

NUSTAR collaboration news

Zsolt Podolyák

NUSTAR week, Prague, 30 September 2025



Finland



France



Germany



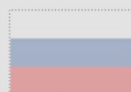
India



Poland



Romania



Russia



Slovenia



Sweden

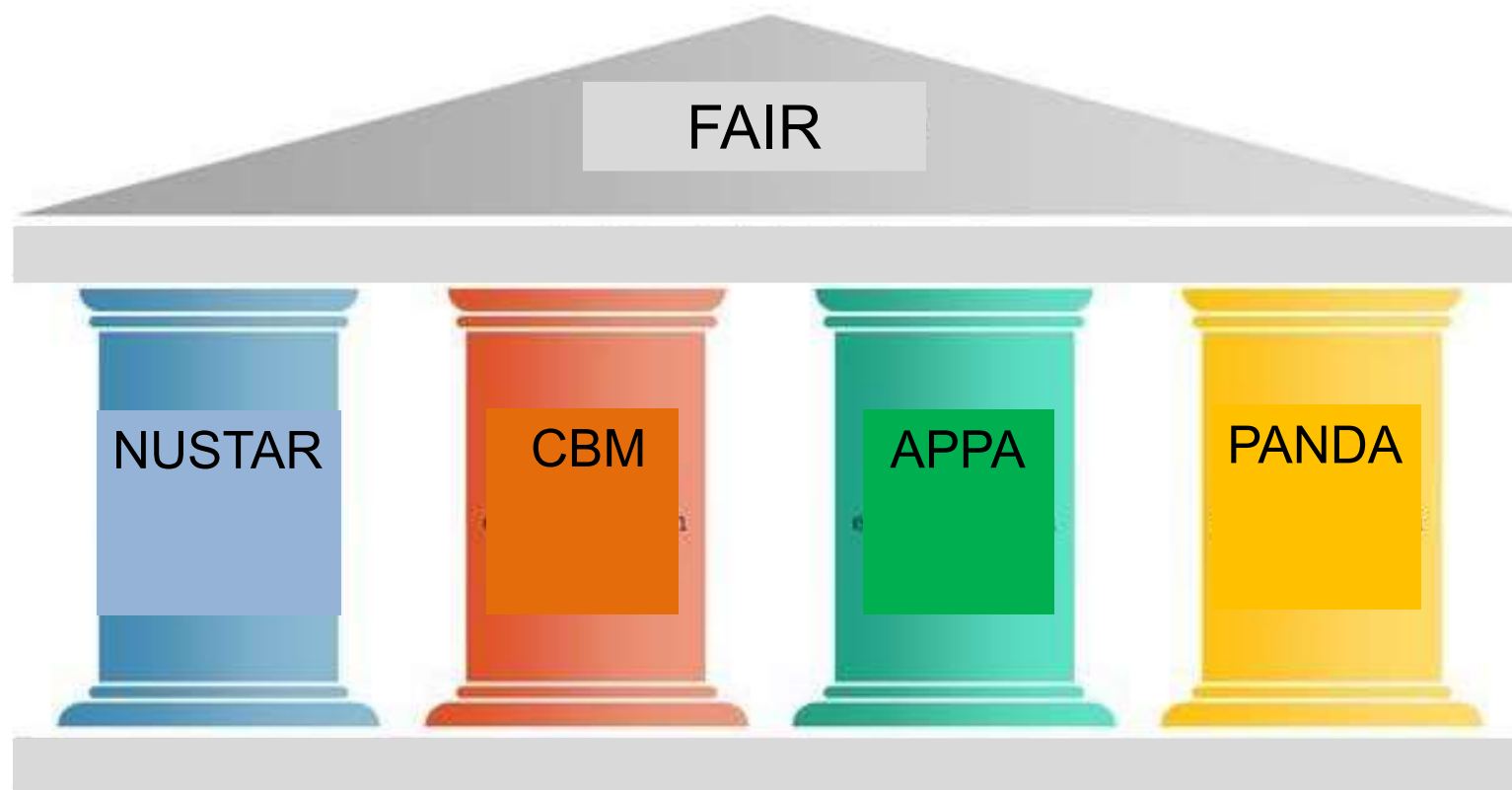


UK



Czech Republic





Overarching physics case: the creation of the (heavy) chemical elements

Big physics question requiring information on:

Equation of State

Limits of existence

Lifetimes,

Masses

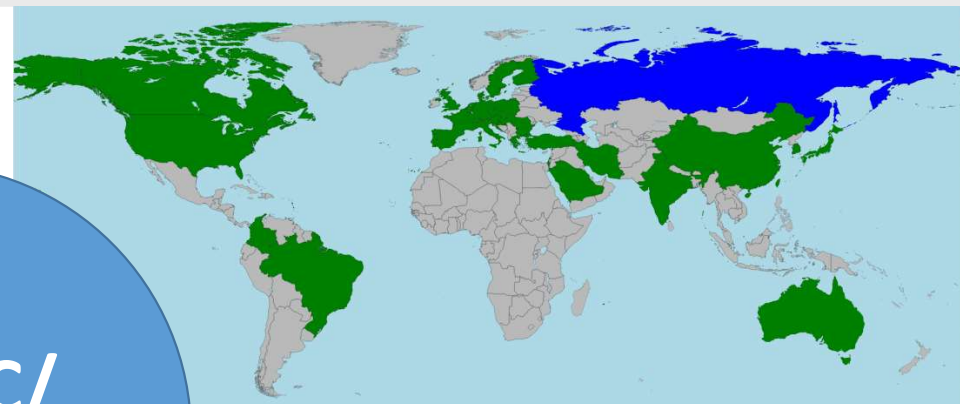
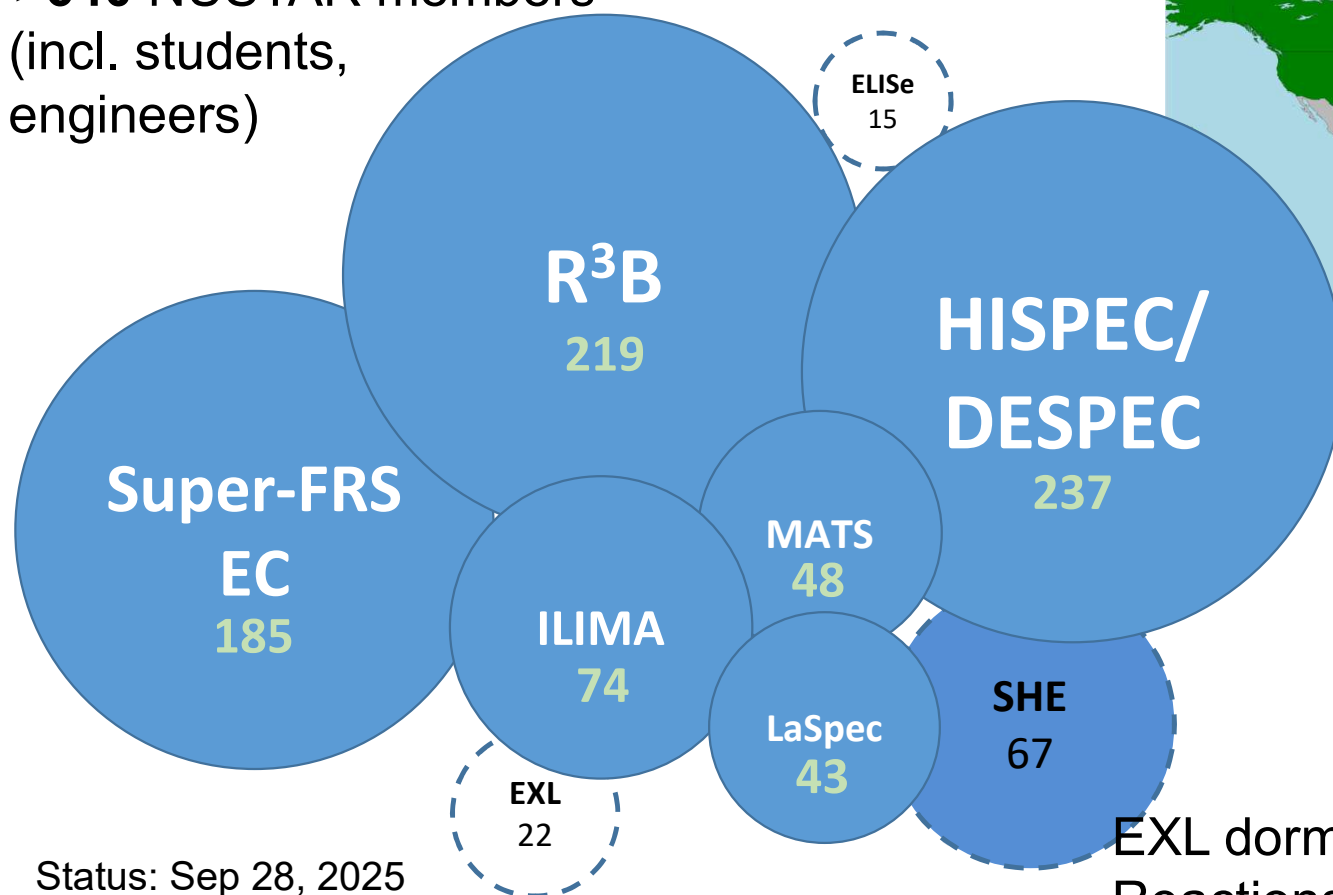
P_{xn} values

