

Superheavy Studies at GANIL-SPIRAL2

TASCA 22 – GSI, Darmstadt, May. 10th-12th 2022

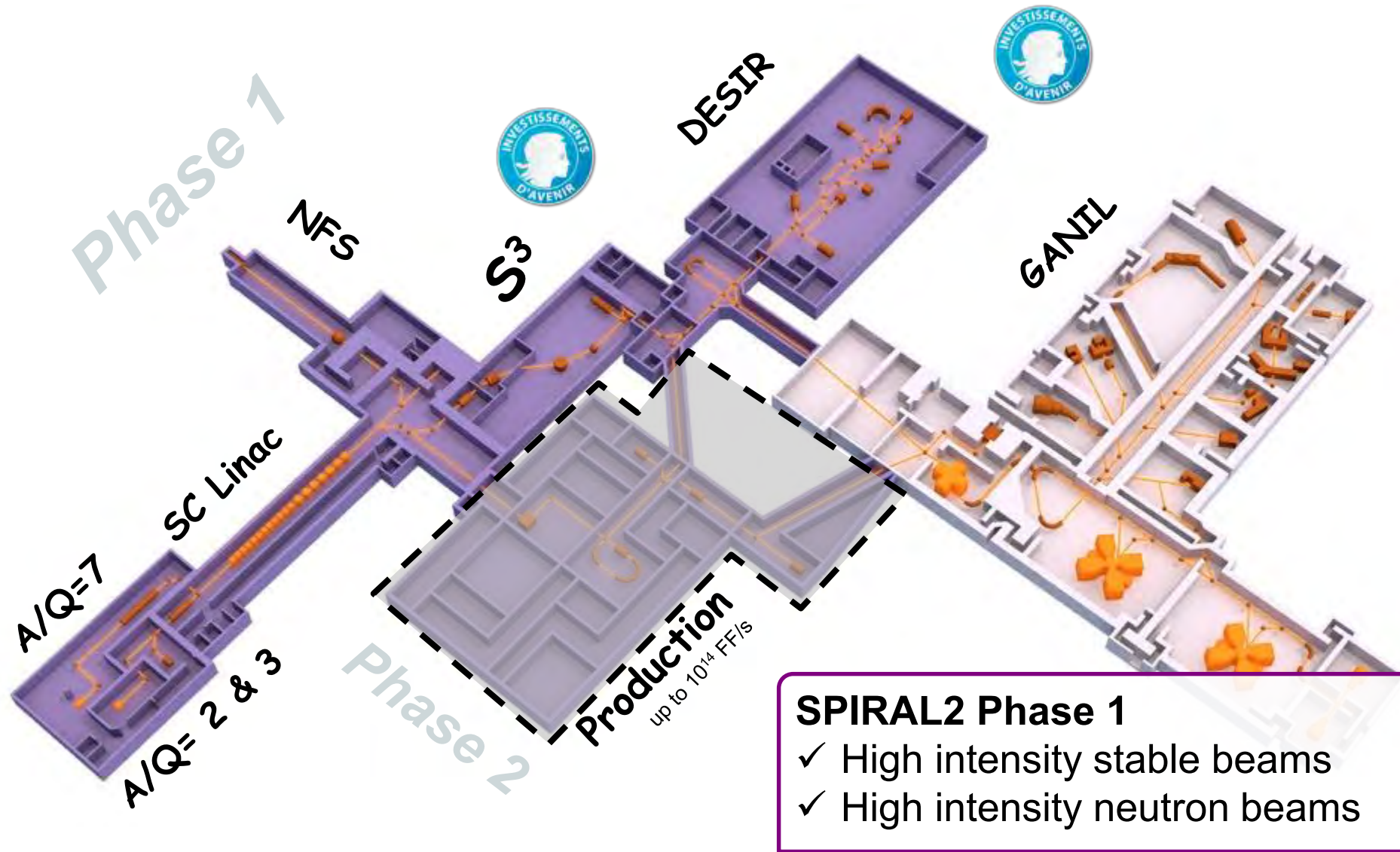
J. Piot (GANIL)
on behalf of the S³ collaboration



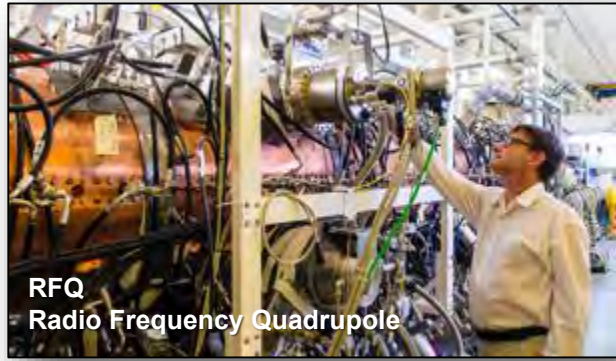
S3 has been funded by the French Research Ministry, National Research Agency (ANR), through the EQUIPEX (EQUIPMENT of EXcellence) reference ANR-10EQPX- 46, the FEDER (Fonds Européen de Développement Economique et Régional), the CPER (Contrat Plan Etat Région), and supported by the U.S. Department of Energy, Office of Nuclear Physics, under contract No. DE-AC02-06CH11357 and by the E.C.FP7-INFRASTRUCTURES 2007, SPIRAL2 Preparatory Phase, Grant agreement No.: 212692.

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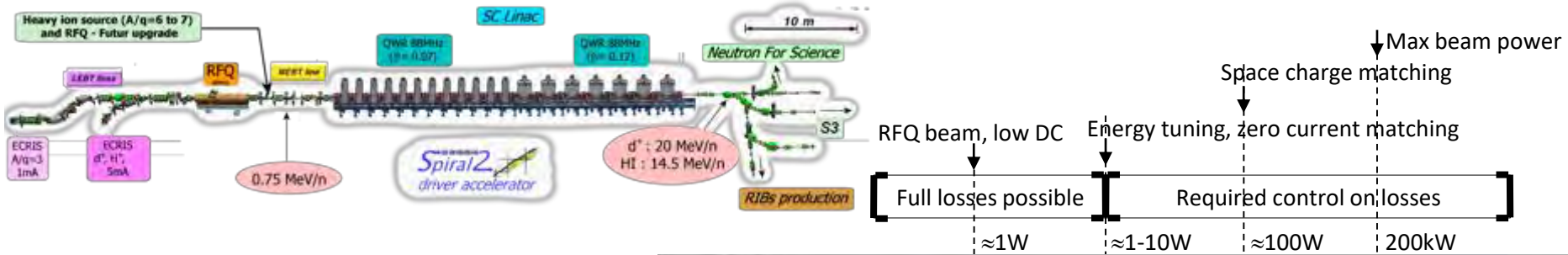
SPIRAL2 layout



