A Detector of Electromagnetic Showers on the basis of Plastic Streamer Tubes

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Abstract

A study of an one-layer sampling detector for EM showers registration on the basis of plastic streamer tubes is presented. Its performance inside an electromagnetic calorimeter is discussed.

1 Introduction

The STAR experiment[1] at RHIC at BNL is going to use an electromagnetic calorimeter (EMC) with granularity $\Delta\eta \times \Delta\phi = 0.05 \times 0.1$ covering the region $|\eta| \leq 1$. The additional detector inside this EM calorimeter is needed for better coordinate resolution and multi-shower separation. The characteristics of such detectors based on proportional tubes, scintillators, ionization tubes, semiconductive counters were studied by various groups (see, for example[3, 4, 5, 6, 7]). In March, 1994, we studied the performance of a plastic streamer tube (PST) using the 26.6 GeV electron beam. The streamer tubes as a presampler were tested earlier[8].

A very high saturated amplitude response of such a sampling counter for each particle in a shower improves the resolution due to the absence of Landau fluctuations. Streamer tubes with graphited walls and external pick up electrodes have another attractive features: large signals generated in the streamer process lead to a noiseless operation and simple electronics; a thick wire simplifies the detector construction. PSTs are widely used in large-scale experiments[9, 10, 11, 12, 13].

2 Experimental Setup

The measurements were carried out at IHEP with the 26.6 GeV electron beam[14]. The beam momentum spread was $\Delta p/p = 2\%$. The nominal intensity was $2 \div 3 \times 10^3 sec^{-1}$. Signals from scintillation counters S1-S4, A0 formed the trigger. The anti-coincidence counter at 2.5 m upstream from the detector had a $5 \times 10 mm^2$ hole and defined the beam spot on the detector.

The experimental setup consisted of the absorber (6 mm Pb + 4.5 mm scintillator layers) of variable thickness, the Iarocci-type[9] streamer tube, analogous to that used in DELPHI[10], and a total absorption electromagnetic calorimeter[15] 15×15 cm^2 in cross-section and 20 radiational lengths (r.l.) in depth. The tube had 8 cells of 9×9 mm^2 in size. Its length was 1 m. The anode wire diameter was $80 \mu m$, the cathode resistivity $\sim 100 k\Omega/\square$.

The read-out was done with pick-up electrodes. Pulses from a pick-up electrode were transferred via 90 m long RG58 coaxial cable to a passive invertor (1:1 transformer on a ferrite ring) and then were digitized by 12-bit ADCs[16] (0.25 pC per channel sensitivity).

The gas mixture mostly used was $50\% Ar + 50\% iC_4H_{10}$ at normal pressure.

The operational H.V. selection for the PST was performed by the following procedure: the minimum ionizing pulse (mip) amplitude in the tube was studied as a function of the high voltage applied to the tube with the converter removed. As an example, Fig.1a shows some amplitude spectra for various values of applied voltage for the 53/47 mixture. A clear transition from the proportional to the streamer mode is seen. The H.V. was chosen so that 95% of events lie in a self-quenching mode region. The value of 3.45 kV was chosen for the tube operation for the 50/50 mixture. The pulse height distributions at this voltage are shown in Fig.1b. A pulse duration was ~ 100 ns.

The calorimeter information was used for an off-line event selection, in particular, for muon and hadron bakground rejection. The calorimeter pulse height spectra for various absorber thicknesses are shown in Fig.2. It is seen that muon and hadron contaminations in the beam were less than 4%.

3 Results

The tube response for mip vs the coordinate was measured. The response uniformity appeared to be not worse than 10%.

The **energy resolution** was measured using the read-out with a single $75 \times 90\ mm^2$ pad. The experimental procedure consisted in measuring the PST pulse height distributions with converters of various thickness. The distributions for the absorber thicknesses 9.7 and 10.6 r.l. are shown in Fig.3. The dependencies of the mean pulse height $\bar{A}$ and the resolution $\sigma_A/\bar{A}$ on the absorber thickness are shown in Fig.4. As it follows from Fig.4, the energy resolution has a wide minimum at 10 r.l. with the value of 22%. A possible systematic error does not exceed 1%. The systematic error was estimated by varying the event selection criteria.

