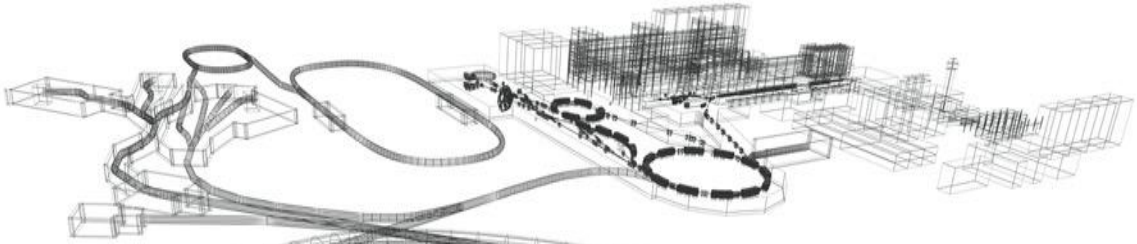


Super-FRS Experiment Collaboration future plans including first experiments at Super-FRS

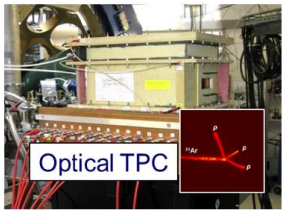
2nd FAIR/GSI Research Retreat 2023
18-19 July 2023
TU Darmstadt

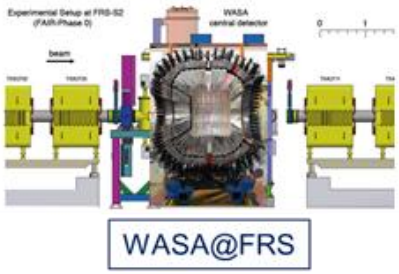
Christoph Scheidenberger
on behalf of
Nasser Kalantar-Nayestanaki
for the
Super-FRS Experiment Collaboration

The science program of the Super-FRS Experiment Collaboration

High-resolution spectrometer experiments with (Super-)FRS and ancillary detectors open up a **rich science spectrum** at the border line of nuclear, hadron and atomic physics:

- **New isotopes**, new reaction studies (e.g. MNT with secondary beams)
- **Nuclear structure, EoS:** nucleon momentum distributions, radii, tensor component of the NN-interaction
- **Exotic nuclei and decays** (proton radioactivity, fission isomers, β-delayed multiple neutron emission probabilities)
- **Atomic-collision** studies
- **Hypernuclei:** nnΛ, ${}^{3}_{\Lambda}$H, ${}^{4}_{\Lambda}$H, and others (heavier, exotic,…)
- **Hadron physics:** search for eta-prime mesic nuclei
- **Applications:** nuclear astrophysics, biology, medical imaging



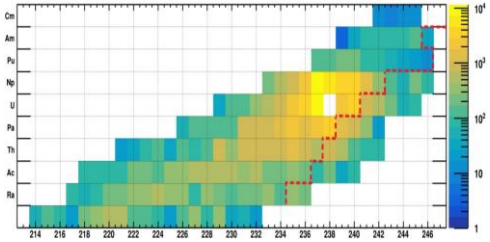


Super-FRS EC experiments scheduled for 2024+2025

G-22-00117, P.Constantin, T.Dickel et al.,

In-cell multi-nucleon transfer reactions at the FRS Ion Catcher

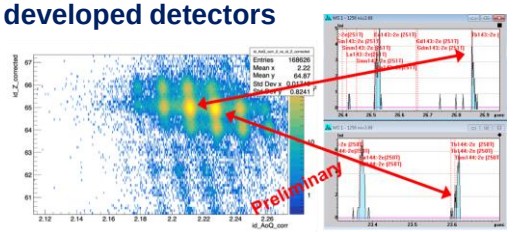
Pilot study for Super-FRS with slowed-down primary beams at FRS



