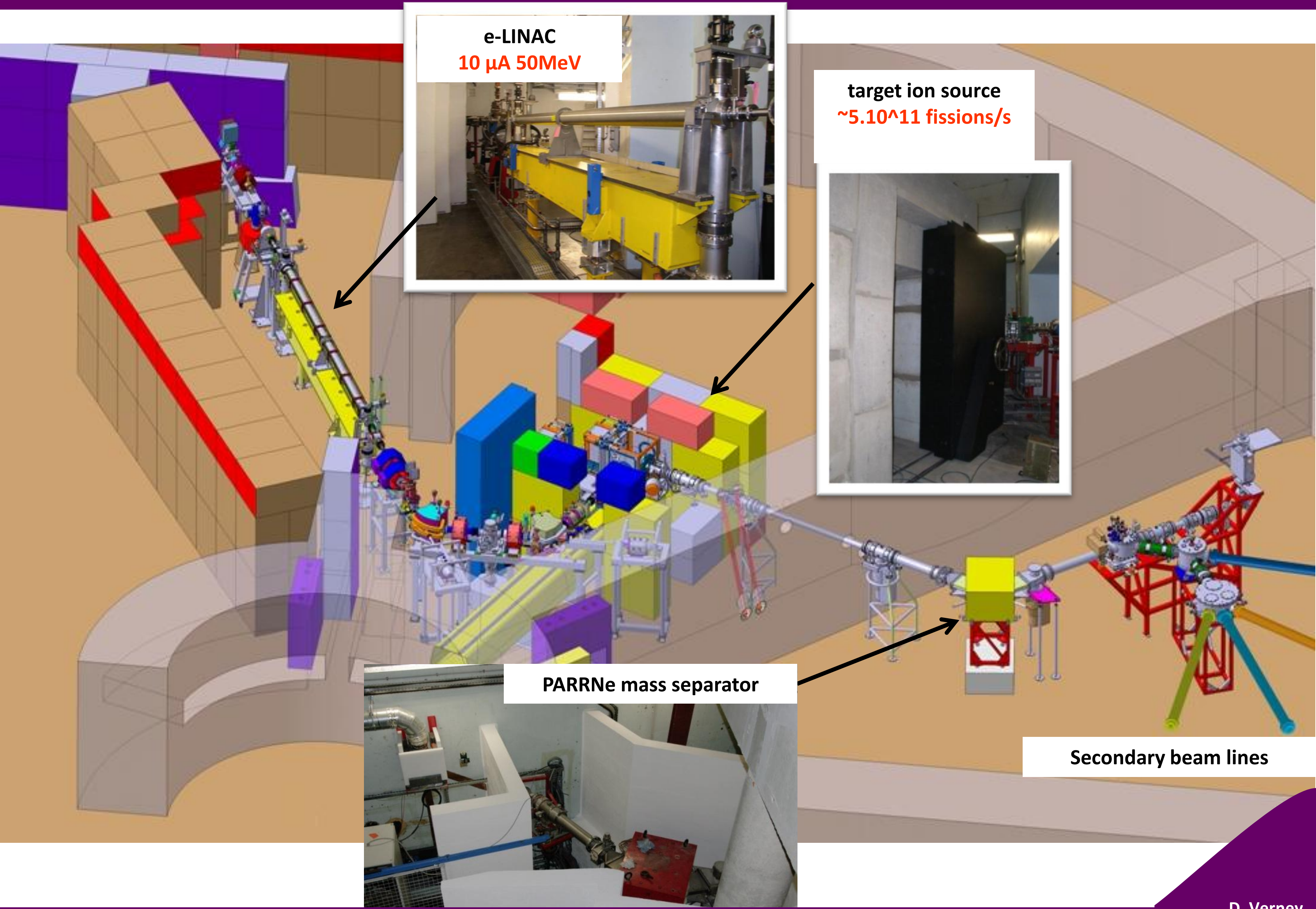
Physics with stopped fission-fragment beams at ALTO and DESIR

1. recent achievements using the ISOL technique at IPN Orsay
   - fast-neutron induced fission and photofission
   - physics addressed (N=50)
2. short term perspectives
3. longer term perspectives : BESTIOL at DESIR

accelerator building of IPN

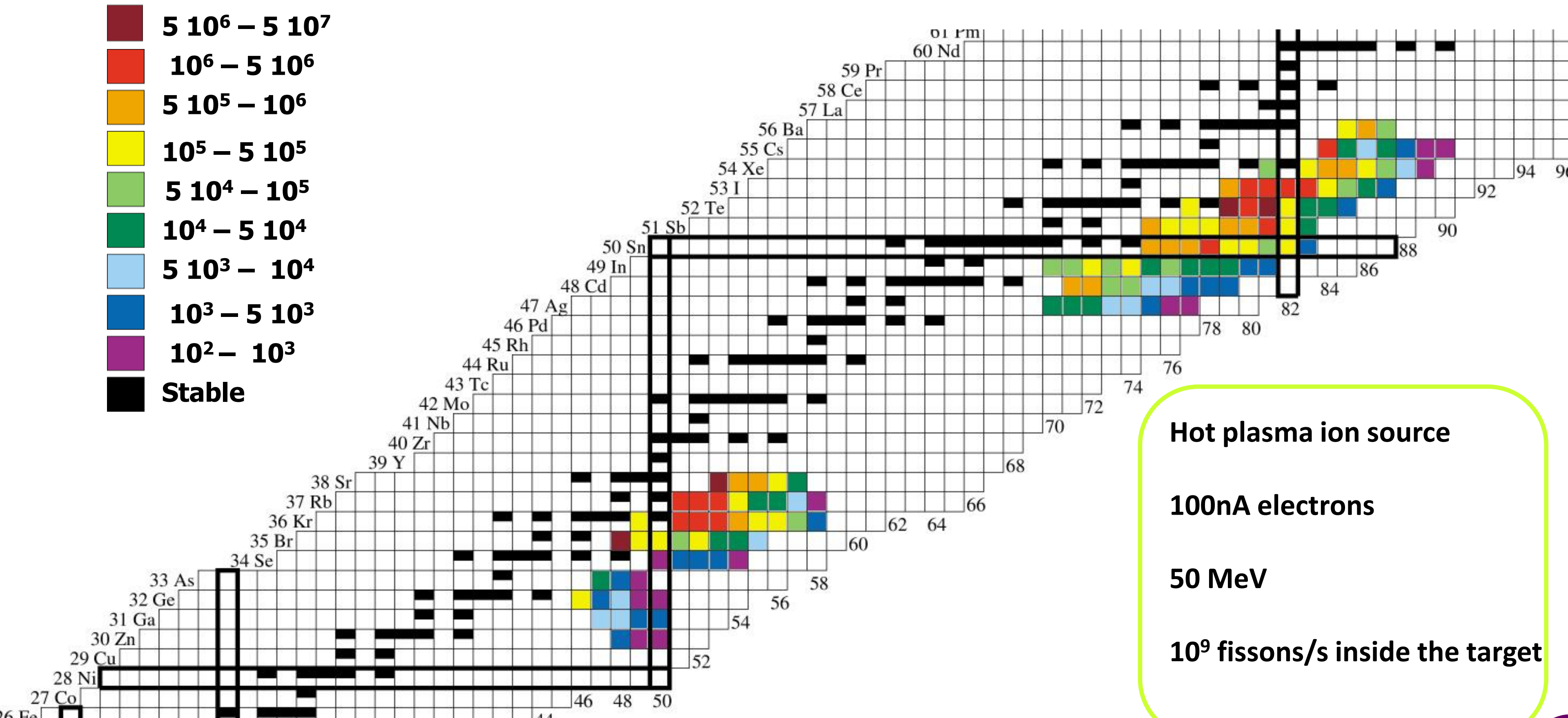
ALTO
Accélérateur Linéaire et Tandem à Orsay

ISOL installation



Measured productions yields at the detection point on line with the PARRNe mass separator
electrons -> gamma induced fission

