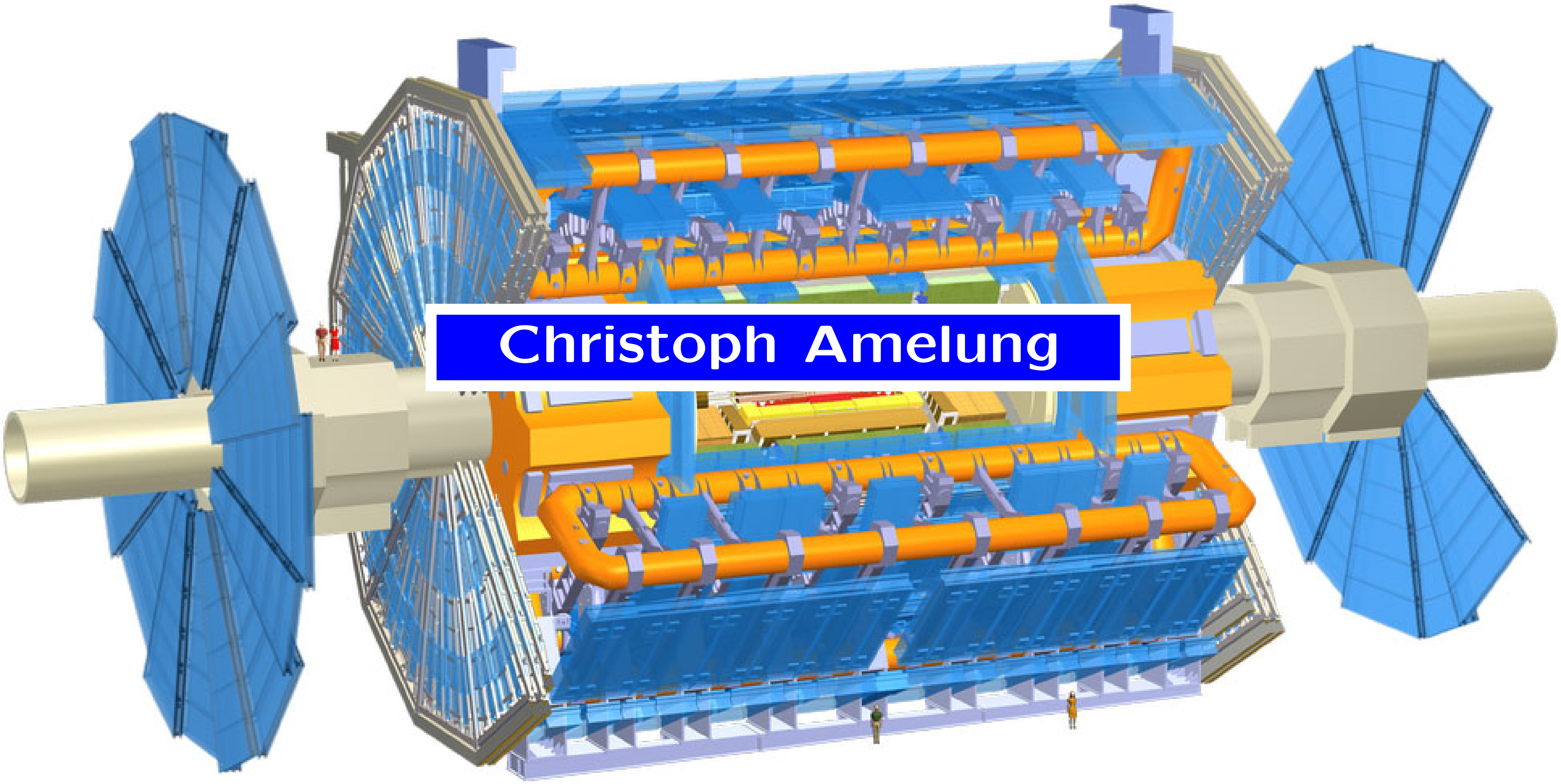
Optical Alignment System,
and Performance Studies with Data



Christoph Amelung

Alignment System – Work Done in 2010

- A year ago, we had convinced ourselves that our optical alignment system can provide alignment corrections with 45–50 μm sagitta accuracy – next challenge: do this continuously for 10–20 years
- This year, we have operated the endcap optical alignment system with 100% availability; the optical system provides *the* alignment used by ATLAS
- We have caught and examined the (very few) devices that failed in the 2009/10 running, fixed those that are reachable, keeping list for shutdown
- We have written software to optimize the sequence in which we read out our alignment sensors
- We have implemented tools to visualize chamber movements vs time, and studied what we observe
- We have started to work on alignment system components for EES chambers and alignment bars

Alignment System Operation

- **Operating the alignment system:**

  now that we are in stable running mode, operating the alignment system readout means (mostly) monitoring that the chain LWDAQ-PVSS-ARAMyS-DB is working:

  - the readout has not stopped/crashed
  - no new sensors have broken
  - no faulty measurements have affected the alignment fit
  - alignment corrections are submitted to DB

  set up a dynamic web page for easy monitoring from anywhere – fixing problems still requires manual intervention, obviously

  readout system development work (Joe Rothberg/Washington) focused on improving stability – no more unexpected crashes

  working on database issues with Andrea Formica/Saclay

  many "users" of the alignment in ATLAS need advice on which alignment to use, what accuracy to expect, etc

- **Maintenance of the alignment system:**

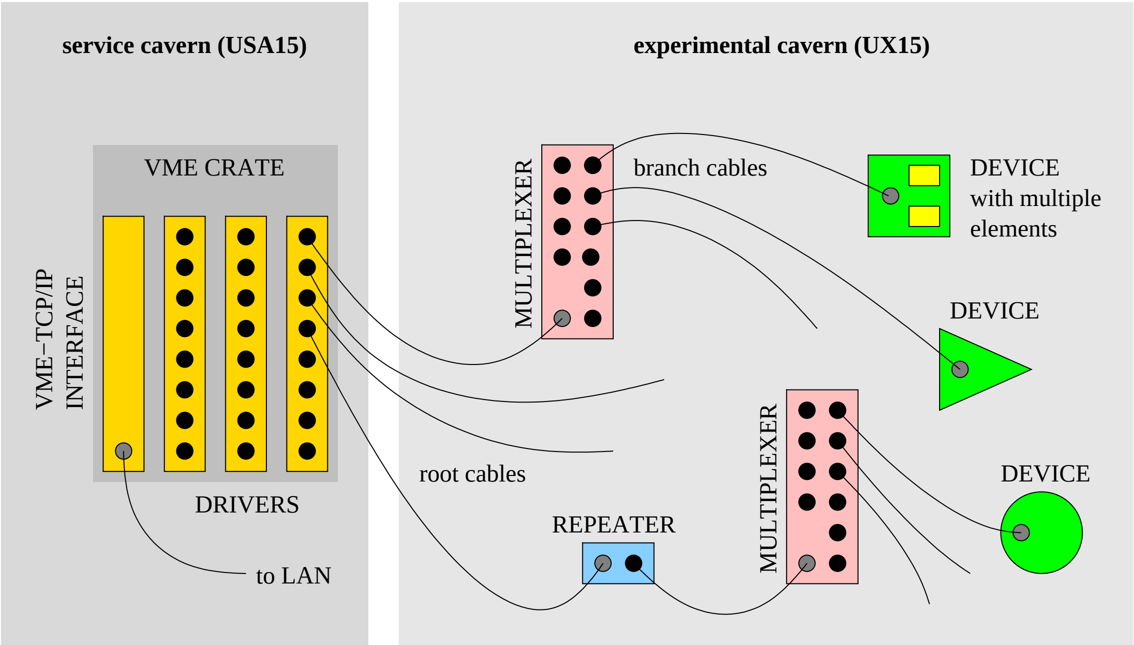
  waiting and preparing for the shutdown . . .