The **estimate of the coordinate resolution** was performed with 8 strips orthogonal to the wires. The strips had the 1 cm spacing. The measurements were performed with the absorber thicknesses of 2.4, 3.5, 5.7 r.l. The detector center was positioned at the center of the beam, i.e. the beam passed beetwen the 4-th and 5-th strips. We take the center of gravity (CG) to get an estimate of the coordinate:

$$x_g = \sum_{i=1}^{8} x_i \times A_i / \sum_{i=1}^{8} A_i$$

We obtained and fitted the CG distributions. The best one for the absorber thickness of 5.7 r.l. is shown in Fig.5. The distribution is well fitted by Gaussian with the parameter $\sigma_x = 1.6\ mm$. The r.m.s. of the distributions at absorber thicknesses of 2.4, and 3.5 r.l. are 2.7 mm and 2.1 mm, respectively.

The **PST properties at high counting rates** were tested with the 7 r.l. absorber. The PST response at different beam intensities was measured. The PST pulse height distributions for beam intensity from $1 \times 10^2\ sec^{-1} \cdot cm^{-1}$ to $3.8 \times 10^3\ sec^{-1} \cdot cm^{-1}$ are shown in Fig.6. A visible degradation is observed at high rate. The dependencies of a mean pulse height $\bar{A}$ and the detector resolution on the electron beam intensity are shown in Fig.7. However, it is well known (see, for example, review[17]), that the gas mixture and pressure strongly affect rate properties. Some mixtures with high rate capabilities of at least one order of magnitude better are known.

Conclusions

These results have shown that plastic streamer tubes could be a promising detector for the STAR EMC. PSTs provide the energy and space resolution similar to that of scintillation hodoscopes[4], proportional[3] and ionization[6] tubes. PSTs also have a number of advantages comparing to other possible options mainly due to low cost and reliability. A more complete investigation of energy behaviour of the detector performance including multi-shower separation and e/π rejection is necessary.

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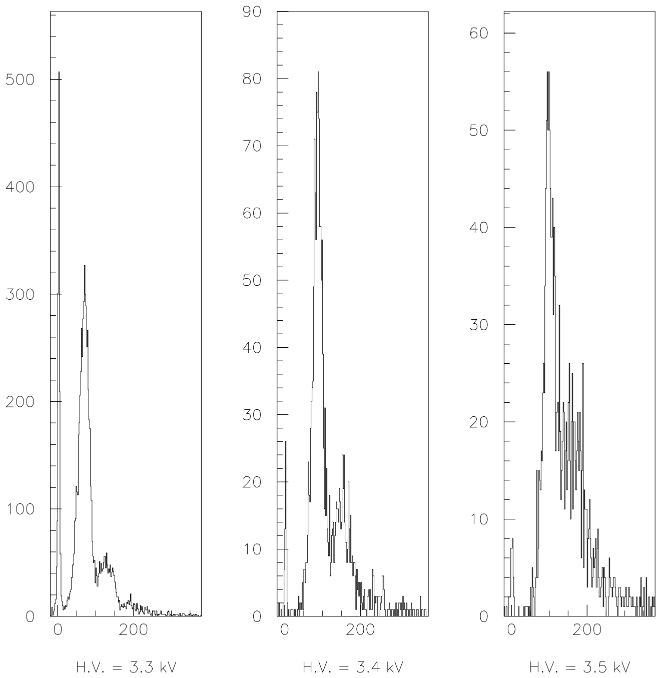
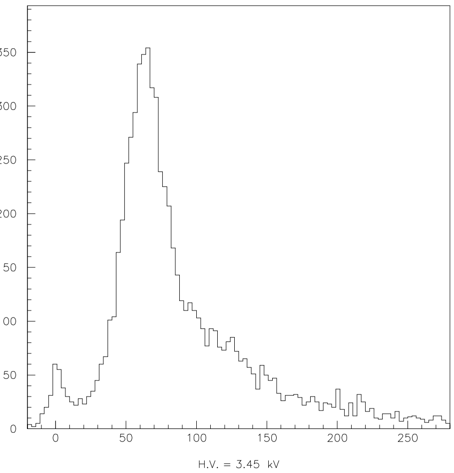


a) gas mixture $53\% Ar + 47\% iC_4H_{10}$



b) gas mixture $50\% Ar + 50\% iC_4H_{10}$

Fig. 1. PST amplitude spectra.

