

# AXIS 1: NUCLEAR PHYSICS CENTER

*Scientific Advisory Board: meeting n°1*



# NUCLEAR PHYSICS CENTER

Presentation of the DESIR work package

*J.-C. Thomas (GANIL), L. Hayen (LPC Caen)*



# DESIR @ GANIL



## « Decay , Excitation and Storage of Radioactive Ions »

Exotic decay modes    Shape, size, structure of the nucleus    Mass, correlations  
 -> Fundamental interactions and nuclear structure as a function of (N,Z)

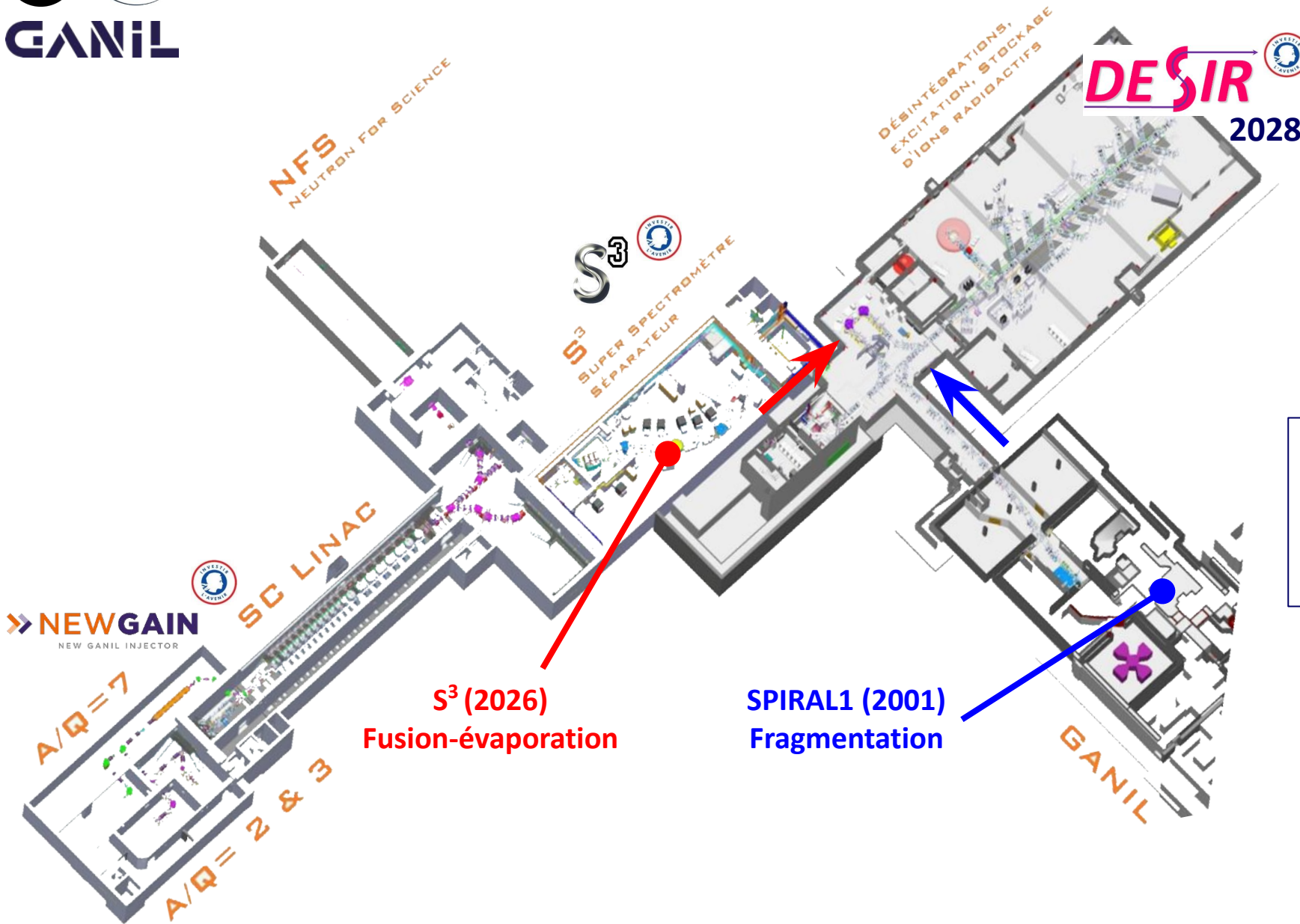
### A new GANIL users facility

- Study of the fundamental properties of the atomic nuclei and underlying forces
- With a high precision using ultra-pure samples of radioactive ions manipulated at very low-energy
- Taking advantage of the various RIBs production methods
- In complementarity to S<sup>3</sup>(-LEB) and other GANIL installations

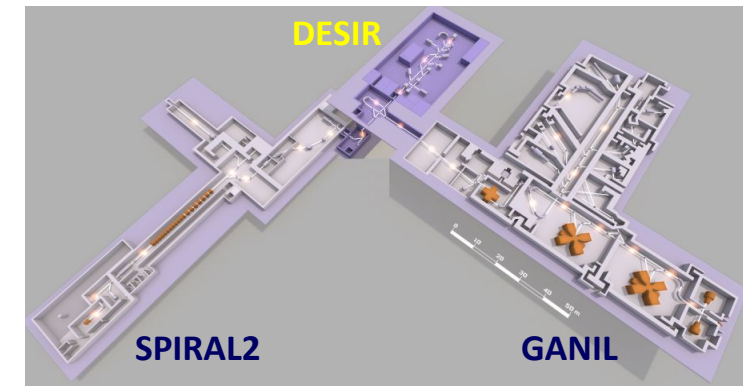
### CaeSAR project

- *Strong contribution to process installation and Day 1 experiments*
- *Strengthening of GANIL and LPC Caen collaboration*
- *Increasing of the scientific impact and visibility of the Nuclear Physics Center!*

# DESIR @ GANIL



Building delivery: mid-2025  
 Commissioning (stable beams): 2027  
 Day 1 experiments (RIBs): end 2028  
**CaeSAR -> December 2029**



# DESIR physics program

- Collinear laser-spectroscopy
- Correlations in  $\beta$  decay (MORA)
- Mass meas. (PIPERADE, MLLTrap)
- (Trap-assisted) decay spectroscopy

LUMIERE

DETRAP

BESTIOL

- ✓ Size & Shape
- ✓ Deformation

(Super) Heavy nuclei

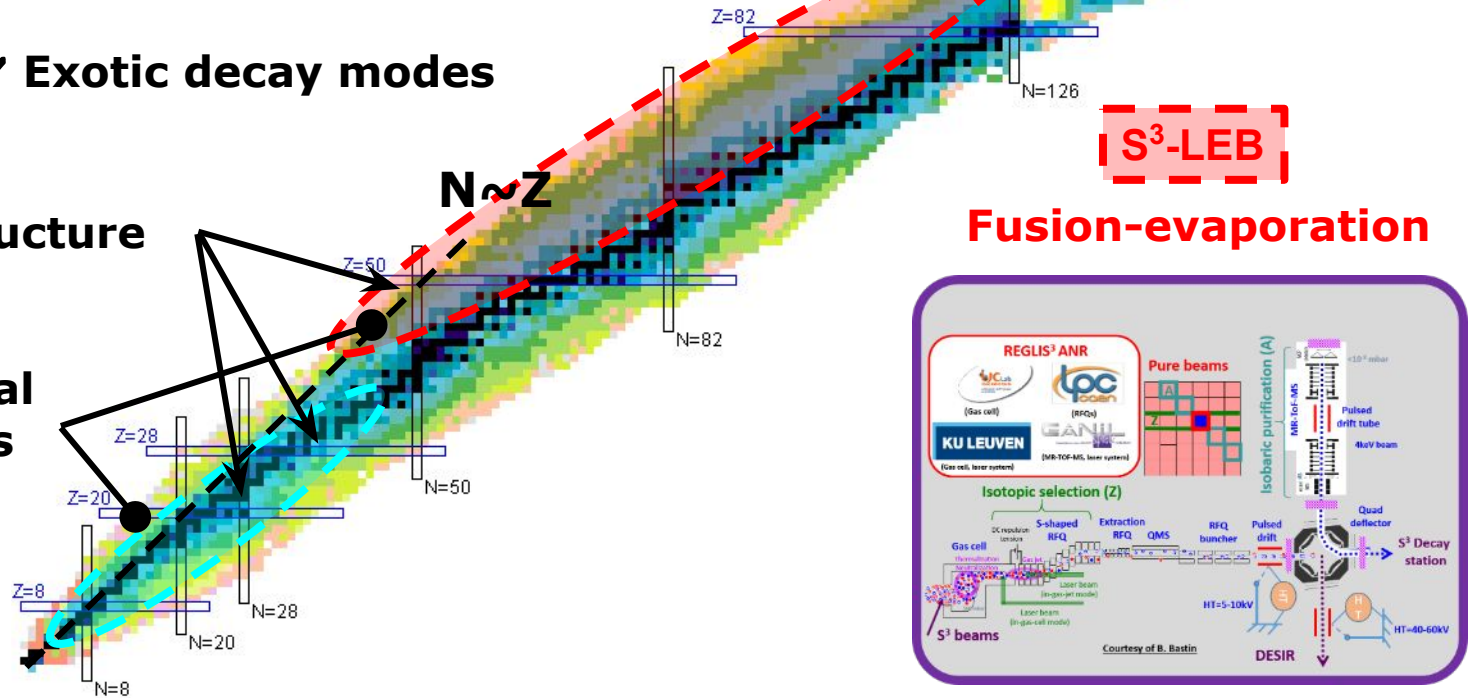
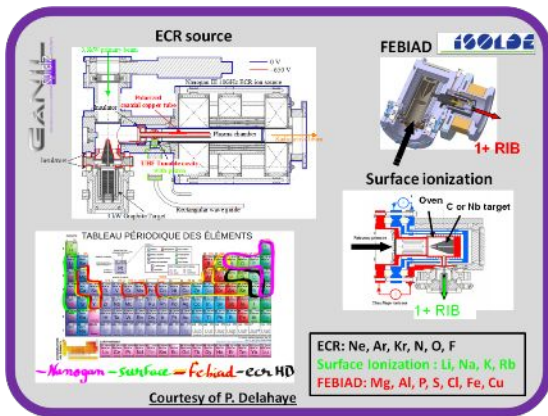
✓ Exotic decay modes

