Open Midplane Dipole Design Status and R&D Issues

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Major change since last LARP meeting in Port Jefferson:

Dipole aperture has gone up from 80 mm to 135 mm.

Computed quench Field is 15 T, with a J_c of 3000 A/mm^2.

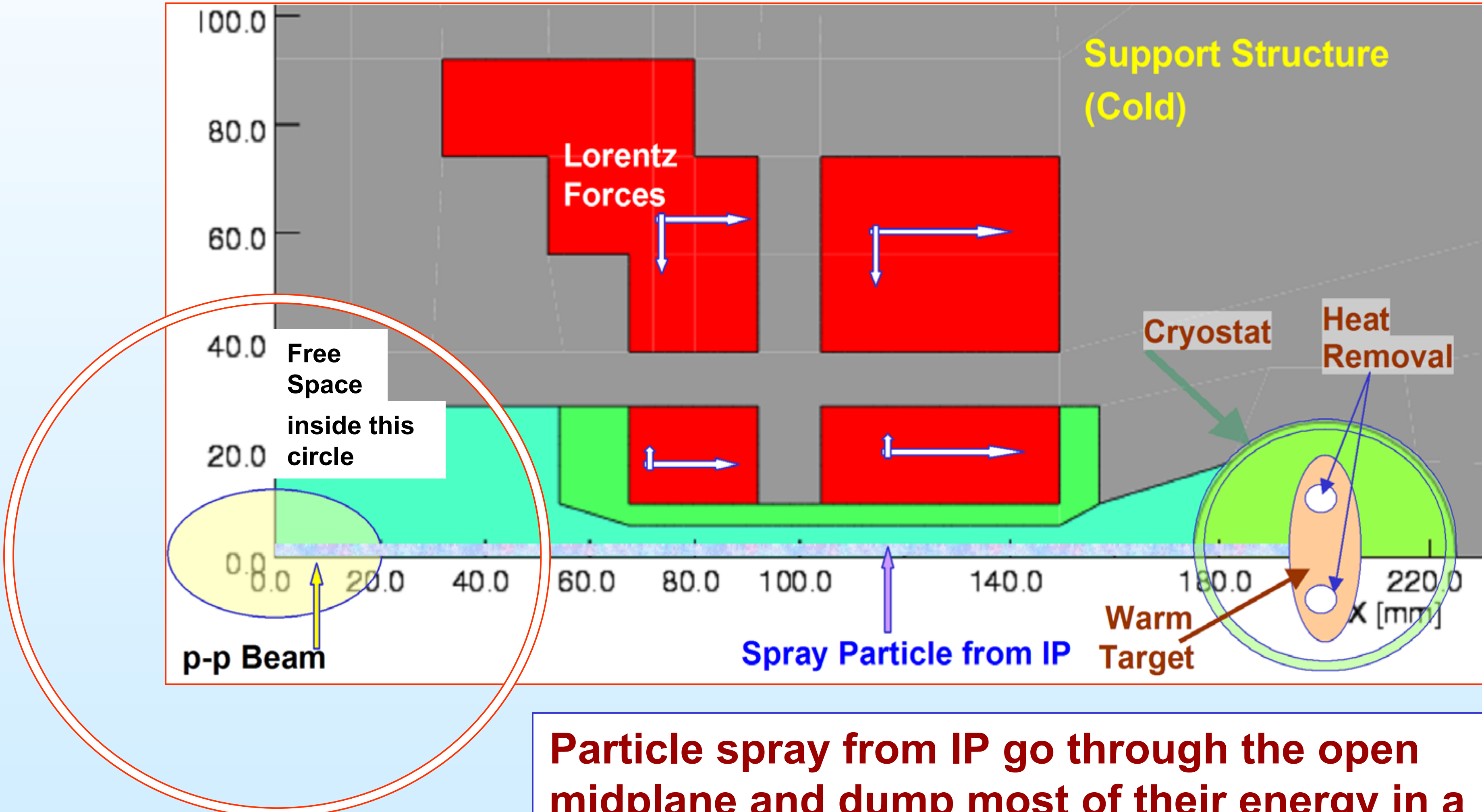
Motivation for the Open Midplane Dipole Design

High luminosity Interaction Regions present a very hostile environment for superconducting magnets :

- ~9 kW of power from each beam for 10^{35} luminosity.
- Large reduction in quench current; may cause radiation damage.
- Excessive heat removal at 4 K brings an enormous increase in operating cost.
- May require a large increase in CERN cryogenic infrastructure.
- Energy deposition is highly anisotropic with a large peak at the midplane.

