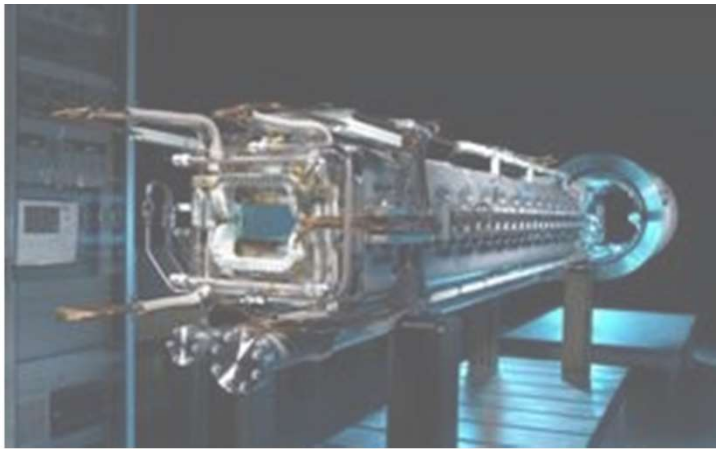




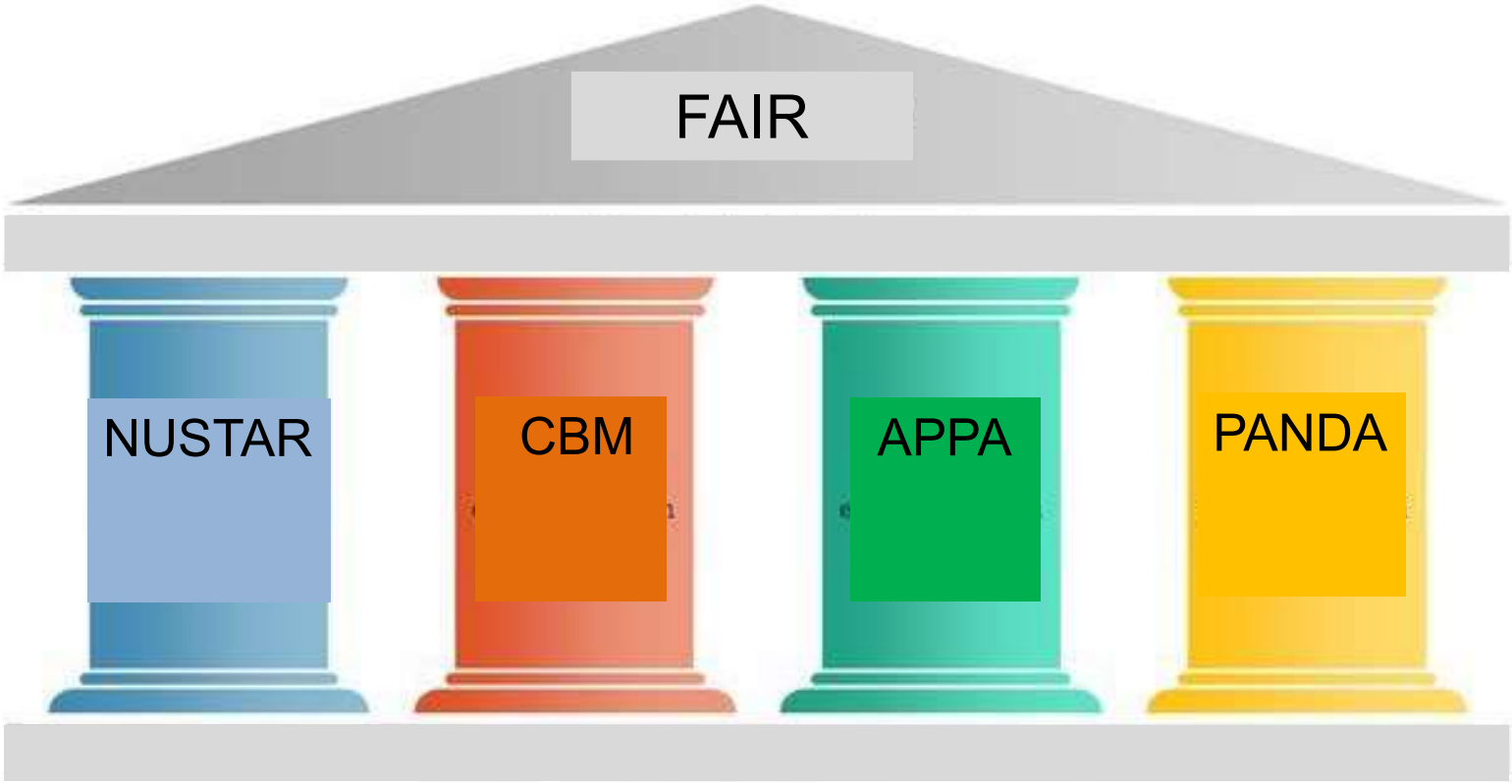
# NUSTAR status

Zsolt Podolyák

**Super-FRS EC meeting, 17 September 2025**

Finland France Germany India Poland Romania Russia Slovenia Sweden UK Czech Republic

# FAIR and its pillars



# NUSTAR at FAIR

(FAIR Council 9-10 July 2024)

NUSTAR week at GSI 7-9 Oct. 2024

**ECE/ECSG 14 October 2024**

**Joint Scientific Council 22-23 October 2024**

NUSTAR “first experiments” presented

