Assembly Experience for DQW Cryomodule

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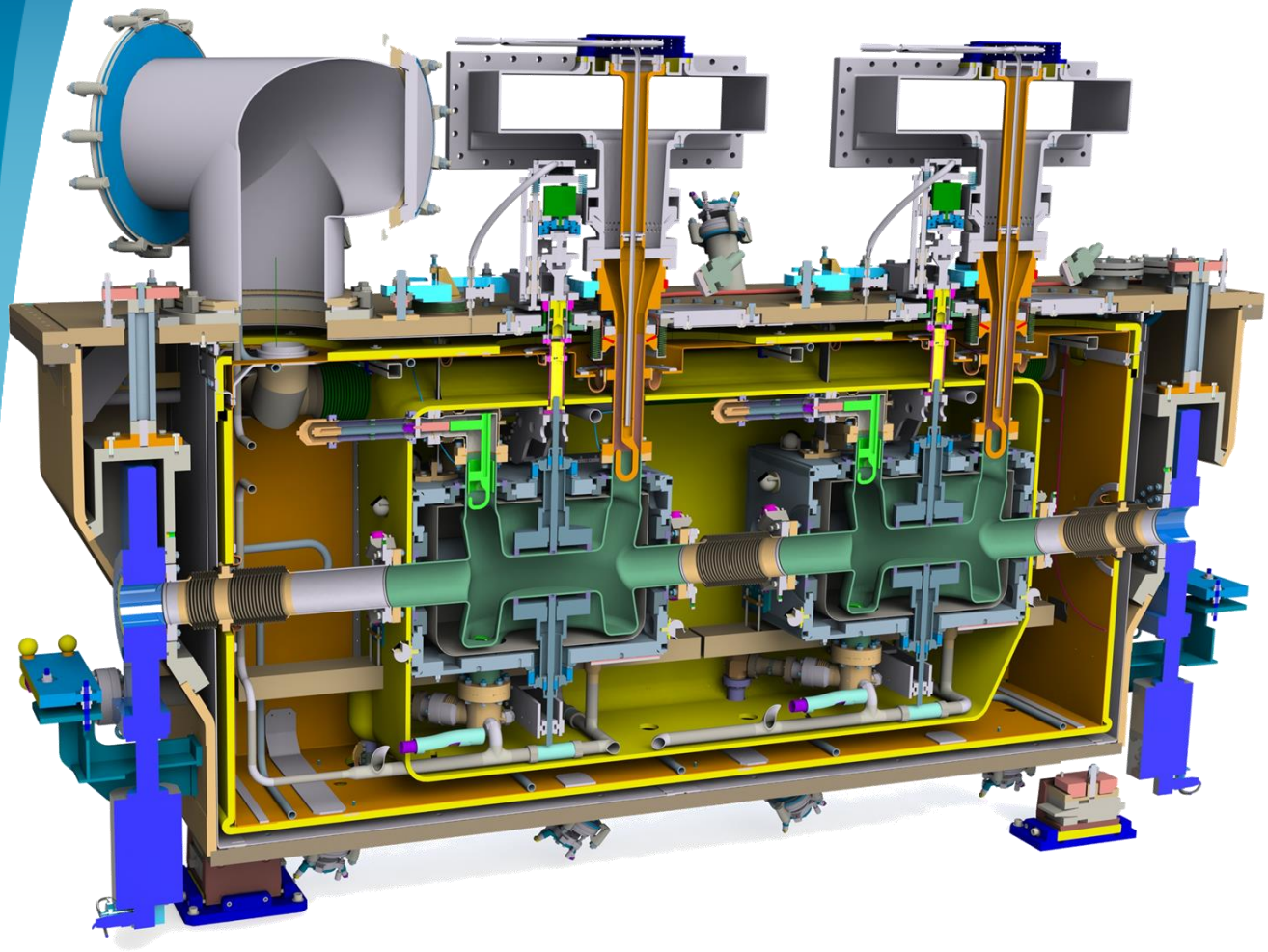
On behalf of Cryomodule Assembly Team

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

DQW Cryomodule



Main Components:

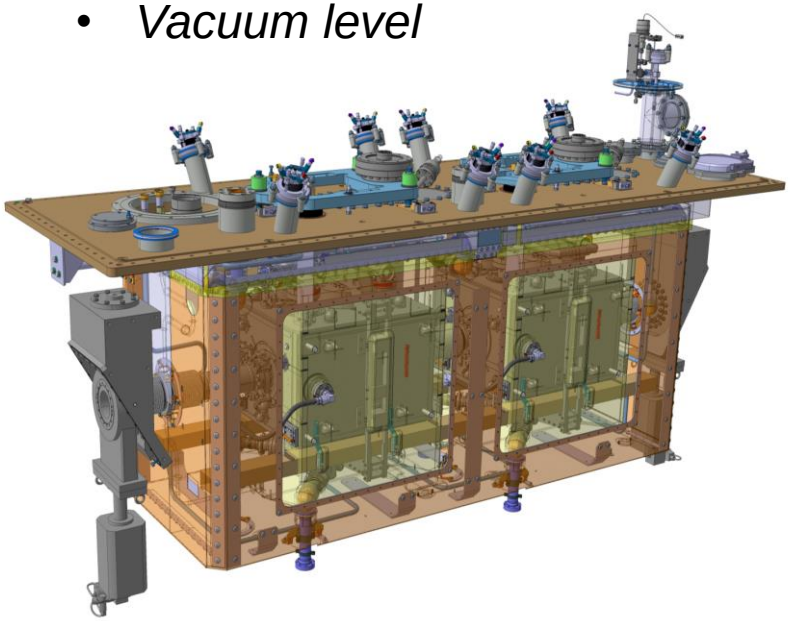
- Jacketed Cavity
- Alignment + supports
- Tuning
- Thermal Shield
- Warm Magnetic Shield
- MLI
- Powering
- Cryogenic System
- Vacuum Vessel

