Inner Triplet BPMs for HL-LHC

Design Review Summary and Cost Estimate

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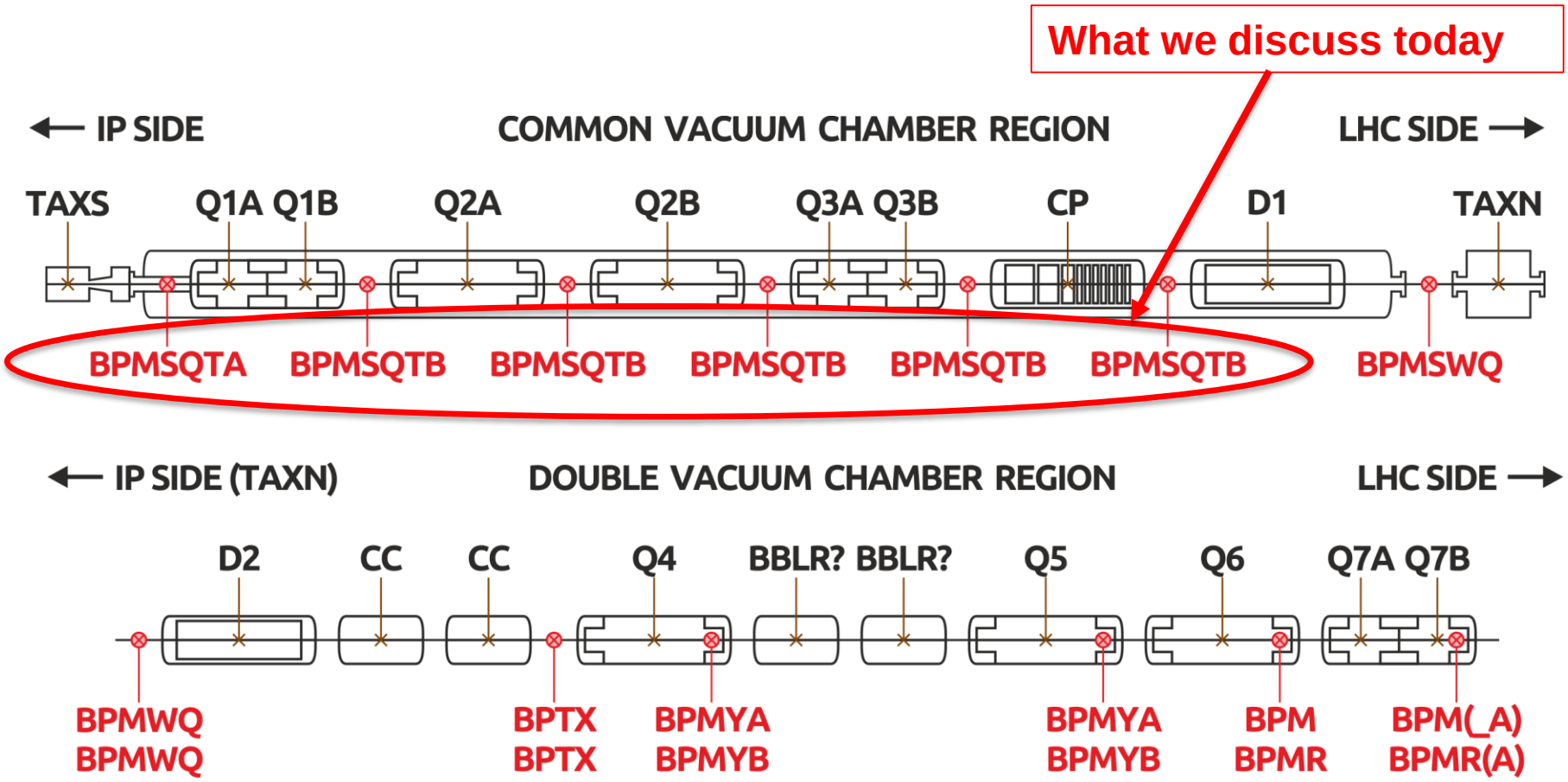
Content

- **Design Review Summary**
  - **Scope and Introduction**
  - **Objectives**
  - **Results**
- **BPM cost estimate**