(FAIR Council 3-4 December 2024)

G-PAC 18-20 February 2025

experiments for 2026-27 approved

NUSTAR Annual Meeting 24-28 Feb 2025

NUSTAR Council

(Project Oriented Funding, POF Evaluation April 2025)

**ECE/ECSG 8-9 May 2025**

**Joint Scientific Council 12-13 May 2025**

**RRB 15-16 July 2025**

(FAIR Council 8-9 July 2025)

NUSTAR week in Prague (Czech Republic) 29 Sept.- 2 Oct. 2025

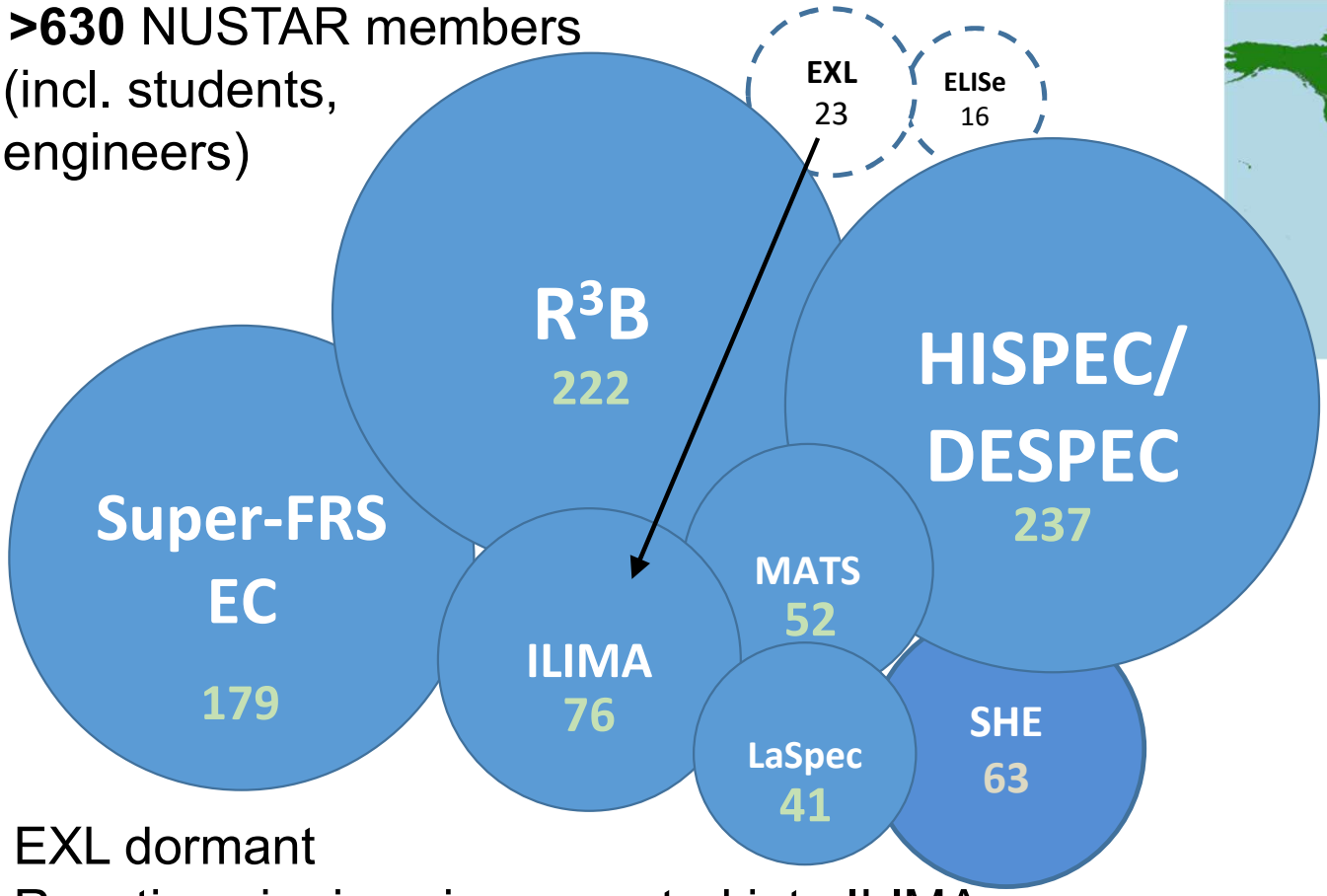
# Overarching physics case: the creation of the (heavy) chemical elements

