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**SELF-QUENCHING STREAMER-TUBE DETECTORS
IN THE WA80 EXPERIMENT**

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Self-quenching streamer-tube detectors in the WA80 experiment

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Abstract

The copious production of charged particles in nucleus-nucleus collisions at SPS energies necessitated new technical solutions for charged-particle measurements. We describe the construction and performance of the streamer-tube detectors used in the experiment WA80 at CERN. Special attention is given to the developed electronic readout system with serial transmission of data from more than 40 000 readout pads. About 100 events per beam spill were collected during data taking. For each event the full angular information is recorded for charged particles with polar angles: $2^\circ < \theta < 29^\circ$.

(Submitted to Nuclear Instruments and Methods A)

1. Introduction

The multiplicity detectors in the WA80 experiment¹ at CERN are built to handle the high multiplicity of charged particles from oxygen- and sulphur-induced nuclear interactions at the CERN SPS energies. They have been used for data taking during the 1987-1988 periods of proton and sulphur runs and, in a slightly different configuration than described here, during the oxygen runs at the end of 1986². The multiplicity detectors are based on larrocchi-type wire detectors running in the self-quenching streamer

mode³. This detector type is lately much used in high-energy experiments, especially in the experimental set-ups at the clashing beam machine LEP⁴.

The multiplicity detectors consist of three arrays, each with an approximate area of $3 \cdot 3 \text{ m}^2$, and a fourth, smaller one, of size $1.5 \cdot 1 \text{ m}^2$. The detectors cover, with double layers, the polar angles $2^\circ < \theta < 29^\circ$ with full acceptance in azimuthal angle. In Fig. 1 a picture of one of the detector planes is shown. Charged-particle multiplicities and angular information of the particles are recorded event-by-event. The streamer-tube detectors are read out by means of capacitively coupled pads. The total number of pads is about 43 000 in the present configuration. The information from these channels is binary, "hit" = 1 or "no hit" = 0. A CAMAC-based serial readout system provides an easy handling of the large number of channels. Apart from providing angular information on the charged particles they also serve as veto-detectors for the lead-glass photon detector¹ and aid in the interpretation of data taken by the calorimeters¹ in the WA80 set-up (See Fig. 2). The wire signals from the streamer tubes provide a fast trigger signal for the on-line event selection.

2. The streamer tubes

The streamer tubes are of the coverless larrocchi-type design. Two different lengths are used, 1.5 m and 3.0 m. Each unit is an open, extruded PVC profile defining an array of eight $9 \cdot 9 \text{ mm}^2$ square-shaped subcells. The inside of each subcell is painted with a graphite solution which results in a surface resistivity of $5 - 10 \text{ k}\Omega / \text{square}$. Each subcell is equipped with a central, silver-plated Cu-Be alloy anode-wire of $100 \mu\text{m}$ diameter. The wire is mechanically supported by PVC-spacers, distributed at 50 cm intervals. At one end of the tube, the strung wires are connected to a circuit board where the eight wires are terminated (220Ω each) and connected to a common high-voltage input. The tube is covered by a plastic container which is sealed at each end with a cap. Those caps have gas inlets and outlets, and one of them is equipped with the high-voltage feeder. The tubes are leak tested by exposing them to slight over-pressure and then watching for bubbles when the tubes are submerged in a water bath. The streamer tubes were manufactured at the Frascati National Laboratory in Italy, they were assembled at CERN and finally tested and mounted on the detector supports at GSI.

The anode wires were held at a voltage of 4750 V in the experiment but during the conditioning and tests voltages up to 4900 V were used. For these tests the wire readout

³ G. Battistoni et al., NIM 152(1978)423, 164(1979)57, 176(1980)297, 202(1982)459, 217(1983)429; E. Iarrocchi, NIM 217(1983)30.

⁴ M. G. Catanesi et al., NIM A247(1986)438;

G. Bagliesi et al., CERN-EP/87-124(1987)1;

V. M. Goloviyuk et al., NIM A236(1985)300;

Opal Detector Technical Proposal CERN-LEPC/83-4(1983)1;

F. Fabbri et al., CERN-EP/87-134(1987)1.

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^b A Post Doctoral Fellowship from the Swedish NFR during 1986-1987 is acknowledged.

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¹ R. Albrecht et al., GSI-report GSI-85-32 (1985)1.

