Pbar Target Station

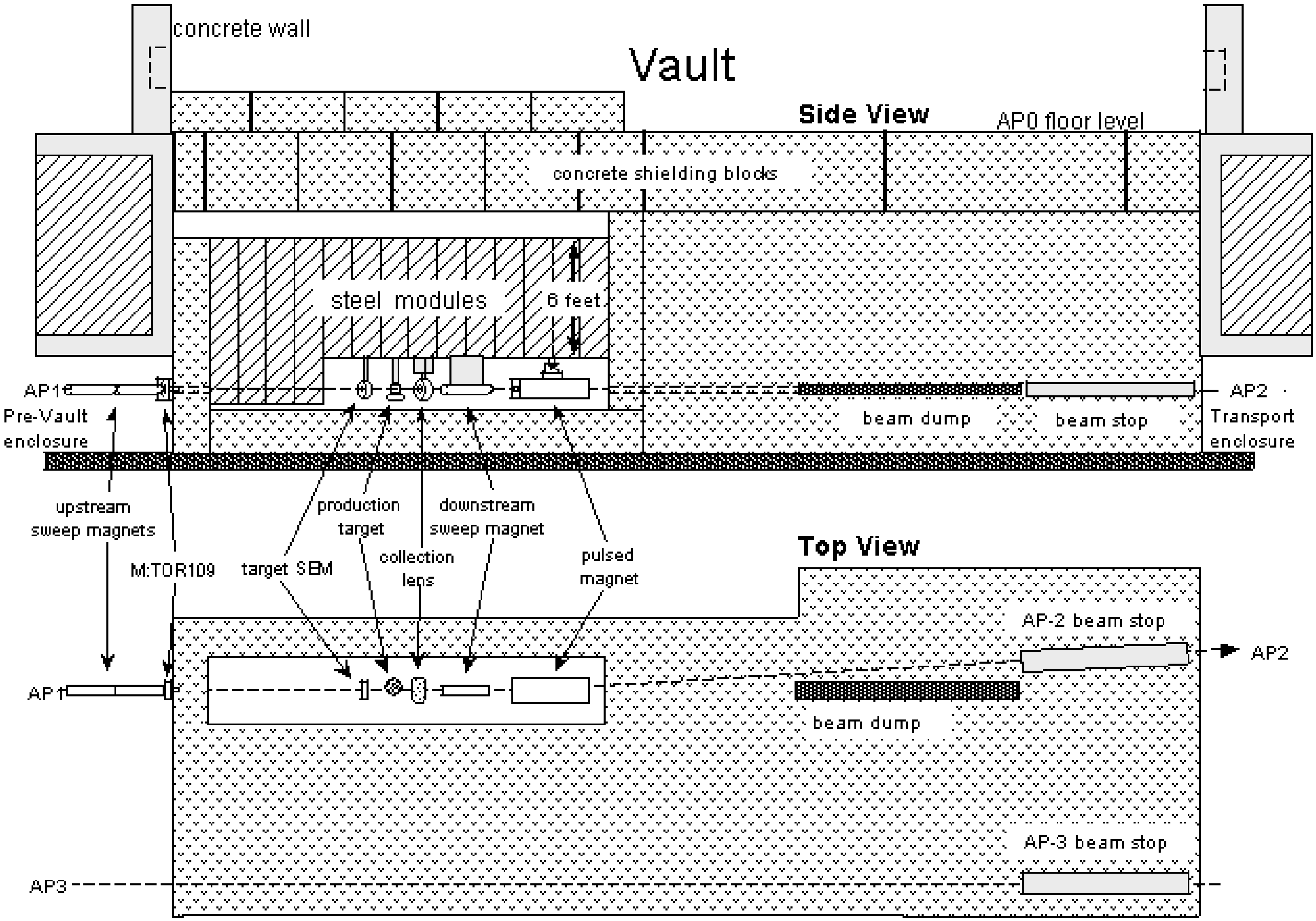
Target and Beam Sweeping
High Gradient Lithium Lens

