ISTITUTO NAZIONALE DI FISICA NUCLEARE
Laboratori Nazionali di Frascati

Sezione di Pisa

INFN/TC-86/17
27 Novembre 1986

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Results of a test on the SGS digital strip readout electronics for limited streamer tubes

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1. Introduction.

Many new high energy physics experiments, among which for instance SLD at SLC, ALEPH and OPAL at LEP, the neutron oscillation experiment at the Grenoble reactor, MACRO and LVD in the Gran Sasso tunnel, are going to use iron sampling hadronic calorimeters the active elements of which are plastic tubes operated in limited streamer mode, the so-called "Iarocci tubes" (Ref.1). Also common to the above experiments is the double readout scheme devised for the calorimeters: in addition to analog "pads", arranged in projective towers and meant to reconstruct the energy deposition in the underlying streamer tubes counting the number of streamers generated, measuring the charge induced on external electrodes, pattern recognition and possibly muon tracking capabilities are retained by adding, on the opposite side of the chambers, another set of external electrodes, the so-called "strips", running parallel to the wires (see Fig.1). The induced signal on the strips can be discriminated upon to establish whether a streamer (or more than one) has occurred in the corresponding tube.

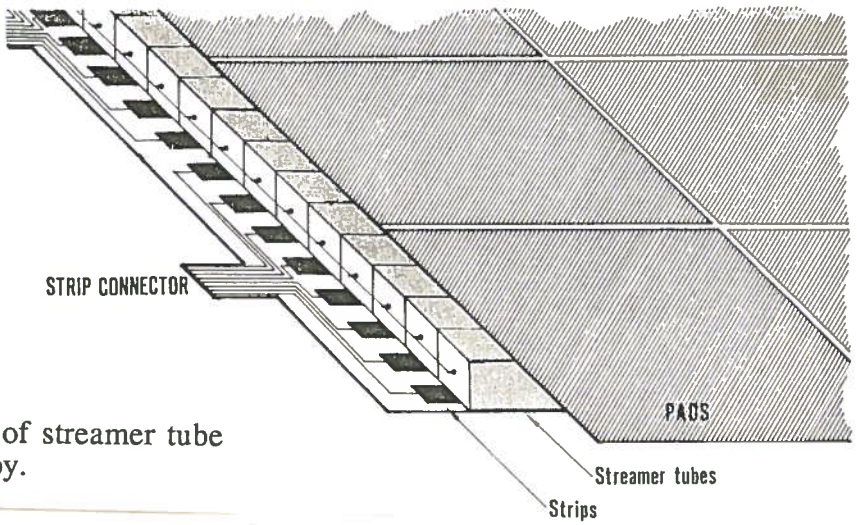

FIG. 1 - Schematic drawing of streamer tube and external electrode assemby.

The high number of wires (the aforementioned calorimeters will have typically 10^5 channels) and therefore of strips makes it unpractical and uneconomical to have an analog readout of the strips information. Hence, the choice has been made by all the above collaborations to have a simple "hit/no hit" information from each strip (which can then be coded in a binary bit, achieving the additional benefit of more compact raw data and easier on-line pattern recognition operations).

Given the massive participation of Italian institutions in the construction of the above devices, our Istituto Nazionale per la Fisica Nucleare (I.N.F.N.) has commissioned a custom-design chip from SGS, containing 4 discriminators and a 4-bit shift-register (see Fig.2) and having daisy-chaining capabilities.

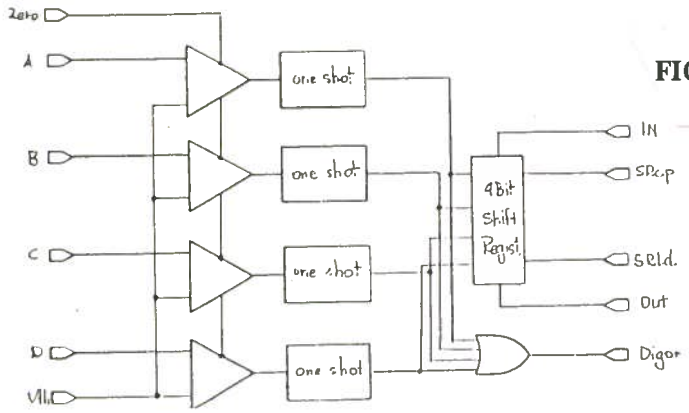

FIG. 2 - Block diagram of the SGS D779 chip.

It has been shown (Ref.2) that the CMOS D779 chip developed by SGS needs an external preamplification stage in front of the chip to safely handle the required threshold settings. The subsequent solution proposed by SGS is based on a dual-in-line hybrid package containing a D779 chip coupled to four preamplifiers as shown in Fig.3.

