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TEST OF AN ARRAY OF CsI(Tl) CRYSTAL TOWERS FOR A LOW OR MEDIUM ENERGY e^+e^- COLLIDER CALORIMETER*

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ABSTRACT

Energy and position resolution results of a test of an array of CsI(Tl) crystal towers in an e^- / π^- beam (120 to 400 MeV) at TRIUMF are presented. The array was designed to study the effects longitudinal and transverse crystal segmentation on energy and position resolution, and background rejection. We also studied a wavelength-shifter and multi-photodiode readout system suitable for use in an electromagnetic CsI calorimeter in a detector at low and medium energy, high-luminosity e^+e^- storage rings. Energy resolution of $(1.69 \pm 0.08)\%/\sqrt{E}$ and $(1.83 \pm 0.05)\%/\sqrt{E}$ were obtained for two different crystal tower configurations. Position resolution of 6.5 (9.0) mm was obtained at 300 (120) MeV for four 4 x 4 cm^2, 4 radiation length CsI crystals.

TRIUMF Beamline and Instrumentation

We [1] tested an array of longitudinally-segmented CsI(Tl) crystals which could be scaled to a full-sized cylindrical calorimeter suitable for low and medium energy e^+e^- particle factory detectors [2]. Results presented here use data taken in the TRIUMF M11 beamline. A low-mass, eight-wire drift chamber was used to measure the position and angle of the beam at the crystal face. Thirteen crystal towers were stacked in an aluminum box through which dry N_2 flowed. The dry box contained a thin aluminum foil beam entrance window.

Crystal Tower Configurations

Three lateral crystal geometries were considered: crystals of rectangular cross section with 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. The front crystals were 4 radiation lengths (rl) long, and the back crystals 12 rl long. The beam test array consisted of 11 6.4 x 6.4 cm^2 and three 8.0 x 8.0 cm^2 crystals. Each crystal within a tower was optically separated from the other crystal(s) in a tower. The light collection for the readout of each crystal was accomplished using a 3 mm-thick wavelength-shifting acrylic plastic (WLS) that covered about 70% of one face of each crystal. Hamamatsu S3588-01 photodiodes (PD's), each with an active area of 3.4 x 0.3 cm^2, were affixed to the WLS edges (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.

Readout Electronics

For each PD, there was a separate preamplifier board stacked behind the crystals in each tower. The circuitry on each preamplifier board consisted of a FET and ASIC-based charge amplifier, a calibration network, and differential line drivers. Differential signals were transmitted out of the dry box on 5 m-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 3 μsec. Shaped signals were sampled with a ~200 ns gate around the peak, and digitized by LRS 2289A ADC's. There were a total of 132 readout channels.

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Energy Resolution

Results are presented for three crystal towers, each having a different geometrical configuration. Tower A refers to a contained 6.4 x 6.4 cm^2 crystal tower, Tower B refers to a contained 8 x 8 cm^2 crystal tower subdivided four-fold in front, and Tower C refers to an uncontained 8 x 8 cm^2 crystal tower. A contained tower is one that is surrounded on all sides by other towers, so that energy shared with adjoining towers can be taken into account in determining resolutions.

Selection criteria were applied to select e^-'s and reject minimum ionizing particles. The total energy spectra (one for each beam energy) for a given tower were fit with a Gaussian to determine the peak and the width, or σ_E/E. To avoid low energy radiative tails, the spectra were fit from 50 to 95% of their central value. Systematic errors resulting from the fit were estimated by varying the endpoints and background shapes in the fit on each side of the central value. The result of a fit to the energy resolution versus incident energy for Tower A and Tower B, respectively, are:

$$\frac{\sigma_E}{E} = \frac{(1.83 \pm 0.05)\%}{\sqrt{E}},$$

and

$$\frac{\sigma_E}{E} = \frac{(1.69 \pm 0.08)\%}{\sqrt{E}}.$$

Position Resolution

We used a corrected-center-of-gravity technique to determine the position resolution, based on a mathematically equivalent technique used by CLEO [3]. The resolution histograms were fit with a Gaussian function to obtain the quoted resolutions. Position resolutions were calculated for Towers B and C. The position resolution for Tower B was determined using the four-4 rl thick front crystals only, taking advantage of their smaller lateral dimensions. As a function of energy, the position resolution can be parameterized in the form $\sigma_X = a + b/\sqrt{E}$, where the values for a and b for Towers B and C are given in Table 1.

Table 1. Position resolution results for Towers B and C for the fit $\sigma_X = a + b/\sqrt{E}$.

Crystal Tower	a (mm)	b (mm-GeV$^{1/2}$)
Tower B, 4 x 4 cm^2 front crystals only	2.5±0.9	2.3±0.4
Tower C, front and back crystals	5.8±2.8	3.0±1.5

Conclusion

We have presented results on energy and position resolution for specific crystal tower configurations in an array of longitudinally-segmented CsI(Tl) crystals, where each crystal is readout with a WLS and multiple 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 can provide 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.

References

[1] Beam test participants were R. Baggs, D. Coward, R. Coxe, D. Freytag, M. E. King, G. Niemi, G. Putallaz, R. H. Schindler, and E. Vokurka of SLAC; A. Foland and G. Gladding of UI, Champaign-Urbana; D. Stoker of UC-Irvine; K. Curtis, J. Dyke, and R. Johnson of UC, Cincinnati, OH; E. Church, V. Cook, F. Toevs, and E. Weiss of UW, Seattle; R. Frey of UO, Eugene, OR; J. Izen and R. S. Davis of UT-Dallas, and W. Lockman of UCSC.

[2] Please refer to SLAC-PUB-6319, to be submitted to *Nuclear Instruments & Methods,* for a detailed report of our beam test results.

[3] E. Blucher, *et al.*, Test of Cesium Iodide Crystals for an Electromagnetic Calorimeter. NIM A 249, 201 (1986).

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