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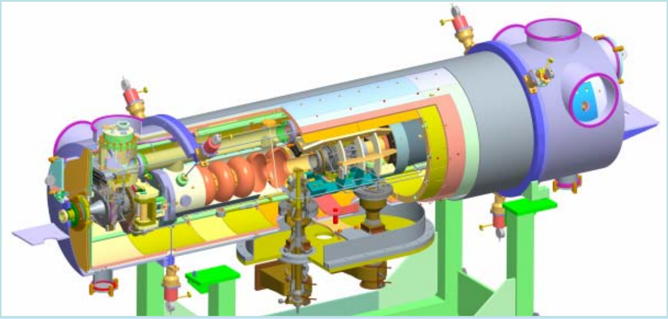
Status of the CW ERL Cryomodule at Daresbury



Shrikant Pattalwar

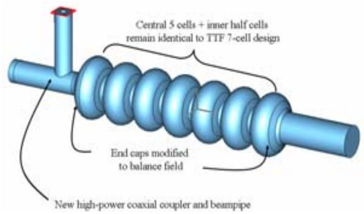
ASTeC, STFC, Daresbury Laboratory (UK)

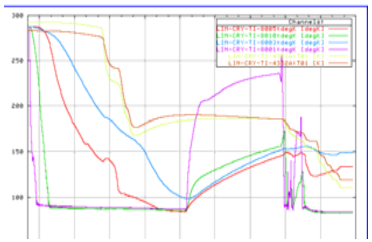
ERL-2013, September 9-13, Novosibirsk

On behalf of

ERL Cryomodule Collaboration

OUTLINE





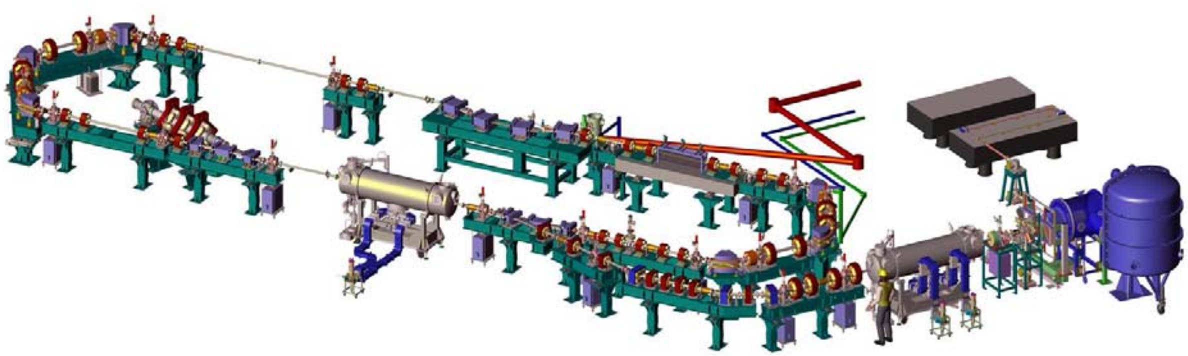
Introduction

Design – Assembly

Offline Tests

Integration and Commissioning

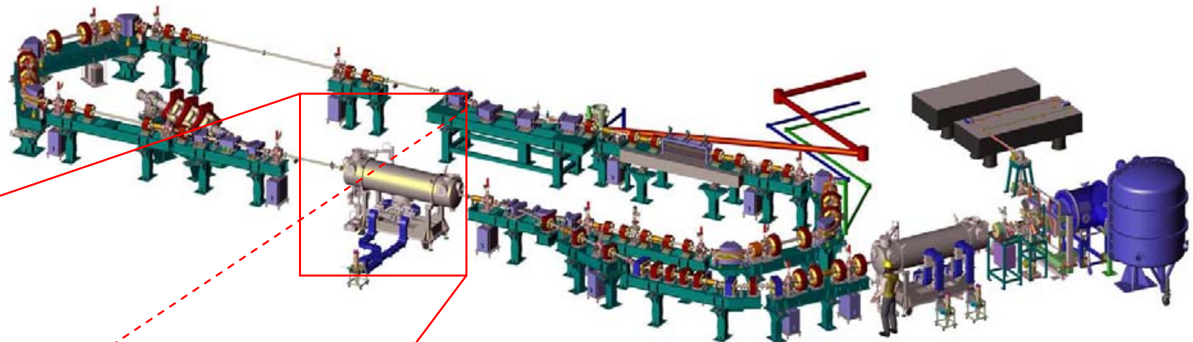
Future Plans

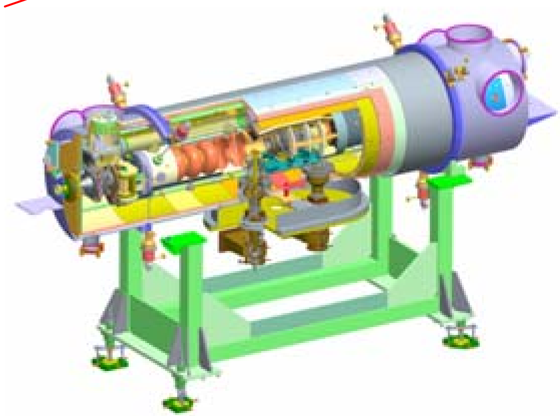


Introduction

The aim – To build and test the ERL Cryomodule with beam on ALICE

Accelerator and **L**asers **i**n **C**ombined **E**xperiment





Dimensioned to fit on the ALICE ERL facility at Daresbury:

- Same cryomodule footprint.
- Same cryo/RF interconnects.
- ‘Plug Compatible’ with existing cryomodule

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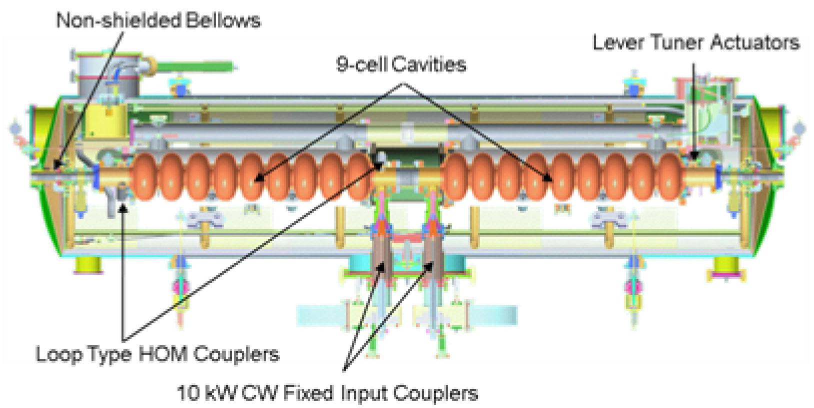
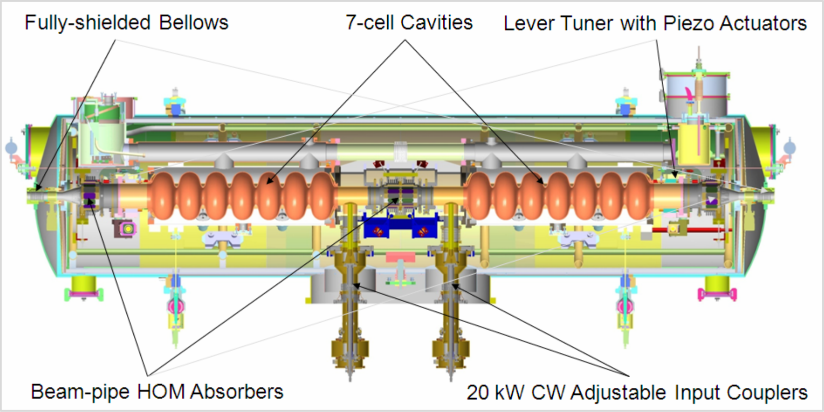
Introduction -The ERL Cryomodule



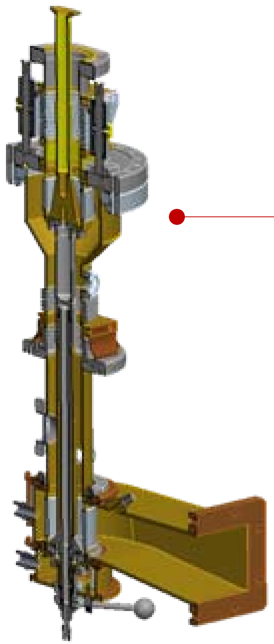
Existing Cryomodule on ALICE

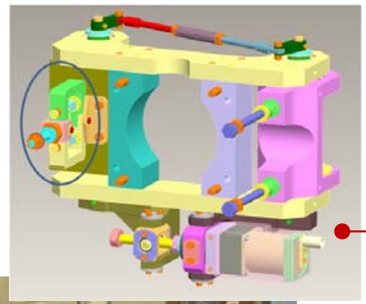


CW-ERL Cryomodule

Parameter	Target
Frequency (GHz)	1.3
Number of Cavities	2
Number of Cells per Cavity	7
Cavity Length (m)	0.807
Cryomodule Length (m)	3.6
R/Q (Ω)	762
E_{acc} (MV/m)	>20
E_{pk}/E_{acc}	2.23
H_{pk}/E_{acc}	46.9
CM Energy Gain (MeV)	>32
Q_o	$>10^{10}$
Q_{ext}	$4 \times 10^6 - 10^8$
Max Cavity FWD Power (kW)	20 SW

