Status of the HINS Linac Front End Focusing Lens Development

Can we use these lenses in the SSR1 crymodule of PXIE ?

Requirements for HINS Linac focusing Lenses

	RT section (CH)	SS1	SS2
Bore diameter	20 mm (warm)	30 mm (cold)	30 mm (cold)
Squared field integral	1.8 T^2-m	3.0 T^2-m	5.8 T^2-m
Magn. field on cavity walls (max) (*)	50 Gs	0.1 Gs(**)	0.1 Gs(**)
Temperature	4 K	4 K (***)	4 K (***)
Length (#)	235 mm	315 mm	350 mm
Dipole Corrector Strength (##)	0.25 T-cm	0.5 T-cm	no data
Alignment precision of ends of the effective length	0.3 mm (with correctors)	0.3 mm (with correctors)	no data

The requirement table was modified several times during the four years of R&D

(*) – The nearest wall was assumed when the fringe field was evaluated.

(**) – initially was 0.01 Gs → see TD note TD-08-006.

(***) - 2K option was discussed, but rejected because of the lack of cooling power at 2 K.

(#) - This length is more like available gap between the cavities. No BPM-s were considered.

(##) – about a third of all lenses were required to have corrector dipoles

HINS Focusing Lend Development Status

CH section lenses (Cross-bar, H-type cavities for the room temperature section of the front end)

Cold masses are in house: totally 23; 10 are equipped with correctors. Assembly in cryostats started in 2010. Two assemblies were finished (one with a prototype lens and one with Type 1 (no correctors) production lens. Three more (with type 2 correctors) are in a waiting line (no activity during this year). Alignment study we planned for this lens is not finished (lack of resources in MD and Test departments)

HINS Focusing Lend Development Status

SS1 lenses
(Solenoids for Superconducting Section 1 of HINS linac)
The lens is prototyped and tested.
Two dipole correctors are embedded in the lens bore. It is assembled on the insulating post and equipped with a prototype adjustment stage to allow fine alignment in a cryomodule. The assembly rigidity test is performed. The lens is equipped with a magnetic shielding. Fringe magnetic field test has been performed in the SSR cavity test cryostat to prove the achieved efficiency of the magnetic shield.

HINS Focusing Lend Development Status

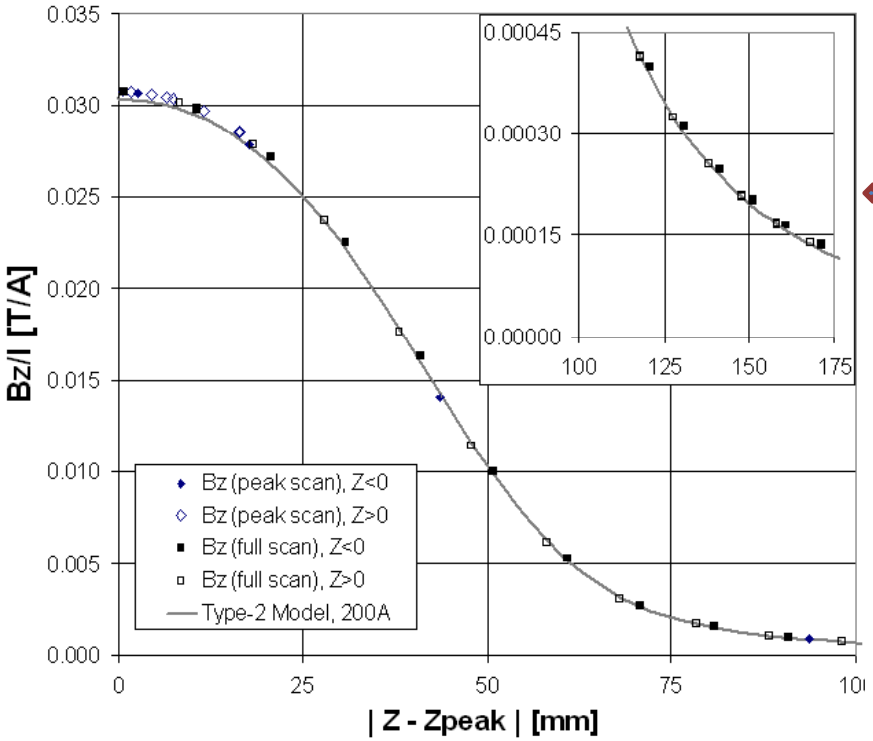
SS2 lenses

The lens is prototyped and prepared for testing. The test has not been scheduled because the test stand is in use by other projects and because of the lack of resources in MD and Test departments.

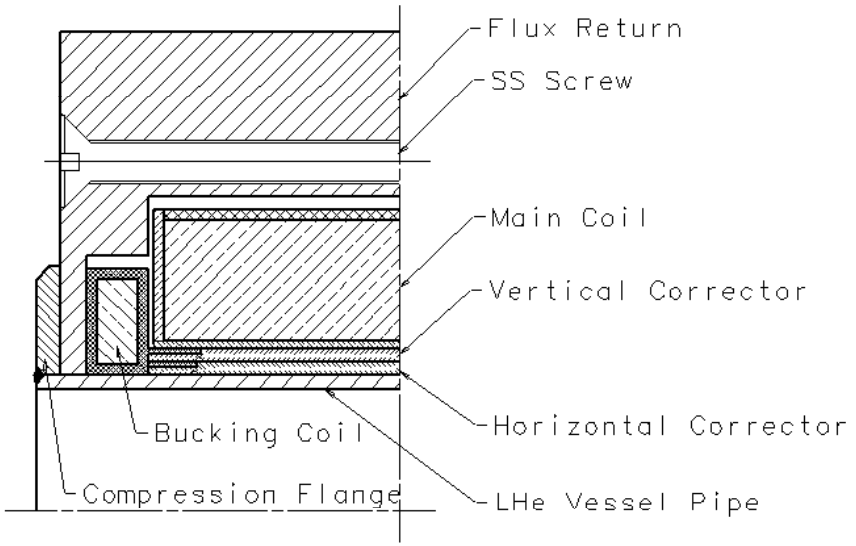
Quench protection issues for the SS2 lens have been resolved by employing different protection scheme.

CH-T2 Lens Design Features and Test Data

CH_T2 axial transfer function profile at 200 A.



Measured magnetic field is compared to model prediction at 200A for as-built geometry. The insert shows fringe field.

