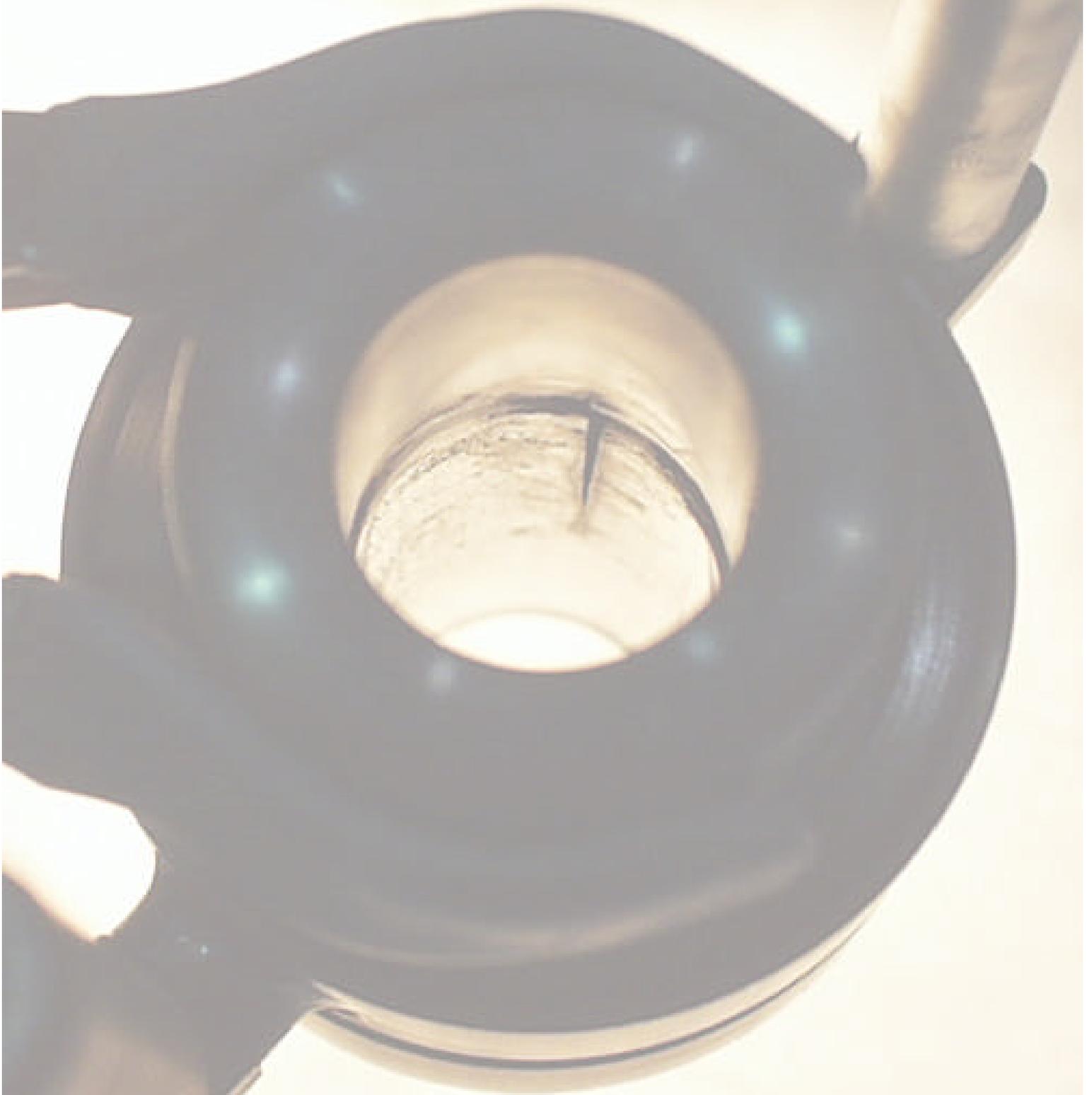
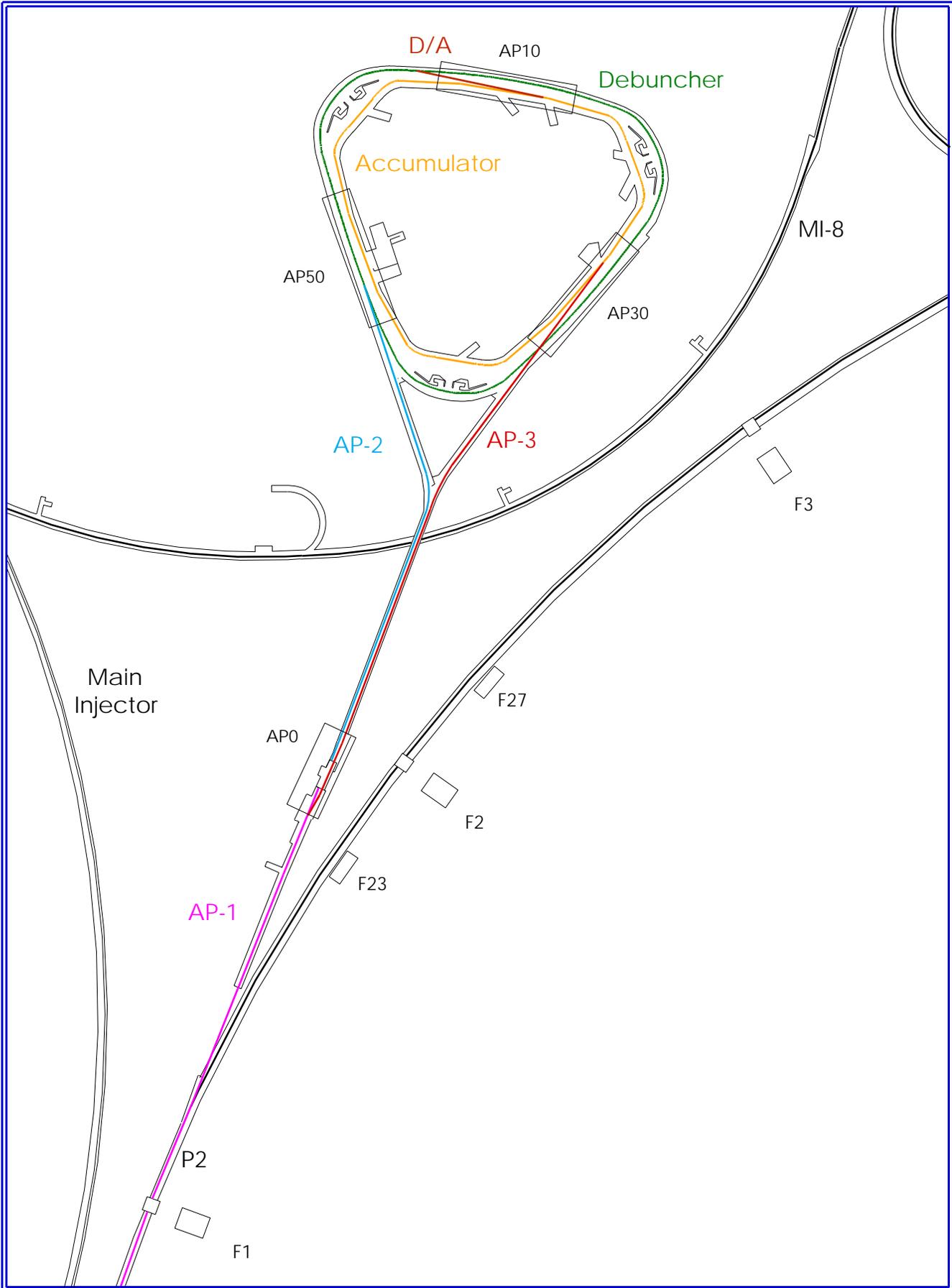
