



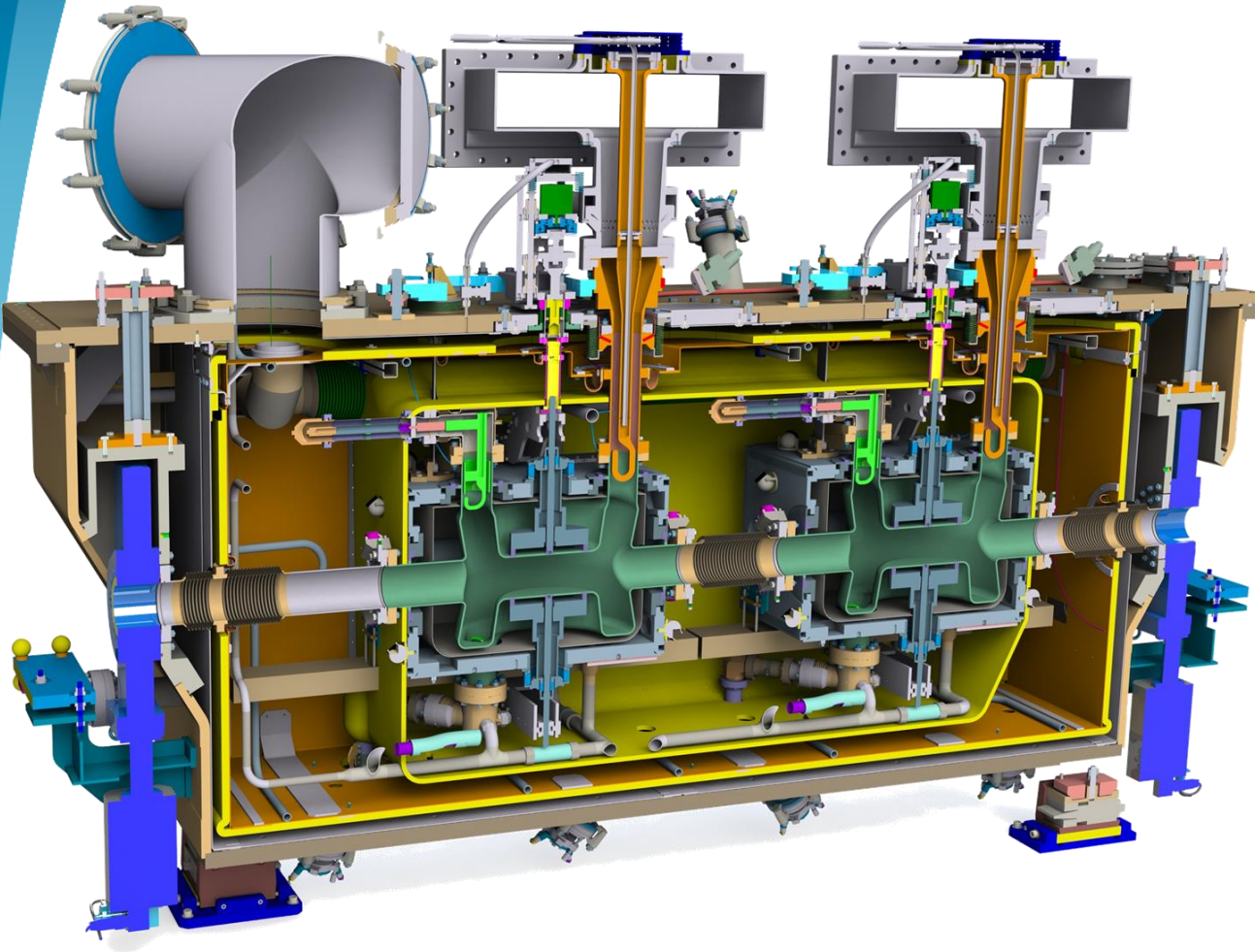
Assembly Experience for DQW Cryomodule

M. Garlaschè

On behalf of Cryomodule Assembly Team

7th HL-LHC Collaboration Meeting – 15th Nov. 2017 (Madrid)

DQW Cryomodule



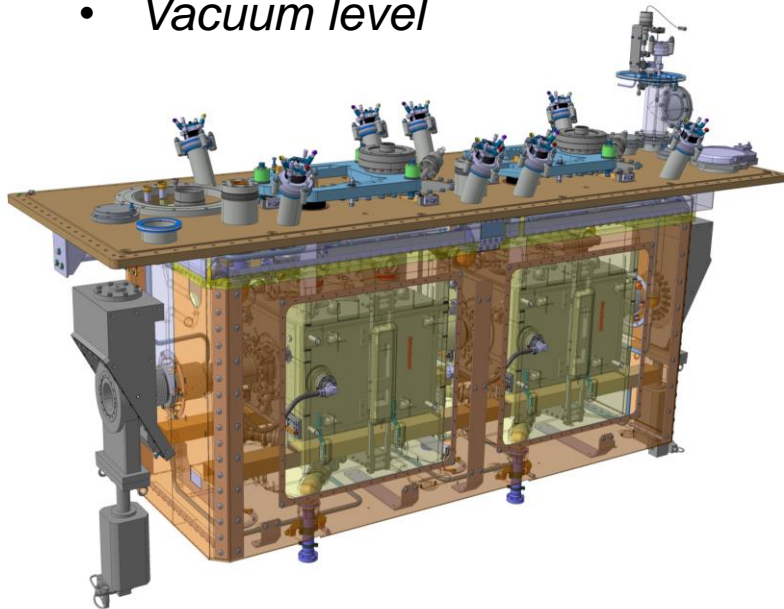
Main Components:

