NOVEL TIME-DEPENDENT ALIGNMENT OF THE ATLAS INNER DETECTOR IN THE LHC RUN 2

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INTRODUCTION

The Inner Detector of the ATLAS experiment comprises its tracking system, used for the reconstruction of the charged particles trajectories. The accuracy of the trajectory reconstruction is determined by the precision of the detector elements, the amount of material in the detector and the precision of the alignment of the detector elements. Misalignments of the detector modules can lead to systematic biases in the measured trajectories and a degraded measurement resolution. A precise alignment of the Inner Detector is therefore essential.

Unlike in the LHC Run 1, in which the Inner Detector was relatively stable for long periods of time, during Run 2, some subdetectors of the Inner Detector have undergone time-dependent deformations or movements that required to introduce a new dynamic alignment scheme. The Inner Detector alignment corrections are updated promptly after the data is collected using a new fully automated system.

CALCULATION OF ALIGNMENT CORRECTIONS

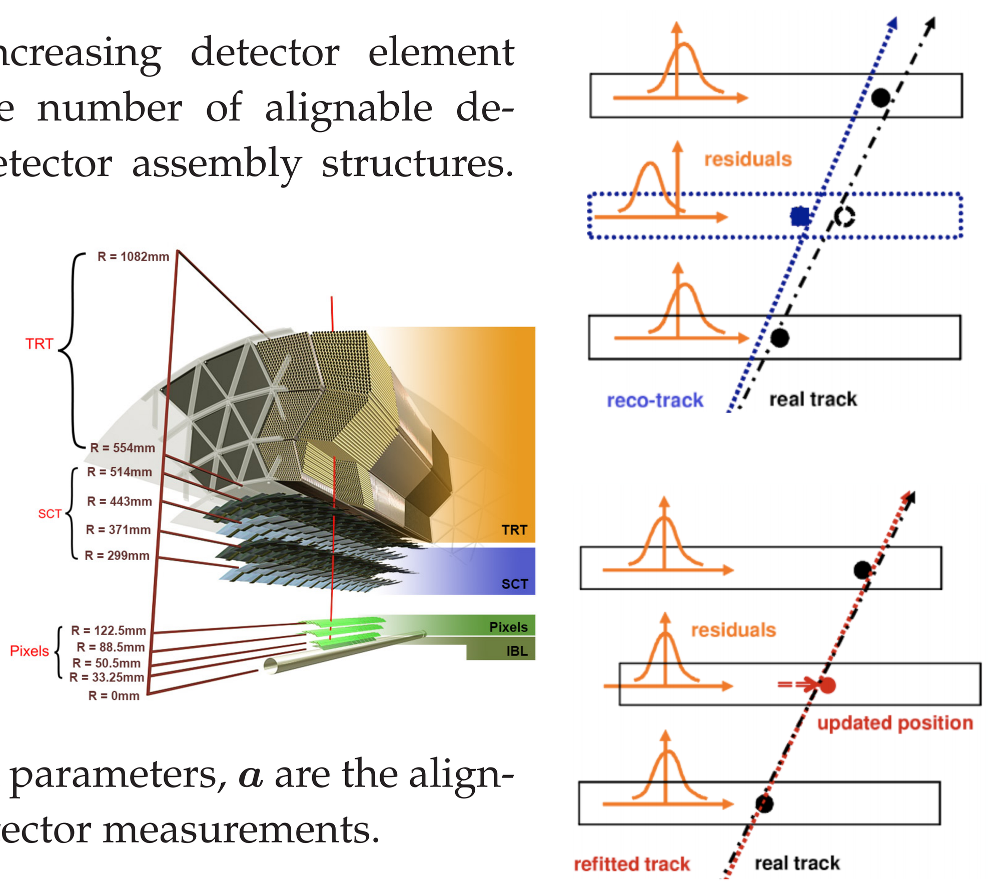
The alignment correction is derived iteratively by increasing detector element granularity step-by-step, in order to cope with a large number of alignable degrees of freedom (shown in table) and to mimic the detector assembly structures.