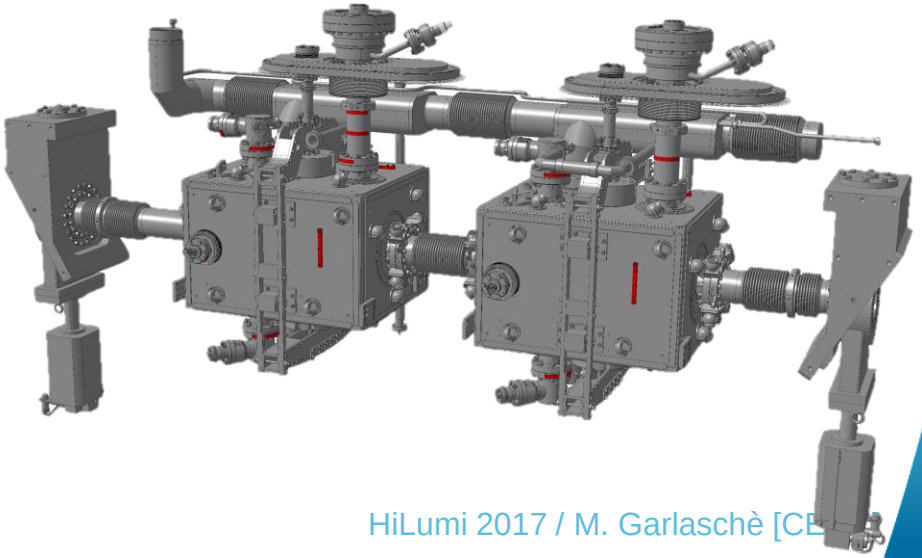
DQW Cryomodule: Instrumentation

Embedded Measurement & Control instrumentation:

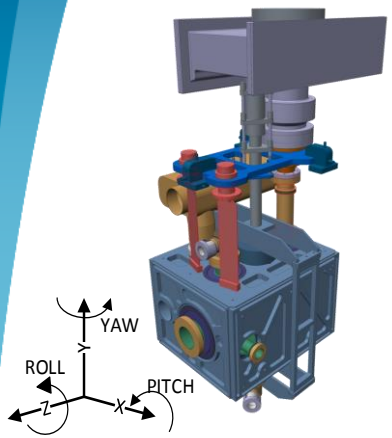
- Powering + tuning
- *Heaters* @ FPC, tuner, Helium Tank

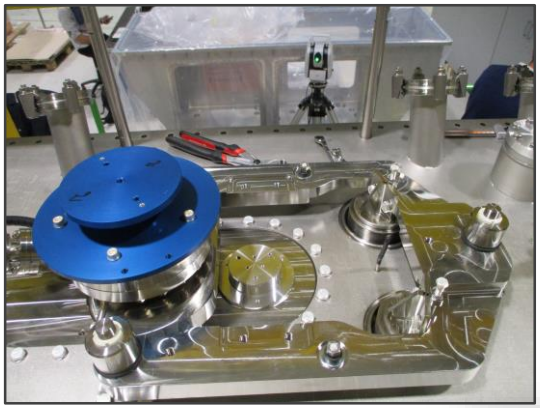
- *Temperature* @ FPC, HOMs, Antenna, Tank, Coaxial lines, Cold Warm transitions
- *Magnetic Flux* @ Helium Tank (nearest to cavities)
- *Strain* @ support blades and FPC
- *Pressure* & *Helium Level* @ Cryo Line
- *Cavity Alignment*
- *Vacuum level*





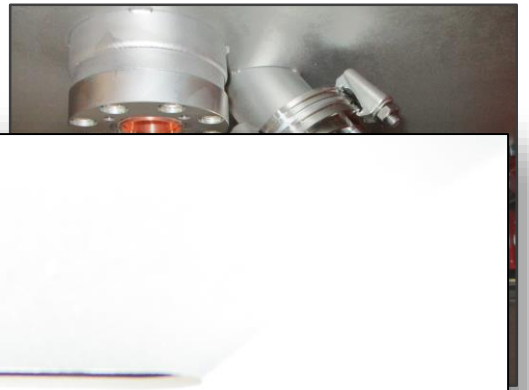
Adjustment and Position Monitoring Systems - Status





Cavity position adjustment system

- Adjustment/suspension system kinematics intuitive for operator
- Adjustment screws resolution < 20µm
- **Intra-cavity position pre-adjustment capability better than 100µm**

