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A Pb SAMPLING e-γ CALORIMETER USING GLASS SPARK COUNTERS

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ABSTRACT

The possibility of using glass spark counters as active detectors in a Pb-sampling digital calorimeter for low energy γ has been investigated. The energy response and resolution using photons ranging between 40 and 80 MeV have been measured

INTRODUCTION

The development of the spark counter started from the idea, introduced by M.V.Babykin et al. in 1956(1), to use a resistive material for at least one electrode in a spark gap. In such a way, one spark discharges only a limited area around the spark. The recovery time of the electric field, depending on the electrode resistivity, avoids self sustaining sparking(2). The relevant features of this kind of detector are the good time resolution and the accurate spatial resolution(3).

A proper design of the detector allows noiseless operation in a wide H.V. range(4,5), i.e. sparks are generated only if an ionizing particle passes through the gap. This property is of extreme importance in large apparatus, because it allows easy monitoring and calibration by performing single counting rate measurements.

A new type of spark counter was developed by our group(5). The electrodes are made of glass with a volume resistivity of about 10^{12} Ωcm. The detectors, operating at atmospheric pressure, are noiseless and show a time resolution of less than 1 ns in a wide H.V. region.

In this paper we have investigated the possibility of using glass spark counters (GSC) as active detectors in a Pb-sampling calorimeter for low energy γ. The basic idea is that counting the numbers of sparks is equivalent to count sampled tracks and therefore to measure shower energy. Then a simple hit counting (digital read-out) of the shower pattern gives the shower energy with a good resolution in the low energy range, because of the low shower track density. In addition this method easily allows the event reconstruction with an accuracy depending essentially on the sampling density and on the granularity of the calorimeter.

The digital read-out allows a good calibration stability of the calorimeter response because of its slight dependence on the working parameters (i.e. HV, gas mixture, temperature and pressure conditions).

The feasibility of a GSC calorimeter has been investigated using tagged photons in the range of 40-80 MeV at the LADON beam(6) facility at the Laboratori Nazionali di Frascati.

GLASS ELECTRODE SPARK COUNTER

A sketch of the GSC used in the calorimeter is shown in Fig. 1. The parallel electrodes are made of commercial float glass with a volume resistivity of about 10^{12} Ωcm, and a thickness of 2 mm. The glass surfaces not facing the gas are varnished by a commercial solution of graphite in water, in order to supply the high voltage. A glass-epoxy frame, 1.6 mm thick and 10 mm wide, delimits the active surface of 20x20 cm^2. The gas flows at atmospheric pressure through two inlets in the frame. A 0.1 mm mylar sheet is interposed between each varnished surface of the electrodes and 16 parallel aluminium strips, 1 cm spacing, that pick up the transient signals associated with the sparks(7). The strips are glued to a 1mm sheet of PVC, acting as dielectric and mechanical support. On the surface of the PVC sheet not facing the detector, an aluminium foils is applied. The strips are connected to the electronics, while the aluminium foils are connected to the ground. Strips mounted on the opposite side are orthogonal in order to perform a bi-dimensional spark localization. The two pick-up planes give pulses of opposite sign. The high voltage is supplied symmetrically with respect to the ground. The gas mixture used is Ar (60%) + C_4H_{10} (38%) + Freon 13B1 (2%).

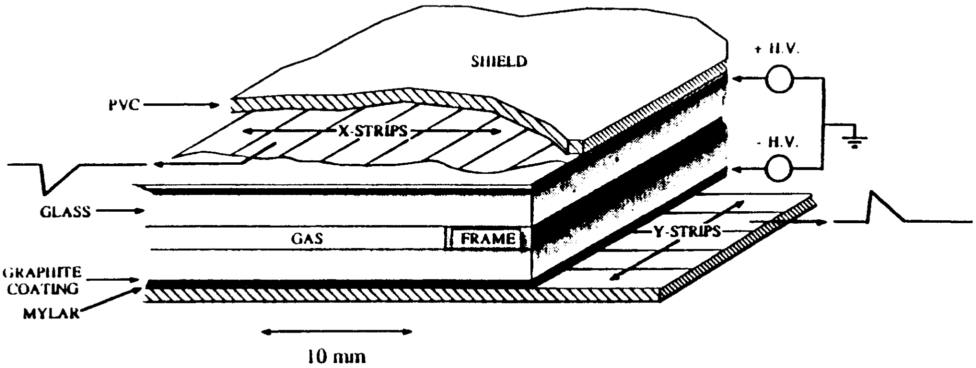


FIG. 1 - Sketch of a glass spark counter prototype.

