Overall integration of target solenoid shielding and cryostats

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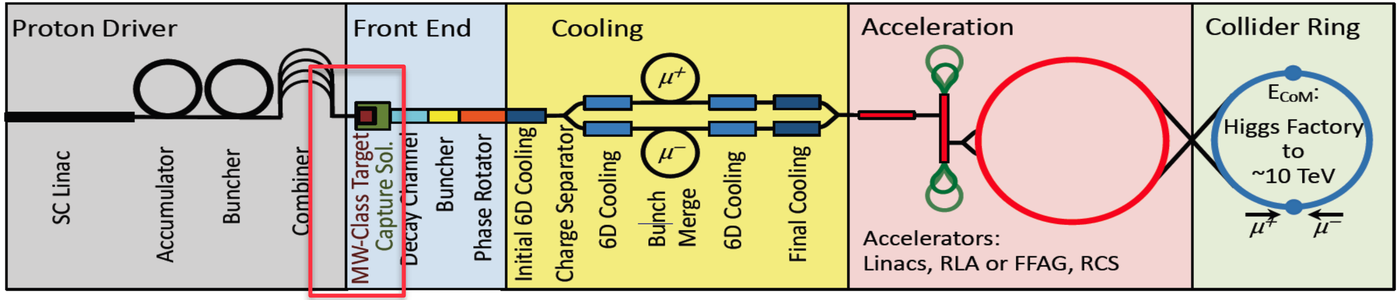
OUTLINE

- Introduction and challenges
- Lay-out overview
- Magnets' support concept
- Cryostat
- Tungsten shield & target
- Integration
- Conclusions

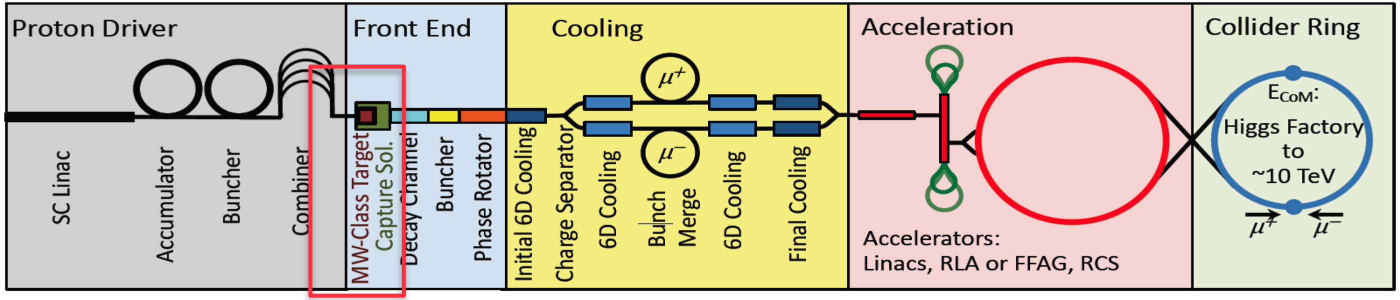
Introduction



"Few" challenges:

- ~MW target
- Large solenoid
- High magnetic field
- High radiation load→ shield
- High heat load

Introduction



"Few" challenges:

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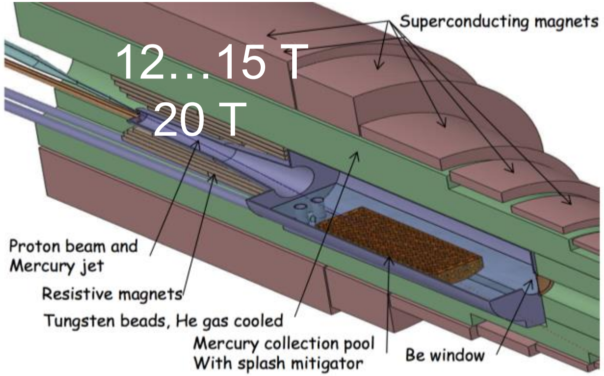
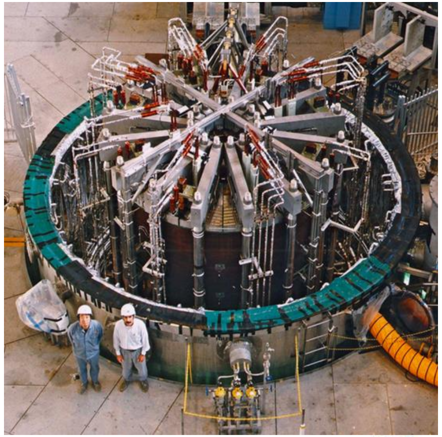
Initial inspirations

MAP target design, K. McDonald, et al.

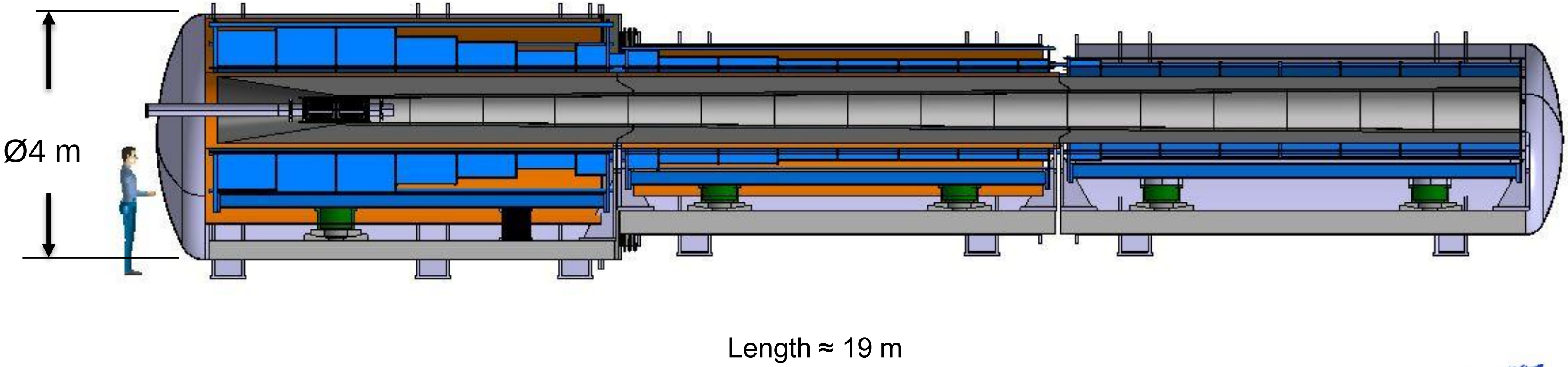


ITER central solenoid



Lay-out overview

- Based on magnetic design inputs
- 19m length



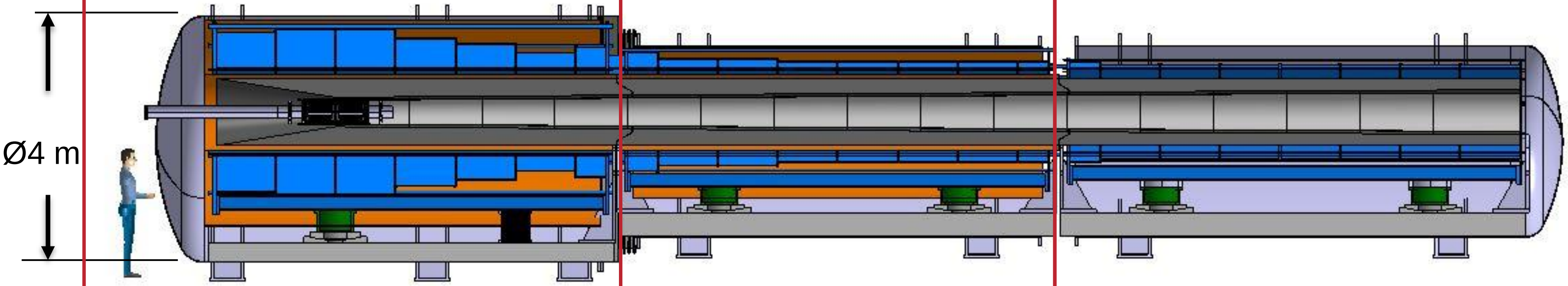
Lay-out overview: Weight

- Based on magnetic design inputs
- 19m length + >300tons → splitting in 3 sections

