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A PROFILE-BASED GASEOUS DETECTOR WITH CAPACITIVE PAD READOUT AS THE PROTOTYPE OF THE SHOWER MAXIMUM DETECTOR FOR THE END-CAP ELECTROMAGNETIC CALORIMETER FOR THE STAR EXPERIMENT

G.Averichev, S.Chernenko, E.Matyushevsky, A.Nikiforov, Yu.Panebrattsev, E.Platner*, E.Potrebenikova, D.Razin, S.Razin, L.Smykov, G.Škoro, A.Shabunov, I.Tsvetkov, V.Yurevich, Yu.Zanevskiy

The results of testing the full-scale prototype of a profile-based shower maximum detector with external pick-up pads for the end-cap electromagnetic calorimeter (EMC) for the STAR experiment at RHIC are presented. It is shown that the plastic streamer tubes with coverless profile operating in proportional mode with low gain are suitable basic unit for shower maximum detector.

The investigation has been performed at the Laboratory of High Energies, JINR.

Газовый детектор на основе профиля с емкостным pad-считыванием как прототип детектора максимума ливня для торцевого электромагнитного калориметра эксперимента STAR

Г.Аверичев и др.

Представлены результаты испытаний полномасштабного прототипа детектора максимума ливня на основе пластикового профиля с емкостным pad-считыванием для торцевого электромагнитного калориметра STAR эксперимента на RHIC. Показано, что пластиковые стримерные трубки с открытым профилем, работающие в пропорциональном режиме с низким усилением, являются подходящим базисом для детектора максимума ливня.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

1. Introduction

In our previous report [1] we presented the results of Monte Carlo (MC) simulations and conceptual design of gaseous Shower Maximum Detector (SMD) with pad (strip) readout of signal for end-cap EMC of STAR experiment at RHIC [2]. Two types of detectors were proposed: MWPC and profile-based chamber. A possibility of using plastic streamer tubes operating in proportional mode with analog readout of external pick-up pads

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*Rice University, Bonner Nuclear Laboratory, Houston, TX77251, USA.

(strips) for precise coordinate measurements is attractive for us. Profile-based particle detector can be as precise as conventional MWPC with pad (strip) readout [3], [4]. Detector mechanical tolerances are significantly relaxed. The space resolution would be determined by the quality of pad (strip) board and readout electronics.

The shower maximum detector will be placed in thin 25 mm gap in the end-cap EMC. The number of γ's in the SMD acceptance is about 800 for the central Au-Au collision at RHIC energies and the number of charged particles is the same. The showers as well as charged particles will be detected. The size of pads decreases going towards the beam axes to resolve ambiguities due to increasing multiplicity. The time between bunches at RHIC will be about 100 ns. So for high time occupancy a readout electronics need have an integration time about 50 ns, wide dynamic range, small signal/noise ratio for various pad's capacitance and as small as possible power dissipation.

Following the above arguments and reasoning our report [1] we have manufactured a full scale profile-based shower maximum detector prototype with pad capacitive readout. In this report we present results of testing the prototype with a certain suitable readout electronics.

2. Description of Prototype

A schematic view of the cross section of the prototype and the layout of measurement is shown in Fig.1. The prototype consists of four plastic profile tubes each with 8 cells of 9×9 mm^2 in size with 1 mm thick separating walls inserted in a gas-tight plastic envelope. The profile used for the prototype was one of those made for the DELPHI hadron calorimeter [5]. The inner cathode surface of profile is coated with resistive carbon paint. The cathode resistivity of the profile is about $200K\Omega$ per square. The anode is the gold plated tungsten wire of 20 μm diameter strung in each profile cell with tension of 80 g and

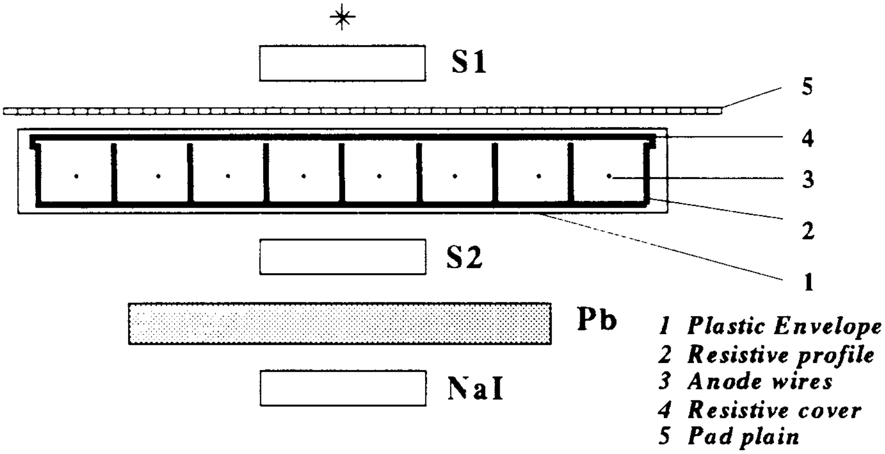

Fig.1. Block diagram of the test set-up

supported by spacer in the middle point. The gas mixture used is argon + isobutane in the ratio 4:1 at normal pressure.

