SPEAR3

43rd Annual California State University Fresno Geomatics Engineering Conference

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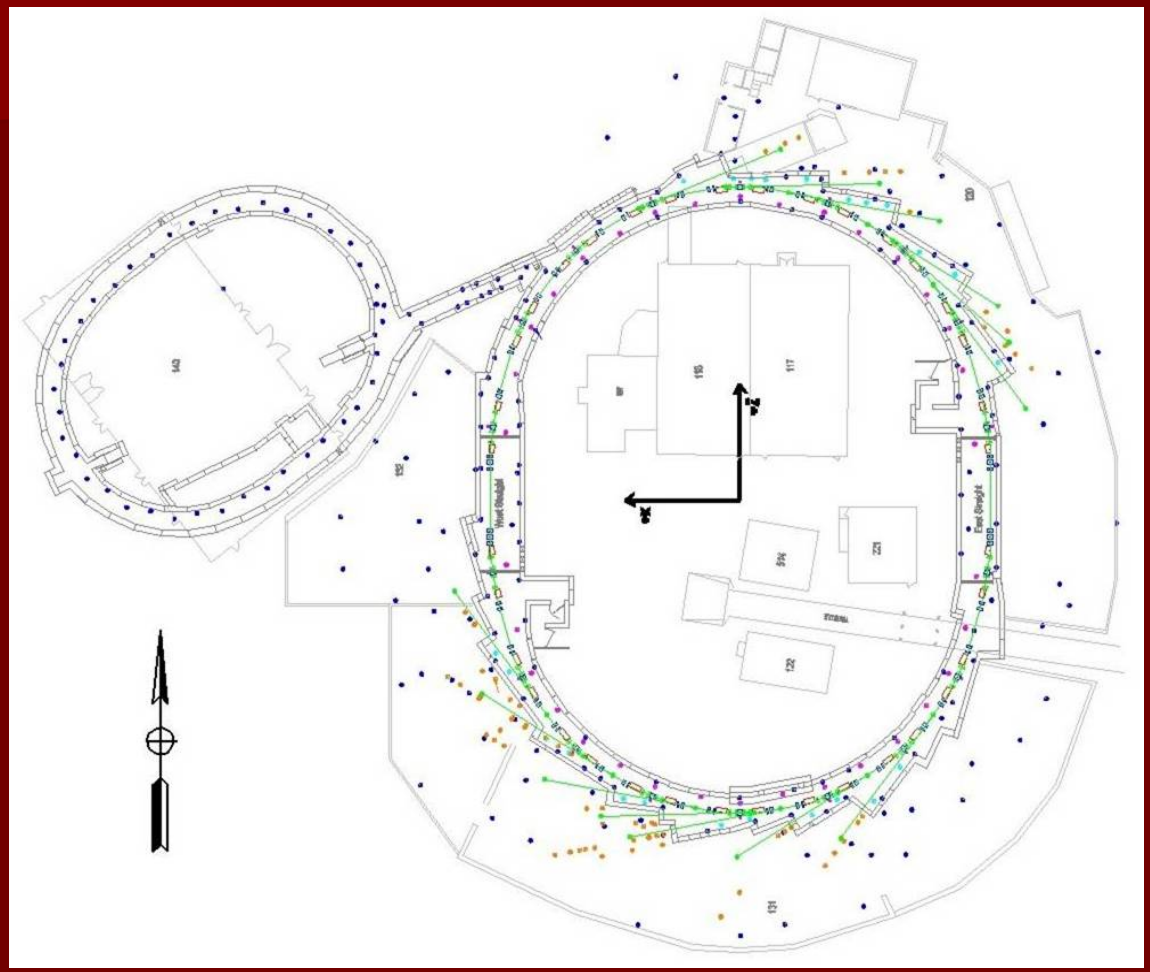
Metrology Department

Stanford Linear Accelerator Center
Operated for the U.S. Department of Energy by Stanford University

Stanford Linear Accelerator Center

Stanford Synchrotron Radiation Laboratory (SSRL)

SSRL



Faro/SMX Laser Trackers

- Angular accuracy 18 μm + 3 ppm
- Interferometer accuracy 10 μm + 1 ppm
- ADM accuracy 20 μm + 1 ppm
- Max. range 35 m

Leica TC2002

- 0.5 arc second gun
- 0.150 mm maximum and minimum differences compared to an interferometer on a 26 m bench

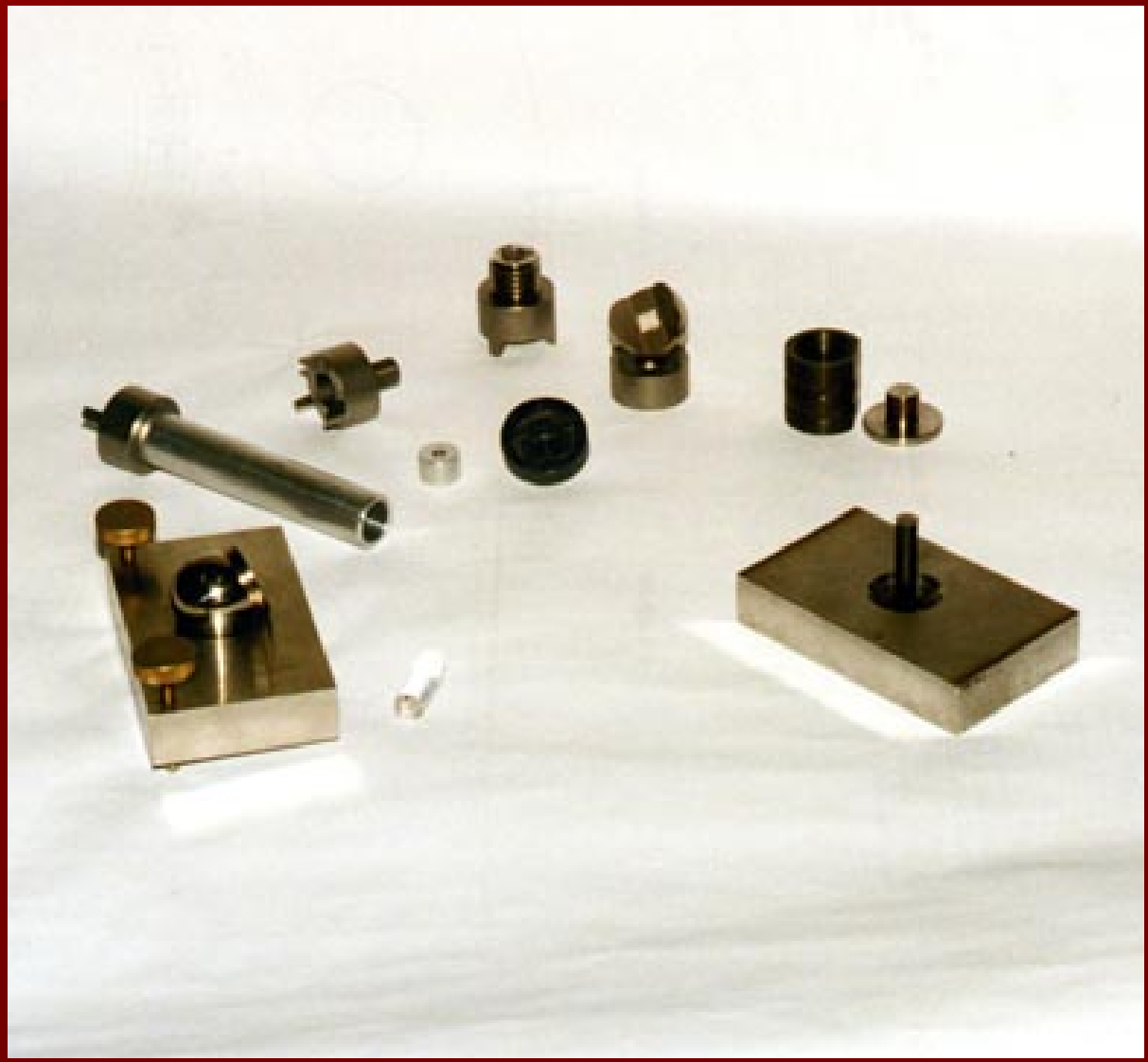
Trimble/Zeiss DiNi 12

- Standard deviation over 1 km two-way is 0.3mm
- NEDO invar rods

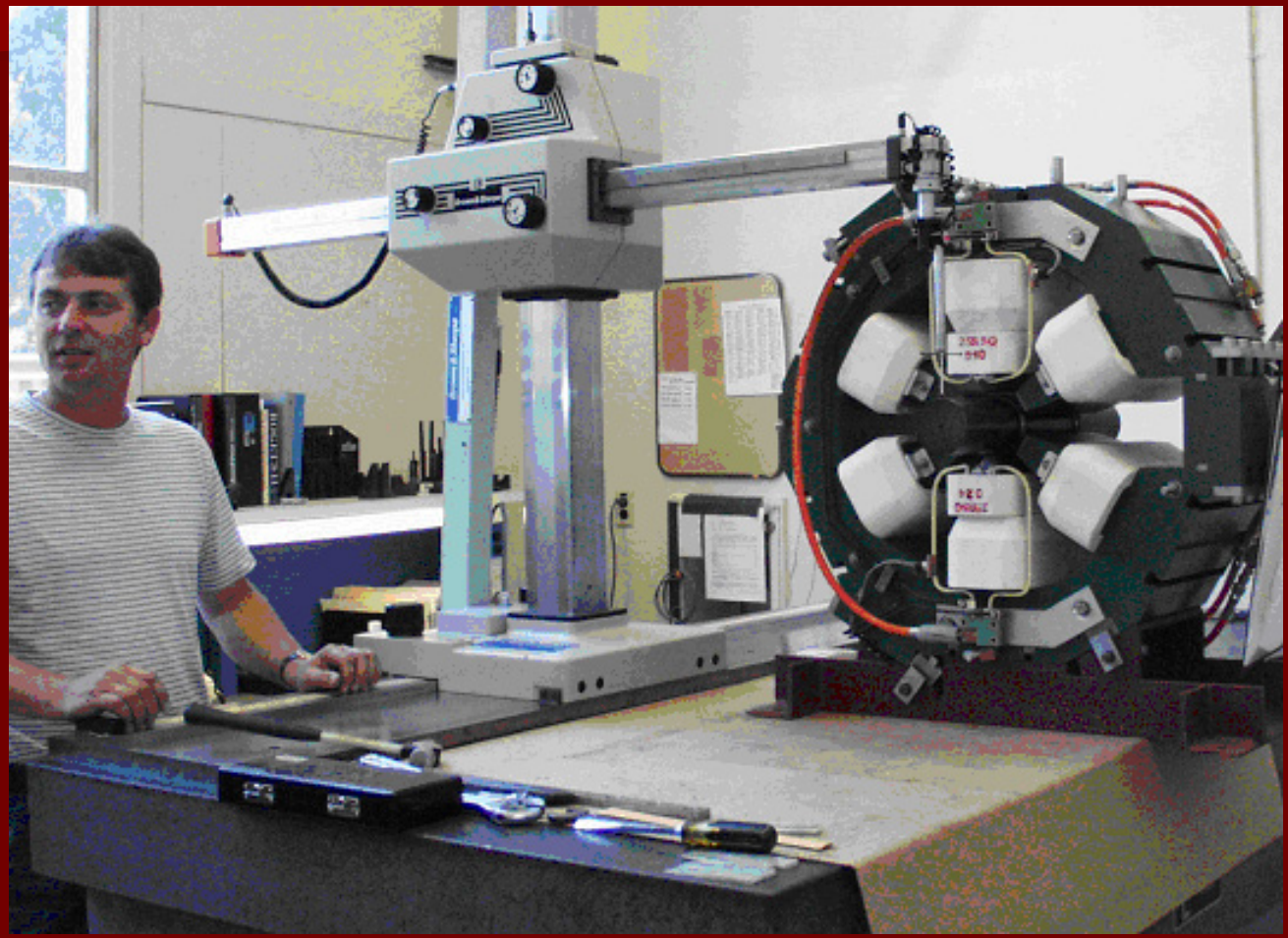
Optical Tooling

- Jig transit and site level
- System of orthogonal instruments
- Relative observations good to +/- 0.002 inches

