Radioactive ion beam production

Some preliminary reflections

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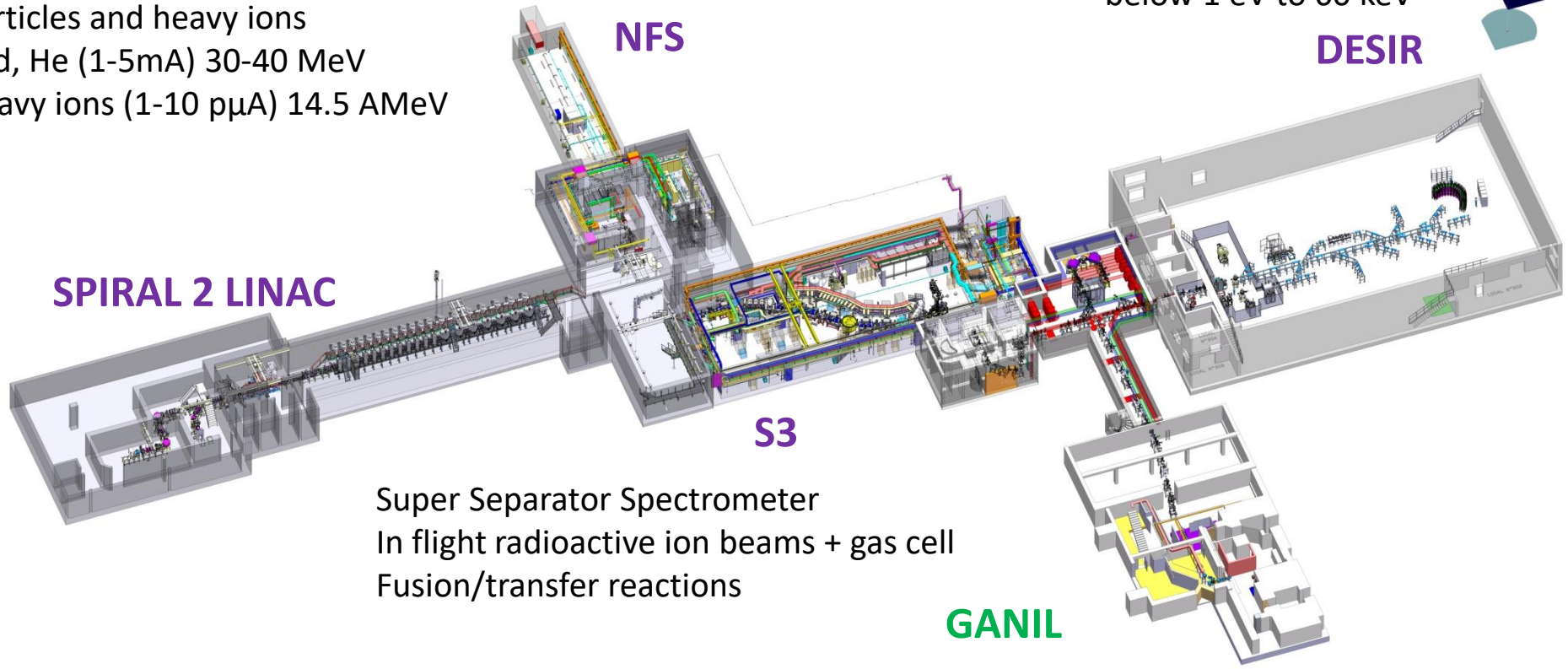
GANIL-SPIRAL 2 – Phase 1

Neutron for Science
Neutrons up to 30 MeV

Experimental areas for very low energy beams:
below 1 eV to 60 keV

High intensity beams of light particles and heavy ions
p, d, He (1-5mA) 30-40 MeV
Heavy ions (1-10 pμA) 14.5 AMeV



Super Separator Spectrometer
In flight radioactive ion beams + gas cell
Fusion/transfer reactions

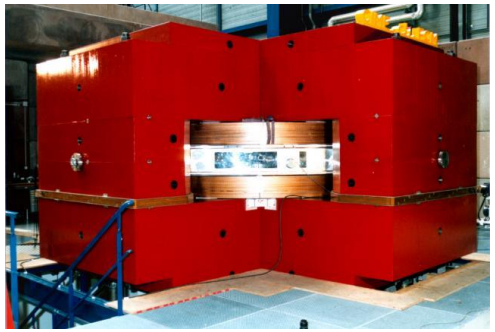
Experimental areas and cyclotrons: heavy ions (pμA) up to 95AMeV
SPIRAL 1 facility: RIBs from fragmentation