- Jacketed Cavity
- Alignment + supports
- Tuning
- Thermal Shield
- Warm Magnetic Shield
- MLI
- Powering
- Cryogenic System
- Vacuum Vessel

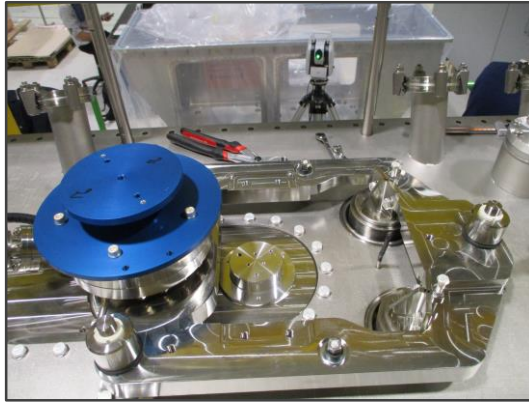
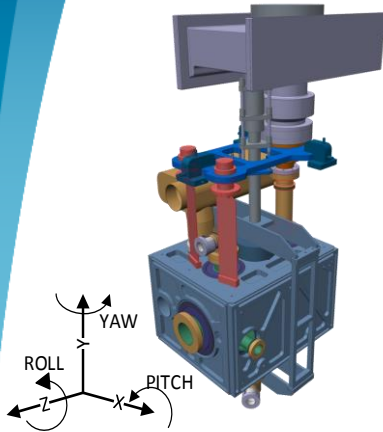
DQW Cryomodule: Instrumentation

Embedded Measurement & Control instrumentation:

- Powering + tuning
- *Heaters @ FPC, tuner, Helium Tank*
- *Temperature @ FPC, HOMs, Antenna, Tank, Coaxial lines, Cold Warm transitions*
- *Magnetic Flux @ Helium Tank (nearest to cavities)*
- *Strain @ support blades and FPC*
- *Pressure & Helium Level @ Cryo Line*
- *Cavity Alignment*
- *Vacuum level*



Adjustment and Position Monitoring Systems - Status



Cavity position adjustment system

- Adjustment/suspension system kinematics intuitive for operator
- Adjustment screws resolution $< 20\mu\text{m}$
- Intra-cavity position pre-adjustment capability better than $100\mu\text{m}$



FSI, BCAM monitoring systems validation

- FSI, BCAM systems precision better than $50\mu\text{m}$ (1σ), crosschecked with AT401 laser tracker measurements
- For now, the tests at room temperature, with open cryostat windows
- Waiting for M7 bunker test:
 - Final validation of the systems under vacuum and cold



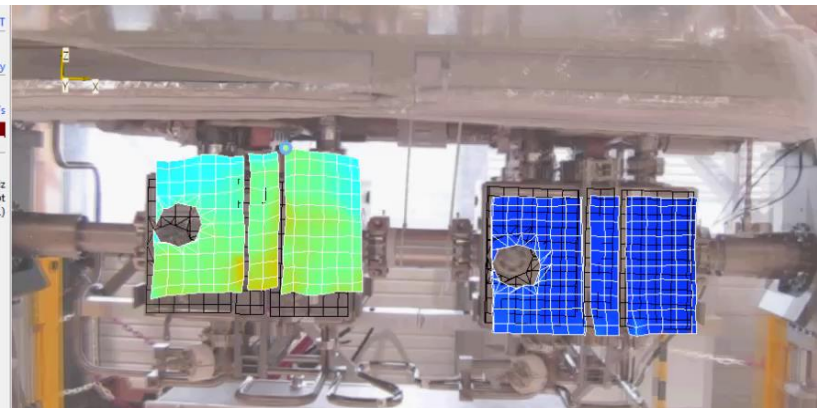
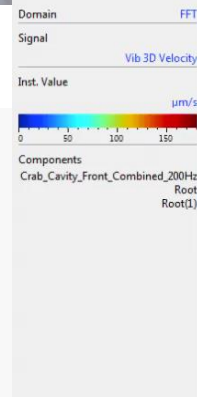
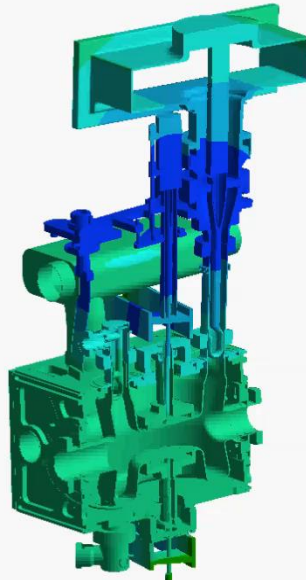
Ad-Hoc Measurement: Vibrational



