STAR Note 226

Design and study of light readout system for scintillator shower maximum detector for the endcap EMC

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Abstract

The possibility of using a strip/fiber type shower maximum detector(SMD) in the EMC endcap for **pp**, **pA** and **AA** collisions was investigate by simulation. It is shown, that strip type SMD is a good option for **pp** and **pA** collisions, but is not suitable for **AA**. The compact 12*12*30 cm module of 16 tiny russian photomultipliers with one HV power supply channel is realized as a unit of a light readout system of the SMD.

1 Introduction

The investigation performed by the IHEP group indicates that scintillator strip/fiber type shower maximum detector (SMD) [1] is a good option for the barrel electromagnetic calorimeter for the STAR experiment[2]. They [1] have been tested only one photoreceiver - russian photomultiplier FEU85. We have continued investigations in this direction with the goal to find a new compact module type sheme of light readout based on low current tiny russian photomultipliers. In this case only one HV channel of a standart power supply source should be enough for feed one light receivers module.

We would like also to reply on the question is it possible or not to use a scintillator strip type endcap SMD not only in investigations of polarized proton collisions at RHIC but in study of **pA** and **AA** collisions as well. For this purpose we have carried out Monte Carlo simulation.

2 Monte Carlo simulation

The Monte Carlo program GEANT3.15 with a 1 MeV cut for γ's and electrons was used to study EM showers and HIJING model event generator have been used to describe proton – nucleus and nucleus – nucleus collisions.

Fig.1 shows the rapidity distribution of γ's and hadrons in **pp**, **pAu** and **AuAu** collisions at energy 200 GeV/nucleon. The distributions of energies of direct gammas and gammas from π^o decays in acceptance of endcap EMC are presented too. It is seen, that main background in SMD is related with π^o channel of γ production. The number of γ's in the SMD acceptance is about 800 in central **AuAu** collision and about 10 in central **pAu** collision.

The γ initiated showers are symmetrical with respect to the line of flight of the primary γ. In **Fig.2** are shown transverse profiles of 15 GeV γ shower in the first and the second plane of SMD, placed into endcap EMC at the depth of $5X_o$'s about the position where the maximum development of shower occurs. To identify the single shower the scintillator strips must have the width not larger than 12 mm. The IHEP group data confirm our results [2]. We use 1 cm width scintillator strip in our investigations.

In **Fig.3a** are shown the charged particles multiplicity distribution on the first SMD plate for the central **pAu** and **AuAu** collisions. Referring to **Fig.3b**, where is presented the energy deposited in SMD scintillator vs. distance from the center of SMD one can see that about 75 % of the showers are in the central area $75 \quad \text{cm} < R < 160 \quad \text{cm}$. This area contains about 600 γ's (**AuAu** collision case). In **Fig.4** is shown the energy deposited in the central 5 cm width ring of SMD vs. azimuthal angle for 6^o, 3^o and 1^o /per bin. The one 3^o bin contains ~ 3 strips and covers an area about 40cm^2. This area contains only one shower. It is seen that using 3^o azimuthal bin the showers could be separated. The $75 \quad \text{cm} < R < 160 \quad \text{cm}$ ring contains about 100 strips per 30^o sector, so we have $\sim 1.5 \quad \gamma$'s per three strips. Then, we can conclude that the strip type SMD is not suitable for separating the showers from **AuAu** collisions.

3 SMD Prototype Design

Following by results of our simulations and experimental study [2, 3] the optimal thickness of scintillator strip is $4 \div 6$ mm and its width is $10 \div 12$ mm in order to obtain needed position resolution. We used a scintillator strip of 10 mm width and 4 mm thickness in our studies. In this case the full SMD will contain about 5300 strips. The SMD strips were read-out with wavelength-shifting (WLS) fibers. The light collected by WLS fiber is transported via a long clear fiber to photodetector. The scintillator and the WLS fiber were wrapped with an aluminum foil. The hodoscope's scintillator plane of prototype contains 16 strips. Our investigations, the results of which are given in the next chapter, show that compact russian photomultipliers like FEU-162, FEU-96 and FEU-60 with the gain more than 10^5 and quantum efficiency of photocathod about 15% can be used in SMD as photodetector. The high resistance dividers of the PMTs with about 100 μA current are used. The tested photomultiplier's specifications are given in **Table 1.** It allows us to use only one 2mA high voltage power supply channel for 16 phototubes module of the SMD and significantly reduce the cost of production of the HV power system. The two stage amplifier with the total gain about 10^3 is used for getting of the suitable PMT pulse height. As an amplifier unit we used the russian charge amplifier chip "Garantija" with the maximum gain about 10^2. The electronics components of the first amplifier cascade is placed just at the PMT divider board to reduce a noise. The photomultipliers are operate at the nominal anode voltage $\sim$ 1000V (FEU-60, FEU-68, FEU-85) and $\sim$ 1500 V (FEU-96, FEU-162).