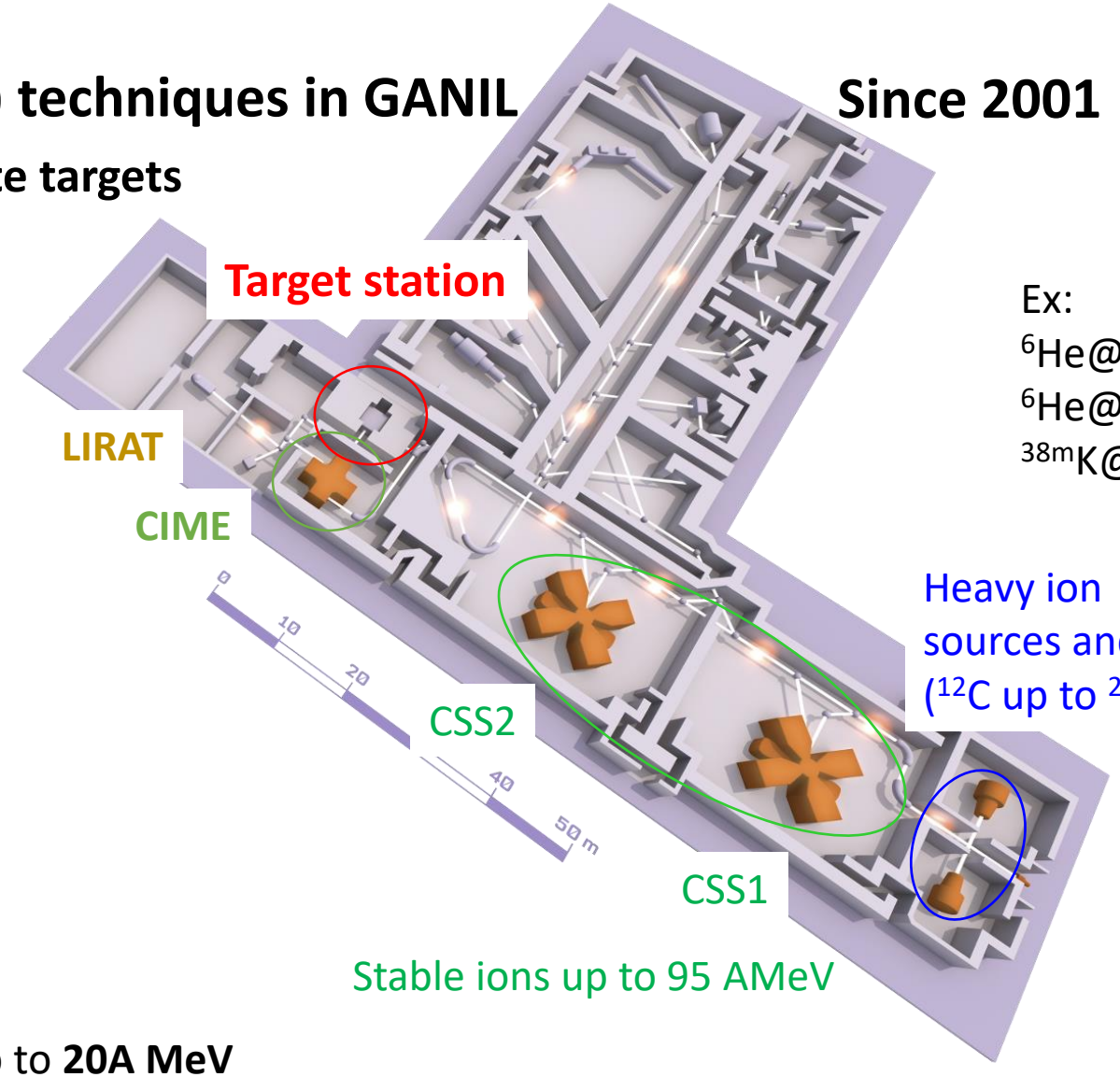
Re-accelerated beams at SPIRAL 1

Isotope Separation On Line (ISOL) techniques in GANIL **Since 2001**

Heavy ion fragmentation on graphite targets

« Cyclotron d'ions de moyenne énergie »