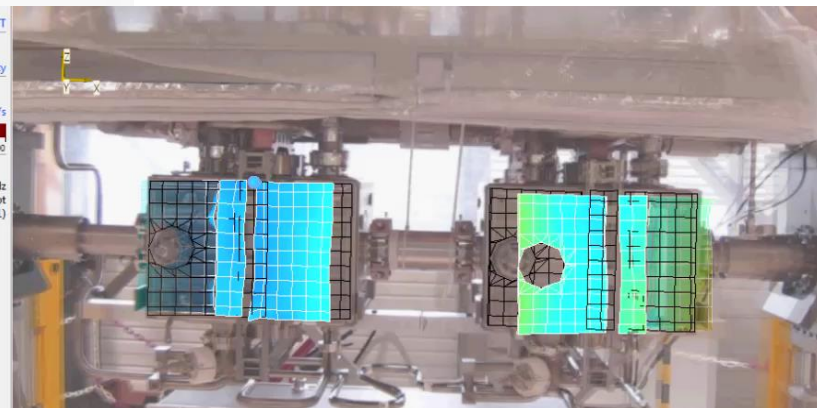
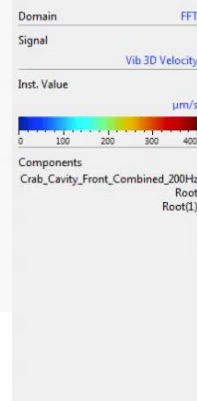
- Vibrometry acquisition via 3D Laser Scanning
- Configuration: hanging top cover and cavity string
- Comparison ongoing between FE analysis and measured data

C:\Modal
Total Deformation 3
Type: Total Deformation
Frequency: 15.247 Hz
Units: m
23/10/2017 08:19

0.1774 Max
0.15769
0.13798
0.11827
0.098556
0.078845
0.059134
0.039422
0.019711
0 Min



| | |
|-------------------|-------------------------|
| Band 3 | 15.25 Hz |
| Angle | -104 ° |
| Index | 110 |
| Scan Point Number | 110 |
| Component | Root |
| Cont. File | D:\Training Projects... |
| Inst. Value | 90.07 $\mu\text{m/s}$ |
| Scan: | Optimal |
| Geom.: | Optimal Meas. |
| Focus: | No Focus |
| Interp.: | Valid |
| 3D Point | |
| X: | 0.32869 m |
| Y: | -0.00367 m |
| Z: | 0.34845 m |
| D: | 2.37194 m |



| | |
|-------------------|-------------------------|
| Band 4 | 33 Hz |
| Angle | -4 ° |
| Index | 110 |
| Scan Point Number | 110 |
| Component | Root |
| Cont. File | D:\Training Projects... |
| Inst. Value | 104.6 $\mu\text{m/s}$ |
| Scan: | Optimal |
| Geom.: | Optimal Meas. |
| Focus: | No Focus |
| Interp.: | Valid |
| 3D Point | |
| X: | 0.32869 m |
| Y: | -0.00367 m |
| Z: | 0.34845 m |
| D: | 2.37194 m |

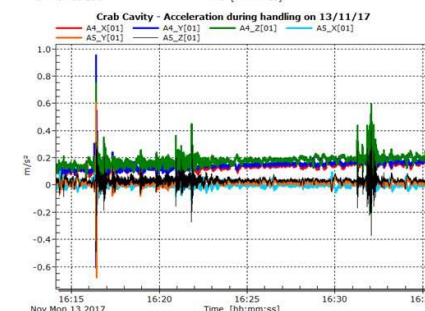
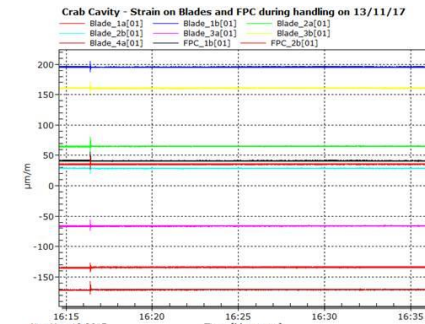
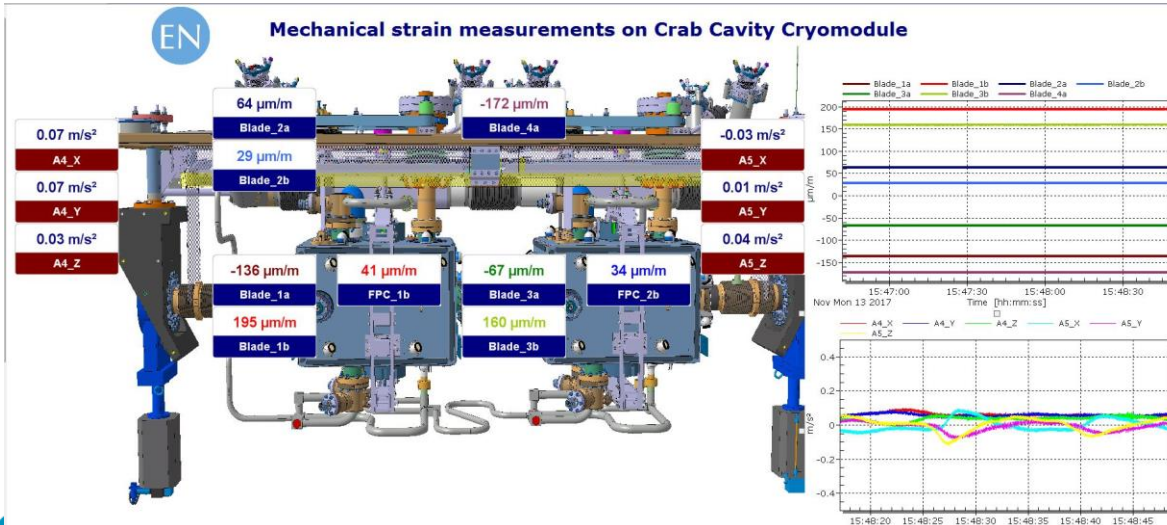
Ad-Hoc Measurement: RF & Transport

Radiofrequency performance monitored during all major steps

- Acceptance
- Tuner Assy
- Connection to to Vessel
- Coax lines + Assy
- Closure



