

# NUSTAR Collaboration Report

10<sup>th</sup> FAIR-NUSTAR Resources Review Board

February 9-10, 2021

FAIR/GSI, Darmstadt, Germany

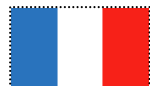
Wolfram Korten

*NUSTAR Spokesperson*

*CEA Paris-Saclay*



Finland



France



Germany



India



Poland



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UK



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# NUSTAR - The Project

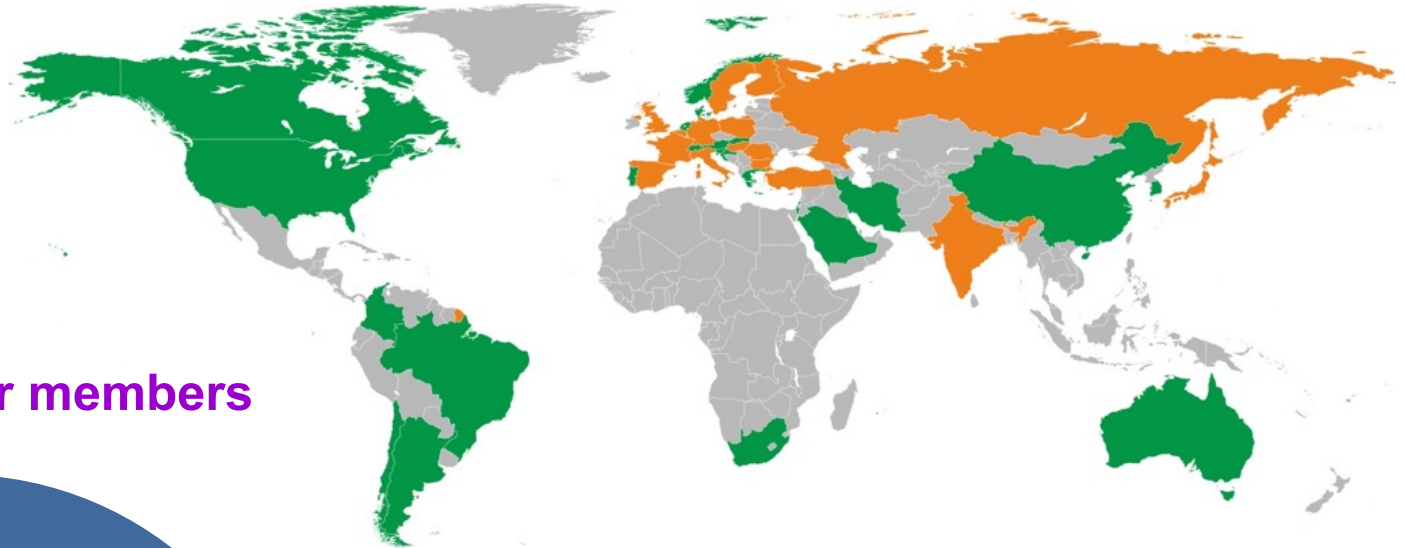


PSP code	Super-FRS	RIB production, separation, and identification
1.2.2	<b>HISPEC/ DESPEC</b>	In-beam $\gamma$ -spectroscopy at low and intermediate energy, n-decay, high-resolution $\gamma$ -, $\beta$ -, $\alpha$ -, p-, spectroscopy
1.2.3	<b>MATS</b>	In-trap mass measurements and decay studies
1.2.4	<b>LaSpec</b>	Laser spectroscopy
1.2.5	<b>R<sup>3</sup>B</b>	Kinematical complete reactions with relativistic radioactive beams
1.2.6	<b>ILIMA</b>	Large-scale scans of mass and lifetimes of nuclei in ground and isomeric states
1.2.10	<b>Super-FRS</b>	<b>High-resolution spectrometer experiments</b>
1.2.11	<b>SHE (#)</b>	<b>Synthesis and study of super-heavy elements</b>
1.2.8	<b>ELISe(*)</b>	Elastic, inelastic, and quasi-free e <sup>-</sup> -A scattering
1.2.9	<b>EXL(*)</b>	Light-ion scattering reactions in inverse kinematics

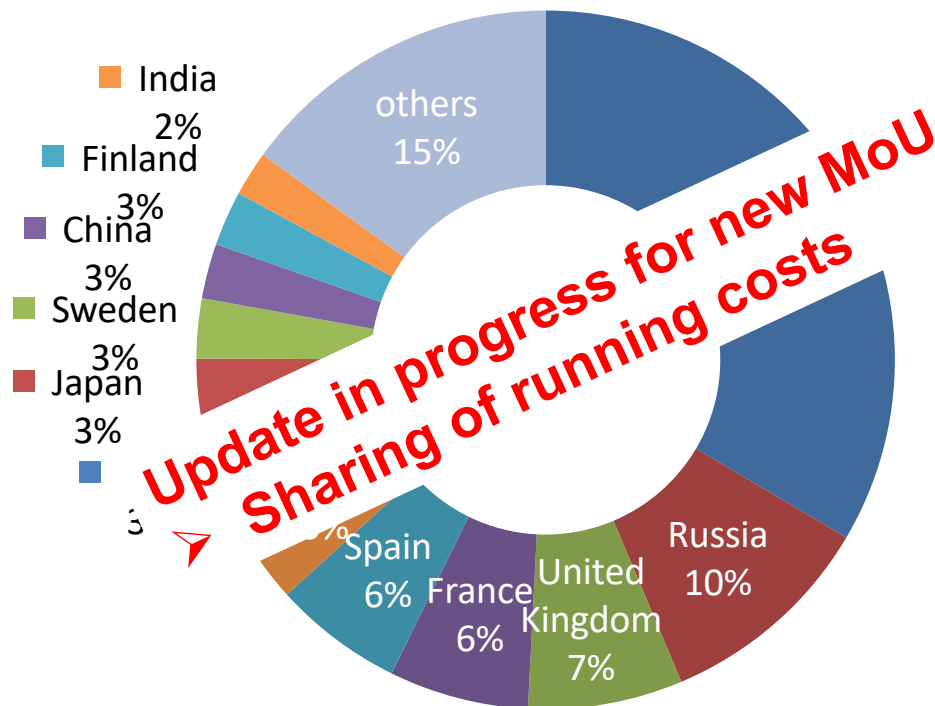
(#) NUSTAR experiments using FAIR MSV accelerators – preparing formal approval by council

(\*) Experiments requiring NESR – alternative solutions within FAIR MSV under consideration

- **NUSTAR MoU for Construction**
  - Similar structure of the MoU for all FAIR experiments
  - MoU for CBM as blueprint, but NUSTAR specific items, e.g. annexes for individual experiments (“collaboration agreements”)
  - Updating NUSTAR organizational structures and procedures
    - Election of 4 members of NUSTAR board (2 year term, renewable)
    - Direct election of spokesperson (chair of the NUSTAR board)
- **Steps towards new MoU (being finalised)**
  - NUSTAR Common Fund (being finalized for ECE/ECSG)
  - Census of the members (PhD holders, ongoing)
  - Definition of the installation procedure (resources)
  - Discussion at NUSTAR council (Q1/2021)
  - Presentation to funding agencies (Q2/2021)



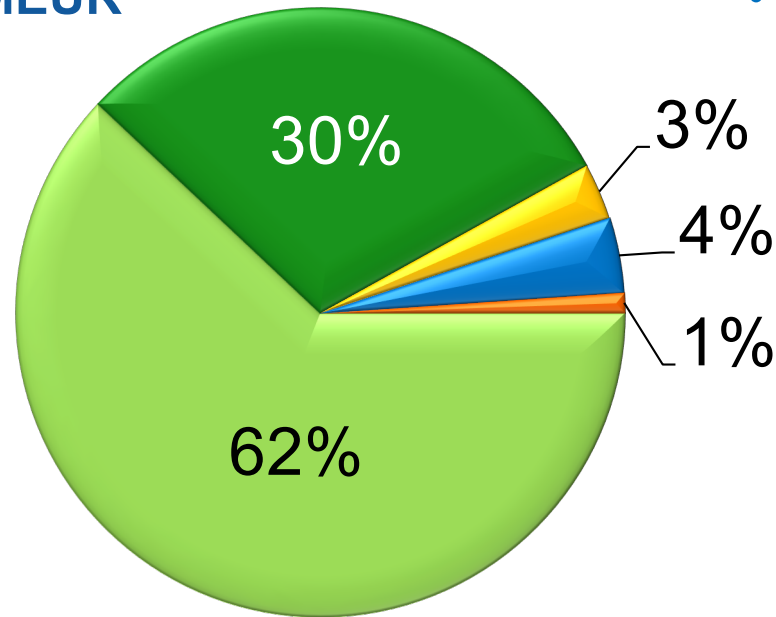
## NUSTAR senior members



- > 1000 “interested” scientists
- > 600 registered members
- > 400 senior members (PhD etc.)
- > 180 institutes from 39 countries

Secured funding and expression of interest in funding **from 19 countries** (incl. 9 FAIR partner countries)