Introduction - Major Variations in the Design

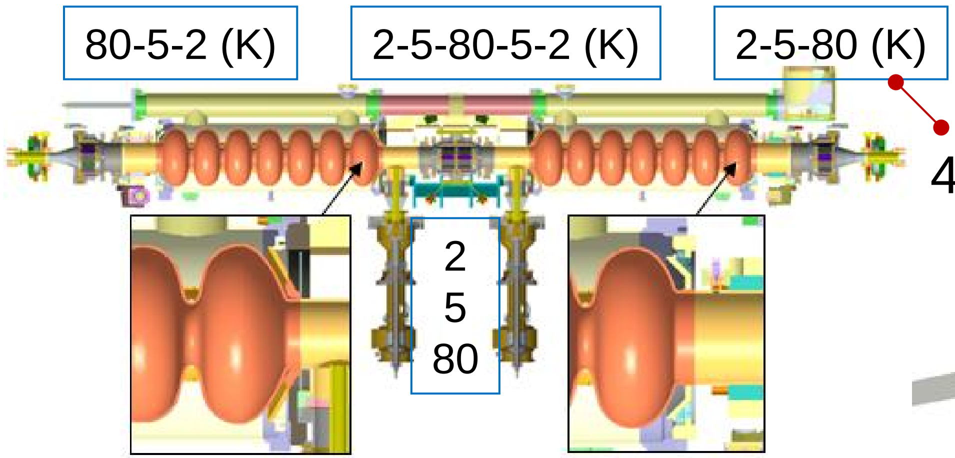




1. High Power Input couplers
   Cornell ERL injector coupler

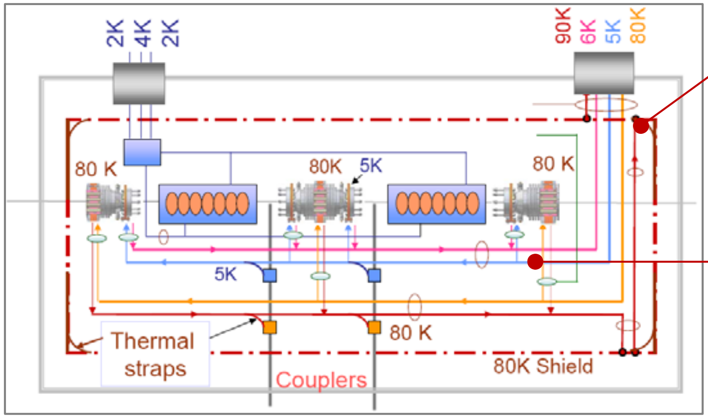
2. Modified Saclay-II tuners
   Wider aperture.
   Low voltage piezo cartridges.

3. HOM absorbers
   Cornell ERL injector CM with
   Ferrite Absorbers (@ 80K)

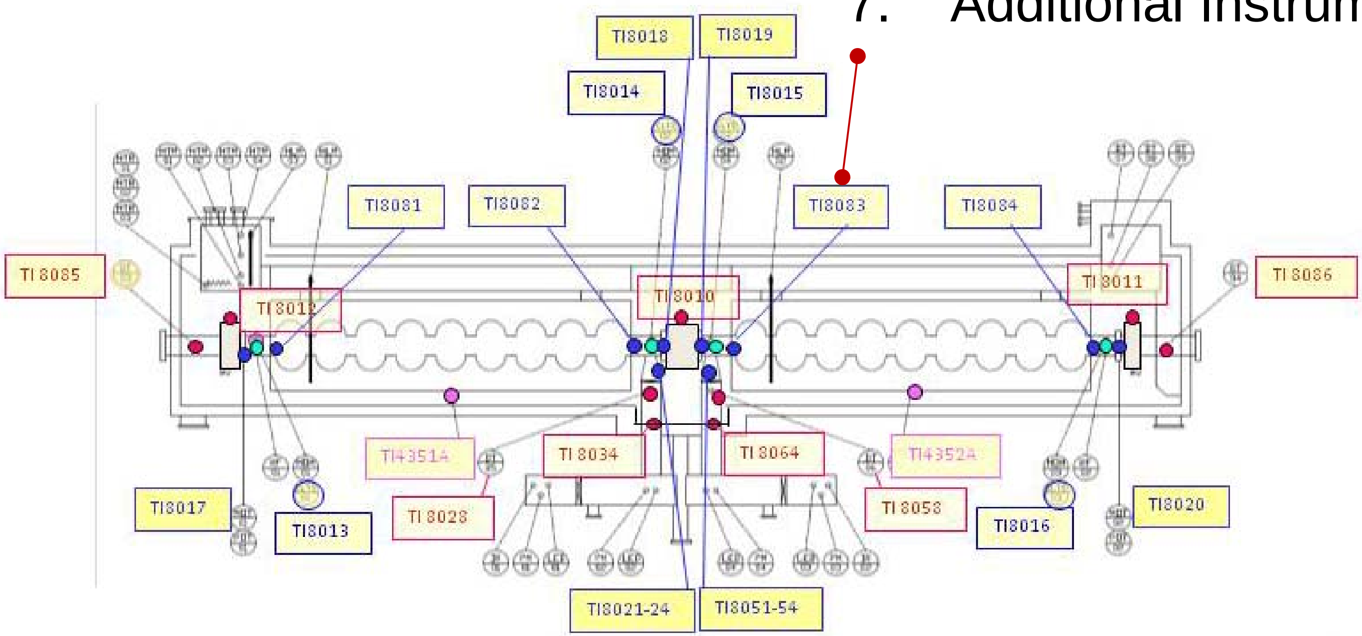


4. Several thermal transitions (intercepts) cooled by GHe

Introduction - Major Variations in the Design

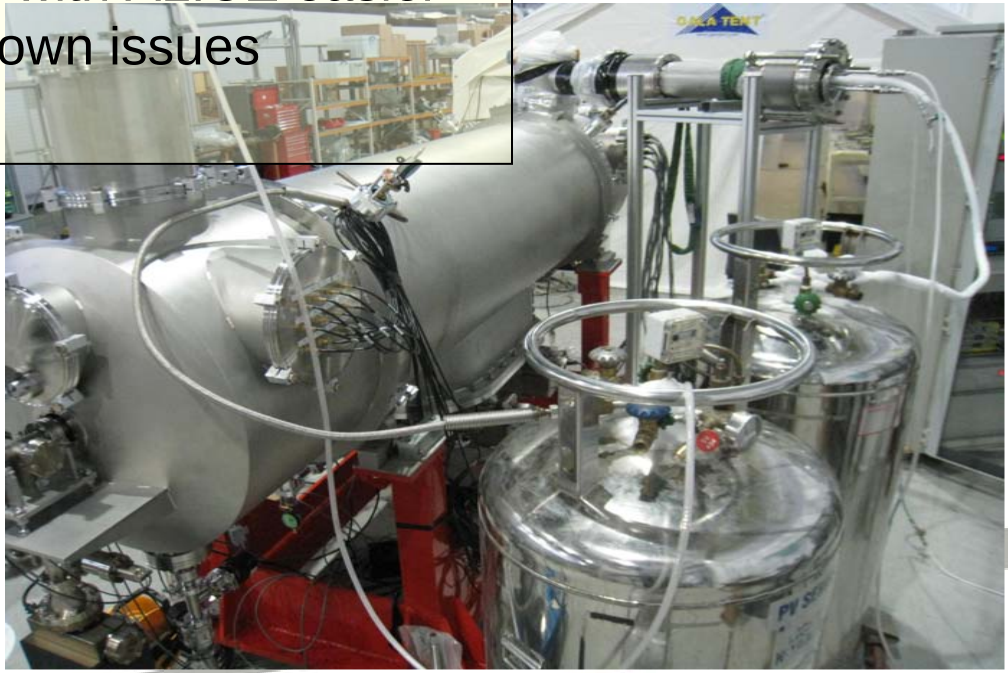


5. Radiation Shield, HOMs and thermal intercepts cooled with GHe
6. Additional thermal management scheme
7. Additional Instrumentation



Off-line Cold Tests

- Check the cryogenic performance
- Understand the processes and establish commissioning and operating procedures
- Validate instrumentation
- Make the task of integration with ALICE easier
- Identify and resolve any unknown issues