G-22-00160, C.Scheidenberger, E.Haettner et al.,

FRS performance improvements and R&D with heavy-ion beams

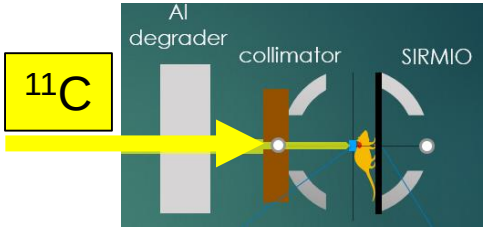
Improvement of separation and identification capabilities
Transmission increase
Improvement of identification and rate capabilities
Test of newly developed detectors

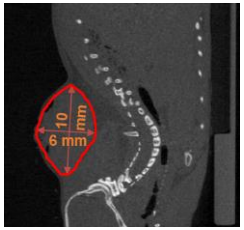


Bio-BARB M.Durante, K.Parodi, C.Scheidenberger

Radioactive beams for the animal tumor treatment

First tumor treatment with RIBs

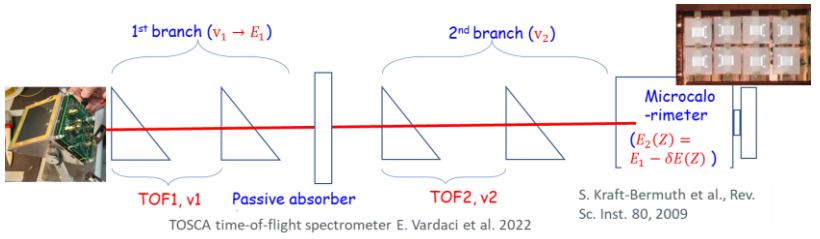




G-22-00174: E.Vardaci, S.Kraft-Bermuth et al.,

In-beam test of a ToF-ΔE-E method for MNT reactions

New ID scheme (A,Z) for low-E beams

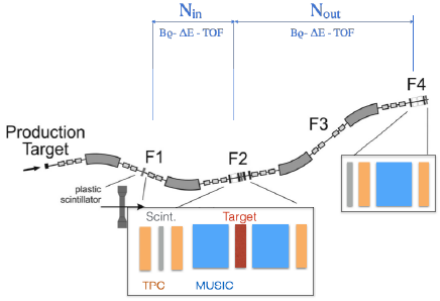


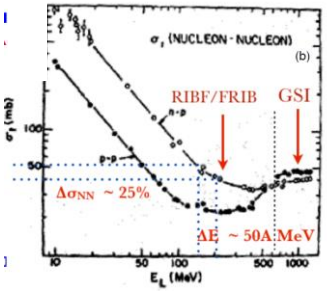
Super-FRS EC experiments scheduled for 2024+2025

G-22-00027, R.Kanungo, S.Bagchi et al.,

Neutron skin measurement of ^{132}Sn and ^{144}Xe

Equation of state of asymmetric nuclear matter
Simultaneous measurement of the interaction cross section and charge-changing cross section

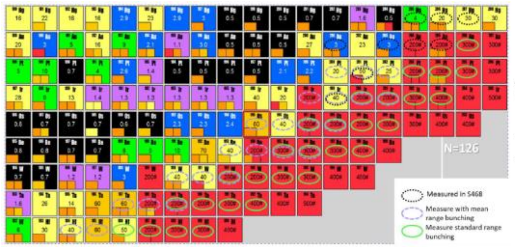


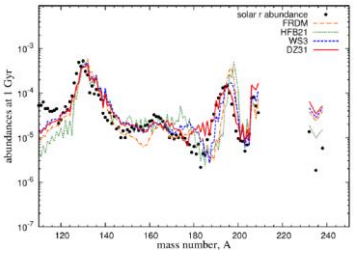


G-22-00150, C.Scheidenberger, G.Martínez Pinedo et al.,

Mass measurements at N≈126 for understanding the 3rd r-process abundance peak

High-accuracy direct mass measurements of neutron-rich exotic nuclides significant for r-process nucleosynthesis network calculations and long-term simulations of neutron-star merger ejecta