34.0 MEUR







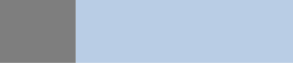













- secured/expected FAIR
- secured external
- EoI
- Common Fund
- to be assigned

Status: February, 2021

- funding (secured and expected) from:  
(**FAIR funding** in bold face)

- Bulgaria
- Canada
- **China**
- **Czech Republic**
- **Finland**
- **France**
- **Germany**
- Hungary
- **India**
- Israel
- **Japan**
- Netherlands
- **Poland**
- **Romania**
- **Russia**
- Slovenia
- Spain
- **Sweden**
- **United Kingdom**

**Common Fund : ~1900 kEUR (2021)**  
**(under preparation for ECE/ECSG)**  
**(~1k EUR per senior member and year)**

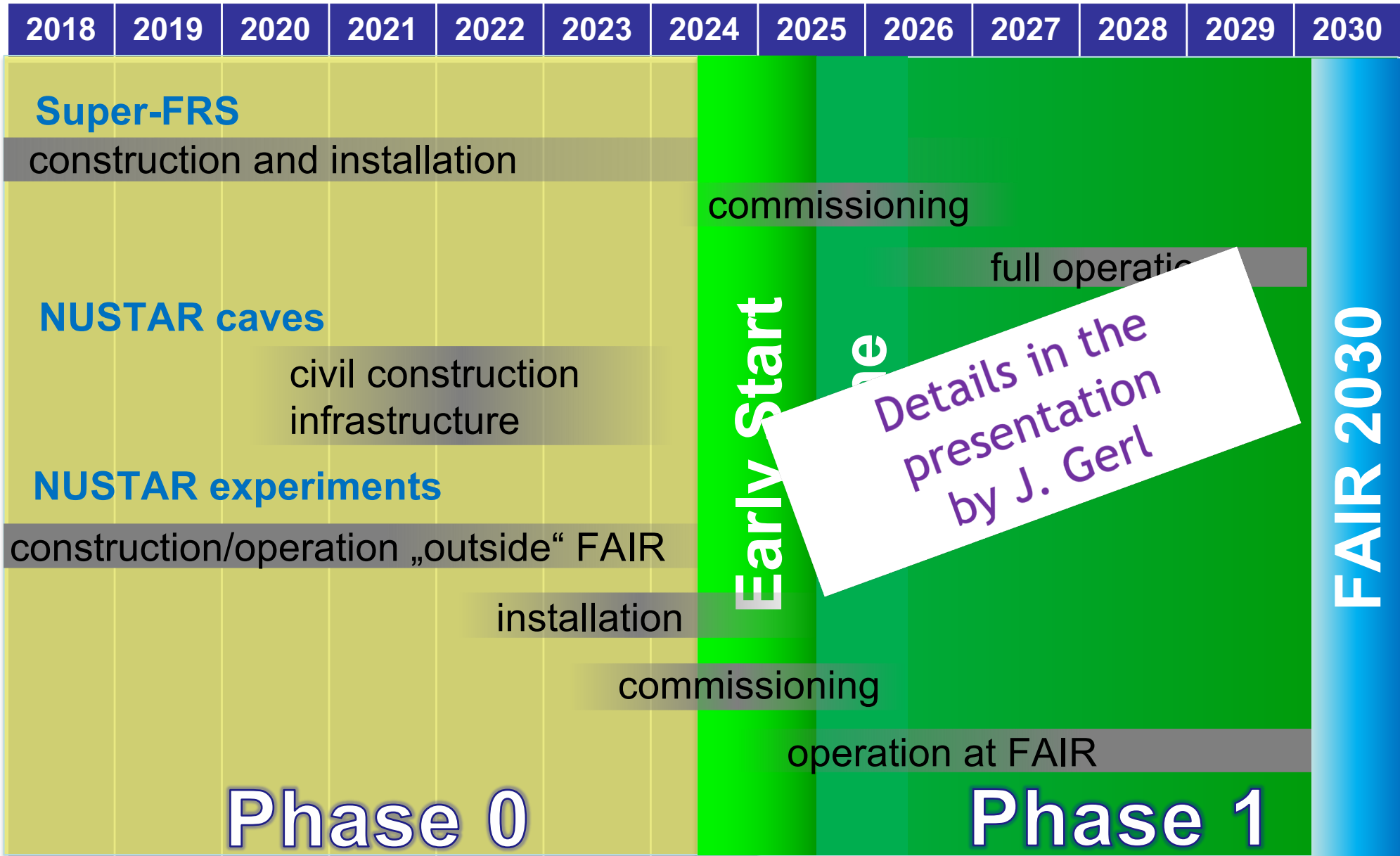
	NUSTAR sub-system	TDR	Cost [k€ 2005]	Funding	Construction	Date completion	Test/Commissioning
Day 1	LEB infrastr.		2,109			06/2023	
	HISPEC/DESPEC		10,881			03/2024	
	MATS		1,219			08/2024	
	LaSpec					12/2021	
	R3B					03/2023	
	ILIMA					12/2023	
	Super-FRS Exp					12/2023	
			91% <i>value weighted</i>	34,015	92% <i>secured</i>	58% <i>value weighted</i>	

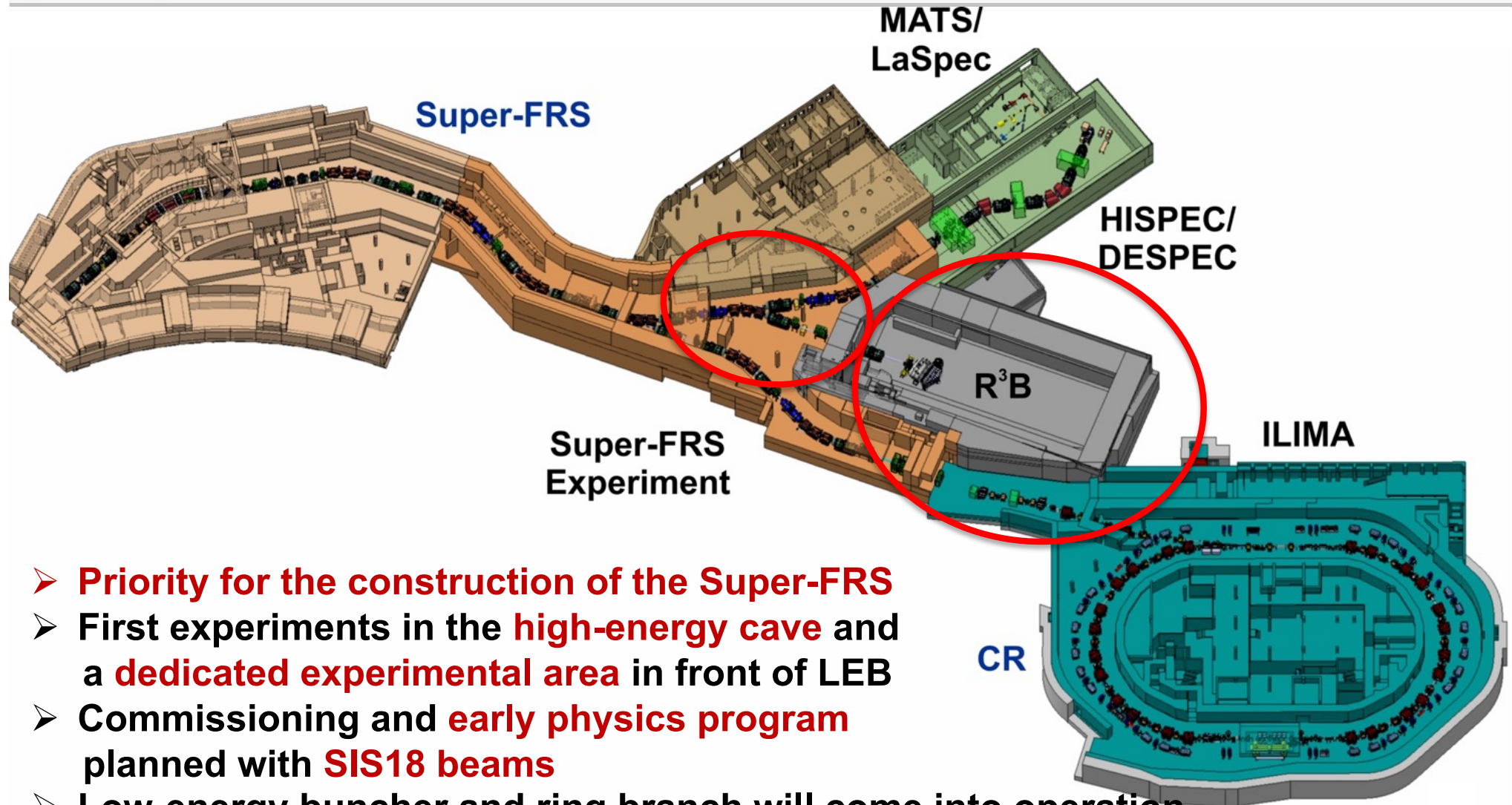
Details in the presentation by A. Herlert

- **New experiment:** Super-FRS Experiment
- R3B infrastructure under evaluation by the ECE, LEB to be submitted soon
- Final TDRs for Day-1 under preparation (LEB infrastructure, R3B Si tracker, S-FRS)
- ECE/ECSG recommendation: RRB and FAIR management is urged to resolve the (*remaining*) funding issue, specially for the LEB infrastructure (*using CCF*).



