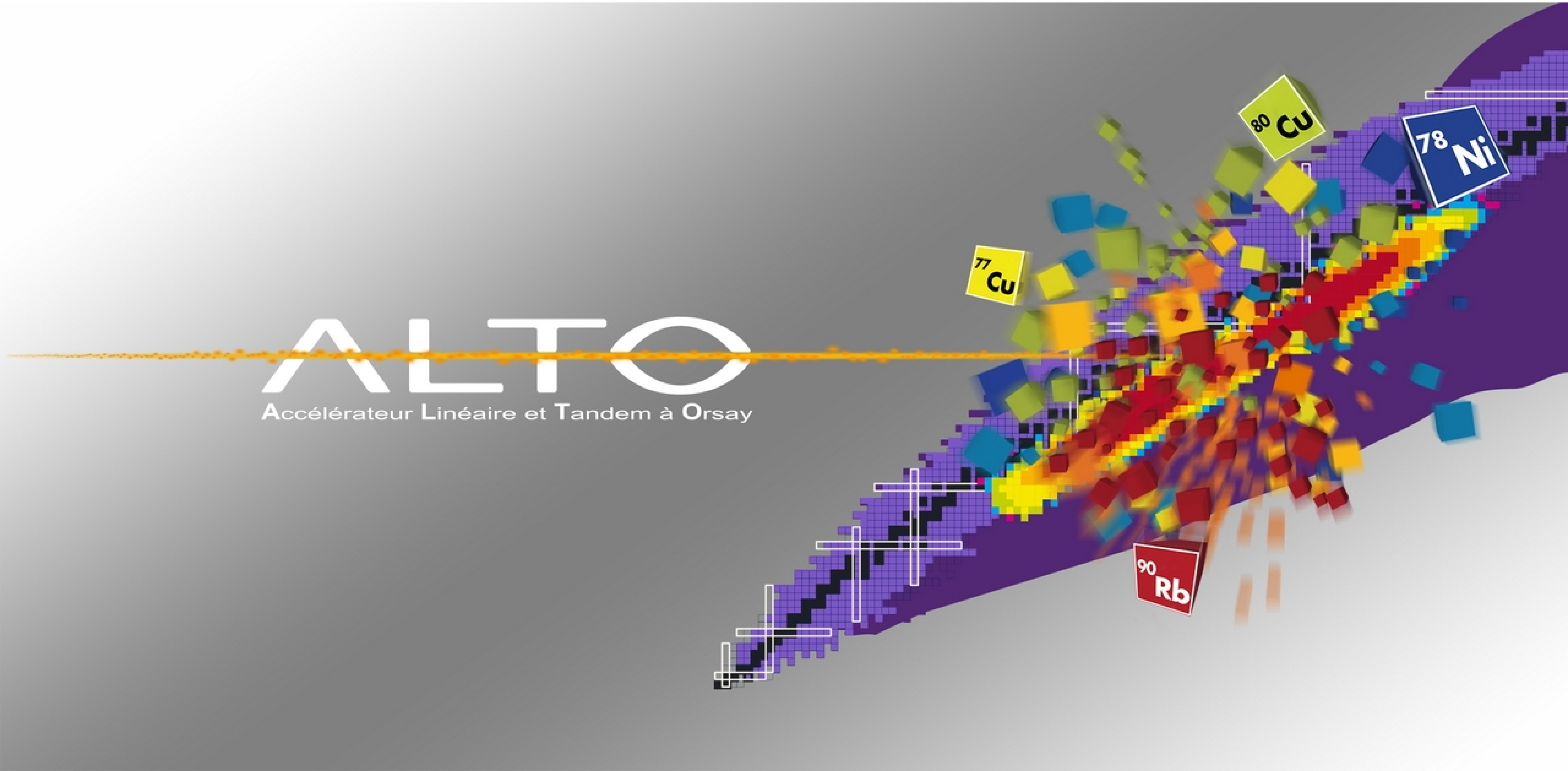
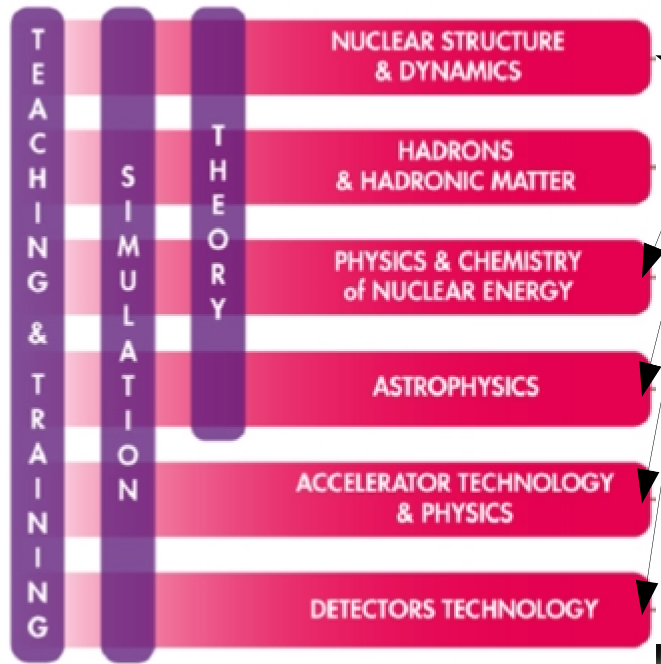
The Alto facility

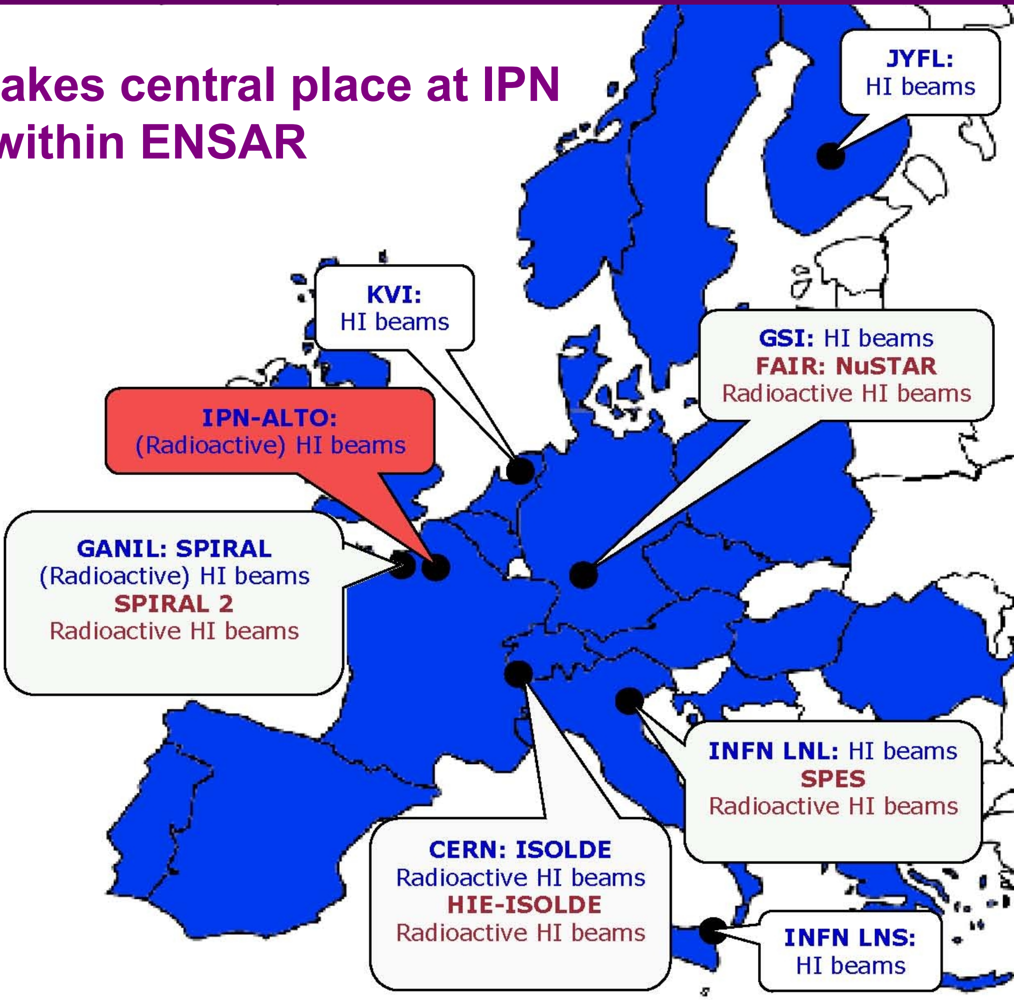
S Franchoo
IPN Orsay



The Alto facility



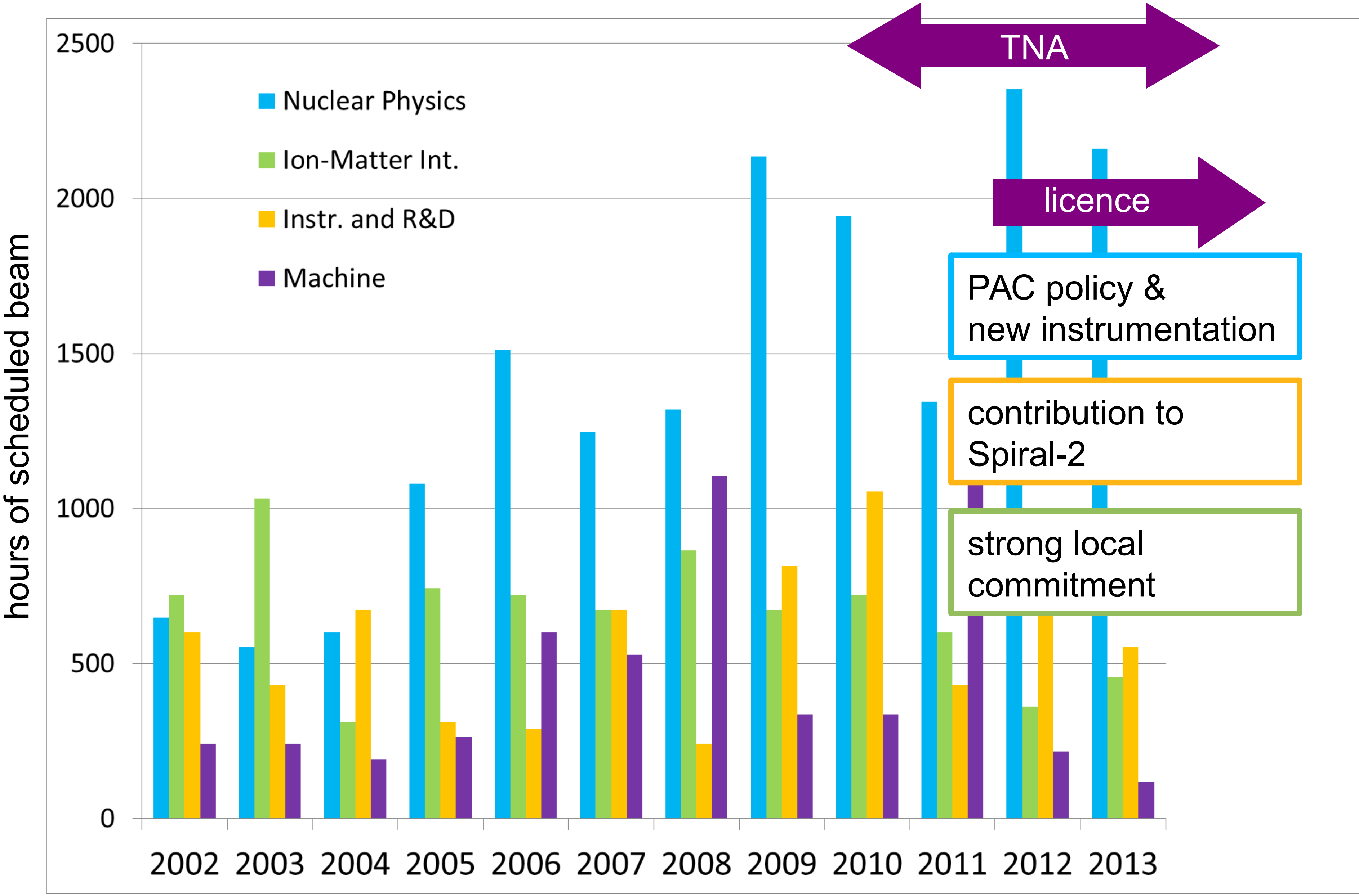
Alto takes central place at IPN TNA within ENSAR



March 2012: operating licence

May 2013: Alto Workshop

The Alto facility



The Alto facility

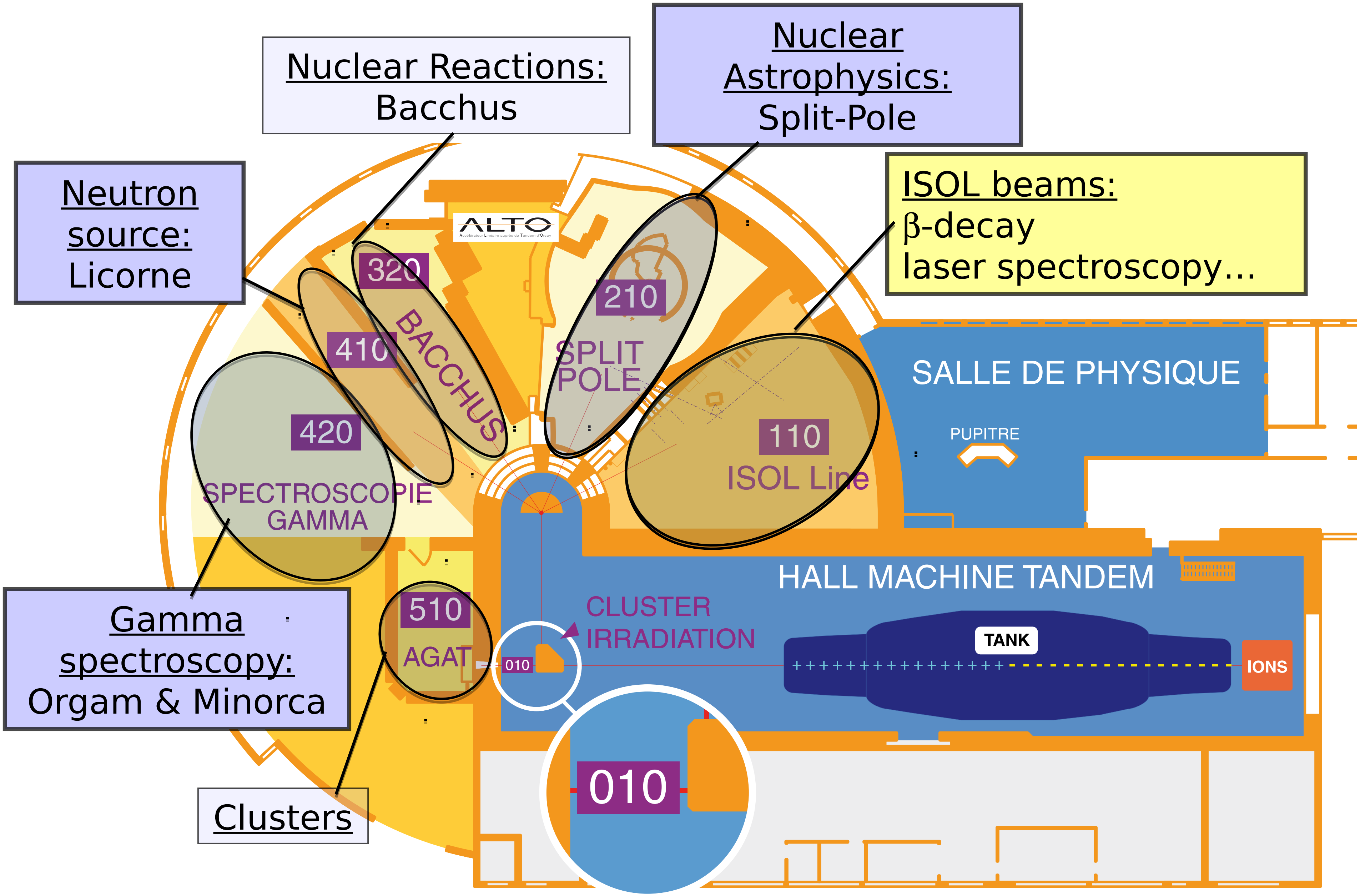
360 staff members
250 outside users (30 countries) /y

Stable beams	**3928 h /y**
25% light ion beams	984 h
75% heavy ion beams	1964 h
RIB	**360 h /y**

IPN INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY

UNIVERSITÉ PARIS SUD

The Alto facility



Orgam: the Orsay Gamma Array
I Matea et al

2012
13 BGO + 13 EUROGAM Phase 1 Ge

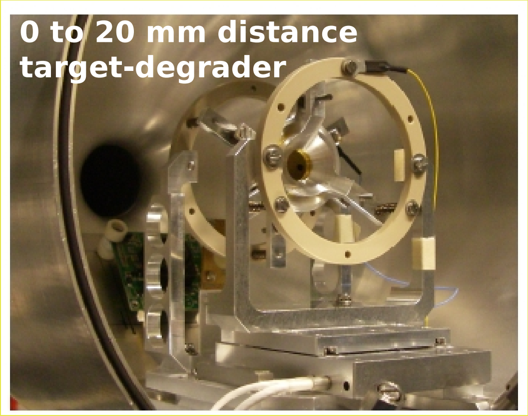
2013
~20 detectors back from Warsaw + Loan Pool

