Collimators for LHC IR3 dispersion suppressors

QTC Bypass cryostat design

May 26, 2011

presented by D. Ramos

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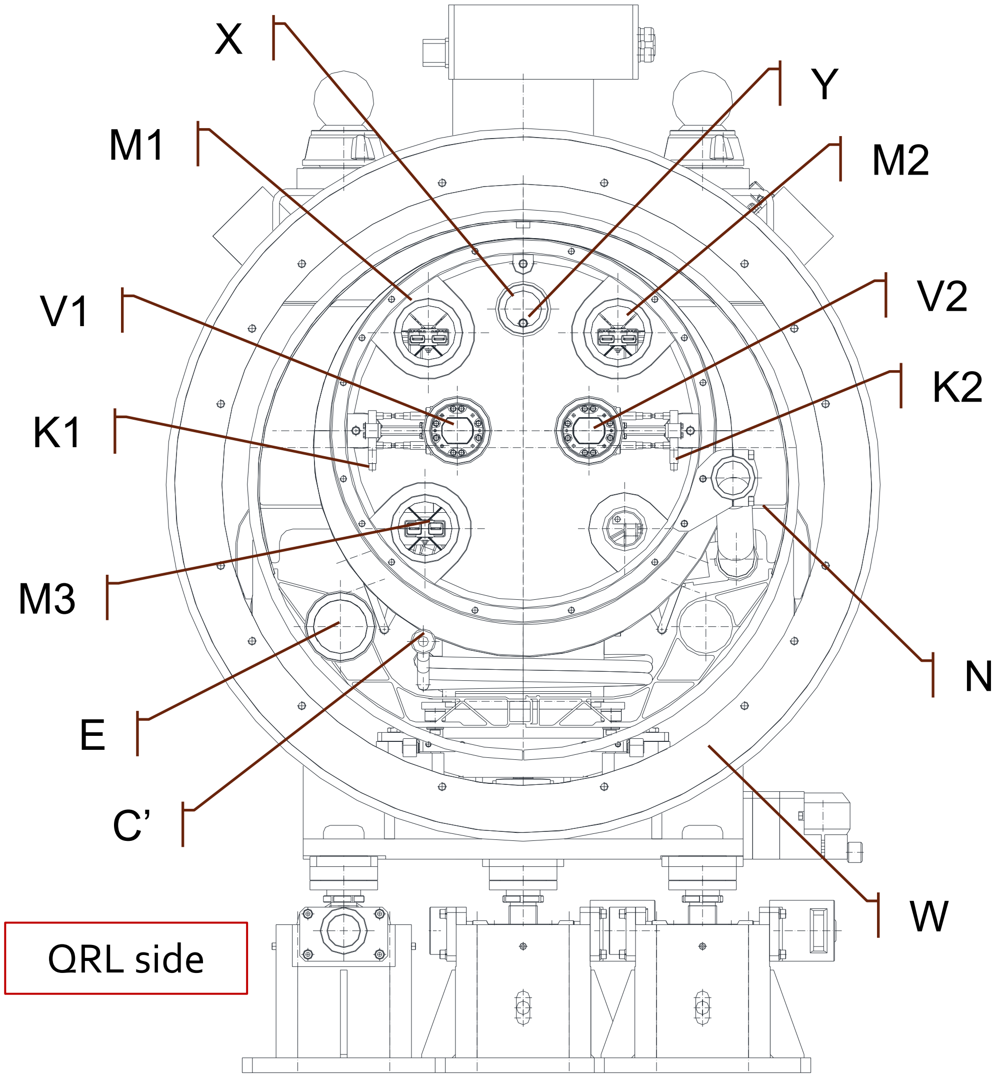
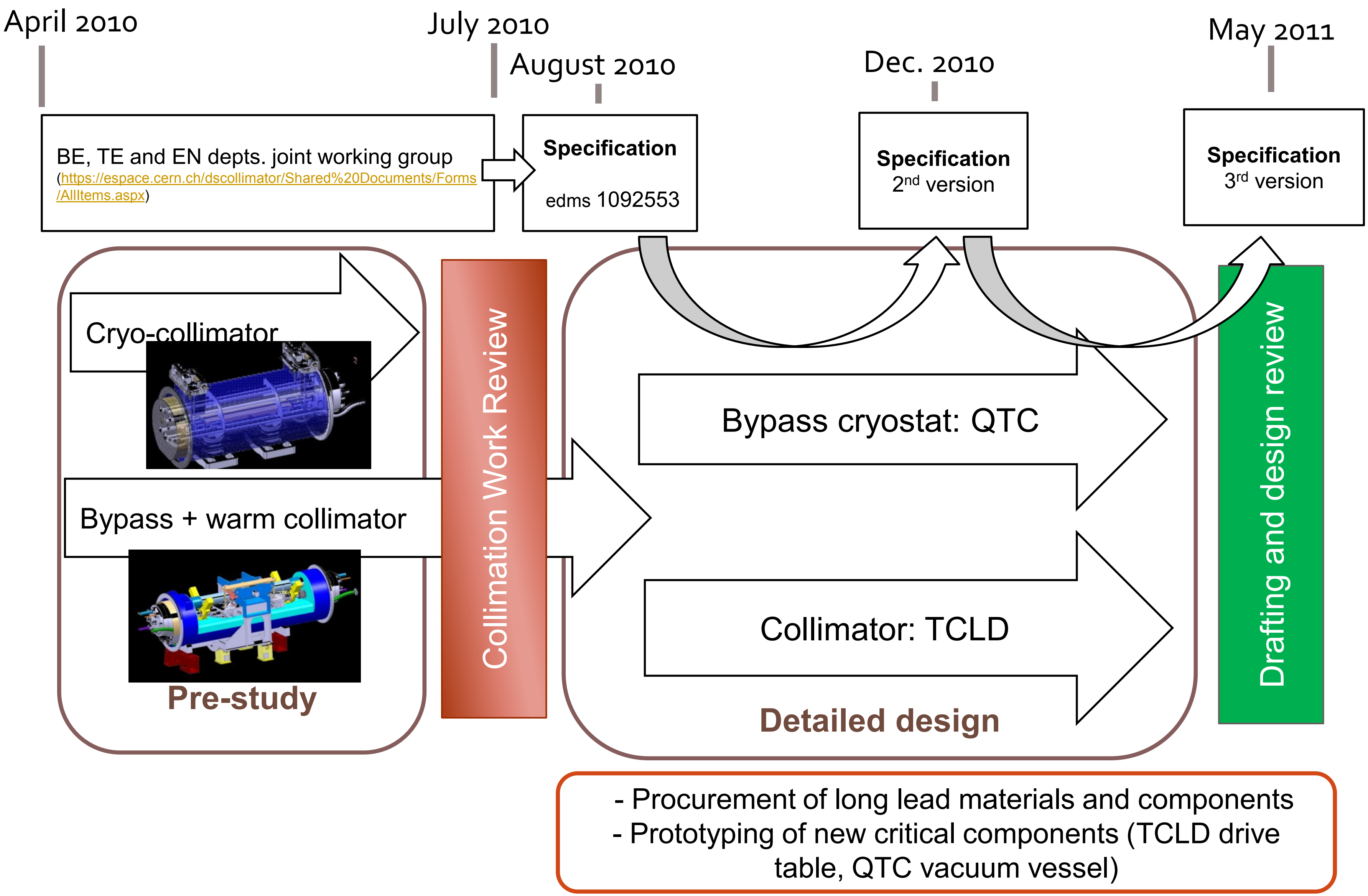
Outline

