# Optimization of the new SC magnetic structure design with hybrid magnet

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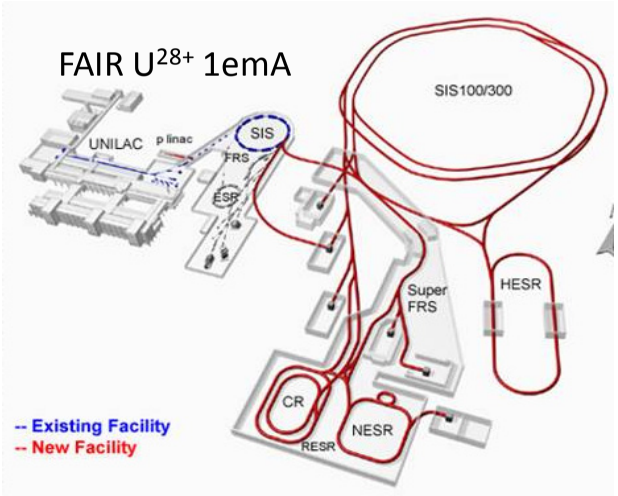
# *Outlines*

- Brief review on the MK-I magnetic structure
- The optimizations
- Preliminary stress analysis
- Discussions

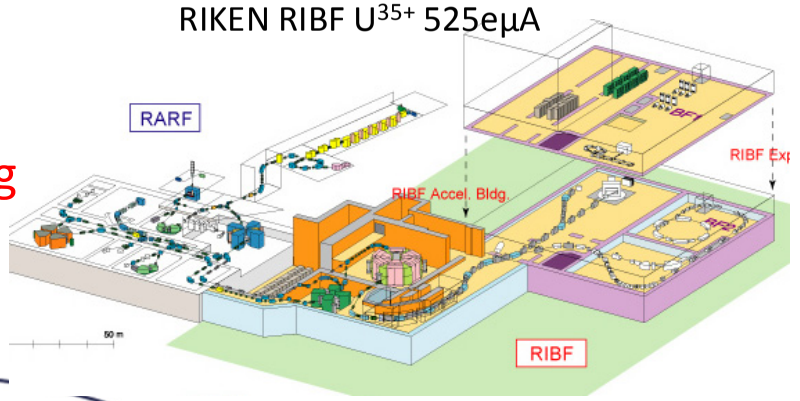
# High Power Heavy Ion Accelerator is the driving force for Intense Multiply-Charged Ion beams

