Status of the 11T cryo-assembly design and integration

Presented at ColUSM #34, February 21, 2014

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Outline

- Recall from last talk (January 2013)
- What are we looking for in the new solution
- The 11 T cryo-assembly
- Main integration issues
- Status of the cold mass and cryostat design

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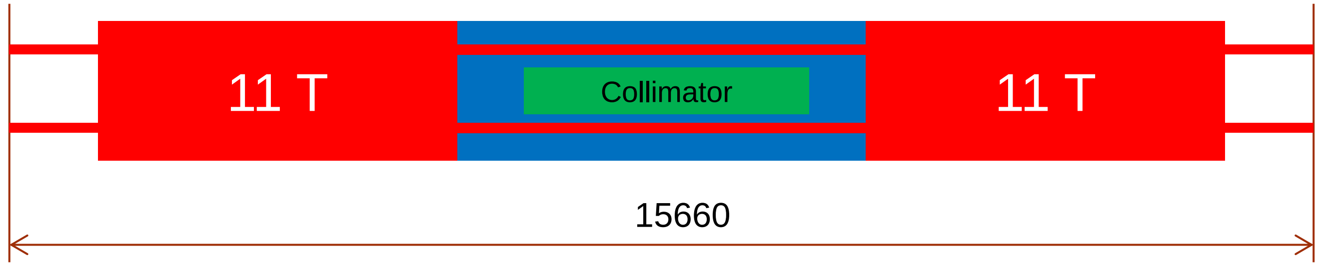
From last talk (Jan. 2013)

- Cold collimator discarded. The baseline is a **room temperature vacuum baked collimator**.
- Remove one MB cryo-magnet and replace it with a new cryo-assembly of **equal length**, integrating:
  - 2x 11T short magnets
  - 1 collimator
- Longitudinal integration benefits from placing the **collimator in the middle**
- Fitting within the **15660 mm length** of a standard MB is a challenge



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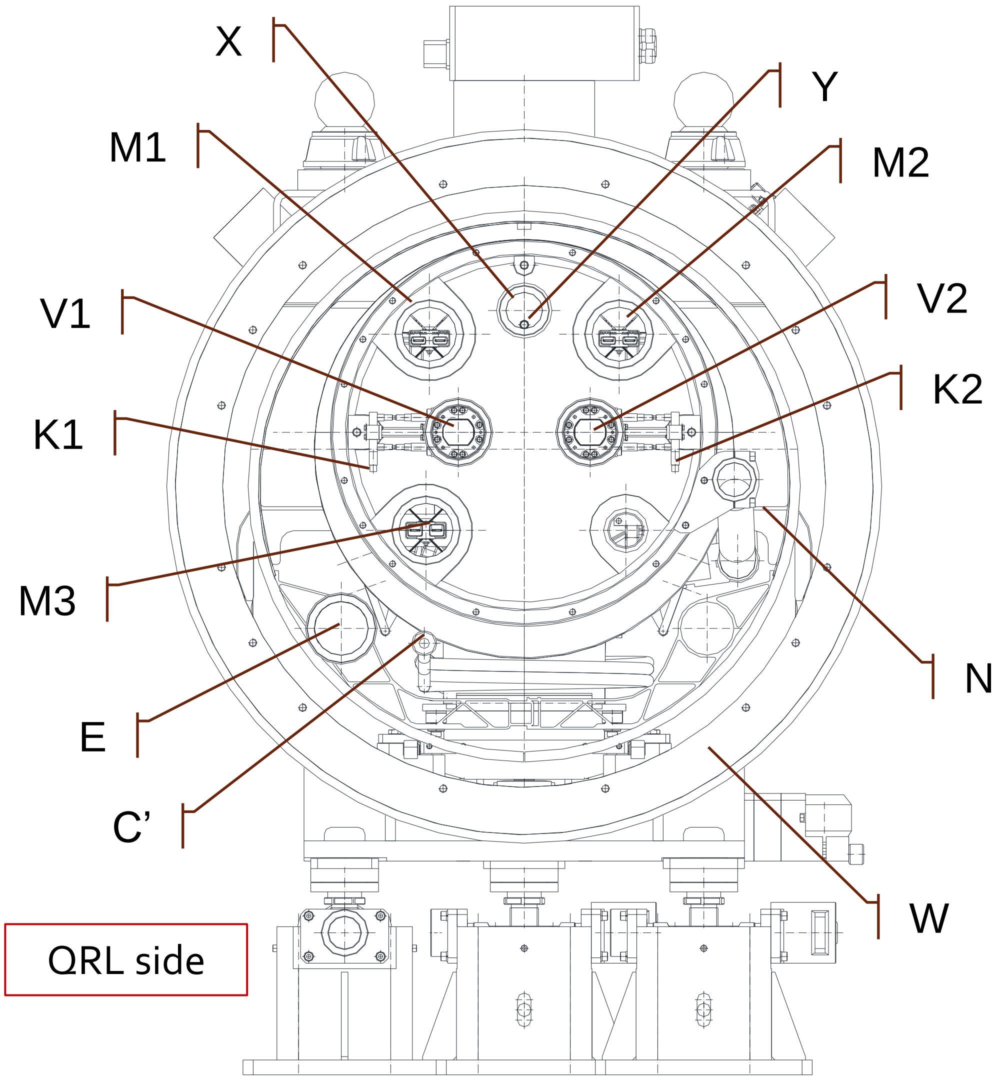
Aim for full interchangeability with a standard dipole

(no changes to neighbouring cryomagnets)



- No changes to cryo, electrical or mechanical interfaces (different jack's position is inevitable)
- 15660 mm long, interc. included
- Inside the 11 T cryostat:
  - **X-line remains straight**
  - He II free cross section: 60 cm^2
  - Pressure drop of He II circuit: 4.3 kPa/m (50 mm smooth pipe)
  - Pressures and temperatures acording to LHC-Q-ES-0001 (edms 90032)

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Operation and maintenance

- Mechanical decoupling from cryostat and collimator for removal and alignment of collimator without warming up the arc ⇨ **bellows between collimator tank and cryostat**, **independent supports to the floor**, compatible integration
- One collimator design fits beam 1 and beam 2
- Minimise exposure to residual radiation ⇨ simplify removal/installation of collimator, ex. quick CF flanges, pre-aligned collimator support system, “rapid” electrical and hydraulic connections (but **not remote handling**), **permanent bakeout insulation**
- **Ports for “RF-ball” test** of new sectors
- Transport constraints: **Stay in the “shadow” of the existing arc cryostat**

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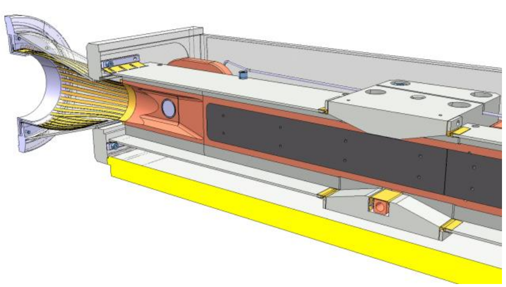
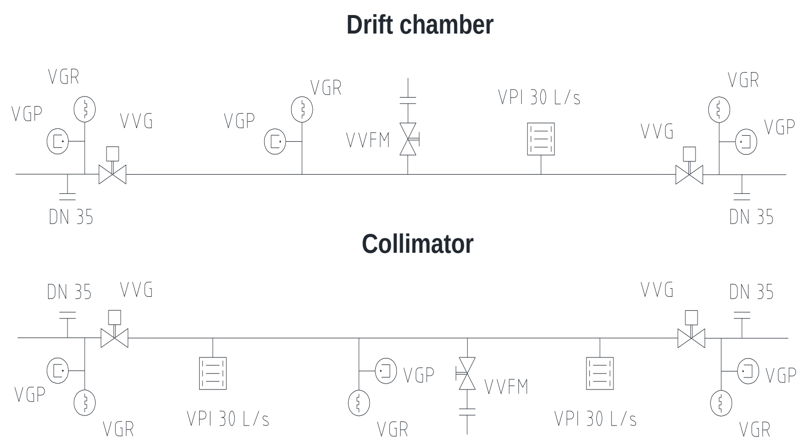
Vacuum

