QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

2nd LHC Detector Alignment Workshop

ALICE alignment Hardware

Raphaël Tieulent

Institut de Physique Nucléaire de Lyon

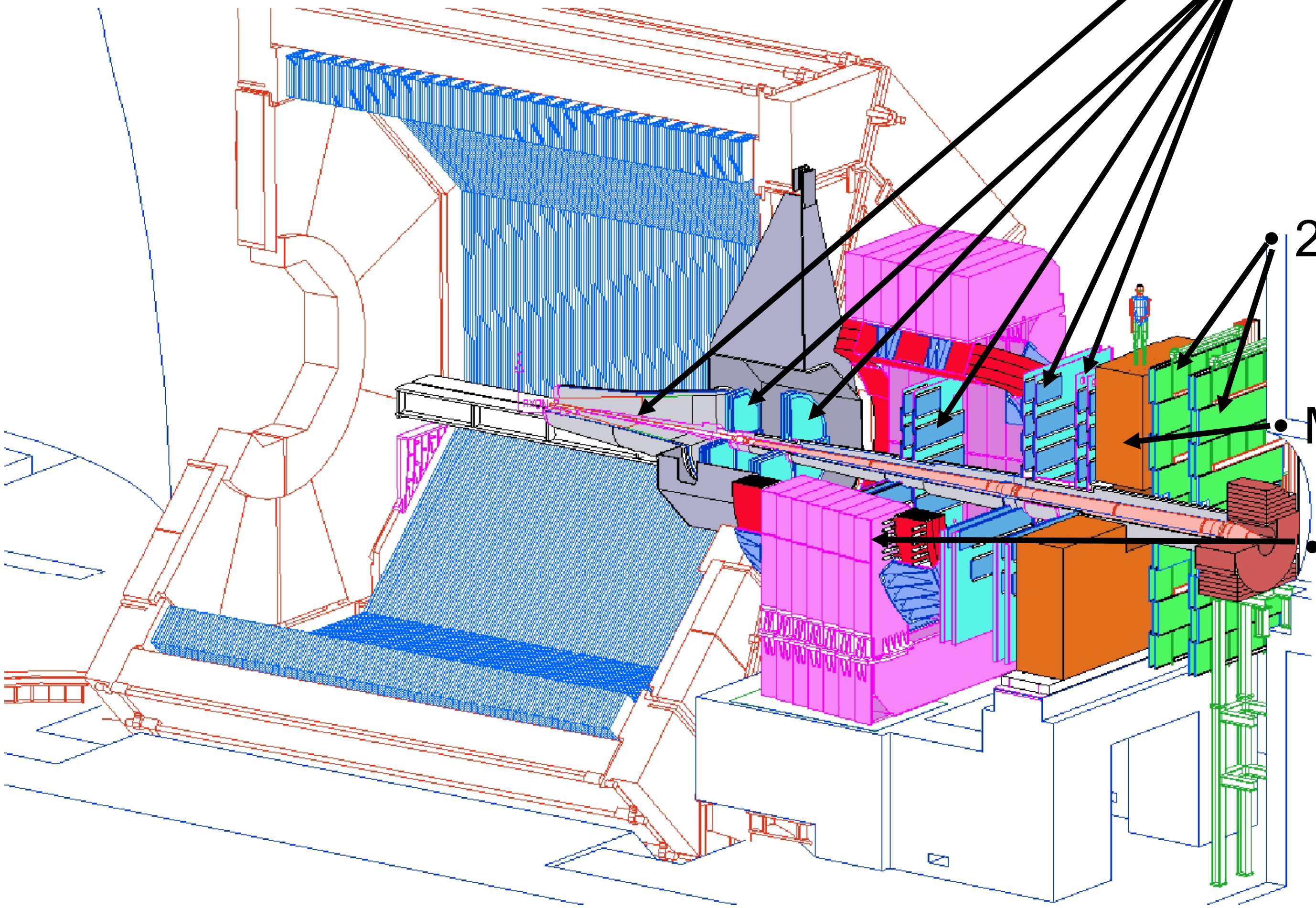
For the ALICE Collaboration

Outline

- The Muon Spectrometer Geometry Monitoring System
  - Misalignment impact on spectrometer performances
  - The BCAM and RasNik concepts
  - Description of the Geometry Monitoring System
  - Performances measured on a mockup of part of the spectrometer

- Control of the ITS - TPC relative displacements (ITS-AMS)
  - The concept
  - Performances
  - Operation and Installation

The ALICE Muon Spectrometer

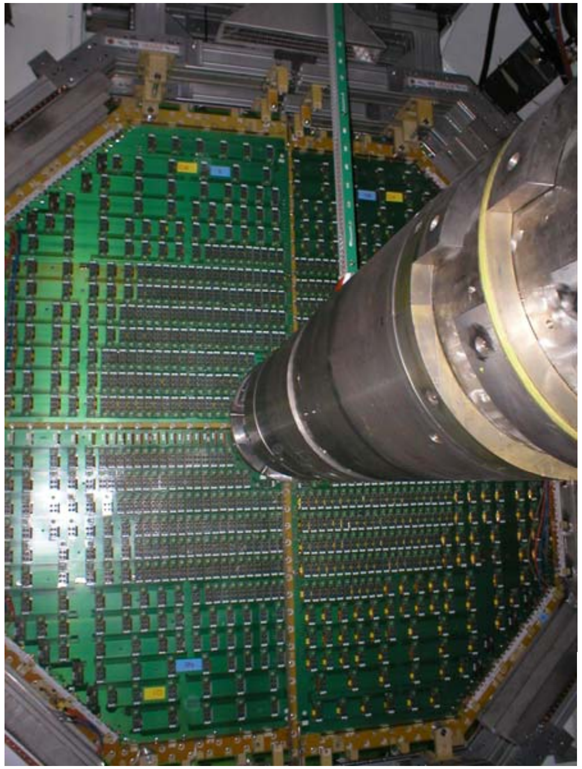


- Absorber
- 5 Tracking Stations
  - ✓ Cathode pad chambers
  - ✓ 1.1 Million Channels
  - ✓ Resolution of 100µm
  - ✓ Tallest is 6 m high
- 2 Trigger Stations
  - ✓ Resistive plate chamber
  - ✓ 2 ns resolution
- Muon Filter (iron wall)
- Dipole
  - ✓ Biggest warm dipole
  - ✓ Yoke height: 9m
  - ✓ Field of 0.7 T

The muon spectrometer detectors

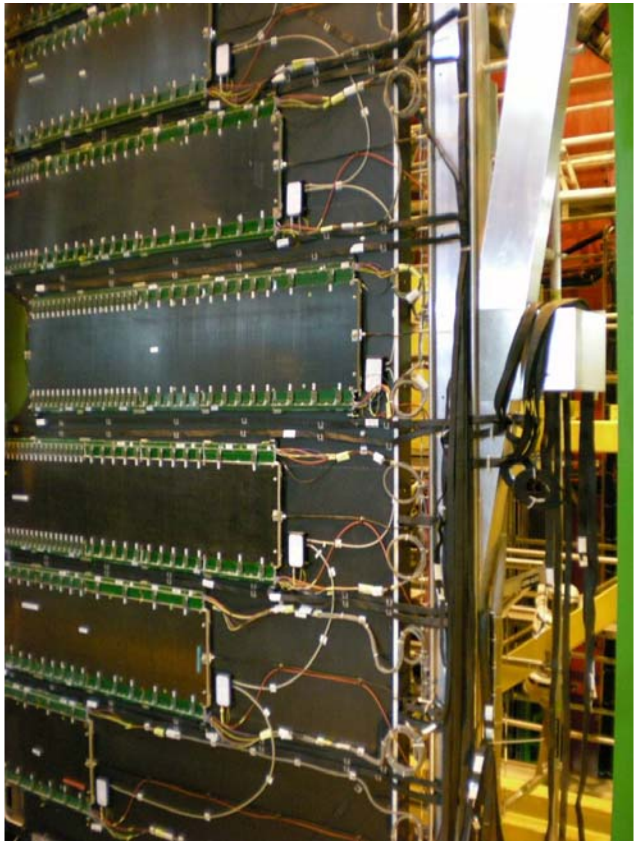
Stations 1 & 2:

- Chambers made of 4 quadrants
- Attached to C-shaped support



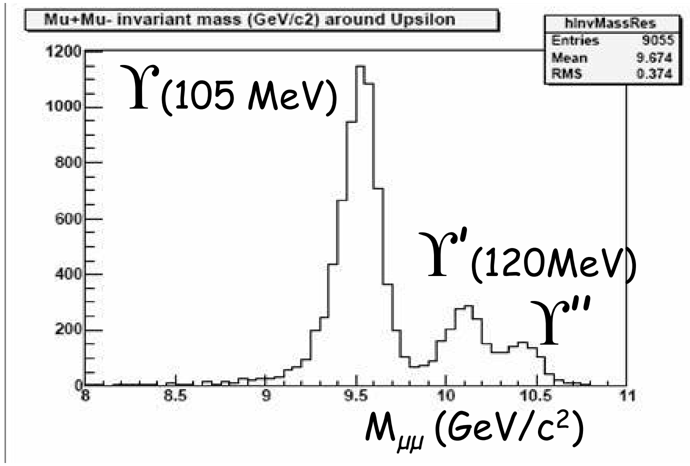
Stations 3 to 5:

- Chambers made of individual slats
- Mounted on carbon fiber supports (tallest is 6m high)

