CERN

The HIE—ISOLDE Cryogenic System, its Infrastructure and Considerations for Phase 3

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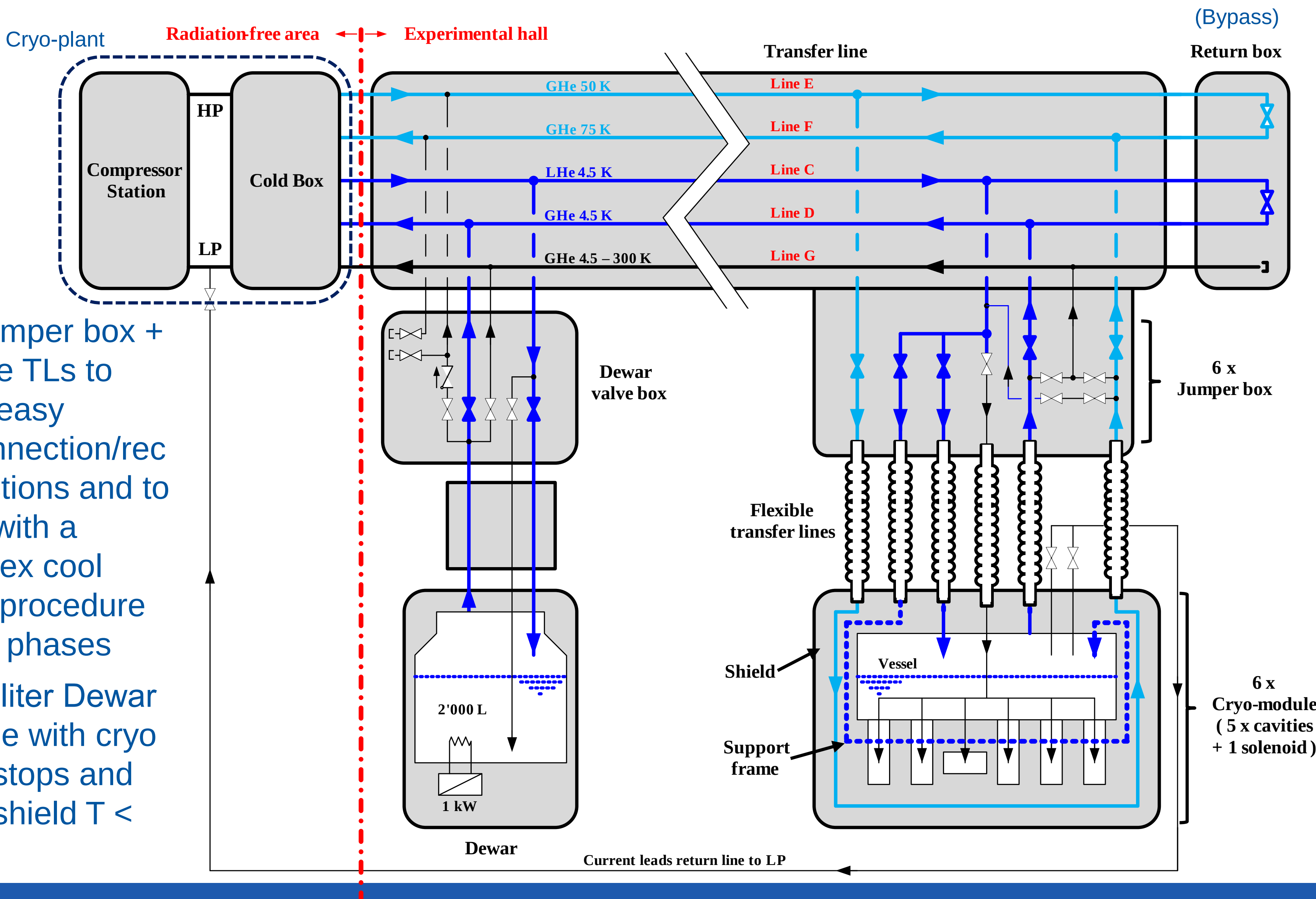
Outline

- Introduction : HIE-Isolde cryogenic system
- Commissioning and operation in 2015
- Commissioning and operation in 2016
- Consolidations during EYETS 2016-2017
- Commissioning and operation in 2017
- Cryogenic system & Phase 3
- Summary

HIE-Isolde cryogenic system: Process Flow Diagram

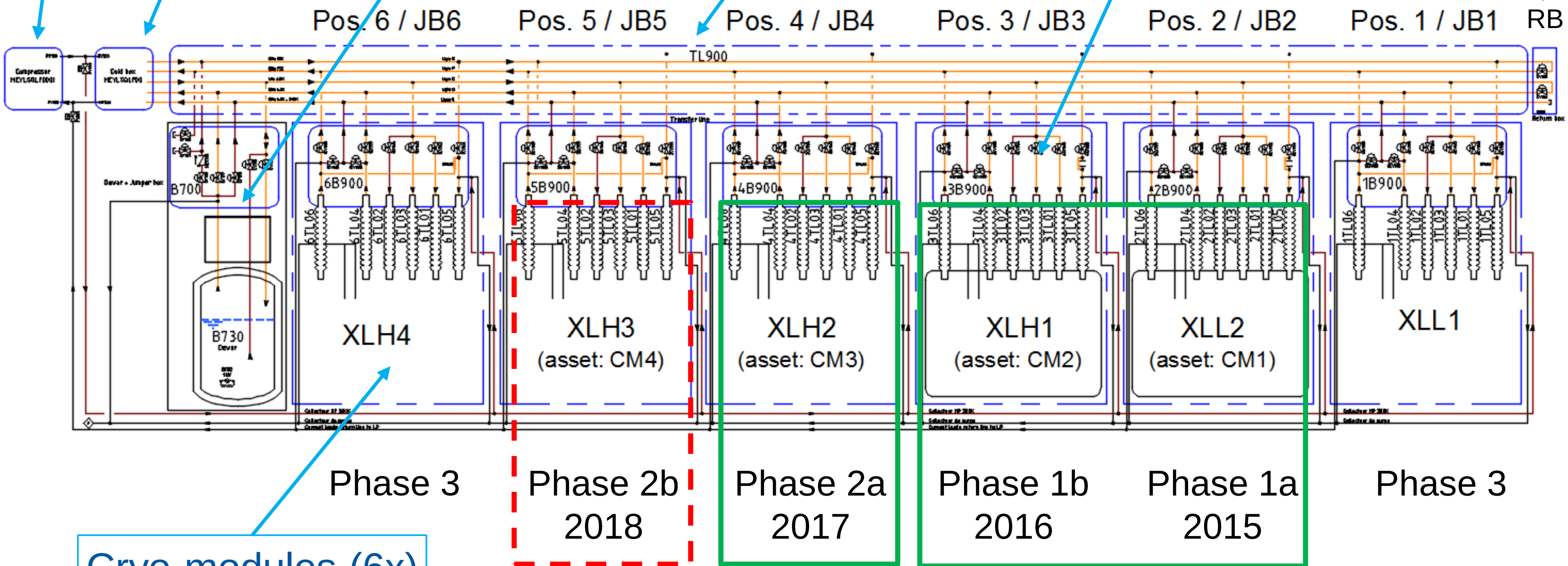


- 6 x Jumper box + flexible TLs to allow easy disconnection/reconnections and to cope with a complex cool down procedure in five phases
- 2'000 liter Dewar to cope with cryo plant stops and keep shield T < 100 K

