LCLS Extruded Aluminum Vacuum Chamber - New Approaches

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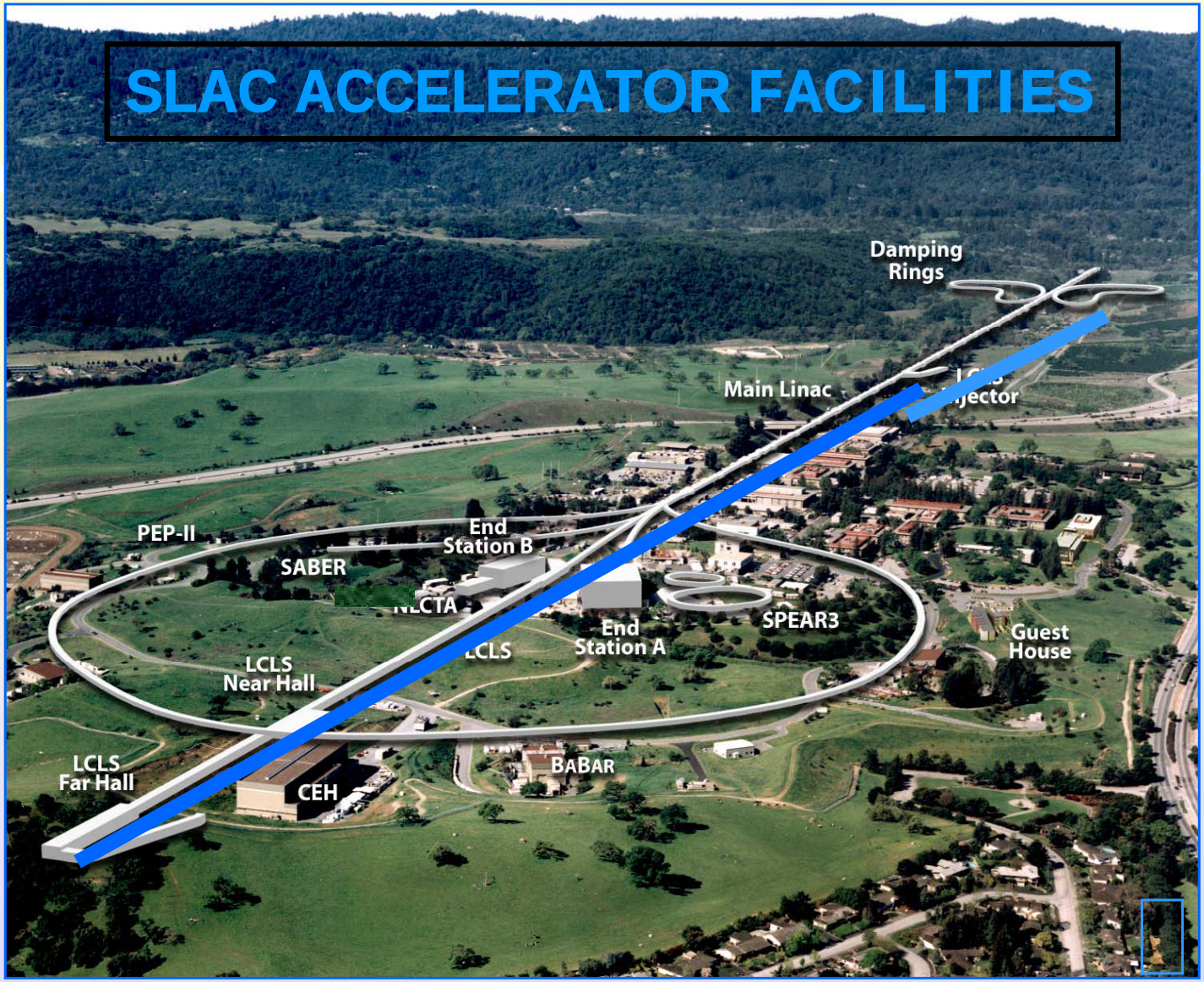
AES/MED



Roger A. Erickson, SLAC

Major challenges to produce extruded aluminum vacuum chamber for X-Ray laser

o Maximum vertical aperture for the small undulator pole gap: (for the LCLS: pole gap is 6.8 mm, desirable aperture 5 mm).

o Wall thickness should be 0.5 mm, vacuum integrity became an an issue.

o The best possible surface finish inside the aperture to keep wakefields small when the bunch length is very short. (150-200 nm desirable – impossible to achieve after extrusion).

o Precision of the machining of the outside vertical dimension and wall thickness to keep the maximum stay clear aperture.

Will thin chamber wall keep vacuum integrity?

This was the first question which should be answered;

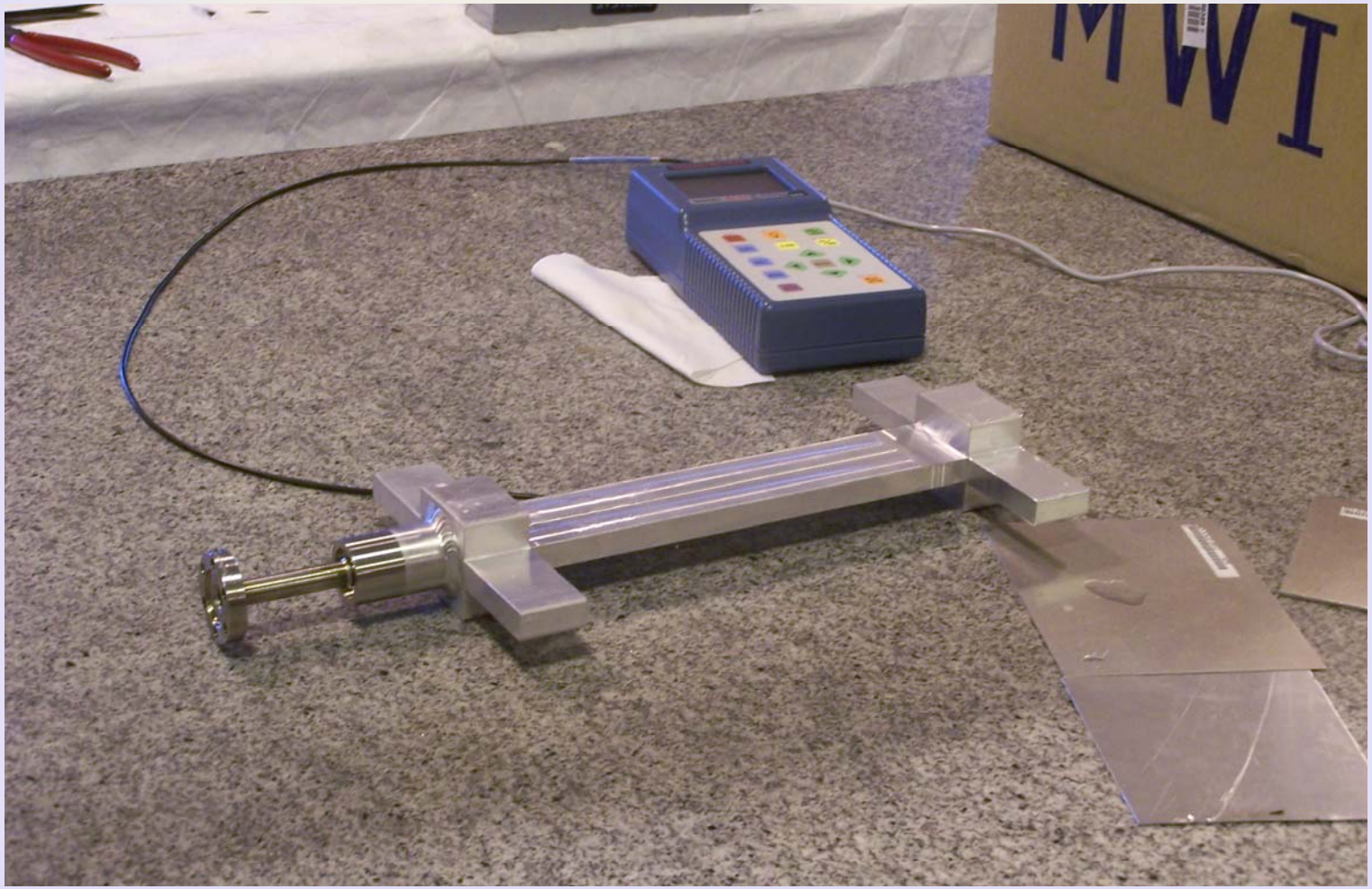
We have made multiple tests using extrusions from two different vendors;