Production /s/100nA **measured in june 2006**



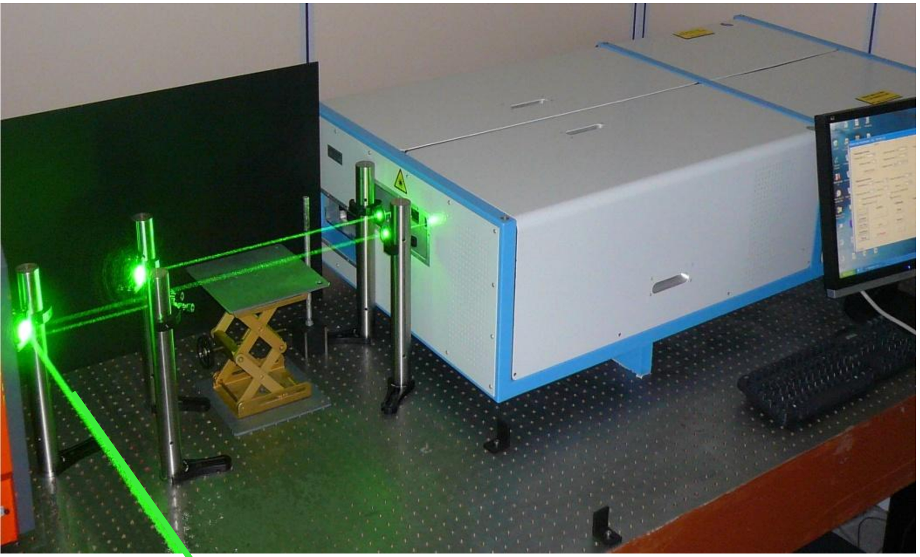
Hot plasma ion source

100nA electrons

50 MeV

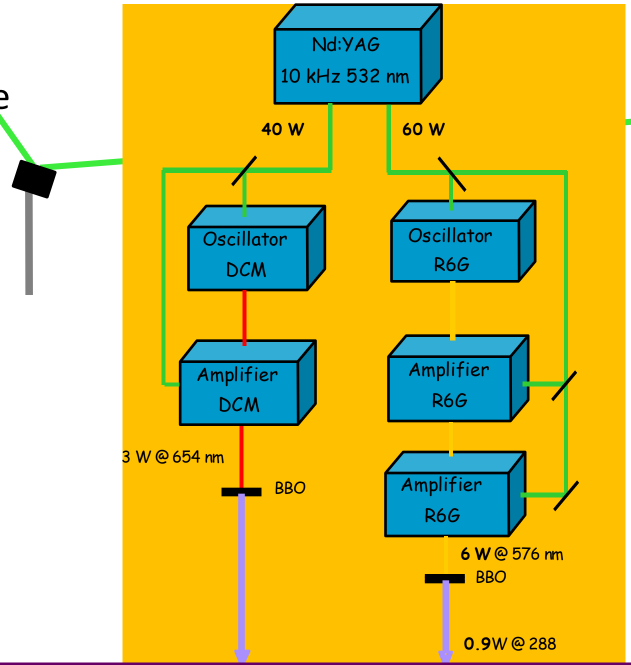
10^9 fissons/s inside the target

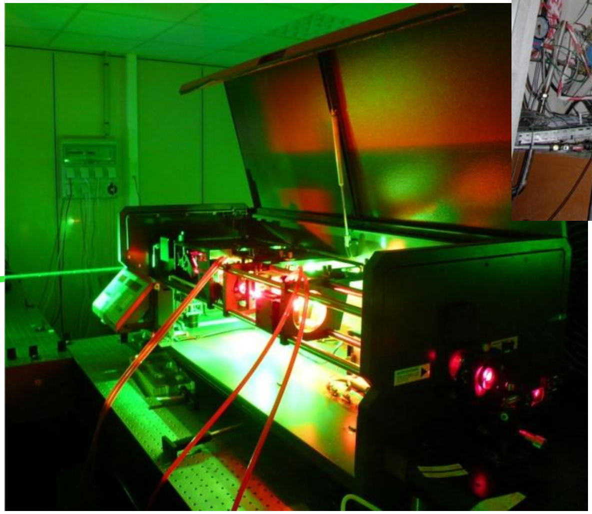
Laser Ion Source Laser at ALTO : LISA



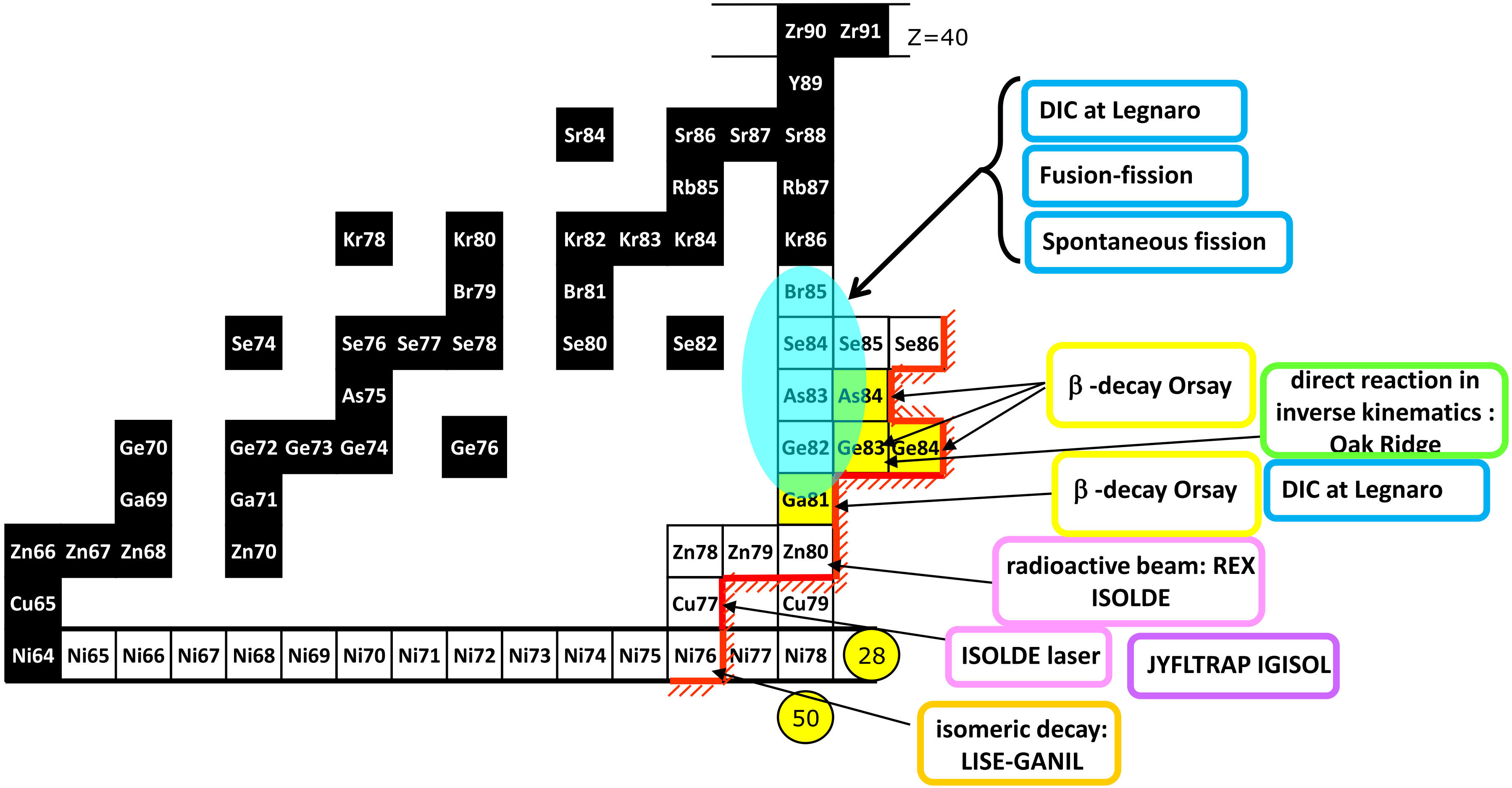
Distance sorties lasers -ECS
~20m
Focalisation à 20m
$\Phi_{\text{tube ionisation}}$: 3mm

Schéma de principe pour le cuivre



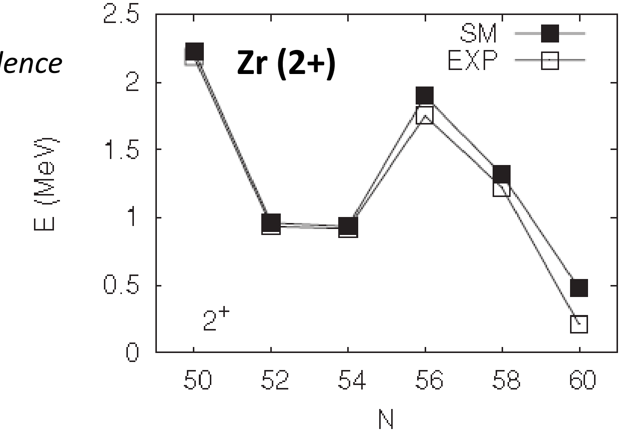


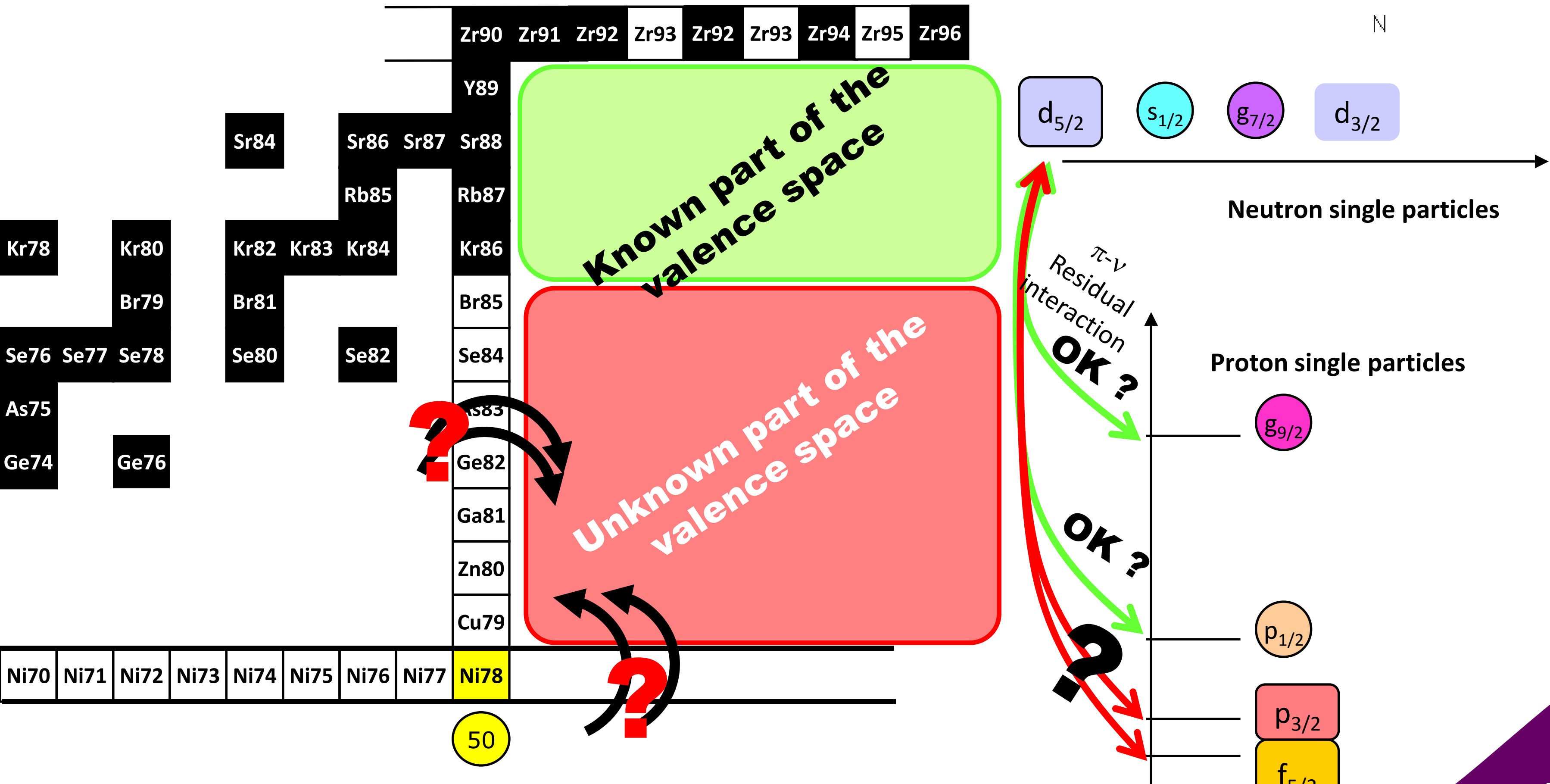
first beam : Ga (test sep-oct 2010)
then Cu


Zr90 Zr91
Z=40
Y89
Sr84 Sr86 Sr87 Sr88
Rb85 Rb87
Kr78 Kr80 Kr82 Kr83 Kr84 Kr86
Br79 Br81 Br85
Se74 Se76 Se77 Se78 Se80 Se82 Se84 Se85 Se86
As75 As83 As84
Ge70 Ge72 Ge73 Ge74 Ge76 Ge82 Ge83 Ge84
Ga69 Ga71 Ga81
Zn66 Zn67 Zn68 Zn70 Zn78 Zn79 Zn80
Cu65 Cu77 Cu79
Ni64 Ni65 Ni66 Ni67 Ni68 Ni69 Ni70 Ni71 Ni72 Ni73 Ni74 Ni75 Ni76 Ni77 Ni78
28
50
DIC at Legnaro
Fusion-fission
Spontaneous fission
β -decay Orsay
direct reaction in inverse kinematics : Oak Ridge
β -decay Orsay
DIC at Legnaro
radioactive beam: REX ISOLDE
ISOLDE laser
JYFLTRAP IGISOL
isomeric decay: LISE-GANIL

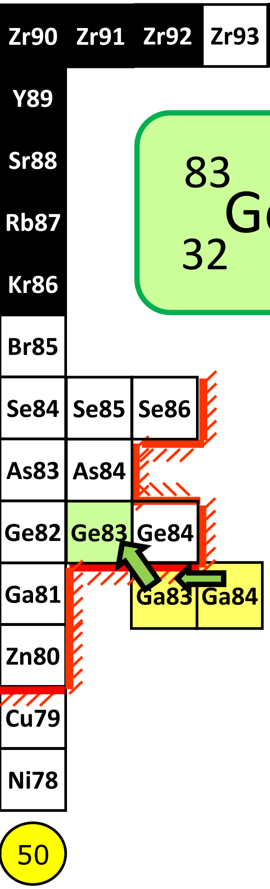
- Is ^{78}Ni a good core? Persistence of Z=28 and N=50, pair promotions from the lower shells
- What is the nature of valence space which opens up just above ? single particle sequence

SM calculations in valence space above ^{78}Ni
*K. Sieja et al. PRC **79**, 064310 (2009)*