Levels	IBL *d.o.f.*	PIX *d.o.f.*	SCT *d.o.f.*	TRT *d.o.f.*
L11 (structure)	6	6	18	17
L2 (layer/disk)	-	54	132	960
L3 (module)	1680	10464	25528	701696

Alignment algorithms are based on residual minimization

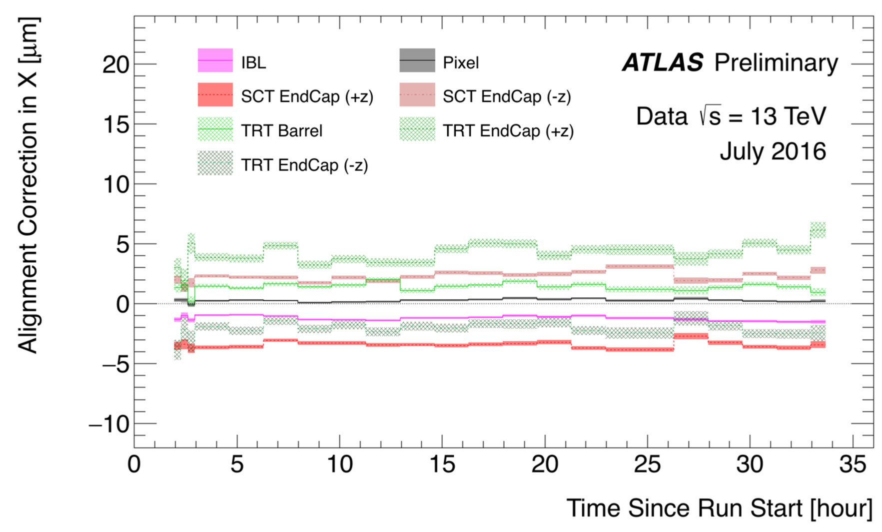
$$\chi^2 = \sum_{\text{tracks}} [\boldsymbol{r}(\boldsymbol{a},\boldsymbol{\tau})]^T V^{-1} [\boldsymbol{r}(\boldsymbol{a},\boldsymbol{\tau})], \qquad \frac{d\chi^2}{d\boldsymbol{a}} = 0$$

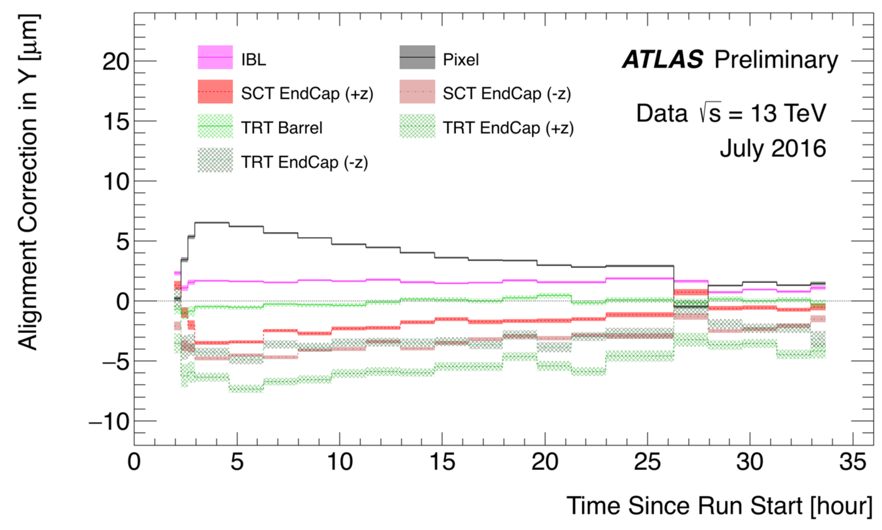
where $\boldsymbol{r}(\boldsymbol{a},\boldsymbol{\tau})$ are the track-to-hit residuals, $\boldsymbol{\tau}$ are the track parameters, $\boldsymbol{a}$ are the alignment parameters and V is the covariance matrix of the detector measurements.

