Superconducting Magnets for LHeC

Solenoids, e-bending Dipoles and a Toroid

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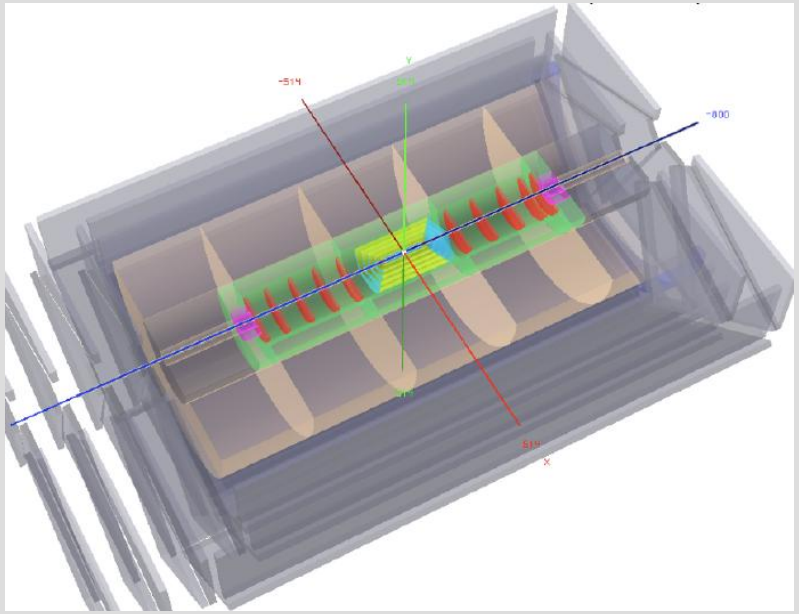
Solenoid and Dipole (LR) Options

1. Large solenoid outside the H-cal
   3.5T, 6.0m bore,12m long
   with iron yoke (CMS like)
2. Large solenoid outside H-cal
   3.5T, 6.0m bore,12m long
   with shielding solenoid for flux return
3. Small solenoid in between E- and H-cal
   3.5T, 2.2m bore, 7.1m long
   with iron return yoke



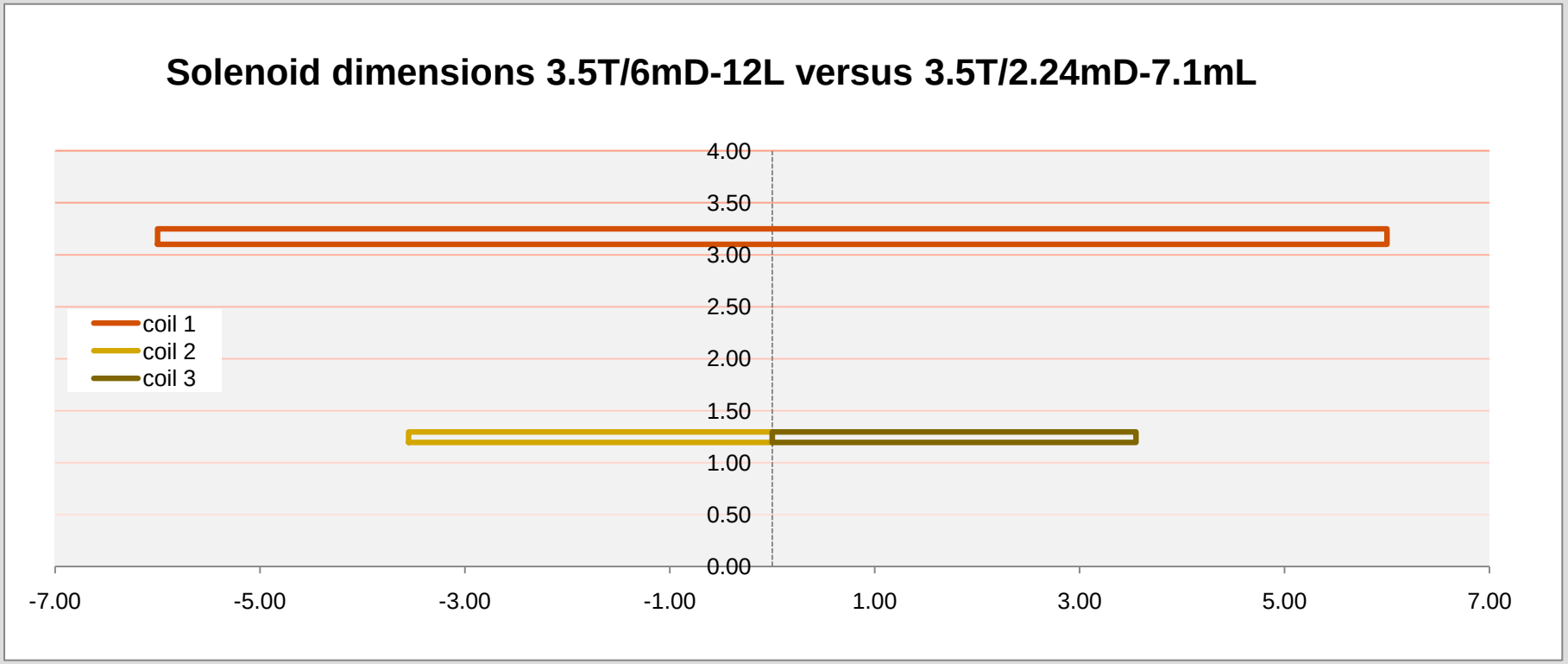
4. Small solenoid in between E-cal and H-cal
   3.5T, 2.2m bore, 7.1m long with shielding solenoid

