Radioactive Ion Beam Post-Acceleration at CERN-ISOLDE

Y. Kadi
for the HIE-ISOLDE Project Team

Outline

- **Introduction**
  - CERN-ISOLDE Facility
  - HIE-ISOLDE Upgrade
- **HIE-ISOLDE Phase 1**
  - Commissioning and operation in 2016
- **HIE-ISOLDE Phase 2**
  - Installation and commissioning activities
  - 2017 Operations
- **Summary & Outlook**

ISOLDE Facility

- ISOLDE is the CERN radioactive ion beam facility
- Oldest experiment at CERN (approved > 50 y ago)
- Provides low energy and **post-accelerated beams**
- Run by an **international collaboration since 1965**


Belgium

CERN


Denmark


Finland


France


Germany


Greece


Italy


India


Ireland


Norway


Poland


Romania


Spain


South Africa


Sweden

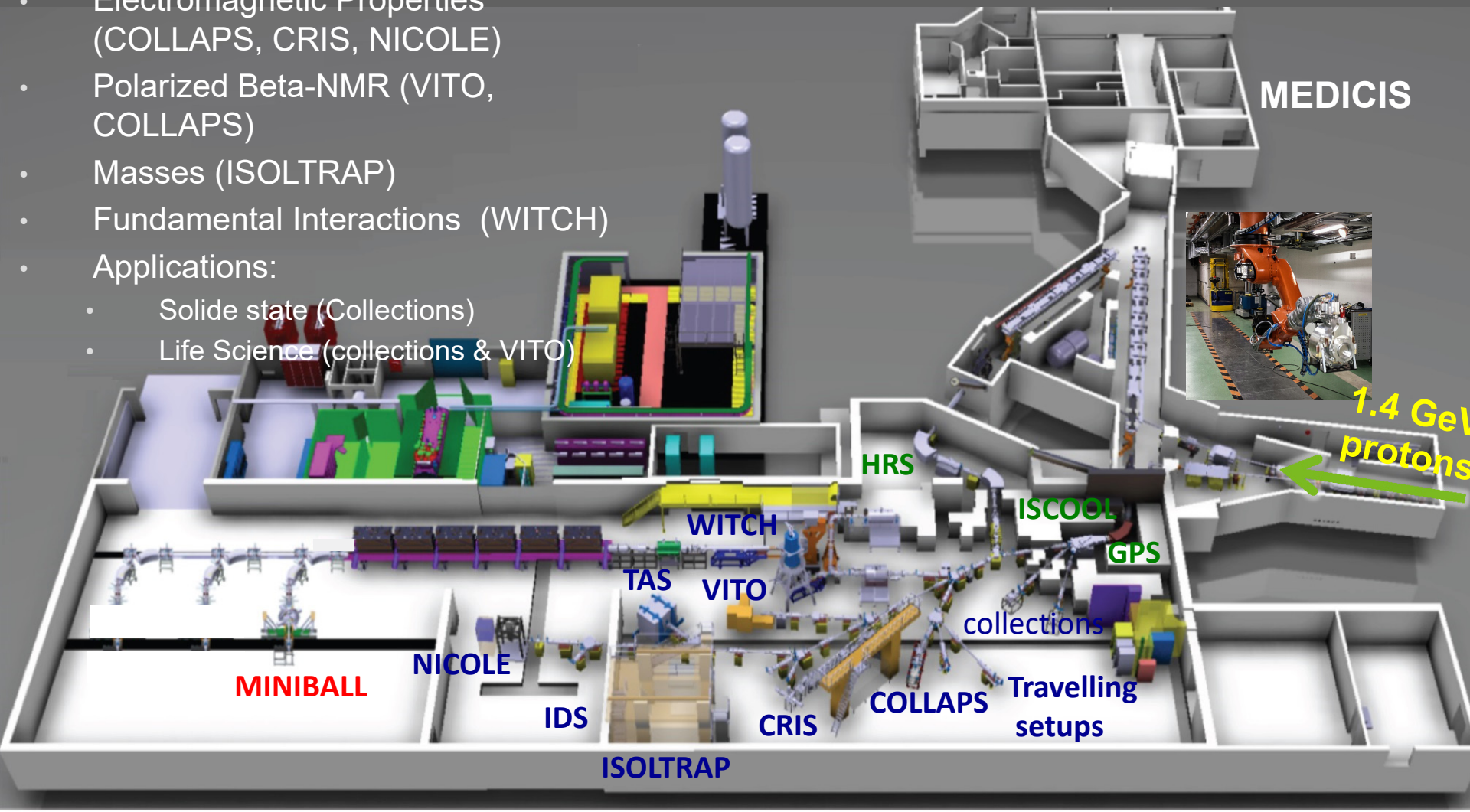

Slovakia


United Kingdom

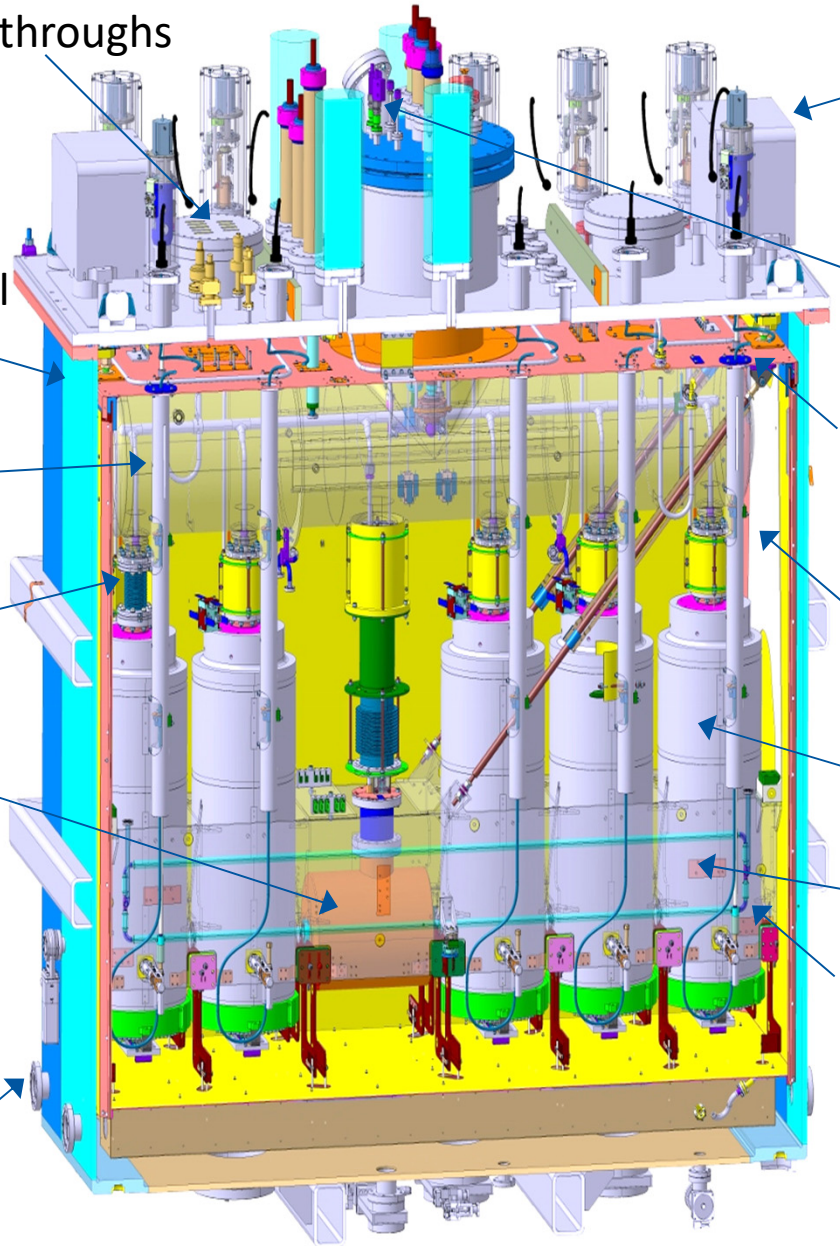
- **> 500 Users from 100 Institutions, 50 experiments / year**

- Decay spectroscopy (IDS, TAS,..)
- Coulomb excitation (MINIBALL)
- Transfer reactions (T-REX, Scattering)
- Electromagnetic Properties (COLLAPS, CRIS, NICOLE)
- Polarized Beta-NMR (VITO, COLLAPS)
- Masses (ISOLTRAP)
- Fundamental Interactions (WITCH)
- Applications:
  - Solide state (Collections)
  - Life Science (collections & VITO)

