Centimeter

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 mm

Inches

1.0 1.1 1.25 1.4 1.6

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APPENDIX A

Beam Solid State Device (BSSD) Performance in the Test Run June-July 1984

For the test run June-July 1984 of E-653 at Fermilab we had partially instrumented four detectors. Solid state detectors from Micron Semiconductor are mounted on 24-inch diameter 1/8" thick boards containing the pre-amplifiers (LeCroy HQ810 at 8 channels each) and the mid-stage amplifiers (made of 10115 ECL integrated circuits and quad delay lines). These are read out into ADC's, one per channel. Fully instrumented, the boards will contain 144 channels each connected to 144 of the 240 3.5 cm long stripes on each Micron detector. There are 1200 lines spaced at 20 microns; the read out is every sixth for most of each side; they are interleaved in the middle such that there are 80 channels with every third read out, and the 80 balance on either side is every sixth read out. We are instrumenting the 80 middle channels plus 32 on either side. Since the beam size is about 1 mm by 3 mm in size, this 14 mm wide region is more than adequate. This reduction in read out channels saves $30,000. The final configuration will contain 9 Micron detectors (we have a total of 11), three X, three U (at 120° to the X) and three V (at 120° opposite rotation). This means that the stripes from the three detectors cross each other forming hexagonal patterns with the maximum stereo available. We can get a straight line in each of the three views but also the XUV's cross and make a small triangle (ideally, a point if there were no errors) representing the passage of the particle. The XUV coordinates are converted into orthogonal XY coordinates for general use. In addition, 3 meters upstream are 18 XUV coordinate read outs of the beam drift chamber (See Appendix B) to double check the position and angle of each beam track.

For the test run, only 4 boards were instrumented, two X, one U, one V, with only 96 of 144 channels (due to the limited number of ADC's available). The devices performed reasonably well, although a number of channels were not working. There were 20% non-functioning stripes in the X planes, and about 8% in the U and V planes. We were able to see correlated X, X, U, V triangles as shown in Figure A-1, a polaroid photograph of a CRT display of one of the beam tracks from tape 15. The cuts distinguishing a hit from background noise were made at 4 sigma above the noise pedestals. Reasonably good efficiency is seen in these data. We
have now fixed all the minor problems and instrumented these four boards to 144 channels each with only 1% dead and with a signal to noise ratio improved by a factor of 1.5.

The performance questions to be addressed are the collection of the charge deposited, the charge sharing between pairs of amplifiers (the position coordinate interpolated between read out of pairs of amplifiers) and the spatial position resolution for a coincidence between different detectors by fitting straight line tracks. The charge collection was checked in the following way. First, for each line read out, a histogram was made, a pedestal found, and a mean signal determined for that data above some cut above the pedestal. For those channels which had a meaningful sigma (not dead and not noisy), histograms of the pulse size were made. These numbers were normalized such that all pedestals came at a known channel and all means of the signals at another channel 1000 counts higher. These show a pronounced Gaussian pedestal peak and a long tail extending to high collected charge. Since the read outs were every one in three (or one in six), a particle passing through the detector will deposit its charge on two neighboring amplifiers (unless a line containing the amplifier is directly struck). Therefore, we do not see in these single stripe histograms a peak and valley but a flat tail extending out to high values. By histogramming "triples", that is, the charge on a given line plus its neighbor on either side as shown in Figure A-2, we see a valley between the pedestal and the signal with a peak to valley ratio on the order of 2.5 to 1. The width of the signal peak is about 50%, which is somewhat wider than the 40% or so which would be expected for 800 GeV protons represented by this data.

In addition, one can look at pairs of stripes that are hit and form the following quantity: the difference in charges seen by the two amplifiers divided by the sum of the charges. This represents a crude coordinate interpolated between the two amplifiers connected to these two stripes. Histograms of this quantity were made for all good stripes and a composite histogram is shown in Figure A-3. We would expect this histogram to be flat if charge sharing were ideal. The charge sharing occurs via capacitance coupling between the floating stripes. But, in addition, there is capacitance coupling to ground; more of the signal gets shunted to ground, the farther it is from an amplifier's stripe. This could explain some of
the increased width of the Landau distribution (Figure A-2) and some of the non-flatness seen in the difference over sum histogram (Figure A-3). However, the valley in this plot is deeper than can be explained on this basis alone, which implies that the electric potential of the floating stripes is not as high as those stripes directly connected to amplifiers. However, Figure A-3 is very similar to the results we obtained (See Appendices C and D - last year's proposal) with our Los Alamos (LAMPF) testing of the Centronix detectors (Micron is a new independent company made up of the same people who built the Centronix detectors). In the LAMPF testing, we achieved a resolution of the order of 8 - 10 microns with similar detectors. For a spacing of one in three in the central region (in other words, 60 microns), we would expect a resolution 60 over the square root of twelve or 17 microns, whereas with ideal charge sharing, one should be able to reach a resolution of 6 microns (corresponding to the 20 micron spacing of the floating stripes). The LAMPF tests found a value somewhere in between these two values. Figure A-3 implies that we will get similar results from these detectors. Thus, our Micron SSD's will perform superbly for the real run with a signal to noise on the order to 20 to 1. We are now working to finish construction of the other five detectors for installation of all nine in January 1985.
**Figure A-1**