Fission

Reactions in star environments



>640 NUSTAR members
 (incl. students,
 engineers)



- > 1000 listed “interested” scientists
- > 640 registered members (incl. students, etc.)
- ~ 449 senior members (PhD holders w/o Russia)
- > 140 institutes from 35 countries

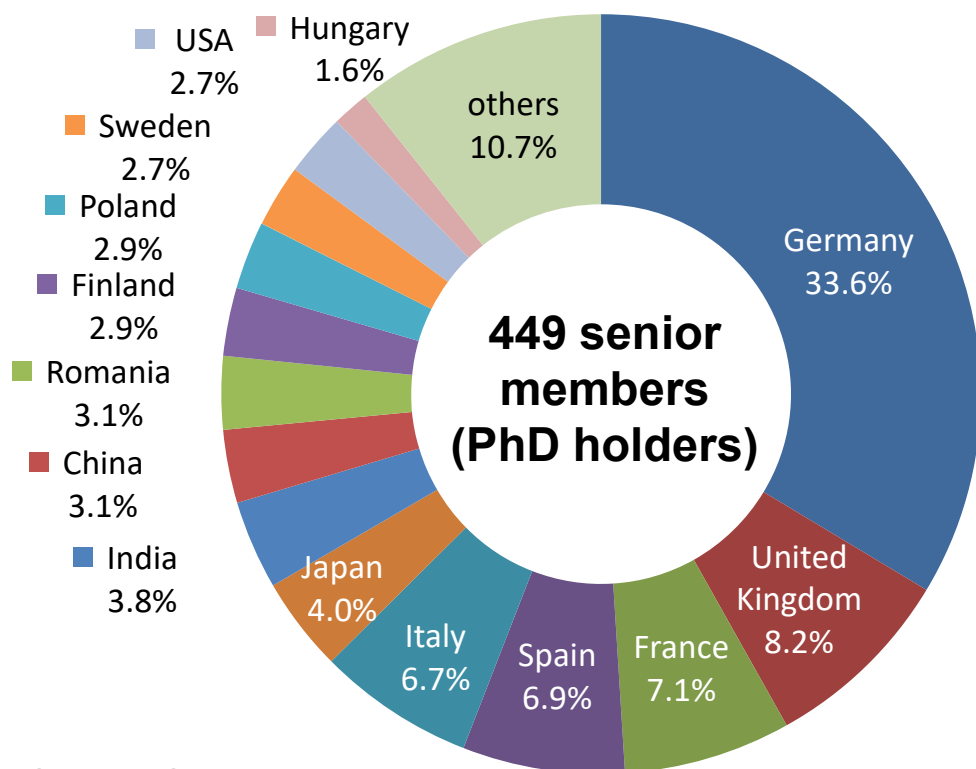
Status: Sep 28, 2025

EXL dormant
 Reactions in rings incorporated into ILIMA



NUSTAR Collaboration senior members

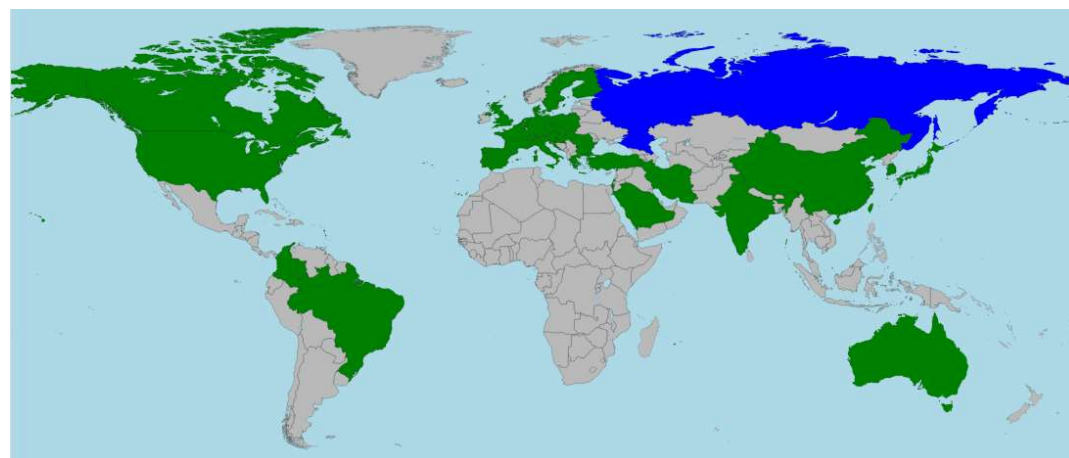
NUSTAR collaboration senior members (PhD holder without Russia) for collaboration common fund from HISPEC/DESPEC, MATS, LaSpec, R3B, ILIMA, Super-FRS EC



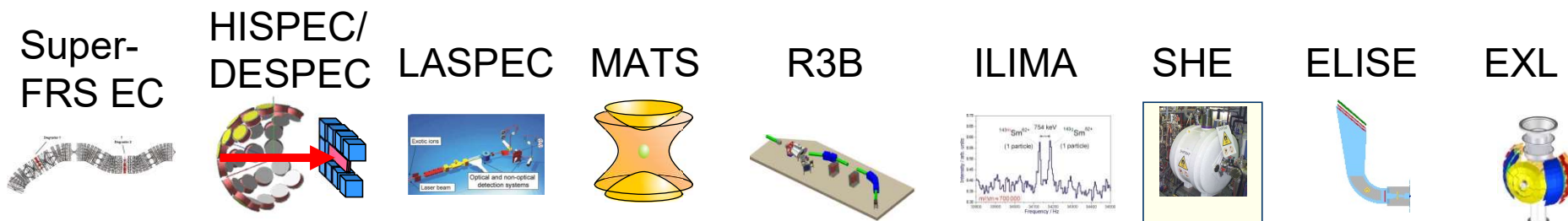
Status: September 28, 2025

- > 1000 listed “interested” scientists
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Secured funding and expression of interest in funding **from 22 countries (incl. Russia)** (incl. 10 FAIR partner countries)



Complementarity of NUSTAR experiments



	Super-FRS	HISPEC/DESPEC	LASPEC	MATS	R3B	ILIMA	SHE	ELISE	EXL
Masses		Q-values, isomers		dressed ions, highest precision	unbound nuclei	bare ions, mapping study	precision mass of SHEs		
Half-lives	ps...ns-range	dressed ions, μ s...s			resonance width, decay up to 100ns	bare ions, ms...years	μ s...days		
Matter radii	interaction x-section				interaction x-section				matter density distribution
Charge radii	charge-changing cross sections		mean square radii		charge-changing cross sections			charge density distribution	
Single-particle structure	high resolution, angular momentum	high-resolution particle and γ -ray spectroscopy	magnetic moments, nucl. spins	evolution of shell str., pairing int., valence nucl.	quasi-free knockout, short-range and tensor	evolution of shell closures, pairing corr.	shell structure of SHEs		low momentum transfers
Collective behavior		electromag. transitions	quadrupole moments	halo structure	dipole response	changes in deformation		electromag. transitions	monopole resonance
EoS					polarizability, neutron skin			neutron skin \rightarrow	neutron skin, Compressibility
Exotic Systems	bound mesons, hypernuclei, nucleon res.								

2021-2022	FAIR-0 experiments (27 NUSTAR exps.+tests)
2023	No experiments (but there were tests)
2024-2025	FAIR-0 experiments (27 NUSTAR exps.+tests)
2026-2027	FAIR-0 experiments (G-PAC in 2025)
End 2027 ->	Early Science (with SuperFRS)
End 2028 ->	First Science (with SuperFRS and SIS100)

Publications 2021-2024



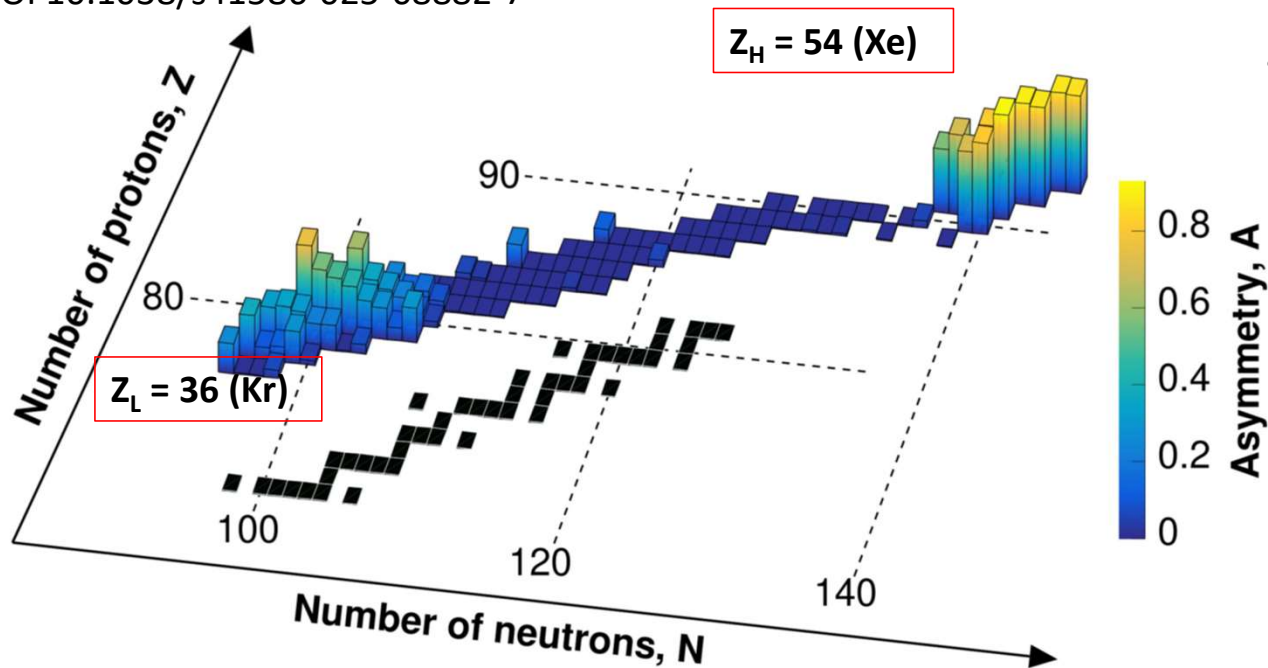
NUSTAR database
(based on GSI repository:
<https://repository.gsi.de/>)