ISOLDE



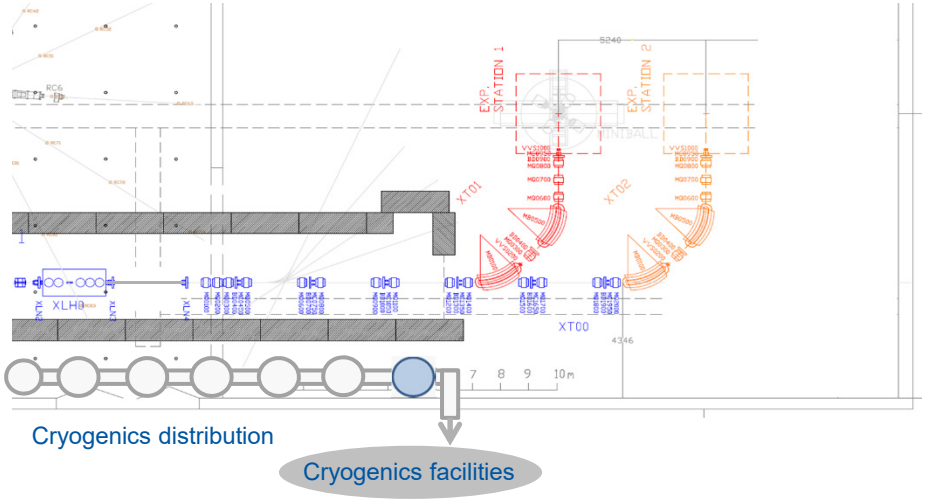
Low Energy (30-60kV) Exps, Post-accelerated Exps (10 MeV/u) Machine elements

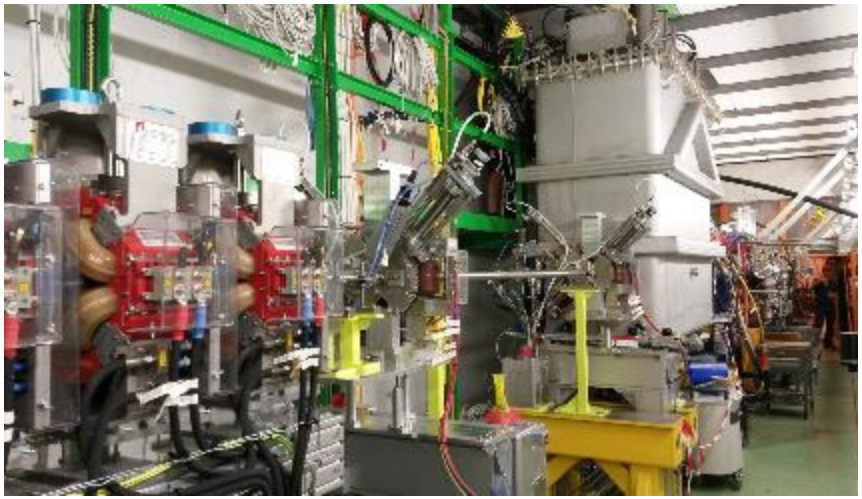

Electrical feedthroughs
Adjusters
Vacuum vessel
Current leads
Helium vessel
Ni-plated thermal shield
Bellows
Mechanical structure
Solenoid
Cavities
Instrumentation
Supporting frame
Viewports

HIE-ISOLDE Cryomodule # 1

- Late August 2014: Assembly start
- Assembly time of CM1: 30 weeks
  Baseline : 27 weeks
- 1 May 2015: Assembly completed
- Mid-June 2015: Successfully cooled to 4.5K

2015 Commissioning Campaign





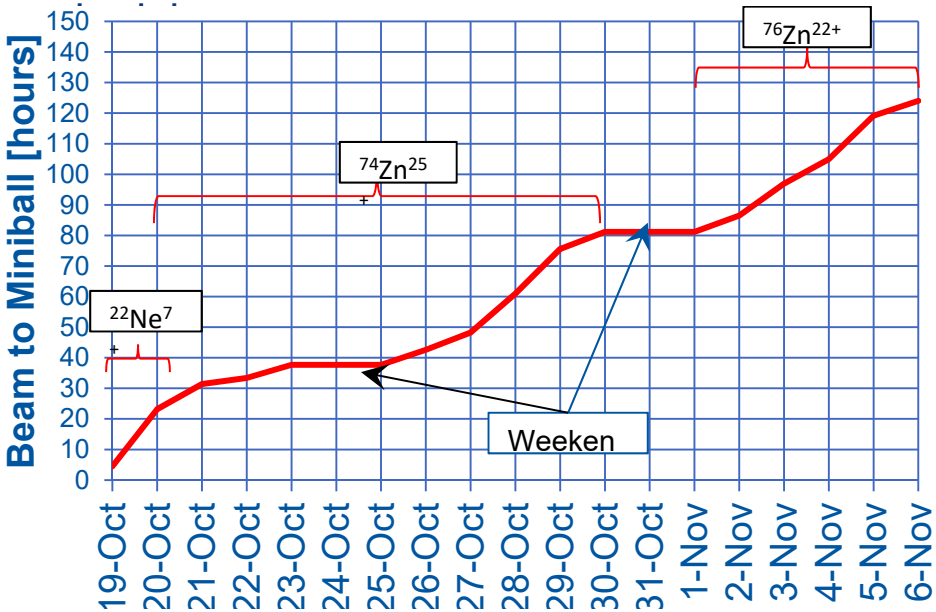
The 2015 Commissioning campaign achieved its goals

CM design choices validated

SC cavities performance were confirmed with beam

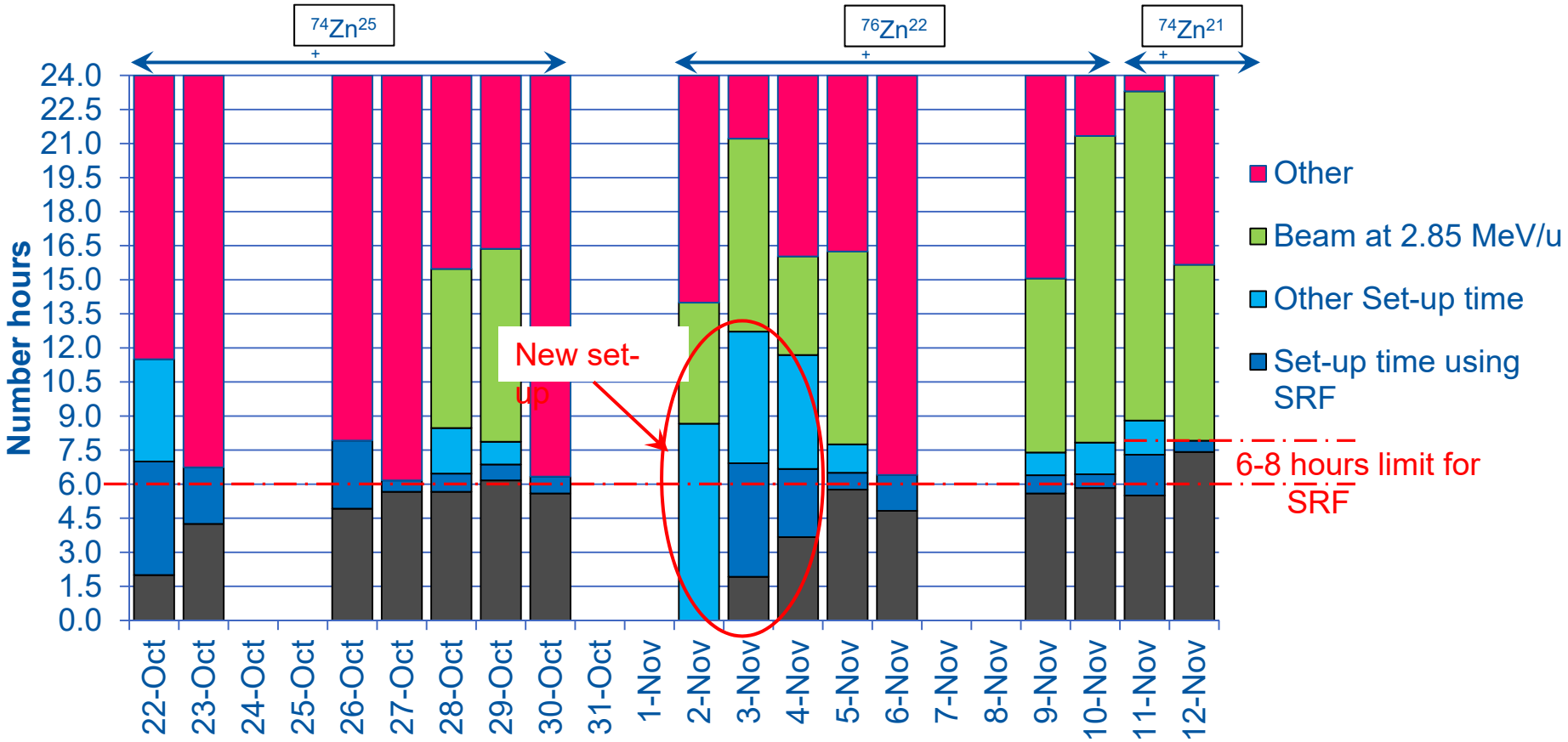
RF coupler problem identified (overheating)