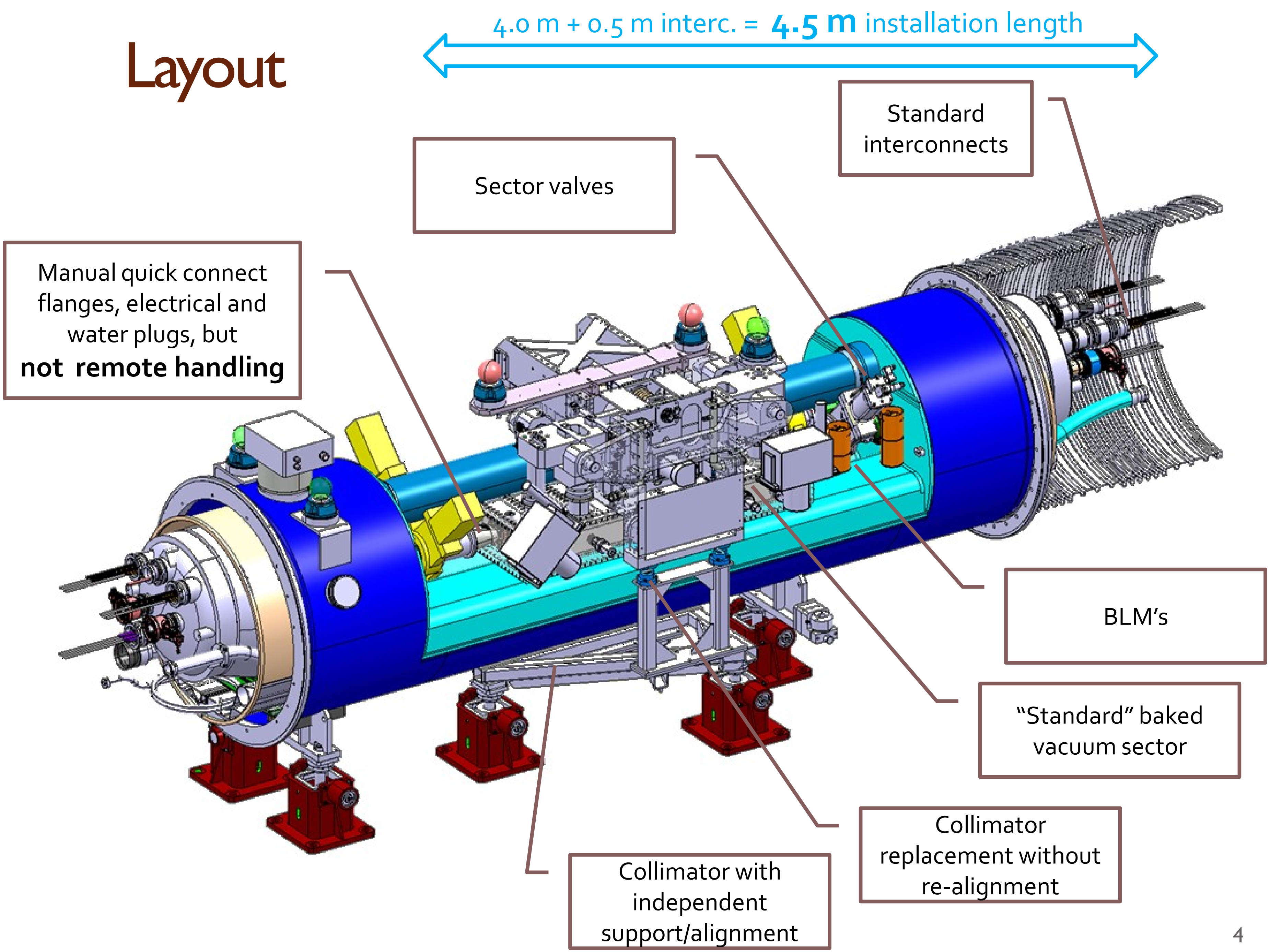


- Overview
- Busbars (M1, M2, M3)
- 1.9 K He II vessel and HX
- 4.6 to 20 K lines (C', K)
- 50 to 75 K level (E, thermal shield)
- Insulation vacuum vessel (W)
- Beam vacuum (V1, V2)
- Supports (cold feet, jacks)
- Conclusion

Project timeline

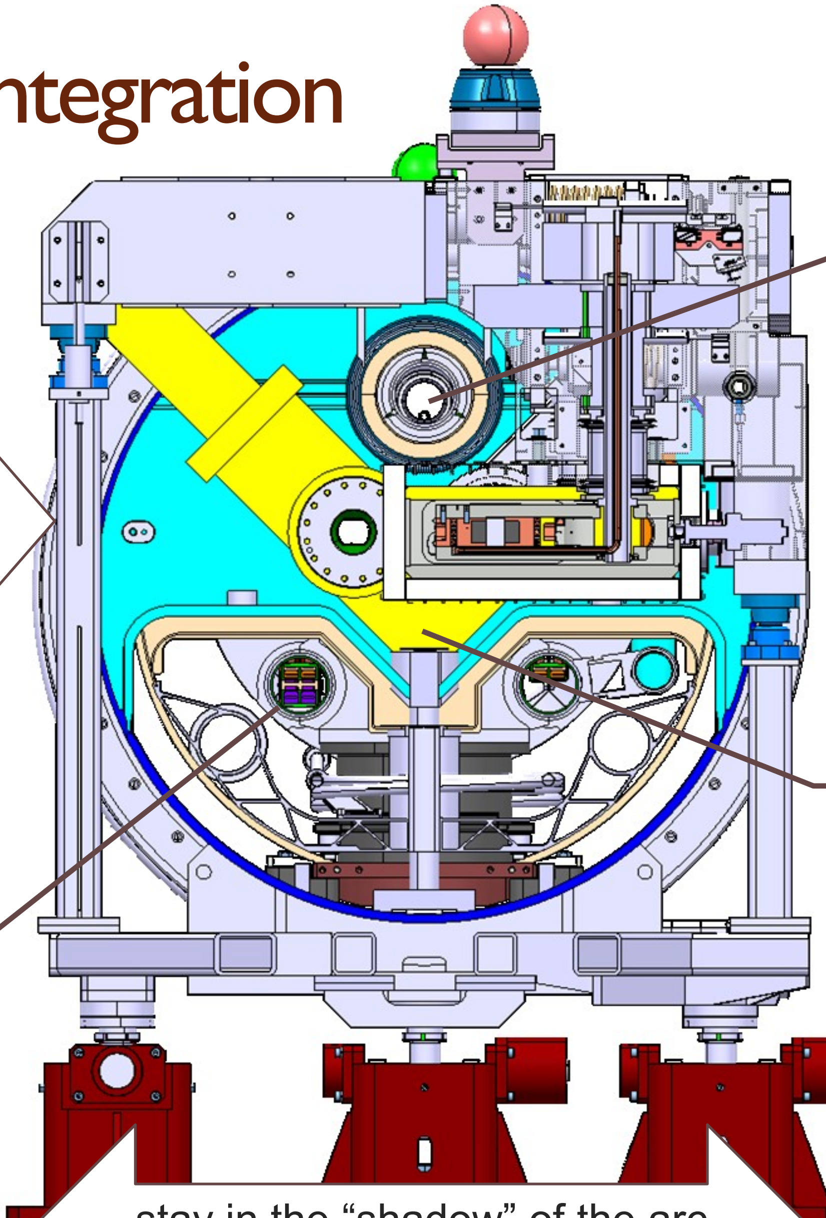


Layout



4.0 m + 0.5 m interc. = **4.5 m** installation length
Standard interconnects
Sector valves
Manual quick connect flanges, electrical and water plugs, but **not remote handling**
BLM's
"Standard" baked vacuum sector
Collimator replacement without re-alignment
Collimator with independent support/alignment

Collimator integration



Σ jaw,
vacuum tank,
bakeout jacket,
assy. tolerances,
installation gap

No bypass for two-phase He flow

RF-shielded sector valves

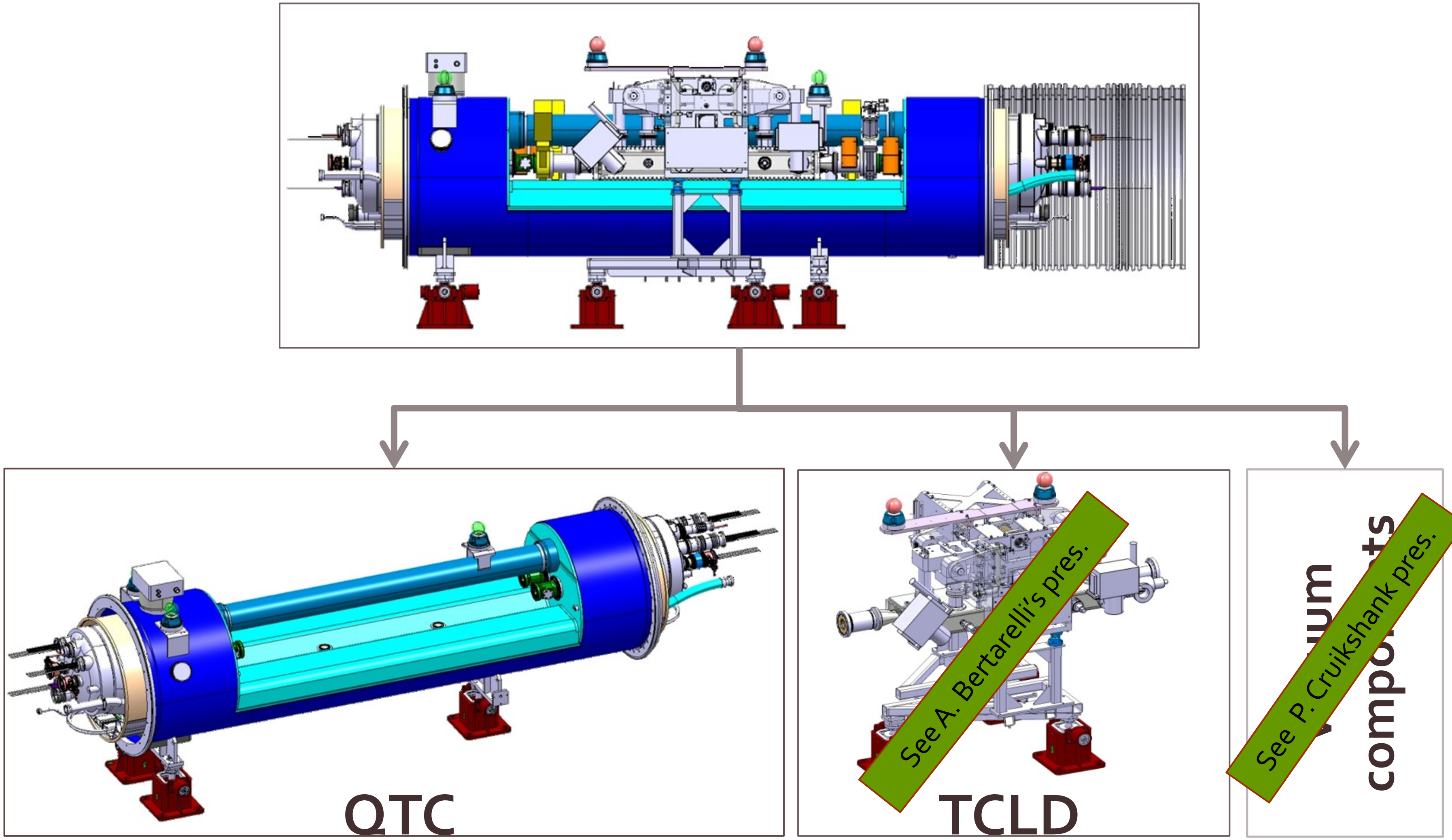
Room for only two bypass tubes
→M1& M3 grouped.