Jim Morgan

DOE Review

February 25, 2003

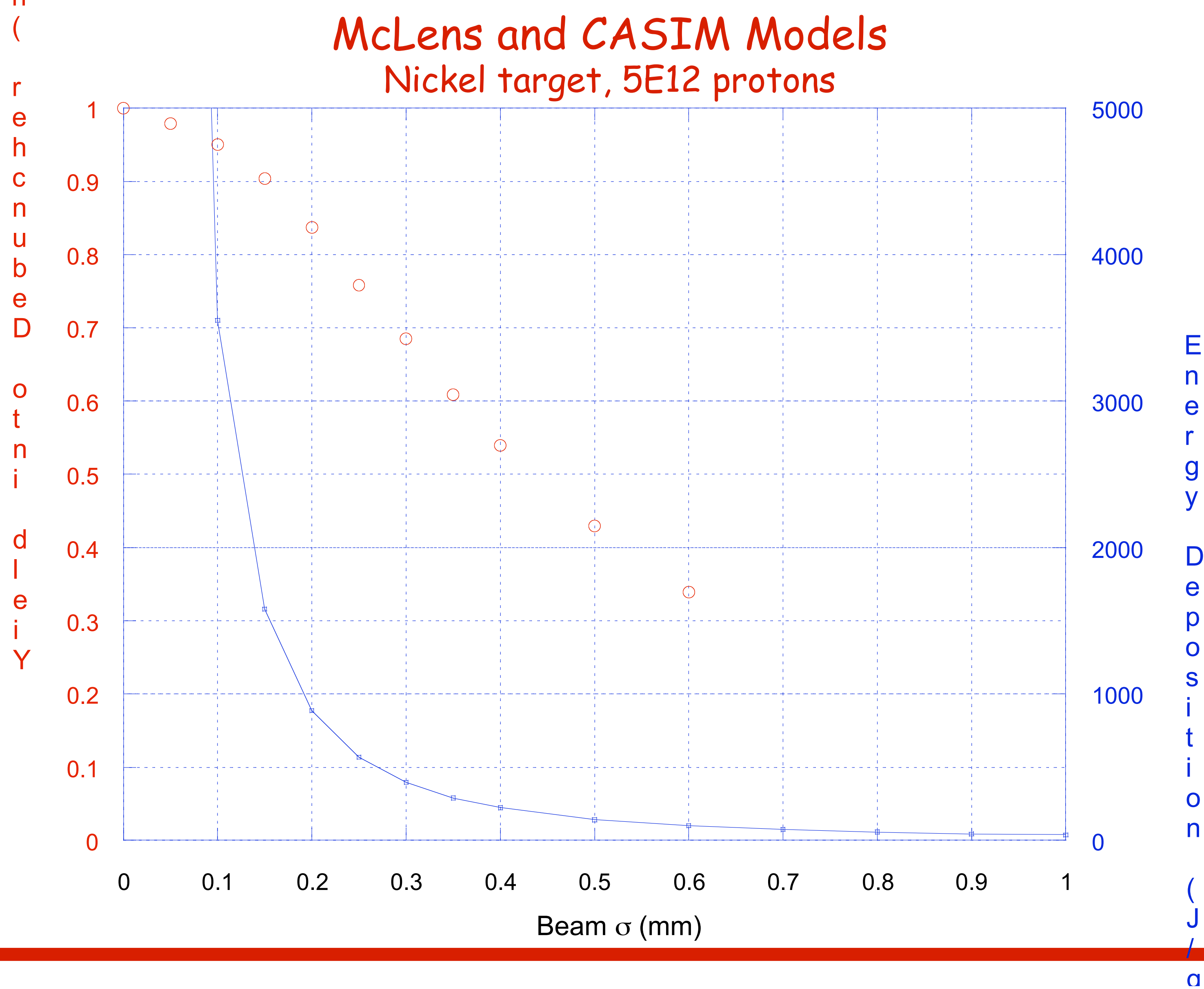
Pbar Target Vault



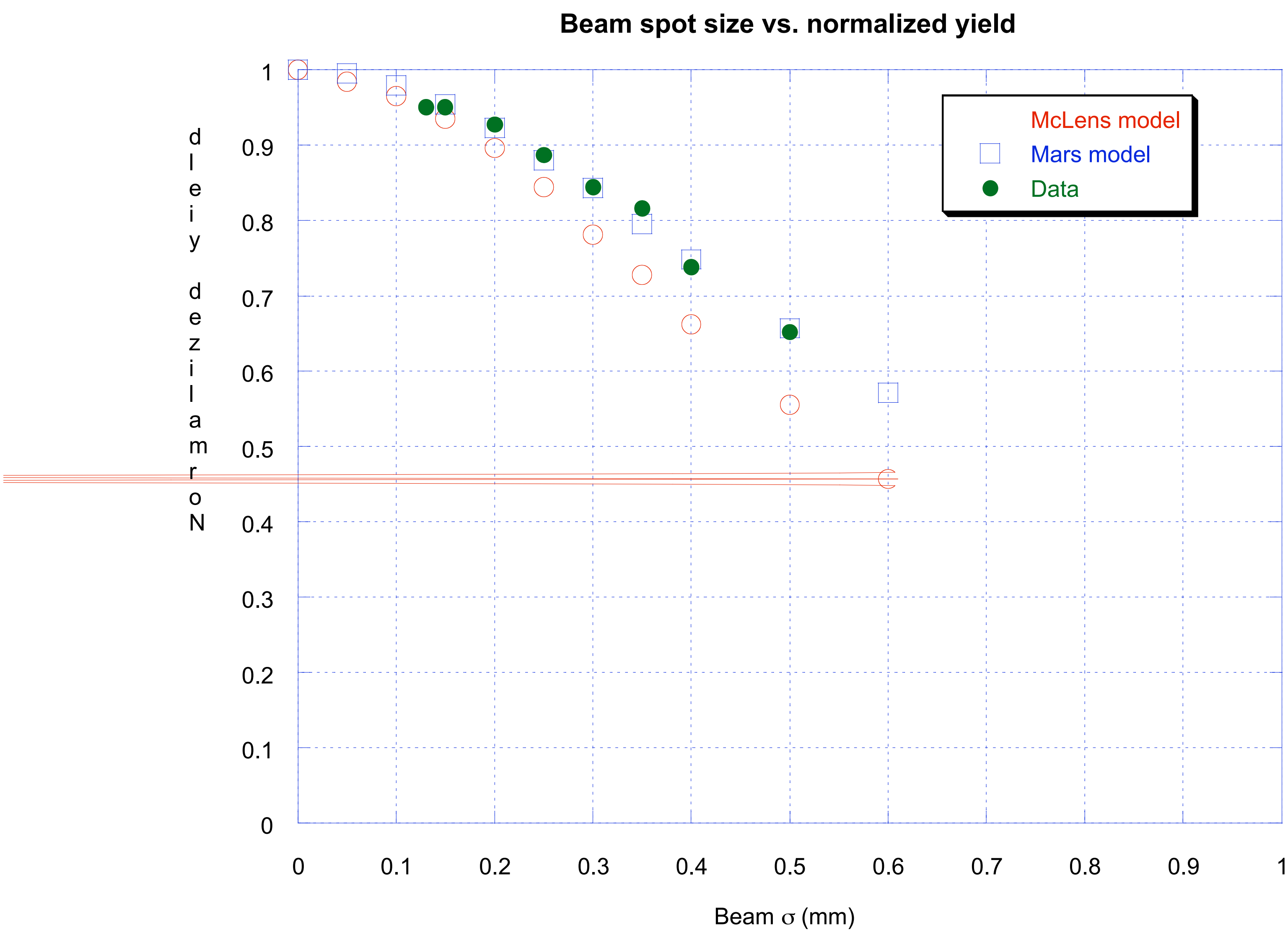
Goals for Target Station upgrades

- Alternative target material
  - Identify target materials that are superior to Nickel in longevity while minimizing the loss of normalized yield
  - Undertake beam studies to confirm pbar yield improvements at small spot sizes predicted by model
- Beam Sweeping
  - Build and commission sweeping system to reduce peak energy deposition in the target
- High Gradient Lithium Lens
  - Disassemble and analyze lenses that have failed
  - Create and refine a Finite Elements Analysis (FEA) model of Lens to better understand mechanical stresses
  - Improve quality control in Lens production
  - Develop a Lithium Lens that can operate at 1,000 T/m for

Pbar yield and peak energy deposition vs. spot size



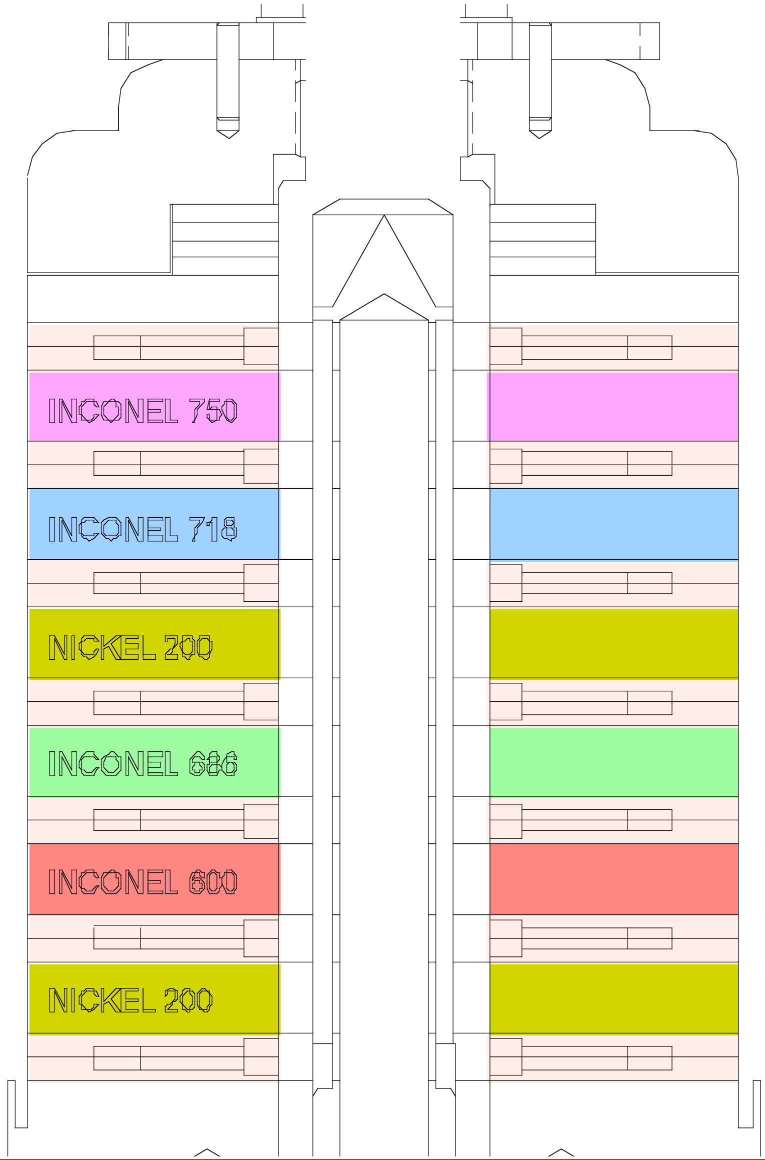
Comparison of model and data yield curves