✓ Nuclear structure

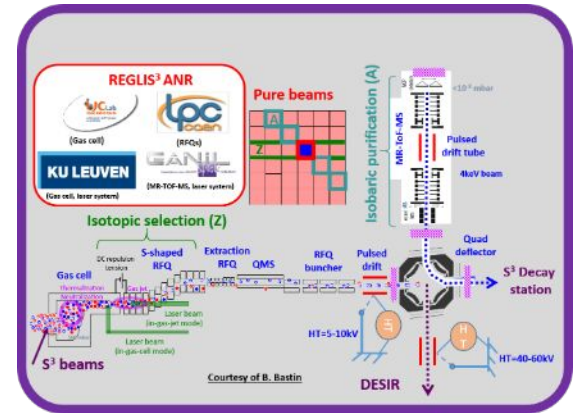
✓ Fundamental interactions

SPIRAL 1

Fragmentation

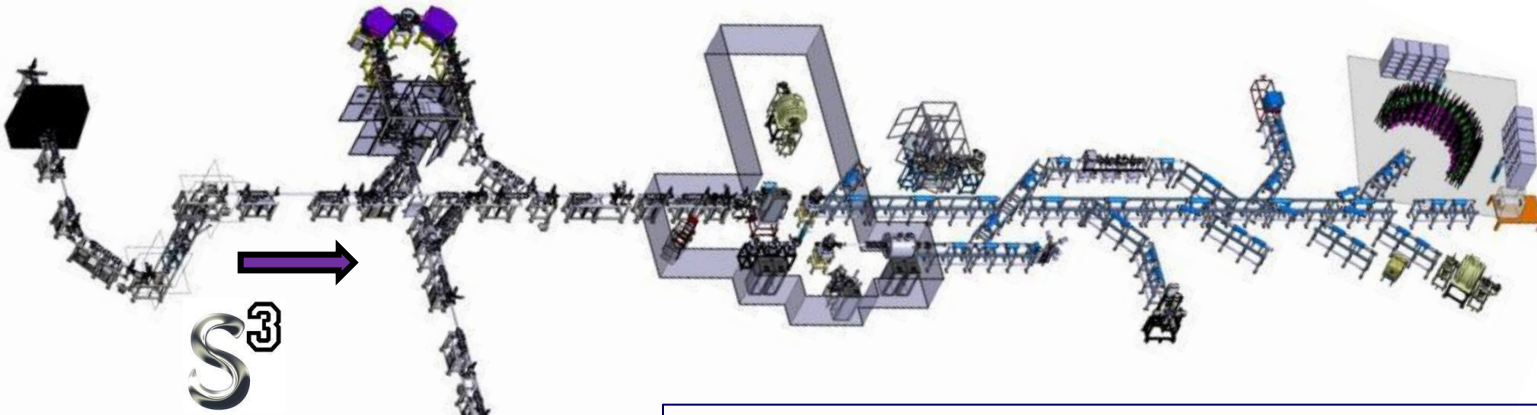


Fusion-evaporation



# Transport beam lines

1+ ions, < 60 keV, < 80  $\pi$ .mm.mrad – fully electrostatic



DESIR Hall

Test bench



LP2i  
Bordeaux

Ph. Alfaut, LP2iB

SP1 -> DESIR beam line



V. Watt-Morel, GANIL

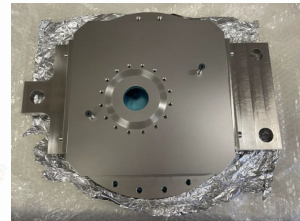
SPIRAL1

- Junction beam lines from SPIRAL1 and S3-LEB to the DESIR Hall: ~100 m
  - Installation starting by the end of 2025
- > ***CaeSAR: Research technician - 36 months – Starting in 2025***