Cross-talk addressed by R. Denz: not an issue

See A. Siemko's pres.

stay in the "shadow" of the arc cryostat

Equipment breakdown



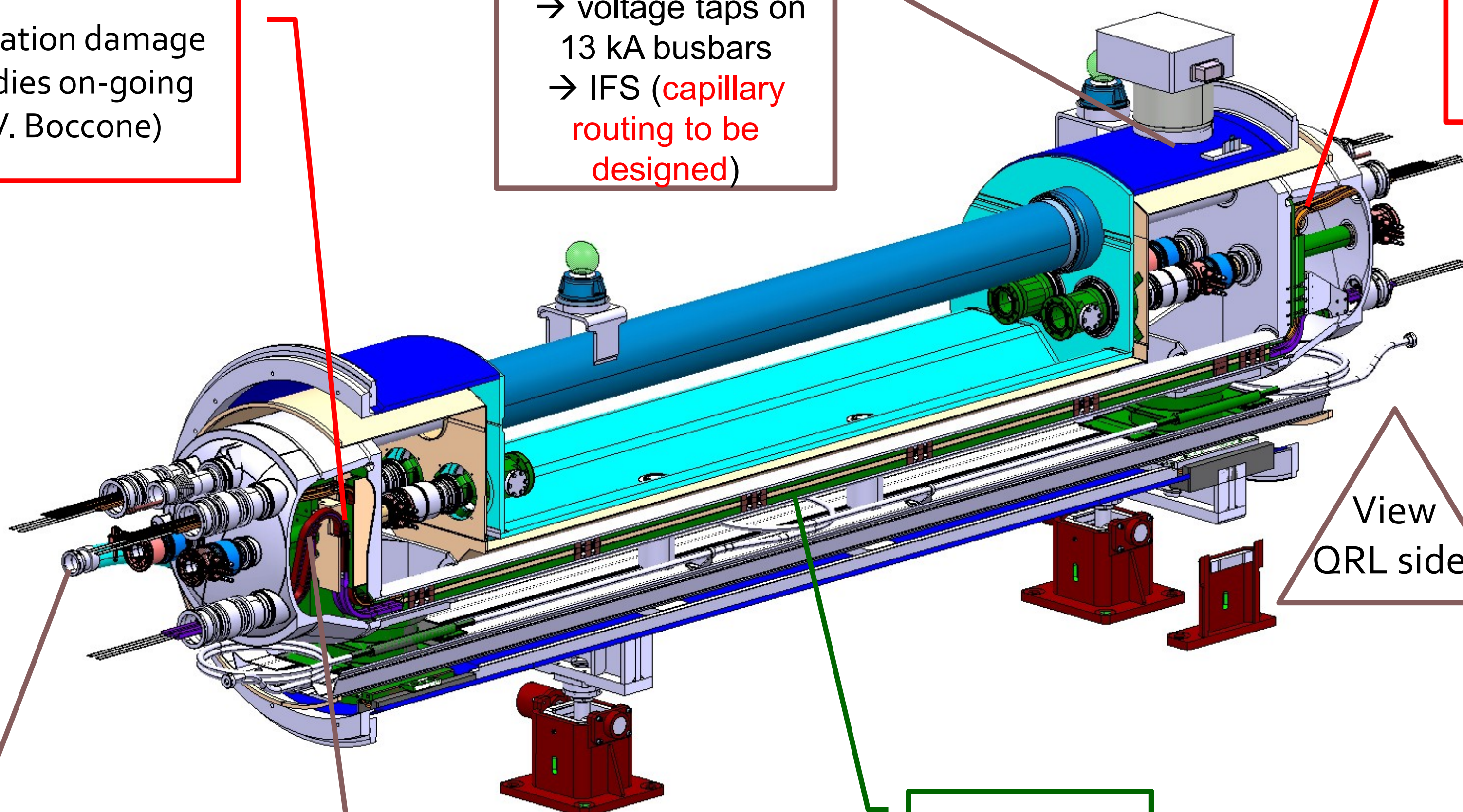
Busbars

See A. Siemko's pres.

New equipment:
→ voltage taps on 13 kA busbars
→ IFS (capillary routing to be designed)

Radiation damage studies on-going (V. Boccone)

Busbar bending in-situ w/ cable already tinned



View QRL side!

Aux. busbars, line N

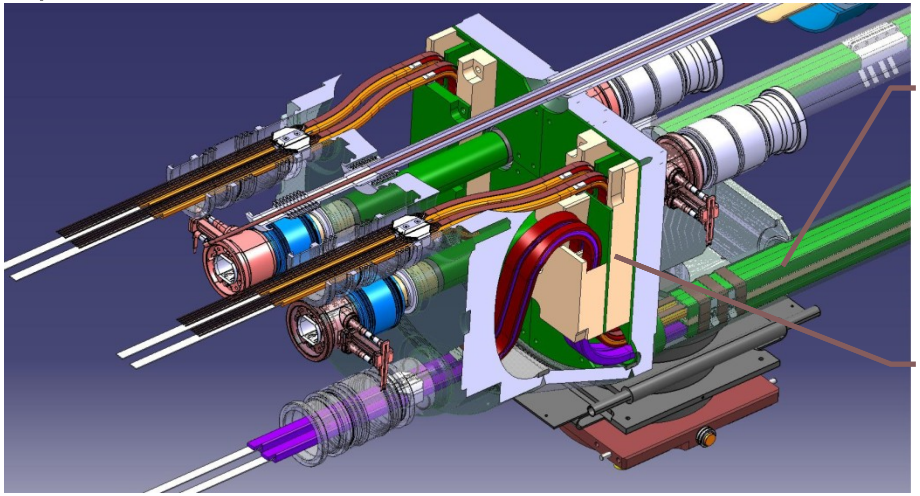
Lyra side pre-assembled before integration

No splices

Weight: ~2.5 ton

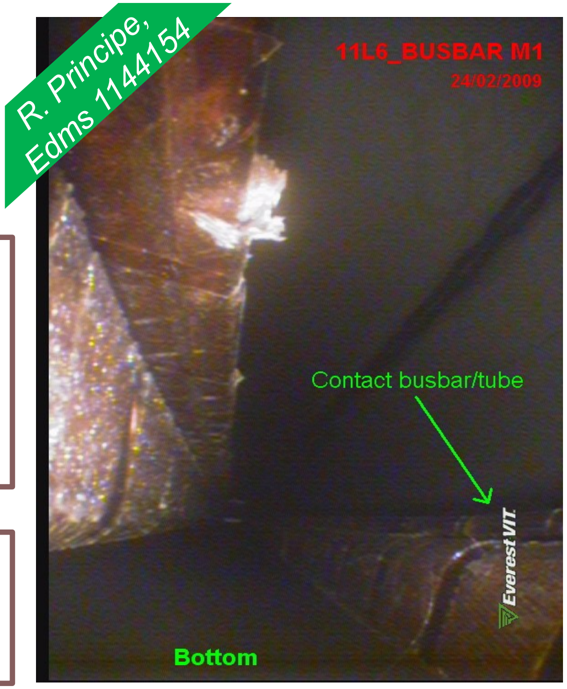
Busbar insulation

Lyra

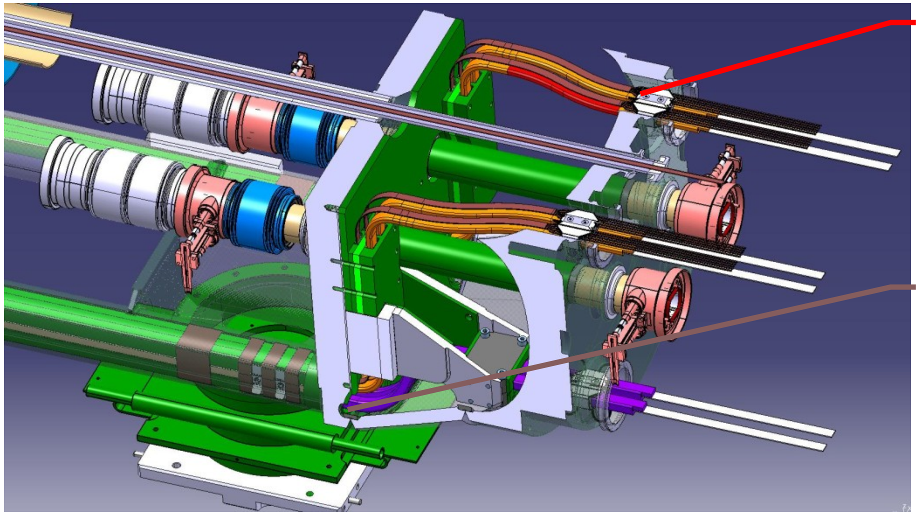


Full length insulation and Lorentz force support (200 kgf/m)