The size of the prototype is $40 \times 120\ \mathrm{cm}^2$. Both tubes with resistive cover and coverless have been used in prototype tests.

The G10 outer pad (strip) board with pads (strips) facing detector is placed directly on the tube plastic envelope. The sizes of the pads are 4×40 mm, 12×130 mm and 12×400 mm. Readout electronics is placed on the opposite pad side of the board.

The anode wires in each tube are connected together serving one readout channel. The anode signals are used only for tuning of operational high voltage applied to the tube.

3. Front End Electronics

Following the results of MC simulation the total electronic channel number of the end-cap EMC shower maximum detector should be about 25000 with analog readout of anode wires (2000 channels) and cathode pads (23000 channels). The position of shower or the entrance point of minimum ionizing particle (MIP) will be measured. Front End Electronics (FEE) is needed for a fast two-dimensional coding of the analog data.

The spatial resolution achievable by using an interpolation method depends on several parameters, in particular on the signal-to-noise ratio S/N. A small noise allows one to reach wide dynamic range at lower gas gain and, consequently, to slow down the detector aging.

The major problem of the FEE design is an extremely limited space (25 mm) given for placing the shower maximum detector with the associated electronics and the cable communications that imposes the request of as small as possible power consumption [2].

Therefore the main parameters of the FEE are: peaking time (T_p), dynamic range, S/N and power dissipation per channel (P_D).

Peaking time T_p should be matched to one half of the crossing time (the time between bunches). At high channel occupancy (up to 100% for Au-Au collisions) the drift time should not exceed the value of the crossing time, i.e., 100 ns. For the typical drift velocity of about 20 $(\mathrm{ns/mm})^{-1}$ this means that in the final design the profile cell size must be about 5-6 mm.

Mean number of particles in shower is about 100, so a noticeable total charge will be collected even at such small peaking time. But for MIP we should increase the gas gain.

To meet the high count rate ($T_p \sim 50$ ns) and the low noise ($< 2000 e^- \alpha C_{\mathrm{pad}} \sim$ hundreds pF) a bipolar IC technology is more preferred instead of CMOS. A common emitter chain in the first stage of the preamplifire (PA) with resistive feedback, forming a transimpedance amplifier, can provide the high gain at acceptable power. To prevent strong the gain and a pulse shape degradation at a large input capacitance, the PA should have a high value of open loop gain [6]:

$$V_{\mathrm{out}} \sim \frac{Q_{\mathrm{in}}}{C_{\mathrm{f}}^{\mathrm{eff}}}; \quad \tau_{\mathrm{rise}} \sim \frac{C_{\mathrm{pad}} C_{\mathrm{c}}}{g_m C_{\mathrm{f}}^{\mathrm{eff}}},$$

where $C_f^{eff} = C_f + \frac{C_{pad}}{g_m R_c}$ — effective feedback capacitance, R_c, C_c — collector resistor and capacitance, respectively, and g_m — transconductance of a bipolar transistor.

If open loop gain $g_m R_c$ is rather large, the sensitivity of PA to C_{pad} value is reduced. However it demands higher $g_m \sim I_c$, i.e., to increase power consumption. Also serial noise must be small at short T_p.

To keep good double pulse resolution and high value of S/N ratio,the PA has to be followed by a multipole shaping amplifier (SA). The shaper should include also $1/t$ tail cancellation and transform input pulse into a near Gaussian shape. From EMC physics considerations the dynamic range is requested as large as 1000. This value is more than enough for getting needed spatial resolution in interpolation method (~ 0.1 of pad pitch) [7]. Concerning the FEE design it is desirable to realize this parameters at low, as possible, noise and, hence, smaller power dissipation.

After amplifying and shaping, the data from SMD have to be delayed and digitized. Since SMD is a fast detector, the readout electronics delay circuits have to provide write and readout modes simultaneously. The delay of ~ 1 μs, needed for level 0 trigger decision, can be performed, in principal, by two ways as shown in Fig.2.