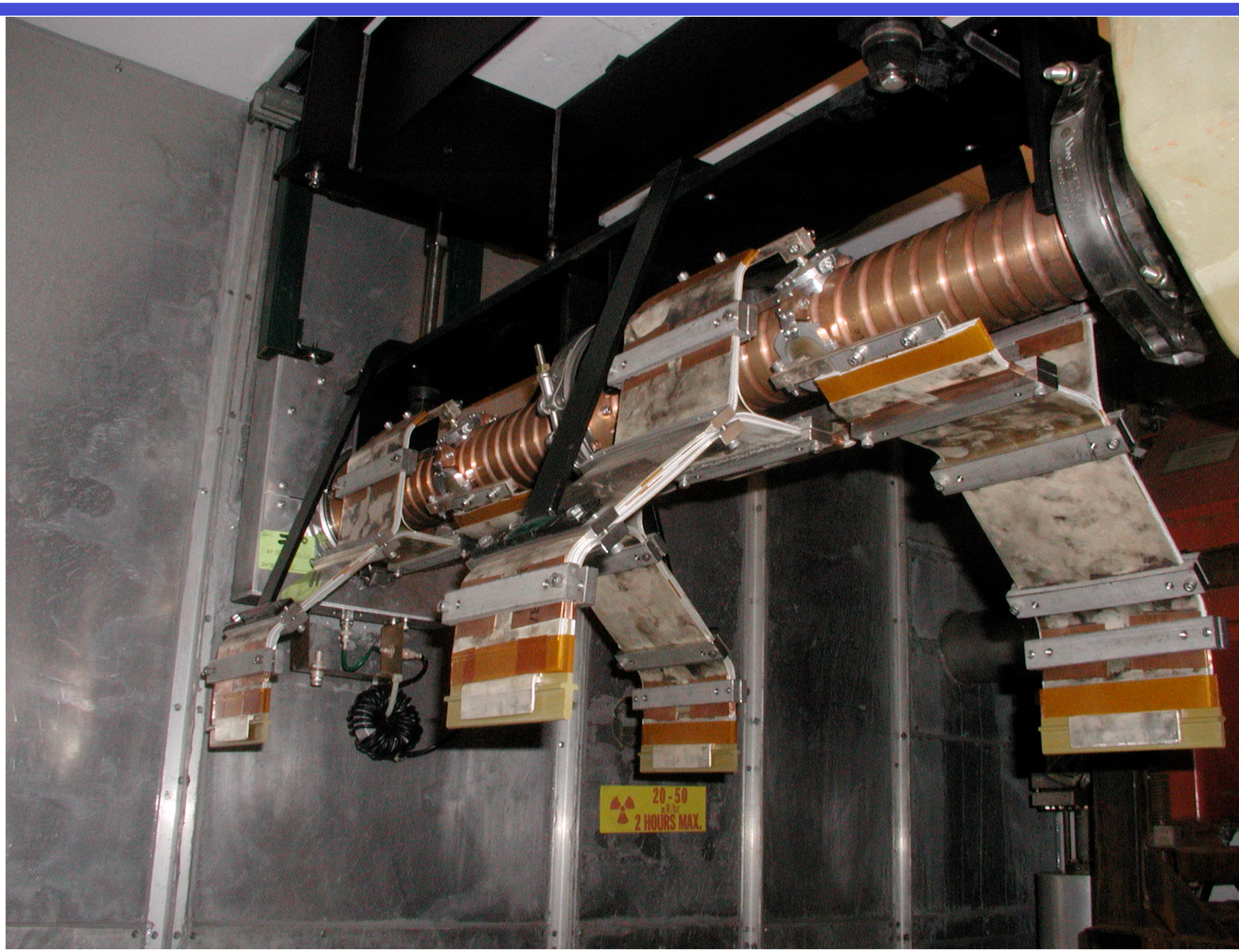
Summary of target material endurance study

Material	Spot size	Starting Yield	Ending Yield	Protons On target	Yield reduction Scaled to 10^{18} protons
Nickel 200	$\sigma xy = 0.15, 0.16$	1.000	0.970	5.7×10^{17}	5.3%
Nickel 200	$\sigma xy = 0.22, 0.16$	0.990	0.935	6.6×10^{17}	8.3%
Inconel® 600	$\sigma xy = 0.15, 0.16$	0.995	0.970	10.6×10^{17}	2.4%
Inconel® 600	$\sigma xy = 0.22, 0.16$	0.990	0.960	10.7×10^{17}	2.8%
Inconel® 625	$\sigma xy = 0.22, 0.16$	0.980	0.970	6.6×10^{17}	1.5%
Inconel® X-750	$\sigma xy = 0.15, 0.16$	0.985	0.965	5.7×10^{17}	3.5%
Inconel® 686	$\sigma xy = 0.15, 0.16$	0.970	0.935	1.0×10^{17}	38.2%
Stainless 304	$\sigma xy = 0.15, 0.16$	1.000	0.965	6.1×10^{17}	5.8%

Pbar target assembly presently in use



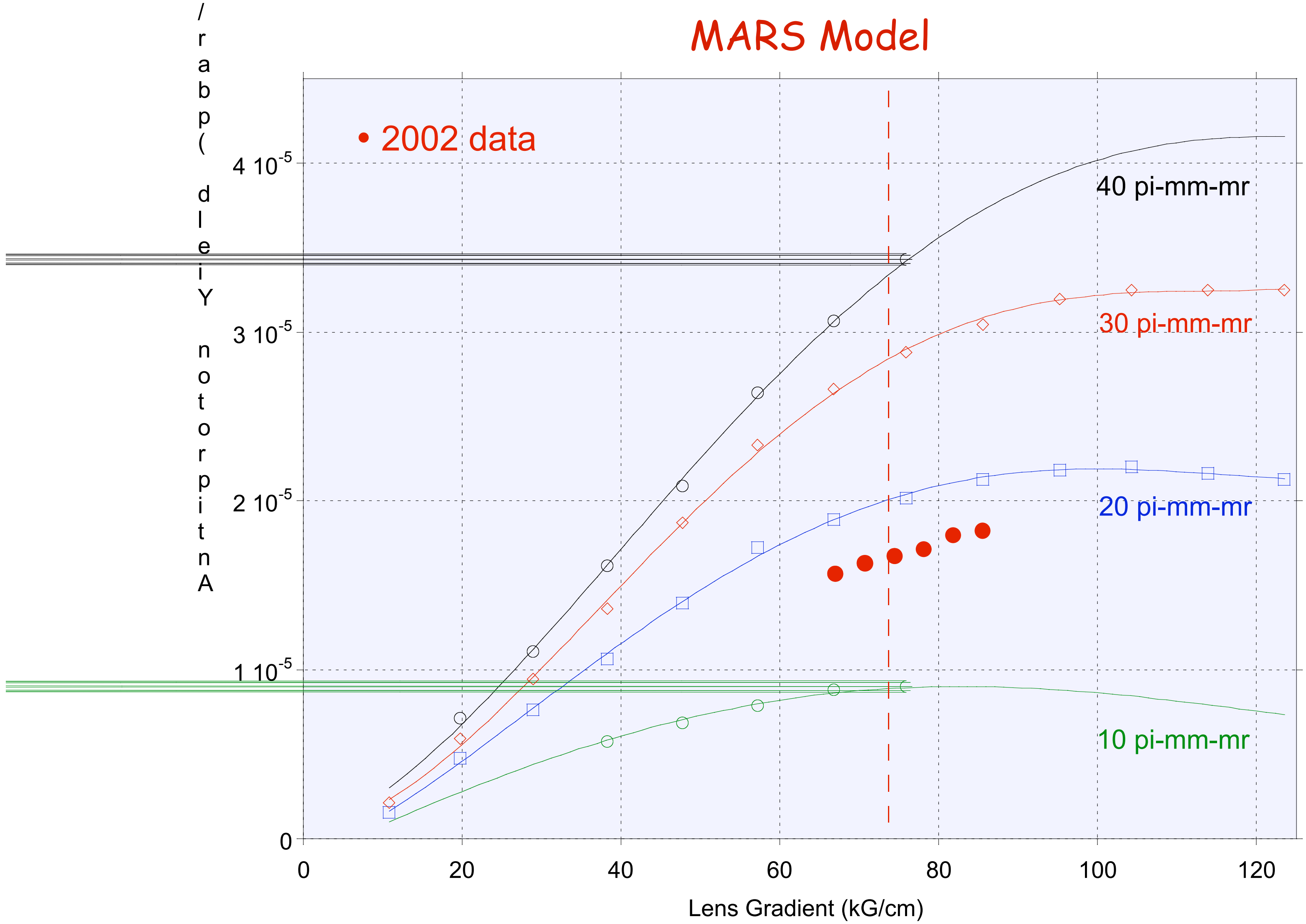
Upstream sweeping magnets installed in AP-1 line