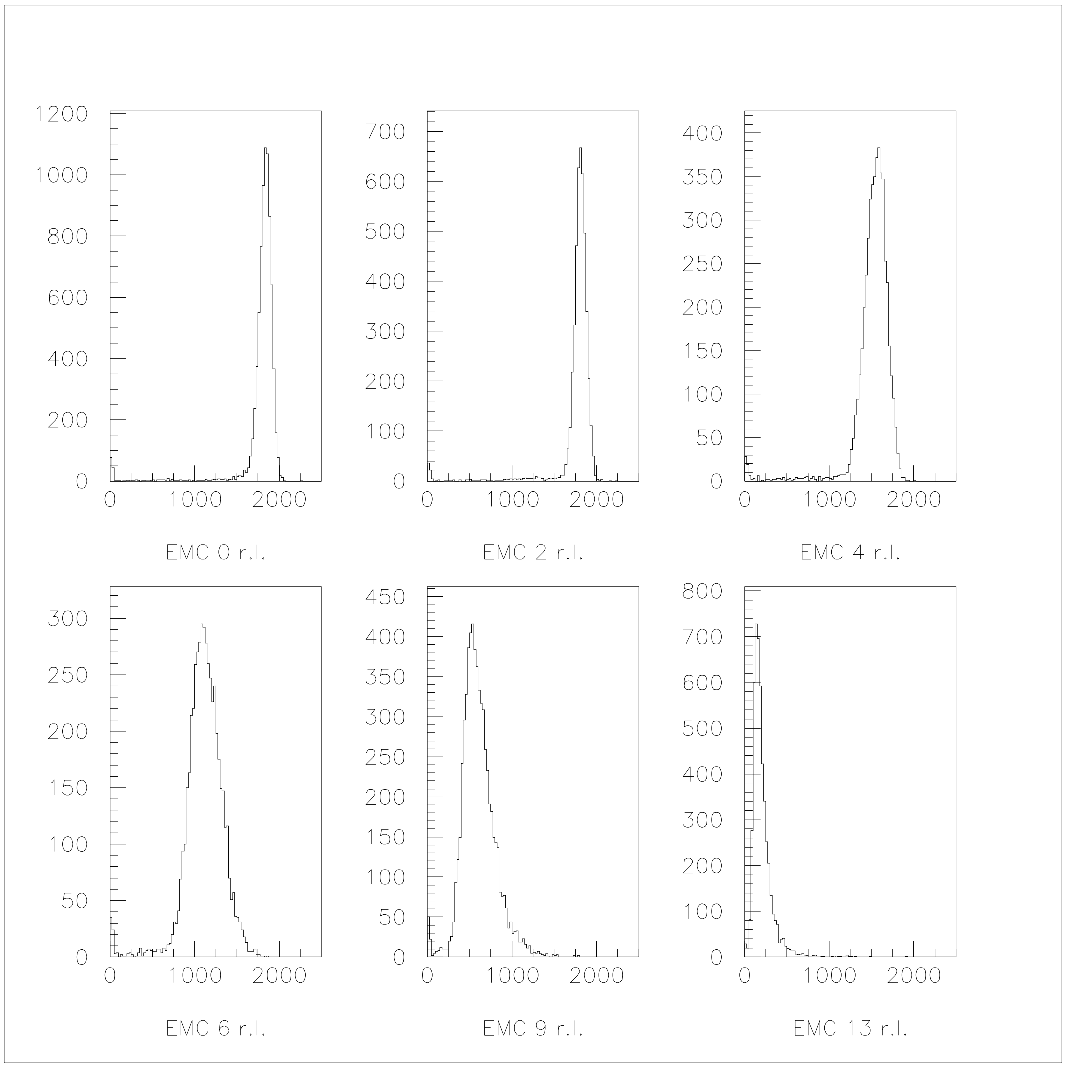


Fig. 2. The calorimeter pulse height distributions with the absorber thicknesses from 0. to 13.6 r.l.