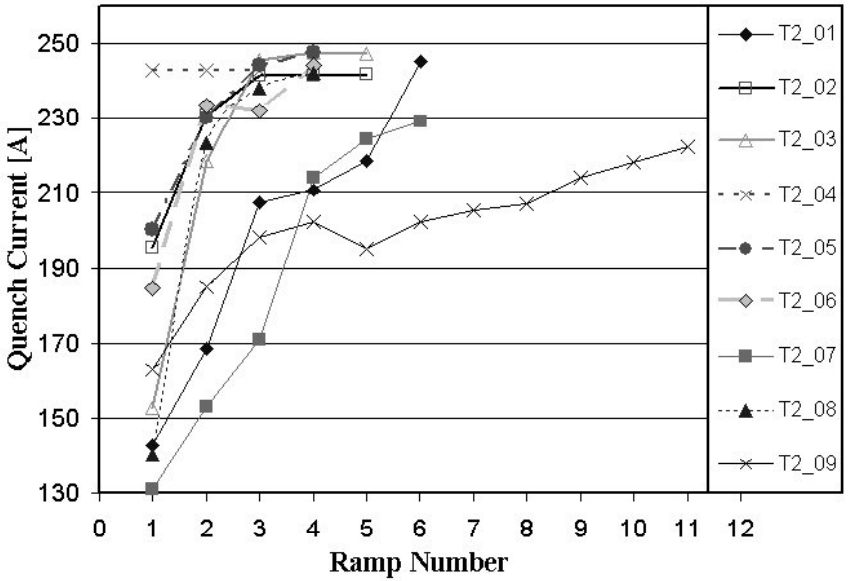


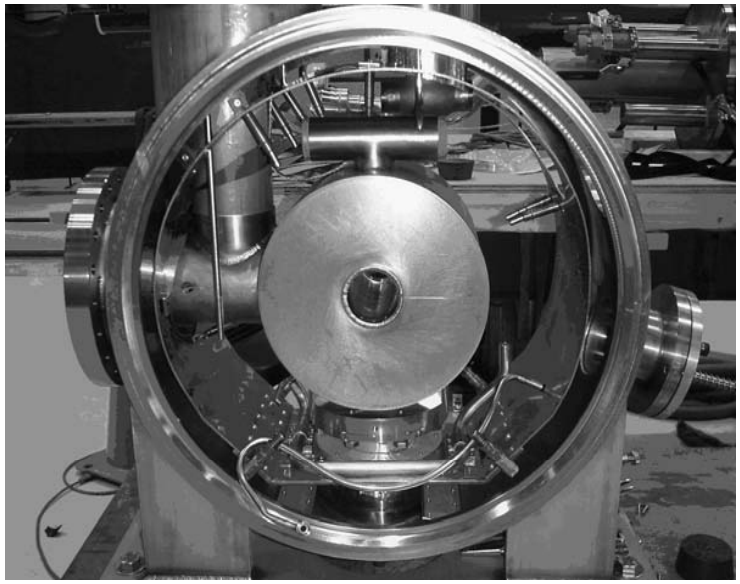
Nominal $\langle B^2 \cdot L \rangle$ ➔ 1.8 $T^2 \cdot m$;
Nominal current ➔ 170 A
Quench current at 4 K ➔ 230 A

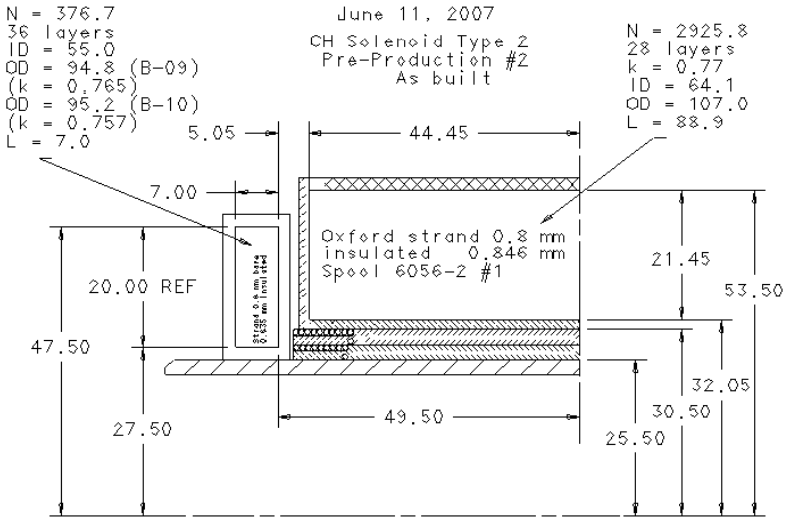
Total Length ➔ 135 mm;
Cold bore ➔ 45 mm;
Outer diameter ➔ 200 mm

CH-T2 Lens Design Features and Test Data

CH-T2 lens quench training by the vendor at 4.2 K.
Expected maximum current is 245 A.