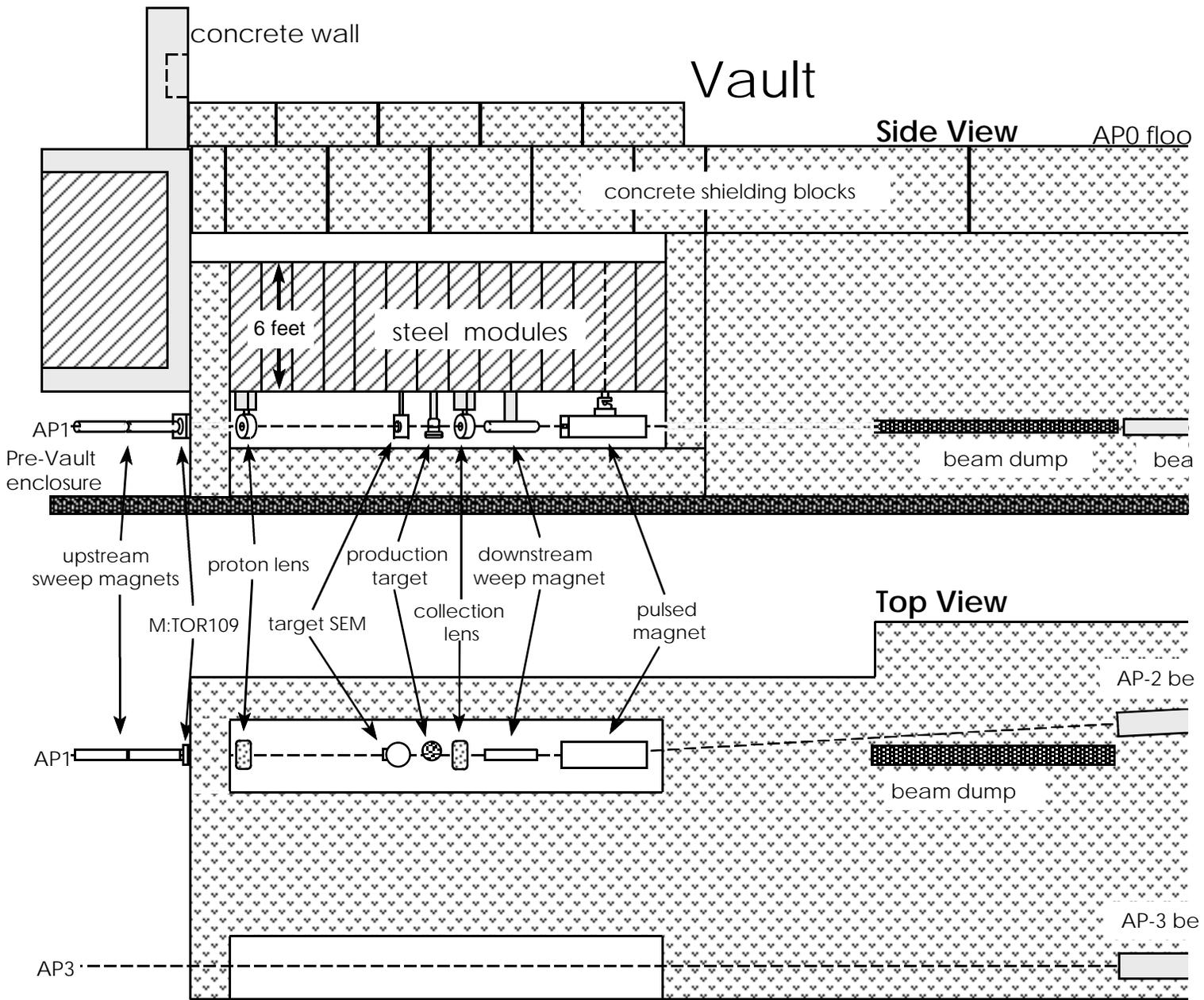