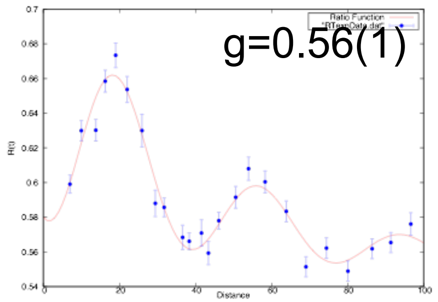
"Development of the Time Dependent Recoil In-Vacuum technique for radioactive-beam geometry"
(G. Georgiev, CSNSM Orsay, France)

"Probing the boundary of shape coexistence south of Z=82: Lifetime measurements of excited states in ^{170}Os"
(J. Ljungvall, CSNSM Orsay, France)

"Search for X(5) symmetry in ^{168}W"
(K. Gladnishki, University of Sofia, Bulgaria)

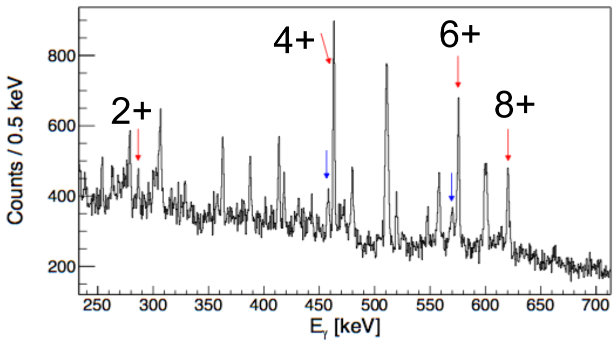
Oups plunger





^{24}Mg 2^+

A Kusoglu
Univ Istanbul



^{170}Os

A Goasduff
CSNSM

"Superdeformed Shell Structure in A~40 Nuclei"
(E. Ideguchi, University of Osaka, Japan)

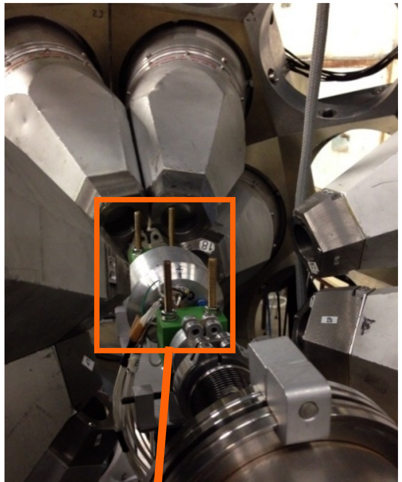
Silicon Ball

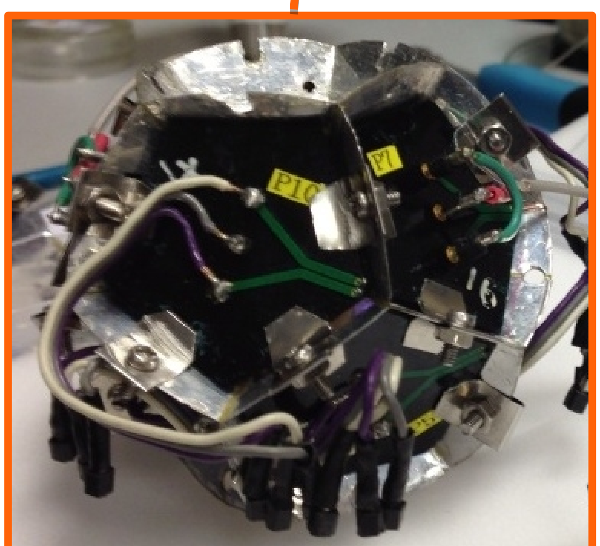
Orgam & Silicon Ball: the Orsay Gamma Array
E Ideguchi & D Suzuki et al

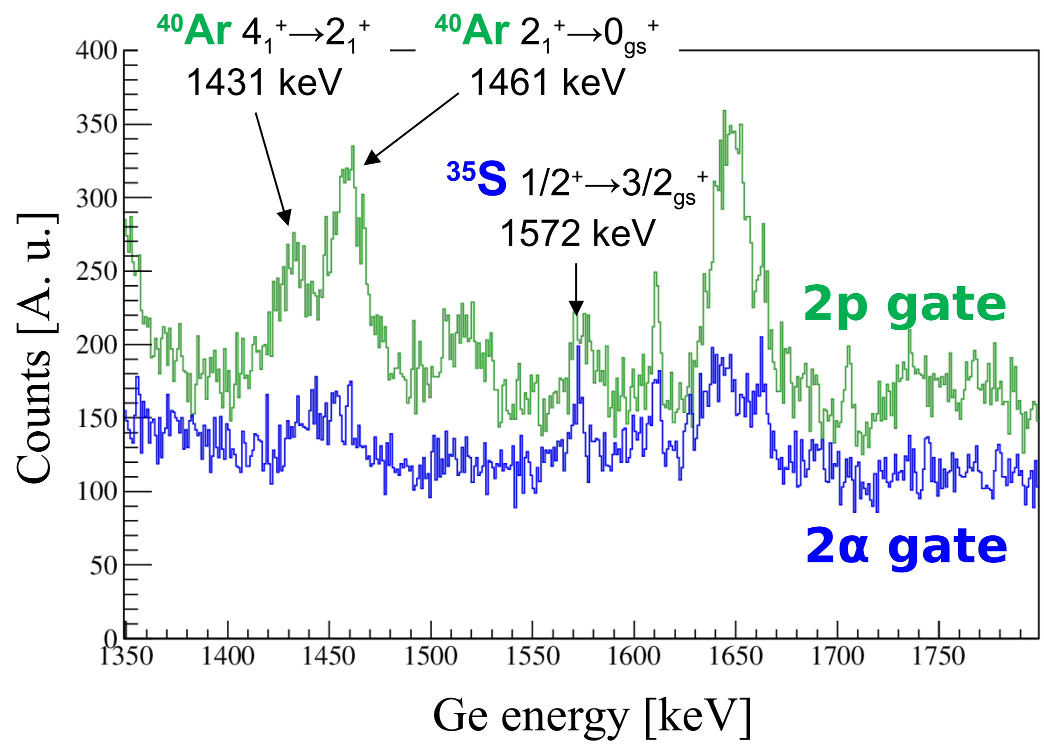
Super-deformation in ^{35,36}S and ^{40}Ar via ^{18}O + ^{26}Mg → ^{44}Ca*

OSAKA UNIVERSITY

IPN INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY







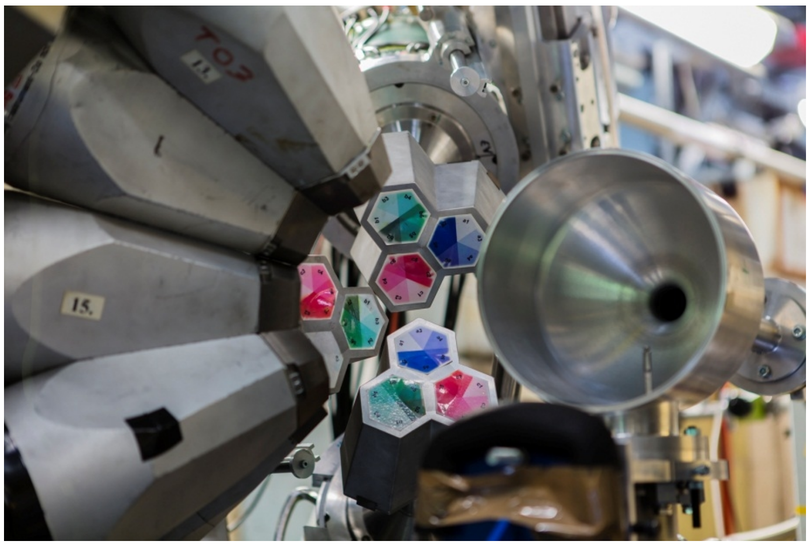
CNS Graduate School of Science University of Tokyo
Center for Nuclear Study (CNS)

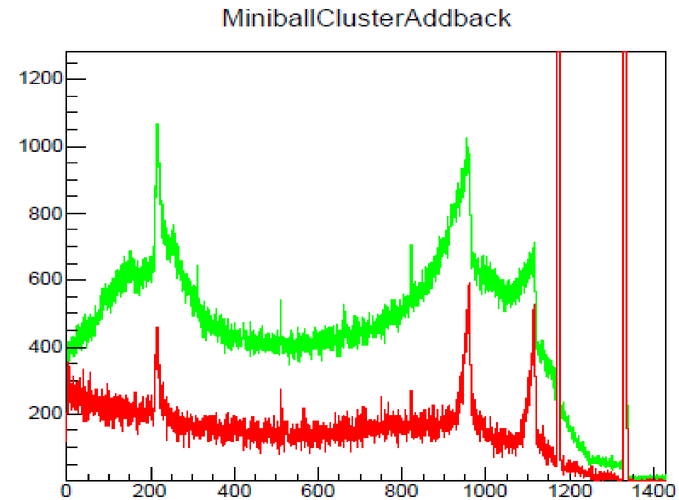
Analysis in progress
by S Go (University of Tokyo)

Minorca: Miniball at Orsay coupled to Orgam
I Matea & G Georgiev et al

15-20 coax Ge
+ 8 Miniball triple clusters
with addback

Efficiency at 1332 keV: 8.1%





J Ljungvall, CSNSM Orsay

Oups plunger, segmented particle detector, ...
possibility of installing a large number of **$LaBr_3$ detectors**

Up to 24 weeks of beam time available for the 2014 campaign

Minorca: Miniball at Orsay coupled to Orgam
I Matea & G Georgiev et al

g factor measurements of short-lived states towards the Island of Inversion: ^{26}Mg and ^{28}Mg (G. Georgiev – CSNSM)

Shape coexistence in ^{74}Se studied through complete low-spin spectroscopy after Coulomb excitation (M. Zielinska – CEA Saclay)

Search for X(5) symmetry in ^{78}Sr (K. Gladnishki – University of Sofia)

Lifetime Measurement of ^{100}Ru: A possible candidate for the E(5) critical point symmetry (T. Konstantinopoulos – CSNSM)

Lifetime measurements in ^{113}Te: Determining optimal effective charges approaching the N=Z=50 doubly-magic shell closure (D. Cullen – University of Manchester)

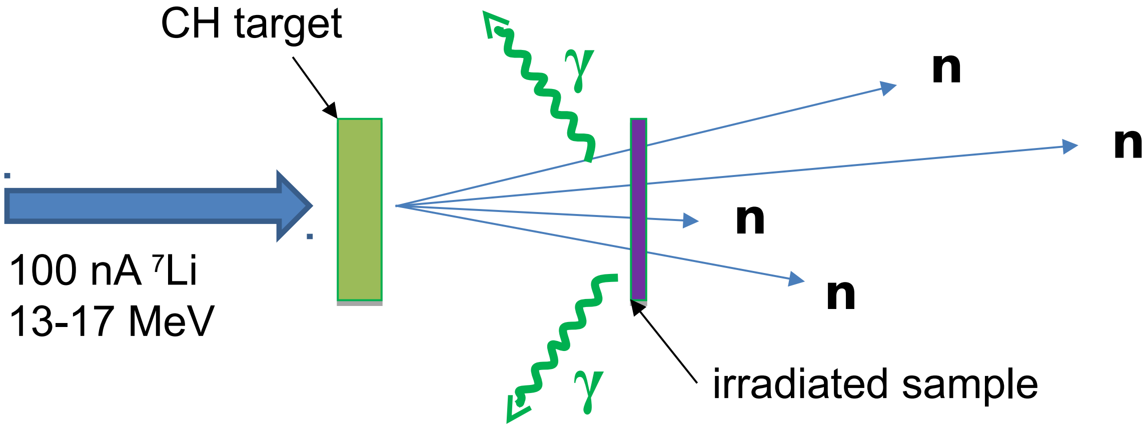
Measurement of octupole collectivity in Nd, Sm and Gd nuclei using Coulomb excitation (P. Butler – University of Liverpool)

Single-particle structure in the second minimum. Search for high-K bands above fission isomers (G. Georgiev – CSNSM)

Spectroscopy of the neutron-rich fission fragments produced in the $^{238}U(n,f)$ reaction (J. Wilson – IPN)

~80 days beam time requested

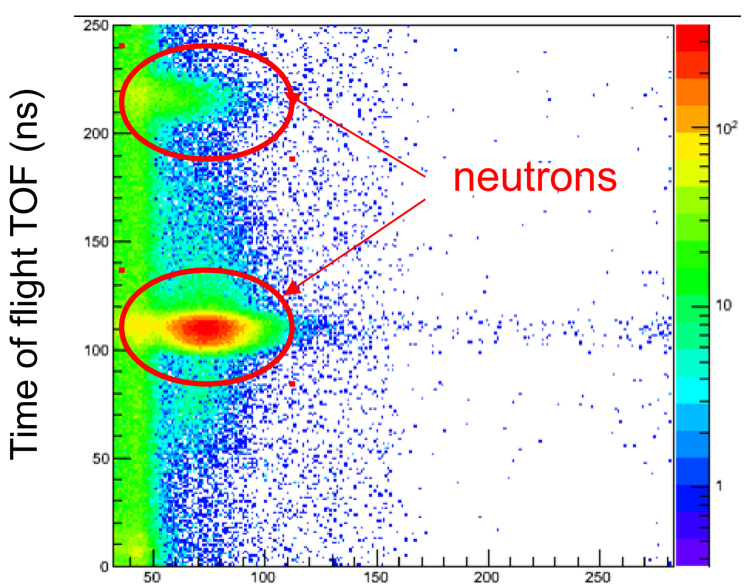
Licorne: Lithium Inverse Kinematic Orsay Neutron Source
J Wilson et al



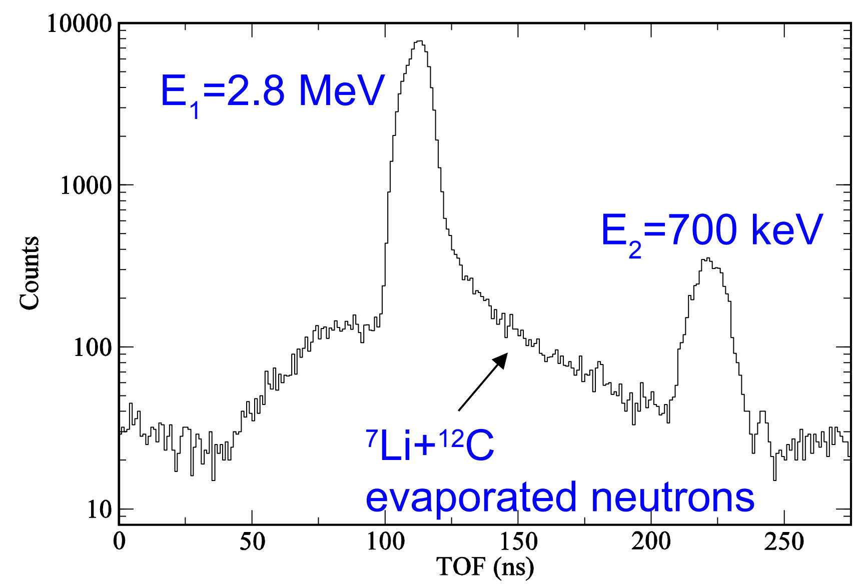
Focused intense mono-energetic neutron source:

10^{7} n/s/sr

$0.5 < E_n < 4$ MeV



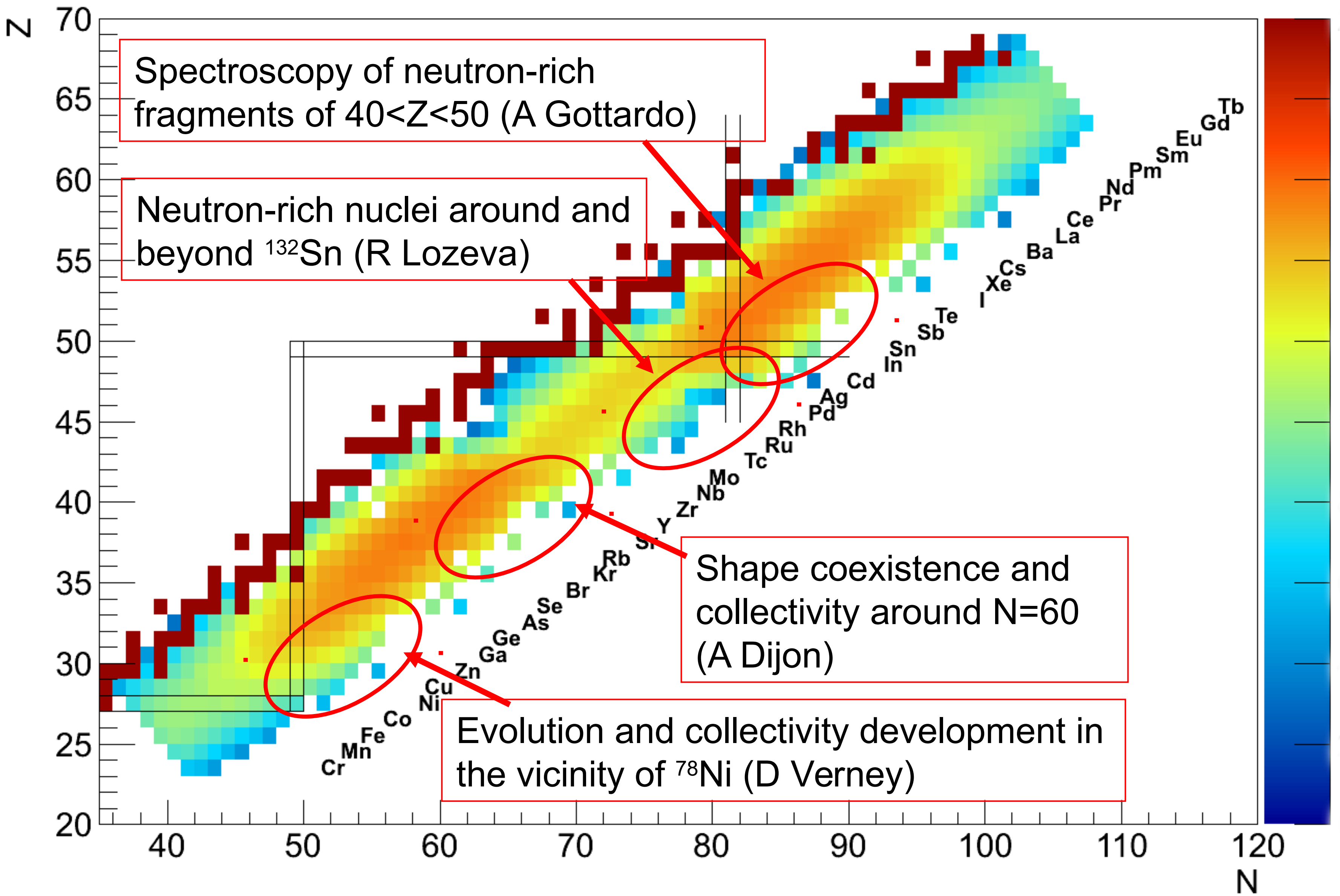
Pulse Shape Analysis (PSA)



