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# PERFORMANCE OF THE SLD WARM IRON CALORIMETER PROTOTYPE*

G. Callegari and L. Piemontese†
Dipartimento di Fisica dell'Università and INFN, I-44100 Ferrara, Italy

R. De Sangro‡, I. Peruzzi and M. Piccolo
Lab. Nazionali di Frascati, CP 13, I-00044 Frascati, Italy

W. Busza, J. Friedman, A. Johnson, H. Kendall, V. Kistiakowsky, T. Lyons, L. Osborne, L. Rosenson and R. Verdier
Massachusetts Institute of Technology, Lab. for Nuclear Science, Cambridge, MA 02139

H.R. Band
Northeastern University, Boston, MA 02115

D. Bisello and M. Loreti
Dipartimento di Fisica dell'Università and INFN, I-35100 Padova, Italy

B. Alpat, R. Battiston, G. Bilei, P. Cenci, A. Codino, G. Mantovani, M. Pauluzzi and L. Servoli
Dipartimento di Fisica dell'Università and INFN, I-06100 Perugia, Italy

R. Castaldi, C. Vannini and P.G. Verdini#
INFN, S. Piero a Grado, I-56010 Pisa, Italy

J.R. Johnson‡
Department of Physics, University of Wisconsin, Madison, WI 53706

## Abstract

A prototype hadron calorimeter, of similar design to the Warm Iron Calorimeter (WIC) planned for the SLD[1] experiment, has been built and its performance has been studied in a test beam.

The WIC is an iron sampling calorimeter whose active elements are plastic streamer tubes[2] similar to those used for the Mont-Blanc proton decay experiment.[3]

The construction and operation of the tubes will be briefly described together with their use in an iron calorimeter - muon tracker.

Efficiency, resolution and linearity have been measured in a hadron/muon beam up to 11 GeV. The measured values correspond to the SLD design goals.

## 1. Introduction

The SLD experiment (Fig. 1) under construction at SLAC will be the 2nd generation experiment at the SLAC $e^+e^-$ collider.

One of its strong points is good e.m. and hadronic calorimetry, over 98% of the solid angle. The hadronic energy will be measured by a 2.87 interaction lengths ($\lambda$) thick liquid argon calorimeter (LAC) inside the solenoidal magnetic field. The hadronic shower will then cross the solenoid coil (0.5 $\lambda$) and its tails will be measured by the 4 $\lambda$ thick WIC.

The planned WIC is made with 14 iron plates, 5 cm thick, which also act as a return yoke for the magnetic field. Interleaved with the iron slabs are 15 "active elements", i.e., chambers made with 1 cm square tubes operated in the limited streamer mode. The WIC, which is also intended to track and identify muons, measures hadron showers with the technique of hit counting. The design resolution for hadrons is $\sigma(E)/E \leq 0.85/\sqrt{E}$. Since on average only 10-20% of the hadronic shower energy is deposited in the WIC, the WIC resolution will not significantly degrade the overall energy resolution, of the Liquid Argon + Warm Iron Calorimeter systems.

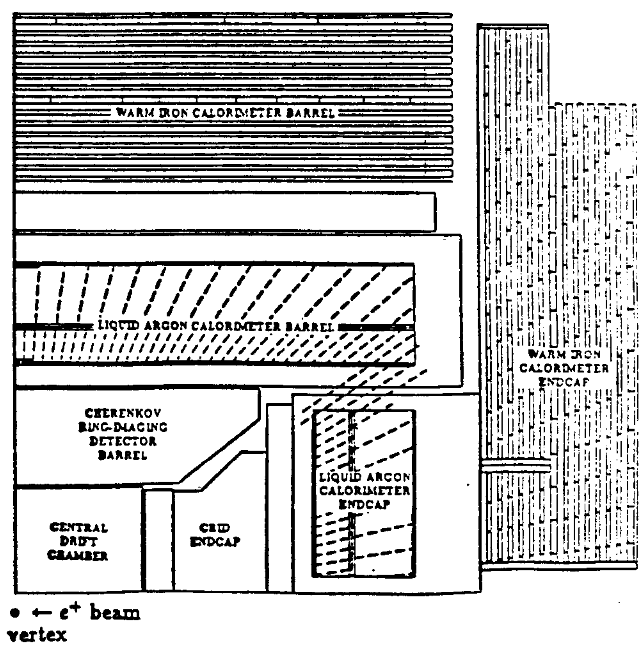


Fig. 1. The SLD Detector (one quadrant shown only).