² R. Albrecht et al., Phys. Lett. B202(1988)596.

was used. A gas mixture of 1 volume unit argon to 2.4 volume units of isobutane at 20° C and 1.21 bar absolute was used. The streamer tubes were placed on a flat surface and the tubes were conditioned at the selected HV-values and subsequently the count rate for cosmic rays and the natural background radiation was measured as a function of HV.

The applied voltage was increased in gradually decreasing steps from 2500 V up to 4900 V over a time of a few hours. When a current above 9 μ A was registered during a time interval which exceeded 10 s, the voltage was dropped to zero and the procedure was repeated. If stability was reached within 10 h, the streamer tube had passed the first test condition.

Thereafter the count rate as a function of the applied voltage was measured. At a threshold of -15 mV for the wire signals and with a maximum allowed current consumption of 9 μ A the count rate was sampled as a function of HV. A sampling time of 5 min for each HV value was used. It was found that the count rate reached a maximum at 4600 V and that a plateau, extending up to 4900 V, was developed. We required that the count rate in each tube should be consistent with having 8 well-behaving subcells. About 90 % of a sample of 450 tubes passed all test criteria.

3. High Voltage and gas supply

For tests and in the experimental set-up we have used two HV supplies of type CAEN SY127. This supply is micro-processor controlled with options for the user to preset voltages, times and allowed ranges for the current consumption. Each channel from the high voltage supply is wired to a distribution box, bolted to the aluminium support frame of the detectors, which subsequently distributes the high voltage to 1 to 4 streamer tubes (8 to 32 subcells). The arrangement is such that those streamer tubes which are closest to the beam pipe, and consequently are exposed to the highest flux of particles, are connected individually or in pairs to one HV-channel while those tubes which are farther away from the beam line are connected in groups of two to four tubes which share one HV-channel. In this way the maximum allowed current per HV-channel could be minimized and the protection against over-current was optimized. Totally we use 68 high voltage channels for the HV supply of the 130 streamer tubes in our set-up.

Fig. 3 shows the principal layout of the HV distribution box. The high voltage is applied to the anode wires of one streamer tube over a 1 M Ω resistor. The maximum current consumption that we allow in any of the streamer tubes is 40 μ A. The wire signals are read out via 50 Ω coaxial cables and these signals are used in the on-line trigger system of the WA80 experiment. Fig. 4a displays typical wire signals as recorded on a LeCroy 9400A oscilloscope.

The gas supply of the detectors is divided into 7 separate systems, two for each bigger detector array and one for the fourth, smaller detector plane. The gas volume in

each system is about 50 l. Each system is flushed (15 l/h) three times with argon before the isobutane is entered into the system. Fig. 5 shows the count rate of one streamer tube as a function of high voltage for three different gas mixtures. The data were obtained by sampling the wire signals, induced by the natural background radiation, during five minutes for each gas mixture and each high voltage setting. The signal threshold was set to -15 mV in all cases. The ratios of the gas volumes are given at a temperature of 20° C and an absolute pressure of 1.21 bar. A judicious choice of gas mixture was Ar : isobutane, 1 : 2.4, which was henceforth used.

4. The assembly

The mechanical support for each detector consists of an aluminium frame housing a 1 mm thick glass-fibre epoxy plate. The plate is attached to all sides of the frame with springs and bolts. This support system permits small changes in the frame, for instance due to thermal effects or deformation of the material by other causes, without building up strains in the glass-fibre plate. On one side of the support plate the streamer tubes are attached with thin double-coated tape and with small clamps at the end of the tubes. It is important to keep the detector areas flat in order to avoid sparking in the streamer tubes. The printed-circuit boards, containing readout electronics and pads, are placed on the opposite side of the support plate. The glass-fibre epoxy material has a high permittivity and hence the induced pulses on the pads will not fade much due to the insertion of the plate in between the streamer tubes and the pads. The boards are mounted in a precision grid which is glued onto the support plate. This grid defines quadratic areas where the boards are kept in place by small plastic knobs attached to the grid. The knobs press the boards gently against the support plate. It is important that the boards are flat so to avoid an air gap between the read-out pads and the support plate.

In order to remove build-up of charge on the outside of the plastic cover surrounding the streamer tubes, the areas facing away from the printed-circuit boards were covered by a 50 μ m thick aluminium foil. This foil is in electrical contact with the frame of the detector. The foil was attached to the tubes by tape and in some places by electrically conducting glue.

