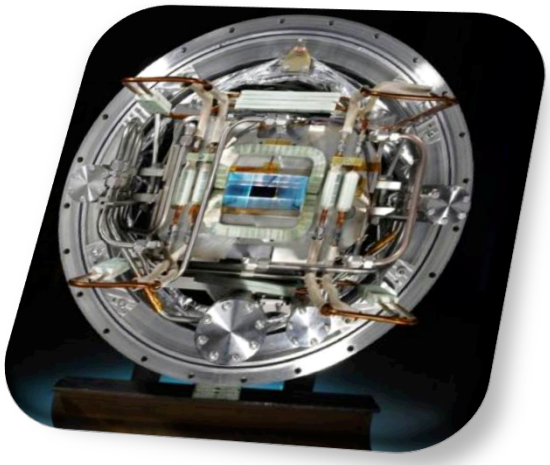
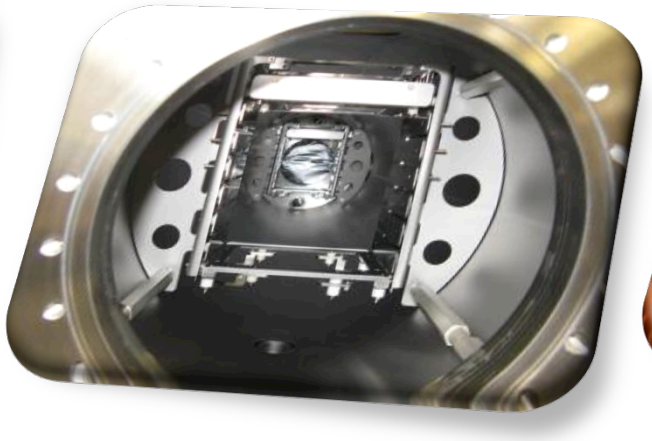
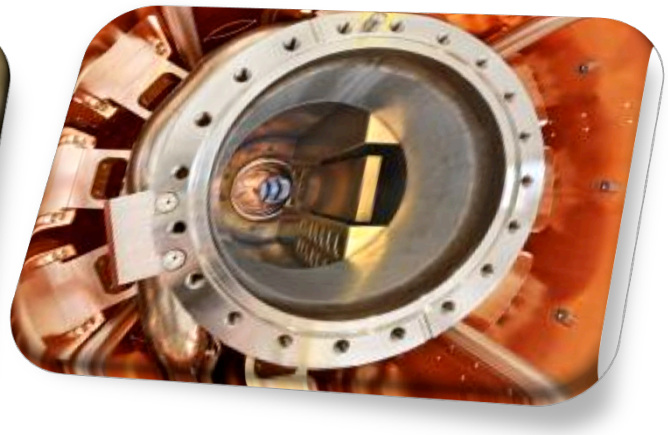
# Beam Instrumentation and Cryogenics: Potential Collaboration topics of FAIR and ESS





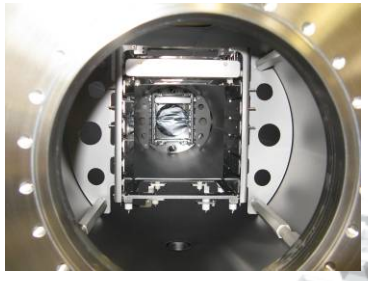


# Outline

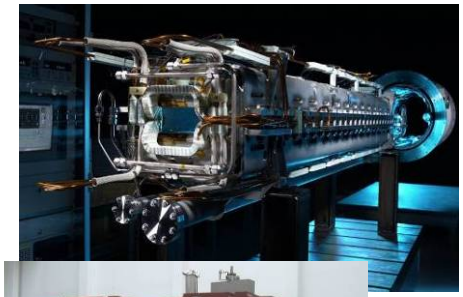
- Overview FAIR accelerators
- Beam instrumentation of the FAIR accelerators
- FAIR cryogenic systems including magnet test facilities
- Other topics: Target handling, Vacuum- and rf-systems

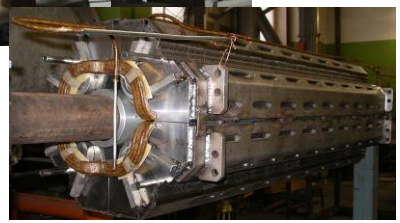
# FAIR accelerator challenges

## Diagnostic and XHV at highest intensities

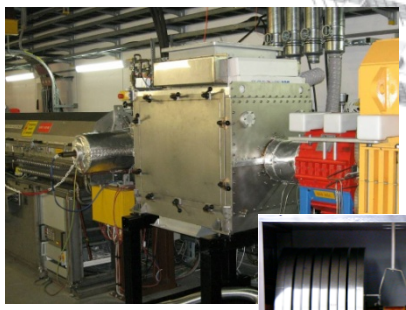


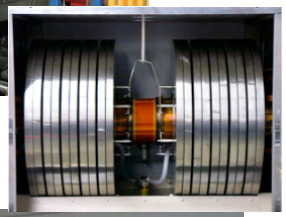
## Superconducting magnets





## Rf-cavities








## Beam cooling



- Overview FAIR accelerators
- **Beam instrumentation of the FAIR accelerators**
- FAIR cryogenic systems including magnet test facilities
- Other topics: Target handling, Vacuum- and rf-systems

# Beam Diagnostics: Common Interest & Applications

**Common applications for accelerator commissioning and operation:**
Beam diagnostics for **high current** LINAC and beam transfer lines

Goal: Start **ESS-GSI collaboration for common development of diagnostic devices** relevant at both facilities to save manpower and reduce development costs.

**Common development and similar realization possible for 5 topics :**

1. development of optimized **Beam Current Transformers**
2. common procurement/test/QA of **Beam Loss Monitors** together with CERN
3. investigations on **Beam Position Monitors** for high current LINACs
4. non-invasive **Beam Profile Monitor** development for high intensity beams
5. design and integration of a **Bunch Shape Monitor** for longitudinal profile observation

- visit of experts at Lund and Darmstadt, e.g. common workshop on Bunch Shape Measurement at Lund in February 2013
- planned visit of ESS employees at GSI in frame of Marie-Curie training network