DESY extrusion and LCLS prototype extrusion were used for the tests.

*Results of these tests were presented at PAC-2007 at Albuquerque, New Mexico

*Emil Trakhtenberg, Greg Wiemerslage. "A Study of the Minimum Wall Thickness for an Extruded Aluminum Vacuum Chamber", PAC-2007, Albuquerque, New Mexico, June 2007.

Test set up for the thin-wall measurements



Final leak test results

Wall thickness	**0.38mm – 0.45mm;**
Deflection	**none detected;**
Vacuum inside the sample:	**a/ $5.6 \cdot 10^{-5}$ Torr;**
	b/ $2.7 \cdot 10^{-5}$ Torr;
Leak checker type	**Alcatel-ASM 180.**

After baking vacuum inside samples changed to: $1.4 \cdot 10^{-7}$ Torr

NOTE: These results are for the test samples only.

Improvement of the aperture surface finish

During preparation for extrusion the inner part of the die (mandrel) was additionally polished at the APS optical shop. It helped to improve surface finish initially to 600-700 nm.

*__Abrasive flow polishing process__ was proposed to be used to achieve surface finish around 150-200 nm.

Special fixtures and technology were developed to apply this process to the 4m long extrusion with the ratio length/aperture ~7000. The standard ratio for this process is 8-10.

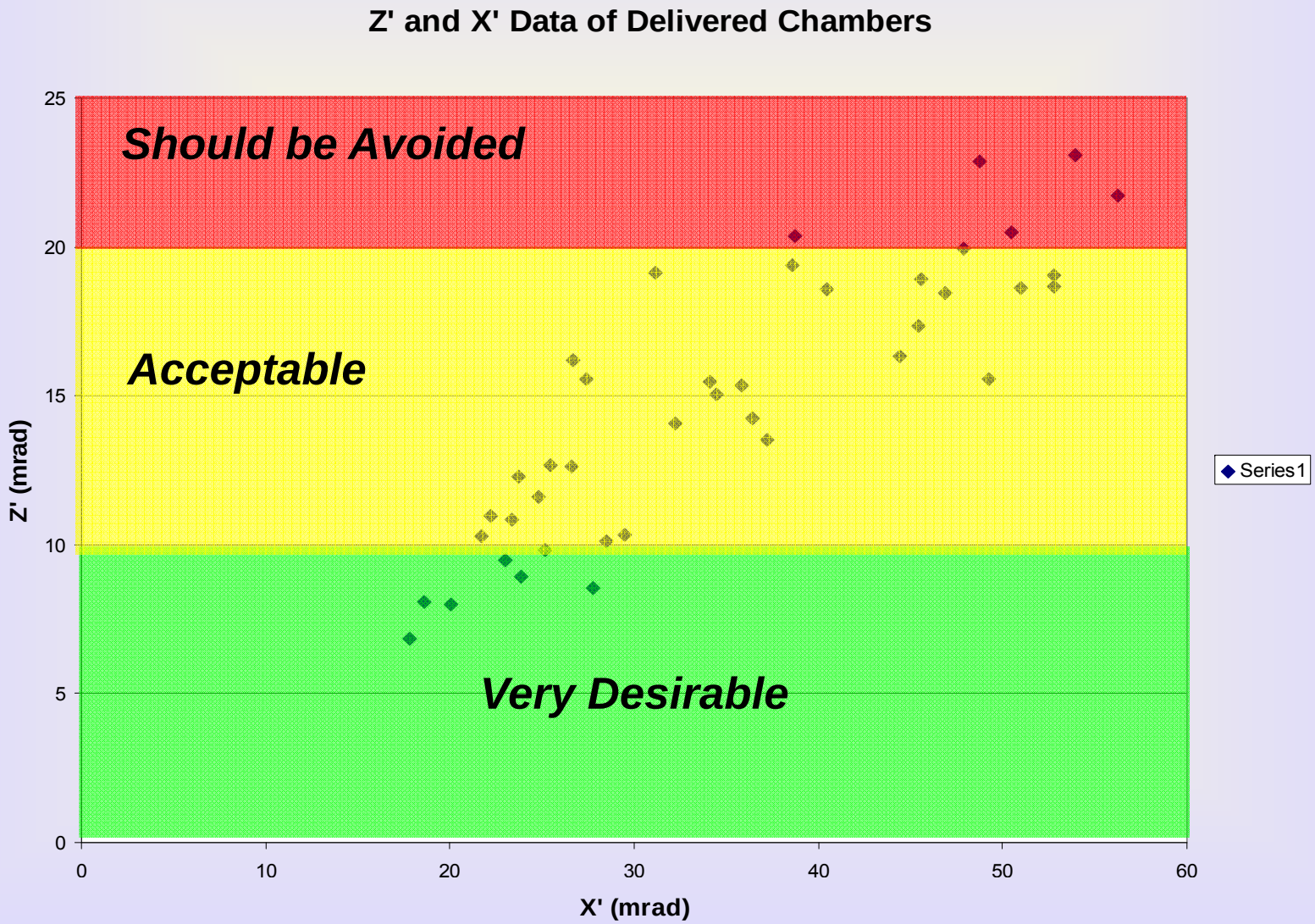
Each chamber was polished from both ends using two different abrasive grits. Aluminum oxide was chosen as an abrasive material. Average polishing time was 50 hours per chamber.

