ADVANCED ALIGNMENT OF THE ATLAS TRACKING SYSTEM

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INTRODUCTION

*In order to reconstruct the trajectories of charged particles, the ATLAS experiment exploits a tracking system built using different technologies, silicon planar modules or microstrips (PIX and SCT detectors) and gaseous drift tubes (TRT), all embedded in a 2T solenoidal magnetic field. Misalignments of the active detector elements and deformations of the structures (which can lead to **Weak Modes**) deteriorate resolution of the track reconstruction and lead to systematic biases on the measured track parameters. The applied alignment procedures exploit various advanced techniques in order to minimise track-hit residuals and remove detector deformations. For the LHC Run II, the Pixel Detector has been refurbished and has been upgraded with the installation of a new pixel layer, the Insertable B-layer (IBL).*
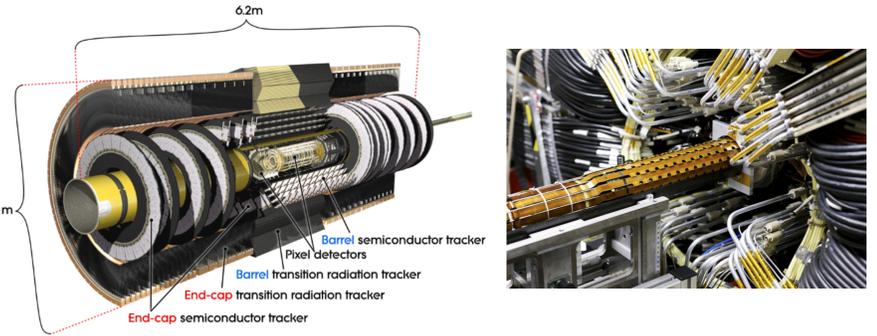
ALIGNMENT PROCEDURE

The alignment procedure is split in three levels, in order to cope with a large number of alignable *d.o.f.*s (shown in table) and to mimic the detector assembly structures

| Levels	PIX *d.o.f.*	SCT *d.o.f.*	TRT *d.o.f.*
L1 (structure)	6	18	17
L2 (layer/disk)	54	132	960
L3 (module)	10464	25528	701696

Alignment algorithms are based on residual minimization

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

where $r(a,\tau)$ are the track-to-hit residuals, τ are the track parameters, a are the alignment parameters and V is the covariance matrix of the detector measurements.
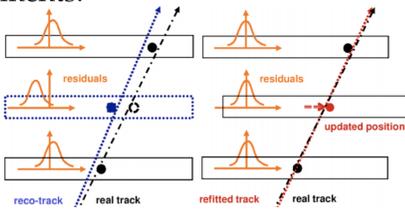
RUN I ALIGNMENT RESULTS

- Level 1 alignment constant determined on per-run basis in order to account for sizable movements of large detector structures due to environmental changes (cooling failures, changes in magnetic field).
- Any remaining sagitta bias ($\delta_{sagitta}$) is corrected using both the $Z \to \mu\mu$ resonance and the E/p method [1]
- Same technique applied to the extraction of the biases on the impact parameters leading to a reduction of the mean bias, by about 80% in d_0 and by 85% in z_0
- A measure of the performance of the alignment is given by the comparison between unbiased residuals in data to those of perfectly aligned Monte Carlo simulation
- The residuals mean distributions show that silicon modules have been aligned at μm level. The discrepancy in Pixel distributions is not to be addressed to residual misalignment.
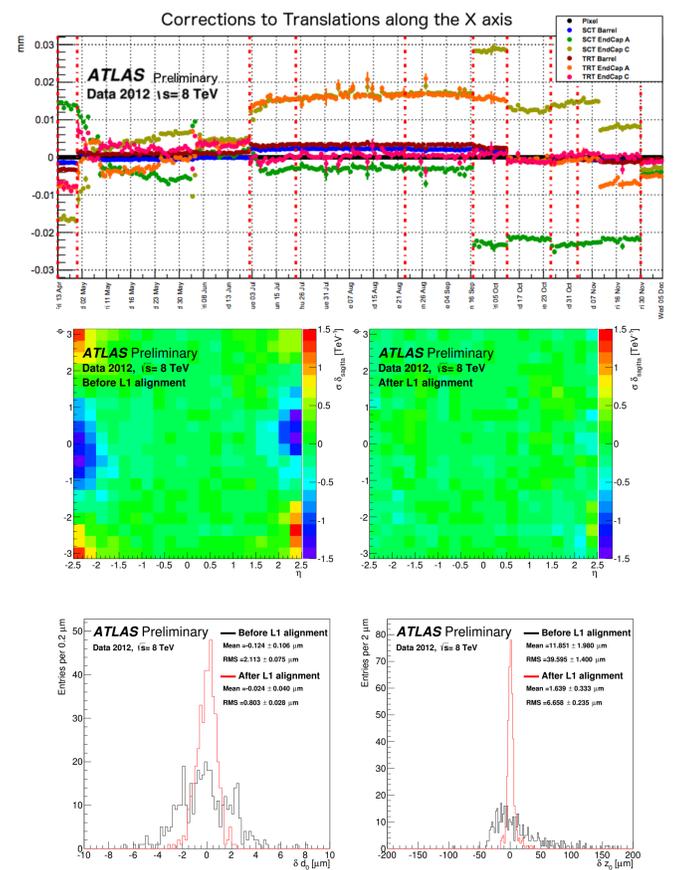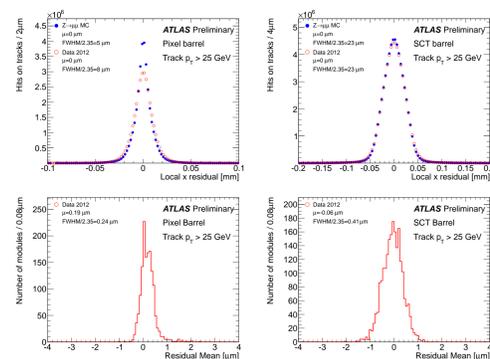
INTEGRATION OF THE INSERTABLE B-LAYER TO THE ALIGNMENT FRAMEWORK