- **Room temperature (bakeable) collimator** vacuum operated and maintained independently from cold beam vacuum ⇨ **sector valves on both lines**
- Beam screens (K-line cooling) with same reliability and performance as rest or the arcs (no helium to beam vacuum welds, testing, etc.)
- No demountable vacuum tight joints in cryogenic system (all welded)
- Ensure pressure safety of each new beam vacuum "subsectors" ⇨ rupture disks on SSS ports
- Ensure pressure safety of insulation vacuum (DN 200's)
- Respect current RF-impedance requirements: ex. **shielded sector valves**, **shielded bellows**, **max 15º taper angle**





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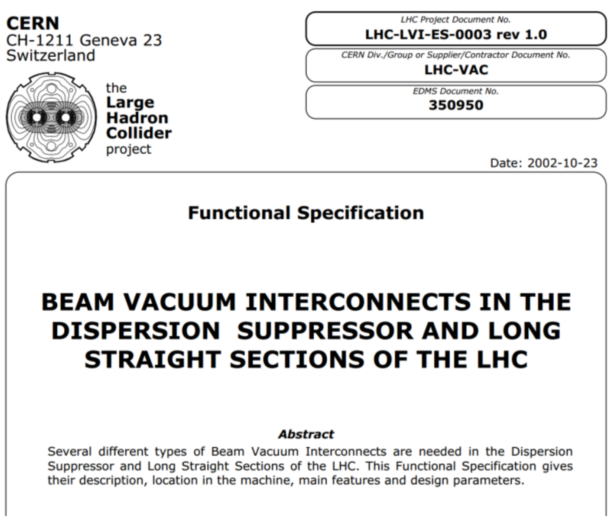
Thermo-mechanical

- **Busbar flexibility** must take into account **adjacent magnets**
- Temperature offset between cold mass and beam screen during transient
- Temperature variation between two cold masses during transient
- Cold to warm transitions on the beam lines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the
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project

LHC Project Document No.
LHC-LVI-ES-0003 rev 1.0

CERN Div./Group or Supplier/Contractor Document No.
LHC-VAC

EDMS Document No.
350950

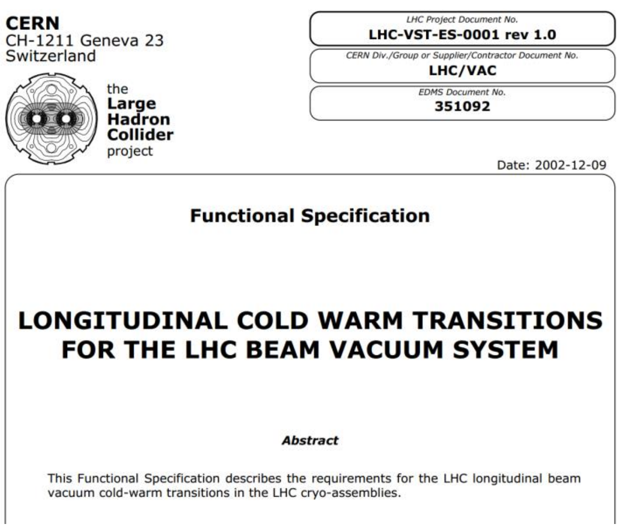
Date: 2002-10-23

Functional Specification

BEAM VACUUM INTERCONNECTS IN THE DISPERSION SUPPRESSOR AND LONG STRAIGHT SECTIONS OF THE LHC

Abstract

Several different types of Beam Vacuum Interconnects are needed in the Dispersion Suppressor and Long Straight Sections of the LHC. This Functional Specification gives their description, location in the machine, main features and design parameters.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LHC Project Document No.
LHC-VST-ES-0001 rev 1.0

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LHC/VAC

EDMS Document No.
351092

Date: 2002-12-09

Functional Specification

LONGITUDINAL COLD WARM TRANSITIONS FOR THE LHC BEAM VACUUM SYSTEM

Abstract

This Functional Specification describes the requirements for the LHC longitudinal beam vacuum cold-warm transitions in the LHC cryo-assemblies.

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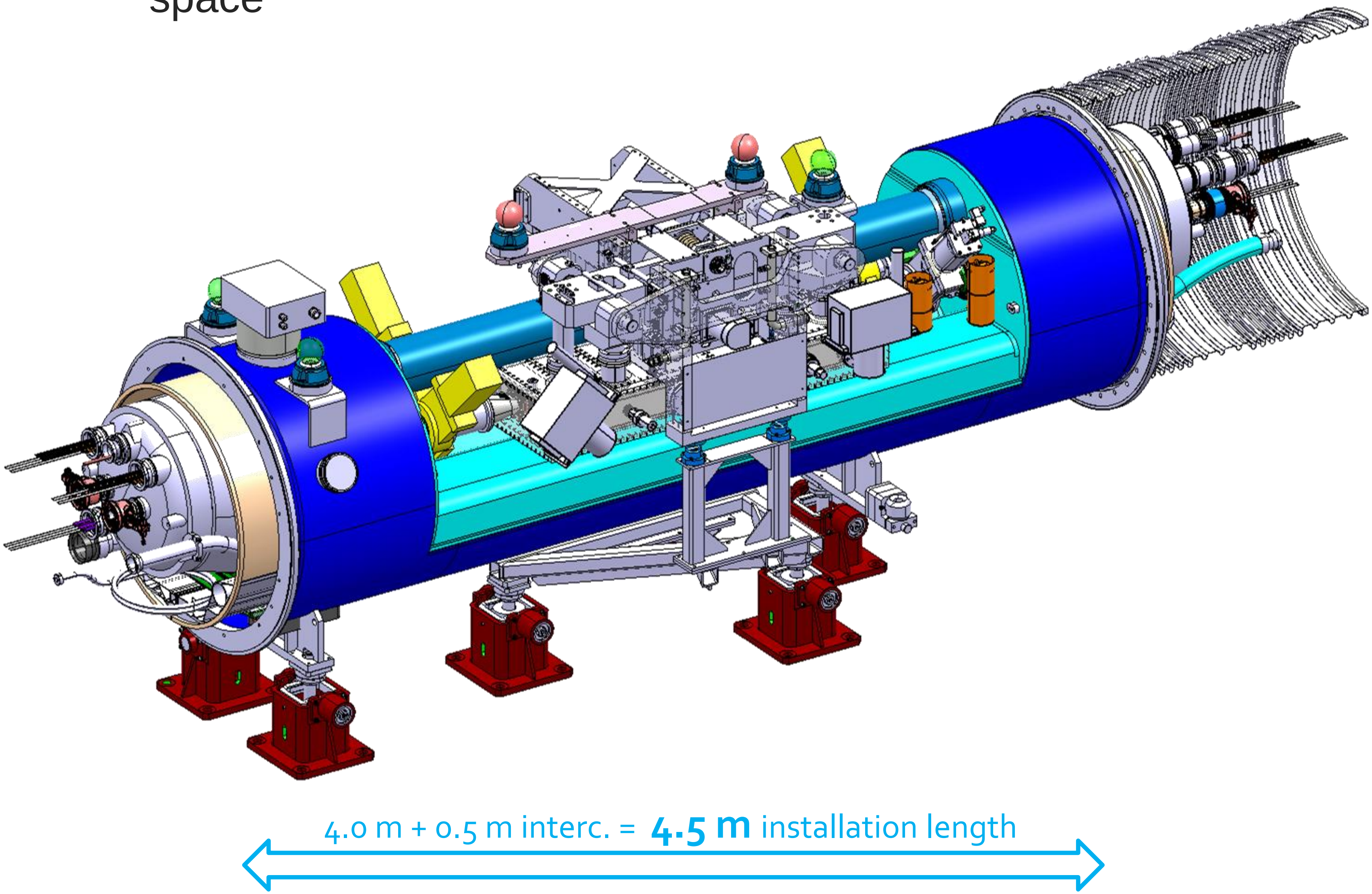
Before the 11 T magnet development: QTC (2010)