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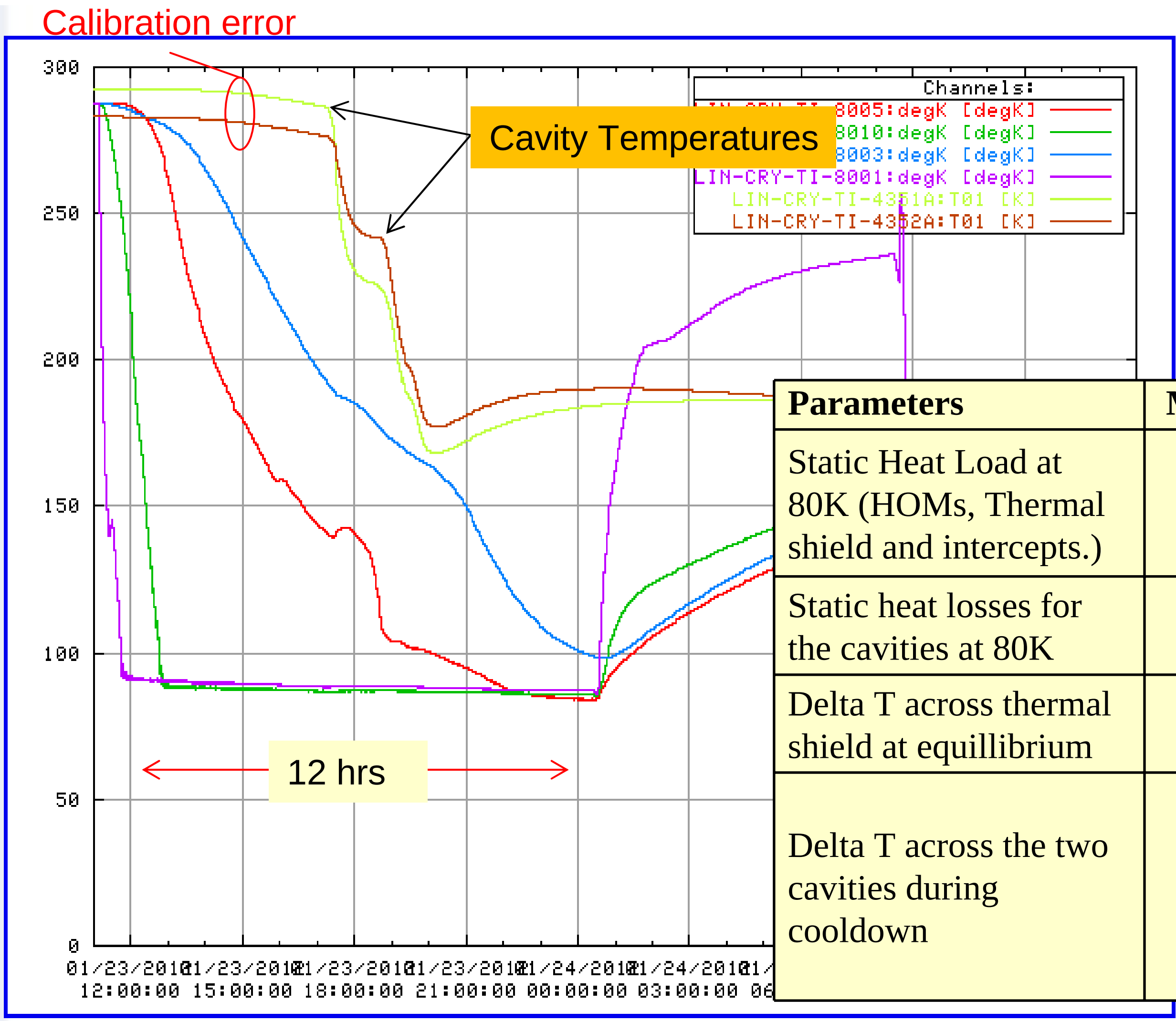
Off-line Cold Tests – with LN2



Parameters	Measured*	Specification
Static Heat Load at 80K (HOMs, Thermal shield and intercepts.)	~ 7 W	20W
Static heat losses for the cavities at 80K	~ 3.5 W	15 W at 4K
Delta T across thermal shield at equillibrium	< 5K	<10K
Delta T across the two cavities during cooldown	< 5K	< 5K Currently 50K to 60K for ALICE

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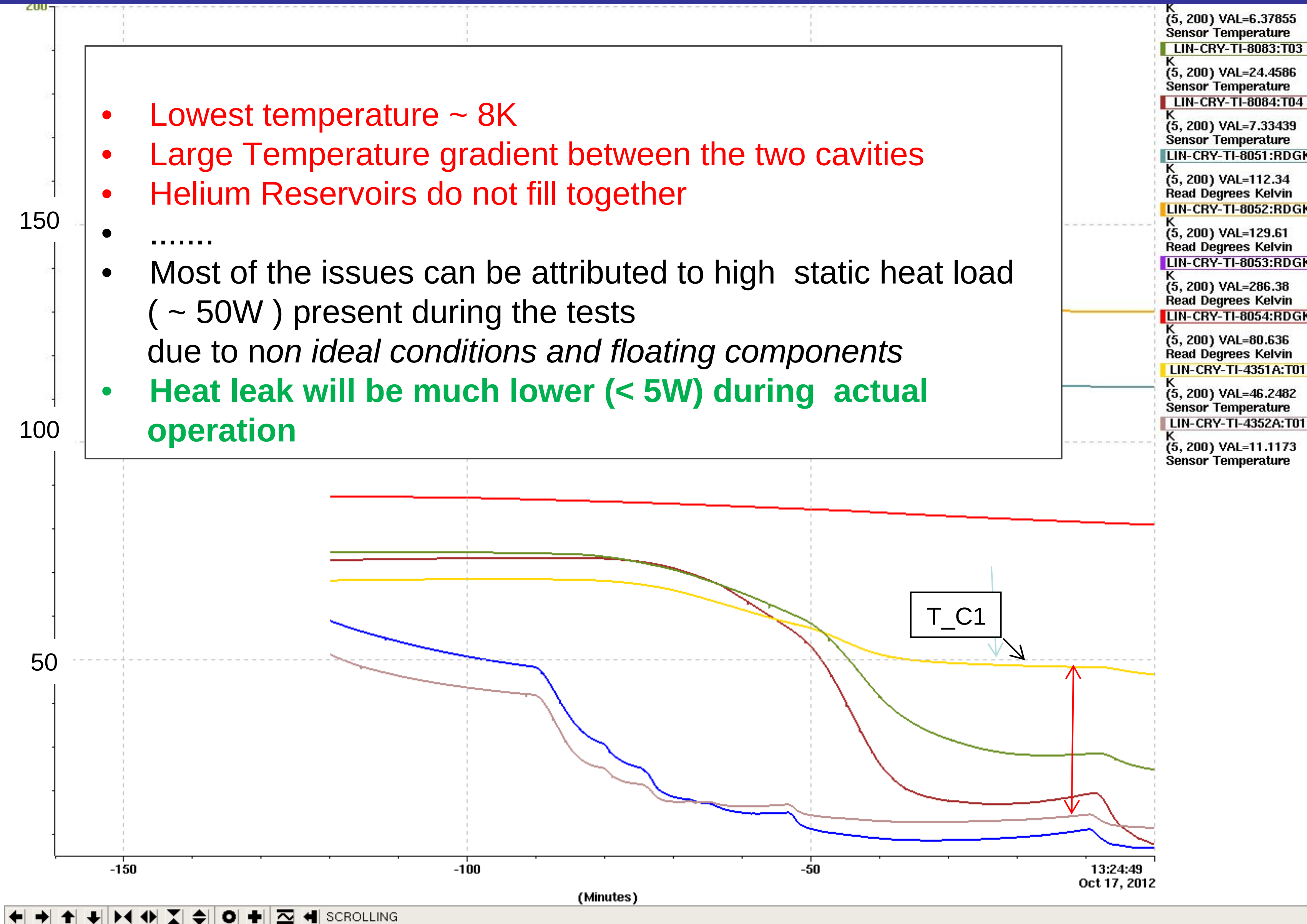
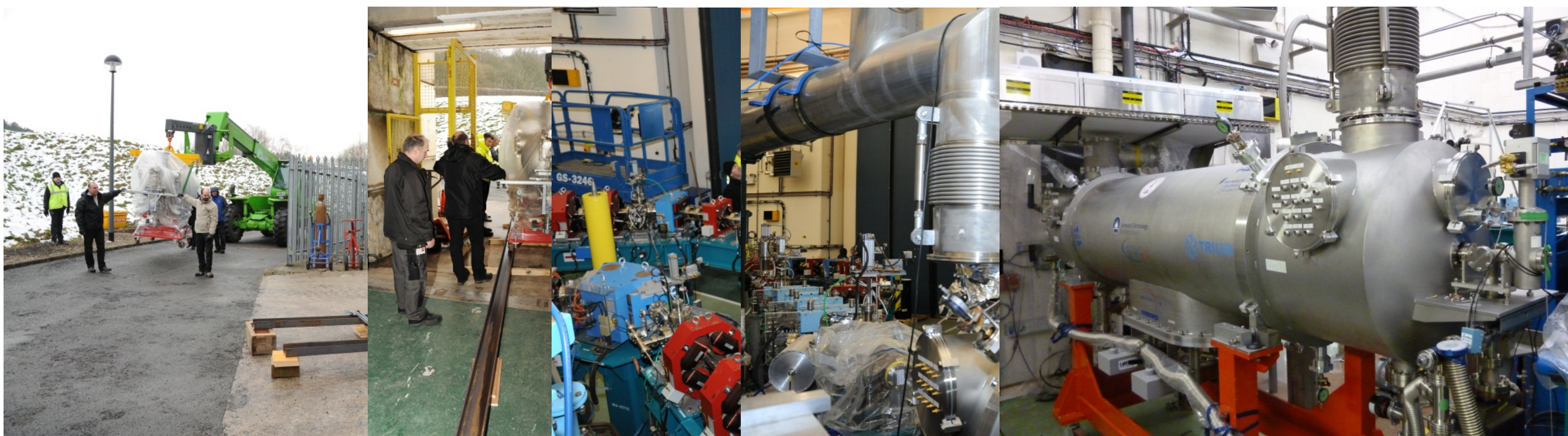
Off-line Cold Tests – with LHe^4

