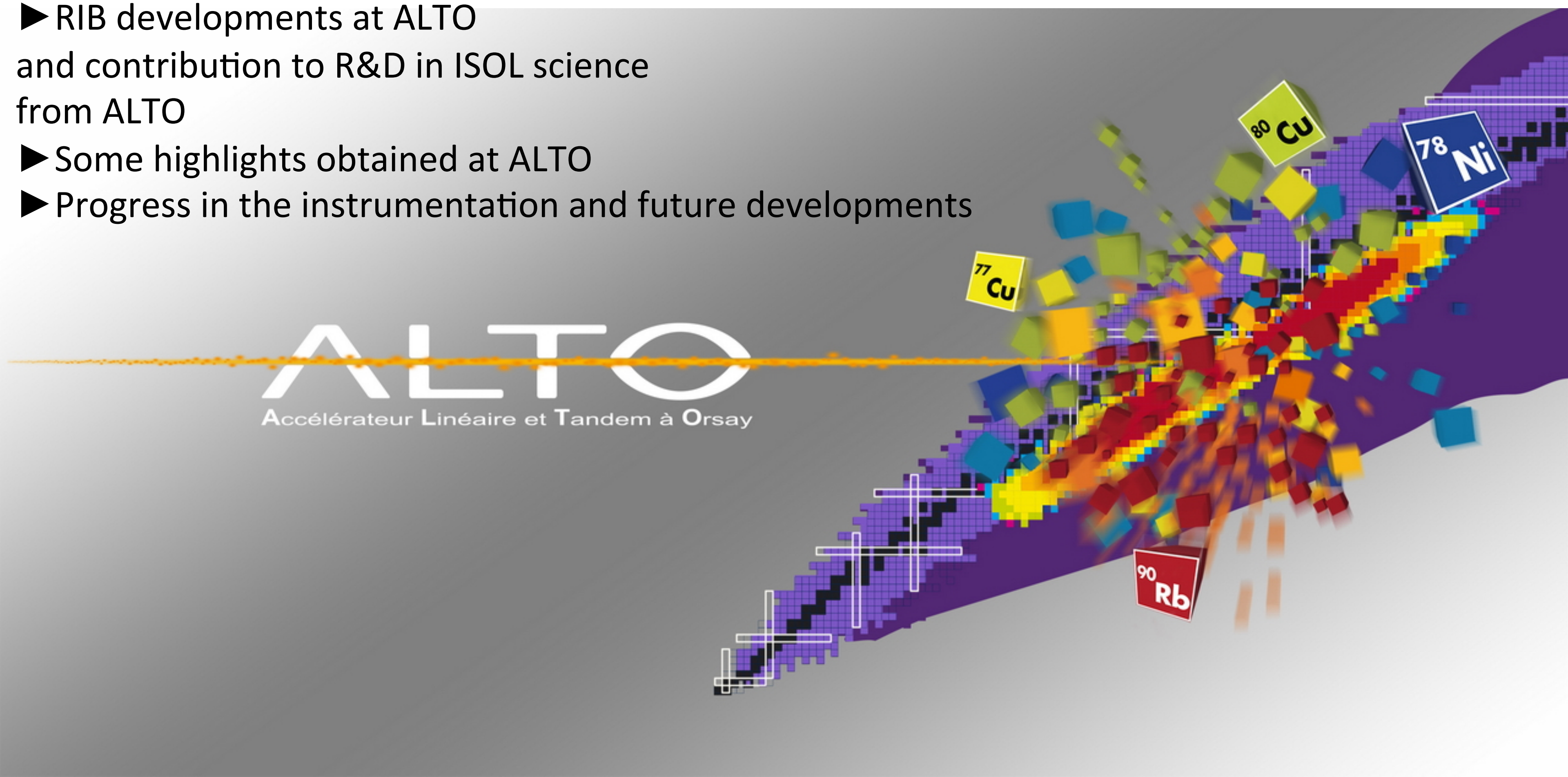
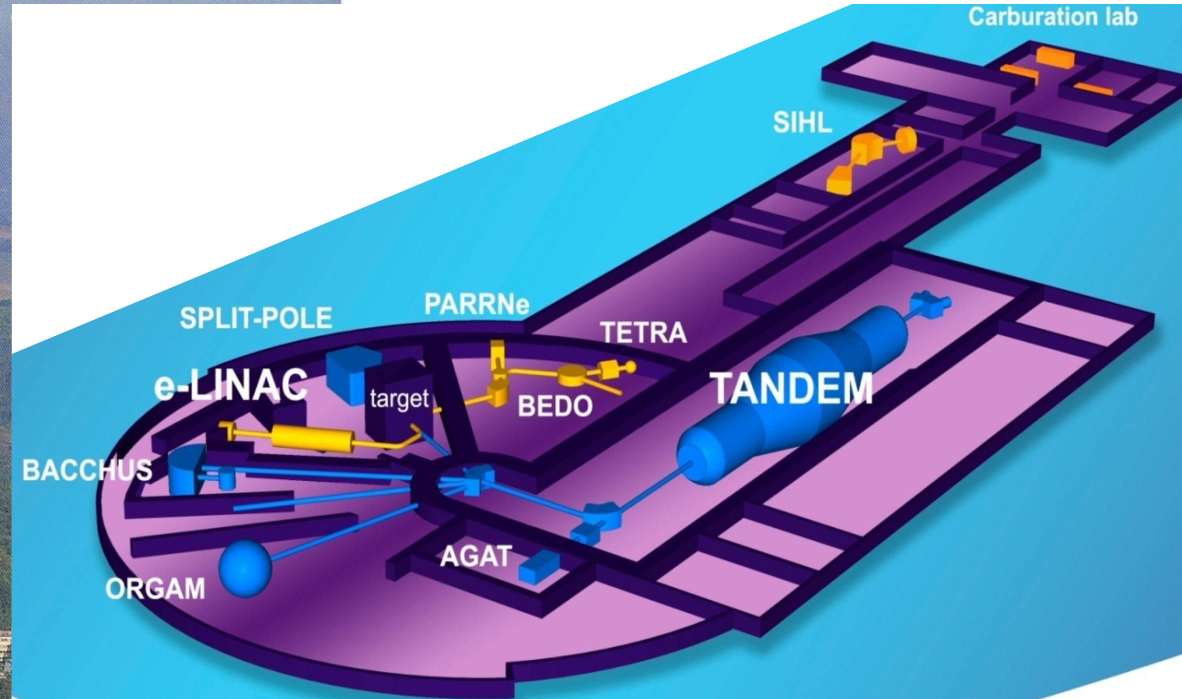
TNA 07: ALTO

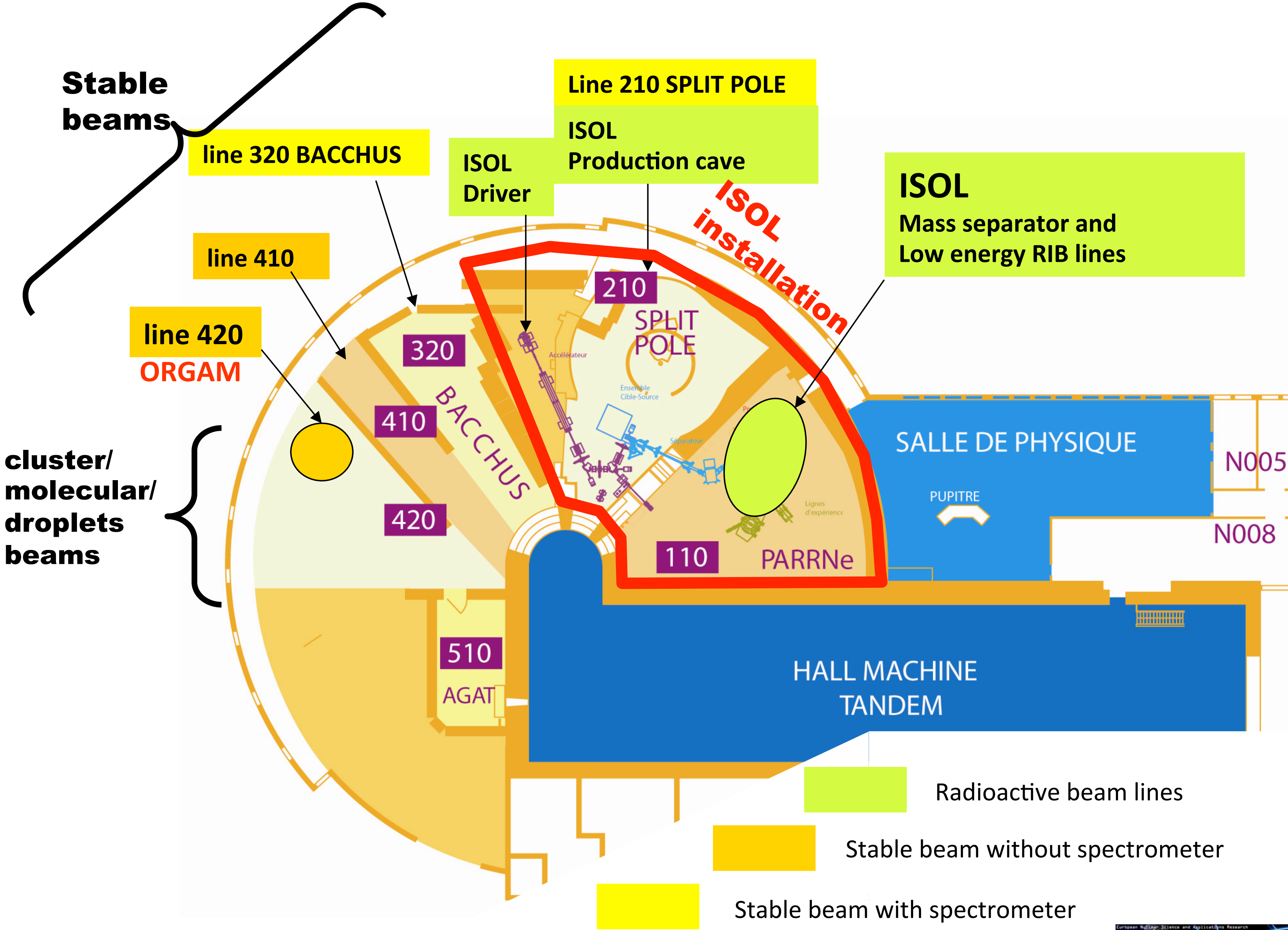
► description of the ALTO facility
► RIB developments at ALTO
and contribution to R&D in ISOL science
from ALTO
► Some highlights obtained at ALTO
► Progress in the instrumentation and future developments



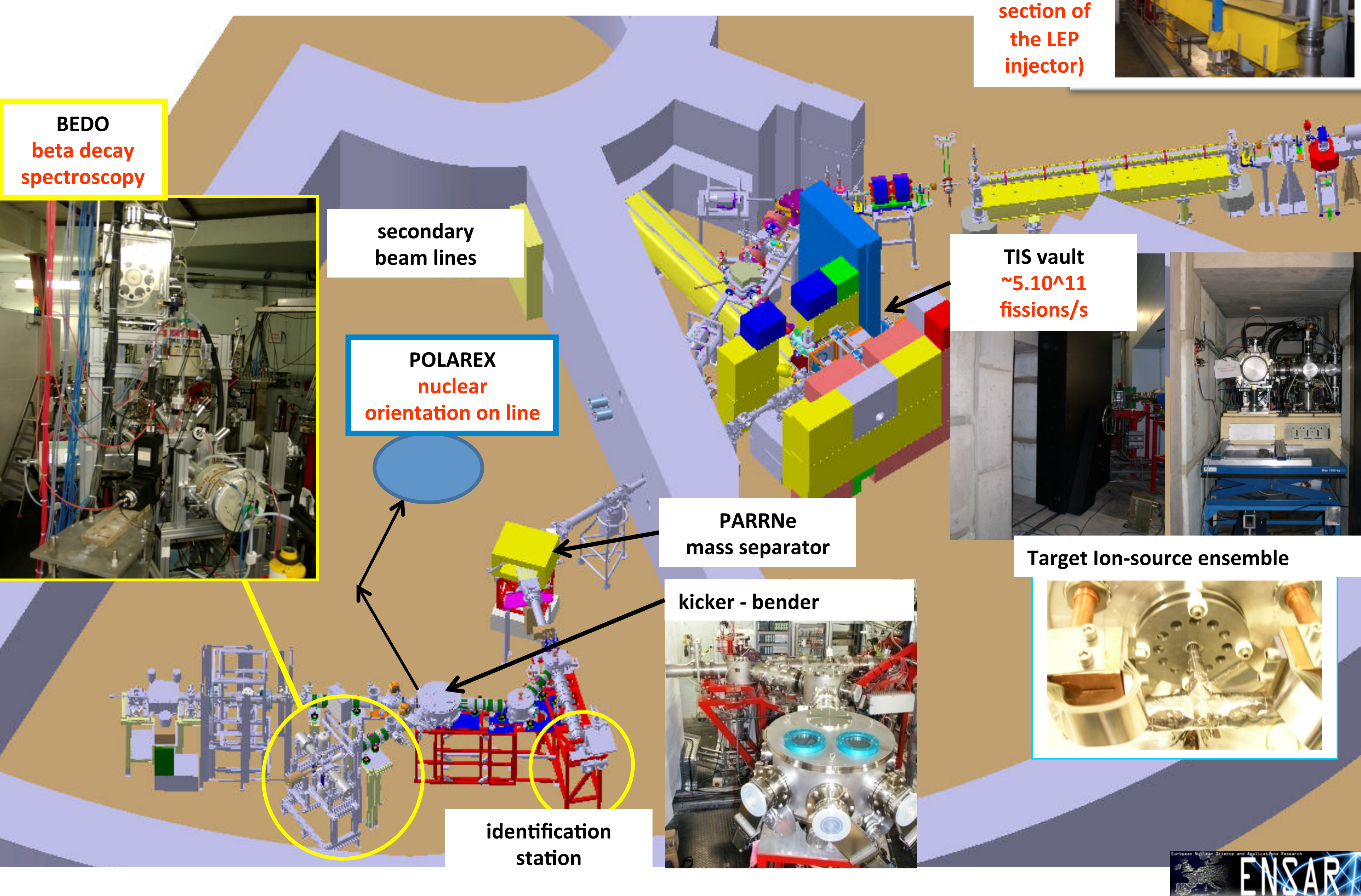


Tandem building
Institut de Physique Nucléaire
Campus of the Paris Sud University
Orsay (France)

Tandem/ALTO general layout



ISOL installation based on photo-fission: the first of its kind in the world



Tandem+ISOL = 4000 h per year

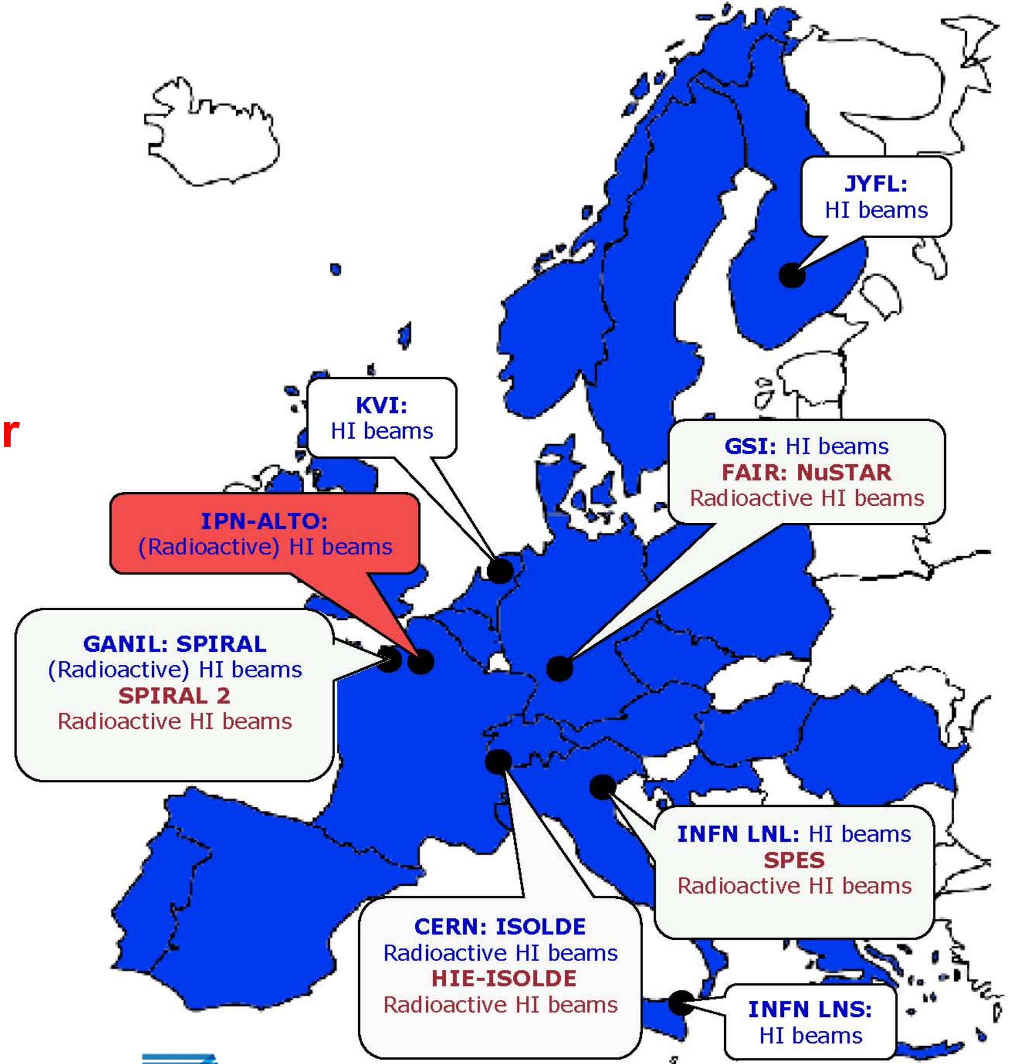
Possibility to run in the future ISOL and Tandem simultaneously

28 engineers and technicians for Technical support

250 outside users (30 countries)/year

PAC: One/year

- R. F. CASTEN , Chair (Yale University)
- E. BALANZAT (CIMAP – Caen)
- D. BALABANSKI (Sofia – Bulgarie)
- S. GREVY (CENBG)
- E. KHAN (IPNO)
- W. KORTEN (SPhN-IRFU-CEA)
- B. RUBIO (IFIC Valencia)
- C. TRAUTMANN (GSI)
- A. TUMINO (LNS -Catania)
- J. C. THOMAS (GANIL)



SEVENTH FRAMEWORK PROGRAMME

ENSAR

ALTO:
TNA within ENSAR
and
Candidate for TNA within ENSAR2

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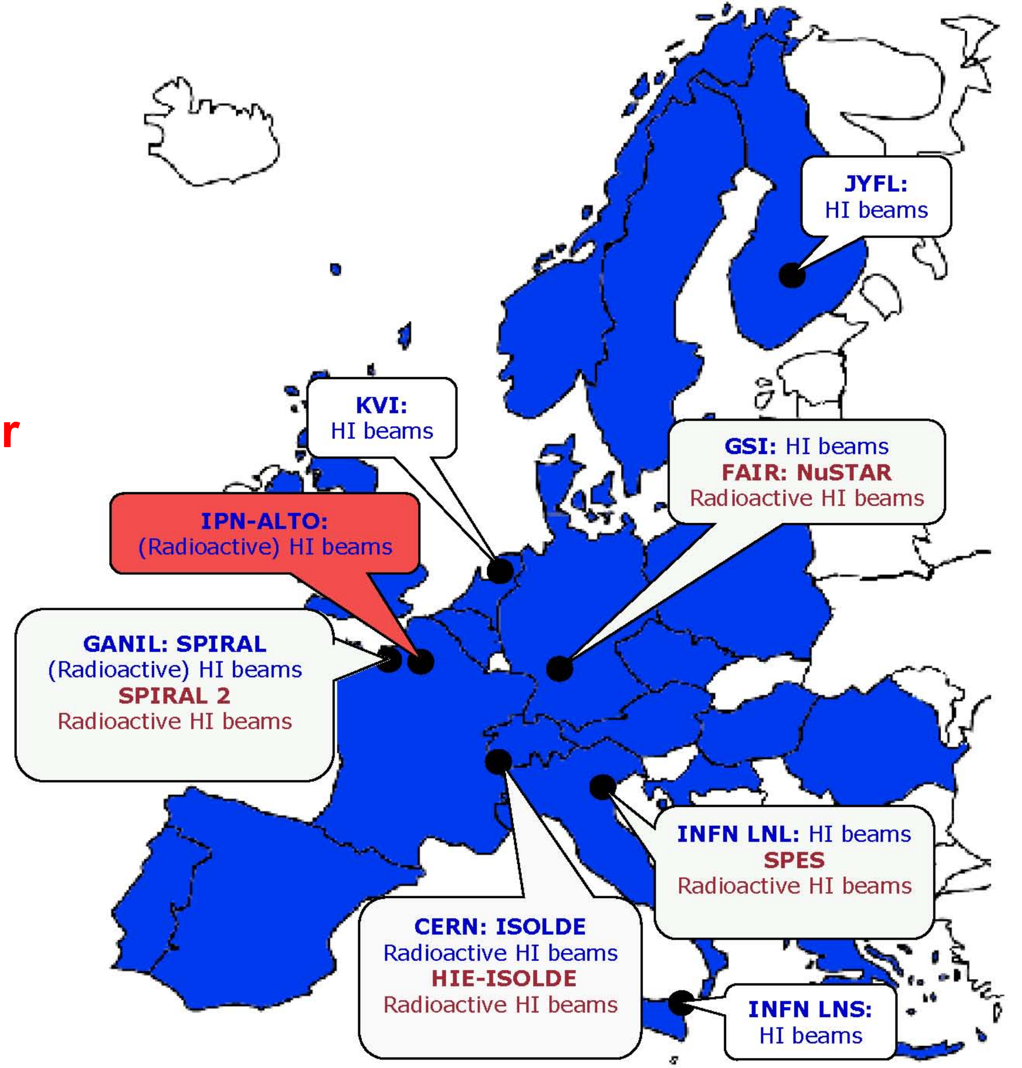

