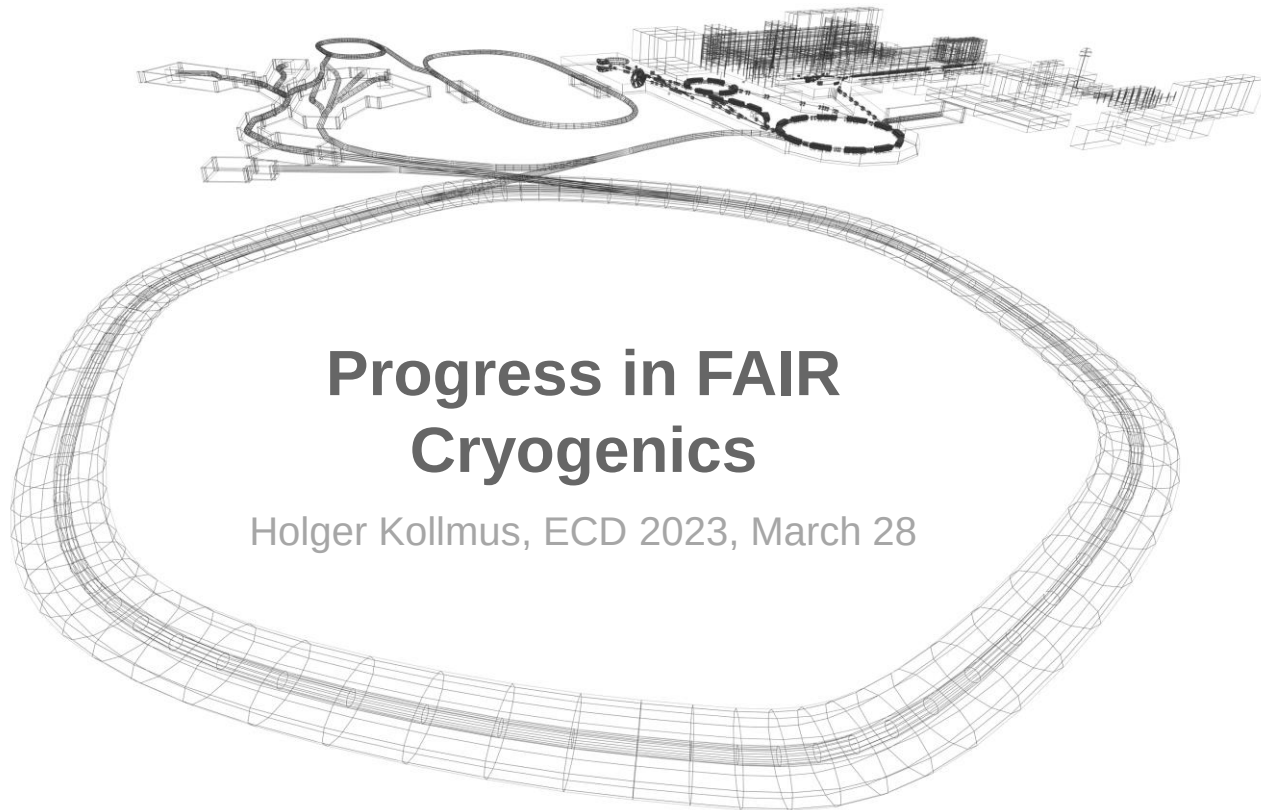




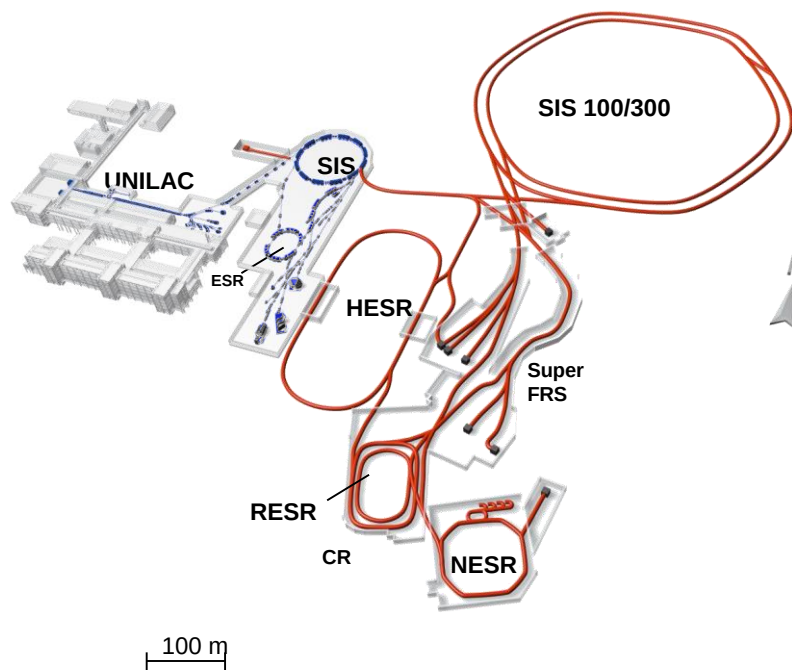
Progress in FAIR Cryogenics

Holger Kollmus, ECD 2023, March 28

- Introduction to GSI and FAIR
- Main scientific pillars
- Laboratories on the GSI Campus
- SIS100 testing
- Cryogenic plant → Delivery in November 2022
- Cryogenic distribution → Installation SIS100 ongoing until October 2023
- Outlook



