New ATLAS RPC chambers and updates of ATLAS RPC software for LHC run II

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The Large Hadron Colloder (LHC) has been running since the start-up in Fall 2010 for two years. A shutdown of the accelerator and of the experiments has taken place in the recent years and the second run (run II) of the LHC will start later during 2015 with center of mass energy of the proton-proton collision $\sqrt{s} = 13$ TeV (almost double with respect to the data taking of 2011 and 2012) and relatively high luminosity. By the end of run II in 2017 the total integrated luminosity delivered to the experiments is expected to be about 100 fb^{-1}.

During the stop of the accelerator a few upgrades of the ATLAS detector took place: the most important is the insertion of a new layer of pixel detectors (the Insertable B-Layer, IBL), close to the beam pipe, with fine spatial segmentation for an improved resolution in tracking and vertex reconstruction. Among the other smaller improvements of the sub-detectors an upgrade of the system of Resistive Plate Chambers (RPC), which has the foundamental role of providing the muon trigger at $|\eta| < 1.05$, has been carried out.

In particular, the acceptance of the RPC system has been increased by equipping with RPC four new muon stations installed in holes of the acceptance of run I in the sector between the ATLAS feet (sector 13). These stations are referred as BME and BOE and they belong logically to the middle layer and outer layer of muon chambers respectively, although they are physically at a different radius with respect to the other chambers of the corresponding layer. The geometry of these chambers in the ATLAS layout is such that two new trigger towers can be configured in sector 13 at intermediate and symmetric η values. The layout of sector 13 with the new chambers is illustrated in fig.1. In addition, in sectors 12 and 14

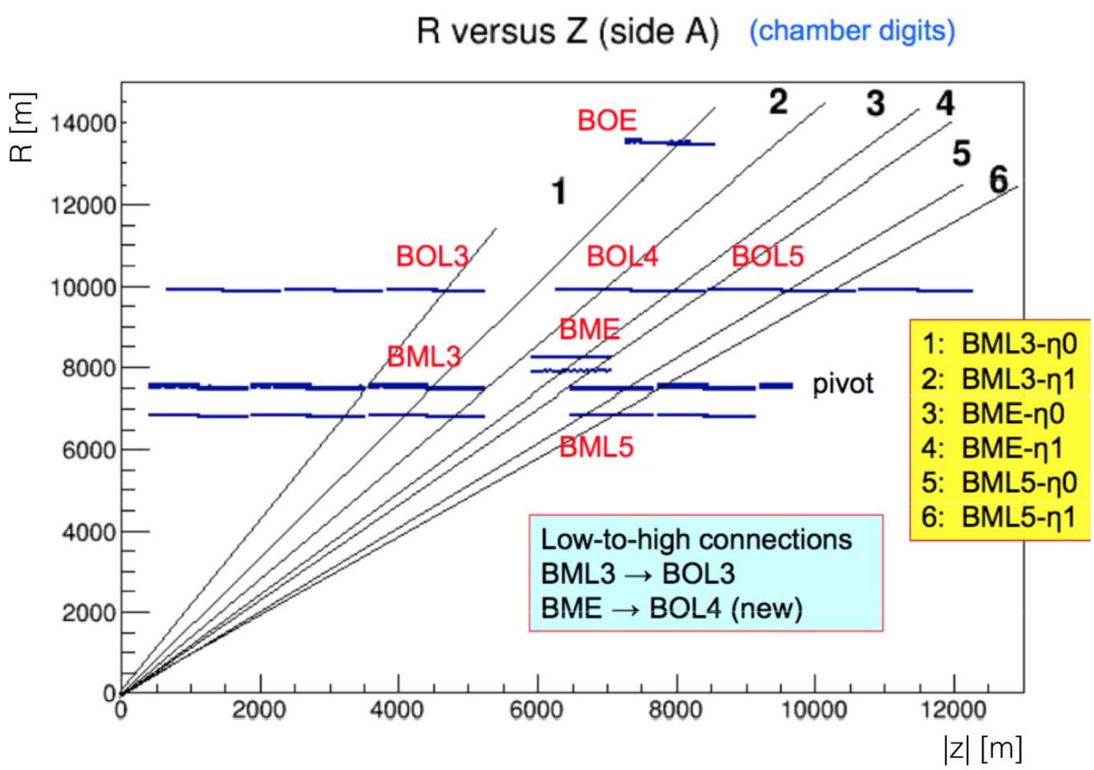

Figure 1. The layout of sector 13 with the new BME and BOE RPC chambers.