The first prototypes of a 32-channels board with eight of these hybrids have been delivered by SGS recently (end of June 86). We have then tested this board extensively both with signals coming from a pulse generator and from the strips of a streamer tube prototype chamber. This note describes the status and results of these tests.

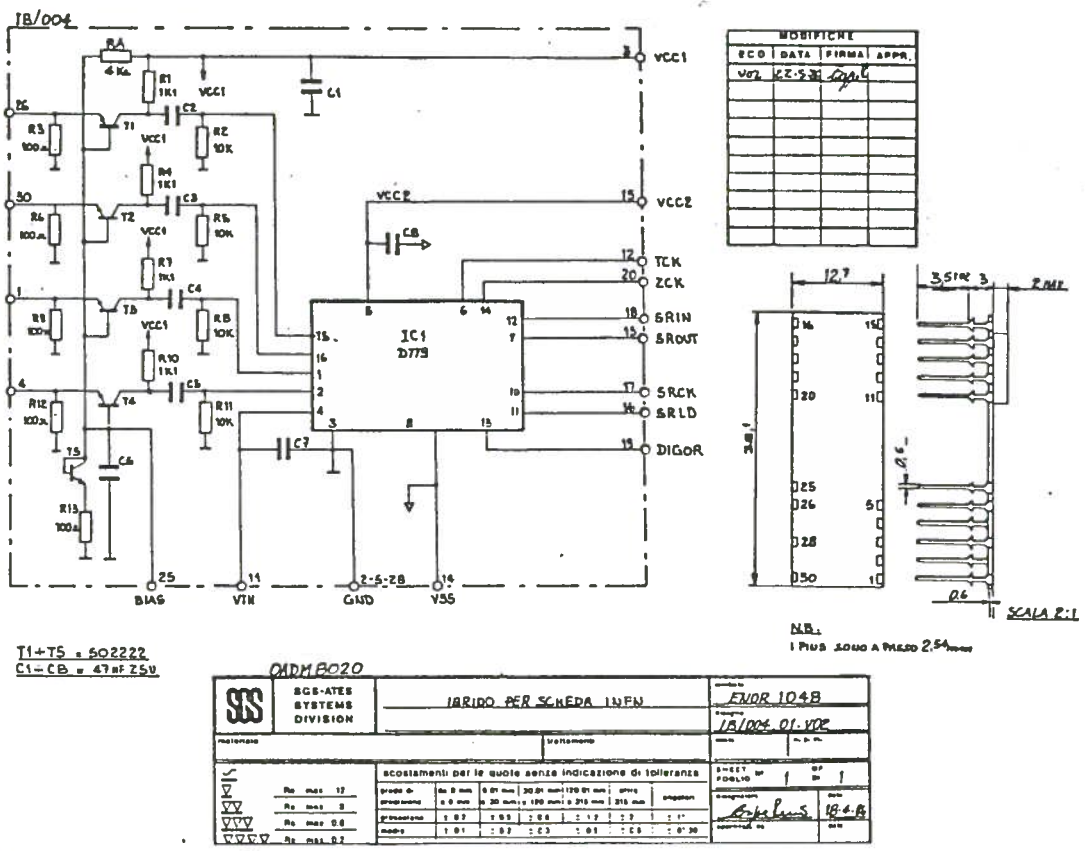

FIG. 3 -Schematic of the SGS hybrid.

2. Test procedure and results.

Signals from a pulse generator or from streamer tube strips are sent to the inputs of a SGS board, preamplified, discriminated and, if a trigger has in the meantime occurred, also loaded into the shift-register chain. The data is then read out by an intelligent controller based on the TMS 9995 microprocessor (3).

The shift-register chain of the prototype board has been thoroughly tested sending many different patterns of data at the beginning of the chain and shifting them up to the end at a clock frequency of 1.5 MHz. In the prototype under test the bit configuration read out always resulted identical to the input pattern.