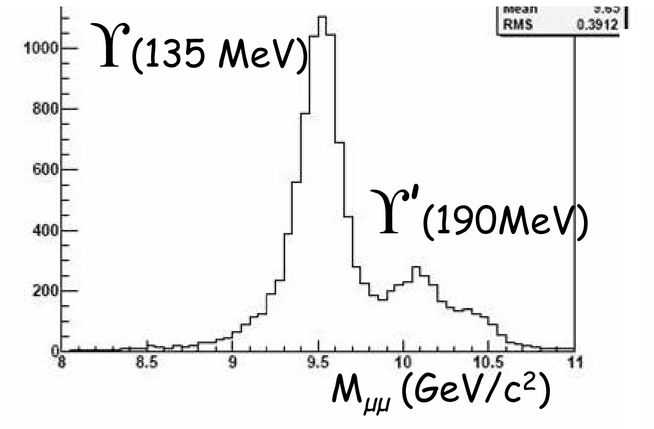


Spectrometer performances .vs. alignment

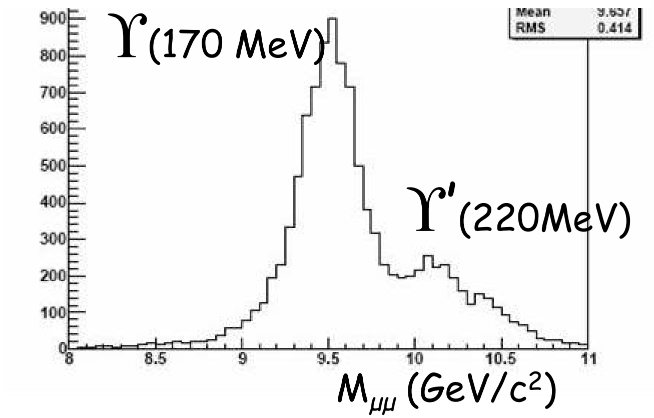
Chamber positions exactly known



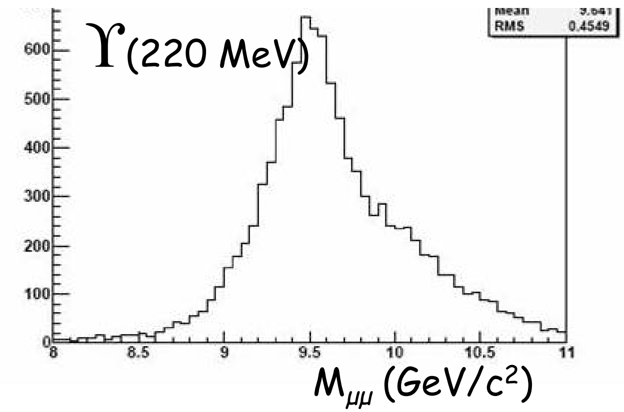
100 µm uncertainty on the chamber positions



500 µm uncertainty



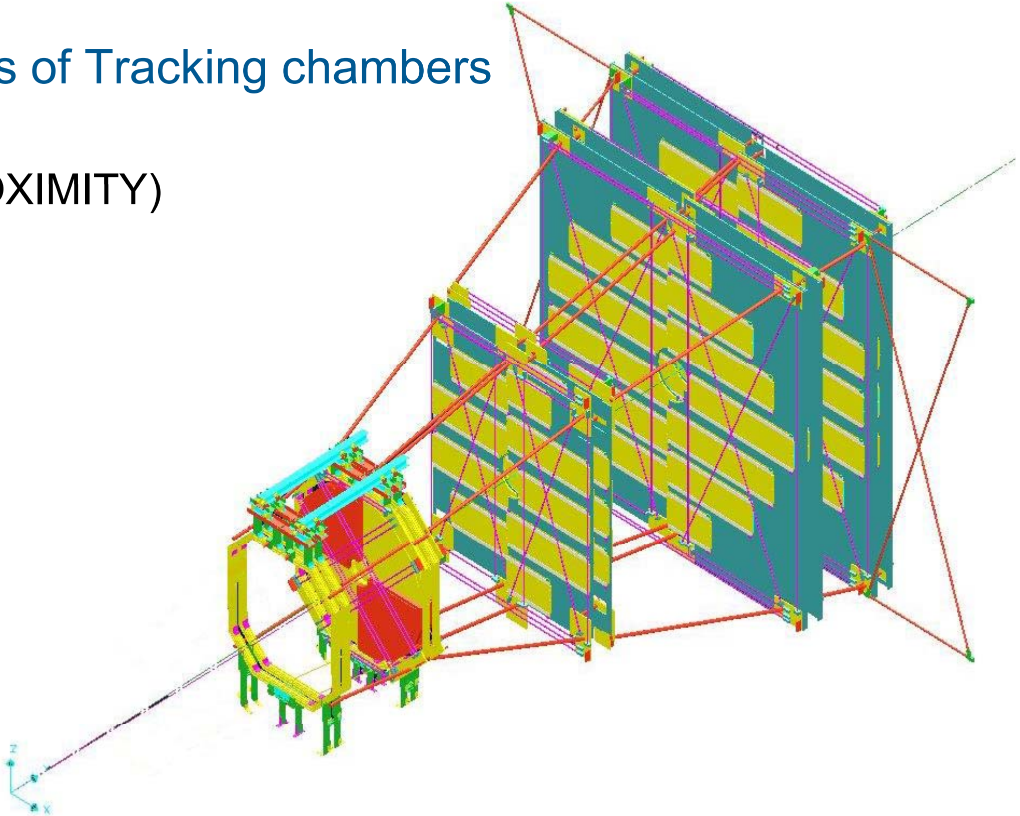
1 mm uncertainty



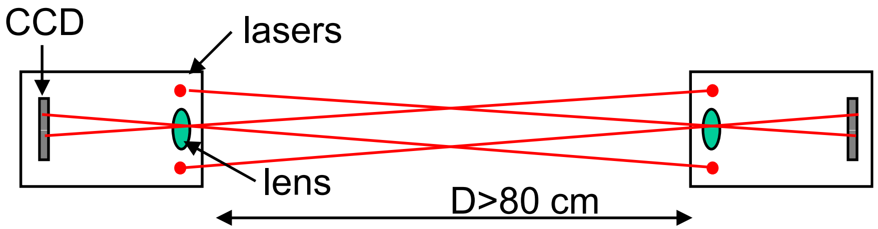
Muon spectrometer alignment requirements is about 40 µm

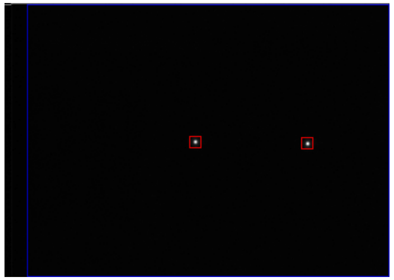
Overview of the Geometry Monitoring System

- Goal : Measure relative displacements of Tracking chambers
- GMS : array of optical sensors
  - 2 types of sensors (BCAM and PROXIMITY)
  - 460 sensors in total
  - 1128 images per measurements

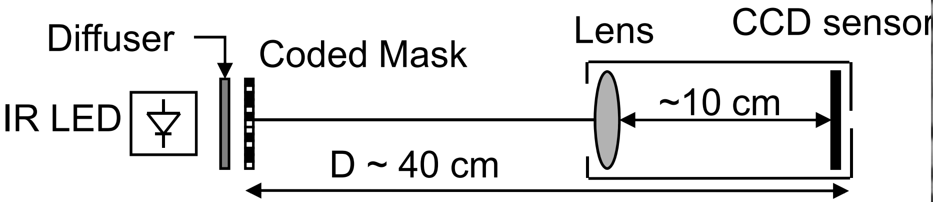


System BCAM



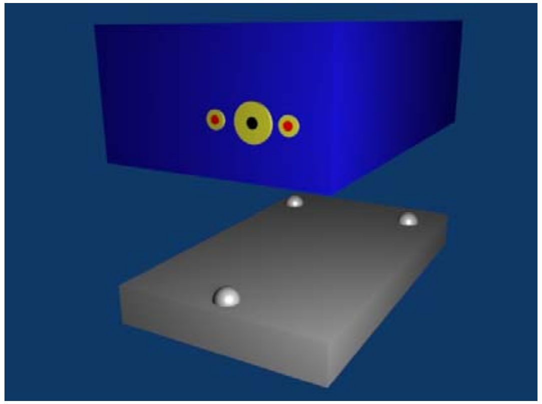


System PROXIMITY



The Boston CCD Angle Monitor

Developed for the ATLAS muon end-cap alignment
Provided to ALICE by Open Source Instrument Inc.



Optical elements:

- CCD sensor + converging lens (aperture about ±20 mrad)
- 2 laser diodes (divergence of about 30deg)

Mechanics:

- Enclosure provides 3 “footprints” (a flat, a slot and a cone)
- Enclosure sit kinematically on 3 steel balls (define a local coordinate system)
- Each BCAM is calibrated to give the positions of its optical elements in this coor. system

Measurements:

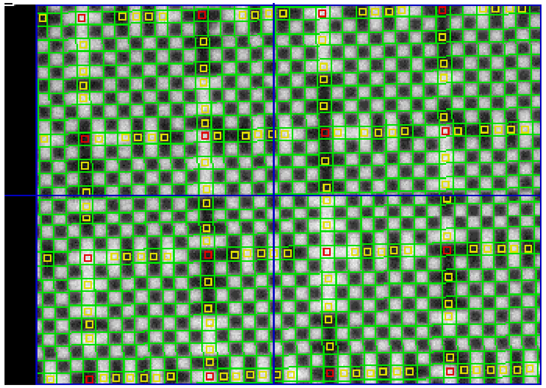
- Measure the position of the laser diodes into the BCAM system (resolution of about 5µrad)
- Calculate the center of intensity of the spot ➔ In focus not needed ➔ easy installation

Limitation:

- Due to the aperture of the camera distance between BCAM should be greater than 80 cm

The Proximity

Based on the RASNIK system developed by Nikhef



Optical elements:

- CCD sensor + converging lens
- Coded mask illuminated by IR diodes (squares $(360\mu m)^2$)

Mechanics:

- CCD and lens enclosed into a cylinder
- Enclosure position fixed by 2 reference holes (defines the geometrical axis of the cylinder)
- Each tube is calibrated to give the orientation of the optical axis with respect to the geo. one

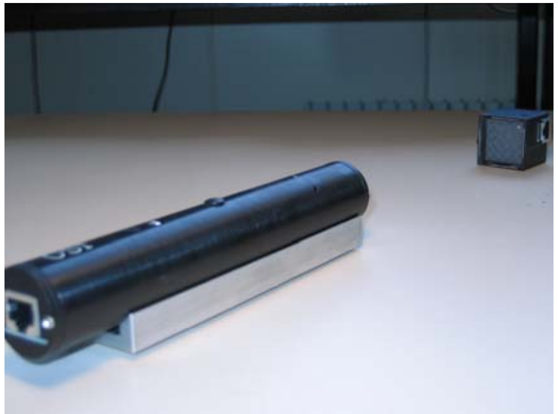
Measurements:

- Measure intersection point of optical axis with mask, in mask system (resolution about 1µm)
- Measure the magnification factor between object and image (resolution $5.10^{-5} * D_{ccd\text{-}mask}$)
- Measure the rotation angle between the mask and the CCD axis (resolution about 100µrad)

