Title

THE LEAD/LIQUID ARGON SHOWER COUNTER SYSTEMS OF THE SPEAR MARK II DETECTOR

Permalink

https://escholarship.org/uc/item/4d52g3k8

Author

Abrams, G.S.

Publication Date

1977-10-01

Published in IEEE Transactions on Nuclear Science,
Vol. NS-25, No. 1, February 1978

LBL-7244
Preprint

THE LEAD/LIQUID ARGON SHOWER COUNTER SYSTEMS OF THE SPEAR MARK II DETECTOR

G. S. Abrams, C. H. Broll, W. C. Carithers, R. G. DeVoe,
C. Y. Pang, S. R. Shannon, E. N. Vella, M. Breidenbach,
B. Couchman, J. Dorfan, D. Hitlin, J. F. Martin and J. Weiss

October 1977

Prepared for the U. S. Department of Energy
under Contract W-7405-ENG-48

IEEE Transactions on Nuclear Science, Vol.NS-25, No.1, February 1978

THE LEAD/LIQUID ARGON SHOWER COUNTER SYSTEMS
OF THE SPEAR MARK II DETECTOR

G. S. Abrams, C. H. Broll, W. C. Carithers, R. G. DeVoe,
C. Y. Pang, S. R. Shannon and E. N. Vella
Lawrence Berkeley Laboratory
University of California, Berkeley, California 94720

and

M. Breidenbach, B. Couchman, J. Dorfan,
D. Hitlin, J. F. Martin and J. Weiss
Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305

Summary

The electromagnetic shower detection system of the Mark II Magnetic Detector consists of ten large lead/liquid argon modules. Eight of these, termed "barrel" modules, are placed outside the aluminum coil which defines the magnetic field volume of the device. The other two, the "end-cap" modules are placed at the ends of the solenoid. The design and construction of the lead assemblies, the tank structure and the cryogenic system will be described, as will the data acquisition electronics. Preliminary results on the performance of the first barrel module will be presented.

The Mark II Detector

The Mark II is a magnetic detector designed for use at SPEAR, the Stanford Linear Accelerator Center (SLAC) colliding e^+-e^- facility, and, at a later time, at the higher energy PEP. The main components of Mark II are the 5.0 kG solenoidal magnet, drift chambers for charged particle tracking, scintillators for time-of-flight information, lead-liquid argon shower counters for π/e separation and photon identification, and iron-proportional tube sandwiches for muon identification.

Liquid Argon Modules

General Design

The electromagnetic shower detector of the Mark II consists of ten lead/liquid argon counters.[1] Eight of these, the barrel modules, are mounted in the vacuum tank "Squirrel Cage" (Fig. 1) immediately outside the magnet coil. The other two, end-cap modules, are mounted on the steel flux return doors of the magnet to extend solid angle coverage down to 20°.

The modules are sandwiches of a high Z material, lead, to provide fullest shower containment in the shortest depth, and an ionizing active medium, liquid argon (LA). The lead is 2 mm thick (0.36 X_o), and alternates with 3 mm gaps filled with LA. Alternate lead planes are divided into strips to allow spatial localization of showers. There are eighteen cell groupings and the device is 14 X_o thick. Upstream of the lead stack is a pair of "massless gaps" which allows discrimination between photons which convert upstream of the shower counter and those which do not. They also allow a possible triggering on minimum ionizing particles due to their optimized signal:noise performance (larger gap size and higher electric field).

High voltage (5 kV) is distributed to the lead strips from a single connector per module. The signals are read out from the strips, which have blocking capacitors in series to contain the high voltage inside the modules. To avoid the loss of an entire module due to an electrical short inside the modules, each channel is isolated by 100 MΩ in series with the applied high voltage. The massless gaps have their own separate high voltage system.

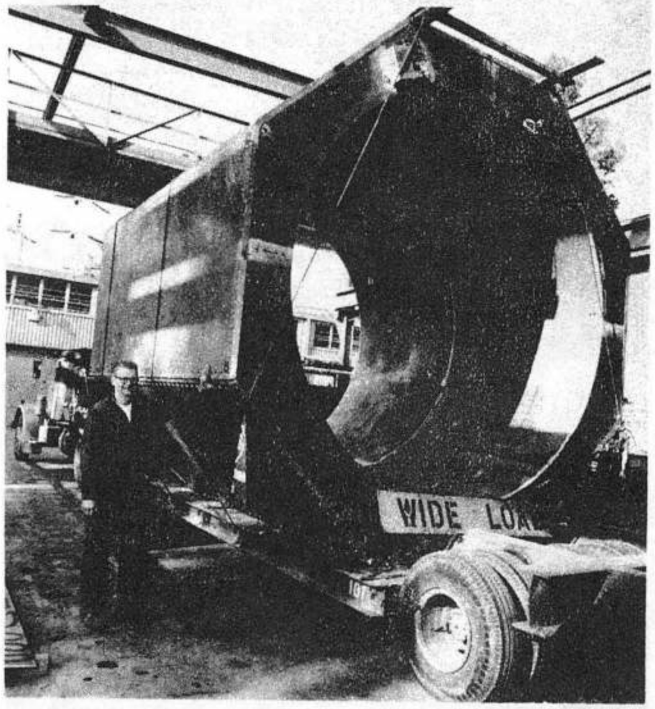

Fig. 1. Octagonal "Squirrel Cage" which provides a vacuum jacket for eight barrel modules as well as their mechanical support.

