Concept for Magnet and Cryostat for a 12x9x5 m^3 sized Li Ar neutrino detector

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1. Introduction, Specs and wish list

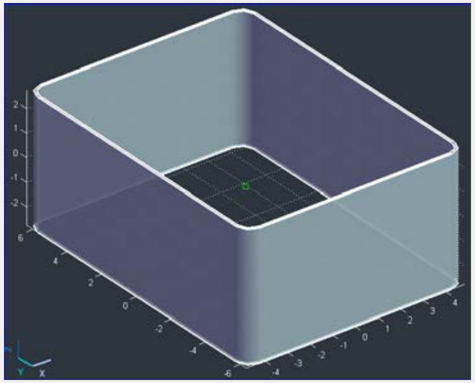
A proposal was requested by Marzio Nessi for a for magnet around a LiAr vessel. In a discussion the following specifications and wish list was defined:

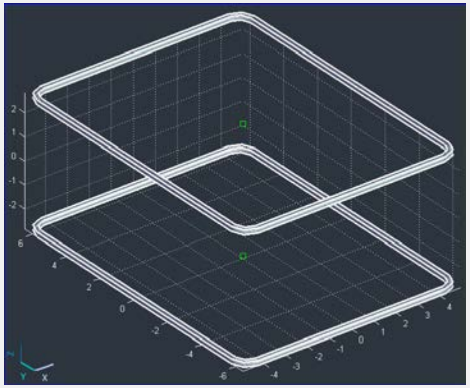
- Net size Li-Argon vessel: LxWxH =12 x 9 x 5 = 540 m^3
- Magnetic field directed in H direction
- Center field in 0.8-1.0 T range
- Minimum useful field at edge 0.5 T
- Field uniformity of secondary importance
- Simple and cost efficient, based on present experience and proven solutions
- Low risk and short production time
- Scalable in length
- Simple cooling and thermal insulation: can a foam type insulation be used?
- Can we use medium (MgB2) or high temperature superconductors?

1. Introduction, First comments

- For generating magnetic field, a solenoid with rectangular section would be most efficient.
- But then big problems with forces (4 bar magnetic pressure) blowing up the solenoid.
- Requires a thick and stiff external structure to limit deflections under vacuum and Lorentz forces load.
- **For simplicity and cost effectiveness, a better solution is 2 identical race track coils, one on top of the vessel and the second under the vessel.**
- Less efficient for field, higher local peak field, but straightforward, simple, a sandwiched plates like structure, **low risk, can be manufactured off-site**.
- **HTS-ReBCO at 30-50K far too expensive; MgB_2 at 20 K is difficult, peak field around 6-7T too high, also no qualified, a real R&D project.**

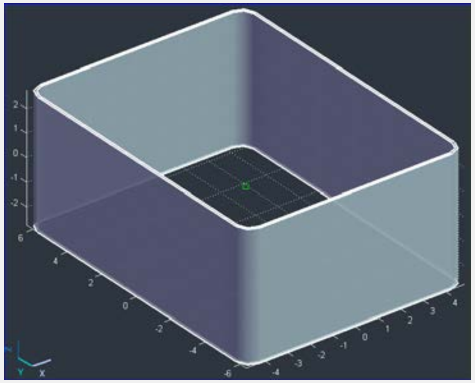
✓ **Stick to very cost efficient NbTi operating at 4.5 K**

