M15 - A BEAM LINE THAT CLIMBS THE WALL

R. Kokke, J. McIlroy, A.J. Otter, D. Revell, H. Sprenger and L. Voboril
TRIUMF, 4004 Wesbrook Mall, Vancouver, B.C., Canada V6T 2A3

Summary

TRIUMF's M15 beam line for surface muons transports particles to an experimental location 23 ft above and 32 ft south of the primary target. This paper deals with the engineering aspects of the project which was completed in 1985 and is now fully operational. The beam line components are mounted on sub-frames which are designed so that if servicing is necessary the components can be removed, repaired and the beam line reassembled without requiring optical realignment. The beam line has sections at 30°, 45°, 60° and 90° to the horizontal and all crane lifts have been arranged to be vertical. The mechanical arrangements and alignment methods are described in detail.

Introduction

Beam line M15 is a channel to transport surface muons from a primary target (1AT1) to an experimental target (focus). The focus is located 12.5 ft west and 32 ft south of the primary target and is 23 ft higher (Fig. 1). The beam line 'climbs up the wall' of the main building (meson hall), penetrates a 3 ft thick concrete wall into the M15 experimental hall, which was specially built to house the experimental area, the power supplies, controls and a counting room. The channel is 58 ft long and consists of 26 magnets, four slit boxes, a beam blocker, two steering magnets and two dc separators (spin rotators) 1.5 m long.

Design Criteria

To install a conventional channel of this size during a typical 5-6 week shutdown does not create a problem. The installation and alignment is usually done in situ and the crews for the installation of electrical and cooling services work alongside without much interference. However, on the M15 channel all of these activities would occur in a much smaller area. Therefore, to avoid parallel employment of installation crews, the construction time for various activities during the shutdown had to be reduced. The main challenges were how to penetrate three layers of existing shielding blocks 12 ft thick, and how to support the new channel while maintaining effective shielding for the primary target area and the primary beam line directly below. Furthermore, access to the primary beam line had to be maintained.

Design Features

The beam line was designed in sections. Each section consists of a main frame and a sub-frame. The components are mounted and aligned on sub-frames which are furnished with three-point supports which match spherical adjustment devices mounted to the main frames. Two permanent magnets installed close to the target inside the primary target shield were mounted and aligned in a special cradle. The permanent magnets have indirect water cooling and temperature sensors.

All sections were assembled and prealigned prior to the shutdown. This reduced the number of components to be installed and aligned during the shutdown from 19 separate elements to only the six modular sections. This modular design allows individual sections to be removed for maintenance or to have access to the primary beam line below. The three-point supports permit reinstallation of the section to its original position without realignment to within 0.010 in. with respect to the mean beam centre.

