Proseminar presentation

Alignment of the sMDT Chambers for the Atlas Detector Upgrade

Leonhard Eidenschink

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Luminosities now and after the upgrade and their consequences

The highest instantaneous luminosity the LHC for pp collisions reached was 1,37e 34 cm^-2 s^-1 in 2016

Two upgrades were made:

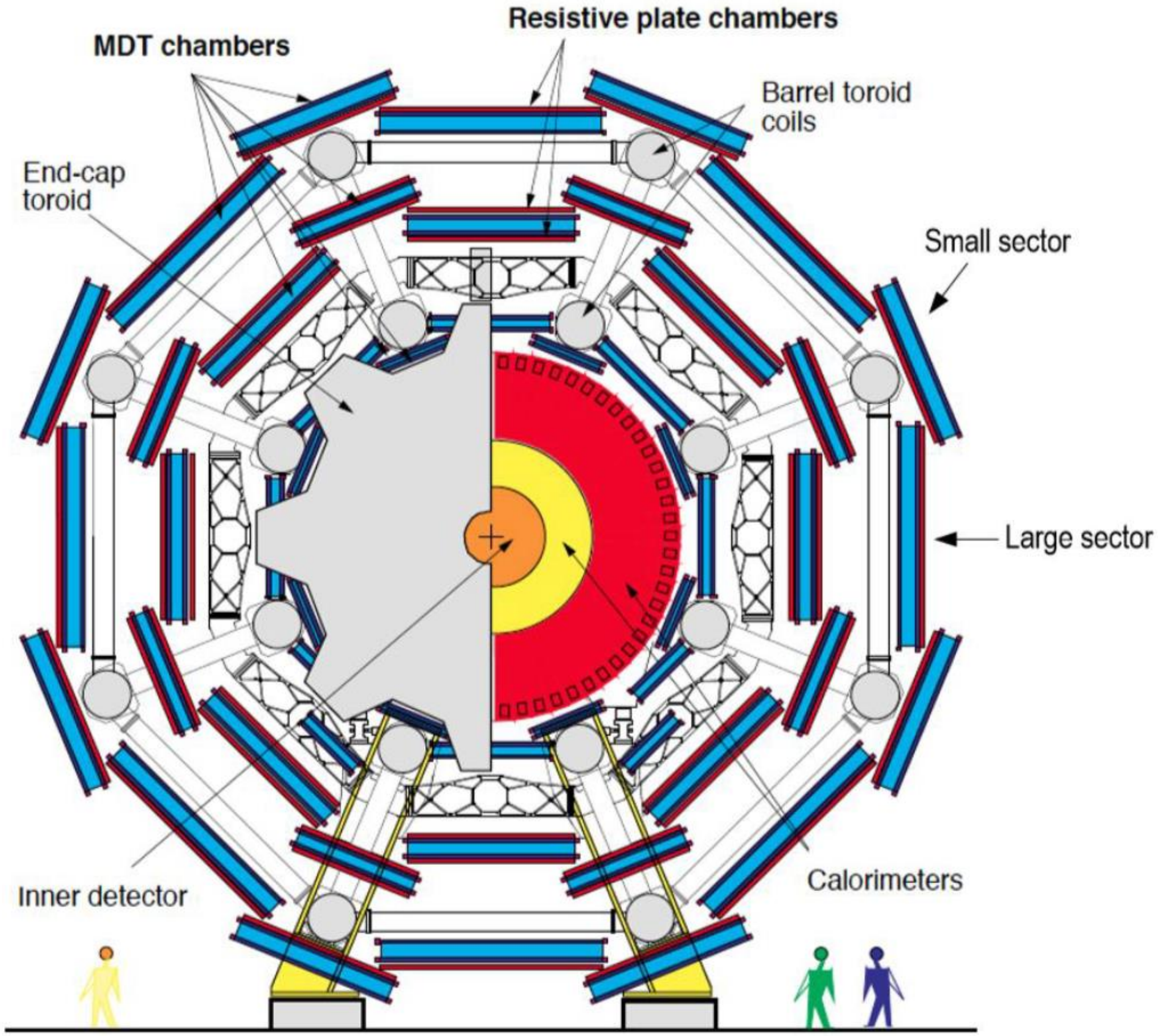
- The Injectors in 2019/20: to reach a luminosity of 2e 34 cm^-2 s^-1
- New focusing magnets at the interaction region

HL-LHC may reach peak luminosities of 7.5e 34 cm^-2 s^-1

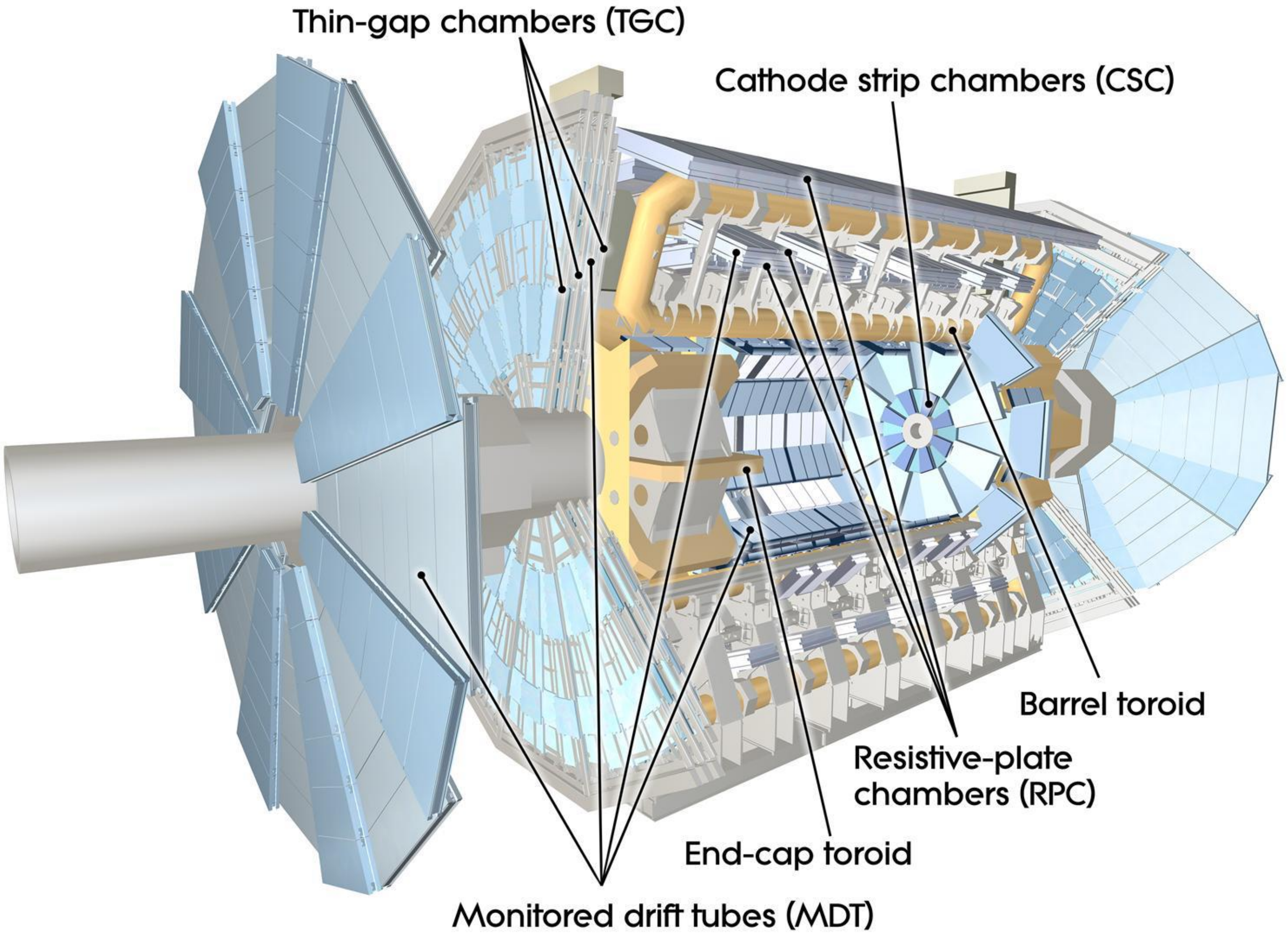
This results in an integrated luminosity of 4000 fb^-1

$$L_{\text{int}} = \int L \, dt$$

Because of the planned increase of the peak luminosity for the HL-LHC the Muon spectrometer must be upgraded to cope with the future conditions



