Status of the HIE-ISOLDE Project

Richard Catherall
ISOLDE Technical Coordinator
And on behalf of Yacine Kadi
Project Leader
EMIS 2012 Matsue, Japan
2nd – 7th December 2012

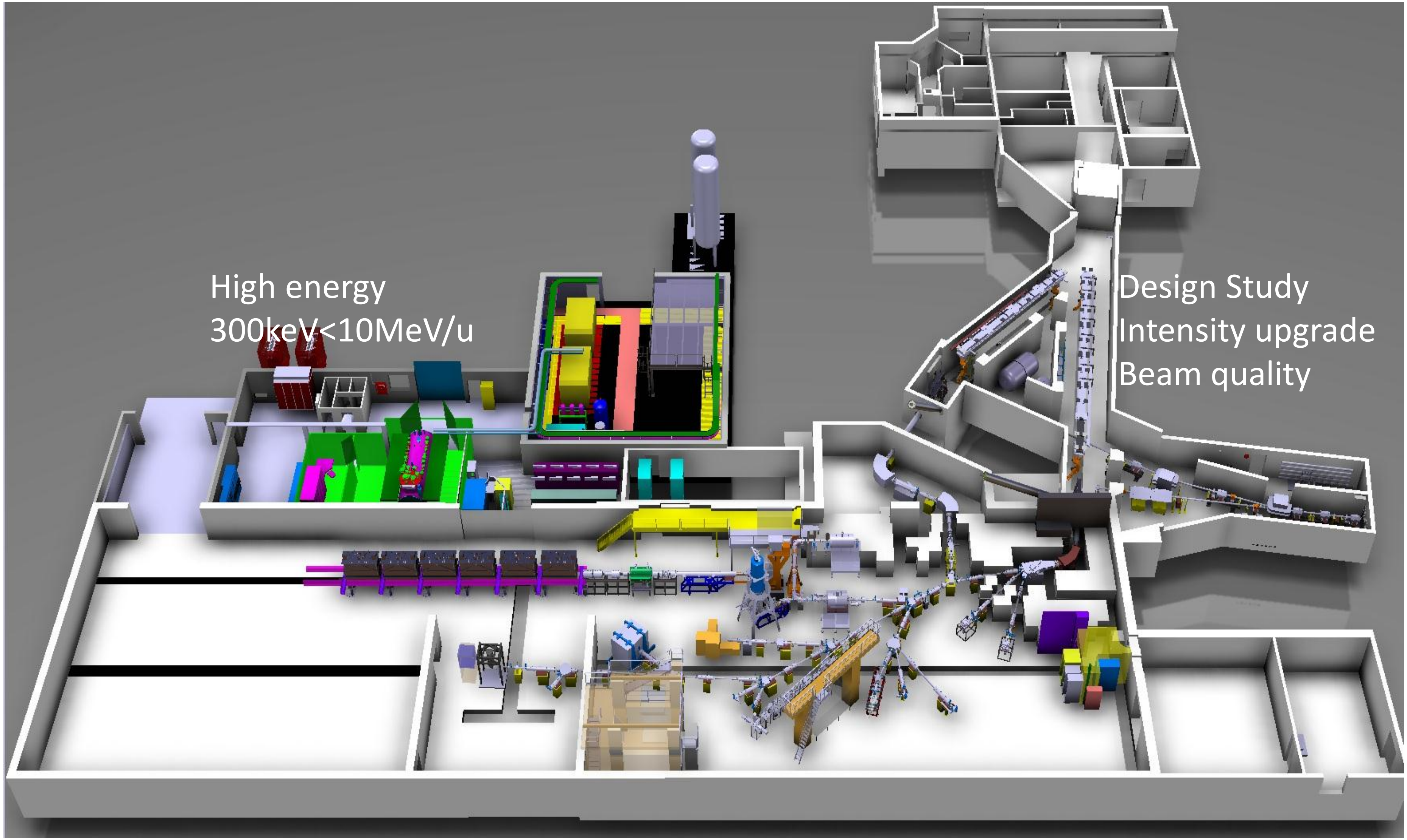
Outline

- Scope
  - Motivation
  - SC Linac Installation Timeline
- High Energy Upgrade
  - RF Cavity status
  - High Beta Cryomodule
  - HEBT
    - Alignment
    - Beam instrumentation
  - Safety
- Design Study
  - High Intensity Issues
  - Beam Quality
- TSR@ISOLDE

Motivation & History

- **The need in Europe of an upgraded ISOLDE facility was established in the NuPAC meeting in October 2005 -> request from users:**
  - Higher energy for the post-accelerated beam
  - More beams (Intensity wise and different species)
  - Better beams (High purity beams, low emittances, more flexibility in the beam parameters)
- **The HIE-ISOLDE proposal was presented to the Research Board in June 2006.**
- **The proposal was reviewed by the SPC in 2007 for which CERN requested an important external contribution.**
- **An R&D programme was set up in 2008 (externally funded) for starting the overall study and the R&D on superconducting RF cavities.**
- **A new proposal was presented to Research Board in Sep. 2009**
- **Project approved in Nov. 2009 without resources !**
- **Resources for the project approved by CERN Council in June 2010**

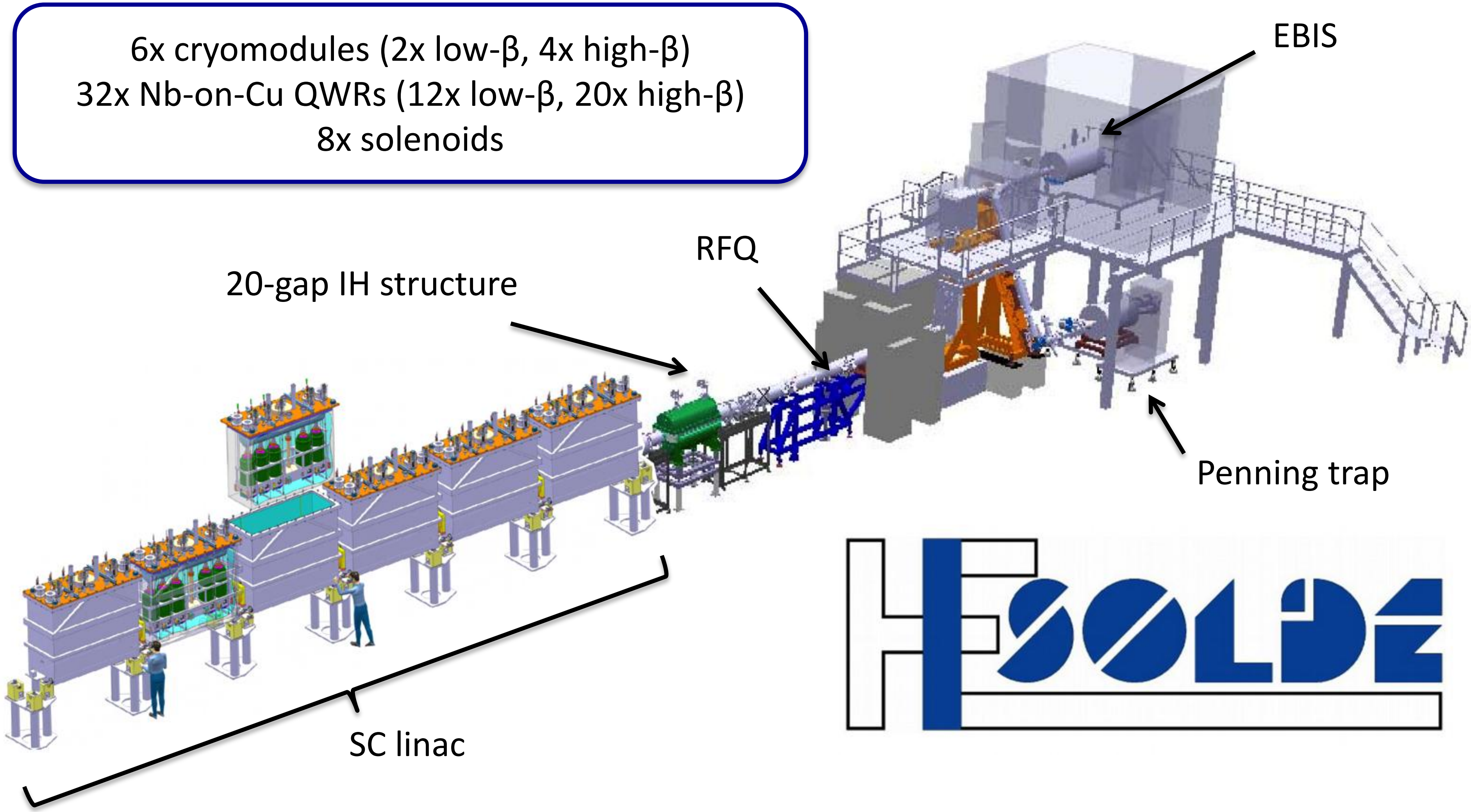
High Intensity and Energy - ISOLDE



High ENERGY:

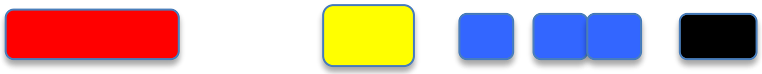
40 MV SC post-accelerator

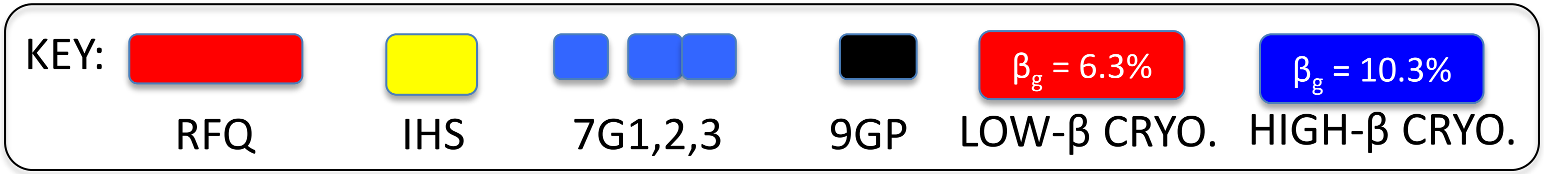
6x cryomodules (2x low-β, 4x high-β)
32x Nb-on-Cu QWRs (12x low-β, 20x high-β)
8x solenoids



Staged Installation of SC Linac

- REX accelerator (existing): W = 3 MeV/u





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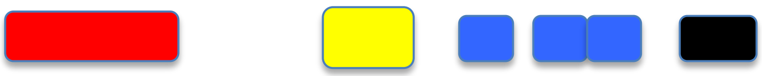


- HIE Stage 1 (2015): W = 5.5 MeV/u

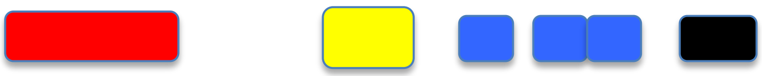
2x cryomodules
10x QWRs
2x solenoids

Cryo-line "jumper" positions

KEY: RFQ | IHS | 7G1,2,3 | 9GP | β_g = 6.3% LOW-β CRYO. | β_g = 10.3% HIGH-β CRYO.

