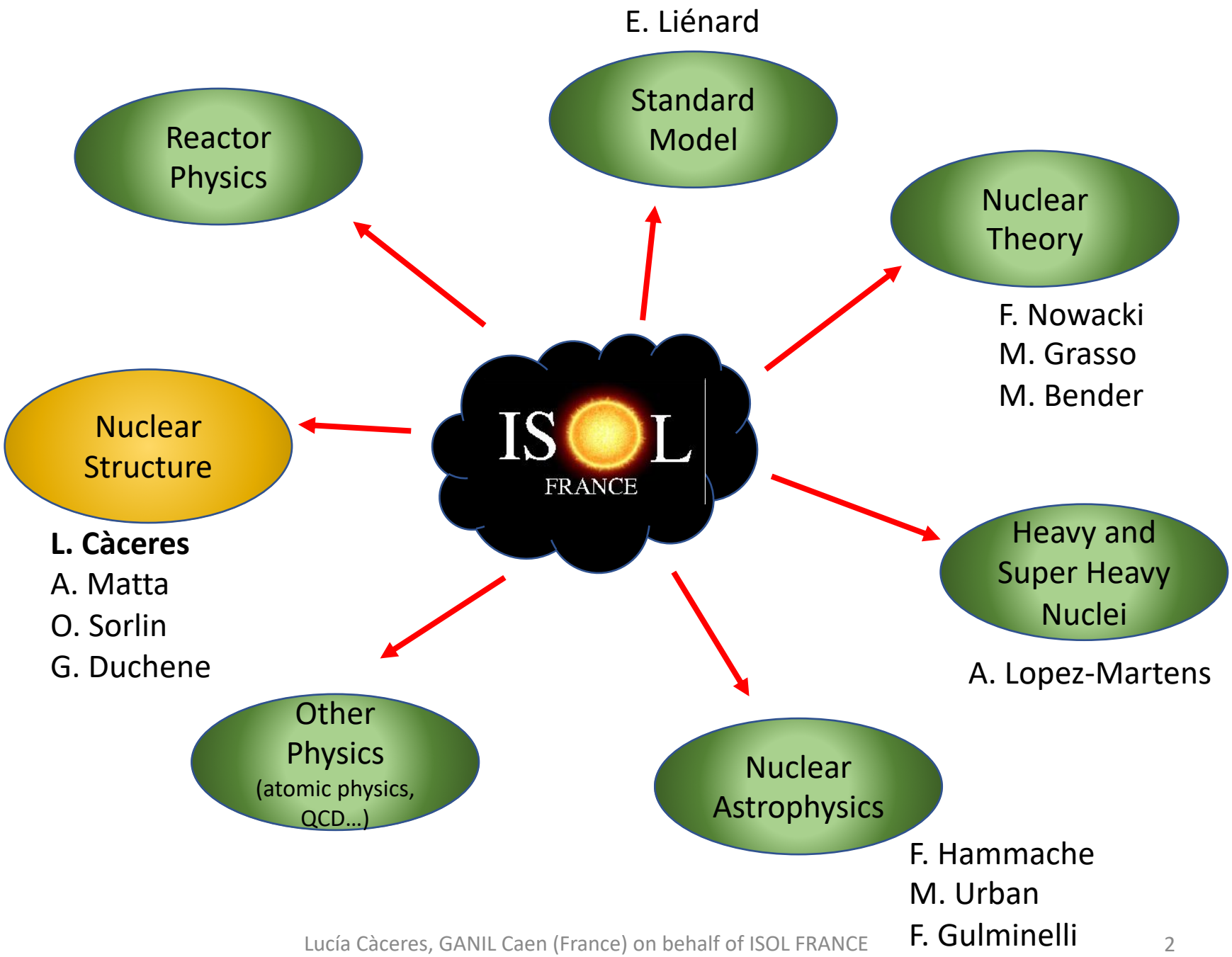
Prospective In2p3 2020

L. Càceres on behalf of the ISOL-France community

(44 collaborators)

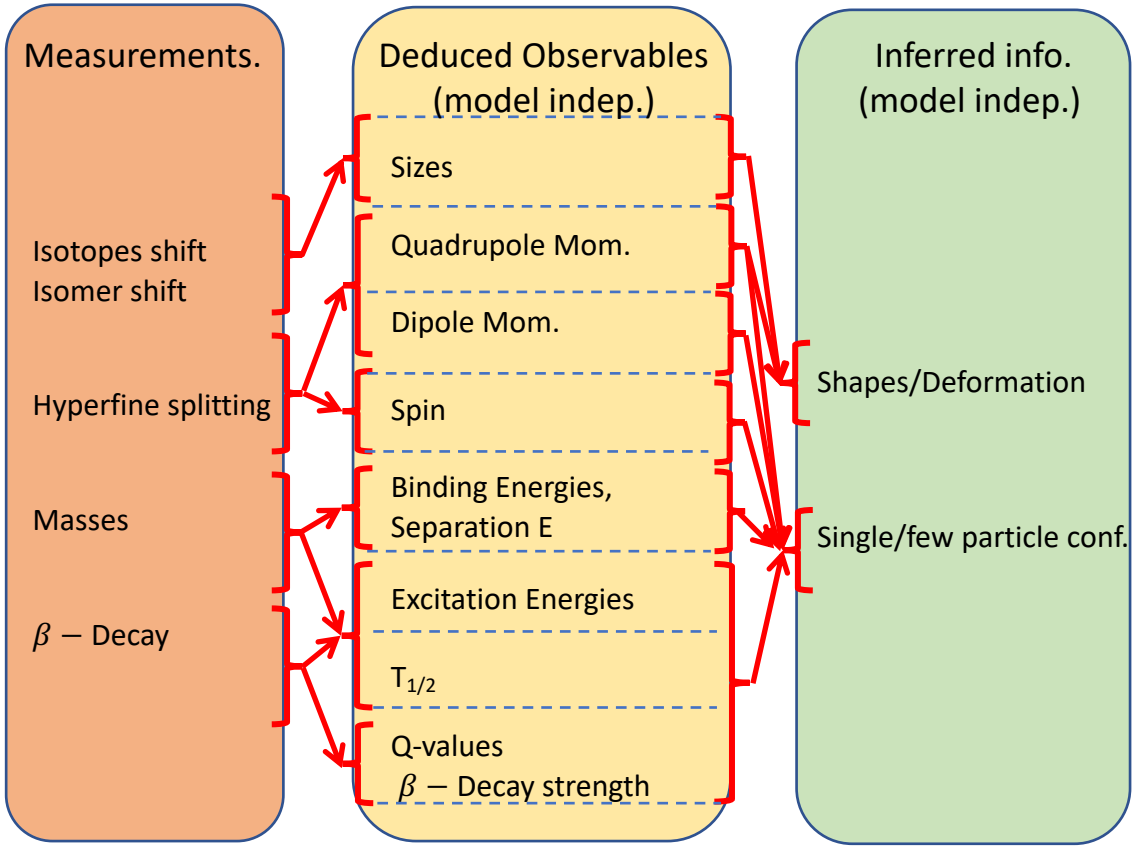

E. Liénard
Standard Model
Reactor Physics
Nuclear Theory
F. Nowacki
M. Grasso
M. Bender
ISOL FRANCE
Nuclear Structure
L. Càceres
A. Matta
O. Sorlin
G. Duchene
Heavy and Super Heavy Nuclei
A. Lopez-Martens
Other Physics (atomic physics, QCD…)
Nuclear Astrophysics
F. Hammache
M. Urban
F. Gulminelli

$$V_{eff} = V_m + V_M$$

Monopole
- Spherical mean field
- Determines Single particle Energies and shell evolution

Multipole
- Quadrupole Correlations (deformation)
- Pairing

- How does shell structure evolve with the isospin?
- How does the nucleon-nucleon interaction affect nuclear observables (shells vs. shapes)?
- How and where do new decay modes appear?
- How our measurements constrains/helps other physics fields?



$$V_{eff} = V_m + V_M$$

Monopole
- Spherical mean field
- Determines Single particle

Multipole
- Quadrupole Correlations (deformation)

This talk focus on laser spectroscopy, masses and beta-decay measurements ONLY!

Systematics measurements from neutron rich to neutron deficient nuclei. Model independent observables -> Direct comparison with theory

Only focused on N = 50 and N = 82.

All the measurements can be extrapolated to other areas, not possible to cover all in one talk !

- Ho
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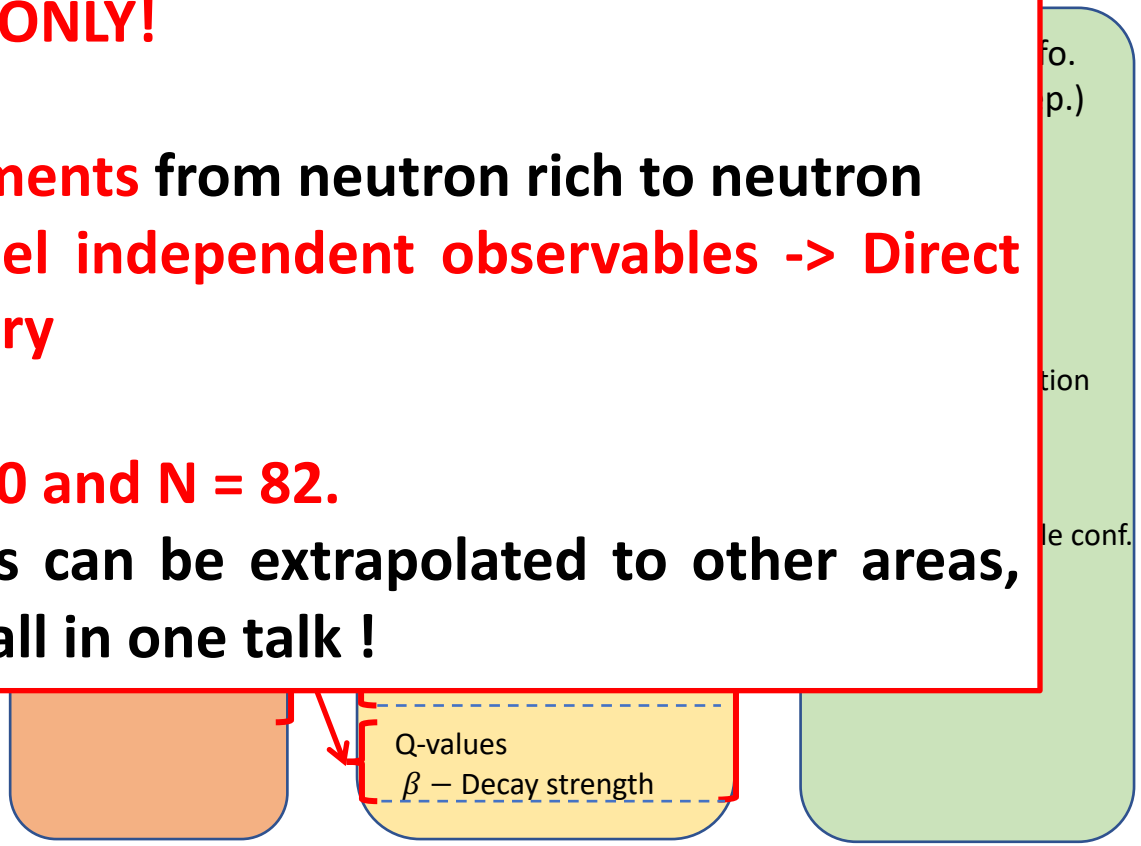
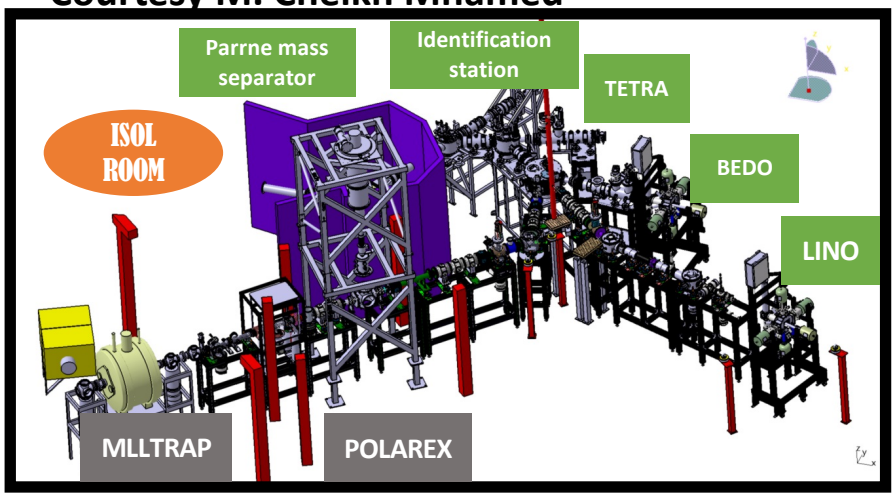
- Ho
  int
- obs
- Ho
  mo
- Ho
  constrains/helps other physics fields?



French Facilities: ALTO & S3-LEB/DESIR

Courtesy M. Cheikh Mhamed



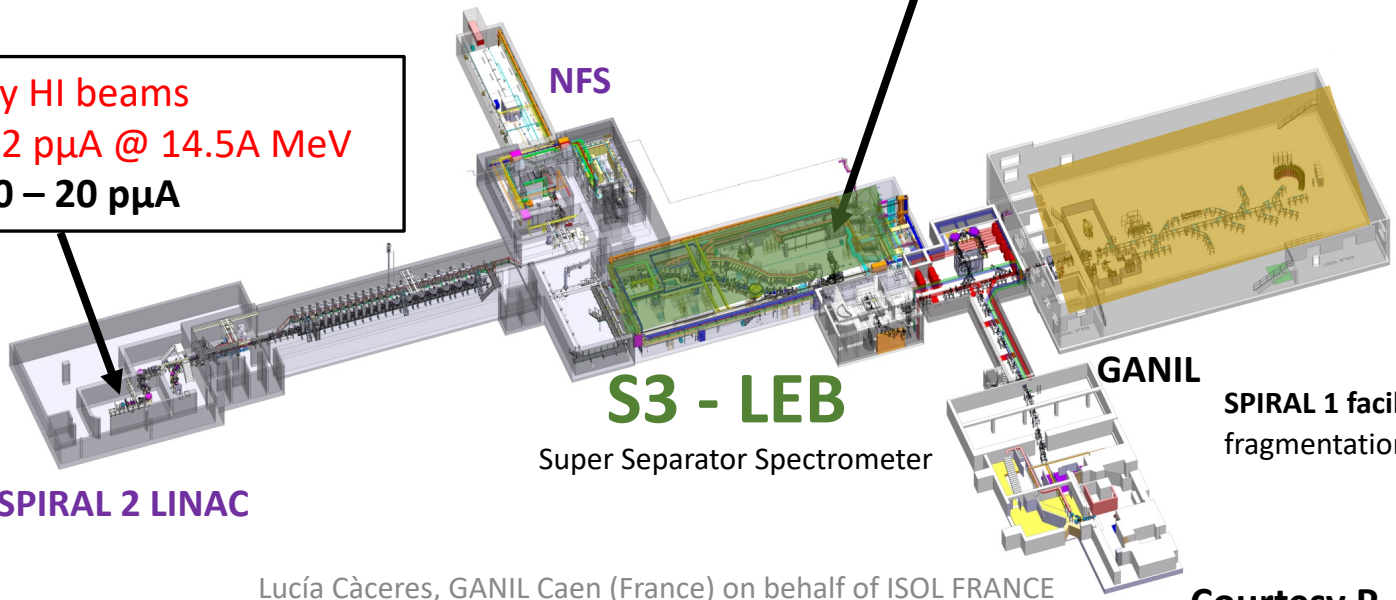
Experiments under construction

Existing experiments

500W e^- sur cible UCx
Faisceaux ISOL de basse énergie
Ex: $3 \cdot 10^7$ pps of ^{132}Sn

