Suite « mission Spiro »

P. Delahaye, on behalf of WG2 & 3 electron probe and reacceleration

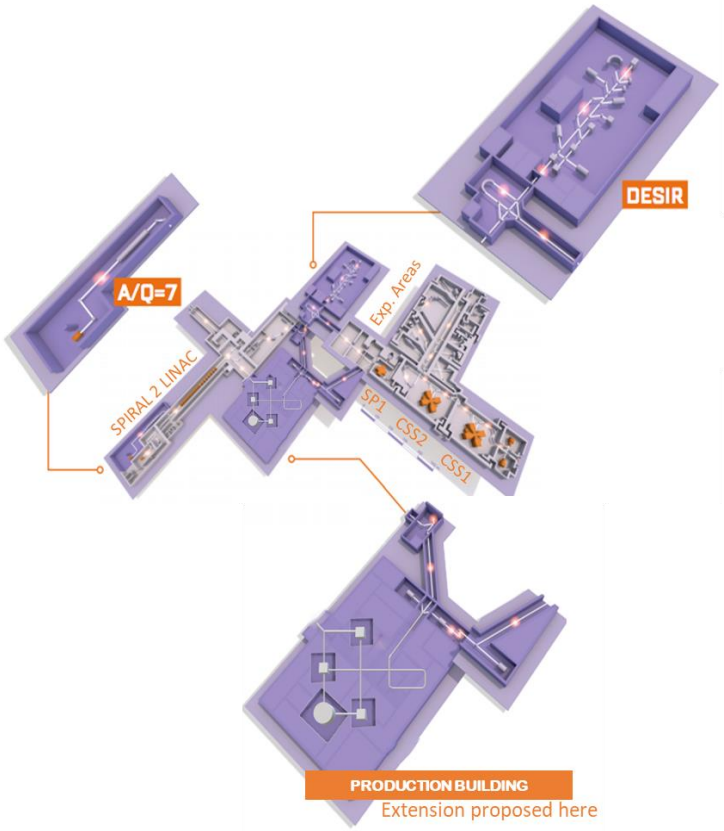
Future of GANIL: schedule

- IN2P3 Prospectives: Feb. 2020, Abbaye aux Dames
- Future of GANIL (with CEA): **LoIs submitted in April 2020**
- Available info on **https://indico.in2p3.fr/event/20534/**
  - May 2020: Analysis of the collected contributions
  - June 9th: 1st meeting of the International Expert Committee
  - June 25th: Presentation to the GANIL CODIR of the International Expert Committee analysis
  - **Decision taken to build 2 working groups**
  - **1/ Interdisciplinary hall (G. de France et al.)**
  - **2/ Electromagnetic probe (V. Lapoux et al.)**
  - September: kick-off meeting of the Working groups.
  - November 12-13th 2020: Meeting to discuss the progresses of the working groups
  - December 1st: Working groups reports: Electromagnetic Probe and Interdisciplinary Hall
  - December 3rd: 2nd meeting of the International Expert Committee. Presentation of the Working Groups Conclusions
  - Discussions show the need for 2 additional working groups
  - **3/ Acceleration of exotic beams (S. Gales et al.)**
  - **4/ Futur of cyclotrons for interdisciplinary research (N. Moncoffre et al.)**
  - December 2020: Meeting with CNRS and CEA directions
  - December 18th: Presentation to the GANIL CODIR of the International Expert Committee conclusions
  - **2021**
  - **March: Reports of the additional working groups** ⟵ We are here!
  - April: 3rd meeting of the International Expert Committee. Presentation of the Working Groups Conclusions
  - May: Final report of the International Expert Committee
  - June: Presentation of the International Expert Committee conclusions to the GANIL CODIR
  - **June: Presentation of the conclusions to CNRS and CEA directions** ⟵ We go there!