Readout Scripts

- **Optimizing the alignment sensor readout:**
  - minimize on-time of devices (extend their lifetime)
  - maximize readout speed (follow detector movements)

each driver can be powered up or down independently, but switching off/on is time-consuming ($\approx 0.5/2$ sec)

several alignment sensor readout instances (LWDAQ) can run in parallel as long as they do not access drivers sitting in the same VME crate (6 crates, 20 drivers each)



Readout Scripts

- **Optimized LWDAQ readout scripts:**

  LWDAQ controlled by acquisition scripts: for each sensor, the script contains all the necessary information for acquiring an image

  scripts used up to this year had been "hand-made", being edited as the installation of ATLAS progressed

  Serdar Gozpinar wrote the software to generate scripts automatically from the alignment DB, with an optimal ordering of power on/off and acquisition steps, and the optimal splitting into several parallel scripts

  now need 35 min/cycle (was 40–45 min), and typical on-time of each device went down to 5–10% (was around 50%)

  further reducing the on-time is possible by pausing the alignment readout after each cycle – if the detector is stable enough

```
acquire:
name: {POWER_SLOT_01_ON}
instrument: {Diagnostic}
config:
  daq_ip_addr {11.0.0.213}
  daq_driver_socket {00100000:1}
  daq_actions {off 500 on 500 sleepall 500 sle
  daq_psc {1}
  max_p15_mA {146}
  max_p5_mA {197}
  max_n15_mA {115}
end.

acquire:
name: {BCB_AEI_01_16_CC_1}
instrument: {BCAM}
config:
  daq_ip_addr {11.0.0.213}
  daq_driver_socket {00100000:6}
  daq_mux_socket {2}
  daq_device_element {1}
  daq_device_type {2}
  daq_source_ip_addr {11.0.0.213}
  daq_source_driver_socket {00100000:1}
  daq_source_mux_socket {2}
  daq_source_device_element {1}
  daq_source_device_type {1}
  daq_flash_seconds {0.011310}
  daq_adjust_flash {1}
  daq_image_left {20}
  daq_image_right {343}
  daq_image_top {1}
  daq_image_bottom {243}
  peak_min {80}
  peak_max {100}
end.
```

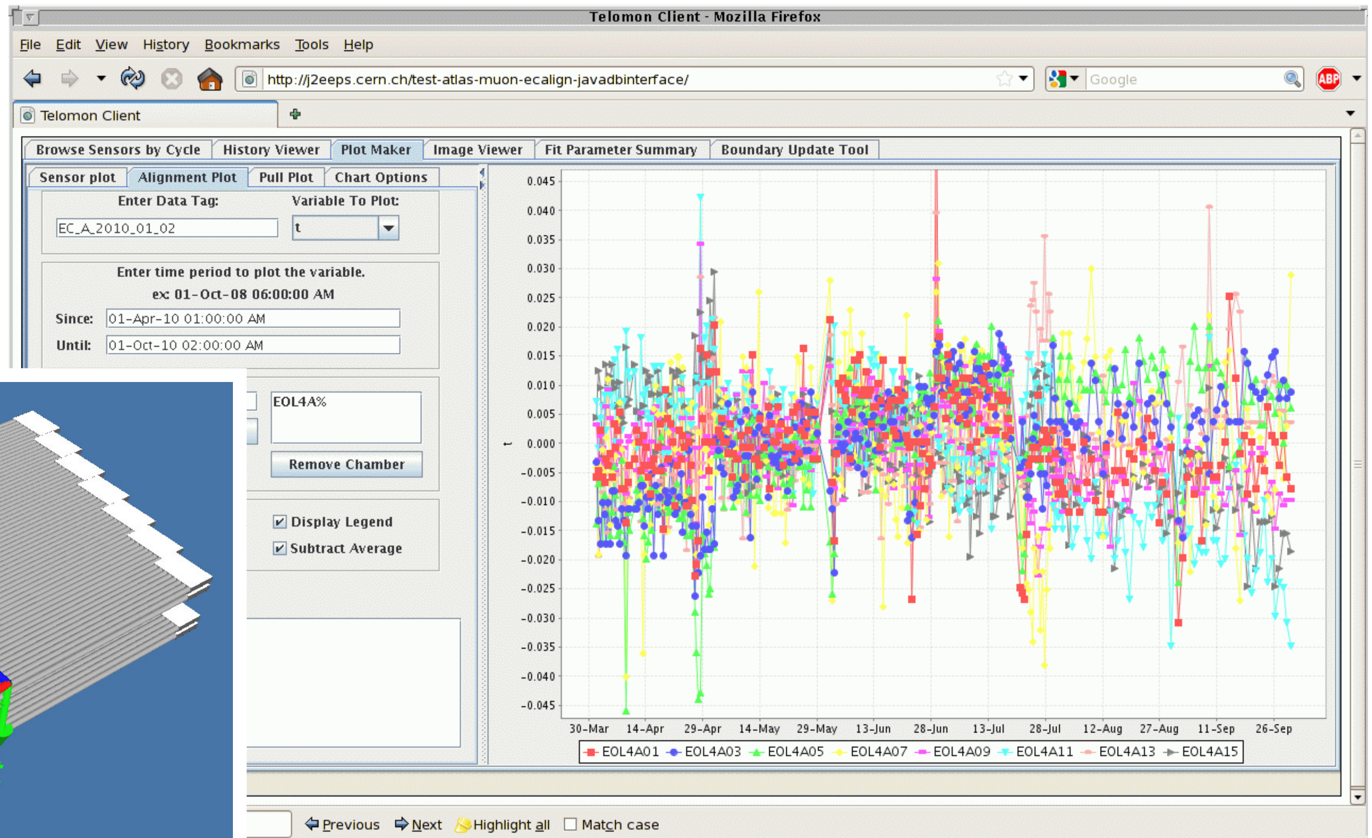
Alignment Results

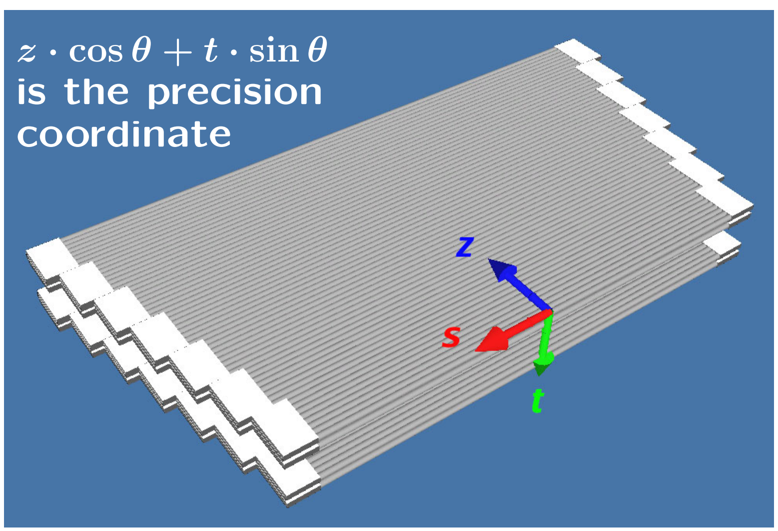
- **Telomon:**

  a Java application originally for monitoring, now mostly used for making on-demand plots of measurements and alignments