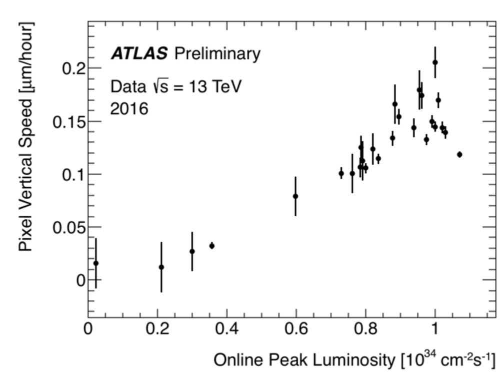


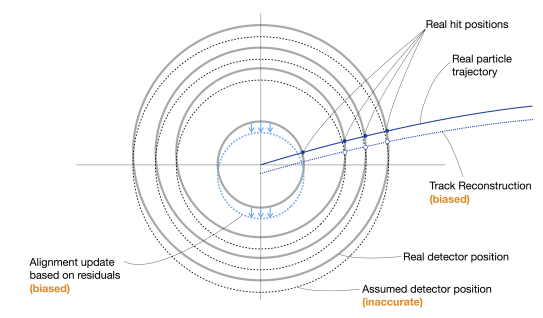
PIXEL DRIFT

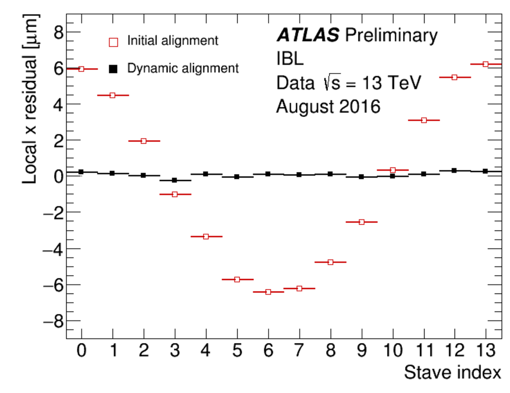
- During Run 1 the pixel detector was observed to rapidly move vertically a few microns at the start of each run before stabilising.
- Is attributed to the change of the mass of cooling fluid in the detector caused by the increased cooling required after enabling the sensor preamplifiers.
- It was never corrected as it affected only a small fraction of the data.
- A slow movement in the opposite direction to the initial one has become significant in 2016 data, and the movement speed is correlated to the peak luminosity of the fill. [5]
- The alignment software infrastructure has been updated to correct for this movement and is expected to be deployed shortly.

