

A photograph showing the interior of a particle accelerator tunnel. The view is from the center, looking down a long, narrow passage. The walls are made of metal and are lined with various cables, pipes, and mechanical components. Two large, black, flexible conduits run along the top of the tunnel. The lighting is bright, and the overall atmosphere is industrial and technical.

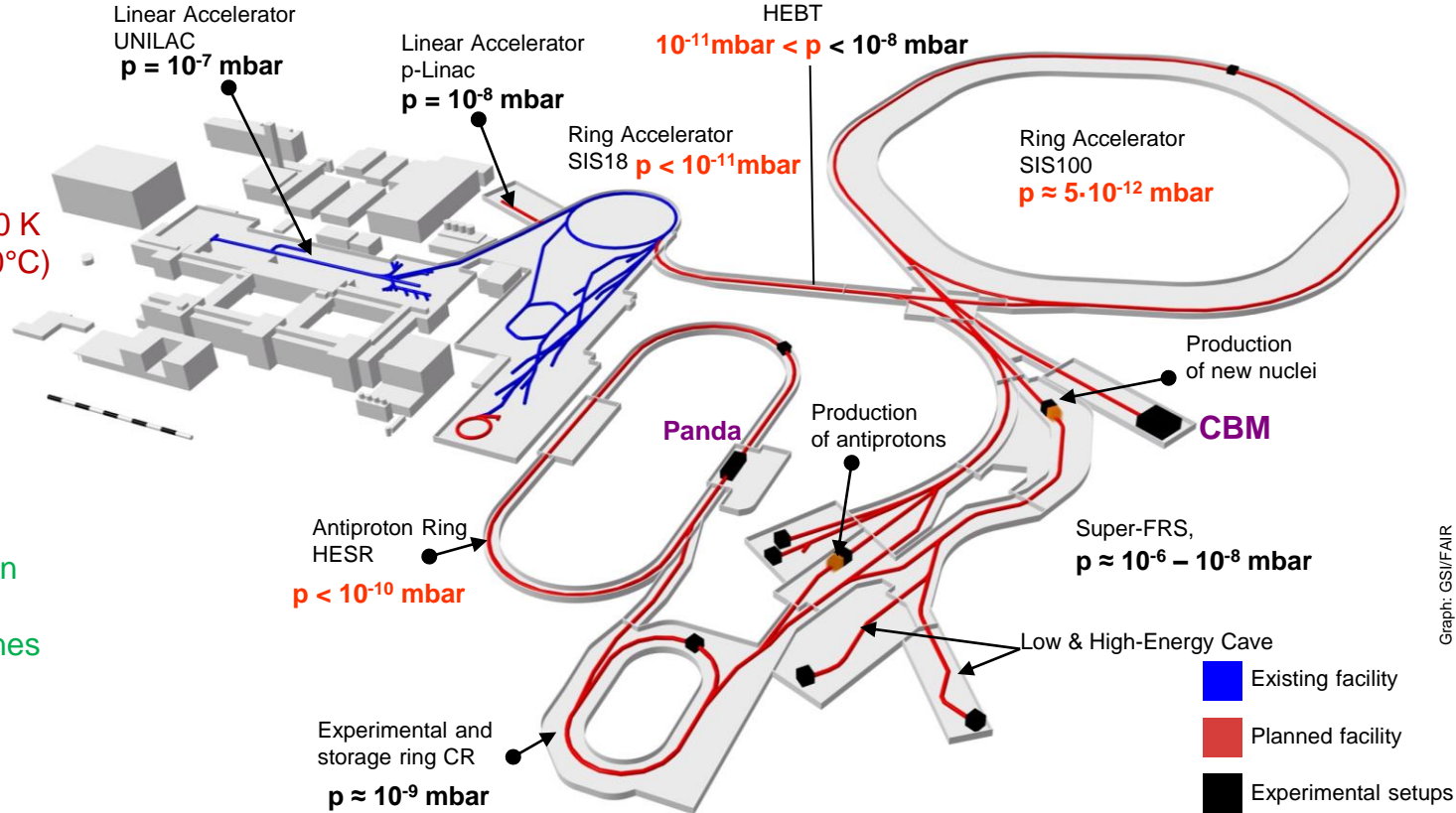
Opportunities in Vacuum and Cryogenics at FAIR

