Hardware-based CMS Alignment

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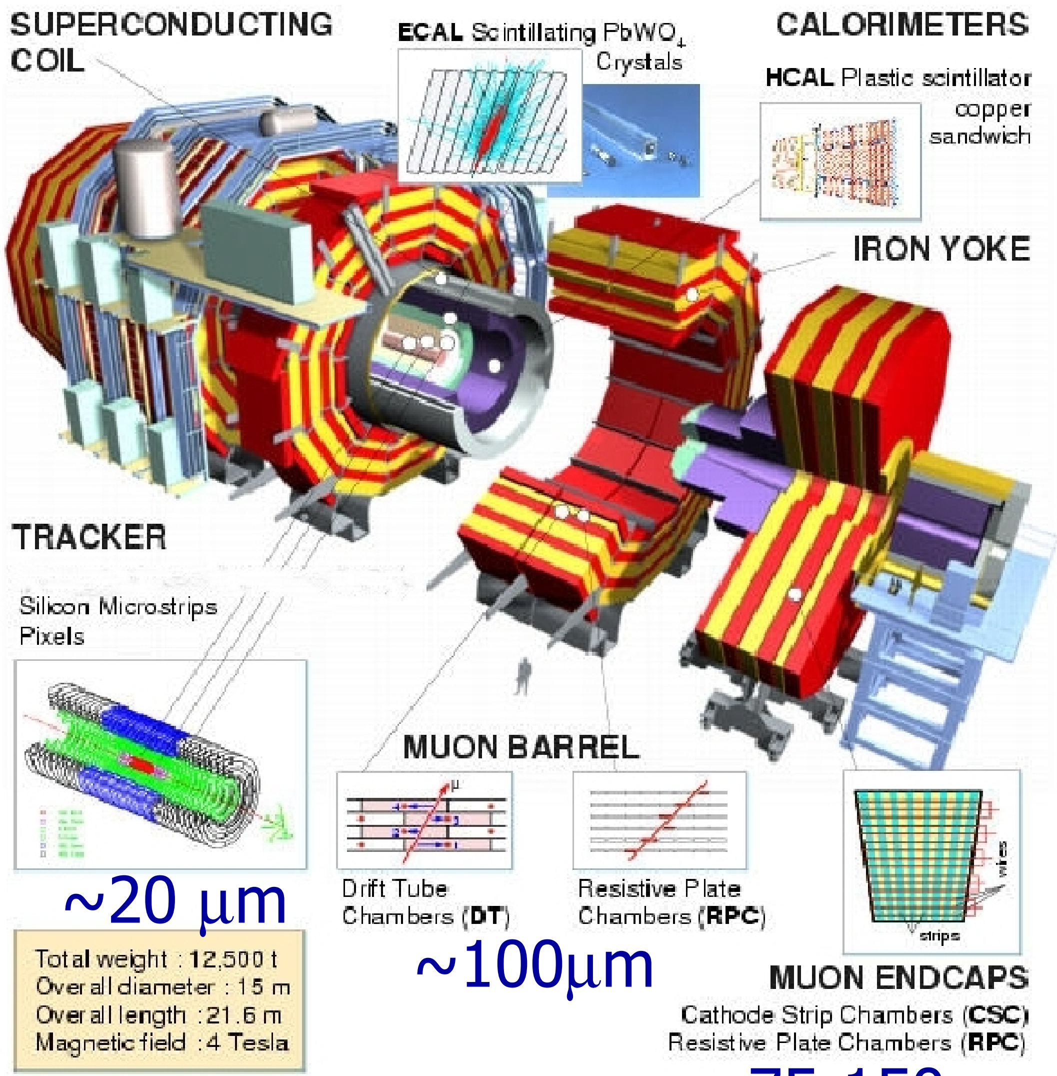
Outline

- Introduction
  - Tracking at CMS
  - The alignment task
  - Steps toward a Hardware alignment.
- Alignment subsystems overview
  - Inner tracker
  - Global alignment: Link system
  - Muon spectrometer: Barrel, Endcap
- Initial Magnet Test and Cosmic Challenge "lessons"
- Summary and conclusions

Thanks to Bruno, Martin, Pablo, Vladimir and Zoltan for their help and plots

Introduction – CMS Tracking



~20 μm

~100μm

~75-150 μm

Range of expected Motions:

~1-3 cm from B on/off

< 500 T and humidity

Radiation

- Hard radiation environment
- Photons, neutrons, charged hadrons
- Dose: 1- 100 x 10^3 Gy (10 years)
- Fluence 5 x 10^{10} - 2 x10^{14} n/cm^2 (10 years)

Magnetic Field

- 4 Teslas
- Gradients up to 600 Gauss/cm
- Complex field map

Introduction – Alignment Overview

- Hardware alignment (position monitoring) tasks:
  - Silicon tracker internal alignment
  - Muon spectrometer internal alignment:
    - Barril zone
    - EndCap zone
  - Global alignment: Relative positioning of TK wrt Muon spectrometer
    - Link system.
- Different geometries, tracking technologies, requirements $\Rightarrow$ 4 systems based on different technologies.

Intro. Common road map to Hw align.

System Design

Design modification

Selection/calibration of components/devices

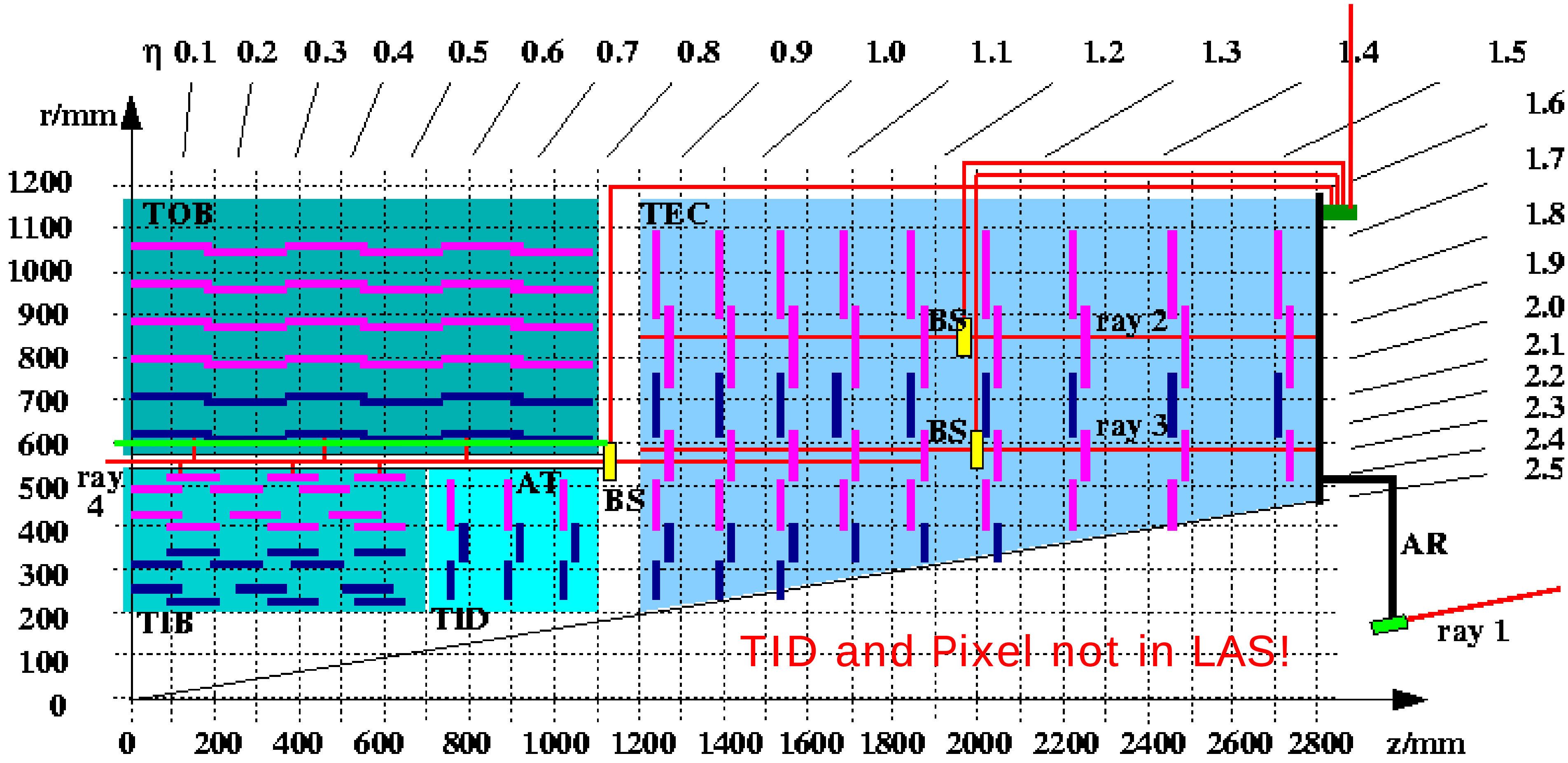
Assembly/mounting/fiducialization of components on “rigid” supporting structures

