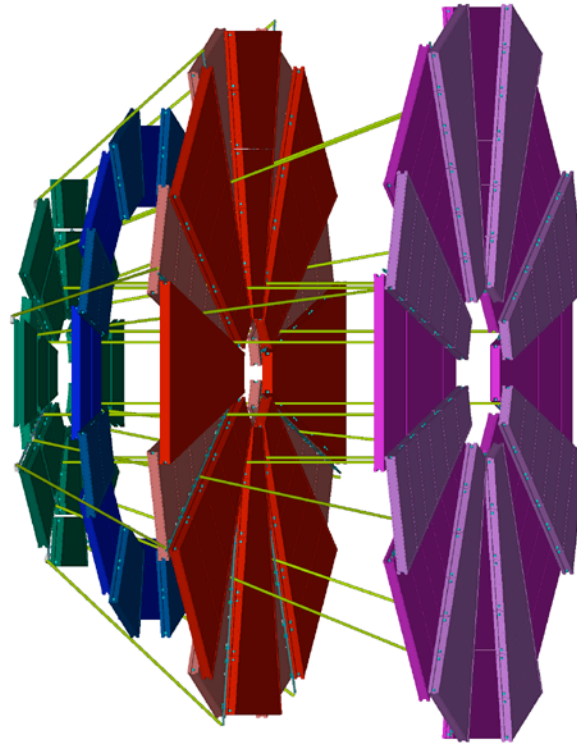




ATLAS Muon Endcap Alignment



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Brandeis University/BMC
Siena_04 – May 24, 2004



Basic Concept of ATLAS Endcap Muon Alignment

To determine the location of the ATLAS muon endcap chambers, a grid is setup with alignment bars and CCD cameras looking at light source, using a quasi-projective geometry. The chambers are then referenced to this grid. Chambers are monitored, not moved.

Aluminum bars, up to 9.6 meters long, form the basic "rulers" of the system. They are instrumented with internal straight-line monitors (RASNIKS) and temperature sensors. They are then carefully measured using a large CMM. The subsequent shape of the bar is determined by calculations, calibrated by the readings of the internal monitors. These bars can be considered precision rulers.

The relationship between the bars is then established by a network of CCD cameras (called BCAMs) that measure the bearing angle of light sources on the other parts of the system. The system is over determined and the location and orientation of each bar and sensor is determined using a fitting program.

Chambers are then referenced to the alignment grid using proximity sensors. For this purpose for each small and large chamber pair is considered a logical unit. The sensors used are a combination of RASNIK proximity sensors and BCAMs.

Chambers are considered "perfect". By construction of the chamber monitors its own deviation from perfect and provides the necessary corrections.

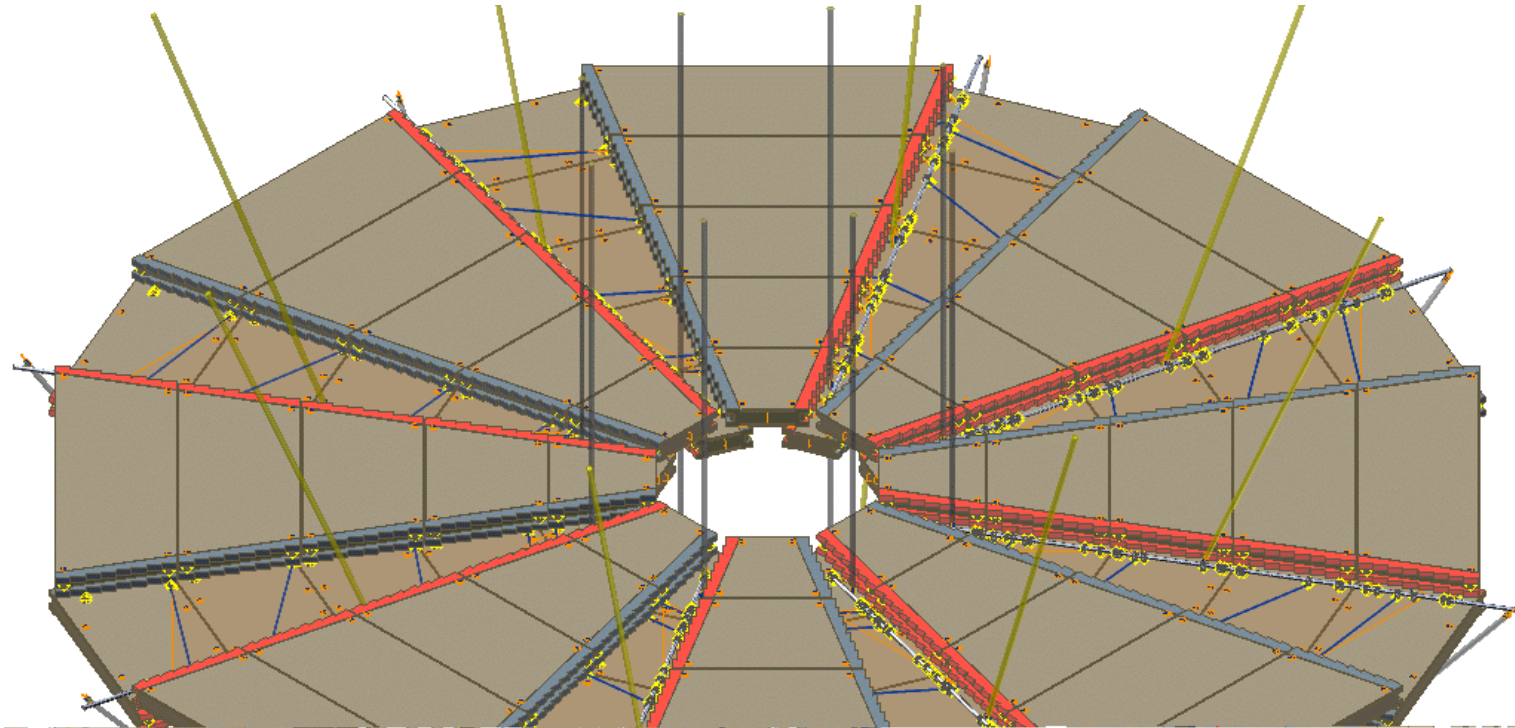


Specifications

- **Monitor chambers – not move them.**
- **Tube wires placed to ± 2 milliradians with respect to each other within a sector. This comes from second coordinate resolution**
- **Dynamic range ± 10 mm. This come from the range of the RASNIK based sensors.**
- **Tube resolution 85 microns \rightarrow the alignment system should contribute no more than 40-50 microns to the sagitta resolution.**
- **Nearly projective geometry \rightarrow non-sagitta resolution ~ 250 microns**
- **System should have redundancy and graceful degradation.**

