S^3 global strategy toward day1 experiments

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on behalf of the S^3 collaboration

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Outline

- LINAC beams
- Target availabilities
- Infrastructure prerequires
- Separator Spectrometer commissioning
- SIRIUS commissioning
- LEB commissioning
- DAY1 experiments

LINAC beams

	Note	Version 1
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Caractéristiques des faisceaux pour S³

A. Drouart, B. Jacquot et H. Savajols

Optical commissioning of the spectrometer

- ^{40}Ar or ^{22}Ne; E = 0,73 MeV/u and 5 MeV/u and I < 10 nAp

Scientific commissioning of the spectrometer

- ^{22}Ne, ^{40}Ar, (^{48}Ca), ^{58}Ni; E = 3-5 MeV/u and I < 10 µAp

Day 1 experiments (list TBU end 2022)

- **LEB**
  Very Intense $^{36\text{-}40}Ar$, ^{22}Ne and ^{18}O; I > 1pµA
  Intense $^{40\text{-}48}Ca$, ^{50}Cr, ^{58}Ni; I ~ 1pµA
- **SIRIUS**
  Very intense ^{22}Ne et ^{40}Ar, I > 1pµA
  Intense $^{48\text{-}50}Ti$, ^{48}Ca and ^{54}Cr; I ~1pµA

- ***Beam characteristics:***

Energy precision better than 0.5% and ΔE (FWHM) < 1%.
Beam spot on target : σx=0.5-1 mm & σy=1-2.5mm
Position fluctuation < 0.25 mm

	Plan de développement	ATRIUM-622204_v1
	Développement faisceaux Linac pour S3	Page 1/18

LBE1

- Ion source reliability @ 60 kV (ongoing)
- Beam development (metallic) (ongoing)
- Beam intensity reduction (pepper pot)

LINAC

- $^{16}O^{6+}$, $^{40}Ar^{14+}$ or $^{20}Ne^{7+}$ @ E = 7 MeV/A and 0.73 MeV/A
- Extrapolated tuning from beam reference setting
- Optimisation of the beam energy resolution/distribution
- Beam chopper in a range of 100Hz to 1 kHz

LHE

- Low beam intensity diagnostic (new ACCT development ongoing)
- Implementation of slits and possibly stripping foils

…

→ LHE commissioning will be validated by the characteristics of the beam at the S³ target point

Target availabilities

Needs : isotopes & timing

➢ **Targets @ S³ for commissioning – 2024-25**

^{116}Sn, ^{144,148}Sm, $^{160, 164}$Dy, ^{60}Ni, ^{45}Sc, ^{170}Er, ^{174}Yb, ^{180}Hf, ^{160}Gd,
^{184,186}W & ^{181}Ta

➢ **Targets @ S³ for 1st day …. Experiments – 2025-XXX**

- **Low Energy Branch**

^{50}Cr , ^{58}Ni (0,5-1 mg/cm²), ^{175}Lu, ^{180}Hf (0,4 mg/cm²),
^{208}Pb (0,25mg/cm²), ^{238}U (0,25mg/cm²) + 0,15mg/cm²

- **SIRIUS – 300-500 µg/cm²**

^{204}Pb (PbS) (300-500 µg/cm²), $^{207-8}$Pb (PbS) (400 µg/cm²)
^{209}Bi : ^{209}Bi (Bi_2O_3) (440 µg/cm²), Bi metallic (300µg/cm2)
^{238}U (400 µg/cm²) (metallic or oxide)

Irradiation hypothesis/beam time :

➢ 3 to 6 months beam time per year
➢ Experiment 2/3 weeks : 1 isotope « experiment » + 1 isotope « calibration (= commissioning) »
➢ 1 target wheel (18 targets) irradiated within 5-7 days

→ 3 wheels/experiment + 2 wheels in spare (extreme case, some targets will certainly be reusable)

→ **500-1000 targets/year**

See C. Stodel talk on Thursday

→ Needs to improve the capability of GANIL to make target (manpower & equipment)
→ Needs to settle collaboration with other target makers (GSI, ORANO, ….)
→ Needs to secure the supply chain for rare elements
→ Actinide target development ?