SPIRAL2 accelerator



SPIRAL2 accelerator



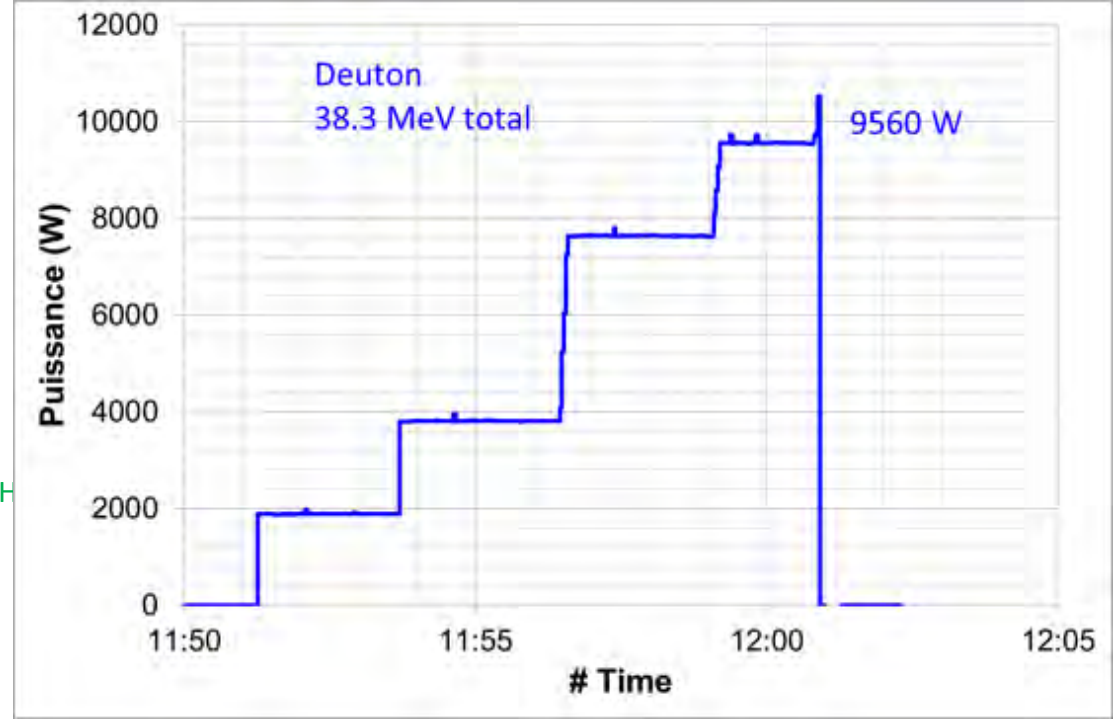
Achievements – chronology

- 2019**
- July 8th Permit from Safety Authority (ASN)
- Oct. 28th First protons in the SC LINAC
- Nov.27th All cavities tuned reaching E_{design} (33 MeV)

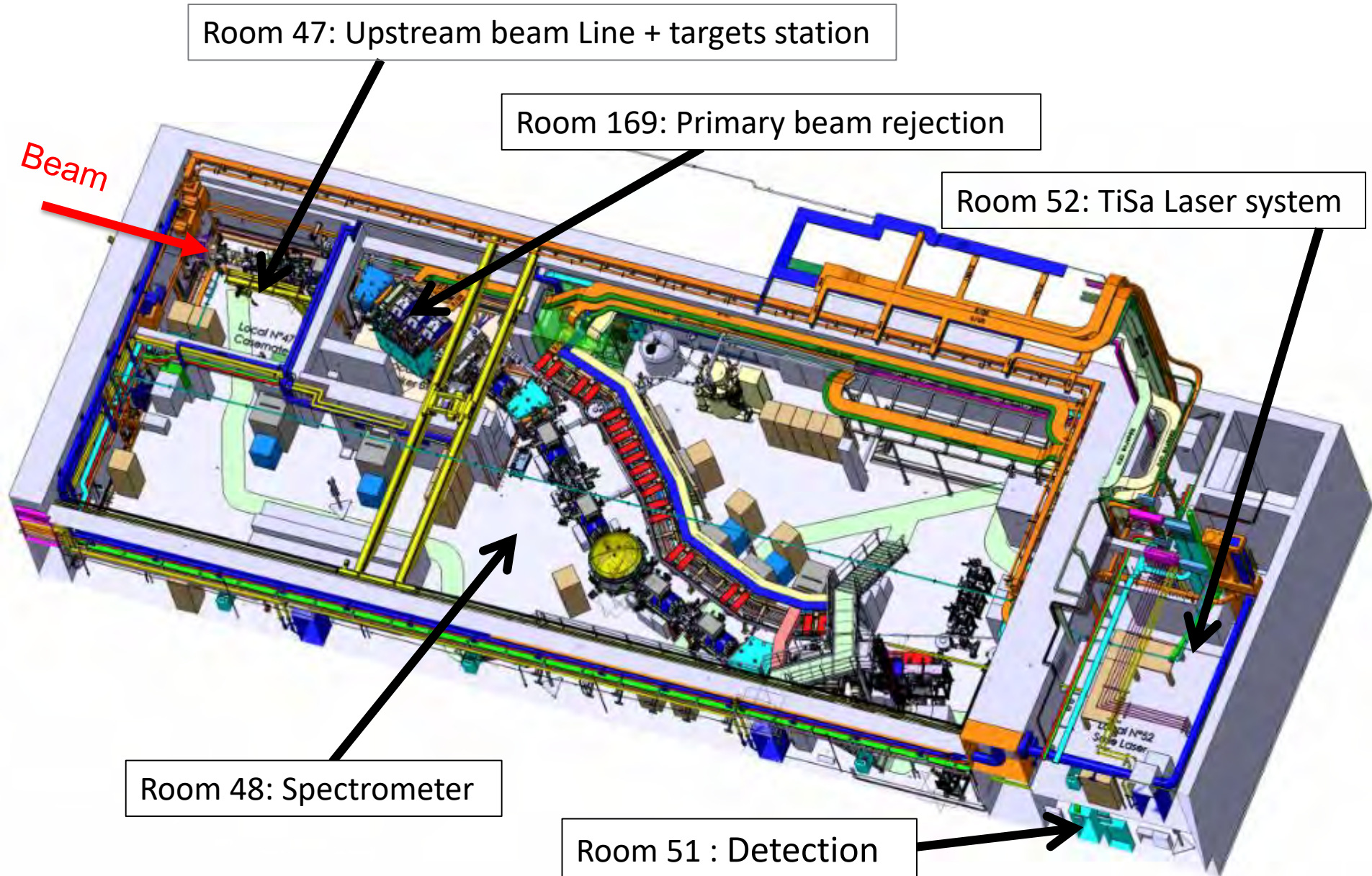
- 2020**
- Oct. 10th, End of phase 3, 4.8mA, 1ms/s
- Nov. 18th Power reached 16kW