Physics run started on 19th October, on



2015 Operations

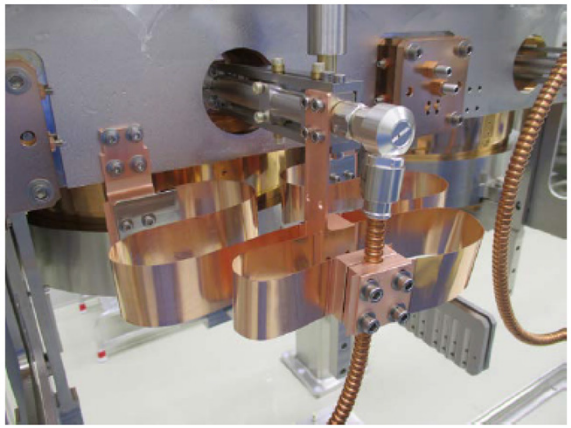
- SRF limited to running ~ 6 - 8 hours per working day due to heating problem in couplers
- Typically: SRF on during the day, REX energy during the evenings and nights
- Approximately 2.5 days needed for a non-scalable new A/Q set-up of the machine

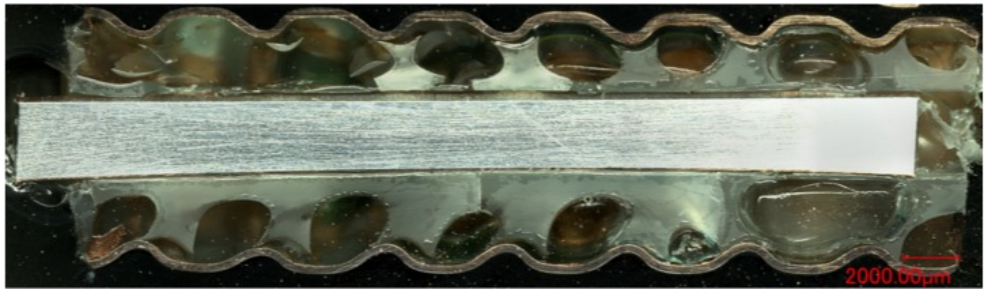


RF Coupler Heating

RF short preventing further cavity loading

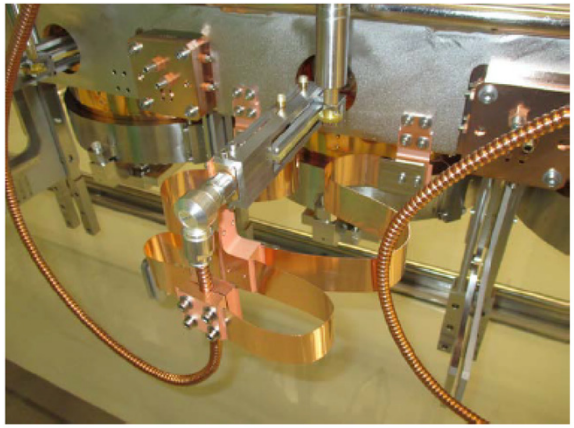
Coupler fully IN





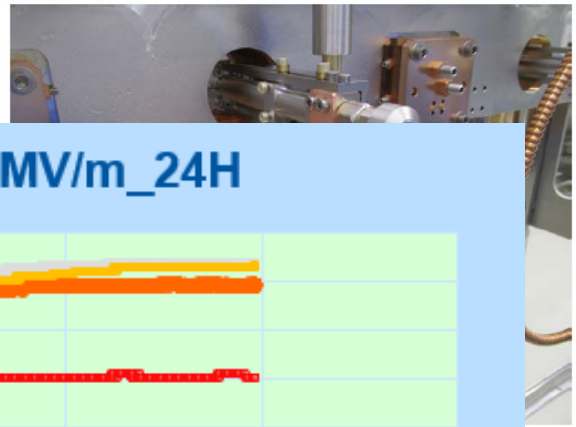
RF cable insulation melt and polymerized

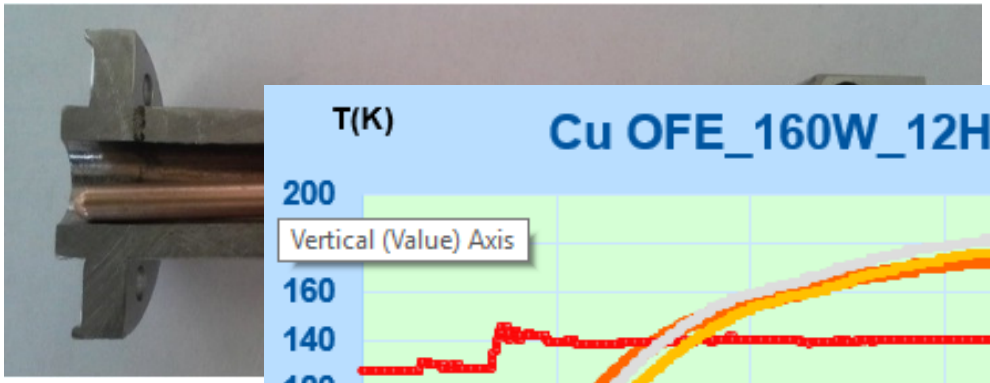
Coupler fully OUT



RF Coupler Heating

Coupler fully IN

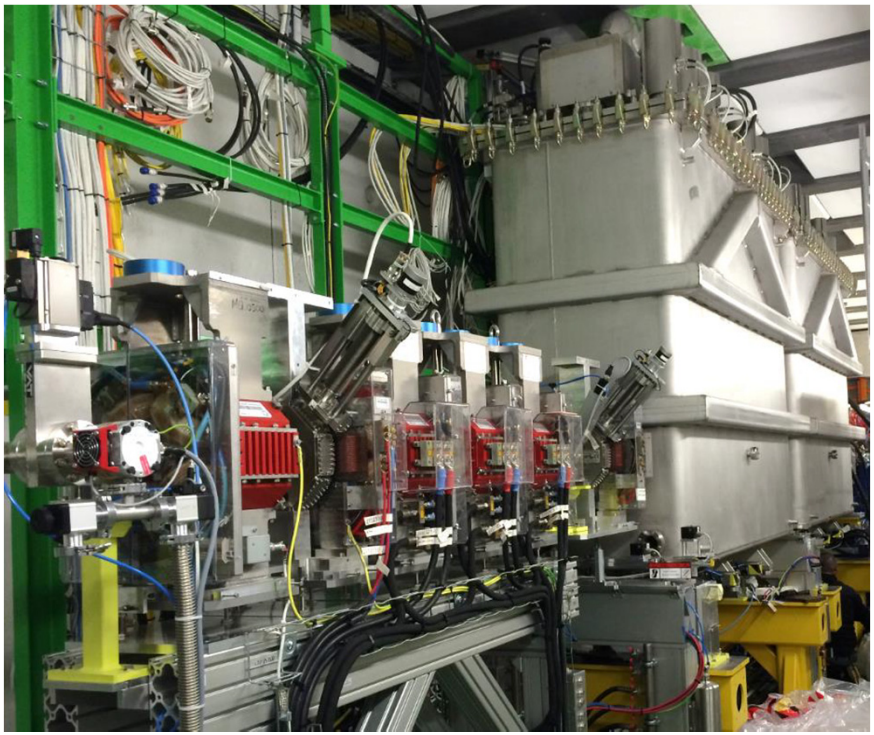


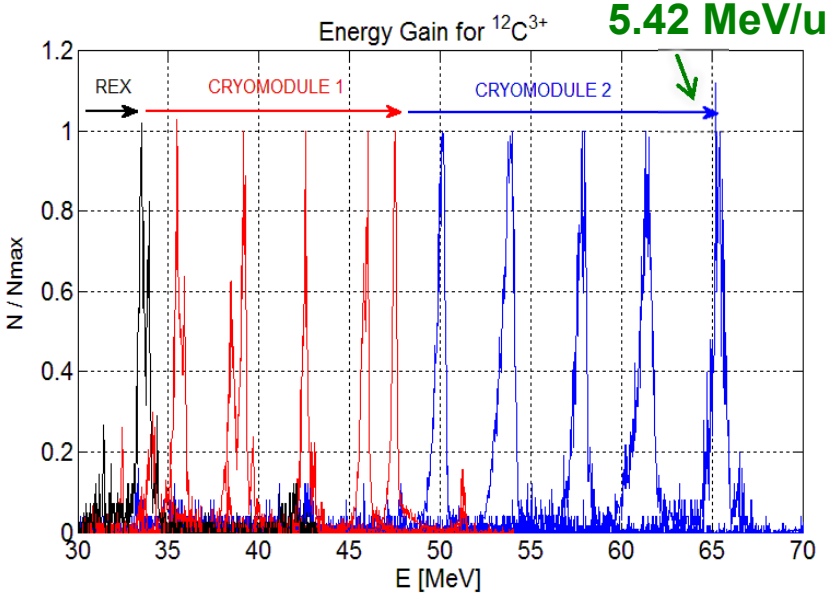


RF short pr

RF cable insulation melt and polymerized

Phase 1: Commissioning & Operation (2016)

