TEST OF THE GEM FRONT TRACKER FOR THE SBS SPECTROMETER AT JEFFERSON LAB

by

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A new Large-Acceptance Forward Angle Spectrometer (Super BigBite) is under development at JLab/Hall A to optimally exploit the exciting opportunities offered by the 12 GeV upgrade of the electron beam. The tracking of this new apparatus is based on the gas electron multiplier technology, which has been chosen to optimize cost/performance, position resolution and meet the high hits rate (>1 MHz/cm^2).
The first gas electron multiplier detector prototypes were designed, built and tested at the DESY test beam facility in Hamburg, by using an electron beam with energy from 2.0 to 6.0 GeV. In particular, two gas electron multiplier chambers (10 10 cm^2 and 40 50 cm^2, respectively) were equipped with a new implementation of the APV25 readout chip. Measurements were performed at different impact points and angles between the electron beam and the plane of the gas electron multiplier chambers.
In this report we present the technical characteristics of the detector and comment on the presently achieved performance.

Key words: gas electron multiplier detector, SBS tracker, electron spectrometry

INTRODUCTION

The Jefferson laboratory (JLab) [1] is one of the most important experimental facilities providing a multi GeV, high intensity, longitudinally polarized, electron beam. The laboratory is undergoing a major upgrade of its CEBAF electron beam and experimental halls. In late 2013, CEBAF will deliver electron with energy up 12 GeV (twice the present limit) with excellent intensity (up to 100 μA) and longitudinal polarization (up to 85%). In order to take advantage of the new scenario, the equipments of 3 existing experimental Halls are under upgrading to optimally exploit the opportunities of the new beam. In particular, members of Hall A collaboration are developing a new reconfigurable spectrometer, the Super BigBite (SBS [2], fig. 1), featuring very forward angle (down to 7 degree), large momentum (2-10 GeV/c) and angular (64 mrad) acceptance, high rate

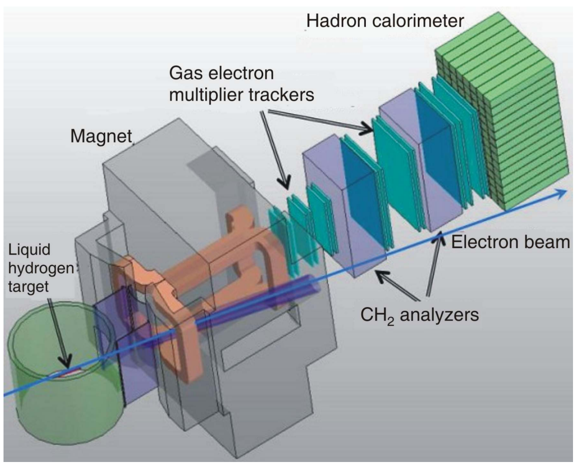

Figure 1. Schematic layout of the SBS spectrometer

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capability (1 MHz/cm^2) and very high luminosity environment (up to 1039/(scm^2)). The new spectrometer will consist, in its full configuration, of a dipole magnet with field integral up to 3 Tm (it will operate at about 2 Tm), a primary charged particle tracker (first tracker), 2 identical proton polarimeters (made of a carbon analyzer and large tracker), and an hadron calorimeter. SBS will initially serve 4 experiments [3] dedicated to the study of the nucleon structure in terms of elastic electromagnetic form factors at high 4-momentum transfer Q^2 up to 15 GeV2 and of transverse momentum distributions of the quarks in the semi inclusive deep inelastic scattering (SIDIS) region. The tracking systems of SBS will be mainly based on the gas electron multiplier (GEM) chambers. In the next section the main features of the SBS tracker and of the GEM detector will be presented and finally the preliminary results of the test performed at DESY will be discussed.

