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Mechanical prototype of tracking chamber in station 2 in dimuon spectrometer of ALICE

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To explore the physics of ultra-relativistic heavy-ion collision, a large ion collider experiment (ALICE) [1] is proposed to carry out at large hadron collider (LHC). Forward muon spectrometer (FMS) [2] is included in ALICE to look for the signals of quark gluon plasma (QGP) using dileptonic decay of heavy quarkonia $(J/\psi, \gamma)$ produced in the collision as a probe. The production of these states will be suppressed in a deconfined medium of QGP which can be estimated from the invariant mass spectrum of dimuonic decay channel. The spectrometer is designed to track down the flight path of the dimuons with the help of five tracking stations from which the opening angle of the pair can be known by reconstruction and extrapolation of their tracks. The momenta of the pairs can be obtained from the deviation of the tracks in a dipole magnetic field. The invariant mass of the pair can be determined from the opening angle and momenta of dimuon pairs. Each of the five tracking stations is equipped with two planes of cathode pad chamber each divided into four quadrants to detect the position of the dimuon passing through them and reconstruct their tracks from their positions.

The tracking chambers are designed following the basic feature of a position sensitive multi-wire proportional counter (MWPC) where an anode wire plane is interposed between two cathode planes and a high electric field is maintained near the anode with respect to the cathodes. The chambers are capable of providing X, Y position readout of an event from the charge distribution induced over the cathode planes equipped with pad matrices due to the avalanche produced in the gaseous medium. However, the mechanical design of the large chamber (diameter $\sim$2 m) for the second tracking station is a challenging task as it concerns good surface planarity to achieve position resolution better than 100 μm (necessary to meet mass resolution about 100 MeV) as well as minimum usage of material to keep radiation length low (2–3% of X_0) in order to minimise the energy loss and scattering of the incident lepton. The calculation was carried out at IPN, Orsay to simulate a full scale quadrant with different design parameters and materials to study its mechanical characteristics [3,4]. In the simulation, various options in material and design aspects were studied to seek an optimum design for the chamber to enhance its mechanical

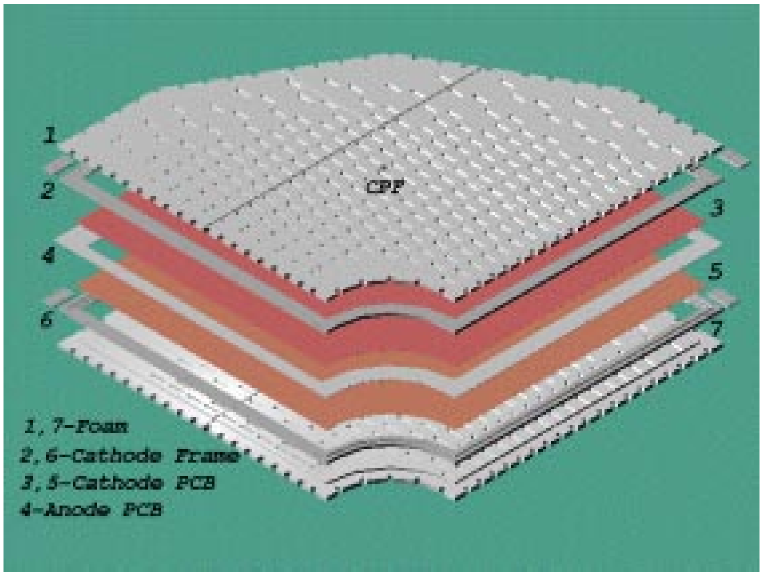

Figure 1. The assembly of mechanical prototype with all the layers except the outermost two exit boards where all the layers are shown except the exit boards at the top and the bottom.

rigidity over the large dimension with a thickness of 25 mm as dictated by the design of the spectrometer. The thickness of the chamber was required to be less to keep the tracking planes close enough to improve upon the track reconstruction efficiency. A guideline to the design and choice of material for the chamber was finalised following the result of the simulation. A full scale mechanical prototype of the quadrant chamber of station 2 was built at SINP to validate the simulation results.

The anode and cathode planes were made from 0.8 mm PCBs. They were fixed on frames made of a glass fibre material (PEEK). To provide mechanical rigidity to the cathode planes, a special kind of foam (Rohacell) with low radiation length was glued to them. Holes were made in the foam layers to provide passage of the (Kapton) connectors to carry out the charge signals from the rear side of the cathodes. Outside the foam layers, two exit boards were glued on the foam surfaces for mounting of readout electronics to which the connectors were attached. The frames were made from several pieces joined together mechanically and glued additionally. Like the frames, the anode PCB was made from joining several pieces of PCBs glued on the frame. The planes of cathodes, foam and the exit boards were also made from segments glued together to make a single piece. All the joints were done on a granite surface to maintain a good planarity over the surface of the planes. The planes were assembled mechanically like a sandwich to make a leak-proof volume. The assembly of the layers of the prototype is depicted in figure 1.