P Halipré, PhD thesis

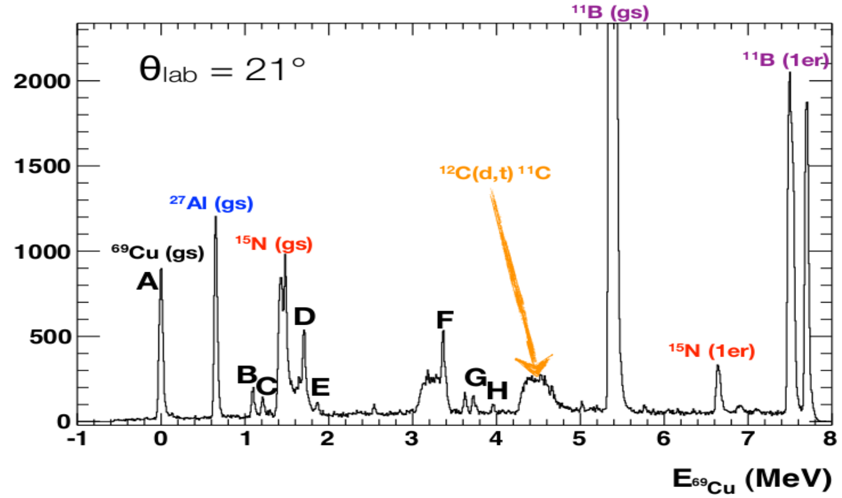
Spectroscopy of neutron-rich fission fragments produced in ^{238}U(n,f)

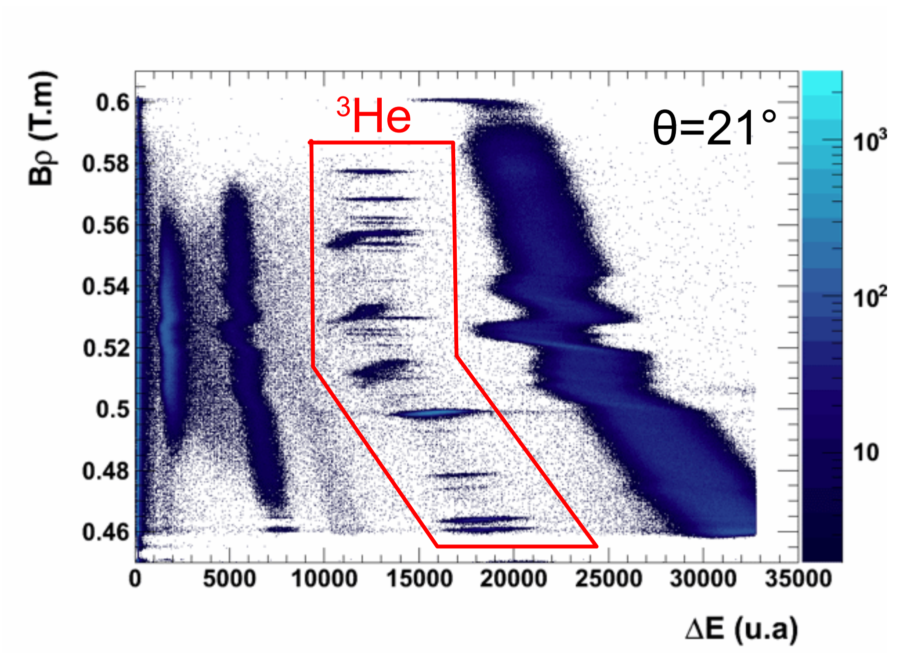
J Wilson et al



Split-pole
I Stefan et al

$^{71}Zn(d,^{3}He)^{69}Cu$ pickup reaction





Transfer reactions...

$^{70}Zn(d,^{3}He)^{69}Cu$, P Morfouace

$^{70}Zn(^{14}C,^{16}O)^{68}Ni$, I Stefan

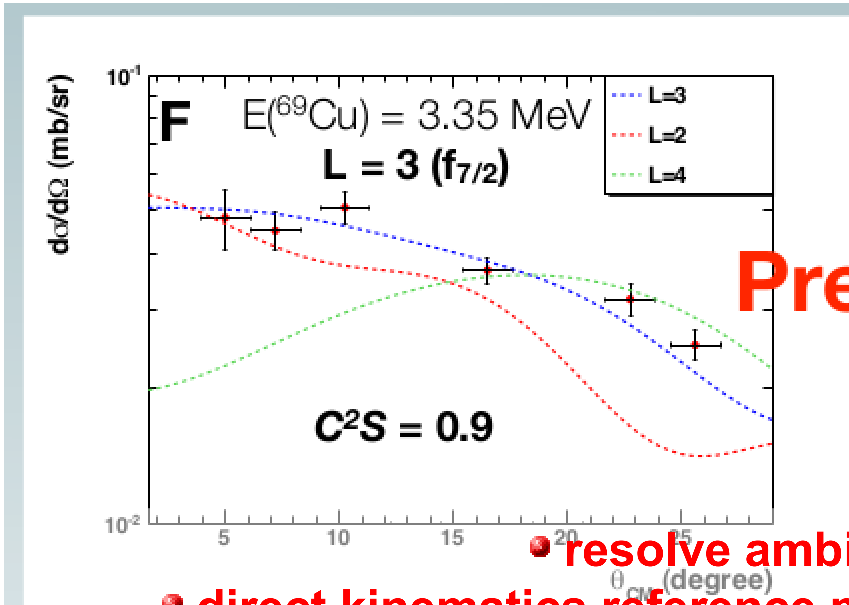
more foreseen for 2014

$^{36}S(d,p)$ & $^{36}S(^{14}C,^{16}O)$

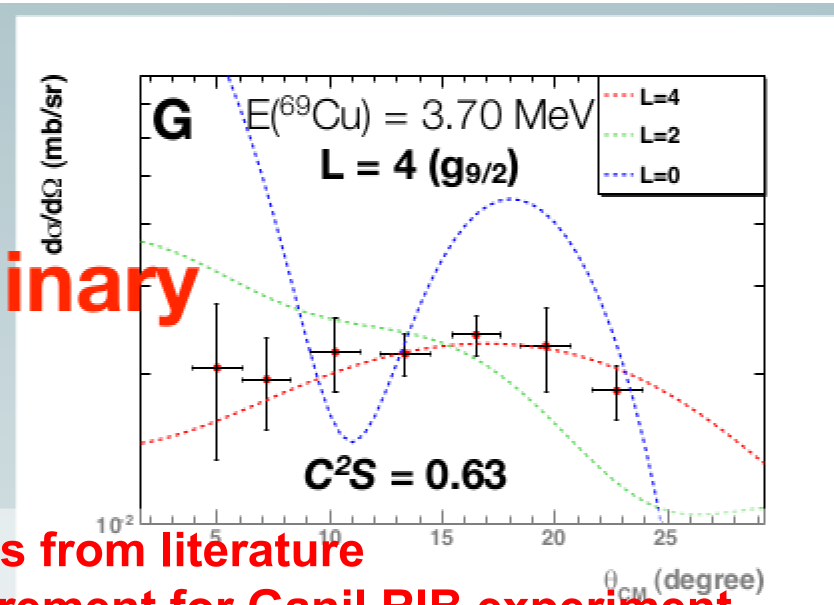
O Sorlin & T Roger

... and nuclear astrophysics

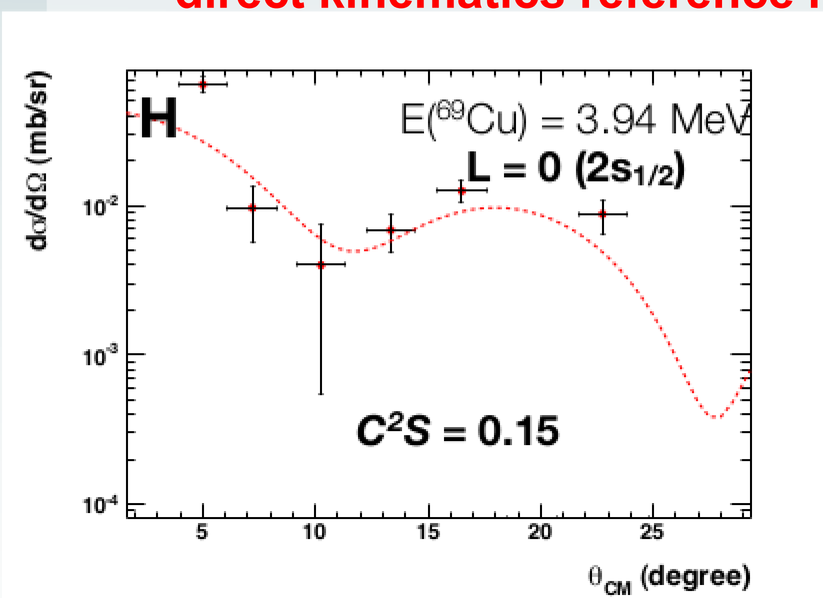
Single-particle strength in neutron-rich copper
P Morfouace et al

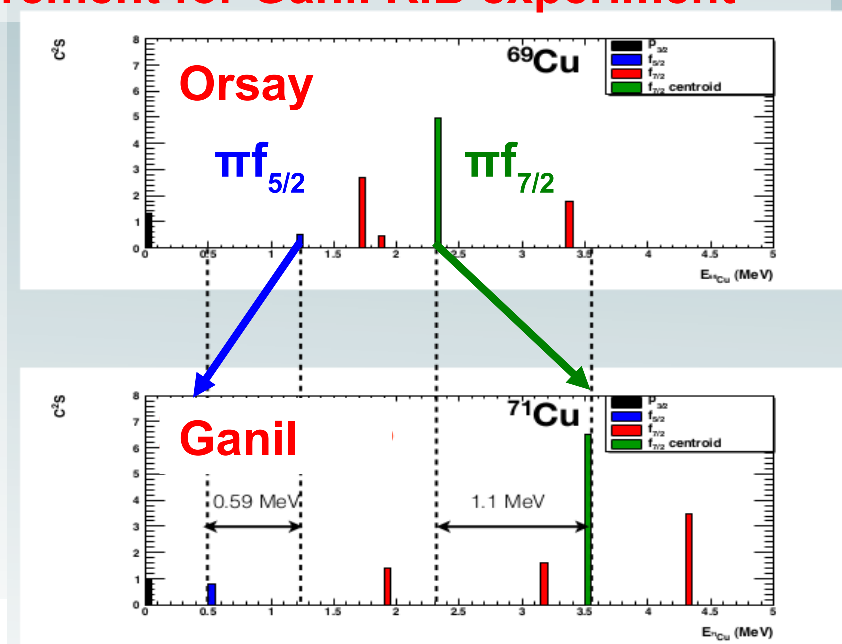


Preliminary



- resolve ambiguities from literature
- direct kinematics reference measurement for Ganil RIB experiment





Nuclear astrophysics
N De Séréville, F Hammache et al

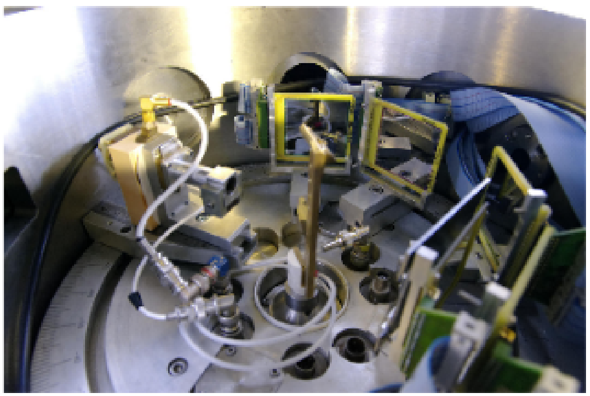
$^{26}Al(n,p)^{26}Mg$ and $^{26}Al(n,\alpha)^{23}Na$ in massive stars

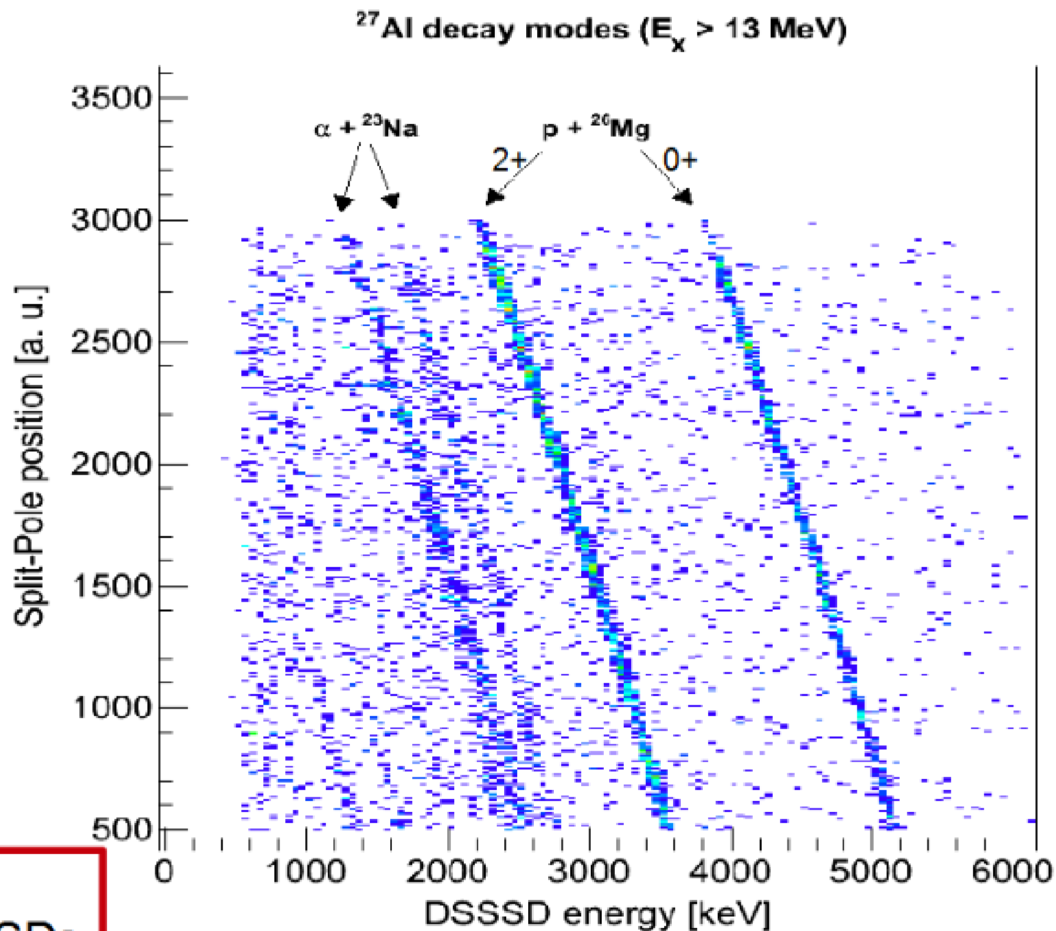
Reaction: $^{27}Al(p,p')^{27}Al$ @ 18 MeV + coincidence measurement

Branching ratios

$$\omega\gamma = \omega\Gamma_n\Gamma_i/\Gamma_{tot}$$

- Split-Pole @ 40°
- 3 DSSSDs in reaction chamber
  - → 5 x 5 cm², 16 strips (W model)
  - → backward angles
  - → d ~ 10 cm, ε ~ 6%



