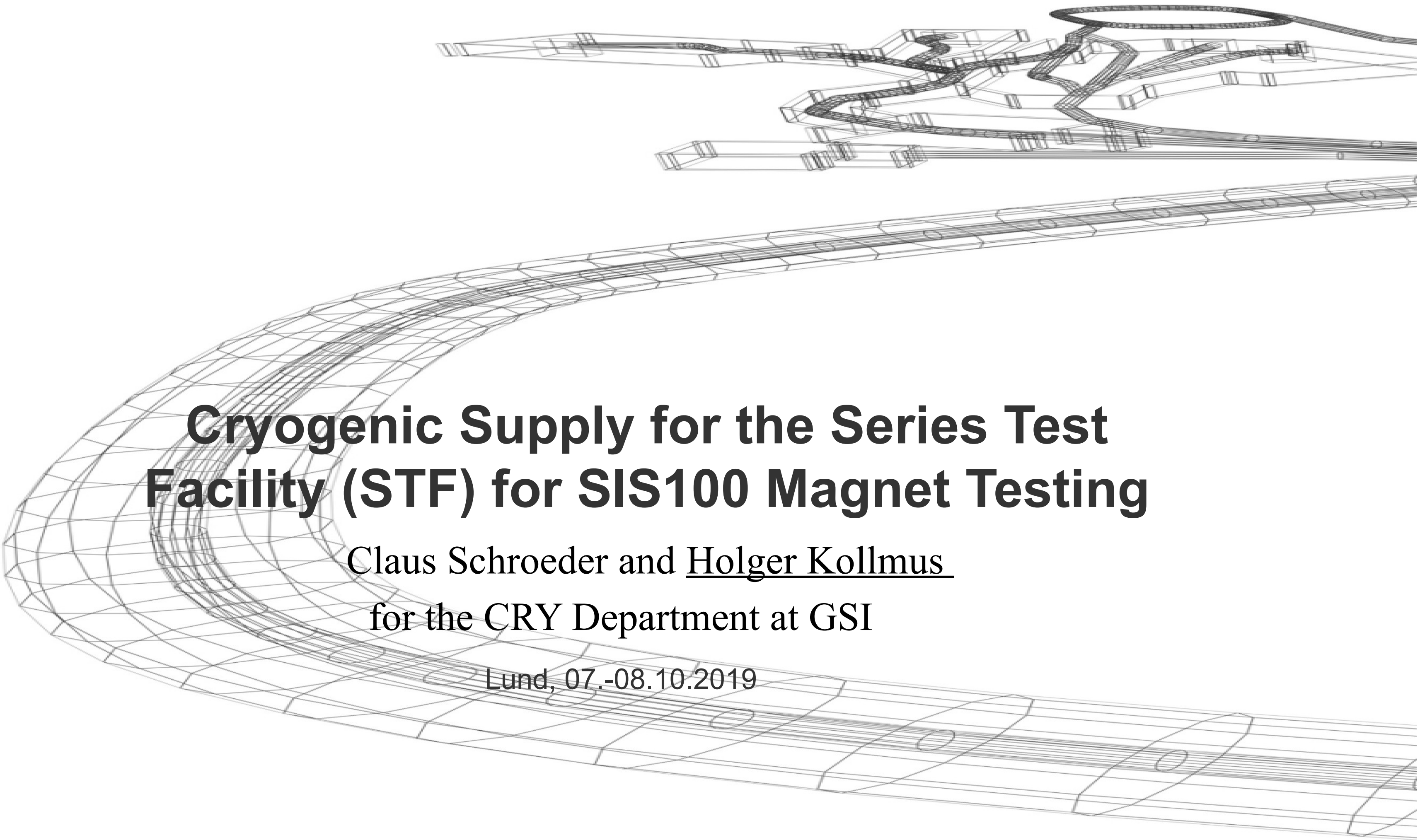


Cryogenic Supply for the Series Test Facility (STF) for SIS100 Magnet Testing

Claus Schroeder and Holger Kollmus

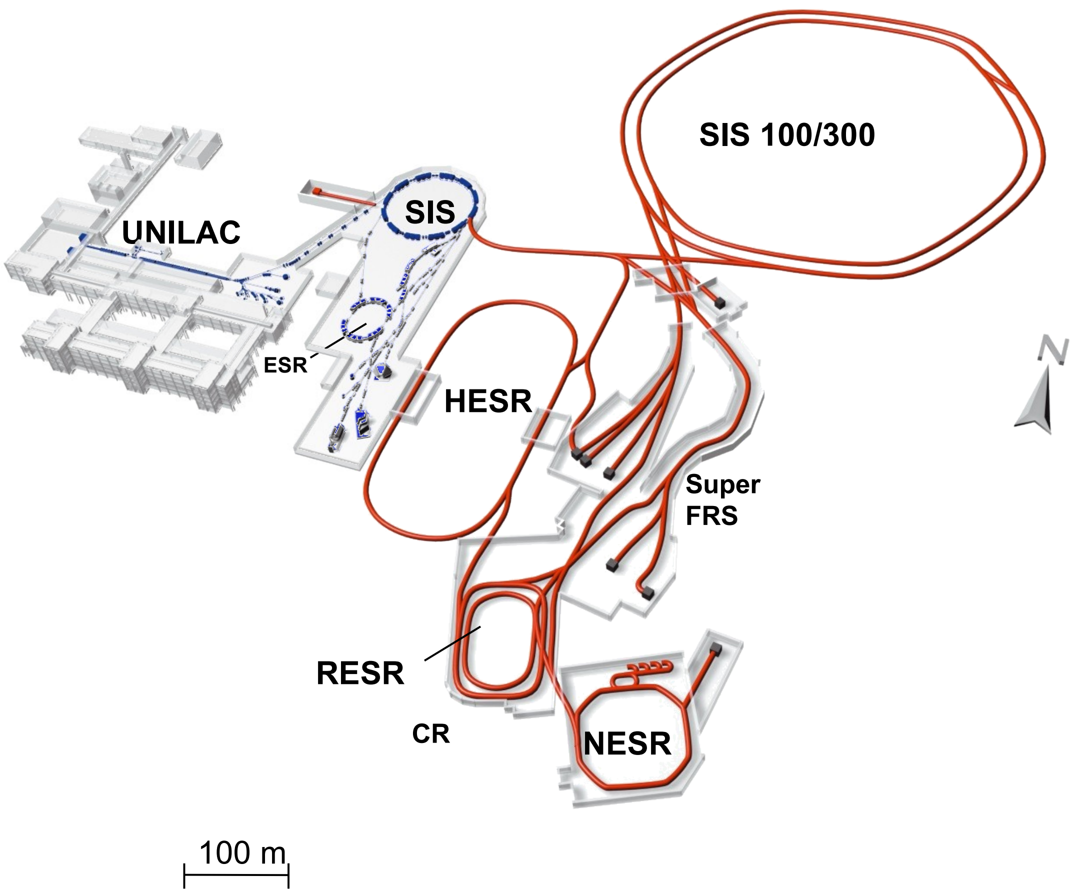
for the CRY Department at GSI

Lund, 07.-08.10.2019

Outline

- Overview
  - FAIR Project
  - Cryogenic Infrastructure @ GSI
    - HeSu
    - R^3B and FoPi plant
  - Cryo Testing
    - PTF
    - STF
- STF
  - Mechanical concept
  - Status
  - Additional tasks
  - Modifications
- Quadrupole testing
- String planning

