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Survey and Alignment of the Fermilab MuCool Test Area Beam Line

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MuCool Test Area (MTA)

- MuCool Test Area (MTA) is designed to develop and test muon ionization cooling components using the intense Fermilab Linac beam
- MTA facility is part of the Muon Collider and Neutrino Factory R&D program
- MuCool stands for Muon Cooling experiment
- The MTA facility is located southwest of the Fermilab Linac. It consists of an experimental hall and a service building
- Fermilab Linac is a **H^-** ion, 400 MeV accelerator which provides beam for the Booster operation

Linac-to-MTA Enclosure

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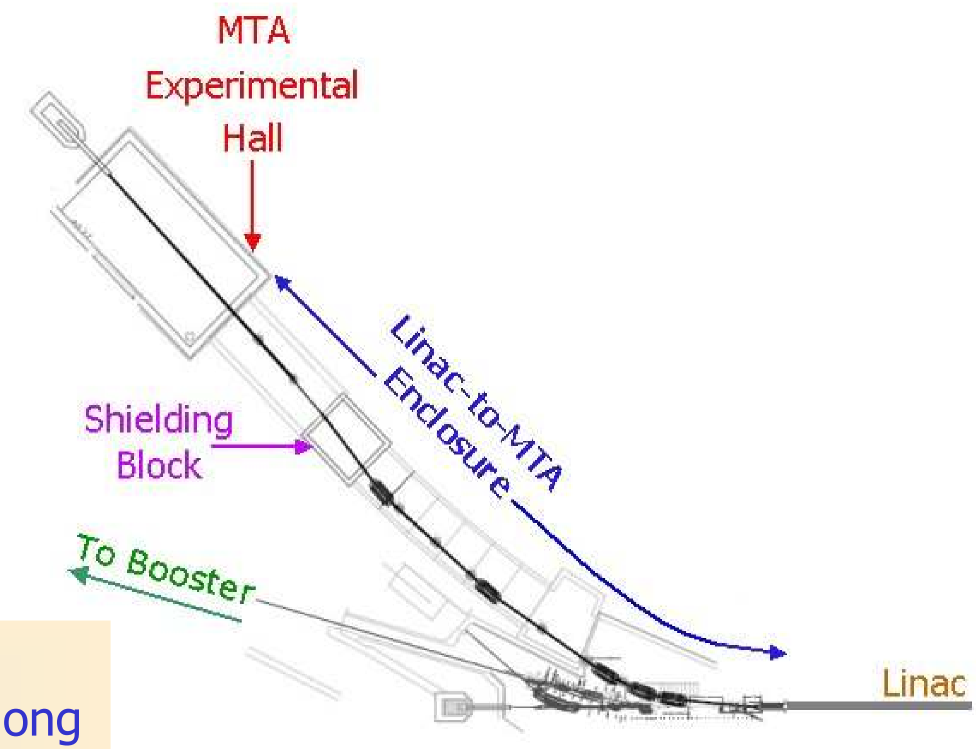
February 11-15, 2008

- MTA Experimental Hall and Linac tunnel are separated by 50 m long connecting (Linac-to-MTA) enclosure

- MTA beam line is located in the Linac-to-MTA tunnel enclosure

- MTA experimental hall is shielded and separated from the Linac by a 3.66 m (12 ft) long concrete block

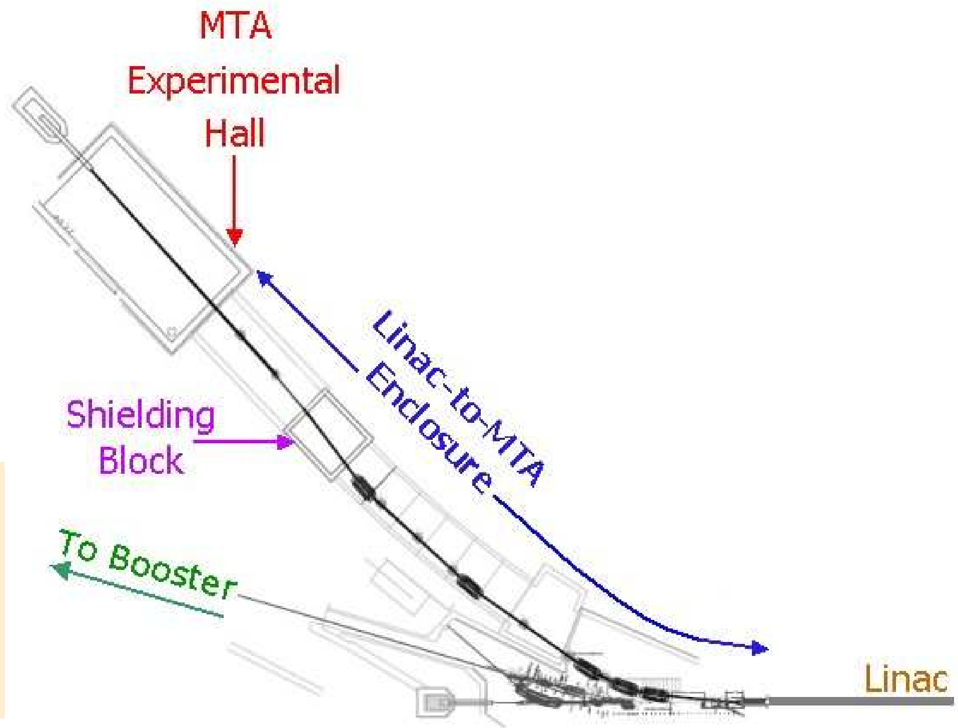
- Beam line penetrates through the shield block to the Hall. The penetration has an inside diameter of 22.23 cm (8.75 in)