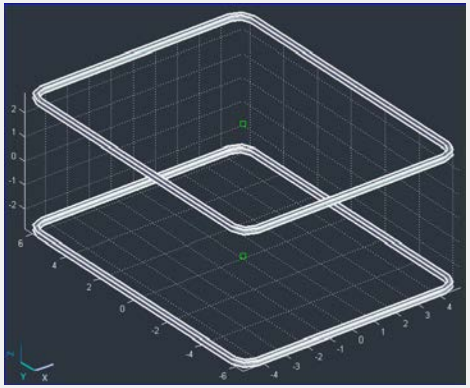




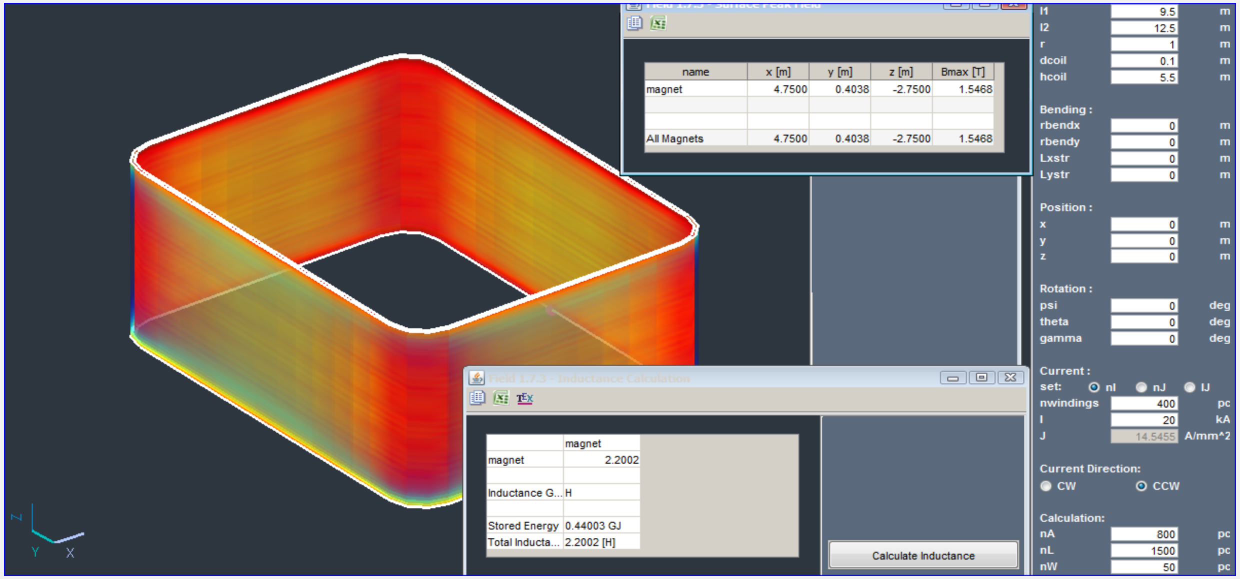
1. Introduction, Coil dimensions

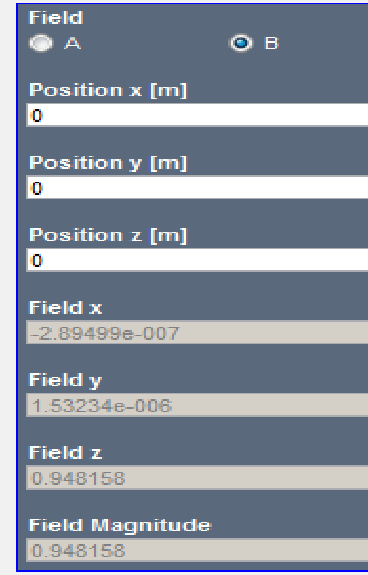
- Vessel outer dimensions: 12 x 9 x 5 = 540 m^3
- For the magnet need space around vessel for the cryostat: take +250 mm as a first guess for accommodating vacuum vessel walls, thermal shield and supports structures.
- Center of current positions of the coil system are then: 12.5m x 9.5m x 5.5m = 653 m^3 (21% more than LiAr vessel)
- Sizes will be fine tuned later to optimize the design, c.q. to minimize the peak magnetic field and overall cost.
- There is also a trade off with the civil engineering cost to be considered depending very much on the local circumstances, conditions of the soil etc.

