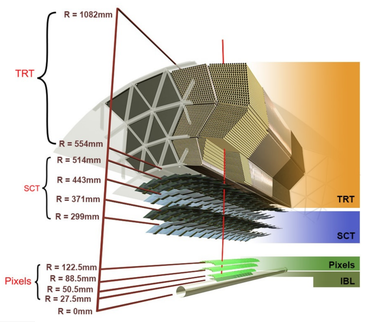
ALIGNMENT OF THE ATLAS INNER DETECTOR IN THE LHC RUN II

Laura Barranco Navarro
IFIC (Universidad de Valencia - CSIC)
on behalf of the ATLAS Inner Detector Alignment Group

Introduction



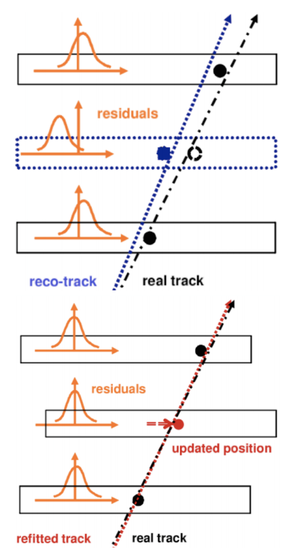
During the Long Shutdown 1 (LS1) several manteinance works were perfomed together with the installation of new detectors. Alignment has thus become a major task during the cosmic campaign and first 13TeV collisions in order to get the detector ready for the stable beams. An important part of the ID alignment has been the study of the IBL performance. The IBL is a new pixel layer attached to the beam pipe which had never been aligned before.
Every time data is recorded in ATLAS, streams of data are processed in the 48h after the recording in the Calibration Loop. A first alignment of the data has been included in the Calibration Loop in order to detect possible movements and deformations of the Inner Detector (ID) as soon as possible. The results of this alignment are monitored in a Web Display.

Alignment

The precise determination of the position and orientation of all the detector modules is known as alignment.
Track based alignment algorithms are based on the minimisation of track-hit residuals (distance between the measured hit and the extrapolated track) via the following χ^2

$$\chi^2 = \sum_{tracks} \left[r(a,\tau)\right]^T V^{-1} \left[r(a,\tau)\right], \qquad \frac{d\chi^2}{da} = 0$$

where $r(a,\tau)$ are the track-to-hit residuals, τ the track parameters, a the alignment parameters and V the covariance matrix of the detector measurements.
each alignable structure has 6 alignment parameters: 3 translations T_i and 3 rotations R_i, being $i = x, y, z$



Alignment Levels

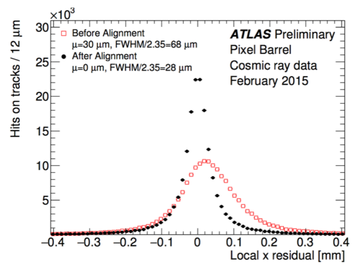
The alignment procedure is split into three levels, in order to cope with the large number of alignable DoFs and to mimic the detector assembly structures. A new L11 has been defined to align IBL indepently from the old pixel.

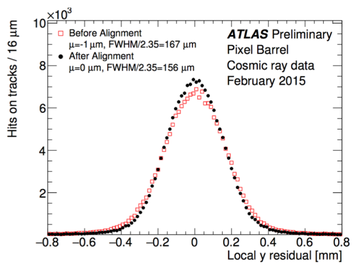
Levels	DoFs			
	IBL	Pix	SCT	TRT
L11(structure)	6	6	18	17
L2(layer/disk)	6	54	132	960
L3(module)	1680	10464	25528	701696

- Level 1: entire pixel system, SCT barrel and SCT end-caps
- Level 2: barrel split in layers and end-caps in disks or wheels
- Level 3: individual modules

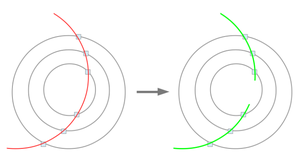
Cosmic Campaign

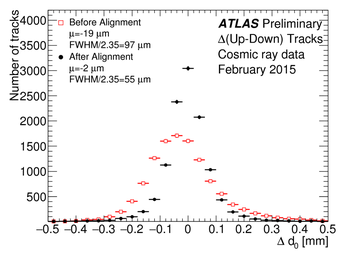
Data collected in February 2015 have been used to perform the first alignment of the ID after the LS1. Results have been used as initial conditions for the 13TeV collisions alignment.