MTA Beam Line

- MTA Beam Line is a simple beam line to transport **H**$^{-}$ or proton beam from the end of the Fermilab 400 MeV Linac to the MTA

- Beam Line design is based on using existing dipoles and quadrupoles and other equipment available at Fermilab from previous projects



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MTA Beam Line Components

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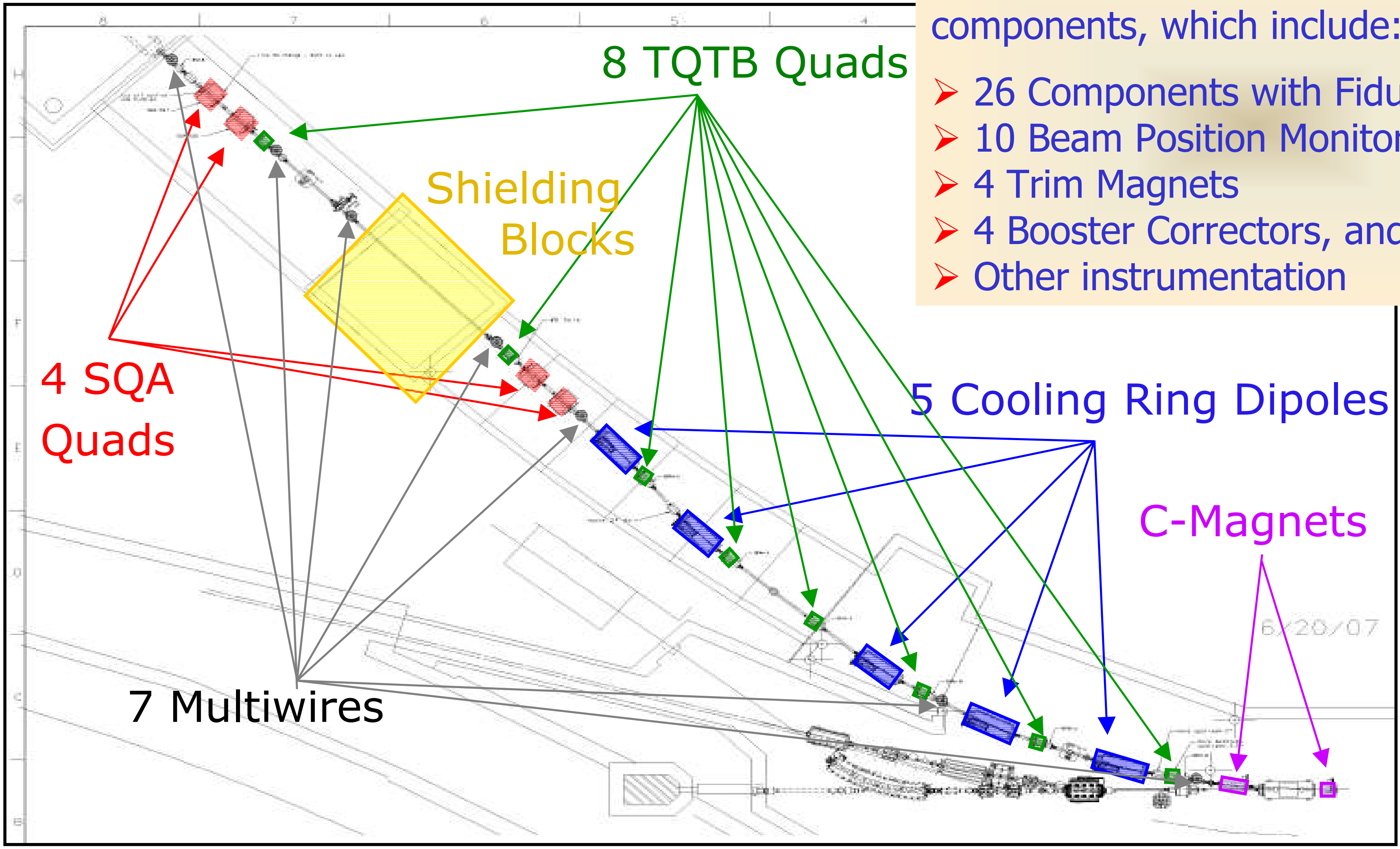

- MTA Beam Line consists of 62 components, which include:
  - 26 Components with Fiducials
  - 10 Beam Position Monitors (BPMs)
  - 4 Trim Magnets
  - 4 Booster Correctors, and
  - Other instrumentation

