Development and test of a large area, high spatial resolution GEM tracker for the 12 GeV physics program at the Jefferson Lab Hall A

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A new and rich physics program is expected from the energy upgrade of the Jefferson Lab due to start in 2013, when all three experimental halls will be fed with 11 GeV high intensity (up to 100 μA), high longitudinal polarization (up to 85%) continuous wave electron beam [1].

The luminosity achievable (10^{38} and 10^{38} cm^{-2}s^{-1} for electron-nucleon experiments with unpolarized and polarized target, respectively) will allow one to access processes with small cross sections, thus opening to new investigation [1] of e.g.: the nucleon electromagnetic form factors at high Q^2; the precise measurement of pion and kaon spin asymmetries in transversely polarized nucleons.

In order to take advantage of the new scenario, members of the Hall A Collaboration are developing a new reconfigurable spectrometer, the Super BigBite (SBS [2], Fig. 1), featuring very forward angle (down to 6°), large momentum (2-10 GeV/c) and angular (64 mrad) acceptance, high rate capability (1 MHz/cm^2).

The SBS tracking system is made of three stations. The primary (front) tracker, placed just after the dipole momentum analyzing magnet, consists of six large area (40 × 150 cm^2) high resolution (∼70 μm) GEM chambers. It is designed to be capable to track accurately 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

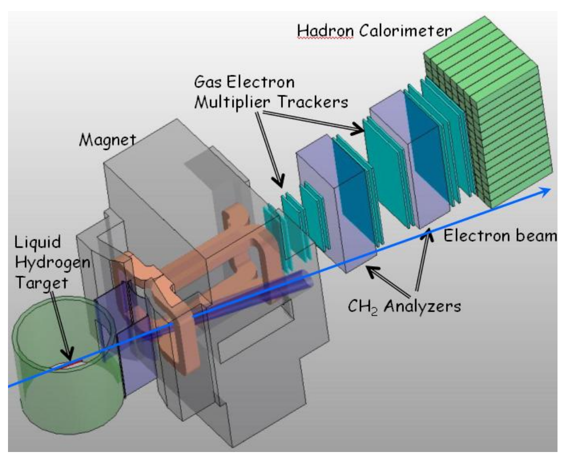

Figure 1. 3D view of the SBS spectrometer under development at JLab Hall A. The primary (front) GEM tracker station is made of 6 large area (40 × 150 cm^2) high resolution (∼70 μm) GEM chambers.

reinforced by combination with two small (10×20 mm^2) planes of silicon μstrips placed in proximity of the target. The other stations are meant to track particles after the two polarimeters and will require less accuracy. The primary tracker is under the responsibility of INFN groups.

GEM technology [3] has been chosen to optimize cost/performance, position resolution and meet the high rate (>1 MHz/cm^2). The chambers are based on a triple GEM module (Fig. 2) with active area 40×50 cm^2, the largest up-to-date standard double mask GEM foil technology limit. The 8 mm wide mechanical frame incorporates high voltage feeding protection resistors and gas inlet/outlet holes. The signals from each triple GEM module are read out in two coordinates through COMPASS-like [4] strip conductors planes.

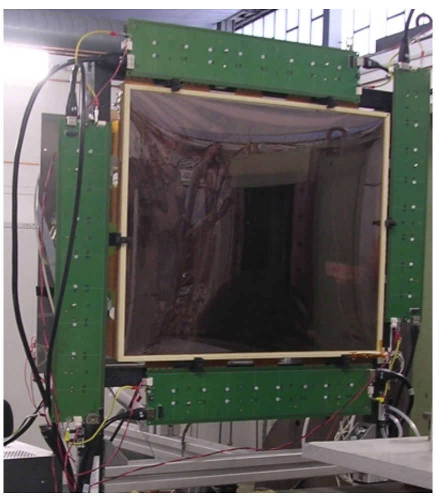

Figure 2. Fully equipped 40×50 cm^2 GEM module prototype setup under test with 2-6 GeV/c electron beam of Dec. 2010 at DESY. GEM chambers, front-end and readout electronics are developed within the JLab12 collaboration, funded through the INFN CSN3.

The front-end electronics [5] (FE) for the ∼100K channels of the tracker is based on the APV25 [6] chip, successfully used in the LHC experiment CMS. The APV25 is a serial output analog ASIC running at 40 MHz. The FE cards, each with 128 channels, are placed around the GEM module. Custom backplanes are used to distribute power and control to the FE cards and to collect the analog outputs.

The readout electronics [5], developed in the VME/VXS standard adopted by the JLab DAQ Group, is based on Altera ARRIA GX FPGA and has on board 16 12-bit digitizers running at 40 MHz, followed by digital frame analyzers used to decode the APV25 serial protocol. With this combination, each board supports the readout of 4096 channels (strips) plus all the control signals (APV25 clock and fast commands). The board has also several different communication ports (USB, Ethernet, optical link), so that it can be used without VME. In addition, the same electronics will also be adopted for the luminosity monitor of the Olympus experiment (http://web.mit.edu/olympus) at DESY.

A test plan aimed at developing a full scale prototype of a GEM chamber for the JLab Hall A SBS has been started. A first small scale (10 × 10 cm^2) triple GEM module was built in 2009, in order to gain confidence with the technology and operation. It was then tested with an electron beam, equipped with existing general purpose front end (FE) and readout (RO) electronics (end of 2009). Afterwards, having understood the signal features and manipulation, the same chamber was successfully tested (July 2010) with prototype FE boards read out by general purpose ADCs. In the meantime the first large scale (40 × 50 cm^2) prototype GEMs were produced at CERN [7], and assembled into a module. FE was finalized with back-end distribution/collection boards, and the readout VME/VXS ADC boards were produced in final version. All this put together as a first full scale prototype fully equipped (Fig. 2) was finally tested in November-December 2010.

All the tests were performed at the test beam DESY facilities in Hamburg, with 2-6 GeV/c electron/positron beams, with the support of the EUDET Program (http://www.eudet.org). Data analysis is in the making, as of today.

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