Monuments/Targets

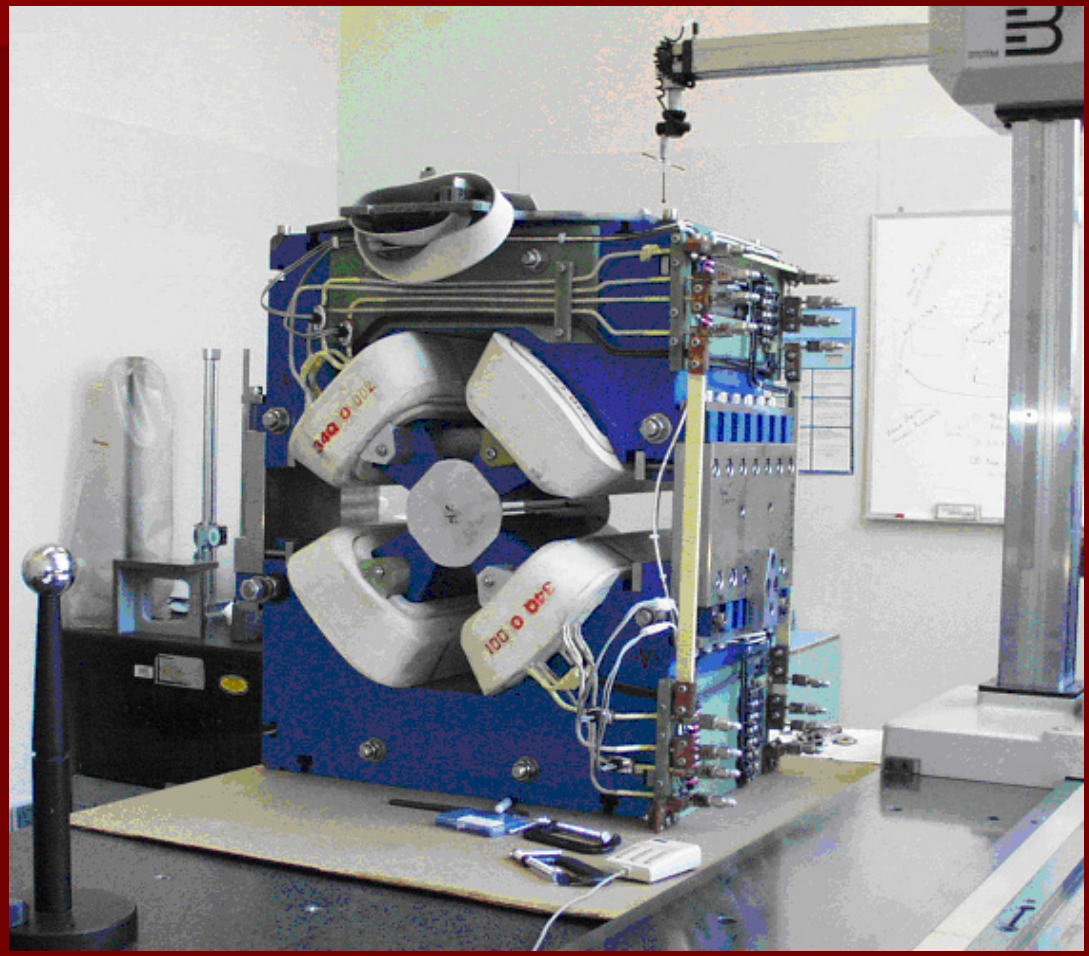


SPEAR 3 Sextapole

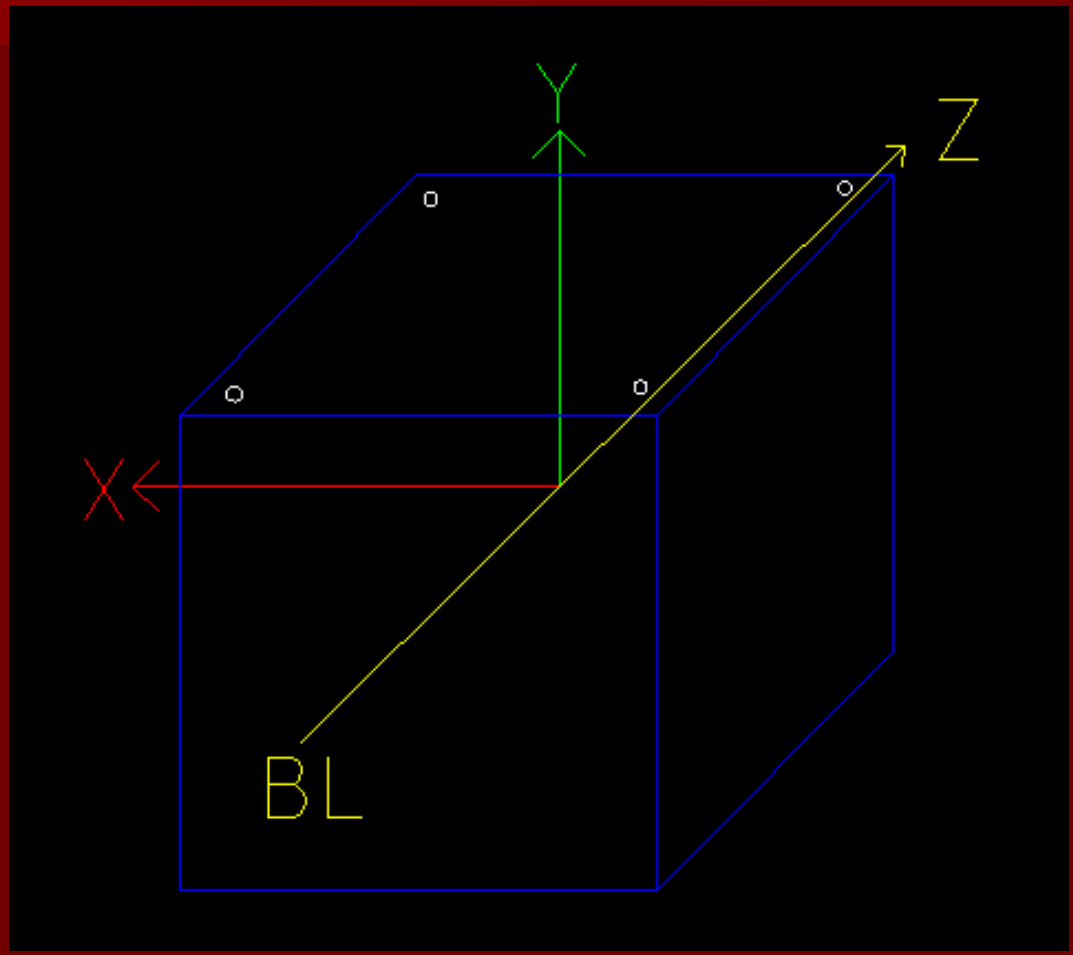


1.5” Target and Hubbs Cup

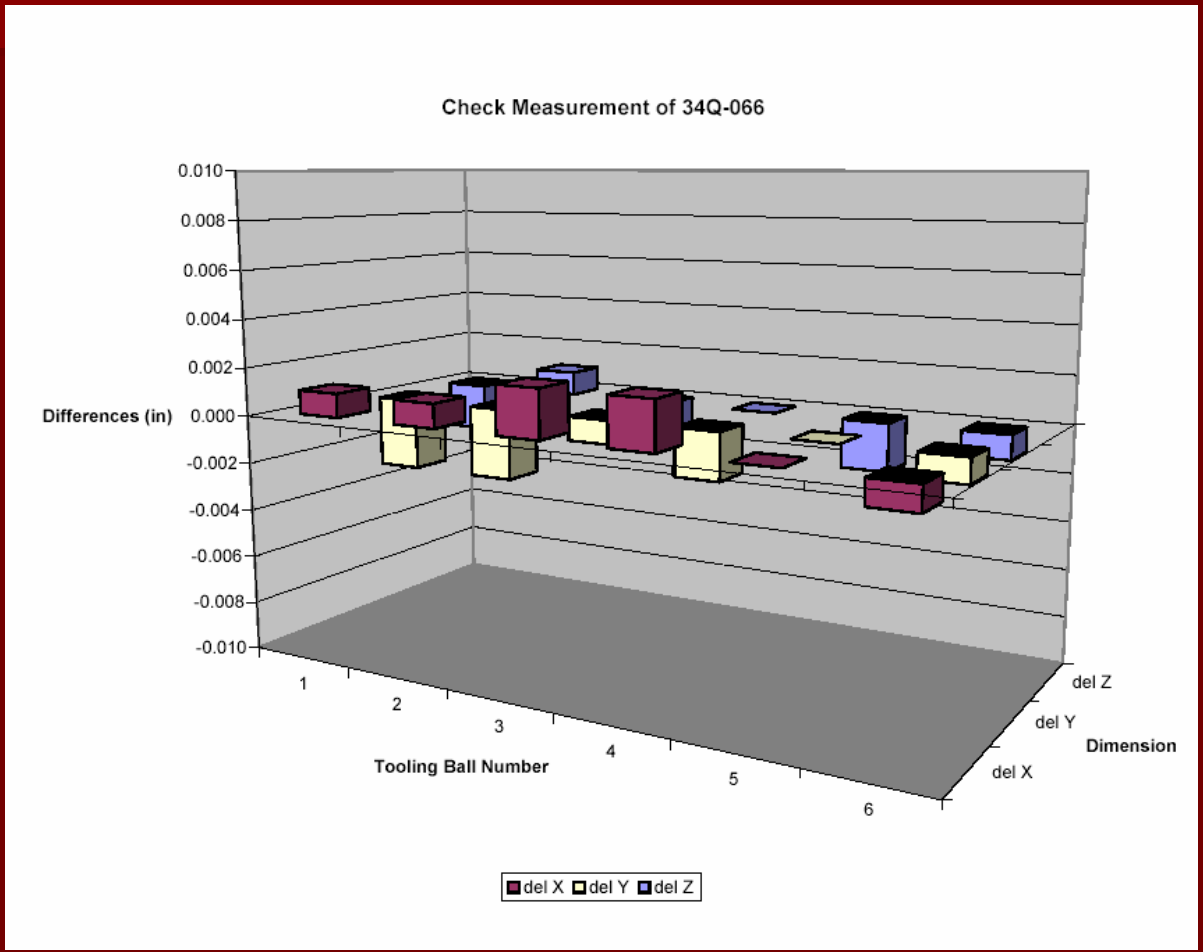
SPEAR 3 Quadrapole



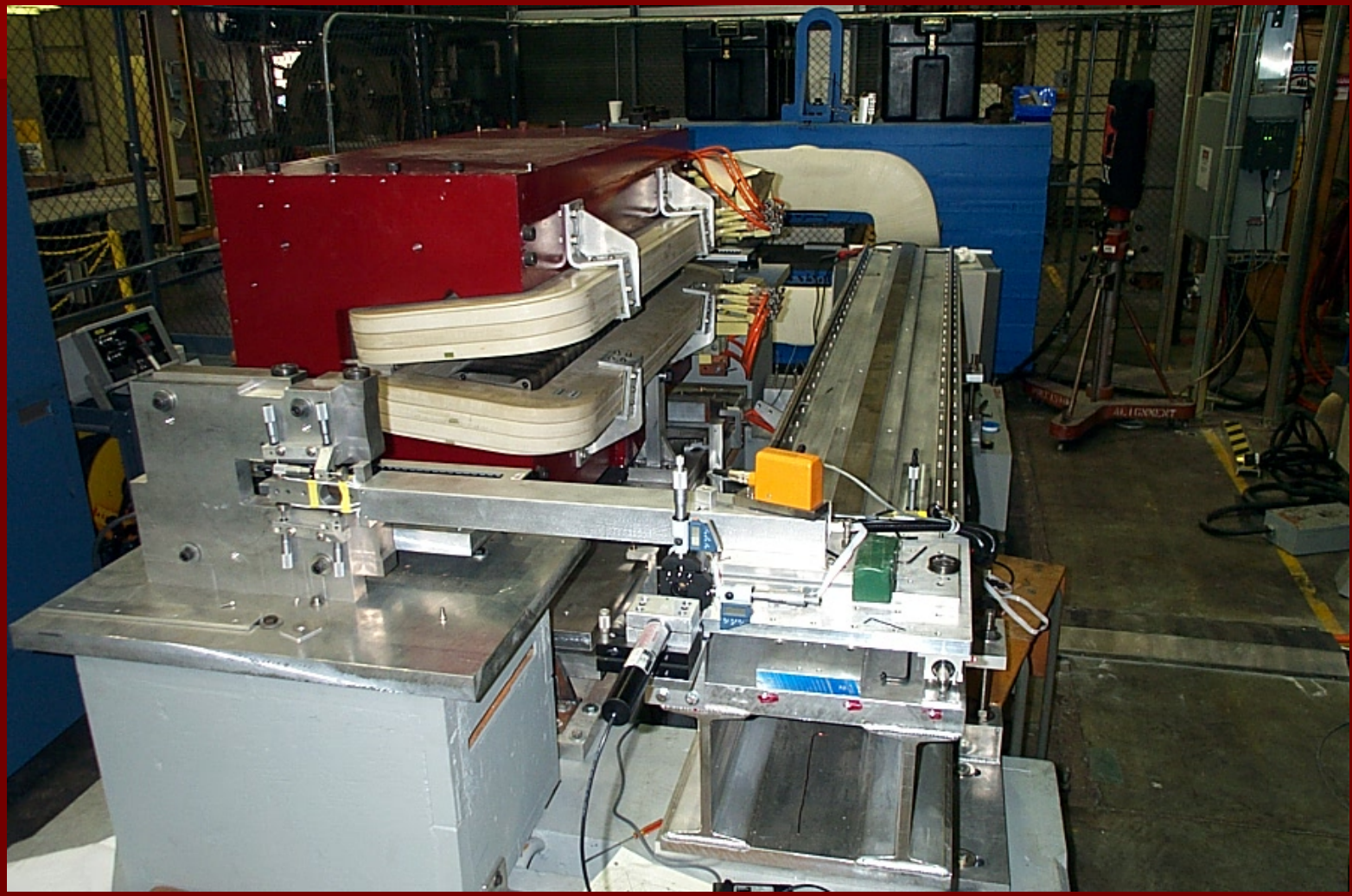
Local Coordinate System



Repeatability Study