HIE-Isolde cryogenic system

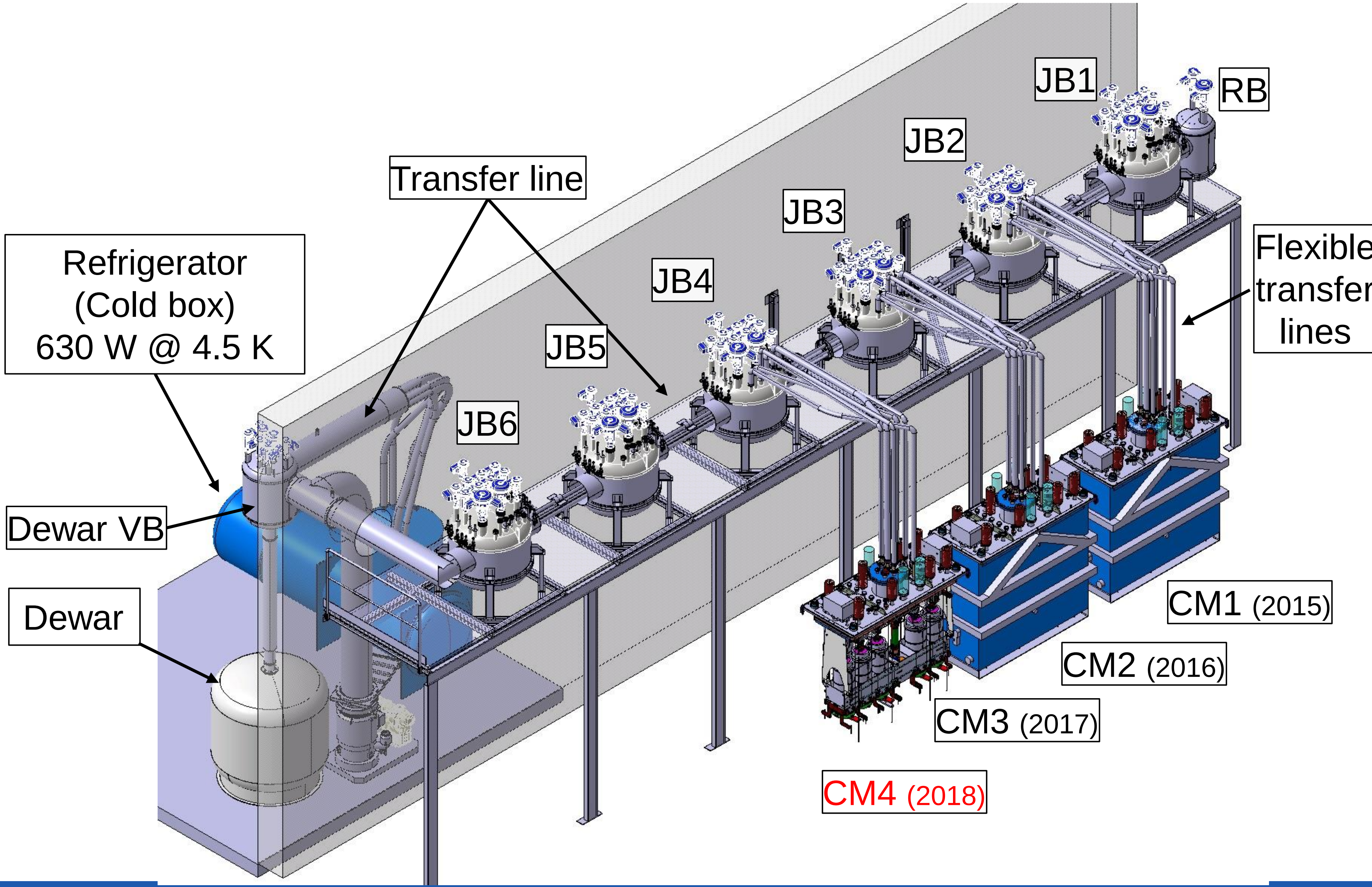
Cryo-plant:
Compressor Station
+ Refrigerator (CB)

Cryogenic Distribution System (CDS):
Dewar +
valve box (DB) + Transfer Line + Jumper Box (6x) + Return Box



Cryo-modules (6x)

HIE-Isolde cryogenic distribution system (CDS)



2015: cryogenic system installation

Cryoplant recovered from former LEP ALEPH experiment's cryogenic installation (1989) on stand-by after the LEP de-commissioning