Example: 45° deflector assembly

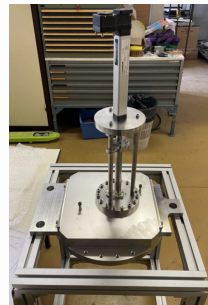
UC Lab  
Irène Joliot-Curie

Base assembly

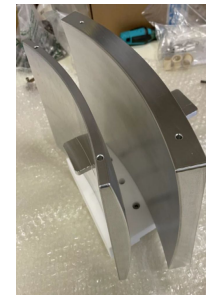


L. Perrot, IJCLab

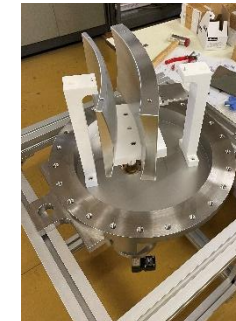
Insertion



Pole assembly



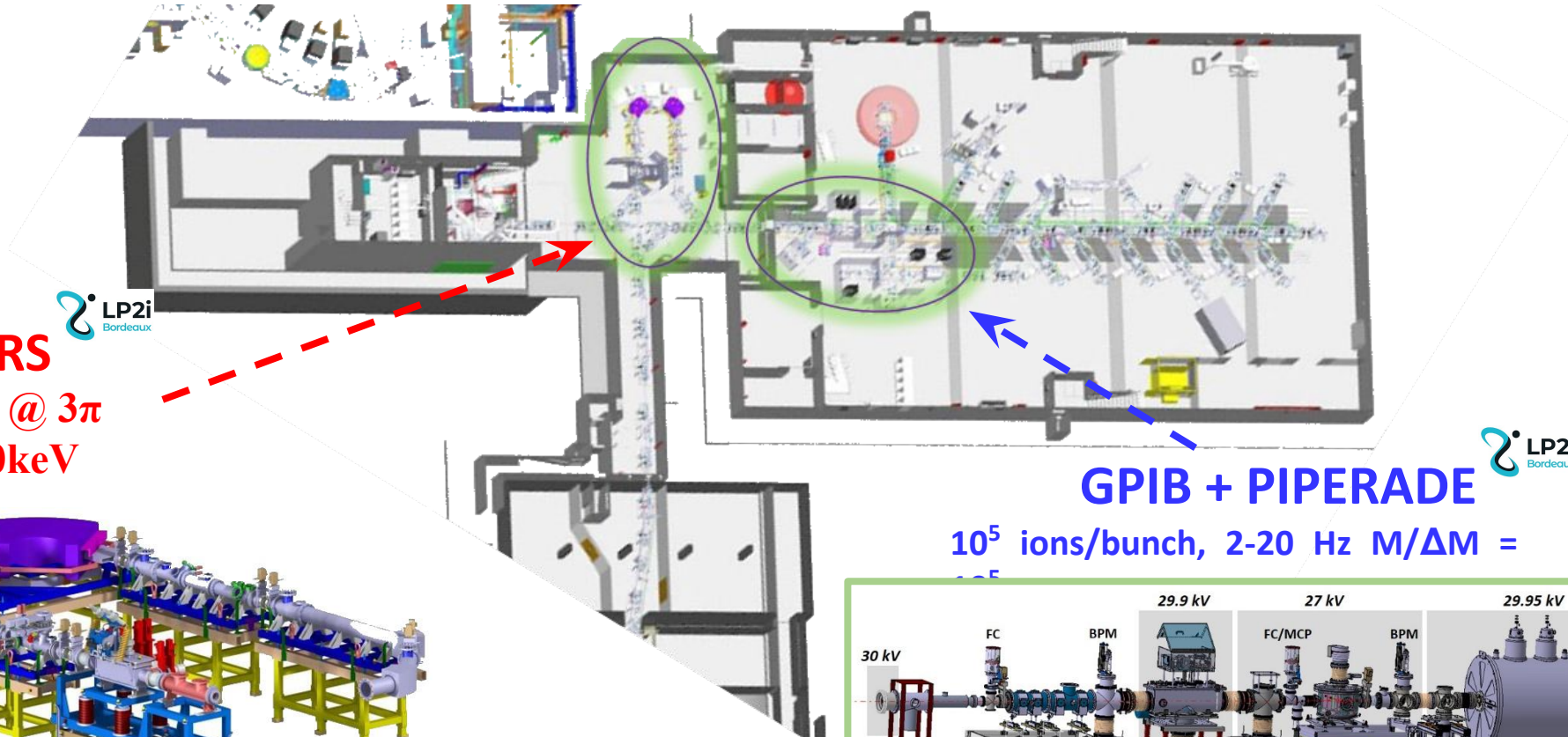
Internal part



Upper part

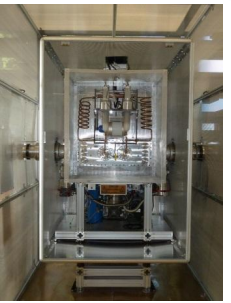
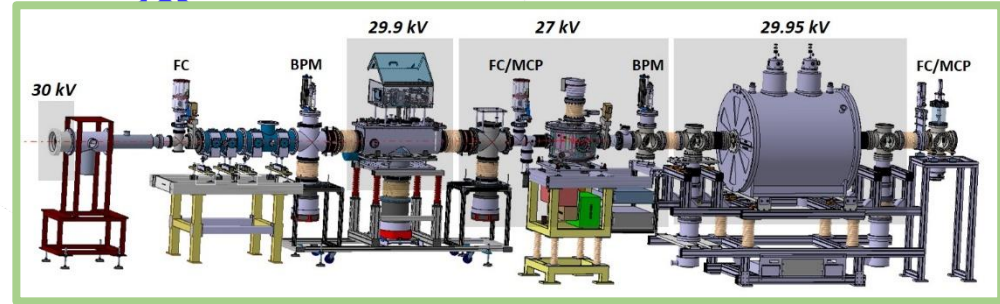
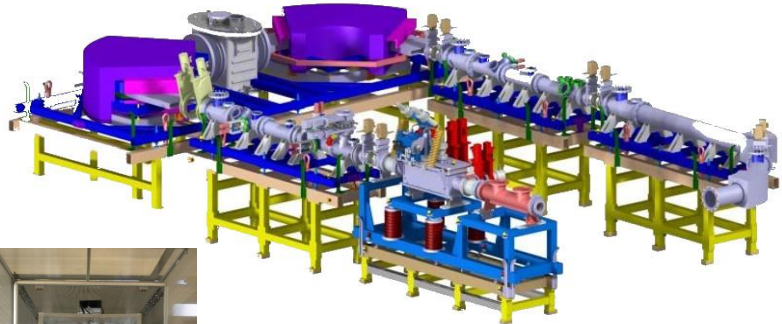


# Beam purification and preparation



**RFQ-1P + HRS**
  
 $M/\Delta M = 20,000 @ 3\pi$ 
  
**mm.mrad / 60keV**

**GPIB + PIPERADE**
  
 $10^5$  ions/bunch, 2-20 Hz  $M/\Delta M =$



Commissioning at LP2iB

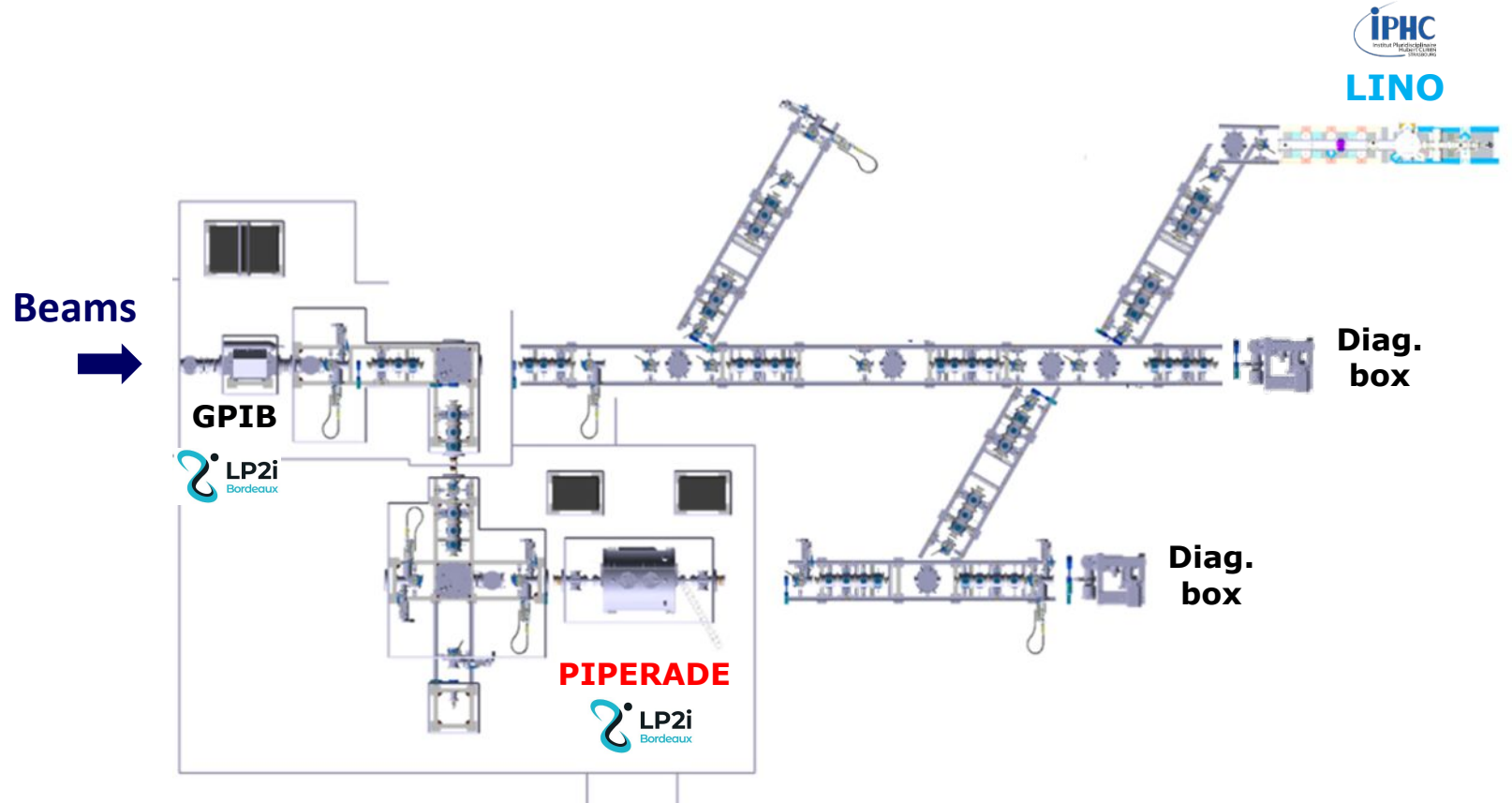
Commissioning at LP2iB

Refurbishment at LPC Caen

- Installation and commissioning: 2026-2027 <-> **CaeSAR Research technician involvement**
- + GANIL-LPCC project for the conception of a MR-ToF-MS (coll. TU-Darmstadt): 2026-2028