S3- LEB
Gas cell extraction time -> 200 – 300 ms
Fas gas cell -> 50 ms

High intensity HI beams
A/Q = 3 -> 1-2 pμA @ 14.5A MeV
A/Q = 7 -> 10 – 20 pμA

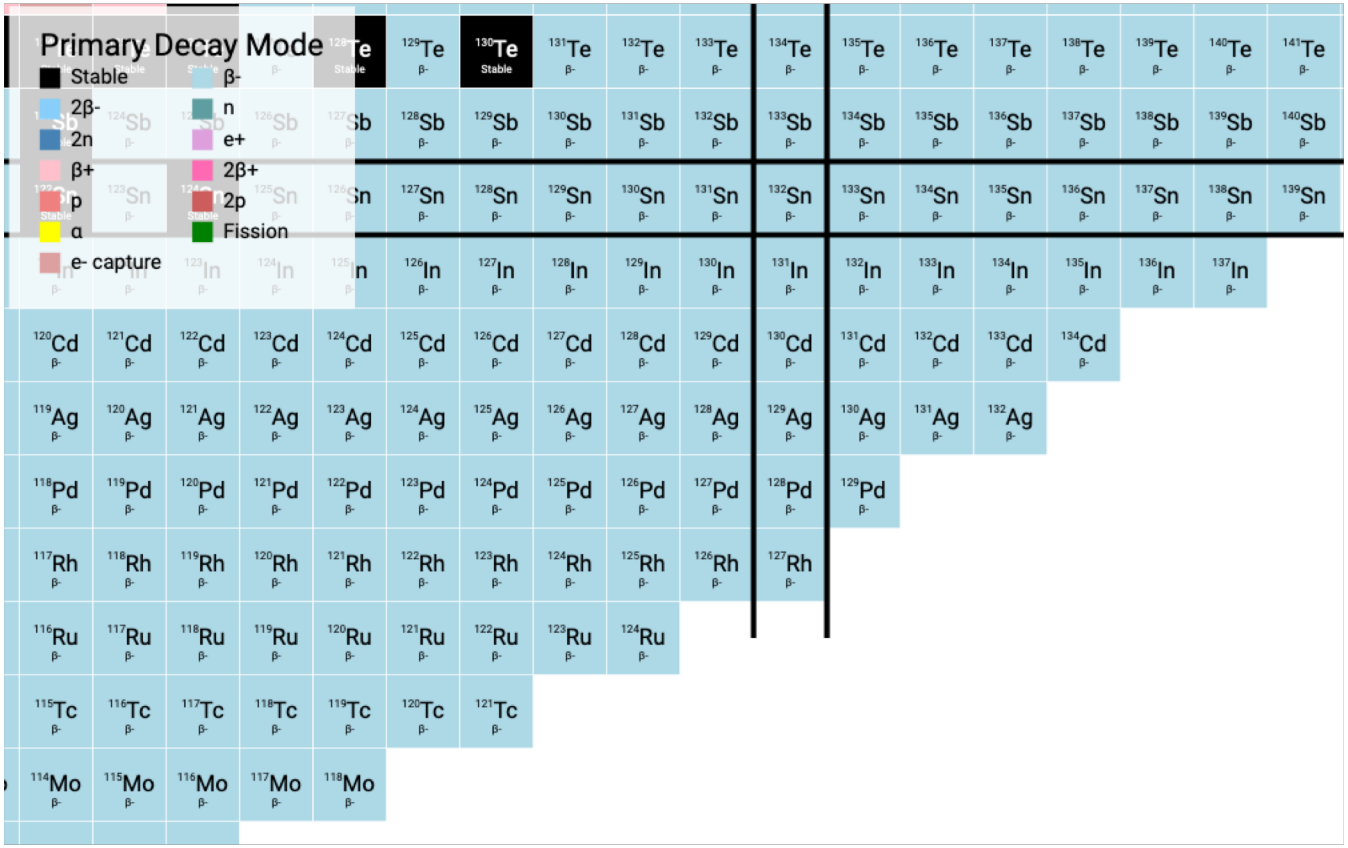


DESIR
low energy beams:
<1 eV to 60 keV

SPIRAL 1 facility: RIBs from fragmentation

Courtesy P. Delahaye

Results at the N = 82



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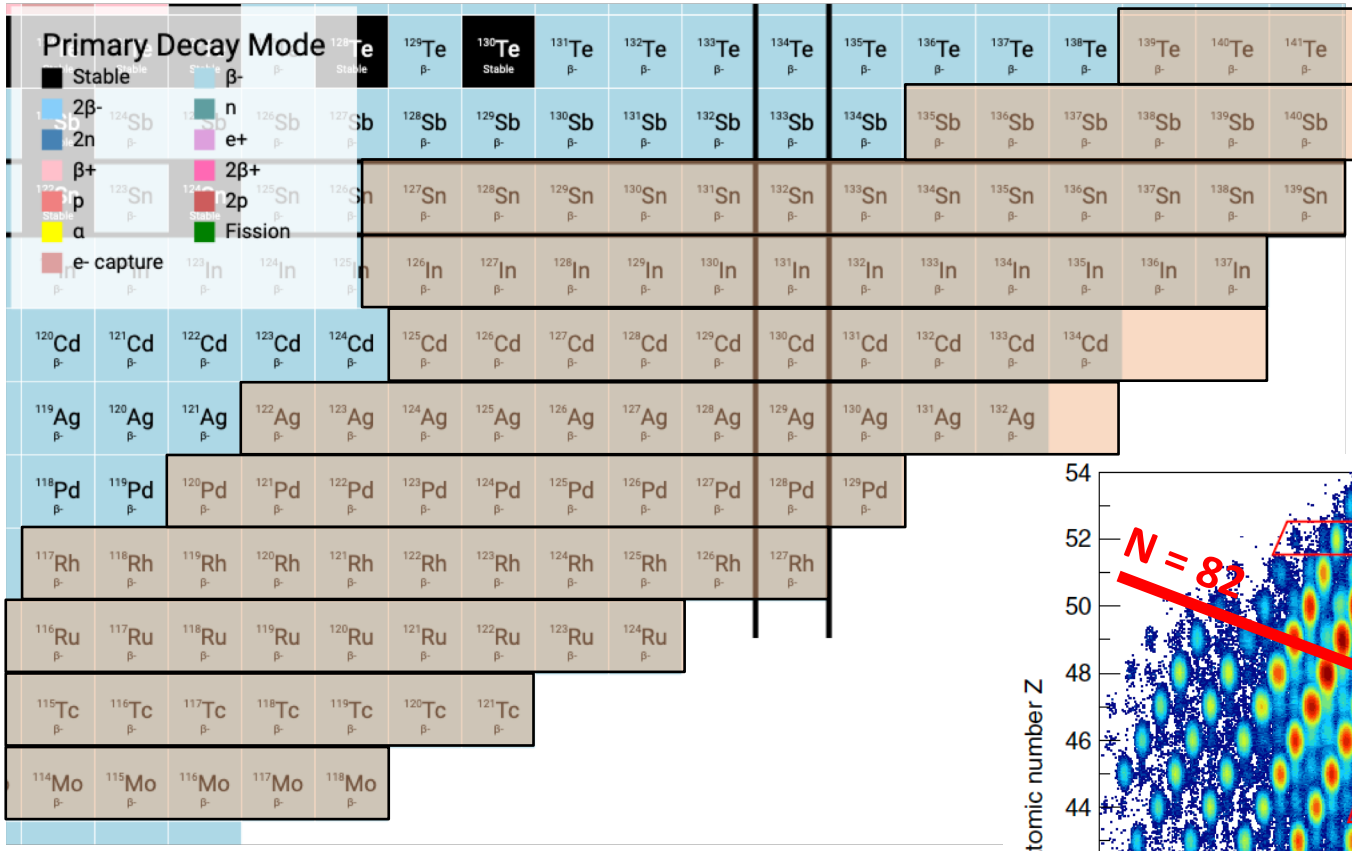
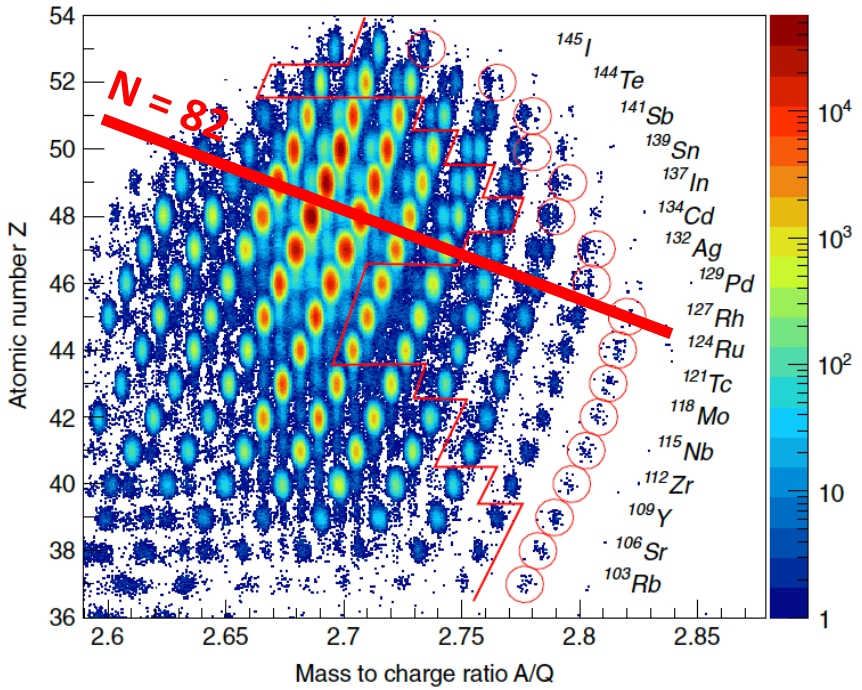


Beta-decay @ RIKEN (2015)

110 β-decay $t_{1/2}$



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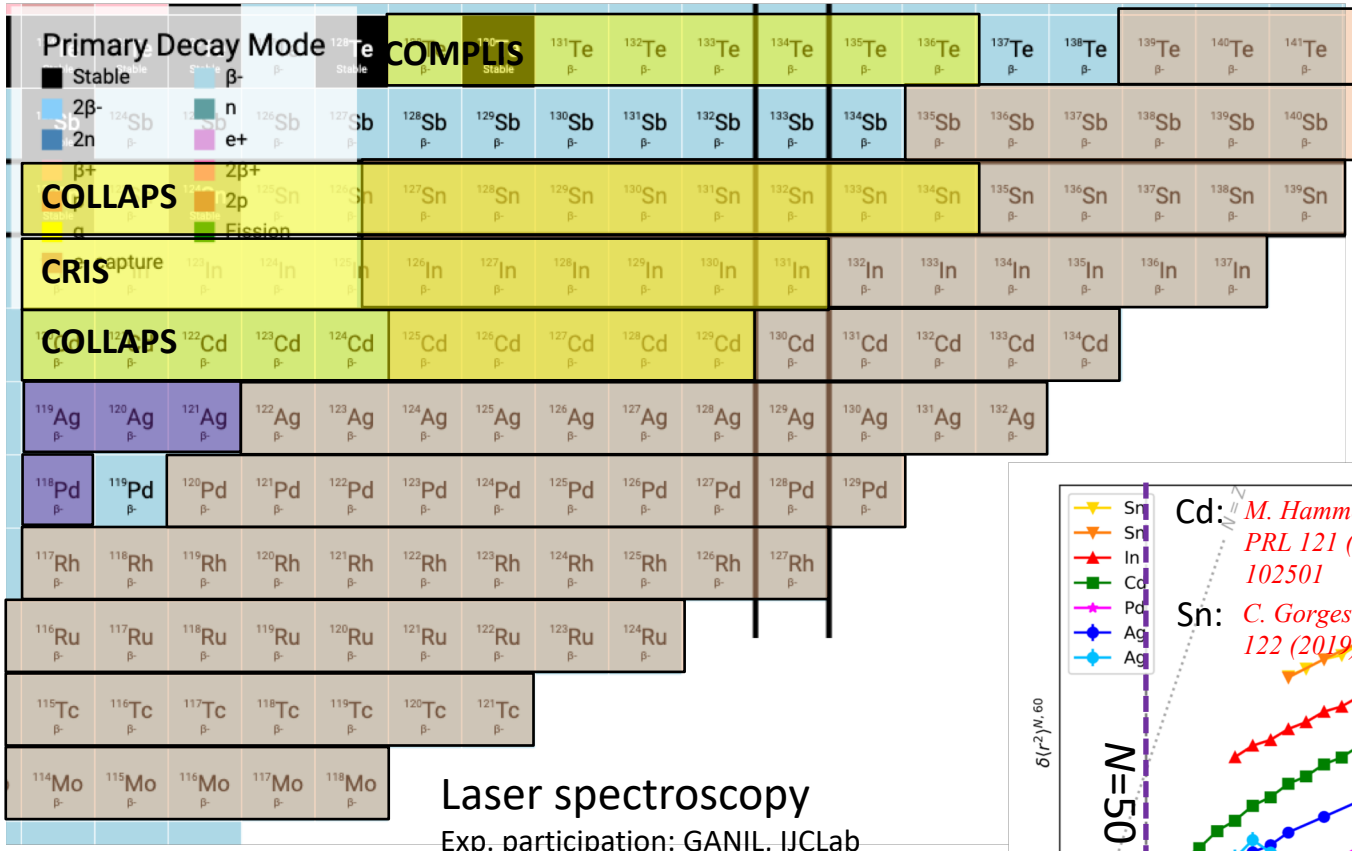
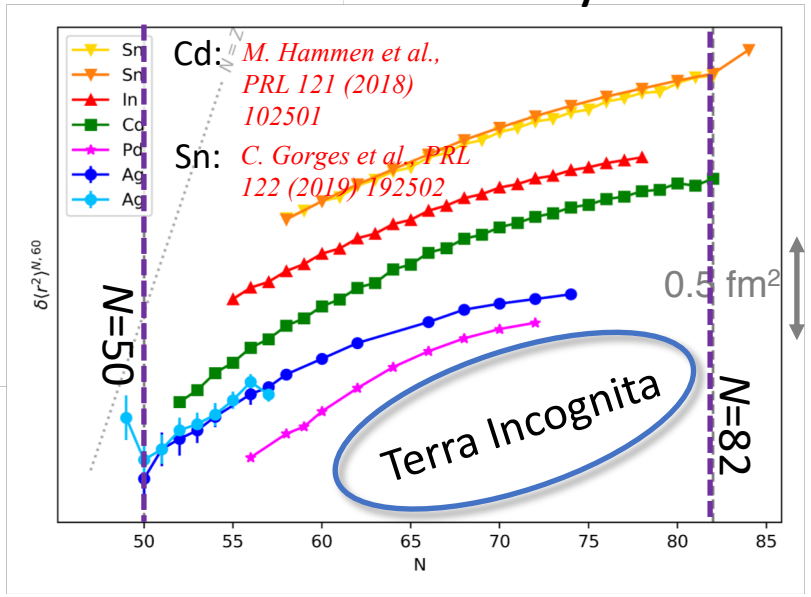


Beta-decay @ RIKEN (2015)

110 β-decay $t_{1/2}$

Courtesy I. Moore



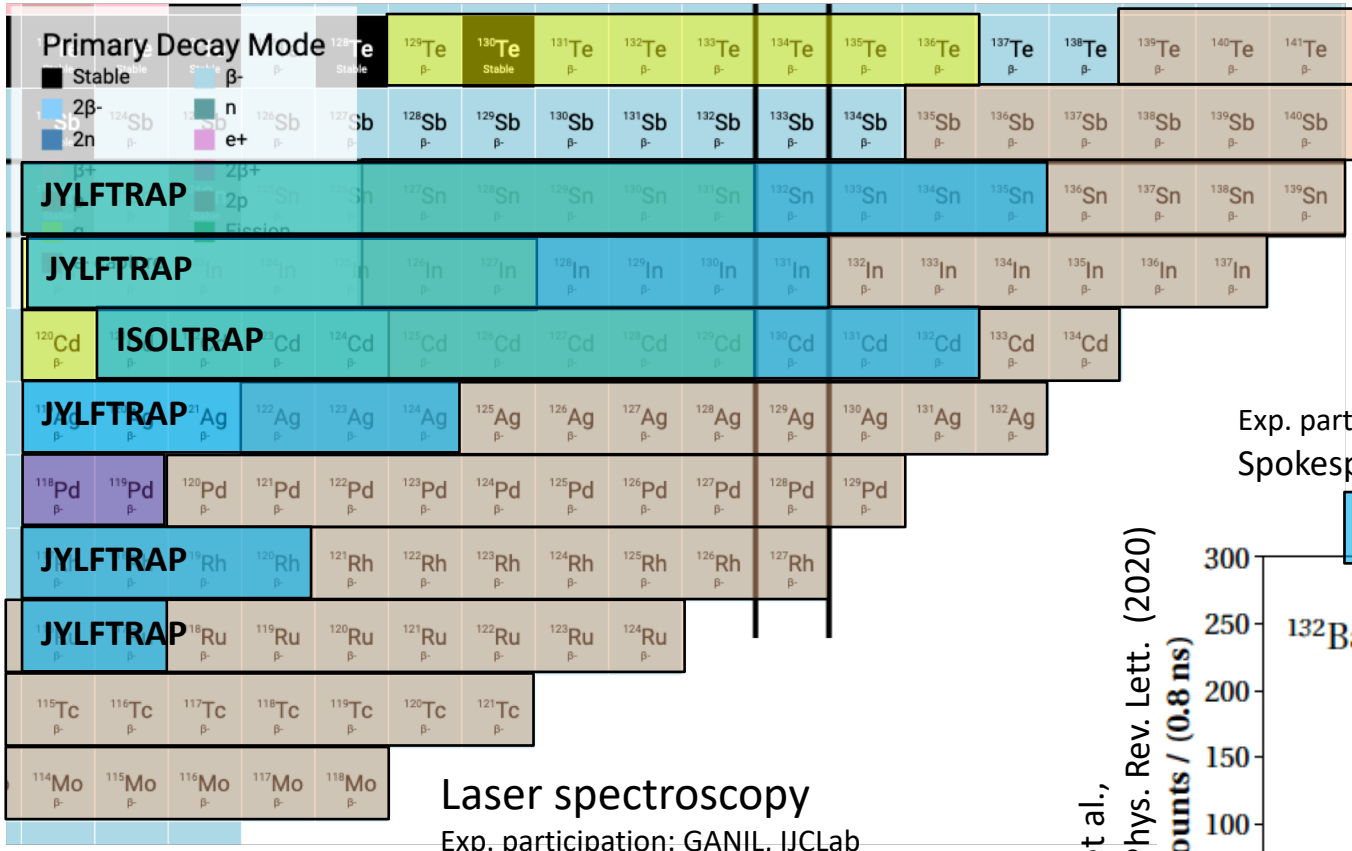
Laser spectroscopy

Exp. participation: GANIL, IJCLab

Spokesperson: L. Càceres et al., (Pd); D. Yordanov (Cd)

IGISOL: Pd **CRIS/COLAPS/COMPLIS**

Results at the N = 82



Beta-decay @ RIKEN (2015)

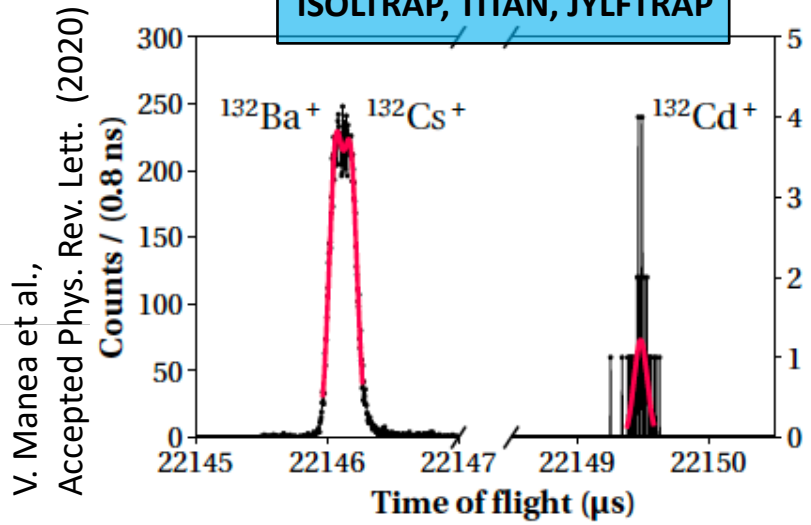
110 β-decay $t_{1/2}$

Mass measurements

Exp. participation: IJCLab, CENBG

Spokesperson: P. Ascher, S. Grevy et al.