- Look for an alternate design with above issues in mind!

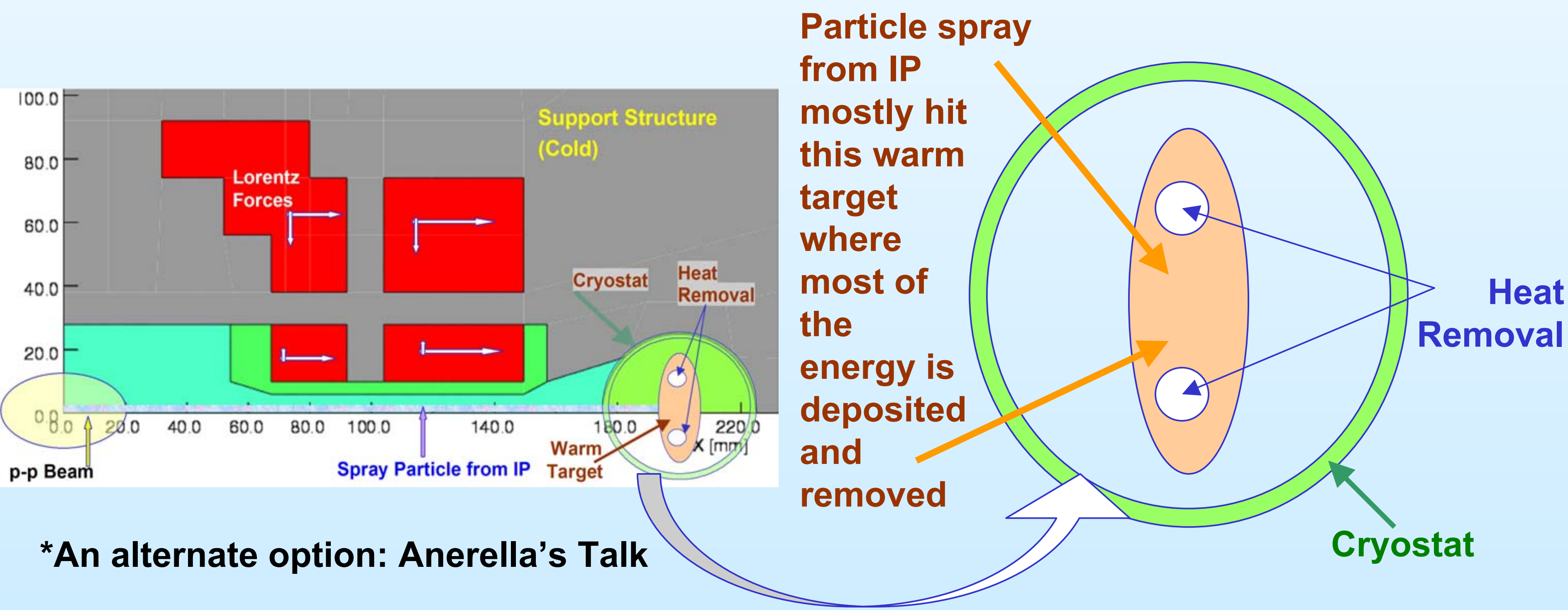
The Basic Open Midplane Design Concept (Warm intercept design for 135 mm aperture)



Particle spray from IP go through the open midplane and dump most of their energy in a cryo- insulated warm absorber at ~80 K.

Design Philosophy on Efficient Energy/Heat Removal

Most of the energy will be deposited in a warm island that is outside the coil structure to avoid secondary particles hitting the coils. The warm (~80 K) island, from where the energy is removed efficiently, is inside the cold support structure but in its own cryostat to minimize heat leak/load*.