Installation and adjust of the system in the detector

Geodesy grids, photogrammetry and other metrology technologies are a must

Thanks to CERN TS-SU Survey Group

TK local Alignment – LAS system

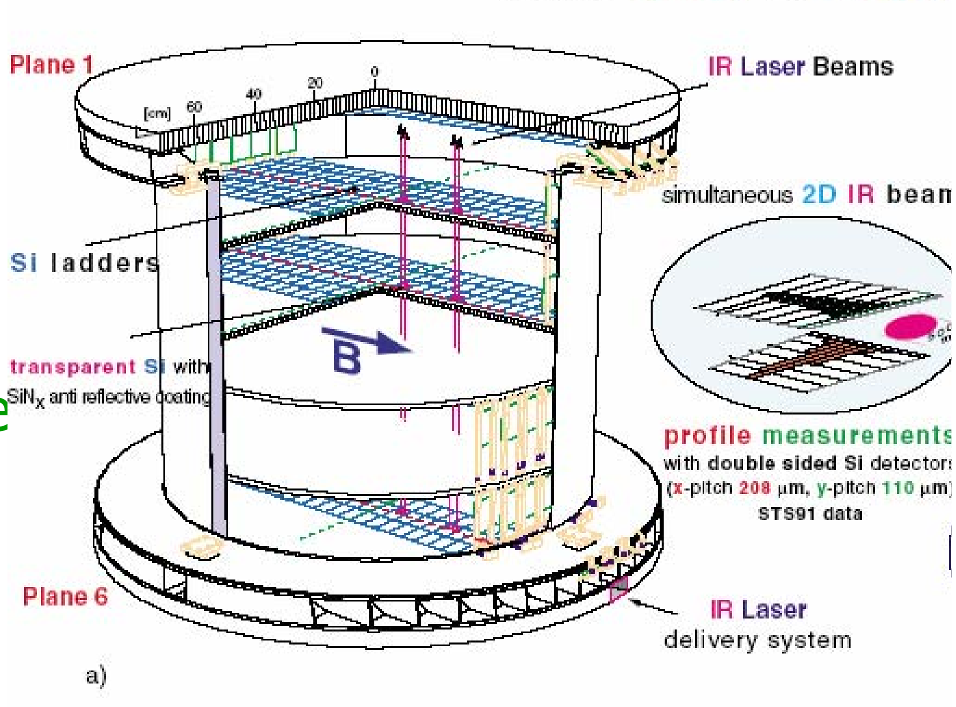


BS: Beam Splitter AT: Alignment tube **AR: Alignment ring**

LAS - Advantages

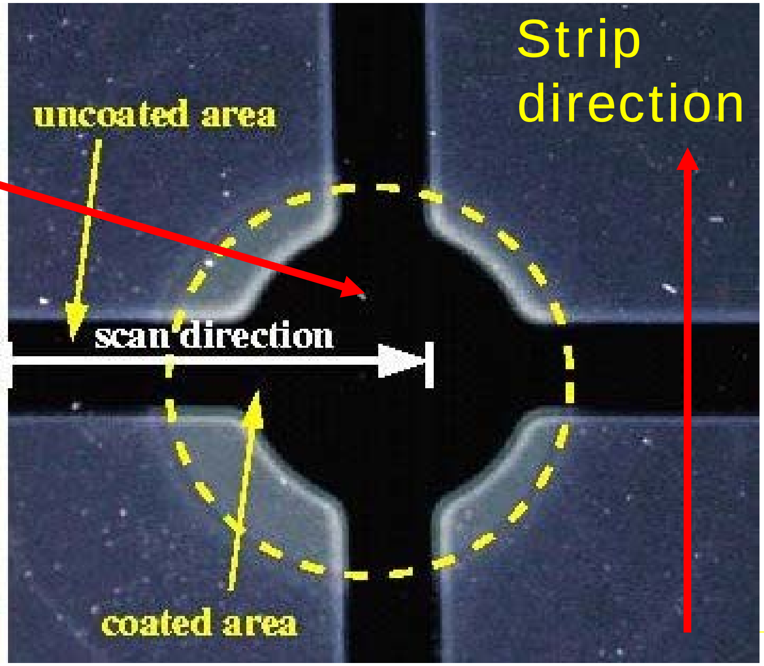
- Main advantages:
  - Particle tracks and laser beam share the same sensors removing the need of any mechanical transfer.
  - Minimum interference with Silicon support structures
  - No precise positioning of the aiming of the collimators. The number of measurements has to be redundant enough

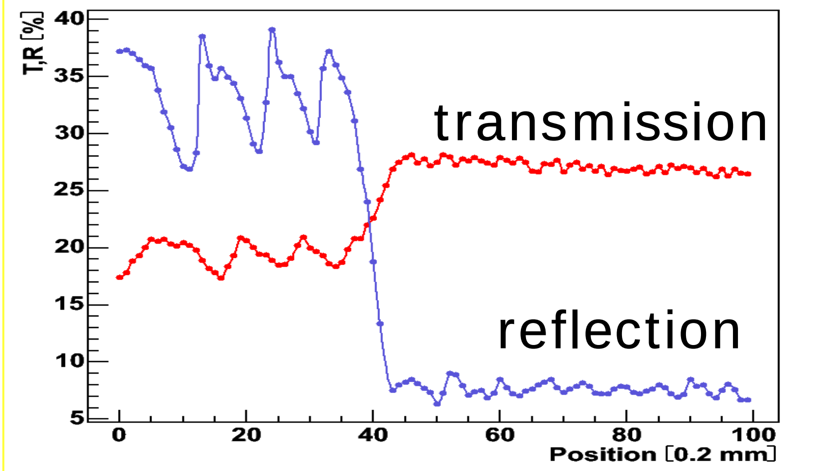
AMS I Align. System



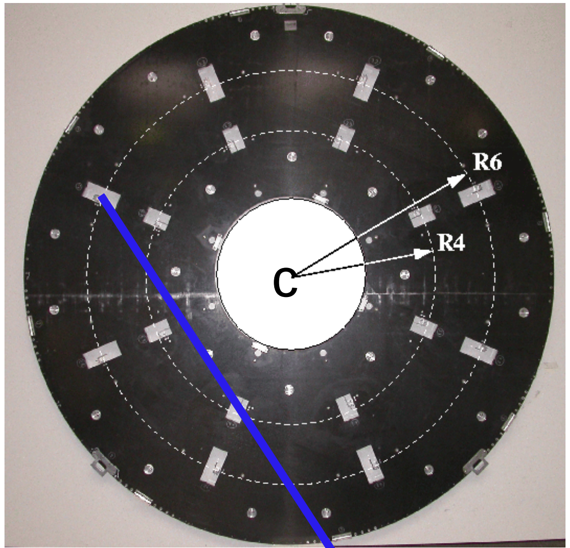
LAS – Optical treatement of sensors

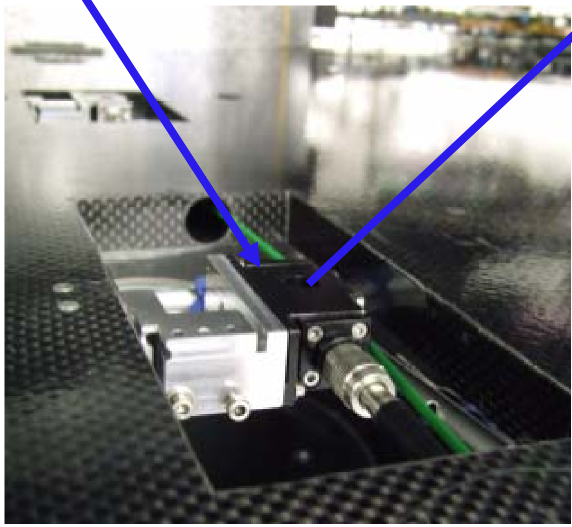
- 10 mm hole in aluminum backside coating
- All sensors with anti-reflective coating
  Transmission measured to be
  14-20% (R4) and
  13-18% (R6)
  (at λ=1075 nm)
- Reflectivity <= 6%