Resistive plate chambers
MDT chambers
Barrel toroid coils
End-cap toroid
Small sector
Large sector
Inner detector
Calorimeters


Thin-gap chambers (TGC)
Cathode strip chambers (CSC)
Barrel toroid
Resistive-plate chambers (RPC)
End-cap toroid
Monitored drift tubes (MDT)

The resistive plate chambers (RPC)

- are gaseous detectors that provide a muon trigger system
- consist of plates to which a voltage is applied.
- therefore, they create a homogeneous electric field

- When a muon ionizes a gas atom the electron creates an electron avalanche
- the signal, created by the avalanche is picked up by external metallic strips
- the pattern of hit strips gives a quick measure of the muon momentum
- the trigger decides with this measurement whether the data are worth keeping

RPCs have a time resolution of 1 ns and a spatial resolution of approx. 1 cm.

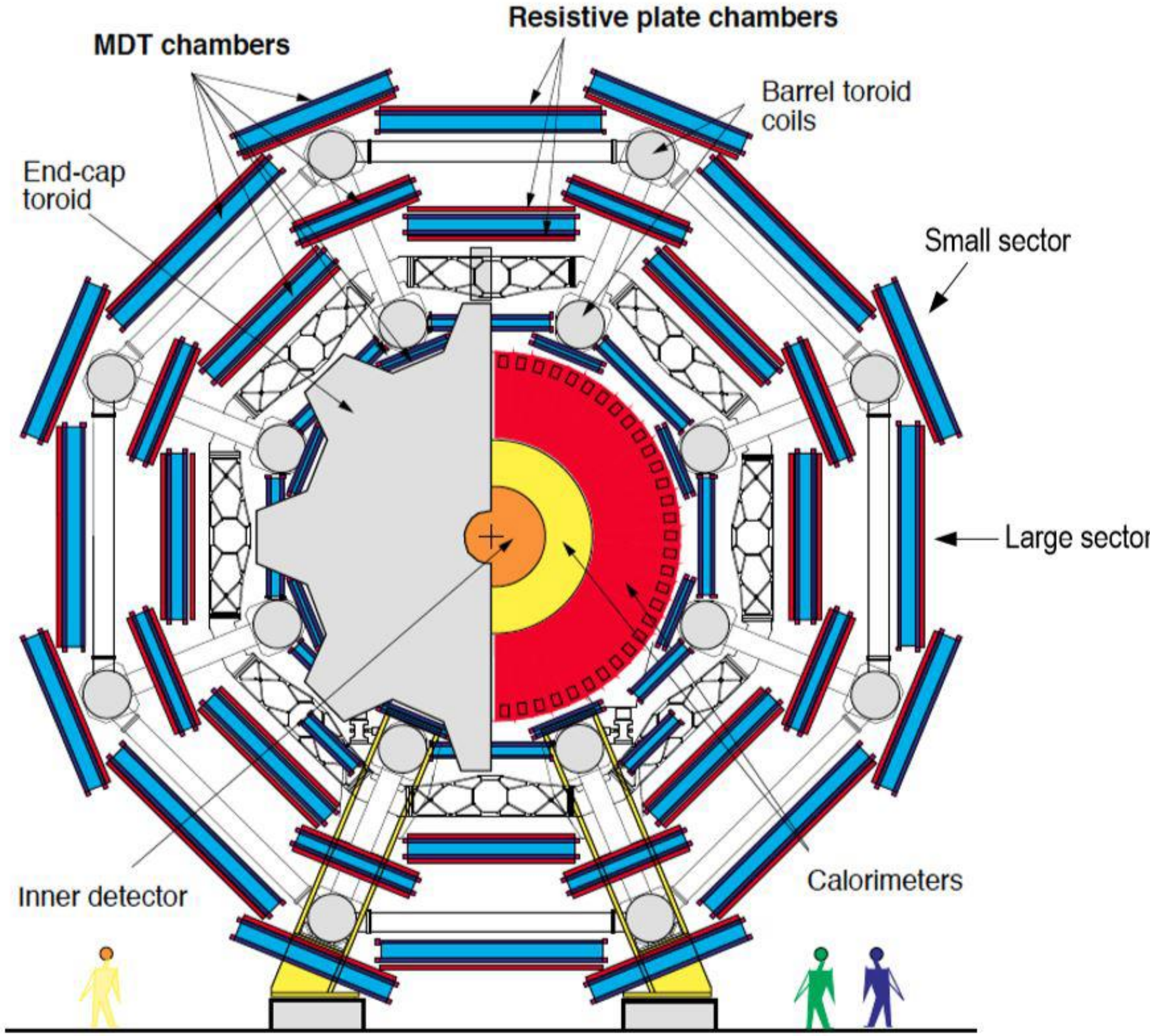
Upgrades on the Muon Spectrometer

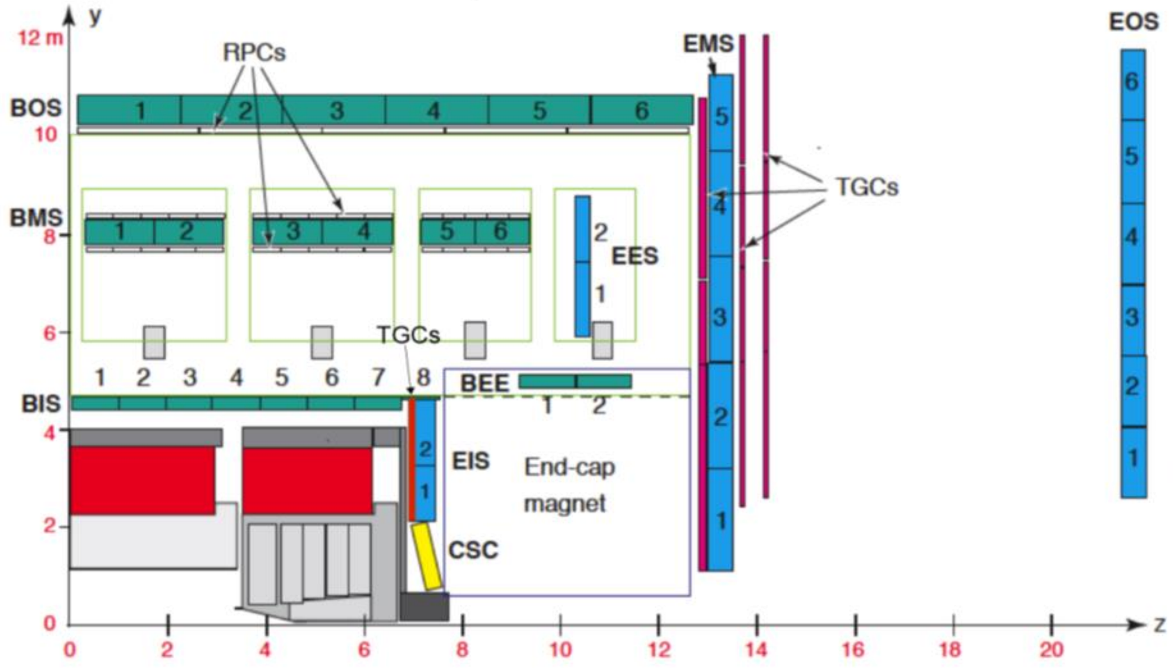
- Although MDT chambers are still working at higher luminosity,
- and therefore, would not actually need to be improved or be replaced
- The efficiency of the muon trigger system must be improved

➢ To ensure the continuing operation of the old RPCs, they must operate at a lower gain and lower voltage, reducing the efficiency by up to 65% in the regions of highest background.