- 2021**
- Aug to Dec Experiments with NFS

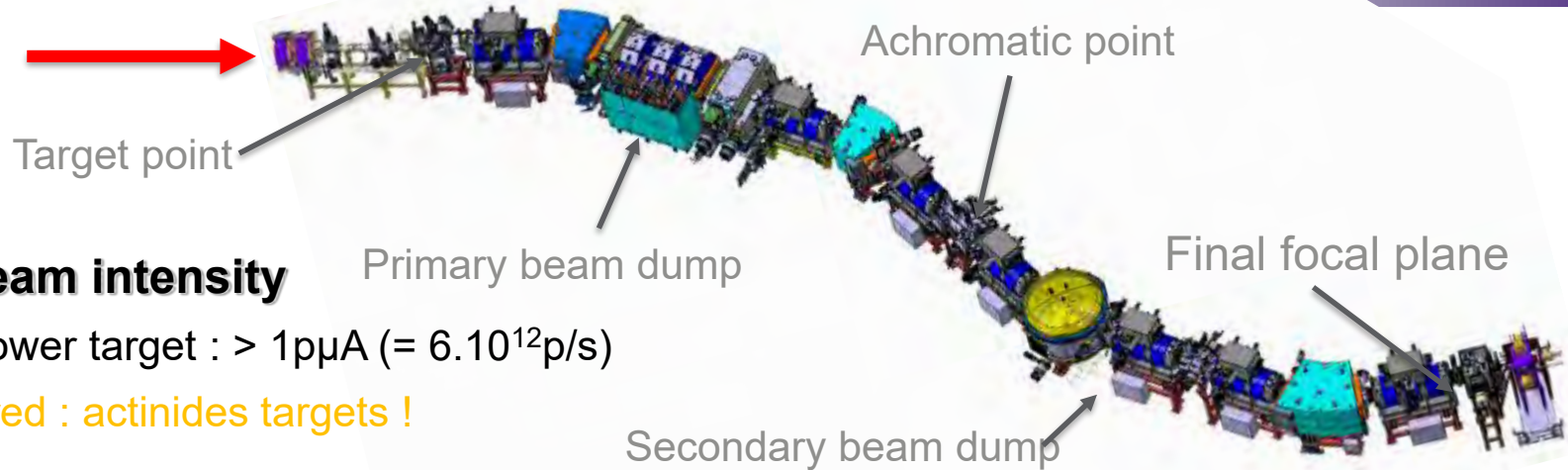
- 2022**
- Feb. 26th 5 mA Deuteron beam accelerated – 10 kW



Heavy Ions commissioning
2022



Performances



✓ High Beam intensity

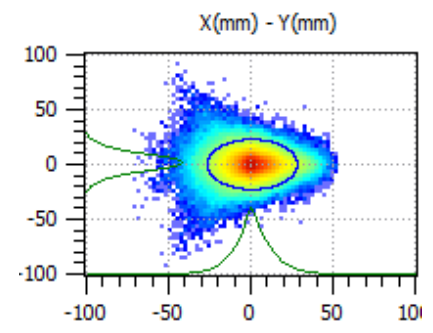
- High power target : $> 1\mu\text{A}$ ($= 6 \cdot 10^{12}\text{p/s}$)
- Required : actinides targets !

✓ Versatility

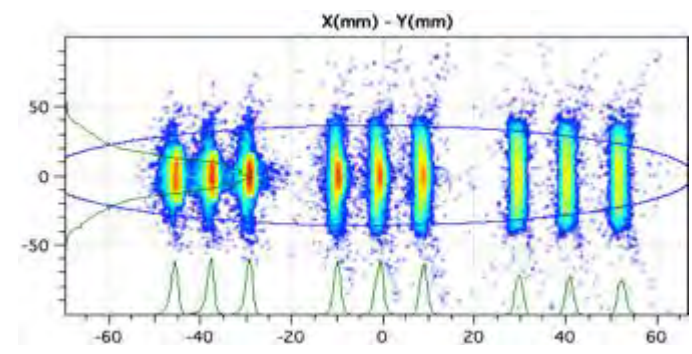
→ 2 extreme optical modes defined

1. Convergent : Simplest mode for 1st expt ($\Delta_{dp/p}=20\%$, $\Delta_p=90\text{mrad}$, $\Delta_\phi=140\text{mrad}$)
2. High mass res.: $M/\Delta M = 505$ ($\Delta_{dp/p}=16\%$, $\Delta_p=45\text{mrad}$, $\Delta_\phi=140\text{mrad}$)