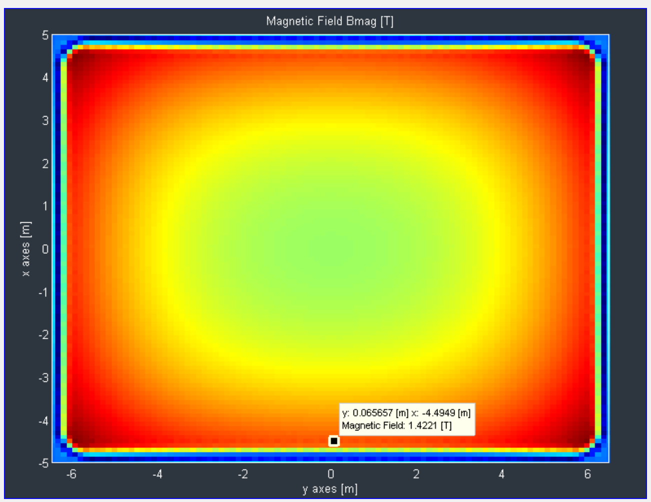




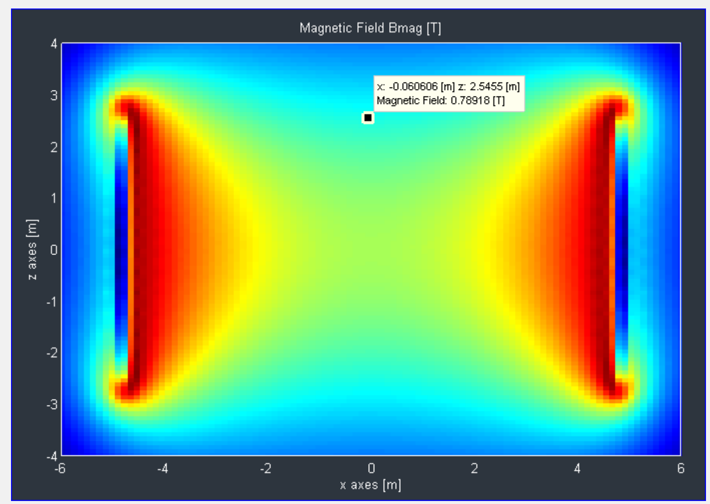
2. Magnet, option 1: Solenoid with block-shaped bore





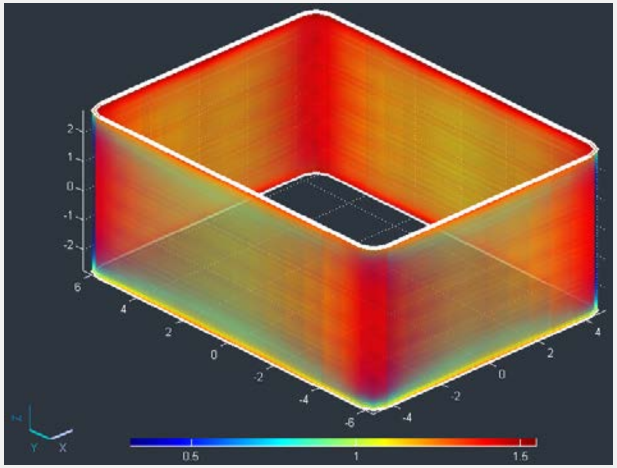


yx plane: 1.42 T at edge of vessel, central field is 0.95 T.



