The Placement of Survey Monuments in the MINOS Far Detector Hall

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Introduction

A team of surveyors from the Fermilab Alignment and Metrology Group has placed and measured a set of survey monuments in the MINOS Far detector hall at the Soudan Underground Laboratory. The purpose of these monuments is twofold. Firstly, they allow the MINOS collaboration to align and locate the components of the detector in a local frame of reference as it is constructed. Secondly, they will allow the local coordinate system to be linked to an global frame of reference to determine its alignment with the NuMI beam. The global reference frame is described in a separate note.[1]

The survey team installed and measured the monuments in two separate visits during July and August of 2001. The measurements included the installation of three types of monument. The first was a set of brass tie rods embedded in the cavern floor, along the centerline of the detector support rails. The second was a set of "Dijak bolts." These are alignment monuments recessed into the floor with an eye-bolt able to accomodate a standard survey target or nest. These are distributed throughout the supermodule and workstation areas. The third was a set of construction ball pads, also having a ¼" hole and welded to the vertical supports for the MINOS detector. A diagram (not to scale) showing the approximate positions of the monuments is shown in Figure 2. The precise location of each monument in the local reference frame is listed in Table 1. The origin of the coordinates differs from that described in [1] in that $z = 0$ at the upstream (south) face of plane 0, rather than at the upstream cavern wall. For survey measurements, the wall is a poor approximation to a planar surface. As in [1], the z axis runs down the center of the detector, with the x axis pointing toward the west wall and the y axis pointing toward the ceiling of the cavern. The accuracy of the measurements is $\pm$ 0.2 – 0.3 mm on each axis (one σ).[2]

Brass tie rods

The survey crew used a gyrotheodolite to establish the centerline of the cavern. Five punched brass tie rods are embedded in the floor, aligned parallel to the centerline but offset by 18" to the east, since the trench for the MINOS coil runs down the center of the floor. These monuments will be used to determine the detector orientation with respect to the NuMI beam and generally are not used in the construction of the detector. The tie rods are indicated by circles in Figure 2.

Dijak bolts

The survey crew, assisted by the Soudan minecrew, installed the Dijak bolts in the cavern floor at locations along the aisleways in the supermodule areas, in the central area where the detector planes are mounted, and in the workstation areas where the planes are assembled. The Dijak bolts accept monuments or monument holders with a ¼" post, a

standard size in survey measurements. The Fermilab surveyors measured their positions with a laser tracker. These monuments are used to define the local reference frame for the detector construction and for calibration of the Vulcan spatial measurement system, which is used to locate the detector components in the local reference frame. The bolts are recessed in the floor and covered with rubber stoppers to keep out dirt and debris. The Dijak bolts are shown as stars in Figure 2.

Construction Ball Pads

The construction ball pads are precision-machined mounting blocks with a central hole that will accept the same monuments and nests as the Dijak bolts, as shown in Figure 1.

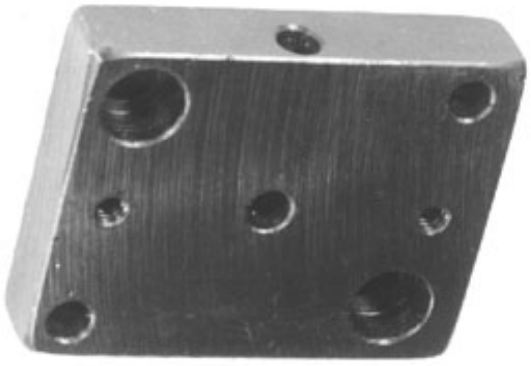

Figure 1 Construction ball pad (actual size)

These are welded to 12 selected columns of the far detector support structure at the mid-level approximately 14 feet above the floor. These positions allow a three-dimensional definition of the local coordinate system and calibration of the Vulcan spatial measurement system. If the Vulcan is calibrated using only points that lie in a common plane, its resolution outside of that plane is degraded. The column positions are chosen since they are least likely to undergo significant displacement due to deformation of the support strucure as detector planes are mounted on it. The rails, on the other hand, can be expected to sag. Since Figure 2 is in plan view, the construction ball pads are not symbolically depicted, but arrows point to their locations in the figure.