Limitation:

- Need to have a focused image in order to analyze the code

➔ installation more difficult than BCAM



The Long-Wire Data AcQuisition (LWDAQ)

LWDAQ is a TCP/IP based DAQ

Driver:

- Coordinates the Data Acquisition
- Provides Low voltages to the devices
- Transmits commands and retrieve data
- Connected to the world by Ethernet

Multiplexer:

- Provides 10 branch sockets

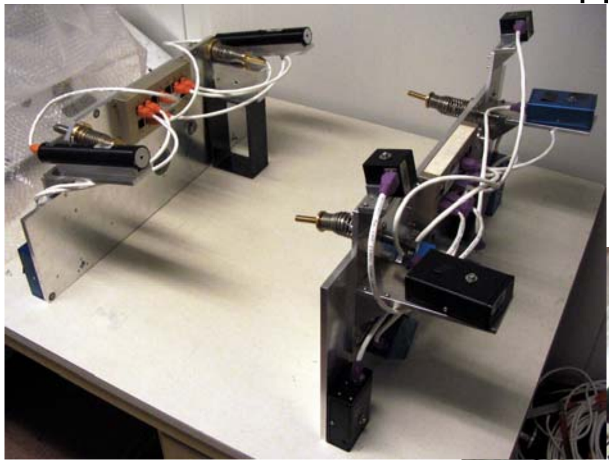
Devices:

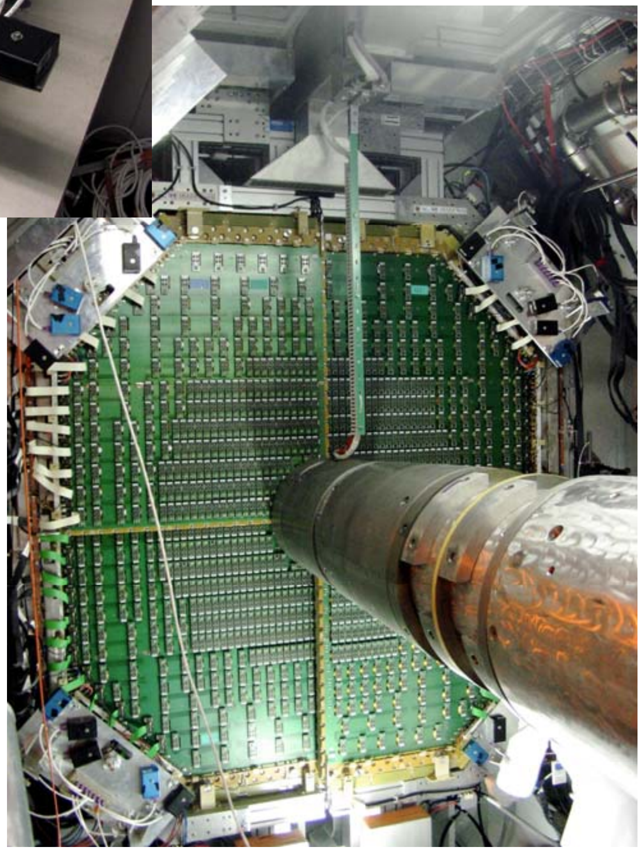
- Receive commands
- Return Digital data
- Can be awake or asleep

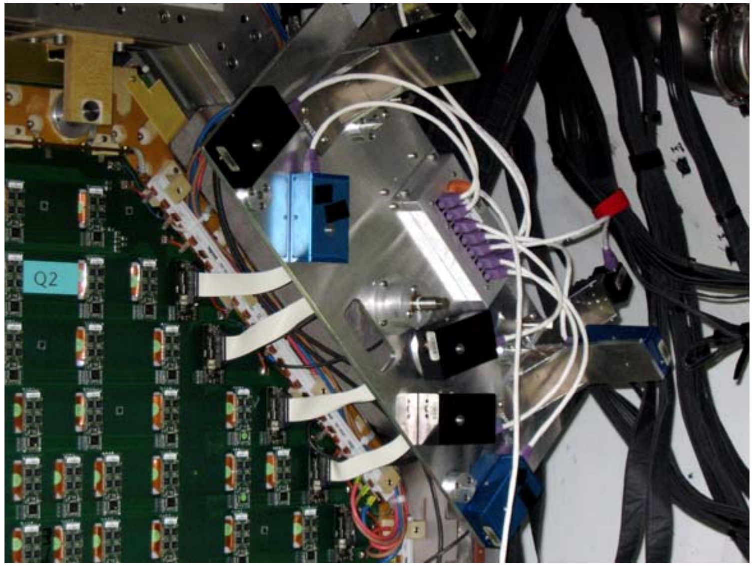
LAN

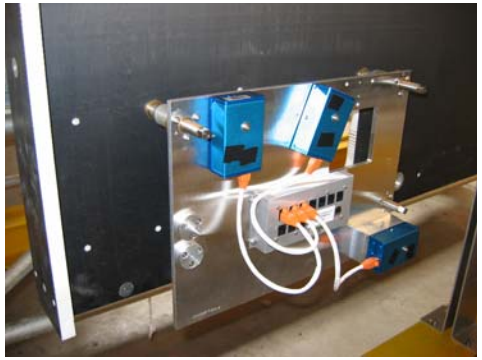
Hardware Installation

Devices: mounted on platforms themselves fixed on chamber support by 3 adjustment feet

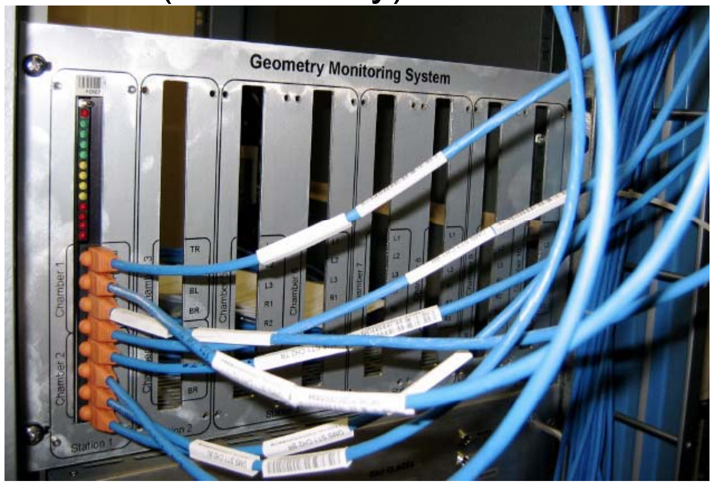








Counting Room (Pit): **8 Drivers** connected to 54 Multiplexers in the cavern (120m away)

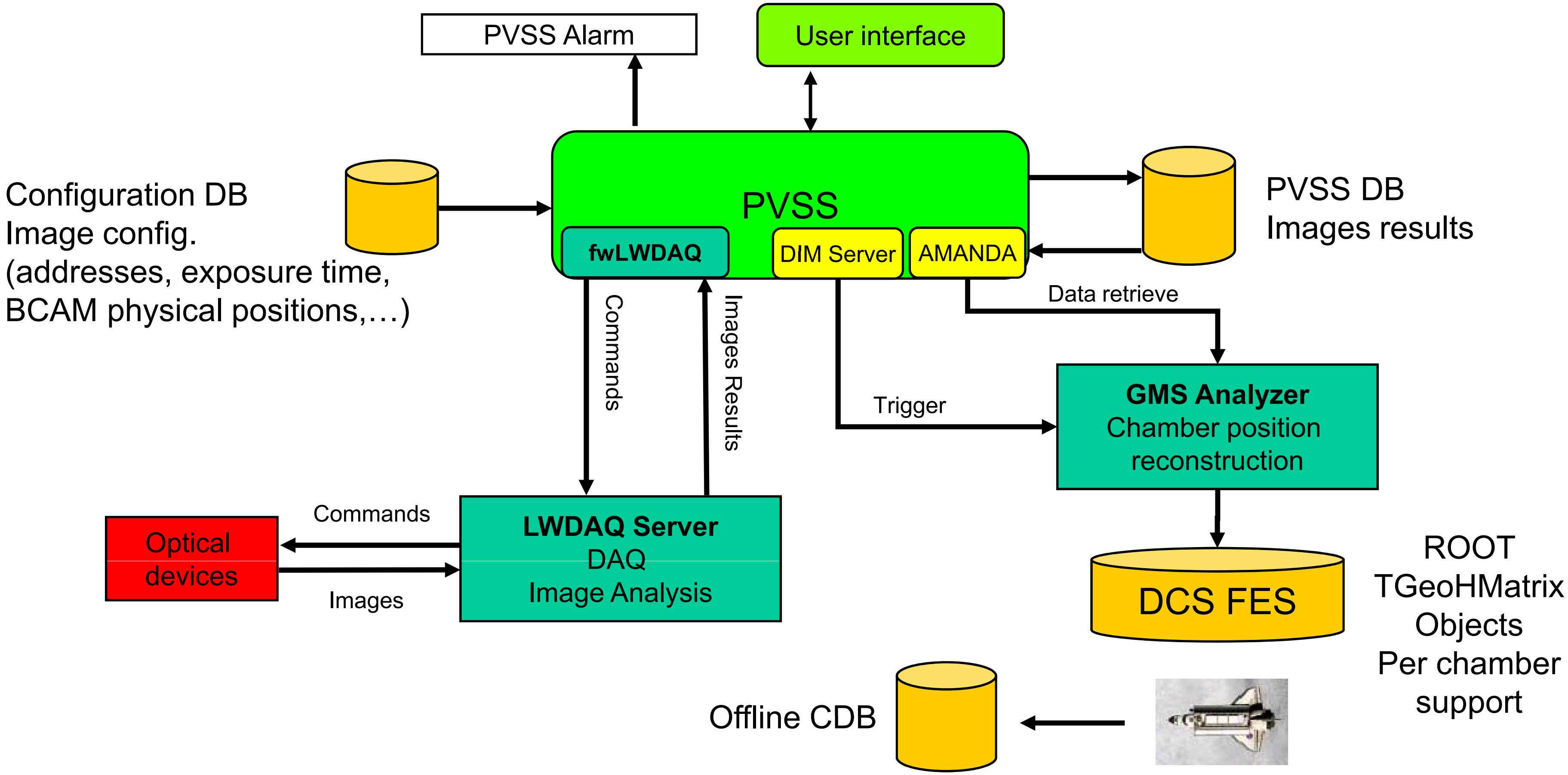


GMS Data Acquisition

GMS is a slow control system (at most few measurements per day)