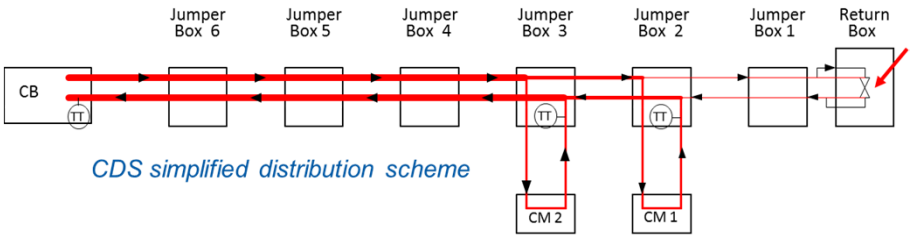




Experiment	Isotope	HEBT	Destination	Energy [MeV/u]	Shifts
IS-562	^{110}Sn	XT01	Miniball Spectrometer	4.5	12
	^{108}Sn			4.5	12
IS-548	^{142}Xe	XT01	Miniball Spectrometer	4.5	30
IS-557	^{80}Zn	XT01	Miniball Spectrometer	4.0	12
	^{78}Zn			4.0	12
IS-551	^{132}Sn	XT01	Miniball Spectrometer	5.5	18
IS-561	^{9}Li	XT02	Scattering Chamber	6.9 (7.2 req.)	15
IS-559	^{66}Ni	XT01	Miniball Spectrometer	5.5	24

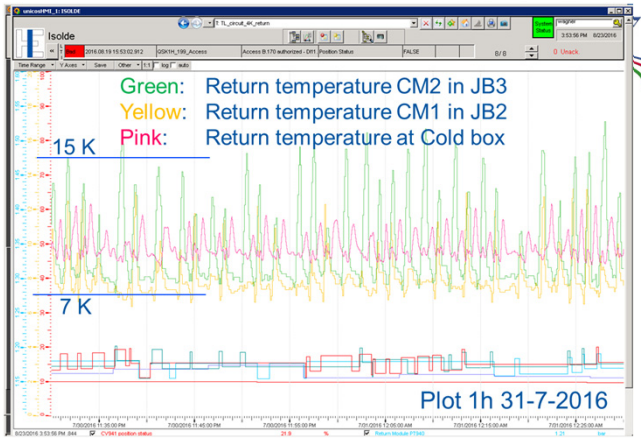
Commissioning and operation : 2016

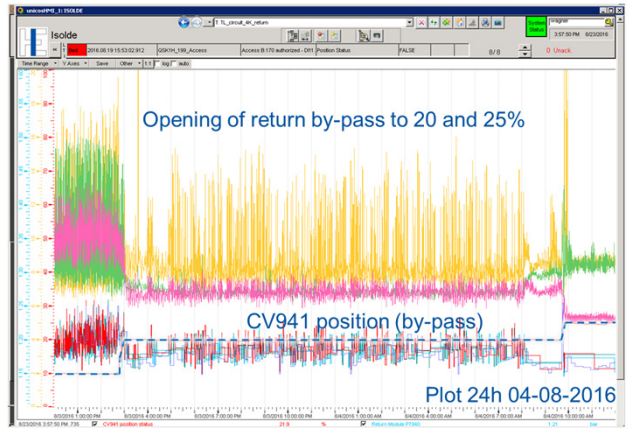
- Cool down and commissioning of CM1+CM2 hardly performed during summer 2016
- Major issues identified : CP flow limitation, bad LHe “quality” supply, and strong oscillations in the 4.5K return line (-> indications of high heat load estimated to 3 x the expected figure)
- Operational conditions found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

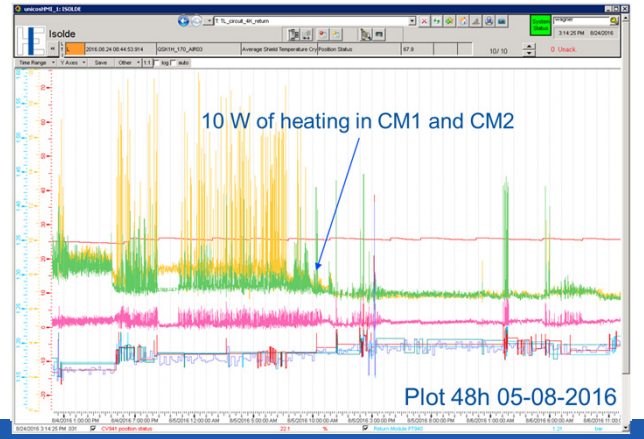


CDS simplified distribution scheme

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

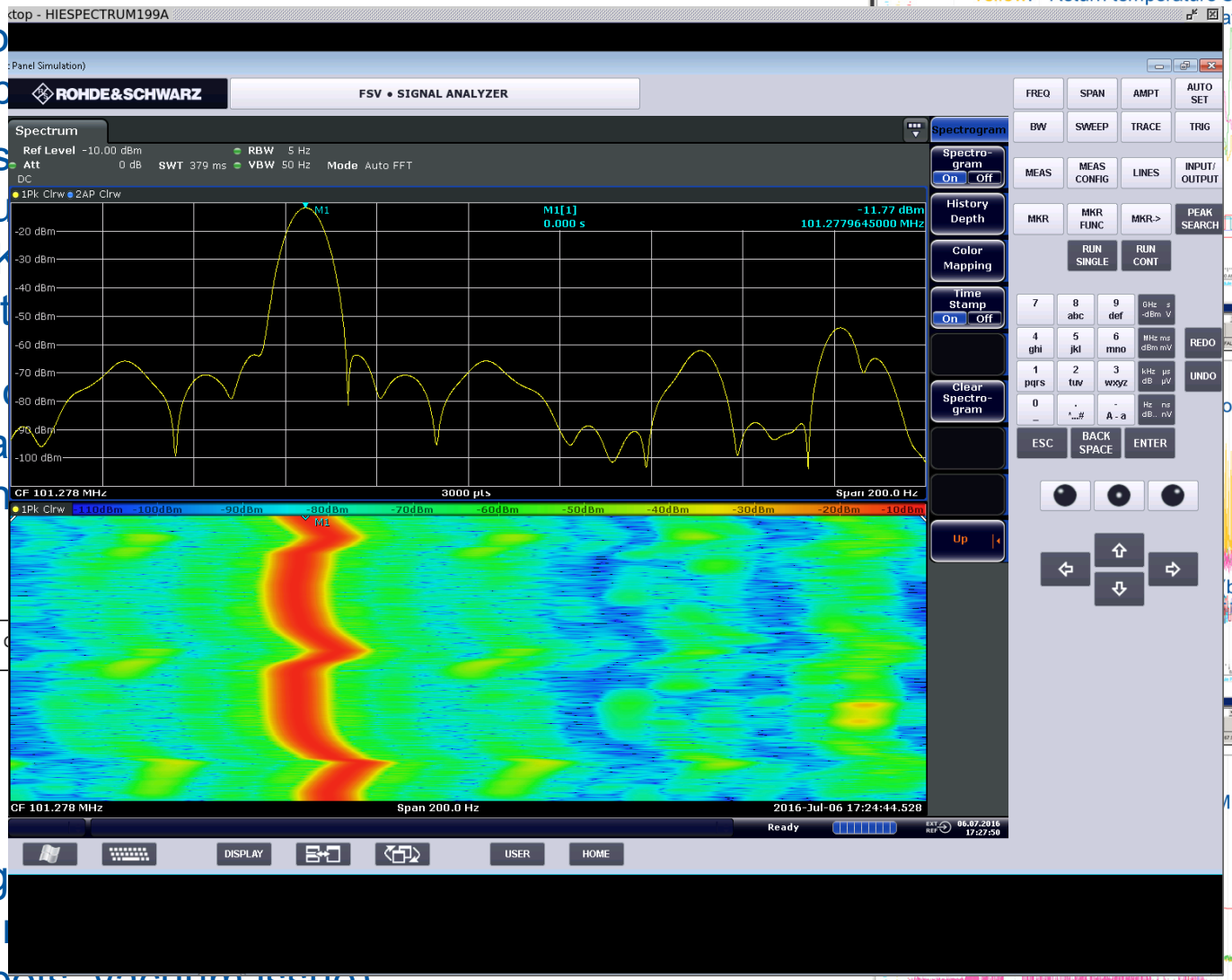






Commissioning and operation : 2016

- Cool do
  hardly p
- Major is
  LHe “qu
  the 4.5k
  load est
- Operati
  pass va
  powerin
- Investig
  (CDS) i
  (cold spots, vacuum issue)



2016 Physics Campaign

IS557: Coulomb excitation ^{74}Zn - ^{80}Zn (N=50): probing the validity of shell-model descriptions around ^{78}Ni

RF structure	REX				HIE
	7GP1	7GP2	7GP3	9GP	SRF02
# Trips	1	1	17	Not stable during the last day of the experiment	2
Downtime [mins]	15	15	255		10
Downtime [%]	0.2%	0.2%	3.2%		0.1%