Independently guided lyra displacements

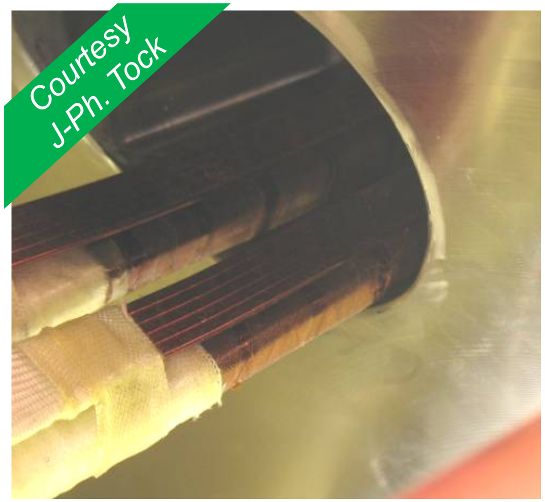


Fixed point



New spiders to be designed

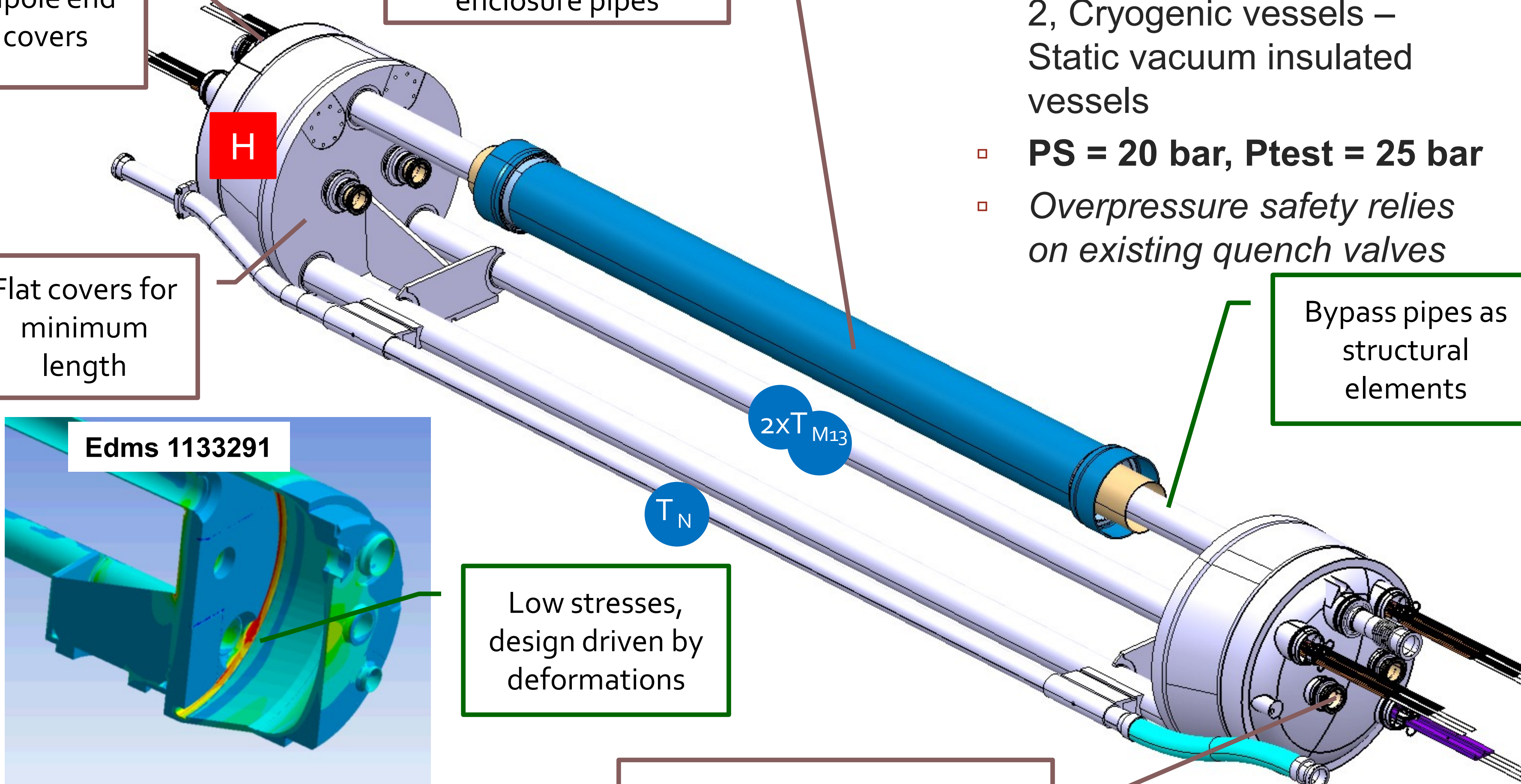
HD polyethylene covering all critical regions



New lyra design: see Edms 1137872

He II inner vessel

- **Pressure vessel**
  - CERN GSI-M3 special equipment
  - EN 13458:2002 parts 1 and 2, Cryogenic vessels – Static vacuum insulated vessels
  - **PS = 20 bar, Ptest = 25 bar**
  - *Overpressure safety relies on existing quench valves*



Dipole end covers

Pre-installed X-line shield and vacuum enclosure pipes

Flat covers for minimum length

Bypass pipes as structural elements

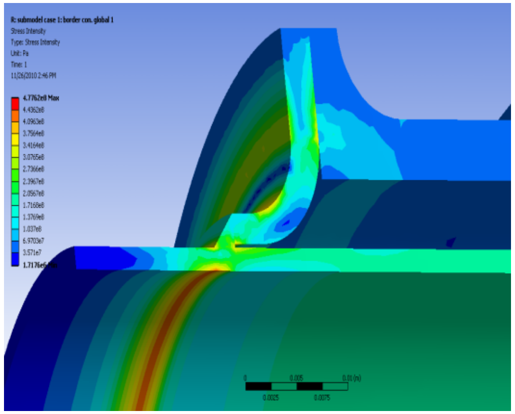
Low stresses, design driven by deformations

Cold bore tubes: installed after vessel closure to avoid welding distortions

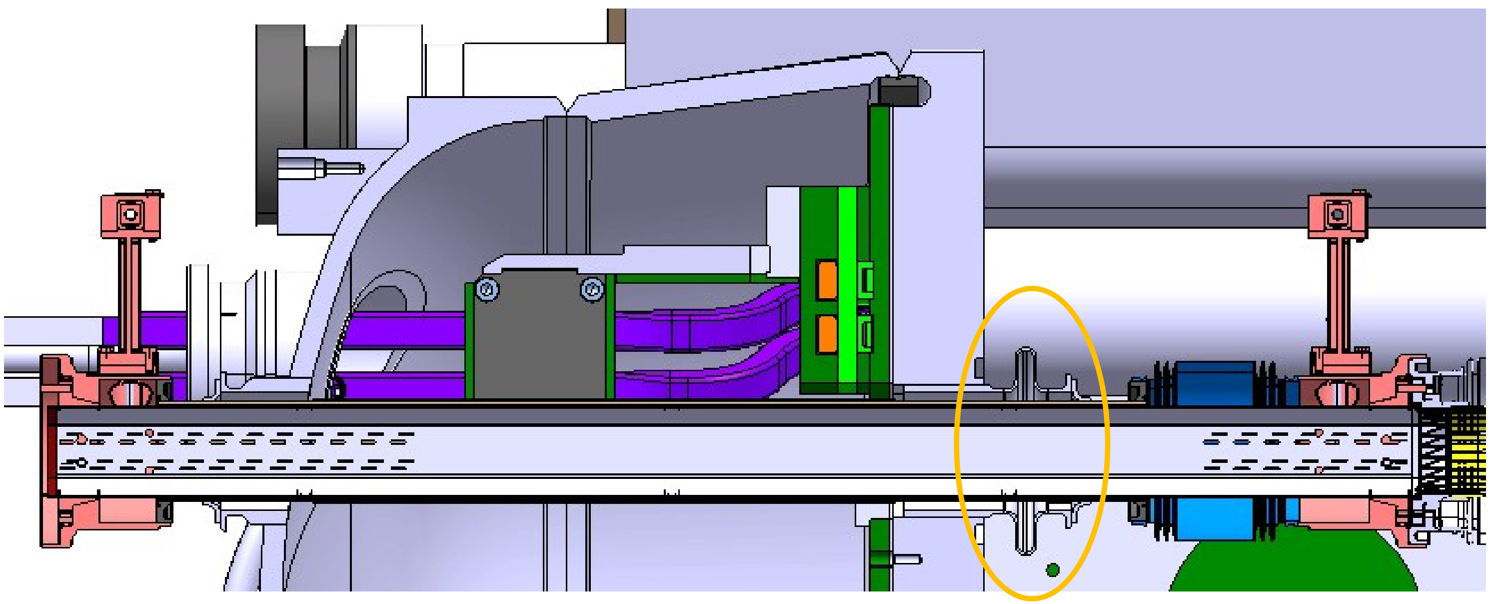
See R. Van Weelderen's pres. for details on instrumentation

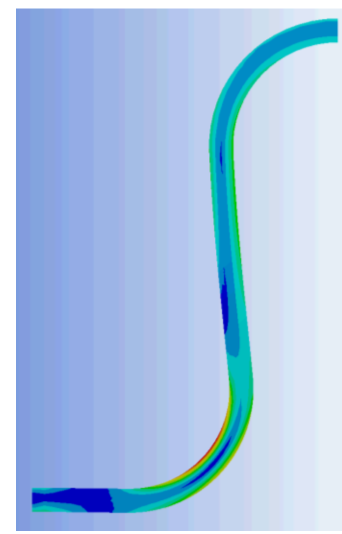
Draft fabrication specification Edms 1132997

Interface with cold bore tube



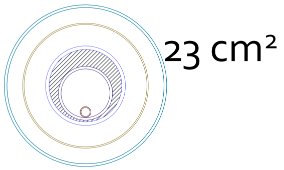
- **Short cold bore tube**
  - Flat cover deflection and short cold bore → High stress
  - Solution: Membrane for longitudinal flexibility
  - Compromise between pressure strength and flexibility: **Design close to maximum allowance**
  - Maintain lateral stiffness for cold bore alignment (64 kN/mm)



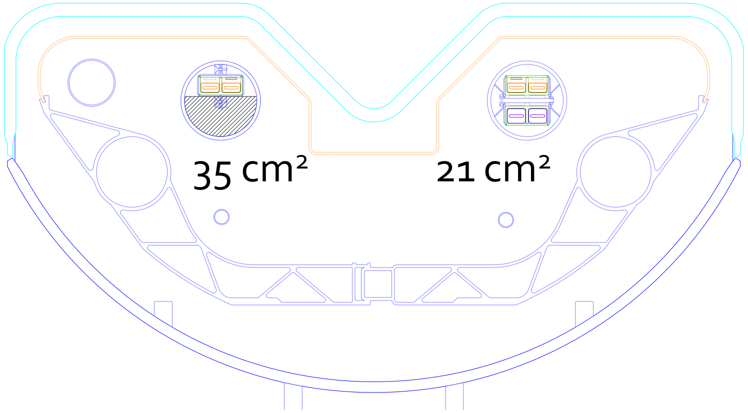


Hydraulic and thermal continuity

- Pressure drop analytical estimations:
  - He flow 6 kg/s, 6 K, 20 bar
  - Specification: Pressure drop of a 50 mm smooth pipe: **4.3 kPa/m**
  - Pressure drop QTC: **3.1 kPa/m** (ε=0.2 mm)
  - *Conservative results according to CFD analysis by H. Alain TE-CRG*