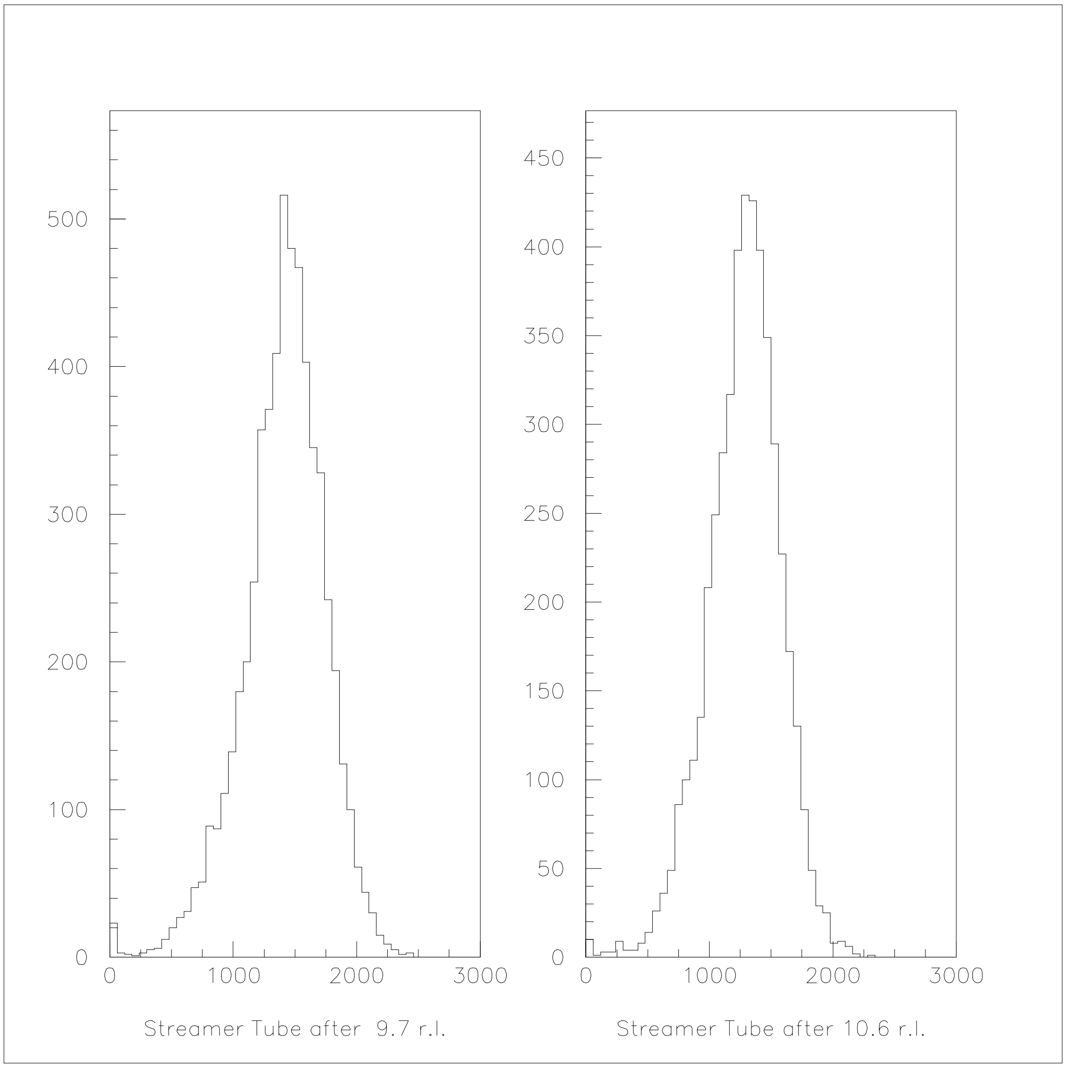


Fig. 3. The PST pulse height distributions for the absorber thicknesses 9.7 and 10.6 r.l.