*Ray Dargis. "'Non-Traditional' Goes Mainstream." http://www.pfonline.com/articles/020802.html

Abrasive flow polishing at “Engineered Finishing C_0” - I

Abrasive flow polishing at “Engineered Finishing Co” - II

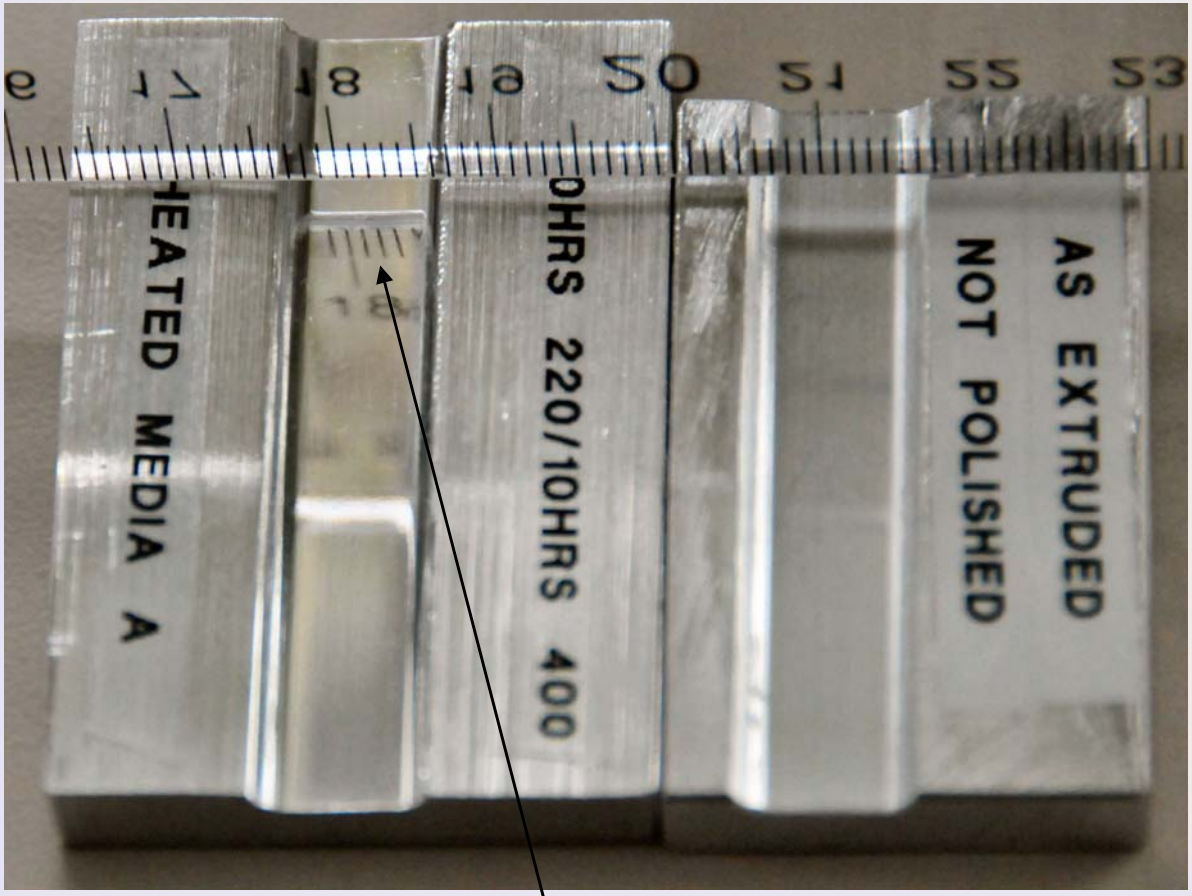
Graphical Display of Surface finish Data



Surface Finish Summary

- The average of all vacuum chambers is 14.86 mrad in Z′ and 35.14 mrad in X′
  - Extrusions 7, 10, and 16 were sacrificed to inspect surface finish in the middle of the extrusions

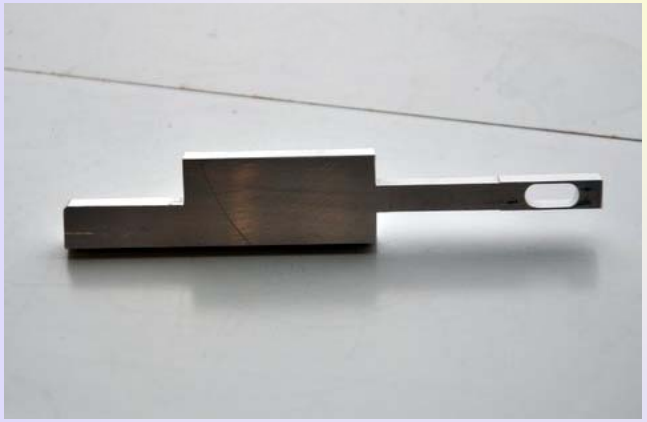
Surface Finish Summary



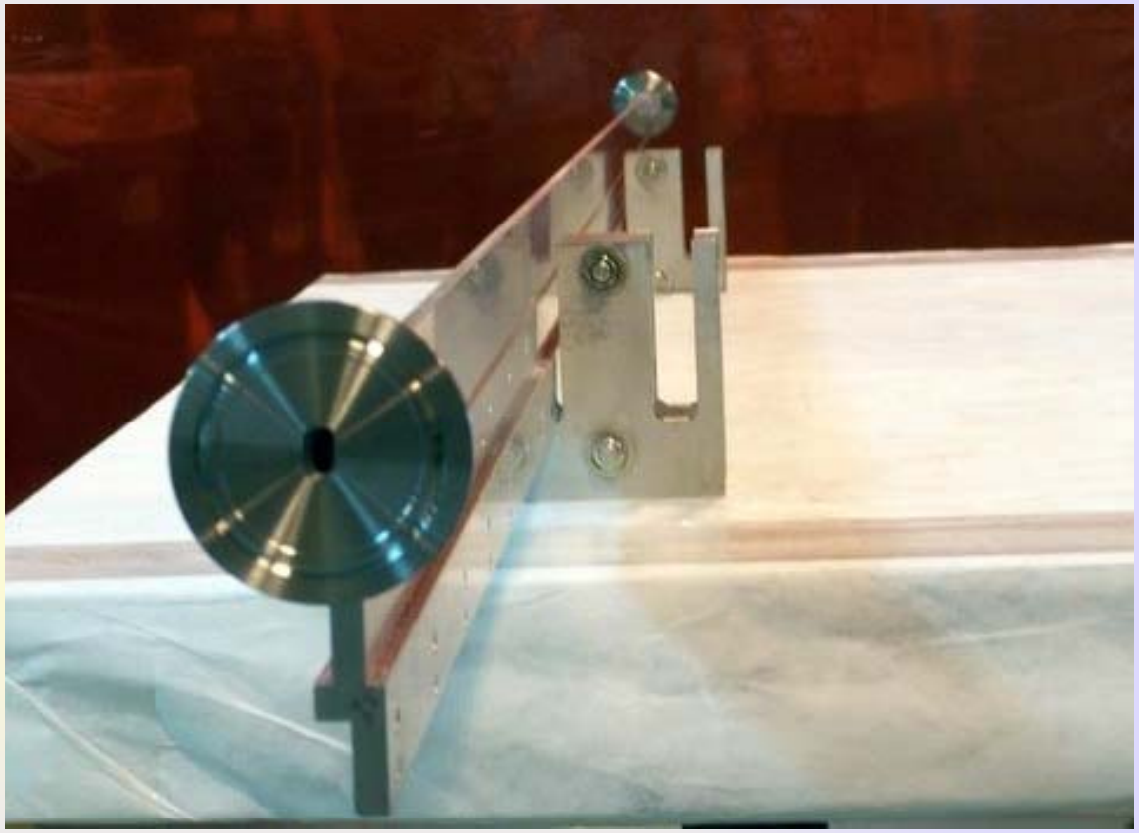
Note reflection of the ruler scale in aluminum surface after polishing