- The IBL is a mechanically independent structure, integrated into the PIX detector
- The Pixel clustering algorithm used in the reconstruction for the IBL is not yet optimised and so residual determinations are expected to improve with experience. Therefore the plots on the right are not yet the final word.

The first alignment test with the IBL inserted in the ATLAS geometry has been performed using a *Multi Muon* Monte Carlo sample. Each event is composed of muons having p_T of [5,15,50,100] GeV and $|\eta| < 2.5$.
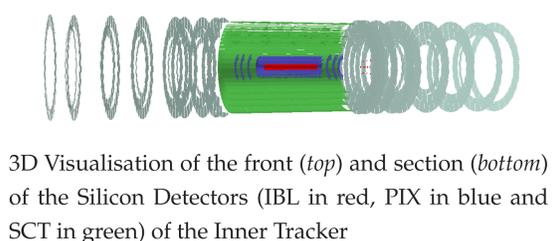
Starting from the misaligned sample, two Level 1 alignment iterations were performed.
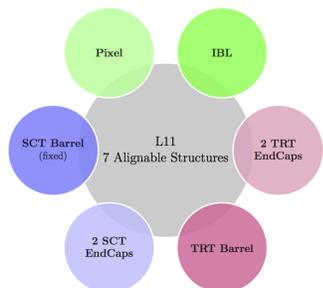
- The Multi Muon MC sample has been reconstructed both with perfect geometry and introducing a misalignment of the IBL sub-detector. We tested the alignment results on the misaligned sample.
- During Level 1 IBL Alignment the SCT barrel is kept fixed as a reference
- In Alignment Level11 the sub-detectors are considered as internally rigid structures and the IBL is treated as a separate structure.
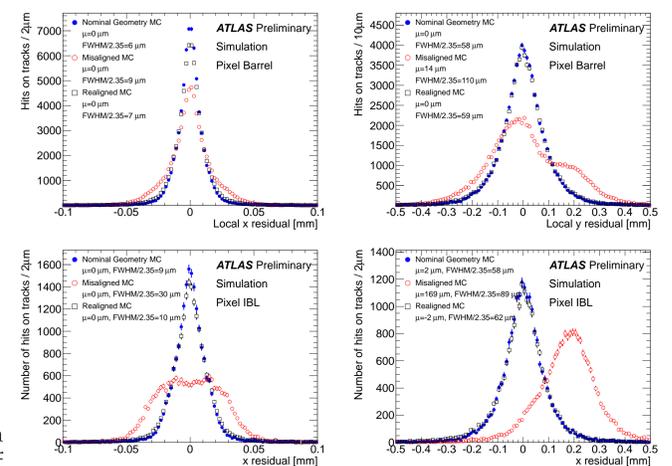
In **blue circles** the residuals for the perfectly aligned MC sample compared with the misaligned (**red circles**) and the realigned (**white squares**) samples. The results show that the alignment framework is able to recover, after a few iterations, the misalignment introduced. Top row for hit-to-track integrated on all the PIX detector, bottom row on only the IBL.

3D Visualisation of the front (*top*) and section (*bottom*) of the Silicon Detectors (IBL in red, PIX in blue and SCT in green) of the Inner Tracker

REFERENCES

[1] ATLAS-COM-CONF-2014-046

[2] ATLAS IBLCommunity, ATLAS-TDR-019

SUMMARY AND CONCLUSIONS

- Alignment 2012 campaign resulted in development of advanced techniques resulting in improved tracking resolution and reduction of track parameter biases.
- Physical movements of the detector have been understood during 2012 data taking.
- The Alignment framework has been updated to include the newly installed IBL layer.