The prototype module of 16 photomultipliers has the sizes $12 \times 12 \times 30$ cm. The total number of modules (324 units) for the hole SMD will have the size $216 \times 216 \times 30$ cm. The prototype module is shown in **Fig.5**.

Table 1

Parameters	**FEU-85**	**FEU-162**	**FEU-96**	**FEU-60**	**FEU-68**
Diameter, mm	30	22.5	22.5	15	15
Length, mm	107	75.0	75.0	70	70
Photocatode type	Sb-Cs	Sb-Na-K-Cs	Sb-K-Sc	Sb-Cs	Sb-Na-K-Cs
Quantum efficiency (λ =480 nm), %	10	15	15	10	15
Gain	$\sim 10^6$	$\sim 10^5$	$\sim 10^5$	$\sim 10^5$	$\sim 10^4$
Current divider, μA	100	100	100	100	100

4 The PMT Test Experimental Setup

A number of tests have been performed with russian photomultipliers FEU-60, FEU-68, FEU-85, FEU-96 and FEU-162. **Fig.6** shows a schematic view of the experimental setup and logic of the measurements.

A WLS fiber BCF-91A with diameter of 1 mm, ($\lambda = 480$ mm) was used. A clean fiber BCF-91B had length $\sim$ 1 m. The thickness and the width of the scintillation strip were 4 mm and 10 mm, respectively. Data were taken with **Ce-144** source. The gate of ADC was $\sim$ 60 ns and have been produced by coincidence of Monitoring Counter (FEU-87) and Coincidencing Counter (FEU-87) signals. The threshold of Monitoring Counter was about 400 KeV and definded the low level of scintillator light.

The Coincidencing Counter threshold was as low as possible in order to detect all electrons passed through scintillator strip.

The testing **PMT** were placed one by one in turn into Experimental Counter area so they were have the equal optical conditions.

5 Results

At the first we have repeated the IHEP test of FEU-85. Pulse heights measured with FEU-85 are shown in **Fig.7**. One can see that our results are in a good agreement with IHEP data and we can conclude that our optical chain works right.

For **PMT** FEU-85, which has a gain about 10^6, we obtain ~ 2.5 photoelectrons per MIP. **Fig.8a, 8b** and **8c** show the results of test for FEU-162, FEU-96 and FEU-60, respectively. They have a gain $\sim 10^5$. The total gain of read-out electronics was 120 (FEU-162), 80 (FEU-96) and 80 (FEU-60). In the case of **PMT** FEU-85 it was $\sim$ 20. The ADC pulse heights distribution for FEU-68 is shown in **Fig.8d**.

The results of our **PMT** tests are summarized in **Table 2.**

Table 2

PMT	**PMT gain**	**read-out gain**	**N$_{p.e.}$/MIP**
FEU-85	$\sim 10^6$	20	~ 2.5
FEU-162	$\sim 10^5$	120	~ 1
FEU-96	$\sim 10^5$	80	~ 1
FEU-60	$\sim 10^5$	80	~ 1
FEU-68	$\sim 10^4$	450	~ 0.7

One can see that the photomultipliers with gain more than 10^5 are suited for using as photoreceiver in SMD.

6 Cost estimate

The summary costs estimates in May 95 prices are identified in **Table 3.**

Table 3

The Estimated Cost for Various Components of the Endcap SMD

Item	number of units	cost per unit, $	total, $
PMT	5,500	75	412,500
Read-out and Front-end electronics	5,500	30	165,000
HV system (Le Croy 1440)	3	100,000	300,000
HV connectors and cables	350	30	10,500
WLS and clear fibers	—	5,500	16,500
Scintillator strip	5,500	—	50,000
Signal cables and connectors	—	—	4,000
Monitoring system	1	—	50,000
Mechanical fabricate	—	—	150,000
Total			1,158,500

7 Conclusions

The possibility of using of a strip/fiber type shower maximum detector(SMD) in the endcap EMC for **pp**, **pA** and **AA** collisions was investigate by simulation. It is shown strip type SMD is a good option for **pp** and **pA** collisions, but is not suitable for **AA**. The compact 12*12*30 cm module of 16 tiny russian photomultipliers with one HV power supply channel is realized as a unit of light readout sistem of the SMD.