TNA	Number of beam hours promised -full contract	**Number of beam hours 01/09/2010 - 30/04/2013**	Estimated number of Users - full contract	**Number of Users 01/09/2010 - 30/04/2013**	Estimated number of days - full contract	**Number of days 01/09/2010 - 30/04/2013**	Estimated number of projects - full contract	**Number of projects 01/09/2010 - 30/04/2013**	Total amount for T&S - full contract	**Amount for T&S 01/09/2010 - 30/04/2013**
ALTO	1470	**2400**	116	**80**	556	**576**	19	**19**	73 720€	**64 320€**

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ALTO	1470	**2400**	116	**80**	556	**576**	19	**19**	73 720€	**64 320€**

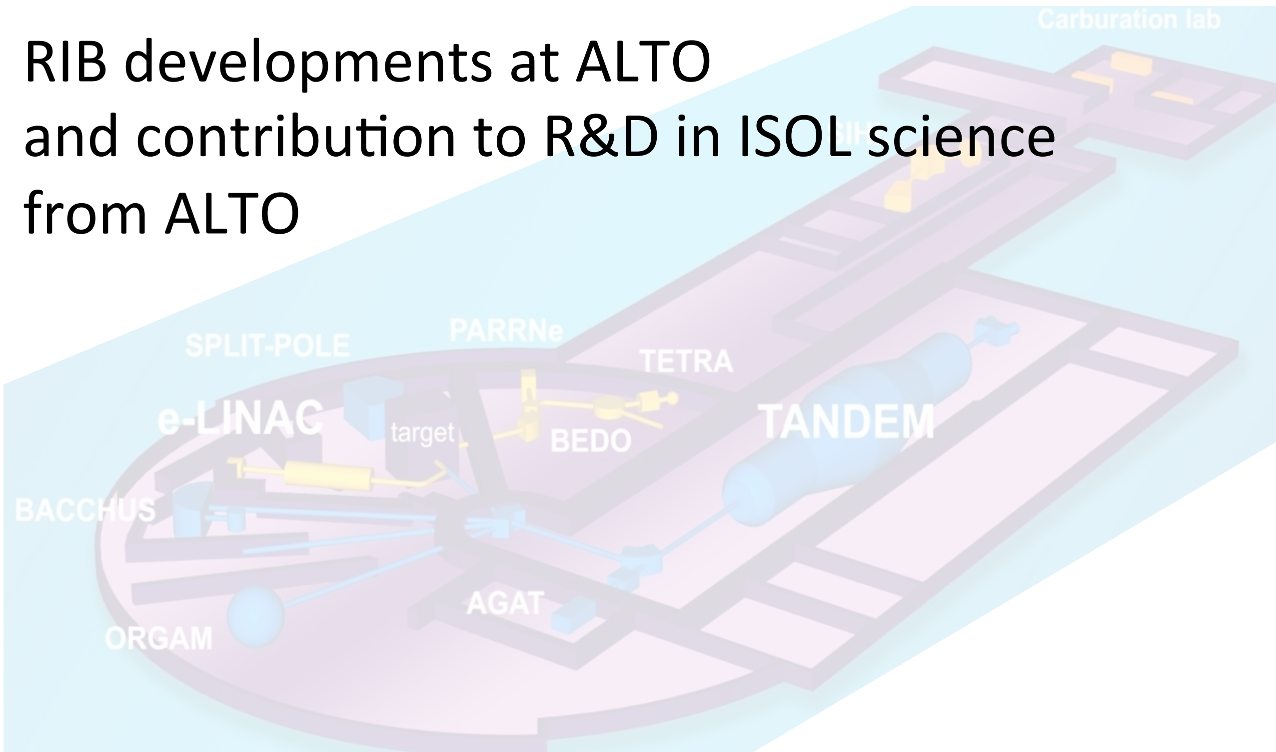
March 2012

green light from French nuclear safety authorities

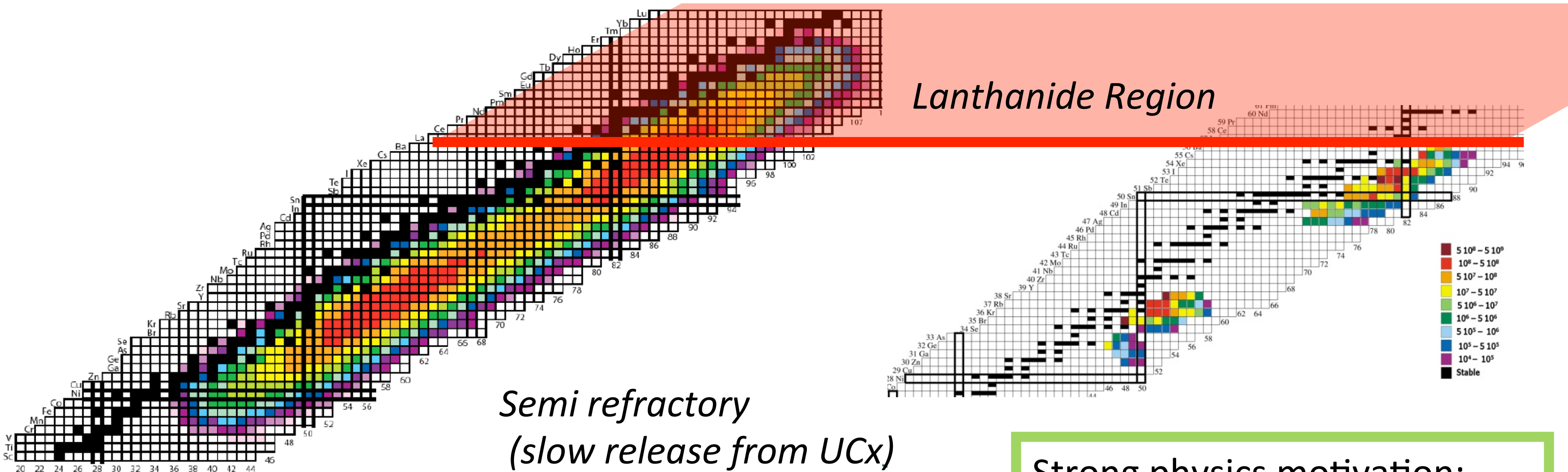
May 13th 2013 – formal inauguration

May 14-15th 2013 – 2nd Workshop on the Physics at ALTO

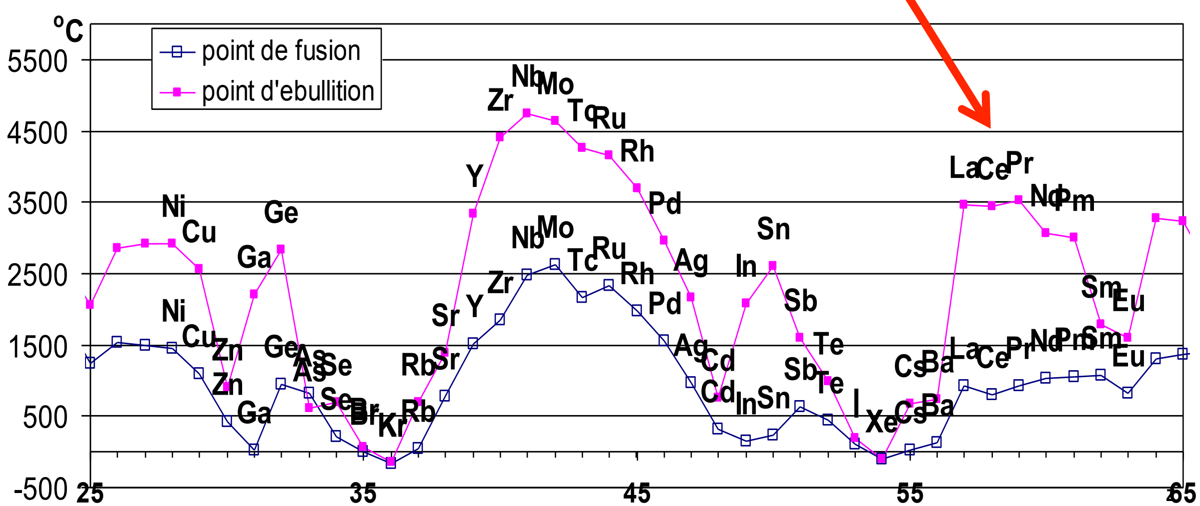
RIB developments at ALTO and contribution to R&D in ISOL science from ALTO



R&D program on the fluorination of Lanthanides



Semi refractory (slow release from UCx)

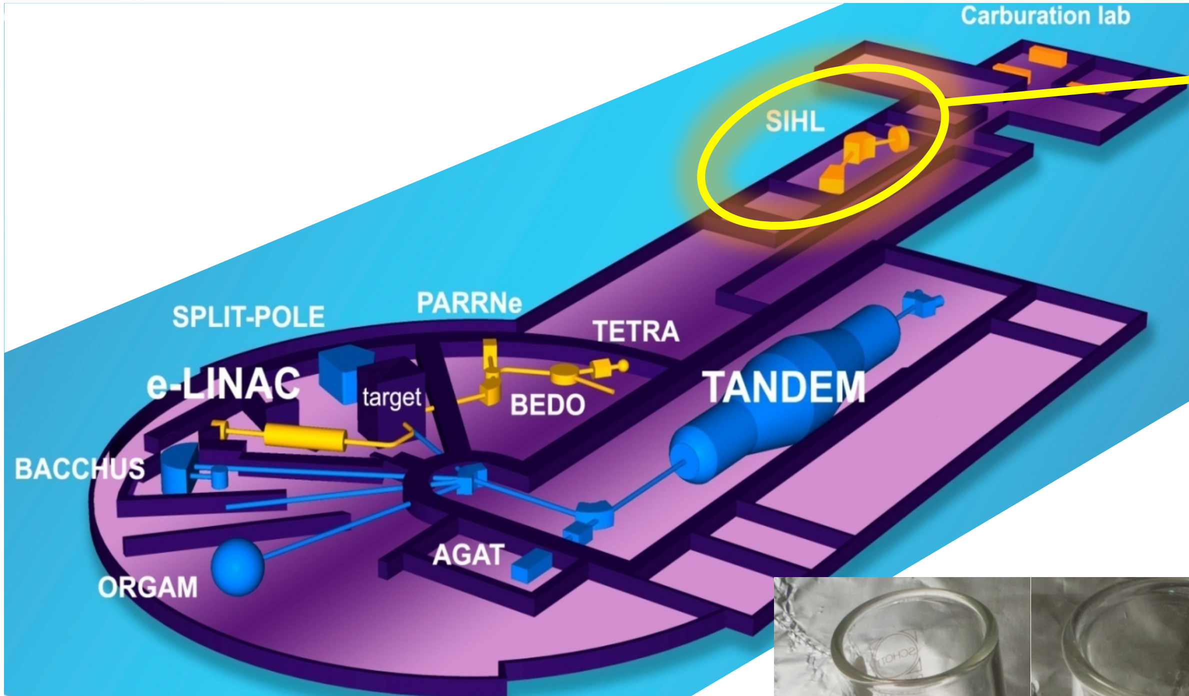


Strong physics motivation: study of mid-shell effects
⇨ B(E2) measurements
⇨ ***fast timing***

Program led by B. Roussière (IPN Orsay), collaboration CSNSM (France), Tandar (Argentina) and INRNE (Bulgaria)

first fast-timing experiment at ALTO with low-intensity e^- beam on $^{137,139}Cs$
Eur. Phys. J. A (2011) **47**: 106

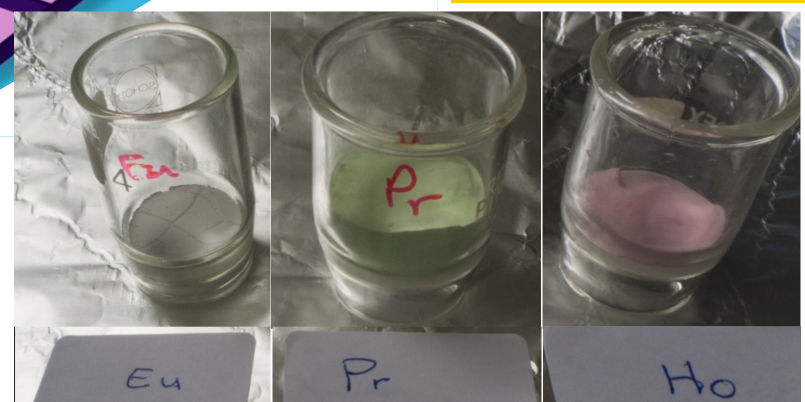
R&D program on the fluorination of Lanthanides



SIHL off-line mass separator

<u>Strategy</u> :
Fasten the release of Ln by formation of LnF_n^+ molecular beams
⇨<u>Tests</u> :
the different parameters:
- injected fluoride gas
- target temperature
- source type

Target made of Lanthanide oxides mixed in graphite powder



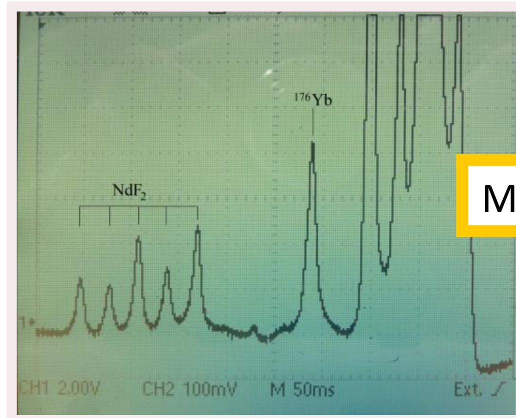
Z	Elément	Potentiel d'ionisation (eV)	T_{fusion} (°C)	$T_{ébullition}$ (°C)	Fluorure
60	Nd	5.53	1021	3074	NdF_3
63	Eu	5.67	822	1596	EuF_2, EuF_3
64	Gd	6.15	1313	3273	GdF_3
65	Tb	5.86	1356	3230	TbF_2, TbF_3, TbF_4
66	Dy	5.94	1412	2567	DyF_3
70	Yb	6.25	819	1196	YbF, YbF_2, YbF_3

R&D program on the fluorination of Lanthanides

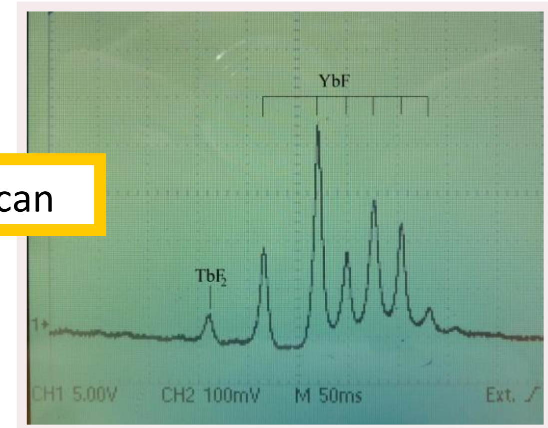
CF4 inlet tube

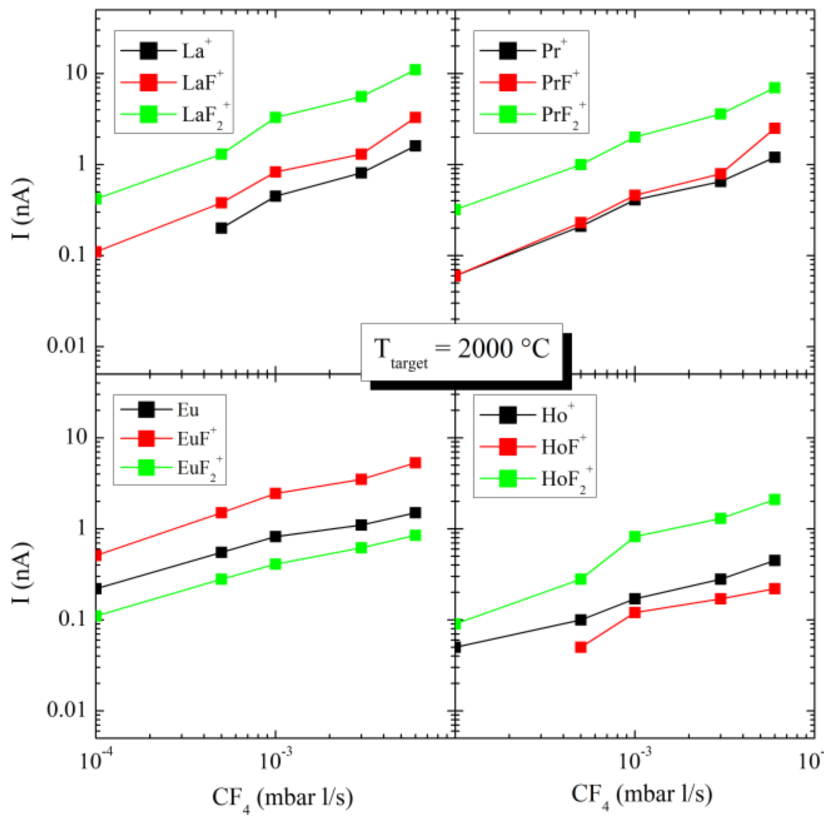
flow max compatible with good running conditions:~6 x 10^{-3} bar.l/s

Reliable T° control



Mass scan



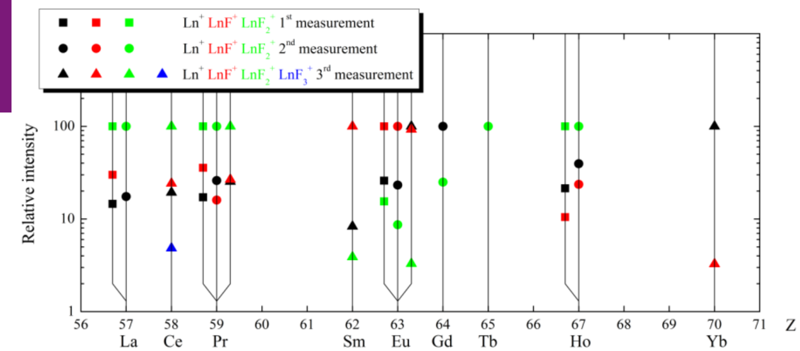


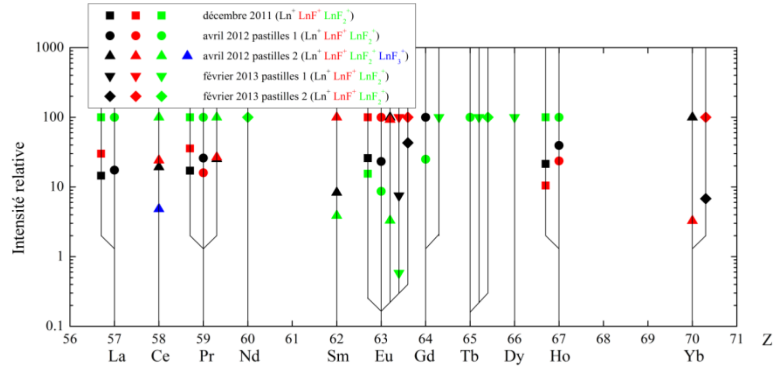
Measurements performesd with hot plasma (Febiad) and surface (W) ion sources

High correlation between the valence of the Ln and the observed ions (Ln^+, LnF^+ or LnF_2^+).