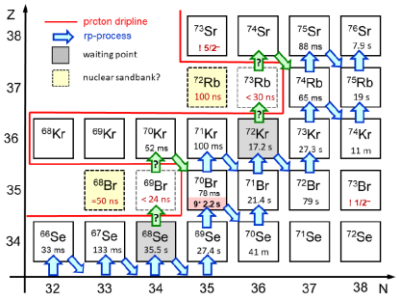


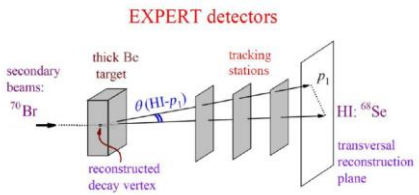


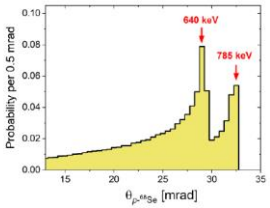
G-22-00115: M.Pfützner, D.Kostyleva et al.,

Study of a nuclear sandbank at the proton unbound bromine isotopes

Investigate the most neutron-deficient isotopes of bromine, $^{68-70}$Br
In-flight decays by proton emission using a method of tracking the decay products







G-23-00xxx, submitted to GSI-FAIR

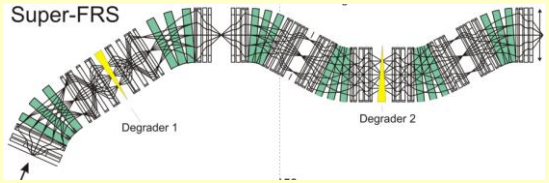
MNT, x-section measurements, Fission isomers

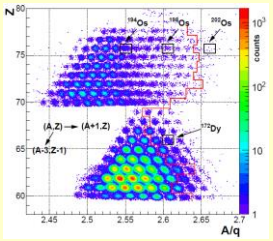
…under review

Plans for ES/FS experiments

Search for new isotopes, radii and momentum distributions

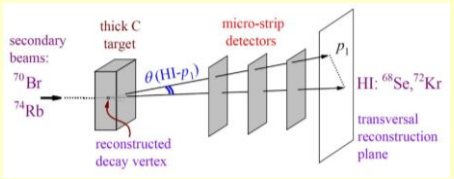
Super-FRS „per se“

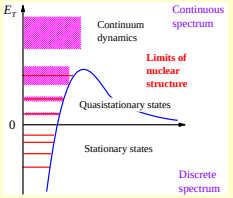




In-flight decay studies beyond the proton dripline

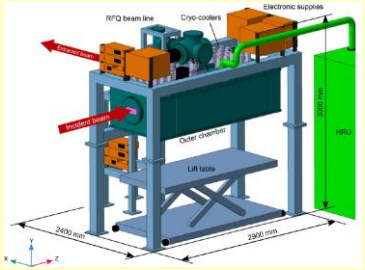
EXPERT (start version) at FMF2

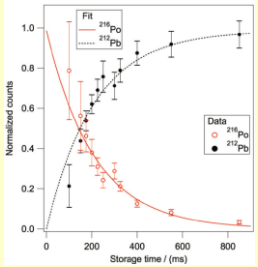




Beta-delayed multi-neutron emission probabilities, MNT reaction studies with secondary beams

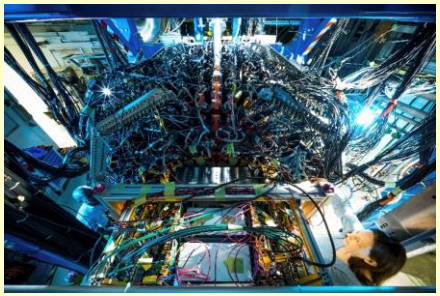
Super-FRS Ion Catcher at FHF1

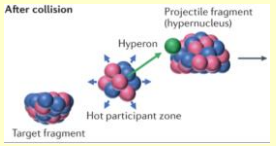


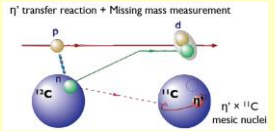


Hypernuclei, nucleon resonances, mesic atoms

WASA-II at FRS (or Super-WASA?)

