

CYREN SURVEY: users' point of view

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On behalf of the **GUEC**

CYREN survey

- Presented at the GCM in 2022 : CSS renovation sessions
 - The Cyren pre-project context and motivations (G. de France)
 - The Cyren pre-project : technical aspects of the renovation (G. Senecal)
- Presented at the Ganil Scientific Committee (February 2024)
 - Cyren whitebook (G. de France, G. Senecal, C. Grygiel)

Why this survey and why now ?

- CYREN working group (M. Rejmund-P. E. Bernaudin) asked the GUEC to :

“To make this session complete, we would like to kindly ask you to present (20 min) the point of view on the future use of CSS cyclotrons by the community (1 decade or more).”

CYREN survey : organisation

- **GANIL Communities**

- DESIR
- Fundamental Interactions
- S3 / S3-LEB / SIRIUS
- NEWGAIN
- ALTO
- Target-Ion Source SP1
- Super-heavies
- Fission : VAMOS
- Nuclear-Dynamics and Thermodynamics : FAZIA-INDRA
- Interdisciplinary Research
- Nuclear Structure (in-beam) : AGATA/GRIT/ACTAR/PARIS/LISE
- Nuclear astrophysics

~30 people contacted

No good deed goes unpunished

CYREN survey : organisation

- First email sent to the GANIL USERS portal (July 2024)
 - Targeted emails sent to the different communities (mid September 2024)
→ Slides specific questions (end of September)
 - What impact do you expect the project to have in your community?
 - Are there any specific/technical aspects that make the project appealing to your community and why?
 - Does your community foresee any upgrades specifically related to the CYREN projects to be implemented in the forthcoming years?
 - Video-conference meeting with all the communities to get their input
-