  Dan Pomeroy added the feature to generate plots of reconstructed chamber positions – showing some examples

  using MDT local coordinates z = radial movements in chamber plane and t = orthogonal to chamber plane





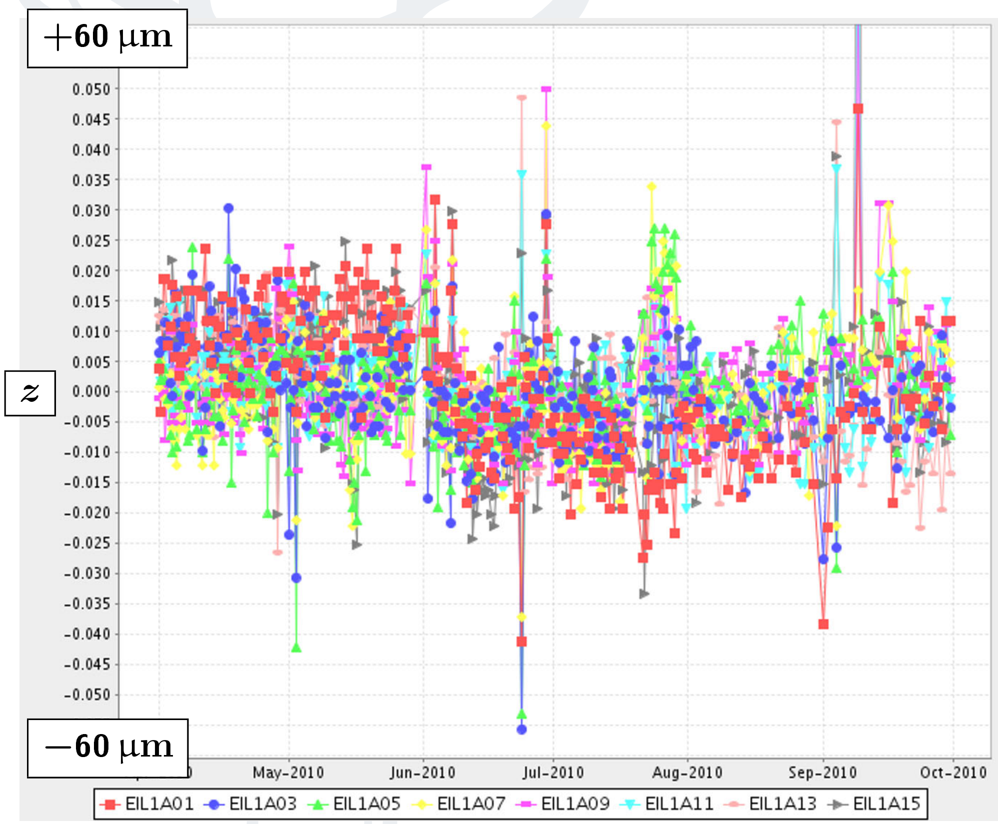
Alignment Results

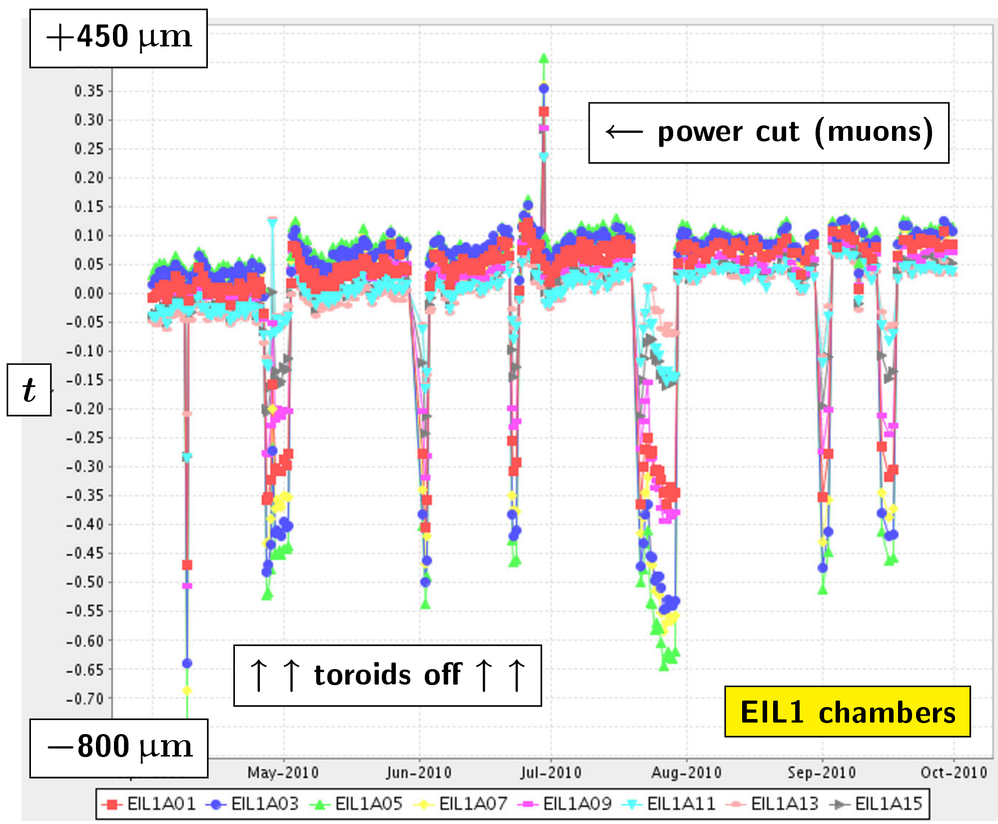
- **EI chambers (EIL1/2/3, EIS1/2):**

  mounted on the Small Wheels

  very stable in radial coordinate z, both short-/long-term

  "fast" movements out of the wheel plane, in t, are due to magnets turning on/off – the wheel tilts very slightly; plus slow long-term trend on top of this (moving away from IP)