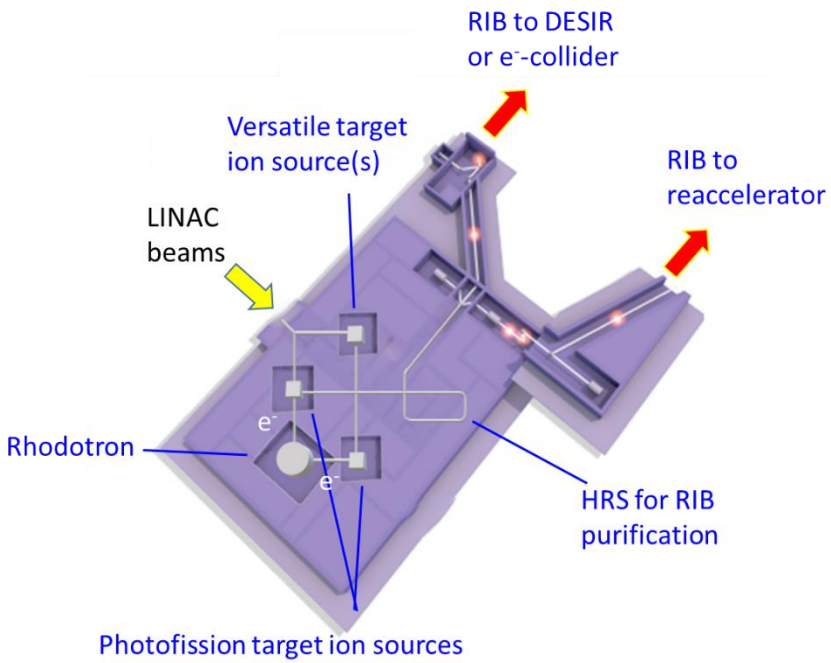
WG2 & 3: electron probe and reacceleration

These are the 2 options proposed by the community of GANIL for Nuclear Basic Science!

Both options based on the same ISOL consolidated production capabilities



Production building

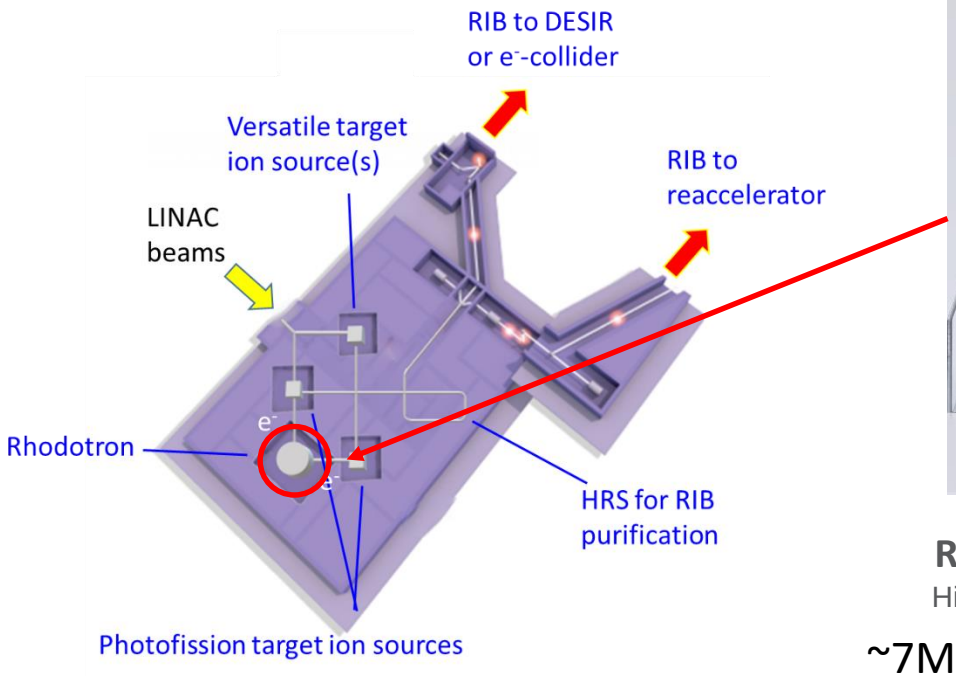


GANIL-SPIRAL2 as a Multifaceted Radioactive Ion Beam Facility, P. Delahaye et al., https://indico.in2p3.fr/event/20534/contributions/81850/

What beams?