- Coldmass = 85000 kg
- Tungsten shield = 54000 kg(as solid)
- Vacuum vessel + support structure = 20000 kg
- **Total assembly = 159 T**

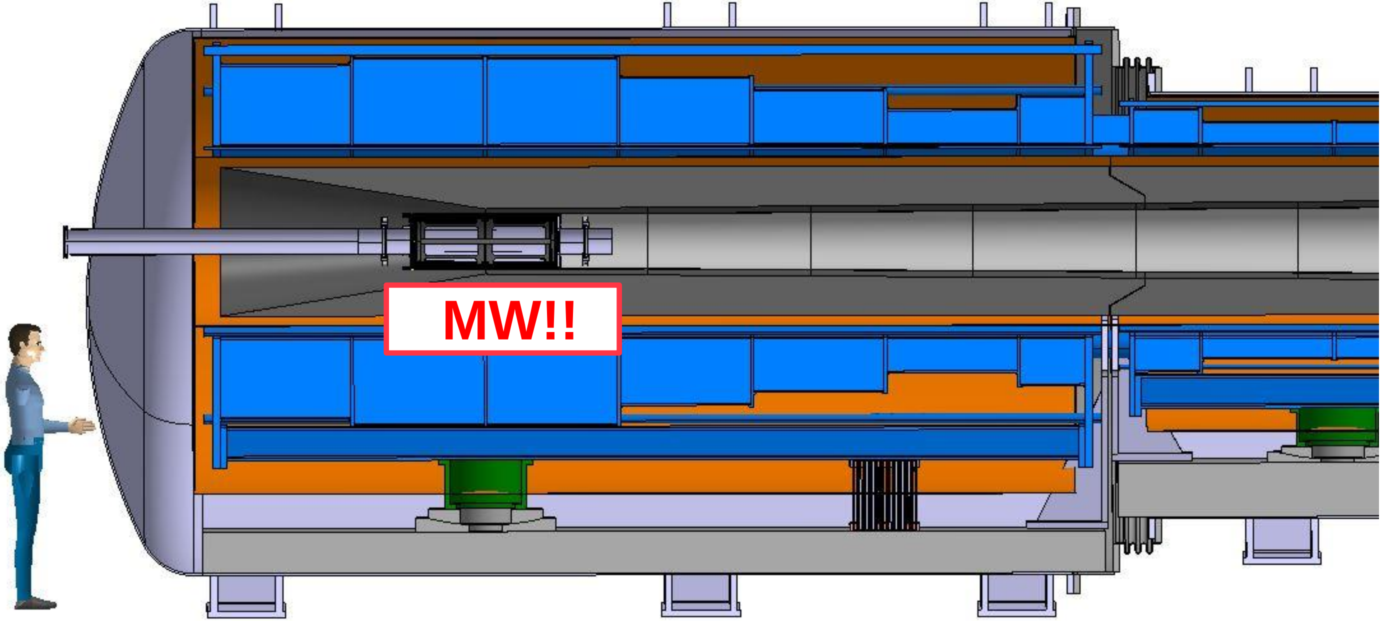
- Coldmass = 22000 kg
- Tungsten shiels = 54000 kg(as solid)
- Vacuum vessel + supports = 10000 kg
- **Total assembly = 86 T**

- Coldmass = 12000 kg
- Tungsten shield = 54000 kg(as solid)
- Vacuum vessel + supports = 10000 kg
- **Total assembly = 76 T**



Length ≈ 19 m

Lay-out overview: Temperature chart



15-20 K

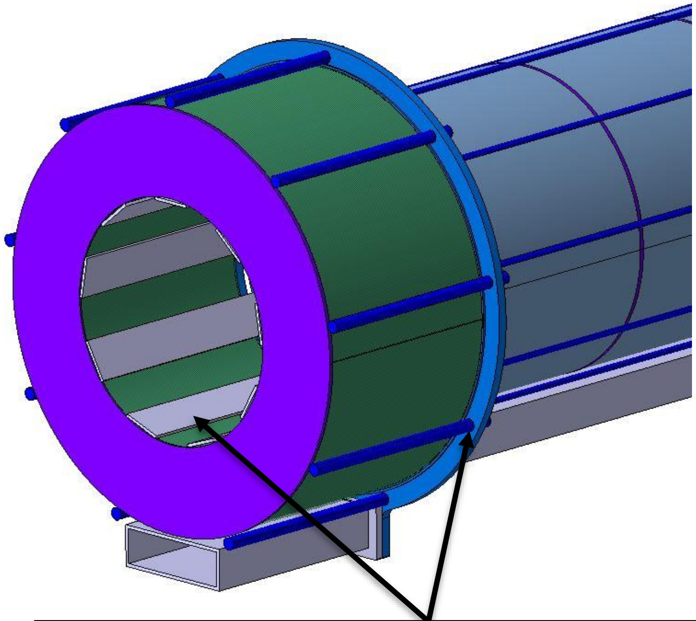
THERMAL SHIELD

SUPPORT 300 K – 20K

300 K

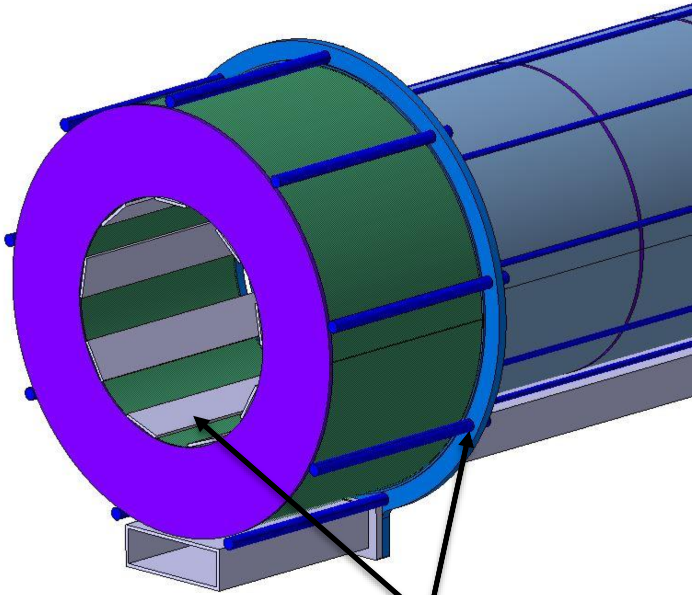
APPLIES TO ALL THREE SECTIONS!