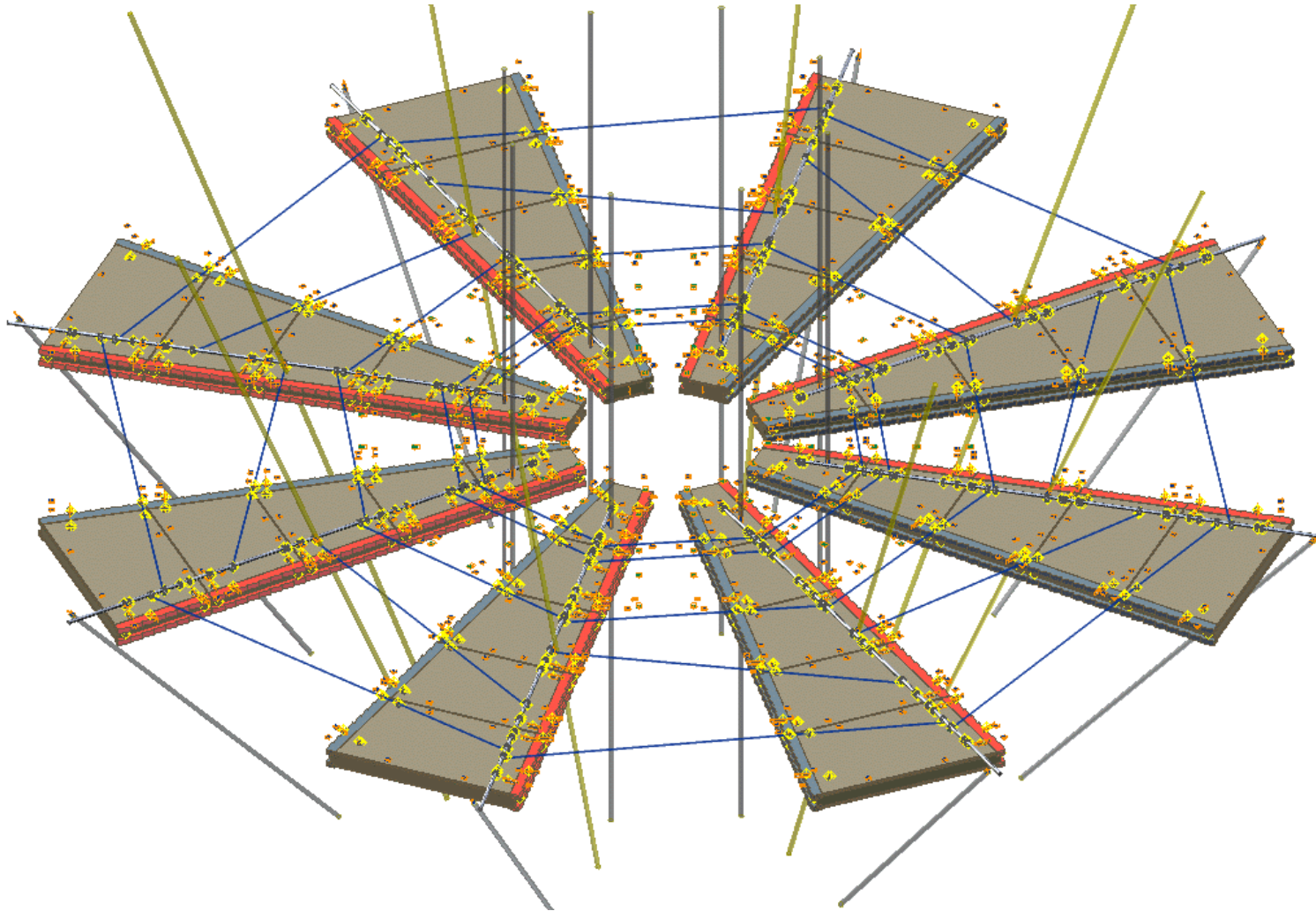


Reference Grid - EM Layer



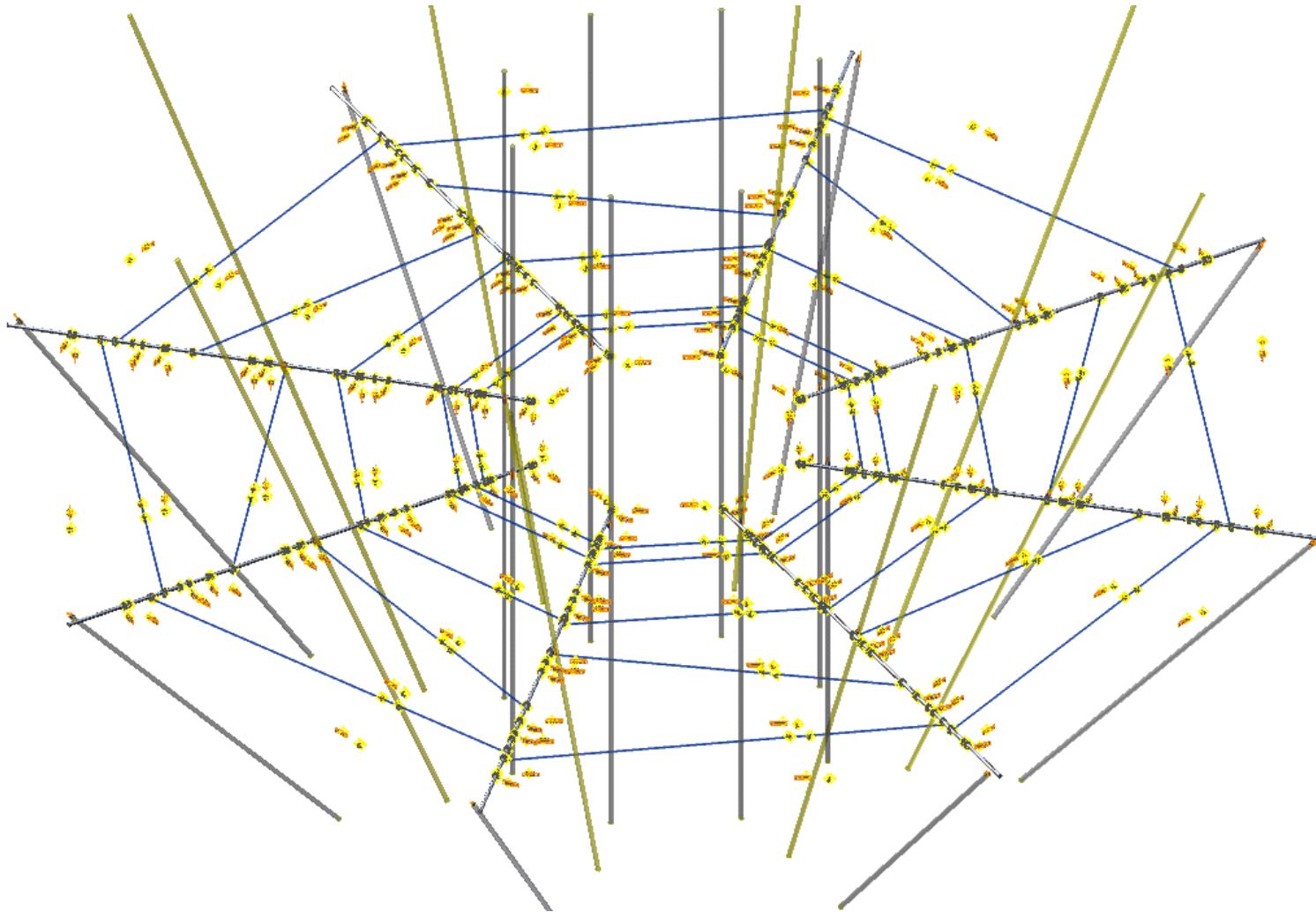


EM Layer Without Large Chambers



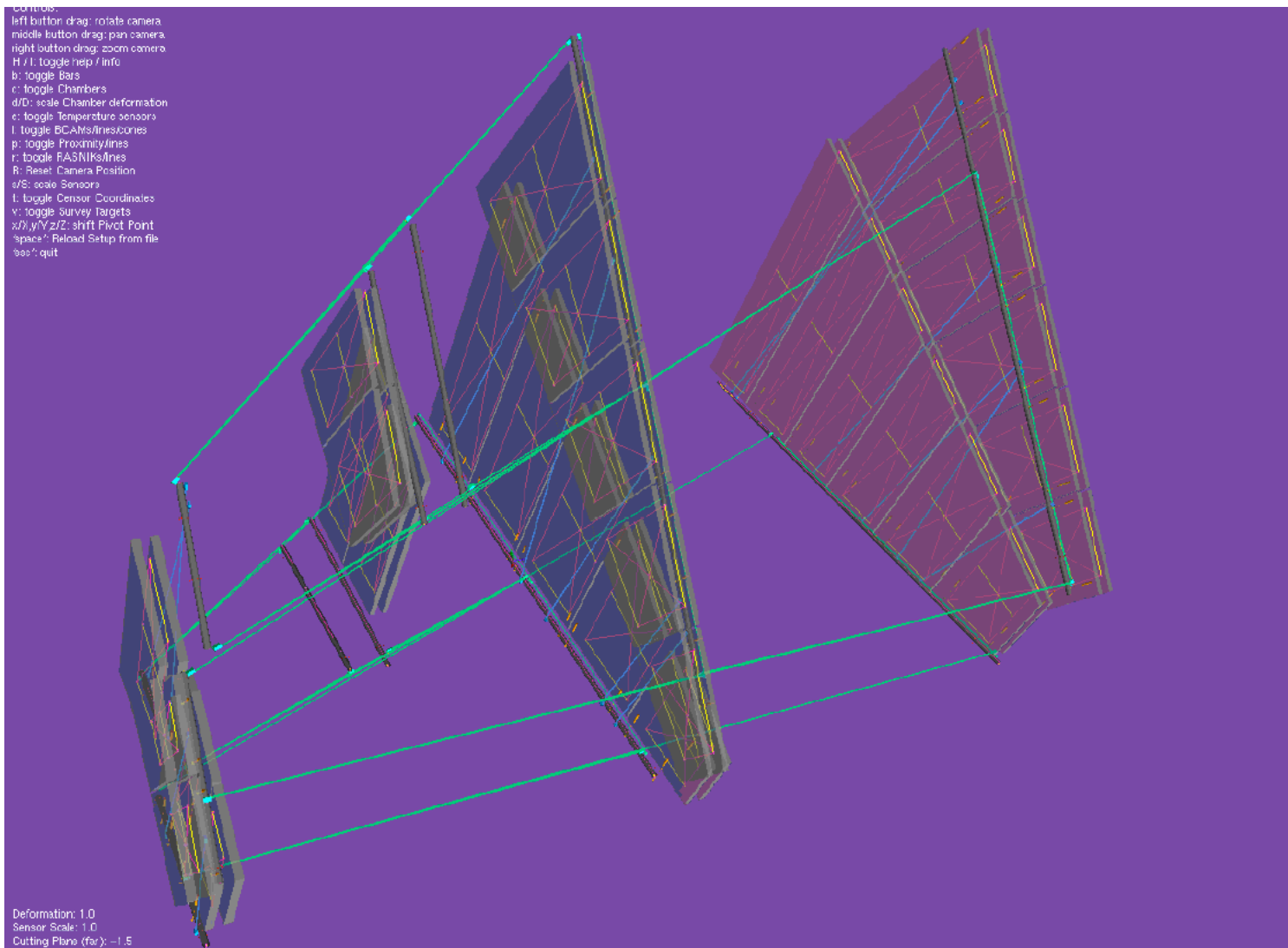


EM Layer Without Chambers





ATLAS Endcap Sector – from Simulation





Alignment Bars

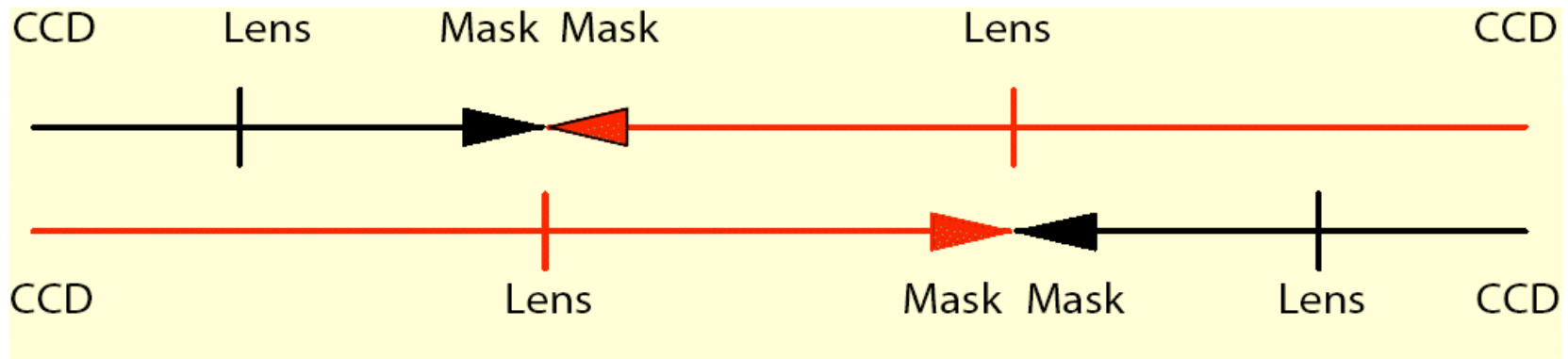


Purpose

- Establish a reference grid. Bars form the rulers in this grid.
- Bars and device mounts on bars are measured by the CMM at Freiburg.
- Bars are monitored internally to track their behavior after measurement.
- Chamber positions are referred to this grid via the proximity system.



RASNIK Layout Inside Alignment Bar