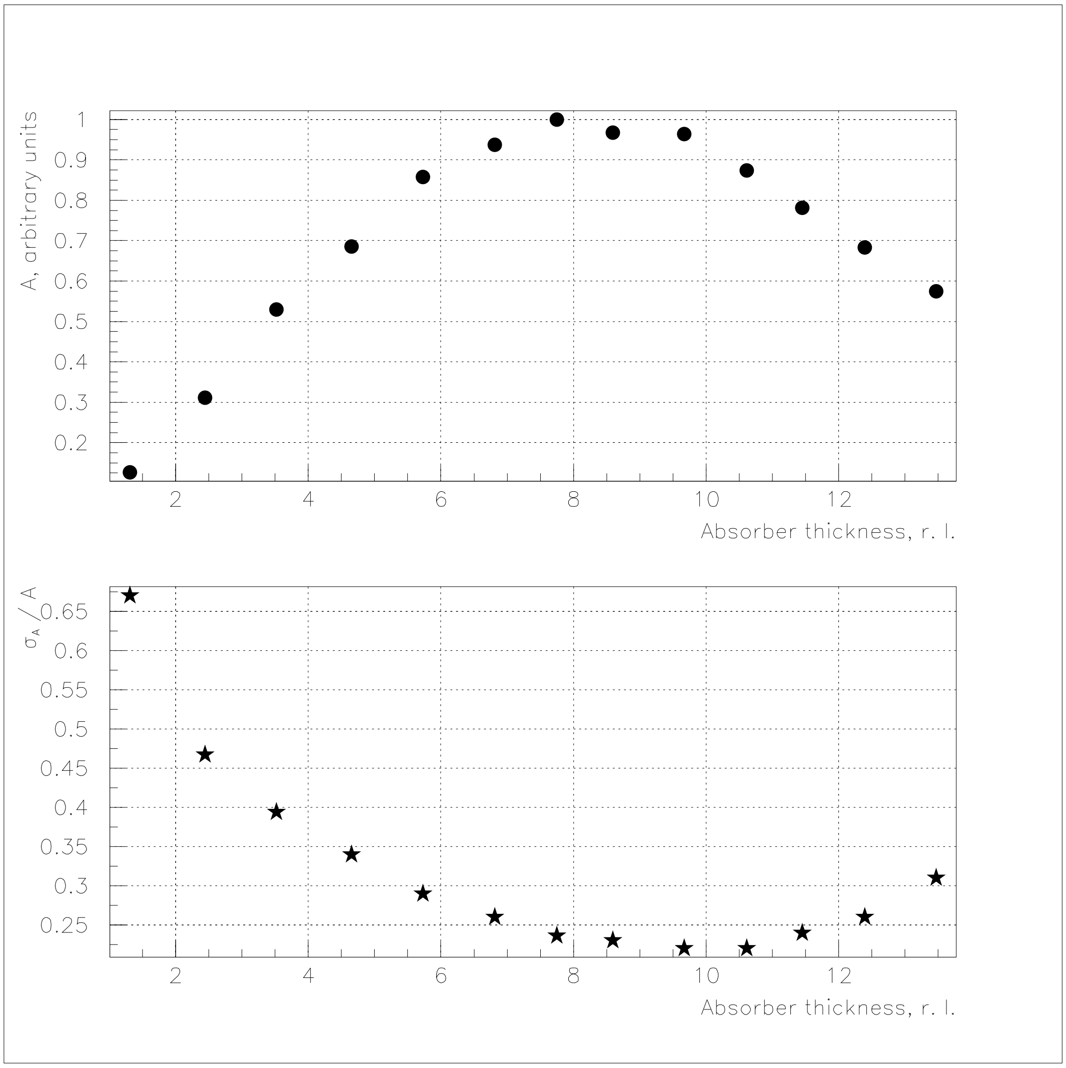


Fig. 4. The dependence of the PST mean pulse height amplitude $\bar{A}$ and the detector energy resolution on the absorber thickness.

