ATLAS Alignment Challenges

Florian Bauer, Saclay

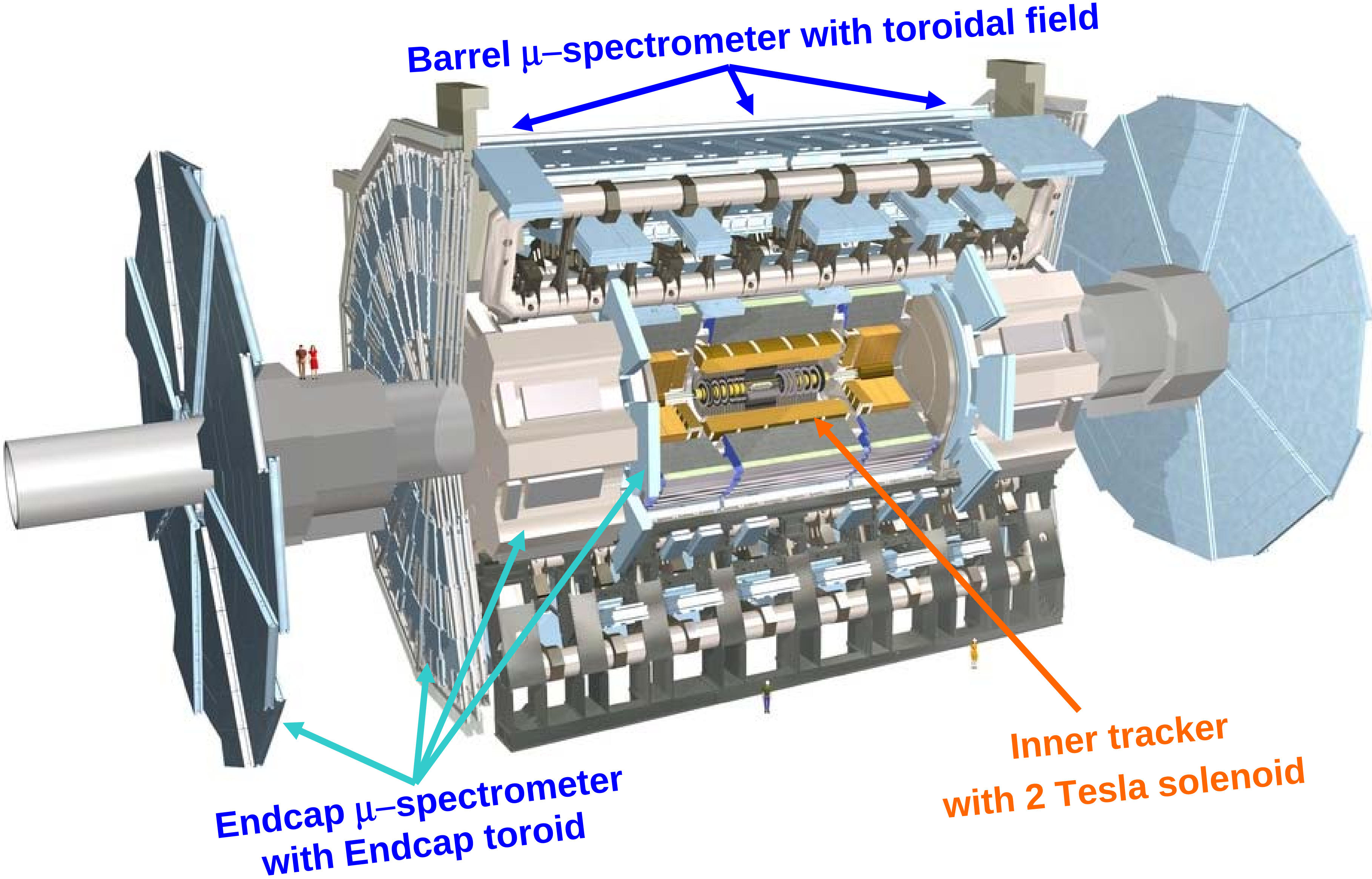
On behalf of the ATLAS Inner Tracker and Muon alignment communities

Outlook:
1. Inner Tracker Alignment
2. Muon Tracker Alignment

RAL

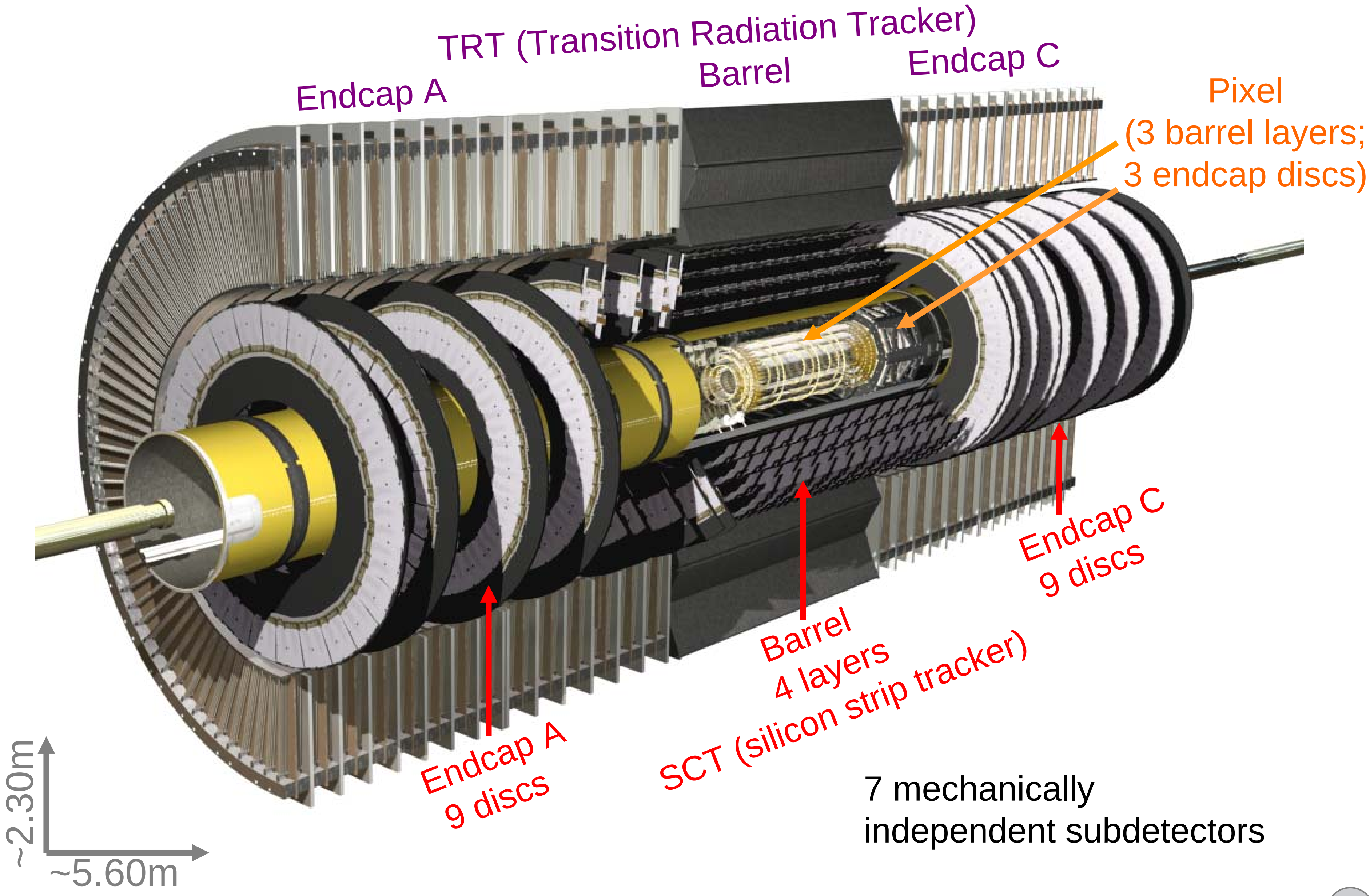
Niels Bohr Institutet

"L'ATLAS"


Barrel μ–spectrometer with toroidal field
Endcap μ–spectrometer
with Endcap toroid
Inner tracker
with 2 Tesla solenoid