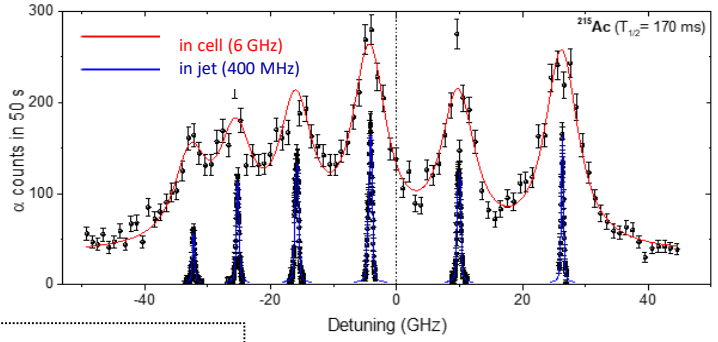


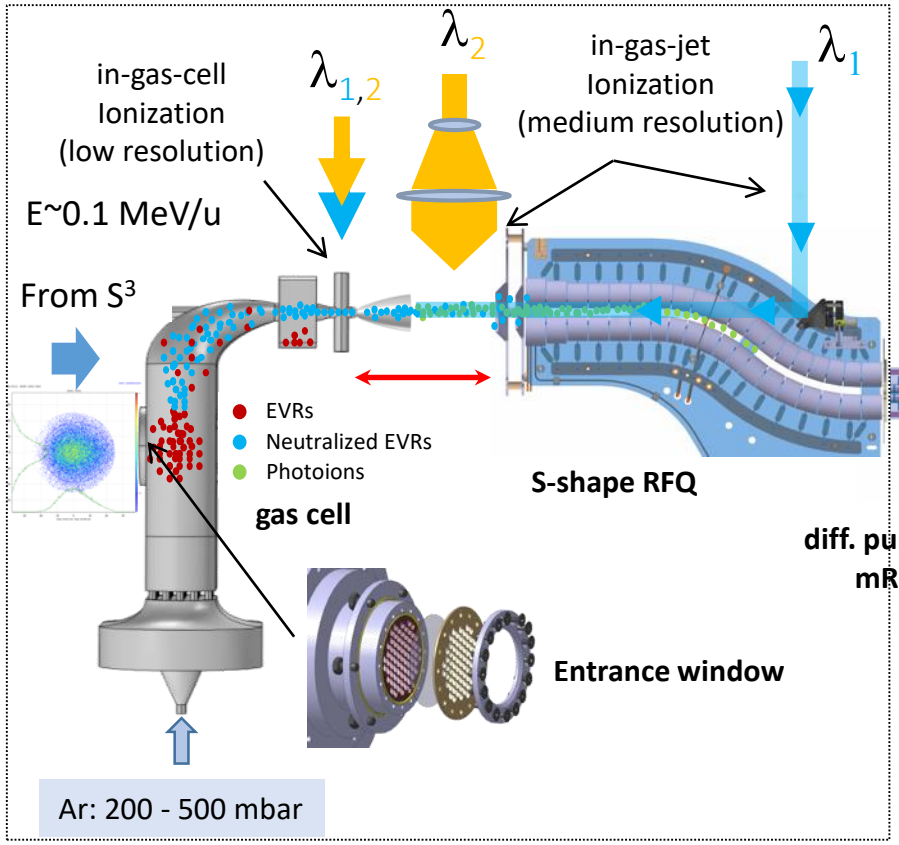
Ex:
^{6}He@10keV 3·10^{8}pps
^{6}He@20AMeV: 5·10^{6}pps
^{38m}K@9 AMeV: 7·10^{5}pps

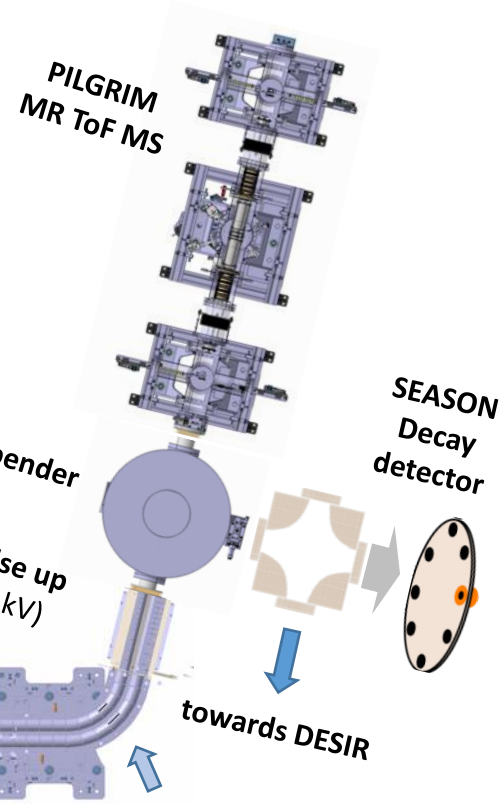
Re-acceleration of radioactive ion beams up to **20A MeV**

Gas cell in S3 - LEB

REGLIS (Rare Element in Gas-jet Laser Ionisation and Spectroscopy)