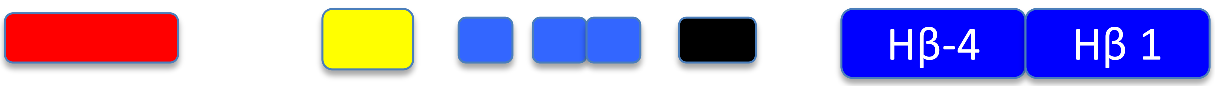
Staged Installation of Linac

- REX accelerator (existing): W = 3 MeV/u

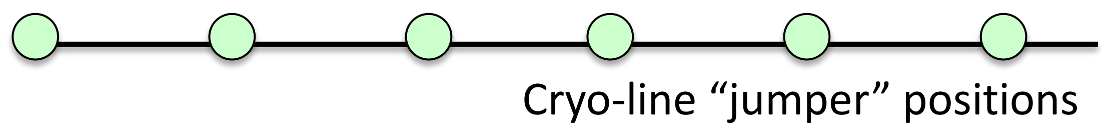


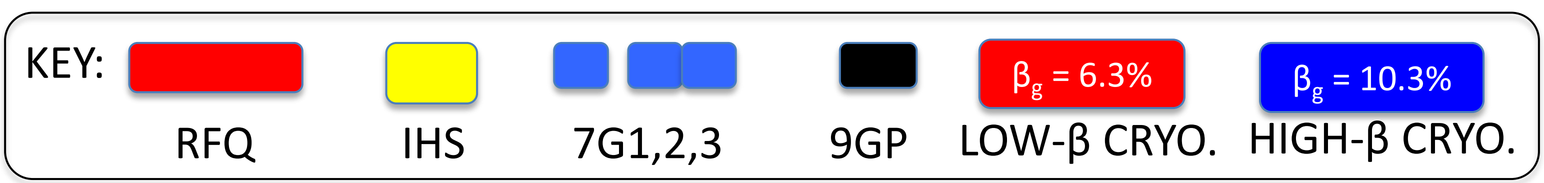
4x cryomodules
20x QWRs
4x solenoids

- HIE Stage 1 (2015): W = 5.5 MeV/u



- HIE Stage 2a (2016): W = 10 MeV/u

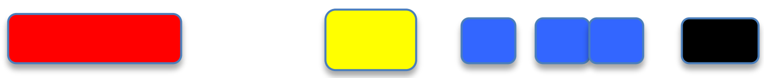




Staged Installation of Linac

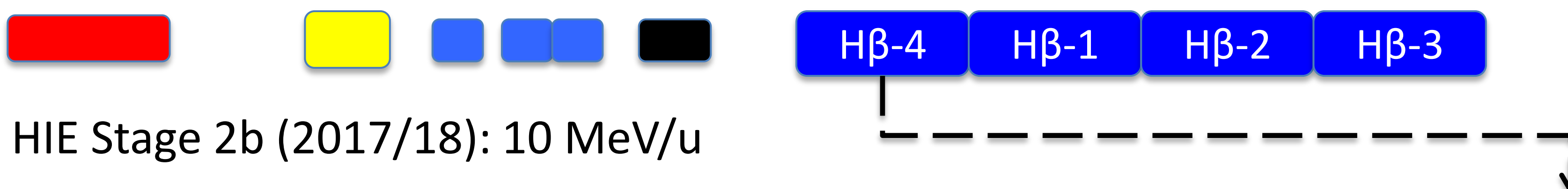
6x cryomodules
32x QWRs
8x solenoids

- REX accelerator (existing): W = 3 MeV/u

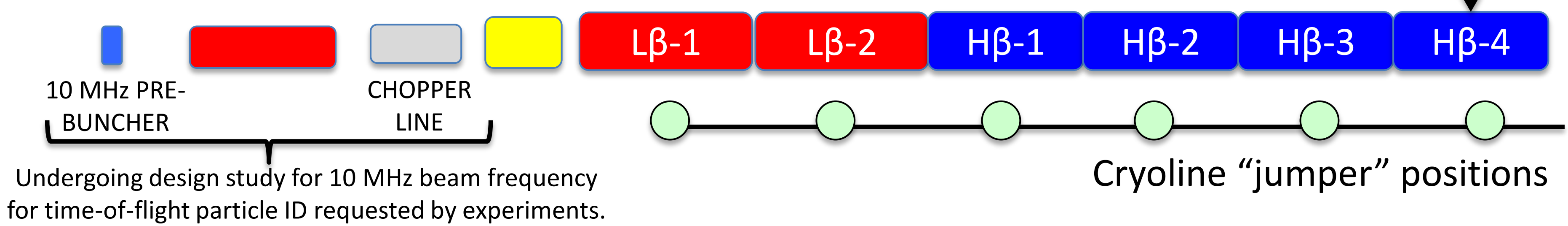


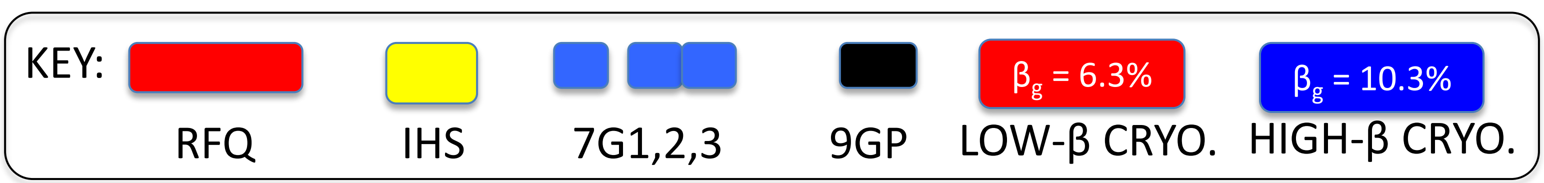
- HIE Stage 1 (2015): W = 5.5 MeV/u

- HIE Stage 2a (2016): W = 10 MeV/u

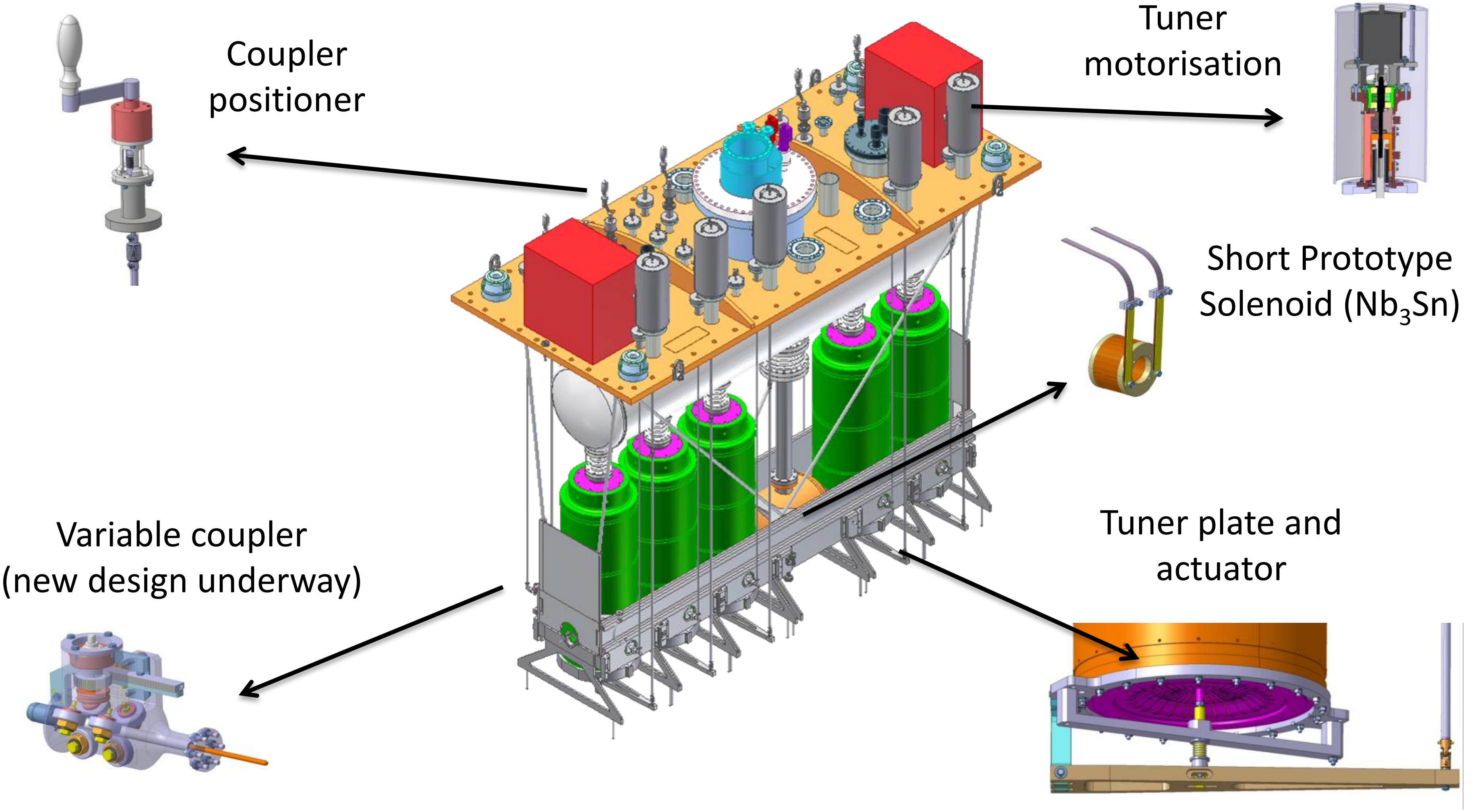


- HIE Stage 2b (2017/18): 10 MeV/u



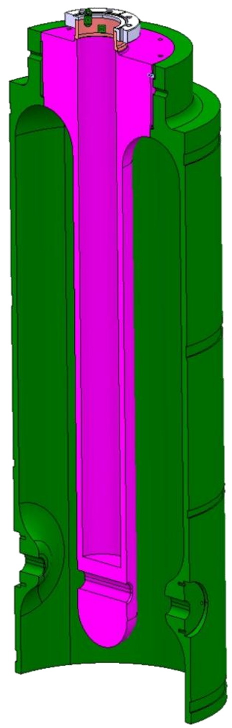


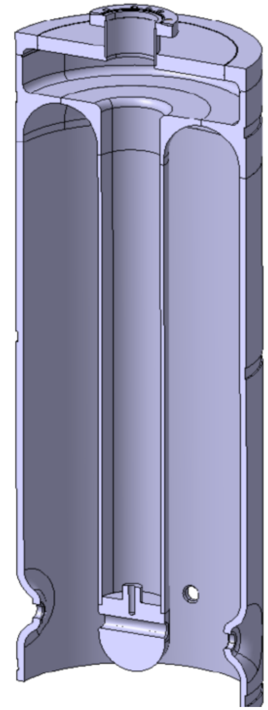
High-β Cavities



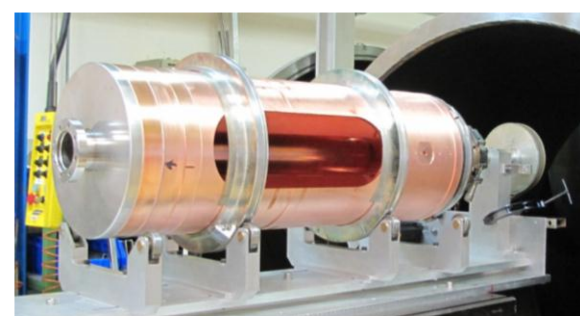
Cavity prototypes designed and built at CERN

- 3 (almost 4) units "old design": Q1-Q2-Q3-(Q5)
  (rolling, EB welding, deep-drawing)
- 1 new design: QP1
  (3D machining in bulk copper, EB welding)





- 1 cavity (Q4) manufactured for sputtering tests on samples



New design chosen: precision machining of two parts from massive, forged copper blocks; thermal shrinkage assembly and EB welding from inside

→ **Aim to have <u>5 coated cavities cold tested ready for October 2013</u>**

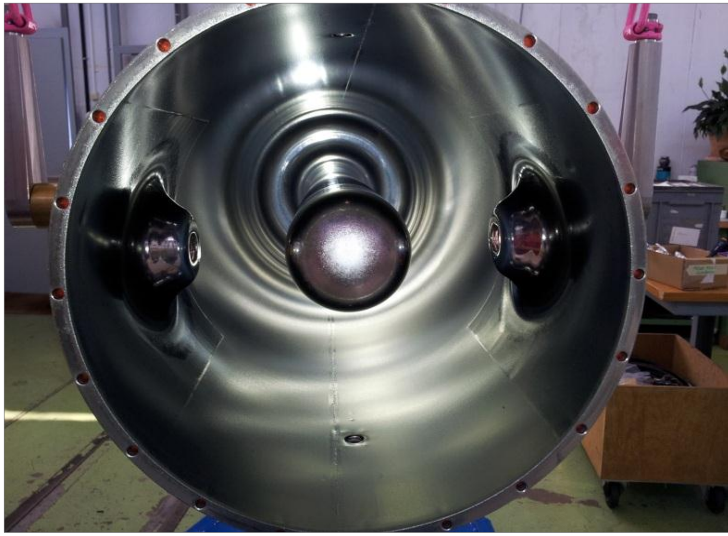
Niobium sputter coating

- 7 test cavities produced focusing on the DC bias sputtering method (used for the ALPI cavities in INFN-LNL)
- Parameters (defined target set as a starting point for further optimization):
  - Bake out / coating temperatures → (650 / 500 °C)
  - Coating rate (discharge power)→ 12.5 kW
  - Minimum film thickness→ 2 µm
- Several hardware modifications to the system were required to approach the desired sputtering parameters
  - Cavity support in coating chamber redesigned
  - Infra red lamps baking system inside chamber with radiation shields
  - Discharge power increased from 2 kW to 10 kW : new power supplies

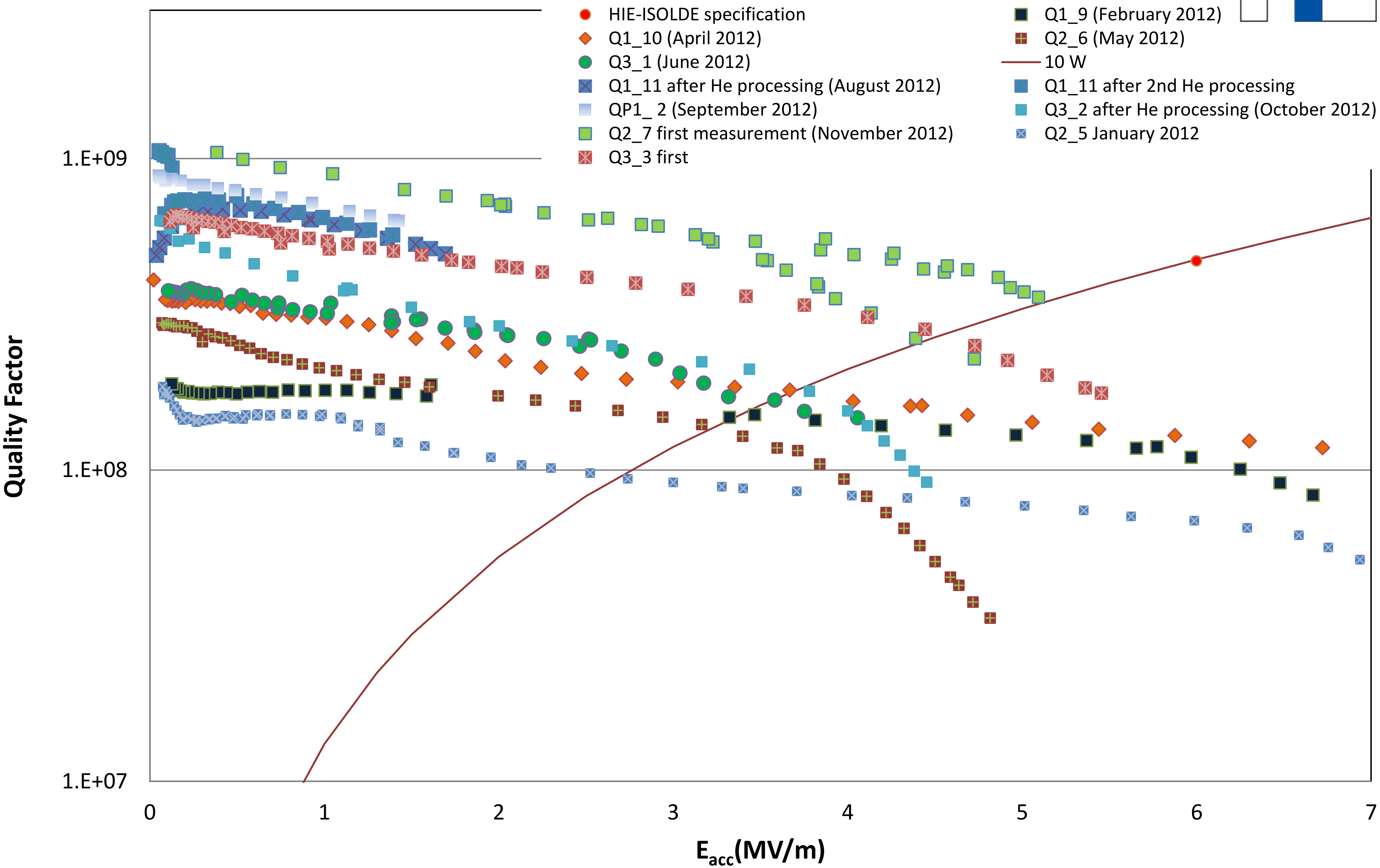
- Specs not fully reached yet, but significant progress →
- 5.3 MeV/u instead of 5.9 MeV/u for A/q=4.5 in stage 1
- Series coating could start in April 2013 with a CERN substrate
- 2 coatings/substrate on average; 3 weeks to produce and RF test
- 6 weeks/cavity

→ 5 cavities could be ready for CM1 end October 2013

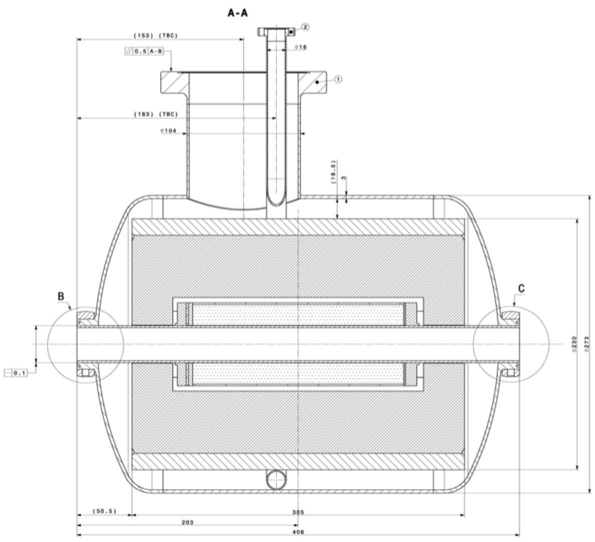
- **Work is planned and resourced to pursue improving the cavity performances at the start of 2013**