ISOLTRAP, TITAN, JYLFTRAP



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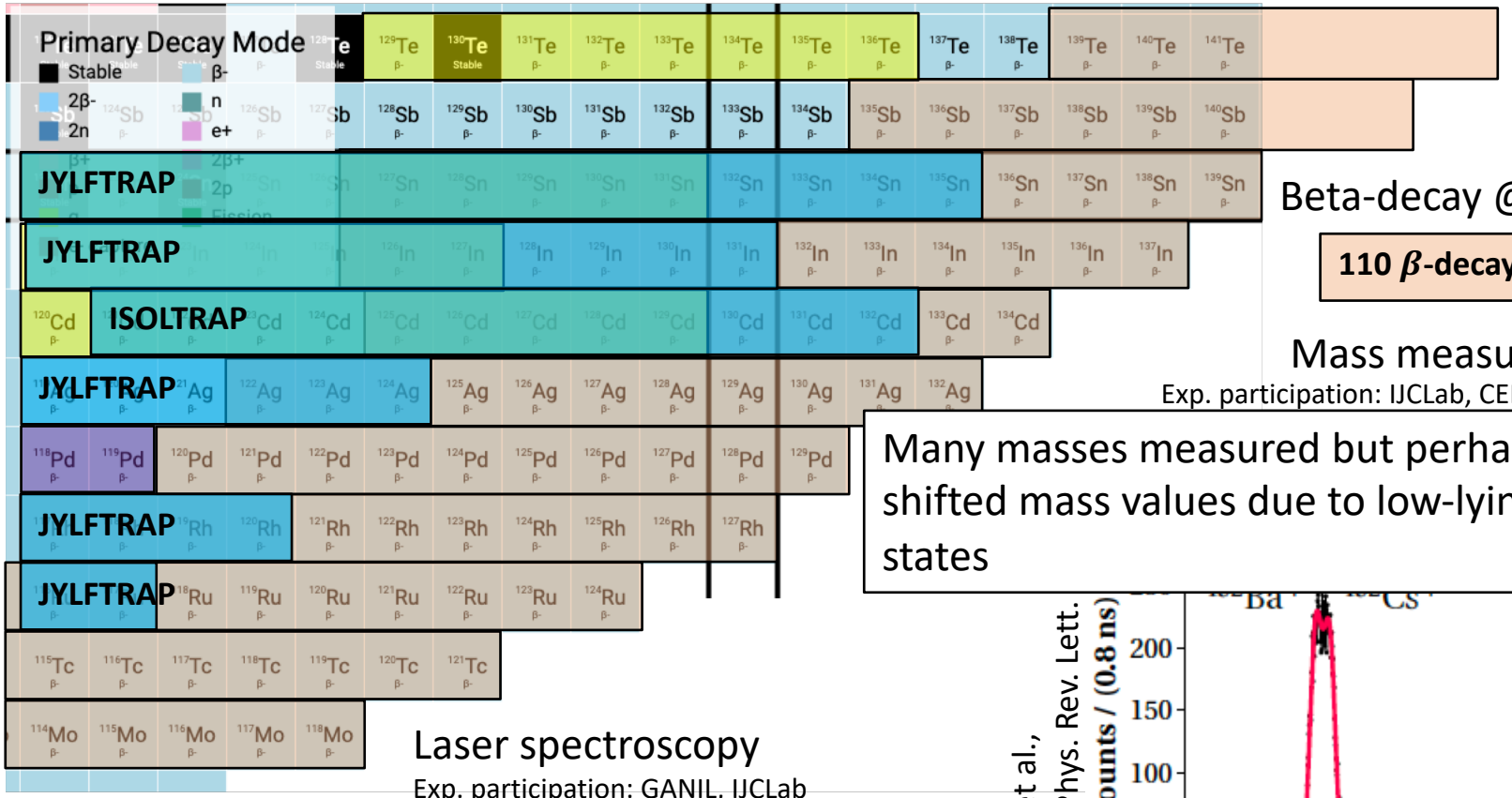
CRIS/COLAPS/COMPLIS

Results at the N = 82



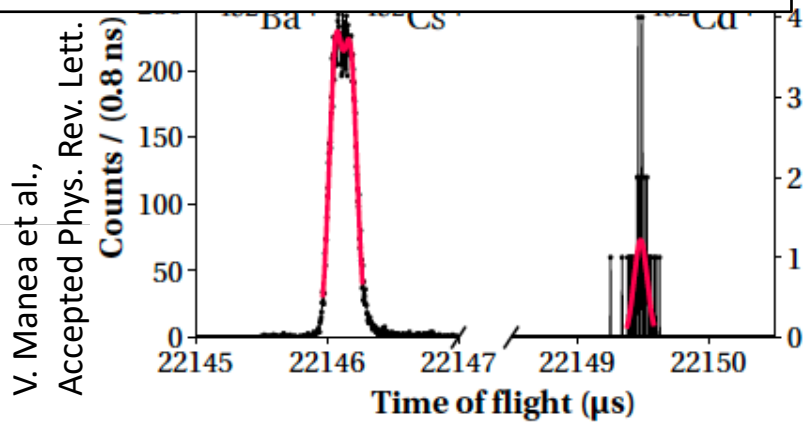
Beta-decay @ RIKEN (2015)

110 β-decay $t_{1/2}$

Mass measurements

Exp. participation: IJCLab, CENBG

Many masses measured but perhaps shifted mass values due to low-lying isomeric states



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CRIS/COLAPS/COMPLIS

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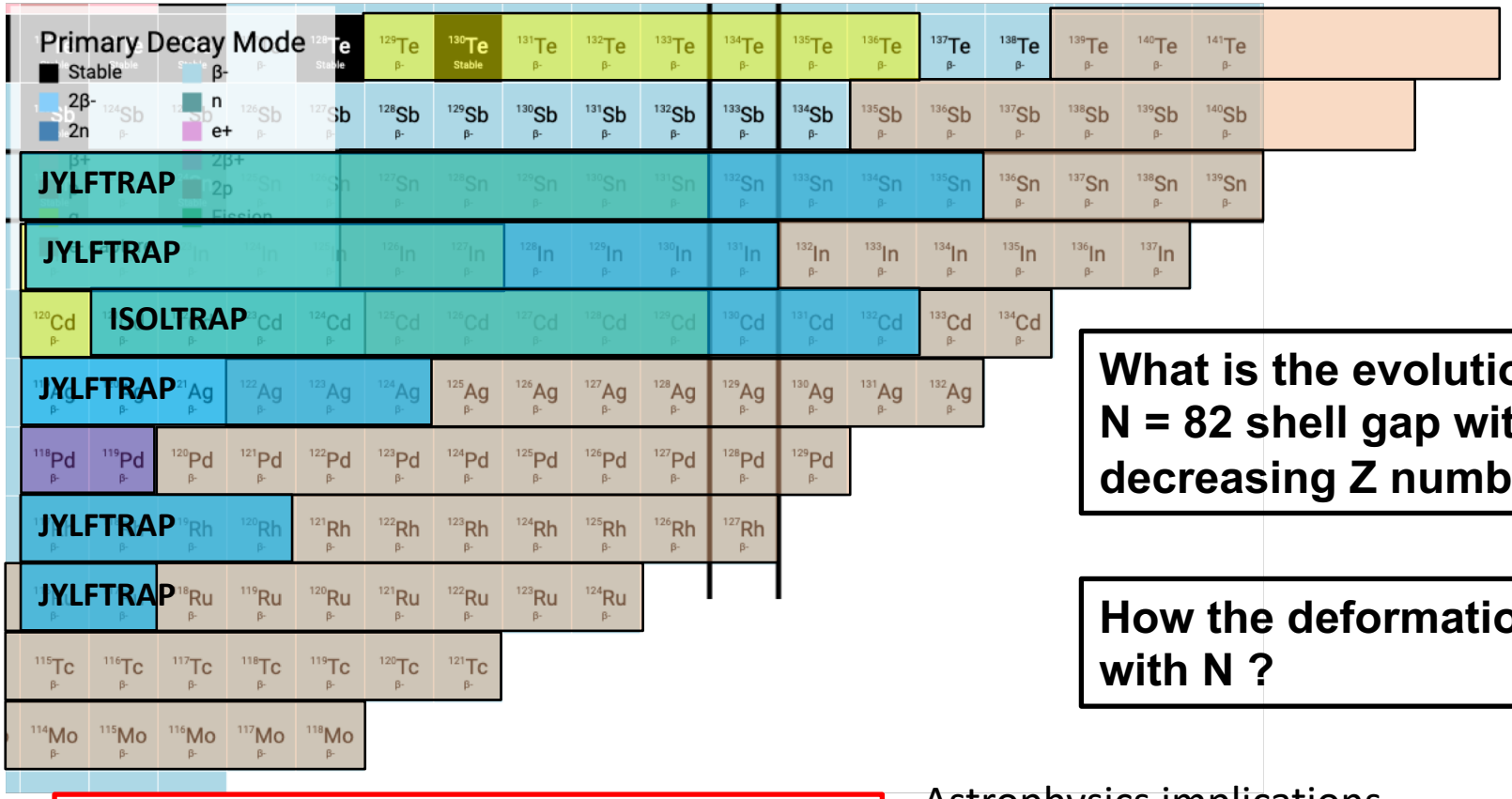


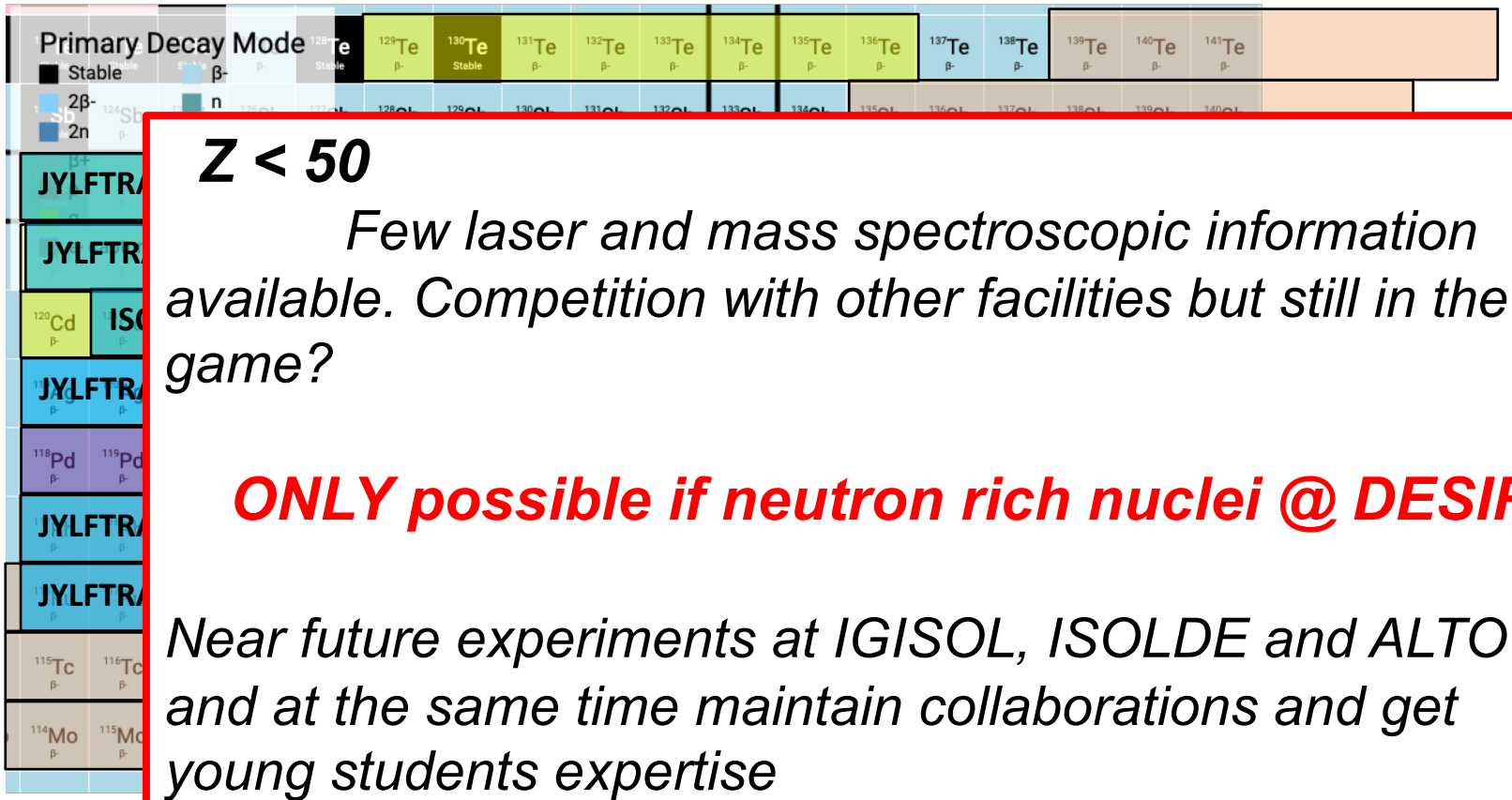
What is the evolution of the N = 82 shell gap with decreasing Z number?

How the deformation evolve with N ?

The evolution of the N=82 below Z<50
MLLTRAP at ALTO (^{129}Ag)
(E. Minaya Ramirez NIM B 463 (2020) 315)

Astrophysics implications
(talks: F. Hammache, M. Urban, F. Gulminelli)
Need for constrain mass models

Results at the N = 82



Z < 50

Few laser and mass spectroscopic information available. Competition with other facilities but still in the game?

ONLY possible if neutron rich nuclei @ DESIR

Near future experiments at IGISOL, ISOLDE and ALTO and at the same time maintain collaborations and get young students expertise

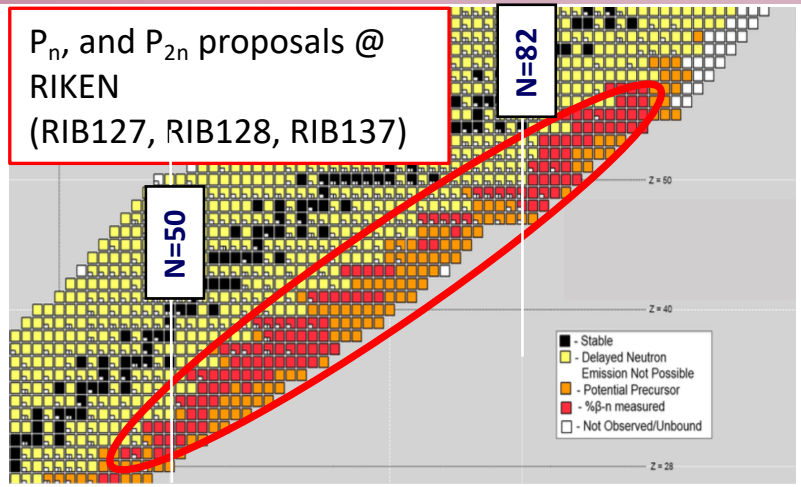
the

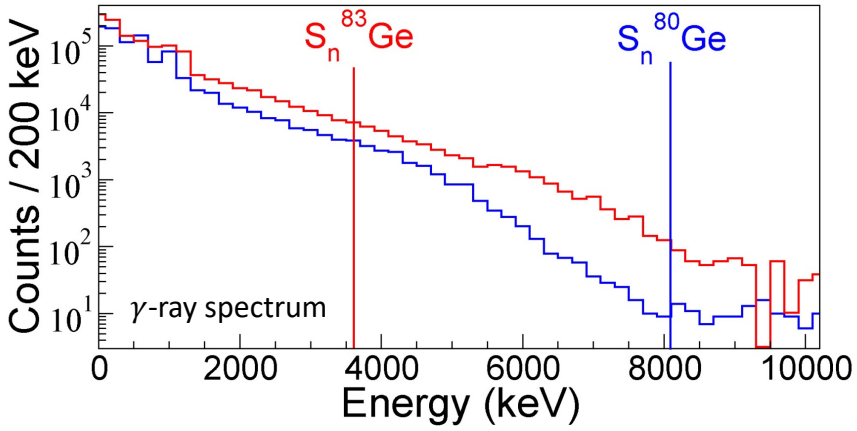
lve

Need for constrain mass models

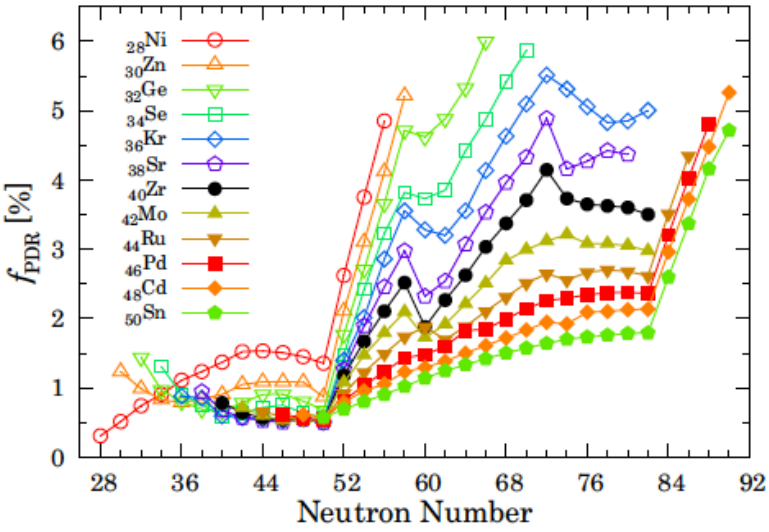
Beta-Decay & Low-lying Collective Modes

- Investigation of the far-above-threshold γ emissions in n-rich nuclei decays: direct GT-feeding of the PDR ?
- Pygmy Dipole Resonance as a universal 'collective' excitation mode
- PDR's study puts constraints on theoretical models
- Connection to neutron skin (neutron stars, EOS of n-rich matter, r-process nucleosynthesis)
- The detection of these high-energy gamma-rays need large efficiency devices (Pandemonium effect!!!) (PARIS/MONSTER + BEDO, TAS measurements)





Canonical basis-TDHFB calculations



A. Gottardo et al., PLB 722, 359 (2017)

Ebata et al. PRC 90 024303 (2014)

Beta-Decay & Low-lying Collective Modes

- Investigation of the far-above-threshold γ emissions in n-rich nuclei decays: direct GT-feeding of the PDR ?
- Pygr
  exci
- PDR
- Con
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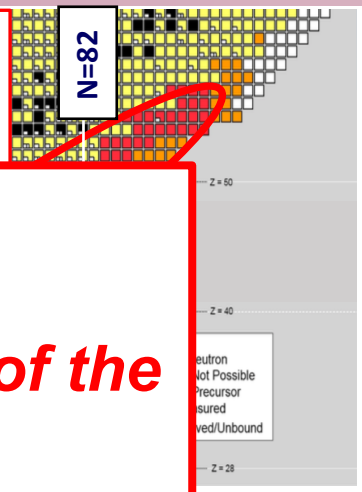
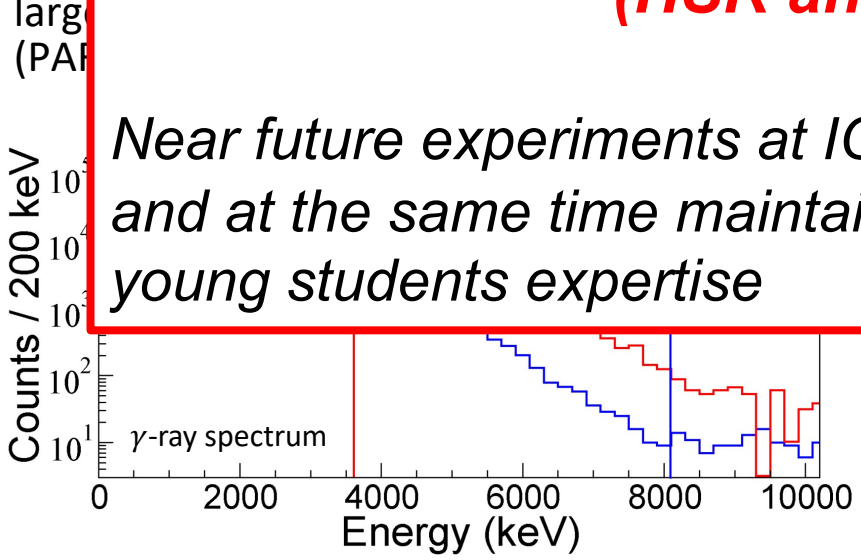
P_n, and P_{2n} proposals @ RIKEN
(RIB127, RIB128, RIB137)



ONLY possible if neutron rich nuclei @ DESIR and THANKS to the purity of the beams delivered by DESIR front-end (HSR and TRAPS)

Near future experiments at IGISOL, ISOLDE and ALTO and at the same time maintain collaborations and get young students expertise



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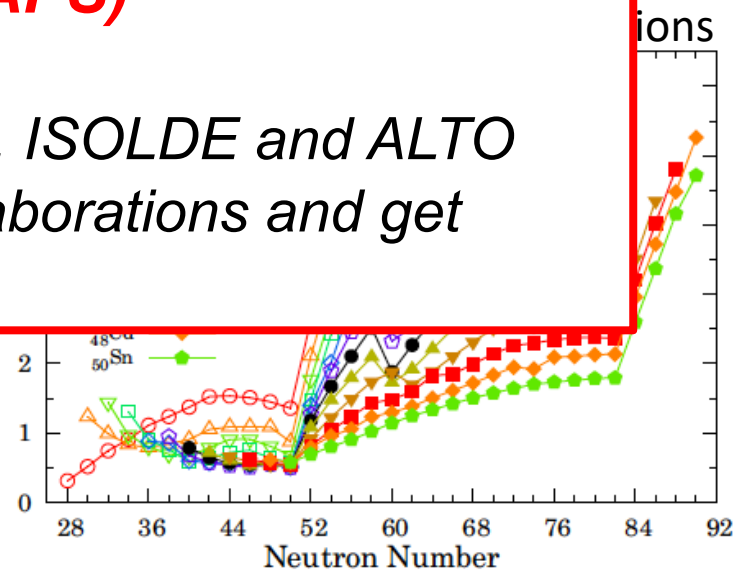