Andreas Krämer

FAIR Vacuum Requirements

Beam Vacuum System:

- Total length: ~ 3.9 km
- Volume: ~ 65 m³
- Vacuum: 10⁻⁶ – 10⁻¹² mbar
- Cryogenic sections with operating temperatures of 5-20 K
- Bakeable sections (up to 300°C) operated at room temperature



Insulation Vacuum System

for superconducting magnets in SIS100 & SuperFRS and cryogenic transfer & bypass lines

- Total length: 2.8 km
- Volume: ~ 300 m³
- Vacuum: $< 10^{-6}$ mbar

FAIR's vacuum procurement needs

Vacuum Chambers SFRS

Type	# of items	Variants	Shape	Dimensions	
Focal Plane Chambers	17	17	rectangular	max 460 x 100 x 100 cm ³	High requirements on overall flatness of the top plate (0.1 mm)
Pumping Chambers	18	18	round DN400	length 20 - 50cm	Incl. hydroformed bellow, flanges 2x DN400CF, 2x DN160CF, 2x DN40CF plus support frame for each chamber
Beam pipes	30	tbd	round DN400	tbd	
Bellows	32	tbd	round DN400& racetrack		

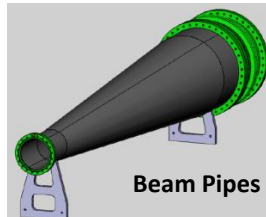
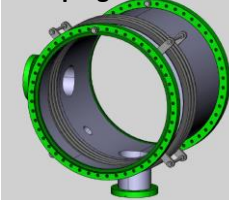
Material:

stainless steel of any type (without specified magnetic permeability) such as 1.4301, 1.4306, 1.4307, 1.4404, 1.4435 or 1.4429. (must follow DIN EN 10088)

Vacuum Requirements:

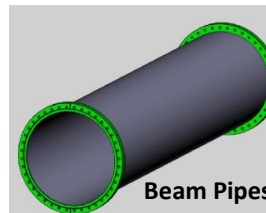
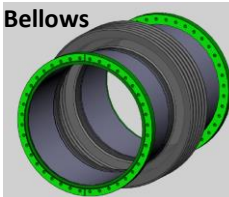
- outgassing rate 1×10^{-9} mbar l/s cm²,
- leak rate 1×10^{-9} mbar l/s,
- special RGA acceptance criteria