Infrastructure prerequisites

➢ **J6 SPIRAL2 Milestone :**
All (11) safety systems must be operational (documentation/control/tests)
→ Ongoing process (feedback from SPIRAL2)

➢ **Emergency fire exit :** prolongation of the derogation to work beyond 40m in the S^3 cave (end March 2023) until the construction of a new emergency exit (DESIR)
→ Ongoing process (first discussion with the labour inspector)

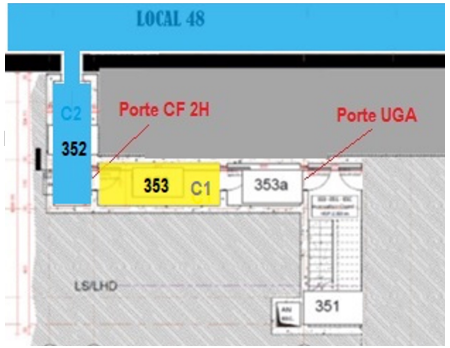
➢ **Prepare safety files related to this new emergency exit to be approved by ASN** (Major modification of the installation : nuclear ventilation, management of access, radiological shielding …) → to be submitted in October to ASN

GANIL laboratoire commun CEA/DRF spiral2 CNRS/IN2P3	Dossier de Sûreté Création d'une sortie de secours dans la salle d'expérience S^3	Page 1/54
PROCESSUS DE RATTACHEMENT : Gérer la sûreté, la sécurité et les déchets (PS02)		

→ New project 3S3 (manage interface between S^3 & DESIR, prepare safety files, impact, ...)

→ We include the capabilities to perform the optical and scientific commissioning of the spectrometer during the construction
Beam : ^{22}Ne, $^{36\text{-}40}$Ar; E =0.73-5 MeV/u and Intensity up to 10 pµA

Qualification UGSX
Qualification EIP 5a Surveillance vide
Qualification EIP 5b VIR
Qualification EIP 11 SRA
Qualification RGA (raccordements définitifs)
Qualification rebouchages (pro bio, CF2h)
Qualification sismique
Qualification EIP 10 (Delta P)
Qualification EIP 8 (rétentions)
Mise en oeuvre Caillebottis
Qualification SGAF
DSQ

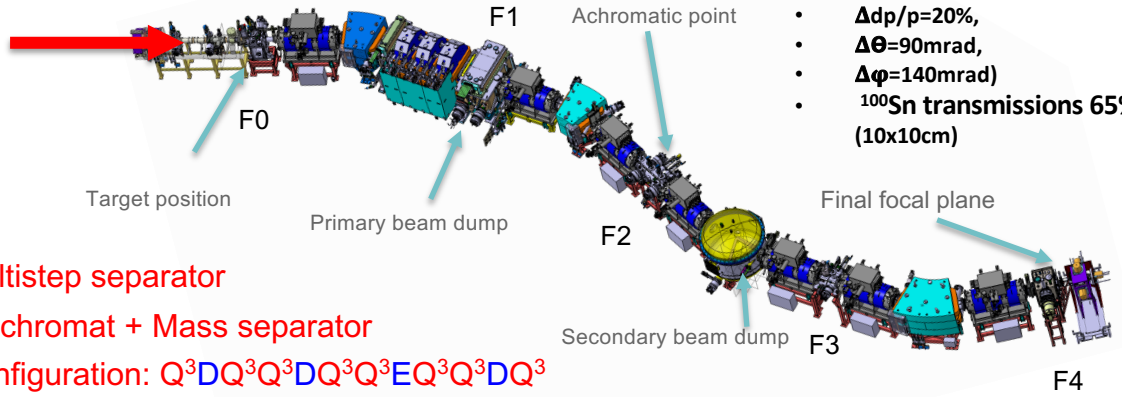


Separator-spectrometer

Basic properties and functionalities

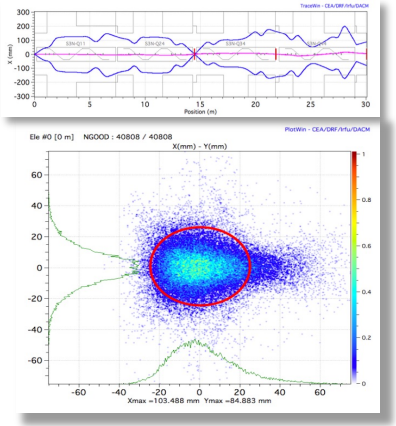
High beam intensity

High power target: >> 1pμA (= 6.10^{12}p/s)