R&D program on the fluorination of Lanthanides

- 1st systematic study on the fluorination for Lanthanides beams
- Dependence on the valence of the Lanthanide
- Process sensitive to heating conditions
- Reproducible results
- No chemical corrosion observed in the front-end (after more than 3 weeks of operation)
- Further tests are scheduled for optimizing the operation conditions before going to online experiments





Towards a more general R&D program on molecular beams

IPN Chemists, engineers and physicists
N. Barré-Boscher, M. Cheikh Mhamed, S. Essabaa, C. Lau, B. Roussière, A. Said, S. Tusseau-Nenez

- R&D of interest for all current ISOL facilities and extendable to develop new radioactive molecular beams.
- Powerful technique to produce chemically reactive nuclei.
- In the framework of ENSAR2: a proposal submitted, involving CERN, GANIL, GSI and INFN: to be discussed…

UCx developments at IPN - ALTO

ENSAR JRA02, ActILab:
Actinide ISOL Target R&D Laboratory

- CERN-ISOLDE
- GANIL-SPIRAL2
- INFN- SPES
- IPN- ALTO

- Laboratory of Chemical Sciences, Univ. of Rennes (France)
for the synthesis of samples and microstructural characterizations (SEM)
- ICMMO-Orsay
for SEM observations and XRD measurements on non-radioactive samples

IPN Chemists, engineers and physicists
N. Barré-Boscher, M. Cheikh Mhamed, S. Essabaa, C. Lau, B. Roussière, A. Said, S. Tusseau-Nenez

Objectives:
Today : ALTO, 10^{11} fissions / sec
Tomorrow : SPIRAL2 >10^{13} fissions / sec
Future : EURISOL, 10^{15} fissions / sec

Nowadays
The most widely used ISOL targets = **uranium carbide + graphite (UCX), mostly UC2**
Concentration of ^{238}U ~ **3 g/cm3**
Operate at temperatures ranging from **2 000 °C to 2 200 °C**

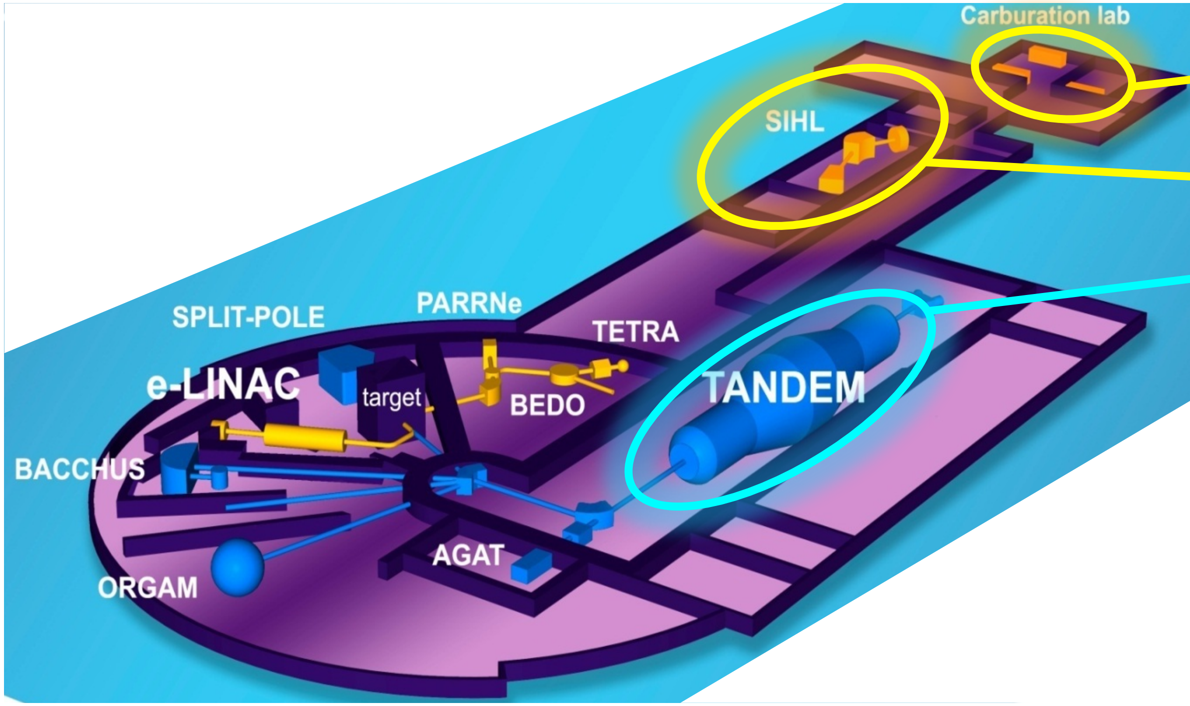
How to increase the RIB intensities ?

Increasing the primary beam
Increasing uranium density → higher production rate of FPs

BUT that cannot be the end of the story:
favor the FPs releases, particularly crucial for the short-lived species

→ **Controlling the porosity**
Reducing the thickness of pellets

UCx developments at IPN - ALTO



Carburation lab

SIHL off-line mass separator

15 MV MP Tandem

Strategy :
Measure the release properties of pellets after irradiation
⇨ Control and characterize :
the different parameters:
- UCx synthesis method
- porosity
- microstructure
- physicochemical properties
- …

Sample	*Precursors*	*Open Porosity (%)*	*Effective density (g.cm^{-3})*
PARRNe	U_3O_8 + 6 C or UO_2 + 6 C	~60	8.5
OXY	UO_2 + 3 C	~40	13.5
OXA	$U(C_2O_4)_2,2H_2O$ + 3 C	~40	13.5
COMP30	$U(C_2O_4)_2,2H_2O$ + 3 C + 30 vol.% graphite fibers	~60	10.5
ARC	U+C	~10	13

Densest samples

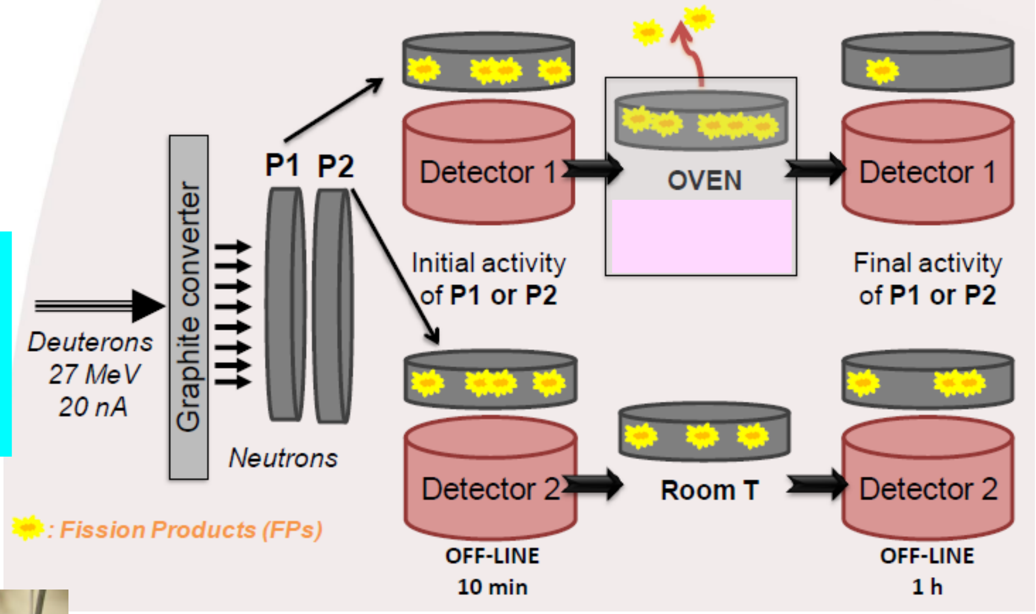
Porous samples

UCx developments at IPN - ALTO

Deuteron Tandem beam

Irradiation time 20 min

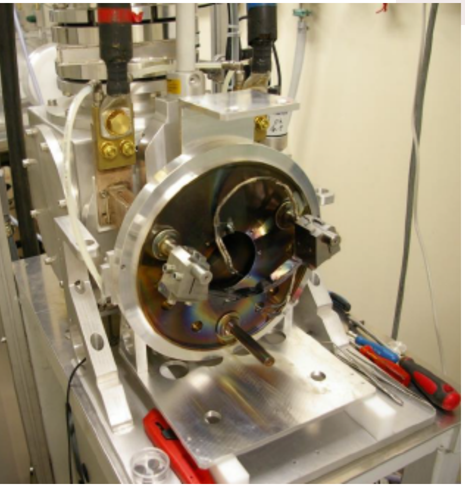
Cooling time 30 min

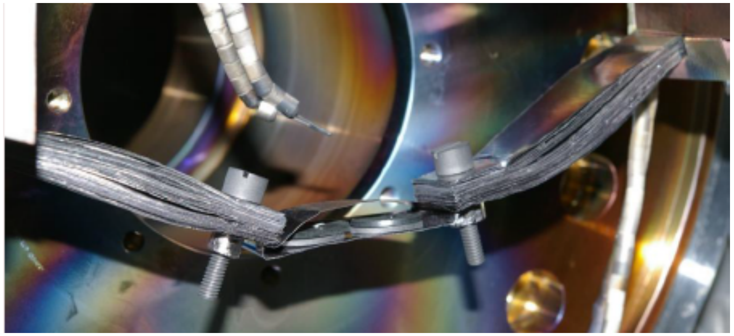


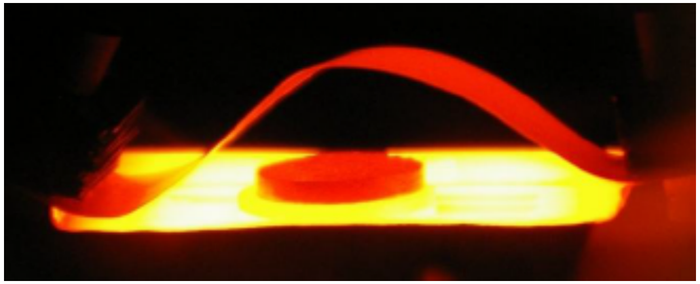
Heating 1700°C during 30 min

Secondary vacuum

Cooling to 70°C in 10 min







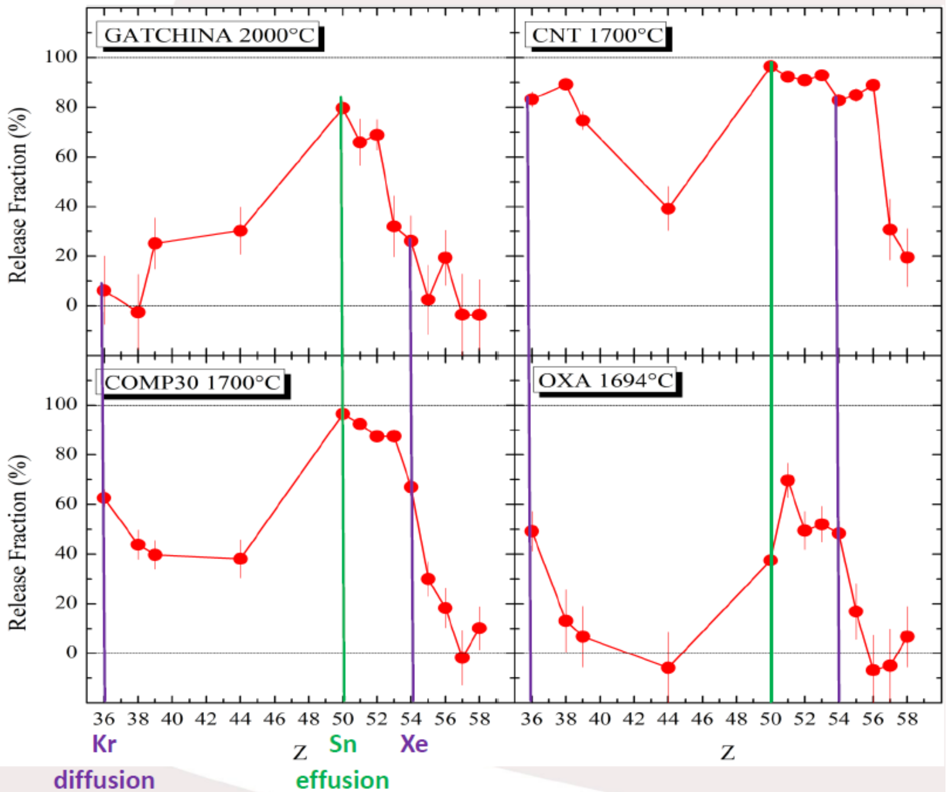
The furnace for heating test is home made.

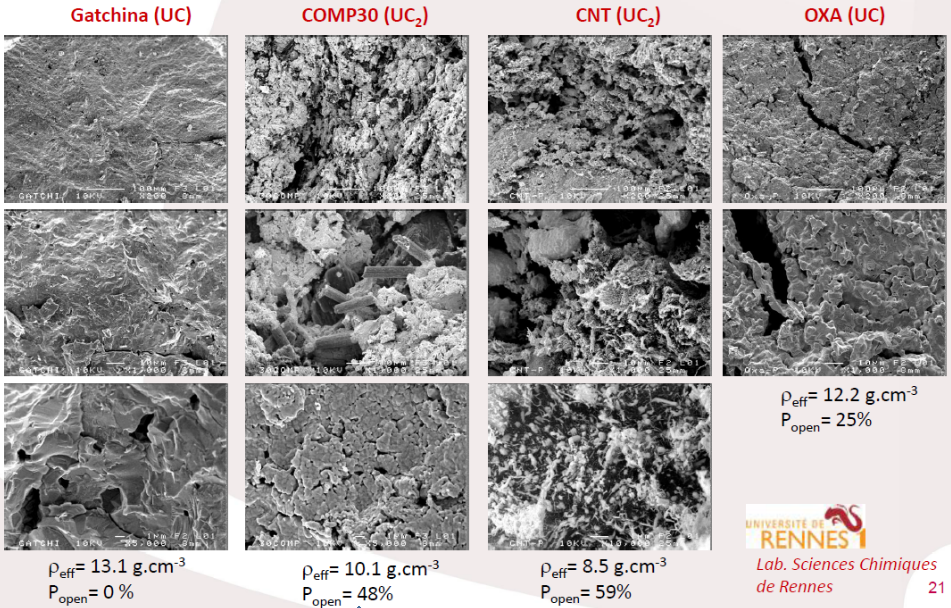
Calibration by melting of Pt

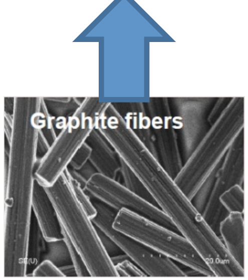
Melting of Pt (T = 1630°C) to calibrate the emissivity of the pyrometer under pressure conditions (5.10^{-5} mbar).

UCx developments at IPN - ALTO

Results from gamma spectrometry







Clearly, diffusion and effusion are correlated with the porosity / pore size distribution of the sample

More on the method in:
B. Hy et al., NIM B 288 (2012) 34

Laser ionized RIBs at ALTO

The ALTO laser ion source **RIALTO** (Resonant Ionization at ALTO)

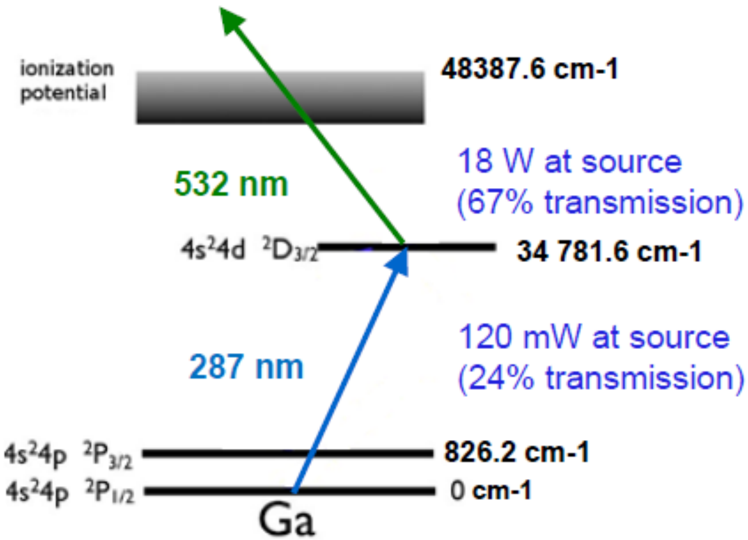
Installation supervised by S. Franchoo
with the collaboration of
ISOLDE:
V. Fedosseev, B. Marsh, T. Goodacre
Univ. Manchester:
K. Flanagan
Univ. Mainz:
T. Kron, K. Wendt

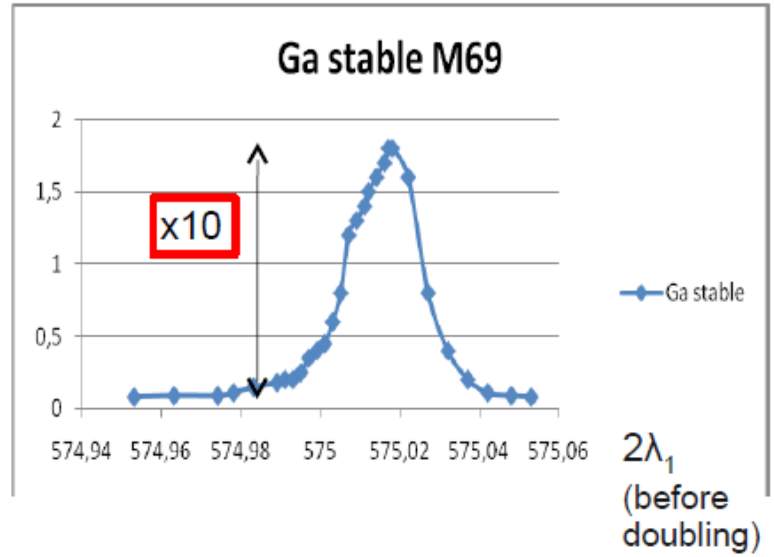
The on-line laser installation validated in 2011
with the production of Ga beams.
2012: Upgrade 2 new lasers (Radiant Dyes).
2013: Reference cell (in progress...)

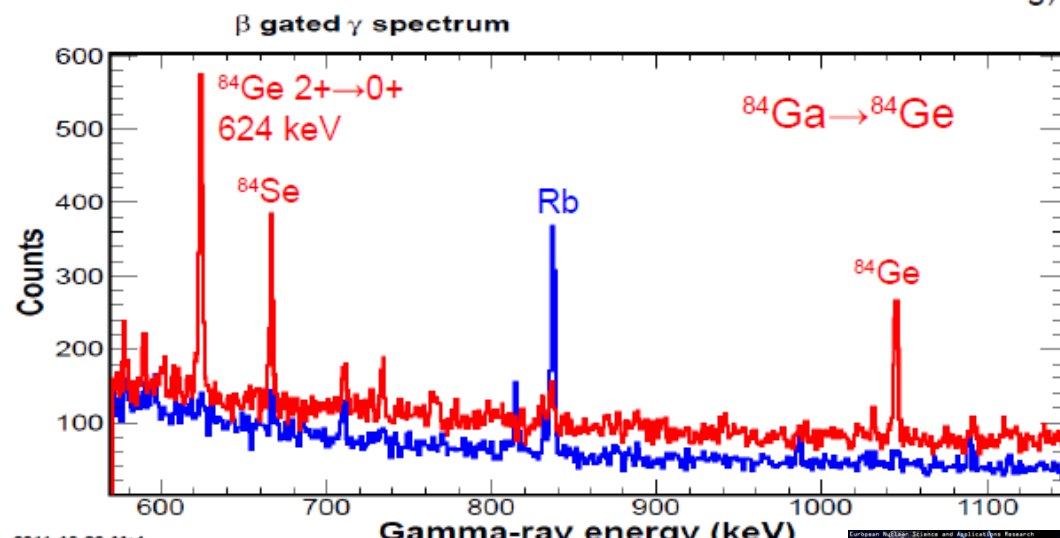
ENSAR

Laser ionized RIBs at ALTO

Ga isotopes on-line delivery in 2011





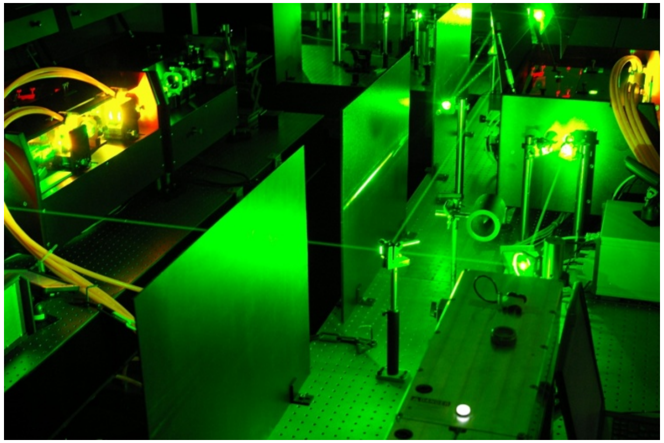


laser ionisation ε~10% (10 μA)

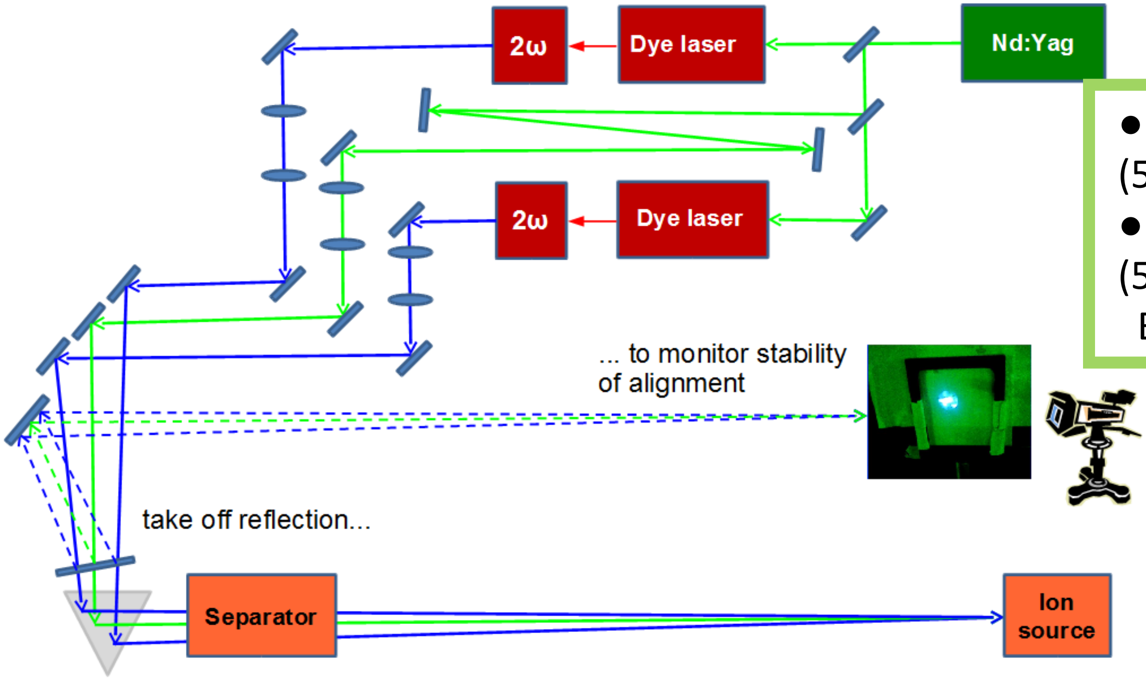
without laser:
surface ionisation ε~1% (1 μA)