SBS TRACKER AND GEM DETECTOR

The SBS tracking system is made of three stations. The primary (front) tracker, placed just after the dipole momentum analyzing magnet, will consist of six large area (40 cm 150 cm) and high resolution (~70 μm) GEM chambers, for a total tracker length of about 50 cm. Each chamber is made by 3 adjacent GEM modules of 40 cm 50 cm active rectangular area, for a total of 18 modules. 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 reinforced by combination with two small (10 mm 20 mm) planes of silicon μstrips placed in proximity of the target. The other stations are meant to track particles after a polarization analyzer wall and will require less accuracy. The primary tracker is under the responsibility of INFN groups.

GEM technology [4] has been chosen to optimize cost/performance, position resolution and meet the high rate (>1 MHz/cm^2) [5]. The single module is made of 3 GEM foils and double layer x/y strips readout with 400 μm strip pitch. 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 [6] strip conductors planes.

The front-end electronics [7] (FE) for the ~100 K channels of the tracker is based on the APV25 [8] chip, successfully used in the LHC experiment CMS. The APV25 is a serial output analogue 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 analogue outputs.

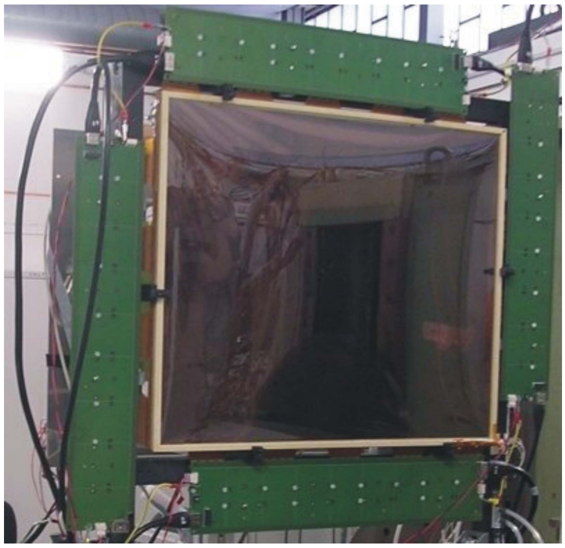

Figure 2. Fully equipped GEM module

In fig. 2 a fully equipped 40 cm 50 cm GEM module prototype set-up under test at DESY is shown. The module is equipped with the APV25 electronics and 18 front-end cards are located behind the 4 rectangular backplanes that sit along the 4 sides of the module. During the test, a gas mixture of Ar (70%) and CO_2 (30%) has been used and HV has been powered by the first version of the HV-GEM system [9] providing seven independent HV levels. Moreover, precise tracking has been performed by small silicon strip detectors located before the GEM.

The test has been performed in the T22 DESY Test electron/positron beam area [10]. The test beam is originated from the lepton synchrotron DESY II by converted bremsstrahlung on carbon fiber target. The energy of the beam varies between about 1 and 6 GeV/c with typical intensity of 1000 particle/(scm^2) (divergence is about 2 mrad).

DATA ANALYSIS AND DISCUSSION

In this section we present preliminary results of data analysis performed on about 60 beam runs obtained by using two GEM chamber prototypes (10 cm 10 cm and 40 cm 50 cm, respectively). Both chambers were readout by the APV electronics which were under development at the same time. During the test, different configuration have been used: energy of the electron beam (from 2.0 to 6.0 GeV), HV settings, angle between the beam and the plane of the chamber and position of the chamber with respect to the beam. Moreover, in order to have pedestals, without beam runs were acquired.