- Lowest temperature ~ 8K
- Large Temperature gradient between the two cavities
- Helium Reservoirs do not fill together
- ....
- Most of the issues can be attributed to high static heat load (~ 50W) present during the tests due to n*on ideal conditions and floating components*
- **Heat leak will be much lower (< 5W) during actual operation**



Integration and Commissioning – Installation on ALICE



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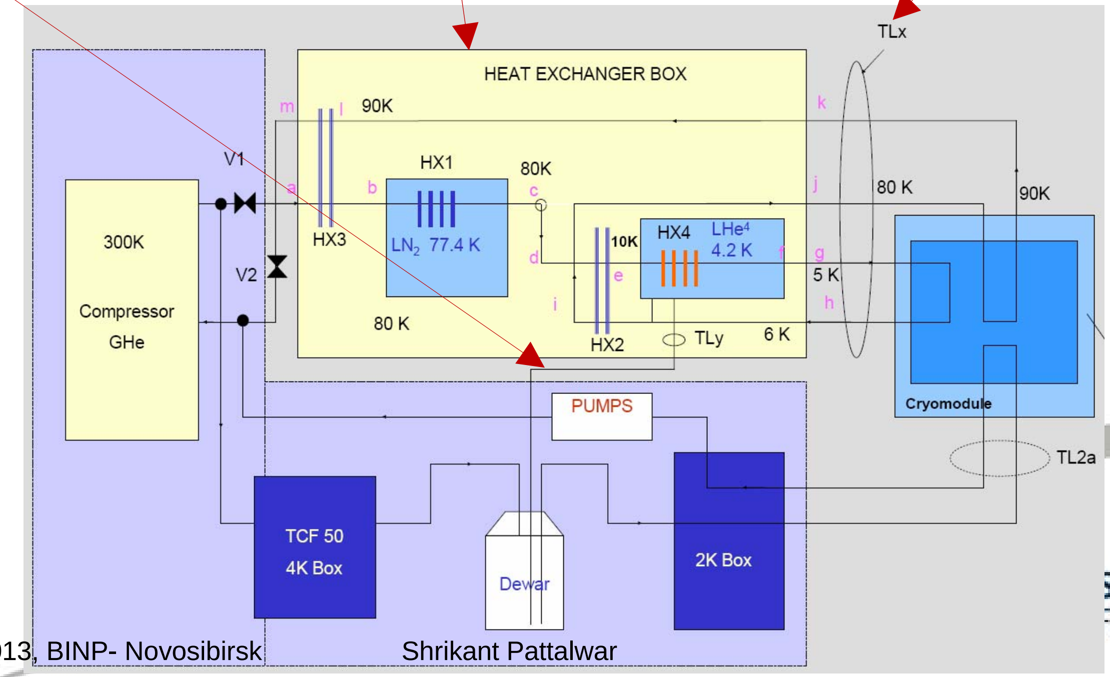
Integration and Commissioning – COOL-IT
(Providing Cooling Power at Intermediate Temperatures)

- Input *He gas at 300 K, maximum 10 bar, 10 g/S*
  LHe at 4 K
- Output He gas at 5 – 6 K, 5 W, ~ 5 bar
  He Gas at 80 – 90 K, 175 W, ~ 5 bar

- Only one control valve for the operation with HOMs as primary cooling load
- Operation fully independent of ALICE Cryo-system (except for LHe and LN2 supply)

- Three main components – Heat Exchanger Box, A compound transfer Line (TLx), and a LHe transfer line (TLy)



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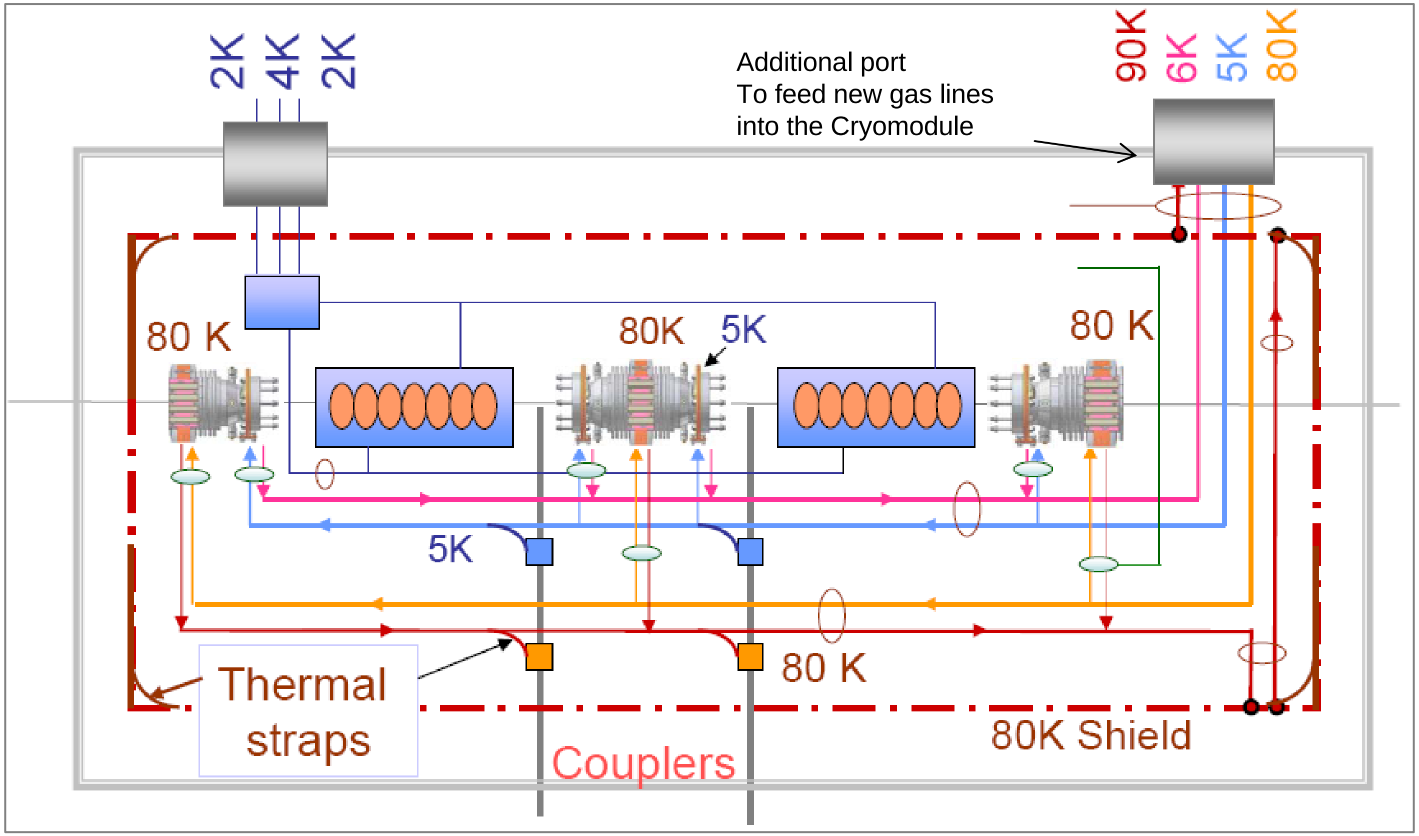
Integration and Commissioning – Cooling Circuits



