Developement of a Fast and Universal GAs CEll

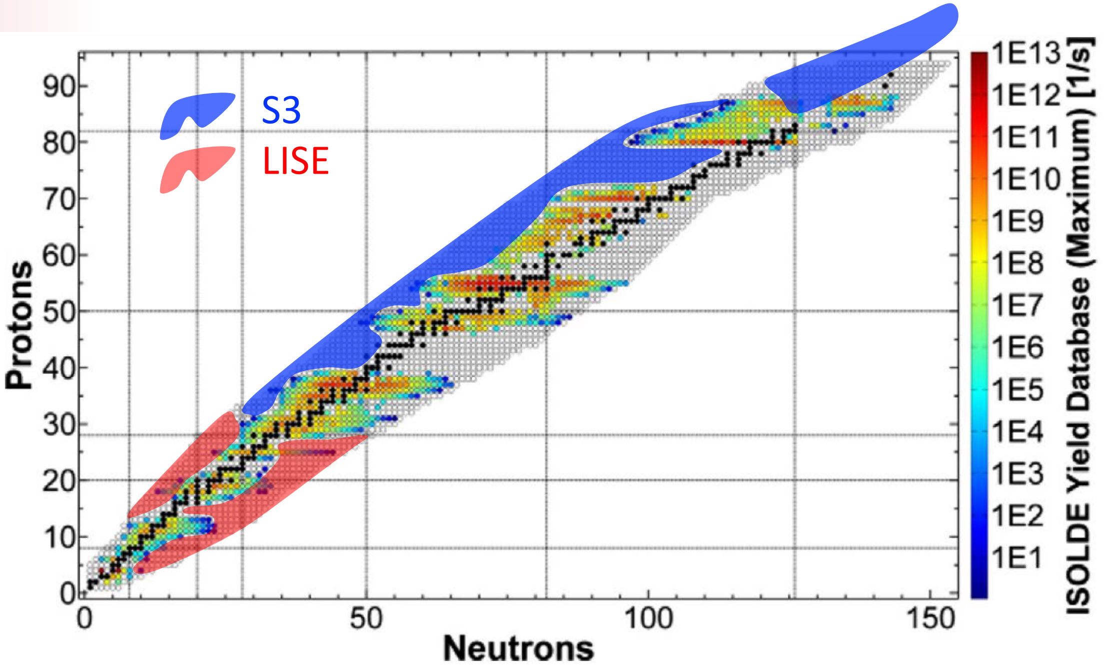
FUGACE

1- Motivations
2- Physics cases for s3-DESIR with FUGACE
- The physics at the N=Z line
- The physics of the heavy/superheavy nuclei
- The physics of neutron-rich nuclei below N=126 produced by MNT reactions

3- Gas cells for fusion-evaporation reactions
- Existing devices
- FUGACE

The FUGACE Project

1- Motivations



- In flight production allows the production of
  - all the chemical elements
  - isotopes with the shortest half-lives

To perform low energy measurements → need to stop them in a gas catcher

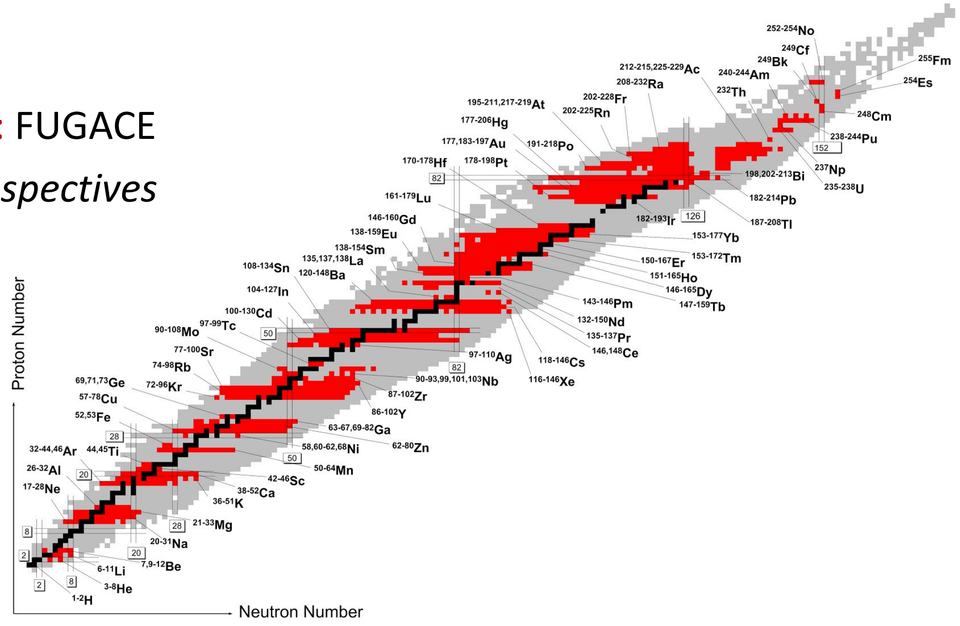
Coupling of DESIR and S3 :