Inner Tracker Alignment

Atlas Inner Tracker



7 mechanically
independent subdetectors

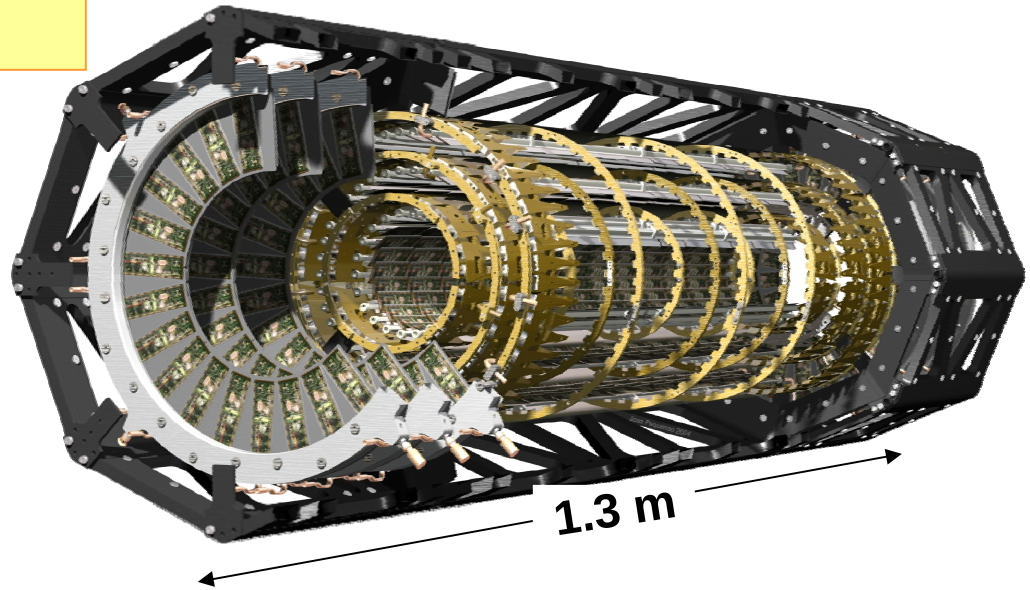
PIXEL

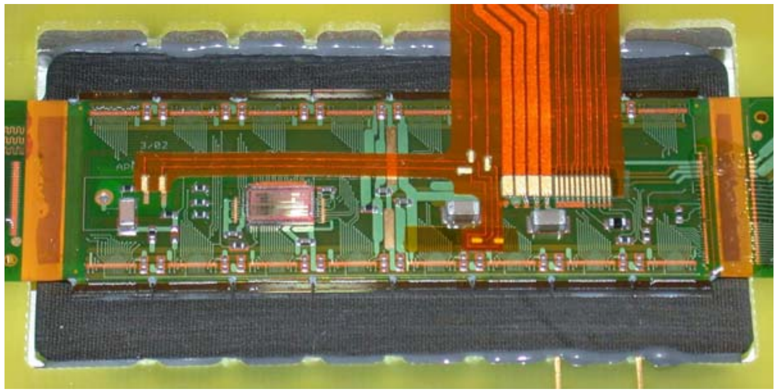
Barrel: 1456 modules
Endcap: 2 x 144 modules
1744 modules

One module: 46.080 pixels
Total: ~80.000.000 pixels

One pixel: 50µm x 400 µm
Resolution: 12µm x 60 µm

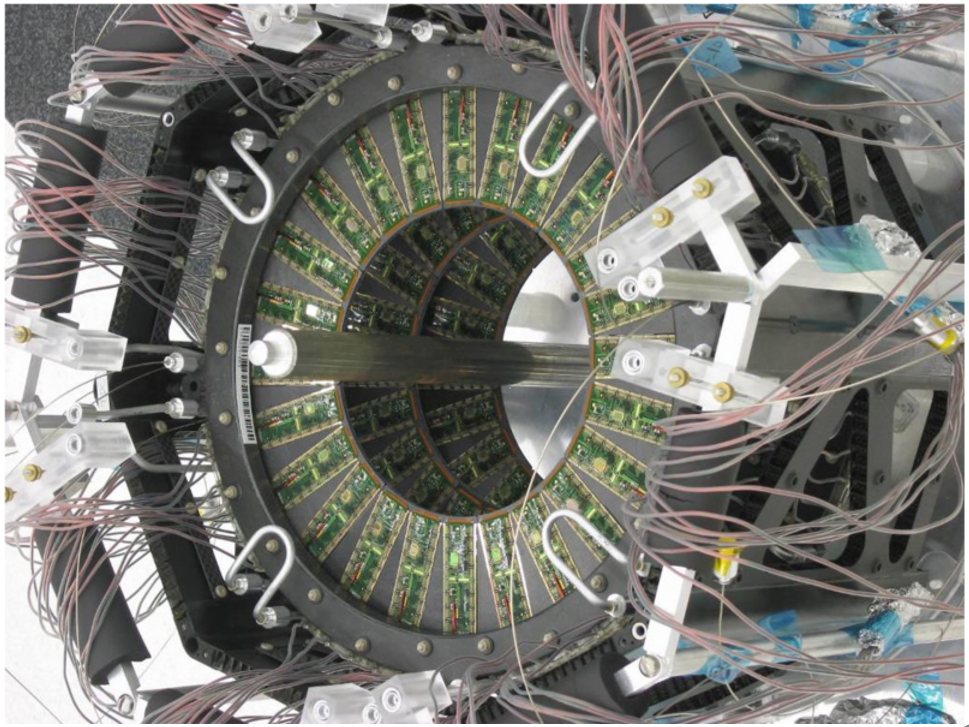
Hits per track: 3





Single Pixel module

All modules have same layout



A view of 3 completed discs of one Endcap

SCT (Silicon Strip)

Barrel: 2112 modules
Endcap: 2 x 988 modules
4088 modules

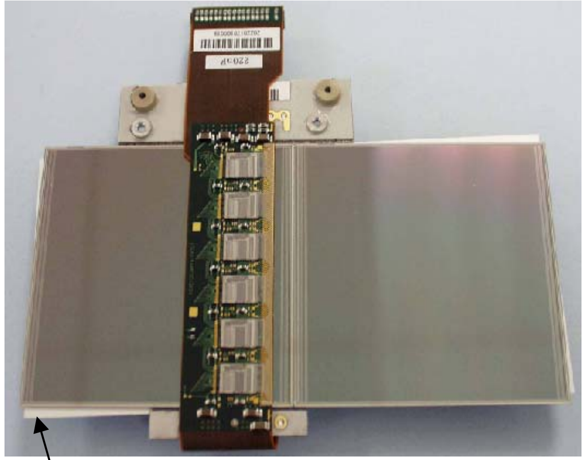
One module: 2 layers x 768 channels
Total: ~ 6.000.000 channels

Channel size: 80μm x 120 mm
Resolution: 16μm x 580 μm

Hits per track: Barrel: 4 Endcap: 9

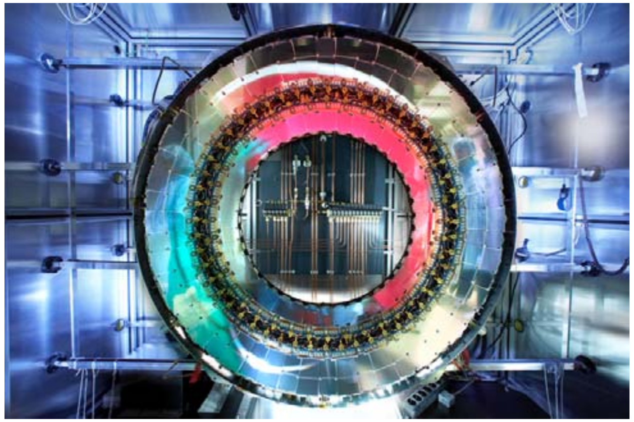
Endcap module

Barrel module

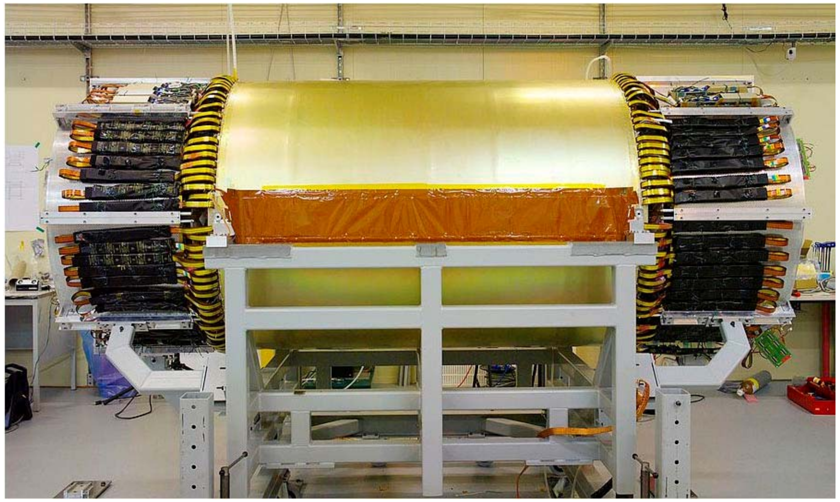


One module has 2 layers with 40 mrad stereo angle

4 different module layouts (3 endcap, 1 barrel)

