IL NUOVO CIMENTO Vol. 33 C, N. 6 Novembre-Dicembre 2010
DOI 10.1393/ncc/i2011-10774-4

Colloquia: IFAE 2010

The commissioning of the ATLAS detector

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(ricevuto l'8 Ottobre 2010; pubblicato online l'8 Febbraio 2011)

Summary. — The early phase of the ATLAS commissioning performed with an integrated luminosity of approximately $9\,\mu\text{b}^{-1}$ of proton-proton collisions at $\sqrt{s} = 900\,\text{GeV}$ is presented. The performance of several sub-detectors is illustrated using the first physics signals. A good agreement is generally observed between data and the Monte Carlo expectations.

PACS 13.85.-t – Hadron-induced high- and super-high-energy interactions (energy $> 10\,\text{GeV}$).

1. – Introduction

The ATLAS detector [1] consists of a tracker immersed in a solenoidal magnetic field of 2 T composed by three layers of pixel detectors, four layers of silicon micro-strips (SCT) and a Transition Radiation Tracker (TRT) that with a mean of 30 hits on track allows an almost continuos tracking at the outer radii. The TRT is also capable of electron identification using the transition radiation generated by the particle traversing the radiator material in its active volume and adsorbed by a xenon-based gas mixture. Outside the solenoid is the liquid argon-lead electromagnetic calorimeter finely segmented in (η, ϕ) and longitudinally segmented in three compartments. The segmentation in $(\eta \times \phi)$ of the three compartments are respectively 0.003×0.1 in the front, 0.025×0.025 in the middle and 0.1×0.1 in the back. The front layer (strip layer) is finely segmented in η for a good photon/neutral pion separation. The accordion shaped electrodes are assembled in a gapless structure in ϕ. The hadronic calorimeter is a sampling calorimeter built of steel and scintillating fibers tiles. Finally the muon spectrometer is immersed in a toroidal magnetic field surrounding the entire detector.

At the end of 2009, ATLAS enjoyed a series of stable LHC runs at a centre-of-mass energy of 900 GeV, successfully recording and analysing about $9\,\mu\text{b}^{-1}$ corresponding to approximately 400000 collisions. In the following section few highlights of the early performance of the detector are presented. A complete collection of public ATLAS results can be found in [2].

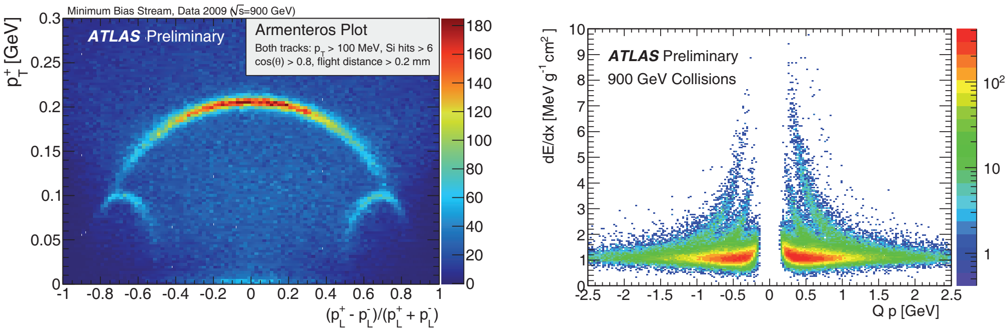

Fig. 1. – Left: Armenteros plot of two tracks candidates. Right: ionization in the silicon sensors of the pixel detector.

2. – Tracker

The commissioning of the tracker had started with the collection of cosmic rays in the previous years and it is reaching its maturity with collision data. The beam spot at the SPS extraction energy of 900 GeV is measured online to be about 300 μm in the transverse directions and about 4 cm in the longitudinal one. The stability of the luminous region has been verified over a time span of entire runs.

The reconstruction of secondary vertices allows to extract the first resonances as showed in the Armeteros plot in fig. 1. Clearly visible is the top ellipse signaling the $K_s^0 \to \pi^+\pi^-$ and the two lateral ones from the $\Lambda^0 \to p\pi$ decays. The extraction of the Λ signal in particular takes advantage of the pixel detector particle identification measured as the time of threshold response to the ionization signal in the silicon (see fig. 1).

Despite the low energy and the reduced statistics the b-tagging algorithms have been exercised on data. Not expecting any significant amount of b-candidates the algorithms have been run removing the K_s^0 veto. In doing this 70 candidates have been reconstructed to be compared to an expected number of 63 (out of which 2.5 are expected to be b-candidates). Of particular importance within the reconstructed secondary vertices are the photon conversions $\gamma \to e^+e^-$ (the dominant interaction of high energy photons with matter). To select conversion candidates the two-tracks vertex is fitted with the constraint of parallel tracks and, among others, an electron identification cut, based on the transition radiation in the TRT, is applied to reject hadron tracks. Each TRT readout channel has a two-levels discriminator. Hadrons will in general deposit enough energy to fire the lower threshold, providing a hit used for tracking reconstruction, while the electrons, due to the transition radiation they generate in the radiator, have higher probability to fire also the high threshold. The ratio of the number of high to total number of hits is used as discriminating variable (see fig. 2).