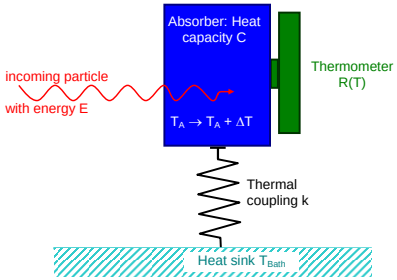






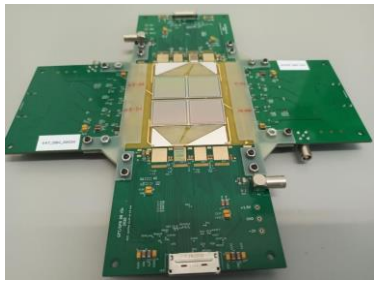
Overview of technical developments planned for 2024+

Micro-calorimeters for PID in MNT-Expt's



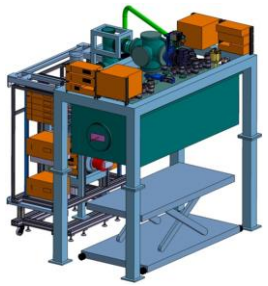
- Test at the FRS
- Design of an array with 4x4 crystals (active detector area 40x40 mm²)

Micro vertex detector for WASA@FRS



Test with off-line sources and with stable-ion beams: efficiency, tracking capability, IP measurement of nucleus-nucleus collisions

Cryogenic Stopping Cell (HADO-CSC) for ES/FS at Super-FRS



Collaboration

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN · GSI · TEL AVIV UNIVERSITY · University of Jyväskylä · eli Nuclear Physics · IFIN-HH · university of groningen · THE UNIVERSITY of EDINBURGH

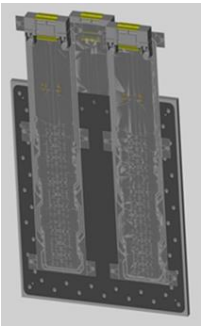
- GSI-FAIR In-Kind Contract signed
- First procurements completed, construction started
- Construction / assembly will be continued in 2024

Tracking detectors for EXPERT

Tests with p-beams at COSY Jülich

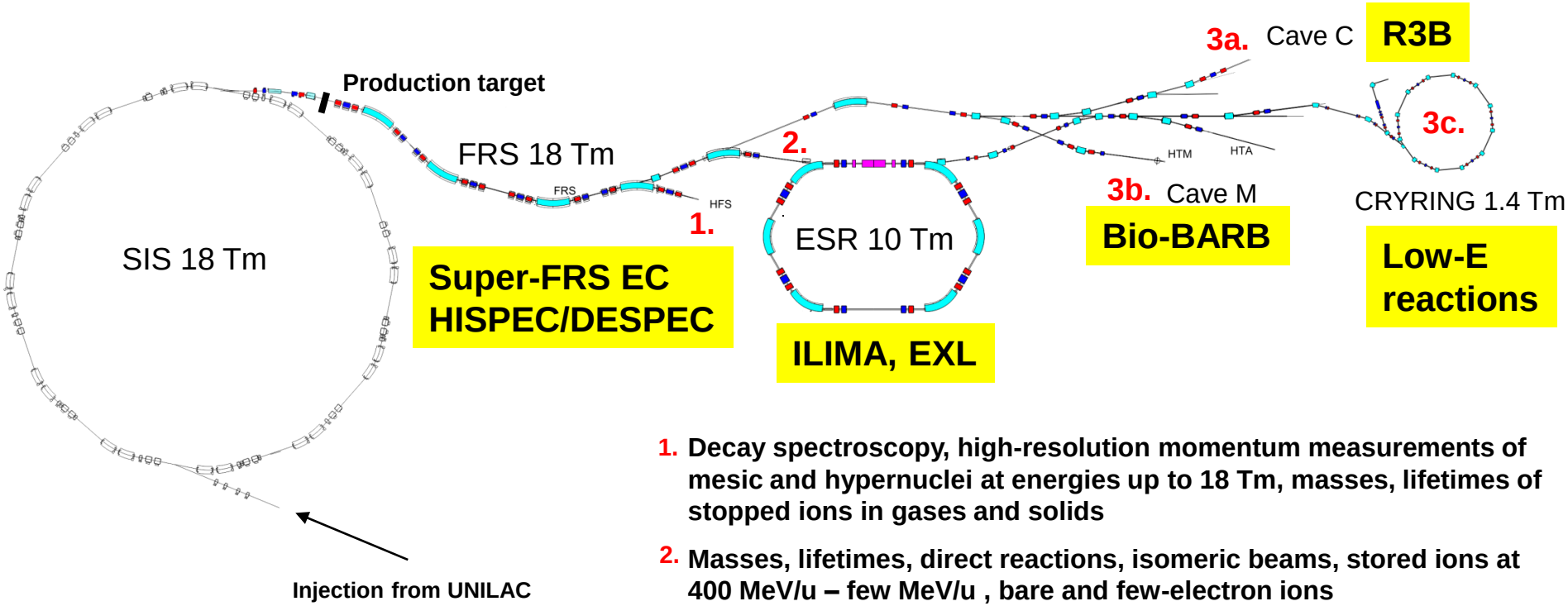
- FOOT micro-strip detectors
- ALPIDE tracking station
- GADAST readout system