Alignment Results

- **EIL4 chambers:**

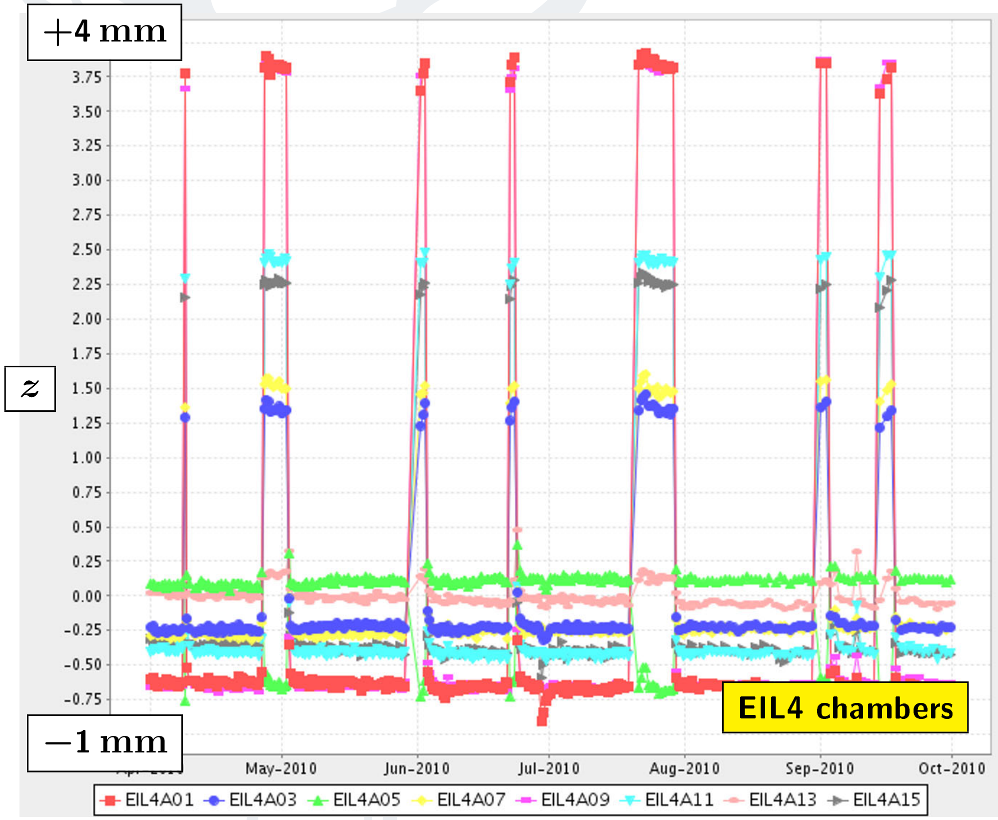
  mounted on barrel toroid structure (like barrel chambers), not on wheels

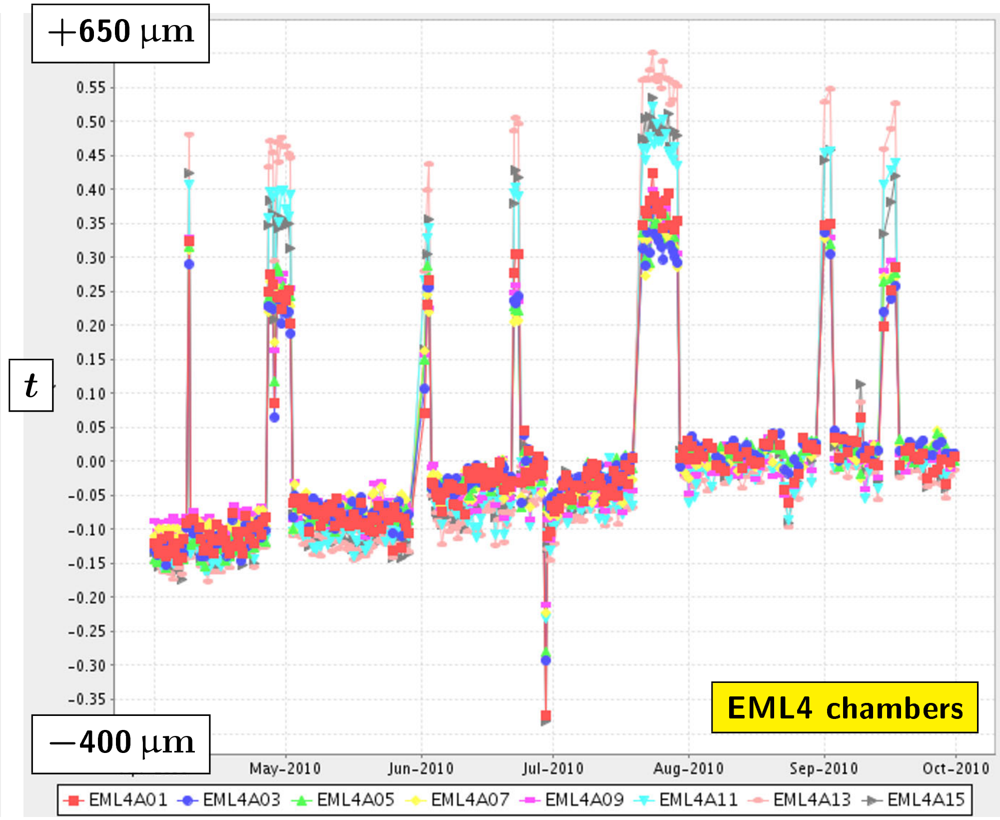
  very large movements in radial coordinate for magnets on/off – seeing egg-shape deformation of barrel toroid structure

- **EM chambers:**

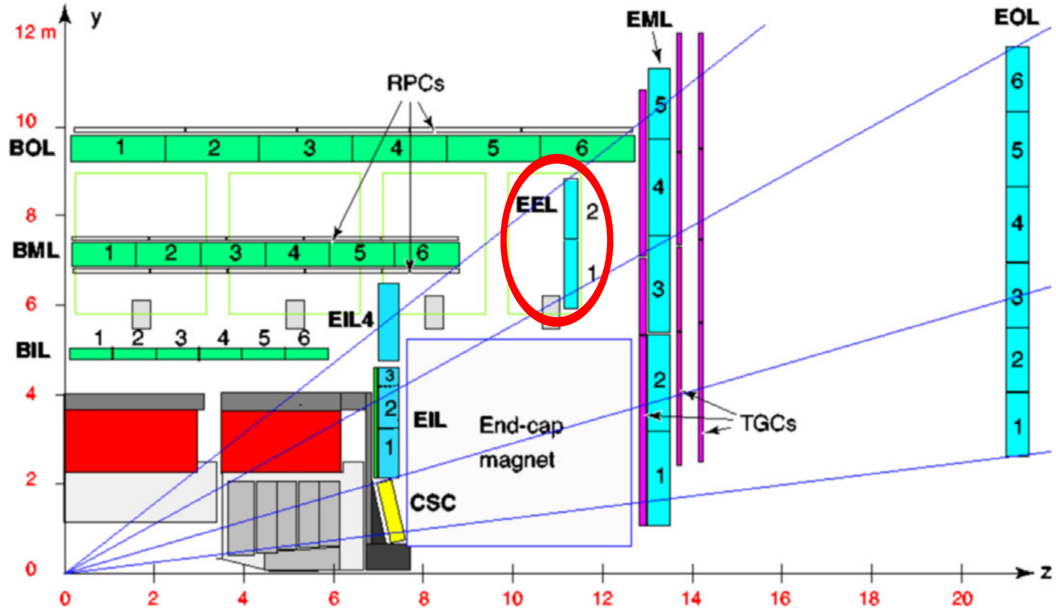
  mounted on the Big Wheels

  movements orthogonal to the wheel plane between toroids on and off – wheel is attracted (and deformed) by the magnet