FAIR $U^{28+}$ 1emA

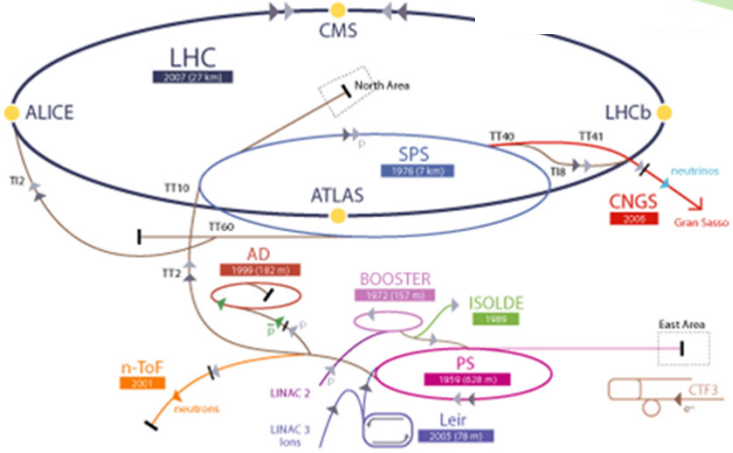



Demands to intense highly charged ion beams are increasing

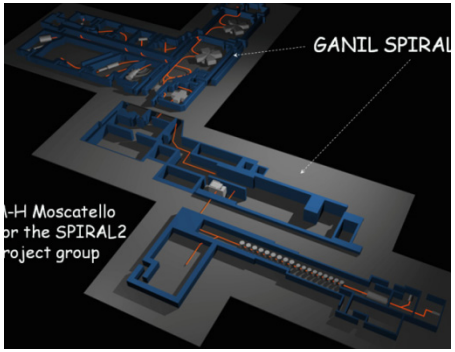
RIKEN RIBF $U^{35+}$ 525eμA

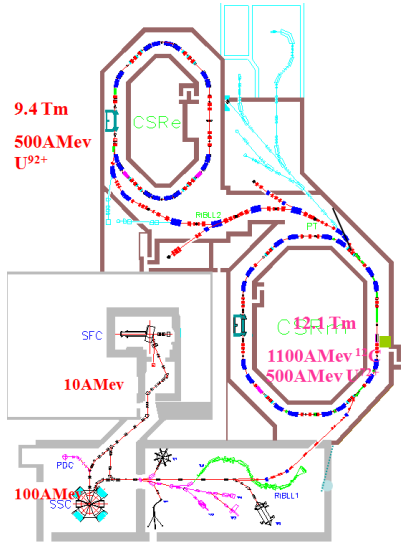



LHC $Pb^{27+}$ 1 emA



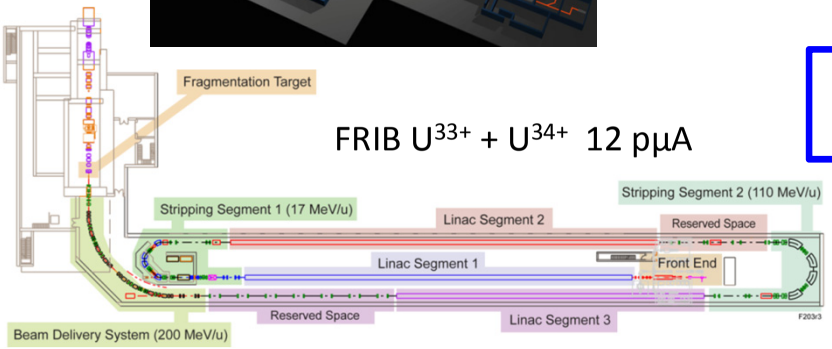

SPIRAL2 $Ar^{12+}$ 1emA



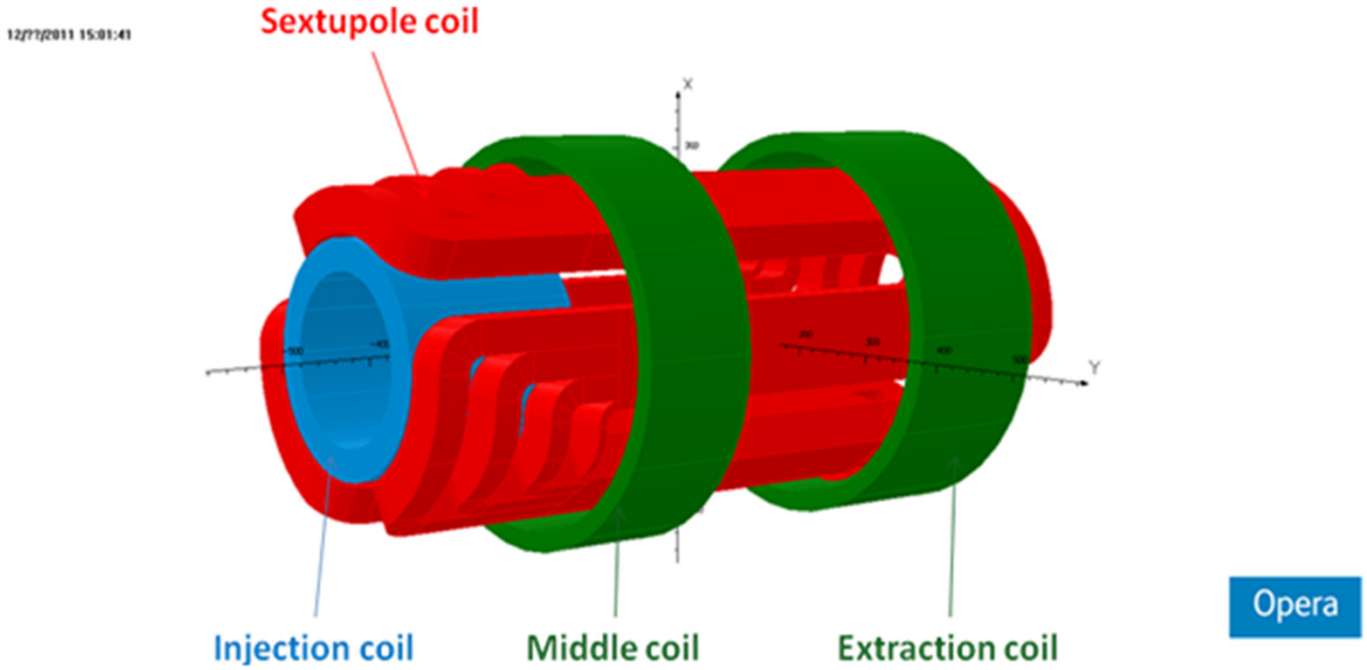

**RISP** $U^{34+35}$ 10 pμA?

FRIB $U^{33+}$ + $U^{34+}$ 12 pμA




IMP New Facility $Bi^{3X+}$ 30-40 pμA

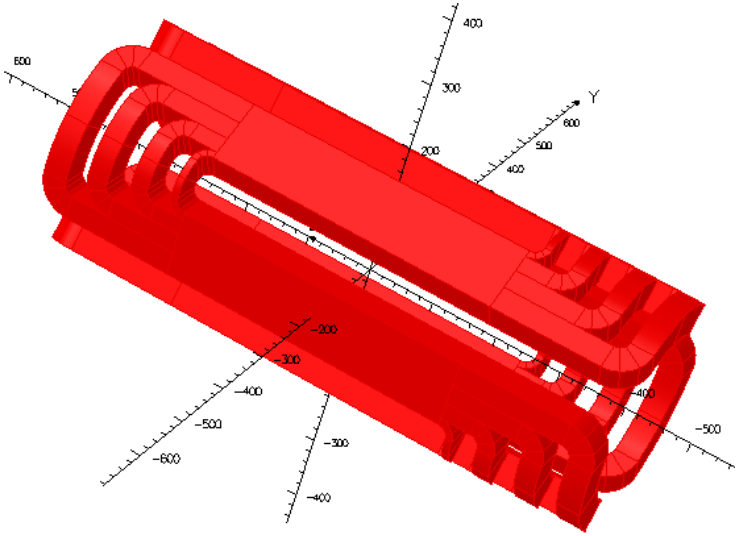
# The MK-I Magnet Structure for the Next Generation Higher-Field ECRIS




*All of the Azimuthal Currents Flows in the same Direction! No Repulsions between the Solenoids and the Sextupole Ends!*

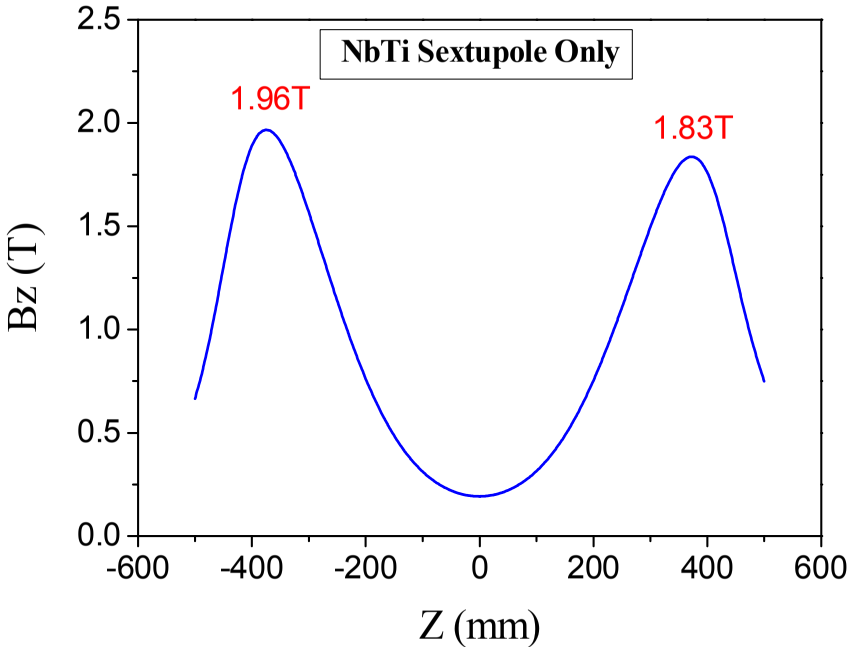
This new structure combines the Pros but avoids the Cons of the classical and the non-classical structures.

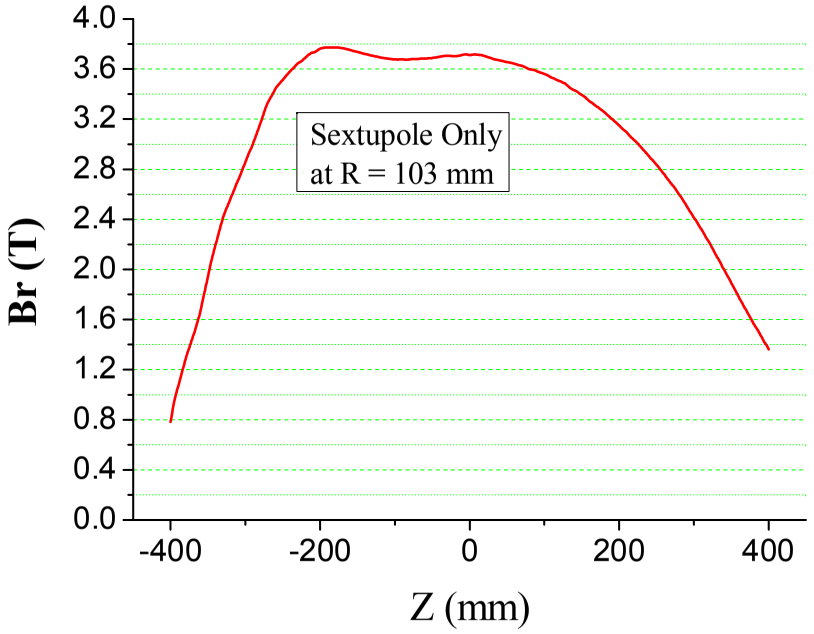
# Field Profiles of the New Close-Loop Sextupole