In collaboration with R³B



Tracking station with 18 ALPIDE detectors

Experiments with exotic nuclei at GSI



1. **Decay spectroscopy, high-resolution momentum measurements of mesic and hypernuclei at energies up to 18 Tm, masses, lifetimes of stopped ions in gases and solids**
2. **Masses, lifetimes, direct reactions, isomeric beams, stored ions at 400 MeV/u – few MeV/u , bare and few-electron ions**

3a. **Reactions studies in complete kinematics**

3b. **Bio-medical experiments with positron emitters**

3c. **Astrophysical reaction studies in the Gamow window**

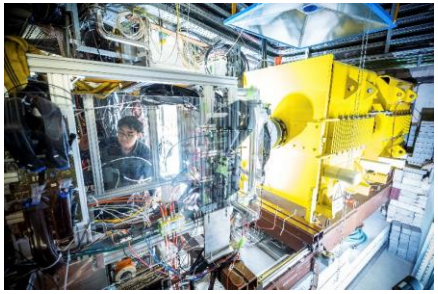
➔ **It will be important to stay compatible with GSI-FAIR to ensure the continuation of FRS experiments in the mid-term future**

Overview of ongoing shutdown activities 2023 and 2024

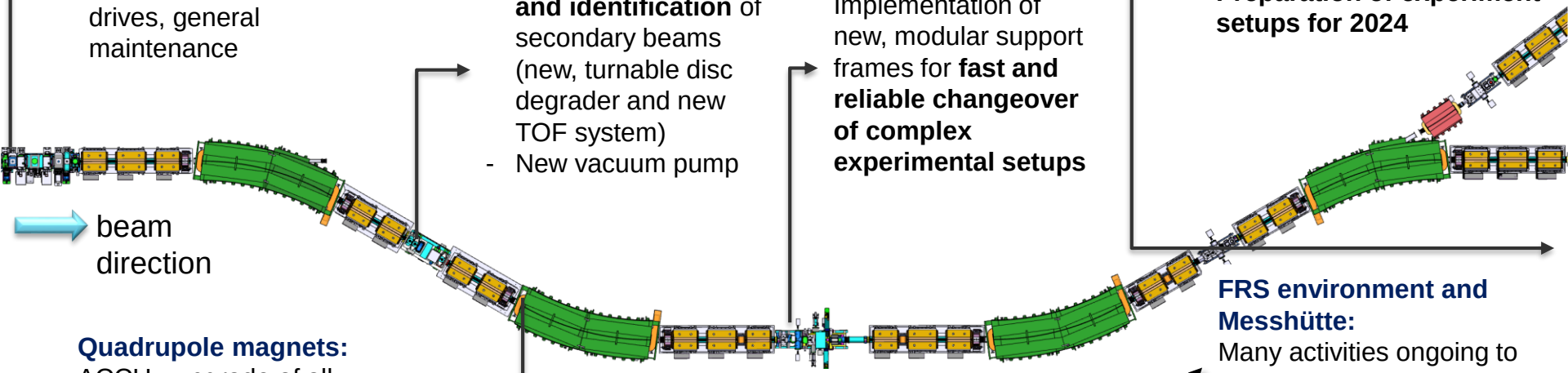
Target Area:
- **Preparation for complete remote handling**
- New vacuum pumps and sensors, modularity of drives, general maintenance