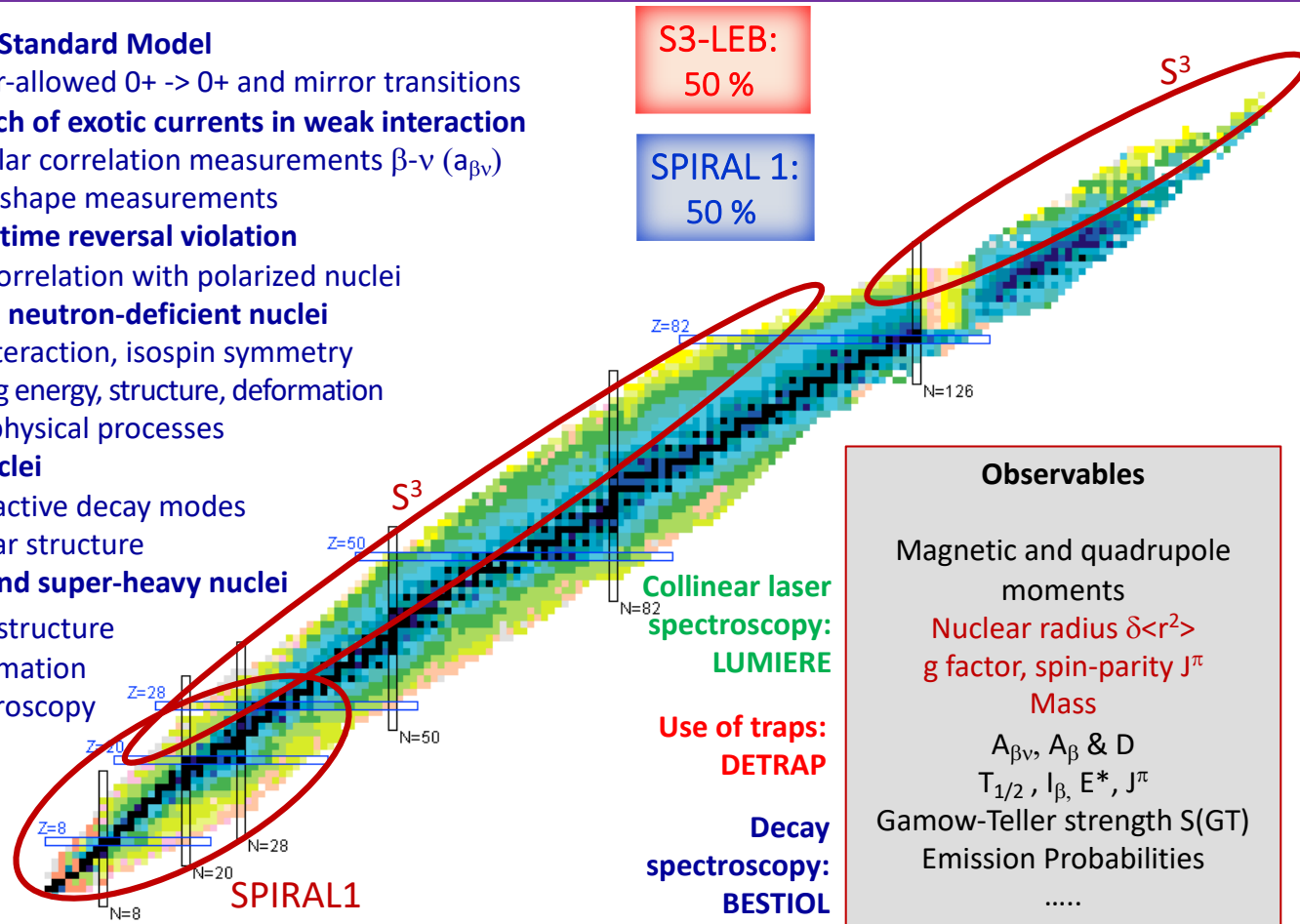
CYREN survey : DESIR



Scientific Programme



- ❑ **Tests of Standard Model**
 - ✓ Super-allowed $0^+ \rightarrow 0^+$ and mirror transitions
- ❑ **Research of exotic currents in weak interaction**
 - ✓ Angular correlation measurements β - ν ($a_{\beta\nu}$)
 - ✓ Beta-shape measurements
- ❑ **Test of time reversal violation**
 - ✓ β - ν correlation with polarized nuclei
- ❑ **N=Z and neutron-deficient nuclei**
 - ✓ π - ν interaction, isospin symmetry
 - ✓ Binding energy, structure, deformation
 - ✓ Astrophysical processes
- ❑ **Light nuclei**
 - ✓ Radioactive decay modes
 - ✓ Nuclear structure
- ❑ **Heavy and super-heavy nuclei**
 - ✓ Shell structure deformation spectroscopy



CYREN survey : Fundamental Interactions

CYREN for fundamental interactions and symmetries

This program depends in big part on the availability of SPIRAL1 beams @ DESIR

Unique perspectives for SPIRAL 1 beams at DESIR

FT-value measurements for the determination of V_{ud} and theoretical corrections

Extension of $0^+ \rightarrow 0^+$ superallowed to

- Mirror transitions eg ^{21}Na , ^{23}Mg , ^{33}Cl , ^{37}K , ^{39}Ca , ^{41}Sc : FEBIAD beams
 - The mirror transitions necessitates also **correlation measurements** (see below)
- Heavier nuclei: TULIP (or TULIP-like) beams
 - Examples: ^{62}Ge , ^{66}As , ^{70}Br , ^{74}Kr (difficult ionization @ S3-LEB)

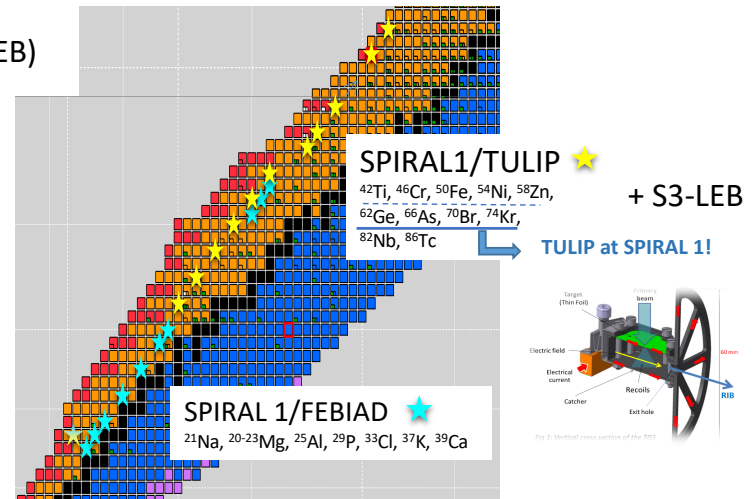
Correlation / spectrum shape measurements for...

- ... Searching for exotic (S, T) currents (ex ^6He , ^{20}Mg ...)
- ... Determination of M_{GT}/M_F for mirror nuclei (see above)
- Superconducting Tunnel Junctions (SALER \rightarrow ASGARD)
- WISArD-like, bSTILED-like experiments

... Searching for CP violation

Test of CP violation in beta-decay
 $^{23}\text{Mg}^+$, $^{39}\text{Ca}^+$ beams from SPIRAL 1

The MORA project



Setups: MORA, ASGARD, WISArD&bSTILED like experiments for correlations
 half-life, BR @ tape station, PIPERADE, MLLTrap for masses

CYREN survey : DESIR+ Fundamental Interactions

- What impact do you expect the project to have in your community?

- **SPIRAL 1 Beams work horse** of both communities

Concern: Take into account DESIR schedule : Cyclotrons should not be shut down when DESIR starts

- Are there any specific/technical aspects that make the project appealing to your community and why?