Pbar target and beam sweeping, Summary

- Pbar Target and Beam Sweeping
  - Stainless 304 identified as operational target material
    - Inconel 600 is almost as good
    - May need larger targets due to lower target density
  - There is no benefit in reducing spot sizes to the original goal of _ = 0.10 mm
    - Beam studies show spot sizes below _ = 0.15 mm produce little or no antiproton yield increase
  - Target damage and yield reduction are not as severe as expected at small spot sizes
  - Yield reduction from target melting has not been observed, although predicted by models
  - Upstream beam sweeping system is installed
  - Target station is ready for intensity increase from slip-stacking
    - Spot size may need to be increased if slip-stacking is

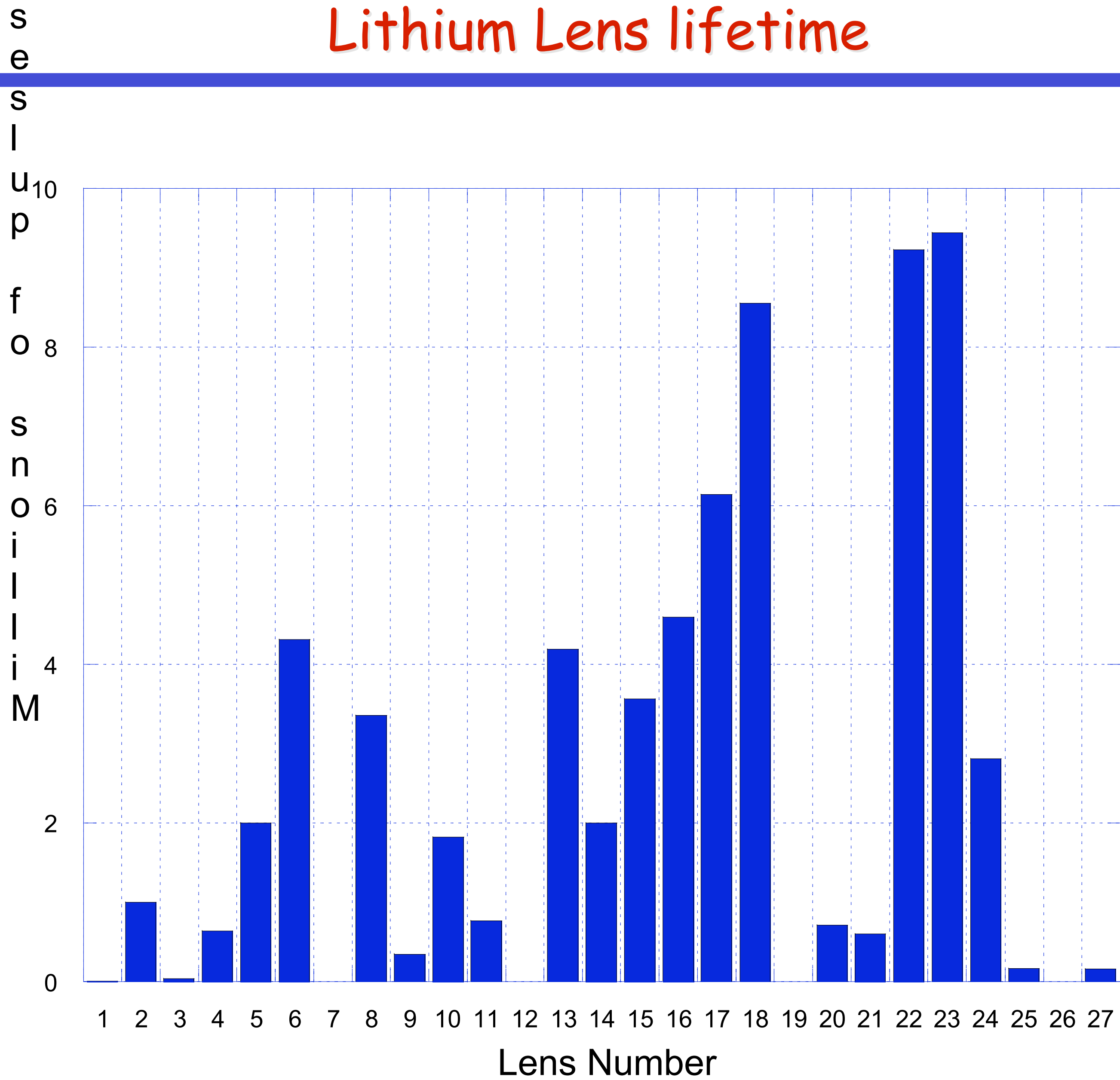
Lithium Lens gradient vs. Pbar yield



Observed Lens Lifetime

Gradient (T/m)	Average Number of Pulses to Failure
1,000	<500,000
900	1,000,000
800	3,000,000
745	9,000,000
700	>10,000,000