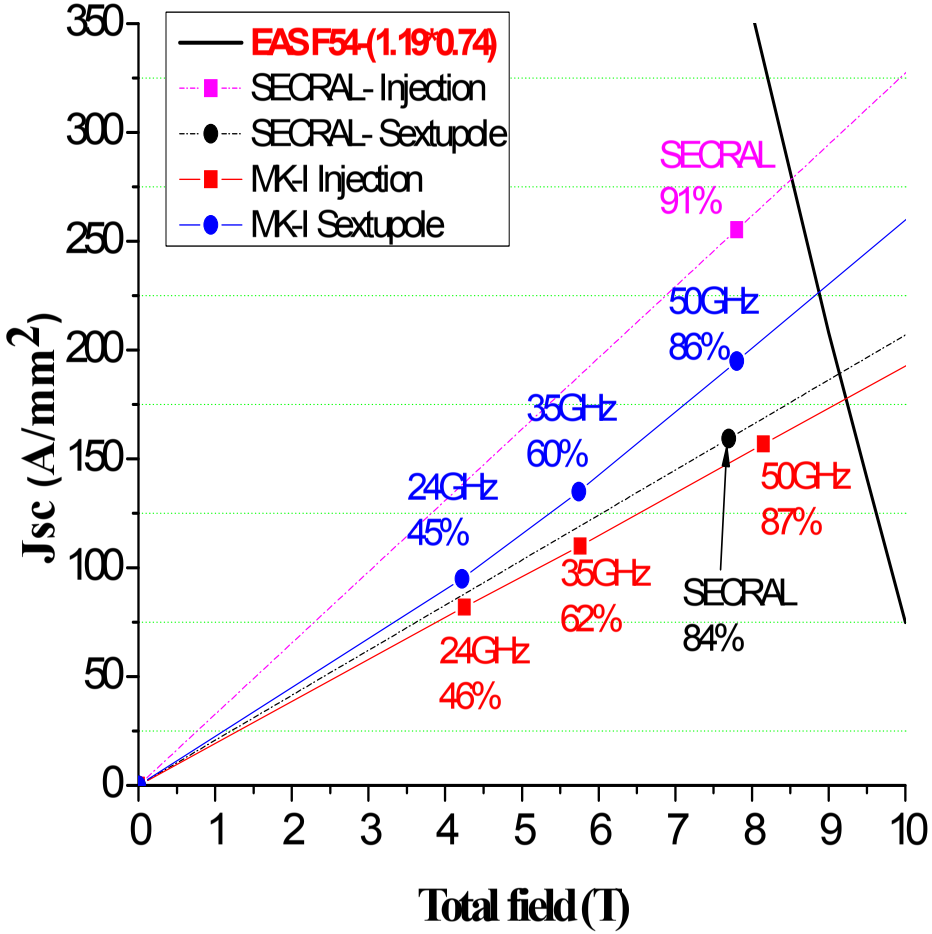
The close-loop sextupole axial contributes a significant axial fields to the injection and the extraction mirror fields.

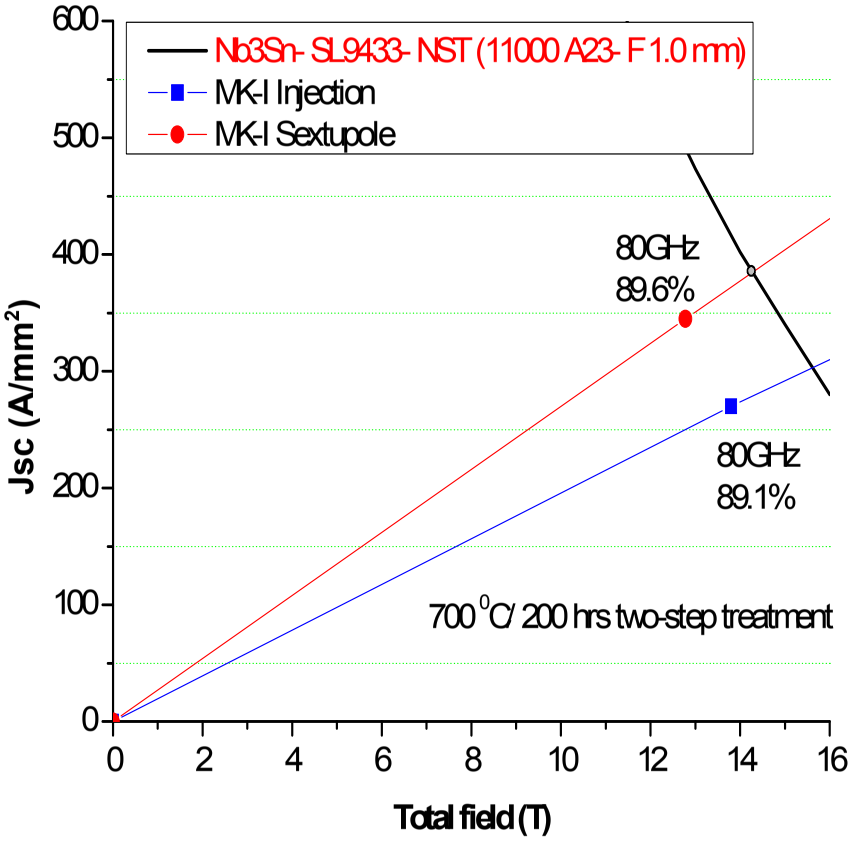
A very nice feature of the new Structure!



