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Micromegas tracker project for CLAS12

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Abstract :

Micromegas detectors on bulk are used in a new design of the central tracker for the future CLAS12 spectrometer in Hall B at Jefferson Lab. Expected performances and mechanical designs are shown for this cylindrical detector. First tests in moderate magnetic field up to 1.5 T, using a laser source, are in good agreement with simulations.

1. Introduction

The Jefferson Lab future upgrade in energy from 6 to 12 GeV has initiated different projects concerning the Halls equipment as they should fit the new requirements of the higher energy range. In Hall B, the Cebaf Large Acceptance Spectrometer (CLAS) [1], designed to study multi-particle, exclusive reactions will be upgraded to CLAS12, a new version of the spectrometer, optimized to study high energy exclusive and semi-inclusive reactions and able to deal with higher momentum tracks and smaller cross sections. It should be able to cope with a luminosity of L = 10^{35} $cm^{-2}s^{-1}$ and have a good vertex resolution. CLAS12 [2] is composed of a Forward Detector covering the 5 to 40° angular range and a Central Detector covering 40 to 140°.

The Central Detector consists of a 5T solenoid, surrounding the target, in which would be set a neutron counter, a central time of flight detector, and the central tracker. The solenoid homogeneous field is designed for target dynamical polarisation, it ensures charge particle momentum determination by the central tracker detector and enables also to focus the Möller electrons scattered from the target envelopes in a dedicated channel along the beam direction

2. Central tracker project

The central vertex tracker will be confined in a cylindrical volume of 60 cm in length, a minimal radius of 5 cm and a maximal radius of 16 cm [2]. We describe here a design based on bulk Micromegas.

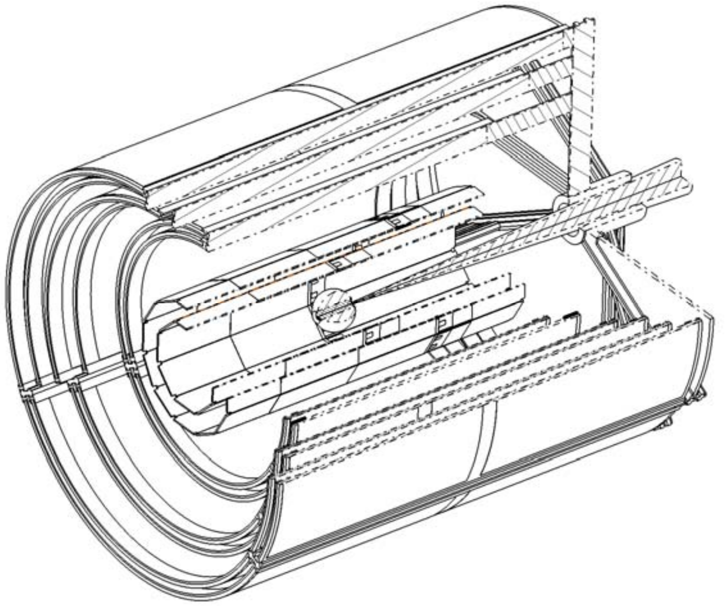

Fig.1 A schematic view of the barrel tracker with three MM double layers around two double layers of Silicon detectors

2.1. Bulk Micromegas

At Saclay, teams of the Service de Physique Nucléaire (SPhN) and of the Service d'Electronique des Détecteurs et d'Informatique (SEDI) have started an R & D project to build the central tracker using the last generation of Micromegas (MM) detectors [3] based on PCB technology and called "bulk Micromegas" [4].

The principle of bulk MM is to make a detector using thin PCB boards (100 μm) with 5 μm thick copper strips, 230 μm wide, as the anode plane. Then a photo resistive film having the right thickness, and the 19 μm thick, 500 LPI, stainless steel cloth mesh cathode are laminated together with the board at high temperature, forming a single object. By photolithographic method the photo resistive material is etched producing the pillars in which the mesh is embedded.The whole detector is nearly built in one process as the drift plane has eventually to be glued above the mesh to determine the conversion gap.

2.2. Bulk tracker project

Simulations have shown that a cylindrical tracker using 3 double layers (X and Y coordinates) of bulk MM, with 10 k channels of electronics, around 2 double layers of Silicon detectors (Fig.1) would give better resolutions than the CLAS12 tracking specifications, for instance 1.6 % is expected as momentum resolution when the specification is 5 %.