example of the N=51 chain



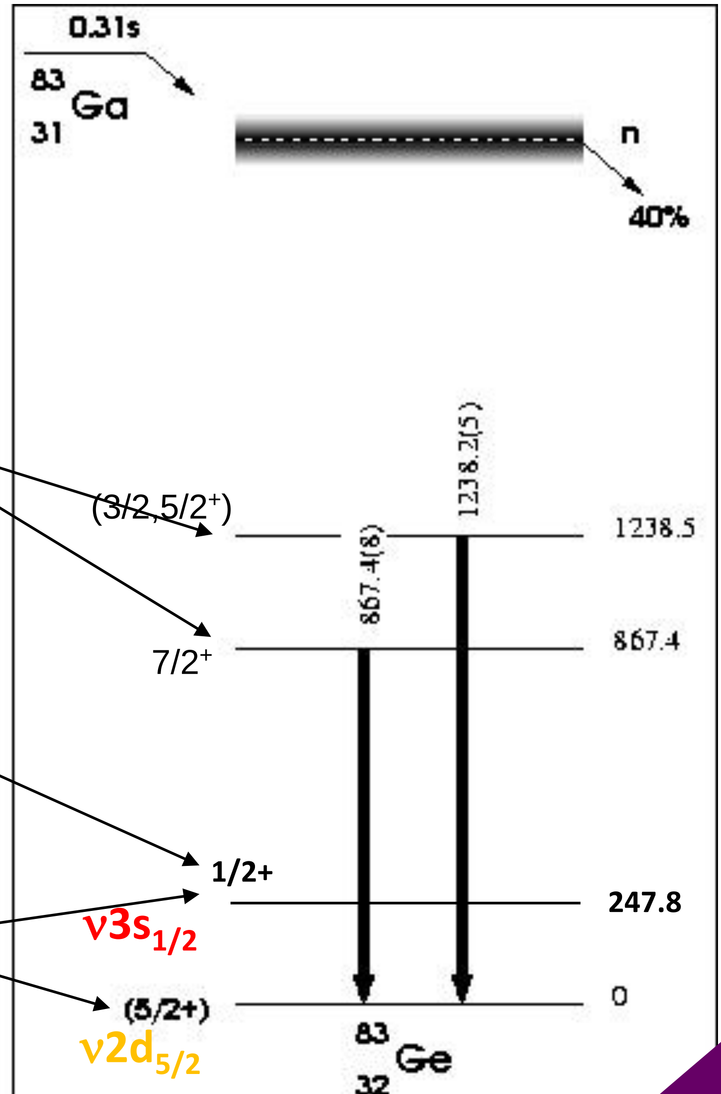
$^{83}_{32}\mathrm{Ge}_{51}$

4 protons + 1 neutron au dessus de ^{78}Ni

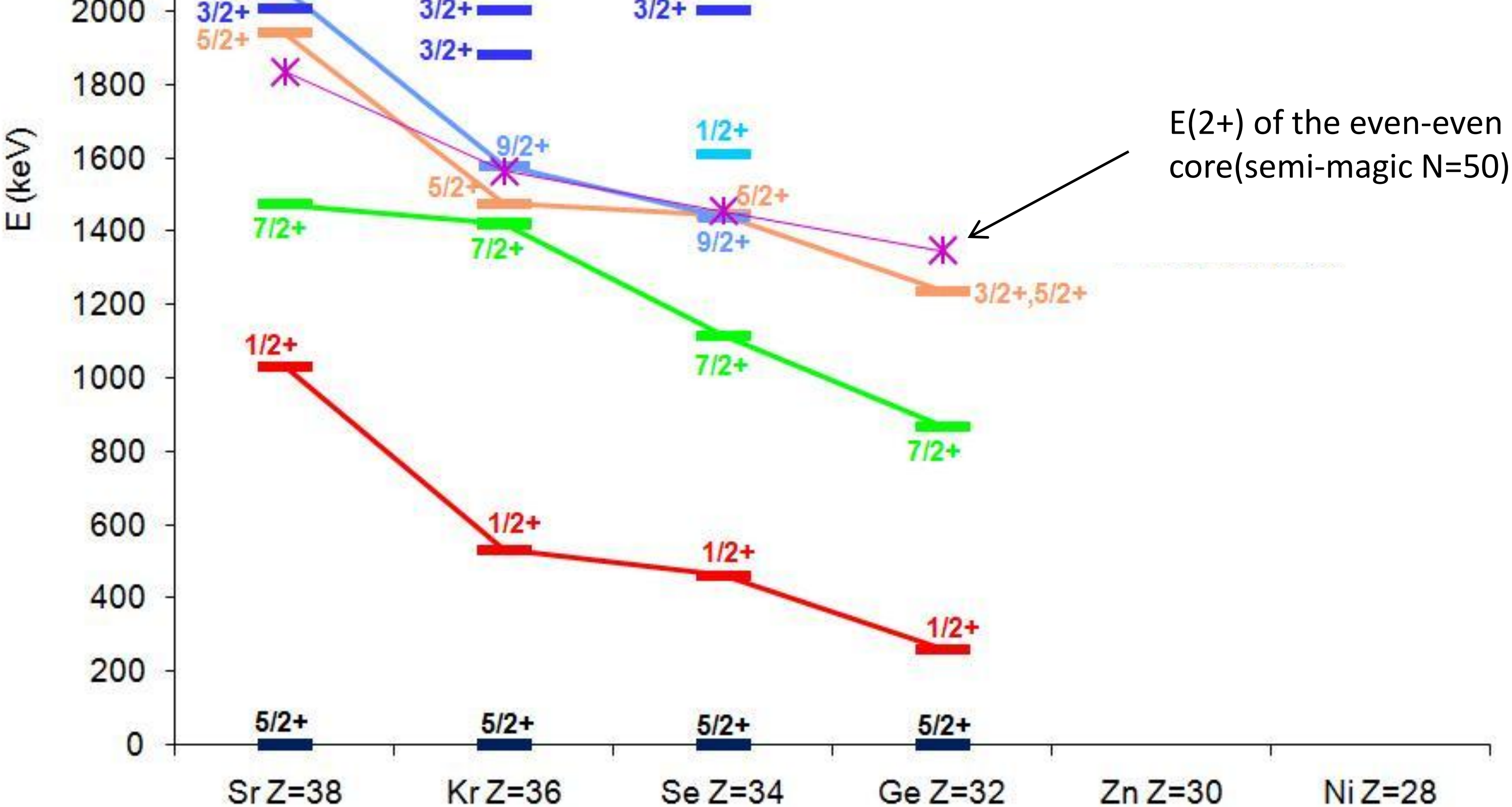
observé en décroissance β-decay
à PARRNe
O. Perru et al.
EPJ **A** 28 (2006) 307
et thèse Paris 11

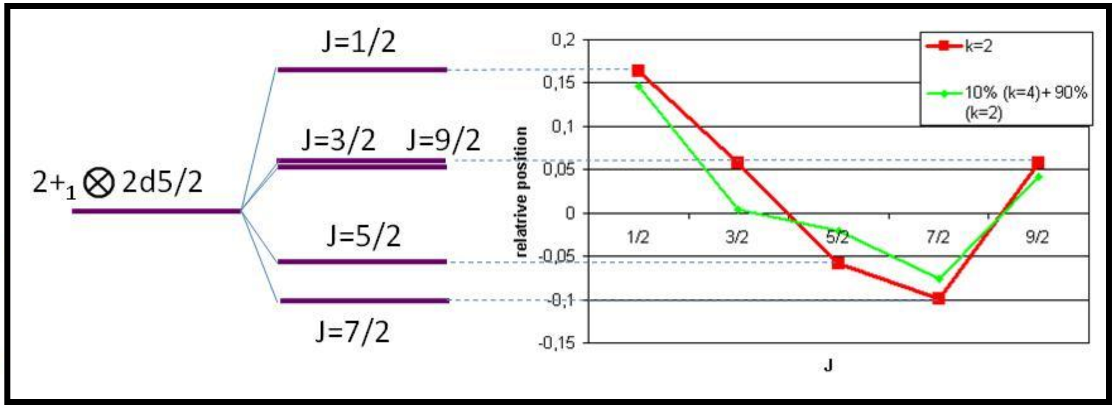
observé en décroissance β**n** avec
ALTO
M. Lebois et al.
PRC 80 (2009) 044308
et thèse Paris 11

observé en ^{2}H(^{82}Ge,p)^{83}Ge
à Oak Ridge
Thomas et al.
PRC 71 (2005) 021302

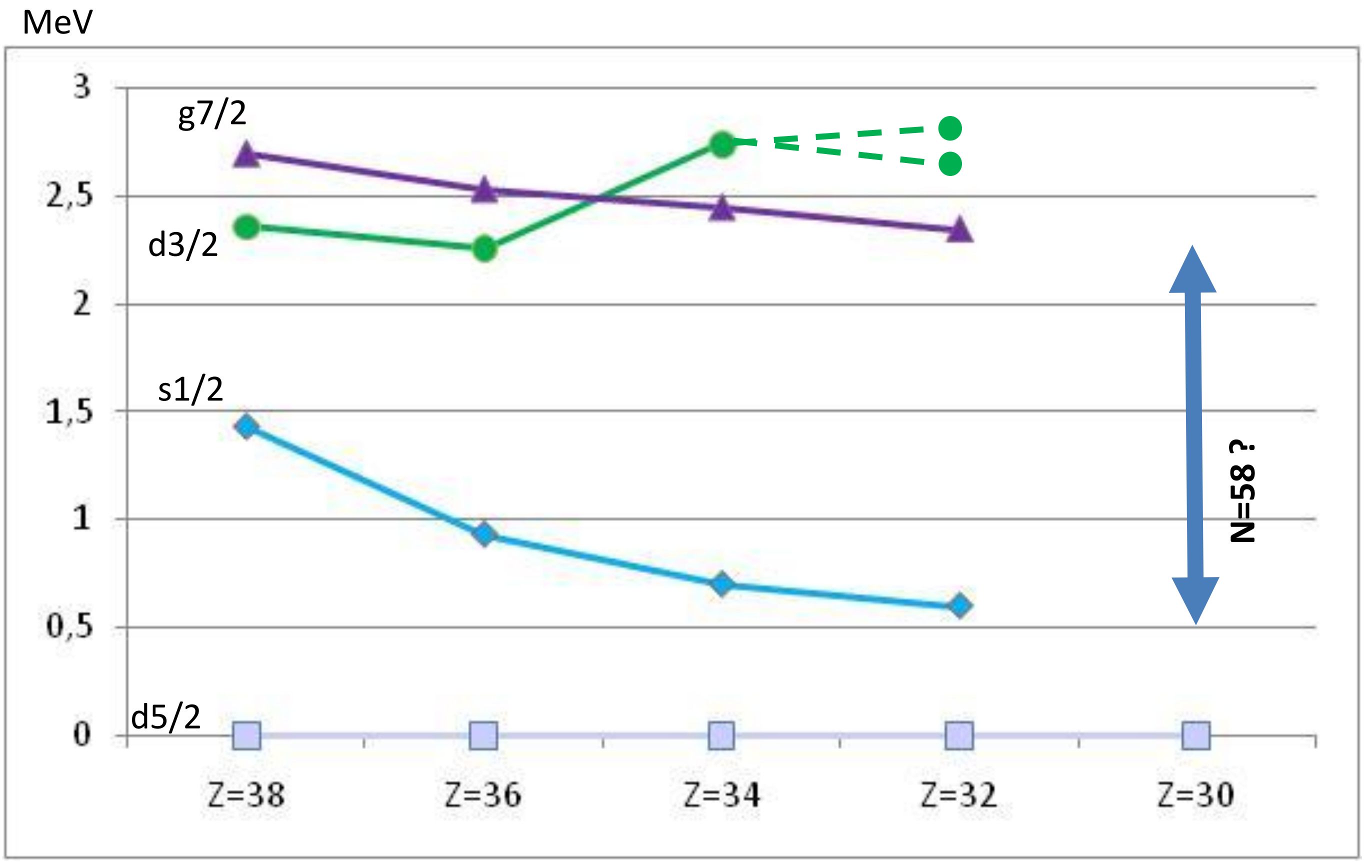


beyond N=50 : N=51 systematics





if we extract the effective single particle energies using the core-particle coupling model :

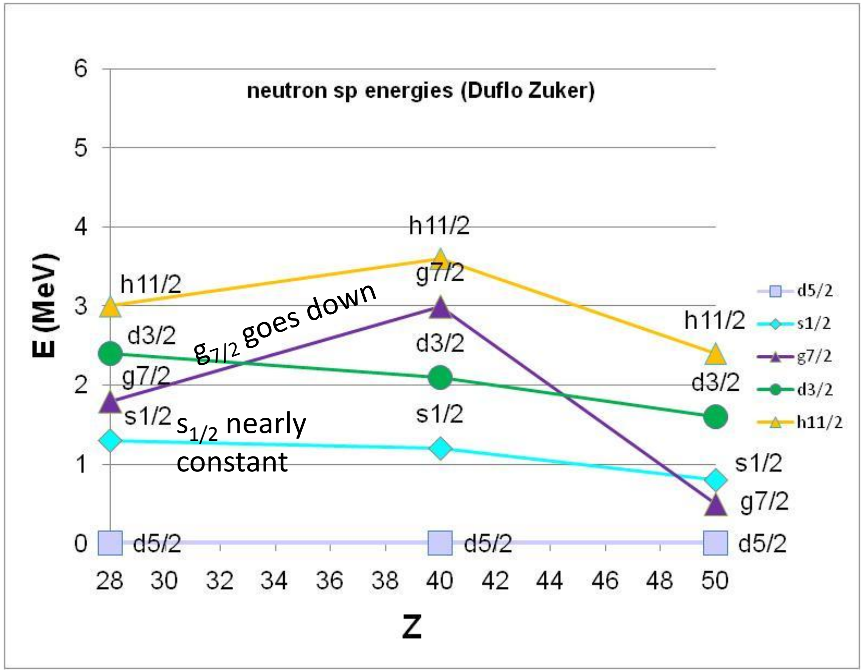


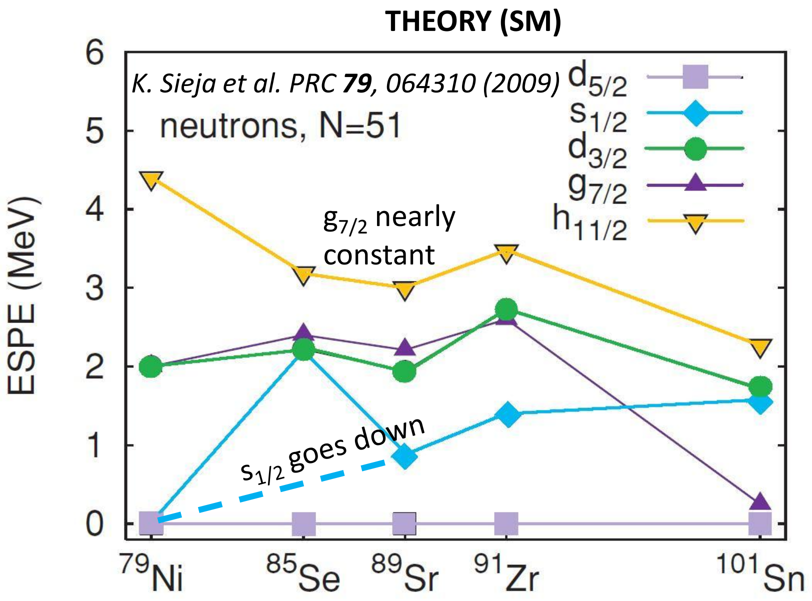
conclusion : appearance of a new neutron subshell gap close to ^{78}Ni ?

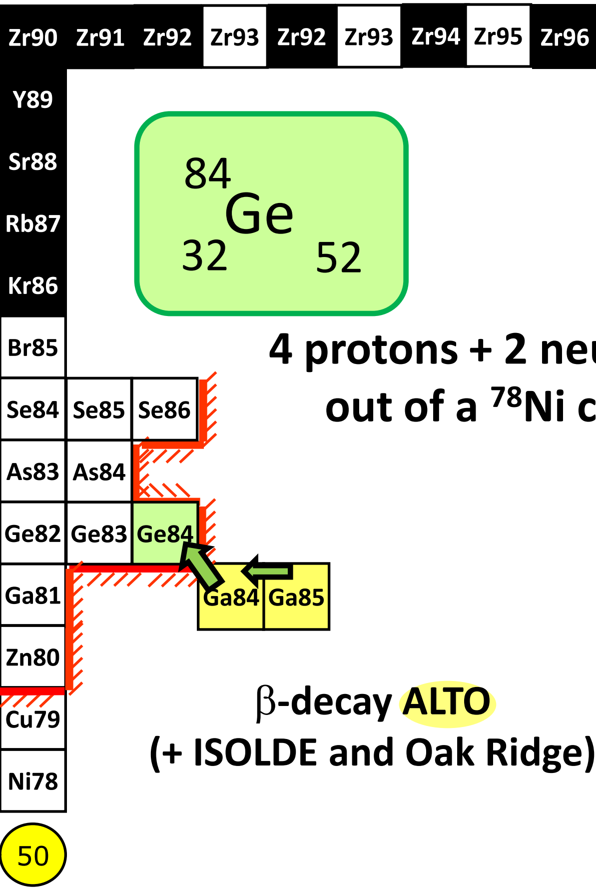
From Duflo Zuker

*PRC **59**, R2347 (1999)*

SM calculations in valence space above ^{78}Ni







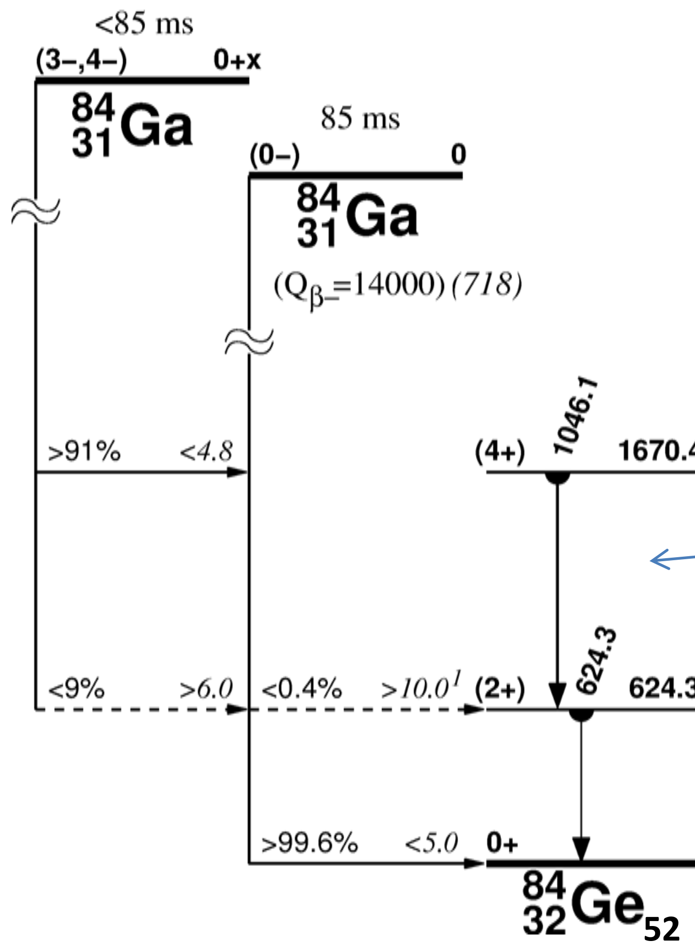
PHYSICAL REVIEW C **80**, 044308 (2009)