- **CYREN will bring Long term perspectives** : more reliability of the primary beams, less break down, more time for beam development SPIRAL1
- Large variety of beams requested in Lol's → Upgrades for new SPIRAL1 beams
- New SPIRAL1 beams with TULIP /FEBIAD sources → Complementary development to n-deficient beams S3-LEB → Release the strain put in S3 (Linac)
- Opportunity to diagnose the stable beam intensities into the target-source assembly for SP1 beams. The primary objective is to ensure that the intensities displayed on the site, obtained previously, remain stable (P. Jardin)

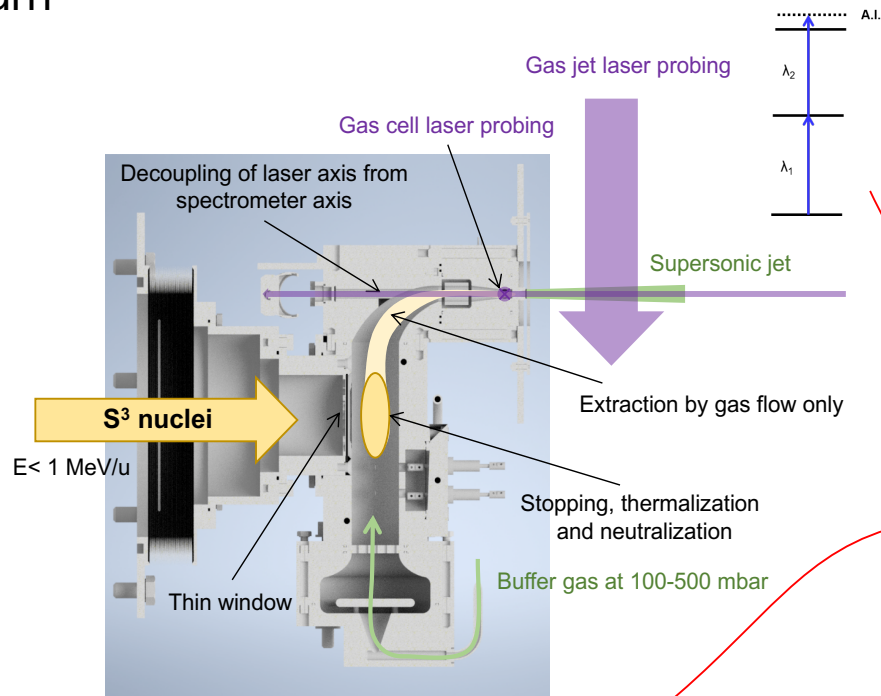
CYREN survey : DESIR+ Fundamental Interactions

- Parallel functioning of SP2 / SP1 → allow beam access for systematic studies
 - Experiments like correlation measurements @ MORA require
 - Long cumulated beam time (~2 months cumulated for a single isotope)
 - Regular access to look for systematics (not 2 months in a row, rather 2 weeks per year)
- Does your community foresee any upgrades specifically related to the CYREN projects to be implemented in the forthcoming years?
- Having a more stable and more reliable machine would help to:
 - Secure stable primary beam intensity > 1500 W → to produce SPIRAL1 beams
 - Upgrade of ECR4 source (Phoenix V3)/Modification of injector 2
 - Laser ion source for SPIRAL 1 for purified beams

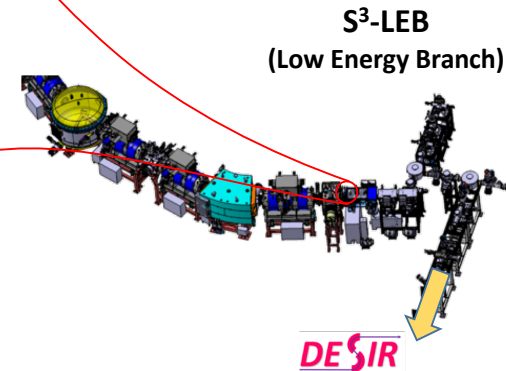
CYREN survey : S3-LEB

No direct impact of the CYREN project → not use cyclotron beams for the scientific program

S³-LEB setup



- Laser spectroscopy on S³ products in a supersonic jet
- Mass and decay spectroscopy measurements
- Possible transport towards DESIR



CYREN survey : S³-LEB/SIRIUS

Impact of CYREN project on S³-LEB program

□ Human resources:

Risk (short and medium term):

- the construction and operation of S³(-LEB) relies on some technical resources and services which will be shared with CYREN project.

Opportunity (medium and long term):

- optimizing the human resource involved in the cyclotron operation is an objective of CYREN
→ positive impact on SPIRAL2

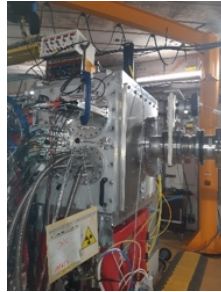
□ Test beams:

- Targets, diagnostics, detectors (some tests already performed with cyclotron beams)

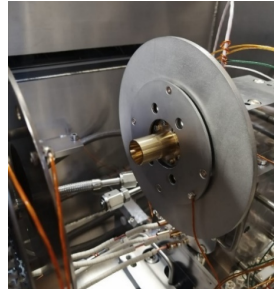
- R&D of gas stoppers for S³ and NEWGAIN
- Test experiments on complementary beams