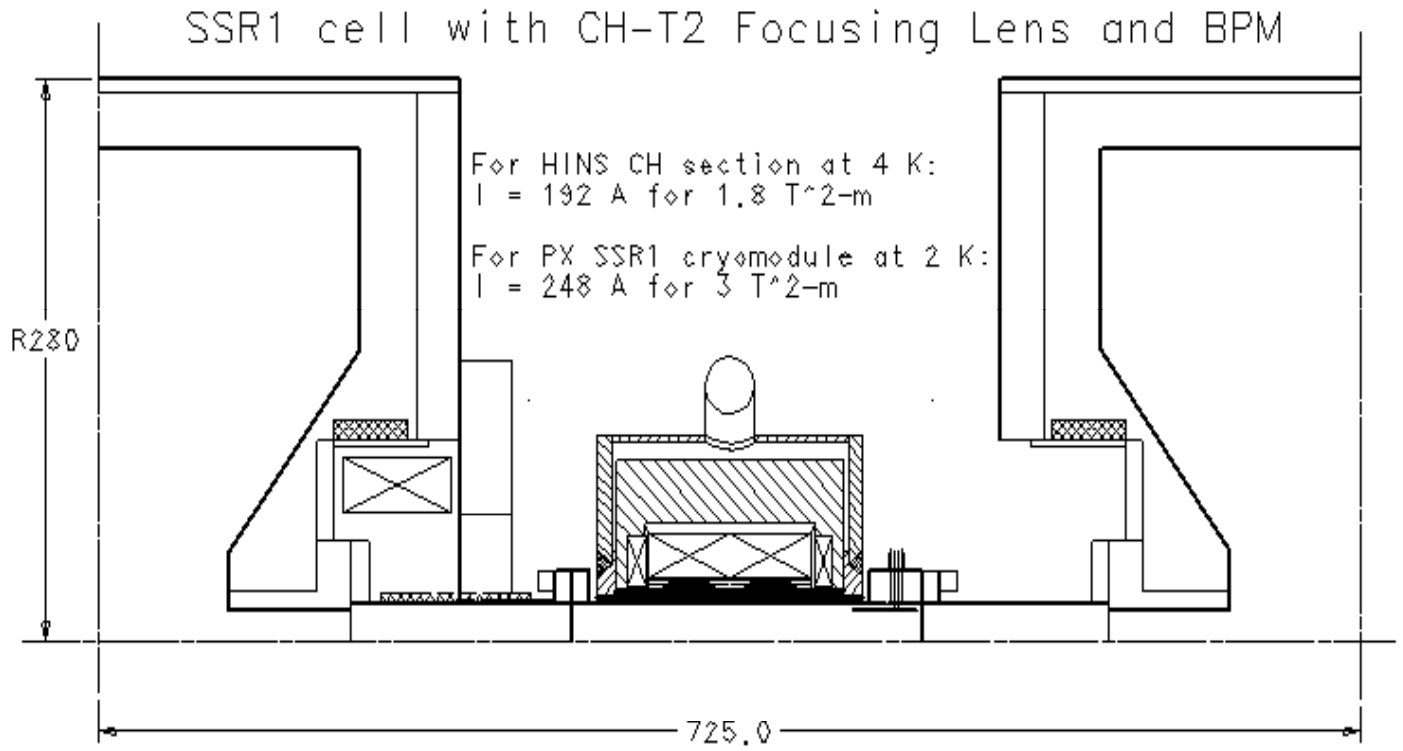


Corrector Dipoles

Nominal strength → 0.25 T ·cm
Nominal current → 135 A
Maximum current → 250 A

PXIE SSR1 cryomodule with CH-T2 cold mass

From PX document #798 (Dec. 2010)

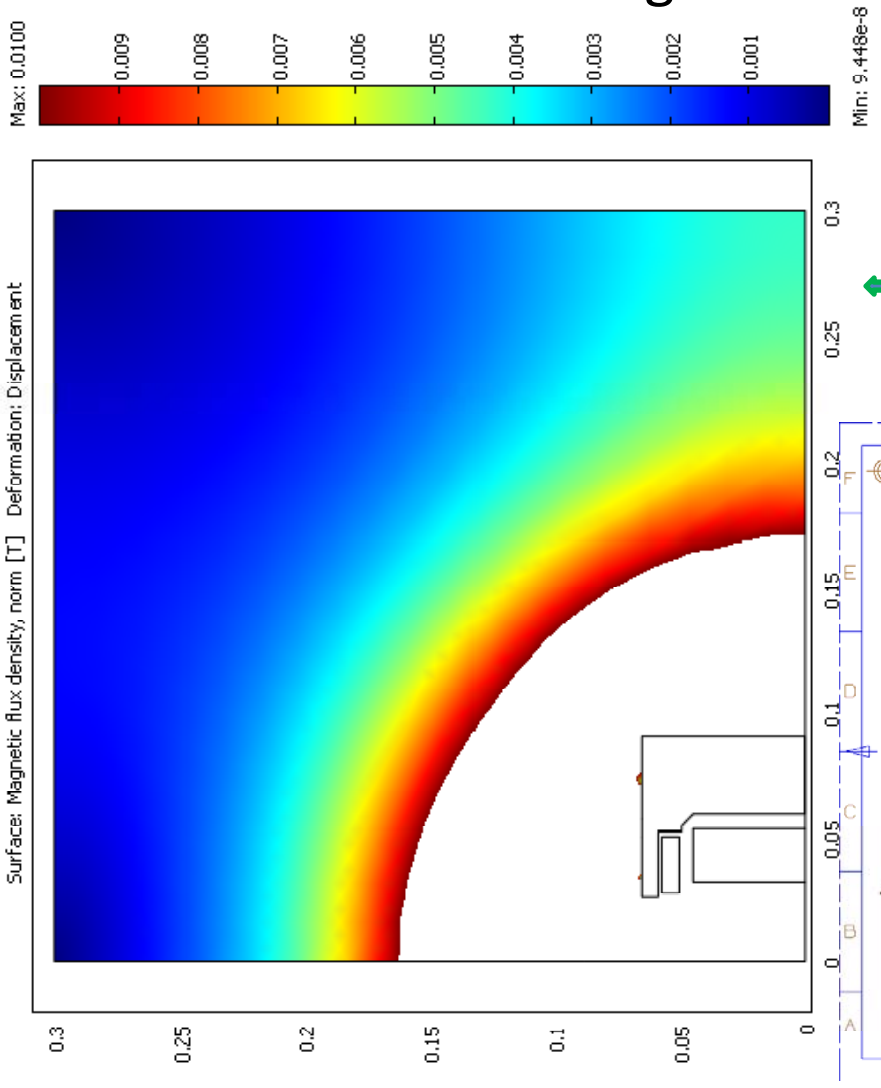


Tests at 2 K are needed to be sure it works and to find the margin

Six current leads rated 300 A (may be less for the correctors) are needed for each lens