Structural loading of cavity supports and acceleration monitored during assembly and transport

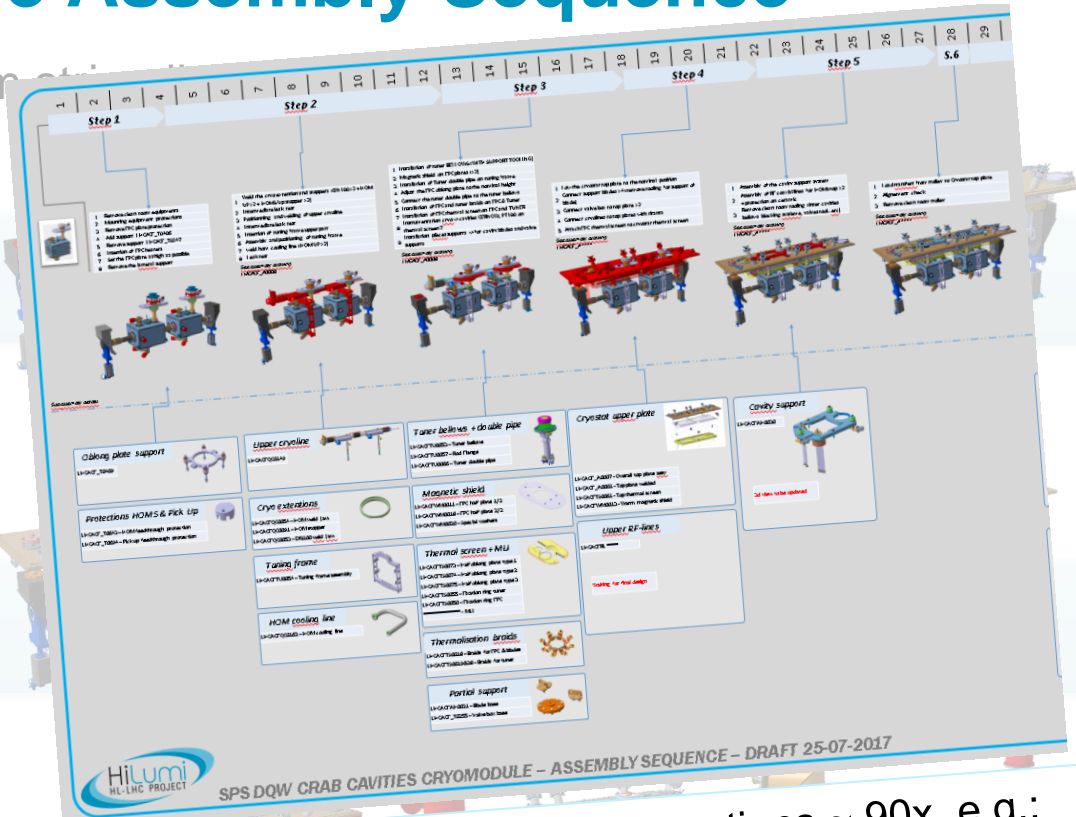
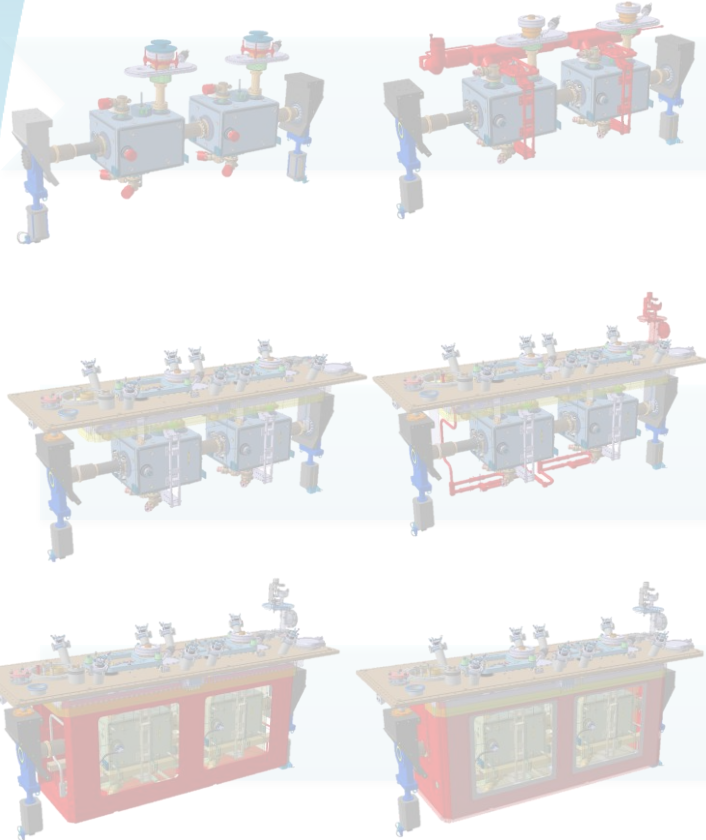


