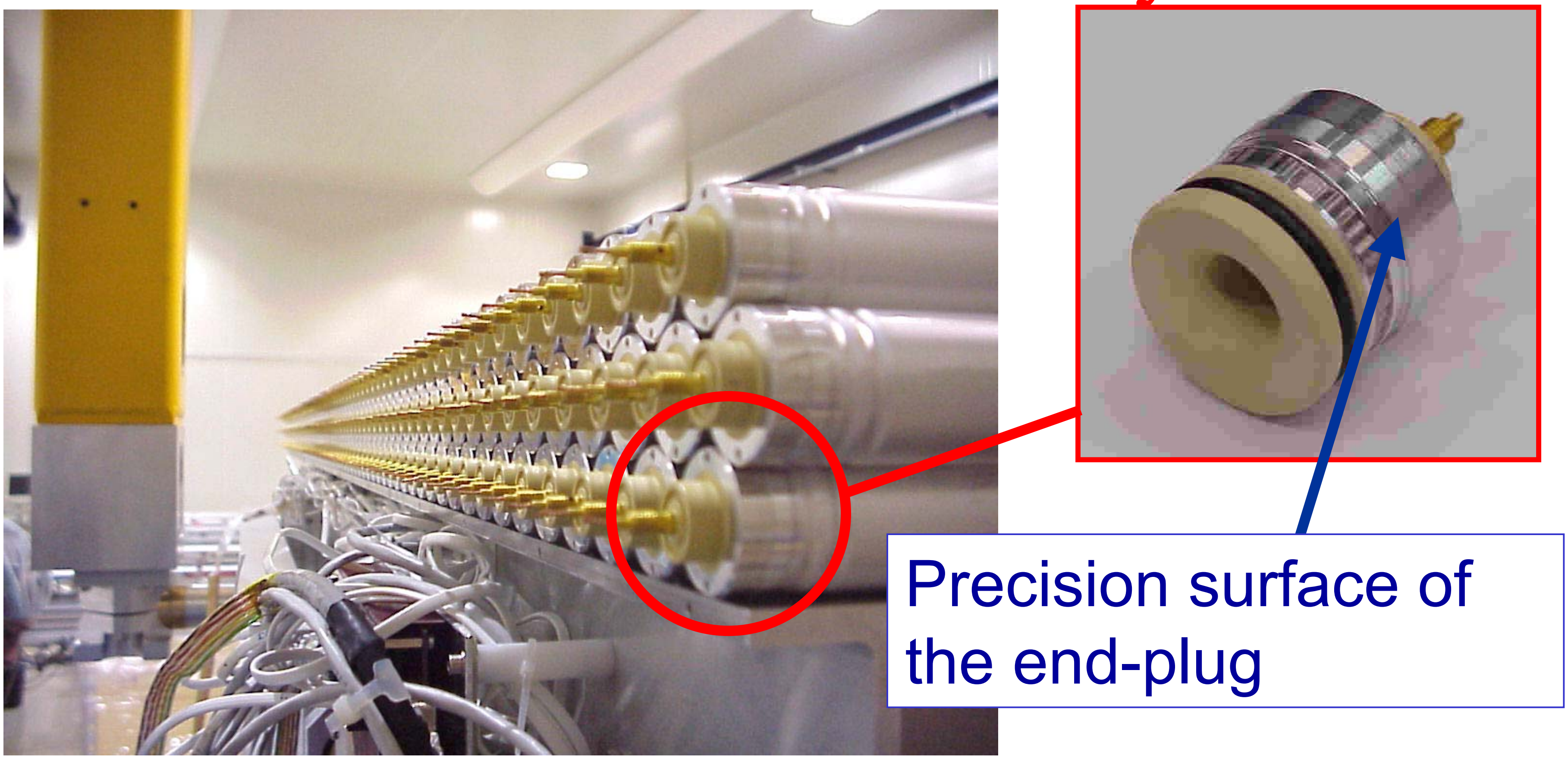
Storage of completed panels

Main precision chambers:
Monitored Drift Tubes

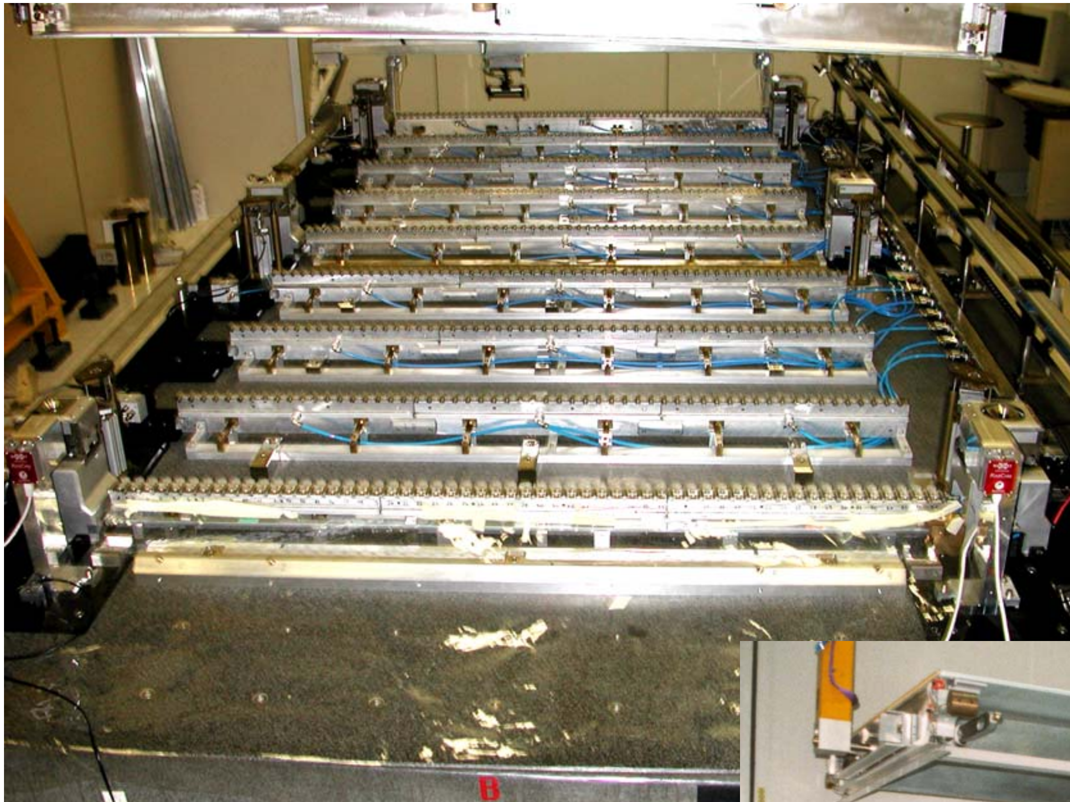




Drift tubes and multi-layers



Tube diameter: 30 mm (walls 0.4 mm Al), wire 50 μm
Operated at 3 bar, $G = 2 \cdot 10^4$