Acknowledgements

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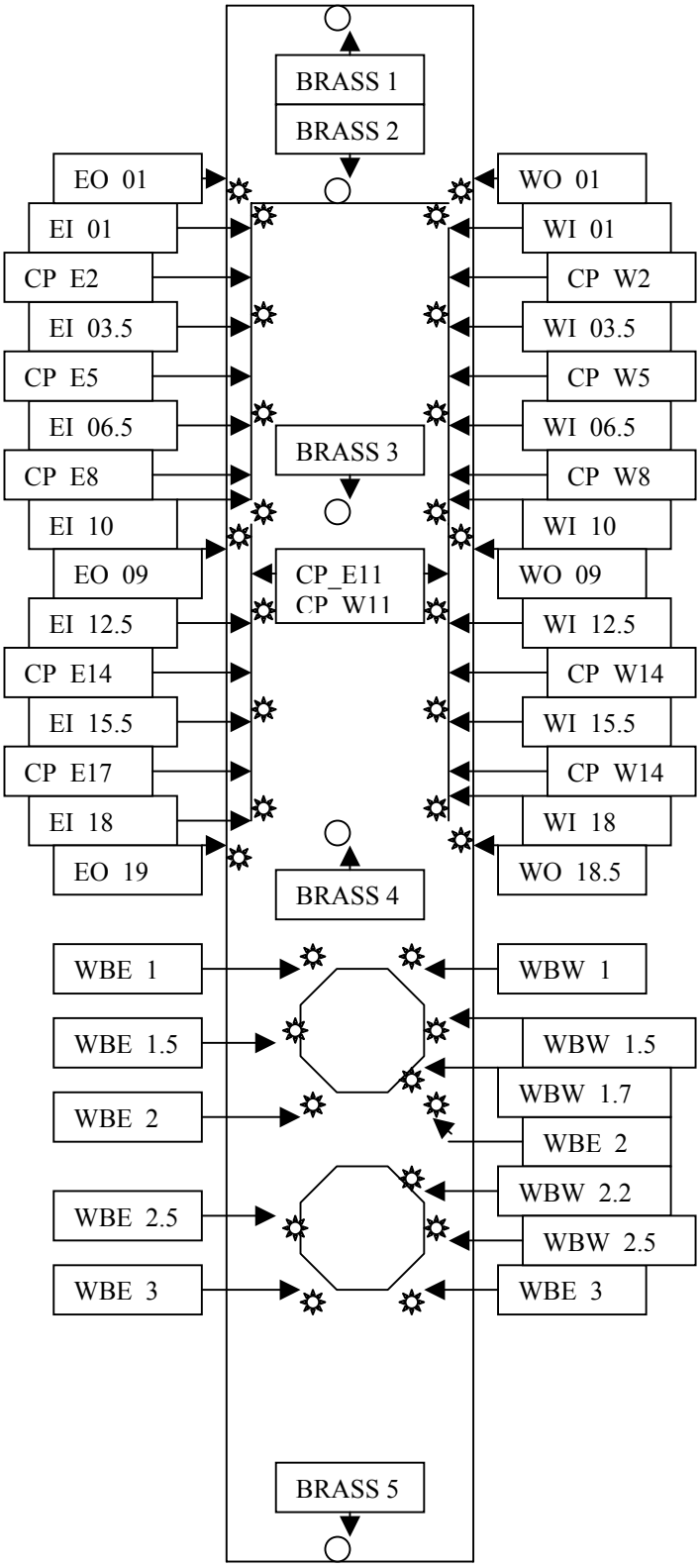

Figure 2 Approximate layout of the survey monuments in the MINOS cavern at Soudan. South is toward the top of the page.