# NUSTAR from Phase-0 to FAIR 2030



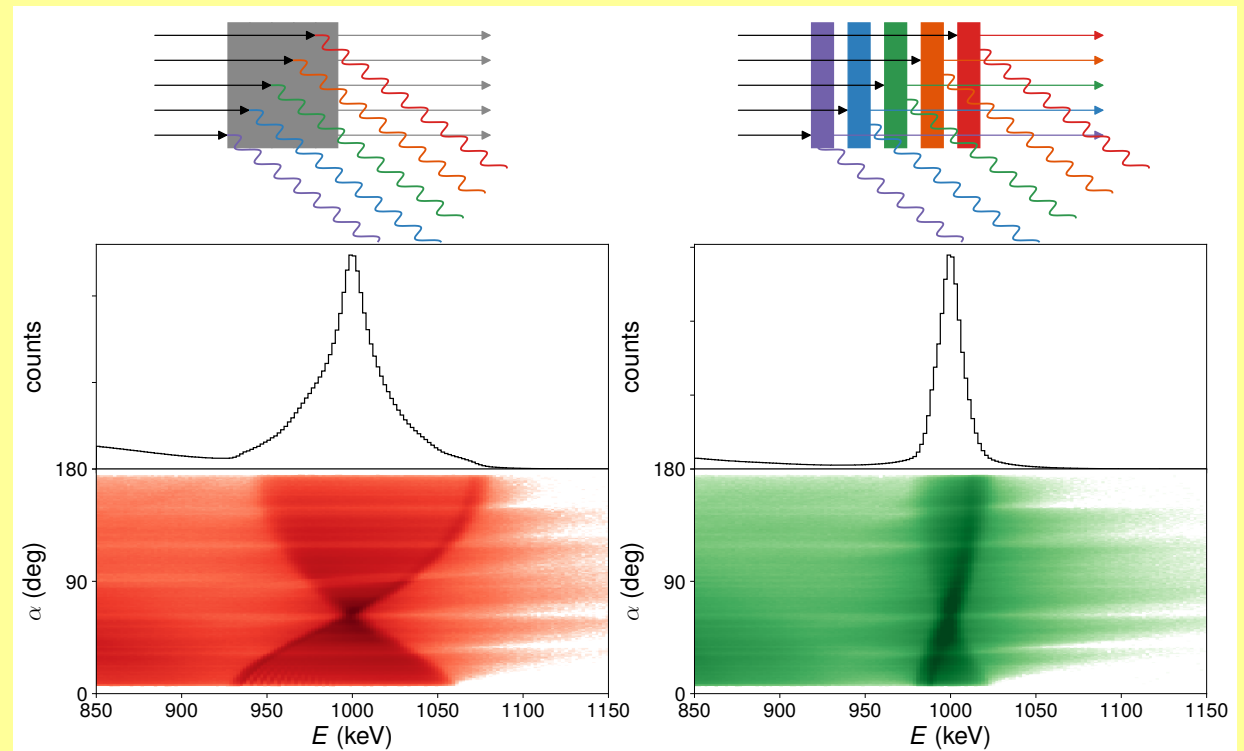
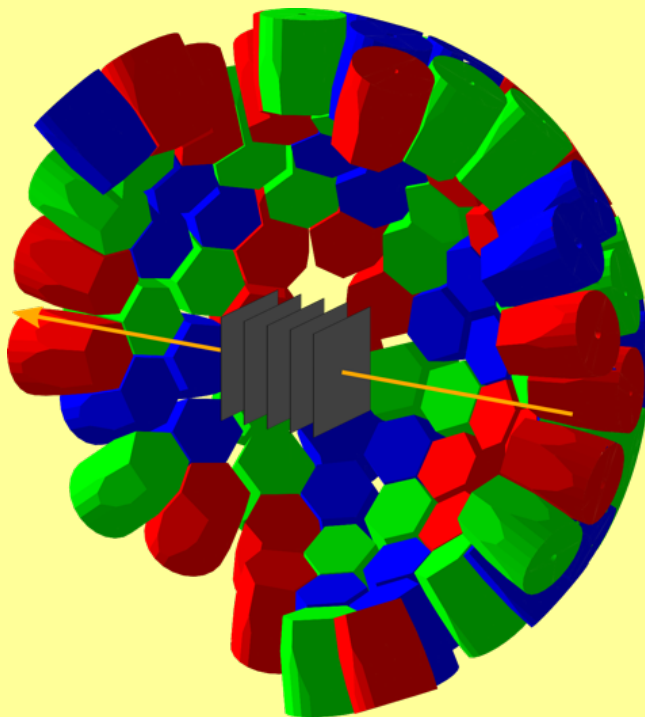


- **Priority for the construction of the Super-FRS**
- First experiments in the **high-energy cave** and a **dedicated experimental area** in front of LEB
- Commissioning and **early physics program** planned with **SIS18 beams**
- Low-energy buncher and ring branch will come into operation consecutively (but should not be delayed)
- Continue **NUSTAR** program at FRS beyond 2025, in particular using ESR and Crying



# News from the NUSTAR experiments

- Grant Holder : Kathrin Wimmer (CSIC Madrid)
- High resolution  $\gamma$ -ray spectroscopy with **AGATA** using **active diamond targets** enhancing the sensitivity for **lifetime measurements of exotic nuclei**.





# NUSTAR Phase-0 experiments in 2020 (as reported to JSC in November 2020)



## Beamtime in 2020 strongly influenced by Covid-19 epidemic

- Safe working conditions possible (limited number of persons onsite etc.) ?
- Experimental set-up complete and team sufficient (locally and remote) ?
- Beamtime schedule relaxed (increased set-up time, extensions possible)
  - **Spokespersons and local teams had to decide whether the experiment could be performed**

**50/70%** of the NUSTAR experiments at **SIS18/UNILAC** could be performed

- **Remote** near-line **analysis** pursued and **controlling** of certain set-ups
- Extended commissioning of **all NUSTAR equipment** incl. **FRS/ESR**
- Additional beam time still needed in several cases
- Expected “backlog” for 2021+: **52 days** at **SIS18**, **23 days** at **UNILAC**
  - **Strong constraints for acceptance of new NUSTAR proposals**

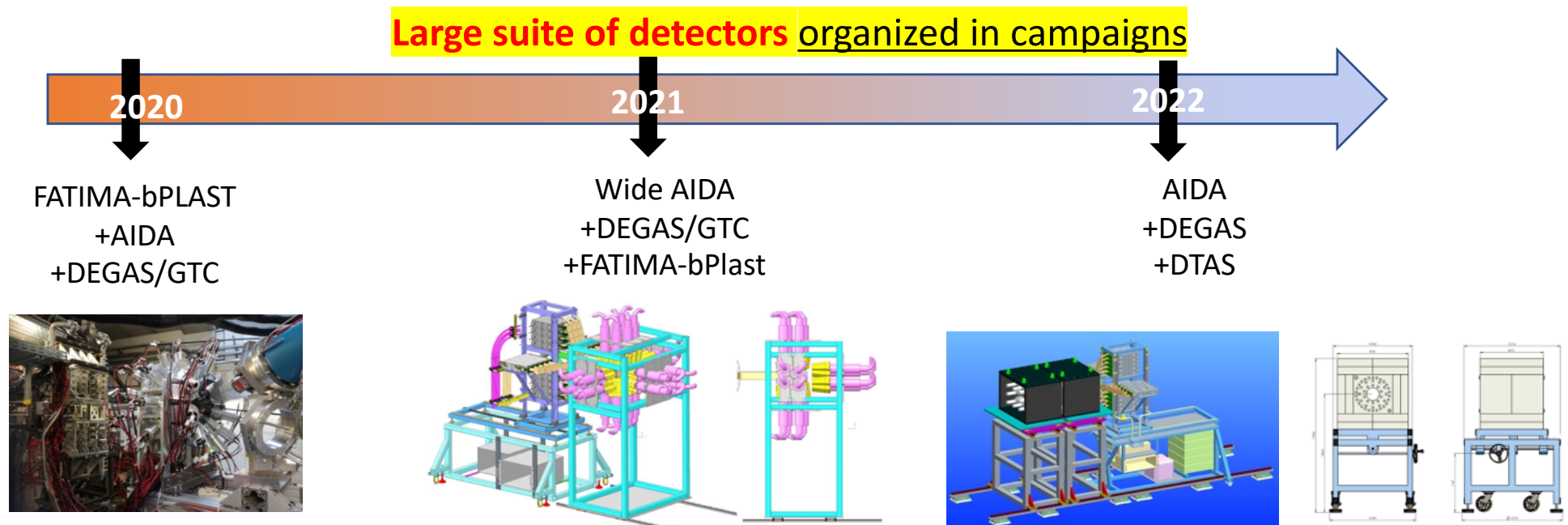
- **G-PAC 44 results for NUSTAR**
  - **19 A ratings**, incl. 6 A-rated resubmissions
  - **295 (main) SIS18** and **232 (main) UNILAC** beamtime shifts
  - Very dense program in 2021/22 (see supplements for details)
  