- Existing facility: GSI Darmstadt (Foundation: 1969)
- Shareholders: federal government (90%), Hesse (8%), Rhineland-Palatinate (1%), Thuringia (1%)
- Further locations in Mainz and Jena
- Future facility: FAIR (Foundation: 2010)
- Employees on location: approx.1450
- Integrated organization FAIR and GSI under one management since 2017



GSI-Today

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

GSI in future / FAIR

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

The four main scientific pillars at FAIR

They all need cryogenics

NUSTAR

Nuclear Structure, Astrophysics and
Reactions: Stars and nuclei
(850 scientists)

Early Science

CBM

Compressed Baryonic Matter:
Inside a neutron star
(500 scientists)

First Science +

APPA

Atomic, Plasma Physics and Applications:
From atoms to planets to cancer research
(720 scientists)

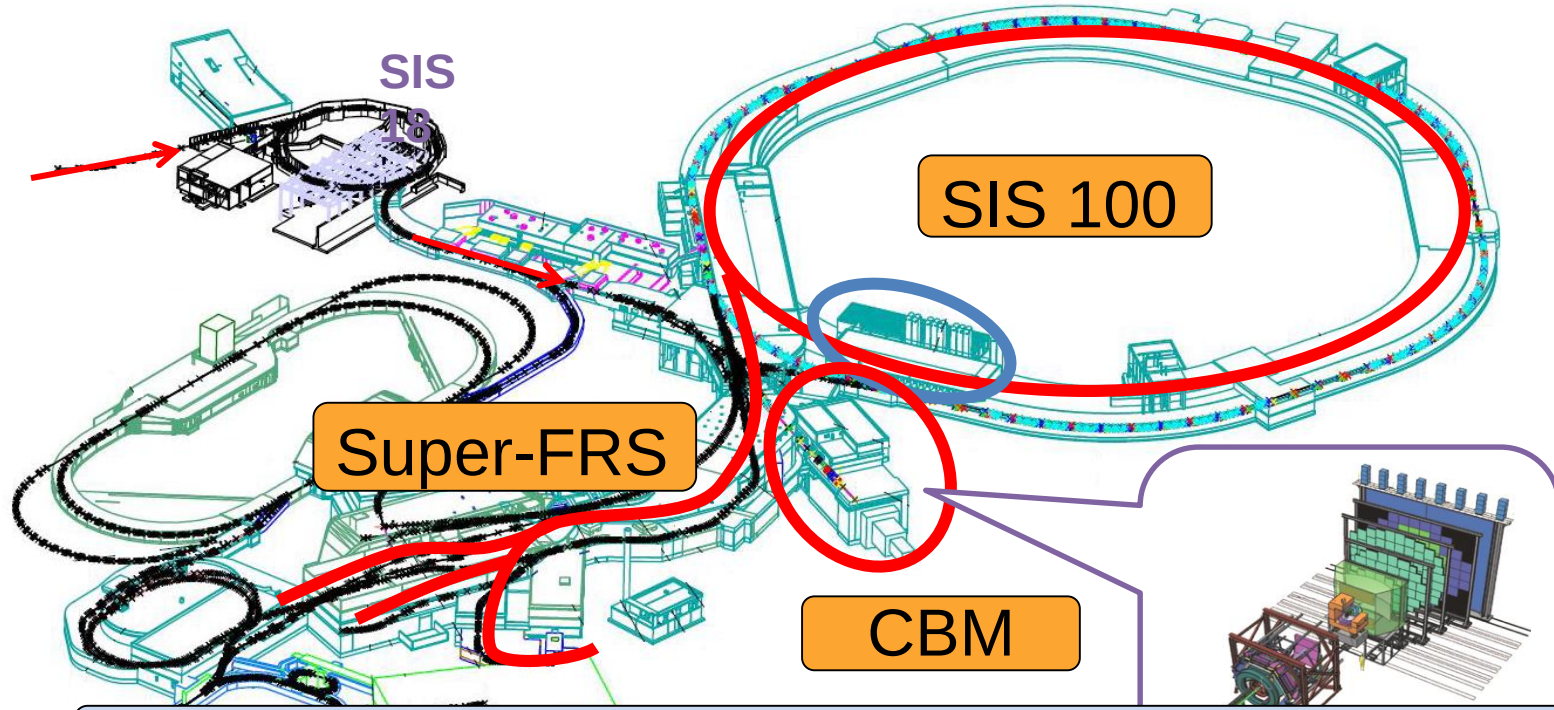
First Science ++

PANDA

Antiproton-Annihilation at Darmstadt:
Antimatter research
(500 scientists)