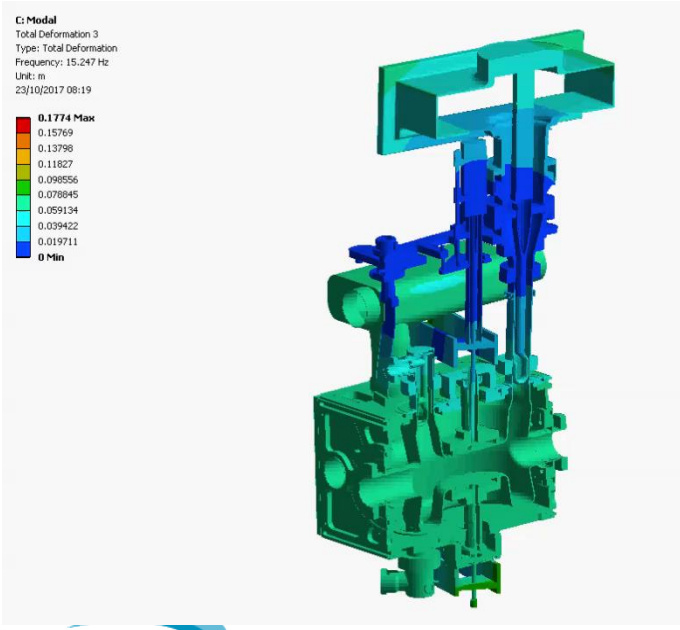


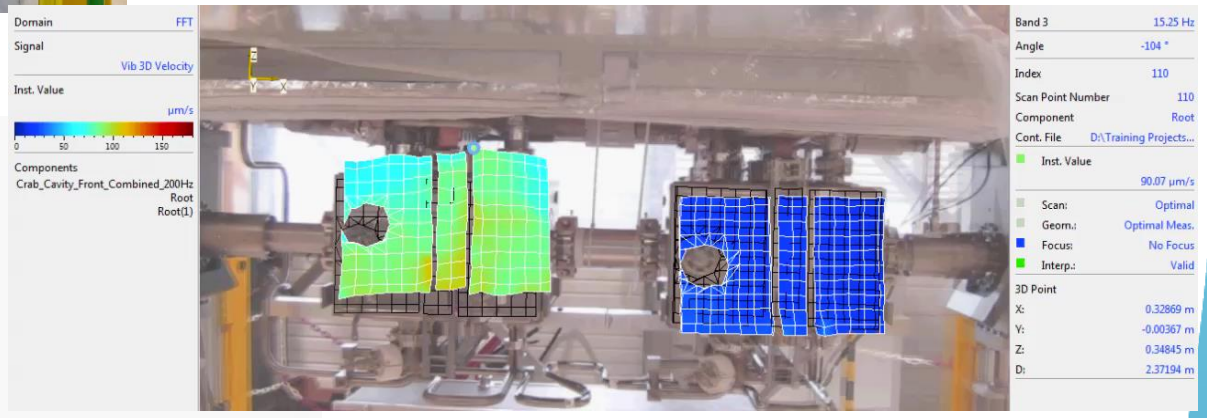
FSI, BCAM monitoring systems validation

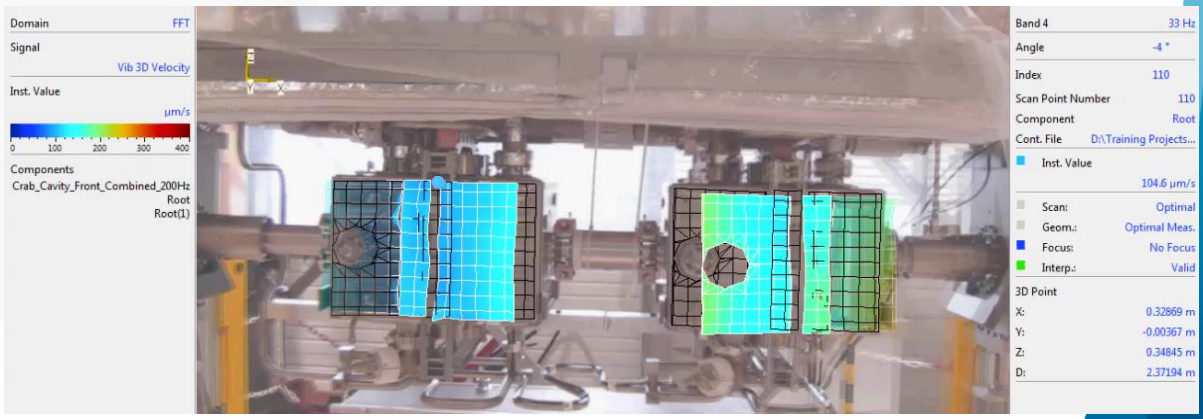
- **FSI, BCAM systems precision better than 50µm (1σ), crosschecked with AT401 laser tracker measurements**
- For now, the tests at room temperature, with open cryostat windows
- Waiting for M7 bunker test:
  - Final validation of the systems under vacuum and cold

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





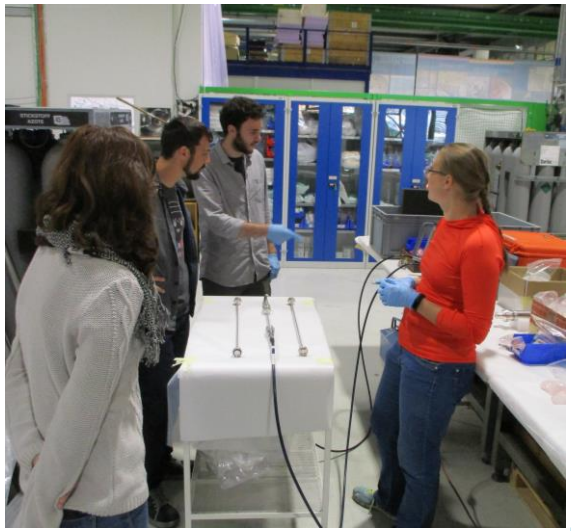


(Courtesy T. Jones [STFC])

