HIE-ISOLDE Project Status Report

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CERN
HIE-ISOLDE Project

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Yokohama, Japan
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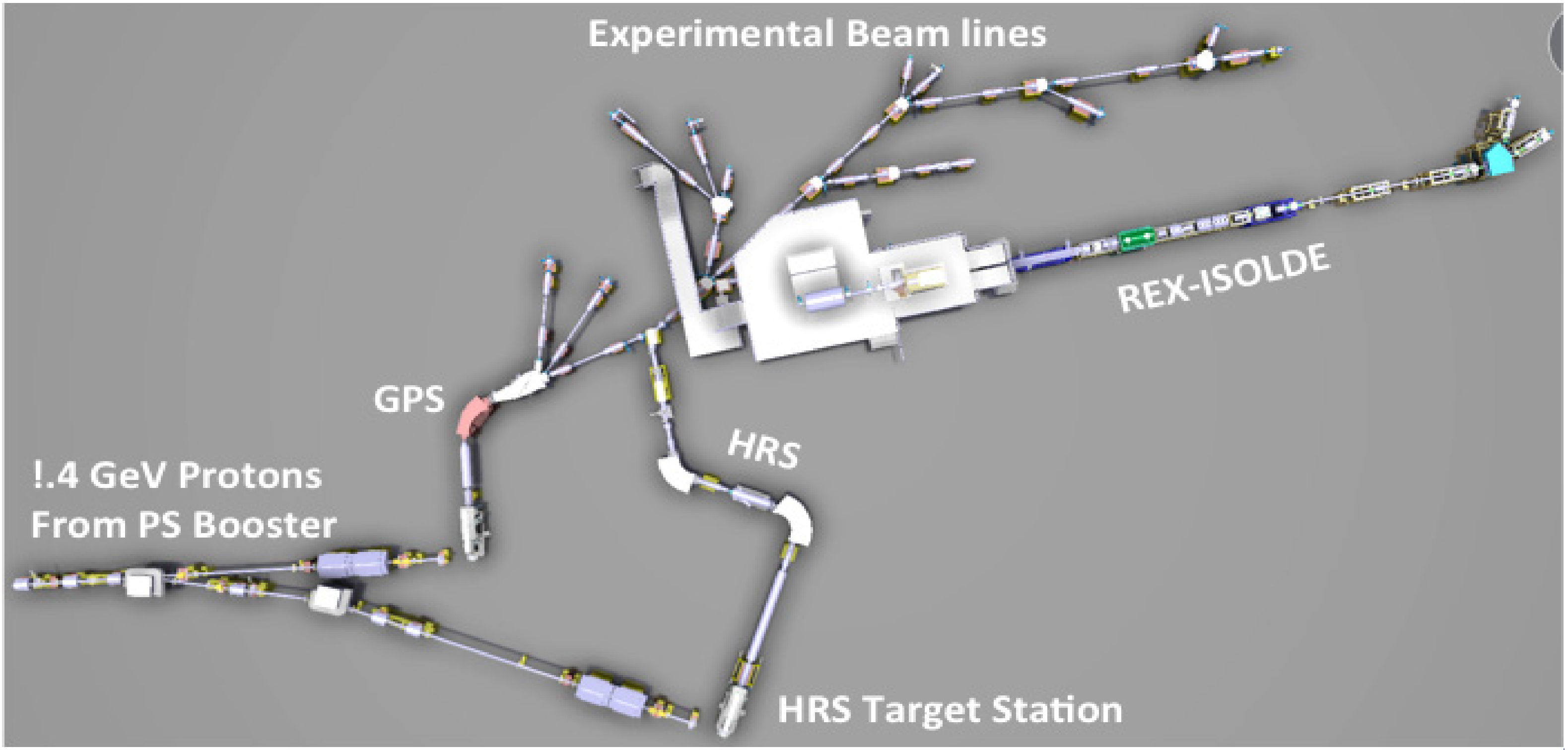
OUTLINE

- ISOLDE Facility
- Scope of HIE-ISOLDE Project
- Results from the Machine Commissioning
- Status of the Beam Commissioning
- Experiments for 2015
- Conclusions

ISOLDE Facility : a few facts

- ISOLDE is the CERN radioactive beam facility (approved 50 y ago!)
- Provides low energy or post-accelerated beams
- Run by an **international collaboration since 1965. Presently 13 members** (B, CERN, Dk, E, F, Ge, Gr, I, India, N, R, S, UK)
- **> 500 Users from 100 Institutions, 50 experiments / year**



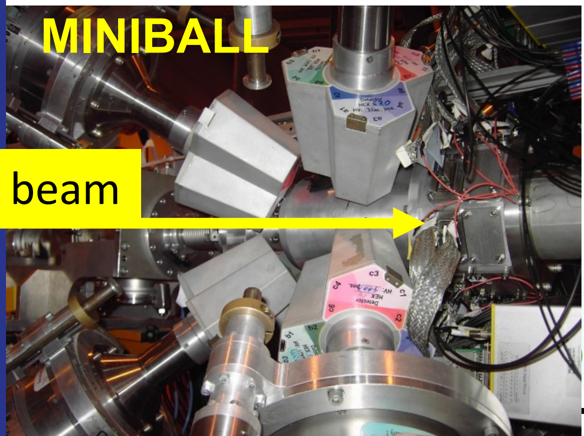
Physics program @ REX

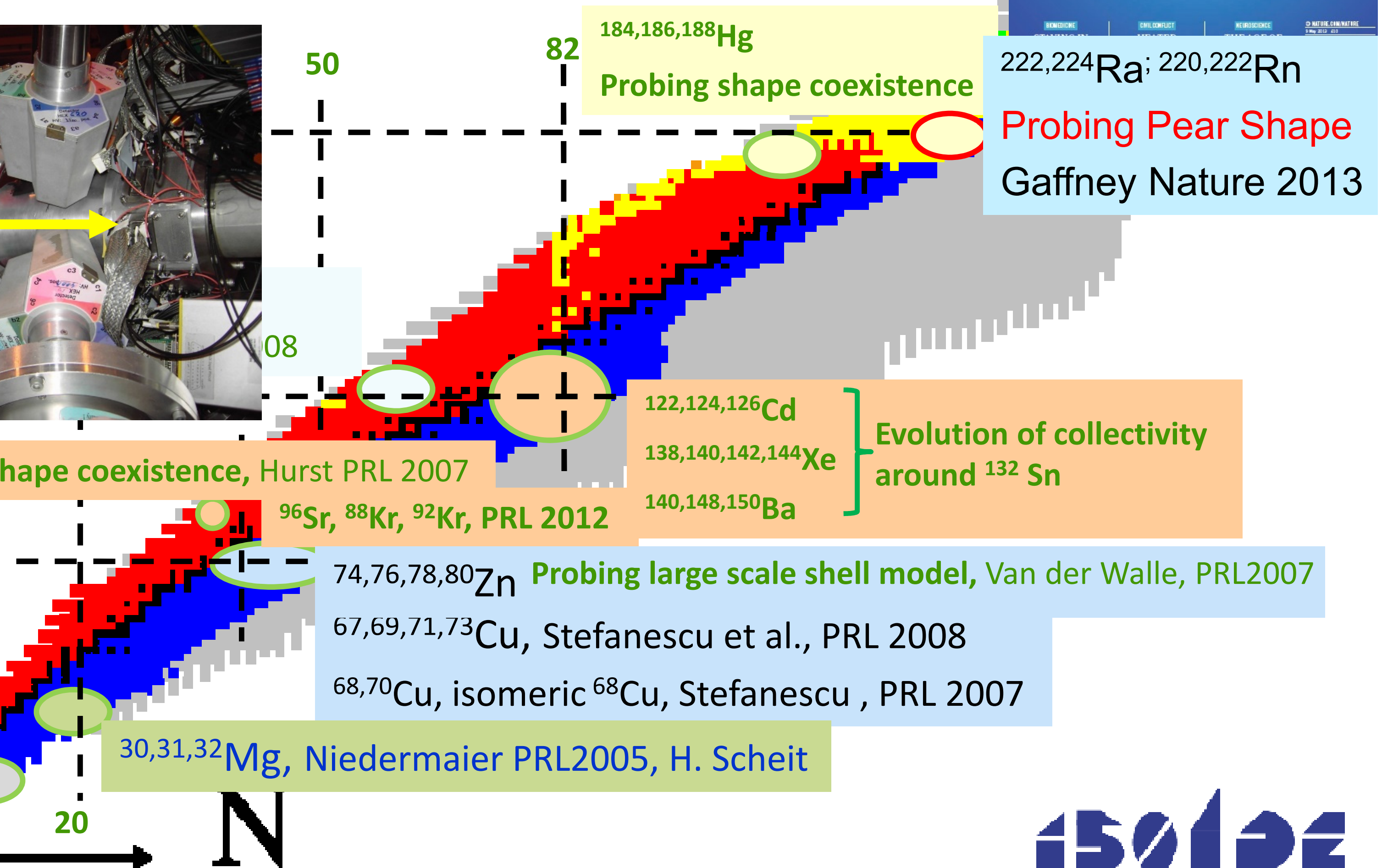
REX-ISOLDE started in 2001

108 different beams already used at REX of 1300 available!

Coulomb excitation with Miniball:

- collectivity versus individual nucleon behaviour

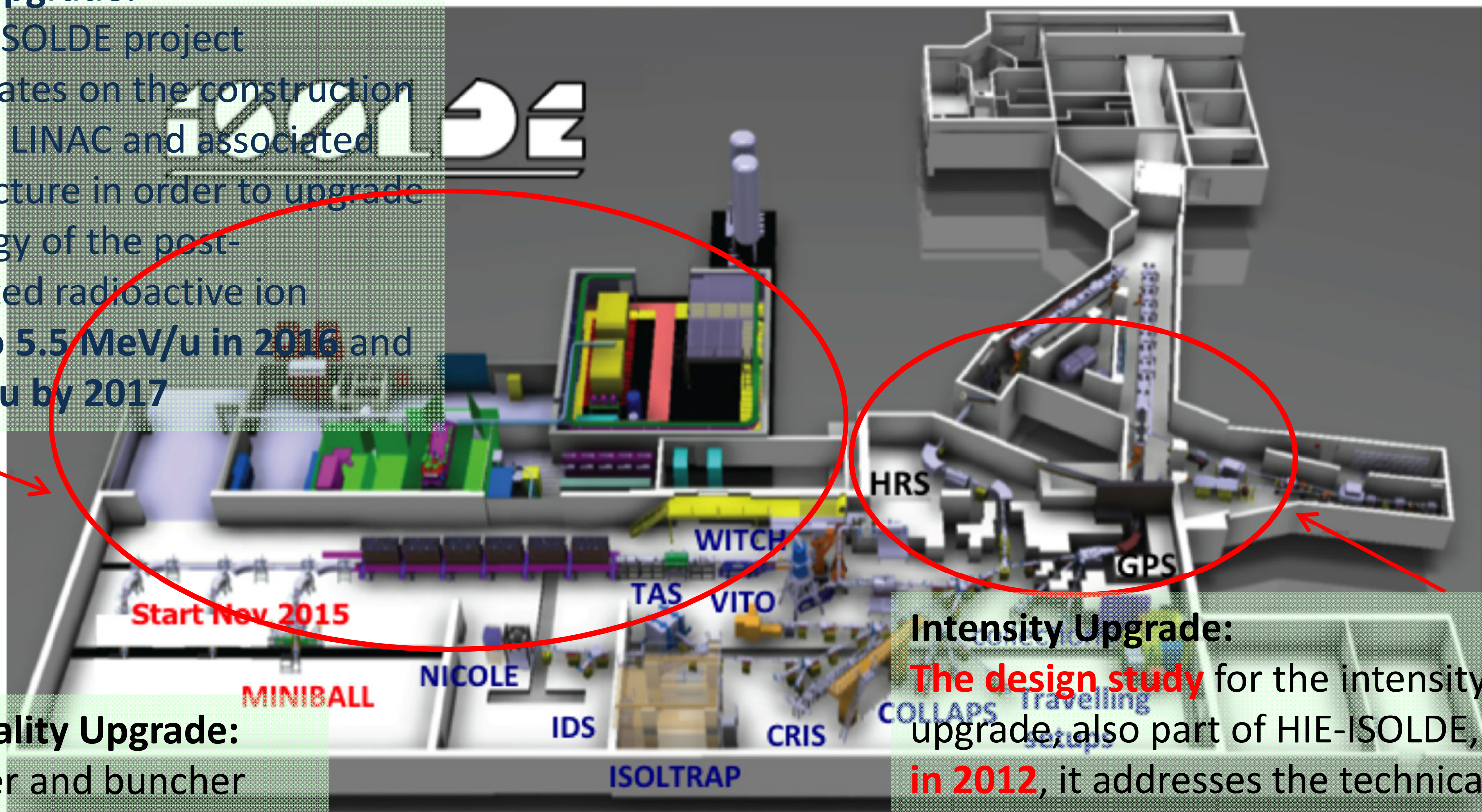




ISOLDE

HIE-ISOLDE aims at increasing the energy of the RIB up to 10AMeV and their intensity by a factor 10

Energy Upgrade:
The HIE-ISOLDE project concentrates on the construction of the SC LINAC and associated infrastructure in order to upgrade the energy of the post-accelerated radioactive ion beams to **5.5 MeV/u in 2016** and **10 MeV/u by 2017**



Beam Quality Upgrade:
RFQ cooler and buncher
Solid state lasers for RILIS
Higher mass resolving power HRS

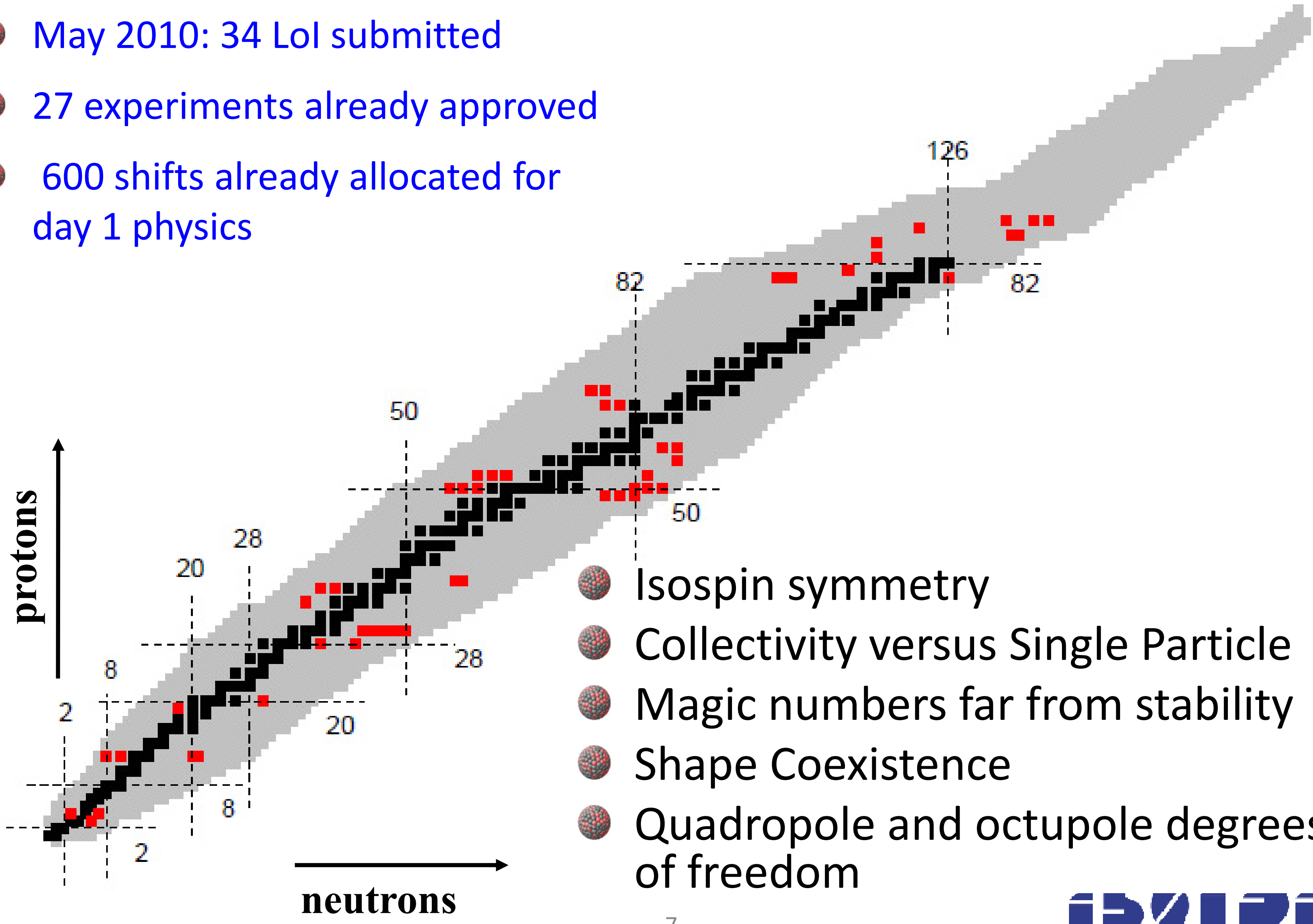
Intensity Upgrade:
The design study for the intensity upgrade, also part of HIE-ISOLDE, **started in 2012**, it addresses the technical feasibility and cost estimate for operating the facility at **15 kW** once LINAC4 and Upgraded PS Booster are online.

