1. The Muon Identification System

The primary purpose of the muon identification system (MUID) is to identify muons coming from the charged-current interaction of muon neutrinos in the emulsion target. In such interactions the muon track will point back to the primary interaction vertex and hence can be rejected as a candidate for a ν_τ interaction. The MUID system will also identify muons from muonic decay of a τ lepton. Tau leptons decay via the muon channel 17% of the time.

The muon identifier is a three-layer array of steel walls and planes of particle detectors. The upstream steel wall is 3.7 m high by 6.25 wide and is 0.42 m thick. The two remaining walls are each 3.25 m high by 5.48 m wide and 0.91 m thick. There are air gaps of 80 – 82 cm between the walls as shown in Figure xx. The total system is 4 m in length. Planes of detectors are placed between the walls to measure the vertical and horizontal positions of charged particles emerging from the steel. Proportional tubes cover 80% of the cross section; the remainder is covered by scintillator hodoscopes. The detectors were constructed at Tufts University and shipped to Fermilab in the summer and fall of 1996.

Proportional Tubes

There are three stations in the MUID system, referred to as A, B, and C, with A the farthest upstream. Each station consists of two H-shaped planes of proportional tubes, one each for *x* and *y* readout. The gaps in the H are where the muon flux was most intense.

The principal structural element of the proportional tubes is a four-cell aluminum extrusion. Each cell is a square 4 cm on a side. A total of 248 four-cell modules were constructed with lengths ranging from 1.3 to 6.25 m to accommodate the H-shape of the planes. The A planes are somewhat larger than those at stations B and C to improve the acceptance for low-momentum muons coming from the emulsion target. The proportional tubes are operated with a 95% - 5% $ArCO_2$ gas mixture. Each cell contains a 60-μm sense wire. The current signals from the sense wires are processed by a four-channel amplifier/discriminator card mounted on each module. The discriminator outputs are translated on the card to differential ECL levels for transmission over 100 m of twisted pair cable to coincidence registers.

Scintillator Hodoscopes

Scintillator hodoscopes fill apertures in the proportional tube planes left in the regions on both sides of the beam line where there is an intense flux of muons from the dump. The 1-μsec resolving time of the proportional tubes is too long to handle this intense flux. The resolving time of the scintillator elements is approximately 15 ns. There are six scintillator hodoscopes, one each at the east end and the west end of the three MUID stations. Each hodoscope has an *x* and *y* readout.

The width of the scintillator elements is 4 cm to match the proportional tube cell width. Each element is 1.5 cm thick. The range of element lengths is 1.0 m to 2.3 m. There are a total of 448 elements distributed over the six hodoscopes. The hodoscopes are constructed within aluminum boxes mounted on movable frames so as to position them in the gaps in the proportional tube stations. Each scintillator element is wrapped in aluminum foil for optical isolation. As this foil is at the same high voltage as the photocathode of the PMT, mylar sheets are used to insulate the horizontal and vertical elements from each other and from the aluminum box. The interiors of the aluminum boxes were cooled by forced air.

Hamamatsu R1666 tubes epoxied to the scintillator are used to view 256 of the elements. The remaining 192 elements are viewed by a set of 12 Hamamatsu 16-ch multianode photomultiplier tubes. Waveshifting fibers of 4 mm square cross section are placed in grooves milled along the lengths of these 192 elements. The fibers are gathered in 4 by 4 bundles and coupled to the multichannel tube by optical grease. The distribution of detector elements at stations A, B, and C is detailed in Table 1.

Readout signals leave the hodoscope box via ribbon twist-n-flat cable, bypassing the preamp on the R1666 cards. The signals then go into 28 N277 Nanocards, which provide ECL output. Thus, the data acquisition system can handle all signals from the MUID system in the same way.

Station	Plane	Gas Tubes	Scintillators	Detector Elements
A	x	264	112	376
A	y	88	48	136
B	x	232	96	328
B	y	88	48	136
C	x	232	96	328
C	y	88	48	136
Total		992	448	1440

Table 1. Detector elements in the muon ID system.

Muon ID Performance

Measurements in a cosmic ray test stand at Tufts showed that the efficiency of the proportional tubes is 97%. The slight inefficiency can be attributed to the insensitive area between the cells formed by the 2 mm thick interior walls.

Muons from PW5 were used to align the proportional tube stations. Figure … shows plots of the residuals of hits extrapolated from drift chamber tracks and the actual prop tube hit. The fits to the data are Gaussian. The flattening of the peaks in the downstream walls is due to multiple scattering in the steel.[1]

Figure 1. Alignment of the proportional tube stations of the muon ID system. Actual hits are compared with extrapolations from tracks using drift chamber information and the residuals plotted in 2 cm bins. Fits are Gaussian.

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[1] M. Skender, Master's thesis, Tufts University, 1997.