Ex:
^{100}Sn@30keV ~10 pps

A few pps to 10^5 pps
N=Z beams and superheavies

Commissioning in 2023

Nominal intensities with A/q=7 injector → 2027

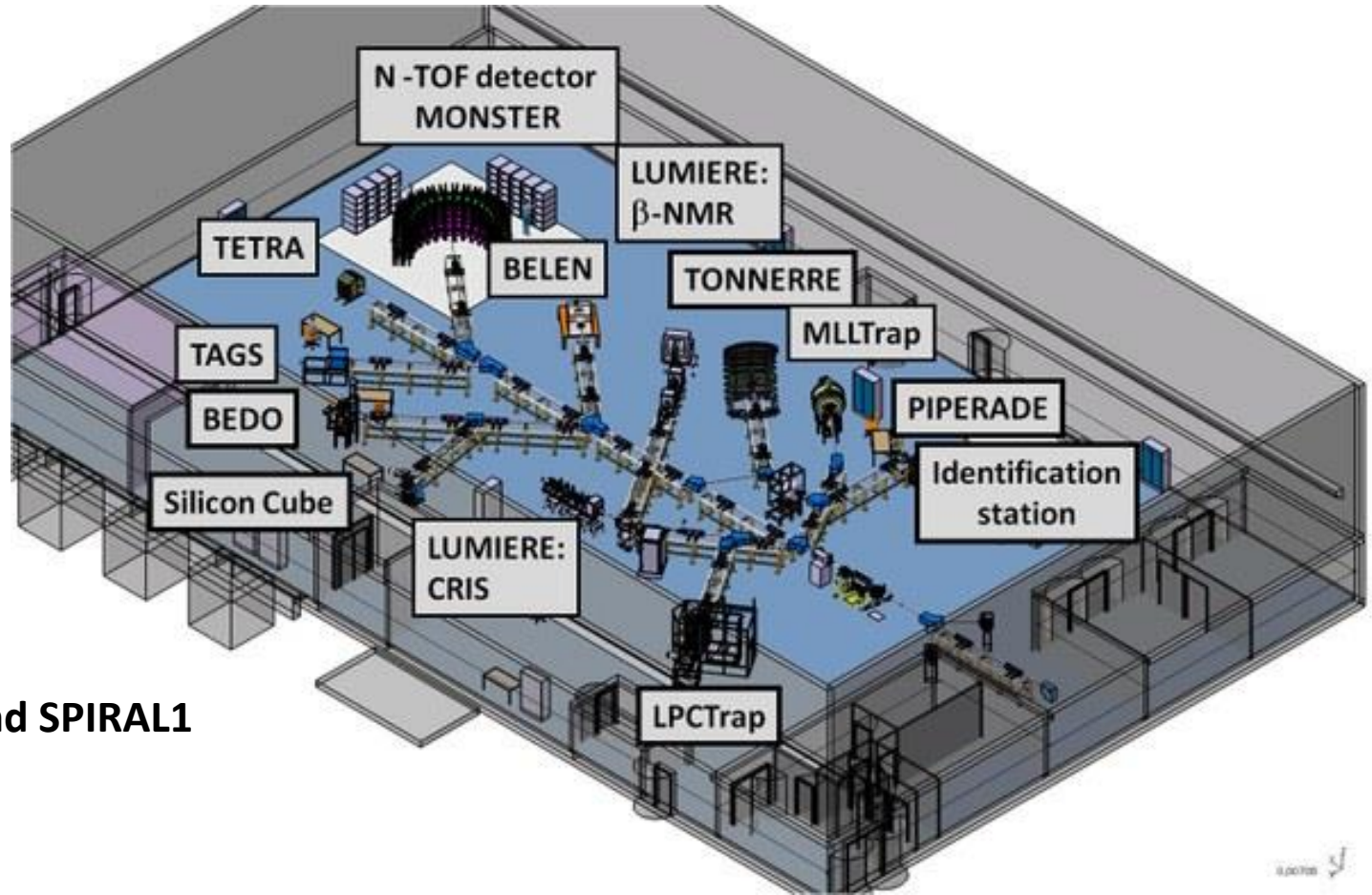
DESIR facility

