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First operational experience with the HIE-Isolde helium cryogenic system including several RF cryo-modules

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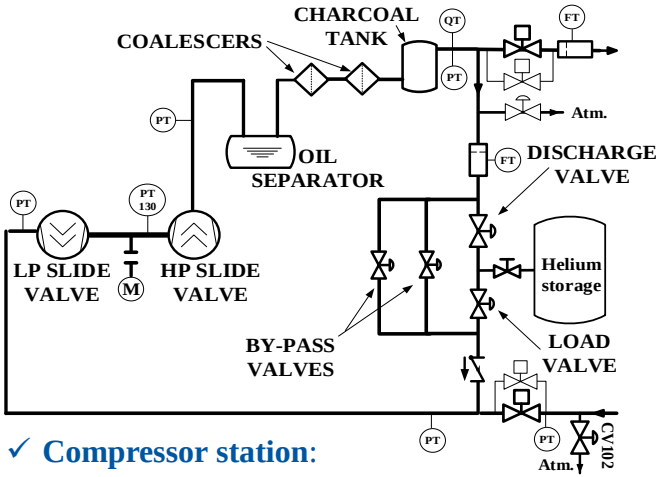
Outline

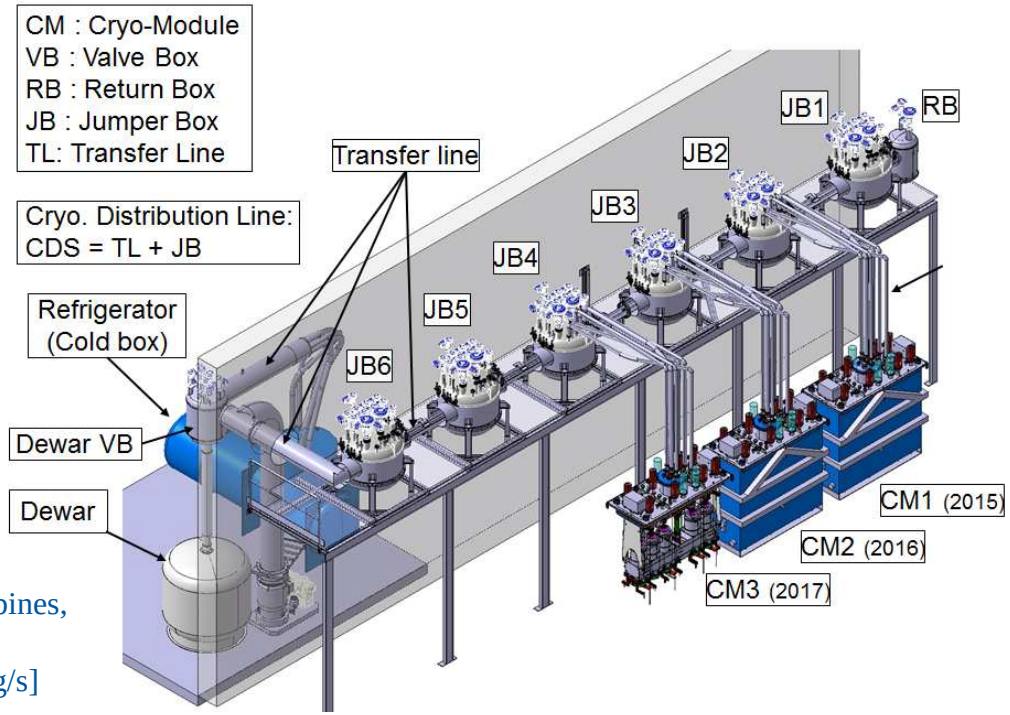
- Introduction
- First cryogenics operation in 2015 with 1 cryo-module
- Cryogenics operation in 2016 with 2 cryo-modules
- Upgrade during the Extended Year End Technical Stop 2016/2017
- Cool down and commissioning in 2017 with 3 cryo-modules
- Conclusion and next milestones