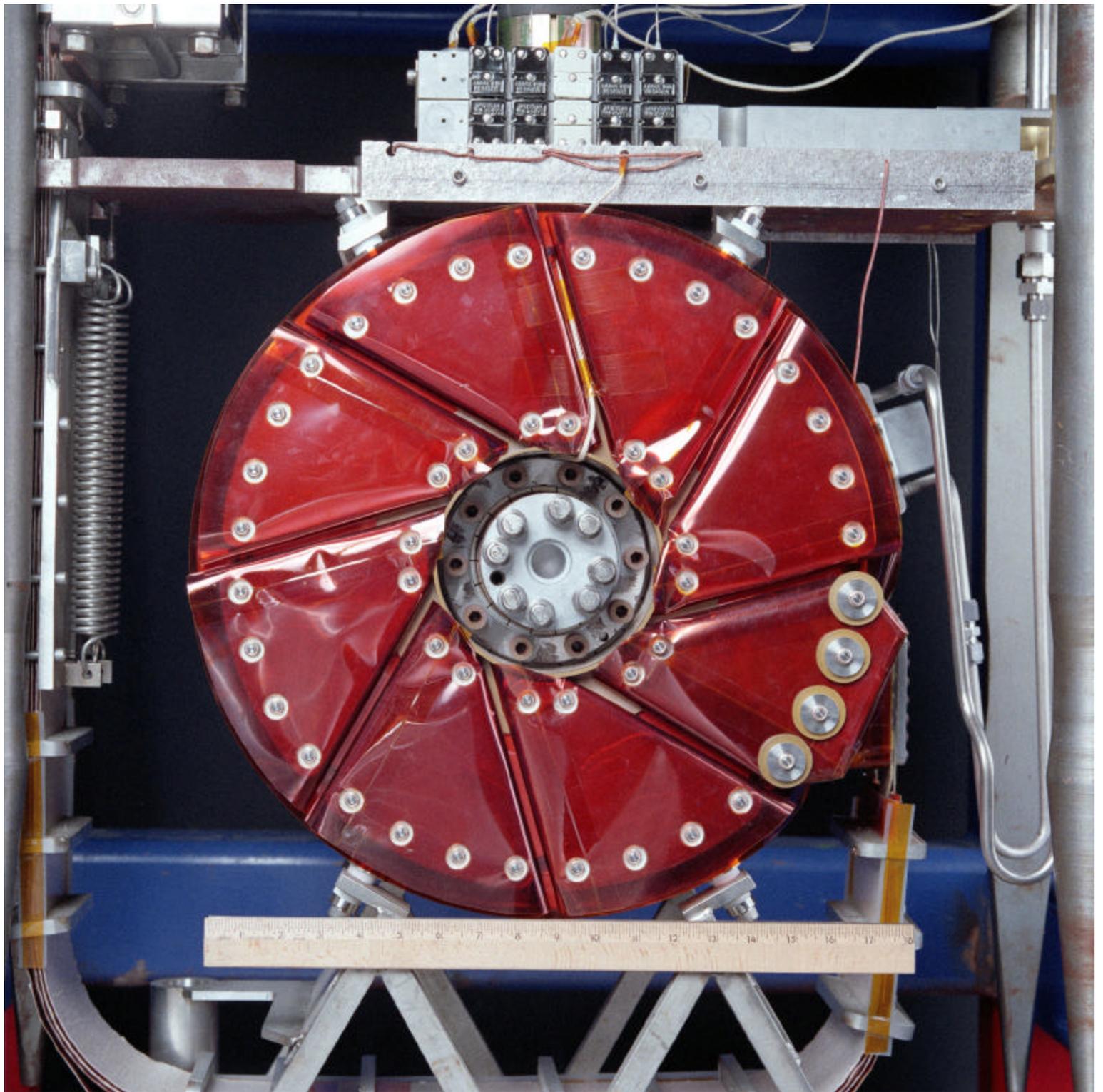
Lithium Lens Upgrade

James Morgan









Lithium Lens Upgrade

Objectives

Produce a reliable 1 cm. radius, 100 kG/cm lithium lens

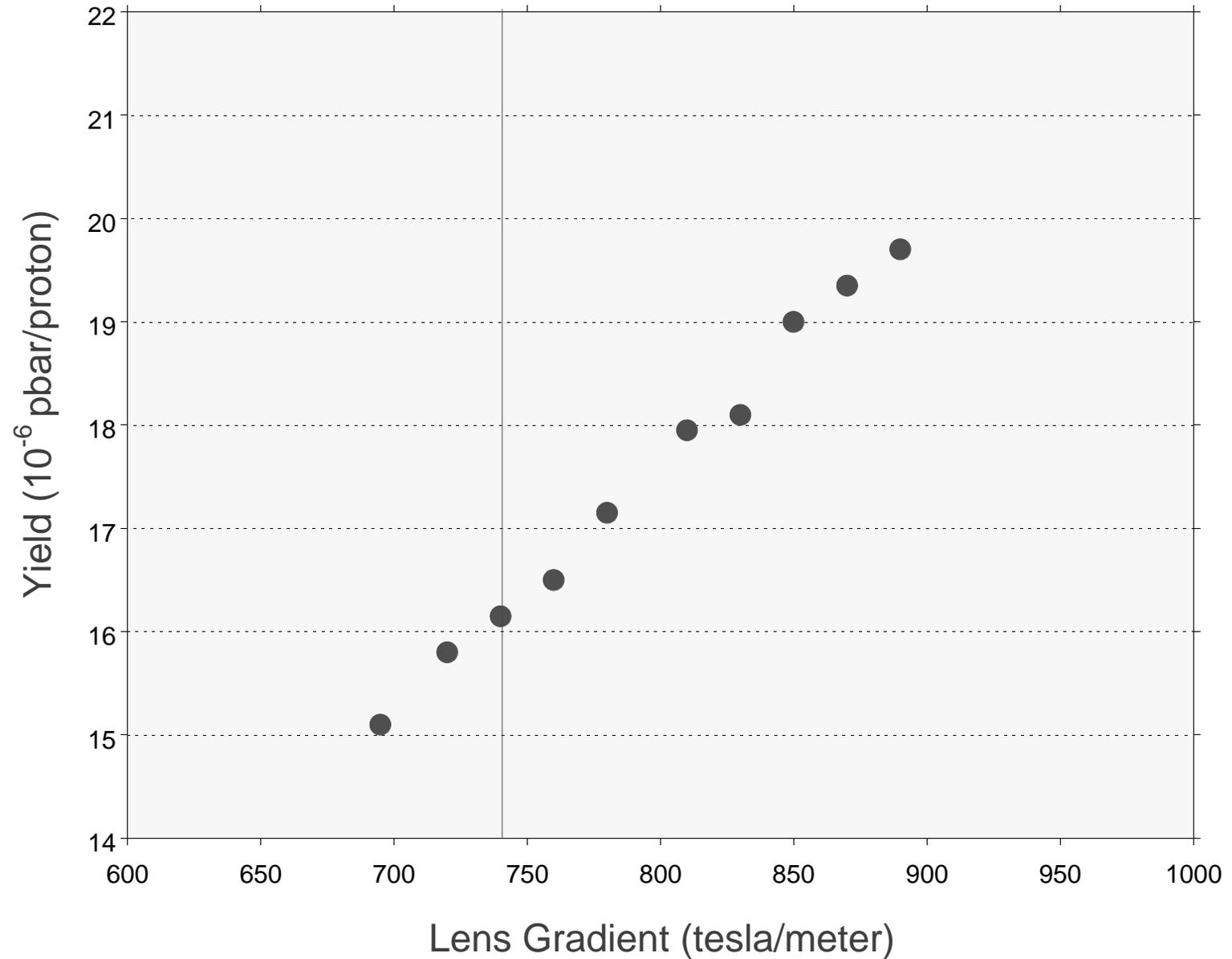
Solid lithium lens

- Disassemble and analyze lenses that have failed
- Create an ANSYS model to better understand mechanical stresses