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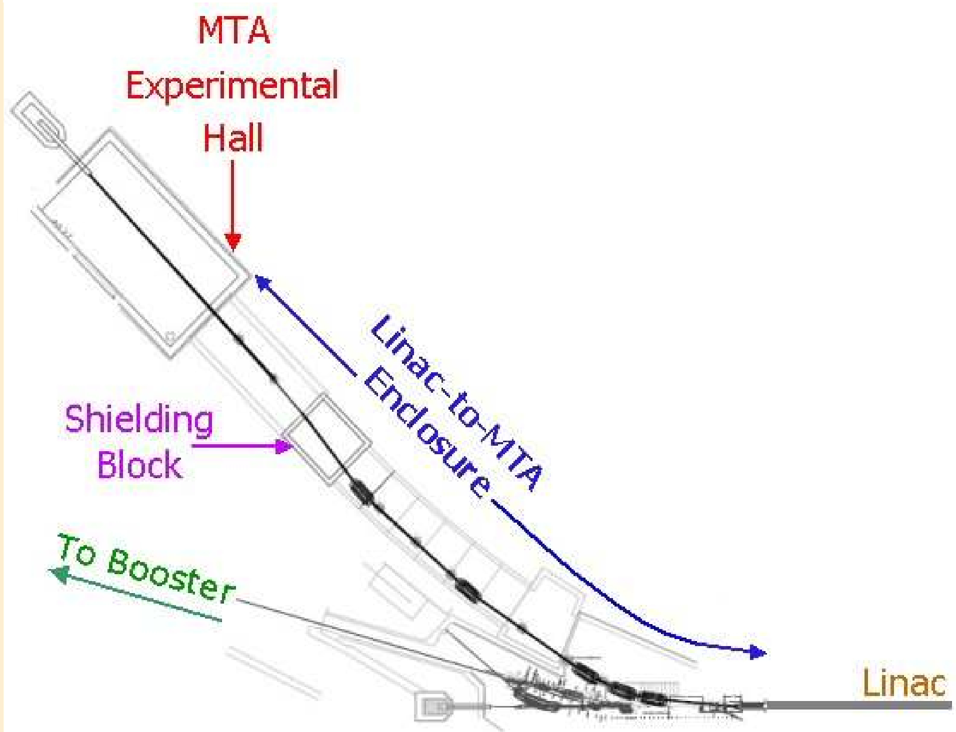
➤ Establish a precision horizontal and vertical control network for positioning MTA Beam Line components in the Fermilab Site Coordinate System (FSCS) to ±0.5 mm at 95% confidence level

➤ Bring horizontal and vertical controls into the
- MTA Experimental Hall
- Linac-to-MTA enclosure, and
- Part of the Linac enclosure

➤ Tie the new MTA Horizontal and Vertical networks to the existing Linac network



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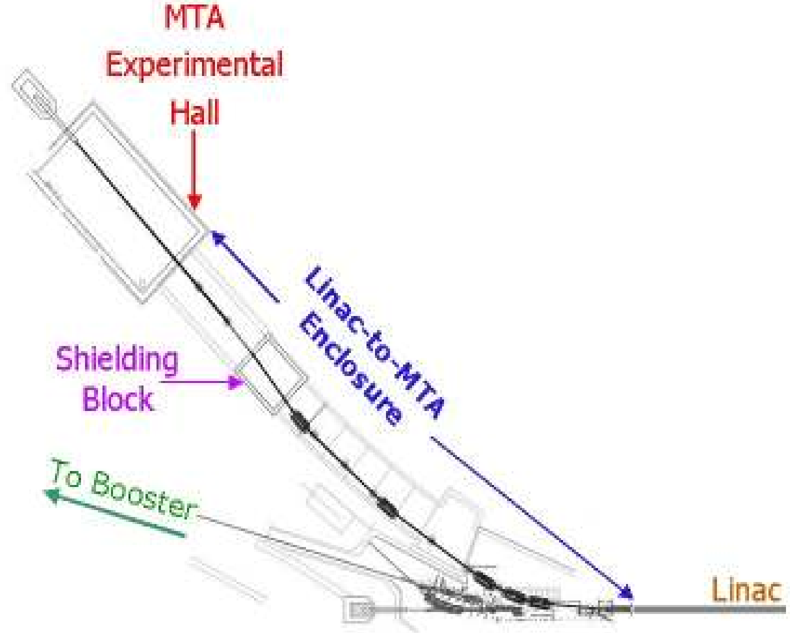
- The 3.66 m (12 ft) long shielding block is removed before for the MTA network measurements

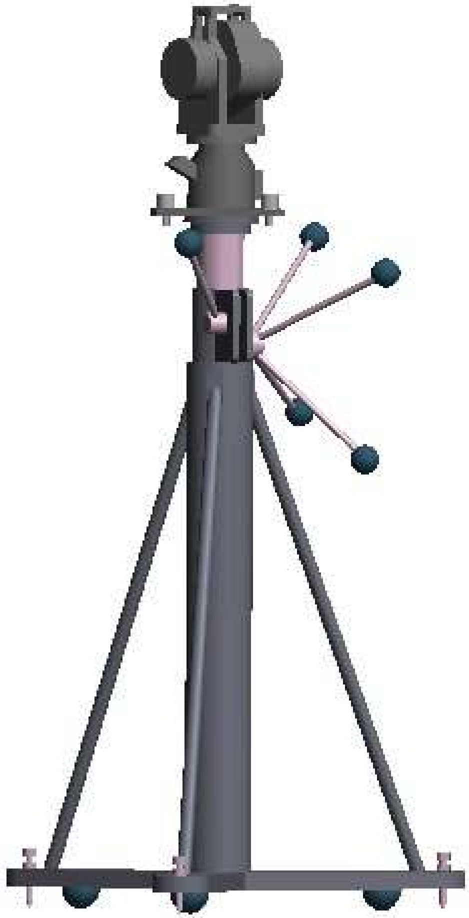


MTA Network consisted of:

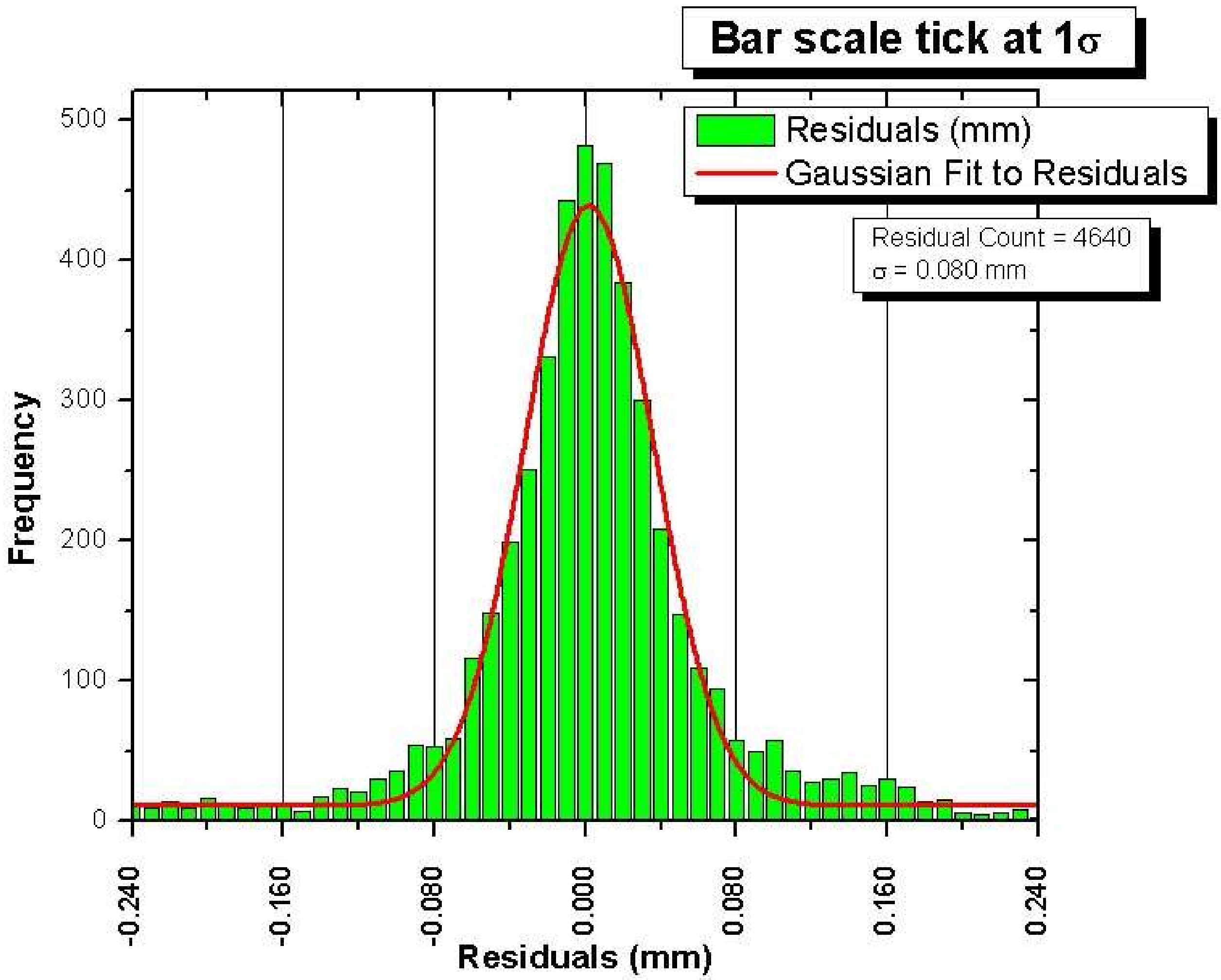
- 25 Floor Monuments
- 34 Wall Monuments
- 12 Tie-Rods on the Wall
- 32 Pass Points
- 6 Brass Points

Survey Methodology

- All Survey and Alignment were done with:
  - Laser Tracker
  - Total Station for Stake-out
  - Electronic Level for Elevations
  - Gyro-Theodolite for Azimuths



