

# Project 18.77

## Studies of very heavy and superheavy elements

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- The study of heavy (HN,  $Z \geq 89$ ) and superheavy (SHN,  $Z \geq 104$ ) nuclei is one of the major research areas in contemporary nuclear physics
- Detailed spectroscopy provide information on the nuclear landscape at the upper limit of the nuclear chart

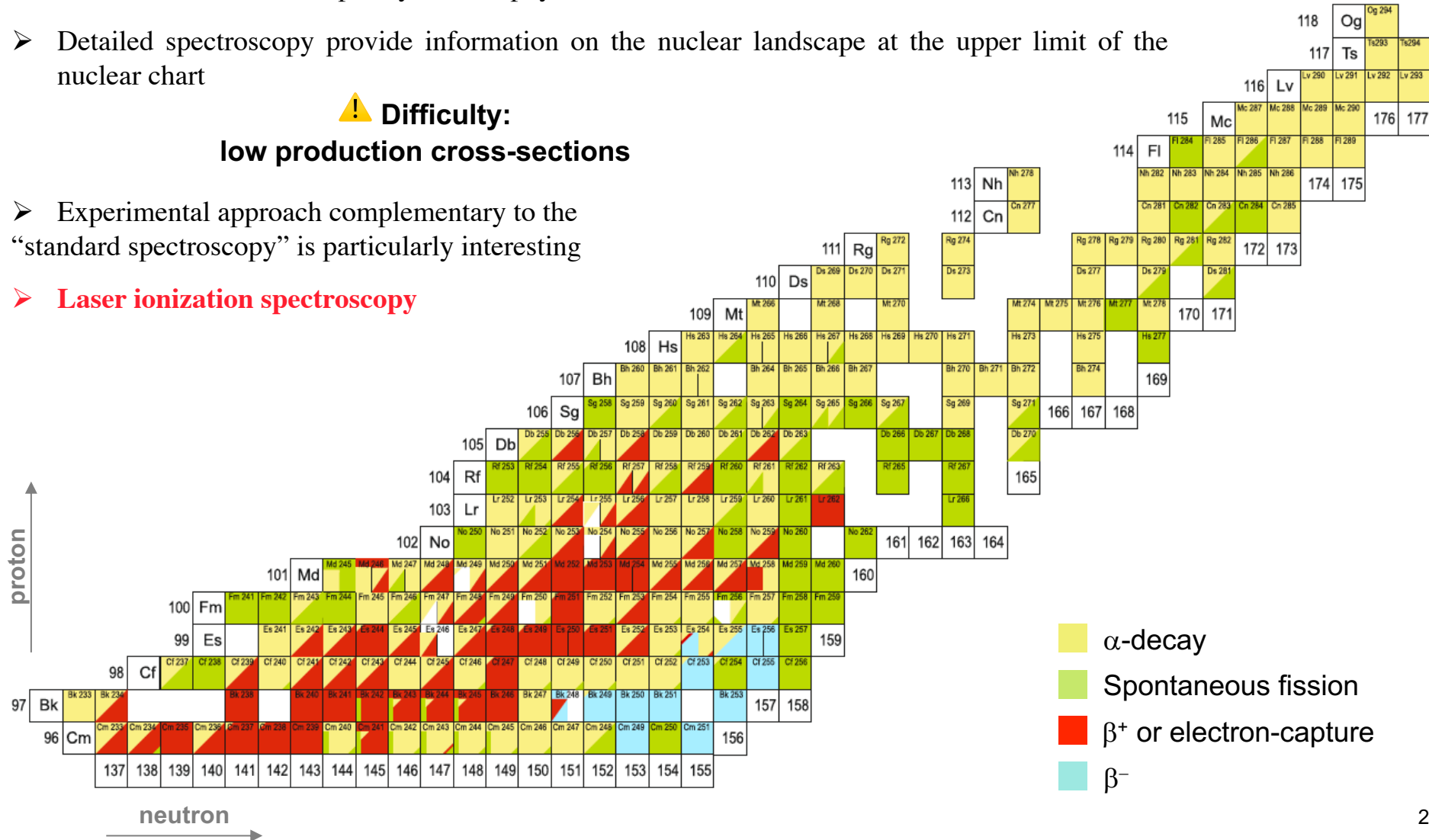


**Difficulty:**

**low production cross-sections**

- Experimental approach complementary to the “standard spectroscopy” is particularly interesting