Tests have been done at Saclay/SEDI on prototypes to characterize cylindrical bulk MM detectors. The gain for curved bulk MM is similar to what can be measured on a flat bulk MM

($3\ 10^4$ at 490 V mesh voltage, see Fig.2) and the energy resolution checked with an ^{55}Fe source, about 30%, is in improving stage since a better preparation of the mechanical setting of the detector has started.

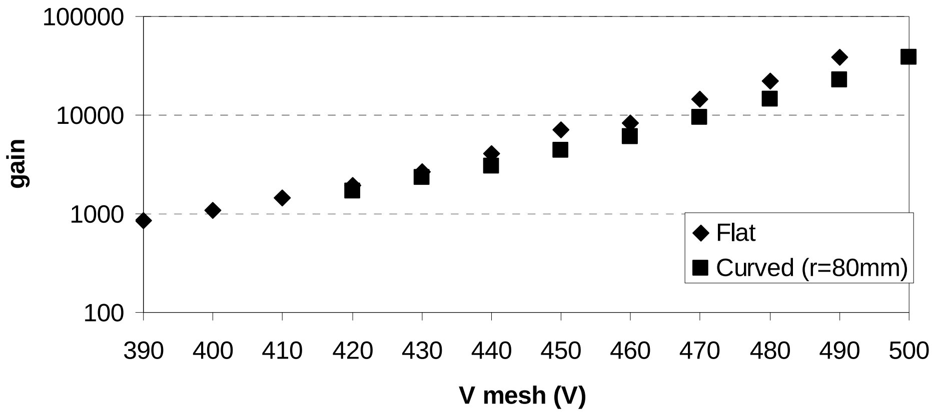

Fig.2 Gains for flat (diamonds) and curved (r = 80 mm) (squares) bulks. The amplification gap is 150 µm and the gas mixture is Argon plus 5% i C_4H_{10}

3. Behaviour in magnetic field

An important issue concerns the behaviour of the detector in the high magnetic field of CLAS12 Central Detector. The detector has to be inside a 5T solenoid the field direction of which is orthogonal to the detector's own electrical field. The Lorentz angle θ which defines the primary electrons direction in the conversion gap towards the ionizing particle direction can be estimated according to:

$$tan\theta = v.B / E \quad (1)$$

With v being the electron drift velocity, E the electrical field and B the magnetic field. In usual gas (Ar plus 5% iC_4H_{10}) and high voltage conditions (drift velocity of 8 cm/µsec, electrical field 1 kV/cm), the Lorentz angle due to the magnetic field would be as high as 75°, preventing any of the primary electrons created in the MM conversion gap to reach the mesh and thus disabling the detector. Recent work [5] showed that increasing the drift electrode high voltage, decreasing the conversion gap, changing the electron velocity using other gas mixtures would decrease dramatically the Lorentz angle. Simulations, using the CERN Garfield code, lead to the same conclusions.

3.1. Tests and results

Tests were performed at Saclay to validate these simulations on a small flat bulk MM, equipped with a 96 channels Gassiplex electronic board, in a low field (up to 1.5 T). A normally incident UV 355 nm wavelength laser (FLARE UV 100-50), with a 2 nsec pulse and delivering lesss than 50 µJ/pulse, was used to produce primary electrons on the drift electrode. This method had been used successfully to study the spatial and energy resolution of a MM detector [6].
The detectors had a 30x30 mm^2 active area, a 300 µm pitch, a 2.25 mm conversion gap, a 128 µm amplification gap and the gas used was 5% iC4H10 mixed with 95% Ar. As seen on Fig.3, results are in agreement with the simulations in the field range covering 0 to 1.5 T.