# Experimental equipment: timeline

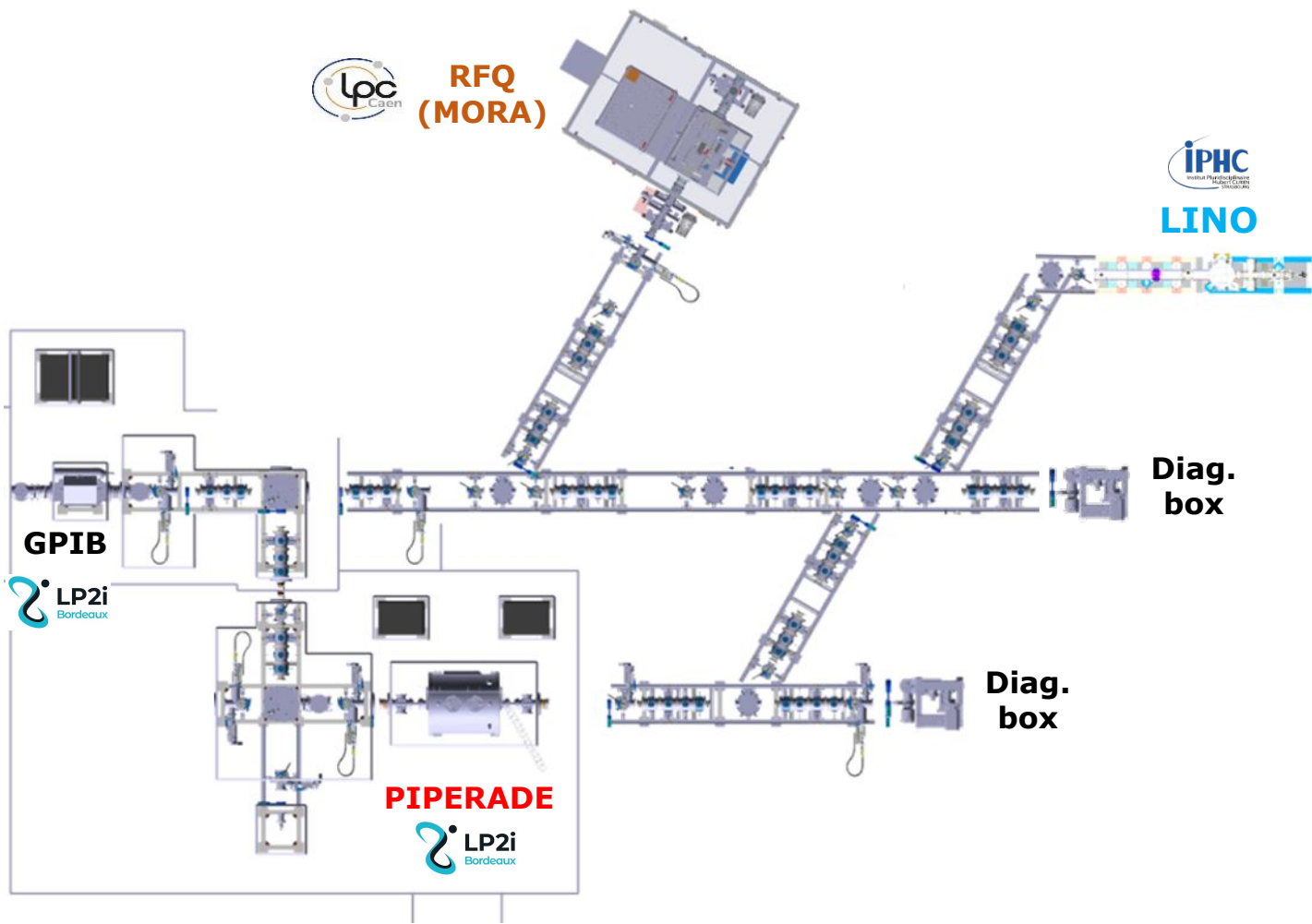
S2 - 2026: GPIB + **PIPERADE** + fluorescence laser line (**LINO**)





# Experimental equipment: timeline

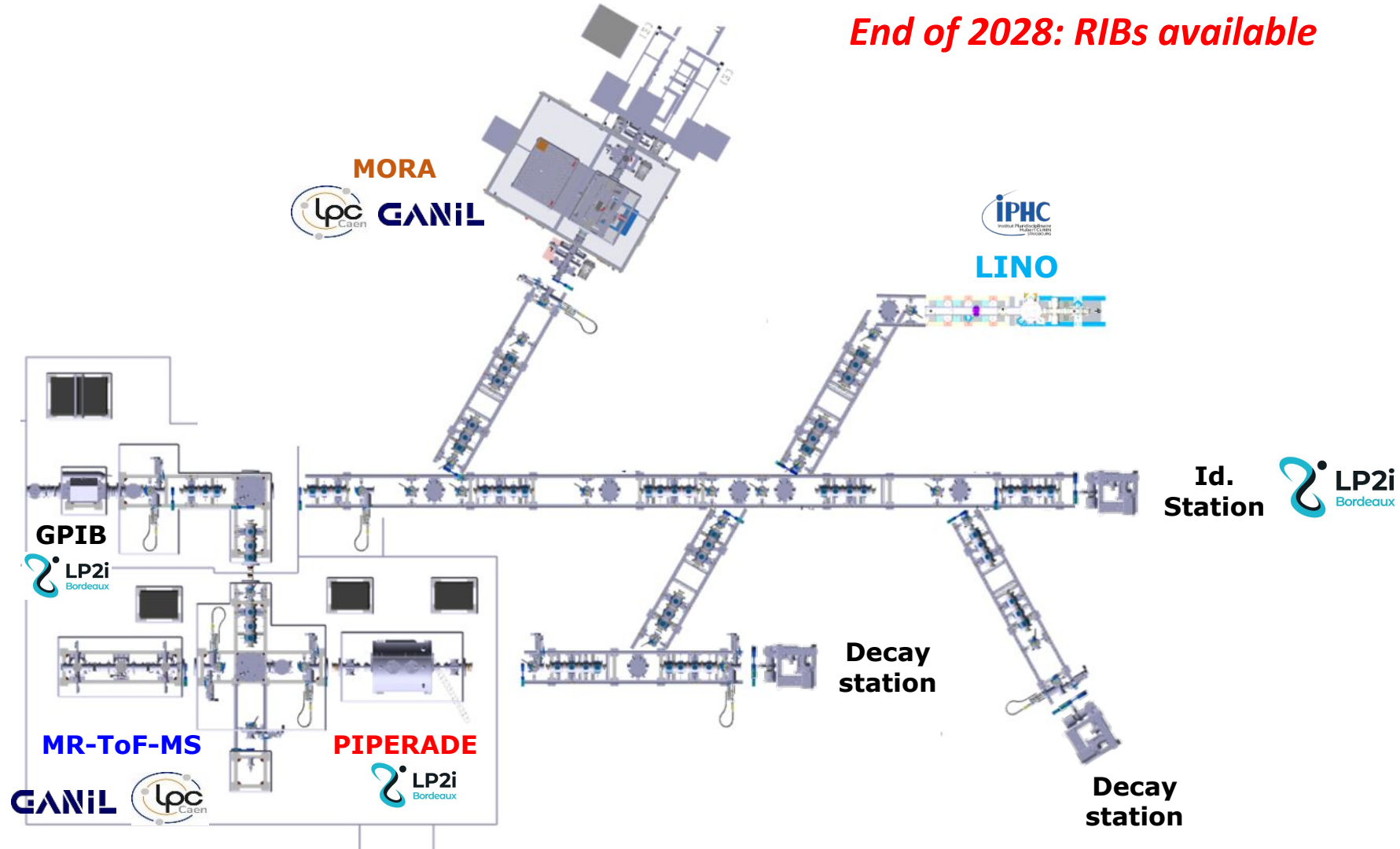
S1 - 2027: **MORA** cooler-buncher (RFQ)