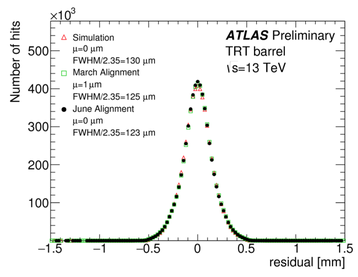
Tracks are split in upper and lower parts in order to independently check the performance of the track parameters reconstruction at the perigee point.

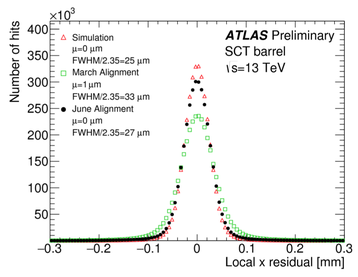




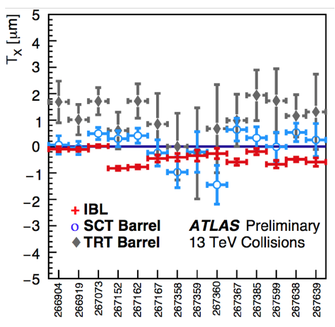
First 13TeV Collision Data

The alignment procedure has been commissioned using first LHC p-p collision data at $\sqrt{s} = 13\text{TeV}$ taken in June 2015 using as starting point the cosmic rays results.



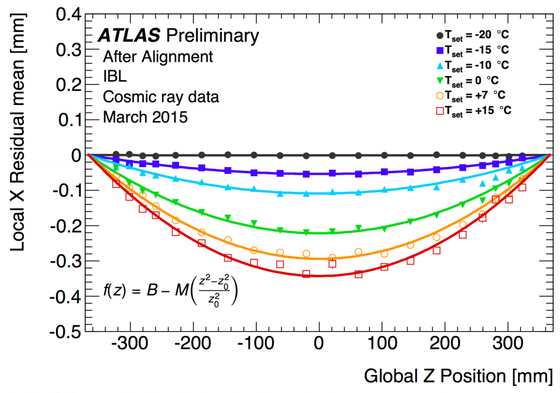


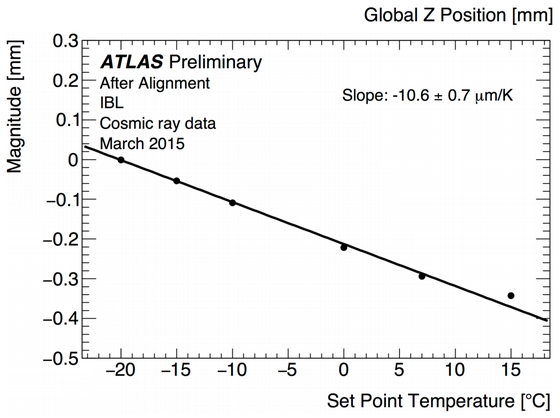
Changes in the environmental conditions may lead to movements of the ID. June 2015 collision data have been used to study the stability of the detector between runs.



Insertable B-Layer

It is a new pixel barrel layer installed during LS1. It is attached to the beam pipe, constituting the closest tracking layer to the interaction point. This new layer has been aligned for the first time within the cosmic campaign.
It was discovered that the IBL shows a temperature-dependent bowing effect that can be seen clearly in the local x-residuals.
The March alignment corrected for the bias with the IBL set to the expected Run 2 operation temperature of $-20°\text{C}$.
The actual set temperature was changed to $-10°\text{C}$, and the June alignment corrects for the residual bowing effect.





Calibration Loop

Apart from the offline alignment, an important part consists on knowing at real time if there is a movement or deformation of the ID in order to correct it as soon as possible. To do so, a first alignment has been implemented in the Calibration Loop and the results can be monitored in a Web Display.

The alignment at the Calibration Loop is performed in three steps:

- Accumulation: reconstructs the tracks and calculates the residuals and the convariant matrices
- Merging: merges matrices and monitoring histograms
- Solving: solves the matrix and obtains the alignment corrections.

Conclusions

- During the LS1 a number of upgrades have been performed on the ATLAS ID, including the addition of the IBL. In order to determine the positions of all ID systems, a first trackbased alignment was performed using cosmic-ray events recorded with the ATLAS detector.
- The initial 7.9pb^{-1} of the 13TeV proton-proton collisions from LHC have been used to align the ID. A special focus on the new IBL detector was necessary as this was the first time this system operated in real LHC conditions.
- An important part of the work consists on knowing at real time if there is a movement or deformation of the ID in order to correct it as soon as possible. To do so, a first alignment has been implemented in the Calibration Loop.

References

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