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SLD LIQUID ARGON CALORIMETER PROTOTYPE TEST RESULTS[*]

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ABSTRACT

The results of the SLD test beam program for the selection of a calorimeter radiator composition within a liquid argon system are described, with emphasis on the study of the use of uranium to obtain equalization of pion and electron responses.

1. Introduction

This paper discusses the results of the calorimeter test program conducted by the SLD group from May 1983 to May 1985. These tests investigated the SLD design concept which employs fine sampling electromagnetic and hadronic calorimetry inside the magnet coil to measure most of the longitudinal development of hadron showers, while using coarser calorimetry outside the coil to measure the tail of these showers. Figure 1 shows the SLD detector.[1] The calorimeter consists of a 2.95 interaction length, Λ, thick (at 90° to the beam) liquid argon-lead calorimeter (LAC) inside the coil followed by a 5 Λ warm iron-Frascati Plastic Tube[2] calorimeter (WIC) outside.

The LAC is constructed in tower geometry with the towers having constant projected length as seen from the interaction point. At 90° to the beam, the tower size is 36 mrad in the polar angle and 33 mrad in the azimuthal angle, yielding 192 towers in this angle.

These test beam studies were also intended to give a basis for understanding the equalization properties of uranium-liquid argon as reported by Fabjan *et al.*[3] Different radiators were used determine whether the equalization of π and e responses were due to suppression of the e response (sampling inefficiency) or enhancement of the π response (fission compensation). This could be determined by comparing the responses of e's and π's to μ's.

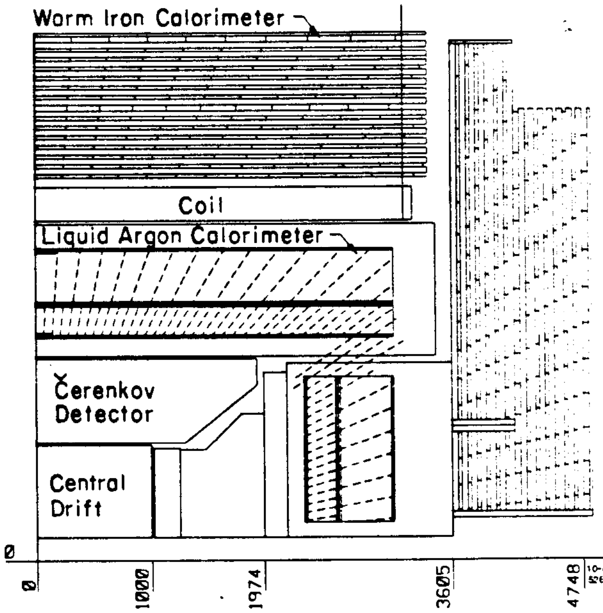

Fig. 1. The SLD Detector.

2. Test Beam and Prototype Layout

The test beam provided e's, π's, and μ's with momenta from 2.5–11 GeV/c from SLAC Beamline 20/21. The beam had a momentum resolution of about 2% and a spotsize of about 1 cm. The π's and μ's were discriminated from e's by a gas threshold Čerenkov counter. A trigger scintillator and Pb–scintillator veto counter package defined a 7.5 cm square hole for the beam incident on the LAC. The pulse height on the trigger counter was used to reject multiparticle events and the veto counter package was used to reject halo particles and also any γ's accompanying the beam particle.

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Four prototype stacks were tested:

- U–Fe radiator, G10 readout (U–Fe–G10),
- Pb radiator, G10 readout (Pb–G10),
- U radiator, U tile readout (U–U), and
- U radiator, Pb tile readout (U–Pb).

These were all arranged into four ganged segments in depth. The transverse tower sizes were 6×6 cm^2, growing slowly projectively in depth in the G10 stacks; 12×12 cm^2 in the U–U stack and 6×6 cm^2 (EM) and 12×12 cm^2 (hadronic) in the U–Pb stack. Tower capacitances ranged from 0.3 to 2.5 nF. The layouts are described in Table 1. The total thickness amounted to between 2.6 and 3.1 Λ and the electromagnetic sections were from 16–30 X_0. Figure 2 illustrates the beamline layout.

For the G10 devices, the WIC following the LAC was a 5 Λ warm iron-gas proportional tube[4] calorimeter arranged in tower geometry, while for the U–U and U–Pb devices, the proportional tubes were replaced by Frascati Plastic Tubes.[2]

The charge from each tower was put through a low noise amplifier based on the Toshiba 2SK147 FET. In the G10 readout devices, the G10 pads were kept at negative high voltage and blocking capacitors were used to provide isolation for the preamps; otherwise, the tiles were kept at virtual ground and no blocking capacitors were used. The preamp output went to a sample and hold module (SHAM)[5] which held the peak output of the integrating preamps. This result was digitized by a BADC[5] and recorded by a VAX 750 computer.

3. Results

To illustrate the data, the response to μ's, π's and e's in the U–U stack are shown in Figure 3(a)-(c). The μ peak is reasonably well separated from pedestal.

The μ response was used to provide a consistent method of weighting the layers for comparison of the four stacks. The μ calibration scheme accounts for any systematic effects having to do with the collection of charge such as argon impurity and integration times.

A simple cluster algorithm was used to reduce the number of channels included in the energy sums; a template of fixed size around the peak energy tower was summed. This was more important for the uranium stacks and resulted in equivalent energy noise of (0.03, 0.03, 0.10, 0.04) GeV/c in the EM section and (0.19, 0.16, 0.35, 0.24) GeV/c in the hadronic section for the (U–Fe–G10, Pb, U–U, U–Pb) stacks respectively.