Experimental study of ^{84}Ga β decay: Evidence for a rapid onset of collectivity in the vicinity of ^{78}Ni

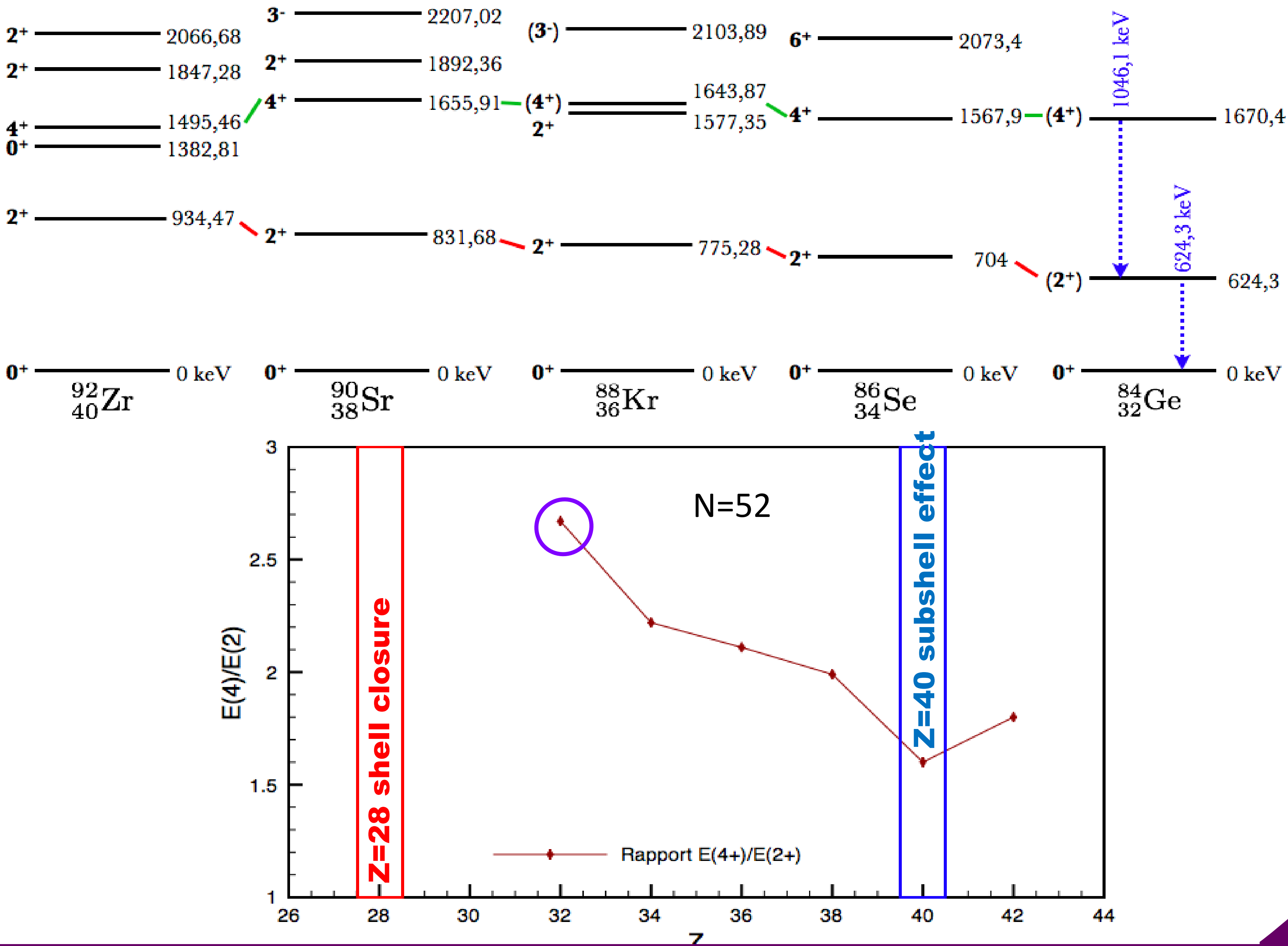
M. Lebois, D. Verney,* F. Ibrahim, S. Essabaa, F. Azaiez, M. Cheikh Mhamed, E. Cottereau, P. V. Cuong,† M. Ferraton, K. Flanagan, S. Franchoo, D. Guillemaud-Mueller, F. Hammache, C. Lau, F. Le Blanc, J.-F. Le Du, J. Libert, B. Mouginot, C. Petrache, B. Roussière, L. Sagui, N. de Séréville, I. Stefan, and B. Tastet
Institut de Physique Nucléaire CNRS-IN2P3/Université Paris-Sud 11, Orsay, France
(Received 21 October 2008; revised manuscript received 12 May 2009; published 9 October 2009)

4 protons + 2 neutrons out of a ^{78}Ni core

β-decay ALTO
(+ ISOLDE and Oak Ridge)

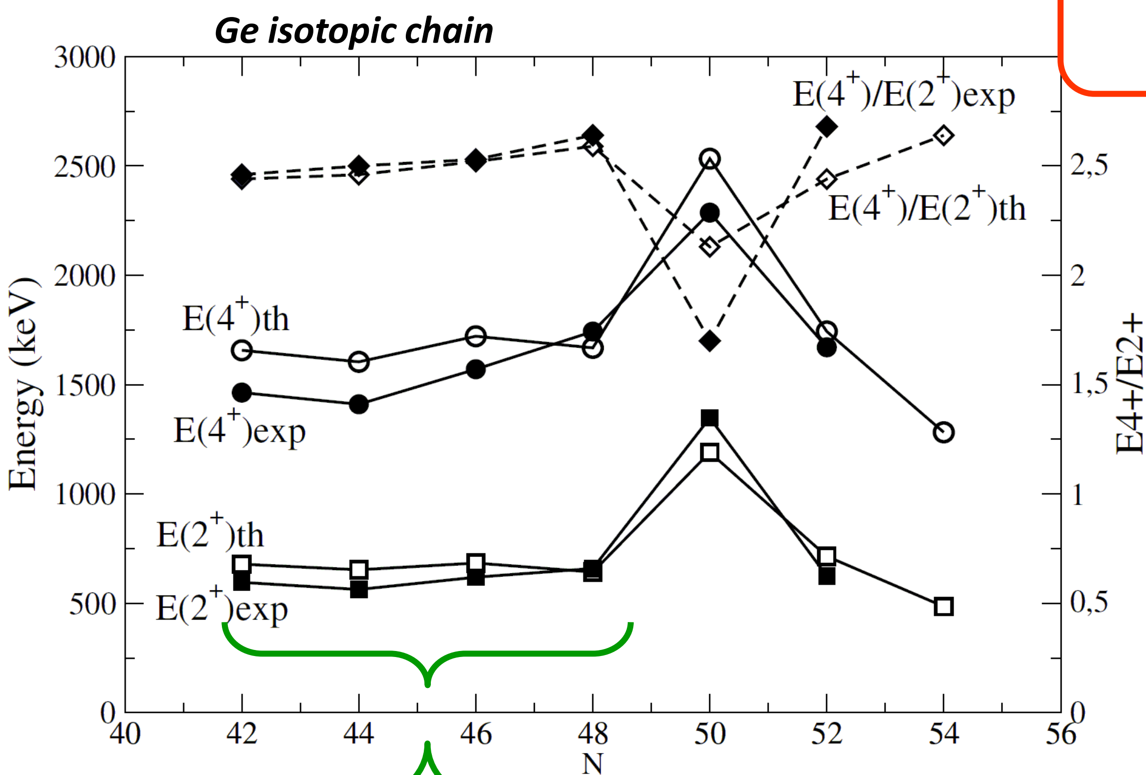


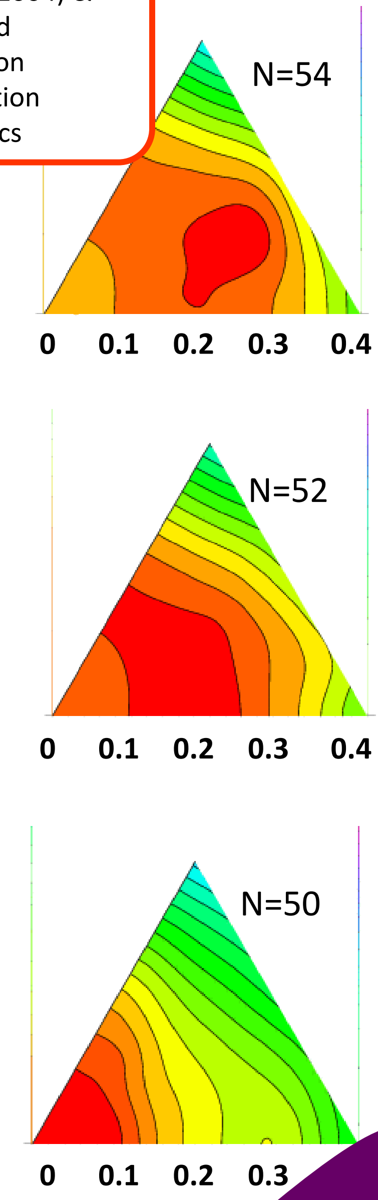
from β-decay at ALTO

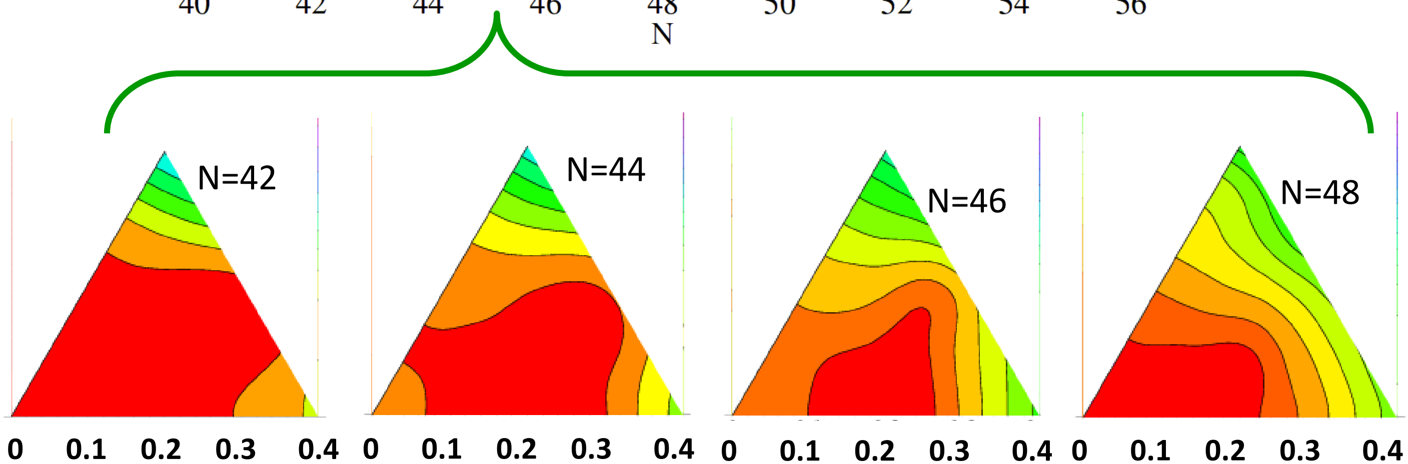

2+ 2066,68
2+ 1847,28
4+ 1495,46
0+ 1382,81
2+ 934,47
0+ 0 keV
$^{92}_{40}$Zr
3- 2207,02
2+ 1892,36
4+ 1655,91
2+ 831,68
0+ 0 keV
$^{90}_{38}$Sr
(3-) 2103,89
(4+) 1643,87
2+ 1577,35
2+ 775,28
0+ 0 keV
$^{88}_{36}$Kr
6+ 2073,4
4+ 1567,9
2+ 704
0+ 0 keV
$^{86}_{34}$Se
(4+) 1670,4
(2+) 624,3
0+ 0 keV
1046,1 keV
624,3 keV
$^{84}_{32}$Ge
N=52
Z=28 shell closure
Z=40 subshell effect
Rapport E(4+)/E(2+)
E(4)/E(2)
Z

but maybe not unexpectable

O Perru thesis Paris-Sud XI (2004) &
J. Libert and M. Girod
private communication
D1S Gogny HFB calculation
GCM → Bohr dynamics