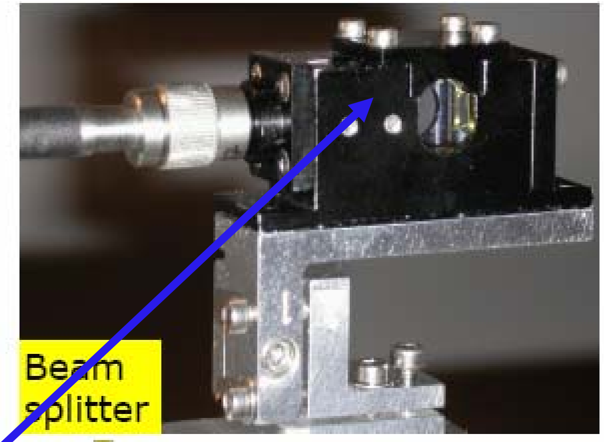


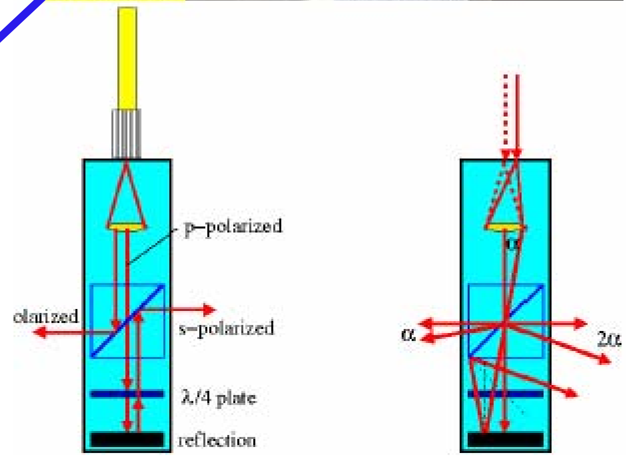


LAS – Collimators/splitters



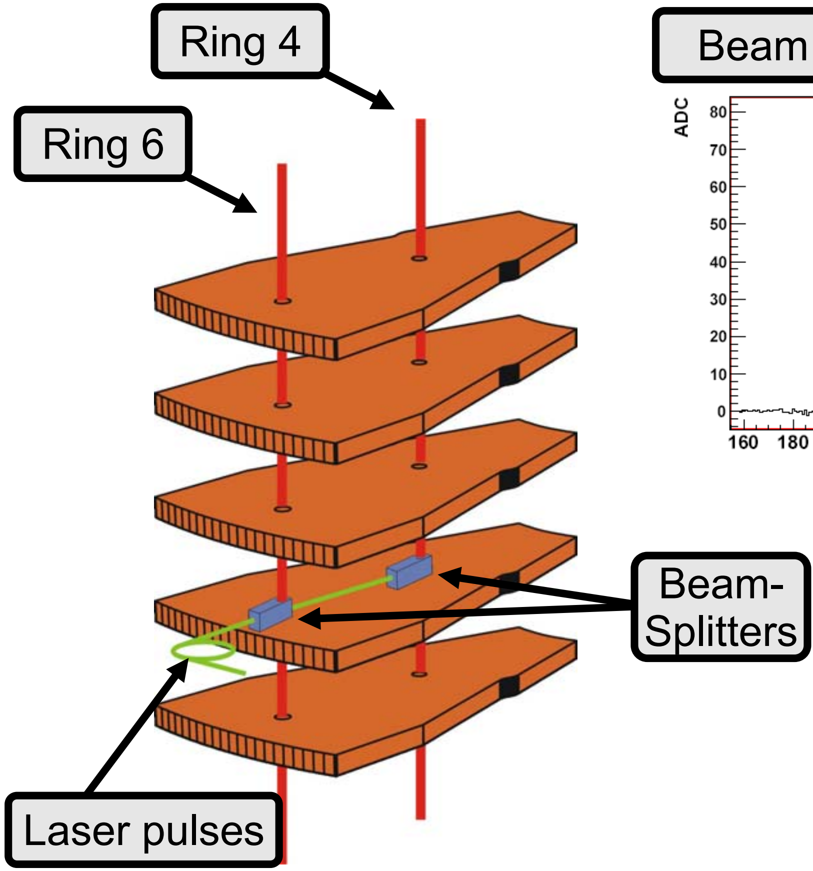




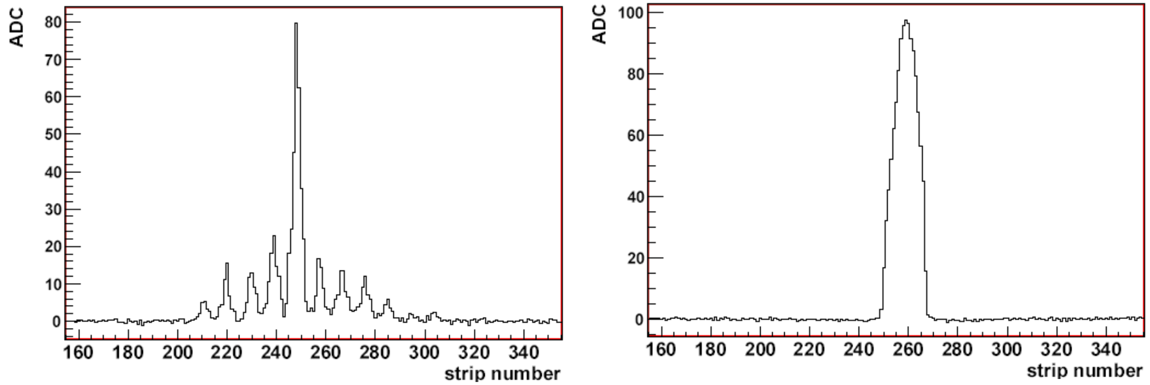


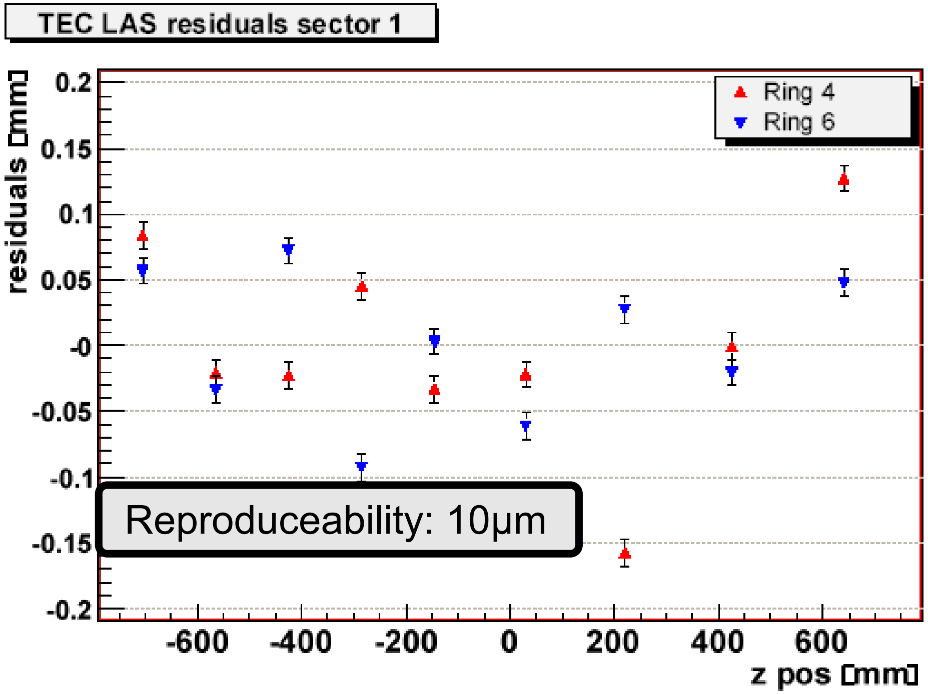
Colinearity of laser beams meas. at 50μRad