HIE-ISOLDE Opportunities:

Reaction	Physics	Optimum energy
(d,p), (^{3}He,α), (^{3}He,d), (d,n),… transfer	Single-particle configurations, r- and rp-process for nucleosynthesis	10 MeV/u
(^{3}He,p), (d,α), (p,t), (t,p)	pairing	5-10 MeV/u
Few-nucleon transfer	Structure of neutron-rich and proton-rich nuclei	8 MeV/u
Unsafe Coulomb excitation	High-lying collective states	6-8 MeV/u
Compound nucleus reactions	Exotic structure at drip line	5 MeV/u
Coulomb excitation, g-factor measurements	Nuclear collectivity and single-particle aspects	3-5 MeV/u
(p,p'γ), (p,α), …	nucleosynthesis	2-5 MeV/u

Physics @ HIE-ISOLDE

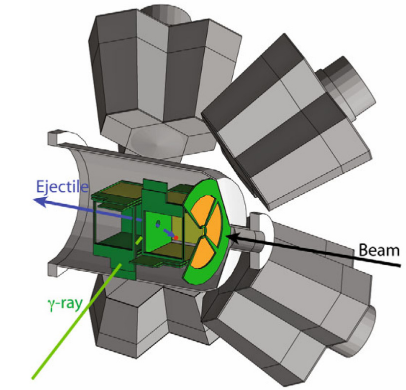
- May 2010: 34 LoI submitted
- 27 experiments already approved
- 600 shifts already allocated for day 1 physics



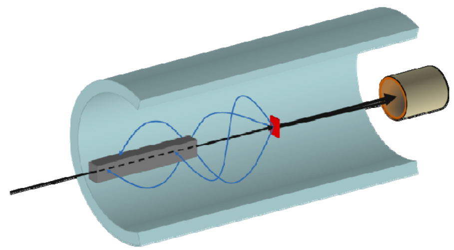
- Isospin symmetry
- Collectivity versus Single Particle
- Magic numbers far from stability
- Shape Coexistence
- Quadropole and octupole degrees of freedom

Instrumentation

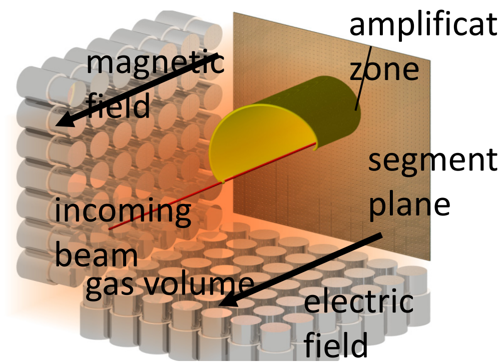
- Miniball + T-ReX (upgrade planned) :
COULEX + Transfer 22



- Multipurpose reaction chamber 2
- CORSET chamber for Fusion-fission reactions 1
- SPEDE: added to Miniball+T-REX 1

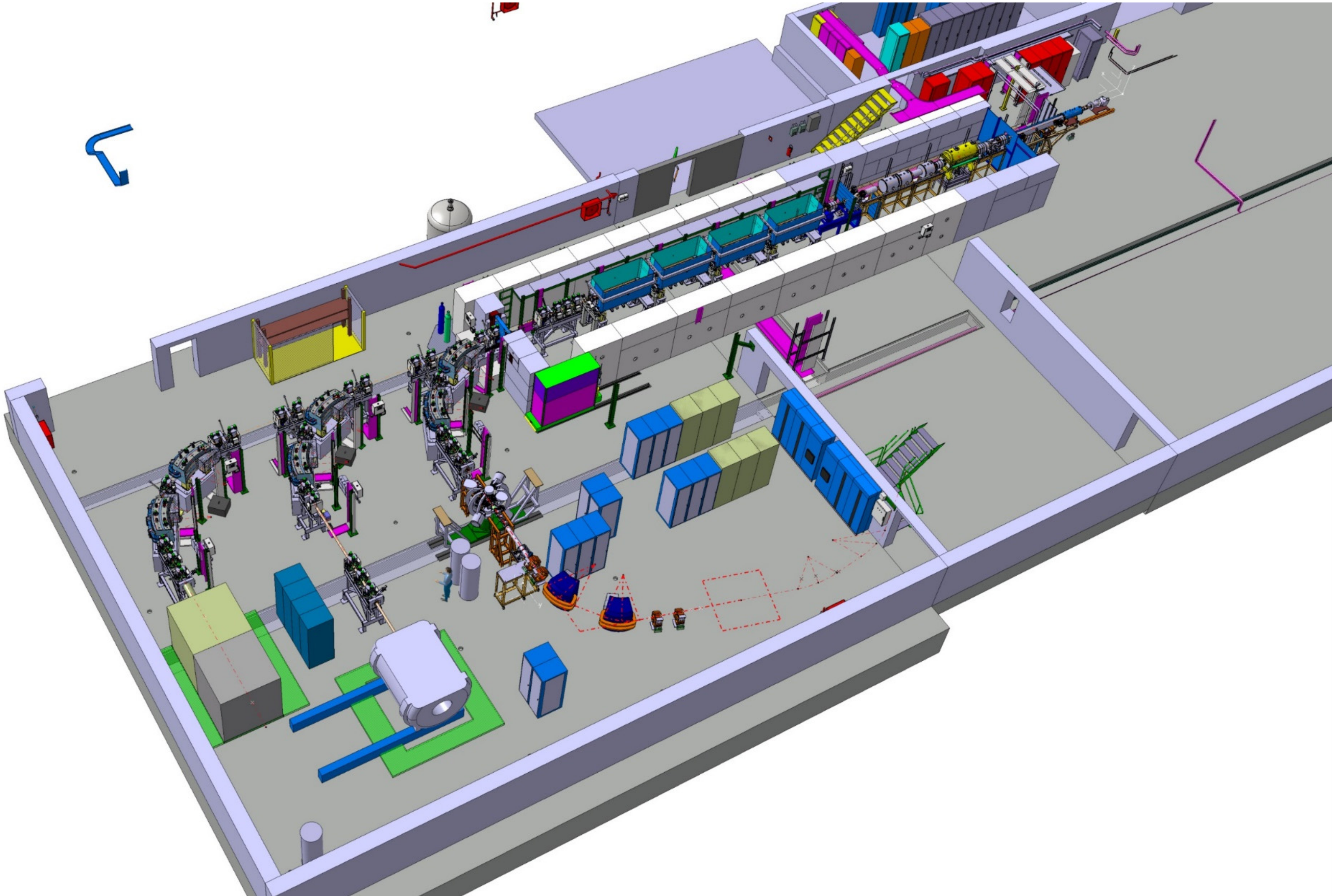


- Helios type device: transfer @ TSR
- MAYA/ACTAR: resonant scattering + transfer. 1

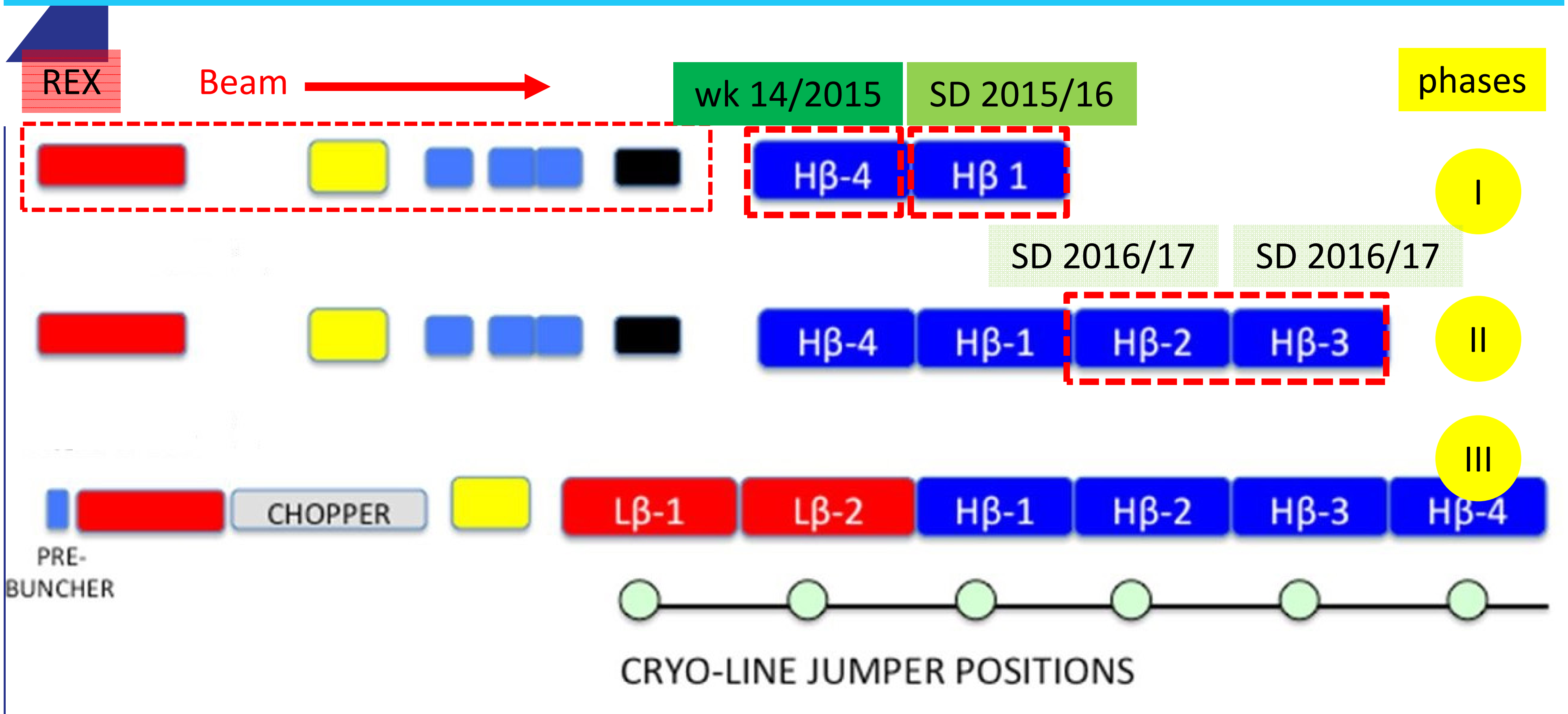


- For LS2: TSR storage ring,

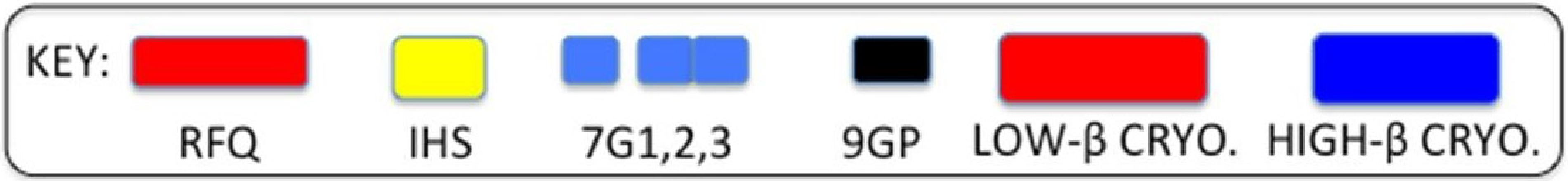
Proposed beam line layout



HIE-ISOLDE Roadmap



Legend:

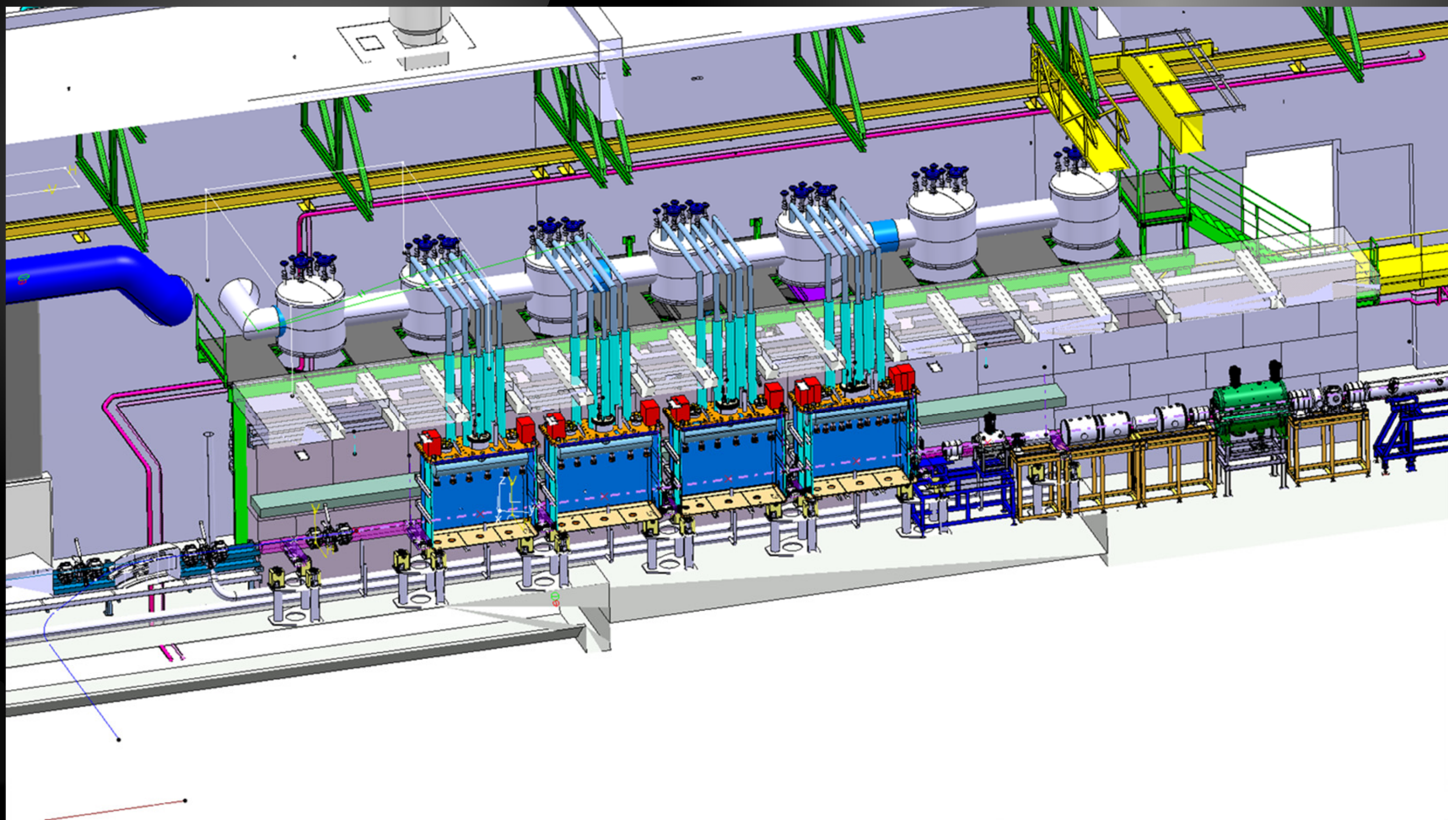


Existing REX-structures:

RFQ, IHS: 20-gap IH-structure, 7GX: 7-gap split-ring cavities, 9GP: 9-gap IH-structure

The HIE ISOLDE Cryomodues

Common vacuum concept - Actively cooled thermal shield-
Superconducting active elements: RF cavities and solenoid



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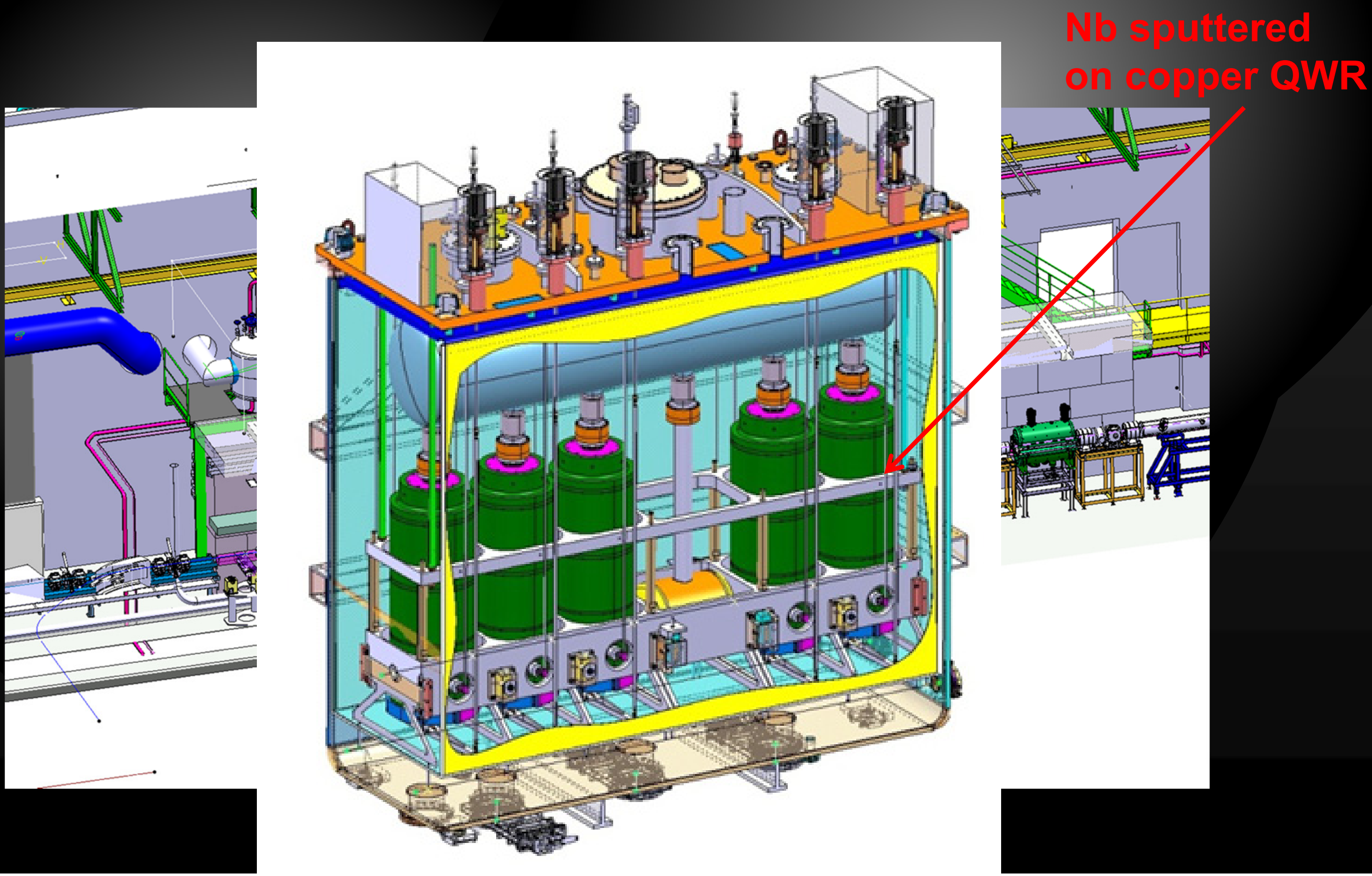