- Review and improve quality control during lens assembly
- Create an alternative lens design

Liquid lithium lens

- R&D effort at BINP, Novosibirsk
- After successful test, significant effort required to modify apparatus

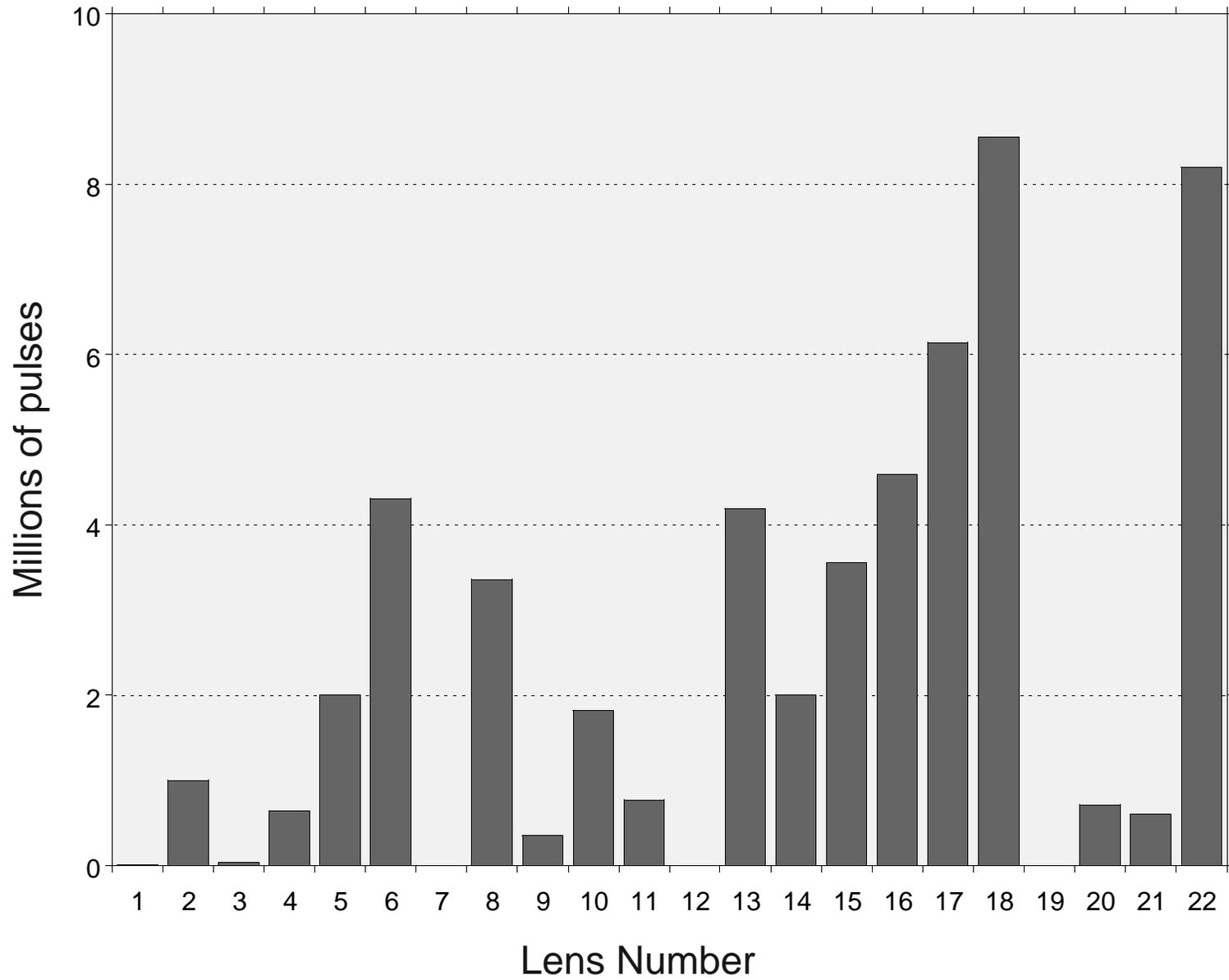
Measured Debuncher Yield vs. Lens Gradient