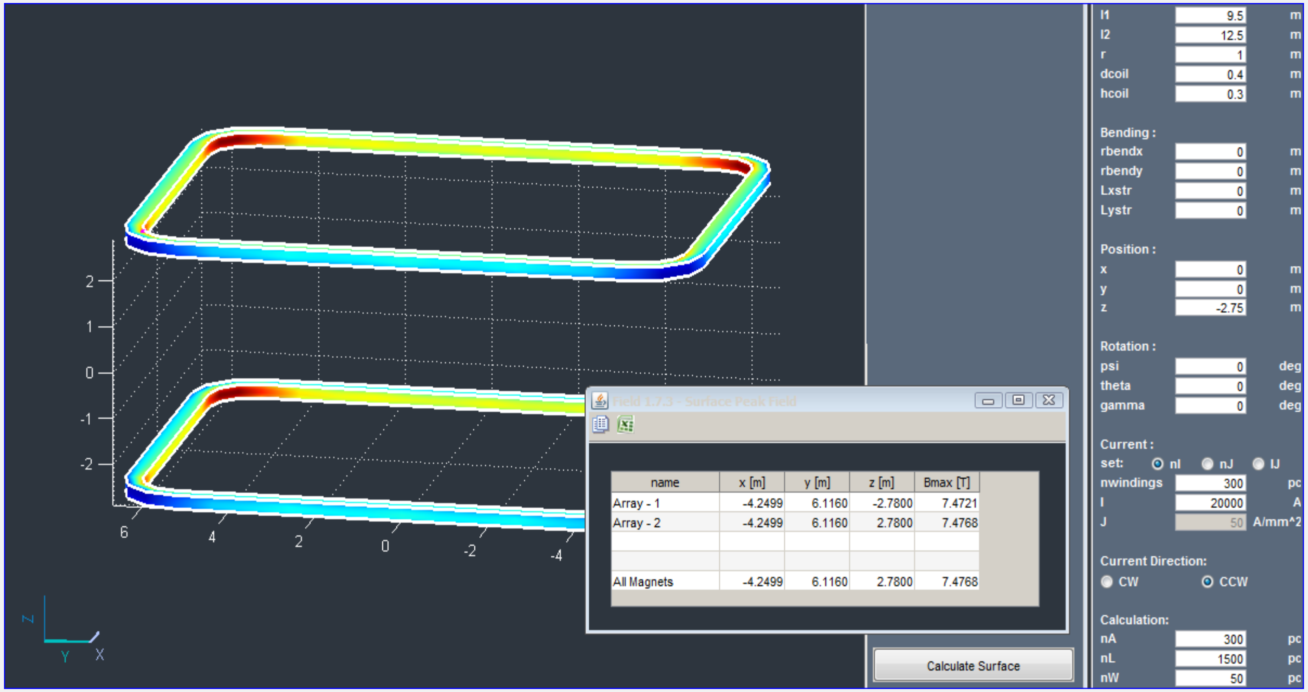
xz plane: 0.79T at upper edge of vessel with 0.85 T in centre.

2. Magnet, option 1: Arguments.....



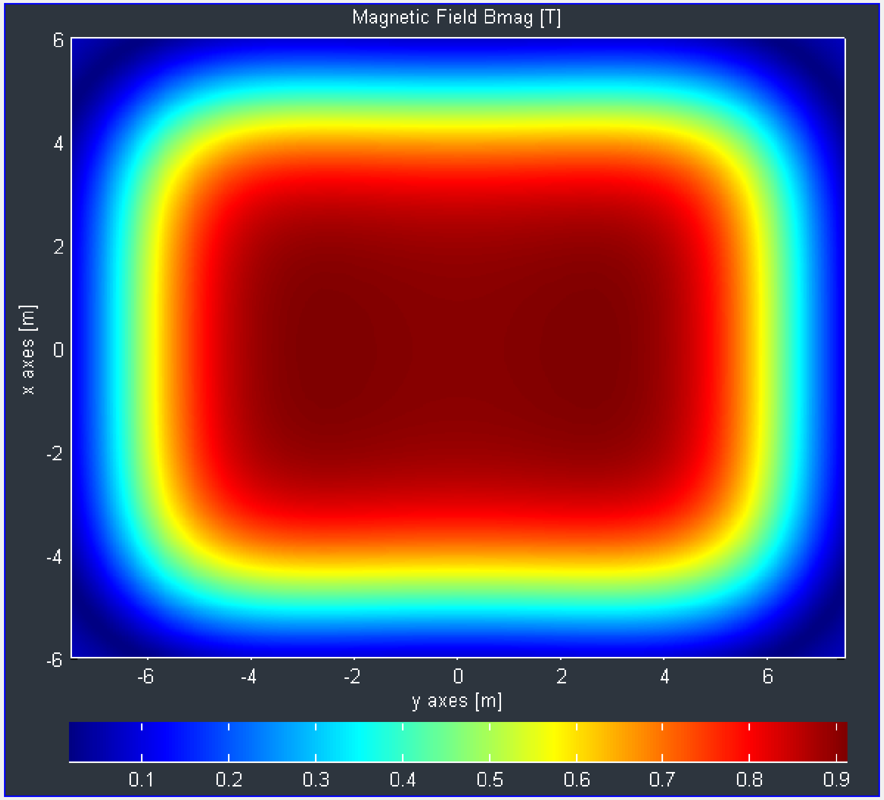
- Peak magnetic field is 1.5T, nice
- So, in principle doable with MgB2 superconductor operating at 20 K, but:
- Requires cabled conductor development and qualification work at 20-20K
- Requires new coil winding technology to be exercised and qualified as well with a demonstration coils
- Requires coil winding, coil assembly on site by a local company
- Requires heavy external structures to handle the forces
- Certainly interesting when schedule allows for a few years of development
- A research project rather than a short-term construction project