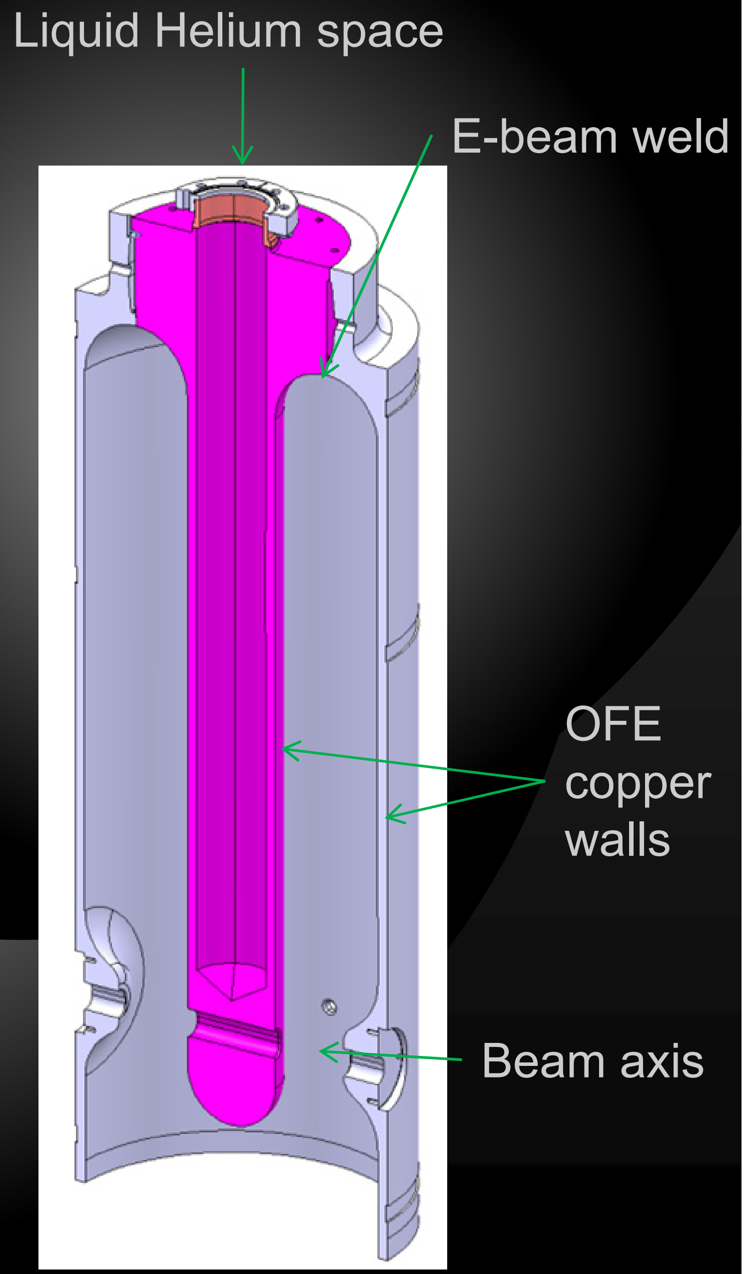
Choice of cavity technology

Superconducting option

- High Q (low power dissipation)
- Cryogenics
- High CW fields (30 MV/m peak)
- Possible field emission, X rays

Niobium sputtering on copper

- Thermal stability
- Mechanical stability→ less sensitive to He pressure fluctuations and to mechanical vibrations→ Low RF power
- Less sensitive to magnetic fields→ no need of shielding the cryostat
- Potentially cheaper (especially for large series)
- Possible to recycle substrates

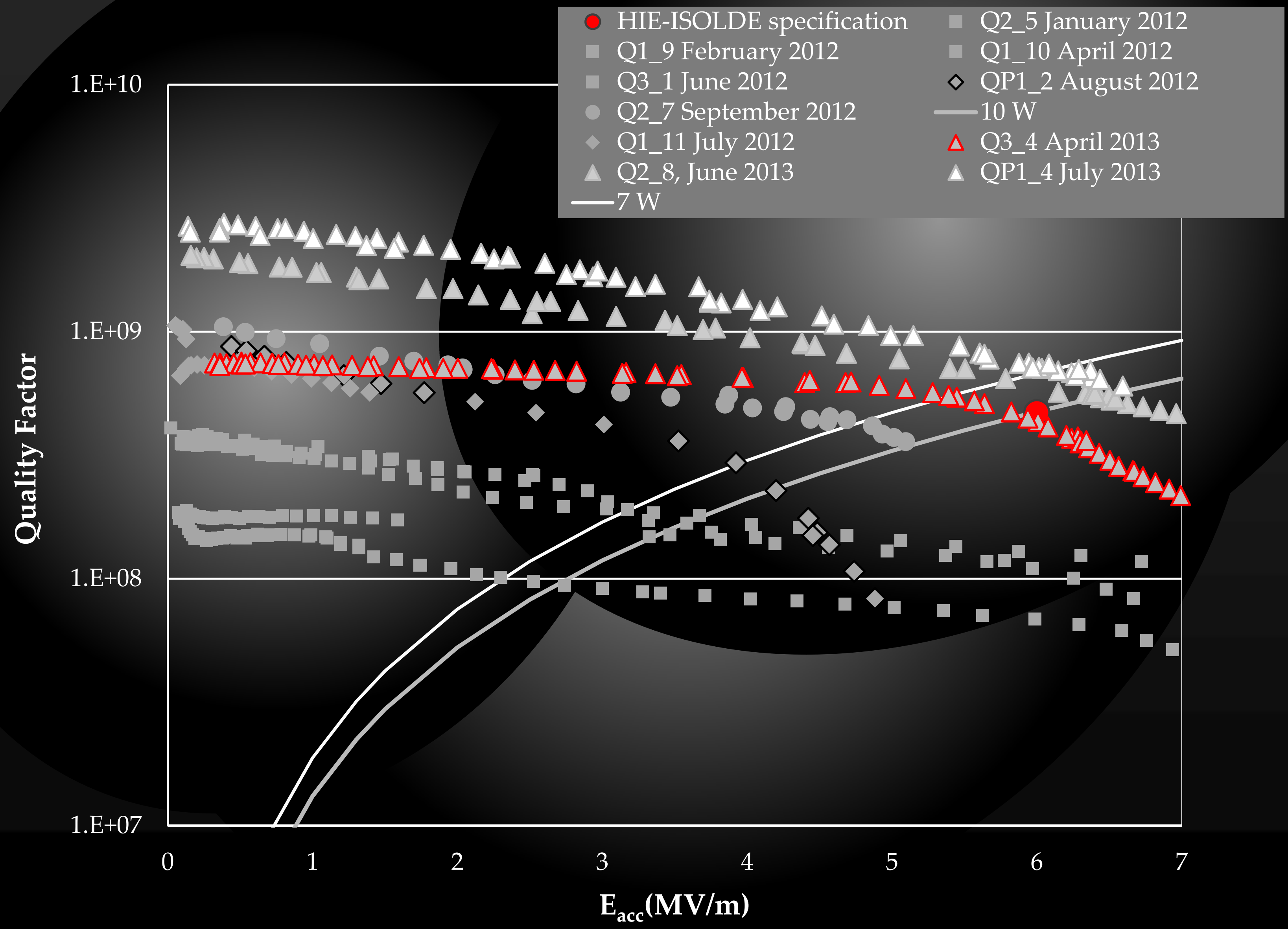


Roadmap of developments (2011-2013)

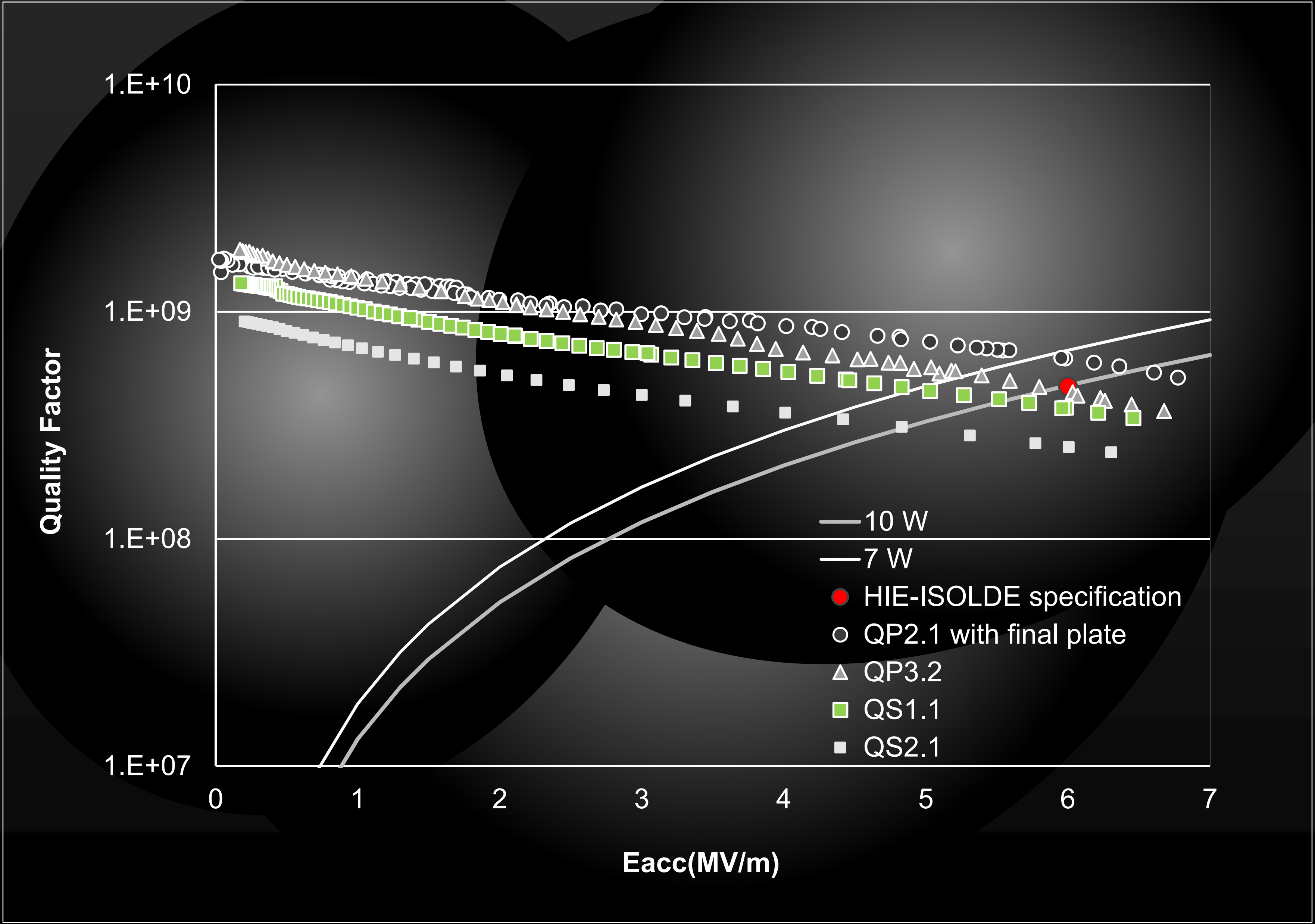
Strong development program focused on bias diode sputtering method. Main steps:

- Increasing baking and coating temperatures
- Increasing sputtering power (global deposition rate)
- Coating in steps
- Sputtering gas, venting gas
- Global film thickness
- Local film thickness

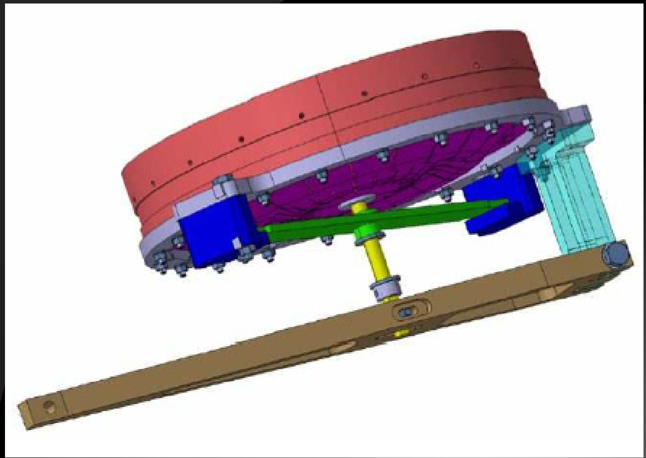
Top gap distance reduced to 22 mm

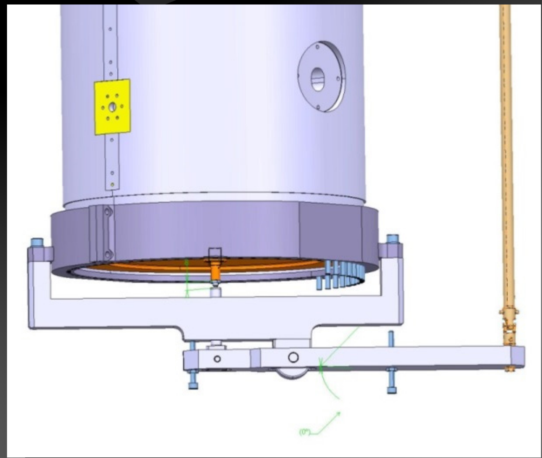


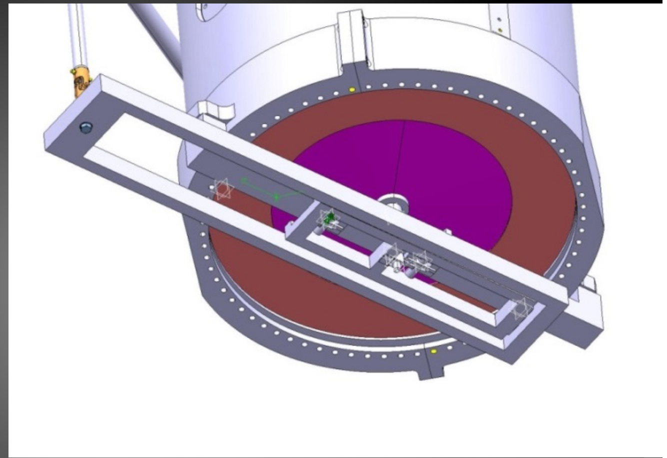
Performance of the first 4 series cavities

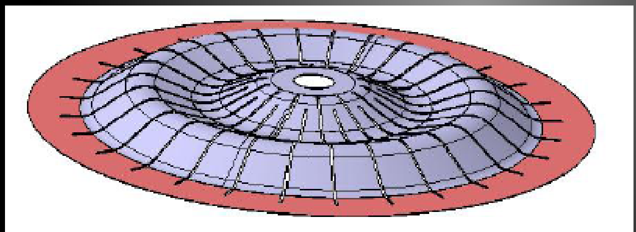


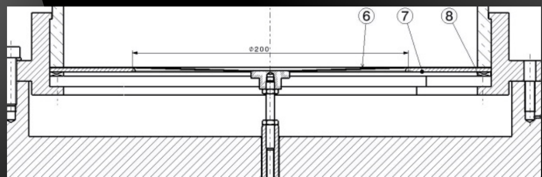
Tuning system evolution (plates and actuators)

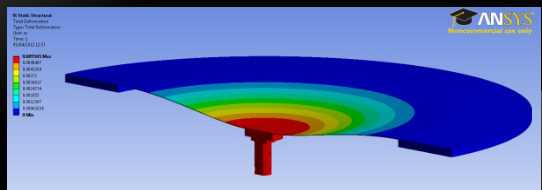


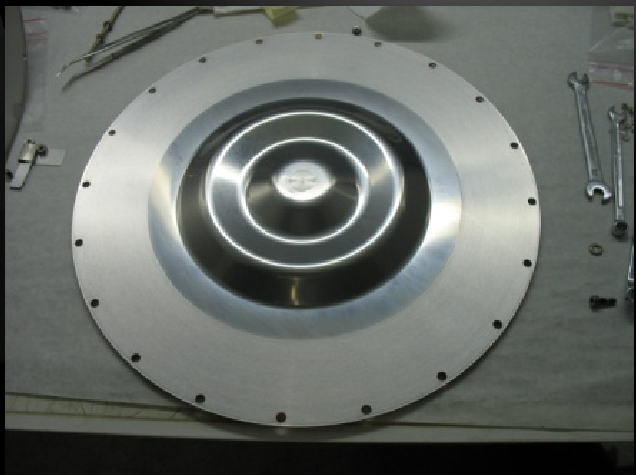


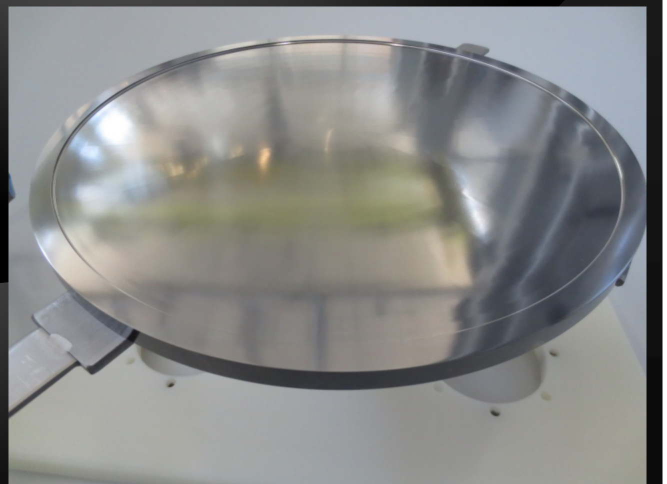












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- 5 QWR cavities (BE/RF)
  - Tuners, couplers, instrumentation
- 1 solenoid (TE/MSC)
  - 116A – 13.5T^2.m – NbTi
  - Immersed in 4.5K LHe 1.5 bara
  - Vapor-cooled current leads
  - Resistive splice
- Supporting frame assembly
  - Actively cooled at 4.5K
  - 316L structure
  - Live monitoring of positions
- Helium reservoir, circuits and interfaces
  - 150l of LHe, 1.5 bara nominal, 4.5K
  - Instrumentation
- Top plate and services
  - Services : 53 ports
  - Seal interface
- Thermal shield
  - Actively cooled to 55-75K Ghe, 13 bara
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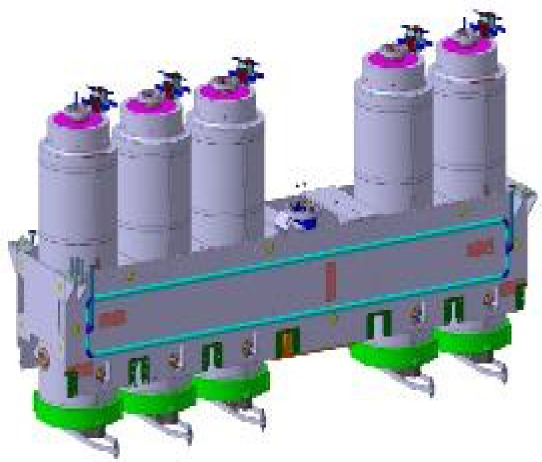