8 Acknowledgements

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References

[1] S.A.Akimenko et al. IHEP Preprint 94-94, Serpukhov,1994.

[2] Conceptual Design Report for the Solenoidal Tracker at RHIC, the STAR collaboration, PUB-5347 (1992).

[3] Solenoidal Detector Collaboration, Technical design Report. SDC-92-201, SSCL-SR-1215, 1 April 1992

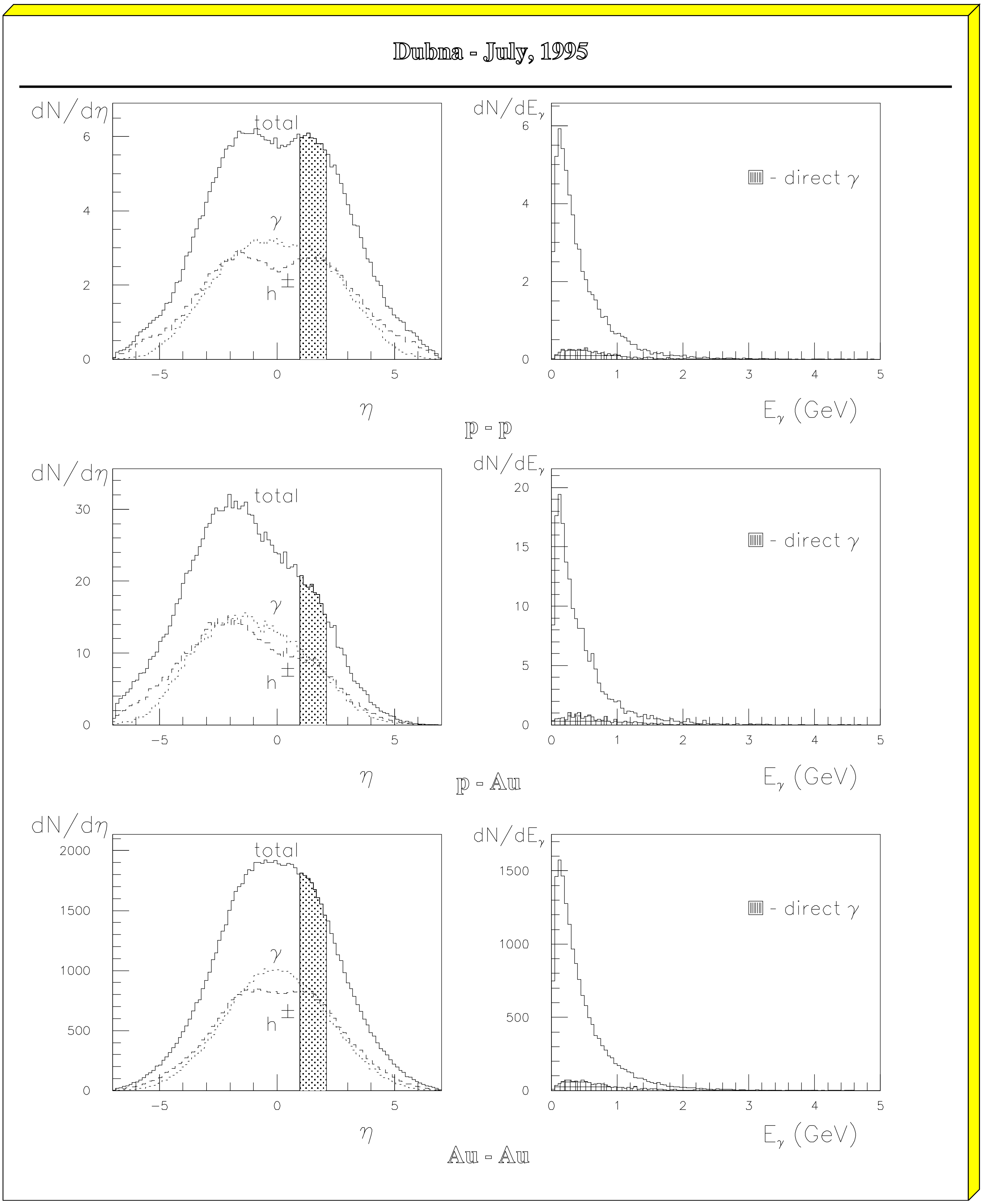

Figure 1: The pseudorapidity distribution of γ's and charged hadrons in **pp**, **pAu** and **AuAu** collisions at 200 GeV/nucleon.