Barrel Modules

Each of the eight modules consists of a welded aluminum box, Fig. 2, wrapped with aluminized mylar and suspended from a 2-inch thick aluminum backplate (which also serves as a vacuum flange). These modules mount onto the Squirrel Cage structure, Fig. 1, which supports the magnet coil (1 X_o thick Al) and which is itself suspended from the magnet steel.

The trigger gap strips, which measure the azimuthal coordinate φ, are 3.8 cm wide, 1.6 mm thick Al, running the full length of the detector, 381 cm. The eighteen layers of lead strips are ganged to provide six samples in depth, although the first four samples are interleaved. The strip patterns map out a rectangular grid for positional measurements. There are three determinations of φ, two of θ (at 90° to φ) and one at 45° for ambiguity resolution, called U. The φ and θ strips are also 3.8 cm wide, the U strips are 5 cm wide. A typical (θ) layer in assembly is shown in Fig. 3. There are 362 electronic channels per module.

End-Cap Modules

The end-cap module (see Fig. 4) consists of a

0018-9499/78/0200-0309$00.75

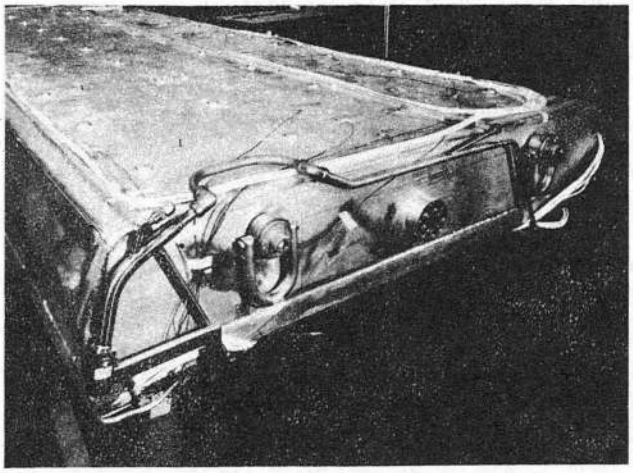

Fig. 2. A sealed barrel module. Visible in this view are the liquid nitrogen cooling coils as well as wiring for heaters and thermocouples. The module is designed to be supported by the cylindrical steel block visible in the center of the end plate (and its complement at the other end).

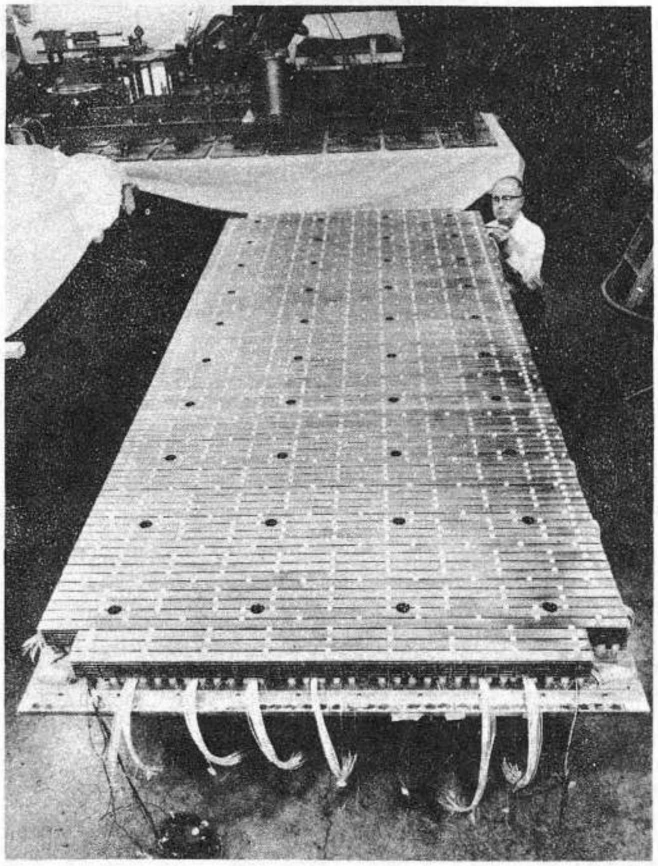

Fig. 3. A θ layer of a barrel module during construction. Ceramic washers and spacers, as well as signal cables, are visible.

cylindrical argon tank within a cylindrical vacuum tank. The design if complicated by the necessity of a cutout in the magnet keyway so that when the end door of the magnet is open, the tank clears the compensating coil and its support.