2.1. Tests with the pulse generator.

In the tests performed with the pulse generator the positive input signals were generated with a triangular shape, a leading edge of 5 nsec and a trailing edge of 50 nsec, in order to reproduce a pulse similar to the one expected from a strip facing a streamer tube. In Fig.4 the threshold voltage V_{th} (mV) required to obtain full efficiency on the bit setting of the shift-register is shown as a function of the pulse-height V_{in} (mV/50 Ω) of the

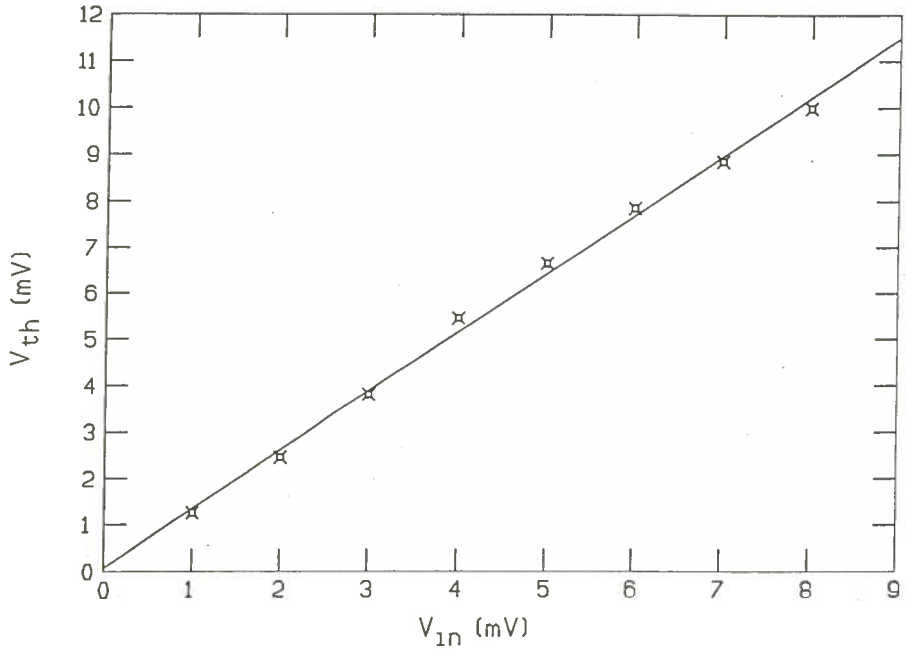

FIG. 4 - Threshold voltage V_{th} required to obtain full efficiency as a function of the pulse-height value V_{in} (mV/50Ω) of the input signal.

input signal. The curve shows good linearity between the two quantities and provides the definition of the threshold value. In Fig.5 a typical efficiency curve is plotted as a function

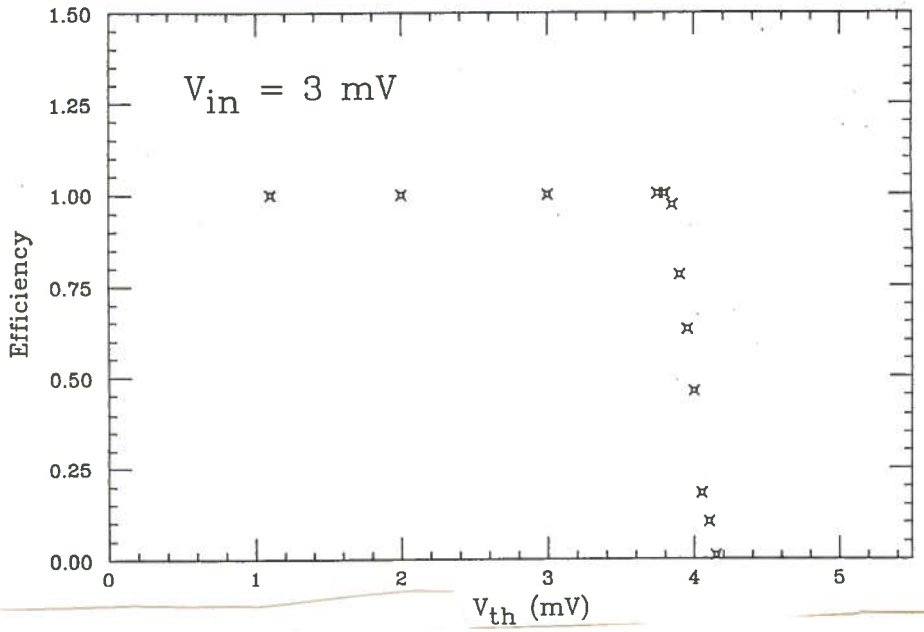

FIG. 5 - Efficiency curve as a function of threshold voltage V_{th} for an input signal $V_{in} \sim 3$ mV.

of the threshold voltage V_{th} for an input signal with a pulse-height value V_{in} of ~ 3 mV. In Fig.6 the same curve is shown with the minimum threshold value that can be safely handled (down to ~ 1 mV/50 Ω). A detailed comparison of the efficiency curves for eight contiguous channels of a board belonging to two different hybrids is done in Fig.7. The