➢ Therefore, new RPCs are added in the inner barrel layer

➢ But because of the sparse place in the small sector of the inner barrel layer the MDTs must be replaced by sMDTs





Small Sector

Comparison of MDT and sMDT

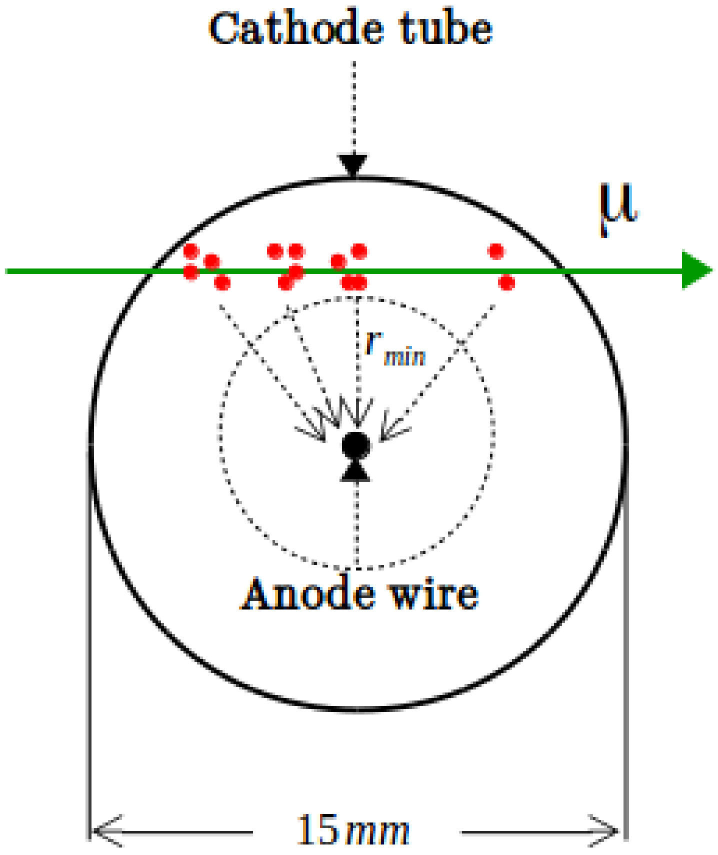
Type	MDT	sMDT
Tube material	Aluminium Aluman100	Aluminium AW 6060-T6/ AlMgSi
Tube inner&outer surface		Surtec 650 chromatisation
Tube outer diameter	29.970 mm	15.000 mm
Tube wall thickness	0.4 mm	0.4 mm
Wire material	W-Re (97:3)	W-Re (97:3)
Wire diameter	50 μm	50 μm
with gold plating, thickness	3%	3%
Wire resistance/m	44 Ω/m	44 Ω/m
Wire pitch	30.035 mm	15.099 mm
Wire tension	350 ± 15 g	350 ± 15 g
Gas mixture	Ar:CO_2 (93:7)	Ar:CO_2 (93:7)
Gas pressure	3 bar (abs.)	3 bar (abs.)
Gas gain	$2 \cdot 10^4$	$2 \cdot 10^4$
Wire potential	3080 V	2730 V
Maximum drift time	720 ns	175 ns
Average tube spatial resolution without backgr. irradiation	83 μm	106 μm
Average tube spatial resolution at 500 Hz/cm^2 backgr. rate	160 μm	110 μm
Drift tube muon efficiency without backgr. irradiation	95%	94%
Drift tube muon efficiency at 200 kHZ/tube backgr. rate	80%	90%
Wire positioning accuracy	20 μm (rms)	10 μm (rms)

operating mode of the MDTs

- MDTs are a further development of multi-wire proportional chambers MWPC
- MWPCs are not dependent on the distance of the ionization but from the drift time
- MWPCs work on the principle of proportional counter tubes
- In proportional operation, the detectors have practically no dead time, because this is exactly as long as the drift time
- Therefore, they can operate at much higher counting rates, as in saturated range where Geiger counters work
- Also, in this mode there are no unwanted recombinations of ions and electrons which would lead to electron avalanches caused by a photon, created by the recombination.
- Proportional counter tubes contain a quenching gas to suppress this specific avalanches.

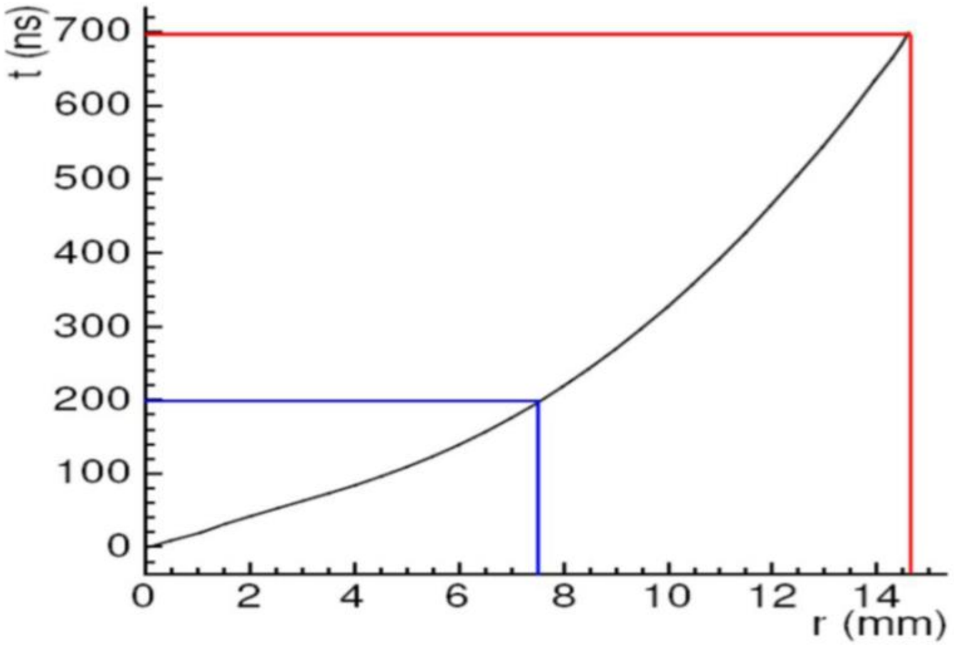
Track reconstruction in one tube

- Muon passes through detector and ionizes the gas in the tubes
- E-Field of the wire causes the electrons to accelerate towards the wire
- This causes more ionizations, which leads to an electron avalanche
- The E-Field is cylindrically symmetrical and has an average value form about 190 kV/m