LAS – Performance @ TEC integration



Beam Profiles for Disc 2 and Disc 6



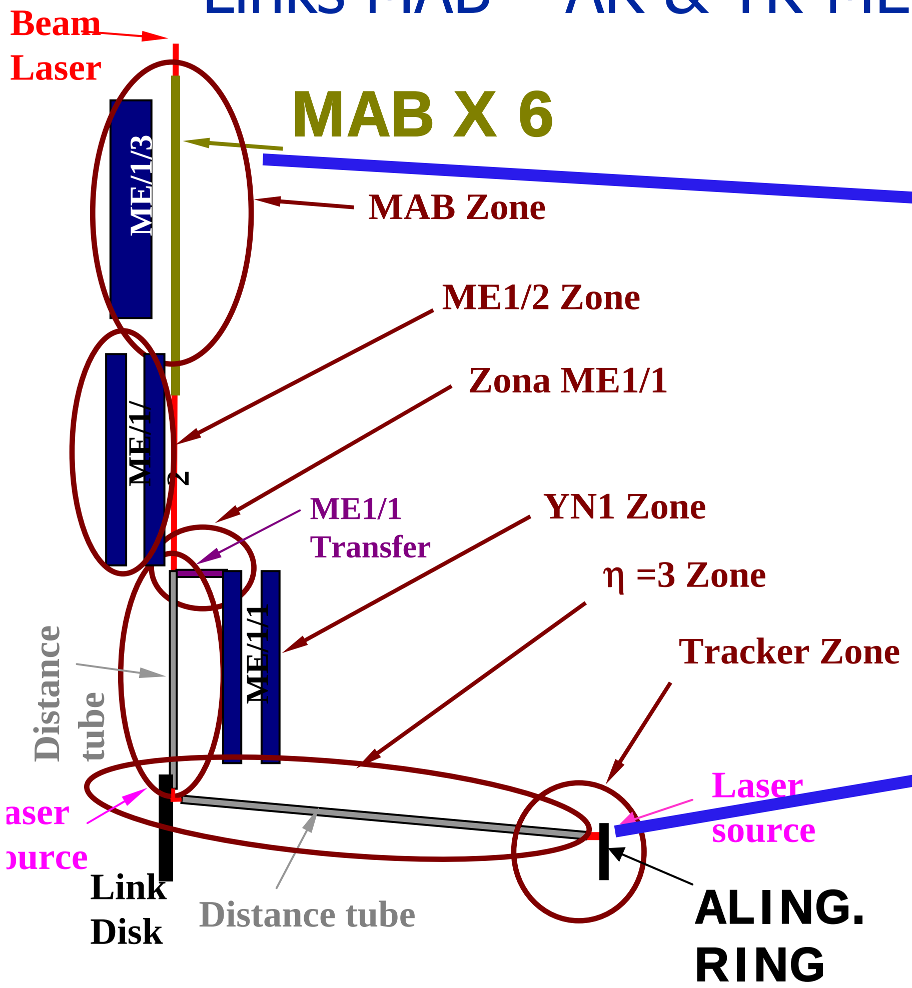


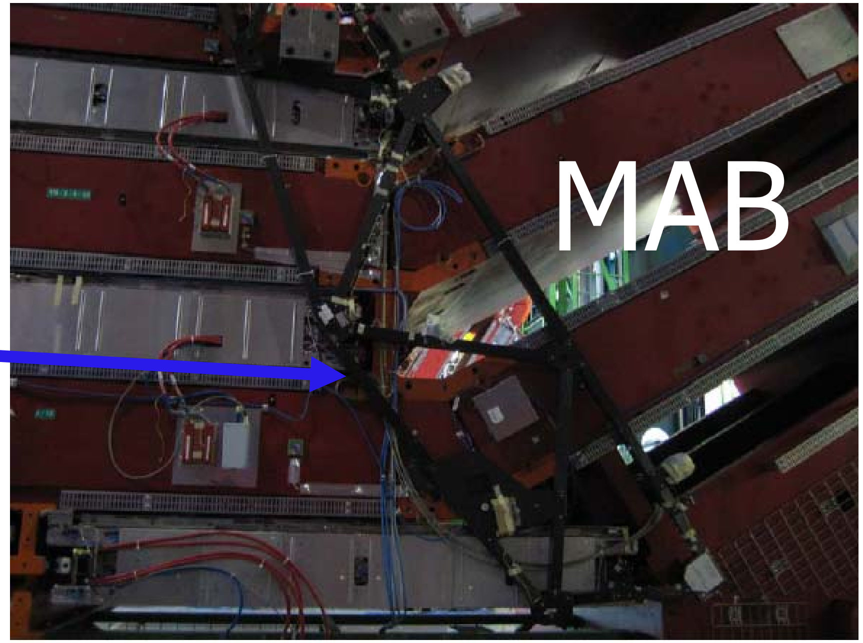
RMS of Residuals in first Sector: <70µm

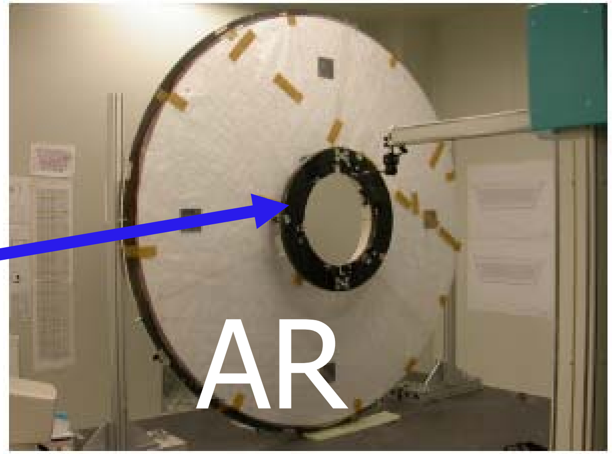
Global Alignment – Link System

Laser-based Multipoint monitor

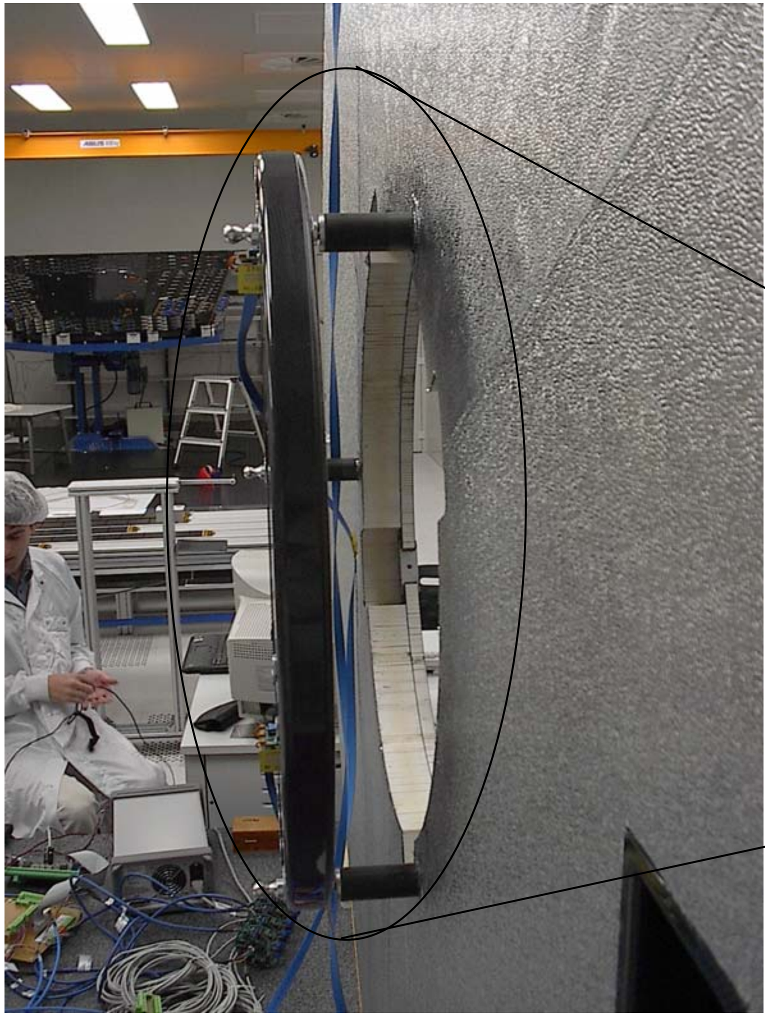
Links MAB – AR & TK-ME1



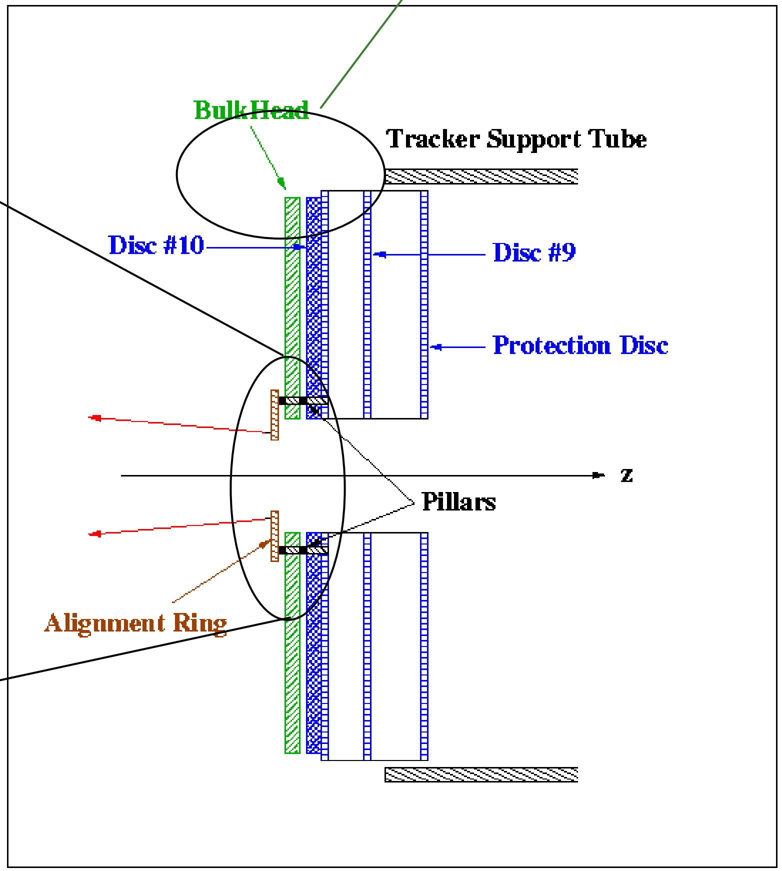




Link – AR / TEC integration



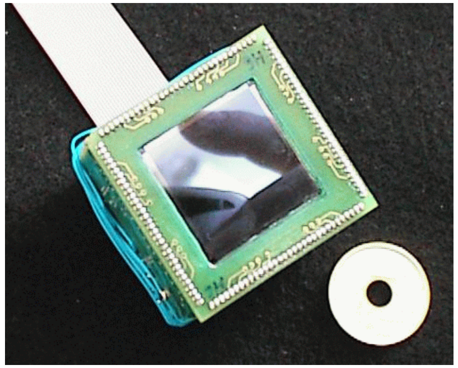
MTCC Configuration
(shorter TK support tube)