Combine solenoid options with twin dipole on 6 or 2.2m bore ?

- ➢ However, dipole on 6m bore is very inefficient and bulky, so needs to be positioned at low radius
- ✓ If space is reserved along 12m for the twin dipole at low radius, then combine with the solenoid

Big and Small Solenoids

- Dramatic difference in size, complexity & cost of these two options



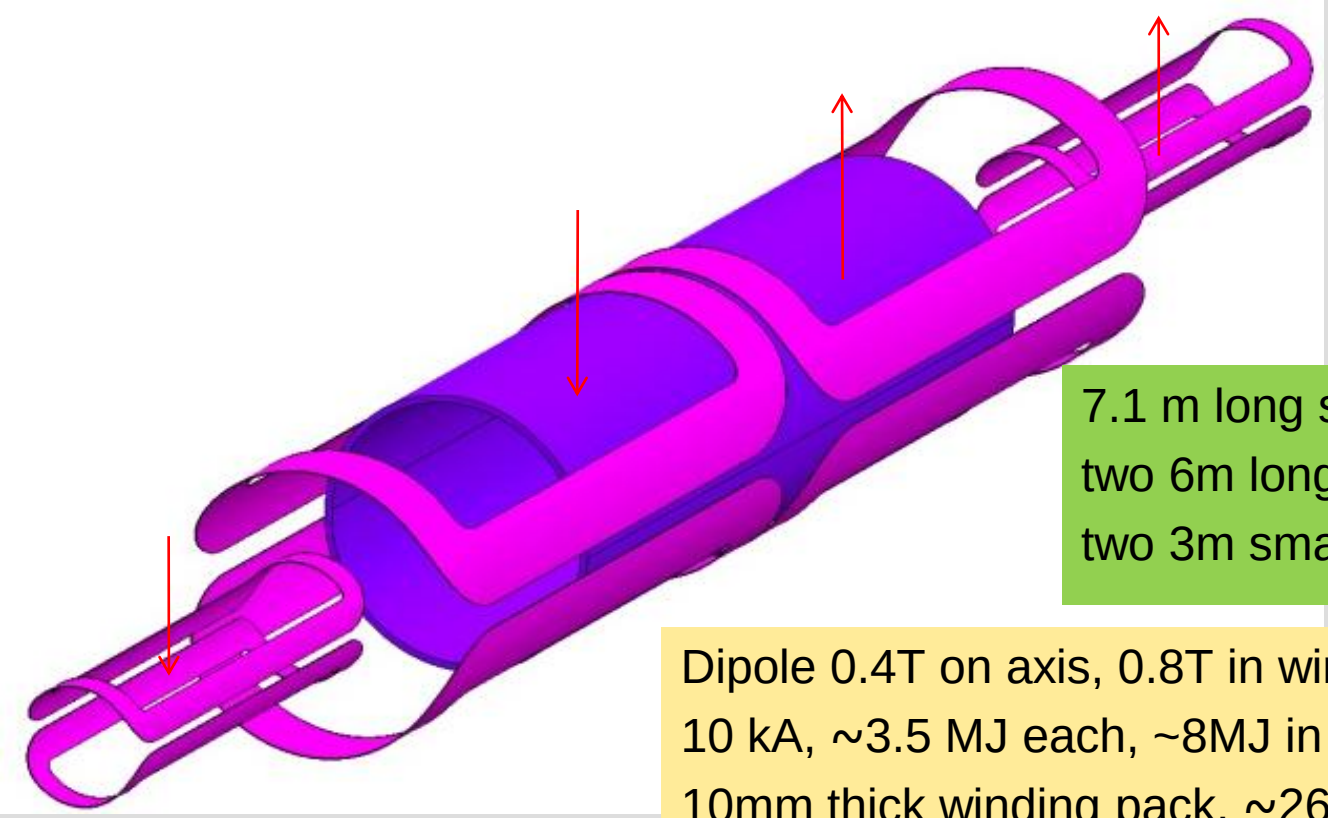
- Big solenoid requires 3m thick iron shielding weighing 10,000 tons
- Small solenoid at 3m radius shows ~0.15T to shield, iron of < 500 tons!
- ✓ If for physics acceptable, take the small solenoid !