LCLS extruded vacuum chamber

Section of extrusion



Section of machined chamber

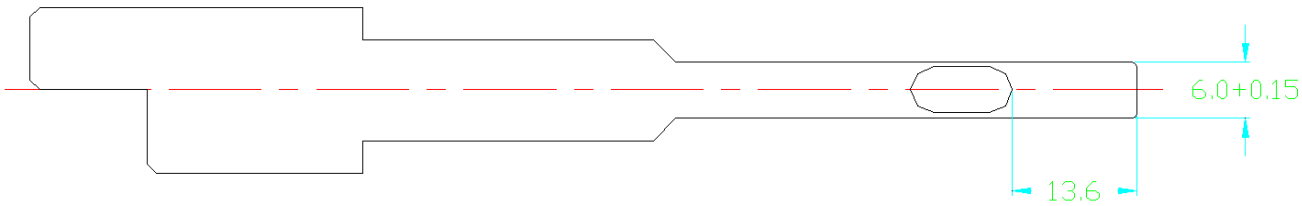


Production chamber prepared for cleaning

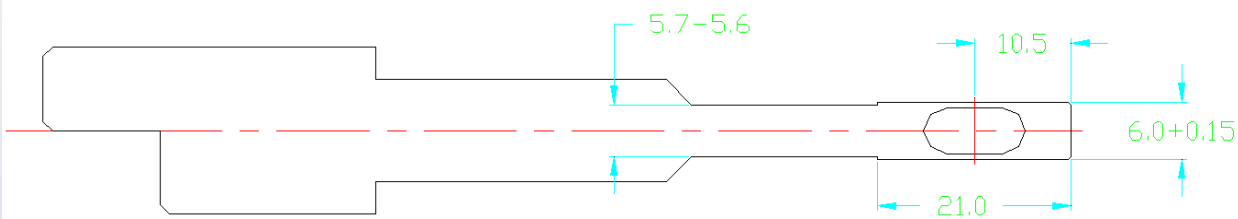
LCLS extruded vacuum chamber in the process of machining

Fixture to achieve the machining precision

Changes in LCLS VC design after production of the first six chamber to simplify its alignment