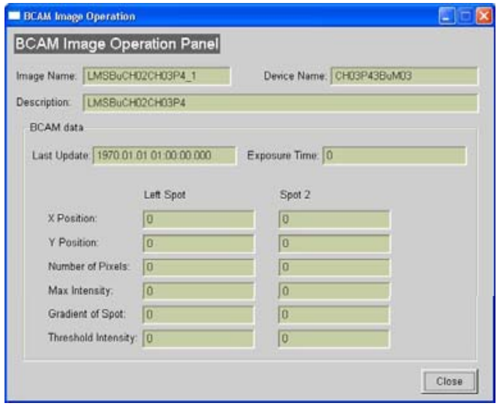
- Uses the Detector Control System (DCS) architecture
  - ✓ PVSS is the user interface
- Needs 3 programs for DAQ, analysis and reconstruction
  - ✓ program to control the images acquisition in PVSS developed by the EP/CO group and myself (included into the JCOP framework, v 0.5.1 available)
  - ✓ program of image analysis (provided by the ATLAS collaboration)
  - ✓ program of geometry reconstruction (developed at Lyon)

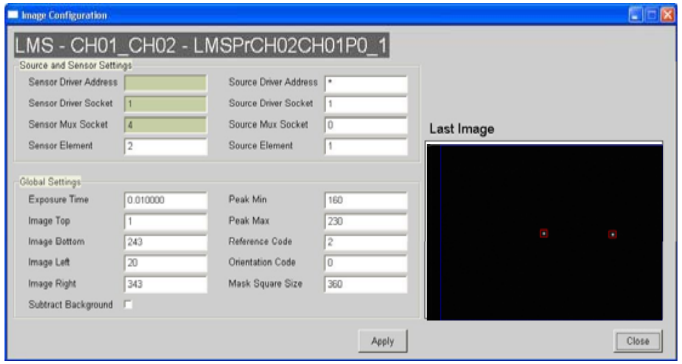
GMS Data Acquisition

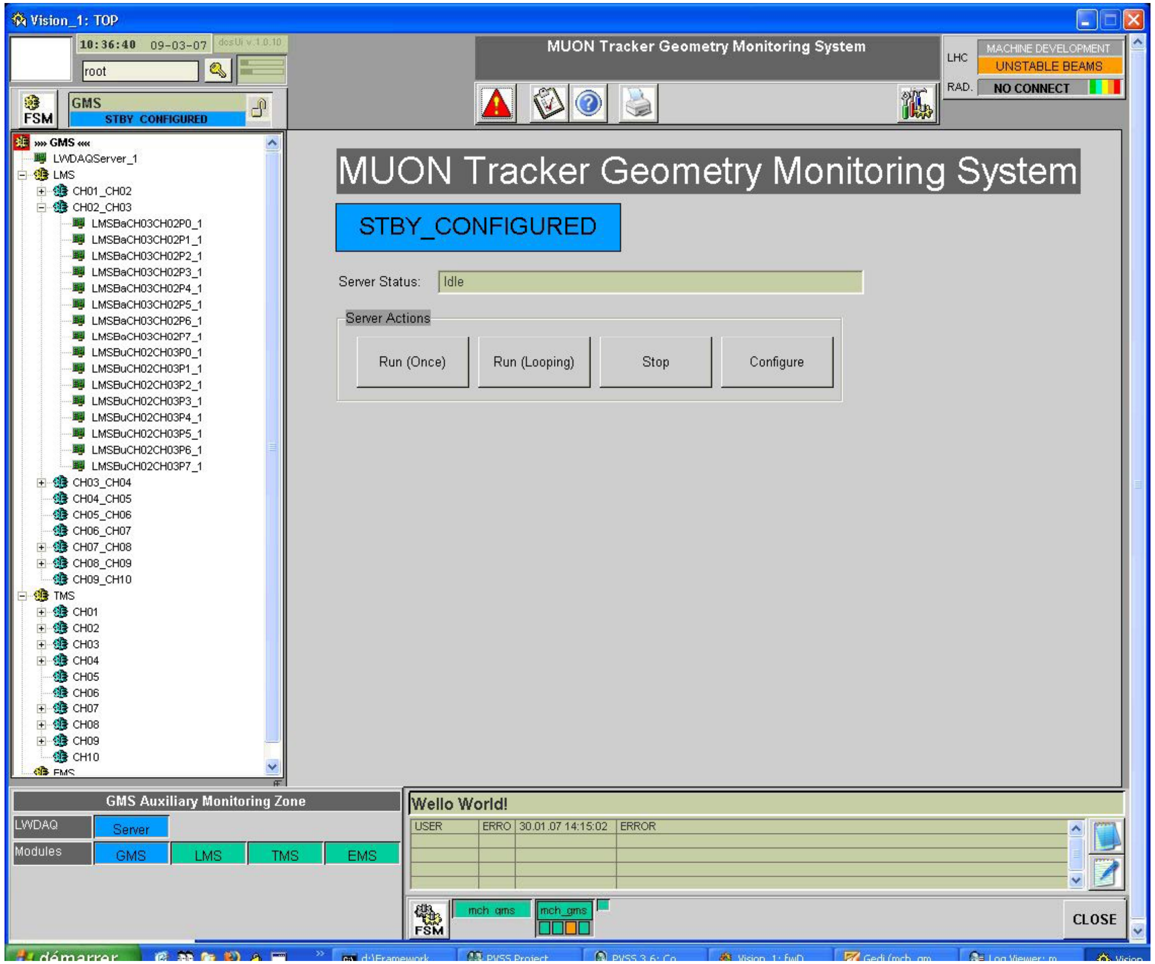


DAQ under PVSS

- Acquisition:
  - ✓ Implementation of the DAQ under PVSS 3.6 completed

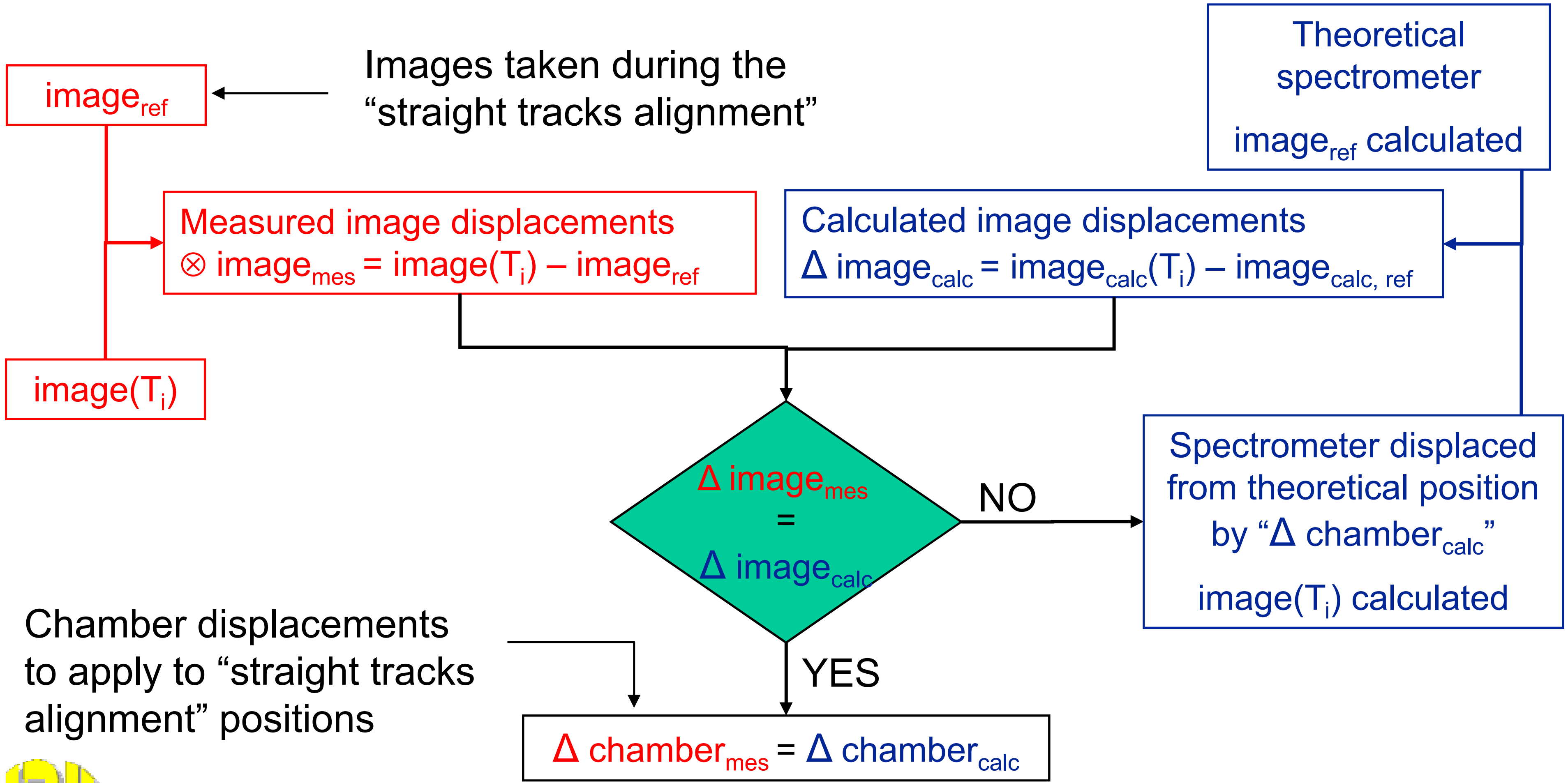






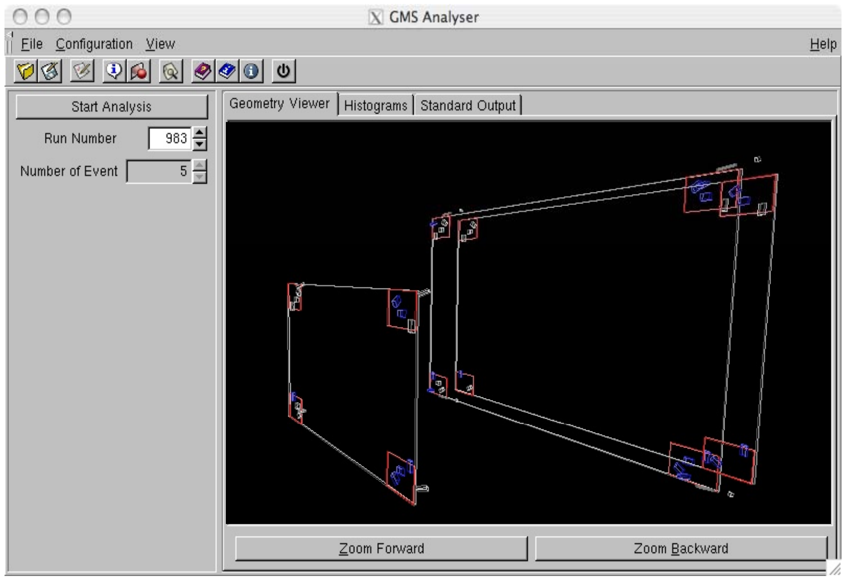
The GMS minimization procedure

The GMS measures displacements of the chambers relative to a reference measurement (Images taken during straight track alignment)