Beam transmission/efficiency (approx.)		
Low energy	REX-TRAP + EBIS	REX/HIE linac
88 %	13 %	68 %

Experiment #	IS557
RIB (A/q)	$^{78}Zn^{20+}$ (3.9)
Energy [MeV/u]	4.3
Target	GPS
Exp. Station	Miniball Spect.
Start date	Oct. 10th (18:00)
End date	Oct. 17th (04:30)
Length [hours]	130
Pilot beam (A/q)	$^{39}K^{10+}$ (3.9)
Target type	UC2
EBIS breeding time [ms]	75

2016 Physics Campaign

IS551: Coulomb excitation of doubly magic ^{132}Sn with MINIBALL at HIE-ISOLDE

RF structure	REX		HIE	
	7GP1	7GP3	SRF02	SRF03
# Trips	30	9	22	53
Downtime [mins]	450	135	110	265
Downtime [%]	5.8%	1.7%	1.4%	3.3%

Beam transmission/efficiency (approx.)		
Low energy	REX-TRAP + EBIS	REX/HIE linac
-	10.5 %	68 %

Experiment #	IS551
RIB (A/q)	$^{132}Sn^{31+}$ (4.26)
Energy [MeV/u]	5.5
Target	HRS
Exp. Station	Miniball Spect.
Start date	Oct. 19th (19:50)
End date	Oct. 26th (08:20)
Length [hours]	130
Pilot beam (A/q)	$^{39}K^{9+}$ (4.33)
Target type	UC2
EBIS breeding time [ms]	194

2016 Physics Campaign

IS561: Transfer reactions at the neutron dripline with triton target

RF structure	REX		HIE			
	7GP1	7GP3	SRF02	SRF04	SRF07	SRF10
# Trips	14	3	7	1	32	1
Downtime [mins]	210	45	35	5	160	5
Downtime [%]	4.7%	1.0%	0.8%	0.1%	3.6%	0.1%

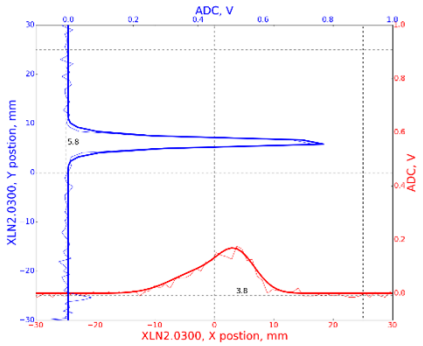
Beam transmission/efficiency (approx.)		
Low energy	REX-TRAP + EBIS	REX/HIE linac
81 %	4 %	75 %

Experiment #	IS561
RIB (A/q)	$^{9}Li^{3+}$ (3.0)
Energy [MeV/u]	6.8 (7.2 req.)
Target	GPS
Exp. Station	Scattering Chamber
Start date	Oct. 28th (22:20)
End date	Nov. 1st (8:30)
Length [hours]	70
Pilot beam (A/q)	$^{12}C^{4+}$ (3.0)
Target type	UC
EBIS breeding time [ms]	21

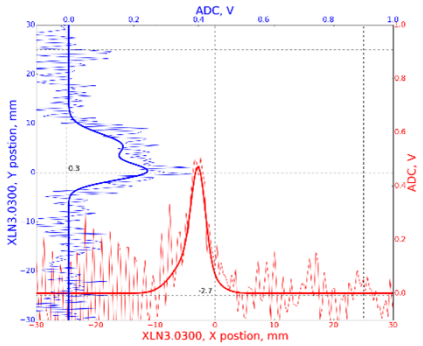
2016 Beam Commissioning

- Beam transverse profiles were measured at different locations
- Comparison w.r.t. optics model were postponed to 2017 => could not optimize beam transmission

