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TEST OF A LONGITUDINALLY-SEGMENTED CsI ARRAY FOR A TAU-CHARM FACTORY DETECTOR*

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ABSTRACT

We present preliminary results on energy resolution and linearity from a test of an array of CsI(Tl) and CsI(Na) crystals in an e^-/π^- beam with momenta ranging from 120 to 400 MeV/c. The array was designed to explore longitudinal and transverse crystal segmentation, and a highly redundant wavelength-shifting plastic and photodiode readout system, suitable for a solenoidal-field Tau-Charm Factory (TCF) detector.

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1. Introduction

Numerous studies[1] of requirements for a TCF detector suggest that many characteristics of CsI crystal calorimetry are necessary to achieve TCF physics goals. Notably, the high light yield (~50,000 photons/MeV) of CsI(Tl) or CsI(Na) facilitates excellent energy resolution, and efficient detection of photons with energies down to a few MeV. The large light output also makes feasible the use of unity gain devices, such as photodiodes, for readout. The dominant drawbacks of CsI scintillators are radiation softness, poor mechanical properties, and long decay times (~1 μsec for CsI(Tl), and ~0.5 μsec for CsI(Na)) which integrate over many beam crossings. For example, at a TCF, the beams cross at 25 MHz. Pileup from lost beam particles, nuclear interactions of pions, and albedo within an event, are serious sources of low-energy "fake" photons, and these crystals should not be considered for such future colliders unless these problems can be resolved.[2] While radiation hardness is not an issue at the TCF[3], evidence from experiments with large CsI arrays suggests that albedo and pileup limit the use of low energy photons if backgrounds are not adequately suppressed.

2. Calorimeter and Test Design

The US TCF Collaboration has designed a CsI detector of ~8.5 m^3 volume. It consists of ~10,000 projective towers, each 16 rl deep, segmented transversely in (40-60 mr) x (40-60 mr) towers. To enhance $\pi/\mu/e$ separation and improve fake photon rejection, towers are segmented longitudinally at ~3-4 rl. We anticipate the need to incorporate coarse timing in the final device, but this is not tested here.

A test of a CsI array for the TCF calorimeter was conducted in the TRIUMF M11 and M13 beamlines. Two geometries were considered: faces of 6.4 x 6.4 cm^2, front and back, and an 8.0 x 8.0 cm^2 face in the back, either subdivided four-fold in the front, or not (Fig. 1). The four-fold segmentation in the front tower may give better position resolution, and provide pattern recognition capability to improve background rejection. The beam test array consisted of 12 (3) crystals of the former (latter) dimensions. Each crystal within a tower was optically separated from the other crystals with a wrapping of three layers of Teflon and one layer of aluminized Mylar. The total thickness of the wrapping was < 0.005 in. Each crystal was "tuned" with a Cs^{137} source such that the variation in light output along the crystal's major axis on all four sides was ≤ 2%.

Readout of each crystal was accomplished using a 3 mm-thick wavelength-shifting plastic (WLS) that covered about 70% of one face of the crystal. The WLS used for the CsI(Tl) crystals was Glasflex-red, which absorbs light of wavelength 550 nm and re-emits it at a wavelength of 650 nm. Hamamatsu S3588-01 photodiodes (PD's), each with an active area of 3.4 mm x 30 mm, were epoxied to the WLS edges with Summers Laboratories

