Letter to the committee “Future of the GANIL”, April 2021

Synthesis and update of our proposal “e-RI collisions” for the future of GANIL

Electron scattering on radioactive ions at GANIL. [Research Report] 1st December 2020.

https://indico.in2p3.fr/event/20534/attachments/57082/85464/WG_EP_Dec2020v.pdf

(cea-03176547, v1) https://hal-cea.archives-ouvertes.fr/cea-03176547v1

From the working group of the proposal “*Electron scattering on radioactive ions at GANIL****“ [eRI]***

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When our project proposal is examined by the scientific committee, we would like the following elements to be considered in the discussion: i) Complements and conclusions about **the techniques of the project;** ii) **The possible timeline.**

Techniques. Our aim is to have an electron beam accelerator at GANIL to perform electron-radioactive ion collisions and measure cross sections observables and excitation spectra giving access to microscopic structure data.

As explained in our proposal (***Sections I.3 p. 9; II.3 p.11***), these studies require luminosities ranging from 10^{26} to $10^{29,}$ up to 10^{30-31} for (e,e'p). Taking into account i) the physical constraints, ii) the state of the art of electron machines, and their potential upgrade in the near future and iii) realistic conditions of the ion-trap techniques, we obtained the envelope of parameters required for the electron machine and ion trap device. That is:

- Electron accelerator with intensity of 100 mA with potential upgrade at 200 mA; beam energies between 500 and 700 MeV;
- Ion trap able to confine up to 10^8 ions/s, which represents the true challenge of the project.

In our document, we compared possible technological solutions for the electron machine, namely synchrotron or ERL (***III.3 p.14 ; III.5, p.22***). Our proposal was submitted in December 2020 to the committee. Afterwards, in January 2021, the electron machine characteristics and potential solutions were re-examined (*see complements here on page 2*). Our conclusions of Dec. 2020 were confirmed in February. **We now consider that we should push forward the synchrotron option as the solution for our project development:**

- It matches the physics constraints of the machine (*see the potential design explored in* ***App. C, p. 52***),
- The institutes from CEA and CNRS have the expertise of this category of machine, which would optimize the engineer developing time for the accelerator implanted at GANIL,
- It has well-known cost estimate, the total price of this solution is under control;
- The building will fulfil the schedule for the electron ion collisions program.
- Furthermore, the operation of a synchrotron is much less demanding than the other types of electron machine.

Therefore, we conclude that the most robust and advantageous technical solution for the electron machine is the synchrotron. Other solutions would be hazardous, time and cost consuming and would constitute a limiting factor for the development of the global project consisting in the building of an electron-ion trap machine.

The planned schedule for the design and building would be straightforward, as shown below, recalling the preliminary schematic project schedule we established in our proposal (*see sect.* ***VI.4, p.34*** *and App.* ***E, p. 68***).

Synthesis of the timeline of the project

2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Collaboration														to 2045++
International	Conceptual Design													
Groups			Photo-Fission source construction					Beam development and exploitation at DESIR						
			Ion trap			Ion trap construction and R&D								PHYSICS
				Electron facility final design					Electron facility construction					PROGRAM
					Detection design and R&D					Detection construction				at
														GANIL2

Complements about our conclusions about the techniques for the electron machine.

They can be summarized as follows:
- The main challenge of the electron-ion machine is to realize an ion trap confining enough RI to end up with the requested luminosity. The main efforts in R&D of the project are for this part of the machine.
- For the electron accelerator, the aim is to build a machine with parameters reaching the requested initial characteristics: for the intensity, 100 mA; for the interaction point size, electron-ion beam overlap size of 0.2mm^2 (ion cloud size constraints, on ***III.4 p.17-19; App.B p.50***).

These numbers are feasible with the present technology known for the synchrotrons, which do not require specific R&D to be obtained. On the contrary, the technology of the Energy Recovery Linear Accelerator (ERL) does not currently ensure the 10 mA intensity as a basis for the machine. The ERL principle was demonstrated experimentally, for instance at JLab. However, it has not been demonstrated that it could reach the beam intensity and CW beam power needed for the e-RI project: 100-200 mA and 100 MW are an order of magnitude above the goals of existing ERL projects. High power ERL projects have been discussed with the idea of reaching 60 GeV, 20 mA for LHe (or even an FCC-ee operated in the ERL mode). This is envisioned for the years 2040-2050 but lies in the domain of the prospective paper-works and the targeted intensities would require intensive R&D works with several demonstrators before showing that a machine could be built, matching the 20 mA intensities.

This would imply to break down several already identified (or not) technology obstacles; there is no guarantee that a solution exists even in a 10 year –timeline of the R&D phase allocated for a potential ERL project. In the best of all possible worlds, the ERL conceived for the years 2030 would hardly reach 10-20 mA intensity, at the price of a considerable expensive R&D work. Moreover, the R&D would have to explore all the unknown running conditions, with several questions regarding the stability of the machine and the location of the interaction vertex point, which are far from being integrated in a conceptual design work as can be seen from the present status of ERL in this beginning of year 2021.

To summarize our conclusions on the electron machine, the table below lists the conditions for synchrotron advantages as compared to the ERL unknown parameters.

Requirements, characteristics of the project at 100-200 mA; 500-700 MeV; with ~ 0.2 mm spot size	**Synchrotron**		**ERL**
Technical challenges and R&D risks	**Known feasibility for the physics requirements.** Moderate R&D for the upgrade at 200 mA		An order of magnitude below the requirement. The 100 mA is not yet achievable.
Time scale	5 years CDR, TDR phase; 10 year-project to build the machine, available for test of electron-ion trap in years ~ 2035.		Demonstrator of 10 mA at E ~500-700 MeV not guaranteed in years 2030, and the timeline for higher power is unclear beyond 2030.
Estimated Cost of the overall project (including infrastructures)	Order of 150 MEuros (see Sect. ***IV. 4 p. 37***; ***App.E, p.68***)		At least a few 100 MEuros (excluding the cost of the necessary R&D program, which is not yet evaluated).

As far as synchrotron technique is concerned, the feasibility of a 100 mA at 500 MeV installation is guaranteed and a roadmap exists to reach 200 mA.

Synthesis of our work plans for 2021

Our goals in 2021 are to:

-enlarge the physicist collaboration, involve International groups with expertise in the ion trap and electron-ion interactions, and define the task sharing with them: TU Darmstadt, Riken-SCRIT, the project (ELISe @ FAIR), GSI PI physicists, FLNR-Dubna project (DERICA);

-progress in the knowledge of ions-electron trap conditions, define quantitatively the technical constraints and include as completely as possible the main physical effects related to Coulomb interactions, ion charge breeding and equilibration, self-confinement and time-dependent instabilities due to charge state saturations.