Fig. 2 shows a typical single counting rate plateau as a function of high voltage. A plateau region of about 1.5 kV is clearly visible. Both cosmic rays and local radioactivity contribute to the plateau level. The efficiency of the detector as a function of high voltage is shown in Fig. 3. The efficiency plateau corresponds to that of the single counting rate, thus reflecting the noiseless operation of the GSC. Time resolution as a function of high voltage is shown in Fig. 4. In the operation range corresponding to the single counting plateau region, a time resolution less than 1 ns is easily achievable.

The estimated dead zone is of the order of ten square millimeters in the plateau region.

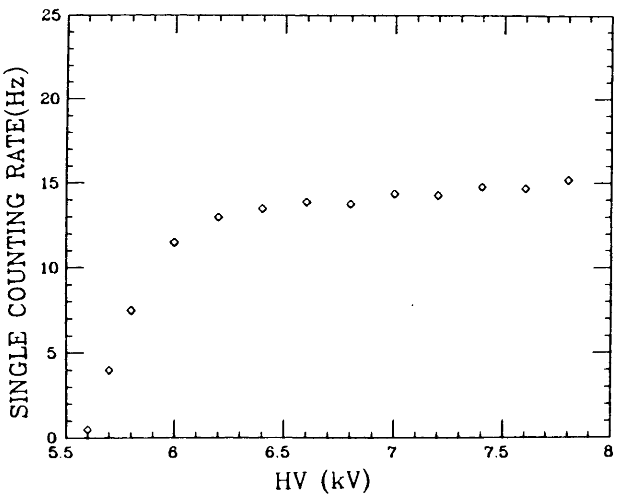


FIG. 2 - Single counting rate as a function of high voltage.

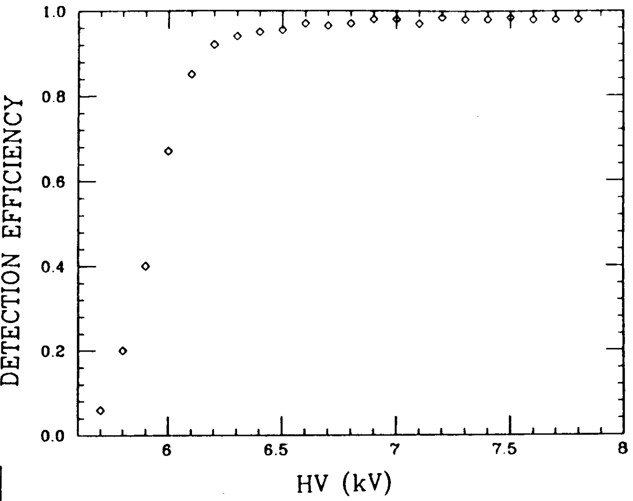


FIG. 3 - Detection efficiency as a function of high voltage.

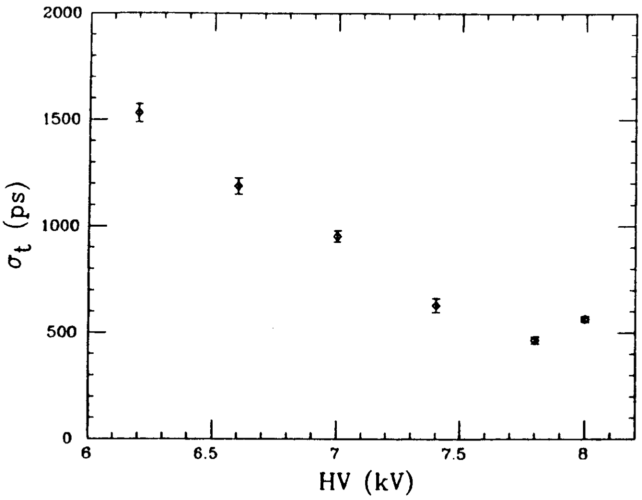


FIG. 4 - Time resolution as a function of high voltage.

LADON BEAM FACILITY

Backward Compton scattering of an Ar laser light ($E\gamma = 2.41eV$) against the high energy electrons circulating in the ADONE storage ring produces the γ ray LADON beam$^{(6)}$. An electron energy beam of 1.5 GeV corresponds to backward scattered photons in the range 20–80 MeV.