Laser ionized RIBs at ALTO

Upgrades 2012 - 2013



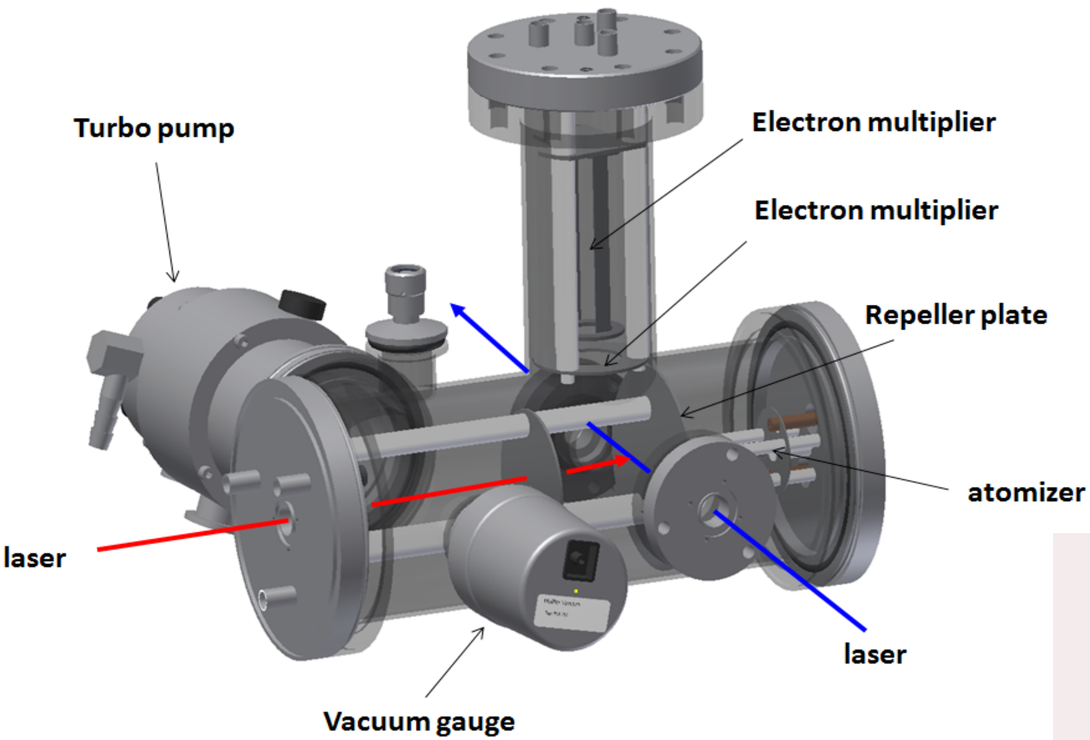
- Validated with Ga beams: 287/297 nm + 532 nm
- **Next run with Zn beams: 214 nm + 636 nm + 532 nm (f tripling) – starting June 17th 2013**
- Laser schemes and optics settled with the support of ISOLDE-CERN



- EdgeWave pump laser (532 nm, 100 W, 10 KHz, 10 ns)
- 2 Radiant Dyes Narrowscan lasers (540 – 900 nm)
  BBO doubling units (270 – 450 nm)

Laser ionized RIBs at ALTO

Reference cell in progress…



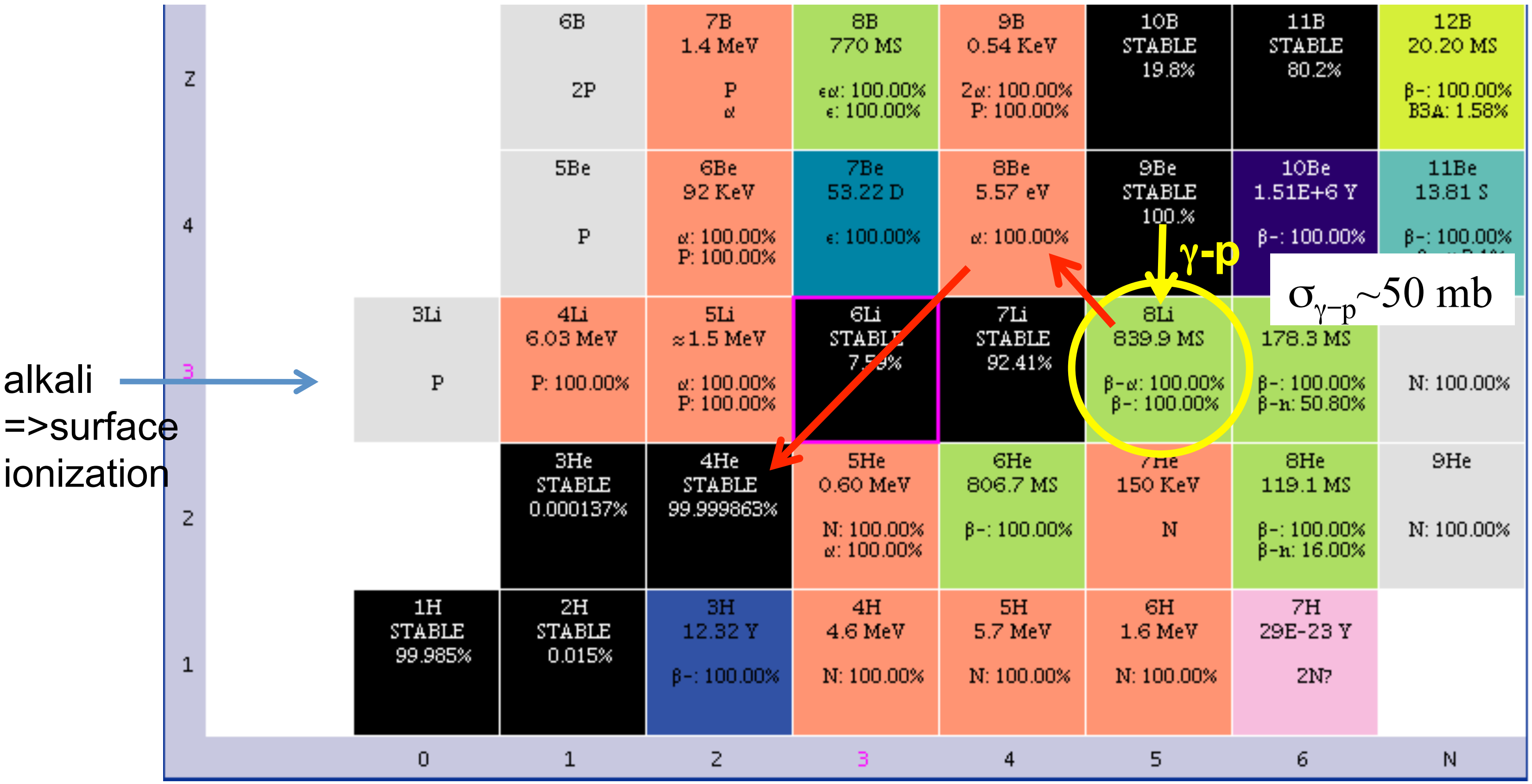
Design: engineering office of the "Accelerators" Division of IPN

Tests: R&D group of ALTO

Collaboration with Mainz University: T. Kron and K. Wendt

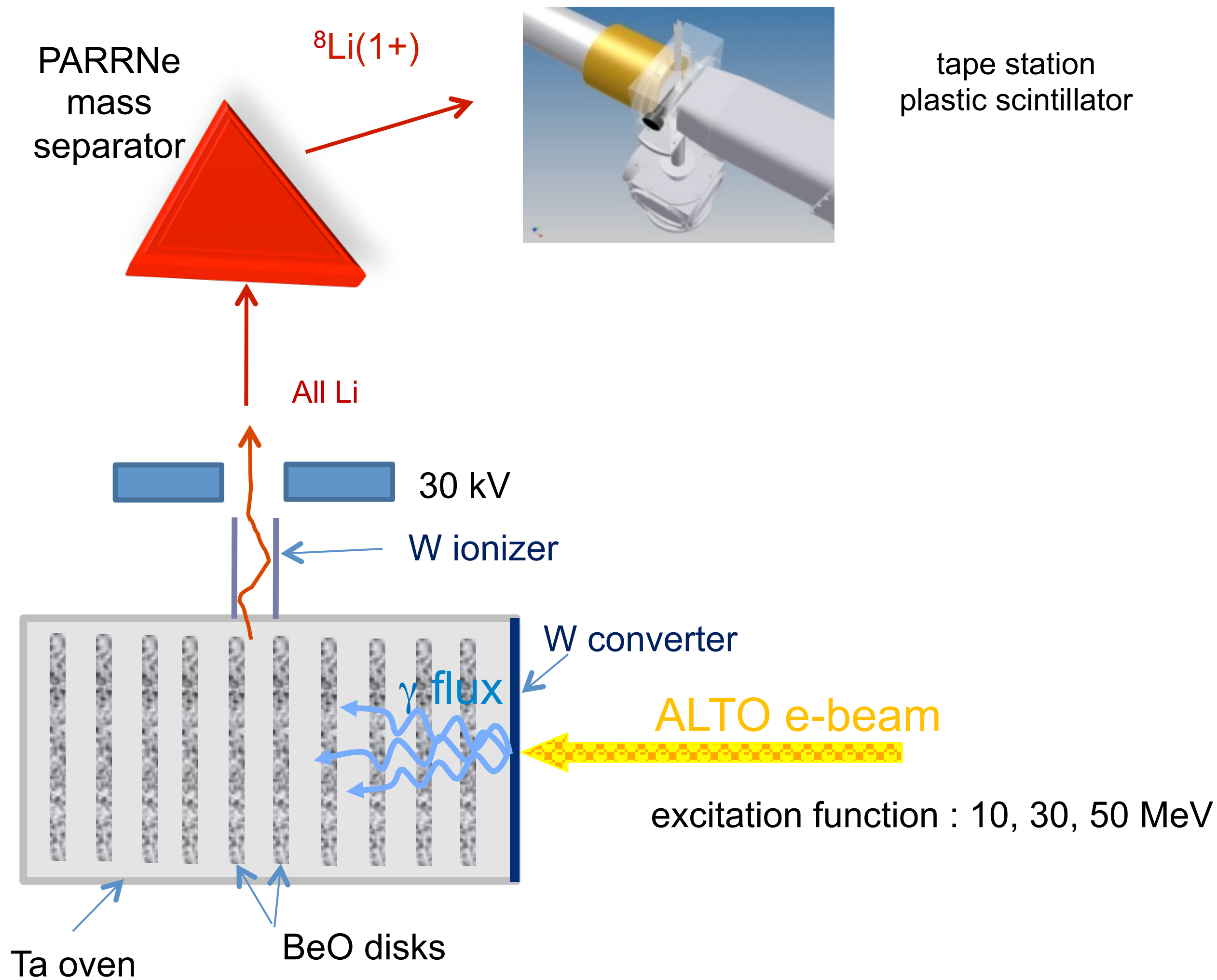
R&D (TRIUMF-IPN MOU) = photo-production of 8Li in ISOL conditions

8Li photo-photoproduction collaboration at ALTO
P. Bricault, M. Lebois, *TRIUMF, Vancouver, Canada*
F. Ibrahim, D. Verney, S. Essabaa, E. Cottereau, Ch. Lau, M. Cheikh Mahmed and the source group *IPN, IN2P3/CNRS, Orsay, France*

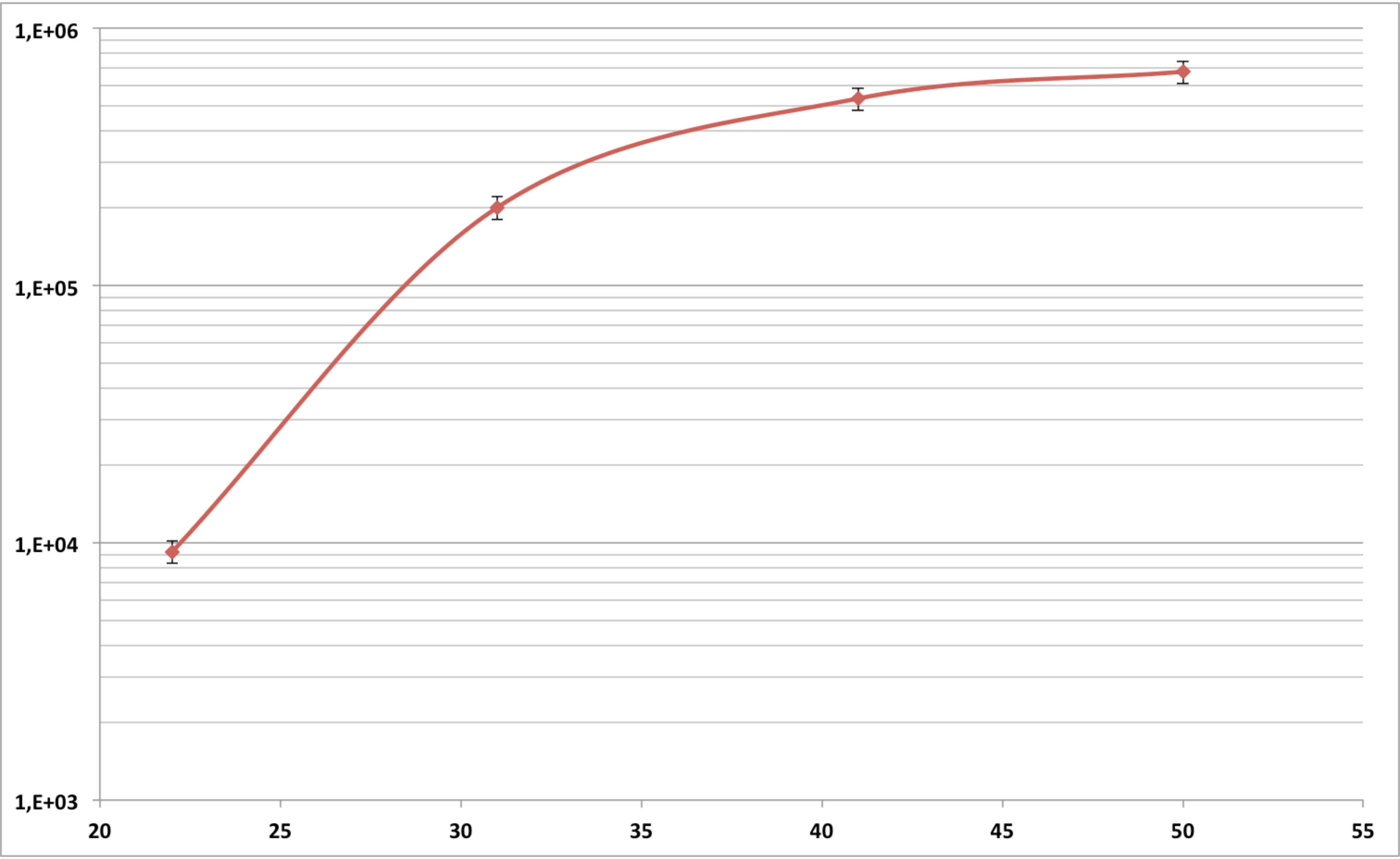


Surface ionization

ECS bunker



Photoproduction of ^{8}Li: the results



R&D (Dubna-IPN) = photo-production of 6He in ISOL conditions

He =>plasma ionization

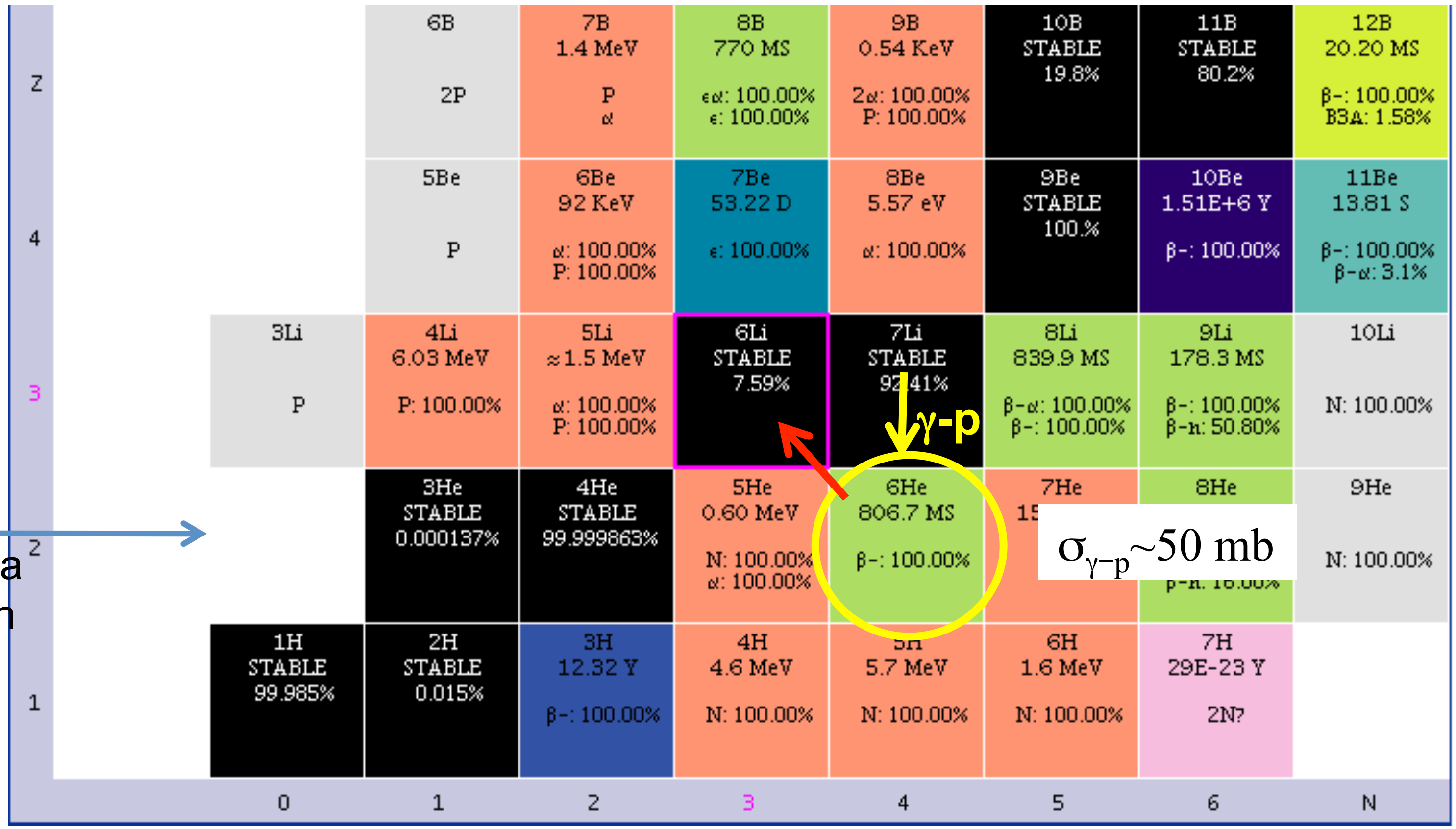
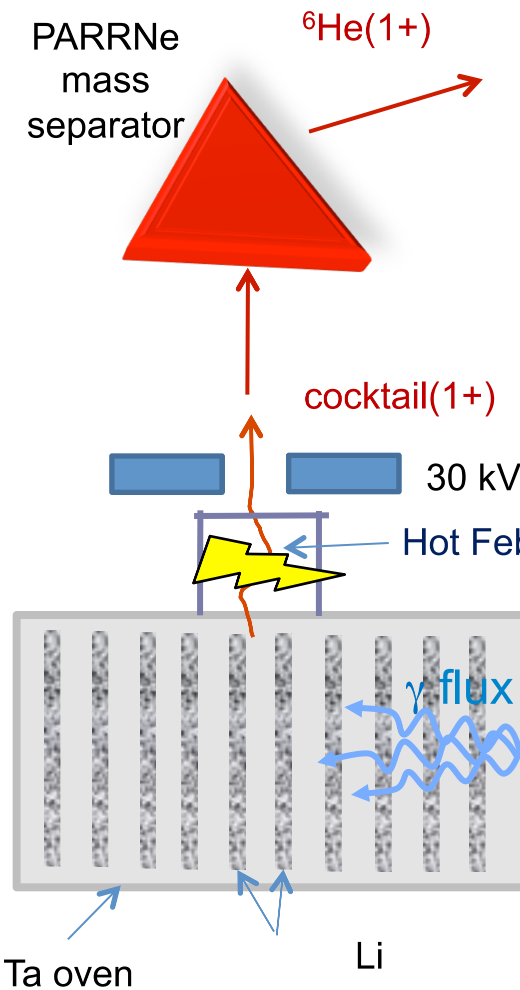
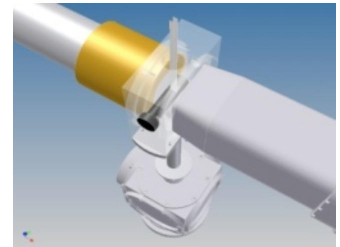