First six chambers

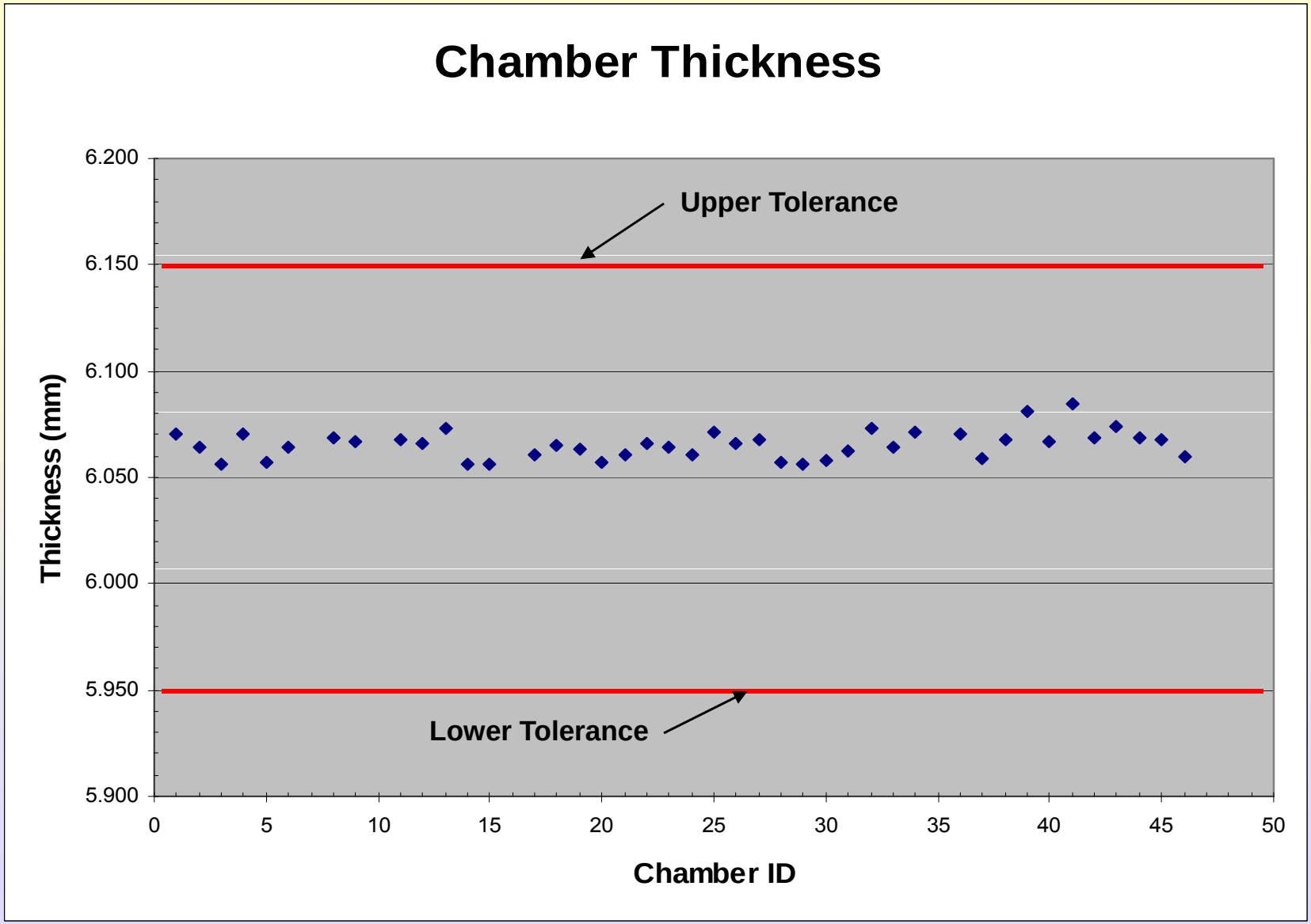


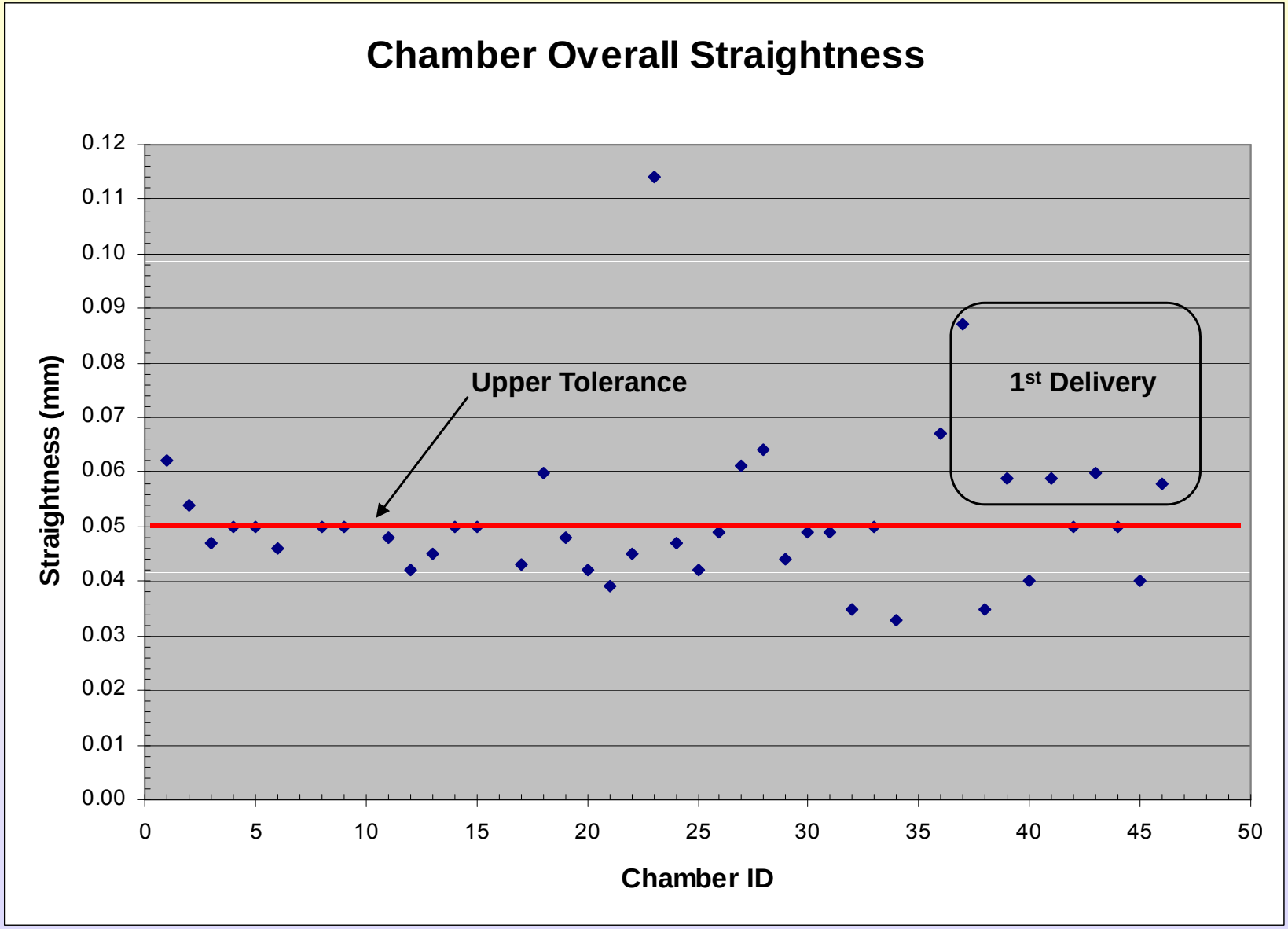
All other chambers

After design modification process of alignment of the chamber especially roll alignment became much less time consuming

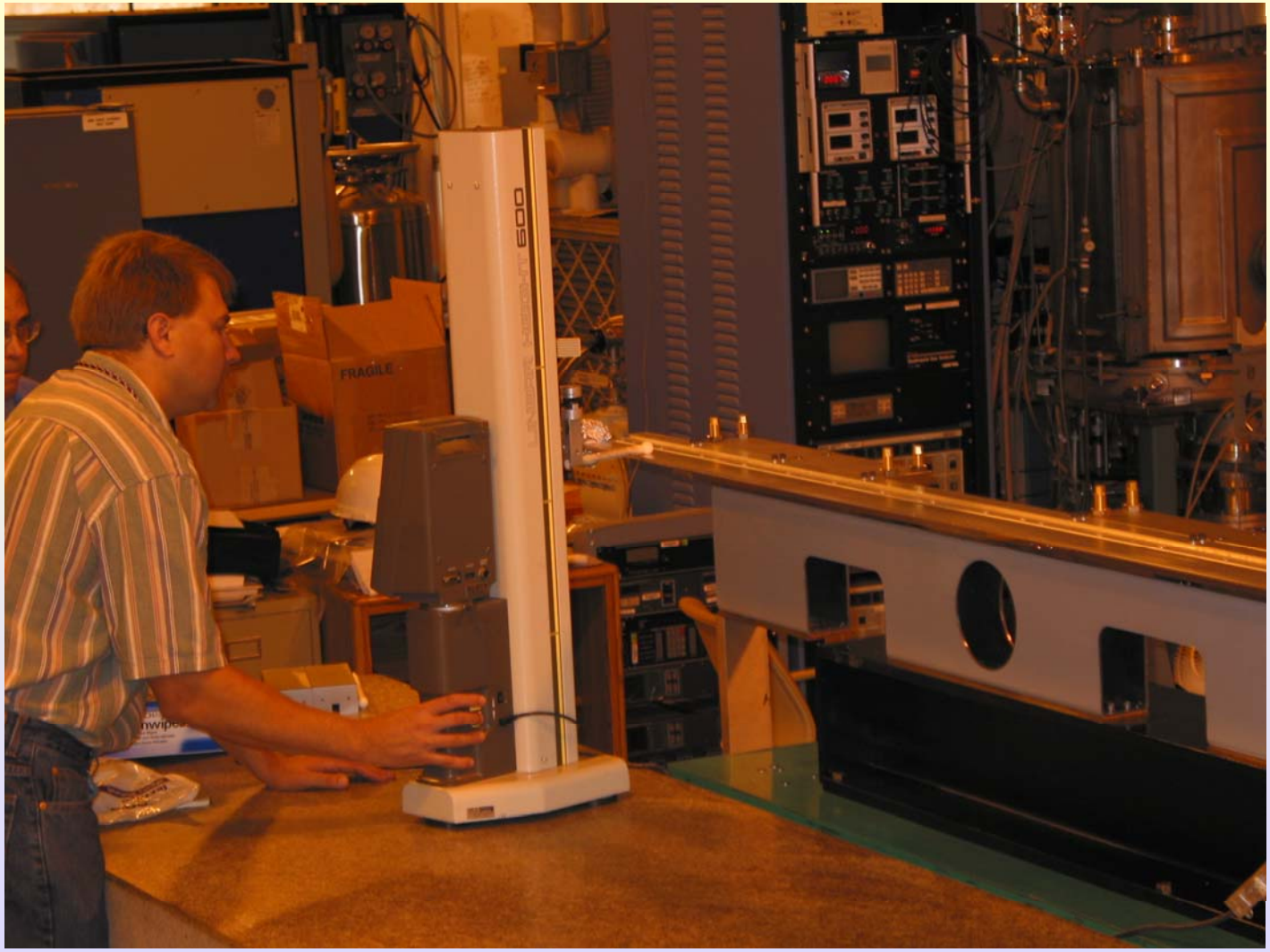
LCLS vacuum chamber adjustment and wall thickness inspection

