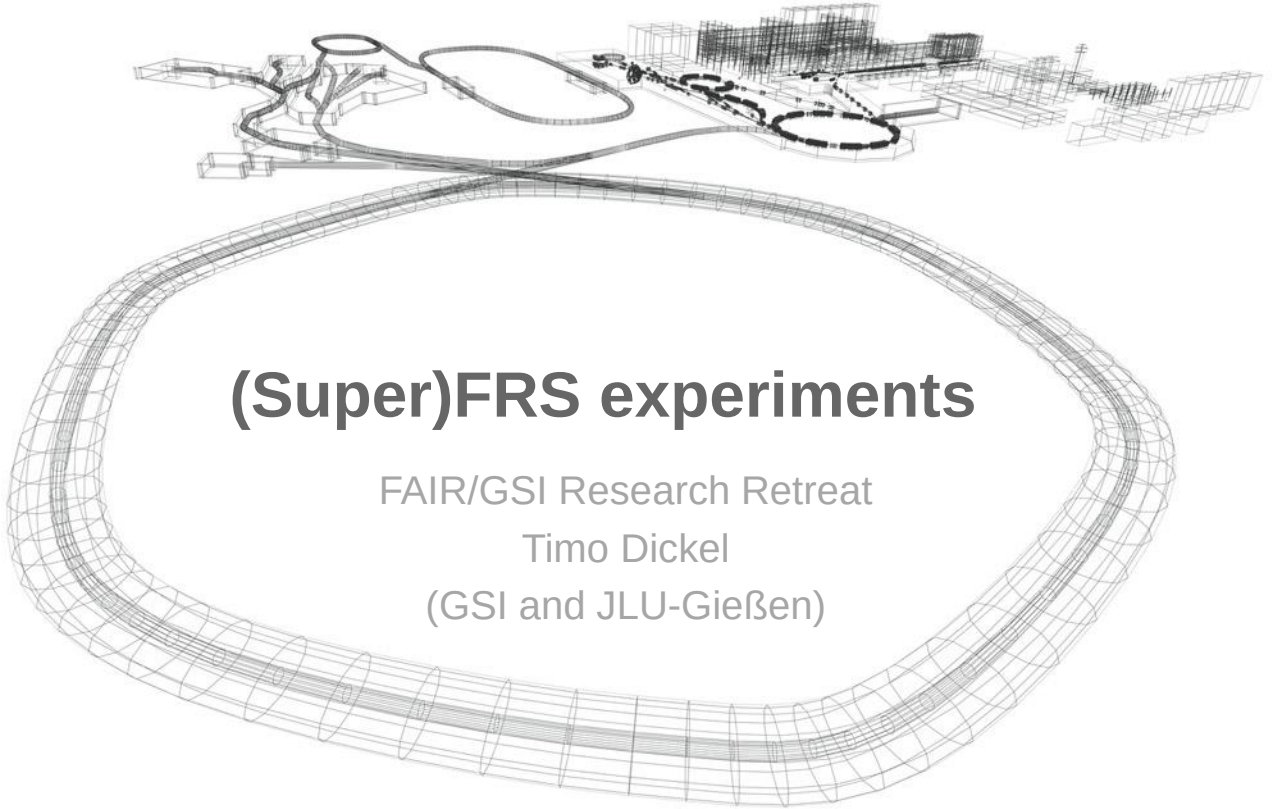


(Super)FRS experiments

FAIR/GSI Research Retreat

Timo Dickel

(GSI and JLU-Gießen)

The Super-FRS Experiment Collaboration: from new-isotope search to applications

(Super-)FRS for mass and charge separation

- *Search for new isotopes and ground state properties*
- *Atomic collisions*
- *Radioactive beams for applications (e.g. PET-imaging)*

(Super-)FRS as high-resolution spectrometer

- *Spectroscopy of meson-nucleus bound system (mesonic atoms)*
- *Exotic hypernuclei and their properties*
- *Importance of tensor forces in nuclear structure*
- *Delta resonances probing nuclear structure*

(Super-)FRS as multi-stage separator and high resolution reaction spectrometer

- *Nuclear radii and momentum distributions*
- *Radioactive in-flight decays and continuum spectroscopy by particle emissions*
- *Low-q experiments with an active target*
- *Synthesis of new isotopes and nuclear reaction studies with RIBs*

Super-FRS Experiment Collaboration: pilot experiments in 2020-2025

High-resolution spectrometer experiments with FRS and ancillary detectors

Broad science spectrum:

- **New isotopes**, new reaction studies (e.g. MNT)
- **Exotic nuclei** (proton radioactivity, fission isomers)
- **Atomic-collision** studies
- **Hyper nuclei:** nnΛ, $^{3}_{\Lambda}$H, $^{4}_{\Lambda}$H
- **Hadron physics:** search for eta-prime mesic nuclei
- **Applications:** nuclear astrophysics, biology, nuclear imaging

2020

S468 New isotope search „south“ of Pb (N~126), masses and half-lives
S469 Gas-solid difference in heavy ion stopping
S474 Direct mass measurements around ^{100}Sn
S459+ In-flight decay spectroscopy of proton-unboun^^d nuclei and mass meas.
S482 Mean range bunching

2021

S483 Beam Instrumentation test for Super-FRS
S511 FRS developments for NUSTAR experiments
S526 Direct mass measurements of heavy N=Z nuclei
S530 Fission isomer studies at FRS
S533 Atomic and nuclear interaction studies for ion-beam therapy with b^{+}-emitting nuclei

2022

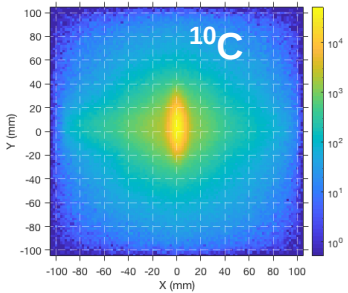
S447 Studies of hypernuclei by new spectroscopy techniques with WASA@FRS
S490 Search for eta‘-mesic nuclei in ^{12}C(p,dp) reaction
U323 Study of MNT processes in different reactions

(Super)FRS Experiment Collaboration:
Experiments performed in 2021

- S483 (Nociforo et al.): **Tests of beam instrumentation equipment for the Super-FRS at FAIR**
  - Tests with different primary beams: C, Xe, Pb, U
  - Gas-filled detectors for tracking and identification
  - SEM-grid and scintillating fiber detectors for high rates

- S511 (Scheidenberger et al.): **FRS developments for NUSTAR experiments: performance improvements and R&D work with heavy-ion beams**
  - FRS ion optics: high transmission mode
  - Microspill structure studies at highest intensities
  - Macrospill optimization for DC-type spill profile

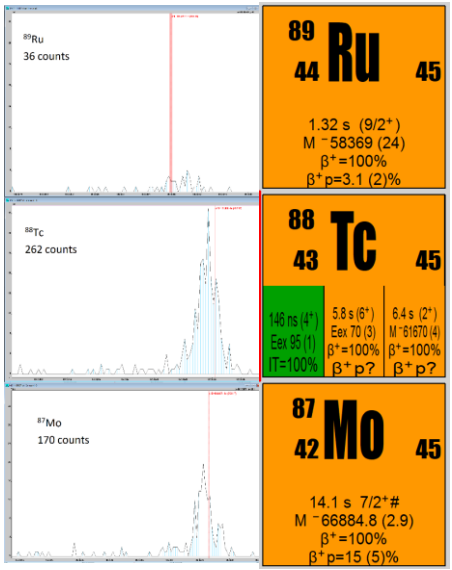
- S533 (Purushothaman et al.): **Measurements of nuclear and atomic interactions needed for ion-beam therapy with positron emitters of carbon**
  and S000 (Scheidenberger, Schütt, Durante et al.):
  Commissioning of radioactive beams in Cave M



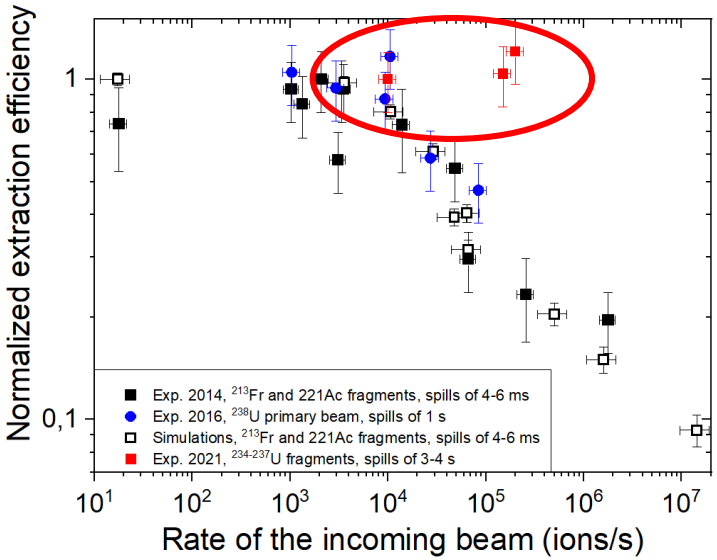
  - Production, separation, identification and transport of PET isotopes (^{10,11}C)
  - Measurement of their interaction and charge-changing cross sections in various materials
  - PET imaging using phantoms