The EE Wheel



- **Preparation for EE chamber installation (in 2012):**

  alignment bars are assembled and calibrated at Freiburg University, at CERN the data are checked and sensors are mounted – 16/16 EEL and 8/16 EES bars ready

  alignment sensors are assembled and calibrated at Brandeis, all EES and most EEL are ready, testing at CERN ongoing – Kathryn Marable working on this

  MDT chambers and bars assembled into sectors (EES) or mounted individually in ATLAS (EEL) – 8/16 EES ready for sensors to be mounted and commissioned (other 8 need bars)

Data Analysis – Work Done in 2010

- Scott Aefsky and I have continued our study of the muon chamber alignment using track segments
- The long-term goal of this study is to arrive at a unified approach to getting the best possible alignment from sensors and tracks together, by minimizing a combined $\chi^2 = \chi^2_{\text{sensors}} + \chi^2_{\text{tracks}}$
- Requires orders of magnitude more data than available – while waiting, we attempt to verify (or disprove) the optical alignment using tracks
- As it turns out, our study is a great tool to find all sorts of bugs that nobody else seems to notice
- Through this, we are making a major contribution to the ongoing effort of understanding the muon spectrometer performance (resolution/efficiency)
- Resolution in particular is a key problem for many physics analyses now: $Z \to \mu\mu$, $W \to \mu\nu$, W', ...

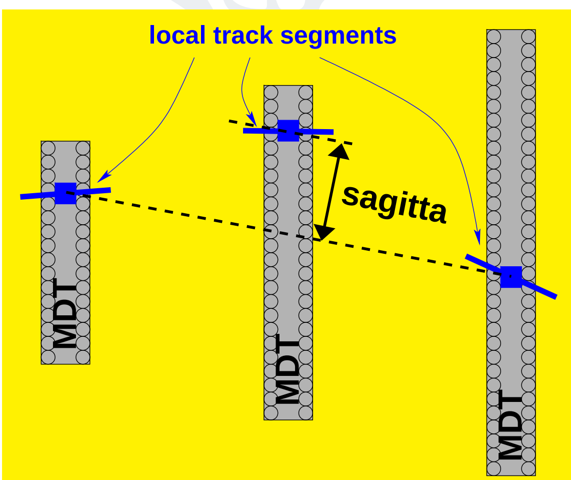
The Method

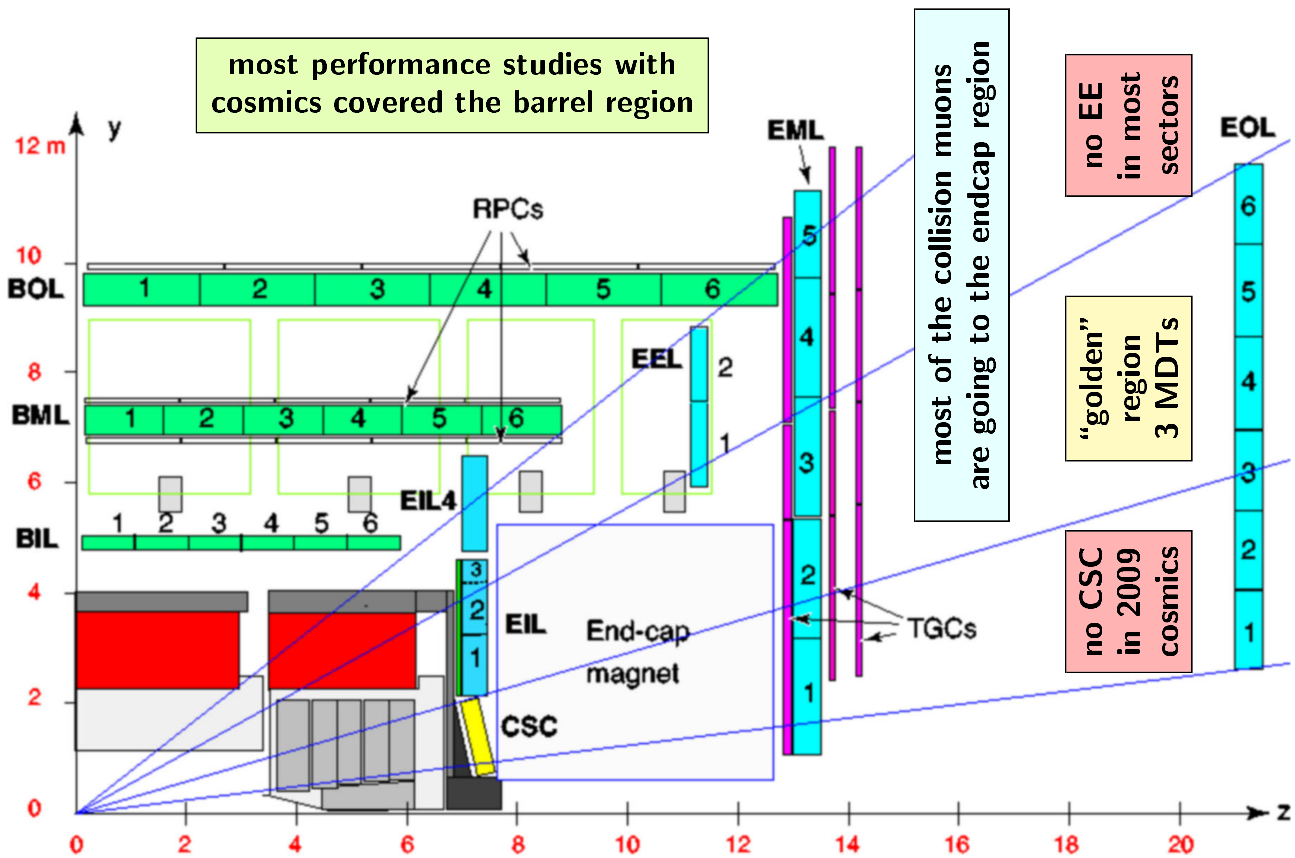
- **Sagitta study using track segments:**

use data with toroid magnets off – $\mathcal{O}(100\,\mathrm{M})$ events from fall 2009 cosmics, $30\,\mathrm{nb}^{-1}$ from summer 2010 collisions

select triplets of segments in three wheels, apply basic quality and isolation criteria

calculate sagitta (deviation from straightness) of the three segments, and for each segment the angular difference w.r.t. the line joining the outer two