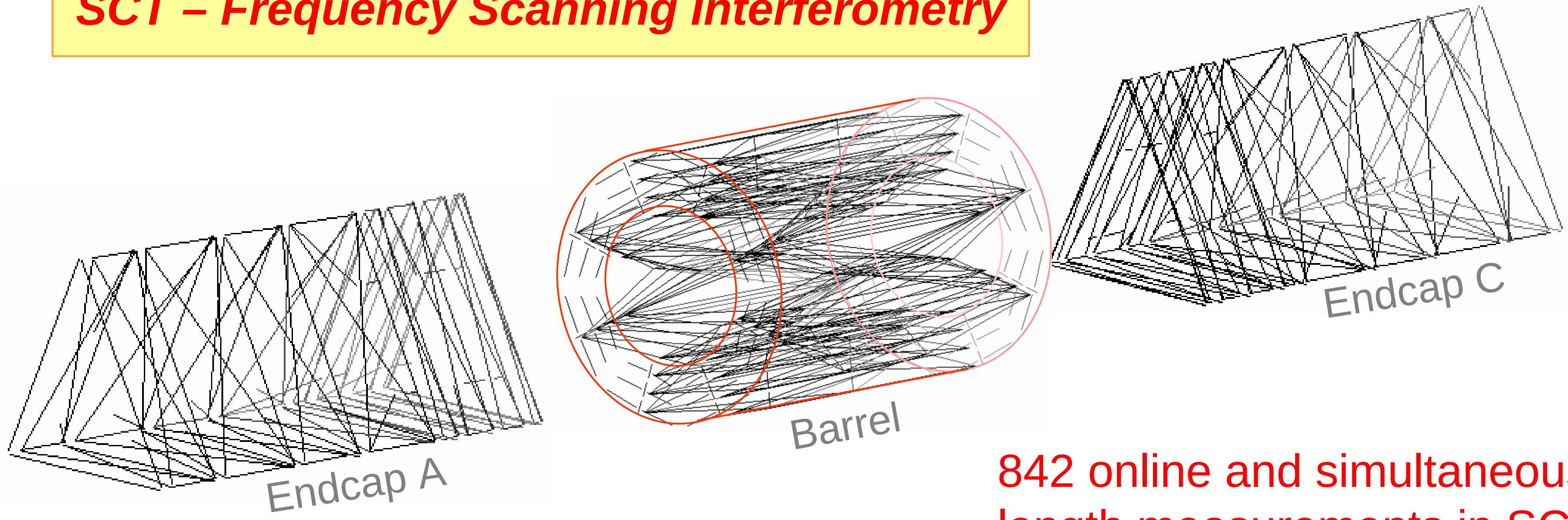


SCT EndCap



Fully assembled SCT Barrel

SCT – Frequency Scanning Interferometry



842 online and simultaneous length measurements in SCT!

- Optical online monitoring of the SCT geometry using a grid of interferometers
- Distance between point close to the optical fiber end and retro-reflectors mounted in the SCT.
- Single FSI Grid Line Interferometer has a precision below 1µm!
- Entire Grid shape can be determined to better than 10µm in 3D.
- FSI is beautifully complementing the offline track alignment wherever the latter is not sufficiently sensitive – lowest modes of global distortions!
- It also provides quasi real-time response to time dependent deformations.

TRT (Transition Radiation using straw tubes)

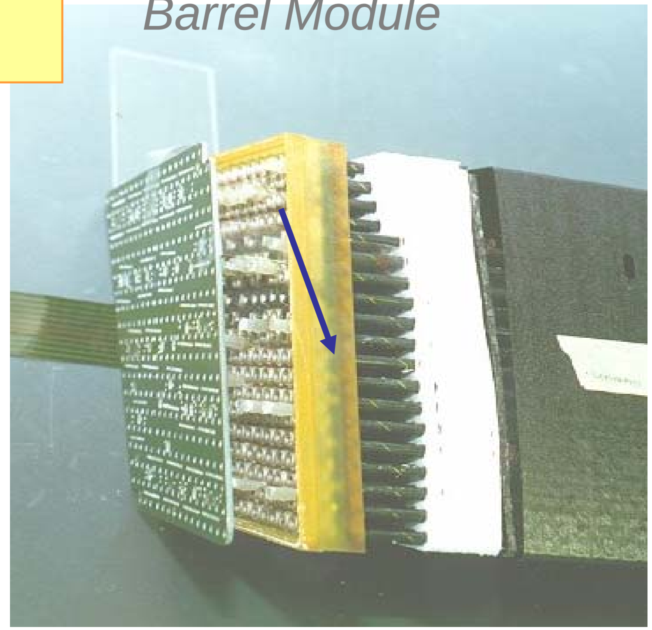
Barrel: 96 modules
Endcap: 28 modules 2

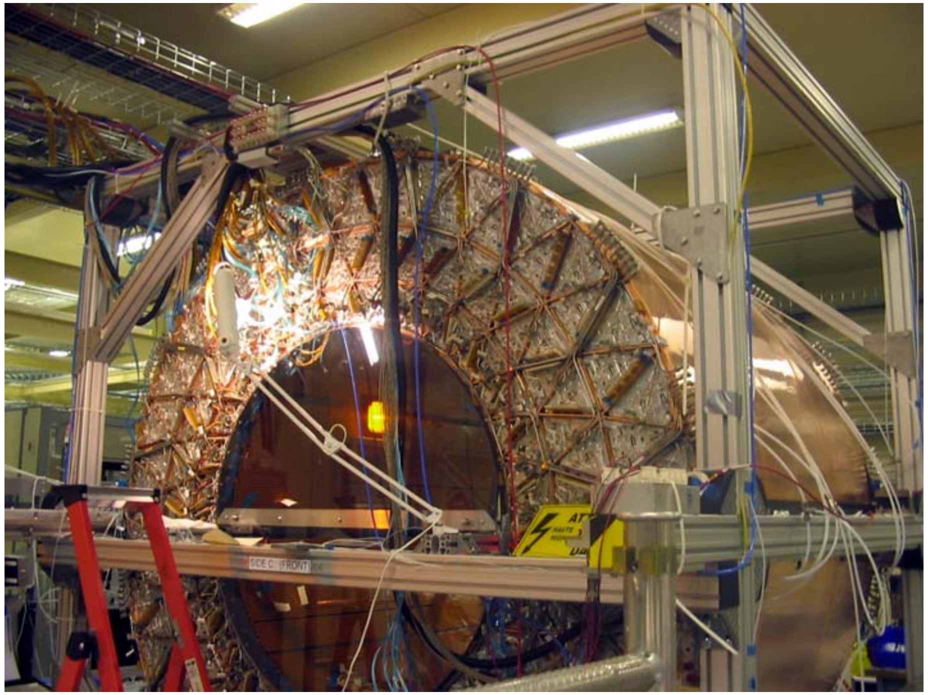
Total: 300.000 straw tubes

Channel size: 4mm x 740 mm
Resolution: 170 µm (perpendicular to wire)

Hits per track: 36

Barrel Module





TRT Barrel detector

radiator: poly-propylene
gas mixture: $XeCO_2O_2$ (70+27+3%)

Important:
RT relation has to be determined

Insertion of SCT Barrel and TRT Barrel into ATLAS final position 10 days ago

Alignment problems are getting closer....

Initial ID geometry knowledge (before alignment)

Uncertainties on the position of the 7 Subdetectors relative to each other:

translation: several mm,
rotation: several hundred μrad

Uncertainties on modules position within the subdetectors:

	x	y	z	α	β	γ
Pixel Barrel modules	0.030	0.030	0.050	0.001	0.001	0.001
Pixel Endcap modules	0.030	0.030	0.050	0.001	0.001	0.001
SCT Barrel modules	0.150	0.150	0.150	0.001	0.001	0.001
SCT Endcap modules	0.100	0.100	0.150	0.001	0.001	0.001

*(displacements in **mm**; rotations in **mrad**)*

TRT 1.0mm in R
0.5mm in the orthogonal plane to R

Tracking requirements

ATLAS ID TDR

Degradation due to geometry knowledge:
<20% on impact parameter and momentum

Reasonable goal:

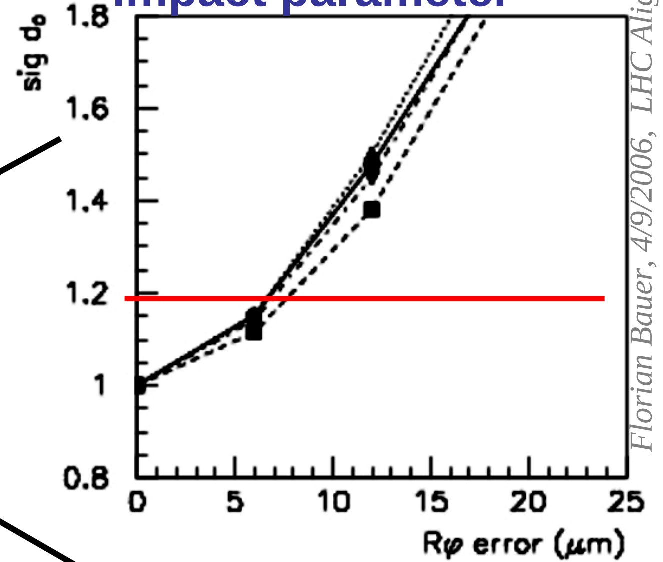
Pixel: $\sigma_{R\Phi}$= 7 µm
SCT: $\sigma_{R\Phi}$= 12 µm
TRT: $\sigma_{R\Phi}$= 30 µm

Furthermore studies
of impact of SCT+Pixel random misalignment
on B-Tagging abilities show:

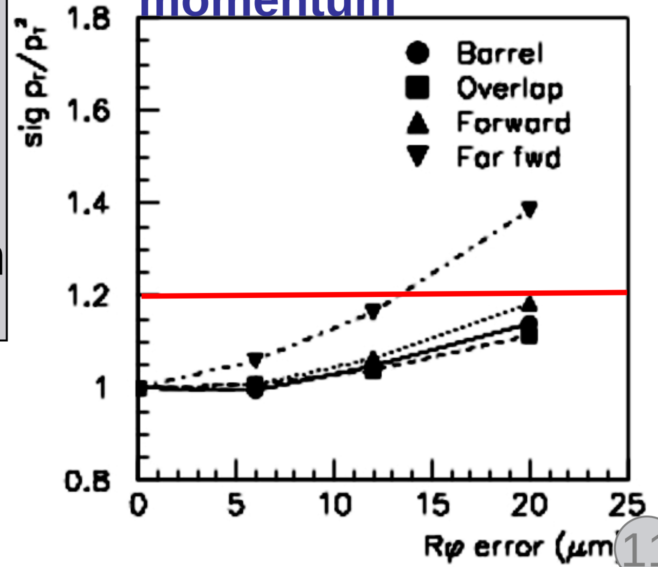
light jet reduction get worse by 10% for $\sigma_{R\Phi}$=10µm
light jet reduction get worse by 30% for $\sigma_{R\Phi}$=20µm

S. Corréard et al, ATL-COM-PHYS-2003-049

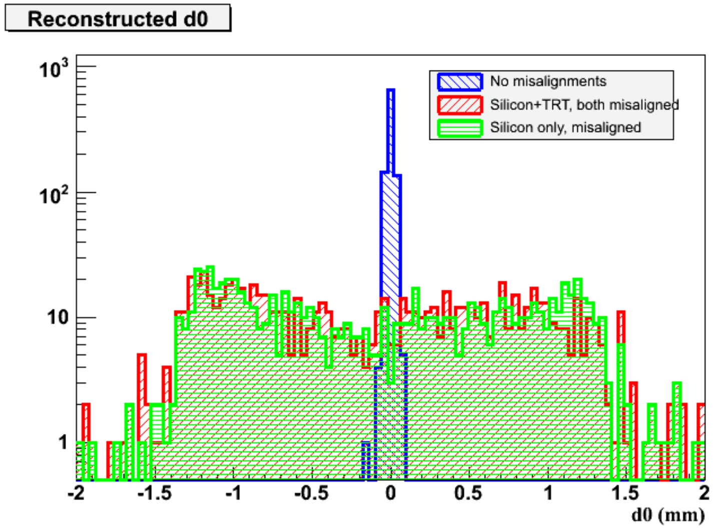
impact parameter

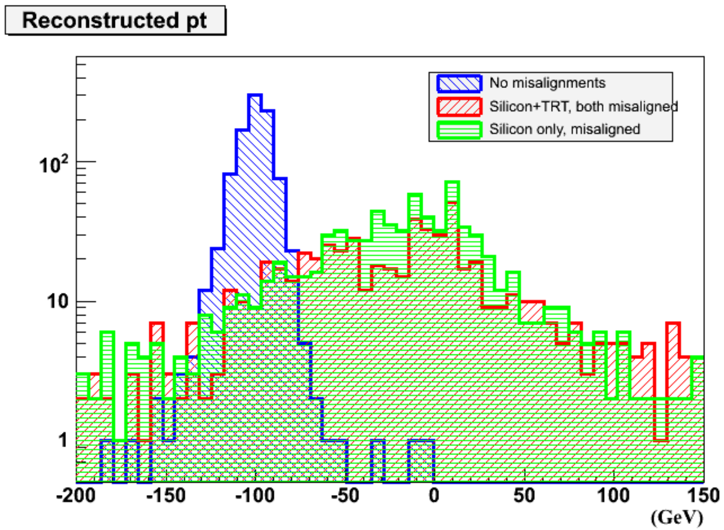


momentum



Initial Misalignment





Sergio Gonzalez, Grant Gorfine

- misalign detector elements on simulation level
- initial misalignment in the order of 1mm to 30 µm has great impact on tracking performance
- misalignment on reconstruction level produces same results

Software requirements

- ID consists of 1744 Pixel, 4088 SCT and 124 TRT modules
  => 5956 modules x 6 DoF ~ 35.000 DoFs
  This implies an inversion of a 35k x 35k matrix

- Use calibration as X-ray and 3Dim measurements to setup best initial geometry

- combine information of tracks and optical measurements like FSI.

- Reduce weakly determined modes using constraints:
  vertex position, track parameters from other tracking detectors, Mass constraints of known resonances, overlap hits, modelling, E/p constraint from calorimeters, known mechanical properties etc.

- ability to provide alignment constants 24h after data taking (Atlas events should be reconstructed within that time)

- And last but not least work under the ATLAS framework: ATHENA

Many approaches

- Global χ^2 minimisation (the 35k x 35k inversion)
- Local χ^2 minimisation (correlations between modules put to 0, invert only the sub-matrices, iterative method)
- Robust Alignment (Use overlap residuals for determining relative module to module misalignment, iterative method)

Furthermore work done on:

- Runtime alignment system (FSI)
- B-field

μ–Spectrometer

MDT chambers

Barrel: 708 MDT chamber
Endcap: 544 MDT chambers
1252

~400.000 readout channels

Used gas: $ArCO_2$ (93+7%)
=> RT relation have to be determined.
Intrinsic resolution of a readout channel: 80μm

Installation of a Barrel MDT

Atlas Barrel Spectrometers

Endcap segment ready for the pit (5 MDTs)

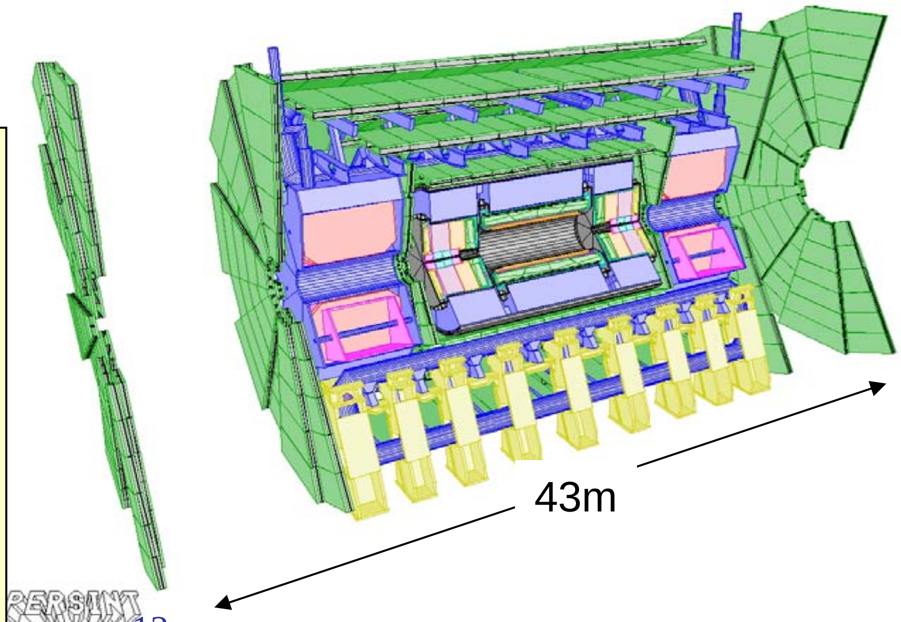
Atlas muon spectrometer

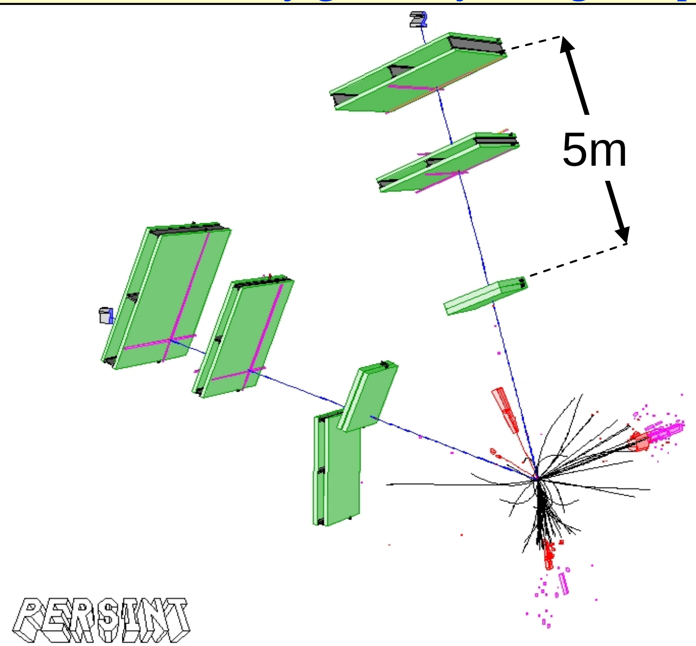
Muon track will be measured
with 3 drift tube chambers (~18-20 layers)