- Main drawback: extensive machine layout changes to create space



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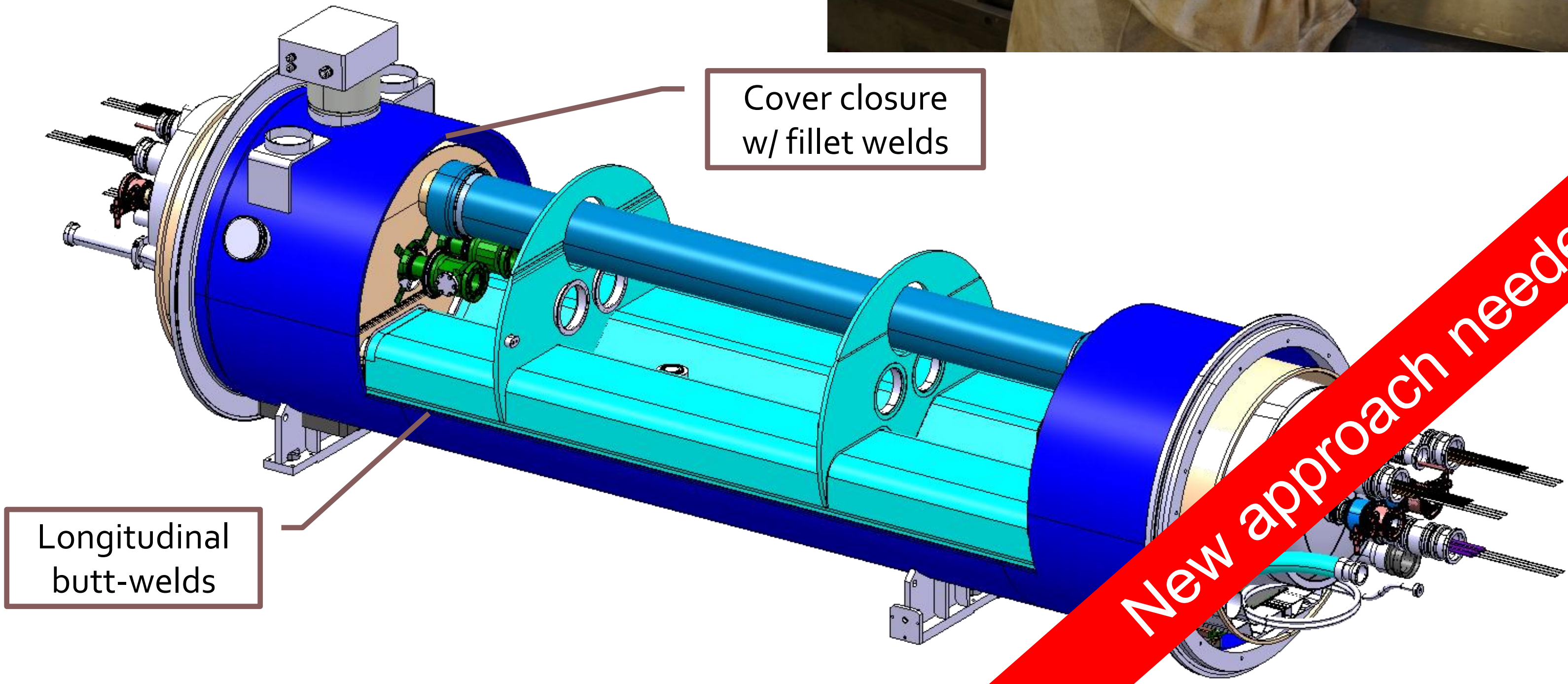
Could the QTC cryostat concept be "extended"?

- Can only be **finished after cryostating**
- Dealing with **welding distortions** is a major issue
  - **Distortions amplified with length**
  - **Adjustment of cold supports posts** is required
  - Complicated assembly procedure



New approach needed

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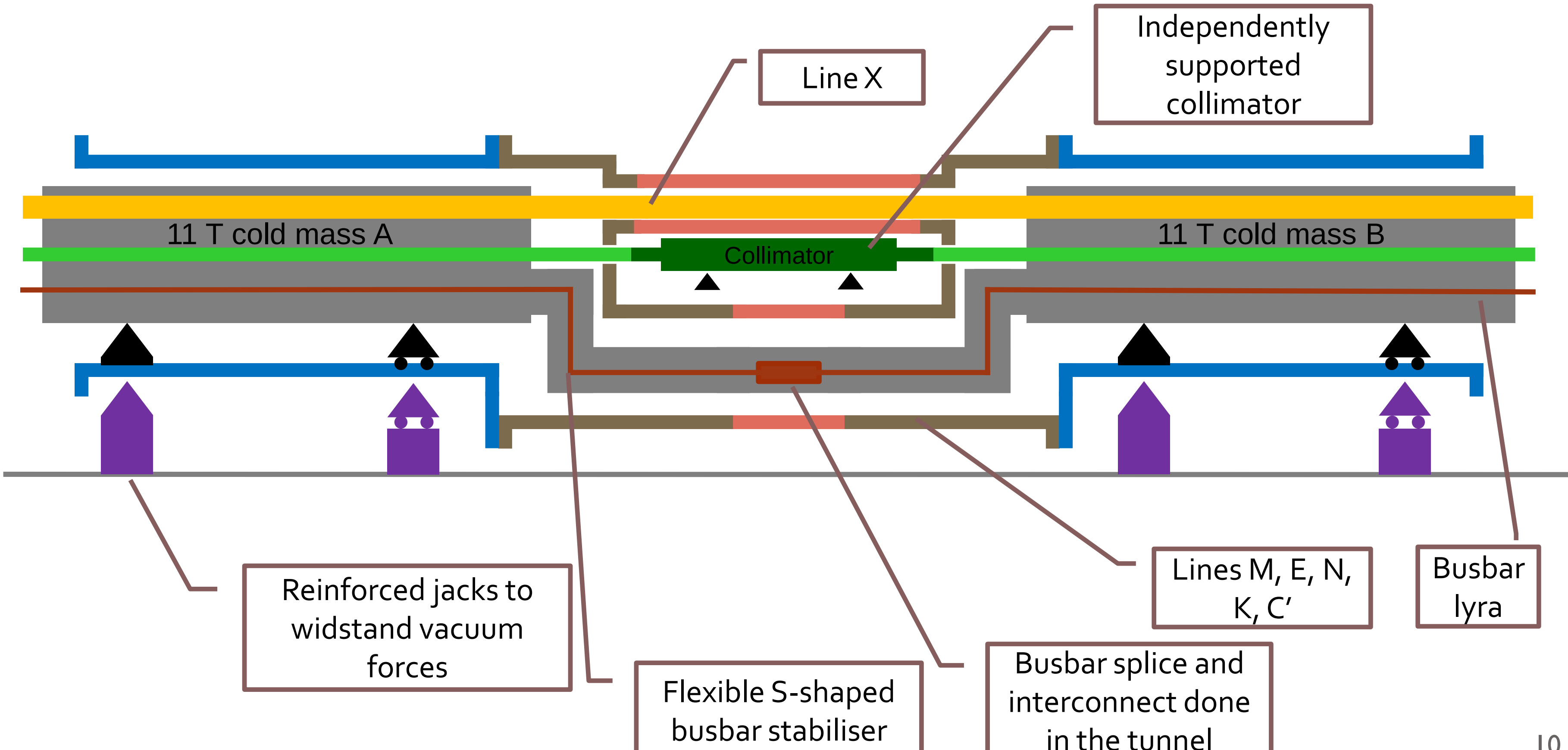
The 11 T cryo-assembly concept

- Independently cryostated and handled cold masses, linked through *two short transfer lines*
- Transfer lines with expansion joints mechanically decouple cryostats A and B
- Splice and piping interconnect in the tunnel, all other work prior to installation
- Can use the **existing TCLD collimator design** with modified the supports