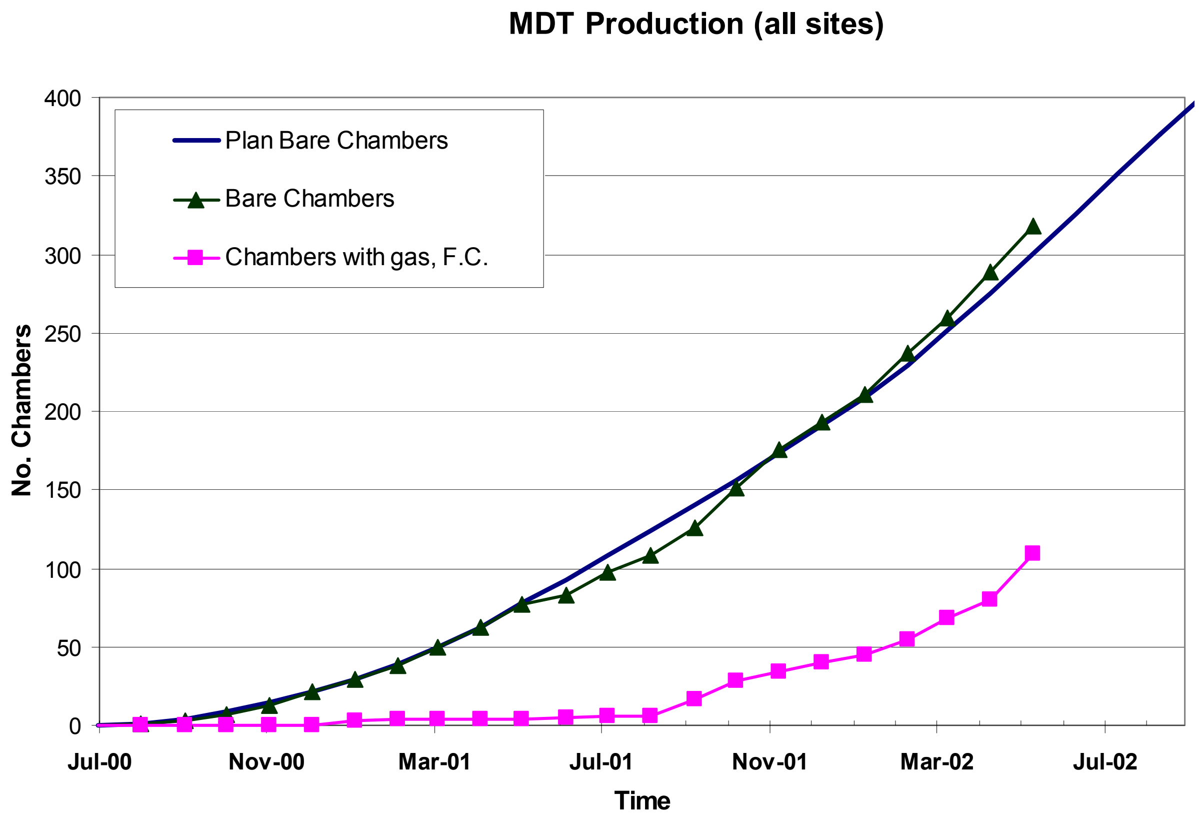


Layer assembly gig

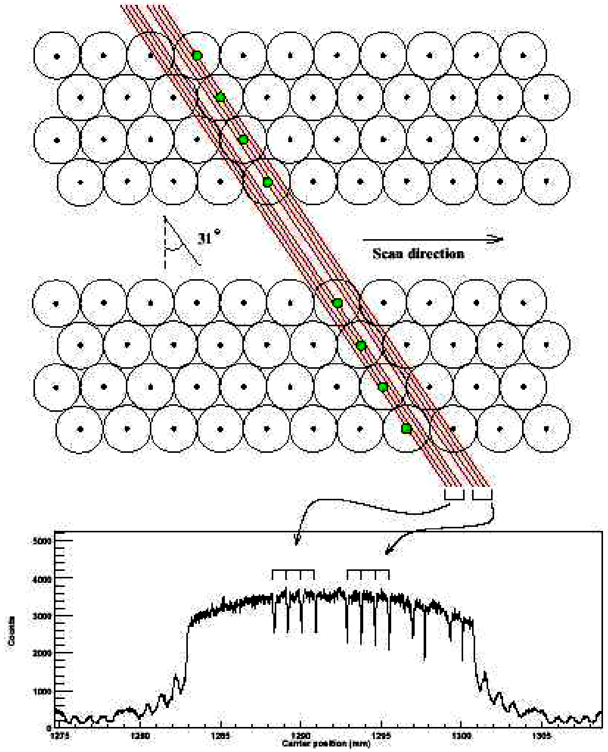
Multi-layer assembly

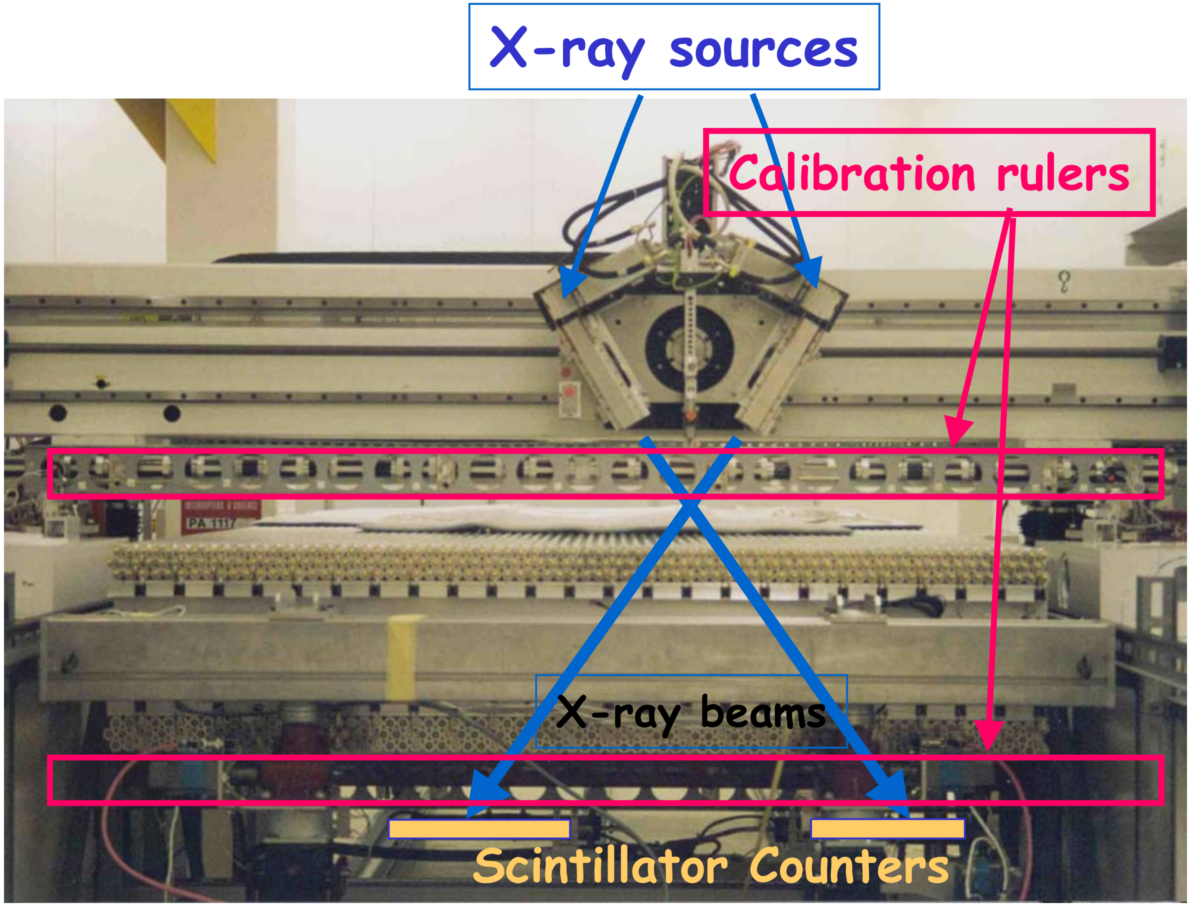
MDT production status

- Production planned in 13 sites (collaborating institutes or consortia of institutes) (9 in Europe, 3 in USA, 1 in Asia)
- 11 sites operating
- ~35 % of chambers produced (mechanics) (15 % complete with gas distribution and some other services)