- **Laser ionization spectroscopy**



## What is measured?

Isotope/Isomer shifts

Hyperfine structure

## Deduced observables (Nuclear model independent)

Charge radii

Quadrupole moment

Dipole moment

Spins

## Deduced information (Nuclear model dependent)

Shapes/deformation parameters

Single/few particle configurations

Our Collaboration : Study of HN and SHN using LIS at GSI and in the future SPIRAL2

## Scientific goal of the project

- obtain atomic and nuclear properties of heavy elements by laser spectroscopy for comprehensive understanding of their structure
- e.g. : study shape and size of nuclei complementary to nuclear spectroscopy

## Strategic goals of the project

- developments new sensitive methods for laser spectroscopy of exotic nuclei
- know-how transfer to build expertise for future experiments @S3-LEB (GANIL-SPIRAL2)
- train next-generation scientists

Our project is performed within the wider framework of an international laser spectroscopy collaboration with additional partners :

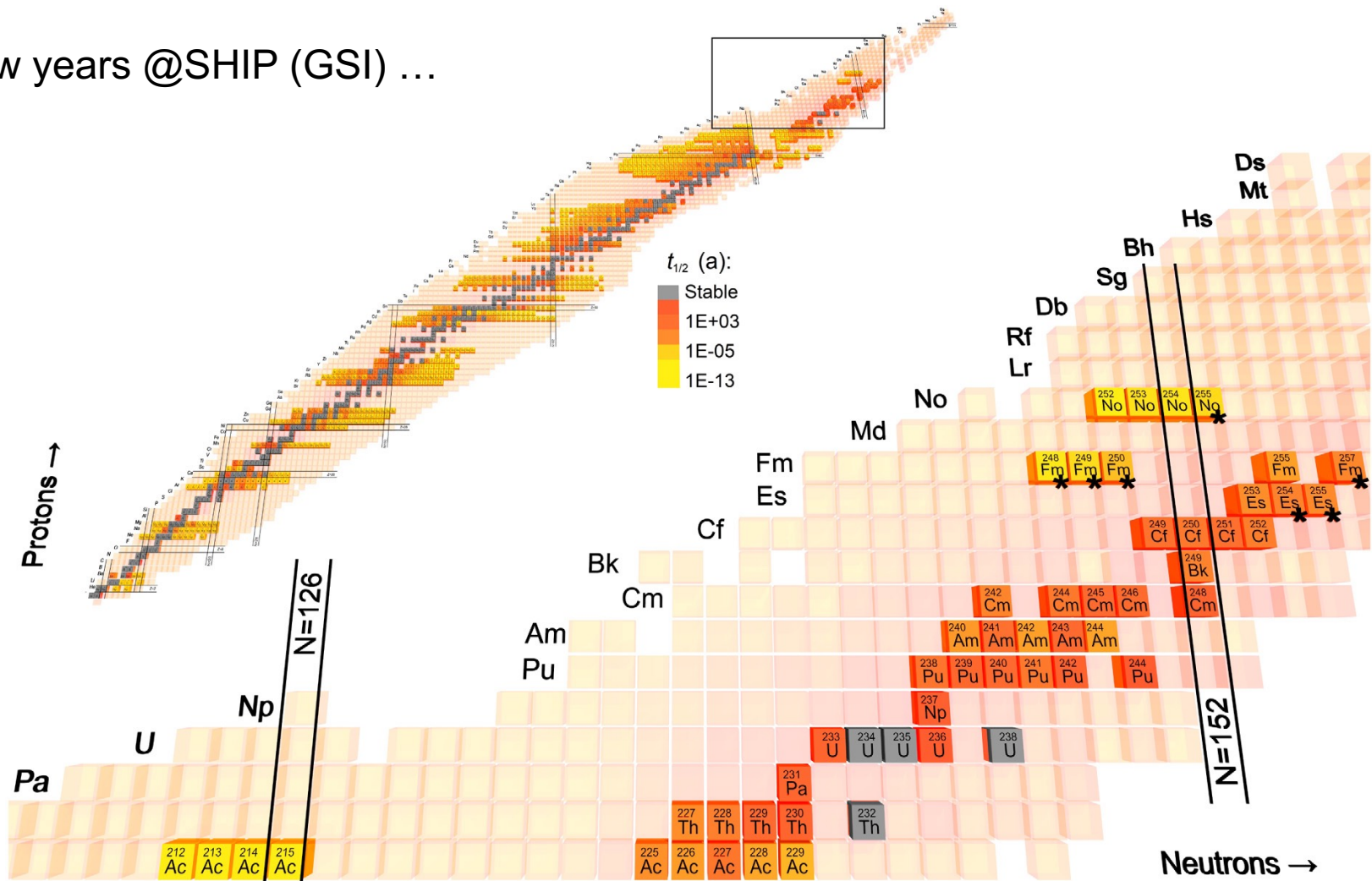


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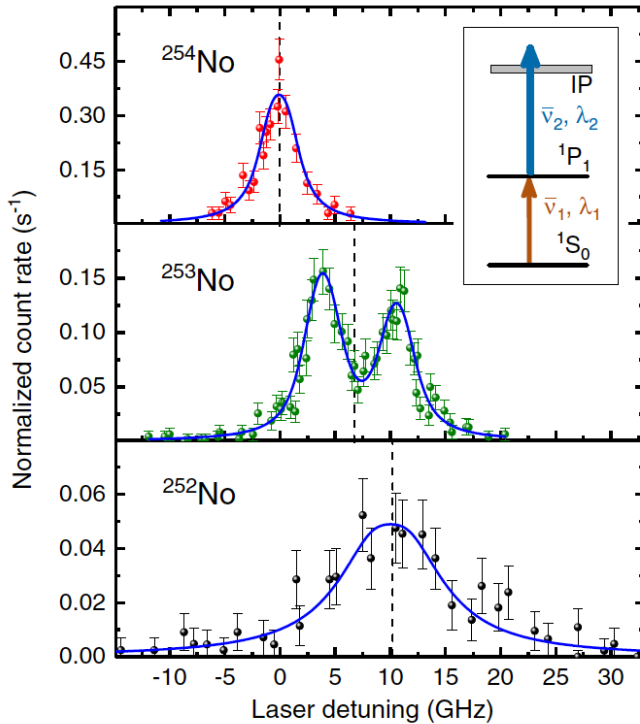


See talk of  
S. Raeder

Since few years @SHIP (GSI) ...



## No (Z=102) isotopes



S. Raeder et al., Phys. Rev. Lett. 120 (2018) 232503

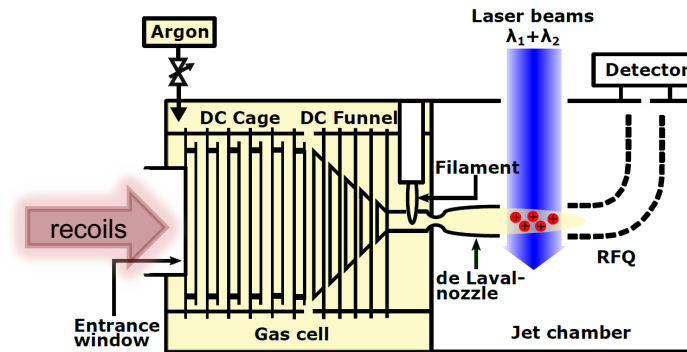
- changes in mean-square charge radii determined from isotopic shift
- magnetic dipole and electric quadrupole moment in  $^{253}\text{No}$  from hyperfine splitting
- $^{255}\text{No}$  hyperfine structure measured in 2019
- $^{251}\text{No}$  in 2022, upgrade setup (J. Warbinek, et al., Atoms, 10(2) 41, 2022) → **see talk of S. Raeder**