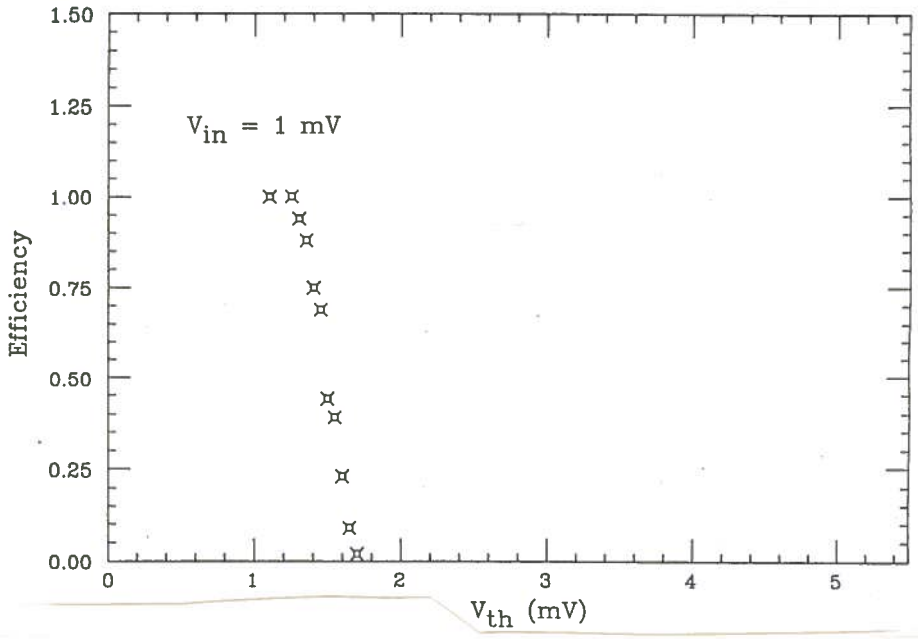

FIG. 6 - Same as Fig. 5 when $V_{in} \sim 1$ mV.

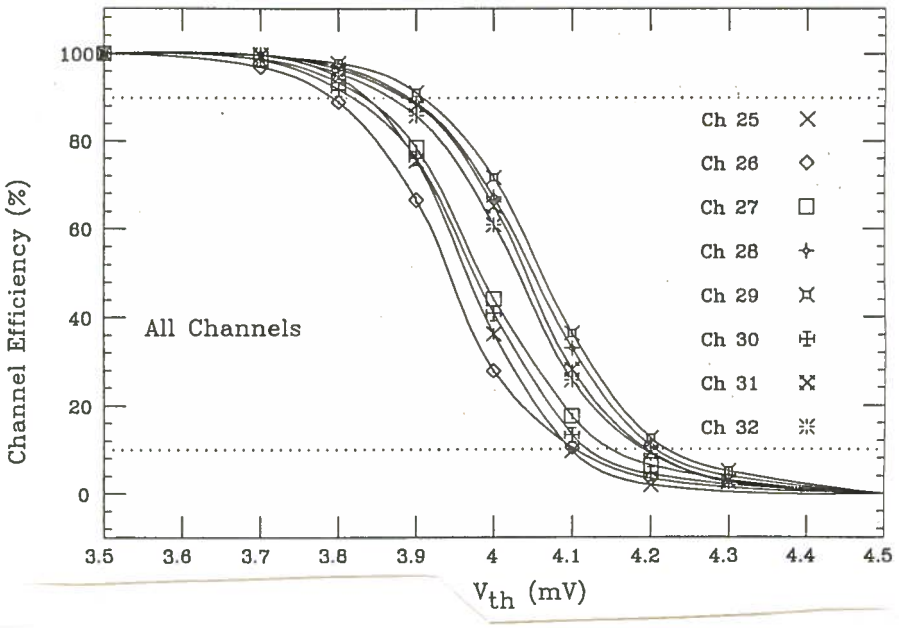

FIG. 7 - Efficiency curves for eight contiguous channels.

efficiency changes from zero to one when V_{th} changes by only few tenths of a mV. The differences between the curves of different channels, even if belonging to different hybrids in the same board, are usually negligible as shown in the previous figure. However, the response of different channels belonging to different boards to the same input signal may differ by even up to $\sim$ 1 mV, as shown in Fig.8. Since it is possible to individually set the threshold value for each board this may not be a serious problem. The problem could be more serious should those differences be present between different hybrids on a same board. This however was not the case for the few prototypes we had in our hands.