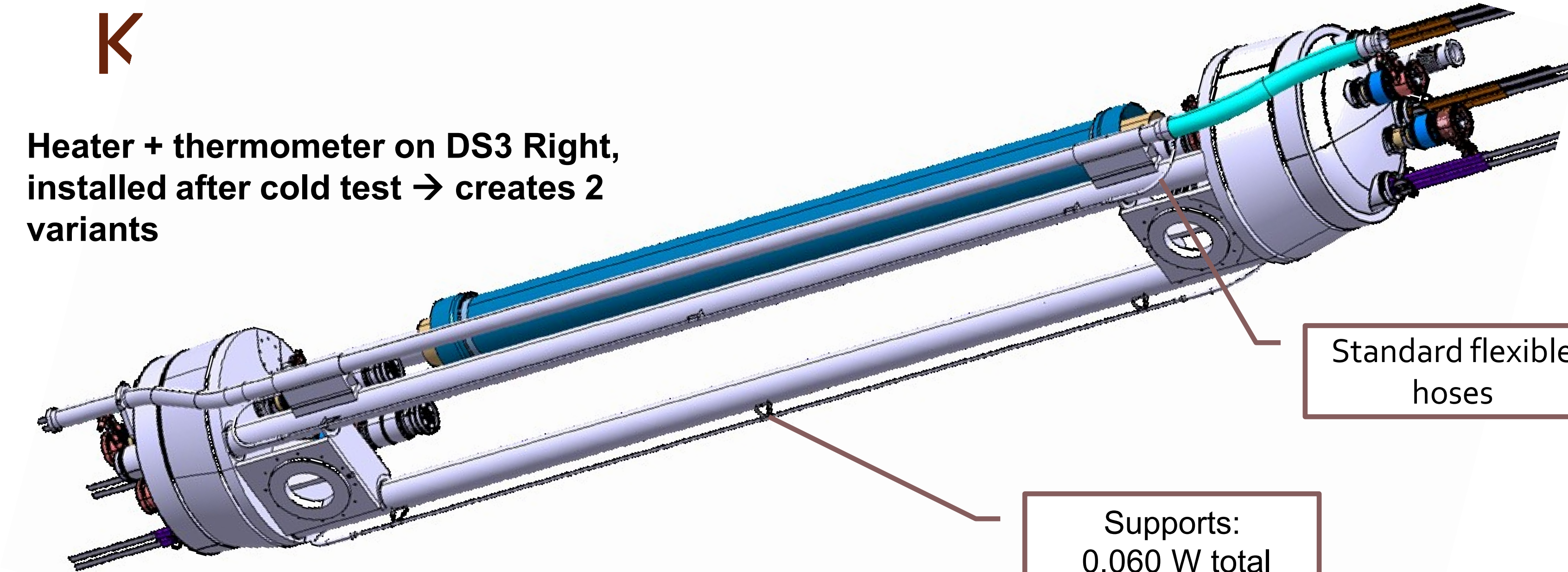


- He II free cross section:
  - **79 cm^2** > specification: **60 cm^2**

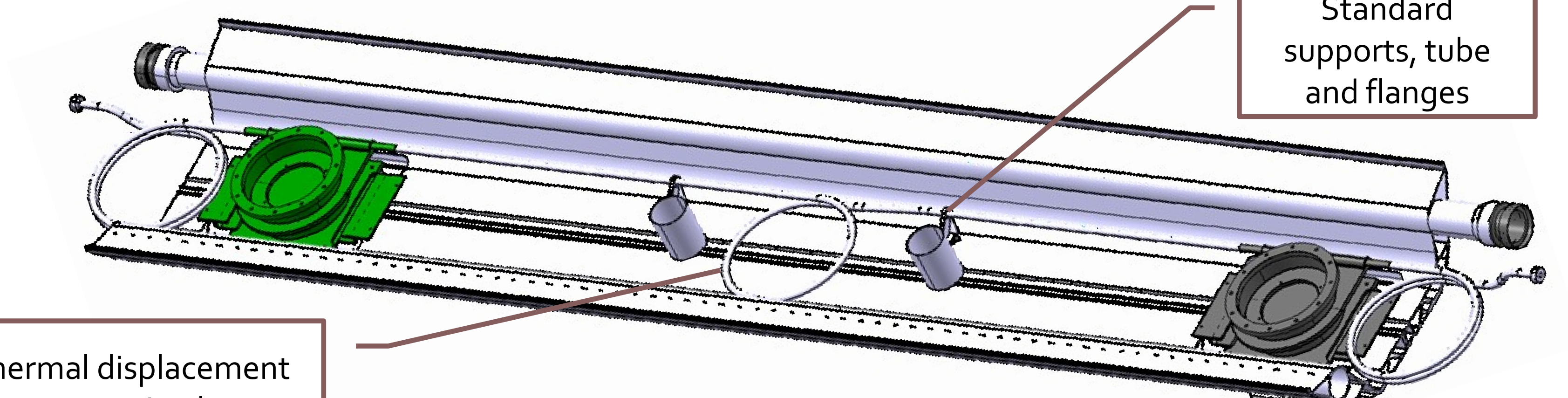


K

Heater + thermometer on DS3 Right, installed after cold test → creates 2 variants

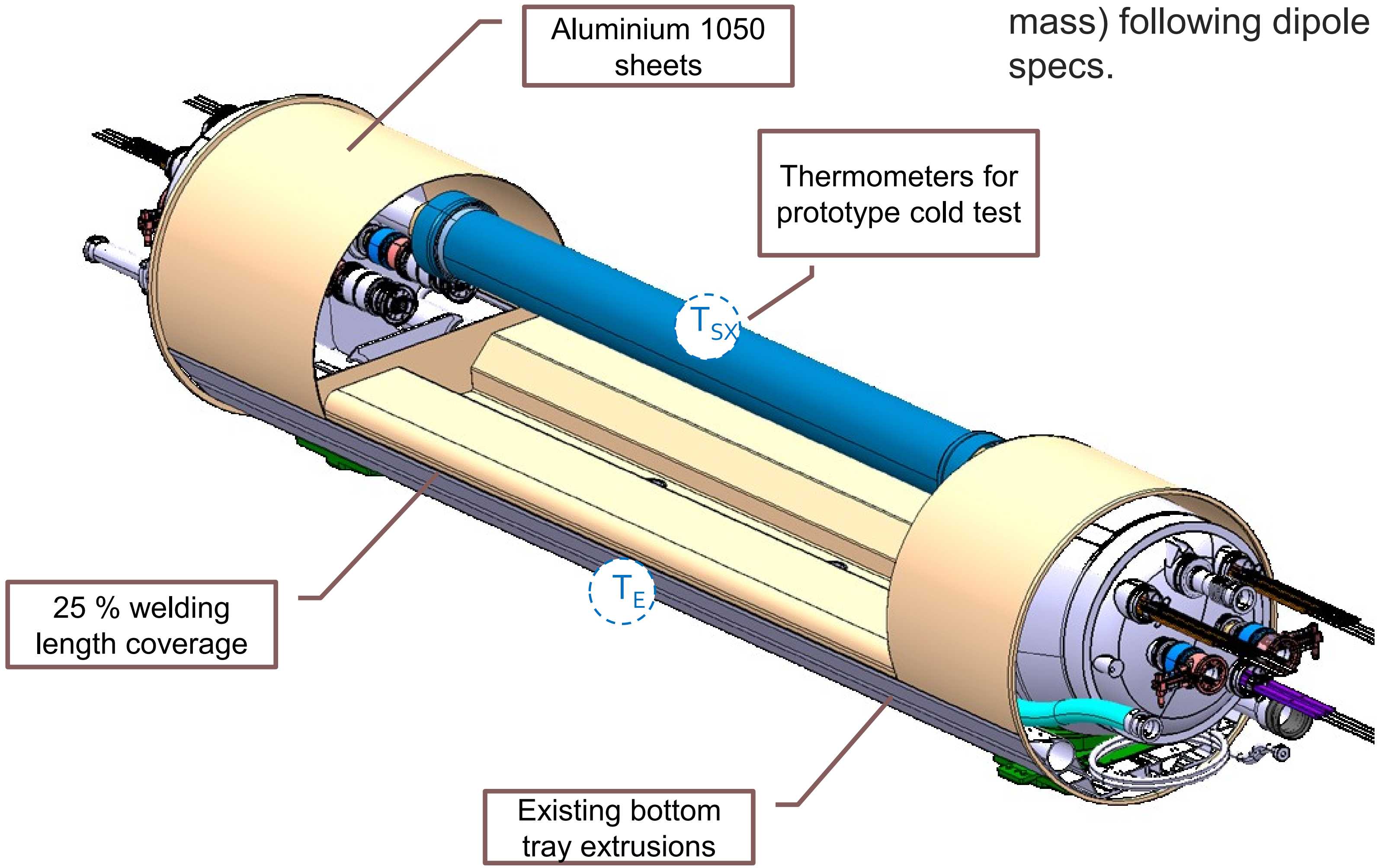


C'-line: support post thermalisation



Thermal shield

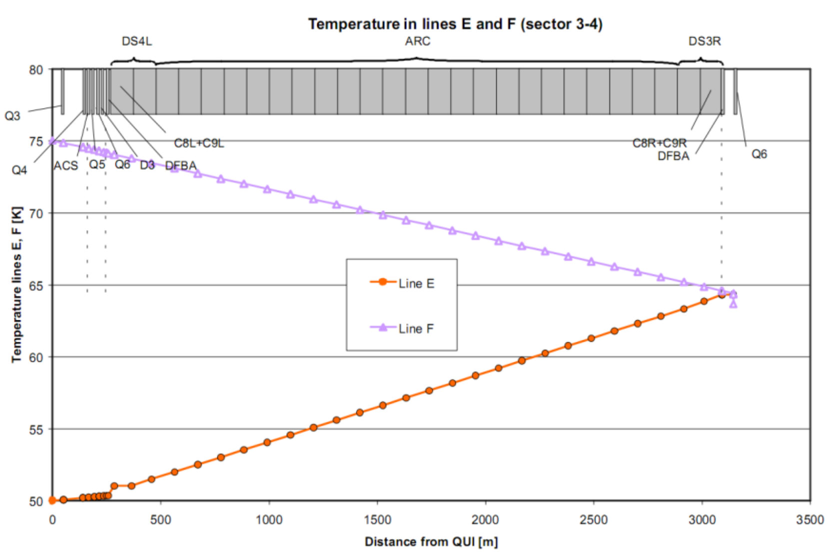
- Subcontracted design and fabrication of MLI blankets (including cold mass) following dipole specs.