Particular care was taken in order to make all supply cables and readout cables of equal length. The signal delay and the ohmic losses should be about the same in all the different readout chains. The detector frames are freely suspended from supporting beams. The detector frame is electrically isolated from the beams in order to avoid ground loops.

5. The printed-circuit boards with the readout pads

The signal from the streamer tubes are read out by capacitively coupled pads. The pads are located on 4-layered printed-circuit boards of the size of $21 \cdot 21 \text{ cm}^2$. They were designed and developed at GSI. These are placed directly at the rear of the detector plane with the 1 mm thick glass-fibre plate separating them from the streamer tubes. Three pad sizes are used: $1.05 \cdot 2.625 \text{ cm}^2$, $2.1 \cdot 5.25 \text{ cm}^2$ and $3.5 \cdot 5.25 \text{ cm}^2$. The pads are cut out in the copper layer on one side of the circuit board, leaving a space of 2 - 3 mm in between them. On the opposite side of the board, shielded by an intermediate ground plane layer, the readout electronics is placed.

Minimum ionizing particles induce pulses at the pads that are larger than 10 mV and have FWHM of the order of 30 - 70 ns. Fig. 4b displays a typical single pulse as recorded on a LeCroy 9400A oscilloscope. The signals are directly fed into a MC3431 comparator, and if they are larger than the preset threshold they are pulse-shaped to a width of 550 ns in a 74HCT32 monoflop. The information from the monoflops is subsequently transferred to 74HC165 shift registers, when a load signal is received on the board. Fig. 6 displays the readout electronics of one pad. Each shift register serves eighth pads. Using SMD technology, we were able to place the necessary readout electronics for each channel, even on the boards with the highest granularity, at the small available area of only 2.5 cm^2 .

We had to use threshold values of at least 10 to 15 mV to get uniform threshold voltages on different boards using only one supply. On the other hand, to achieve good efficiency the thresholds could not be set much higher. A supply voltage of 100 to 150 mV was reduced a factor of ten by a voltage divider on every board. Differences in threshold values were evened out by adjusting a potentiometer on each board. The absolute accuracy of the levels within the boards, were then 2 - 3 mV due to the individual variations of the IC's.

The assembly of the boards was done in the following manner. Solder paste was printed on the boards, the components were placed by hand and final soldering was done in a reflow solder oven. After visual control and pulser tests an automatic test was performed using a CES5 "firecracker", an auxiliary CAMAC controller, an STC2000 module (described below), and a CAMAC multiplexer. In this way more than 750 readout boards have been produced.

The power distribution to the boards, load-signal input and level control of the comparators are done via twisted pair cables connected to a central MA-PS1 module (size like a NIM bin), which contains the power supply, fuses and cross cabling. Each cable distributes the comparator level and the power to the electronics of up to 160 pads. The fan-out of the load signals and the level control is performed by separate NIM modules

LD1000 and LE1000, respectively⁵. One detector array, of $3 \cdot 3 \text{ m}^2$ area, with up to 8000 channels, is typically connected via 50 cables, each consisting of 5 twisted pairs, to one MA-PS1 module and an additional NIM bin.

6. Positions and geometrical layout of the detector arrays

The positions of the detectors during the 1987 sulphur run were as follows: the detectors LAM1 and LAM2 (Large Angle Multiplicity arrays) were placed at a distance of 227 and 268 cm from the target. The overlapping region approximately cover the angular range $8^\circ < \theta < 29^\circ$ for all azimuthal angles. The LAM detector arrays both consist of 30 tubes of 3 m length and 10 tubes of 1.5 m length. The shorter ones are placed above and below the $42 \cdot 42 \text{ cm}^2$ quadratic holes at the centre of each of the detector planes. These holes allow the beam pipe to be extended further downstream. LAM1 is equipped with 12 boards with 160 pads of the pad size $1.05 \cdot 2.625 \text{ cm}^2$, 84 boards with 40 pads of the pad size $2.1 \cdot 5.25 \text{ cm}^2$ and 96 boards with 24 pads of the pad size $3.5 \cdot 5.25 \text{ cm}^2$, totally adding up to 7584 pads. The readout of LAM2 is more fine-granular and it has 104 boards with pads of the smallest pad-size, 48 boards with pads of the intermediate pad-size and 44 boards with pads of the largest pad-size, totally summing up to 18 976 pads.