Facility for Antiproton and Ion Research



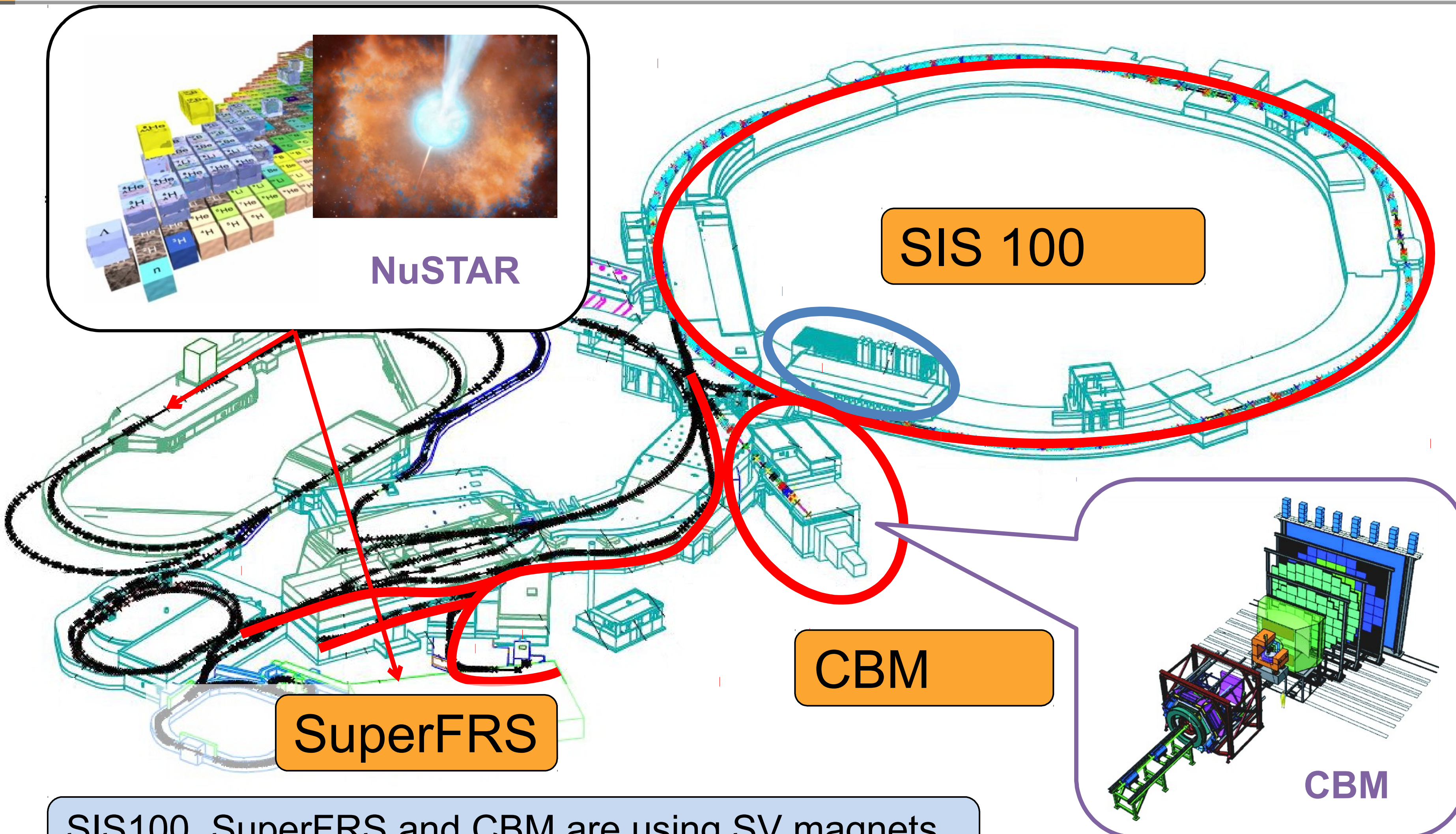
GSI-Today

- Protons to Uran
- max 1 GeV/u Uran and 2 Gev/u for Neon

GSI in futue / FAIR

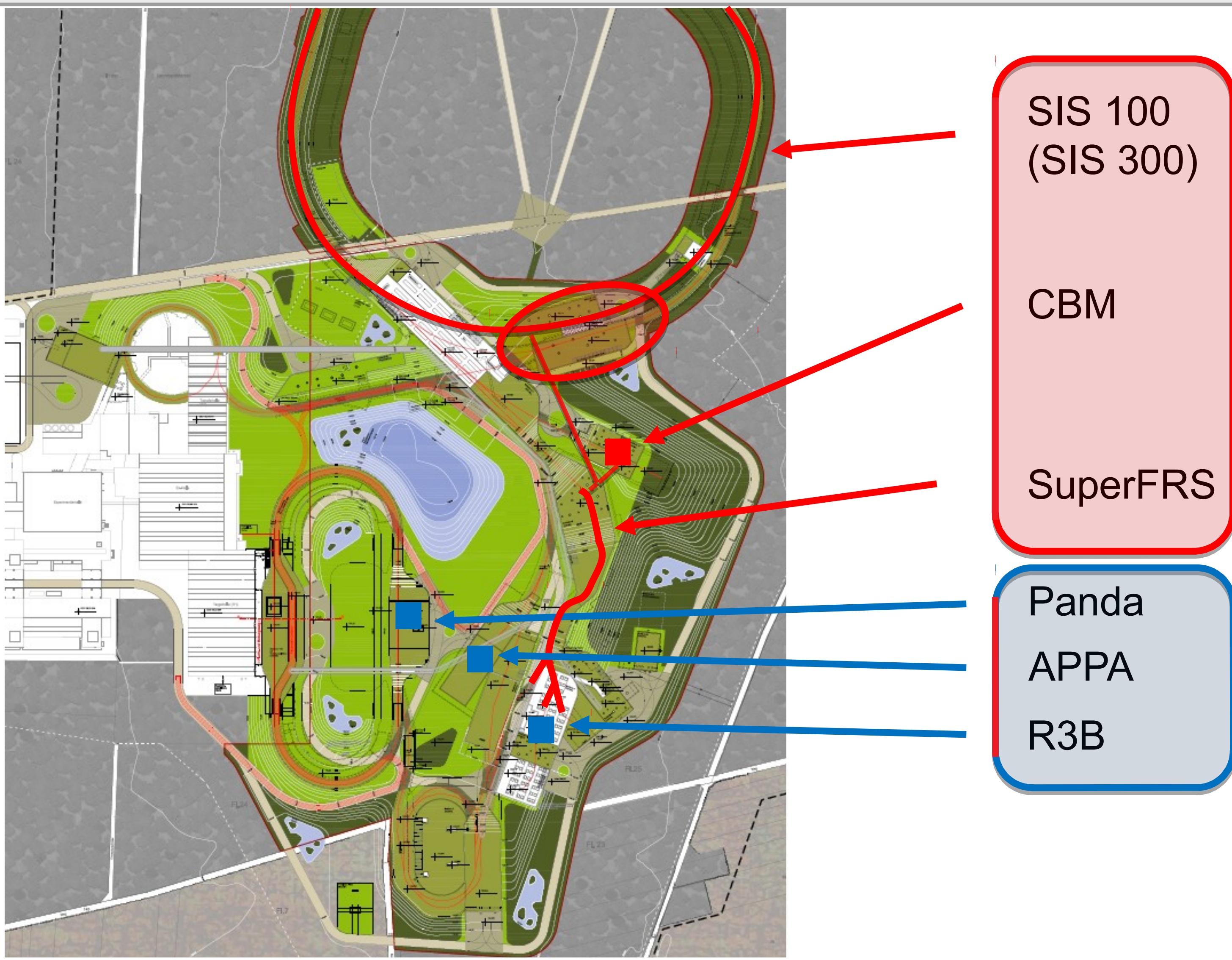
- Rare isotopic beams
- Anti protons
- Higher Beam Current
- At higher energies

SIS100 with SuperFRS and CBM



SIS100, SuperFRS and CBM are using SV magnets supplied by one central plant

Cryogenic Supply for FAIR



Overview of FAIR cryogenic Infrastructure at GSI-campus

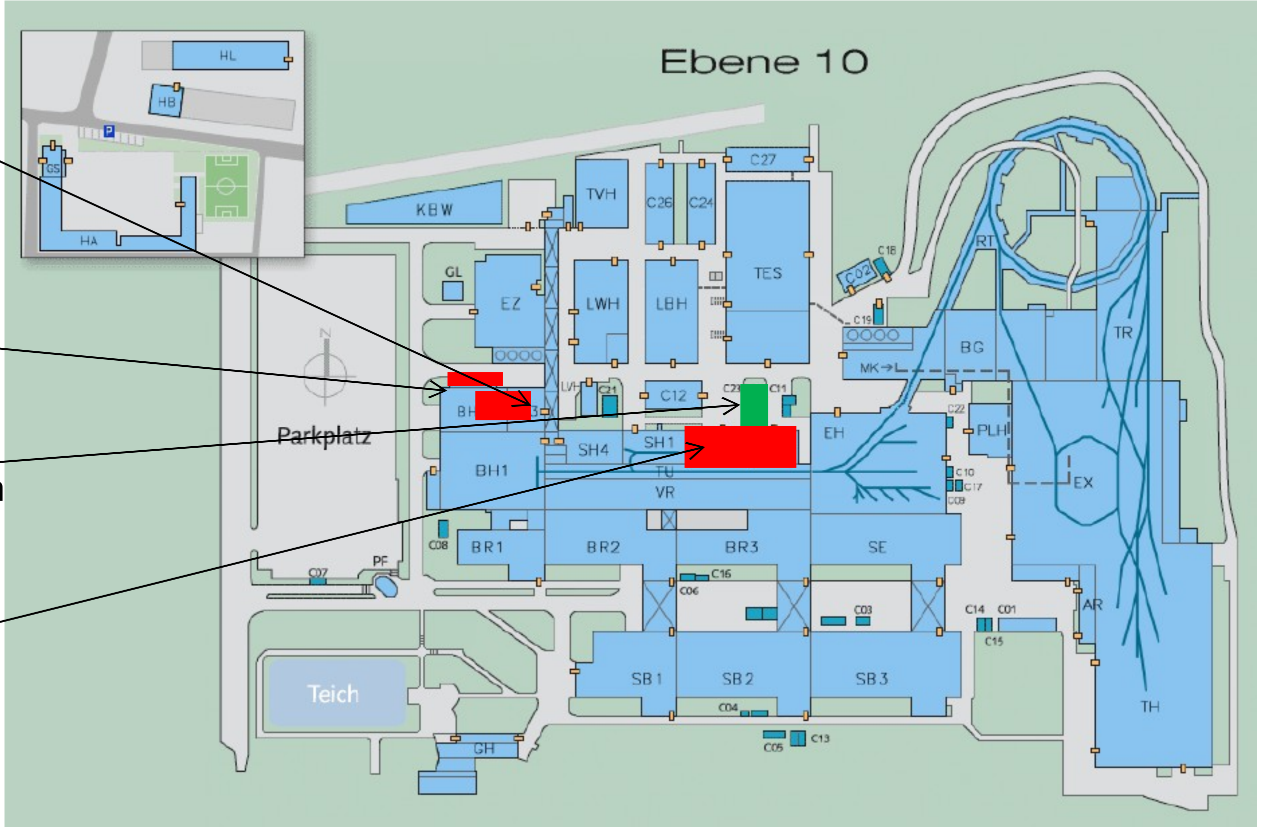
Overview of GSI-campus, with the location of the existing PTF and the STF-area.