## Fm (Z=100) isotopes

- $^{248-250,254}\text{Fm}$  LIS performed in 2020
- $^{245,246}\text{Fm}$  in 2022
- Off-line measurements  $^{255,257}\text{Fm}$  at Mainz

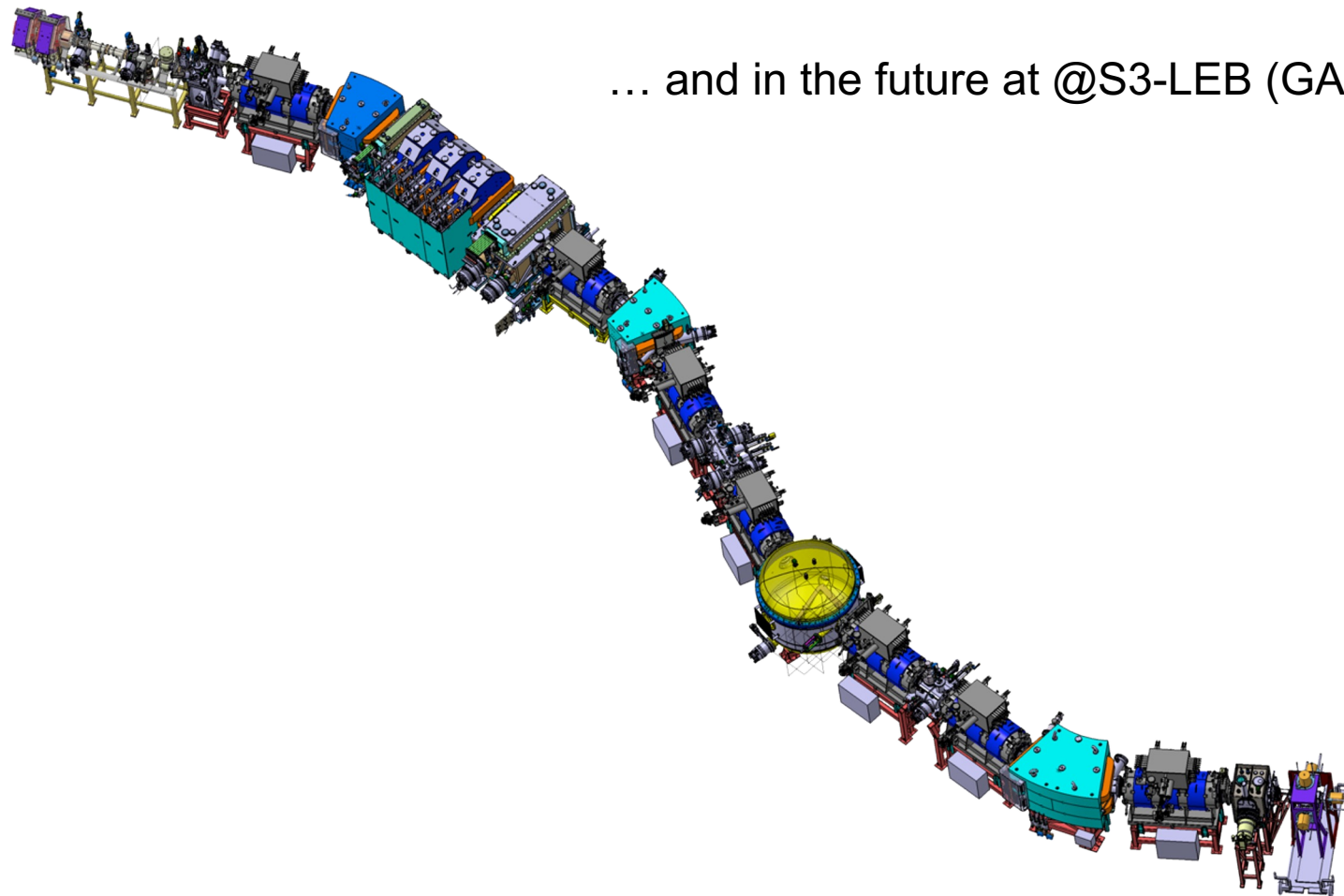
**Study of the isotopic shift (→ deformation) across the N=152 shell closure**