2. Magnet, option 2: Double Racetrack Magnet

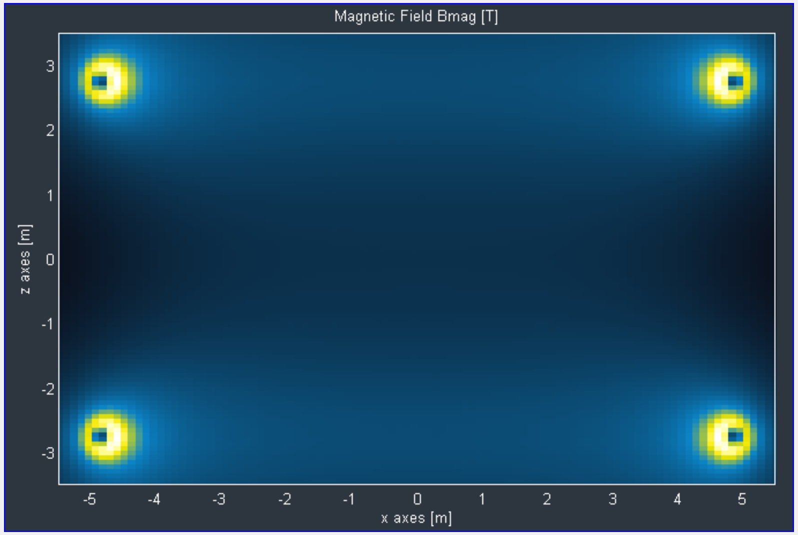


Coil data:	L(center)	B(center)	d	h	r	distance
	12.5	9.5	0.4	0.3	1	5.5
	L [H]			6.34		
	E [GJ]			1.27		
	I [kA]			20		
	Turns/coil			300		
	Conductor length [km]			26.4		
	Peak field [T]			7.5	(reduce by reshaping)	
	Bore central field [T]			0.92		
	Force between coils [MN]			31		

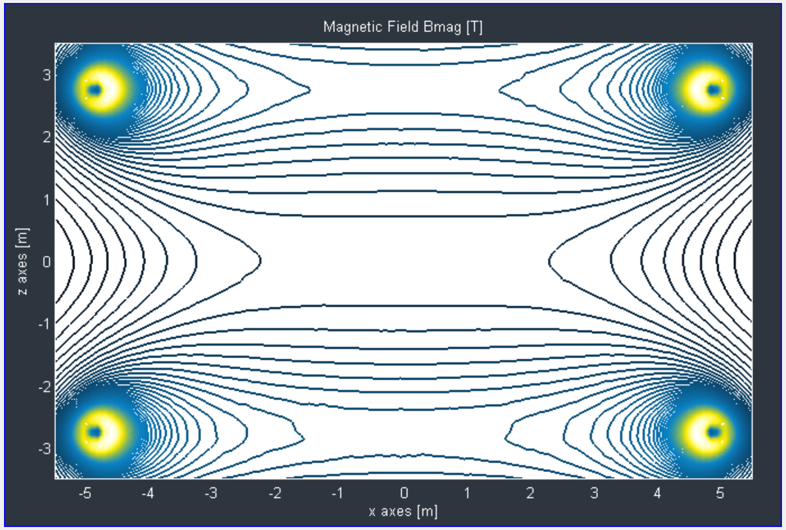
Option 2: Double Racetrack Magnet, local field



Field in yx plane through (0,0):