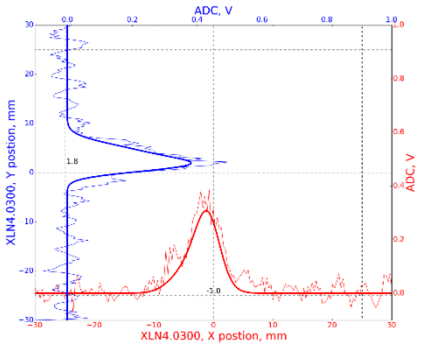
XLN2.0300



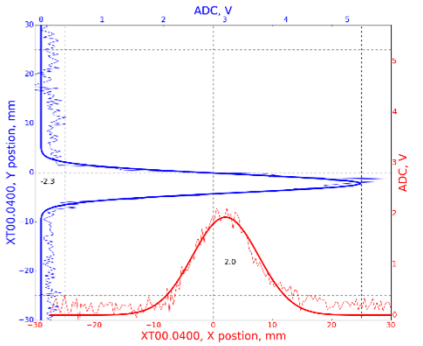
XLN3.0300



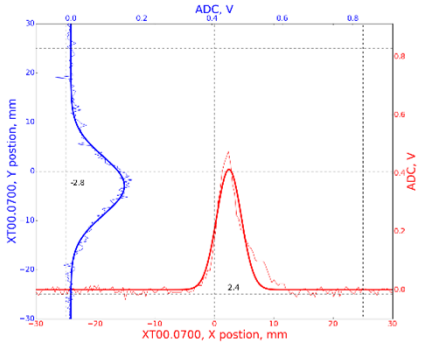
XLN4.0300



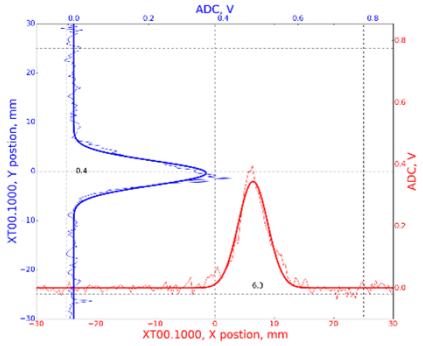
XT00.0400



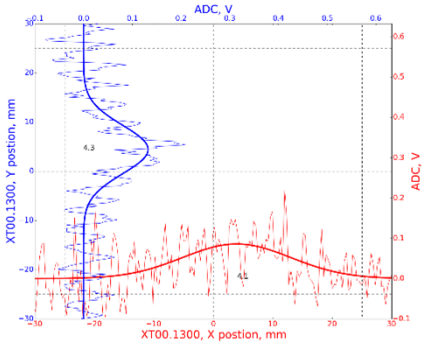
XT00.0700



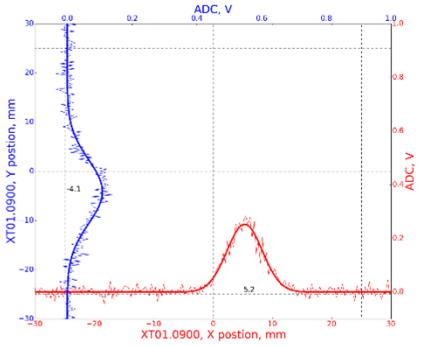
XT00.1000



XT00.1300



XT01.0900

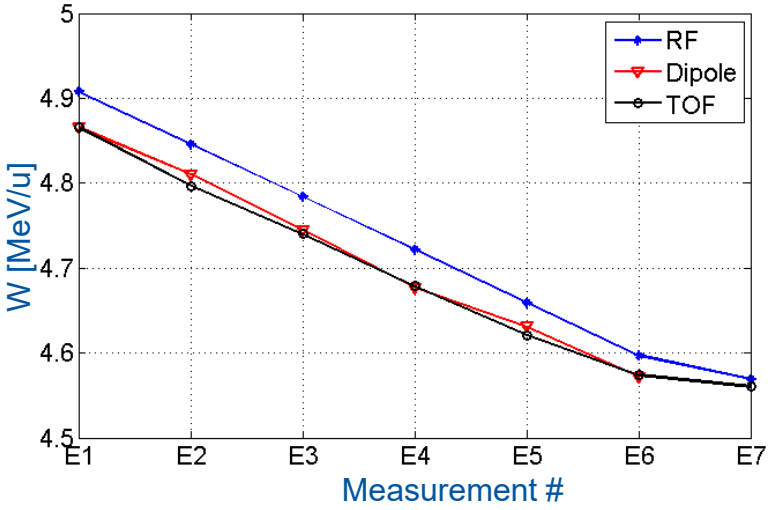


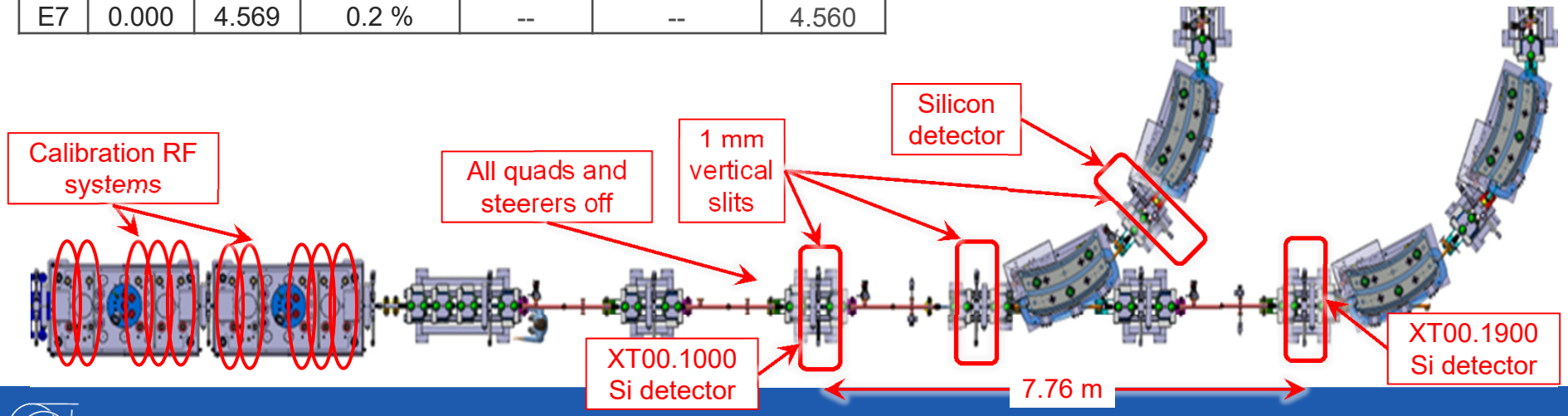
2016 Beam Commissioning

The energy of the beam was measured using three independent methods :

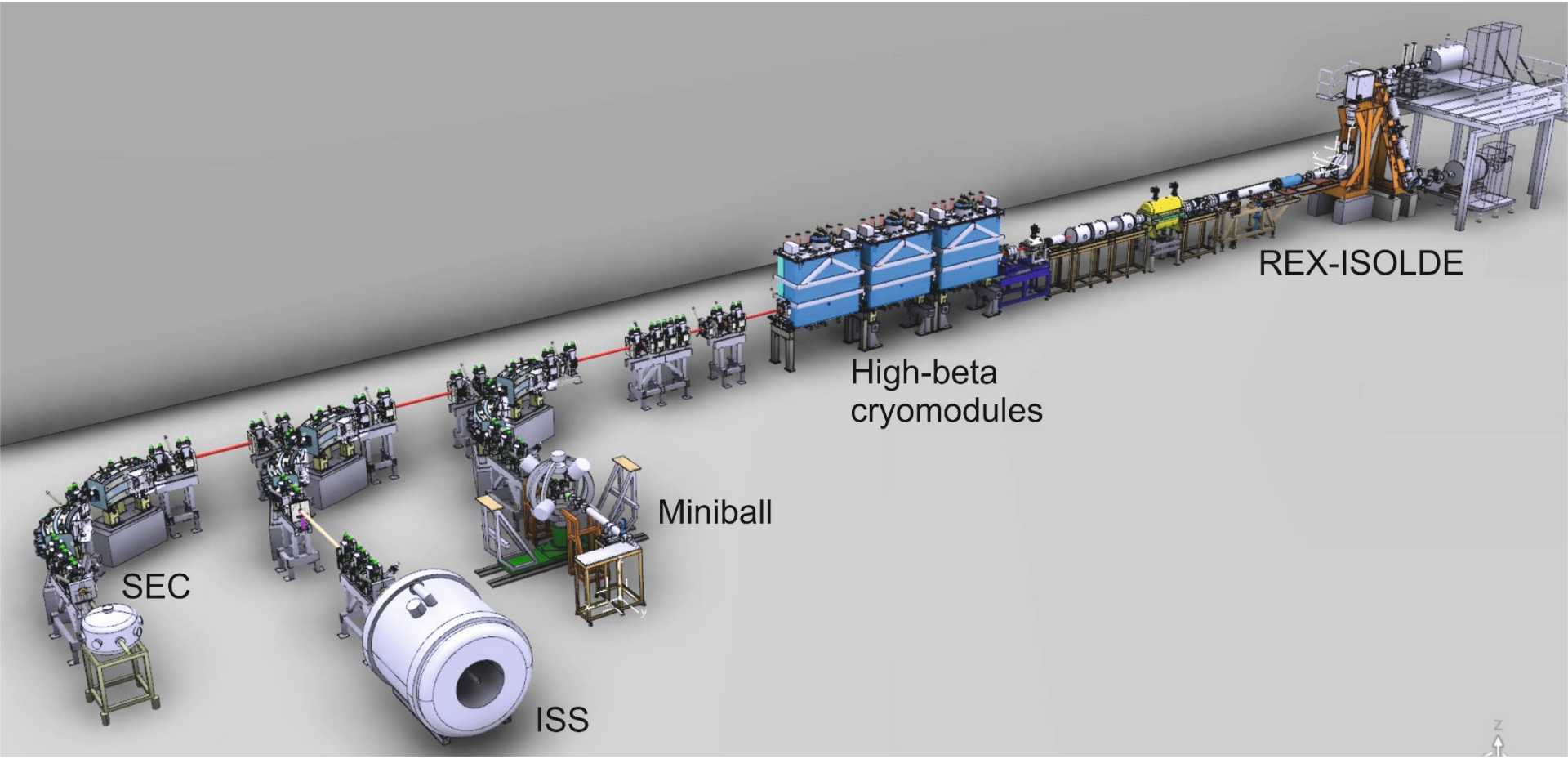
- Calibration of the RF systems (W_{RF})
- First dipole of the XT01 HEBT line (W_B)
- TOF between silicon detectors in XT00 (W_{TOF})

#	E_{SRF08} [MV/m]	W_{RF} [MeV/u]	$\frac{W_{RF}-W_{TOF}}{W_{TOF}}$	W_B [MeV/u]	$\frac{W_B-W_{TOF}}{W_{TOF}}$	W_{TOF} [MeV/u]
E1	5.455	4.908	0.9 %	4.866	0.0 %	4.866
E2	4.455	4.846	1.0 %	4.810	0.3 %	4.797
E3	3.455	4.784	0.9 %	4.745	0.1 %	4.740
E4	2.455	4.722	0.9 %	4.677	-0.0 %	4.679
E5	1.455	4.659	0.8 %	4.631	0.2 %	4.621
E6	0.455	4.597	0.5 %	4.572	-0.0 %	4.574
E7	0.000	4.569	0.2 %	--	--	4.560

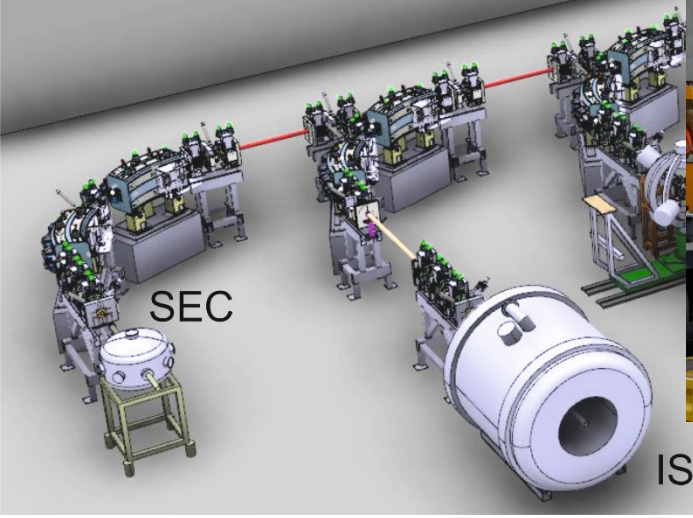


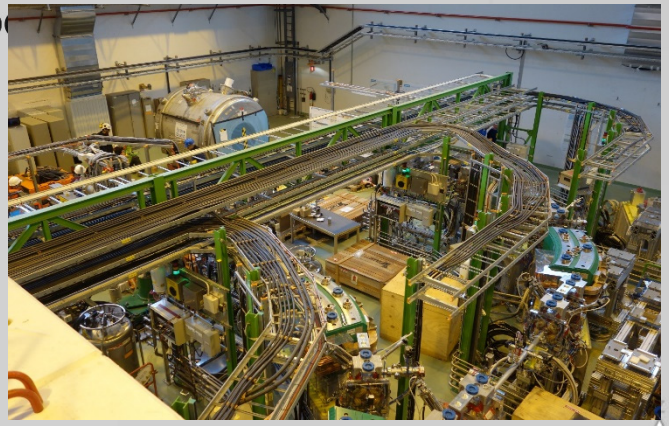


Phase 2: Installation & Commissioning (2017)