Quality control with the *Tomograph Facility* at CERN

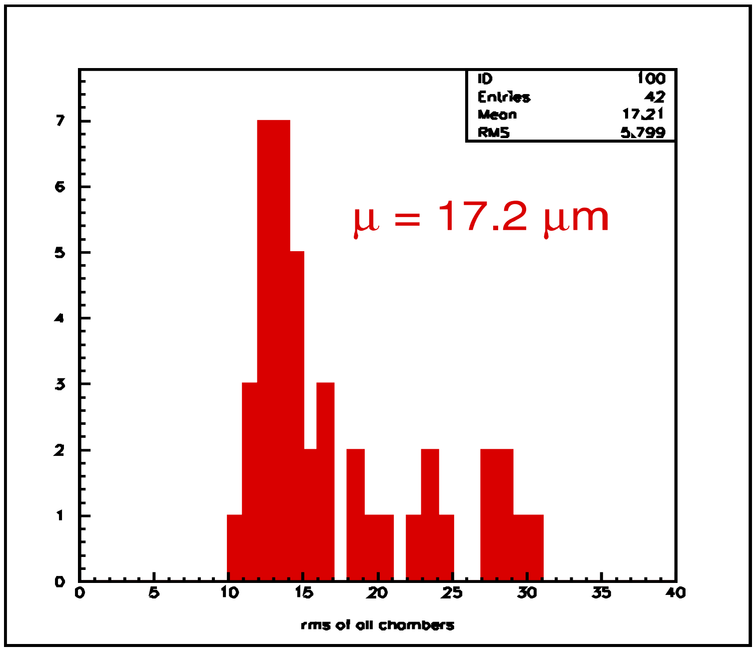




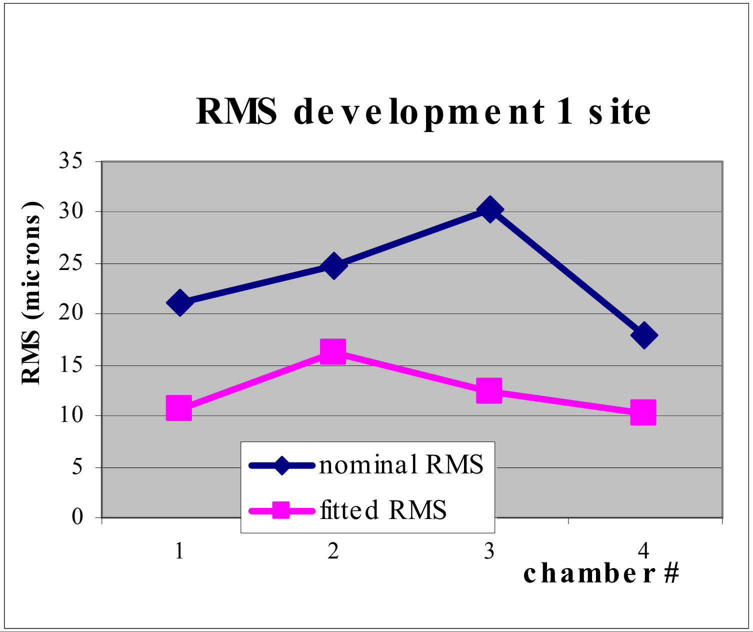
•Measure the cross sections of a chamber near the end-plugs (verify assembly accuracy),

• and near middle plane (measure wire sag)

•Help production sites in reaching optimal assembly procedure



Chamber RMS (μm)



Fitted rms: residuals referred to chamber parameters (e.g.: wire pitch, multi-layer separation) determined for each production site

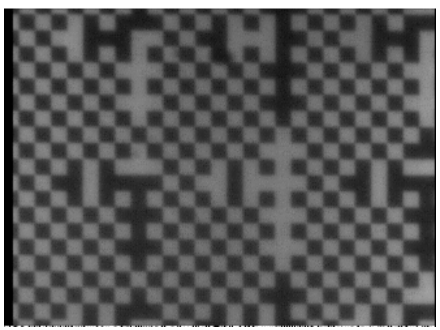
Alignment system

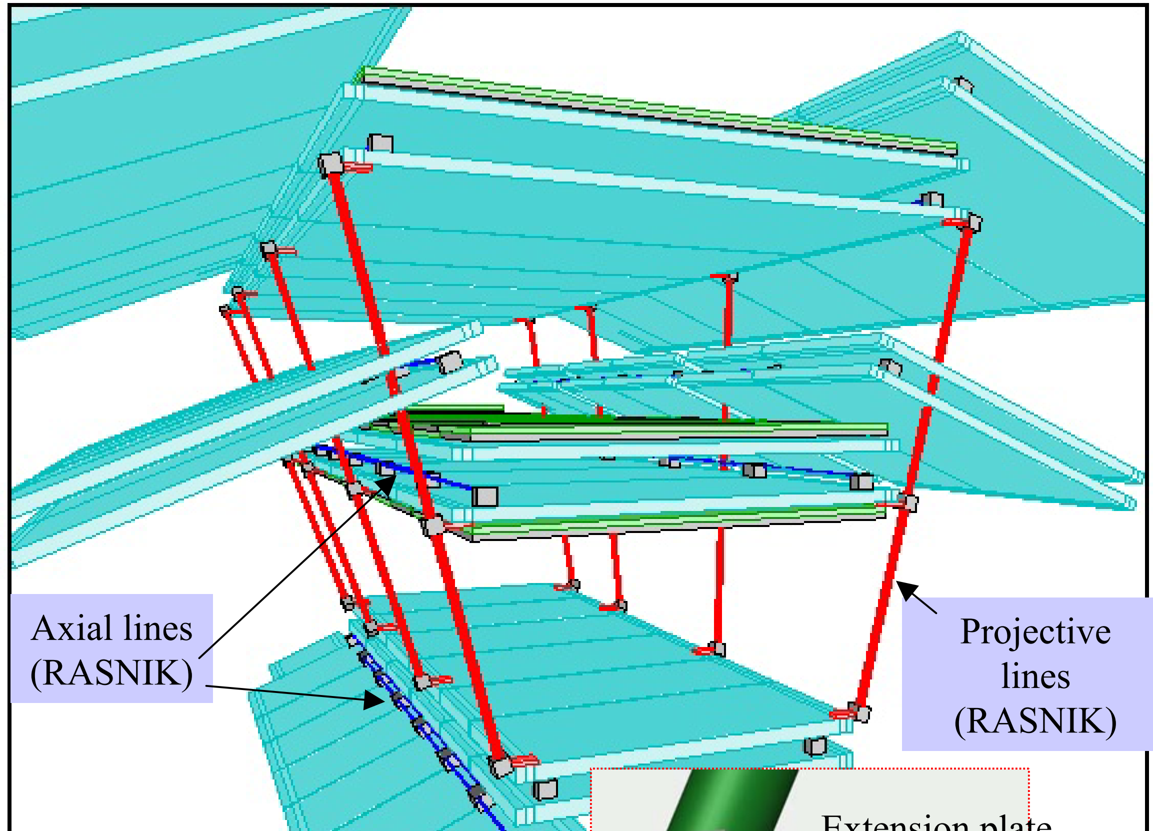
- An accurate alignment (~30 μm) is necessary not to affect the performance of the spectrometer
- An accurate monitor of chamber and spectrometer geometry is needed
- Limited use can be made of magnet-off muon data, since the spectrometer geometry is expected to vary on mm scale when turning on the B field

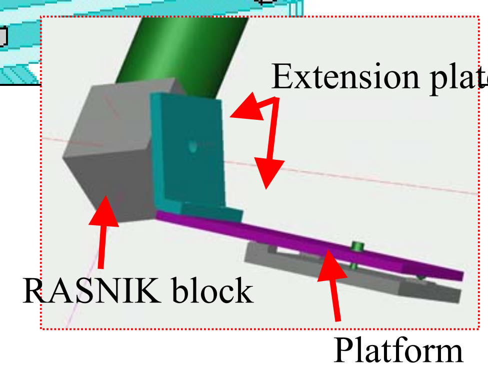
Use an alignment system, based on optical element, capable of reconstruction and monitor of the geometry of the spectrometer

Alignment in Barrel

- RASNIK: determine the relative position of a lens between a CCD and a target mask