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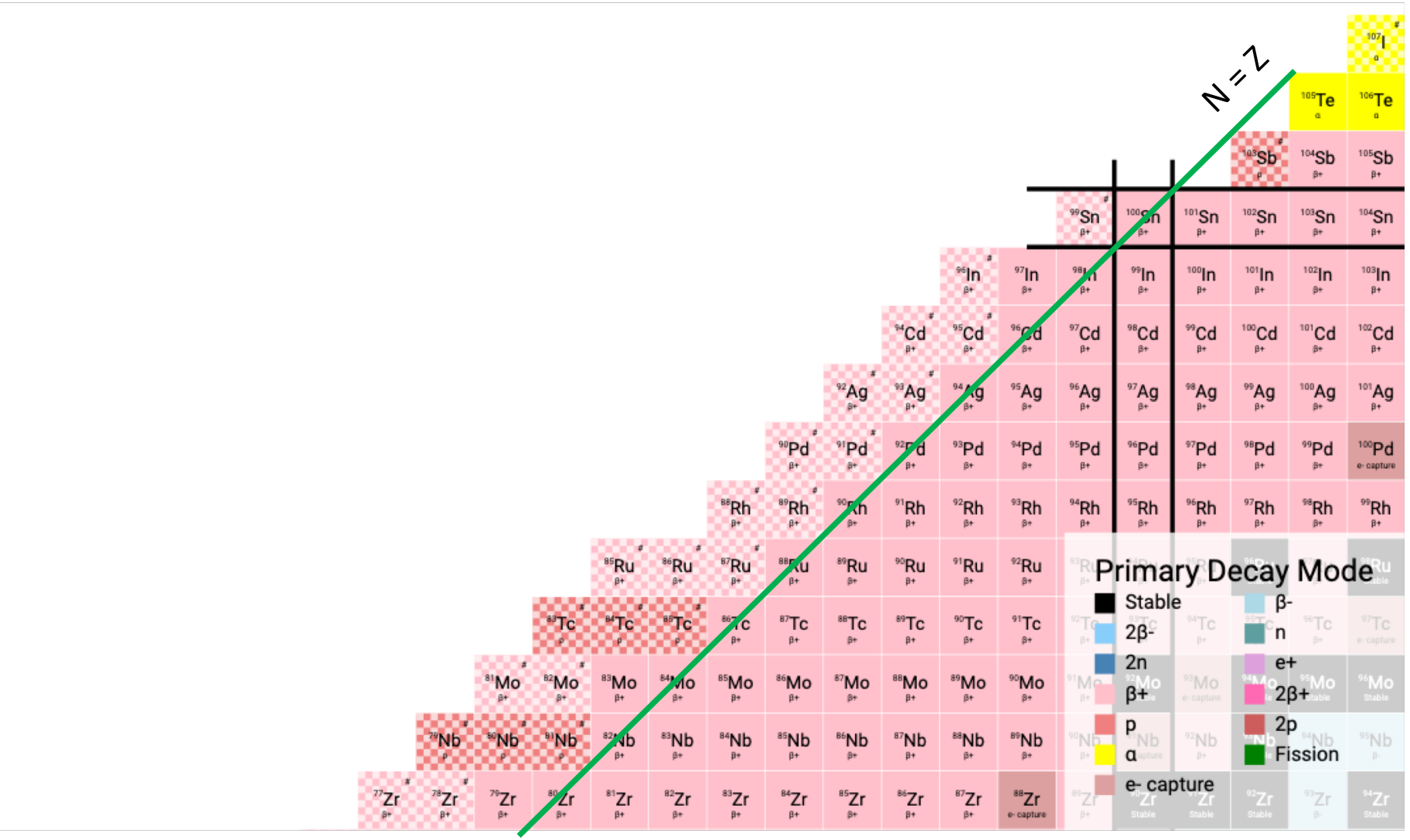
Recent results at the N = Z line



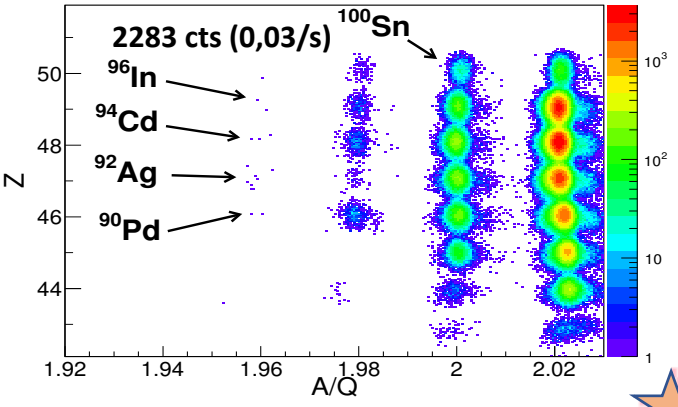
Recent results at the N = Z line

Beta-decay @ RIKEN (2016) Spokesperson: M. Lewitowicz (GANIL)

Discovery – new isotopes | **new proton emitters** | spectroscopy

new half-lives | **precise half-lives**

Celikovic, I.; Lewitowicz M. et al., Phys. Rev. Lett. 116, 161102 (2016)



N=Z

Primary Decay Mode

Stable
2β-
2n
β+
p
α
e- capture
β-
n
e+
2β+
2p
Fission

Recent results at the N = Z line

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Discovery – new isotopes | **new proton emitters** | spectroscopy

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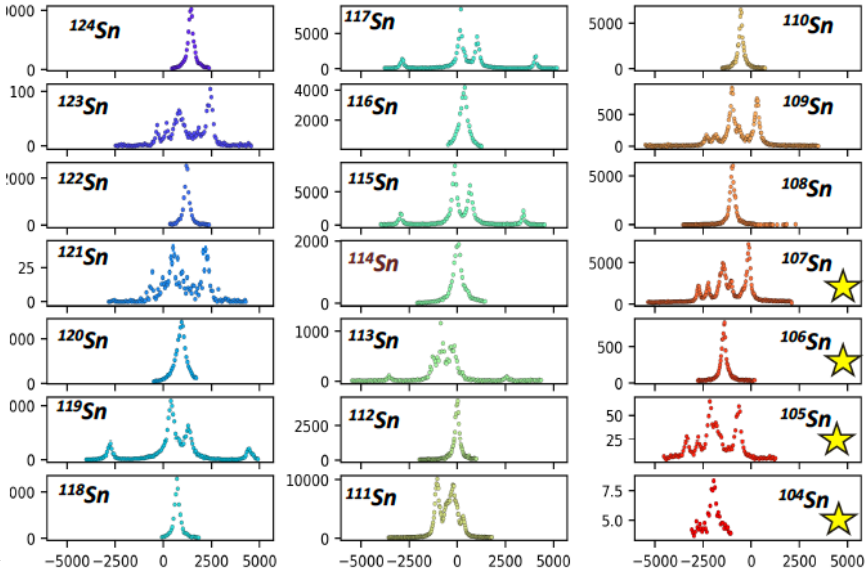
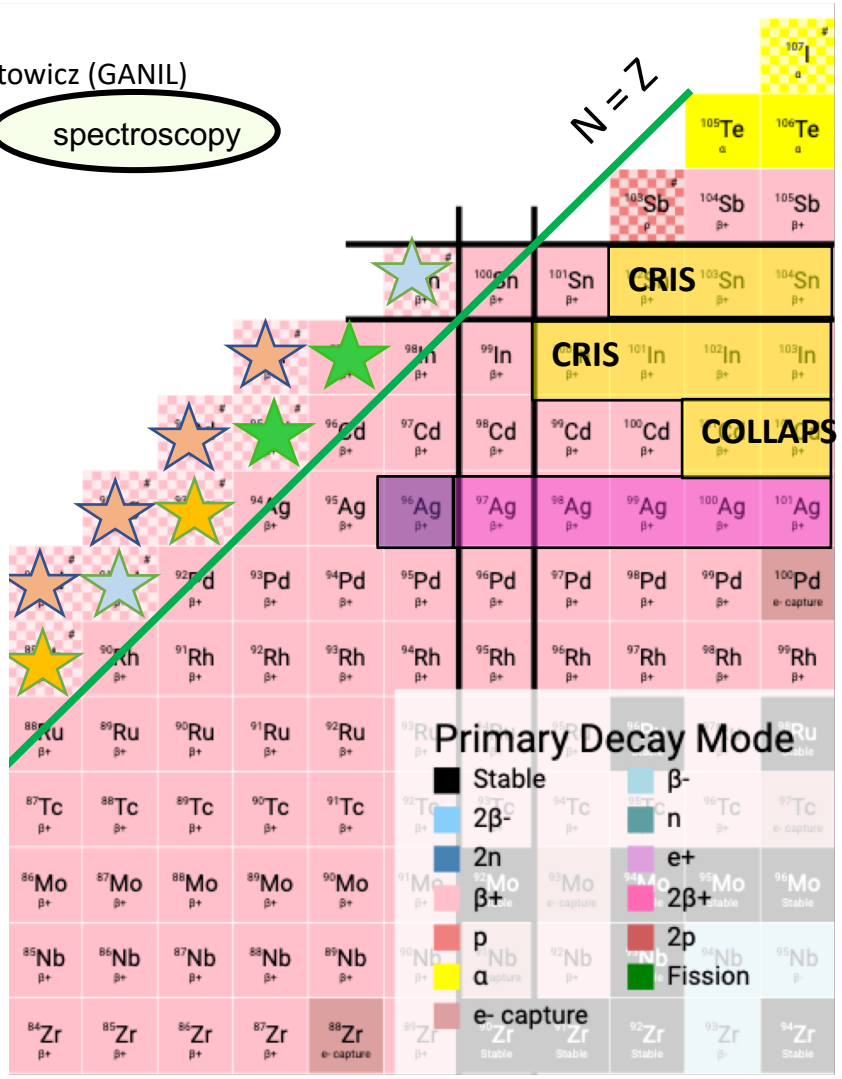
Laser spectroscopy Exp. participation: GANIL, IJCLab

Spokesperson: D. Yordanov (Cd)

CRIS/COLAPS: In and Sn | **LISOL: Ag** | **IGISOL: Ag**

Picture taken from talk K. Flanagan (ESNT 19) (20 pps) **Sn**





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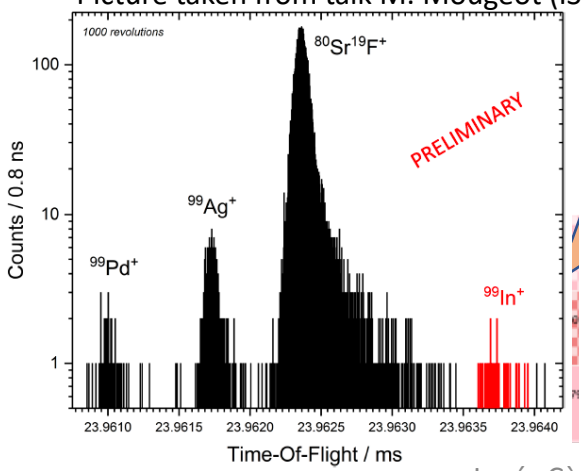
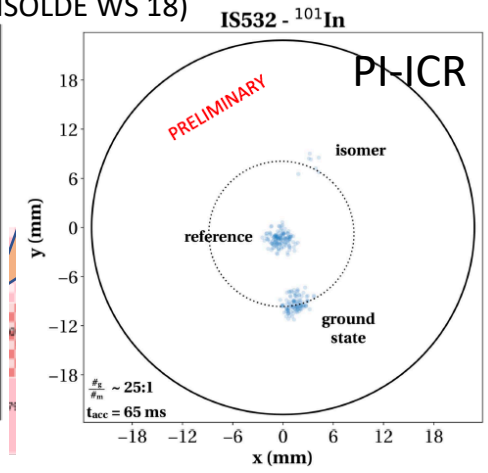
CRIS/COLAPS: In and Sn | **LISOL: Ag** | **IGISOL: Ag**

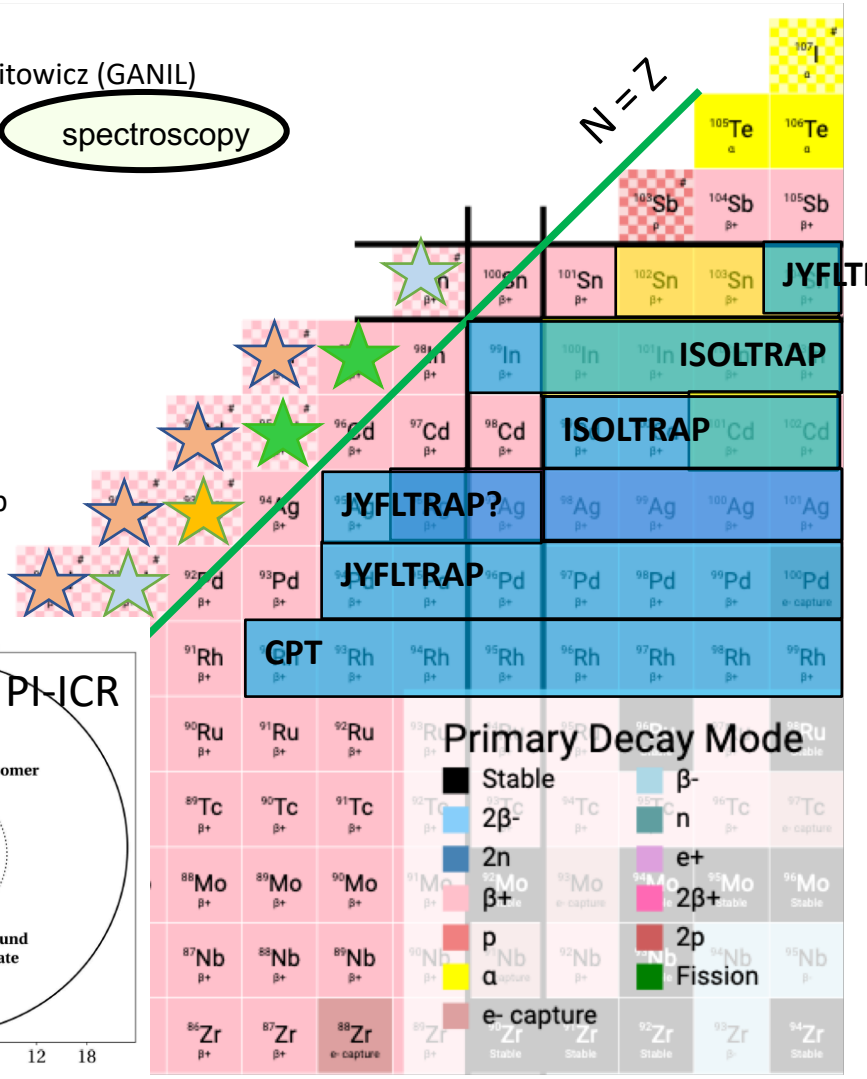
Mass measurements Exp. participation: CENBG, IJCLab

ISOLTRAP, JYFLTRAP, SHIPTRAP, CPT

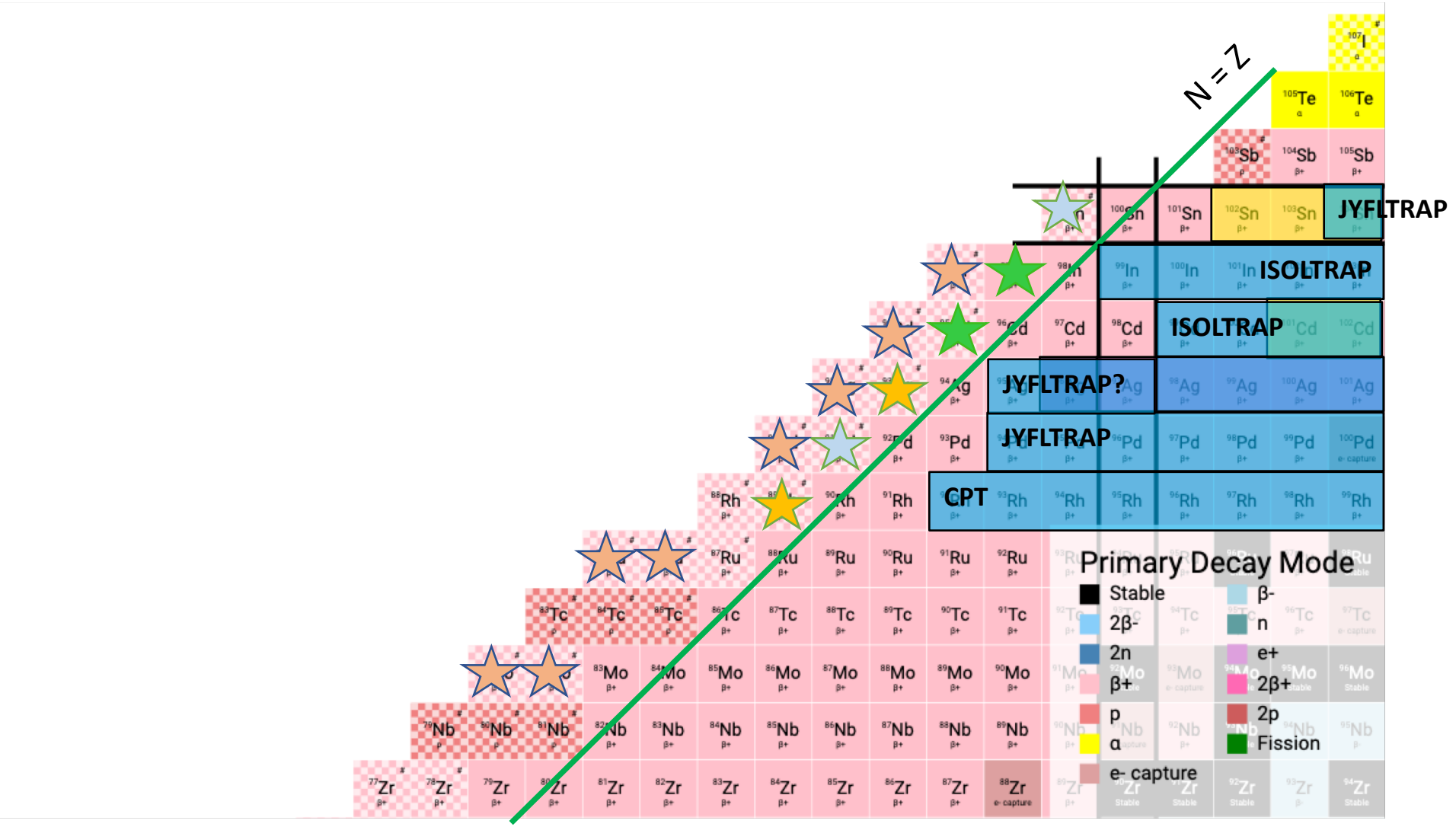
Picture taken from talk M. Mougeot (ISOLDE WS 18)