- **All PAC approved experiments should be carried out by 2022**
  - Preparation for campaign in 2021 is well advanced
  - **“Remote” operation** and/or participation largely developed
  - Relatively **few external participants** expected (some long-term visitors)
  
- **Prolongation of Phase-0 program until the start of FAIR**
  - Optimise experiments for Day-1 at Super-FRS
  - Keep collaborations active at FAIR

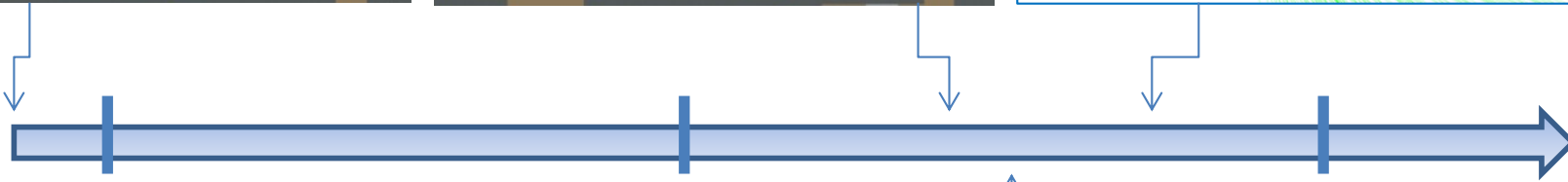
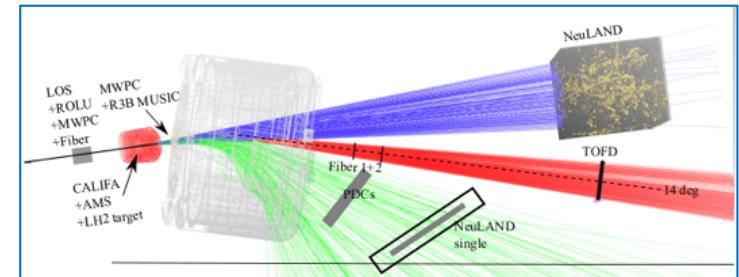
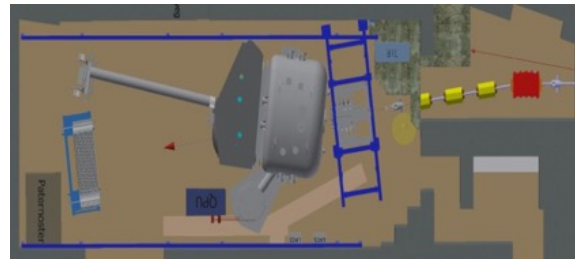
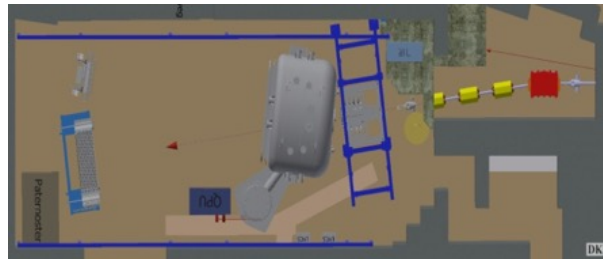
- **DeSpec** instrumentation is being used (besides **GSI/FRS**) at:
  - **RIKEN (J): AIDA, DTAS, BELEN**
  - **ALTO (F): FATIMA, MONSTER**
  - **JYFL (FIN): MONSTER**
  - **U. Cologne (D): LYCCA**
- **ILIMA** experiments principally at **GSI/ESR**
- **LaSpec** beamline at **CARIBU/ANL** (until LEB ready)
- **MATS** beamline at **TRIGA/Mainz** (until LEB ready)
- **R3B** is installing **the full phase-0 set-up** at **GSI/FRS**
- **SHE** experiments mainly performed at **GSI/UNILAC**
- **Super-FRS** collaboration is preparing at **GSI/FRS**:
  - **FRS Ion Catcher (2020+)**
  - **WASA@FRS (2021)**
  - **Expert (2022+)**

See presentation  
by J. Gerl

Complete picture of the  $\beta$ -decay process requires both **high-resolution** and **high-efficiency studies**

- **high-resolution:** aiming at a **detailed reconstruction of decay scheme**. Exploits combination of AIDA+HPGe detectors, coupled to ancillaries such as FATIMA and BELEN to enhance the sensitivity to specific observables (levels lifetimes or delayed neutron spectroscopy).
- **high-efficiency:** Total Absorption Spectrometry technique measuring the **full decay strength**, requires the use of highly efficient scintillator detectors.





**2020**  
**CALIFA Barrel**  
**NeuLAND (8 DP)**  
**SOFIA tracking detectors**  
**R3BMusic**

**2021**  
**CALIFA iPHOS**  
**NeuLAND 12 DP**  
**+ LH2 +**

**New Fiber Detectors**

**2022**  
**+ Proton arm behind GLAD**



**S509** Study of multi-neutron correlations in drip-line nuclei  
**S522** First characterization of Short-Range Correlations in exotic nuclei @R3B

**S444** Detection system comm.  
**S467** Single-particle structure of neutron-rich Ca isotopes

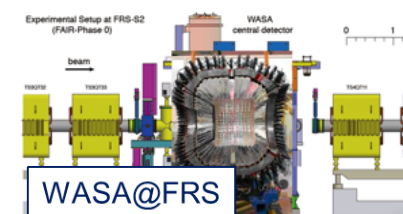
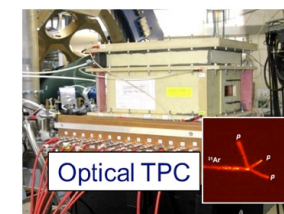


**S455** Fission studies @R3B  
**S515** Constraining energy-density functionals and the density-dependence of the symmetry energy  
**S494** Coulomb dissociation of  $^{16}\text{O}$  into  $^{12}\text{C}$  and  $^4\text{He}$ .

High-resolution spectrometer experiments with FRS and ancillary detectors

→ **broad science spectrum**

- **New isotopes**, new reaction studies (MNT etc.)
- **Exotic nuclei** (proton radioactivity, fission isomers)
- **Atomic-collision** studies
- **Hyper nuclei**:  $nn\Lambda$ ,  ${}^3_{\Lambda}\text{H}$ ,  ${}^4_{\Lambda}\text{H}$
- **Hadron physics**: 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  ${}^{100}\text{Sn}$
- S459+** In-flight decay spectroscopy of proton-unbound nuclei and mass meas.
- S482** Mean range bunching

**2021**

- 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  $\beta^+$ -emitting nuclei

**2022**

- S447** Studies of hypernuclei by new spectroscopy techniques with WASA@FRS
- S490** Search for eta'-mesic nuclei in  ${}^{12}\text{C}(p,dp)$  reaction
- U323** Study of MNT processes in different reactions
- S523** In-cell MNT reactions at the FRS Ion Catcher

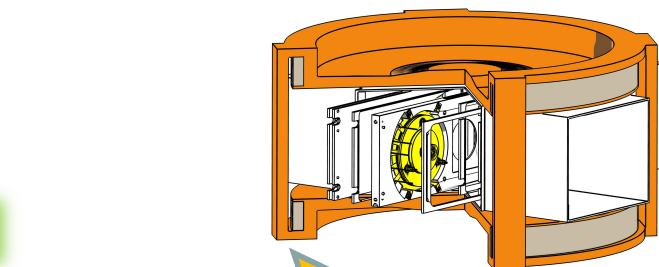
**2023**



Phase-0 experiments aim both at exciting physics goals and at the development of detection systems and methods which are indispensable for ILIMA@FAIR

## Detectors

ILIMA




Time-of-Flight

Telescopes

Schottky

In-kind contract signed -- in production --

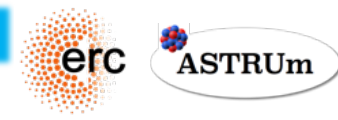
N. Kuzminchuk-Feuerstein, et al., NIM A (2016)

One detector was commissioned in **E121** (2020)   
 New detector and DAQ upgrade as in-kind from Canada -- to be tested in **E156**, not approved

A. Najafi, et al., NIM A (2016)

A prototype for CR/HESR was tested in the ESR in **E121**  
 Major characteristics (sensitivity) will be determined in **E143**  
 (**E147** and **E156** not approved)

M.S. Sanjari et al., Rev. Sci. Instrum. 91, 083303 (2020)