Purpose of Shape Reconstruction: Obtain from in-bar sensors the positions and orientations of all sensors mounted on the bar in any gravitational orientation. The RASNIK system is a straight-line monitor with a 1 micron resolution in both transverse directions.

Two measurements of the bar have to be combined:

- Use Initial Bar Shape - set of ball positions with corresponding RASNIK values and temperatures. This is done on a large CMM.
- Use the in-bar instrumentation to correct for small differences in shape.



Small Wheel Alignment Bar With Sensors

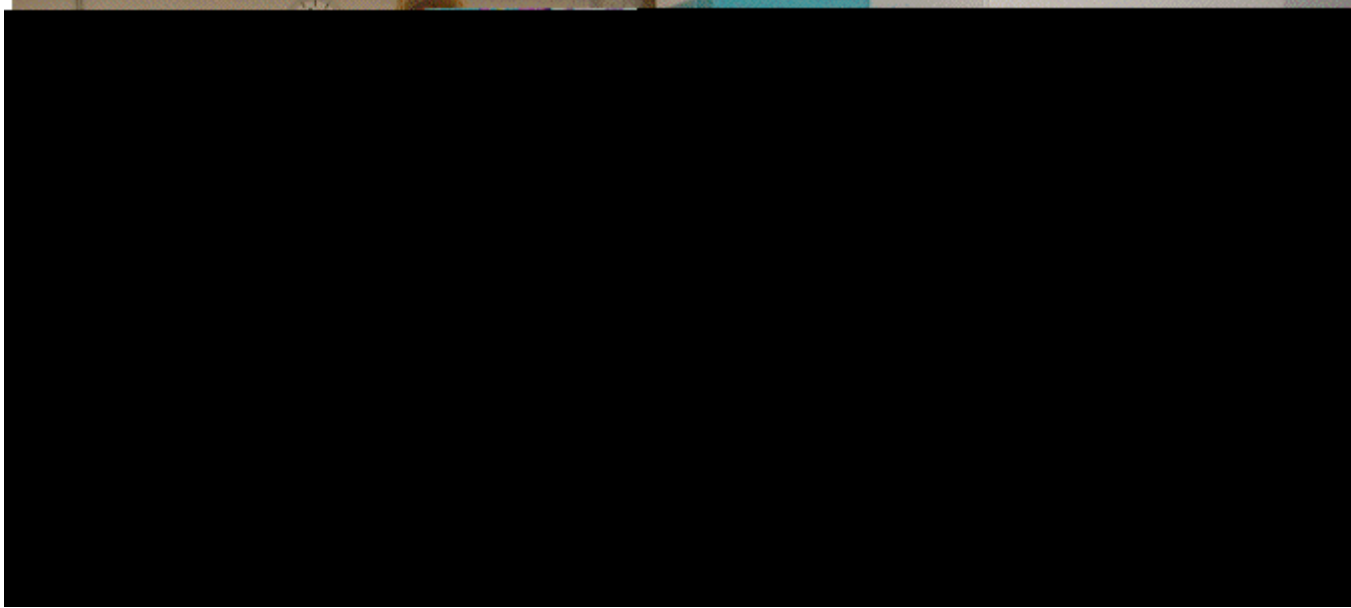
Bar in arbitrary orientation:

- From RASNIK readings: **change in shape** in 5 points.
- Calculate deformation: take into account **change of gravitational sag due to sensors & platforms on the bar.**
- Add **effective correction (3-load fit)** to reproduce RASNIK readings.
- **Calculated deformation plus 3-load fit = change in shape.**

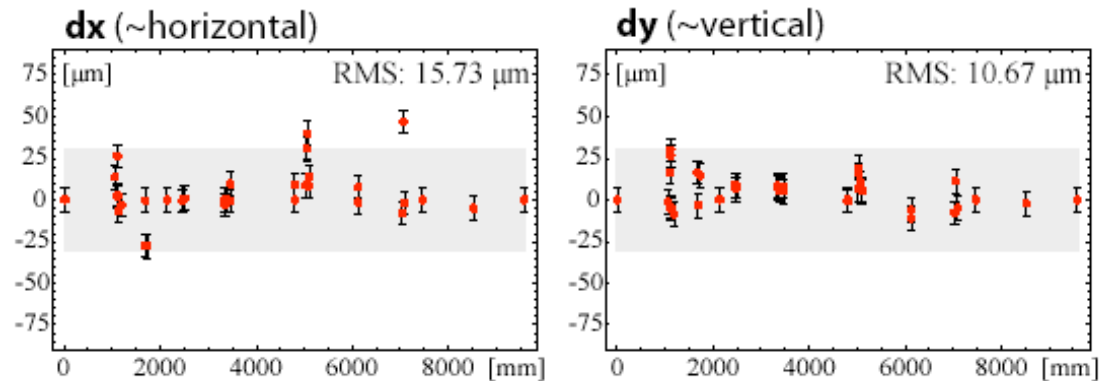
Initial shape + change in shape \Rightarrow shape in new orientation.



Alignment Bars - Measurement



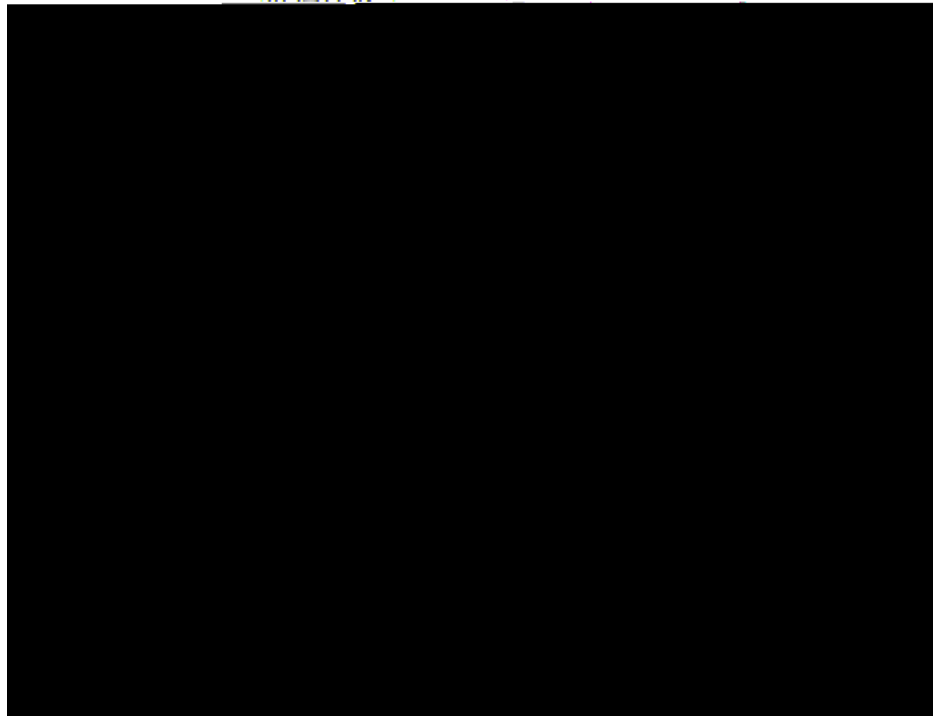
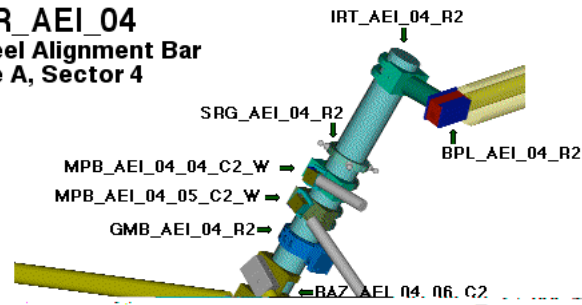
Reconstruction of a 9.6 meter bar. External sensor positions are measured then the bar is rotated by 180° and re-measured. The actual bar motion is several mm but locations are reconstructed with an RMS of 10 to 15 microns.