(Super)FRS Experiment Collaboration: Experiments performed in 2021

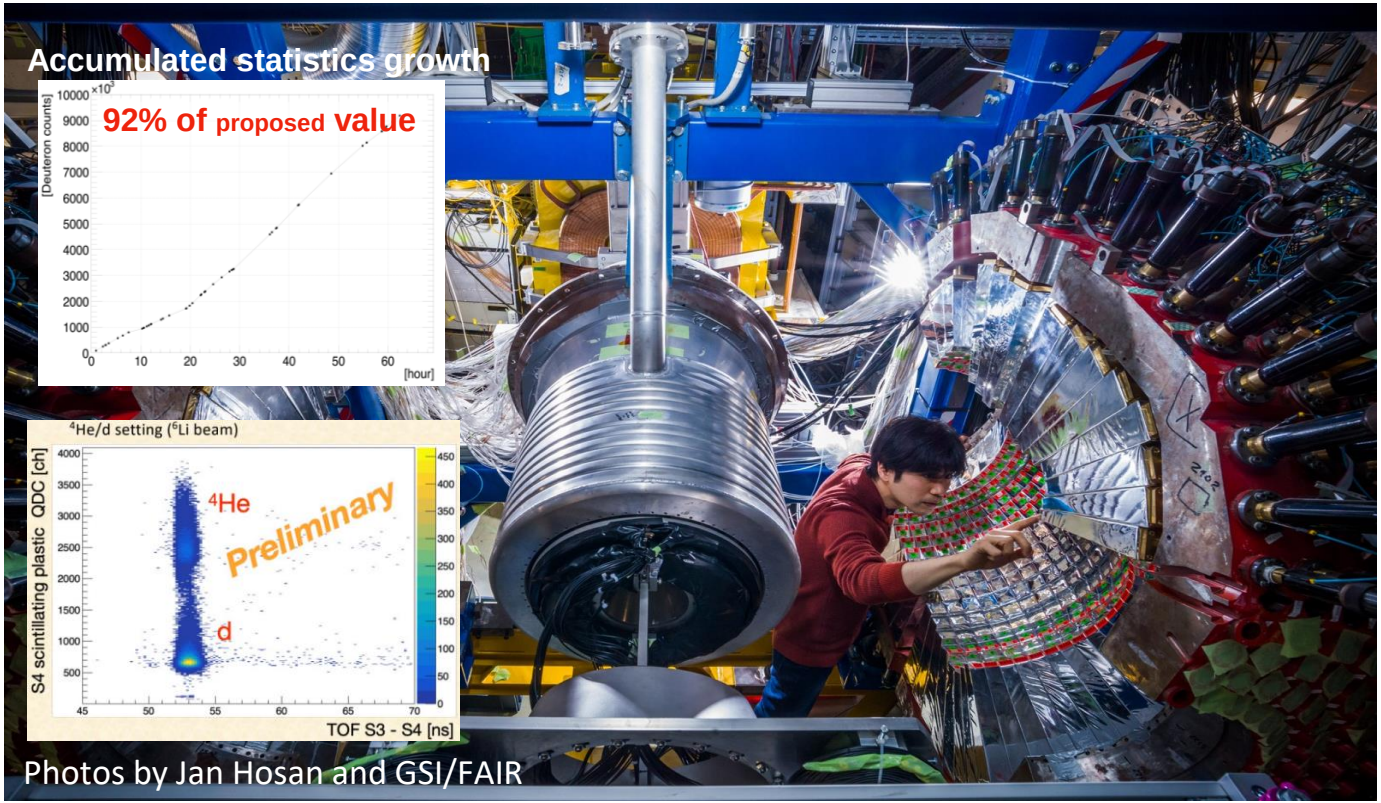
- S526 (Plass et al.): **Direct mass measurements of heavy N=Z and N=Z-1 nuclides**