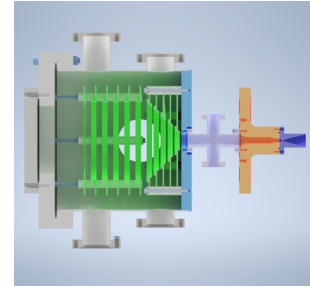
S³ target wheel



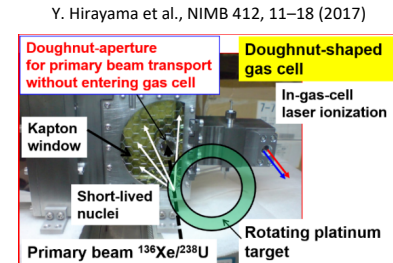
S³ diagnostics box



Existing S³-LEB gas cell



Electrical gas cell
(FRIENDS³ project)



Gas cell for MNT
(example KISS project)

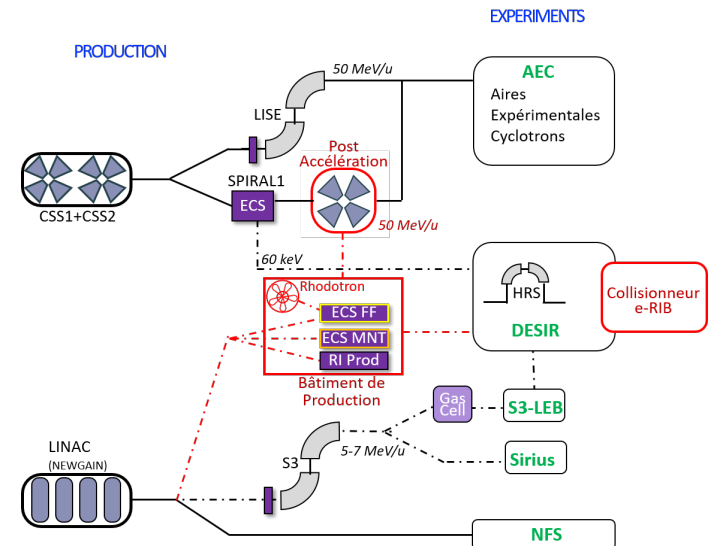
Parasitic beams for testing (Large E range covered) → Dedicated experimental rooms
V. Manea, J. Piot, H.Savajols

CYREN survey : NEWGAIN/MNT

- What impact do you expect the project to have in your community?

CYREN → study of reaction mechanism at VAMOS for future use at SPIRAL2 with fission and MNT


- Heavy n-rich species : MNT at VAMOS opens a new possibility for production scheme of radioactive beams. Primary beams of U & Th ~6-7 MeV/u
- Medium mass n-rich → Feasibility study of production scheme for lighter beams : Complementary to the target-ion source for SPIRAL1
- Does your community foresee any upgrades specifically related to the CYREN projects to be implemented in the forthcoming years?
- Outcome of present studies MNT



CYREN survey : Super-heavy

- What impact do you expect the project to have in your community?
- No direct impact on decay/laser spectroscopy and mass measurement experiments of SHE
- Impact will come through study of the fission reaction mechanism & MNT at VAMOS

Multi Nucleon Transfer as an alternative tool
- n-rich very heavy and superheavy nuclei, RIB production



Science cases and applications

neutron-rich nuclei

region around $N=126$ south of ^{208}Pb

region around $N=152$ n-rich actinides

superheavy nuclei

Installations at GANIL/CYREN

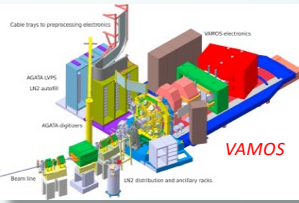
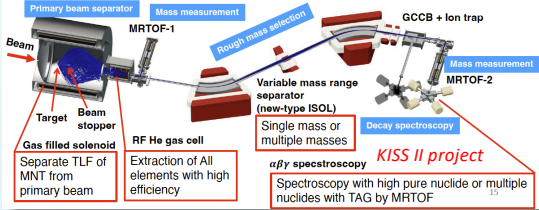
VAMOS++ and second arm
EXOGAM
→ upgraded VAMOS spectrometer

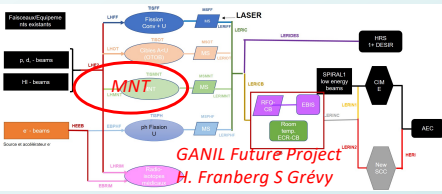
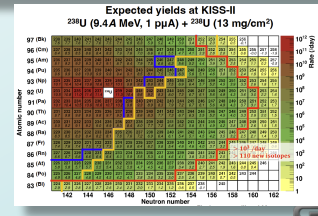
Perspectives

Present - GANIL PAC 2024:
proposal $^{232}\text{Th}(6 \text{ AMeV}) + ^{96}\text{Zr}$ at GANIL PAC 2024


Future of GANIL:
MNT as one RIB production scheme (Spiro initiative)