- At S3-LEB : REGLIS → neutralization gas cell + laser ionization
  - very selective method
  - allows in-jet laser spectroscopy

  - no access to all the elements
  - extraction time ~250 msec → no access to the shortest lifetimes

➥ Quite old idea to develop a Fast and Universal GAs CEll : FUGACE

It is a recommandation of the 2020 French national prospectives



LISE-LEB :

- FUGACE will have to be tested with beam before being installed on S3
  - LISE2000 is most of the time available
  - interesting physics cases with limited developments

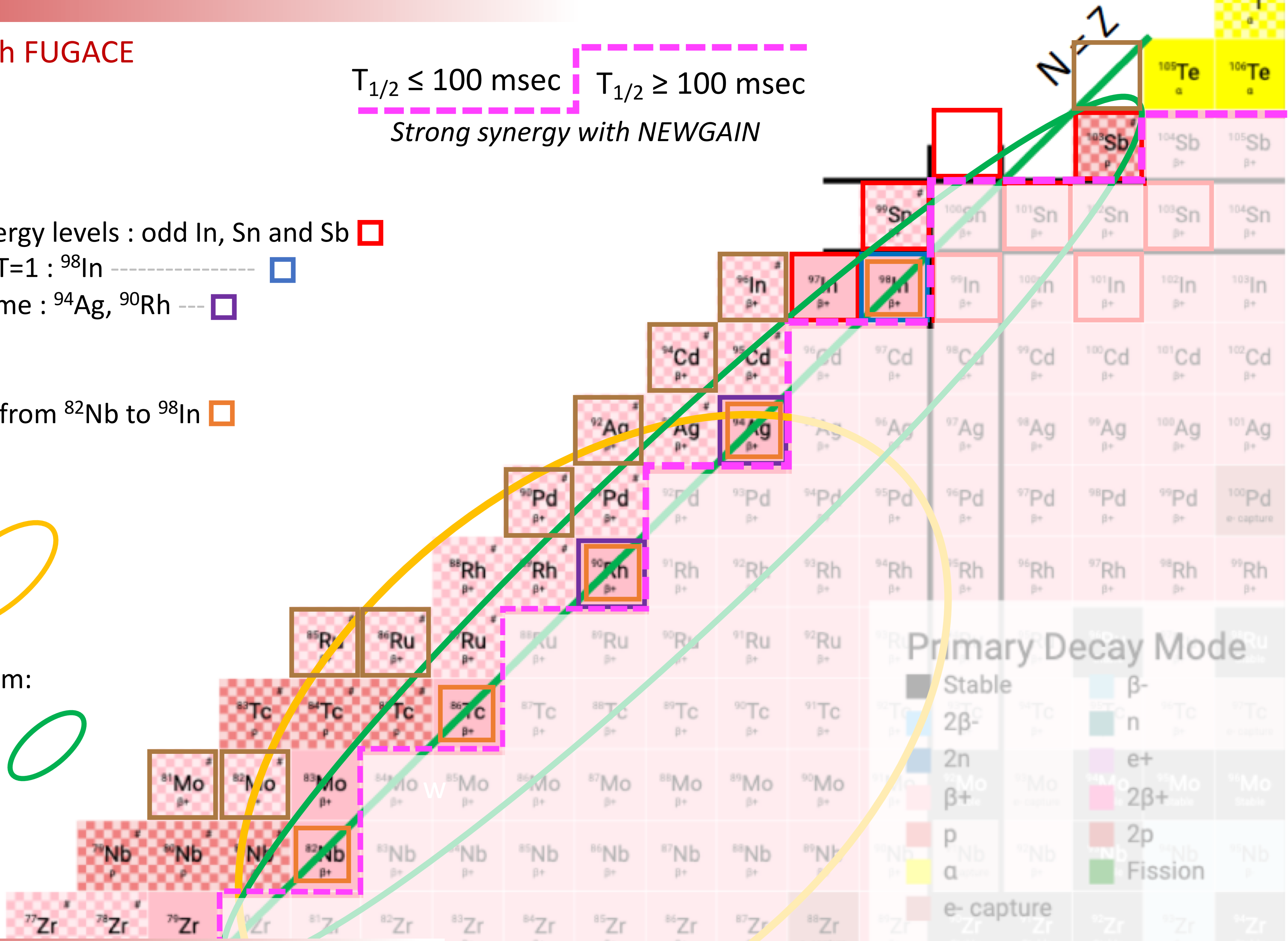
  - *possibility to develop a more ambitious "low energy" program at GANIL (not in the scope of the project)*

Courtesy L. Caceres – Prospective IN2P3 2020

2- Physics cases for S3-DESIR with FUGACE

The physics at the N=Z line

- Nucleon-Nucleon interaction
  - Effective Single Particle Energy levels : odd In, Sn and Sb
  - Pairing interaction T=0 vs. T=1 : ^{98}In
  - Spin aligned coupling scheme : ^{94}Ag, ^{90}Rh
- Decay modes:
  - Weak interaction studies : from ^{82}Nb to ^{98}In
  - β-p, β-2p decay :
- Collectivity and deformation:
  - B(E2) in Sn chain
  - Refractory chains
- Binding energies and Wigner term:
  - Masses
  - Astrophysics implications