@
handling

Cryomodule Assembly & Lessons Learnt

Cryomodule Assembly Sequence

15x macro assembly steps from start

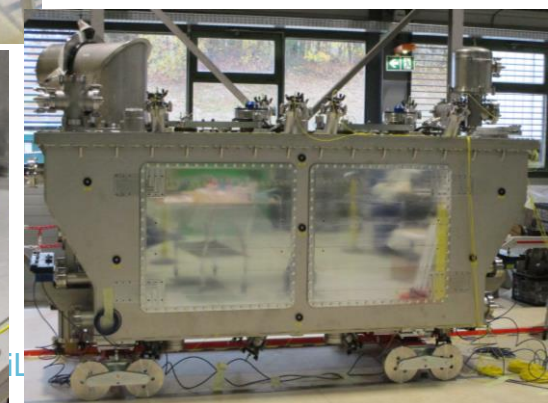
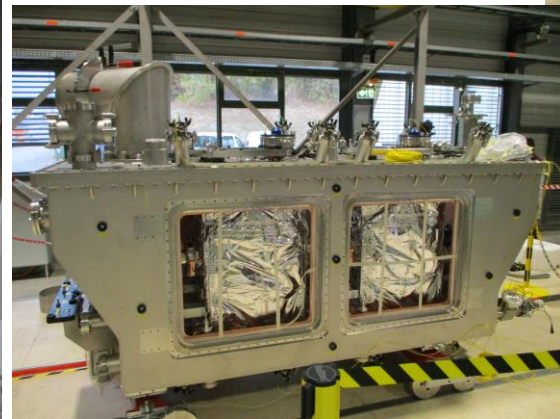
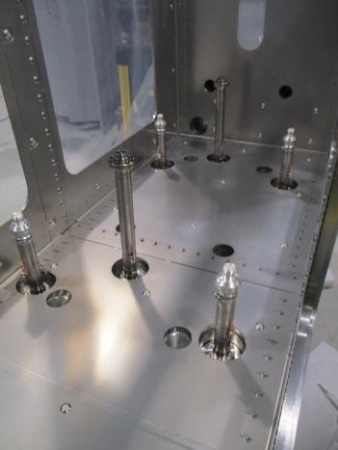
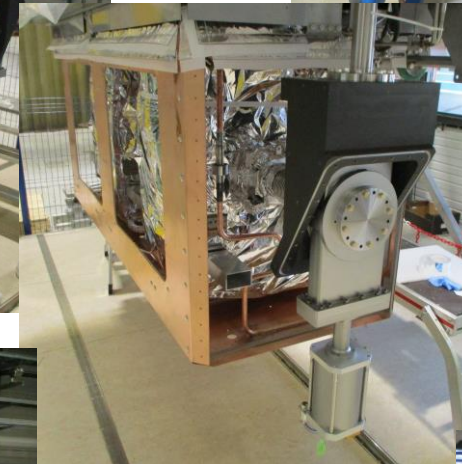
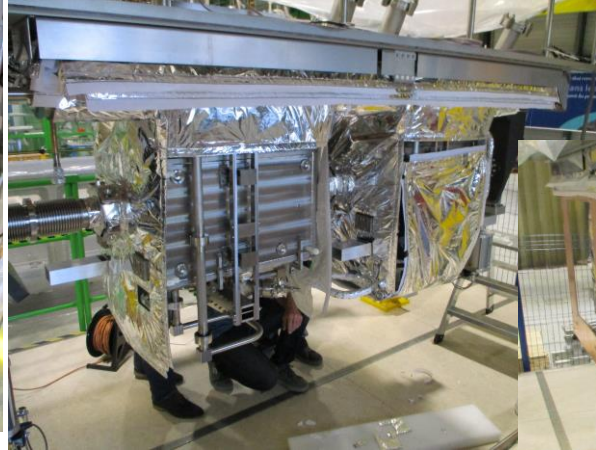


Current Total number of Assembly actions ~ 90x, e.g.:

- Remove clean room equipment...
- ...Positioning and welding and control of upper cryoline...
- ...Assembly and positioning of tuning frame...

The plan: perform these steps in 11x Weeks

Deadline for delivery to bunker for test: 15th November (today..)



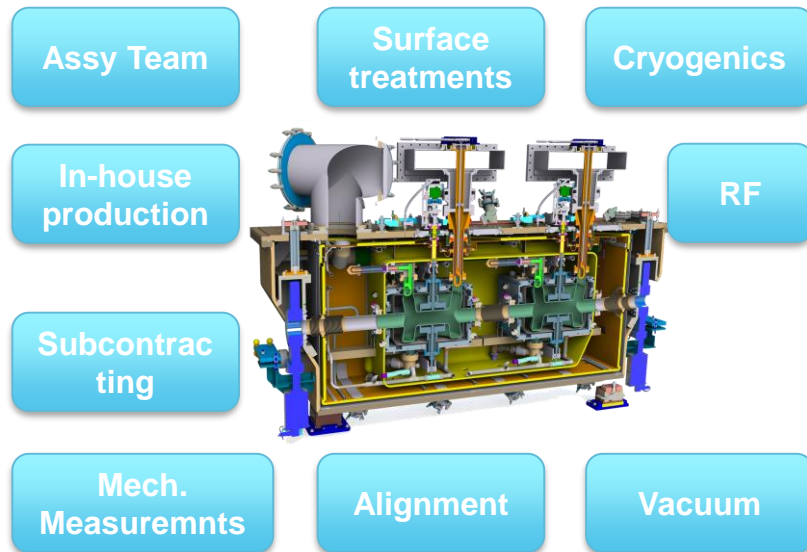
Manpower & Coordination

The Core team

- 1x Assembly Pilot
- 2x Mechanical Technicians
- 2x Welders
- 1x Area & Logistics Manager
- 3x Designers (!)



many stakeholders & many steps..