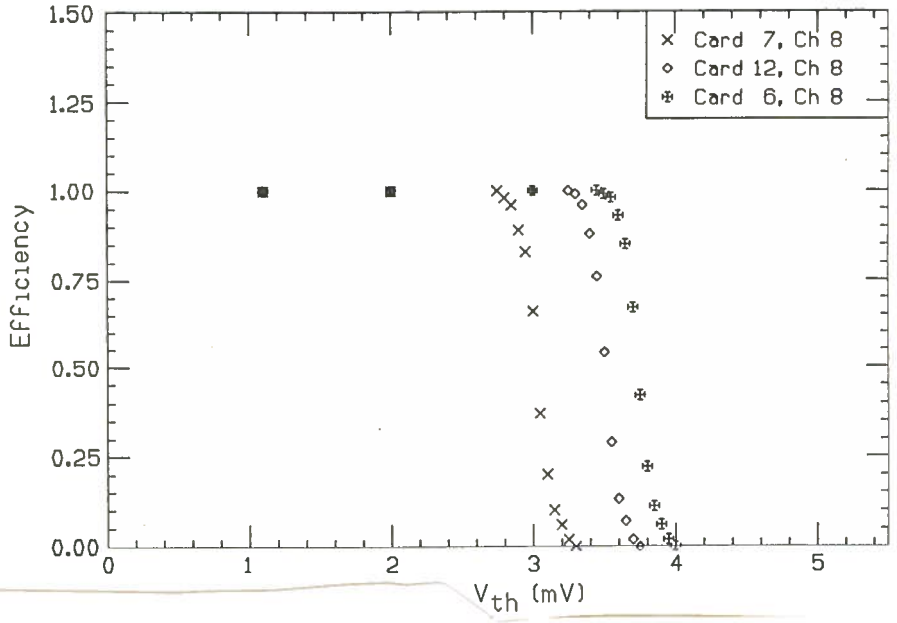

FIG. 8 - Comparison between the efficiency curves of three different channels belonging to three different boards.

2.2. Tests with strip pulses.

After these preliminary (but satisfactory) tests with the pulse generator, we studied the response of the SGS boards to the real pulse-height spectrum coming from the strips of a chamber. The first setup was assembled in our laboratory in Pisa and consisted of a streamer tube chamber 1.5 m long with the strips ends shaped as foreseen (see Fig.1) for the SLD experiment (Ref.4). The strips of the chamber were connected to the inputs of the board through a standard flat cable 1.5 m long to simulate the experimental conditions in SLD. The coincidence of two very thin finger counters (1 mm thick) was used as trigger both with cosmic rays and with a Ruthenium source. As shown in Fig.9, the trigger configuration selected a particular wire corresponding to a well defined bit in the shift-register of the board.

The gas mixture used was the standard 75% Isobutane and 25% Argon which is the current choice for the SLD device. Setting the high voltage at +4650 V to insure that the tubes were operating in limited streamer mode, the threshold curve shown in Fig.10

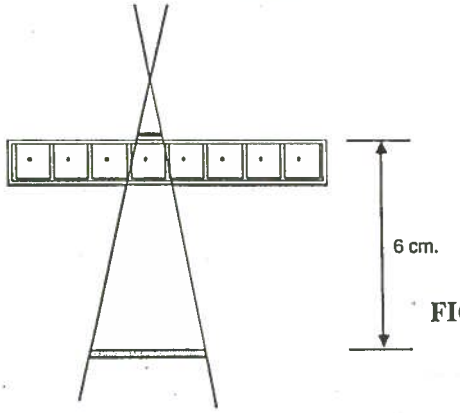

FIG. 9 - Trigger telescope for cosmic rays and Ruthenium source.