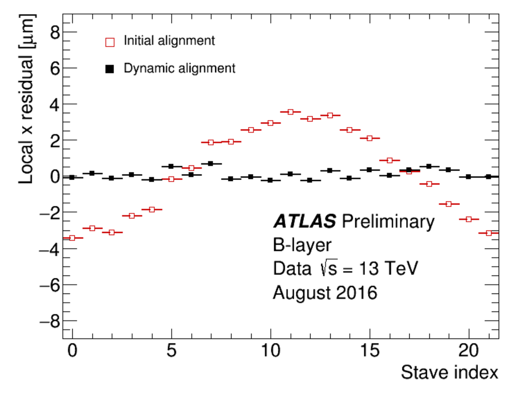








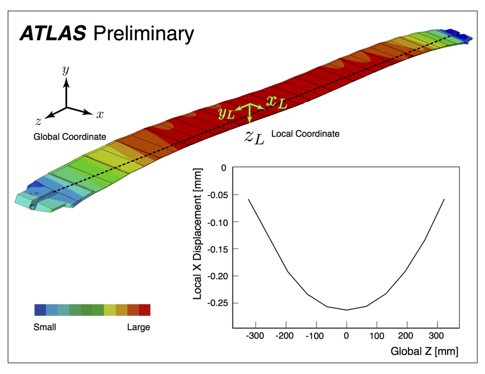


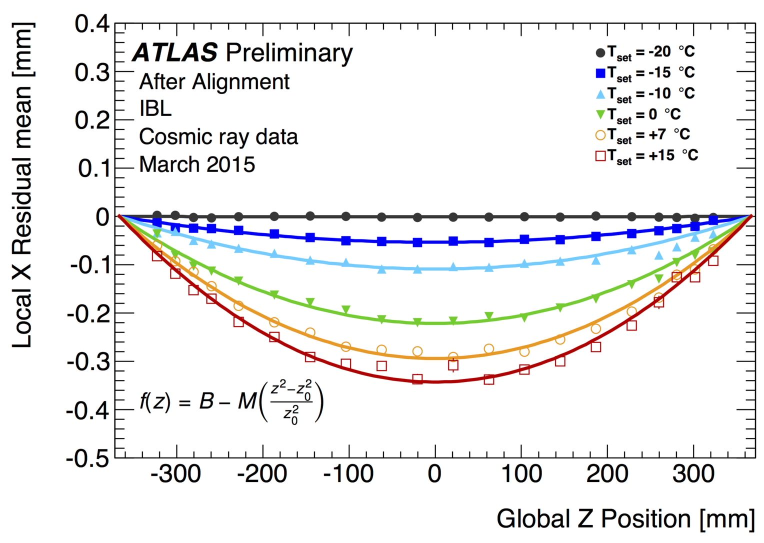


IBL BOWING

Temperature-dependent IBL distortion

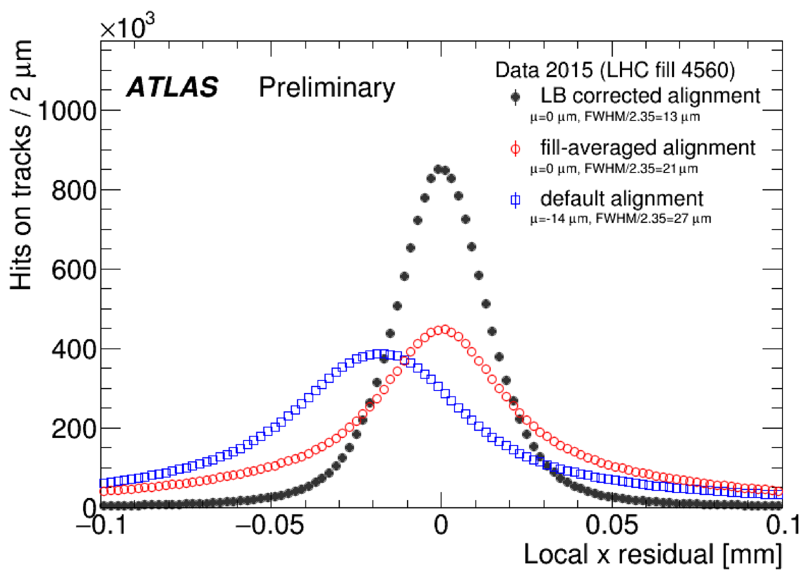
- During the commissioning phase with cosmic data in 2015, the IBL staves were found to bow in plane depending on their temperature.[1]
- Introduced dofs to describe the bowing distortion.