Compressor station

Refrigerator

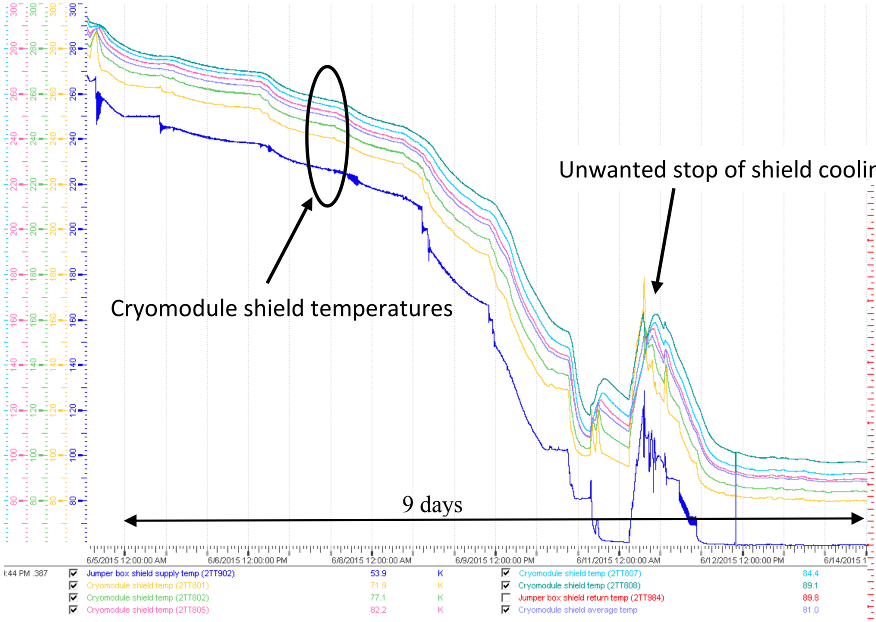
Cryogenic Distribution System

Connection of cryo-module CM1

2015 : First commissioning and operation with CM1

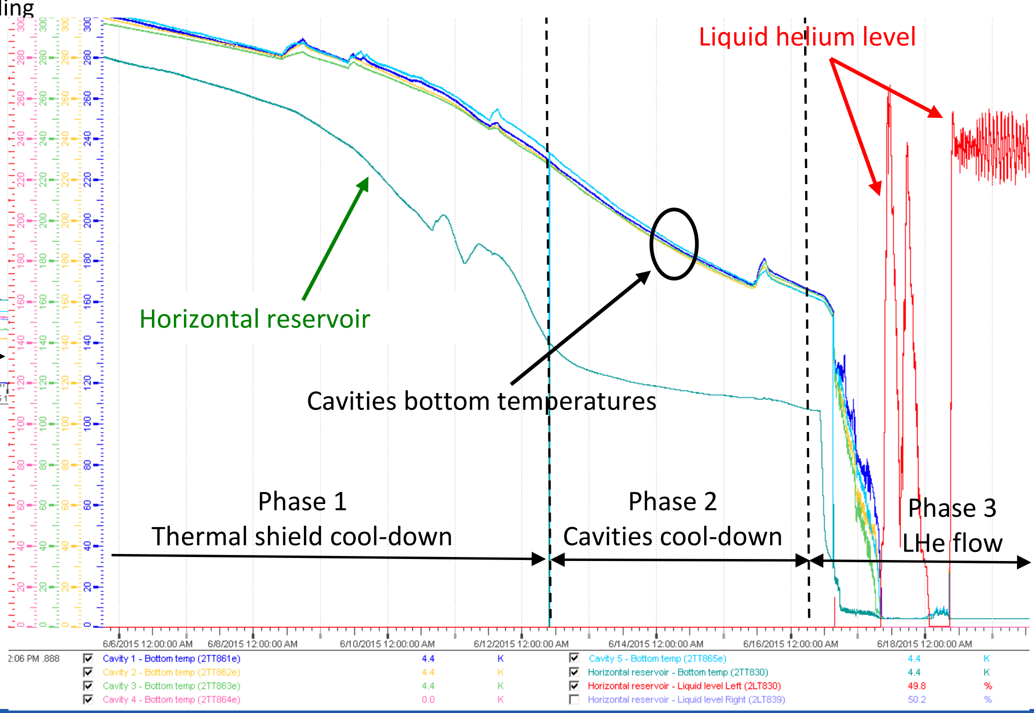
- Very short time to perform commissioning of cryoplant
- First cool down and commissioning of CM1 performed manually
- Operation performed with basic automatisms and interlocks
- One incident : over-pressurization of CM1 -> burst of rupture disc

100 % availability during run of physics



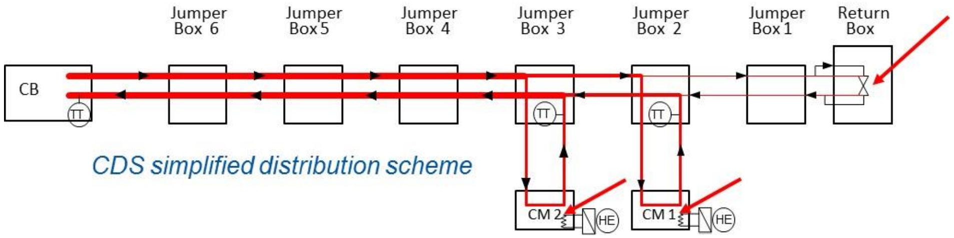
Thermal shield cool-down from ambient temperature down to 90 K

Cavities cool-down to 4.5 K



2016 : Commissioning and operation with 2 x CM

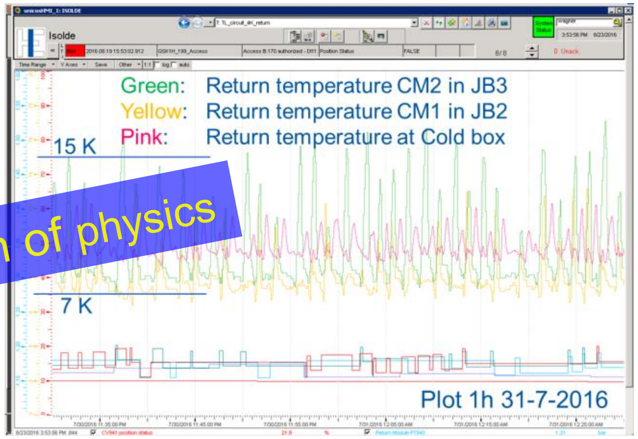
- Cool down and commissioning of CM1 + CM2 hardly performed during summer 2016
- Major issues identified :
  - CP flow limitation,
  - bad LHe "quality" supply,
  - strong oscillations in the 4.5K return line and cavities tripping (-> indications of high heat load estimated to 3 x the expected figure)
- Operational conditions found by increasing by-pass valve opening in the Return Box and by powering heaters in each CM

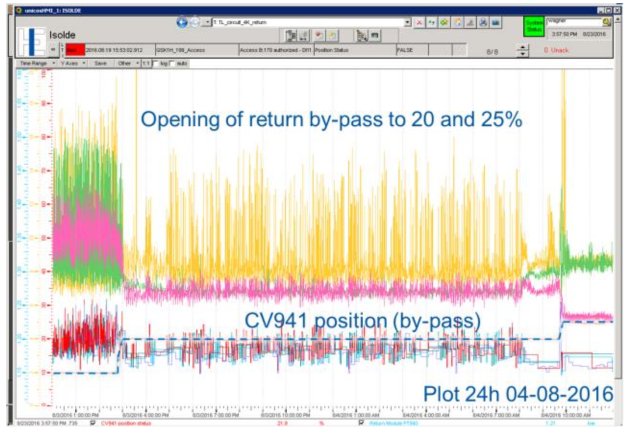


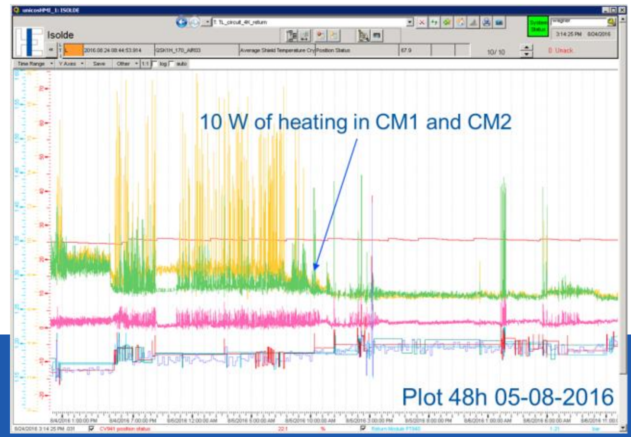
CDS simplified distribution scheme

- Investigations of Cryogenic Distribution System (CDS) in situ did not show evidence of problem (cold spots, vacuum issue)