# Current Loading of NbTi and Nb3Sn Wires

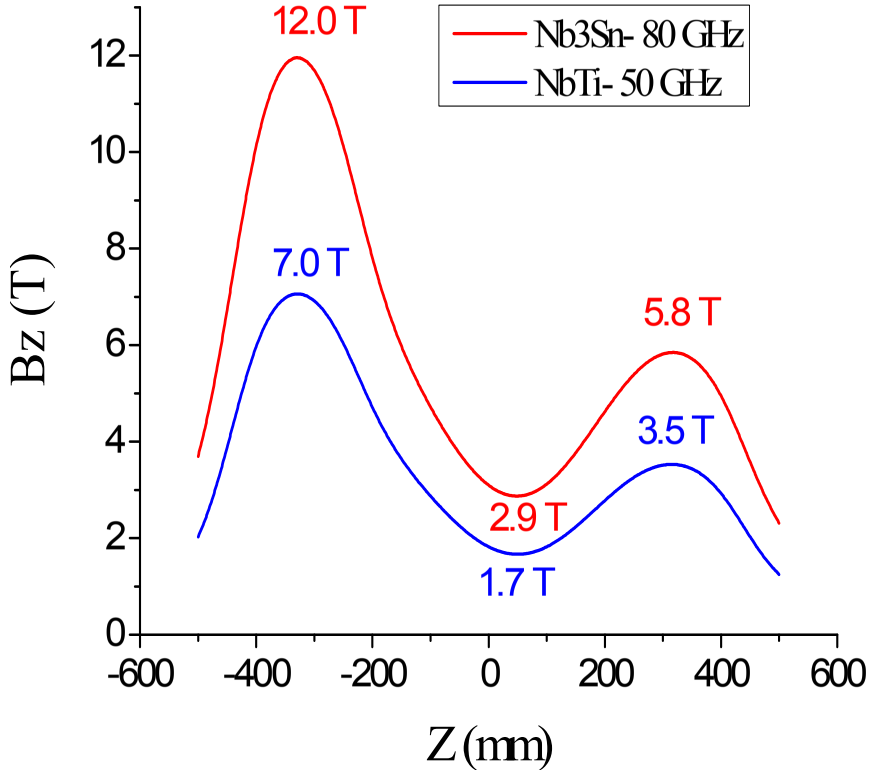


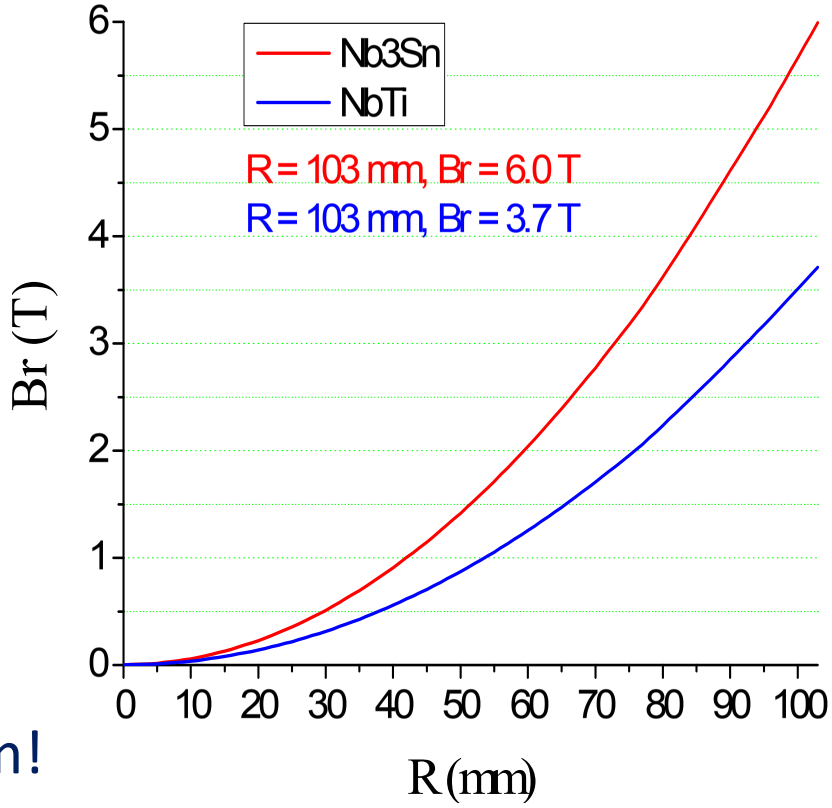




EAS F54- NbTi

Nb3Sn- SL9433- NST (BRUKER)

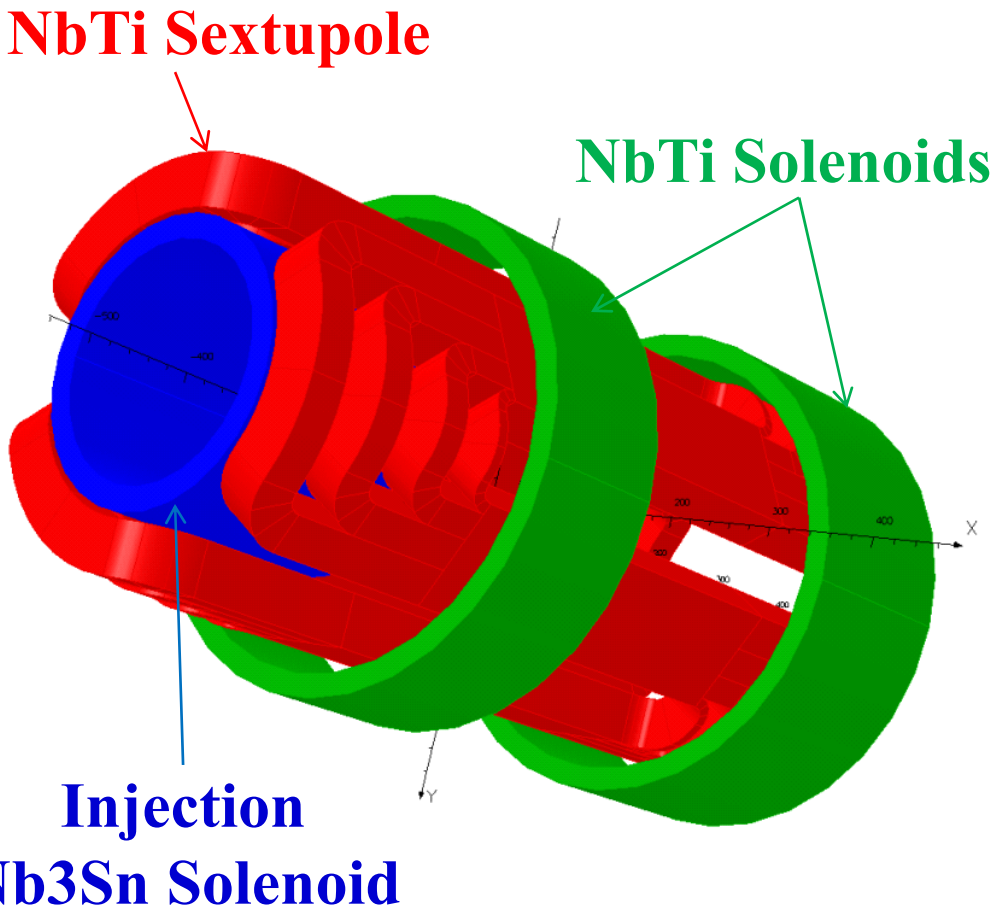
# Field Profiles Produced with the MK-I Structure




The field profile produced with a set of NbTi wires may not be the optimum!