Example:
KISS II project at RIKEN, Japan

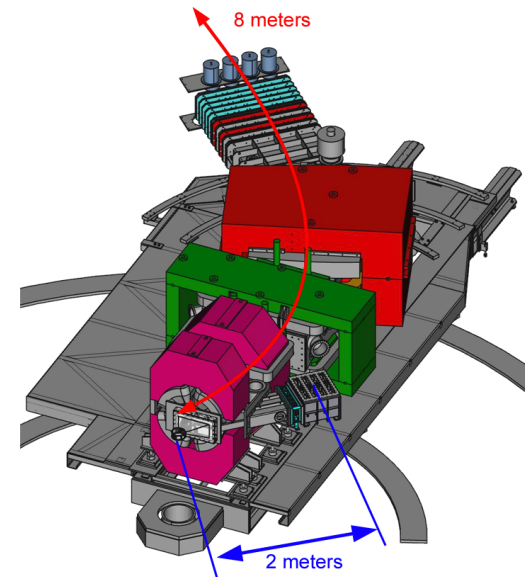



Barbara Sulino, Dieter Ackermann, Iulian Stefan

MNT 

CYREN survey : Fission

- What impact do you expect the project to have in your community?
- A better resilience of the Cyclotron. This would translate into a better duty cycle. In the last year, we faced major issues with the operation of the CSS1. In summertime notably, there are clear difficulties. **Reliability and time structure of the beam (instantaneous intensity)**
- Are there any specific/technical aspects that make the project appealing to your community and why?
- Increased intensity for the heavy beams. One of the big plus of the GANIL is the availability of the ^{238}U and now ^{232}Th beams. We aim at increased intensities for both these beams. The source to cyclotron transmission is probably currently a bottleneck . Vamos set-up can not accept all the primary intensity



CYREN survey : Fission

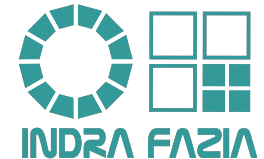
- Does your community foresee any upgrades specifically related to the CYREN projects to be implemented in the forthcoming years?
- Maintenance and development of the current experimental areas. We need to see these experimental areas still going forward. Technical developments are needed there.

CYREN survey : Nuclear dynamics and thermodynamics

Q: What do you expect to be the impact of the CYREN project in your community?

A: INDRA-FAZIA collaborations are deeply involved in the study of the EoS.

1.5 Nuclear dynamics and thermodynamics: the equation of state of nuclear matter



In particular, we are fully involved in many fields described in the CYREN « Physics Motivations » document.

- 1.5.1 - Exploring the properties of clusters in dilute systems.
- 1.5.2 - Neutron-proton equilibrium and transport processes in semi central collisions.
- 1.5.3 - Thermodynamics of exotic systems in central collisions.
 - 1.5.3.1 - Chemical instabilities in multifragmentation.
 - 1.5.3.2 - Study of the limiting temperature and level density in fusion-type reactions.
- 1.5.4 - Persistence of structure effects at high excitation energies.

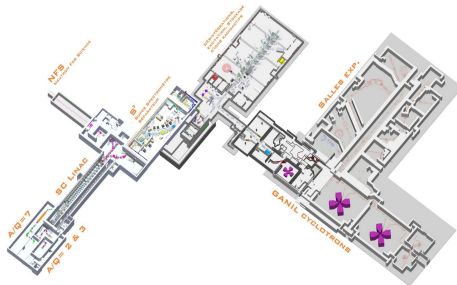
All of them will be deeply impacted by the CYREN project.

CYREN survey : Nuclear dynamics and thermodynamics

1.5 Nuclear dynamics and thermodynamics: the equation of state of nuclear matter

Q: Are there particular/technical aspects that make the CYREN project appealing to your community and why?

Main interests for CYREN and GANIL future



Q: Does your community foresee upgrades specifically Related to the CYREN projects to be implemented in The forthcoming years?

Improvements on the detectors etc..

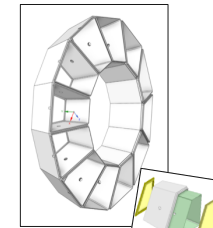


Developments in progress

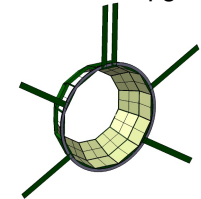
Beam monitor



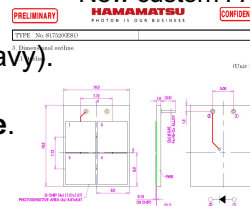
INDRA Chlo upgrade



INDRA Si upgrade

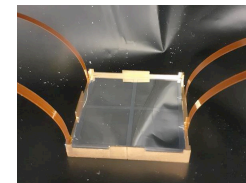


New custom FAZIA photodiodes

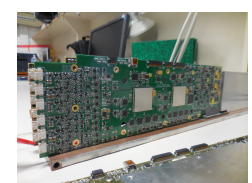


EXCELITAS TECHNOLOGIES

New FAZIA silicons



New FAZIA FEE cards



- Large variety of accelerated ions (light to heavy).
- Beam energies from few MeV to 95 A MeV.
- Good **quality** and **intensities, more reliable**.
- Radioactive beams (SP1/SP2).
- Larger beam time scheduling.
- Many **dedicated experimental rooms. (testing)**
- More beam time
- **Beam lines problems** → Beam delivery up to the detector. Renovation of the arret de poisson. Diagnostic missing.