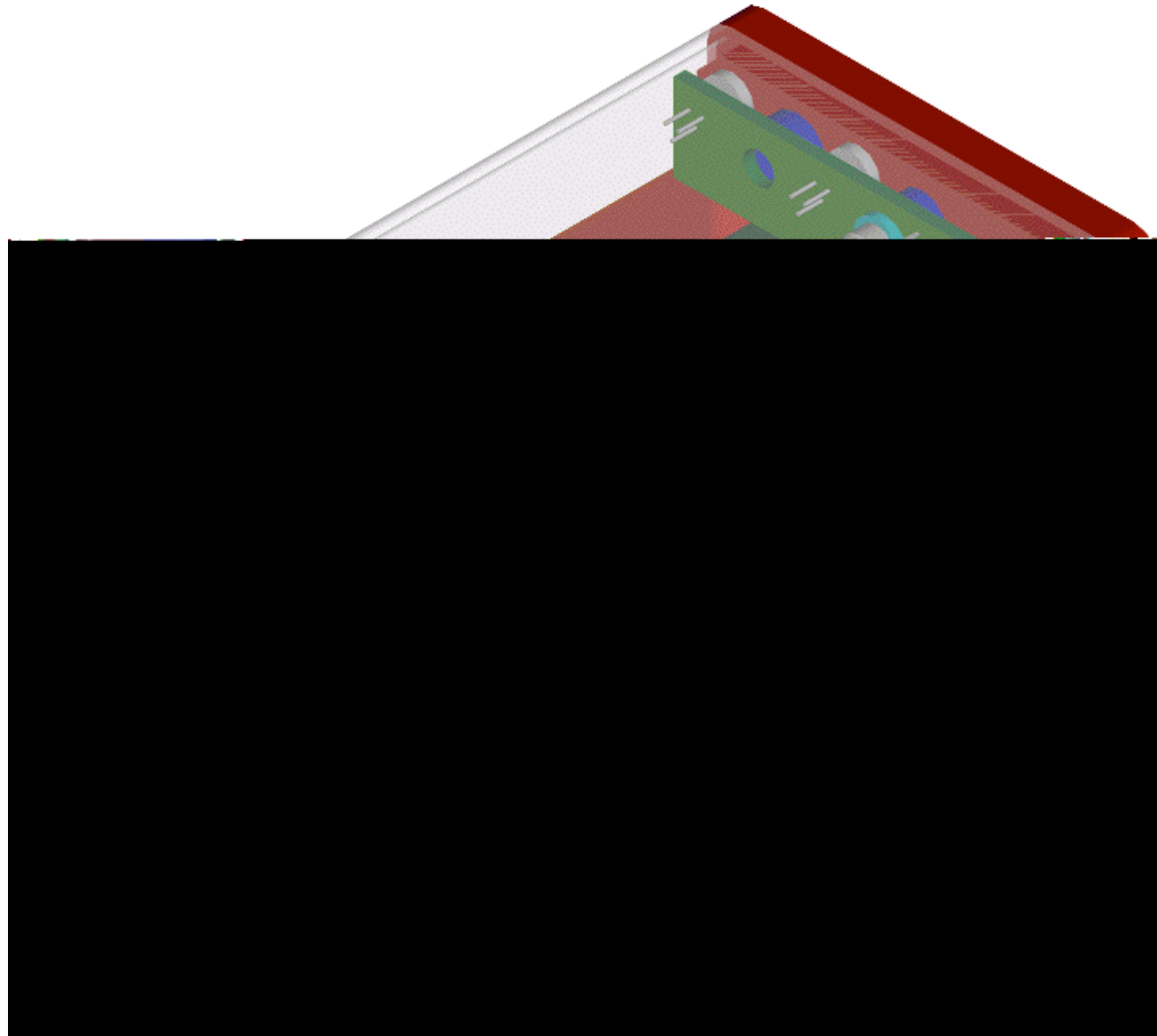
Small Wheel Alignment Bar With Sensors

ABR_AEI_04
Small Wheel Alignment Bar
Side A, Sector 4



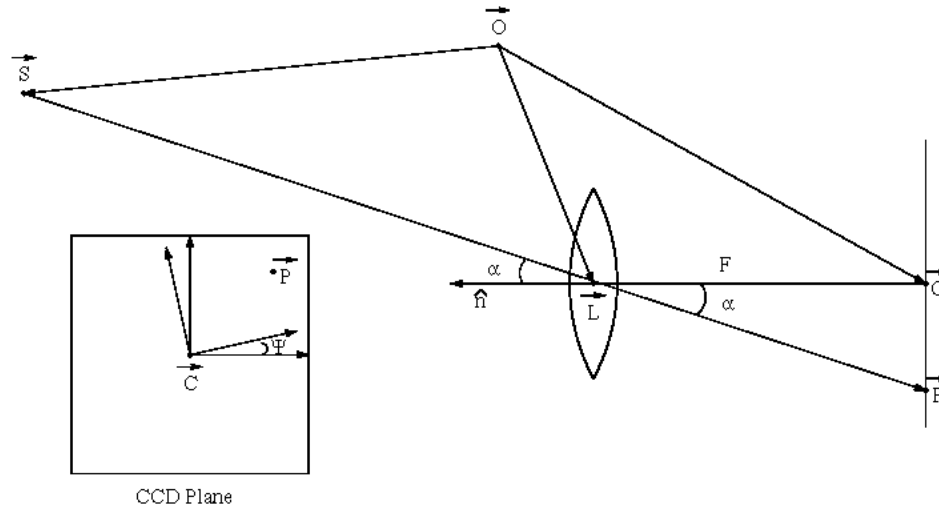


BCAM (Brandeis CCD Angle Monitor)





BCAM Calibration Constants



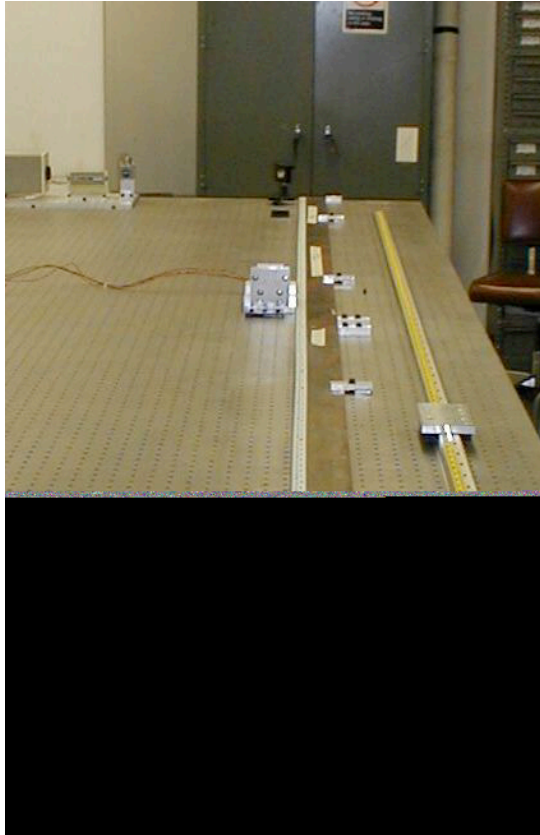
$L_x, L_y, \text{ and } L_z$	Pivot Point - Effective Center of the Lens
F	Distance from Pivot Point to CCD (effective focal length of the lens)
$t_x \text{ and } t_y (\hat{n})$	Direction Cosine (angle in mrad.) of the Line Connecting the Center of the CCD to the Pivot Point
Ψ	Rotation Angle of the CCD



BCAM Calibration Stand

Several Types of BCAMs

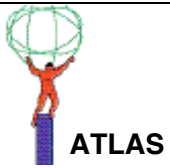
- Polar (Single and Double Ended)
- Azimuthal (Low Profile)
- Mirror version of both (Blue)



BCAM in roll cage, 4 positions, and source at two distances. From these 8 sets of data a program finds the calibration constants.

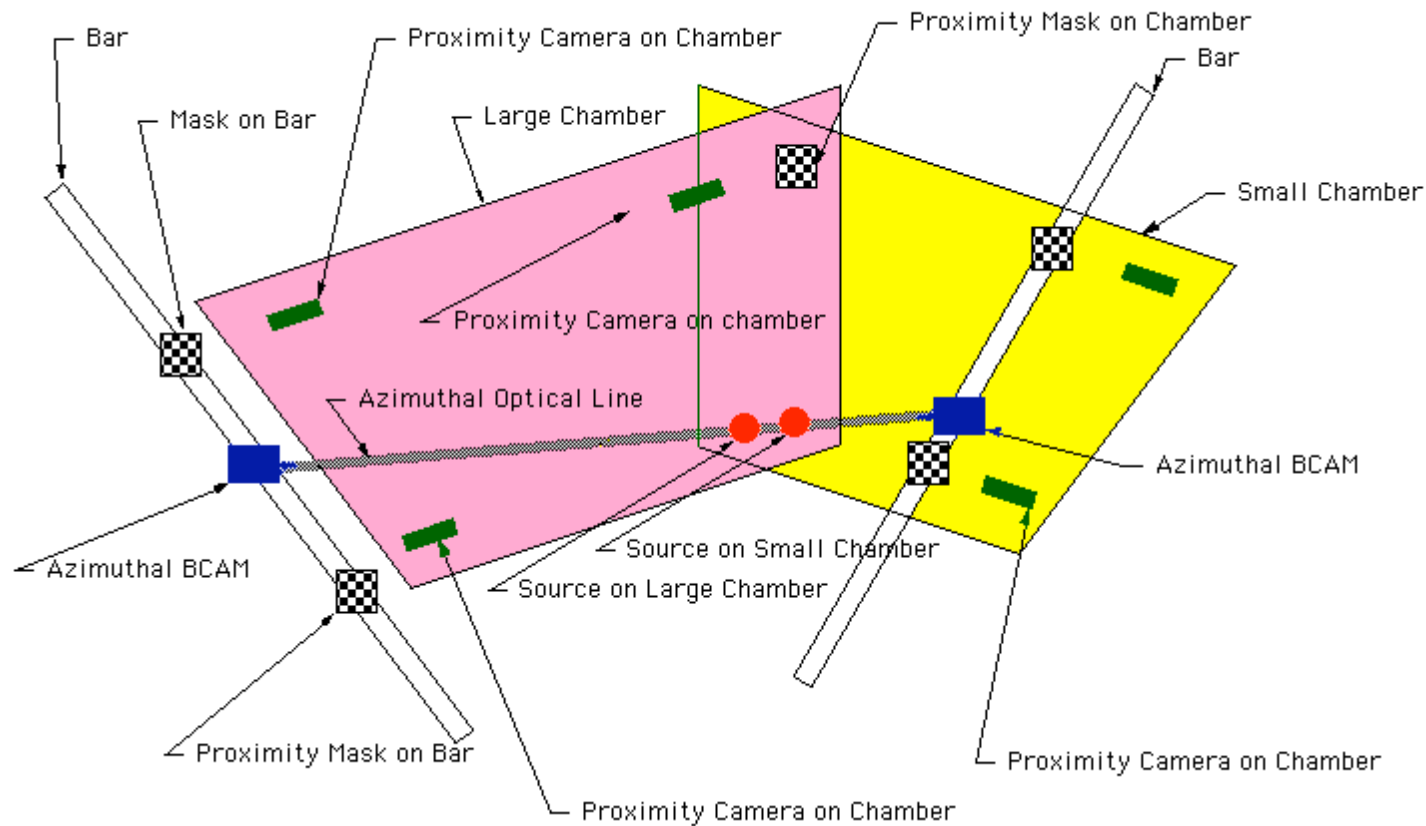
We use the same calibration system for all types. Transfer plates are used to adjust for different types of BCAMs.