BPMs per HL-LHC IP side

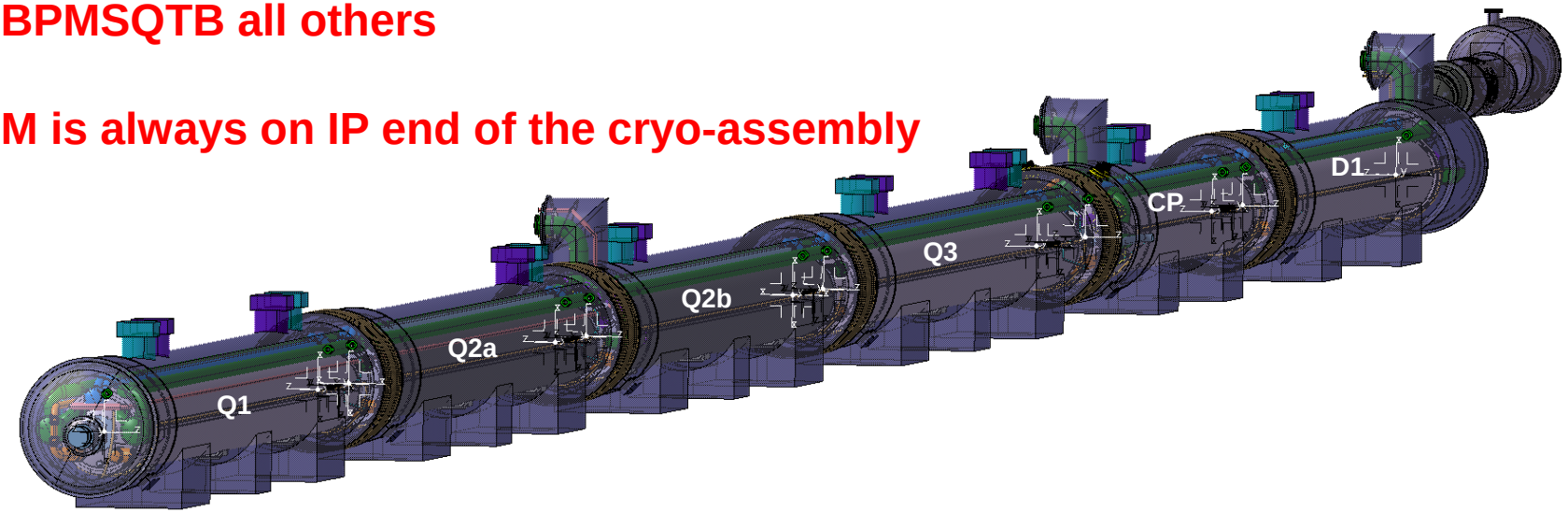


IT Layout

6 Cryo-BPMs per IT side (Points 1 & 5) x 4 sides =
24 BPMs of 2 types

4 BPMSQTA only for Q1
20 BPMSQTB all others

BPM is always on IP end of the cryo-assembly

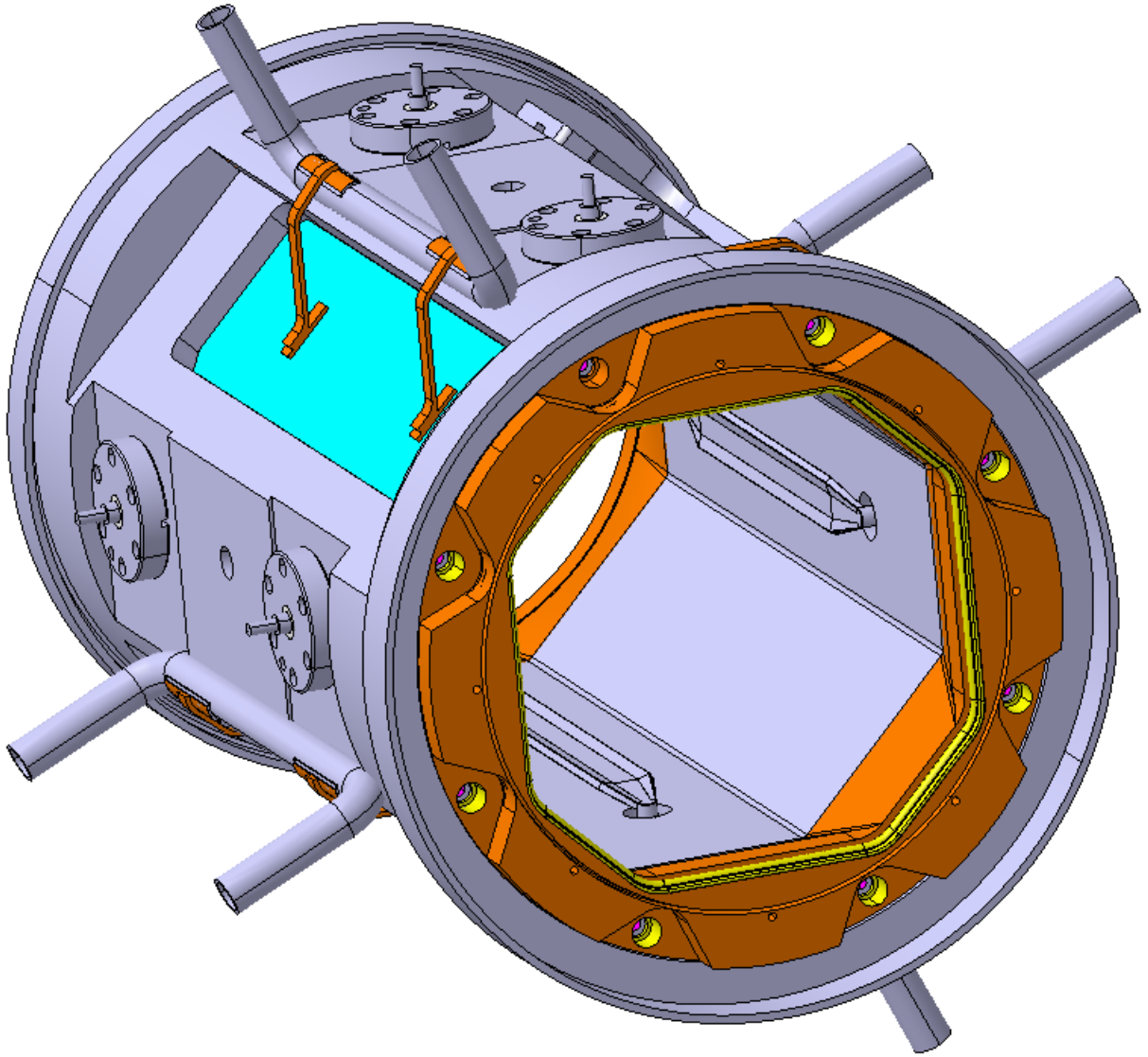


Courtesy M. Gonzalez de la Aleja

Design, Installation and Alignment Philosophy

- **Use experience from LHC construction**
  - **Proven installation alignment principles**
  - **BPMS installation experience**
- **Follow VSC on cooling design, tungsten selection and procurement, common approach on installation and welding**
- **Consider aperture and collision debris absorption issues**
- **Consider weight**

BPM Design



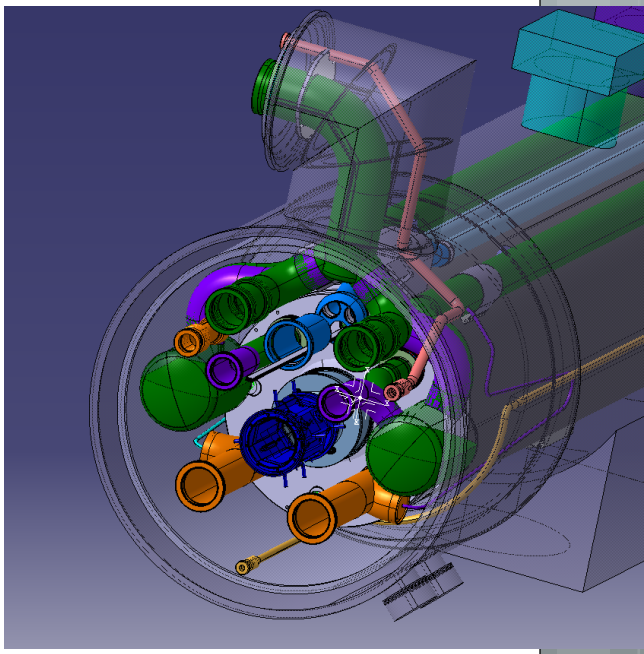
The Review Should Address:

- Function
  - Do the following aspects meet requirements?
    - Absorption of particle debris, cooling, impedance
  - Is the electro-magnetic design of the BPM sound?
- Integration
  - Are the alignment references and precision required agreed?
  - Is the integration of the BPMs possible?
  - Are the interfaces to other systems agreed and clear?
- Engineering
  - Is Beam Screen & BPM design optimised to reduce cost, risk & duplication?
  - Is material selection & fabrication procedure as expected?
    - For a precision device
    - For a cold, UHV, radioactive environment with a stray magnetic field
  - Is the BPM design sound and ready for detailed drawings?
  - Is the documentation adequate for the project at this stage?
- Planning
  - Is the planning in agreement with the global schedule?
  - Is the deliverable to the IT String test agreed?
  - Is the prototyping strategy clear?

Integration of BPM in Cryostat

(D. Ramos)

- **BPM and Beam screen installation after service module assembly**
  - **Could be inversed if space constraints are dominant. BPM protection against mechanical and vacuum damage must be guaranteed. Inversion is not baseline. Sequence under discussion.**
- **Tooling should be added to the installation drawings**
- **Designers should be always take the latest integration model**
- **BPM cable routing should be added**

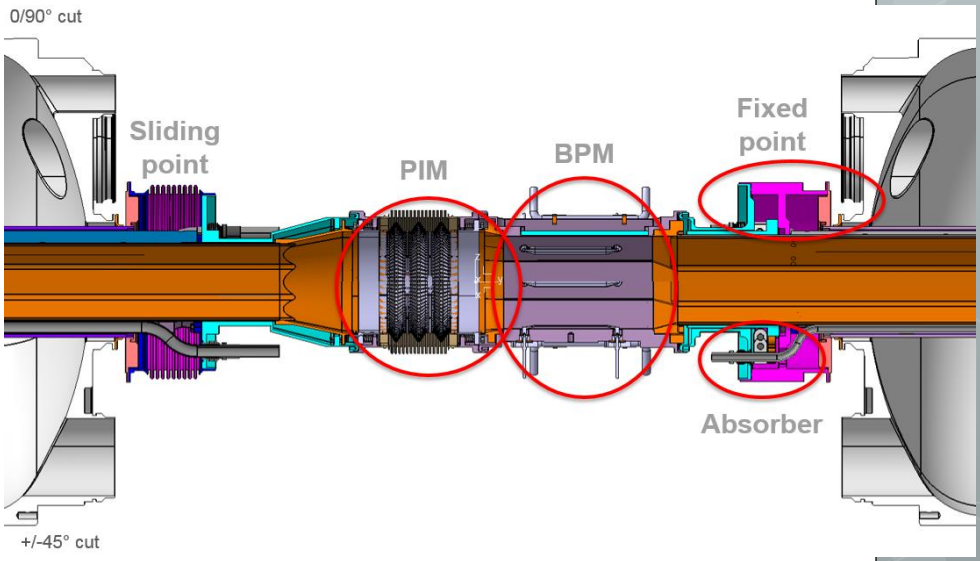


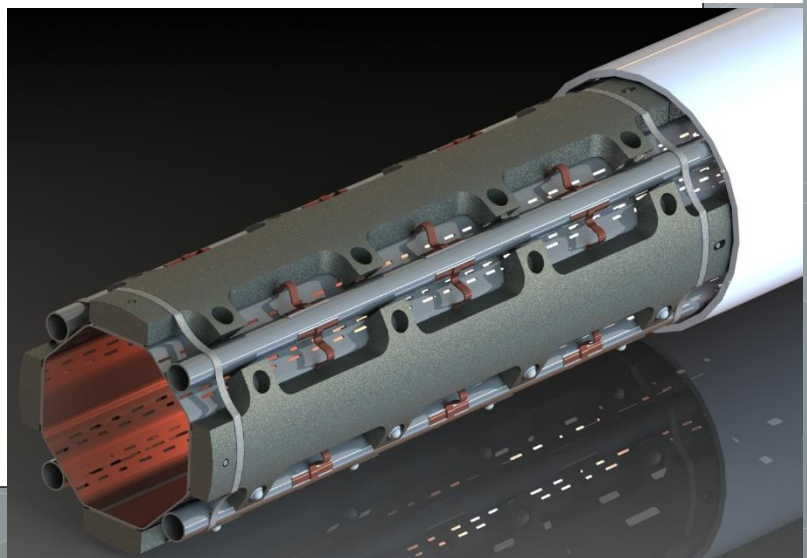
Beam Screen concerns

(C. Garion)

Assembly sequence beam screen

1. **Beam screen installation:**
    1. **Beam screen assembly**
    2. **Insertion in the cold mass**
    3. **Bending of the cooling tubes (sliding point side)**
    1. **Fixed point**
    2. **Sliding point**
2. **Cryostat completion**
3. **Beam vacuum line finishing**
    1. **aC coating**
    2. **BPM assembly**
    3. **Cooling tube connections**





Photos courtesy C. Garion

Beam Screen discussion

- **Can the BPM/beam screen be installed together as in the LHC arc?**
  Answer after the review by Cedric: No
  Problems:
  - **The BPM opposite cooling tube bending requires that the beam screen is pushed over its nominal position in the cold bore**
  - **Consider beam screen weight and BPM fragility (Not k.o. criteria)**

- **Following the beam screen offset shown by Cedric, an optimum position of the BPMs should be found**

BPM functionality
(M. Krupa)

- **Dimensions: About 100 mm for type A, 120 mm for type B**

- **Impedance Budget: Agreed with BE-ABP, negligible compared to other items. Reference: 76th HL WP2 Meeting 02/09/2016. A re-iteration should be made when final model exists.**

- **Heat load:**
  - **8 W for amorphous Carbon coated vs 26 W for an un-coated BPM**
    Main source: Electron cloud
  - **Active cooling is required**
  - **Heat load budget not significant**