The two detector planes MIRAM1 and MIRAM2 (Mid Rapidity Multiplicity arrays) were positioned at distances of 501 and 549 cm from the target, respectively. The overlapping region approximately cover the angular range $2^\circ < \theta < 6^\circ$ for all azimuthal angles. MIRAM1 has 31 tubes of 3 m length and 4 tubes of 1.5 m length. MIRAM2 is built out of 11 tubes of 3 m length and 4 tubes of 1.5 m length. Both detector arrays have a central hole for the beam pipe of $21 \cdot 21 \text{ cm}^2$. MIRAM1 has 11 072 pads distributed over 88 boards with 160 pads of the pad size $1.05 \cdot 2.625 \text{ cm}^2$, 32 boards with 40 pads of the pad size $2.1 \cdot 5.25 \text{ cm}^2$ and 48 boards with 24 pads of the pad size $3.5 \cdot 5.25 \text{ cm}^2$. MIRAM2 has 5440 pads on 34 boards with the best geometrical resolution.

If one uses square cuts when analyzing the data from the LAM and MIRAM double-layer detectors, full angular information is available in the polar angular region $2^\circ < \theta < 29^\circ$.

7. The readout system and the STC2000 module

The Streamer Tube Controllers, STC2000⁵, are placed in two CAMAC crates in the electronics hut, 30 m from the detector. Each STC module can handle up to 2048 channels in a serial readout chain. This device is similar to the unit LeCroy 4700 STOS CT which, however, has too few channels for our needs. The boards on the detector arrays are connected together so that each chain contains as many channels as possible in order to minimize the number of STC modules. Fig. 7 displays the principal

⁵ Technical write-ups are available at GSI, Darmstadt, FRG.

layout of the readout lines of LAM1. Each of these CAMAC modules contains fast ECL acquisition logic, programmable $2K \cdot 16$ bit address memory, $2K \cdot 16$ bit data memory, and CAMAC readout and control logic. The module performs all control and encoding functions. For our detectors we need 23 STC modules for the handling of the 43 072 channels.

Streamer-tube wire-signals from at least one of the two pairs of adjacent detector-arrays trigger the load circuits of the boards. A load signal is produced and fed back to the detectors 200 ns after an initial trigger. The content of the comparator output, held by the 550 ns monoflop, is then loaded into the shift register on the board, overwriting the old data. For each accepted event a signal is generated by the trigger logic which blocks the load circuits until the shift registers are read out. A valid event signal is subsequently fanned out to the start input of all STC2000 modules. The STC modules then send 7 - 8 MHz ECL level clock pulses, over twisted pair cables to the readout chains of the boards. The first board in a chain contains a circuit which generates an identifier burst on the shift-out line. Starting with that burst the clock pulses are applied to the shift registers and the contents of the registers are sent serially to the STC2000 modules. The clock pulses are regenerated on each board and sent to the next board. The STC2000 module receives the content of the shift registers via the shift-in line. The identifier burst is taken as the reference in time for the data of the readout chain. During each outgoing clock pulse the status of the shift-in line is determined and a counter is incremented. This counter serves as an address pointer to a look-up table residing in the programmable $2K \cdot 16$ bit address memory of the STC2000 module. If the shift register content is high the address pointer is used, and the word in the look-up table is copied to a 2048 word fifo (first in-first out). The generation of clock pulses stops after 2048 cycles. At this time, 200 μ s after the initial trigger, all the multiplicity boards are read out and the data describing the position of the fired pads in each of the readout chains are stored in the STC2000 modules fifo's.

The look-up table in the STC2000 module can be loaded with arbitrary 16 bit words. In the first run of experiments in 1986 the words were coded to provide the geometrical position of the pad. The 16 bit word was split in three parts: a 7 bit x-coordinate, a 7 bit y-coordinate, and 2 bits describing the board type. The coordinate multiplied with the proper pad size gave directly the geometrical position of the fired pad. Due to the fact that the readout chain on each board does not connect straight rows of pads, but rather zigzag paths on serpentine, adjacent pads are normally not read out in consecutive words. Therefore it was almost impossible to detect transmission errors in the readout chain. In 1987 the look-up tables of the STC2000's were loaded with numbers from 1 to 2048. Non-existing pads (at the end of each readout chain) were marked with a negative sign. In each readout chain one pad was always set to "fire" in order to act as a resynchronization point. The "hot" pad was marked in the look-up table with a distinct