photo-production of ^{6}He at ALTO : experimental setup

Surface ionization

ECS bunker

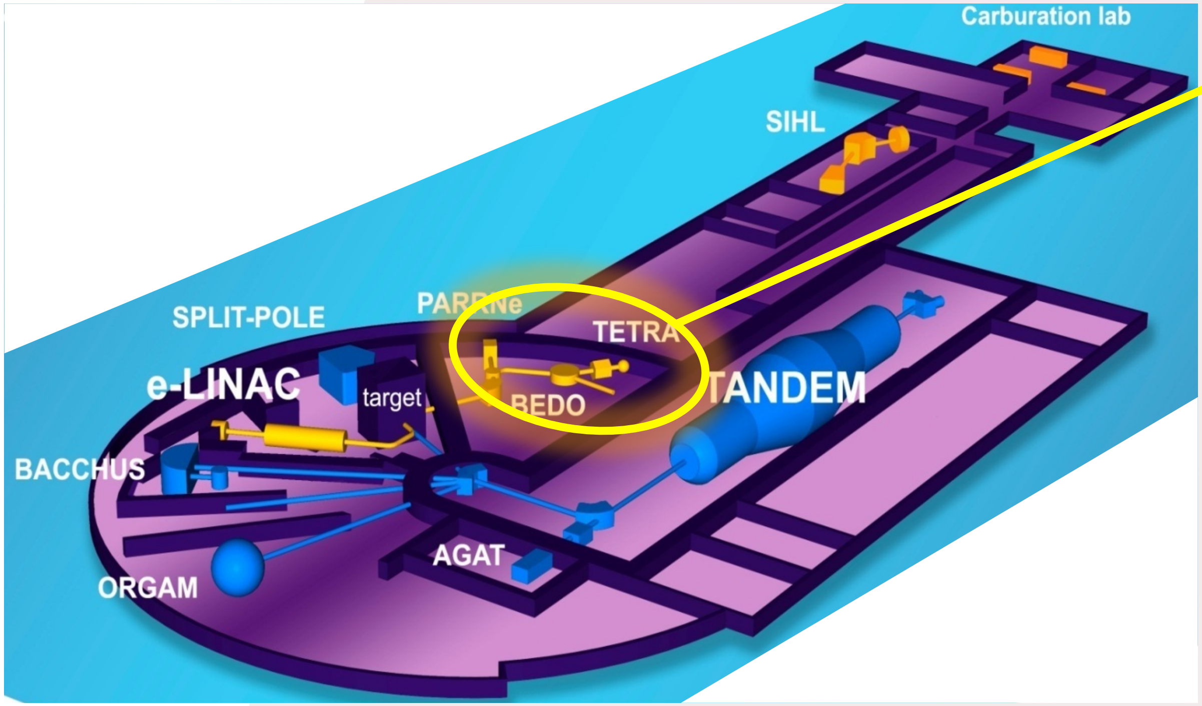




tape station
plastic scintillator

Some Highlights obtained at ALTO

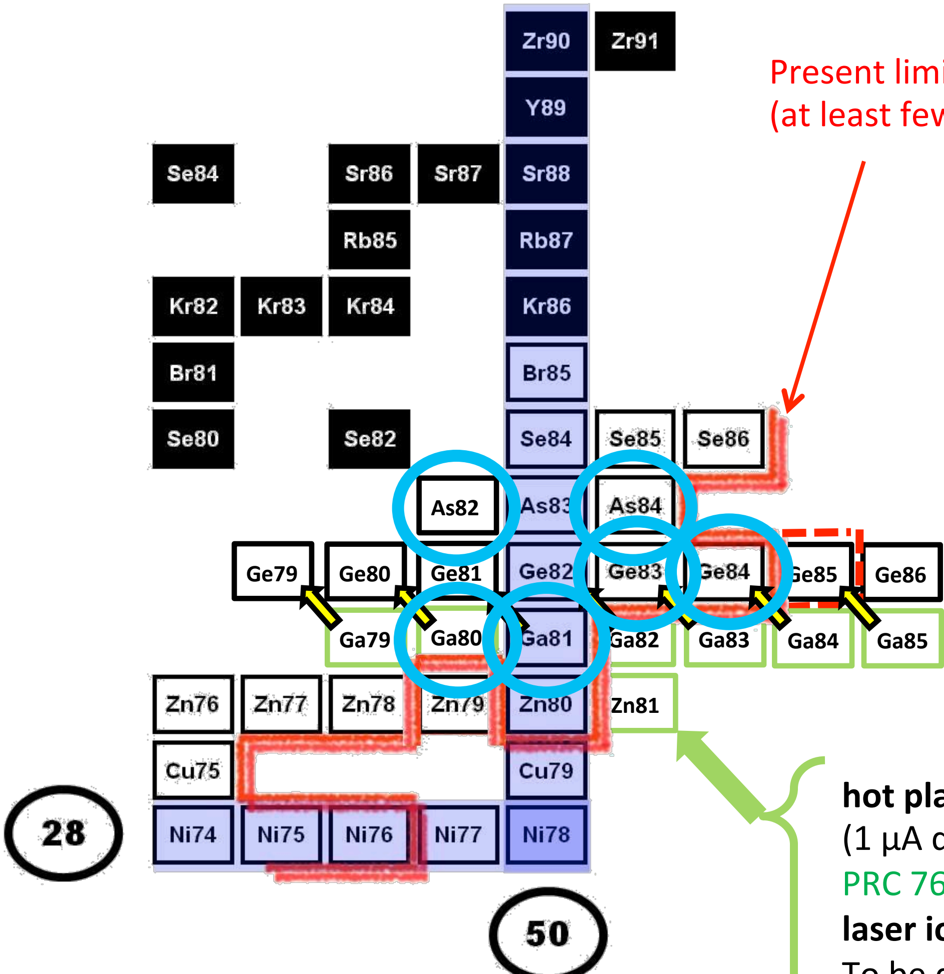
RESULTS OBTAINED WITH THE E-LINAC



Radioactive secondary lines

beta-decay spectroscopy in the N=50 region

more than 10 years of experiments in the ^{78}Ni region
at the PARRNe mass separator (Tandem/ALTO)



hot plasma ionization
(1 μA deuteron primary beam)
O. Perru PhD – def. 10th December 2004
Eur. Phys. J. A 28, 307 (2006)
surface ionization
(2-4 μA electron primary beam)
M. Lebois PhD – def. 23th September 2008
PRC 80, 044308 (2009)
B. Tastet PhD – def. 13th May 2011
PRC 87, 054307 (2013)
D. Testov PhD – def. November 2013
laser ionization
(10 μA electron primary beam)
K. Kolos PhD – def. September 2012

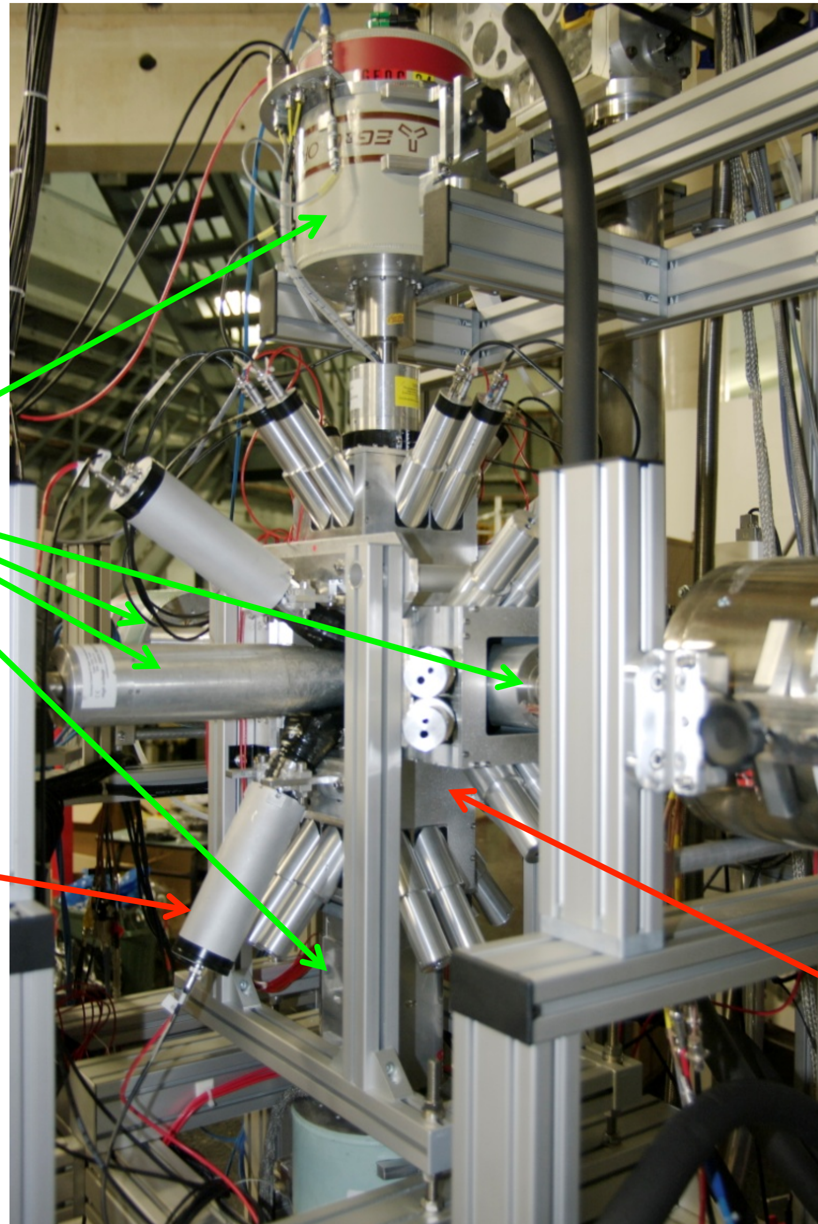
hot plasma ionization
(1 μA deuteron primary beam)
PRC 76 (2007) 054312
laser ionization
To be done in June 2013 PhD A. Etile

BEDO : BEta Decay studies at Orsay

4 EXOGAM small prototypes
Source-cap distance = 5 cm

measured $\varepsilon_{\gamma\ (1\ \mathrm{MeV})}$ = 5-6 %
(previous system 1-2%)

sensitivity 0.1 pps

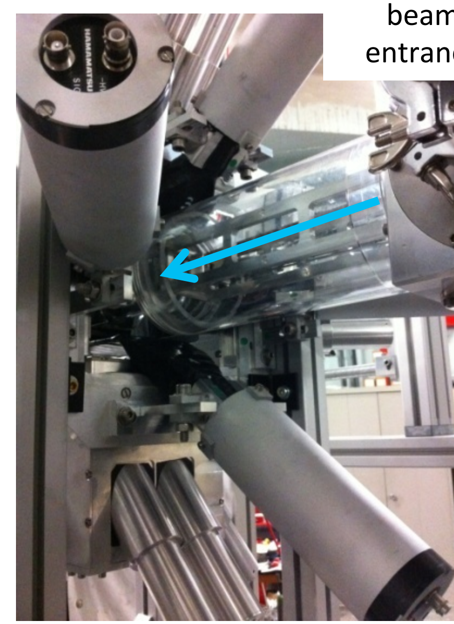


up to 5 Ge detectors

6 plastic detectors

Anti-Compton belt

beam entrance

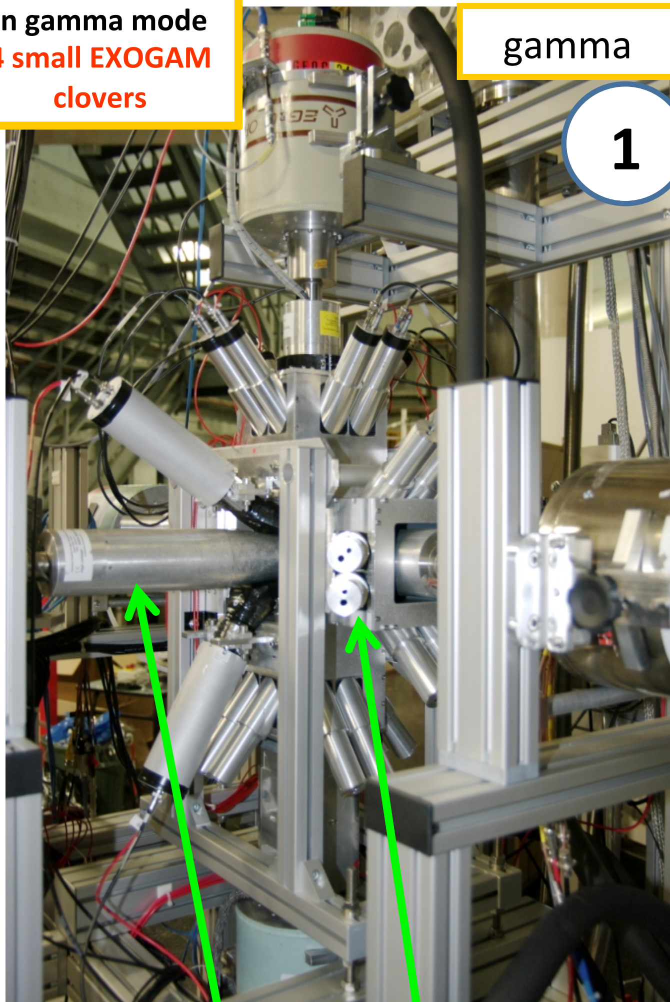


BEDO : BEta Decay studies at Orsay

BEDO setup in gamma mode
4 small EXOGAM clovers

gamma

1



Ge detectors

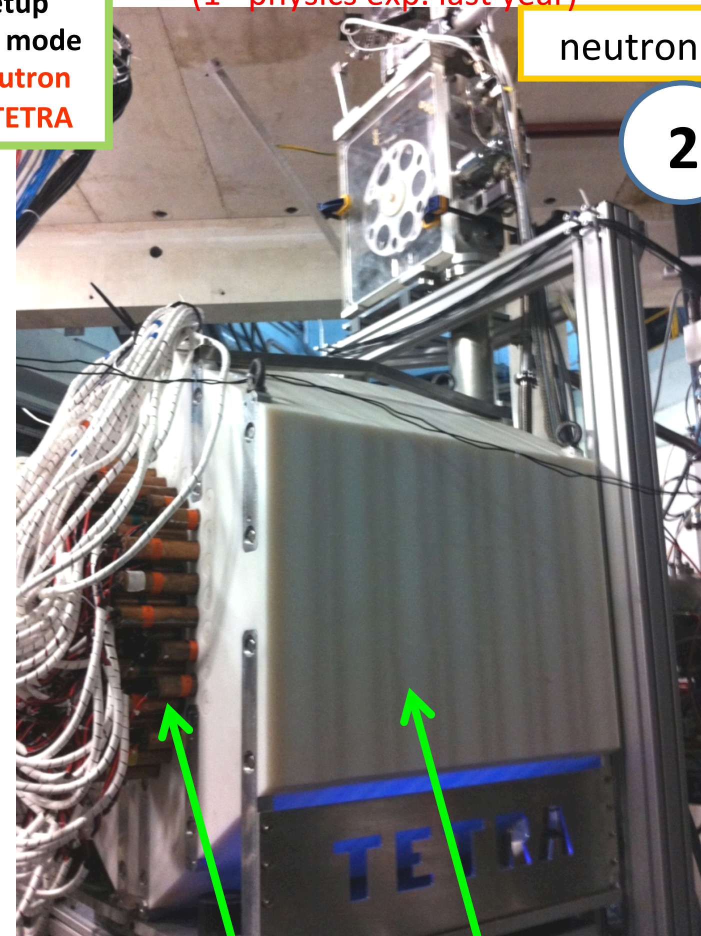
BGO shields

BEDO setup in neutron mode
Dubna neutron detector TETRA

(1st physics exp. last year)

neutron

2

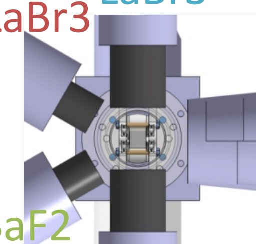


~90 ^{3}He tubes

borated polyethylene shielding

3

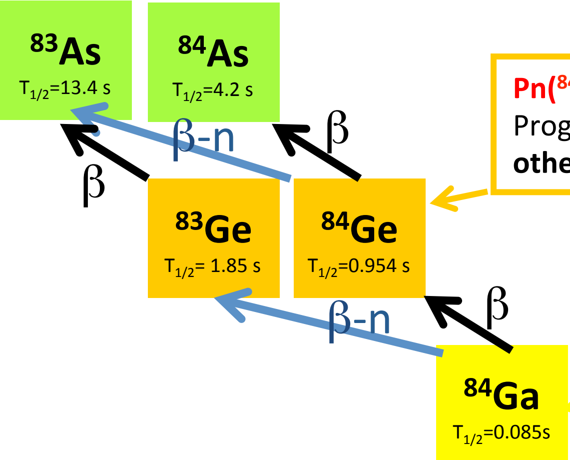
fast timing mode



Distances / source :

- Ge = 40 mm
- LaBr3 = 25 mm
- BaF2 et LaBr3 = 40 mm
- Plastique = 25 mm

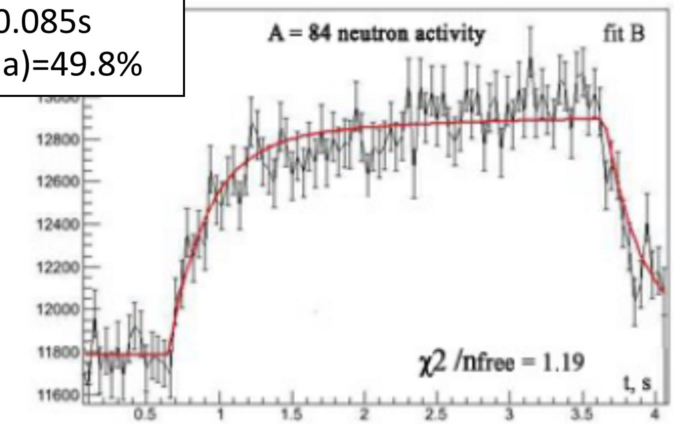
Direct β-delayed neutron emission measurement of ^{84}Ga with TETRA

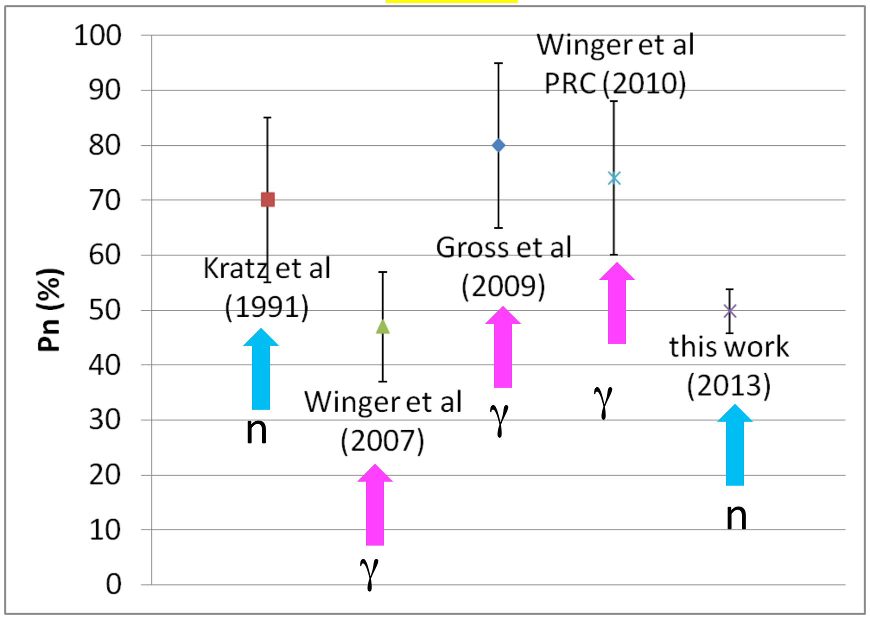


Pn(^{84}Ge)=10.2(9) B.Pfeiffer et al.
Prog. Nucl. Energy 41, 39 (2002)
others: 10.8(6) , 9.5(20) , 9(3)

Pn (^{84}Ga)= (49.8±4)%

T1/2=0.085s
Pn(^{84}Ga)=49.8%

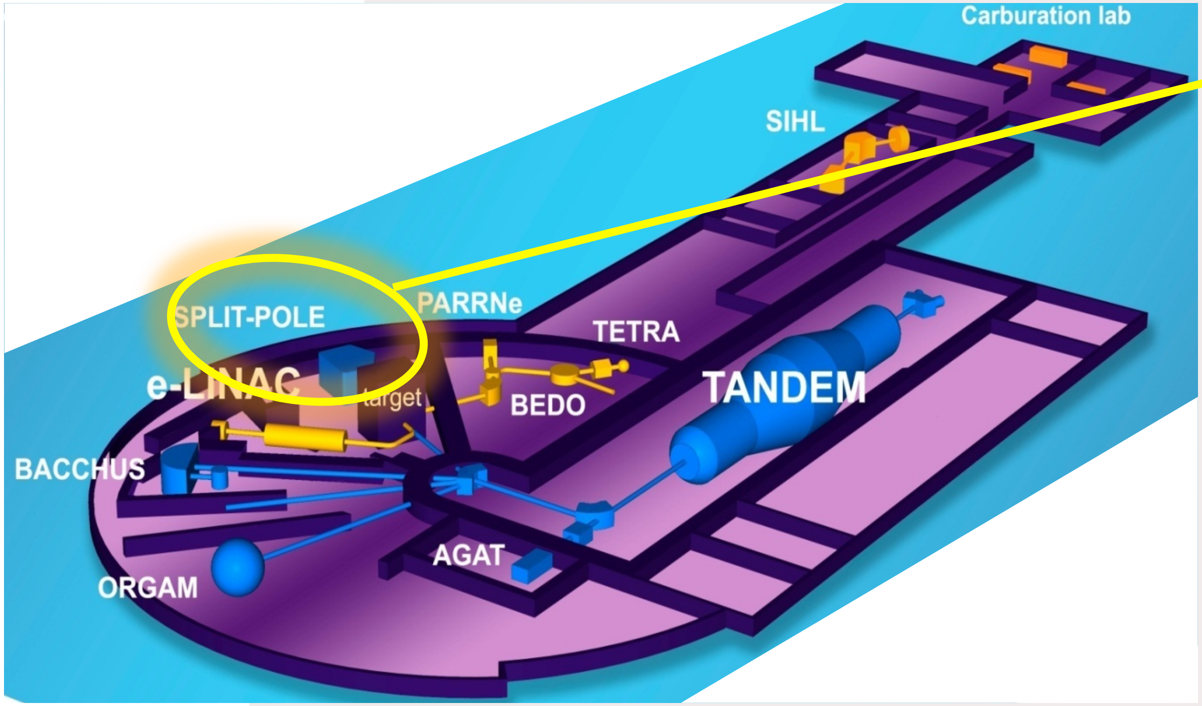




Pn=70(15) K.-L.Kratz et al. Z.Phys. A340, 419 (1991) and B.Pfeiffer et al. Prog. Nucl. Energy 41, 39 (2002)
Pn=80(15) C.J.Gross et al. Acta Phys.Pol. B40, 447 (2009)
Pn=47(10) J.A.Winger et al Proc.4th. Intern. Conf. Fission and Properties of Neutron-Rich Nuclei, Sanibel Island, Florida (2007);
Pn=74(14) J.A.Winger PRC 81, 044303 (2010)