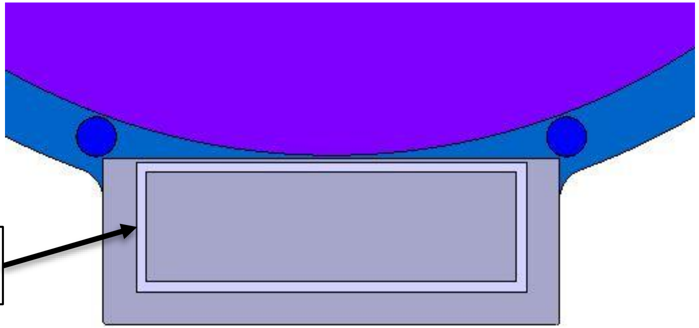
Coil assembly



2x/9x Ø60 rods/flat bars for clamp load to keep coils together until electromagnetic forces are created
Supports might need active cooling or another solution to guarantee the clamp load during cool down

Coil assembly





Beam for support interface

2x/9x Ø60 rods/flat bars for clamp load to keep coils together until electromagnetic forces are created
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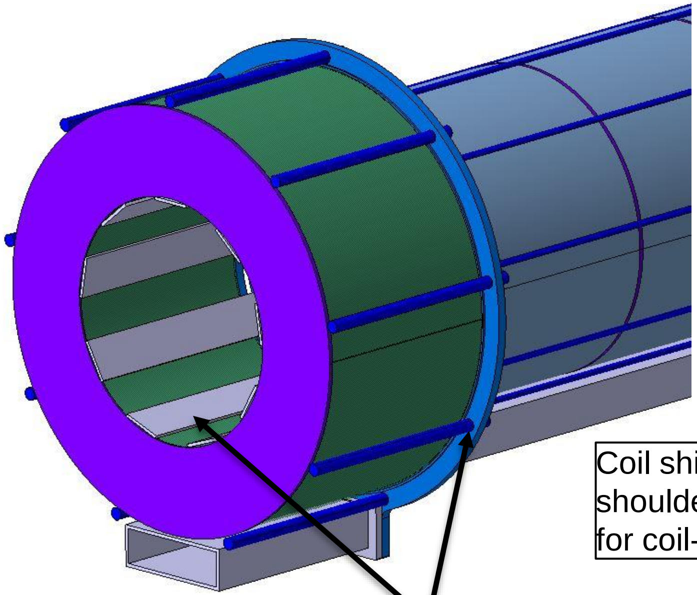
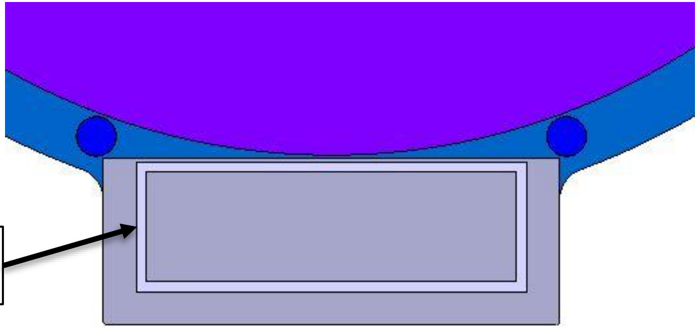
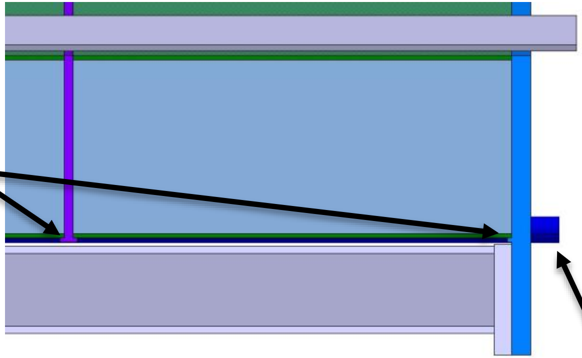




Beam for support interface

Coil shims and end plates with shoulders on external diameter for coil-to-coil centring



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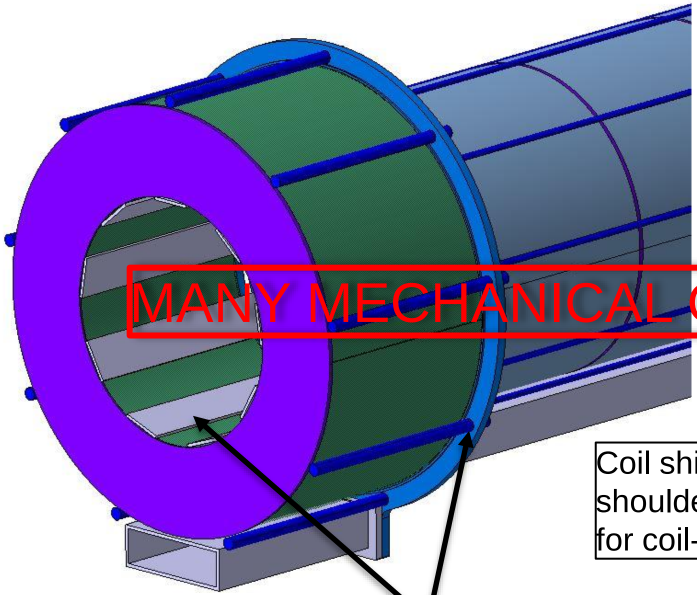
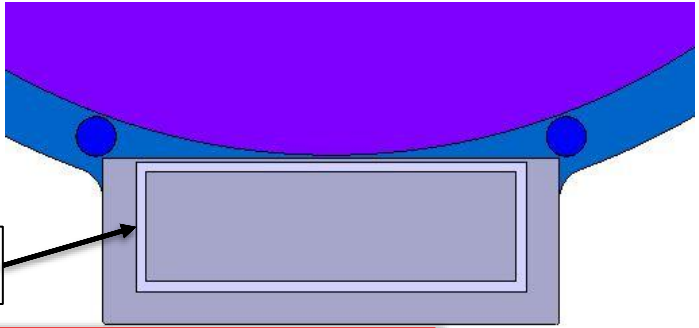
Supports might need active cooling or another solution to guarantee the clamp load during cool down

End plates and rod tensioning probably needs more space

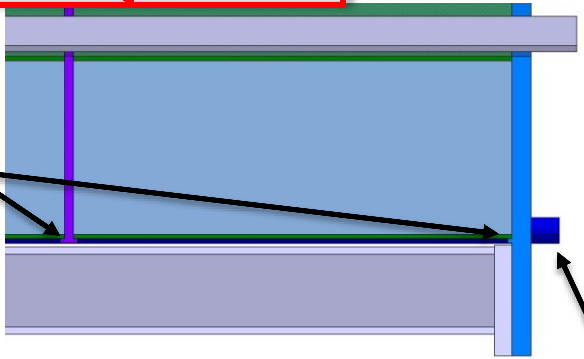
Coil assembly





Beam for support interface

MANY MECHANICAL CALCULATIONS REQUIRED!



Coil shims and end plates with shoulders on external diameter for coil-to-coil centring

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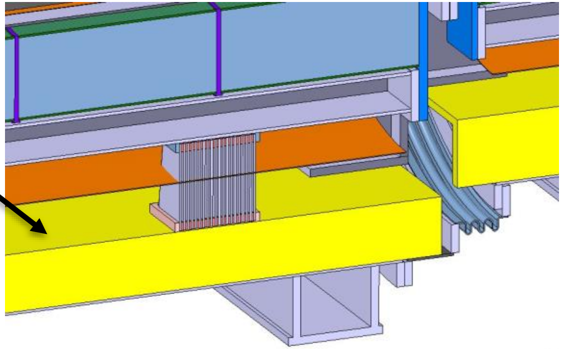
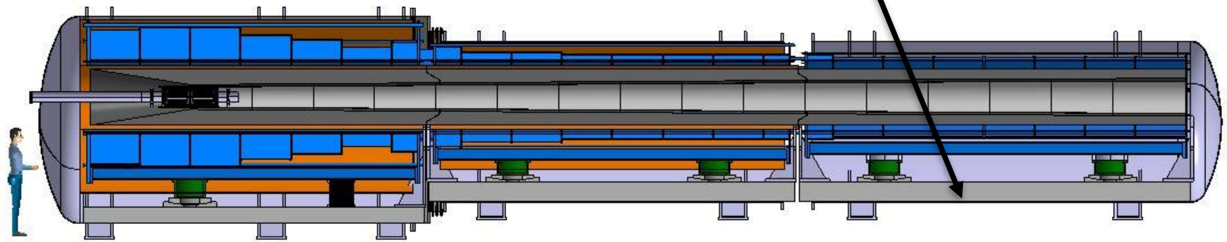
Coil assembly supporting