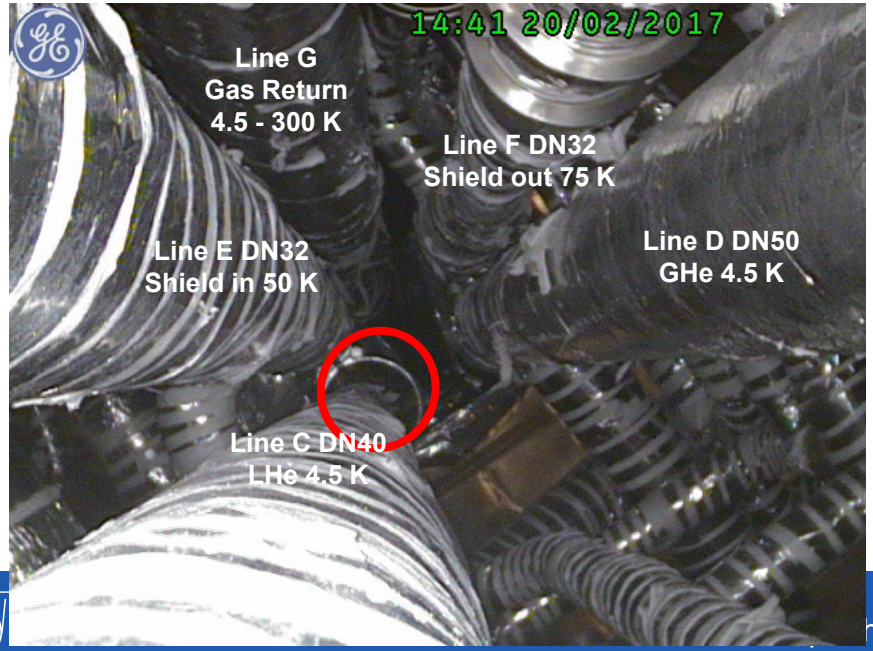
Phase 2: Installation & Commissioning (2017)

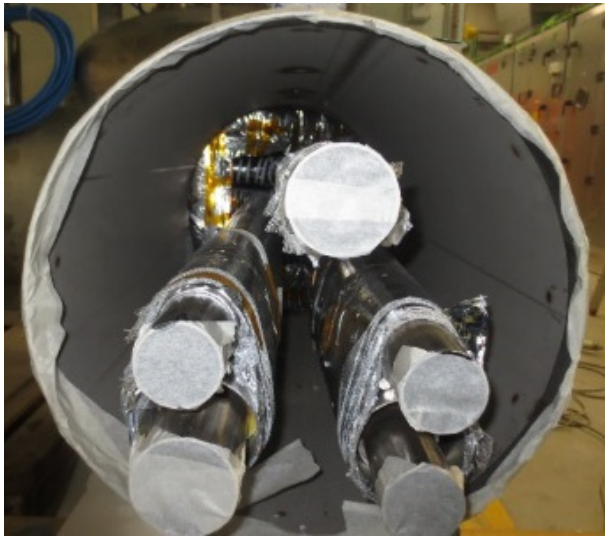




2017 Cryogenic Maintenance and Repairs

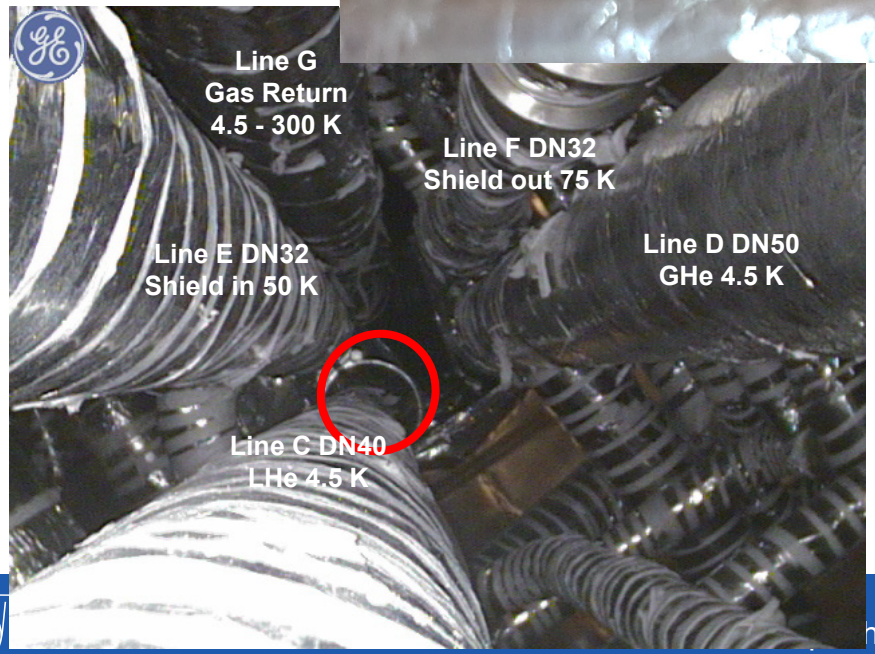
- Preventive and corrective maintenance *(10'000 h)* : charcoal, filters, gearbox, safety valves, calibration check of whole instrumentation, valves, vacuum syst, …
- Update of CP logic -> allow full CP performance and ease restarts ;
- Update of refrigerator process control -> more robust process with automatisms allowing reconnection of cryomodules in all cool down situations
- **endoscopic investigations of the inner parts of the cryogenic distribution line:** Obvious contact of LHe and GHe lines (headers C & D) with the shield in the TL interconnecting the Jumper Box (JBs)



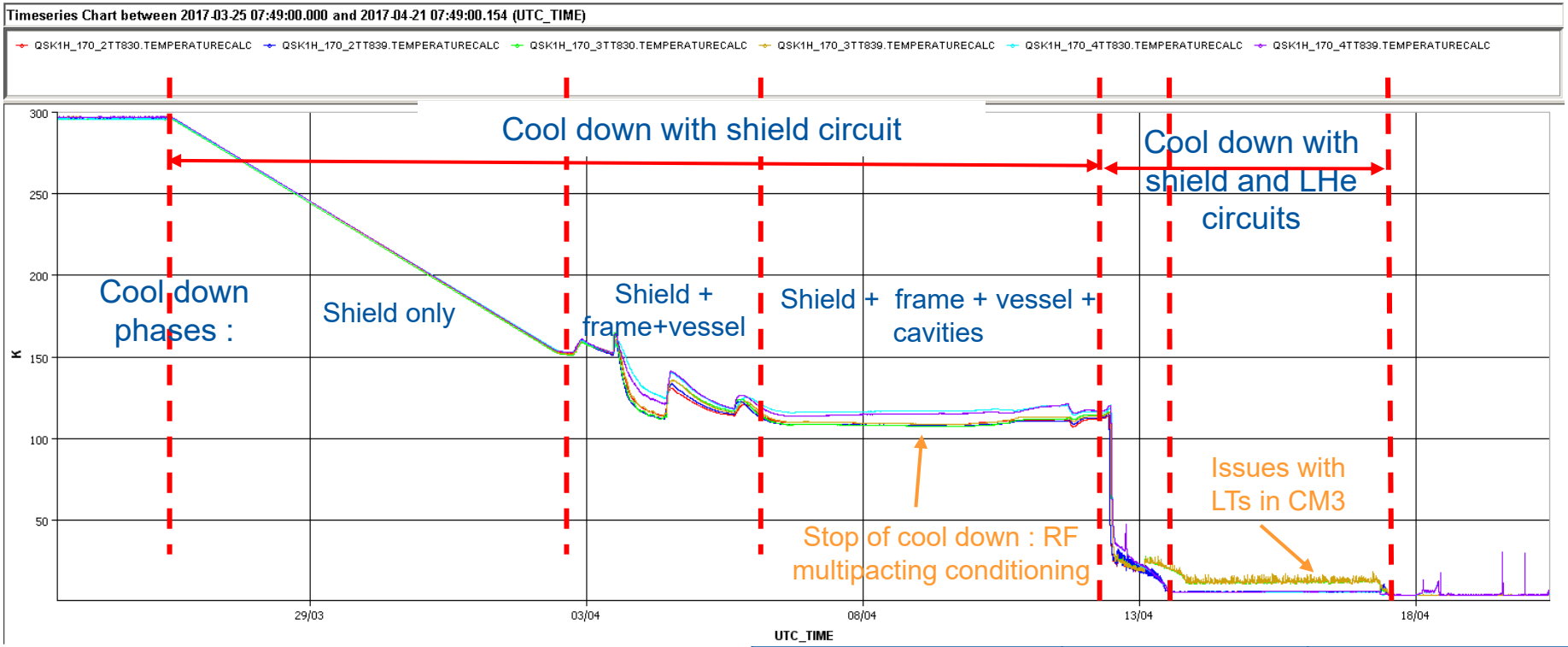


2017 Cryogenic Maintenance and Repairs

- Preventive an… gearbox, safety valves, …uum syst, …
- Update of CP lo…
- Update of refri… tomatisms allowing reconne…
- **endoscopic inv… ution line:** Obvious contact … the TL interconnecting …