Two Cooling Circuit in Series -

\>> HOM at 5-6K >> HOMs at 80-90 K >> Shield 90-100 K >>

Coupler Intercepts Cooled by Conduction

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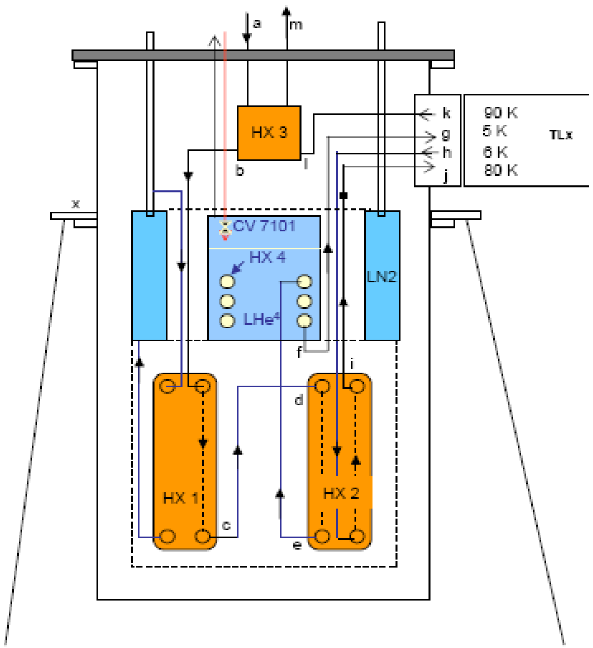
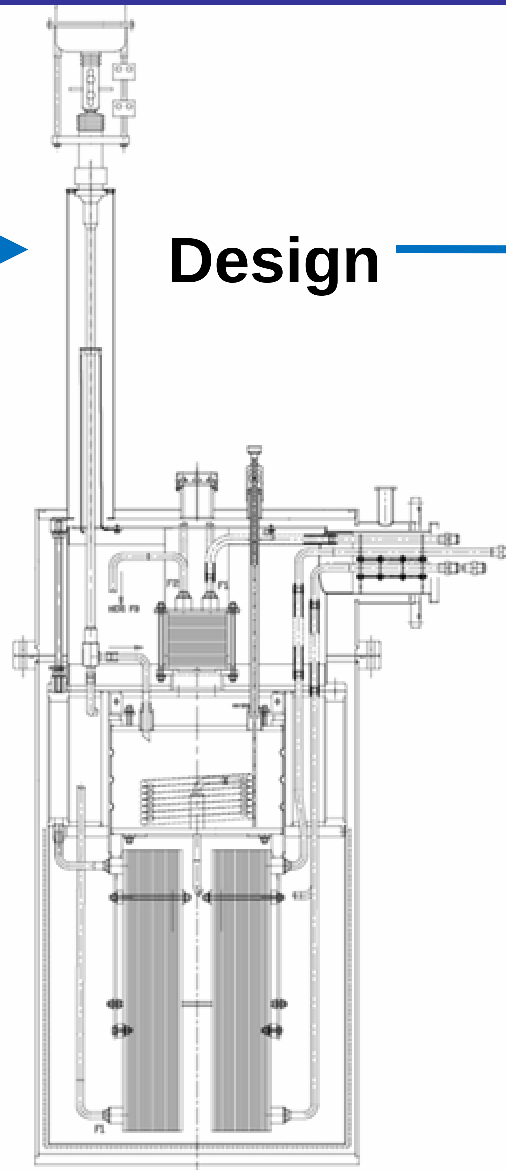
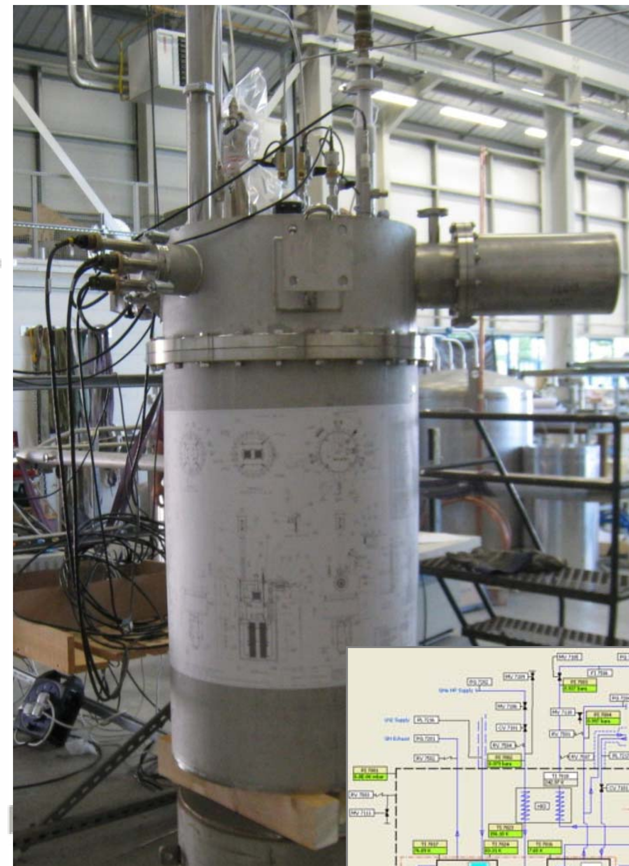
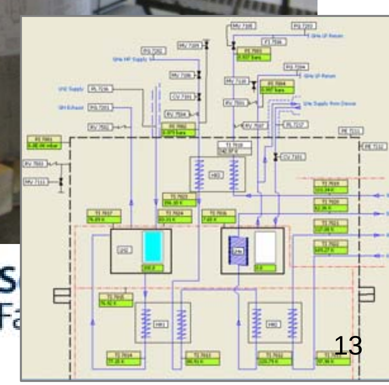
Integration and Commissioning – COOL IT evolution