# A Hybridized MK-I Magnet Structure (Hybrid-I)

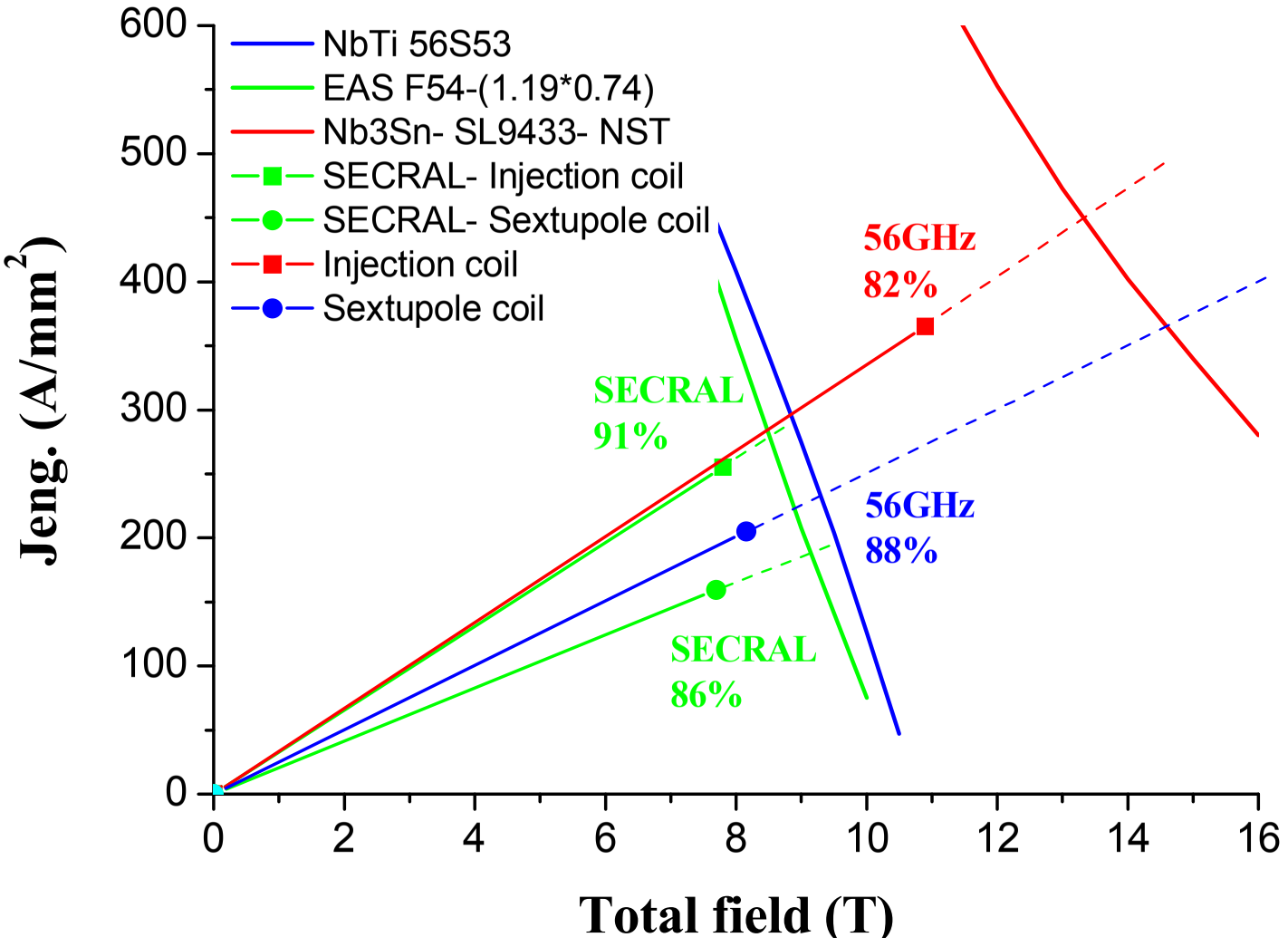



The hybridized structure keeps all the Pros of MK-I and adds a few more.

# *Other Optimizations and Variations*

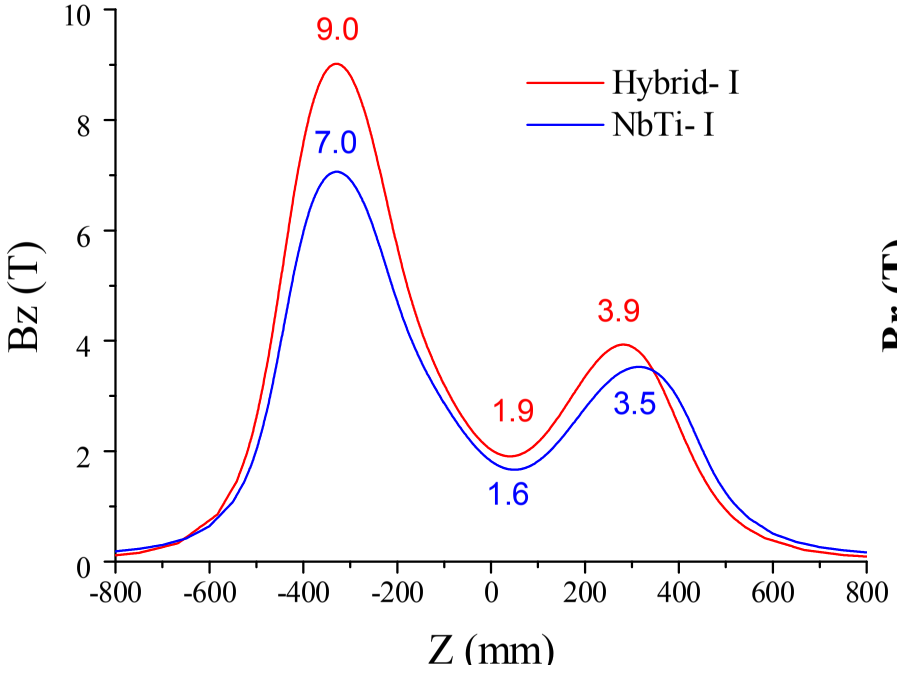
- Increase the injection solenoid ID by 24 mm but keep the OD constant;
- Shorten the extraction side of the sextupole magnet by 60 mm;
- Replace the intended EAS NbTi (F54) wires with Supercon NbTi (56S53) wires