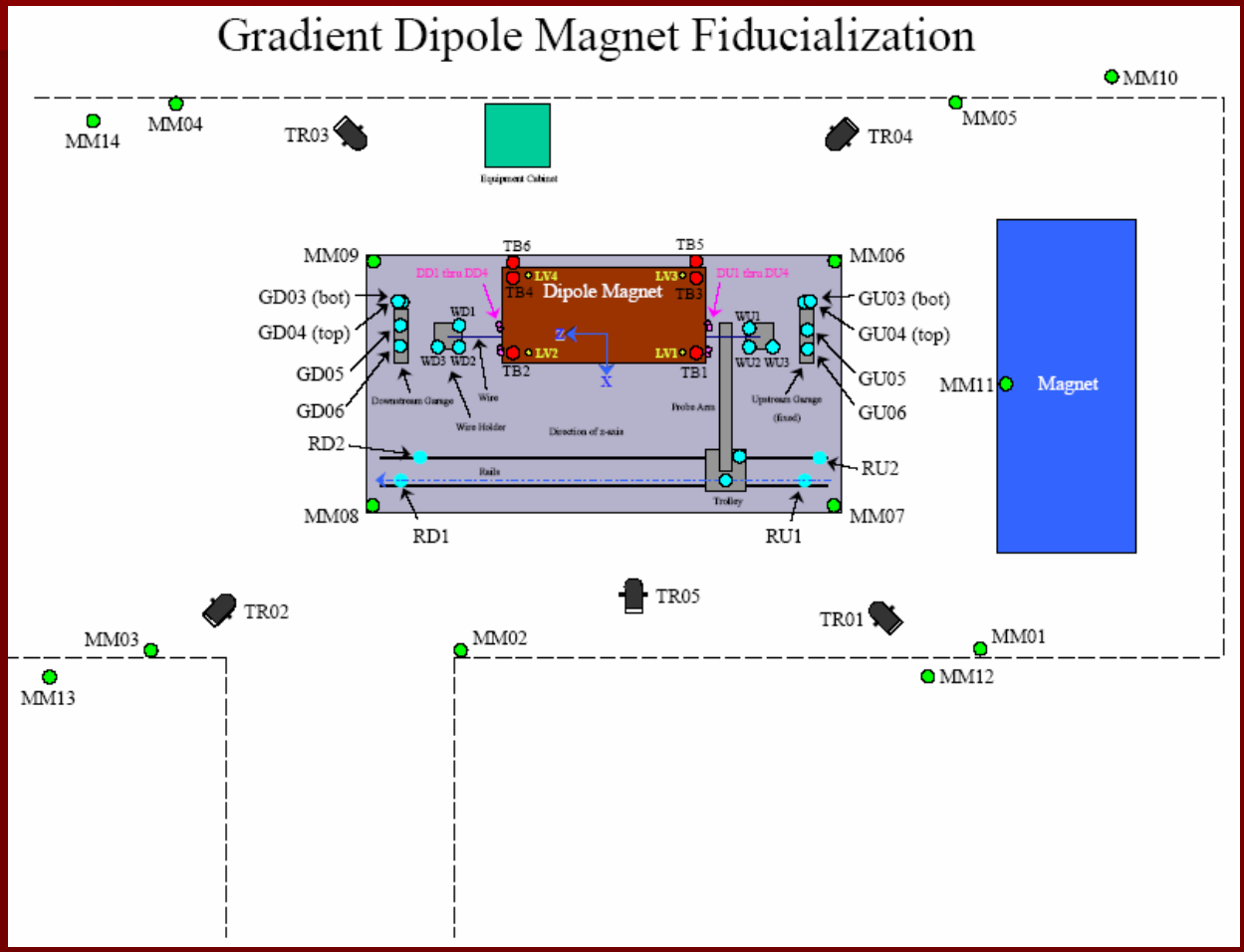


SPEAR 3 Gradient Magnet



Positioning of Dipole

Dipole Observation Layout



Data Reduction

- 5 Stations
- 36 points
- 115 Triplets (horz. and vert. angles, slope dist.) observed
- Distances weighted to 15 μm
- Angles weighted to 20 μm/dist.
- Error ellipses < 20 μm