Convergent mode

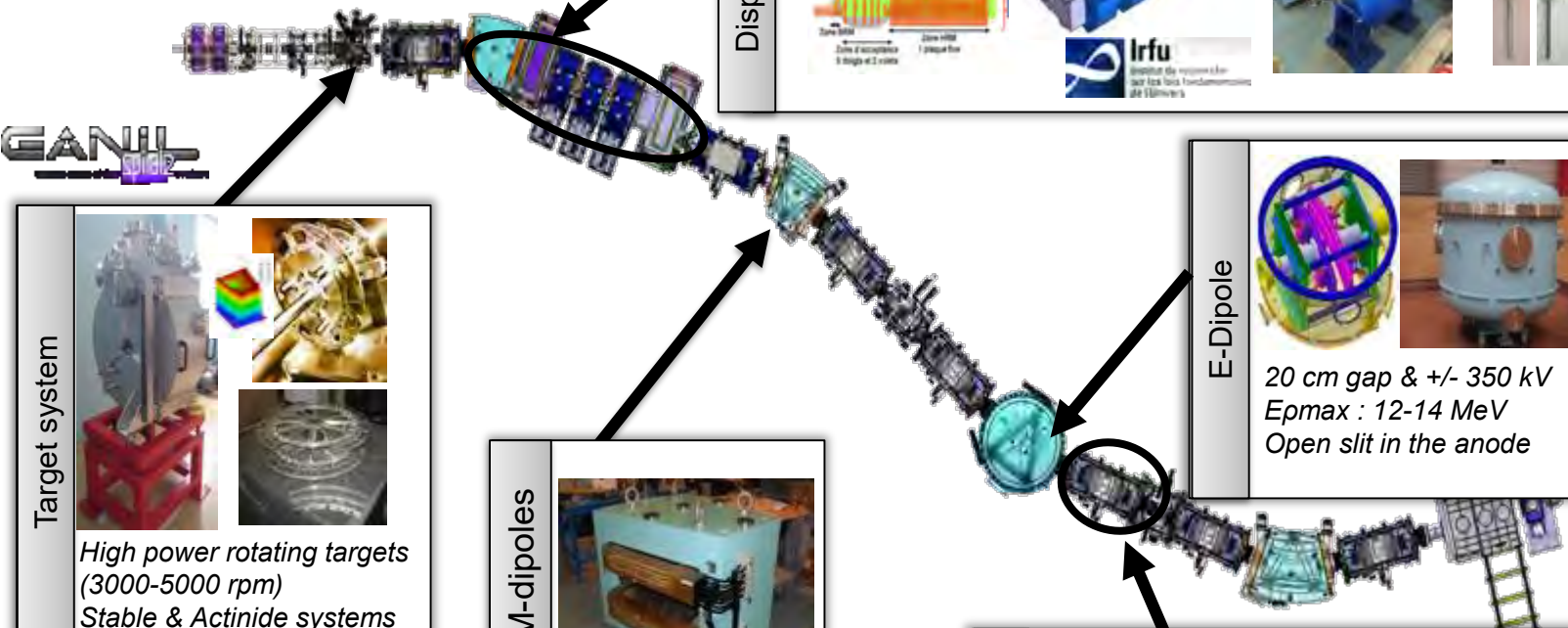


Mass Resolution mode



Main equipments

- ⊙ Multistep separation
- ⊙ Large acceptance
- ⊙ Variable modes
- ⊙ Mass resolution



Dispersive zone

(beam dump & Movable fingers)

tested for 5kW/cm²

lrfu

Target system

High power rotating targets (3000-5000 rpm)
 Stable & Actinide systems

(L=26m)