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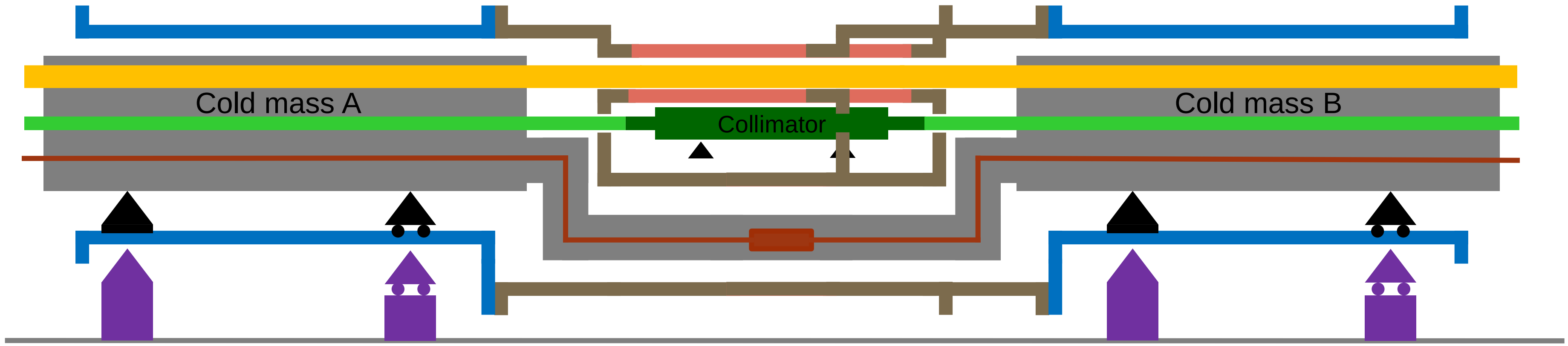
Access for in-situ repair



- Once the collimator removed, the vacuum vessel cover can slide open
- Good to have in-situ access for repair of «fragile» components:
  - Expansion joints
  - Flexible hoses
  - Diode
  - Instrumentation feedthrough (IFS)
  - Current leads (?)

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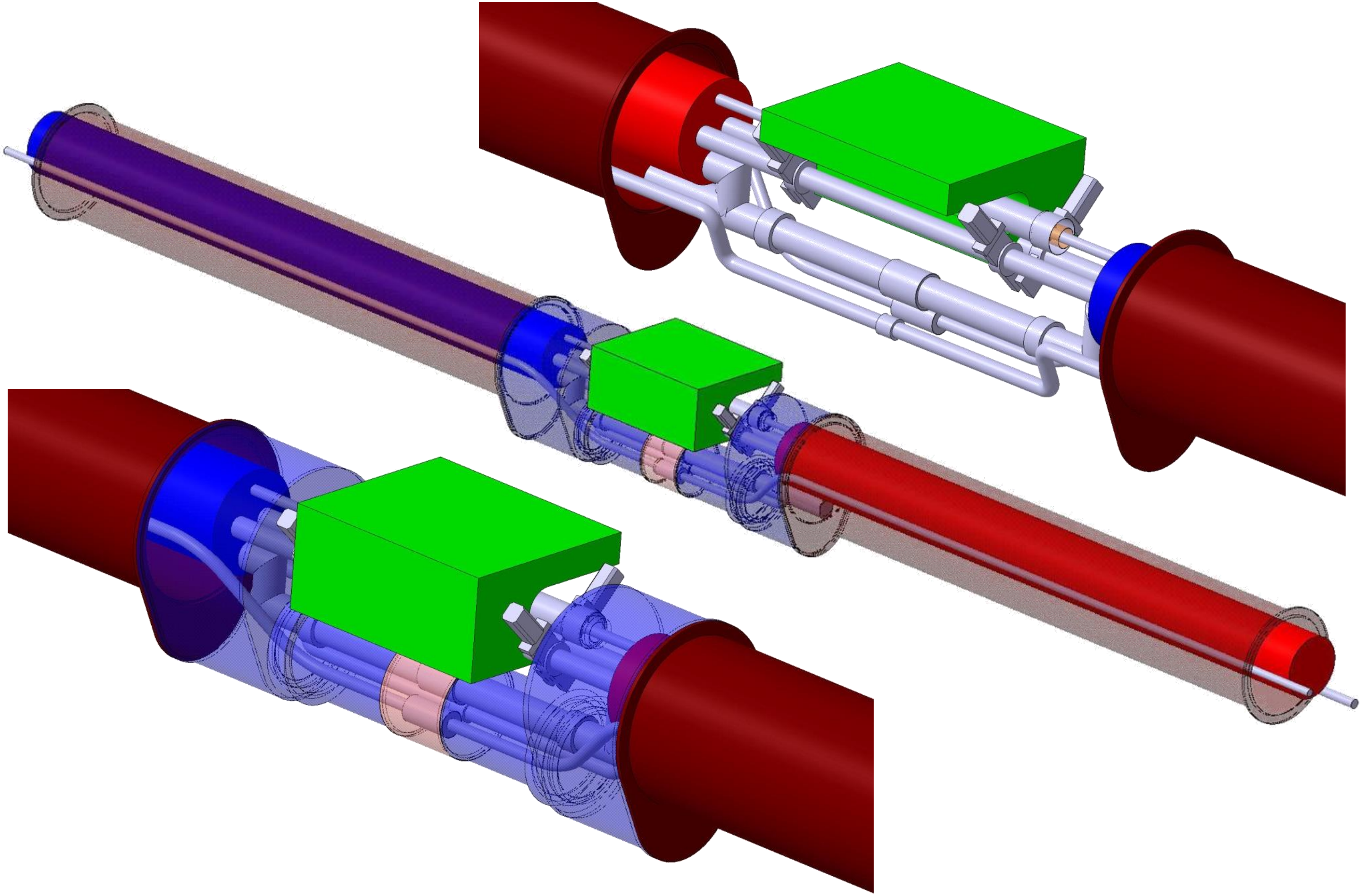
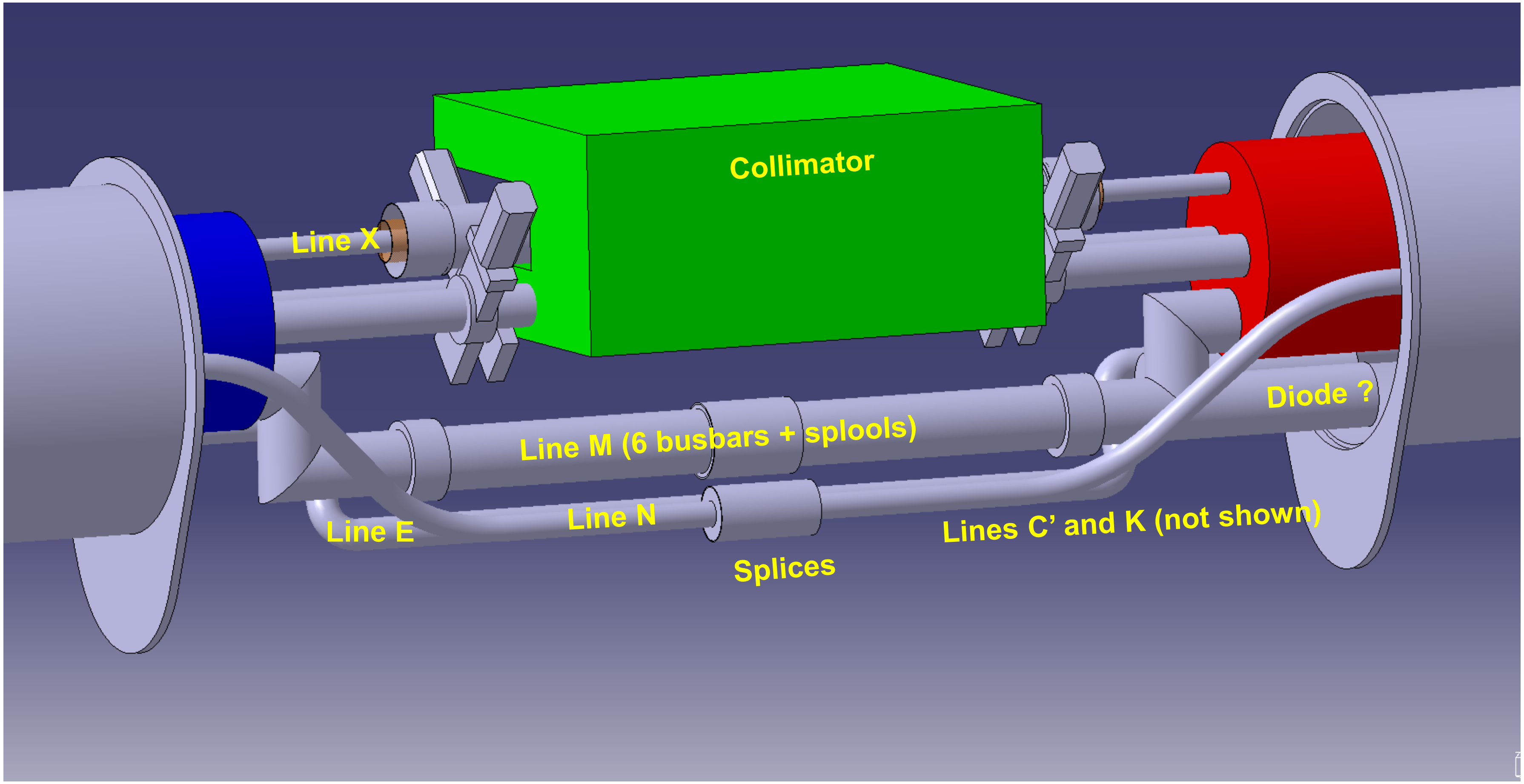
3D Integration