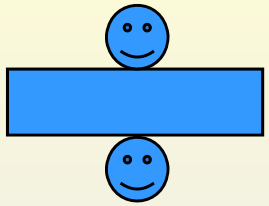
- After changing the chamber and adjustment system design, chamber alignment usually took about 4 hours.
- Wall thickness variation for most of the chambers is within ±25μ.
- Some results of the vacuum chamber inspection are shown on the next slides


Chamber Thickness
Upper Tolerance
Lower Tolerance
Thickness (mm)
6.200
6.150
6.100
6.050
6.000
5.950
5.900
0
5
10
15
20
25
30
35
40
45
50
Chamber ID


Chamber Overall Straightness
Straightness (mm)
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
5
10
15
20
25
30
35
40
45
50
Chamber ID
Upper Tolerance
1st Delivery

LCLS VC alignment and thickness inspection



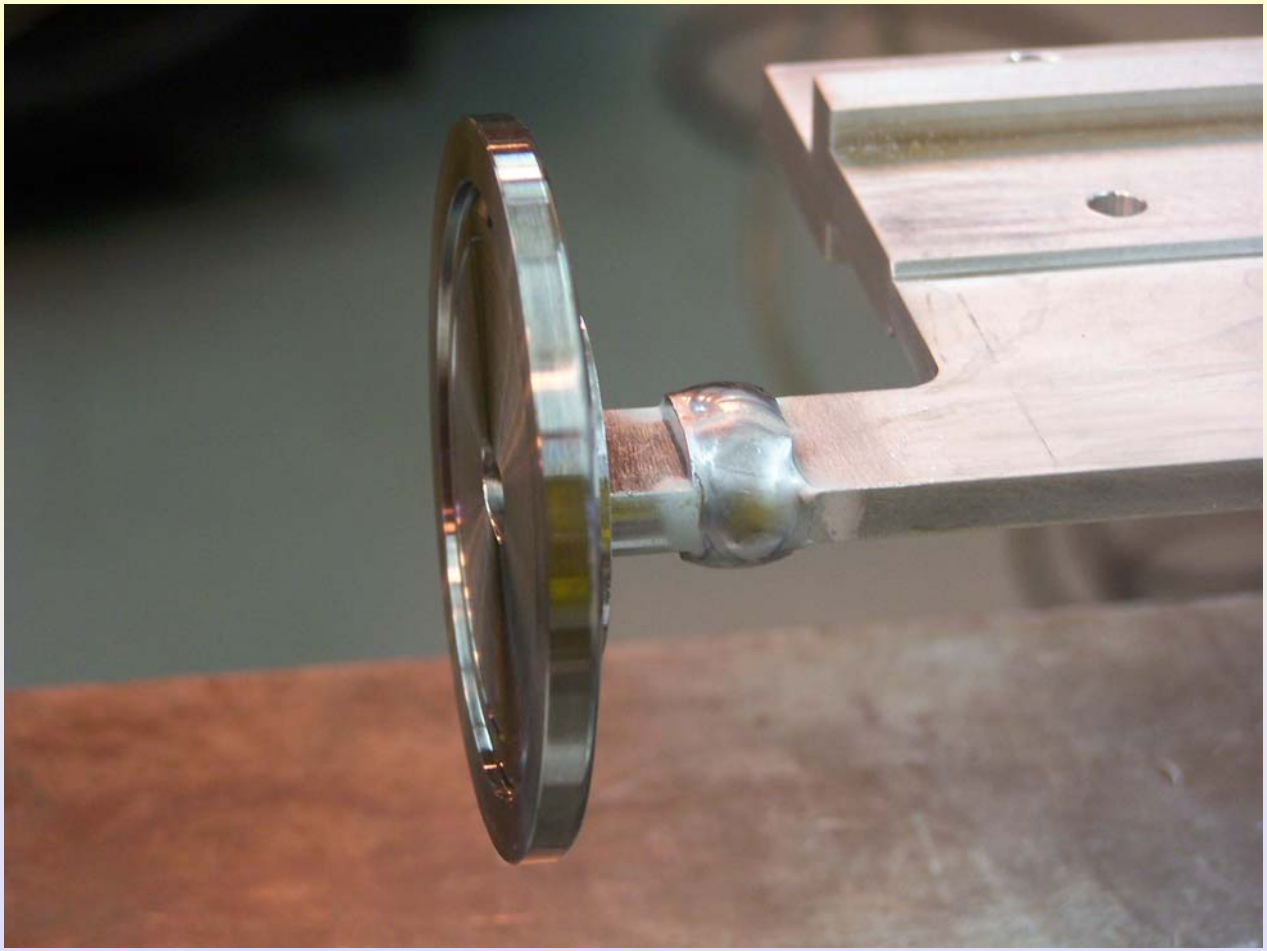


Measurements of the chamber thickness

LCLS VC on the weldment table

Flange installation fixture

End bi-metal flange welding



All bi-metal flanges were inspected, leak checked, polished and cleaned before welding

Inspection and correction of the LCLS VC end flange perpendicularity (.005 tolerance)

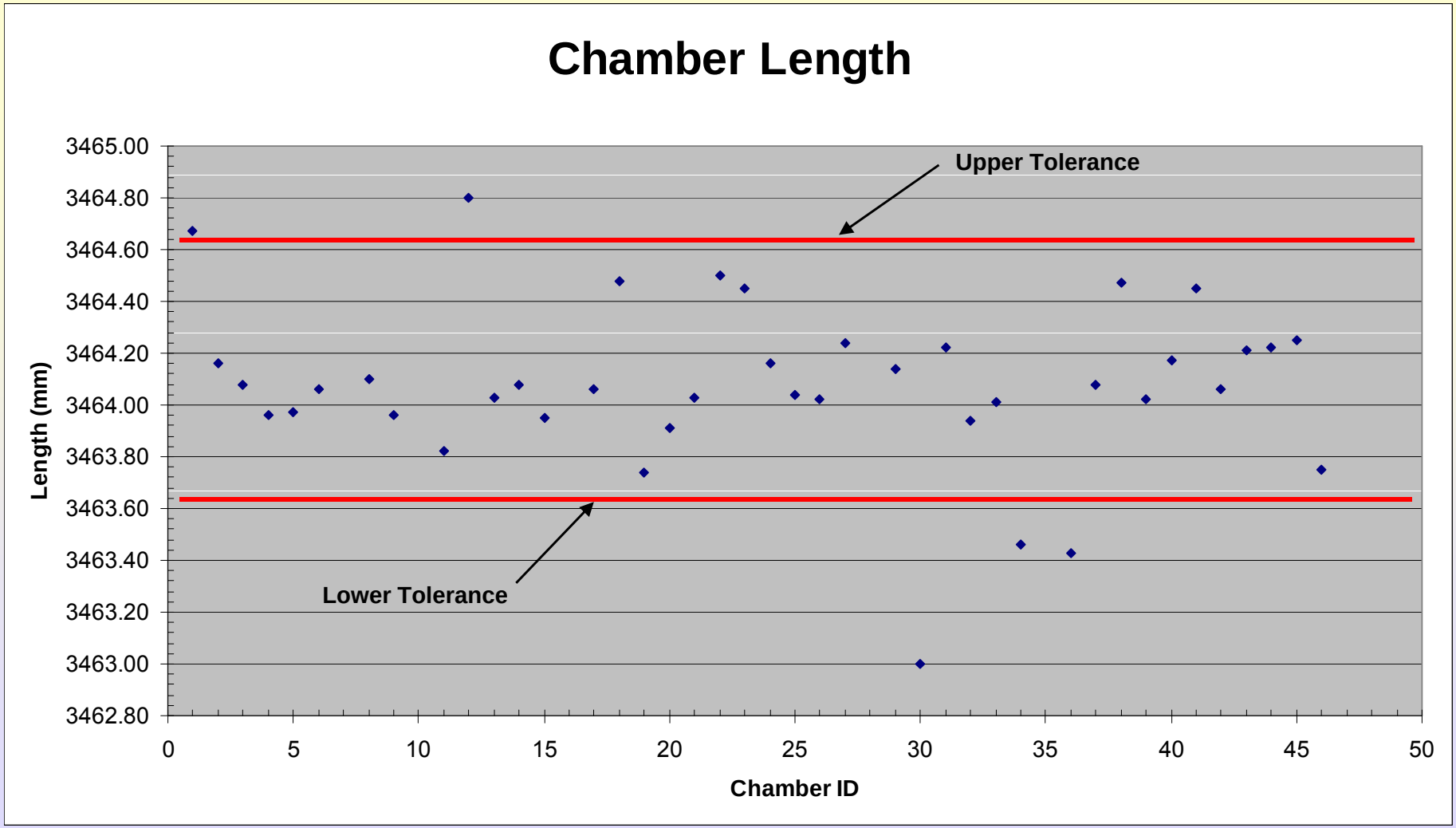
Inspection of the total length of the LCLS VC