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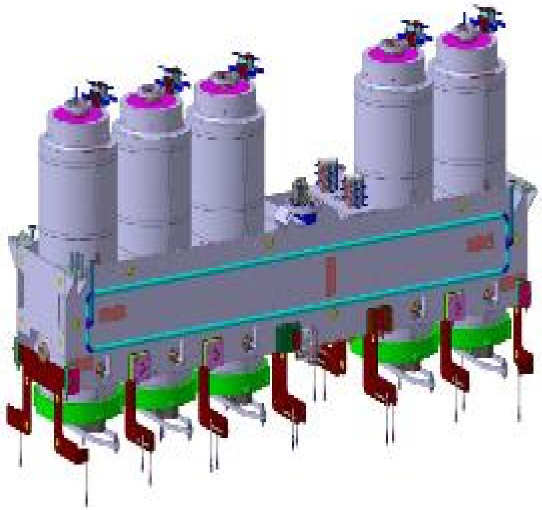

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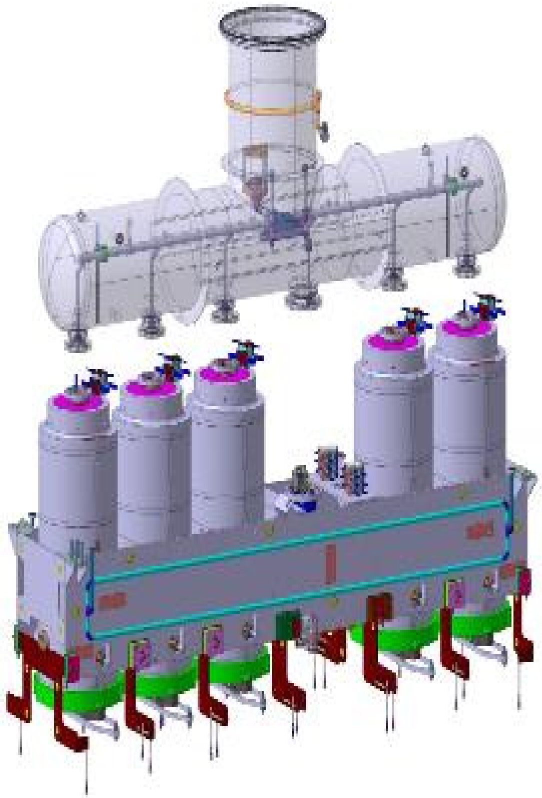

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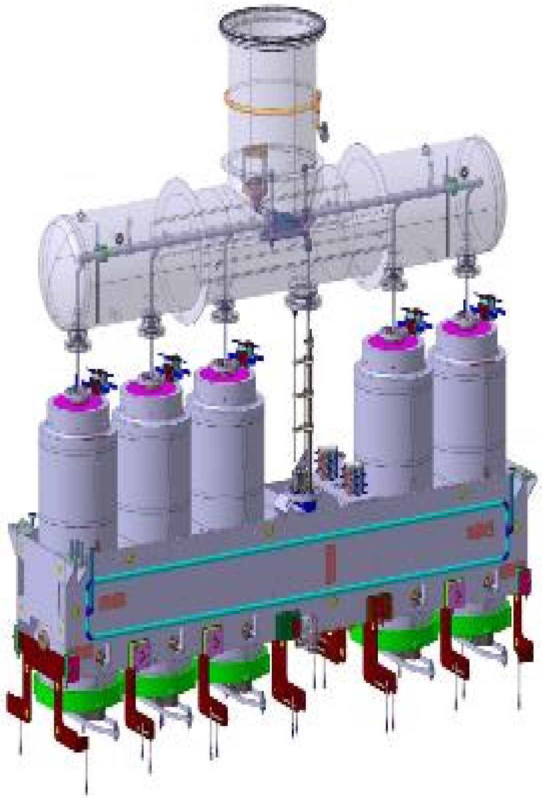

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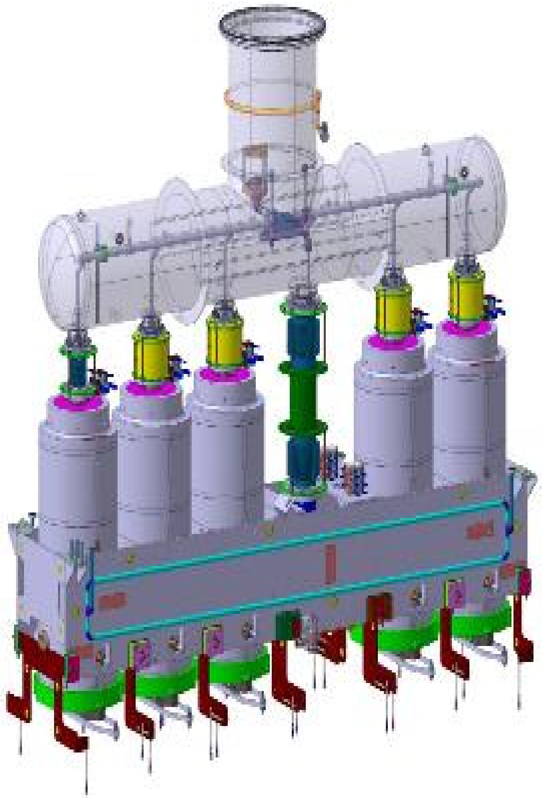

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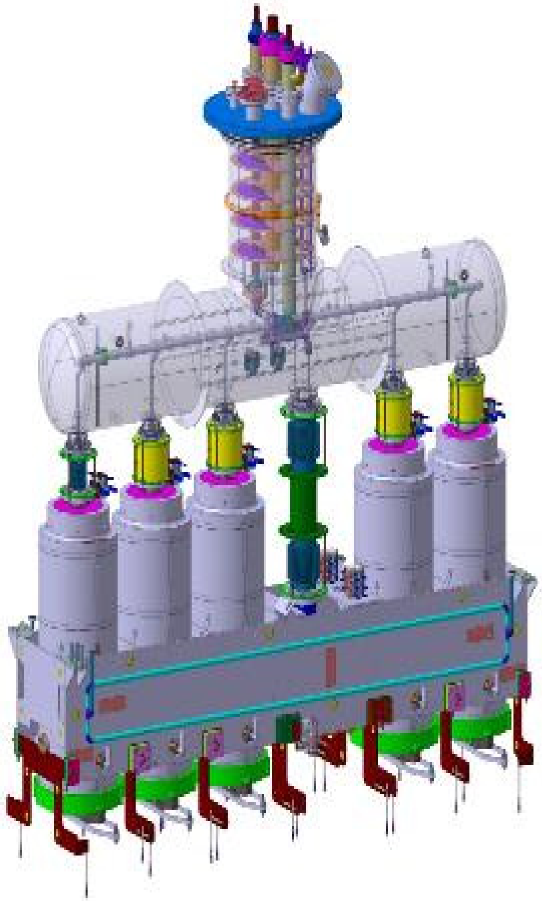

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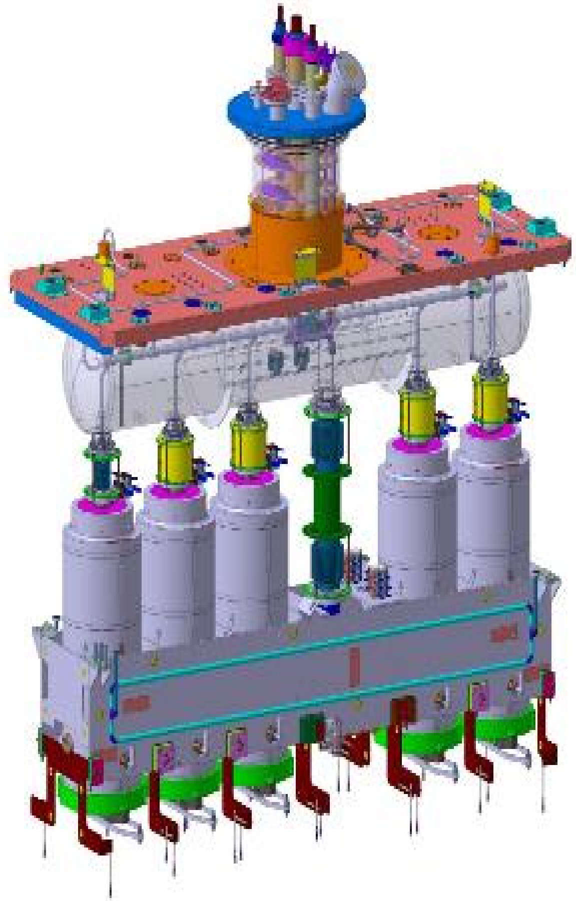

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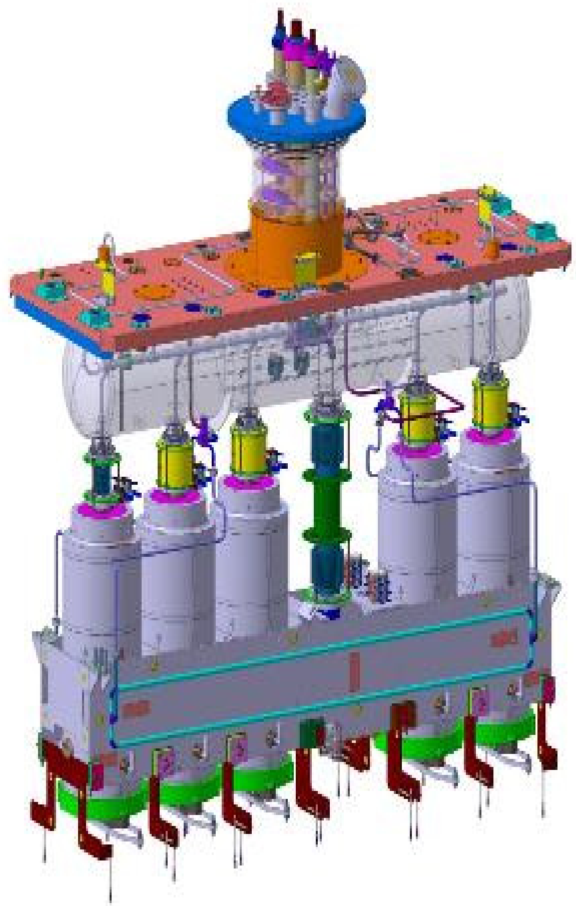

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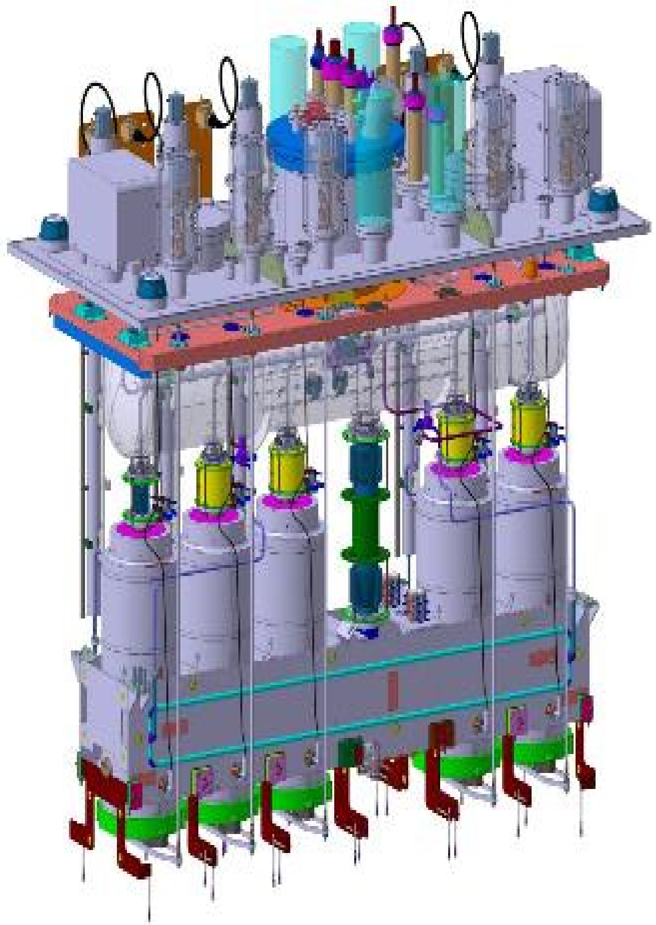

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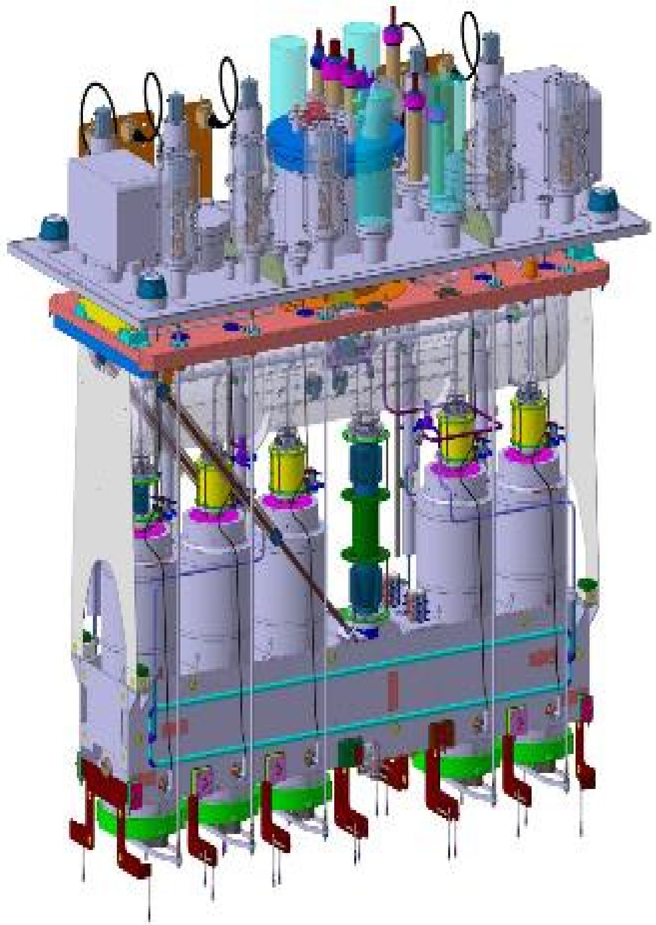

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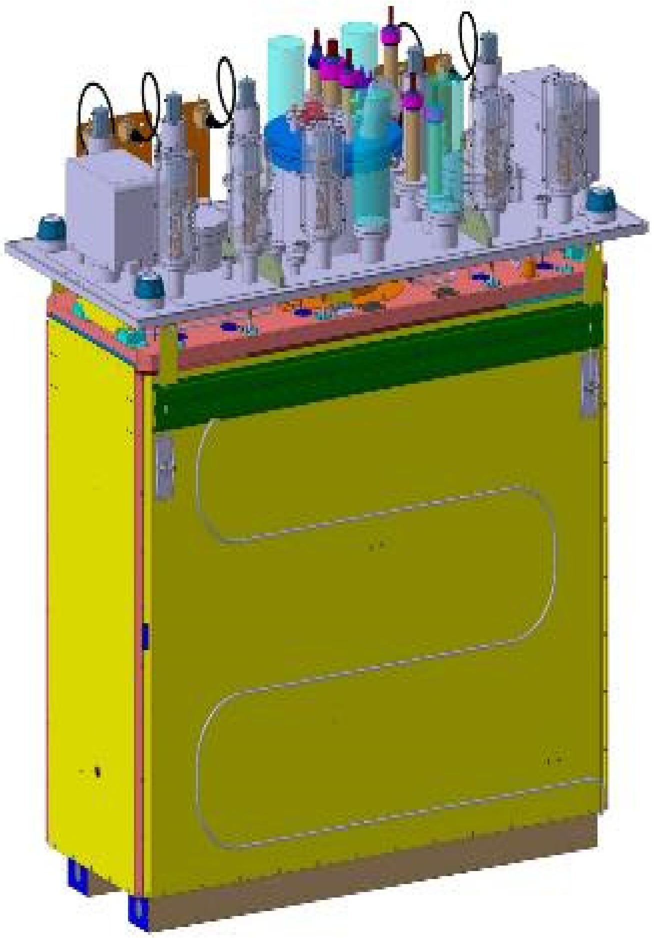

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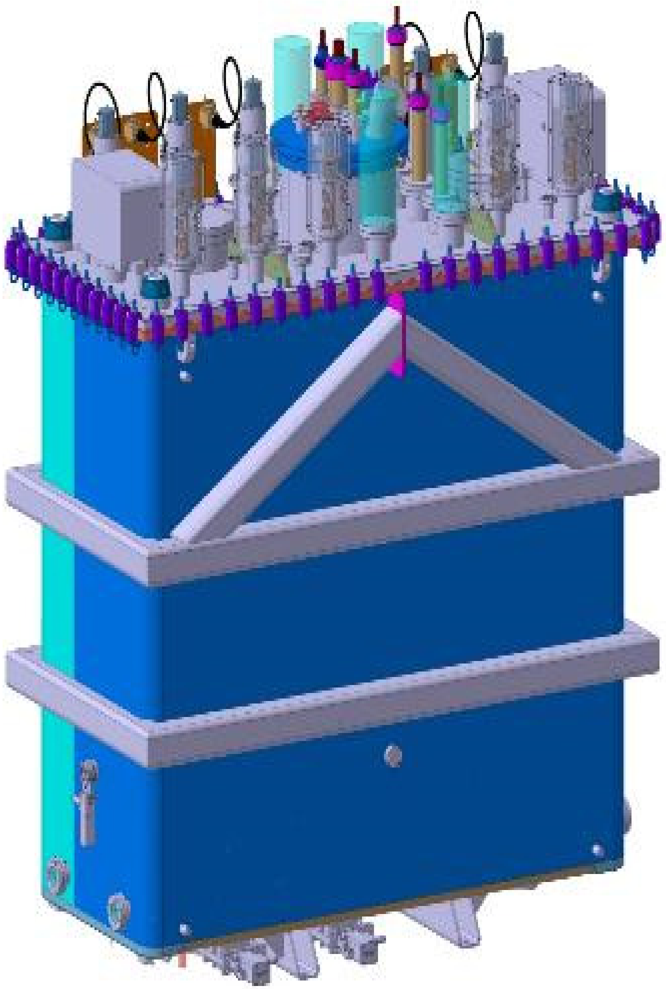
  - Services : 53 ports
  - Seal interface
- Thermal shield
  - Actively cooled to 55-75K Ghe, 13 bara
  - Nickel plated copper
- Vacuum vessel
  - 15mm thick 316L plates
  - Vacuum interfaces
  - 10-8 mbar.l.s-1