2024-…

Very low energy beams:

Spectroscopy of ground state properties of exotic nuclei produced at S3-LEB and SPIRAL 1

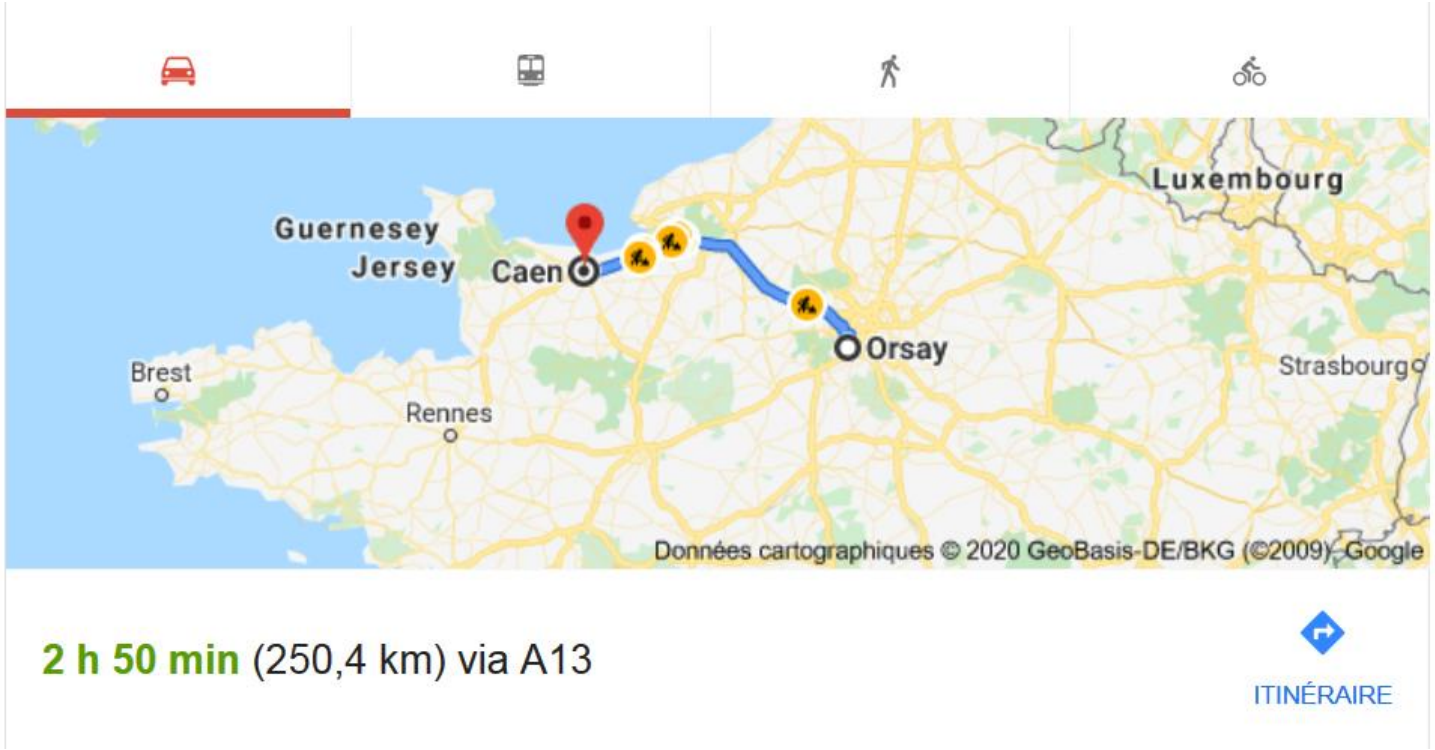
Traps, laser systems, and decay spectroscopy