HIE-ISOLDE Cryogenic System



✓ **Compressor station**:
Two-stage – 160g/s with HP @14bara
and LP @1.04bara

✓ **Cold Box**: Sulzer TCF200 cold-box type with 2 turbines, refurbished for HIE-Isolde
[refrigerat. power ~630W @4.5K and He liq. rate ~1.5g/s]

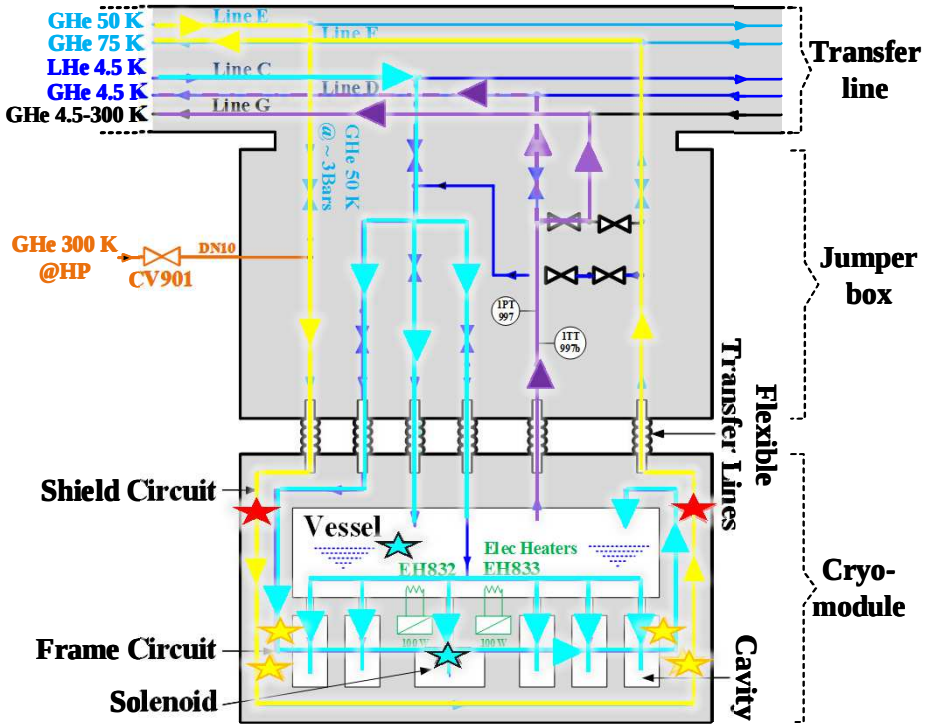


First cool down in 2015 with CM1

❑ **Cool-down in five phases:**

- ✓ Shield cool-down to 80K with **GHe**
- ✓ Vessel and frame cool-down to ~100K with **GHe**
- ✓ Cav. and solenoid cool-down to ~ 100K with **GHe**
- ✓ Vessel and frame cool-down to 4.5K with **LHe**
- ✓ Cav. cool-down and filling with **LHe** at 4.5K