- S530 (Dickel et al.): **Fission isomer studies with the FRS**



(Super)FRS Experiment Collaboration:
Experiments performed in 2022

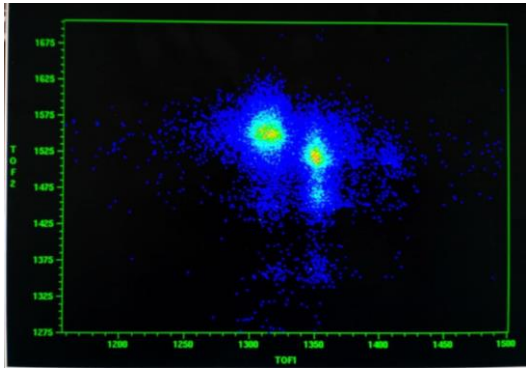


(Super)FRS Experiment Collaboration:
Experiments performed in 2022

(Super)FRS Experiment Collaboration:
Experiments performed in 2022

U323: MNT studies with TOSCA @ UNILAC

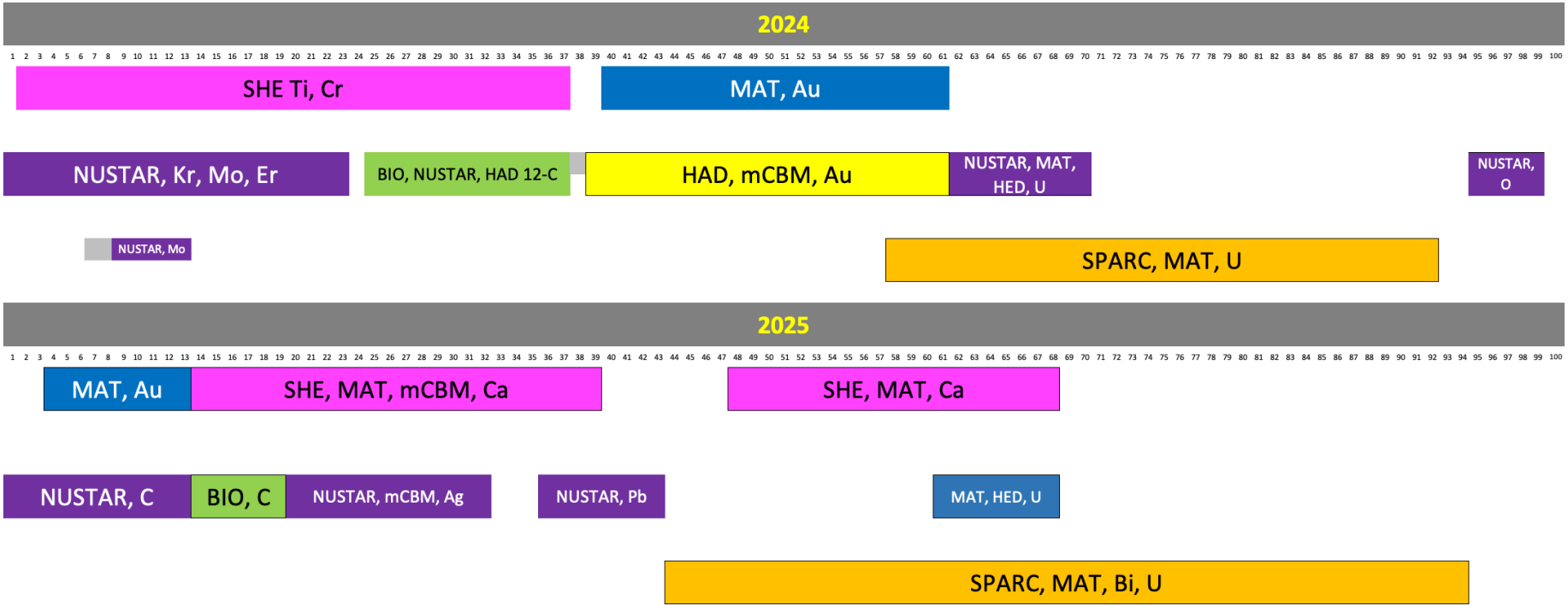
^{136}Xe (700MeV)+ ^{197}Au



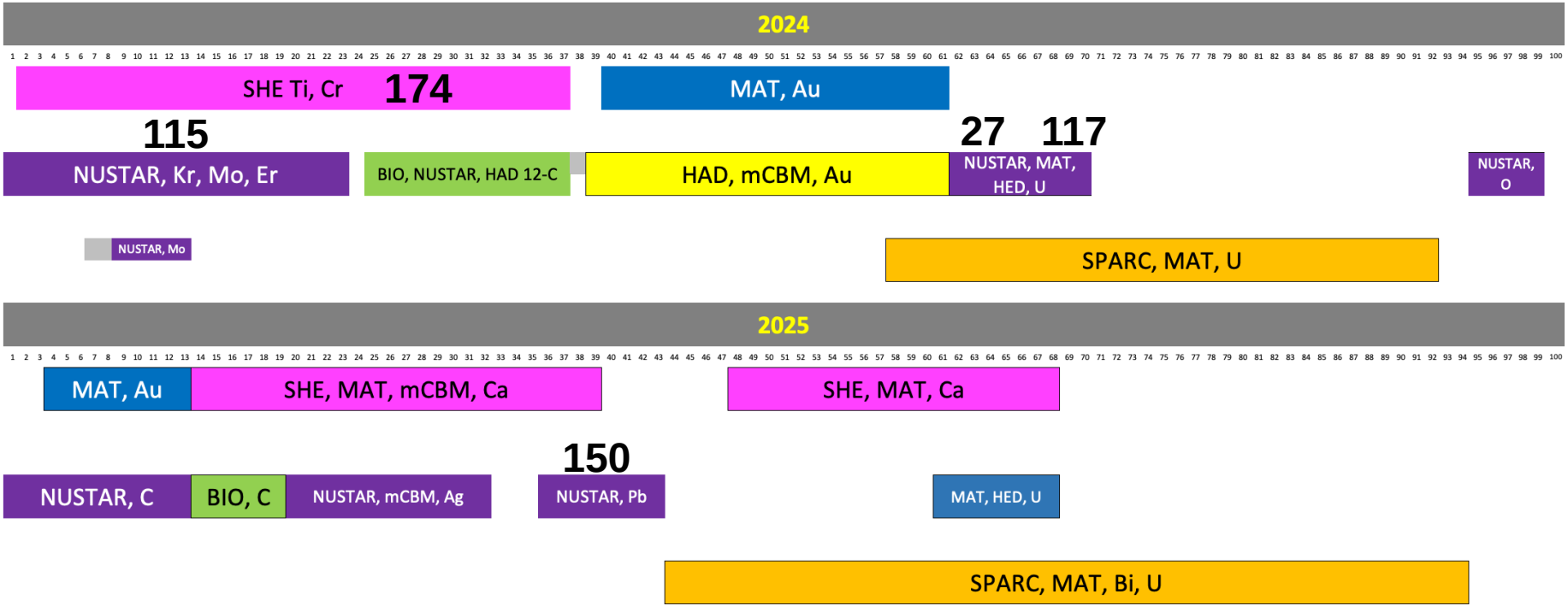
Approaved Experiments in 24/25

Experiment	Nr.	Spokesperson	A Shifts	A-Shifts	Beam
In-beam test of a TOF-DE-E method for complete identification via mass-(A) and charge-(Z) number of fragments produced in Multi Nucleon Transfer reactions	G-22-00174	Vardaci, Emanuele	12	12	@UNILAC: 136Xe (A~50 for A-)
In-cell multi-nucleon transfer reactions at the FRS Ion Catcher - a new perspective towards broadband heavy neutron-rich isotope studies with stable and unstable beams	G-22-00117	Constantin, Paul	5	8	238-U
Nuclear symmetries and structure studies via mass measurements at the N=Z line from Ge to Rh	G-22-00056	Plaß, Wolfgang		17	107-Ag and 78-Kr
Mass measurements at N≈126 for understanding the 3rd r-process abundance peak	G-22-00150	Scheidenberger, Christoph	21		208-Pb
Neutron skin measurement of 132Sn and 144Xe	G-22-00027	Kanungo, Rituparna	5		238U
Towards limits of nuclear structure by using a 9C beam	G-22-00111	Chudoba, Vratislav		11	12-C
Study of a nuclear sandbank at the proton unbound bromine isotopes	G-22-00115	Pfutzner, Marek	11		78Kr
FRS developments for APPA and NUSTAR experiments: Performance improvements and R&D work with heavy-ion beams	G-22-00160	Scheidenberger, Christoph	10		Light and heavy
		∑	64	48	