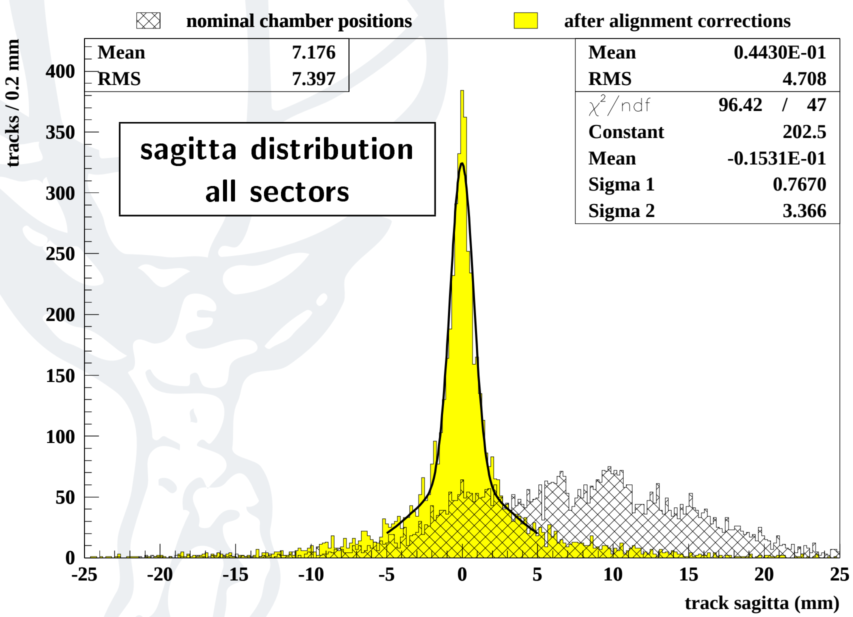


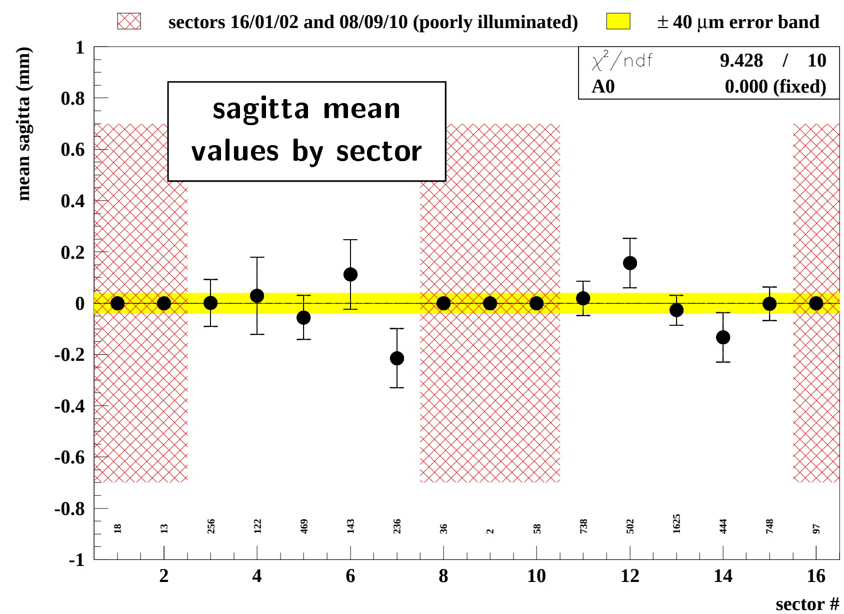
Sagitta Study Results

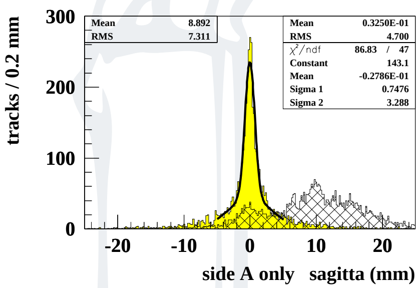
- **"Golden region" EI-EM-EO (2009 fall cosmic data):**

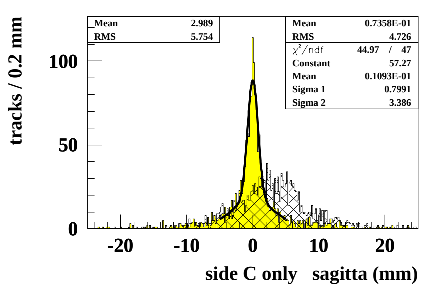
  mean value of sagitta distribution zero within errors, the width is dominated by multiple scattering (not by alignment quality)

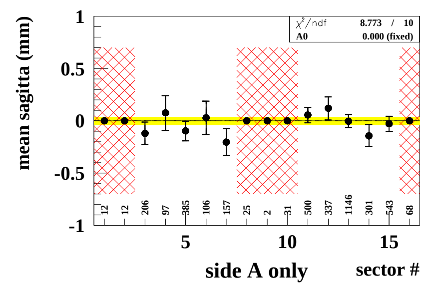
  to prove the alignment is correct, would need to break down by side, sector, and tower – sector results already statistics-limited

