PROCEEDINGS OF SCIENCE

Study of the correlation between the construction parameters of the MM readout boards and performance of the Micromegas detectors

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The ATLAS experiment has been upgraded to take advantage of the improved running conditions foreseen for the Run 3 and High Luminosity LHC operation phase. Part of this upgrade consists in removing the original Small Wheels located in the Muon Spectrometer, and replacing them with two New Small Wheels (NSWs). The exploited technologies for the upgrade are Small-Strip Thin Gap Chambers (sTGC) and MicroMegas (MM). The readout boards of the MicroMegas detectors, before being installed in ATLAS, underwent a detailed QA/QC at CERN, during which many construction parameters were measured and stored in databases. Then, the boards have been mounted in Double Wedges and moved to BB5 integration site at CERN, where their final performance and operation have been validated with cosmic rays. Studies of the correlation between several construction parameters of the MM readout boards, as minimum resistance, surface resistivity, pillar height, and operational parameters, as maximum reachable HV per sector, are presented.

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1. Introduction

In anticipation of the increase of luminosity foreseen for the Run 3 and the High Luminosity LHC operation phase (end of 2027), the ATLAS experiment has been upgraded. Part of this upgrade consists in removing the original *Small Wheels* located in the forward-backward side of the *Muon Spectrometer* and replacing them with two *New Small Wheels* (NSWs), to better handle the expected background conditions and pile up rates.
Two different technologies have been exploited for the upgrade: *Small-Strip Thin Gap Chambers* (sTGC) and *MicroMegas* (MM) which have both excellent precision tracking performance (at the level of 100 μm) and fast timing response. The two NSWs (called A and C) are characterized by 16 *sectors* (or *double wedges*, DWs) formed by 8 layers each of sTGC and MM detectors. Each of the MM layer has 8 MM *Printed Circuit Boards* (PCBs), with 1024 readout strips covered by resistive strips (to better handle spark effects), powered by two high voltage sectors and read out by two MMFE8 readout boards (each MMFE8 reads 512 strips). Sectors are also distinguished in *large* (L) and *small* (S) in terms of their sizes. Furthermore, for each sector, PCBs are grouped into two different modules: starting from the bottom of the sector, PCBs from 1 to 5 are classified as LM1/SM1 module, instead the remaining three, from 6 to 8, are referred to LM2/SM2 module, where the first letter ("L" or "S") is referred to the large/small type of the sector itself. Finally, PCBs can also be classified as *eta*, if they are tangent to the ϕ direction in order to measure the η coordinate, or *stereo*, if they are rotated by a stereo angle, of $\pm 1.5°$, in respect to the η direction.

2. Performance of the MM board working HV

The MM detectors used in the NSW are characterized by two parallel planar electrodes, a drift cathode and a read-out anode (defined by parallel readout strips), about 5 mm away from each other. The anode has a resistive-strip protection schema, powered by an HV system, and an amplification mesh, just above the strips, directly connected to ground. The HV potential is chosen such that the electric field in the drift region is a few hundred of V/cm and 40-50 kV/cm in the amplification region. Each PCB is powered by two high voltage (HV) sectors, one on the left and the other on the right side, using a gas mixture of 93:5:2 $Ar:CO_2:iC_4H_{10}$, which allows to reach a very stable HV. Structural and construction differences can affect the maximum reachable HV value, thus affecting the final detector performance. Some studies on this have been carried out by using measurements taken with 93:7 $Ar:CO_2$ gas mixture, given that the HV with this mixture is less stable than that with the nominal one, highlighting more such problems. In particular, the measurements of the HV for each double wedge have been taken from the validation runs performed at the BB5 facility at CERN, before applying the passivation procedure[1]. From these studies appears that large sectors have a large fraction of HV sectors away from the nominal value, unlike the small ones, which are instead more stabilized to the nominal value of 570 V. Also looking at the single PCB level, and distinguishing in board size, large and small sectors have different performance, as shown in Figure 1 for just a single type of PCB. Instead, no differences arise in terms of the eta or stereo type of a PCB, whose performance behaves pretty similar, as shown in Figure 2.

[1]Some boards showed a high instability in the HV. This problem is strictly correlated to low resistance values of the strip anode. The *passivation* procedure solves this issue, deactivating the regions where the resistance is under a threashold of 0.8 MΩ.

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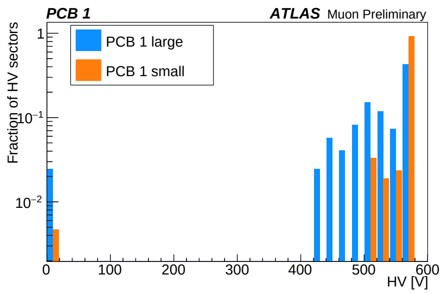

Figure 1: Working HV spread for large/small PCBs of type 1.

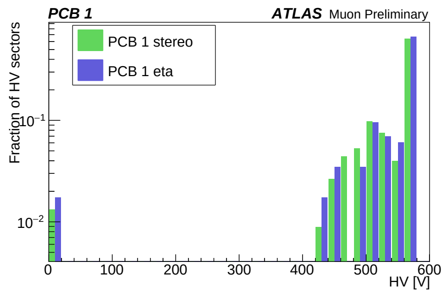

Figure 2: Working HV spread for eta/stereo PCBs of type 1.