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† Also INFN, Trieste, Italy.
‡ Presented address: Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94305.
# Presented address: University of Utah, Department of Physics, Salt Lake City, UT 84112.

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The longitudinal segmentation of the calorimeter is in 15 chambers, but the cables of the active elements (pads) are OR-ed to form only two signals, front and back energy respectively. The lateral segmentation is in bins of 66 mrad x 66 mrad. Due to the longitudinal OR-ing of pads, these have to be arranged in the form of "towers" pointing towards the interaction vertex (Fig. 1), in order to have a hadron shower as well contained in one tower as possible.

## 2. The Limited Streamer Tubes (Iarocci Tubes)

The active element of the test calorimeter is an 8 cm wide, 1 cm thick and 2 m long extruded PVC profile (Fig. 2), which provides 8 open square cells, each 0.9 x 0.9 $cm^2$. A 100 μm thick sense wire is strung in each cell, and is held in position every 0.5 m by plastic spacers. The cell walls are coated with a graphite paint to obtain surface resistivity of 100 kΩ to 1 MΩ per square, which provides a constant and stable electric field and at the same time is transparent to fast transients such as those due to a streamer on the wire.

The profiles are inserted in extruded PVC containers (Fig. 2) which provide gas tightness and improve overall rigidity. The container is sealed with two end pieces providing connections only for gas, HV and ground. The building blocks of the detector are these 8 x 1 $cm^2$ rectangular tubes: chambers are made by juxtaposition of tubes of the appropriate length. Note that one side of the cell (the inner face of the container) is not coated with graphite and therefore is not conductive. Such a cell configuration[4] has been shown to work as well as the original design tubes with four coated sides, at the expense of a slightly higher HV, but with the advantage of a simpler construction.

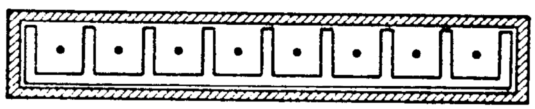

Fig. 2. Front view of a plastic streamer tube.

The gas is a mixture of 75% Argon and 25% Isobutane, a highly quenching mixture which allows operation in the limited streamer mode, a "quasi-spark" mode which gives large and saturated (~1 mA over 40 ns) pulses on the wire. The streamer pulses, being so large, are not read directly from the wires, but are picked up from external electrodes facing the wires. The pulse can be sensed on both sides of a tube, thus providing two separate coordinates, or allowing the use of whatever geometry of electrodes is appropriate.

## 3. The Test Calorimeter

The test calorimeter consists of 17 iron plates, 5 cm thick, and 1.2 x 1.2 $m^2$ wide, for a total of 5λ, interleaved with 18 planes of chambers made with Iarocci tubes.

Two different types of electrodes have been used on the two sides of a chamber (Fig. 3): pads, i.e., rectangular electrodes of size ranging from 22 x 22 to 25 x 30 $cm^2$, and 6 mm wide strips, running parallel to the wires. The former are intended, in the final WIC design, for hadron calorimetry, and were equipped after OR-ing with analog electronics to measure the total number of hits in the tower via measurement of collected charge. The latter, equipped with digital electronics, will perform μ tracking and identification by measuring its trajectory in the yoke magnetic field. The strips will also be used as a back-up calibration device for the pad system, by directly counting the number of hits in a shower.