100 % availability during run of physics



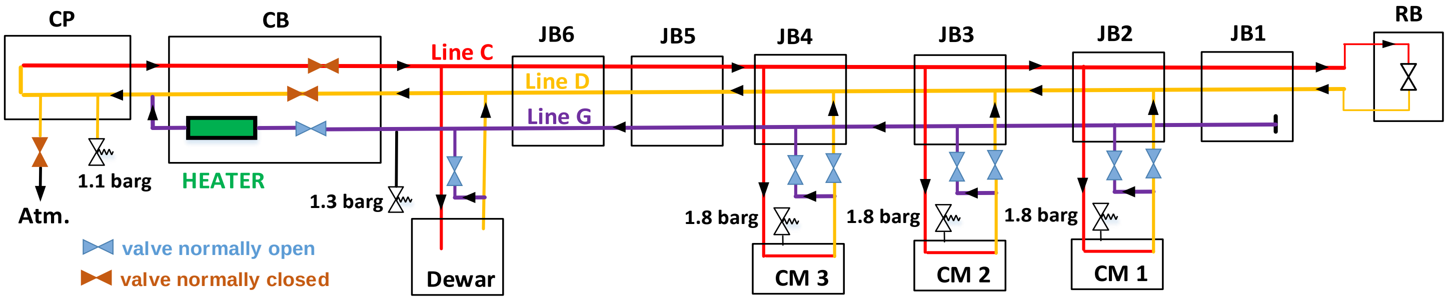




EYETS 2016-2017 : consolidation action plan

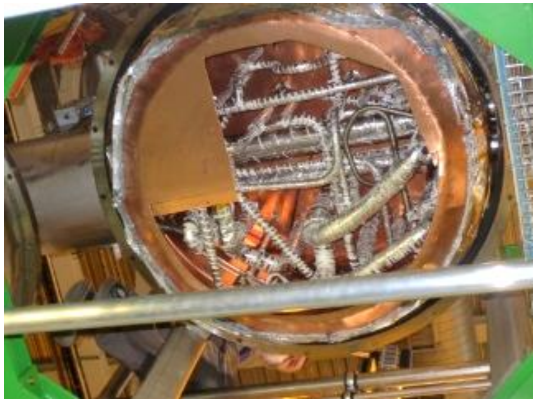
Compressor station and Refrigerator :

- Revision of the safety system with respect to overpressure events ;
- Review and simplification of safety chains;
- Update of CP logic -> allow full CP performance and ease restarts ;
- Update of refrigerator process control -> more robust process with automatisms allowing reconnection of cryo-modules in cool down situations



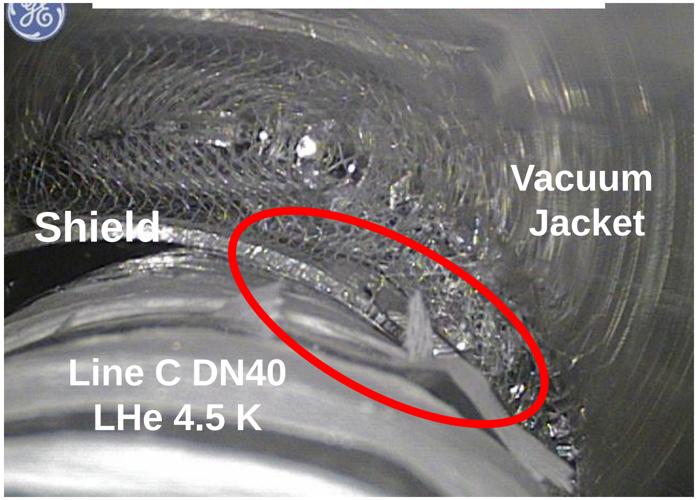
CDS :

- Full commissioning of all jumper box;
- Upgrade of PLC and logic including automatisms easing restarts and reconnection in cool down situations
- Installation of CM3 and CDS endoscopic investigations

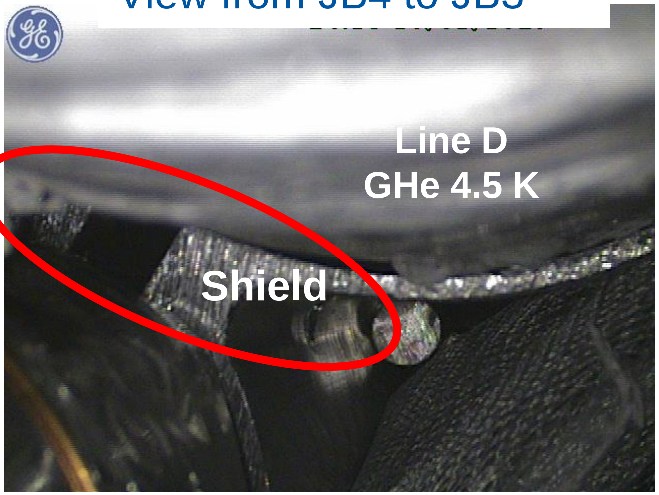


Main finding of endoscopic investigations : contact of 4.5K process pipes with shield