TETRA detector at **BEDO** setup:
- 4Pi neutron detector 90 counters ^{3}He 7 atm [measured eff. 63±5% (on line)]
- 4π beta detector
- 1 Ge detector
- movable tape

ASTROPHYSICS WITH THE SPLIT POLE SPECTROMETER



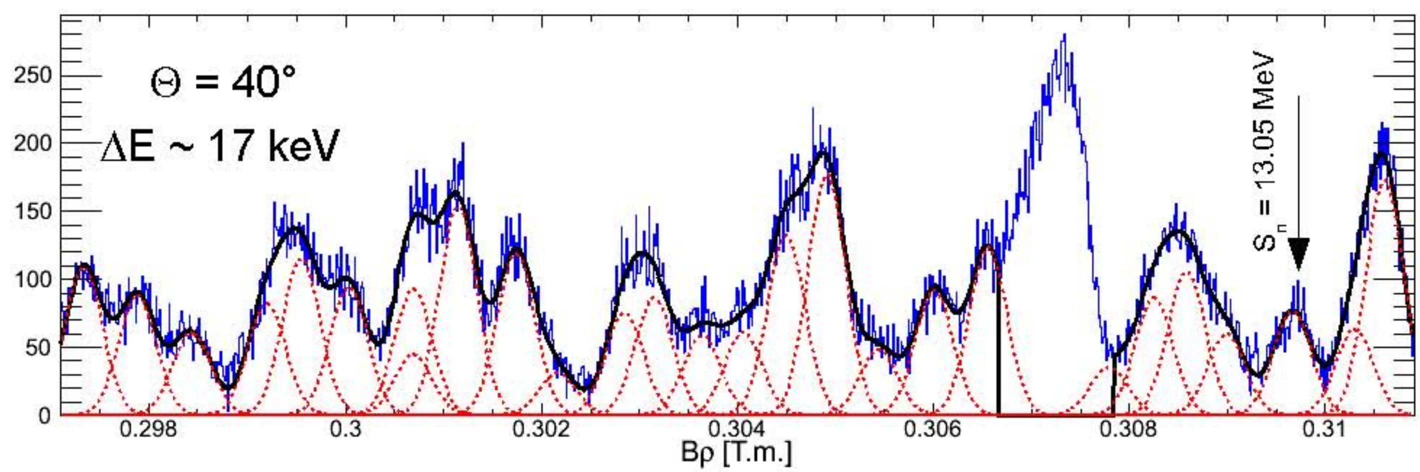
SPLIT POLE SPECTROMETER

$^{27}Al(n,p)^{26}Mg$ and $^{27}Al(n,\alpha)^{23}Na$ in massive stars

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

- Targets: ^{27}Al, ^{12}C & mylar ~ 80 μg/cm²
- Split-Pole: high-resolution measurement
  → θ = 10°, 25°, 40° & 45°

- ^{27}Al levels: kinematics displacement between Θ = 40° and 45°
- Many new states above (and below) neutron threshold
- Good agreement with known resonances



$^{27}Al(n,p)^{26}Mg$ and $^{27}Al(n,\alpha)^{23}Na$ in massive stars

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

- Split-Pole @ 40°
- 3 DSSSDs in reaction chamber
  - → 5 x 5 cm^2, 16 strips (W model)
  - → backward angles
  - → d ~ 10 cm, ε ~ 6%

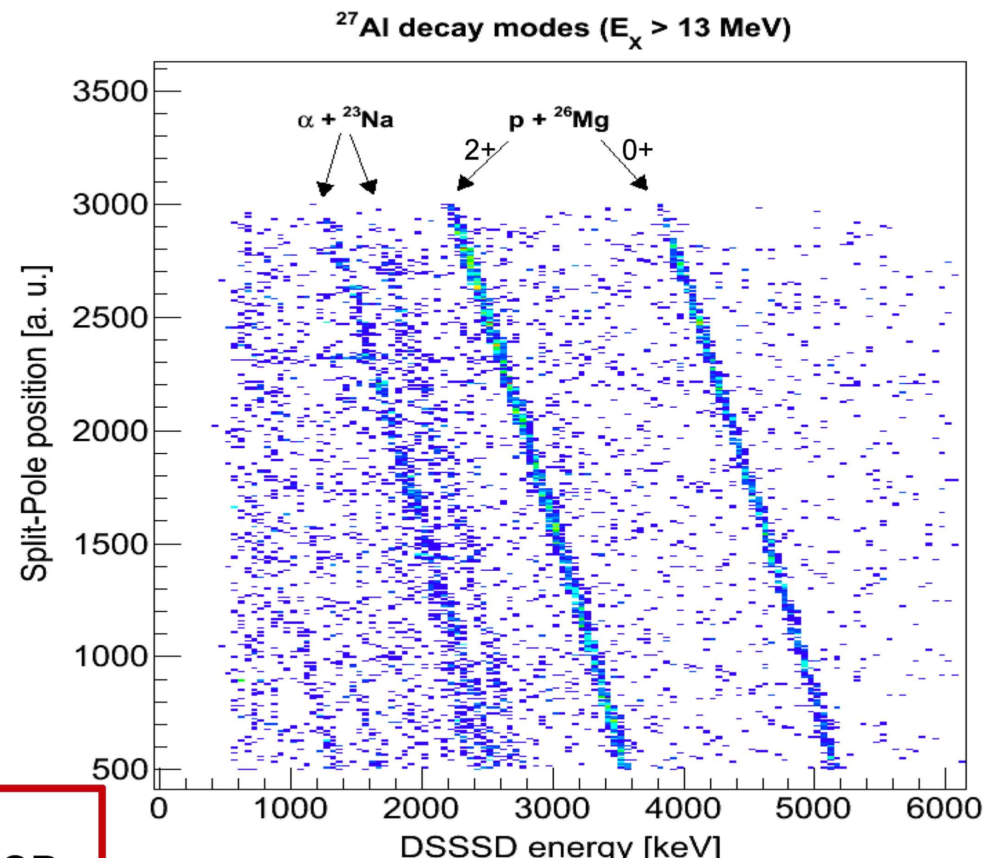
SP - DSSSDs coupling successful

- I ~ 80 – 100 enA (!)

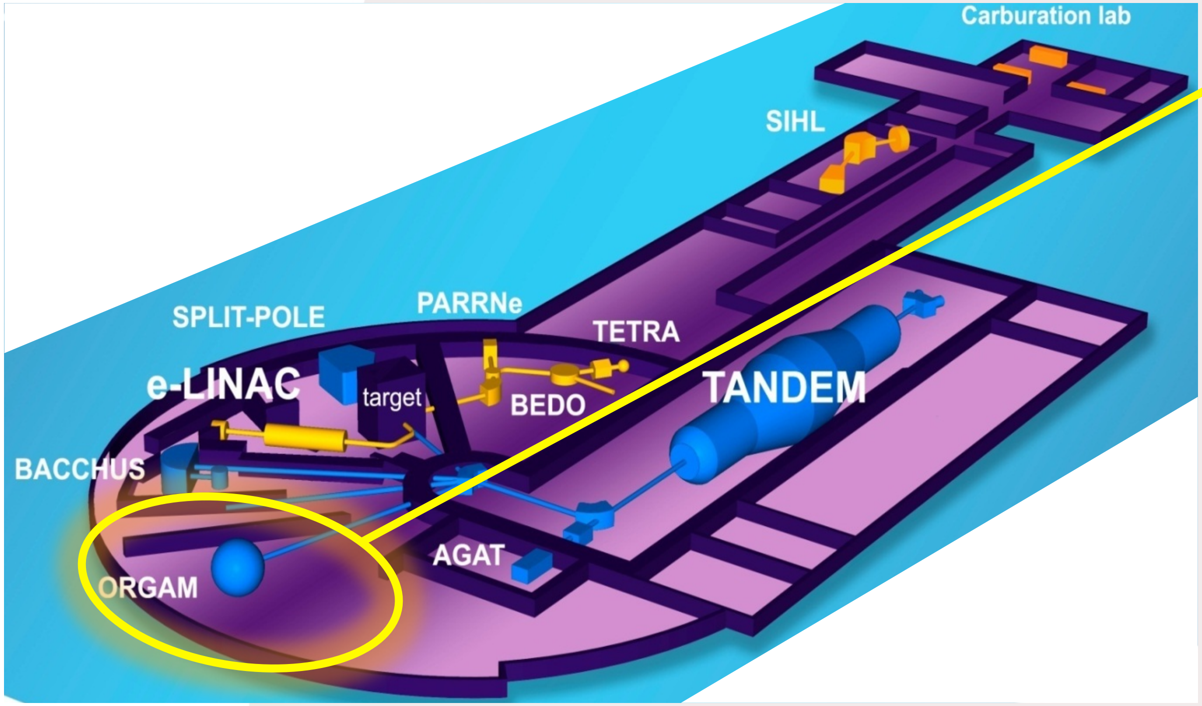
Very good beam tuning
Low background environment for DSSSDs

Branching ratios

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



THE ORGAM ARRAY

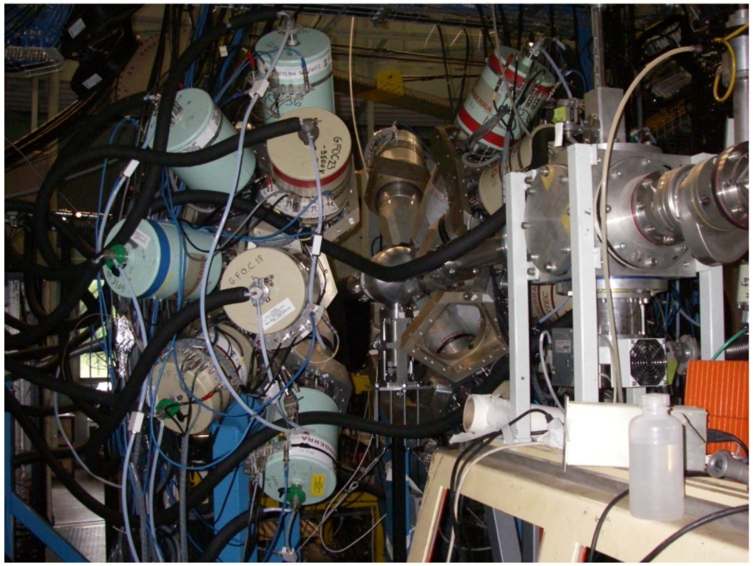


The ORsay GAMma array

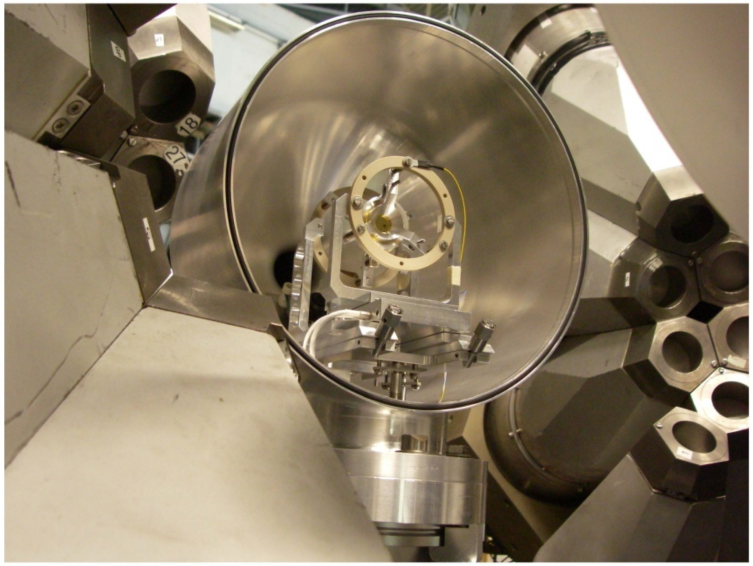
The OUPS: the first campaigns

Performed experiment

$^{45}Sc(^{35}Cl,2p2n)^{76}Kr$, 126 MeV



- Well known lifetimes in yrast band
- Simple beam
- Simple target
- High cross section, $\gamma\gamma$
- Experiment 5 days with 7 Compton Supressed Phase-I detectors

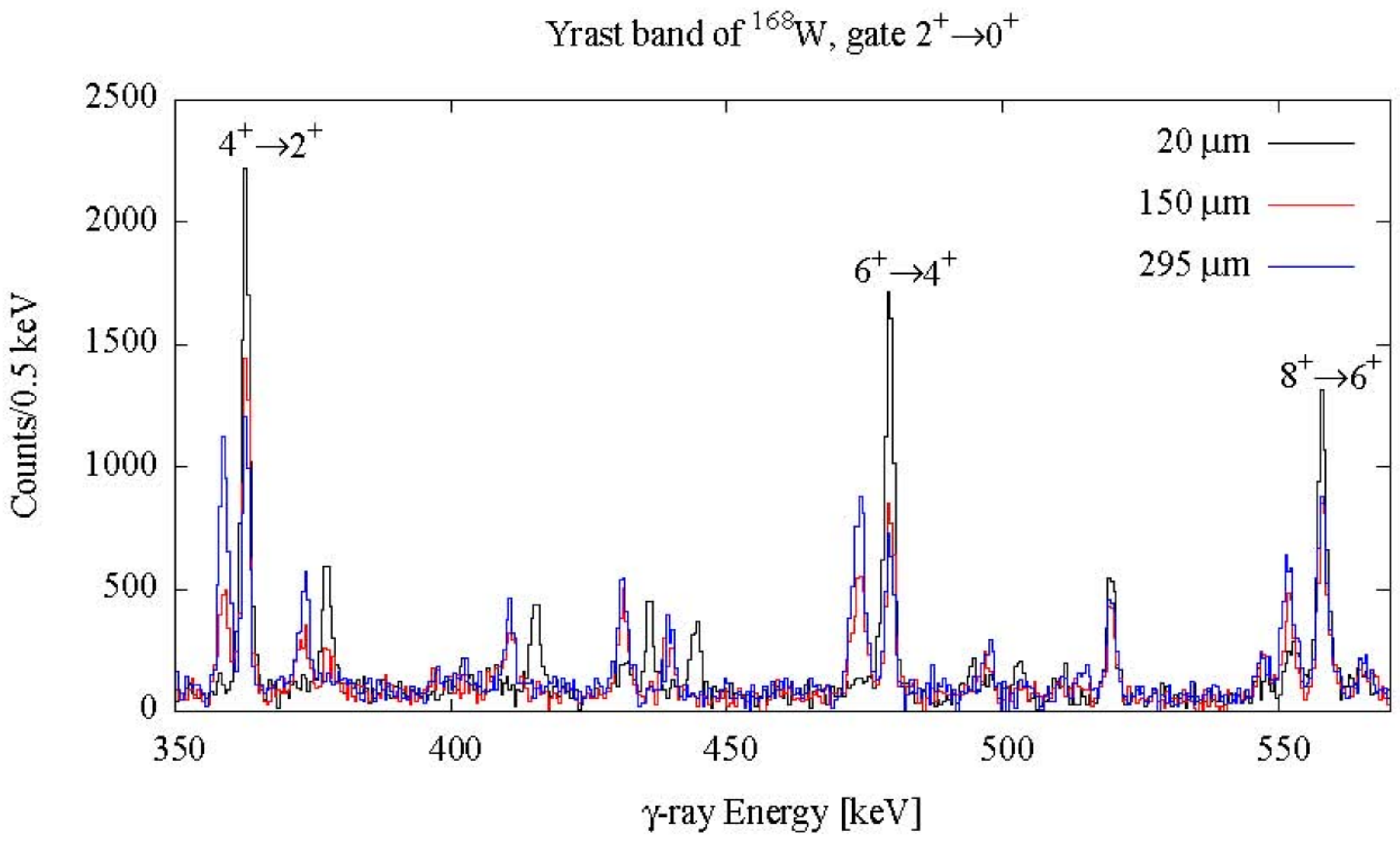


Search for X(5) symmetry in ^{168}W nucleus. K. Gladnishki

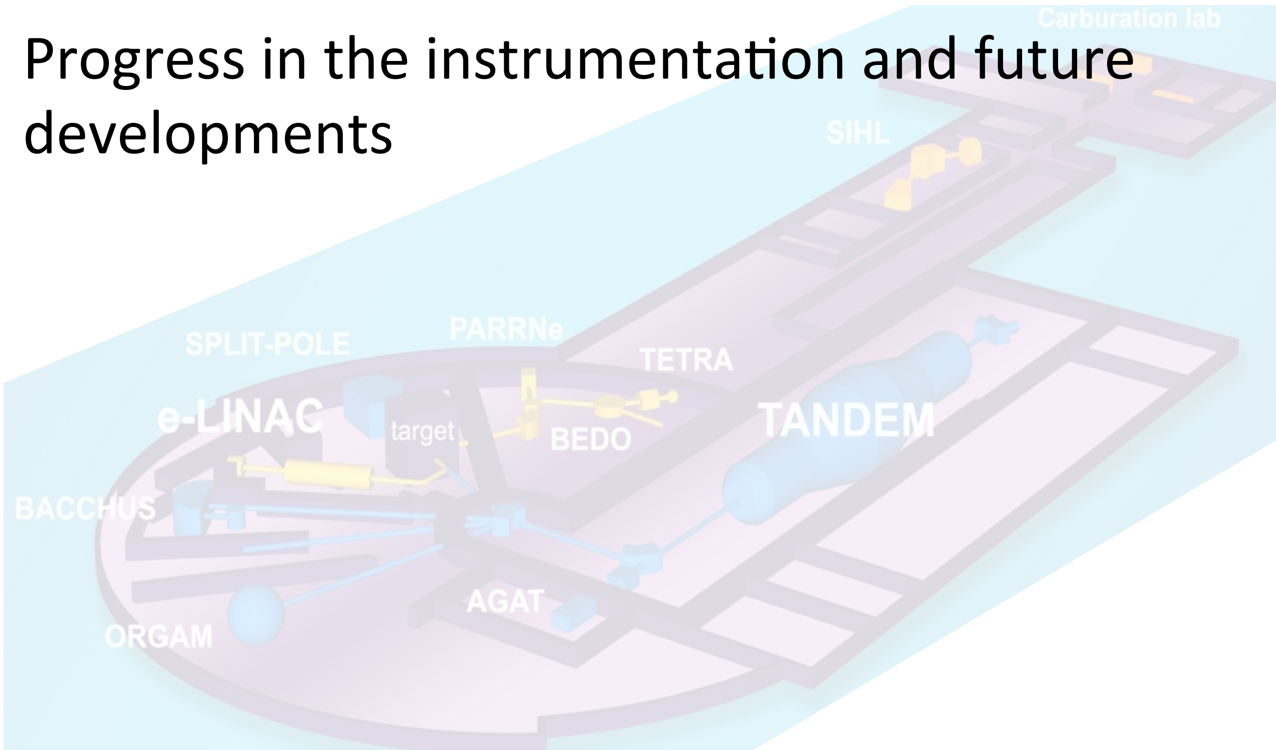
- ^{168}W is a candidate for a X(5) nucleus
- To test this ratios of excitation energies and transition probabilities are used
- Higher precision of and/or new lifetime values needed

- $^{141}Pr(^{31}P,4n\gamma)^{168}W$
- ^{141}Pr target on Ta backing (made at IKP Cologne)
- 13 Phase I HPGe mounted in Orgam
- Au gold stopper foil
- Short lifetimes - γ-gated DDCM+DSAM

Search for X(5) symmetry in ^{168}W nucleus. K. Gladnishki



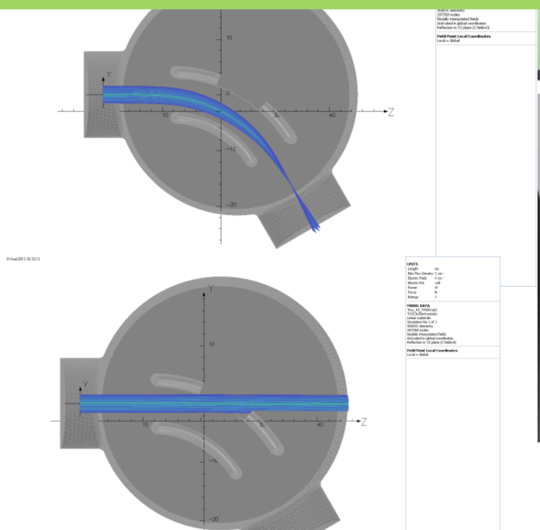
Progress in the instrumentation and future developments