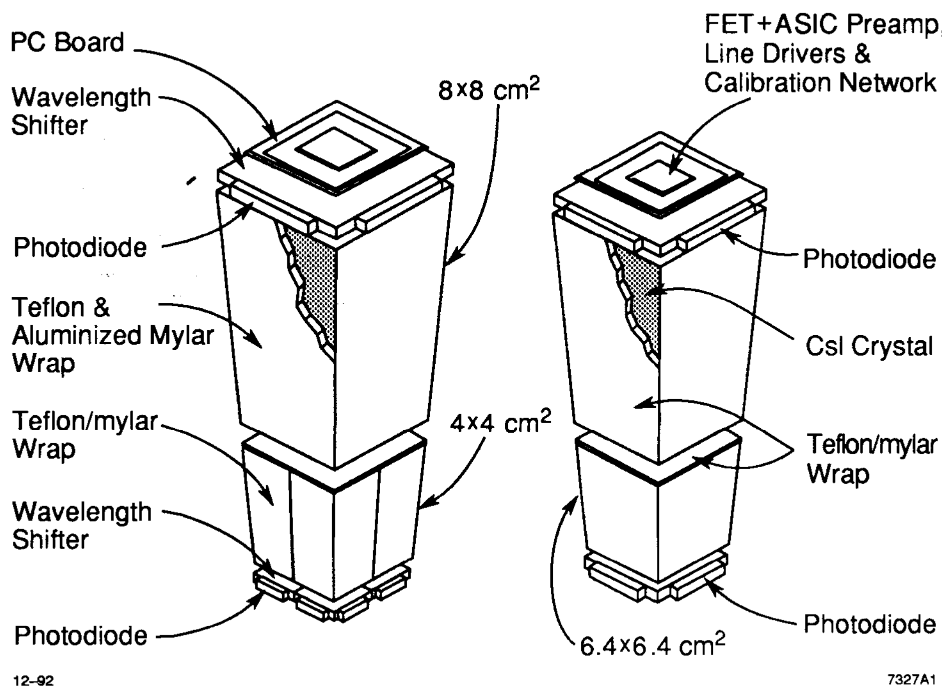

Fig. 1. Schematic of two of the three configurations of CsI calorimeter crystal towers tested, showing longitudinal and transverse segmentation of crystals, and wavelength shifter-photodiode-preamplifier readout.

Lens Bond F-65 adhesive. To provide redundancy and a reduction in net noise, four photodiodes were placed on each WLS (one/edge), except for the WLS's associated with the 4 x 4 cm^2 crystals, where spatial constraints permitted the use of only two PD's/WLS. White reflective paint coated the balance of the WLS edges. The PD's were selected for low leakage currents (< 2.5 na at 20 V bias voltage at 23°C). For each PD, a pc-board was placed at the back of the associated crystal tower. The circuitry on it consisted of an ASIC-based charge amplifier, a calibration network, and differential line drivers. To reduce pickup, all PD signals were carried to the preamplifiers on 0.3 mm-diameter micro-coax. The cables were placed along the edges of the tower housing, composed of 0.5 mm-thick, Cu-clad G-10 boxes. The towers were stacked in a N_2 dry box containing a thin foil entrance window .

Differential signals passed out of the dry box on 15 foot-long ribbon cables. They were received single-ended by CLEO-II-style shaping amplifiers which performed a single integration with shaping and peaking times of 1 μsec. Shaped signals were sampled with a ~200 ns gate and digitized by LRS 2289A ADC's. There was a total of 132 readout channels. The preamplifier and shaping amplifier gains were separately preadjusted to give equal signals for a fixed charge injected at the inputs. Each calibration circuit was trimmed to produce a constant charge for a fixed input. The final calibration employed a sequence of 100 DAC-set pulses, at 15 values, readout through the ADC's. To remove a small nonlinearity at the low end of the ADC range, the calibration data was fit with a quadratic function. In the lab, ~1000 photoelectrons/MeV/PD of deposited energy and noise of ~0.5 MeV/PD was observed, whereas about 1.5 MeV of noise/channel was seen in the beam test. The increase in electronic noise may be accounted for by higher PD leakage currents arising from a thermal problem observed in the packaging, and possible noise pickup in the electronics.

In this paper, only results from data taken in the TRIUMF M11 beamline (Fig. 2) are presented. Readout of data was triggered by a coincidence of RF timing with signals in two 0.125 in. thick scintillators (S1, S2). A low-mass, eight-wire drift chamber was used to measure the position and angle of the beam at the crystal face. To avoid pileup, collimators were used to reduce the rate to ~100 Hz. S1 and RF were used to measure time-of-flight (TOF), which provided π/e separation up to ~400 MeV.