RMS mean values for each front-end card obtained by using the 40 cm 50 cm GEM chamber and by using both chambers for different pedestal runs were estimated. In both cases (single or double GEM

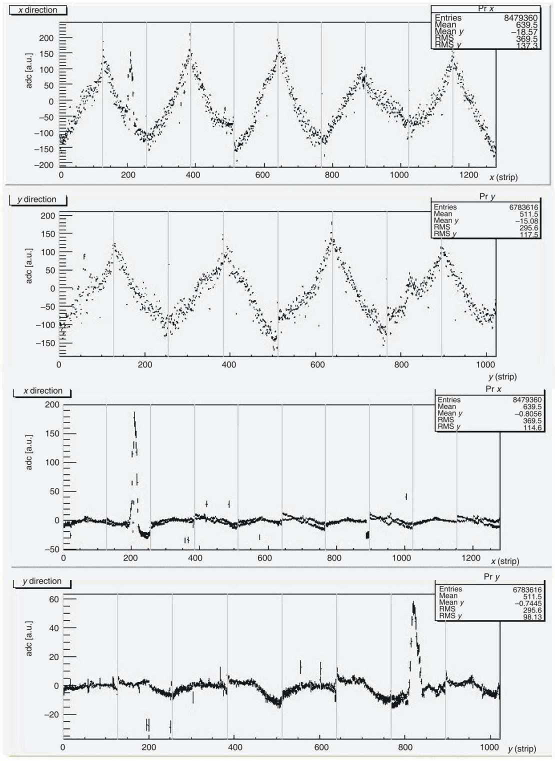

Figure 3. Spectrum without (top panels) and with (bottom panels) pedestal subtraction, both in the x- and y-directions

chamber), the values of a single front-end card RMS are very similar in different runs.

Standard analysis process includes: hot channels masking, common noise suppression and pedestal subtraction. In fig. 3 a spectrum of ADC signal vs. number of strips before (top panels) and after (bottom panels) the pedestal suppression, obtained by using a single GEM chamber (40 cm   50 cm), is shown. In the x-direction, the signal is present after the strip 200 and, in the y-direction, after the strip 800; each strip has a size of 0.4 mm.

In order to select the single events of a run, each axis is divided in two regions: empty region (where signal is not expected) and beam region of about 2 cm (where the beam is expected to pass) where the charge maximum, max_B, and its position, $pos(max_B)$, are searched (fig. 4). Moreover, peak region is defined as $pos(max_B)$ 10 bins and the baseline as the mean charge m_B calculated in the beam region excluding the peak region. The level of noise is represented by the root mean square of the strip charge RMS_E evaluated in the empty region. Events have been classified as "good" if $(max_B - m_B) / RMS_E > 2$, all the remaining are "noisy events".

Centroid evaluation has been performed for both x- and y-directions (fig. 5-top and 5-bottom), and a value of about 4-6 mm (similar to the nominal value of the spot size) has been measured.

The classification criteria provide a reasonable profile of the beam, reported in fig. 6-top. In fig. 6-bot-

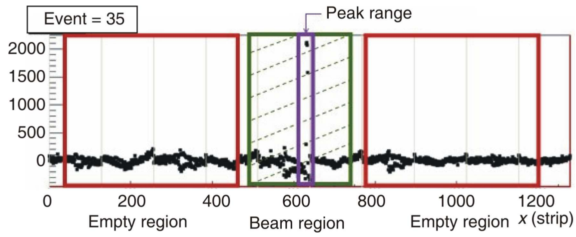

Figure 4. Typical "good" event recorded (x-direction). empty, beam, and peak regions are pointed out

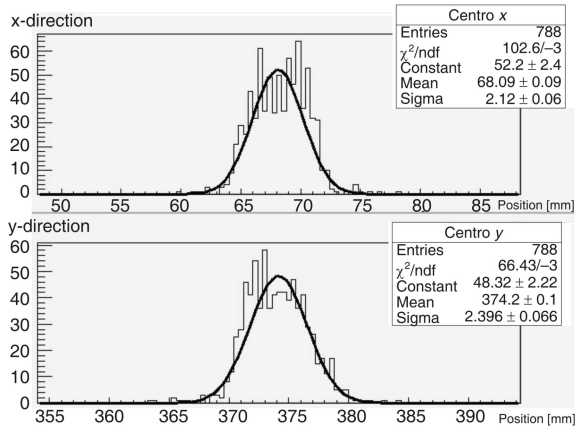

Figure 5. Centroid evaluation for both x- and y-directions (top and bottom panel, respectively)