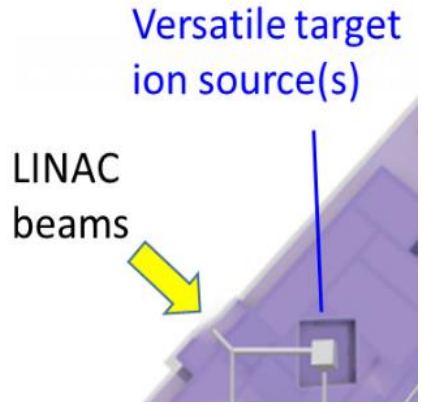
Facility	Beams	Reaction mechanism	When	Comments
SPIRAL 1	A<80, intensities up to ~10^9 pps	Fragmentation	Many are ready, some to develop	Fusion evaporation possible (TULIP)
S3-LEB	Mid-heavy to heavy neutron deficient beams A >40 → ~270 Intensities up to 10^6 pps	Fusion evaporation	Starting on-line development 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?	

A deeper look into the production building



Rhodotron® TT300-HE
High Energy Electron Generator

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



Gas cell for reactions
with A/q=7 beams

A/q=7 beams:
NEWGAIN
EQUIPEX
accepted

Rhodotron: an independant « on-off » driver

- Less competition for beam time with the LINAC
- Grants DESIR ambitious program with fission fragments

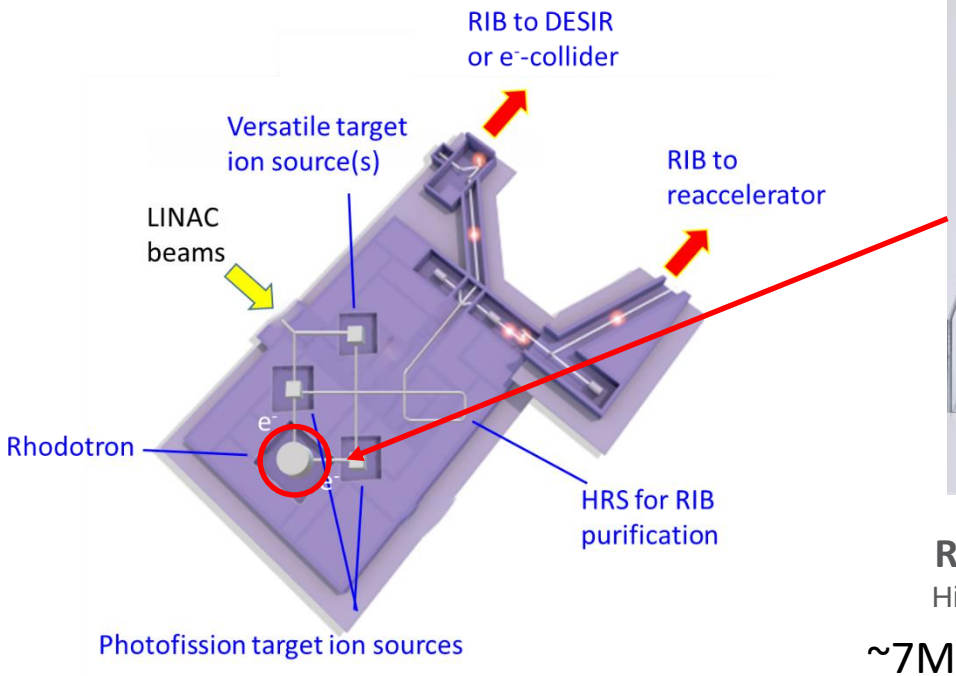
Making full use of A/q=7 beams

- Trans-lead and Actinide production
- Light ($A \lesssim 50$) neutron rich beams from MNT

RFQ injector A/Q = 7 for the production of exotic nuclei using fusion-evaporation and multinucleon transfer reactions, C. Theisen et al., https://indico.in2p3.fr/event/20534/contributions/81871/

A deeper look into the production building

All of this would a priori fit in the original cave foreseen for SPIRAL 2 phase 2



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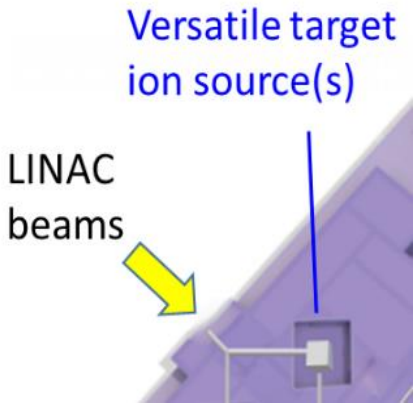