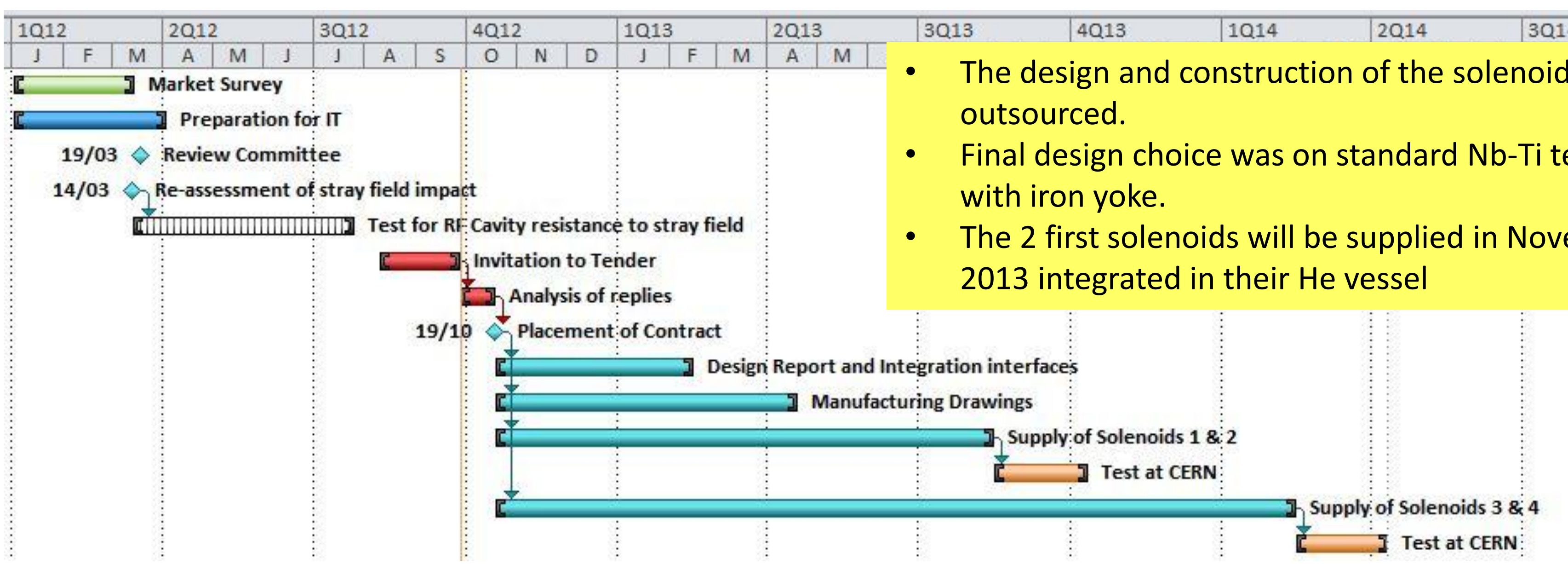
Cavity performance → November 2012



SC Solenoid status



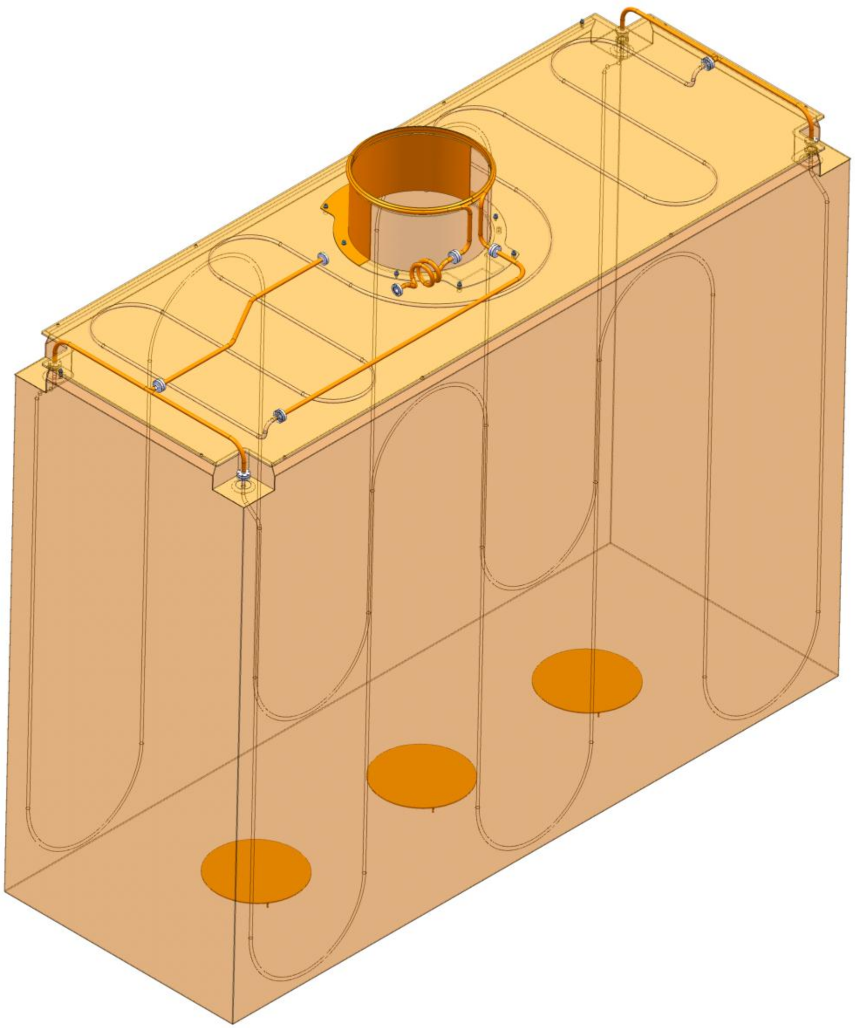
HIE-Isolde Compact Linac Solenoid Parameters	
Cold bore diameter [mm]	≥ 30
Field integral $\int B^2.ds$ at I_{nom} [T^2m]	≥ 16.2
Stray field [G] at I_{nom} and at 230 mm from solenoid centre (1)	≤ 180
Magnetic remanence B_r [G] at I= 0 A, at 230 mm from solenoid centre (1)	≤ 0.65
Operating temperature [K]	4.5
Helium bath operating pressure [bar]	1.3 +/- 0.01 bar
Operating current [A] (I_{nom})	≤ 500
Maximum operating current	1.2 x I_{nom}
Maximum stored energy [kJ]	≤19
Minimum ramp rate [A/sec]	≥0.5 % I_{nom}
Solenoid magnet diameter without He vessel [mm]	≤ 230
Solenoid magnet length without He vessel [mm]	≤ 305



- The design and construction of the solenoid are outsourced.
- Final design choice was on standard Nb-Ti technology with iron yoke.
- The 2 first solenoids will be supplied in November 2013 integrated in their He vessel

The Cryomodule:
Helium Gas Cooling at ~70K

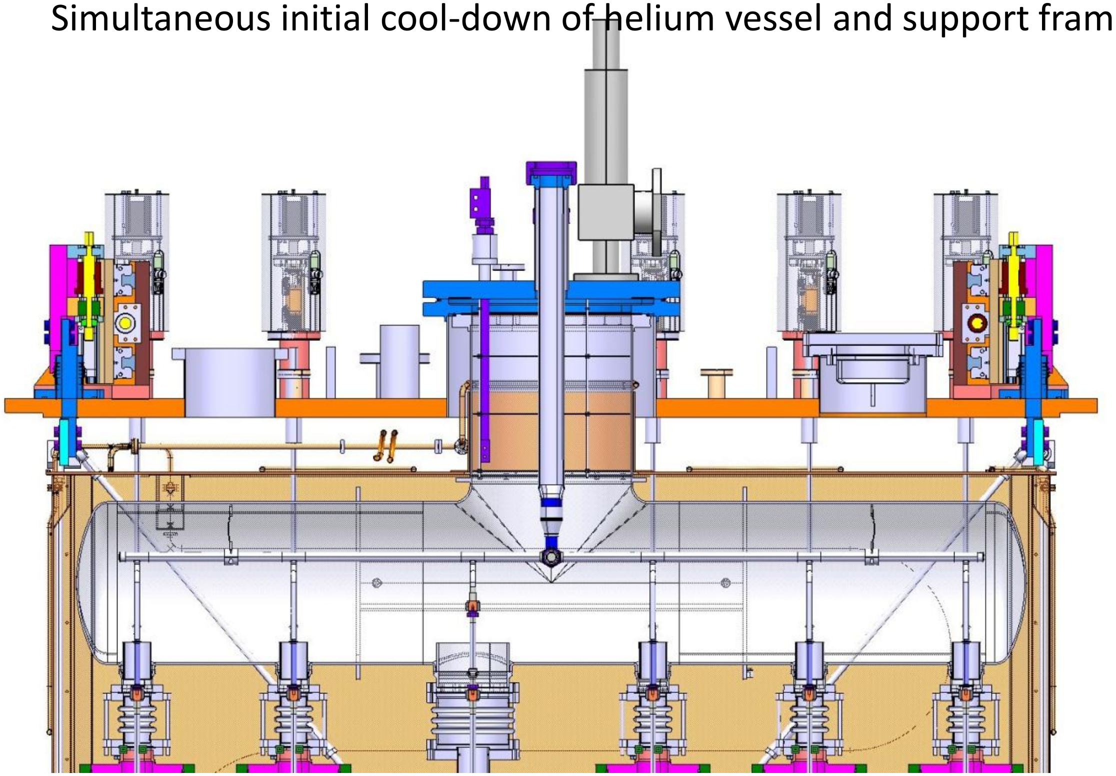
- Thermal shield
  - Externally Bolted assembly of nickel plated copper
  - Delivered as pre-plated pre-cleaned panels for on-site assembly
  - **All panels on one series cooling circuit to reduce the number of flanges**.
  - Stainless steel serpentine cooling tube
    - To slow heat transfer and reduce initial thermal shock and deformations to the shield structure
    - To allow welding of stainless steel flanged ends and a cryogenic circuit entirely in stainless steel
  - An industrial study to identify the best brazing technique for stainless steel tubes to copper is under way now at CERN.
- Cryogenics Failures
  - Revised estimates show that the thermal shield can be maintained on standby for **5h below 75K with 1000 l of helium from a dewar.**
  - This is considered to provide an adequate backup time to intervene on most cryo-system breakdowns.

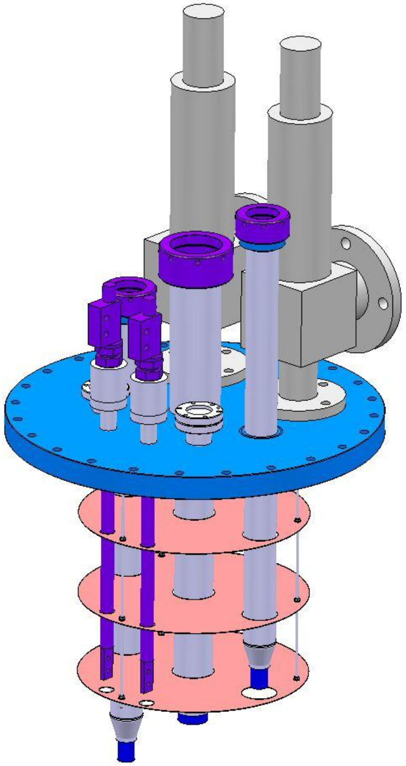


Liquid Helium 4.5K circuit

- The issues concerning operating pressure, helium discharge density (relieving temperature) and safety valves sizing have been re-addressed.
  - Calculations with the help of CERN HSE have been re-done and the revised discharge valve sizes are approved.
  - Pressures now 3 bar transient, 1.4 bar steady state;
  - these values have been incorporated into the cavity design programme
  - Two safety valves of diameter DN 40 are now incorporated on the cryo-module chimney

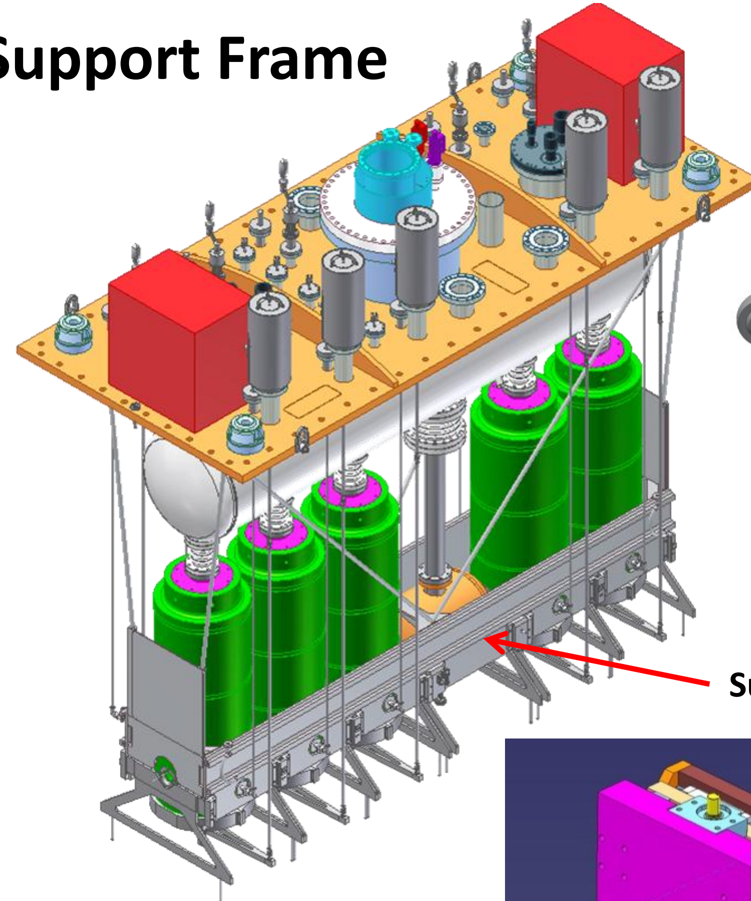
- Reverted to a cryogen feed via disconnectable bayonets, the designs are derivatives of existing proven CERN designs.
- The chimney design is complete.
- Forced flow now only for transient conditions - cool-down/warm-up
- Simultaneous initial cool-down of helium vessel and support frame is implemented



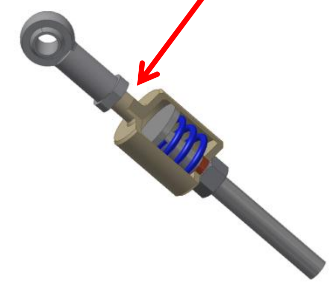


Cavity and Solenoid Support Frame

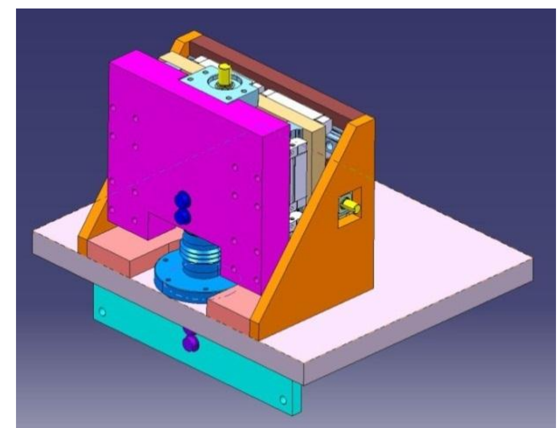
- **Support frame** Design is done, detail design to start end October
- **Individual and independent removal** of the solenoid or any cavity is now possible
- **Suspension system** now incorporates a spring preloaded differential length adjustment in the suspension bars
- Industrial design and production contract is placed for the **frame position adjusters**
- Design concept for **solenoid positional adjustment** is fixed, detailed design is in progress
- **<u>All</u> positional adjustments to be motorized** (in particular due to restrictions on shielding tunnel access with cryomodules helium filled)
- **Adjusters** equipped with on-board measurement and remote readout as a cross-check on the B-cam system.