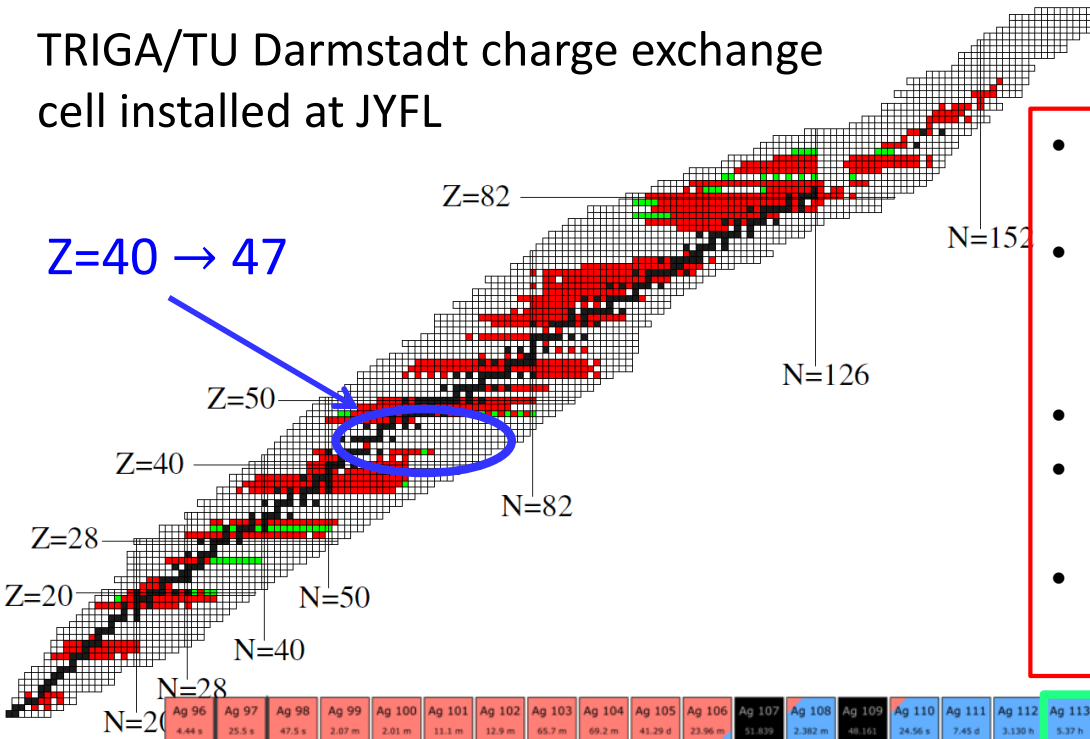
## FAIR phase 0:

- operation of **MATS prototype TRIGA-TRAP** at TRIGA Mainz for technical and methodical developments:
  - single-ion mass spectrometry with cryogenic trapping systems
  - optimization of novel phase-imaging technique (PI-ICR) for short-lived nuclides and low-lying isomers
- construction of RFQ system at JYFL
- on-line experiments at different laboratories within the collaboration: ISOLTRAP, JYFLTRAP, SHIPTRAP ...

## FAIR phase 1:

- Experiments on neutron-rich nuclides relevant for 3rd r-process peak
- Experiments on selected neutron-rich isotopes, e.g. Zr isotopes

TRIGA/TU Darmstadt charge exchange cell installed at JYFL



## Phase 0 at JYFL and CARIBU

- Spectroscopy on  $^{113-121}\text{Ag}$  (2018) at JYFL (green)
- Fission yield predictions (yellow, JYFL) assuming >5000 ions/s needed for collinear laser spectroscopy on atoms
- Zr, Nb, Mo (red) from JYFL
- CRIS developments lead to 1-2 isotopes further (not shown)
- Phase 1 at LaSPEC aiming at, eg  $^{106}\text{Zr}$  and beyond!

	Ag 96	Ag 97	Ag 98	Ag 99	Ag 100	Ag 101	Ag 102	Ag 103	Ag 104	Ag 105	Ag 106	Ag 107	Ag 108	Ag 109	Ag 110	Ag 111	Ag 112	Ag 113	Ag 114	Ag 115	Ag 116	Ag 117	Ag 118	Ag 119	Ag 120	Ag 121	Ag 122	Ag 123	Ag 124	Ag 125	Ag 126	Ag 127	Ag 128	Ag 129	Ag 130
46	Pd 95	Pd 96	Pd 97	Pd 98	Pd 99	Pd 100	Pd 101	Pd 102	Pd 103	Pd 104	Pd 105	Pd 106	Pd 107	Pd 108	Pd 109	Pd 110	Pd 111	Pd 112	Pd 113	Pd 114	Pd 115	Pd 116	Pd 117	Pd 118	Pd 119	Pd 120	Pd 121	Pd 122	Pd 123	Pd 124	Pd 125	Pd 126	Pd 127	Pd 128	
44	Rh 94	Rh 95	Rh 96	Rh 97	Rh 98	Rh 99	Rh 100	Rh 101	Rh 102	Rh 103	Rh 104	Rh 105	Rh 106	Rh 107	Rh 108	Rh 109	Rh 110	Rh 111	Rh 112	Rh 113	Rh 114	Rh 115	Rh 116	Rh 117	Rh 118	Rh 119	Rh 120	Rh 121	Rh 122	Rh 123	Rh 124	Rh 125	Rh 126	Rh 127	Rh 128
42	Ru 93	Ru 94	Ru 95	Ru 96	Ru 97	Ru 98	Ru 99	Ru 100	Ru 101	Ru 102	Ru 103	Ru 104	Ru 105	Ru 106	Ru 107	Ru 108	Ru 109	Ru 110	Ru 111	Ru 112	Ru 113	Ru 114	Ru 115	Ru 116	Ru 117	Ru 118	Ru 119	Ru 120	Ru 121	Ru 122	Ru 123	Ru 124			
40	Tc 92	Tc 93	Tc 94	Tc 95	Tc 96	Tc 97	Tc 98	Tc 99	Tc 100	Tc 101	Tc 102	Tc 103	Tc 104	Tc 105	Tc 106	Tc 107	Tc 108	Tc 109	Tc 110	Tc 111	Tc 112	Tc 113	Tc 114	Tc 115	Tc 116	Tc 117	Tc 118	Tc 119	Tc 120						
	Mo 91	Mo 92	Mo 93	Mo 94	Mo 95	Mo 96	Mo 97	Mo 98	Mo 99	Mo 100	Mo 101	Mo 102	Mo 103	Mo 104	Mo 105	Mo 106	Mo 107	Mo 108	Mo 109	Mo 110	Mo 111	Mo 112	Mo 113	Mo 114	Mo 115	Mo 116	Mo 117								
	Nb 90	Nb 91	Nb 92	Nb 93	Nb 94	Nb 95	Nb 96	Nb 97	Nb 98	Nb 99	Nb 100	Nb 101	Nb 102	Nb 103	Nb 104	Nb 105	Nb 106	Nb 107	Nb 108	Nb 109	Nb 110	Nb 111	Nb 112	Nb 113	Nb 114	Nb 115									
	Zr 89	Zr 90	Zr 91	Zr 92	Zr 93	Zr 94	Zr 95	Zr 96	Zr 97	Zr 98	Zr 99	Zr 100	Zr 101	Zr 102	Zr 103	Zr 104	Zr 105	Zr 106	Zr 107	Zr 108	Zr 109	Zr 110	Zr 111	Zr 112											

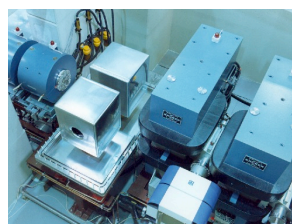
Comprehensive study of **superheavy elements: production, nuclear, atomic, and chemical** properties at SHIP and TASCA:

	2020	2021	2022	Day-1
<b>Nuclear structure:</b>				<b>Day-1 Setups</b>
Focal plane det. (FPD)	✓ new $^{244}\text{Md}$			FPD, COMPASS
TASISpec → LUNDIUM	✓ $\alpha$ - $\gamma$ $_{114}\text{Fl}$ chains	Construct. LUNDIUM	👍 Commiss. ( $_{94}\text{Pu}$ )	LUNDIUM
ANSWERS Setup	Construction	👍 Commiss. ( $_{104}\text{Rf}$ )		ANSWERS
<b>Atomic properties:</b>				
Masses (SHIPTRAP)	✓ $_{102}\text{No}$ - $_{104}\text{Rf}$	👍 $_{104}\text{Rf}/_{105}\text{Db}$	👍 $_{104}\text{Rf}/_{105}\text{Db}$	SHIPTRAP
Laser spec in gas-cell	✓ $_{100}\text{Fm}$	👍 $_{102}\text{No}/_{103}\text{Lr}$	👍 $_{103}\text{Lr}$	RADRIS
in gas-jet	Construction	👍 Commiss.	👍 $_{102}\text{No}$	In-Gas-Jet
<b>Chemical properties:</b>				
RTC-based ( $T_{1/2} > 500$ ms)	✓ $_{113}\text{Nh}$ (RTC)	👍 $_{115}\text{Mc}$ (RTC / miniCOMPACT)		miniCOMPACT
UniCell ( $T_{1/2} > 2$ ms)	Design UniCell	Construction	Commiss. UniCell	UniCell

