Fundamental data processing for GEM detector measurement system applied for X-ray diagnostics of fusion plasmas

T. Czarski[1], M.Chernyshova[1], W.Dominik[2], K. Jakubowska[1], G.Kasprowicz[3], K. Pozniak[3], J. Rzadkiewicz[1], M.Scholz[4], W. Zabolotny[3]

[1] *Institute of Plasma Physics and Laser Microfusion, Warsaw, Poland*

[2] *Warsaw University, Warsaw, Poland*

[3] *Warsaw University of Technology, Warsaw, Poland*

[3] *Institute of Nuclear Physics PAN, Cracow, Poland*

INTRODUCTION

The Triple Gas Electron Multiplier (T-GEM) is considered as soft X-ray (SXR) energy and 1D position sensitive detector for high-resolution X-ray diagnostics of magnetic confinement fusion plasmas. The paper describes the GEM detector based multi-channel measurement system and essential data processing necessary for X-ray energy and position recognition.

TRIPPLE-GAS ELECTRON MULTIPLIER (T-GEM)

The X-ray T-GEM detectors [1, 2, 3] are based on collection of electrons created by direct ionization within the gas through application of a large electric field that initiates an electron avalanche. The multiplied space charge, which is injected to the final segment of the detector, so-called induction gap, and collected on the multi-strip plane, generates current anode signals detected by electronics. The structure of the detector is presented in Fig. 1.

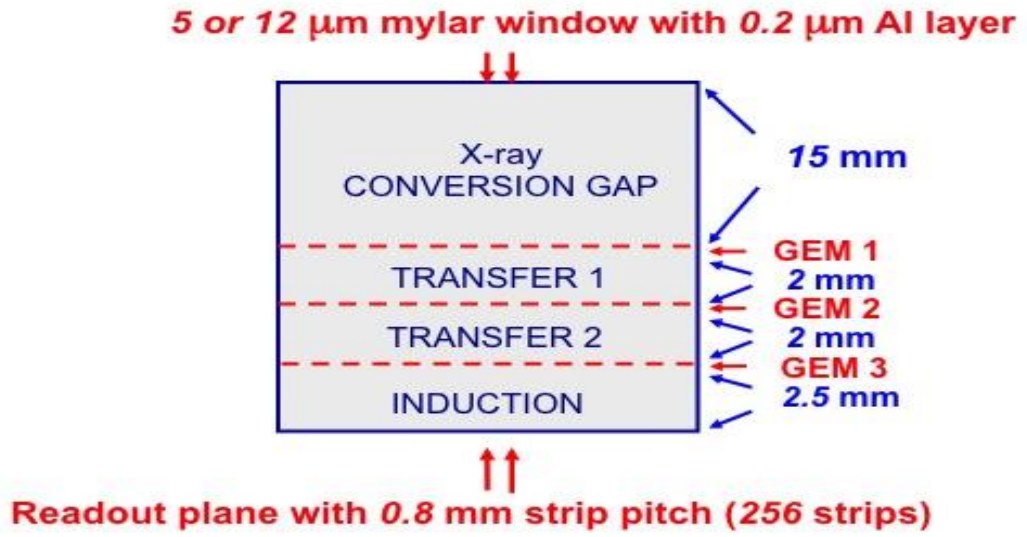

Fig. 1 Structure of the T-GEM

MULTI CHANNEL MEASUREMENT SYSTEM

Pulse signals from each detector strip are shaped by 15 Mhz filter and amplified by analogue front end boards - AFE. Analog signal is sampled with 77.7 MHz frequency and converted to the 10 bit resolution by ADC converter. After the analogue to digital conversion data are sent to the memory block of Digital Processing Unit. FPGA based system performs the basic functions of data processing: the identification of charge clusters and the distributions of cluster charge and position for the current series of events. Selected data series are transferred to a PC in order detailed analysis and visualization of results. The system provides monitoring of the actual event rate by an additional reading from the FPGA. The system is equipped with weather station to monitor temperature, humidity and ambient atmospheric pressure gas detector. MATLAB software package is a universal interface providing user control, communication, data processing functions, and imaging results. This allows to studying properties of the detector and the measuring system diagnostics.