- Final length of the all vacuum chambers after welding were measured successfully using a laser tracker through the vacuum chamber aperture.
- Specified tolerance of the chamber length is:

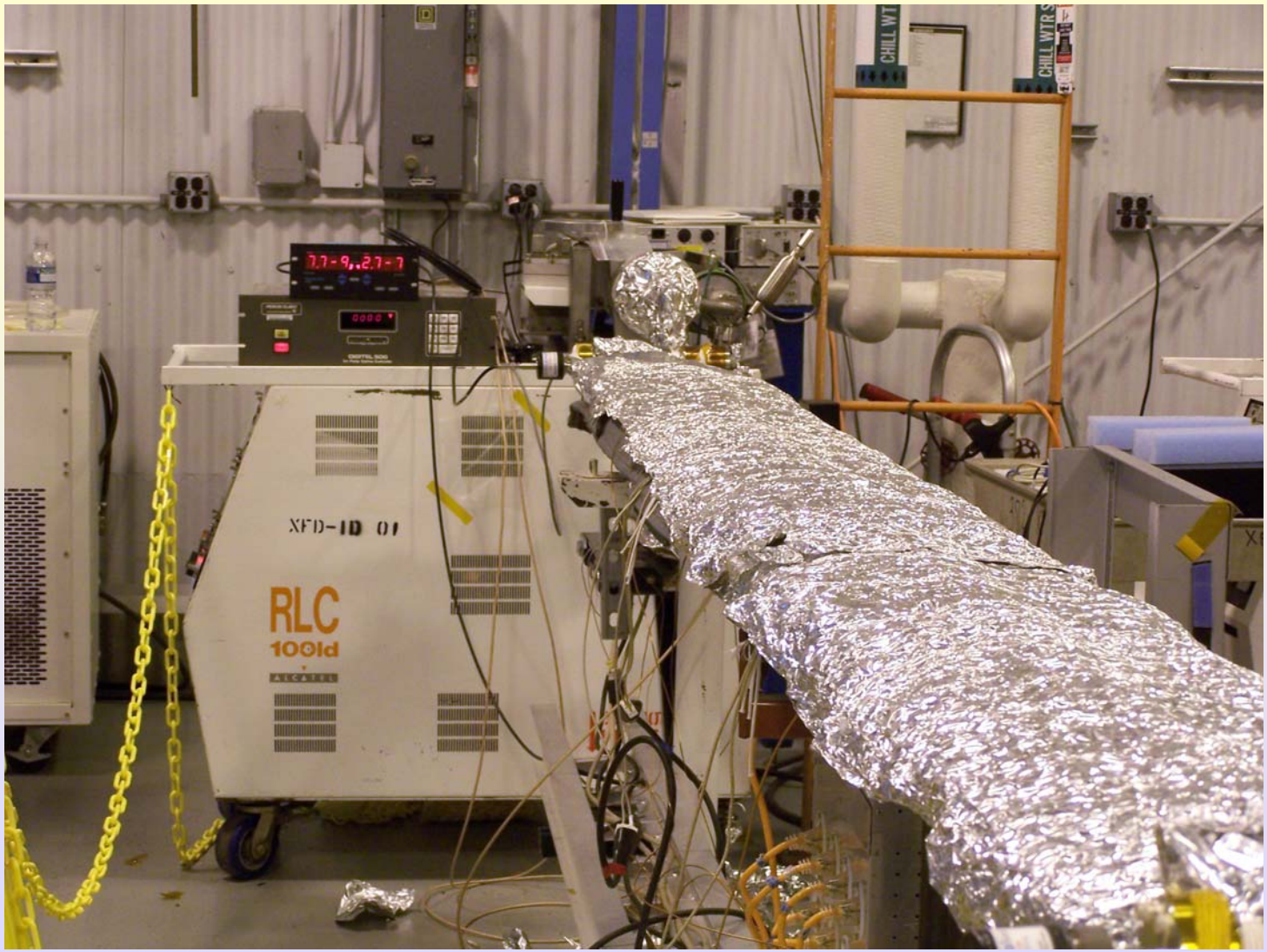
Upper limit $3464.44^{+0.2}$

Lower limit $3464.44_{-0.8}$

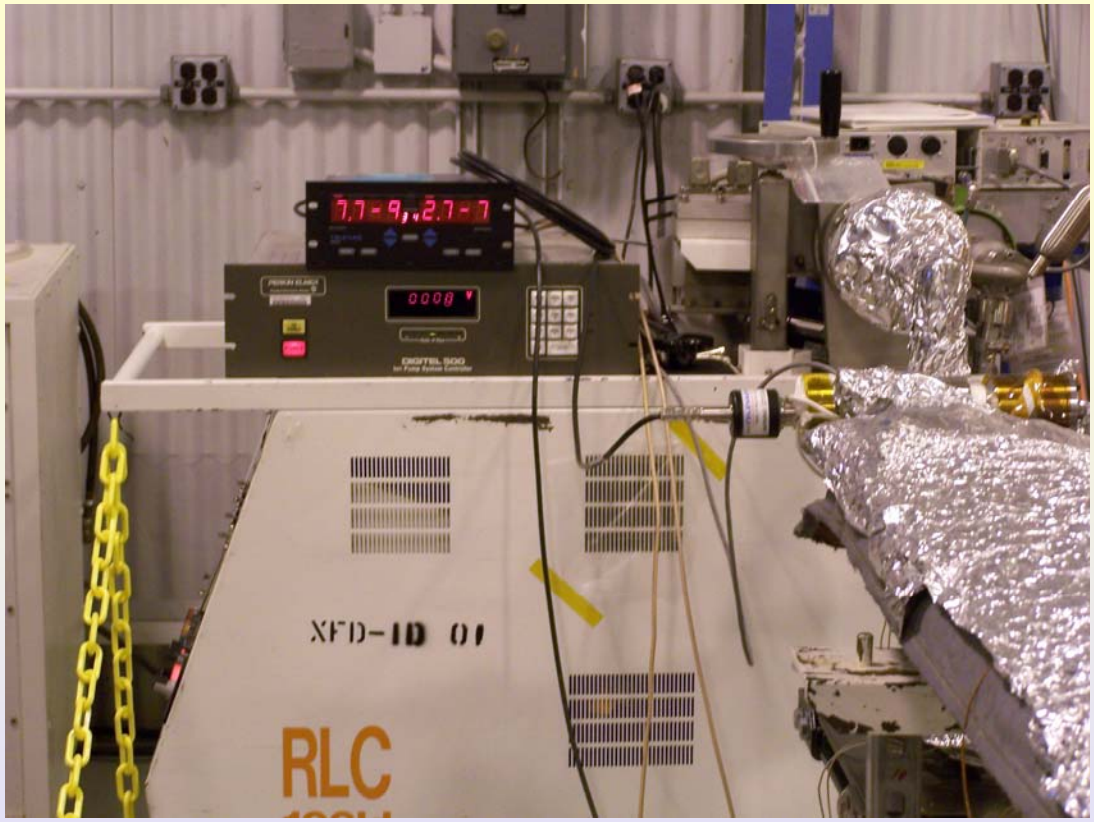
Summary of the Inspection of the total length of the LCLS VC



LCLS VC on the baking stands



LCLS VC on the baking stands

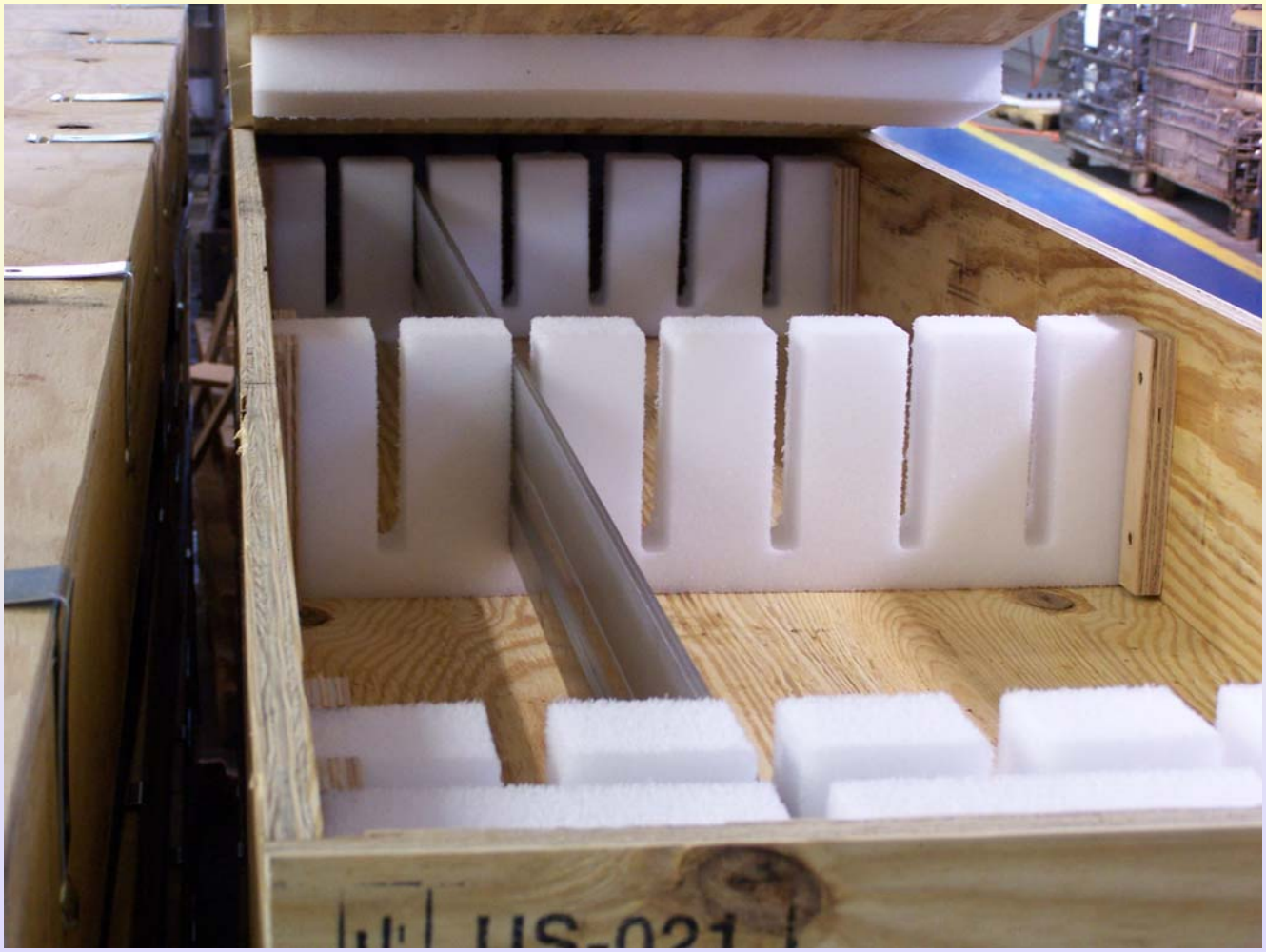


Notes: 1.Ion-pumps are still off;
2. RGA tests showed no pikes above mass 44.

LCLS vacuum chamber current status

- All 41 chambers were fully machined, welded, inspected, and certified. (82 welding joints – zero leaks).
- 40 shipped to SLAC, one left at APS for the Long Term Test.
- Three polished extrusions were sacrificed to measure the surface finish in the middle of the chamber.

LCLS first vacuum chamber in the shipping crate



LCLS last five vacuum chambers before shipping to SLAC

Technological challenges we have overcome (together with our vendors)

- **High-quality long and precise extrusion (“Cardinal Aluminum”).**
- **Stretching of an extrusion to eliminate major waviness and twist (“Cardinal Aluminum”).**
- **Abrasive flow polishing of the chamber aperture to achieve a mirror finish for the 4 meter long extrusion (“Engineered Finishing Co”).**
- **Additional straightening of the extrusion within ± 0.05 mm over 4 m length (“Hi-Tech Mfg.”) .**
- **Precise machining to the specifications (“Hi-Tech Mfg.”).**
- **Vacuum-tight bimetal end components (“Atlas Technologies”).**
- **Special ultra high vacuum cleaning procedure after abrasive flow polishing while keeping aperture surface intact (in house).**
- **TIG hand welding with no underbead (in house).**
- **Baking and vacuum certification (in house).**

CONCLUSION

Manufacturing and certification of the extruded LCLS vacuum chambers is complete (meeting all the design goals) with full agreement with our schedule and within the allocated budget.

ACKNOWLEDGMENTS

A special “thank you” to all involved in the successful completion of this project:

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