HeSu (Helium Supply plant) central liquefier for Helium-Dewar filling

existing PTF with annex, housing compressor and transformers

new annex building, housing compressor, cold box, distribution box and electrical infrastructure

given area for STF in existing hall



GSI campus

Helium Liquefier (HeSu)
Operation since 2015

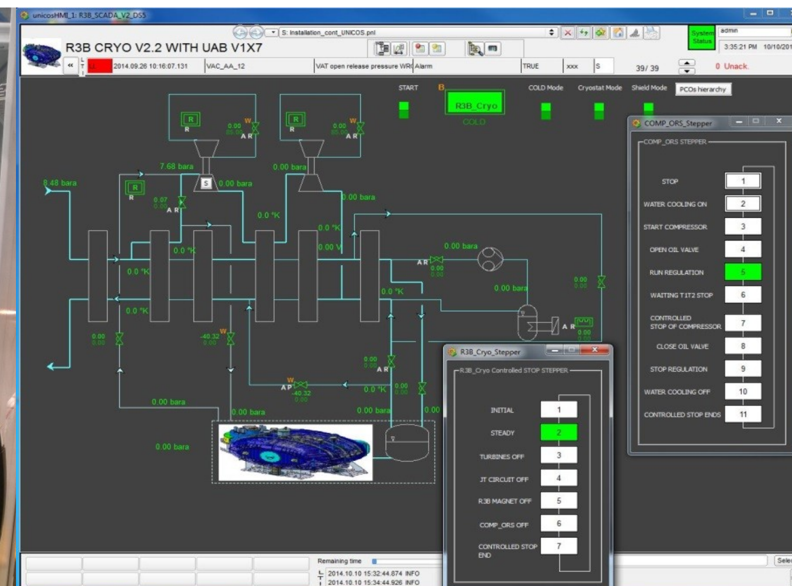
- Liquefaction rate ~ 20+ l/h
- 3000 l LHe storage, 8000 l delivered so far
- Decant Station and campus wide recovery system

R3B Cryo Plant and FoPi Cryo Plant Refurbished and Migrated to UNICOS

TCF50 including new cabinet

Cabinet

UNICOS + WinCC OA



Supported by CERN and INFN:

M. Pezzetti, Ph. Gayet, R. Pengo and B. Gallese

PTF Infrastructure

Cryogenic infrastructure at PTF:

- 70.000 h operation of the PTF
- in operation at GSI since 2005
- 2.200 h with 60 g/s
- 90.500 h total operation of the cryo plant
- only 300 m³ Helium inventory
- 40-80% Helium losses/year

Cryo plant:	PTF
Cooling power @ 4,5 K	300 W
Helium circulation pump	60 g/s- 200 g/s
Helium liquefaction rate	2 g/s
Max. power consumption	250 kW

Distribution box (blue)
Feed boxes and universal cryostat

Preparation area, Cryogenic infrastructure is located in the middle of the hall

The Series Test Facility Operating since 2015

- 1.5 kW 4 K equivalent, 6 g/s liquefaction, four test benches
- SIS 100 dipoles, quadrupoles and SuperFRS Magnets can be tested
- Testing of SIS100 and SuperFRS local cryogenics

STF: Overview and Key Paramenters

Coldbox in the cryo room (1.5 kW@4.5K eq.)

Helium tanks and annex building with 1,1 MW water cooling

Cryogenic infrastructure at STF:

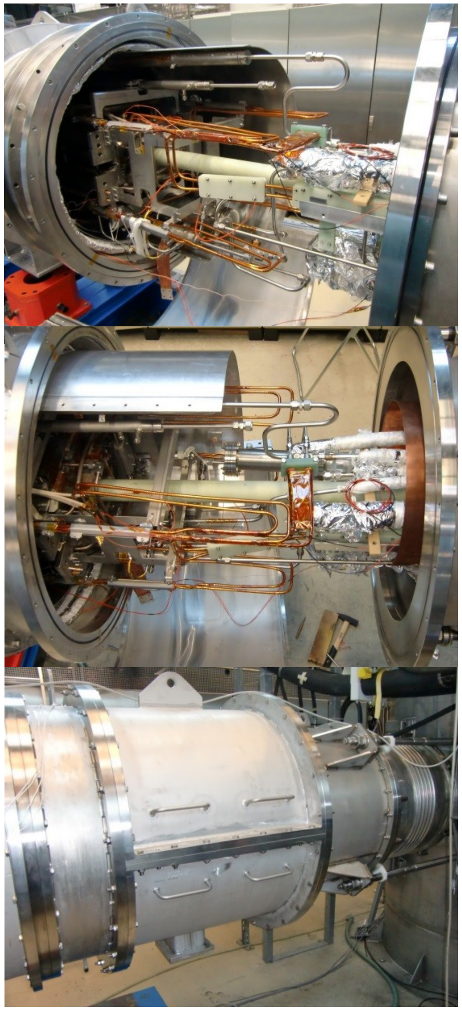
- 25.000 h operation of the STF
- sub-cooling in the Feedboxes
- in operation since 2015
- 1.000 m³ Helium inventory @ warm
- up to 3.000 l Helium at cold

Cryo plant:	STF
Cooling power @ 4,5 K	700 W
Cooling power @ 50 K – 80 K	2000W
Helium liquefaction rate	6 g/s
Max. power consumption	434 kW

„Cold End“ in the STF testing hall

Easy excess to the connection area

Mechanical concept I: PTF versus STF


Connection area at PTF

Evolution from prototype- to serial-facility

Magnet connection at PTF:

- 2 meters extra length
- lot of flange connections
- hard to install
- needs strut sections at the bellow
- needs additional bus bar

Endbox (Endcap) is:

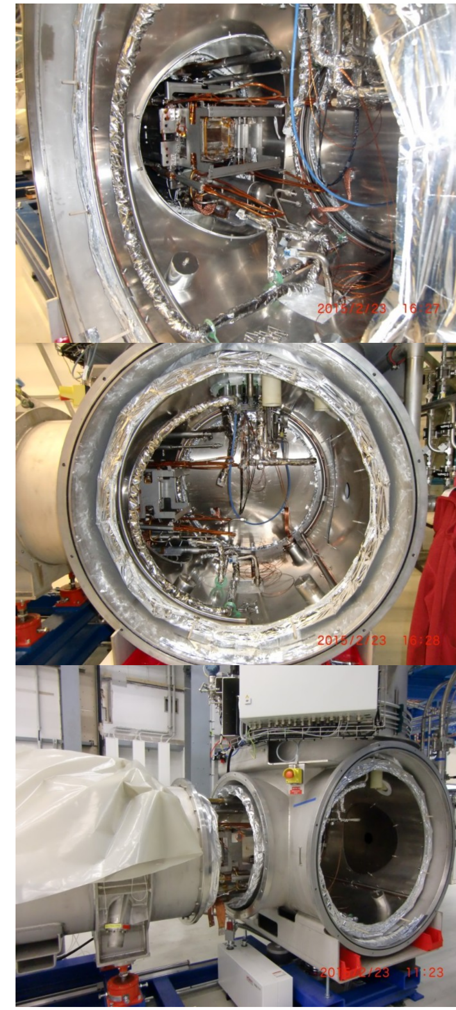
- direct mounted to the magnets
- needs a crane

