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DESIGN, CONSTRUCTION, QUALITY CHECKS AND TEST RESULTS OF THE FIRST RESISTIVE-MICROMEGAS ANODE BOARDS FOR THE ATLAS EXPERIMENT

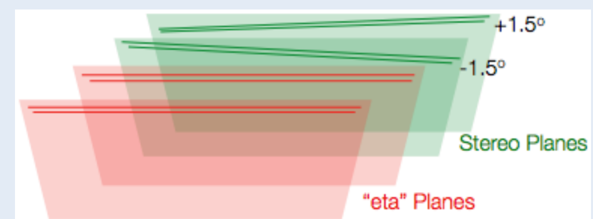
The development work carried out at CERN to push the Micromegas technology to a new frontier is now coming to an end. The construction of the first read-out boards for the upgrade of the ATLAS muon system demonstrate in full-scale the feasibility of the project.

Introduction

The innermost stations of the ATLAS endcap muon detector (Small Wheels) will be upgraded during the LHC long shutdown in 2018. The New Small Wheel (NSW) project consist in the construction of two detector disks about 10 m in diameter instrumented with small-strip Thin Gap Chambers and Micromegas detectors. Each wheel has eight layers of Micromegas arranged in two quadruplets, leading to 1280 m² of active detector area.

The Micromegas read-out boards, representing the heart of the detector, are manufactured in industries, making the NSW Micromegas the first MPGD for a large experiment with a relevant part industrially produced. Micromegas for the NSW projects have to fulfill the following requirement:

- Spatial resolution O(100 µm) for particle angle up to 38° in the precise coordinate and O(mm) in the 2nd coordinate
  - → Each Micromegas quadruplet has two layers with parallel strips (eta) and two with strips inclined by ±1.5° (stereo)
  - → Each pair of layers defines a Micromegas duplet in a back-to-back configuration
- Bunch crossing identification (at 40 MHz LHC bunch crossing frequency)
- Angular resolution of 3 mrad at Level1 trigger stage (1 mrad at HL-LHC)
- High rate capability (> 15 kHz/cm²)
- Good aging properties



Schematic of the arrangement of the readout strip in a NSW Micromegas quadruplet. Two boards have parallel (eta) strips and two have inclined (stereo) ones.

Anode board design

Main design aspects of the anode boards allowing to reach the desired physics performance while making them suitable for industrial production:

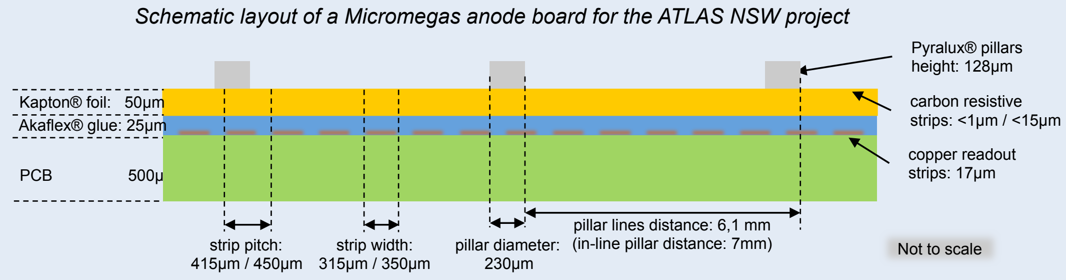
- Board dimensions: 50 cm wide, up to 220 cm long. The limitation of the width to <60 cm is dictated by the standard size of the machines available in PCB industries.
- Left-right symmetric boards. The symmetry reduce by a factor two the number of different board types to be produced
- Copper readout strips running along the large board dimension. The readout strips have a pitch of 415 µm or 450 µm (depending on the board type) with a fixed distance between strips of 100 µm.