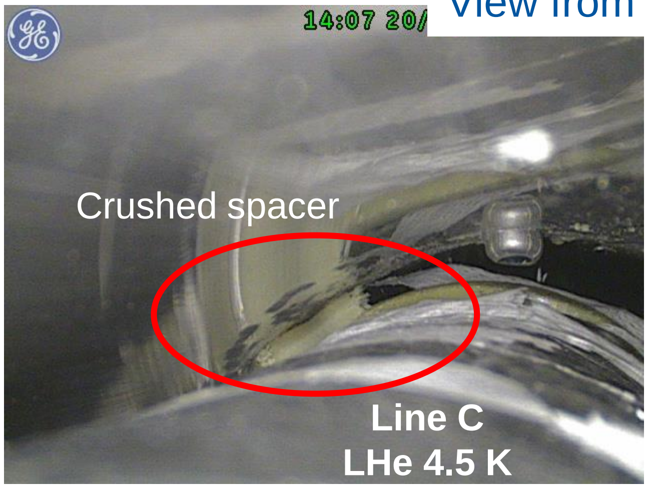
View from JB4 to JB5

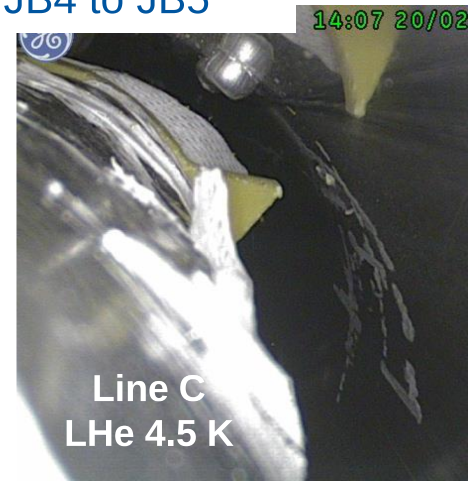


View from JB4 to JB3

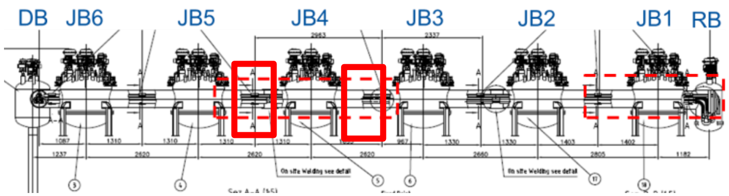


View from JB4 to JB5





- Spacers too fragile ? Incorrect design wrt thermal contraction force ?
- Too narrow gap between 4.5 K process pipes and shield

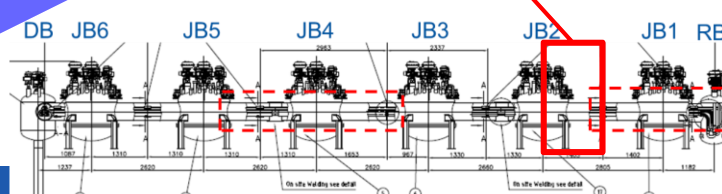


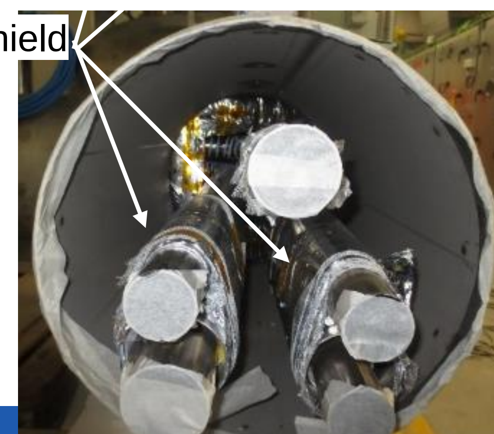
Main finding of endoscopic investigations : contact of 4.5K process pipes with shield

Obvious contact of LHe and GHe 4.5 K lines (headers C & D) with the shield in the TL interconnecting the Jumper Box (JBs)

=> *Implies significant contact all the way along transfer line*

View from return box of Jumper Box 1 to 2





Meeting in situ with the manufacturer

Full repair : new design required -> postponed to next YETS

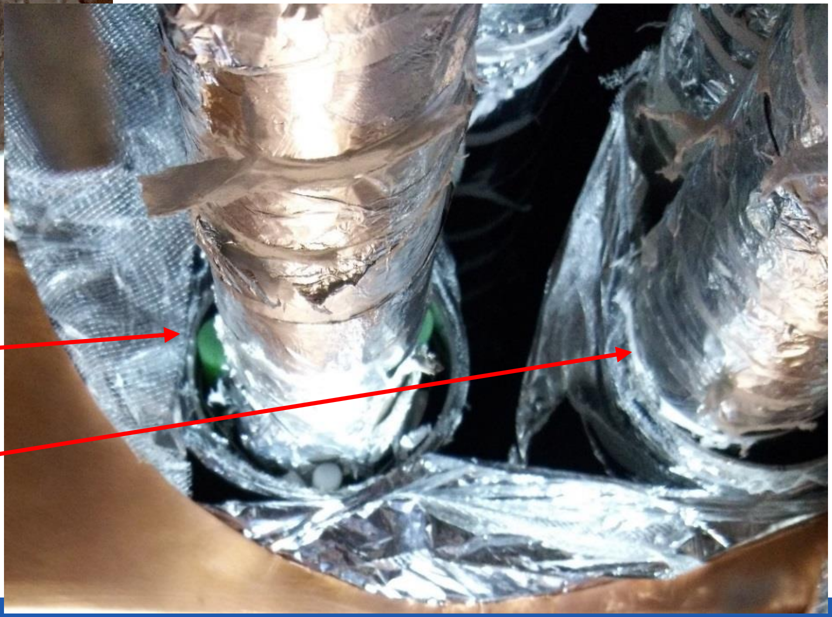
Setting up by TE-CRG of a crash program to repair "at best"

and with no impact on the HIE-Isolde program

EYETS crash program: removal of contacts

- Opening of all JBs
- Insertion of spacer material to remove direct contacts

- Operation successful for LHe 4.5 K process pipe
- Not fully for GHe 4.5 K process pipe (requires too much force -> risk of breaking)