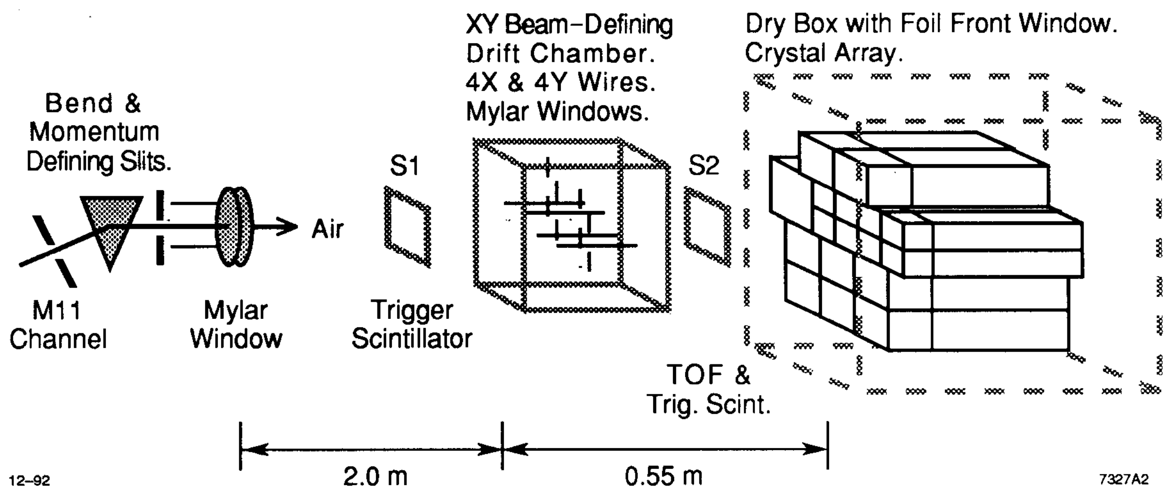

Fig. 2. Schematic of the TRIUMF M11 beamline and test configuration.

3. Preliminary Results

An example of one data run is shown in Fig. 3, where the energy deposited by particles of momenta 400 MeV/c in the front and back crystals of a 6.4 x 6.4 cm^2 CsI(Tl) crystal box are plotted. Note that only the signal from one PD on the WLS associated with the front crystal, and one PD on the WLS associated with the back crystal, is plotted. At 400 MeV/c, the beam contained less than 5% electrons. A TOF cut was made to enhance the signal from electrons, and reject most pions and muons in the beam; the small minimum-ionizing band at ~50 MeV indicates pion and muon leakage. As illustrated in Fig. 3, the front and back signals from pairs of PD's were scaled such that their intercepts are equal to the beam energy. This process was repeated for the calibration of each neighboring crystal using 400 MeV/c data. That this procedure minimized the resolution is demonstrated by Fig. 4, where δE/E is plotted as the front-to-back energy weighting is varied around the calibration point (where the front-to-back weighting ratio is unity). In Fig. 5, spectra are shown from a single CsI(Tl) crystal at three beam momenta, 120, 250, and 400 MeV/c. The neighboring crystals are

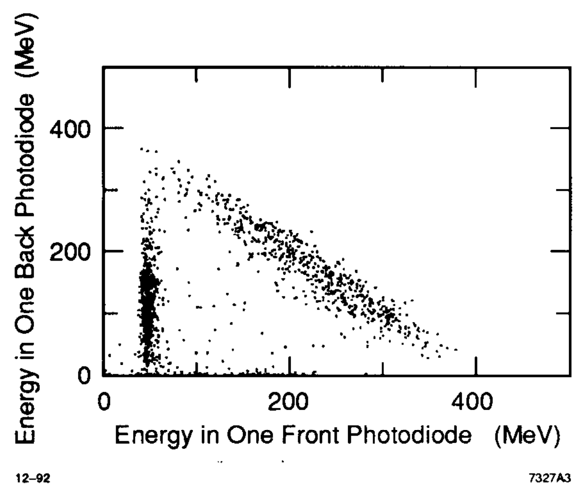

Fig. 3. Front vs. back energy at 400 MeV, for one 6.4 x 6.4 cm^2 box, using only one photodiode for each of the two CsI(Tl) crystals in the tower.

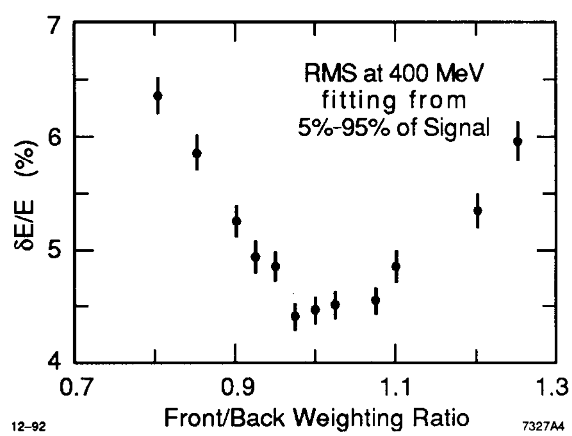

Fig. 4 Variation in δE/E as the front-to-back weighting is varied around the calibration point of unity.