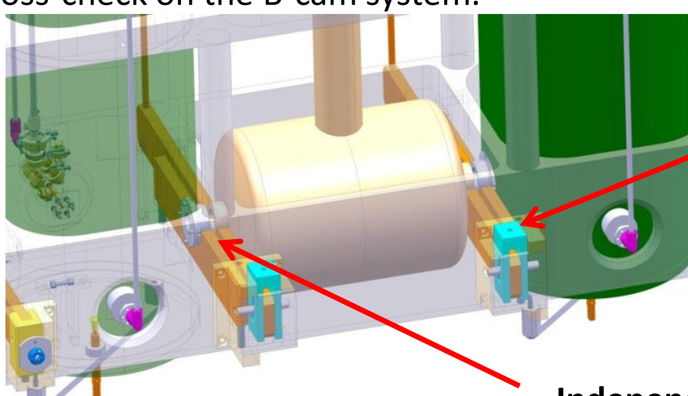
Suspension length adjustment



Support Frame



<u>Frame Position Adjuster</u>

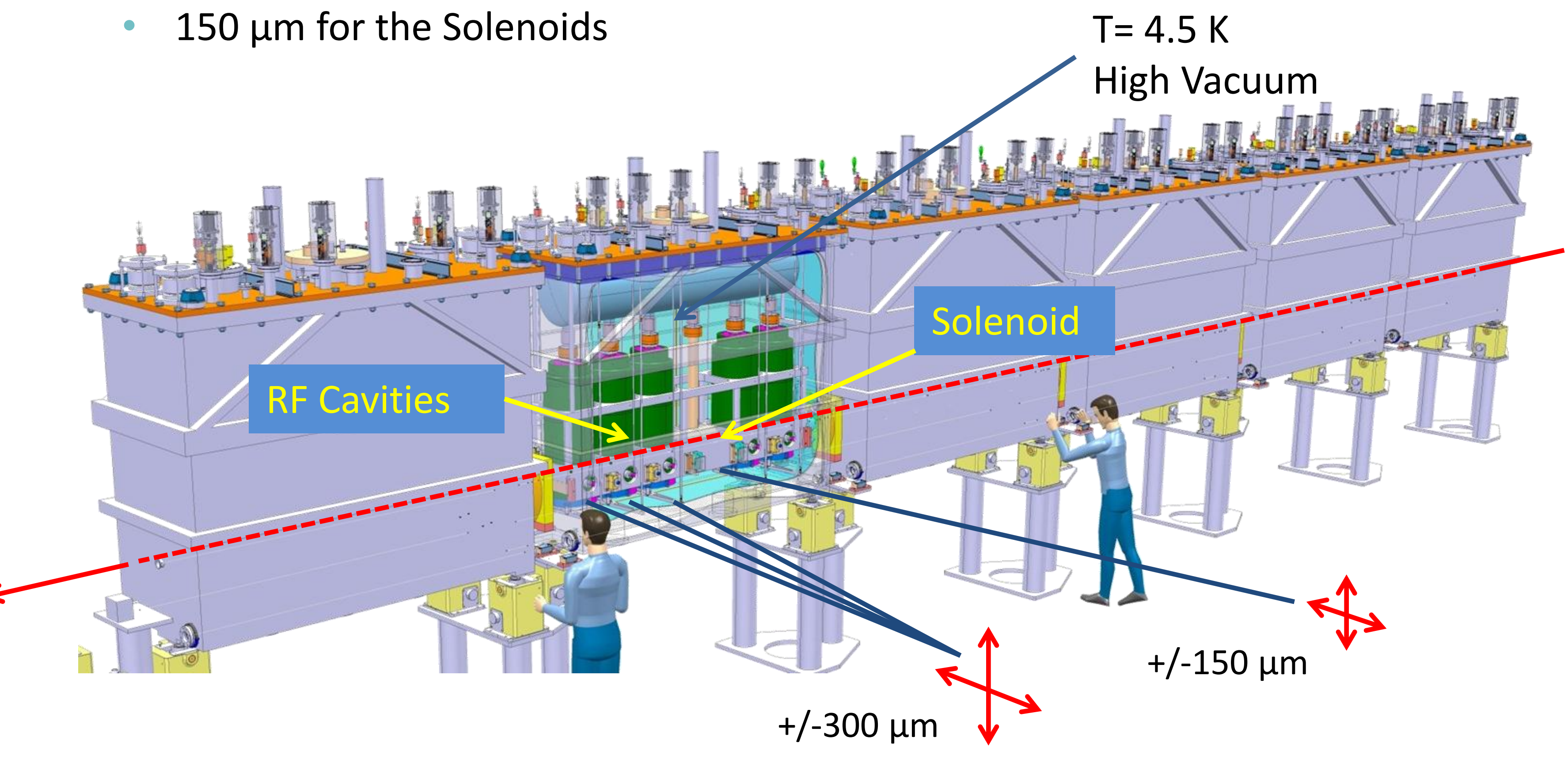


Solenoid positional adjustment

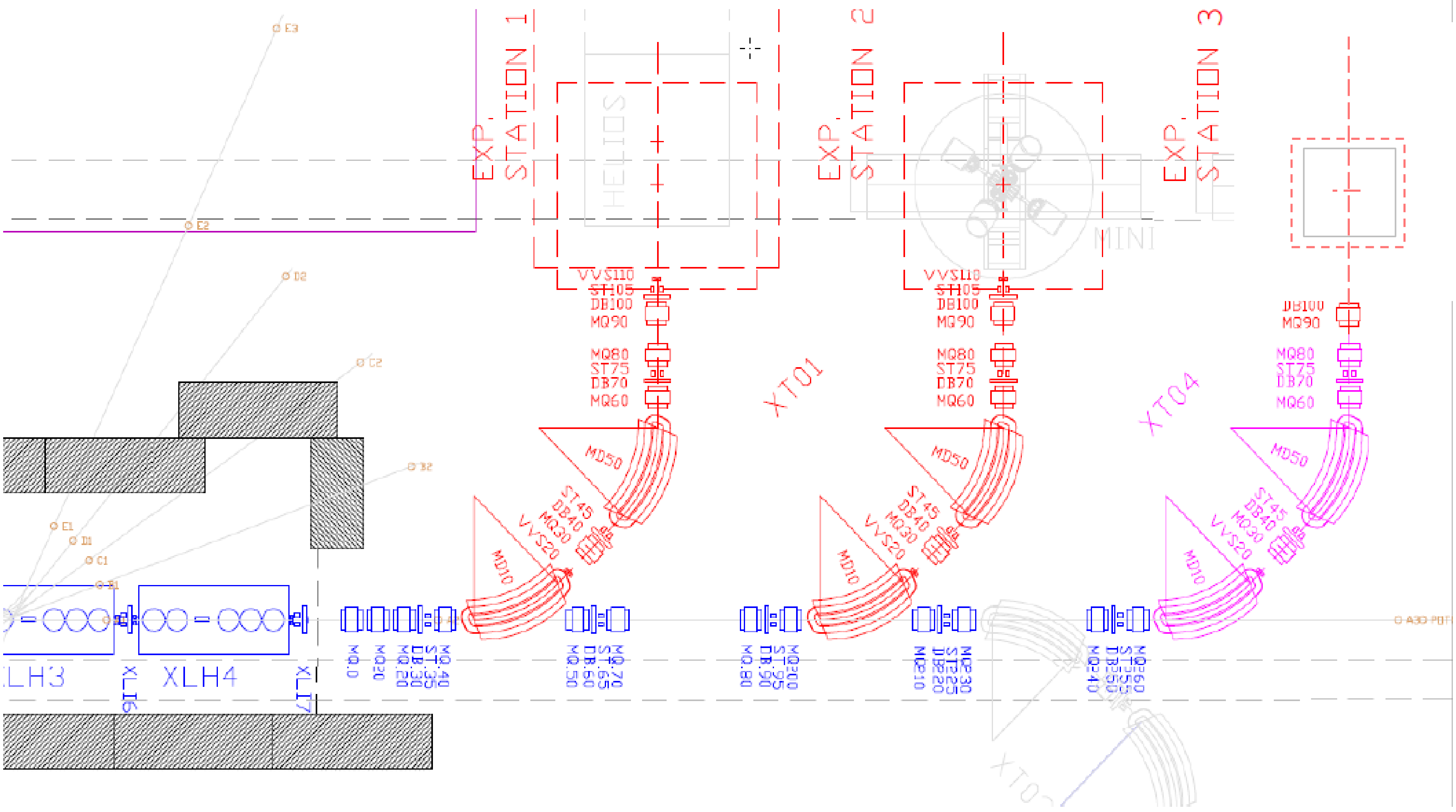
<u>Independent and individual support alignment and removal</u>

(Survey) and monitoring System

- Alignment and monitoring of the Cavities and Solenoids in the Cryomodules
- w.r.t a common nominal beam line along the Linac
- Permanent system
- Standard uncertainty required (1 sigma)
  - 300 µm for the RF Cavities
  - 150 µm for the Solenoids



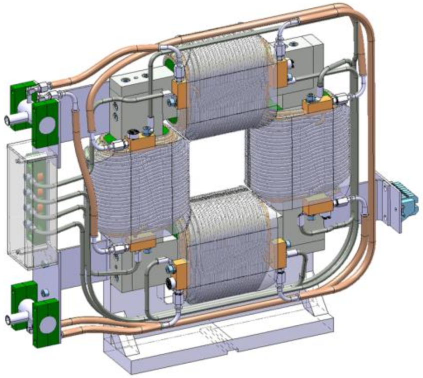
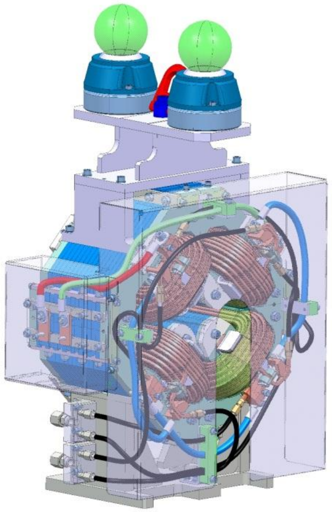
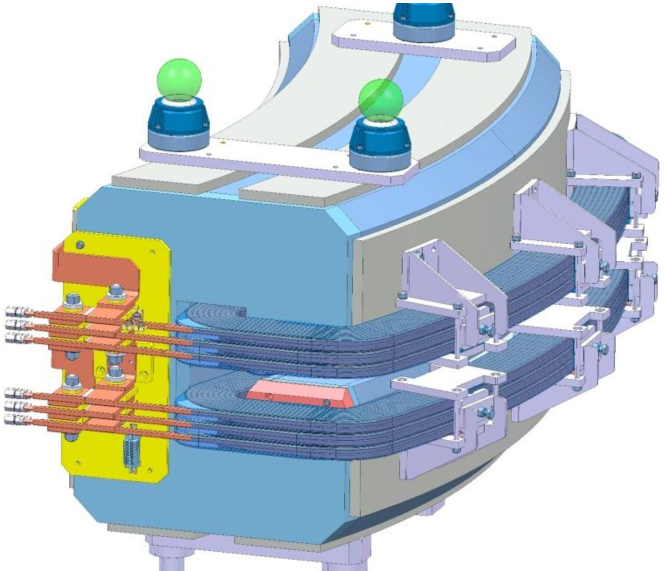
HEBT layout



EXP. STATION 1
EXP. STATION 2
EXP. STATION 3
HELIOS
MINI
XT01
XT04
VVS110
ST105
DB100
MQ90
MQ80
ST75
DB70
MQ60
MD50
ST45
DB40
MQ30
VVS20
MD10
XLH3
XLH4
XLI6
XLI7

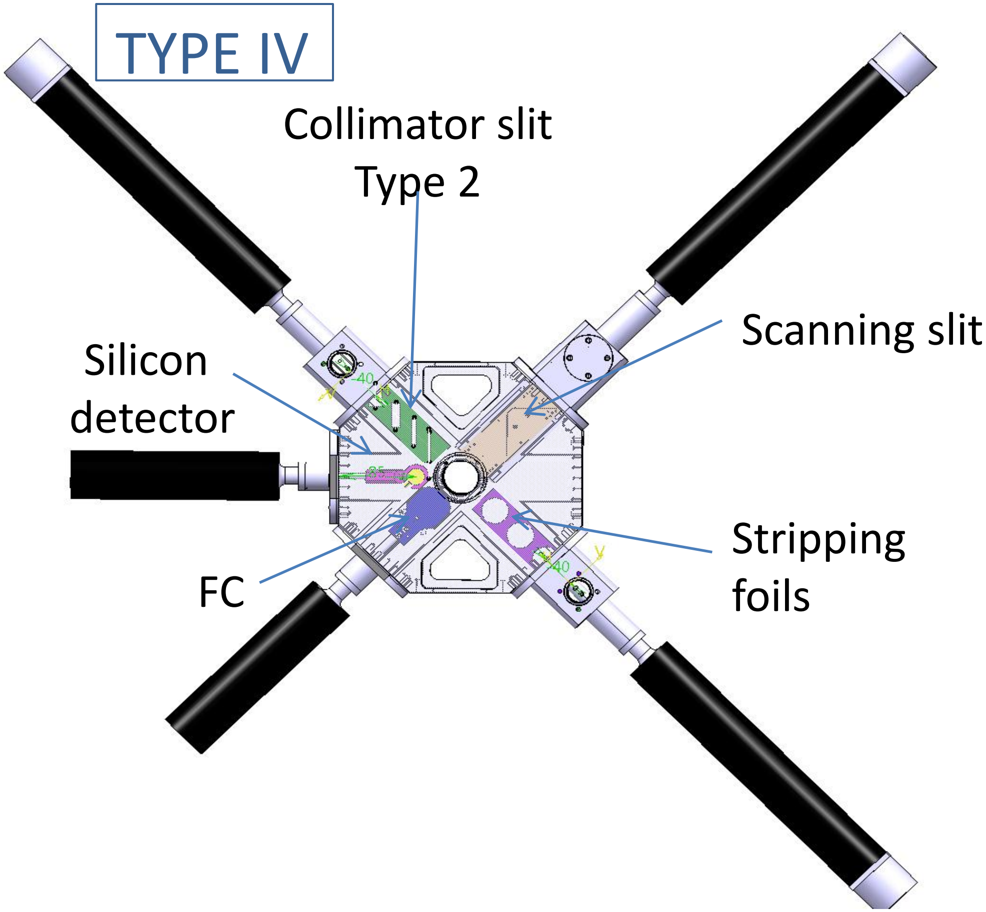
Magnets

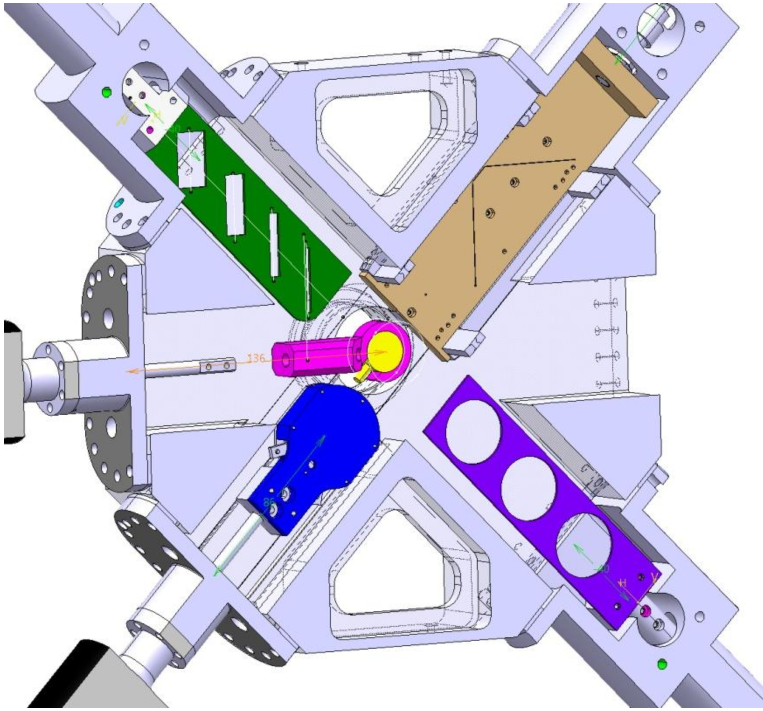
- **45 deg dipoles:** Electrical, cooling and vacuum interfaces defined, magnetic design done, mechanical design and technical specifications ongoing.
- **Quadrupoles:** Electrical and cooling interfaces done, vacuum and survey ongoing, magnetic design, mechanical design and technical specification ongoing.
- **Steerers:** electrical, cooling and vacuum interfaces defined, magnetic design done, mechanical design being adapted to watercooled version, technical specifications started.