C’ and K lines not shown

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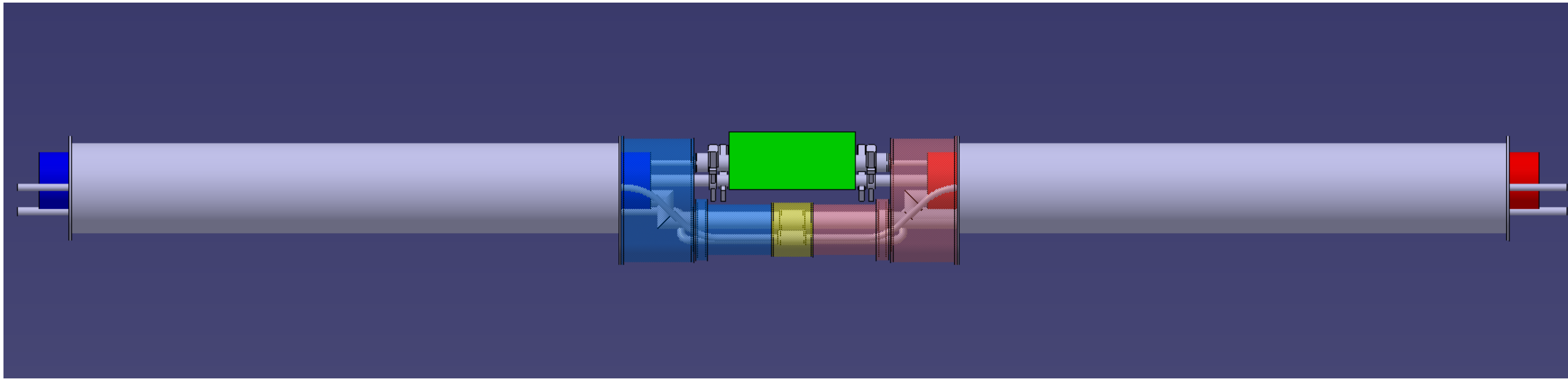