The trigger gaps are read out by a printed circuit board which consists of 32 concentric circles of equal area, split about a vertical line to form 64 channels which measure θ. To allow measurement of the shower coordinates with ambiguity resolution in cylindrical geometry the lead is shaped into pie shaped pieces, which measure φ (2π divided into 144 sections, with 16 deleted because of the keyway) and into spiral shapes, $r = e^{\pm\varphi}$ (2π divided into 144 sections with 9 deleted because of the keyway). The intersection of two spiral sections defines a square with its axis oriented along a diagonal, the size of the square increasing linearly with radius. The φ sections serve to resolve ambiguities among groups of crossed spirals and also enter into the track-finding secondary trigger as the logical extension of the drift chamber cells. Ganging in depth is done in a slightly different way than in the barrel modules.

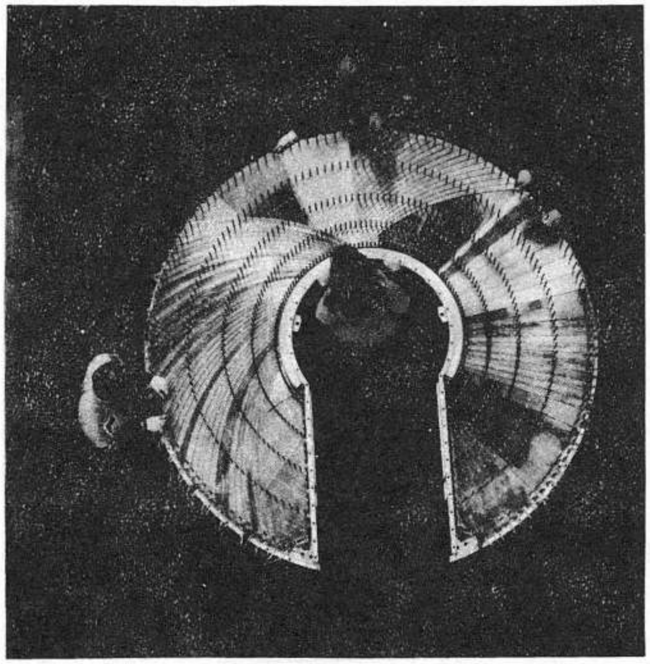

Fig. 4. The end-cap module during construction, showing each of the strip types as well as the ground plane.

Cryogenic and Vacuum Systems

A closed system of liquid argon ($\approx 15{,}000\ \ell$ in the entire system) is maintained at approximately 90°K (and slightly positive pressure) with cooling provided by the boiling of liquid nitrogen, venting to air. Each module is surrounded by cooling tubes (Al) welded to the outside (see Fig. 2). Electric heaters are attached to the outside for warm-up. Thermal insulation is provided by multilayer aluminized mylar in a vacuum space. The operating vacuum (designed to be 10^{-6} Torr) is maintained by two six-inch diffusion pump systems.

Cool-down and warm-up are performed with one atmosphere of helium inside the modules to provide efficient heat transfer from the outer aluminum to the lead stack within. The rate of cooling (and warming) is held to $\sim 2.5^{\circ}$ K/hour to limit the build-up of thermal stresses in the lead.

To monitor the liquid argon system temperature sensors (thermocouples, platinum resistors and vapor bulb thermometers) are arrayed both in the interior and on the exterior of the modules; the level of liquid inside the modules is measured with capacitive tubes and a set of carbon resistors.

Signal Processing

Signal Amplification

The detected signal is the pulse due to the collection of charge produced by ionization of the liquid argon.[1] There is no charge multiplication in the argon, so the signal level is quite low: a typical magnitude of deposited charge in a single channel is measured in fC (10^{-15} Coul). To minimize noise we use a charge sensitive preamplifier with a junction field effect transistor coupled with a very small capacitor in a feedback loop. The input capacitance of the FET (10 - 20 pF) is small compared to the detector capacitance (typically ~ 5000 pF); to minimize the noise due to this impedance mismatch a transformer is used.