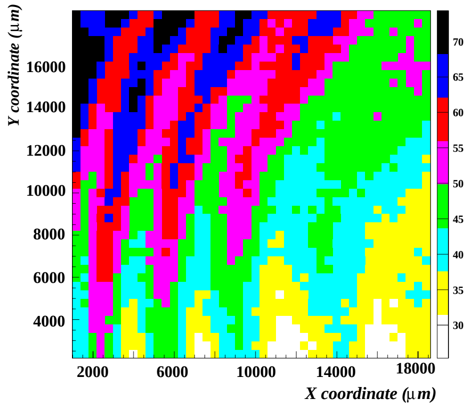


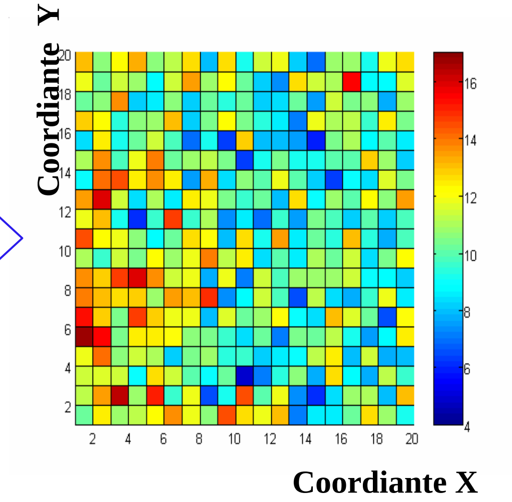
CF pillar attached directly to Disk 10 (outside the cold mass and tension-free suport design)
3D relative position of AR wrt silicon supports of disc 10 are measured in Aachen

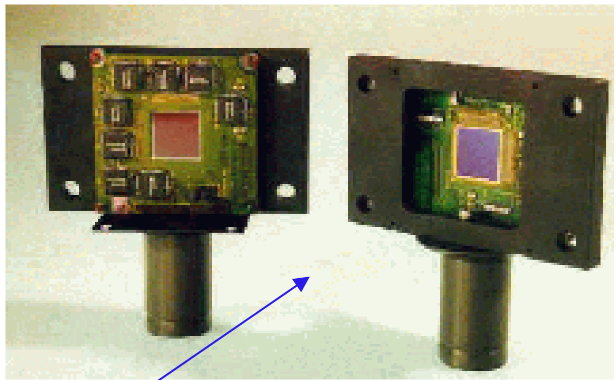
Link – Semitransparent ASPD sensors

- At lot of R&D on amorphous silicon semitransparent sensors
  - Improved version based on previous “ALMY” sensors for Atlas muon alignment







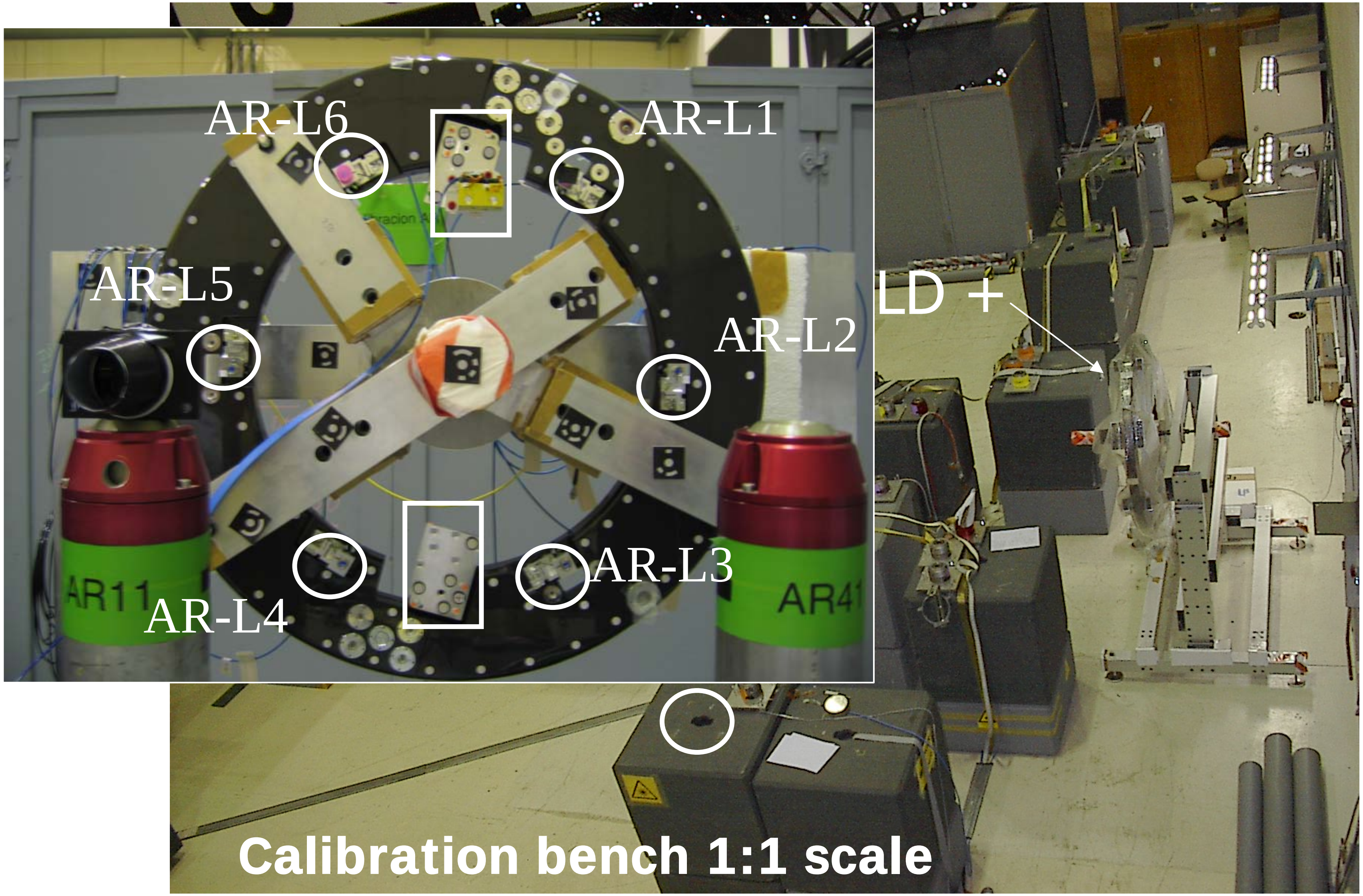


Deflex ~Tens of μRads

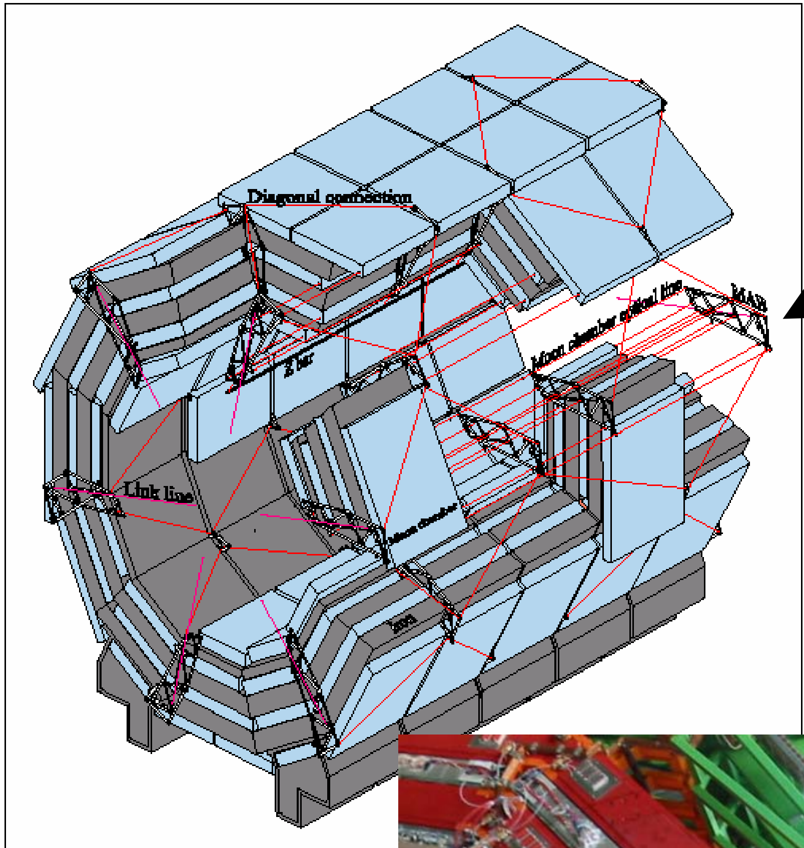
Deflex ~few μRads

Used as a tool at the geodesic grid for calibration too!