# Beam Current Transformer and Beam Loss Monitor

## 1. Collaboration on Beam Current Transformers:

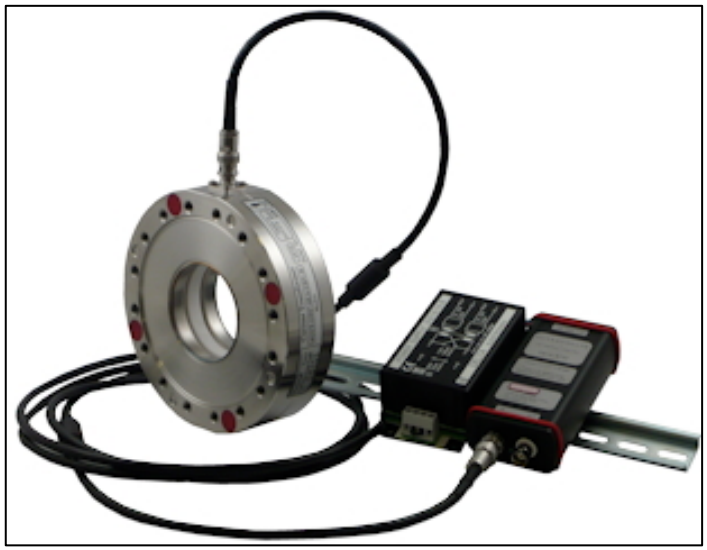
Commercial transformers available, **however**

- ➢ increase of bandwidth to several MHz required
- ➢ lower droop time < 1 %/ms required
- ➢ improvement of magnetic shielding
- ➢ common mechanical design

⟶ Common development of analog electronics
ESS – GSI – company Bergoz (France)

⇒ man power saving at both institutes
⇒ cost reduction due to large quantity

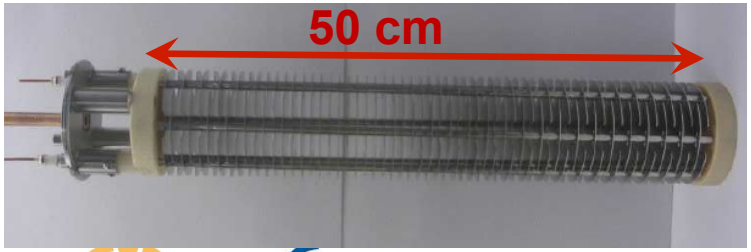
*Example: Commercial device*
*(but with insufficient performance)*



## 2. Ionization Chamber for beam loss detection:

**reference detector designed by CERN and produced by IHEP (Russia)**

- ➢ design of analog electronics
- ➢ common procurement (ESS, GSI) of detectors to reduce costs and efforts
- ➢ possible synergies: joint detector tests and Quality Assurance



# Beam Position Monitor

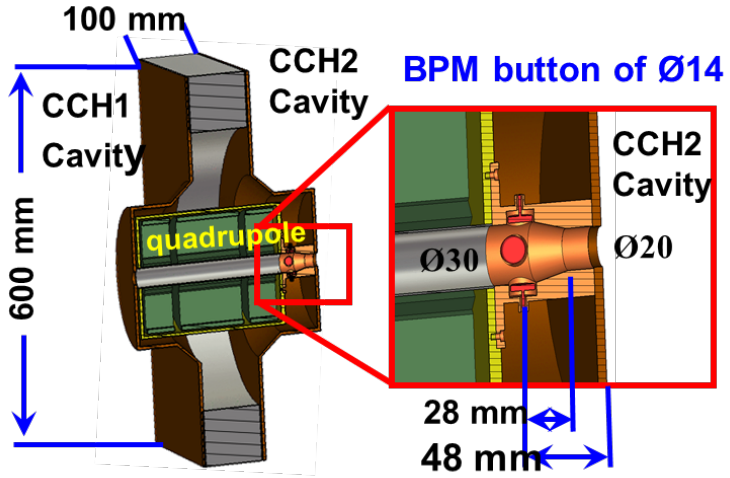
**Frequently used operation device**

**Collaboration tasks:**

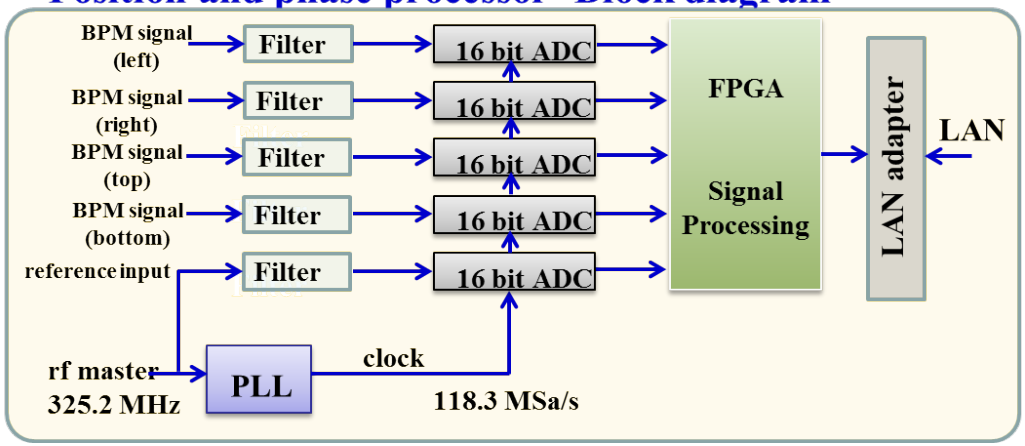
- electro-magnetic simulation (extensive work)
- mechanical design
- analog electronics (low noise pre-amplifier)
- digital electronics for position measurement and high-precision phase determination

⇒ man power saving at both institutes
⇒ cost reduction due to large quantity

*Example: pick-up design foreseen for FAIR Proton LINAC*




**Position and phase processor 'Block diagram'**




*Example : Kyocera type with ∅ 11 mm:*

# Non-invasive Beam Profile Measurement

**High beam power can destroy intersecting material ⇒ non-invasive methods preferred**

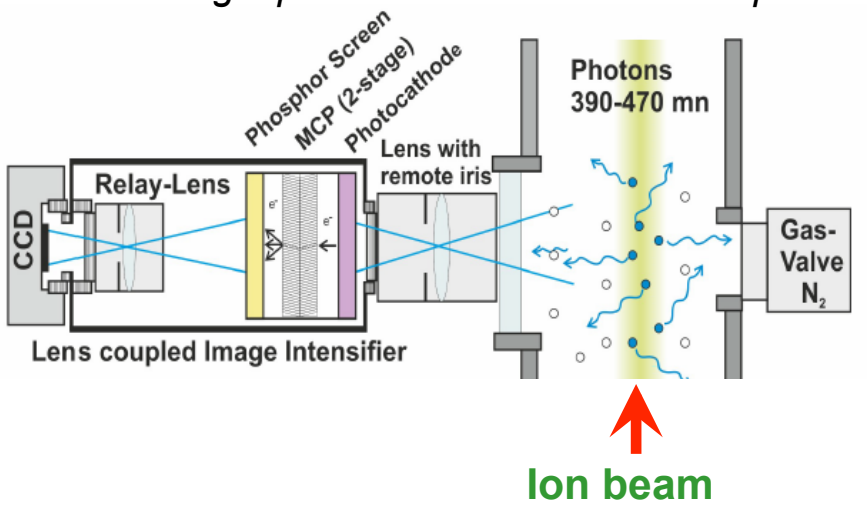
## A) Beam Induced Fluorescence Monitor

**Advantage:** short insertion compared to IPM

**Collaboration tasks:**

- investigation of underlying atomic physics
- simulation of beam created background & shielding layout
- experimental verification & optimization
- common design incl. rad-hard components