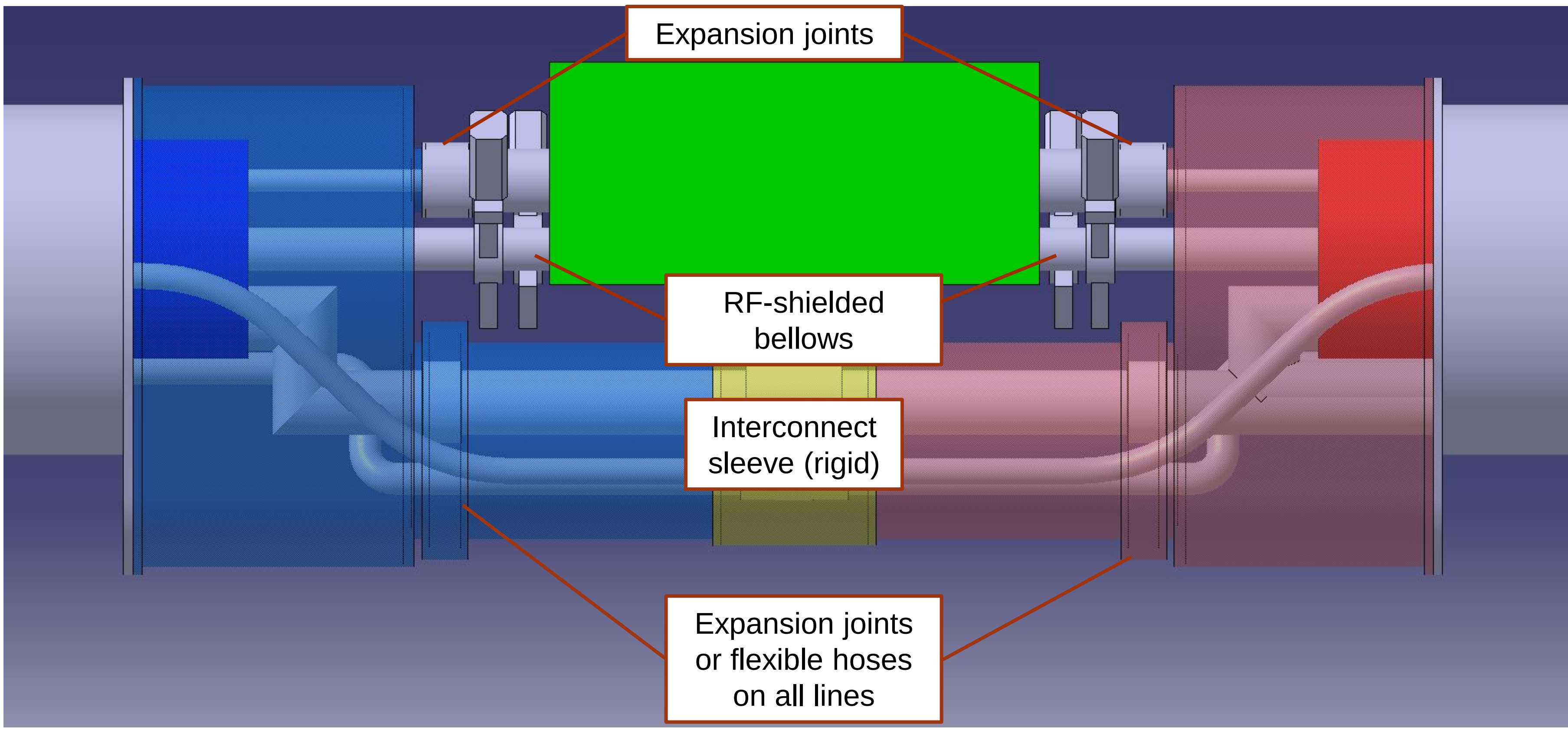

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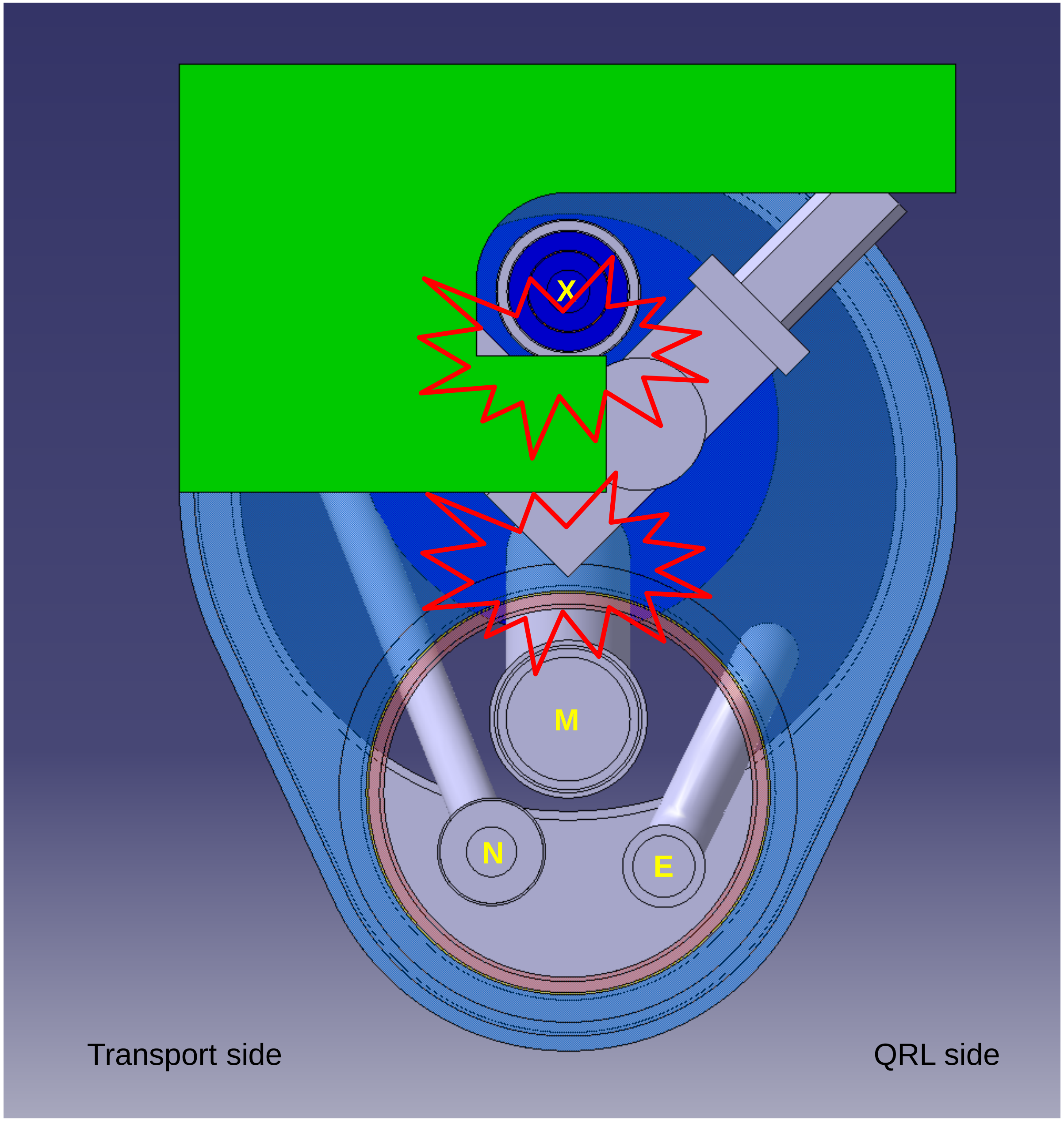
Elements defining the design in the transverse plane

- Line X insulation
- RF-shield module of gate valve



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Main features

- Seen by neighbouring magnets as standard MB cryo-assembly: Staightforward **replacement in case of major problem**
- Can be **cold tested as a single unit** in a dipole test bench and split in two for handling and transport
- **Standard alignment** procedures
- Completely **independent operation** of collimator and cryogenic systems
- Access for some **in-situ repairs**
- **Simplified construction**
- **Non-compromised functionality** wrt existing arcs
- Passed a first iteration with simplified CAD model
- Minimised impact on the collimator design (assuming 800 mm long TCLD)

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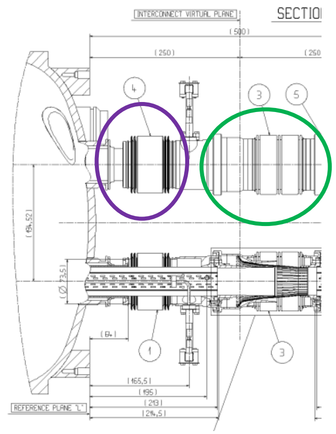
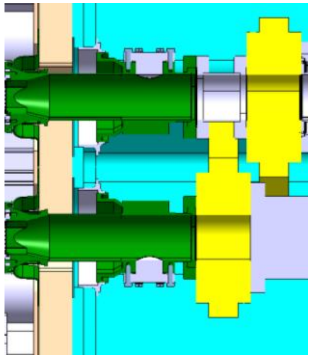
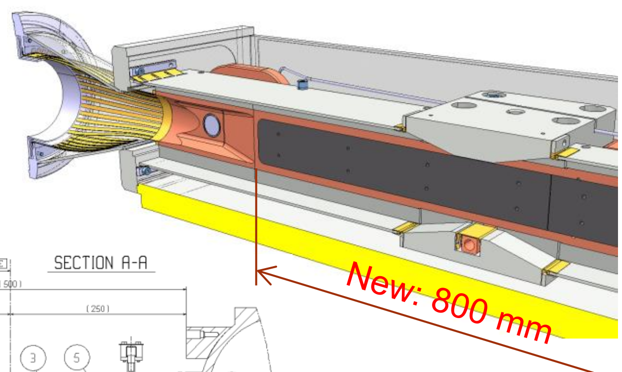
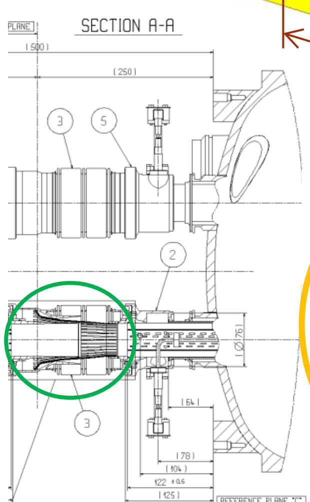
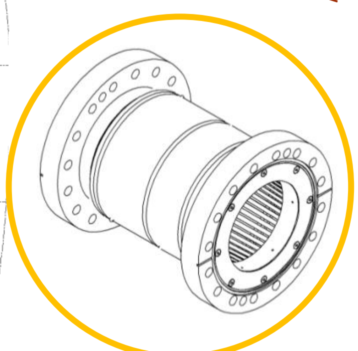
Will it fit in 15660 mm? *(Layout of beam line equipped with collimator)*











Section	Element	Length standard	Length optimised
Interconnect upstr.	Interconnect	250	250
Interconnect upstr. Total		**250**	**250**
Cold mass A	Cold mass A		
Cold mass A	End cover	154	154
Cold mass A	Outer shell extension	56	56
Cold mass A	End plate	75	70
Cold mass A	Coil	5622	5622
Cold mass A	End plate	75	70
Cold mass A	Outer shell extension	56	56
Cold mass A	End cover	154	154
Cold mass A Total		**6192**	**6182**
Cold line A	beam screen termination with nested bellows	213	181
Cold line A	Plug-in module	165	147
Cold line A	Cold warm transition with RF ball insertion port	263.5	263.5
Cold line A Total		**641.5**	**591.5**
Warm line A	Sector valve	75	75
Warm line A	RF-shielded bellows	163	121
Warm line A Total		**238**	**196**
Collimator	RF transition and flange	140	140
Collimator	Jaw tapering and pick-up	100	100
Collimator	Tungsten	1000	800
Collimator	Jaw tapering and pick-up	100	100
Collimator	RF transition and flange	140	140
Collimator Total		**1480**	**1280**
Warm line B	RF-shielded bellows	163	121
Warm line B	Sector valve	75	75
Warm line B Total		**238**	**196**
Cold line B	Cold warm transition with RF ball insertion port	263.5	263.5
Cold line B	Plug-in module	165	147
Cold line B	beam screen termination fixed side	122	122
Cold line B Total		**550.5**	**532.5**
Cold mass B	End cover	154	154
Cold mass B	Outer shell extension	56	56
Cold mass B	End plate	75	70
Cold mass B	Coil	5622	5622
Cold mass B	End plate	75	70
Cold mass B	Outer shell extension	56	56
Cold mass B	End cover	154	154
Cold mass B Total		**6192**	**6182**
Interconnect downstr.	Interconnect	250	250
Interconnect downstr. Total		**250**	**250**
Grand Total		**16032**	**15660**
Dipole length		**15660**	**15660**
Margin		**-372**	**0**

Estimated potential for optimisation, design work will start now...