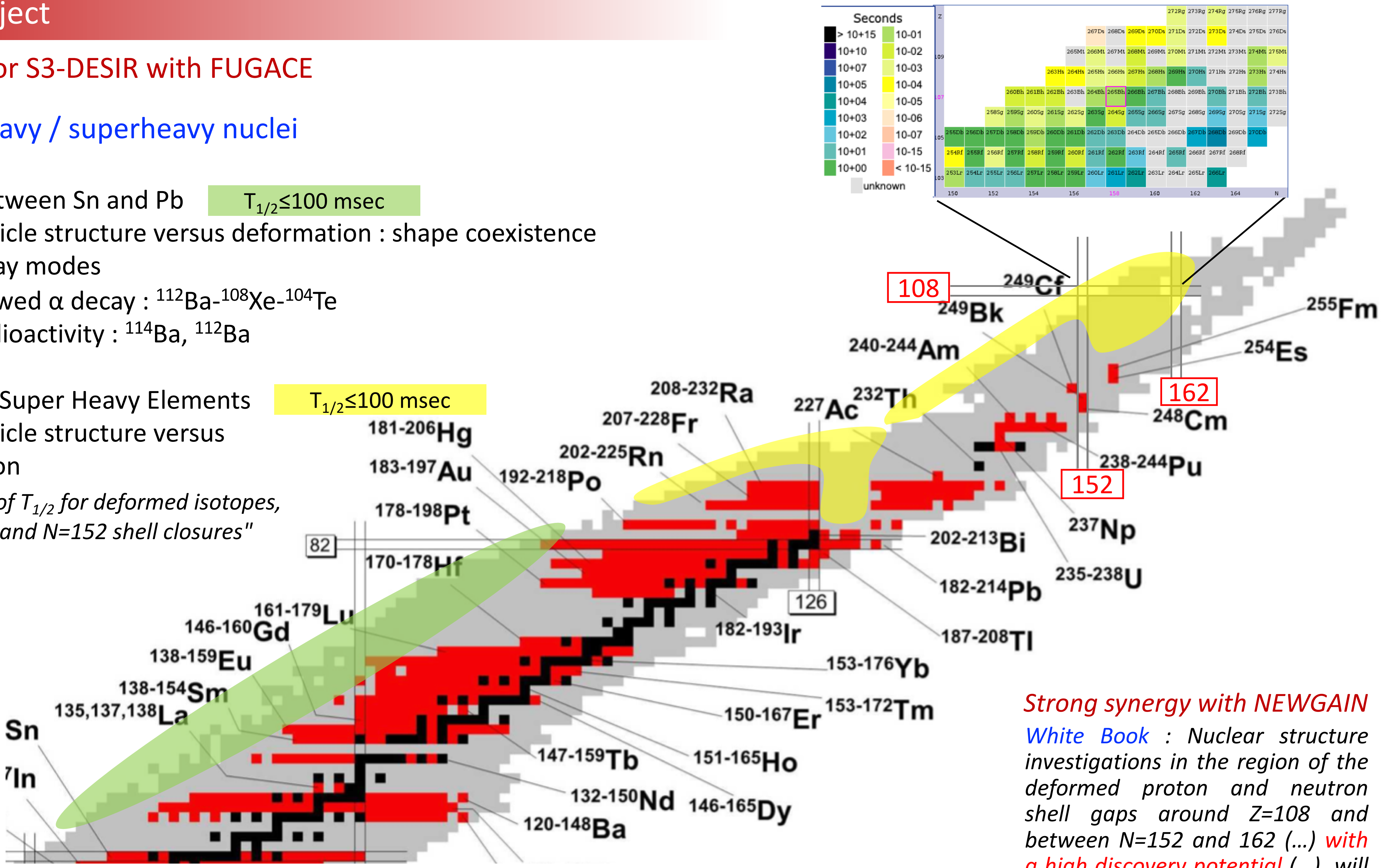
2- Physics cases for S3-DESIR with FUGACE

The physics of heavy / superheavy nuclei

- Heavy nuclei between Sn and Pb $T_{1/2} \leq 100$ msec
  - Single Particle structure versus deformation : shape coexistence
  - Exotic decay modes
  - Super-allowed α decay : ^{112}Ba-^{108}Xe-^{104}Te
  - Cluster radioactivity : ^{114}Ba, ^{112}Ba

- Very Heavy and Super Heavy Elements $T_{1/2} \leq 100$ msec
  - Single Particle structure versus deformation

  "Very fast drop of $T_{1/2}$ for deformed isotopes, i.e. after N=126 and N=152 shell closures"



Strong synergy with NEWGAIN

White Book : Nuclear structure investigations in the region of the deformed proton and neutron shell gaps around Z=108 and between N=152 and 162 (…) with a high discovery potential (…) will be at the main focus