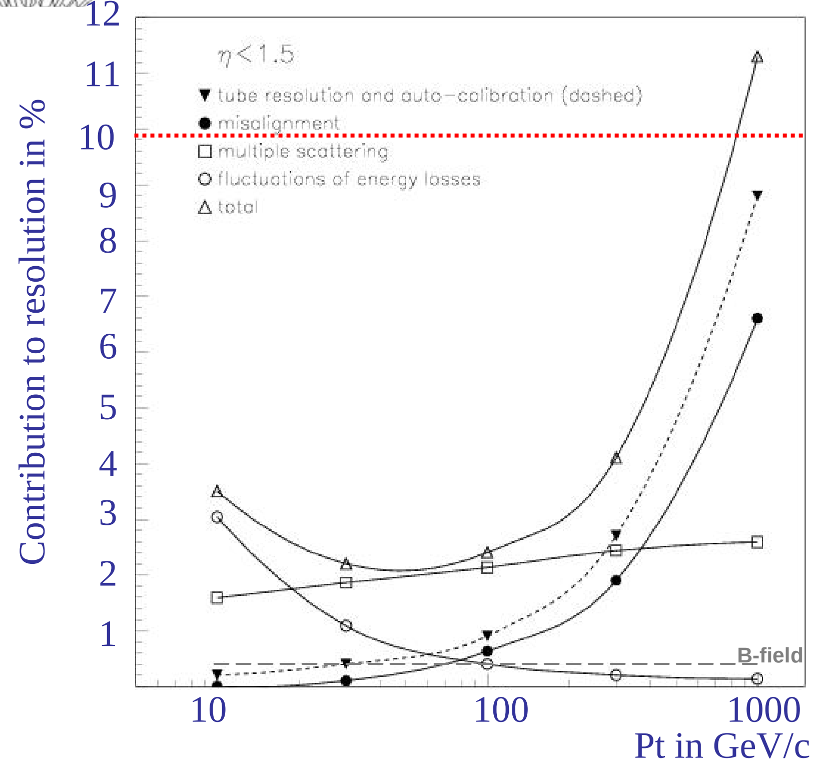
Requirement:
10% tranverse momentum resolution on 1TeV muon:

Track curvature : 400-700 µm
10% resolution : 40 µm

When Toroid is put on, chambers will move by severall mm. => Optical alignment needed.
Furthermore hourly geometry changes expected.



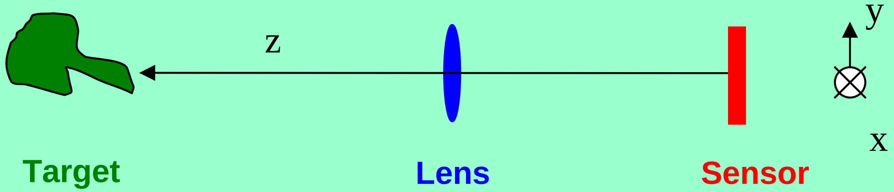


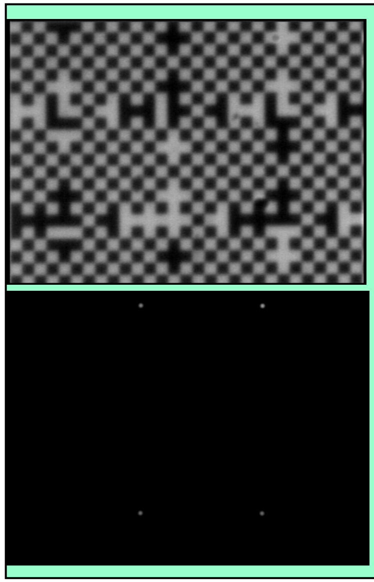


Florian Bauer, 4/9/2006, LHC Alignment Workshop

Main optical alignment ingredients

3 point system: target, lens and a CCD





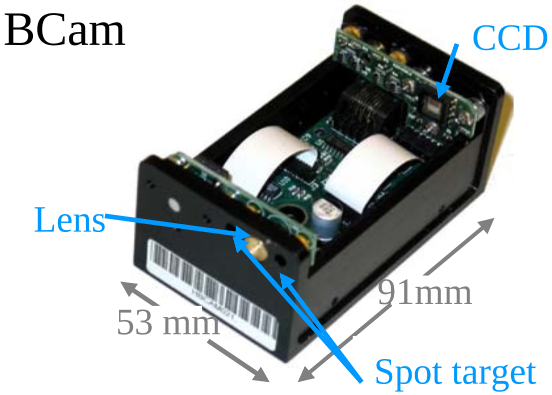
2 target types in Atlas:

a) Checker board (Rasnik)
b) 1-4 spot targets
(BCam & Sacled)

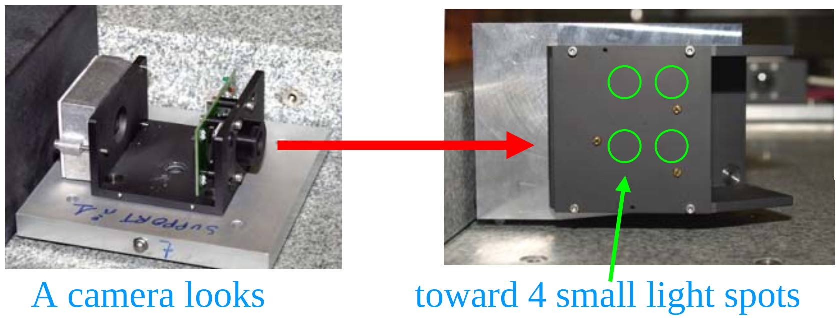
Image parameters are:
1) Translation in x
2) Translation in y
3) Rotation around optical axis
4) Magnification