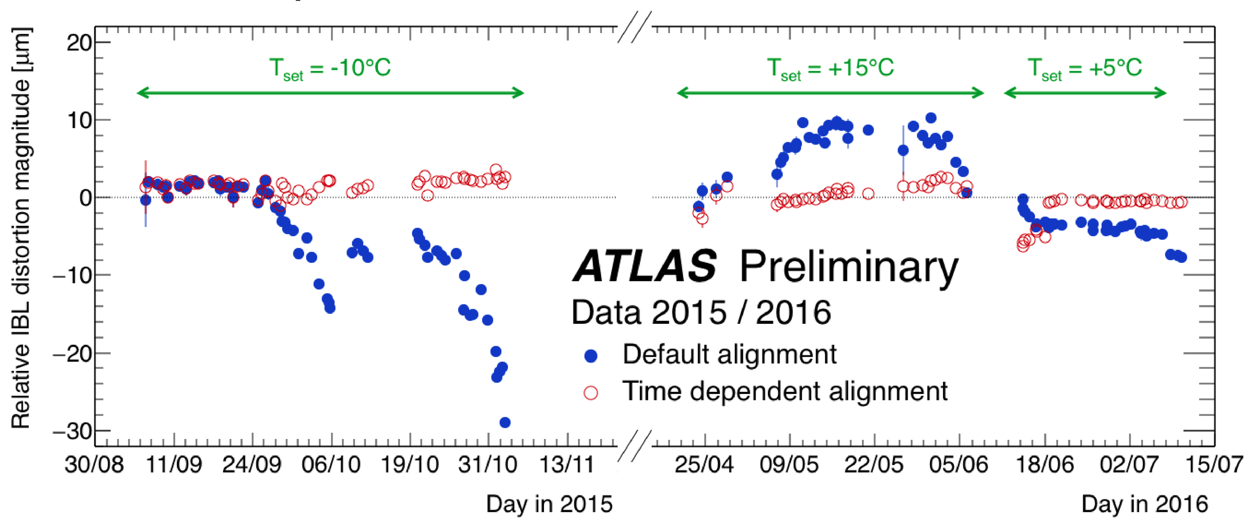


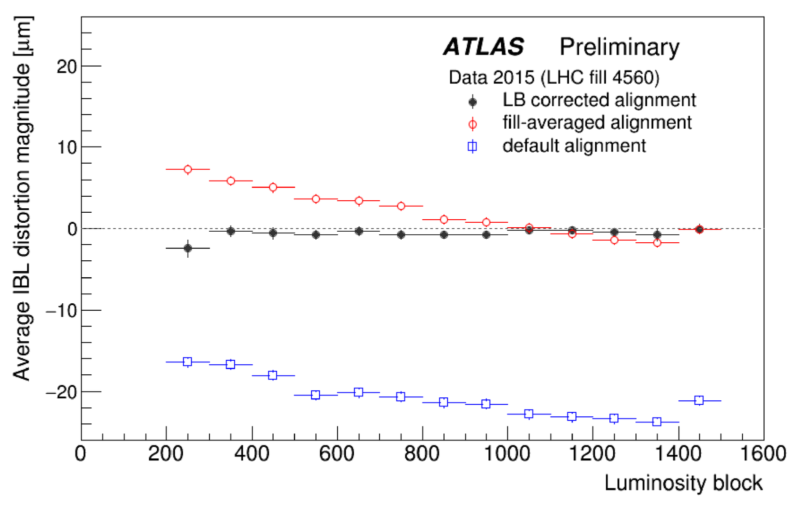


Time-dependent IBL distortion

- During collisions data taking, the staves were seen to bow within a run. This was caused by an increased power consumption of the modules induced by irradiation, known as *total ionization dose effect*. [2]
- The distortion varies with the integrated radiation dose and as a function of the LHC luminosity within a fill.
- A time-dependent alignment correction was introduced and is now automatically calculated for each run immediately after the data taking. [3, 4]
- The new procedure completely mitigates the impact on the track parameter resolution.