		Nature family; PRL	PLB	PRC/ PRA	NIM	Other	PhD diss.	Total
R3B	2021-24	5	3	10	4	20	9	51
HISPEC/D ESPEC	2021-24	3	8	6	6	18	4	45
SuperFRS- EC	2021-24	2	3	3	17	16	2	43
ILIMA	2021-24	3	0	2	1	6	0	12
SHE	2021-24	8	4	15	9	52	4	92
LASPEC/ MATS	2021-24	3	0	0	0	1	0	4
NUSTAR	2024	7	5	3	5	30	13	63
	2023	6	5	5	14	35	4	69
	2022	6	4	16	10	31	0	67
	2021	5	4	12	8	17	2	48
NUSTAR	2021-24	24	18	36	37	113	19	247

A New Island of Asymmetric Fission

P. Morfouace *et al.* Nature 641, 339 (2025)

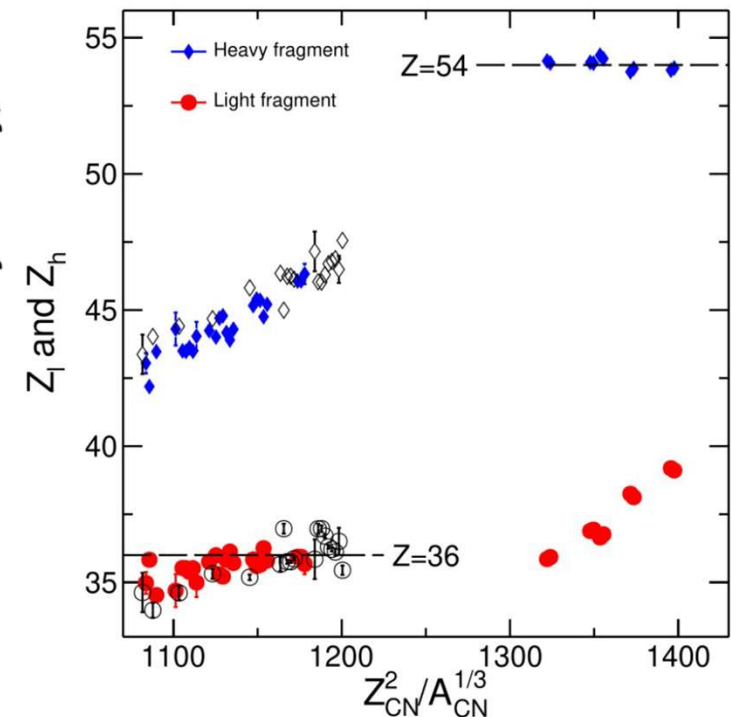
DOI 10.1038/s41586-025-08882-7

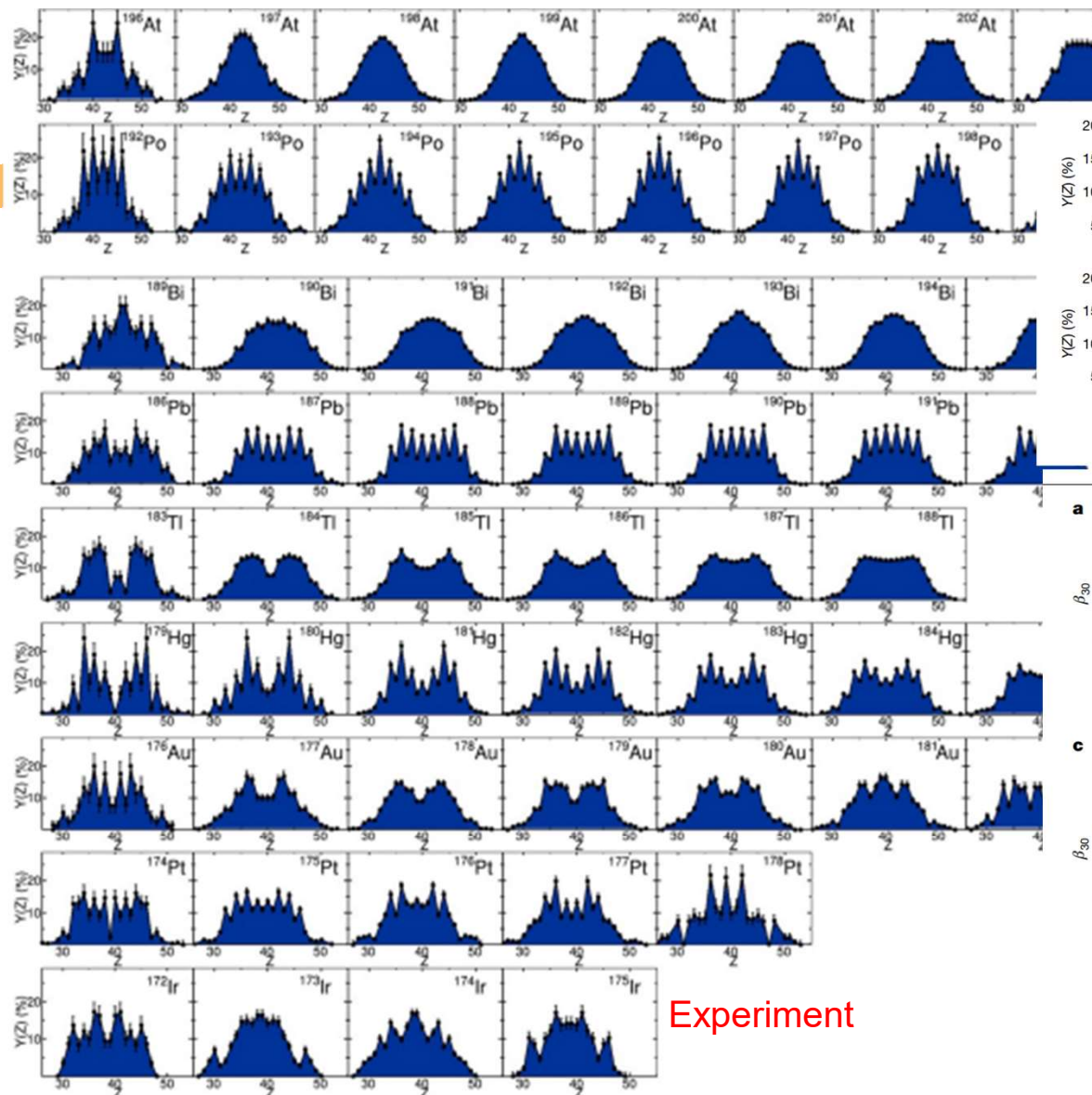


Unlike the actinides, the asymmetric fission in the neutron deficient sub-lead region is driven by shell effect in the light fragment.