Big physics question requiring information on:

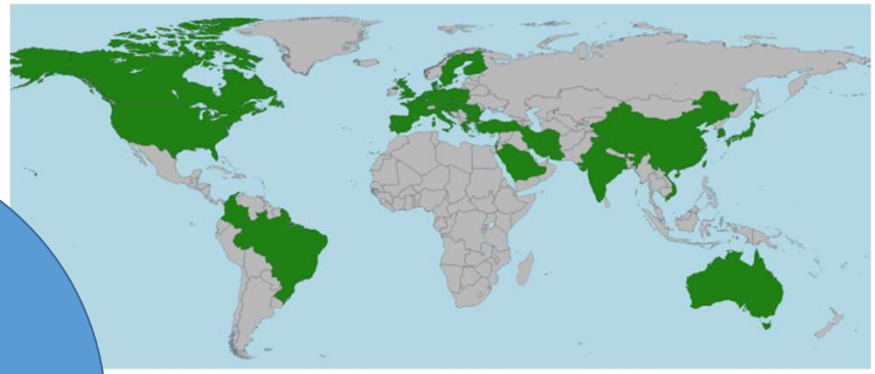
- Equation of State
- Limits of existence
- Lifetimes,
- Masses
- $P_{xn}$ values
- Fission
- Reactions in star environments

# NUSTAR
## One science, different observables, instrumentations

**>630** NUSTAR members (incl. students, engineers)




EXL dormant
Reactions in rings incorporated into ILIMA



**> 1000 listed "interested" scientists**

**> 630 registered members (incl. students, etc.)**

**~ 420 senior members (PhD holder w/o Russia)**

**> 150 institutes from 36 countries**

# Timeline 2021 –

| | |
|---|---|
| 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)** |

# G-PAC outcome: experiments in 2026-2027

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

Draft schedule soon

# Publications 2021-2024

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

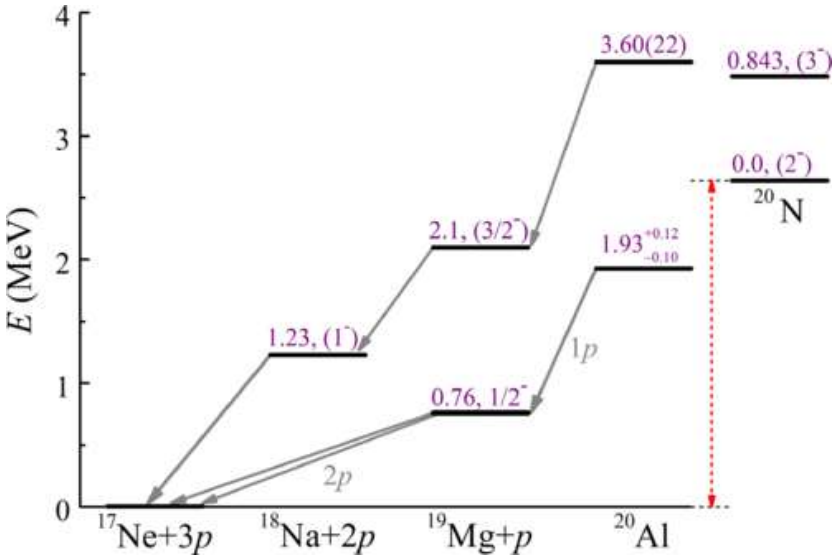
| | | Nature family; PRL | PLB | PRC/ PRA | NIM | Other | PhD diss. | **Total** |
|---|---|---|---|---|---|---|---|---|
| R3B | 2021-24 | 5 | 3 | 10 | 4 | 20 | 9 | 51 |
| HISPEC/DESPEC | 2021-24 | 3 | 8 | 6 | 6 | 18 | 4 | 45 |
| **SuperFRS-EC** | 2021-24 | 2 | 3 | 3 | 17 | 16 | 2 | 43 |
| ILIMA | 2021-24 | 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 |