Support structure to transfer cold mass (and tungsten shield) load to cryostat supporting





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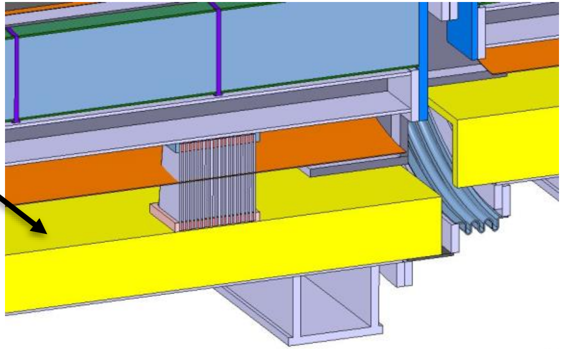
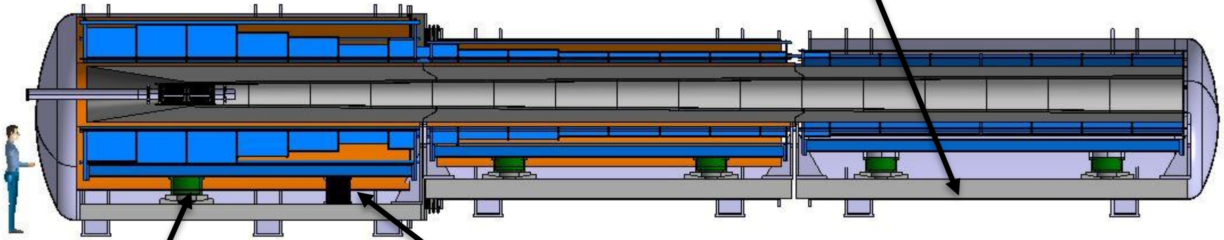




Fixed support

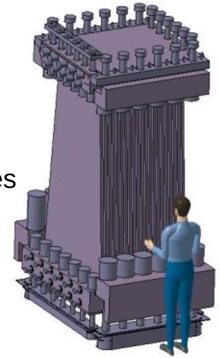
Charge 50 T

Flexible support

Charge 50 T

May be swopped

ITER inspired flexible support = several plates together



Courtesy of Jose Lorenzo

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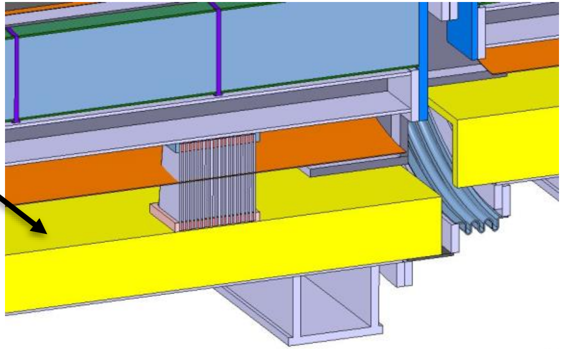
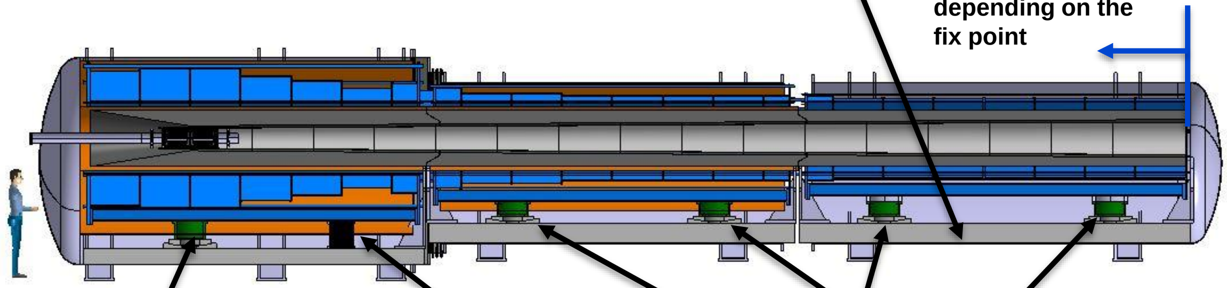


Thermal contraction(0.3%): 37 – 45 mm depending on the fix point



Fixed support

Charge 50 T

Flexible support

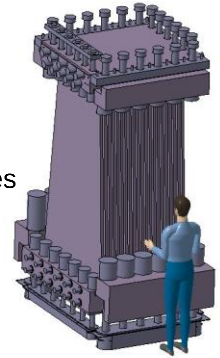
Charge 50 T

Sliding supports

Charge 15 – 6 T

May be swopped

ITER inspired flexible support = several plates together



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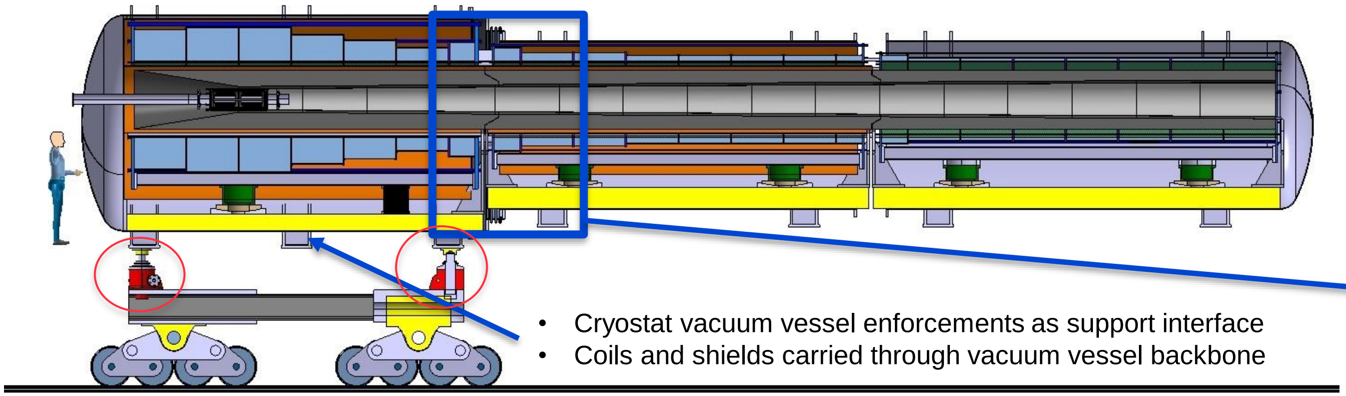
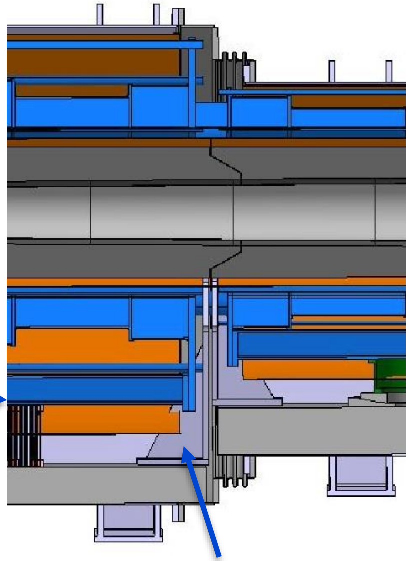
Sliding supports = GFRE supports on spherical bearing, shim the height = LHC dipole concept(similar mass)