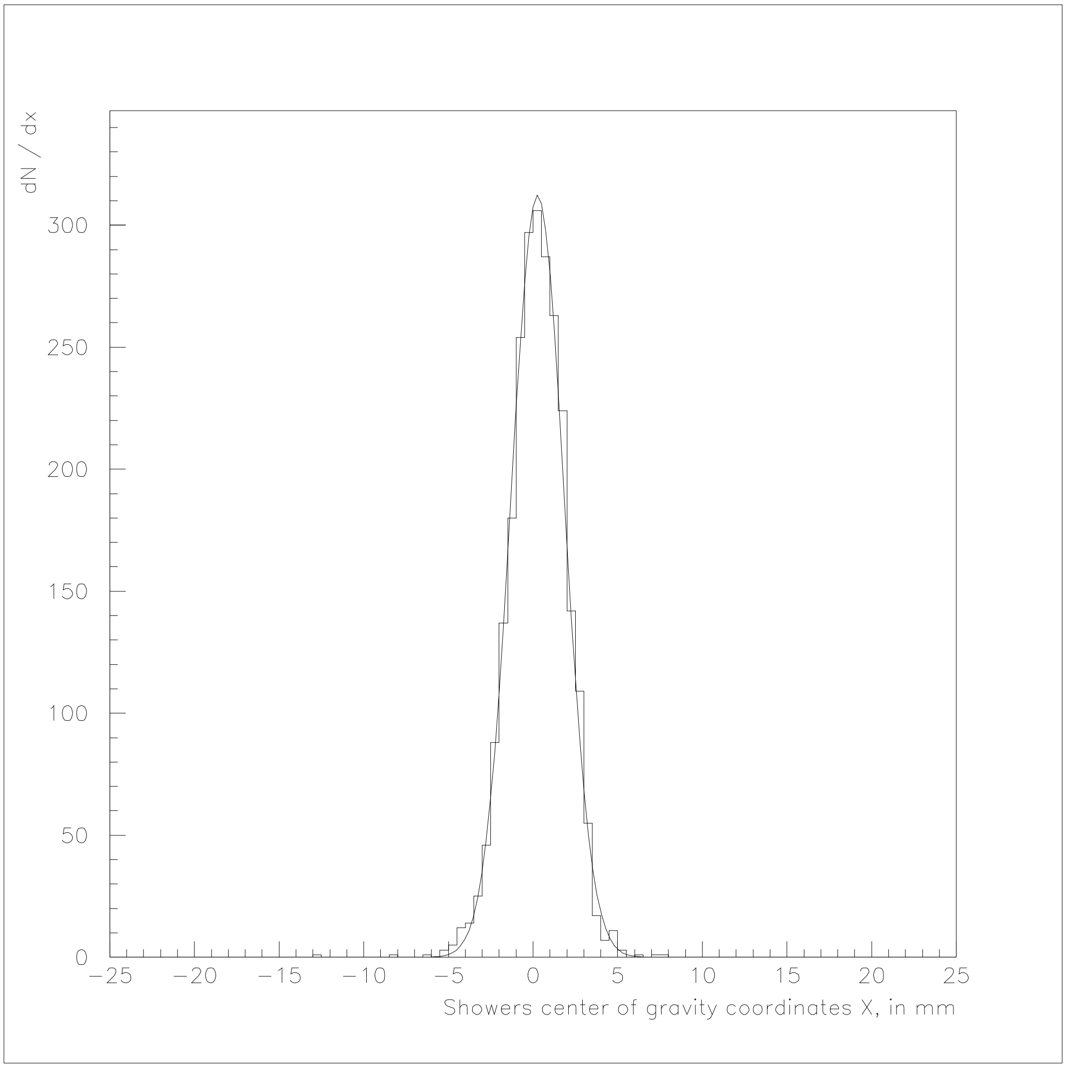


Fig. 5. The center of gravity distribution for 26.6 GeV electrons with the 5.7 r.l. absorber.