Convergent mode

- No mass resolution
- 6 charge states
- **Δdp/p=20%,**
- **ΔΘ=90mrad,**
- **Δφ=140mrad)**
- **^{100}Sn transmissions 65% (10x10cm)**



Versatile multistep separator

Momentum achromat + Mass separator

Ion optics configuration: $Q^3DQ^3Q^3DQ^3Q^3EQ^3Q^3DQ^3$

F1 : R16=1.15cm/%

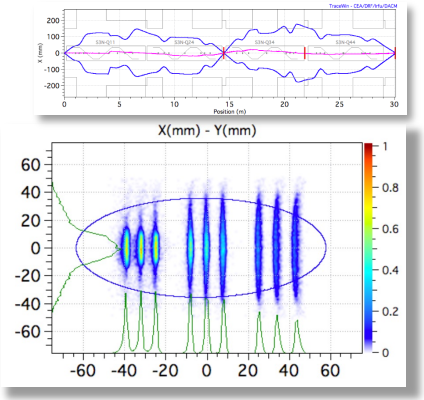
F2/F4 : R16 = R26 = 0

F3 : R16 = -1.73 cm/% / -1.59 cm/%

→ **Two basic optical modes of operation:**
High transmission vs high mass resolution
The momentum achromat (MA) optic is common to all modes

High mass resolution mode

- **m/q dispersion = 8 mm/%**
- **3 charge states & M/ΔM = 450**
- **Δdp/p=16%**
- **ΔΘ=45mrad**
- **Δφ=140mrad)**
- **^{100}Sn transmissions 40% (10x10cm)**



Separator Spectrometer commissioning

Global strategy

1. **Equipment commissioning :** F. Lutton/ M. Authier
   - Commissioning of individual elements (target system, magnets, power supplies, control-command, diagnostics…)
   - Alignments of magnets, slits and diagnostics

2. **Optical commissioning :** B. Jacquot
   - Progressive tuning of the elements with direct and slowed beams (Momentum achromat + Mass spectrometer)
   - Setup : dedicated diagnostics at the focal plane (SIRIUS & LEB not connected)

3. **Scientific commissioning :** A. Drouart / H. Savajols
   - Optimize the rejection and the transmission for relevant kinematics to reach the required performances in the Converging Mode (CM) for day1 experiments
   - Test the High Resolution Mode (HRM) important for the SIRIUS scientific program (*The experience gained in this first HRM tuning will help to optimize this mode for next beam time campaigns)*
   - Setup : SIRIUS or the diagnostic box in LEB mode depending of the first campaign selected for day1 experiment

→ Review to be organized with external experts (ANL, Jyvaskyla, TRIUMF, …) + help during the commissioning phase

→ Dedicated team to be setup @ GANIL (physicist, accelerator groups, technical support)

Optical commissioning

Step 0 : Prerequisite

Commissioning of individual elements (magnets, power supplies, control-command, diagnostics…)
Beam on target : commissioning de of LHE-S^3 with validation by S^3 of the beam characteristics at the target point
Alignments of magnets, slits and diagnostics by the geometers
Safety systems of elements must be operational

Step 1 : Momentum Achromat (common mode)

Progressive Qualification/tuning of the elements
Increasing optical order (measure of matrix elements)
Momentum achromat with multipole elements
Qualification of the optics (pencil beam 0/1st orders,
slowed down/scattered beam 1/higher orders)