pattern. This scheme allow us to check the data from the readout chains: all positive numbers have to be in ascending order, the pattern of the hot pad should always be present, negative numbers should not appear and any number should not be present more than once. Imperfections in the STC2000 modules, in the boards, and noise on the readout cables led to an error rate of less than 2 in 100 events. Most of those errors could be corrected for after a tedious study. The events with errors in the STC's are flagged by the off-line reconstruction software and they can optionally be discarded in the analysis.

8. The performance of the detectors

Before each data taking period the streamer tubes are conditioned up to 4900 V and stable operation during a few days is required. During data taking the HV's of the streamer tubes are set to 4750 V. The beam level is kept below $1.5 \cdot 10^6$ ions per spill. The current consumption is then below the recommended level of 40 μ A per streamer tube. About 100 events are sampled in each spill which has an effective length of about 2 s per machine cycle of 14.4 s.

Some problems with deterioration of the tubes and breakdown of the cathode coating⁶ have been observed by us. Before and during the 1986 data taking we had to exchange a few tubes which previously seemed to operate well. Due to the relatively easy access to our detectors this was no major problem. However, during the run periods in the autumn of 1987 and in the spring of 1988 all tubes have been operating well and no further problems have been encountered. We have also noticed that after the tubes have been exposed to a high number of produced charged particles for some hours, their performance improve considerably and tubes that earlier sparked or drew overcurrent for shorter time intervals settle down into a smooth mode of operation.

The electronics on the printed-circuit boards creates an appreciable amount of heat. Some boards, where too small amount of solder had been used, lost channels. This was presumably due to temperature effects and fans were installed to improve cooling.

Due to the insensitivity in between the subcells of the streamer tubes, an upper limit of the detection probability of the order of 93 % exists for charged particles impinging perpendicular to the detector. Furthermore, in between the pads on the printed-circuit boards there are small, less sensitive areas. These effects limit the detection probability of the detector device. The probability to detect charged particles was estimated by correlating the hits seen in the overlapping parts of three detector arrays. Fig. 8 exemplifies this by showing the detection probability of LAM2 in the inner part of the detector array. Each square represents one readout board. The quadratic area in the centre of the plane is not active. The number of random coincidences is determined by

6 P. Guz Yu et al., IHEP preprint 86-208(1986)1,
J. E. Bateman and J. F. Connolly, RAL-87-081(1987)1.

interchanging the sign of the x- and y-coordinate of the hits in the investigated plane and this effect is corrected for.

We have also measured the detection probability using the signals from plastic scintillation counters, on each side of the plane, in coincidence as trigger. These results are displayed in Fig. 9. The detection probability includes the effects of geometrical acceptance as well as the efficiency in the active areas of the detectors.

9. Comments on the analysis of the data

A discharge in the streamer tubes is sometimes sensed by more than one readout pad. The actual hits in the detector arrays are calculated as the centre-of-gravities of clusters of "fired" pads having common borders. The large number of "fired" pads in each plane, typically of the order of several hundred in the case of central, high energy nucleus-nucleus collisions, necessitates a fast algorithm to merge the "fired" pads into clusters. In the case of a plane with only one type of pad (e. g. MIRAM2) the following strategy is used:

- 1) Each plane is represented by a two-dimensional logical array where each pair of indices represents one pad in the detector plane. The array contents are initialized to "false".
- 2) For each treated event the array positions corresponding to "fired" pads are set to "true".
- 3) For each position representing a "fired" pad the 8 surrounding locations are examined. Whenever a neighbouring "fired" pad is found it is merged to a cluster.
- 4) A search is then performed around the merged pads and this continues until no more neighbouring "fired" pads are found.

The position of each pad that is merged into the cluster is set to "false", thereby avoiding a time consuming re-initialization of the two-dimensional array before the next event is treated. This algorithm avoids double loops over all the "fired" pads in the plane and is therefore preferred. When treating the data from a detector plane which has pads of more than one size, a two-dimensional logical array is assigned to the pads of each different type and the procedure to form clusters then continues in the way described above. Whenever a "fired" pad is close to a region where another pad size is used, the first stage in 3) is substituted by special routines so that the cluster can extend into the area of the other pad types.