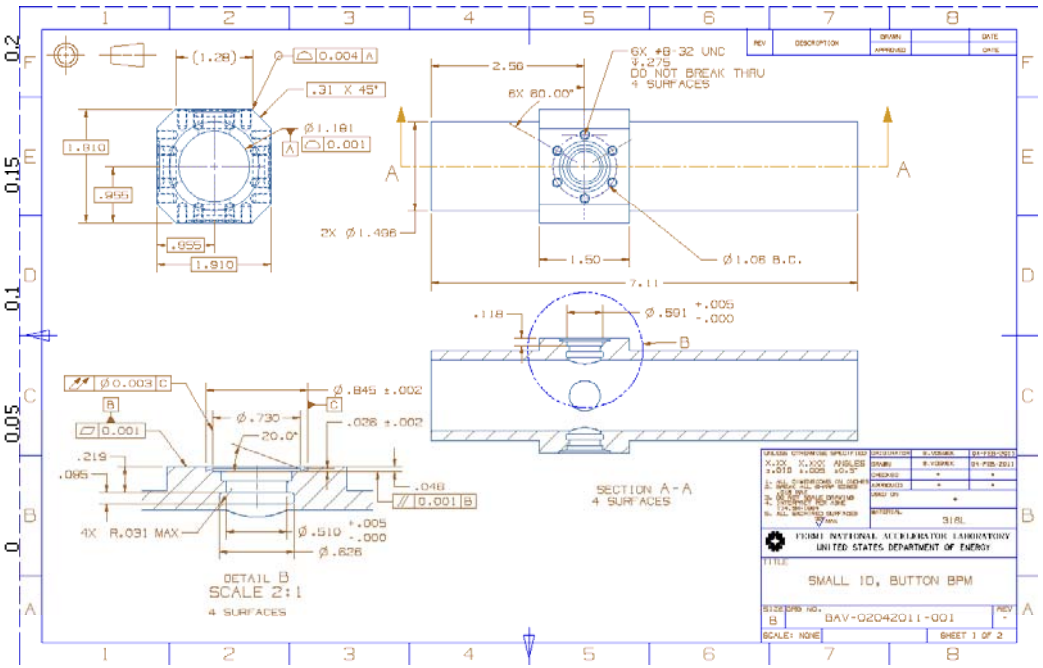
PXIE SSR1 cryomodule with CH-T2 cold mass

Possible obstacle – fringe field



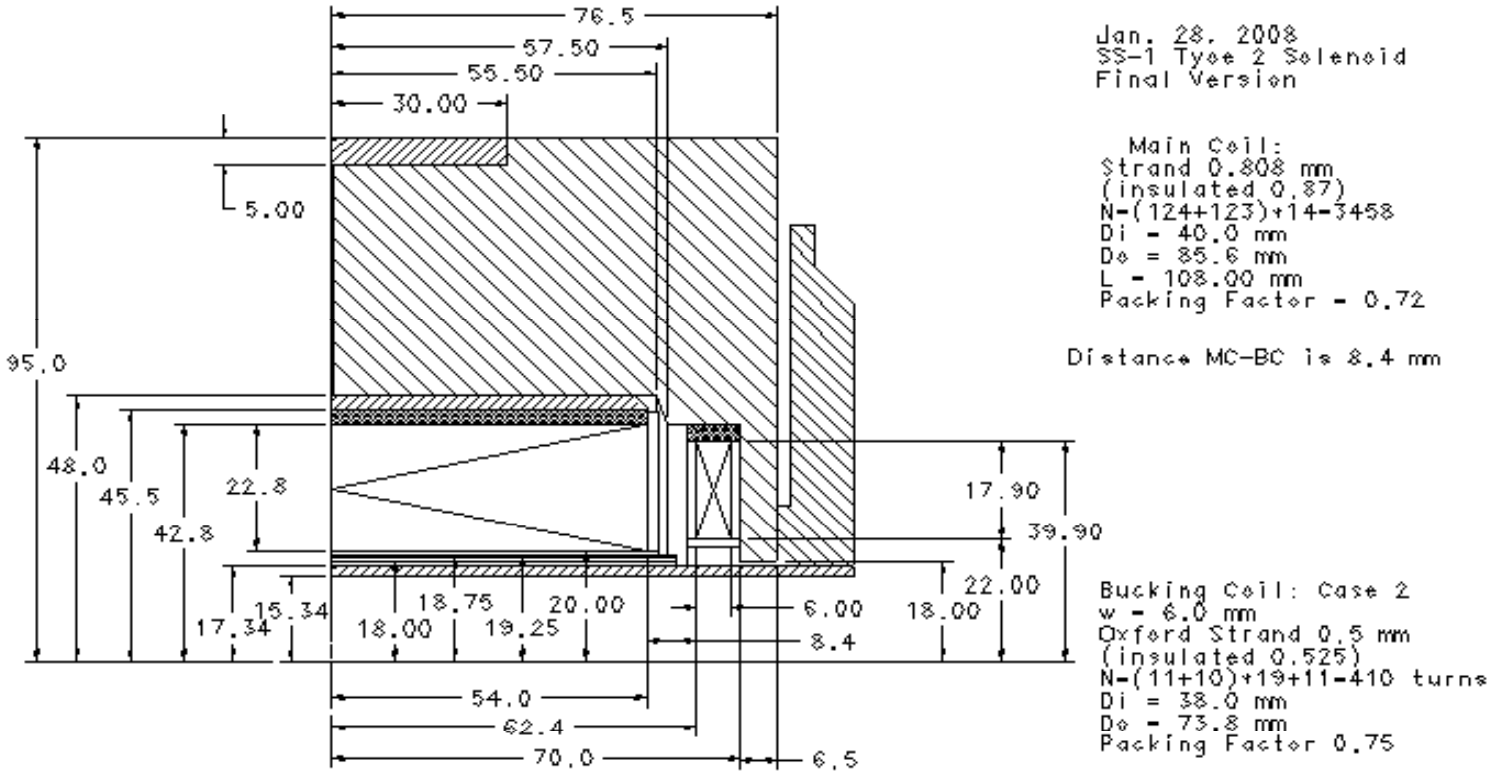
Finding what field we can allow on the outer surface can be relieving. Corresponding R&D is ongoing – waiting for a test cavity in IB1 test area

30-mm bore BPM concept



HINS Linac SSR1 Section Lens

As built SS1-T2 focusing lens



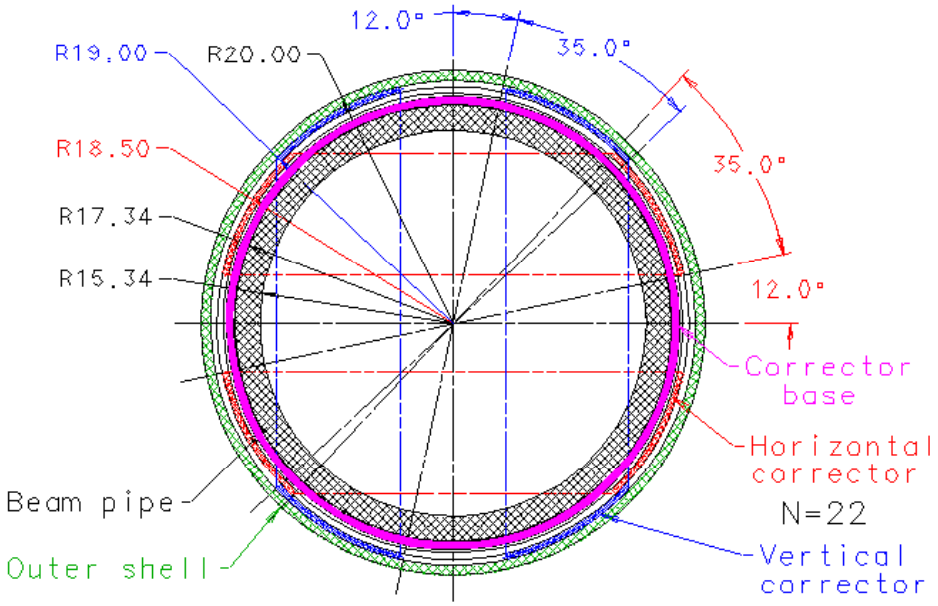
Nominal Field Integral → 300 $T^2 \cdot cm$