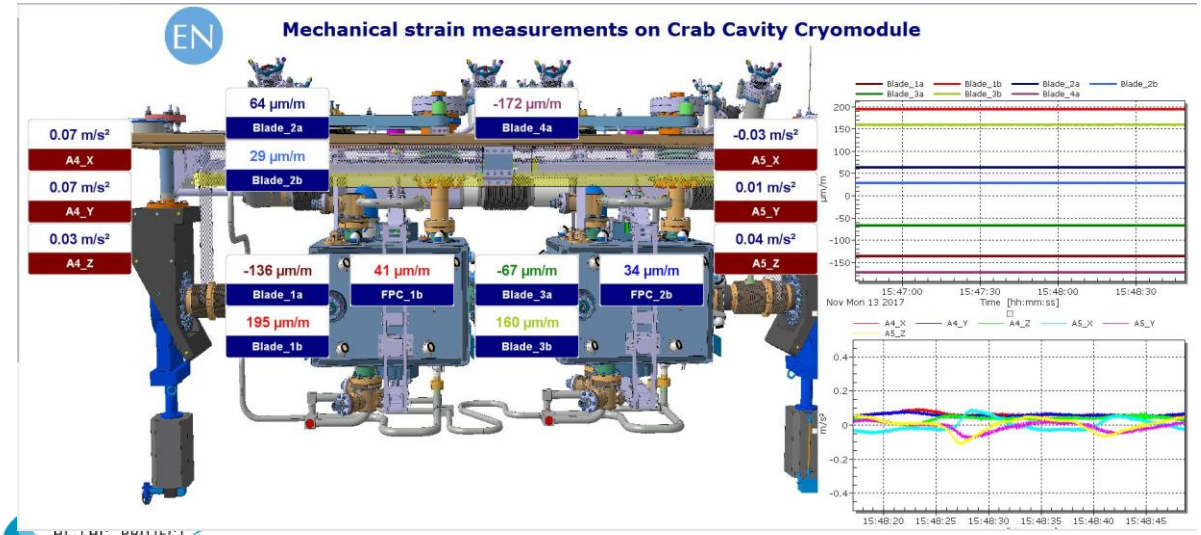
Ad-Hoc Measurement: RF & Transport

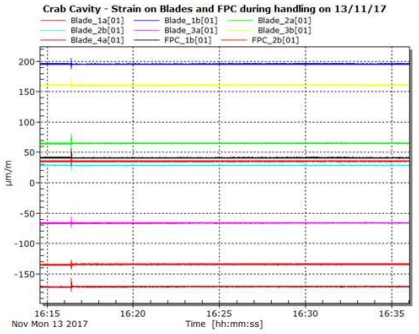
Radiofrequency performance monitored during all major steps

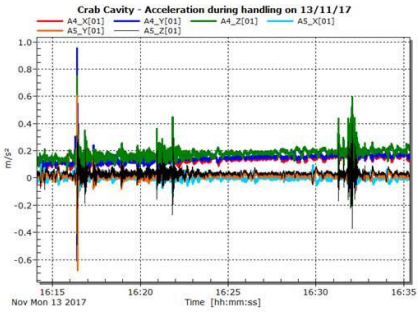
- Acceptance
- Tuner Assy
- Connection to to Vessel
- Coax lines + Assy
- Closure