*Scheme: Single photon detection for beam profile*

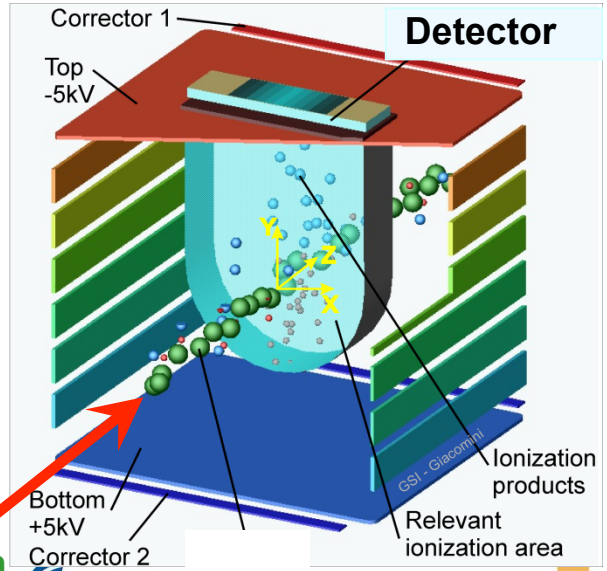



## B) Ionization Profile Monitor

**Advantage**: larger signal compared to BIF

**Collaboration tasks:**

- layout of various hardware components
- simulation of beam's space charge contribution, correction scheme development
- experimental verification
- common design, incl. rad-hard components

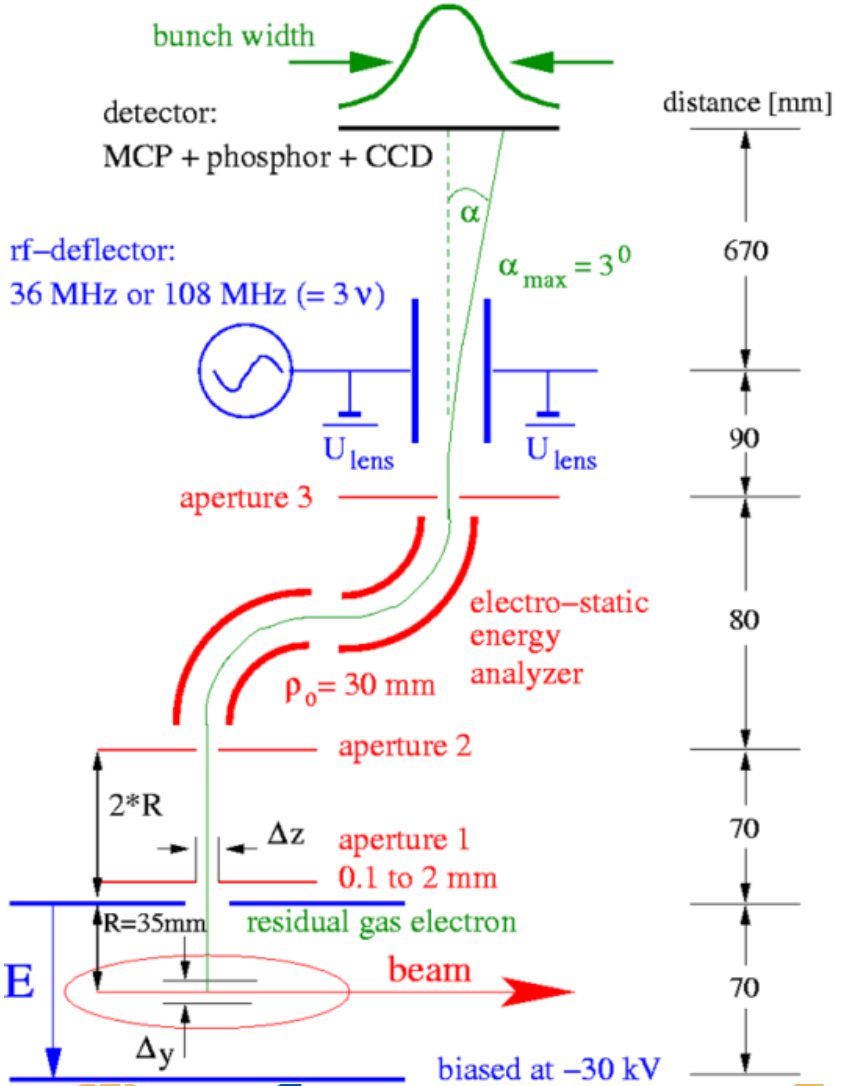


# Longitudinal Bunch Shape Monitor

**Longitudinal matching between the LINAC cavities is required for optimal transmission!**

**Determination of bunch length with ps time resolution**

*Scheme: non-invasive monitor based on residual gas electrons*




**Collaboration tasks:**

- investigation of underlying physics
- experimental verification & optimization
- common, simplified design