- ✓ Successful beamtime
- 👍 Beamtime in schedule



TASCA



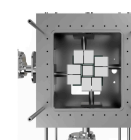
SHIP



SHIPTRAP



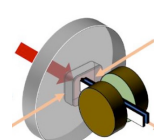
COMPASS



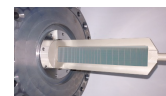
LUNDIUM



RADRIS



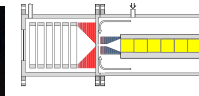
ANSWERS



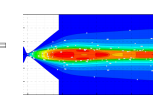
miniCOMPACT



TASCA FPD

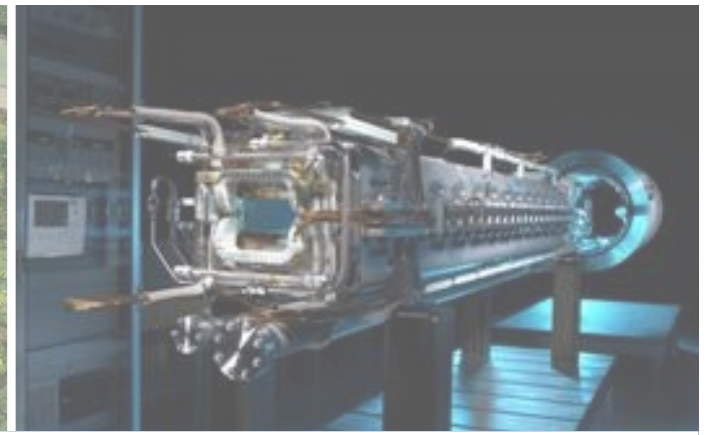


UniCell



Laser Gas-Jet

- **NUSTAR experiments are progressing constantly towards their Day-1 configuration**
  - Equipment for Day-1 **ready in 2025** (92% secured funding and 58% constructed)
  - Common funds are needed for the completion of the experiments
  - Few critical items (R3B Si Tracker & DEGAS, under discussion with ECE/ECSSG)
  - Future emphasis to **complete the full MSV configurations**
  
- **Phase-0 experiments are an integral part of our preparation for Day-1**
  - Extended commissioning of **all NUSTAR equipment** incl. **FRS/ESR**
  - Several **successful experiments** despite limitations due to Covid-19
  - Preparation for campaign in 2021/22 will have to deal with similar limitations
  - Collaborations are investigating secondments for **experiments** and **beam team**
  - Need **sufficient phase-0 beam time** to keep collaborations **competitive**



Thank you for your attention

**RRB10 NUSTAR Meeting**

Darmstadt, February 9-10, 2021



Finland



France



Germany



India



Poland



Romania



Russia



Slovenia



Sweden

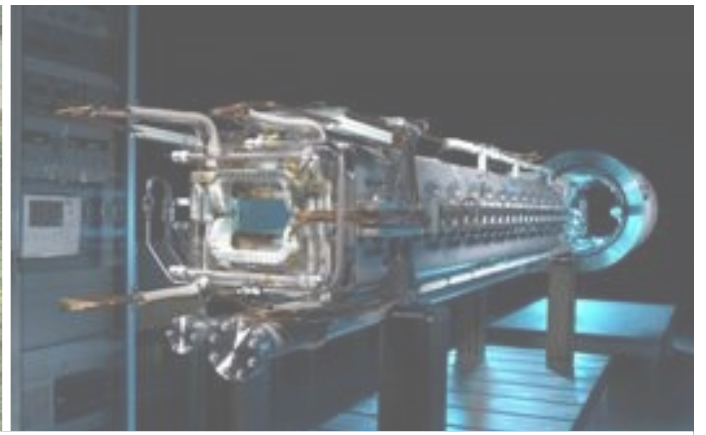


UK



Czech Republic

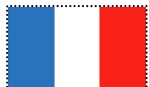




# Supplementary information



Finland



France



Germany



India



Poland



Romania



Russia



Slovenia



Sweden

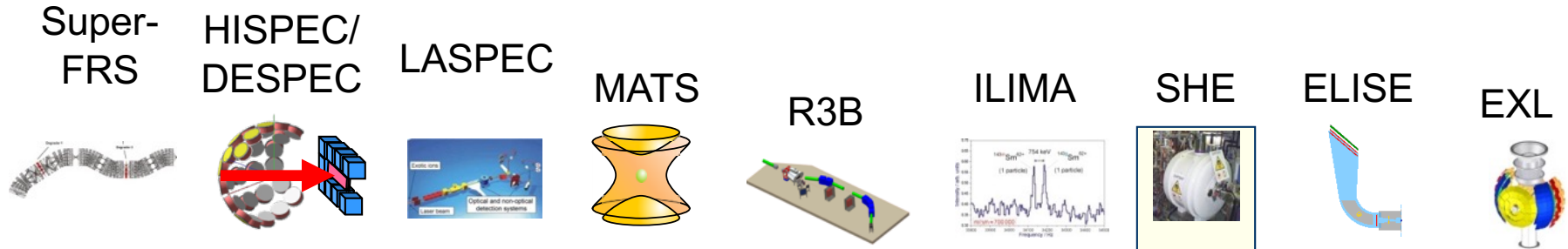


UK



Czech Republic





	Super-FRS	HISPEC/DESPEC	LASPEC	MATS	R3B	ILIMA	SHE	ELISE	EXL
<b>Masses</b>		Q-values, isomers		dressed ions, highest precision	unbound nuclei	bare ions, mapping study	precision mass of SHEs		
<b>Half-lives</b>	ps...ns-range	ground state and isomers $\mu$ s...s			resonance width, decay up to 100ns	bare ions, ms...years	$\mu$ s...days		
<b>Matter radii</b>	interaction x-section				interaction cross sections				matter density distribution
<b>Charge radii</b>	charge-changing cross sections		mean square radii		charge-changing cross sections			charge density distribution	
<b>Single-particle structure</b>	high resolution, angular momentum	high-resolution particle and $\gamma$ -ray spectroscopy	magnetic moments, nucl. spins	evolution of shell str., pairing int., valence nucl.	quasi-free knockout, short-range & tensor correlations	evolution of shell closures, pairing corr.	shell structure of SHEs		low momentum transfers
<b>Collective behavior</b>		electromagnetic transition strength	quadrupole moments	halo structure	dipole response, fission	changes in deformation		electromagnetic transition strength	monopole resonance
<b>EoS</b>					polarizability, neutron skin			neutron skin	neutron skin, compressibility
<b>Exotic Systems</b>	bound mesons, hypernuclei, nucleon resonances	rare and exotic e.m. and particle decays			n-rich hypernuclei	exotic decay modes			



## NUSTAR Collaboration

### NUSTAR Council (NC)

Institutes (secured financial/manpower contribution)

### Collaboration Committee (CC)

#### NUSTAR Experiments

representatives of all  
experiment collaborations

#### Board of Representatives (BR)

Five members elected by  
Council and TC/RC ex-officio  
Chair: NUSTAR Spokesperson

#### Technical Board (TB)

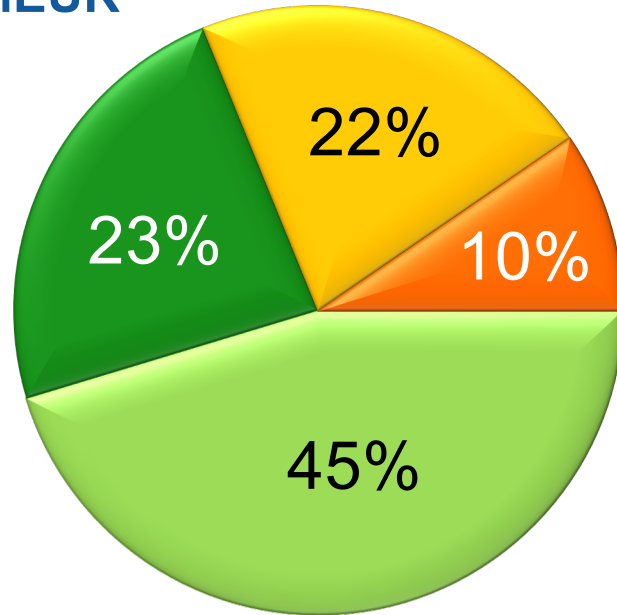
Chair: Technical Coordinator

#### Resource Board (RB)

Chair: Resource Coordinator

- New NUSTAR Council constituted at the annual meeting in spring
  - Any *secured* contribution to *any* of the sub-collaborations which goes beyond the **threshold of 50 k€/sub-collaboration (2005 price)** should result in a *voting right* in the council.
  - If funding is not yet secured: **observer status**
  - Any *manpower contribution* by any institute to NUSTAR which is equivalent to a **minimum of 100 k€ or 2 FTE** should result in a *voting right* in the council.
- Election of new chair and chair-elect
  - Chair: N. Kalantar (KVI)
  - Chair-elect: B. Rubio (IFIC Valencia)
- Procedures for new MoU (being discussed)
  - Rules for the election of spokesperson and board of representatives
  - Duration of their mandates (also with respect to other FAIR collaborations)