S1 focal plane:
- **Improved separation and identification** of secondary beams (new, turnable disc degrader and new TOF system)
- New vacuum pump

S2 focal plane:
Implementation of new, modular support frames for **fast and reliable changeover of complex experimental setups**



S4 focal plane
- Preparation of detectors for test run in Nov. 2023
- **Preparation of experiment setups for 2024**



beam direction

Quadrupole magnets:
ACCU - upgrade of all power supplies (in order to **stay compatible with FAIR control system**)

Steppermotors and insertions:
64-channel COSYLAB system available; installation in 2024

FRS environment and Messhütte:
Many activities ongoing to **maintain/improve safety, reliability** of all technical areas and sub-systems

DAQ: Upgrade to higher rate capability ongoing

Remote Control of the FRS

- NB: Technically, the separator can be controlled from anywhere in the world
- However, in practice the approach must be different:
  - ***Compatibility with every experiment***
  - ***Flexibility at all phases of an experiment***

  ➔ the separator controls and diagnostics (particle detectors for ID, DAQ etc.) are used at the place „where presently the music plays“ (can be HKR, can be FRS shack, Cave-A-M, can be from home…)

  ➔ ***…fulfilling the individual needs of an experiment at any time***

- What is needed to control the FRS in future also from FCC?

	Invest* (k€)	Personpower* (FTE)	Support from ACO
Necessary	46	2.0	X
Desirable	54	1.5	X
Sum	**100**	**3.5**	

* figures are present (July 2023) estimates

NUSTAR Beam Team: availability of participants

	Person no.	2020*	2021	2022	2023	2024	2025
Super-FRS EC	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						
	11						
	12						
	13						
	14						
Despec	15						
	16				?	?	?
R3B	17						
	18						?

Available throughout beam time period, but not full time available

Available part of beam time period, e.g. when contract starts/ends in the middle of beam time block

Not available

* The NUSTAR Beam Team was launched in fall 2020, after the end of the beam time

Plans and needs in coming decade

We plan to…

- **perform high-resolution spectrometer experiments at FRS and Super-FRS**: combine FRS and Super-FRS with ancillary detectors of the Super-FRS Experiment Collaboration
- **prepare the collaboration equipment for the ES/FS era at FAIR**: test detectors, diagnostic devices, ion optics, materials, algorithms etc. needed for the Super-FRS era
- **continue to contribute to and participate in experiments with exotic nuclei from FRS** at various destinations (F2/F4, F6->ESR/CRYRING, F8->HTC/HTM): HISPEC/DESPEC, ILIMA, EXL, R3B, Bio-BARB, CRYRING,…
- **make appropriate plans in the coming 3 years to keep both, FRS and Super-FRS, running once FAIR starts**, with the goal to maximize the use of beam time and of the technical infrastructure and the science output at GSI-FAIR (e.g. WASA@FRS while other experiments are running at Super-FRS)

To stay competitive worldwide, FRS experiments at GSI need…

- the continuation of FAIR Phase-0 experiments in POF-5
- a team of scientists able to run the experiments
- to maintain the high-level experience and extend it to the Super-FRS
- …a few more items, e.g. high-intensity primary beams, parallell operation, careful optimization and preparation of every experiment, continuous effort for maintenance, …

Thank you for your attention!