Different Assembly **Step Responsibles** inside core team, depending on task

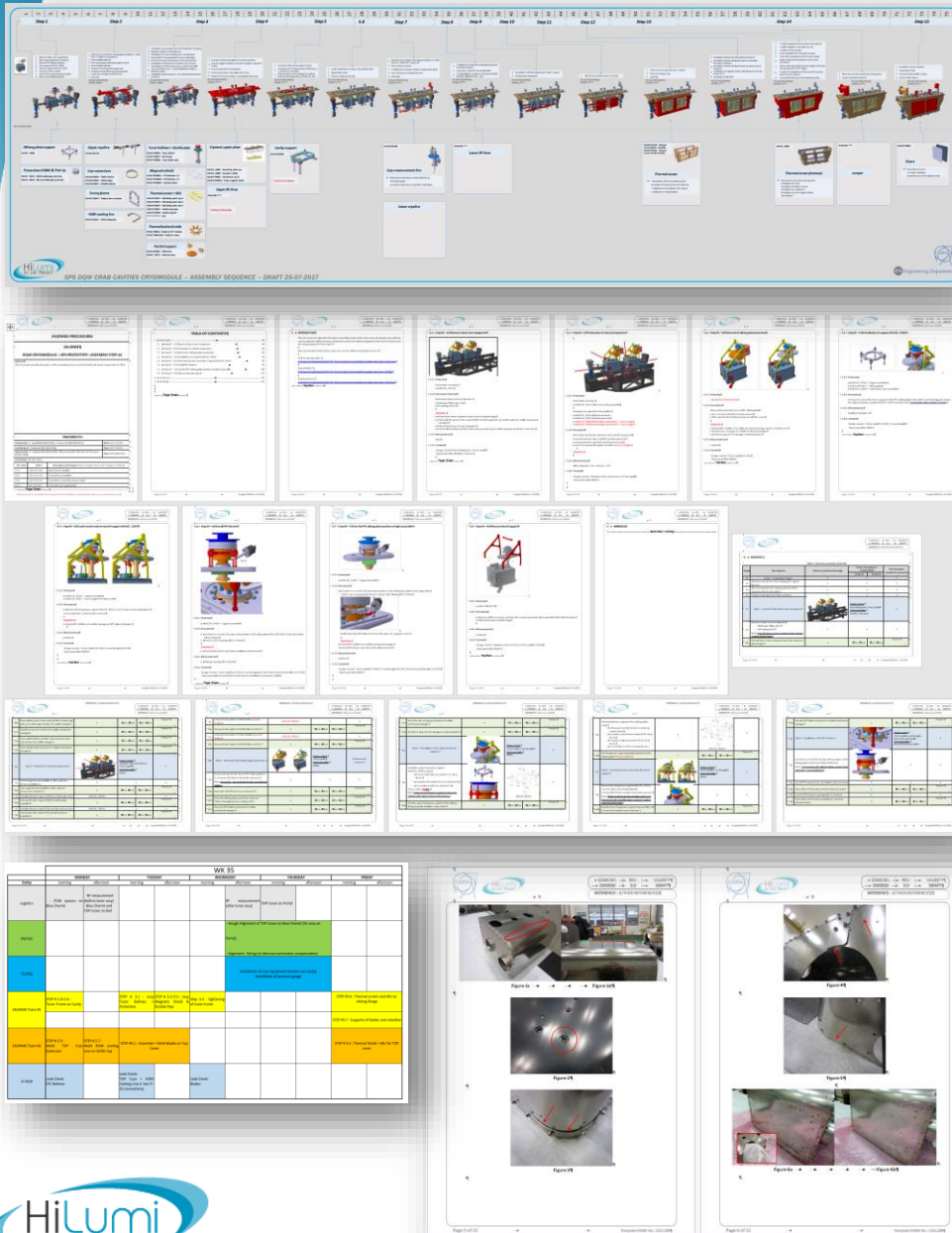
Involvement of **Equipment Responsibles** interacting at different levels:

- Information on criticalities
- Supervising task or directly performing it
- Providing greenlight at Hold Points

Daily Coordination:

- Many units working simultaneously..
- Granular Weekly Planning
- Assembly docs for concerned steps

Documentation



Master **Assembly Sequence**

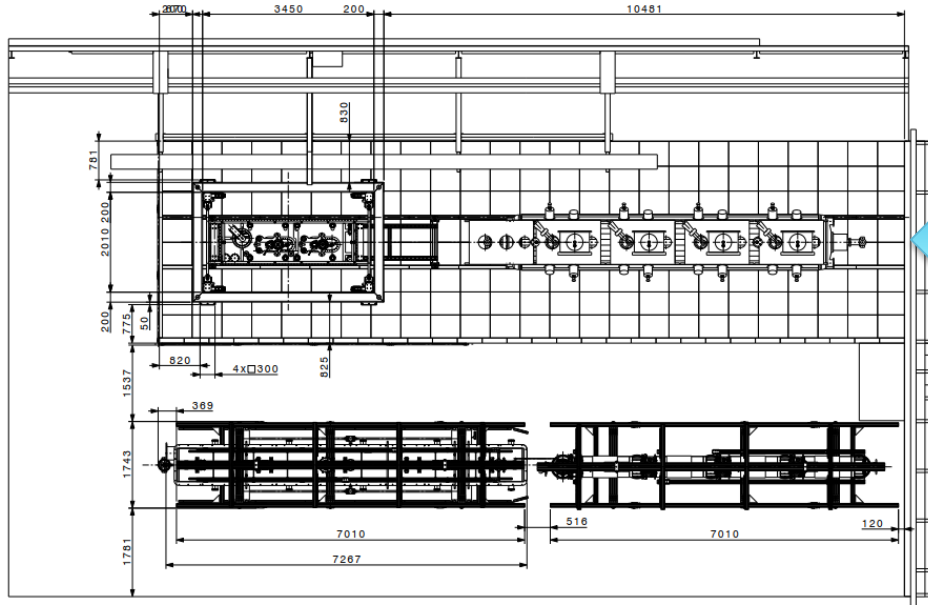
Information repository for **each step**, containing