Pumping Chamber

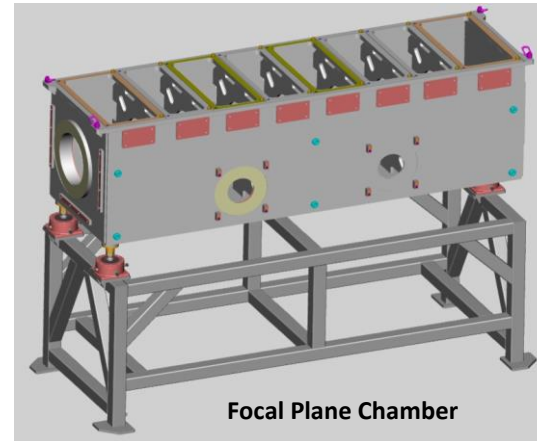


Beam Pipes

Bellows



Beam Pipes



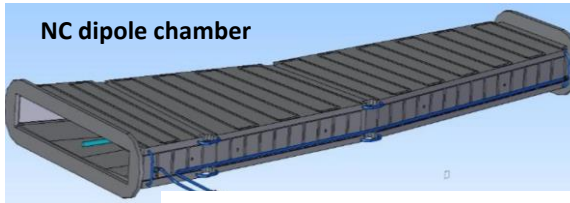
Focal Plane Chamber

FAIR's vacuum procurement needs

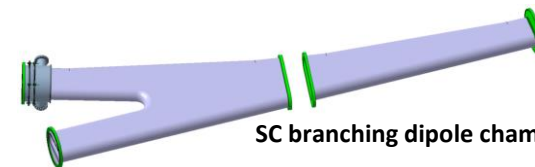
Magnet Vacuum Chambers SFRS

Type	# of items	Var.	Shape	Dimensions	
NC dipole chambers	3	2	rectangular/ trapezoidal	length max 365cm, aperture entrance: 50x14cm ² aperture exit: 120x14cm ²	Material Ti6Al4V, complex structure, high power deposition from beam, water cooling required, Helicoflex type sealing, support frame for each chamber required
Dipole chambers bended for SC magnets	3 +15	1 + 4	rectangular/ racetrack	bending angle type 1: 11° bending angle type 2: 9,75° length= 3 - 3.2m aperture: 38x14cm ² wall thickness: 6 – 11mm	Material stainless steel 316LN or other non-magnetic alloy Support frame for each chamber Type 9.75° has included bellow and pumping chamber
Dipole chamber branching for SC magnets	3 + 3	2 + 2	Y-shaped & V-shaped	length 2.8m aperture: 38x14 (resp 68x14)cm ² wall thickness max 11mm	Material stainless steel 316LN or other non-magnetic alloy Support frame for each chamber Type 9.75° has included bellow and pumping chamber

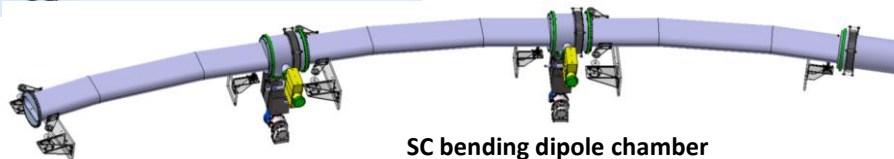
NC dipole chamber



SC branching dipole chambers



SC bending dipole chamber



Vacuum Requirements:

- outgassing rate 1×10^{-9} mbar l/s cm²,
- leak rate 1×10^{-9} mbar l/s,
- special RGA acceptance criteria
- Required relative magnetic permeability: ≤ 1.01

FAIR's vacuum procurement needs

Magnet Vacuum Chambers HEBT

Type	# of items	Var.	Shape	Dimensions	Remarks
Dipole chambers	11 (24)	6 (9)	rectangular trapezoid	length: 2.5 – 3.8m aperture: 110x67mm ² , 120x60mm ² , 120-200x60mm ² wall thickness: ~4-6mm	Incl. holders
Quadrupole / Steerer Chambers round	120 (200)	32 (57)	round	length 0.5 – 2m aperture 100mm, 120mm, 150mm wall thickness 2-3mm	Some chambers will have one or two bellows included Flanges DN160CF
Quadrupole Chambers elliptical	26 (47)	5 (9)	elliptical	length 1.4 – 2.1m aperture: 138x68mm ² wall thickness 2-5mm	Some with one or two bellows included Flanges DN160CF & DN400CF (4 chambers)

Material:

- Chamber/bellow/flanges: material according to EN 10088: 1.4301, 1.4306, 1.4429 or 1.4435
- Flange material: material according to EN 10088: 1.4306 or 1.4307 or higher quality
- Magnetic permeability $\mu_r \leq 1.01$ (or $\mu_r \leq 1.05$ for components outside of yoke)

Vacuum requirements:

- Integral leak rate $\leq 1 \times 10^{-10}$ mbar l/s
- Outgassing rate $\leq 5 \times 10^{-10}$ mbar l/(s cm²)
- Residual gas composition as acceptance criteria
- UHV suitable cleaning
- non-bakeable



FAIR's vacuum procurement needs

Vacuum Chambers HEBT

Type	# of items	Var.	Shape	Dimensions	
Straight beam pipe	84 (251)	~30 (~90)	round	length: 0.5 – 6m aperture: 154mm wall thickness: ~2-3mm	Flanges DN160CF
Pumping Chambers	~25 (65)	3	round	length ~400-800mm diameter ~160mm height ~650mm	Flanges: 5x DN160CF, 1x DN40CF Material for flanges 1.4429ESR, support structure welded to chamber
Special Chambers	1 (6)	3	branching x-cross	~2100 x ~500 x ~500mm ² ~2545 x ~600 x ~450mm ²	Flanges: 2x DN160CF, 1x DN400CF Flanges: 6x DN160CF Both chambers have a support structure
Bellows	216 (567)	~10	round	length: ~186mm aperture: 154mm	Flanges DN160CF (one fixed/one rotatable) Material bellows: 1.4404, 1.4406, 1.4435, 1.4541, 1.4571

Material:

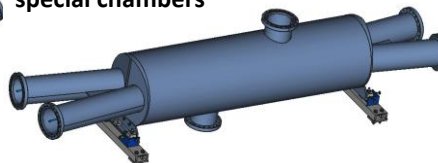
- Chamber material according DIN EN 10088: 1.4304, 1.4306, 1.4307, 1.4429 or 1.4435
- Flanges according ISO 3669, material according DIN EN10088: 1.4306 or 1.4307 or higher quality
- magnetic permeability chamber $\mu_r \leq 1.3$ flanges $\mu_r \leq 1.05$
- Surface quality Rz=25

Vacuum requirements:

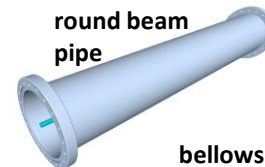
- Integral leak rate $\leq 1 \times 10^{-10}$ mbar l/s
- Outgassing rate $\leq 5 \times 10^{-10}$ mbar l/(s cm²)
- Residual gas composition as acceptance criteria
- UHV suitable cleaning
- non-bakeable



special chambers



pumping chamber



round beam pipe



bellows

FAIR's vacuum procurement needs

Vacuum Chambers SIS100

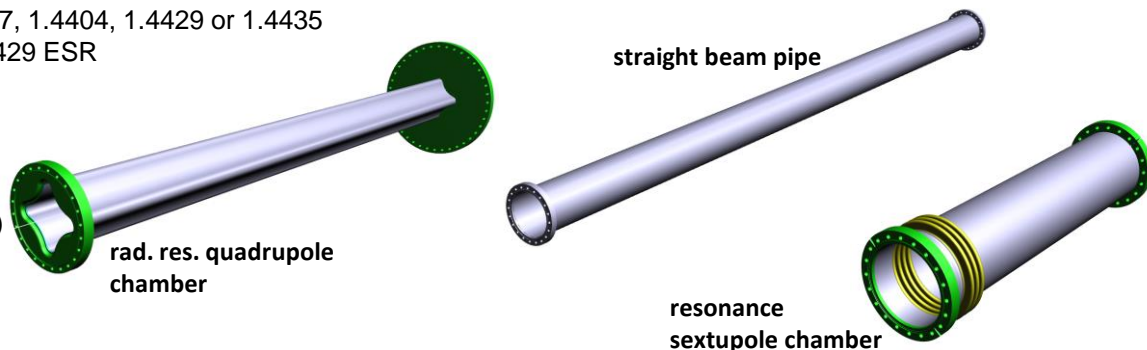
Type	# of items	Var.	Shape	Dimensions	
Straight beam pipe	11	2	Round	Length: ~1.3 & ~3m Aperture: DN160 Wall thickness: ~2 - 3mm	Bake-out jackets and chamber support stands part of delivery
Chamber for resonance sextupole	6	1	Round with bellow	length 730 mm diameter ~160mm height ~650mm,	With integrated corrugated (hydroformed) bellow Magnetic permeability $\mu_r \leq 1.01$ Bake-out jackets and chamber support part of delivery
Chamber rad. res. Quadrupole	2	1	Star-shaped	Length: ~2m Aperture: 135 x135 mm ²	Flanges DN160CF & DN300CF Magnetic permeability: $\mu_r \leq 1.01$ Thin bake-out jackets (8 – 10 mm) part of delivery NEG coating required

Materials:

- Chamber material according to EN 10088: 1.4306, 1.4307, 1.4404, 1.4429 or 1.4435
- Flanges DN160CF, material according to EN 10088: 1.4429 ESR
- Surface quality Rz=10
- Vacuum firing (950°) required

Vacuum requirements:

- Integral leak rate $\leq 1 \times 10^{-10}$ mbar l/s
- Outgassing rate (after bake-out) $\leq 1 \times 10^{-12}$ mbar l/(s cm²)
- UHV suitable cleaning
- Bakeable up to 300°C
- Bake-out cycle for acceptance test required



FAIR's vacuum procurement needs

Vacuum Chambers SIS100

Type	# of items	Var.	Shape	Dimensions	Remarks
Bellow cryogenic	~120	3	round	length: ~0.1 & ~0.3m aperture: DN160	Operational temperature < 20 K Corrugated (hydroformed) bellows Surface Rz ≤ 6.3
Bellow bakeable	~70	~10	round	length: ~0.1 & ~0.3m aperture: DN160	Corrugated (hydroformed) round bellows Flanges DN160CF & DN200CF Bake-out jackets part of delivery
Beam Vacuum Cold Warm Transitions (BV-CWTs)	50	6	star-shaped / elliptical inner tube	length: ~0.5m aperture: 133 x 133 mm ² & 133 x 65 mm ²	Operational temperature (on cold side) < 20 K Surface Rz ≤ 6.3 Bake-out jacket part of delivery (on warm side) Additional Helicoflex type seal