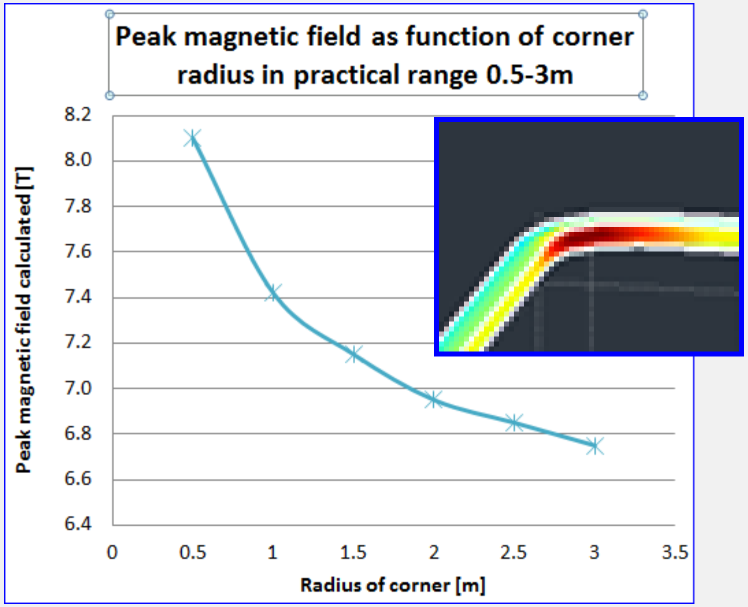
Magnetic field in xz plane through (0,0):



Option 2: Double Racetrack Magnet, optimization

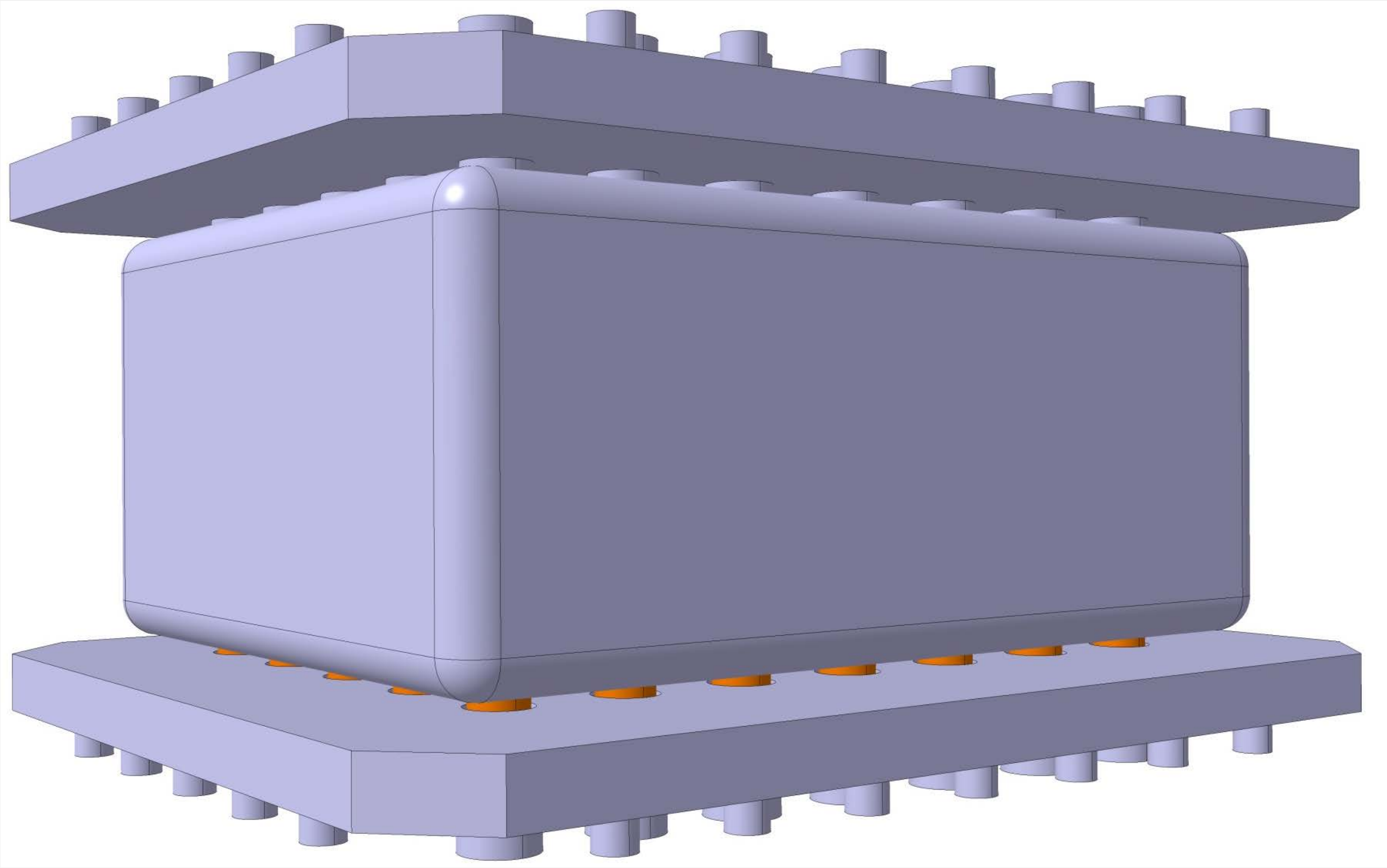
Peak magnetic field reduction with minimum overall magnet cost in mind.