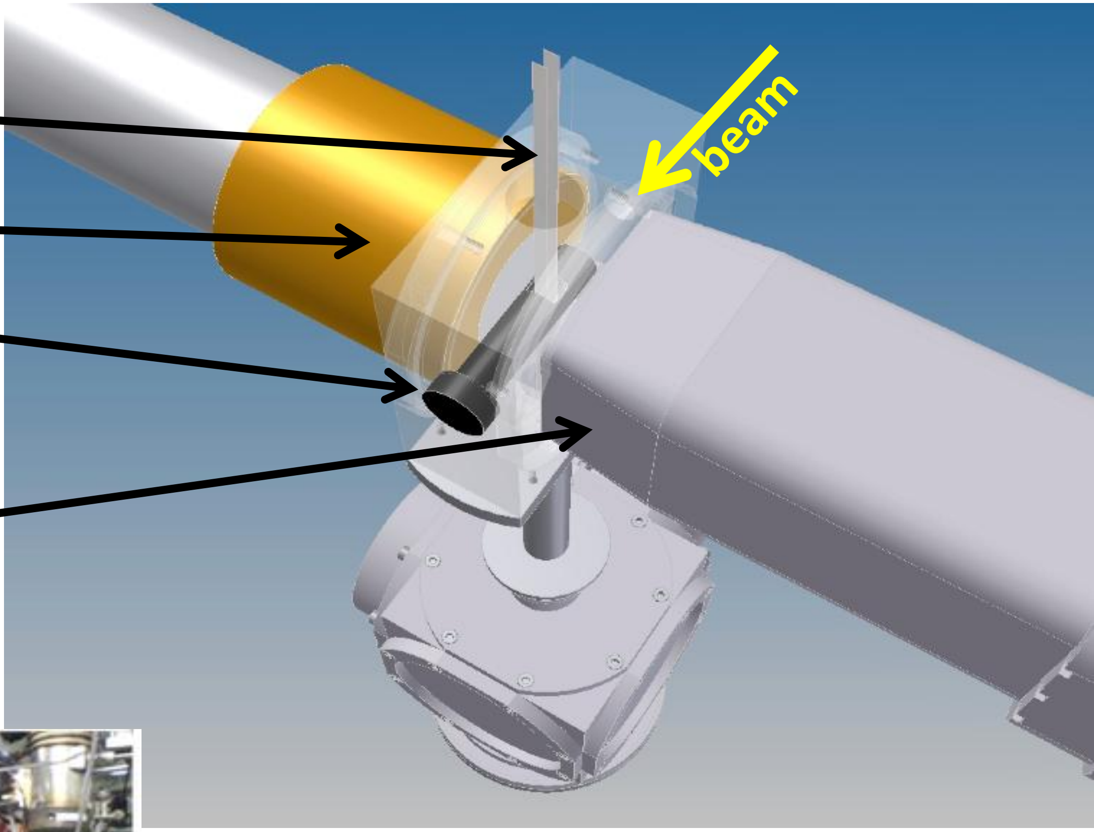
Tape station, closed geometry

Mylar tape

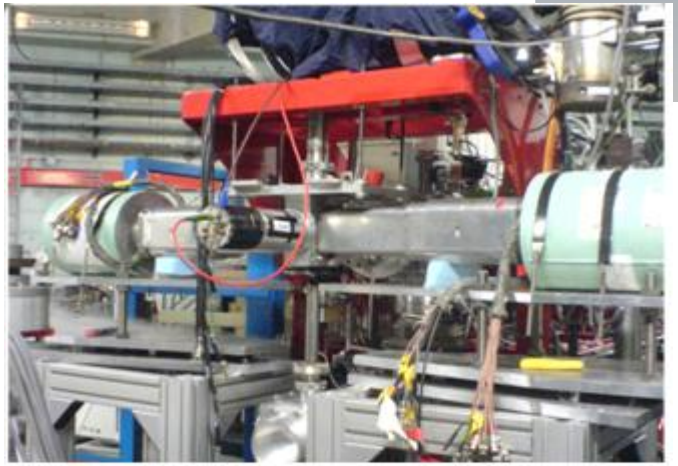
Ge coaxial large volume or CLOVER (small EXOGAM : OSCAR)

Plastic scintillator

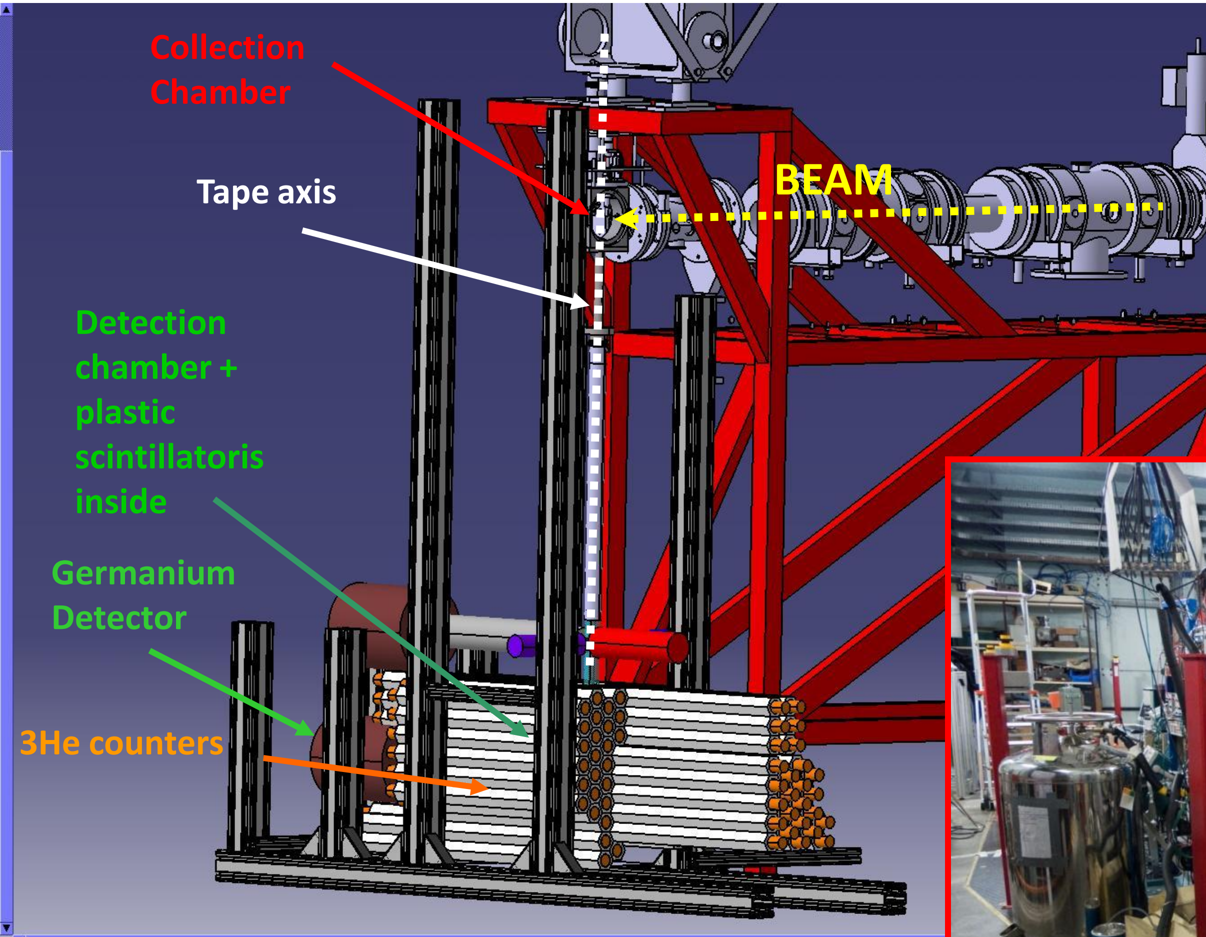
Ge CLOVER (small EXOGAM : OSCAR)

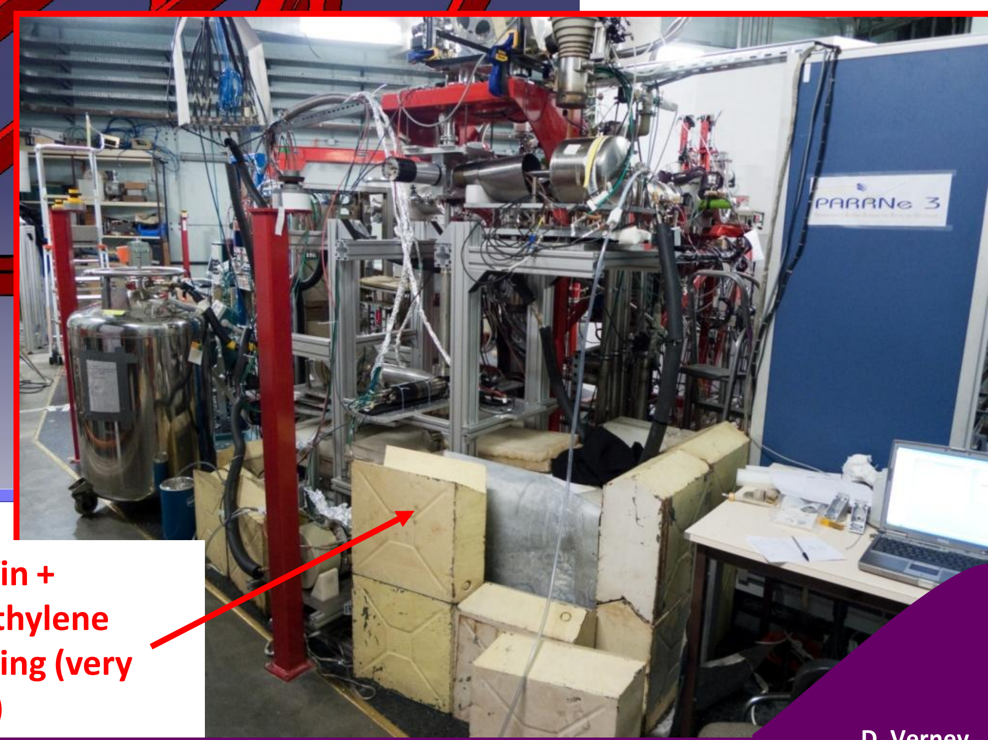


$\varepsilon total_{(\text{photo-peak } 1.3\text{MeV})} \sim 3\%$



neutron detection collaboration at ALTO
Y. Penionzhkevich, Y. Sokol, D. Testov, *Flerov Lab., JINR, Dubna, Russia*
F. Ibrahim, D. Verney, *IPN, IN2P3/CNRS, Orsay, France*