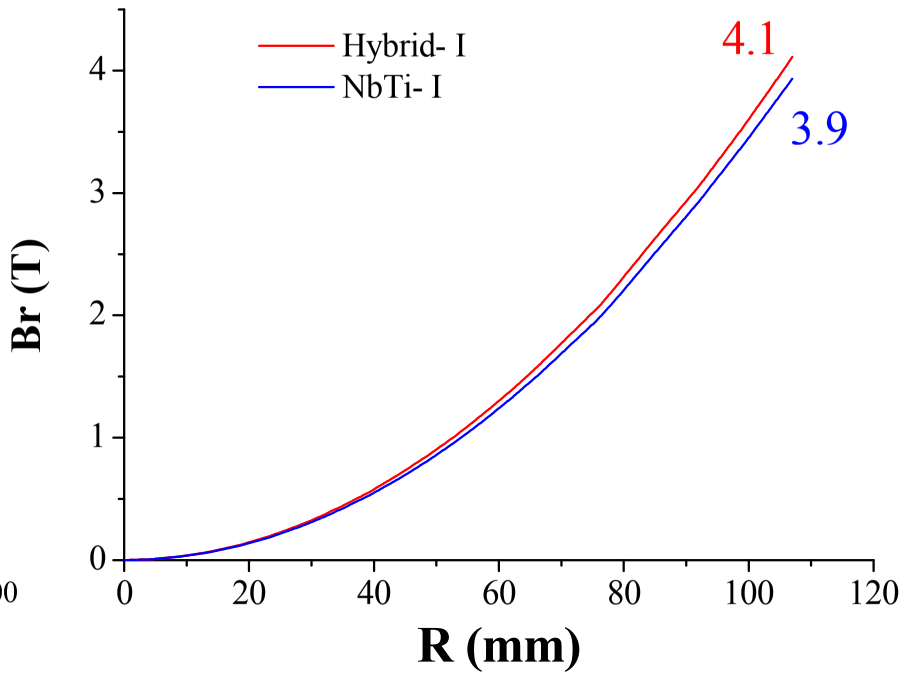
# Current Loading of NbTi/Nb3Sn Wires at 4.2 K



# Field Profiles of Hybrid-I

## (Injection Solenoid: Nb3Sn and the rest: NbTi)




*~30% higher axial field and slightly shorter peak field distance*

*Slightly higher radial field at the chamber*

*Should be good for operations up to 56 GHz and more space at the injection snout, and a less bulky magnet system and cryostat.*

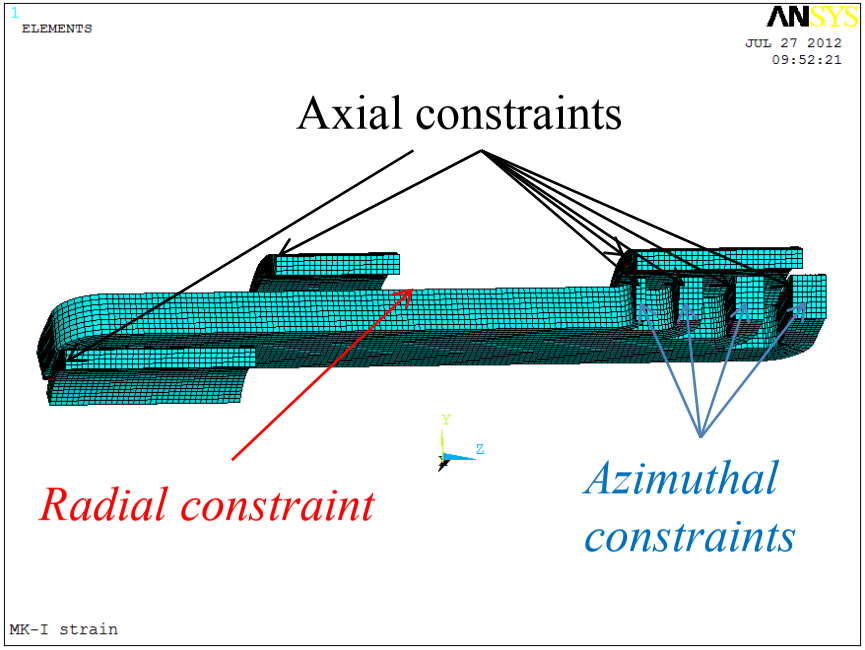
# *Summary and Comparisons*

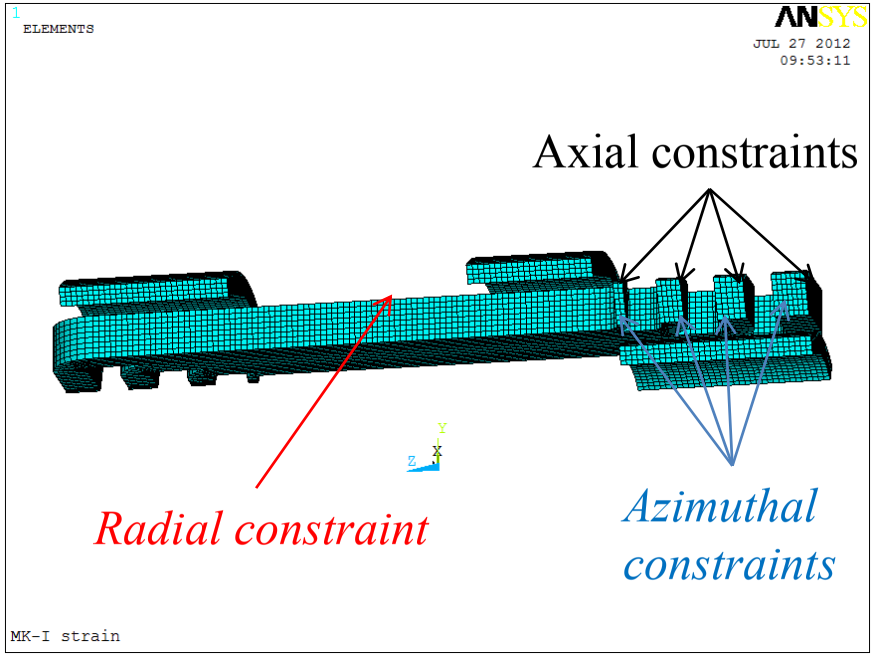
| | Hybrid-I | NbTi-I |
|---|---|---|
| Total Magnet Length (mm) | 800 | 860 |
| ID (mm) of the Injection Solenoid (OD = 240 mm) | 200 | 176 |
| Peak Axial Field/Radial Field at Chamber Walls (T) | 9.0/4.1 | 7.0/3.9 |
| Axial Peak Field Distance (mm) | 612 | 644 |
| System Stored Energy (MJ) | 1.4 | 0.9 |