3.5T – 2.24mD – 7.1mL Solenoid arrangement

Solenoid and Twin Dipole arrangement as required for LR option

Elegant solution: combine solenoid and the 9m long dipoles

- ✓ 6m long sections of dipoles within the detector bore in one cryostat, add the remaining 3m long side dipoles separately

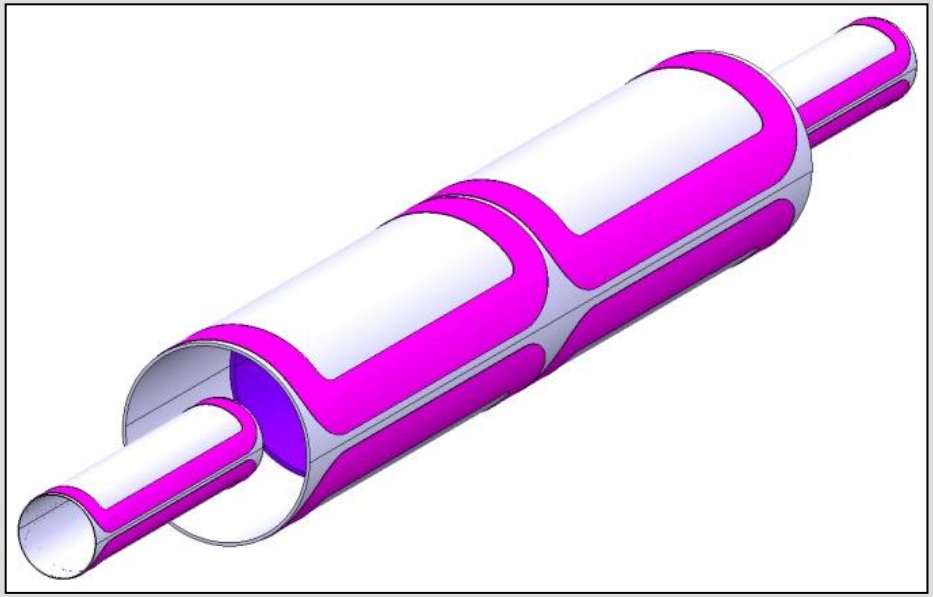


7.1 m long solenoid combined with
two 6m long dipoles and
two 3m smaller radius side dipoles