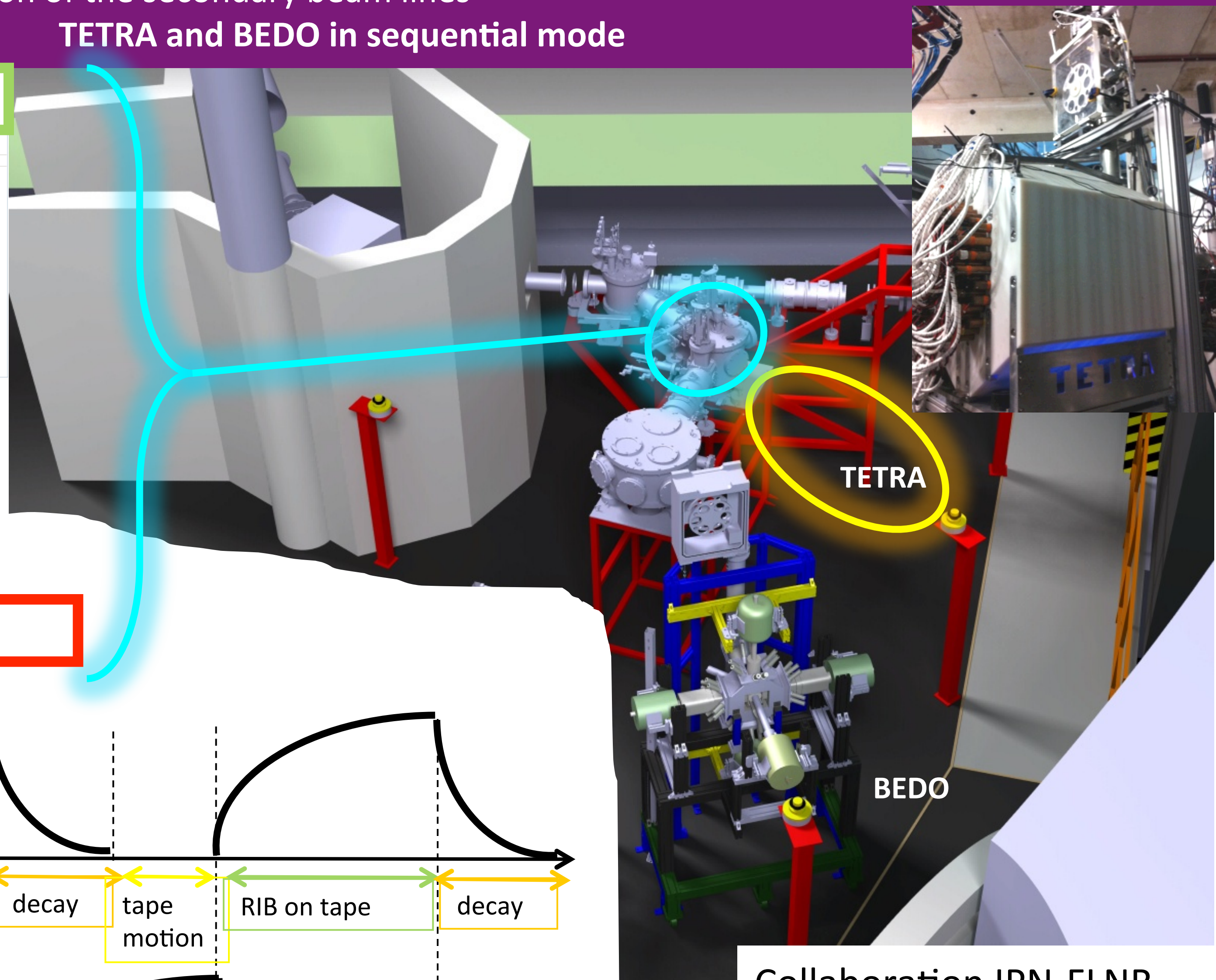
Progress in the instrumentation of the secondary beam lines

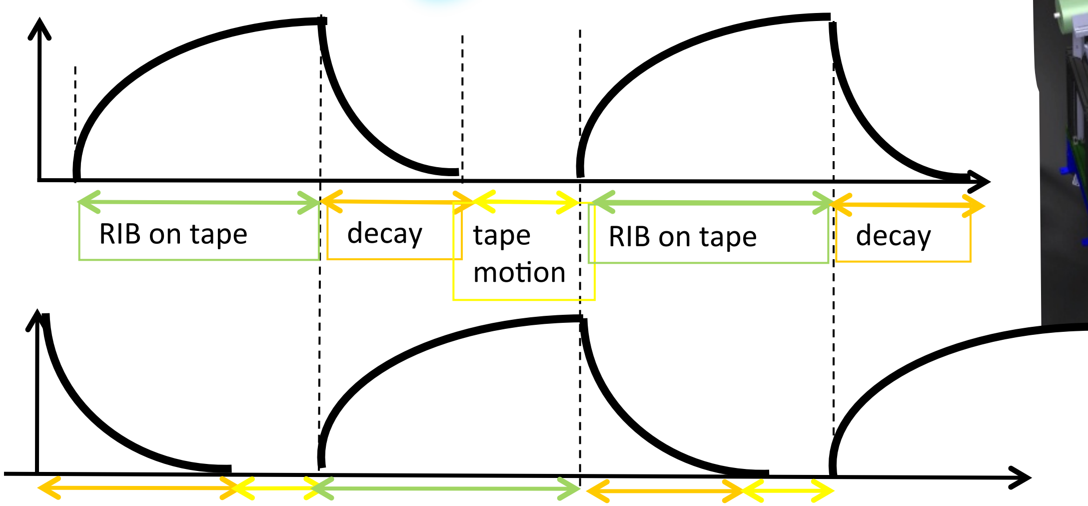
TETRA and BEDO in sequential mode

dipole ON -> towards BEDO



dipole OFF -> towards TETRA



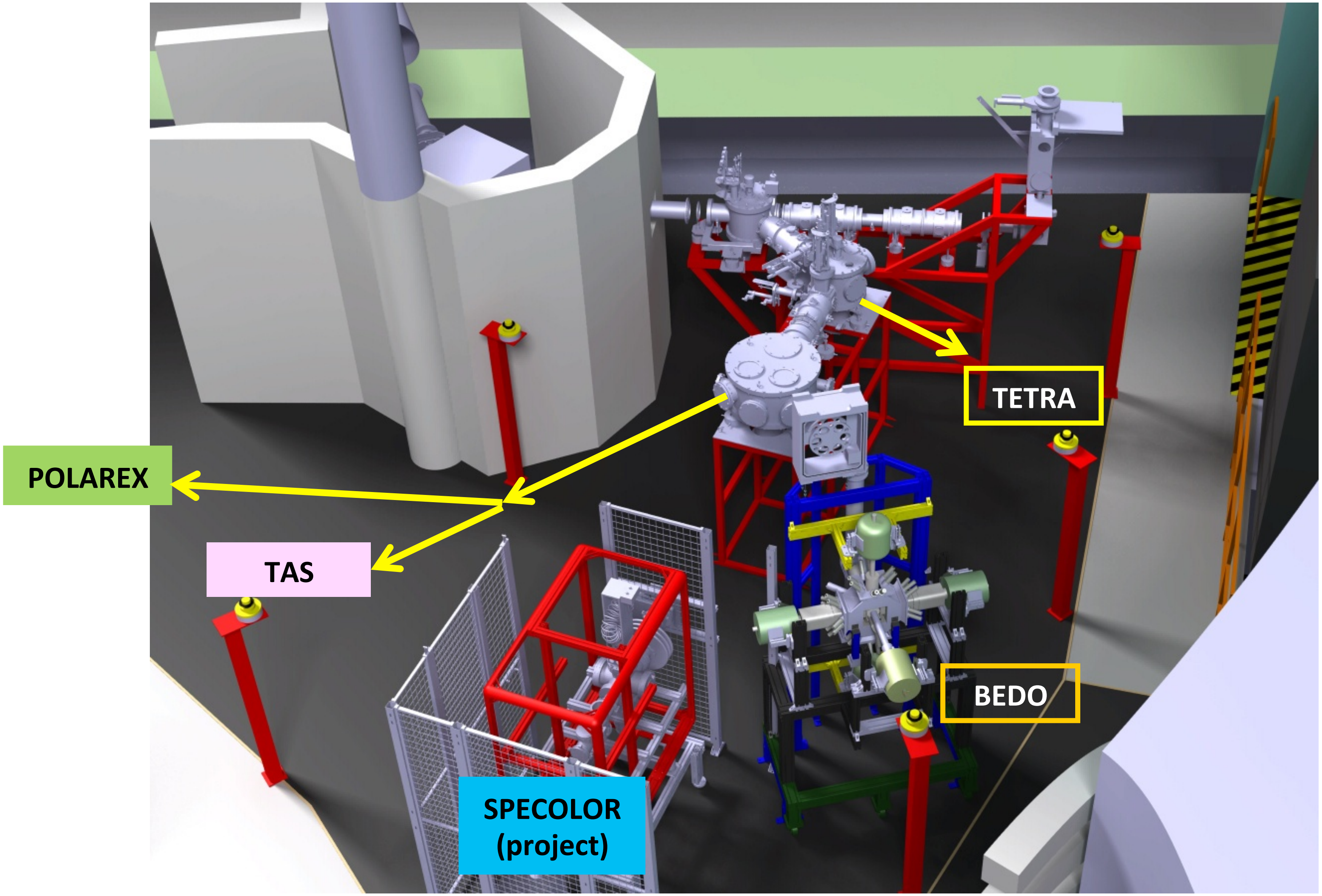


Collaboration IPN-FLNR Orsay-Dubna

Expected on line March-April 2014

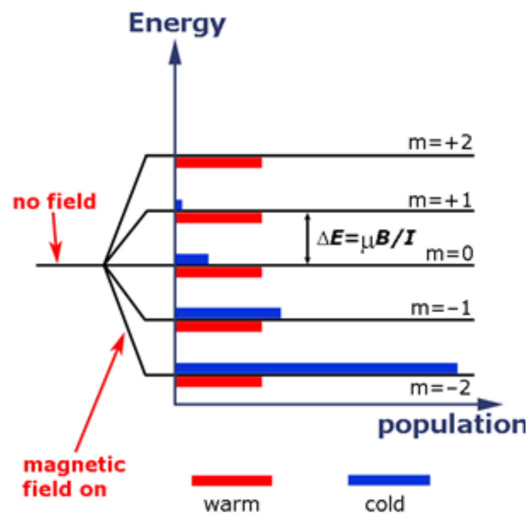
Nuclear orientation on line: the POLAREX project at ALTO

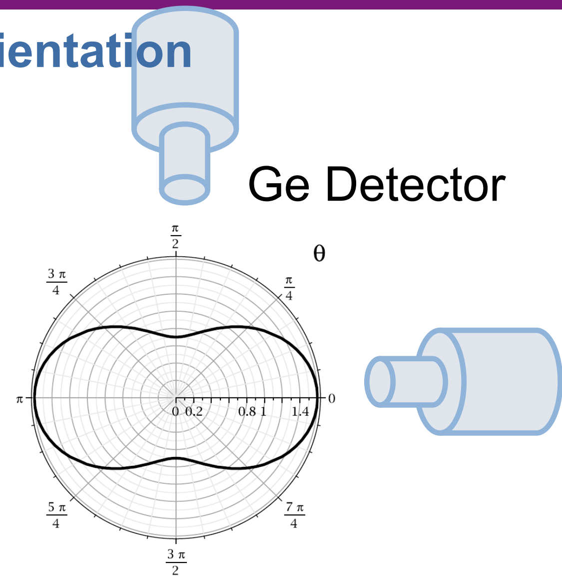
Physics at the right arm of the kicker-bender



Low Temperature Nuclear Orientation

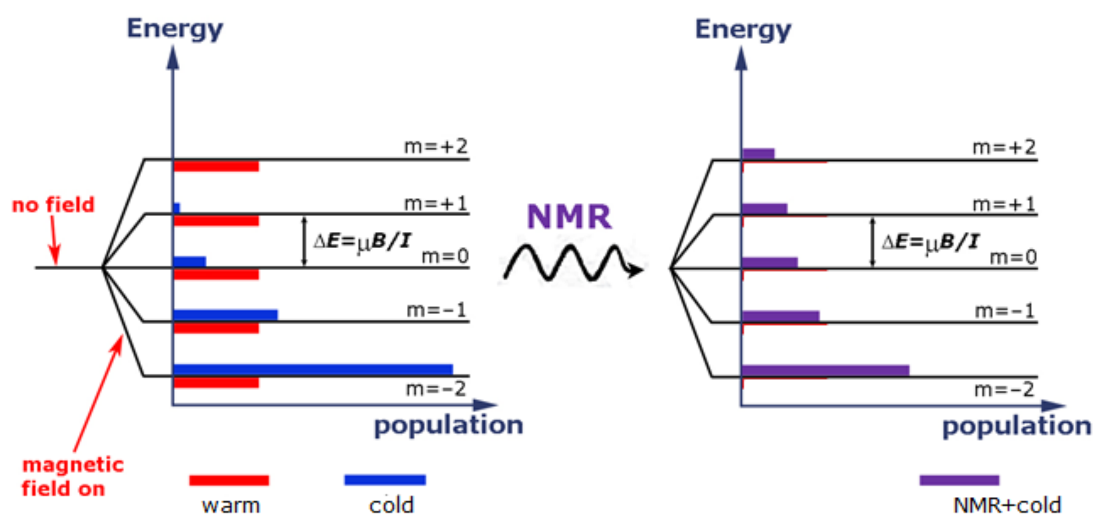
Courtesy S. Roccia





The detail of the shape of the angular distribution depends on the particular transition: **spins** of the nuclear states involved, **transition multipolarities**, and also on the environment of the nuclei like the **total magnetic field** and the **temperature**.

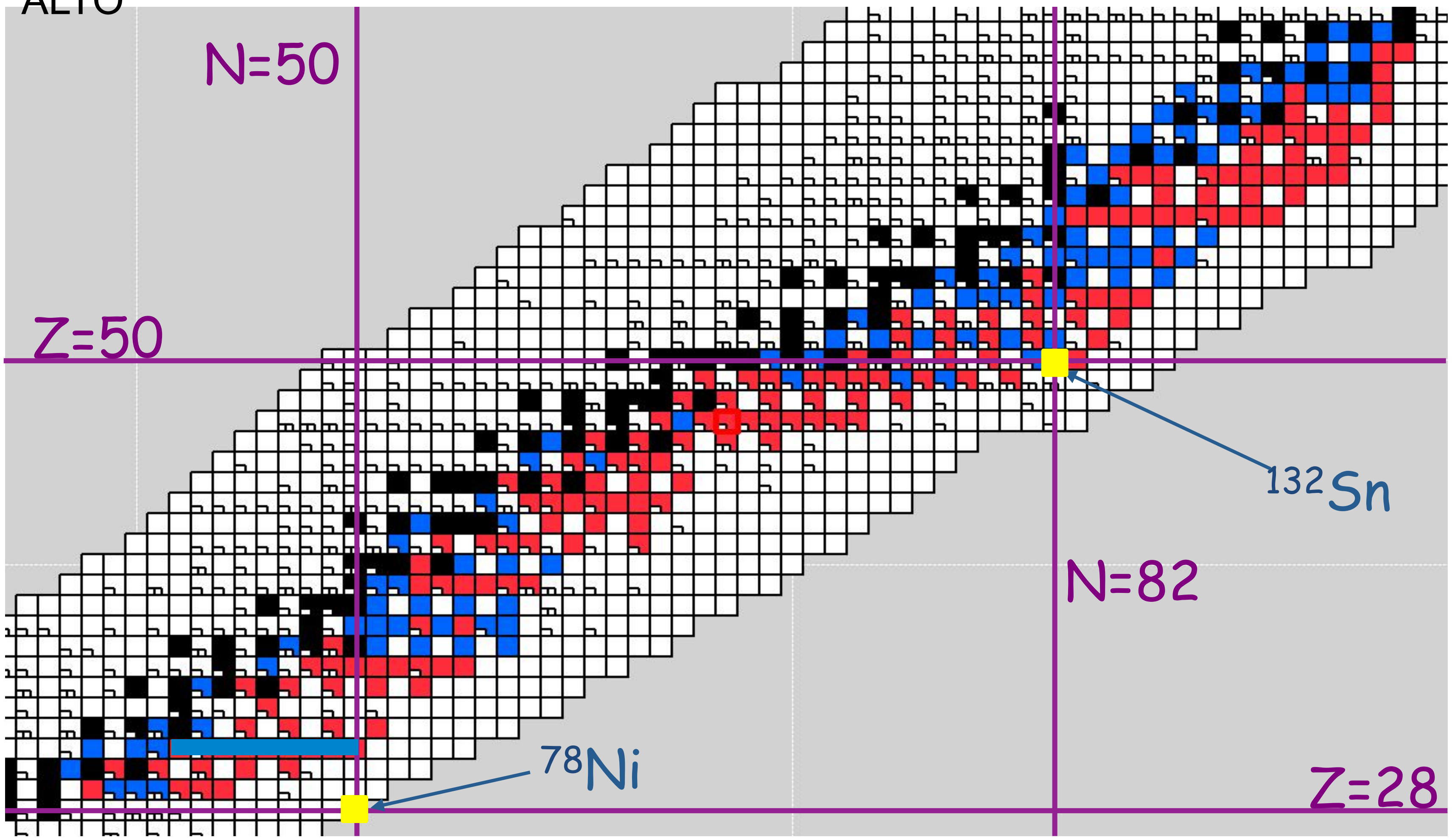
AND Nuclear Magnetic Resonance



The **good frequency** -> the **magnetic moment**
Provided the **magnetic field** and the **temperature** are known

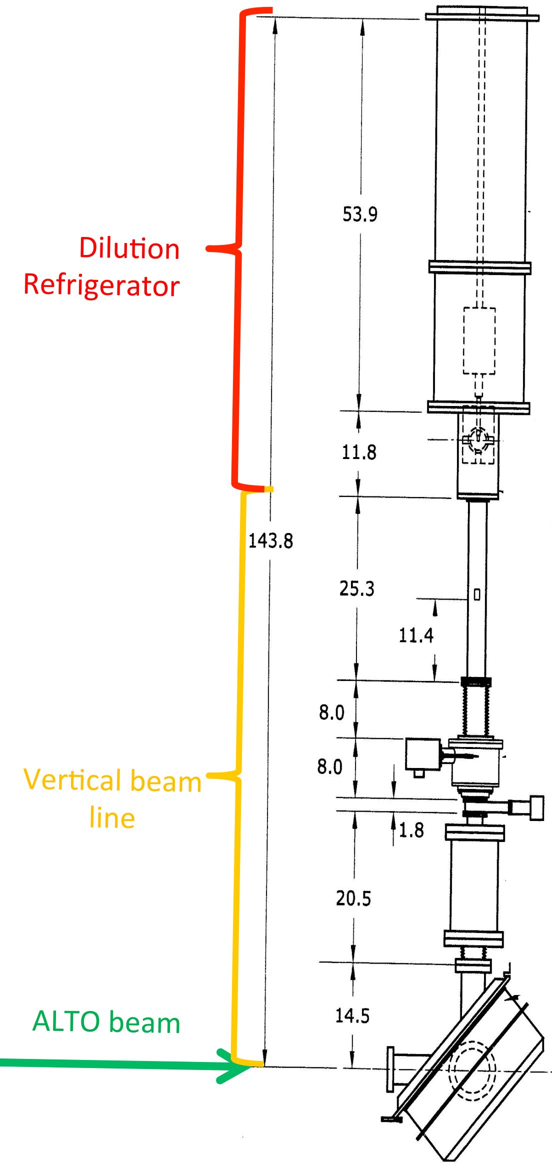
- Hyperfine information
- Nuclear thermometer

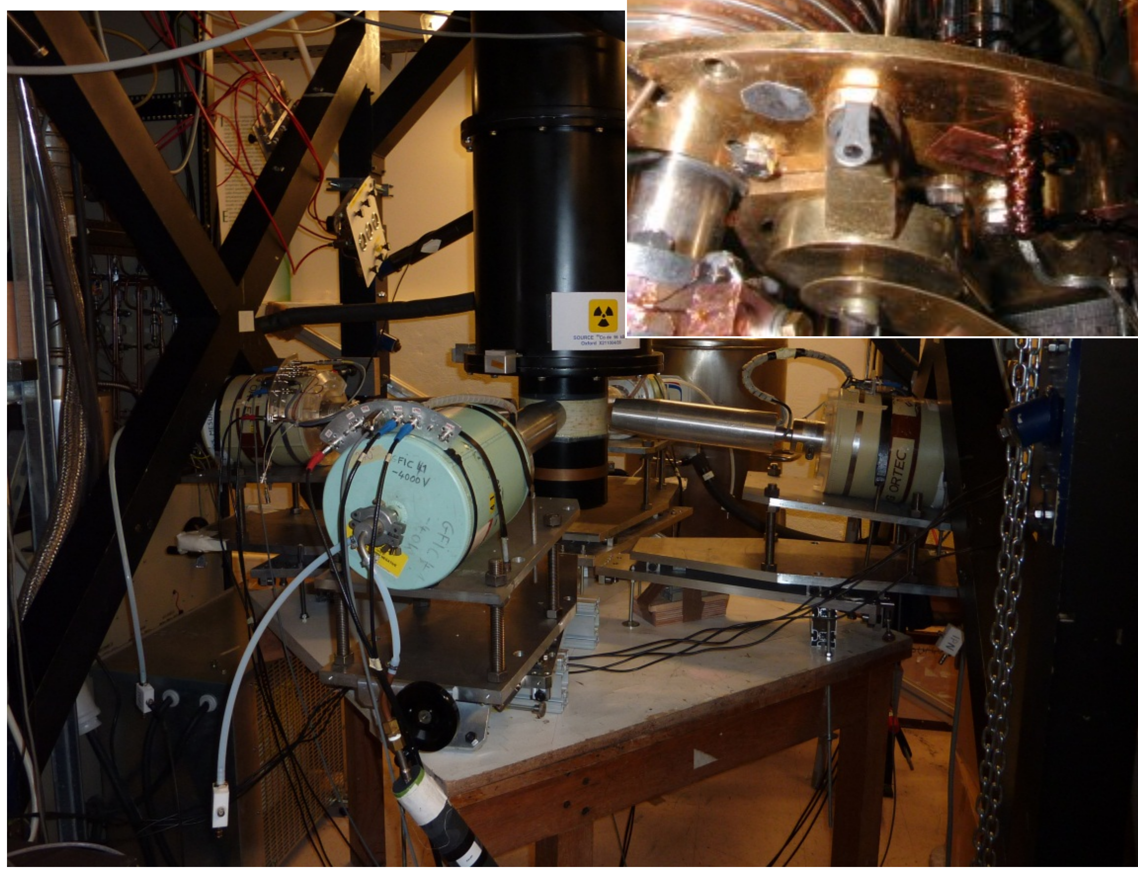
Possible and/or interesting measurements at ALTO