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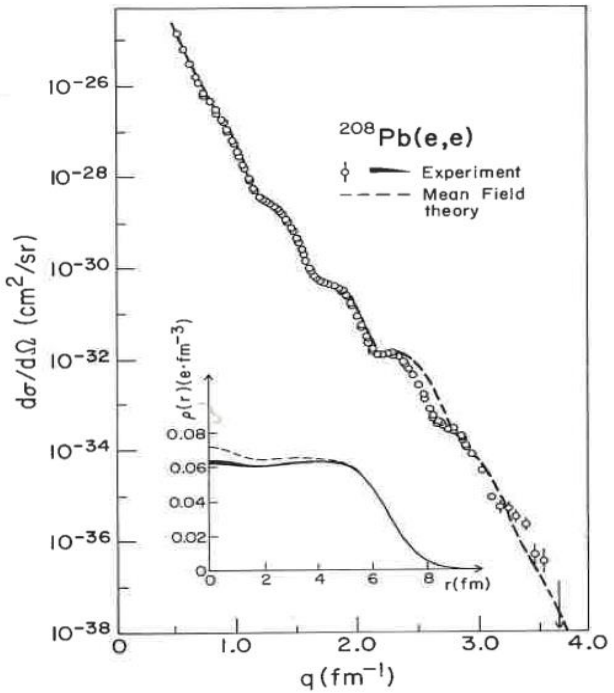
Electromagnetic probe

A microscope on nuclear densities

Goal: luminosities $\gtrsim 10^{28}$ cm^{-2}s^{-1}

at least x10 compared to SCRIT, with radioactive ions

(e,e), (e,e') reactions
(e,e'p) require 10^{30} cm^{-2}s^{-1}



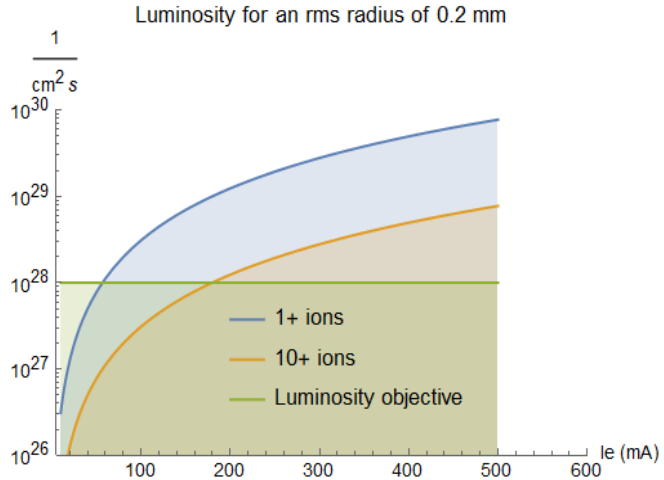
$$L \sim \frac{I_e}{q_e} \frac{N_A}{2\pi \left({\sigma_e}^2 + {\sigma_i}^2\right)}$$

First ion trapping study shows that:

- An ion beam radius of ~100 – 200µm is already around the achievable physical limit because of electron heating
- An electron beam intensity of $\gtrsim 200$ mA is desired to achieve the luminosity objective

A synchrotron is a preferred solution a priori

- Achievable performances with readily existing technology (eg. SOLEIL 500mA)
- High current for ERL (eg. PERLE aims at 20 mA)



Report sent to the committee: V. Lapoux et al. , *Electron scattering on radioactive ions at GANIL*, https://indico.in2p3.fr/event/20534/attachments/57082/85464/WG_EP_Dec2020v.pdf
Original LoI: https://indico.in2p3.fr/event/20534/contributions/81059/