The unprecedented amount of material characterizing the typical tracker at the LHC is the major cause of performance deterioration in electron and photon reconstruction. To properly correct back for material effects it is of paramount importance to precisely locate the material upstream the electromagnetic calorimeter. Several methods are presently used to overconstrain the material measurement (resonances mass stability *versus* transverse momentum, tracks length, single-tracks extension efficiencies). The plot in fig. 2 shows the radial position of the conversion vertices clearly revealing the position of the

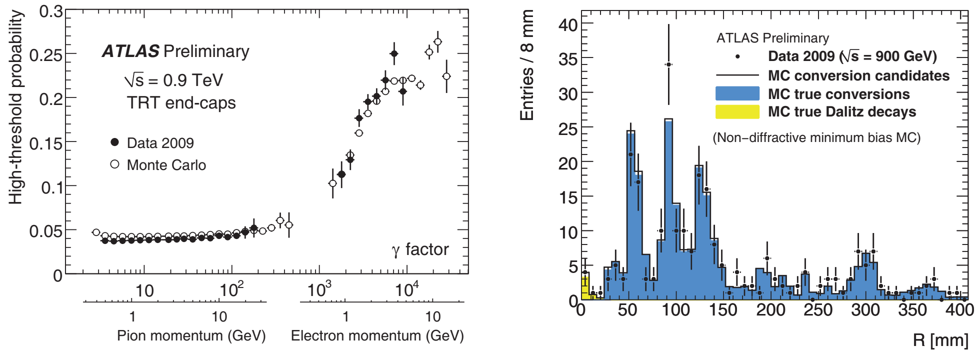

Fig. 2. – Left: ratio of high threshold to total number of hits in the TRT as a function of the track momentum. Right: radial position of the conversion candidates. In the same figure the Dalitz decays of neutral mesons appear as an excess at small radii.

first tracker layers. There is in general very good agreement between the reconstructed material and its model in simulations.

3. – Calorimetry

The commissioning of the calorimetric system is performed at different levels. The first is to compare the energy deposited at the cell level (the finest granularity) with simulations. The first measurements show a good agreement with the Monte Carlo expectations over several orders of magnitude in occupancy for signal and for noise. At a higher level the electromagnetic calorimeter is tested reconstructing electron and photon signals while the hadronic calorimeter is tested with reconstructed jets and isolated hadrons.

3˙1. *Electrons and photons.* – The reconstruction of photons and electrons in ATLAS proceeds in steps: first, a window of 5×5 cells in (η, ϕ) is used to scan the second layer of the calorimeter looking for energy local maxima; the obtained cluster is checked against a track match to separate out, at a very early stage, electrons from photons (this is important because different cluster calibrations are applied to the two species); then the size of the clusters is redefined to 3×5 cells for unconverted photons and 3×7 cells for converted photons and electrons (this larger width in ϕ is applied to collect the energy lost in the emission of bremsstrahlung photons); finally the energy of the cells is summed over the longitudinal layers of the calorimeter to build the clusters, and the calibrations are applied.

The identification of electrons and photons from fakes is structured in three levels (loose, medium and tight) going from high efficiency but low background rejection at the loose level up to lower efficiency but much higher rejection at tight. The identification is cut-based and it utilizes calorimetric information using shower shapes in the different longitudinal compartments and tracking information (especially the TRT-particle identification).

It is observed in general a good agreement for all distributions between data and Monte Carlo. Figure 3 shows R_η (η extension of the shower in the second compartment) and F_{side} (variable calculated on the finely η segmented strip layer as fraction of energy

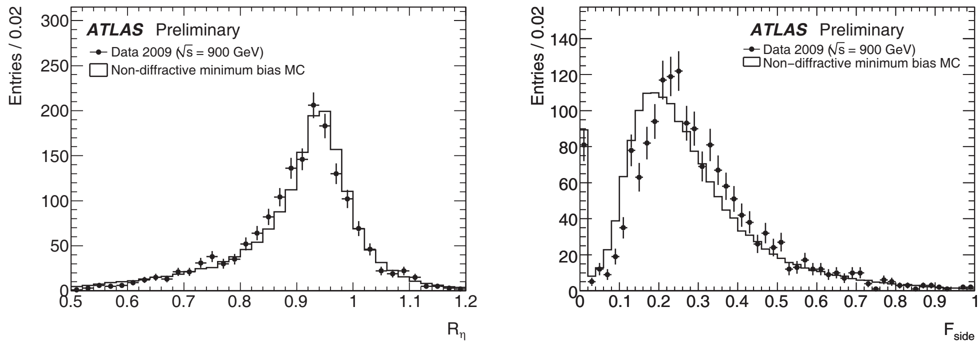

Fig. 3. – Left: R_η, η extension of the shower in the second compartment). Right: F_{side}, variable calculated on the finely η segmented strip layer as a fraction of the energy outside the core of three central strips but within seven strips.

outside core of three central strips but within seven strips). This second variable shows a clear shift towards higher values of F_{side} and studies are ongoing to understanding the source of the discrepancy (cross talk between electrodes, material effects, etc).