46.5 MEUR



- secured/expected FAIR
- secured external
- EoI
- to be assigned

- Funding (secured and expected) from:  
(**FAIR funding in bold face**)

- |                  |                         |
|------------------|-------------------------|
| ■ Australia      | ■ Israel                |
| ■ Belgium        | ■ Japan                 |
| ■ Bulgaria       | ■ Netherlands           |
| ■ Canada         | ■ <b>Poland</b>         |
| ■ China          | ■ <b>Romania</b>        |
| ■ Czech Republic | ■ <b>Russia</b>         |
| ■ <b>Finland</b> | ■ Slovenia              |
| ■ <b>France</b>  | ■ Spain                 |
| ■ <b>Germany</b> | ■ <b>Sweden</b>         |
| ■ Hungary        | ■ Turkey                |
| ■ <b>India</b>   | ■ <b>United Kingdom</b> |

Status: February, 2021

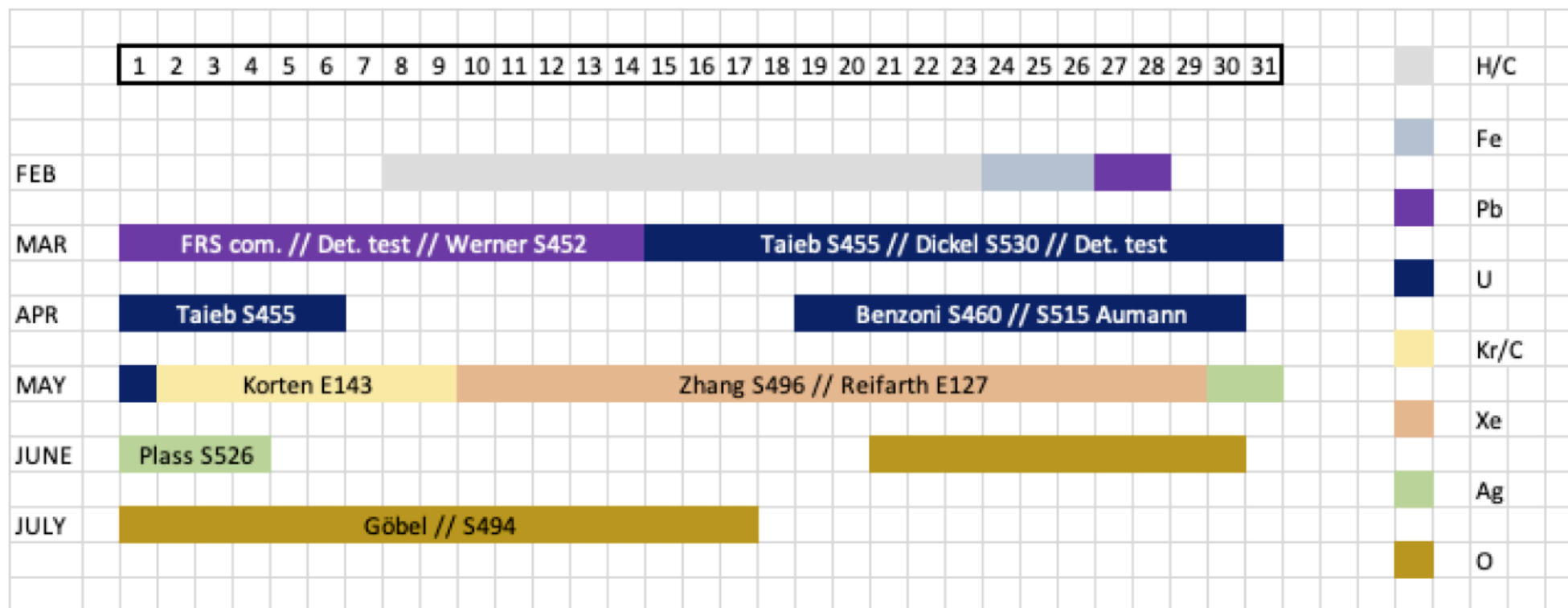


# NUSTAR G-PAC 44 results



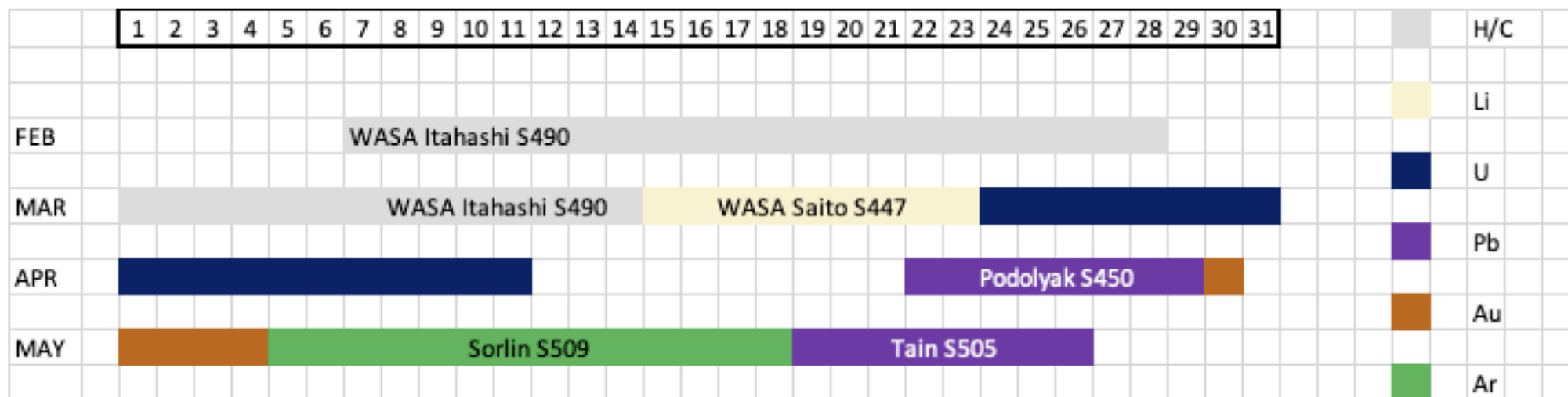
DESPEC	(S-)FRS	ILIMA	R3B	SHE
22 proposals 12 “new”	14 proposals 6 “new”	3 proposals 2 “new”	10 proposals 6 “new”	6 proposals 6 “new”
A: 5 (+3 dev.) (w. 3 resubm.) A-: 1	A: 4 (+3 dev.) (w. 1 resubm.) A-: 1	A: 1 (no resub.)	A: 4 (w. 2 resubm.) A-: 1	A: 5
SIS shifts: 108 (main) 30 (second.)	SIS shifts: 73 (main) 46 (second.) UNILAC shifts: 27 (second.)	SIS shifts: 6 (main)	SIS shifts: 108 (main) 18 (second.)	UNILAC shifts: 232 (main) 149 (second.)

NUSTAR: 19 A ratings, incl. 6 A-rated resubmissions  
 SIS beamtime shifts: 295 (main) + 94 (second.)  
 UNILAC beamtime shifts: 232 (main) + 176 (second.)