Reacceleration

Reacceleration of RIBS up to Fermi energies

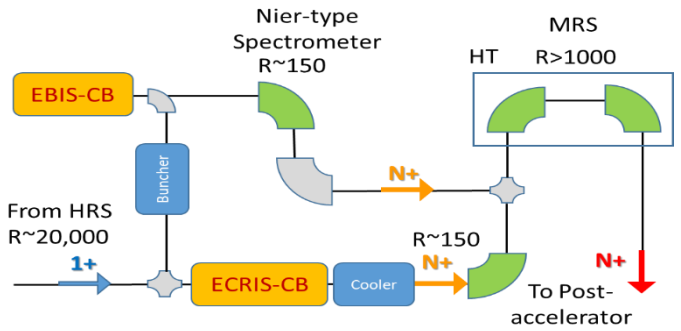
- **Nuclear equation of State**
  - ➢ Accessing the isovector parameters of the EOS via heavy ion collisions and geant resonances with exotic RIBs
- **Nuclear shell evolution away from stability**
  - ➢ Coulex for probing deformation, (p,t) for pairing, study of Pygmy Dipole resonance transfer reactions and and pairing, fissionning system studies

3 options for reacceleration

- LINAC + CSS1 + CSS2
- Superconducting cyclotron from IBA
- Superconducting LINAC

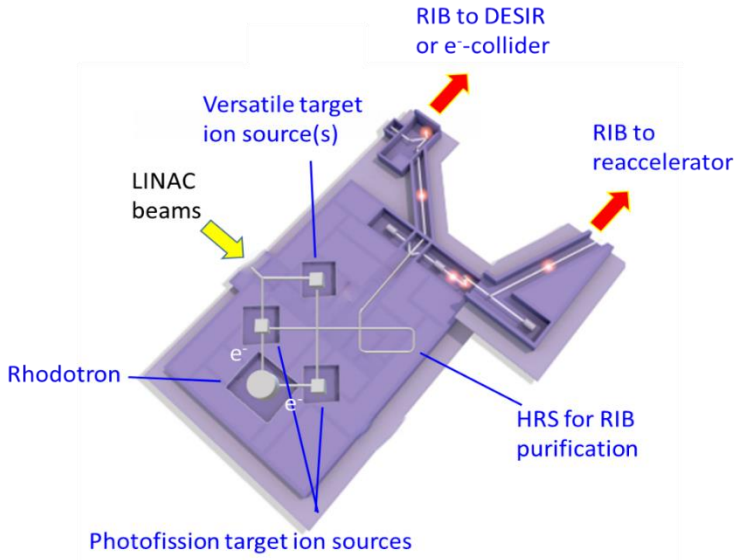
	CSS upgrade with LINAC injector	Superconducting Compact Cyclotron	Superconducting LINAC
Cost of accelerator	25	70-80	100
Cost Accelerator building	5	5	20
Main advantage	lower cost	compact	Upgrade possible flexibility
Main problem	- CSS ageing -33MeV/A max for ^{132}Sn	New Design effort	Manpower cost

EBIS + ECRIS Charge breeding



Report in preparation: S. Galès et al. , *Post-Accelerated Radioactive Ion Beams*, to be sent these days to the committee
Original LoI: N. Le Neindre et al. *Reacceleration of radioactive ion beams at GANIL*, https://indico.in2p3.fr/event/20534/sessions/13351/

Overview



- **Production building: ~10 years**
  - SPIRAL 2 phase 2 was estimated between **80 M€** (end of 2012) and **150 M€** (GANIL 2025 initiative, in 2015)
  - Includes 45 M€ for the production building, in which all the processes shown here are a priori fitting
- **Electromagnetic probe ~12 years**
  - Overall cost **~150 M€**, including the electron machine ~100 M€
  - ~12 years: 4 for R&D, Design, 8 for construction
  - Synchrotron preferred, role for PERLE?
- **Reacceleration ~ 10 years with variations according to the option**
  - 3 options with very different costs and capabilities
    - ~30M€ for existing CSS, cost effective, but range limited in energy
    - 80M€ for SuperConducting Cyclotron, full preservation of existing facilities is a priori possible (inc. CIME), design efforts on IBA side
    - 120 M€ for LINAC, highly flexible, but new experimental areas to build

- **A detailed study for each of these options is highly desired for the coming year(s)**
- The realization of whole project is only possible in the frame of an internationalisation of GANIL
- Next steps are the meeting of the WG with the committee in April, **and final report of the committee in May**