First (Fig.2a), analog is based on Sequential Capacitors Array (SCA) and second (Fig.2b), the flash ADC with digital pipeline is used. The solution based on SCA approach is cheaper and consumes significantly lower power. The suitable number of pipeline cells is $10 \div 20$. Application of higher clock frequency (up to 40 MHz) can give a possibility to know a channel history and make an amplitude correction. The number of the ADC bits

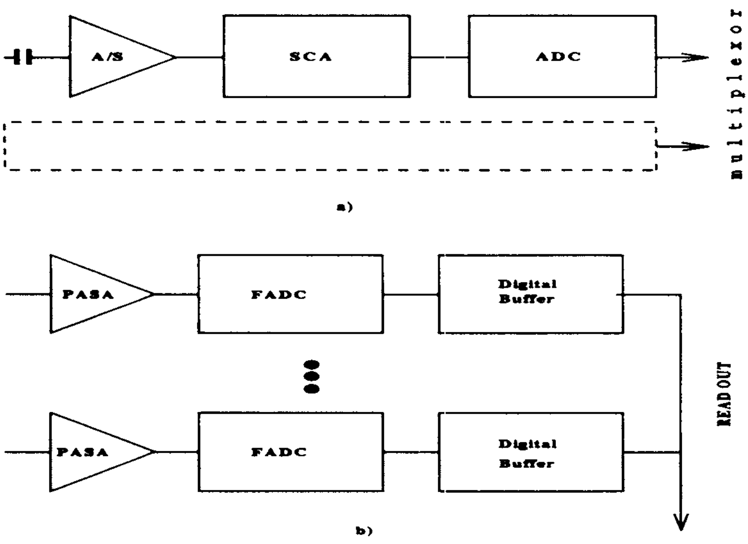

Fig.2. The scheme of different variants of shaped SMD signal delay

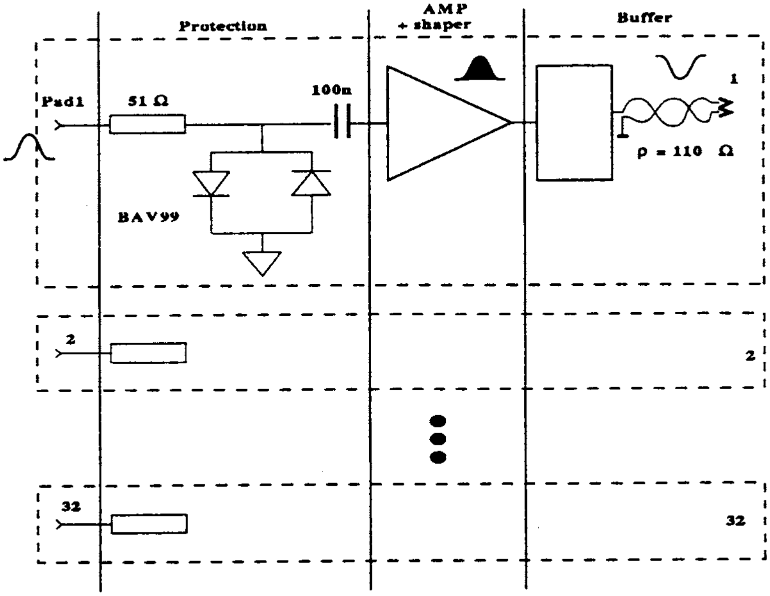

Fig.3. The scheme of readout electronics based on 32-channel chip for the SMD prototype test

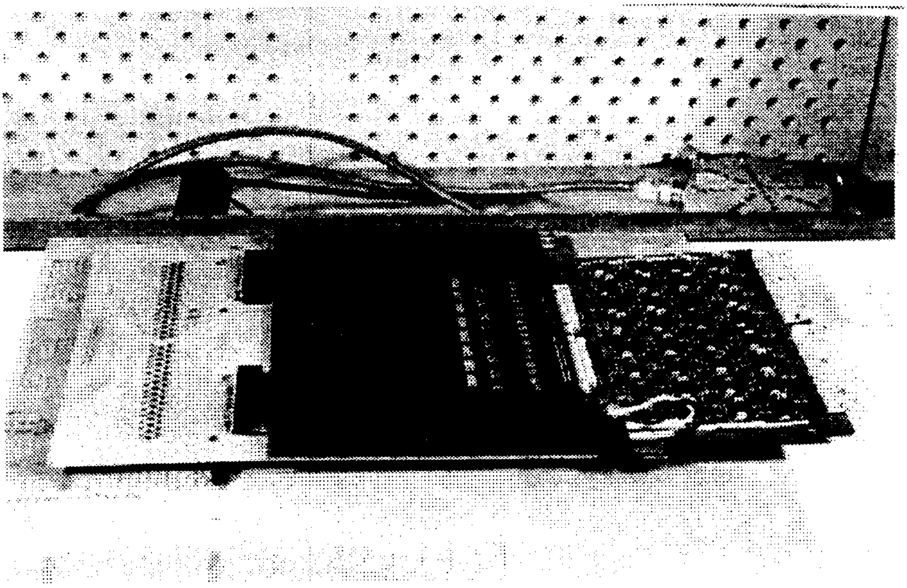

Fig.4. View of the shower maximum detector prototype

must be matched to dynamic range. Therefore FEE should use 10-bits linear or 8-bits non-linear ADC.

