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INTRODUCTION

The impurity concentration, the ion temperature, and the toroidal rotation velocity are key parameters which have to be monitored at a high level of accuracy for all the operating phases and for different operating scenarios of the ITER-oriented JET research programme. Therefore, a high resolution KX1 Bragg spectrometer [1] operated in so-called Johann geometry will be equipped with new detectors. Both, Ni (7.8 keV) and W (2.4 keV) characteristic X-ray lines will be measured by a new generation energy-resolved micropattern gas detectors [2-6] providing 1-D position reconstruction capability. Here we would like to address main characteristics and the first laboratory tests of the prototype Triple Gas Electron Multiplier (T-GEM) detectors designed for the KX1 diagnostic at JET.

1. DETECTORS STRUCTURE

The T-GEM prototype detectors with an active window area of $100\times100mm^2$ (final KX1 detectors will have ~$200\times100mm^2$ detection area) consist of three GEM foils in cascade (Fig.1). Each of the foils is etched with a high density of holes and is metal coated on both sides. Such a structure of the foils under high voltage assures high multiplication of the charge [4, 5, 6] produced as a result of the interaction of photons (entering the detector) with a working gas. The T-GEM gas amplification structure is directly coupled to the gas gap, where X-ray conversion liberates a primary ionization charge. Electric charges amplified in the avalanche process is collected by the strip readout electrode closing the gas volume. In this geometry the strip electrode can be kept at ground potential. The high voltage of negative polarity increases gradually reaching the maximal value of the potential applied to the window. Thus, seven individual channels of high voltage should be employed. The charge gain (collected charge) is controlled by the voltages across individual GEM electrodes and electric field in gas gaps. Each detector consists of the strip readout plane with 0.8mm pitch (128 strips in each detector).

It has been calculated, that the conversion gap of 15mm thickness closed by a 12μm mylar window with a thin aluminum layer (~0.2μm) on the inner surface and filled with an $ArCO_2$ (70:30) mixture at atmospheric pressure should provide 35% detection efficiency for photons emitted by W^{46+} at 2.4keV monitored in the first reflection order by KX1 diagnostic. Efficiencies in the second and third reflection order are expected to be 55% and 25%, respectively.

2. EXPERIMENTAL SETUP FOR LABORATORY TESTS

First experimental results have been obtained with the prototype detector irradiated by the ^{55}Fe source of 5.9keV X-rays. The detector has been filled with an Ar 87% : CO_2 13% gas mixture operated in the gas-flow mode at a gas flow rate of ~30 ml/min. The gas mixture has been deliberately chosen with a low quenching agent content to verify detector operation in unfavorable conditions from the point of view of charge amplification stability. An electric current induced on the individual strips has been amplified by fast current feedback amplifiers (AFE board). The signals from the AFE board of 8 channels have been measured by two sysnchronized oscilloscopes with sampling frequency

of 2.5GHz. Digital data from the scopes have been read out and stored using a PC controlled by the Matlab application.
Single photon induced strip current have been recorded during 400ns time window related to the trigger. The induced strip charge has been estimated as the integral of the current within a time window of 200ns inside of the time window related to the trigger.

A typical anode current signal distribution corresponding to a single X-ray avalanche recorded with 8 bit resolution for eight channels and the corresponding integrated charge are presented in Fig.2. An offset correction for each channel and the noise level estimation were based on the current integration outside the detection time window.

Charges exceeding the noise level and induced on adjacent strips form a cluster corresponding to the single photon impact. Total cluster charge is related to the photon energy deposited in gas. The cluster charge distribution in the strip plane allows the reconstruction of one coordinate of the conversion point.

3. RESULTS OF LABORATORY TESTS

Typical distributions of detected cluster charges for 25000 events are presented in Fig.3. The energy spectrum shows a double-peak spectrum with an 55Fe peak at 5.9keV and argon escape peak at 2.9keV. The energy resolution of 20% at FWHM assures clear separation of the two peaks. This demonstrates the energy measurement capability of the detectors. The most probable spread of a charge cluster has been found to be three and four strips for 2.9keV, and 5.9keV energy deposited, respectively (Fig.4). This allows, in both cases, determination of the effective position by the center of gravity method. Cluster size sampled by 0.8 mm wide strips provides position resolution better than the strip pitch.

As expected high dependence of the charge gain on the total GEM voltage has been observed and a smaller but substantial dependence on transfer and drift voltages has been encountered.

In order to verify the operational stability of the detectors, a medium-term test has been performed for more than 100 hours. The charge gain and the energy resolution for the 5.9 keV line were monitored. The detection energy resolution remained stable but the relative charge gain exhibited strong dependence on the atmospheric pressure (Fig.5).