- Assembly drawings
- BOM
- **Step Assembly sequence**
 - Major tasks and criticalities
 - Laid out substeps & detailed information

Further documentation:

- Additional Info for assembly (tightening torques, pressure test procedure...)
- Incoming inspections of major equipment
- Traceability and controls (NDTs, material spec, nonconformities...)

The Assembly Area



Clean Room



- Assembly Area: 100m²
- Short-term parking in front of clean room exit
- additional 45m² storage area
- If same assembly area for future cryomodules, then storage needed for semi-assembled equipment nearby

Tools

Many tools needed (transport, mechanical assembly, intermediate leak checks, protection..)

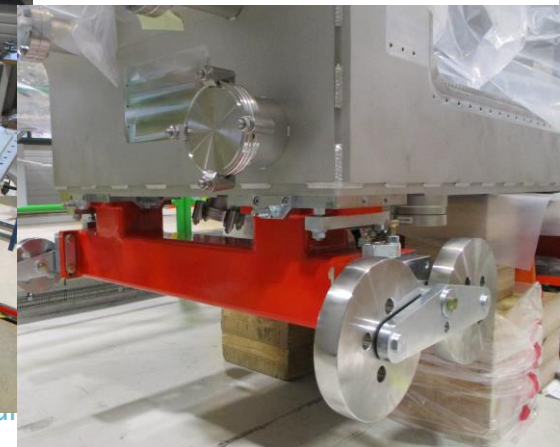
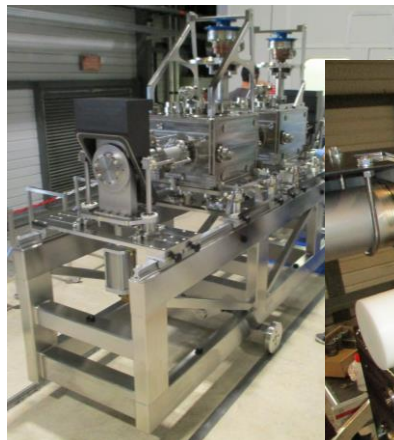
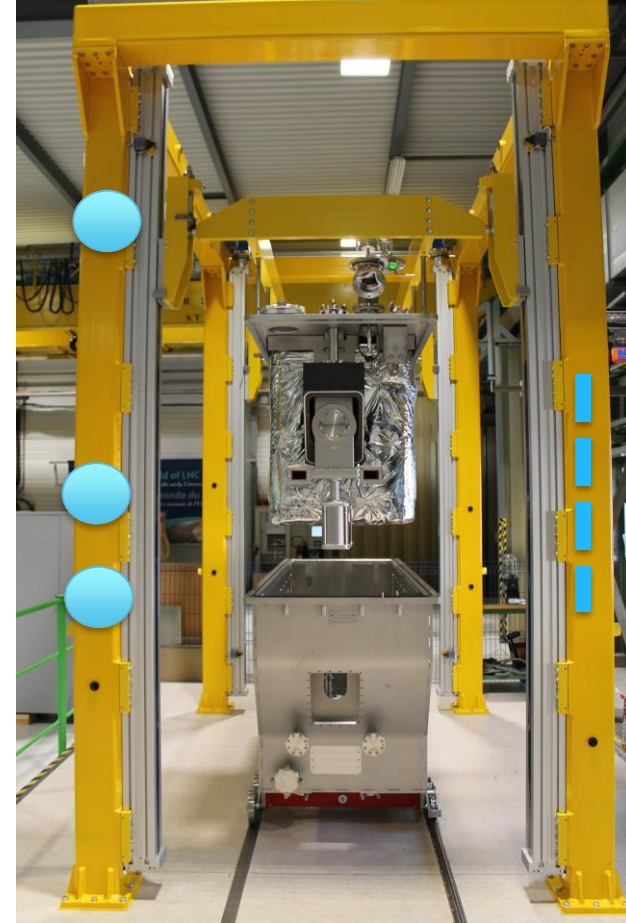
To be considered when planning for design and manufacturing manpower

Watch out for **difficult access** during assembly. To be accounted for in design

Portal:

- 3x long-term parking positions
- 1x range of smooth and controlled descent
- Upgrades: precise descent controlled via GUI