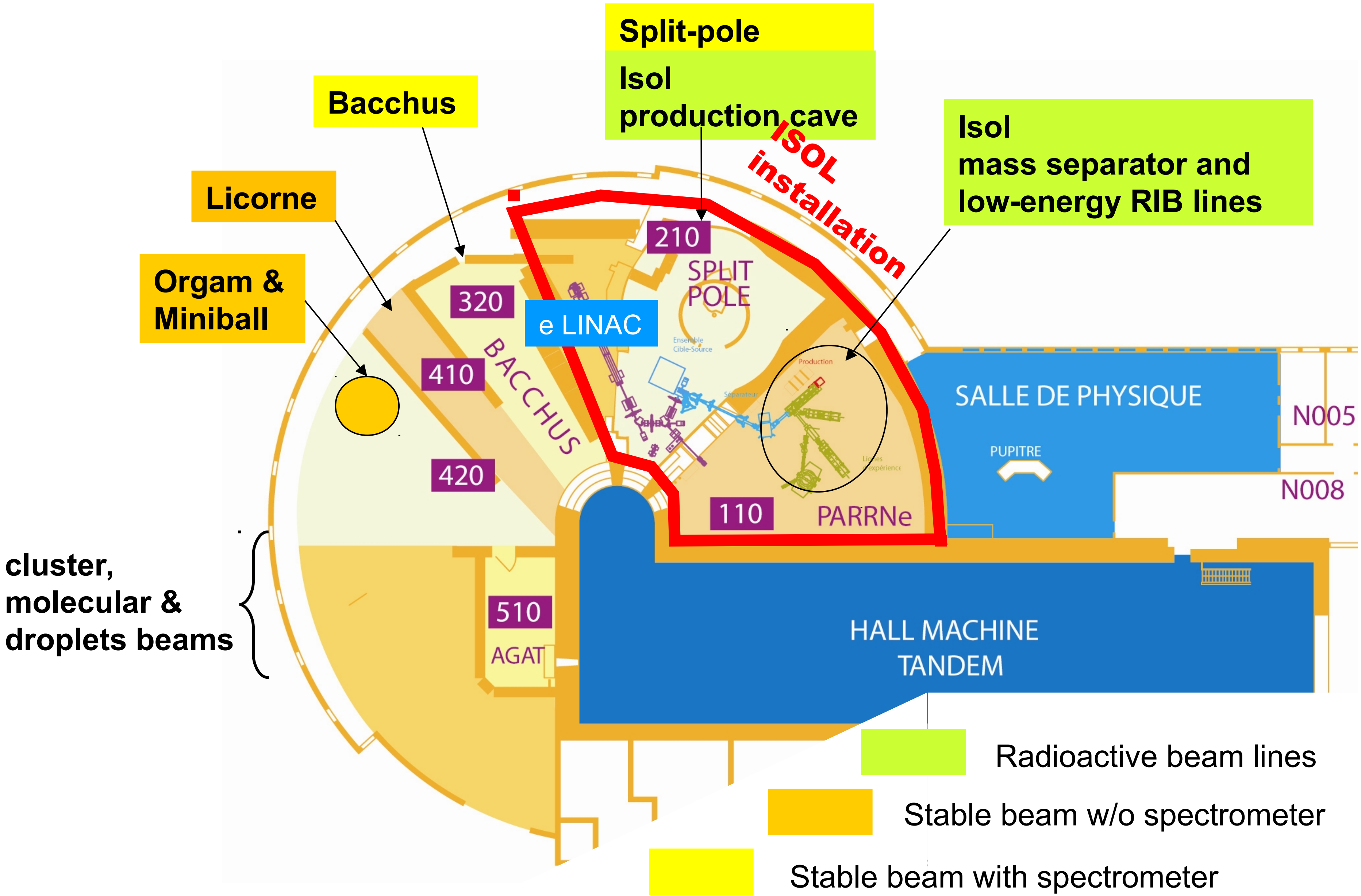


SP - DSSSDs coupling successful

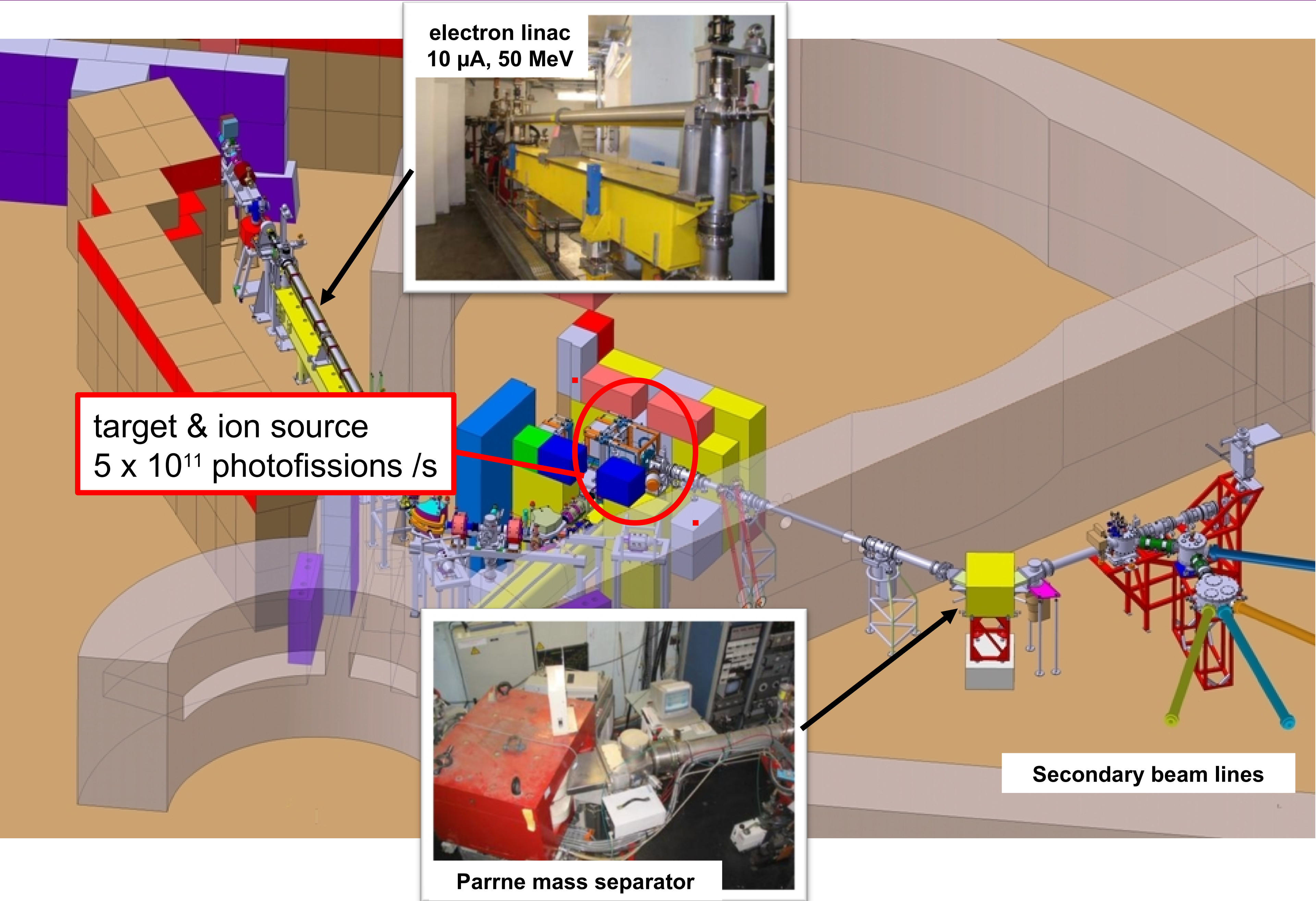
- I ~ 80 – 100 enA (!)

Very good beam tuning
Low background environment for DSSSDs

Low Energy Radioactive Ion Beams at Alto
D Verney et al



Low Energy Radioactive Ion Beams at Alto
D Verney et al

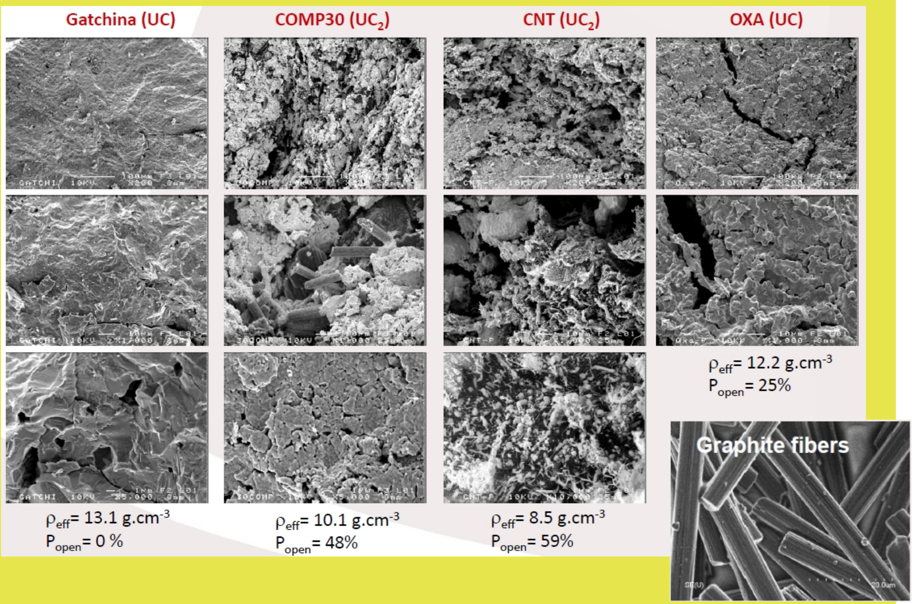


UCx development, C Lau et al
Fluorination of lanthanides, B Roussière et al

Higher yields: increase UCx density up to 13 g/cm^3

Control porosity

Reduce pellet thickness

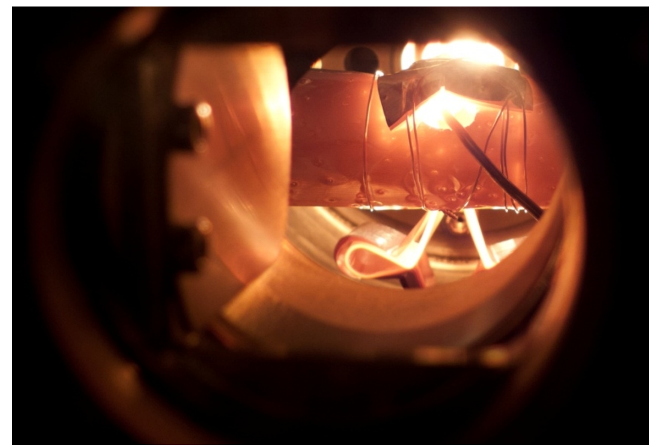


B Hy et al., NIM B 288 (2012) 34

Ensar Actilab: IPN, Cern, CMMO, Ganil, INFN, Univ Rennes

accelerate release of Ln and other chemically reactive elements through fluorinated molecular beams

Ensar2: IPN, Cern, Ganil, GSI, INFN

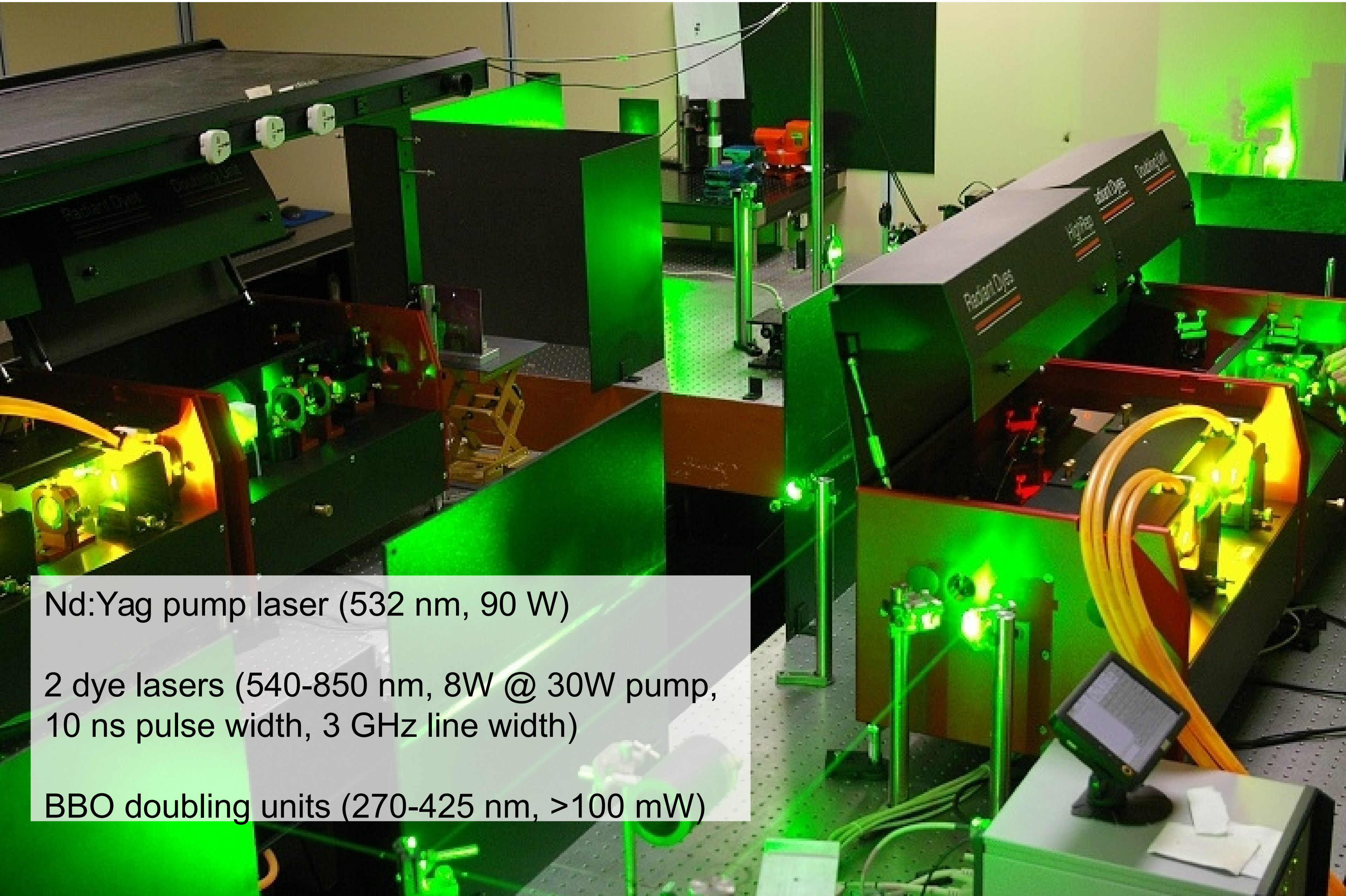


Physics: B(E2) through fast timing test case ^{137,139}Cs

B Roussière et al, EPJA 47 (2011)

IPN, CSNSM, INRNE-Sofia, Tandar-Buenos Aires

Rialto: Resonant laser ionisation at Alto
S Franchoo et al



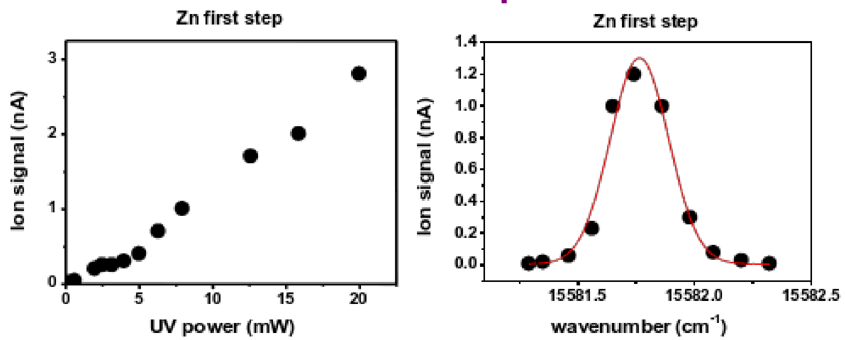
Nd:Yag pump laser (532 nm, 90 W)

2 dye lasers (540-850 nm, 8W @ 30W pump,
10 ns pulse width, 3 GHz line width)

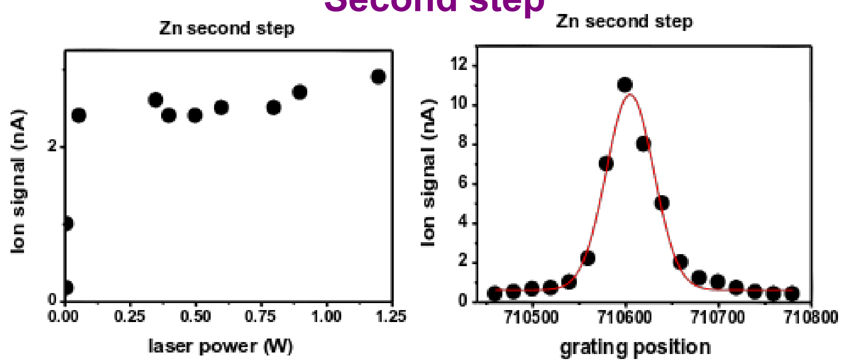
BBO doubling units (270-425 nm, >100 mW)