MTA Network Results



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Component Fiducialization

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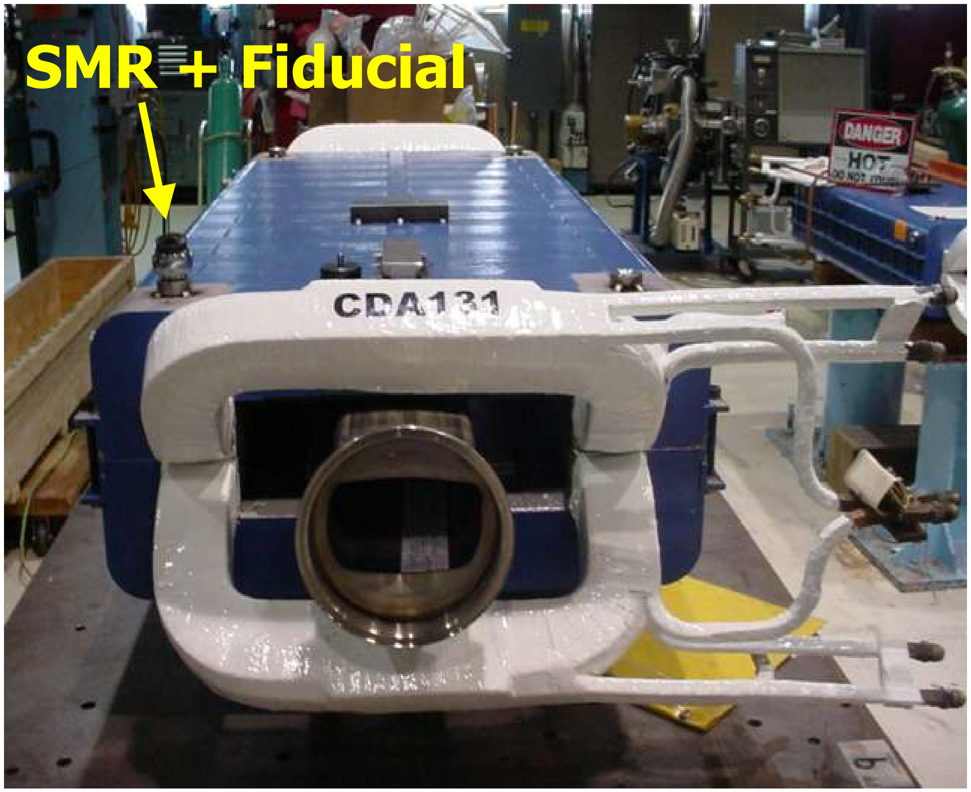

- Fiducial is a stainless steel (Shegjak) lug with a magnet in the center to hold SMR

- Shegjak = O'Sheg + Dijak

Component Referencing

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- Components with Fiducials were Referenced with Laser Tracker in a local magnet coordinate system

- Referencing Methods used
  - Plane Fits
  - Plane-Plane Intersections
  - 3- Plane Intersections
  - Line Fits
  - Plane-Line Intersections
  - Line-Line Intersections
  - Cylinders Fits
  - Circle Fits

- Magnets Referenced to better than ±0.15 mm

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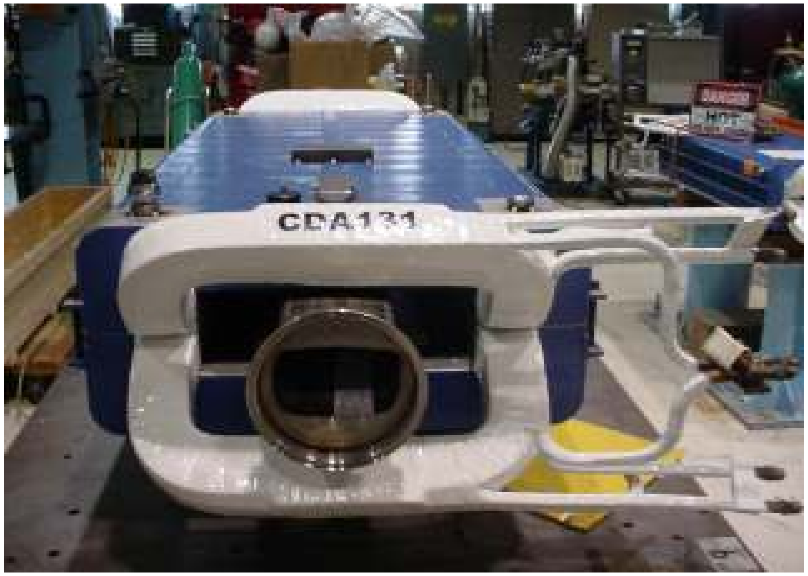
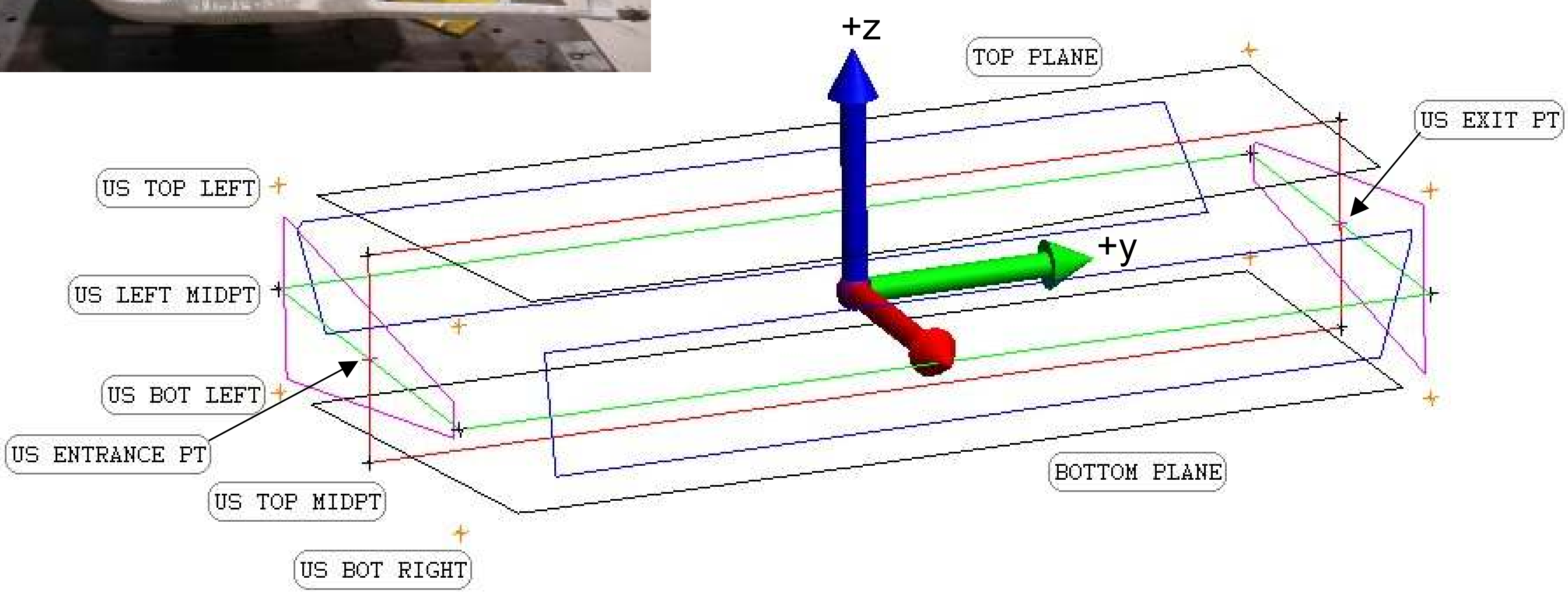
Magnet Reference - Method 1