not included in the sum, since the crystal was on the border of the array. Even without full containment, the linearity of the signal determined from these three momenta is better than 1%. Signals from a central 6.4 x 6.4 cm^2 CsI(Tl) crystal tower and its neighbors are summed and shown in Fig. 6, for two beam momenta, 250 and 400 MeV/c. Constraining a line to pass through zero, and

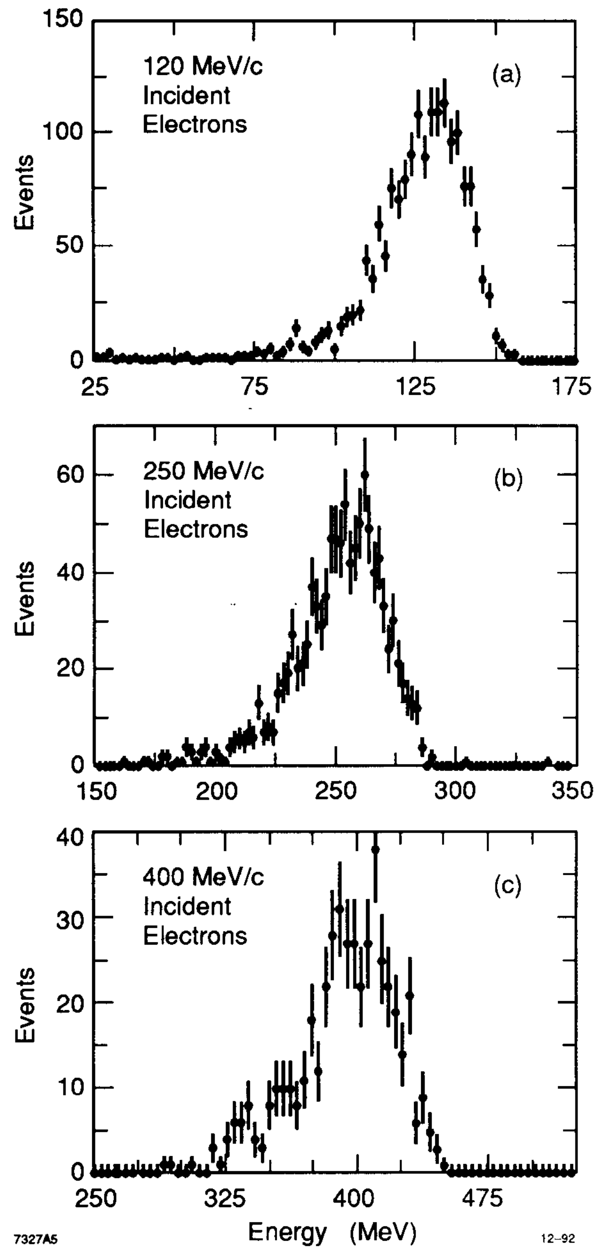

Fig. 5. Spectra of total energy at (a) 120, (b) 250, and (c) 400 MeV in a CsI(Tl) 6.4 x 6.4 cm^2 crystal tower.

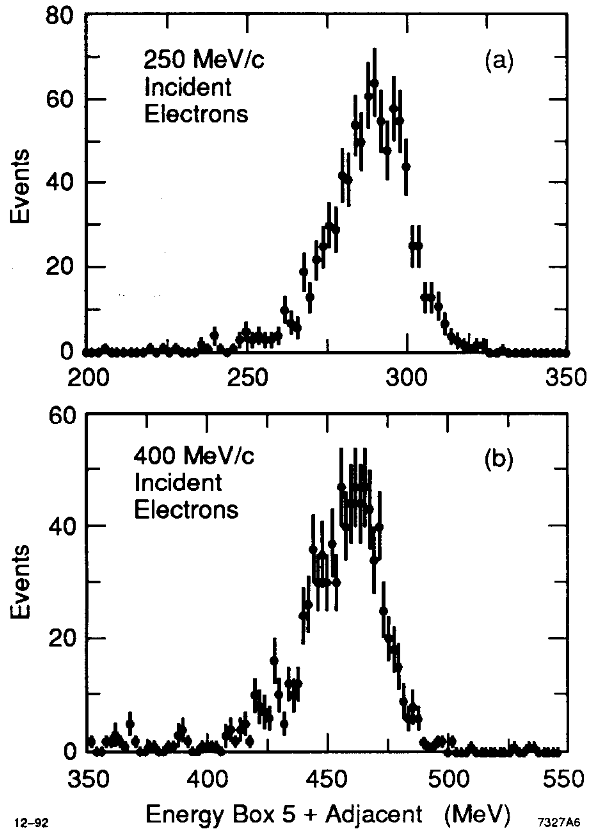

Fig. 6. Spectra at (a) 250 and (b) 400 MeV from a single 6.4 x 6.4 cm^2 CsI(Tl) crystal tower summed with its neighbor CsI(Tl) crystal towers.