Magnet connection at STF:

- magnet penetrates FBx and EBx
- easy flange connections
- easy to install
- no bellows needed
- direct connection to the main current leads (MCLs)

Endbox (Endcap) is:

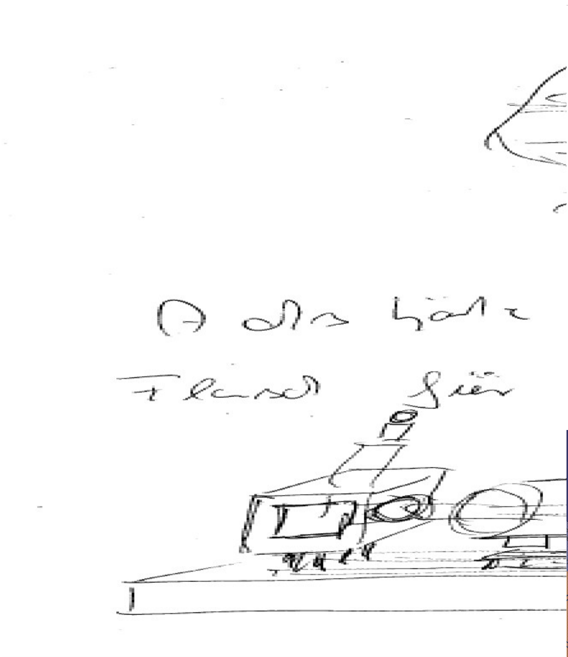
- movable on the rail system
- no crane needed


Connection at STF

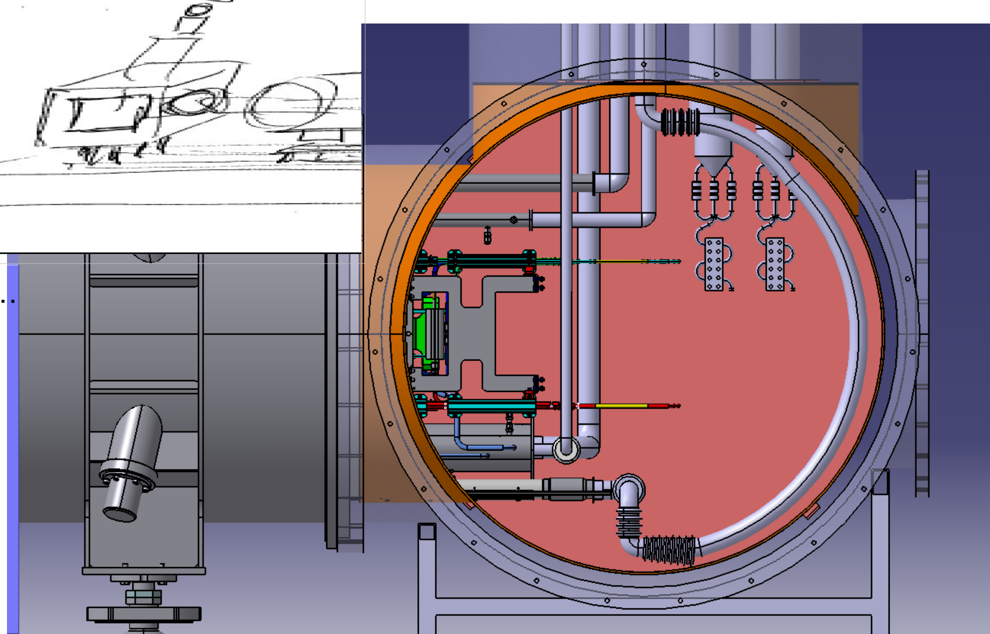
Mechanical concept II

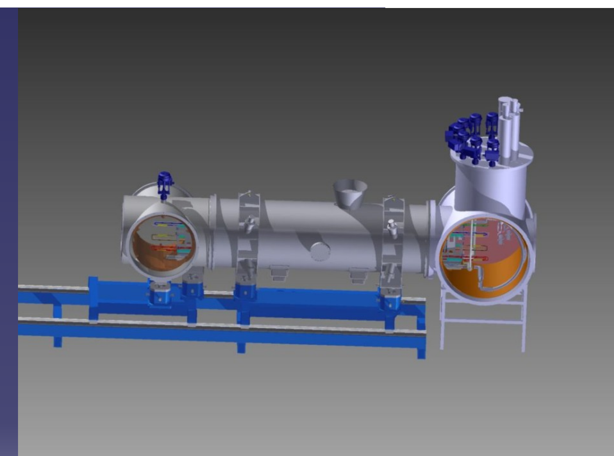
Feedbox connection at STF:

- save space
- easy excess to the connecting zone
- as less as possible crane action
- less flanges
- no bellows, no additional bus bar



From first ideas…



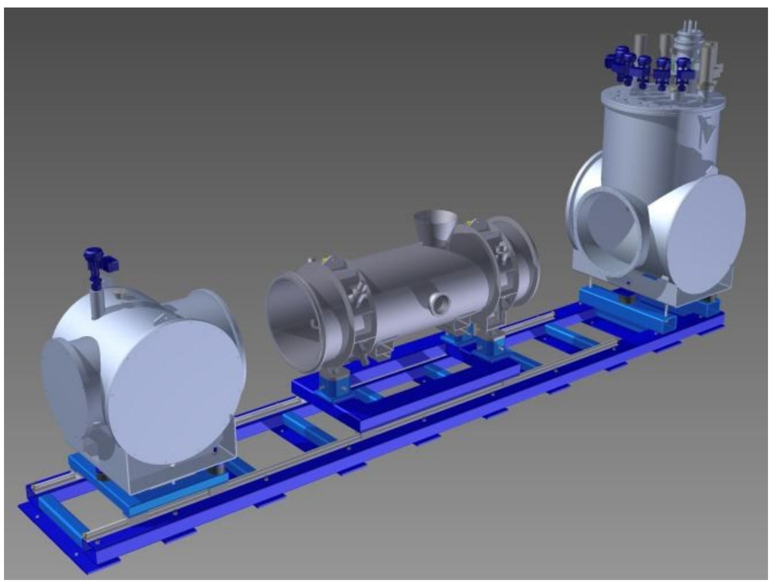


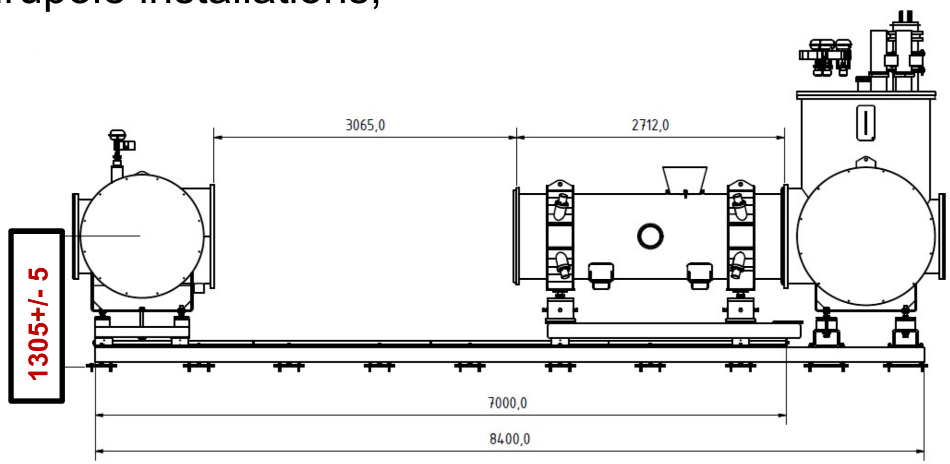
…to final concept

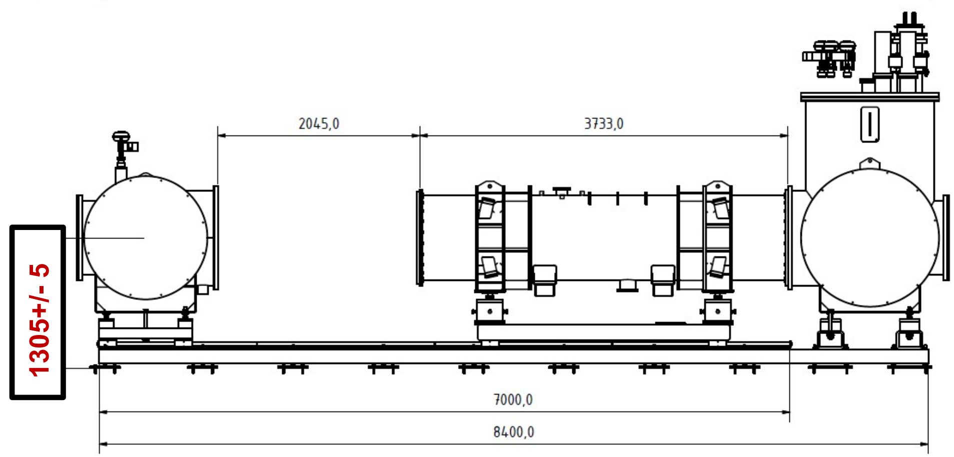
Mechanical concept III

Rail system enables dipole and quadrupole installations; high precision was requested:

- ± 0,1 mm horizontal
- ± 1 mrad

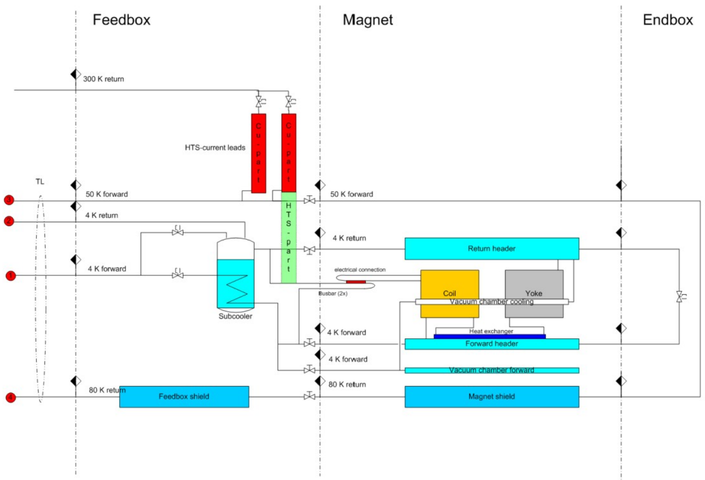




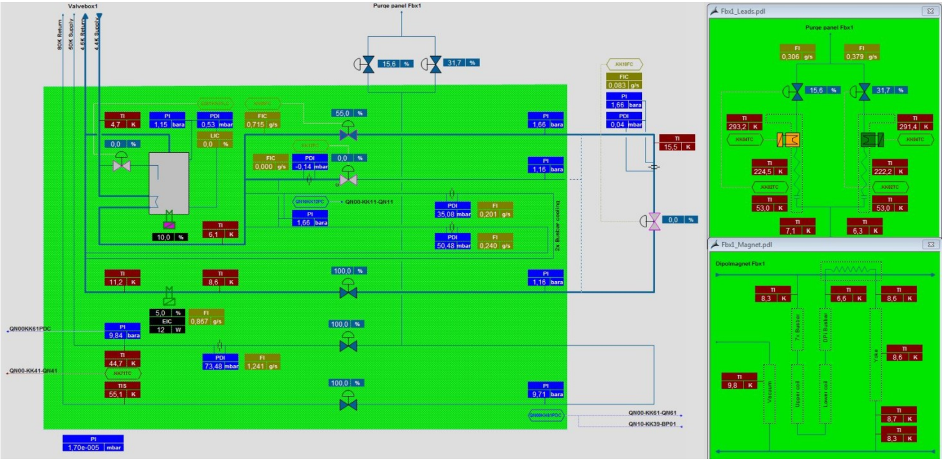


Rail system is prepared to also test SIS100-quadrupols

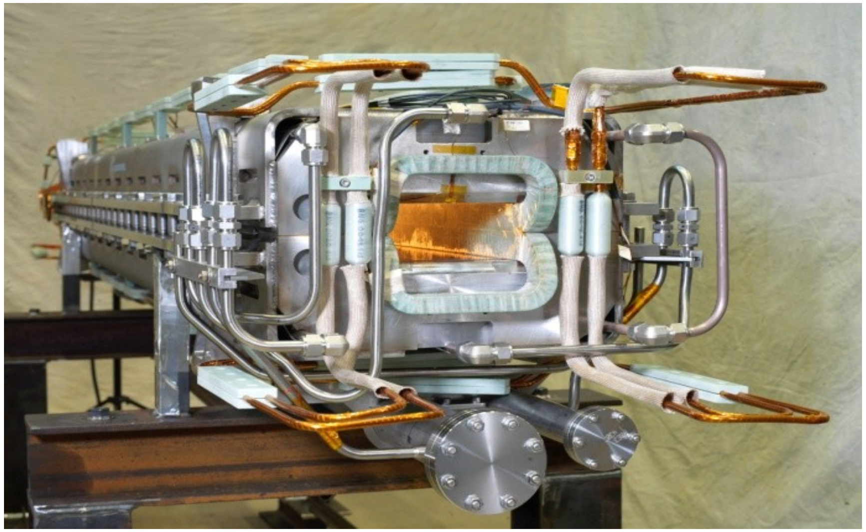
Serial Testing Status



Sketch of process lines



HMI for the operation of one Feedbox during magnet test



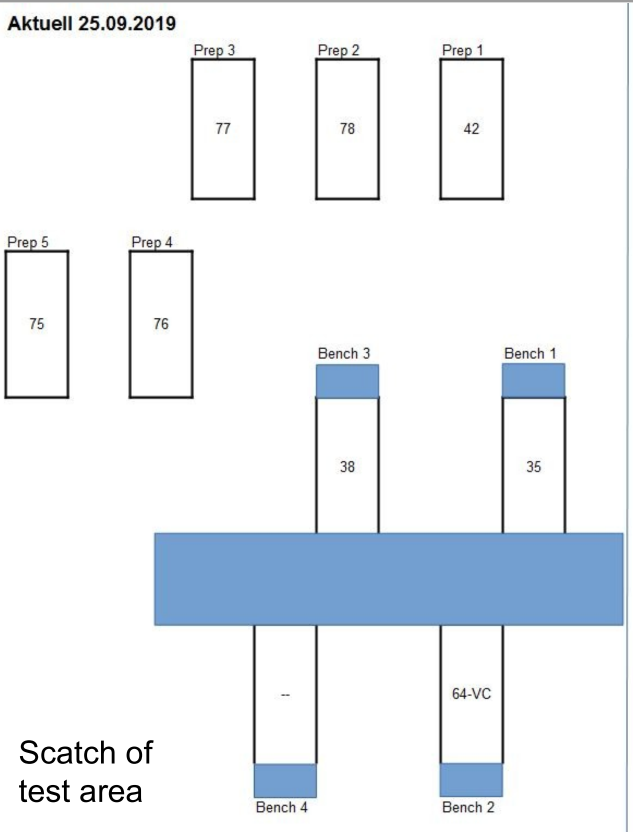
SIS 100 Dipole:
cooling by forced-two-phase-Helium-flow
at entrance subcooled
108 pieces

aperture:	130x60 mm²
ramp rate.	4T/s
max. field:	1,9 T
cold mass length:	3060 mm
over all length:	3700 mm

Serial Testing Status

Preparation area; incoming and outgoing tests

View in the testing hall with warm calibration magnet in front



Scatch of test area

- 100 % of MCLs
- 50 % of SIS100-Dipols
- one bypass-line
- one Beam-vacuum-chamber
- 2 cryo-pump-prototyps

Magnete

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100
101	102	103	104	105	106	107	108		

55 von 108 getestetet

Main Current Leads Paare

1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	

19 von 19 Testing abgeschlossen

- wieder getestet nach Umbau
- getestet (altes Prozessleitungsdesign)
- getestet
- an der STF vor/während Test
- getestet und im Betrieb (FBx1-FBx3)

Half of the SIS100 Dipole magnets are successfully testet

Additional Testing:
SIS100 By-Pass Line (Polish *In-Kind*)

- Successfully tested at GSI STF
- Series production in started
- Production time until 2022

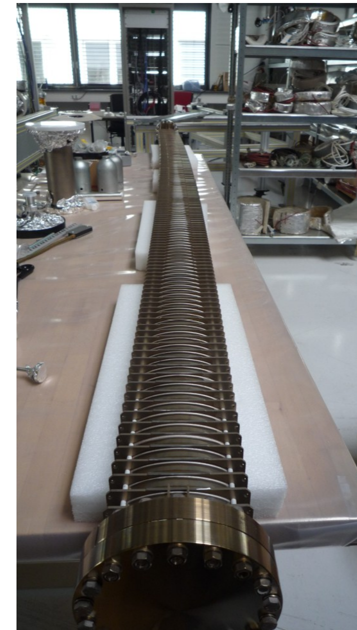
Additional Testing II:
MCL SIS100, Cryo-Adsroption Pump, Beam Pipe Chamner