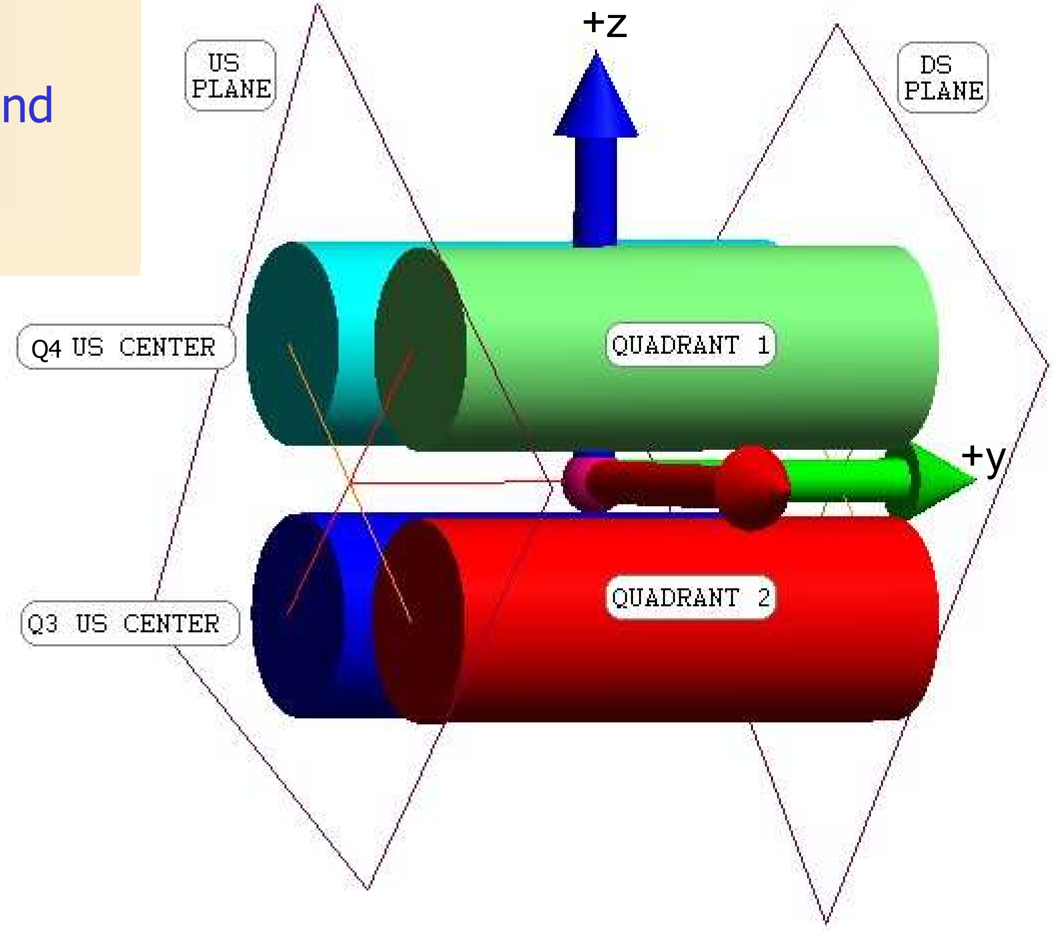


- No dimensions of component
- Six planes are created from Laser Tracker measurements made on six sides of the component