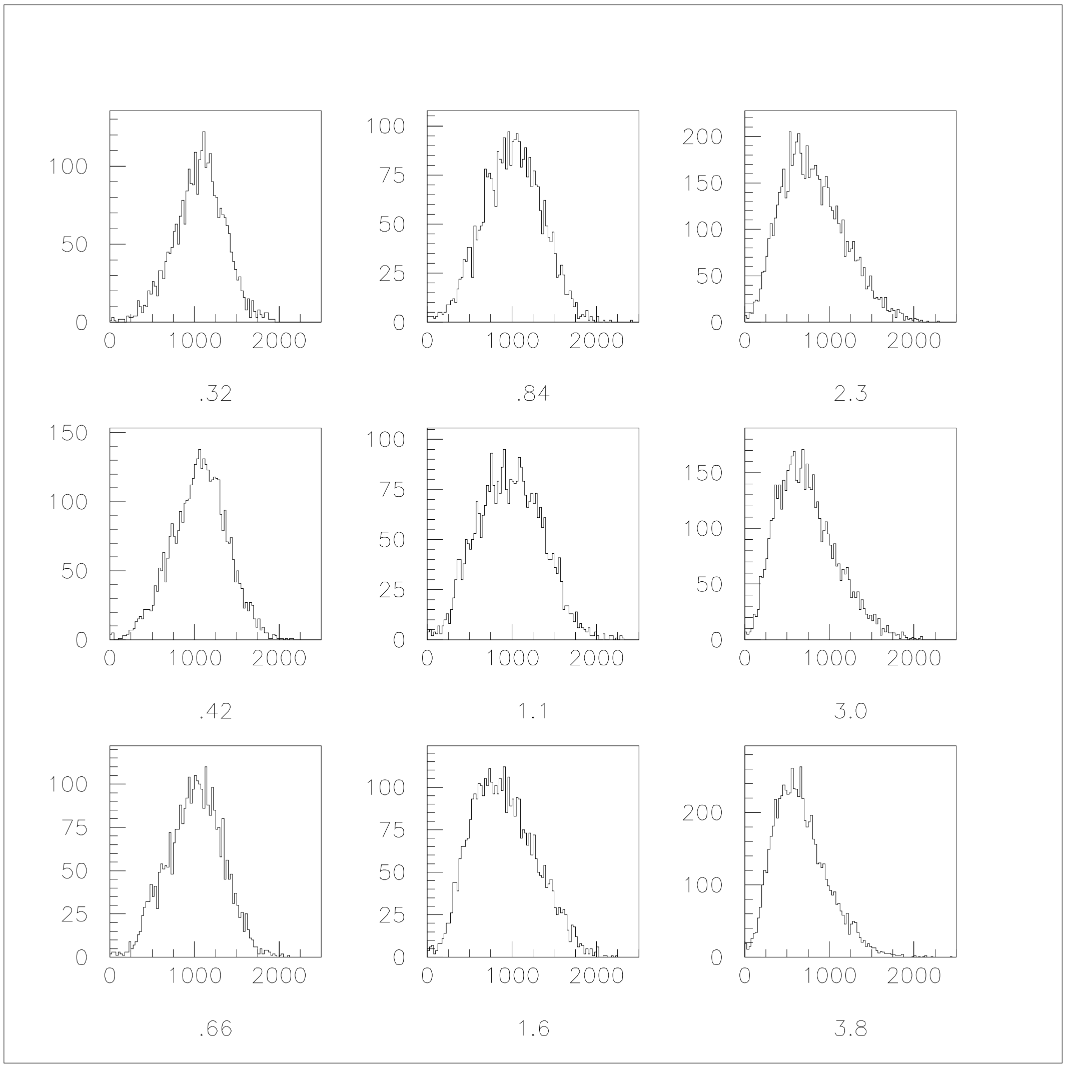


Fig. 6. The PST amplitude spectra at different electron beam intensities. Numbers under the plots are the beam intensity in units $10^3\ e \cdot sec^{-1} \cdot cm^{-1}$.