Materials (according to EN 10088):

- Flanges DN160CF, material: 1.4429 ESR
- Chamber material: 1.4404 or 1.4571
- Bellow material: 1.4404, 1.4406, 1.4435, 1.4541, 1.4571
- Bellows single-walled, wall thickness ~0.3mm



Bellows



BV-CWT with
star-shaped inner tube



BV-CWT with
elliptically shaped inner tube

Vacuum requirements:

- Integral leak rate ≤ 1x 10⁻¹⁰ mbar l/s
- Outgassing rate (after bake-out) ≤ 1x 10⁻¹² mbar l/(s cm²)
- UHV suitable cleaning
- Bakeable up to 300°C
- Bake-out cycle for acceptance test required

FAIR's vacuum procurement needs

Standard Components

Standard components will be procured via call for tender as framework contract (including minimum and maximum number).
Contract duration 4 years

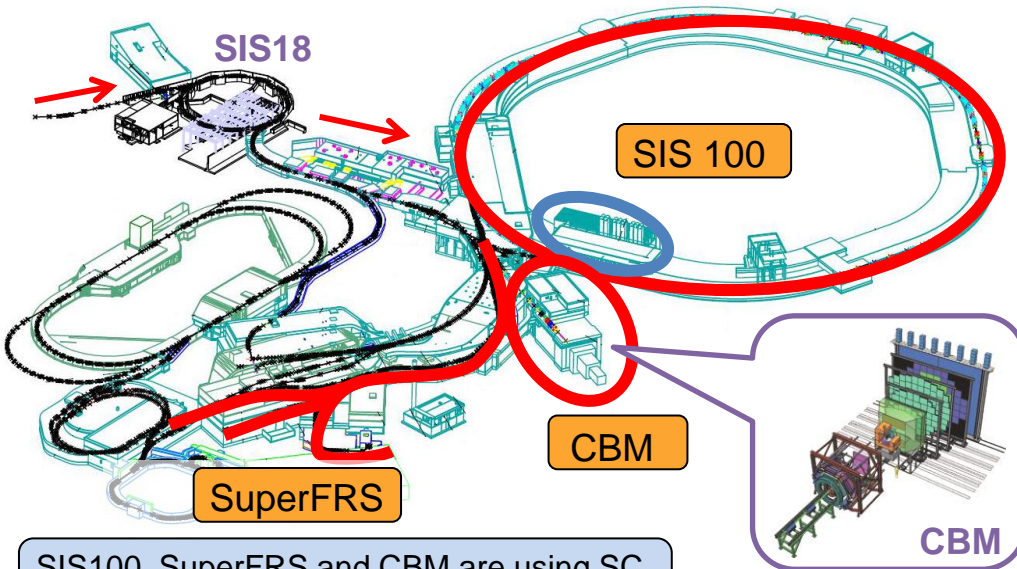
Type	# of items	Variants	Shape	Dimensions
Gate & Angle valves all-metal	~50 - 230	3 - 7	Gate valves: DN63 – DN400 Angle valves DN100 – DN200	CF flanges
Gate & Angle Valves Viton/EPDM	~150 - 500	13 - 18	Gate valves: DN63 – DN400 Angle valves DN100 – DN200	CF flanges & ISO-K flanges
Turbo molecular pumps	~ 50 - 170	7	Pumping speed 300l/s – 1200l/s Flanges CF & ISO-K	Hybrid bearing some have to be radiation hard, communication to controller via ProfiNet or ProfiBus
Roughing Pumps	~ 50 – 170	tbd	Pumping speed 15-65m ³ /h	Dry pumps, some have to be radiation hard
Mobile pumping stations	~ 40 - 100	2 - 5		Consisting of a TMP, roughing pump, periphery, stations shall include a PLC
Residual Gas Analyser	~10			Faraday & SEM

There will be more to come in the next years, like

- KF-parts
- Small valves for venting
- Fast closing valve system
- Leak detectors
- Bake-out jackets
-