Modular Start Version

Biggest FAIR cryogenic users: SIS100 and Super-FRS



SIS100, Super-FRS and CBM are using SC magnets supplied by one central cryo plant

The Prototype Test Facility (PTF) Operating since 2005

Cryogenic infrastructure at PTF:

- 100.000 h of operation at the PTF
- 2.200 h with 60 g/s
- 135.000 h of operation of the cryo plant
- only 300 m³ Helium inventory
- 40-80% Helium losses/year

Test bench area,
SIS100 prototype,
and universal
cryostat



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



Distribution box (blue)
Feed boxes and
universal cryostat



Helium Liquefier (HeSu)

Operation since 2015



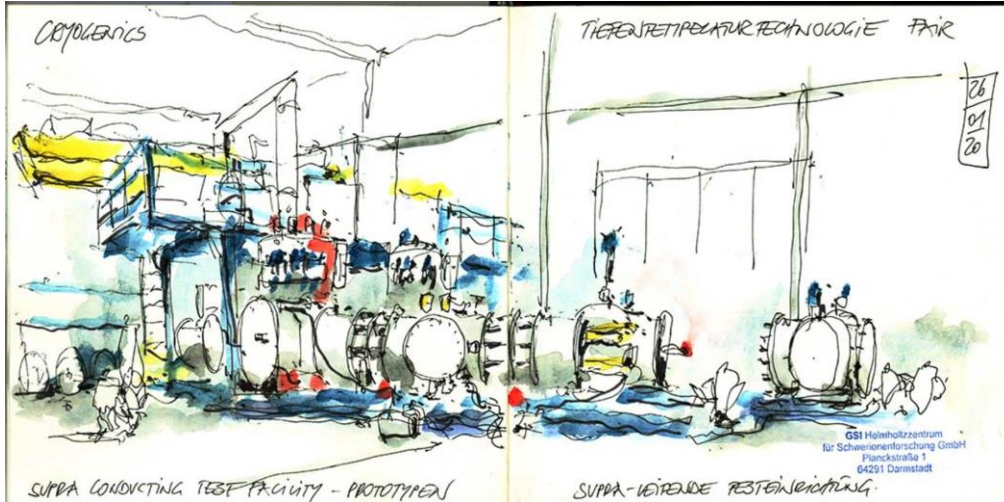
- Liquefaction rate ~ 20+ l/h, 35 l/h with LN₂ precooling
- 3000 l LHe storage, 15.000 l delivered so far
- Decant Station and campus wide recovery system

The Series Test Facility (STF) Operating since 2015



- 800 W @ 4-5 K, 2 kW @ 50-80 K, 6 g/s liquefaction and four test benches
- SIS 100 dipoles, quadrupoles and Super-FRS Magnets can be tested
- Testing of SIS100 and Super-FRS local cryogenics

STS – Test facility (Tour Tomorrow)