Nominal current → 175 A

Maximum current → 220 A

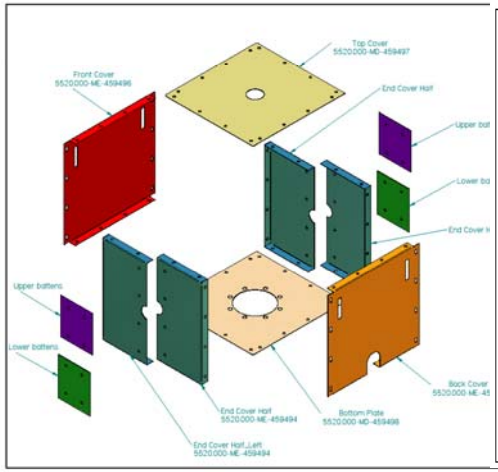
HINS Linac SSR1 Section Lens

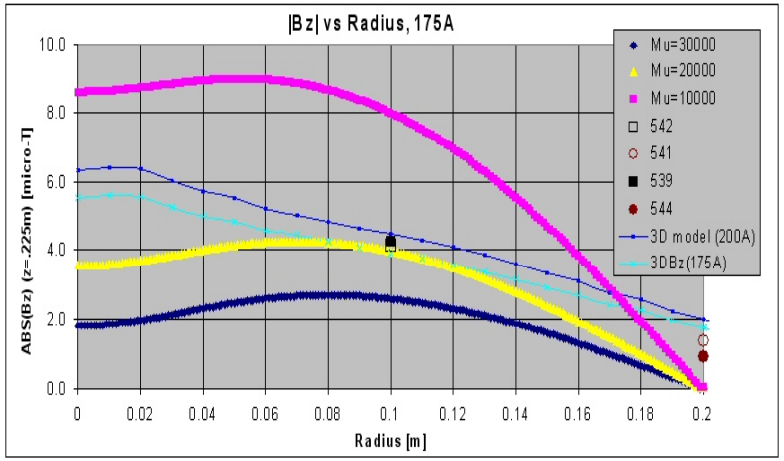
Dipole Corrector Assembly

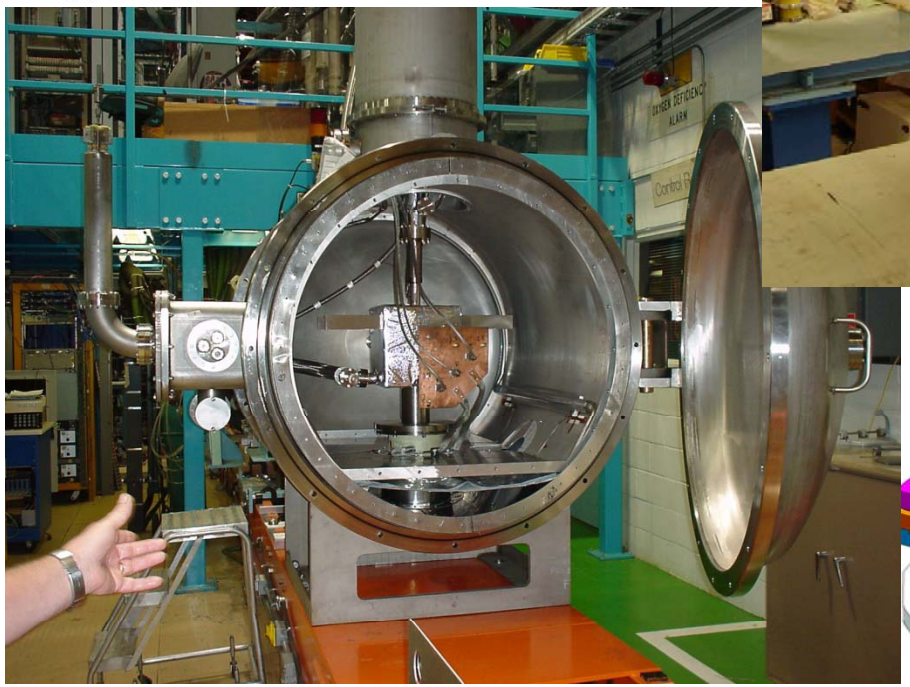


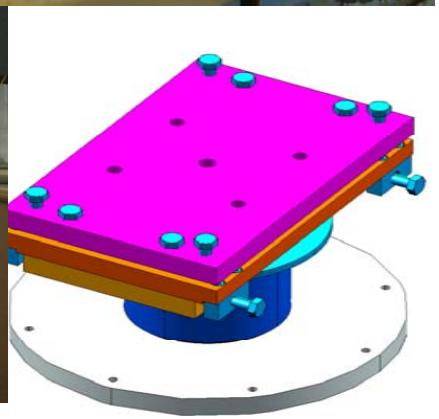
Nominal strength → 0.5 T·cm
Nominal current → 30 A
Maximum current → 40 A