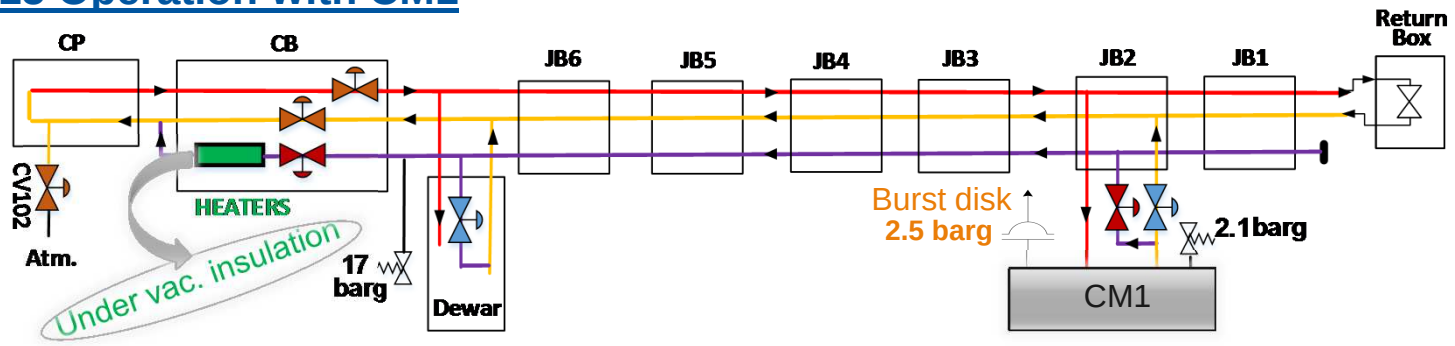
Thermal gradients	Localisation	ΔT
Shield: Outlet - Inlet	★	< 50K
Frame	★	< 40K
Frame – Vessel	★	< 100K



❑ **13 days for the CM1 cool down - June 2015**

- ✓ Cool down phases managed manually;
- ✓ Basic interlocks to respect the temperature gradients;

2015 Operation with CM1



- Overheating of the ~10kW electrical heater in the cold box – by-pass return line;
- Burst of the CM1 rupture disk (> 2.5 barg) ⇔ combination of hardware/software unappropriated settings;
  - ↳ Quick and efficient repair

- From Sept. to Nov. 2015 (physics run) : availability of the cryo plant = 100% ✓

- Measure of CM1 static heat load : 9.5W at 4.5K (expected design value);
- Warm-up of CM1 ⇒ sent to the clean room to upgrade the RF couplers

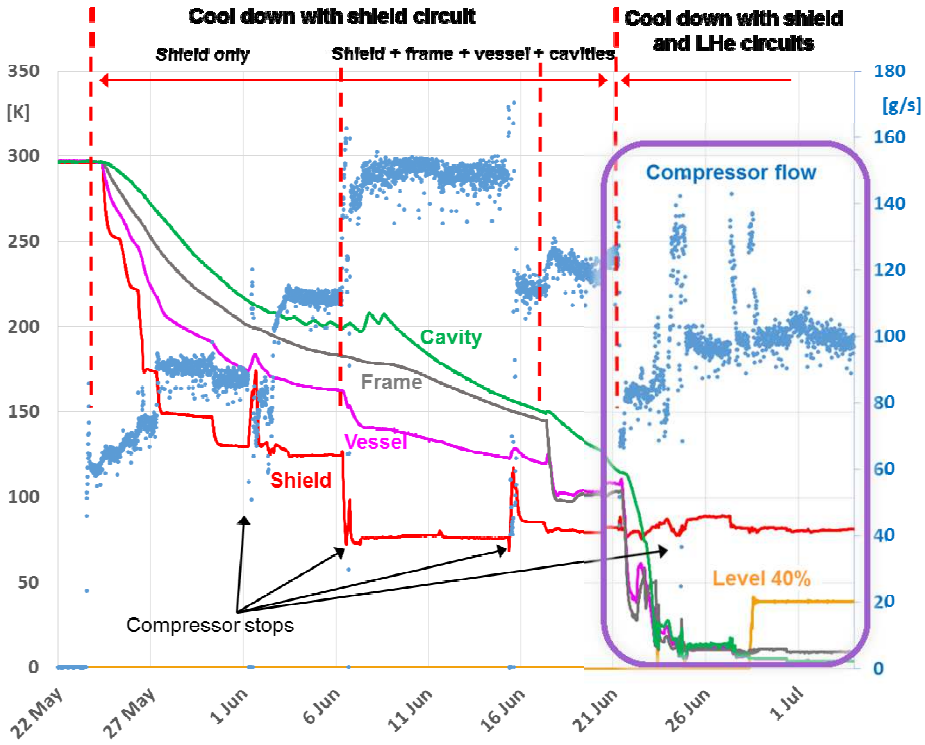
2016 Operation with 2 CM

- **Compressor conditioning and CM1 + CM2 cool down hardly started in May:**
  - ✓ CP Helium circuit with H2O and N2 pollution,
  - ✓ CP flow limitation (140 g/s max)