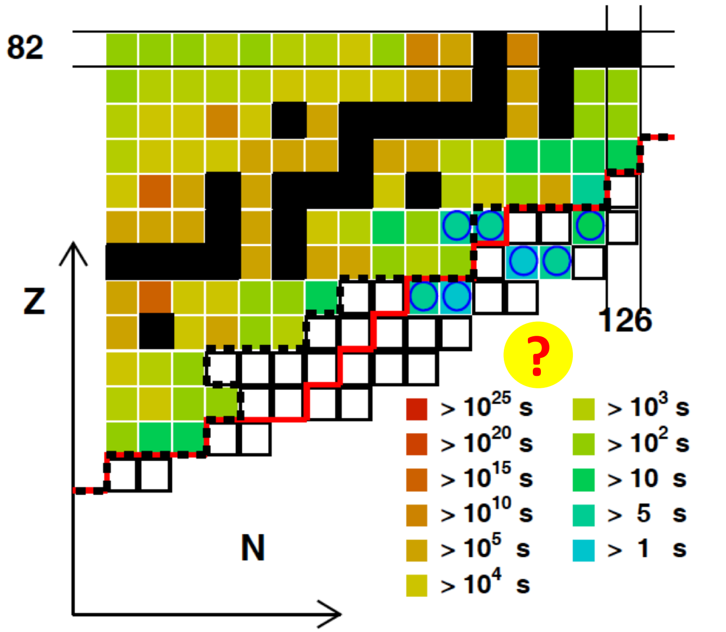
2- Physics cases for S3-DESIR with FUGACE

The physics of neutron-rich nuclei below N=126 produced by MNT reactions

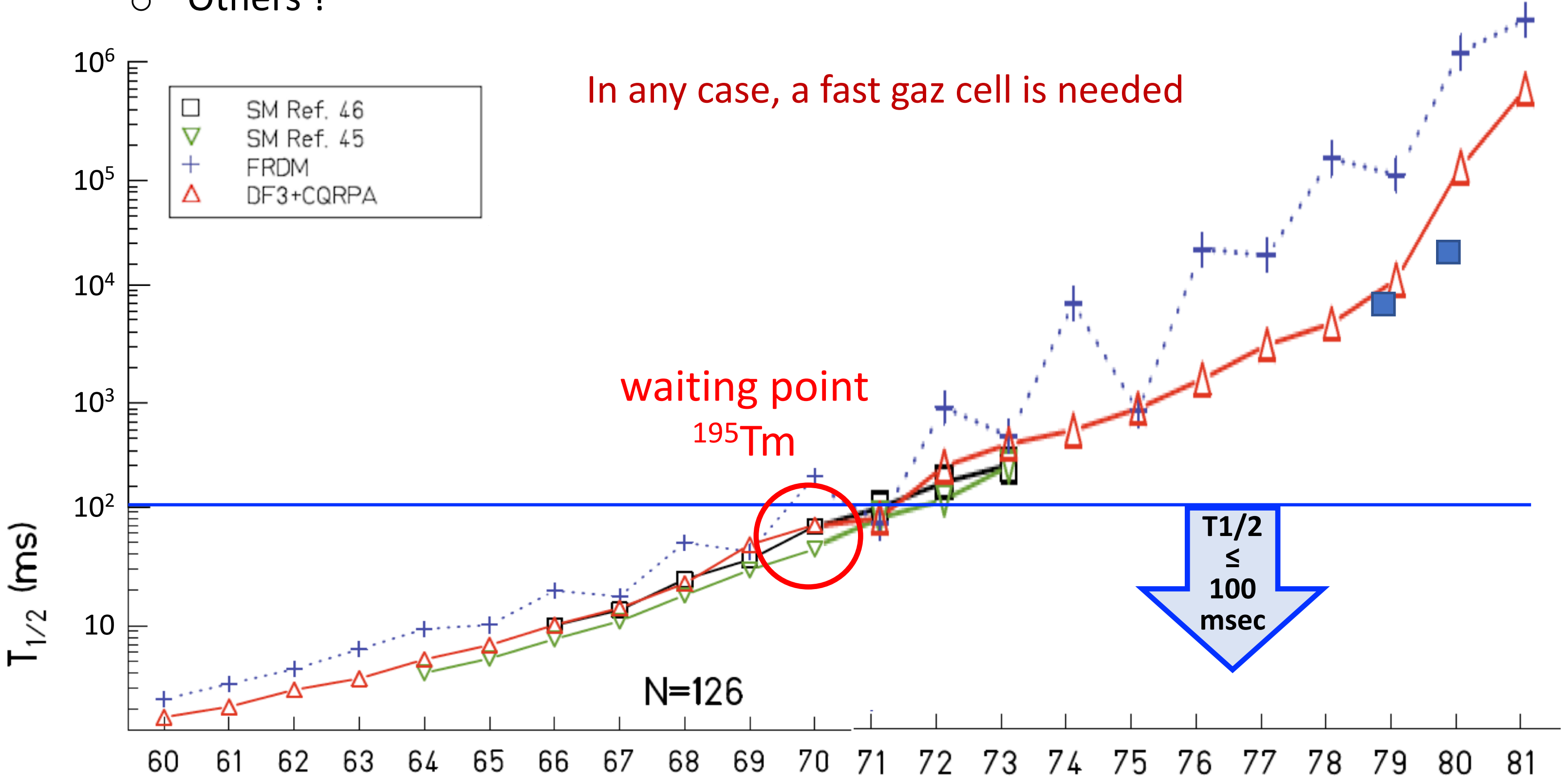
- Need reactions like : $^{136}Xe+^{208}Pb$, $^{136}Xe+^{198}Pt$, $^{238}U+^{198}Pt$