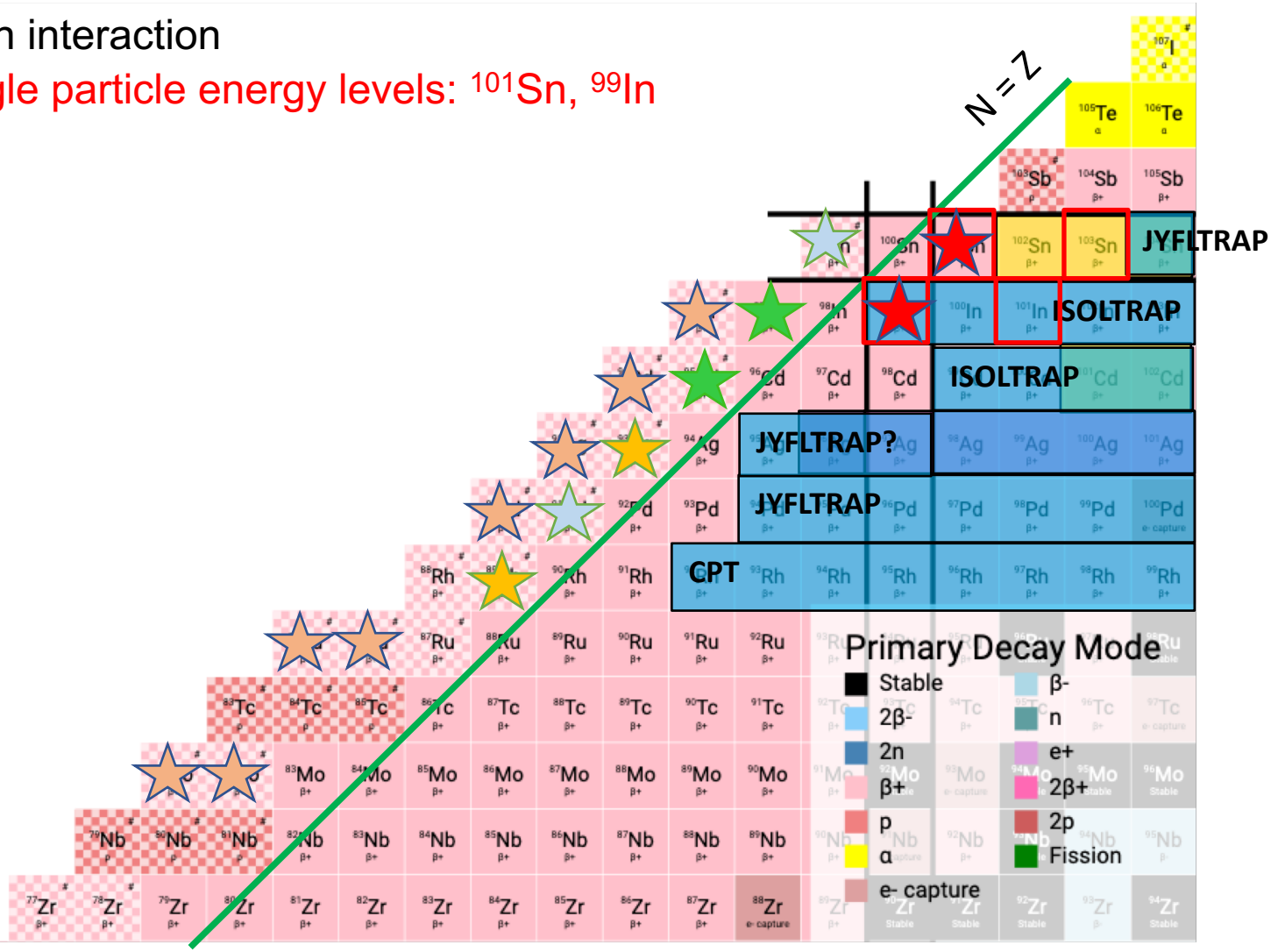
Physics around N = Z region



Physics around N = Z region

Nucleon-Nucleon interaction

- Effective Single particle energy levels: ^{101}Sn, ^{99}In



Physics around N = Z region

Nucleon-Nucleon interaction

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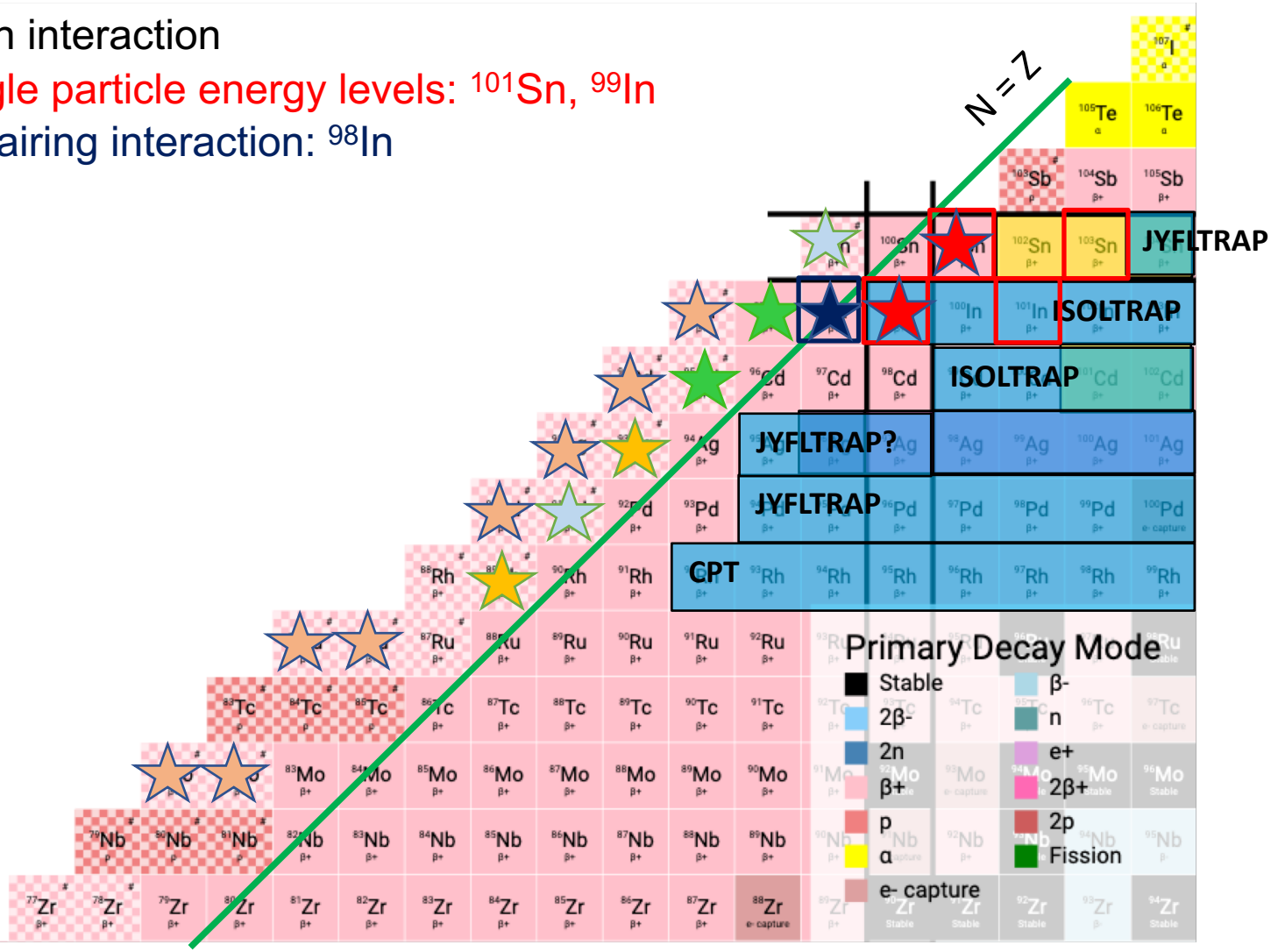
- T = 0 T = 1 Pairing interaction: ^{98}In



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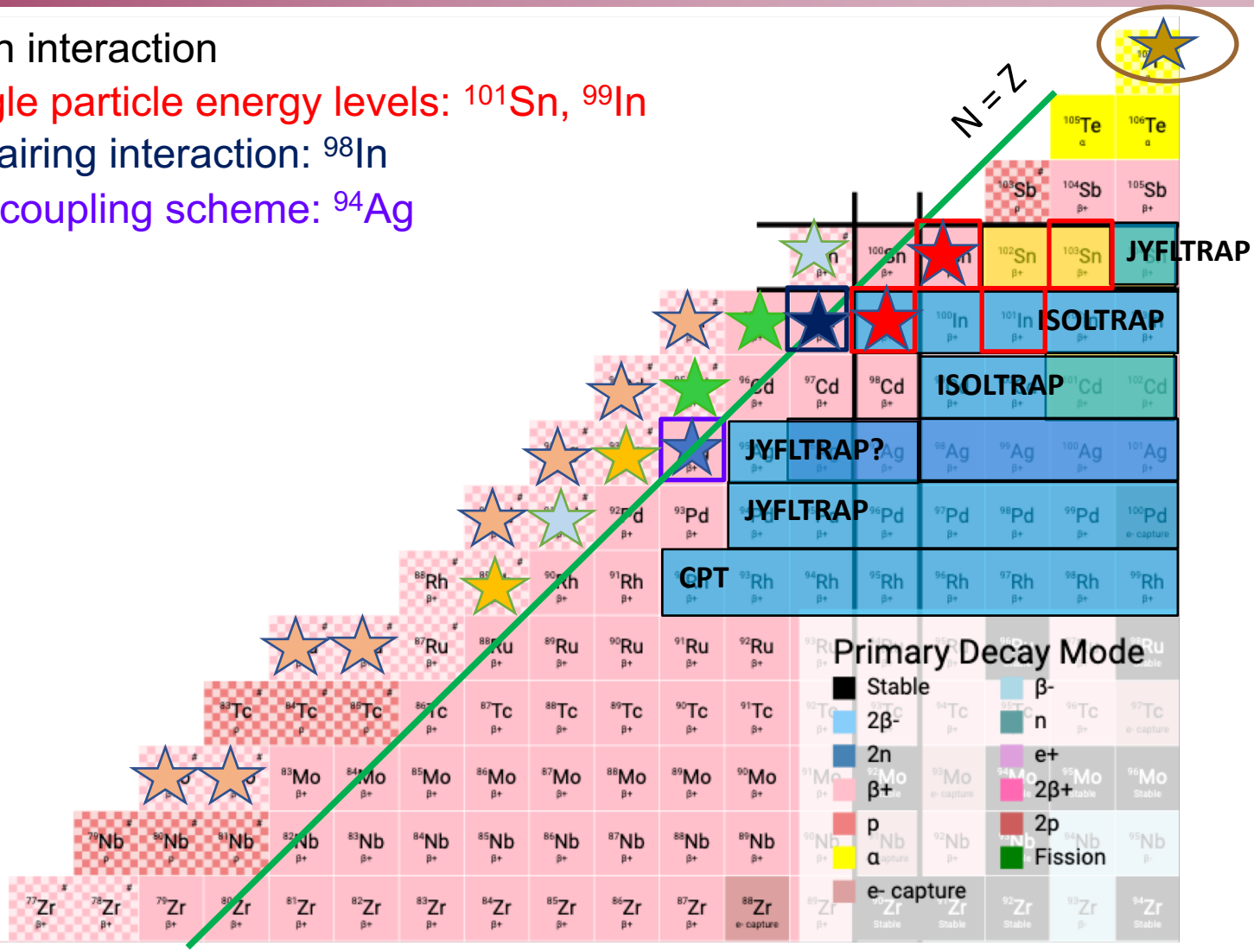
- Spin-aligned coupling scheme: ^{94}Ag



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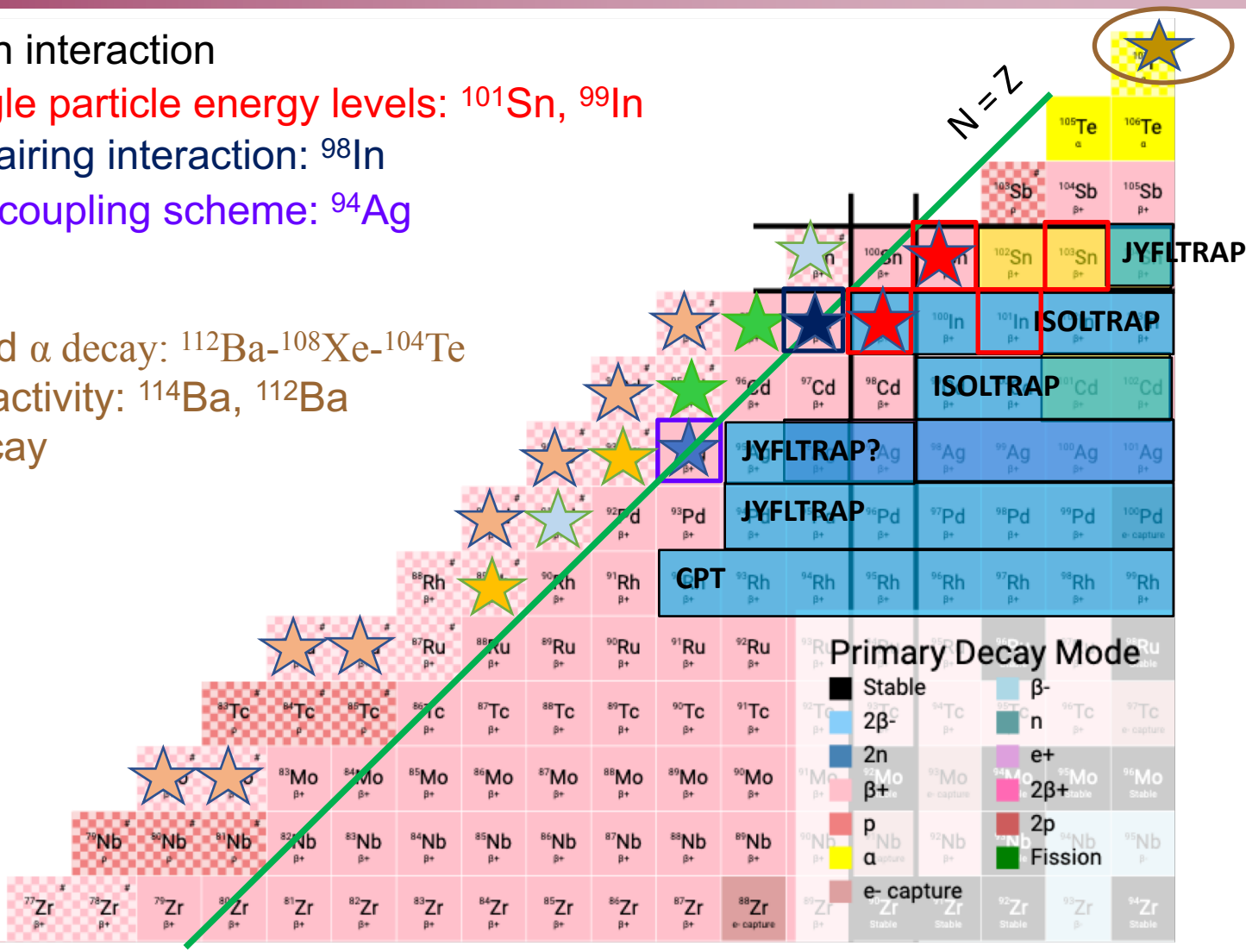
Decay modes:

- Super-allowed α decay: ^{112}Ba-^{108}Xe-^{104}Te
- Cluster radioactivity: ^{114}Ba, ^{112}Ba
- β-p, β-2p decay



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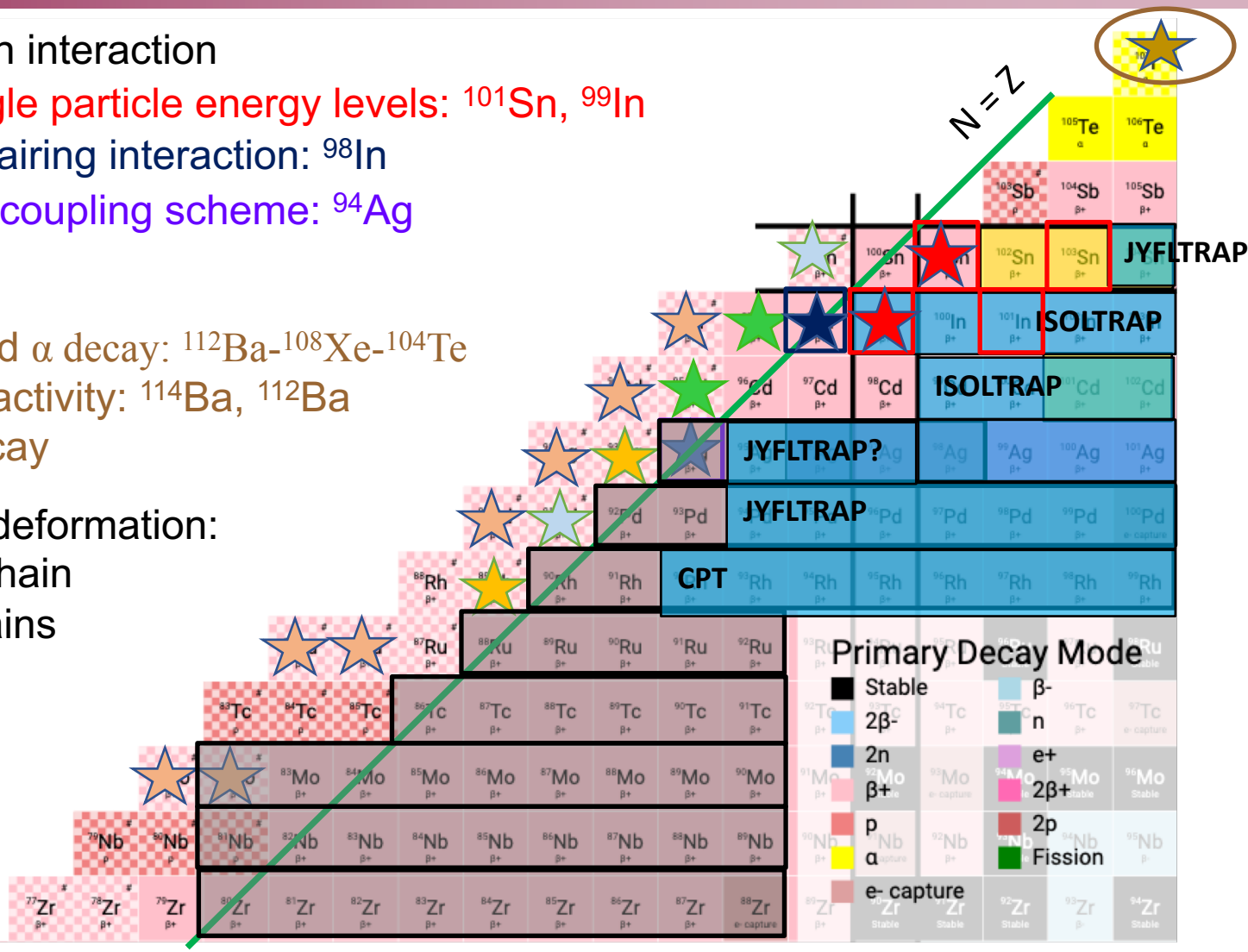
Collectivity and deformation:

- B(E2) in Sn chain
- refractory chains



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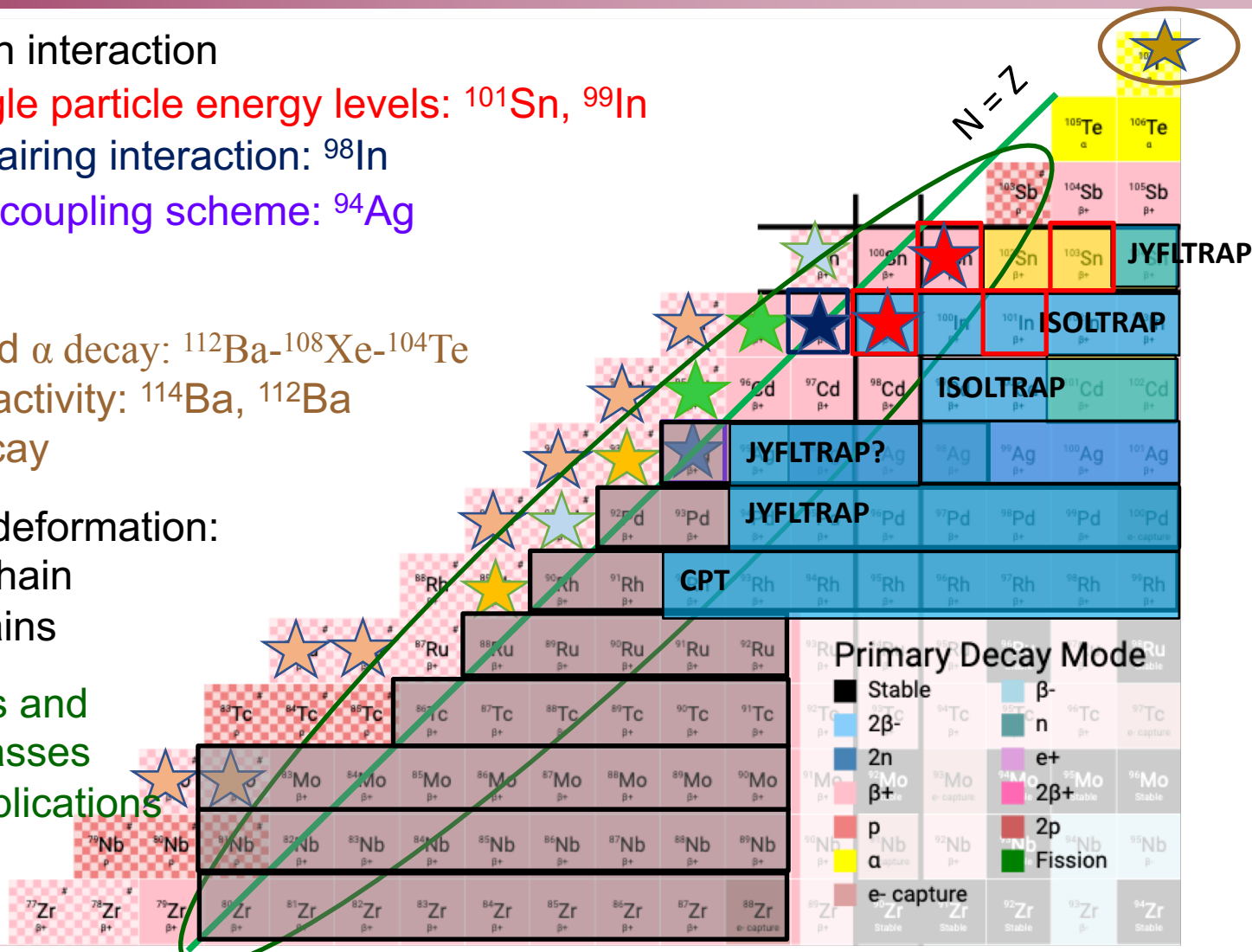
Binding energies and
Wigner term: masses
Astrophysics implications



Physics around N = Z region

80 < A < 100 and beyond

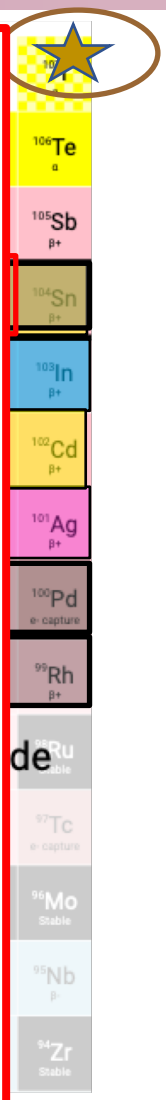
S3-LEB / DESIR will offer unique opportunities with immediate high visibility (SC GANIL/SPIRAL2 2018)

A < 80

Competition with FRIB but in the game!

Factor 10-100 improvement with A/Q = 7, complete laser system operational (DESIR) and a fast gas cell

Near future experiments at IGISOL, ISOLDE and ALTO and at the same time maintain collaborations and get young students expertise



Nuclei static & dynamic properties

D. Lunney, Conseil Scientific IN2P3 physics ISOL (17)

Ground-state property (lab)	Now	(Near) Future
masses (CENBG, GANIL, IJCLab)	ISOLTRAP-ISOLDE TITAN-ISAC, GARIS-MR-TOF JYFLTRAP	MLLTRAP-ALTO/DESIR S^{3}LEB-PILGRIM, PIPERADE-DESIR
charge radii, moments & spins (IJCLab, GANIL)	COLLAPS-ISOLDE CRIS-ISOLDE Collinear @ IGISOL	LINO-ALTO/DESIR S^{3}LEB-REGLIS, LUMIERE-DESIR
moments & spins (IJCLab, IPHC)		POLAREX-ALTO
β-delayed part. & γ spectro. (IJCLab, SUBATECH, CENBG, IPHC)	BEDO/TETRA-ALTO TAGS-Jyvaskyla, ISOLDE	BESTIOL-DESIR

- Studies of ground-state properties important & complementary – results (involving IN2P3) of high quality
- Instrumentation developed for ISOL experiments → coupled via gas cell to in-flight facilities
- Implication of many IN2P3 physicists in present experimental programs concerning *all* gs properties
- France now developing many ISOL-based instruments for the national facilities

Nuclei static & dynamic properties

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Ground-state property (lab)	Now	(Near) Future
masses (CENBG, GANIL, IJCLab)	ISOLTRAP-ISOLDE TITAN-ISAC, GARIS-MR-TOF JYFLTRAP	MLLTRAP-ALTO/DESIR S^{3}LEB-PILGRIM, PIPERADE-DESIR
charge radii, moments & spins (IJCLab, GANIL)	COLLAPS-ISOLDE CRIS-ISOLDE Collinear @ IGISOL	LINO-ALTO/DESIR S^{3}LEB-REGLIS, LUMIERE-DESIR
moments & spins (IJCLab, IPHC)		POLAREX-ALTO
β-delayed part. & γ spectro. (IJCLab, SUBATECH, CENBG, IPHC)	BEDO/TETRA-ALTO TAGS-Jyvaskyla, ISOLDE	BESTIOL-DESIR

- Studies of ground-state properties important & complementary – results (involving IN2P3) of high quality
- Instrumentation developed for ISOL experiments → coupled via gas cell to in-flight facilities
- Implication of many IN2P3 physicists in present experimental programs concerning *all* gs properties
- France now developing many ISOL-based instruments for the national facilities

Nuclei static & dynamic properties

D. Lunney, Conseil Scientific IN2P3 physics ISOL (17)

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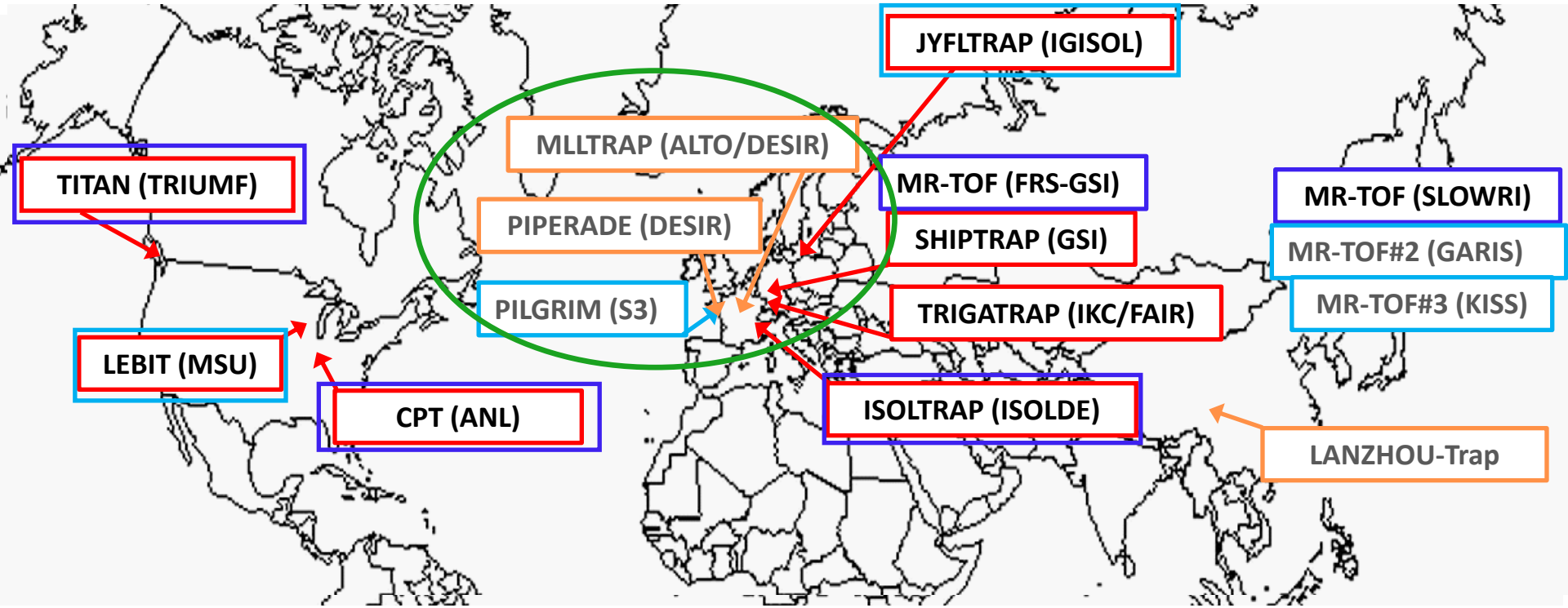
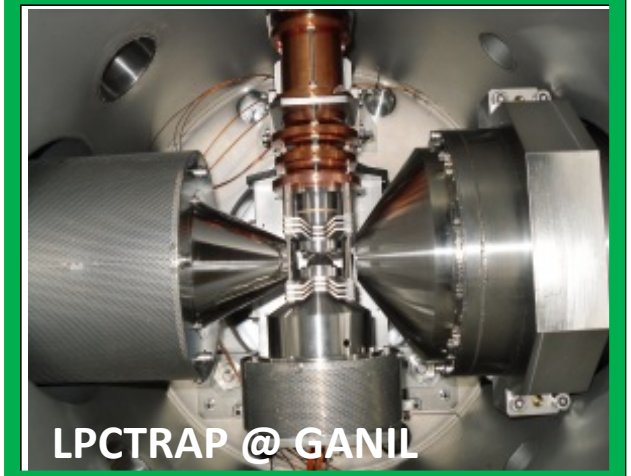
Mass spectrometry worldwide



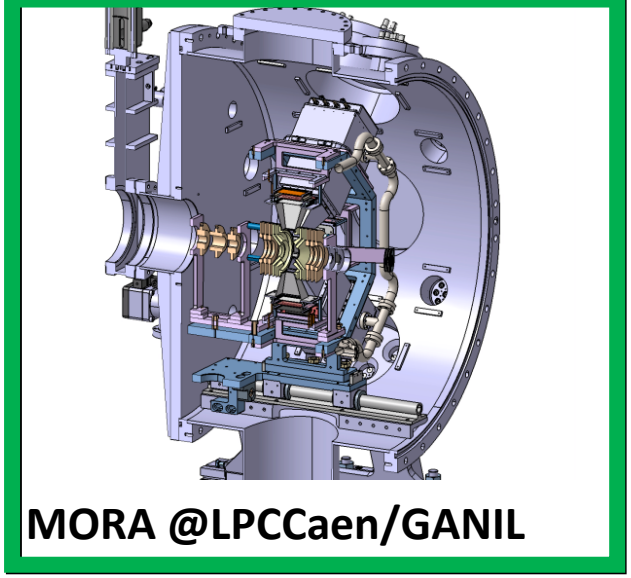
Courtesy P. Ascher

Existing experiments for beam manipulation



LPCTRAP @ GANIL

PAUL TRAP



MORA @LPCCaen/GANIL

PILGRIM @ LPCCaen

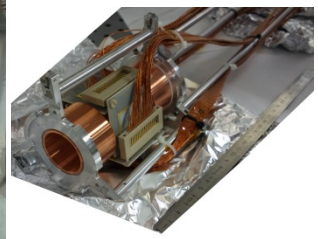
MR-TOF-MS LEB

Mass measurements of ground and isomeric states

life-time measurements, E0 decay strengths

PIPERADE @ CENBG

PENNING TRAP



MLLTRAP @ ALTO

Courtesy E. Minaya Ramirez

Nuclei static & dynamic properties

D. Lunney, Conseil Scientific IN2P3 physics ISOL (17)

Ground-state property (lab)	Now	(Near) Future
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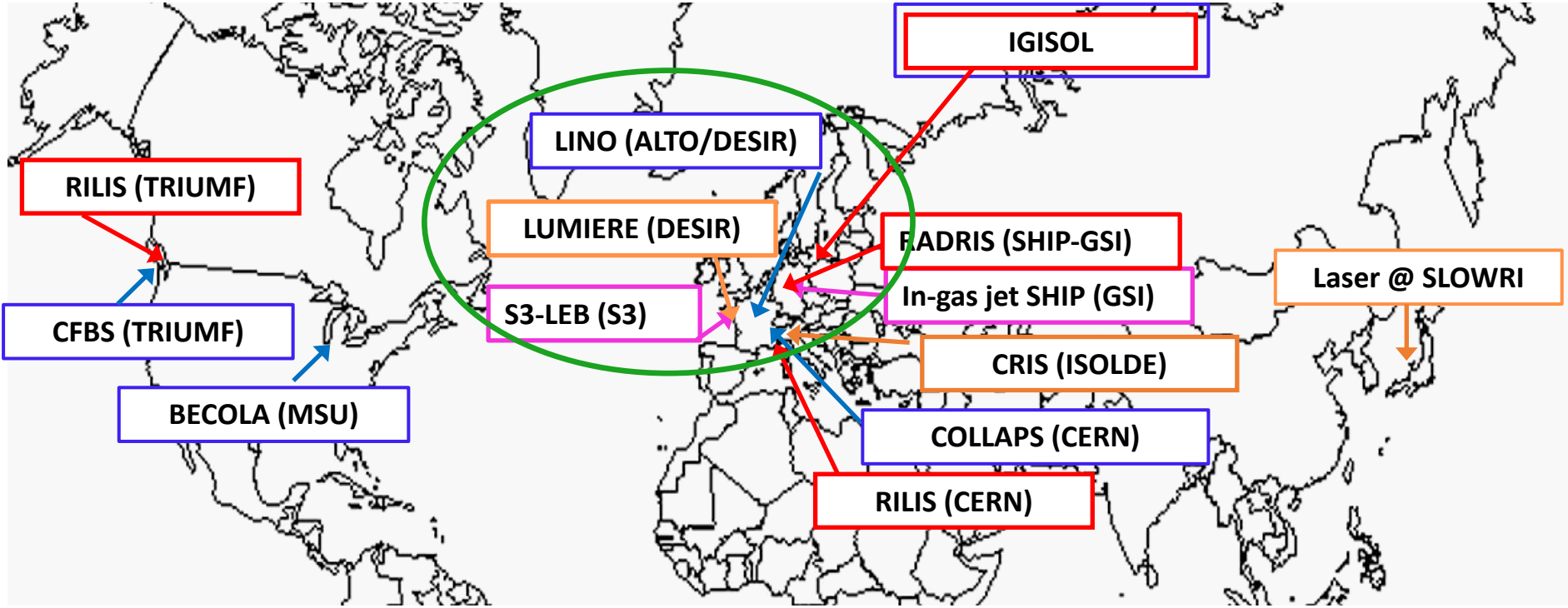
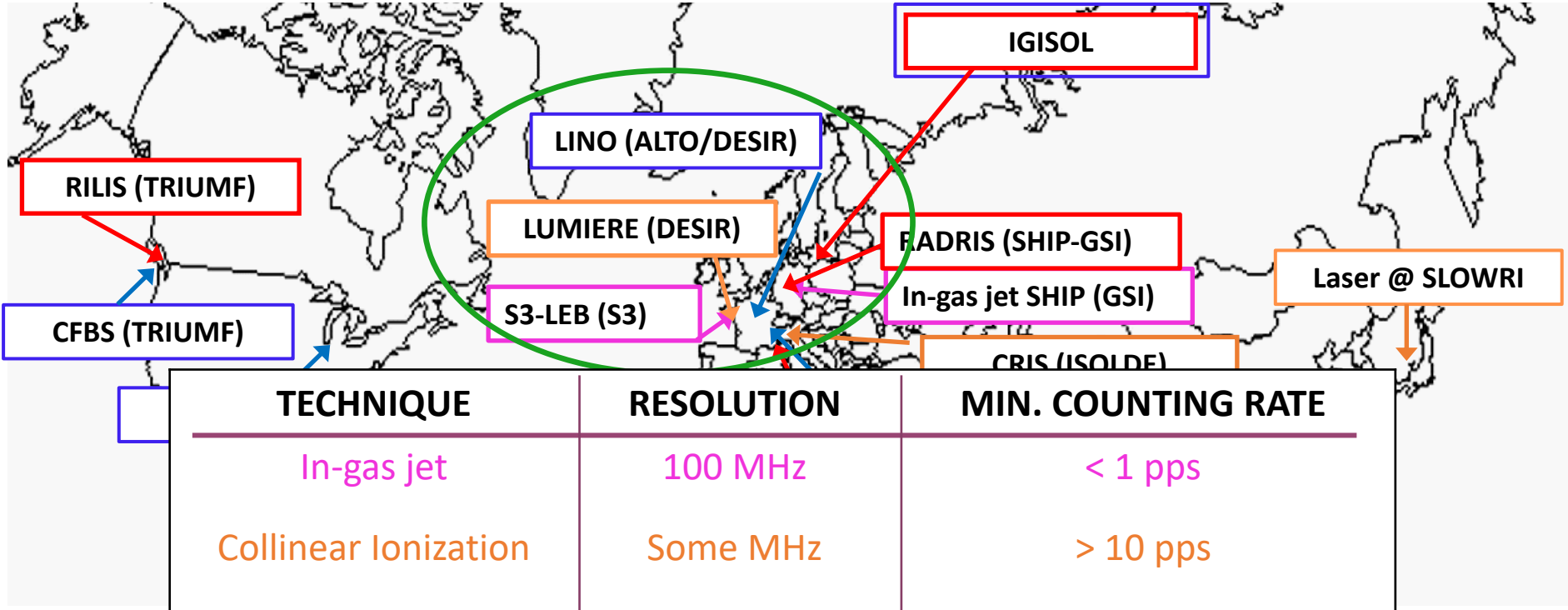
Laser spectroscopy worldwide