Magnet Reference - Method 2

- No dimensions of component
- Two planes are created from measurements made on upstream and downstream sides of the component
- A cylinder is constructed from measurements made on the upstream and downstream circular pole tips in each quadrant of the component



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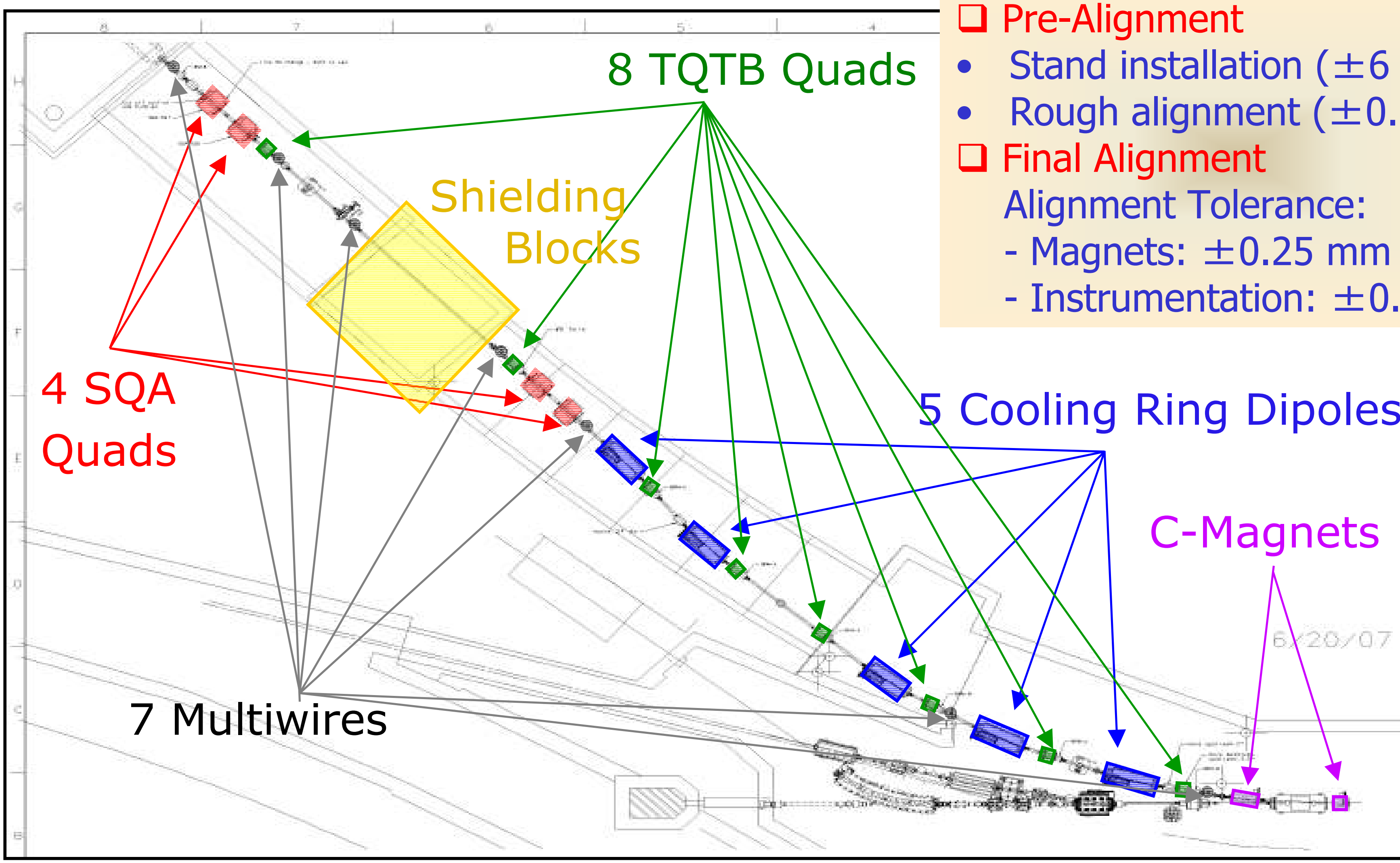
Component Alignment



- ❑ Pre-Alignment
  - Stand installation (±6 mm)
  - Rough alignment (±0.5 mm)
- ❑ Final Alignment

  Alignment Tolerance:

  - Magnets: ±0.25 mm
  - Instrumentation: ±0.5 mm

Error Analysis of Magnet Alignment

Total radial standard deviation of a magnet alignment (1σ) :

$$\sigma_{Mag\_Align} = \pm\{\sigma_n^2 + \sigma_m^2 + \sigma_f^2 + \sigma_s^2\}^{1/2} = \pm 0.165 \text{ mm}$$

σ_n = standard deviation of the relative errors in the network = (±0.158 mm)
(relative transversal errors between points)