Reconstruction Program

- Object Oriented Program (BCAM, Proximity, Platform, Chambers)
- Based on ROOT
- Uses MINUIT as Minimization package
- Needs as input the “reference” and “current” images as well as the spectrometer geometry
- The reconstruction will be done online just after the data taking



GMS test bench

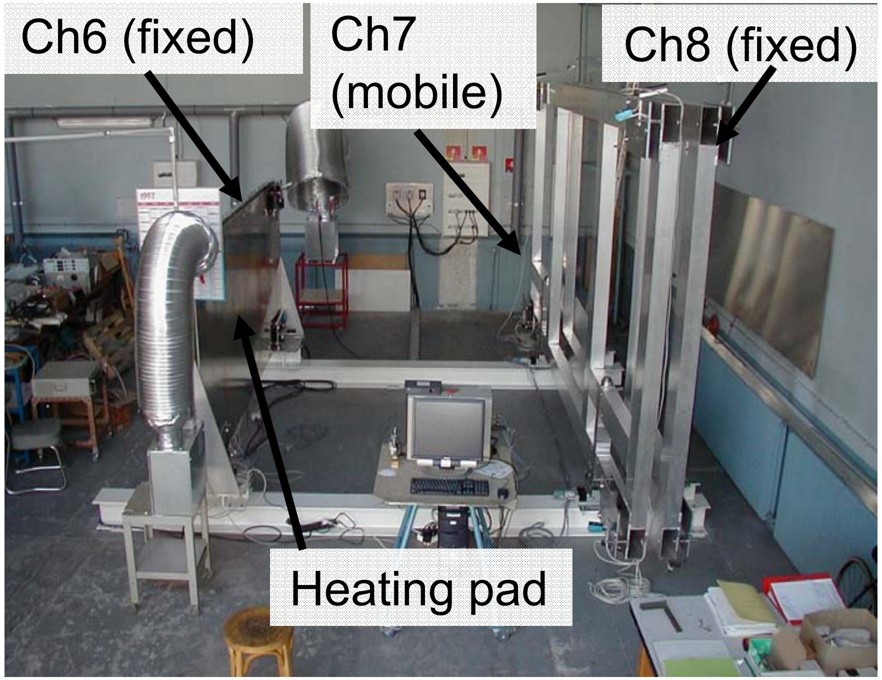
Mockup of 3 half chambers of stations 3&4 at scale 1

✓ 1 mobile chamber (Ch7 controlled displacement per 5 µm steps)

✓ Heating pad installed on chamber 6 to study the effect of thermal gradient

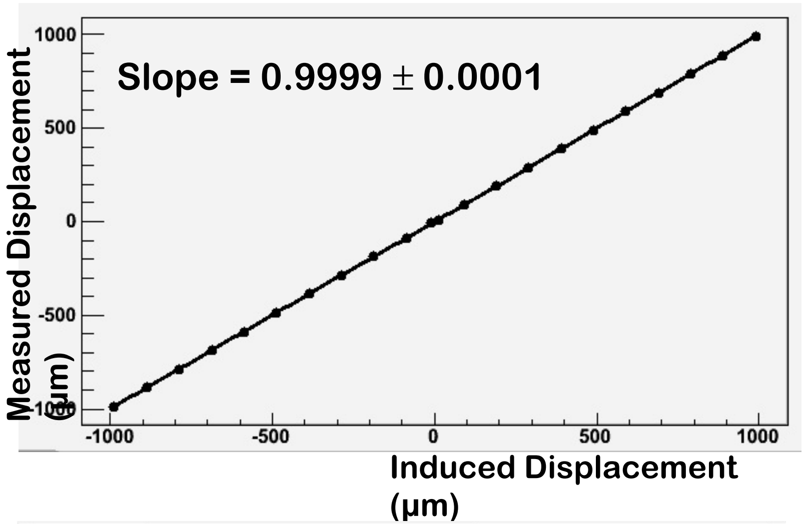
Rotation axis

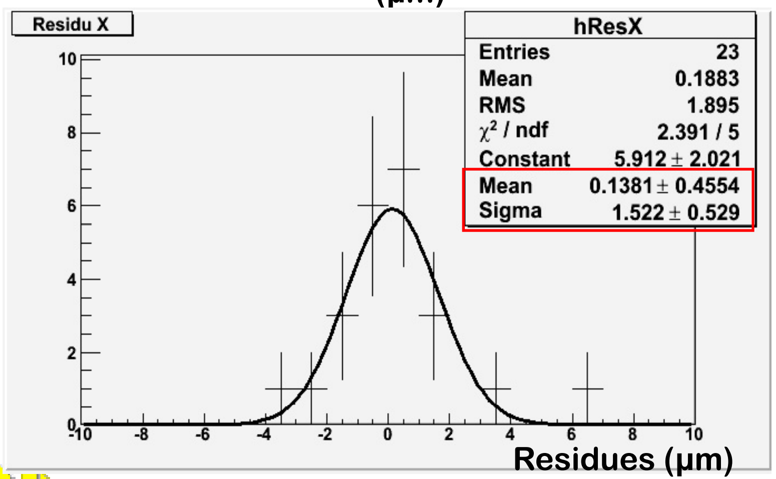
Motorized tables (5 µm steps)