Rasnik

BCam

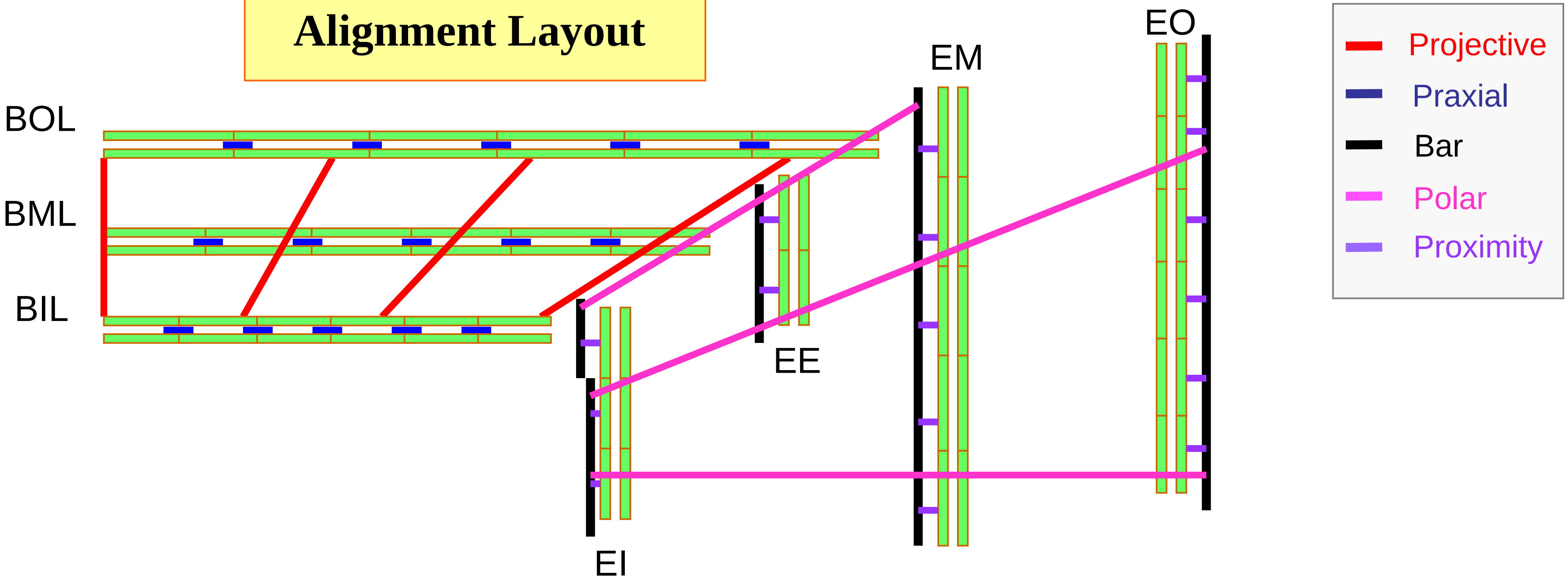


SaCam

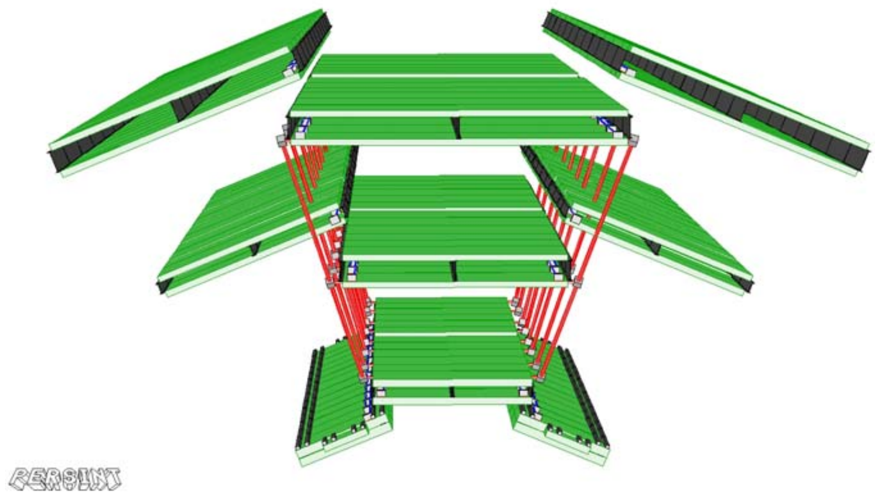


Atlas Barrel : ~6000 Images
Atlas EndCap: ~7000 Images

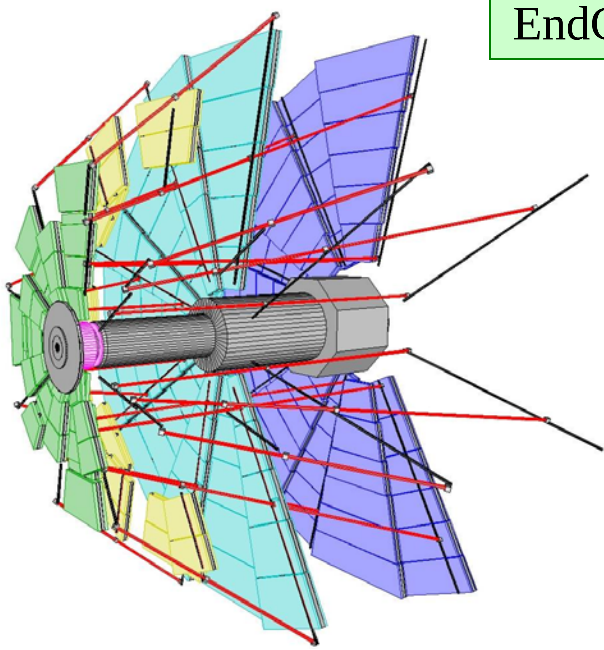
Alignment Layout



Barrel

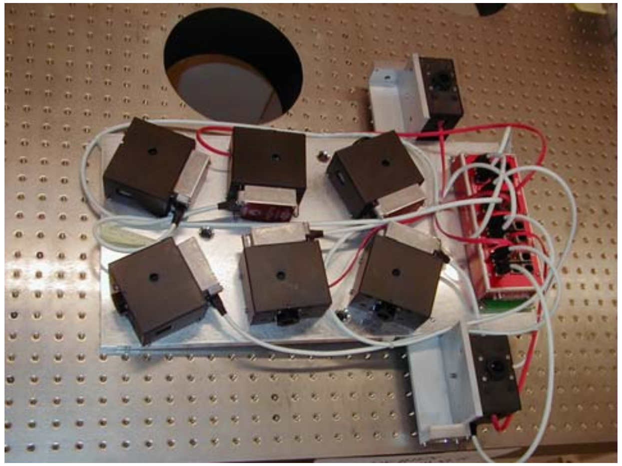


EndCap

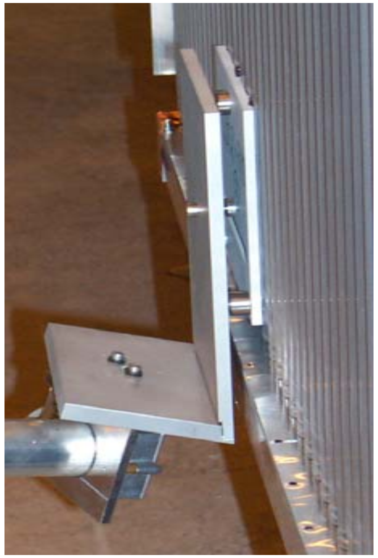


Implementation

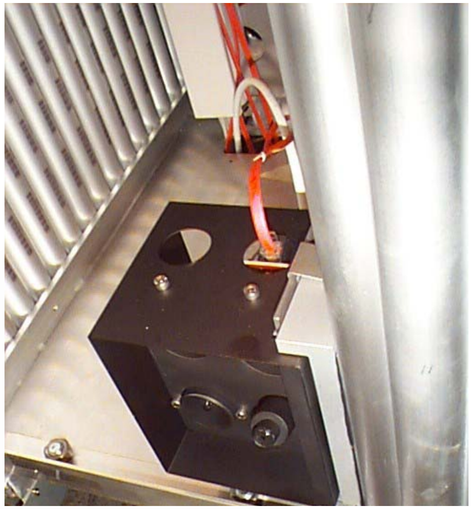
Barrel reference system
Mounted to toroid coils



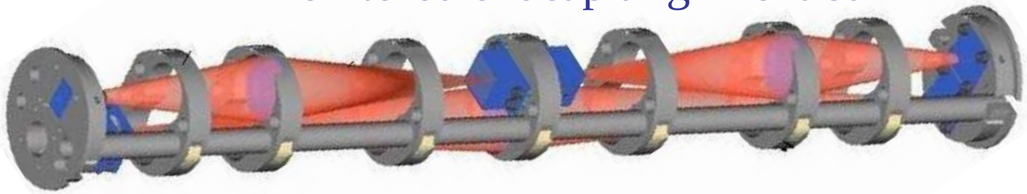
Precise gluing of sensors
on chambers via platforms
and extensions



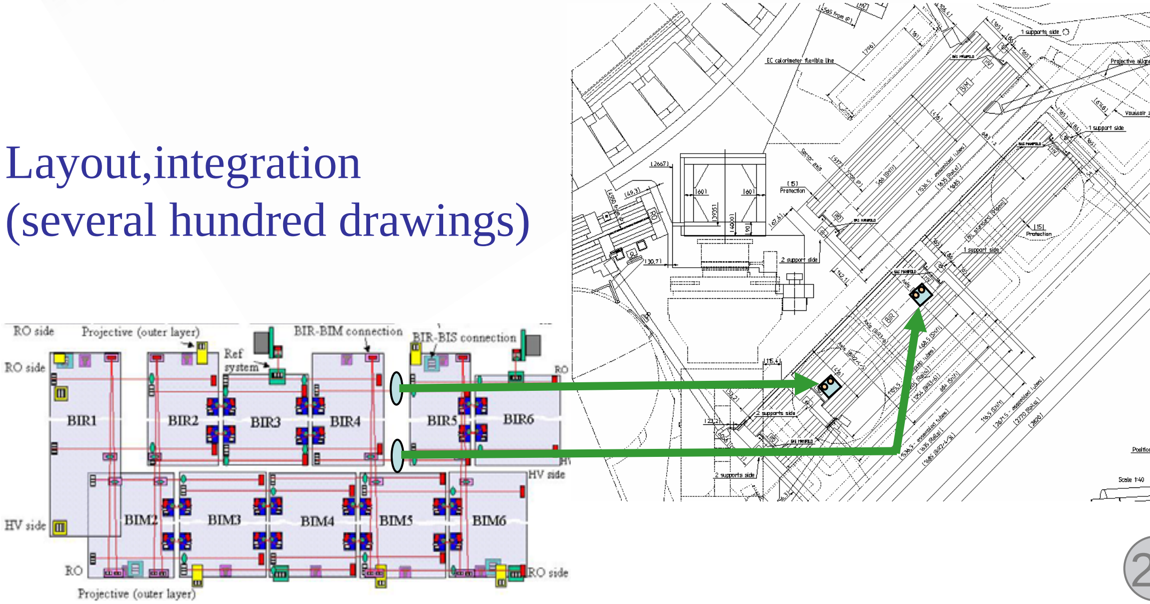
Praxial/Axial
mounted on chamber



Monitored endcap alignment bar



Layout,integration
(several hundred drawings)