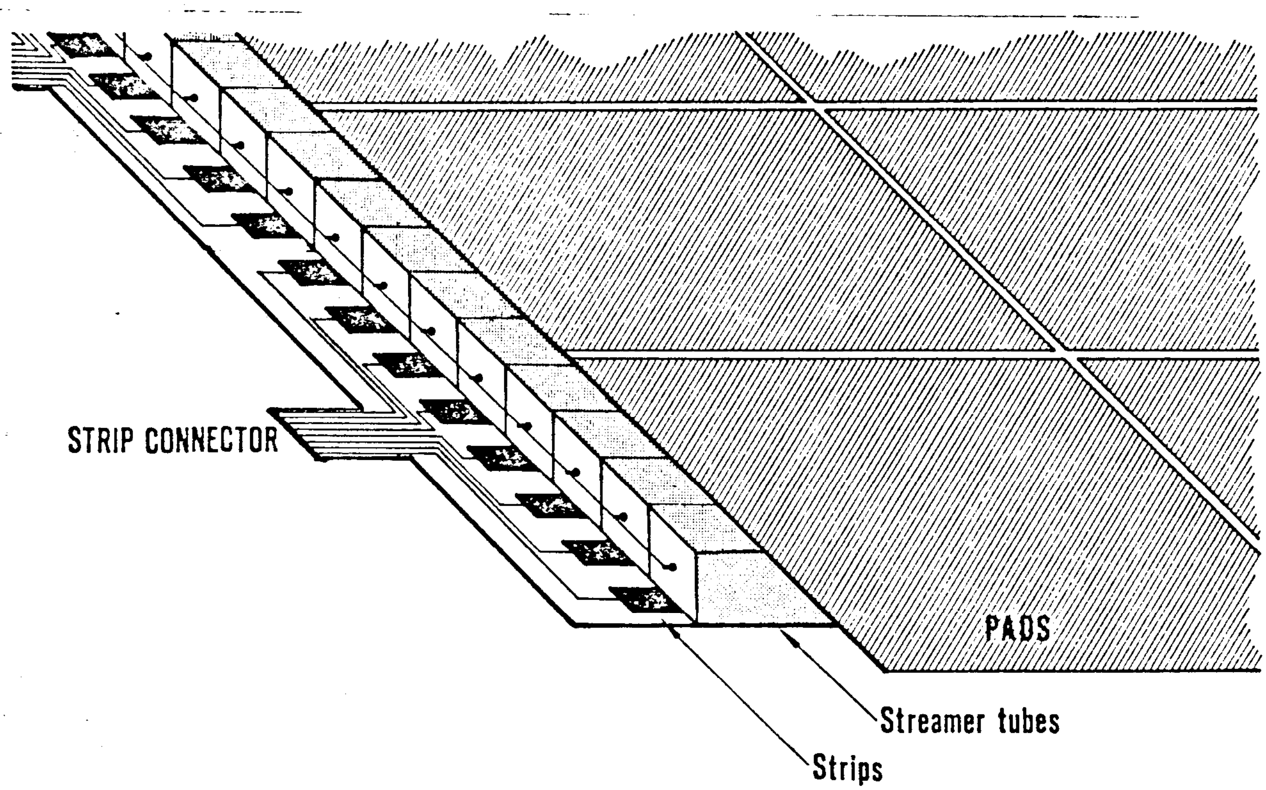


Fig. 3. Layout of the pick up electrodes of a chamber.

The chambers for the test calorimeter has been made (Fig. 3) by gluing 14 2m long tubes on a 112 x 200 $cm^2$ Glasteel† electrode on which strips were etched. On top was then glued another sheet of Glasteel which had the pattern of pads. A third sheet provided a good ground to the pad system. The pad geometry was similar to that of the WIC design, i.e., projective geometry with the pads in the last plane larger than those in the first.

The pad signals were taken out to a connector at the end of the plate, where they were OR-ed (Fig. 4) with a twisted pair cable connecting all pads belonging to the same semi-tower (front/back). The signals, which showed considerable ringing due to the long distances of cables involved in the wired-OR, were amplified and integrated, and the charge was digitized with the SHAM IV/BADC system[5] developed at SLAC. The signals from the 64 central strips of each plane, covering completely the two central rows of 6 towers, were also amplified and sent to ADC's, due to the availability of a large number of analog channels in the test beam facility.

## 4. Experimental Results

The tubes were run at voltages varying from 4.2 to 4.5 kV, the bulk of data being taken at 4.35 kV, and data have been taken at the beam energies of 5.5, 8.2 and 11 GeV, with muons and pions.

A HV curve, made with a source and by reading the pulse from the wires (via the HV connector) with a 2 mV threshold on 50 Ω is shown in Fig. 5. The dependence of the charge collected on the pads from the HV has been measured, and the standard value of $\delta Q/Q = 8 \times \delta V/V$ has been found. The uniformity between various pads (and also between different strips) was within ± 5%.