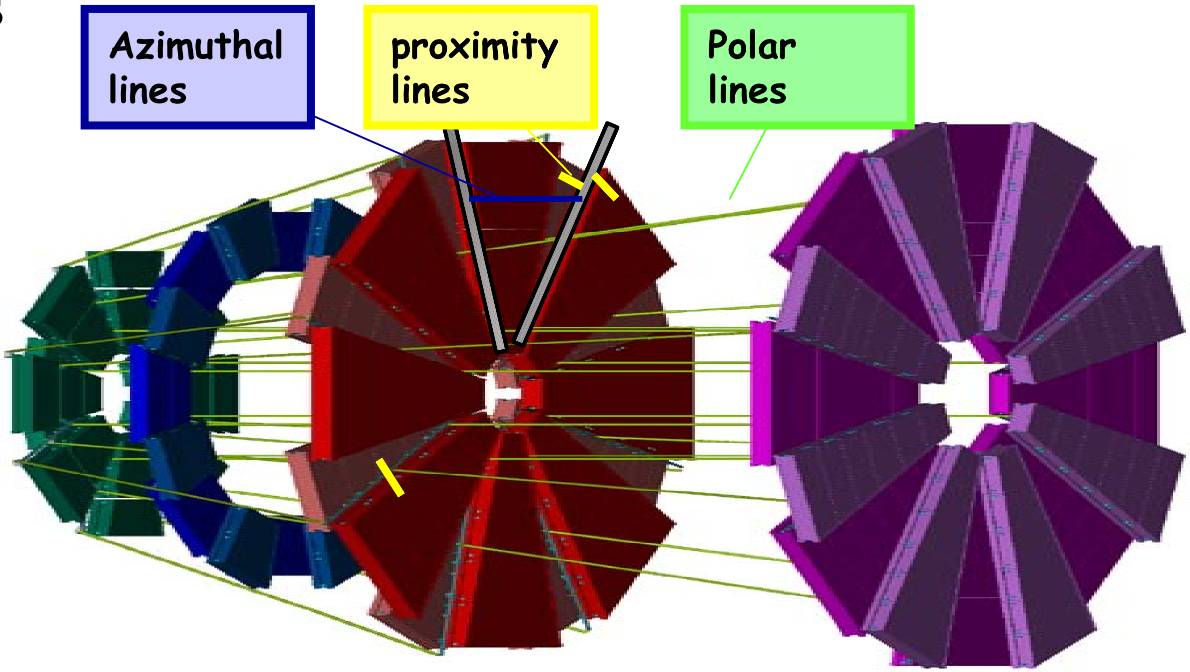


RASNIK typical parameters:
Each square 120x120 μm^2
CCD pixel 7x7 μm^2

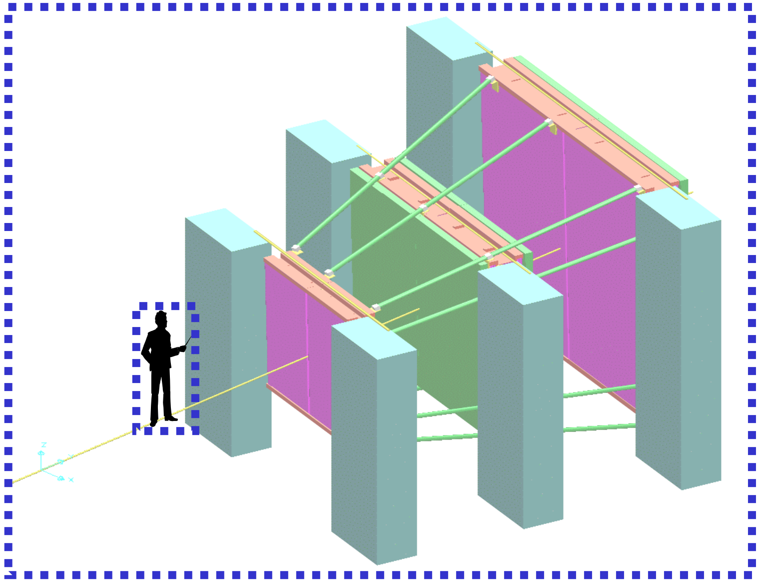
Intrinsic precision on transverse position few μm

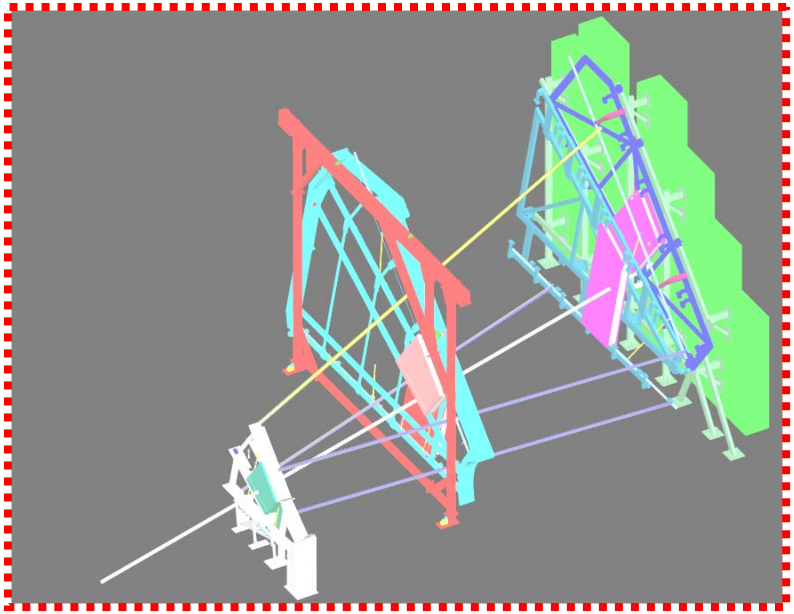
Alignment in EndCap

- To avoid the need of too many projective lines, with many holes in the EC cryostat:
  - Less projective (polar) lines (2-3 per sector)
  - Intermediate reference system based on monitored alignment bars connected to MDTs via proximity monitors



Realistic Test of alignment in one barrel tower, and of one EC sector

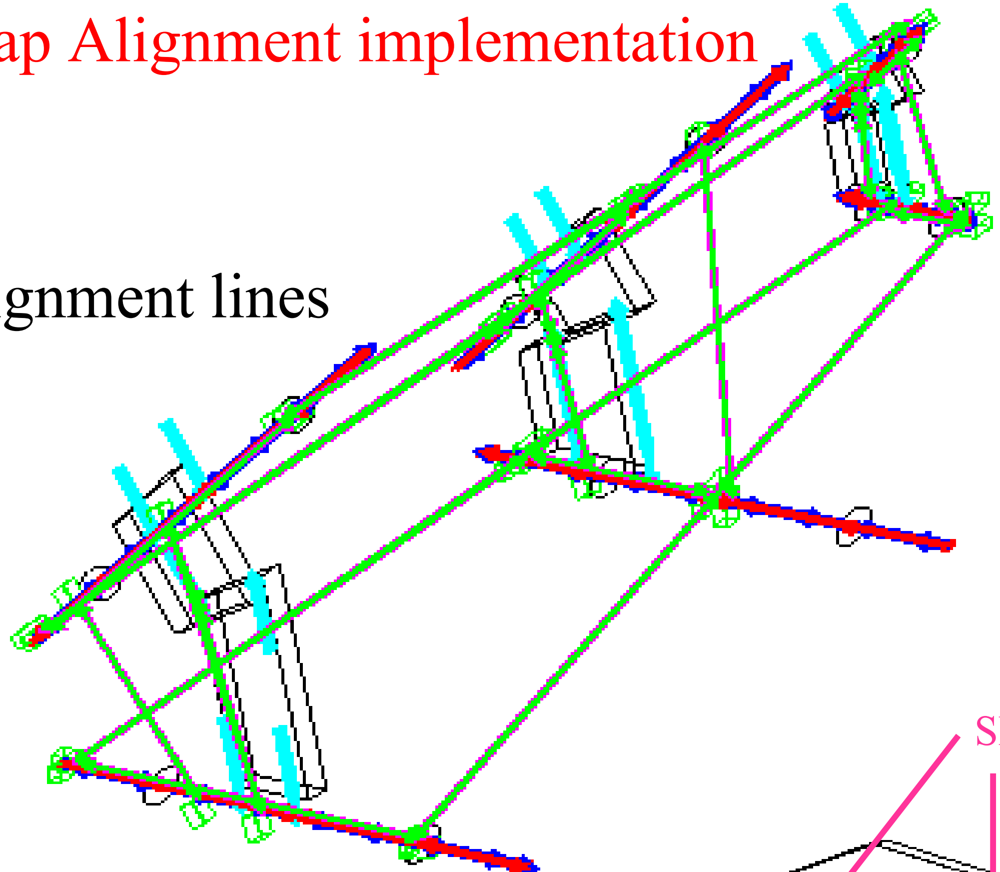




Also integration test of detectors, r/o and DAQ, services, DCS, software development and integration