Rialto: Resonant laser ionisation at Alto
S Franchoo et al

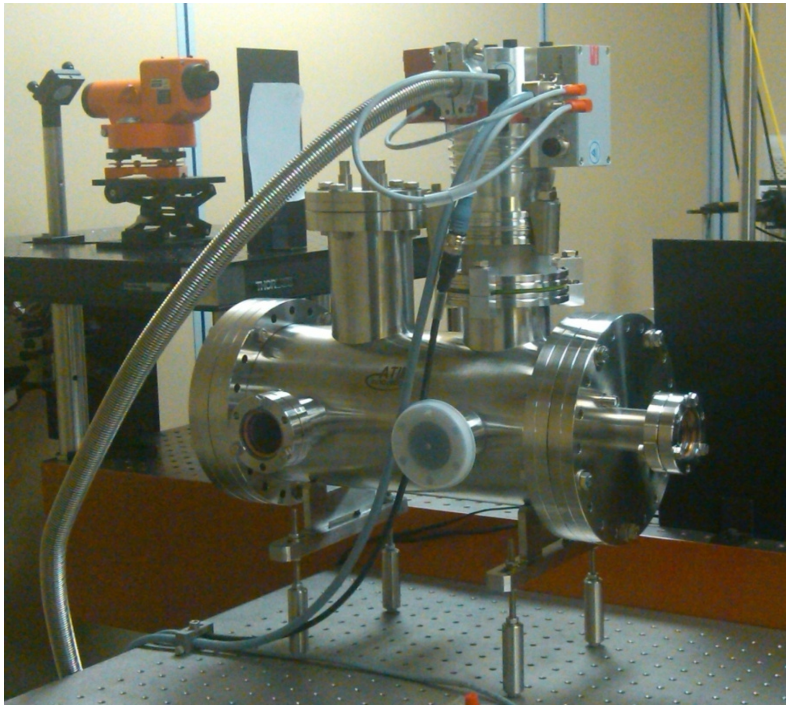
First step



Second step

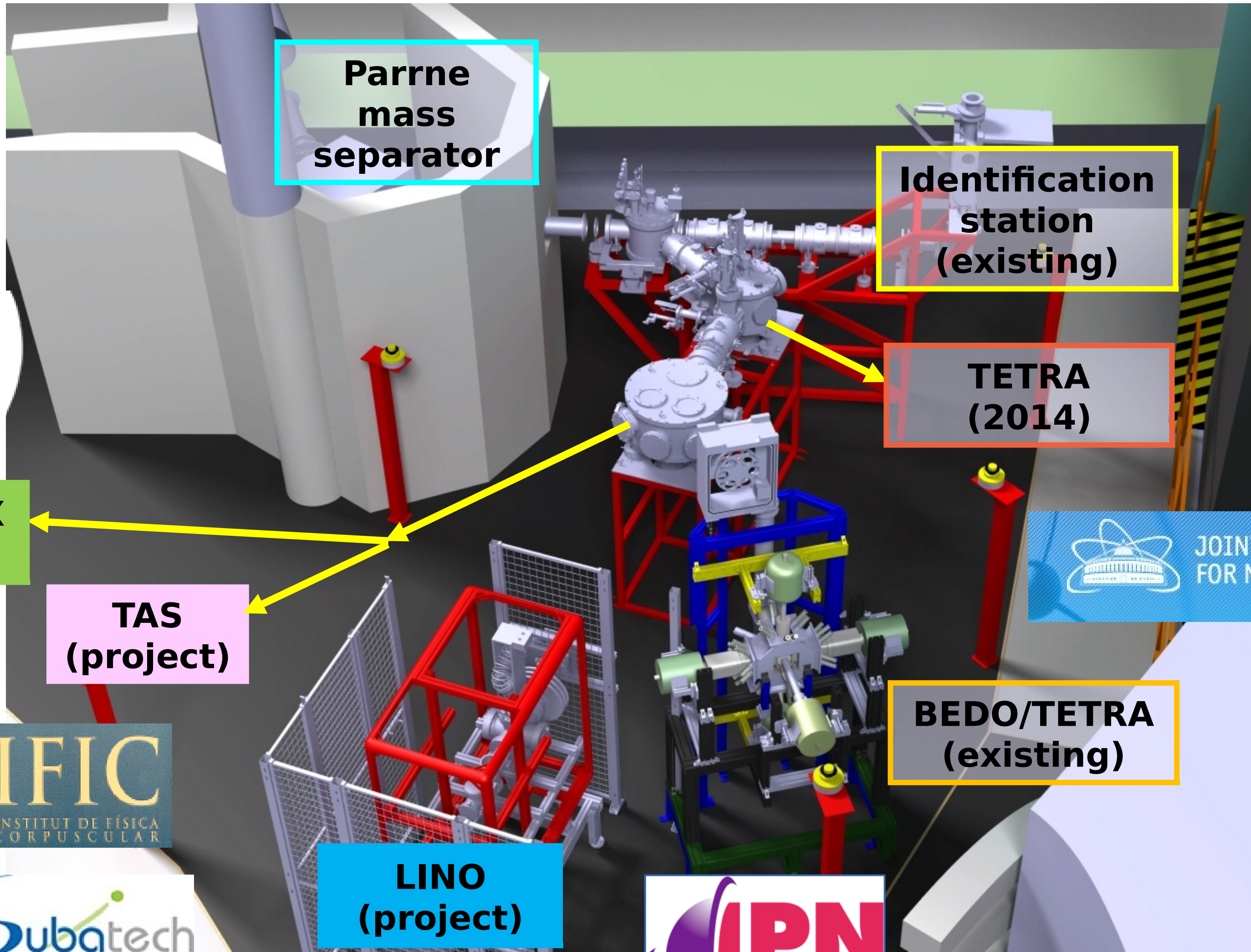


2011, 2012: Gallium with two ionisation schemes
2013: Zinc with frequency tripling
2014: Off-line chamber for development of laser schemes



R. Li, D. Yordanov, IPN Orsay
V. Fedosseev, T. Day Goodacre, B. Marsh, Isolde
K. Flanagan, University of Manchester
T. Kron, K. Wendt, University of Mainz

Low Energy Radioactive Ion Beams at Alto



CSNSM

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IFIC INSTITUT DE FÍSICA CORPUSCULAR

Subatech

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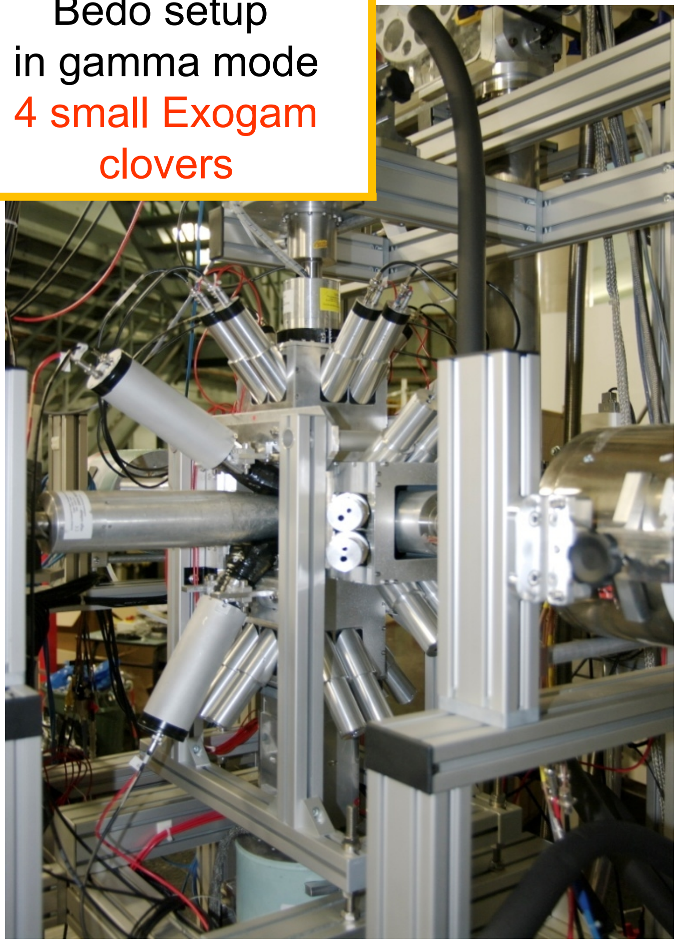
Low Energy Radioactive Ion Beams at Alto
Physics Case

Observable	Experimental technique	Physics case
Energy level pattern	$\beta\gamma$–spectroscopy	**Evolution of N=50 near ^{78}Ni and N=82 near ^{132}Sn** shell effects far from stability Onset of collectivity and nature of correlations
Electromagnetic transitions	Electron conversion	
$\delta\langle r^2\rangle$, μ, Q	Laser spectroscopy	
$T_{1/2}$ of excited levels, B(M1), B(E2)	Fast timing	
P_n, P_{2n} and $T_{1/2}$	Neutron detection	Gross properties, shell model
g-factor and spin	Nuclear orientation	
γ emission	Total absorption spectrometer	Decay heat in reactors

Bedo: Beta decay at Orsay
D Verney et al

Bedo setup
in gamma mode
4 small Exogam
clovers



up to 5 Ge detectors ε = 5-6%
4π β trigger
BGO anti-Compton

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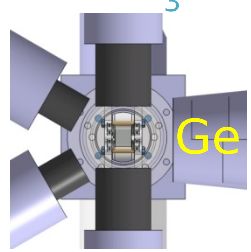
ORSAY

fast timing
B Roussière



Bedo setup
in neutron mode
Dubna neutron
detector Tetra

~90 ^{3}He tubes
borated polyethylene shielding

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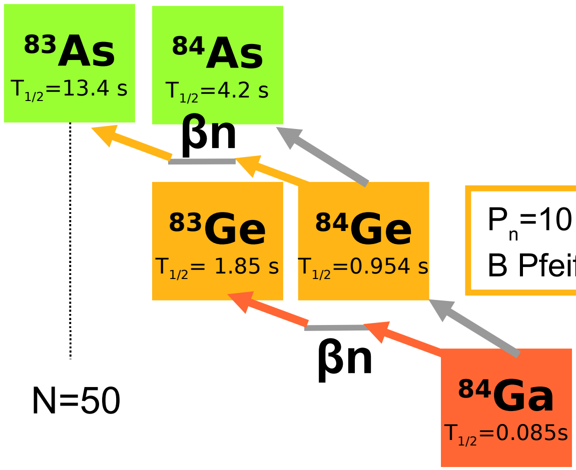
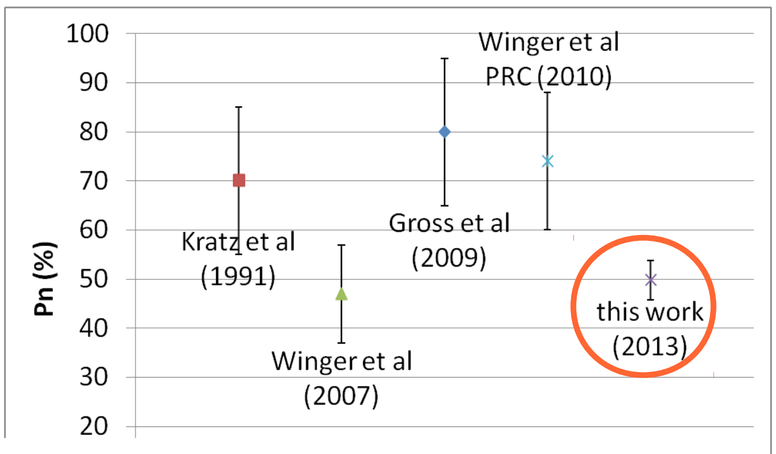
FOR NUCLEAR RESEARCH

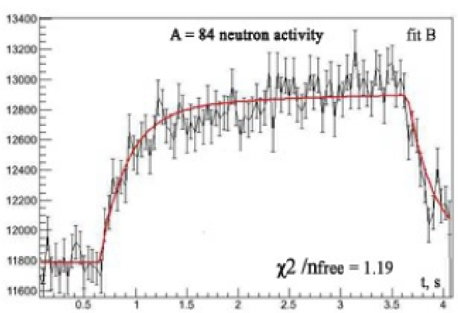
Tetra: Beta-delayed neutron emission
Y Penionzhkevich & D Verney et al