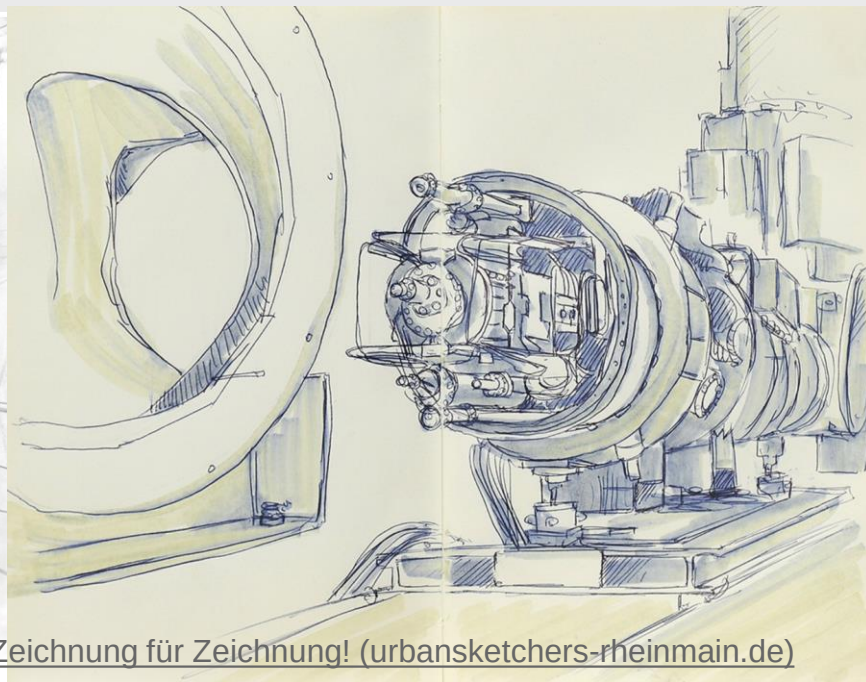
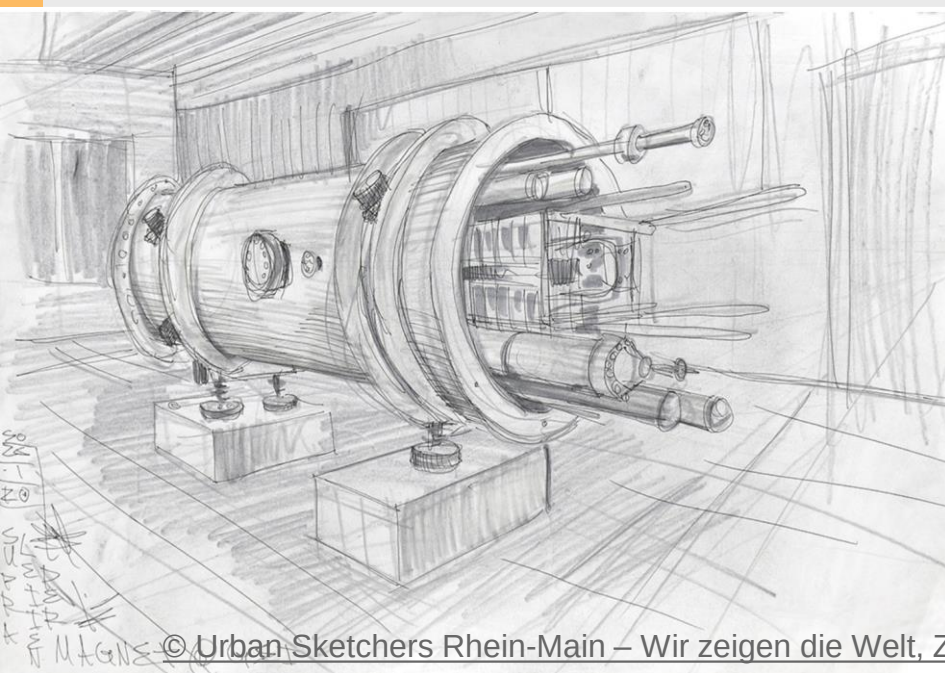
Cryogenic infrastructure at STF:

- 50.000 h operation of the STF
- sub-cooling in the Feedboxes
- in operation since 2015
- 1.000 m³ (100 m³ @ 10 bar) Helium inventory @ warm
- up to 3.000 l Helium at cold



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

SIS100 – Magnet testing



Dipole testing finished (110 dipoles)

Quadrupole testing started
parallel to Salerno at the STF

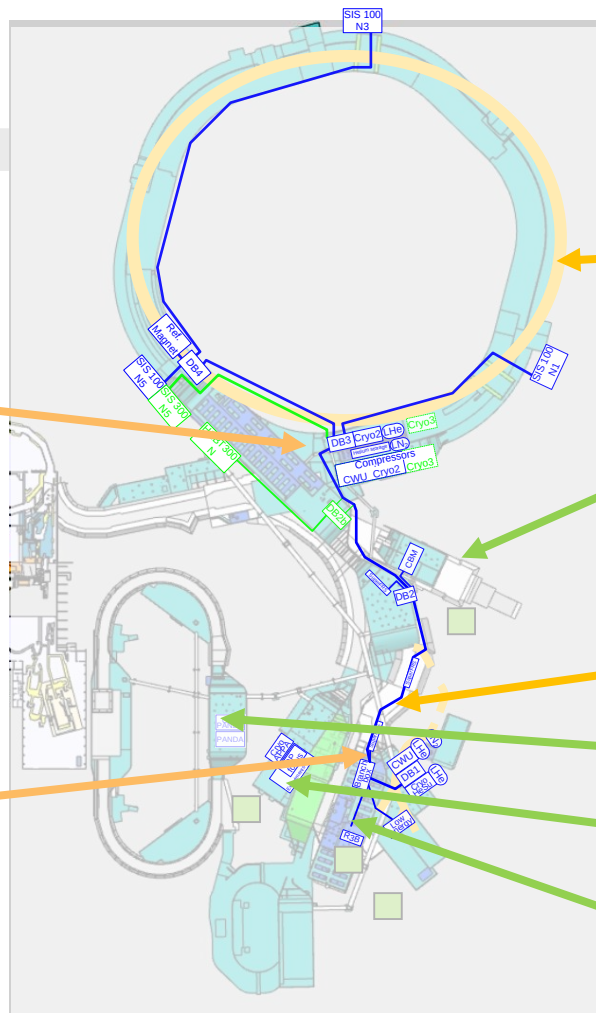
Cryogenic topology

CRYO plant: CRYO2

common
compressor station

Cool down/
Warm up Unit

CWU



SIS 100
(SIS 300)