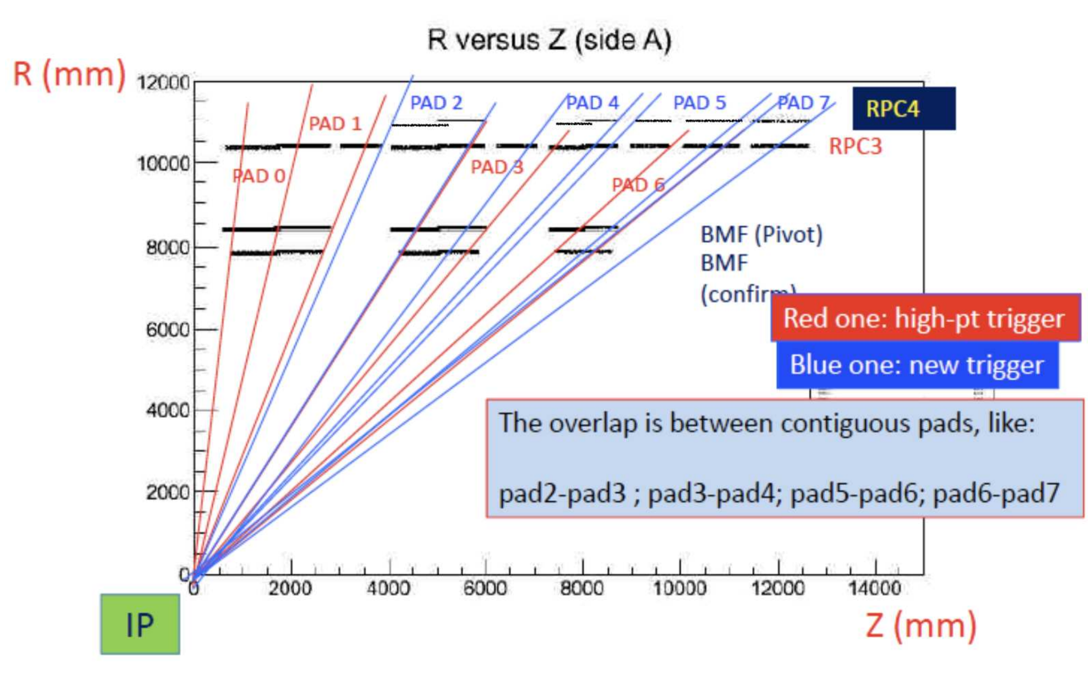

Figure 2. The layout of sector 12 and 14 with the newly equipped RPC chambers (labelled RPC4) on the external side of the outer chambers.

where the supports (feet) holding the entire ATLAS detector above the floor are located, the outer muon stations consist since the installation of two RPC chambers, instead of one like in the other 14 sectors. The extra chambers were installed in order to compensate partially the various acceptance holes in these sectors due to the mechanical constraints and the reduced size of the RPC chambers in the cleareance between the feet structures. However, the extra chambers, mounted on the external side of the outermost muon stations, were not equipped with readout and trigger electronics before the ongoing shutdown. In run II the layout of the RPC chambers in the feet sectors will therefore be peculiar with respect to all other sectors: in several regions a muon from the interaction point (IP) will cross four RPC chambers, each made of a gas-gap doublet, instead of three. This is illustrated in Fig.2 where the new four readout and trigger boards (PAD2, PAD4, PAD5 and PAD7) introduced to deal with the new chambers are shown.

These changes in the hardware and DAQ of the RPC system have required the integration of the new RPC chambers in all steps of the ATLAS software and in the related data-preparation procedures. Our group has been responsible for the description of the new chambers in the ATLAS Detector Description Software, directly feeding simulation and reconstruction, in the Digitization Software which is responsible for translating the GEANT4 hits into a digital response of the detector, in the decoding and encoding of the RPC hits through the implementation of a new version of the cabling maps describing the complex relation between RPC strips and electronics readout channels and of the extension of the offline monitoring software used, together with other monitoring tools, to establish the quality of the RPC data and subsequently the status of the detector with minimal delay during data taking.

The software tools necessary to handle the RPC mapping, i.e. the conversion from electronic channels to detector strips (in data) and detector strips to electronic channels (in simulations), are not trivial because the same electronics implements the trigger logic and the readout. In addition, to avoid trigger inefficiency, a large fraction of RPC strips are readout by two adjacent coincidence matrices in the low-pt and high-pt planes (this situation is referred as cabling overlaps). Moreover, the pointing geometry requires cabling overlaps which depend on the position along the beam axis and, when chamber boundaries are crossed in the bending view, a full non-bending view overlap is required between chambers (named logical-or). Finally, in order to reduce the number of electronic channels, the non bending view strips of two near-by RPC chambers are often wired-or and readout by the same electronic channel. For all the above reasons the mapping is a multi-value function connecting one channel to several strips and vice versa. The unusual layout of sectors 12 and 14 has required the revision of the software services responsible for parsing the maps and implementing the mapping in both directions in the ATLAS simulation and reconstruction software. Fig.3 shows the x-y view of RPC hits produced in the RPC chambers of sectors 12 and 14 both at the level of digits (left) produced in the simulation process and at the level of prepared raw data (PRD), i.e. hits ready for input to reconstruction algorithms obtained from the decoding of the online format of the RPC data (right). The implementation in the simulation of a new mapping schema for sectors 12-14 of the RPC system has been a preliminary step for the definition of the trigger roads for prompt muons of selected transverse momenta in this region of the detector. The new roads, studied though dedicated simulations, are going to be loaded in the firmware of the trigger electronics to allow a proper coincidence logic to be implemented in the on-detector Level-1 trigger. The data collected in the forthcoming planned data takings with a cosmic-ray trigger will be used to commission the new mapping in addition to the detector itself and its readout before the LHC start-up.