## JetRIS – gas-jet setup



S. Raeder, et al., NIMB, 463 272, 2020

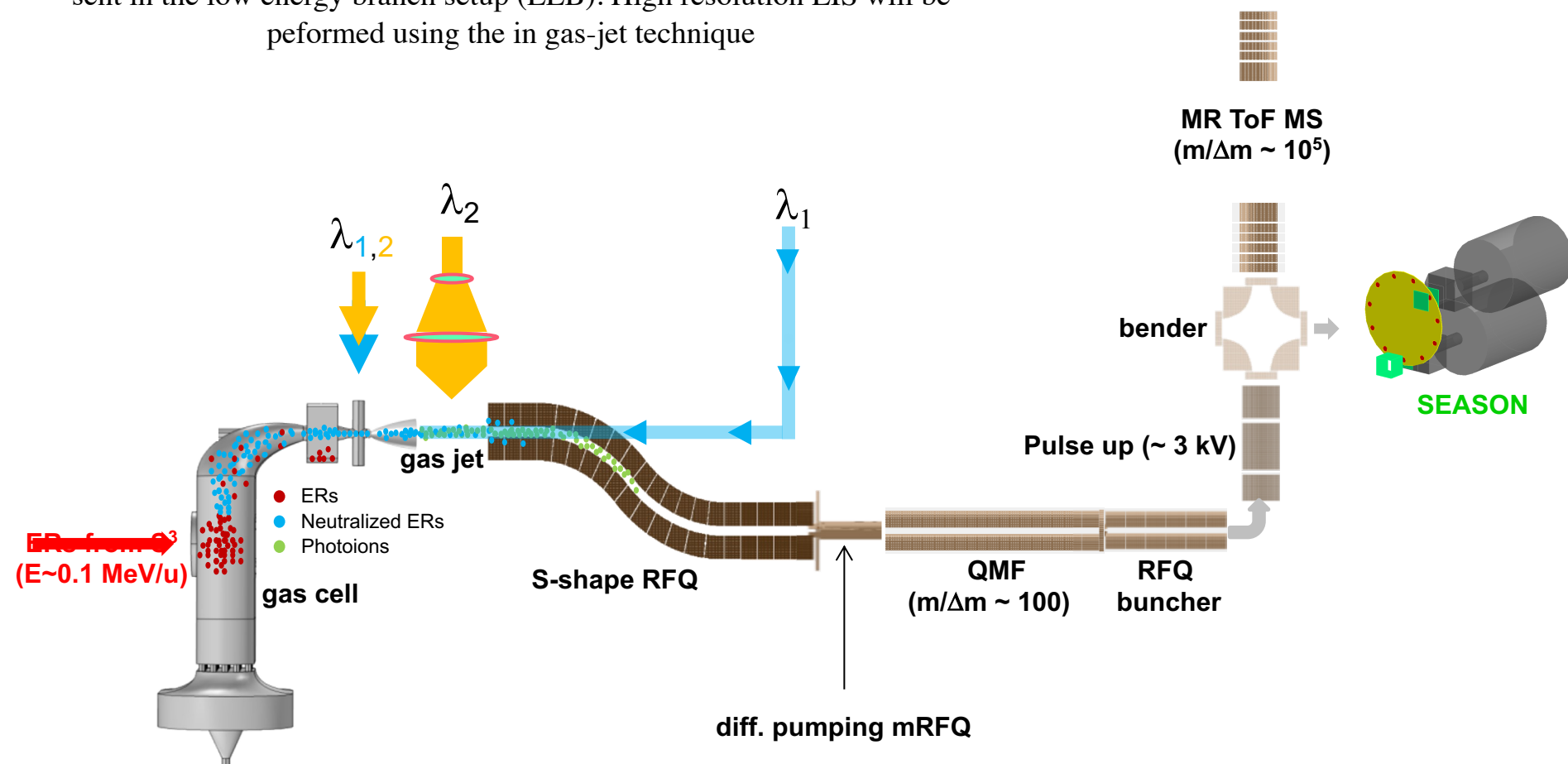
- High resolution laser spectroscopy in low-temperature and low-density supersonic gas jet
- In 2022, commissioning measurement  $^{254}\text{No}$   
**see talk of S. Raeder**