- **Tungsten Block alignment: Assumes perfect alignment. Now simulations should be made to estimate impact with mechanical and alignment tolerances**

String Test 1/2
(M. Bajko)

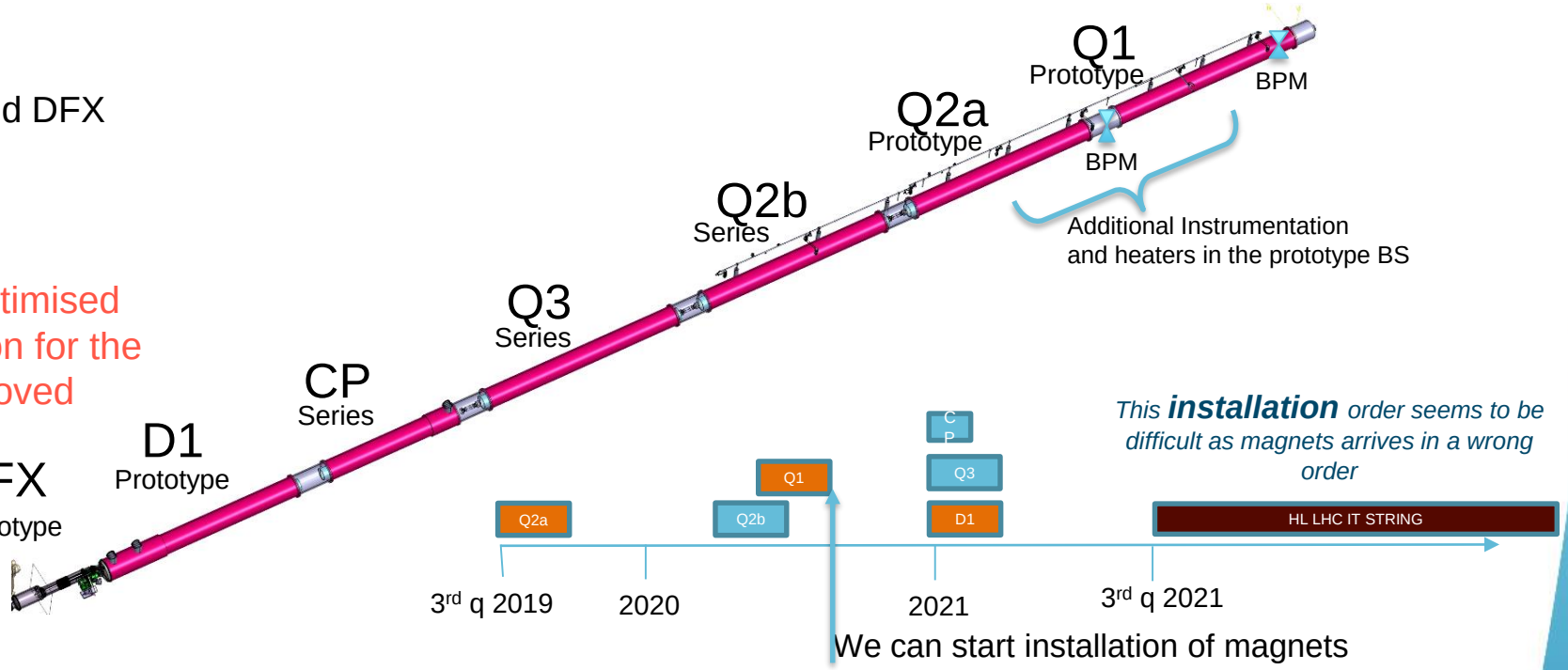
Which components are we going to use?

IP5

Installation | Inter-connection | Cooling | HWC | Exp @ Inom | Training to Iultimate | Thermal Cycle | HWC to Inom | Exp @ I nominal | Warm up

The magnets and DFX

This is the most adequate but optimised cost configuration for the moment not aproved



This is a layout under discussions as we were asked to minimize the cost and more specifically the one related to the beam screens

Slide courtesy M. Baiko

String Test 2/2
(M. Bajko)

- **Design will be as for Point 5 Left**
- **String will be a mix of prototype and series cryo-assemblies**
- **Q1 and Q2a magnet with full BPM, beam screen and interconnect desired – Issue is financing. Working towards this scenario.**
- **Magnet delivery:**
  Q1 in 2nd half 2020
  Q2a in 3rd quarter 2019, but Q1 will be installed first

BE Beams Department

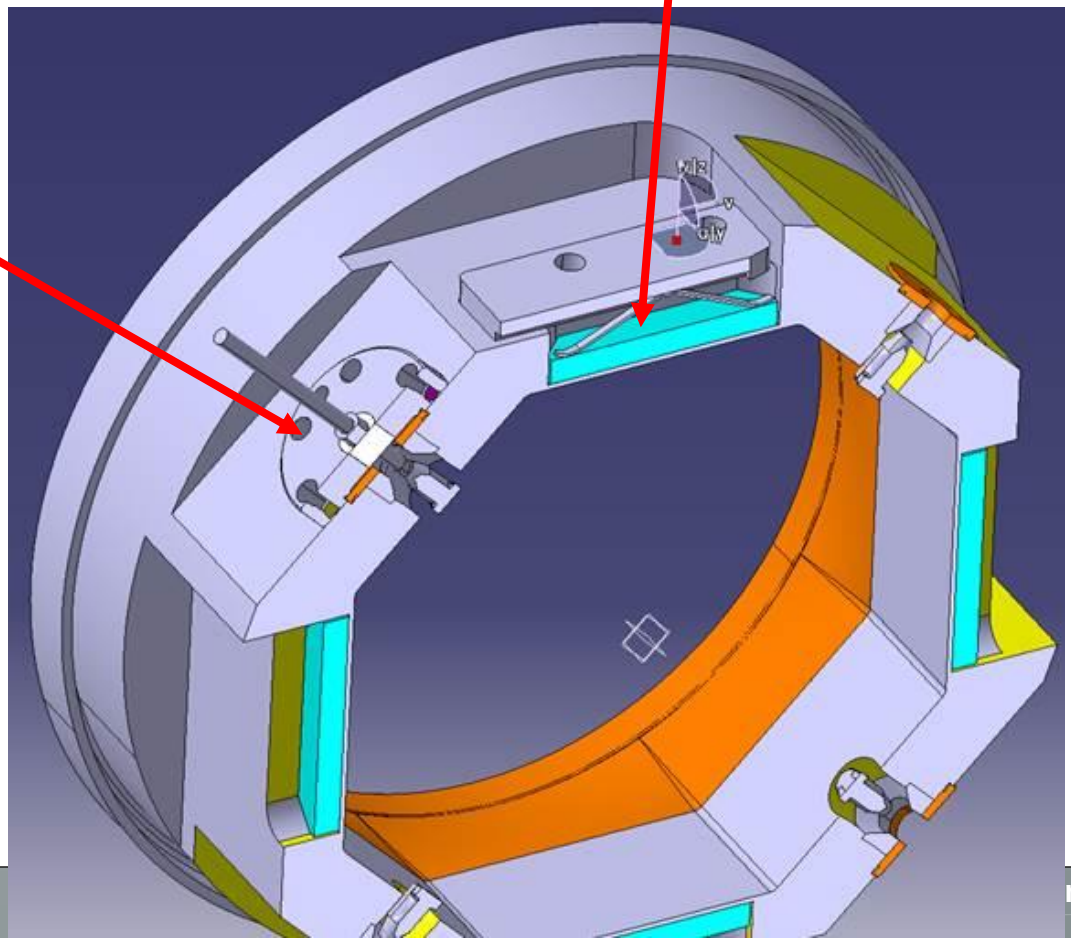
BPM design, integration and planning
(G. Schneider)