Concept → **Design** → **Build**

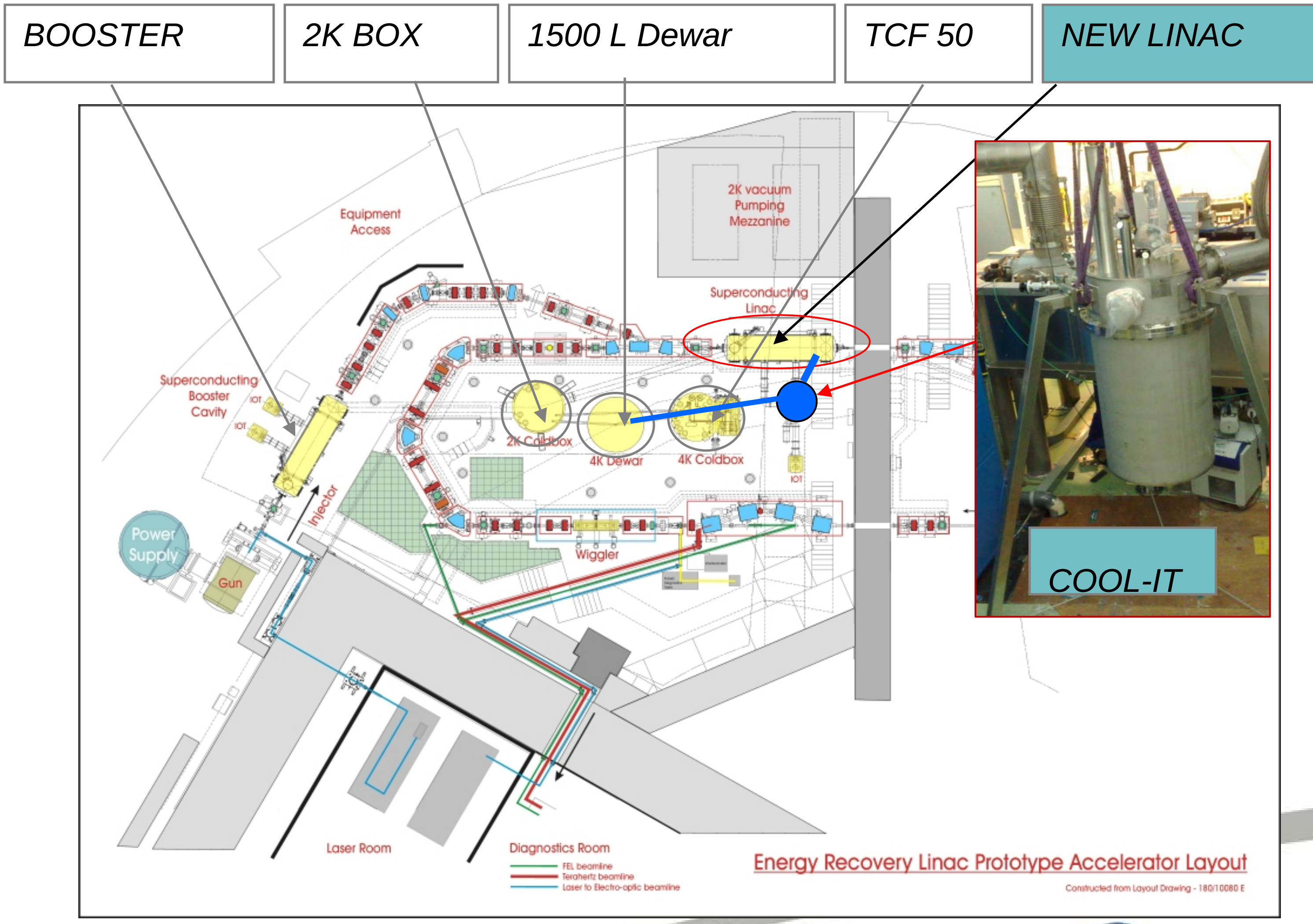








Integration and Commissioning



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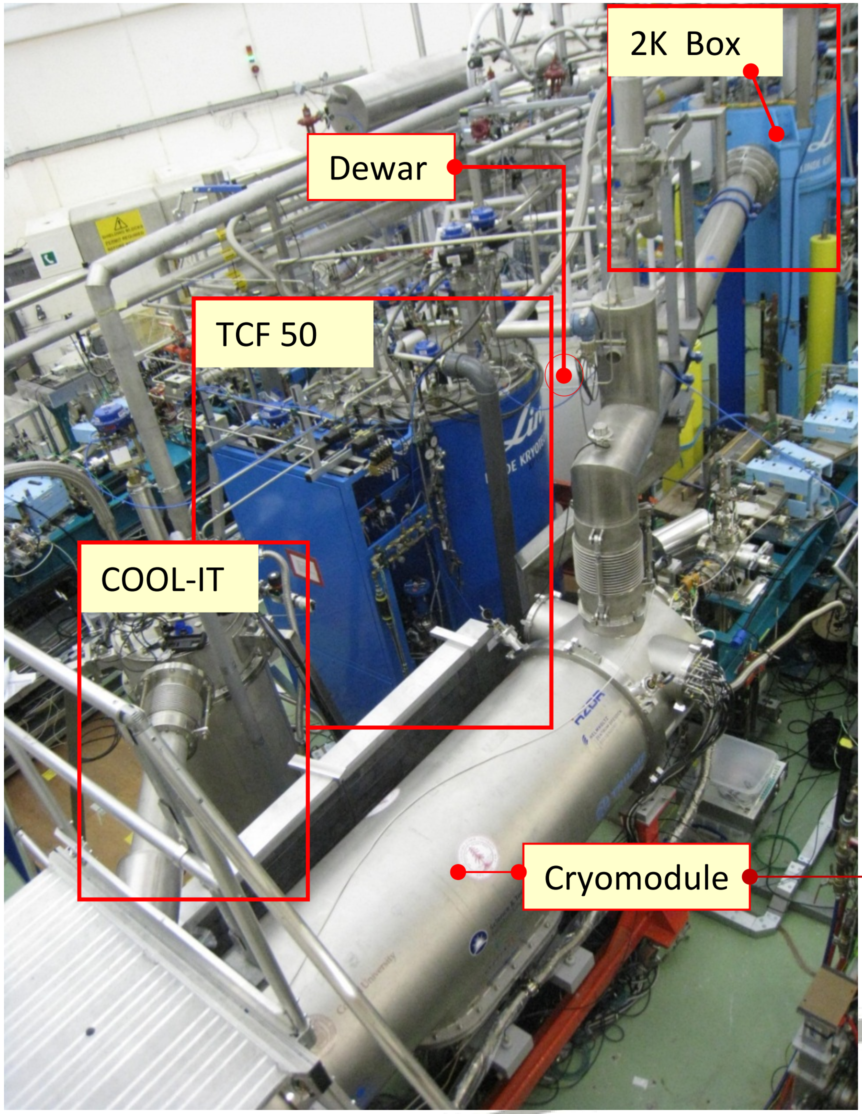
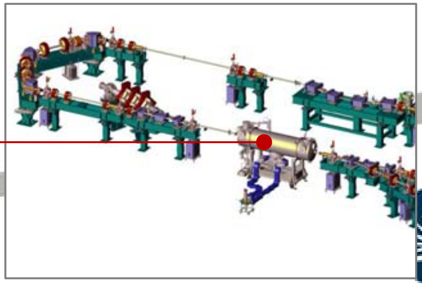
Integration and Commissioning – ALICE Cryogenics



Preliminary cool down

- Cryomodule cooled to 2K
- Static heat load measured at 2K~ 6W
  Similar to previous cryomodule, Spec- 15W
- Base heat load measured at 2K ~ 2.5 g/s
  Similar to previous cryomodule
- Intermediate Temperatures has been achieved with GHe using **COOL-IT**
  Gas pressure ~ 2 barA
- HOMs, coupler intercepts and thermal shield are connected in series
  - *Circuit 1: T_{in} ~ 89K , T_{out} ~ 99K*
  - *Circuit 2: T_{in} ~ 13.5K , T_{out} ~ 15.5K*
- Pressure stability at 2K (30mbar) ±0.05 mbar

➢Further optimisation is in progress



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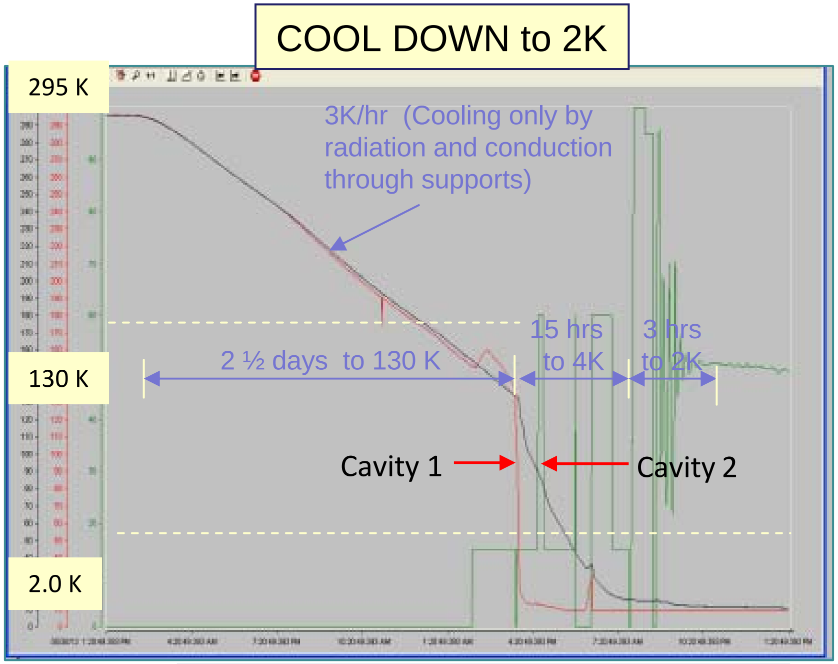
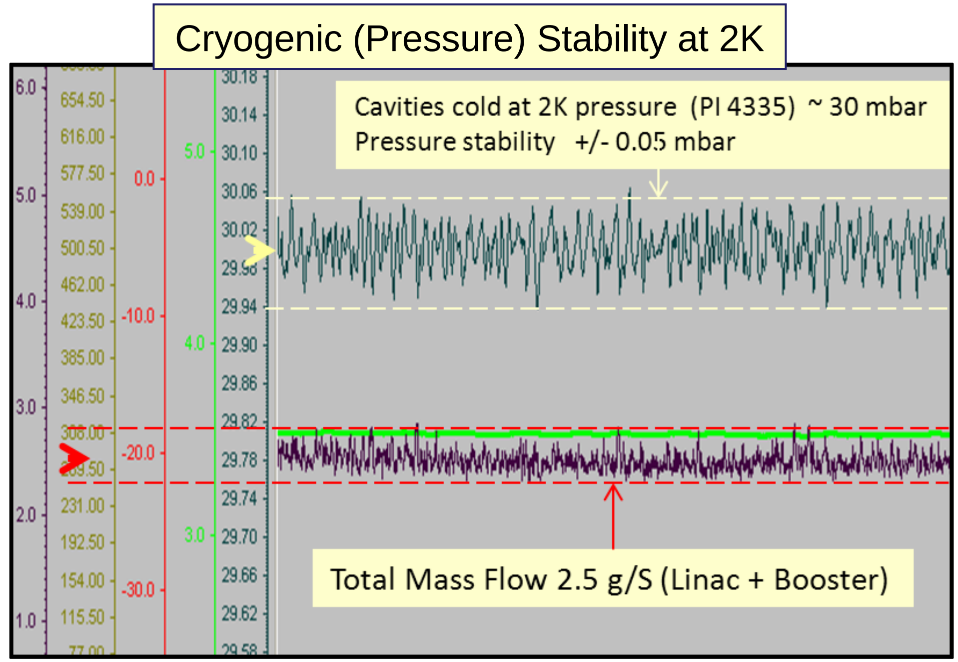
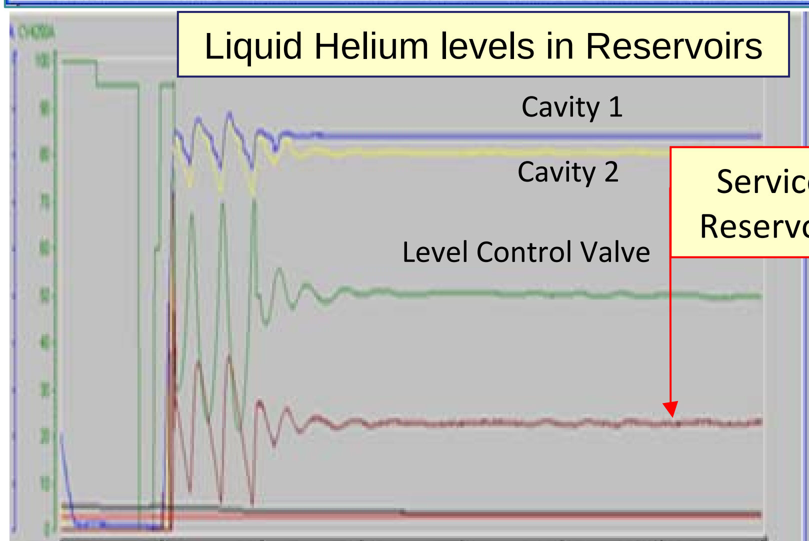
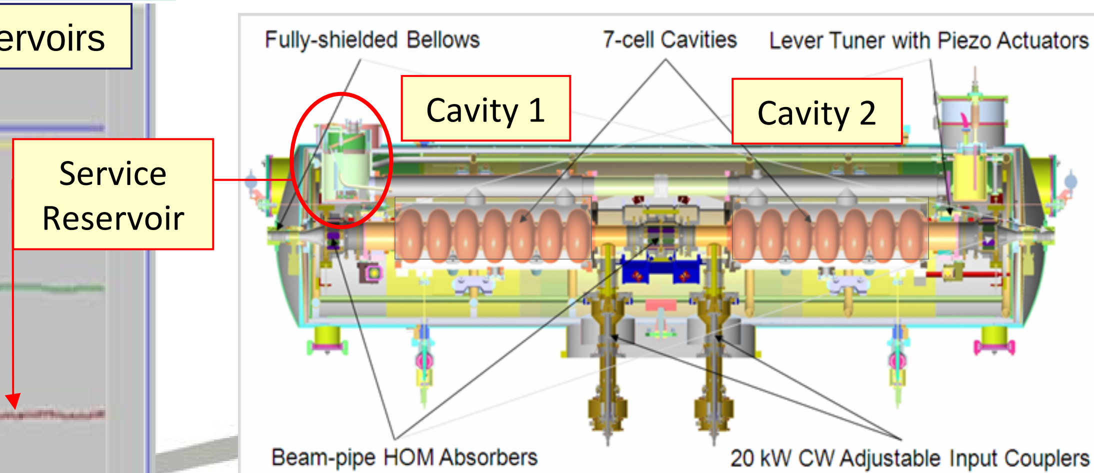
Integration and Commissioning – CM Cryogenic Performance