Beam Instrumentation

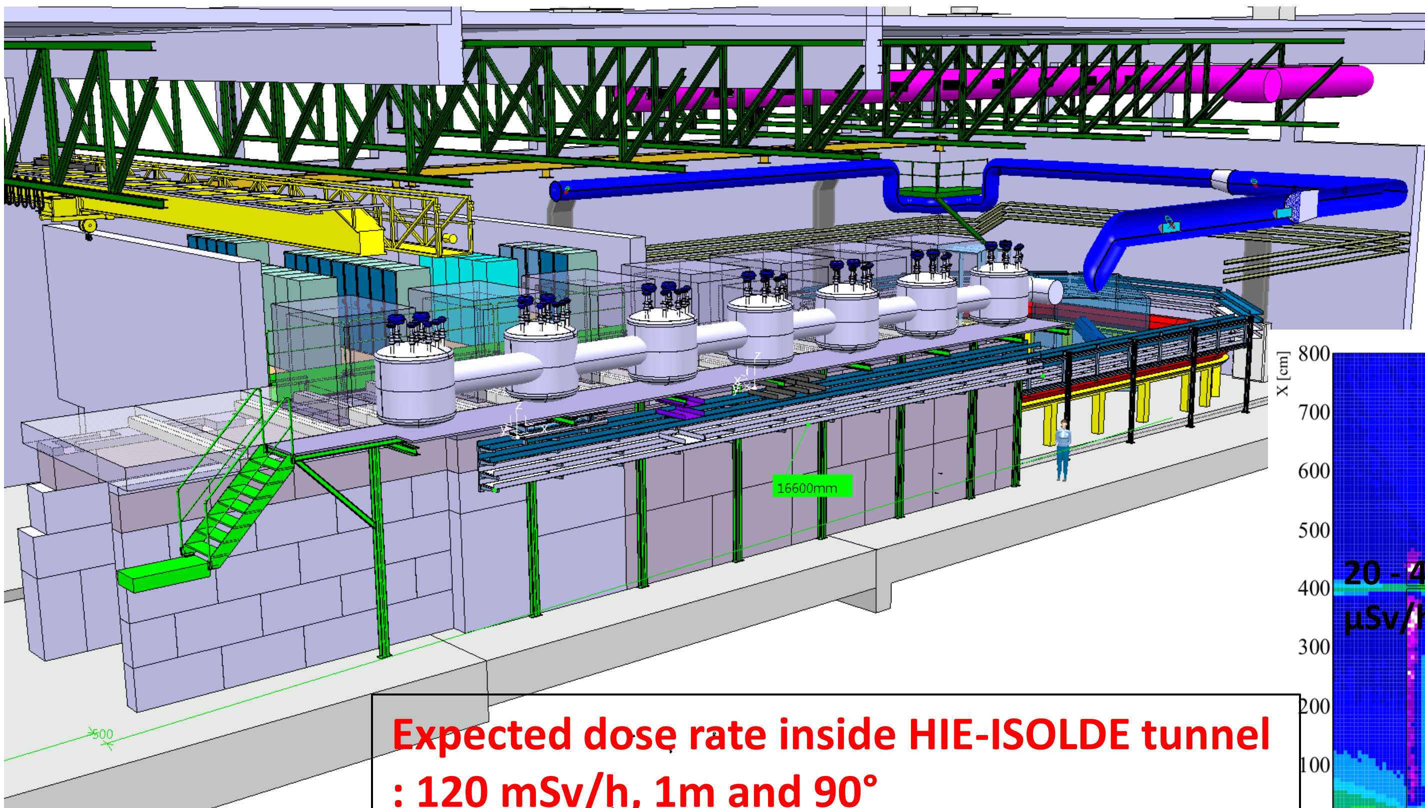
- Prototype Faraday cup being tested at REX-ISOLDE



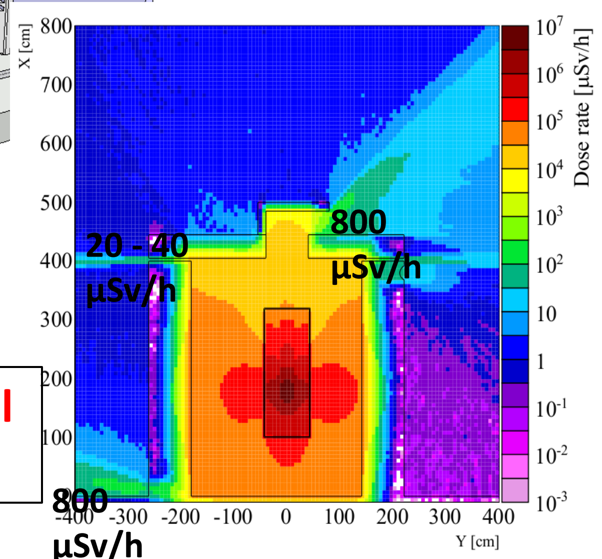


Safety: Radioprotection

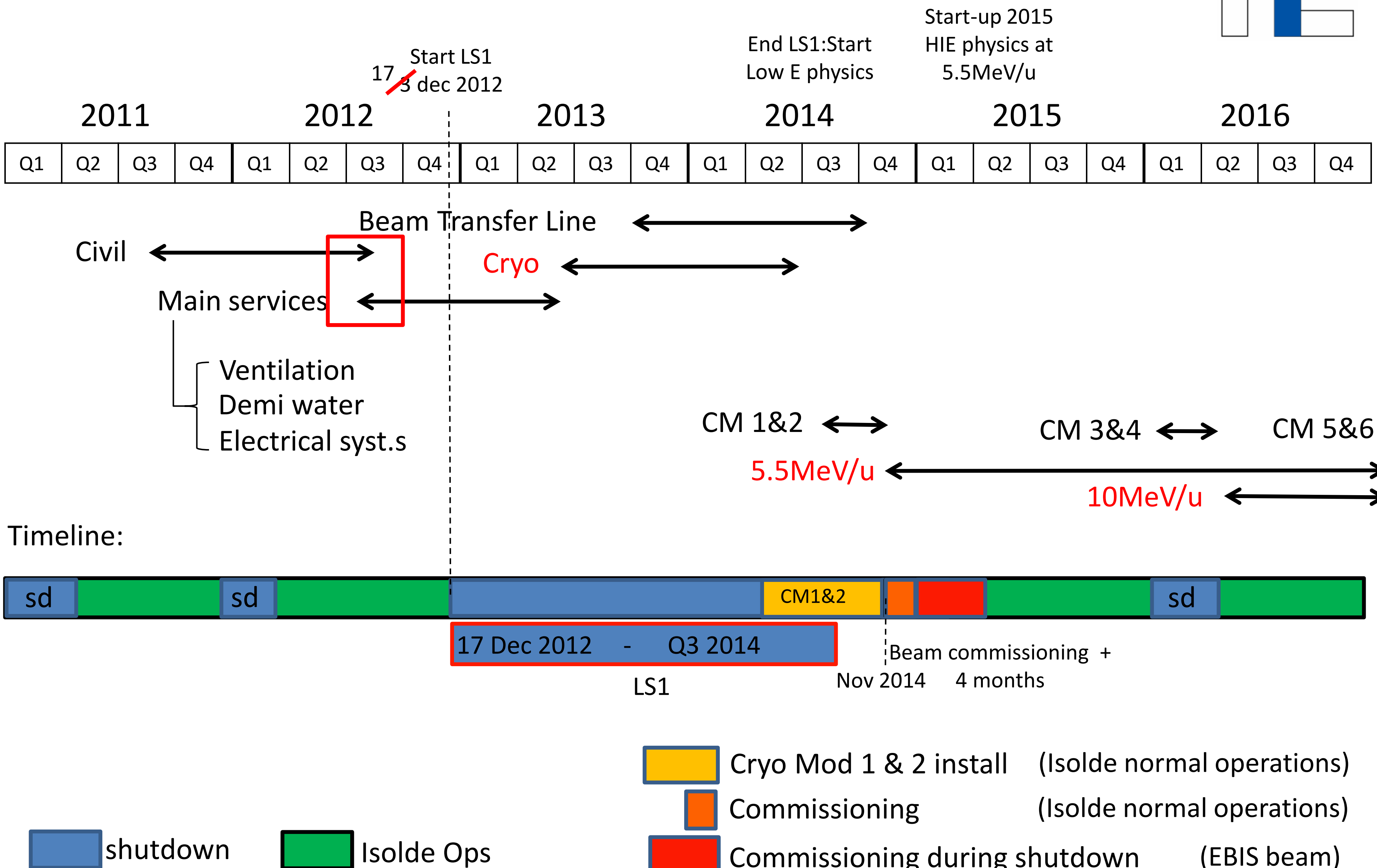
<u>Shielding:</u> **X-rays drive the design for the HIE-ISOLDE tunnel shielding** (Neutron dose rate coming from ions interactions contribute a few μSv/h – Dose rate from X-ray production from RF > 100 of mSv/h



Expected dose rate inside HIE-ISOLDE tunnel : 120 mSv/h, 1m and 90°



Hie-Isolde Planning



Civil Engineering Progress

The HIE-ISOLDE Design Study

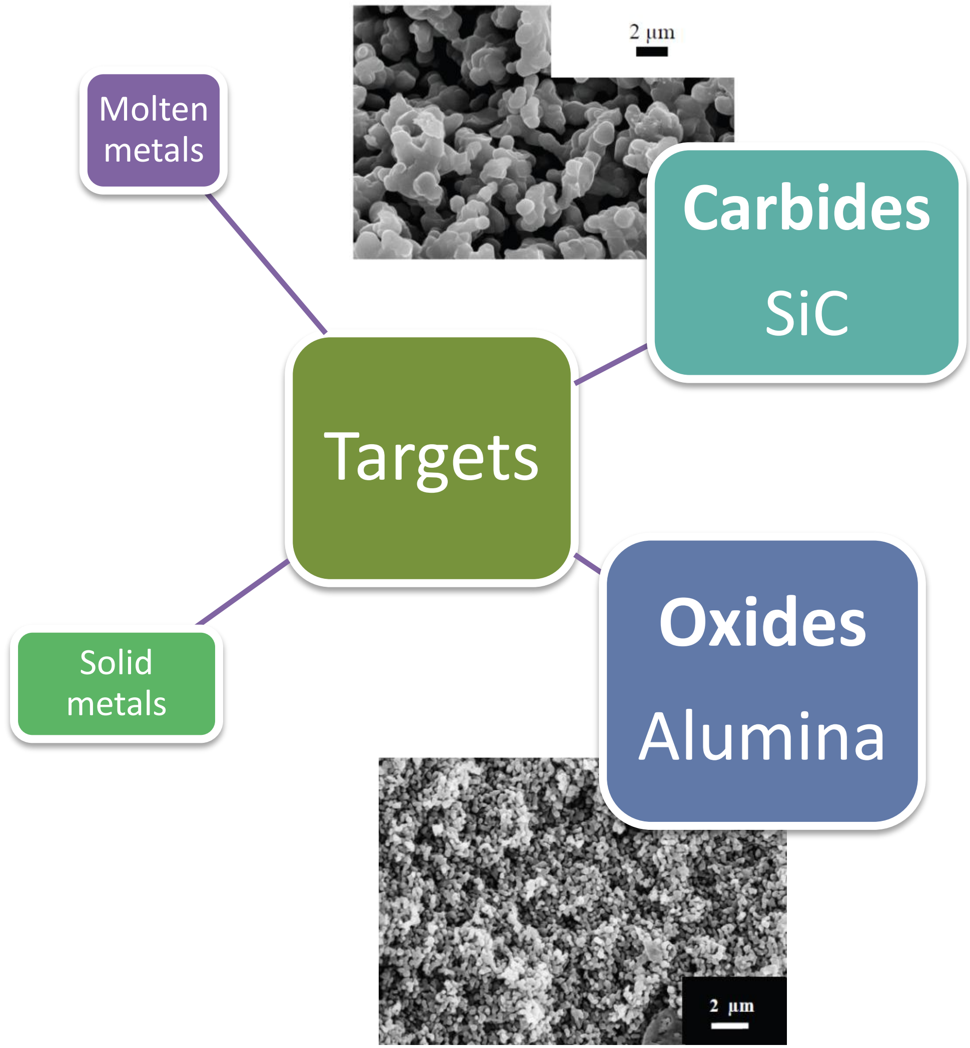
Baseline parameters due to Linac 4 and PSB upgrade
$1x10^{14}$ protons per bunch ($3x10^{13}$)
900ms Booster supercycle? (1200ms)
2GeV beam energy? (1.4GeV)
~ 14kW of primary beam (2.8kW)

Target Materials

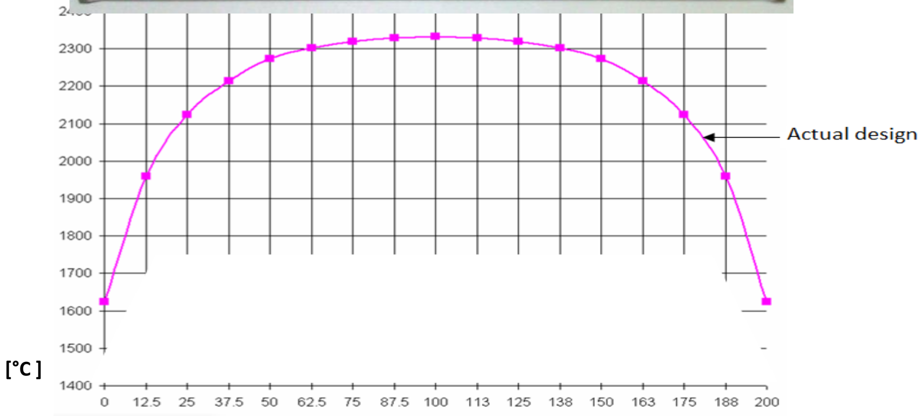
- Carry out simulations of proton beam interactions with existing and potential target materials using FEM structural codes
- Establish experimental programme to validate the simulations and verify the production rates and diffusion constants for different material prototypes.
- Post analysis of samples