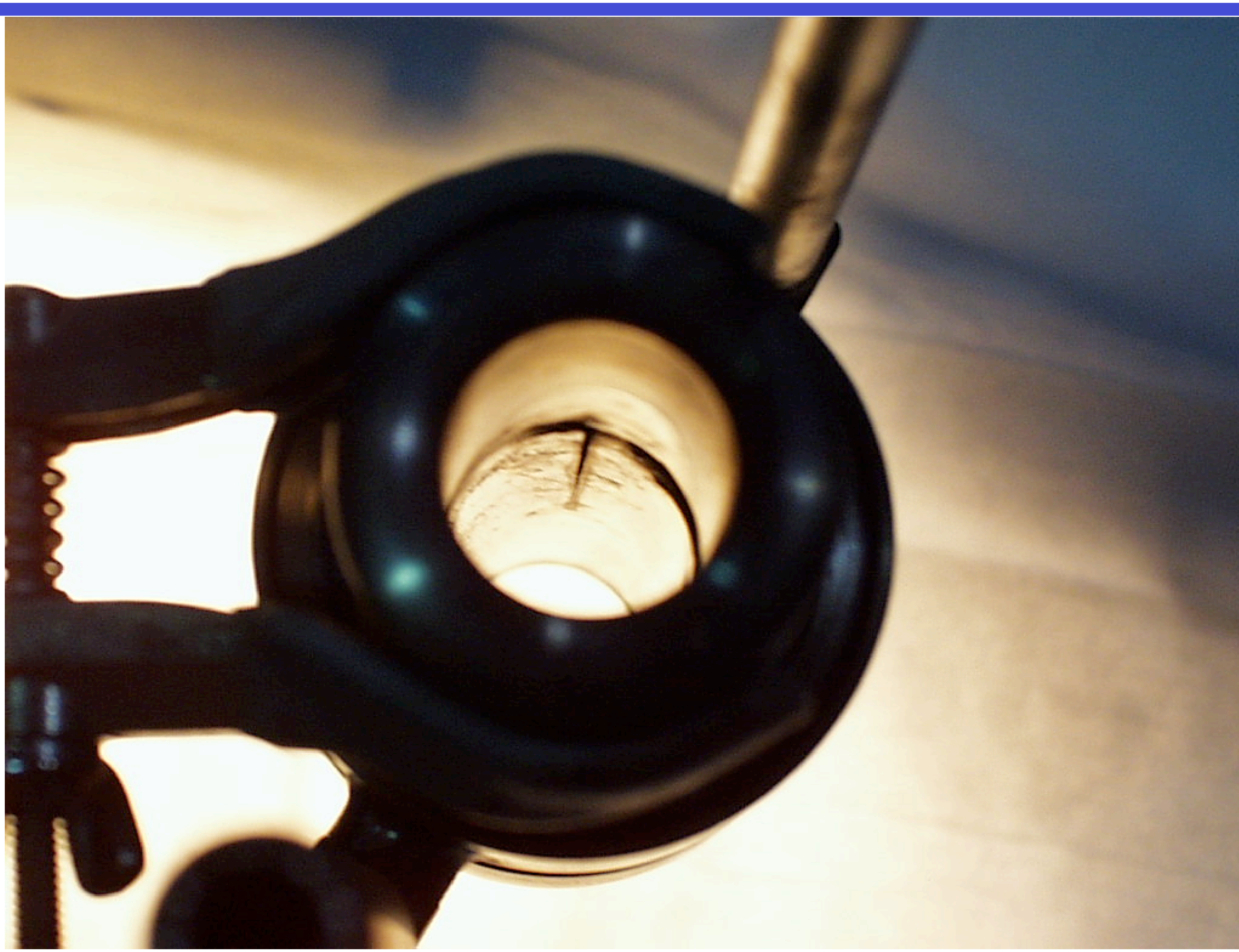
Lithium Lens lifetime



Lens autopsy results

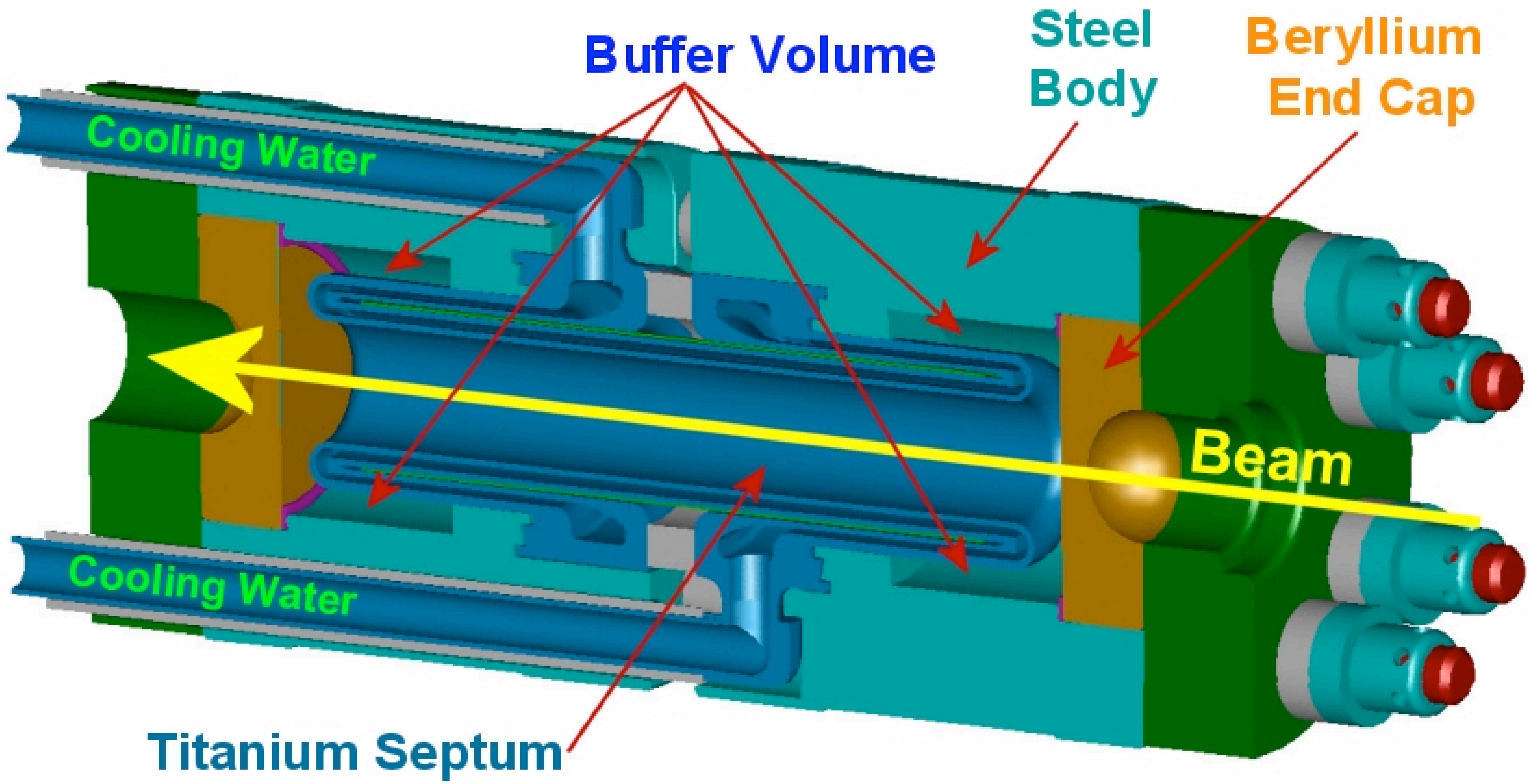
- Progress of Lens disassembly and analysis
  - Lenses 20, 21, and 26 have been finished
  - Lenses 16, 17 and 18 have been examined
    - Lens 16 had a high pulse count, but no septum breach
  - Lens 22 has been disassembled and analyzed
    - Only weld failure out of autopsied lenses
- General Results of Analysis
  - Axial intergranular fracture followed by ductile fracture
    - Intergranular nature of crack more consistent with corrosion
    - Length of remaining tube wall prior to ductile fracture consistent with lower loads from ANSYS
  - Circumferential channels burned through some septum
    - Suggests internal arcing, possibly from Li/Ti separation
    - Small cracks may be obliterated after arcing begins
  - Multiple micro-cracks and pits found on the inside