Link Calibration geodesic network

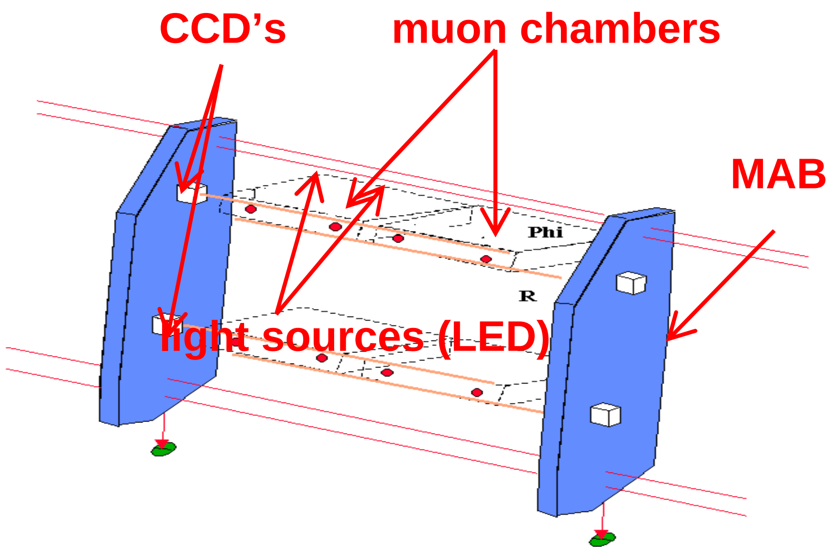


Muon Barrel Local Alignment



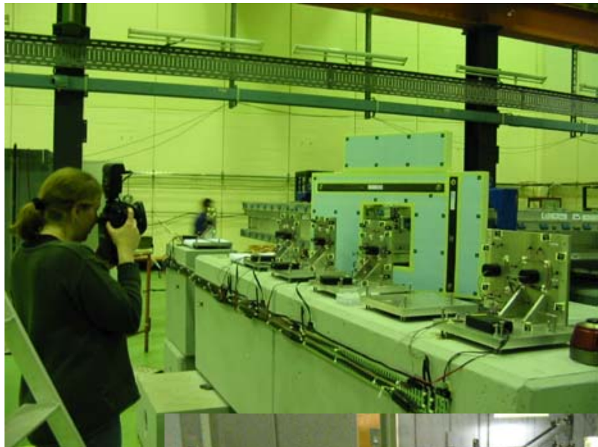
Highly reduntant triangulation measurement.

LED sources installed in the muons chambers monitored by Video cameras located in rigid CF structures (MAB)



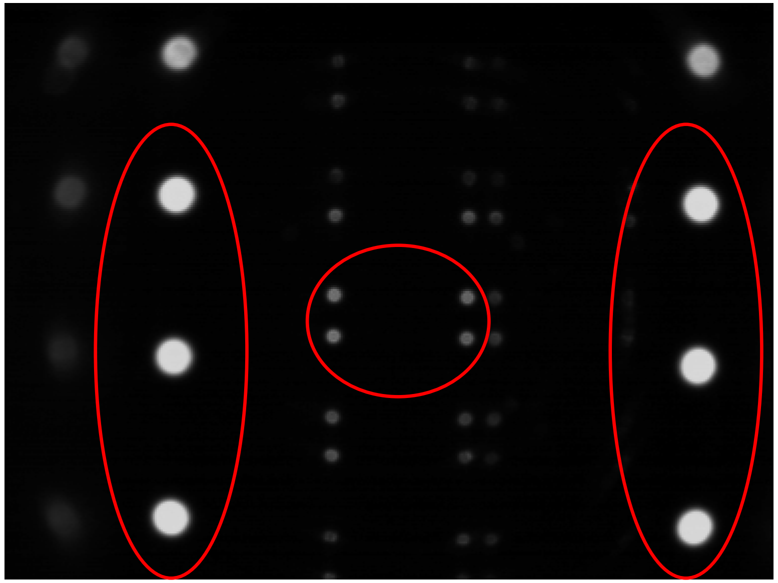
Muon Barrel – Calibration challenge

- ALL muon chambers are instrumented and monitored
  - Thousands of components are to be installed and “calibrated” before installation…



Muon barrel second challenge

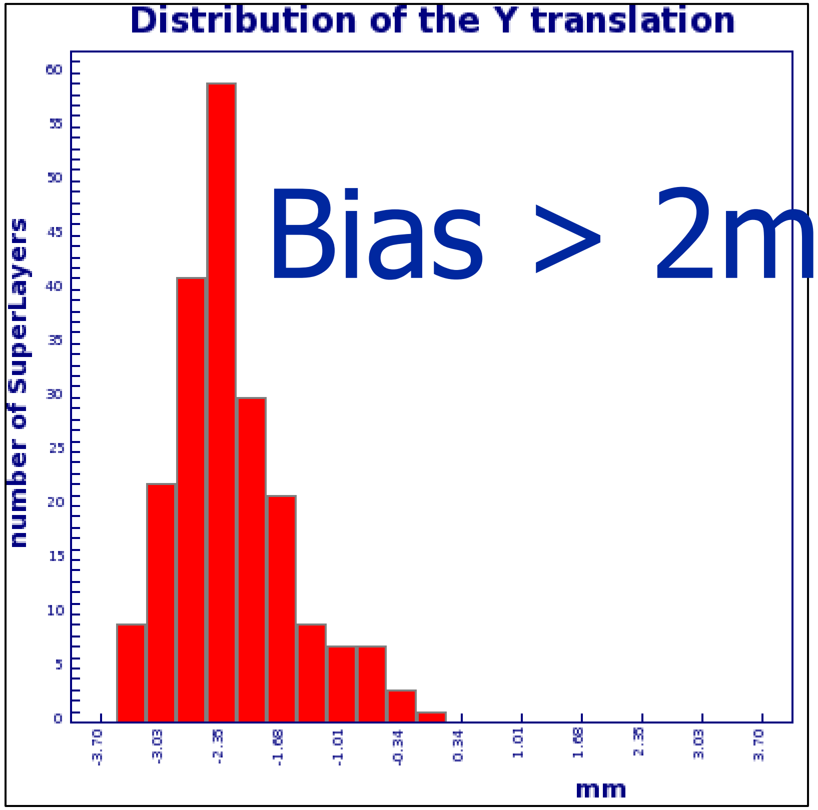
- Recognition of real vs. reflected LED spots



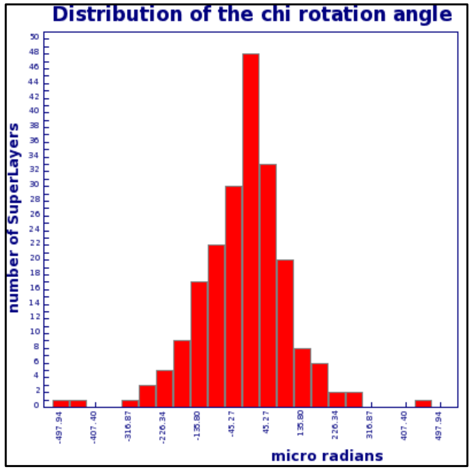
This is a real image taken on forks installed on a chamber. Larger dots belong to the closer fork, while smaller dots are spots of the farther fork. Inside the red markers the real spots can be seen. All the other spots are reflections.

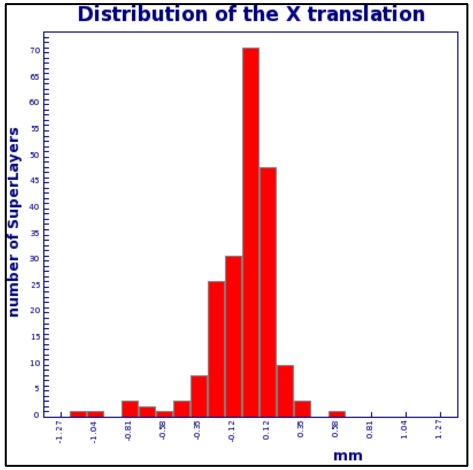
Barrel – First "results"

- Event before starting… wire layer "SL3" nominal location from calibration.