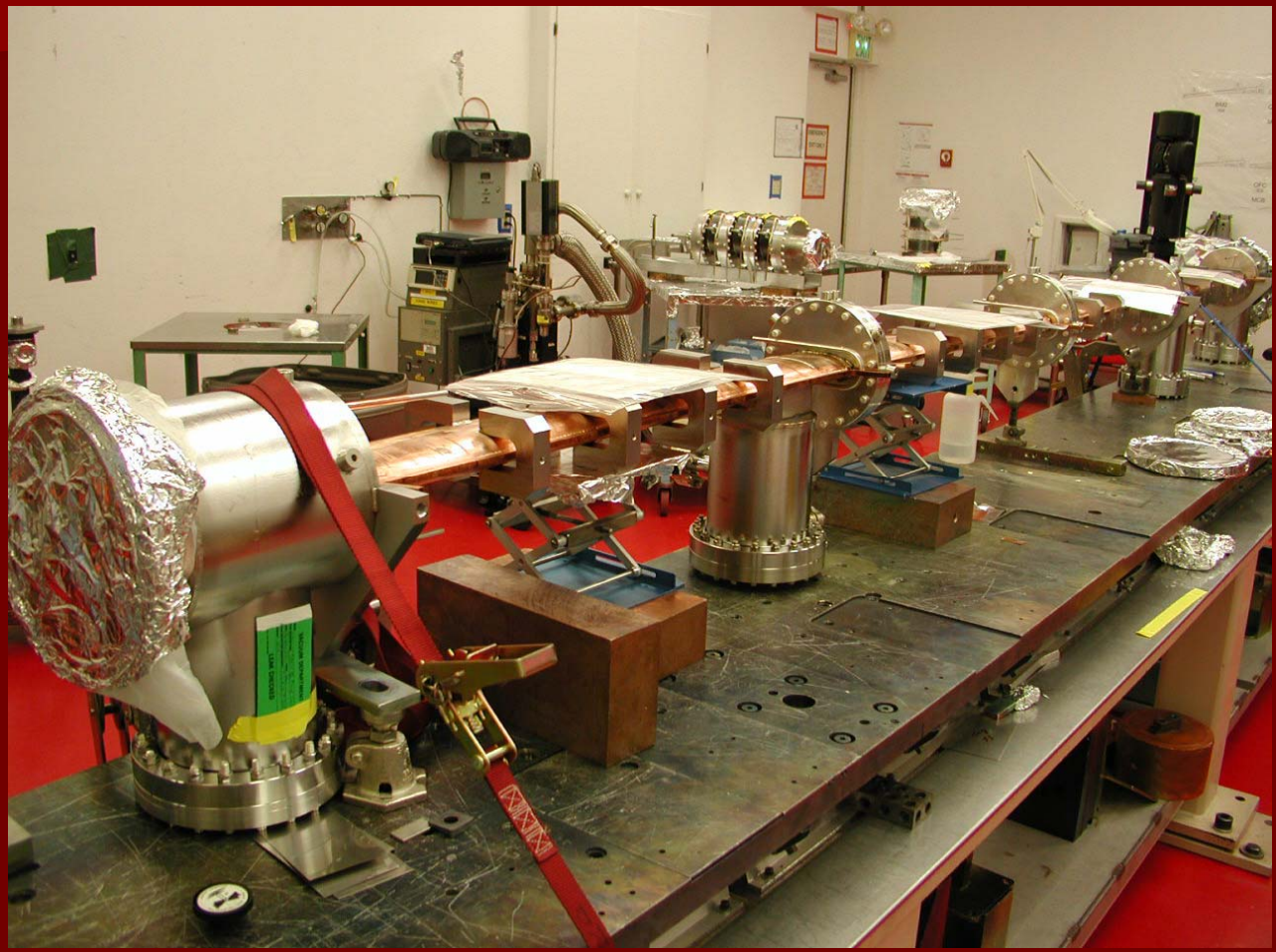
Local Coordinate System

SPEAR 3 Chambers

Mouse

Chamber

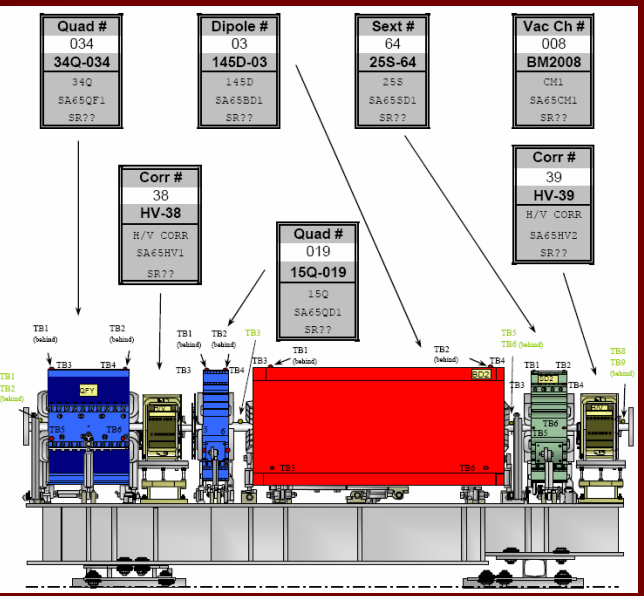
Straight Section Elliptical Chamber

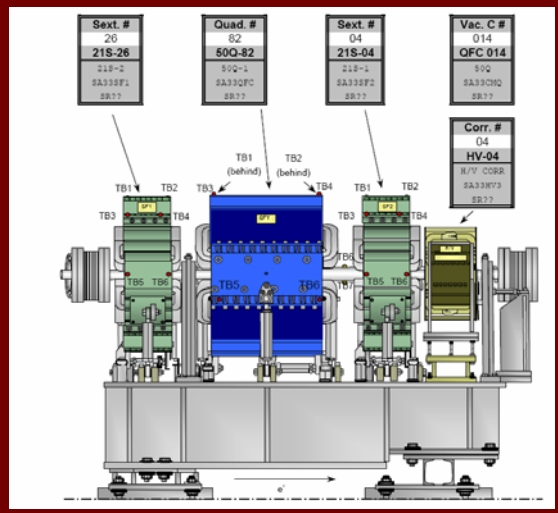


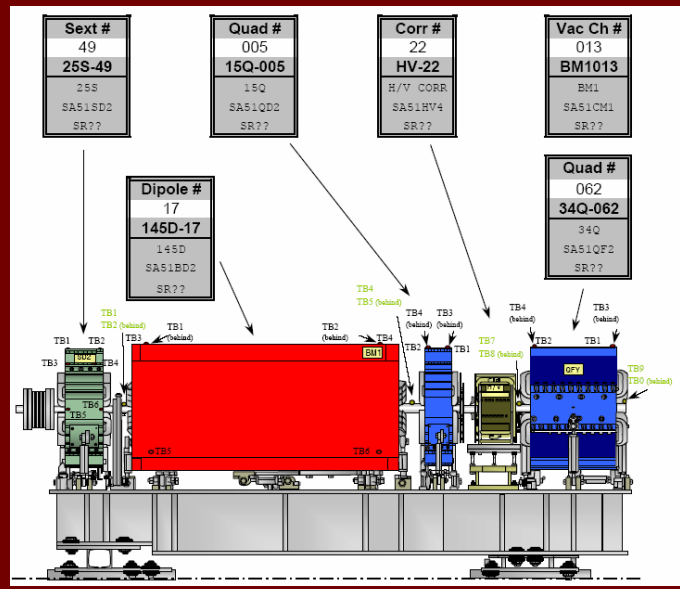
Pre-alignment

Set Chambers

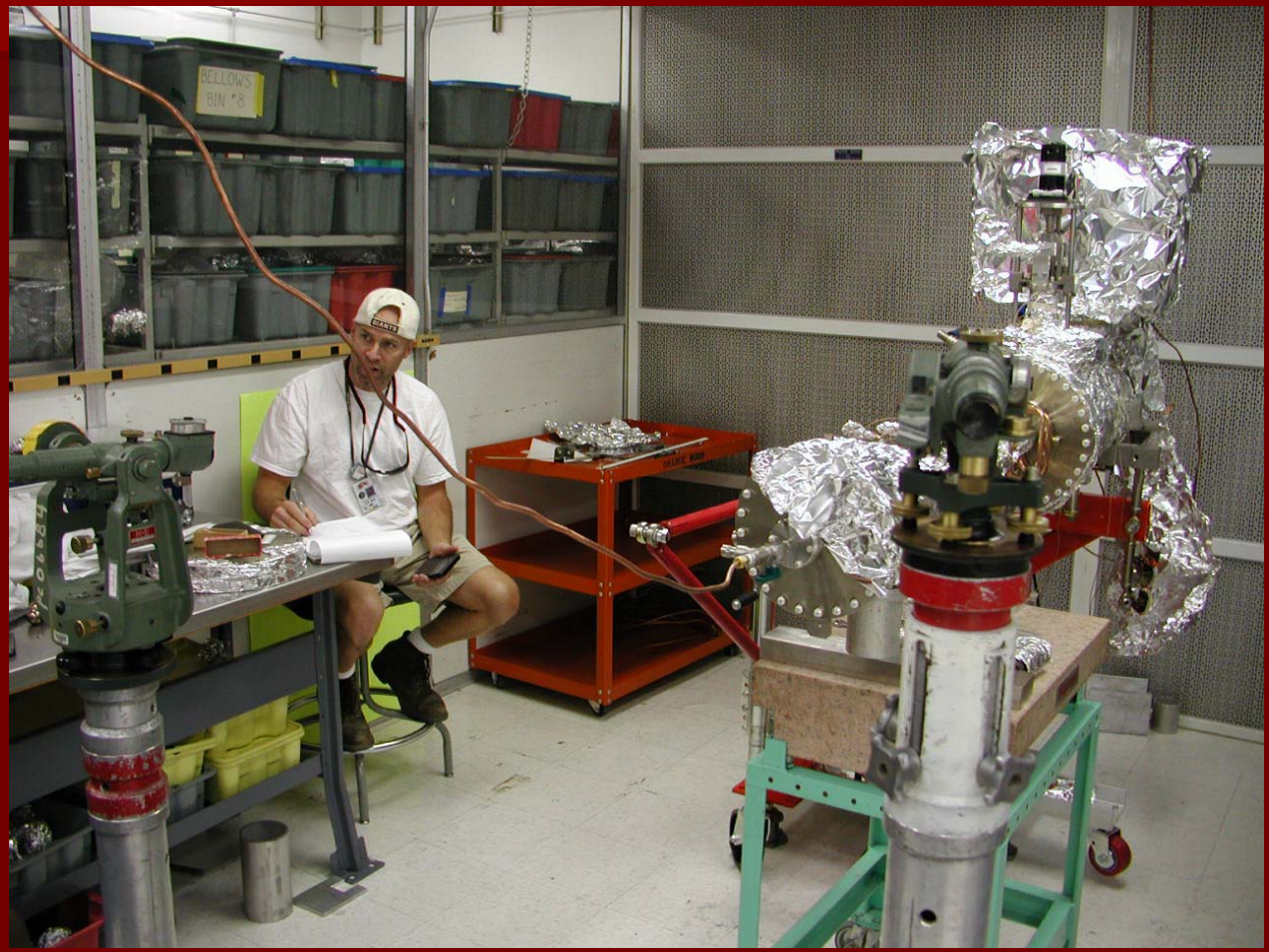
Standard Cell





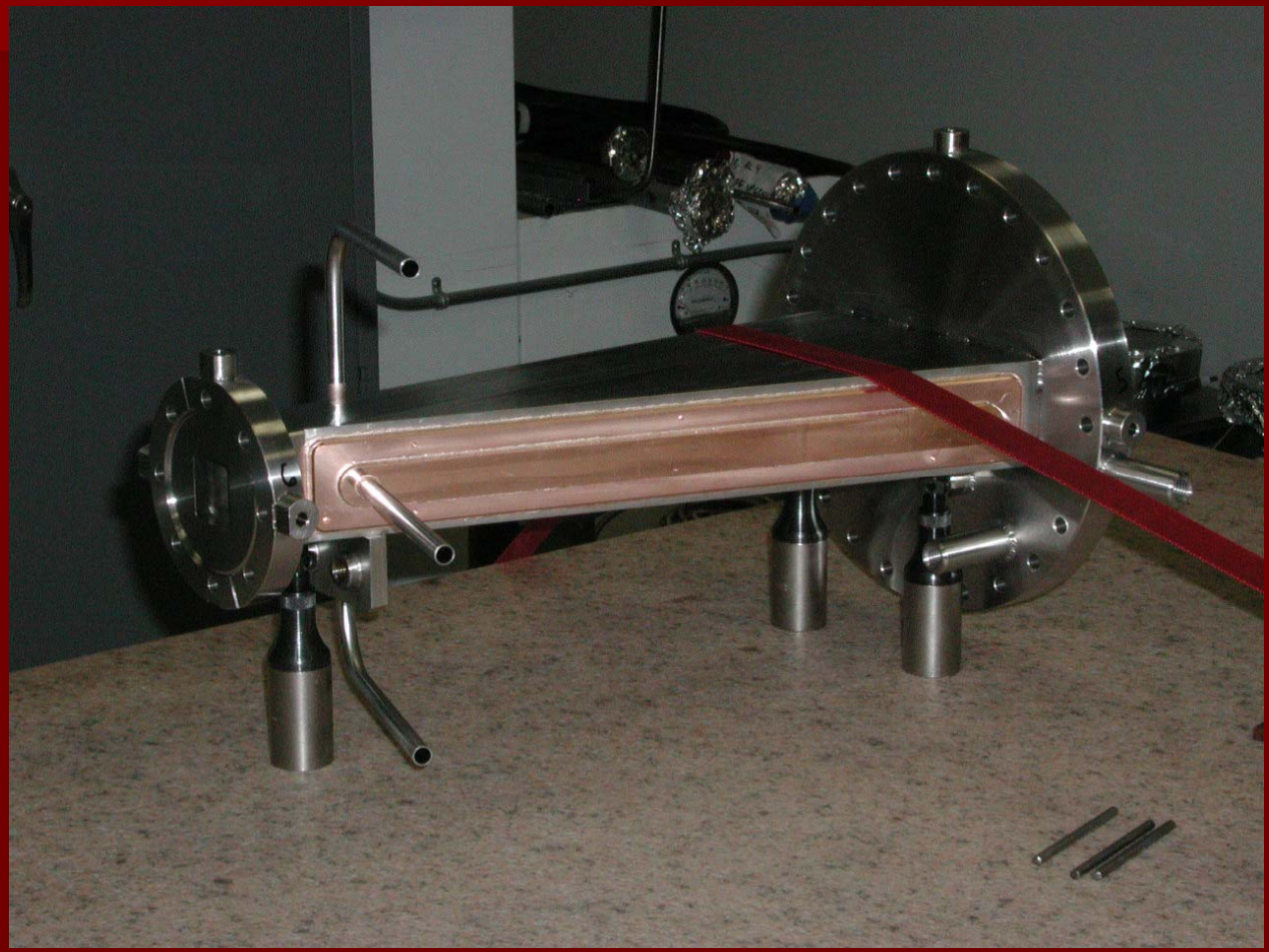


Beam Line Devices

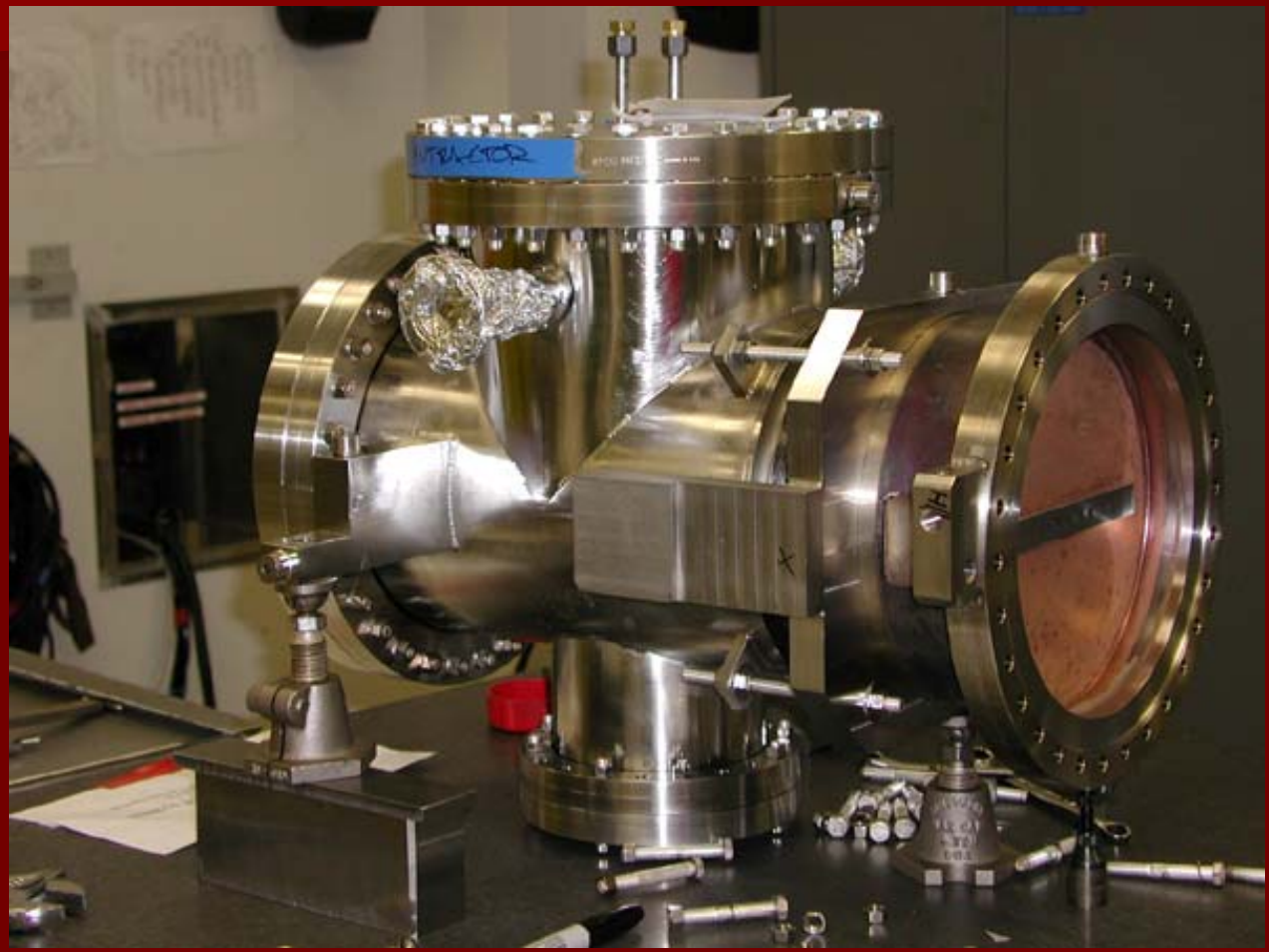


Stopper

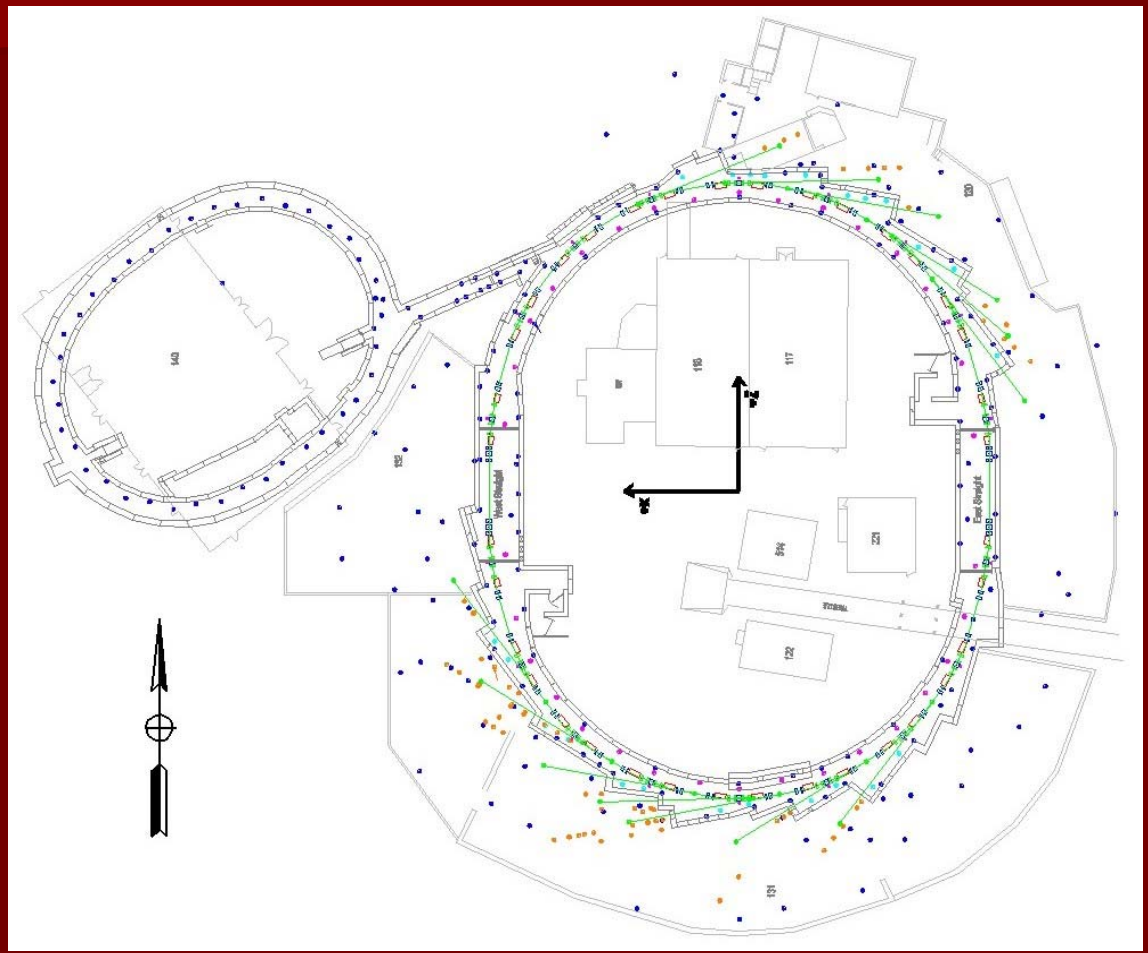
Fixed Mask



Beryllium Window

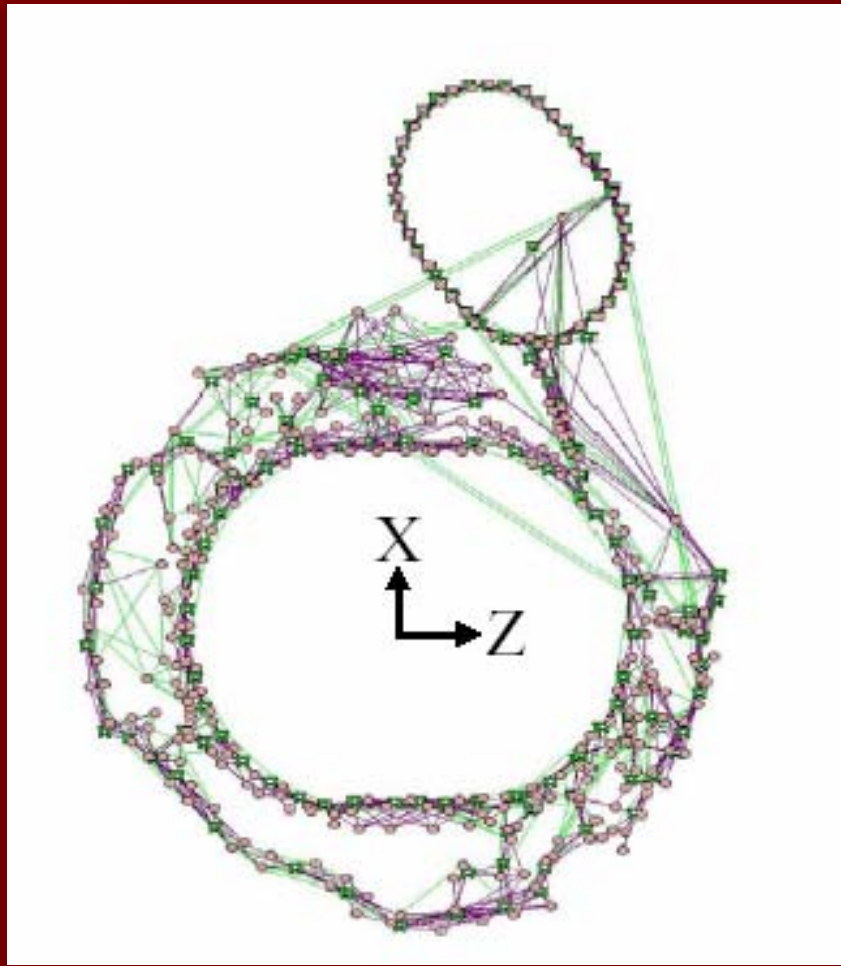


SPEAR Reference System



SPEAR 2 Network

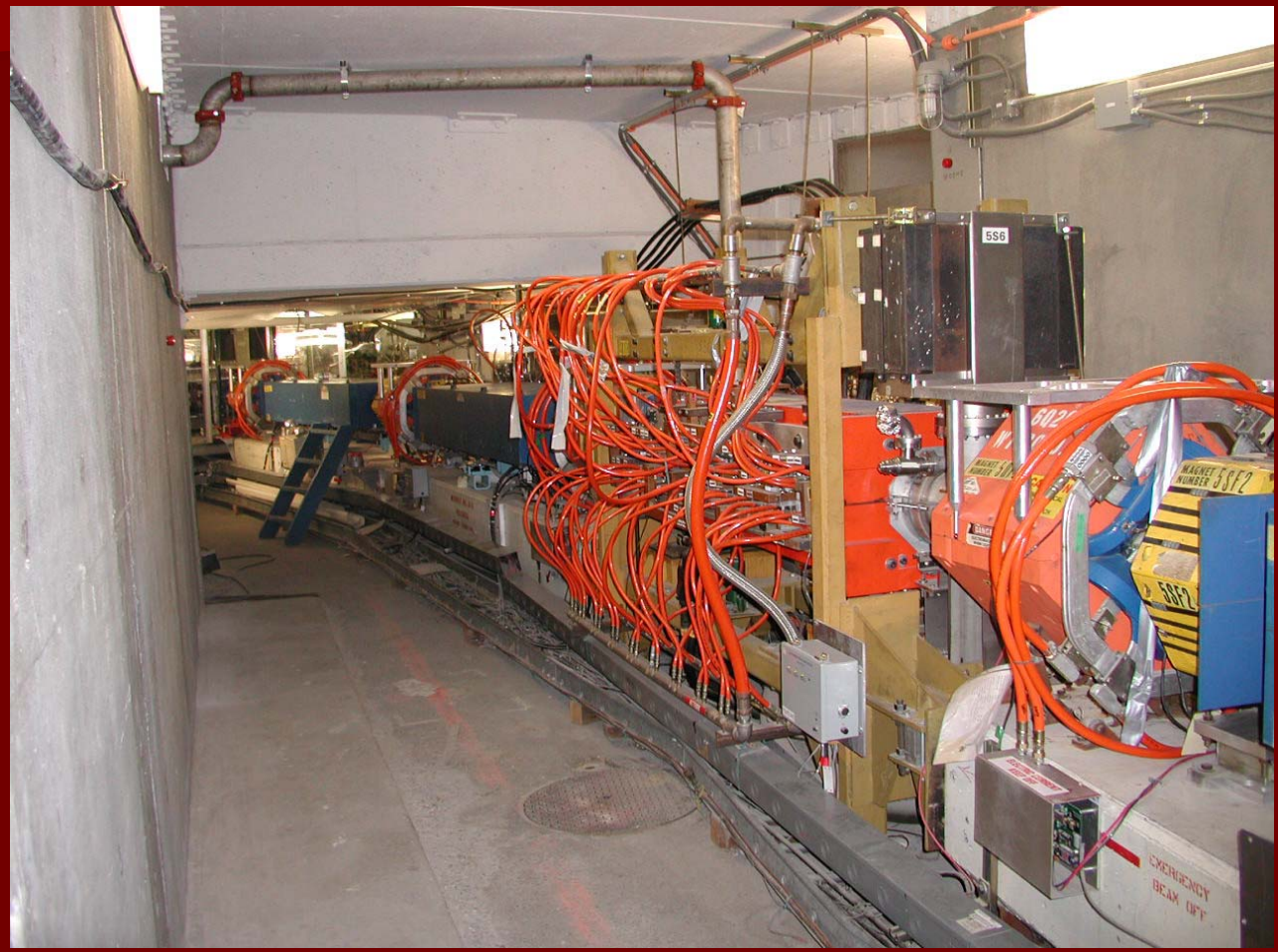
- Booster 9/2001
- BTS 3/2002
- Bldg. 130 9/2002
- SSRL 11/2002
- SPEAR 11/2002
- SSRL BL0 2/2003



SPEAR 2 Network

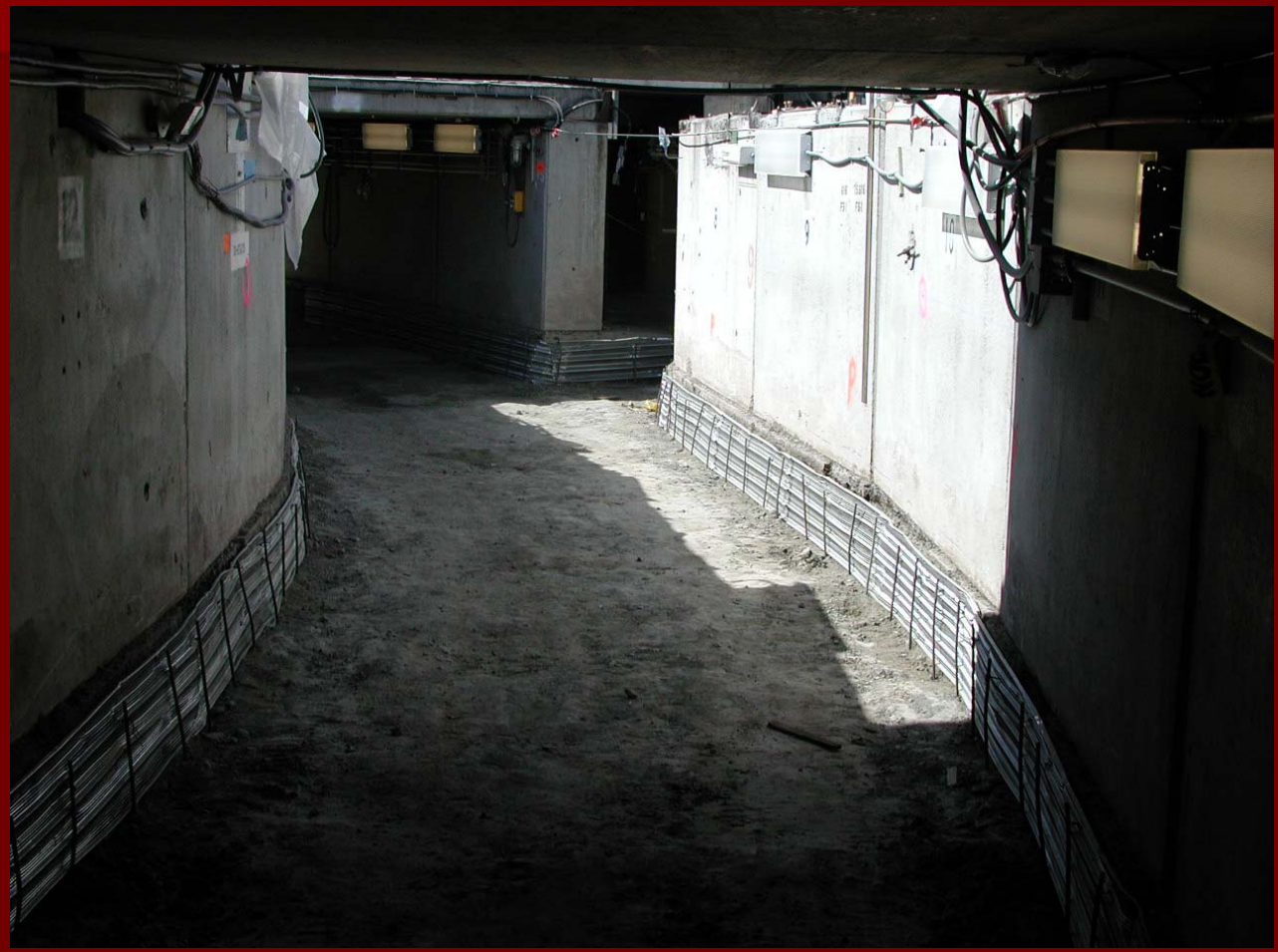
- 330 Points
- 175 Stations