Rollers: could be upgraded to tool for transport and support during test



Lessons Learnt: Design

Overall **assembly smooth** and **successful**

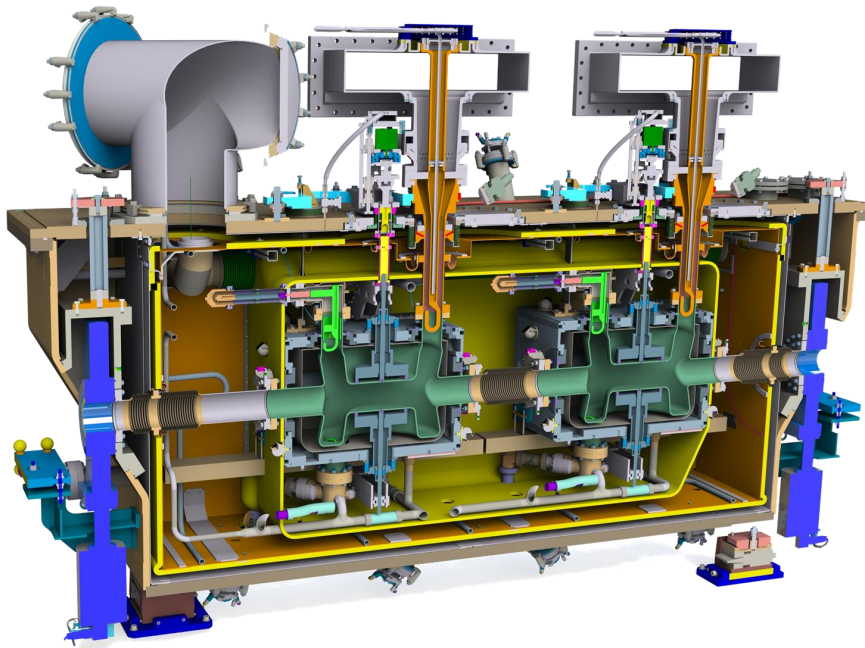
Few **minor adjustments**

...Valve Boxes: design upgrade foreseen for easier assembly and leak check

Tuner: design modifications foreseen for easier assembly

Bellows on lower cryoline...

Memorandum being compiled



MLI:

- More space allowance needed (geometry, sagging)
- Eventual containment grid in epoxy
- Sheets less geometry-dedicated, more universal
- Redesign of 70K MLI at FPC and lateral windows

Shields:

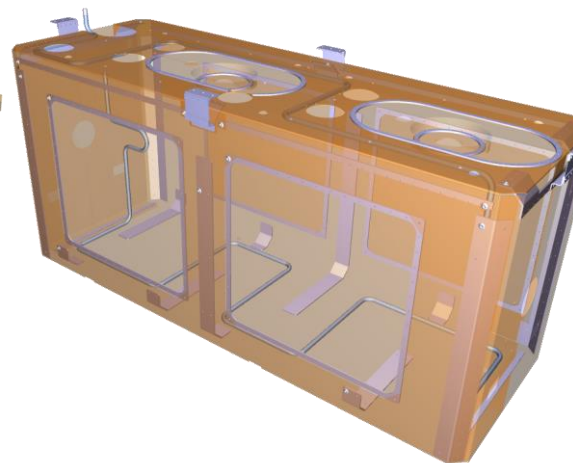
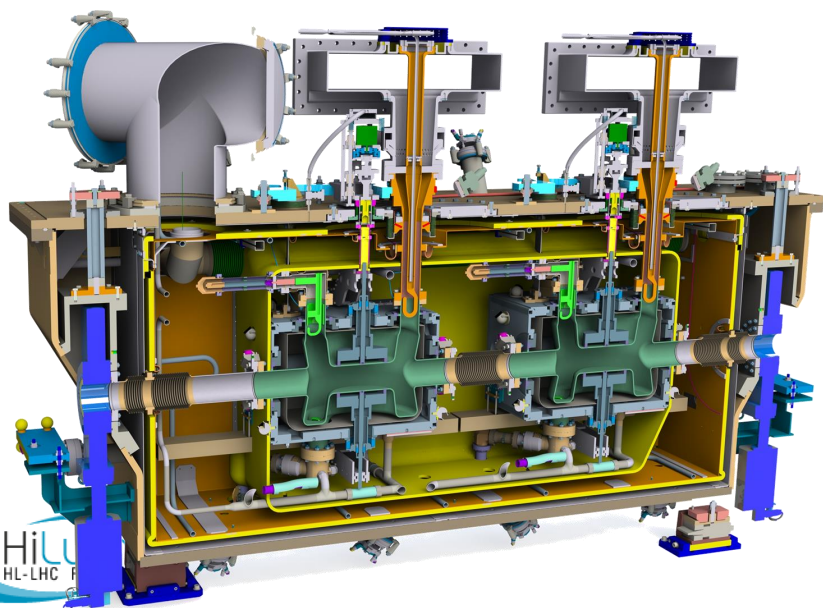
Worked really well (connection to vessel, gap allowance sheets)

μ shield: bigger holes for screws, magn fingers welded only on one side

Lessons Learnt: Assembly

- **Long delivery items** to be procured asap (e.g. Titanium vented screws, Ag Coating, bellows). Eventual design around them
- Double of **consumables** (screws washers, schnorr...) barely/not enough at times, due to unforeseen disassembly
- **Mitigation of bad news** at latest stages
 - As many intermediate leak checks as possible
 - Maximum disassemblability
- Insertion inside vessel as late as possible
- **Traceability** and 100% control of utmost importance

Future : grouping of activities depending on stakeholder involved



Conclusions

- Tight **schedule successfully respected!**
Cryomodule ready and being transported tomorrow
Thanks to **great effort from everybody**
- **Lessons learnt to be implemented** in upcoming design and manufacturing activities. **Documentation** available for each assembly step.
- **Manpower & Planning**
 - Assembly team : 6x FTU, skilled technicians
 - Design team: 3x FTU in the last 2.5 years, up to 4x FTU in last semester
 - Assembly at ~1.5 shift per day
 - tasks kept parallel, up to 4x tasks at the same time
- **RFD** cryomodule: no time to lose on production of components
Design + Long delivery Items to be launched beginning of 2018



Thanks!