Following the arguments described above we have designed the multichannel electronics based on 32-chip (PASA) [8] developed by D.Dorfan (US, Santa Cruz) for testing the SMD prototype. This IC has extremely low power consumption $\sim 2mW/ch$. Other parameters such as peaking time ~ 75 ns, $1/t$ cancellation and low noise (5 nA, r.m.s) are near needed for the prototype.

Our goals were:

1) to design electronics for prototype test with a radioactive source and a beam,

2) to investigate possibilities of a low power consuming chain implementation for readout of signals from large pads.

The arranged scheme of protection diodes at inputs and drivers at outputs to route data on cable is shown in Fig.3. The output pulses are transferred via 5 m long TWP flat cable to 9-bit ADCs.

Figure 4 shows a general view of the shower maximum detector prototype on the side of the pad board. The 32-channel PASA chip has been mounted on individual board. The connection with pads was realized via input protection circuits by means of 32-pins connectors. Various type pads can be connected by turns to the chip inputs.

4. Test Studies of Prototype Performances

Two types of plastic tubes were used in test studies: with profile closed by resistive cover and with coverless profile. The measurements were carried out using electrons (the energy up to 3 MeV) from ^{144}Ce radioactive source. The unnecessary substance from upper and lower prototype screening boards were removed. The narrow upper collimator (2 mm diameter slit) was used to define a narrow beam over pad.

The electrons with the energy more than 2 MeV are passed through scintillation counters S1—S2 (energy loss ~ 1 MeV) and a plastic tube (energy loss ~ 1 MeV). Signals from scintillation counters (S1 and S2 in Fig.1) form the trigger for the ADC gate.

In experiments with cosmic muons additional large NaI counter was used for the ADC gate trigger, too.

Figure 5a shows the amplitude spectra of an individual pad (4×40 mm) at various operating voltage. The pedestal peak is well separated from the minimum ionizing signal.

Measurements data with cosmic muons for six nearby pads at 1725 V operational voltage in Fig.5b shows the same (the ADC's pedestals were subtracted).

The data for middle 12×130 mm and large 12×400 mm pads are shown in Fig.6.

It is seen that at operating voltage value of about $1700 \div 1750$ V we have well defined signal from minimum ionizing particle. The tube operates in the proportional regime with the gain at the level of 10^4—10^5. The pulse duration does not exceed ~ 150 ns at 1/10th of maximum height for different input pad capacitances of readout electronics. The output signal amplitude is nearly proportional to the value of pad capacitance that means the preamplifier gain doesn't change noteceably.

