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Measurements of the relative alignment of the muon spectrometer precision chambers in $\sqrt{s} = 13$ TeV proton-proton collisions with the ATLAS detector

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Summary. — A good muon momentum resolution in the region from hundreds of GeV to several TeV is crucial for searches for new physics, such as $W' \to \mu\nu$ and $Z' \to \mu\mu$ (ATLAS Collaboration, *Phys. Lett. B*, **796** (2019) 68) at the LHC. A new physics signal in one of these channels could manifest itself as an excess over the Standard Model (SM) prediction in the form of a handful of muon candidates in the high-end tail of the transverse mass or invariant mass distribution. It is therefore important to reject poorly measured muons, where the reconstructed p_{T} is much higher than the true value, to avoid the contamination of the high-mass region with events migrating from lower masses. The ability to reconstruct high-momentum muon tracks in ATLAS with good momentum resolution is closely connected to a good understanding of the ATLAS tracking detectors alignment and of the related uncertainties. This contribution provides an overview of the method used in muon reconstruction to account for the differences in position and orientation of the various detector elements, between the geometry used in simulation and the real position of the detector.

1. – ATLAS muon spectrometer alignment system

The ATLAS Muon Spectrometer (MS) [1] is designed to provide excellent momentum measurements of muons at the energy scales expected in several new physics scenarios. The transverse momentum is expected to have a resolution ($\Delta p_{\mathrm{T}}/p_{\mathrm{T}}$) at a level of 10% for a muon with p_{T} of 1 TeV. Due to the magnetic field inside the spectrometer, the path of a 1 TeV muon will be bent by only 0.5–1.0 mm (depending on the pseudorapidity of the track). To measure the momentum with a precision better than 10%, the uncertainty on the track sagitta s must be less than 50 μm. Different techniques have been deployed to measure the relative alignment of the MS precision chambers [2]. First of all, the positions of the precision chambers were estimated using a sample of cosmic ray tracks with toroid magnets turned off. If truly straight tracks travel through the MS, the distribution of

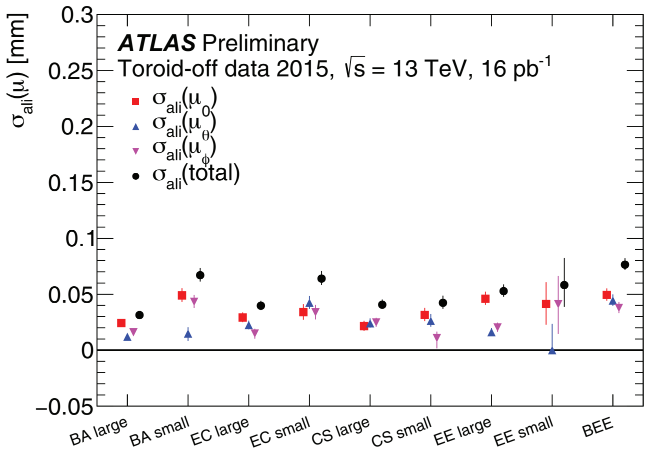

Fig. 1. – Performance of the MS alignment measured using pp collision runs with the toroidal magnetic field turned off. The figure shows the width of the distributions of the sagitta bias measurements ($\sigma_{\rm ali}$ (μ_0), $\sigma_{\rm ali}$ (μ_θ) and $\sigma_{\rm ali}$ (μ_ϕ)) with their statistical uncertainty for different regions of the muon spectrometer. The quadratic sum of the three ($\sigma_{\rm ali}$ (total)) is also given, which measures the overall goodness of the alignment.

the sagitta should be centered at zero with a width dominated by multiple scattering, because most of the tracks have a transverse momentum of few GeV. The misalignment is evaluated as the mean of the distribution of the sagitta. Considering that chambers can move as much as several mm when the magnet is switched on or off, an optical system made by more than 5800 optical sensors is used to monitor the relative alignment. Finally toroid-off proton-proton dedicated runs have been used to validate the alignment system.

For each MS projective tower, composed by inner-middle-outer muon stations, the average sagitta $\mu_0 = \langle s \rangle$ was calculated, as well as its correlation with the polar and azimuthal coordinates ($\mu_\theta = \langle (\theta - \theta_0) \cdot s \rangle$, $\mu_\phi = \langle (\phi - \phi_0) \cdot s \rangle$). The RMS distribution of μ_0, μ_θ and μ_ϕ is shown in fig. 1 for different types of towers.

2. – Conclusions

All the results of the ATLAS measurements and searches using muon information depend on the understanding and the optimization of muon reconstruction and identification. In particular, in this document a focus on the ATLAS MS alignment system has been presented. A MS precision chamber alignment of 50 μm has been achieved in almost all the MS sectors.

REFERENCES

[1] ATLAS Collaboration, *JINST*, **3** (2008) S08003.
[2] Aefsky S. on behalf of the ATLAS Collaboration, *Phys. Procedia*, **37** (2012) 51.