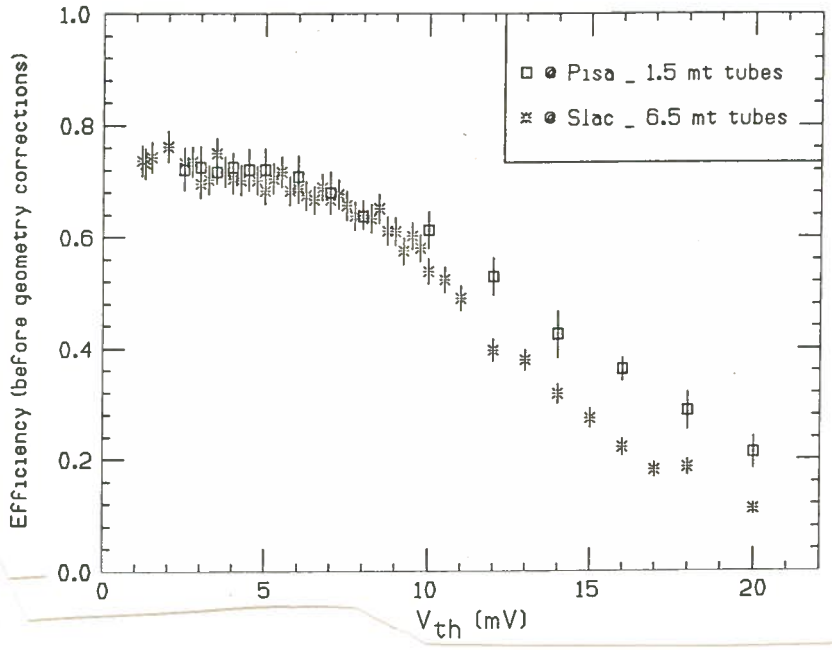

FIG. 10 - Efficiency curves for strips of streamer chambers operated at +4650 V, as a function of threshold voltage V_{th}.

as square points was obtained. The observed plateau is rather large and extends up to V_{th} values of $\sim$ 7 mV. The conclusion drawn is that when tubes are operated in limited streamer mode, rather conservative threshold settings can be chosen to guarantee full efficiency in the strip readout.

A more extensive study was performed at SLAC on a full-size (6.5 m long) chamber. Since the above mentioned processor (Ref.3) was not available for this test, instead of reading the contents of each individual shift-register loaded by the trigger, the digital OR signal provided on the board was set in coincidence with a cosmic ray trigger and then counted on a scaler. The trigger consisted of a four-fold coincidence of scintillation counters and was counted on a separate scaler. The solid angle covered by the cosmic rays telescope was large enough to cover more than a complete module of eight tubes and consequently the geometrical acceptance of the module under test was $\sim$ 75% of the trigger acceptance. The accuracy of the gas mixture (still 75% Isobutane and 25% Argon) was guaranteed to within 0.5 % by a precision mass-flowmeter. The threshold curve obtained under these conditions with the chamber operating at 4650 V is shown in Fig.10 as cross-points. The plateau level corresponds to full efficiency in the strips readout.

The similarity of this result with the one obtained in Pisa and previously described (also shown in Fig.10 after a relative normalization) indicates that the information provided by the digital OR reflects the contents of each individual shift-register (as already tested with the pulse generator) even with the pulse-height distribution from the strips of a full size streamer chamber.

A systematic study of the dependence of the threshold curve upon the high voltage applied to the chamber was also carried on. Detailed plots for each individual HV setting ranging from 4100 to 4700 V are shown in Figg. 11 and 12.