σ_m = standard deviation of the errors in measurement from control points to fiducials
= $\pm\{\sigma_{nm}^2 + \sigma_{LT}^2\}^{1/2}$ = (±0.017 mm)

σ_{nm} = standard deviation of nest to control monument repeatability = (±0.008 mm)

σ_{LT} = standard deviation of the Laser Tracker measurement
for aligning components from one setup = (±0.015 mm)

σ_f = standard deviation of the errors in measurement from
fiducials to magnet (±0.035 mm)

σ_s = standard deviation of the errors in resolution of the stands
adjustment (±0.025 mm)

The resulting standard deviation is within the specified accuracy of ±0.25 mm

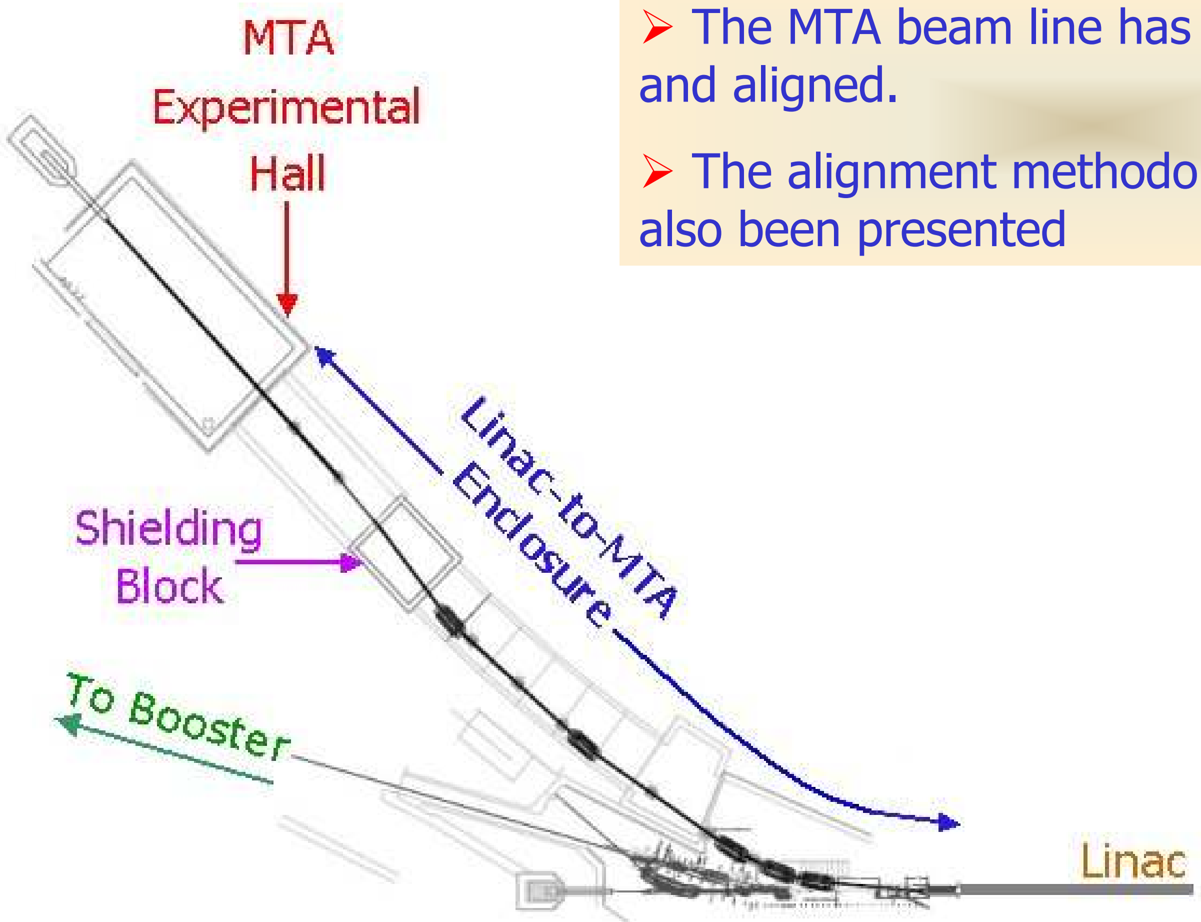
Challenges

- Stands are of poor quality. MTA used components from previous projects and very old stands
- Time constraints. Network was done over a period of six months because access to Linac-MTA enclosure depended on the Linac downtime
- High congestion in the Linac-to-MTA enclosure, too many jobs going on at the same time
- Unstable floor at some locations. Stands were sitting over a metal ledge

Status of MTA Beam Line

- The C-magnets has to be installed during a Linac downtime sometimes in 2008
- Since all the components have been put under vacuum and leak checked, a final alignment would be completed during a Linac downtime sometimes in 2008
- Full commissioning is expected to be sometimes in 2008

Conclusion



- The MTA beam line has been surveyed and aligned.
- The alignment methodology used has also been presented

Acknowledgment

- I would like to thank
  - Alignment and Metrology Group members who participated in the MTA project
  - Dr. Fernanda Garcia - MTA Beam Line Installation Manager

ありがとう

Domo Arigato !!!

質問ですか？