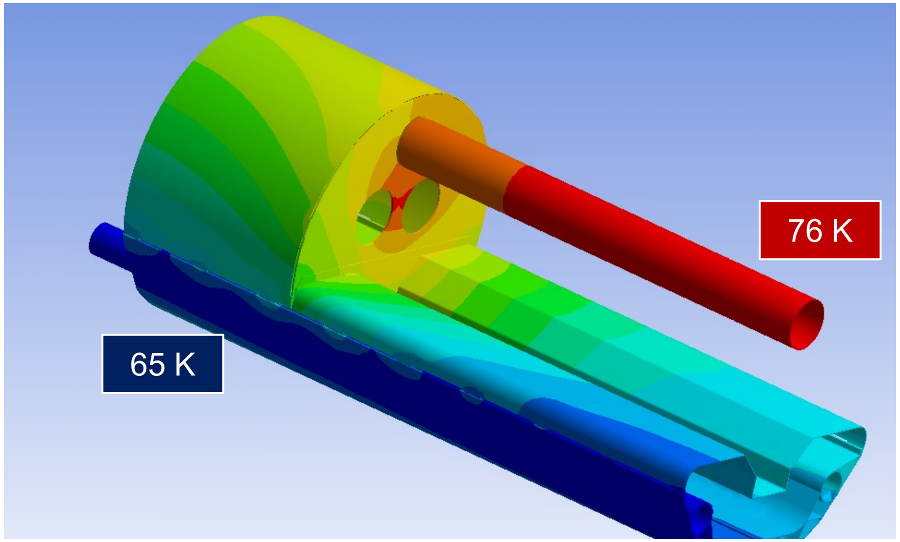


Temperature gradient

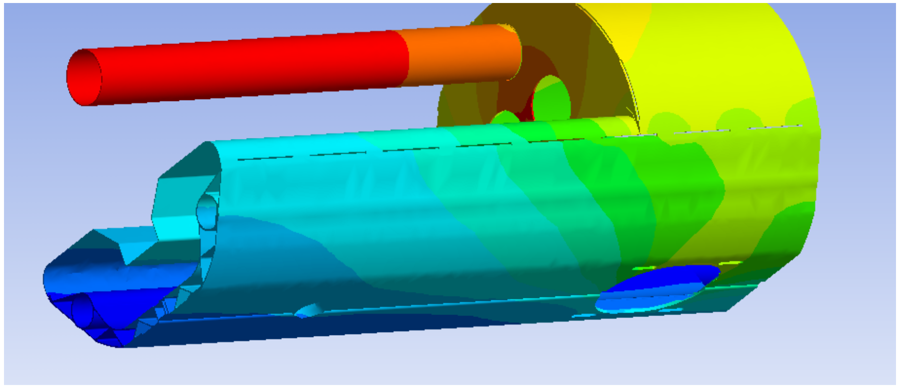
- Heat loads
  - Radiation: 1.5 W/m$^{2(*)}$
  - Supports: 7.1 W$^{(**)}$ p/unit
  - CWT: 6 W p/unit
  - Total: 52 W
- Cooling
  - T_{He} = 65 K
  - h = 489 W/m^2 K
- 25% welding coverage
  - ~2 K increase wrt full welded length

Temperature profiles for sector 3-4 : lines E and F





assuming 80K → ~0.008 W/m, 100K → 0.020 W/m to the X line enclosure pipe, w.r.t 0.350 W/m avg. static heat load in DS (R. van Weelderen)***



* Typical heat load from 290K, MLI 30 layers, pressure < 1 mPa. average from DS3 and DS7 total load is 1.2 W/m^2

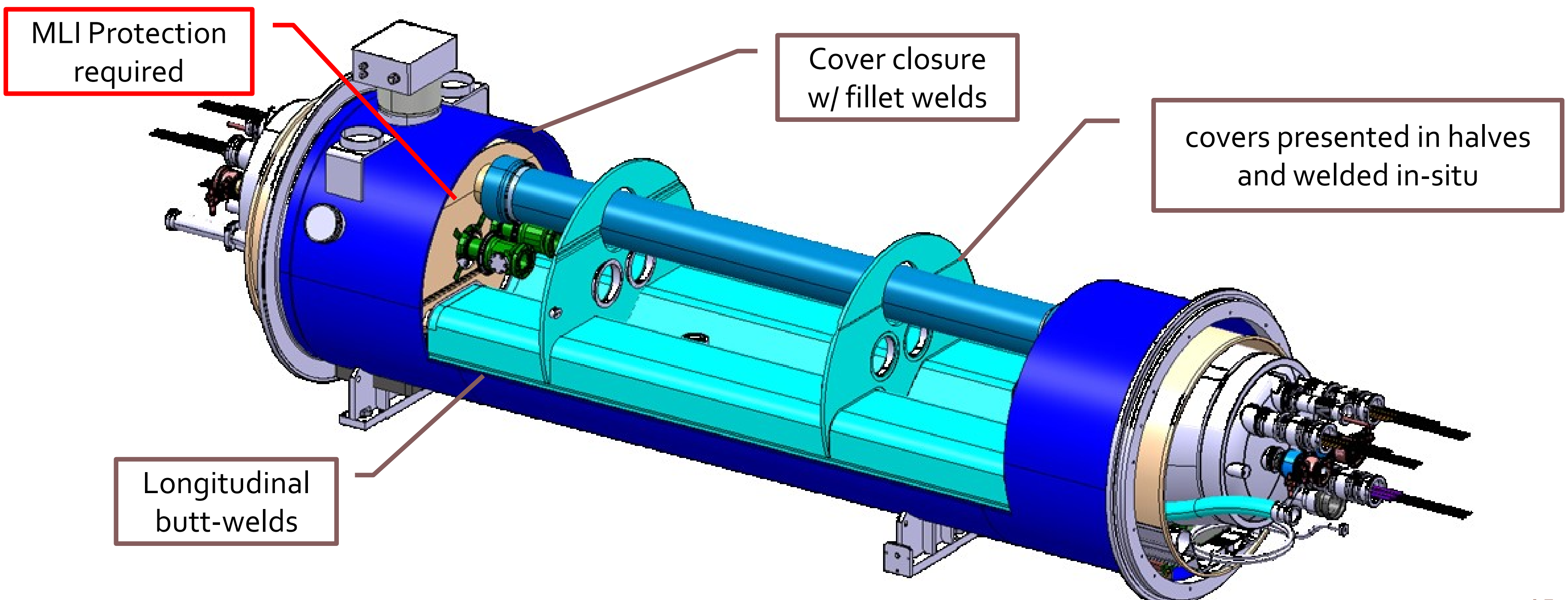
** M. Castoldi et al. LHC project report 335

***Calculated without MLI, Al foil on cold surface (e=0.01), Al shield as delivered (e=0.12). Total heat load: 0.020 W (80K) static + 0.420 W dynamic (FLUKA, 10s)

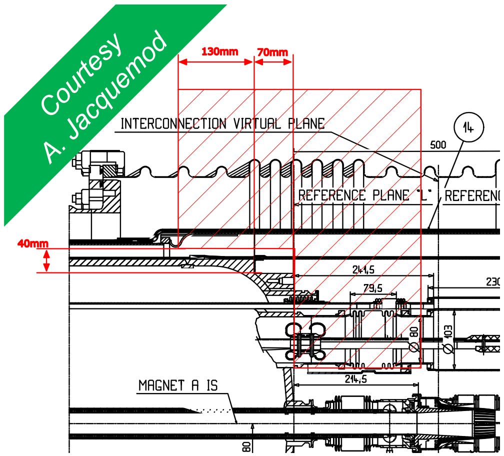
Vacuum vessel design

An assembly challenge!

- Can only be finished after cryostating
- Dealing with **welding distortions** is a major issue
  - **Mock-up** under fabrication for welding tests
  - **Adjustment of cold mass supports** is required
  - Elaborated assembly procedure
- Material: magnetic shielding for coollimator LVDT accuracy
  - Charpy test min. **27 J at -50 ºC** test temperature (as LHC dipoles)
  - P355NL2 chosen for low temp. resilience and availability