SS1 Focusing Lens Assembly&Testing





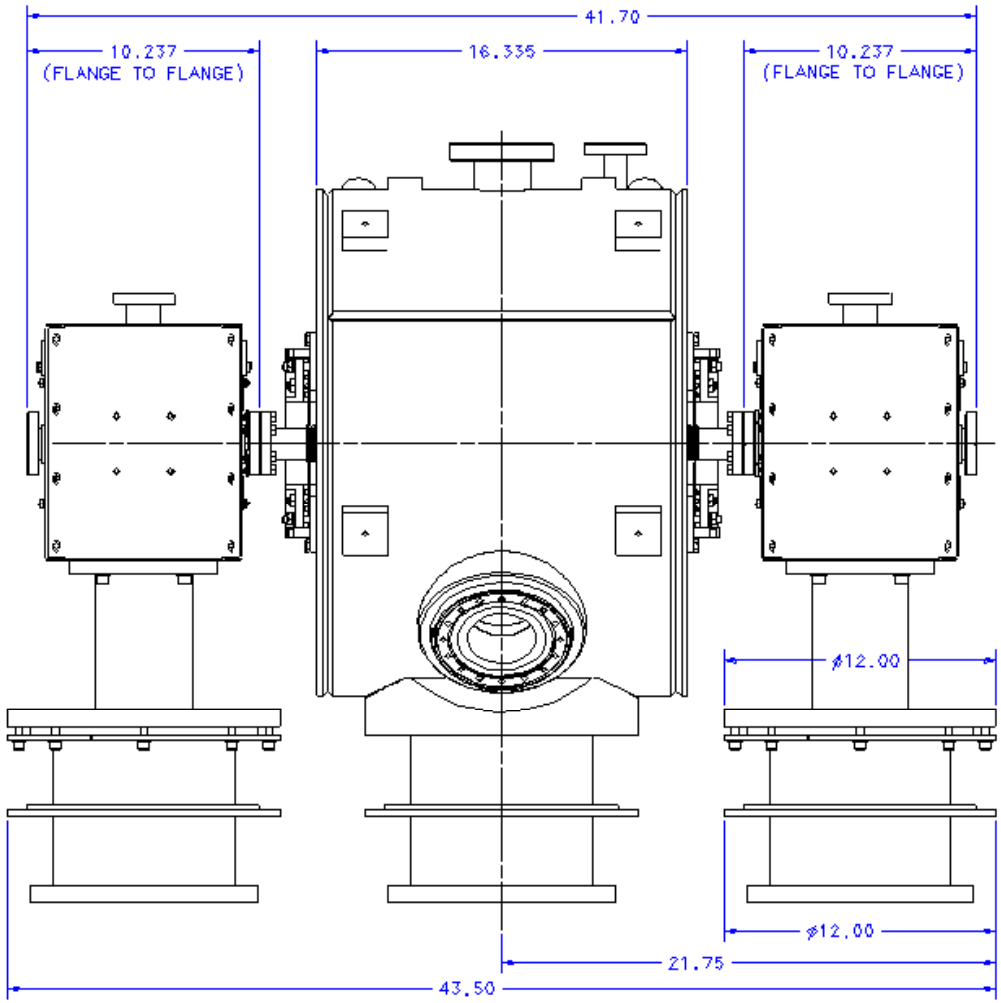


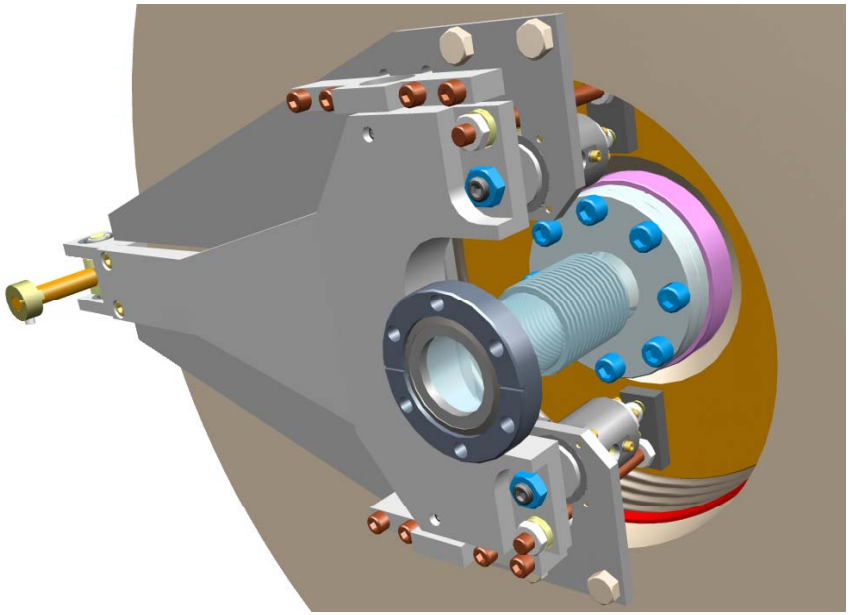


PXIE SSR1 cryomodule with SS1-T2 cold mass

From PX document #798 (Dec. 2010)