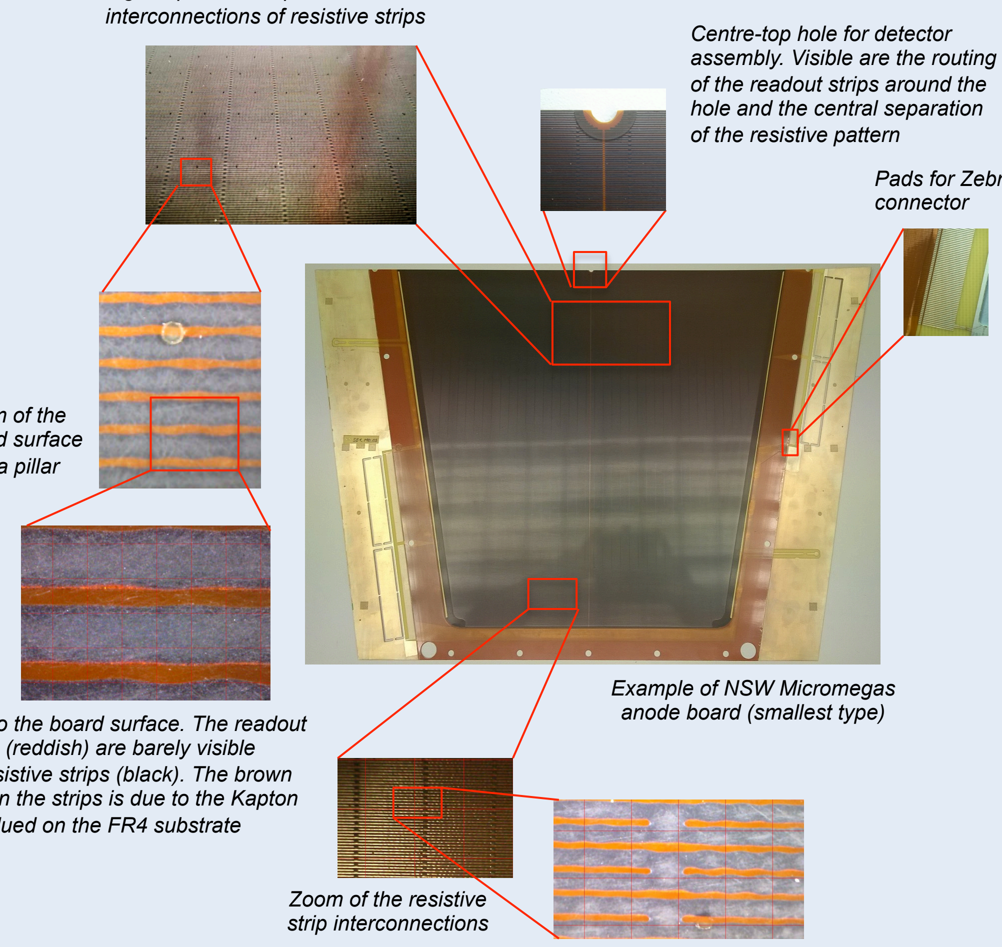
→ This a design provides the required resolution in the precision coordinate (muon bending) for inclined tracks by exploiting the µTPC operating mode.

- Each board has 1024 readout strips. The top 512 strips are routed to the right of the board, the bottom 512 to the left, ending in a pad-shaped copper pattern. The pads (2 cm long, 200 µm wide strips 200 µm spaced) transmit the signal to the front-end electronics via silicon-based zebra connectors. The advantage of this solution is to avoid connectors soldering on the boards.
- The routing of the readout copper strips accounts for the positioning of assembly holes without strip cuts or interruptions.
- Spark protection is provided by interconnected resistive strips (same width and pitch as the copper strips), screen-printed or sputtered on a 50 µm thick Kapton foil. Interconnections are placed every 10 mm in an alternate configuration (see picture) between those lines.
- The strips are interrupted in their middle, thus each board has two independent high voltage sectors (left- and right- side), to achieve a finer granularity in the HV distribution.
- Cylindrical pillars (128 µm high, 230 µm diameter), arranged in a triangular array 7 mm aside, define the amplification gap.

In 2048 boards of 32 different types will be produced for the ATLAS NSW.

Schematic layout of a Micromegas anode board for the ATLAS NSW project





Surface structure of the board, with regular patterns of pillars and interconnections of resistive strips

Centre-top hole for detector assembly. Visible are the routing of the readout strips around the hole and the central separation of the resistive pattern

Pads for Zebra connector

Zoom of the board surface with a pillar

Example of NSW Micromegas anode board (smallest type)

Closer look to the board surface. The readout copper strips (reddish) are barely visible below the resistive strips (black). The brown color between the strips is due to the Kapton foil directly glued on the FR4 substrate

Zoom of the resistive strip interconnections

Board construction procedure and requirements

I. Copper pattern creation by photolithography
(PCB material :FR4 0.5 mm, 17 µm Cu clad double-sided)

- PCB material thickness accurate to < ± 50µm
- Copper pattern absolute accuracy: <30 µm for the short side and <100 µm/m for the long side
- Line and space accuracy 20% w.r.t. the design file
- Maximum 1% of cut on the copper lines, as long as cuts are not on neighboring lines
- Maximum of 0.1% of shorts between two lines, as long as no more than two successive lines are shorted

II. Selective plating on connector pads

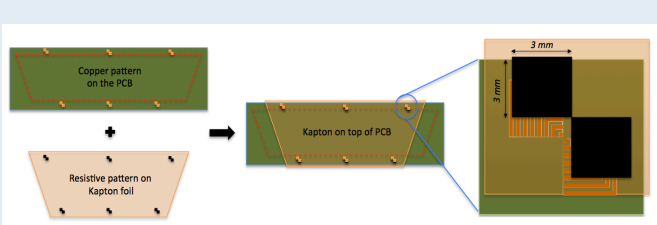
- Layer thickness depending on plating choice: Au/Ag/Pd