Beam's Eye View of One 800 GeV Proton Track

**Figure A-2**

Charge ('Triples') Collection
Figure A-3

Zero-th order interpolated position

(0→1.0 equivalent to 0-30μ)

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Graph showing the distribution of hits in different gaps between tracks, with markers for 8μ gap and amplifier connected stripe.
APPENDIX B

Beam Drift Chamber Test Run Results

The OU-HEP beam drift chamber is comprised of 18 planes of 2 cells each. Each cell has a drift distance of 18 mm on either side of the sense wire. They are arranged as six X, six U and six V. Furthermore, the six X (U, V) are broken up into three X and three X' planes, X' being rotated 180 degrees around the vertical direction so that the sense wire in X is halfway between the two sense wires in the X' (and vice versa), resolving the right-left ambiguity. The 18 planes are spread out in three groups over a distance of about 18 inches long the beamline. The planes were set up in such a way that the beam passes between the sense wires of, eg, X and X' wires. In this way, the electrons drift equal distances to all the wires. We expected to achieve a resolution under 200 microns, maybe approaching 100 microns per point. The mechanical set up is a priori aligned to an accuracy on the order of 1 to 2 mils (a fraction of the resolution expected). The chambers worked quite well. The 36 channels were read out through LeCroy 2735A amplifier discriminator cards into a LeCroy 1879 FASTBUS TDC.

One cell, X2, did not work properly. This has been traced to a bad high voltage distribution pod on that card, where one wire was essentially disconnected and floating. This pod has been replaced. In addition, the detector had a track multiplicity of about 1.5, in other words, sometimes a single pulse, sometimes a double pulse. We expect to fix this by inserting a small series resistance in the signal line into each amplifier to match impedances. We found that the first pulse arriving at the TDC in all cases corresponded to the correct pulse. We found that the efficiency of each plane was in excess of 95%. We get good chi-square distributions and find a resolution of 150 microns at the middle of the cell. The resolution as a function of drift distance from the sense wire is shown in Figure B-1.
Resolution vs Distance from Wire at 2.3 kV (E36 = 1110 V/m-min)

DV = 42 kV/ms  T=81 channels

Figure B-1

Line is guide to the eye
and cell resolution ~ 140 μm

KES 1 X 10^4 N/C 7 X 10^4 N/C

T-Tp 10 channels

5.25 mm 16.5 mm 15.25 mm

Distance from wire 10 mm
APPENDIX C

Time-of-Flight Counters (October 1984)

The time-of-flight system consists of 48 scintillators, 1 1/2" x 1 1/2" x 66", mounted vertically, situated at a distance of 4m from the target. Each scintillator has Amperex XP2230 phototubes on both ends. All scintillators have been polished and wrapped, and have light guides and phototubes glued on. A prototype base has been tested. Receipt of all base parts and their assembly will be accomplished shortly. Construction of high-voltage and signal cables are progressing.

Twenty counters with bases from E-531 borrowed from McGill University were used during the test run in June and July. Because no position information was available from the upstream spectrometer, the only counter whose time resolution could be measured was the central one. With no emulsion, the size of the beam was approximately 7 mm vertically (FWHM). Assuming that light travels at a velocity of c/2 in the scintillator, and that a shift in vertical position increases the time to one tube as much as it decreases the time to the other, a shift of 7 mm changes the differences in the times read out by the two tubes by 90 psec. Plotting this time difference for an entire run, which should be constant if all the hits are in the same vertical position, gives a distribution with a width (σ) of 150 ps. (figure C-1). Subtracting the two times eliminates any fluctuations in the start time; the fluctuation due to the change in position (40 ps sigma) is small compared to 150 ps. Assuming that the two tubes contribute equally to the width, the time resolution of each tube is then 105 ps. In the full experiment, the position will be determined by the drift chambers upstream; each tube then gives an independent measurement of the time-of-flight, which should then have a resolution of 75 ps. Given this resolution, protons can be identified at the 90% confidence level up to 7.1 GeV, kaons up to 3.8 GeV, and pions to 1.1 GeV.