CONCLUSIONS

Two prototype detectors of 100×100mm^2 active window area, sensitive to characteristic X-ray lines at 2.4keV (W^{46+}) and 7.8keV (Ni^{26+}) have been constructed. We have performed preliminary verification and optimization of the detector working parameters to achieve significant charge gain with the sufficient energy resolution and required cluster size. A single cluster size measured on the strip electrode is of the order of 3-4 strips, which allows position estimation (using a center-of-gravity algorithm) well better than the strip pitch. The energy resolution measured on the group of strips is about 20% (FWHM). It should provide separation of the first two orders (~2.4 keV and ~4.8keV, respectively) for soft Xrays measured by KX1 diagnostics system.

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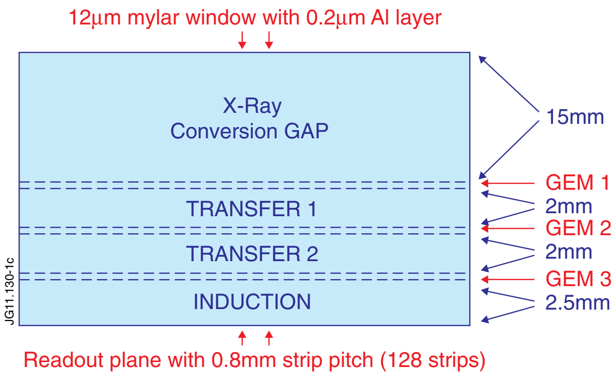

Figure 1: The detector structure.

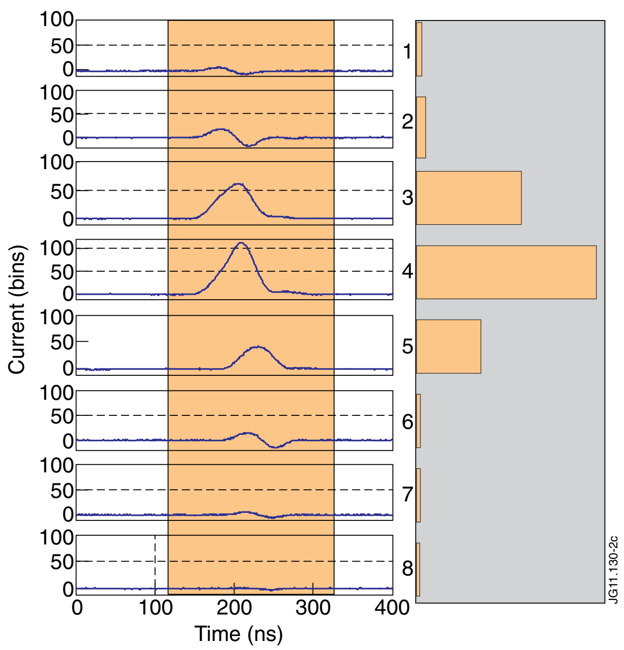

Figure 2: The anode current signals for 8 strips (left) and corresponding relative charges (without offset compensation) (right) calculated within time of 200ns.

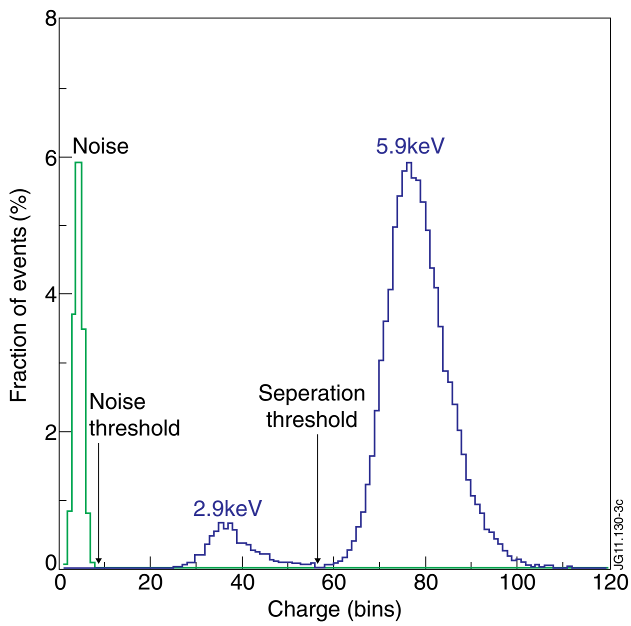

Figure 3: Collected charge distribution.