- Effect of coil corner radius: with r=1 m the peak field is 7.4 T, 7.0 T for 2 m, 6.8 T for 3 m, so we gain when radius is as large as possible.
- Peak field can be reduced further for any r when reshaping the winding pack and reducing current density.



- Also, we can reduce the local peak field in the corner by locally reducing the current density by inserting dummy turns (like done for ATLAS-ECT). Current density optimization is to be done.
- And, we can reduce the peak field by increasing the racetrack window, by placing the 0.5 T area more central in the coil and allowing for a slightly larger coil, for example by increasing the coil dimensions to 13x10.
- **This is a trade-off between coil & cryostat sizes and cost, versus the superconductor cost; and civil engineering cost, to be optimized later.**

3. Concept for Cryostat of LiAr-vessel and Magnet

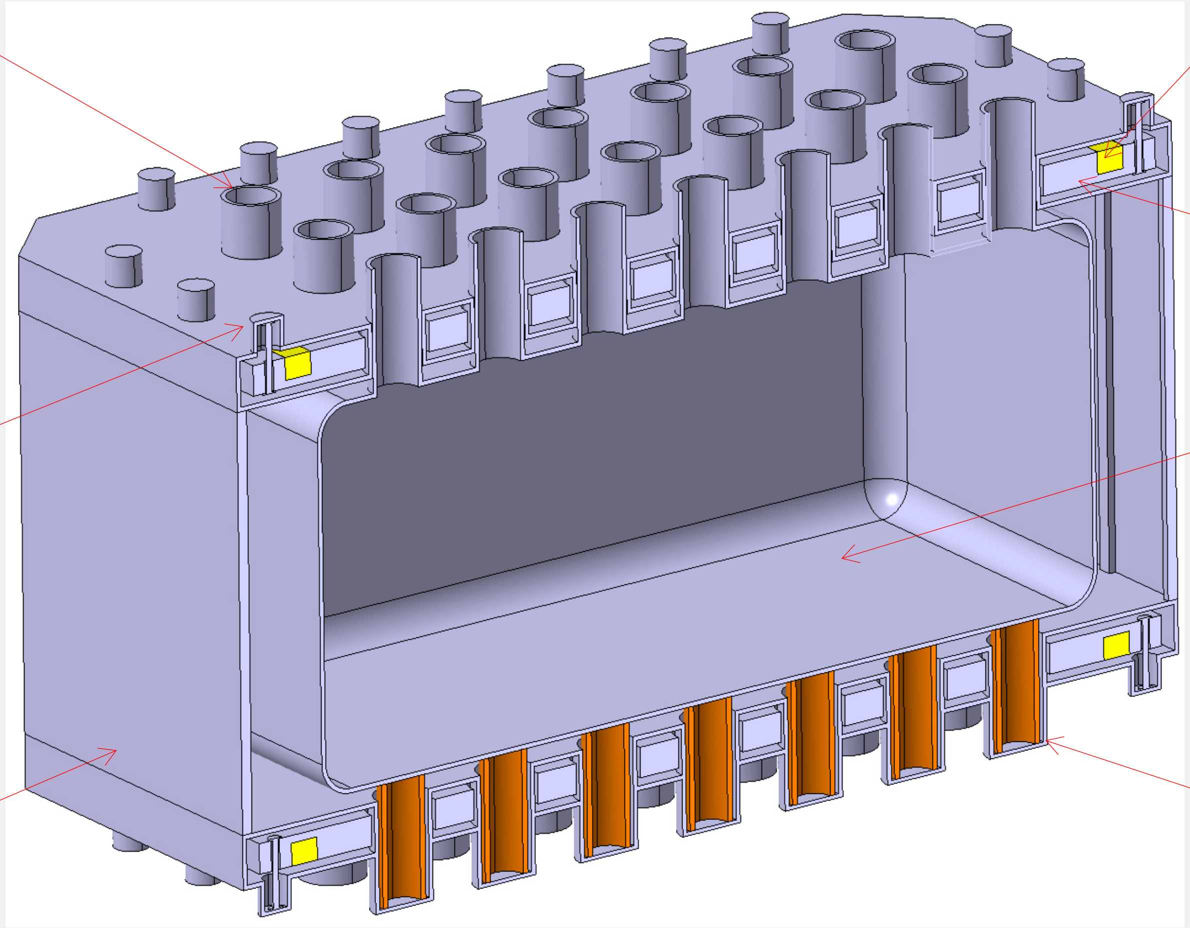


3. Concept for Cryostat of LiAr-vessel and Magnet

Array of service ports for LiAr detector cabling

Line of tie rod ports with vacuum seal for taking coil weight and Lorentz force

Vessel wall with reinforcement ribs takes the 30MN Lorentz force + 10MN vacuum load