Cryostat supports

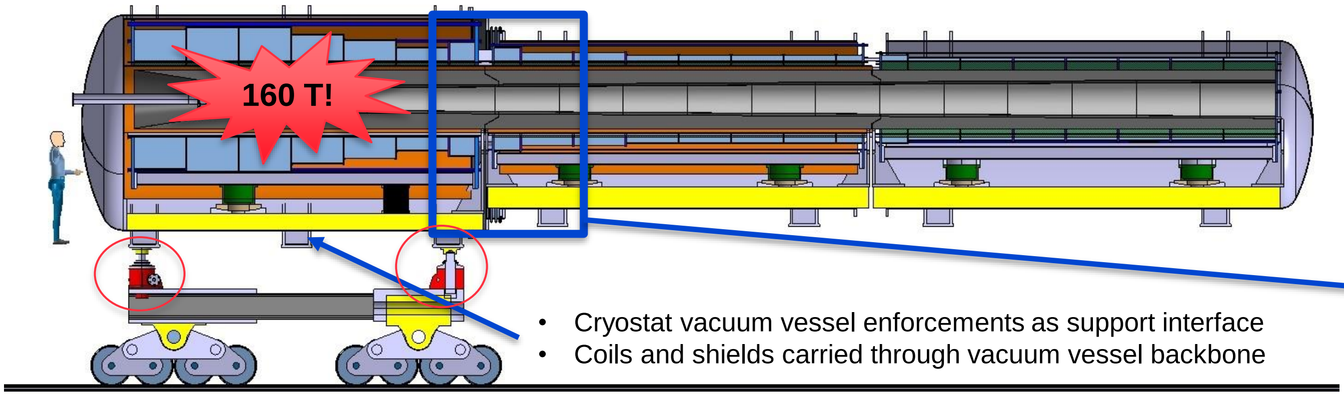


- Cryostat vacuum vessel enforcements as support interface
- Coils and shields carried through vacuum vessel backbone



- Tungsten shield carried through vacuum vessel backbone
  - All at 300K!

Cryostat supports



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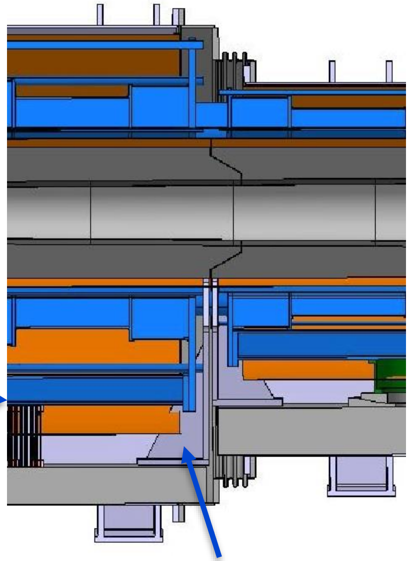

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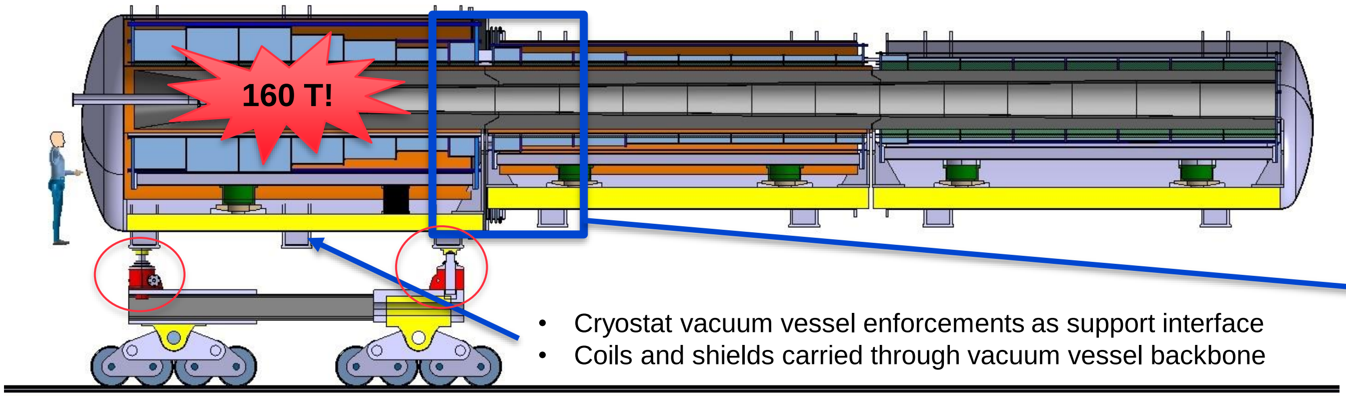
- Rail mounted carriage for the three sections
  - May be scaled according to section weight

Cryostat supports



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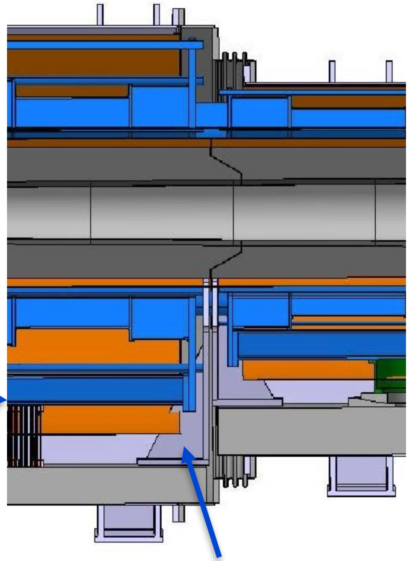
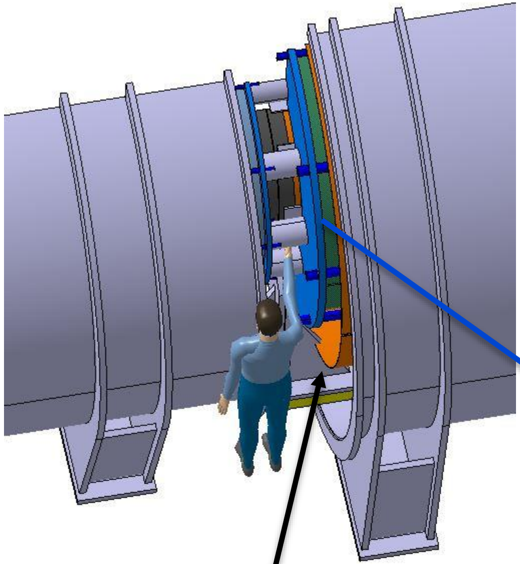


- Tungsten shield carried through vacuum vessel backbone
  - All at 300K!