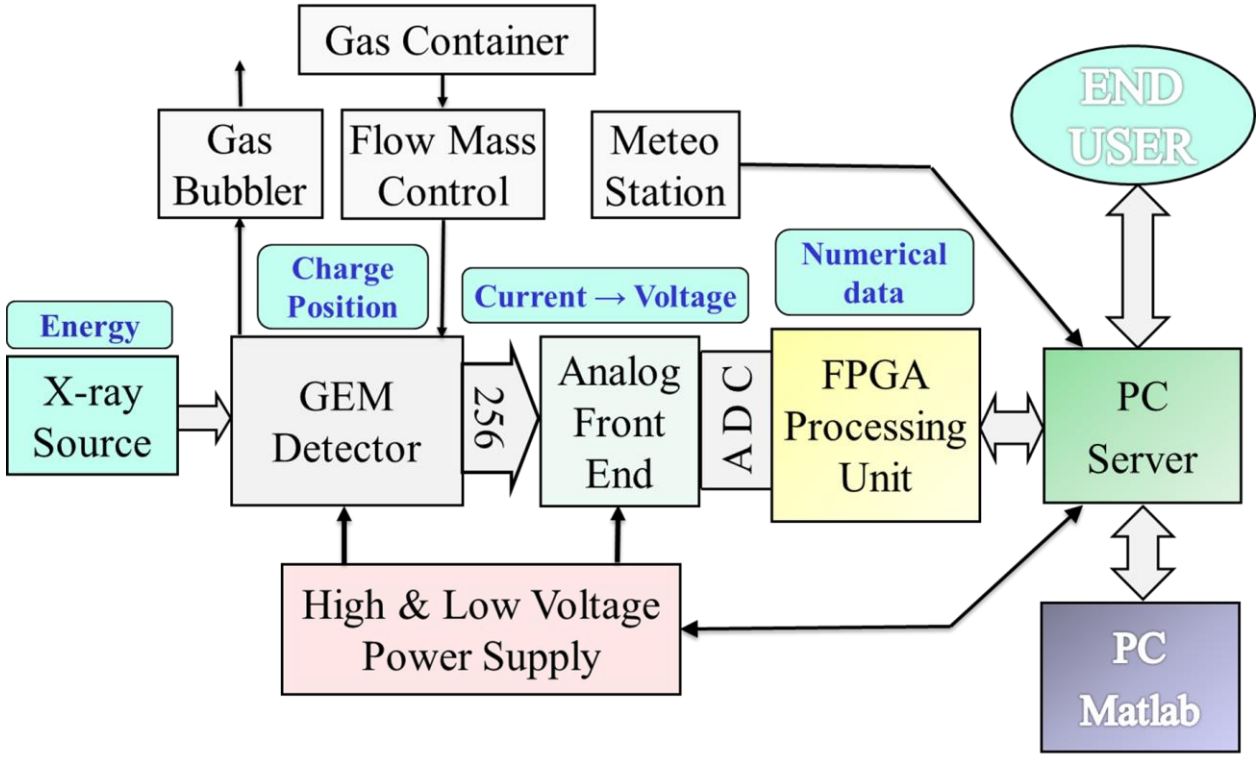

Fig 2. Multichannel measurement system detector.

MODES OF DATA ACQUISITION

The measurement procedures for different processing level FPGA based firmware have been developed as different type of data acquisition DAQ for Matlab system. Signal DAQ – ADC data forms data table of 256 channels x 40 samples x N events. Charge DAQ – FPGA firmware calculates strip charges (Fig.3) and forms data table of 256 channels x N events. Histogram – DAQ – FPGA creates histograms for each strip during given time and forms data table 256 charges value x 256 channels x N measurements. Measurement interval time can be set from 10 ms.