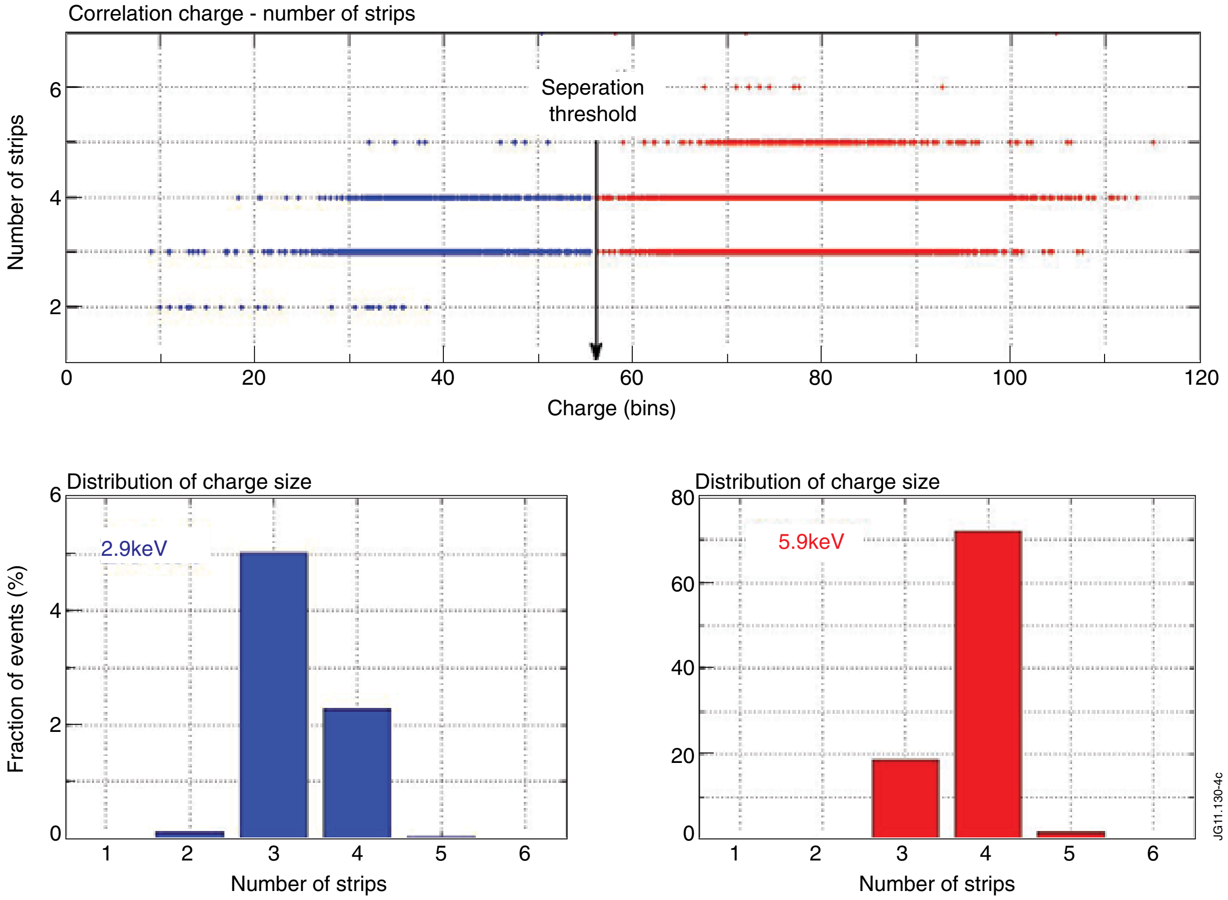

Figure 4: Correlation between cluster charge and its size measured in strip multiplicity (top). Distribution of cluster size for charges related to 2.9keV (bottom-left) and charges related to 5.9keV (bottom-right).

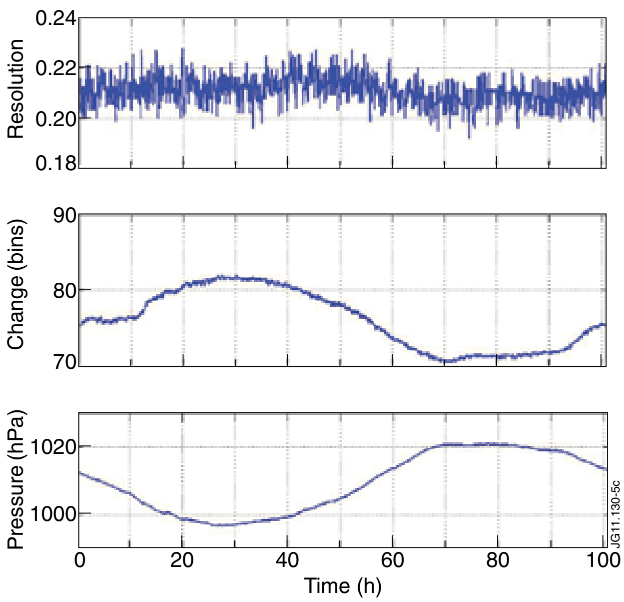

Figure 5: Medium-term measurement of the detector characteristics: resolution and gain along with atmospheric pressure versus time.