The electromagnetic clusters have been used to reconstruct neutral mesons decaying into photons. Figure 4 shows the π^0 and η resonances extracted vetoing clusters with a pointing track and applying simple cuts on the transverse energy of the single clusters, on the cluster pair and on the fraction of energy deposited in the first layer of the electromagnetic calorimeter.

3·2. *Jets and* $\not\!\!E_T$. – The default jet reconstruction in ATLAS uses the anti-k_t algorithm with $R = 0.6$ [3]. Jets are reconstructed both from calorimeter towers and from tracks, the advantage of the second being independent of the jet calibrations. The transverse momentum of both calorimetric-jest and track-jets are in good agreement with Monte Carlo expectations. Isolated hadronic tracks are used to check the E/p measurement. Figure 4 shows the good agreement between data and simulations. The large spike at zero is produced by low momentum tracks that are recorded by the tracker but get scattered

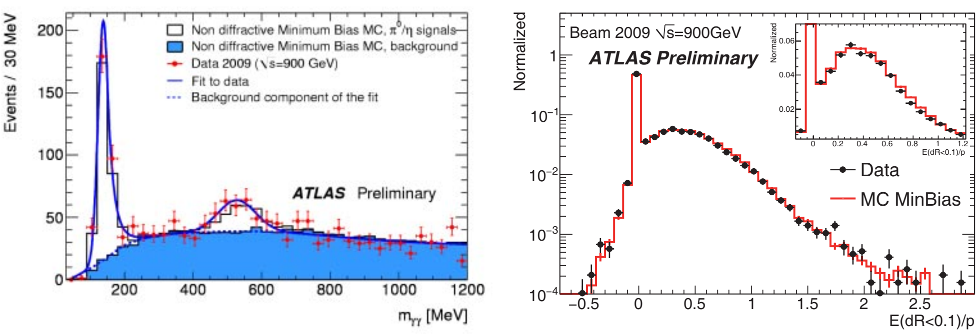

Fig. 4. – Left: Di-photon mass distributions showing the π^0 and η resonances. Right: E/p distribution for isolated hadronic tracks.

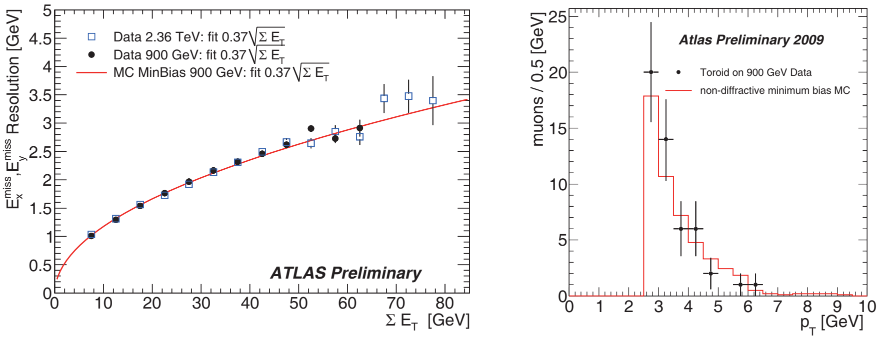

Fig. 5. – Left: $\not{E}_T$ resolution as a function of ΣE_T. Right: transverse momentum of the muon candidates.

away from the original trajectory failing the cluster match and hence obtaining a zero value of cluster energy. Figure 5 shows the comparison between the measured missing transverse-energy resolution and the Monte Carlo prediction. The resolution is readily computed just as the $\not{E}_T$ in the event, the minimum bias expected $\not{E}_T$ being on average zero because of the absence of any hard scattering.

4. – Muon spectrometer

The commissioning of the muon spectrometer has started in the past years with the cosmic rays data taking. The 900 GeV collisions only resulted in about 50 muon candidates at very low momentum (see fig. 5). As soon as the LHC provides 7 TeV collisions, large statistics sample of muons will be collected allowing the commissioning of the detector.

5. – Conclusion

The early phase of the ATLAS commissioning with 900 GeV collisions data have been presented. The different sub-detectors performance have been described and compared with the Monte Carlo expectations showing in general good-agreement events at such an early stage of the experiment. This represents a very solid foundation for the ATLAS high energy physics program.

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