Later investigations have shown that the discriminator output drifts as much as 200 ps in a several hour period (Figure C-2). Monitoring of these drifts, and correcting for them, should get the resolution down to about 80 ps/tube. This will allow identification of protons to 8 GeV, kaons to 4.2 GeV, and pions to 1.2 GeV.
FIGURE C-1

Distribution of time difference of two tubes on central scintillator from test run (July 1984). Beam trigger. Cuts have been placed on pulse height to eliminate double hits and spurious triggers.

**FWMH ~ 350 psec. \( \Delta \sim 150 \text{ psec} \)**
Figure C-2

Time fluctuation of discriminator and TDC over a 27 hour period. Start and stop pulses come from the same source, a Lecroy Instapulser. Short runs (approx. 10 minutes) show a time fluctuation of about 20 picoseconds.
APPENDIX D

Hadron Calorimeter Test Run Results

The hadron calorimeter for E-653 at Fermilab consists of 16 planes of graphite loaded extruded plastic tubes interleaved between 16 steel plates, each 2 inches thick, 8 ft. high, and 10 ft. wide. Each layer of tubes is sandwiched between 1/16 inch thick printed circuit boards which have a pattern of rectangular pads etched in them. The pad signals, which are capacitatively coupled from the tubes, can be used to measure positions in both transverse directions and energy in a tower geometry. Alternate layers of tubes are rotated 90 degrees. Each plane is made up of three modules, each 30" wide and 94" long. The center module in each plane has 316 pad and 48 tube signals while the outer modules each have 96 pad signals and 48 tube signals (See Figure D-1a,b). The pad and tube signals will be ganged together along the beam direction to form two longitudinal segments in each view and will then be amplified and digitized. Altogether, the calorimeter will have 2208 readout channels.

During the June-July E-653 test run, four of the center modules were installed in every fourth gap in the calorimeter and the center 16 tube and 78 pad signals were read out as shown in Figure D-1a with the tube and pad signals ganged together along the beam axis. The detector was operated at a voltage of 2.1 KV and the signals were amplified x 20 before digitization by LeCroy 2285 ADC's.

Figure D-2 shows the pad signals for several typical beam trigger events and Figure D-3 shows several interaction trigger events. The center of each small pad is indicated by an intersection of the XY grid lines. Two to eight intersection points at the same pulse height level indicates a hit in a medium or large pad. Figure D-4 shows the average amplified charge for 685 beam trigger events for each instrumented channel. (The channel number along the abscissa is the same as the signal number shown in Figure D-1a). Good correlation is observed between overlapping pad and tube signals. It can also be seen that most of the shower charge is contained within the size of one small pad so that the segmentation is well matched to the shower size.
Figure D-5 shows the total pulse height on the 32 pads on which the 9 mm (at the calorimeter) FWHM 800 GeV proton beam was centered. The low energy tail is caused by upstream interactions. The FWHM of the peak is 2492 channels so we obtain an rms resolution of 18%. This implies a resolution of 9% for the full detector assuming the energy resolution scales with $1/\sqrt{N}$ where $N$ is the number of sampling layers. This is consistent with an extrapolation of results at lower incident beam energies presented by M. Atac, et. al. (Gas Calorimeter Workshop, Fermilab, 1982). Those authors observed a saturation of the energy resolution at about 8% for energies higher than 100 GeV for a similar detector design using aluminum tubes. For energies below 100 GeV, they obtained a resolution of $102%/\sqrt{E}$.

Figure D-6 shows a histogram of the beam position in tube widths ($1$ tube width = 16 mm) from a pulse height weighted centroid calculation using the tube signals. We obtain an rms position resolution of 0.4 cm.
Fig. D-1 (a)
Center Module

Looking Downstream

Hadron Calorimeter Signal Map for July '84 Test Run

Tube # 1 mm = 6 cm

Tube width = 16 mm
Fig. D-2  • Beam Trigger Events

**Signal vs Pad in 3-D**

**Event = 8841**

**Max Value = 1394**

**Event = 8843**

**Max Value = 1571**

**Event = 8828**

**Max Value = 1078**

**Event = 8616**

**Max Value = 1448**
Fig.D-3  Interaction Trigger Events

Signal vs Pad In 3-D
Event = 19
Max Value = 928

Signal vs Pad In 3-D
Event = 23
Max Value = 832

Signal vs Pad In 3-D
Event = 22
Max Value = 786

Signal vs Pad In 3-D
Event = 22
Max Value = 940
Fig. D-4

CHARGE VS. CHANNEL

Charge in pC

Channel