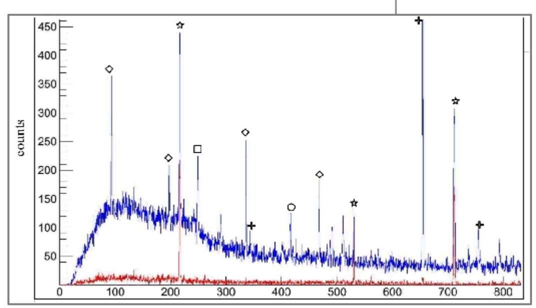


P_n=10.2(9)%
B Pfeiffer et al

P_n=49.8(4)%
this work



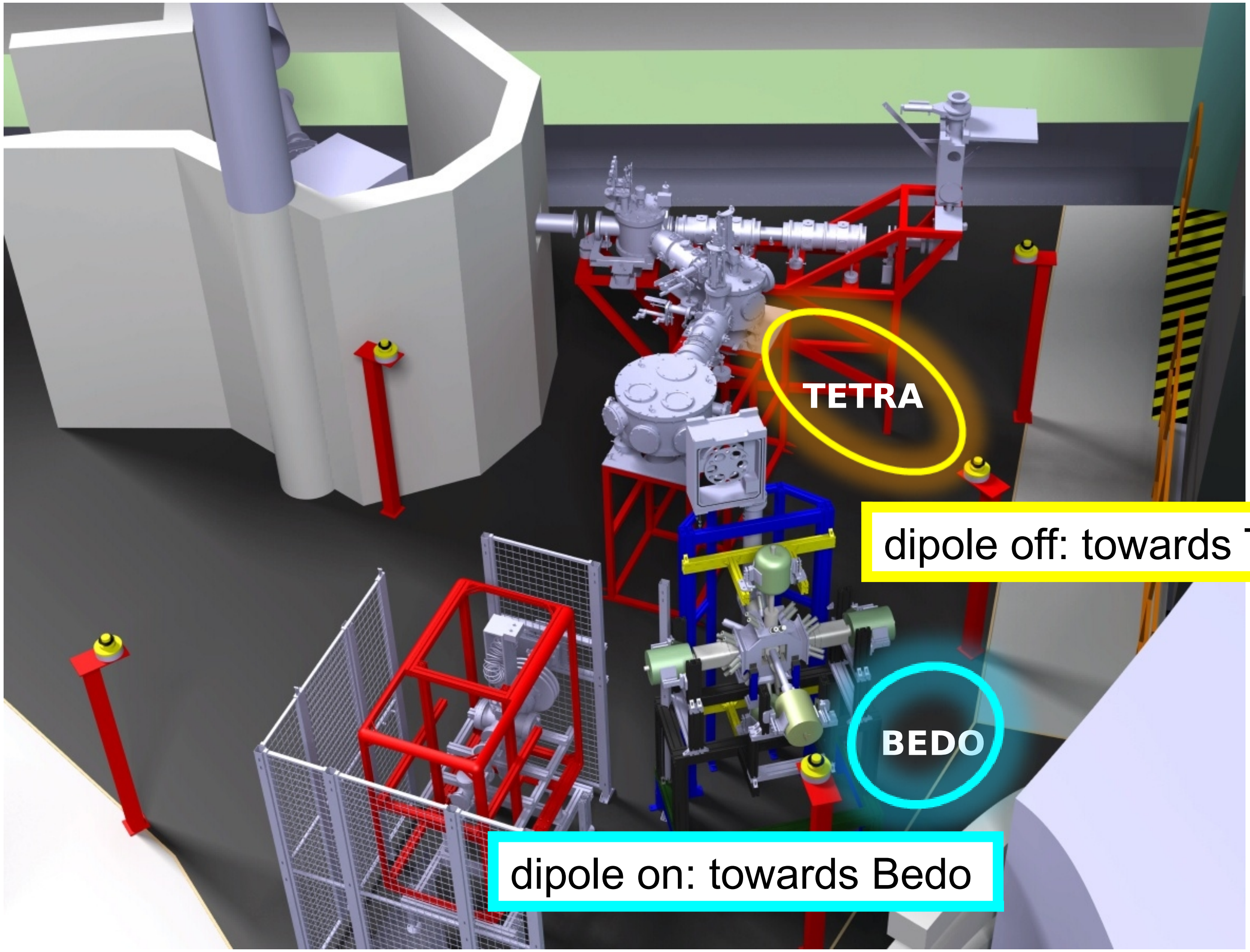




4π neutron detector of
90 ^{3}He counters ε = 63%
4π beta detector
1 Ge detector

D Testov, PhD thesis

Tetra and Bedo in alternating mode



Collaboration IPN
Orsay - FLNR Dubna

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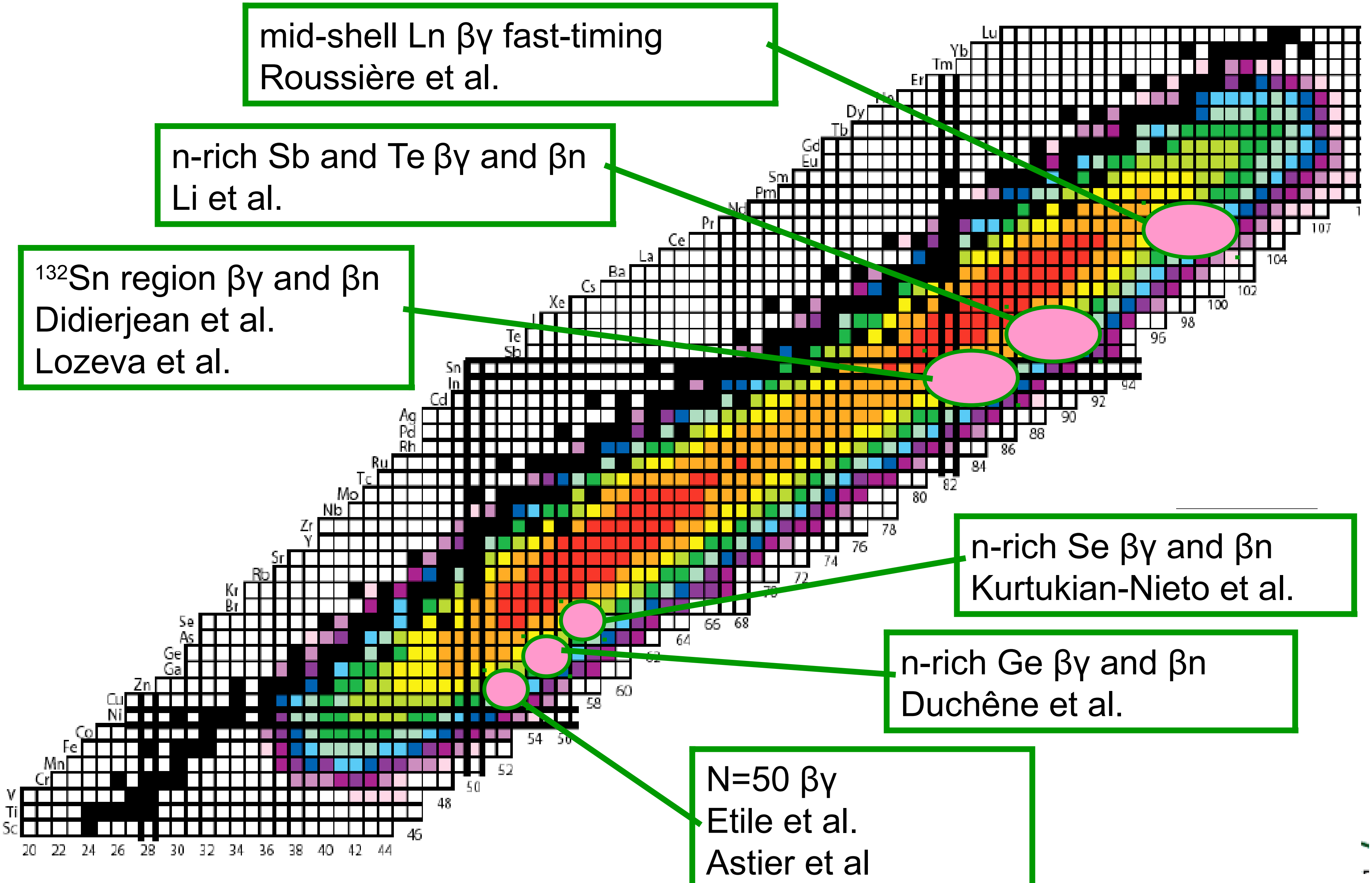
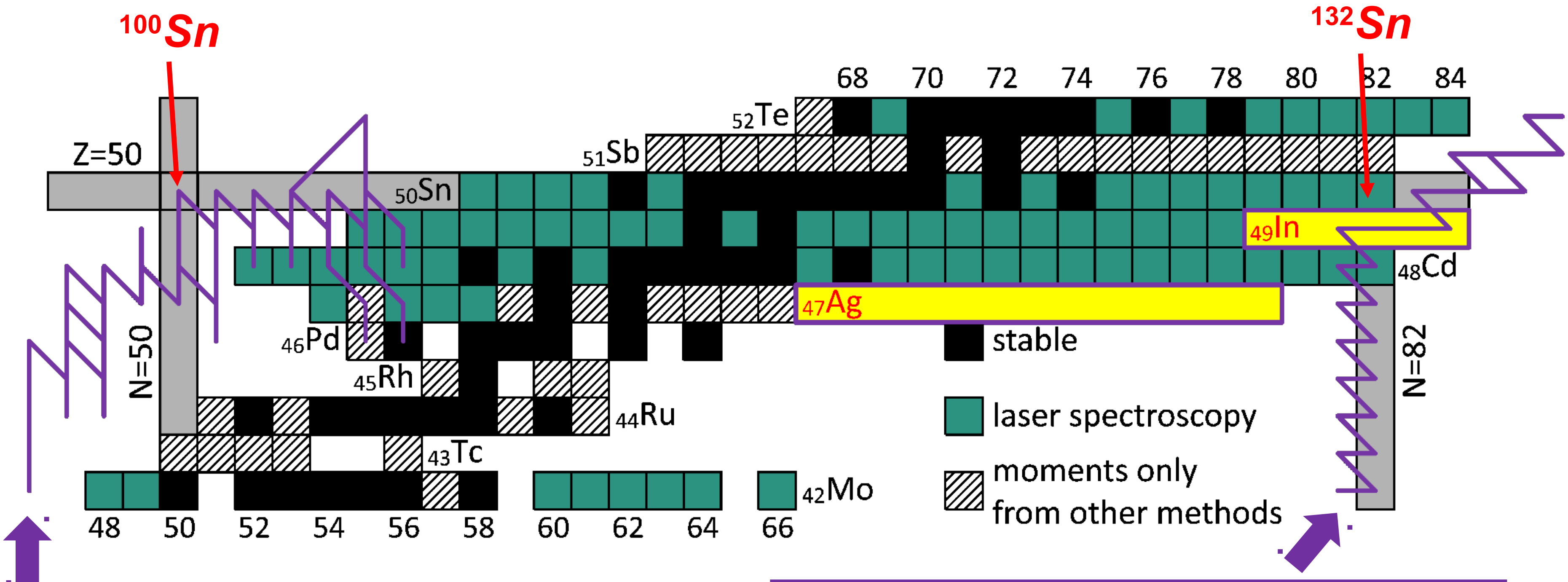
Tetra and Bedo in alternating mode



Lino: Laser-induced nuclear orientation
D Yordanov et al

laser spectroscopy in the Sn region:
ground and isomeric state properties of $^{110-126}$Ag and $^{128-133}$In
β-decay of polarised $^{121-126}$Ag and $^{128-133}$In

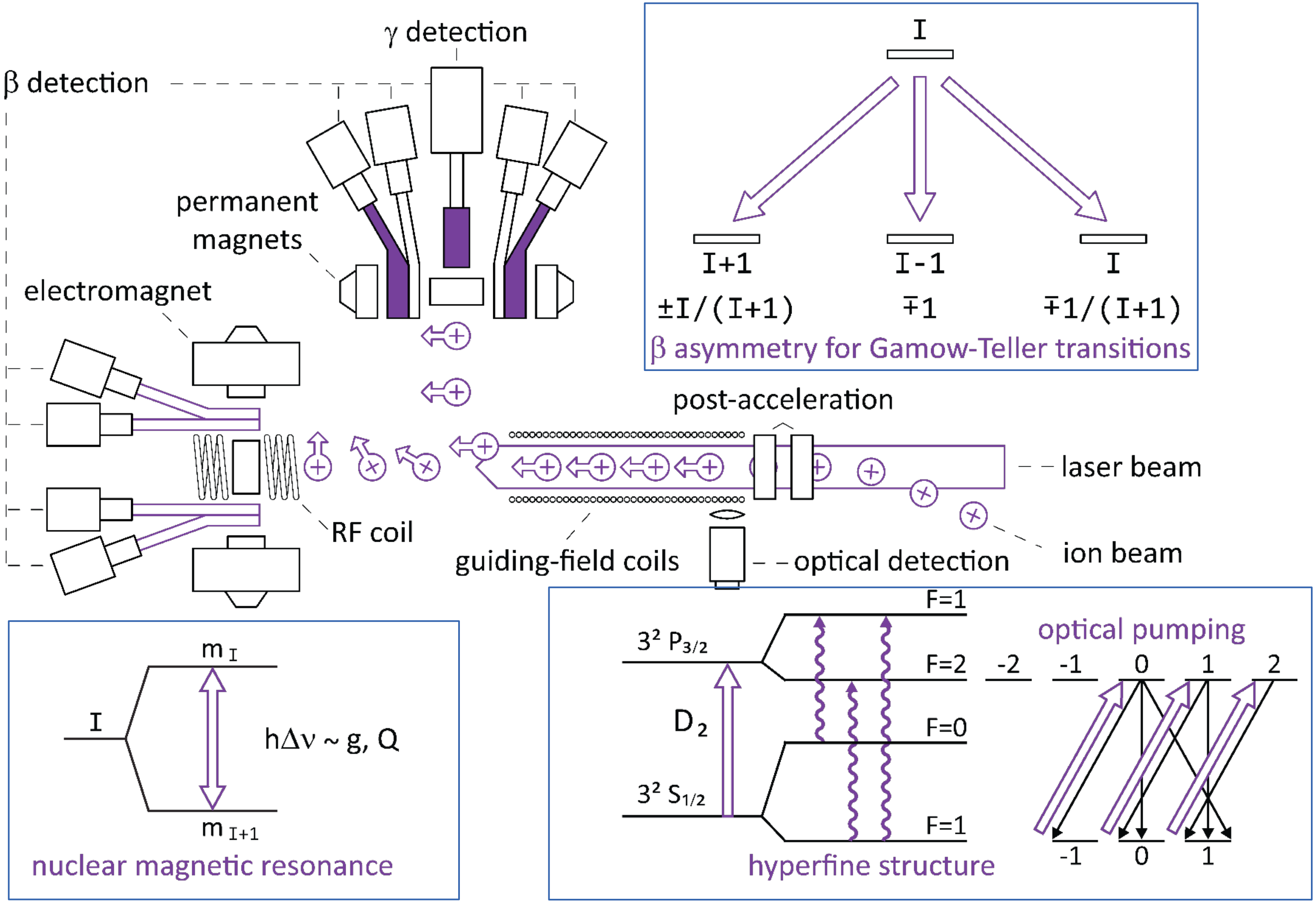


rp process

r process
- ***more accurate theoretical lifetimes of the N=82 isotones below ^{129}Ag***
- ***shell quenching vs deformation***
- ***shell effect in radii***

Lino: Laser-induced nuclear orientation
D Yordanov et al

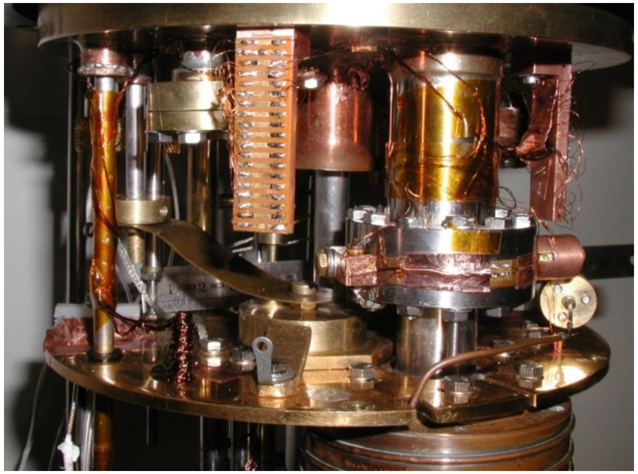
- polarisation by optical pumping
- μ & Q from nuclear magnetic resonance
- β-delayed spectroscopy of laser-polarized beams

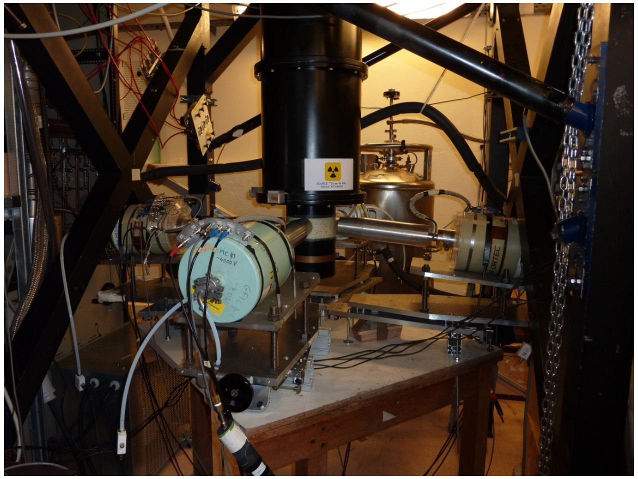


Polarex: Nuclear Orientation On-Line
C Gaulard et al

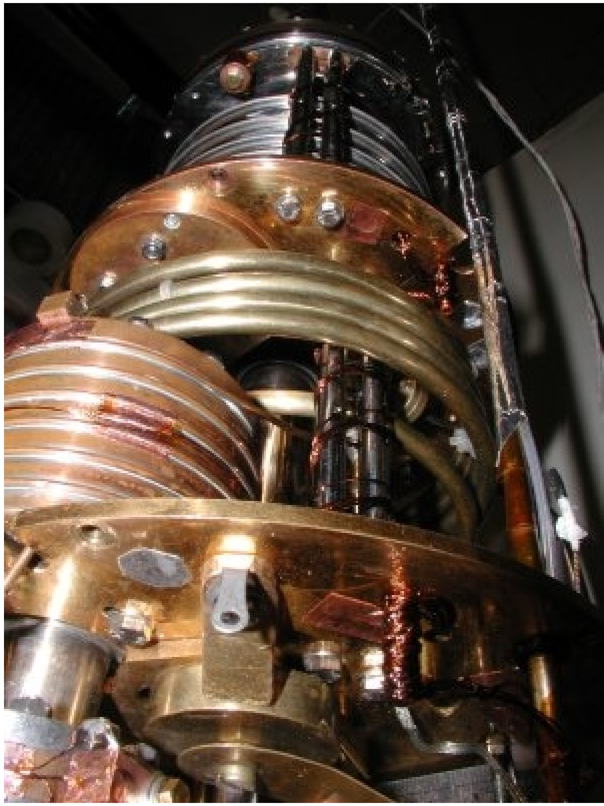
CSNSM off-line validation
Rejuvenation of the dilution cryostat
Letters of intent received

Preparation at the Alto site
Structure and platforms
Faisceaulogie and beam line design





CSNSM Orsay
LPSC Grenoble
IPN Orsay
INM Paris
University of Tennessee
University of Maryland
University of Oxford
University of Novi Sad



Tas: Total Absorption Spectroscopy
M Fallot & B Rubio et al

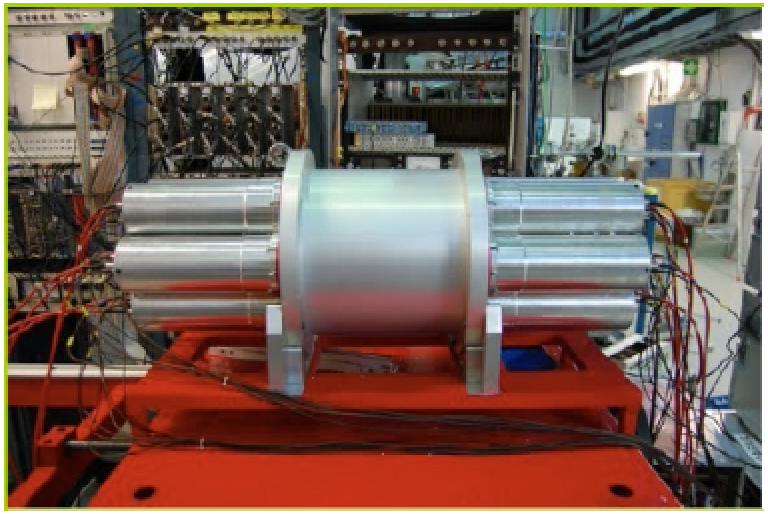
Proposed roadmap at Alto:

• Phase 1 (2014-2015): install the Valencia-Surrey **TAS@ALTO (12 BaF_2)** at the **existing beam line**, for nuclei of interest that could be easily selected

• Phase 2 (2014-2016): more challenging cases that the **laser ion source** for selection, in parallel with development of a **dedicated TAS beam line**

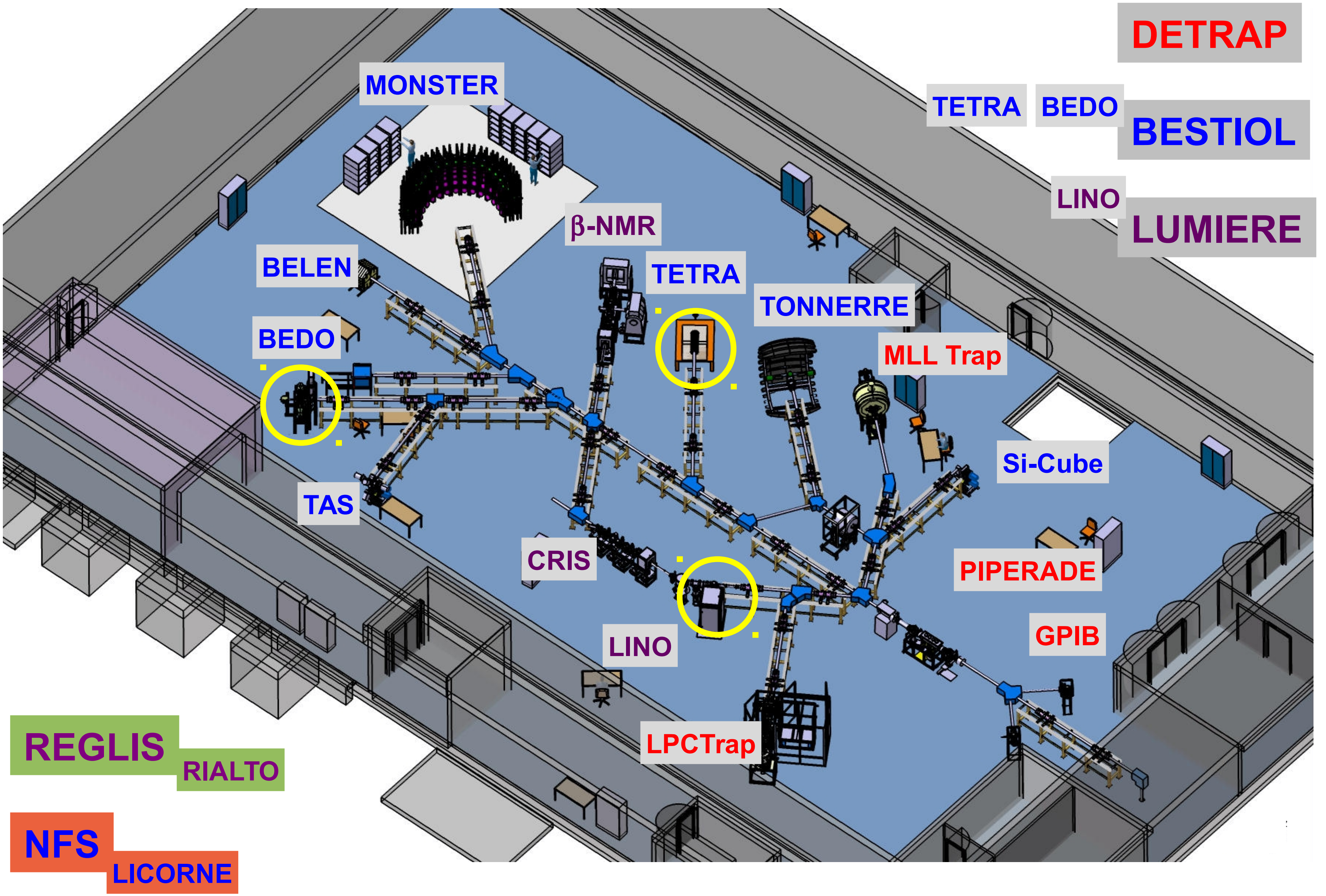
• Phase 3: **synergy with Bedo and Tetra** for βn emitters and more exotic isotopes. Common measurement campaigns with complementary beam lines?