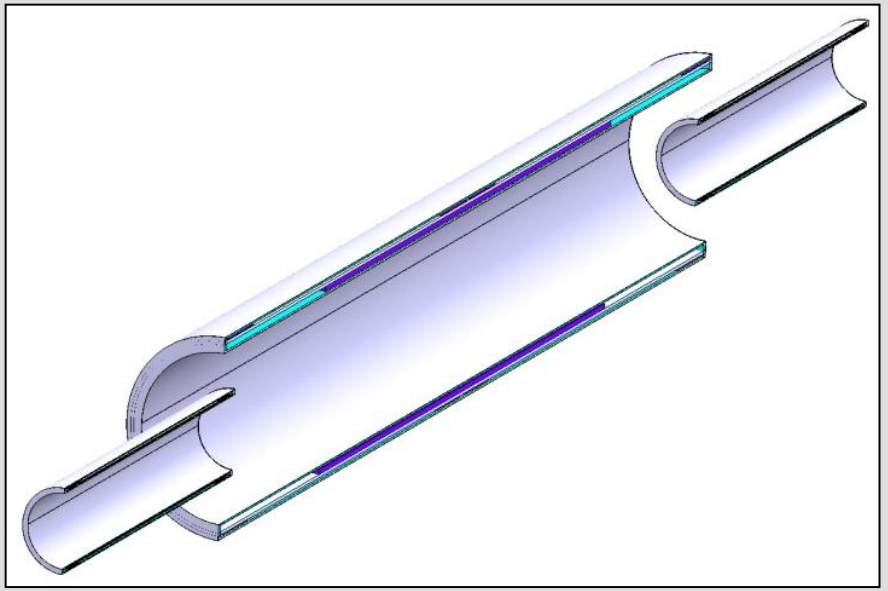
Dipole 0.4T on axis, 0.8T in windings
10 kA, ~3.5 MJ each, ~8MJ in total
10mm thick winding pack, ~260t force/6m

Small solenoid – dipole layout

- Dipoles wound on top (low return field) of Solenoid and put in single cold mass and cryostat, effective thickness ~150mm Al alloy
- Identical side dipoles in separate cryostats positioned outside and at both ends of the detector



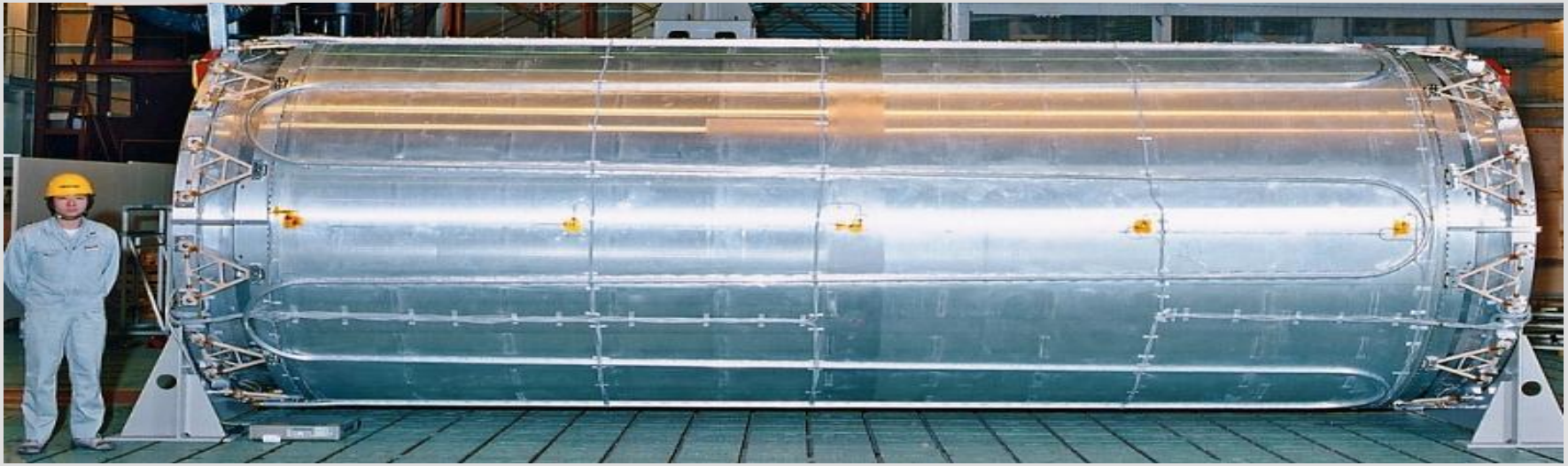
Solenoid and Dipoles on 1 coil former
12m long central part
and 2 x 3m side coils



Cryostat longitudinal section
About 250mm thick
including 150mm Al alloy material