# Experimental equipment: timeline

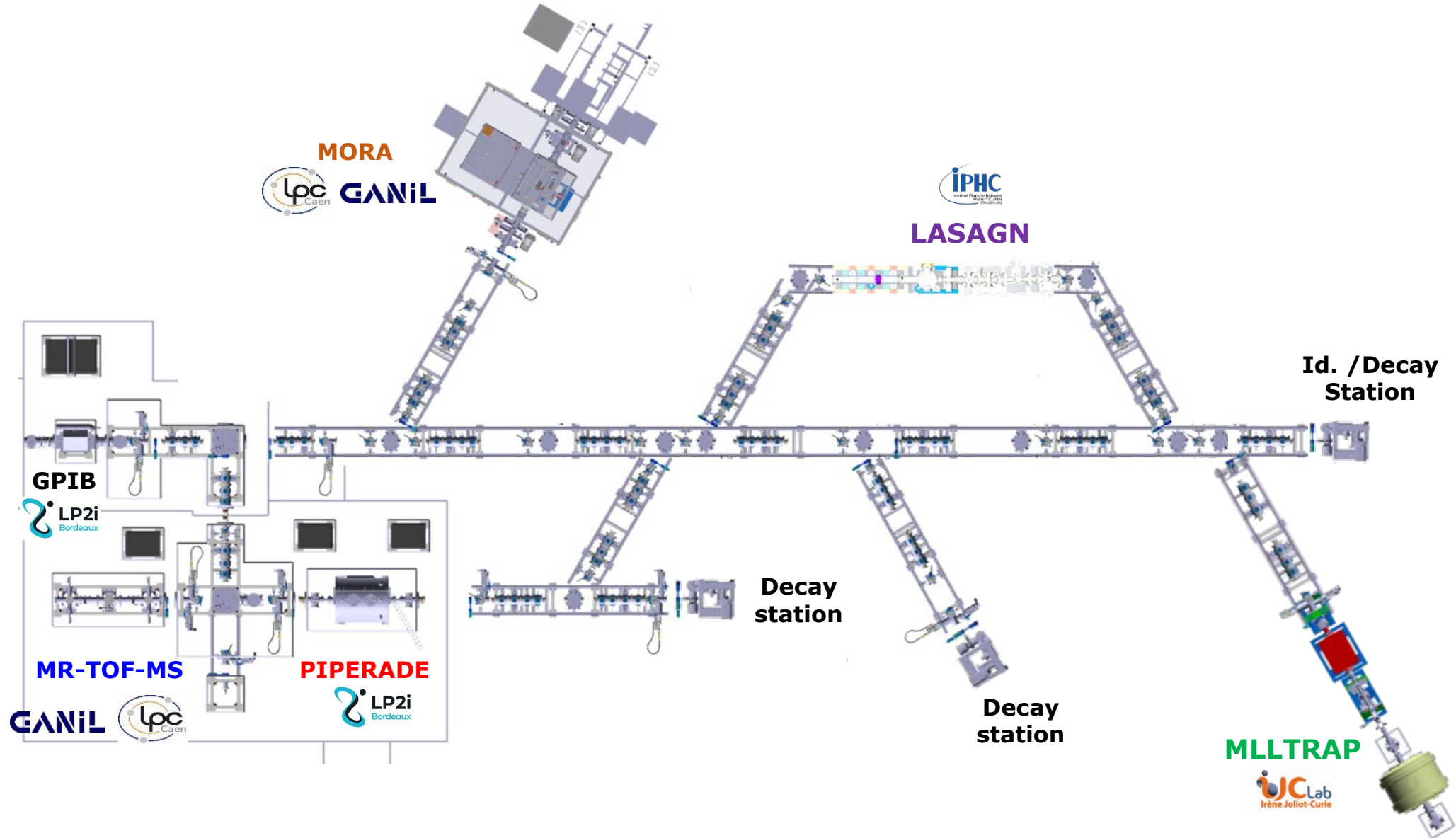
2028: **MORA** completed, **MR-ToF-MS**, decay stations

*End of 2028: RIBs available*



# Experimental equipment: timeline

2029: collinear laser spectroscopy (**LASAGN**) completed, **MLLTrap**



## **GANIL: Chair - External - 36 months, Post-doc - 18 months, PhD student - 36 months**

- *Research project driven by the first equipment available at DESIR and managed by GANIL  
-> GPIB + PIPERADE for high-precision mass measurements and trap-assisted spectroscopy:  
fundamental interaction studies, nuclear structure, astrophysics...*
- *Scientific coordination of the GPIB + PIPERADE installation and commissioning at GANIL  
-> From the end of 2025 (setup installation preparation) to the end of 2028 (first RIBs)  
=> Contract extension DESIRable beyond 2028 to allow the Chair running experiments with RIBs*
- *Help of a research engineer hired by GANIL between 2025 to 2028 (4 years)*
  
- *PhD student: Oct. 2026 -> Oct. 2029*
- *Post-doc: S2-2026 - Dec. 2027*

## **LPC Caen: Post-doc - 18 months, PhD student - 36 months**

Leader in several world-class experiments, benefit from proximity to GANIL

*DESIR* brings **high beam purity**, significant benefit for **high-precision measurements**

*CaeSAR* brings **support in HR** enabling **flexibility** to **optimize DESIR's high impact**

LPCC has strong roots in fundamental symmetries, current efforts in

- Ion trapping (MORA)
- Beta spectroscopy (bSTILED)
- Novel detection methods (ASGARD)

and significant efforts in laser spectroscopy (S3-LEB)

Planned installation at DESIR in 2028

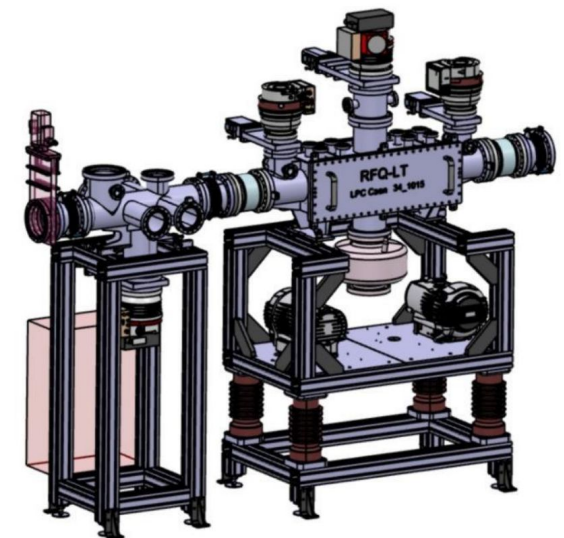
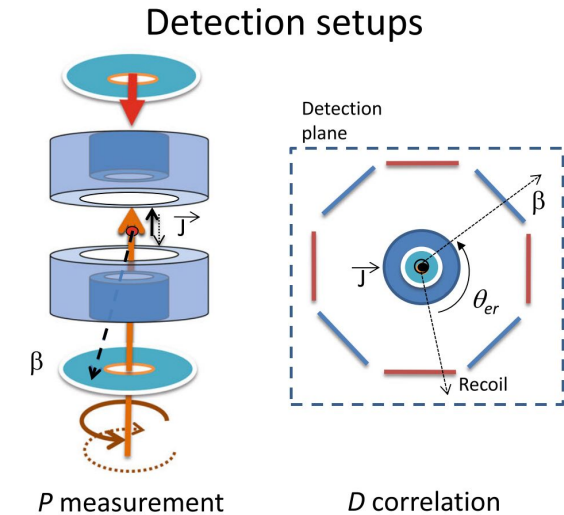
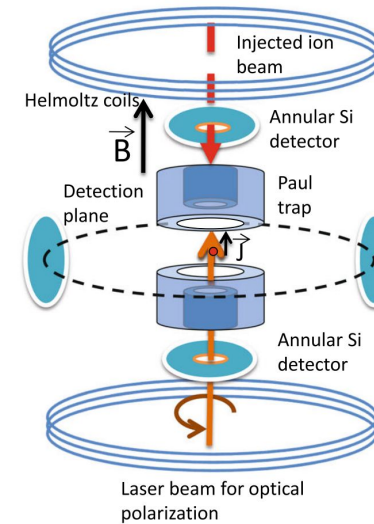
LPC is leading **RFQ-CB coupling** of MORA@DESIR

Relies on **laser system** for optical polarization

Space at DESIR is foreseen (Laser room), but requires

- setup and transport of laser system
- extension to enable select isotopes ( $^{23}\text{Mg}$ ,  $^{39}\text{Ca}$ , and future candidates)
- measurement and fine-tuning

Overlap with LASAGN, synergy possible



# bSTILED CaeSAR opportunities

Precision measurements in  ${}^6\text{He}$  beta decay at GANIL

Systematic effect analysis underway, statistical precision already competitive

Study of detector non-linearity effects look promising

bSTILED-Phase II at DESIR in the next 3+ years can benefit strongly from CaeSAR support