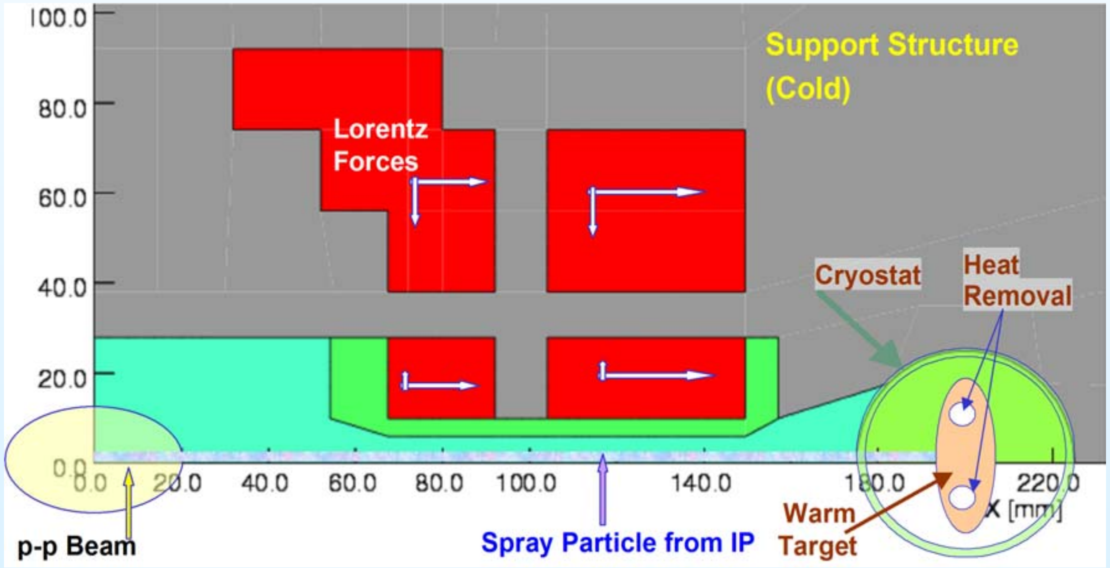


*An alternate option: Anerella's Talk

Navigation of Lorentz Forces
(an additional consideration in design optimization)

Lorentz forces in the first quadrant

Block	Horizontal Component (N/mm)	Vertical Component (N/mm)
Inner Lower	1632	16
Outer Lower	728	-4
Inner Upper	6908	-2248
Outer Upper	1302	-3909



Lorentz Forces on the Blocks

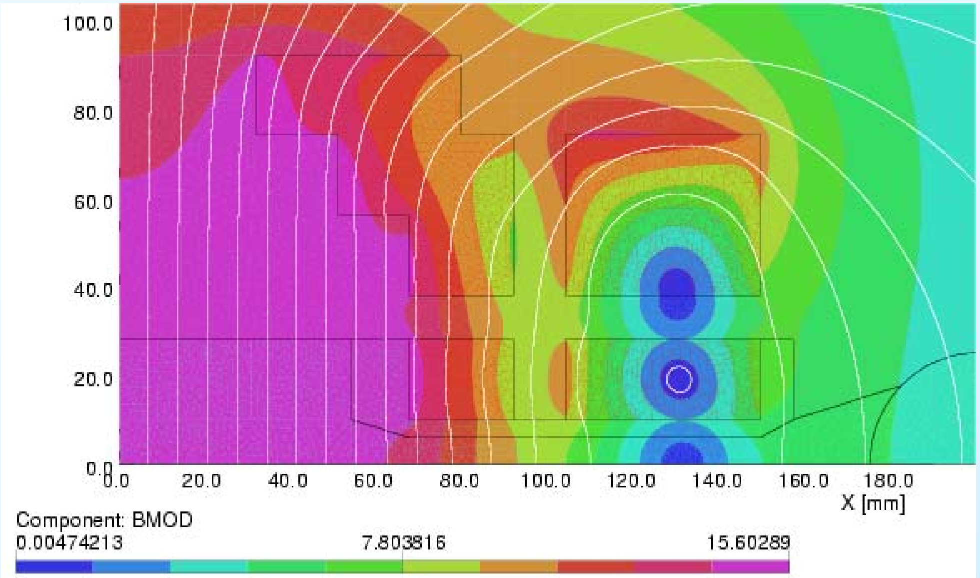
- Total (Upper + Lower Blocks)
  - Vertical: -6 kN/mm
  - Horizontal: 11 kN/mm
- Lower Coil Block Only
  - Vertical: +0 kN/mm
  - Horizontal: ~2.4 kN/mm

Since there is no downward force on the lower blocks (there is slight upward force), we do not need much support below it, if the structure is segmented. The support structure can be designed to deal with the downward force on the upper block using the space between the upper and the lower blocks.