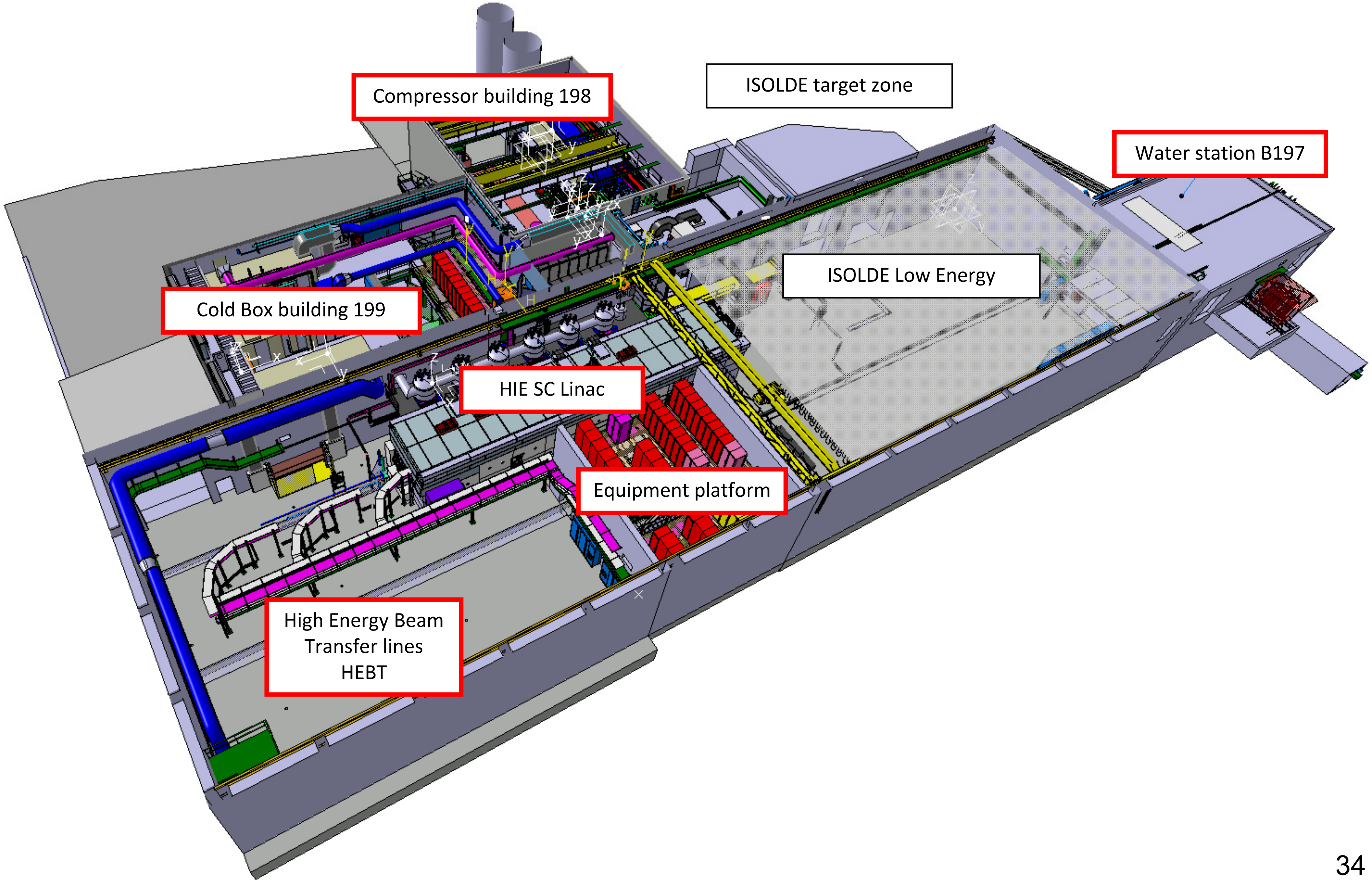
CM1 assembly

- Late august 2014: Assembly start

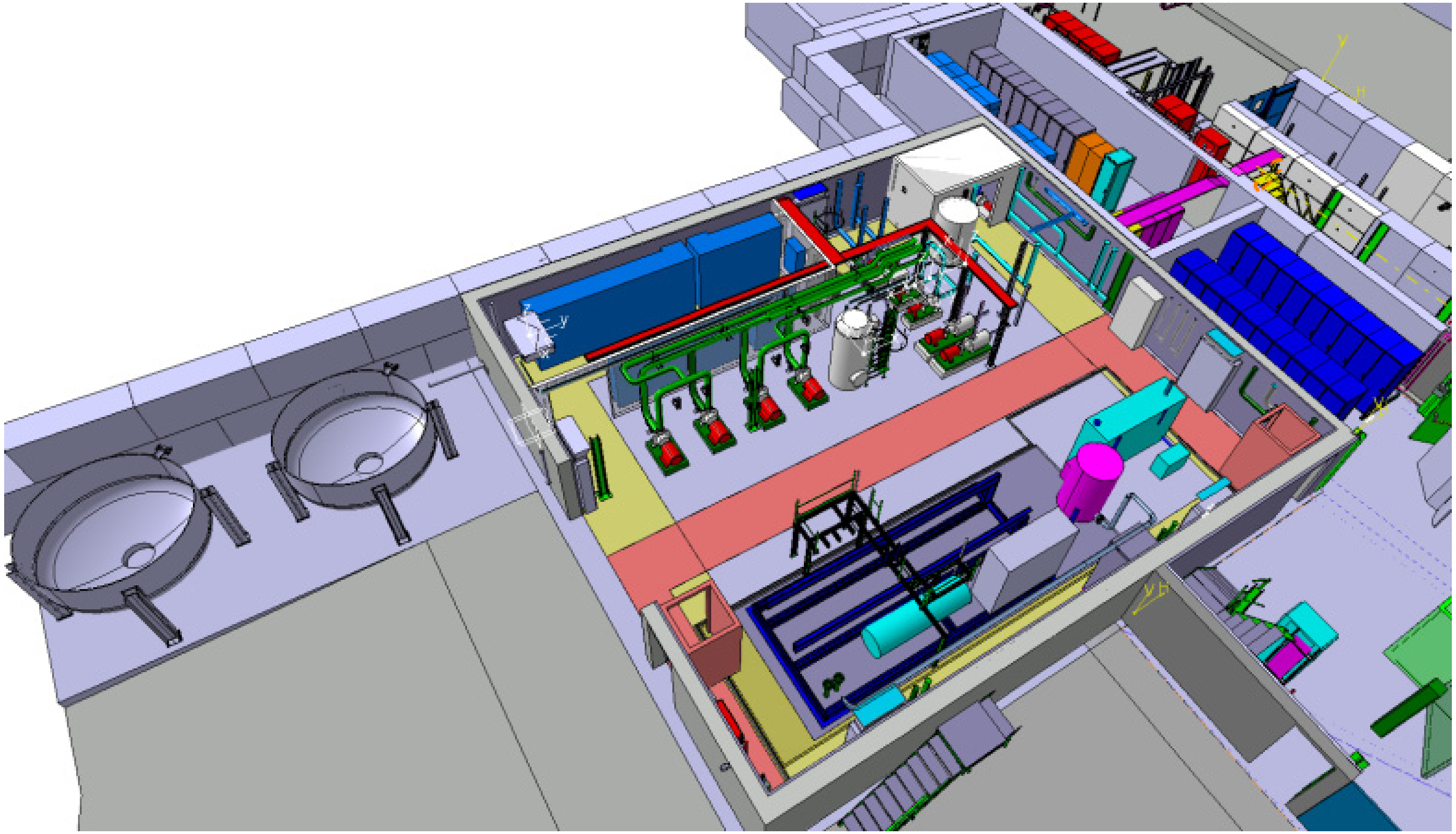
Assembly time of CM1: 30 weeks
Baseline : 27 weeks

- 1 May 2015: Assembly completed
- Mid-June 2015: Successfully cooled to 4.5K

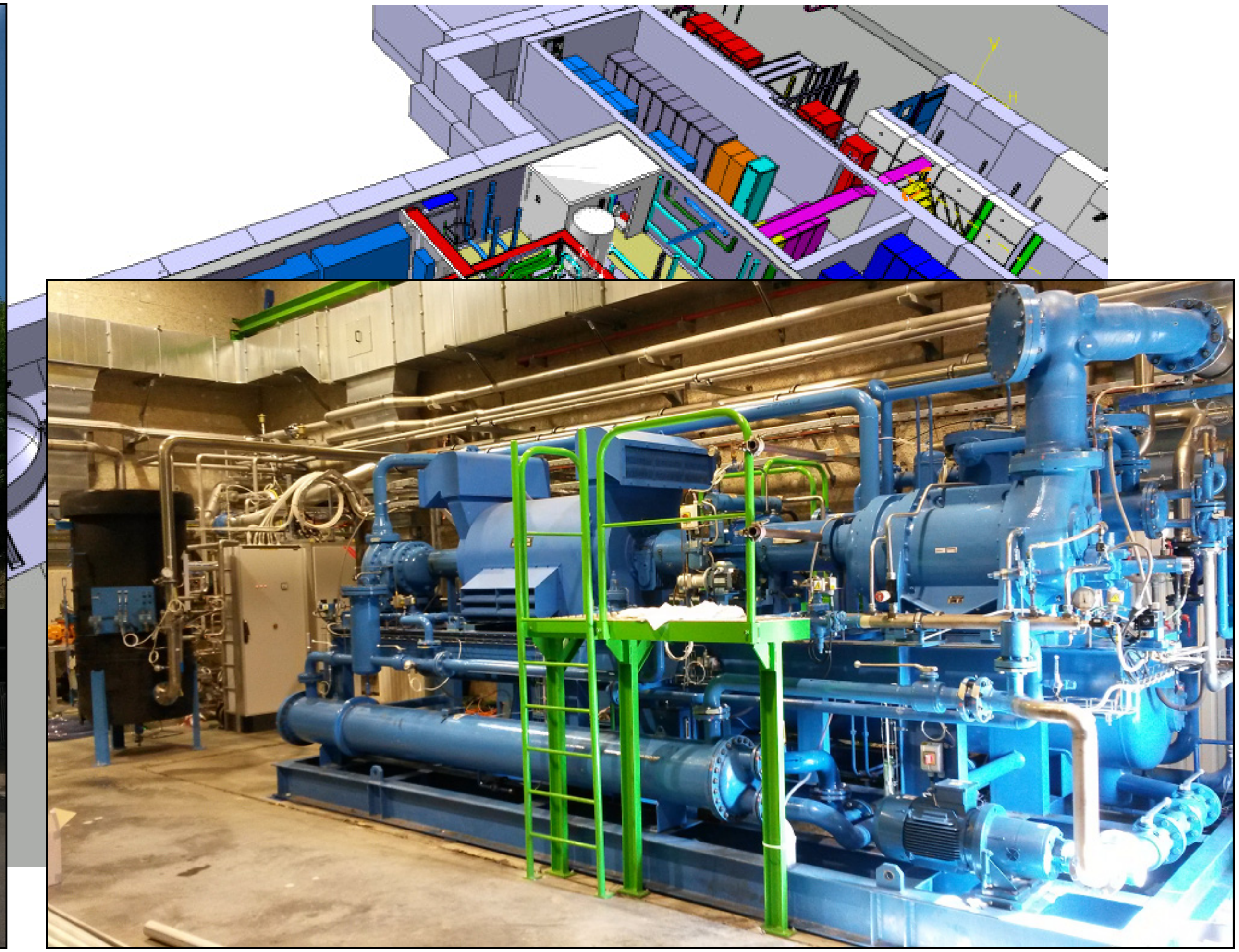
Machine Commissioning



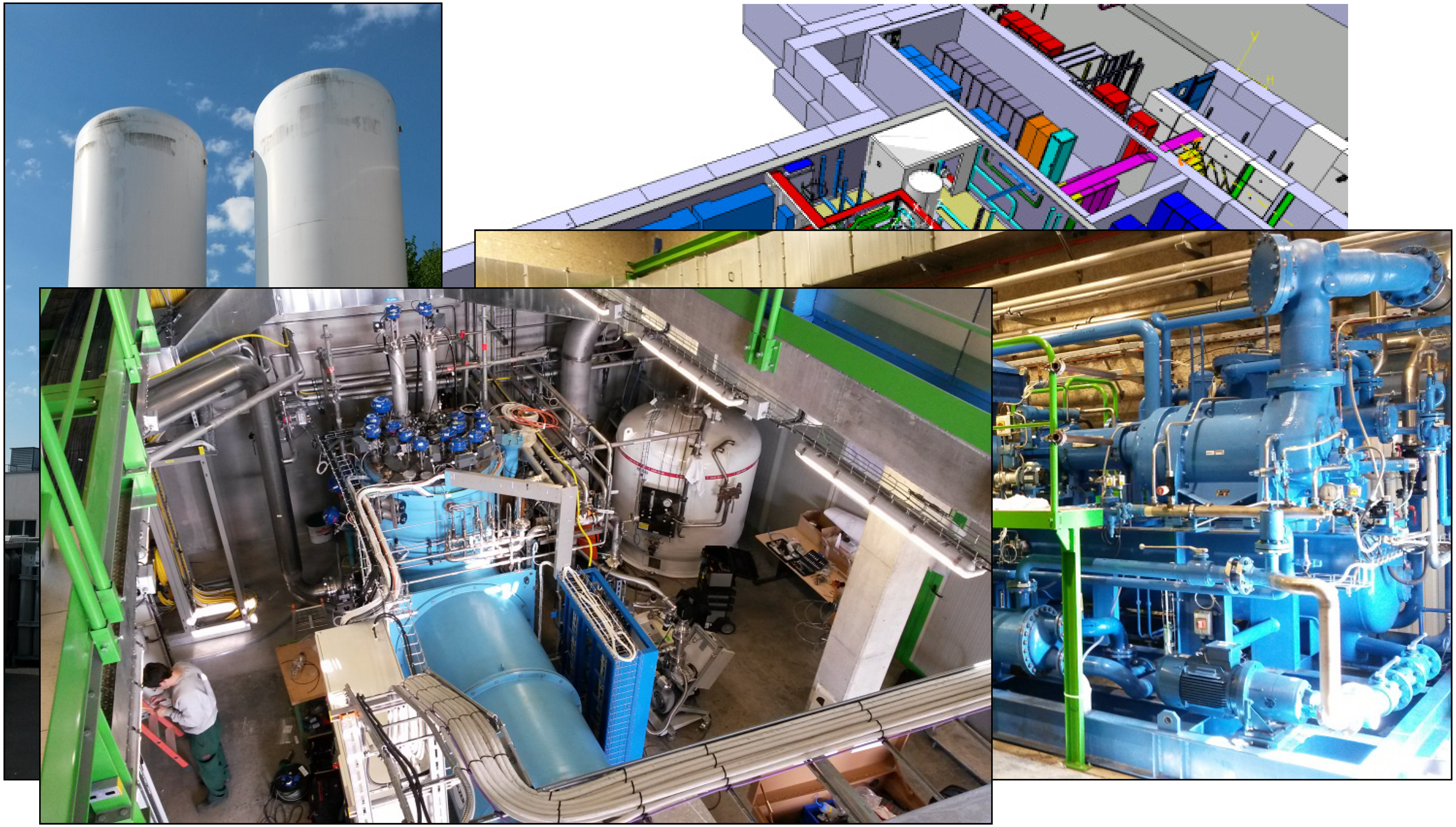
Cryogenic Plant



Cryogenic Plant

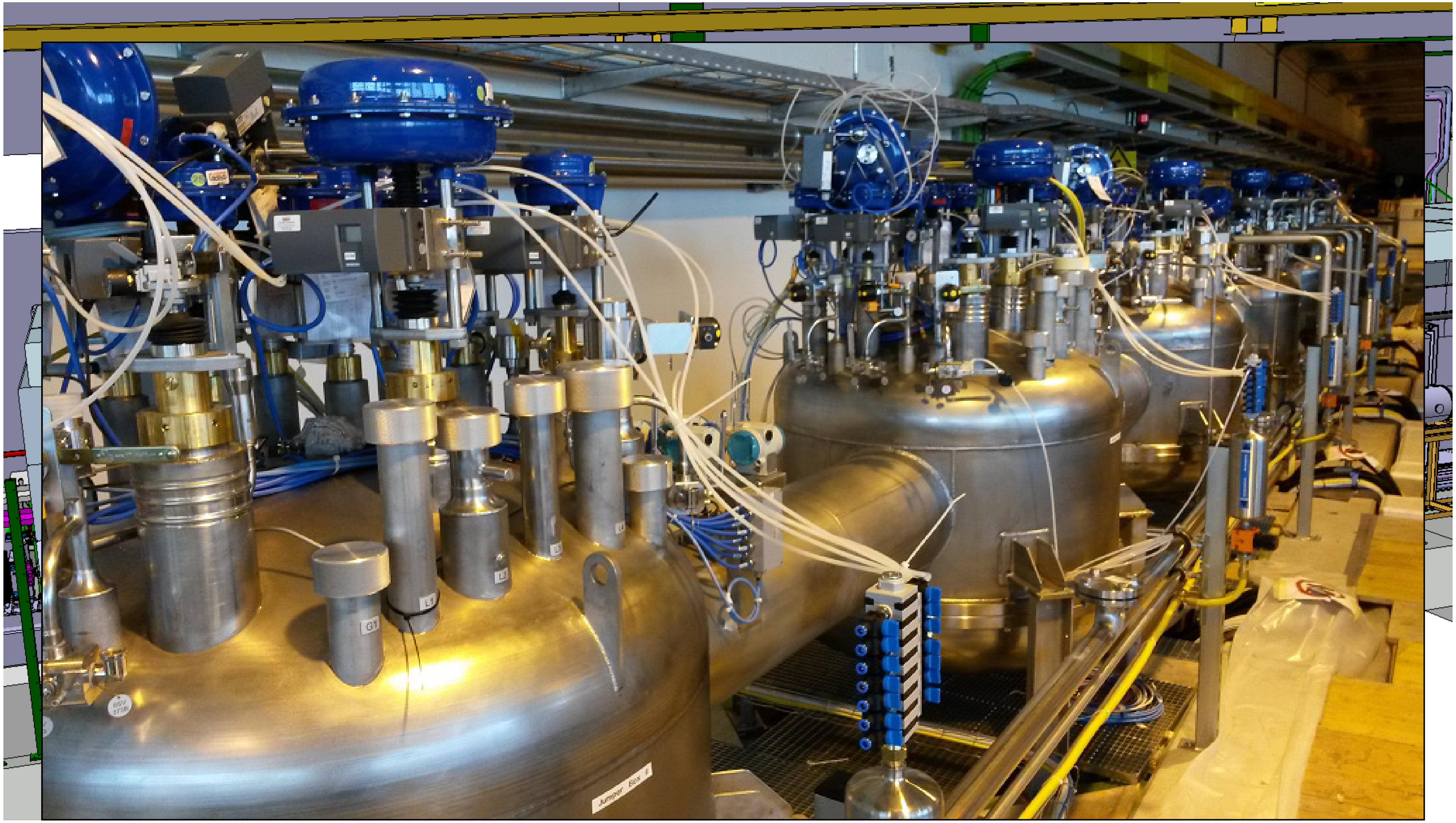


Cryogenic Plant



Cryo System: fully commissioned. Liquid He made.