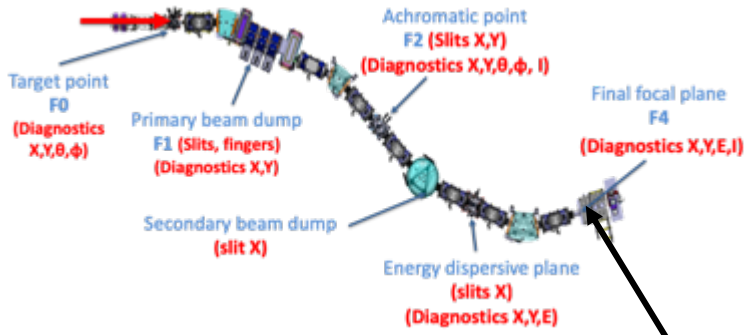
Step 2 : Mass Spectrometer (converging mode)

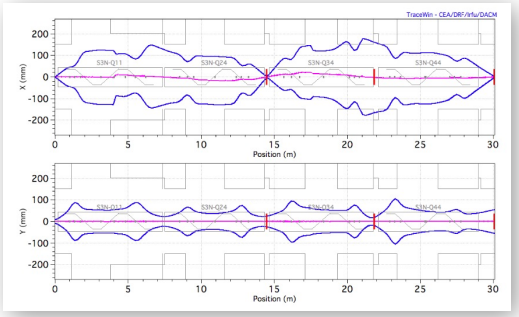
Progressive Qualification/tuning of the elements
Increasing optical order (measure of matrix elements)
Qualification of the optics (pencil beam, slowed down/scattered beam)

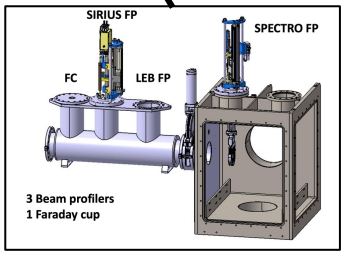
Step 3 : Test of the dispersive mode

Multipoles used in the MS to optimize the mass resolution at F4

Steps 1-3 ≈ 1-3 months







Scientific commissioning

Step 4 : Qualification for Physics

Easy (beam, target, detection)

High and known cross sections

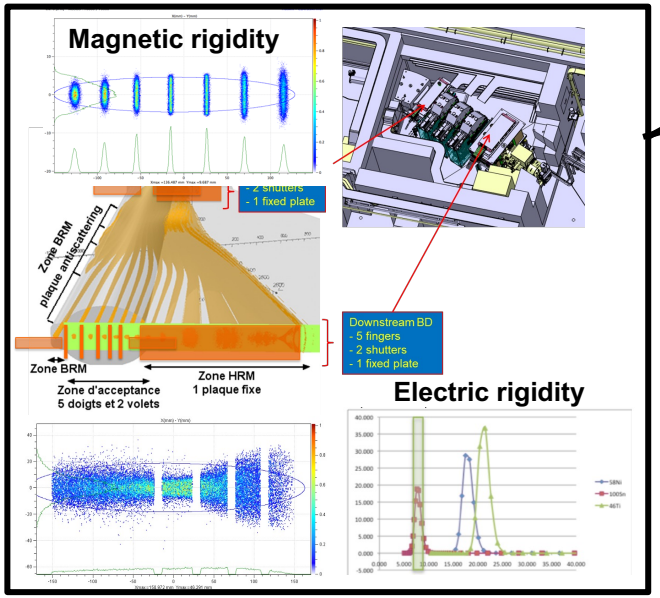
Identification of the reaction products (alpha, gamma tagging)

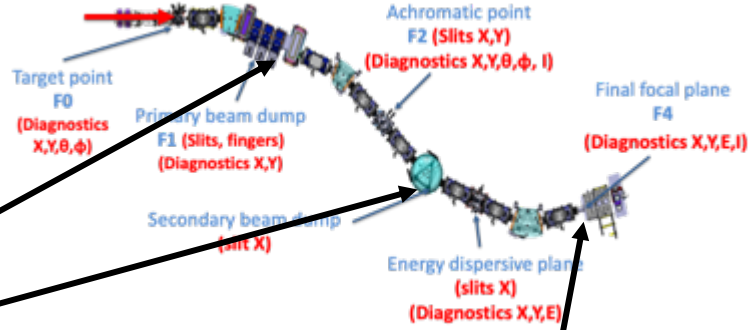
Various kinematics

➔ Measure and optimise the rejection (case by case)