From the analysis of the muon data, the efficiency of a chamber for tracks at normal incidence has been measured to be 91.6%, which is accounted for by the dead spaces of the plastic cells.

A pulse height spectrum obtained at 11 GeV is shown in Fig. 6. The peaks of μ and π's are well separated. From a comparison of the charges collected at the two peaks, and assuming that a μ will, on average, hit 16.4 of the 18 planes, a π of 11 GeV will give 7 streamers/GeV, the relative energy resolution being about 25% as shown in Fig. 7.

If we parametrize the energy resolution as $\sigma(E)/E = k/\sqrt{E}$, we obtain for k a value of the order of 80%.

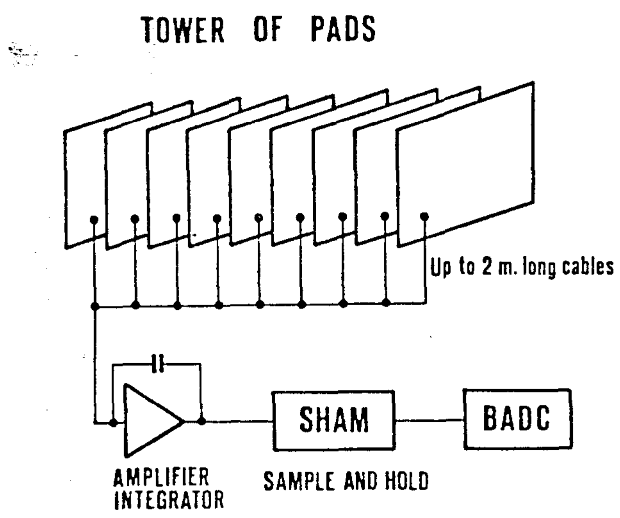


Fig. 4. Scheme of the read-out of a tower of pads.

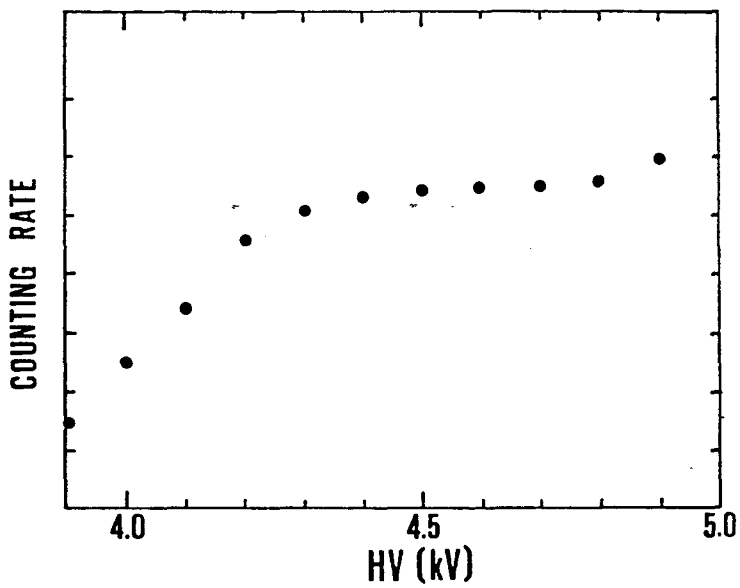


Fig. 5. Plateau in singles - with cosmic rays - of streamer tubes.

## 5. Conclusions and Further Studies

The preliminary tests performed on the test beam have confirmed that the design values of the calorimeter were realistic. Measurements have been taken with the WIC installed downstream of a prototype of the liquid argon calorimeter, in order to check the resolution of the complete system, and is currently being analysed. A new series of test runs is due to start at the time of this Conference.


References

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†A printed-circuit like product by Industrial Laminates, Duarte, California.