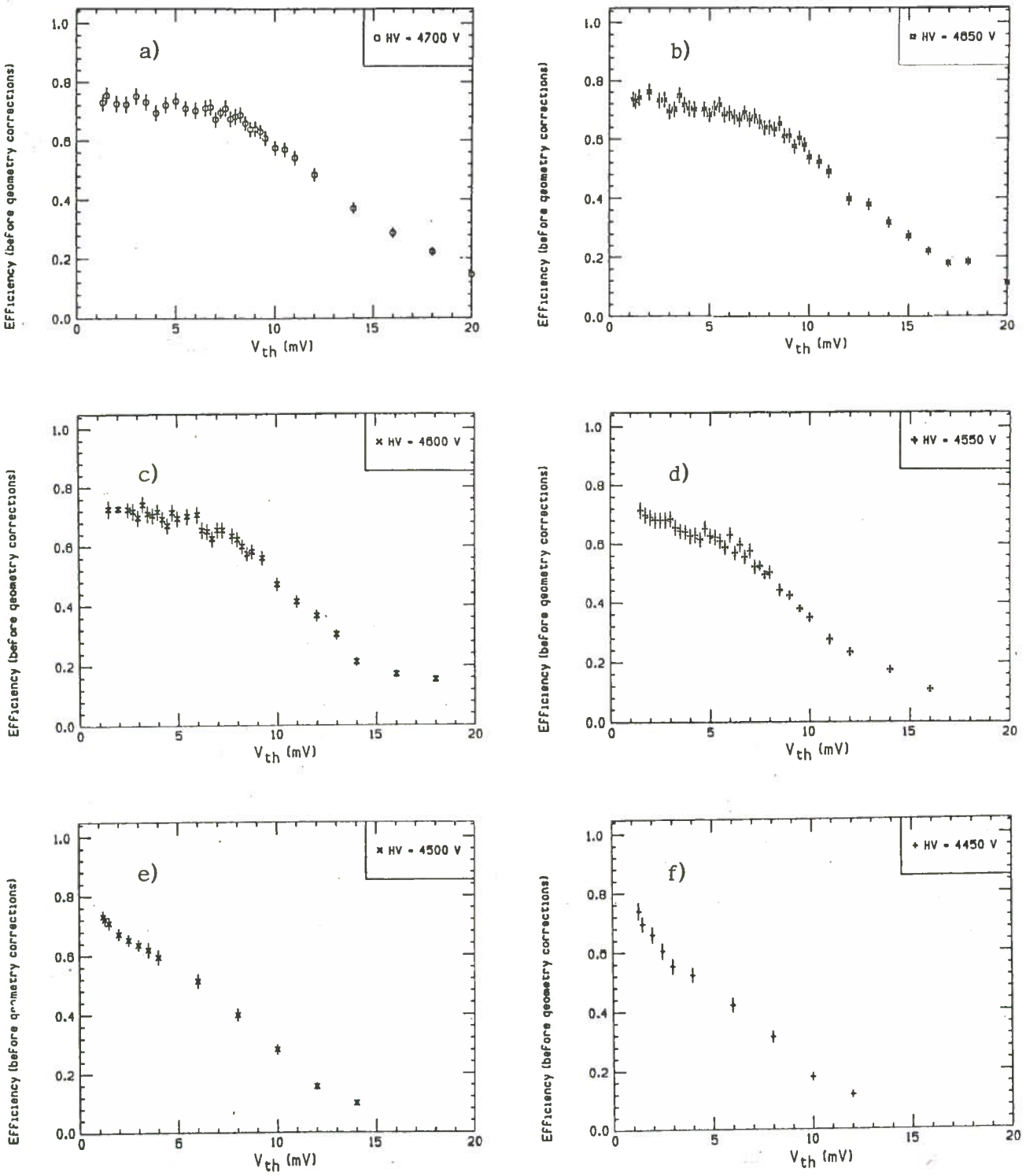

FIG. 11 - Efficiency curves for strips of a chamber with HV setting ranging from 4450 to 4700 V, as a function of threshold voltage V_{th}.