- 1365 Triplets
- 400 delta Heights
- 2625 Degrees of freedom
- 50 μm weights on tracker dist.
- 200 μm weights on TC2002 dist.
- 100 μm/dist. weights on angles
- 70 μm weights on ΔHs
- A-posteriori standard deviation of 0.981740

Good Bye SPEAR 2



Adjust Beam Lines

Hello SPEAR 3



Elevation of Screed Rails

A New Floor

New Floor Monumentation

1.5 inch Spherical Target

Network Description

- 204 Points
- 71 Stations
- 762 Triplets
  - Distances weighted to 30 μm
  - Horizontal angles weighted to 40 μm/distance
  - Vertical angles weighted to 50 μm/distance
- 242 Height Differences
  - ΔHs weighted to 50 μm

Point Distribution

- Ring Points
  - 38 floor monuments: 34 new & 4 old
  - 82 wall monuments: 50 outer & 32 inner
  - 1 ceiling
- SSRL Points
  - 32 in Beam Line Front Ends
  - 25 in SSRL Building
- Others
  - 5 in BTS
  - 21 Temporary Points

Datum Determination

- Goal: Reproduce the coordinate system of SPEAR 2 to keep the Beam Lines in the same positions
- Strategy: Select a set of points that have no special reason to have moved and that are well observed in the new survey
- Decide on a computational method: free, weighted, or constrained

Haves and Haves Not

- **Scale**: laser tracker
  - Set of all distances
- **Orientation**: precise level
  - Set of all height difference
    - Missing orientation around the Y axis
- **Translation**: nothing
  - Missing 3 parameters

Control Points

- Free net, best fit (nothing fixed)
- 3D coords.:
  - 2 floor points in the east straight
  - 2 floor points in the west straight
  - 5 floor points in SSRL/front end beam lines
- 1D coords. (height):
  - 10 front end beam line floor points
  - 20 SSRL building floor points