Results

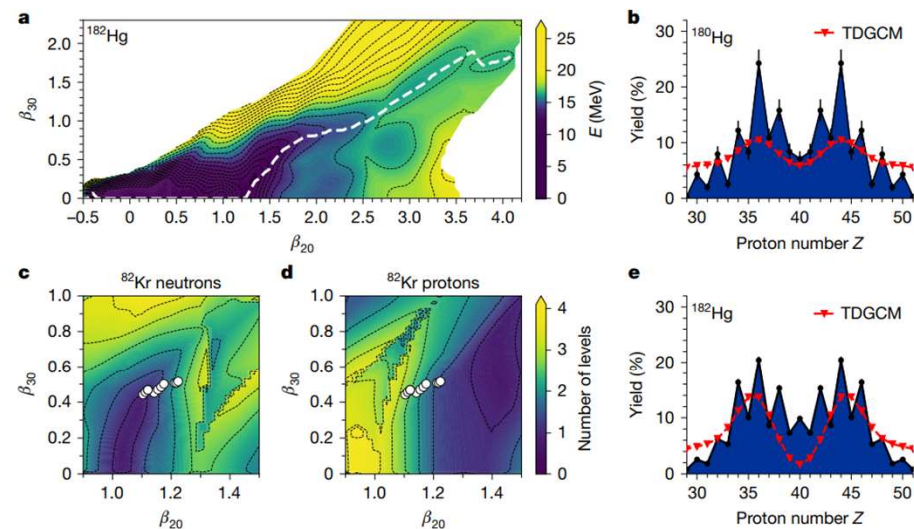
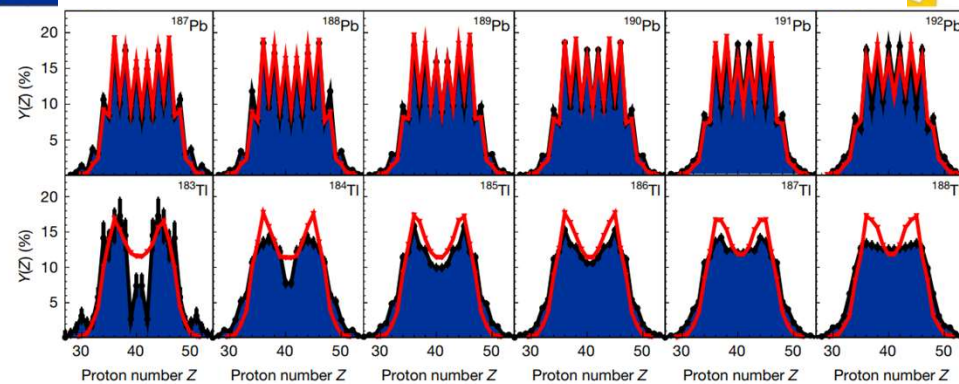
- First set of charge distribution across a wide range of exotic fissioning systems.
- Experimental evidence of strong proton-shell stabilization at $Z=36$





Experiment

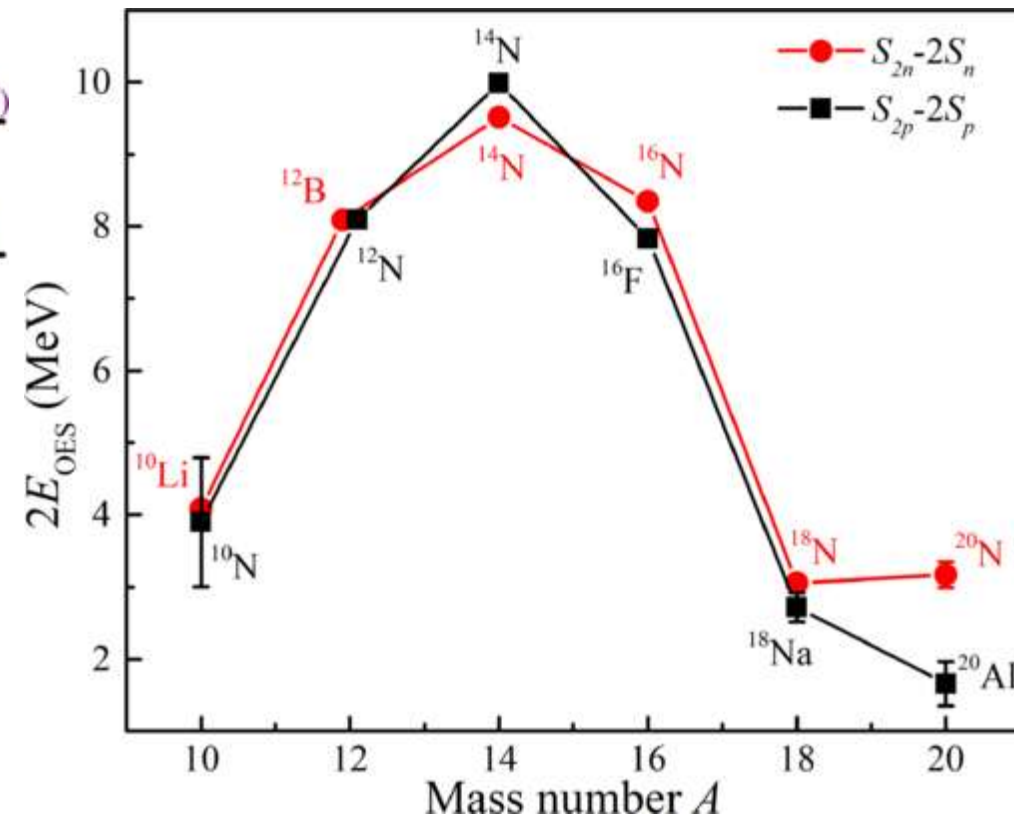
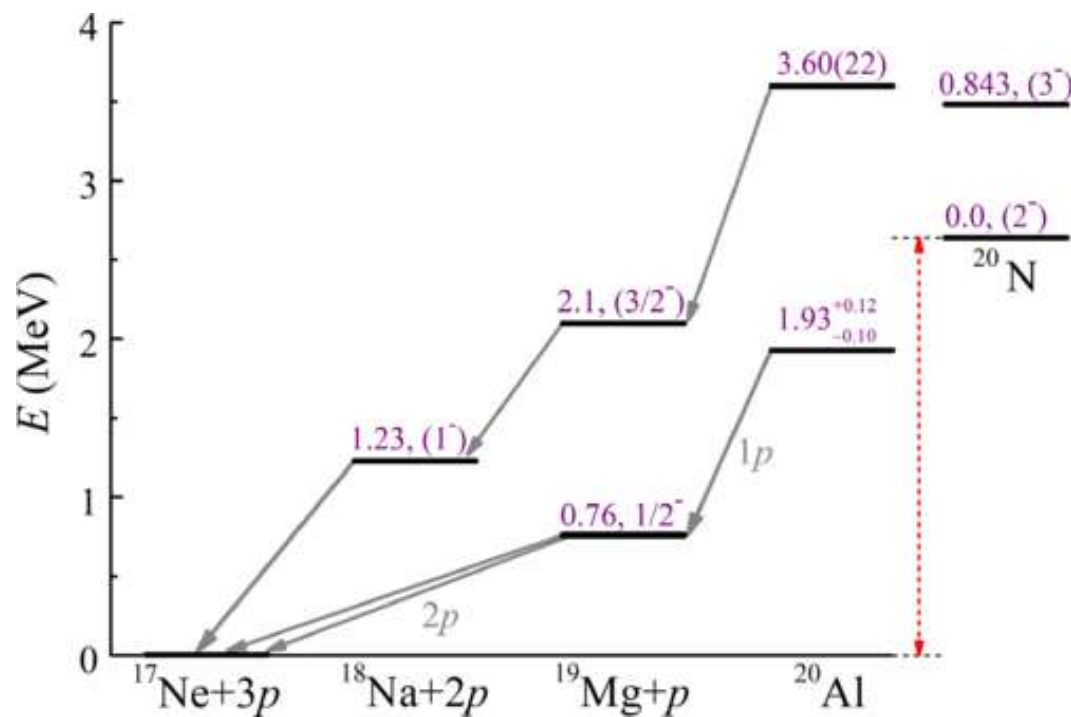
General Description of Fission Observables, phenomenological Monte Carlo approach



Time-dependent
generator coordinate method

Isospin symmetry braking in three-proton emitter ^{20}Al

OES: Odd-even staggering
of nuclear masses



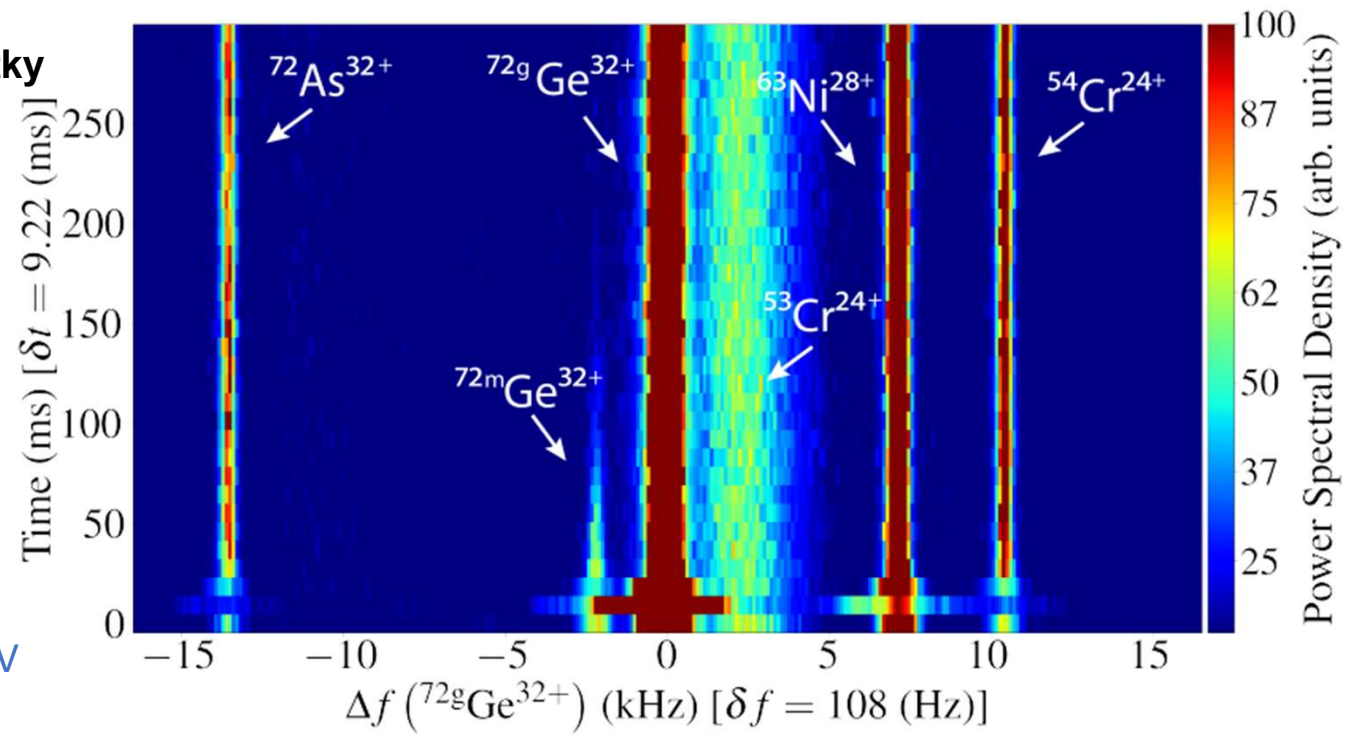
X.-D. Xu et al., Phys. Rev. Lett. 135, 022502 (2025)