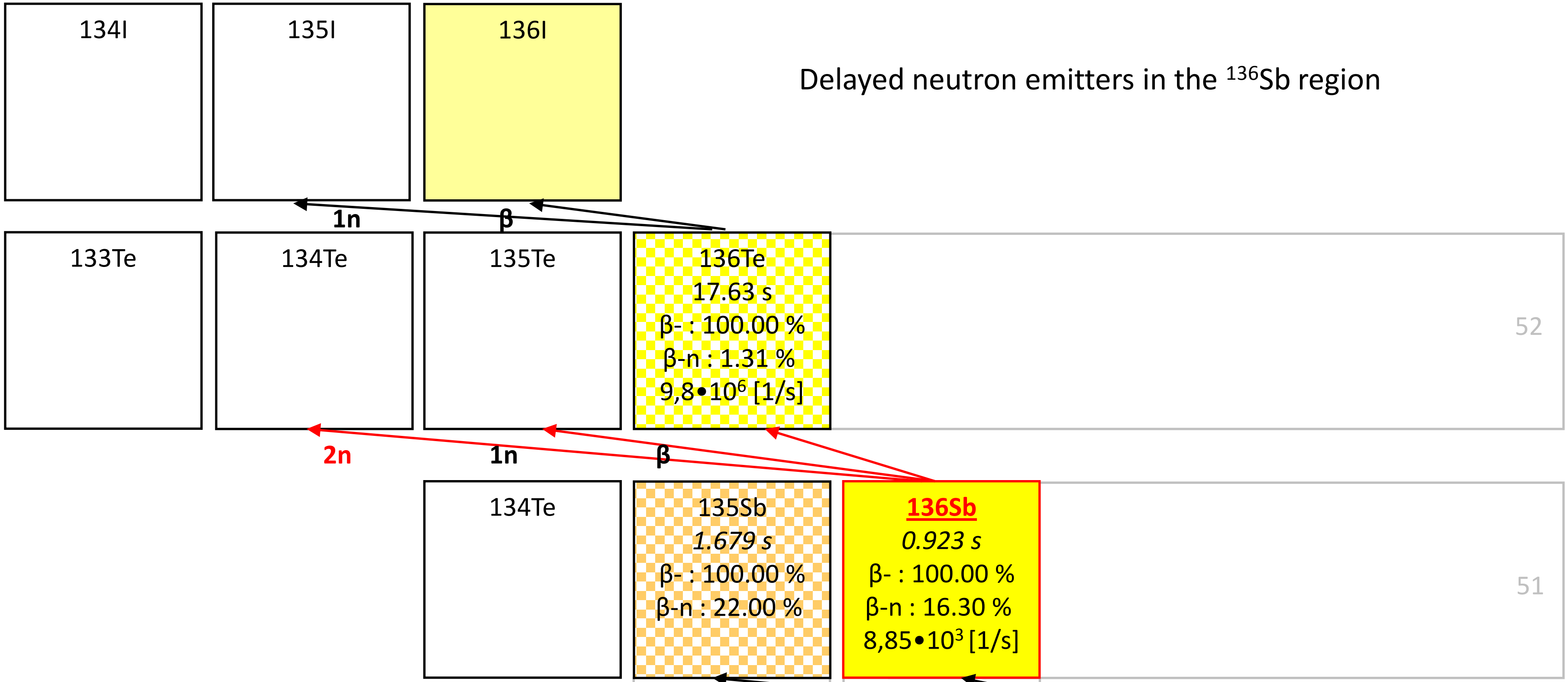


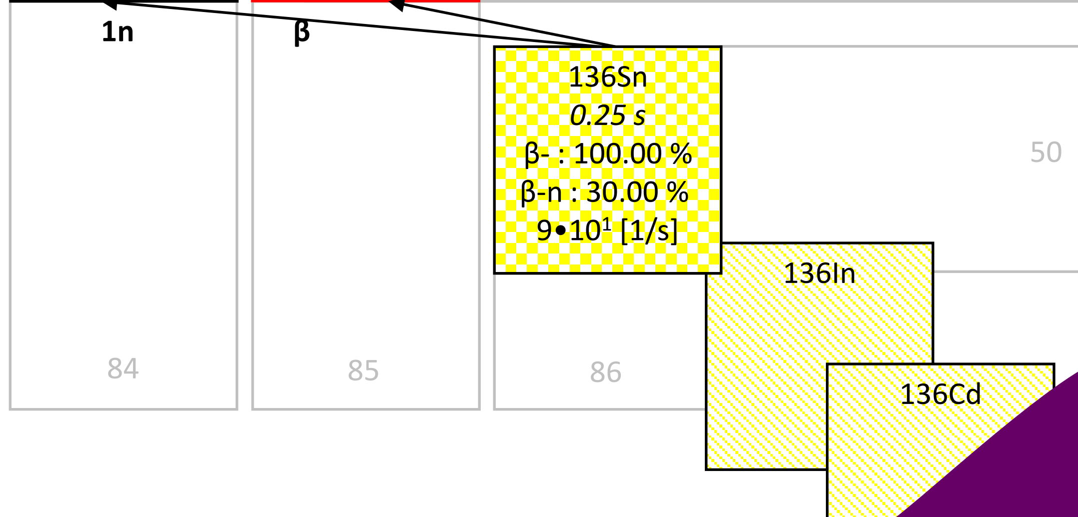


The efficiency measured is up to 35%

Neutron lifetime in the detector is 35 μs

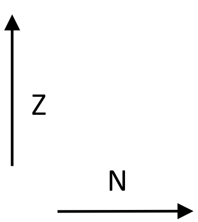
Delayed neutron emitters in the ^{136}Sb region





Intensity: calculation [1], primary electron beam, 50MeV, 10µA

[1] F. Ibrahim et al., Nucl. Phys. A787, 110c (2007).



	ALTO, yield [a]	$T_{1/2}$	
^{88}As [1,2]	1,699E+00	>300 ns	β-: 100.00 %, β^{-}n: ?
^{89}As [1,2]	2,61E-01	>300 ns	β- : ?
^{136}Sb	8,85E+03	923 ms	β^{-}n 16(3)%; β2n: 0.28% - 10.6% (prediction [1])
^{137}Sb [1]	7,64E+02	450 ms	β-: 100.00 (nndc); β^{-}n : 49.00 %;
^{138}Sb	1,080E+02	300 ns	β^{-}n : ? (98.3% prediction[3])
^{139}Sb	3,113E+00	>300 ns [1]	β-n : ? (100% prediction [3])
^{139}Te	7,184E+03	>150 ns	β- ?, β^{-}n (4,8% prediction [3])
^{142}I	1,220E+05	0,2 s	β- : 100.00 % (nndc)

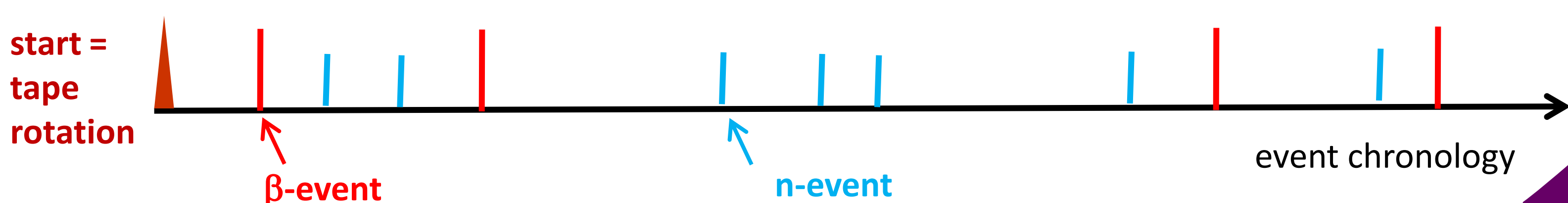
[1] Nucl. Phys. A 729 (2003) 3–128
[2] Phys. Rev. C 71, 065801 (2005)
[3] ADNDT vol. 51 issue 2, p. 243-271 (1992)
[a] F. Ibrahim et al., Nucl. Phys. A787, 110c (2007).

(we are at the very beginning…)

possible if (and only if) β-n time correlations can be found. One should find a working zone taking into account

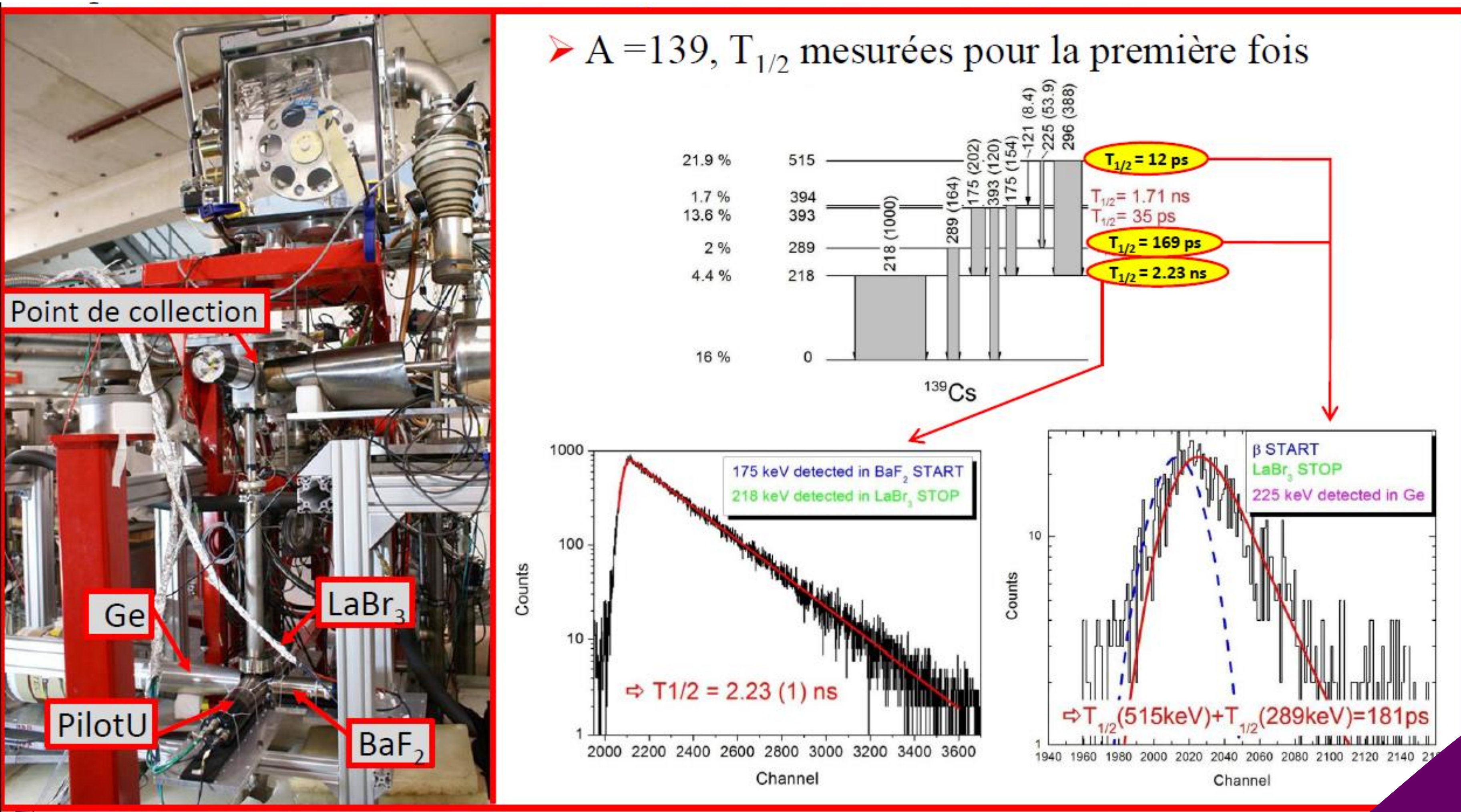
- ΔT : tape evacuation
- T1/2 : precursor half-life
- Y : production yield of the precursor
- ….

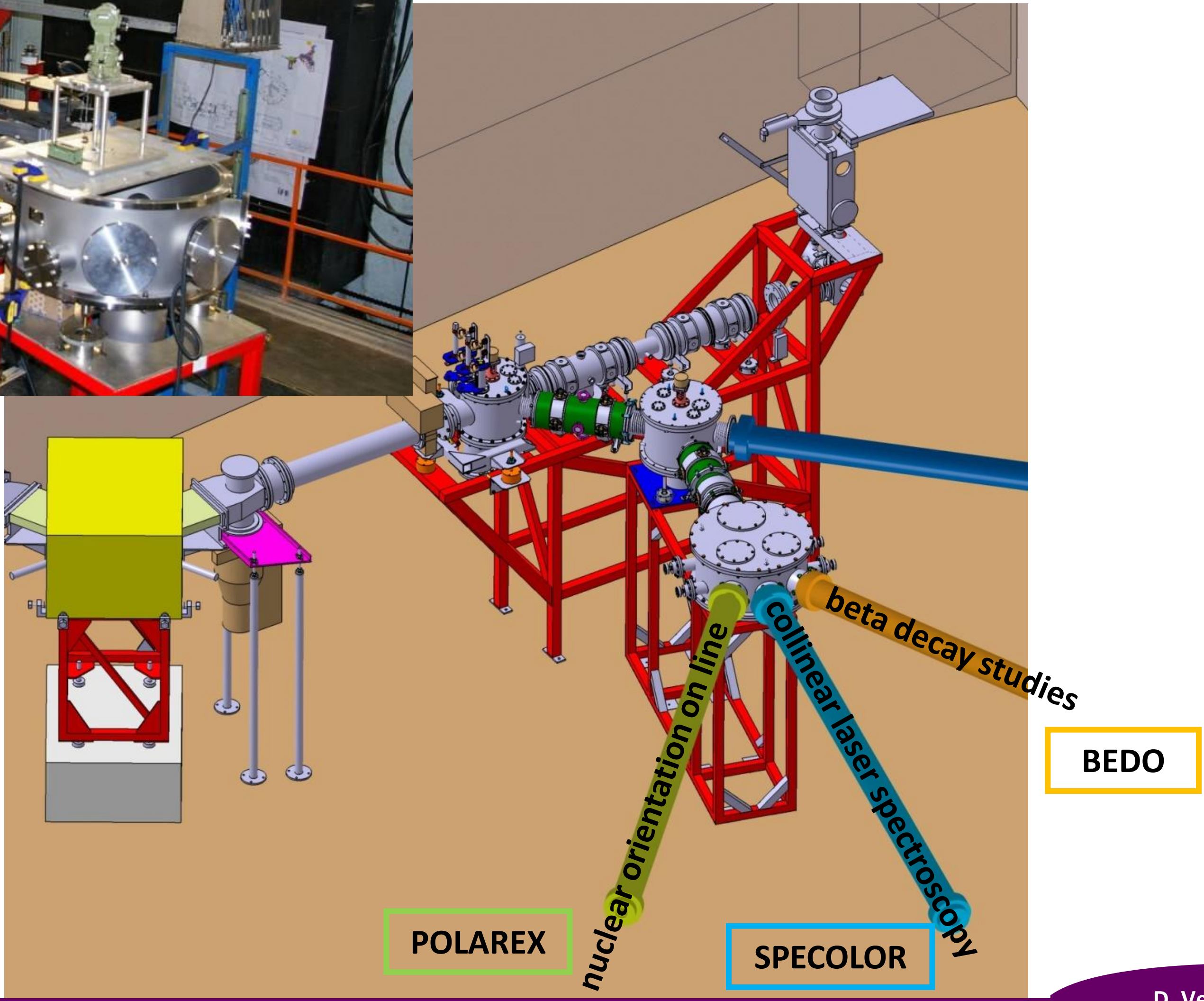
COMET triggerless acquisition system (δt=400 ps)



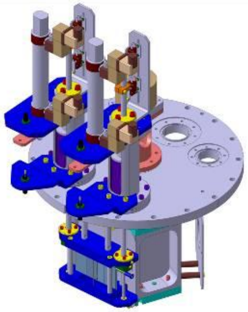
Fast-timing collaboration at ALTO

B. Roussière, *IPN, IN2P3/CNRS, Orsay, France*
I. Deloncle, J. Kiener, *CSNSM, IN2P3/CNRS, Orsay, France*
M.A. Cardona, D. Hojman, *Departamento de Física, CNEA, Buenos Aires, Argentina*
P. Petkov, D. Toneev and Ts. Venkova, *INRNE, BAS, Sofia, Bulgaria*

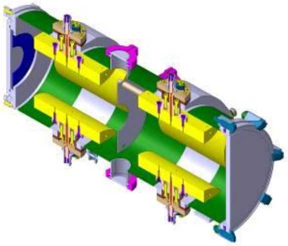


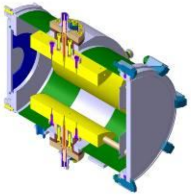

beta decay studies
collinear laser spectroscopy
nuclear orientation on line
BEDO
POLAREX
SPECOLOR