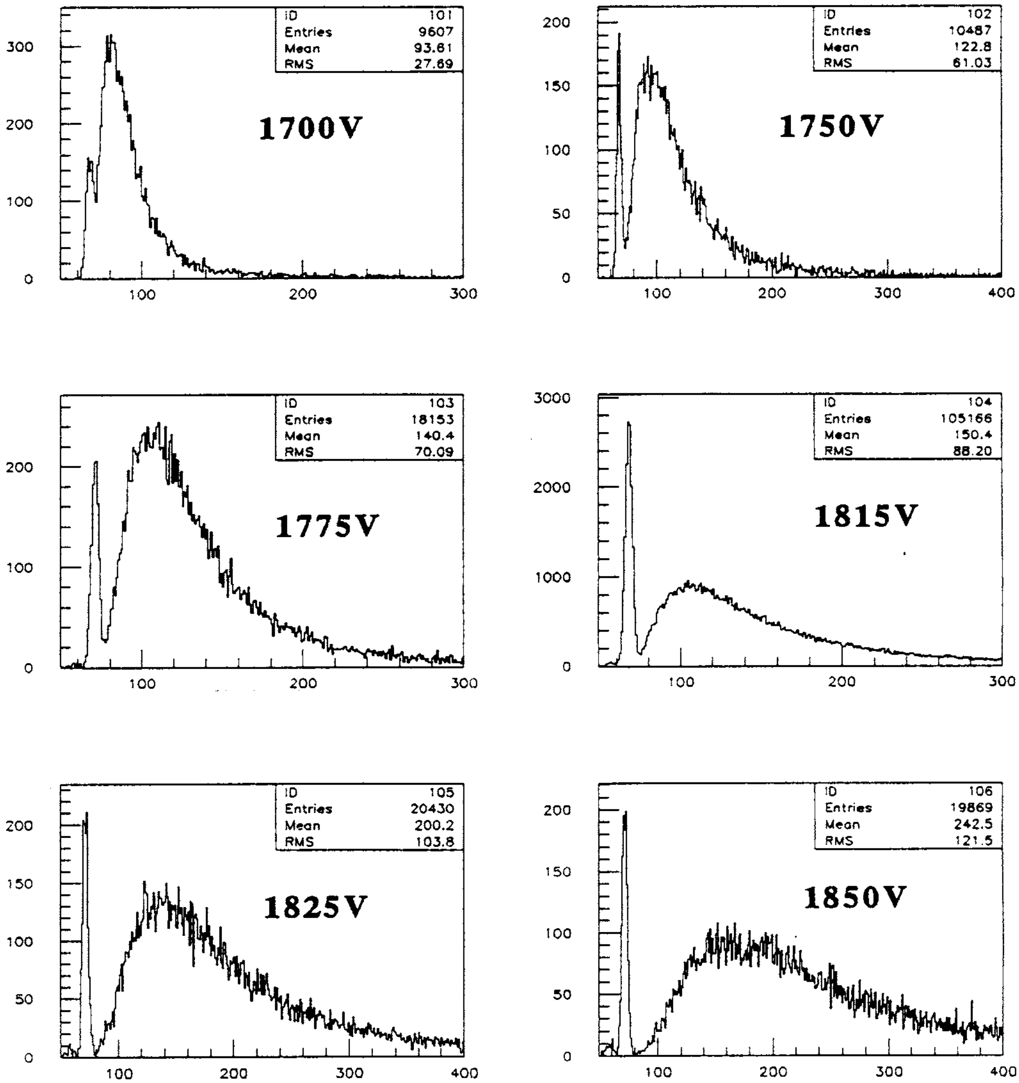

Fig.5a. The amplitude spectra of individual 4 × 40 mm pad at various operation voltage. Measurements with radioactive source ^{44}Ce

The amplitude spectra for a tube with coverless profile for four nearby 4 × 40 mm pads is shown in Fig.7.

To investigate the position resolution we have measured a distribution of charge induced on the six nearby pads. The measurements with the tubes with profile closed by resistive cover have been made using cosmic muons. In experiments with the tubes with coverless profile the collimated radioactive source was used. The events with maximum charge on the middle (third) pad were selected.