Beams from S3-LEB and SPIRAL1

Radioactive ion beam facilities in France

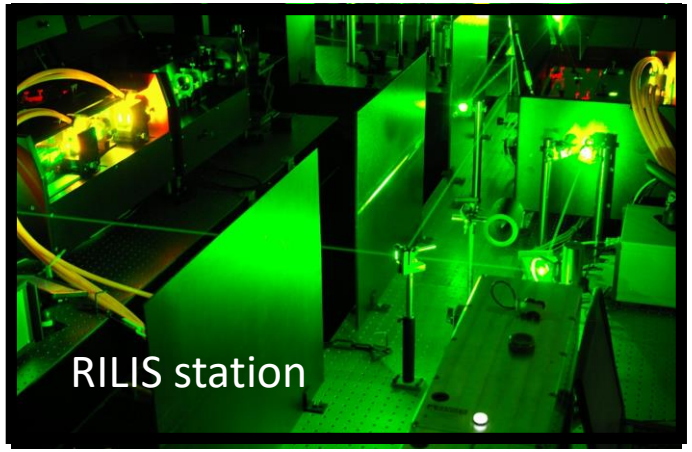
- 2 facilities: ALTO @IJCLab and GANIL-SPIRAL2

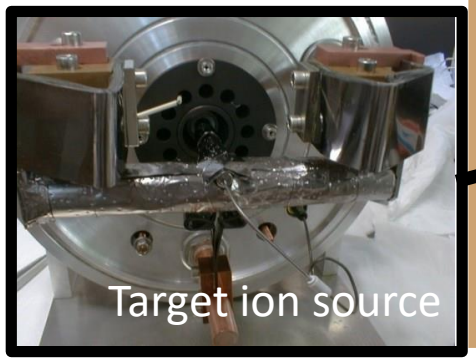


Photofission (installation pilote)

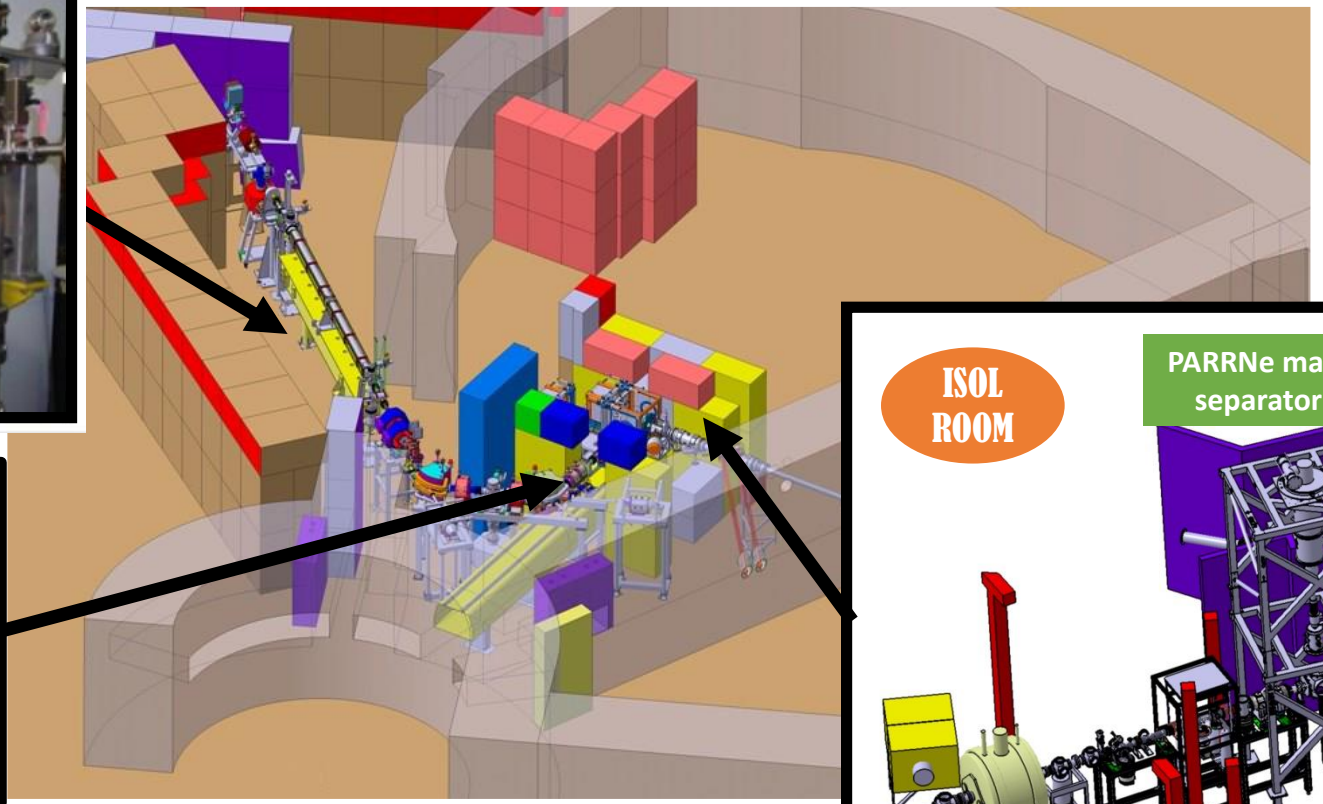
ALTO
Accélérateur Linéaire et Tandem à Orsay