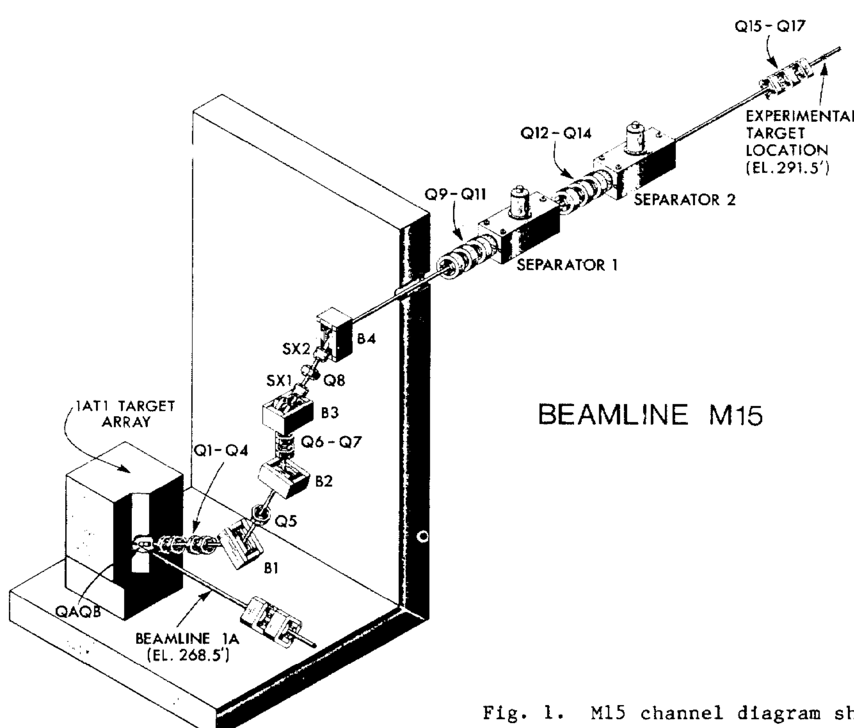

Fig. 1. M15 channel diagram showing the beam path and change of beam planes.

To support the channel and at the same time maintain effective shielding for the primary beam line and target array, the existing shielding blocks were removed and replaced by special concrete shielding blocks weighing close to 300 tons. These blocks also serve as the support structure for the new channel.

Installation of the M15 components inside the meson hall was scheduled for two shutdown periods. The special shielding/support was installed first, together with the front-end components not supported by the special shielding/support. Any settling or shrinkage of the new concrete could now occur before the sections it supports were installed.

Remote Handling Capability

All components close to the primary target were designed for remote removal and installation. The permanent magnet cradle can be removed and installed by using a special lead shielded flask. All services for sections I and II and the permanent magnets including their temperature sensors can be connected remotely. Beam pipe vacuum connections up to the second section have indium seals which can also be disconnected and removed remotely.

Alignment

Because the M15 channel was unusually complex, with two vertical beam planes and changing slopes, and because some of the alignment work would take place in a high radiation area, we had to identify early on the objectives, constraints and techniques to develop an alignment procedure. This procedure became an integral part of the design.

The alignment was divided into four major parts:

1. Site survey
This was done before the shutdown for the M15 installation. With this survey we wanted to find out any discrepancies of the existing target array (built 14 years ago) and to fix the basic M15 parameter, the 30° line (first leg of M15), on which we would base all other M15 metrology. This 30° line is located in the vertical plane of the primary beam line (1A) and intersects the centre of 1A at the primary target (Fig. 2). Existing ports, used to connect the M15 channel, were then surveyed for their true position with respect to the 30° line. The instrument position was then fixed with sufficient benchmarks north/south and east/west to mark the vertical and horizontal beam planes. The instrument position, hence the 30° line, could now be reproduced at any time independent from its support and without looking at the centre of the primary target.

2. Section alignment
All components were prealigned on their sub-frames. The sections were all aligned horizontal regardless of their final position when installed in the beam line. This was possible by specially designed gimbal-type mountings (Fig. 3) which permit alignment for X,Y,Z axes and angular displacements (total of six degrees of freedom). This type of mounting is not an ideal way to eliminate systematically one degree of freedom at a time during alignment. However, since the gimbal mount was located at or near the centre of gravity of the components the sections could be assembled and aligned horizontally and then turned into their operating positions (30°, 45°, 60° and horizontal) without affecting the alignment (this was tested during pre-assembly).

Also, all components had the same mounting which eliminated much guesswork as to which adjustment screw to turn for what direction.

3. Installation of sections (channel assembly)
During the installation each section was handled as a single 'component'. Only targets installed at each end of a section were used for positioning. The sub-frames, some as long as 12 ft, were designed stiff enough to avoid twist and bending. The targets installed during section alignment were left in place to avoid cumulative errors. Because the alignment was broken up into three phases (individual sections, channel installation and recording of external alignment marks) and because mounting errors and installation errors are cumulative and together make up the desired installation tolerance (Table I), the actual measurements during prealignment of the sections were limited to one-third of the desired tolerance of the complete channel.