Main integration topics

Topic	Issue	Status
Sizing of cold beam lines	• Standard 50 mm cold bore tubes and beam screens	Approved
Powering	• Current baseline: In series with MB magnets • Trim circuit required • 2x 300 A current leads integration	In-work
Magnet protection	• Difficult integration of diode stack in cryo-assembly B	Starting soon
Spools	• One pair integrated in cold mass B, downstream end cover	To be confirmed
Longitudinal integration	• Re-design vacuum components to optimise length	Starting soon (TE-VSC)
Electromagnetic interference	• Interference between busbar magnetic field and collimator LVDT's?	To be discussed
Over pressure safety devices	• Insulation vacuum: number and placement of DN 200's • Beam vacuum: rupture disks	To be discussed Done: All SSS equipped with rupture disks during LS1 (TE-VSC)
Interfaces	• Prepare and approve interface specification	On-going

Current boundary conditions

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- One pair of spool pieces needed; any of the four magnet ends of a complete assembly (2 x 11T dipoles and 1 collimator) is acceptable, will be likely on the far right end
- A cryo-magnet assembly (1 x 11T dipole in its cryostat) shall be exchangeable (the collimator, and the other cryo-magnet assembly to remain in place)

Designation	Current L [mm]	Optimized L [mm]
End cover	154	154
Shrinking cylinder extension (w.r.t. end plate)	56	56
End plate (longitudinal limit of the active part of the magnet)	75	70
Collared coil assembly	5622	5622
End plate (longitudinal limit of the active part of the magnet)	75	70
Shrinking cylinder extension (w.r.t. end plate)	56	56
End cover	154	154
Cold mass length "C-plane" to "L-plane" (not including IC)	**6192**	**6182**

Two concepts under study

Frederic Savary

A. Integrated bus bars, all (M1, M2, and M3) inside the cold mass assembly
B. Externally routed bus bars, for the lines M1 and M2 (quadrupoles, and spools)

- The integration of the bus bars is a challenge, and a detail design study is needed to confirm the conceptual design. There are **good indications today that it will be possible**
- In both cases, apply the solutions known from the past experience, as much as possible
- The integration of a **second diode stack**, should it be needed for the protection, is also extremely challenging, in particular to make possible maintenance or repair **work in situ**. A preliminary study will be initiated in the next 2 weeks.

Possible bus bar routing – left of collimator

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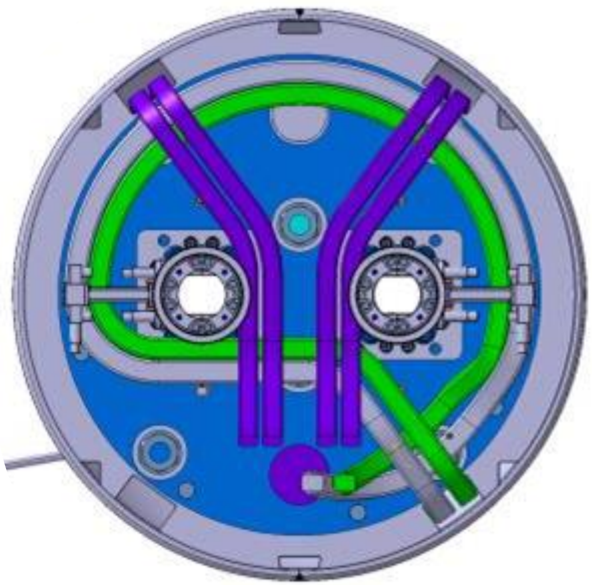
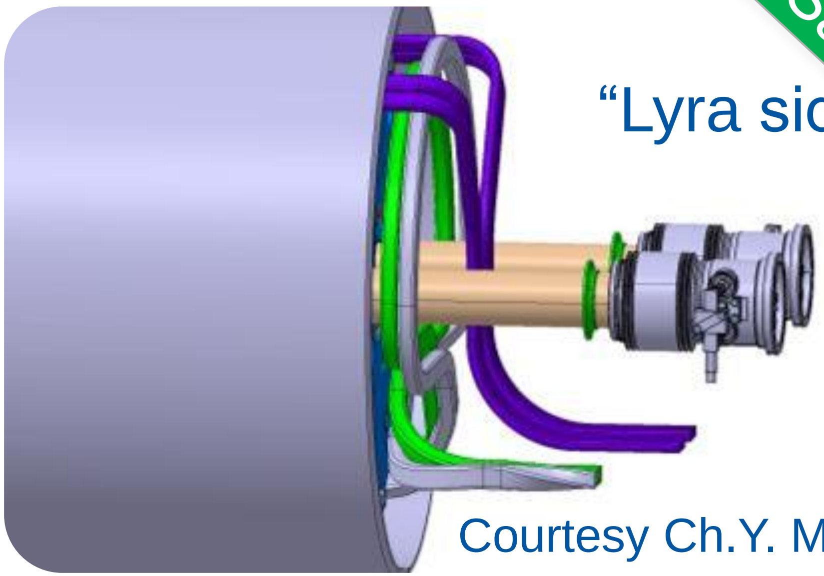
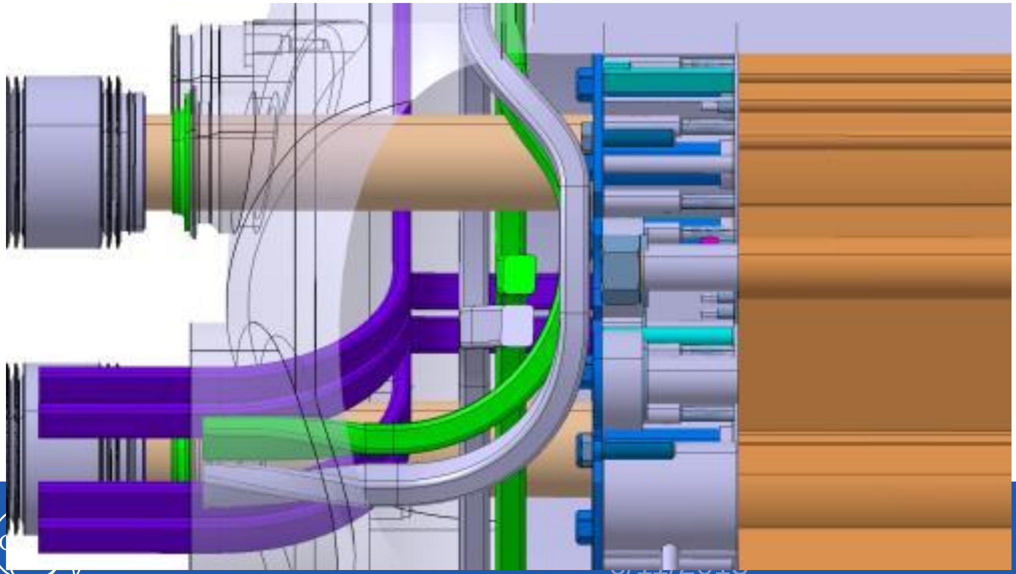
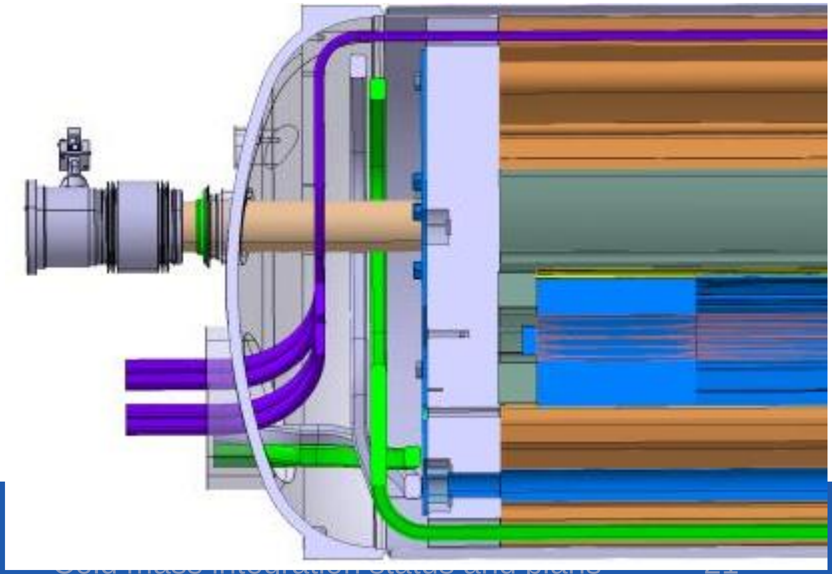




"Lyra side"