Determination of the isochrons with the space to drift time relation

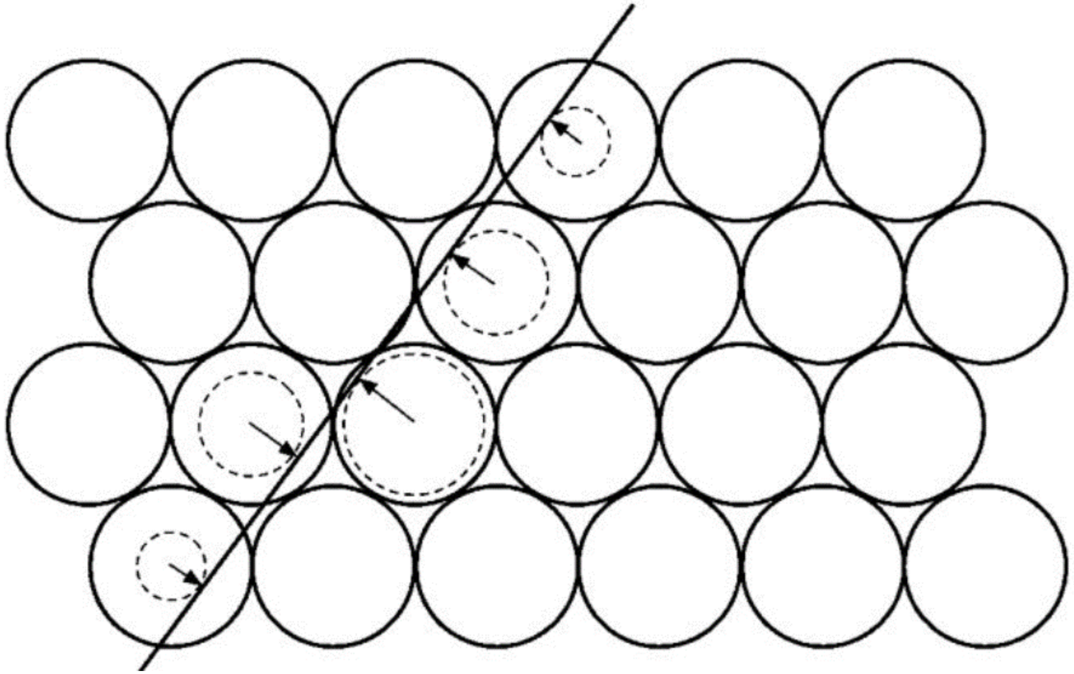
- The Isochrones can be determined by converting the measured drift times to the drift radii
- this is done by using the calibrated space to drift time relation
- the space to drift time relation depends on the gas mixture
- In this case it is nonlinear
- but for a radius 7.5mm which is the case with the sMDT's, it is linear to good approximation



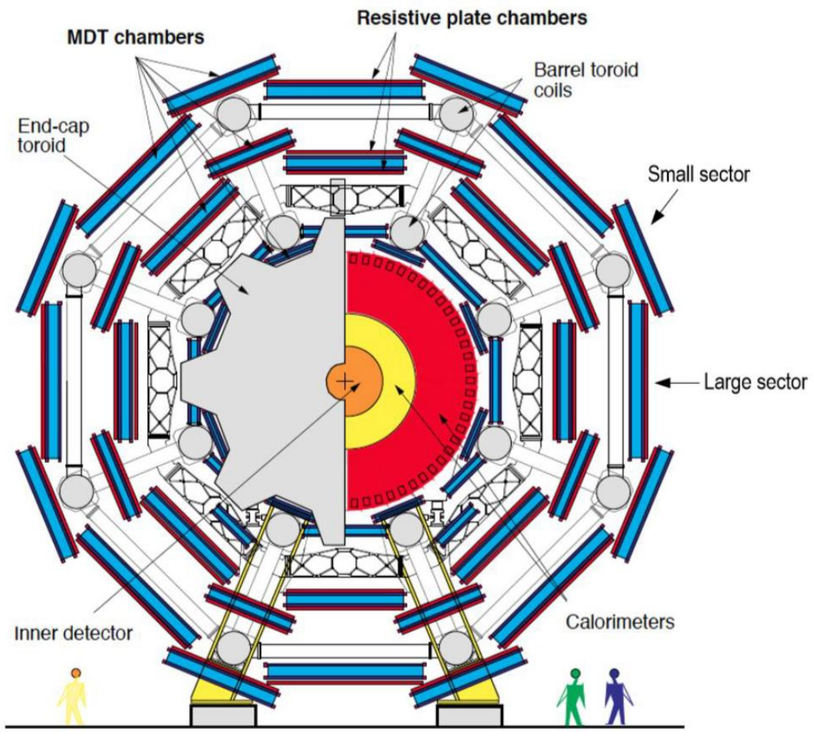
space to drift time relation

Track reconstruction in multiple layers

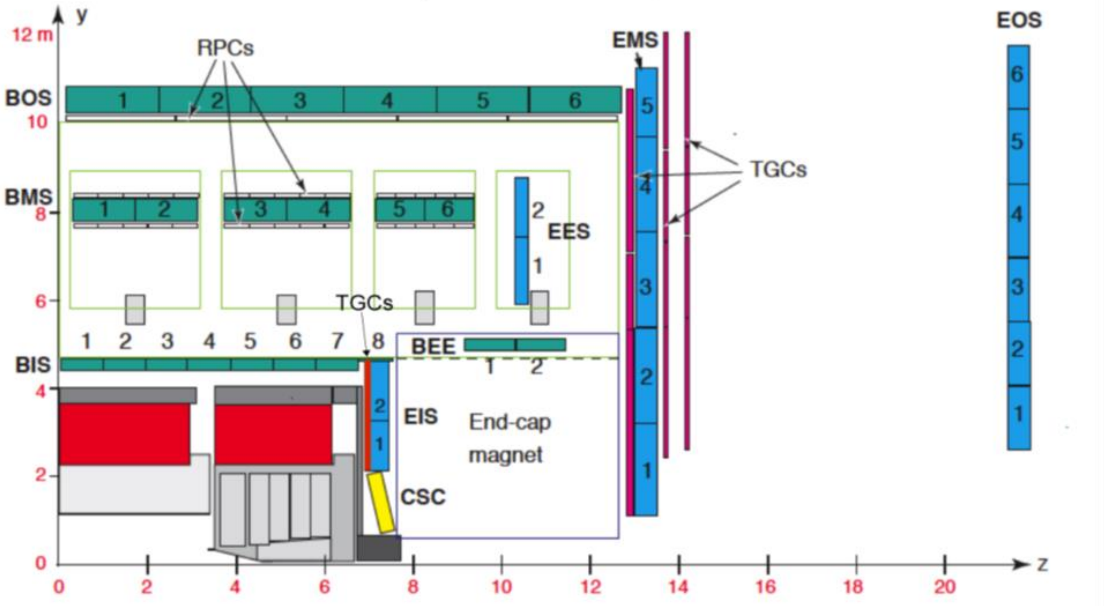
- Drift time is measured with a time-to-digital converter (TDC), with the arrival time of the electrons on the wire relative to the timestamp of the central LHC clock.
- By fitting a line to the different isochrones, we get the track of the charged particle



magnetic and electric Field in the Detector



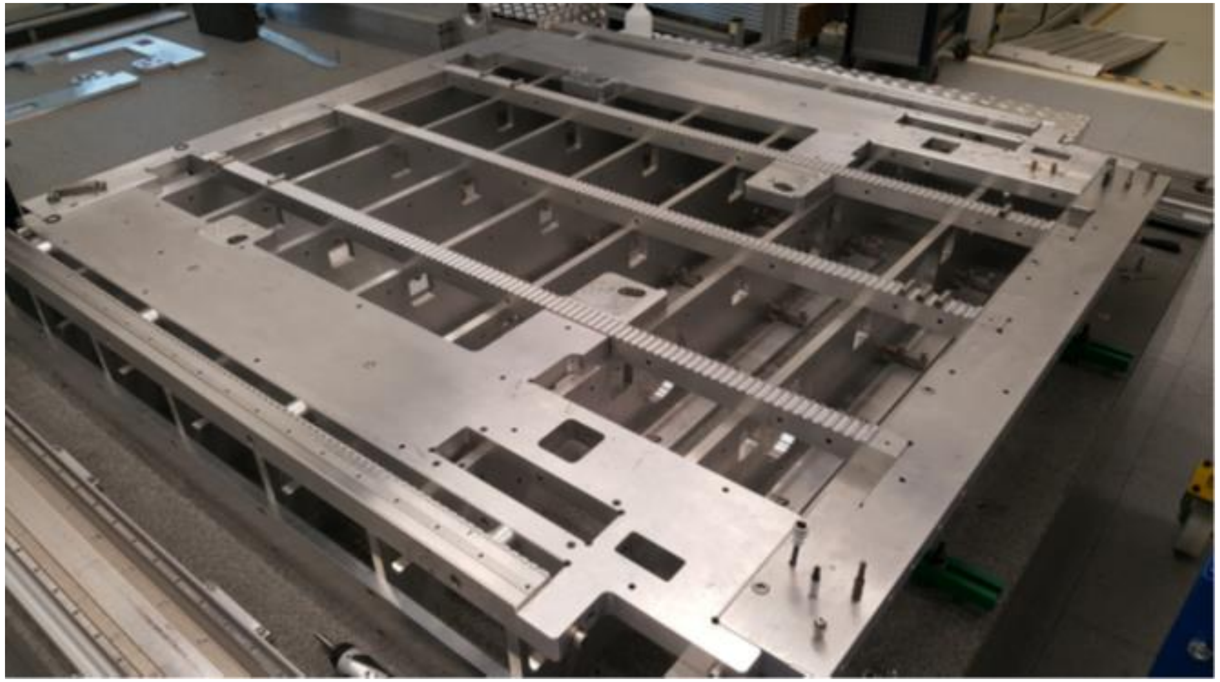
- the wires are parallel to the B-field
- This means that the E-field is perpendicular to the magnetic field
- this causes the muons to be deflected from their path, by the Lorentz Force