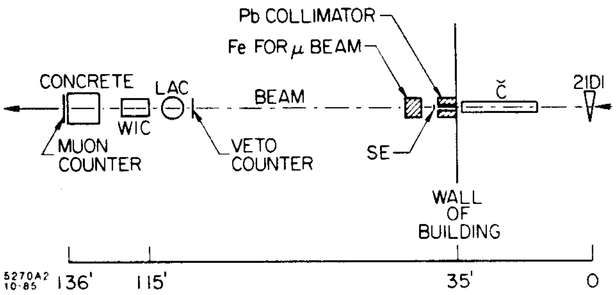

Fig. 2. Test Beam Line and Prototype Layout. The test beam configuration: the beam is defined by SE and the veto counter package.

Table 1. Layout of LAC Prototypes

Device	U–Fe–G10	Pb	U–U	U–Pb
ΣX_0 – EM	16	16	30	26
ΣΛ – total	2.6	2.8	3.1	2.7
Radiator – EM (mm)	3 Fe, 1.6 U	3	1.6	1.6
Readout – EM (mm)	1.6	1.6	1.6	2
Argon Gap – EM (mm)	4.6	2.4	4.4	3
Radiator – Hadron (mm)	12 Fe, 3.2 U	12	4.8	6.4
Readout – Hadron (mm)	1.6	1.6	7	7
Argon Gap – Hadron (mm)	2.4	2.4	2.7	2.7
% Λ of Uranium	35	0	90	65

The results of this analysis are given in Table 2 for all four prototypes at 5.5 and 11 GeV/c incident momenta. The Table shows the relative response of π's and e's to μ's. Typical errors on σ/E are about ±0.01, ±0.05 on e/μ and π/μ and ±0.10 on e/π.

It can be seen that both the π/μ and e/μ responses have been significantly reduced from unity. Within errors, the e and π responses are linear as functions of energy and the e/π ratio remains unchanged in all cases. In addition, the hadronic resolution for all four devices ranges from 18–21% at 11 GeV/c.

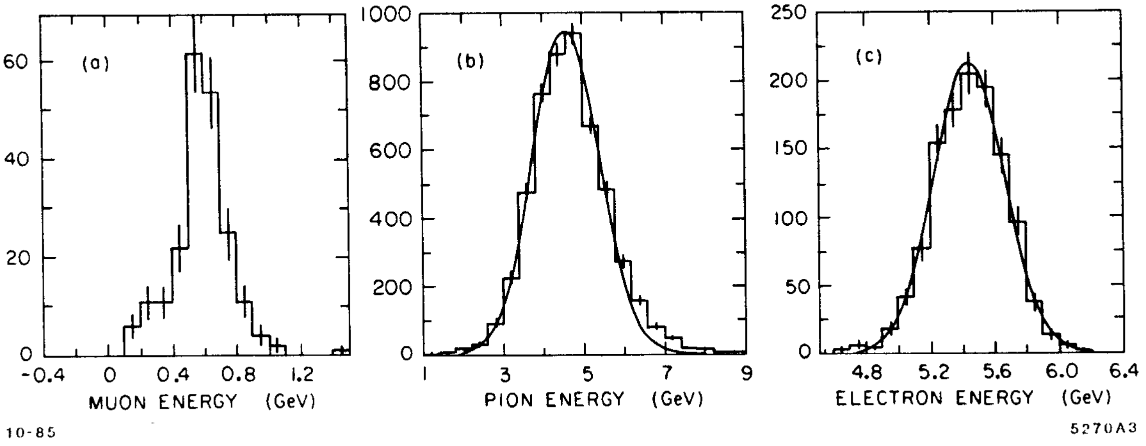

Fig. 3. Response to e's, π's and μ's in the U–U stack

Table 2. Results from Prototypes

Device	E_{inc} (GeV)	$\frac{\sigma_\pi}{E_\pi}$	$\frac{\pi}{\mu}$	$\frac{\sigma_e}{E_e}$	$\frac{e}{\mu}$	$\frac{e}{\pi}$
U–Fe–G10	5.5	0.29	0.57	0.05	0.70	1.23
	11	0.18	0.56	0.04	0.69	1.23
Pb	5.5	0.30	0.40	0.06	0.54	1.35
	11	0.19	0.43	0.04	0.54	1.24
U–U	5.5	0.26	0.45	0.06	0.52	1.16
	11	0.18	0.43	0.03	0.51	1.19
U–Pb	5.5	0.29	0.44	0.06	0.57	1.29
	11	0.21	0.46	0.04	0.56	1.22

4. Conclusions

Similar resolutions and e/π ratios can be obtained in Pb– and U–liquid argon calorimeters. The SLD configuration of a U–liquid argon calorimeter followed by a WIC does not achieve the resolution of U–scintillator calorimeters.[6] This is thought to be caused by relatively smaller amount of fission compensation, presumably because the liquid argon does not efficiently detect neutrons as compared with hydrogenous material. There is no evidence for an enhancement of the pion response from the Pb stack to the U–U stack, supporting this presumption. Equalization of e and π response appears to be due to greater suppression of the electron than pion signals. This is thought to be due to sampling inefficiency in which low energy electrons attain greater path lengths in the high–Z material from multiple scattering than seen in the liquid argon. The ionization sampled in the argon is then not simply related to that in the radiator by dE/dx loss in the two materials.

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