Combined Schottky + Isochronous Mass Spectrometry



**New lifetime record: 1 ms in April 2025,
bridge to decay spectroscopy**

- High precision isochronous condition
 - Mass resolution $\sim 10^{-6}$
- Single-ion sensitivity of new Schottky



excitation energies down to ~ 100 keV
and half-lives as short as ~ 10 ms.

D. Freire-Fernandez, W. Korten et al., Phys. Rev. Lett. 133, 022502 (2024)

Discoveries of the new ^{257}Sg and K-isomer in Sg

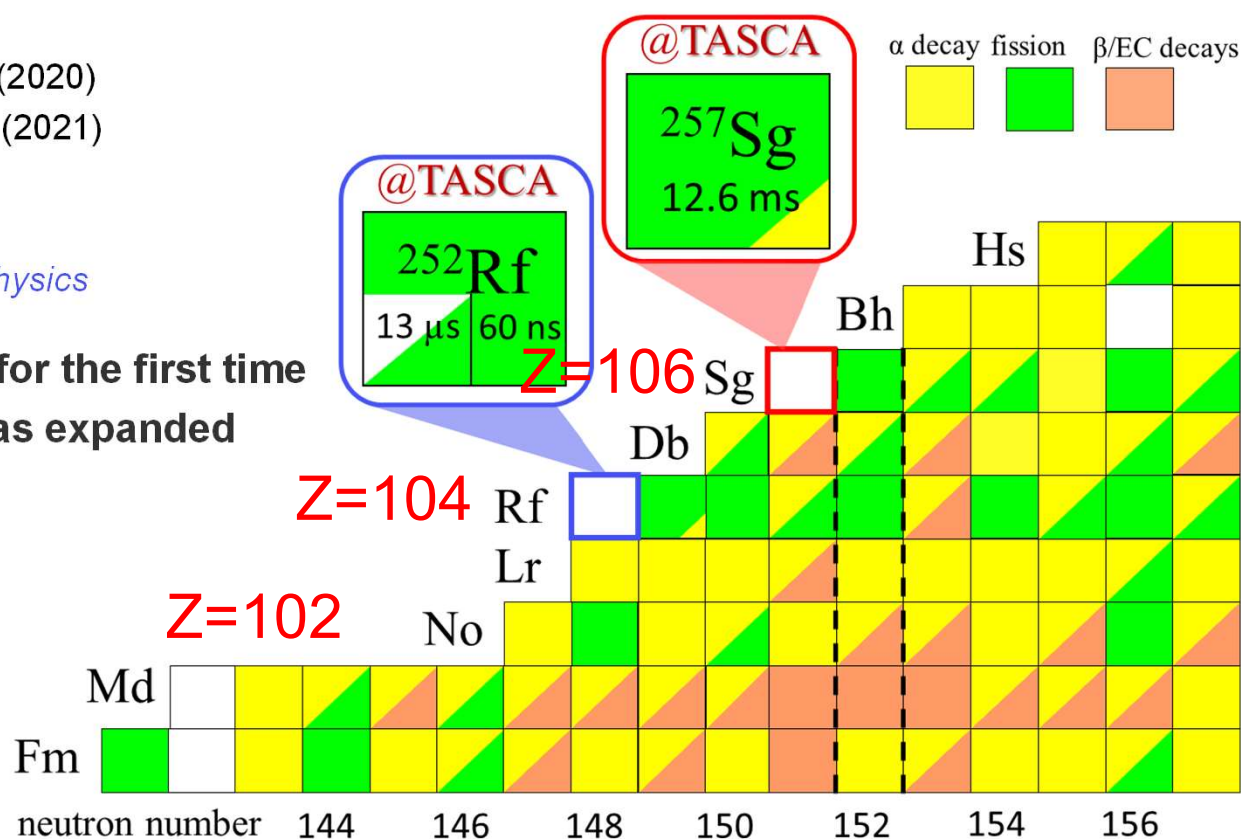
Successful program on the K-isomers of superheavy nuclei @TASCA

- ^{254}Rf : J. Khuyagbaatar *et al.*, NPA 994, 121662 (2020)
- ^{256}Rf : J. Khuyagbaatar *et al.*, PRC 103, 064303 (2021)
- ^{252}Rf : J. Khuyagbaatar, P. Mosat *et al.*,
Phys. Rev. Lett. 134, 022501 (2025)

Editors' Suggestion / Featured in Physics

- Detection of a high- K state in Sg isotope for the first time
- The border for the known Sg isotopes was expanded by the discovery of the new ^{257}Sg

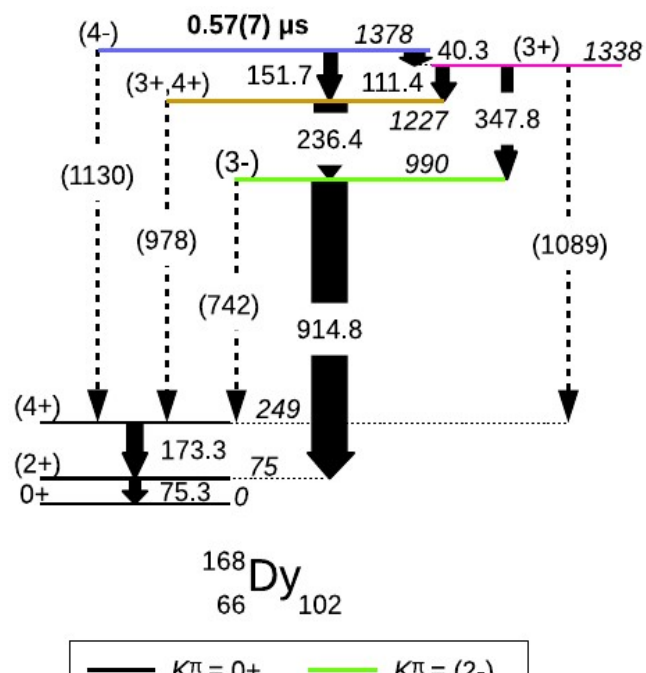
P. Mosat, J. Khuyagbaatar *et al.*,
Phys. Rev. Lett. 134, 232501 (2025)
Editors' Suggestion



Rare-earth nuclei approaching N=104: $^{168}\text{Dy}_{102}$

Albers (GSI), Grahn (JYFL), Petrache (Paris-Saclay), Werner (TUD), Analysis: Johan Emil Larsson