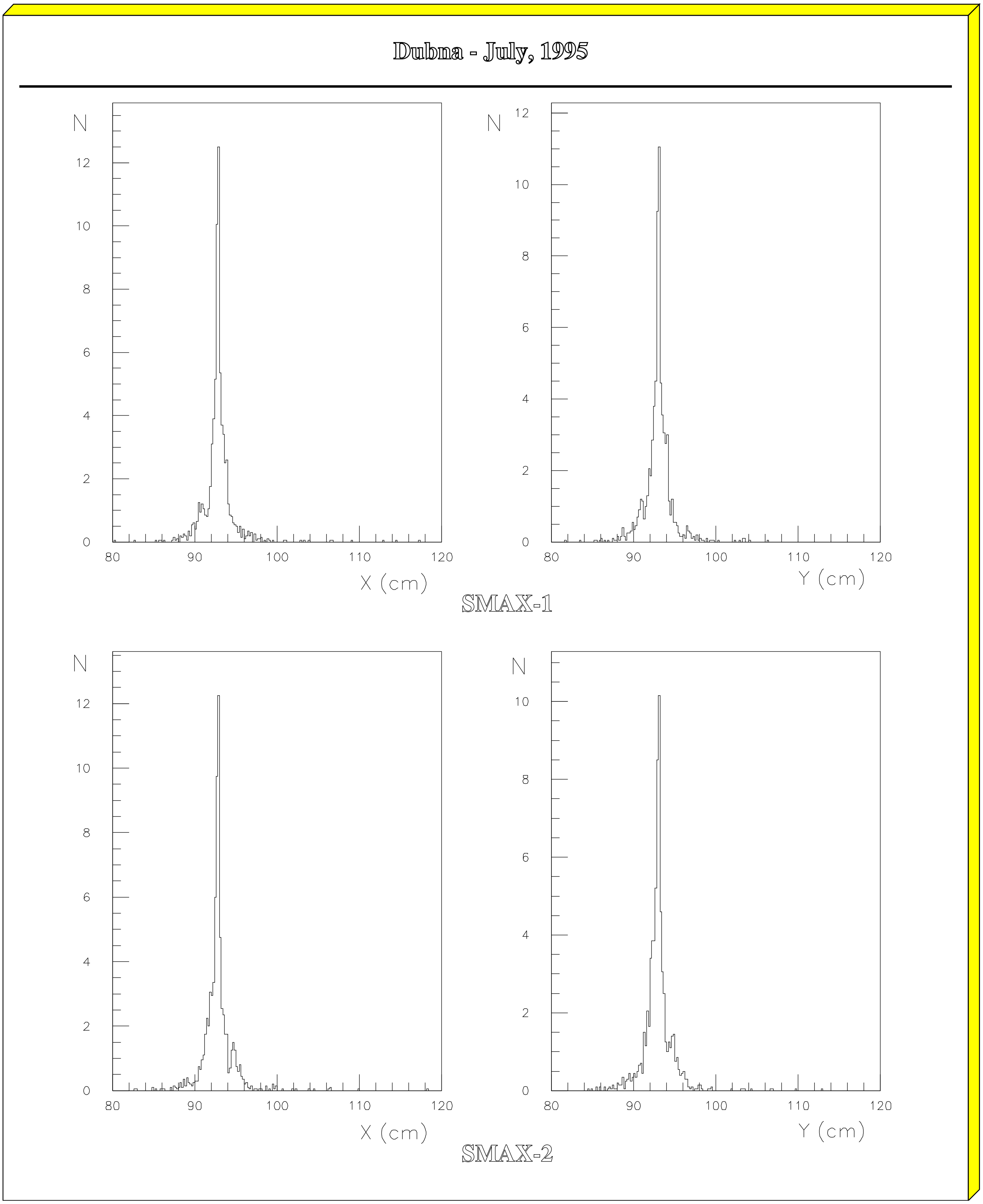

Figure 2: The transverse profiles of shower, induced by 15 GeV gamma

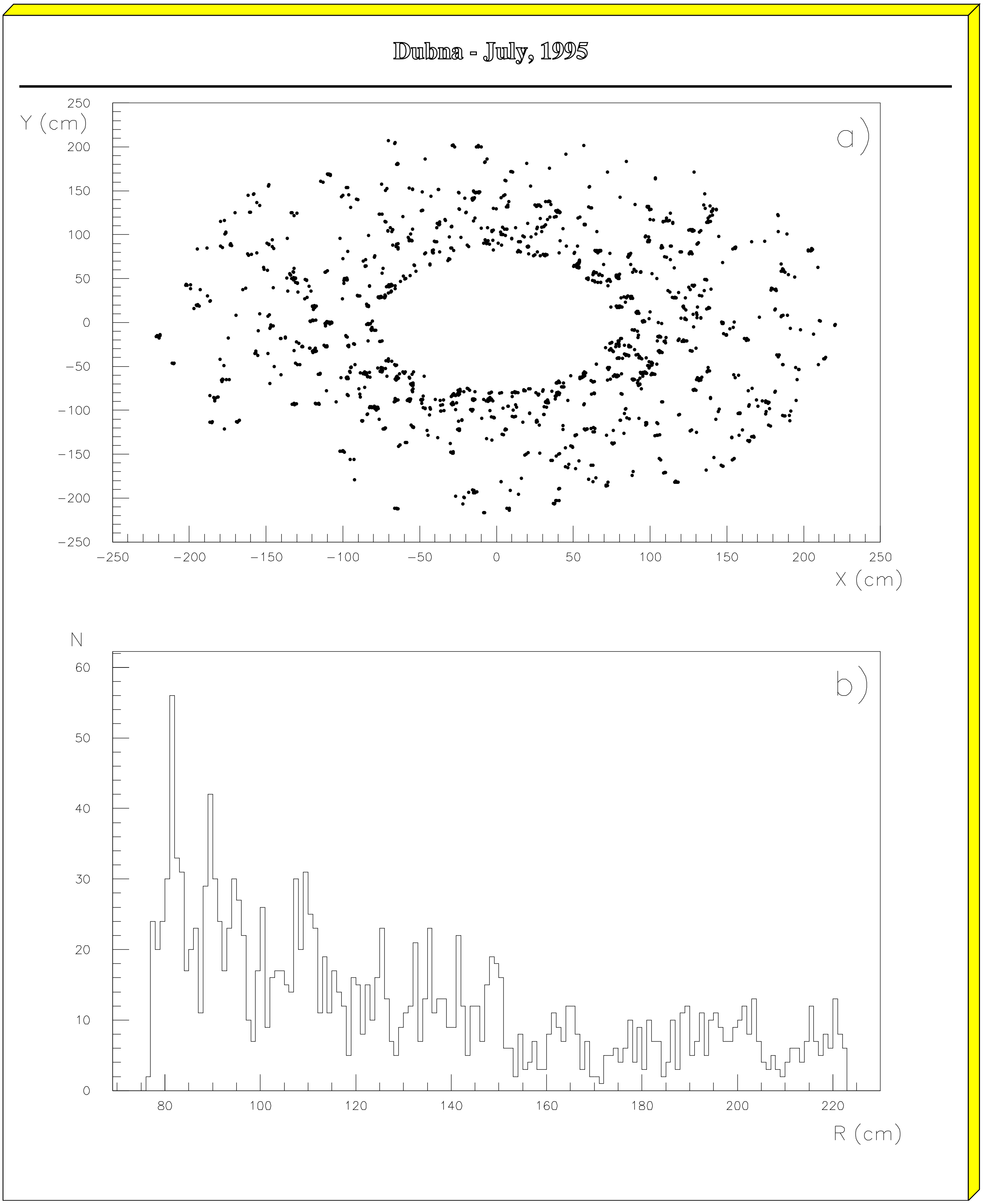

Figure 3: **(a)** Scatter plot of shower charged particles distribution on the first **SMD** layer; **(b)** The number of shower charge particles vs. the distance from the **SMD** centre