calibrating at 400 MeV/c, the data at 250 MeV/c is found to deviate from linearity by less than 0.6%. Fitting a Gaussian plus linear background from the 50% to the 95% points, we find a preliminary resolution $\delta E/E = (2.78 \pm 0.25)\%$ at 400 MeV, and $(3.55 \pm 0.28)\%$ at 250 MeV, close to the design resolution expected from an EGS calculation.[4] The linearity and energy resolution obtained is summarized in Fig. 7.

4. Conclusions

We have presented preliminary results on energy resolution and linearity for a large array of CsI(Tl) crystals, longitudinally-segmented, and readout with individual wavelength shifters and photodiodes. These measurements demonstrate that linearity and energy resolution are preserved in the presence of a longitudinal division of the crystals, near shower maximum. The longitudinal division of crystals within the towers provides additional information on particle identification, range, and direction. This additional information may be necessary for background rejection in high luminosity e^+e^- and hadron colliders. In a subsequent publication, we will present additional results on energy and position resolution from data collected with front sections of even finer granularity.

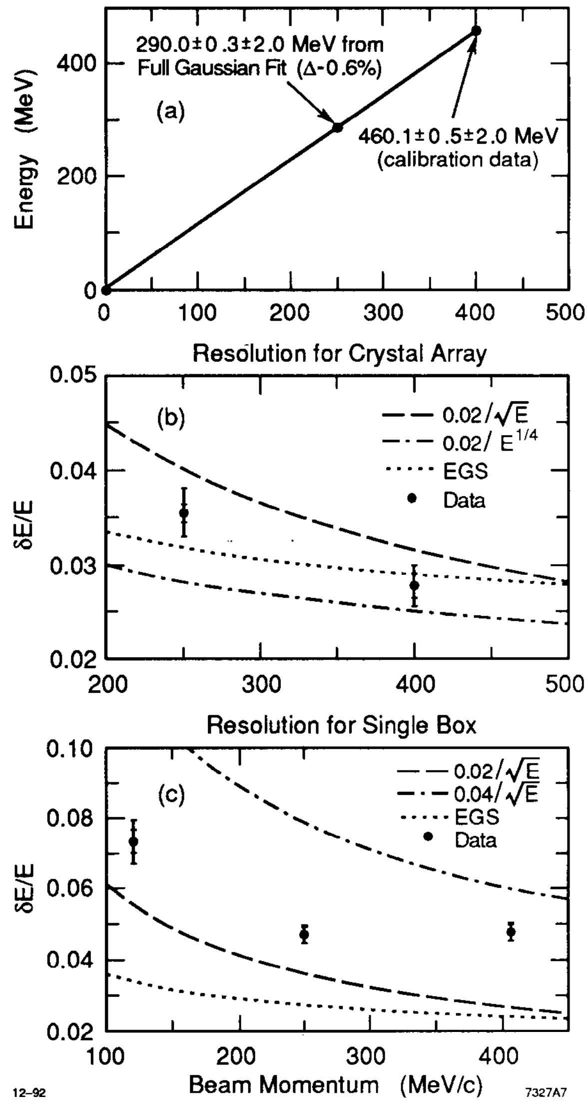

Fig. 7. (a) Linearity using single crystal tower calibration and (b) energy resolution for 6.4 x 6.4 cm^2 CsI(Tl) crystal tower summed with its neighbor CsI(Tl) crystal towers, and (c) energy resolution of uncontained 6.4 x 6.4 cm^2 CsI(Tl) crystal tower.

Acknowledgements

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References

1. See for example, R. H. Schindler, *Proceedings of the Tau-Charm Factory Workshop,* SLAC, Ed. L. Beers, SLAC REPORT-343 (1989) 127.
2. R. Schindler, *Proceedings of the Tau-Charm Factory Workshop,* Universidad de Sevilla, Andalucia, Spain (May 1991).
3. D. Stoker, *Proceedings of the Tau-Charm Factory Workshop,* Universidad de Sevilla, Andalucia, Spain (May 1991).
4. R. Frey, C. Beauvais, J. Brau and N. Wermes, *Proceedings of the Tau-Charm Factory Workshop,* Universidad de Sevilla, Andalucia, Spain (May 1991).