3 x M-dipoles

Large H & V gaps

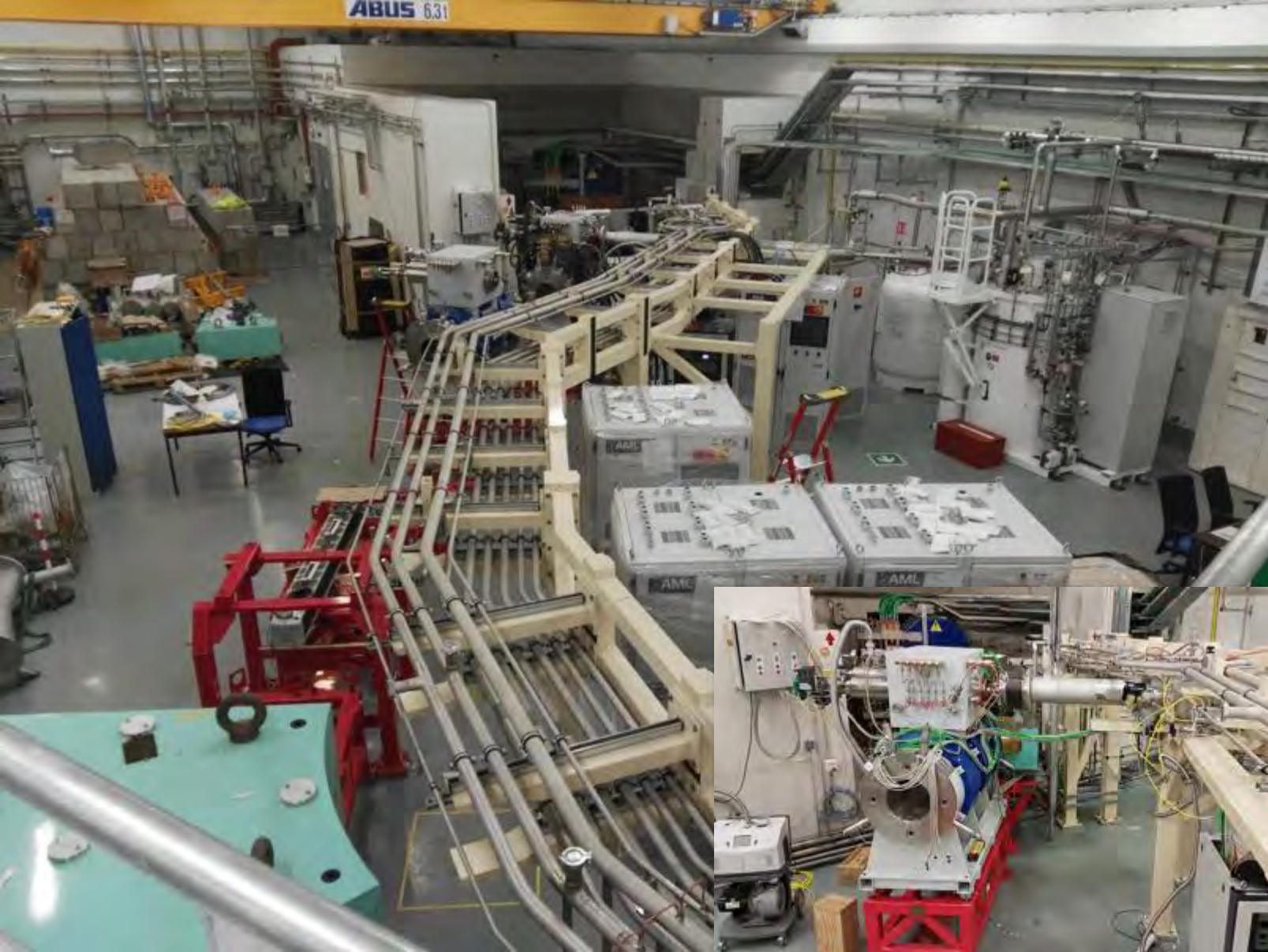
E-Dipole

20 cm gap & +/- 350 kV
 E_{pmax} : 12-14 MeV
 Open slit in the anode

IPN

SC Multipoles

Q+S+O fields PSS Cold Box

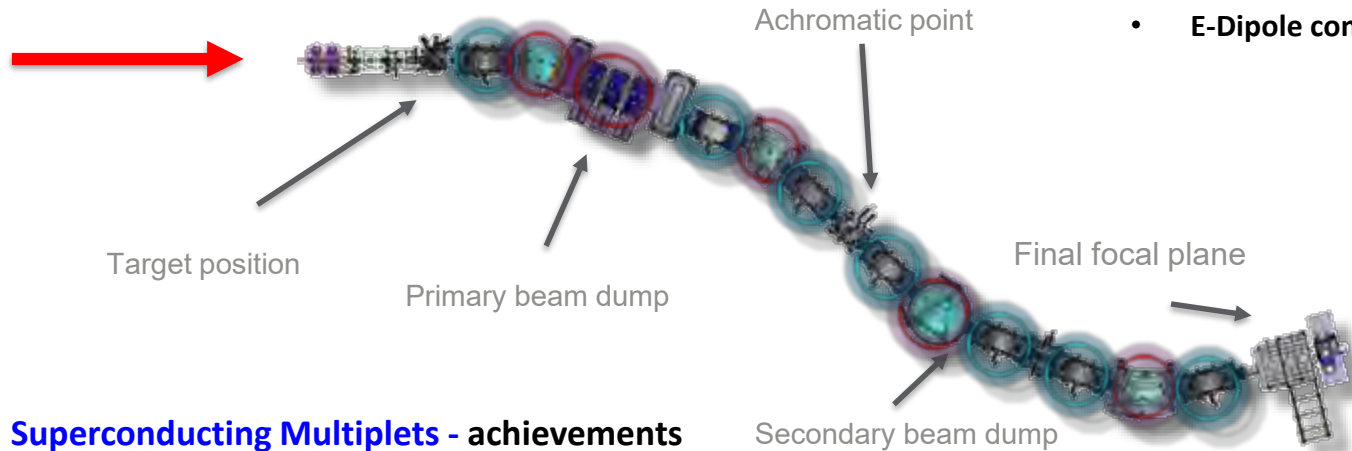




Latest news - Optical Elements

Room temperature elements - achievements

- Open Triplet – installation completed
- B-Dipoles (3) – installation completed
- E-Dipole – installation completed



Room temperature elements - next steps

- Ceramic feedthroughs (long delivery times)
- E-Dipole conditioning March-April 2023



Superconducting Multiplets - achievements

- Power Supplies Systems (PSS) commissioning completed & all 7 units installed
- 2nd SMT cryogenic test station available since Q1 2021
- 3D mapper delivered April 2021 (ANL WP) and first magnetic field measurement & alignment
- 3D magnetic field measurement ongoing

Superconducting Multiplets - next steps

- Finalize 3D magnetic field measurement & alignment in 2022, completion with the last SMT 7 test planned in Q3 2022
- All SMT in final position, tested and connected Q1 2023

SMT 1-6 arrived at GANIL – 2022
SMT 7 expected at GANIL – 2022

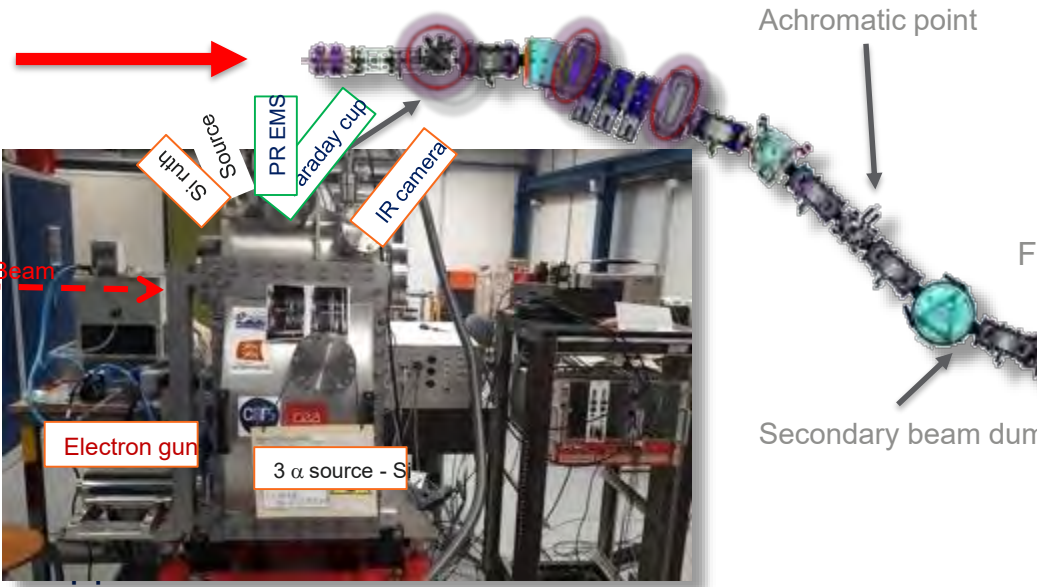
Courtesy of D. Ackermann

achievements

- **Target station:** being tested and commissioned offline
- **Beam Dump:** cooling system completed; upstream and downstream chamber installed on S³ line and vacuum tested