- **14 days to cool down the shields to ~75K**, due to:
  - ✓ Several unwanted stops of the compressor
  - ✓ Unappropriated interlocks for CB and JB
  - ✓ Process predominantly manual

- **2 additional weeks necessary to revise interlocks and process**

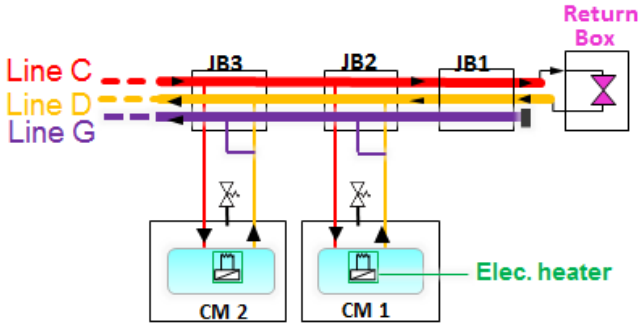
- **Then cool down with LHe:**
  - ✓ Not possible to fill in parallel the 2 CM with LHe



- **Machine commissioning with CM1 + CM2**

  Strong thermal and pressure oscillations in the 4.5K return **line D**

  ⇒ **tripping of the cavities**



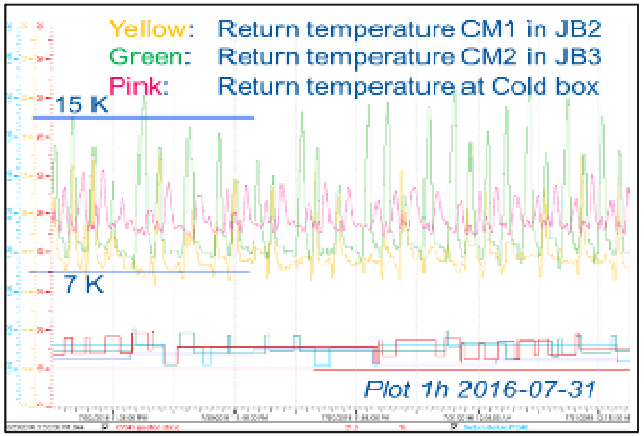
Nominal operation: 60 W 50 W

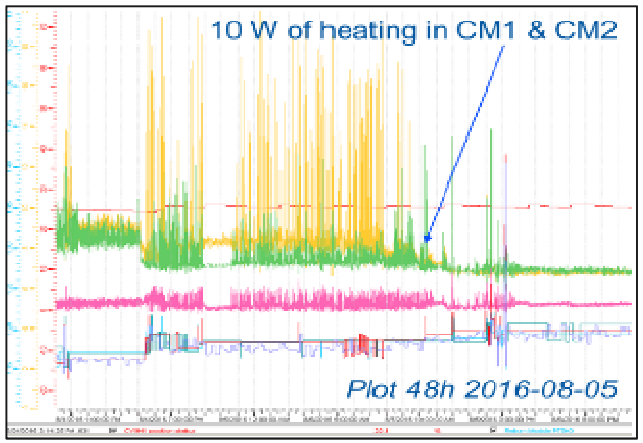
- Capacity test: 220 W 120 W ✓

➡ Oscillations reduced by **activating the elec. heaters in each vessel + opening (+10%) of the by-pass valve in the return box**