LHeC Solenoid 3.5T - 2.24mD - 7.1mL

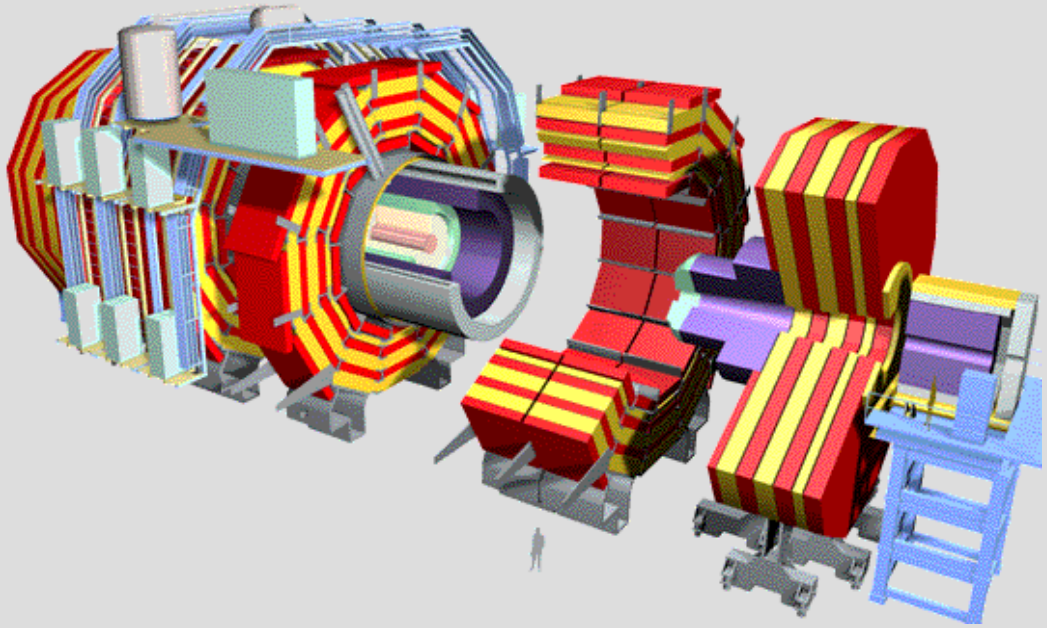
Looks like…?.... ATLAS solenoid, 2T scaled up to 3.5T (2 layers)



- A relative small but long, thus very efficient coil
- 2.24 m free bore, 7.1 m long (~8m external size)
- 21 MA-turns, ~ 15km conductor of 10kA
- ~ 160 MJ stored energy,
- ~ 25-30 tons including cryostat

LHeC Solenoid 3.5T - 6mD - 12mL

- Looks like…?.... 4T CMS scaled down to 3.5T and a bit shorter



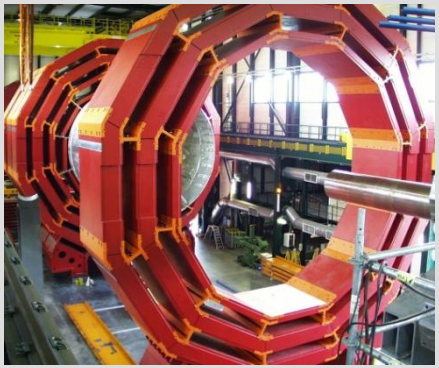
- A big and very long with iron shielding
- 6 m free bore, 12 m long
- 38 MA-turns, ~ 40 km conductor at 20 kA
- ~ 1.9 GJ stored energy (12 times more than with small solenoid)
- ~ 200-250 tons coil + 10k tons iron (about 200-300 times heavier)