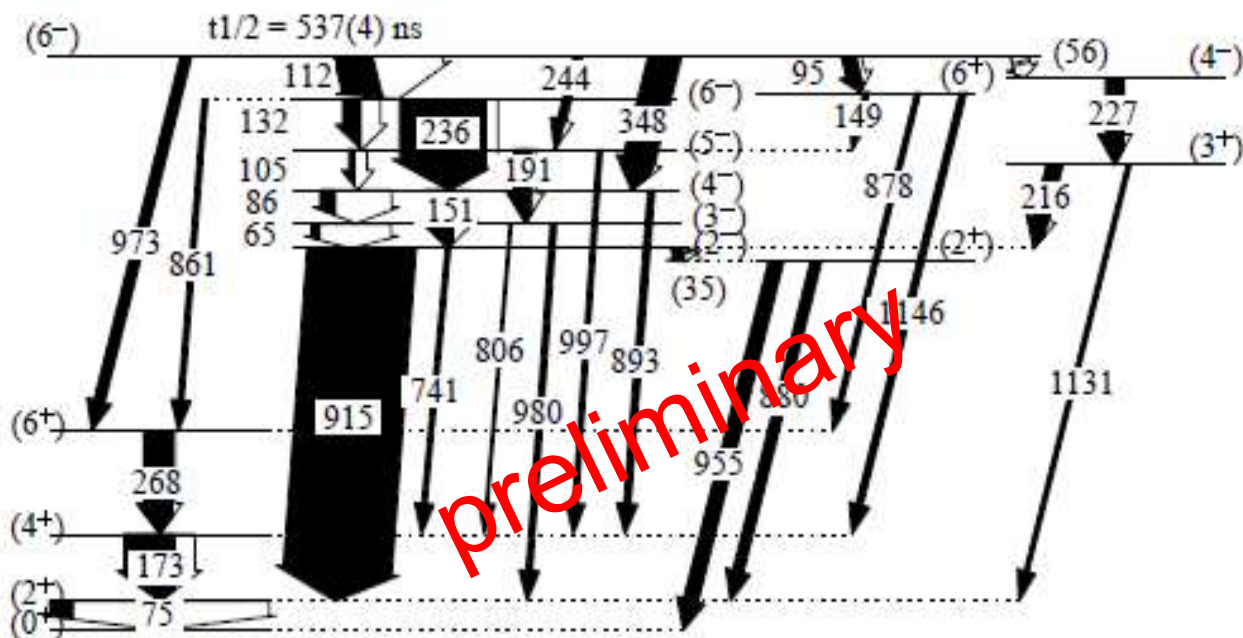
238U beam



Almost 2000x
increase in
statistics

170Er beam

$\nu 5/2^- [512] \times \nu 7/2^+ [633]$





G-PAC outcome: experiments in 2026-2027



	outcome	A shifts	A- shifts
ILIMA	1 A; 3 A-; 3 B	15	27
HISPEC/DESPEC	3 A (1 resubmitted); 1 A-; 2 B	36	14
SuperFRS-EC	4 A; 0 A-; 3B; 4C; (one A for applications proposal)	48	0
R3B	2 A (1 resubmitted); 1 A- ;3 B	48	9
SHE	4 A ;2 A-	216	81
NUSTAR:	TOTAL:	363	131
	<u>granted experiments has also been made public:</u> https://gate.gsi.de/cgi-bin/prop-overview?ranking=a		

New 186W beam;

Draft schedule soon;

test/commissioning time?



From GSI to FAIR (simplified)



GSI exps.

2025

2026

2027

FAIR

2028

etc.

Early Science: SIS18-SuperFRS
increased secondary beam intensity

First Science:
SIS18-SIS100-SuperFRS
increased primary beam
intensity

End of 2026: NUSTAR equipment moving to High-Energy Cave at FAIR
To be ready to take beam from end of 2027

Main aim to show that FAIR is running

⇒ Need to be **published fast**

⇒ Low risk (follows directly from SuperFRS commissioning)

⇒ Use some new capability:

secondary beam intensity

from primary beam

from transmission

higher beam energy ($> 1 \text{ GeV/u}$)

higher SuperFRS transmission

equipment

Lessons from FRIB (and RIKEN):

Exps.: May 2022 first exp

First publications:

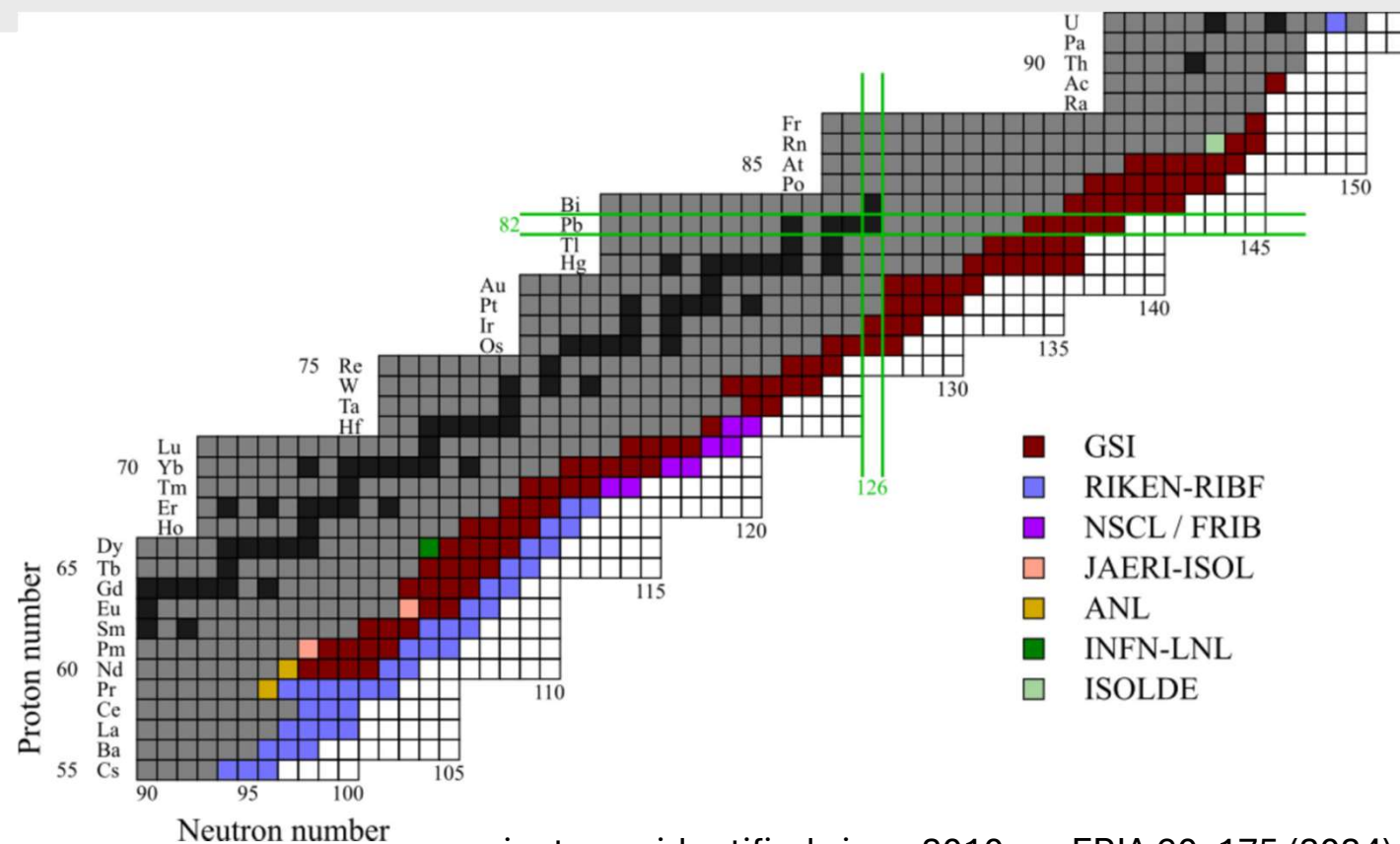
PRL on **new lifetimes** $N > 28$ (published Nov. 2022)

PRL on unexpected **isomer** ^{32}Na (June 2023)

PRL on **new isotopes** ^{198}Pt beam (Feb. 2024;
exp Feb. 2023)

Rank	Laboratory	Isotopes
1	Berkeley	640
2	Darmstadt	445
3	Dubna	223
4	Cambridge	218
5	RIKEN	196
6	Argonne	114
7	CERN	111
8	GANIL	84
9	Oak Ridge	79
10	Michigan State	77
11	Orsay	71
12	Chicago	53
	Los Alamos	53
14	Brookhaven	46
15	Jyväskylä	44
16	Grenoble	39
17	Berlin	38
18	Studsвик	34
	Lanzhou	34
20	Ohio State	33
	McGill	33
22	Amsterdam	29
23	Mainz	23
	Harwell	23

New isotopes (+lifetimes, isomers)



isotopes identified since 2010 ; EPJA 60, 175 (2024)

<https://frib.msu.edu/public/nuclides>

Ranking of (co) Author: Top 1000

[go to search page](#)

Rank	(co) author	# of Isotopes
1	H. GEISSEL	279
2	T. KUBO	245
3	M. PFUTZNER	233
4	G. MUNZENBERG	220
5	F. W. ASTON	205
6	P. ARMBRUSTER	203
7	N. INABE	172
8	N. FUKUDA	171
9	M. BERNAS	164
10	D. P. BAZIN	163
11	H. TAKEDA	155
12	K. SUMMERER	154
13	T. SUMIKAMA	149
14	H. BABA	148
15	A. HEINZ	146
16	S. CZAJKOWSKI	133
17	J. BENLLIURE	132