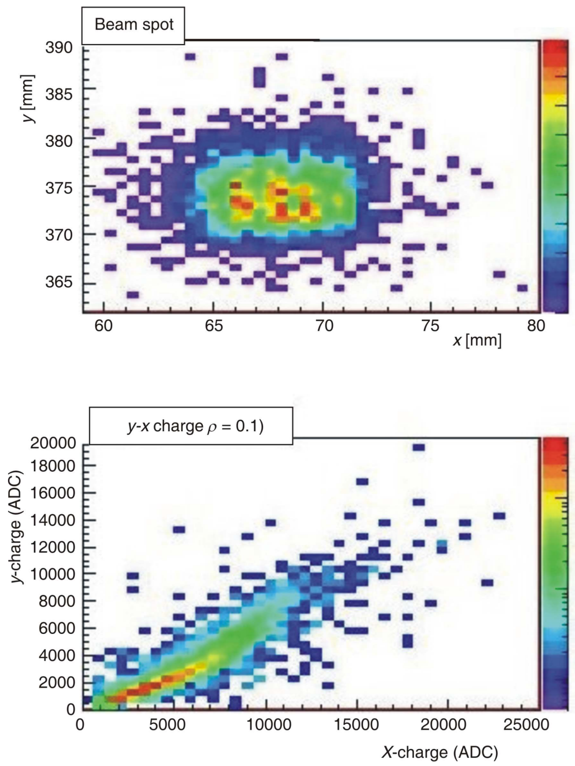

Figure 6. Beam profile (top panel) and charge correlation (bottom panel) where ρ is the correlation factor