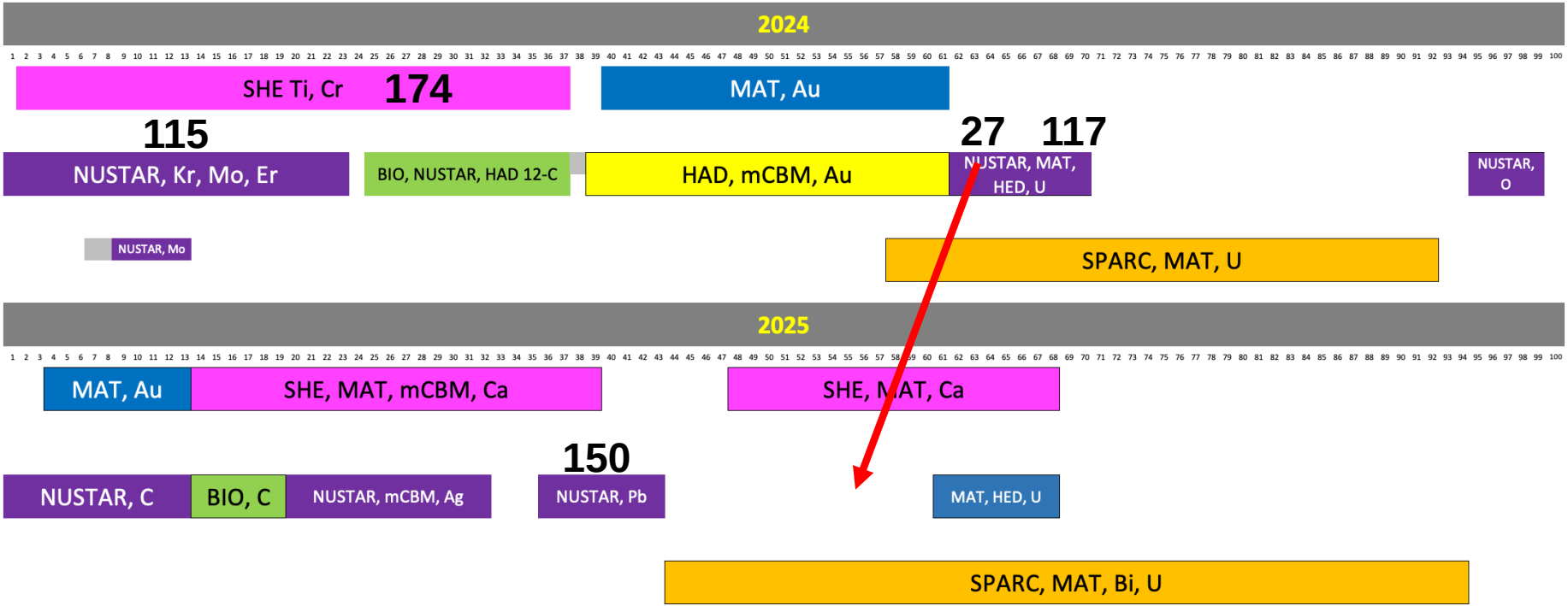
Beamtime schedule



Beamtime schedule



Beamtime schedule



„Our“ priorities for Eng. Run

- **Re-Commissioning of the FRS after the shutdown and upgrades**
- *Transmission improvement FRS-ESR*
- Test of Helium-Recovery Unit (FAIR in-kind)
- Improvement to the Micro and Makro spill structure in routine operation for all experiments and beams
- **High intensity for beams on FRS target, especially for ^{208}Pb**
  - High/full transmission from SIS18 to FRS target at highest rigidities
  - High spill rate: 1 per second at 100ms slow extraction

Ideas for 26+ at FRS and ES

26+ @ FRS:

- Detector Tests (e.g., SAFARI (high rate TOF))
- Ion-Optical developments
- WASA@FRS
- Selected experiments (under discussion in the collaboration)

Early Science 27+ @ Super-FRS:

New Isotope search: N>126

- Higher Transmission ~2x
- Reduction of fission fragments

Beta-delayed neutron emission

- Higher Transmission ~10x
- Higher Beam cleanliness
- New CSC

Conclusions

Plans for near future

Eng. run

- Re-Commissioning FRS
- high-int. Pb
- …

Beamtime 24/25

- Mass measurements
- Neutron skin
- Nuclear structure at the proton dripline

Ideas for mid-term future

Experiments @ FRS ´26+

- WASA, detector tests,…

Early Science @ Super-FRS ´27+

- New Isotope search
- beta-delayed neutrons

Continuation of beamtime
(> 3 weeks per year)
to keep collaboration together and know-how sustained