- Rail mounted carriage for the three sections
  - May be scaled according to section weight
- Jacks for height and angles
- Lateral alignment system to be defined

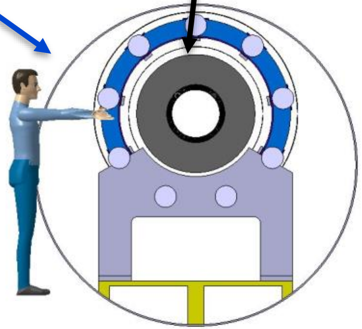
Coil gap

- 9x Ø168 bars for coil attraction force 40 MN(w/ zero gap) max
- Thermal shielding required
- Must be attached to the coil assemblies for thermal contraction w/o electromagnetic force – <u>may lead into hyperstatic supporting!</u>



The tungsten shielding and anything within it will be difficult to reach in the first opening

Gap = 480 mm, cannot be extended as the coldmass and tungsten shield are supported at vacuum vessel extremities

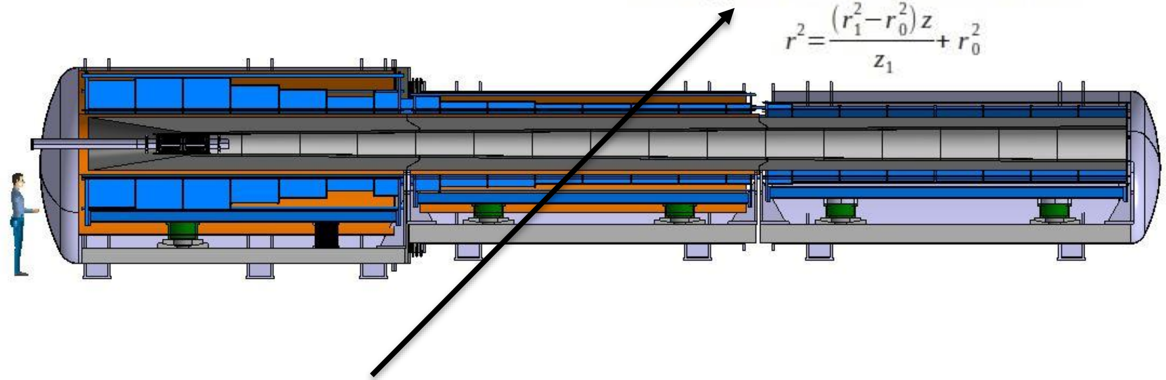


Tungsten shield

In target region fields are defined by a coil set

Beampipe radius in target area follows

$$r^2 = \frac{(r_1^2 - r_0^2)\,z}{z_1} + r_0^2$$



Inner radius defined by formula

- Sufficient clearance between the shield and the beam pipe is required

Outer radius estimated from the surrounding coils assembly with thermal shielding

- Resulting shield thickness to be assessed by radiation studies
- Simplified model weights 160 T
- Tungsten price > 100 CHF/kg

Cooling – see next slide

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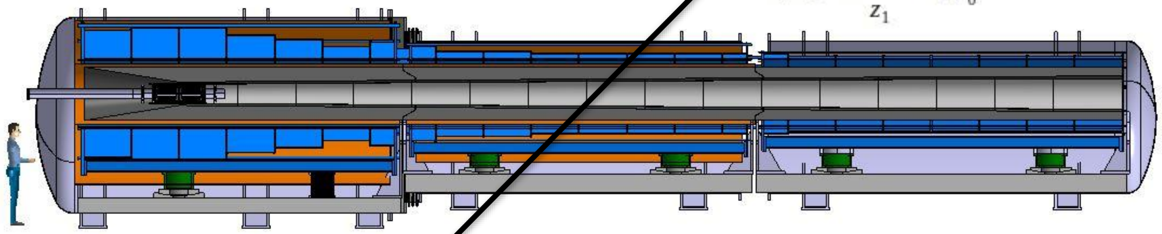

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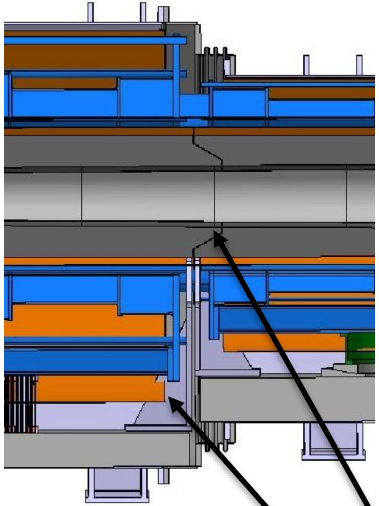
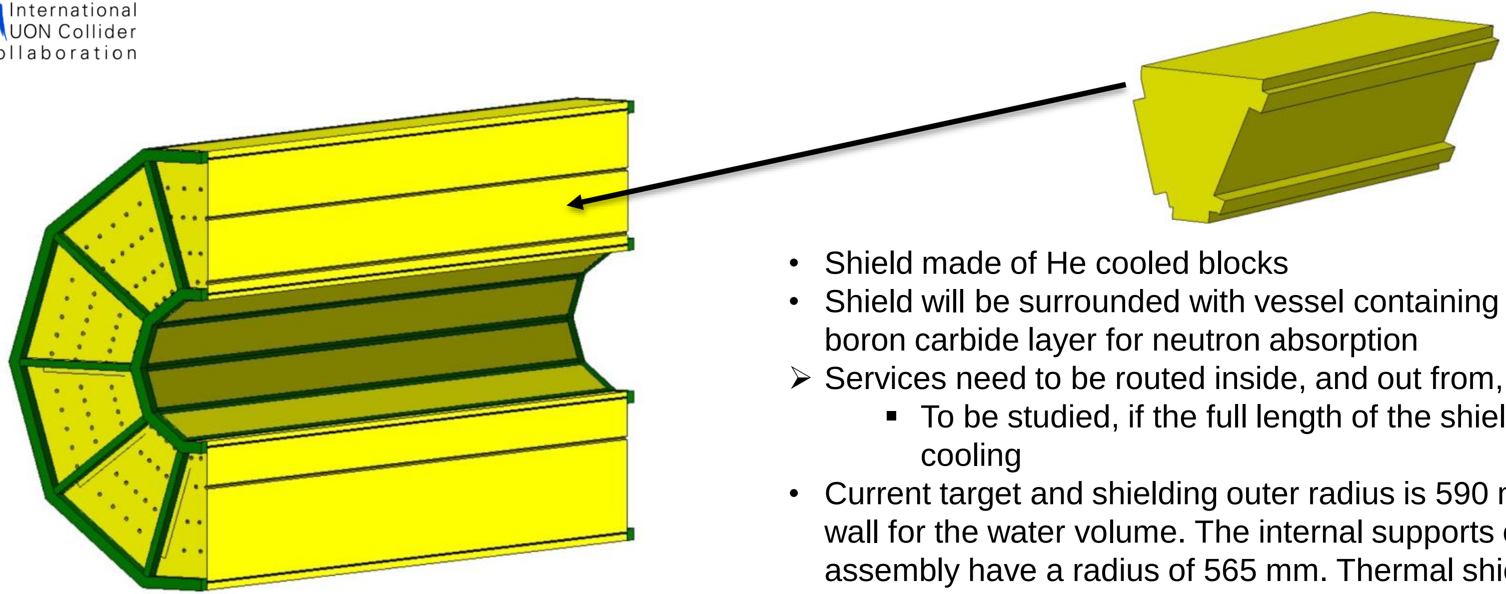


- Split into three sections of 50 T supported through the warm structure at the bottom of the vacuum vessel
- Conical interface to avoid gaps for radiation
  - Align w.r.t. the magnets to guarantee fit during the final assembly of the target magnets, no assembly actions on the shield at this point
- The temperature variation during operation?
  - the supports system must cope with it -> may lead to complication
- Mechanical behaviour, i.e. deformation to be studied
- Should target for service free life – can this be achieved?