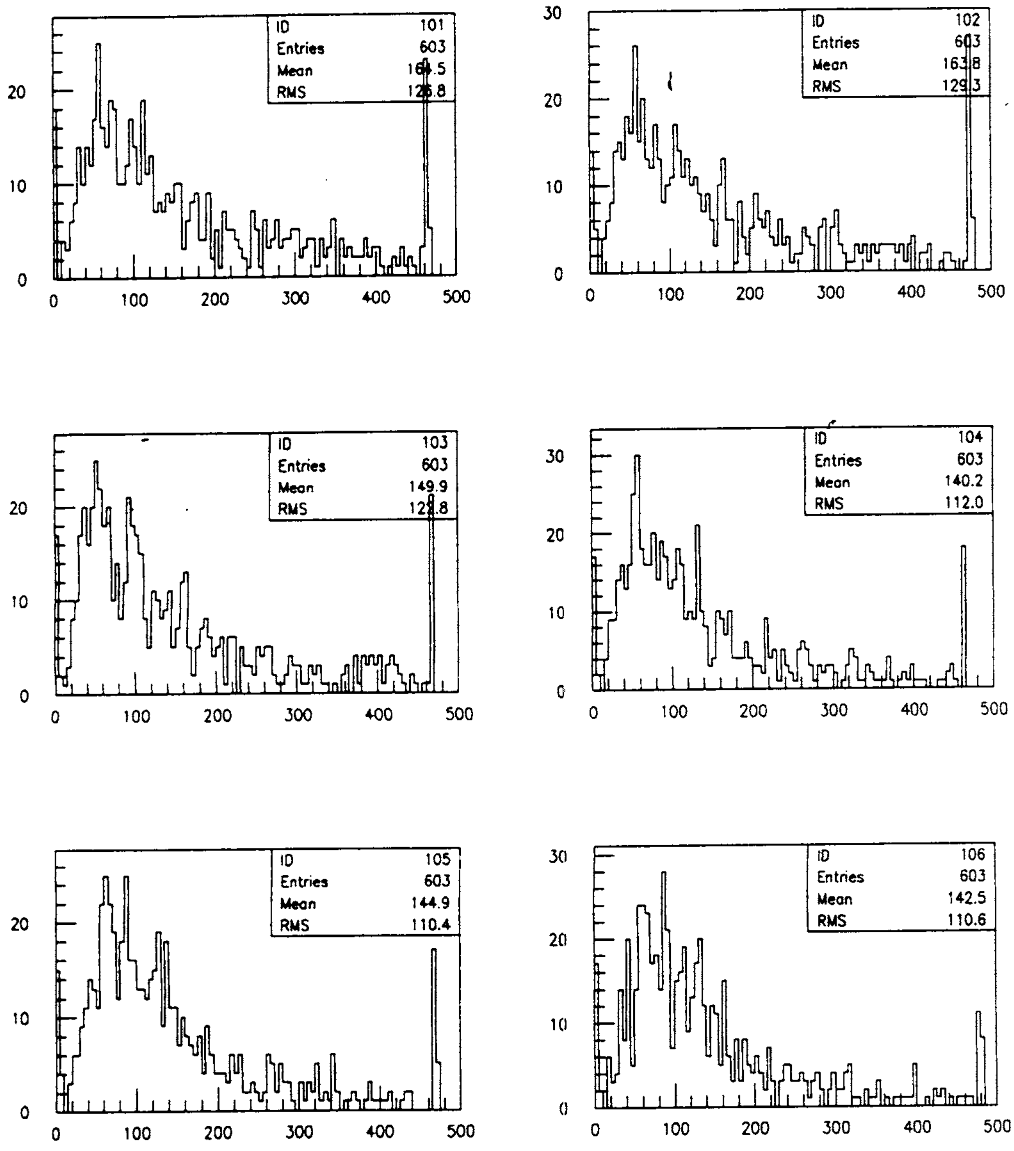

Fig.5b. The same as Fig.5a at 1725 V operation voltage. Measurements with cosmic muons for six nearby pads

In Fig.8 the distributions of charge over six 4 × 40 mm nearby pads for a tube with coverless profile and for a tube with profile closed by the resistive cover are shown.

It is seen that the distribution for the tube with coverless profile is narrow enough so it will be possible to separate particles in high multiplicity collisions.