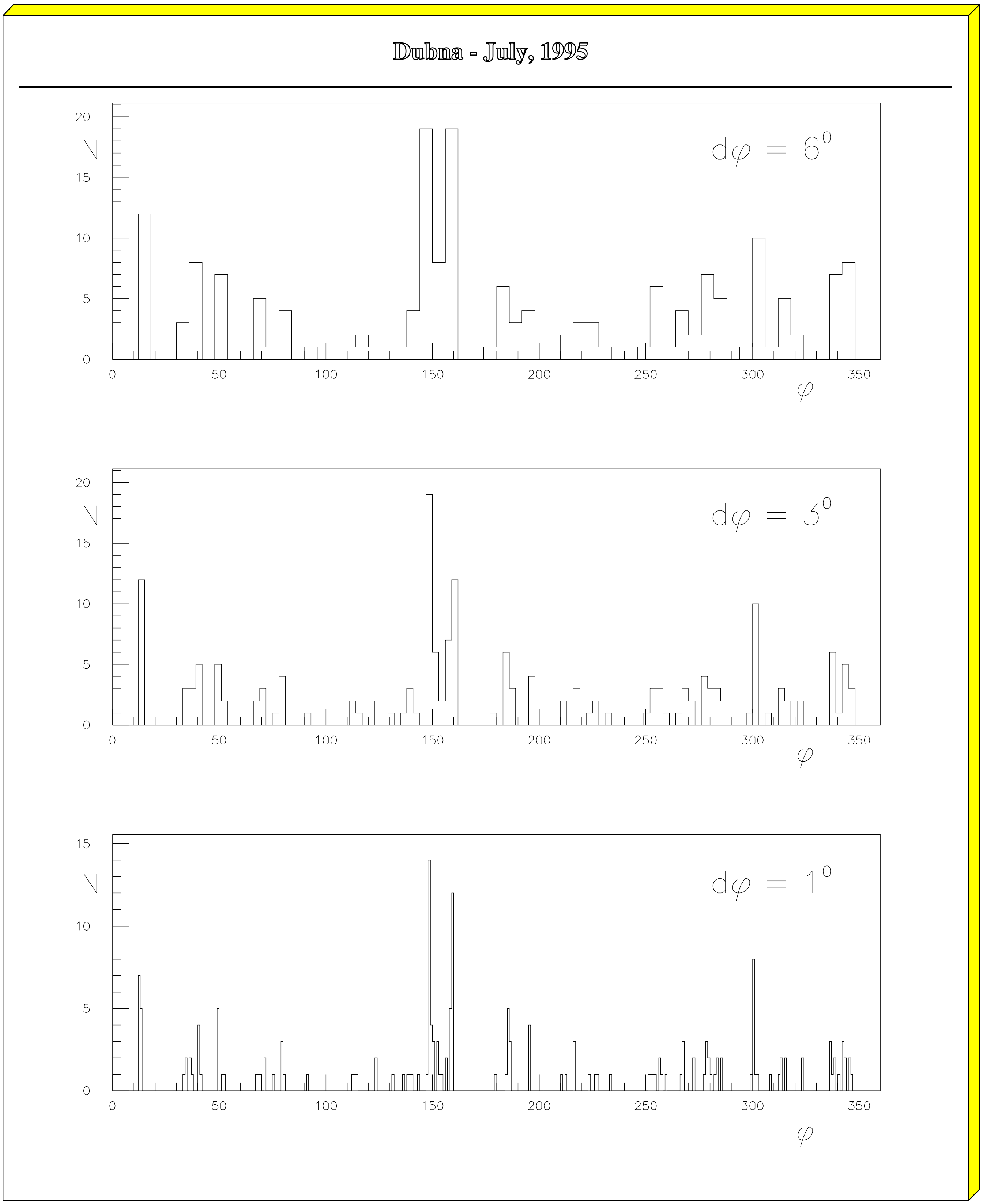

Figure 4: The energy deposited in the central 6cm width ring of **SMD** vs. azimuthal angle for 6^o, 3^o and 1^o per bin for the central **AuAu** collisions