It takes about 10 minutes to calibrate a BCAM.



Proximity System

Azimuthal BCAM and Proximity Camera Layout per Chamber Pair

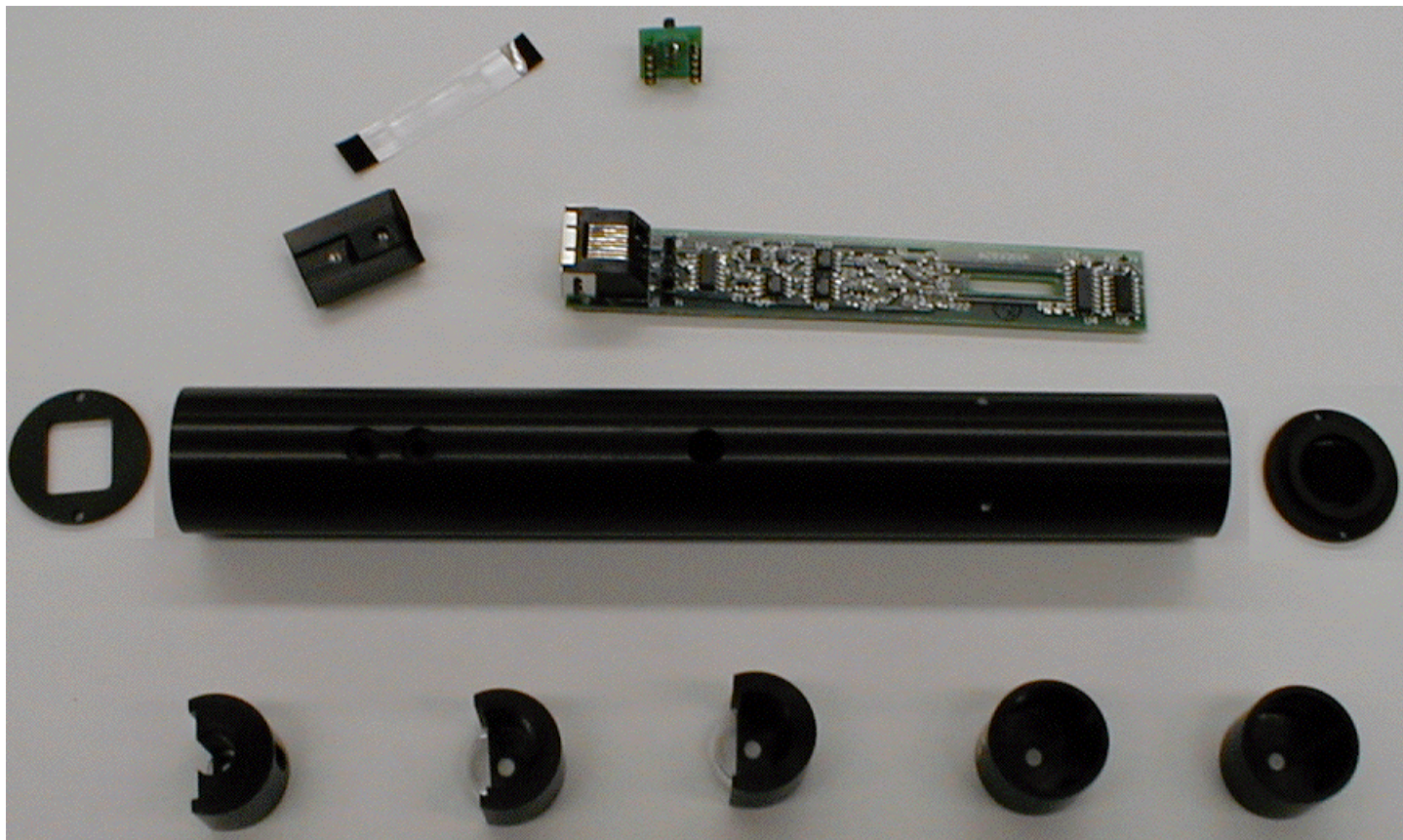




Proximity Monitors - Cameras

Purpose

- Provides the connection between the reference grid and chambers.
- Components: Cameras, Bar Masks, Chamber Masks, and Chamber Sources.