- *Silicon Carbide and Alumina prepared with ice-templating method in collaboration with St. Gobain*
- *Irradiation of SiC samples already done*
- *More samples to be irradiated using the HIRADMAT facility*

See poster by Michal Czapski



Thermo-mechanical properties



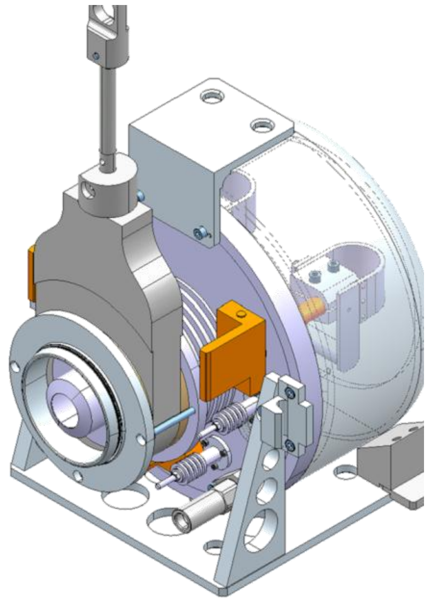
- *Development of a script in the code Mathematica to foresee analytically the temperature of the Containers in the hypothesis of Grey Body.*
- *Measurements and calibration of different containers to obtain base line and to validate code*

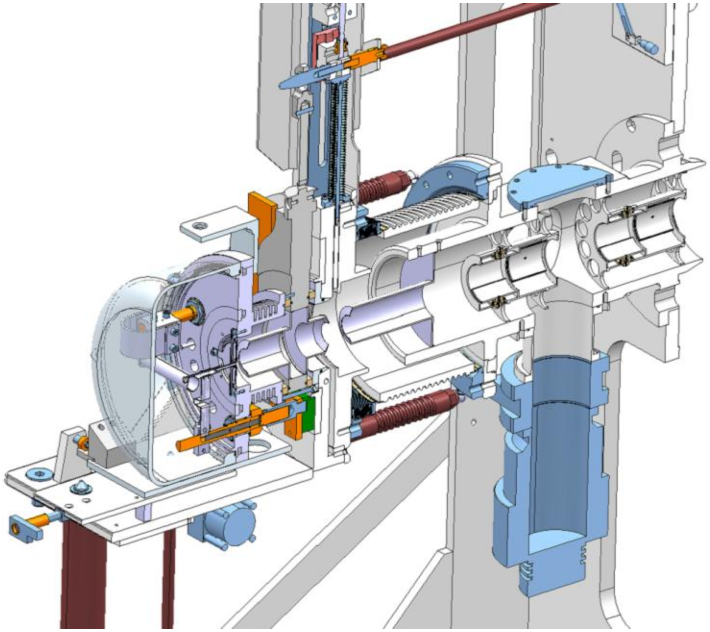
- Obtain a uniform temperature distribution in the container.
  - Maximize the isotopes production rate on the cold edges;
  - Avoid re-condensation of isotopes on the edges.
- Investigate the use of heat pipes as a solution to removing water from the target unit
  - Safety issue

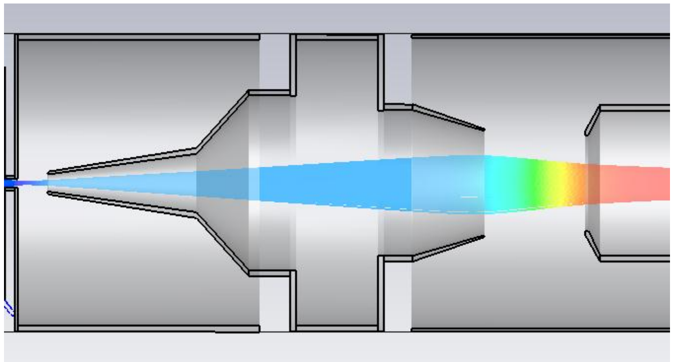
See poster by Serena Cimmino

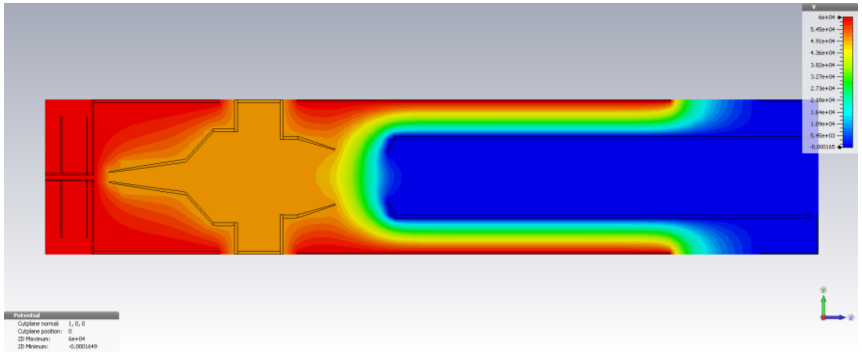
Redesign of Extraction System

Fixed electrodes,
larger apertures,
simpler and more
compact frame





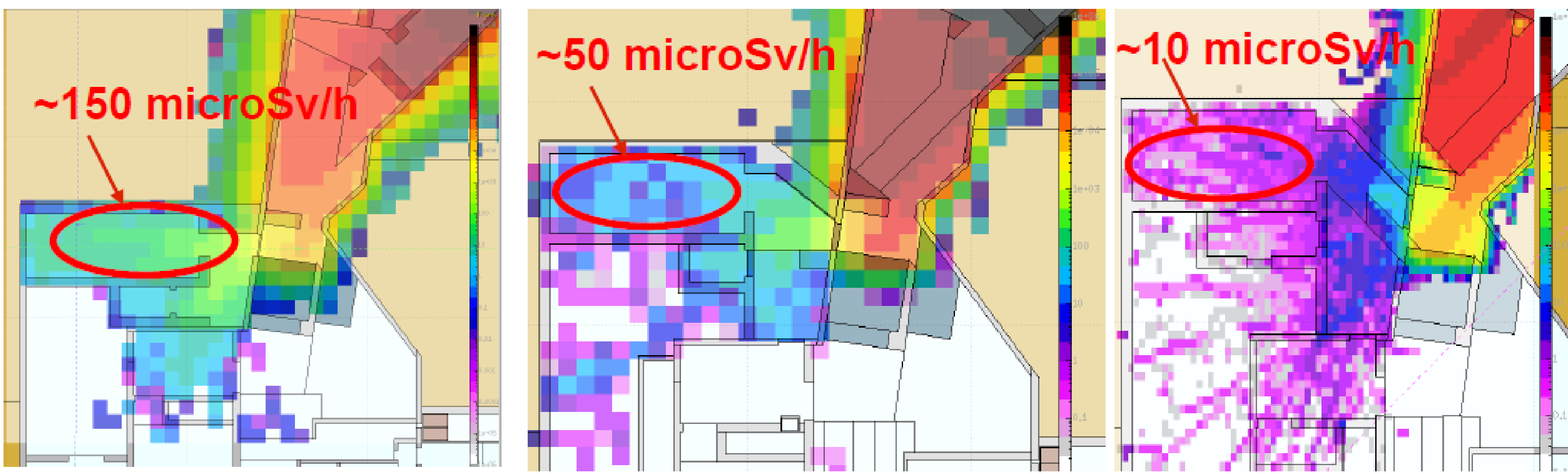




See poster by Jacobo Montano Carrizales

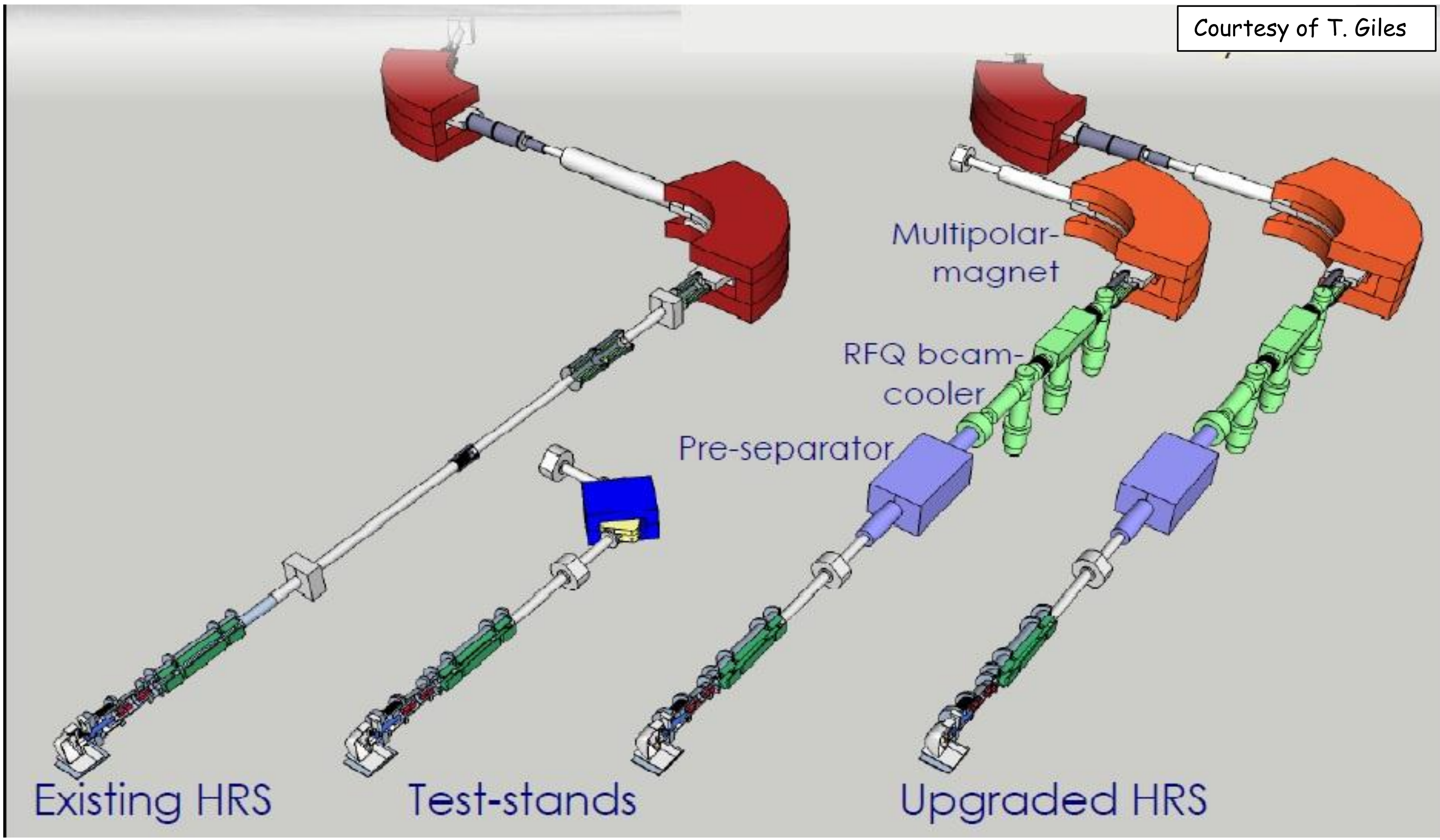
Fluka Simulations

- Fluka simulations to validate dose rates associated with the proposed modifications of building 179
- Now ready to simulate possible scenarios depending on beam parameters and shielding