JCLab
Orsay

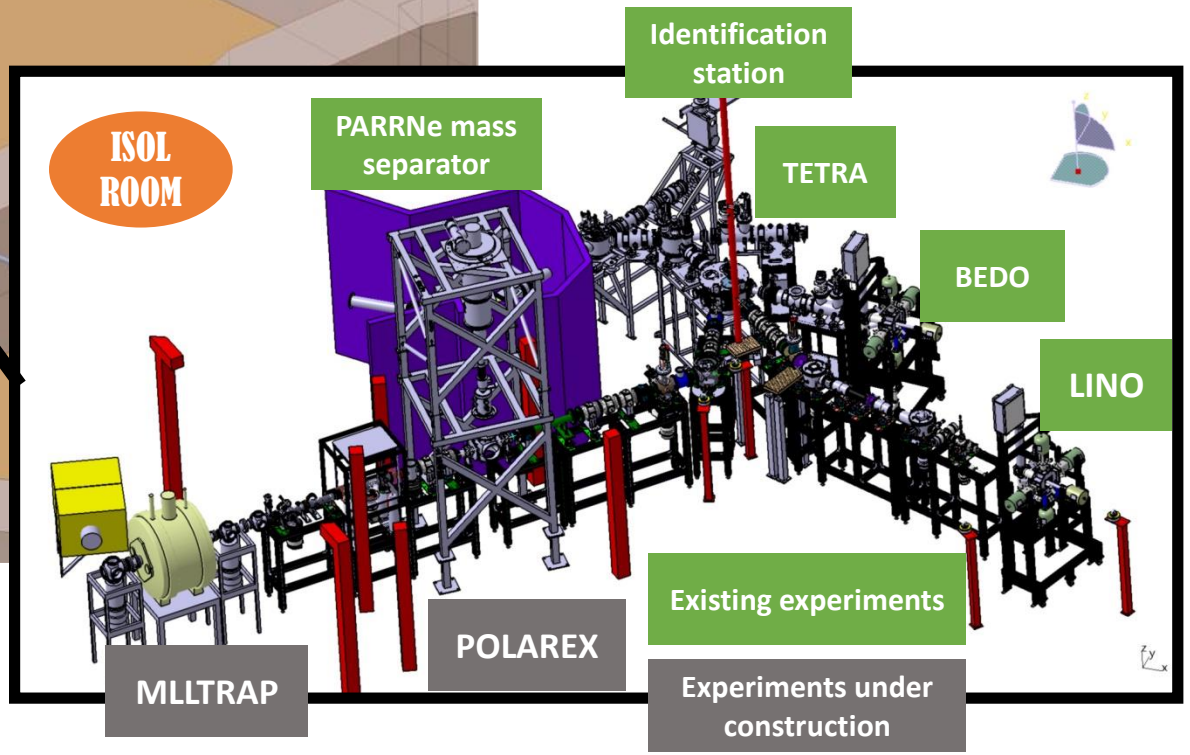




Ex: $3 \cdot 10^7$ pps of ^{132}Sn



500W e⁻ sur cible UCx
Faisceaux ISOL de basse énergie
Décroissance, piégeage



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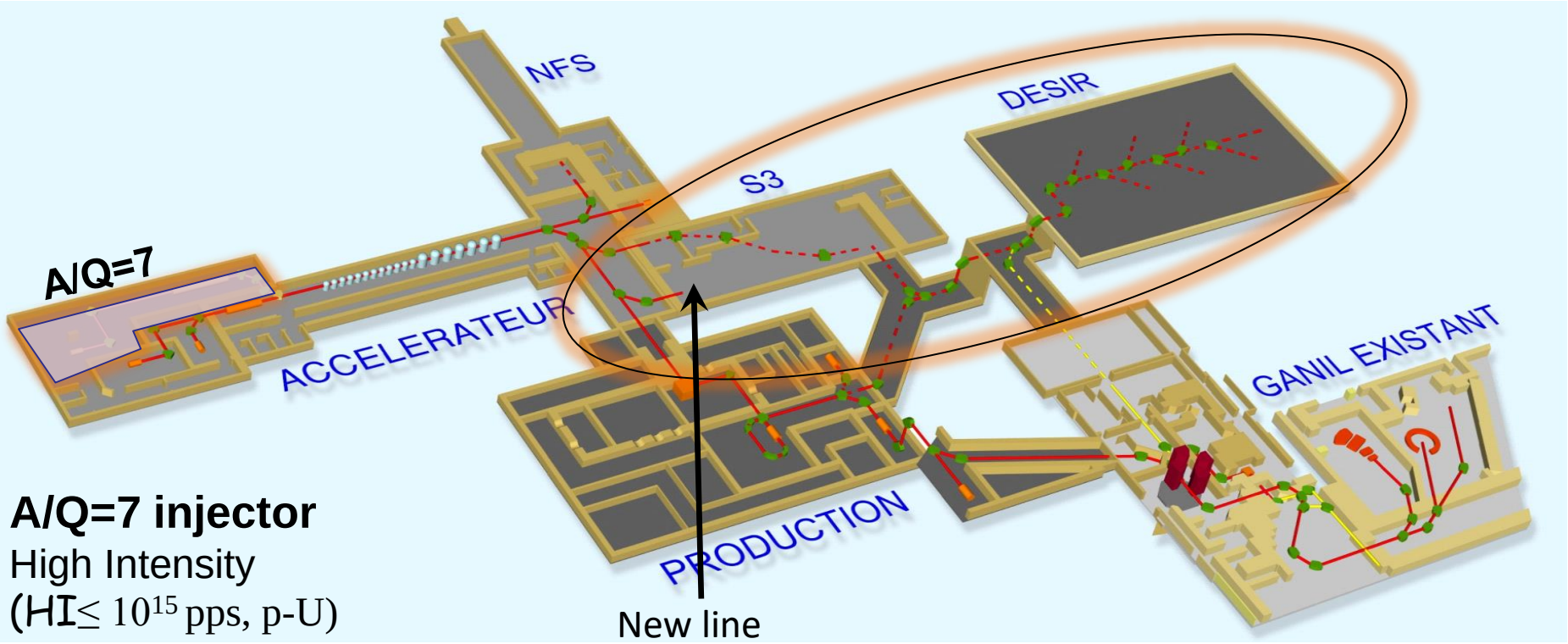
A/Q = 7 Injector

I. Stefan *Scientific Coordinator* M. H. Moscatello *Technical Coordinator*



A/Q=7 injector
High Intensity
(HI≤ 10^{15} pps, p-U)

New injector for Linag presented in:
Spiral2 Physics Case, page 171 (2006)

A/Q=3 (existing): E<=14.5 MeV/A
A/Q=7 : E<=7 MeV/A

New beamline?

- not part of this project
- good future opportunity
- independent of S3
- advantageous use of heavy beams (Pb,U)

7 years project: estimated cost ~12 MEuro

Starting year (2020!?)	Starting year+1 (2021!?)	Starting year+2 (2022!?)	Starting year+3 (2023!?)

- Preliminary Definition Phase
- Detailed Definition Phase
- Construction -> End starting year+7 (2027!?)