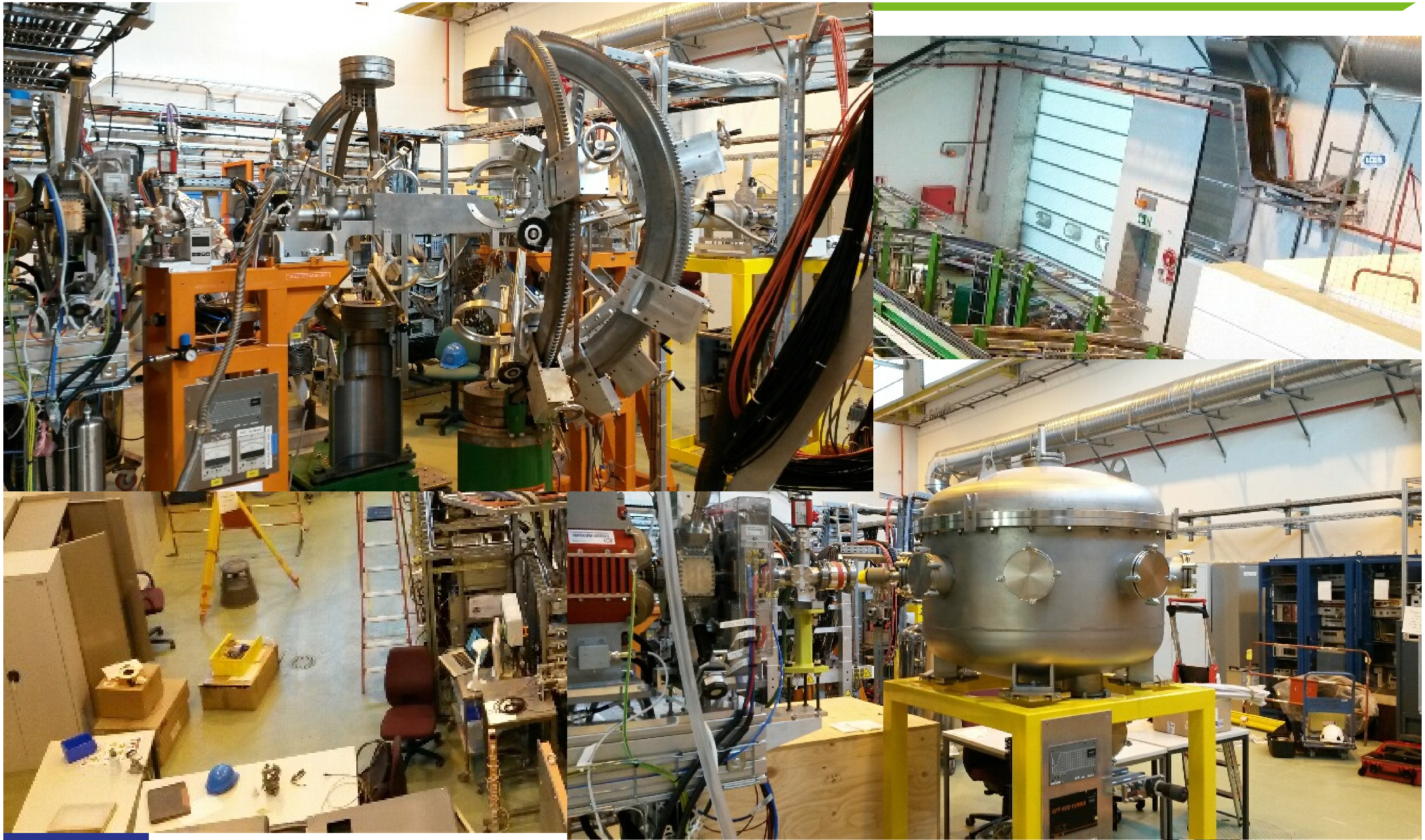
Cryo Distribution Line



Cryo Cold Line & Jumper Boxes instrumentation: installation finished
Pressure tests done on Cold Line.

HEBT Lines

HEBT Lines



HEBT commissioning: all circuits done

Slot name:	Magnet cable id.	Power Converter name	PC cable id.	PC IST	DC cable connection	Water check	ELQA OK/Not OK	WIC-magnet interlock test	WIC-PC interlock test	PC-circuit connection	PS setup 10% Inom	Performance test	I min op	I nominal	Released for OP
XT02.MB.0100	2731769A	XT02.RB.0100	2731836A										0	423	
XT02.MQ.0300	2731770A	XT02.RQ.0300	2731814A										2	132	
XT02.MB.0500	2731771A	XT02.RB.0500	2731837A										0	423	
XT02.MQ.0600	2731772A	XT02.RQ.0600	2731809A										2	132	
XT02.MQ.0700	2731773A	XT02.RQ.0700	2731810A										2	132	
XT02.MQ.0800	2731774A	XT02.RQ.0800	2731811A										2	132	
XT02.MC.0950	2731775A	XT02.RCH.0950	2731866A										0	45	
		XT02.RCV.0950	2731867A										0	45	

Slot name:	Magnet cable id.	Power Converter name	PC cable id.	PC IST	DC cable connection	Water check	ELQA OK/Not OK	WIC-magnet interlock test	WIC-PC interlock test	PC-circuit connection	PS setup 10% Inom	Performance test	I min op	I nominal	Released for OP
XT01.MB.0100	2731762A	XT01.RB.0100	2731842A										0	423	
XT01.MQ.0300	2731763A	XT01.RQ.0300	2731808A										2	132	
XT01.MB.0500	2731764A	XT01.RB.0500	2731841A	SPARE RPADA.TFU.SPARE.1							OK for operation (minor diag issue)		0	423	
XT01.MQ.0600	2731765A	XT01.RQ.0600	2731803A										2	132	
XT01.MQ.0700	2731766A	XT01.RQ.0700	2731804A										2	132	
XT01.MQ.0800	2731767A	XT01.RQ.0800	2731805A										2	132	
XT01.MC.0950	2731768A	XT01.RCH.0950	2731870A										0	45	
		XT01.RCV.0950	2731871A										0	45	

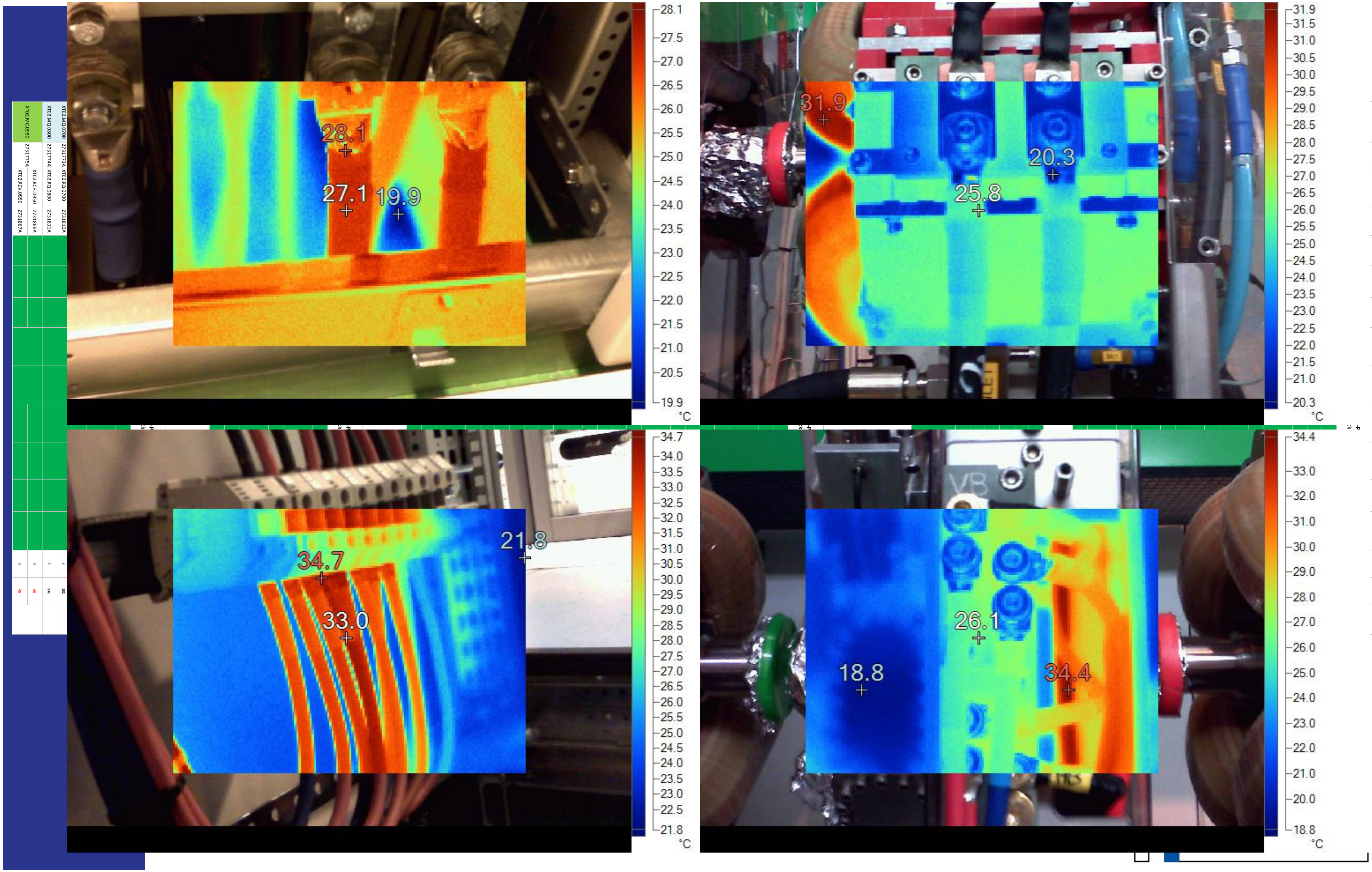
Slot name:	Magnet cable id.	Power Converter name	PC cable id.	PC IST	DC cable connection	Water check	ELQA OK/Not OK	WIC-magnet interlock test	WIC-PC interlock test	PC-circuit connection	PS setup 10% Inom	Performance test	I min op	I nominal	Released for OP
XT00.MQ.0100	2731739A	XT00.RQ.0100	2731823A										2	132	Operational
XT00.MQ.0200	2731740A	XT00.RQ.0200	2731826A										2	132	Operational
XT00.MQ.0300	2731741A	XT00.RQ.0300	2731829A										2	132	Operational
XT00.MC.0450	2731736A *	XT00.RCH.0450	2731847A										0	45	Operational
		XT00.RCV.0450	2731848A										0	45	
XT00.MQ.0500	2731742A	XT00.RQ.0500	2731832A										2	132	Operational
XT00.MQ.0600	2731743A	XT00.RQ.0600	2731821A										2	132	Operational
XT00.MC.0750	2731737A *	XT00.RCH.0750	2731850A										0	45	Operational
		XT00.RCV.0750	2731851A										0	45	
XT00.MQ.0800	2731744A	XT00.RQ.0800	2731822A										2	132	Operational
XT00.MQ.0900	2731745A	XT00.RQ.0900	2731824A										2	132	Operational
XT00.MC.1050	2731738A *	XT00.RCH.1050	2731852A										0	45	Operational
		XT00.RCV.1050	2731853A										0	45	
XT00.MQ.1100	2731746A	XT00.RQ.1100	2731825A										2	132	Operational
XT00.MQ.1200	2731747A	XT00.RQ.1200	2731806A										2	132	Operational
XT00.MC.1350	2731748A	XT00.RCH.1350	2731868A										0	45	Operational
		XT00.RCV.1350	2731869A										0	45	
XT00.MQ.1400	2731749A	XT00.RQ.1400	2731807A										2	132	Operational
XT00.MQ.1500	2731750A	XT00.RQ.1500	2731830A										2	132	Operational
XT00.MC.1650	2731751A	XT00.RCH.1650	2731862A										0	45	Operational
		XT00.RCV.1650	2731863A										0	45	
XT00.MQ.1700	2731752A	XT00.RQ.1700	2731831A										2	132	Operational
XT00.MQ.1800	2731753A	XT00.RQ.1800	2731812A										2	132	Operational
XT00.MC.1950	2731754A	XT00.RCH.1950	2731864A										0	45	Operational
		XT00.RCV.1950	2731865A										0	45	
XT00.MQ.2000	2731755A	XT00.RQ.2000	2731813A										2	132	Operational

Slot name:	Magnet cable id.	Power Converter name	PC cable id.	PC IST	DC cable connection	Water check	ELQA OK/Not OK	WIC-magnet interlock test	WIC-PC interlock test	PC-circuit connection	PS setup 10% Inom	Performance test	I min op	I nominal	Released for OP
XSEP.MB.0100	2731723A	XSEP.RB.0100	2731875A										0		
XLBFQ.MQ1.1100		XLBFQ.RQ1.1100	2731800A										2	200	Operational
XLBFQ.MQ1.1200	2731724A	XLBFQ.RQ1.1200	2731801A										2	200	Operational
XLBFQ.MQ1.1300		XLBFQ.RQ1.1300	2731802A										2	200	Operational
XLHS.MQ.0300		XLHS.RQ.0300	2731794A										2	200	Operational
XLHS.MQ.0400	2731725A	XLHS.RQ.0400	2731795A										2	200	Operational
XLHS.MQ.0500		XLHS.RQ.0500	2731796A										2	200	Operational
XLHS.MQ.0600		XLHS.RQ.0600	2731792A										2	150	Operational
XLHS.MQ.0700	2731726A	XLHS.RQ.0700	2731793A										2	145	Operational
XLHS.MQ.0800		-	.												Operational
XLHS.MQ.0900		XLHS.RQ.0900	2731789A										2	175	Operational
XLHS.MQ.1000	2731727A	XLHS.RQ.1000	2731790A										2	195	Operational
XLHS.MQ.1100		XLHS.RQ.1100	2731791A										2	175	Operational
XLTGP.MQ.0110		XLTGP.RQ.0110	2731797A	[illegible]									2	170	Operational
XLTGP.MQ.0120	2731728A	XLTGP.RQ.0120	2731798A										2	170	Operational
XLSGP.MQ.0100		XLSGP.RQ.0100	2731786A										2	195	Operational
XLSGP.MQ.0200	2731729A	XLSGP.RQ.0200	2731787A										2	190	Operational
XLSGP.MQ.0300		XLSGP.RQ.0300	2731788A										2	170	Operational
XLSGP.MC.0400	2731730A	XLSGP.RCH.0400	2731877A										0		
		XLSGP.RCV.0400	2731876A										0		
XLSGP.MQ.0600		XLSGP.RQ.0600	2731783A										2	200	Operational
XLSGP.MQ.0700	2731731A	XLSGP.RQ.0700	2731784A										2	170	Operational
XLSGP.MQ.0800		XLSGP.RQ.0800	2731785A										2	200	Operational
XLN2.MC.0200	2731733A	XLN2.RCH.0200	2731872A										2	45	Operational
		XLN2.RCV.0200	2731873A										0	45	
XLN3.MC.0200	2731734A	XLN3.RCH.0300	2731874A										0	45	Operational
		XLN3.RCV.0300	2731844A										0	45	
XLN4.MC.0200	2731735A	XLN4.RCH.0400	2731845A										0	45	Operational
		XLN4.RCV.0400	2731846A										0	45	

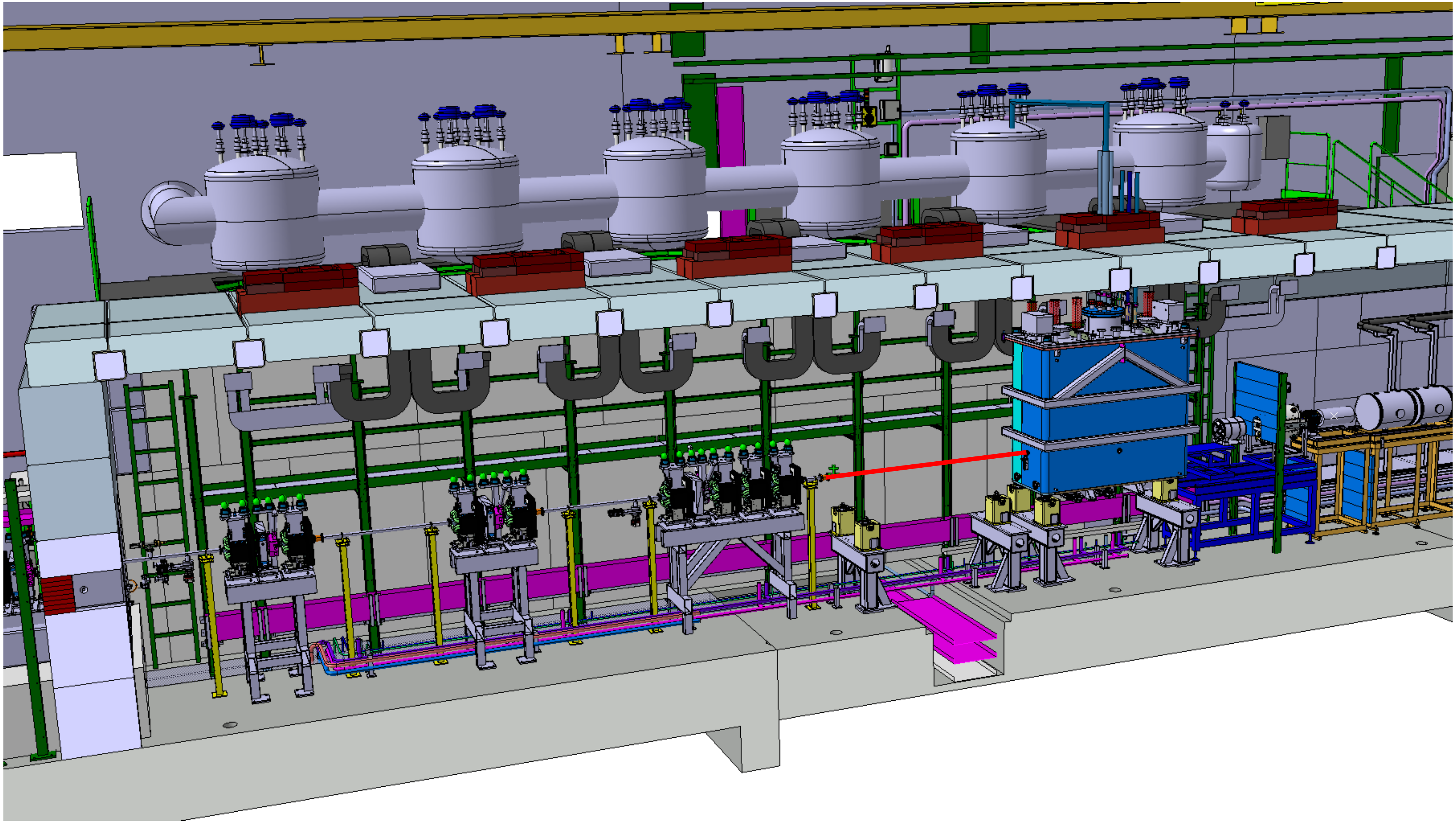
[illegible]	[illegible]
[illegible]	[illegible]