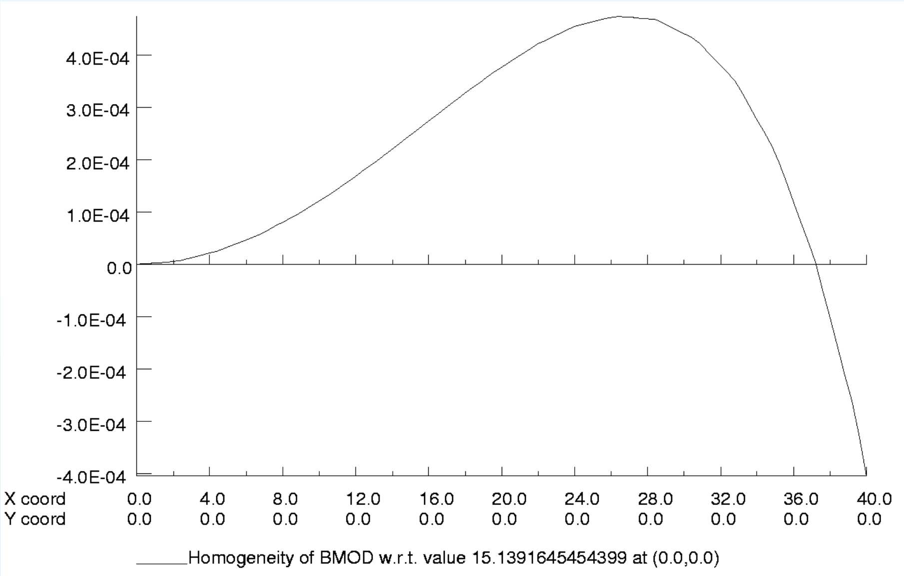
Field Quality Optimization

A reduction in midplane gap, straightens the field lines at midplane and improves the field quality.

The actual field quality optimization will be done with the coil optimization programs. But 10^{-4} relative error implies that a magnetic design with low field harmonics is possible.



Magnetic model of 135 mm horizontal aperture with field contour and field lines superimposed.



Relative field error on the X-axis

R&D Issues in Open Midplane Dipole Design
(a) Mechanical Design Tolerance

How much deflection in Nb_3Sn coils and proposed support structure can be tolerated?

- Absolute value of deflection (coil moves as a whole)?
  - Field quality: can one accommodate in magnetic design.
  - Pre-mature quench: Need experimental data.

- Relative deflection within coil: 1 mil (25 μm) or 4 mil (100 μm)?
  - It has a major impact on the structure design.

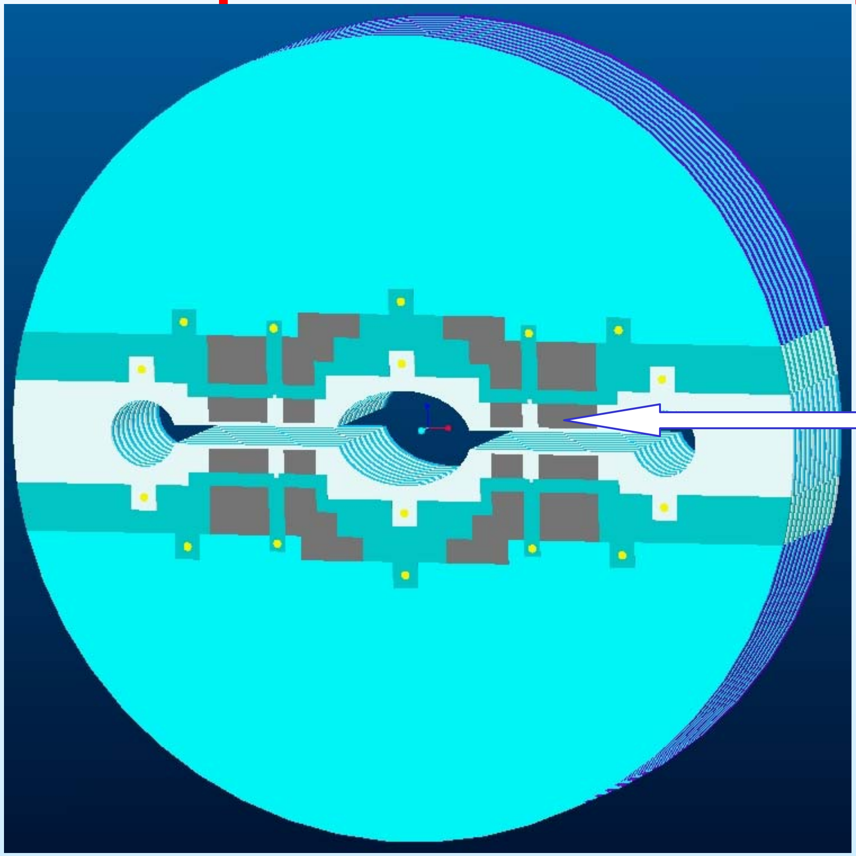
Need scientific database to answer this important question
☞ Do experiments on working LBL coils.