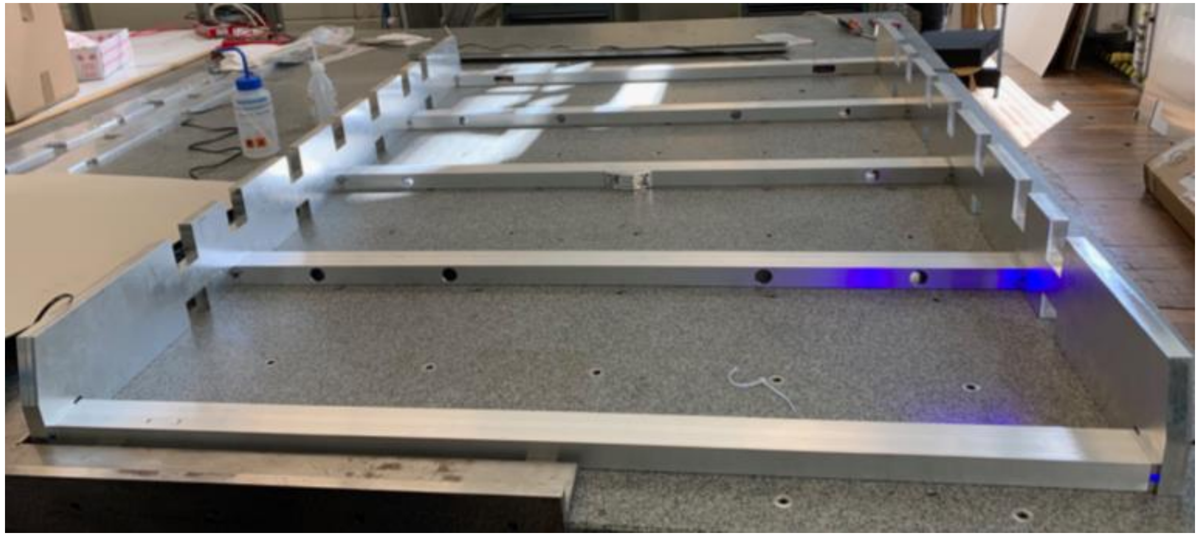


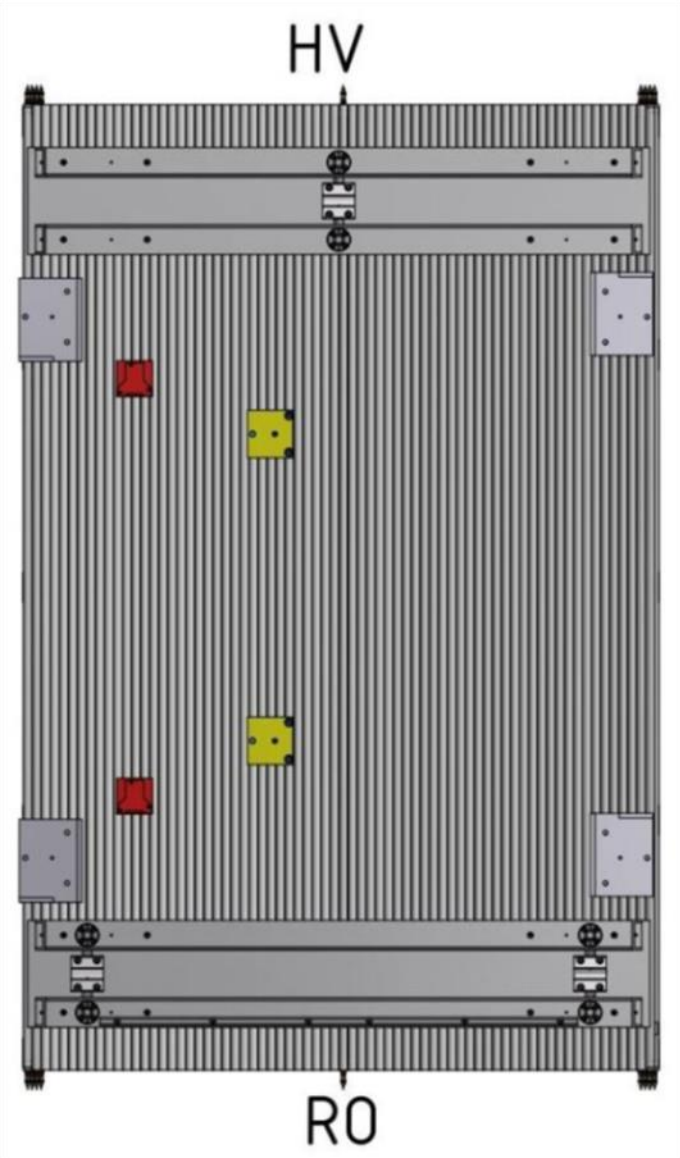
- ➢ drift tube chambers can only measure the coordinate vertical to the wire
- ➢ The Direction perpendicular to the proton beam is measured by the RPCs

Construction of sMDT chambers

- tubes and chambers are assembled in climatized room on a granite table
- The endplug reference surfaces are inserted into a grid of bores in the assembly jigs at each chamber end
- the tubes are then glued together
- After 4 layers of tubes the spacer is glued on top of the layers
- Then 4 more layers are attached
- After that, the gas and electric connections are assembled and the suspension points on which the chamber can later be transported are attached.






HV
RO

in-plane Alignment System

- sMDT chambers carry the Alignment System in the Spacer between the layers
- optical sensors are placed in the corners for more reliable measurements
- the System is needed, because deformations will appear in the chambers, due to suspension points and gravity, when they are moved or mounted in the Atlas detector
- different deformations: gravitational sag along the tubes and on the HV and RO side and a torsion angle between the HV and RO Side