- **Next 7 slides**

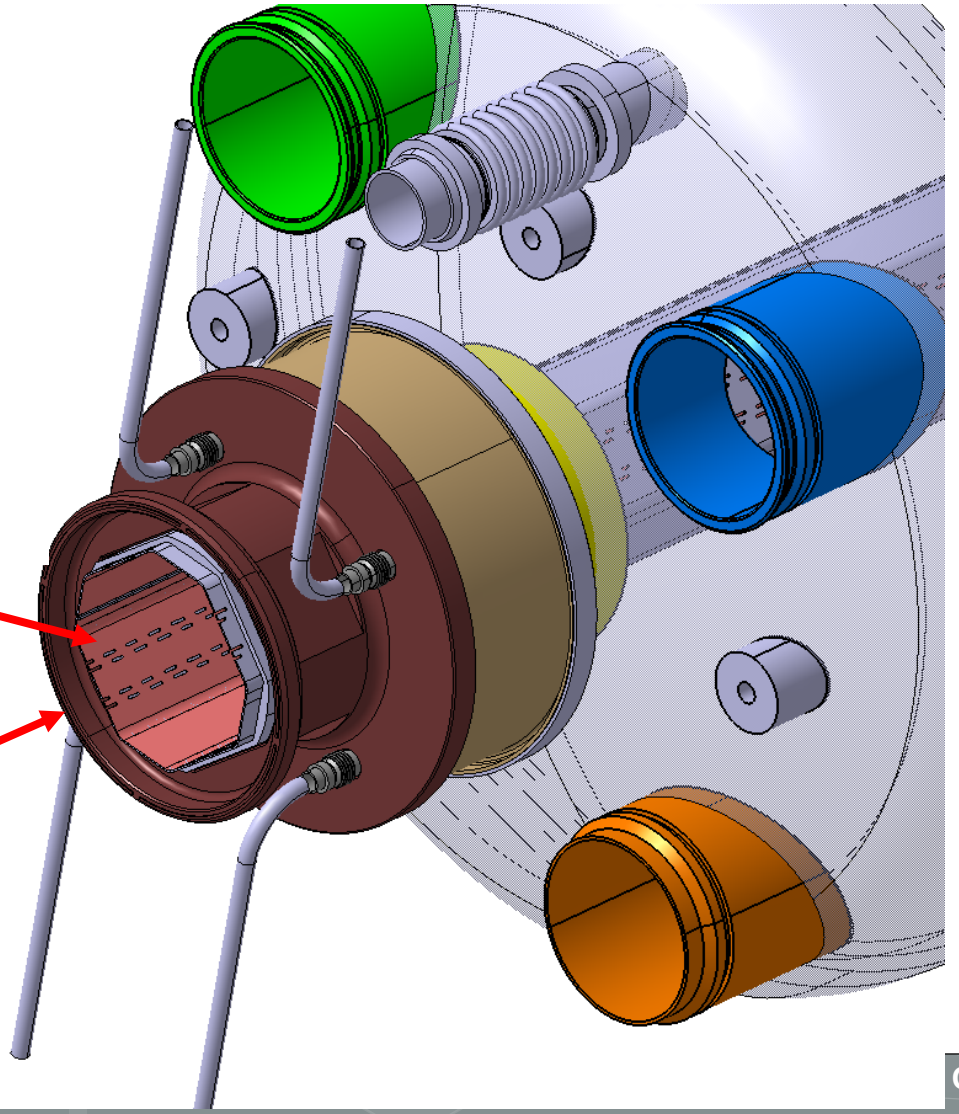
Octagonal BPM design

Tungsten (Inermet) precise position by maching and holding by clamps

BPM electrodes on Conflat DN16 flanges

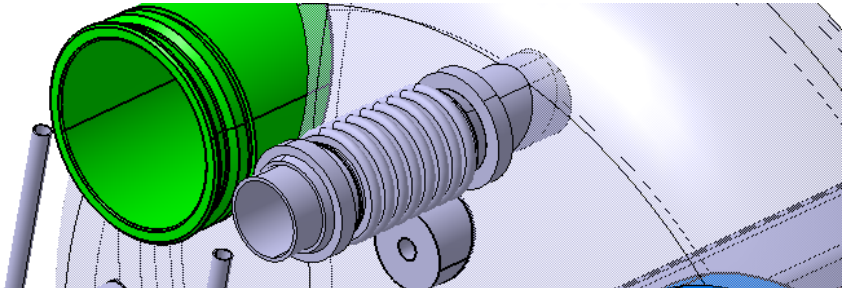


BPM installation and alignment 1



BPM installation and alignment 4

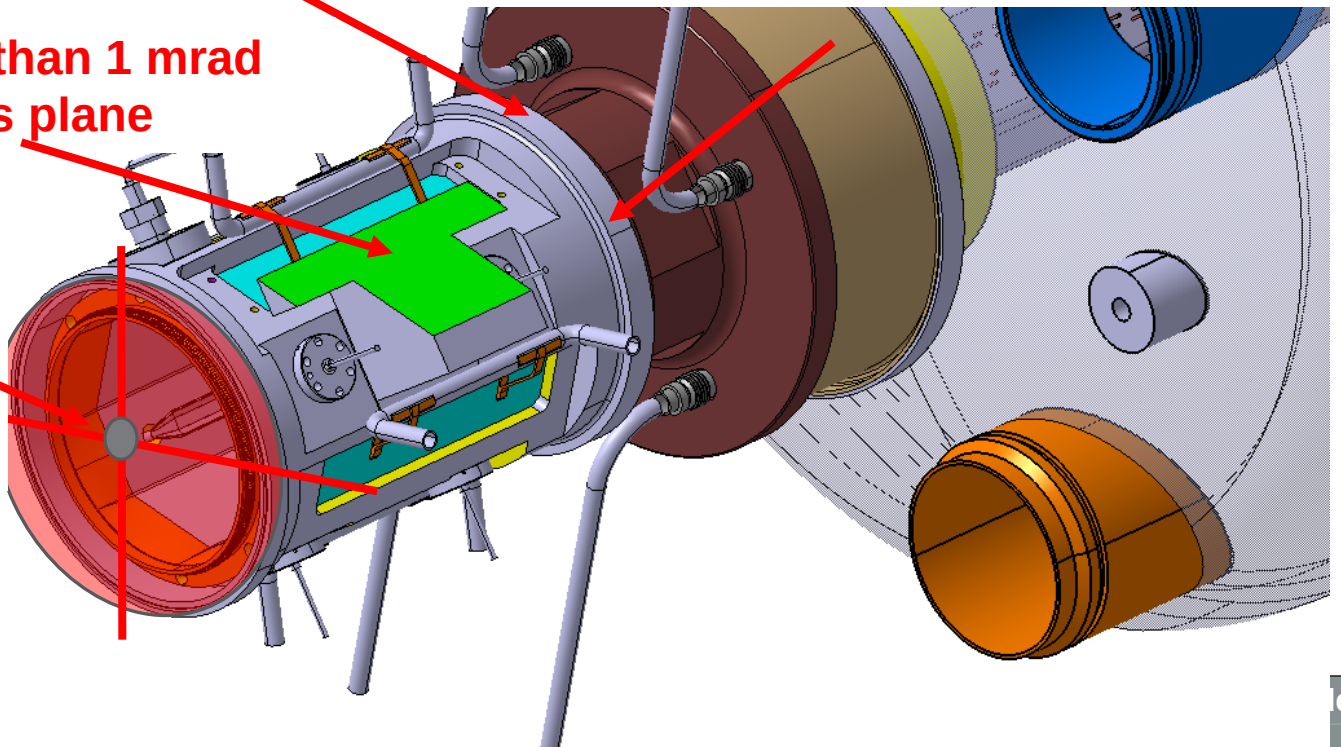
Position must be better than 0.5 mm wrt cold bore axis
BPM start = Beam Screen end (+/- 0.2 mm)



Perpendicularity of the welding plane better than 0.2 mm wrt cold bore axis

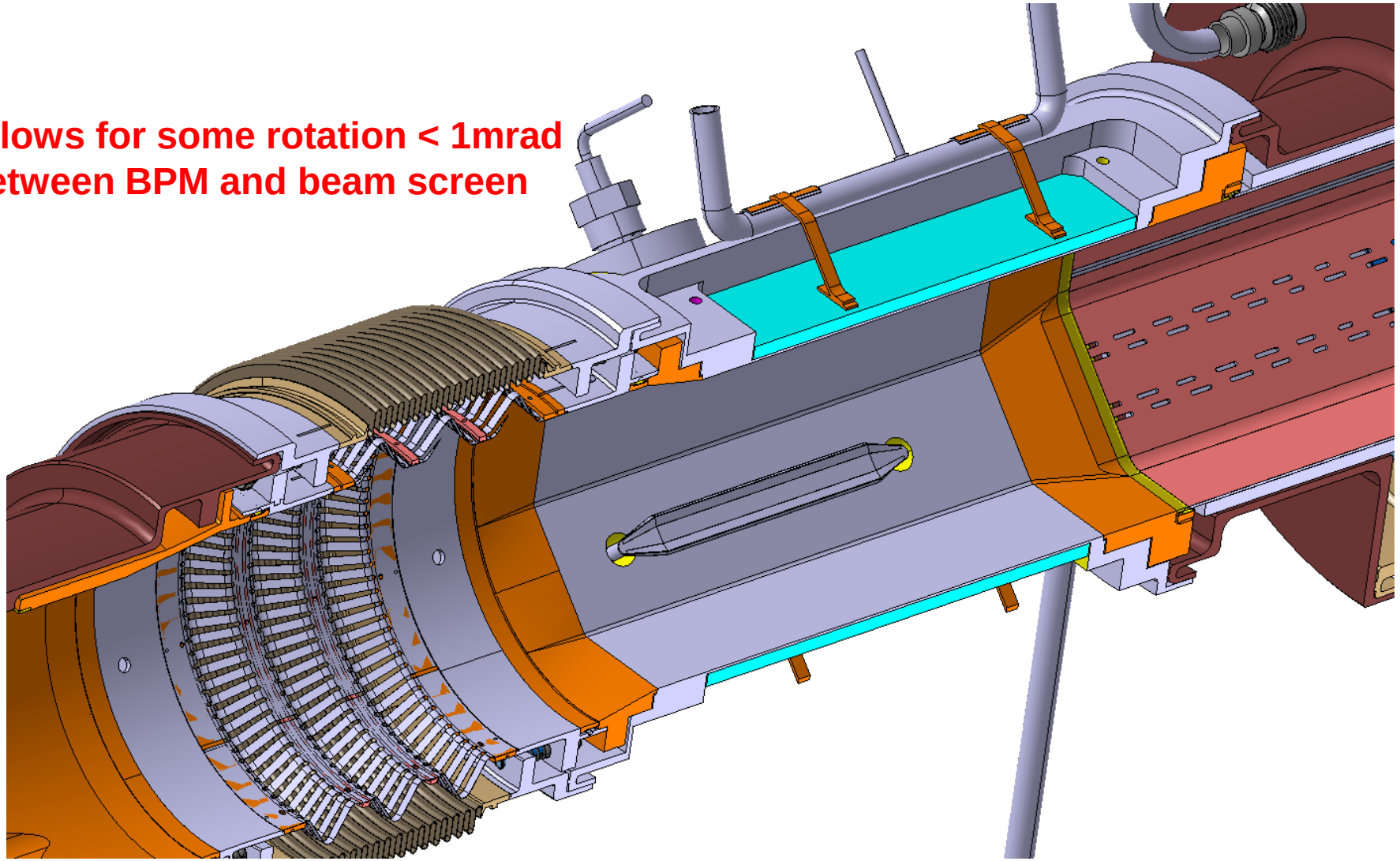
Rotation better than 1 mrad wrt to cold mass plane