A multi-user facility

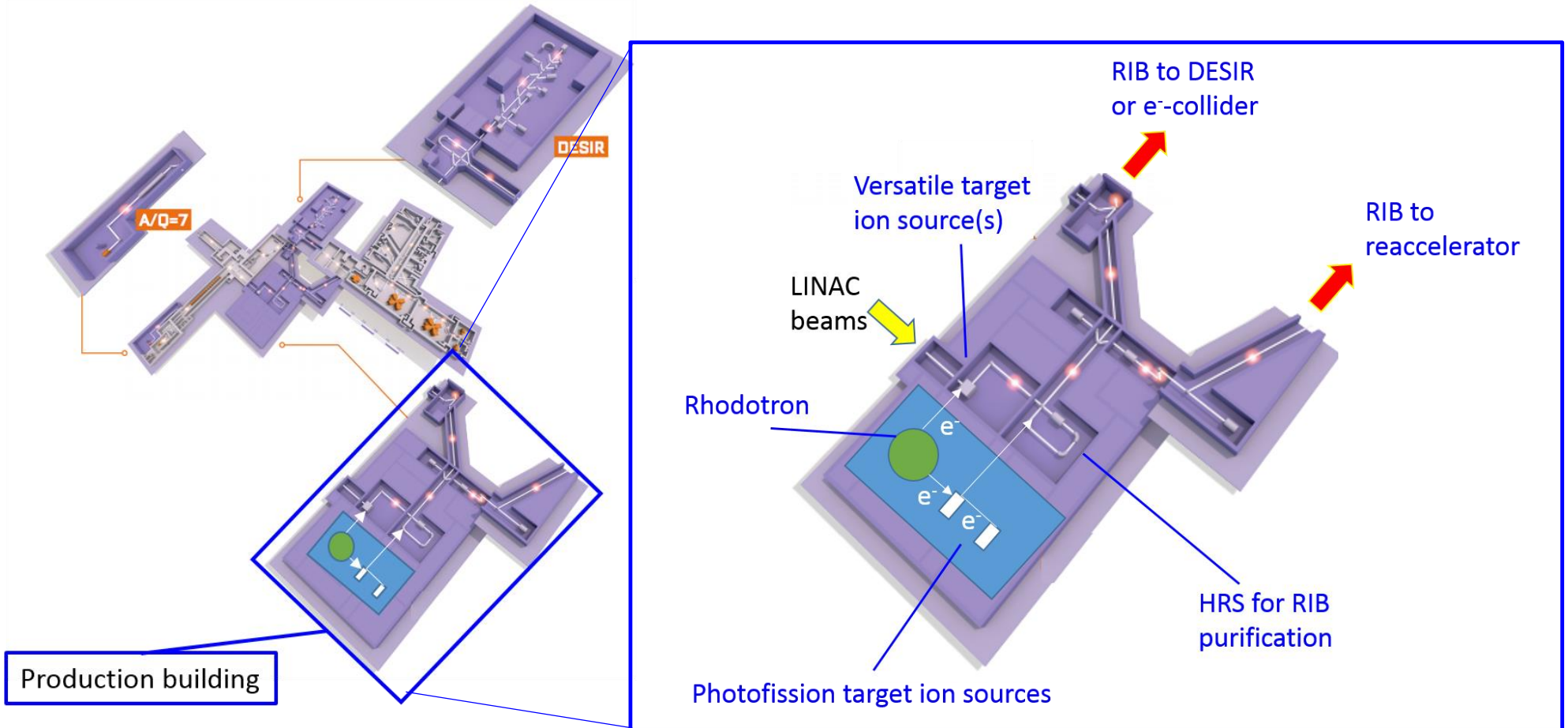
In the next **~10 years**

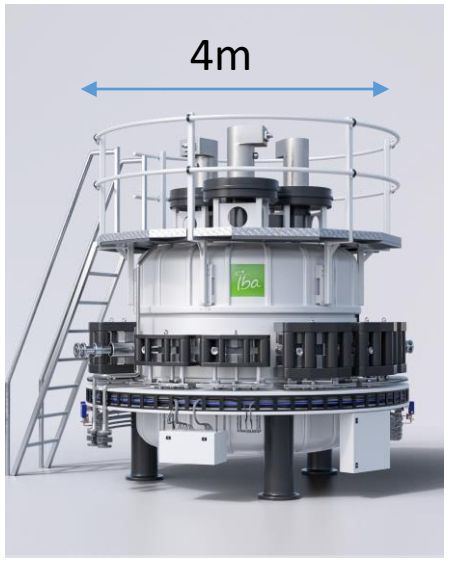
A production building with several production caves

ISOL / gas cell with dedicated driver to complement the LINAC

- Fusion and transfer reaction with the LINAC beams (including A/Q=7)
- Photofission or light particle induced fission (p,d, ^{3}He/^{4}He): **up to ~10^{13} fissions/s** using ALTO's expertise

Instead of expensive, quite inadapted SPIRAL 2 phase 2 original production mechanism





Rhodotron® TT300-HE
High Energy Electron Generator

~7M€ according to IBA inc. Beam line and diagnostics

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Summary table: production for ERL / e- ion scattering facility

Facility	Beams	Reaction mechanism	When	Comments
SPIRAL 1	A<80, intensities up to ~10^9 pps	Fragmentation	Many are ready, some to develop	Fusion evaporation possible (TULIP)
S3-LEB	Mid-heavy to heavy neutron deficient beams A >40 → ~270 Intensities up to 10^6 pps	Fusion evaporation	Starting on-line development as of 2023	
Gas cell/ production cave with **A/q=7**	Light to heavy (N=126) neutron rich beams, with intensities up to 10^5 ?pps	Multinucleon transfer	* After A/q is ready > 2027 * ideally in the production building ~2030?	See contribution of C. Theisen
Fission fragments from **LINAC**	70<A<150 with intensities up to ~10^9 pps	Fusion reactions Light particle induced fission (p,d,3He,4He)	Production building, ~2030?	See contribution of Delahaye et al.
Fission fragments from Rhodotron	70<A<150 with intensities up to ~10^9 pps	Photofission à la ALTO	Production building, ~2030?	

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Requires a production building

Some remarks

- The **ISOL technique** proposed here is well suited to the production of the beams requested by the e^- - ion scattering facility
  - 10^4 – 10^8 pps max with min half life ~1s because of trapping
  - No need to go for a full scale SPIRAL 2 phase 2 in the original production scheme
    - Scheme not optimized / is a penalty for many exotic isotopes with half lives ~s / min
    - Highest intensity for some isotopes of no use: ^{132}Sn at more than 10^8 pps is enough and is readily available at existing facilities such as ISOLDE
- The production building would allow an **optimized use of DESIR** instrumentation in an intermediate phase
- A **driver for photofission** is advantageous in many respects
  - Real **multi-user** facility
    - Ambitious programs with long beam times become possible at S3
    - Ambitious programs for DESIR with neutron rich beams becomes possible
    - Continuous R&D for fission fragment production from photofission becomes possible
      - Rhodotron with 2 outlets
- **Interdisciplinary research** will increase the need for LINAC beams availability
- **Several production caves** are mandatory for R&D and operation
  - Striking example: number of available beams and beam time at SPIRAL 1 (1 target station) vs ISOLDE (2 target stations)
  - Several caves: possible adaptation to different production mechanisms

Next steps

- Table for photofission fragment intensities can relatively easily be compiled
  - Starting from estimates for SPIRAL 2 phase 2
- Intensity estimates for transfer reactions is practically not feasible
- A feasibility study of the production building is only possible if including engineers (H. Franberg, X. Hulin + ?)