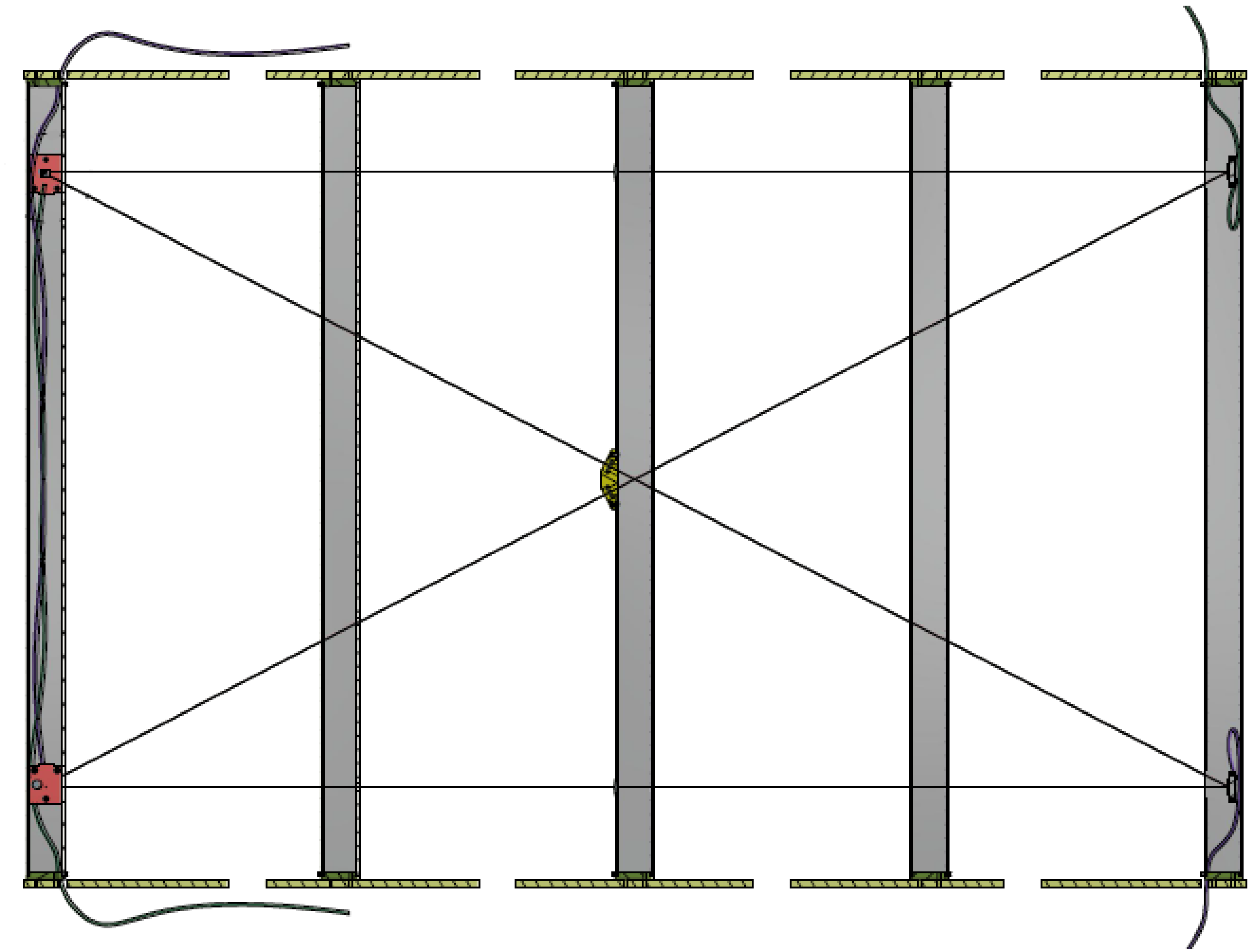
optical System:

4 Lenses, 2 CCDs, 2 LEDs with a Mask

➢ results in 4 optical paths: LL, LR, RL, RR

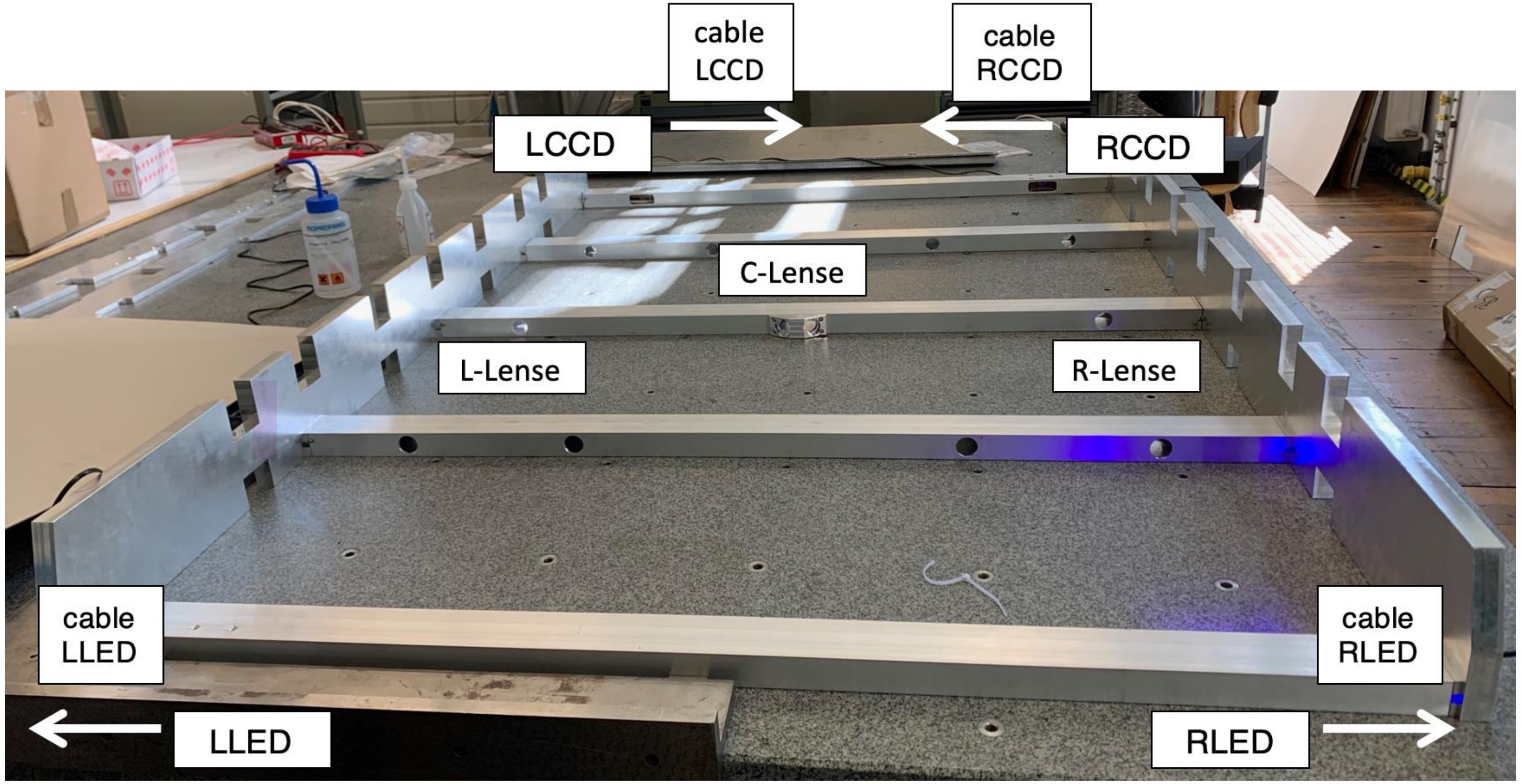
Drawing of the Spacer with the four optical paths