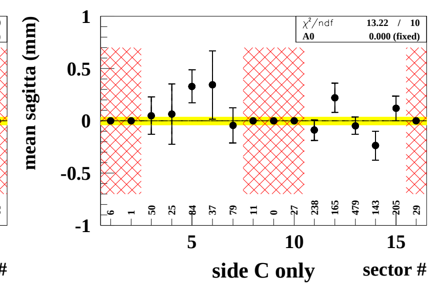












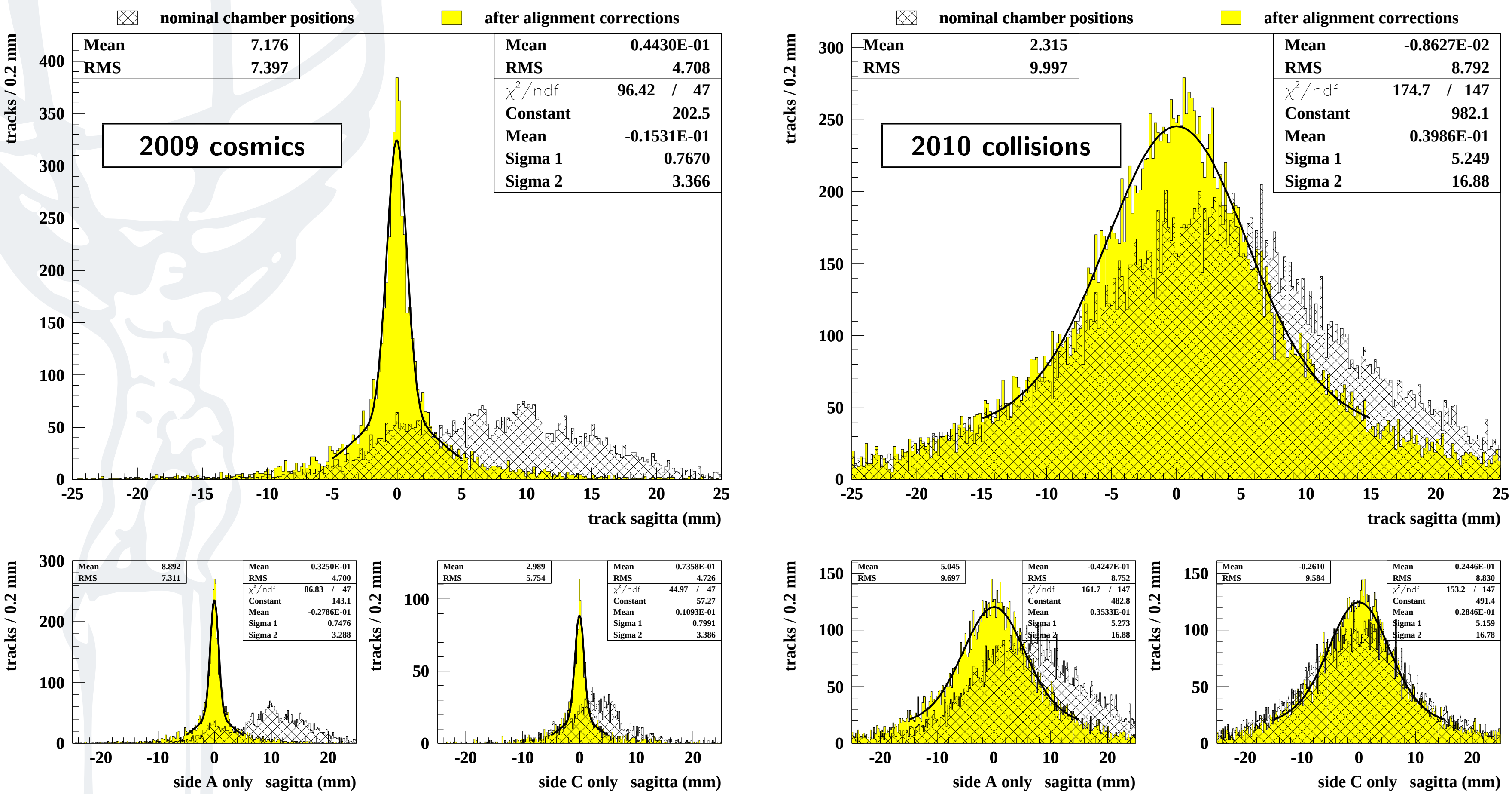
Sagitta Study Results

- For comparison – same plot from 2010 collisions:

  no explicit momentum cut applied for cosmics

  for collision data, used matching inner detector track to apply a momentum cut $p > 15$ GeV

  factor 3 less sensitivity to the mean value with 2010 data set

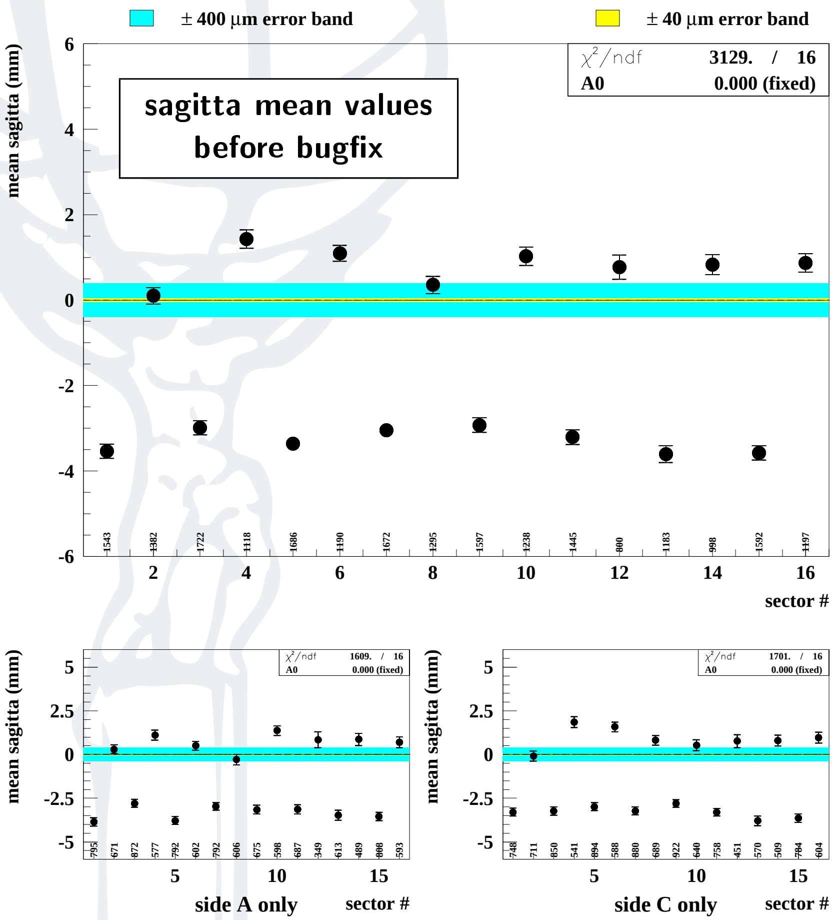


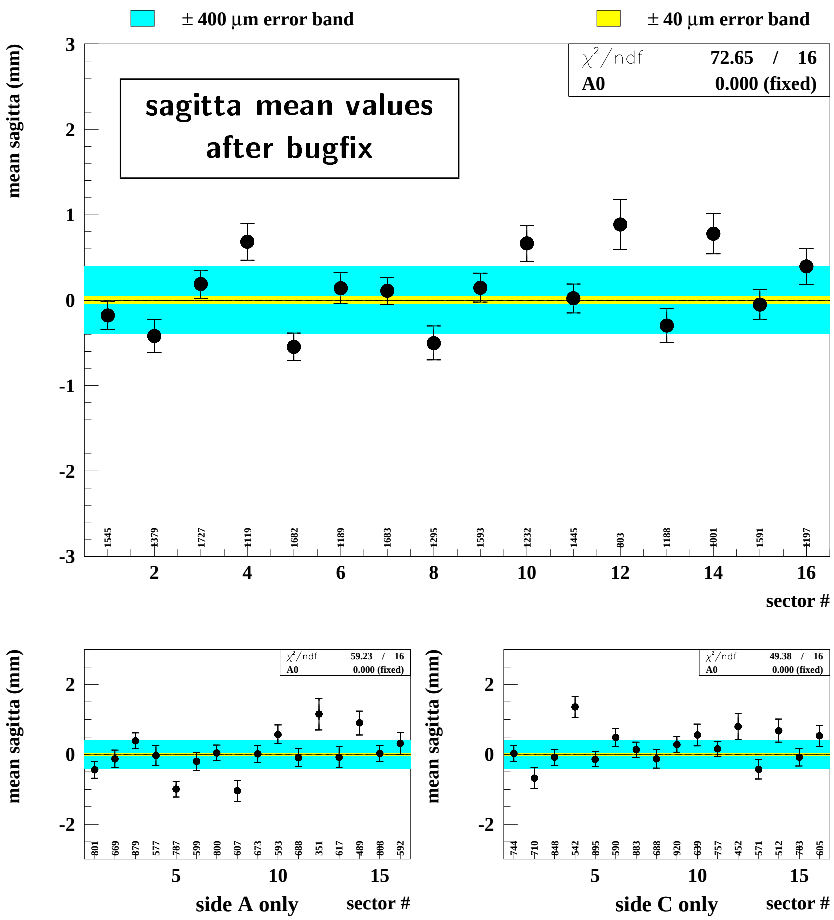
Sagitta Study Results

- **CSC-EM-EO region (2010 collision data):**

  first look with collision data revealed a bug – in relating the CSC local coordinate system to the alignment sensor mounts

  much improved after the bugfix, residual scattering of sagitta values is due to non-conformities of CSC internal geometry