In parallel, new detector developments combining higher resolution with efficiency such as **$LaBr_3$ or $CeBr_3$ for Alto then Spiral-2**

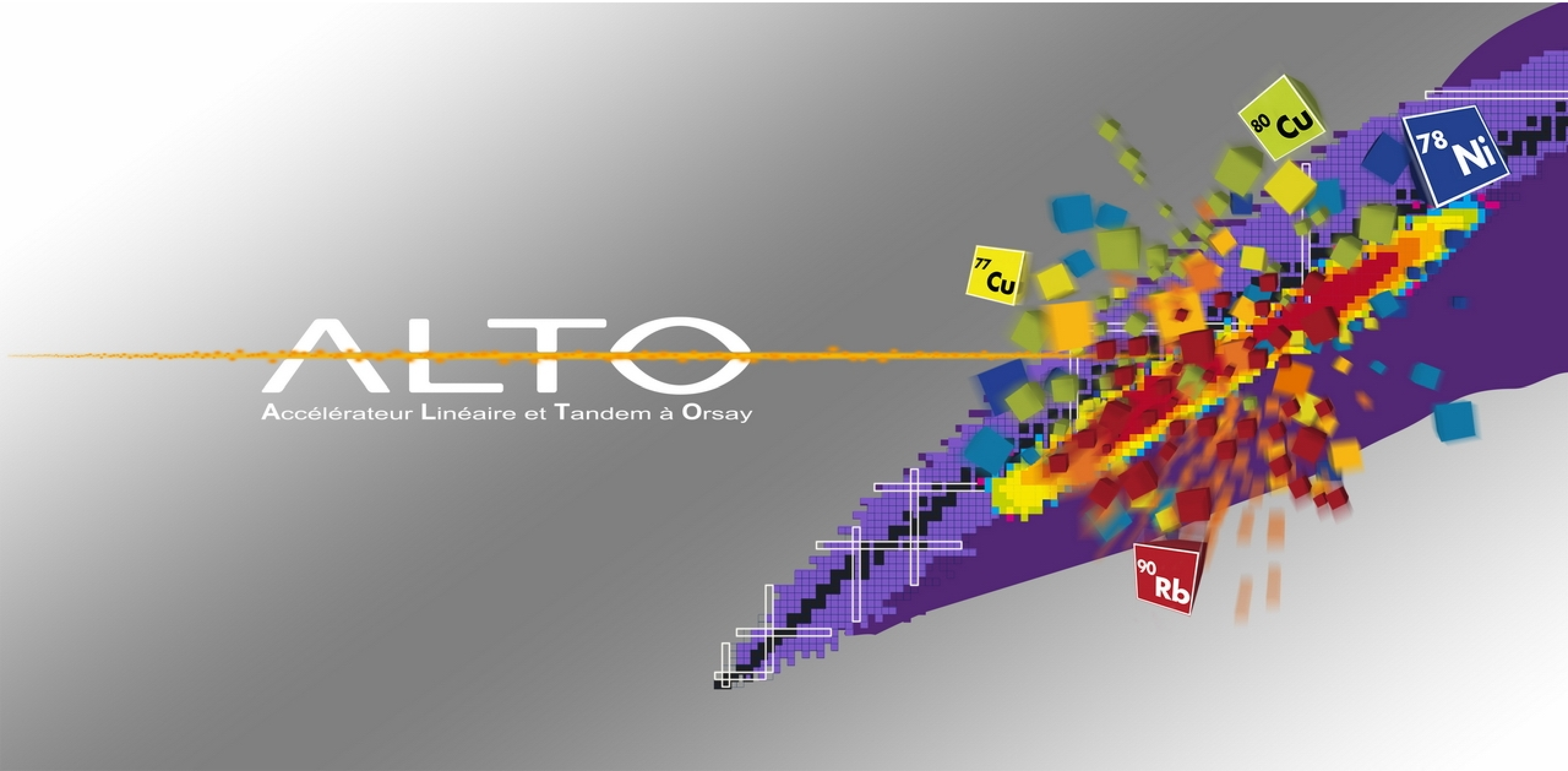


IFIC, Valencia
Subatech, Nantes
University of Surrey, Guildford
University of Jyväskylä
Ciemat, Madrid

Initiate the physics for Spiral-2 at Ganil: Desir, S3, NFS



► niche with stable beams
► R&D on Isol & RIB
► low-energy physics programme based on photofission
► R&D and physics at Alto pave the way to Spiral-2 at Ganil: initiate physics program, train new generation of isol physicists, develop instruments and methodologies



Clusters & ion-matter interaction

Beroff, K et al (2009) NIMB 267,866

M. Chabot et al A&A524,(2010) A39

M. Chabot et al; PRL104 (2010), 043401

K. Béroff et al : PRA84 (2011) 032705

M. Chabot et al ; Rev.Sc.Inst82(2011) 103301(high-lighted paper)

Krauser, J. et al. New Journal of Physics (2011) 13, 083023

Nuclear physics

Lebois M. et al. Physical Review C, 80 (2009)

Q. T. Doan et al. Acta. Pol. B40 (2009) 725

R. Lozeva et al AIP Conf. Proc. 1224, 143 (2010)

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D. Curien et al. J. of Phys. CS 205 (2010) 012034

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B. Hy et al., Nucl. Instrum. and Meth. B288 (2012) 34

J. Duenas et al NIMA 676 (2012) 70

J. Duenas et al NIMA714 48 (2013)

Licorne

Outgoing Neutron kinematic curves

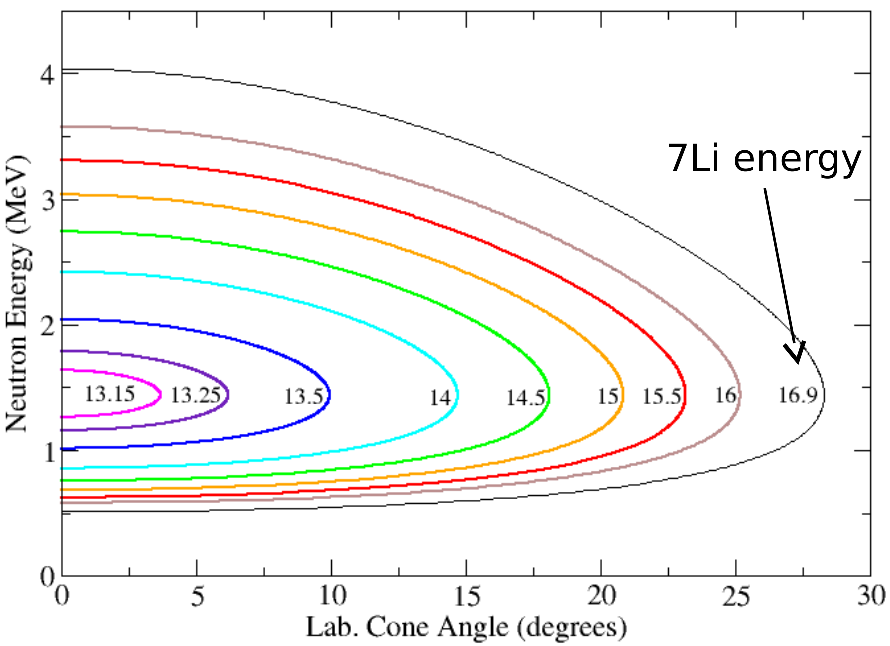
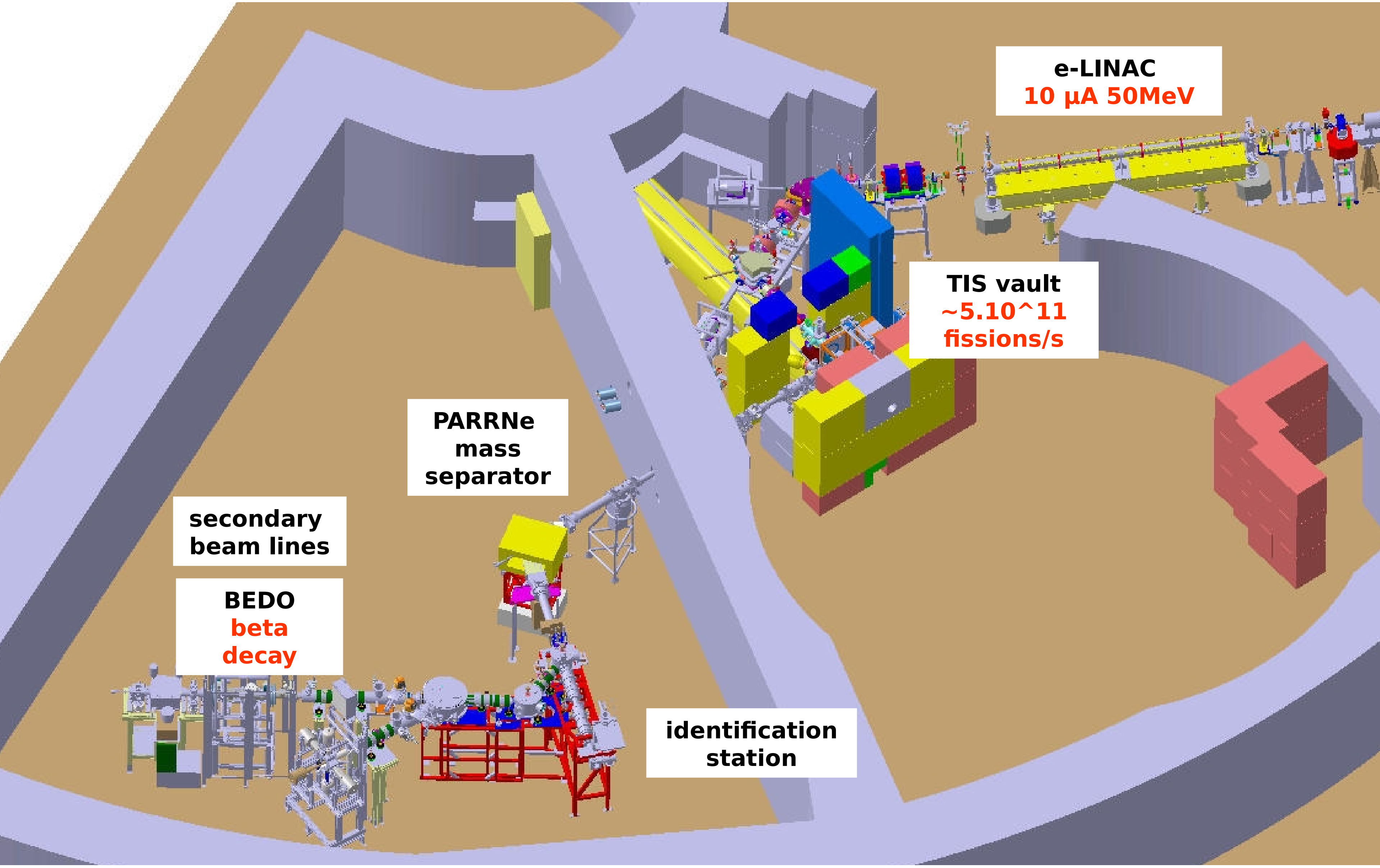


Photo-fission based isol facility

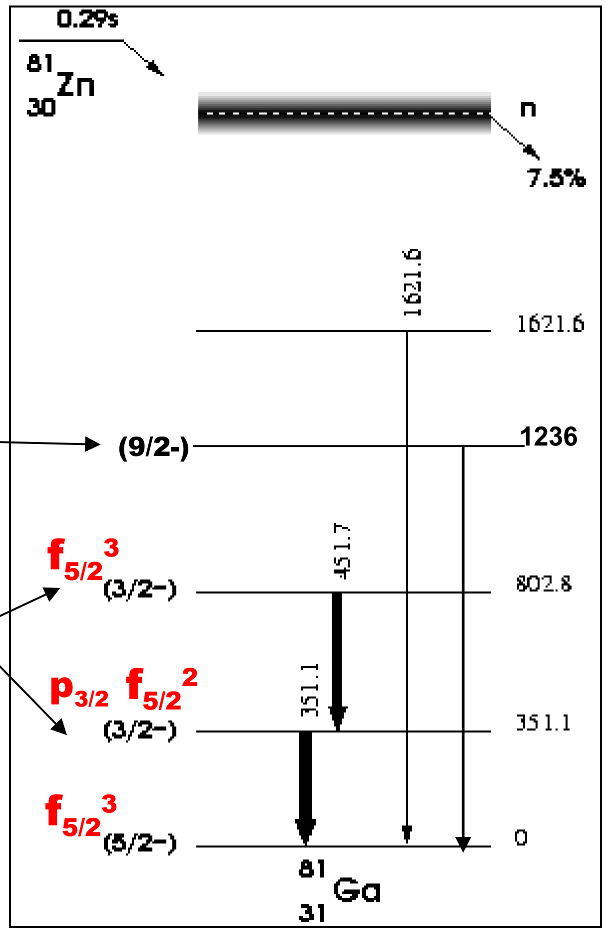


$^{81}Zn \rightarrow {}^{81}Ga$ β decay

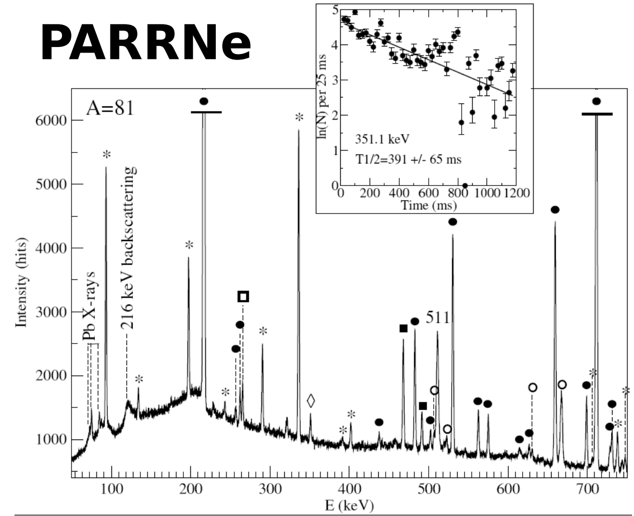
no evidence for neutron excitations at low energy in 81Ga: N=50 is effective

Deep inelastic at Legnaro
G. De Angelis et al. NPA 787 (2007) 74c

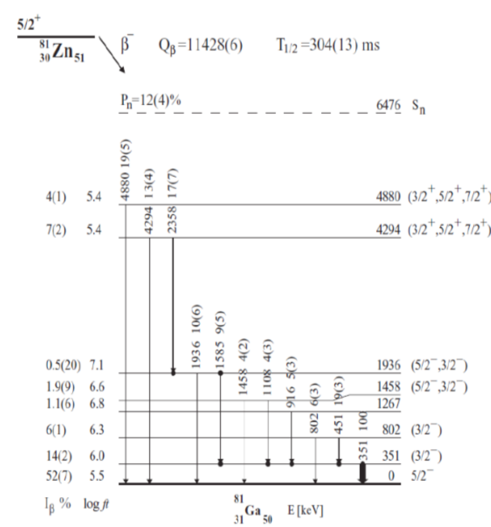
observé en décroissance β à Orsay (PARRNe)
D. Verney et al PRC 76 (2007) 054312



PARRNe



Oak Ridge,
Phys. Rev. C 82, 064314 (2010)



$^{84}Ga \rightarrow {}^{84}Ge$ β decay

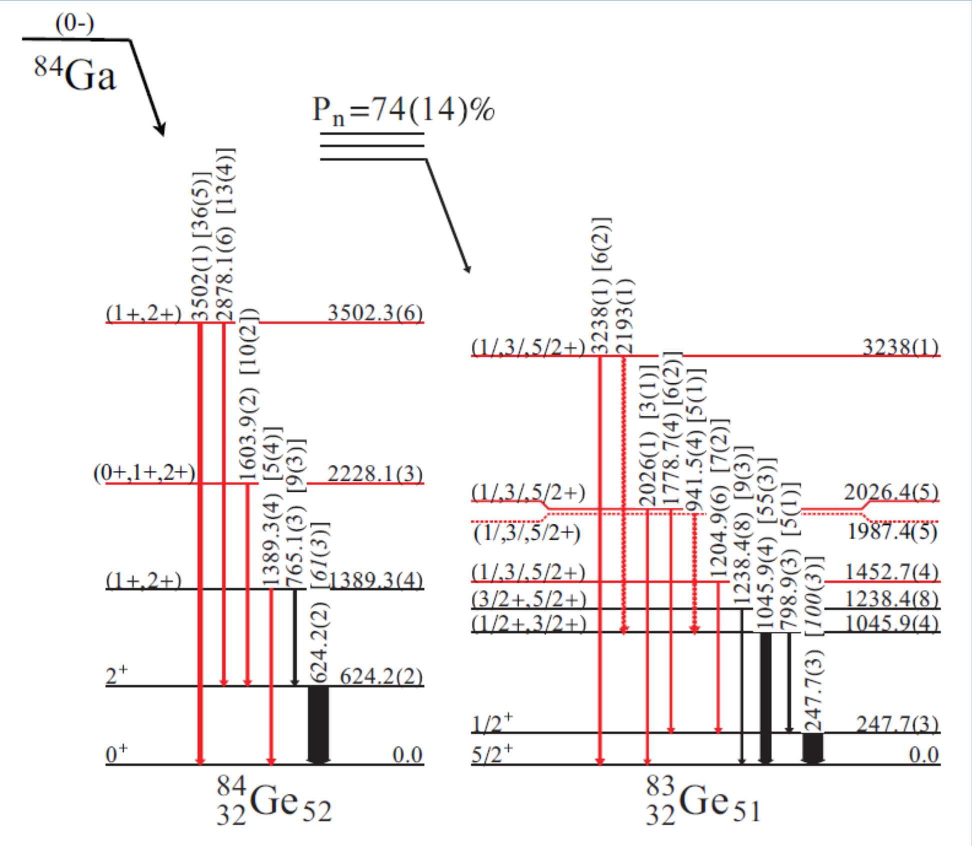
Ga: hot-plasma ionisation (1 μA deutons)
O. Perru et al, EPJA 28, 307 (2006)

Ga: surface ionisation (2-4 μA electrons)
M. Lebois et al, PRC 80, 044308 (2009)
B. Tastet et al, PRC 87, 054307 (2013)

Zn: hot plasma ionization
(1 μA deutons)
Verney et al, PRC 76, 054312 (2007)

Zn: laser ionisation
(10 μA electrons)
$^{82}Zn \rightarrow {}^{82}Ga$ A. Etilé et al.