Indication of bad LHe quality supply + high heat load in CDS

- **2016 availability of the cryo plant = 100%** ✓

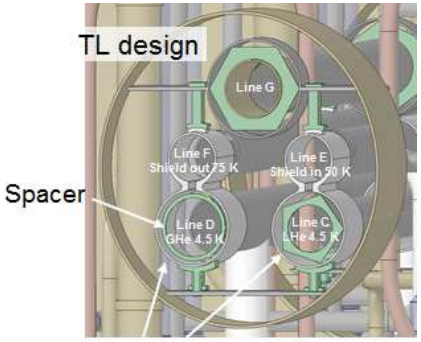


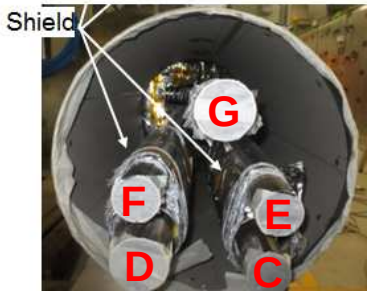


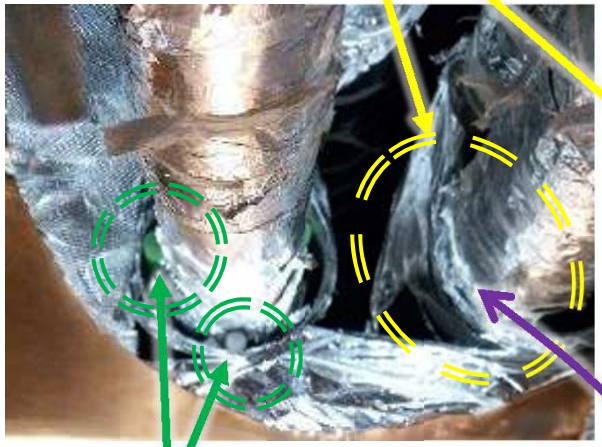
Upgrades during the Extended Year-End Technical Stop 2016/2017 (EYETS)

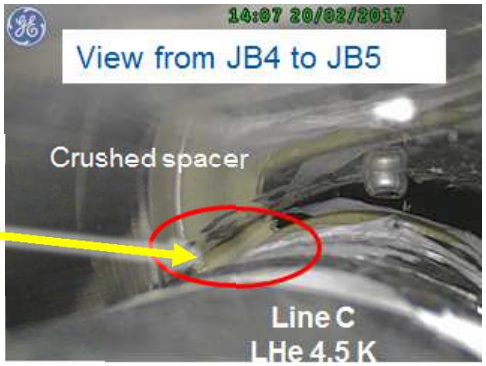
❑ **Endoscopic investigations of JB and TL:**

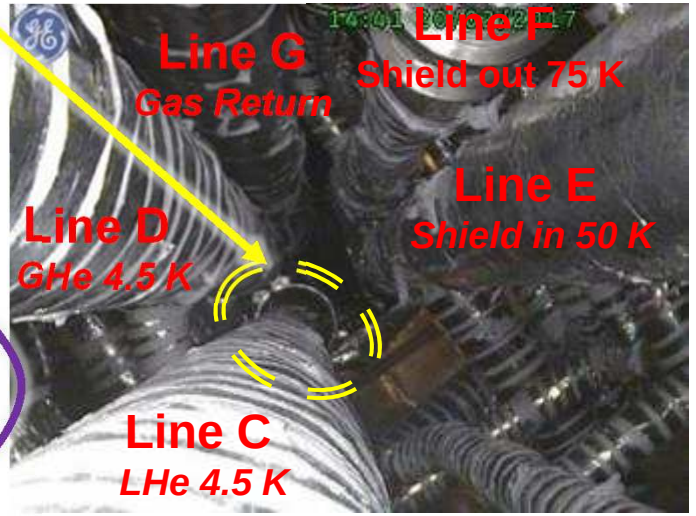
✓ Revealed contacts of 4.5K pipes with Al shield