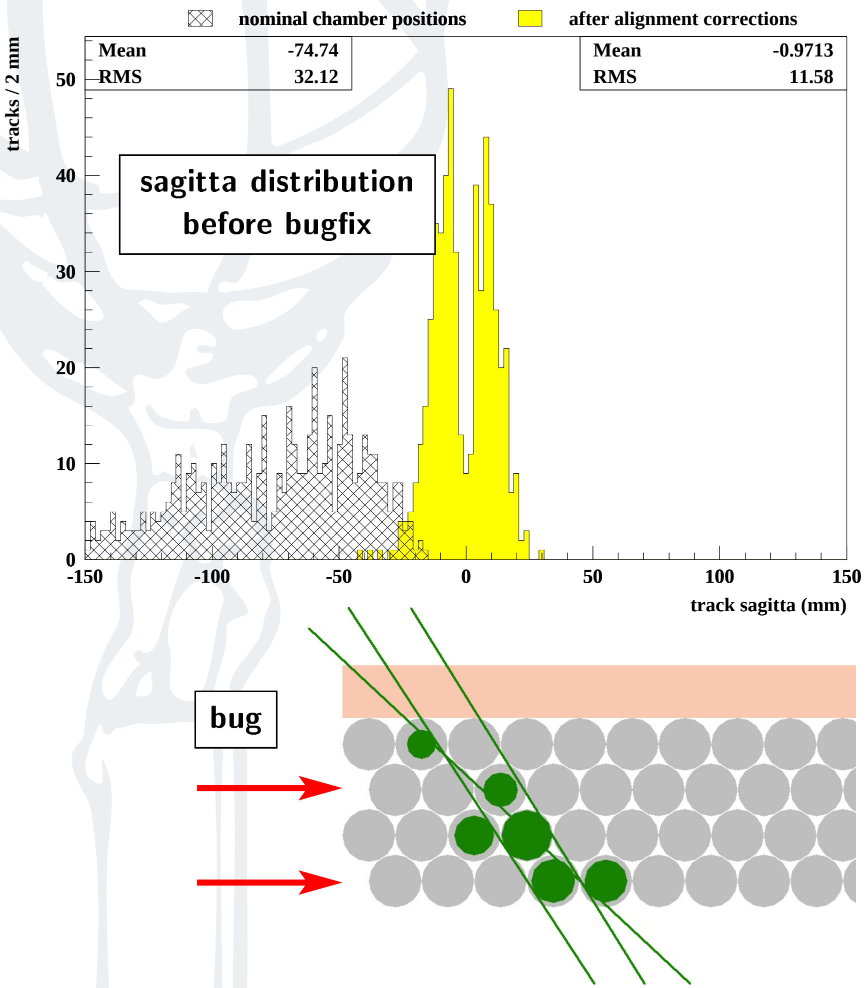


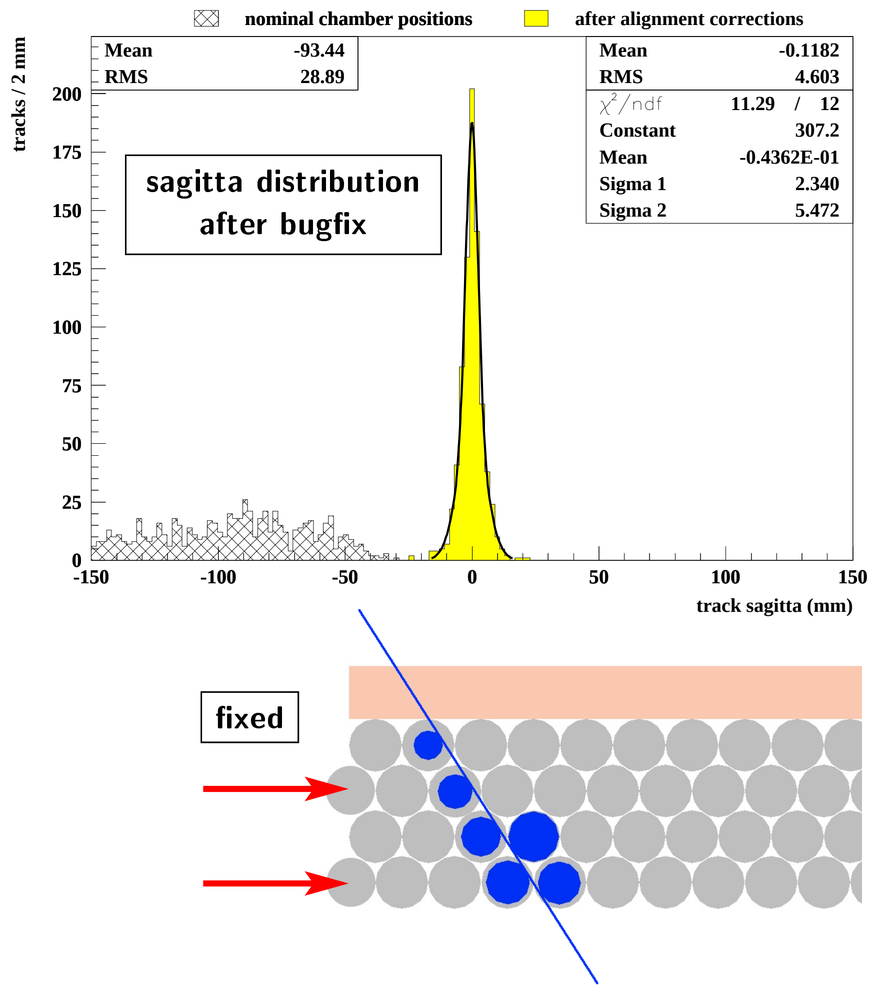


Sagitta Study Results

- **EI-BEE-EM region (2009 cosmic data):**

  bizarre double-peak structure after alignment corrections (from survey; BEE have no alignment sensors) – traced back to a bug in the chamber geometry description (tube staggering inverted)





Sagitta Study Results

- **All the bugs that we found:**
  - CSC local chamber coordinate system – alignment bug
  - BEE tube staggering – geometry bug
  - EEL and EES spacer height – geometry bug
  - BEE2A16 mezzanine card cables swapped – cabling bug
  - EEL1C13/EEL2C13 readout fibers swapped – cabling bug
  - too small TGC errors in segment/track fitting – software bug

  ... all of which manifested themselves as very "obvious" bugs: we made the plots, saw something was wrong, investigated

- **Future plans for this study:**

  continue looking for bugs

  improve CSC alignment to a level comparable to MDTs – $2\,\mathrm{pb}^{-1}$ of toroid-off collision data would be sufficient

  with $20\,\mathrm{pb}^{-1}$ of toroid-off collisions, we could check sagitta distributions for all MDTs at the tower level – end of 2011 ?

  then tackle combined sensors + tracks alignment