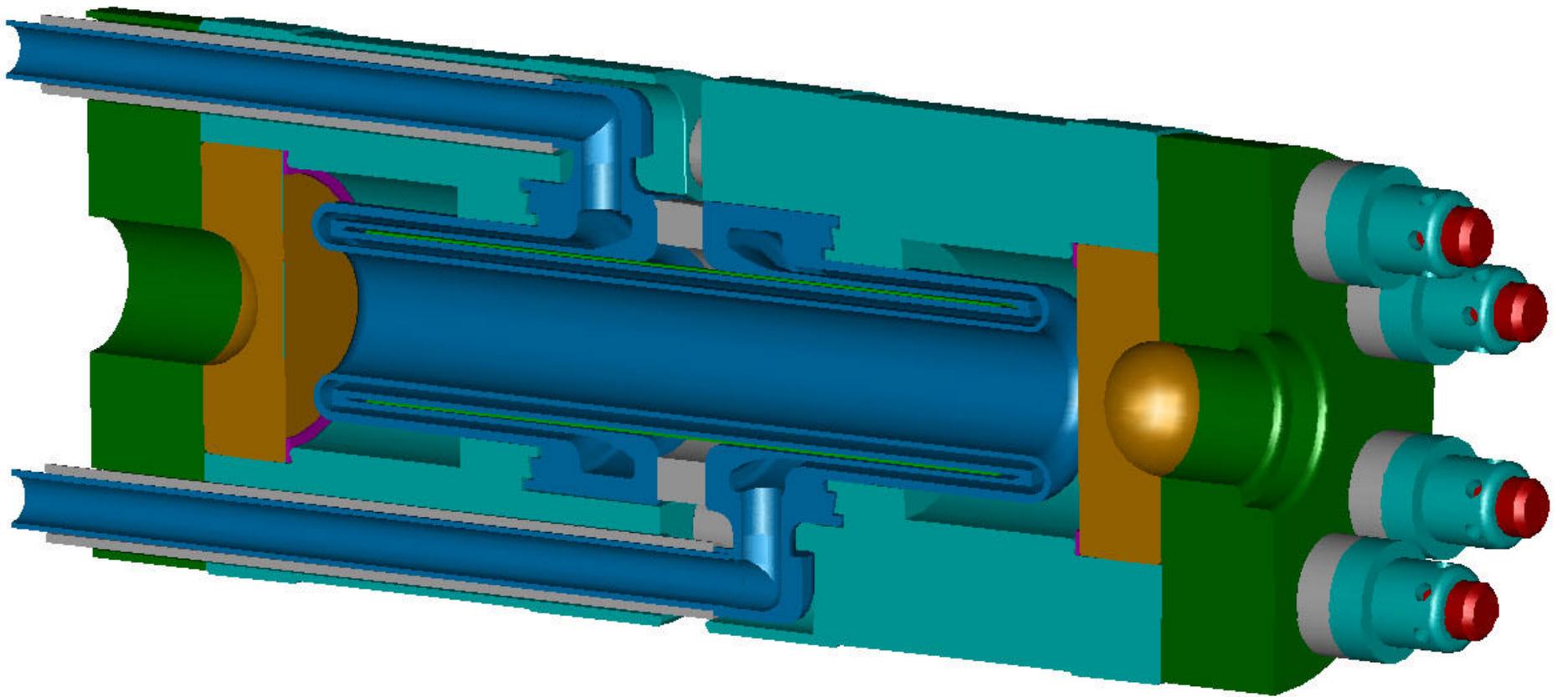


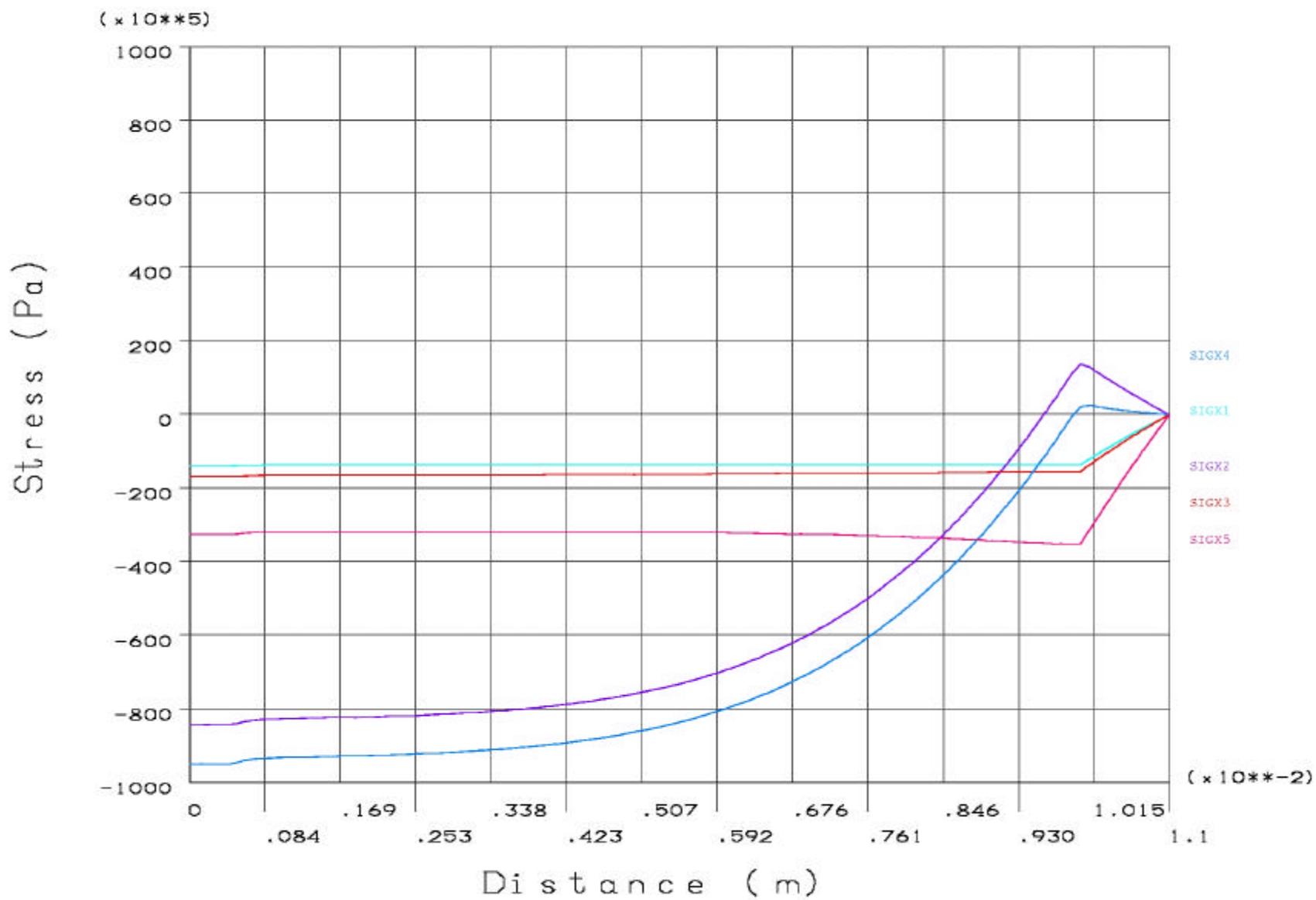
Observed Lens Lifetime

Lens Gradient (T/m)	Average Pulses to Failure
1,000	< 500,000
900	1,000,000
800	3,000,000
740	9,000,000
700	> 10,000,000