3. Study of the MM mean pillar height

The amplification mesh rests on supports named *pillars*, whose typical height of around 120 μm defines the amplification region where the avalanches happen. Measuring the pillar height is very important, since it can impact on the uniformity of the electric field in the amplification gap, and consequently in the signal formation processes. The factors that can affect their characteristics are several. The applied HV could engrave on the construction integrity of the pillars and then lead to structural differences of the same. However, as shown in Figure 3, this doesn't happen, and no correlation between the HV stability and the pillar height is observed. Furthermore, since the production process of each MM boards was assigned to two different companies, Eltos and Elvia, some differences can appear comparing PCBs from different productions: as clearly appears from Figure 4, there is a difference in the mean pillar height for the two productions, in fact, pillars produced by Eltos are generally higher then those produced by Elvia (∼2 μm in average).

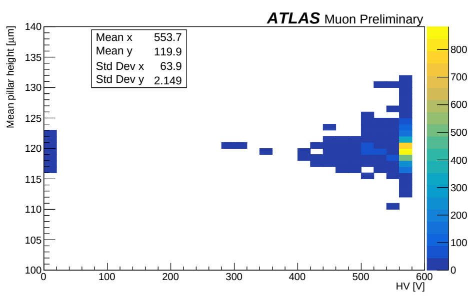

Figure 3: Mean pillar height vs. the working HV.

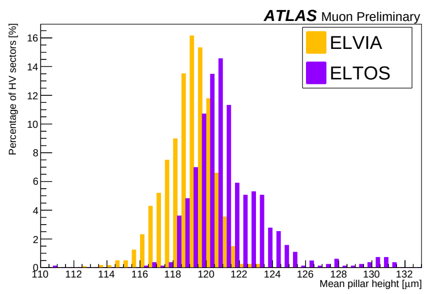

Figure 4: Mean pillar height for Elvia and Eltos productions.

Some differences could also appear in the same PCBs between pillars in different zones of the board. By distinguishing the mean pillar height evaluated on the left side of the board and that one evaluated on the right side, the difference between them, called left/right asymmetry, should be ideally zero, but is expected to be not zero because construction or structural differences in the board itself could be. In Figure 5 is shown the absolute value of this asymmetry as function of the HV, showing that there is actually an asymmetry significantly different from zero and, more, that there is no correlation with the applied working HV.

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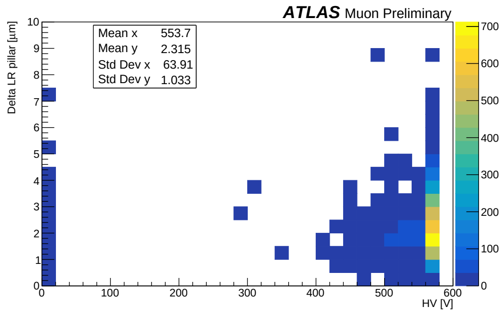

Figure 5: Absolute value of the left/right asymmetry vs. the working HV.

4. Study of the MM mean resistivity

Another aspect which can be considered is about the MM resistive strips, using measurements of the mean resistivity taken during the QA/QC phase. As shown in Figure 6, only for eta type boards, there is a difference among PCBs placed on different modules, in fact those placed on LM1 or SM1 modules have a tighter mean resistivity distribution, peaked around 0.8 MΩ/sq, than the ones on LM2 or SM2 modules, which have instead a long tail. Furthermore, as shown in Figure 7, clearly appears that there is a correlation between the applied working HV and the mean resistivity when approaching the nominal value, in fact the resistivity tends to be higher close to 570 V and, with a cut at ∼1.2 MΩ/sq, almost all sections reach the highest nominal voltage.

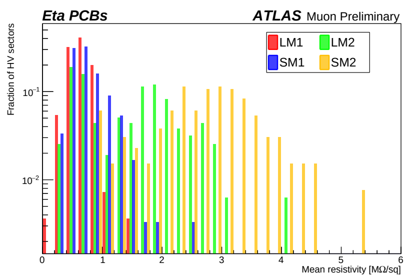

Figure 6: Mean resistivity distribution for each module type, selecting only eta type PCBs.

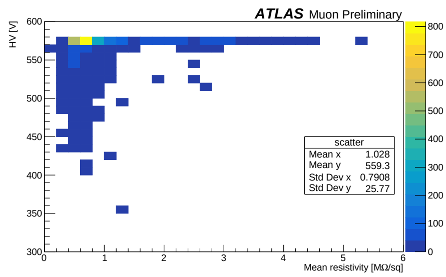

Figure 7: Working HV vs. mean resistivity.

5. Conclusions

After performing these studies, the Micromegas detectors installed in the NSW in ATLAS show generally good performance. In particular, the working HV is well performed throughout the PCBs. Furthermore, there isn't any evidence of correlation between the working HV and the mean pillar height and the relative asymmetry, whereas there is a clear correlation between the working HV and the mean resistivity when approaching the nominal value.

References

[1] ATLAS Collaboration, 2008 JINST 3 S08003

[2] T. Kawamoto et al., *New Small Wheel Technical Design Report*, CERN-LHCC-2013-006, 2013

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