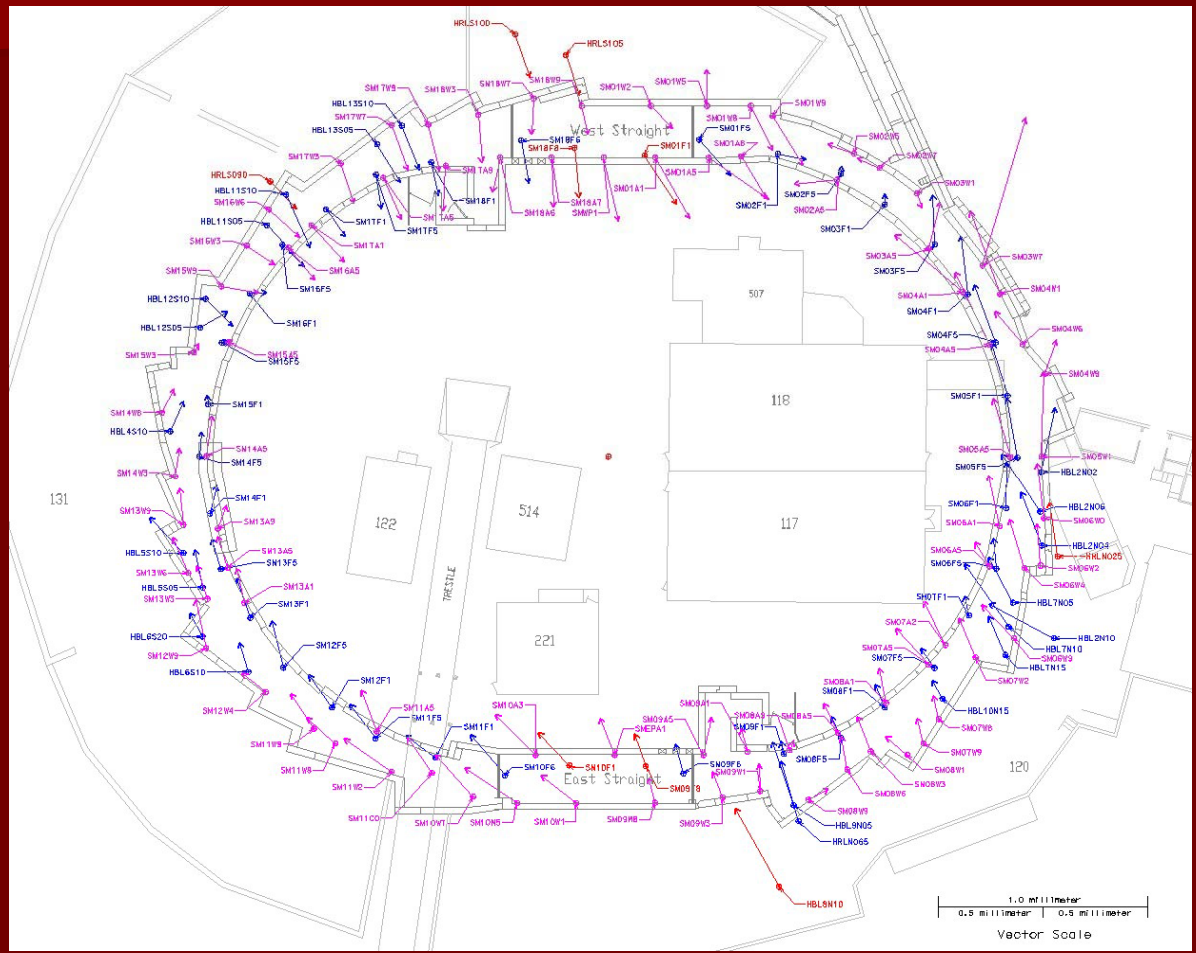
Network Results

- DZ, DX, DY in meters (free net)

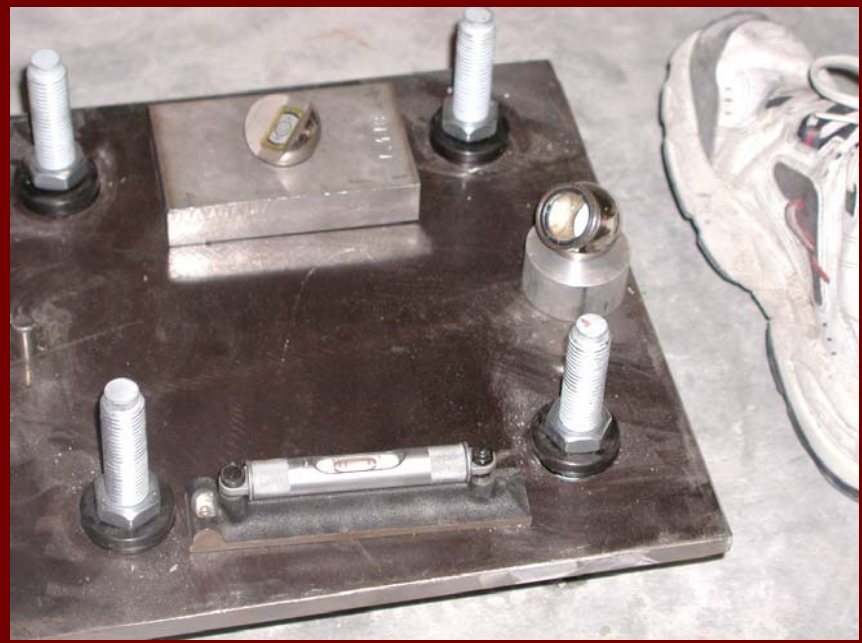
SM09F8	-0.000084	-0.000021	-0.000295
SM10F1	0.000041	-0.000038	-0.000351
SM01F1	-0.000063	0.000209	-0.000133
SM18F8	0.000190	0.000074	-0.000176
HRLS100	-0.000041	-0.000084	-0.000102
HRLS105	-0.000005	-0.000095	-0.000185
HRLS090	-0.000064	0.000058	0.000113
HRLN025	-0.000189	-0.000135	-0.000161
HBL8N10	0.000214	0.000031	-0.000074

Bolt Hole Layout

Re-network for Potential Floor Deformation



Set Pedestals

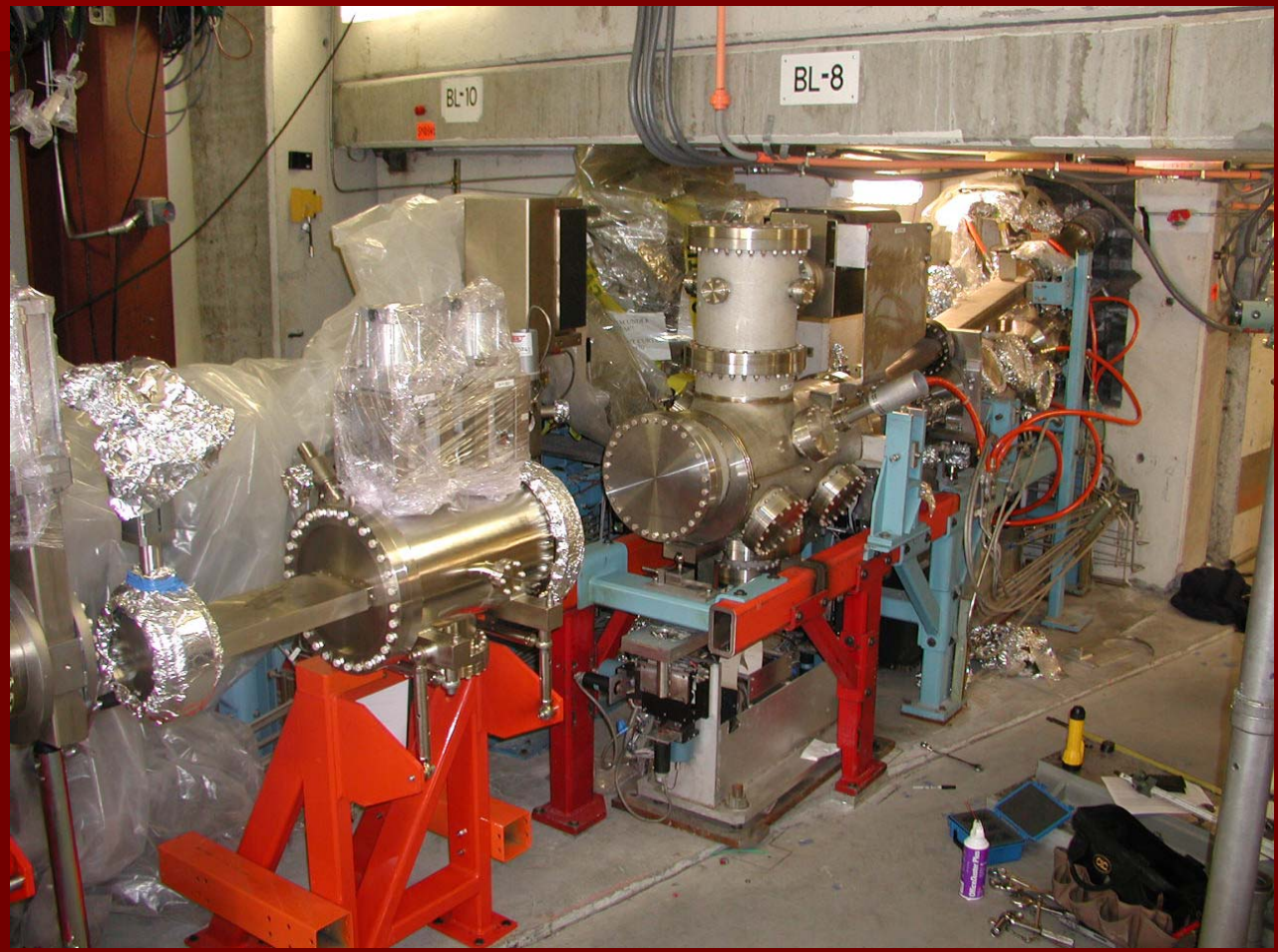


Cool Bulldog

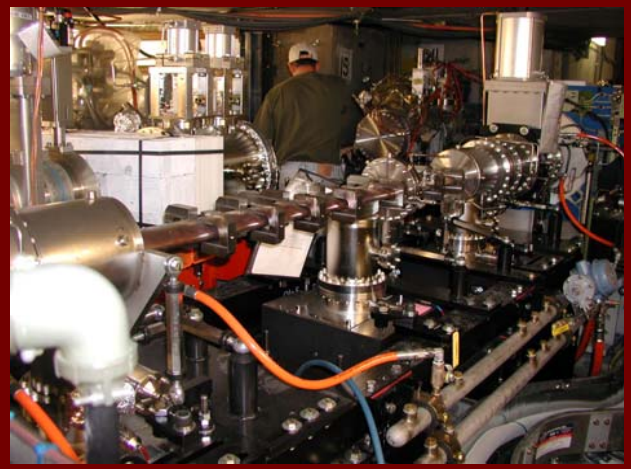
Map Plate Positions

Just about everything installed

Front Ends



Straight Section Alignment



BTS

Final Map

Network

- 368 Points
- 40 Stations
- 636 Triplets
  - Distances weighted to 40 μm
  - Horizontal angles weighted to 40 μm/distance
  - Vertical angles weighted to 50 μm/distance
- 303 Height differences
  - ΔH weighted to 60 μm

Points

- 167 Monuments
  - 122 ring monuments
    - 38 floor
    - 83 wall
    - 1 ceiling
  - 45 other monuments
    - 42 SSRL points for level observation only
    - 3 miscellaneous
- 201 Magnet TBs (missed one, there are 202 total magnets)