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





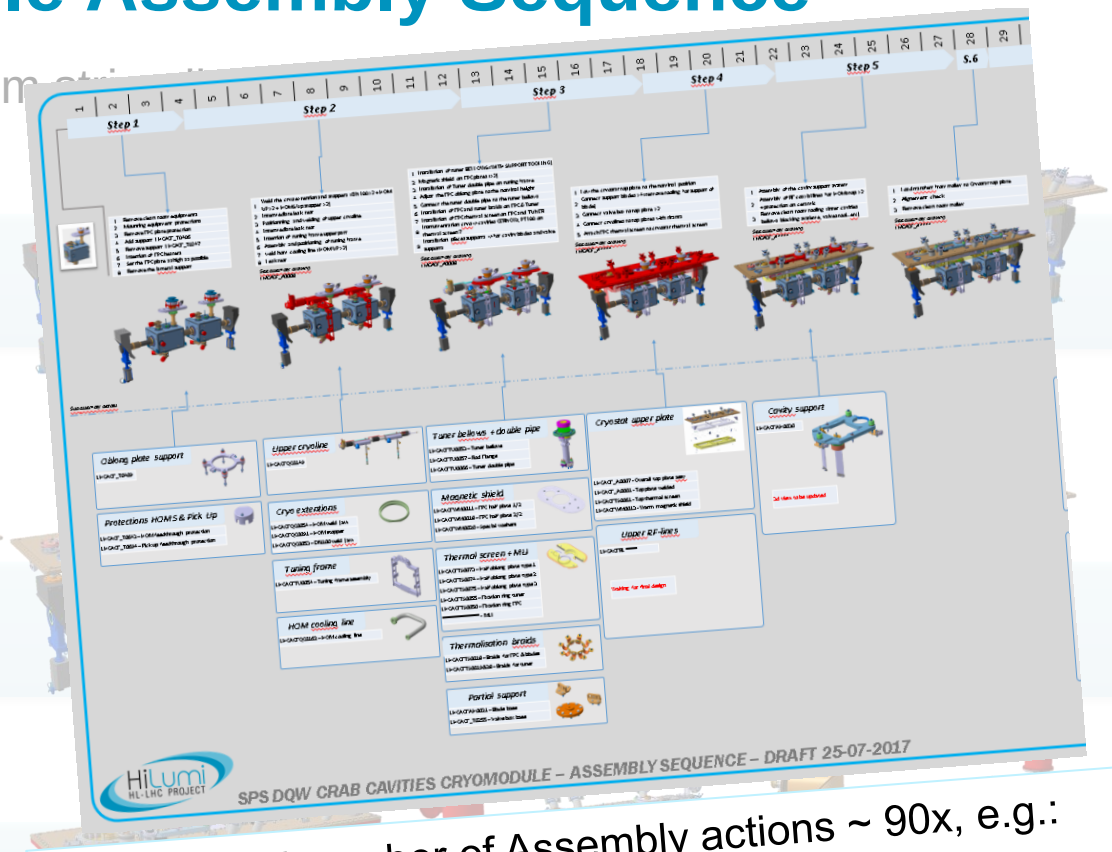


@ handling

Cryomodule Assembly & Lessons Learnt

Cryomodule Assembly Sequence

15x macro assembly steps from str...

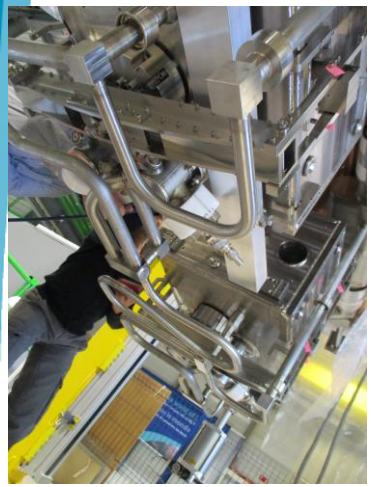


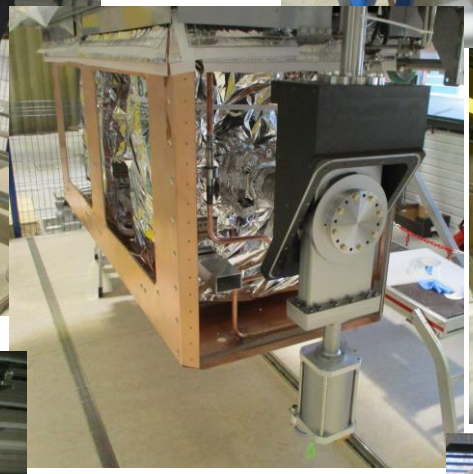
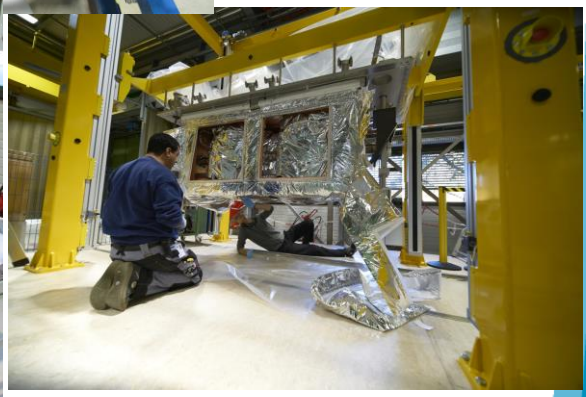
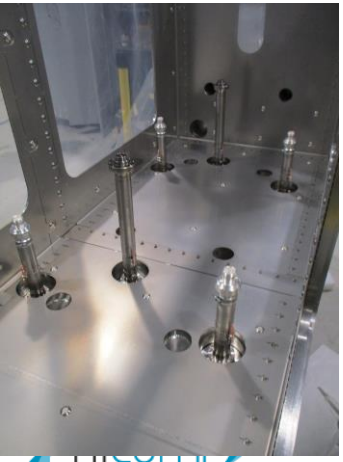
Current Total number of Assembly actions ~ 90x, e.g.:
Remove clean room equipment…
…Positioning and welding and control of upper cryoline…
…Assembly and positioning of tuning frame…

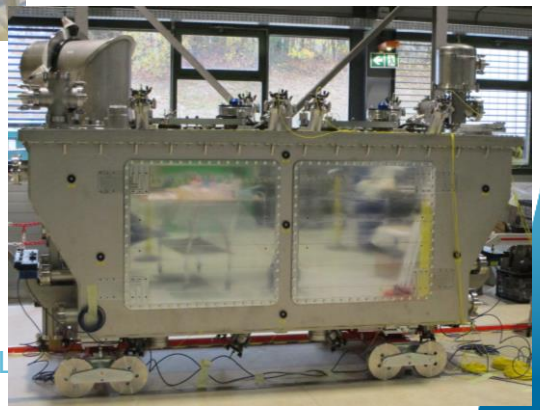
The plan: perform these steps in 11x Weeks
Deadline for delivery to bunker for test: 15th November (today..)