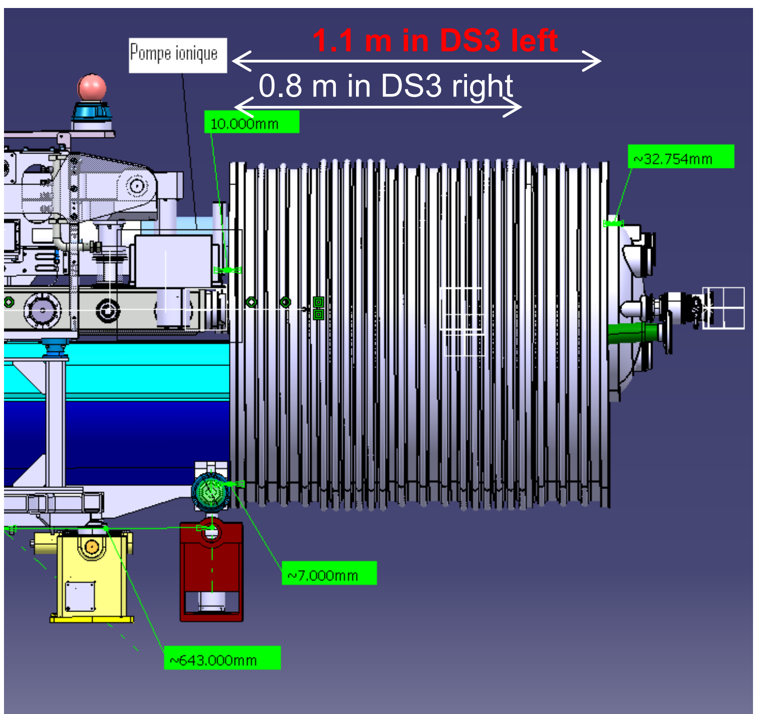
Interconnect accessibility

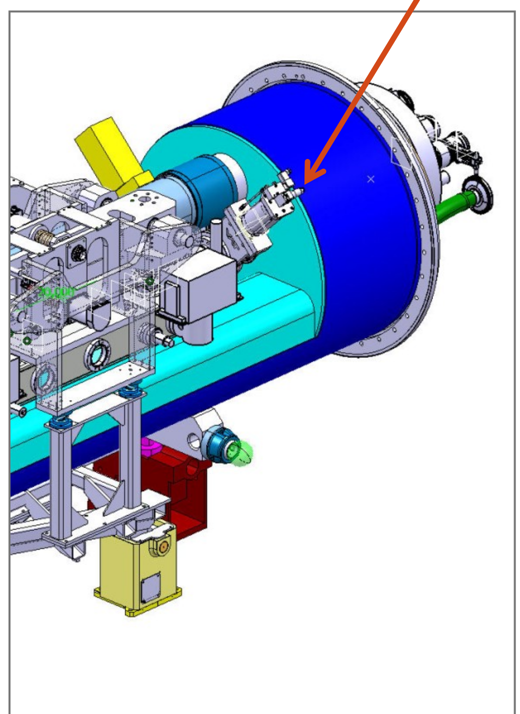


Alternative support for the US welding machine required

All interconnect components remain standard

- Interference with sector valve
  - Valve actuator removed prior sleeve opening
  - Actuator removal test has proven the feasibility in closed position (W. Maan)



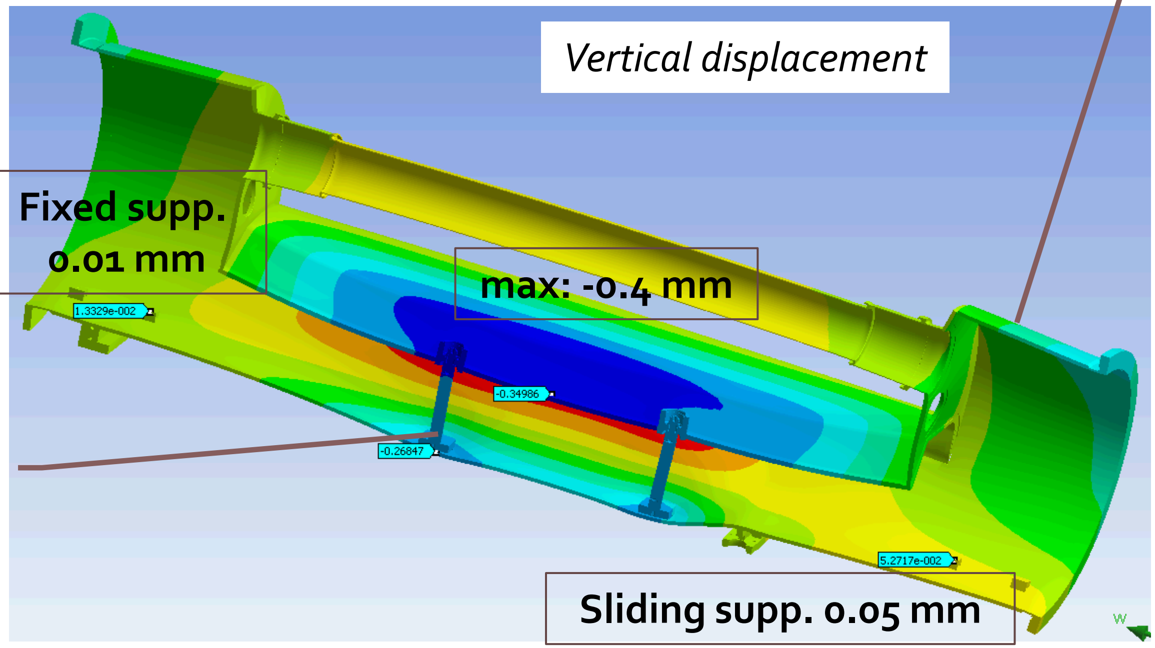


Beam vacuum and insulation vacuum operations decoupled

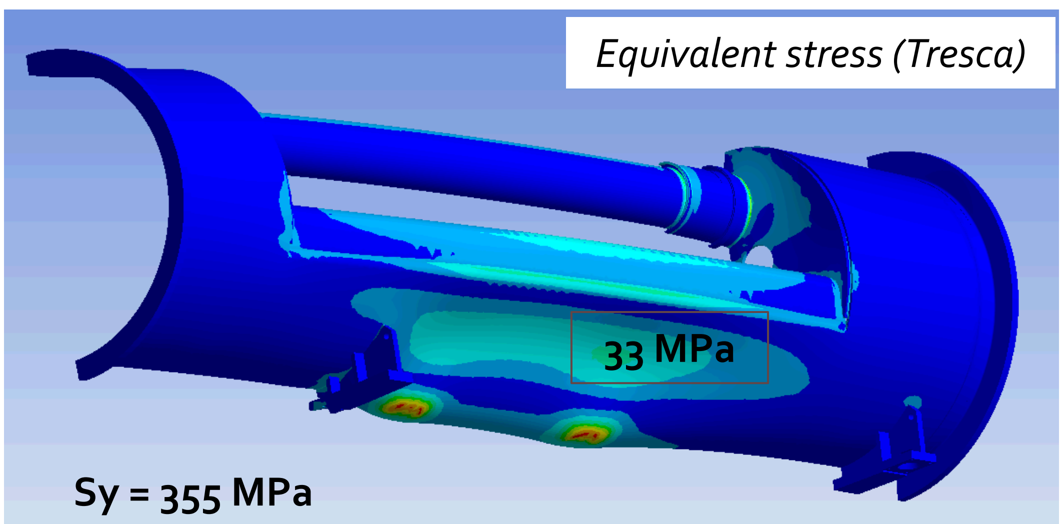
Mechanical stability

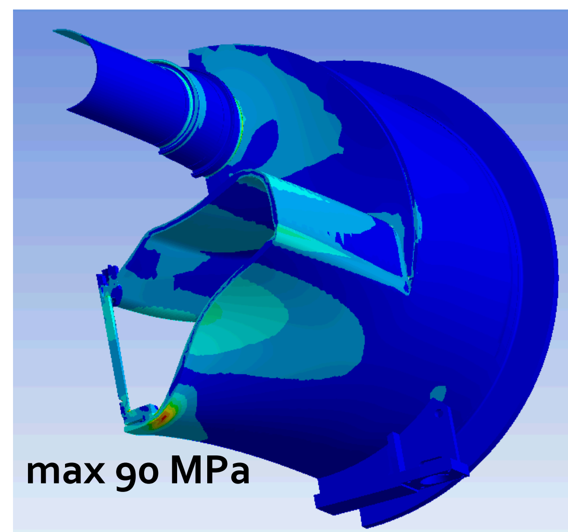
Draft fabrication specification
Edms 1132998

Cylindrical extremities for support base rigidity and flange flatness



Internal pillars to limit displacements



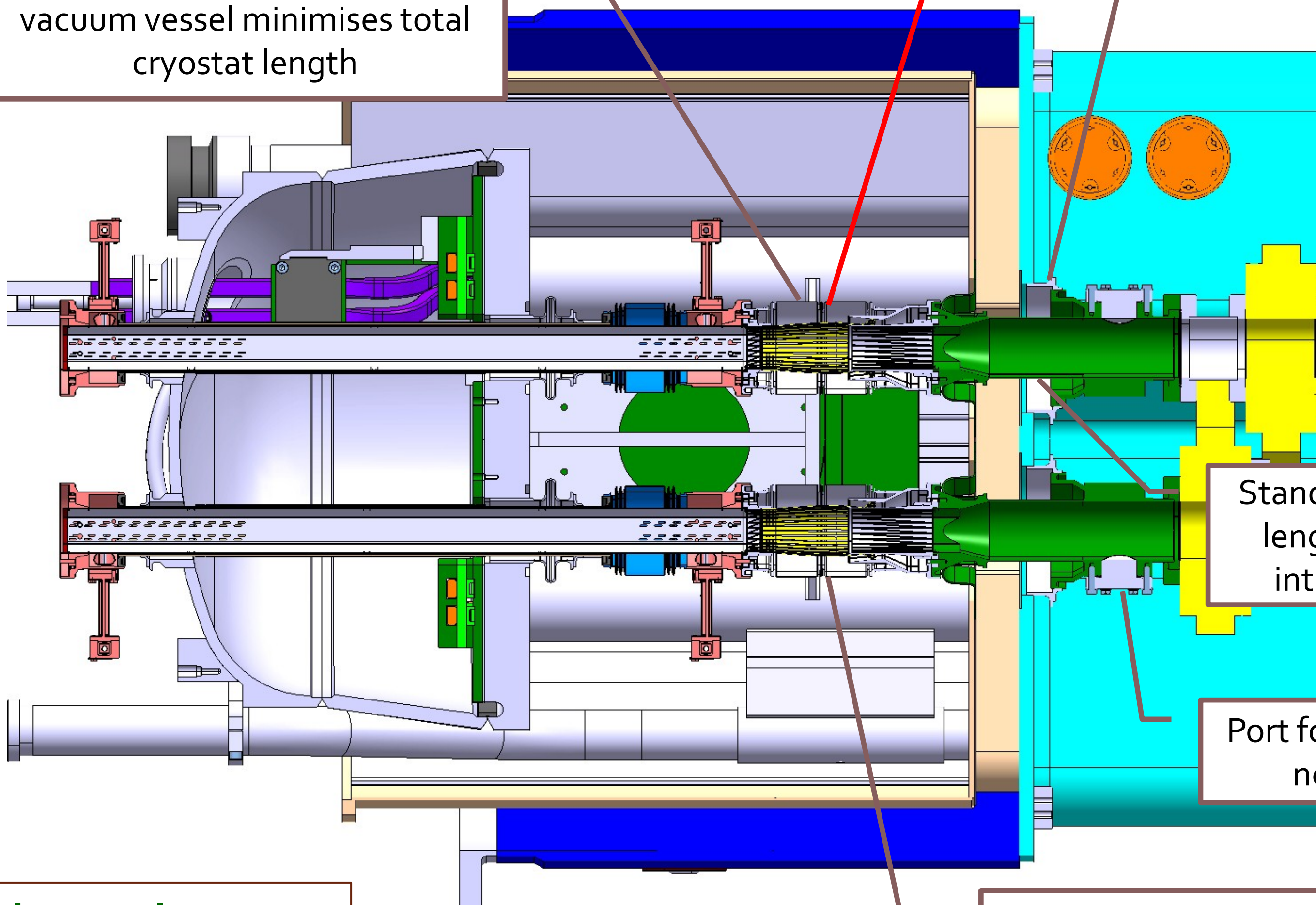


Cold beam vacuum

No access after vacuum vessel closure (as Q1 magnets)