Cool down of 3 CMs

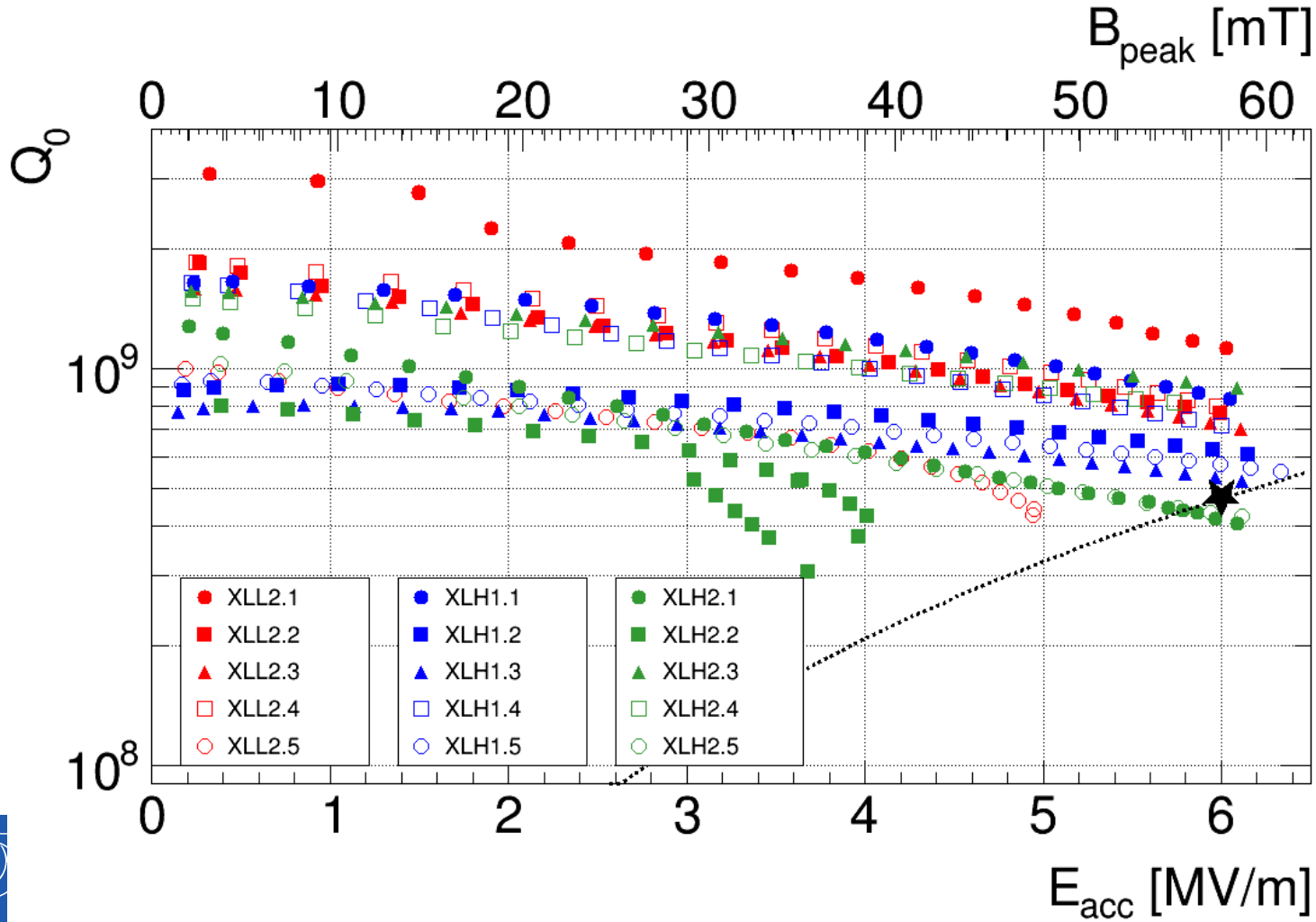


LHe filling of cryomodules achieved much quicker wrt 2016 and via the frame circuit only ⇒ proof of better LHe «quality»

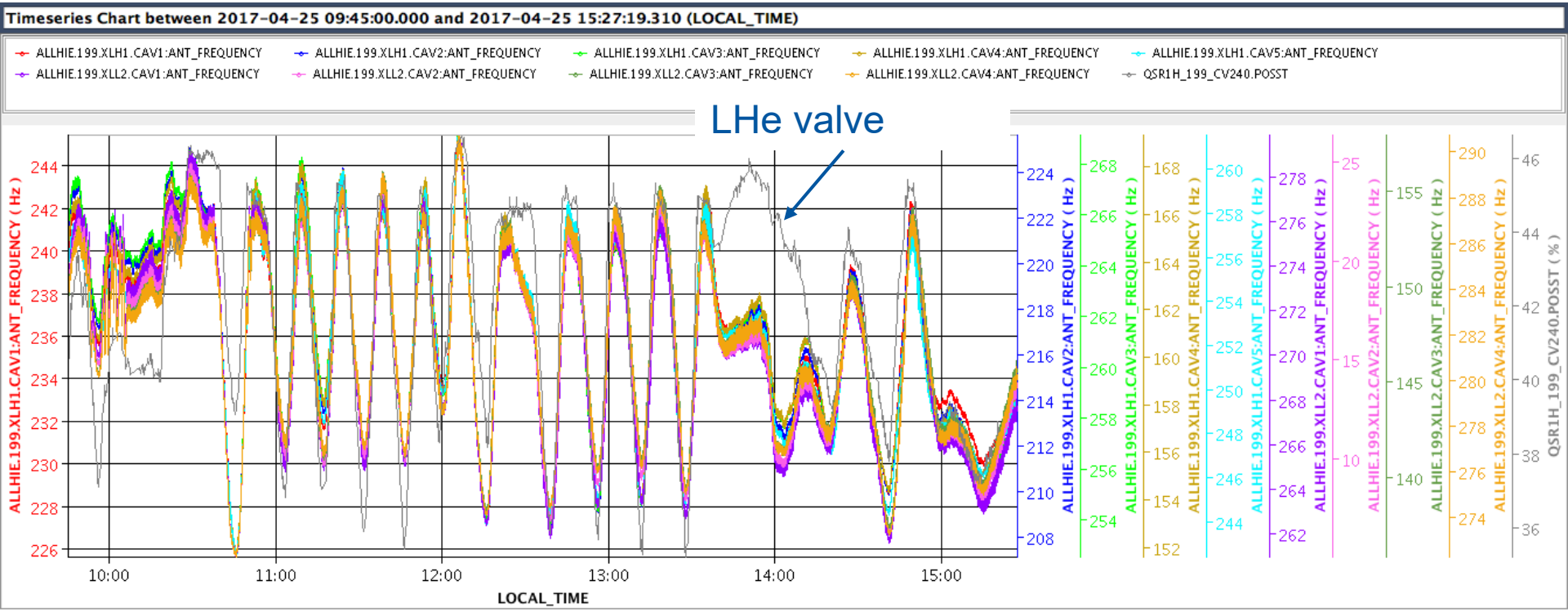
Phases	2016 *2 CMs*	2017 *3 CMs*
300K → 5K	≈ 15 days	≈ 9 days
LHe Filling (stable)	5 days	4h for CM1&2 + 4h for CM3

Cavity performance on line in 2017

- MP conditioning and **RF measurements at cold done on all 15 cavities**
- **Performance gain on line due to smaller temperature gradients across Tc**



Frequency perturbation



- Reminder: the cause of sudden cavity trips last year
- The frequency shift has positive correlation to LHe pressure and valve
- Slow (10-20 min) and “small”’ (~10Hz) can be easily followed by the tuner moved by stepping motor.

Summary & Outlook

- **Phase 1 has been completed**
- **Quite successful Physics Run in 2016**
- **Schedule for 2016/2017 Shutdown:**
  - ✓ Installation of CM3 completed
  - ✓ Installation of 3rd beam line + ISS magnet on XT02 completed
  - ✓ Cryogenics maintenance & consolidation completed
- **HW commissioning work on track, due to finish at end of May:**
  - ✓ Overall RF performance of SC cavities is very good
  - ➢ Only 2 cavities suffer from field emission
  - ✓ Frequency perturbation is much less severe, still worth improving
  - ✓ LLRF setting up (ongoing), solenoids powering, cold alignment
- **Physics Run to start early July 2017:**
  - ✓ Only 13/27 requested beams in 2017 could be scheduled (235 shifts)
  - ✓ typical acceleration is 4.4 – 5.5 MeV/u (exceptions: ^{9}Li and ^{11}Be)

THANK YOU

ACKNOWLEDGEMENTS

- The ISOLDE Collaboration
- The HIE-ISOLDE project team and in particular all the groups within the CERN Accelerator and Technology Sector.
- The Belgian Big Science program of the Research Foundation - Flanders (FWO), the Research Council KU Leuven and the "Interuniversity Attraction Poles (IAP) Programme - Belgian Science Policy
- The CATHI Marie Curie Initial Training Network: EU-FP7-PEOPLE-2010-ITN Project number 264330.
- The COFUND-CERN Marie Curie Fellowship programme.
- The Spanish Programme “Industry for Science” from CDTI.
- The CATE Consortium, EU interregional program IV