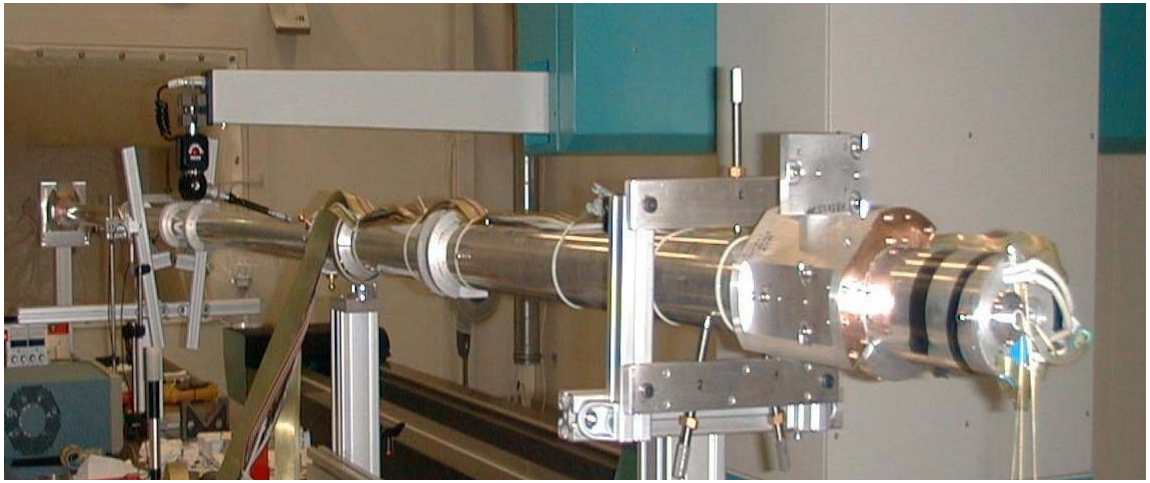


Alignment Device Positions

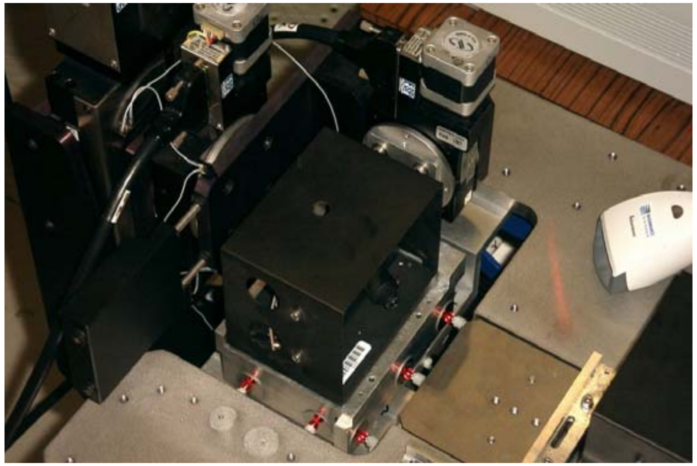
Calibration: knowledge of x,y,z,θx, θy, θz for all platforms, extension plates, alignment bars sensors, leds, targets with respect to the tubes/wire.
Many sites involved: Alignment sites + 13 chamber construction institutes.

Positionning tools (BML chamber)

Alignment bar under XMM (Freiburg)

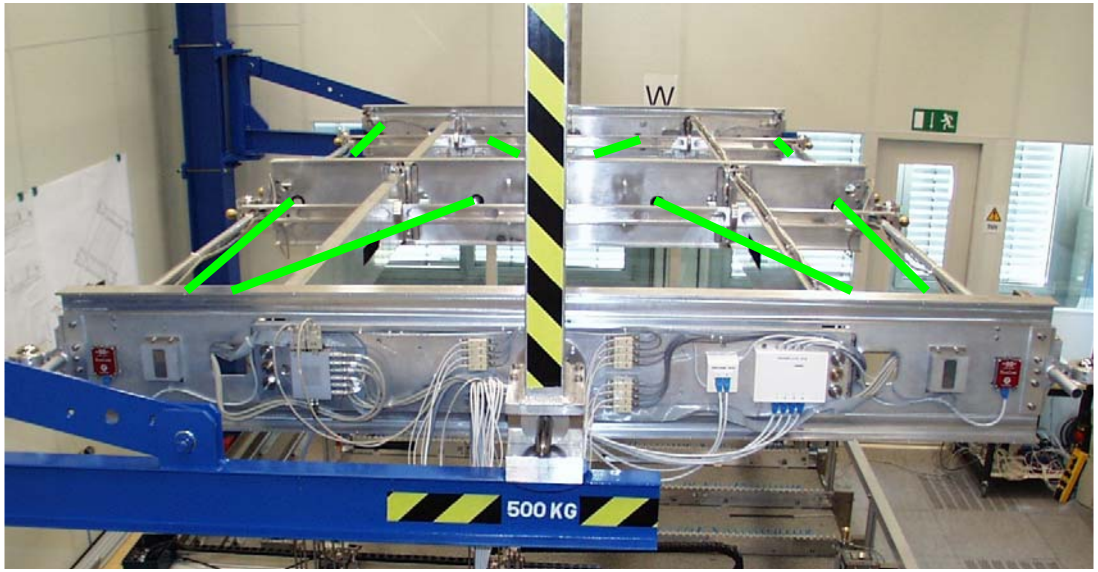


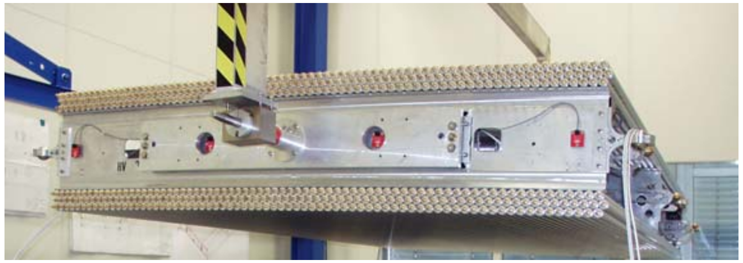
Praxial calibration (Saclay)



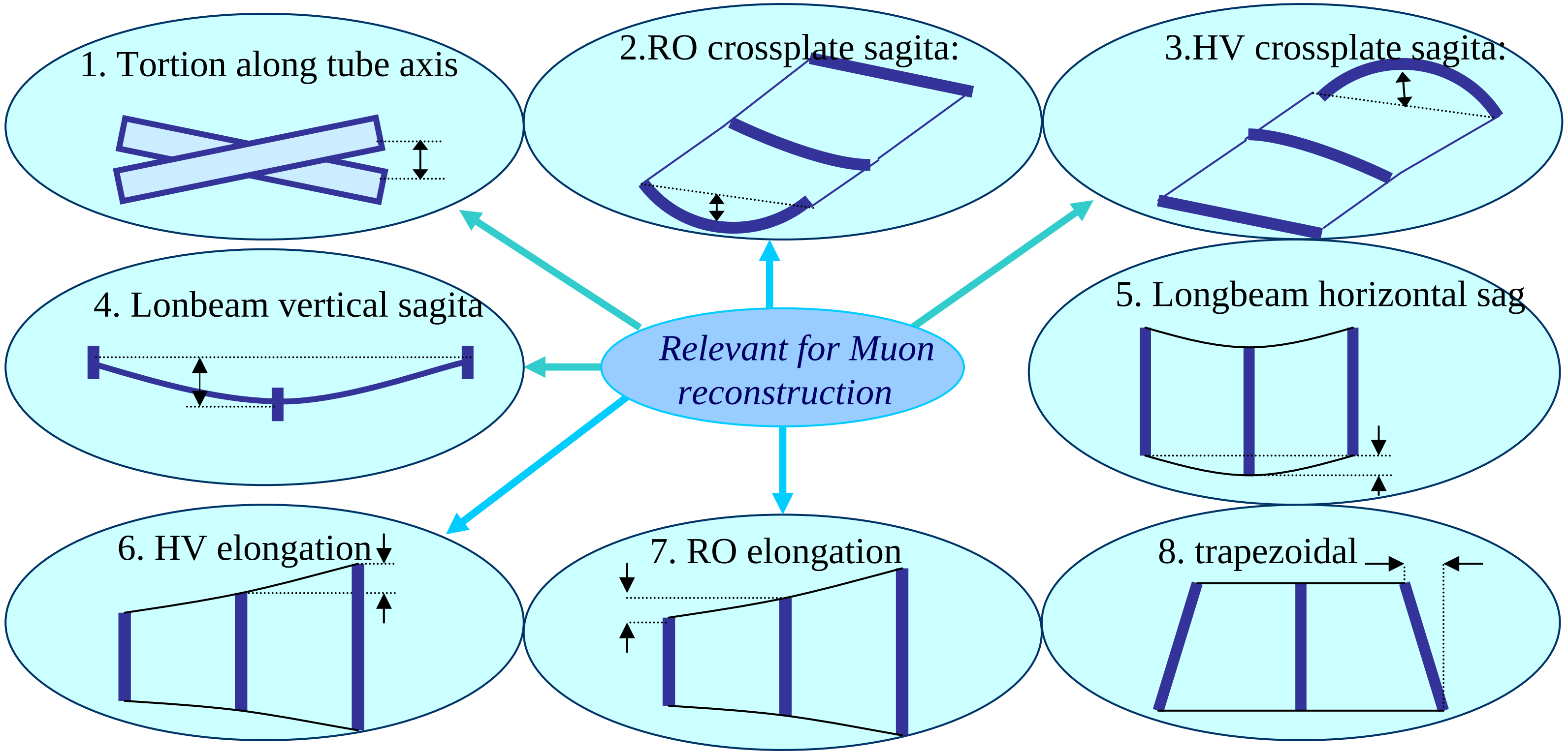
Projective calibration (Nikhef)

Chamber deformation





All MDTs monitored



Alignment Software requirements

- Describe detector taking into account calibration for all optical elements, chambers. Description is 80% of the alignment software job…. Visualisation tools vital.

- Ability to combine optical information with straight or High Pt tracks

- Describe the 9 chamber deformations parameters: in the fit 6 + 9 DoFs per chamber.