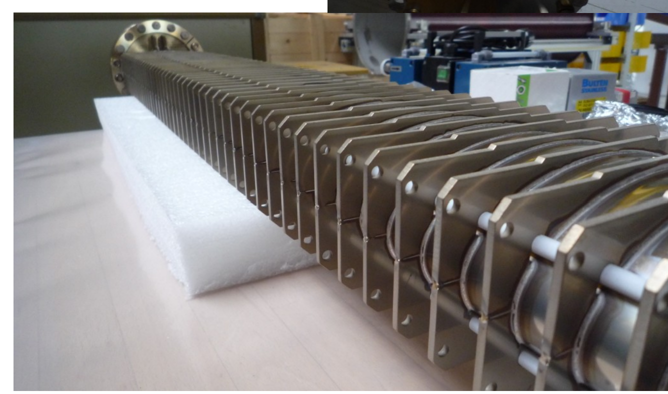
Electrical switch for 14 kA between 2 benches
The 4. bench operated mainly for the serial testing of main current leads (MCLs)

Cryogenic pump

Jumper-line during installation on the side of one Feedbox

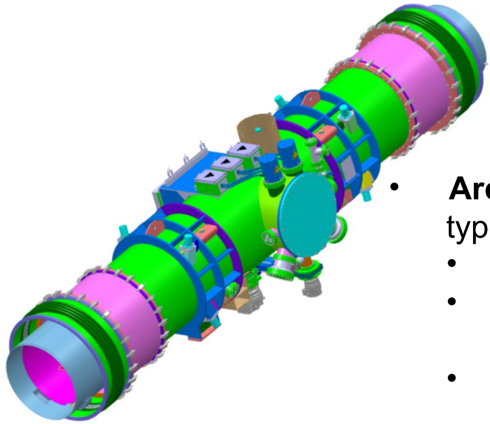
One key item of SIS100 are the cryo-cooled, bended beam-vacuum-cambers



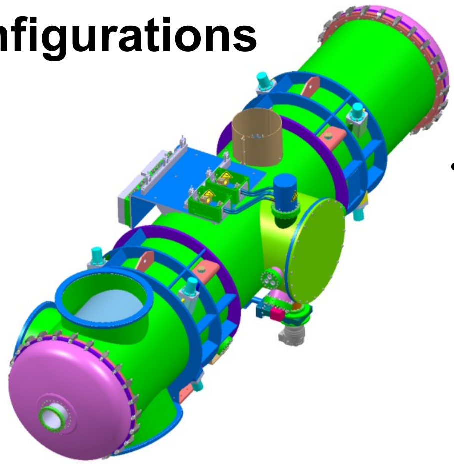


SIS100-quadrupol at STF

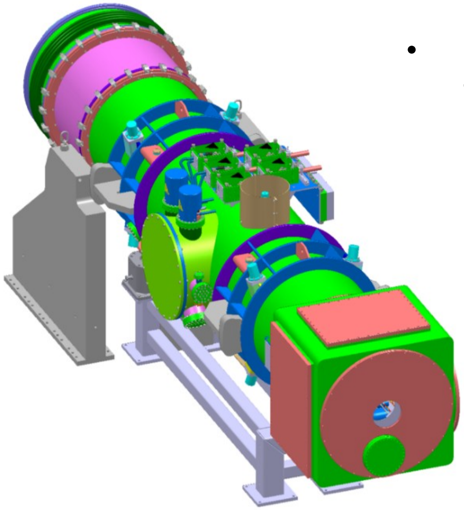
4 different configurations



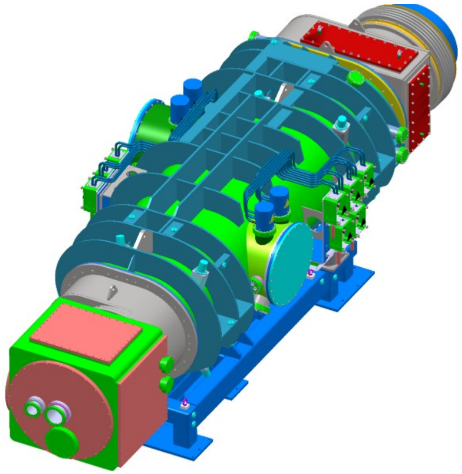
- **Arc section modules**
  types 2.5 to 2.9D
  - **54 modules**
  - Arc section module type incline of the arc-section
  - Cryogenic supply in line of the arc section



- **Straight section modules**
  types 2.123 and 2.13s
  - **17 modules**
  - Stand-alone module types are in between two warm sections
  - Cryogenic supply through attached by-pass line

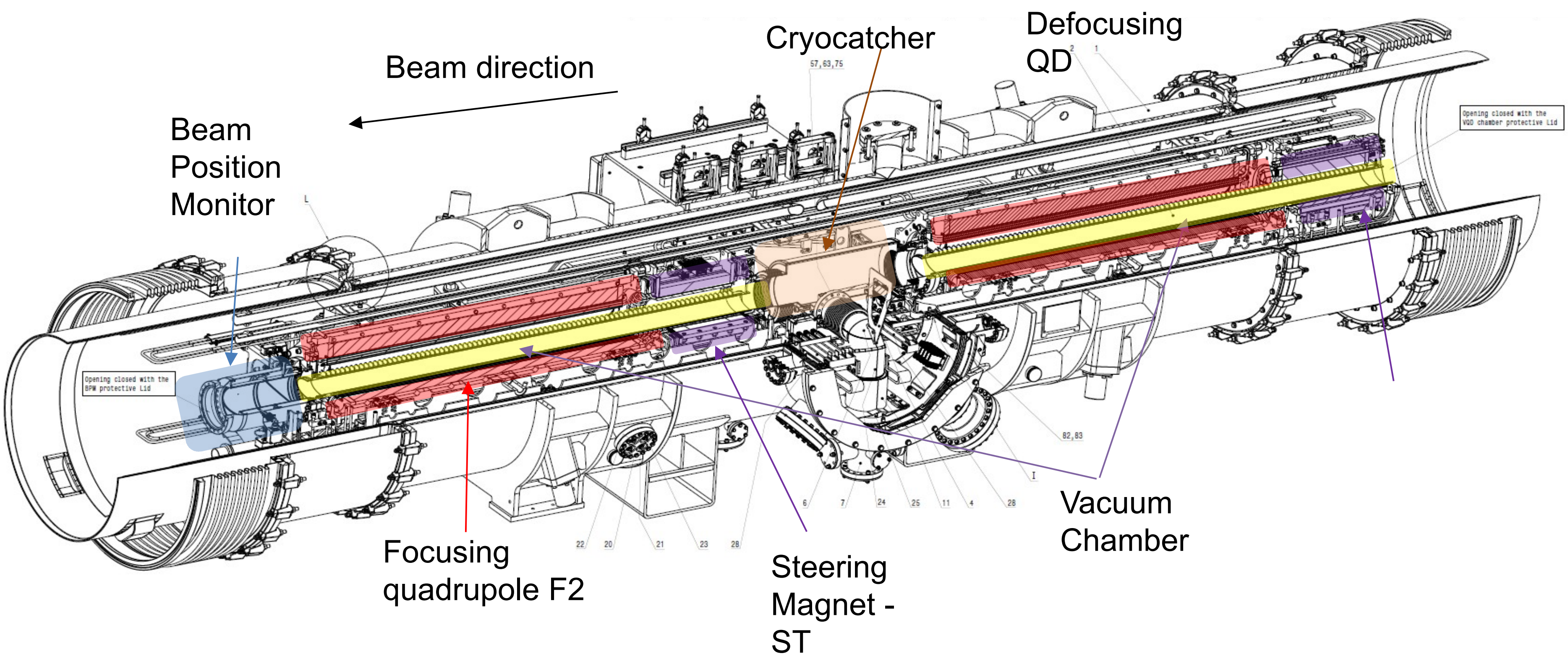


- **Arc termination modules**
  types 2.4 and 1.E
  - **10 modules**
  - US- and DS-termination of the arc section of SIS100
  - Cryogenic supply by attached by-pass line
  - Additional support for vacuum forces



- **Special modules**
  types 2.4x and 1.Ei
  - **2 modules**
  - US- and DS-terminations of sector 5 in SIS100
  - Additional Injection- and extraction QP-doublets separately supported
  - Cryogenic supply by attached by-pass line

