Optimizing the manufacturing method of detector parts *

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For the Forward GEM-Tracker of the PANDA experiment at FAIR [1, 2], as part of structural elements of the so called GEM-Disc detectors, rings with high dimensional stability and optimized material budget need to be produced. The parts are up to 1.5 m in diameter, 8 mm width and only 0.5 mm thick. They need to withstand forces of up to 15 $N\,cm^{-1}$ in radial direction. Parts made from conductive material as well as highly isolating ones are required. Industrial products with the appropriate features are not available and thus the process was set up and optimized at GSI.

Finite Element Method (FEM) simulations (see figure 1) were done precedent to manufacturing sample parts. The results of these calculations show the necessity of uniform material properties in direction of the load. This can be achieved by compounds with specific material orientation. Composite materials of carbon fibre and resin have excellent properties in elastic modulus and tensile strength, and are electrically conductive. Compounds of glass fibre are non conductive but have a lower elastic modulus. Currently fibres made from basalt are under test which offer intermediate properties. They are non conductive, stiffer than glass fibres and commercially available at moderate prices.

Figure 1: Left: FEM simulation is used to estimate the deformation of the part. Right: small test parts of basalt and glass fibres.

To achieve a uniform fibre orientation in the rings appropriate for the orientation of the radial loads they should withstand, a winding apparatus (see figure 2) has been build where the fibres are wound up to a spool. The winding motion is achieved by rotating the spool around its axis. A motor/gear/brake combination applies a constant tractive force on the roving (a bundle of fibres) which allows a controlled stacking of the fibres without larger flaws and with the desired high amount of fibre content (>60 %) in order to maximize the stability and minimize the material budget. Several types of resin have been used in the tests, the final choice will be made taking into account the need for ageing-free operation of the detectors. The winding is made up to a larger outer diameter of the ring than necessary. The excess material is later removed by milling. Also the connection to the centre bar and additional geometry (holes, chamfers, fillets etc.) are milled.

Figure 2: The devices to wind the rings with variable size, thickness and fibre content. The roving comes from the right, goes through a impregnating bath, and is kept on a constant force by a controlled brake before it is wound to the spool (shown on the left).

After producing parts of different material combination test for mechanical, chemical and physical properties will be performed together with the collaborating universities. Based on this tests both material and geometry will be optimized. By comparing the FEM results with the actual behaviour of the parts the simulation settings will be optimized. This will be very helpful for the simulation of other detector parts made of composite material.

References

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* Work supported by FAIR@GSI PSP code: 1.4.1.

doi:10.15120/GR-2014-1-FG-S-FRS-09