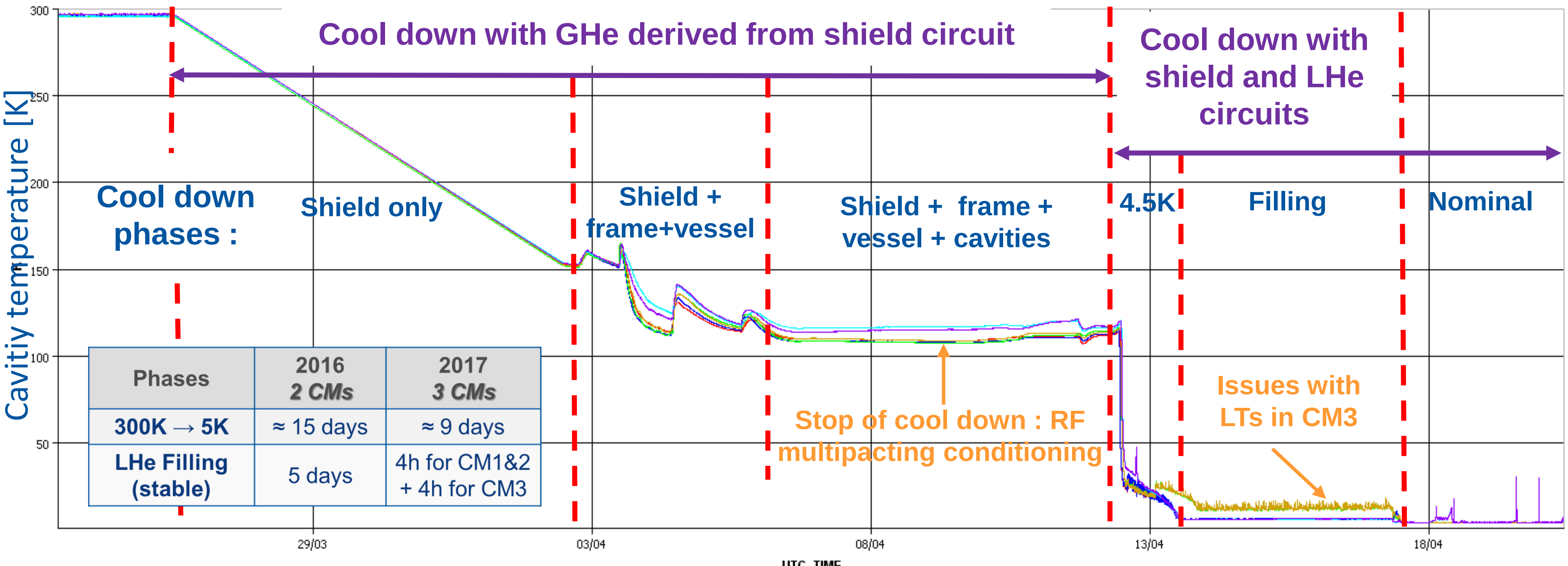
2017 : Commissioning and operation

- Recommissioning of the cryo-plant (compressor station and refrigerator) ✓

Full nominal power available from cryoplant

- Successfull cooling and filling of the 3 CMs and dewar

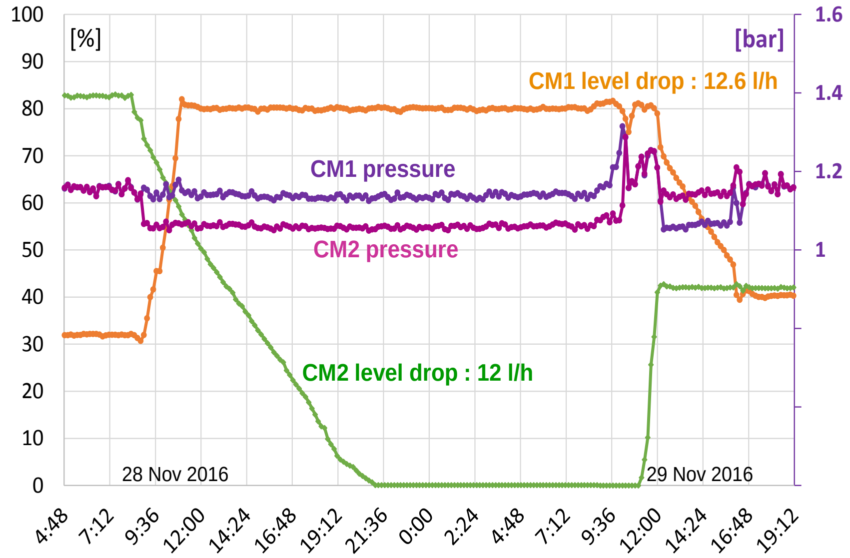
⇨ LHe filling of cryomodules achieved much quicker wrt 2016 and via the frame circuit only → proof of better LHe «quality»



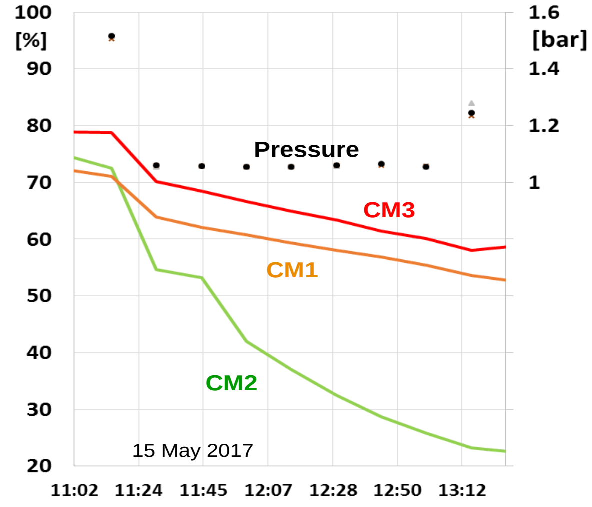
Phases	2016 *2 CMs*	2017 *3 CMs*
300K → 5K	≈ 15 days	≈ 9 days
LHe Filling (stable)	5 days	4h for CM1&2 + 4h for CM3

2017 : Commissioning and operation

- Static heat load tests : LHe level drop



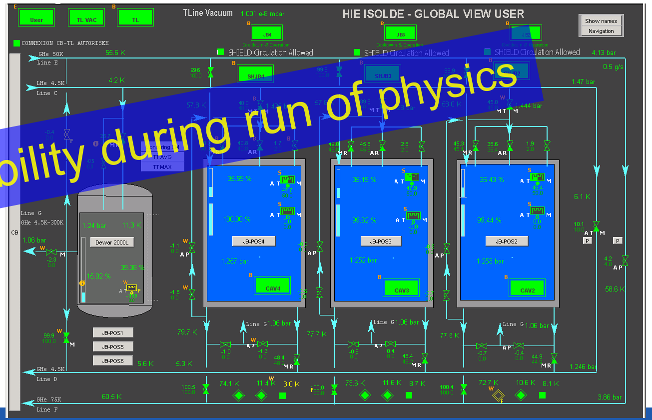
2016 : ~11W, shield actively cooled



2017 : ~13W, shield stopped

Issue with CM2 : 3 times higher => under investigation

- Commissionning of new control system and processes
  - Restart tests : done for most credible and expected cases (power cut, …)
  - Automatisms : tested sucessfully
    Only the refilling with LHe is semi-automatic (waiting for CM4 and final version)



Cryogenic system & Phase 3

In 2012 a dedicated MS and IT-3777/TE was launched for the cryogenic system including the a cryo-plant and a cryo-distribution system (main transfer line and 6 jumper boxes), with the following technical specification and overall capacity (extract from IT-3777/TE):

	Reduced mode (2 cryo-modules)	Maximum mode (6 cryo-modules)	Design mode (Max. cryogenic power)
Cooling power @ 4.5 K	250 W	700 W	1'400 W
Cooling power @ 50 K – 75 K	700 W	2'000 W	4'000 W
Helium liquefaction rate	0.5 g/s	1.5 g/s	3.0 g/s

The Invitation to Tender was cancelled early in 2013 due to the very high price of the proposed offers (9.8 MCHF) well above the HIE-Isolde available estimated budget for cryogenics (4.9 MCHF)

In common agreement with the HIE-Isolde collaboration, the decision was taken to use the former LEP ALEPH experiment's cryogenic installation (1989) on stand-by after the LEP de-commissioning.