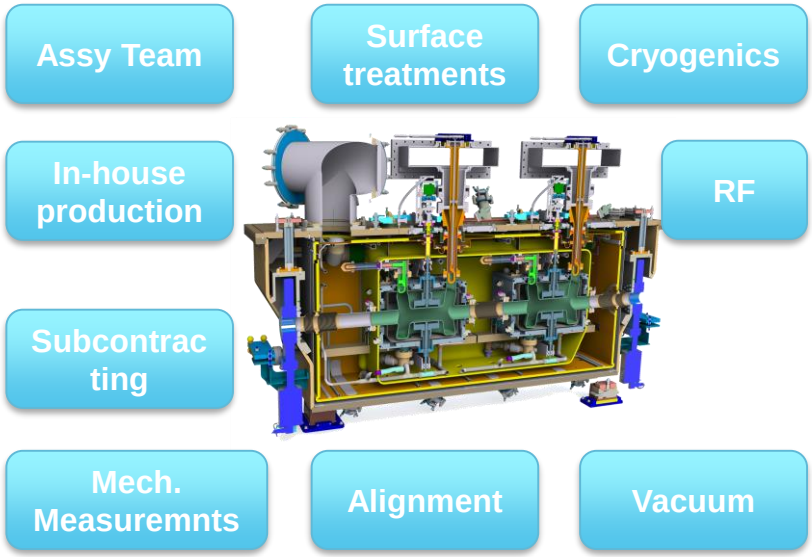



Manpower & Coordination

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

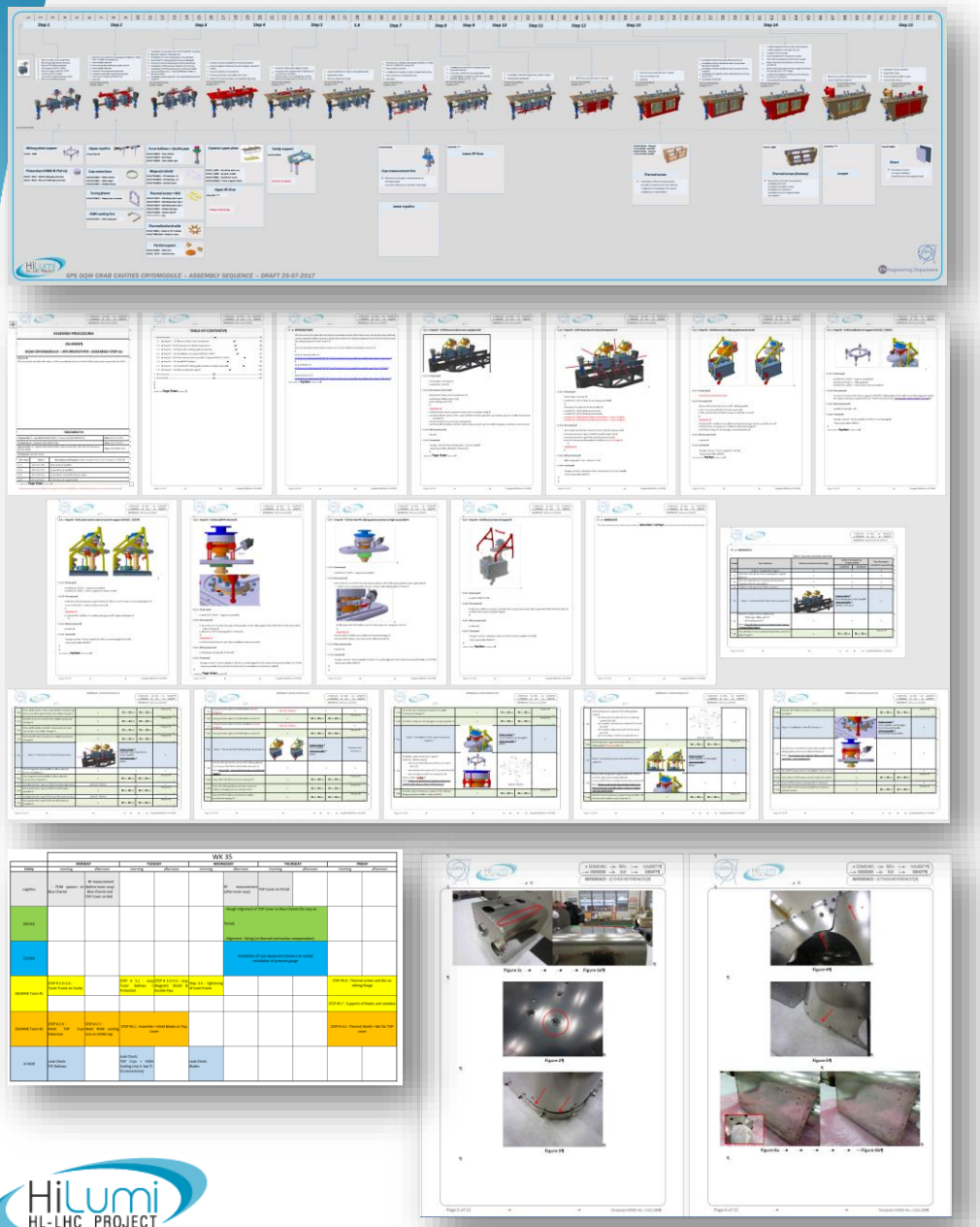
Involvement of **Equipment Responsibles** interacting at different levels:

- 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**

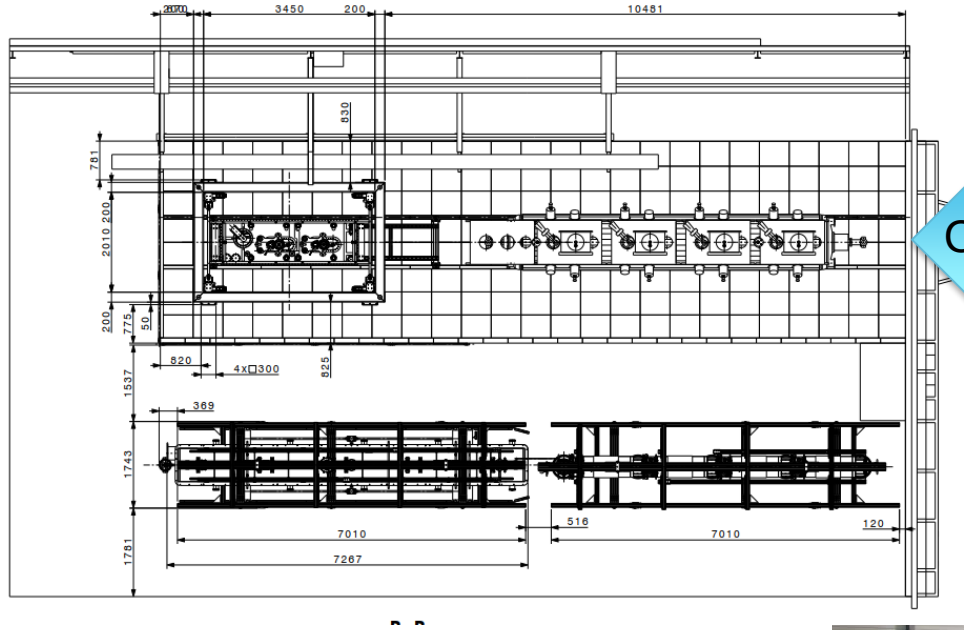
Information repository for **each step**, containing

- 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: 100m^2
- Short-term parking in front of clean room exit
- additional 45m^2 storage area
- If same assembly area for future cryomodules, then storage needed for semi-assembled equipment nearby

Tools

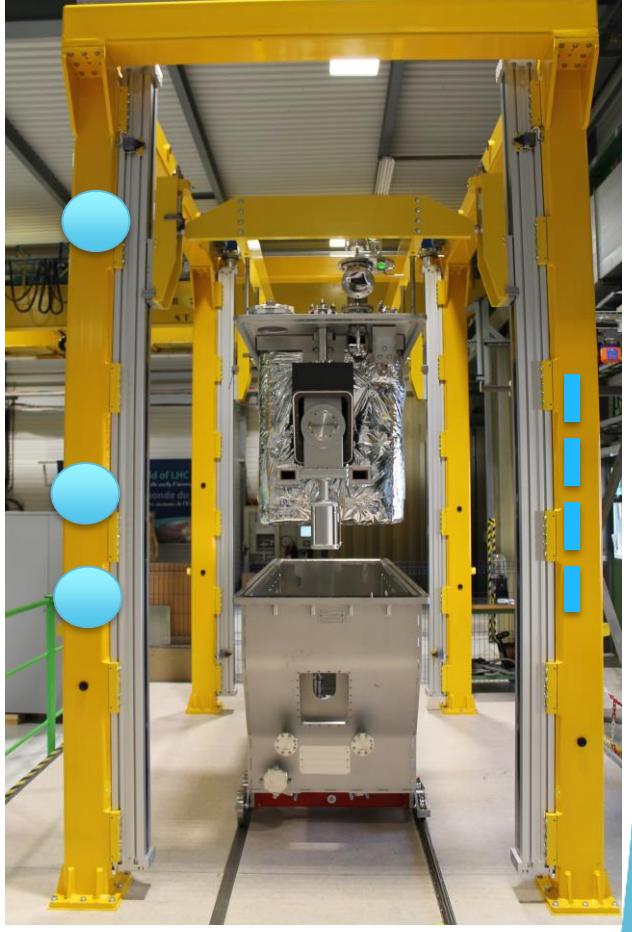
Many tools needed (transport, mechanical assembly, intermediate leak checks, protection..)

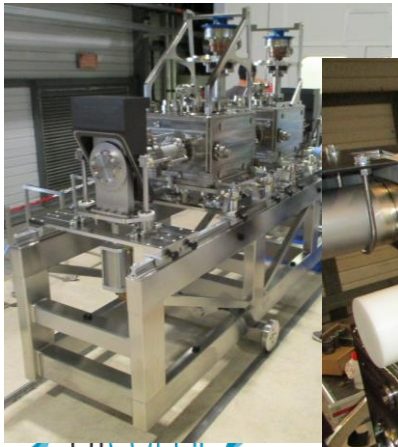
To be considered when planning for design and manufacturing manpower

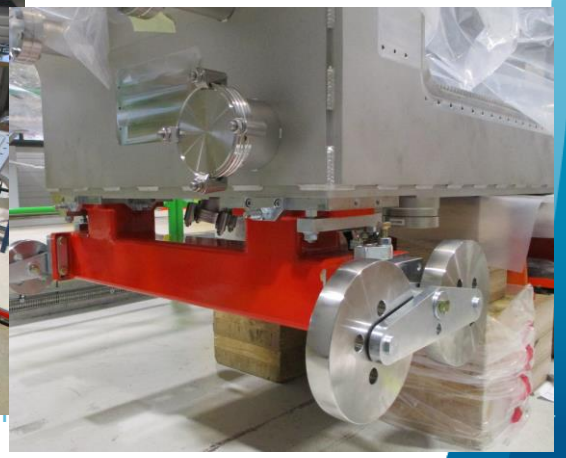
Watch out for **difficult access** during assembly. To be accounted for in design