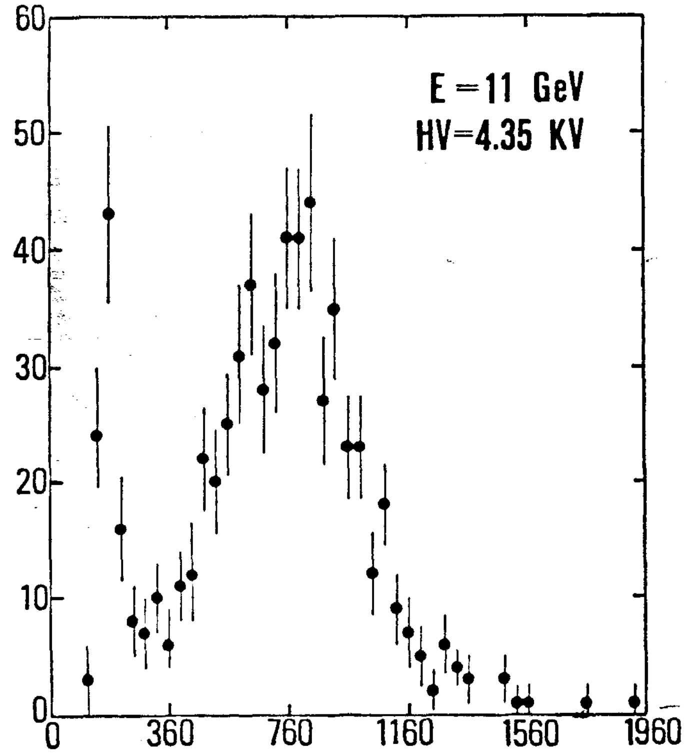


Fig. 6. Pulse height spectrum for pions at 11 GeV, showing the μ and π peaks.

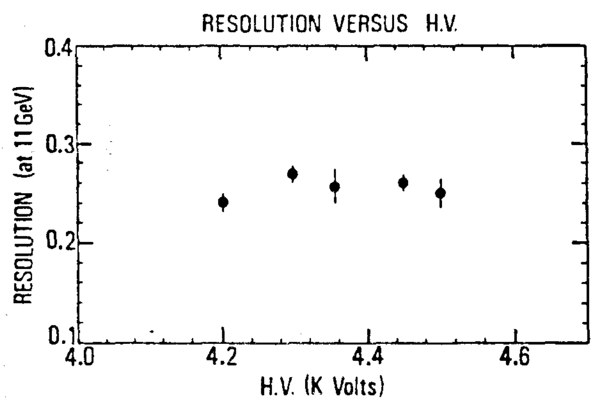


Fig. 7. Resolution at 11 GeV (pions) as a function of HV setting.

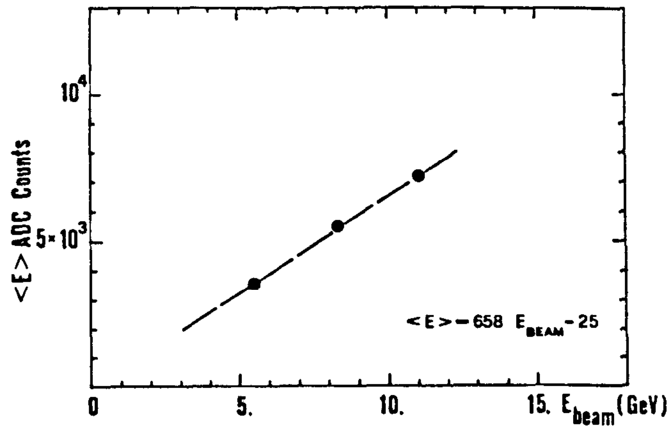


Fig. 8. Mean of the pion spectrum vs. beam energy.

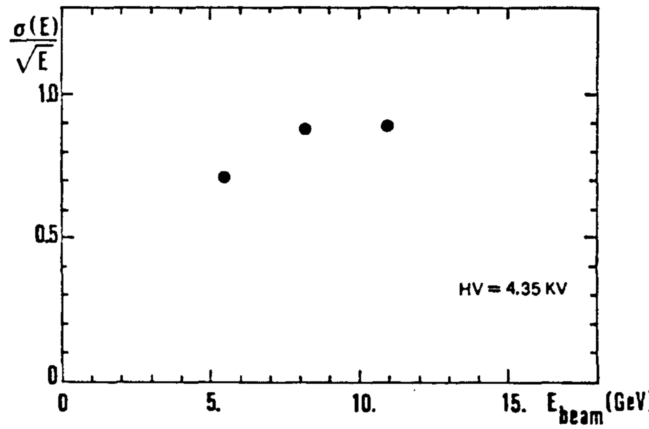


Fig. 9. $K = \sigma/\sqrt{E}$ vs. beam energy.