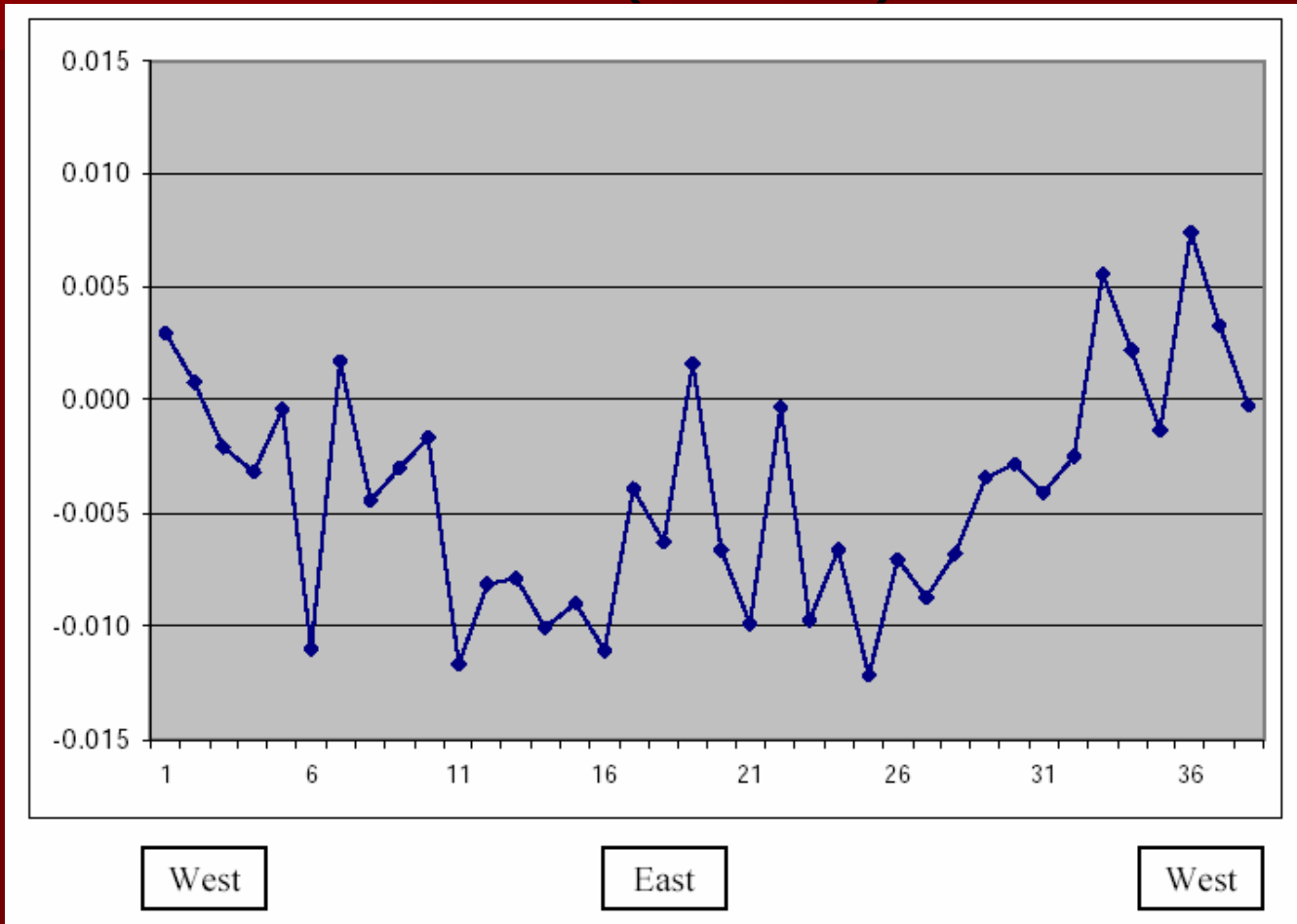
Datum Choice

- Bundle
  - Minimally constrained in the horizontal plane
    - SM05F5 fixed in Z and X
    - SM14F5 fixed in X
  - Over constrained for the vertical axis
    - 6 SSRL points fixed in height
- After the adjustment
  - Best fit the 38 floor points
    - Shift in Z: -38 μm
    - Shift in X: -187 μm
    - Rotation around Y: 0.0735 mrad

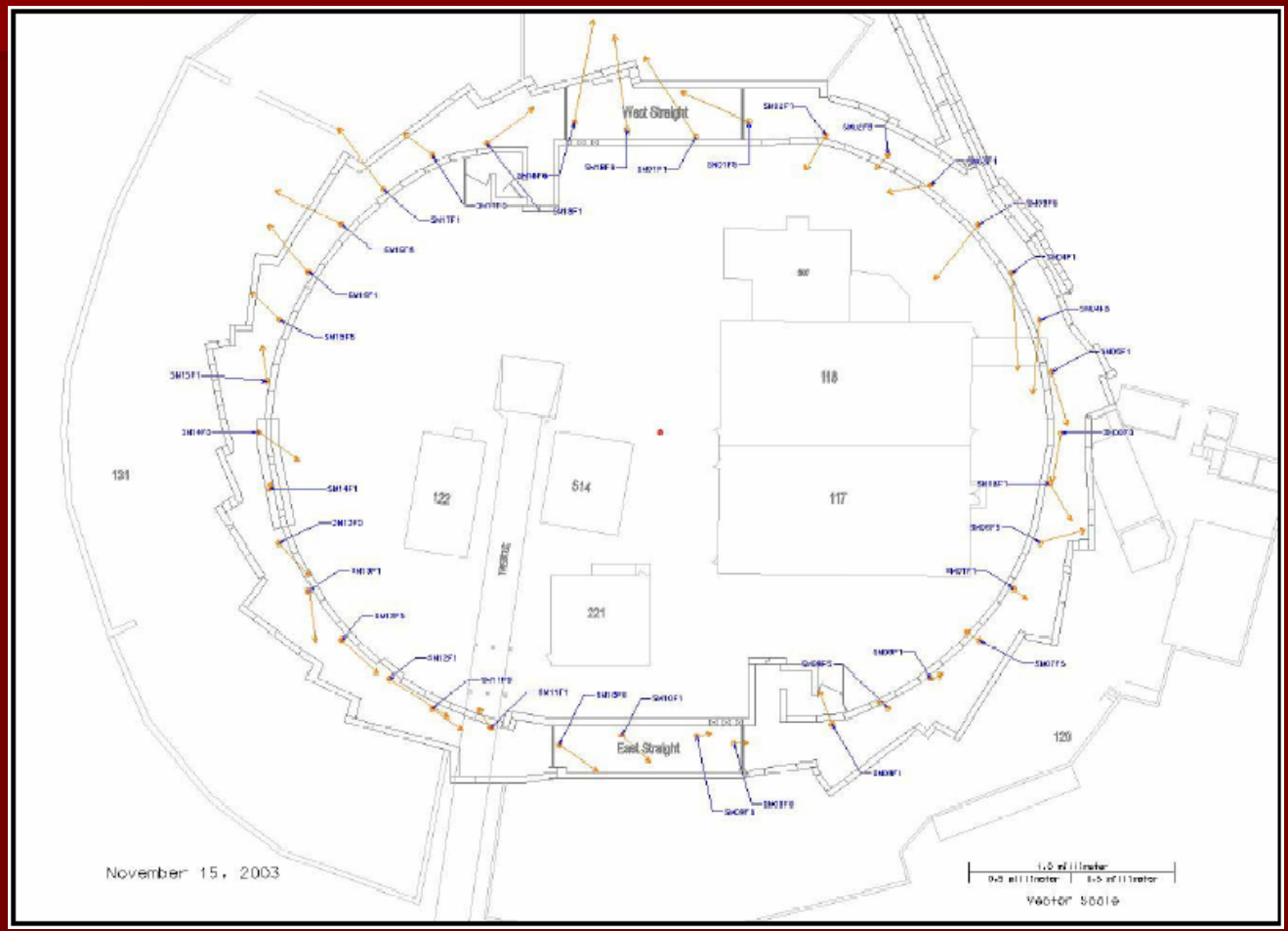
Results

- Variance Analysis
  - 966 degrees of freedom
  - 1.046304 a-posteriori
    - Dist: 0.891794
    - Horz. Angle: 0.802313
    - Vert. Angle: 1.206194
    - ΔH: 1.245124
- Residual Analysis
  - All 4 types of observations pass the Chi^2 goodness of fit test individually as well as the whole observation distribution

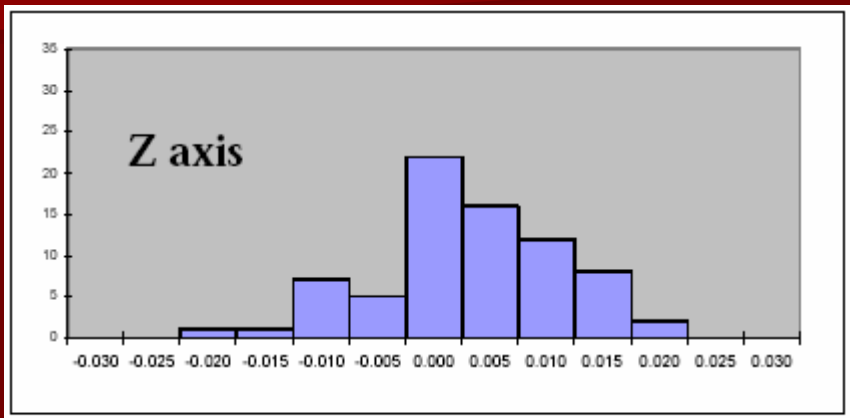
Floor Monument Elevation Changes since the control network results in July 2003 (inches)

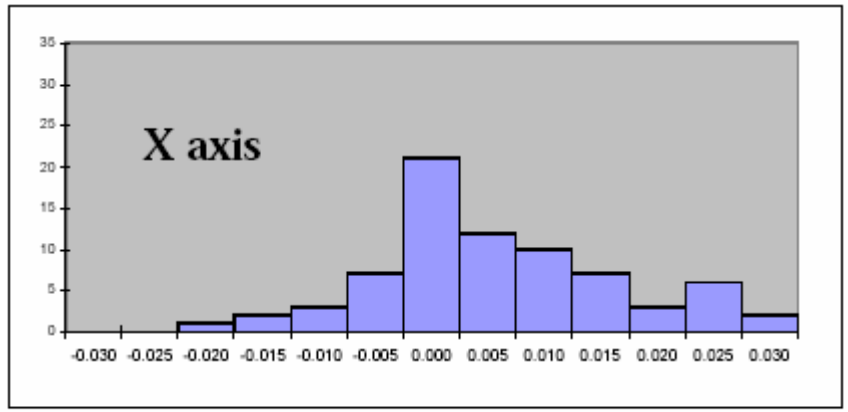


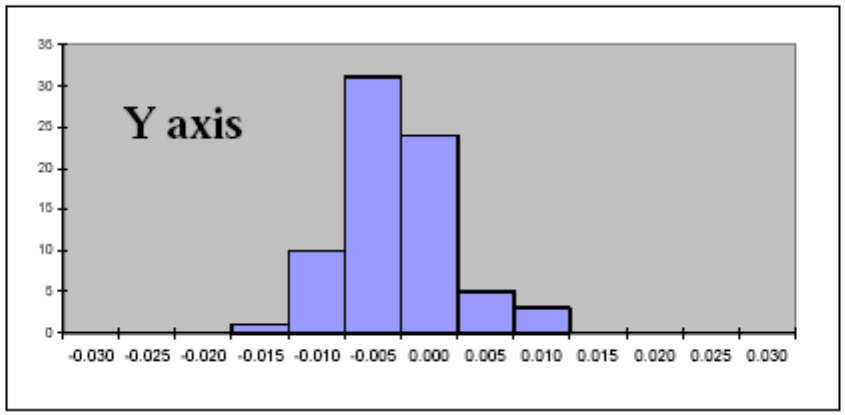
Floor Monument Horizontal Changes since the control network results in July 2003



Wall Monument Coordinate Changes (inches)







Stored beam with no correctors!!