Proximity Monitors - Calibration



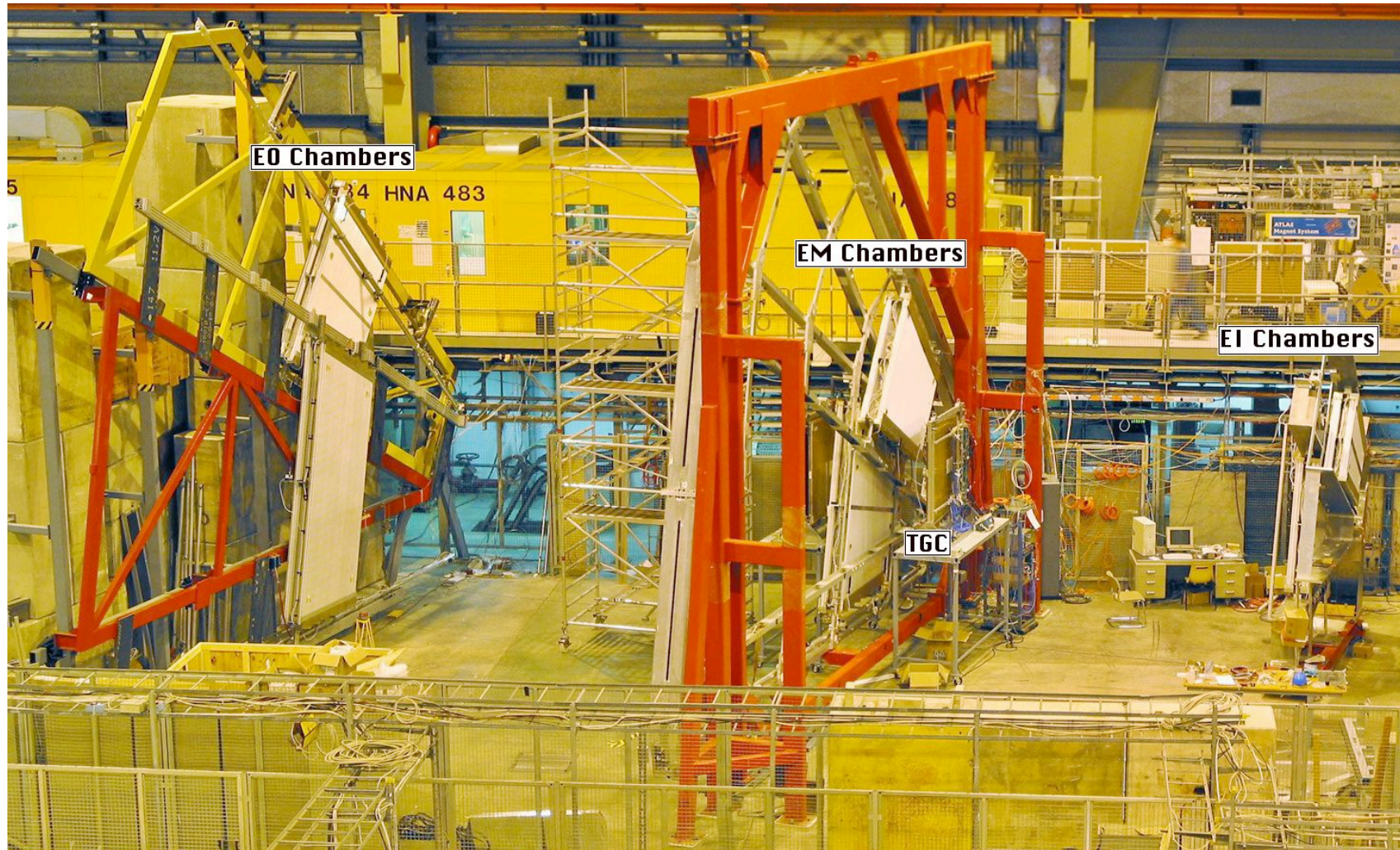


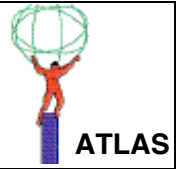
LWDAQ (Long Wire Data Acquisition)

- An integrated system - all alignment devices are controlled and readout by a single system.
- Retrieve images from BCAM and RASNIK devices.
[NB: To get the required precision, we need to readout the CCDs directly.]
- Control light sources.
- Control endcap alignment environmental sensors.



H8 Test Beam - Muon EC Setup



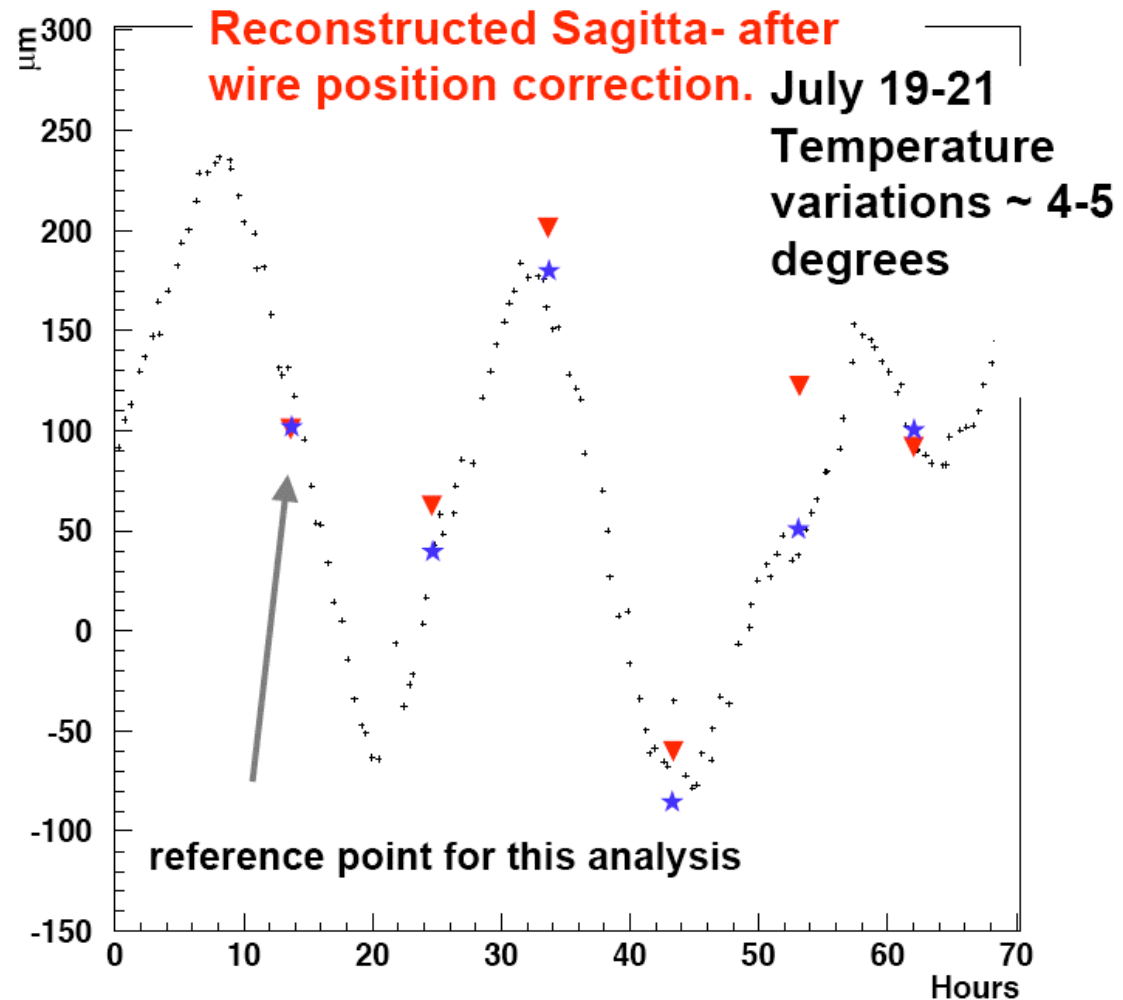


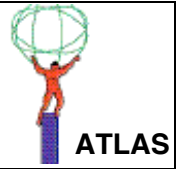
H8 Results

Normal Temperature Variation

Comparison of the sagitta as seen by the tracking data with the predictions of the alignment system (ARAMyS program). Normal temperature variation over several days.