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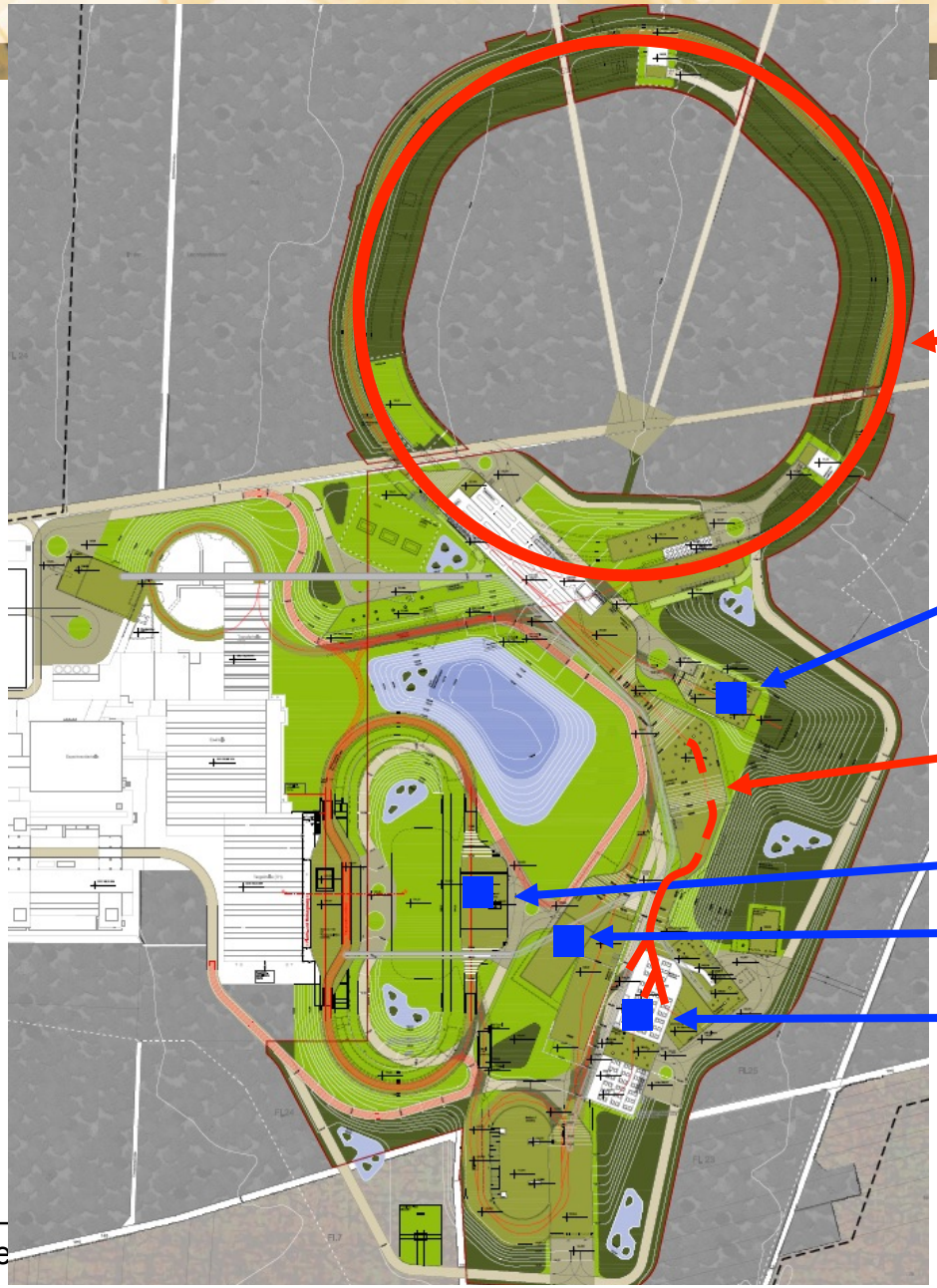
- **FAIR cryogenic systems including magnet test facilities**
- Other topics: Target handling, Vacuum- and rf-systems

# Cryogenic systems of FAIR



SIS 100
(SIS 300)

CBM

SuperFRS

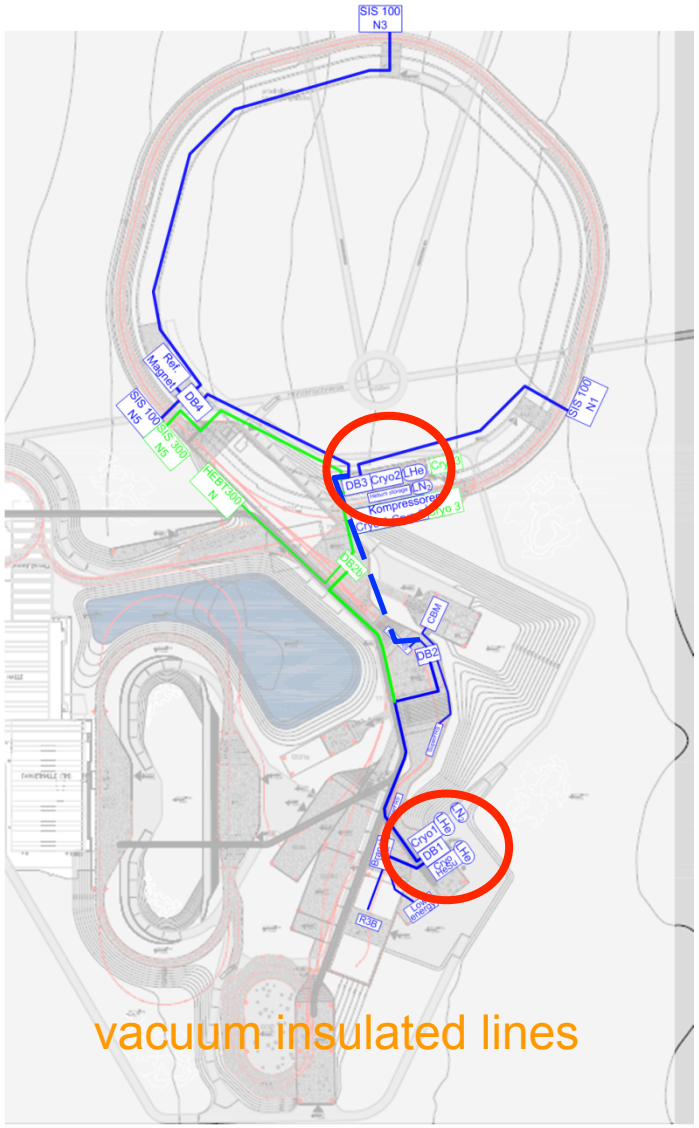
(Panda)