An internal tagging of the scattered electrons, momentum analyzed by the magnets and quadrupoles of the storage ring , permits to obtain a γ energy resolution better than 1 MeV at 80 MeV. The internal tagging counters consist of a solid state microstrip detector (μSD) composed of 96 vertical strips with a pitch of 0.55 mm, backed by a fast plastic scintillator viewed by a photomultiplier.

The spectrum of the gamma rays is measured with a magnetic pair spectrometer and monitored with a large NaI (Tl) detector located in the experimental hall.

EXPERIMENTAL SET-UP

Fig. 5 shows the experimental set-up. A 25 mm thick lead absorber is placed in front the collimator to reduce the photon beam intensity, because of the low rate capability of the GSC realized with commercial high resistivity float glass electrodes(5). The toroidal magnet, shown in the picture, is used to clean the beam from charged particles.

Furthermore, we have placed two counters in front of the calorimeter as a veto for charged particles.

A picture of the calorimeter is shown in Fig. 6. It consists of 50 GSCs interleaved by a 1 mm thick Pb radiator foil, for a total radiation length of about 10 X_0. The sixteen parallel strips of each pick-up plane are connected to the front end digital SGS cards[1]. A total of 1600 digital channels (800 X + 800 Y) was read-out.

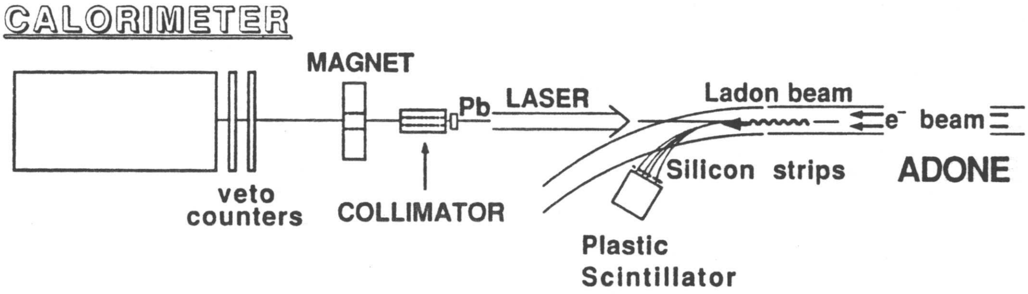
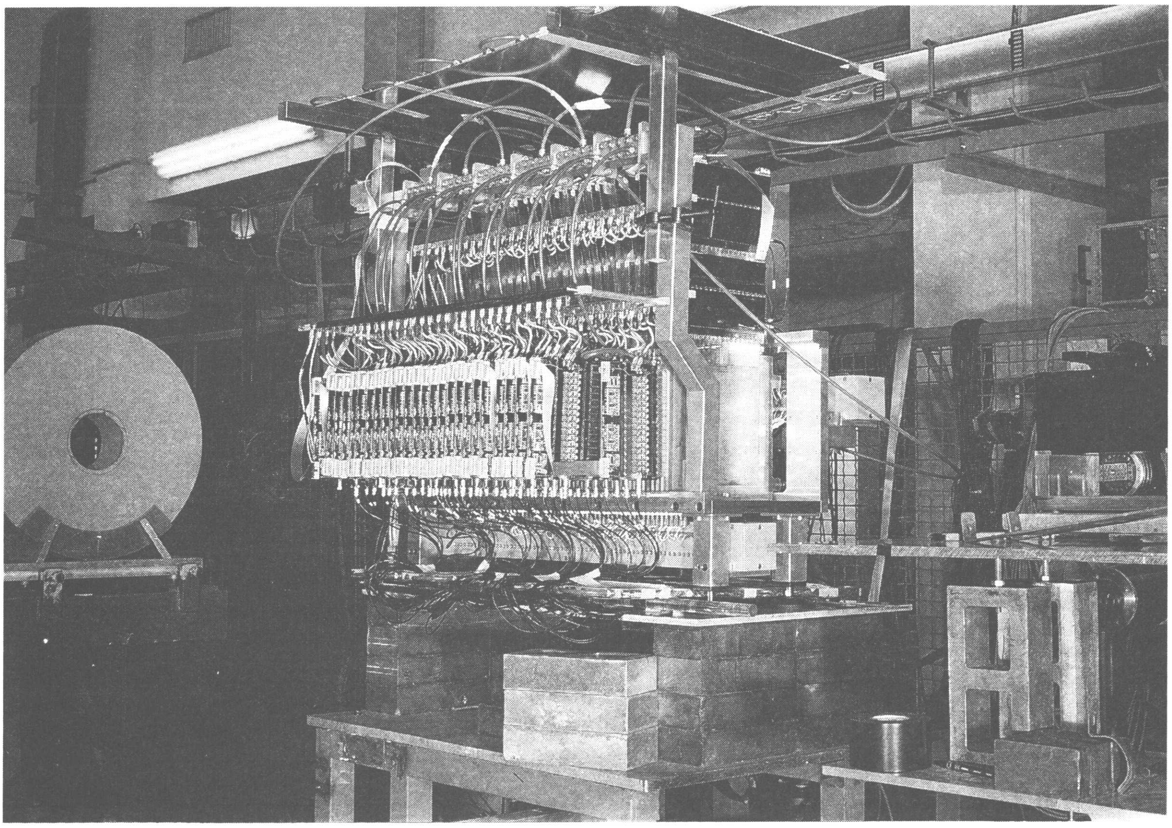