# *Preliminary Stress Analysis of Hybrid-I*

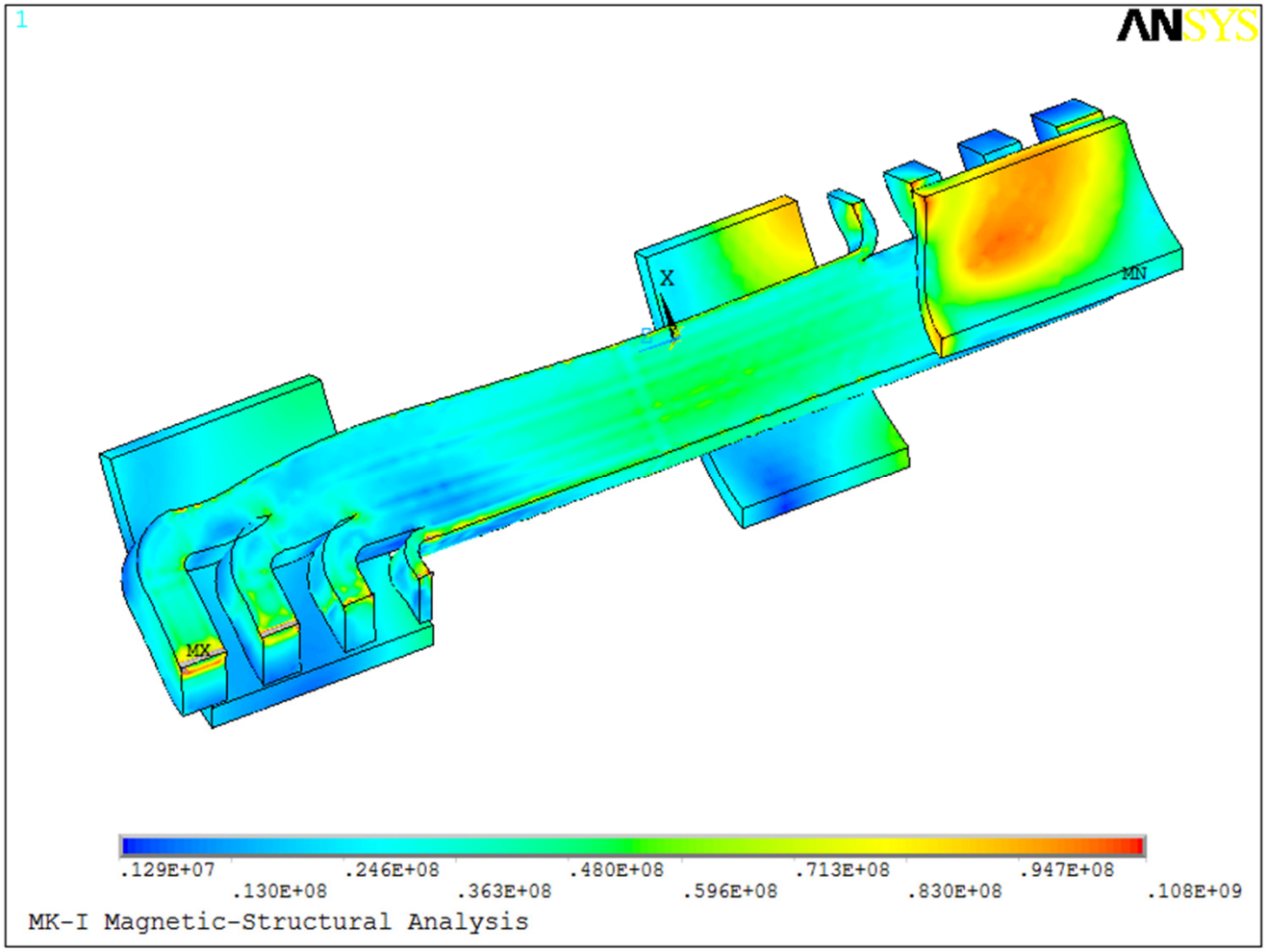
- *A 3D ANSYS model has been established to calculate both the magnetic field and stress*
- *Assuming the cold iron segments are infinite rigid in the first step analysis*
- *The ANSYS calculated magnetic field are about 8% lower than TOSCA computations*