Tungsten shield

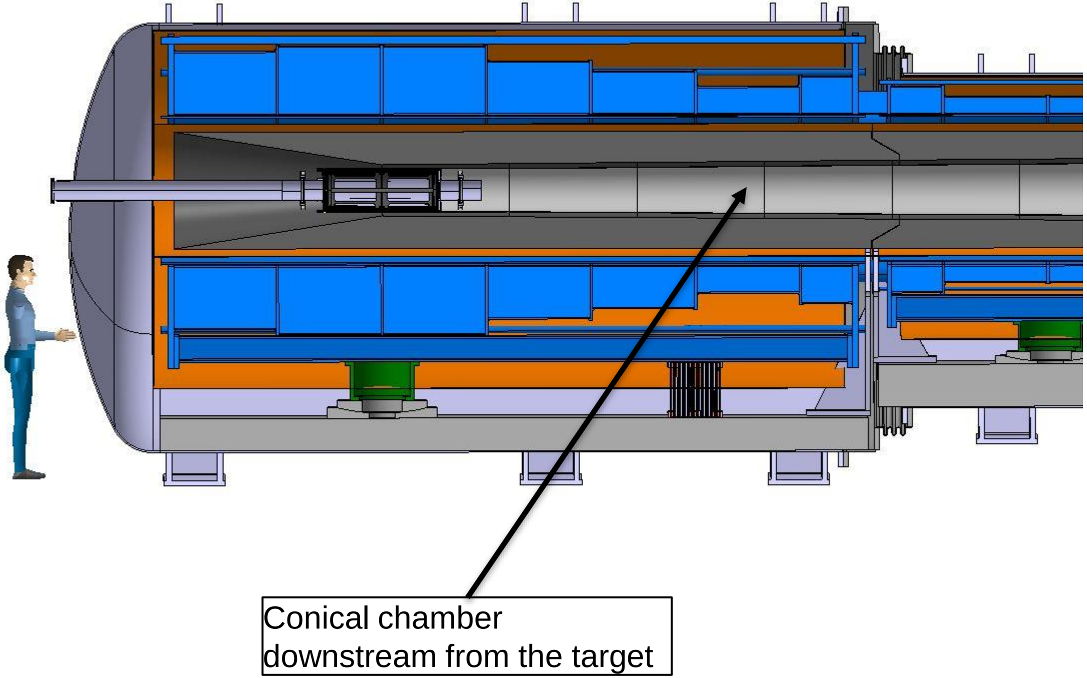


- Shield made of He cooled blocks
- Shield will be surrounded with vessel containing water and boron carbide layer for neutron absorption
- ➢ Services need to be routed inside, and out from, the cryostat
  - ▪ To be studied, if the full length of the shield requires cooling
- Current target and shielding outer radius is 590 mm + vessel wall for the water volume. The internal supports of the coil assembly have a radius of 565 mm. Thermal shield and gaps around it is required. A need for a cooling circuit on the thermal shield inside remains TBC. If we preserve 15 mm for the two gaps and 5 mm for the shield, we get 530 mm for the radiation shield outer diameter. Thus we have around 65 mm clash to solve.

For further details on the target – please see the talk of R. Ximenes, Design of the target system and shielding

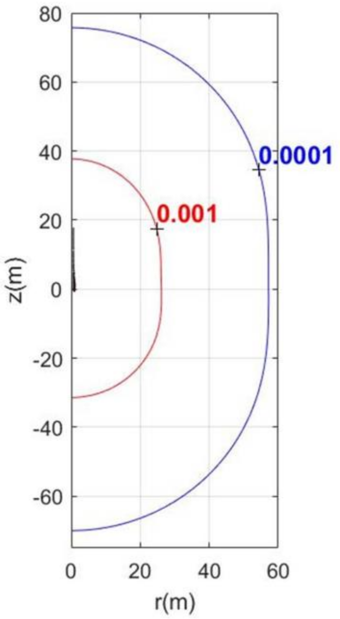
Target and beam vacuum

- One conical beam vacuum chamber downstream from the target
- Insert from downstream side, 15 m clearance required downstream from the cryostat
  - Installation order & minimized service
- Move assembly upstream to allow target service
  - Must be with robot due to radiation
  - Upstream equipment might have to be removed for service.
  - Enough clearance between vacuum chamber and tungsten shield required
  - Support system must allow this
- Beam instrumentation inside the cooling channel?
- Beam vacuum level and the required technology to achieve it?
  - E.g. Bake-out system required?



Magnetic shielding

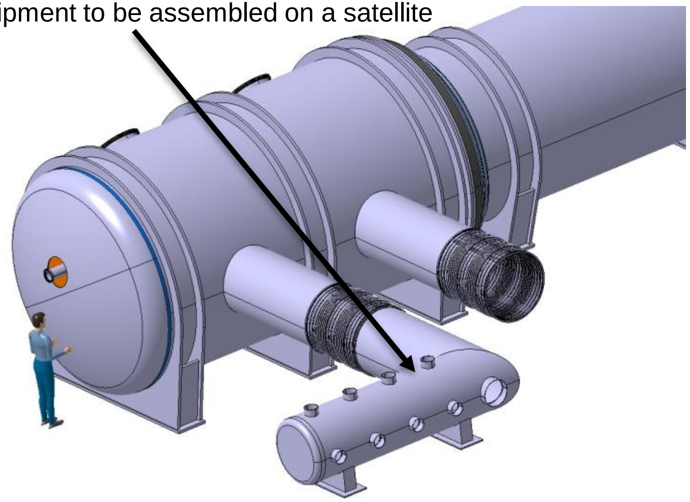
Magnetic field around the target solenoid
- **Red** = 1 mT
- **Blue** = 0.1 mT



Courtesy of Alfredo Portone

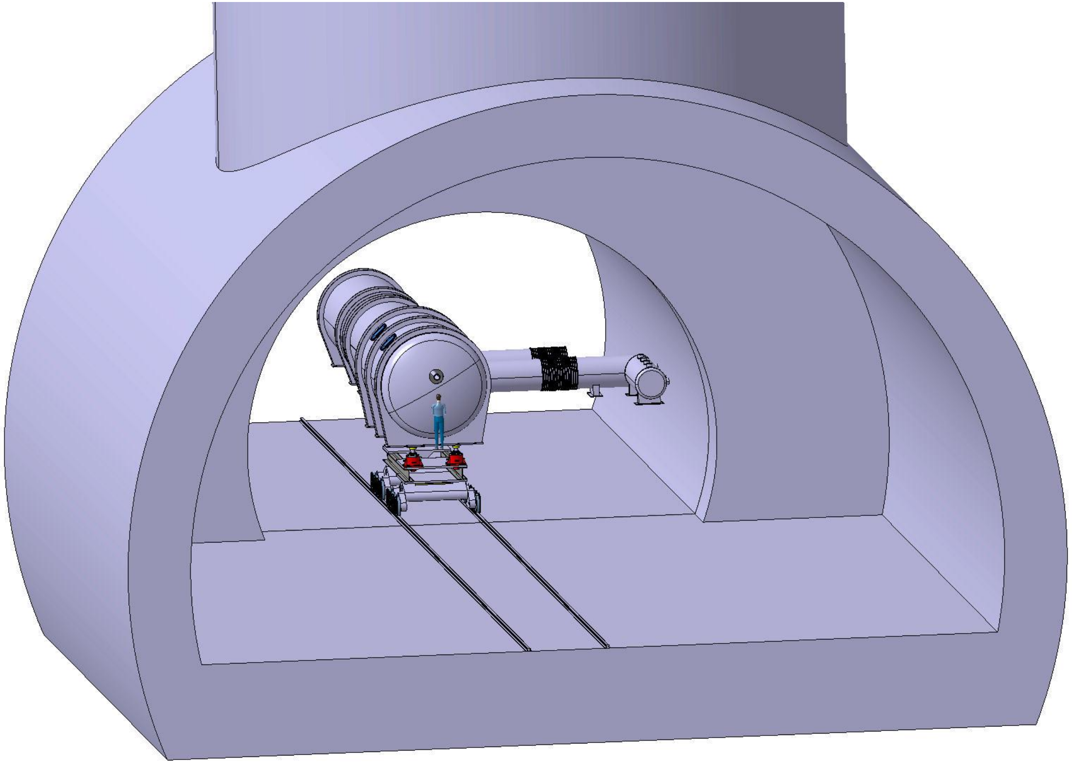
- We assume a magnetic shield is required
- To be studied in detail
  - Could be massive if made of iron
  - Coils for magnetic shielding – no details for now