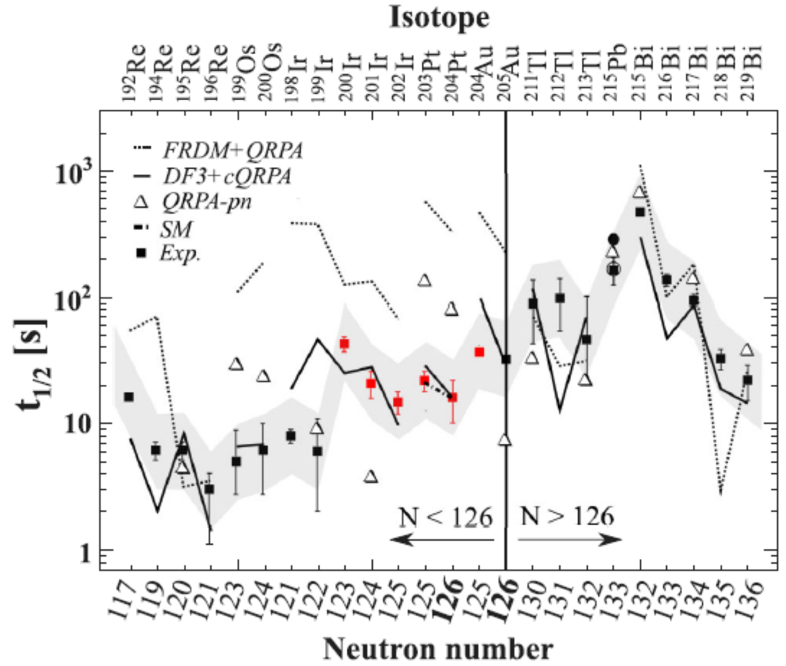
Strong synergy with NEWGAIN

- How ?
  - S3 with a new electric dipole ?
  - At a new beam line in the S3 room ?
  - Others ?



In any case, a fast gaz cell is needed





3- Gas Cells for fusion evaporation reactions

"Existing" devices : REGLIS (GANIL) and SHIPTRAP (GSI)

Nuclear Instruments and Methods in Physics Research B 338 (2014) 126–138
Contents lists available at ScienceDirect
Nuclear Instruments and Methods in Physics Research B
journal homepage: www.elsevier.com/locate/nimb

The cryogenic gas stopping cell of SHIPTRAP

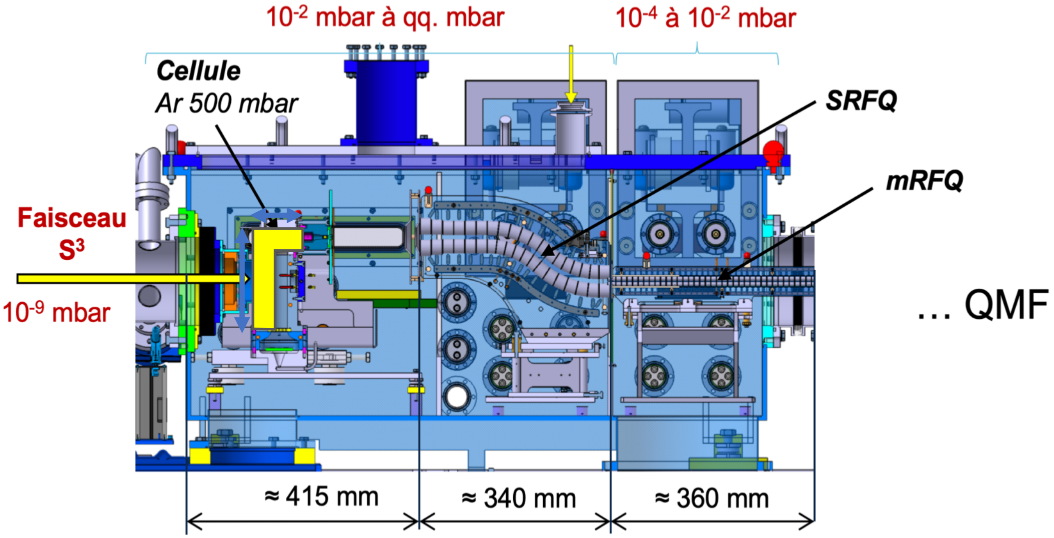
C. Droese [a,b,*], S. Eliseev [c], K. Blaum [c], M. Block [d], F. Herfurth [d], M. Laatiaoui [b], F. Lautenschläger [e], E. Minaya Ramirez [b,c], L. Schweikhard [a], V.V. Simon [b], P.G. Thirolf [f]