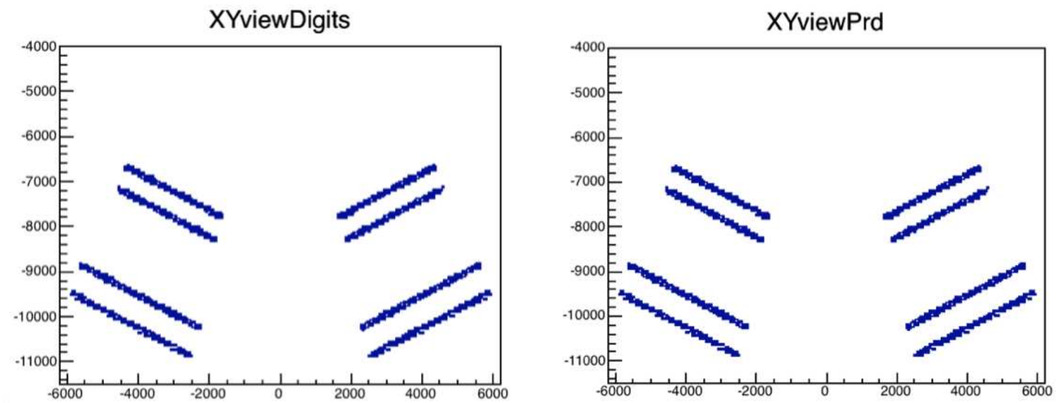

Figure 3. Sectors 12 and 14. The x-y view of RPC digits, from GEANT4 hits converted in signals on the strips (left) andof RPC simulated hits ready for input to the reconstruction, obtained by decoding the online-data format. The consistency of the distributions is an indication of the correct encoding and decoding process.

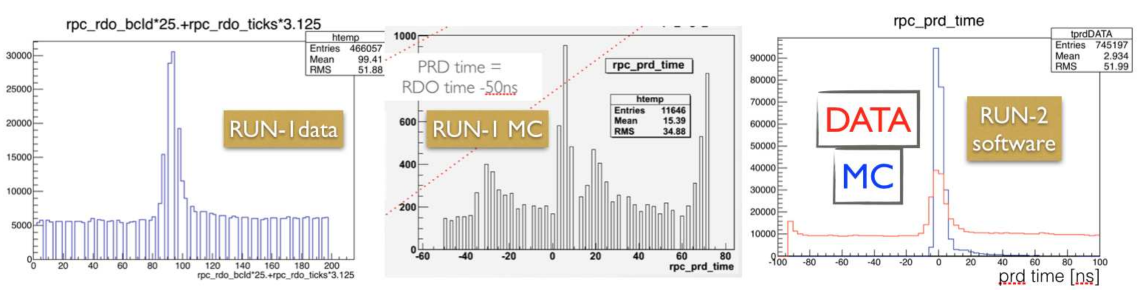

Figure 4. Time distribution of RPC hits in data and simulation processed with run I software (left and center) and in data and simulation from run II software (right).

Another software activity related to the ATLAS RPC is the tuning of the simulation to data in terms of the time structure of the RPC system. The readout of the RPC is configured to collect data from the RPC chambers in a time window 200 ns wide when a Level-1 trigger occours. The clock of the system allows to distinguish a minimal time span of 3.125 ns. The programmable delays of the electronic output channels are adjusted, in groups of four, according to the requirement that hits from prompt muons (muons with $\beta = 1$ originating from the interaction point) are in the middle of the readout window, within the error of the online calibration procedures. The offset of the RPC readout window with respect to the time of the level-1 trigger, distributed to all sub-systems by the central trigger processor is another parameter that has been measured and must be taken into account, along with the internal features of the RPC trigger/DAQ, for a proper simulation of the system. During run I several differences between the time distributions of RPC data in simulation and in data were observed. The inaccuracies in the simulation and digitization leading to such differences have been cured for the forthcoming simulation campaign aiming at predicting the behavior of the ATLAS detector in run II with improved precision. Fig.4 shows the time distribution of RPC hits prepared for reconstruction in run I data (left) and simulation (center) and the data prepared with run II software overlayed with run II simulation (right). The peak corresponds to the time of hits from prompt muons while the flat background represents the hits out of time, from instrumental or physical background unrelated to the trigger; the simulation for run II does not include this effect in the sample used for this plot, while the simulation for run I corresponds to high pileup conditions, responsible for the structures superimposed to the central peak from prompt muons.