The total budget for cryogenics was reduced to 3 MCHF. However it clearly appeared that the maximum mode with 6 cryo-modules (phase 3 not approved) is not any more achievable with the as below LEP ALEPH cryo-plant available cryogenic power at 4.5 K (presented to the HIE-Isolde collaboration in the Cost & Schedule review of the 27th October 2014)

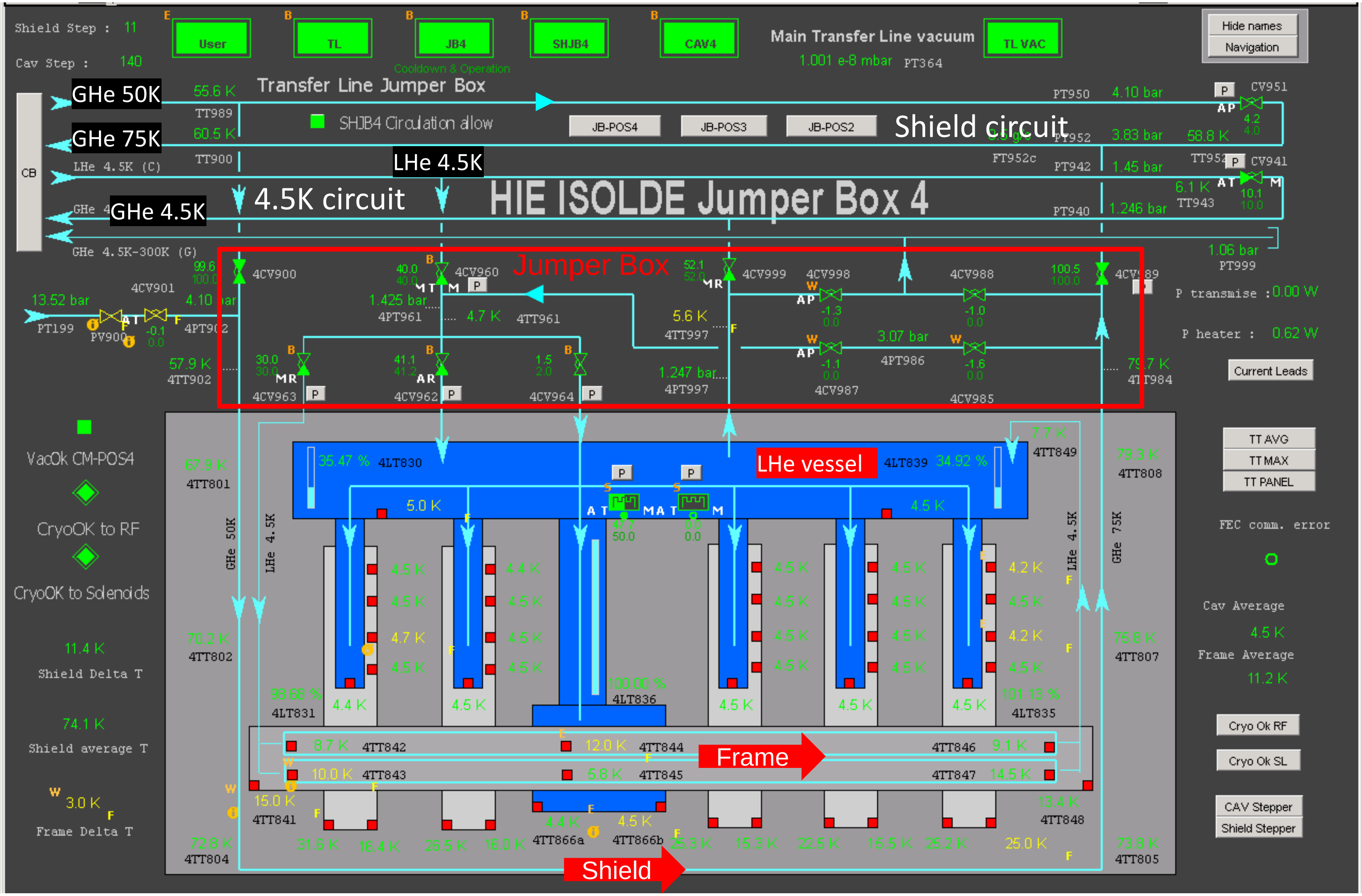
	LEP ALEPH cryogenic plant specification
Cooling power @ 4.5 K	630 W
Cooling power @ 50 K – 75 K	2700 W
Helium liquefaction rate	1.5 g/s

Summary

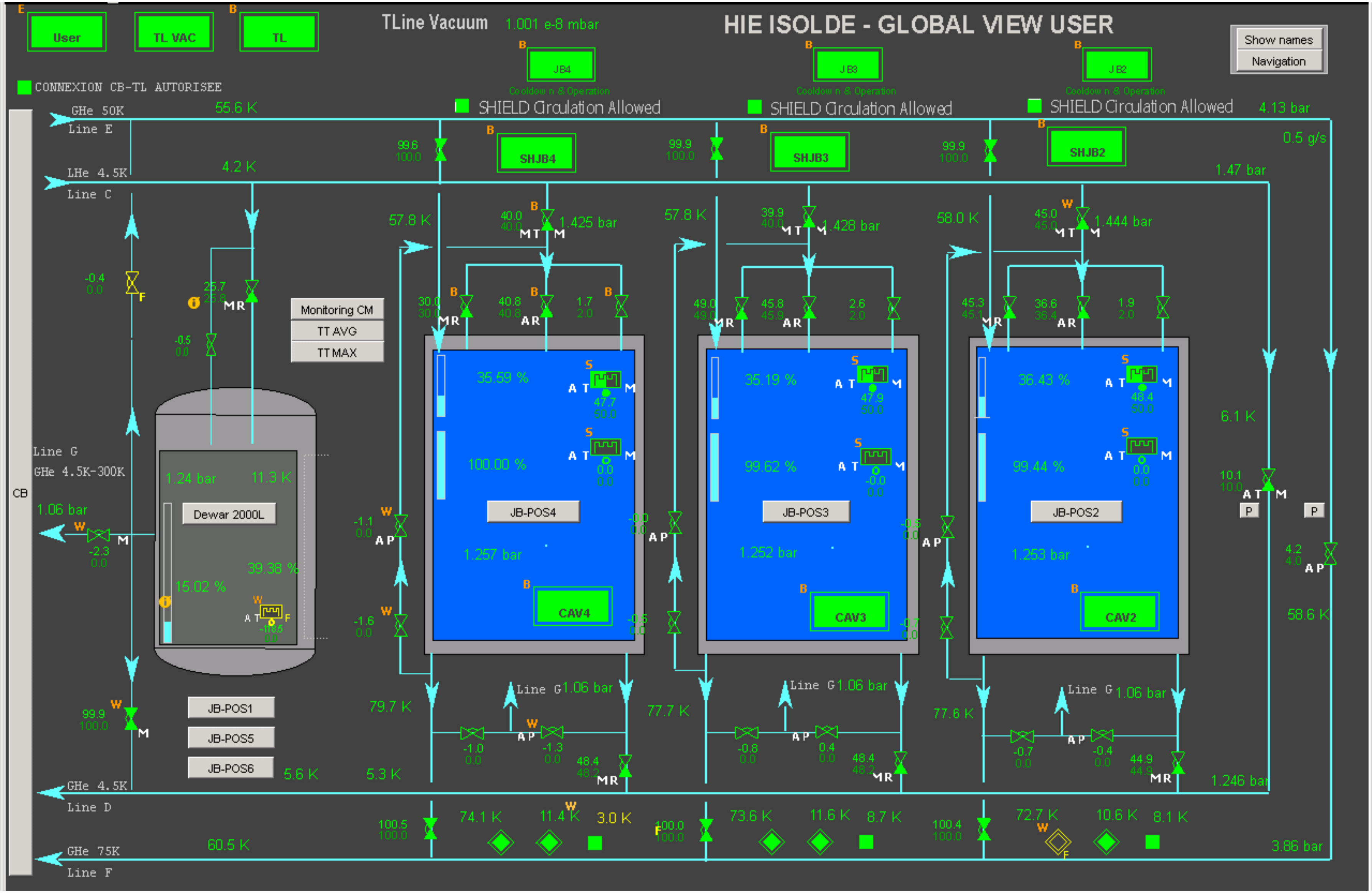
- Long series of issues due to lack of time to commission the cryo-plant and the CDS with the associated control logic
- A major issue consisting in excessive heat load in the distribution system has been found and will be repaired during YETS 2017-2018
- The former LEP ALEPH cryoplant has been now commissioned and is operational for HIE-Isolde phase 2.
- The dewar commissioning is on-going
- The final control system for the CDS will be completed with the CM4 installation
- 100% availability of the cryogenic system during all run of physics
- The present cryo-plant will not be able to deal with Phase 3