Existing elements can be assembled if the lattice period is 800 mm

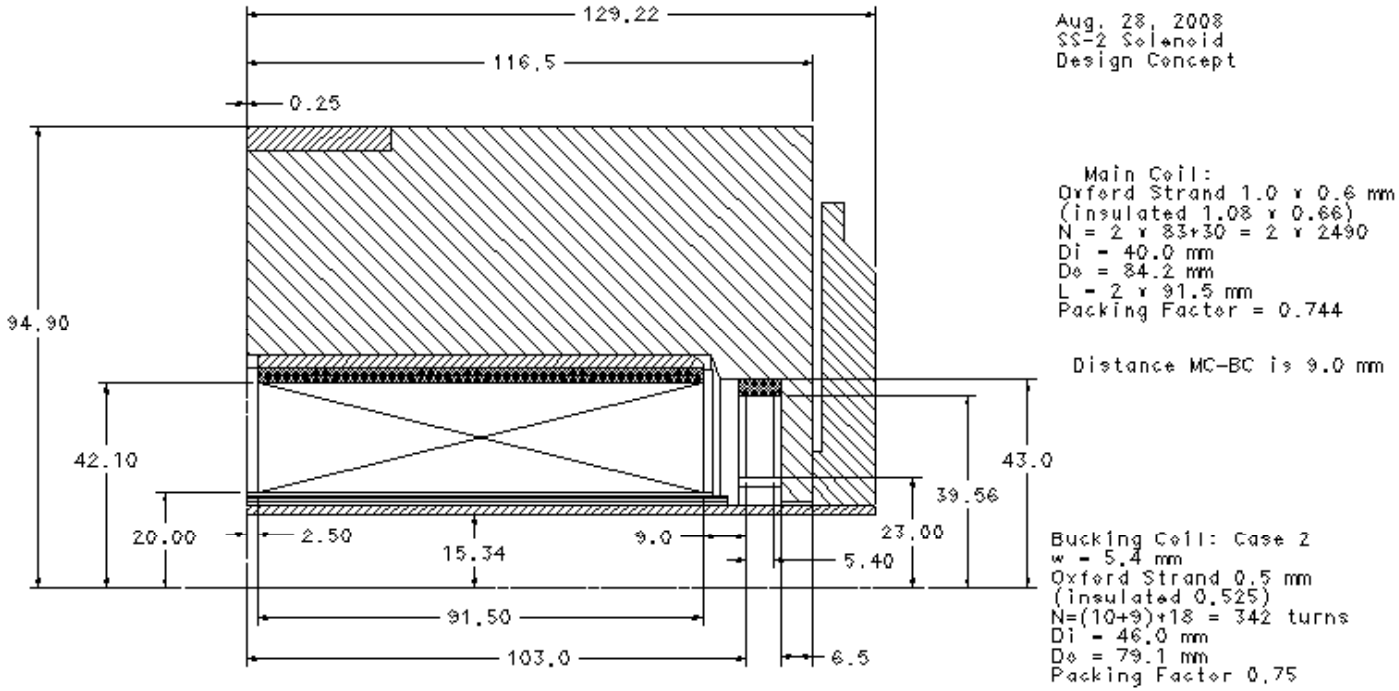




BPM is not a part of the SS1 lens
No space for a BPM in the beam line

HINS SSR2 Section Focusing Lens

SS2-T2 Focusing Lens



Nominal Field Integral → 580 T^2·cm
Nominal current → 190 A
Maximum current → 250 A

Steering Dipoles:

Nominal strength → 0.5 T·cm
Nominal current → 25 A
Maximum current → 40 A

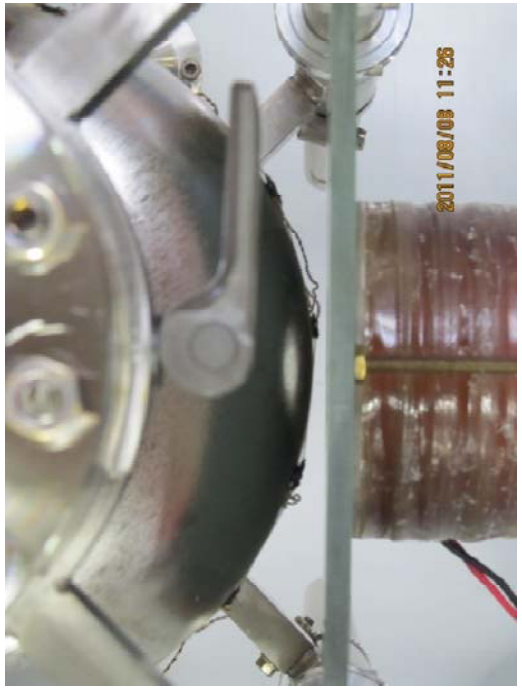
HINS SSR2 Section Focusing Lens

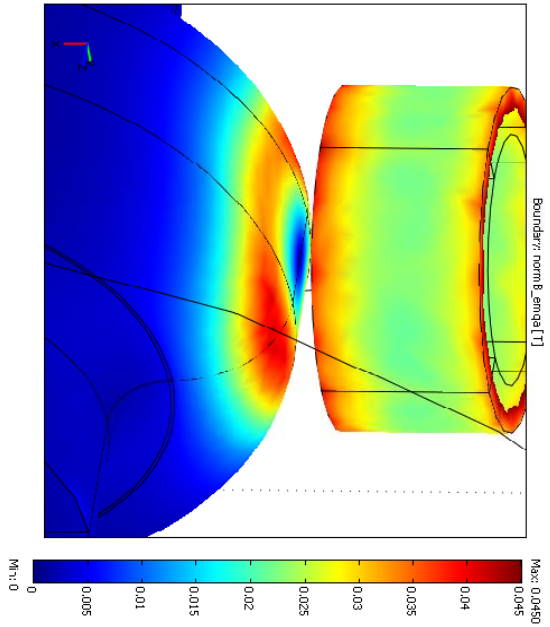
Main problem for the SS2 focusing lens was inadequate quench protection.
The problem was solved by applying different protection scheme and by using a specially developed quench propagation modeling tool .
Having a new QP analysis tool allows to consider using smaller diameter of superconducting strand and smaller current.

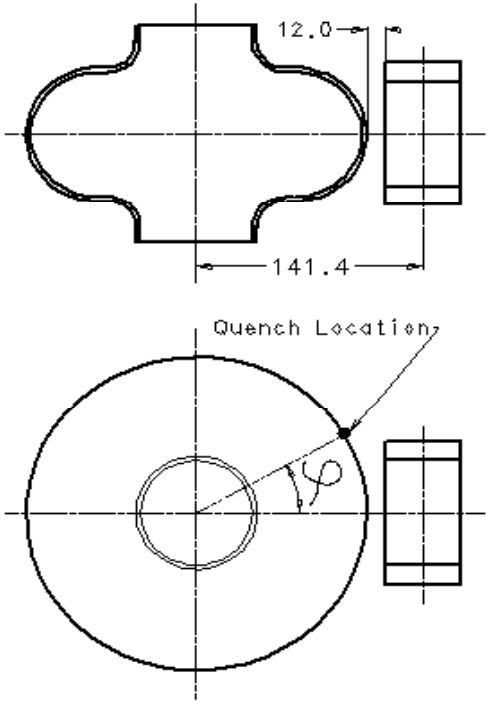
Ongoing Activities

Understanding fringe magnetic field requirements.

Several tests were made in the existing test cryomodule in MDB with the SSR1 cavity that indicated that a possibility exists of having significantly relaxed requirements for a fringe field of focusing lenses. The ultimate test with an SSR1 cavity in a vertical test cryostat in IB1 can provide enough data to come with a reasonable requirements for magnetic field on cavity walls. Because we still do not have SSR1 cavity in the IB1 test area, several tests were made with one-cell 1.3 GHz cavities. Write up of the tests is in preparation.