EndCap Alignment implementation

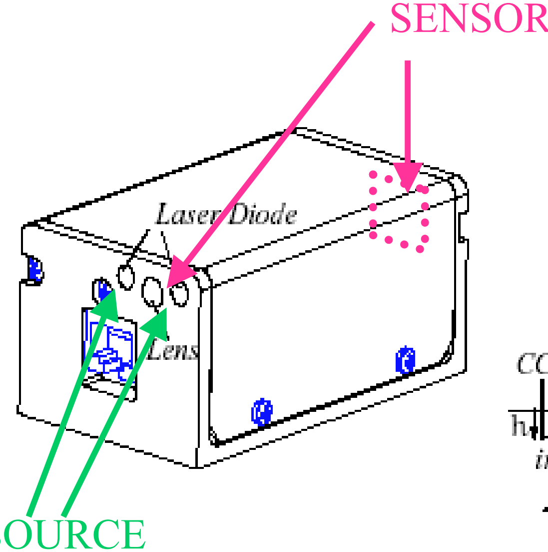
alignment lines

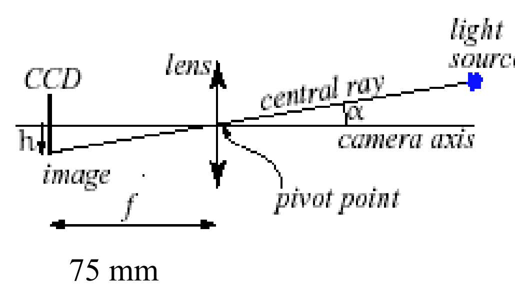


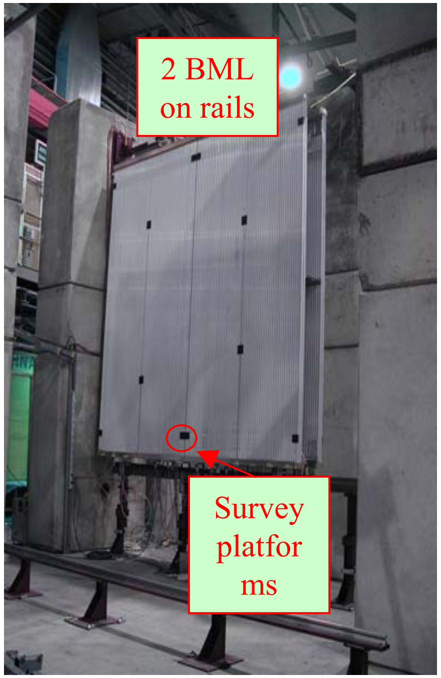
BCAM

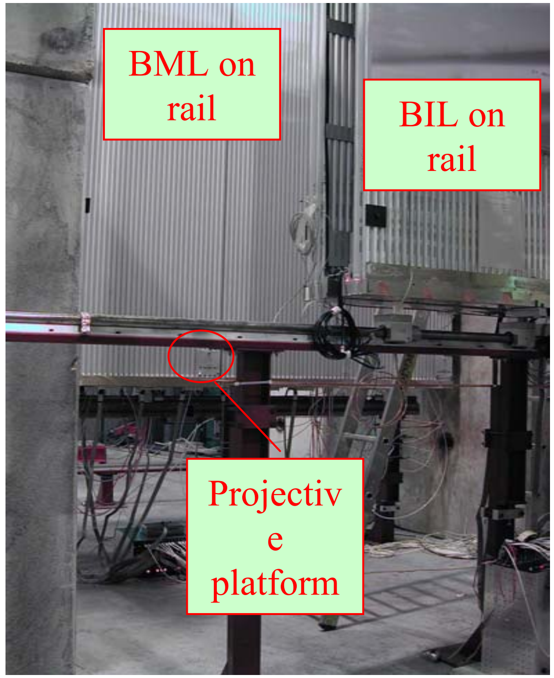
σabsolute = ~50 μrad

σrelative = ~ 5 μrad

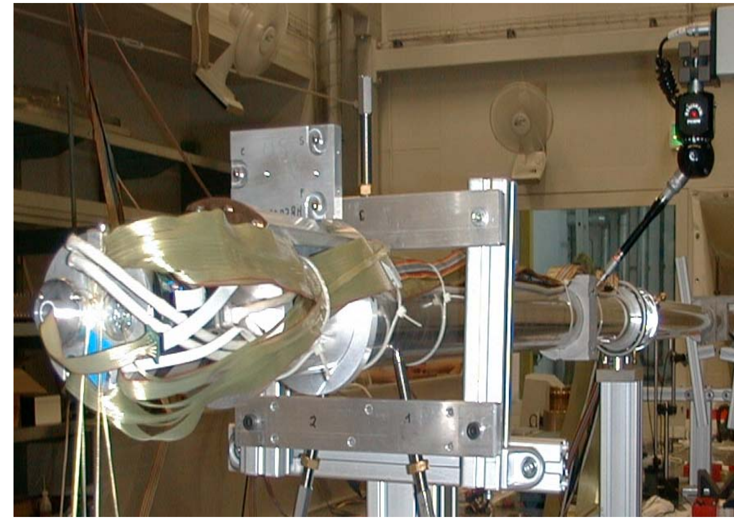


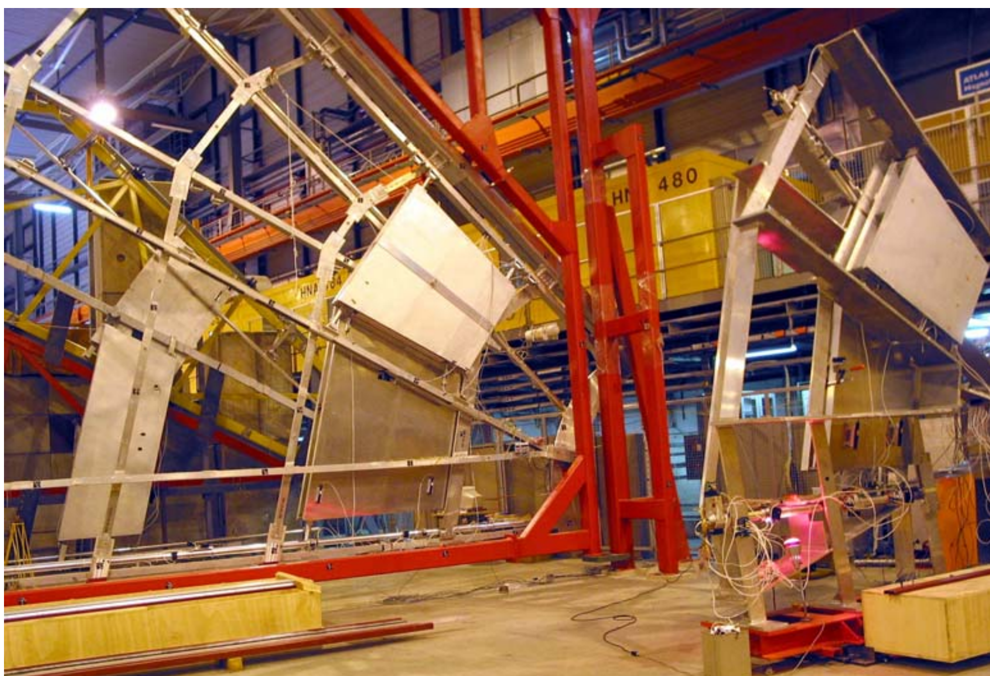




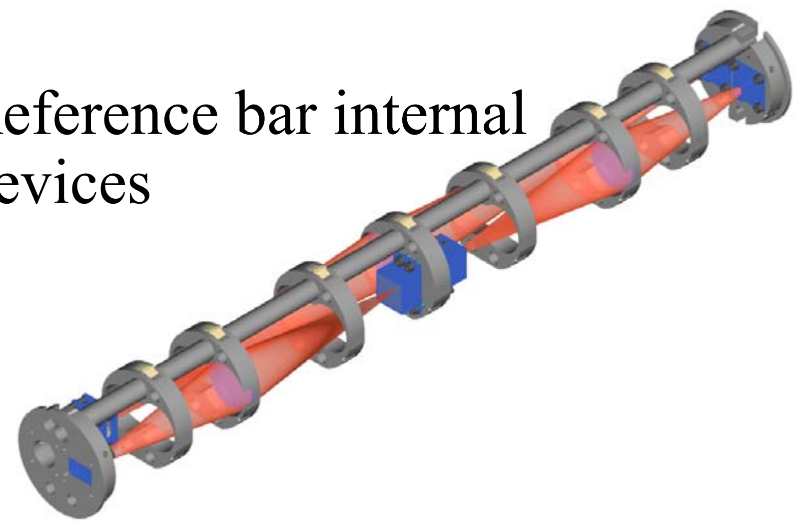


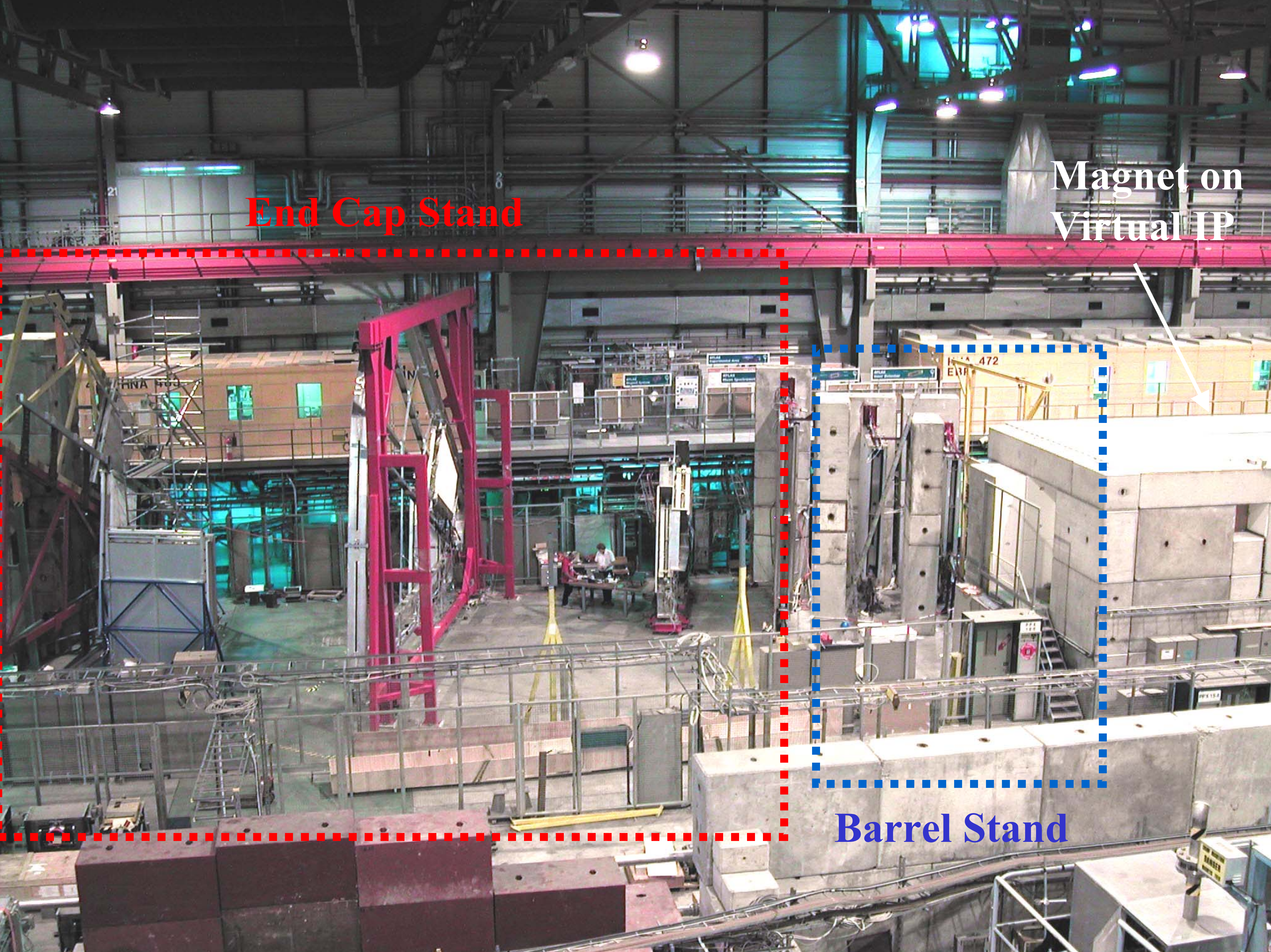
Reference bar calibration



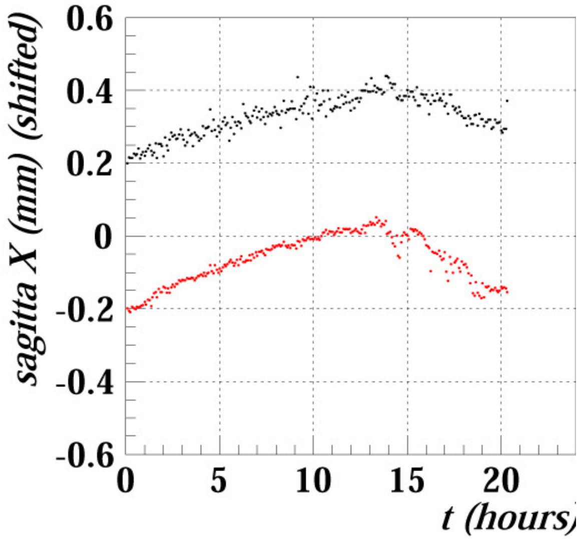


Reference bar internal devices



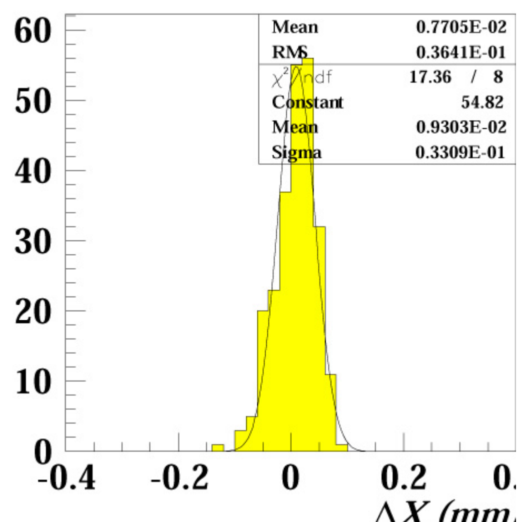