In source | Collinear ionization | Collinear fluorescence | In-gas jet

French Development

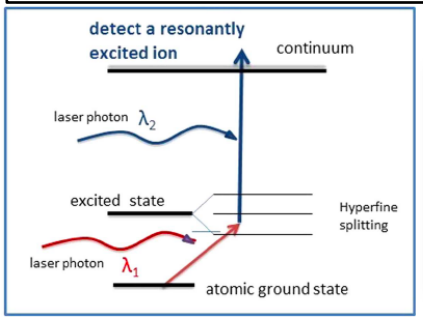
Laser spectroscopy worldwide

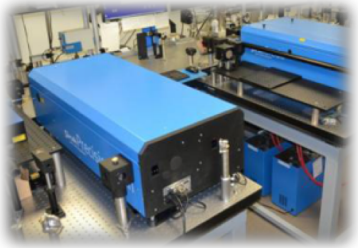


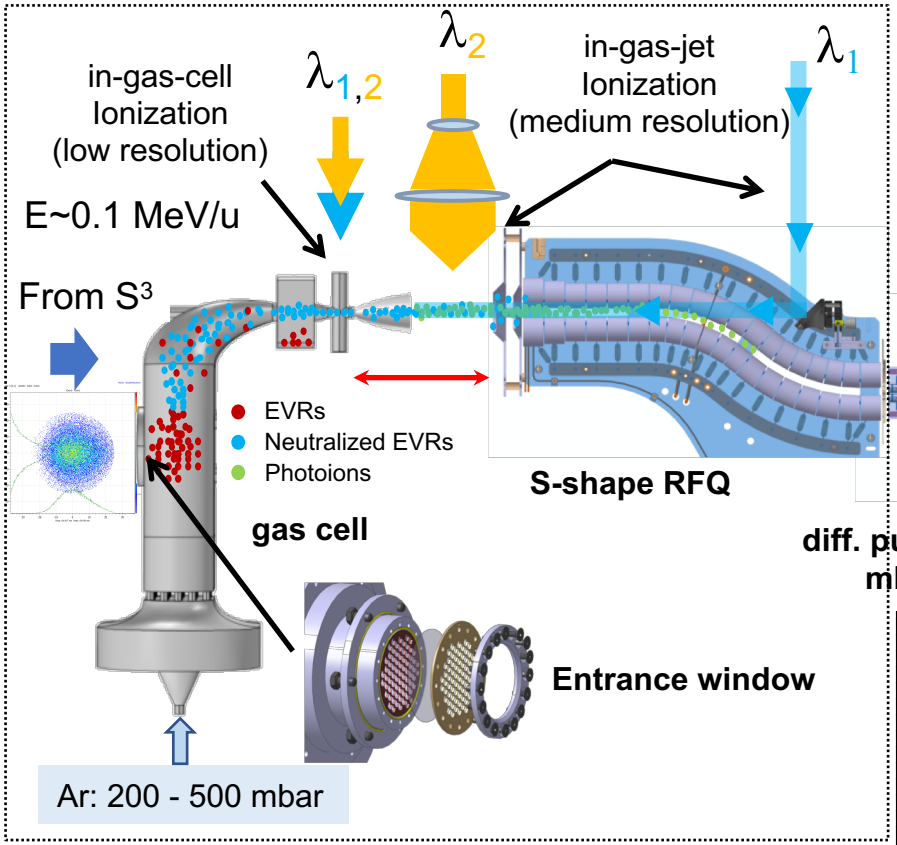
TECHNIQUE	RESOLUTION	MIN. COUNTING RATE
In-gas jet	100 MHz	< 1 pps
Collinear Ionization	Some MHz	> 10 pps
Collinear Fluorescence	Some MHz	> 100 pps

French Development

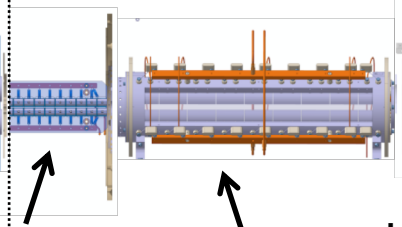
Low Energy Branch

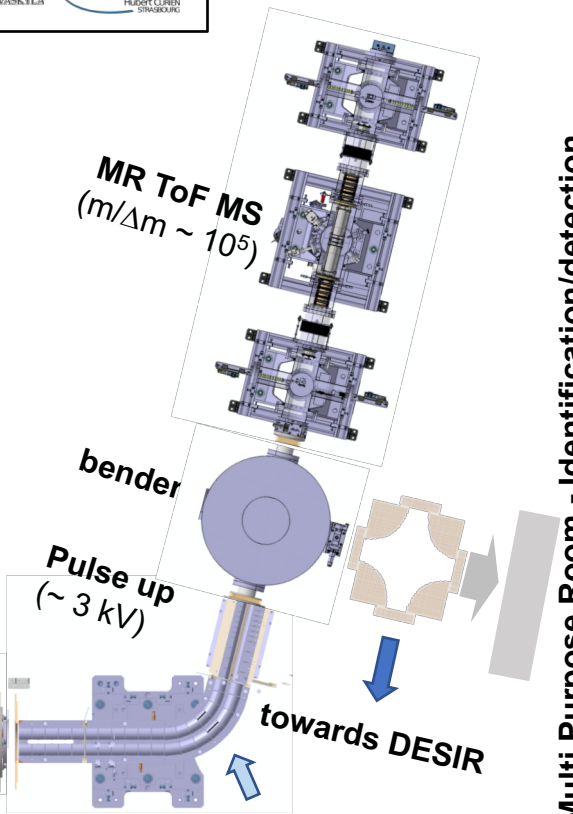






Two lasers systems: TiSa and dye



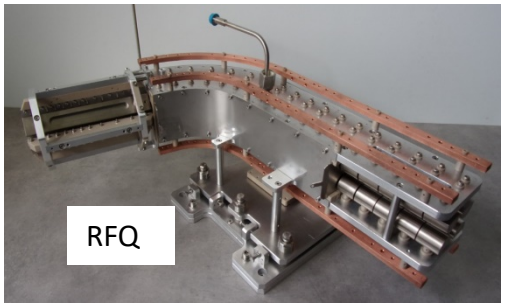


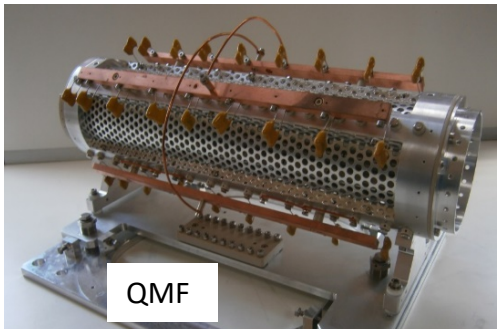
towards Multi Purpose Room - Identification/detection

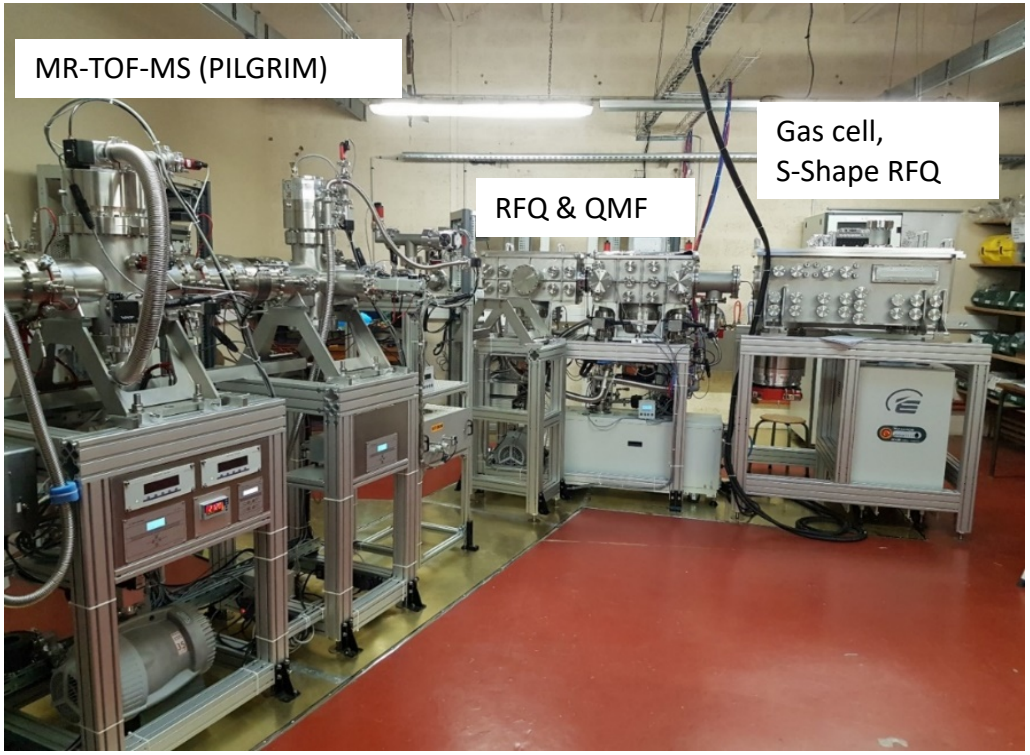
- Provide pure & low energy beams from S³
- Spectroscopy with only 0,1 pps
- Perform medium resolution laser spectroscopy 100-300 MHz & Eff > 10% & ~300 ms extraction
- MR-TOF-MS extraction time ~100 ms, 100 keV

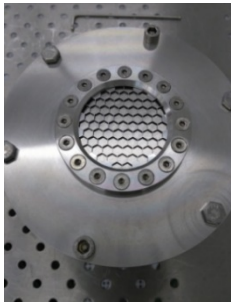
Courtesy N. Lecesne

S^3 – LEB STATUS - REGLIS

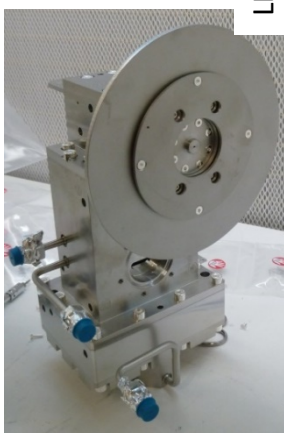


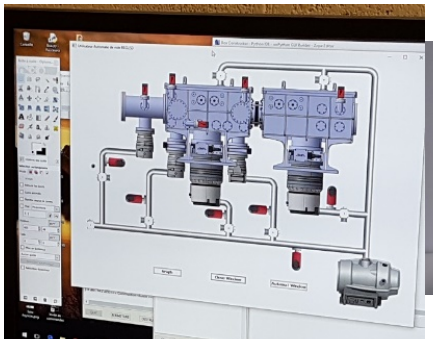


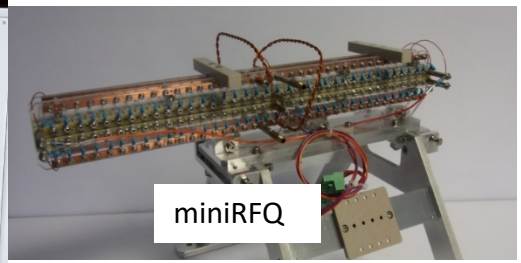


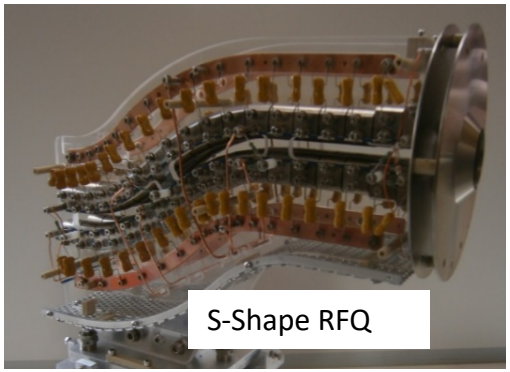


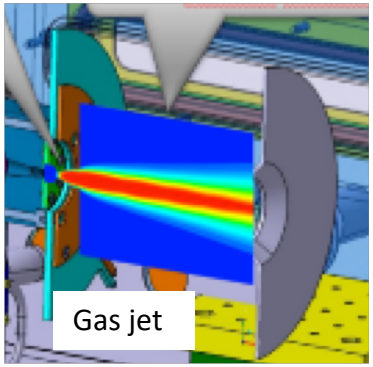
LEB entrance window







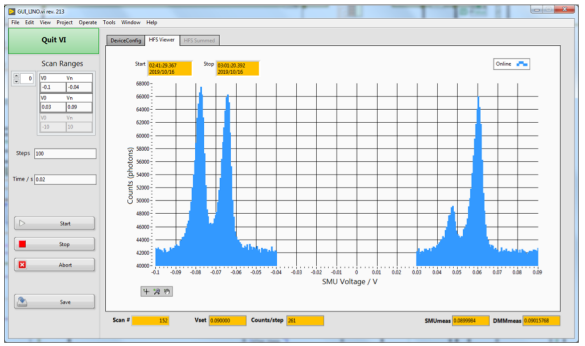




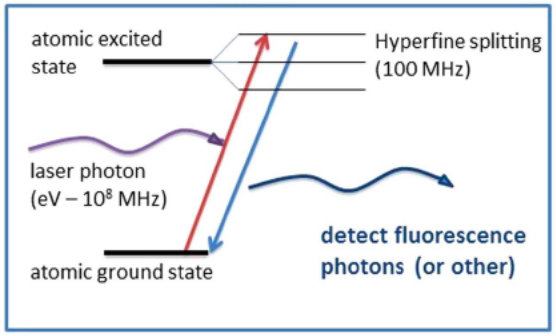
LINO at ALTO / DESIR

Courtesy D. Yordanov

SUCCESFUL TEST 2019
(stable ^{23}Na)



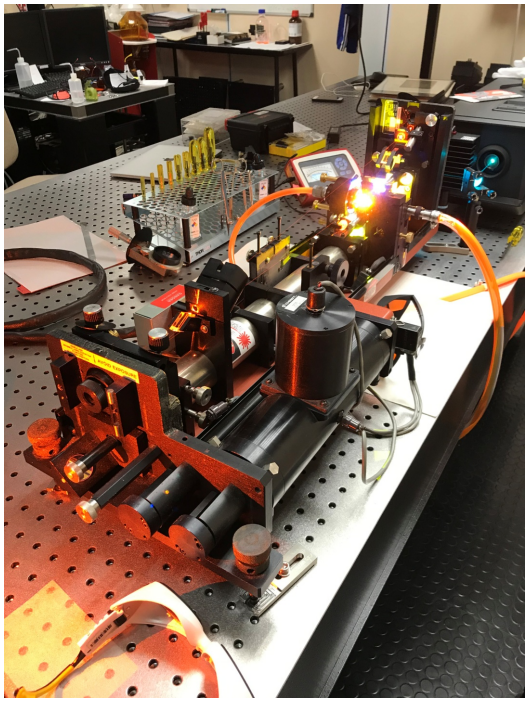
fluorescence detection



post acceleration & neutralization

Beam diagnostics and handling

laser and ion beam coupling



Nuclei static & dynamic properties

D. Lunney, Conseil Scientific IN2P3 physics ISOL (17)

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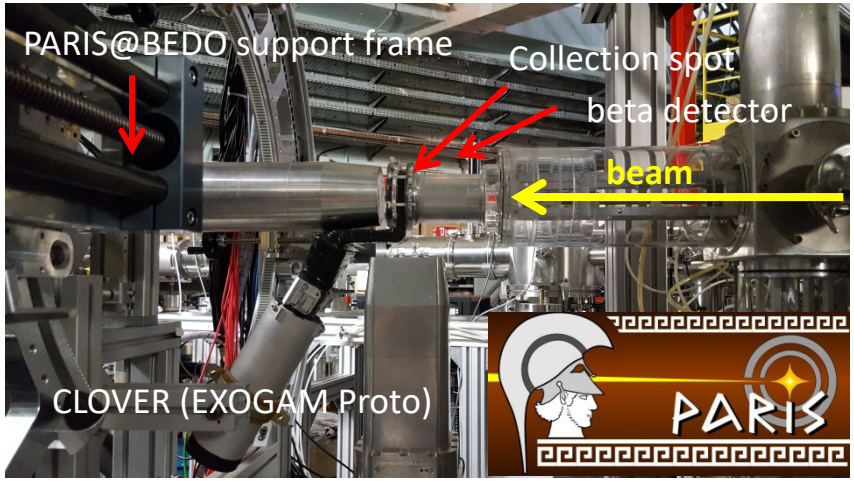
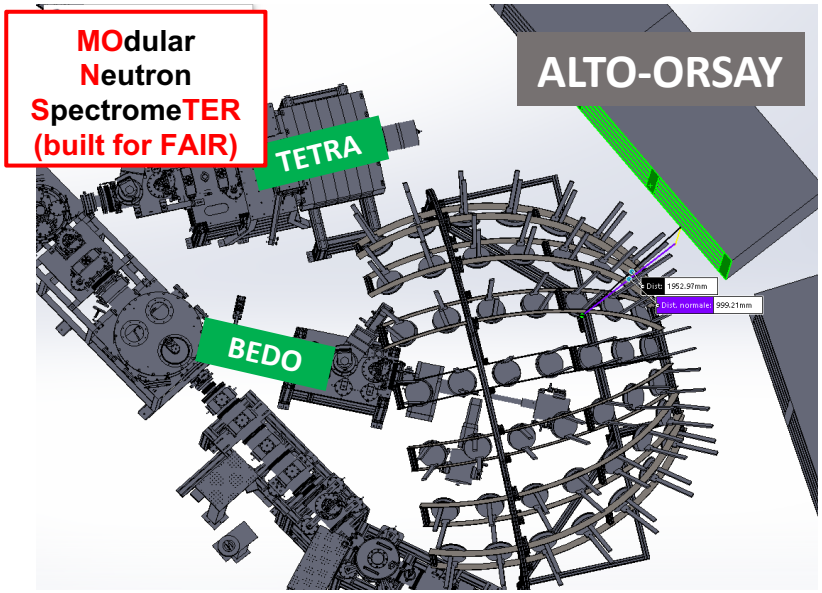
Experimental devices

Combination of high energy gamma measurements (PARIS) with high resolution (Clover) -> First campaign of measurements at ALTO, prospectives at DESIR





Spanish-Finish collaboration

- 100 cylindrical BC501A cell of 20 cm x 5 cm
- Energy threshold E_n ~150 keV
- Good neutron timing ~1ns
- Digital DAQ 14bits & 1 Gsample/s

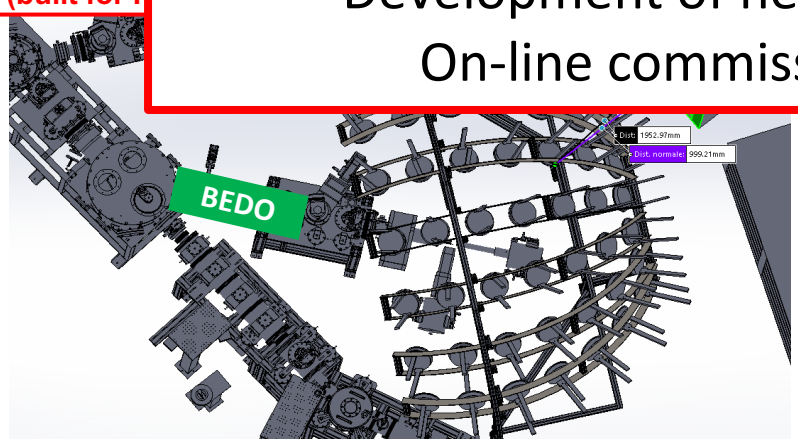
Experimental devices

Combination of high energy gamma measurements (PARIS) with high resolution (Clover) -> ALTO, pros