CWT welded to the vacuum vessel: supports sector valve

Placing flexible element inside vacuum vessel minimises total cryostat length



Standard insulation length with heat intercept (6 W)

Port for RF-ball test: new design

Cold and warm beam vacuum operation decoupled

See P. Cruikshank's presentation for changes in vacuum sectors

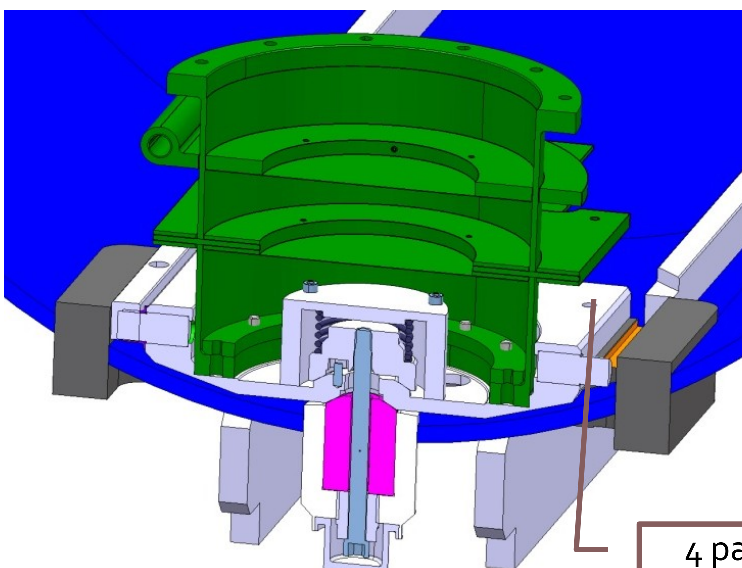
Off the shelf components: bellows and cooling tubes feedthroughs

Cold supports

Cold mass weight: ~1 ton

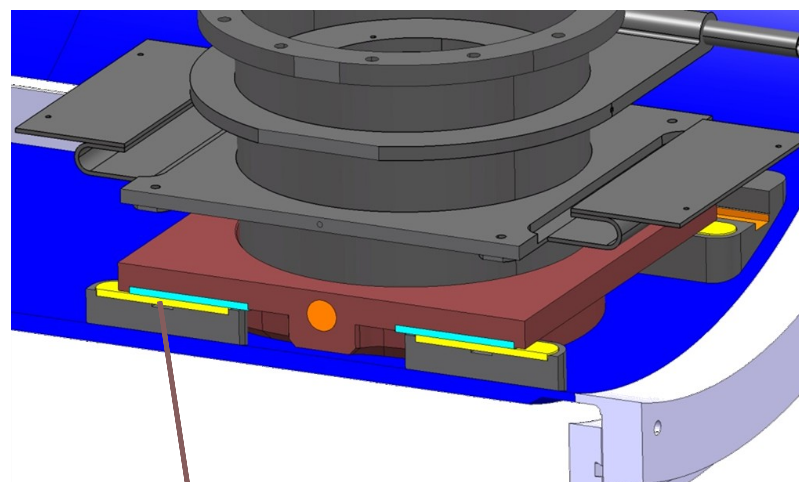
- Dipole type cold support posts
- Comparatively low cold mass weight (~5 kN/support):
  - Roll and lift must be restrained ($|F_{transv}|$=6.3 kN, $M_{y,max}$=5000 Nm*)
  - Support post additional inner ring for vertical restraint
- Compensation for displacements of support bases due to welding distortion
  - Intermediate base plates with angle adjustment

Fixed support



4 pairs of push/pull screws as anti-roll restraint (My)

Sliding support

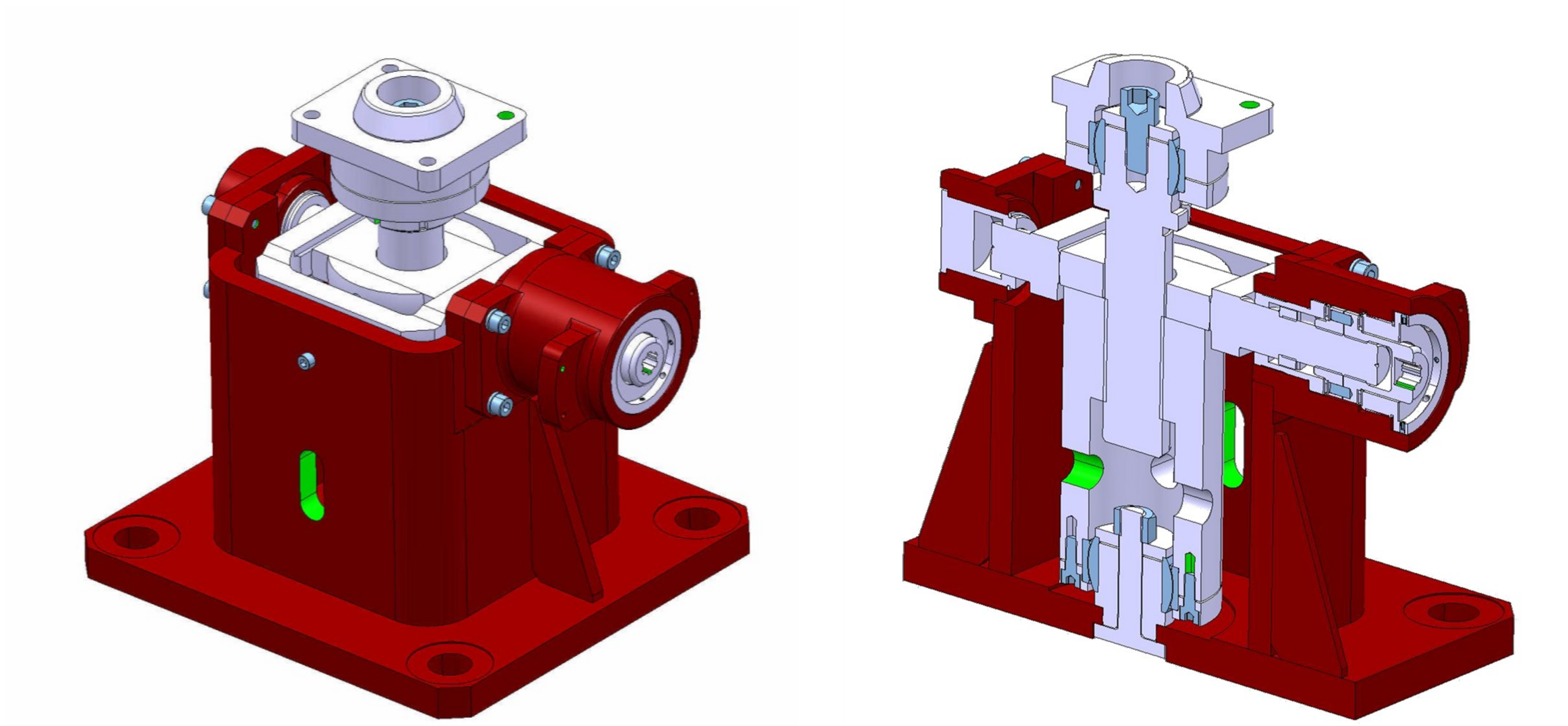


Sliding shims can be re-machined if needed

* Per support post, including load safety factor 1.5

Jacks

- Same alignment principle as LHC jacks
- Shorter design with additional **vertical restraint**
- Welded construction instead of forged block (small series)



Remarks

- **Unique design** up to cold test, declines in 2 variants as installed (C' line circuit)
- Operation **independency of vacuum systems** is preserved
  - Sector valves between warm and cold beam vacuum
  - Insulation vacuum accessible with sector valves closed (but actuator must be demounted to open W sleeve)
  - RF-ball test of cold sectors possible without venting the collimator
- **Pressure limiting devices**
  - He volumes and lines: existing pressure relief valves in the QRL service modules
  - Beam vacuum: additional burst disks on SSS pumping ports
  - Insulation vacuum: DN200's on neighbouring dipoles
- **Flow and thermal continuity** of the cryogenic and vacuum systems is kept
- The design profits from **experience** with connection cryostats and DFBA shuffling modules
- **Busbar supports and insulation** design thoroughly studied

Acknowledged challenges

- **Intricate assembly** procedure relying on good craftsmanship
- **Welding distortions** during vacuum vessel closure
- **MLI fire hazard** during vacuum vessel closure
- **Short gaps** between busbars insulation and He vessel walls (electrical insulation, damage during welding)
- **Access for repairs** may imply destruction of the vacuum vessel
- **Beam vacuum lines partly inaccessible** after cryostat closure
- **Cold test can reveal some possible defects but not all** (wear and fatigue damage, interaction with neighbouring magnets...)

- More detailed information
  - Edms hardware baseline
    - QTC https://edms.cern.ch/nav/P:LHCPM001:V0/P:LHCPM065:V0
    - TCLD https://edms.cern.ch/nav/P:LHCPM001:V0/P:LHCPM076:V0
  - Meeting minutes and working documents at

Project sharepoint site:

espace.cern.ch/dscollimator

Thank you for your attention!