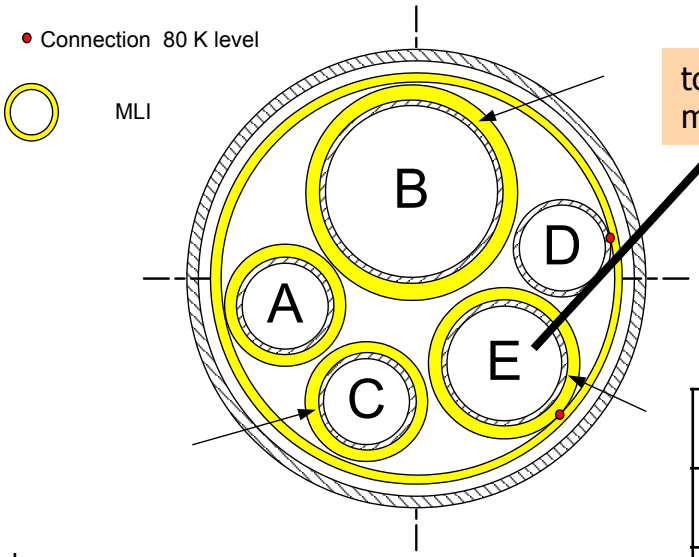
APPA

R3B

Holger Kollmus, CSCY

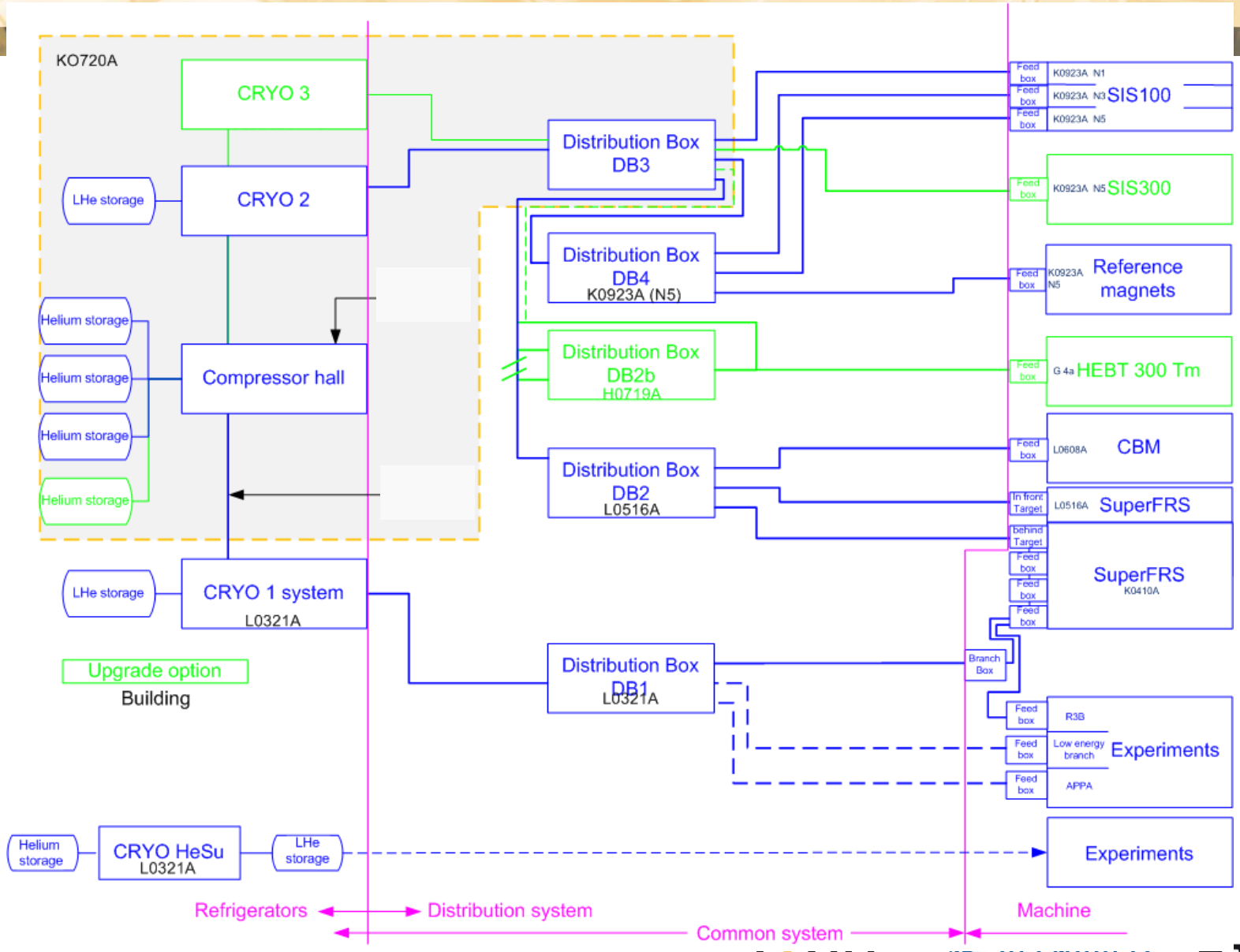
# Cryogenic system – distribution



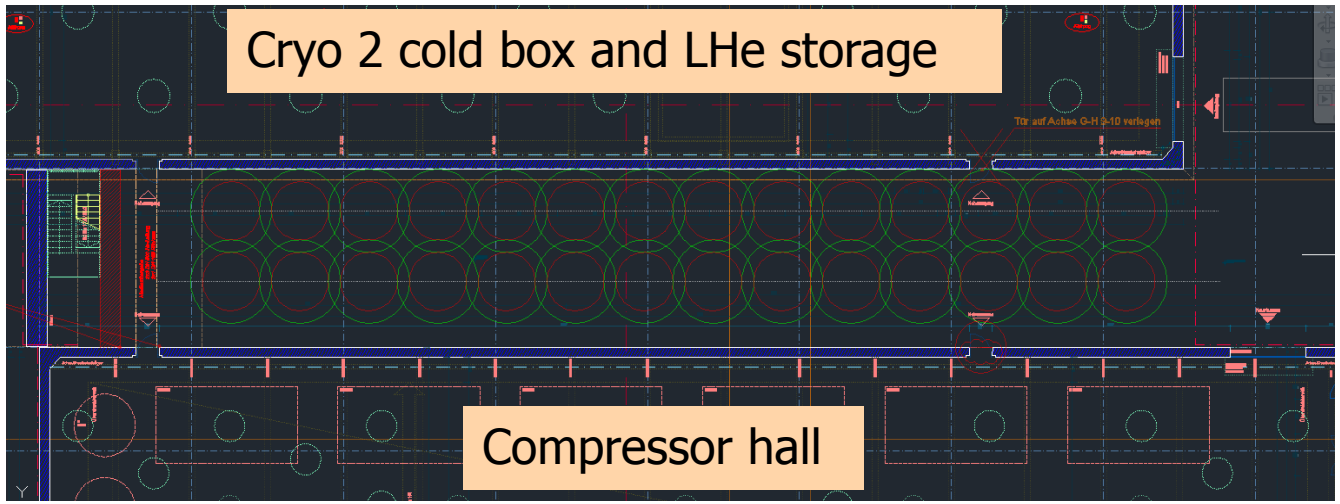

| | | | label | |
|---|---|---|---|---|
| | | | drawings | Nomen clature |
| 4K level | | | | |
| Normal operation | Supply | 4.6 K, 3 bar | A | 1 |
| | Return | 1.1 bar | B | 2 |
| Cool down distribution system | Supply | 18 bar | A | 1 |
| | Return | 4 bar | B | 2 |
| Intermediate level | | | | |
| Supply | | 50K, 18 bar | C | 3 |
| Return | | 80K, 17 bar | D | 4 |
| Multipurpose line | | 1.1 (– 4) bar, pure helium | E | 8 |

# FAIR cryogenics system



# Liquid Helium mass and storage

- total mass of helium 8,230.8 kg
- 2,000 kg will be stored as lHe
- 6,230.8 kg will be stored as warm gas
- 1 l helium are 125g
- 2,000 kg /0.125=16,000 l
- 6,239.8 kg lHe correspond to 2,232.34 $m^3$ at 35° C and 18 bar