Requirements = 40 microns
Observed = 15 microns



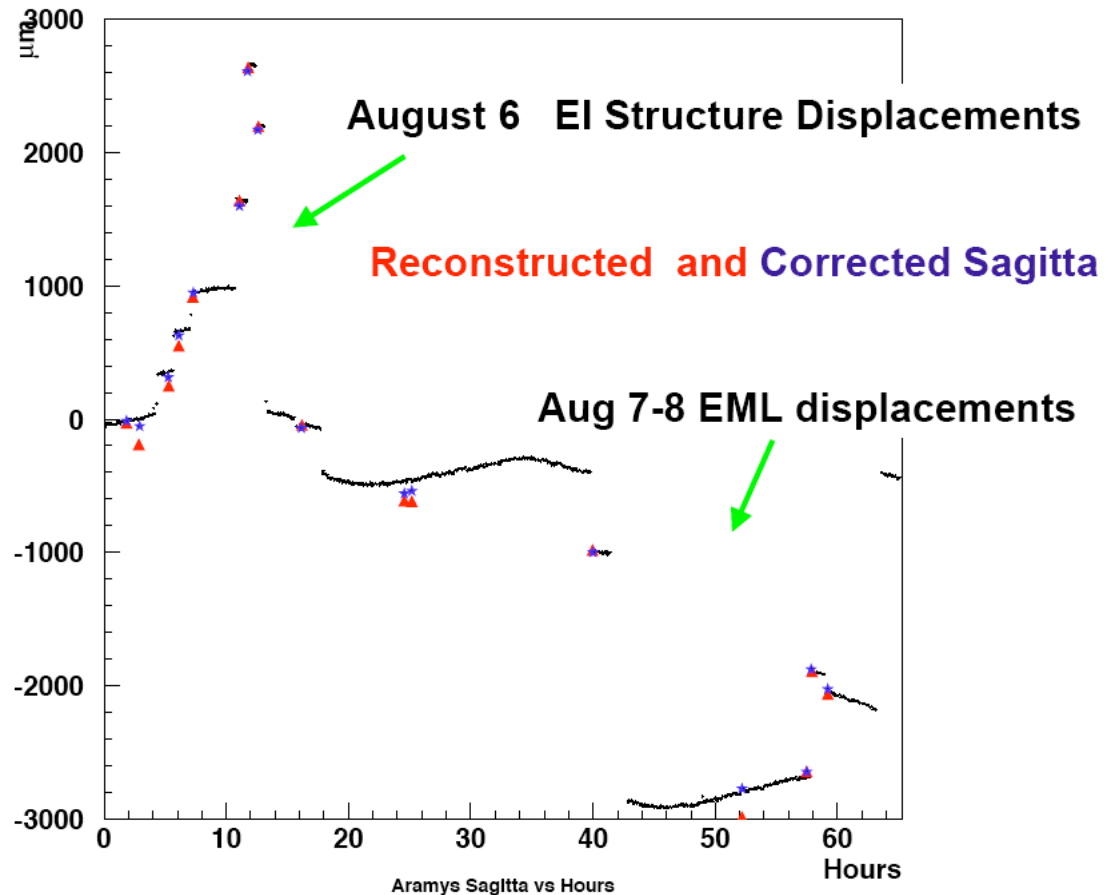


H8 Results

Chamber Motion

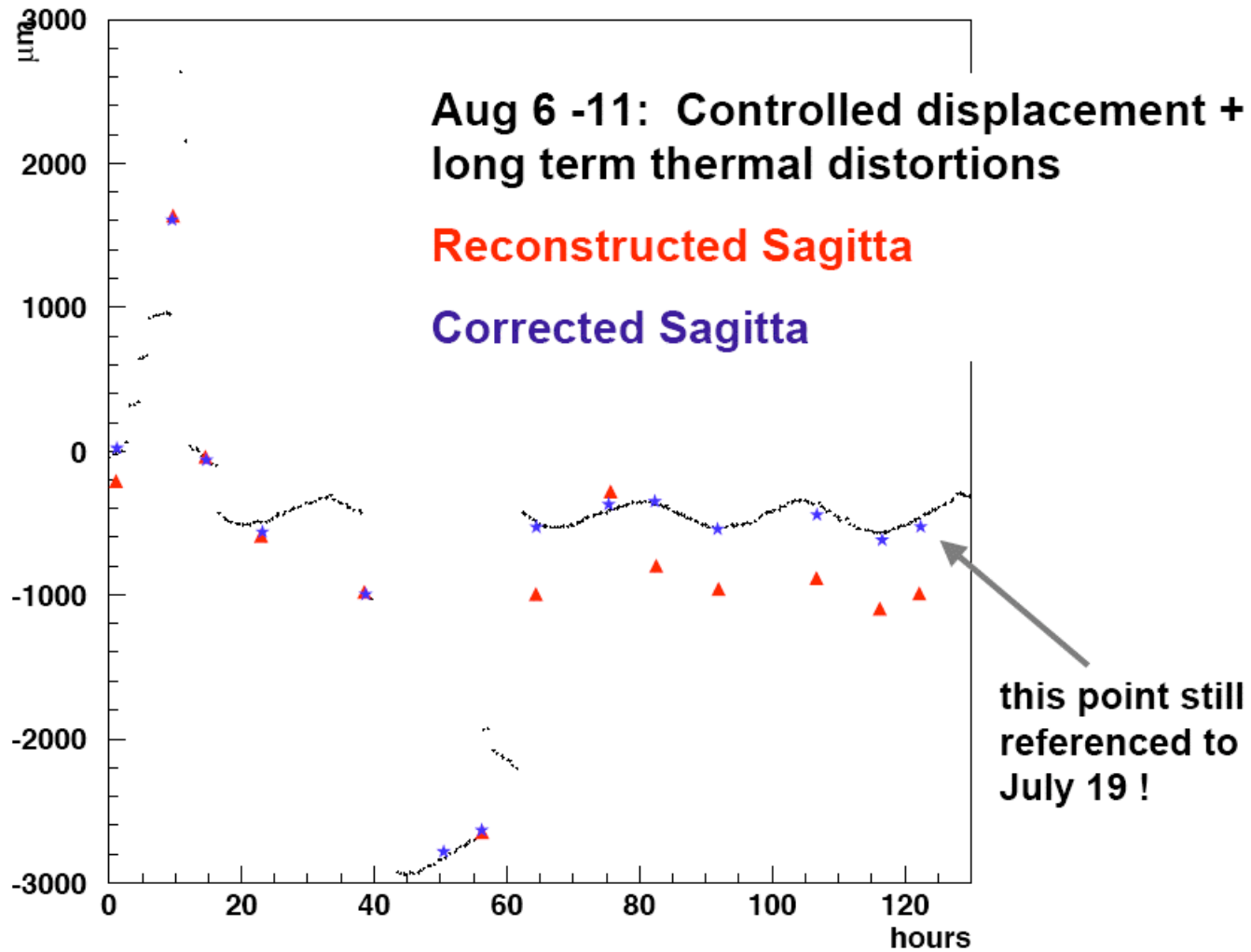
Comparison of tracking data with the predictions of the alignment system (ARAMyS program). Chambers were moved, first the EI structure then EML2.

Requirements = 40 microns
Observed = 15 microns





H8 Comparison With Tracks





Detailed Comparison With Each Data Run

Agreement Better Than ± 15 Microns

EndCap : Muonbox Tracking with geometrical corrections from alignment system
 Chamber misalignments provided thanks to I. Trigger and C. Amelung

ARAMyS Conditions data for 3 runs taken with the 10x10 trigger : 3 rotations+3 translations per chamber in local coordinate system

```

*-- Adjustment of SZZ position of Stations -----
* Jff Job <---- Translation (mm) ----> <---- Rotation (Rad) ---->
* Typ | Jzz | S | Z | T | S | Z | T
*-----*-----*-----*-----*-----*-----*-----*-----*
*Date: 08/06 time: 09:58:05
A EOL 1 -3 0 -0.498 -0.364 -26.865 -0.002032 -0.000271 0.001381
A EOS 1 -3 0 -3.767 1.428 -29.943 -0.000078 0.000297 -0.002849
A EML 1 -2 0 -9.060 0.755 -0.863 -0.002555 -0.000039 -0.001393
A EMS 1 -2 0 -37.491 17.000 -8.666 -0.004220 0.000586 -0.000267
A EIL 1 -1 0 0.859 -19.813 0.289 -0.000329 0.001210 -0.001447
A EIS 1 -1 0 9.954 30.800 -9.420 0.000039 0.000864 0.001925
*-----*-----*-----*-----*-----*
*Date: 08/06 time: 10:48:05
A EOL 1 -3 0 -0.646 -0.325 -26.850 -0.002033 -0.000272 0.001376
A EOS 1 -3 0 -3.830 1.455 -29.936 -0.000077 0.000288 -0.002858
A EML 1 -2 0 -9.216 0.802 -0.805 -0.002567 -0.000047 -0.001405
A EMS 1 -2 0 -37.611 17.000 -8.610 -0.004216 0.000558 -0.000279
A EIL 1 -1 0 1.255 -21.668 0.443 -0.000331 0.001200 -0.001461
A EIS 1 -1 0 11.020 32.447 -9.278 0.000038 0.000845 0.001926
*-----*-----*-----*-----*-----*
*Date: 08/06 time: 11:28:05
A EOL 1 -3 0 -0.609 -0.308 -26.830 -0.002035 -0.000274 0.001366
A EOS 1 -3 0 -3.806 1.490 -29.936 -0.000077 0.000292 -0.002864
A EML 1 -2 0 -9.128 0.844 -0.714 -0.002575 -0.000044 -0.001412
A EMS 1 -2 0 -37.598 17.000 -8.535 -0.004222 0.000573 -0.000283
A EIL 1 -1 0 1.026 -20.847 0.316 -0.000296 0.001191 -0.001517
A EIS 1 -1 0 10.442 31.780 -9.439 0.000093 0.000833 0.001896
  
```

EIL forced displacements :
 +2 mm (Jura), -0.8 mm (Saleve)

Chambers deformations : to be implemented, possible need to introduce new parameters in the detector description model

Sagitta distributions with alignment corrections