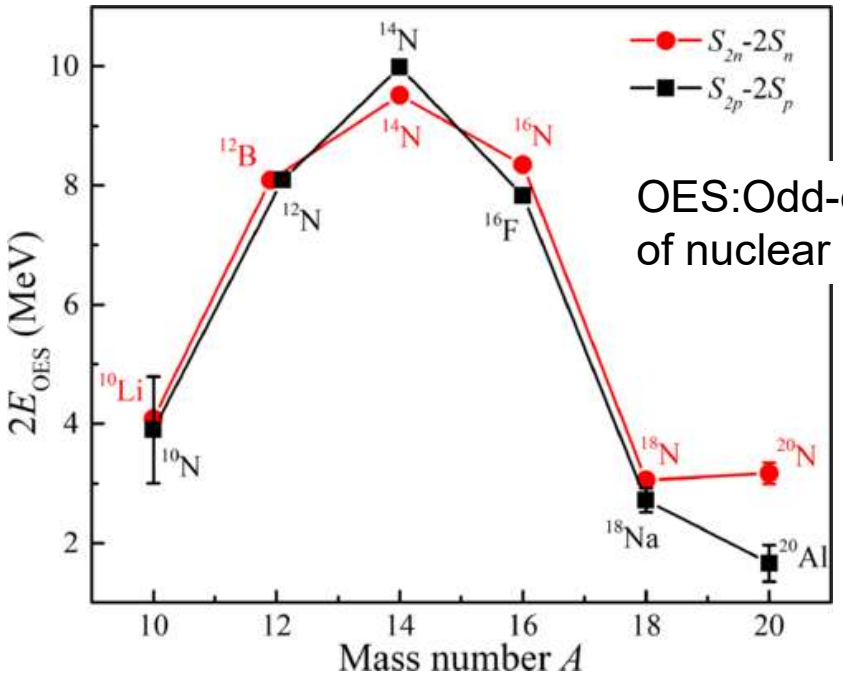
PHYSICAL REVIEW LETTERS **135,** 022502 (2025)

# Isospin Symmetry Breaking Disclosed in the Decay of Three-Proton Emitter $^{20}$Al

X.-D. Xu,[1,2,3,*] I. Mukha,[3,†] J. G. Li,[1,2,4] S. M. Wang,[5,6] L. Acosta,[7,8] M. Bajzek,[3,9,10] E. Casarejos,[11] D. Cortina-Gil,[12] J. M. Espino,[13] A. Fomichev,[14] H. Geissel,[3,9,‡] J. Gómez-Camacho,[13] L. V. Grigorenko,[14,15,16] O. Kiselev,[3] A. A. Korsheninnikov,[16] D. Kostyleva,[3] N. Kurz,[3] Yu. A. Litvinov,[3] I. Martel,[17] C. Nociforo,[3] M. Pfützner,[18,3] C. Rodríguez-Tajes,[19] C. Scheidenberger,[3,9,20] M. Stanoiu,[21] K. Sümmerer,[3] H. Weick,[3] P. J. Woods,[22] and M. V. Zhukov[23]