During installation we used three T2 theodolites placed at the M15 beam centre (Fig. 4). Instruments A and B sweep the vertical plane of the primary beam line

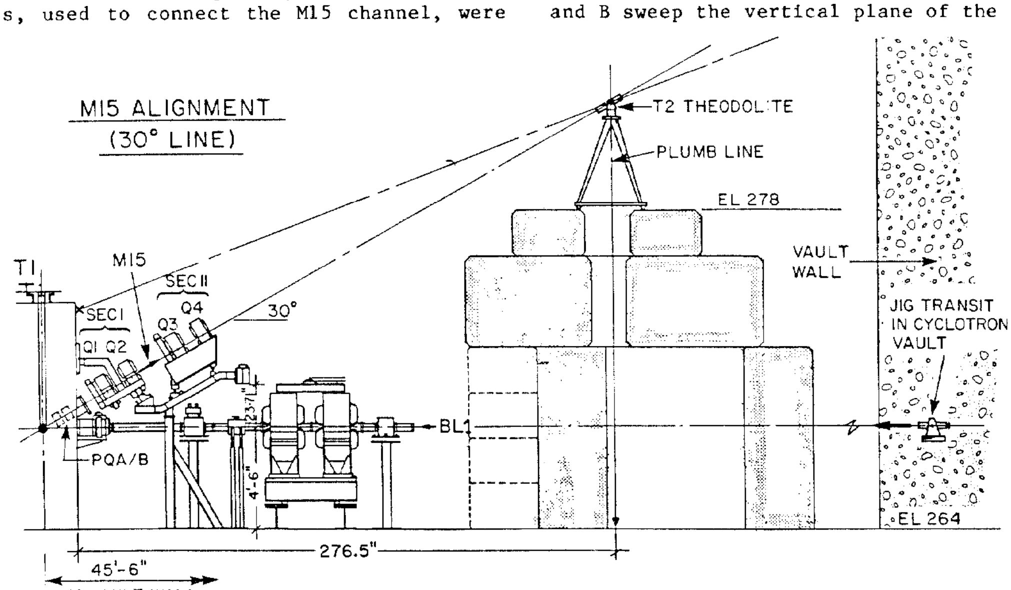

Fig. 2. The 30° line. Base line for the M15 metrology is located in the vertical plane of B/L1A and intersects at the center of target T1.

Table 1. M15 - Installation tolerances.

		Quadrupoles Sextupoles	Dipoles
Rectilinear Placement (1) +/-	Z	0.030	0.060
	X	0.005	0.015
	Y	0.005	0.062
Angular Placement	PITCH (2)	0.0025	-
		(0.024)	(0.125)
	ROLL	-	0.005
gradient (1)		(0.125)	(0.015)
(degrees)	YAW (2)	0.0025	0.005
+/-		(0.024)	(0.022)

(1) in Inches
(2) over total pole length

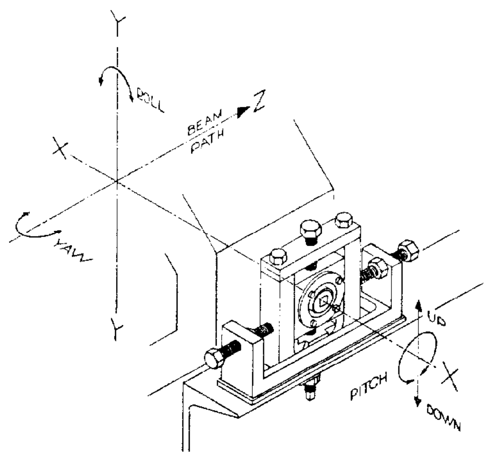

Fig. 3. Gimbal mount allowing rectilinear and angular placement.