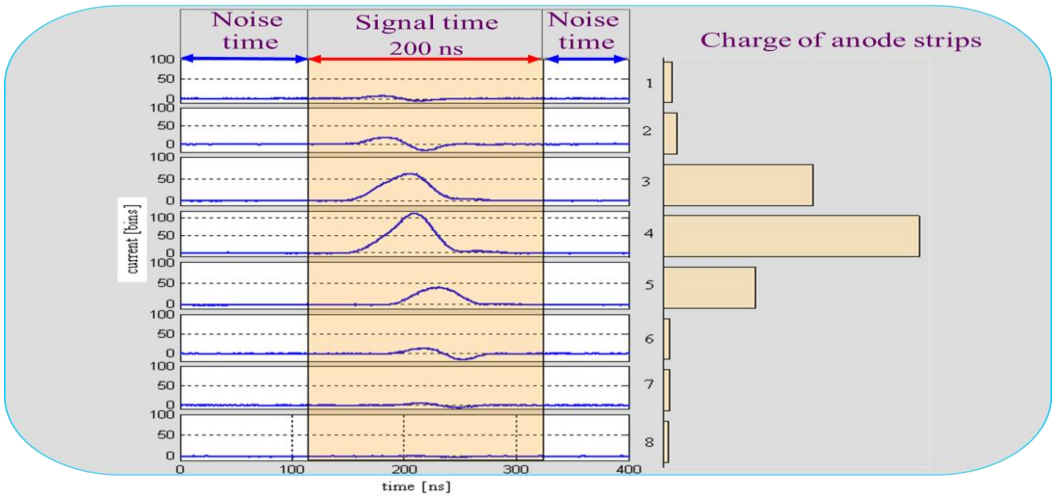

Fig 3. Signal to charge conversion.

CALIBRATION AND AUTO-SCALING

Linear calibration and auto scaling procedures have been developed to correct no uniformities and variation of channel gains for Fe55 as a reference source. The individual channels characteristics for charge value distribution are considered for its parameters assessment and calibration. For regular charge distribution parameter value for each strip is adjusted to the mean value for all strips. The mean of the strip charge (Fig. 4) is considered for calibration purpose. The most probable value of charge called gain corresponding to the energy ~5.95 keV is the reference value for the scaling procedure.

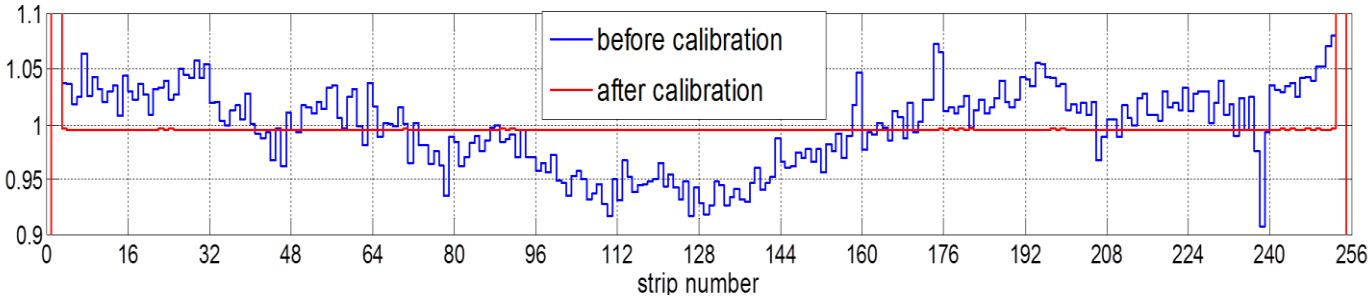

Fig 4. Normalized mean charge for 256 strips.