ISOLDE

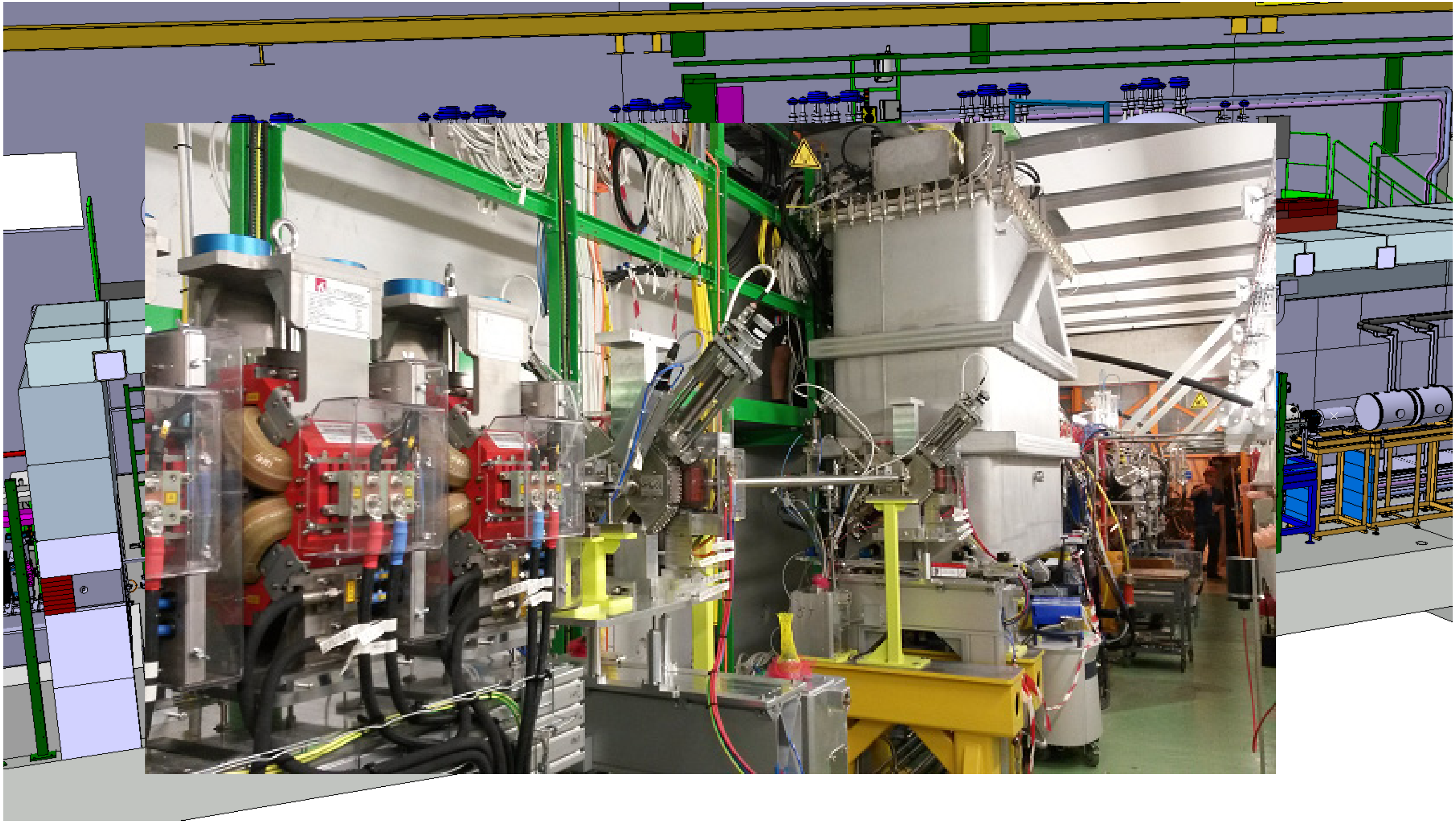
HEBT commissioning: all circuits done



SC Linac

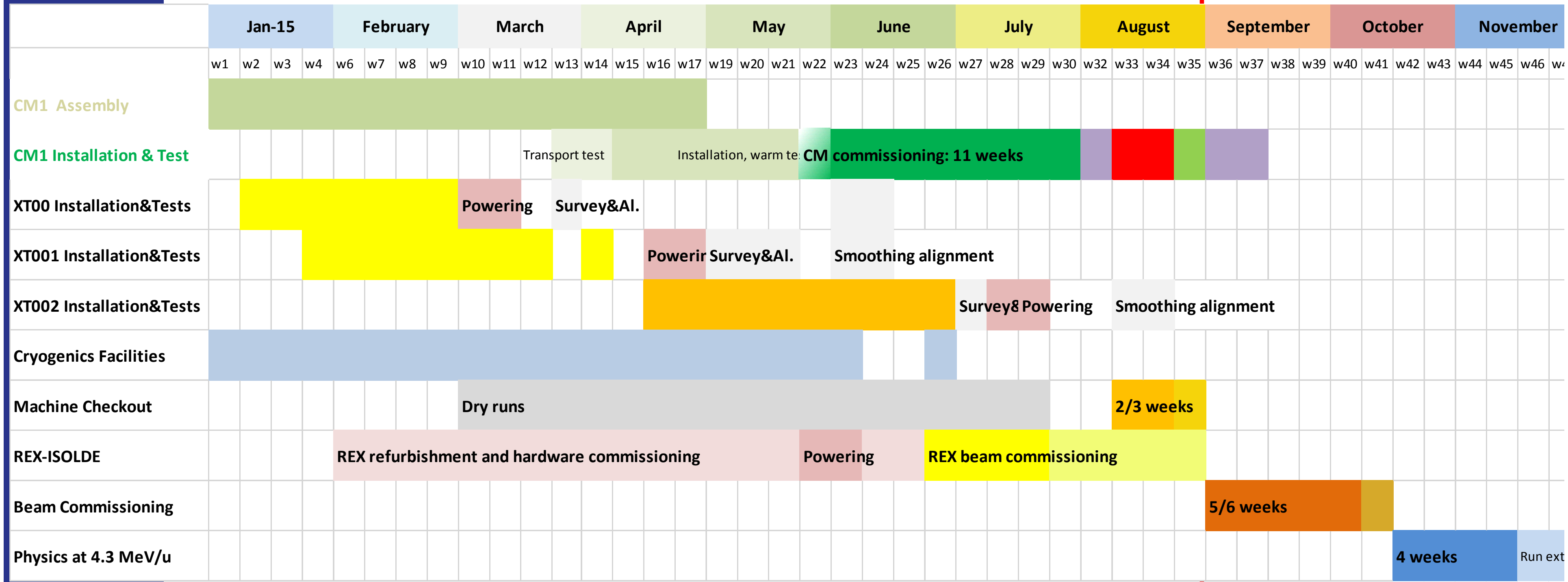


SC Linac

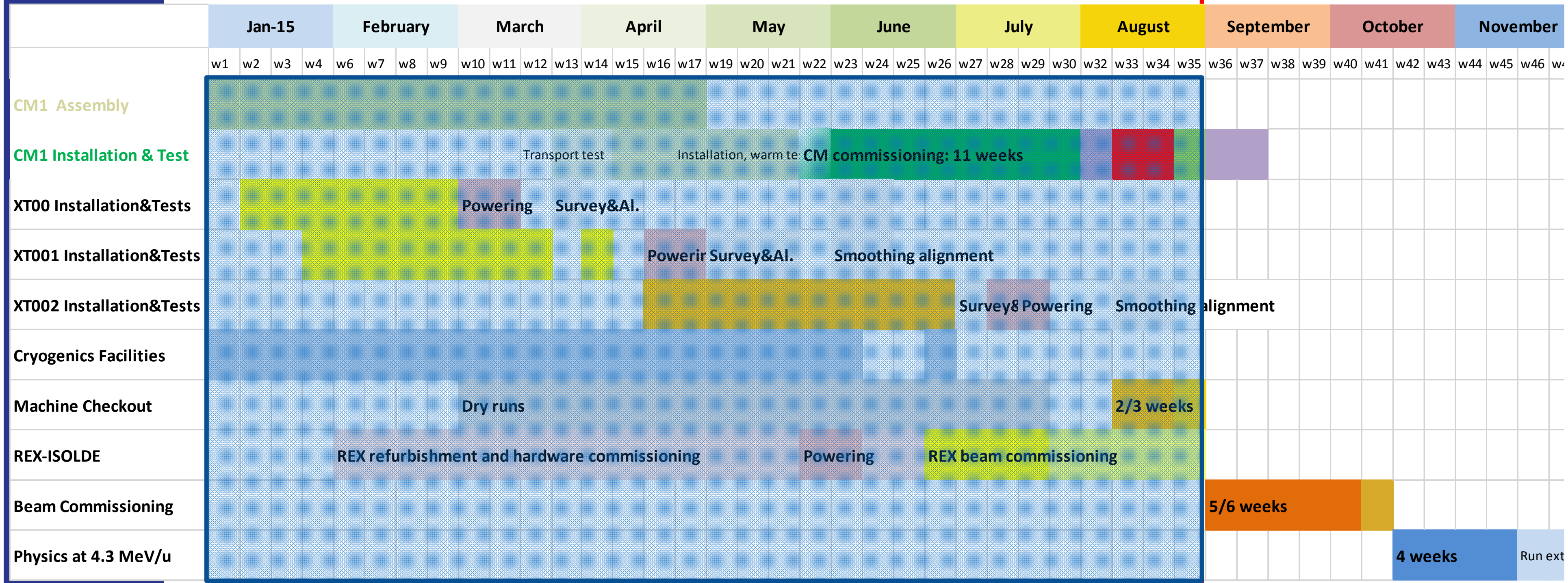


Cryo-Module 1 installed on Saturday 2nd May.
Cool-down: mid-June to mid-July

HIE ISOLDE roadmap 2015



HIE ISOLDE roadmap 2015



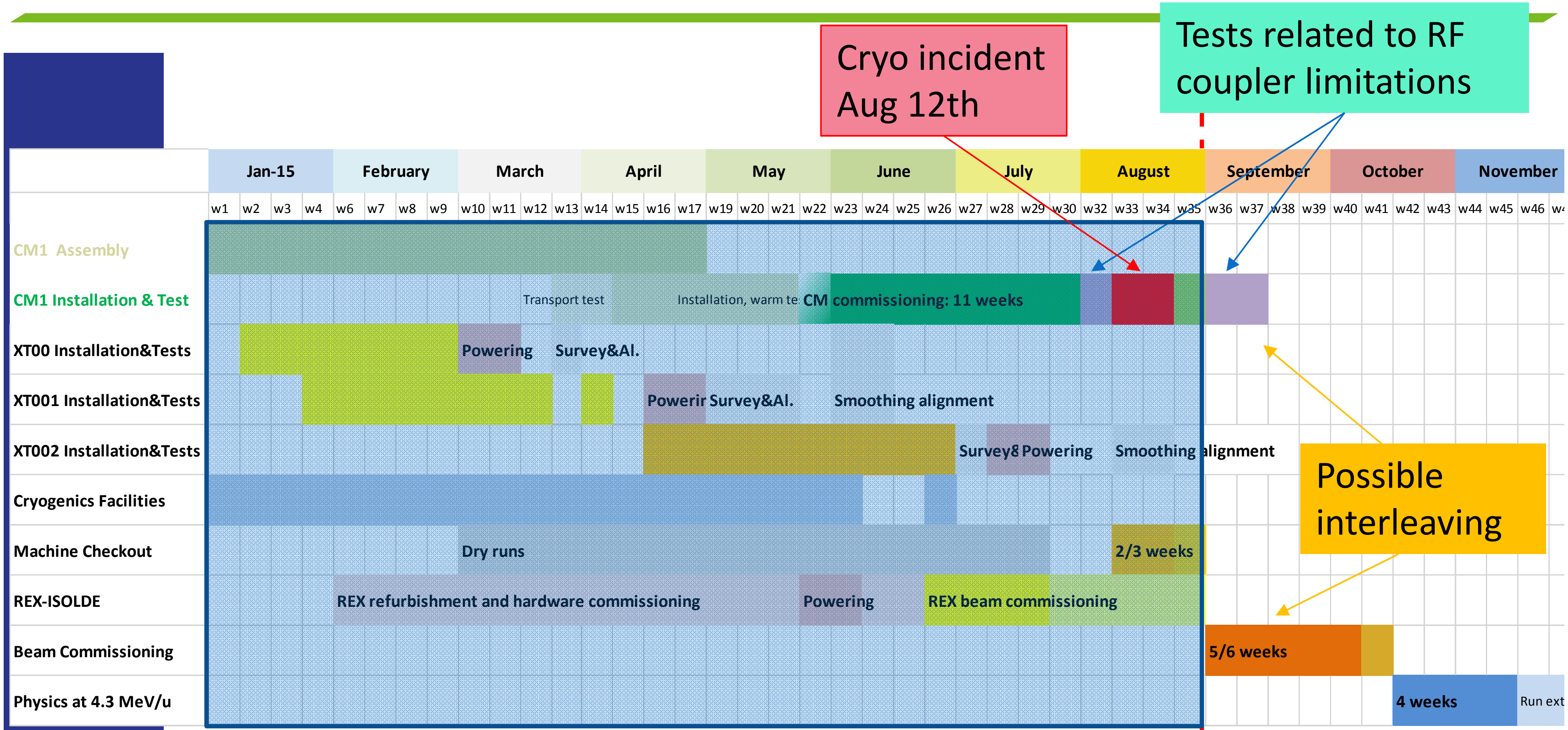
All HEBT hardware commissioned on schedule

CM1 cooled down and hardware tests complete

Issue with power coupler→ looking for an operational point

Cryogenics Incident on 12th August

HIE ISOLDE roadmap 2015



All HEBT hardware commissioned on schedule

CM1 cooled down and hardware tests complete

Issue with power coupler→ looking for an operational point

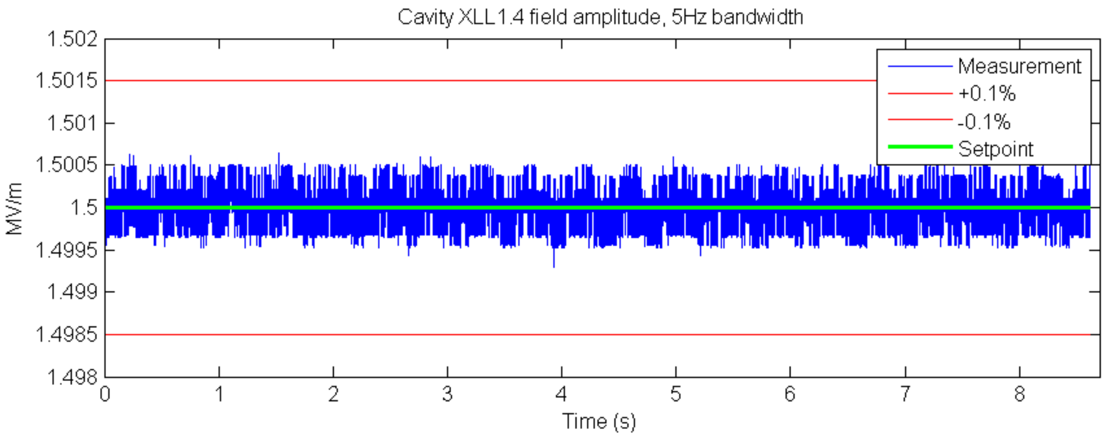
Cryogenics Incident on 12th August

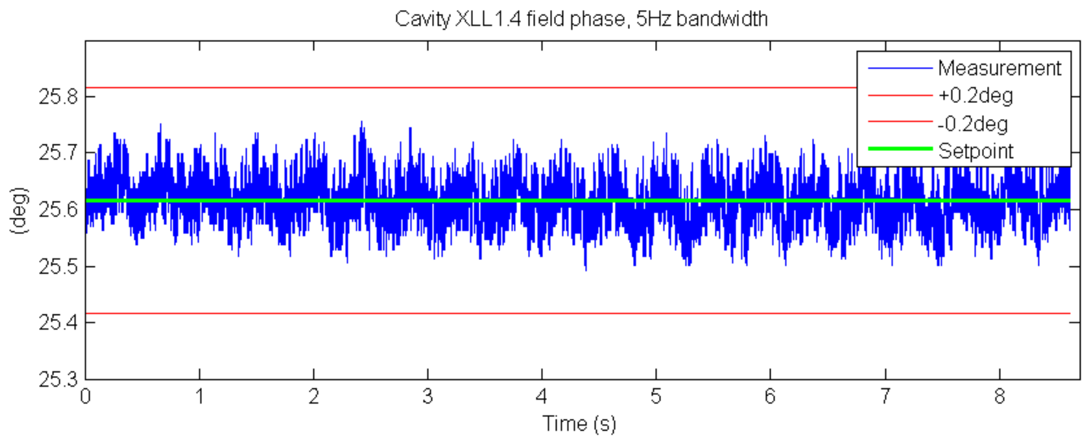
CM1 HW commissioning: main results

- ✓ Cryogenics: ~100% availability over 2 months, then problems (4 CB stops + incident)
- ✓ Vacuum: in range of 10^{-11} mbar
- ✓ Cold alignment: ~1.2 mm vertical offset corrected
- ✓ Cavity conditioning OK, only CAV2 has FE
- ✓ Cavity tuning OK: all cavities at 101.28 MHz, mid range
- ✓ Cavity performance: 6 MV/m/CAV with less than 50 W
- ✓ Serious issue with power coupler identified
- ✓ Solenoid performance: OK, “feature” under control
- ✓ Combined powering cavities and solenoid OK
- ✓ Static heat load measured within specs (~ 10 W)
- ✓ LLRF loops working well beyond specs at 2 MV/m