FIG. 5 - Sketch of the experimental layout.



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[1] These cards were developed by SGS Company for the strip read-out of the ALEPH Hadron Calorimeter.

In Fig. 7 the block diagram of the acquisition system is shown . The trigger is defined by the coincidence between the plastic scintillator and the signal from a majority circuit, that occurs when at least 2 planes are fired. The anticoincidence with the OR signal coming from the veto counters is also required.

The acquisition system is constituted by a STOS module for SGS card read-out, two latch register modules for tagging μSD read-out and one TDC to measure the time difference between a prompt signal derived from the calorimeter (independently of digital read-out electronics) and the plastic scintillator one.

The H.V. supplied to the GSC detectors was 6.4 kV.

The data read-out is performed by a Macintosh II computer. A Hypercard stack based on Hippocampus (8) controls the whole system.

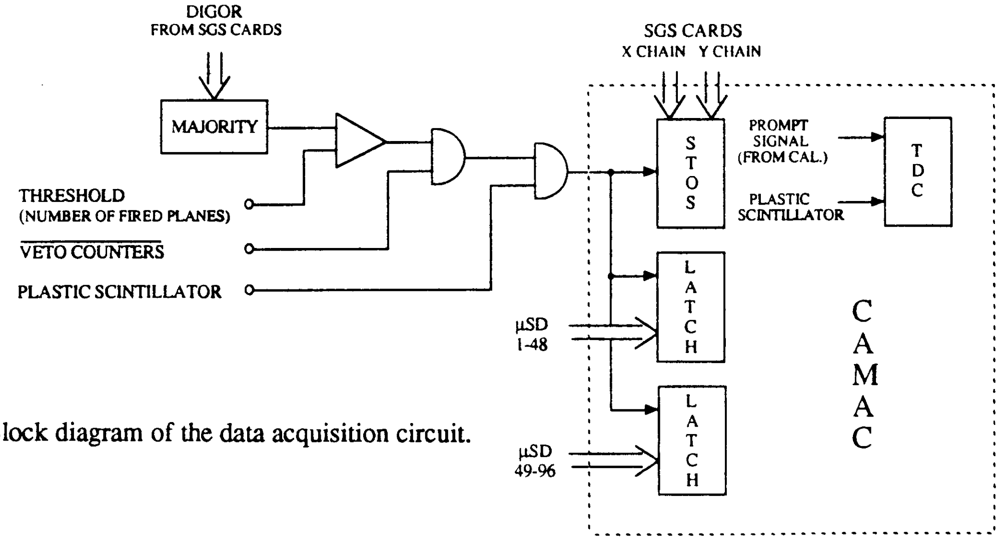


FIG. 7 - Block diagram of the data acquisition circuit.

EXPERIMENTAL RESULTS

In our test, background is mainly due to cosmic rays. The events have been selected with the following requirements:

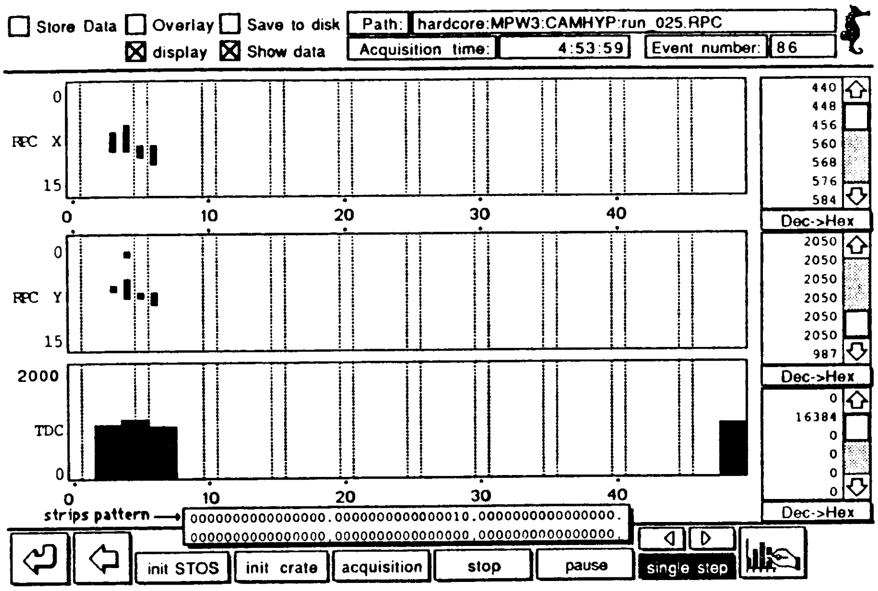
a) the time coincidence between the plastic scintillator and the calorimeter prompt signal inside a window of ± 15 ns;

b) the right tagging.

The residual background is less than 1%. No further cuts were performed on the selected events.

A typical event coming from the on-line monitoring display is depicted in Fig. 8. As an example in Fig. 9 we report the hit distribution obtained from events with an energy of 75 ± 5 MeV. The average number of planes versus the beam energy is reported in Fig. 10.

Fig. 11 shows the average number of hits in one of the views as a function of the photon energy. The hit response shows a good linearity with the energy, and a calibration constant of 0.243 ± 0.002 hits/MeV is obtained. In Fig. 12 the energy resolution as a function of the photon energy is reported. The resolution of $8.6\%/(E(GeV))^{1/2}$ is essentially limited by sampling fluctuations. Only statistical errors are reported in the plot.



☐ Store Data ☐ Overlay ☐ Save to disk

☒ display ☒ Show data

Path: hardcore:MPW3:CAMHYP:run_025.RPC

Acquisition time: 4:53:59

Event number: 86

strips pattern →

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0000000000000000.0000000000000010.0000000000000000.
0000000000000000.0000000000000000.0000000000000000.
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FIG. 8 - A 48 MeV photon event (from the on-line computer display).

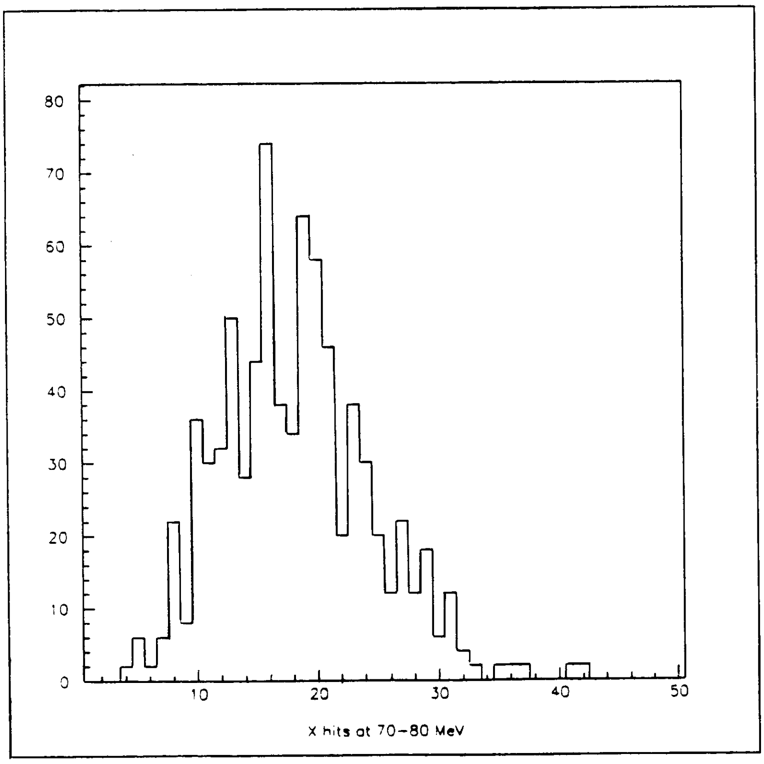

FIG. 9 - Hit distribution for 75±5 MeV energy photons.