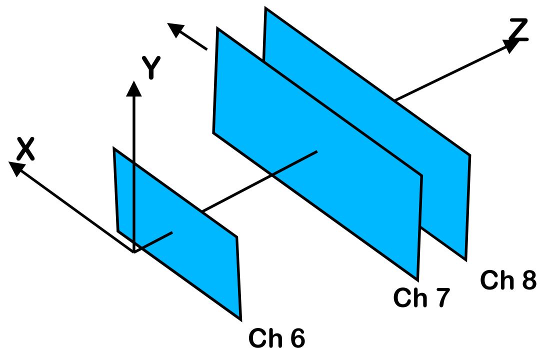


Translation along X axis

Translate Chamber 7 by steps of 100 μm in the X direction





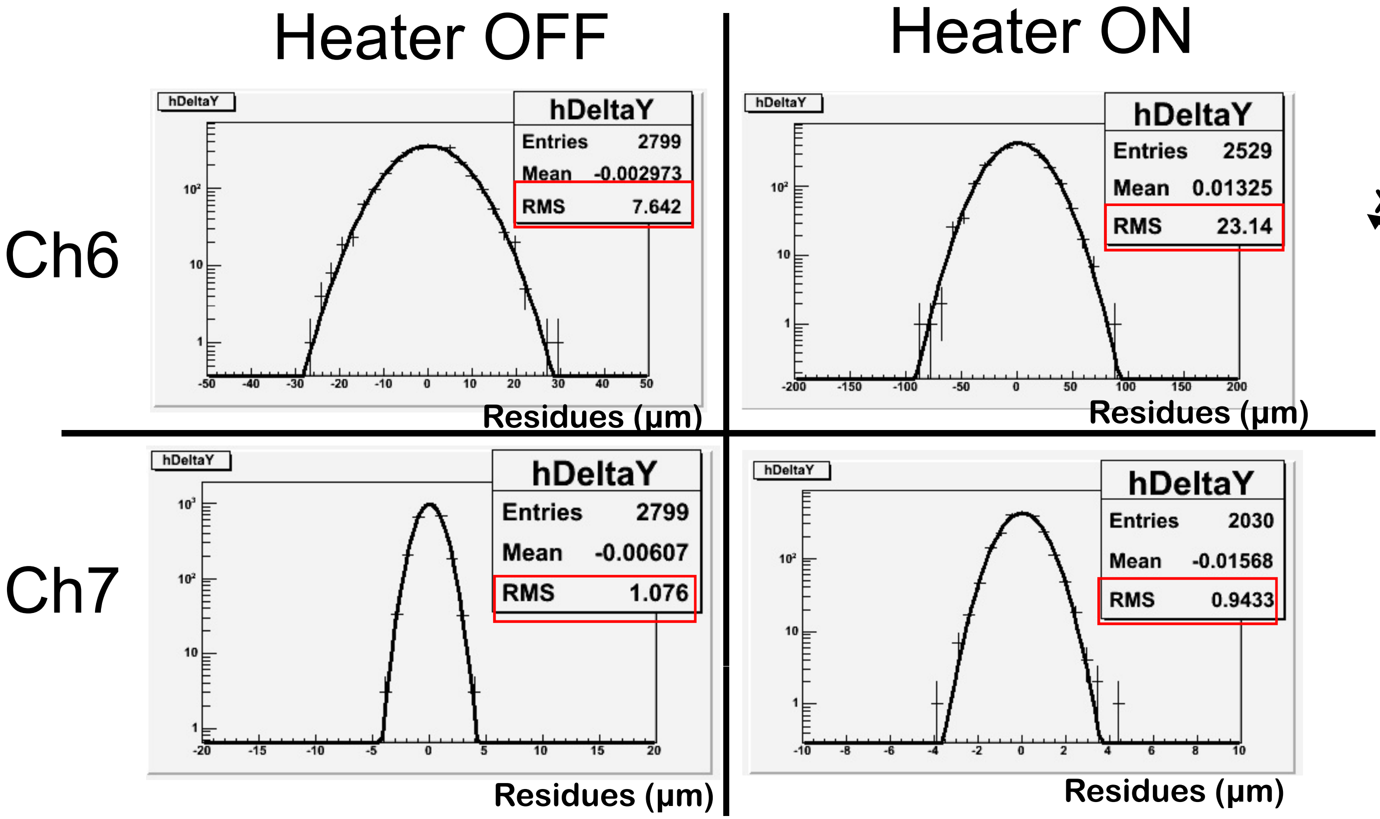


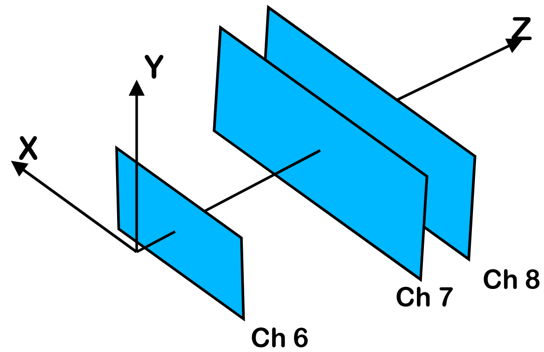
➔ Residues are consistent with zero

➔ Resolution of 1.5 μm on the position of the chamber 7

Thermal gradient test

Apply Temperature gradient to Chamber 6

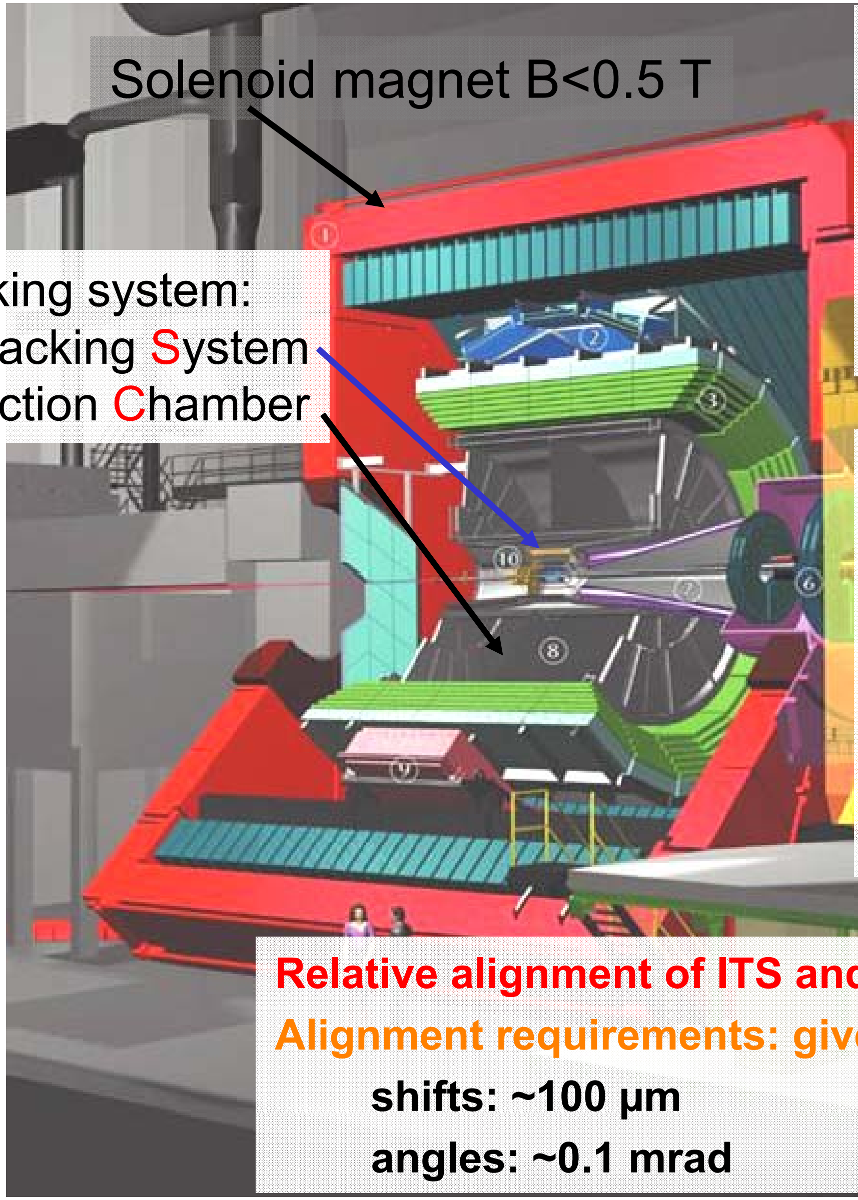




In this reconstruction Ch8 is the reference and supposed to be fixed

- Ch7 position is not affected by thermal gradient on CH6
- Ch6 lost about a factor 4 in resolution but still within requirements

Control of ITS-TPC relative displacements



TPC (the largest ever…):
88 m^3 , 510 cm length, 250 cm radius
Ne (90%) + CO_2 (10%)
88 µs drift time
160 pad rows
570312 pads - channels
main tracking device

ITS
6 Layers, 3 technologies
Material budget < 1% of X_0 per layer!
Silicon Pixels: vertices resolution in xy
(0.2 m2, 9.8 Mchannels)
Silicon Drift: resolution in z
(1.3 m2, 133 kchannels)
Double-sided Strip: connection w/TPC
(4.9 m2, 2.6 Mchannels)

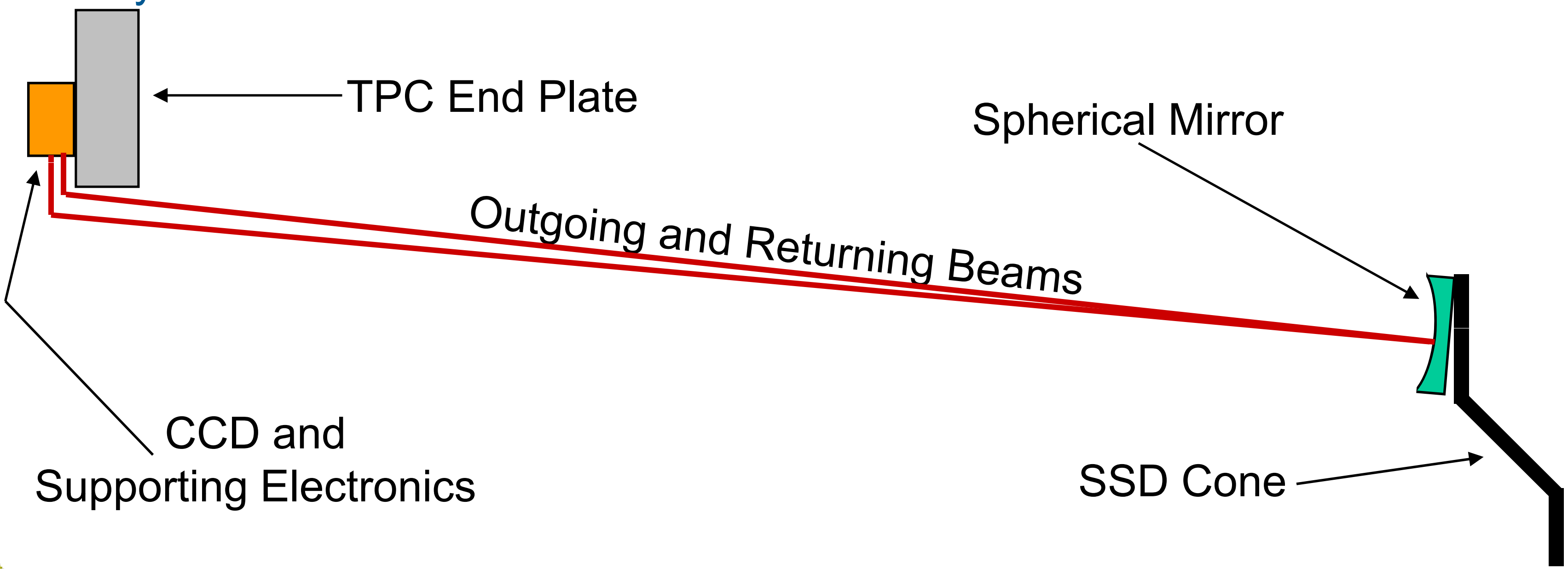
Relative alignment of ITS and TPC needs 3 shifts + 3 angles
Alignment requirements: given by TPC resolutions:
shifts: ~100 µm
angles: ~0.1 mrad

The Concept of the ITS-AMS

Slide prepared by D. Truesdale & B. Nilsen

- Four spherical mirrors placed on the ITS reflect collimated laser beams onto a CCD imager.
- As the focal point of the mirror coincides with the CCD's linear distance, any movement of the mirror is translated exactly to the image on the CCD.
- Movement of the images on all four cameras are read out and the motion of the ITS is computed.

Three translational and three angular degrees of freedom can be measured with only three cameras.



Calculating Motion

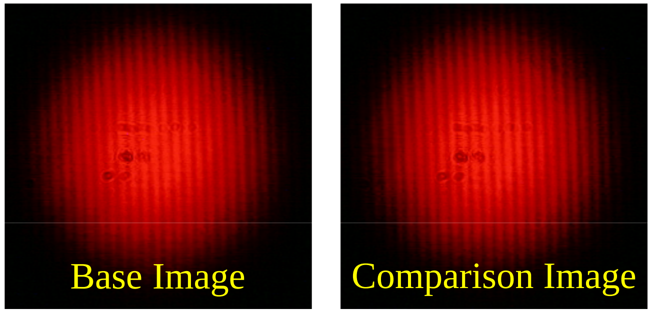
Slide prepared by D. Truesdale & B. Nilsen

- The cameras take an image at specified intervals and compare it with previous images taken.

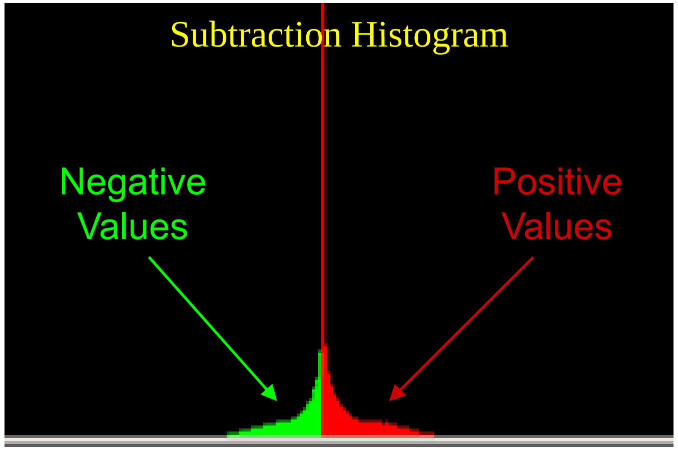
- The slight angle at which the beam travels allows measurement of motion in the transverse plane and along the beam axis.