Ongoing Activities

Conduction Cooling Study

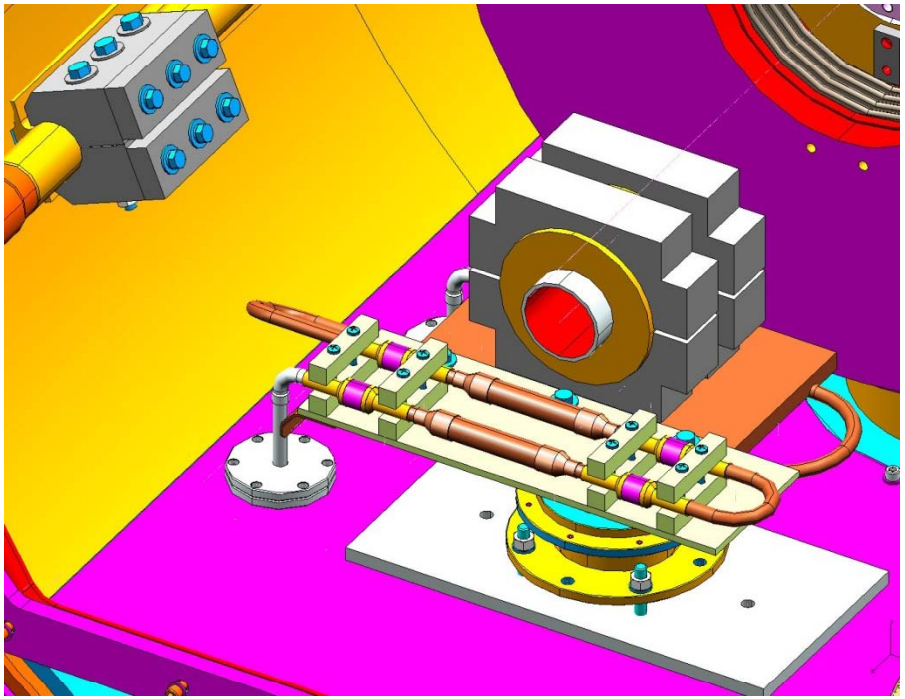
As part of the fringe magnetic field R&D, several attempts were made to use a conduction-cooled coil in the MDB test cryostat.

This branch of the study resulted in a conduction cooling R&D . If implemented properly, results of the R&D can provide another option for a cryomodule design – with no special LHe cooling line for focusing lenses. In turn, this way to configure a cryomodule will significantly relax requirements for the alignment system.

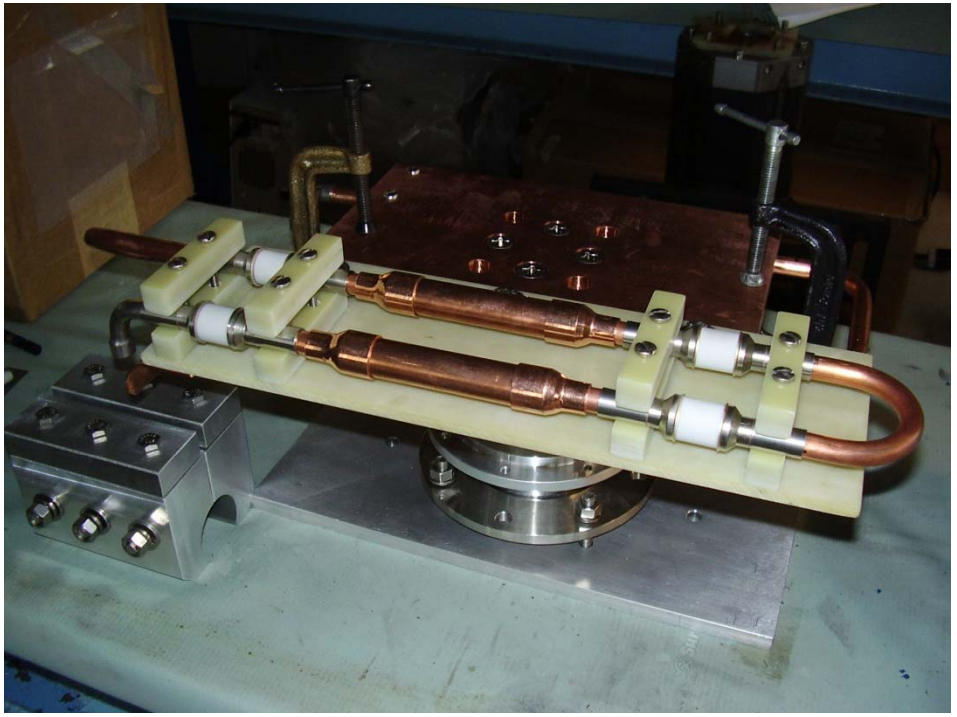
Positive results of this work can generate strong motivation for lower nominal current in the lenses, which is only possible when the quench protection problem is solved for each specific lens design.

That's why it was so important not to stop SS2 lens design activities (with its quench protection issues) back two year ago, when the section was dropped out of the HINS program.

Ongoing Activities



Conduction Cooling Test:
Heat Influx Two-Stage Filter



Dream Lens Design

#	Feature	Result	Condition
1	No bucking coils	more compact lens better defined optical axis	fringe field requirements must be understood
2	Conduction cooling	no LHe line → significantly simpler cryomodule design no LHe line → no forces from the cooling line applied to the lens assembly	conduction cooling R&D must be completed
3	Low excitation current	lower heat influx in the cryomodule may allow use of standard connectors	quench protection study must be made; conduction cooling R&D must be made
4	Optical alignment scheme	simpler and cheaper than the BPM-based	Alignment R&D must be completed

What is missing or lost

1. **Alignment concept**
   Existing one for SS-type lenses is based on the use of a special "certification" cryostat that would allow making "warm" magnetic axis position measurements during all stages of lens activation: pumping out, cooling down, and powering. The design work was stopped after the reorganization of the drafting department (with the goal to provide better support for mu2e magnetic system R&D)
2. **Optical alignment study**
   Several options were investigated: although results are promising, some problems (common to all systems) require more study. Long base alignment experiment must be completed, to start with that will provide an ultimate accuracy that can be achieved in a long cryomodule.
3. **Lens development team**
   There were at least 12 people involved at different stages of the HINS focusing lens **design, prototype fabrication, and testing**. Although we can probably rely of the IB1 testing area personnel with some planning (~4 people), those from the magnet department and from drafting department are mainly lost to other projects that have some priority. The team was formed during 4 years of the HINS linac lens R&D.

HINS Focusing Lens R&D Team

Magnet department:

J. Tompkins	– head of the measurement group, team leader
M. Tartaglia	– magnetic measurements
J. DiMarco	– magnetic axis position
T. Wokas	- prototyping

Test department:

D. Orris	- test configuration
R. Rabehl	- cryo-system
C. Hess	- test stand support (cryo)
F. Lewis	- test stand support (electrical)
W. Schappert	- optical alignment

SRF department:

T. Page	- LHe vessel, current leads, cryostat
I. Terechkine	- lens design, R&D program coordinator

Design&Drafting

S. Meredith	- cryo-vessel design
G. Davis	- lens design