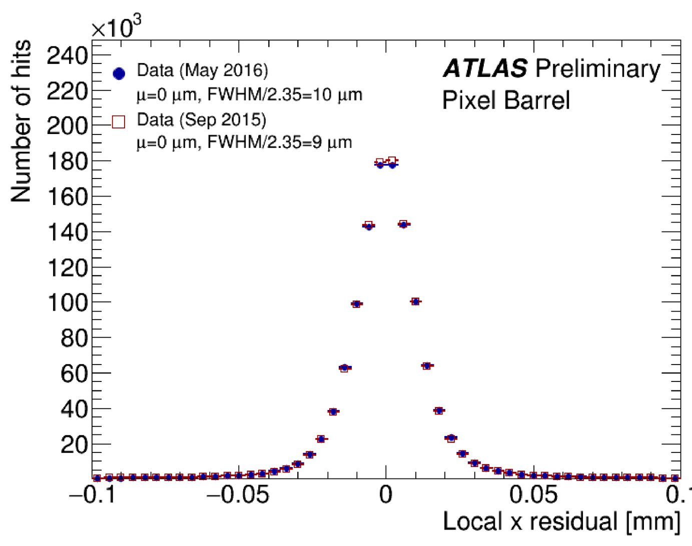


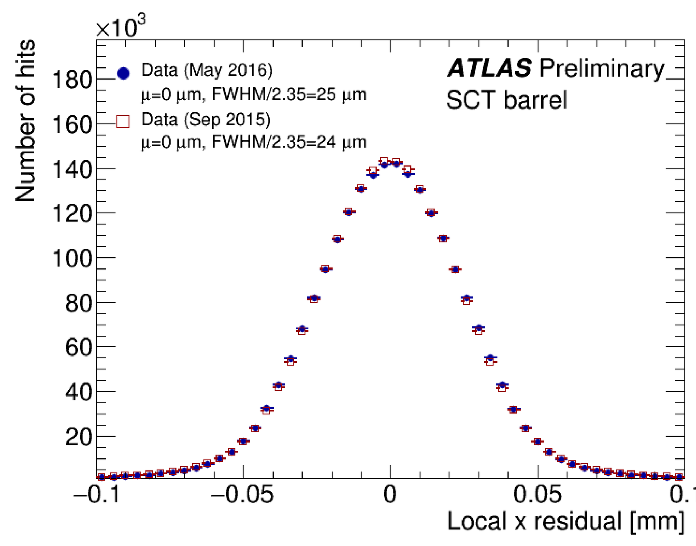


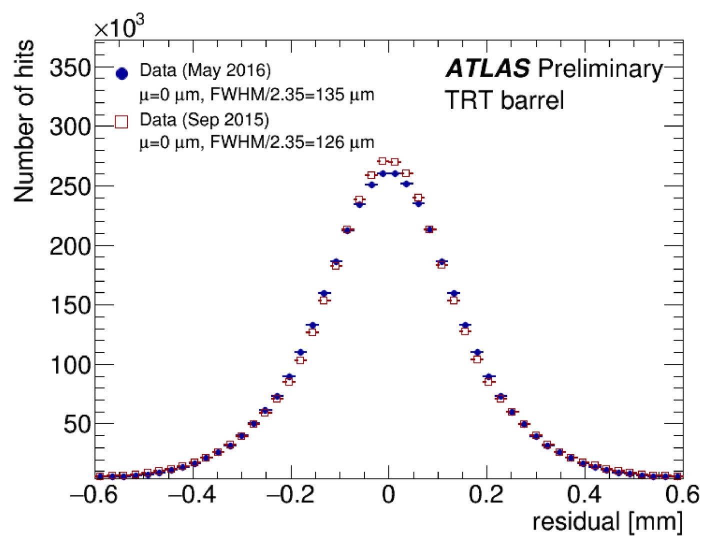


ALIGNMENT RESULTS IN EARLY 2016 DATA

- The basic quality of the alignment is assessed by track-hit residual distributions.
- Final 2015 alignment and initial 2016 configuration results are compared in plots aside.
- The alignment correction output by the automatised prompt calibration gives same alignment accuracy as the reprocessed data in 2015. [6]







SUMMARY AND CONCLUSIONS

- The Inner Detector alignment framework has been succesfully upgraded to cope with Run 2 requirements.
- A new developed time-dependent scheme is under implementation to correct for IBL and Pixel misalignments.
- A fully automatized process aligns and updates the geometry database just after the recording of a new run stops.
- This has allowed us to achieve alignment of the same quality as in 2015 despite the more challenging operating conditions.

REFERENCES

[1] ATL-INDET-PUB-2015-001
[2] PIX-2015-007
[3] IDTR-2016-005
[4] IDTR-2015-011
[5] IDTR-2016-009
[6] IDTR-2016-002