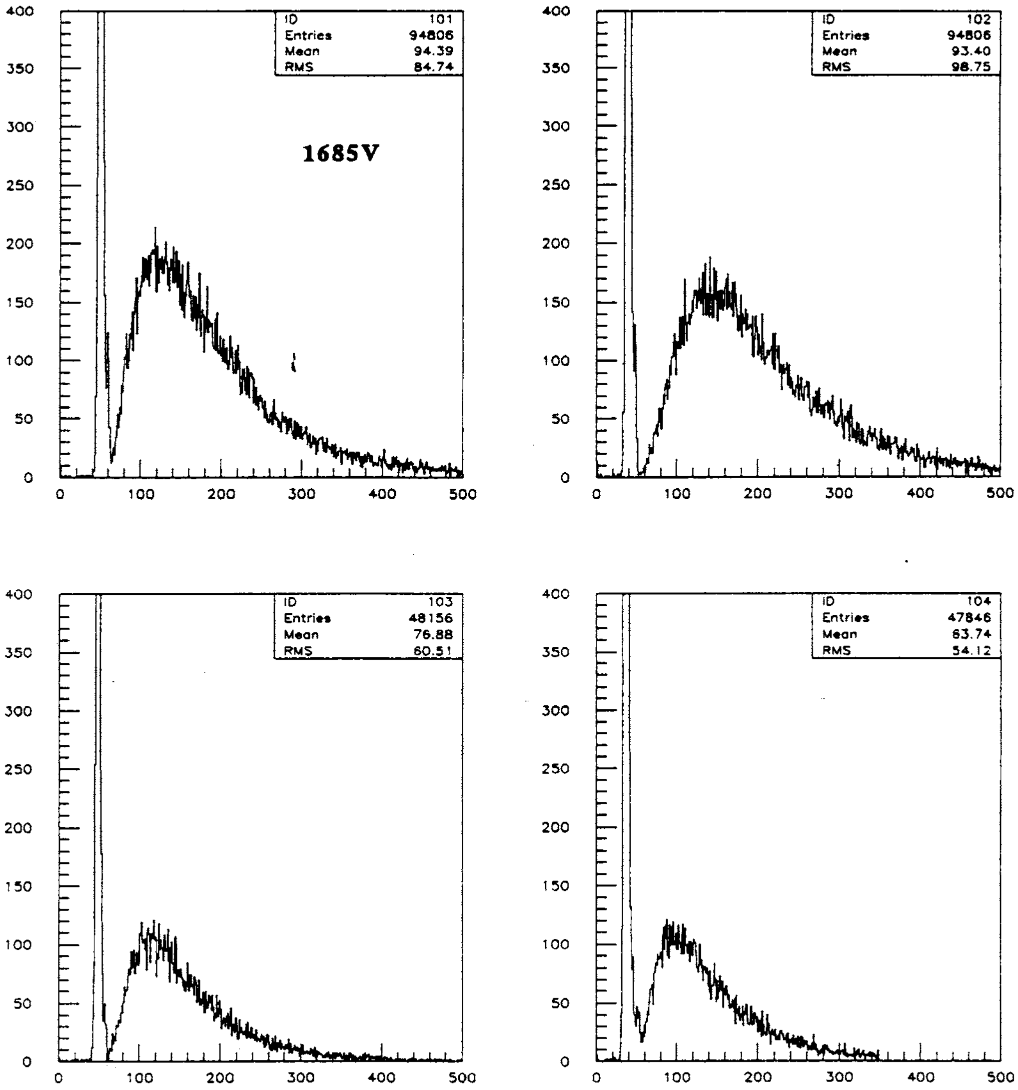

Fig.6. The amplitude spectra for two nearby 12 × 130 mm (top) and 12 × 400 mm (bottom) pads. Attenuation is 5 (top) and 10 (bottom)

In Ref.9 the detector of electromagnetic shower on the basis of plastic streamer tubes has been investigated but there the tubes operated in high saturated mode with worse spatial resolution and lower rate capability.

The spatial resolution of detectors on the base of plastic streamer tubes with capacitive readout has been investigated in [3,4,10]. It was found that nonuniformity of cathode resistivity significantly impairs the spatial resolution and to use the tube with very high cathode resistivity ($> 10 M\Omega$) or with low resistivity and coverless profile is preferable.