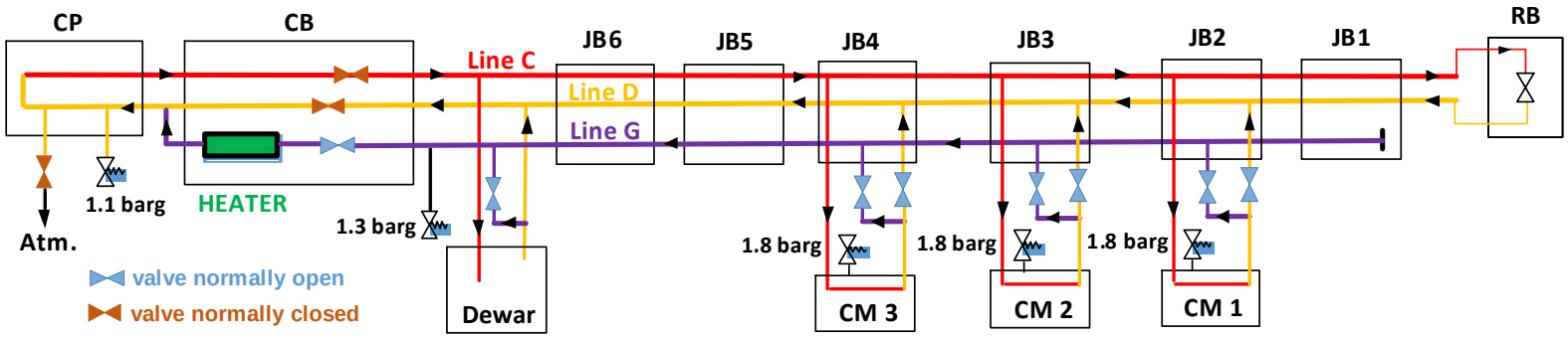




Direct contacts were suppressed (G10 or PTFE rollers), but **not in all points of the line D** (risk of breaking)

❑ **Review during the EYETS of the safety concept concerning :**

- ✓ Global process ⇒ ease gas exhaust before a significant CM pressure increase;
- ✓ NO / NC valve status on all return lines up to Compressor;
- ✓ Installation of 2 additional safety valves ⇒ gradually release of over-pressure



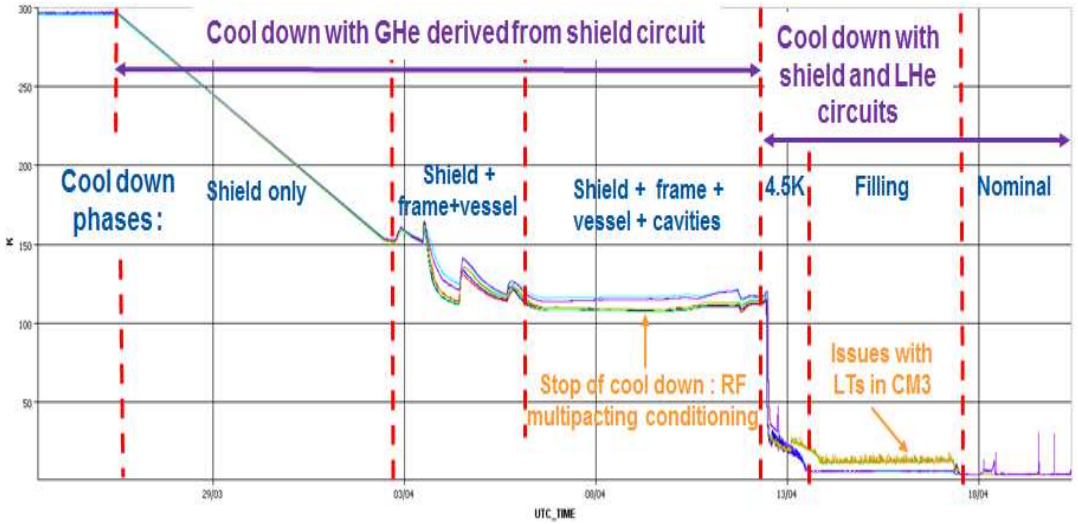
❑ **Complete revamping of the process of Cold-Box and CDS (JB + TL)**