CBM

Super-FRS

PANDA

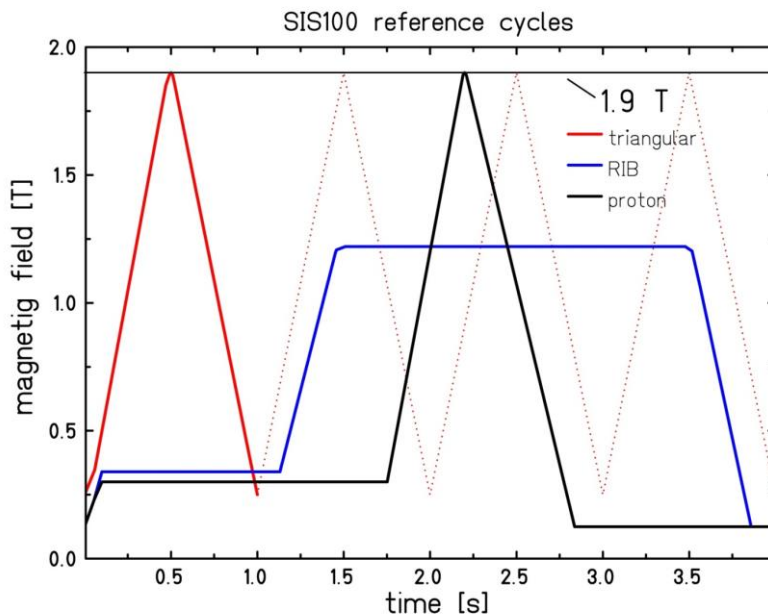
APPA

R3B

Challenges for the Cryogenic System

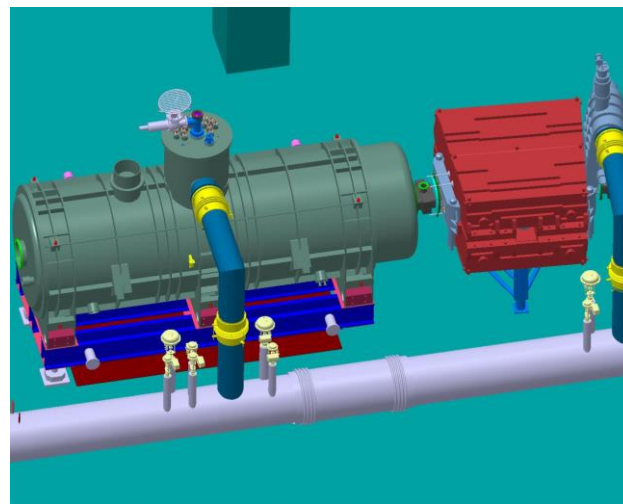
SIS100

- ❖ moderate mass of 420 t
- ❖ high dynamic load

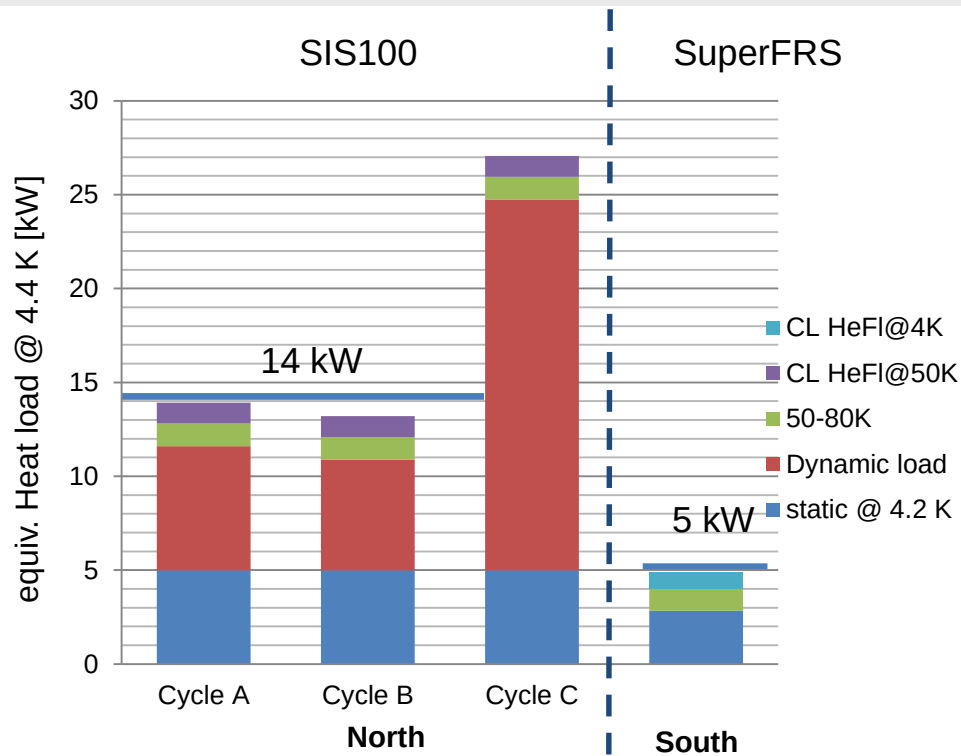


SuperFRS

- ❖ large mass of 1300 t
- ❖ DC load



Heat Loads including Safety Margin of 50%



Cryo plant - Evolution

Design proposed by CRY: two independent plants for SIS100 and Super-FRS

Due to the time schedule of the experimental set-up of FAIR → first experiments with SIS100 beam on CBM target

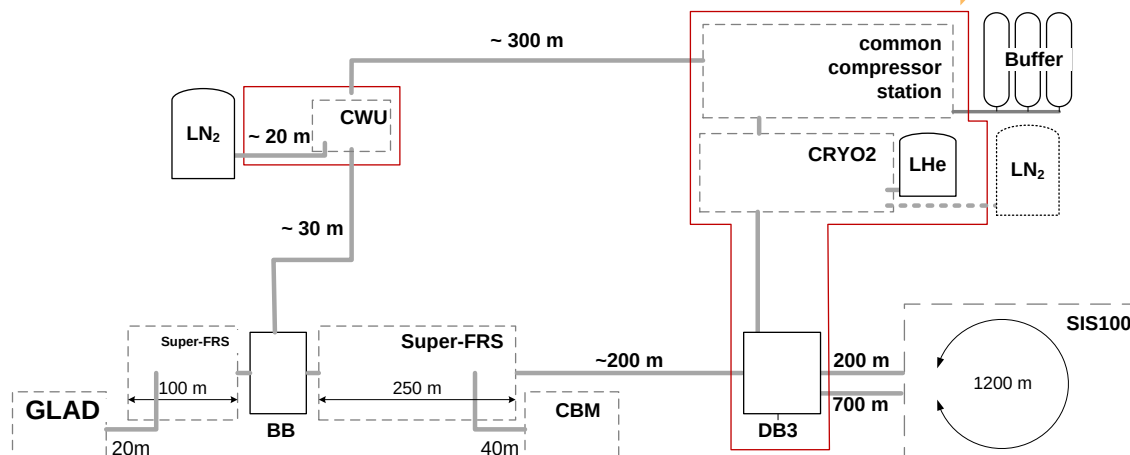
Due to the uncertainties of the heat loads caused by the experimental schemes in the start phase

Due to the large cold mass of the Super-FRS

5-fold transfer line between north (SIS100) and south

single plant in the north, later adaptation to the real needs (⇒ second plant)