Two further amplifying stages on the same circuit board shape the pulse and drive the twisted pair output line. The shaper consists of a double differentiator-integrator and produces a bipolar output pulse. The observed gain of this circuit is approximately 3.2 V/pC, which includes a ballistic efficiency of ~ 80% (for an electronic drift velocity of 200 ns/mm in LA). Due to the use of high voltage blocking capacitors on the strips, a further loss of ~ 70% of the signal appears since the magnitude of the blocking capacitance does not greatly exceed the magnitude of the detector capacitance. The observed noise performance of a typical channel is ~ 1 MeV (rms), where, for comparison, the energy deposited by a minimum ionizing particle is ~ 5 MeV.

Signal Read-Out[2]

The (shaped) analog signal of each channel is sampled at the peak and held by a Sample and Hold Analog Module (SHAM), capable of holding it for as long as a few msec without degradation. Each SHAM, with 32 channels per circuit board, is read out onto the CAMAC system by micro-processors which do the digital conversions as well as arithmetic calculations (data editing and discriminating). This so-called "brilliant" ADC[3] provides each group of 640 channels with its own autonomous controller.

Calibration Procedure

During routine running, the channel-to-channel relative gains are measured by the Calibration System, with the results stored in the "brilliant" ADC. The gains are determined by injecting a (computer-controlled) series of pulses at several voltage steps on a small (~ 10 pF) capacitor C_{CAL} located immediately downstream of the high voltage blocking capacitor inside the LA modules. Thus the calibration pulses are processed by the same electronics (preamp-shaper, SHAM, etc.) as genuine data pulses. The output of each channel can then be normalized relative to all other channels (with a precision of 1 - 2%). An additional correction, which is measured prior to sealing up a LA module, is necessary to compensate for a variation in response occurring when charge is injected directly onto a strip rather than onto C_{CAL} (a factor ranging from 1.0 to 2.2).

System Performance

A test of the performance of the liquid argon system was made in a beam line at SLAC. A barrel module was suspended in a specially designed vacuum tank which allowed the module to translate and rotate while cold. The module was cooled with liquid nitrogen and operated much as it will be in-place at SPEAR, with a microprocessor providing monitoring of the LA sensors. Cool-down, warm-up, and normal running in the cold state with a LA fill were executed in accord with expectations.

High voltage was applied to the module when filled with LA, and beam test data was taken with all system electronics: preamp-shapers and SHAMs. For electrons data was recorded for momenta between 0.125 and 4 GeV/c; for pions between 0.5 and 4 GeV/c.

Some of the results of a preliminary analysis of the data are presented in Fig. 5. The energy response is seen to be linear over the entire range of incident electron energies that are of interest at SPEAR. The observed energy resolution when no aluminum radiator is introduced upstream of the detector,

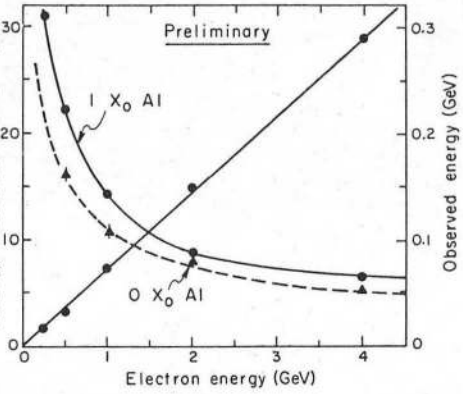

Fig. 5. Preliminary data from the beam test electron runs. The straight line through the data points (●) shows the observed energy response (right-hand scale) as a function of incident electron energy. The other two curves show the energy resolution as a function of electron energy for two configurations: no Al upstream of the shower counter (▲), and 1 X_o Al (approximately 3 inches) just upstream of the shower counters (●).

$$\frac{\sigma}{E} = \frac{10.8}{\sqrt{E(\mathrm{GeV})}}\ \% \qquad (1)$$

shown as the curve in Fig. 5 with "0 X_o Al," is in agreement with both earlier test results and with theoretical expectations. The degradation in resolution when one radiation length of aluminum is introduced upstream is also shown.

Analysis of this data to understand strategies to discriminate between pions and electrons is proceeding. Previous test results indicate that pion rejection at 1 GeV at the level of 99% can be achieved behind one radiation length of aluminum with a loss of electron acceptance of only about 10%.

Acknowledgements

We wish to acknowledge the contributions of Ralph Peters, Knut Skarpaas and Gene Miner in mechanical engineering; Bob Watt, Don Hunt and Frank Barrera in cryogenics; and Don Landis, Charlie Carr and John Kieffer with the electronics.

References

1. W. J. Willis and V. Radeka, Nucl. Instr. and Meth. 120, 221 (1974).
2. E. L. Cisneros, H. K. Kang, J. N. Hall and R. S. Larsen, IEEE Trans. on Nucl. Sci. N5-24, No. 1, 413 (1977).
3. M. Breidenbach, J. N. Hall, D. Nelson, "A Semi-Autonomous Controller for Data Acquisition," contributed to this Symposium.

TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720