Lens 21 septum after Lithium removal



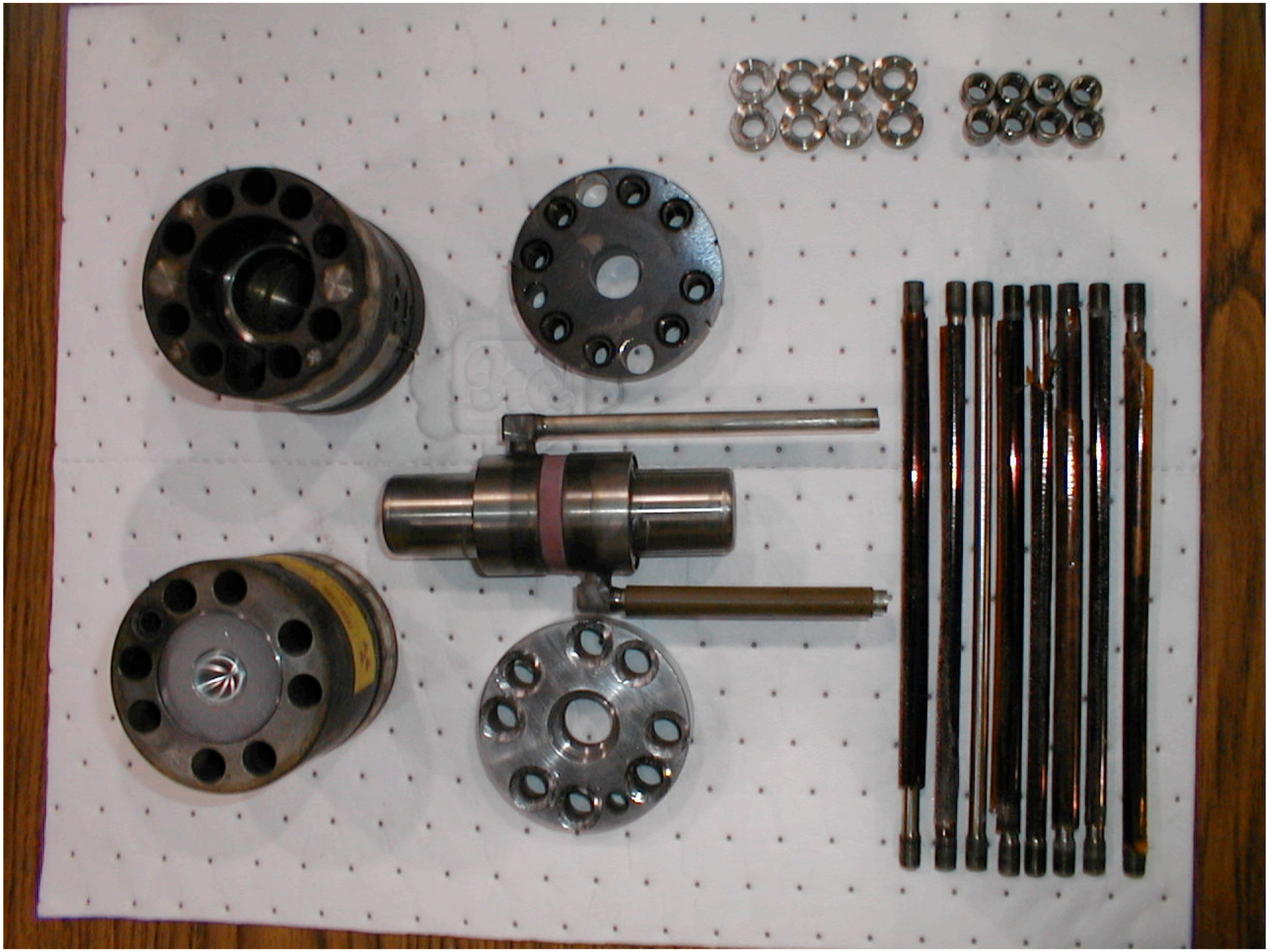
Lens #21, outside of inner septum

Operational Lithium Lens



Complete lens septum assembly

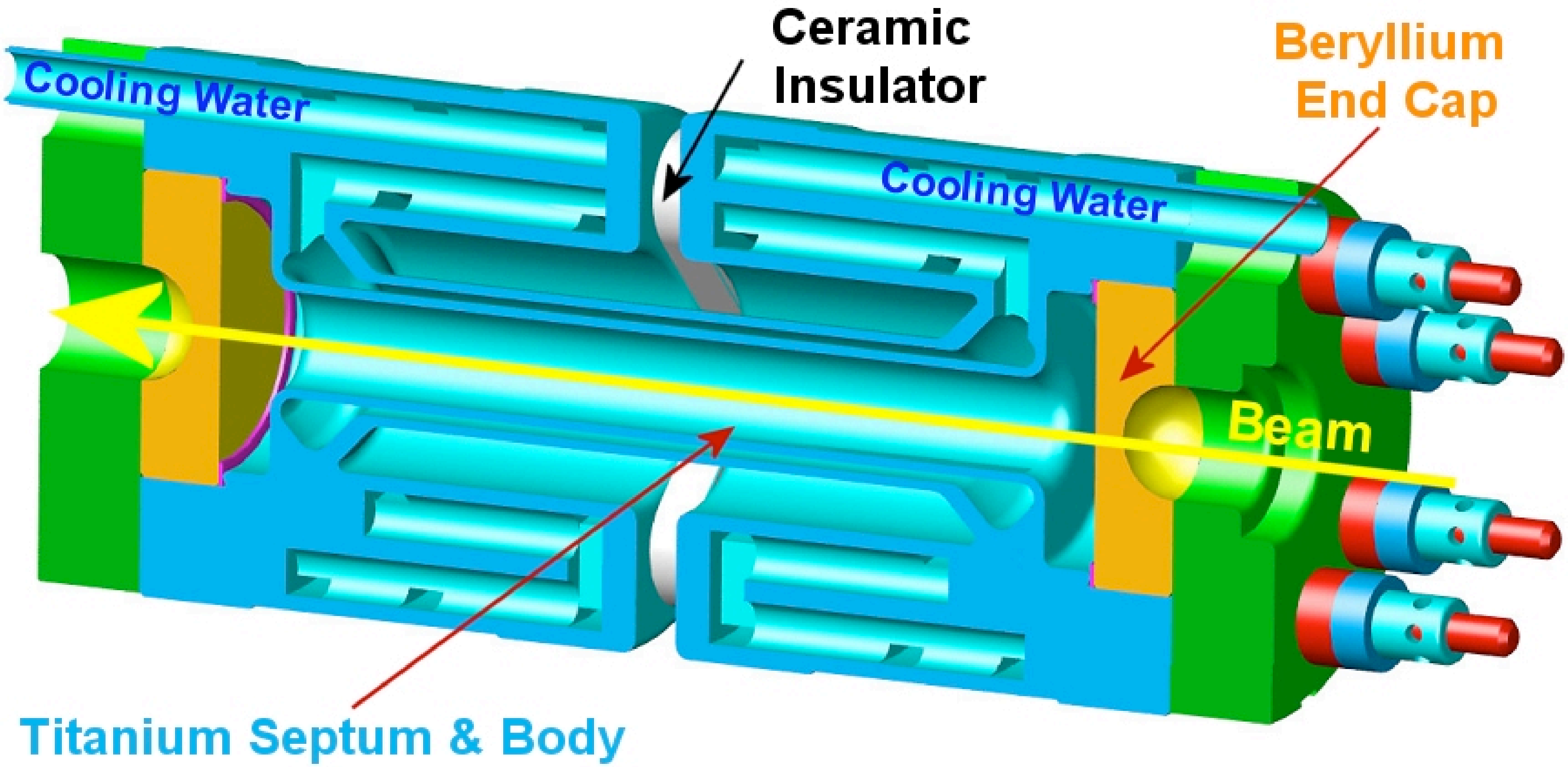
Lithium lens after disassembly



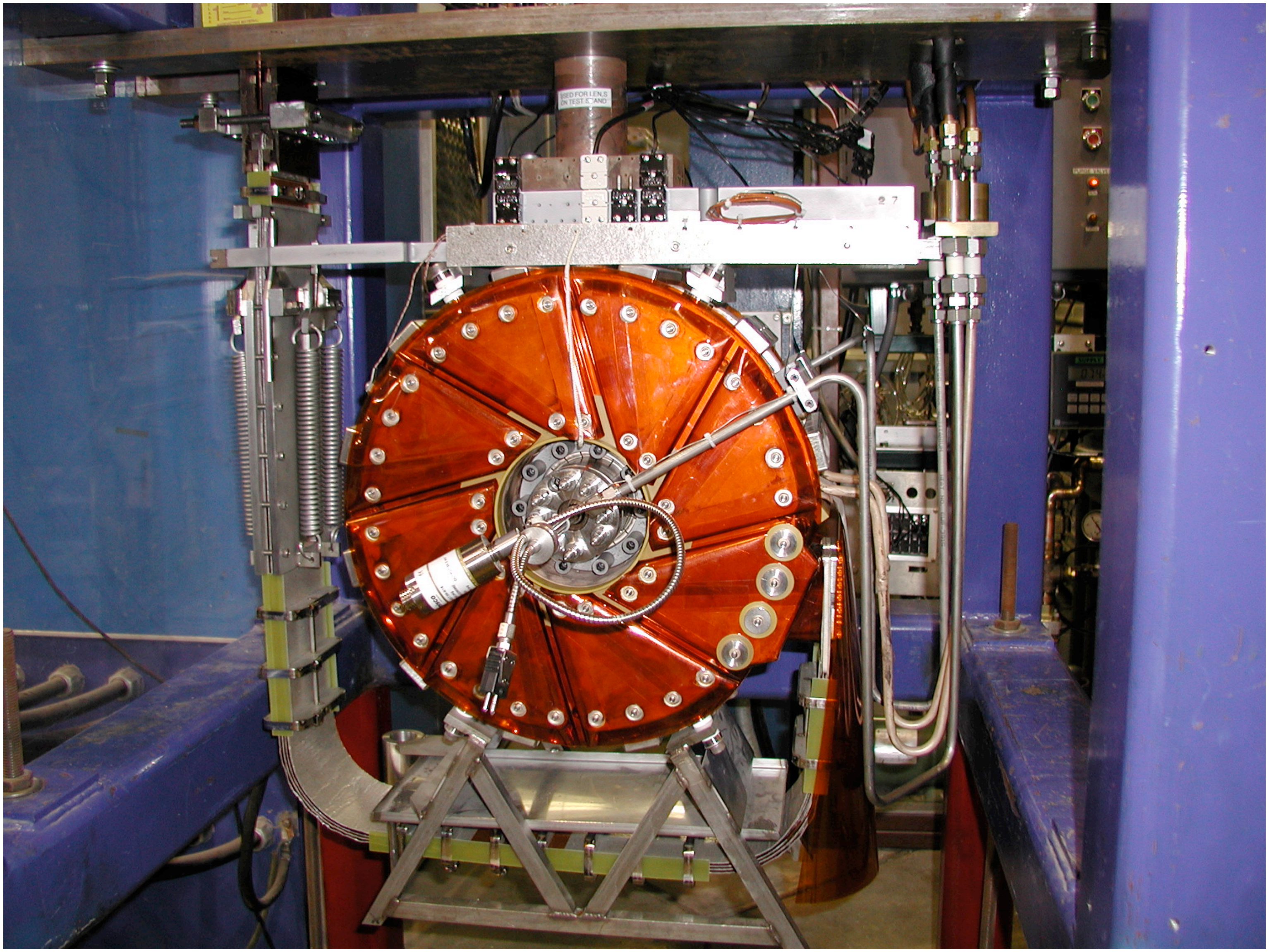
Prototype Lens Summary

- Single piece Titanium septum and body
- Diffusion bonding
  - Eliminates complicated seal between septum and body
  - Only one joint in high stress region
  - All joints bonded simultaneously, easier to maintain joint quality
  - No residual stress
- Simplified construction and assembly
  - Several lenses can be bonded at the same time
  - Significantly fewer etching, welding and machining steps
  - Lens septum construction costs may be reduced by a factor of two
- Additional water cooling to lens body
  - Made possible by diffusion bonding process
- Two prototypes, the first is “proof of principal”
  - Prototype 1 is being pulsed on the test stand (>1.5 million pulses)