CYREN survey : Nuclear structure (in-beam)

- ✓ The CYREN project brings a perspectives for 2 decades in using the cyclotrons of GANIL (ie it will not close)
- ✓ The project will induce a significant improvement of the duty cycle of the cyclotrons complex

The in-beam spectroscopy community projects are :

- Coulomb barrier with heavy stable beam (Fission, MNT, fusion). Even if many things have been done, high precision measurements remains relevant for nuclear structure studies
- In-flight fragmentation at the LISE separator with dedicated setup
- ISOL post-accelerated RIB for direct reaction (nuclear structure, nuclear dynamic and astrophysics)

The physics cases are

- Resonance and near threshold high resolution spectroscopy, including cluster, at the proton and neutron drip-lines in the *sd*-shells
- Charge exchange and pair transfer
- Ab-initio testing
- Astrophysics spectroscopy
- Surrogate methods
- Study of nuclear deformation by coulex

CYREN survey : Nuclear structure (in-beam)

This long-term perspective (CYREN) gives **arguments and credence** to further developments relevant to several aspects of the in-beam spectroscopy program at the CSS complex.

The SPIRAL1 facility is central in our perspectives and should benefit from this long term perspective for improvements

We acknowledge the recent efforts made by GANIL in this direction which were crucial in the AGATA decision

Our expectations as a consequence of the CYREN refurbishment for SPIRAL1 are :

- Increase of the beam power on target up to the authorized 6kW (C0 source development, ECS improvement)
- Increase of the diversity of chemical species (ions source, primary target)
- Increase of the beam quality (intensity, purity)
- ideally an increase of the energy (higher charge states for instance) of the mid-mass isotopes

→ All these improvements must be seen as a **win-win attitude** for both DESIR and CIME communities

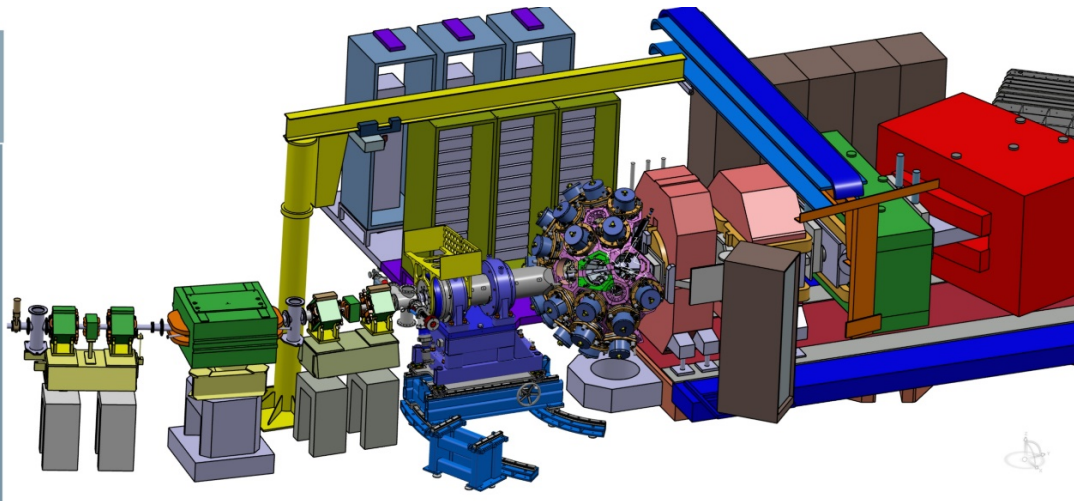
The high precision and high resolving power are the keys for the future of our field at GANIL

This can only be achieved with high quality SPIRAL1 beams requiring a reliable driver system (CSS) and state of the art instruments

We support the refurbishment of the CSS complex in the perspectives of improvements for SPIRAL1

CYREN survey : Nuclear structure (in-beam)

Our mid term future is [AGATA@GANIL.2](#) with GRIT and SPIRAL1 from mid-2028



The main motivation for the return of AGATA at GANIL is the availability of SPIRAL1 beams