Courtesy Ch.Y. Mucher





Another solution …

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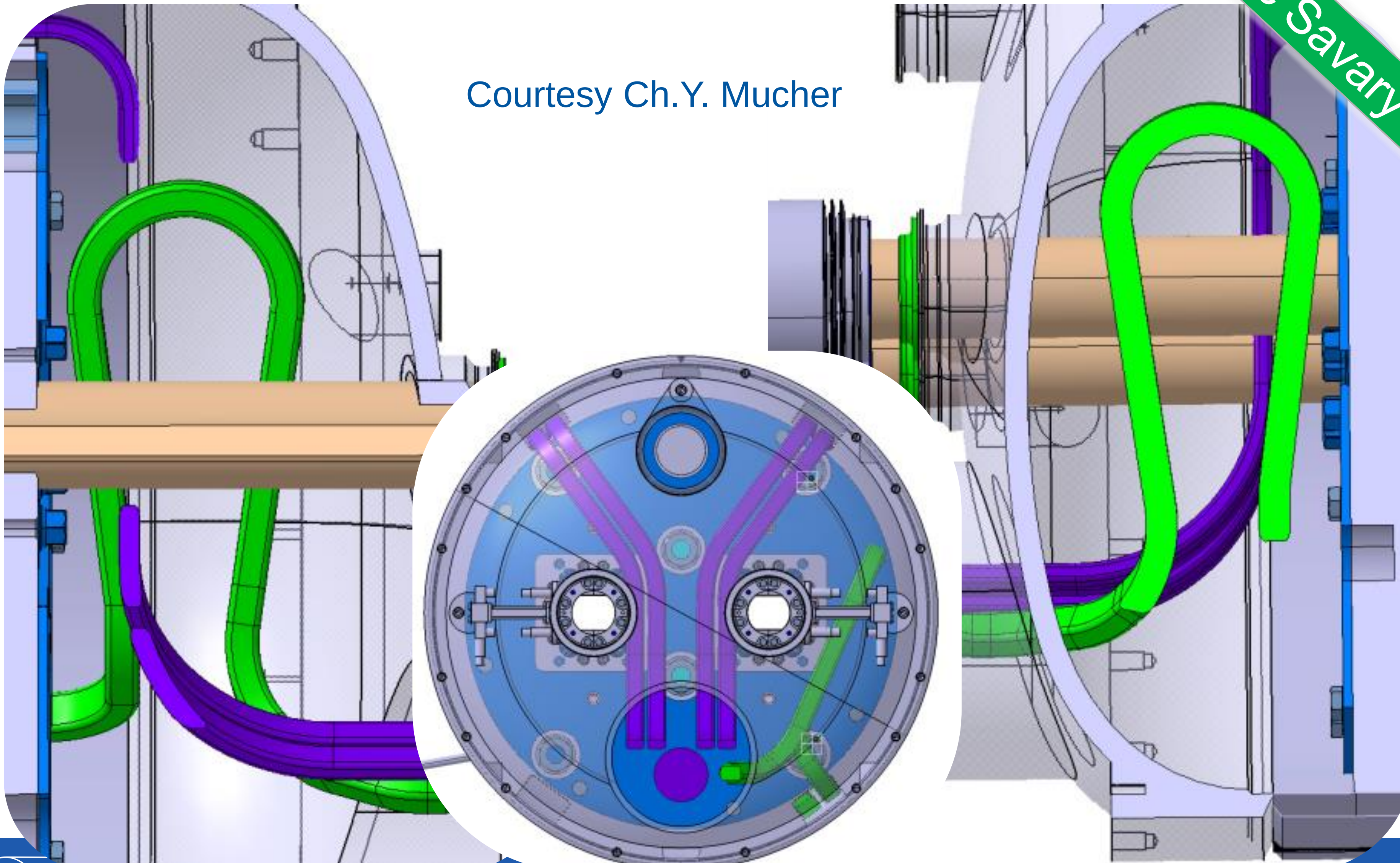
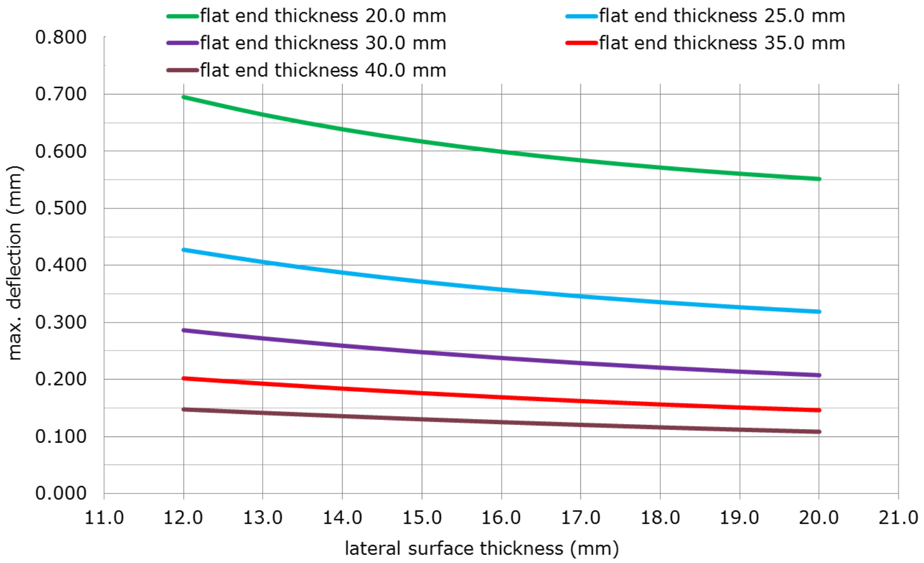
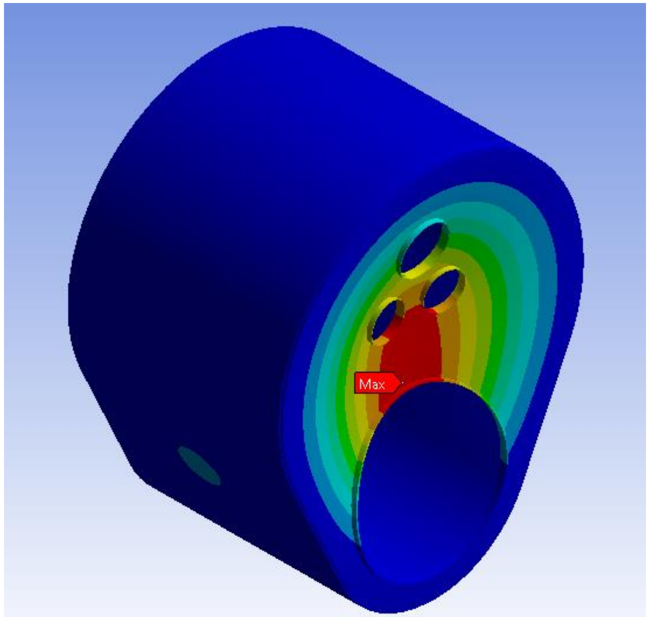
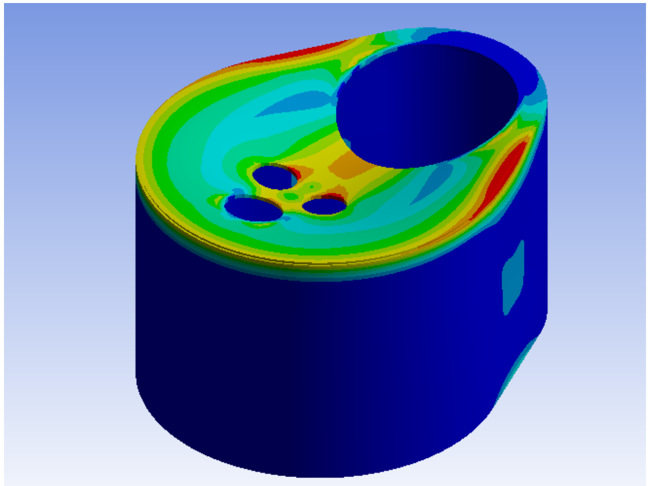
Courtesy Ch.Y. Mucher



Vacuum vessel design







- Engineering design of vacuum vessel cover on-going
- Driven by the displacements at the beam lines
- Stress analysis according to EN 13458 (European code for vacuum insulated cryostats)
- Detailed design starting now, since busbar routing seems feasible

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