Symposium in honour of Hans Geissel

25 November 2025

Ranking of (co) Author: Top 1000

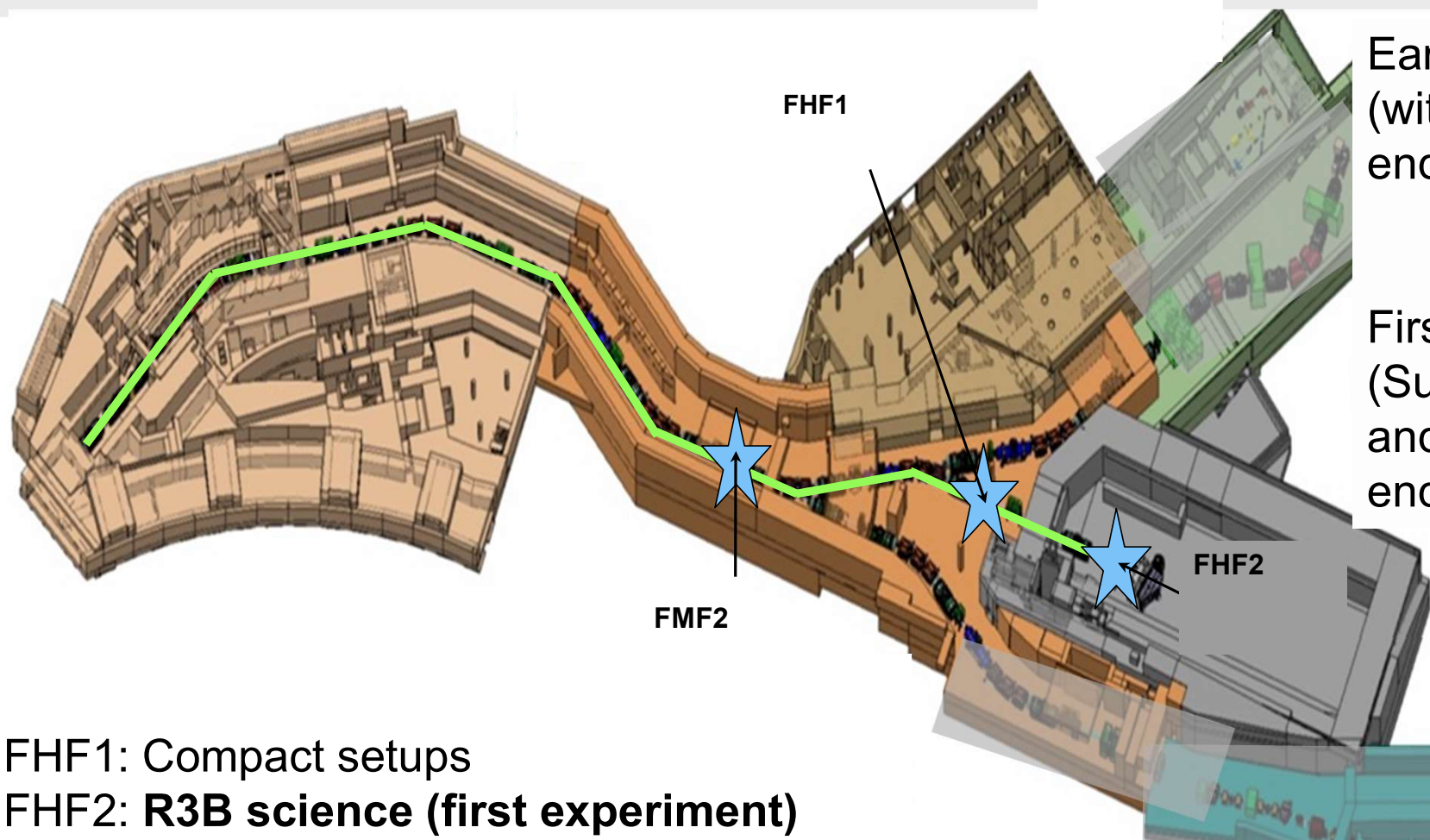
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12	K. SUMMERER	154
13	T. SUMIKAMA	149
14	H. BABA	148
15	A. HEINZ	146
16	S. CZAJKOWSKI	133
17	J. BENLLIURE	132

13 May 1950 – 29 April 2024



Experiments location at Super-FRS: ES and FS

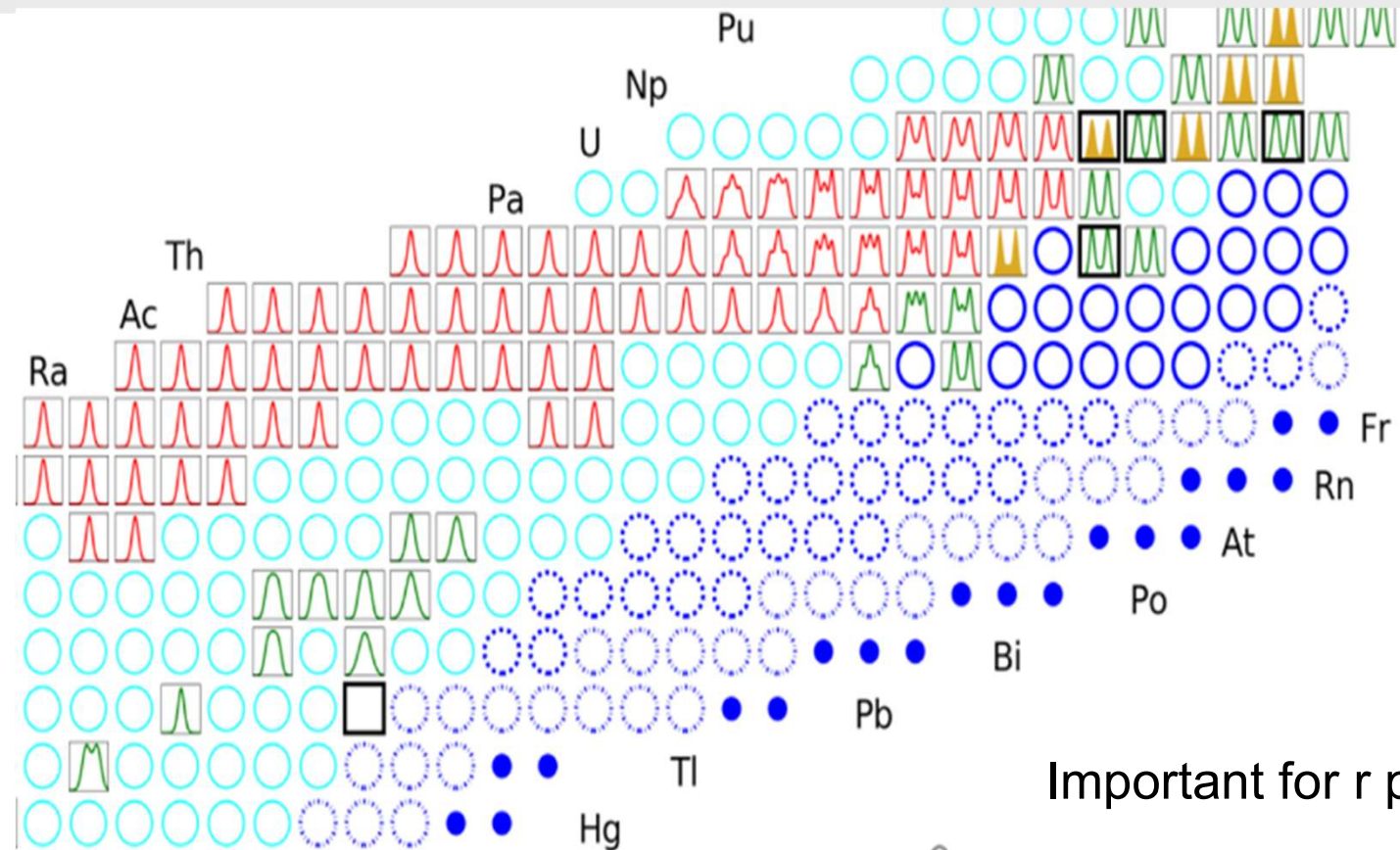


Early Science
(with SuperFRS)
end of 2027 ->

First Science
(SuperFRS
and SIS100)
end of 2028 ->

FHF1: Compact setups

FHF2: **R3B science (first experiment)**



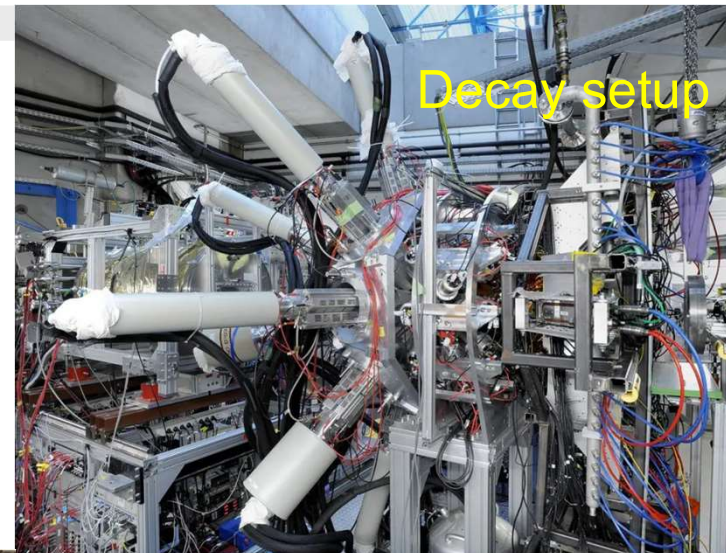
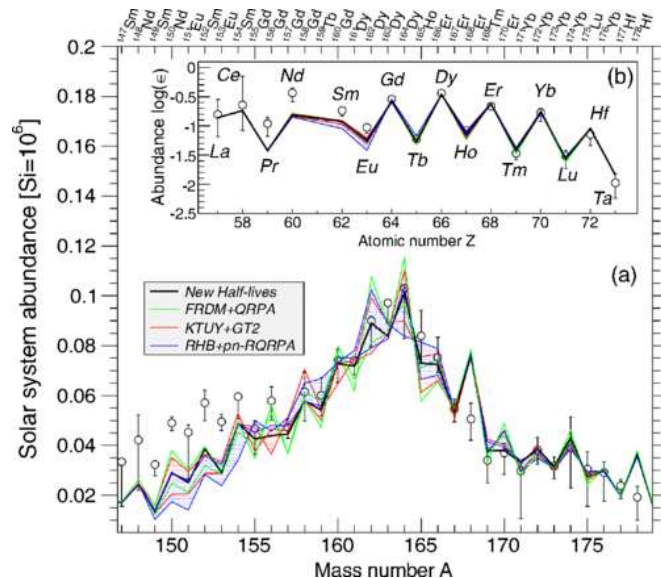
Important for r process

measured Z (red) and A (green) fission yields in actinides and pre- actinides together with the neutron-rich (dark blue circles and dots) and other nuclei (light blue circles) that can be investigated at FAIR