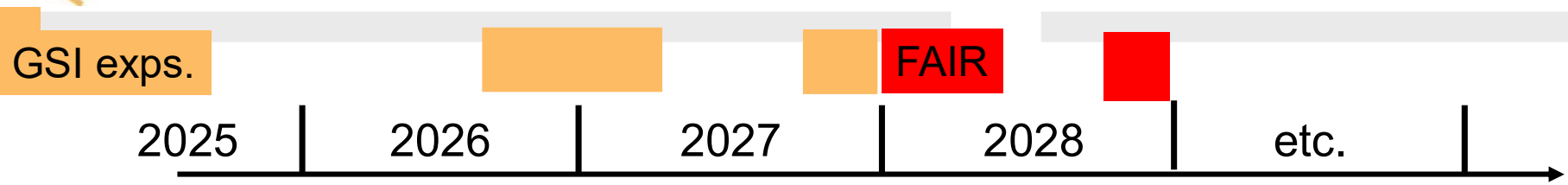
[1]*Institute of Modern Physics, Chinese Academy of Science, Lanzhou 730000, China*
[2]*School of Nuclear Science and Technology, University of Chinese Academy of Sciences, Beijing 100049, China*




OES:Odd-even staggering of nuclear masses

# From GSI to FAIR (simplified)

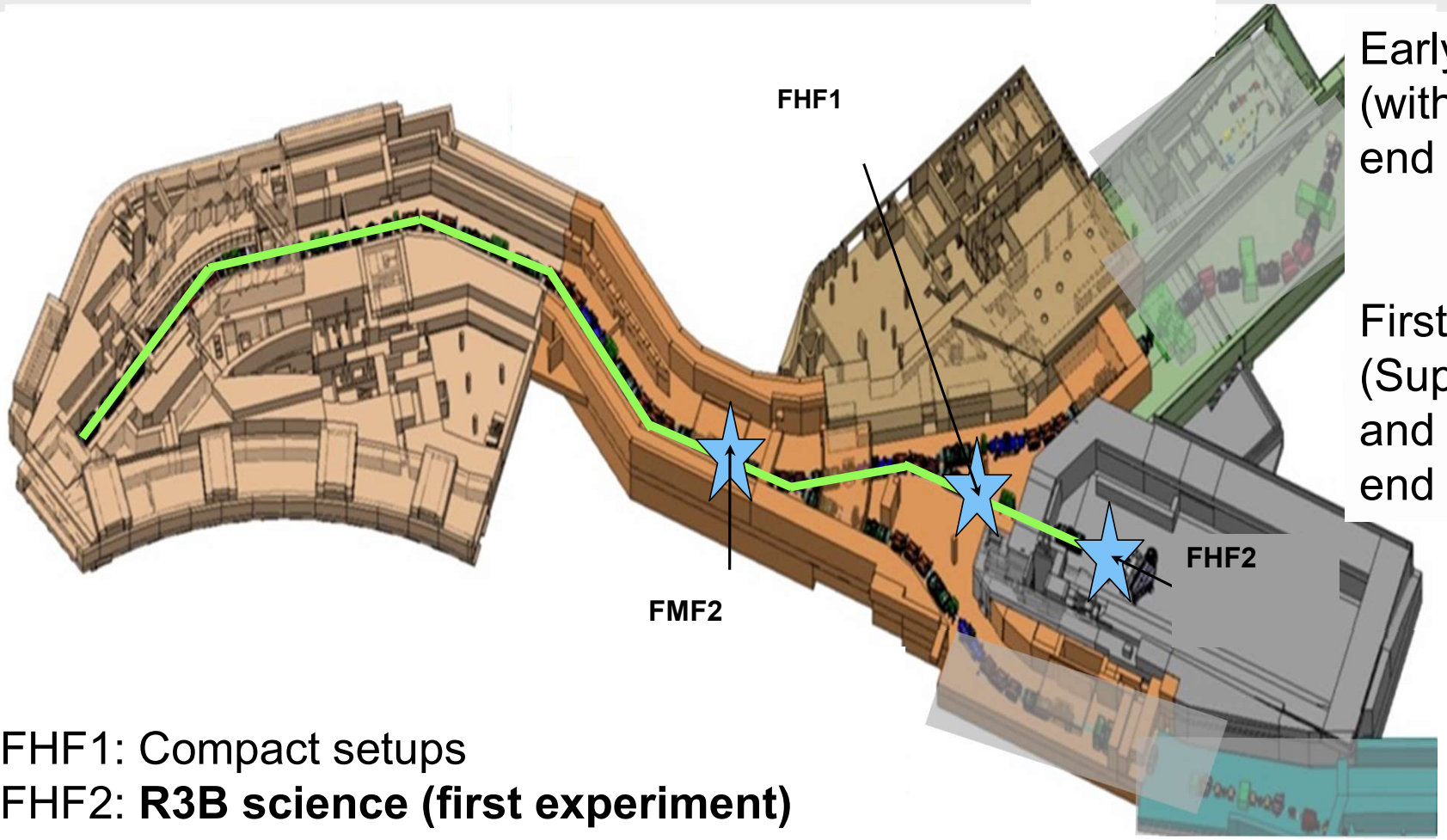



Early Science: SIS18-SuperFRS
increased secondary beam intensity

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

# Experiments location at Super-FRS: ES and FS




Early Science (with SuperFRS) end of 2027 ->