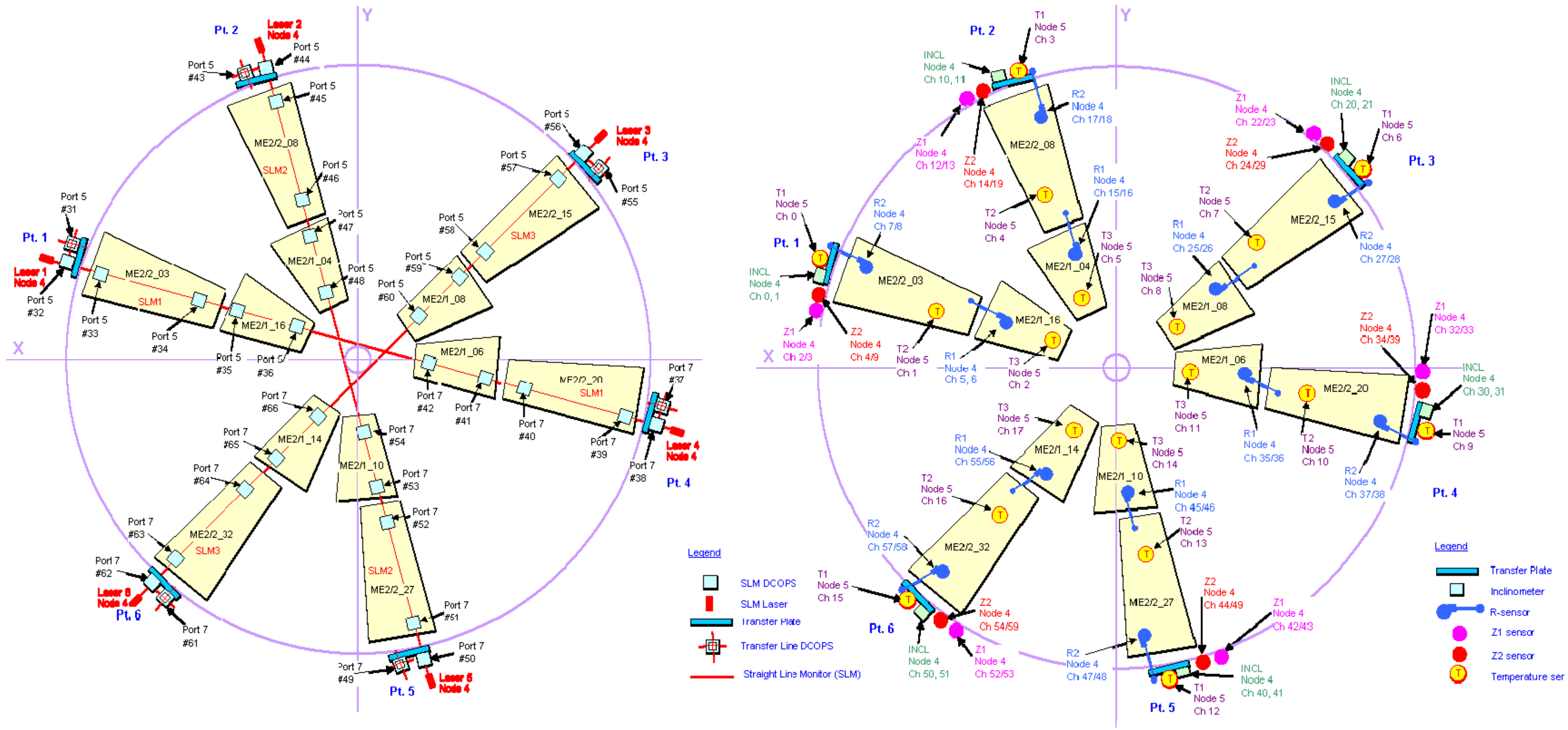
Bias > 2mm





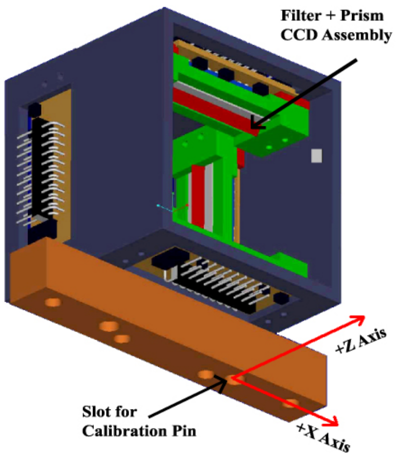
Muon EndCap Local Alignment

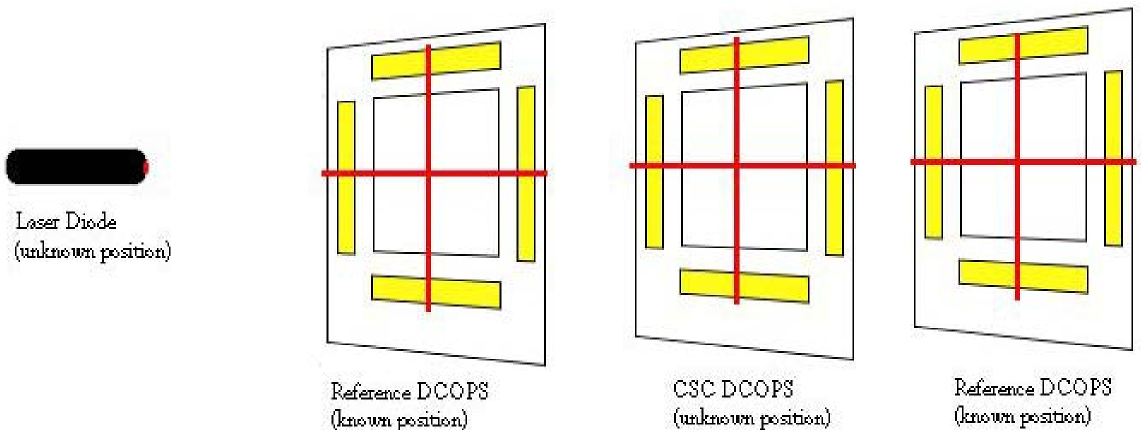
- Straight line monitors + potentiometers network



Muon Endcap – “Transparent” sensors

- Crosshair laser beam + CCD window frame





Muon Endcap – Hardrad CCD?

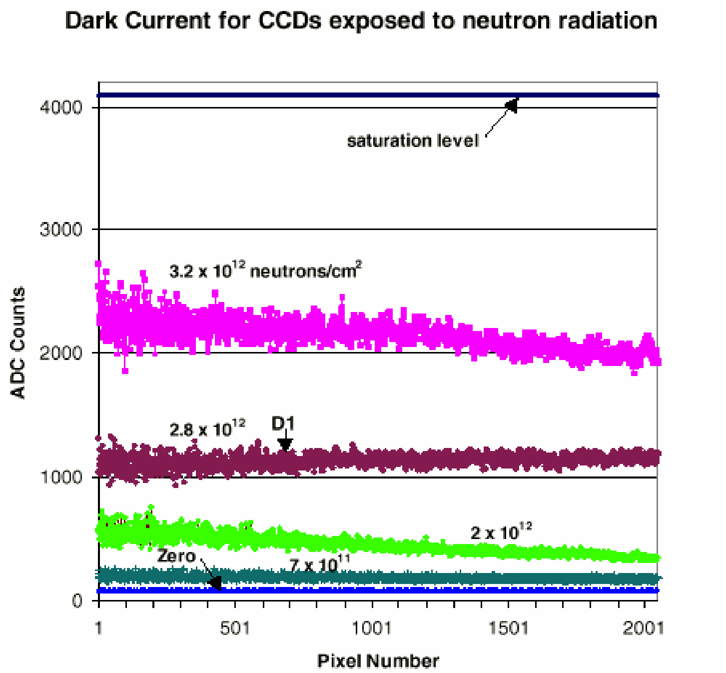


Fig 1. Dark current spectra for irradiated CCDs, taken with the new COPS prototype. The number next to each spectrum is the corresponding radiation dose, in neutrons/cm2. The lowest line corresponds to a non-irradiated CCD.