Bremsstrahlung photons  
from collimator

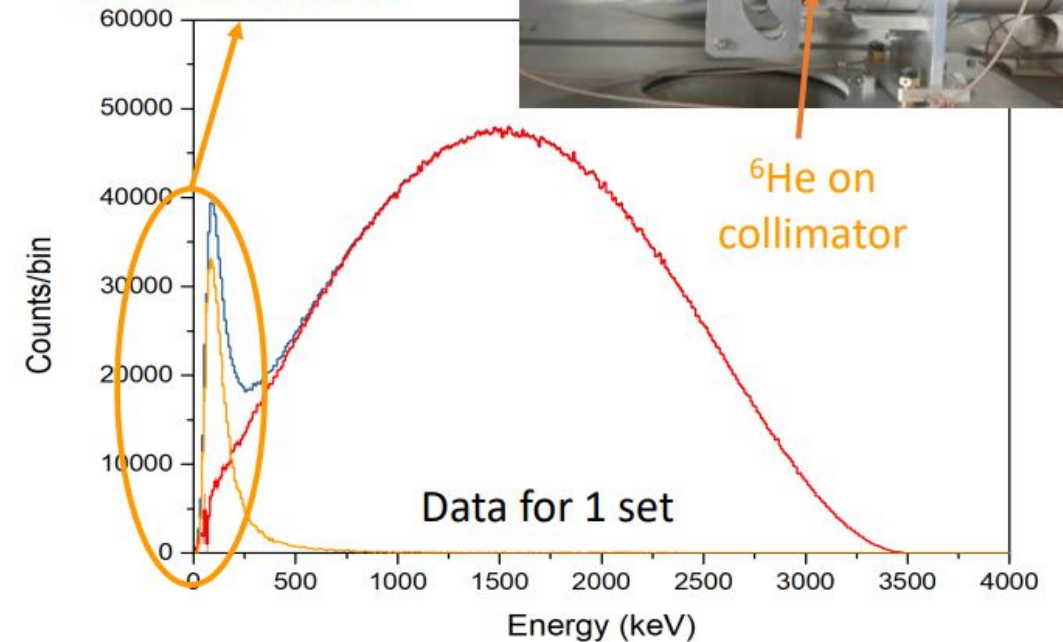


Fig by X. Flechard, Conseil Scientifique June 24

First **precise recoil spectroscopy** after beta/EC decays, planned at DESIR (28-)

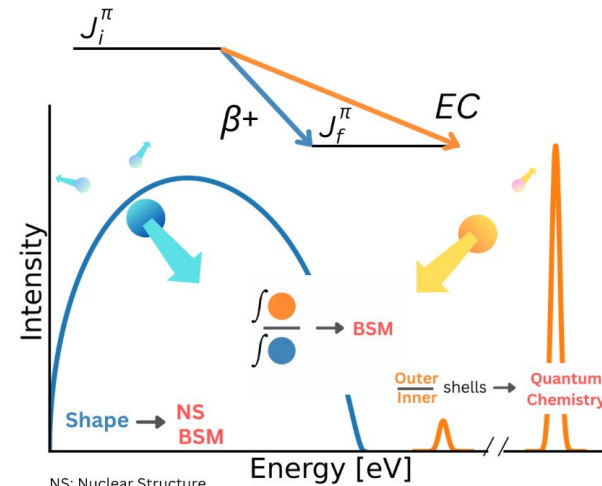
Beyond Standard Model searches

Open doors to:

- Nuclear structure
- Auger spectroscopy for medical studies

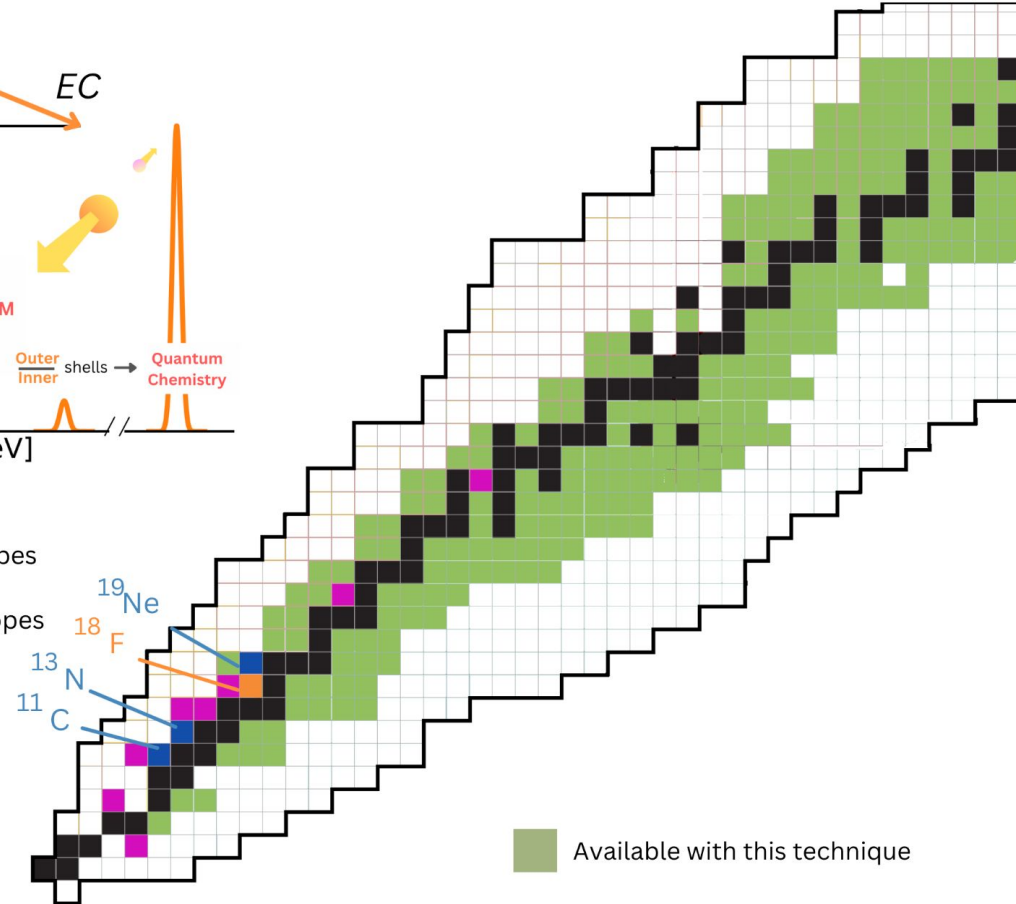
Submitted for ERC, support from Label D'Excellence de Normandie

Unique project, HR gets training in **quantum sensors**



NS: Nuclear Structure  
BSM: Beyond Standard Model

- Proposed Type-I isotopes
- Proposed Type-II isotopes
- Isotopes of interest



■ Available with this technique





Besides highlighted experiments (MORA, bSTILED, ASGARD), opportunities can be available in

- Construction of MR-ToF-MS
- Sympathetic laser cooling
- Support of the LINO/LASAGN program

within the context and timeline of CaeSAR

**Flexibility offers opportunity for impact maximization at DESIR**

Schedule for HR (Postdoc + PhD) depends on **developments in the next year** (bSTILED, ASGARD), and overlap with DESIR operation (2027+ for stable beam, 2028+ radioactive)

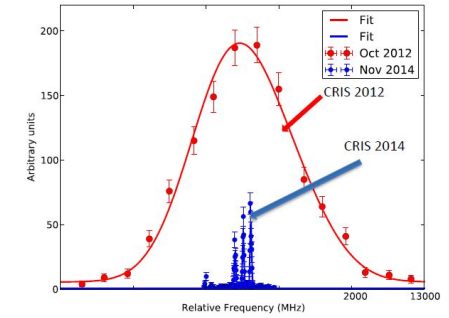
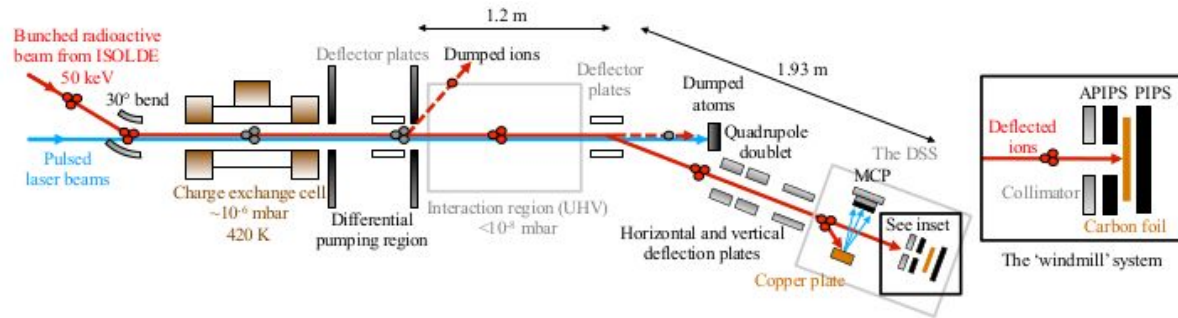
# Backup slides