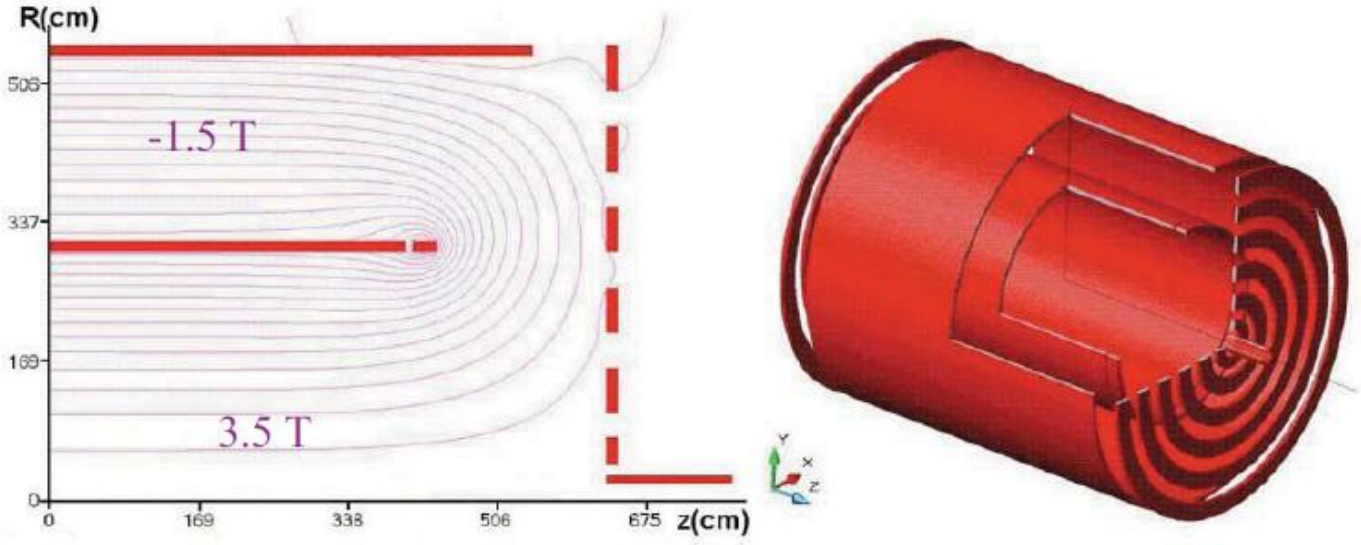
Iron or actively shielded solenoid

Flux return by active outer solenoid in stead of iron: much lighter, more elegant, muon tracking space for “free”, possibly cheaper as well

4th detector design for ILC
3.5T in 6mD - 9mL

- inner solenoid like CMS
- outer solenoid and end coils driven in opposite direction
- zero fringe field
- outer solenoid is “only” big
- iron-free (less massive by 15,000 t)