Figure 5: The prototype **SMD** module of 16 photomultiplier

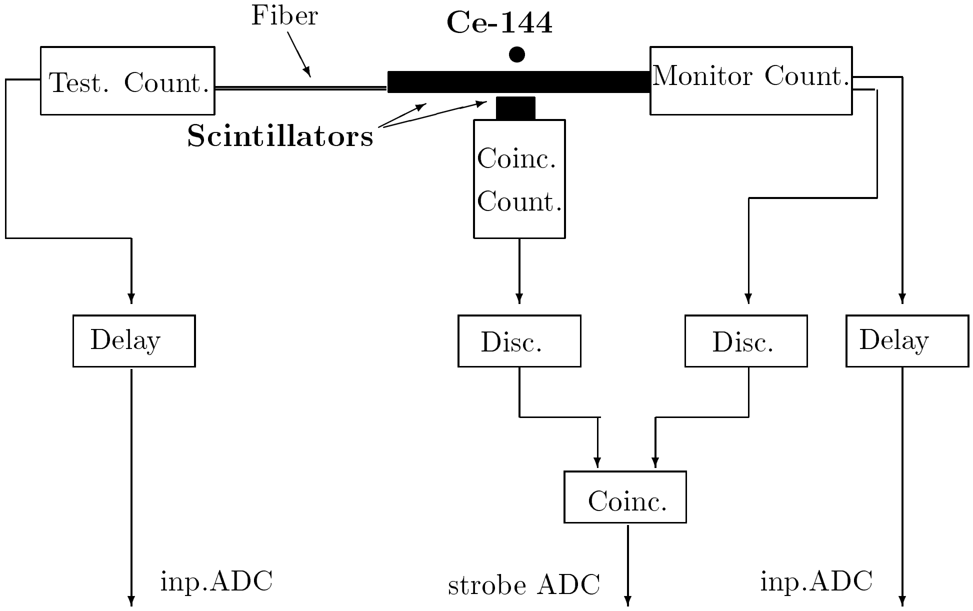

Figure 6: The experimental setup and logic of the test measurements

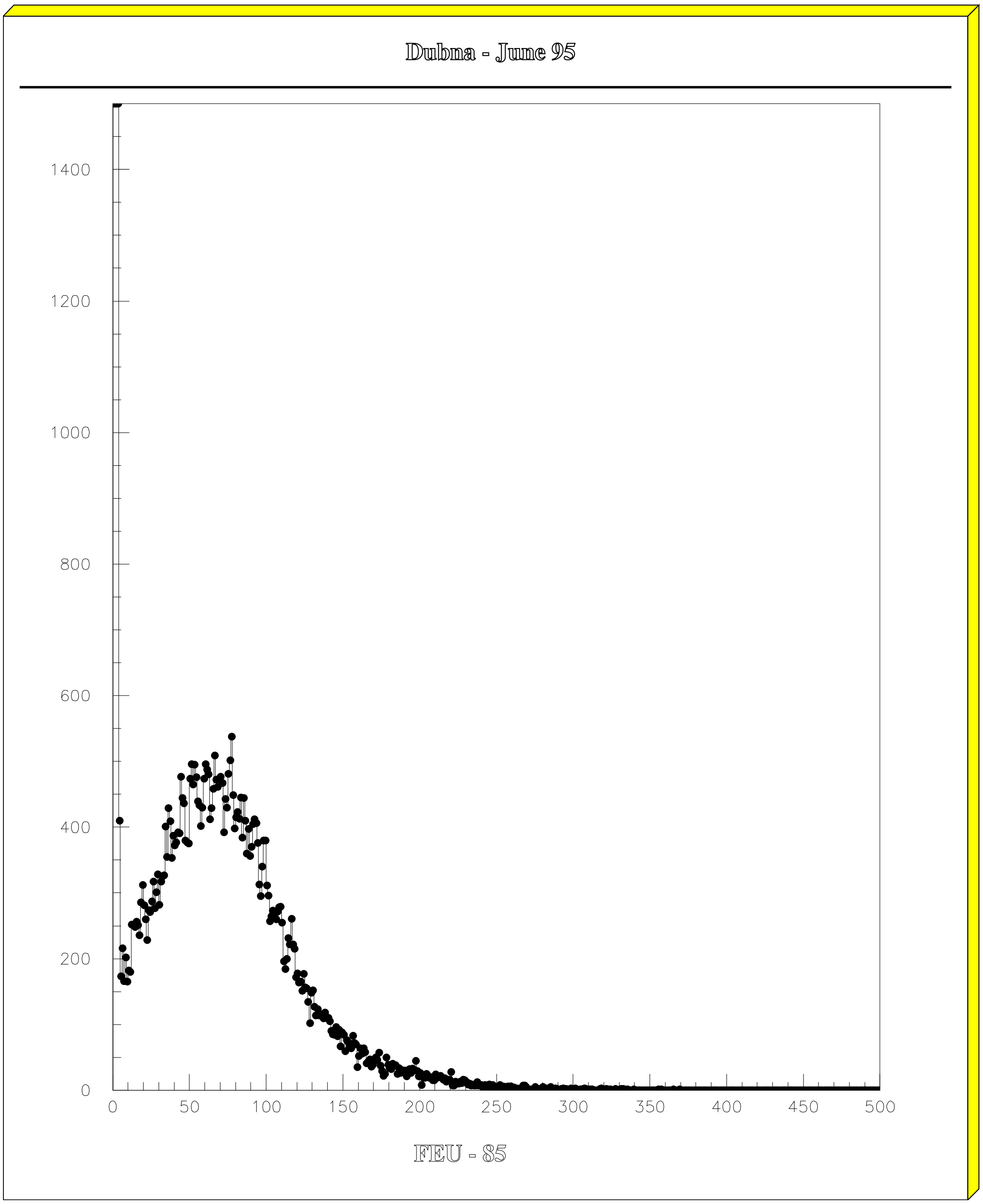