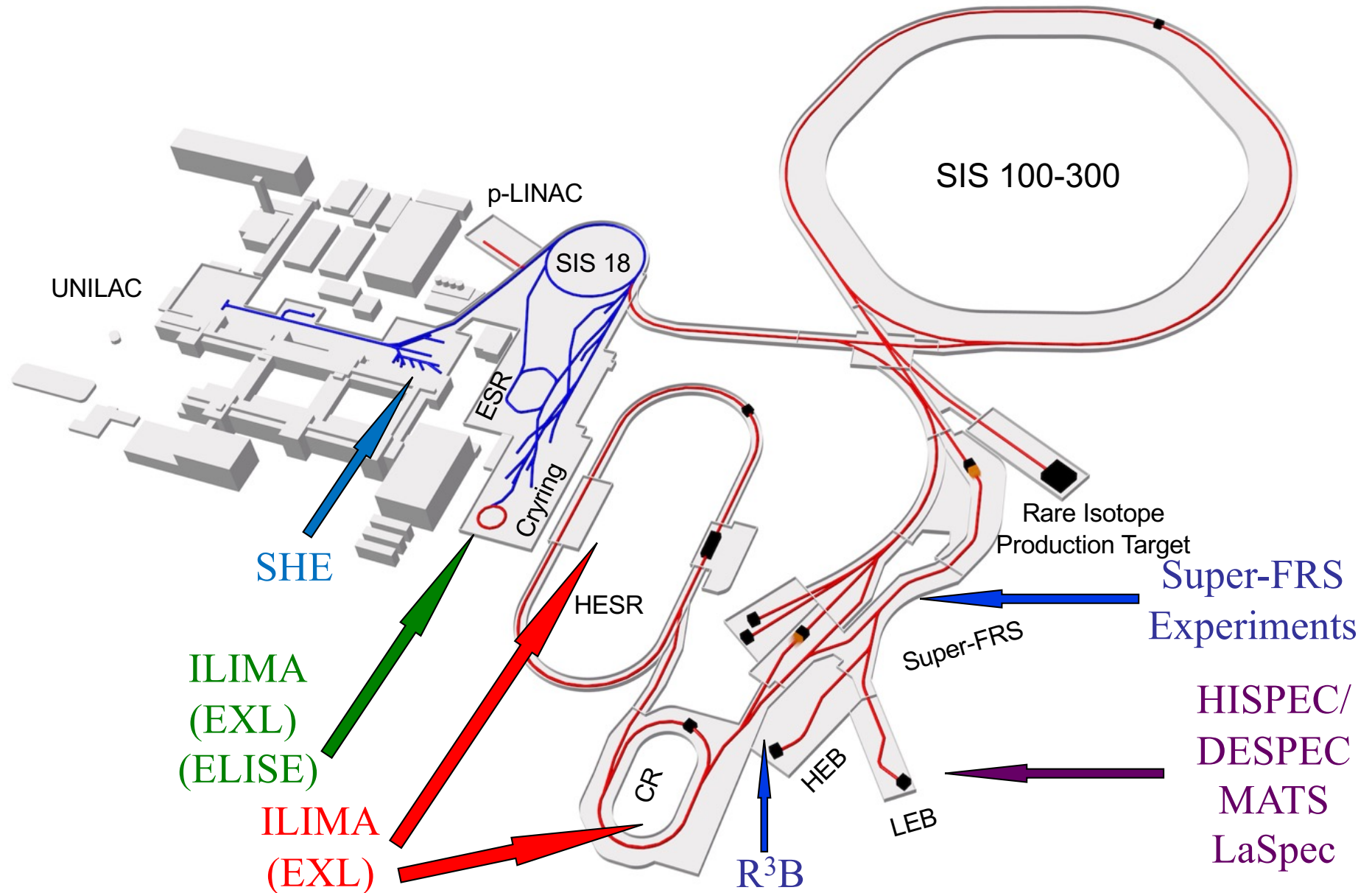
- All NUSTAR “A” experiments can be scheduled in 2021/22
- Very busy schedule with several set-up changes
- Need to take into account COVID-19 restrictions

Courtesy of D. Severin



➤ WASA occupies FRS/S2 until late April 2022

Courtesy of D. Severin





# The NUSTAR road towards FAIR MSV



Facility	U beam intensity/spill at production target	Luminosity [fb <sup>-1</sup> ]
Today at GSI with <b>FRS</b> (Phase 0)	1...2x10 <sup>9</sup>	~0,1
<b>Super-FRS</b> with upgraded <b>SIS18</b>	5x10 <sup>9</sup>	~1
Commissioning phase <b>SIS100</b>	2x10 <sup>10</sup>	~5
Full final intensity with <b>SIS100</b>	4x10 <sup>11</sup>	100

<b>Phase 0</b>	→	<b>Day-1</b>	→	<b>Full MSV</b>
<b>preparation</b>	→	<b>discovery</b>	→	<b>detailed studies</b>
• <b>0.1 fb<sup>-1</sup></b>	→	<b>2-5 fb<sup>-1</sup></b>	→	<b>100 fb<sup>-1</sup></b>
• (near) stability	→	exotic	→	very exotic nuclei



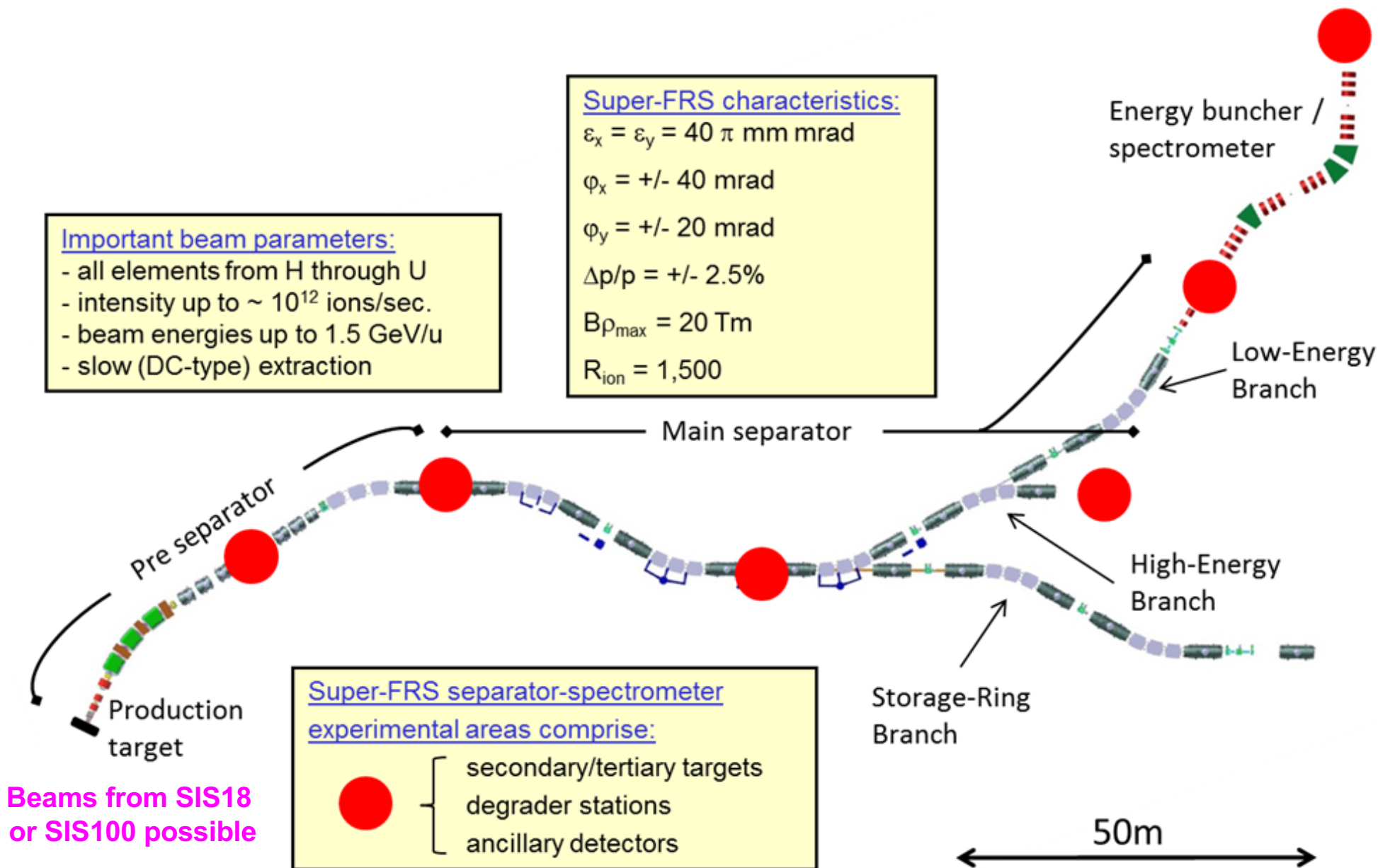


# Uniqueness of the NUSTAR Day-1 program



- **Understanding the 3<sup>rd</sup> r-process peak** by means of comprehensive measurements of lifetimes, masses, neutron emission probabilities, dipole strength, and the level structure along the **N=126 isotones**;
- **Equation of State (EoS) of asymmetric nuclear matter** by measuring the dipole polarizability and neutron-skin thicknesses of **heavy neutron-rich isotopes** (in combination with the results of the first highlight);
- **Exotics: Hypernuclei** with large N/Z asymmetry and **nucleon excitations** in nuclei

- “In summary, the FAIR Modularized Start Version (MSV) is to be constructed and completed in full as soon as possible. All else would be an extreme loss of science and waste of resources.”
- **The first machine to be commissioned should be the Super-FRS. In the case of resource conflicts, priority is to be given to the Super-FRS.**
- Any further delay of the Project is to be avoided, as any delay will increase the price by at least 50 M€ per year.



## Complete instrumentation for MSV (approved TDRs):

- **DESPEC:** Full **DEGAS** Ge and **MONSTER** neutron detector array
- **HISPEC:** Complete **AGATA** (externally funded)
- **ILIMA:** Complete detectors (ToF, HI, Schottky) for **CR**
- **R3B:** Full **CALIFA** CsI/LaBr<sub>3</sub> calorimeter and **NEULAND** neutron wall
- **S-FRS EC:** Complete **EXPERT** set-up

## Add new capabilities (Eols):

- **LEB:** Instrumentation for experiments with **slowed-down beams**
- **DESPEC:** **g-SPEC** for g-factor measurements
- **HISPEC:** **HYDE** charged-particle array
- **LASPEC:** **CRIS** capabilities for collinear beamline
- **R3B:** **High-resolution spectrometer**
- **EXL:** Detection system(s) for **ESR** and **HESR**
- **(S-FRS EC: SuperWASA)**