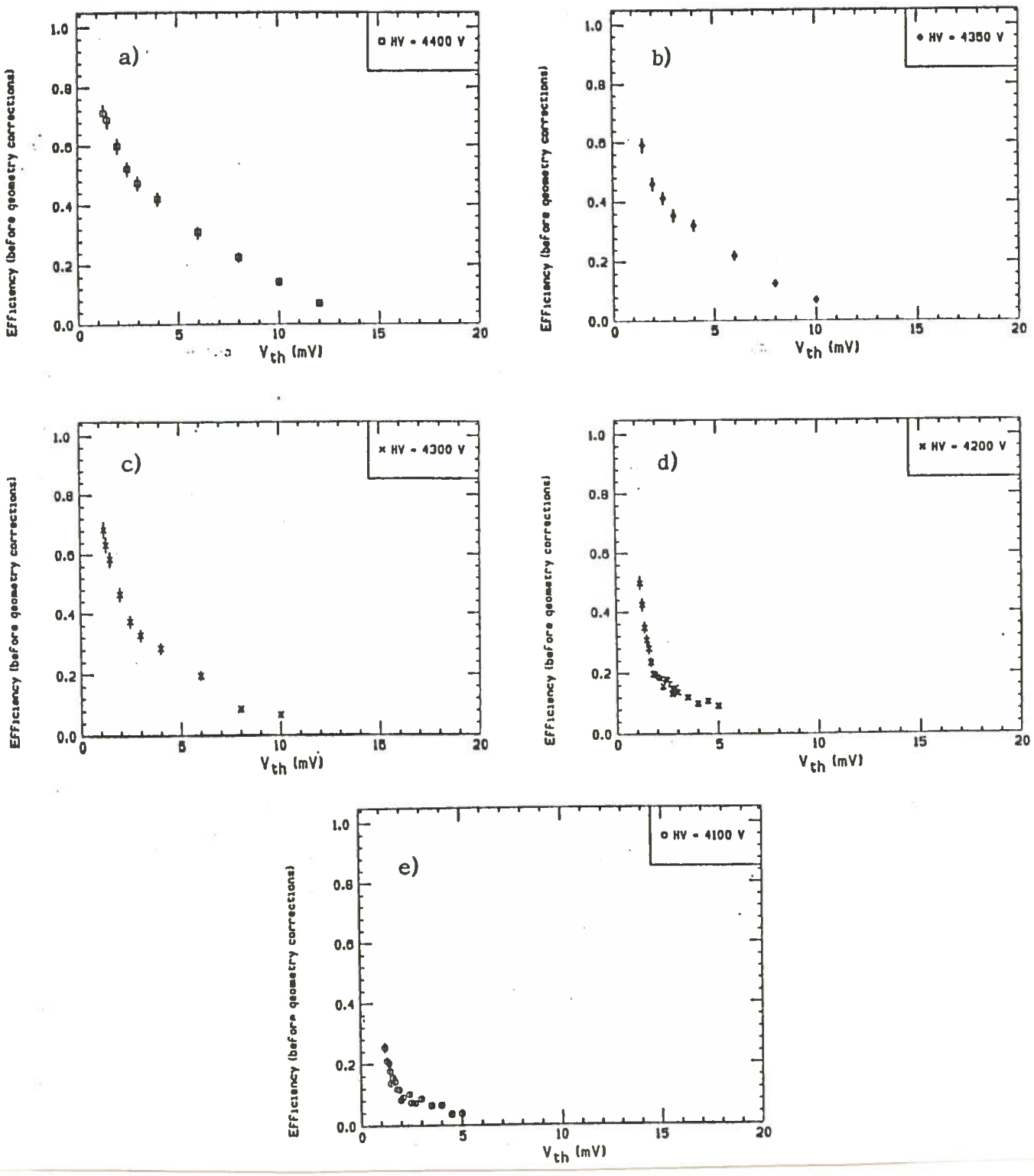

FIG. 12 - Same as Fig. 11 for a HV range from 4100 to 4400 V.

Fig.13 shows for comparison the simultaneous plot of all the data collected. In this figure the experimental points referring to the settings from 4200 to 4650 V have been omitted while the curves are smoothed interpolations of the data.

In the range from 4600 up to 4700 V, where the chamber is operating fully in limited streamer mode, a large and safe plateau is clearly visible while it suddenly disappears as the voltage is lowered. This pattern is probably due to the onset, at lower voltages, of the proportional regime, the pulse-height spectrum of which extends down to much lower values than in the streamer mode.

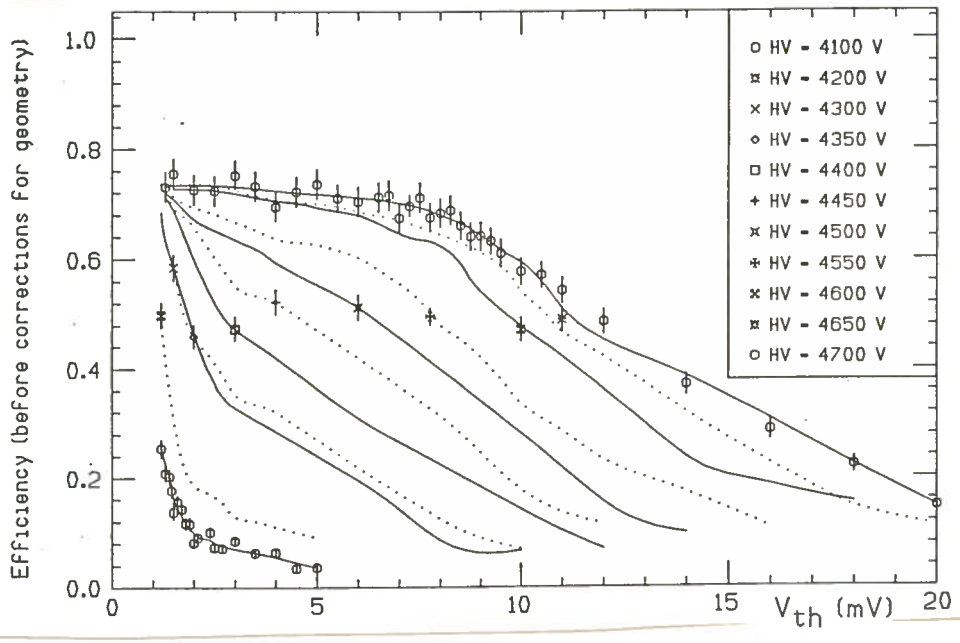

FIG. 13 - Comparison between efficiency curves with HV settings ranging from 4100 to 4700 V.

3. Conclusions.

The results of the tests previously described on the first boards delivered by SGS are rather satisfactory. Of course when the proportional regime, as the chamber operating voltage is lowered, starts to "contaminate" the limited streamer spectrum, this hybrid may not be adequate to reach the very low threshold values required.

While a longer term test program is going on, we can already state that this front-end electronics developed by SGS can be safely used for the digital readout of the strip information from a chamber operated in limited streamer mode.

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