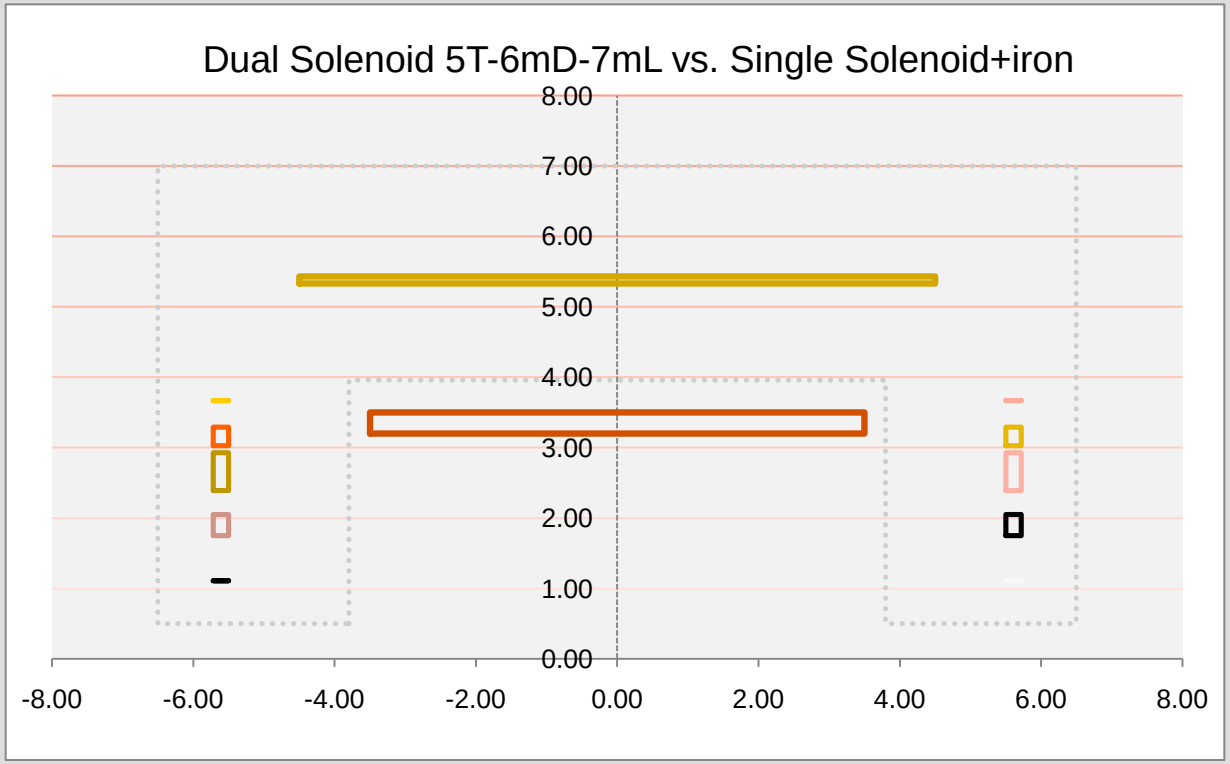


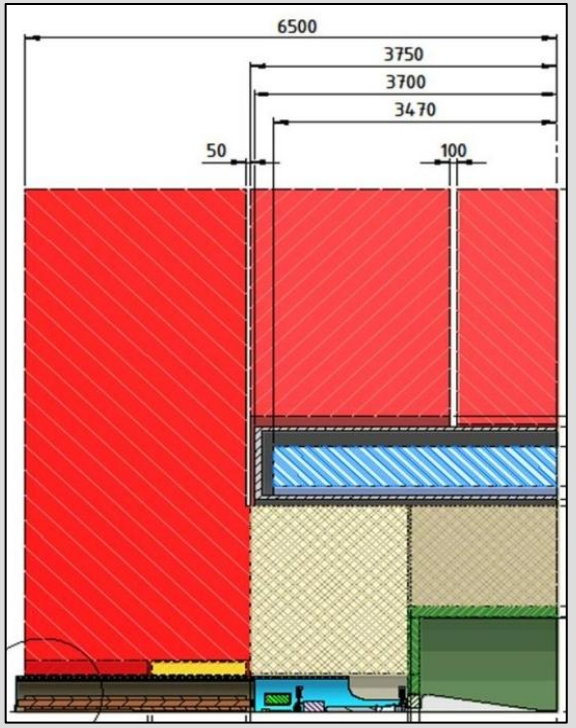
Example LCD-CLIC SiD 5T-6mD-7mL

Alternative Conceptual Design of a 5T CLIC detector magnet

50% smaller, 20 times lighter, easy to move, “modern in 2025-2035”

(but not X-ray closed, like ATLAS and most detectors are not hermetic)





~400t Solenoids + ~200t Structures = ~600t only!