Neutralization gas cell

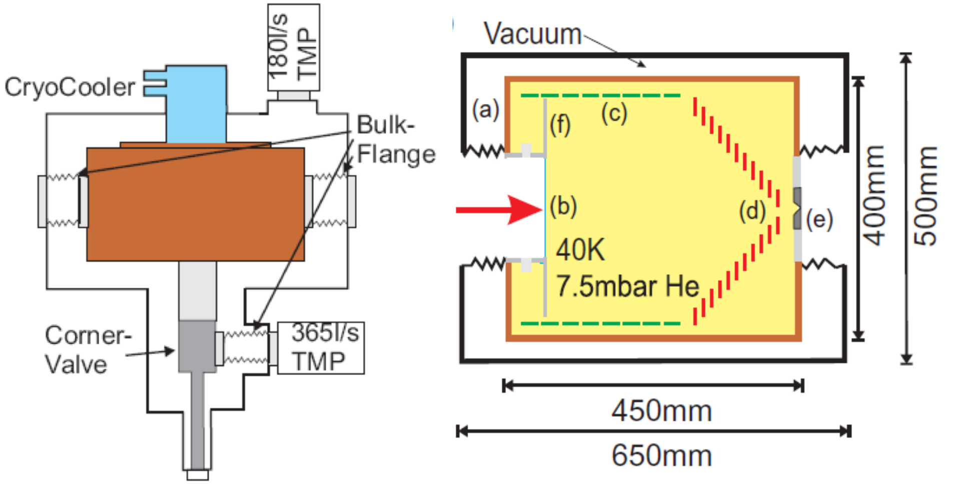
- No electric field
- Argon (larger recombination coefficient).
- High pressure (200-500 mbar) for reducing diffusion
- Small in order to extract as quickly as possible
- Extraction time ≈ 500-600 ms
- Efficiency 70-80% at 500 mbar (on paper).

Universal gas cell

- Electric field
- He (better for E-field) or Ar
- Low pressure (50 mbar room T) due to E field.
- Bigger to stop in lower pressure
- Extraction time ≈ 10 ms
- Efficiency 10-15% at room temperature, 70% cryogenic (tested).



… QMF



FUGACE : acceleration to 30 keV for the transport towards DESIR needed
→ internal chamber at HV
→ HV plateform ?

3- Gas Cells for fusion evaporation reactions

The FUGACE project :

➢ Submitted at the ANR AAPG 2021

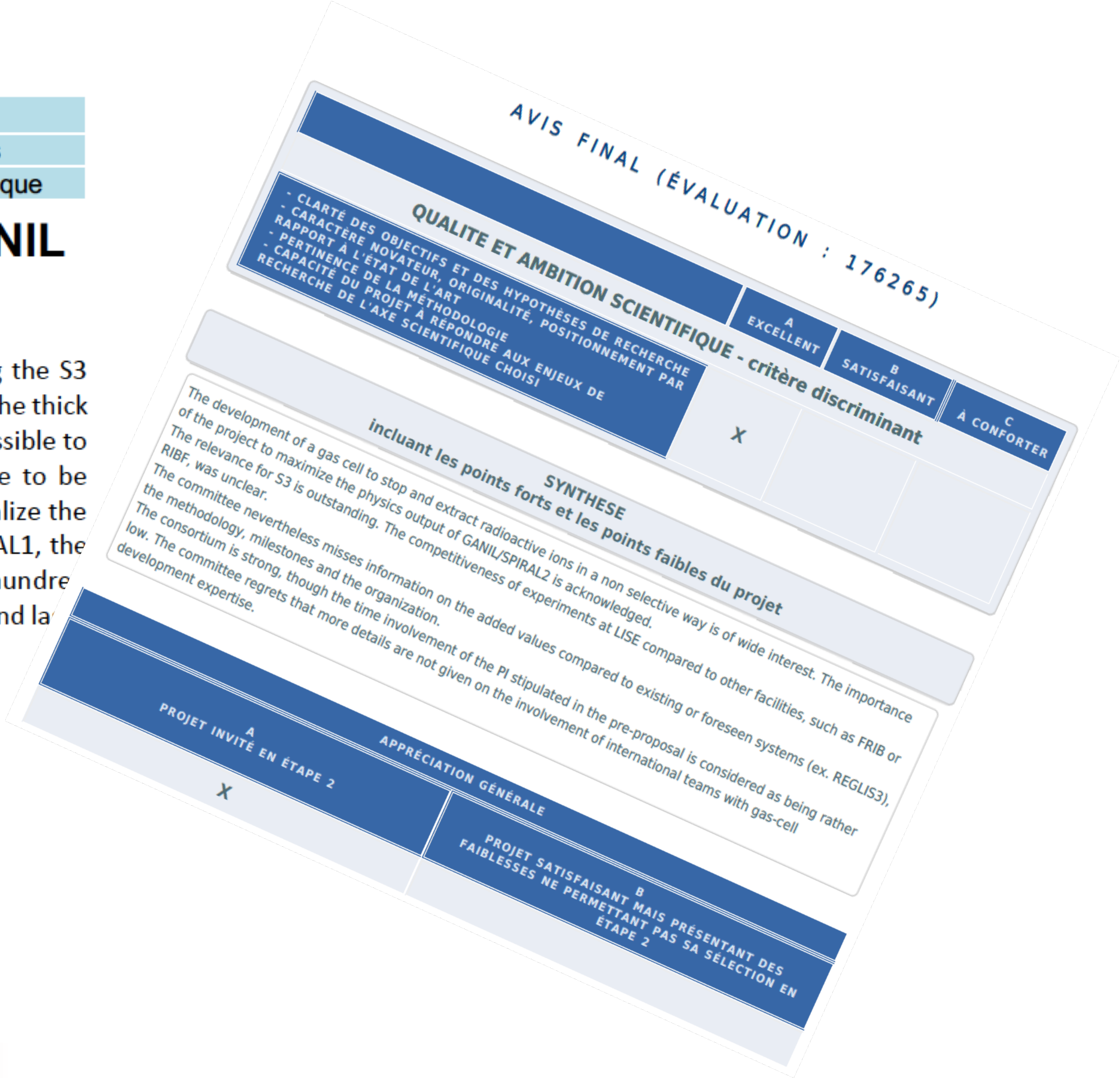
AAPG2021	**FUGACE : Fast Universal GAs CEll**	PRC
Coordinated by :	Stéphane GREVY	48 months
Physique de matière, hautes énergies, Planète-Univers : Physique subatomique et astrophysique		