Dedicated cool-down (and warm-up) unit in the south (nitrogen based)



Operation Modes	Refrigeration at 4.4 K ^{1.)}	Shield 50-80 K ^{2.)}	Hybrid current leads ^{3.)}	Resistive current leads ^{4.)}	Compressor Motor and corresponding VFD input power ^{5.)}
	[kW]	[kW]	[g/s]	[g/s]	[kW]
Option A					
Maximum load	14	49	33	17	≤5'740
Max. liquefaction	7.4	49	33	41	≤5'540
SIS100 min. ramp	9.7	49	33	17	≤5'330
Super-FRS	3.1	25	0	17	≤2'880 ^{6.)}
80 K hold	0	49	11	0	≤1'790 ^{7.)}
Minimum load	3	8	11	0	≤2'030 ^{7.)}

Delivery of Warm Compressor system in Q4/2022



Five Compressors

- 2 x LP
- 2 x HP
- CWU (1. stage)

CWU Compressor can be used as redundancy for either HP or LP

- 2 Oil removal systems

Delivery of Cold Box and DB3 in Q4/2022

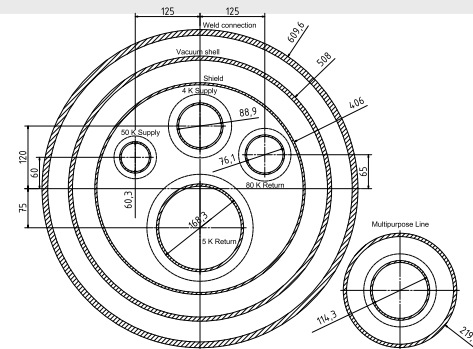
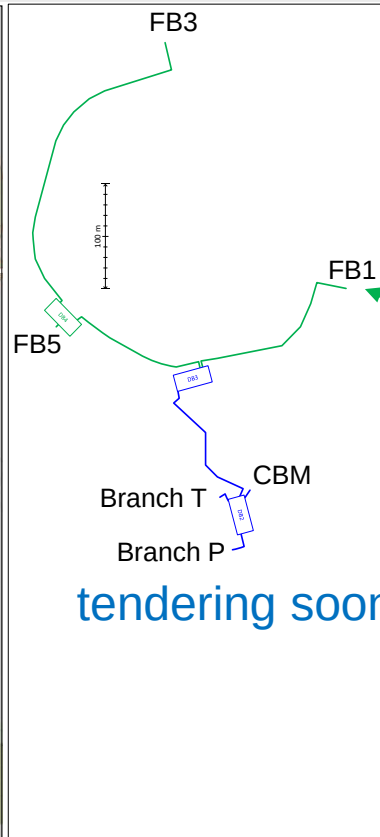