## Laser Utilization for Measurement and Ionization of Exotic Radioactive Elements

### □ LASAGN (L. Lalanne, IPHC)

#### ▪ Collinear laser spectroscopy (CRIS like, ISOLDE)

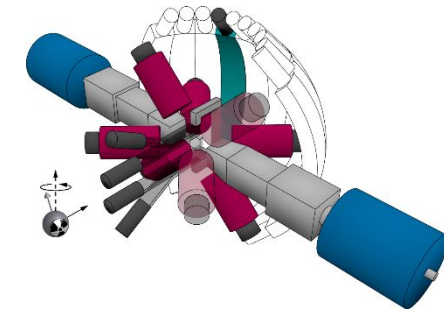
-> hyperfine structure (magnetic and quadrupole moments, mean square charge radii)



#### ▪ Optical pumping line (LINO, D. Yordanov et al.)

->  $\beta$ -decay study of laser polarized beams

Commissioned at ALTO (IJCLab)



D.T. Yordanov et al., JINST 15 (2020) P06004

⇒ Static moments, shape evolution, nuclear structure

*P. Delahaye, GANIL, L. Hayen, LPC Caen*

- RFQ-CB associated with a Paul trap
  - >  $\beta$ - $\nu$  angular correlation coefficient
  - > D correlation with laser polarized beams

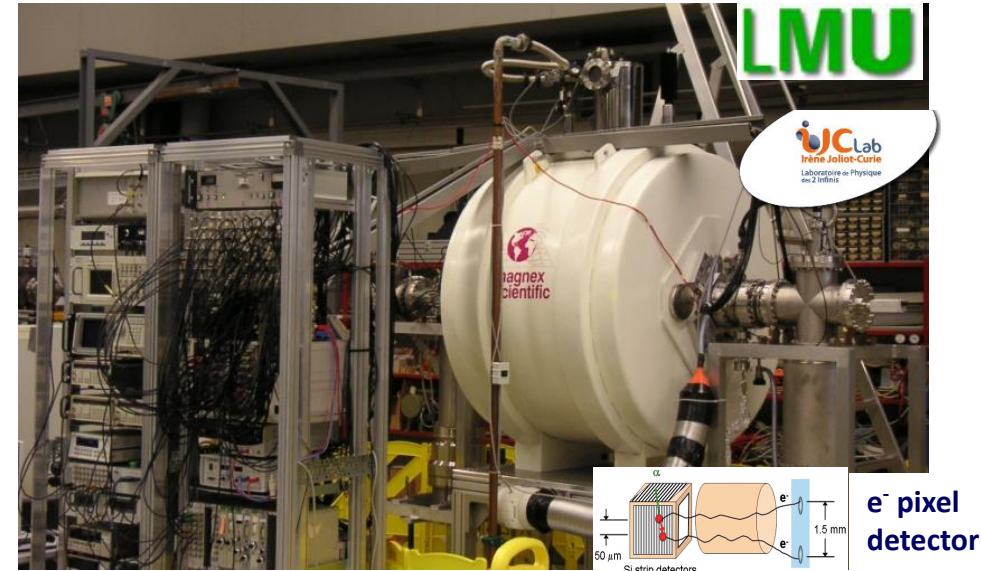


*P. Delahaye et al., Hyperfine Interaction 240 (2019) 63*

- ⇒ Fundamental interaction physics
    - exotic currents, CVC,  $V_{ud}$ , CP-violation
- Commissioning at JYFL

*P. Thirolf, LMU Munich – E. Minaya Ramires, IJCLab*

- Double Penning trap
  - > high precision mass measurements
  - > in-trap decay



*E. Minaya-Ramires et al., NIM B 463 (2020) 315*

*P. Chauveau et al., NIMB 463 (2020) 371*

- ⇒ Nuclear structure & Decay properties
    - shell evolution, deformation
    - (super-) heavy nuclei decay spectroscopy
- Commissioning at ALTO (IJCLab)

# The BESTIOL facility

BETA decay STUDIES at the SPIRAL2 IsOL facility

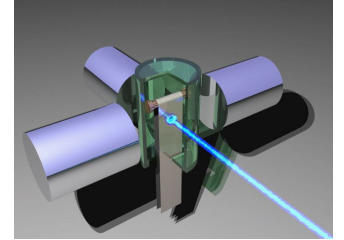
Beam cooling and purification using PIPERADE for (trap-assisted) decay spectroscopy

-> High-precision measurements with ultra-pure samples using:

- $\beta$ - $\gamma$  decay stations (BEDO, ...)
- total absorption spectrometers (DTAS)
- neutron detection arrays (BELEN, MONSTER, ...)

-> Fundamental interaction, nuclear structure, decay properties

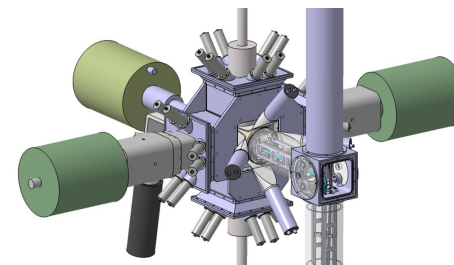
- CVC,  $V_{ud}$
- lifetimes,  $P_{(2)n}$
- exotic decays ( $\beta$ -2p, cluster emission)
- Gamow-Teller strength