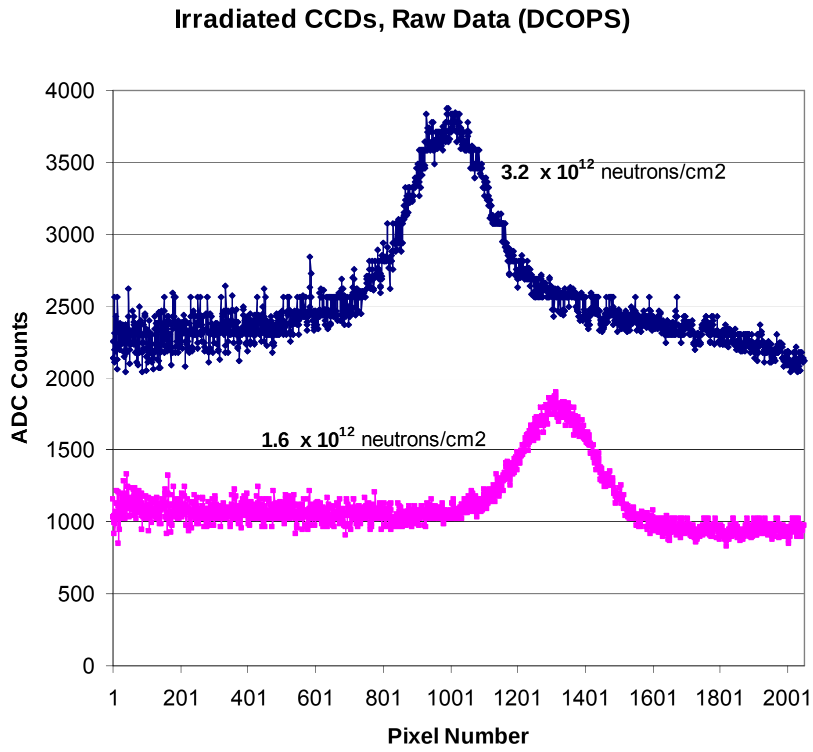
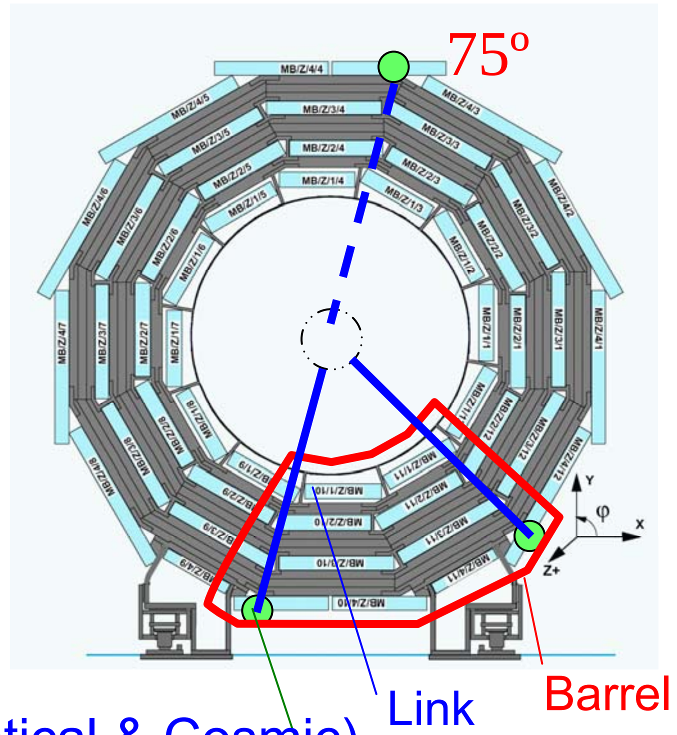


Fig 3. Raw spectra of two of the irradiated CCDs, showing the peaks produced by the laser lines.

Magnet Test and Cosmic Challenge a.k.a MTCC

Very significant fraction of all the muon alignment system commissioned.

- Let's switch the magnet on and see how things move:



Aims:

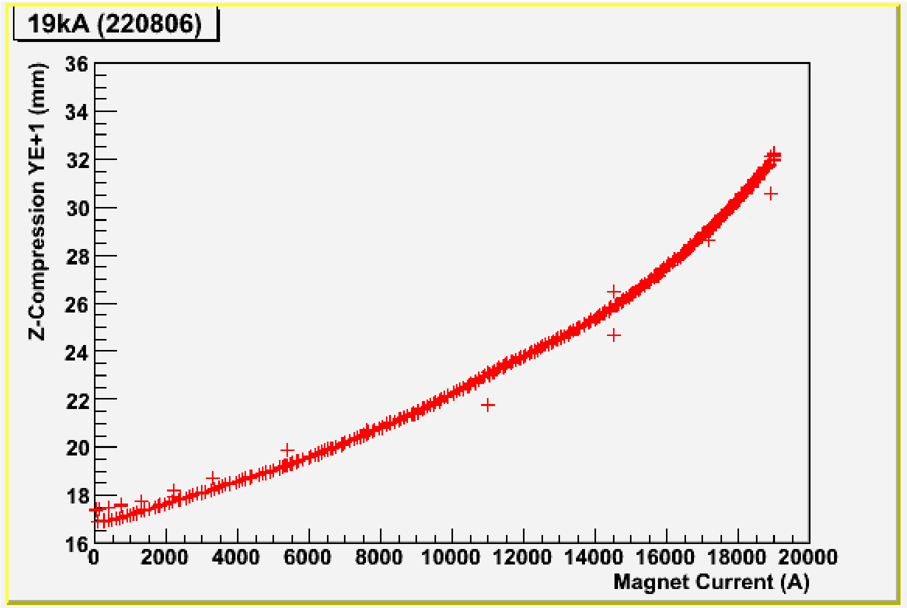
- System Commissioning (Hard & Control)
- Check Detector Assembly Tolerances & field effects vs system dynamic range
- Monitor Iron deformation (endcap disks)
- Extract initial CMS geometry from B = 0 T (Optical & Cosmic)
- Compare Cosmic data vs optical alignment (@ B: 0 and max field)

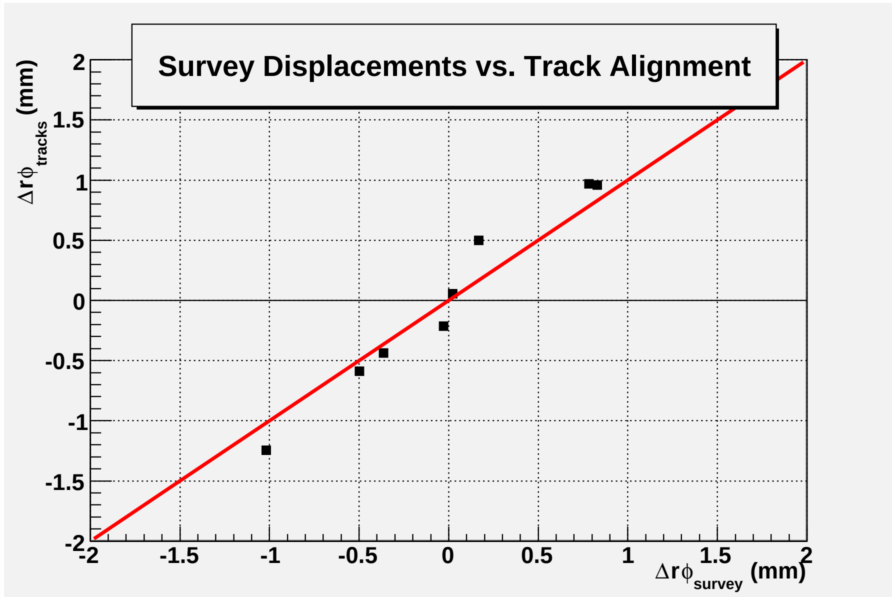
MTCC aftermath (very, very preliminary)

- What we have learn ?
  - How (some)things move (next)
  - How (not) to install/adjust some of the components.
  - The actual help (accuracy) we can expect from survey at field B=0.
  - Installation tolerances far from promised in some cases.
- What we have encounter?
  - "Anticipated" issues (not all of them solved).
    - Crashes when closing the yokes.
    - Difficult adjustments of components.
  - Non anticipated issues (sensitivity to B of electronics.)

MTCC – First results/observations

- Real time monitoring of Iron yoke movements vs. magnetic field.
- Track vs. Muon chamber Survey (Sector 10)





Summary

- Hardware alignment systems extremely complex (thousands of r/o channels)
- Large collaborative effort (Atomki, CERN, Ciemat, Fermilab, Florida, Cantabria, RWTH, University of Debrecen…)
- Many ad-hoc solutions & innovative developments.
- This is just a very coarse overview…*precision* is in the details.
- First performances under real fire (MTCC) tell as that we are in the right track toward a "Fast" alignment, BUT there is still a long way to go…

BackUp

Introduction – Main Technologies

- Local TK alignment:
  - Gaussian profile laser lines monitored with optically treated microstrips detectors.
- Local alignment of μ-spectrometer (Barril):
  - LED placed on chambers and monitored by video cameras on very rigid FC structures
- Local alignment of μ-spectrometer (EndCap):
  - Cross-hair laser profiles monitored by ccd frames on top of the chamber covers.
- Global alignment:
  - Gaussian profile laser lines monitored by custom made semitransparent PSD sensors on top of rigid FC structures.

Alignment systems - The challenges

- Barril Muon spectrometer:
  - 240 chambers to be monitored directly with a few hundred microns precision
- End Cap Muon spectrometer:
  - Precision better than a few hundreds of micron.
- Global alignment: Link system
  - Linking the TK and μ-spectrometer reference frames with a few hundred microns and tens of microRads.