turnover: 1 day, travel time ship 6 days, turnover: 1 day, 1 night on street

Linde Schalchen ➔ Bayernhafen Passau ➔ Mainhafen Stockstadt ➔ FAIR

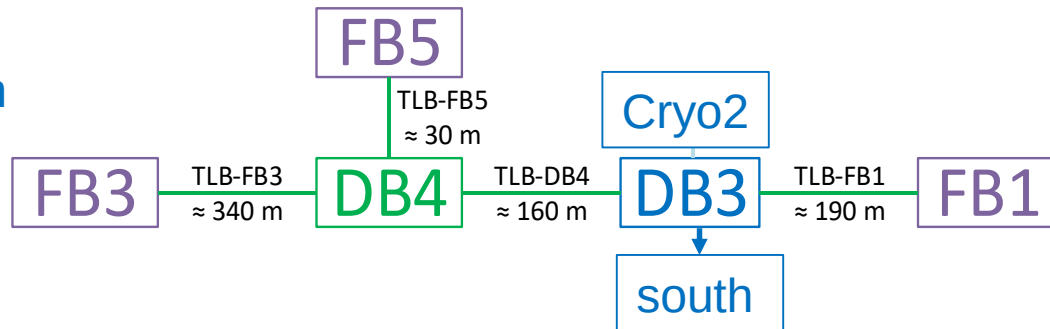
Bringing into the Building





Main Transfer Line and MPL

awarded in December 2019



Production SIS100 DS finished Q2/2022

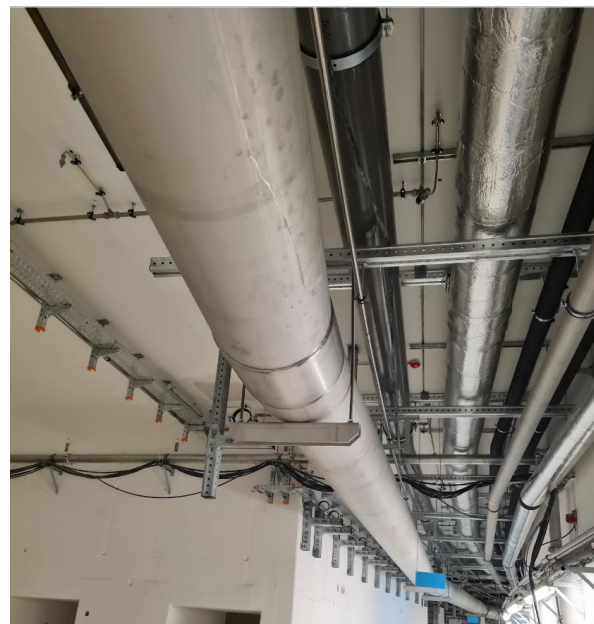


FAT straight spool and triple arc



Storage at Demaco

Installation SIS100 DS Started in October 2022

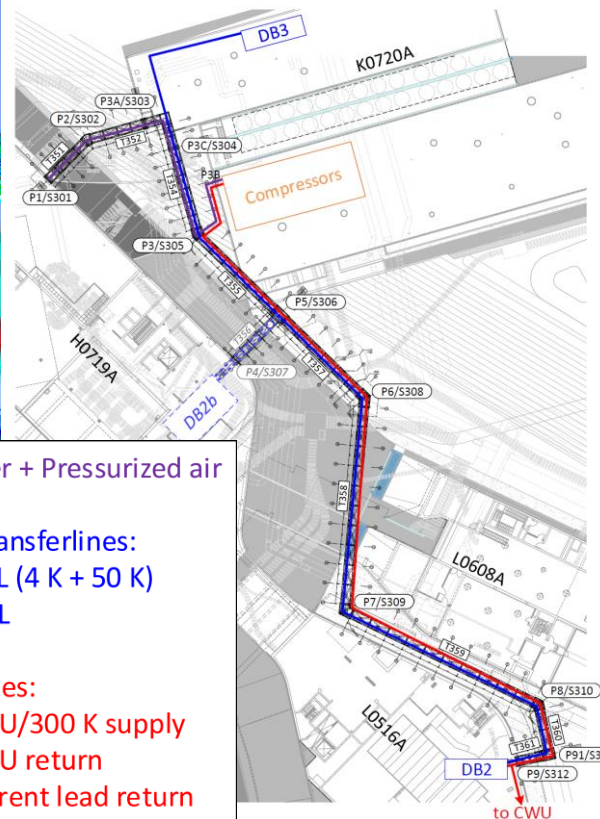
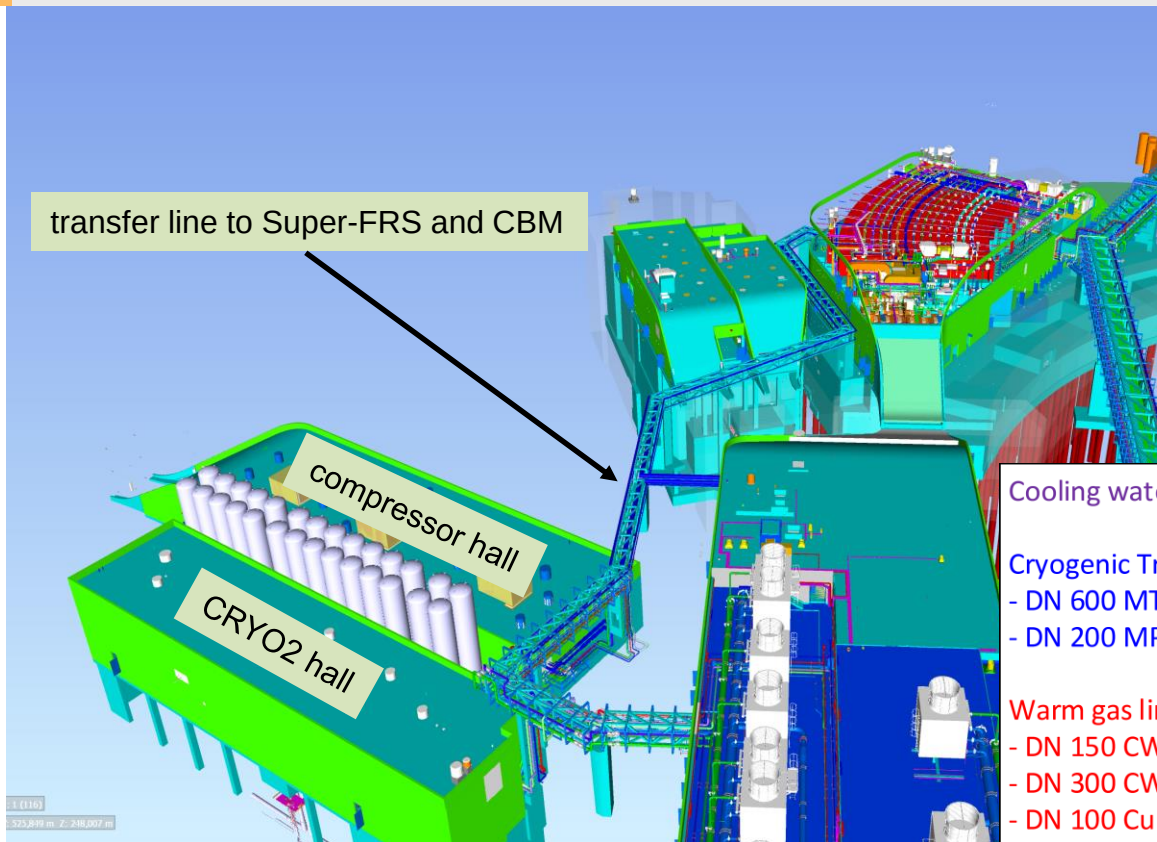


Delivery and Installation of DB4 in niche 5 Installation in the tunnel

SIS100 distribution system will be finished in October 2023

Cryogenic Distribution System for Super-FRS and CBM

transfer line to Super-FRS and CBM



Cooling water + Pressurized air

Cryogenic Transferlines:

- DN 600 MTL (4 K + 50 K)
- DN 200 MPL

Warm gas lines:

- DN 150 CWU/300 K supply
- DN 300 CWU return
- DN 100 Current lead return

Cryogenic Distribution System Super-FRS: Time Line



- Specification ongoing → strong interface to building issues
- Tendering of north/south line and DB2 in one lot
- Start tendering in early Q3/2023
- Contract signed in Q1/2024
- Start Installation in Q4/2024
- Commissioning in Q4/2025

- Different cryo plants are running at GSI since 2005 for FAIR
- Magnet testing of SIS100 dipoles successfully finished
- Magnet testing quadupole modules started
- Testing of local cryogenics components ongoing
- CRYO2 and DB3 close to Mechanical Completion
- Distribution system SIS100 → installation phase
- Distribution system Super-FRS → close to tender
- Local cryogenics of machines in good progress
 - → See talks by Marion and Felix

Thanks for your kind attention

