GEM tracker for high luminosity experiments at the JLab Hall A

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The physics program of the Thomas Jefferson National Accelerator Facility (Jefferson Lab) [1] is the experimental study of quark-gluon confinement, dynamics of quarks in the nucleon and nucleon in the nucleus, nuclear structure, and standard model limits, through the scattering of a continuous beam of electrons in the multi-GeV range. Starting in 2013, the CEBAF (Continuous Electron Beam Accelerator Facility) will deliver to all three experimental halls 11 GeV high intensity (up to 100 μA), high longitudinal polarization (up to 85%) continuous wave electron beam.

The Hall A Collaboration are developing a new reconfigurable spectrometer, the Super BigBite (SBS [2]), featuring very forward angle (down to 7°), large momentum (2-10 GeV/c) and angular (64 mrad) acceptance, high rate capability (1 MHz/cm^2), for the precision measurements of e.g. nucleon electromagnetic form factors at high Q^2 (up to 15 GeV^2), transverse momentum distribution of quarks in the semi-inclusive deep inelastic scattering (SIDIS) regime, pion and kaon spin asymmetries in transversely polarized nucleons with luminosity as high as 10^{38}cm^{-2}s^{-1} for electron-nucleon experiments.

INFN groups share responsibility of building the primary (front) GEM tracker of the SBS, placed just after the dipole momentum analyzing magnet. It consists of six large area (40 × 150 cm^2) high resolution (∼70 μm) GEM chambers [3]. It is designed for accurate tracking particles emerging from the electron scattering in a large background of soft photons (∼0.5 MHz/cm^2) and mips (∼0.2 MHz/cm^2). The primary tracking will be reinforced by combination with two small (10×20 mm^2) planes of silicon μstrips placed in proximity of the target.

The basic module of a chamber is a triple (double mask foil) GEM with active area 40×50 cm^2. High voltage feeding protection resistors and gas inlet/outlet holes are embedded into the 8 mm wide mechanical frame. The signals are read out in X-Y coordinates through strip conductors planes with 0.4 mm pitch. Both GEM foils and readout planes are manufactured by the CERN TD-DEM Photo Mechanical Technologies group. One side of the GEM foil is divided into twenty sectors to quench discharge propagation. Each sector is loaded onto proper SMD protection resistor. PERMAGLASS TE630 frame where the GEM foils are glued, plus terminal honeycomb structure, where the readout foils are glued, give the module the needed mechanical stiffness. A carbon fiber outer frame integrates the modules into one single chamber, and supports all services (readout electronics, cabling, gas, HV). GEM foils sagittae of the fully equipped chamber (Fig. 1) have been studied by finite element analysis, and are expected to be within 6.5 μm.

Mechanical mounting of the GEM modules is accomplished with appropriate tools, all operating on an assembly table (Fig. 2) equipped with gauges for process control.

The read-out electronics developed for the tracker (Fig. 3) is composed by an APV25 [4] based front-end (FE), a serial output analog ASIC running at 40 MHz and a custom VME Multi-Purpose Digitizer (MPD), which handles up to 16 FE cards (2048 channels). It is based on Altera ARRIA GX FPGA and has on board 16 12-bit ADCs running at 40 MHz, plus all the control electronics (APV25 clock and fast commands).

The first full scale (40×50 cm^2) module of a GEM chamber was built at the end of 2010 and tested in 2011 with electron (at DESY Hamburg with the support of the EUDET Program (http://www.eudet.org)) and proton (at CERN Geneva) beams, also using final FE with back-end distribution/collection boards, and the read-out VME/VXS ADC modules.

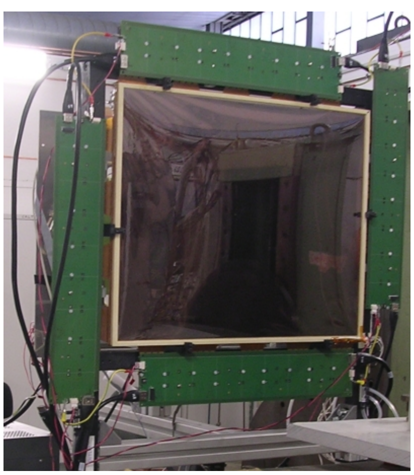

Figure 1. Fully equipped 40×50 cm^2 GEM module prototype. GEM chambers, front-end and readout electronics are developed within the JLab12 collaboration, funded through the INFN CSN3.

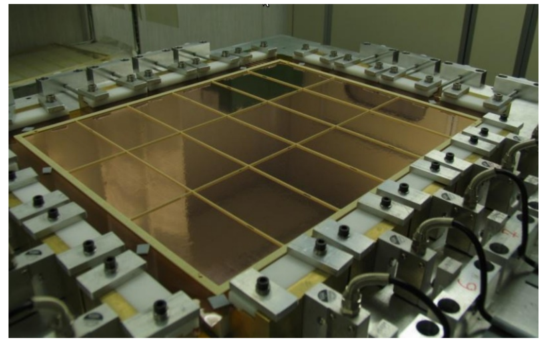

Figure 2. GEM assembly table. The GEM foil and the spacer frame which will keep the distance between two foils are clearly visible. All around the automatic press with load cells for control.

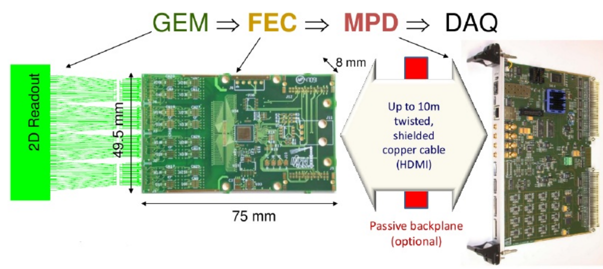

Figure 3. The readout electronics chain developed for the GEM tracker and based on APV25 chip.

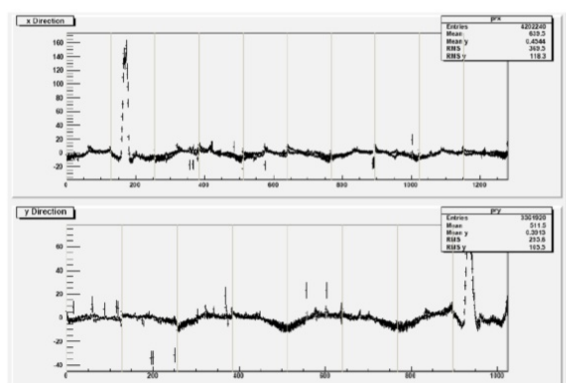

Figure 4. X-Y beam profile reconstruction from test-beam data measured by the first full scale GEM module equipped with final read-out electronics.

REFERENCES

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