- Averaging over the pixels, a minimum translational motion of 0.5 - 2 microns can be determined in the transverse plane and a minimum of 7 - 15 microns along the beam. Angular motion can be determined to .00005° about all axes.

- Current intensity subtractions allow for image shift resolutions of about 1 μm. More sophisticated Gaussian regression subtractions should improve resolutions by an order of magnitude.



These two images were taken before and after a lateral shift of 1 μm. The resulting histogram from the intensity subtraction clearly shows a shift to the right.

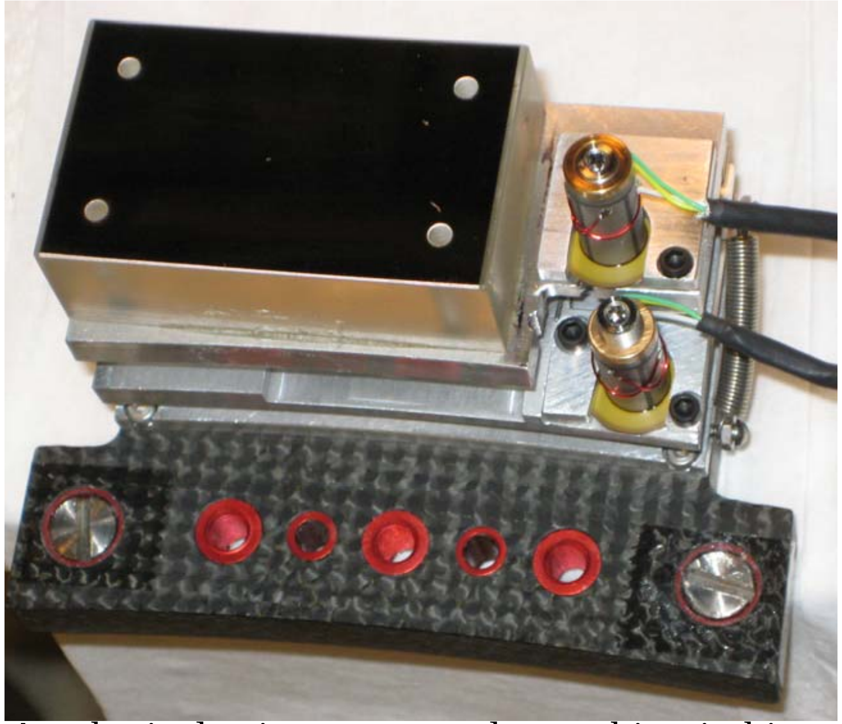


Operation and Installation

Slide prepared by D. Truesdale & B. Nilsen

- The camera is and off-the-shelf USB 1.1 webcam. Its signal is encoded via a proprietary commercial USB extender and transmitted over a duplex multimode optical fiber.

- Due to the size of the CCD and the distance spanned by the optical path, the system's dynamic range is ~.05º. To precisely align the optical beam, the cameras have been mounted on a moving stage with 30mm of travel along the TPC arc. The mirrors, have two axes of angular adjustment. Small piezoelectric motors allow computer controlled angular adjustment at the micron scale.



A spherical mirror mounted on a bi-axis hinge. The two motors mounted to the right of the mirrors allow remote adjustment after the ITS is inaccessible. The hinge is mounted onto wings, which are part of the SSD. There are four wings located at 90º increments.

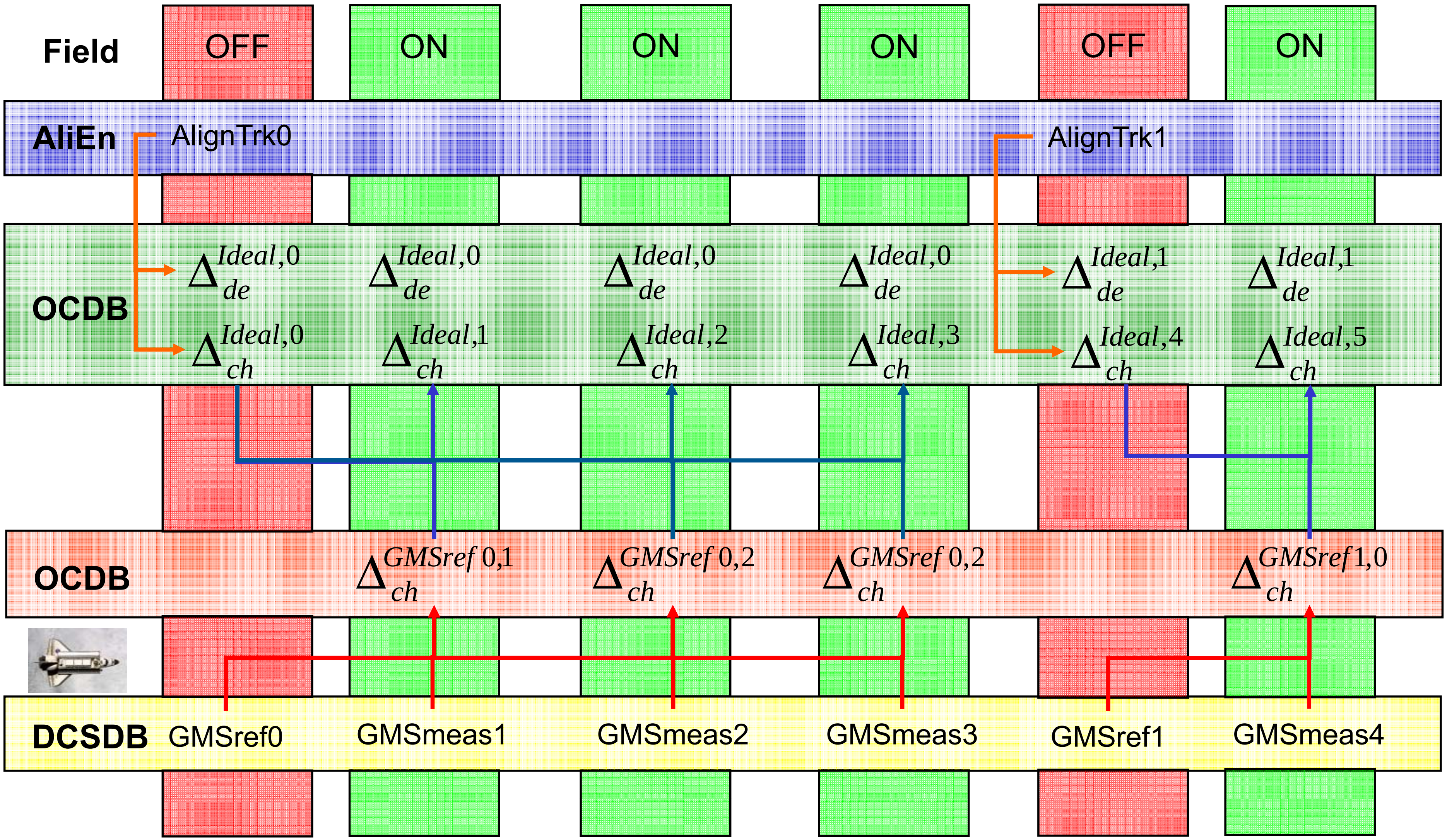
Summary & ToDo List

- Muon Geometry Monitoring System
  - Installation of the system on going
  - Reconstruction program completed and tested
  - Test bench demonstrated the very high level of performance of the system
  - First version of PVSS framework component available
  - Work needed on the final software integration (I/O with DB)

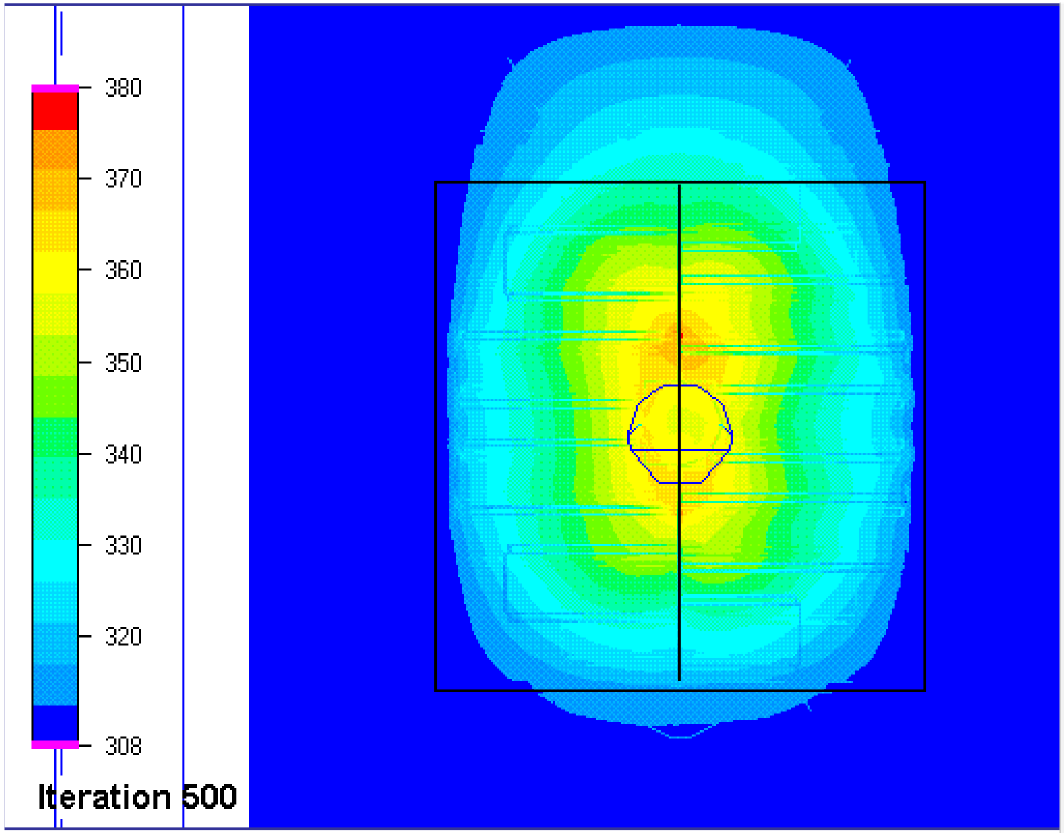
- ITS - TPC positioning control
  - Concept defined
  - System demonstrates a high precision in angular and translation shift determination
  - Remote adjustment capabilities during the initial alignment phase mean a significantly reduced reliance on the precision of the installation