For 200 A GeV S+Au data, about 50 % of the hits consist of clusters having one associated pad, 25 % of the hits are associated with two pads and so on with decreasing probabilities. Cluster sizes larger than 4 are found for about 10 % of the hits. Such clusters can arise when two or more particles are close in space. If a cluster contains more

than 4 and less than 11 adjacent pads they are split up by the cluster routine into more probable geometrical configurations. The two most distant pads of the cluster are used as starting points and the remaining pads are assigned to these to form two new clusters. If several combinations are possible the pads are assigned to the clusters by a probability method which takes into account that it is more likely to have clusters elongated along the streamer-tube direction. For those few clusters which are really large (a few per mill of the total number of hits have more than 10 adjacent pads) such a procedure is not possible due to the lack of information. These clusters are left as one hit and bias the data.

A multiple hit in one pad or in two or more nearby pads that are not split up by the cluster routine cannot be distinguished from a single hit. In S + Au collisions at 200 A GeV we have about 500 - 600 charged particles for central collisions. In spite of this, the multiple-hit probability for charged particles is typically of the order of a 5 - 12 % for these collisions. However, in the regions, $5^\circ < \theta < 8^\circ$, close to the beam pipe in the LAM detectors, this figure rises to 15 - 20 %. In the extreme forward direction, $\theta < 2.5^\circ$, the multiple-hit probability is 40 - 50 %. For peripheral and less central 200 A GeV S+Au interactions the multiple hit probabilities are typically a few per cent.

In the analysis a good track is defined as one which produced signals in two adjacent overlapping planes, i. e. in either LAM1 and LAM2, or in MIRAM1 and MIRAM2. A hit in the first plane is projected onto the second plane and we search for correlations within an area of a few square centimetres around the prediction. The necessary kinetic energy for a proton to penetrate two detectors planes deep enough to produce a signal in both of them is 25 MeV. The corresponding threshold for pions is 14 MeV. It is possible to produce false correlations in the regions where the particle density is high. If the incident charged particle is observed in one detector array but not in the other, a correlation can be made with a nearby hit in the second plane. This effect has been simulated with Monte Carlo methods where the detection probability of the detectors have been taken into account and it can contribute as much as 10 % to the yield of charged particles, but is usually only of the order of a few percent. The effects from the multiple-hits were also simulated in the same program. When inclusive particle distributions were sampled in the off-line data analysis, each track was weighted with the inverse of the average detection probability times the correction factor found in the Monte-Carlo event simulation.

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Figure captions

Fig 1: A photograph of LAM1 showing the readout boards with electronics (Photo: Gabriele Otto GSI).

Fig 2: The WA80 experimental set-up.

Fig 3: The layout of the high-voltage distribution box.

Fig 4a: A negative wire signal from the streamer tubes. The unit for the ordinate is 10 mV per division and the unit on the abscissa is 50 ns per division.

Fig 4b: A positive pad signal. The unit on the ordinate is 10 mV per division and the unit on the abscissa is 50 ns per division.

Fig 5: Counts versus HV for different gas mixtures.

Fig 6: The layout of the readout electronics of one pad.

Fig 7: The layout of the readout chains of LAM1.

Fig 8: Detection probabilities, inner part of LAM2.

Fig 9: Detection probabilities versus HV for different thresholds.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4a.

Fig. 4b.

Fig. 5

Fig. 6.

- Boards with 160 pads
- Boards with 40 pads
- Boards with 24 pads
- Readout boards with 24 pads

STC 1-4 each handles 1896 channels.

Fig.7.

.87 ± .04	.87 ± .04	.78 ± .03	.79 ± .03	.87 ± .04	.89 ± .04
.88 ± .02	.86 ± .01	.80 ± .01	.72 ± .01	.85 ± .01	.88 ± .02
.93 ± .02	.89 ± .01			.87 ± .01	.93 ± .02
.93 ± .02	.90 ± .01			.89 ± .01	.94 ± .02
.88 ± .02	.85 ± .02	.83 ± .01	.85 ± .01	.85 ± .02	.90 ± .03
.93 ± .03	.90 ± .02	.84 ± .02	.85 ± .02	.91 ± .02	.93 ± .03

Average within area: 87 %

Fig.8.

Fig.9.