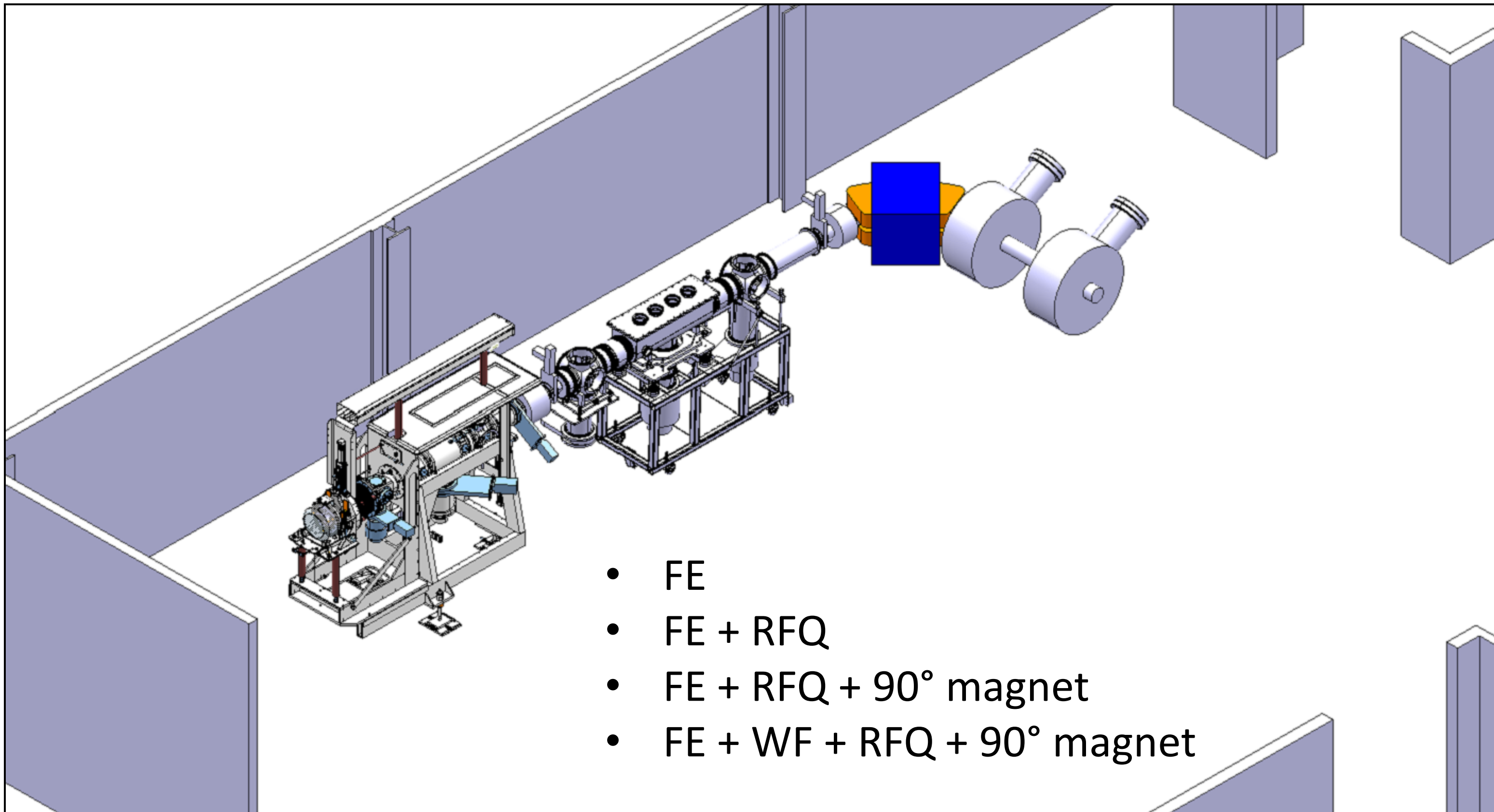


Leonel Morejon Hernandez

Beam quality Upgrade

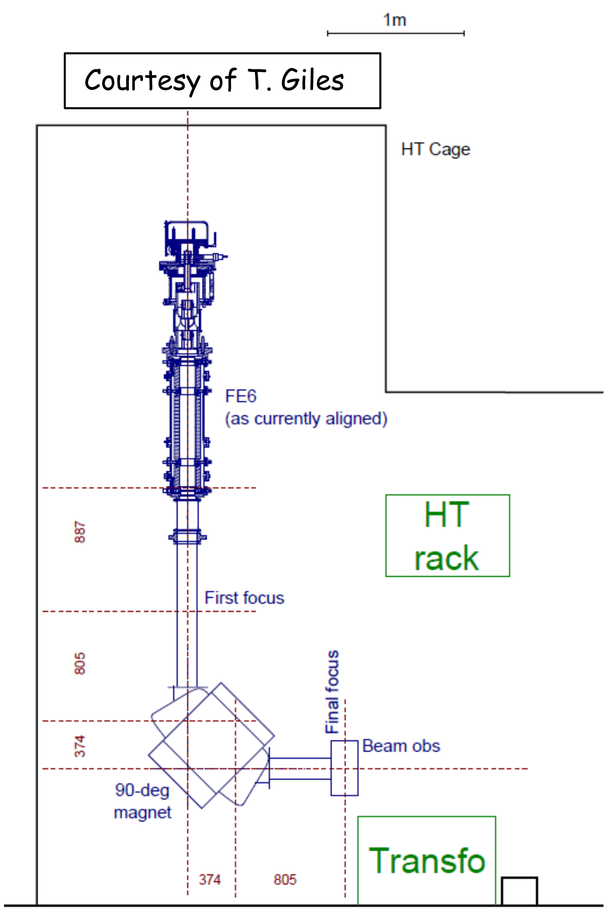


Off-line 2 Mass Separator Layout
A test bench for validation



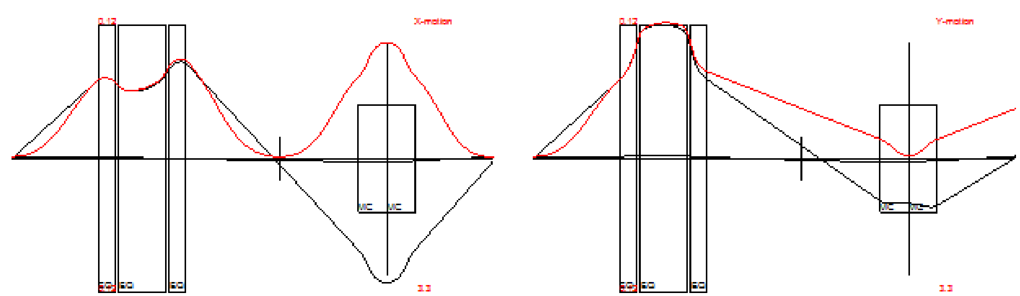
- FE
- FE + RFQ
- FE + RFQ + 90° magnet
- FE + WF + RFQ + 90° magnet

Off-line Separator



- ☑ Proposal of a mechanical layout for the off-line test
- ☑ Beam optics simulations
  performed
- ☑ *Off-line Separator Specifications*": layout proposed, beamline items are being gathered, finite element design software simulations to be carried out;

  Assembly and commissioning of off-line separator": magnet test certifications to be performed within the coming weeks ;
- ☑ *Beam optics simulation codes*" : numerical simulations completed for off-separator, ongoing activity for HRS magnet
- ☑ Definition of magnet controls requirements
  in progress
  (with M. Colciago, STI-ECE section)
- ☑ Contact with IVM group for vacuum requirements

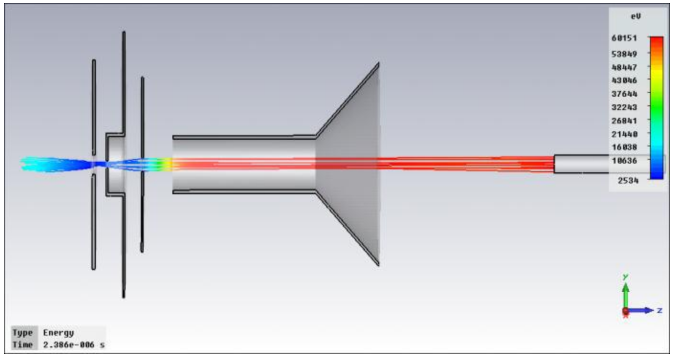


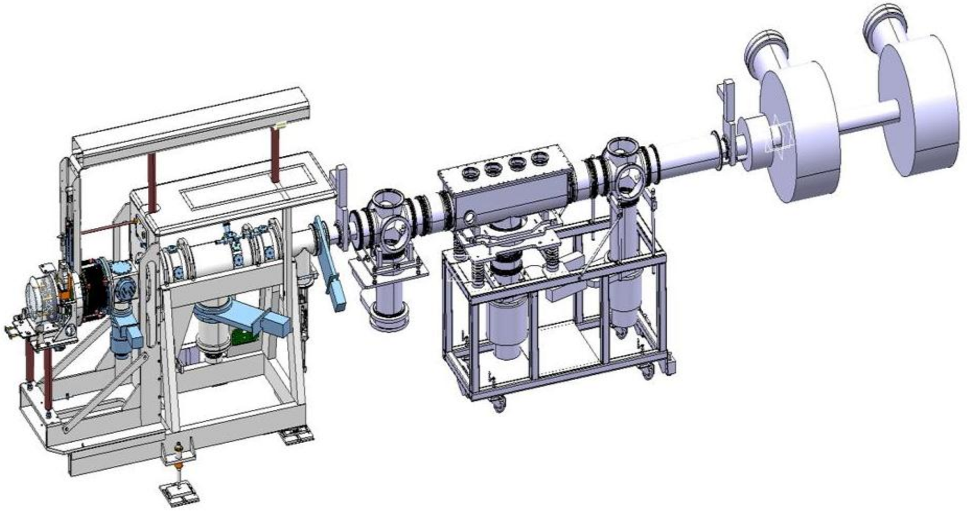
See poster by Matthieu Augustin

RFQ Cooler

- Approach
  - Alignment
    - Adjustable alignment of the electrodes
  - Pressure gradient
    - Reduce pressure at injection and extraction electrodes by adding more holes to the plates
- RFQ Cooler will be part of the test stand
- Drawings done and procurement started
- RFQ Cooler design report done

- CST Particle Studio used:
  - To simulate particle trajectories
  - To provide acceptances on parts of the machine
  - To diagnose electrical charge build up
  - Shapes, voltages and distances can be simulated

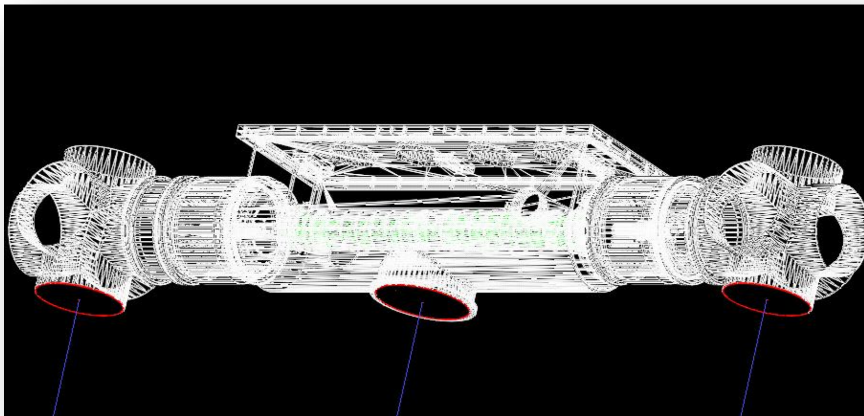




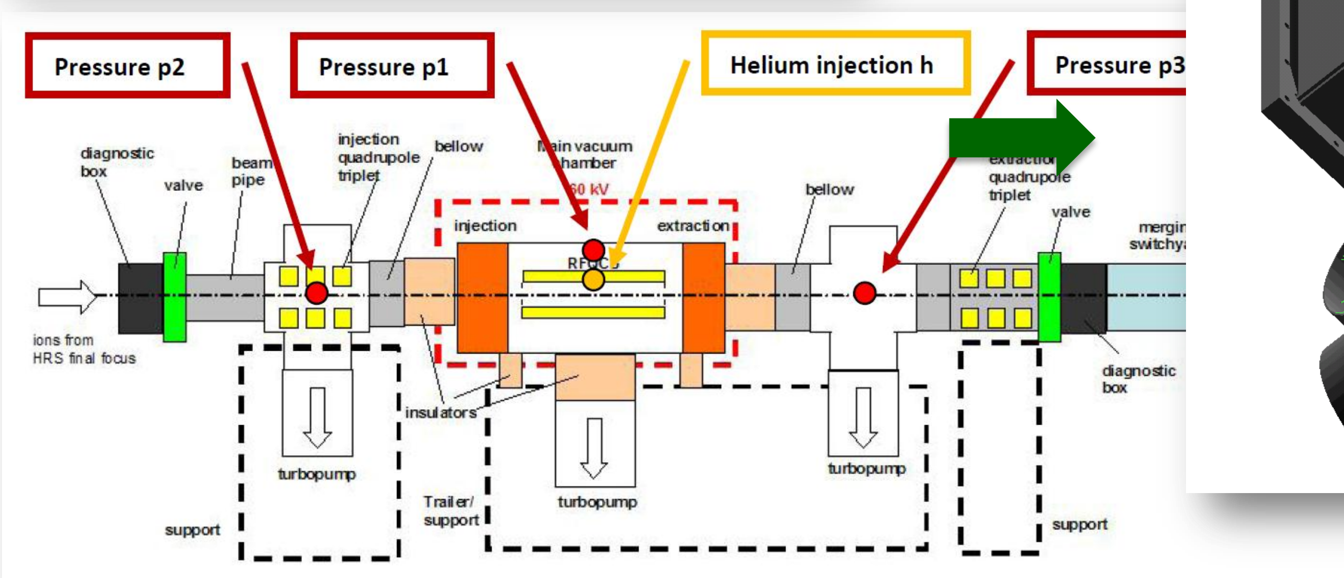
See poster by Carla Babcock

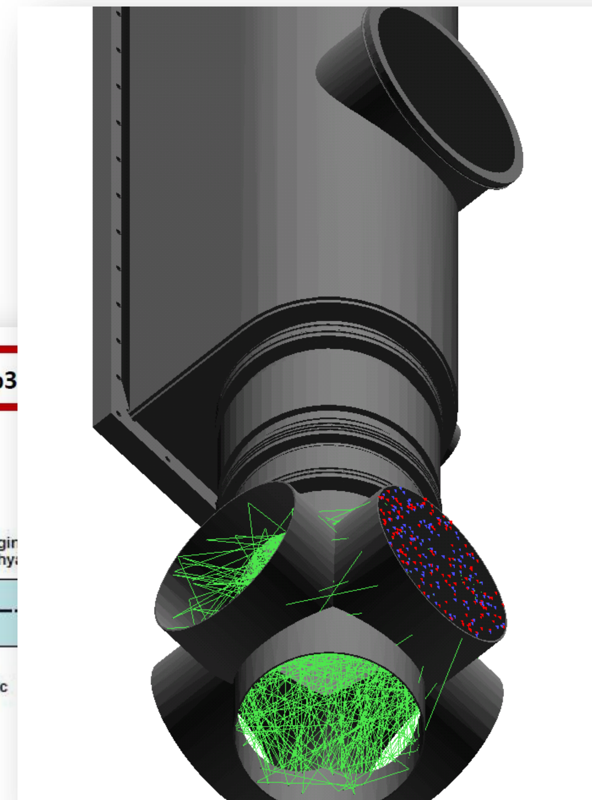
Vacuum

Simulation of vacuum profiles at ISCOOL



Optimization of beam quality at future Radio-frequency quadrupole cooler and buncher



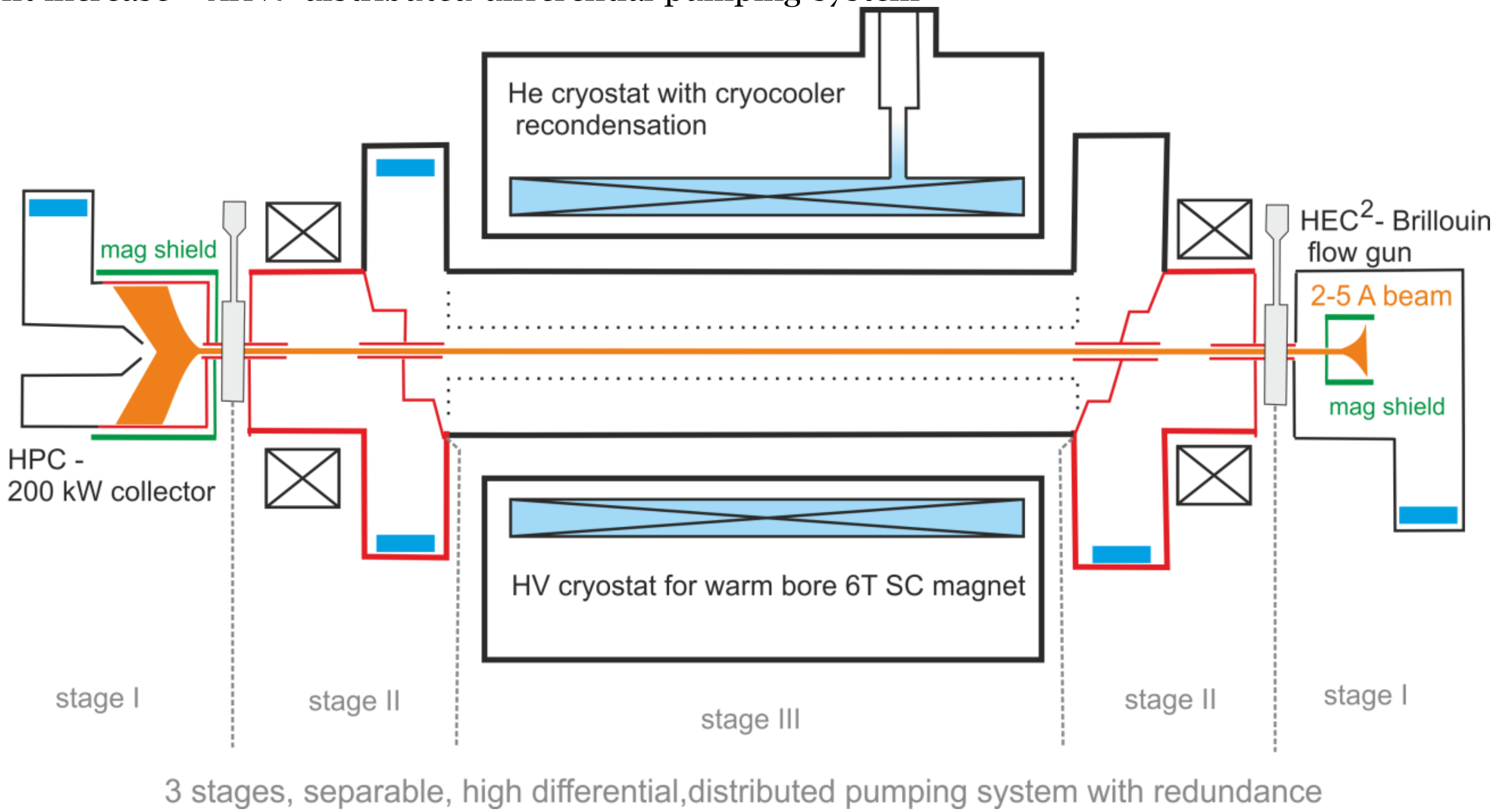


See poster by Mario Hermann

Design layout for upgraded breeder

A.Go to >10 MeV/u beam energy B. Cover all TSR physics cases

Important changes compared to REXEBIS:
Electron energy increase (x30) : HV design
Electron current increase (x10-20): HEC^2 electron gun
Current density increase (x50-100) : high compression Brillouin type gun, magnetic field increase (2→6 T)
Current increase (x10-20) + HV: high power dissipation at the collector
Current increase + XHV: distributed differential pumping system