SIS100-quadrupol at STF

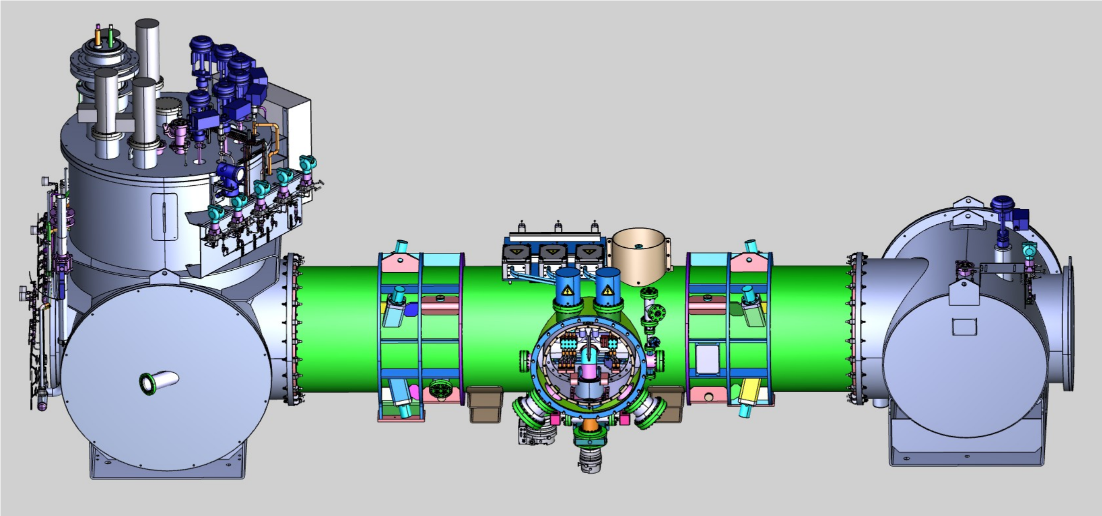


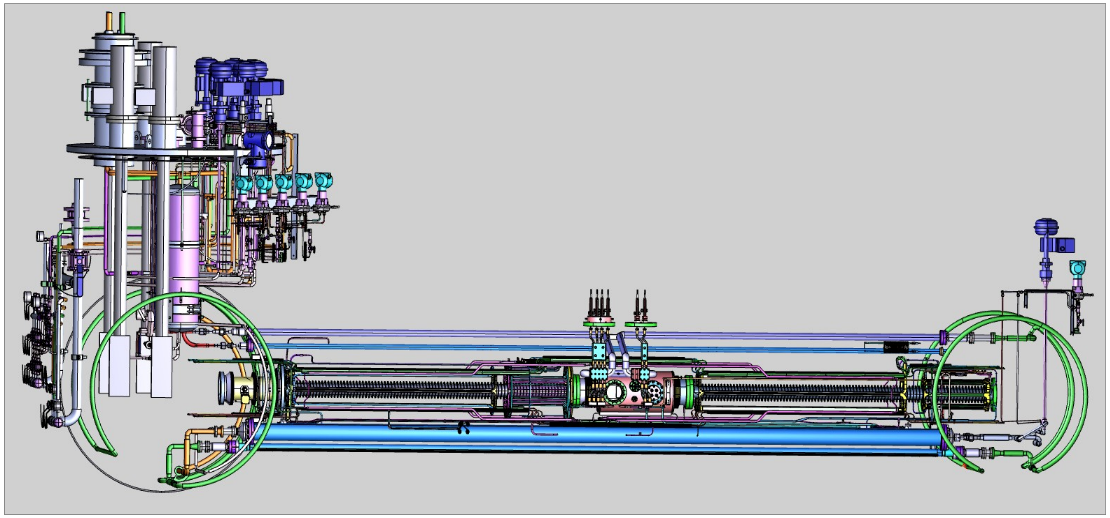
Downstream unit SF2B (F2 + steerer)

Upstream unit VQD (QD + sextupole)

SIS100 Quadrupole-module is a highly complex system of two quadrupole magnets and various additional components

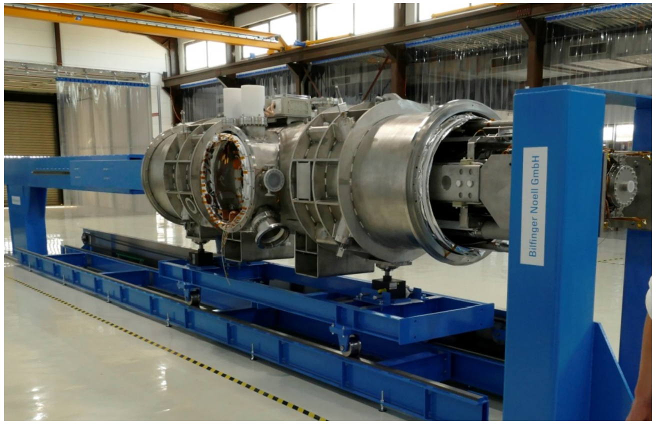
SIS100-quadrupol at STF





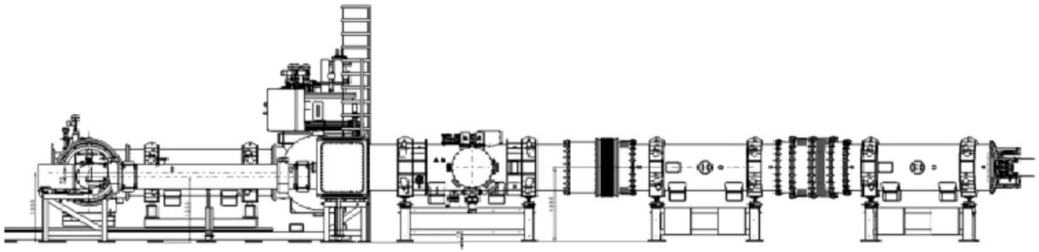
Mounting scheme at Series Test Facility station

1. Magnet units, vacuum chambers, beam diagnostic and other module components available at Bilfinger Noell for prototype assembly.
2. Integration of QDM prototype advanced, module will be delivered in October 2019 to GSI.
3. Testing campaign of the magnet module is planned and will start in November 2019 at GSI series test facility.

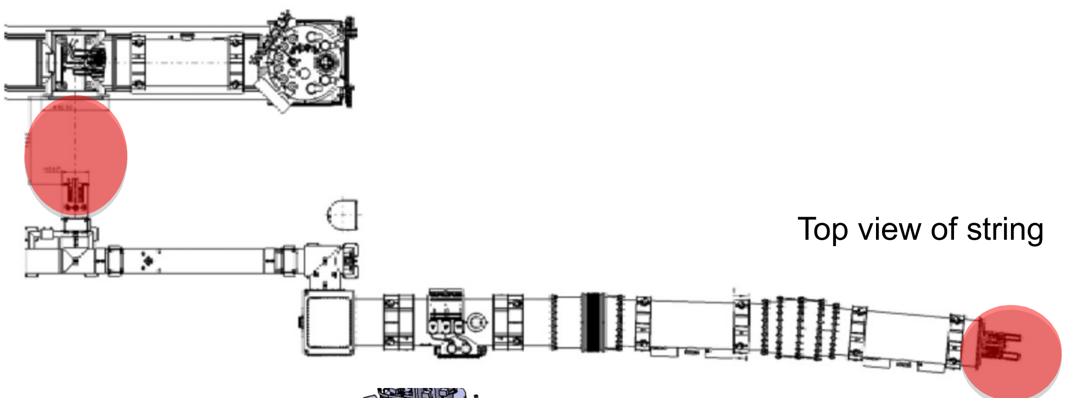


Assembly of prototype at Bilfinger-Noell

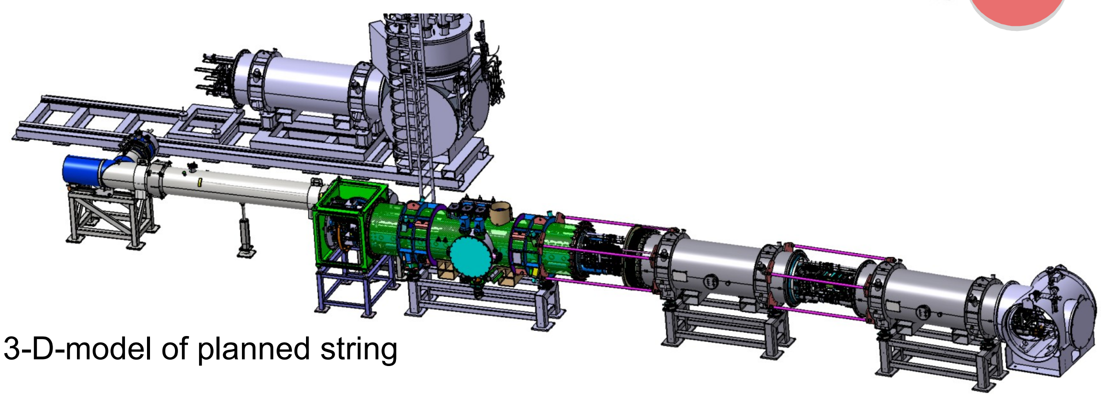
String plannings



Side view of string



Top view of string



3-D-model of planned string

Next big step in preparation is the installation of a string at STF.