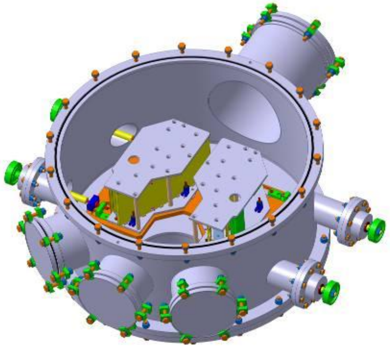
deflector 45°&60°



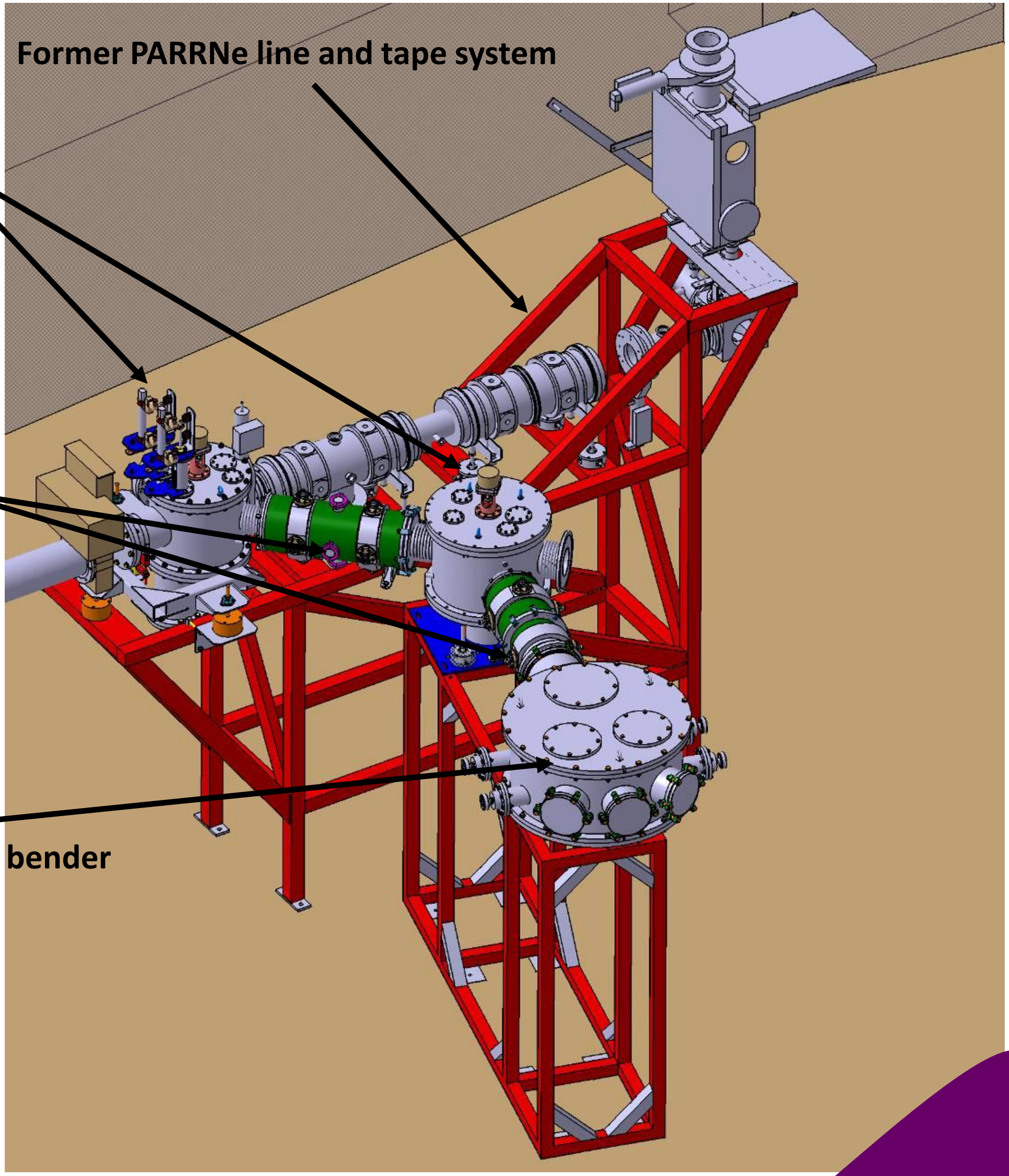
Electrostatic QP







Kicker bender



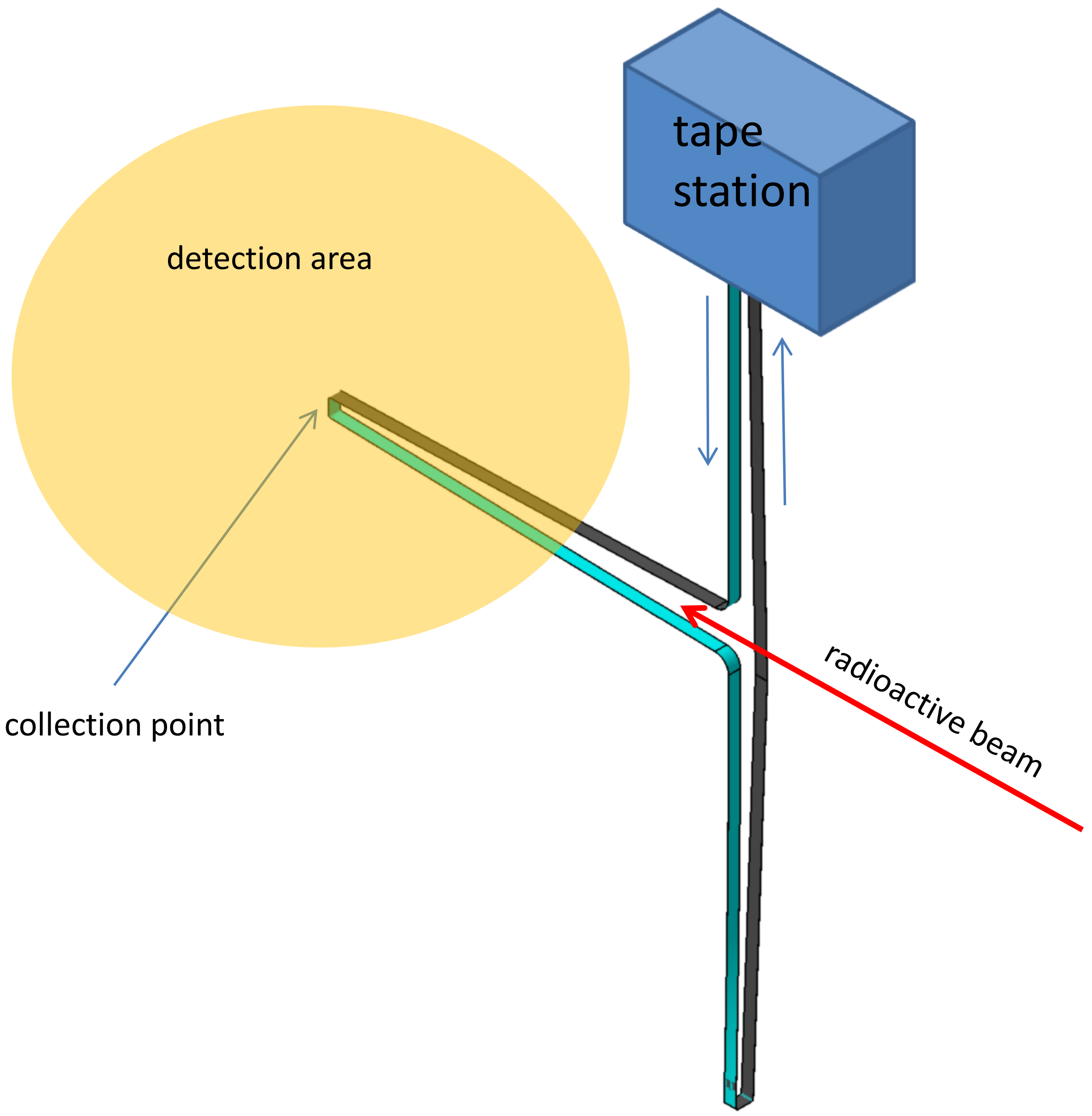
BEDO BEta Decay studies at Orsay

- gamma spectroscopy following β-decay
- fast-timing
- detection of β-delayed neutrons + gammas

in order to study the shorter lived species :

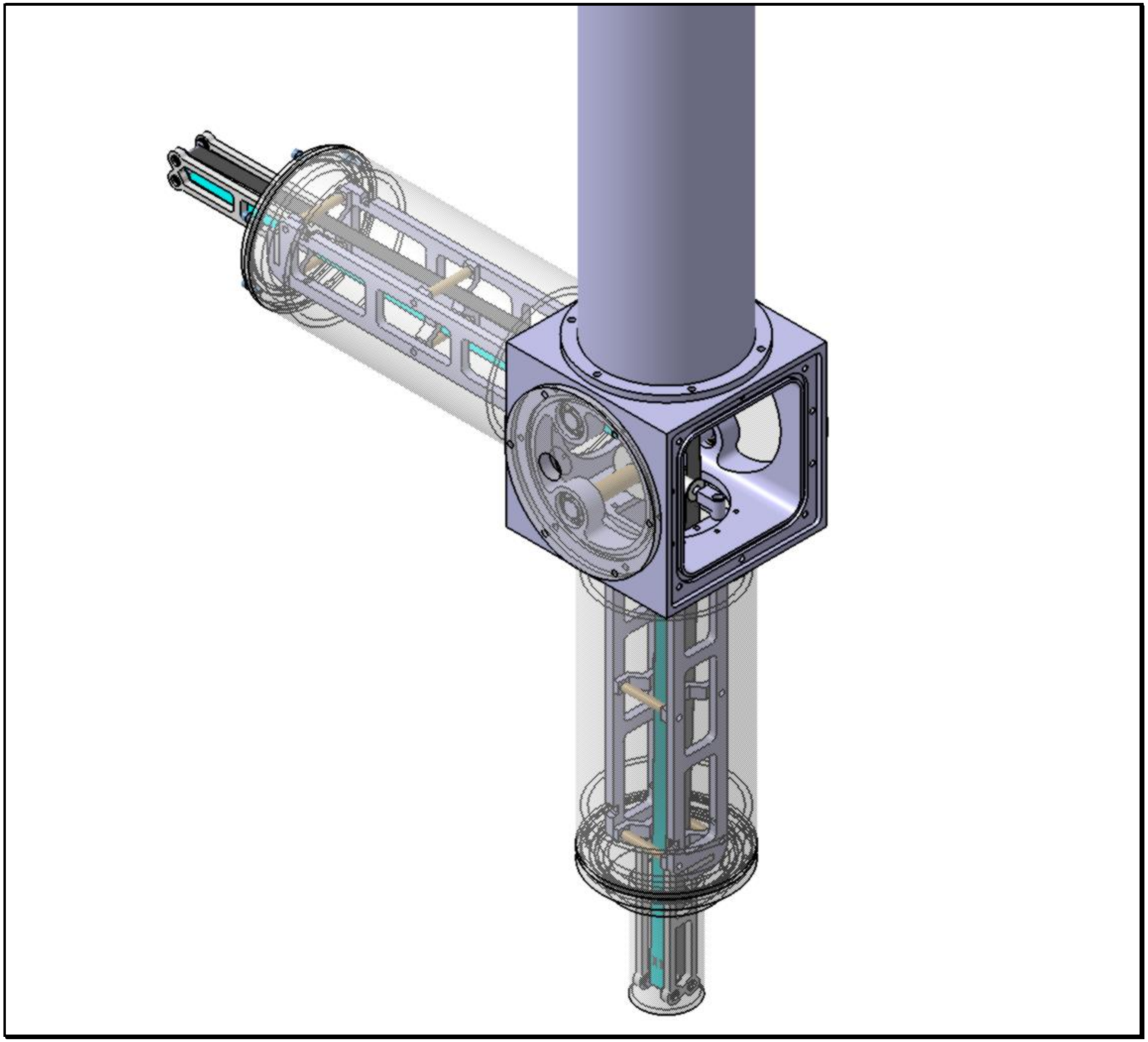
detection point = collection point

(no motion of the source prior to measurement)