Ga: laser ionisation (10 μA electrons)
K. Kolos et al, PRC 88, 047301 (2013)
D. Testov et al, to be published



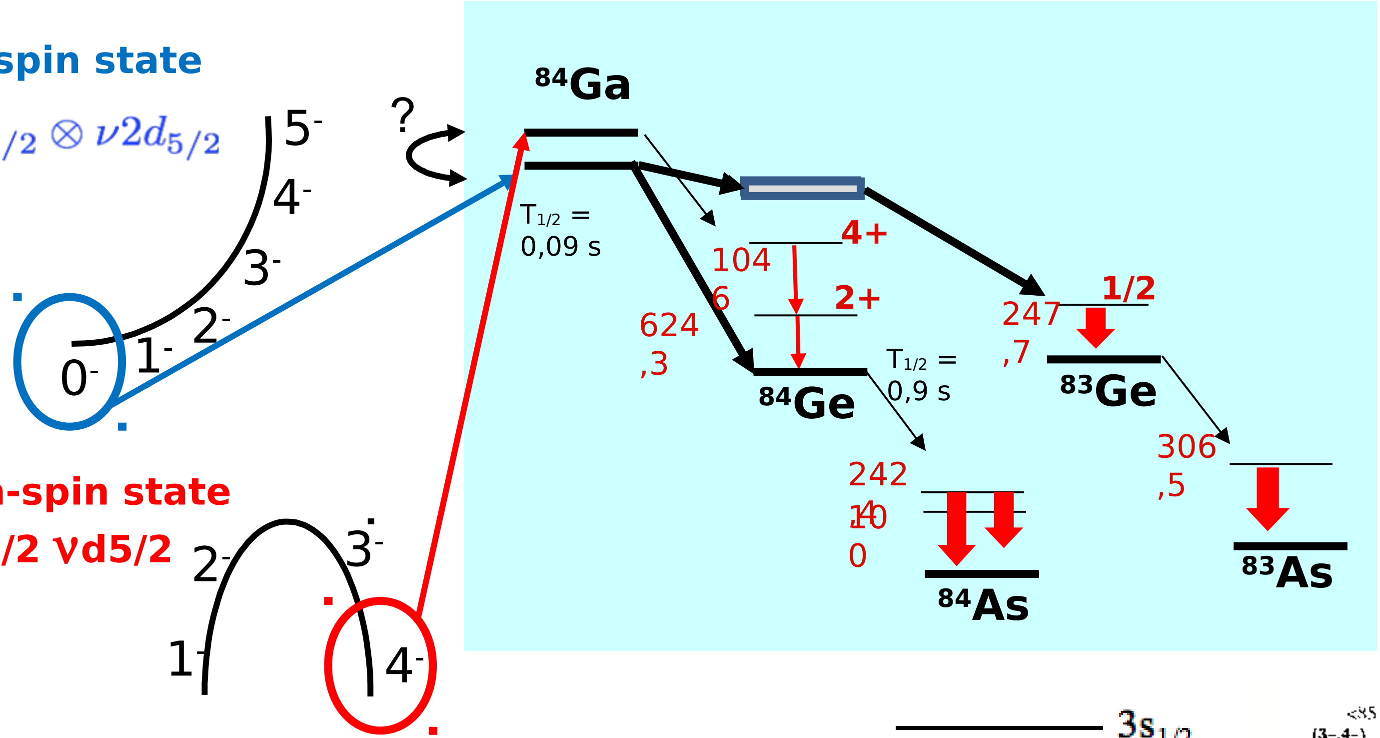
Two long lived isomers in ^{84}Ga

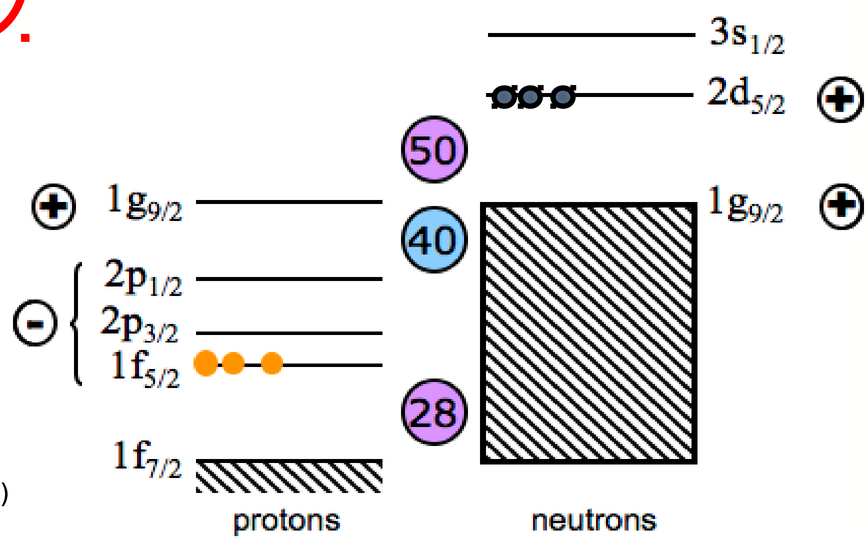
low-spin state

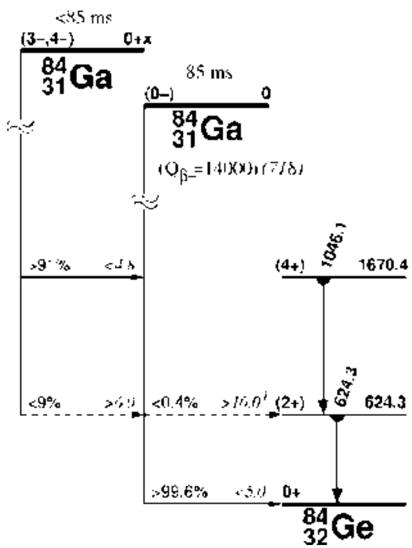
$\pi 1f_{5/2} \otimes \nu 2d_{5/2}$

high-spin state

πp3/2 νd5/2





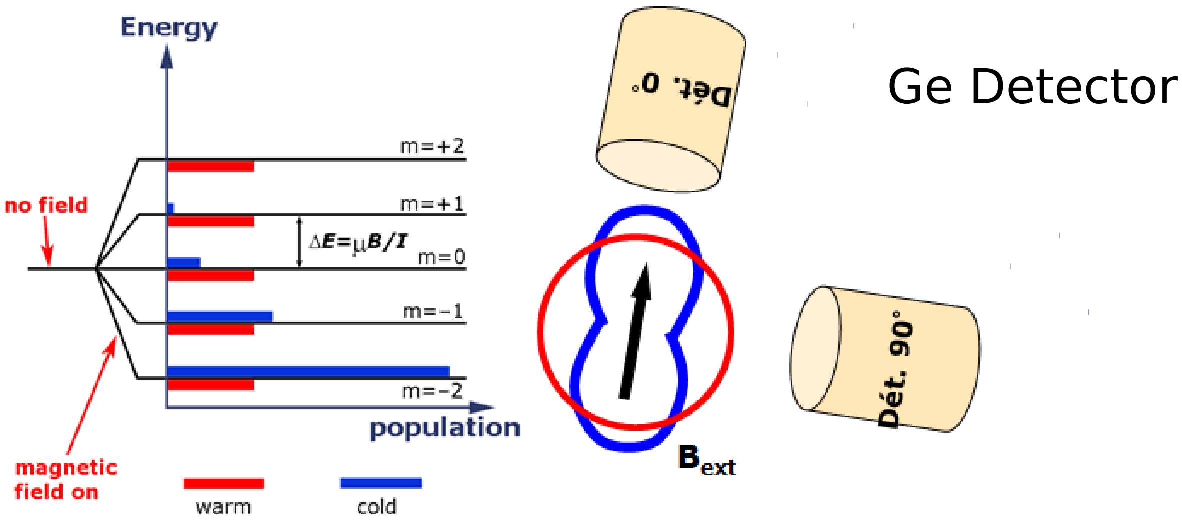


O. Perru *et al.*, EPJA, **28**,p. 307 (2006)

J. S. Thomas PRC **76**, 044302 (2007)

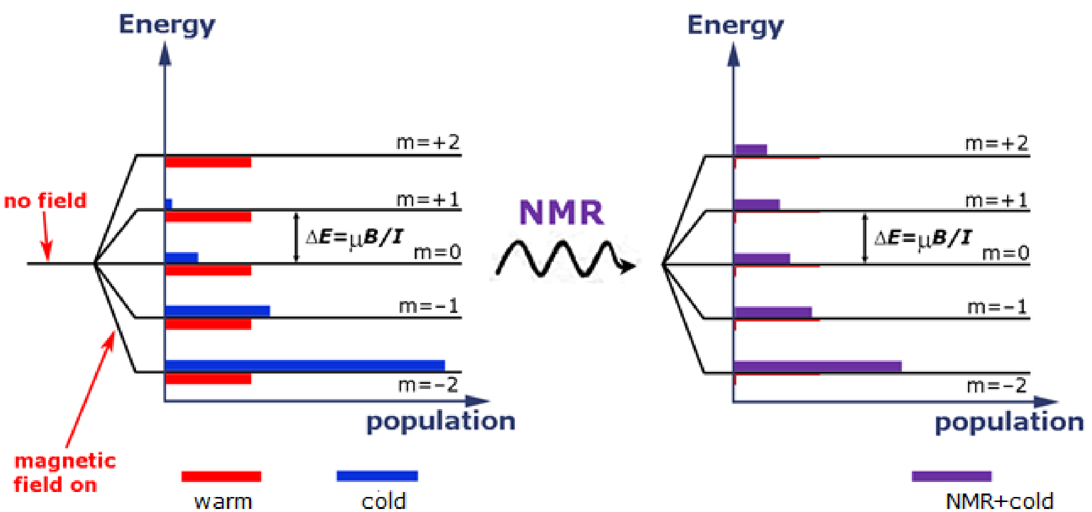
D. Verney *et al* PRC **76**, 054312 (2007)

Low Temperature Nuclear Orientation



Angular distribution depends on **spins** of the nuclear states, **transition multipolarities**, **total magnetic field** and **temperature**.

AND Nuclear Magnetic Resonance



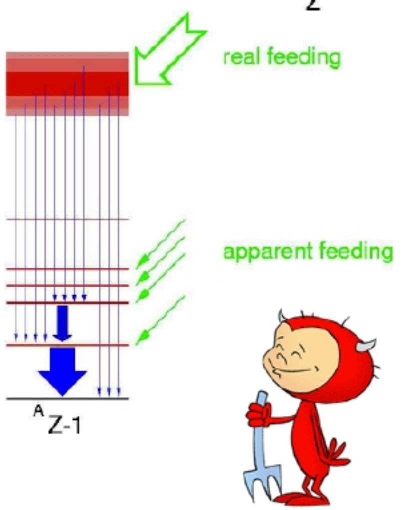
The **good frequency**
-> **magnetic moment**
-> Hyperfine structure
-> Nuclear thermometer

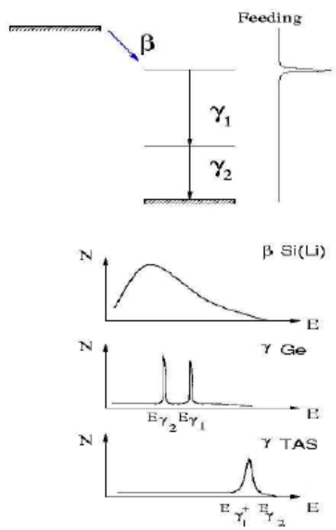
TAS Technique

Pandemonium effect**:

Due to the use of Ge detectors to measure the decay schemes: lower efficiency at higher energy

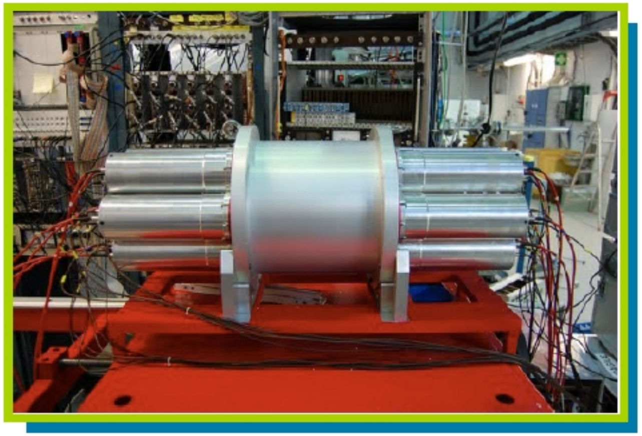
→ underestimate of β branches towards high energy excited states: overestimate of the high energy part of the FP β spectra





Picture from A. Algora

Solution: Total Absorption Spectroscopy (TAS)
Big cristal, 4π => A TAS is a calorimeter !



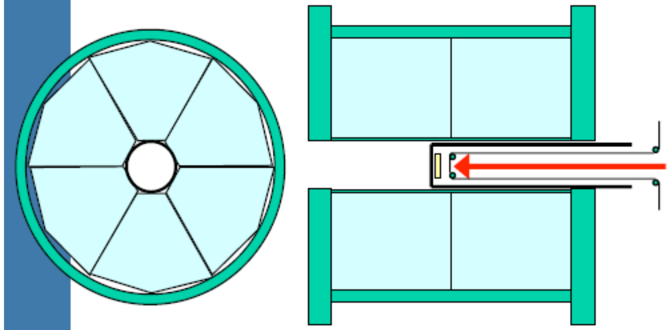
- 12 BaF_2 covering ~4π
- Detection efficiency of γ ray cascade ~ 100%
- Si detector for β

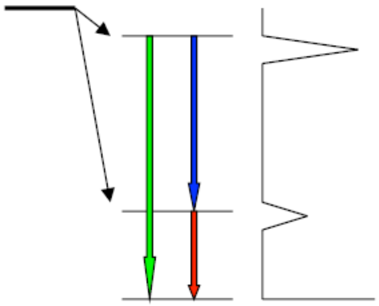
** J.C.Hardy et al., Phys. Lett. B, 71, 307 (1977)

Subatech

TAGS developed by the Valencia team (Spain, B. Rubio, J.L. Tain, A. Algora et al.) : Proceedings of the Int. Conf. For nuclear Data for Science and technology (ND2013)

Observable: beta feeding => beta strength





An ideal TAS would give directly the β-intensity I_β which is linked with the β-strength S_β:

$$S_i = \frac{I_i}{f(Q_\beta - E_i)T_{1/2}} \quad [s^{-1}]$$

Statement of the problem:

$$I_i = \frac{f_i}{\sum_k f_k}$$

Relation between TAS data and the β-intensity distribution:

$$d_i = \sum_j R_{ij} f_j$$

$$\mathbf{R_j} = \sum_{k=0}^{j-1} b_{jk} \mathbf{g_{jk}} \otimes \mathbf{R_k}$$

Deconvolution (Inverse problem) algorithms

Monte Carlo simulations
+
Nuclear statistical model

- Spectrum must be clean
- Response must be accurately known
- Solution of inverse problem must be stable

NIM A430 (1999) 333 NIM A571 (2007) 719
NIM A430 (1999) 488 NIM A571 (2007) 728

Subatech