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

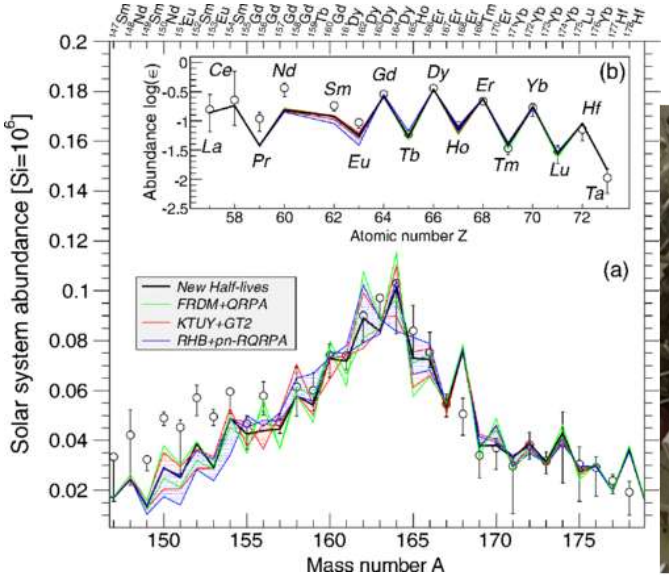
FHF1: Compact setups

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

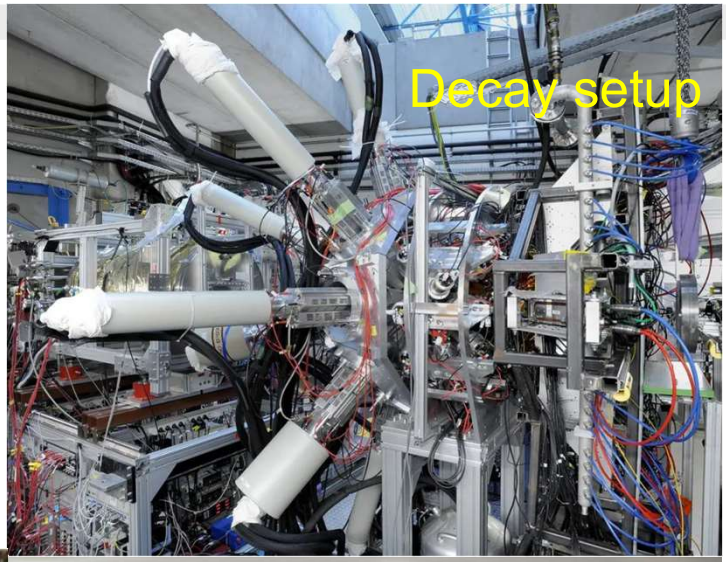
# Physics in the SuperFRS tunnel

Production of exotic neutron-rich isotopes
- Measurement of their beta-decay lifetimes
- Measurement of their masses

Astro impact, based on theory








# Start of FAIR: First NUSTAR results

Main aim to show that FAIR is running

⇒Need to be **published fast**

⇒Low risk (follows directly from SuperFRS commissioning)

⇒Use some new capability:

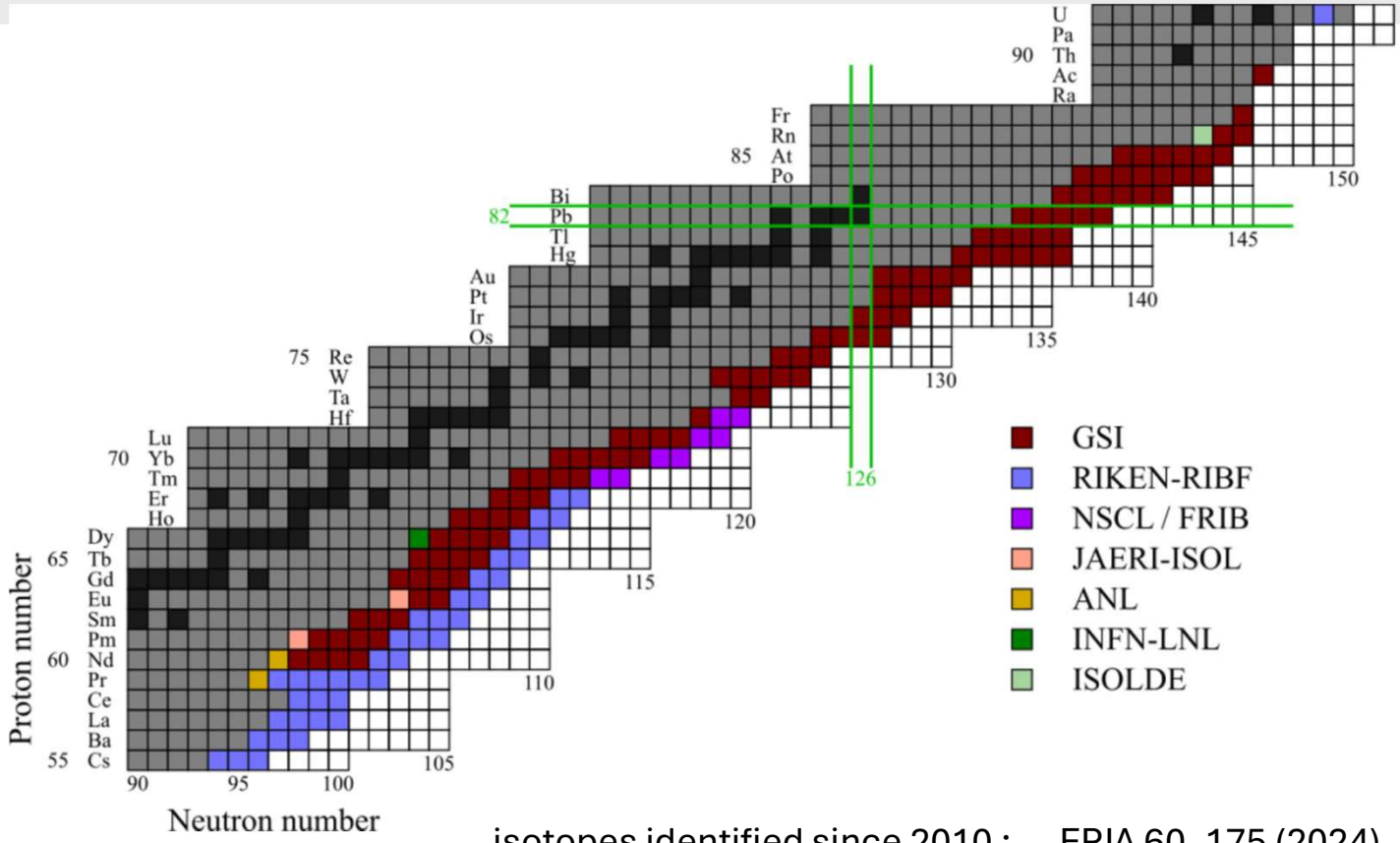
- secondary beam intensity
  - from primary beam
  - from transmission
- higher beam energy (> 1GeV/u)
- higher SuperFRS transmission
- equipment

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 32Na (June 2023)
PRL on new isotopes 198Pt beam (Feb. 2024;
exp Feb. 2023)