End Cap Stand
Magnet on
Virtual IP
Barrel Stand

Preliminary (partial) results from EC alignment test



Additional view line *(muon simulator)*

Fake sagitta from EC alignment system

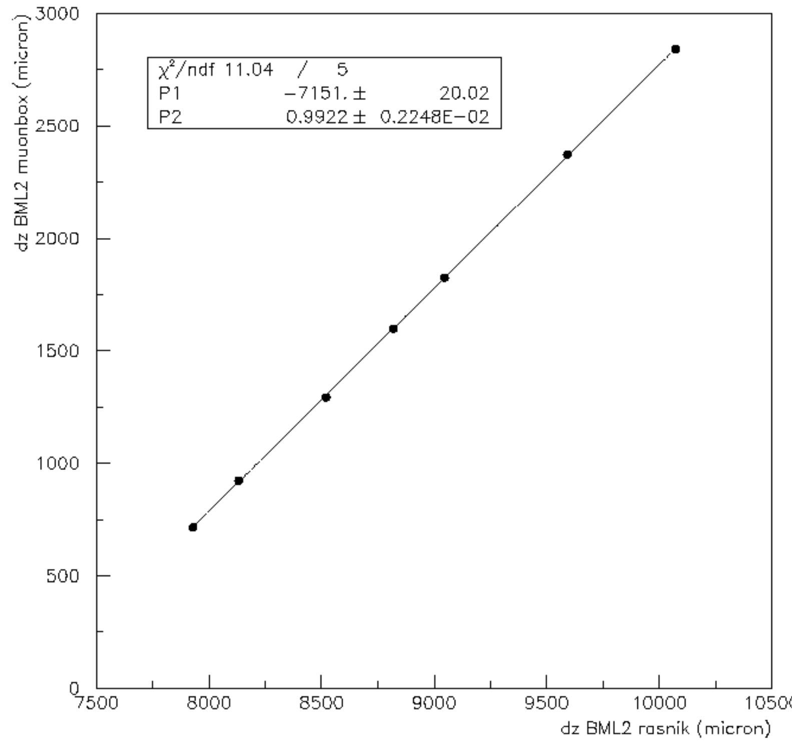


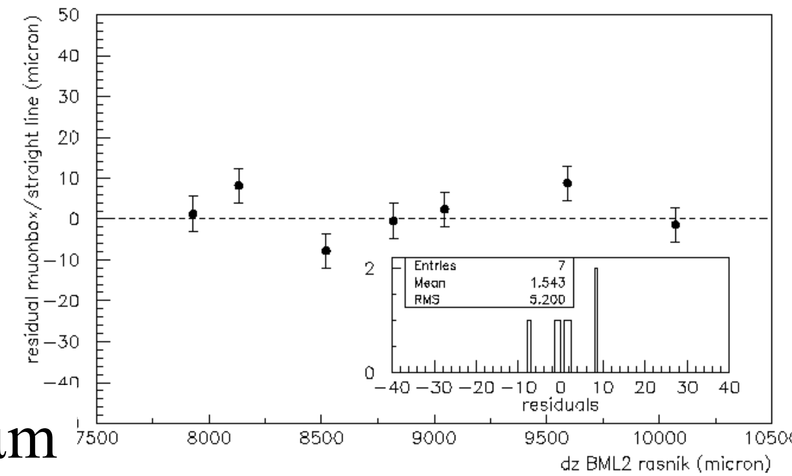
Residual: ~33μm rms

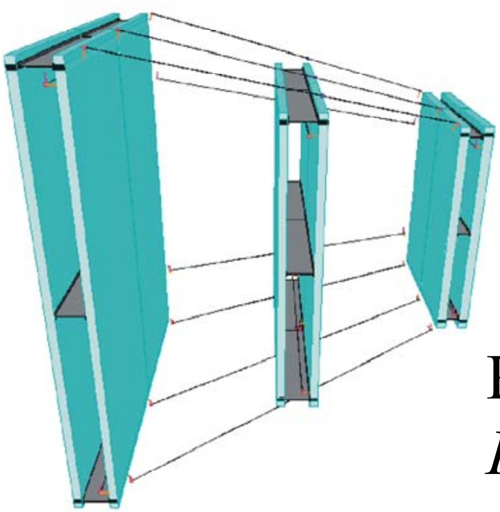
PRELIMINARY

Preliminary results from Barrel Alignment test

- Displacement of one chamber from middle station, along supporting rail, comparing data from track reconstruction and from alignment system







Residuals < 10 μm

PRELIMINARY

Tests at the CERN Gamma Irradiation Facility