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





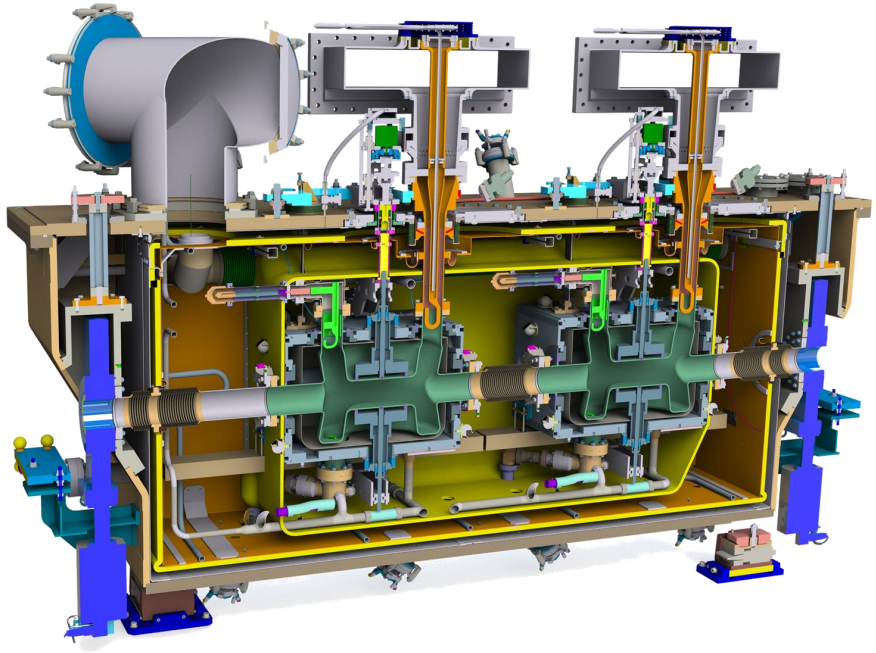


Lessons Learnt: Design

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:

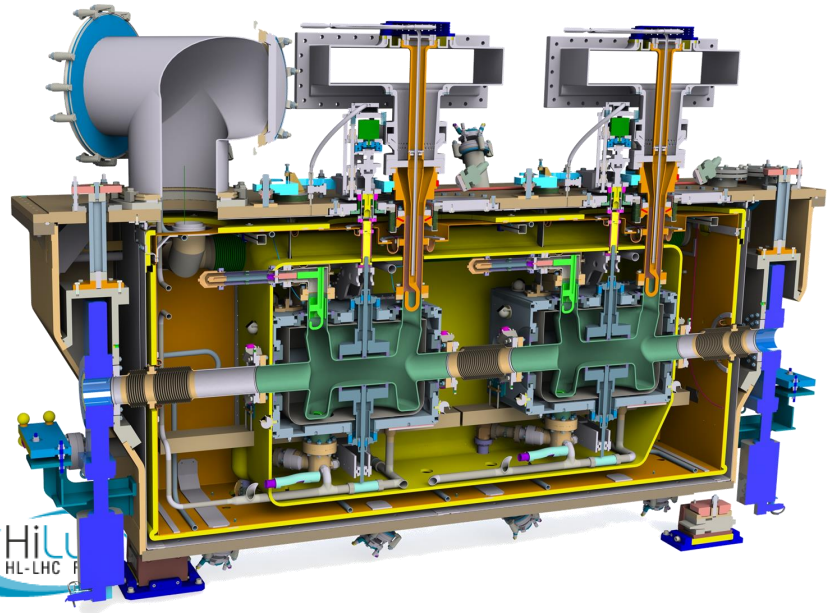
Worked really well (connection to vessel, gap allowance sheets)

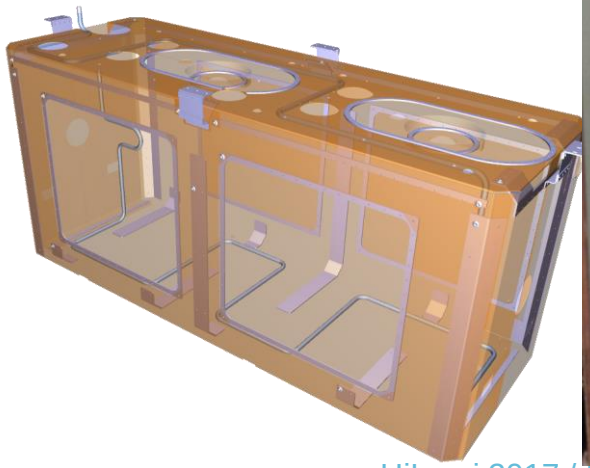
μ shield: bigger holes for screws, magn fingers welded only on one side

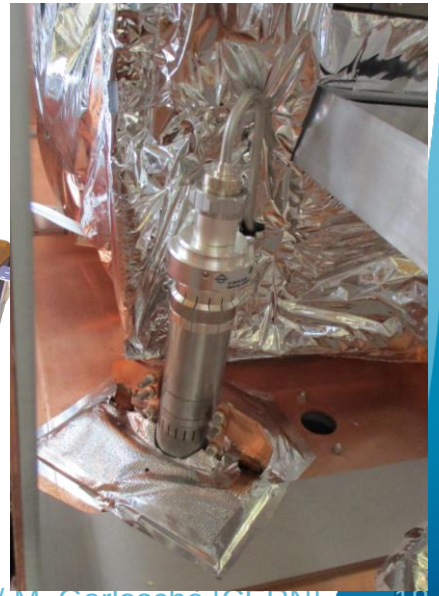
Lessons Learnt: Assembly

- **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

HiLumi
HL-LHC PROJECT

Thanks!