HIE-ISOLDE LLRF status (as of 27.8.2018)

- Loops at nominal gain on a cavity with 5 Hz bandwidth, 1.5 MV/m
- Amplitude noise ~0.1%$_{pk\text{-}pk}$, phase noise ~0.2°$_{pk\text{-}pk}$





D. Valuch

REX Commissioning

- 2.5 < A/Q < 4.5 acceptance
- Beam from 5 keV/u to ~2.85 MeV/u
- RF frequency: 101.28 MHz (9gap: 202.56 MHz)

RF Systems:

RF Structure	Final Energy [MeV/u]
4-rod RFQ	0.3
Buncher	0.3
IHS	1.2
7gap 1	1.55
7gap 2	1.88
7gap 3	2.2
9gap	2.85

Magnets:

Triplets	6
Doublets	1
Steerers	1H, 1V

Power converters:

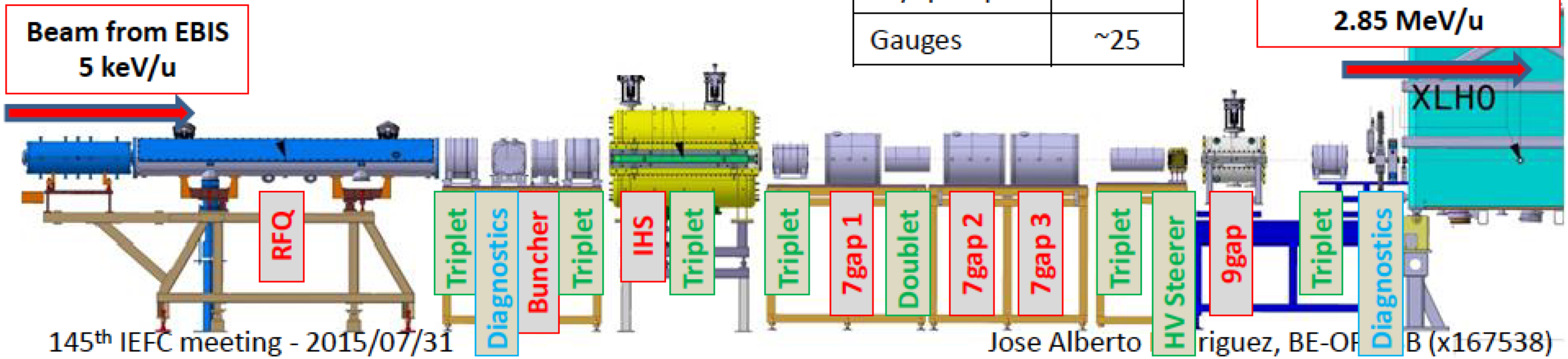
200 A, 50 V	20 (1 spare)
bipolar 3.5 A	2

Diagnostics:

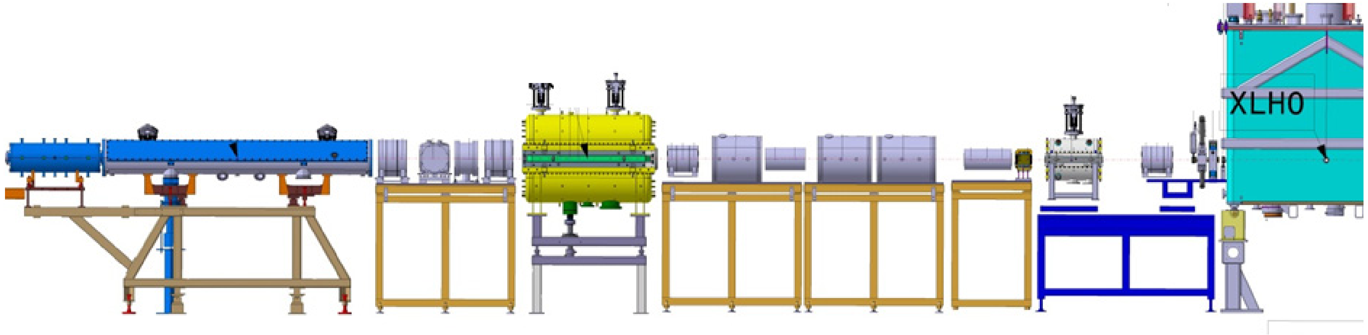
REX	HIE-ISOLDE
FC MCP Collimator apertures Beam attenuators	FC Si detector Scanning Slits Collimator apertures

Vacuum (incl. low energy):

Sectors	10
Turbopumps	~20
Cryopumps	3
Gauges	~25

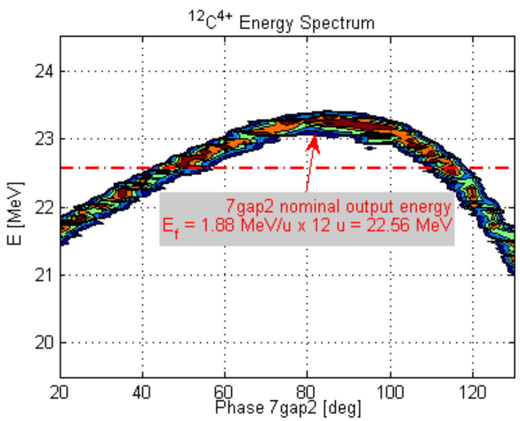


REX commissioning highlights

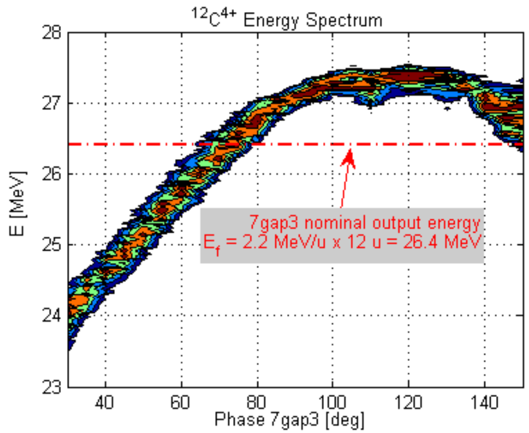


- All vacuum, magnets, power converters and diagnostics systems ready
- All RF systems ready for commissioning with beam
- Beam commissioning well advanced. Achieved beam up to 2.2 MeV/u
- Phasing of 9-gap completed this week (to reach 2.85 MeV/u)

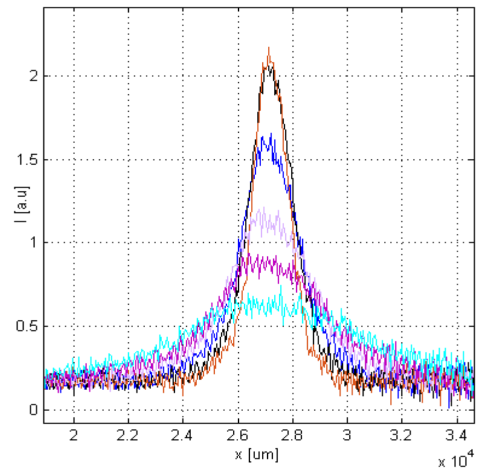
Phasing of the 7gap2 structure



Phasing of the 7gap3 structure



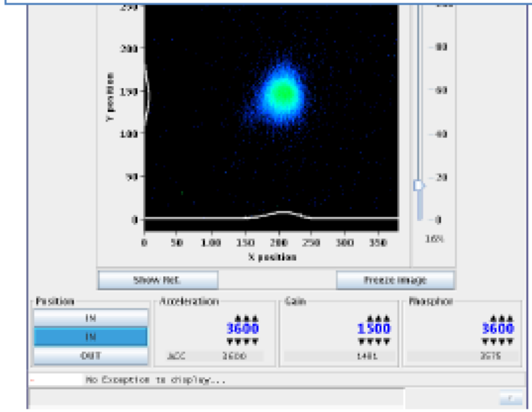
Quad scan using scanning slits (I = 15 pA)



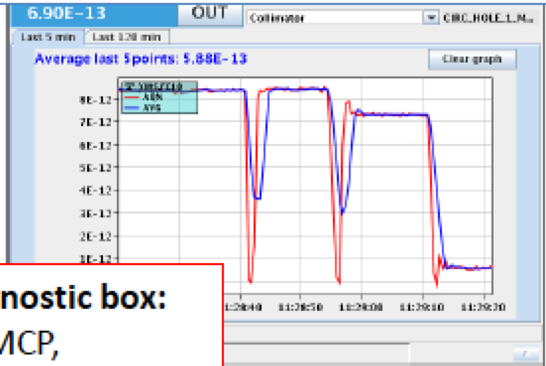
REX Beam Commissioning

- ✓ Commissioning with beam started on wk. 25 (June 16th)
- ✓ Beam with an A/Q=4.0 was accelerated to 0.3 MeV/u (RFQ output energy)
- ✓ We reached the first diagnostic box and commissioned the FC, MCP and collimator wheel on wk. 25
- ✓ Beam transmission through RFQ for different power levels on wk. 26

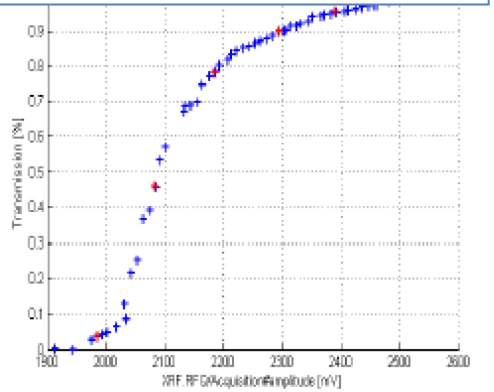
MCP image of the beam after the RFQ



Beam in FC after RFQ for different collimator aperture sizes (15, 5, 3 and 1 mm)

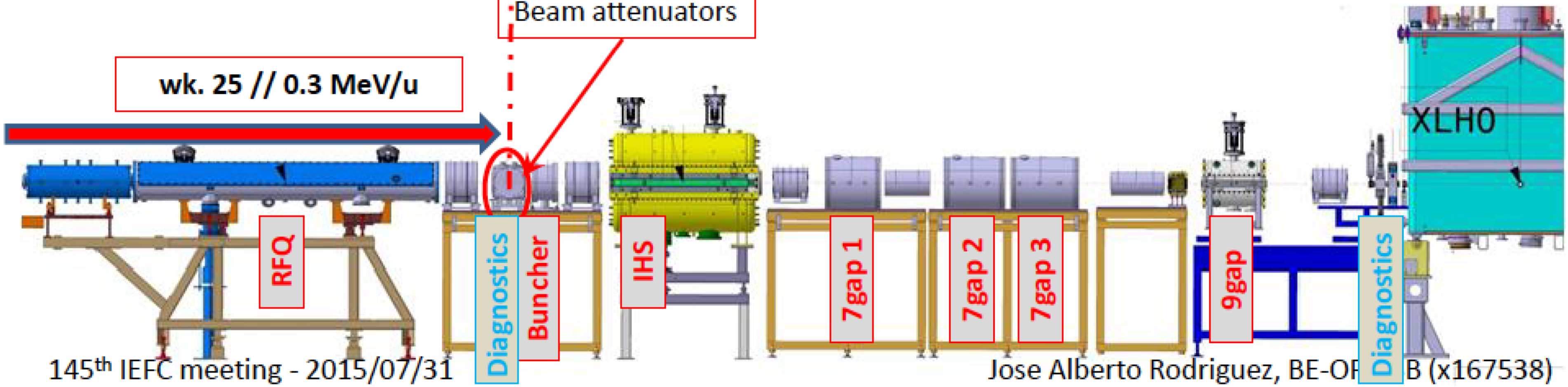


Beam transmission thru the RFQ vs RF power for A/Q=4.0



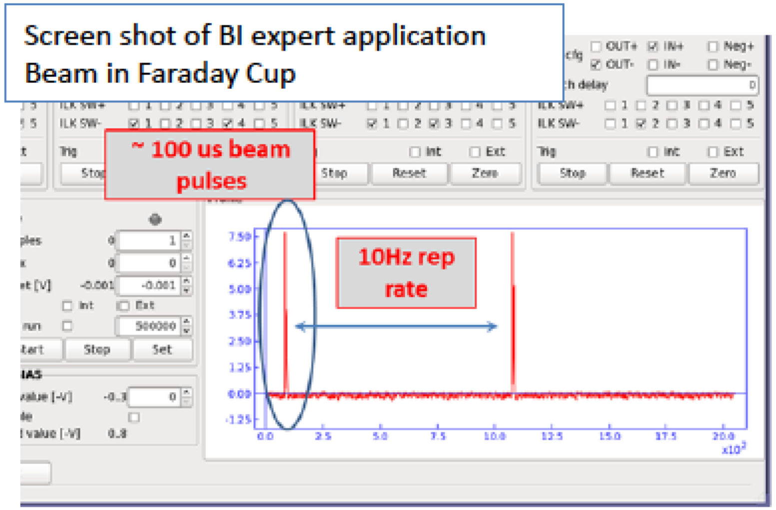
Diagnostic box:
FC, MCP,
Collimator Wheel
Beam attenuators

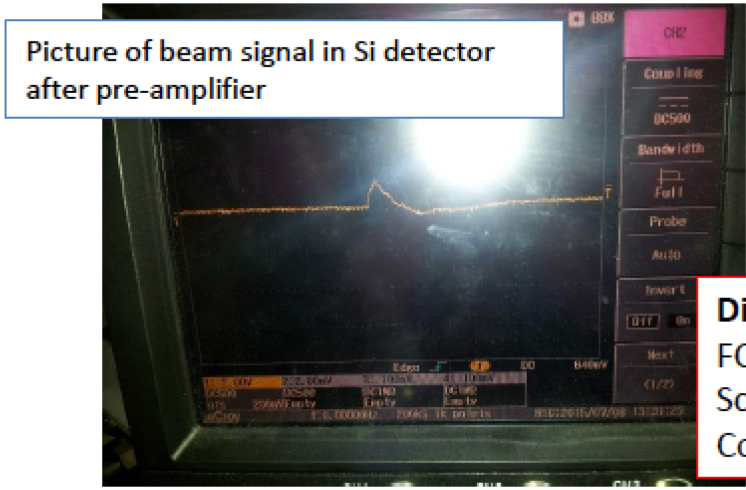
wk. 25 // 0.3 MeV/u

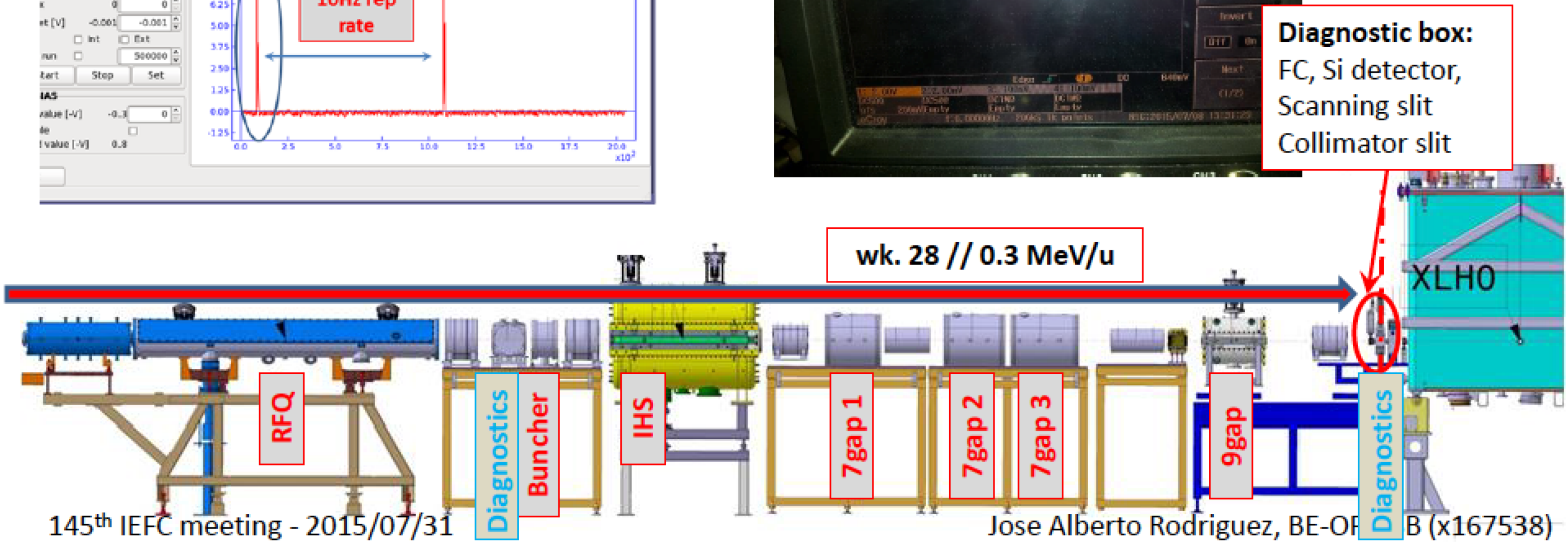


REX Beam Commissioning

- ✓ First diagnostics box of HIE-ISOLDE installed at the end of wk. 27
- ✓ First beam in FC and to the Si detector (used for relative beam energy measurements) with 0.3 MeV/u energy on wk. 28







Experiments for 2015 (wk.42)

- IS557: Coulomb excitation ^{74}Zn - ^{80}Zn (N=50): probing the validity of the shell-model descriptions around ^{78}Ni on experimental station XT01 using MINIBALL Ge detector array
- IS561: Transfer reactions at the neutron dripline with triton target on experimental station XT02 using Scattering chamber
- IS563: Coulomb excitation of 182-184Hg: Shape coexistence in the neutron-deficient lead region on experimental station XT01 using MINIBALL Ge detector array + SPEDE spectrometer

Overall Summary

- Plenty of challenging physics waiting for the starting of HIE-ISOLDE!
- Many new groups and devices have been attracted by the increase of energy of the post-accelerated beams.
- The physics cases approved expand over the wide range of post-accelerated beams available at ISOLDE with more than six hundred shifts approved for day one physics.
- Enormous progress since April 2015
    - Infrastructure in place
    - HEBT hardware commissioning completed
    - CM1 installed, cooled and powered. Full test campaign carried out
    - REX beam commissioning well advanced
    - Beam commissioning of SC Linac is possible in September
- **However: the results of hardware tests (problem on RF couplers) highlighted that CM1 is not fully qualified for sustained operation as planned**
- **Agree with Collaboration on a common scope for 2015 Physics run**

Thank you for your attention