- Photons < 1 MeV with rates exceeding LHC rates for muon detectors
- Muon Beam also available

- Here report on some results with MDT chambers

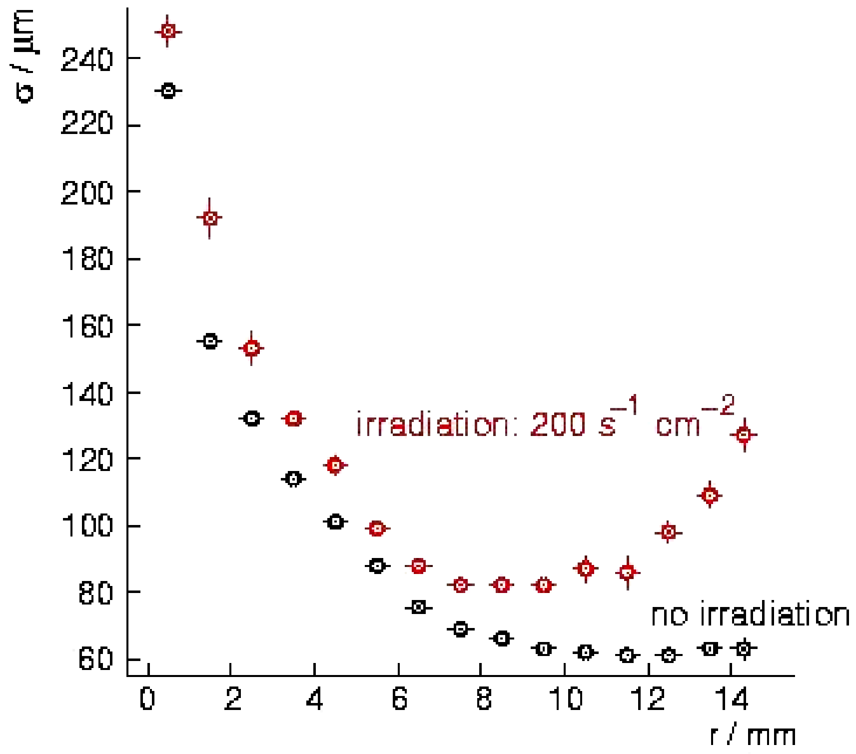
Single-Tube Resolutions

Operation point:

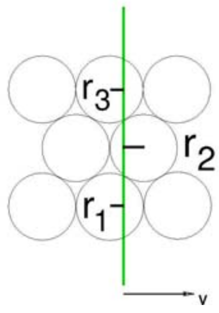
3080 V high voltage,

60 mV threshold,

Ar/CO_2(93/7) at 3 bar.



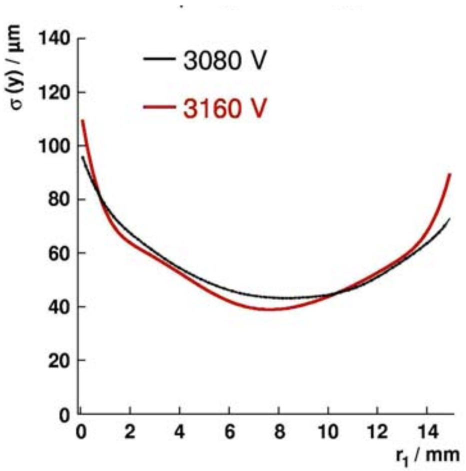
Comparison of the superpoint resolutions



Multi-layer resolution at high rate:
40 – 90 μm (3080 V)

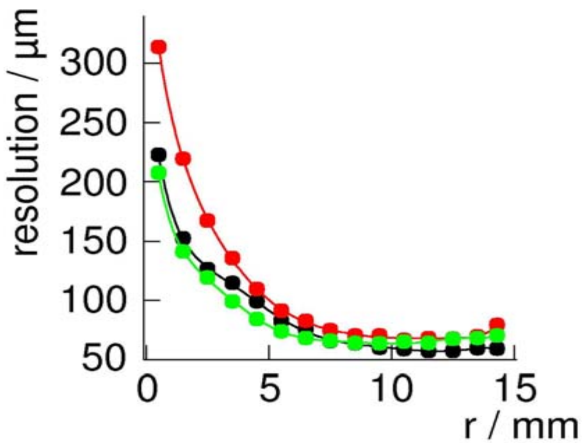
At low rate: 40 – 60 μm

(tracks normal to chamber)