Lithium Lens Lifetime







Stress sigma_x

Lithium Lens Upgrade

ANSYS summary for current lens

Analysis completed and report written

Indicates relatively moderate cyclic stresses

Evidence of lithium separation from titanium septum

Model needs refinement to include more realistic material properties

Need to understand differences between model and autopsy results

Lithium Lens Upgrade

Autopsy results

Five lenses scheduled for disassembly and analysis

Lenses #20 and #21 completely done

Lenses #17 and #18 disassembled, awaiting analysis

Lens #22 cooling down

Two general failure modes to inner septum

Axial fatigue fracture followed by a ductile fracture

Indicates higher loads than predicted by ANSYS

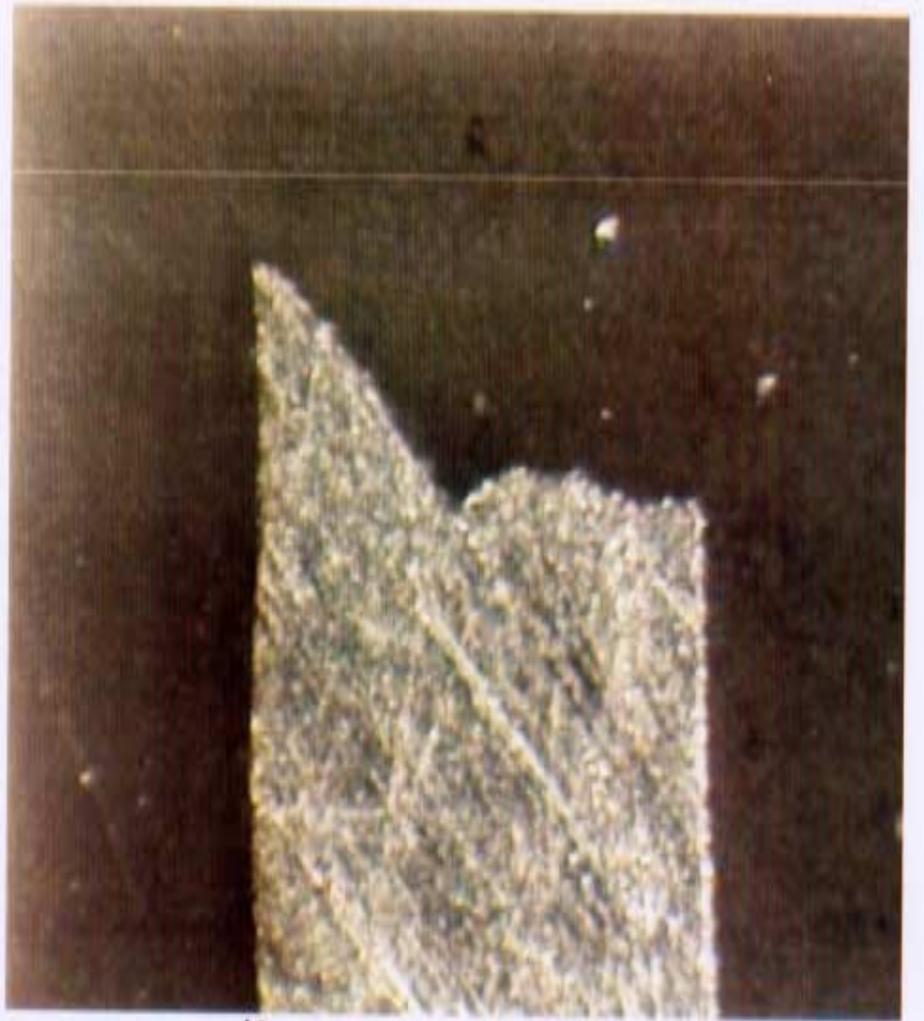
Circumferential channels apparently burned through septum

Suggests internal arcing, possibly from Li/Ti separation

Multiple cracks and pits found on inside surfaces of septa



#20



#21

1

NODAL SOLUTION

STEP=7

SUB =4

TIME=7

NLSEPL (AVG)