Development of a Fast Universal Gas Cell for GANIL

- Pre-proposal's context, positioning and objective(s)

- *Description des objectifs et des hypothèses de recherche ;*

The exotic nuclei can be produced at GANIL [1] either by *fusion-evaporation* reactions using the S3 spectrometer or by *projectile fragmentation*, in flight using the LISE spectrometer or at rest in the thick target of SPIRAL1. In order to study them at low energy (a few tens of keV), which makes it possible to obtain beams of high purity and therefore to carry out precision experiments, nuclei have to be stopped in a catcher and extracted. With S3, nuclei will be stopped in a buffer gas that neutralize the atoms which will then be extracted through a gas flow (S3-LEB setup [2]). In the case of SPIRAL1, the target itself is the catcher. In both cases, the process of extraction is slow (up to a few hundre milliseconds) and selective (refractory elements for example cannot be produced at SPIRAL1 and la ionization is mandatory for S3-LEB and is not available for all the elements).



AVIS FINAL (ÉVALUATION : 176265)

QUALITE ET AMBITION SCIENTIFIQUE - critère discriminant	A EXCELLENT	B SATISFAISANT	C À CONFORTER
- CLARTÉ DES OBJECTIFS ET DES HYPOTHÈSES DE RECHERCHE - CARACTÈRE NOVATEUR, ORIGINALITÉ, POSITIONNEMENT PAR RAPPORT À L'ÉTAT DE L'ART - PERTINENCE DE LA MÉTHODOLOGIE - CAPACITÉ DU PROJET À RÉPONDRE AUX ENJEUX DE RECHERCHE DE L'AXE SCIENTIFIQUE CHOISI	X		

SYNTHESE incluant les points forts et les points faibles du projet

The development of a gas cell to stop and extract radioactive ions in a non selective way is of wide interest. The importance of the project to maximize the physics output of GANIL/SPIRAL2 is acknowledged.
The relevance for S3 is outstanding. The competitiveness of experiments at LISE compared to other facilities, such as FRIB or RIBF, was unclear.
The committee nevertheless misses information on the added values compared to existing or foreseen systems (ex. REGLIS3), the methodology, milestones and the organization.
The consortium is strong, though the time involvement of the PI stipulated in the pre-proposal is considered as being rather low. The committee regrets that more details are not given on the involvement of international teams with gas-cell development expertise.