- ✓ To optimise the cool down & nominal operation ;
- ✓ To allow quasi-automated restarts and cope with short stops of the cryo-plant ;

❑ **Complete revamping of the CS interlocks to avoid unwanted stops**

Cool down and commissioning in 2017 with 3 cryo-modules

- CM1 & 2 were cooled & filled in parallel ;
- CM3 probably also filled, but issues with level transmitters ⇒ confirmed a few days later (after repair)

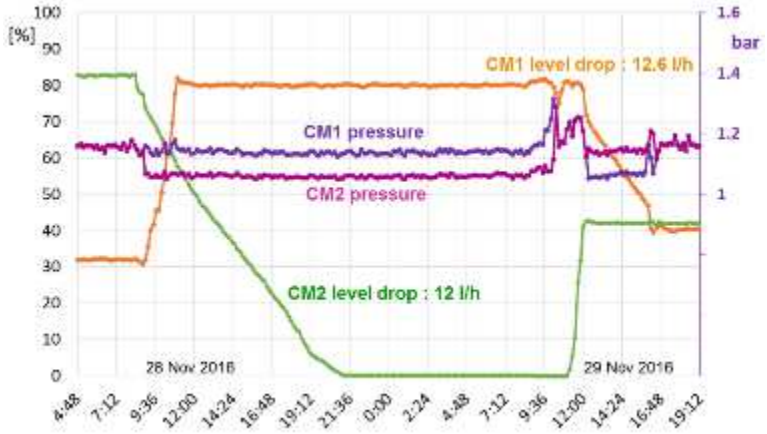


Phases	2016 *2 CMs*	2017 *3 CMs*
300K → 5K	≈ 15 effective days	≈ 9 effective days
LHe Filling (stable/reg.)	5 effective days	4h for CM1&2 + 4h for CM3

Proof of improvements executed during the EYETS

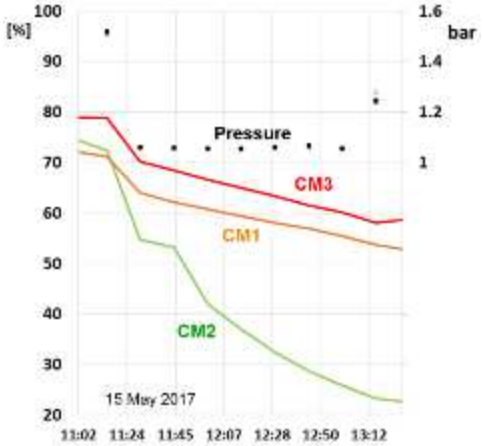
❑ Static heat load tests of CM (derived from level drops)

✓ 2016 : ~11W, shield actively cooled



LEVEL DROPS 2016: CM1 & CM2

✓ 2017 : ~13W, shield stopped, but issue with CM2 (3 times higher, investigations on going)



LEVEL DROPS 2017: CM1 & CM2 & CM3

❑ Capacity test : stable operation tested with 100 W in each CM ✔

Conclusion

- ❑ Long series of issues due to lack of time to commission the cryo-plant and the CDS with the associated control logic;
- ❑ Endeavors performed to diagnose and overcome issues like CDS have been efficient;
- ❑ Static heat load of CM are within design specification
- ❑ In 2015 and 2016: 100% of cryo availability during physics run

Next milestones

- ❑ Restore full performance of the CDS ⇒ repair during next YETS 2017/2018
- ❑ Review of the control logic of the CDS ⇒ taking into account lessons learnt during the last cool down
- ❑ Improvements ⇒ pollution issue in the compressor station, overheating of the heater in the cold box
- ❑ Commissioning of the dewar

Thank you for your attention.
Questions ?

Nicolas Delruelle took the responsability of the HIE ISOLDE cryogenics system from 2010 to 2015;
A special thought is brought to him.