Position must be better than 0.5 mm wrt cold bore axis



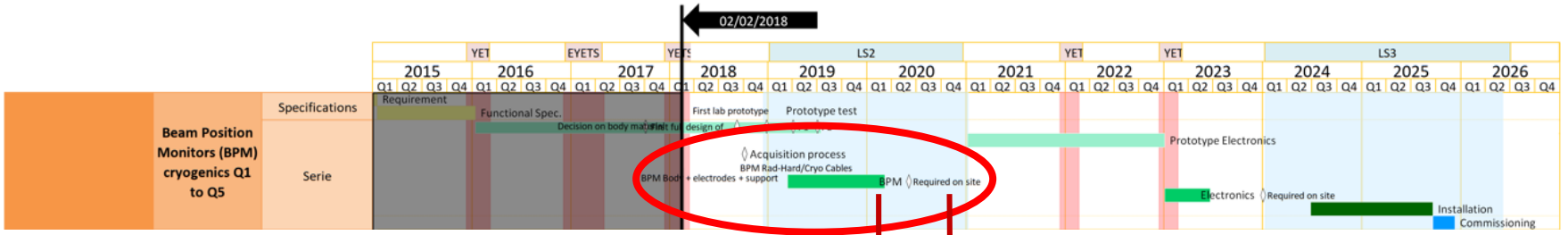
BPM interconnect cut

Allows for some rotation < 1mrad between BPM and beam screen



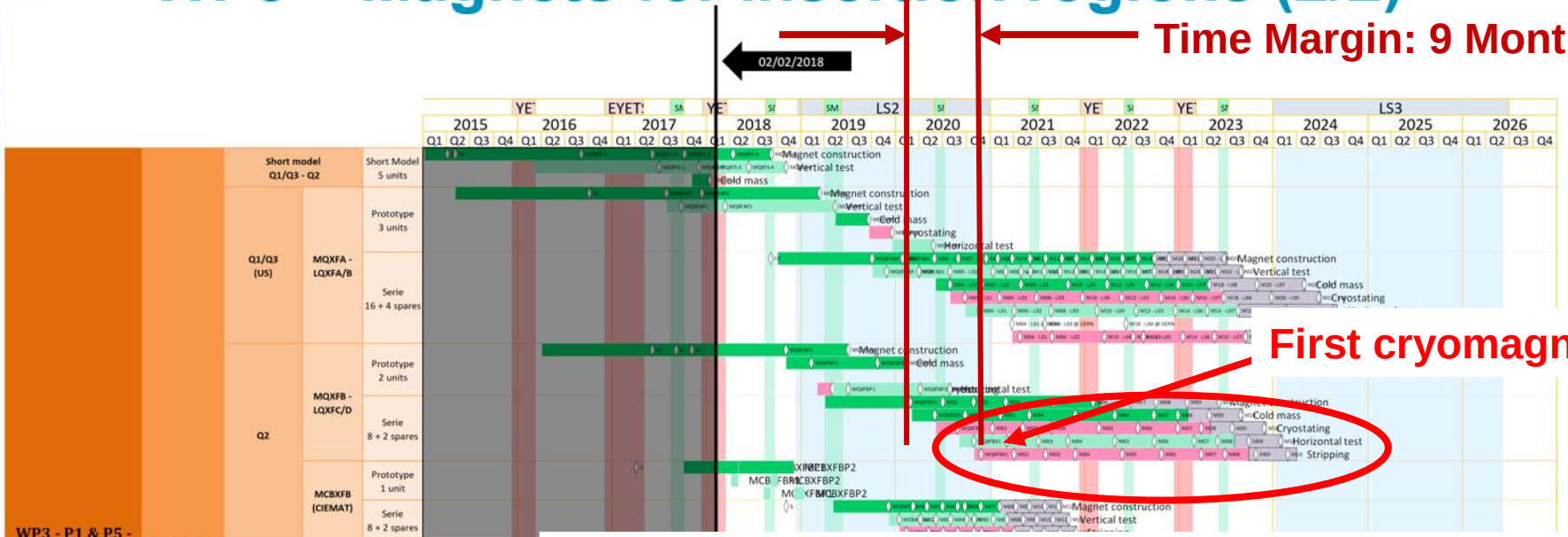
Planning - Global

WP13 – Beam Diagnostics



WP3 – Magnets for insertion regions (2/2)

Time Margin: 9 Month



First cryomagnet

Cost and Schedule 2018 (EDMS 1920253). Courtesy L. Tavian

Planning - BPM

- **Manufacture Drawings: 2018 - Q3**
- **Prototype Manufacture: 2018 - Q4 to 2019 - Q1**
- **Materials order: 2018 - Q3**
- **Price inquiry: 2018 - Q3**
- **Contract placement: 2019 - Q1**
- **Manufacture: 2019 – Q2 to 2020 Q2**

Under discussion

BPM design, integration and planning
(G. Schneider)

Summary:

- **BPM vs Beam Screen position:**
  - **Assume mechanical and alignment tolerances in the BPM tungsten offsets**
  - **Model position of BPM vs theoretical cold bore axis when following the beam screen exit**

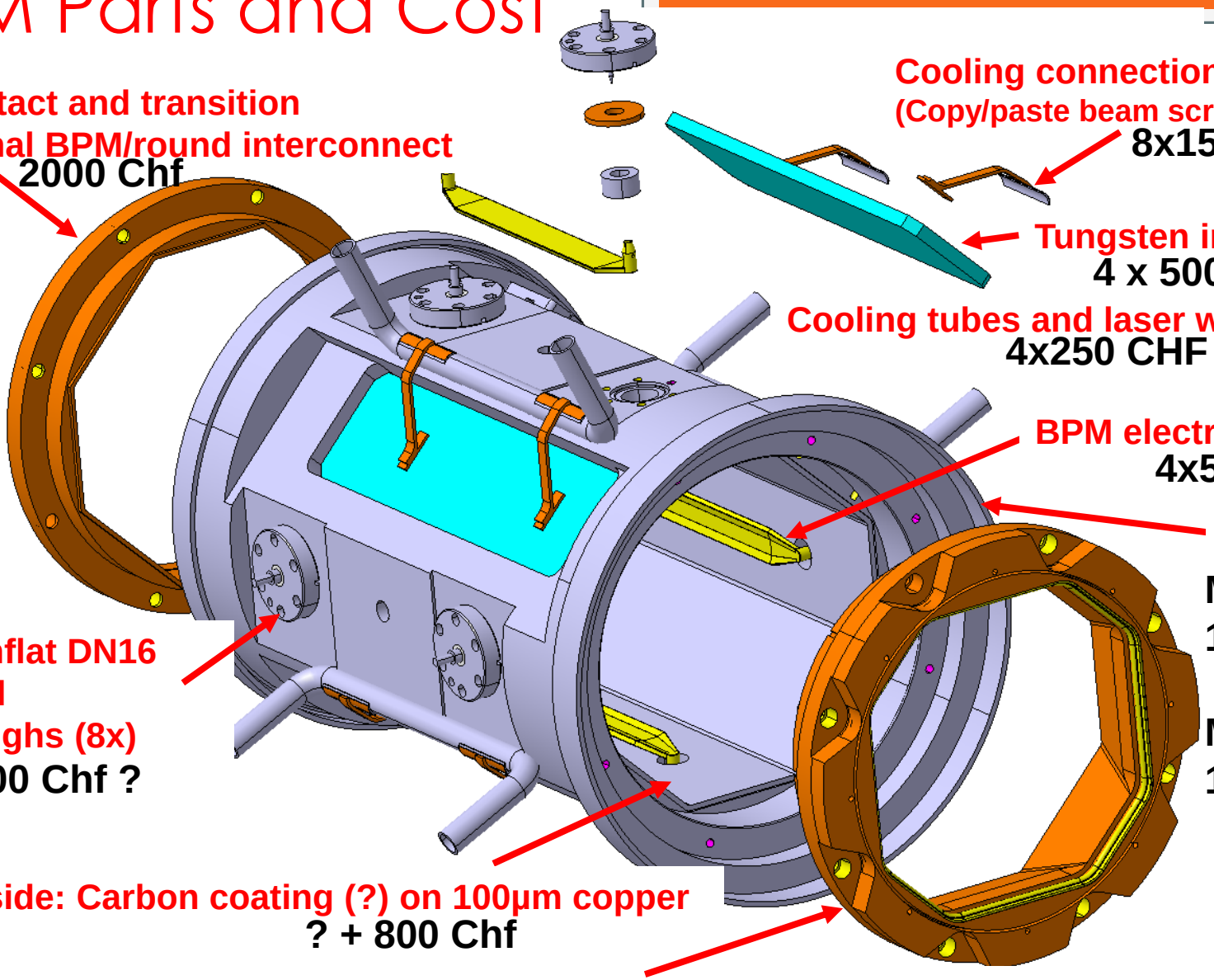
- **Planning should be revised, distinguish between stripping and beam screen/beam screen installation**