Racetrack Coil

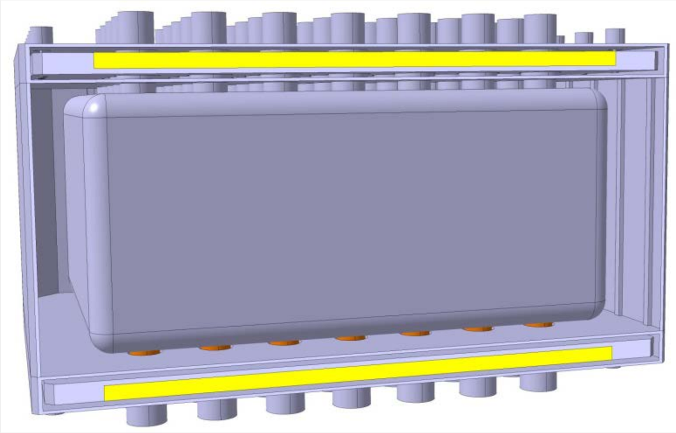
Coil casing

500 m^3 LiAr 83 K; 900 t liquid + vessel, 1000t in total

Array of support tubes for 1000t including vacuum seals; Heat load 300-83 K

3. Concept for Cryostat of LiAr-vessel and Magnet

- Three contracts for conductor, coil winding/cold mass modules and cryostat in modules
- Production off site in company, then transport in modules to site for assembly



- Can be realized within shortest possible time since based on known designs thereby mitigating cost and schedule risks
- So, looks all doable
- To do: agree on this concept first before the next step of going to more details!

4. Other dimensions, impact on design

Presently analyzed:

(1) 9.00 x 5.00 x 12.00

Other dimension of Li Ar cold vessels mentioned:

(2) 8.38 x 4.34 x 19.92 m3

(3) 3.94 x 4.24 x 11.92

(4) 6.00 x 6.00 x 3.40

No major changes in section impacting peak field, but much shorter or longer.

The proposed design is a solution per meter length, so no impact on the technology as long as transport of the modules is feasible.

Impact ? None on principles, but of course on cost