- Instrumentation inside the cryostat?
- Vacuum pumps and other equipment, if any, in the magnetic field – some pumps tolerate 5.5 mT
- ➢ All possible equipment to be assembled on a satellite



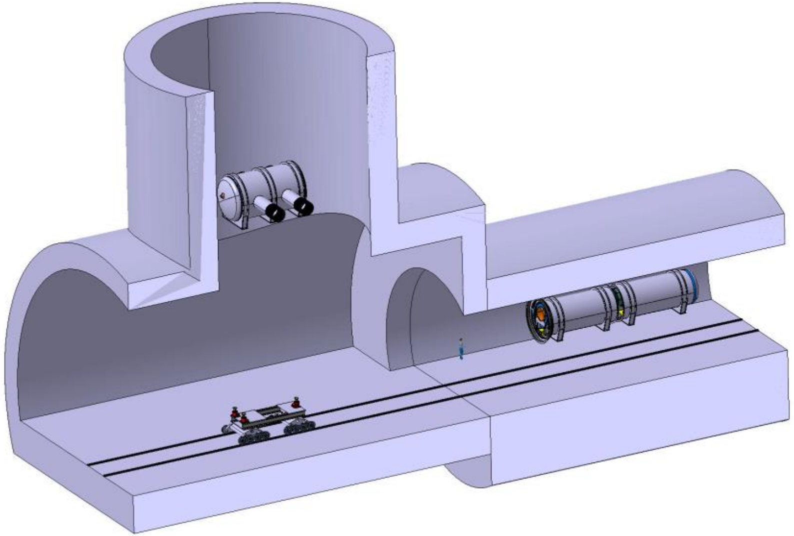
Tunnel – first look

- Tunnel diameter 15 m
- Tunnel height 10 m
- Installation shaft diameter 16 m, can be less if defined by the first section(L ≈ 7 m) of the target and capture installation
- Shaft cavern diameter 26 m
- Shaft cavern height 15 m



Installation

200 T crane required to lower
the sections to the tunnel



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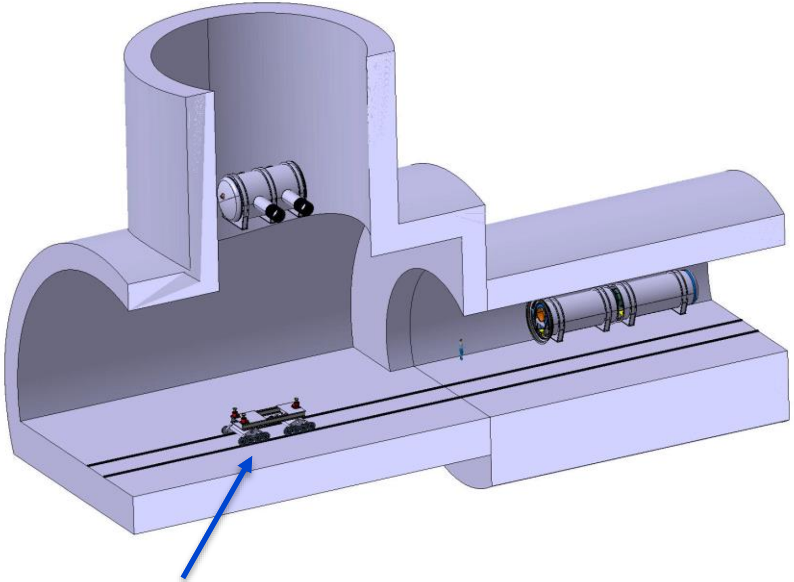

Rail carriages to transport sections

Installation

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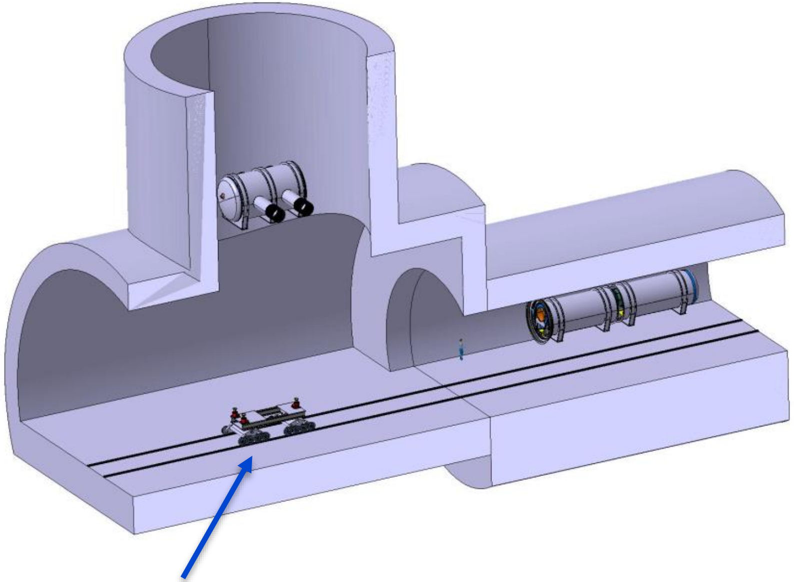

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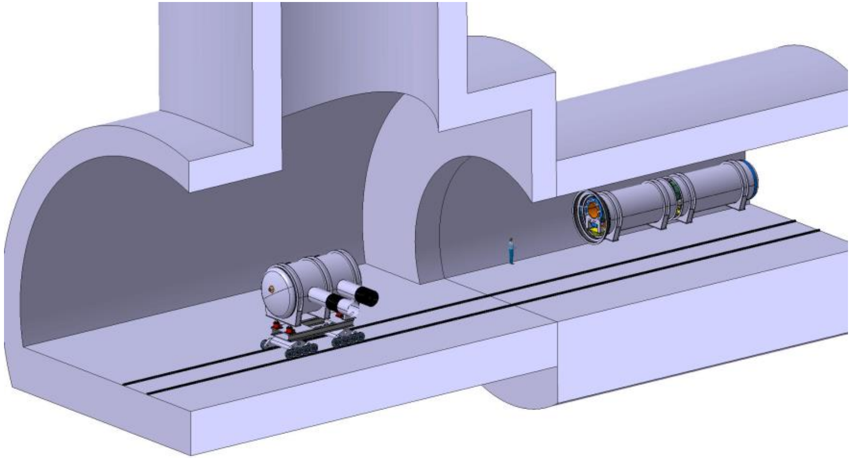

- Carriage drive system to be defined
- Transport sections one by one to rough position
- Alignment system for final positioning
- Connection of the three sections and all services

Past layout studies R. F. Ximenes et. Al, 1st Muon Community Meeting

Conclusions

- A preliminary integration study of the target solenoid assembly has been performed:
  - Muon collider target and capture assembly is **19 m long and 320 - 350 T** cryostat which could be divided into three sections, **max 160 T**, for handling and installation
  - A preliminary supporting system for coil and cryostat is proposed: cold masses of **85 T, 22 T** and **12 T** requiring robust cold supports allowing also thermal contraction
  - Coils are protected by a > **100 T** tungsten shield requiring active cooling and room temperature supports inside the cryostat
  - Beam vacuum system may include a 15 m chamber requiring large space for assembly, target service would also need a significant space
  - Very high magnetic field may lead into issues with cryostat instrumentation and equipment
  - High radiation levels are expected. How to service sub-systems during the lifetime? Disposal at the end of the life?
- **Updated design after defyning final parameters: maximum dose on the coil→minimum shield volume→coil aperture→ thermal shield and cryostat**

International
MUON Collider
Collaboration

CERN

Thank you for your attention!
Your questions please?