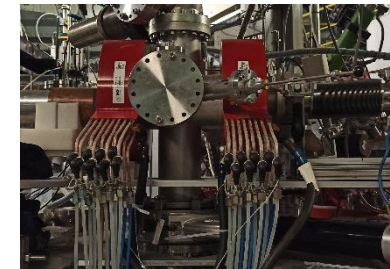
SiCube



BELEN



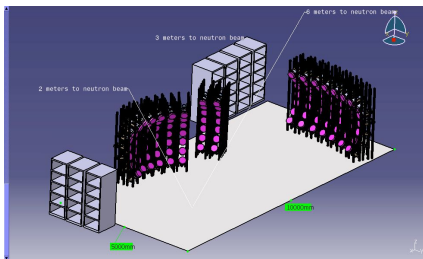
BEDO



COeCO



DTAS



MONSTER

# ASGARD: Objectives

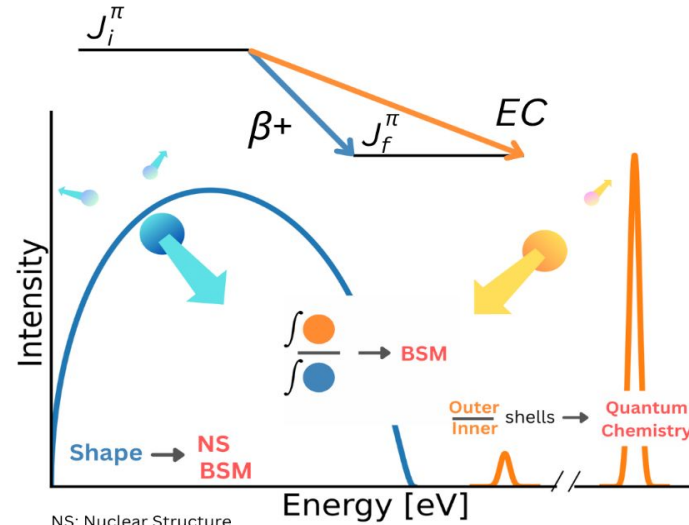


First precise recoil spectroscopy after beta/EC decays

Beyond Standard Model searches

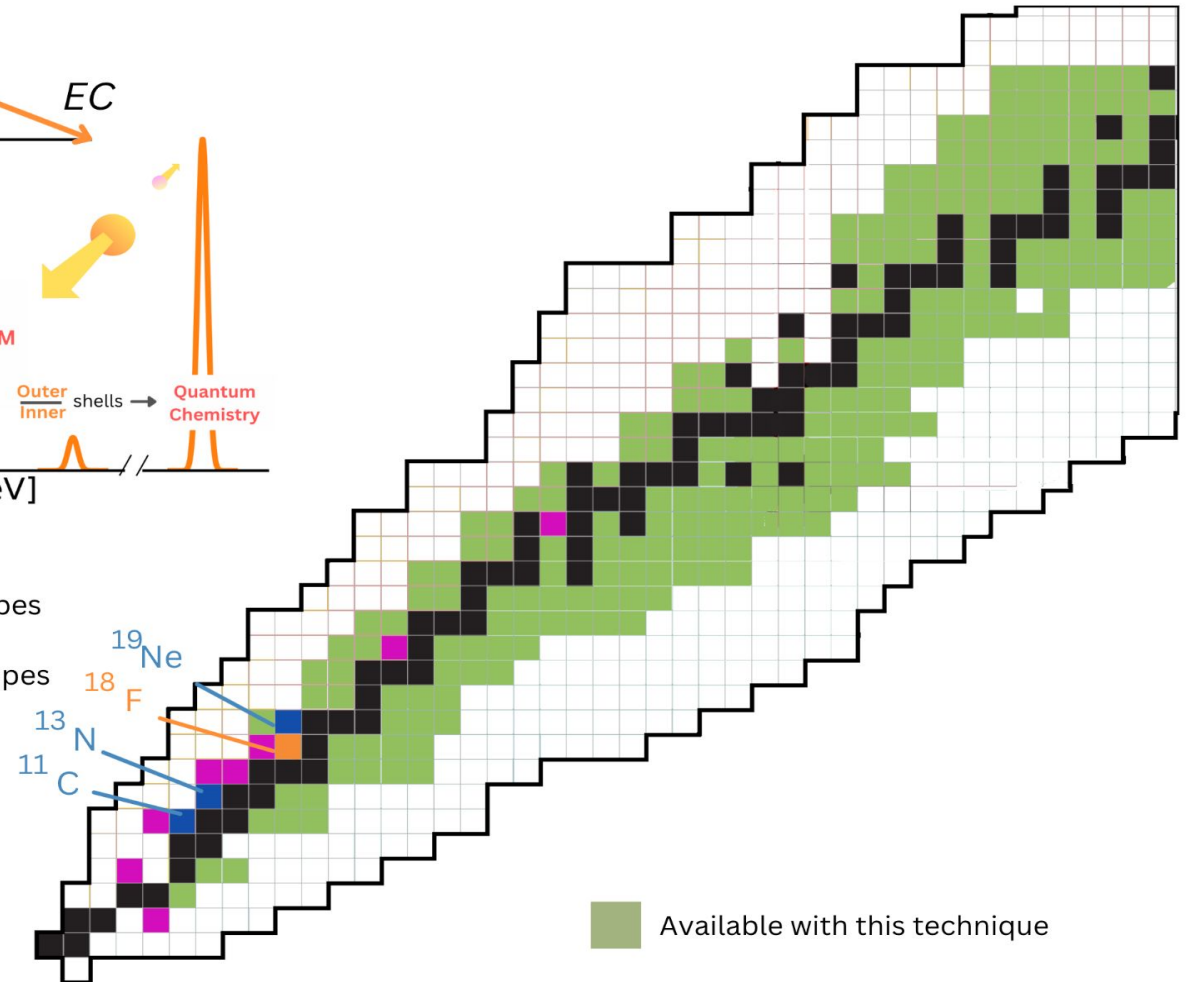
Open doors to:

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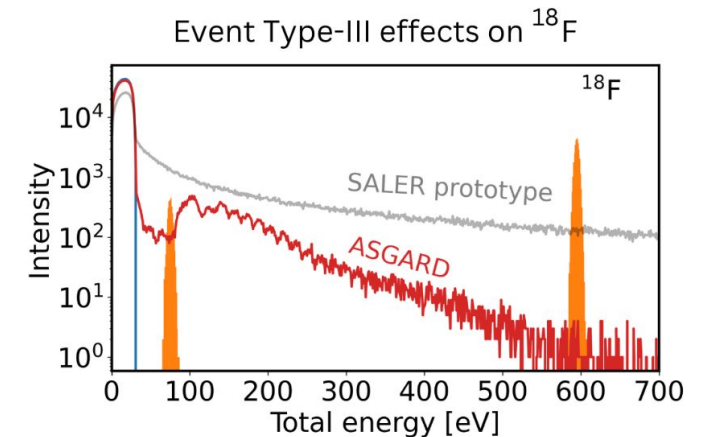
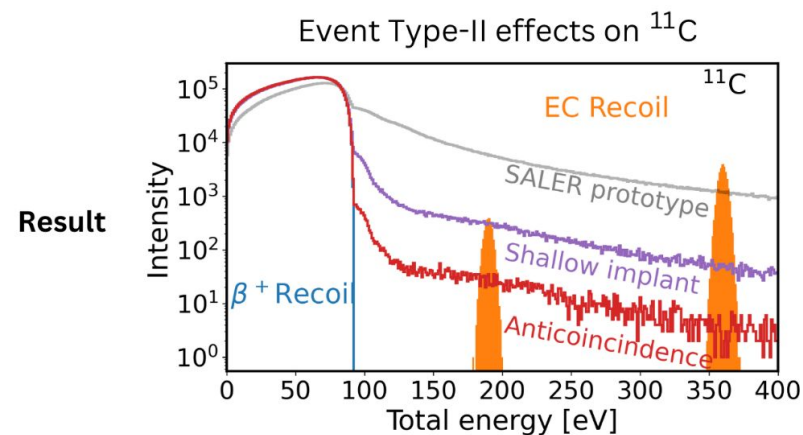
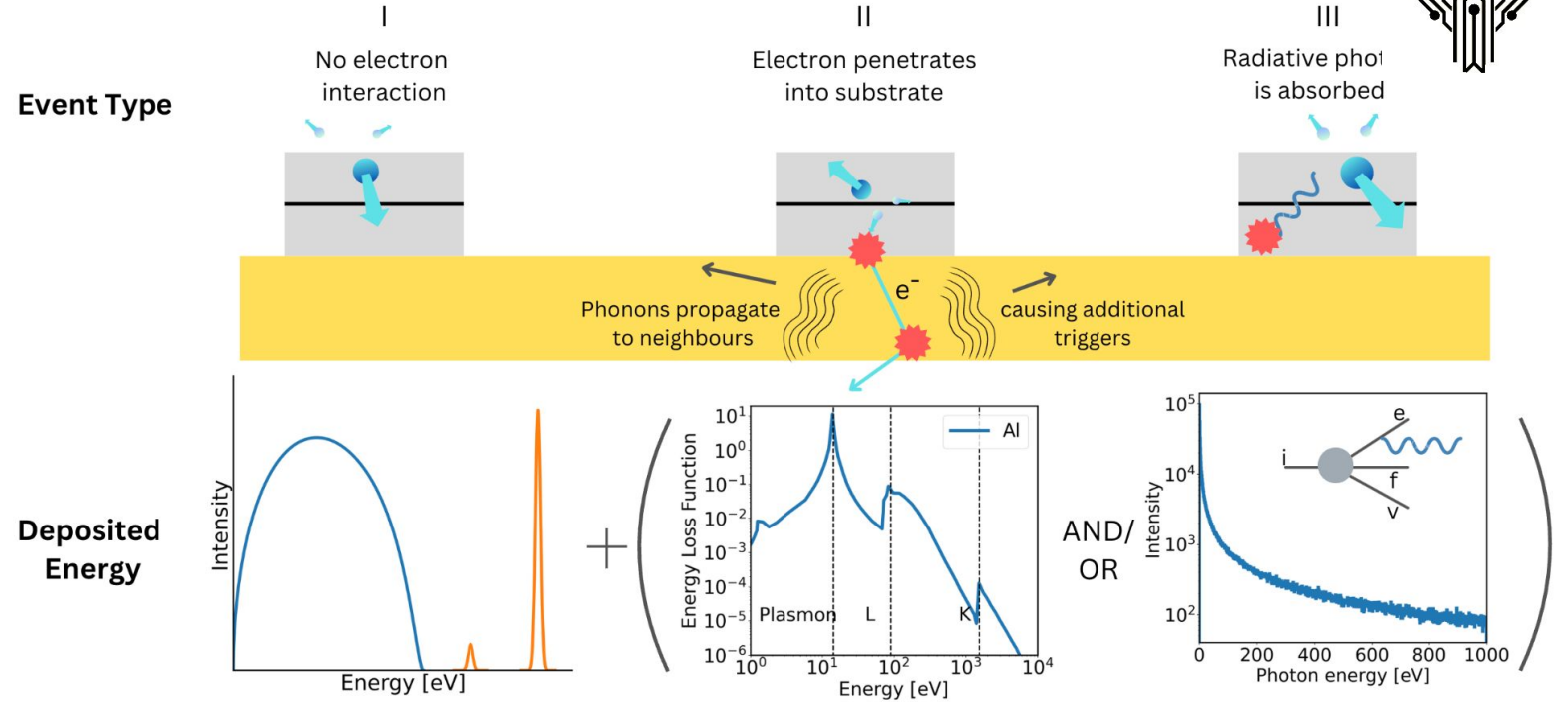
# ASGARD: Measurement principle



Use open dilution fridge  
& injection beam line

Direct implantation of all ISOL  
isotopes

Ultra-thin Al-STJ



# ASGARD: Current status



Project was submitted 15/10 to ERC Starting Grant 2025

Total budget: 2.4M euro

- 800k equipment
- 3 PhD, 2 postdoc
- Travel, margin, overhead



Current budget: Label D'Excellence (94k)

- 1 postdoc (M. Kanafani)
- Travel



V. Dumenil thesis on theory,

M2 (+thesis) planned on BeEST/SALER/ASGARD