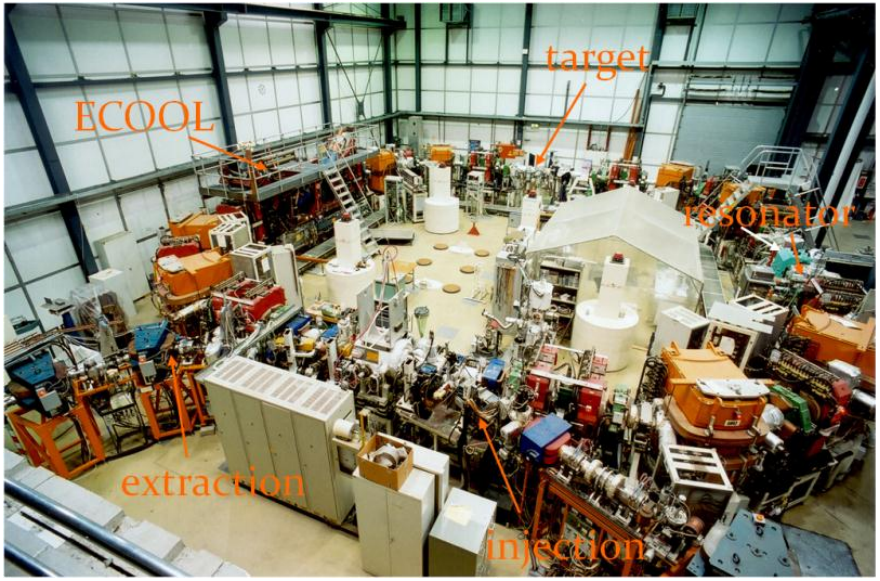
See poster by A. Shornikov et al.

TSR@ISOLDE

Combine HIE-ISOLDE beams with Heidelberg heavy-ion Test Storage Ring

TSR and HIE-ISOLDE a nice couple with:

- broad range of elements and isotopes
- wide energy range
- e-cooled beams
- cw beams
- in-ring and external experiments



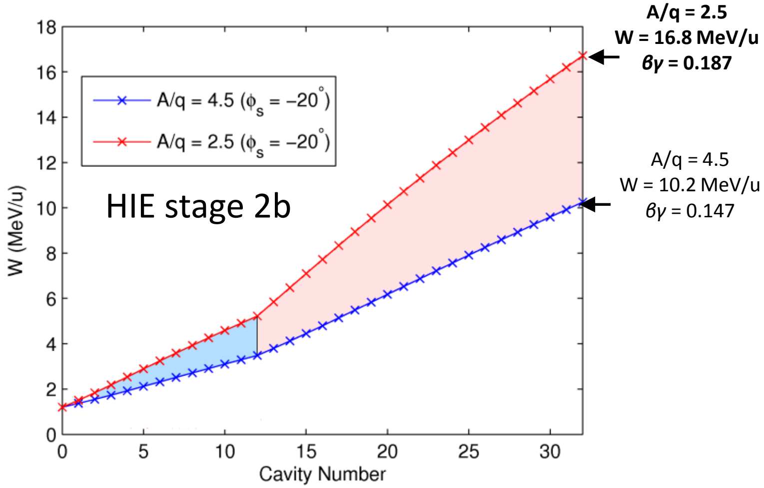
TSR at MPI-K Heidelberg

Circumference:	55.42 m
Vacuum:	~few 1E-11 mbar
Acceptance:	100 mm mrad
Multiturn injection:	mA current
Electron cooler:	transverse T_{cool} in order of 1 s
RF acceleration and deceleration possible	

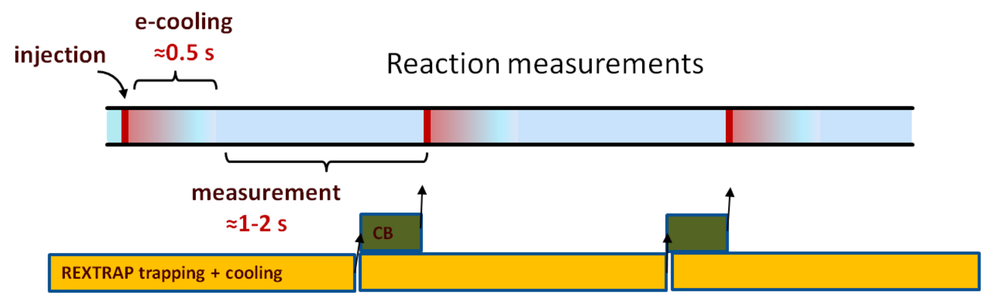
First storage ring with ISOL-facility!

HIE/REX and TSR compatible

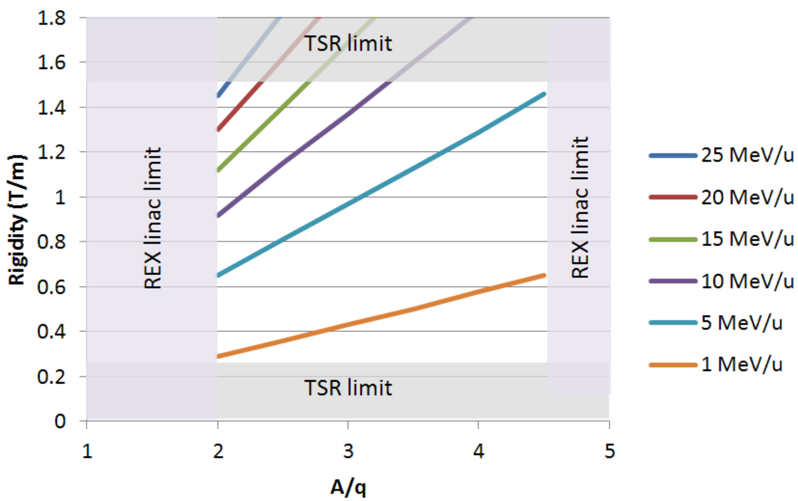
1. REX/HIE and TSR well adapted energy wise



Many different ways of operating the TSR



2. Need to hold the ions for up to 2 s in REX low energy stage => REXTRAP essential

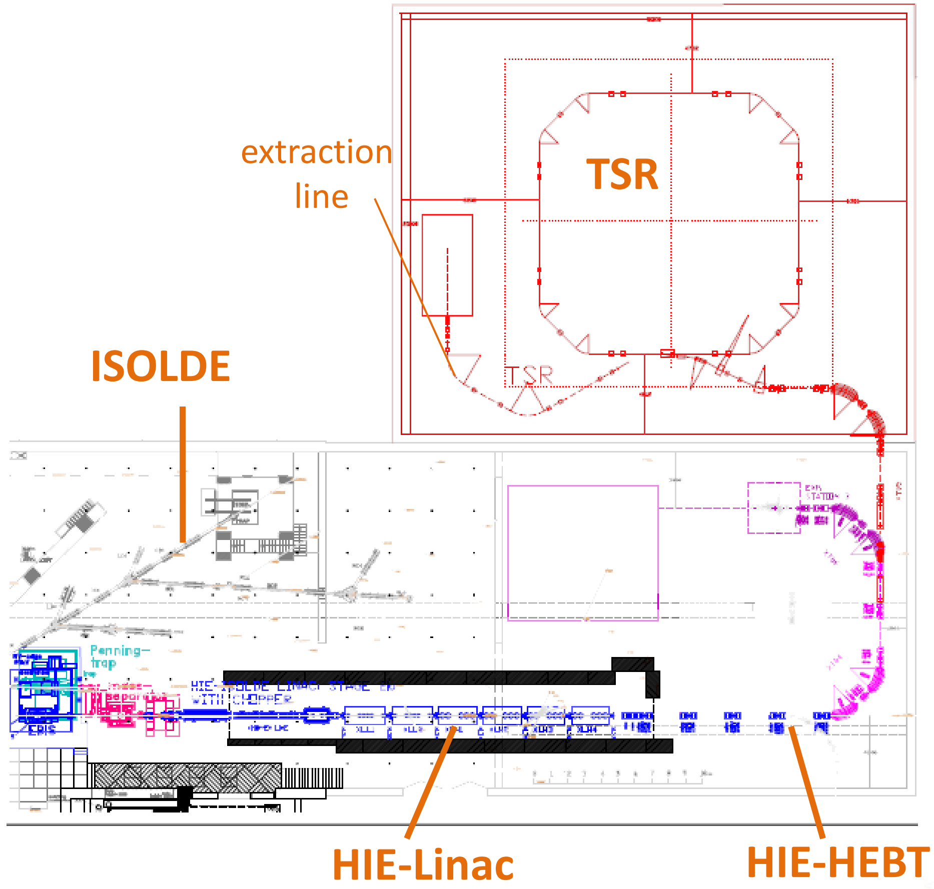


Ion	Z	q	A/q	Breeding time (ms)
^{7}Be	4	3	2.33	20
^{18}F	9	9	2	100
^{70}Ni	30	25	2.33	350
^{132}Sn	50	30	4.4	120
^{132}Sn	50	39	3.38	700 *
^{182}Pb	82	53	3.43	1000 *
^{182}Pb	82	64	2.84	EBIS upgrade needed

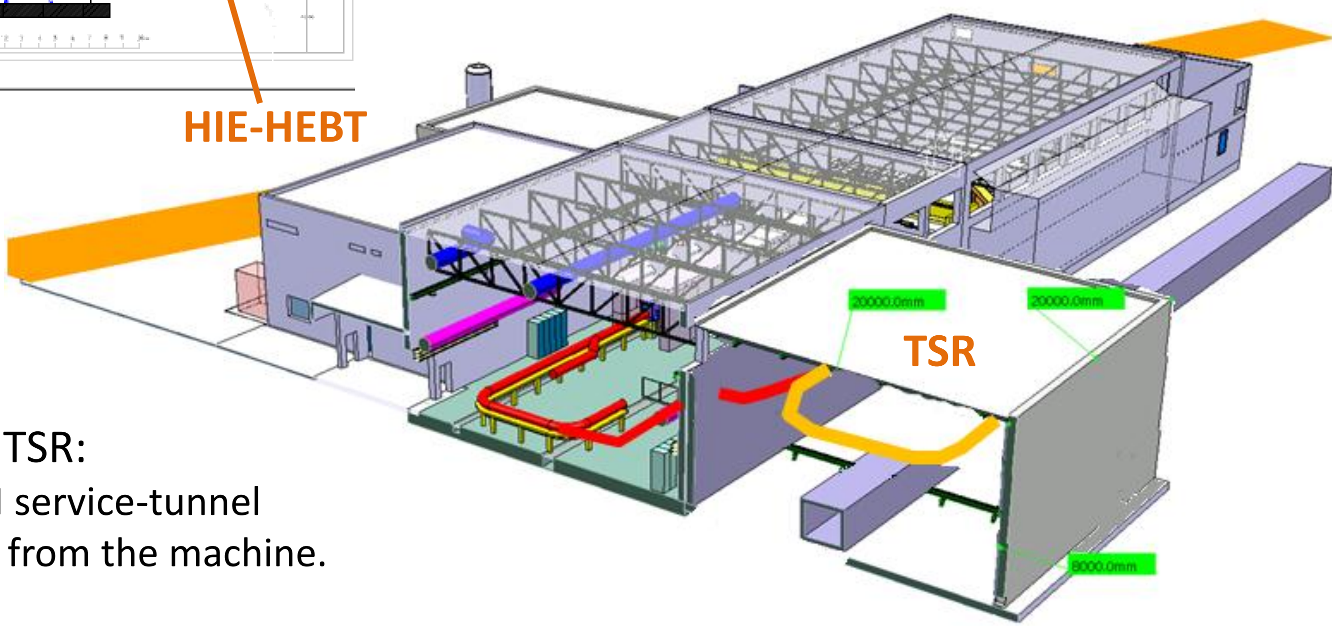
* to be tested

3. REXEBIS capable of producing sufficiently low A/q for almost all elements (< 10 MeV/u)

Possible TSR installation



* Injection beam-line calculated
* Study of building performed



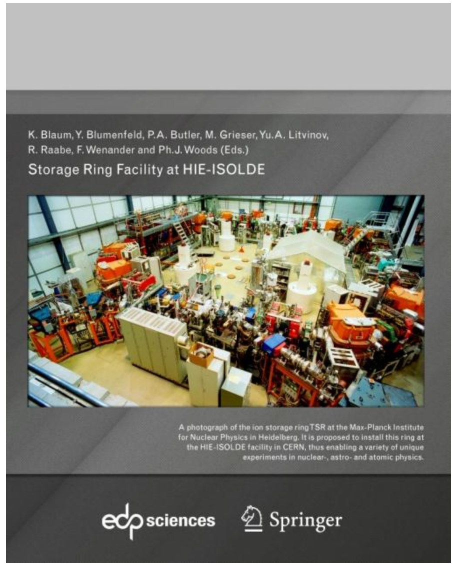
Proposed layout to fit the TSR:

* Installation above the CERN service-tunnel
* Tilted beam-line coming up from the machine.

TSR: Next steps

1. TSR at ISOLDE technical design report

M. Grieser et al., EPJ Special Topics May 2012, vol 207, Issue 1, pp 1-117



2. Approved by CERN Research board, May 2012

"The installation of TSR, as an experiment to be included in the HIE-ISOLDE programme, was approved by the Research Board. The timescale will be defined once the study of its integration has been completed."

3. Integration study on-going

Report to CERN management Q3 2013

Summary

- High Energy ISOLDE is moving out of the R&D phase and into the procurement and production phase
  - Civil engineering completed, work on services will commence end of December
  - Improved performance on cavities is promising
  - 2013 will be a crucial year for the project
- The Design Study is progressing well with a dynamic team assessing the issues associated with both the intensity upgrade and beam quality
- The TSR@ISOLDE progress is impressive…

Acknowledgements

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- Brennan Goddard
- Lloyd Williams
- Fredrik Wenander

ISOLDE Workshop 17th – 19th December 2012
http://indico.cern.ch/conferenceDisplay.py?confId=202232

Thank you for your attention
Thank you to the organizsrs for an excellent EMIS 2012
Have a safe trip home!