- **Welding machines supplied by VSC, joint development. Space constraints seem to be important.**

My interpretation of the review:

- Function
  - Do the following aspects meet requirements?
    - Absorption of particle debris, cooling, impedance Yes, to be reviewed with mechanical tolerances
  - Is the electro-magnetic design of the BPM sound? Yes, to be re-iterated with final design
- Integration
  - Are the alignment references and precision required agreed? Globally yes, fine tuning needed with alignment working group, VSC, Geometers
  - Is the integration of the BPMs possible? Theoretically yes, mock-up and String test for verification needed – welding and connections remain to be fully clarified.
  - Are the interfaces to other systems agreed and clear? Yes, tooling and welding machines to be integrated on assembly drawings. Welding machine supply with VSC to be formally confirmed.
- Engineering
  - Is Beam Screen & BPM design optimised to reduce cost, risk & duplication? Yes
  - Is material selection & fabrication procedure as expected? Yes
    - For a precision device
    - For a cold, UHV, radioactive environment with a stray magnetic field
  - Is the BPM design sound and ready for detailed drawings? Yes
  - Is the documentation adequate for the project at this stage? Technical Specification needed
- Planning
  - Is the planning in agreement with the global schedule? Globally yes, String and LHC planning feedback still needed
  - Is the deliverable to the IT String test agreed? Yes
  - Is the prototyping strategy clear? Yes for String, for mock-ups ongoing

BPM Parts and Cost



RF-Contact and transition octagonal BPM/round interconnect
2000 Chf

Cooling connections (8x)
(Copy/paste beam screen)
8x150 CHF

Tungsten inserts (4x)
4 x 500 CHF

Cooling tubes and laser welding
4x250 CHF

BPM electrodes (4x)
4x500 Chf?

BPM body
Material
1800 CHF

Machining:
10000 CHF

BPM conflat DN16 electrical feedthoughs (8x)
8x500 Chf ?

Inside: Carbon coating (?) on 100µm copper
? + 800 Chf

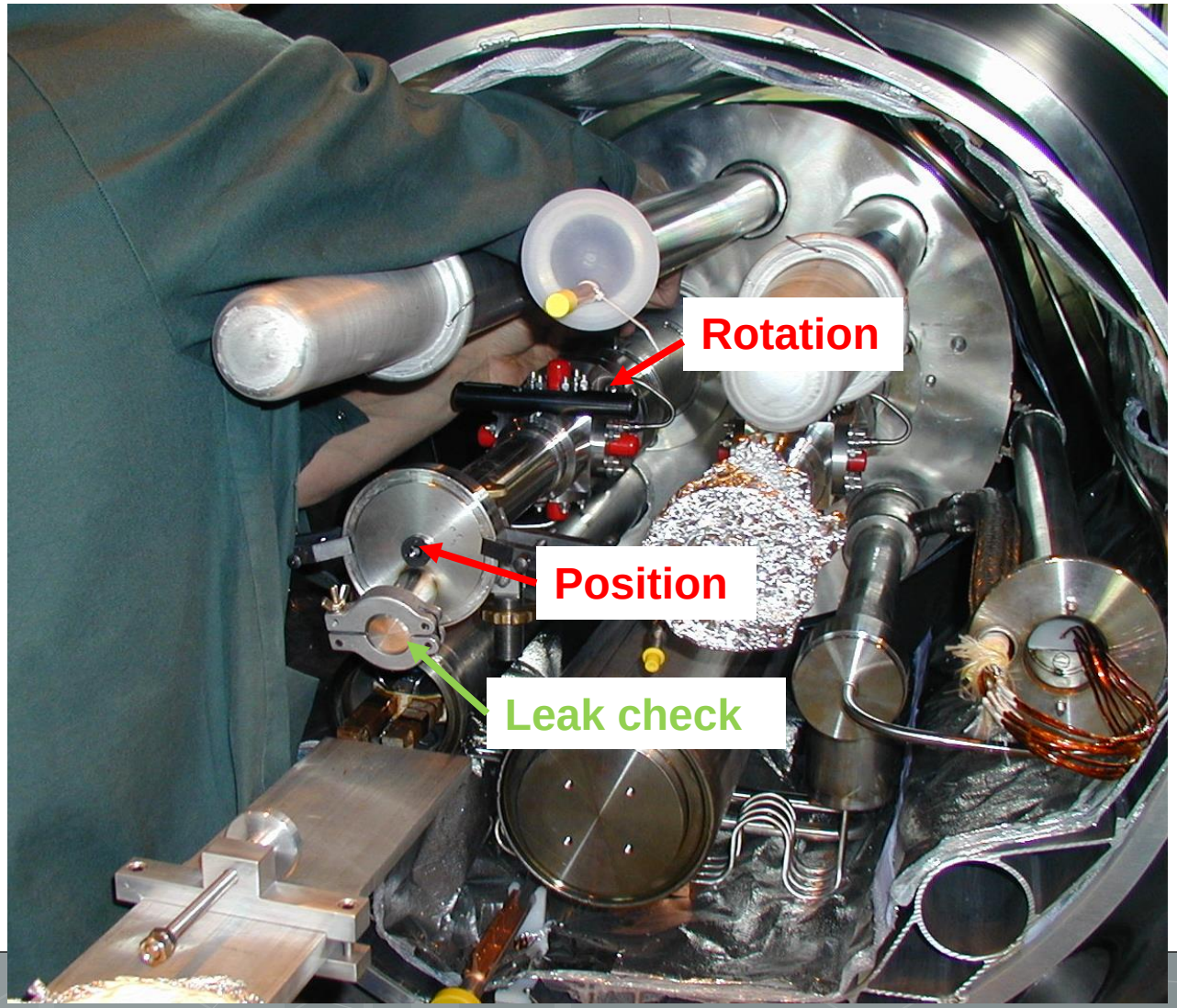
RF-Contact and transition octagonal BS/octagonal BPM
similar to BPMS, change from contact assembly from brazing to electron beam welding
2000 Chf

BPM Parts and Cost

Item	N° of Pieces	Unit cost	Items cost	Comment
316 LN Stainless Steel forged	1	1800	1800	
Machining BPM body	1	10000	10000	
RF-transitions	2	2000	4000	
Cooling tubes and laser welding	4	250	1000	
Copper plating	1	800	800	
Carbon coating	1		0	?
Tungsten inserts	4	500	2000	
Cooling tubes connestions	8	150	1200	
BPM electrodes	4	500	2000	?
BPM electrical feedthroughs	4	500	2000	?
Vacuum leak/acceptance tests	2	400	800	
Vented silver coated Class 100 Screws	48	5	240	
Copper gaskets	8	5	40	
Small material (screws, washers..)			100	
Total/unit (for some 30 units)			**25980**	
Trips + tooling			20000	