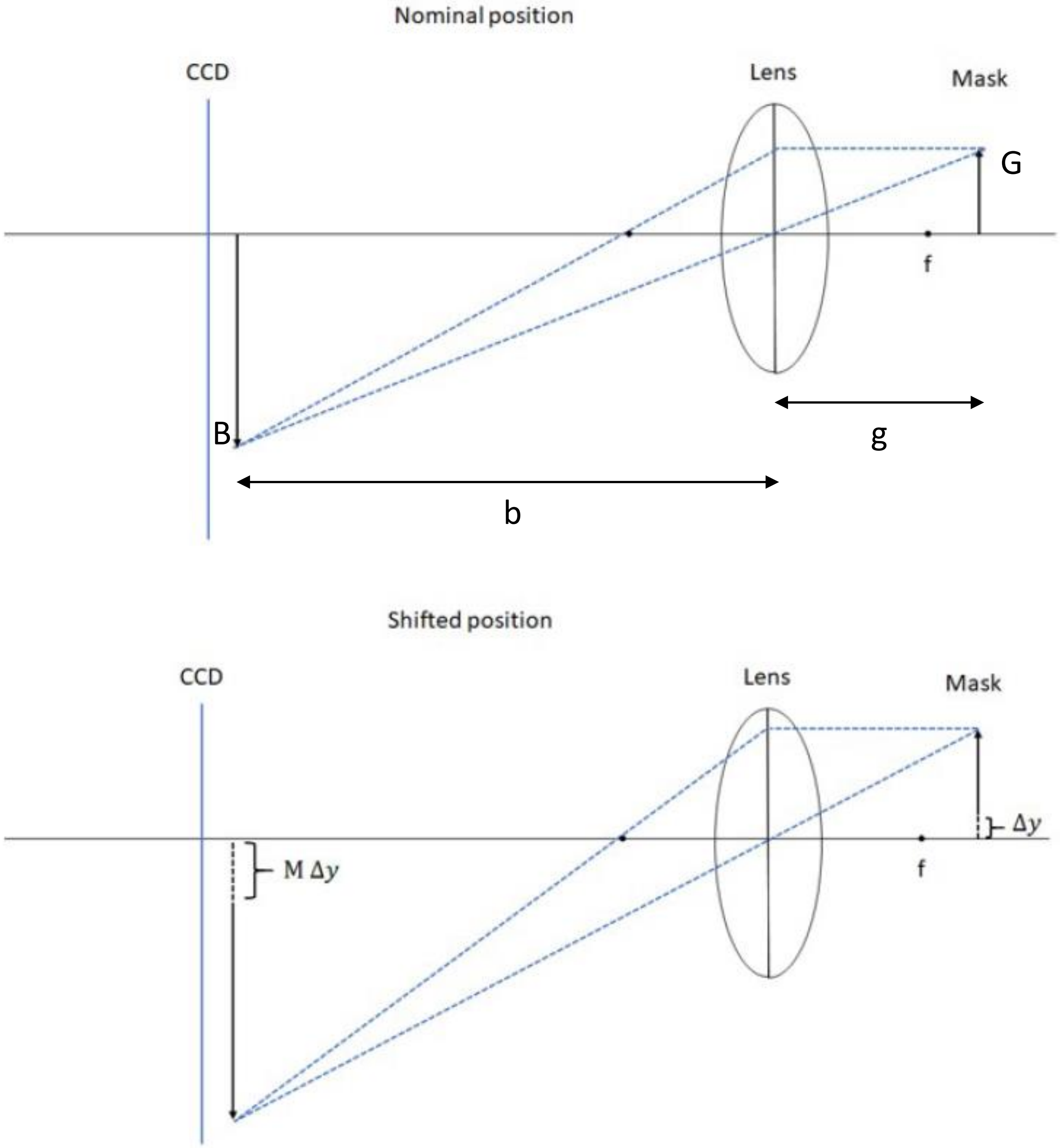
RO Side
with CCDs



HV Side
with LEDs

Spacer with the in-plane Alignment System





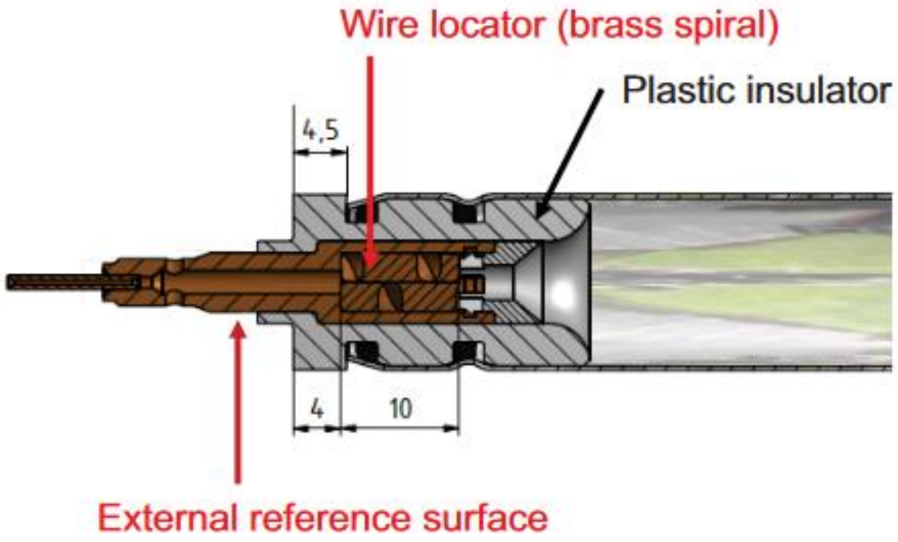
- Mask is shifted by delta y
- distance gets magnified by lens
- resulting shift on CCD must be multiplied by magnification

$$\frac{1}{b} + \frac{1}{g} = \frac{1}{f}$$

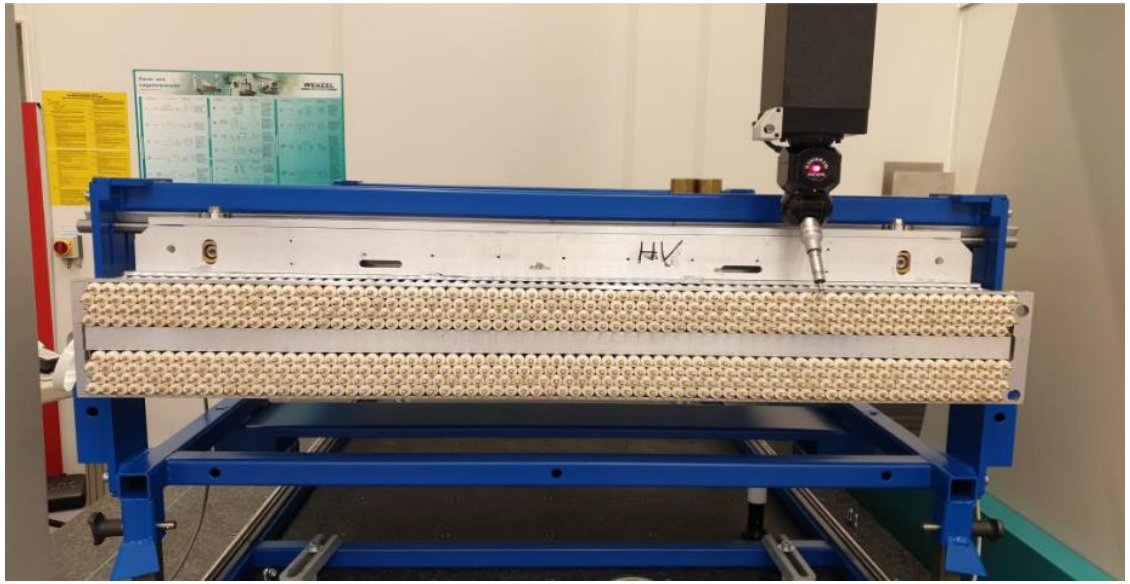
$$M = \frac{B}{G} = \frac{b}{g}$$

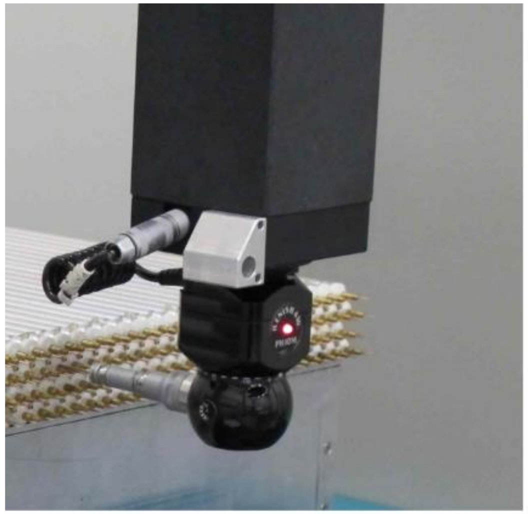
Endplug measurement

- The wire locator provides a reference for the wire itself
- And the external reference surface provides a reference for the wire locator
- So, the external reference surface is scanned with 6 points
- Then the wire position is derived by these 6 measured points