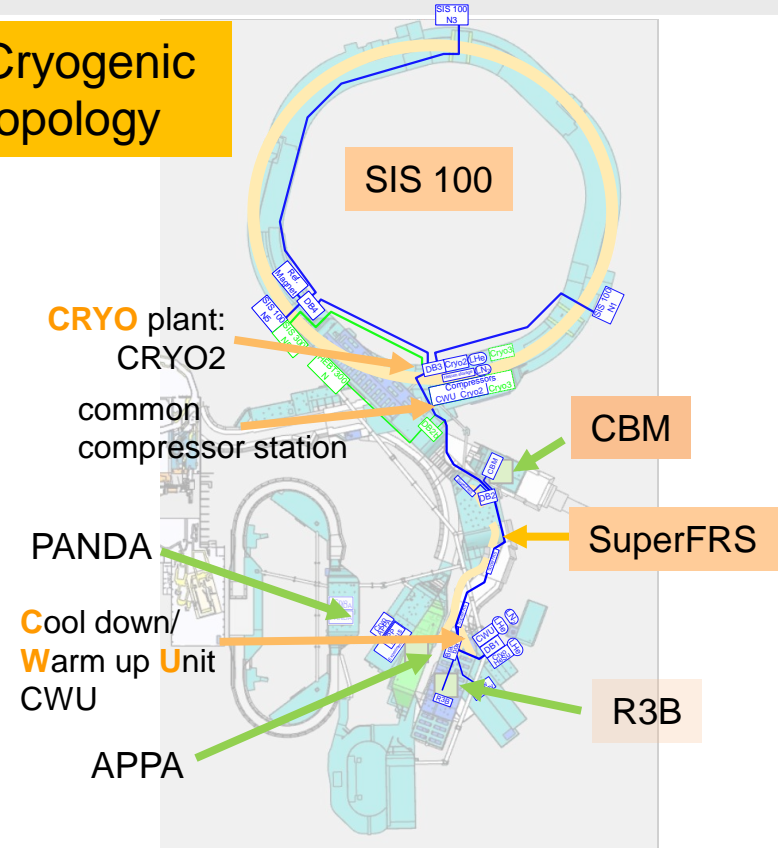
FAIR Cryogenics Overview

Major FAIR Cryogenic Users



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

Cryogenic topology



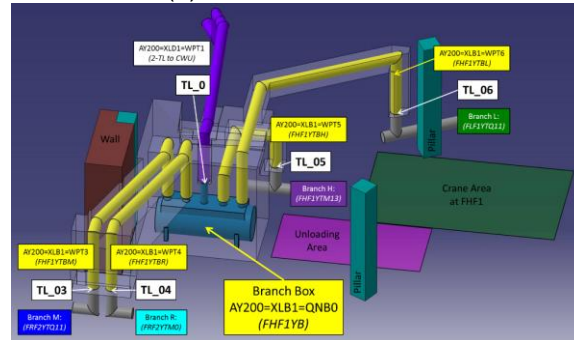
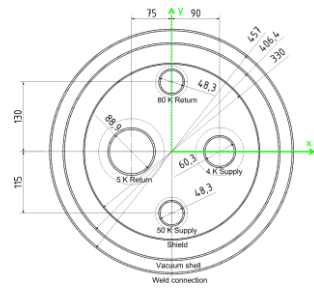
FAIR's Cryogenic Procurement Needs

SFRS Local Cryogenics

Transfer Lines of Branch B – central link

Branch B is the central distribution Branch of the Super-FRS Helium Cryogenic system: **Four Transfer Lines** connect the Branch Box to the neighbouring branches (incl. installation)

- Four pieces of vacuum-insulated helium cryogenic transfer lines
 - 62 m total length
 - Vacuum jacket DN 400
 - Active thermal shield
 - 4 process headers (DN80, DN50, DN40, DN40)
 - Design Pressure PS = 20 bar(a)

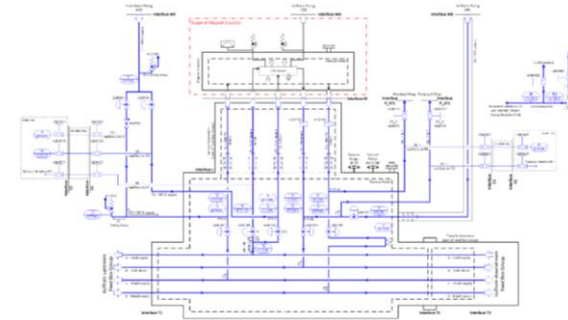
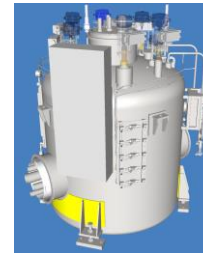