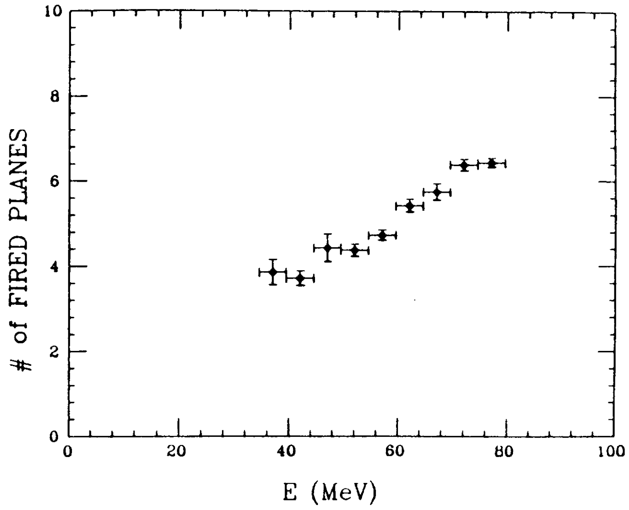

FIG. 10 - Average number of the fired planes as a function of the photon energy. Only statistical errors are reported.

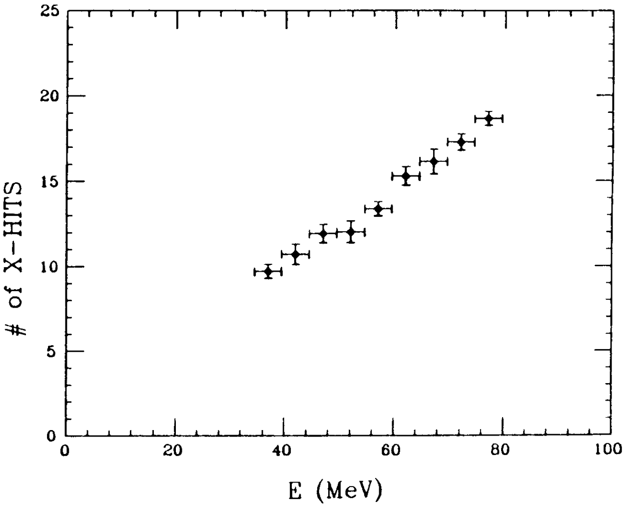

FIG. 11 - Average number of the fired strips in one view as a function of the photon energy. Only statistical errors are reported.

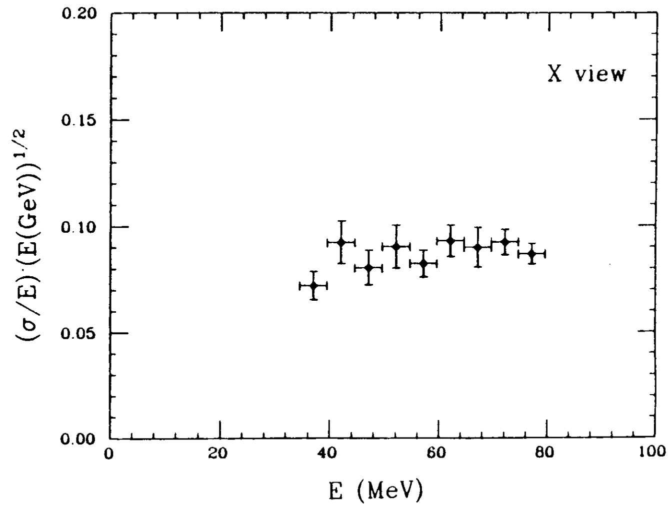

FIG. 12 - $(\sigma/E)\cdot(E(\mathrm{GeV}))^{1/2}$ as a function of the photon energy.

CONCLUSIONS

Our measurement shows that digital calorimetry with spark counters can be done with good linearity. The energy resolution depends essentially on the sampling density and on the pick-up granularity. The digital read-out is cheap, and permits a very fine reconstruction of the shower event.

It is important to outline that a good rejection of the background has been obtained only on the basis of time rejection due to the good time resolution of the detector.

The advantages that the GSC calorimeter offers are manifold:

a) a good calibration stability, allowed by the possibility of using digital read-out;
b) an easy monitoring and calibration, based on single counting rate measurements;
c) the high modularity and then the possibility of realizing particular chamber geometries;
d) good performances at a good price.

The possibility to tune the glass resistivity varying its composition allows to reach a very high particle flux without saturation effects. As an example, glass with a volume resistivity of the order of 10^{10} Ωcm is able to work at particle fluxes on the order of 10^6 particles $sec^{-1}m^{-2}$. The excellent planarity and the dielectric homogeneity of the glass is encouraging in building large area detectors with the same performances mentioned above. Work in this direction is in progress.

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