➔ Estimate transmission

➔ Qualification of the detection on site (Diagnostic box, Sirius, LEB)



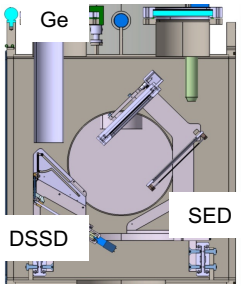


Rejection

Setup @ Focal Plane

Steps 4 ≈ 4-6 months to reach required performances for data taking.
Availably of beam time is crucial !

DiagBox LEB mode



DiagBox + SIRIUS

SIRIUS commissioning

1) Commissioning with alpha/electron/fission sources @ GANIL

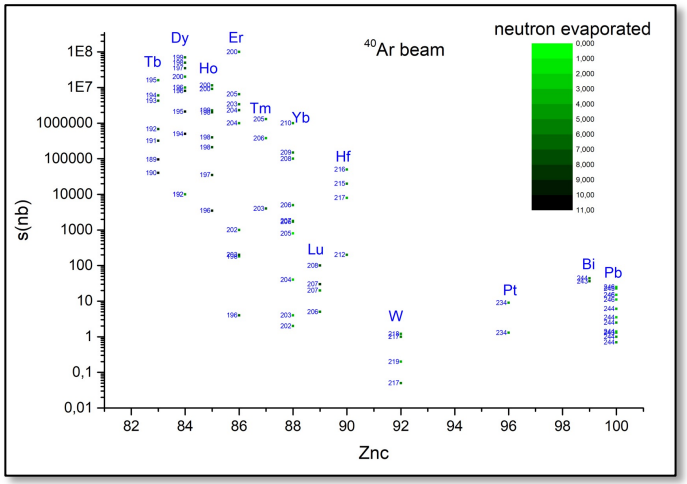
- SIRIUS DSSD and TUNNEL detectors & associated electronics (ongoing)
- Qualification of the silicon box with full electronics (ongoing)
- Tests of ToF measurement between DSSD and ToF (ongoing)

2) In-beam commissioning of SIRIUS @ GANIL

- Diagnostic Box + tracker : in beam tests in 2022 at GANIL cyclotrons
- Reaction ^{40}Ar(^{174}Yb,4-5n)^{209,210}Ra (High cross section, known reaction, alpha emitters) : beam time request in 2023
- Realistic experimental condition (ToF-DSSD coincidence) : : beam time request in 2023

3) SIRUS @ S^3

- Evaluate S^3 Rejection/transmission with various kinematics
- Standard calibration reactions such as ^{40}Ar+^{116}Sn, ^{40}Ar+^{174}Yb or ^{48}Ca+^{170}Er (High XS)
- Push the limits with low XS reaction (^{40}Ar + W/Ta)
- Ca/Ti beams on Pb/Bi targets to produce known isotopes such as ^{254}No, ^{253}No and ^{256}Rf
- Asymmetric reactions : Ne on heavy targets (Pb, Bi, Th, U)
- First Scientific output



LEB commissioning

1) Laser development @ GISELE/GANIL

- Narrow bandwith Ti:Sa laser development for stable erbium isotopes (spectral resolution 30-70 MHz)
- Continuous-wave seed-laser for wide scanning ranges (ongoing)
- Day one experiment @ GISELE : laser scheme developments and optimizations Sn, Pd, Zr, U, Th … (ongoing)

2) Off-line Commissioning @ LPC

- S^3-LEB fully commissioned off-line with stable Erbium at LPC (In gas jet laser spectroscopy of Er with spectral resolution 200MHz)
- PilGRIM (MR-ToF-MS) precision improved ($dm/m \approx 10^{-7}$)
- Optimization of the whole system to be ready for day1 experiment (ongoing)