DMX =.261E-03

SMN =.607E+09

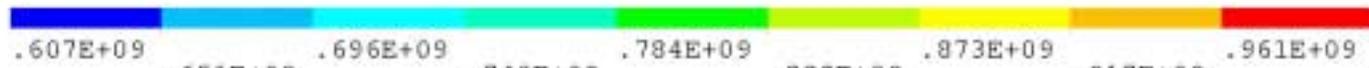
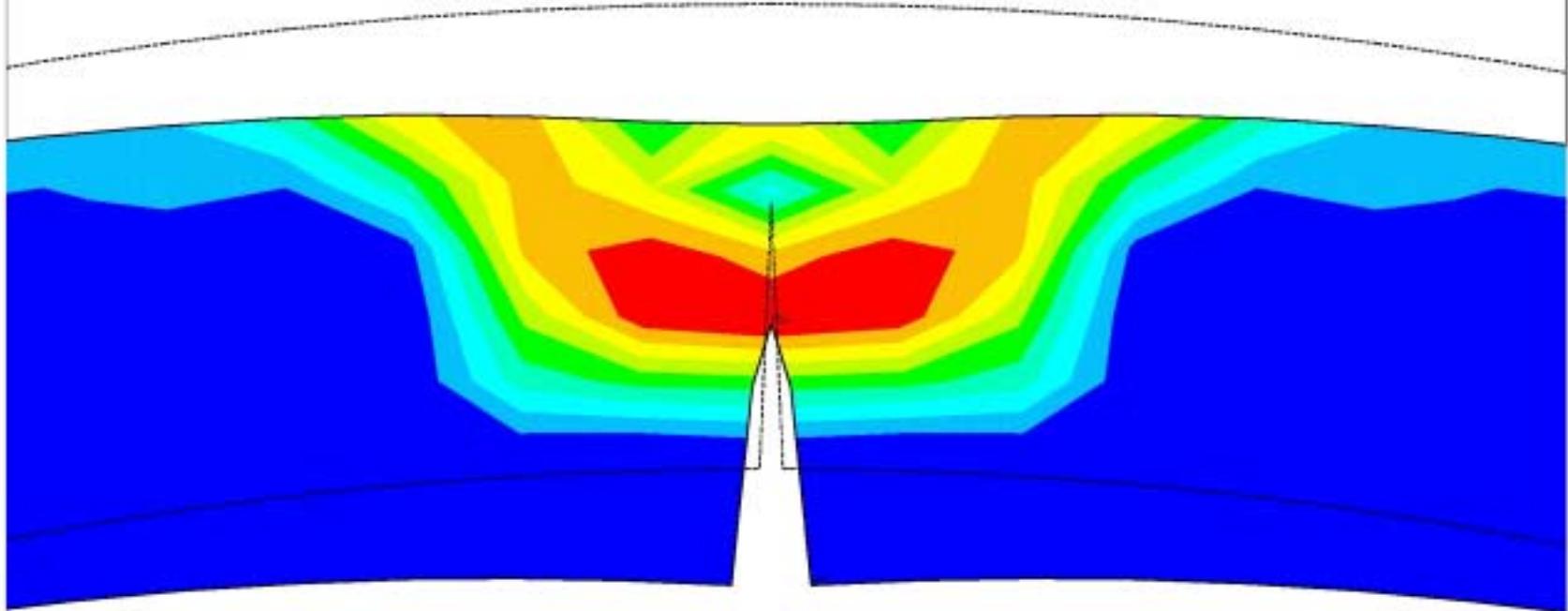
SMX =.101E+10

ANSYS

NOV 30 2001

13:44:47

PLOT NO. 1



Lens crack KINH 8,000 psi int (cycle)

Lithium Lens Upgrade

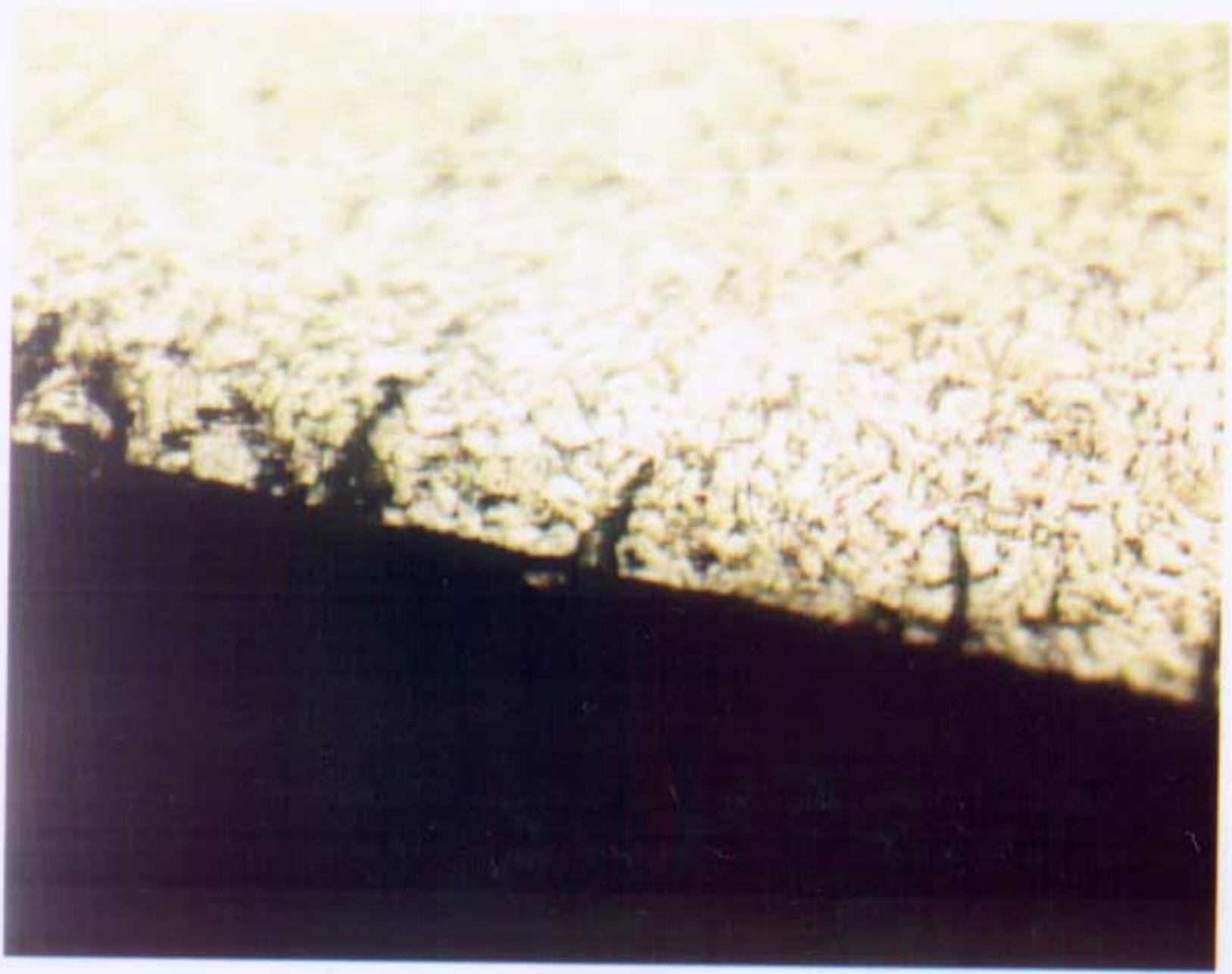
Quality Control Improvements

Lens Fill

- Added instrumentation to lens body
- Changed strain gages to improve accuracy
- Pressure transducers upgraded
- Created dummy lens to calibrate instrumentation