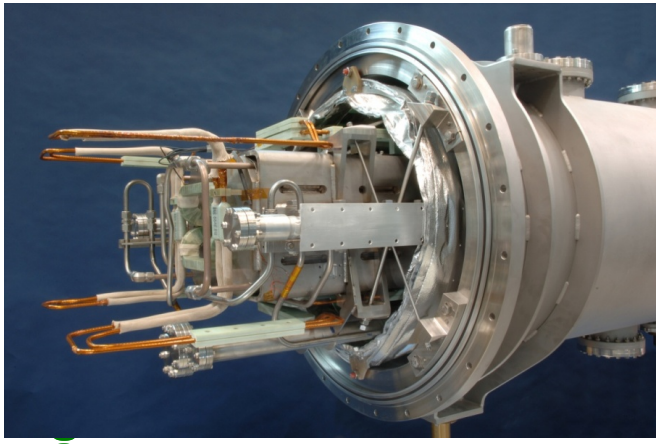


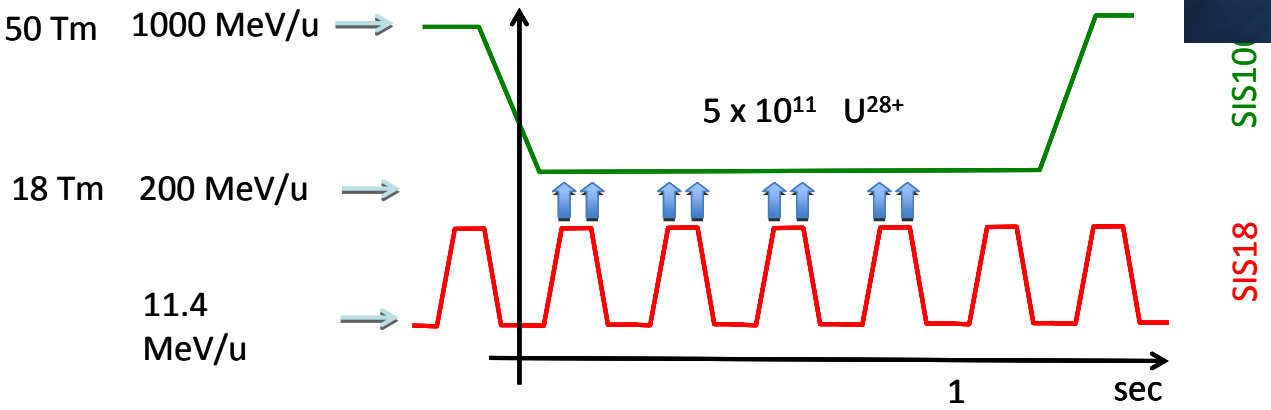

Basement part of CC, 28 * 93 $m^3$ = 2,604 $m^3$
There is space for 4 more tanks

# Challenges of the SC-magnets development for SIS100

## Fast ramped magnets (synchrotrons)

- Dynamic load and AC heat losses
  Bρ= 100 Tm - Bmax= 1.9 T - dB/dt= 4 T/s
- High field quality, low multipole strength

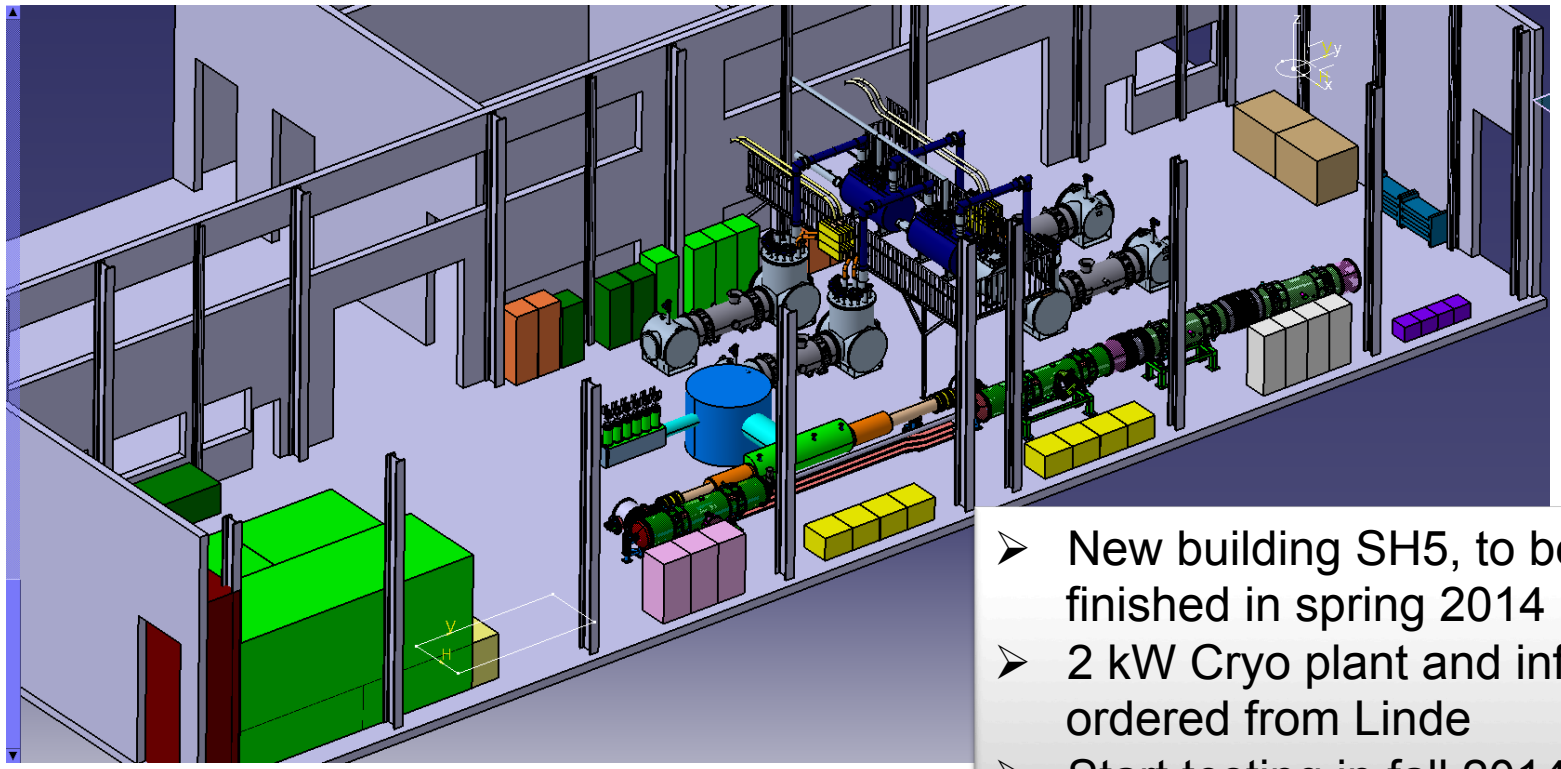





## R&D Goals

- Reduction of eddy / persistent current effects
- Guarantee of long term mechanical stability (≥ 2*10$^8$ cycles )
  (mechanical stress →coil restraint)

# Preparation for Testing: The Series Test Facility



- New building SH5, to be finished in spring 2014
- 2 kW Cryo plant and infrastructure ordered from Linde
- Start testing in fall 2014

- ✓ 3 — 4 Test benches for SIS100 dipoles
- ✓ String test preparation in parallel
- ✓ Utilities in Annex building (cryo supply, power converters, ...)