Figure 7: The **ADC** pulse heights distribution measured with FEU-85

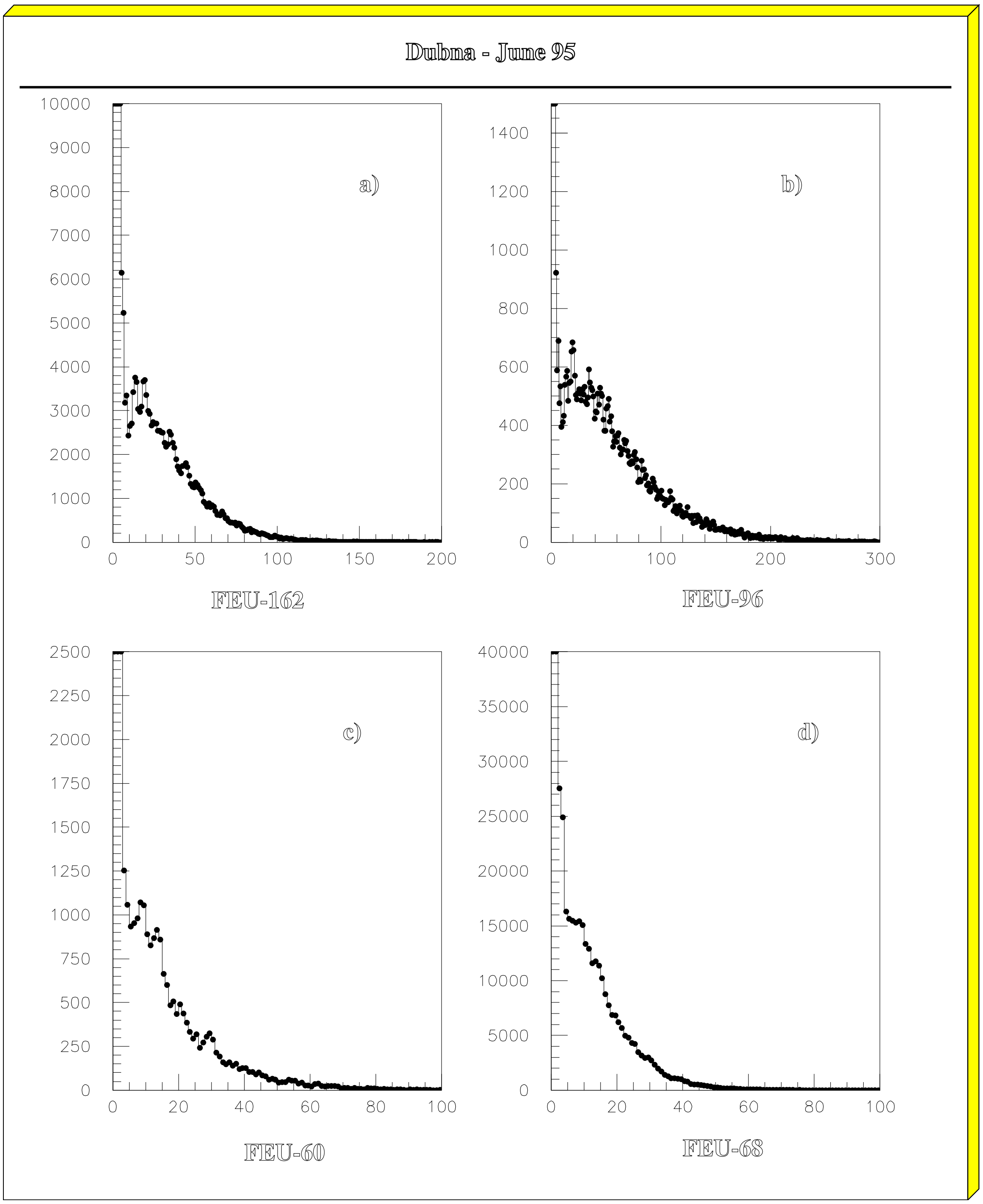

Figure 8: The same as in **Fig.7** for the FEU-162, FEU-96, FEU-60 and FEU-68