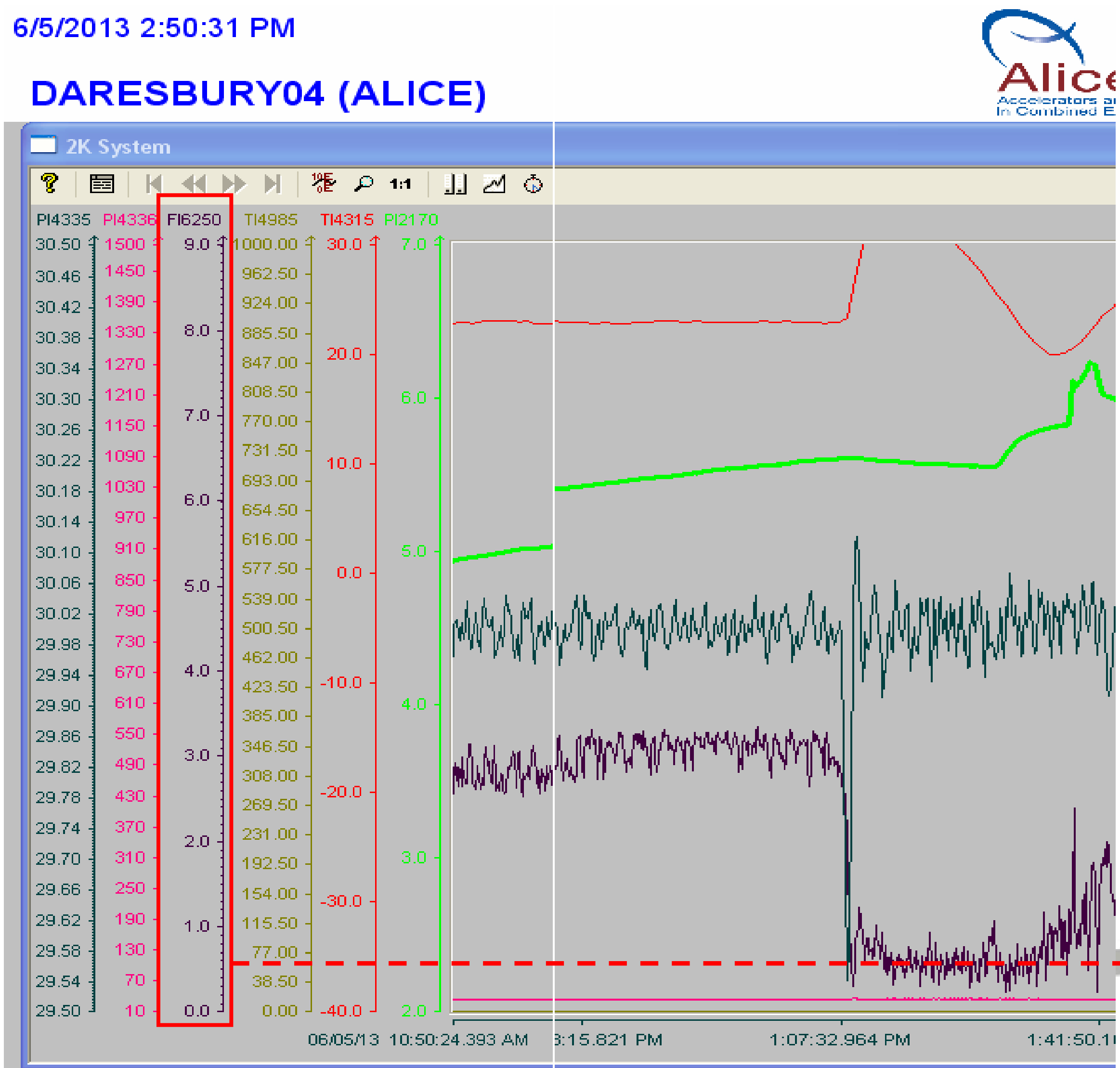








Integration and Commissioning – CM Static Heat Load at 2K



- Static heat load measured with all the input valves closed to ensure that only the boil off from the cryostat is measured
- 0.6 g/S total mass flow Linac + Booster

➪ 0.3 g/S per module

➪ ~6.2 W per cryomodule

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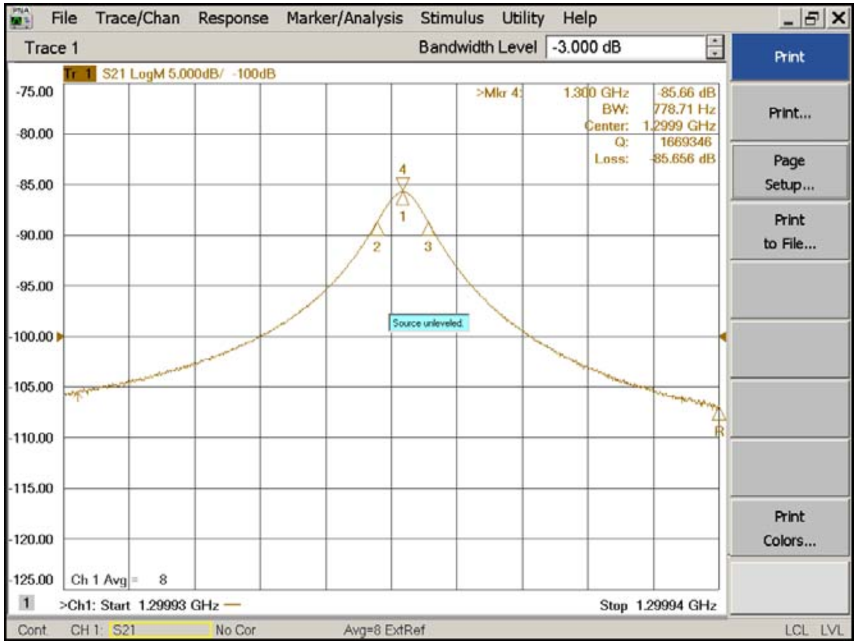
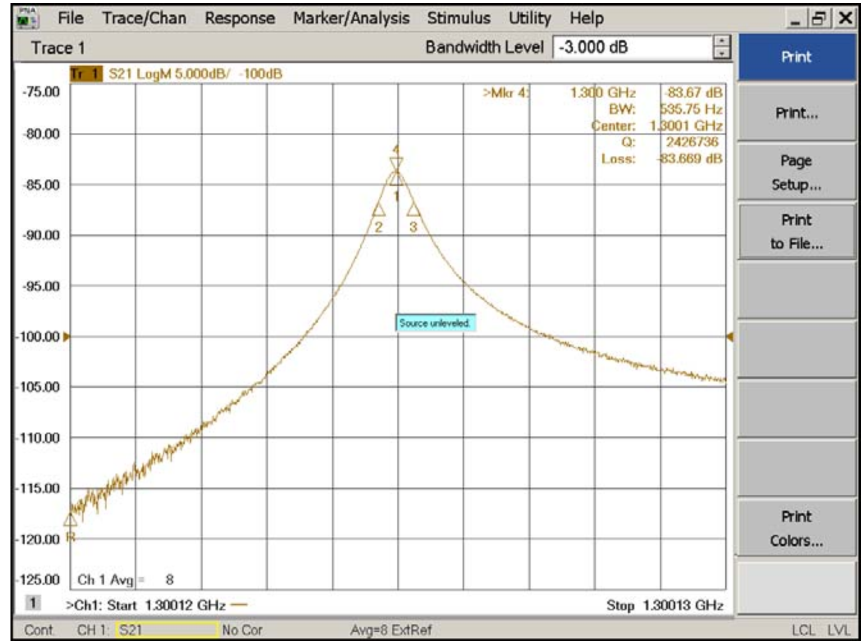
Integration and Commissioning – Cavity Frequency