Our community is enthusiastic about this future campaign

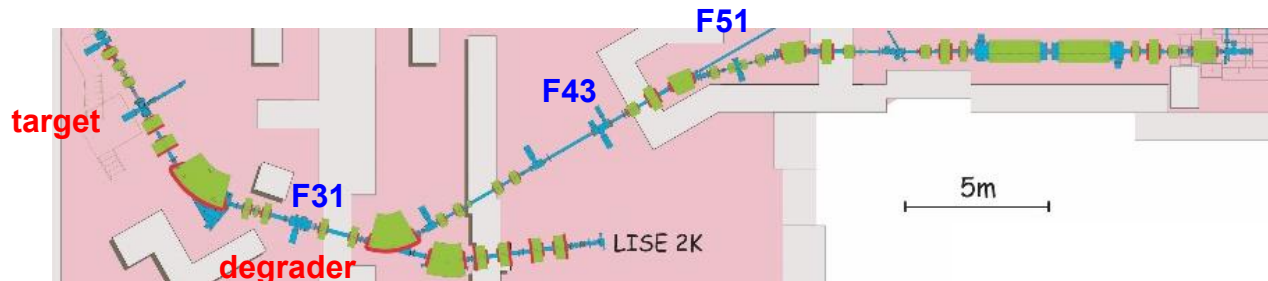
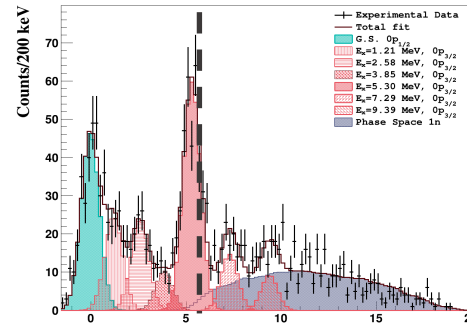
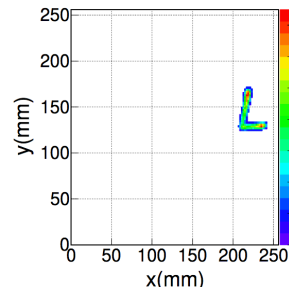
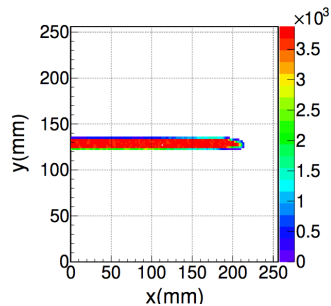
Our immediate needs are :

Development of new beams : ^{44}Ti , ^{62}Zn , ^{13}O , ^{55}Co , $^{56,57}\text{Ni}$

A cryo He and H solid target are needed

CYREN survey : Nuclear structure (in-beam)

CYREN → Decay and direct reactions fragmentation beams at LISE
(ACTAR TPC)



- Reliable cyclotrons improves the performance
- Upgrade of LISE spectrometer : CLIM to reach original specifications ($P < 800$ W)
→ GCM22
- Risk to see the current experimental caves LISE being slowly disengaged due to the increased demand on the SPIRAL 2/CYREN side.

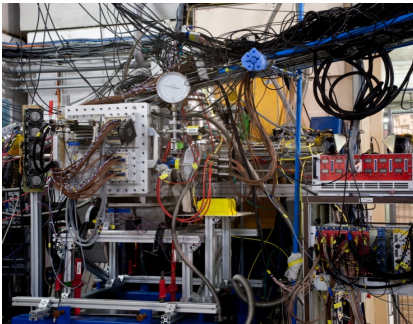
CYREN survey : Nuclear structure (in-beam)

Study of Giant Resonances at GANIL Cyclotrons

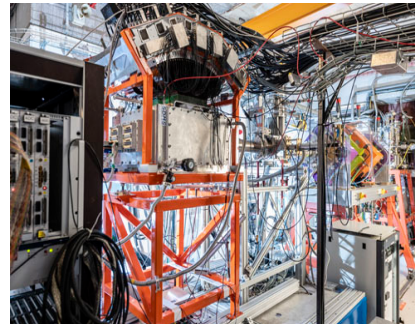
I. Matea (IJCLab) – M. Vandebrouck (CEA/Irfu/DPhN)

- Inelastic scattering reactions (α, α'), (p, p'), ($^{12}\text{C}, ^{12}\text{C}'$) ... @50 MeV/nucleon are particularly suited to study giant resonances
- Several experiments performed at GANIL Cyclotrons
e.g. Study of the Giant Monopole Resonance in unstable nuclei using active targets

MAYA



actar
TPC



C. Monrozeau *et al.*, Phys. Rev. Lett. 100, 042501 (2008)
M. Vandebrouck *et al.*, Phys. Rev. Lett. 113, 032504 (2014)
M. Vandebrouck *et al.*, Phys. Rev. C 92, 024316 (2015)
S. Bagchi *et al.*, Phys. Lett. B 751, 371 (2015)

Study of GMR in $^{58-68}\text{Ni}$ via $^{58}\text{Ni}(\alpha, \alpha')^{58}\text{Ni}^*$ and $^{68}\text{Ni}(\alpha, \alpha')^{68}\text{Ni}$ reaction using ACTAR.
Experiment performed in 2019 at LISE. Ongoing analysis.