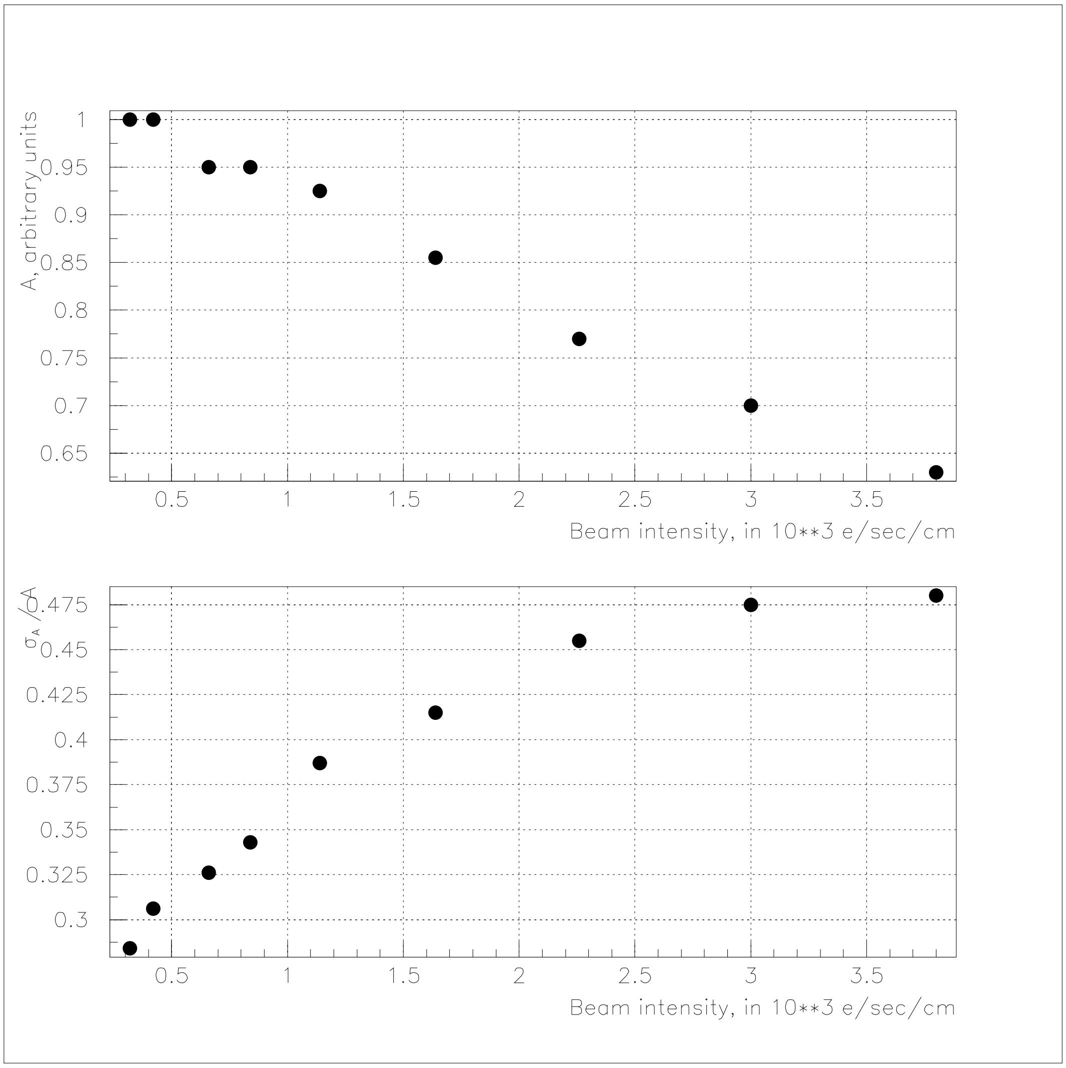


Fig. 7. The dependence of the PST mean pulse height amplitude $\bar{A}$ and the detector energy resolution on the beam intensity.

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