3) SEASON detector commissioning

- Equipment tests and alpha/electron source tests performed at Saclay (ongoing)
- On-line commissioning @ JYFL

4) Diag-box LEB mode @ S^3

- Evaluate S^3 Rejection/transmission with various kinematics (High rejection is not mandatory)

5) LEB @ S^3

- Ti:Sa laser room (ongoing)
- On-line commissioning will be performed with ^{152}Er ($^{116}Sn(^{40}Ar,4n)$)
- First scientific output

Day 1 experimental plan

Physics topics:

- ***SIRIUS***

  Decay and isomer spectroscopy of Transfermiums (N=152), odd Z/N nuclei, alpha/proton decay for p-rich N=82 nuclei, New SHE isotopes $^{252\text{-}254}$Rf, exotic decay channels (pxn), Cluster radioactivity

  5 research groups from France, and from Germany, UK, Finland, Slovakia, Russia and USA

- ***LEB***

  Medium-mass nuclides along the N = Z line from Z = 40 (Zr) to Z = 56 (Ba), doubly magic ^{100}Sn, the heavy actinide region (Ac and U) and the super heavy element region (around No Z=102).

  8 research groups from France and 15 from Belgium, Germany, Finland, Slovakia, Poland, U.K., Hungary, Switzerland, Sweden, Spain and USA.

➔ 21 pre-proposals (2018)

The selection of possible day 1 experiments was made to determine out the list of pre-proposals with “high impact” (discovery & unique proposals for S^3) and feasibility.

➔ 3 months day 1 campaign selected for each set-up and presented at GSC 2019

➔ **2022 : update scientific program**

Day 1 experimental plan

Workshop “Physics with stable ion beams at SPIRAL2” planned 12-16 dec 2022 at GANIL

	Monday	Tuesday	Wednesday	Thursday	Friday
9:00AM-10:00AM		Intrumentation 1	General introduction on the physics with S3 beams	Interdisciplinary research with NEWGAIN	Concluding Remarks RoadMap per Programs
10:00AM-10:30AM					
10:30AM-11AM		Coffee	Coffee	Coffee	Coffee
11:00AM-12:00AM		Instrumentation 2	S3 Day-1 scientific program (SIRIUS)	New opportinities with S3 beams in the framework of NEWGAIN	VISIT SPIRAL2
12:00AM-12:30AM					
	Lunch	Lunch	Lunch	Lunch	
2PM-3PM	SPIRAL2 LINAC, S3, NEWGAIN	Instrumentation 3	S3 Day-1 scientific program (LEB)	New opportunities with S3 beams in the framework of NEWGAIN	
3PM-4PM					
4PM-4:30PM	Coffee	Coffee	Coffee	Coffee	
4:30PM-5:30PM	S3 spectrometer/Target	General introduction on the physics with S3 beams	Beyond Day-1 experiments at S3 New idea - further developments	New oportunities with NEWGAIN	
5:30PM-6:30PM					
			S3 UCC (closed meeting)		
	Cocktail			Diner	

- First campaign
- Discussion on new idea & further developments

https://www.ganil-spiral2.eu/event/physics-with-spiral2-heavy-ion-beams/

Round table

- **Beam time availability** (campaigns, long beam time request for some SIRIUS experiment, some experiment will required beam time sequences spread over several years)

- **Organisation for the S³-Spectrometer operation to be settled @ GANIL**

- **Manpower for S³-SIRIUS & S³-LEB operation**
  - How do we organize the experimental campaigns from manpower point of view?
  - The local team does not have enough members to be on shift for 3-4 months / year
    - We need at least one expert per shift, plus one or two to help.
    - We need external support from the collaboration (external people to come for more than 2-3 weeks ?)
    - We need dedicated post-doc and PhD thesis on cotutelle
  - S3-LEB will need continuous development and upgrades => manpower and involvement of external collaboration mobilized all along the year

  → Reinforcement of GANIL and collaboration involvement
  → Rough planning of operation needs to be known 2 years in advance

- **Actinide targets**