Additional slide(s)

Nominal operation of new CM3 with 50W additional power



Nominal operation with 3x50W additional power

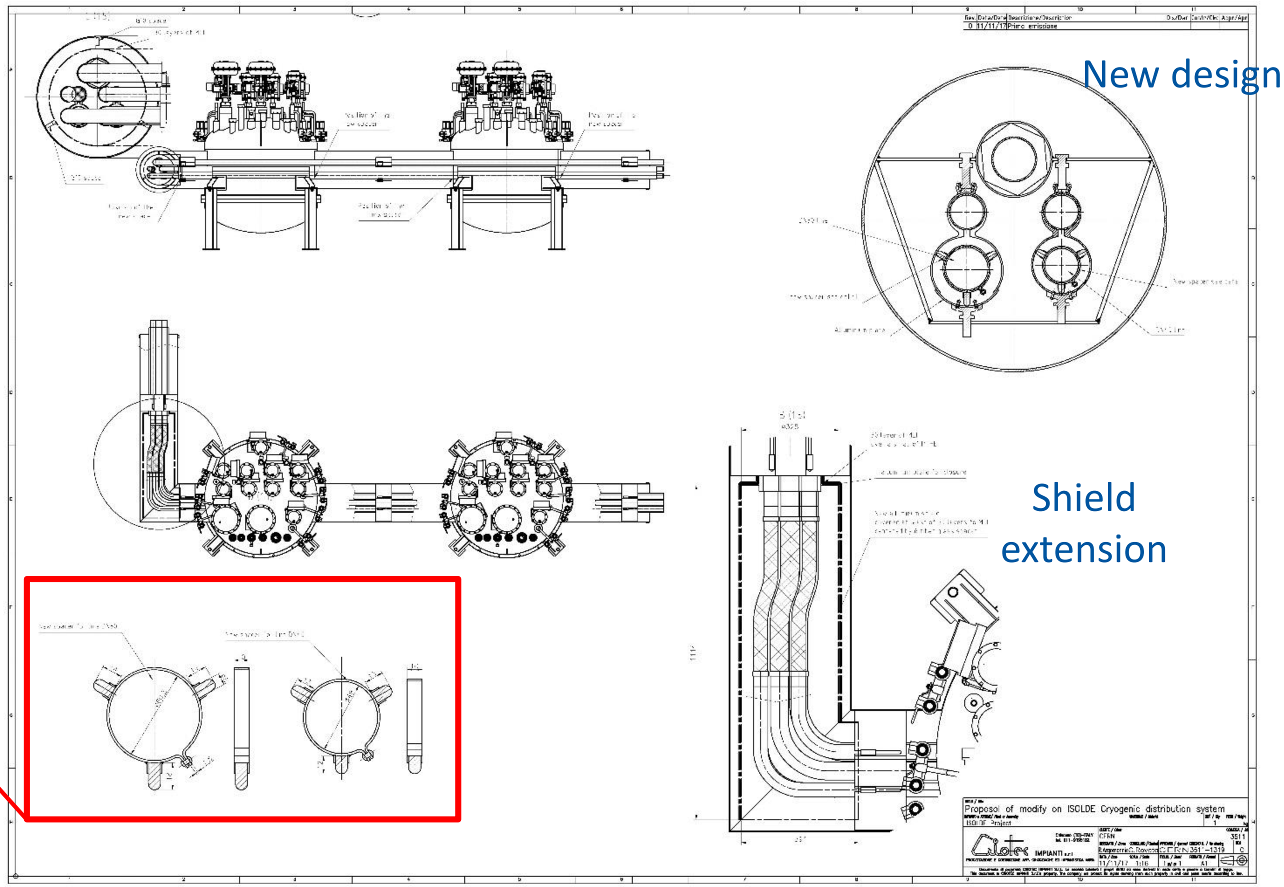


CDS repair : new design

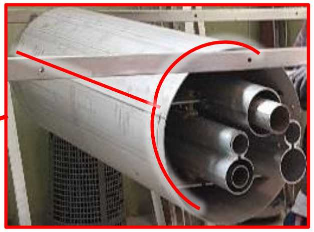
Requirements:

- Control of gap between 4.5 K process pipes and shield;
- Correct alignment and freedom for pipe movements during thermal shrinkage
- Continuous shielding of 4.5 K process pipes (MLI issues)

New internal spacers



CDS repair : execution



Criotec workshop:

- Development of special toolings
- Test and validation on mockups

Repair procedure :

- Opening of JB and removal of temporary spacers
- Removal of vacuum jacket of TL
- Removal of MLI around the shields
- Cutting shields with portable milling machine
- Opening, widening and shaping of the shield
- Cleaning
- Removing of spacers and evaluation of "freedom" of the pipes
- Lowering and re-centring of 4.5K pipes (lowering by ~ 20 mm)
- Assembly of new internal spacers (one at each extremities)
- Completion of shield with pre-folded Al pieces (tag welded)
- MLI
- Re-assembly of the vacuum jacket
- Leak test

Repair time estimated to 4 weeks