After testing the first quadrupole-module we will immediately start building up a string with one quadrupole-module and two dipoles using also existing ring parts as feed-in-line and feed-in-cryostat.

Missing parts (red) as special end-box and connecting part are in design phase.

After first tests with electrical dipole- and quadrupole circles in series, we will be also able to operate the dipole circles and quadrupole circles independently.

During installation we will test all possible installation processes we will also have later during ring installation.

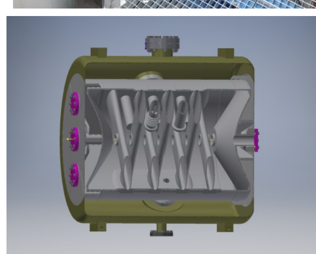
Modifications of the STF

Cryoplant was planned from very beginning to serve in a later stage superconducting cw-linac via the String-End-box.
By installing new distribution-box between Cold-box and test-area we will enable cw-linac-tests from the very beginning.

As a first step the new box and 20m transfer line was installed during shutdown-phase beginning 2019.

In 2. step we will install the residual transferlines and needed cryogenic infrastructure in the cw-linac-testbulding beginning October 2019 by DeMaCo.

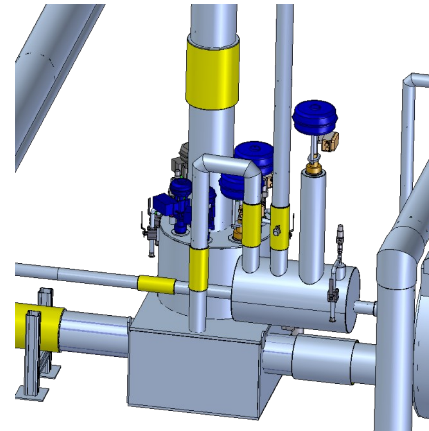
This infrastructure will be later used to serve also the real cw-linac without any additional modifications.

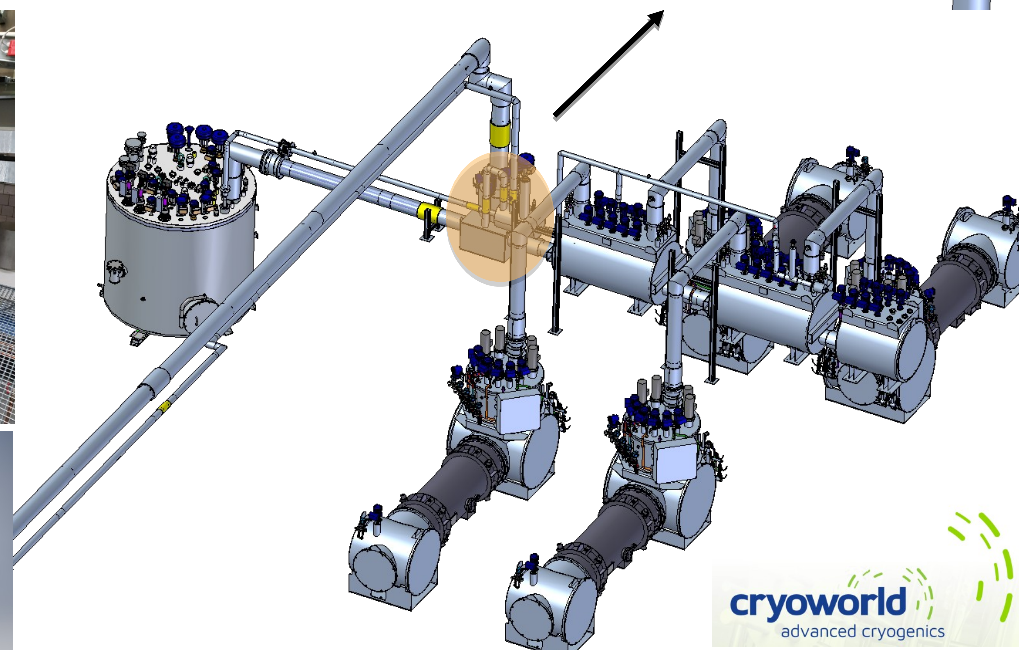


Cw-linac superconducting accelerator cell

We used some space between cold-box and first distribution box to cut the fourfold- and singelfold-transferline and installed additional distribution box for cw-linac supply.

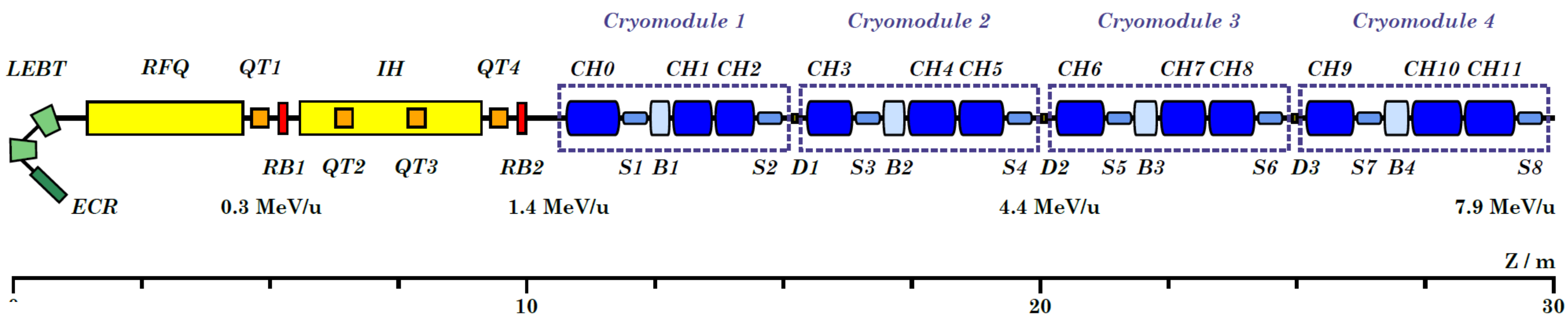
New box is already implemented to the HMI of the cryoplant.



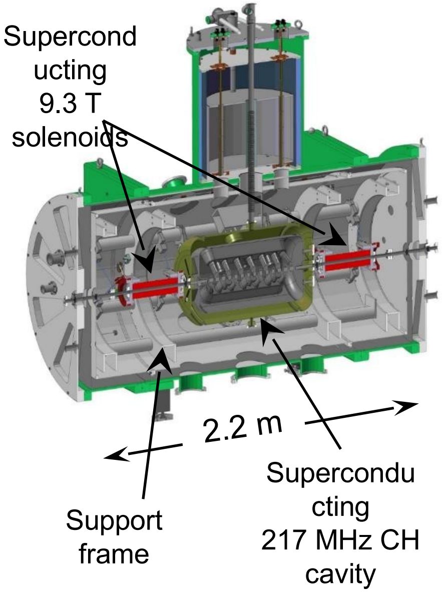


cryoworld advanced cryogenics

CW-Linac at GSI



Layout of demonstrator

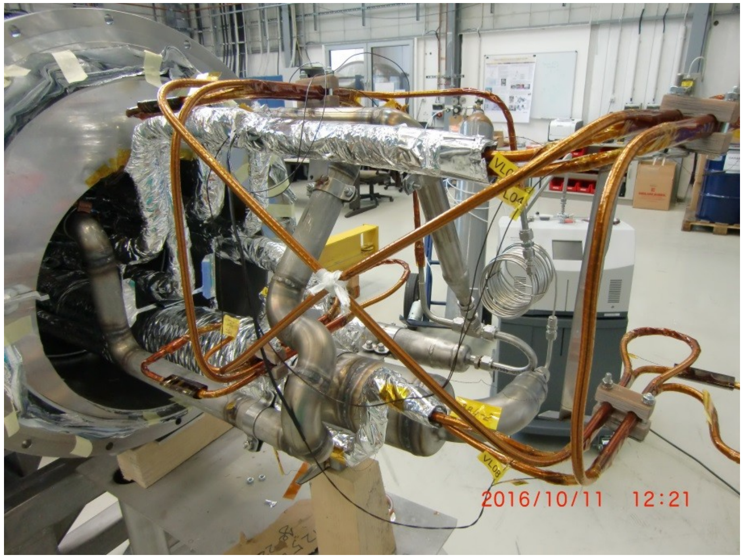


Design par
A/q
Frequency
Beam curre
Injection en
Output ener
Length
CH cavities
Rebuncher
Solenoids

Layout properties

- Multigap CH cavities
- Cavities with short lengths (<1 m) and small transverse dimensions (<0.5 m)
- Modular construction with 4 cryomodules
- Each containing 3 CH cavities, 1 buncher, 2 solenoids
- E_a= 7.1 MV/m enables compact linac design
- First step → Demonstrator project

Thank you for your interest



Magnet side of jumper-line; all bus bars are shorted