BACKUPS

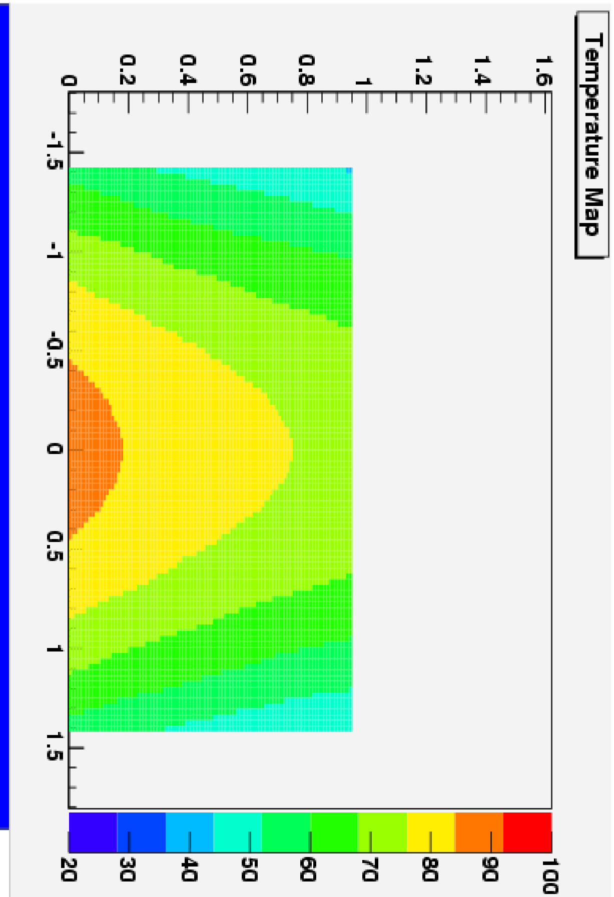
Combining the different data



Results in natural convection



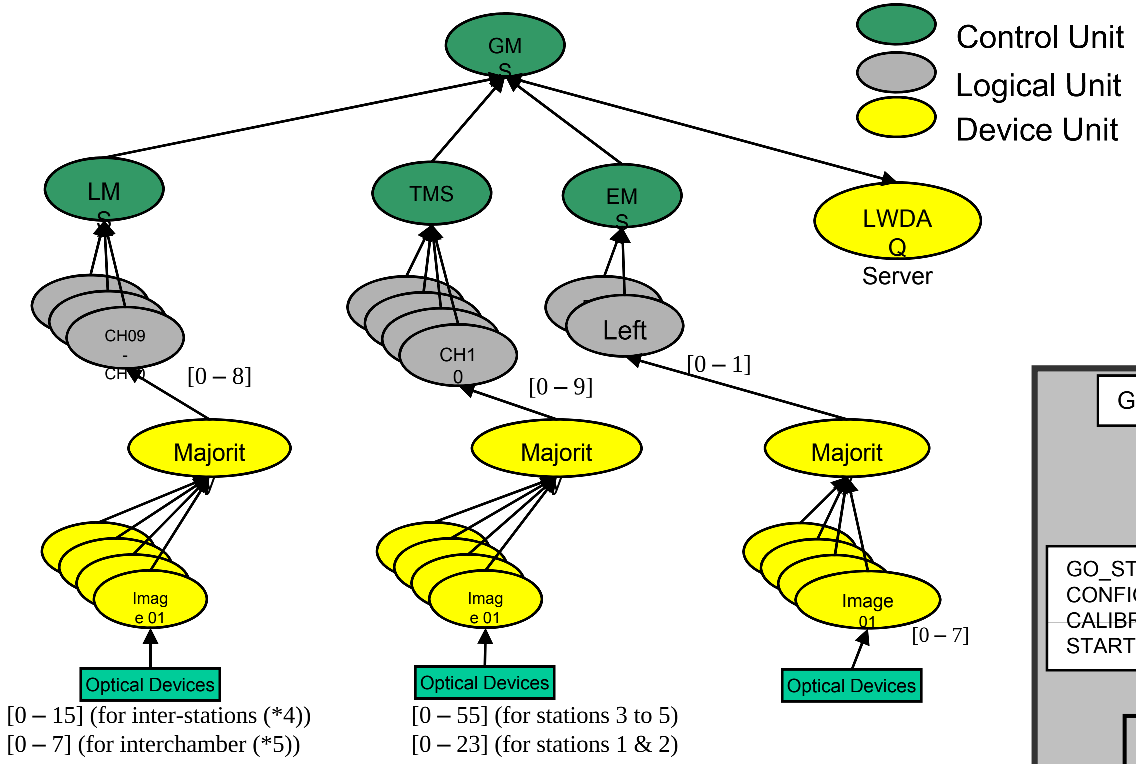
Simulation Thermique Station 3 (S. Salasca)

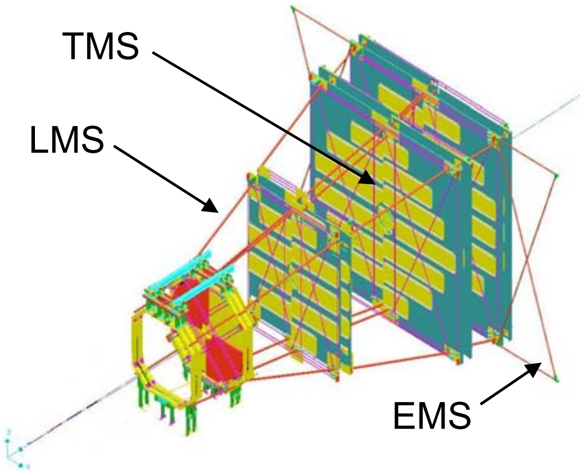


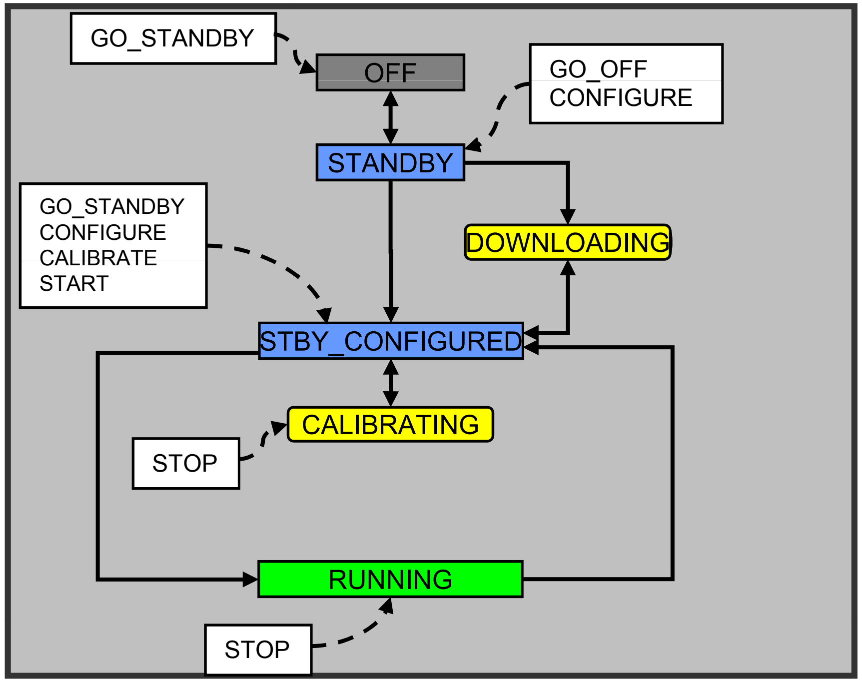
Temperature map obtained on the test bench

Finite State Machine

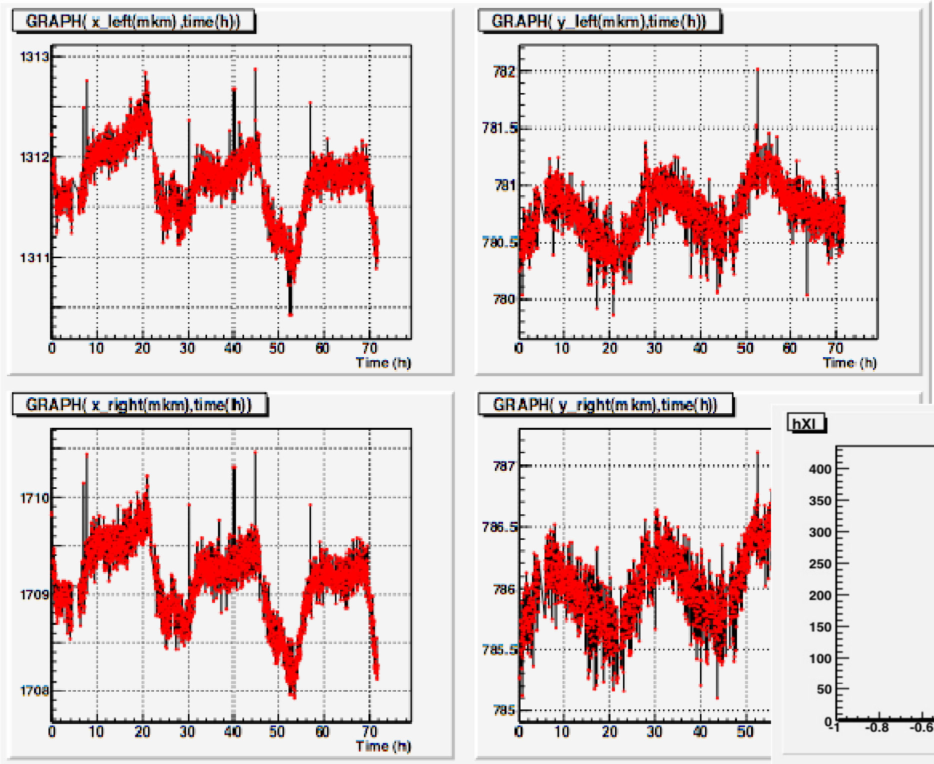
FSM completed and tested in lab







Long time measurement



3 days running

- Determination of the resolution of each BCAM
- Needed by the reconstruction program to weight each measurement

Resolution of about 0.1 µm on the CCD