How much stress and strain on potted coils can be tolerated in a field/stress combination as present in actual designs. Again, need experimental results.

R&D Issues in Open Midplane Dipole Design
(b) Coil Aperture

What is the need of vertical aperture and horizontal aperture?

- **Need input from accelerator physicists.**



To obtain more vertical aperture, we will need to lift these coils up in the end.

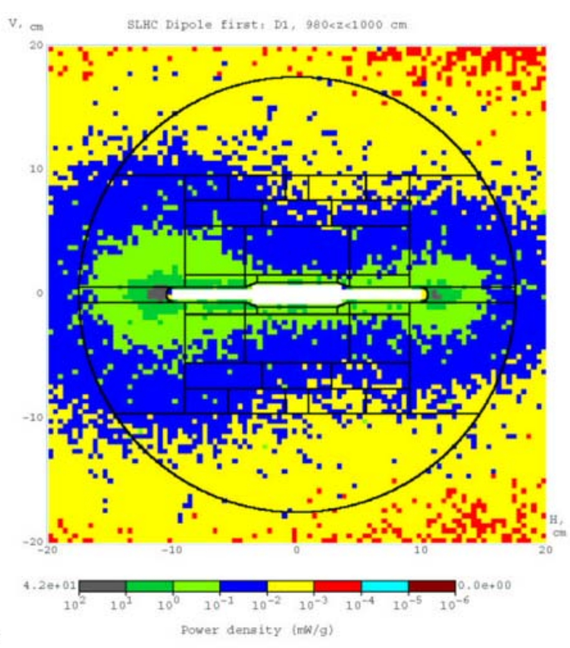
Need for horizontal aperture increases the challenge and size of magnet. Present size 135 mm. Is it coil to coil or beam tube or good field aperture?

R&D Issues in Open Midplane Dipole Design
(c) Energy Deposition in New Design

What is the energy deposition in the present design?

It was small before, so we reduced the midplane gap.

Is it still acceptable? Calculations from Mokhov needed.



Old design: worked well

Details of the design (with everything included) will be provided to Nikolai, when ready (hopefully soon).

- What is the temperature increase and heat loads on superconducting coils? Are we still OK?
- What is the temperature increase on target. Study design issues for cooling, life time, etc.
- How much is the energy deposition on coldmass?
- What is the additional load on cryogenic system?

R&D Issues in Open Midplane Dipole Design
(d) Magnet Technology: R&W and W&R

Develop collaboration.

For example BNL and LBL could develop some common parameters together, so that, e.g., LBL's "Wind & React" coils fit in BNL's open midplane dipole support structure.

Cable R&D issues specific to "React & Wind" technology

- What is the acceptable bending strain?
- Does it depend on conductor design?
- How much sintering should be allowed between the wires in the cable? None (present R&W version), Full (W&R version some how applied cleverly to R&W), Partial (allow between upper and lower wires, but not between side by side)?

LARP Dipole R&D Goals

Develop an integrated design for open midplane dipole that

- Has a support structure concept which can accommodate large forces in an open midplane design.
- Has field harmonics at the level of 10^{-4} .
- Has an open midplane that is adequate for removing most spray particles from IP.
- Is technology independent ("React & Wind" Vs. "Wind & React") in 2-d magnetic and mechanical design.

The design is being developed in an iterative way, where the "magnetic", "mechanical" and "energy removal" aspects are optimized together. The goal is to demonstrate soon that there are no "show stoppers".

SUMMARY

- “Open Midplane Dipole Design” seems to offer a good technical and an economical option for LHC luminosity upgrade in removing large energy deposition and minimizing the increase in cryogenic facility requirements.
- The design is being iterated. The option appears promising because:
  - ➢ The energy deposition in coils can be made so small that temperature increase remains below the quench tolerance of superconducting coils.
  - ➢ The energy/heat is removed at a higher temperature (~80 K rather than ~4 K) which brings a significant reduction in operating cost.

Steps needed to establish the above design:

❑ Show by model calculations that an acceptable and self-consistent magnetic, mechanical and thermal (energy/heat removal) design exist.

❑ Prove design (a) first by establishing quench field and then (b) by performing simulated thermal experiments for energy removal, etc.