Lens Preparation

- Improved electron beam welding techniques
- Lithium handling procedures changed to minimize contamination
- Created new septum cleaning procedures to avoid stress-corrosion cracking



LENS 21 ID SURFACE 400X

10-11-01

Lithium Lens Upgrade

Prototype High Gradient Lens

Description

Lens body and septum both made of titanium

Diffusion bonding utilized for joining titanium pieces

Joint fatigue testing program beginning at ANL

Some problems with integrity of central bond

Septum construction simplified

Thicker inner septum

Second generation design eliminates central joint

ANSYS analysis

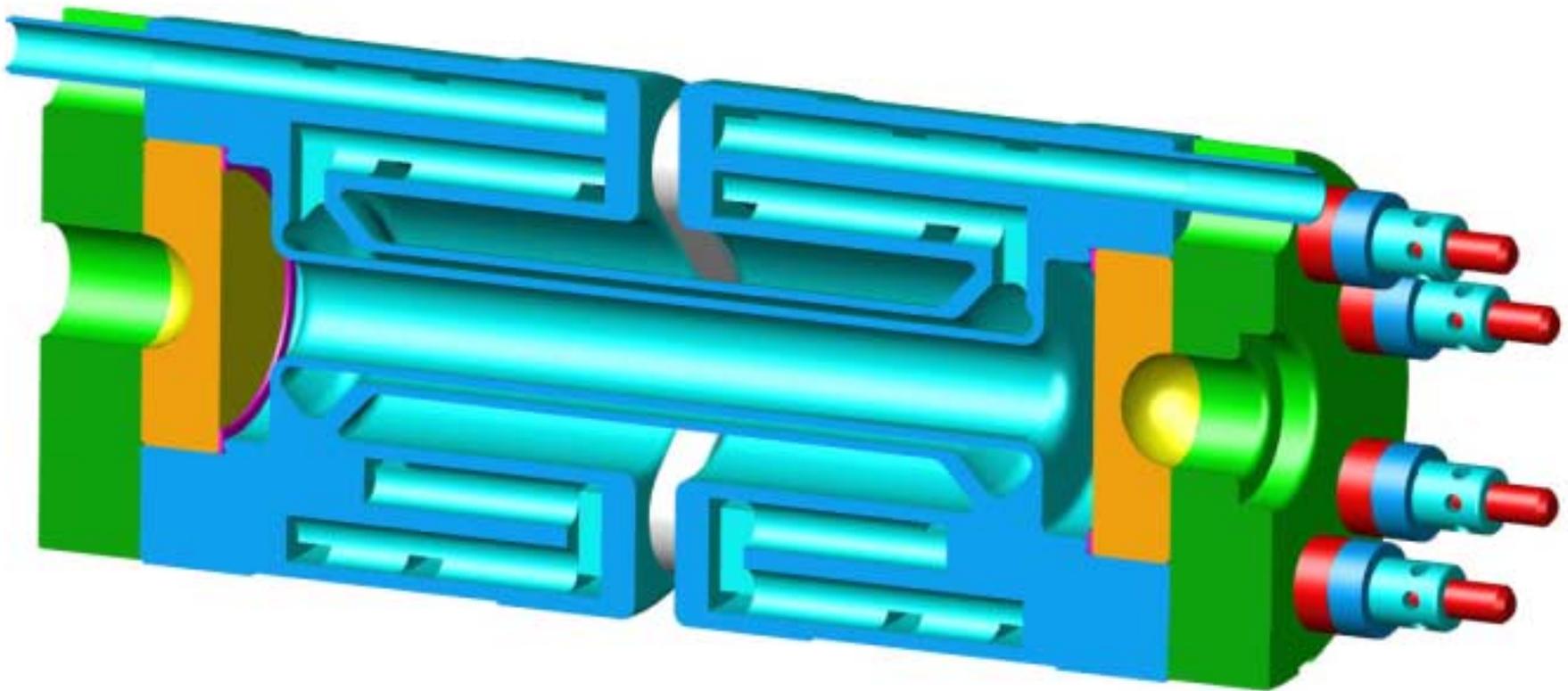
Analysis completed, report forthcoming

Indicates same level of stresses for higher gradient (130 kG/cm)

Model needs same refinement as current analysis

Liquid lithium system much more hazardous than solid lens

High Gradient Solid Lens Prototype Design



Lithium Lens Upgrade

Liquid lithium lens

Advantages

- Lower mechanical stresses on septum from lithium in liquid state
- Functional buffer volume to reduce pressure from thermal expansion
- Liquid lithium circulated to remove heat from lens
- Better regulation of lens preload

Disadvantages (don't get me started)

- Challenges associated with circulating liquid metal
- Locking valves required to prevent damage to circulating system
- Reliability of such a complex system will probably be much lower
- Elaborate control system required to regulate temperature and pressure
- "Bench top" set-up will need to be heavily modified to fit in vault
- Liquid lithium system much more hazardous than solid lens

Liquid Lithium Lens

Original Schedule

Phase	Goal	Completion Date
1a	Conceptual Design	12/31/97
1b	Produce drawings and report	3/31/98
2a	Assemble liquid lithium lens	12/31/98
2b	Design power supply	12/31/98
3	Test lens to 1,300 T/m, ship to Fermilab	12/31/99
4	Testing at Fermilab, build spare lens	6/30/00

Lithium Lens Upgrade

Summary

Solid lithium lens

Lens autopsy

Lenses 20 and 21 have been disassembled and analyzed
Lenses 17 and 18 will be analyzed in the next two months
Lens 22 will be disassembled in 3-4 months.

ANSYS modeling

Analysis complete on current lens design
Prototype lens analysis complete, report being generated
Some refinements to model planned for the next year

Prototype Lens

First prototype has been bonded, machining and fill to follow
Second prototype is being designed with no central joint
First prototype will be tested to failure while second is being built

Quality Control

Lenses 27 and 28 have been assembled with the new techniques
These lenses are about to be filled with the new system

Liquid lithium lens

R&D effort continues at BINP, but will need to be reexamined next year
Anticipating success, a major effort will be required to make the system operational