NAME	X (in)	Y (in)	Z (in)	Comments	X (m)	Y (m)	Z (m)
EI_01	-129.337	-186.364	12.818	Floor point E side between columns	-3.285	-4.734	0.326
EI_035	-129.425	-186.523	213.147	Floor point E side between columns	-3.287	-4.738	5.414
EI_065	-128.514	-186.341	413.586	Floor point E side between columns	-3.264	-4.733	10.505
EI_10	-128.847	-186.015	623.607	Floor point E side between columns	-3.273	-4.725	15.840
EI_125	-128.767	-186.158	823.654	Floor point E side between columns	-3.271	-4.728	20.921
EI_155	-128.814	-185.878	1023.717	Floor point E side between columns	-3.272	-4.721	26.002
EI_18	-129.413	-186.550	1213.522	Floor point E side between columns	-3.287	-4.738	30.823
WI_01	129.422	-186.336	11.546	Floor point W side between columns	3.287	-4.733	0.293
WI_035	129.239	-186.226	212.490	Floor point W side between columns	3.283	-4.730	5.397
WI_065	128.950	-186.289	412.174	Floor point W side between columns	3.275	-4.732	10.469
WI_10	129.297	-186.220	622.463	Floor point W side between columns	3.284	-4.730	15.811
WI_125	128.821	-186.327	822.692	Floor point W side between columns	3.272	-4.733	20.896
WI_155	129.325	-186.313	1023.035	Floor point W side between columns	3.285	-4.732	25.985
WI_18	129.216	-186.661	1214.161	Floor point W side between columns	3.282	-4.741	30.840
CP_E11	-167.446	-19.273	708.416	Point on E column	-4.253	-0.490	17.994
CP_E14	-167.812	-20.174	924.718	Point on E column	-4.262	-0.512	23.488
CP_E17	-167.921	-20.184	1140.474	Point on E column	-4.265	-0.513	28.968
CP_E2	-167.723	-20.593	82.104	Point on E column	-4.260	-0.523	2.085
CP_E5	-167.646	-20.251	298.243	Point on E column	-4.258	-0.514	7.575
CP_E8	-167.770	-19.803	514.262	Point on E column	-4.261	-0.503	13.062
CP_W11	167.928	-19.714	709.225	Point on W column	4.265	-0.501	18.014
CP_W14	167.727	-19.899	925.294	Point on W column	4.260	-0.505	23.502
CP_W17	167.764	-19.711	1140.797	Point on W column	4.261	-0.501	28.976
CP_W2	167.931	-20.112	84.169	Point on W column	4.265	-0.511	2.138
CP_W5	167.887	-20.582	299.584	Point on W column	4.264	-0.523	7.609
CP_W8	167.761	-20.407	515.290	Point on W column	4.261	-0.518	13.088
EO_01	-234.724	-186.173	-33.323	Floor point E aisle outside columns	-5.962	-4.729	-0.846
EO_09	-235.572	-186.020	594.656	Floor point E aisle outside columns	-5.984	-4.725	15.104
EO_19	-227.400	-186.719	1333.269	Floor point E aisle outside columns	-5.776	-4.743	33.865
WO_01	207.945	-186.141	-30.477	Floor point W aisle outside columns	5.282	-4.728	-0.774
WO_09	210.734	-185.947	592.767	Floor point W aisle outside columns	5.353	-4.723	15.056
WO_185	211.766	-186.595	1252.783	Floor point W aisle outside columns	5.379	-4.740	31.821
WBE_1	-107.512	-186.476	1423.367	Floor point E side workbench area	-2.731	-4.736	36.154
WBE_1_5	-169.510	-186.238	1622.682	Floor point E side workbench area	-4.306	-4.730	41.216
WBE_2	-108.252	-186.271	1807.065	Floor point E side workbench area	-2.750	-4.731	45.899
WBE_2_5	-170.617	-186.318	2066.493	Floor point E side workbench area	-4.334	-4.732	52.489
WBE_3	-110.678	-186.285	2259.170	Floor point E side workbench area	-2.811	-4.732	57.383
WBW_1	200.713	-186.337	1423.634	Floor point W side workbench area	5.098	-4.733	36.160
WBW_1_5	232.430	-186.591	1606.107	Floor point W side workbench area	5.904	-4.739	40.795
WBW_1_7	188.756	-186.647	1747.222	Floor point W side workbench area	4.794	-4.741	44.379
WBW_2	202.455	-186.452	1806.914	Floor point W side workbench area	5.142	-4.736	45.896
WBW_2_2	184.091	-186.772	1928.855	Floor point W side workbench area	4.676	-4.744	48.993
WBW_2_5	232.780	-186.268	2077.142	Floor point W side workbench area	5.913	-4.731	52.759
WBW_3	201.142	-186.344	2255.217	Floor point W side workbench area	5.109	-4.733	57.283

Table 1 Survey monument coordinates in English and metric units. All floor points are Dijak bolts. Brass tie rods are not included in this table.

[1] Robert Hatcher, *Numbering Conventions and Co-ordinate Systems in gminos*, NuMI-L-243, Feb. 1997.
[2] Virgil Bocean, private communication