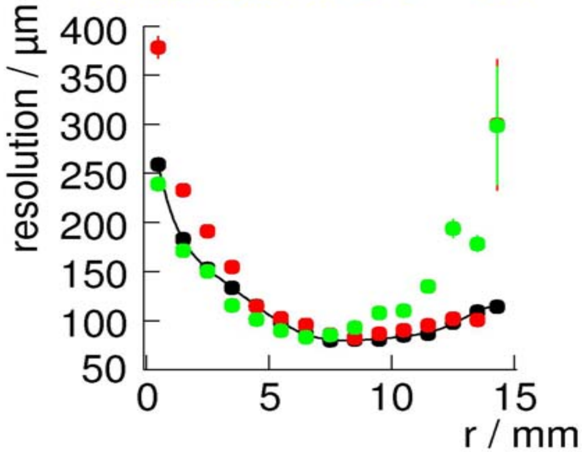


Resolution Curves for $Ar/CO_2(80/20)$ at 1 bar

No irradiation



Irradiation: 183 s^{-1} cm^{2}

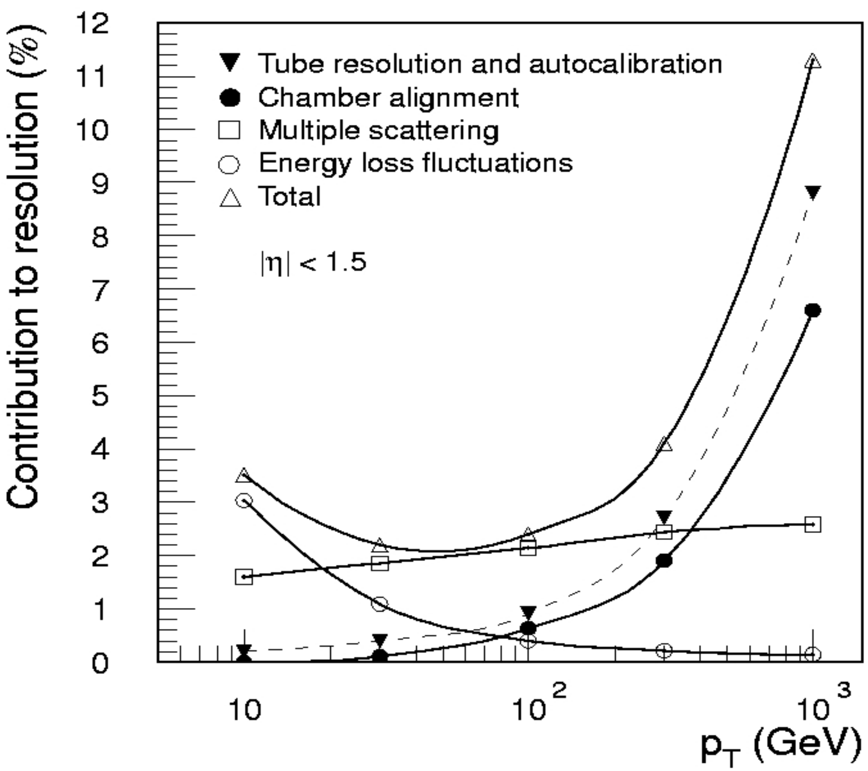


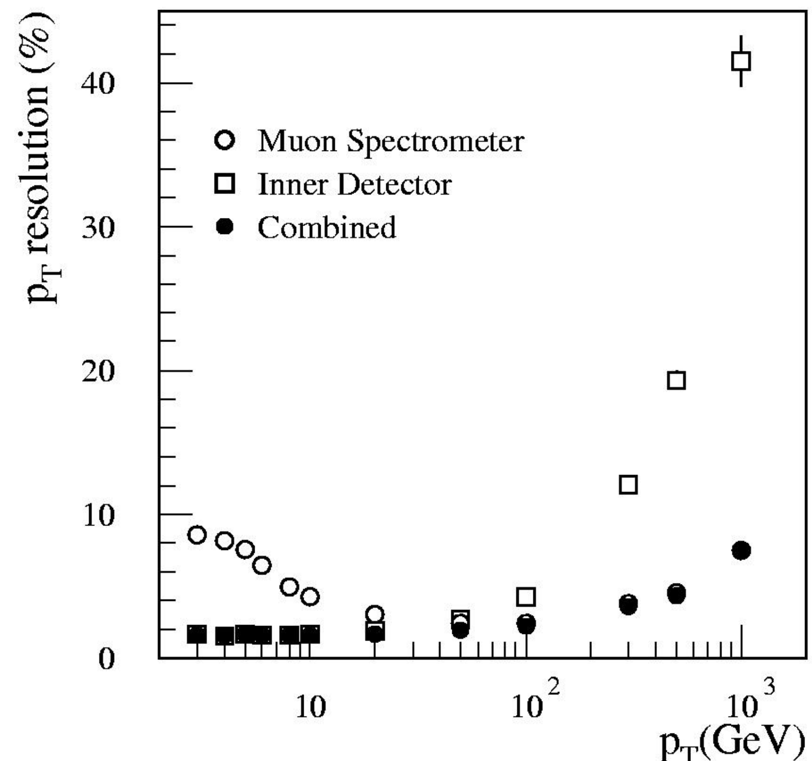
Threshold: 60 mV.

2 voltages at 1 bar:
2350 V ($2 \cdot 10^4$ gas gain),
2500 V ($6 \cdot 10^4$ gas gain).

Reference:
Ar/CO_2 (93/7), 3 bar,
3080 V.

Spectrometer resolution



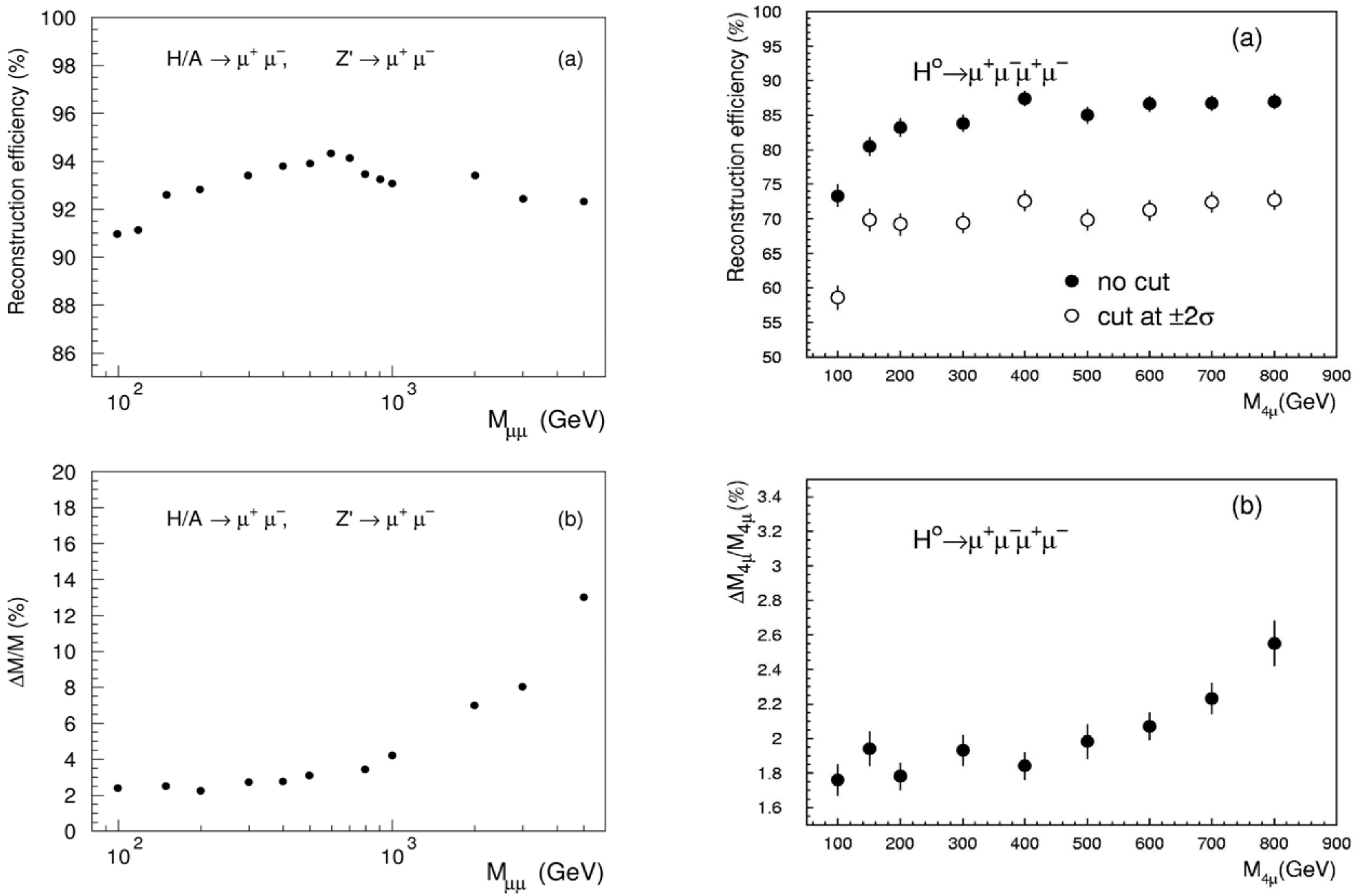


$\sigma(P_T)/P_T \sim 10^{-4}\times P_T \oplus 2\times 10^{-2} \oplus 0.3/P_T$

The muon spectrometer resolution dominates for P_T>50 GeV/c

Remark: trigger chambers provides 2nd coordinate to MDTs, relevant for reconstruction and optimal resolution

Efficiency and resolution in 2 / 4 muons channels



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