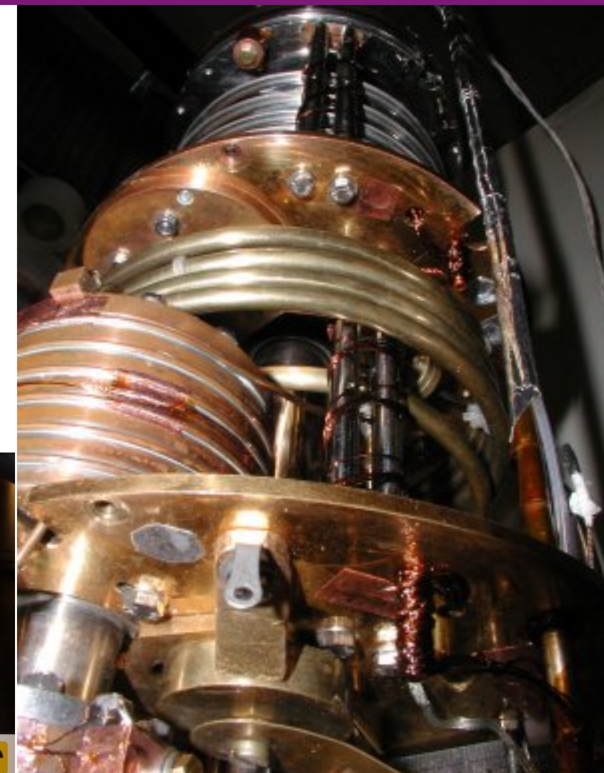


Progress in the instrumentation of the secondary beam lines

POLAREX





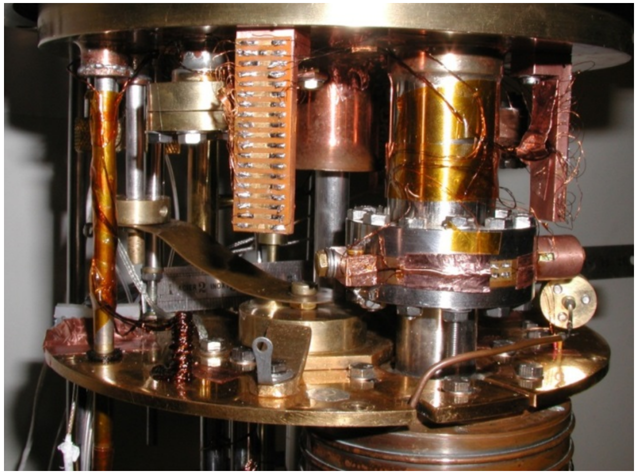


POLAREX

POLAREX

PolarEx
Rejuvenation of the dilution cryostat
Thermometry
Electronics
Acquisition control

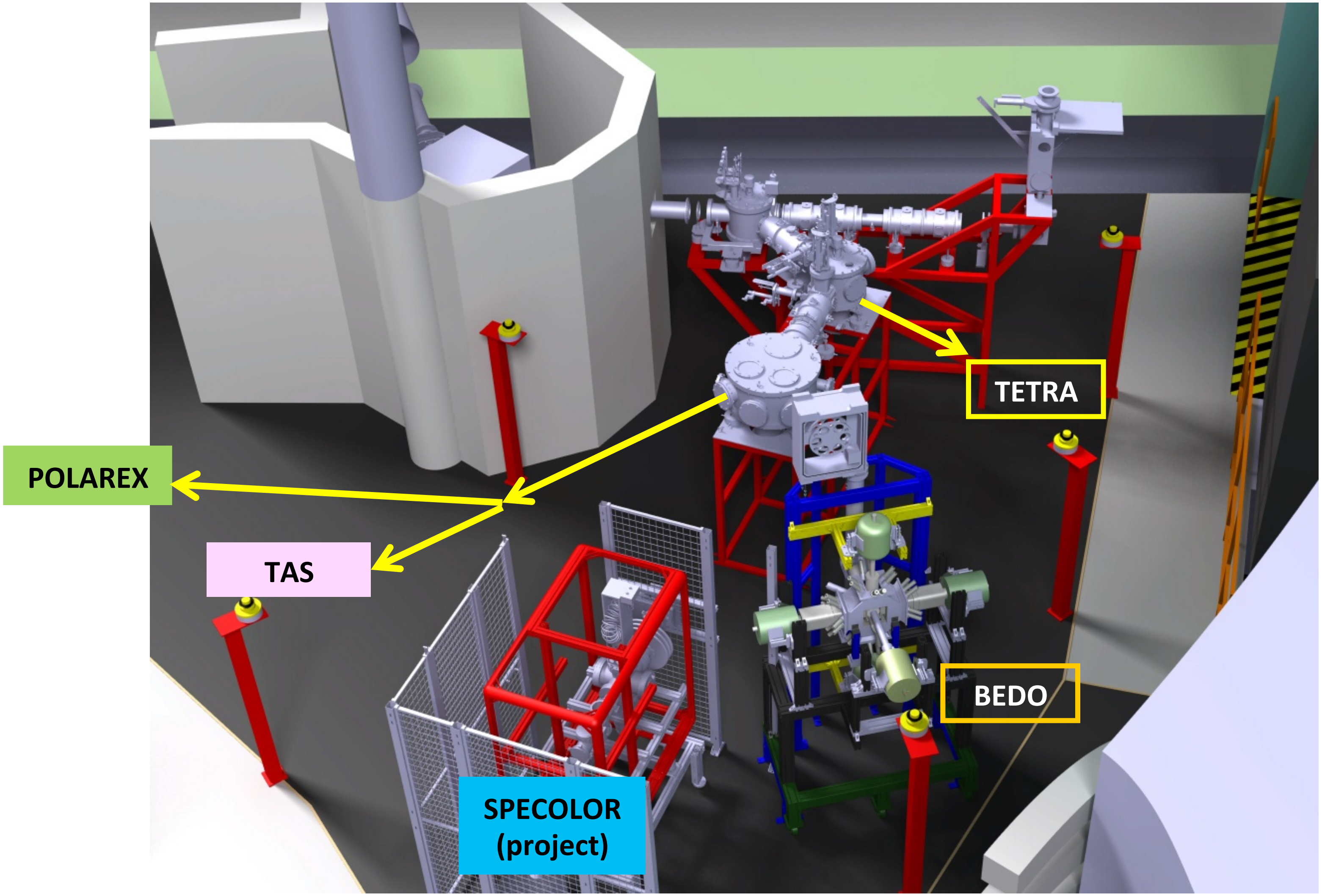
Preparation on the ALTO site
Structure and platforms
Faisceaulogie and beam line design



- letters of intent received
- **OFF line measurements at CSNSM** √
- OFF line measurements at ALTO ×
- ON line measurements at ALTO ×

Collaboration
- ***CSNSM Orsay*:**
A. Astier, G. Audi, S. Cabaret, A. Etilé, C. Gaulard, G. Georgiev, S. Roccia
- ***LPSC Grenoble*:**
G. Simpson
- ***IPN Orsay*:**
F. Ibrahim, D. Verney
- ***INM* :**
L. Risegari
- ***University of Tennessee*, University of Oxford**
N.J. Stone
- ***University of Maryland*,University of Oxford**
J.R. Stone
- ***University of Novi Sad* :**
M. Veskovic J. Nikolov

Physics at the right arm of the kicker-bender



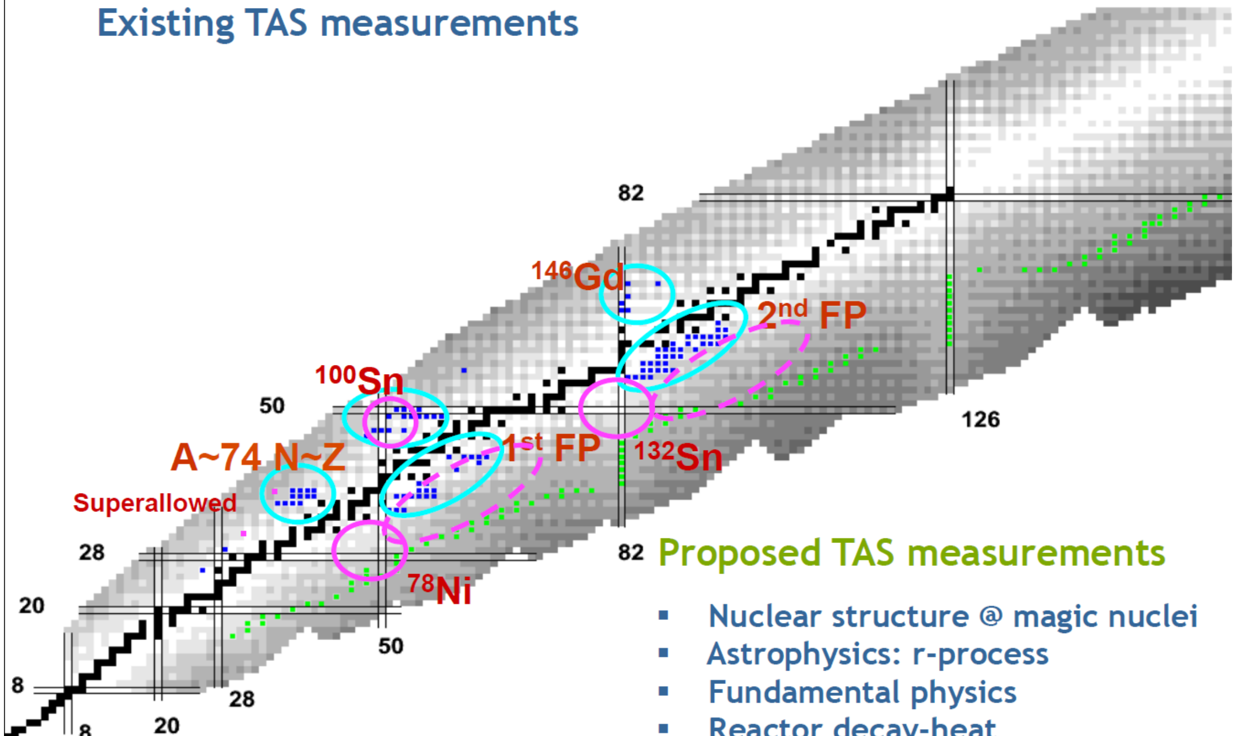
TAS: **Total Absorption Spectroscopy program**

The TAS Collaboration

J. Agramunt[1], A. Algora[1], J. Äystö[4], V.M. Bui[2], D. Cano-Ott[5], C. Domingo-Pardo[1], V. Eloma[4], E. Estévez[1], T. Eronen[4], M. Fallot[2], W. Gelletly[3], G. Giubrone[1], J. Hakala[4], A. Jokinen[4], M.D. Jordan[1], A. Kankainen[4], E. Mendoza[5], F. Molina[1], ,I. Moore[4], S.E.A. Orrigo[1], A. Pérez[1], Zs. Podolyák[3], H. Penttilä[4], A.Porta[2], P. H. Regan[3], S. Rice[3], J. Rissanen[4], B. Rubio[1],J.L. Taín[1], E. Valencia[1], C. Weber[4], A. Zakari[2] + IGISOL people

1 IFIC, CSIC-Univ. Valencia, Valencia, Spain
2 Subatech, CNRS/IN2P3, Univ. Nantes, EMN, Nantes, France
3 Univ. Surrey, Guilford, UK
4 IGISOL, Univ. Jyväskylä, Finland
5 Ciemat- Madrid, Spain

Existing TAS measurements



Proposed TAS measurements

- Nuclear structure @ magic nuclei
- Astrophysics: r-process
- Fundamental physics
- Reactor decay-heat
- Reactor antineutrino spectra

A. Algora, B. Rubio, J.-L. Taín – IFIC-Valencia

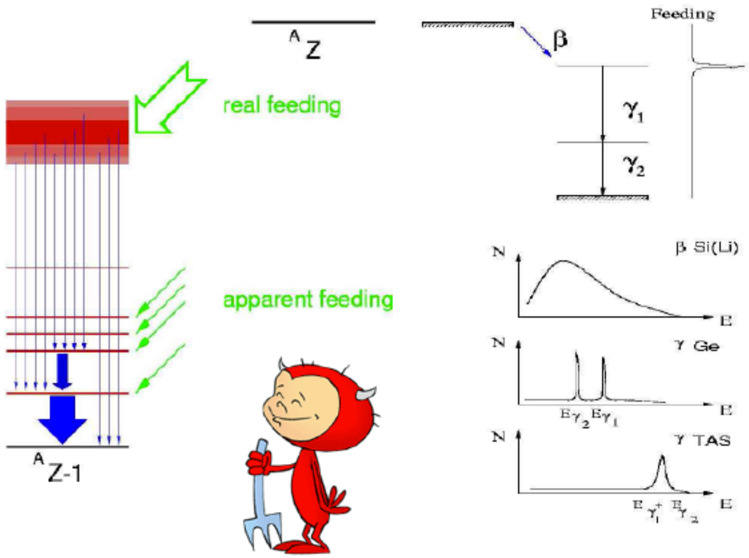
TAS Technique

Courtesy M. Fallot

Pandemonium effect**:

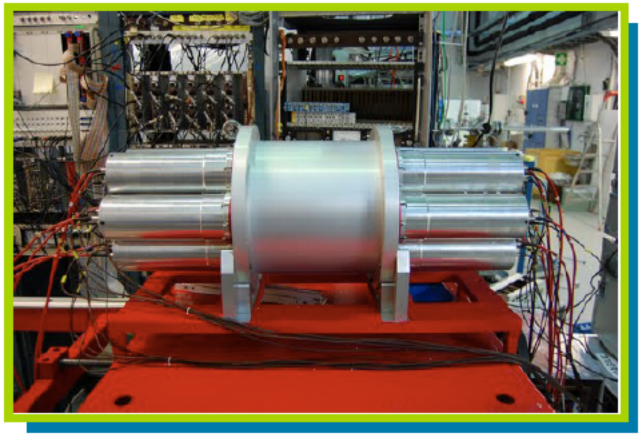
Due to the use of Ge detectors to measure the decay schemes: lower efficiency at higher energy

→ 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 !



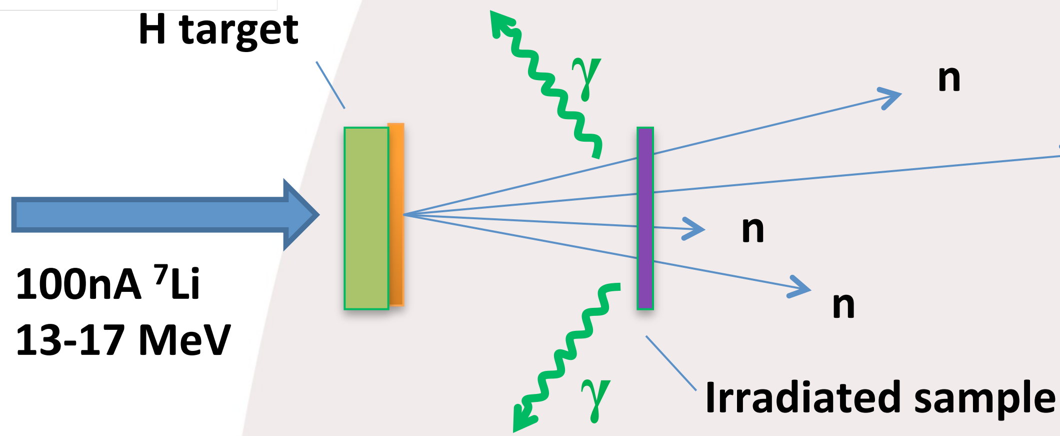
- 12 BaF_2 covering ~4π
- Detection efficiency of γ ray cascade ~ 100%
- Si detector for β

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

Subatech

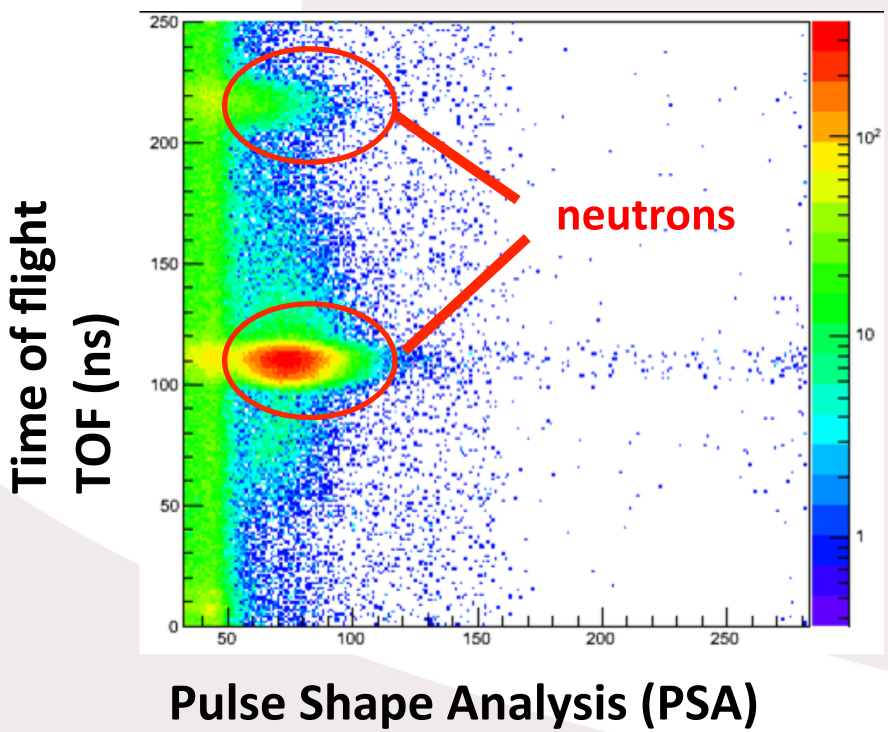
TAGS developed by the Valencia team (Spain, B. Rubio, J.L. Tain, A. Algora et al.) : Proceedings of the Int. Conf. For nuclear Data for Science and technology (ND2013)

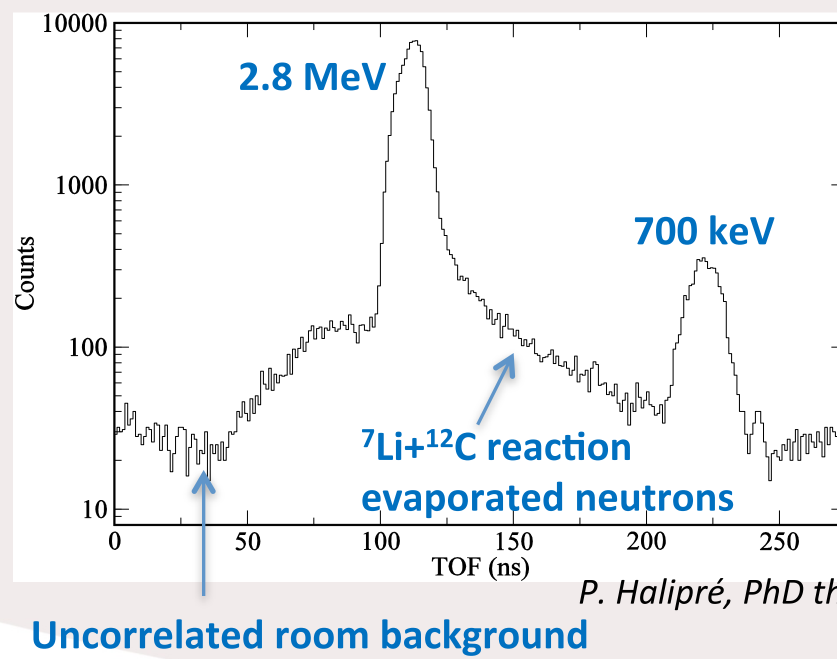
LICORNE 2013: COLLABORATION IPNO/IRMM



Focused intense source of mono-energetic neutrons:
10^{7} n/s/steradian

E_n=0.5 – 4 MeV





P. Halipré, PhD thesis

The LICORNE Project: Neutron production at the ALTO facility

M. Lebois and J.N. Wilson and, P. Halipré, B. Leniau
IPN, Orsay, France

S. Oberstedt
IRMM, Geel, Belgium

Uppsala University, Sweden
Chalmers University, Gothenburg Sweden
University of York, UK
University o Manchester, UK
Lawrence Livermoore Laboratory, USA

TNA	Number of beam hours promised -full contract	Number of beam hours 01/09/2010 - 30/04/2013	Estimated number of Users - full contract	Number of Users 01/09/2010 - 30/04/2013	Estimated number of days - full contract	Number of days 01/09/2010 - 30/04/2013	Estimated number of projects - full contract	Number of projects - 01/09/2010 - 30/04/2013	Total amount for T&S - full contract	Amount for T&S 01/09/2010 - 30/04/2013
ALTO	1470	**2400**	116	**80**	556	**576**	19	**19**	73 720€	**64 320€**