APPRÉCIATION GÉNÉRALE	
A PROJET INVITÉ EN ÉTAPE 2	B PROJET SATISFAISANT MAIS PRÉSENTANT DES FAIBLESSES NE PERMETTANT PAS SA SÉLECTION EN ÉTAPE 2
X	

3- Gas Cells for fusion evaporation reactions

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Development of a Fast Universal Gas Cell for GANIL

- Collaboration : CENBG – LPC Caen – Subatech – GANIL - GSI
- Workpackages :

WP 0 : Administration et gestion du projet	CENBG
WP 1: Dimensionnement de la gaz cell	
1a- dimensionnement corps central :	CENBG
1b- Géométrie et technologie de l'extraction :	LPC
WP 2 : Gestion HT	CENBG
WP 3 : Système RF	LPC
WP 4 : Pompage / Régulation de gaz et Cryogénie :	Subatech, expertise LPC
WP 5 : Etude et Réalisation Mécanique :	Subatech, LPC, CENBG
WP 6 : Controle Command/Automatismes	LPC
WP 7 : intégration globale et installation	CENBG, GANIL

- Planning :
  - 2021 : pre studies
  - 2022 : Simulations / Design
  - 2023 : Construction
  - 2024 : integration and off-line tests
  - 2025 : installation at GANIL and in-beam tests

- Budget :

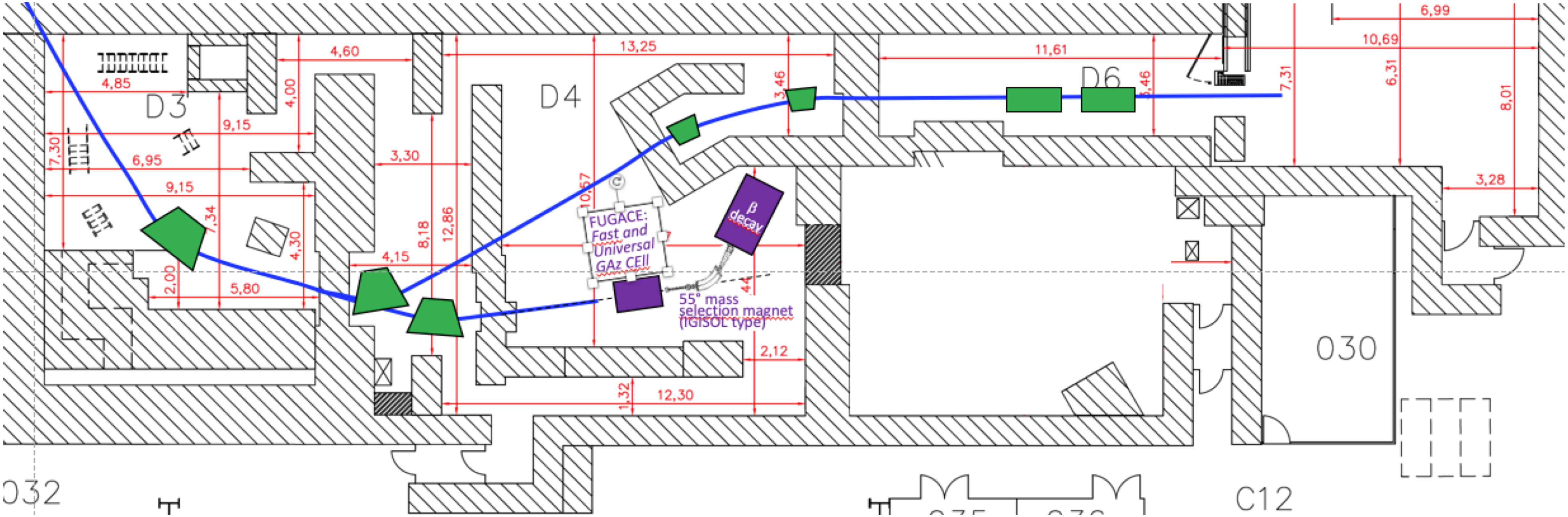
- Outer chamber:	51 000
- Inner chamber:	80 600
- Cryogenic system:	36 600
- Electrodes system:	15 800
- Extraction RFQ:	3 200
- Vacuum and gas:	99 000
- Devices (RF ampli…):	80 600
- Support structure:	5 800
- Control-command:	75 000
- *Total Investments:*	*447 600*
- Overhead investment (20%):	89 520
- CDD:	138 000
- Travels/meetings	20 000
- Total Project:	**695 120**
- Financial management (8%):	55 610
Total cost:	**750 730**

based on E.M. Ramirez estimations, 2015

LISE-LEB : what it could be ?

A "simple" setup for the commissionning of FUGACE

- beta decay setup for efficiency measurement of exotic nuclei
- TAS measurements for "physics output"



Thank you for your attention

Physics cases for LISE-LEB

The physics for light exotic nuclei produced by fragmentation

- Masses of light nuclei
  - Constraints on nuclear forces : n-rich F, O isotopes
  - Shell closures : N=32 and N=34 in Sc, Ti and V isotopes
  - Shell closures : N=20 towards N=28 in Si, P and Cl isotopes
  - β-2p and 2p emissions : ^{22,23}Si, ^{22}Al, ^{26}P, ^{35}Ca
  - IMME, mass models : ^{36}Ca, ^{20}Mg, ^{24}Si, ^{28}S

- Precise beta decay spectroscopy
  - N=20 and N=28 shell closures
  - Astrophysic interest : βp,$\beta\alpha$ and TAS measurements of of ^{45}Cr, ^{46}Mn

- Laser spectroscopy
  - 3N force sensitive to charge radius → O and Si chains
  - N=20 and N=28

Poorly-known regions in term of masses (n-rich)