III. Cutting of Kapton foils with resistive pattern

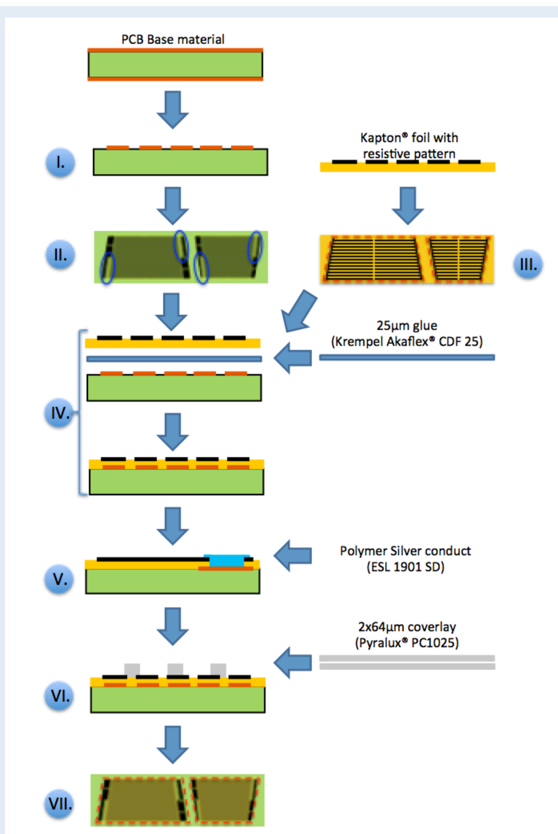
- Cutting accuracy shall be better than ±1mm

IV. High pressure Gluing of Kapton foil on the PCB

- Alignment accuracy shall be better than ±0.5mm



Alignment targets for Kapton vs. PCB positioning



Schematic of the anode boards production process

V . Connection between HV input line and resistive strips (screen printed: silver conductive paste)

- Position accuracy w.r.t. the copper pattern < ±1m
- Resistance of the silver HV connection line < 10Ω

VI. Pillar creation (2x 64µm Pyralux coverlay)

- Coverlay pattern absolute accuracy < ±1 mm
- Accuracy of the diameter of the pillars ±25 µm
- Missing pillars maximum 0,1% of the total number, as long as no neighboring pillars are missing
- Max. 10 extra coverlay structures of a size < 1mm in each dimension are tolerated per square meter
- The mean height of the coverlay layer / pillars in different 25x25 cm² regions has to be homogeneous on a level of <5µm over the full surface of the board

VII. Cutting of the boards and drilling of the non-precision holes
(holes for mechanical assembly and alignment)

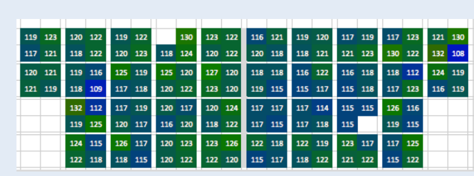
- Cutting absolute accuracy w.r.t. the copper pattern shall be better than ±100µm
- Holes absolute position accuracy referring to the copper pattern shall be at least ±100µm.

Quality control on first prototype boards

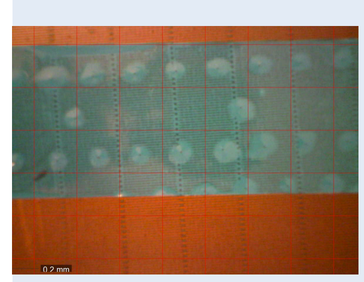
The first anode boards to be used for the construction of NSW Micromegas full-scale prototype detectors (Module-0) have been produced in Summer 2015 in two Companies.

The boards have then undergone a severe control of quality at CERN to verify the construction requirements. While some assumed critical requirements (e.g. homogeneity of the pillar height) where fulfilled on most of the boards, several common issues have been discovered:

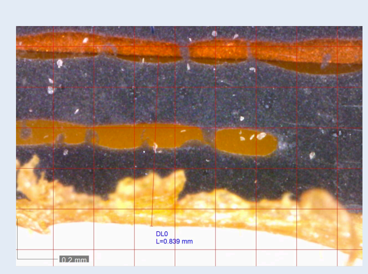
- Missing and weakly attached pillars
- Inaccurate and unclean edge cutting
- Bubbles or dust enclosed between the Kapton foil and the PCB



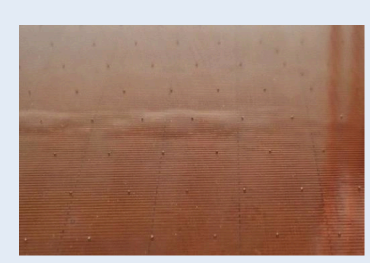
Pillars height measured on one board



Missing pillars



Edge cutting



Bubbles

These issues have been addressed with regular feedbacks and visits to the Company premises, leading to a second delivery of higher quality boards. The board production for the Module-0 will be completed soon.

A tender process to assign the production of the 2048 boards needed for the NSW project is going to be initiated soon. The mass production will start in the first half of 2016 and will span over about 18 months.

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ATLAS EXPERIMENT