Target station

Beam dumps



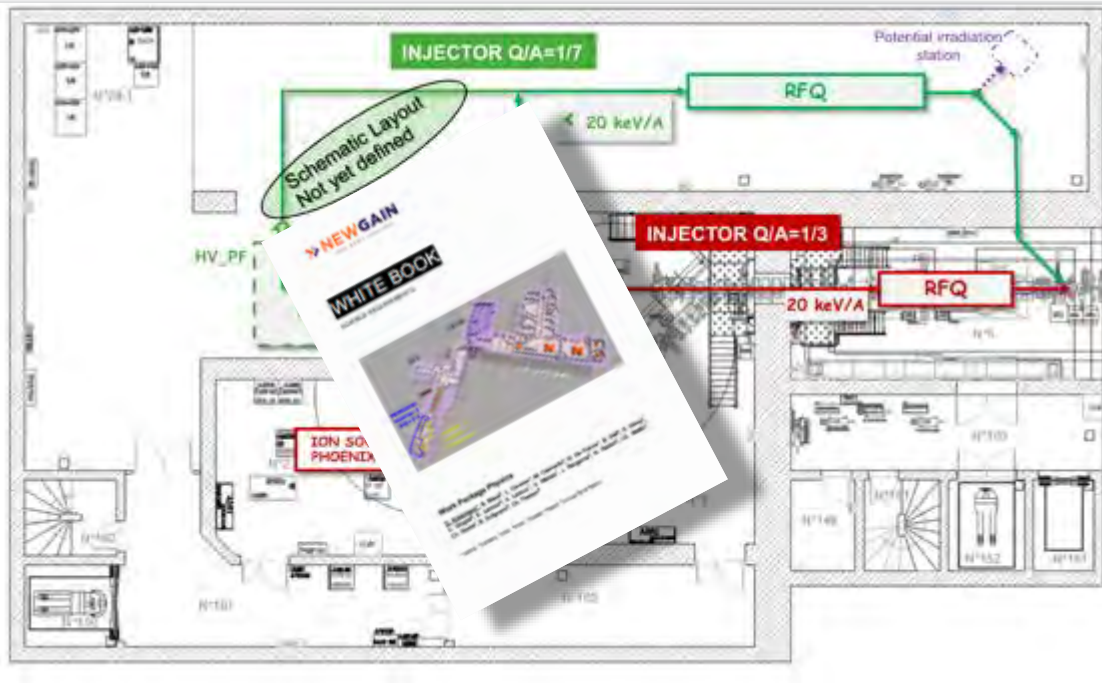
next steps

- **Target station:** mounting in S³ vault - September 2022
- **Beam Dump:** Internal translation mechanisms & 11 dump parts (5 fingers, 4 shutters, 2 stationary plates) & shielding integration planned in Q3 2022 at Irfu and Q4 2022 at S³
- **Actinide target development**

Courtesy of D. Ackermann

SPIRAL2 - NEWGAIN

- floorplan and design intensities



beam intensities

Ions	injector1 2023	NEWGAIN (injector2) 2028 ≥ 2030	
	Intensity (pμA) Phoenix V3 RFQ A/Q≤3	Intensity (pμA) Phoenix V3 RFQ A/Q≤7	Intensity (pμA) SC Ion Source RFQ A/Q≤7
¹⁸ O	80	*	375
¹⁹ F	>15	>40	>40
³⁶ Ar	16	70	45
⁴⁰ Ar	3.6	70	45
³⁶ S	2.3	*	*
⁴⁰ Ca	2.9	10	20
⁴⁸ Ca	1.2	10	20
⁵⁸ Ni	1.1	4	8
⁸⁴ Kr	0.1	10	20
¹³⁹ Xe	0.001	7	>10
²³⁸ U	<<0.001	0.1	6

Measured Estimated * -> no estimation

NEWGAIN White Book

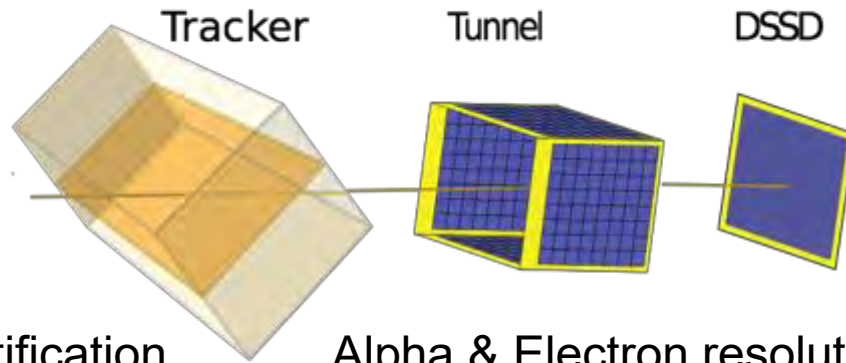
NEWGAIN time line

<https://www.ganil-spiral2.eu/scientists/ganil-spiral-2-facilities/accelerators/newgain/>



Courtesy of D. Ackermann

SIRIUS (Spectroscopy & Identification of Rare Ions Using S³)



Mass Identification
 $A/\Delta A \sim 300$

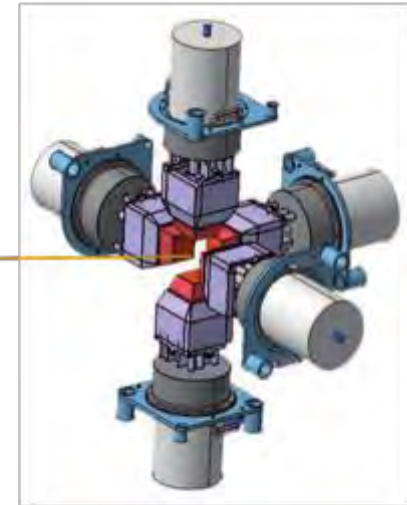
Isotopic identification

Alpha & Electron resolution
down to 14 keV

High resolution alpha and

Observables :
Decay mode
Half-life
Excitation energy
Transition mixing

Spontaneous fission



Y-ray efficiency of
40% at 121 keV

*Higher collected
statistics for the
energies of interest*

Digital Electronics with PSA & Absence of deadtime
Dual-gain preamplifiers

Discrimination between escaping α particles & conversion electrons

Access to short decay times

SIRIUS (Spectroscopy & Identification of Rare Ions Using S³)

Achievements :