ALTO as a R&D installation for the ISOL-community while obtaining interesting results

Specific beams in the neutron rich area
Development of new targets and ion sources
On-line commissioning for new setups

MOdula
Neutro
Spectrome
(built for F



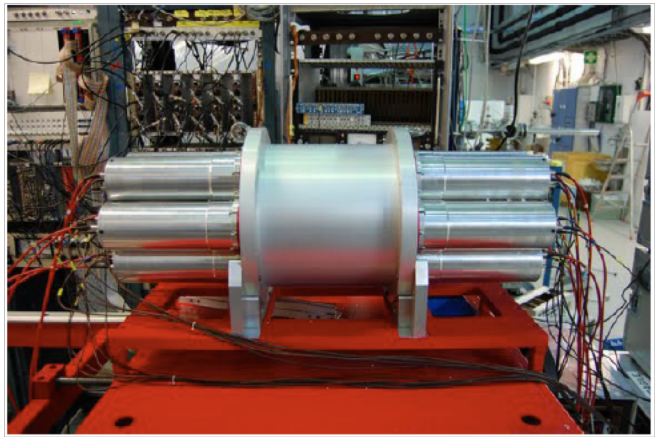
ish collaboration

m x 5 cm

- Energy threshold E_n ~150 keV
- Good neutron timing ~1ns
- Digital DAQ 14bits & 1 Gsample/s

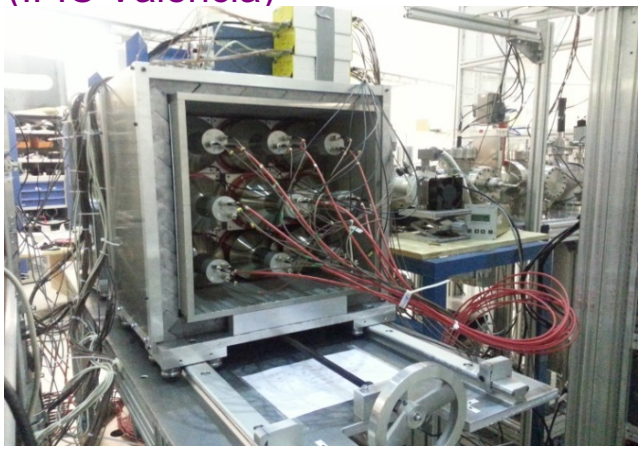
TAS available

❑ ROCINANTE
(IFIC Valencia/Surrey)



- 12 BaF_2 covering 4π
- Detection efficiency of γ ray cascade >80% (up to 10 MeV)
- Coupled with a Si detector for β
- 7 nuclei (4 delayed neutron emitters) measured (6 for DH and 2 for anti-ν)

❑ DTAS
(IFIC Valencia)



- 18 NaI(Tl) crystals of 15cm × 15cm × 25 cm
- Individual crystal resolutions: 7-8%
- Total efficiency: 80-90%
- Coupled with plastic scintillator for β
- 12 nuclei for anti-ν measured & 11 for DH

TAS set-ups that could be placed @ DESIR

(NA)²STARS: Neutrinos Applications Nuclear Astrophysics - Segmented Total Absorption with high Resolution Spectrometer

French-Spanish collaboration

Short term needs vs. Threats

NEED	RISKs	CONSEQUENCES
Finalization IN A TIMELY MANNER **S3**	First experiment later than 2023	Competition with other labs, fewer nuclei left to study
Accomplishment of the A/Q = 7	No A/Q = 7	N = Z physics program strongly affected, loose of the leadership. Not competitive with respect to FRIB (A<80)
Fast gas cell	No manpower for R&D	Difficulties to measure exotic nuclei with $t_{1/2} \lesssim 100$ ms
Full development of **DESIR**	Partial development	Reduction of physics output
Complete laser system for DESIR	No budget assured	No laser spectroscopy experiments at DESIR

Long term needs

NOW!!!

(Ganil 20??)

Neutron rich nuclei @ DESIR

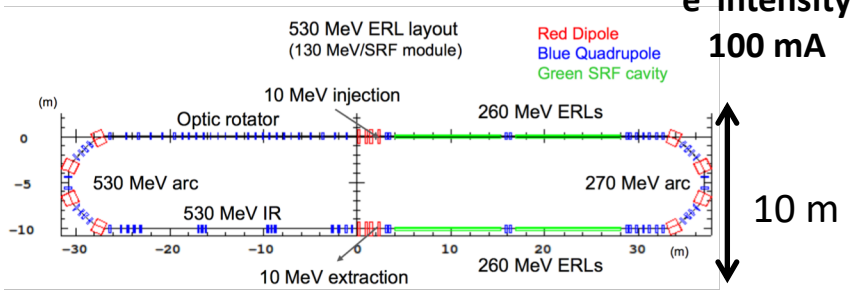
Open new horizons for the physics @ DESIR exploiting full capabilities of the facility (talk P. Delahaye)

ETIC: Electron-Radioactive Ion Collider

- **1000 gain in luminosity** compared to fresh state of the art instruments (10^{30} cm^{-2} s^{-1} at reach)
- Relies on high-intensity low-energy RI production at GANIL (SPIRAL, fission products, S3)
- **New exciting and world-unique physics program** with Radioactive Ions possible at GANIL

First step: demonstrator to validate some of the key points of such a machine ***(Talk F. Flavigny)***

Energy Recovering LINAC (ERL)



e⁻ intensity
100 mA

10 m

- Halos, molecular states…➔ SPIRAL1
(ex $^{6-8}$He, ^{12}Be, ^{17}C, ^{8}B,^{14}O, $^{17-18}$Ne, …)
- Density depletion (spin-orbit interaction)➔ SPIRAL1 / DESIR neutron rich
(ex : ^{34}Si bubble nuclei)
- Alpha clustering around N=Z=50…➔ SPIRAL2-S3
(ex : Xe et Ba isotopes)
- Very heavy nuclei (charge radii)➔SPIRAL2-S3
(ex : unknown territory)

Long term needs

NOW!!!

(Ganil 20??)

Neutron rich nuclei @ DESIR

Open new horizons for the physics @ DESIR exploiting full capabilities of the facility (talk P. Delahaye)

ET

-
-
- N

First

Energy R

The ISOL France community support the development of such facility.

We consider that the purity and high quality beams to be delivered by the DESIR facility is a niche for this type of measurements

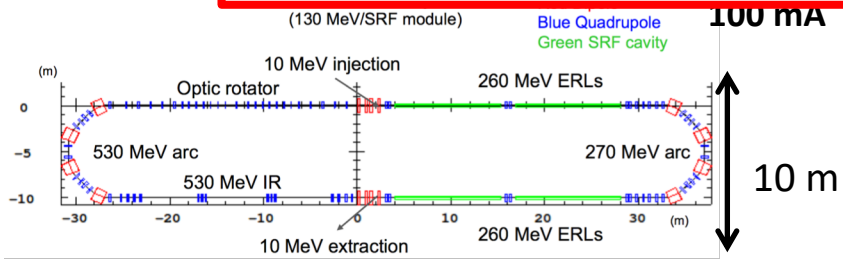
-1 at reach)

ts, S3)

GANIL

Flavigny)

n)➔



SPIRAL1 / DESIR neutron rich

(ex : ^{34}Si bubble nuclei)

➢ Alpha clustering around N=Z=50…➔ SPIRAL2-S3

(ex : Xe et Ba isotopes)

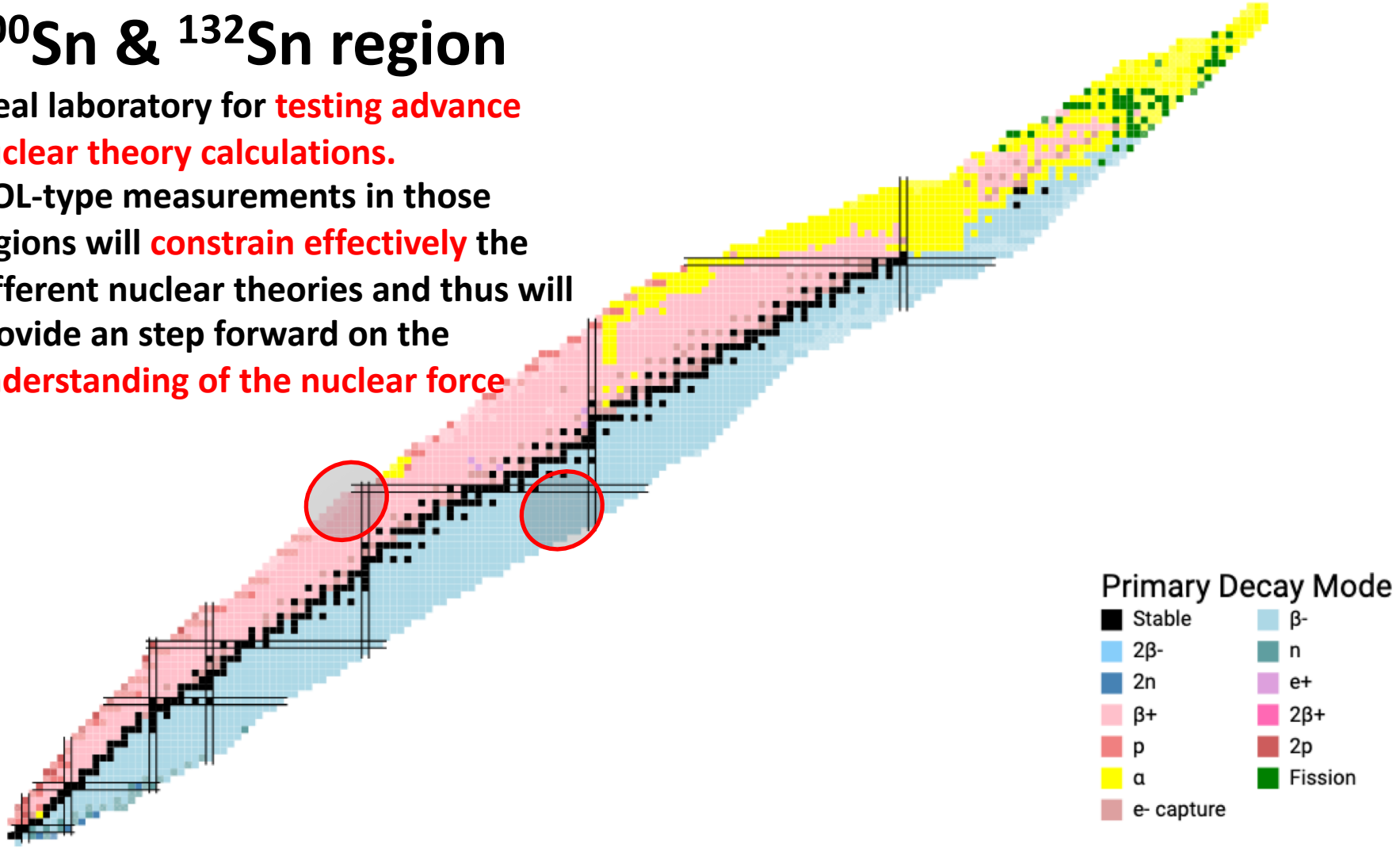
➢ Very heavy nuclei (charge radii)➔SPIRAL2-S3

(ex : unknown territory)

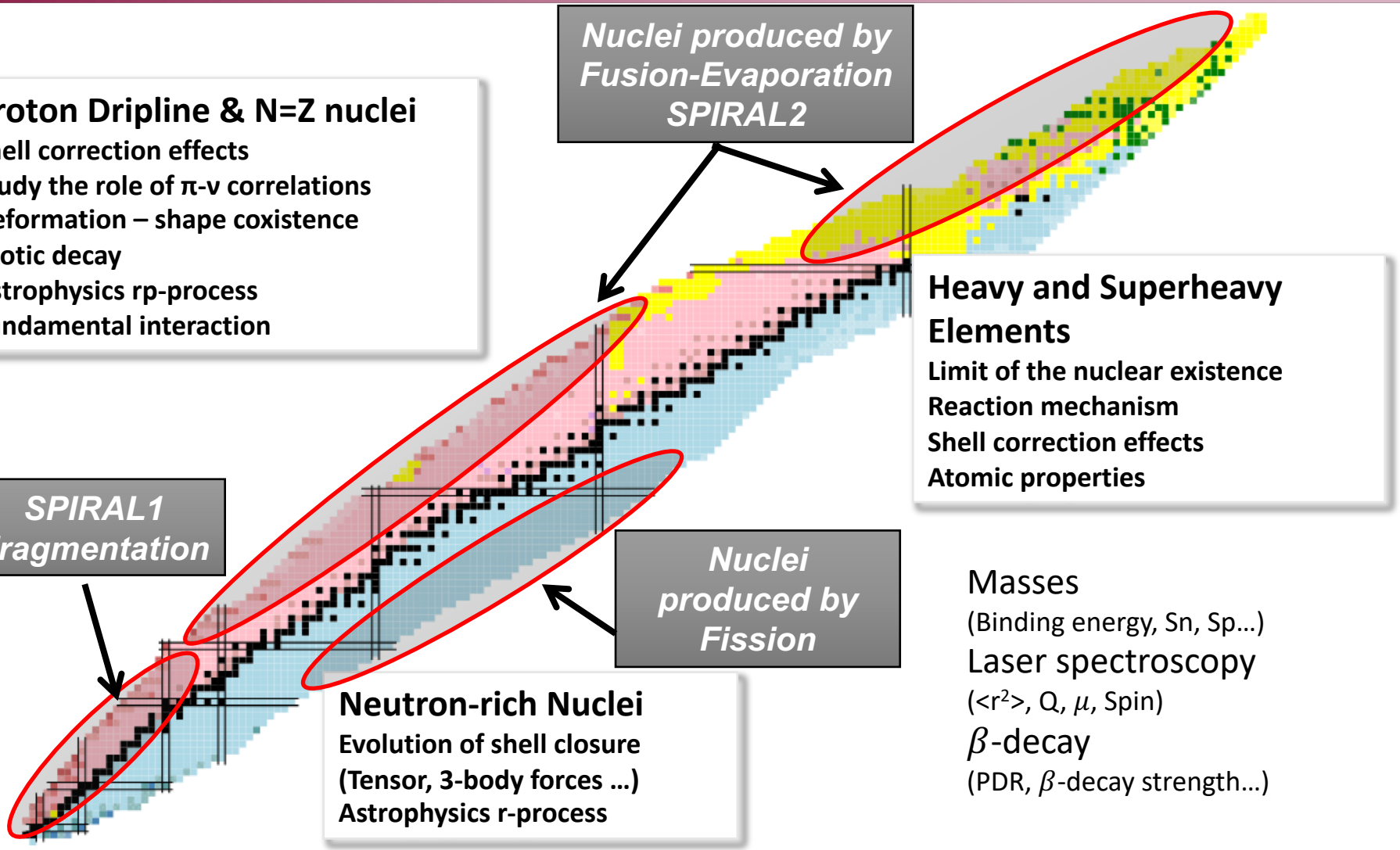
High light

^{100}Sn & ^{132}Sn region

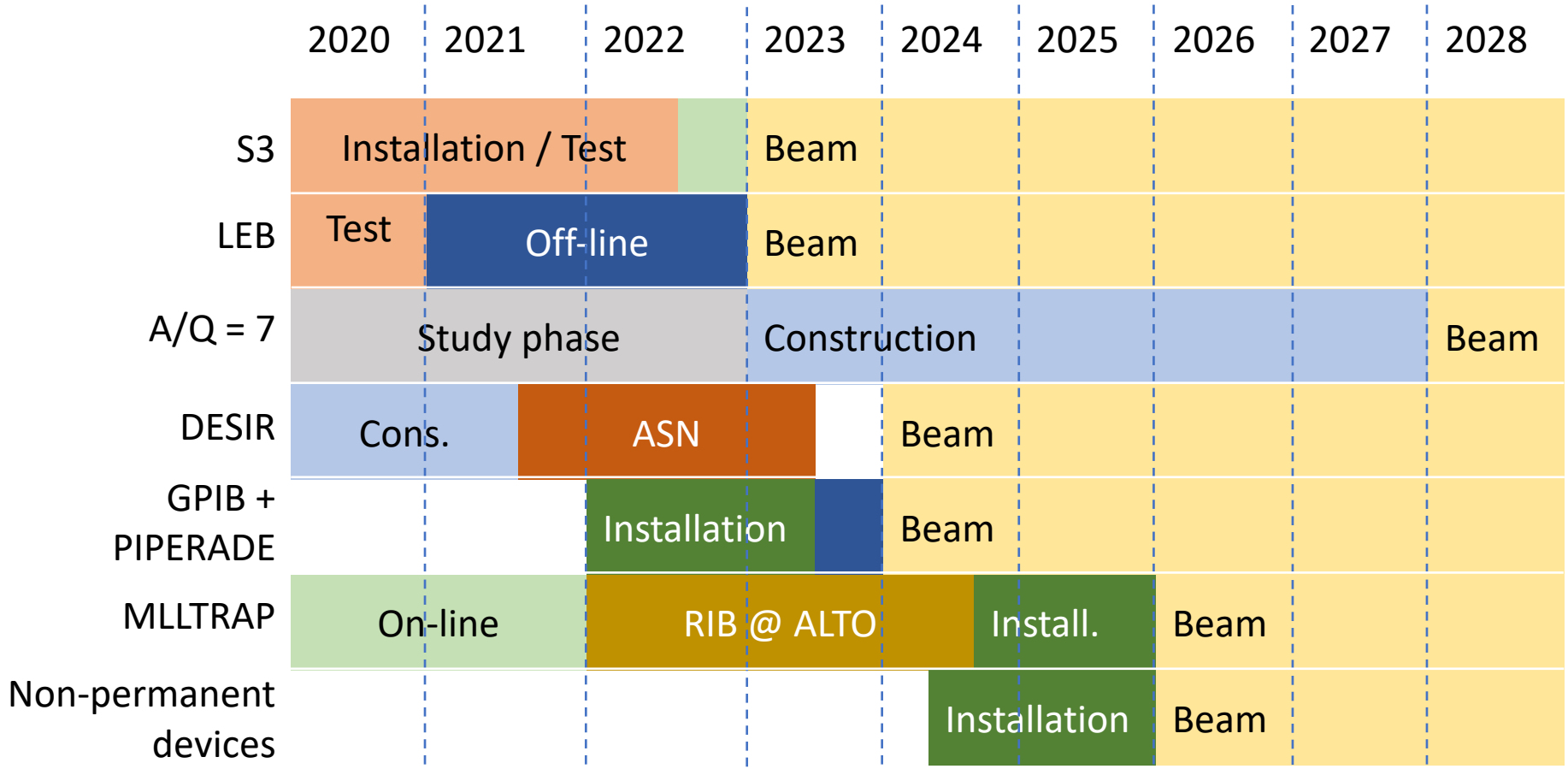
Ideal laboratory for testing advance nuclear theory calculations.
ISOL-type measurements in those regions will constrain effectively the different nuclear theories and thus will provide an step forward on the understanding of the nuclear force



Finally here it is the nuclear chart!



Time Line


2020
2021
2022
2023
2024
2025
2026
2027
2028
S3
Installation / Test
Beam
LEB
Test
Off-line
Beam
A/Q = 7
Study phase
Construction
Beam
DESIR
Cons.
ASN
Beam
GPIB +
PIPERADE
Installation
Beam
MLLTRAP
On-line
RIB @ ALTO
Install.
Beam
Non-permanent
devices
Installation
Beam

Thank you !!!