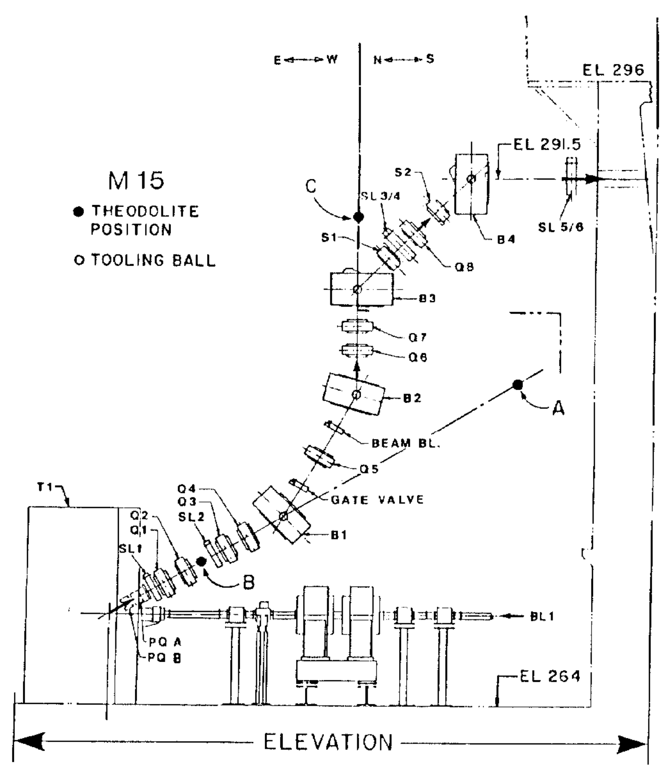

Fig. 4. Theodolite set-up; theodolite A & B in vertical plane EW, theodolite C in vertical plane EW & NS. O = Tooling Ball

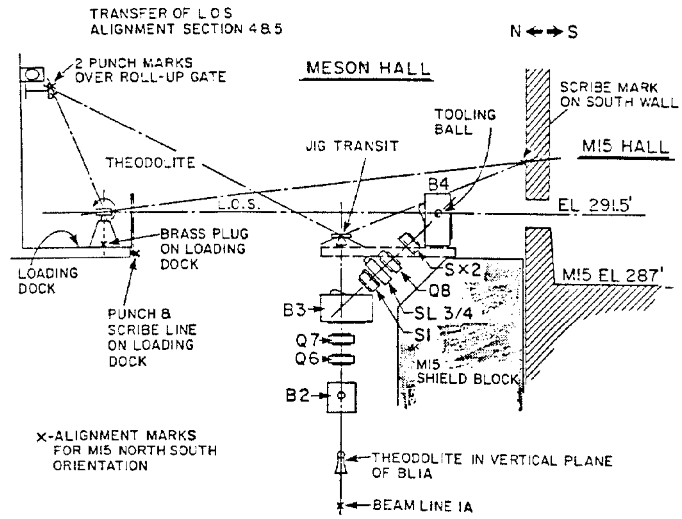

Fig. 5. Transfer of LOS theodolite on loading dock defines horizontal LOS from B4 to M15 focus.

(NS) and instrument C can sweep two vertical planes, in the NS and EW direction. Sections I and II were aligned first on spherical support points on the main frame using instrument A. Sections I and II were then temporarily removed and replaced with instrument B mounted to a special frame supported on the same spherical mounts. With this set-up it was now possible to sweep two vertical planes perpendicular to each other. Alignment of all remaining sections was now straightforward.

4. Transfer of LOS (line-of-sight) and alignment records

With all the sections in place inside the meson hall, a fourth theodolite was positioned approximately 70 ft away from dipole B4, LOS perpendicular to the vertical plane of the primary beam line. Permanent benchmarks were made to precisely repeat the instrument position at any time (Fig. 5). This instrument was not only used to transfer the LOS from the meson hall into the M15 hall but also to record the position of all external alignment targets and scribe lines made during section alignment.

We would like to mention that the validity of this instrument was tested shortly after commissioning of the new channel. An accidental 'bump' while moving shielding blocks displaced some upper sections by as much as 6 mm. Within two hours we managed to realign the channel without loss of beam quality.

The M15 channel was energized at 16:30 h on October 21, 1984 and surface muons were immediately extracted a few hours after the installation was complete.

Acknowledgement

We wish to thank Roy Cuthbert of Cuthbert Engineering Ltd, Delta, B.C. for his support during the alignment. We would also like to thank Anna Gelbart and Mindy Hapke for the illustrations.