Thank you

Assembly during LHC construction 1

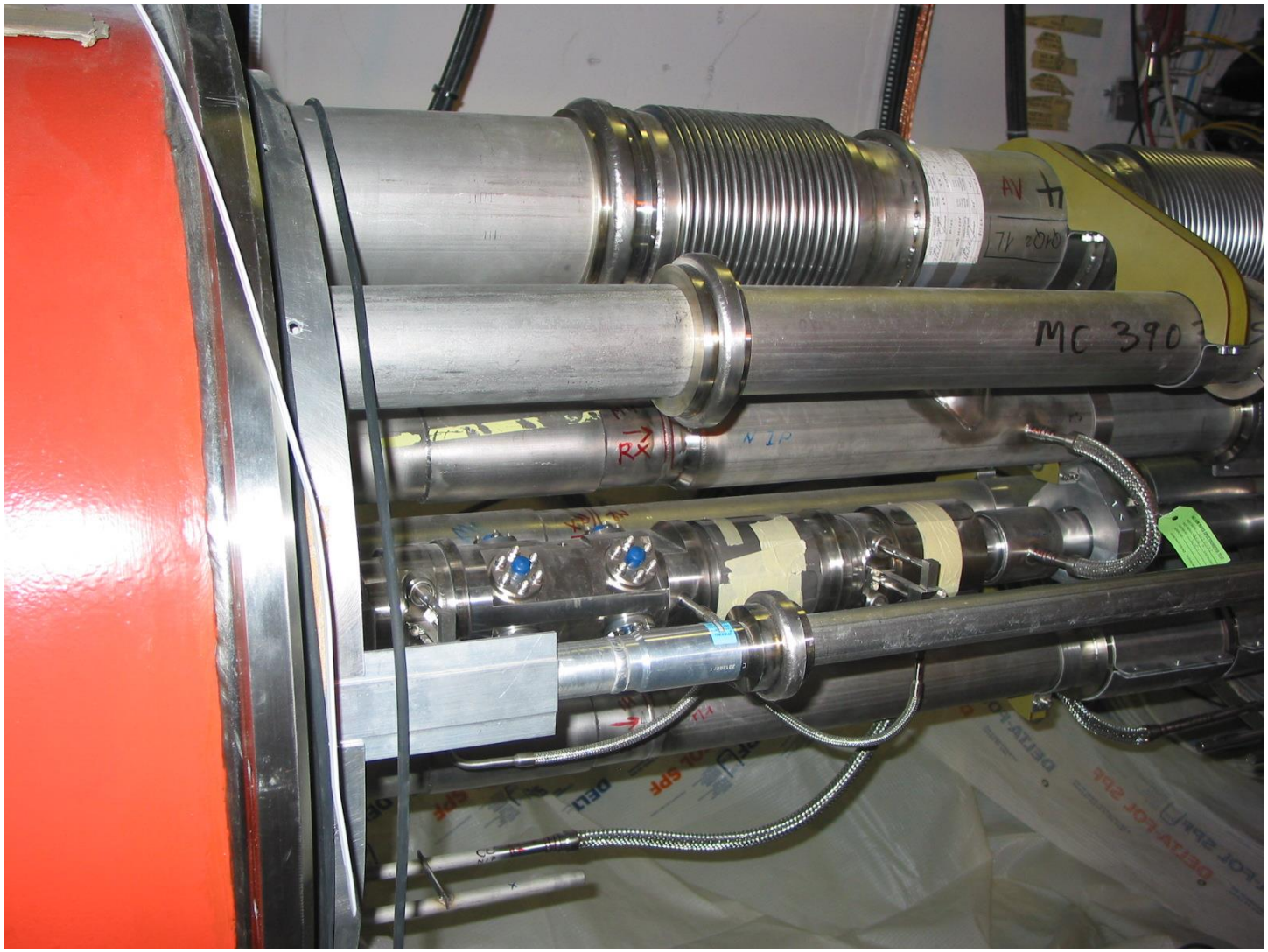


Assembly during LHC construction 2

BPM Design - Materials

- **BPM body:** **316LN (3D-forged)**
- **Cooling tubes:** **316L or 316LN (procurement driven)**
- **Flanges:** **316LN**
- **Copper:** **OFE type**
- **RF-contacts:** **copper-beryllium, (coating?)**