# New isotopes

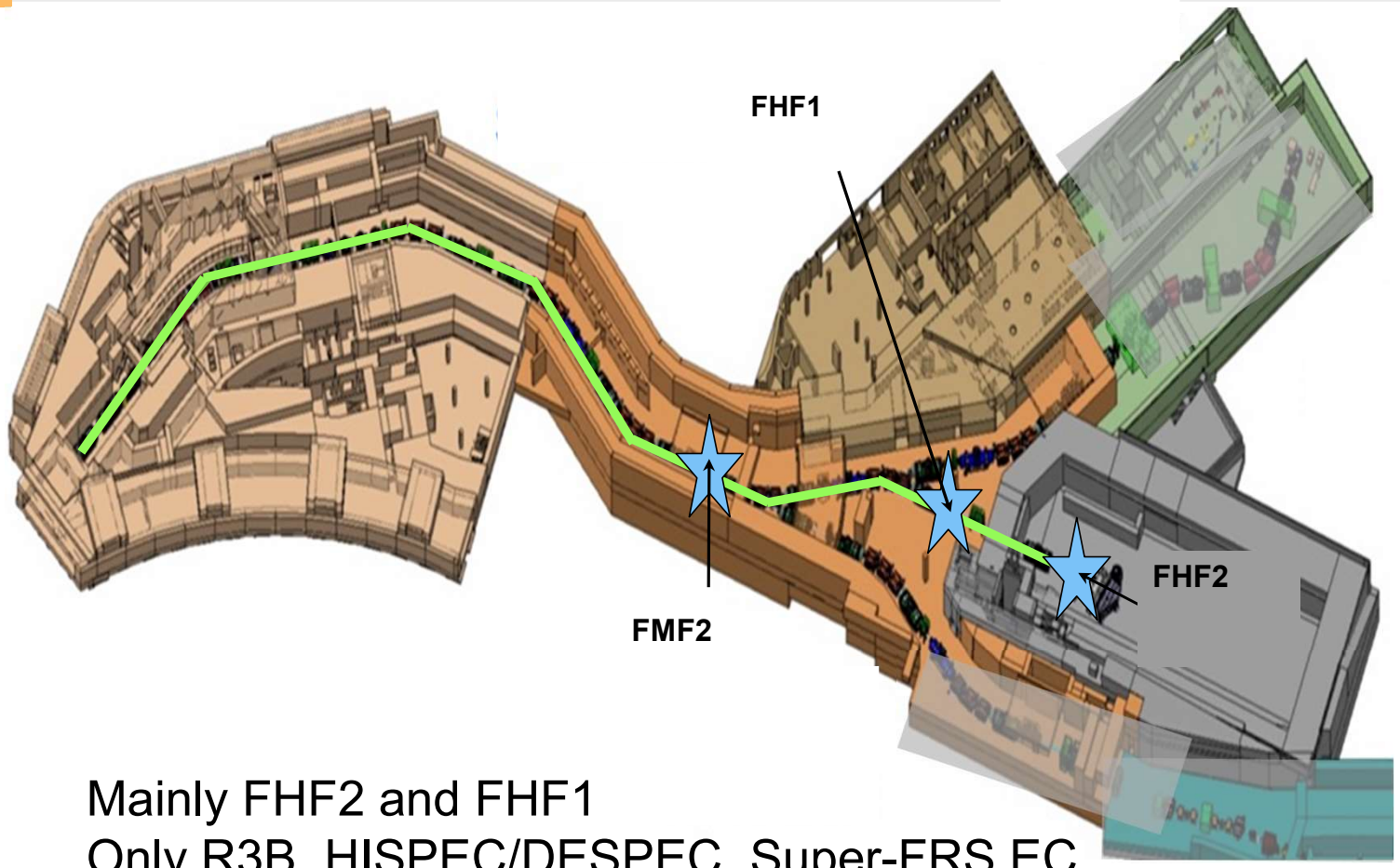
| Rank | Laboratory | Isotopes |
|---|---|---|
| 1 | Berkeley | 640 |
| 2 | Darmstadt | 445 |
| 3 | Dubna | 223 |
| 4 | Cambridge | 218 |
| 5 | RIKEN | 196 |
| 6 | Argonne | 114 |
| 7 | CERN | 111 |
| 8 | GANIL | 84 |
| 9 | Oak Ridge | 79 |
| 10 | Michigan State | 77 |
| 11 | Orsay | 71 |
| 12 | Chicago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




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

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

# Low-energy branch?




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

Overarching physics case: creation of the chemical elements

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 week in Prague 29 Sept.- 2 Oct. 2025 https://indico.gsi.de/event/21640/

Low-energy branch workshop, Wednesday 1 October 14:00-18:00