DSSD

- Energy resolution within specifications
- Traces analysis ready

Tunnel

- Energy resolution within specifications
- Preamplifiers validated

Infrastructure

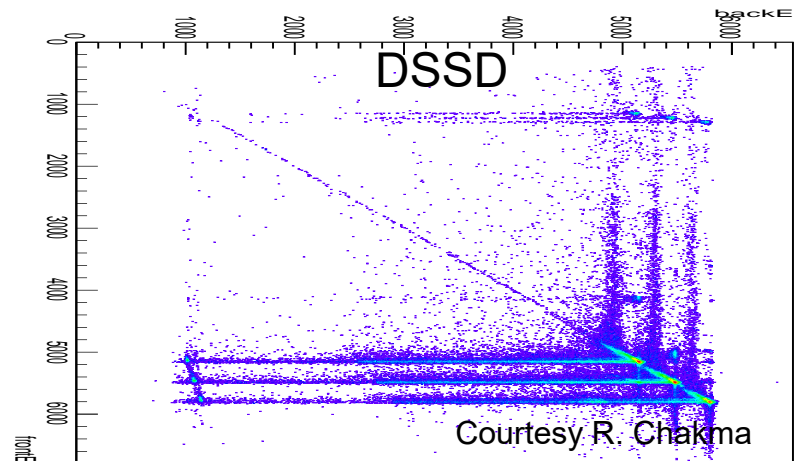
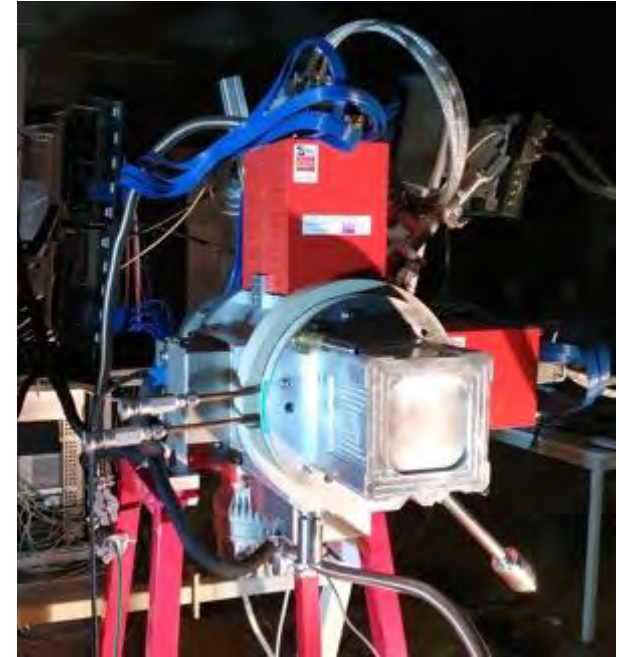
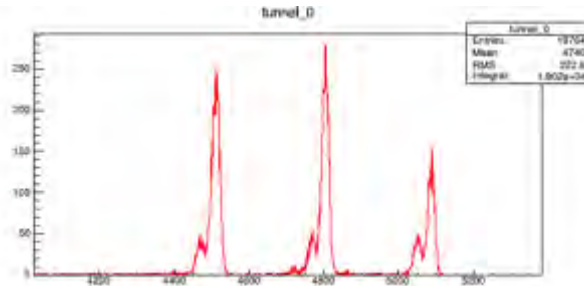
- Detector complete
- Full assembly this week.

Tracker

- Time & position resolution validated in beam
- X&Y : 0.4 mm Sigma
- Times resolution : 120ps Sigma

Milestones :

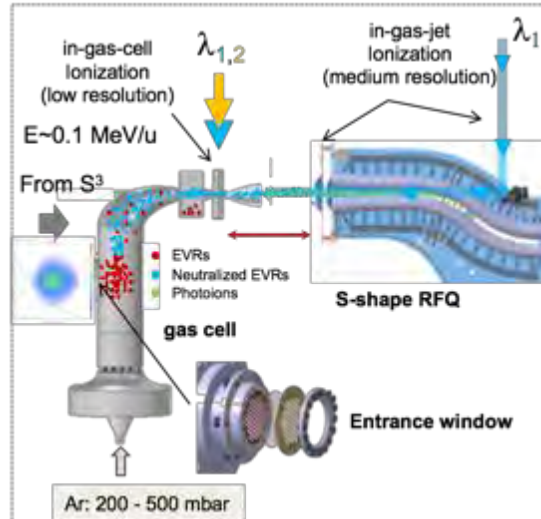
- Test of gain switching capabilities – Q2 2022
- Test of time of flight – Q2 2022
- Ready for Day 1 experiments in 2023/2024



REGLIS3

Observables :

Nuclear magnetic dipole moment
Nuclear Electric quadrupole moment
Variation of the Mean charge radii
Spin



PILGRIM

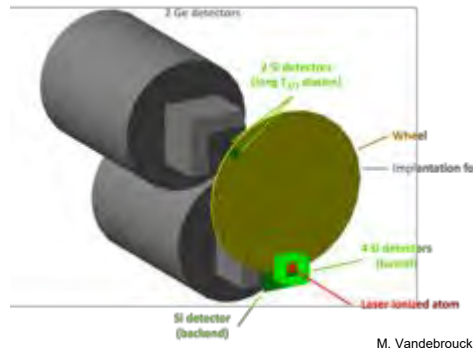


Observables :
Mass (100keV)

SEASON

Observables :

Decay mode
Half-life
Excitation energy



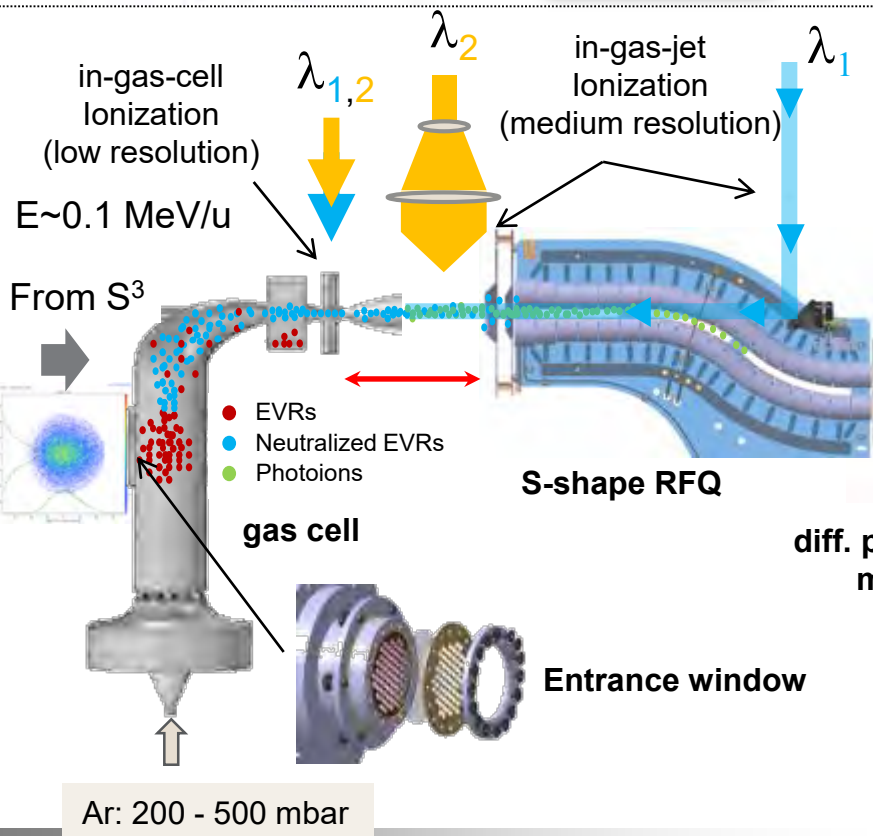
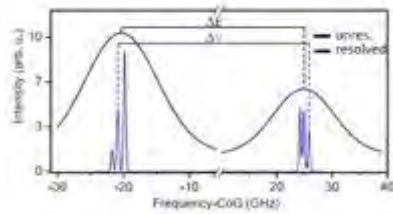
Complementary observables
Model independent spin measurement