Production of exotic neutron-rich isotopes

- Measurement of their beta-decay lifetimes
- Measurement of their masses

Astro impact, based on theory



SuperFRS Ion Catcher



NUSTAR Score Card (ES / FS) – Sept. 2025



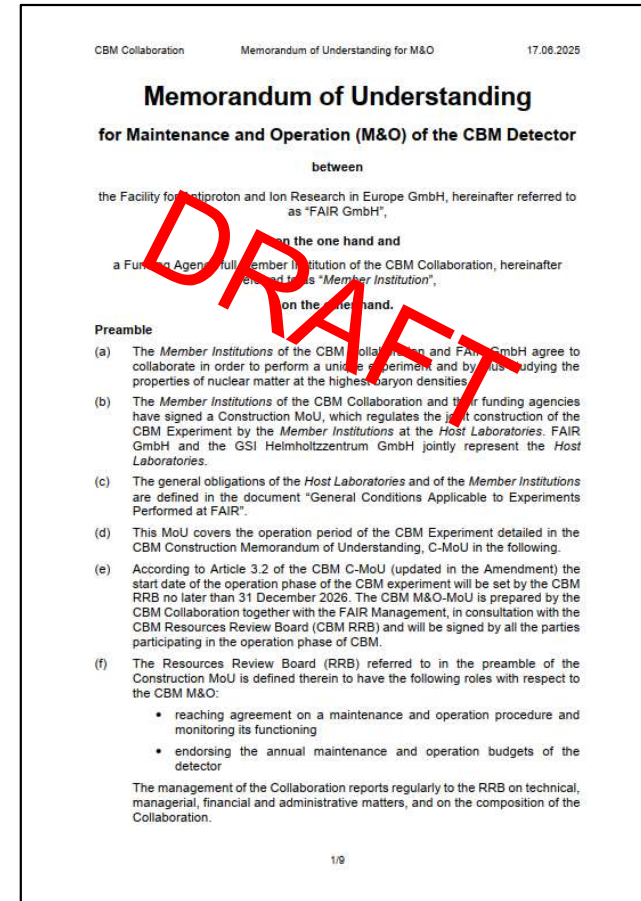
	NUSTAR sub-system	TDR	Cost [k€ 2005]	Funding	Construction	Date completion	Test/Commissioning
	Early and First Science (ES / FS)						
ES / FS	Cave infrastr.		1,618			12/2026	
	HISPEC/DESPEC		10,841			07/2027	
	MATS		462			08/2024	
	LaSpec		67			06/2021	
	R3B		18,462			09/2027	
	ILIMA		424			12/2027	
	Super-FRS EC		568			07/2026	
		99.4% <i>value weighted</i>	32,442	95.5% <i>secured</i>	66.7% <i>value weighted</i>		58.3% <i>value weighted</i>
Change since report 2025 I		+ 0.9%	- 312.0	+ 0.1%	+ 2.0%		+ 1.1%

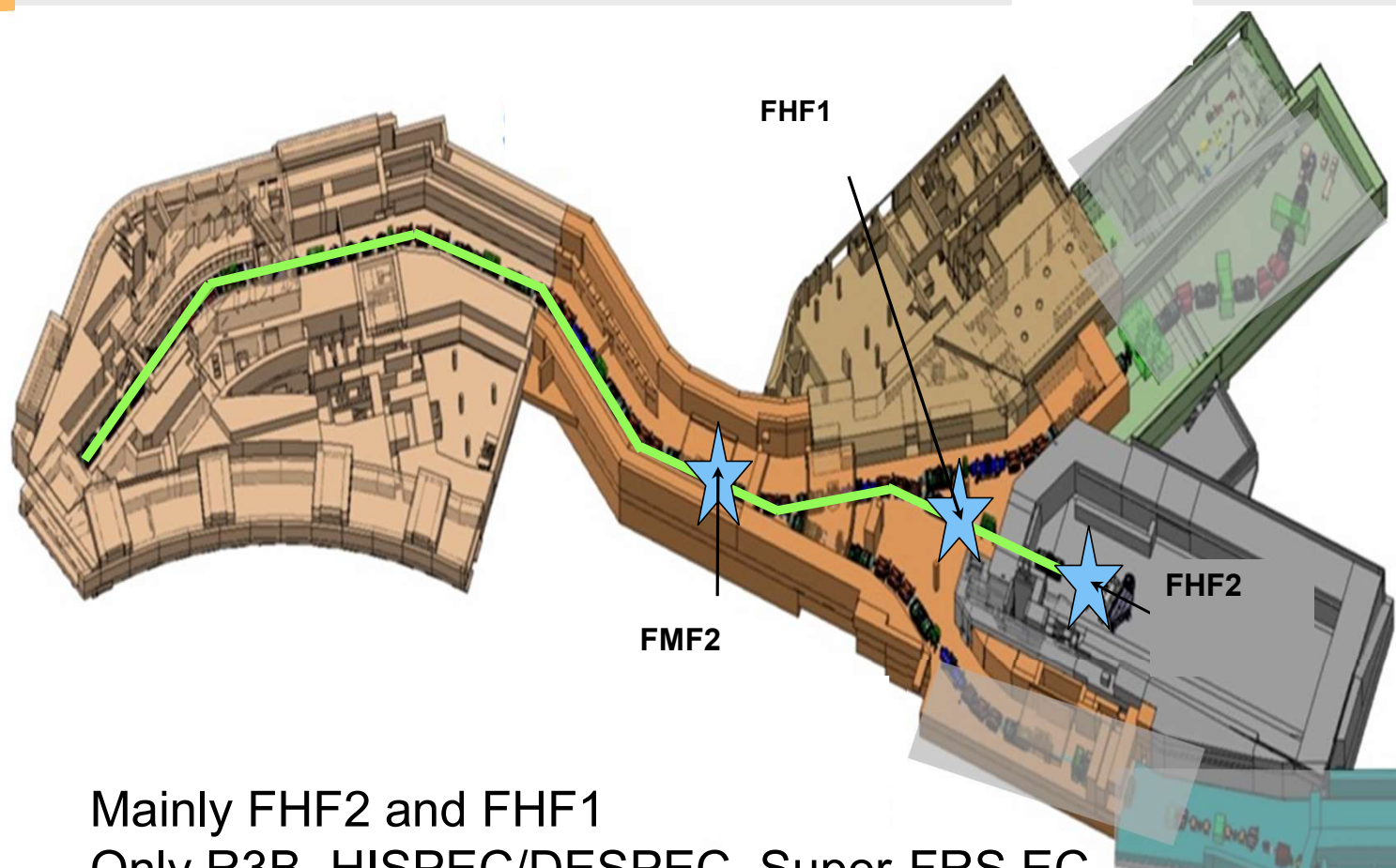
- Infrastructure: CSC **construction progress**
- R3B: TRT, ACTAF, Proton Arm Spectrometer, NeuLAND: **construction progress**
- Super-FRS EC: TDR ice target/tensor force detection **submitted**

Operation MoU – (1st Draft of CBM)



- **Draft version** from June 17, 2025
 - **Based on Maintenance & Operation MoU of CERN** (e.g. ALICE)
 - Adapted to CBM experiment
 - Basis to **discuss principle concept of cost categories** and cost sharing during the operation phase
 - Cost taken over by host lab(s)
 - Cost per sub-system/detector
 - Common Collaboration cost
 - Presented and discussed at ECE/ECSG meeting in **May 2025**
 - **Draft submitted to FAIR-RRB** and concept presented at the FAIR-RRB meeting in **July 2025**
- To be further **refined/edited**
 - **Harmonizing** with respect to Construction MoU (CERN → FAIR)
 - **Adapting to NUSTAR** (worked together with CBM on draft but **change text where needed**)





Mainly FHF2 and FHF1
Only R3B, HISPEC/DESPEC, Super-FRS EC

Low-energy branch

-needs infrastructure

-serves:

Super-FRS EC,
HISPEC/DESPEC,
MATS,
LASPEC

-**physics workshop:**
1 October 2025



Summary and conclusions



FAIR Phase-0 is productive and assures readiness for Early and First Science

NUSTAR ES&FS experiments will mark the start of FAIR

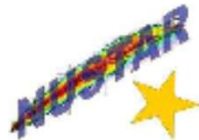
Highest priority

Optimisation of the FAIR injector chain already for Early Science in parallel to FAIR construction (beam intensities!)

Vision for the completion of Super FRS low-energy branch (FS++)

NUSTAR Annual Meeting
GSI 23-27 Feb. 2026

NUSTAR Week 2025



- Prague, Czech Republic