... and in the future at @S3-LEB (GANIL-SPIRAL2)



At GANIL-SPIRAL2 the HN/SHN produced and selected by S3 will be sent in the low energy branch setup (LEB). High resolution LIS will be performed using the in gas-jet technique



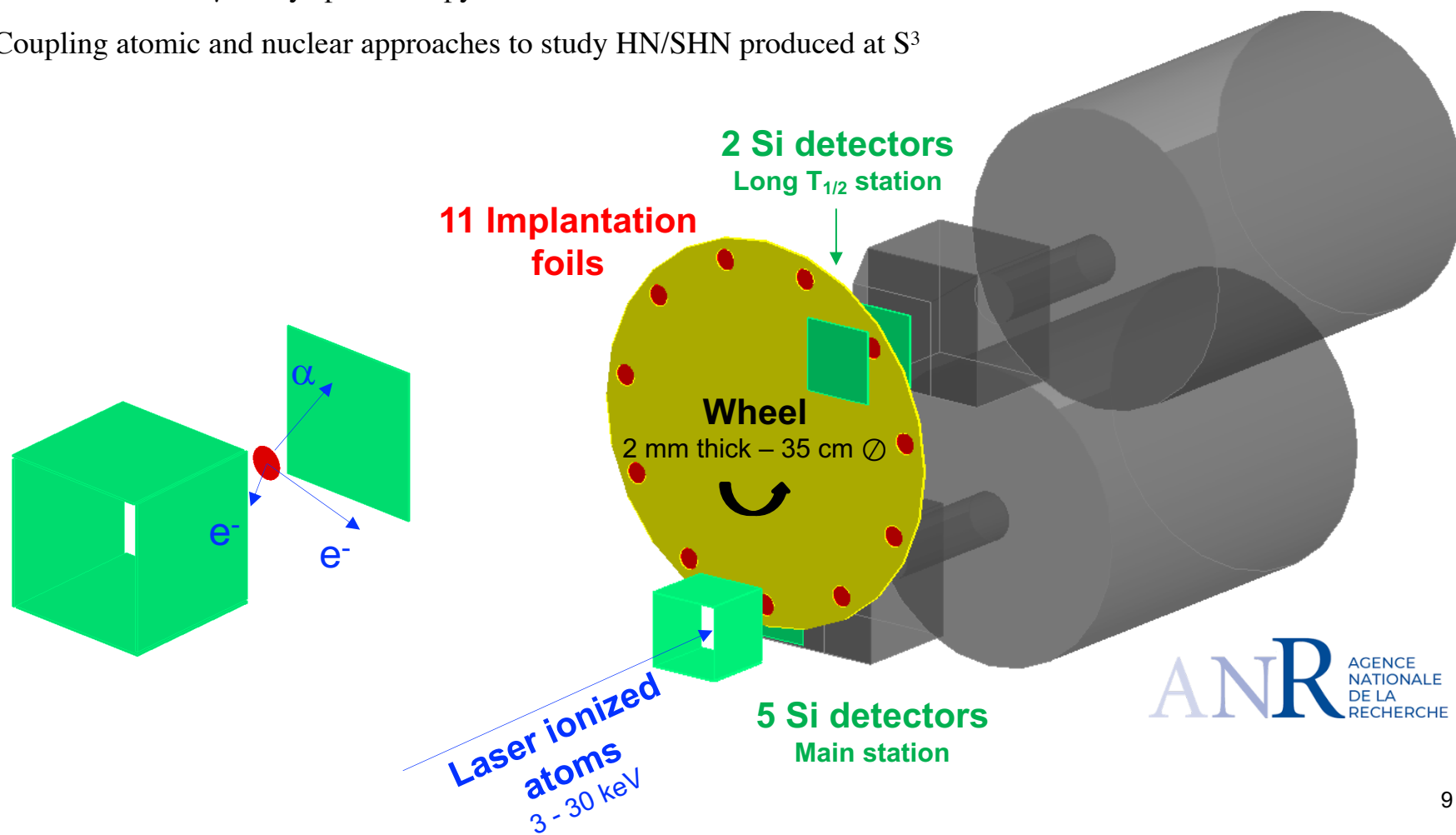


- **SEASON** will be mounted at the end of the S<sup>3</sup>-LEB for the study of HN/SHN