- Unstable beams @50 MeV/nucleon would enable to continue this kind of investigation. Some examples :
 - Continue GMR studies in unstable nuclei using ACTAR (interest along isotopic/isotonic chain)
 - Study of the PDR along the unstable $N = 50$ isotones (^{84}Se)

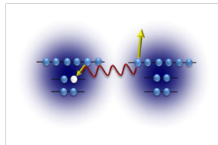
CYREN survey : Interdisciplinary Research

Interdisciplinary research at CIRIL-GANIL

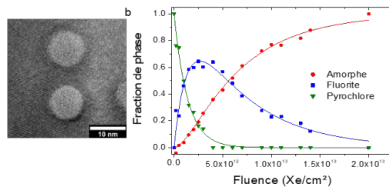
Diluted matter, molecules, clusters



Atomic physics, plasma



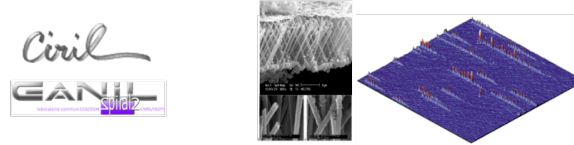
Materials science



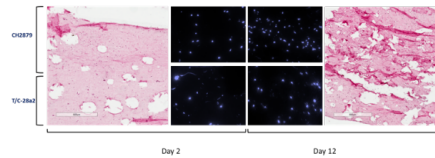
Radiochemistry, Astrophysics/chemistry



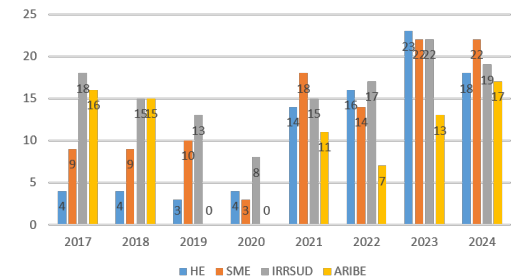
Nanostructuration, ITT, surface



Radiobiology



Number of realized experiments per beamline



Uniqueness of the CIRIL-GANIL facility:

- **Multiple lines and parallel operation** (IRRSUD + ME + HE pilot + ARIBE)
- Broad range of :ions, energies (6 orders of magnitude), stopping powers, intensities, charge states
- **Online devices can be installed on all 4 lines with standardizing dosimetry**
- Many **ex-situ Post-Irradiation Experiments open for users** (AFM, XRD, SEM, TEM, SIMS, PELICAEN) as well as **synthesis lab** of materials, polymers, biological samples

CYREN survey : Interdisciplinary Research

The following critical points emerged from the community consultation for the CYREN white paper

- Large diversity of accelerated ions (from the lightest to the heaviest)
- **Sufficient beam time on a regular basis**
- **Reliable accelerators** (cavities + power supplies + beam devices + electronics + vacuum, etc)
- Powerful instrumentation open to users, at the top of the technology (detectors, online analysis, etc)

To ensure the continuation of interdisciplinary research experiments, investments have been already made to renovate the lines in addition to the CYREN project

- **Renovation of the 4 beamlines for CIRIL platform (ARIBE, IRRSUD, ME, HE)**
Through CNRS, CPER, RIN funding (1,3M€) for all vacuum system, power supplies, instrumentation, mechanics, and ARIBE casemate (under progress)
- **Instrumental developments (via ANR, H2020, RIN,...) to improve the possibility for users in the interdisciplinary research** : MIRRPLA, Flash Irradiation, AFM, ESR, EIBT,...

CYREN survey : Interdisciplinary Research

Impact of CYREN in the community of interdisciplinary researches:

- Getting experiments with high beam quality : maintain and increase the community around GANIL
- Communicate asap with the scientific communities the renovation schedule: anticipation of beamtimes for PhD students, avoid temporal conflicts with funded projects
 - participation to the optimized renovation schedule for the scientific researches continuation

Specific/technical aspects making CYREN appealing to our community:

- Getting reliable accelerators
- Obtain stable beam (position, intensity), beam time structure
- Renovation of all beam diagnostic devices (even **slits**, **profilers**, choppers, etc)
- Renovation of the specific dipole for Medium Energy D35 in the septum included in the project ?

- Make beam schedule easier (C01/C02)

CYREN survey : SUMMARY

Strong agreement on the **benefit** of the CYREN Project for the future of GANIL

- Reliability, stability of the cyclotrons
- More beam time for developing new SPIRAL1 beams

Renovation is an Opportunity to pursue further developments :

- Renovation of beam diagnostic devices (slits, profilers, choppers, etc...)
- Increase of the beam power on target
- Increase of the beam quality (intensity, purity)
- Increase of the diversity of chemical species (ions source, primary target)
- Running SPIRAL1 in parallel with SPIRAL2
- Dedicated experimental rooms for testing
- Upgrade of (C02)

Concerns :

- Human resources
 - Shutdown would affect the outcome of the physics programmes.
 - Schedule of the operation should be made available to the users in advance
-

CYREN survey : contributors

- Franco Galtarossa & GUEC members
 - B. Blanck, H. Savajols, J. Piot. V. Manea. J.C-Thomas
 - D. Ackerman, A. López-Marténs, H. Franberg
 - P. Delahaye, P. Jardin
 - M. Caamaño, C. Schmitt, J. Taieb, M. Rejmund
 - M. Assié, E. Clément
 - M. Vandebrouck, I. Matea
 - N. Le Neindre, D. Gruyer, J. Frankland
 - C. Grygiel
 - P. Anger, P.E. Bernaudin
-

No part of the talk

GUEC