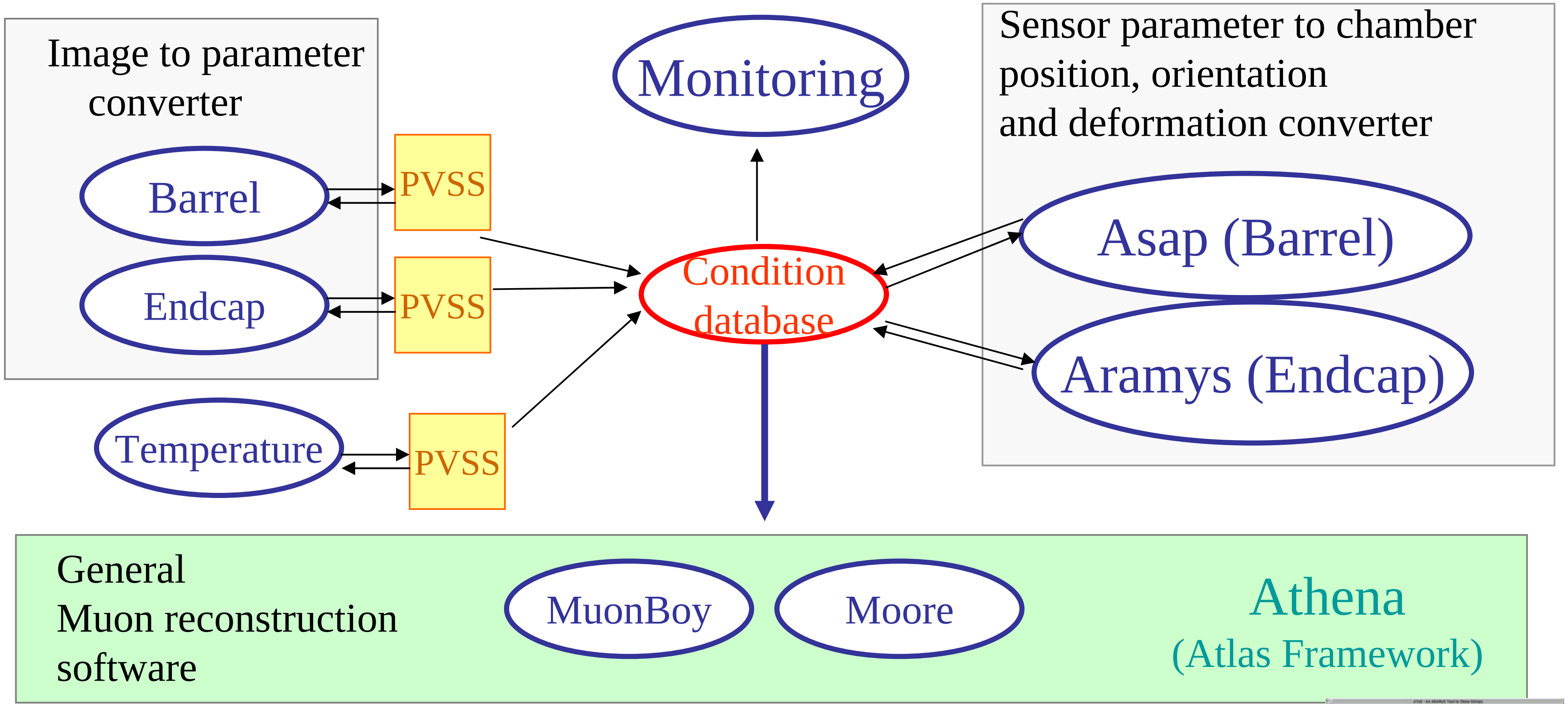
- Handle up to 10.000 DoFs in the Barrel and roughly the same in the Endcap

- Run online (1 correction per hour) with a latency of 24h.
  => robust algorithms, automated dataflow, monitoring, use of Databases as IO

Today we have 2 alignment softwares:
ASAP describing the Barrel alignment
AraMyS describing the EndCap alignment

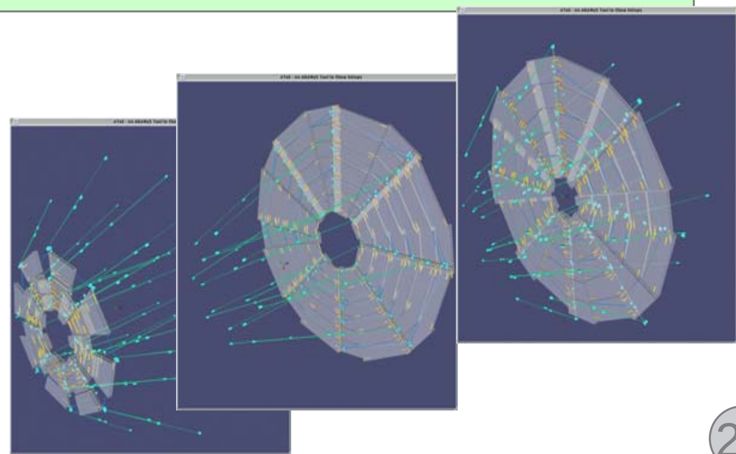
ASAP: uses iterative χ^2 fit, segmentation into sub-alignments foreseen
AraMys: Minuit, segmentation into sub-alignments

Alignment Software



Chain fully implemented at the H8 testbeam.
Online mode planned.

ASAP/Aramys very precise description
of sensor positions in the detector.
80% of the coding job is description.

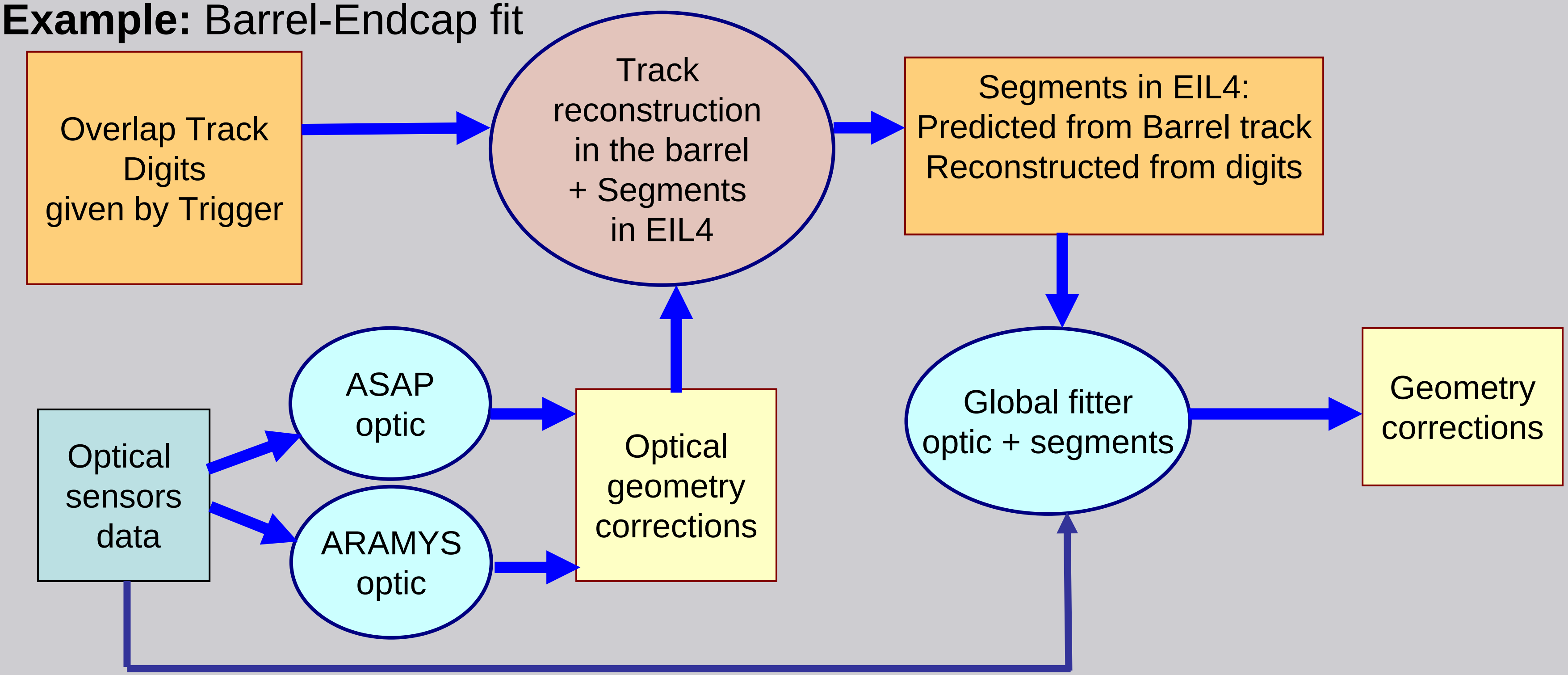


Straight and High Pt tracks

Straight and High pt tracks are used to align:
(1) Online for optically unconnected chambers
(2) Muon Barrel to Endcup (3) Inner tracker to Muon spectrometer
(4) Cosmics (5) Beam halo (6) Toroid field B=0 straight tracks

For cases (1)-(3) complex and automated dataflows to be managed, use of Tier2 center in Munich, ~50 Pcs running online

Example: Barrel-Endcap fit



On this topic: A lot of work has still to be done…..

Conclusion

- Installation and validation of the Muon hardware alignment components on the way
- Muon: optical alignment software exists and validated at H8 test-beam
- Muon straight and High Pt track alignment still under development

- Inner tracker alignment: many algorithms exists today
- Validation in the H8 testbeam done

Between ATLAS Inner Tracker and Muon Spectrometer many synergies can be gained !

This should be even more true on LHC level !