# *Constraints Applied to the Preliminary Stress*



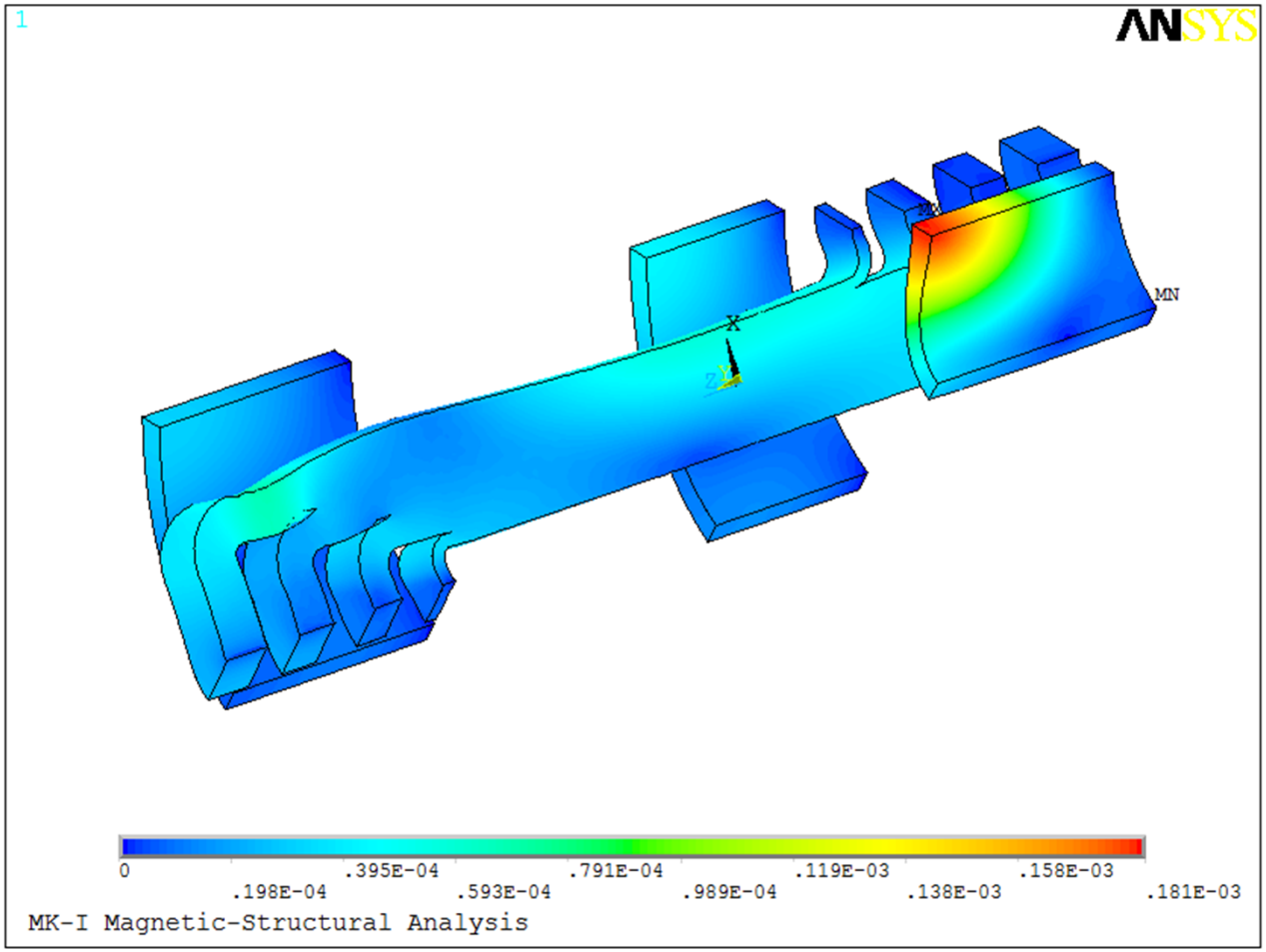



# *Preliminary: Stress Distribution*



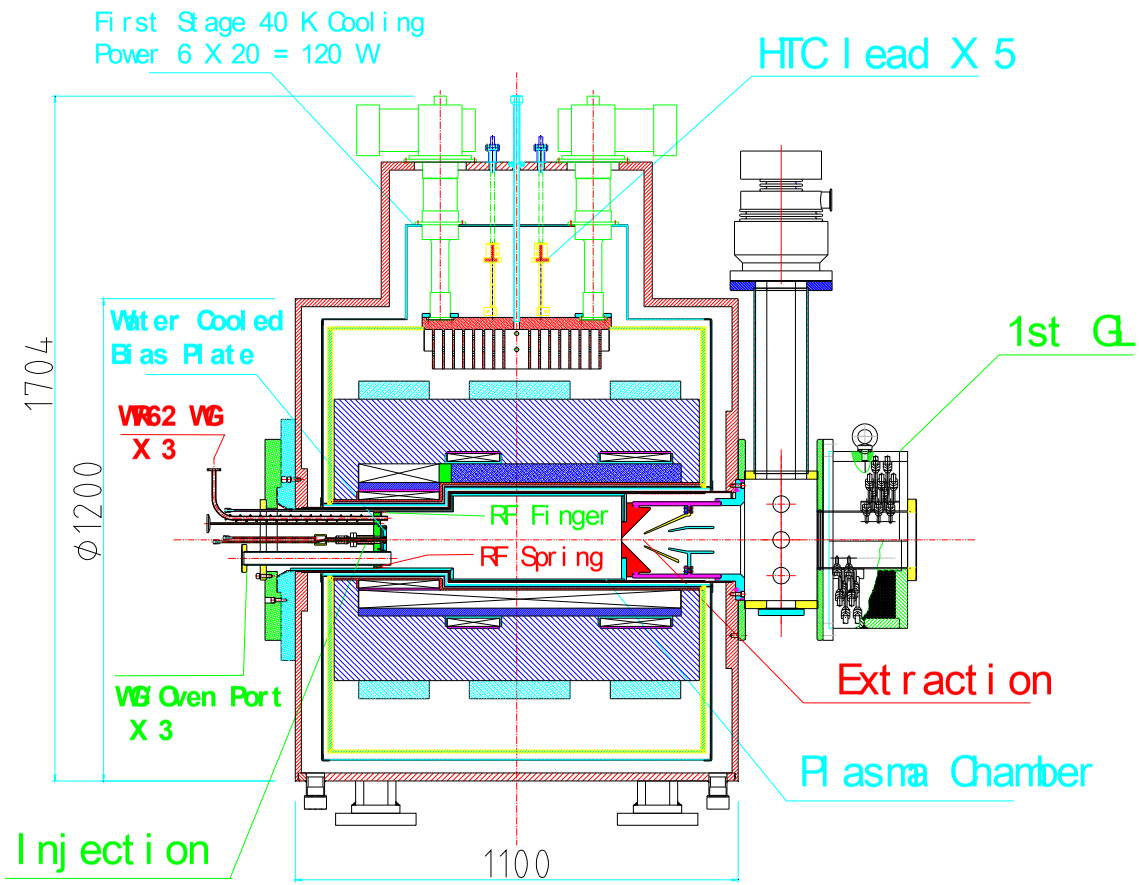

***Maximum Stress: 108 MPa***

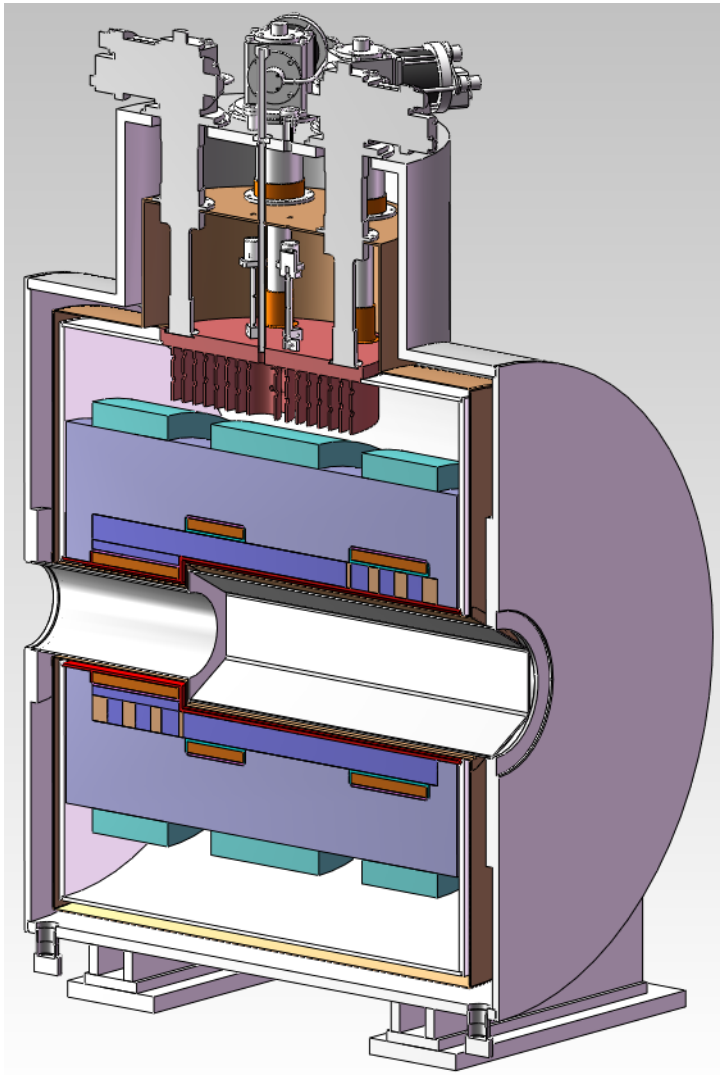
# *Deformation Distribution*




*Under the applied conditions, the maximum deformation ~ 0.18 mm occurs mostly and axially at the injection solenoid.*

# *A Preliminary Layout of the Next G. High-Field ECRIS*



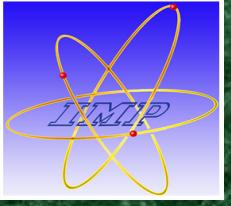



***SECRAL:* L = *1000 and* Dia. = *970***

# *Discussions*

- Hybrid-I generates substantial increase on the axial peak field, a good optimization to the NbTi-I;
- More space at the injection region for insertions;
- A less bulky magnet and cryostat;
- The preliminarily analyzed peak stress is well within the yield stress limits;
- A good base for designing the detailed system clamping and supports;

- The Hybrid-I is a better option for the next generation ECRIS if a set of full Nb3Sn magnets is not readily available.




*Thank you for*

*your attention!*