Of the several options studied in the simulation to enhance the mechanical rigidity, the central point fixation (CPF) method came out to be the best suitable method where the planes of the chamber were anchored at a central point. In figure 2, the calculated deformation of the chamber for station 2 is shown as a function of thickness of the foam with and without the CPF which shows that the method reduced the deformation by a factor of

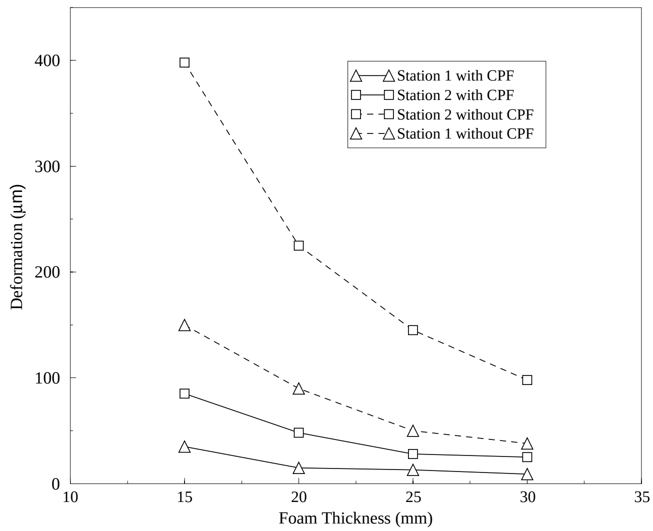

Figure 2. Deformation of the chamber as a function of foam thickness with and without CPF.

4.5 at the thickness of 25 mm and foam density of 51 kg/m^3 which were opted in the final design. Although the increase in the density of the foam produced nominal change in the deformation of the chamber, the higher density was opted for better resistance during machining. The calculation was carried out at 0.5 mbar overpressure of the filling gas which could be endured by the chamber without affecting its performance. Reinforcement of the carbon epoxy composite with high Young's modulus ($Y \sim 1,50,000$ MPa) in the structure of the chamber instead of the glass epoxy material provided similar order of improvement in the deformation of the chamber when considered with identical parameters. However this option was not accepted due to several problems like electrical isolation, noise, greater radiation length, higher cost involved in the machining, etc.. Another method considered was of adding plastic skin (PETP film) of thickness 0.1 mm on the foam layer to enhance the rigidity of the chamber due to its high Young's modulus ($Y \sim 8,000$ MPa). However, the calculation done with foam density 31 kg/m^3 and thickness 30 mm showed nominal change in the deformation.

The mechanical prototype was tested for its mechanical characteristics to compare with the results of the simulation. The surface planarity of the prototype was studied by measuring the deviation of the surface of the cathode at various points from a horizontal reference with filler gauges. The histogram of the measurement of deviation from surface planarity is plotted in figure 3 which reflects the order of planarity of the prototype surface. The deformation of the prototype with overpressure was measured using the lamp and scale technique before and after adding the central point fixation (CPF) to see the improvement over the deformation. In figure 4, the simulation and test results are depicted together for comparison. The measured values of the prototype deformation with and without the CPF are illustrated by open symbols as a function of the overpressure of the filling gas.The simulated values of the deformation with and without the CPF at overpressure of 0.5 mbar are represented by solid symbols which showed a good agreement with the measurements.

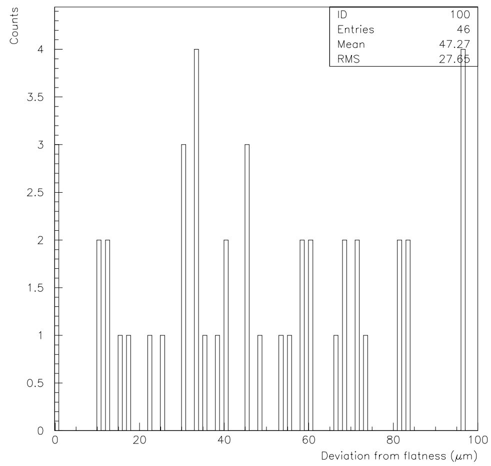

Figure 3. Histogram of measurement of deviation from flatness of the mechanical prototype built at SINP with station 2 parameters.

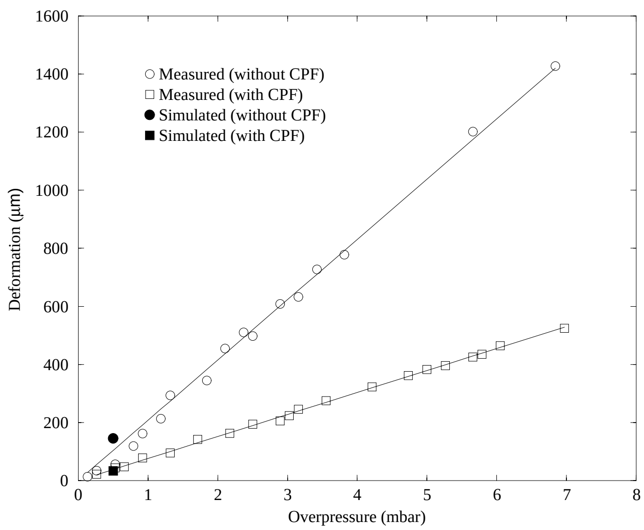

Figure 4. The measurement of deformation of the prototype as a function of overpressure done before and after addition of CPF. The simulated results are shown by solid symbols for comparison.

Also the measurement showed a linearity of the prototype in its deformation pattern as predicted by the simulation.

Acknowledgements

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