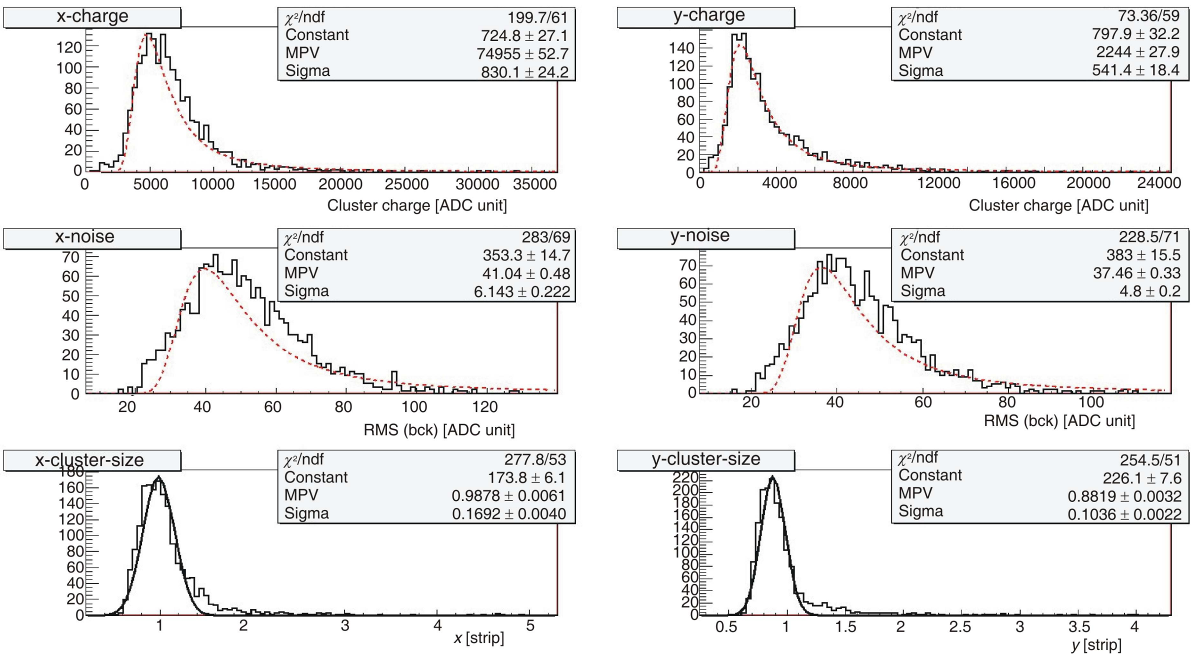

Figure 7. Cluster charge (top panels), noise (middle panels), and cluster size (bottom panels) for both x- and y-directions. Dashed lines represent the fit of Landau distributions (top and middle panels) and solid lines represent the fit of Gaussian distributions (bottom panels)

tom, the total charge collected in the y- *vs*. x-direction is plotted and a value of about 90% for the correlation coefficient has been found.

Adjacent firing strips are grouped in clusters and the *x* and *y* charges are estimated (fig. 7 top panels); both signal and noise distributions (fig. 7 top panels and fig. 7 middle panels, respectively) are reported. Finally, in fig. 7 bottom panels, cluster size is also reported. Distributions are consistent with the data from COMPASS GEM characterization [11].

CONCLUSIONS

The main purpose of the test was to verify the overall functionality of the main solution adopted in the first GEM prototype under simplified beam conditions. Both GEM hardware and readout electronics were under early development and therefore final results on efficiency and chamber resolution were not very indicative due to the relevant cuts used to select good events (to take into account mainly bugs in the electronics). In particular, the "noisy events" were affected by random misalignment of the raw acquired data due to problems in the electronics firmware, which have been lately fixed. This misalignment causes a wrong compensation of the pedestal, ending up with different types of periodic patterns which shuffle the signal. In spite of these problems, the GEM chambers operated fairly stably during the test and the preliminary results show reasonable indications of the general validity of the adopted solutions for the distribution of the collected charge, the spatial and charge correlation between strips, and the signal to noise ratio. The data analysis also pointed out some critical aspects to be further investigated. A new test in high intensity gamma and electron background has been carried on at Mainzer Mikrotron (MAMI), showing excellent on-line data without relevant noisy events; analysis is in progress.

AUTHOR CONTRIBUTION

Theoretical analysis was carried out by E. Cisbani, F. Mammoliti, and G. Ruscica. The manuscript was written by F. Mammoliti and E. Cisbani, the figures were prepared by F. Mammoliti and E. Cisbani. Experiments was carried out by E. Cisbani, V. Bellini, M. Capogni, F. Mammoliti, P. Musico, F. Noto, R. Perrino, and C. M. Sutera.

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ТЕСТ ТРАГАЧА ГАС-ЕЛЕКТРОНСКОГ МУЛТИПЛИКАТОРА ЗА SBB СПЕКТРОМЕТАР У ЏЕФЕРСОНОВОЈ ЛАБОРАТОРИЈИ

У току је развој новог унапред оријентисаног широкоугаоног спектрометра у Џеферсоновој лабораторији за оптимално искоришћење нових могућности које доносе повећање енергије снопа на 12 GeV. Праћење трагова у новој апаратури заснива се на технологији гасне мултипликације електрона, која је одабрана да оптимизује однос цене и својстава, резолуције и велике брзине удара (>1 MHz/cm^2).

Први прототипови детектора са гасном мултипликацијом електрона дизајнирани су, направљени и тестирани у постројењу за тестирање снопова DESY у Хамбургу, користећи електронски сноп са енергијама од 2.0 до 6.0 GeV. Две коморе за гасну мултипликацију електрона (димензија 10 cm 10 cm и 50 cm × 50 cm) опремљени су новом верзијом APV25 чипа за очитавање. Мерења су спроведена за различите тачке удара и различите углове између снопа и равни комора за гасну мултипликацију електрона.

У овом раду представљамо техничке карактеристике детектора и коментаре о досадашњим перформансама.

Кључне речи: детектор са гасном мултипликацијом електрона, SBS трагач