CLUSTER CHARGE VALUE AND POSITION DISTRIBUTION

The current signal generated by the detector carries all information required for the energy estimation and position reconstruction for X-rays. Cluster charge value distribution corresponds directly to the energy spectral line of X-ray source. Cluster charge position distribution corresponds to the energy for Bragg diffraction spectroscopy. Only regular charge clusters are considered for final histograms charge value and position distribution. The basic parameters of the histogram are estimated for Fe^{55} reference source: relative resolution, gain, linearity. The Gauss fitting is performed for cluster charge distribution for reference Fe source. Approximation by polynomial splines for multi-line spectrum is implemented to identify lines for energy and position histograms (Fig.5)..

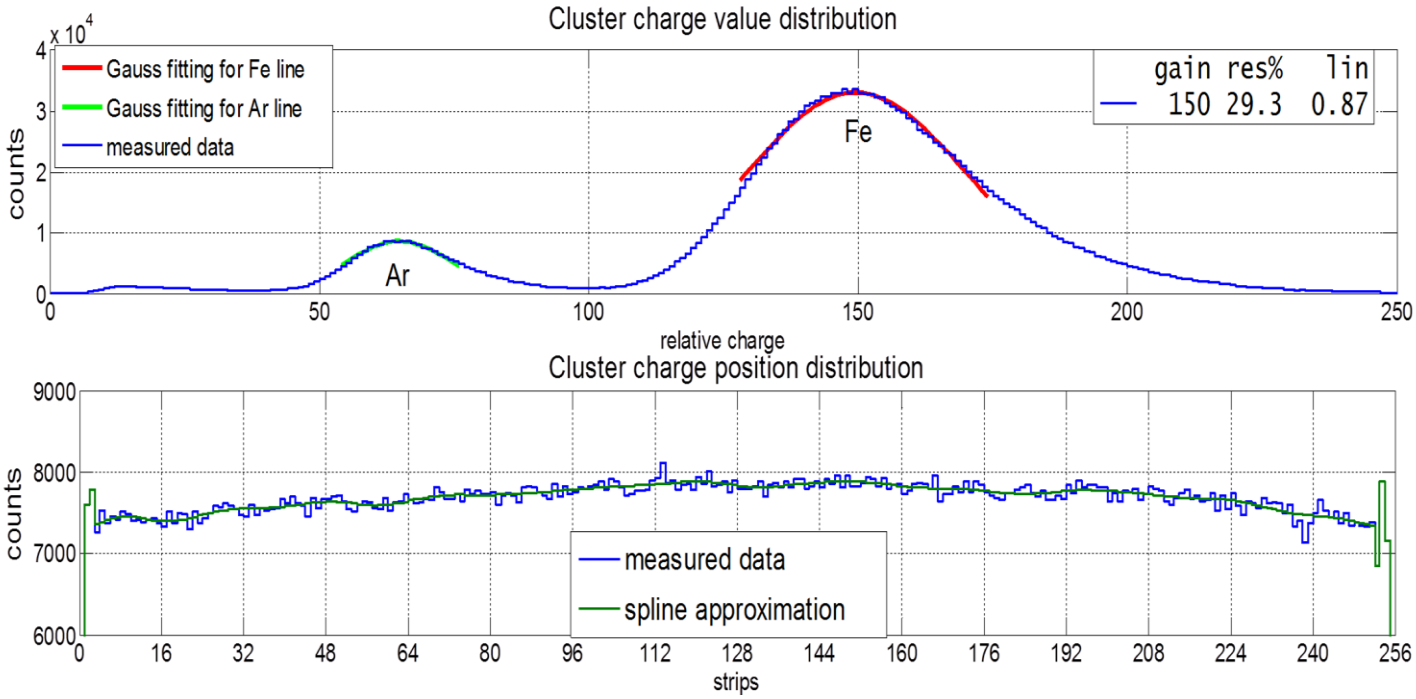

Fig 5. Histograms for charge value and position distribution

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