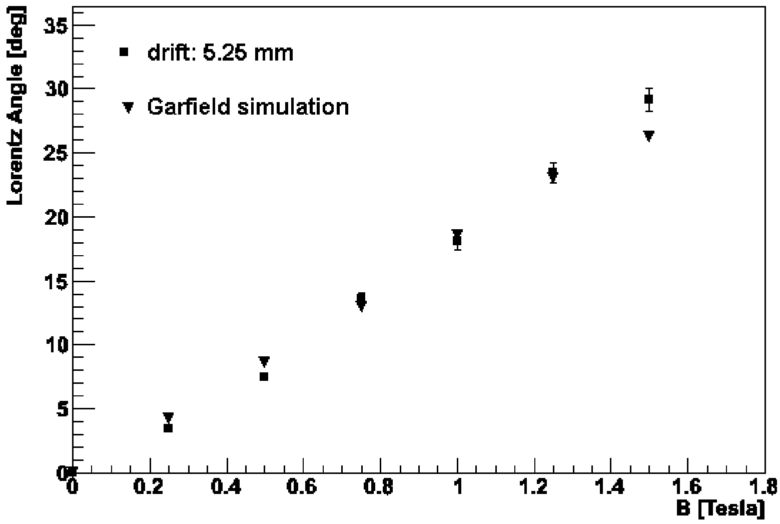

Fig.3. Lorentz angle versus Magnetic field for a flat bulk MM. Simulation points (triangles) are in good agreement with test measurements (squares).

The Lorentz angle, at 1.5T, could be diminished from 56° to 10° by increasing the drift electrode high voltage from 550 V to 1000 V (see Fig.4).

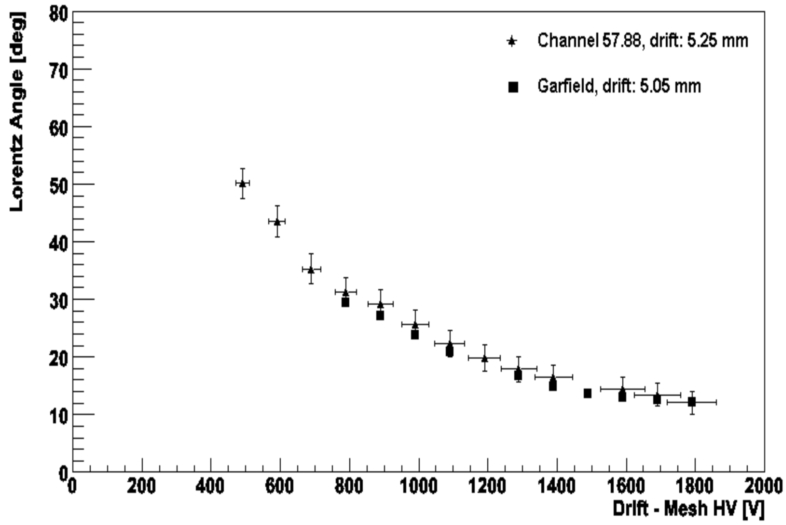

Fig . 4 . Behaviour of the Lorentz angle at 1.5 T versus Drift-Mesh high voltage. The experimental points are measured for a 5.25 mm drift gap (triangles) and the Garfield points (squares) worked out for a 5.05 mm drift gap. Gas was 5% iC4H10 – 95 % Ar.

3.2. Spatial resolution

The spatial resolution of the tracker predicted by simulation is 220 µm. The tests performed with the laser in magnetic field enabled us to measure a global spatial resolution. It is determined event by event by working out the sigma of the average position given by the strips.

This spatial resolution (σ) involves the contribution from the detector itself (σ_{det}) and from the laser (σ_{las}) according to (2):

$$\sigma^2 = (\sigma_{det}^2 + \sigma_{las}^2) / N_e \quad (2)$$

where N_e is the number of primary electrons generated on the drift electrode by the laser.

Table1. Spatial resolution vs magnetic field

B (T)	0	0.5	1.0	1.5
σ (µm)	5.5	6.8	8.5	10.0

Table1 shows that σ is increasing with magnetic field as the signal collected on the strips gets spread.

To access σ_{det} , the laser has to be calibrated in order to determine the number of primary electrons generated. This number, N_e , is expected to be large, between 100 and 400 which would lead to σ_{det} ranging from 100 to 200 µm. This range is suiting the 220 µm foreseen by simulation, in agreement with the tracker specifications.

4. Conclusions

The R&D of the tracker project for CLAS12 using curved flexible bulk Micromegas has demonstrated that such types of detectors were feasible and the first tests indicate that their performances would reach the required specifications. As the energy resolution is improving, calibration of the laser used to create primary electrons in the lab will be performed and the actual spatial resolution of the detector, $\sigma_{det,}$, will be determined.

Mesurements in moderate magnetic field, up to 1.5 T, are in good agreement with the simulations concerning the behaviour of the Lorentz angle. A new series of tests are programmed, during Fall 2008 at Jefferson Laboratory. A larger bulk Micromegas prototype will be set in the 4.7 T magnet of the deeply virtual Compton scattering (DVCS) experiment to validate the simulations at high field.

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