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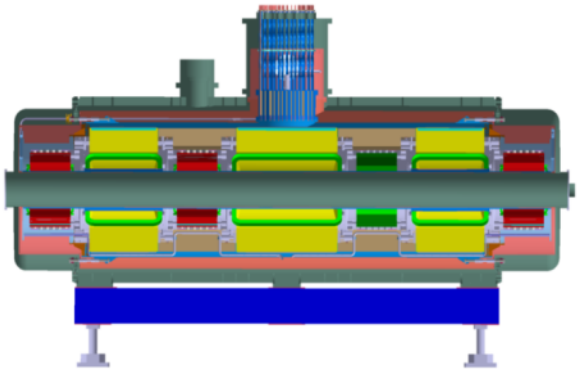
# Super-FR(agment) S(eparator)

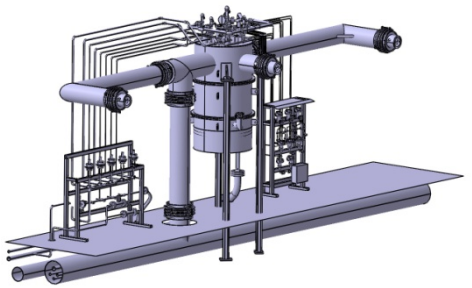
Remote Handling

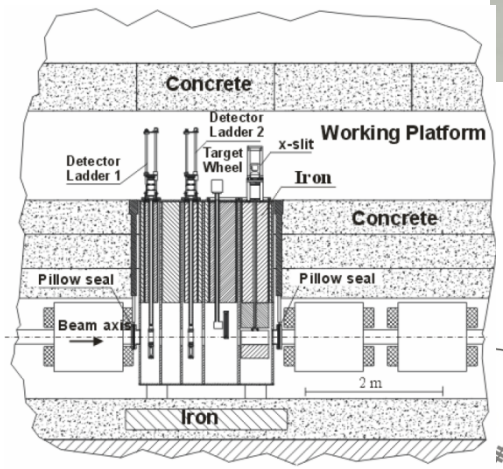
Target

SC Multiplets



Local Cryogenics






Beam Dumps

Exit Slit Pre-Separator

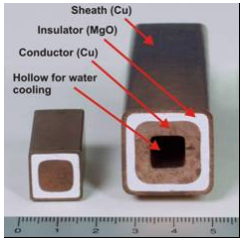
Degrader 1

Main-Separator

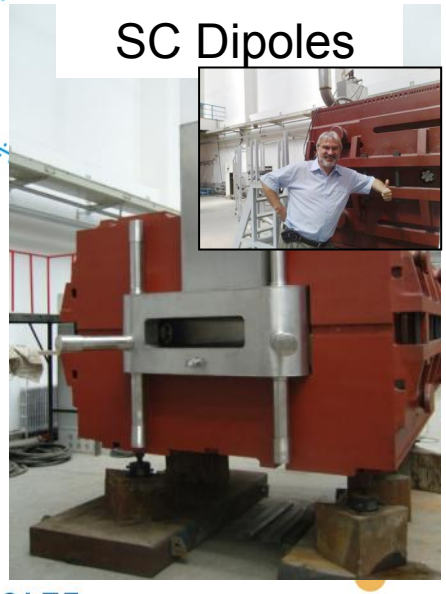
-Energy Branch

Driver Accelerator

Radiation Resistant Magnets




SC Dipoles

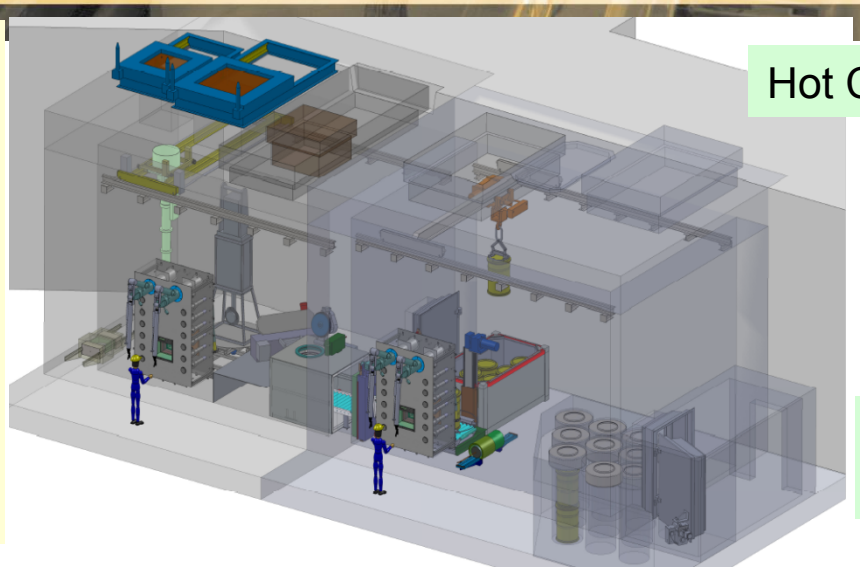




FAIR — HELMHOLTZ ASSOCIATION — GSI

# Super-FRS target region- remote handling

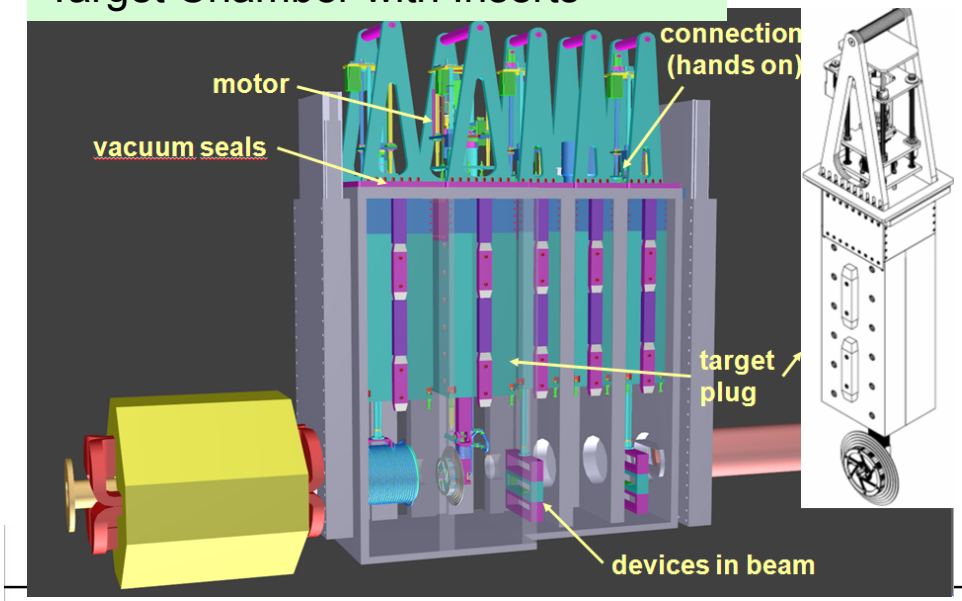
- Target Chamber with plug inserts
- Target Wheel
- Collimator
- Target Detectors
- Hot Cell Complex
- Transport Flask
- Remote Handling
- Beam Catcher
- Energy Degrader