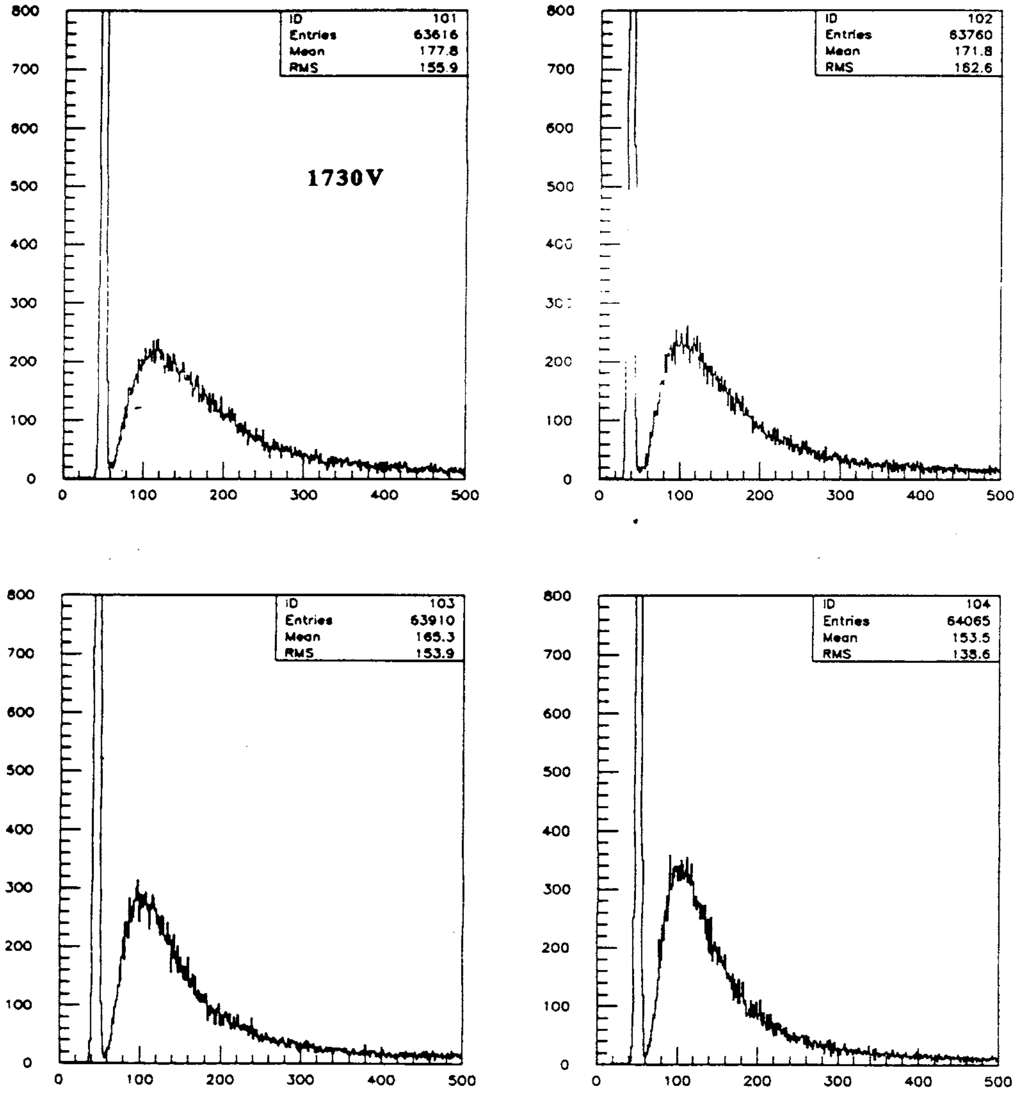

Fig.7. The amplitude spectra for 4 × 40 mm four nearby pads for a tube with open profile

5. Conclusion

The test investigations of the prototype based on the plastic streamer tubes show that the coverless tubes with capacitive readout operating in proportional mode with low gain are suitable basic unit for the end-cap EMC shower maximum detector. The uniformity of

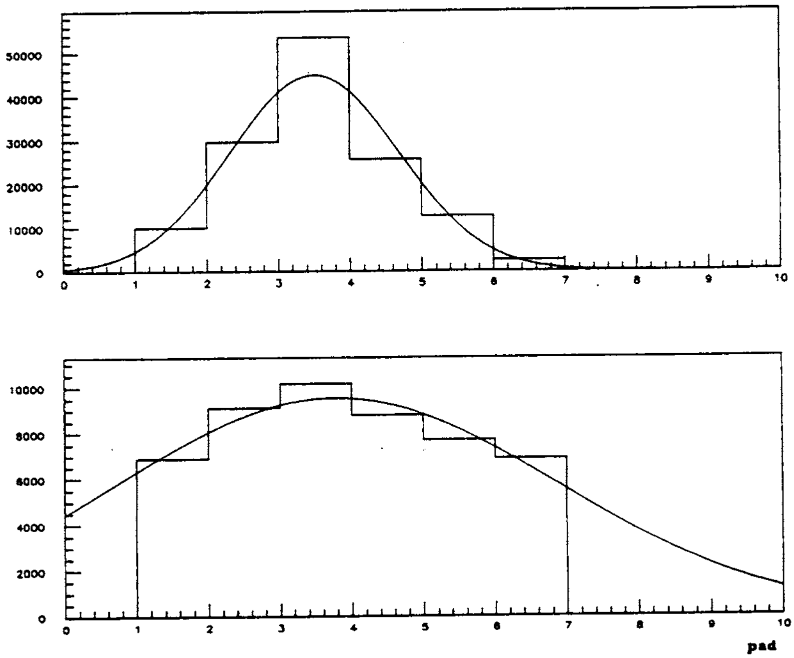

Fig.8. Charge distribution on six nearby 40 × 40 mm pads for a tube with opened (top) and closed (bottom) profile

the cathode resistivity has a major influence for spatial resolution. The tubes with coverless profile and low resistivity are more preferable.

The readout electronics based on the 32-channel chip PASA [8] can be used for the detector with the 9×9 mm^2 cell plastic tubes.

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References

1. Averichev G. et al. — JINR Rapid Communications, 1996, No.6[74]-95, p.95-108.
2. The Electromagnetic Calorimeter for the Solenoidal Tracker at RHIC. A Conceptual Design Report, Pub-5380 (1993).

3. Khovansky N. et al. — Nucl. Instr. and Meth., 1994, v.A351, p.317.
4. Bonushkin Yu. et al. — Nucl. Instr. and Meth., 1991, v.A300, p.268.
5. The DELPHI Technical Proposal, CERN/LEPS/83-66/1 (1983); DELPHI collaboration (P.Aarnoi et al.); Nucl. Instr. and Meth., 1991, v.A303, p.233.
6. Newcomer F.M. et al. — IEEE Tr. on Nucl. Sci., 1993, v.40, No.4, p.630.
7. O'Connor P. — Proceedings of the International Conference on Electronics for Future Colliders. New York, May 4-5, 1993, p.16.
8. Platner E., Theman H. — STAR Note 173, April 1994.
9. Belousov V.I. et al. — STAR Note 184.
10. Korytov A. et al. — Nucl. Instr. and Meth., 1994, v.A338, p.375.

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