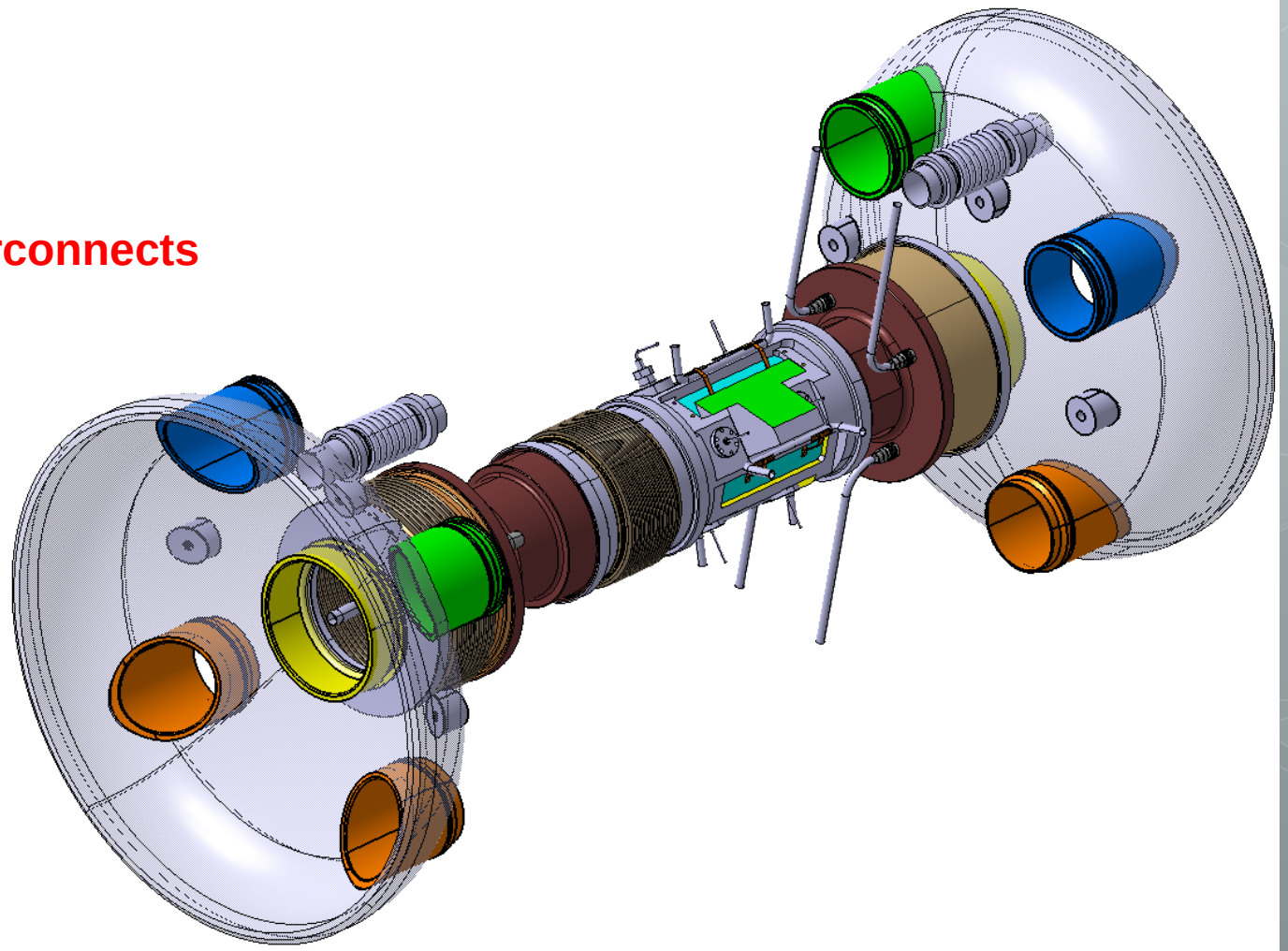
BPMS installation



Finished installation in the tunnel

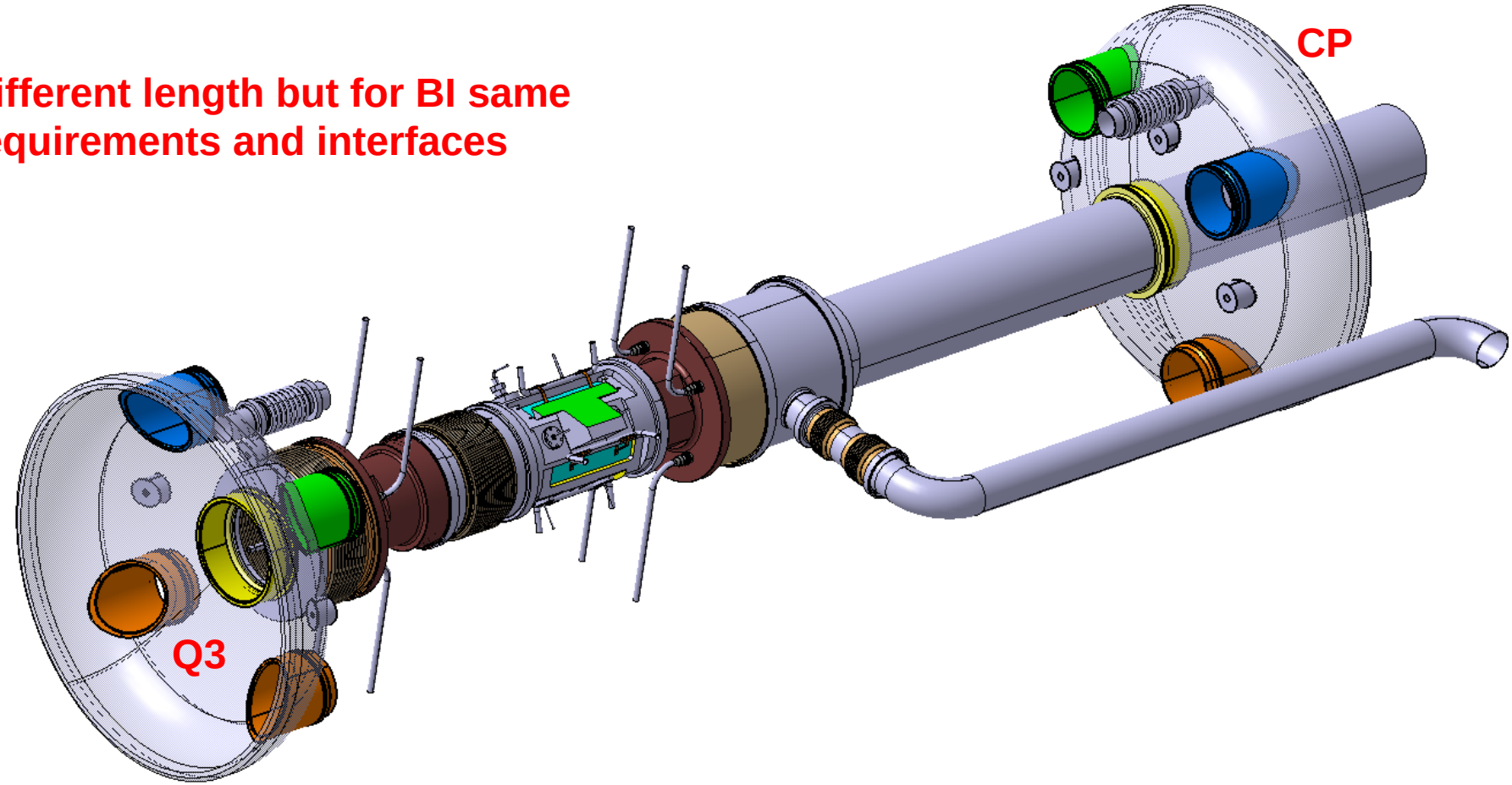
Standard for 4 interconnects

Q1 – Q2a
Q2a – Q2b
Q2b – Q3
CP – D1



Q3 to CP interconnect

Different length but for BI same requirements and interfaces



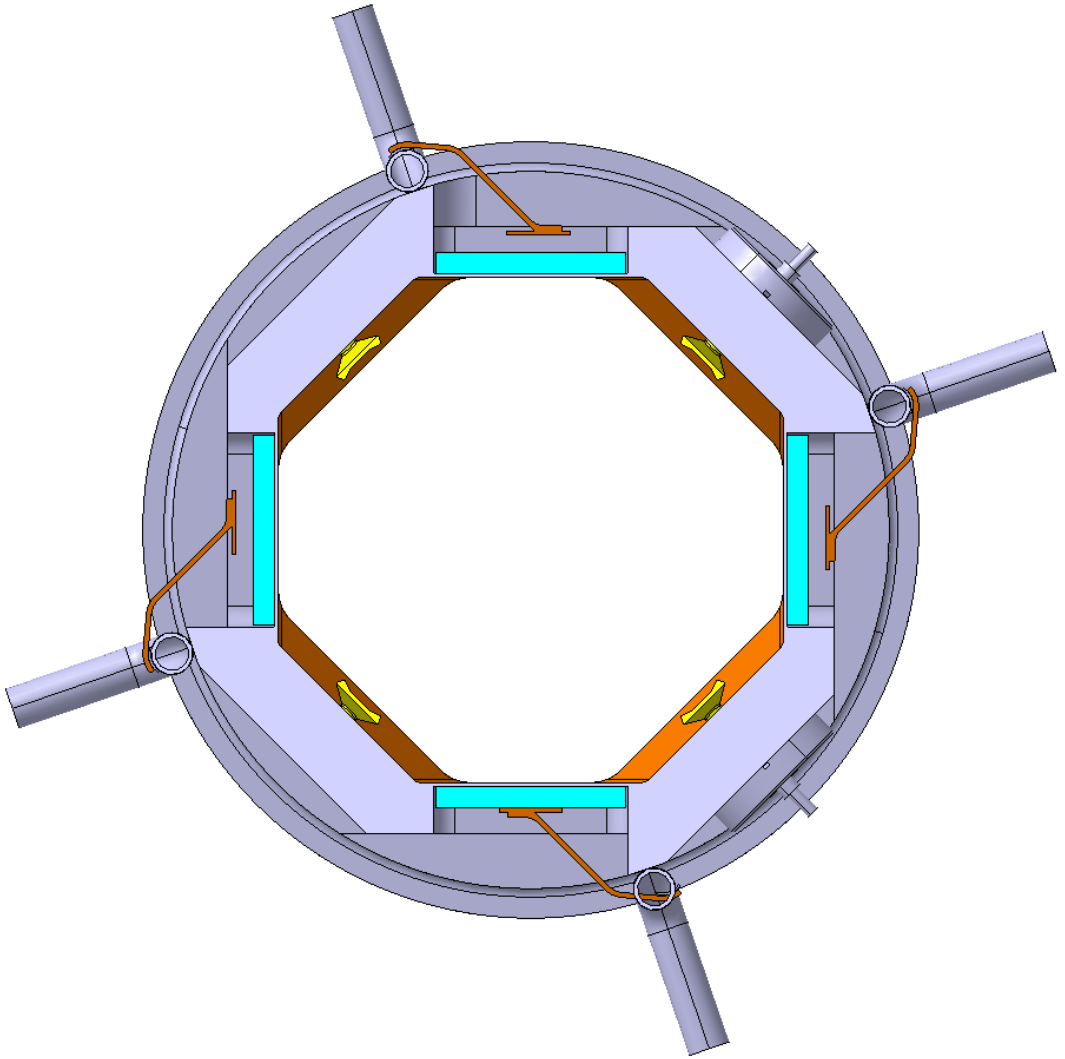
Q1- Cryostat

Same requirements – work on model ongoing

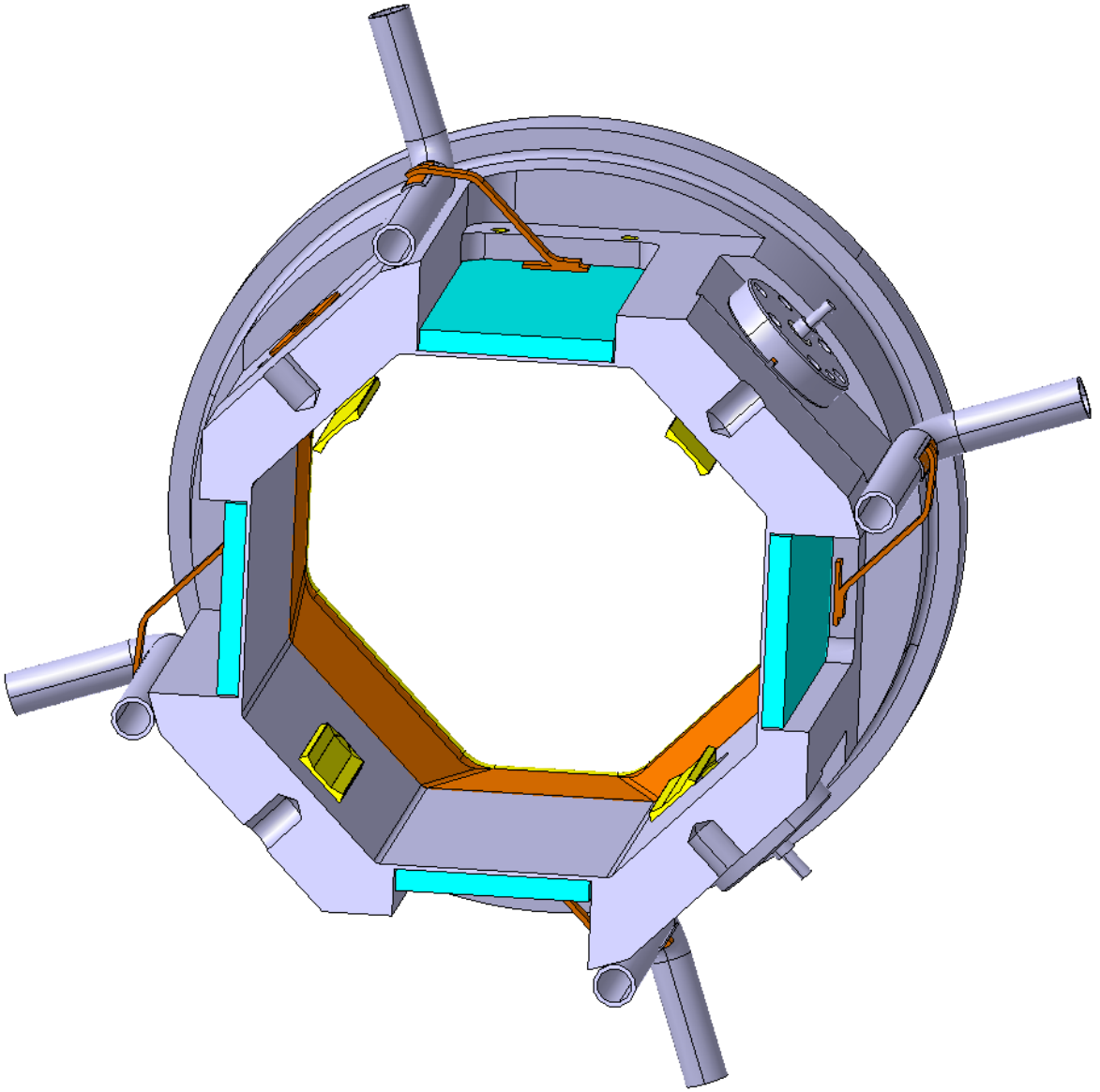
Discussion round or octagonal BPM → Favourable for octagonal

BPMC alignment

BPM Design - inside



BPM Design - cut



Detail Copper Transition- Parts for welding