And a nice ~3T muon tracking volume for free

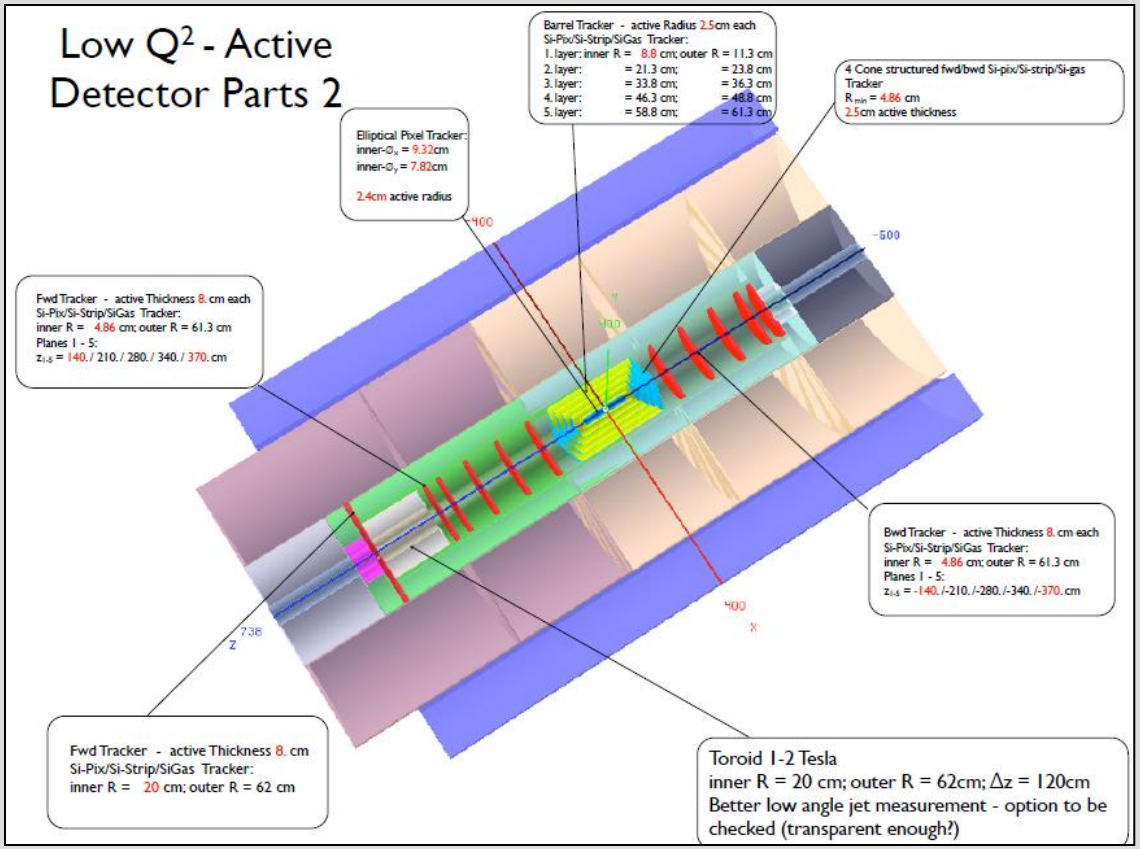
~ 14000t iron

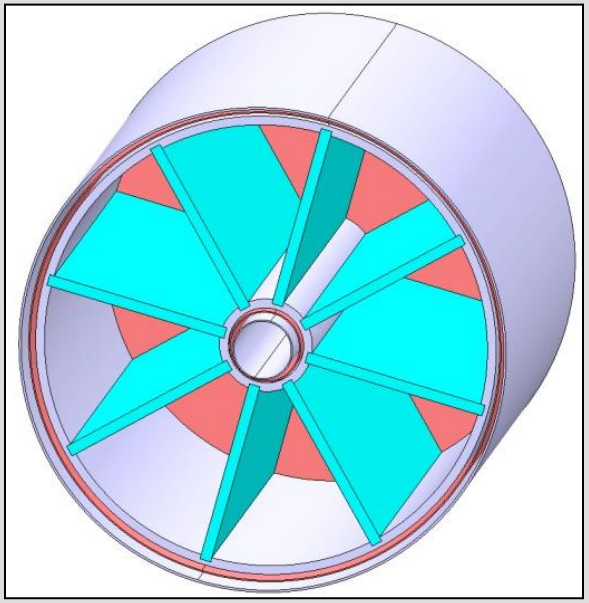
~ 20 times heavier !

Heavy and expensive

Forward superconducting Toroid

- Toroid to bend effectively the secondary particles in forward direction to better track jets, but minimize the radiation length
- Quick design made and option looks feasible





2 T Toroid
20 cm bore
size about 1 m^3

Conclusion

- ✓ LHeC detector requires a 3.5T Solenoid and two 9m long dipoles
- ✓ Solenoid can be put around the H-cal with 6m bore or around E-cal with 2.2m bore
- ✓ For the 3.5T/6m bore we see a CMS-like magnet with either classical 10k tons iron and an 0.4k tons active shielding coil
- ✓ For the 3.5T/2.2m bore solution an elegant solution is proposed by integrating the twin dipoles within a single 12m long cryostat
- ✓ For the big solenoid, a modern actively shielded magnet provides a modern, light and cost effective solution also offering a 1m gap for muon tracking
- ✓ Engineering all options in parallel is too much, so choose…..
- ✓ An optional toroid in forward direction seems feasible