High gradient prototype Lithium Lens



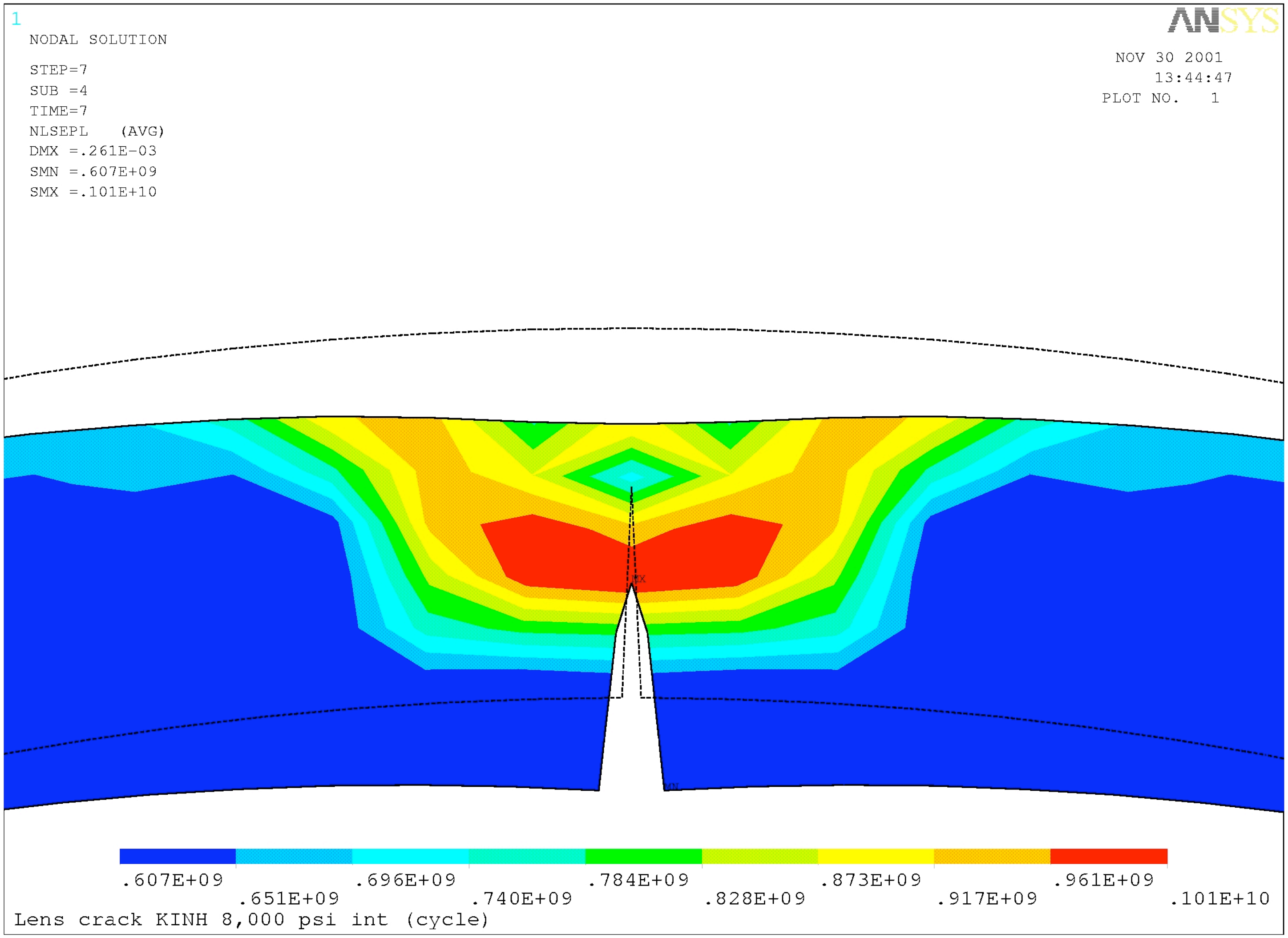
Prototype lens on test stand



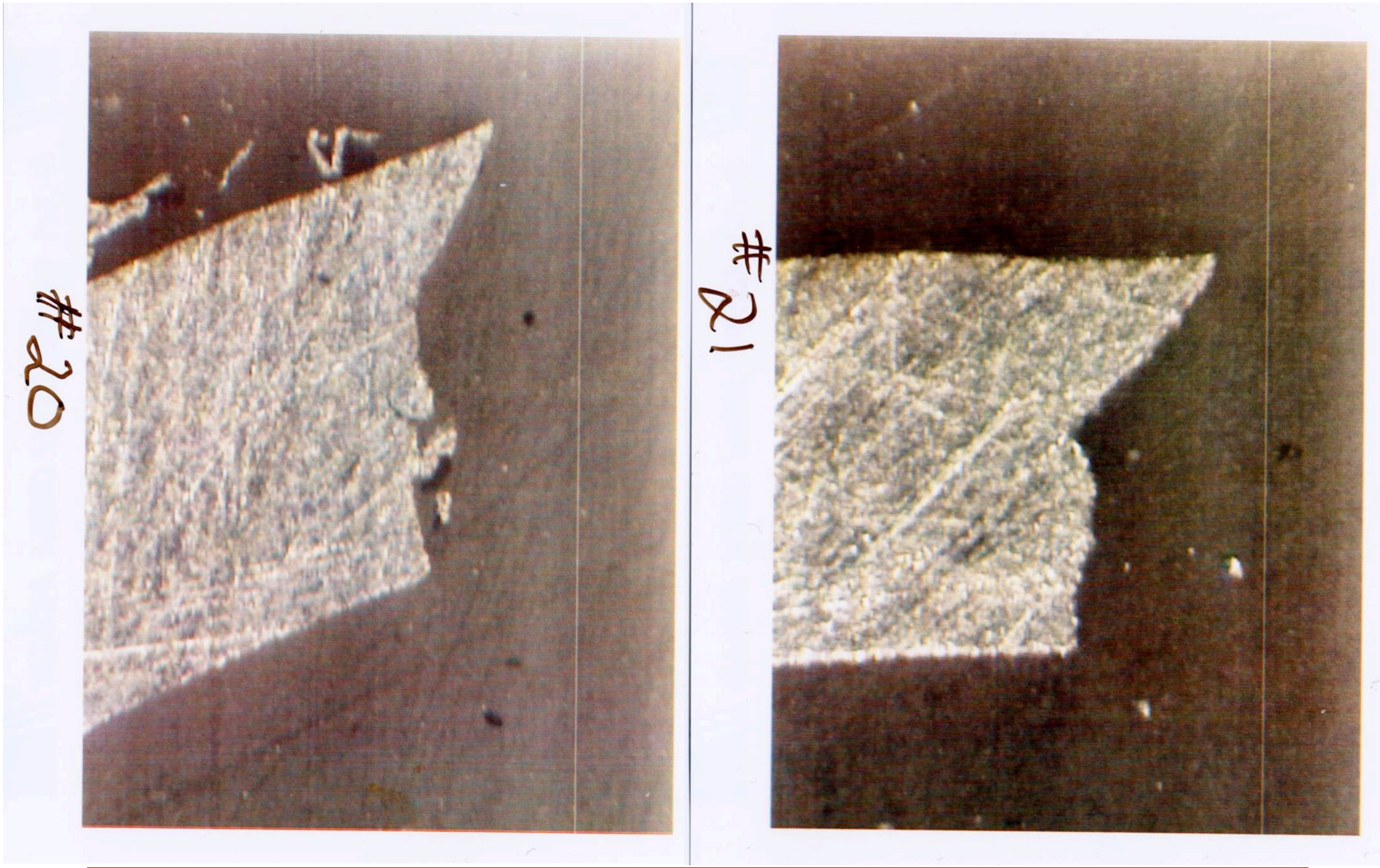
FEA and testing Summary

- FEA
  - Viscoplastic and creep properties of lithium incorporated into full analysis
  - Existing lens and Prototype 1 lens analysis complete
  - Prototype 2 E-M/Thermal modeling almost complete with structural analysis to follow
- Material Testing
  - Viscoplastic tensile lithium testing complete
  - Lithium creep parameters quantified from pressurized tube testing
  - Initial compression tests of lithium indicate viscous fluid behavior rather than fracture (future tests on hold)
  - Fatigue testing of diffusion bonded Ti 6-4 tube joints complete (joints as strong as parent material)
  - Fatigue testing of diffusion bonded Ti 10-2-3 tensile samples indicate insufficient bond
  - More diffusion bond tests of Ti 10-2-3 underway in attempts to

Crack propagation on Lens septum



Cross section of failed septa in Lenses #20 and #21



Quality control Summary

- Lens Fill
  - Improved data acquisition
  - Changed strain gages to improve accuracy
  - Pressure transducer upgrade
  - Created dummy lens to calibrate instrumentation
  - R&D of Lens seals and Lithium properties

- Lens Preparation
  - Improved electron beam welding techniques
  - Lithium handling procedures changed to minimize contamination
  - Created new septum cleaning procedures to reduce the possibility of Hydrogen embrittlement/stress corrosion cracking

Lithium Lens upgrade, Summary

- Lens Autopsy
  - Lenses 20, 21, 26 have been disassembled and analyzed
  - Lenses 16, 17, 18 and 22 have been examined
  - Lens 22 is only weld failure
- ANSYS Modeling
  - Existing Lens and Prototype 1 Lens analysis complete
  - Prototype 2 E-M/Thermal modeling almost complete with structural analysis to follow
- Quality Control
  - Lenses 27 and 28 were assembled and filled with new techniques. Lens 27 failed due to installation error.
  - Titanium embrittlement being investigated
- Prototype Lens
  - First prototype is being tested
  - Second prototype is in the design phase (thermal/structural analysis and geometric layout)