- It will be dedicated to :

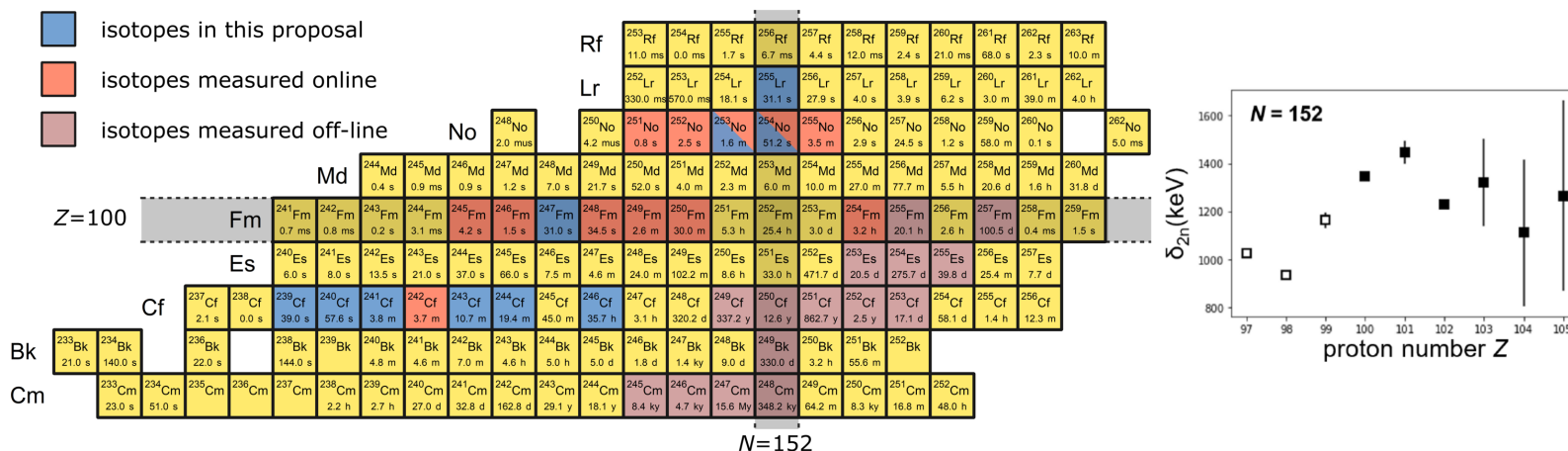
1. Counting laser ionized atoms (laser ionization spectroscopy)
2.  $\alpha$ , electron,  $\gamma$  decay spectroscopy

⇒ Coupling atomic and nuclear approaches to study HN/SHN produced at S<sup>3</sup>



- CEA joined collaboration in 2018 after pioneering laser spectroscopy experiments on No at GSI
- Regular exchange of personnel for training, discussions, and experiments
- Due to pandemic no visits in 2020
- PhD student from CEA (Emmanuel Rey-Herme) participated in 2021 beamtime for **30 days**
- PhD student from CEA (Emmanuel Rey-Herme) participated in 2022 beamtime for **15 days**

- Accepted experiments to be performed in 2024 (from “Laser spectroscopy of californium, fermium, nobelium and lawrencium isotopes around N=152” S. Raeder et al.) :



- Workshop at CEA during the in-source SEASON commissioning during which we will discuss :
  - the ongoing analysis
  - the future program at GSI and SPIRAL2
- Request
  - From CEA (16 days): M. Vandebrouck 8 days, D. Thisse 8 days
  - From GSI (17 days): M. Block 5 days, S. Raeder 5 days, J. Warbinek 7 days

**Thank you for your  
attention**