MLL Trap



Observables :
Mass (1keV)
Decay time

S³-LEB & DESIR



Two lasers systems:
TiSa and dye

MR ToF MS
($m/\Delta m \sim 10^5$)

bender

Pulse up
(~ 3 kV)

towards DESIR

diff. pumping
mRFQ

QMF
($m/\Delta m \sim 100$)

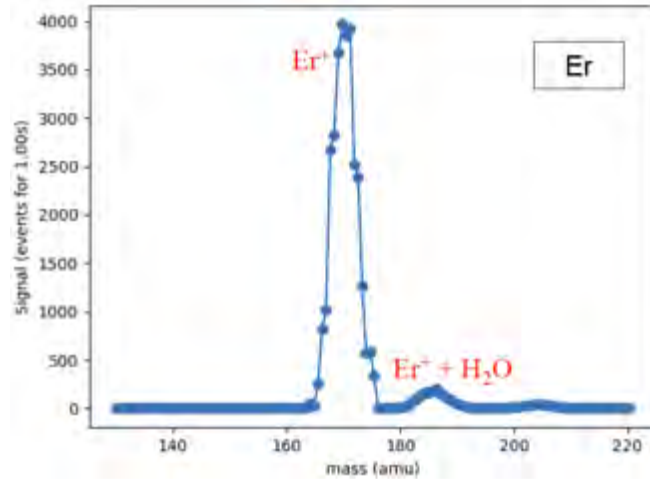
RFQ
buncher

He: $10^{-2} - 10^{-3}$ mbar

towards Multi Purpose Room - Identification/detection

- Provide pure & low energy beams from S³
- Perform medium resolution laser spectroscopy
 → 100-300 MHz & Eff > 10%
 (charge radii, spin, magnetic dipole moment, electric quadrupole moment)

Gas-Cell test : Courtesy A. Ajayakumar

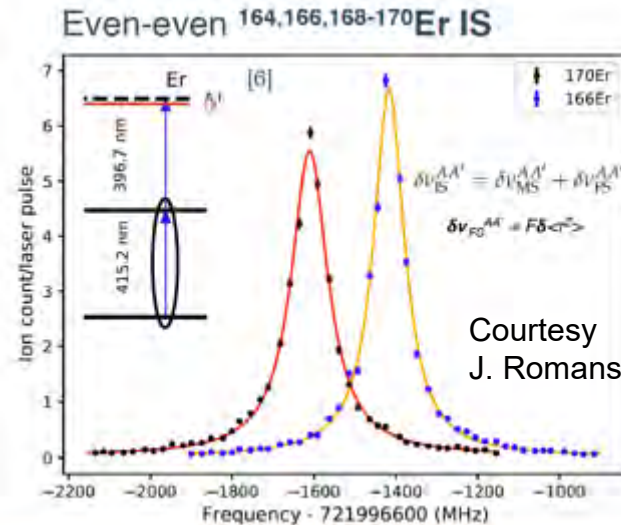


- Laser ions were detected in the gas cell
- Transmission till QMF has been tested
- Mass scans were performed
- Characterisation of laser ions in the gas cell

Milestones :

- *Ti:sa laser development @ GISELE for laser spectroscopy*
- *Development of efficient ionization scheme for day one experiment @ GISELE*
- *Test in gas jet high resolution @ LPC with Er: second half of 2022*
- *Ready for day 1 @ S³ in 2023/24*

Ionization Scheme development :



developed for Sn I RIS



Update S³ meeting in June 18th – 22nd 2018

S ³ detection system	proposed subject
LEB	2 focal plane detection systems
LEB	In-gas laser ionization and spectroscopy of ^{210,214} Ac and ^{213,215} Th
LEB	In-gas laser ionization and spectroscopy of silver isotopes down to N=7, ⁹⁴ Ag
LEB	In-gas laser ionization and spectroscopy of nobelium and Lawrencium isotopes
LEB	Search for octupole deformation
LEB	Single-particle states and proton-neutron interaction in the ¹⁰⁰ Sn region studied through the neutron deficient In nuclei
LEB	Physics topics: Mass measurements and laser spectroscopy around ¹⁰⁰ Sn
LEB	Mass measurements and laser spectroscopy on n-deficient isotopes in A~80 region of deformation
LEB	• SHN Fundamental properties of Fermium isotopes around N=152 <i>basic nuclear properties (masses, ionization potential, quadrupole moments, radii ...)</i>
LEB	Dipole moment in molecules K-isomers
LEB	Spectroscopy and mass measurements on deficient Rh isotopes: from shell to shapes single partial states
SIRIUS	Detail study of the K-isomers new isotopes
SIRIUS	Detail spectroscopy of odd-Z nuclei odd-Z nuclei
SIRIUS	Detail spectroscopy of N=82 through recoil decay-tagging and proton emission from isomeric states reaction mechanism
SIRIUS	Search for the end of stability of the No isotopes N=152, 162
SIRIUS	Search for new isotopes: ²⁵² Rf and ²⁵⁶ Rf
SIRIUS	Alpha-decay spectroscopy of odd-Z isotopes in fermium region • N=Z
SIRIUS	Decay spectroscopy of odd-Z isotopes in fermium region <i>basic nuclear properties (masses, ionization potential, quadrupole moments, radii ...)</i>
SIRIUS	Search for high-K isomers single particle states
SIRIUS	Search for cluster radioactivity in the region above ¹⁰⁰ Sn ¹⁰⁰Sn region
SIRIUS	N=162 (LoI) cluster radioactivity
SIRIUS	Mechanism de réaction...
SIRIUS	The ¹⁰⁰ Sn Factory: Super-allowed alpha decay ¹¹² Ba- ¹⁰⁸ Xe- ¹⁰⁴ Te- ¹⁰⁰ Sn
Others	In-beam neutron-rich spectroscopy

Thank you for your attention



SHE France



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