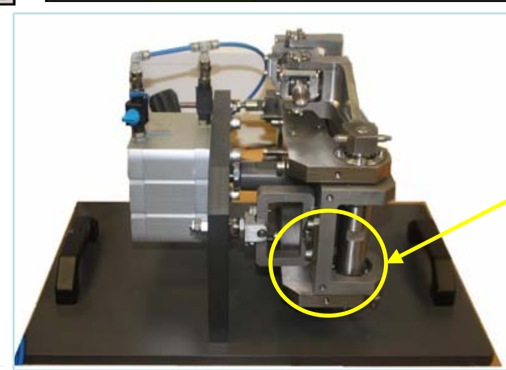
- Linac 1



- Linac 2



- Cavity tuner operation verified
- Tuning achieved
- Tuning range ±350 kHz
- Q_{ext} adjusted
- Full extent of adjustment to be determined



Previous mechanical issue

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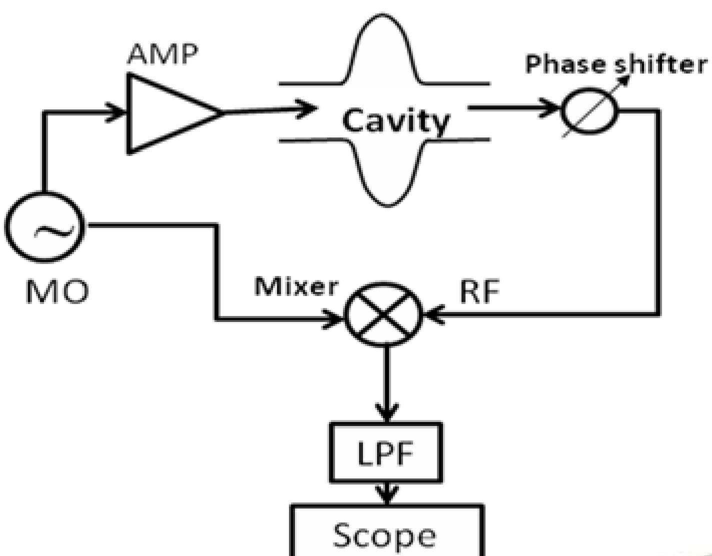
Integration and Commissioning – Microphonic Tests

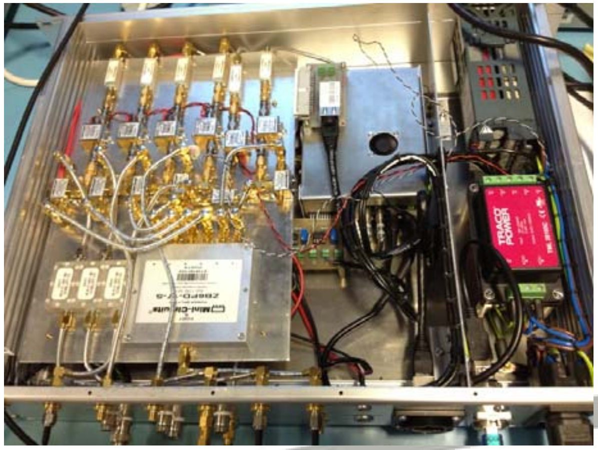
• Original Linac

- The microphonics were tested in CW mode, open loop operation.
- Cavity was driven by signal generator
- A Hittite phase detector was used to measure the phase difference between the cavity probe signal and the system generator signal.



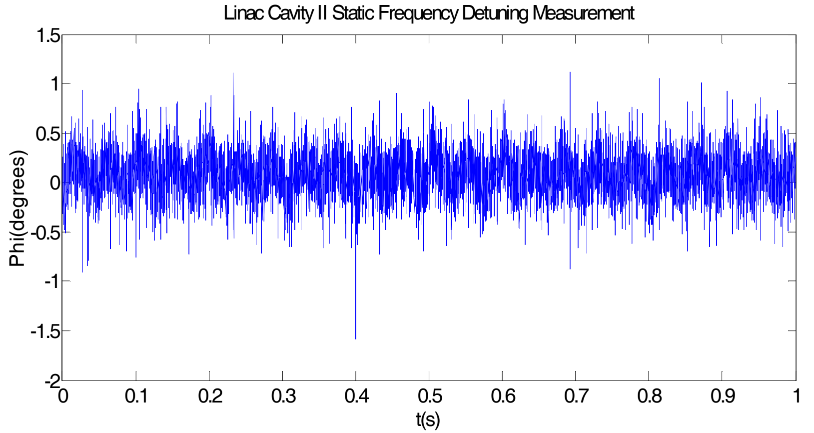
• New ERL Linac

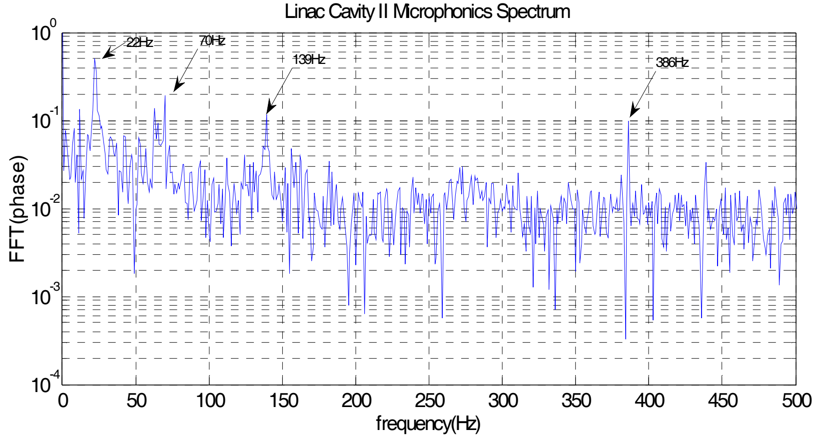
- The new ERL cavities were driven with a CW wave from the digital LLRF system. The cavity probe signal is then mixed with the forward RF signal and filtered by a low pass filter.
- The cavities have been analysed in self excited loop and open loop operations.



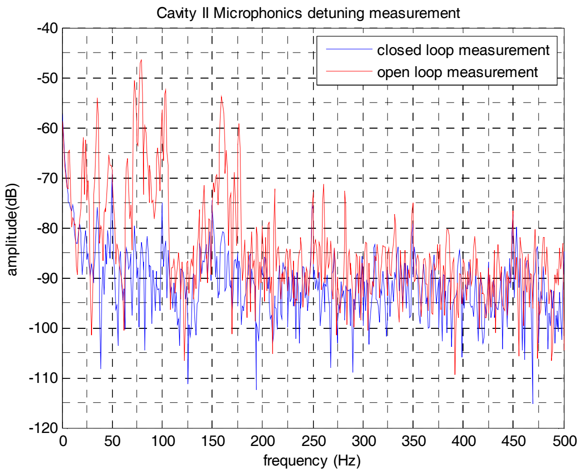
Based on the LLRF4 development board, designed by Larry Doolittle of LBNL

Integration and Commissioning – LINAC Cavity 2





Detuning peaks at 22Hz, 70Hz,63Hz,139Hz,386Hz.



- Open loop operation, strong resonances have been observed at:-
- ⇨ 1Hz, 7Hz , 21.5Hz, 23.5Hz, 35Hz, 48Hz, 68Hz, 71Hz, 78Hz, 82Hz, 98Hz, etc.
- Loop closed, resonances remain at 1Hz, 37.5Hz, 50Hz and its side bands.

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Integration and Commissioning – Cryogenic Performance

Parameter	Unit	Measured Value	Spec	
Base temperature	K	2.0	2.0	
Static heat load	W	6.2	15	Single shot mode at 2K
Static base heat load	g/S	2.5	1.5	With flash gas (additional heat leak from external components)
Pressure stability	mbar	±0.05	±1.0	at 2K
HOM Intercepts	K	13.5 < T < 15.5	< 20	CKT -1 at GHe 2.0 barA
HOM Intercepts	K	89 < T < 99	< 90	CKT -2 at GHe 2.0 barA
Shield	K	89 < T < 99	< 90	CKT -2 at GHe 2.0 barA
Cavity Frequency	GHz	1.3	1.3	
Tuning range	KHz	±350		
Dynamic performance to be measured				
Static performance similar to ALICE LINAC				

Integration and Commissioning – Status

Held up due to major blockage in helium liquefier (TCF 50).

Operation expected to resume in mid October

Integration and Commissioning – Future Plan

Evaluation Programme:-

- Establish gradient and Q_0
- Measure Lorentz force detuning at high gradient
- Performance measurements with piezo tuners
- Determine DLLRF control limitations wrt Q_{ext}
- Evaluate the effect of beam loading with DLLRF, piezo control for various Q_{ext} levels under pulsed and CW conditions
- Characterise cavities in CW mode at high gradient:
  – Evaluate thermal transients across cavity string and 2-phase line

Cryomodule installed on ALICE

Thank You

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