CMM Machine





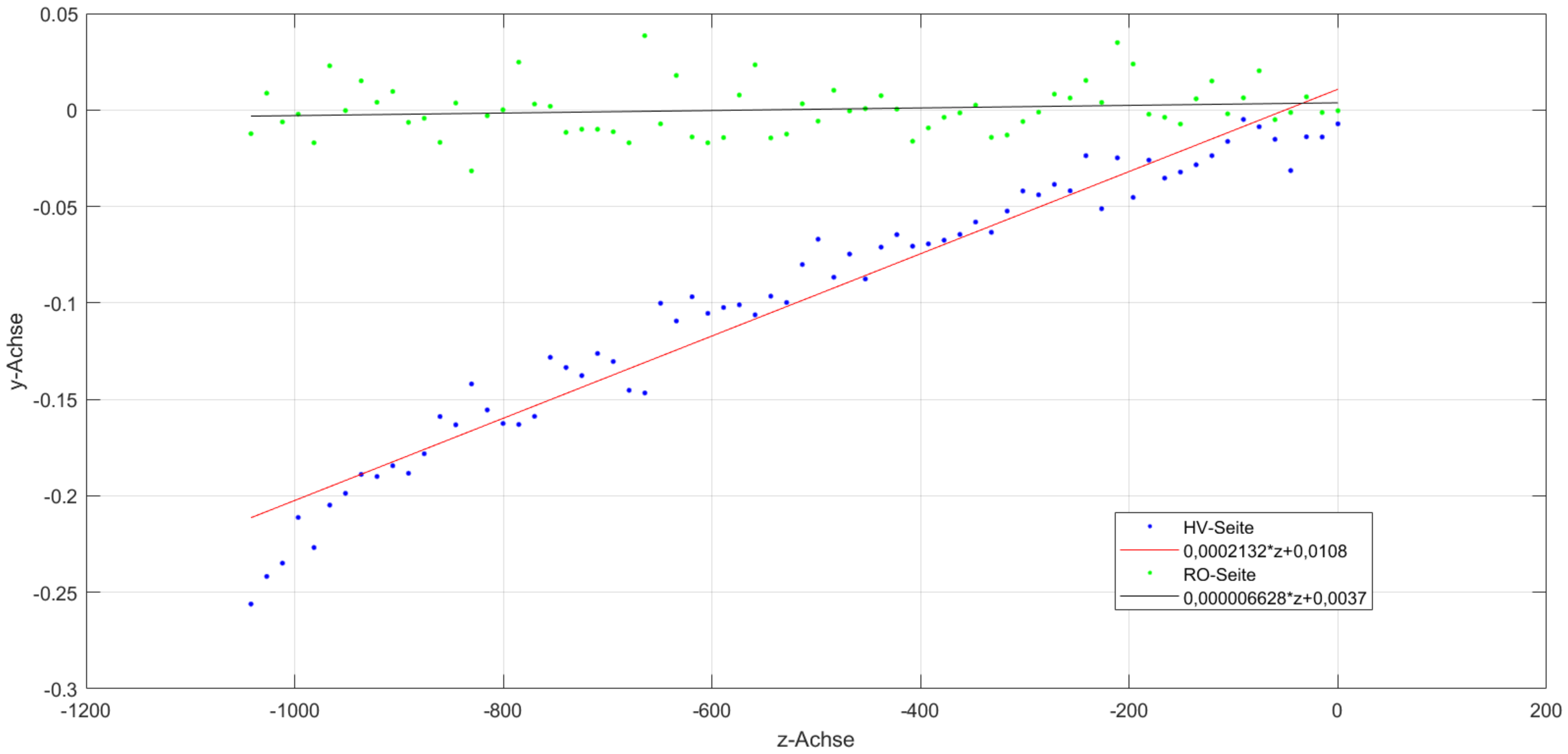
Deformation program of the MPI

- The program is fed with the in-plane data measured on the granite table and the measurements with the weights
- Also, the dimensions of the chambers and the positions of the optical components are entered.

➢ The program reconstructs from these data the positions of the end plugs on the RO and HV sides

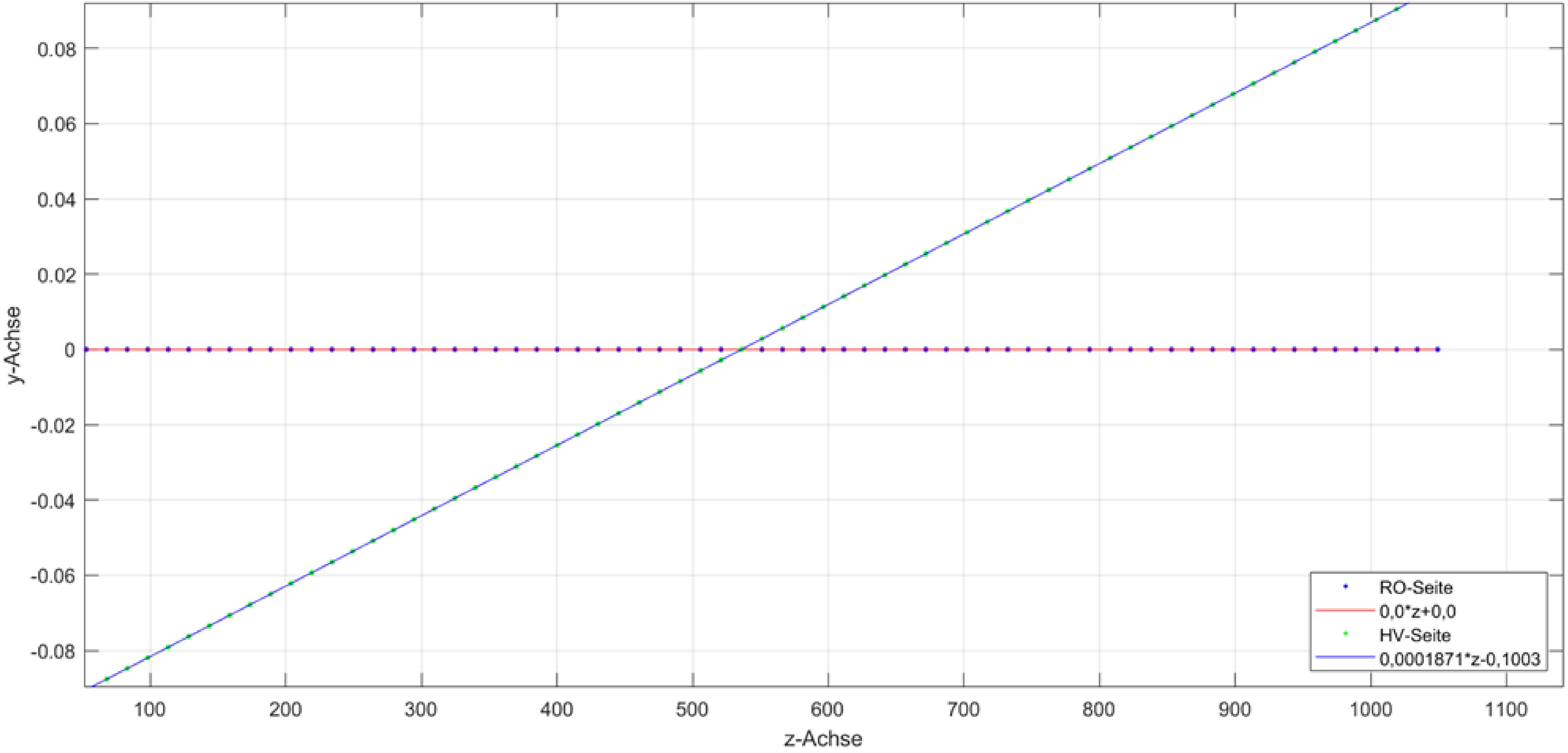
➢ And the values of three gravitational sags and the angle of the torsion

CMM Data



Torsion 206,5 µrad

in-plane Alignment Data



Torsion 187,1 µrad

Summary

- For the upgrade of the LHC to the HL-LHC, the ATLAS Muon Spectrometer requires upgrades
- In order to install new RPCs in the barrel inner layer the MDTs must be replaced by sMDTs
- An in-plane alignment system will be installed to each chamber to measure the chamber deformations, like torsion or gravitational sag
- To understand the various deformations, the in-plane alignment system must be tested
- Therefore, various artificial deformations are made, by placing weights on the chambers
- After that, the in-plane alignment data is compared with the measured positions of the endplugs of the HV and RO Side of the chamber

Thank you for listening

Questions?