Branch B of Super-FRS Local Cryogenics system:
4 Transfer Lines (yellow) connect the Branch Box to neighbouring Branches (M, R, H, L)

Feed Boxes – Branch E and R

18 Feed Boxes for **Branch E** and **Branch R** of the Super-FRS Local Cryogenics, for the supply of magnet cryostats with cold / liquid helium (4K)

- ~4 FB design subtypes
- Design Pressure PS = 20 bar(a)
- 6 cold control valves
- 2 warm control valves
- 1 warm check valve
- two 4-header ports (DN400: TLs/EB)
- one 5-header port (DN400: JC), incl. VB
- one 1-header port (DN65: MPL), incl. VB
- several warm hand valves, capillary outlets
- electrical terminal box
- cryogenic instruments



FAIR's Cryogenic Procurement Needs

SFRS Local Cryogenics

Capillary Piping for remote pressure sensors

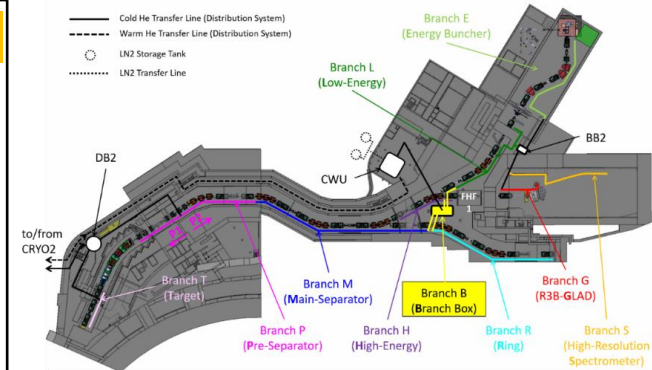
Cryogenic Valve Boxes located in the Super-FRS beam tunnel are exposed to radiation
Sensitive pressure sensors need to be placed remotely on racks in service rooms

- Connections to:
 - 63 Feed Boxes, 7 End Boxes, 1 Branch Box
 - 22 remote racks, to host the pressure sensors
- **~500 capillary pipes** required
 - 6x1 mm (stainless steel or copper)
 - 20-100 m individual lengths
 - **in total ~16 km** of piping
 - Design Pressure PS = 20 bar(a)
 - Incl. design, production and installation

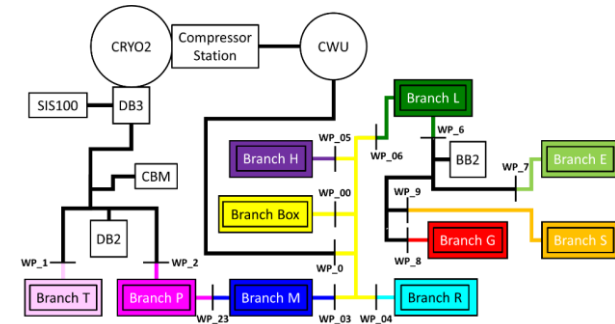
Warm Piping System – auxiliary process lines

The Warm Piping System (WPS) – **3 auxiliary process headers** for the Super-FRS Local Cryogenics system (incl. installation)

- Multipurpose Return (MPL)
 - Cooldown Return and Quench Buffer
 - Vacuum insulated 1-header TL
 - DN200 (VJ), DN125 (header), Design Pressure PS = 20 bar(a)
 - Top = 5 – 300 K, Pop = 1.3 – 20 bar(a)
 - ~550 m (including T-pieces)
 - Valves and instruments
- Warm GHe Supply (WGS)
 - GHe Supply to 63 FBs, 7 EBs, 1 BB
 - DN80, Design Pressure PS = 20 bar(a)
 - Top = 300 K, Pop = 18 bar(a)
 - ~1100 m length (including T-pieces)
 - Valves and instruments
- Current-Leads Return (CGR)
 - GHe Return from 63 Magnet Cryostats
 - DN80, Design Pressure PS = 20 bar(a)
 - Top = 300 K, Pop = 1.2 bar(a)
 - ~1100 m length (including T-pieces)
 - Valves and instruments



The Super-FRS Local Cryogenics Warm-Piping System: 9 Branches with 3 auxiliary process headers each: MPL, WGS, CGR. Connections to all Feed Boxes, End Boxes, Branch Boxes, and Magnet Cryostats.