Hot Cell

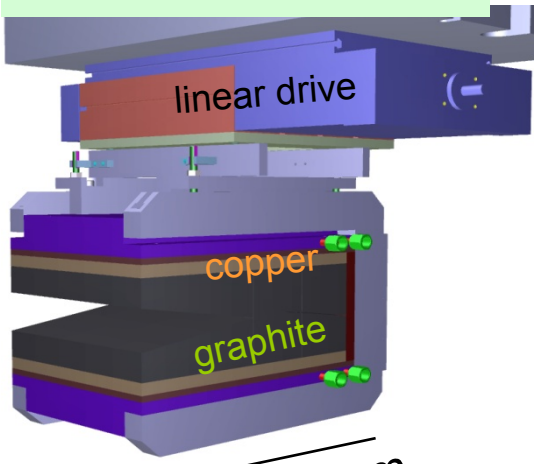
Transport Flask

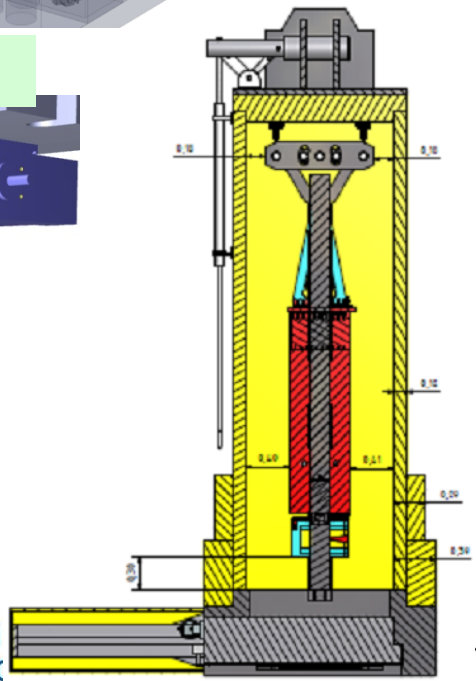
Target Chamber with Inserts



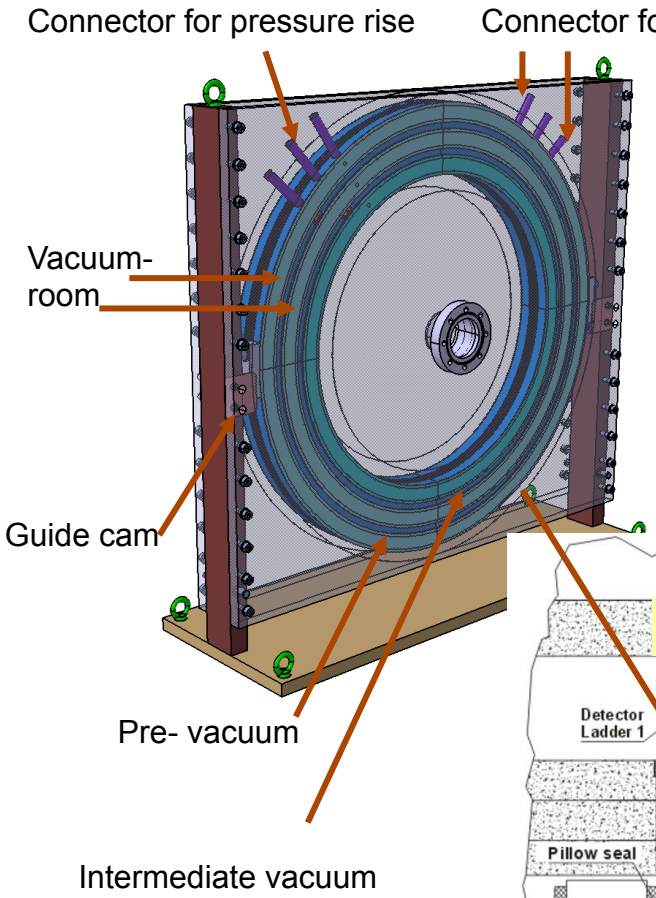



movable beam catcher



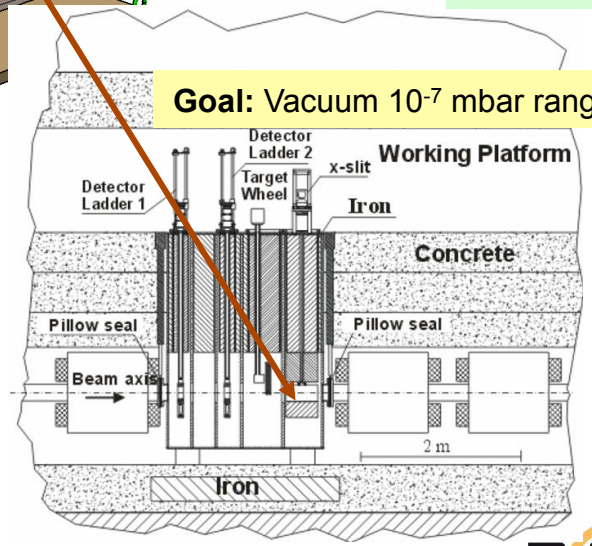



# Remote Controlled Seal for Super-FRS

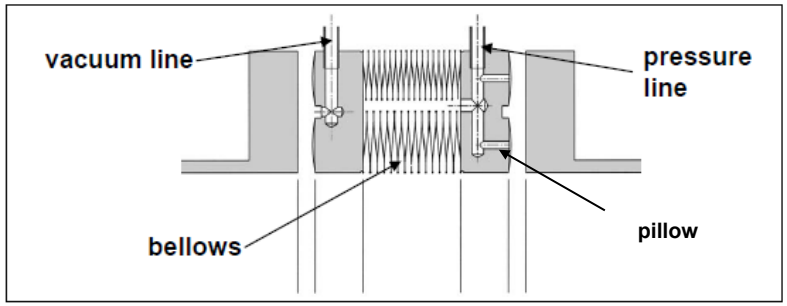



**Specifications**

- Process is to work with round and rectangular shape
- Inner diameter from round 500mm and 1200mm for the rectangular
- Three stainless steel sealing rings
- Two intermediate vacuum rings
- Bellow and Sealing pressure <1.8 bar
- Leakrate $3*10^{-6}$ mbarl/sec




Function- sketch



# P-Linac rf-systems

pLinac RF High Power Components

Klystrons, Modulators, Circulators, Wave Guides, Driver Ampl., Buncher Amplifiers...