FAIR's Cryogenic Procurement Needs

SIS100 Current Lead Box

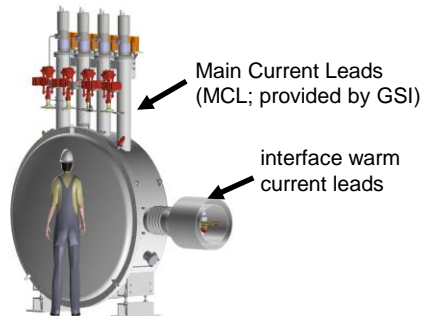
in-kind provided by:



- 6 current lead boxes
- 1 current lead box link
- transport frames
- incl. 2D design / documentation, production and integration
- mild steel for warm, G10/11 for cold supports
- stainless steel and aluminium for vacuum vessel and shield, resp.
- vacuum vessel bellows
- stainless steel for process pipes (small for PED; no hoses due to small diameters)
- ceramic vacuum barrier feedthroughs (design existing, already used in BPL)
- instrumentation ~ 20 TVOs; 18 ball valves; 8 control valves @ cold, 6 safety valves; 6 lift plates; 24 filters @ warm

GSI delivery

- main current leads incl. warm valves attached to MCLs
- voltage breakers
- bus bar cable



Cryogenic North-South-Link

About 200 m of cryogenic helium transfer line DN500 (vacuum insulated with 4 inner process lines: 4K supply/return, 50 K supply/return), one vacuum insulated line DN 200, three warm gas lines PN20 with DN100, DN150, and DN300

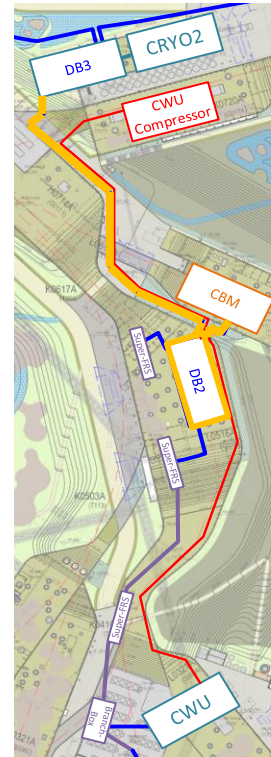
Cryogenic distribution box DB2 build as two connected valve boxes including 4K re cooler

Requirements:

- Design along predefined installation space according to 3D model
- Maximum allowed pressure drop and heat load given

Additional Request:

- Complete design/engineering by manufacturer
- Vacuum and mechanical requirements to be proven by FAT from manufacturer
- Full documentation of design/engineering and FAT tests
- Complete installation of the system on the FAIR construction site, finalized by vacuum/welding tests as SAT





Open Tender for FAIR by Wroclaw University of Science and Technology (Poland):

- Components Branch T:
 - 3 Feed Boxes, 1 End Box, 2 Transfer Lines, 3 Jumper Connections, 1 Rack, 3 components for FoS-tests
 - <https://przetargi.pwr.edu.pl/zamowienia-publiczne-lista/szp-242-137-2022-2028.html> or <https://ted.europa.eu/udl?uri=TED:NOTICE:519302-2022:TEXT:EN:HTML&tabId=1>
 - Deadline for participation in tendering: 12th of October 2022

There will be more to come in the next years, like

- Cryogenic plant for APPA and compressor
- Cryogenic connection for APPA
-

Upcoming Opportunities at FAIR/GSI
Industry contact officer: s.utermaann@gsi.de



Current call for tenders can
be found at:
[https://www.gsi.de/en/start/
business_industry](https://www.gsi.de/en/start/business_industry)



An aerial photograph of a large industrial or research facility, possibly a particle accelerator, surrounded by dense green forest. The facility consists of numerous interconnected buildings, some with large white roofs, and winding paths. A semi-transparent white rectangular box is overlaid in the center of the image, containing the text "Thank you for your attention!".

**Thank you for
your attention!**

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