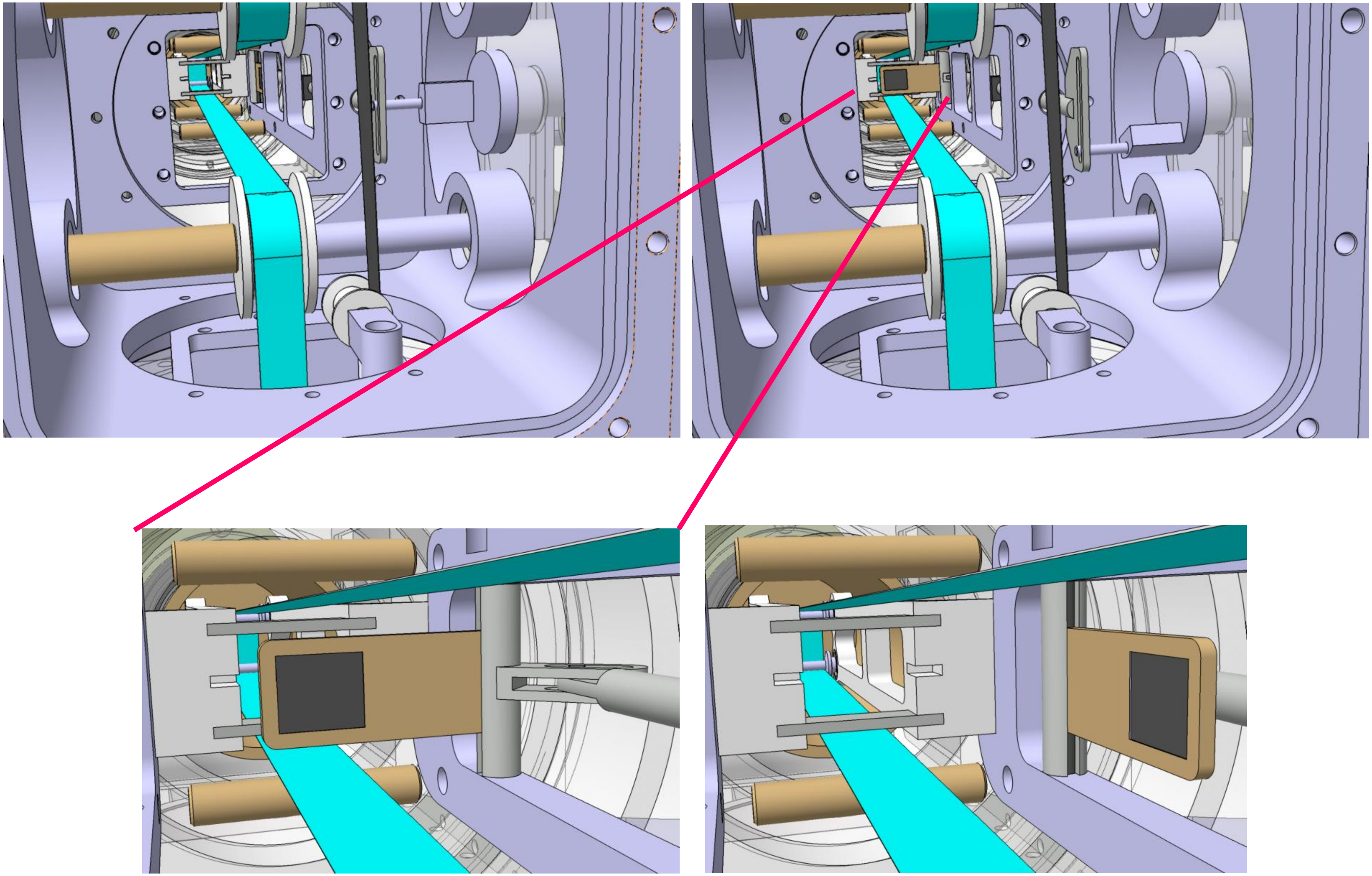

tape
station
detection area
collection point
radioactive beam

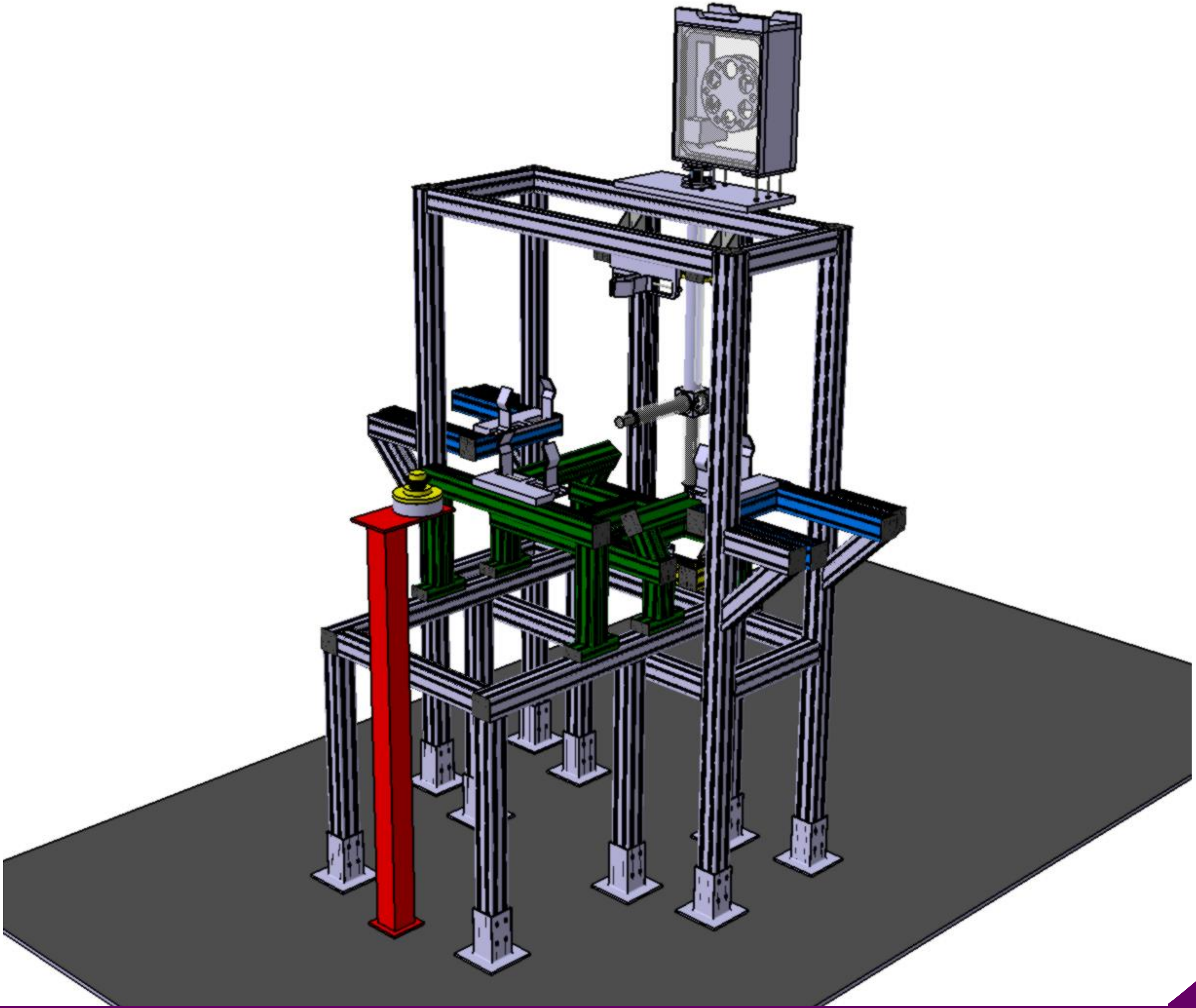
all drawings by Julien Bettane

Detector Department of IPN Orsay



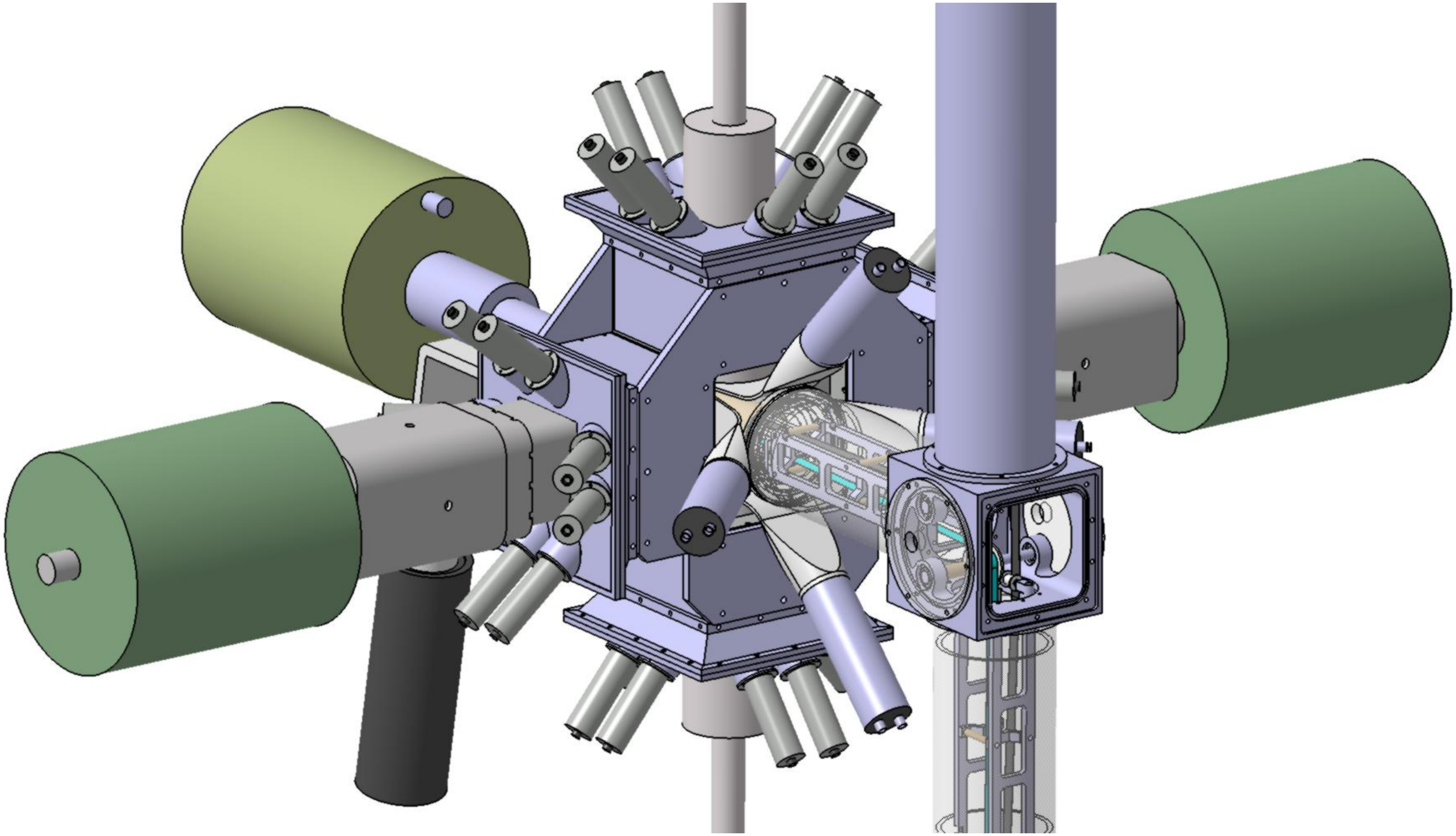
The BEDO project

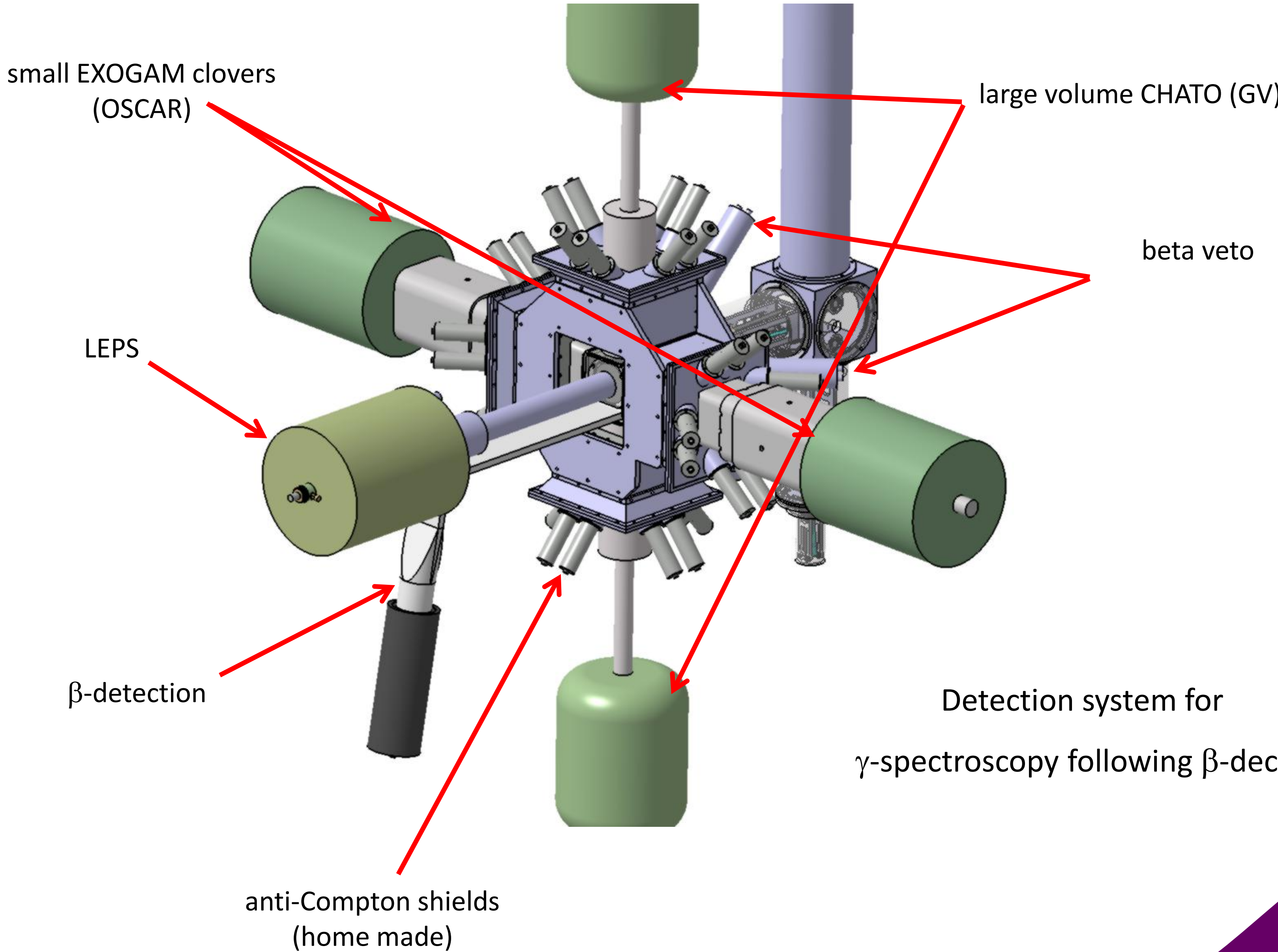




Detection system for

γ-spectroscopy following β-decay



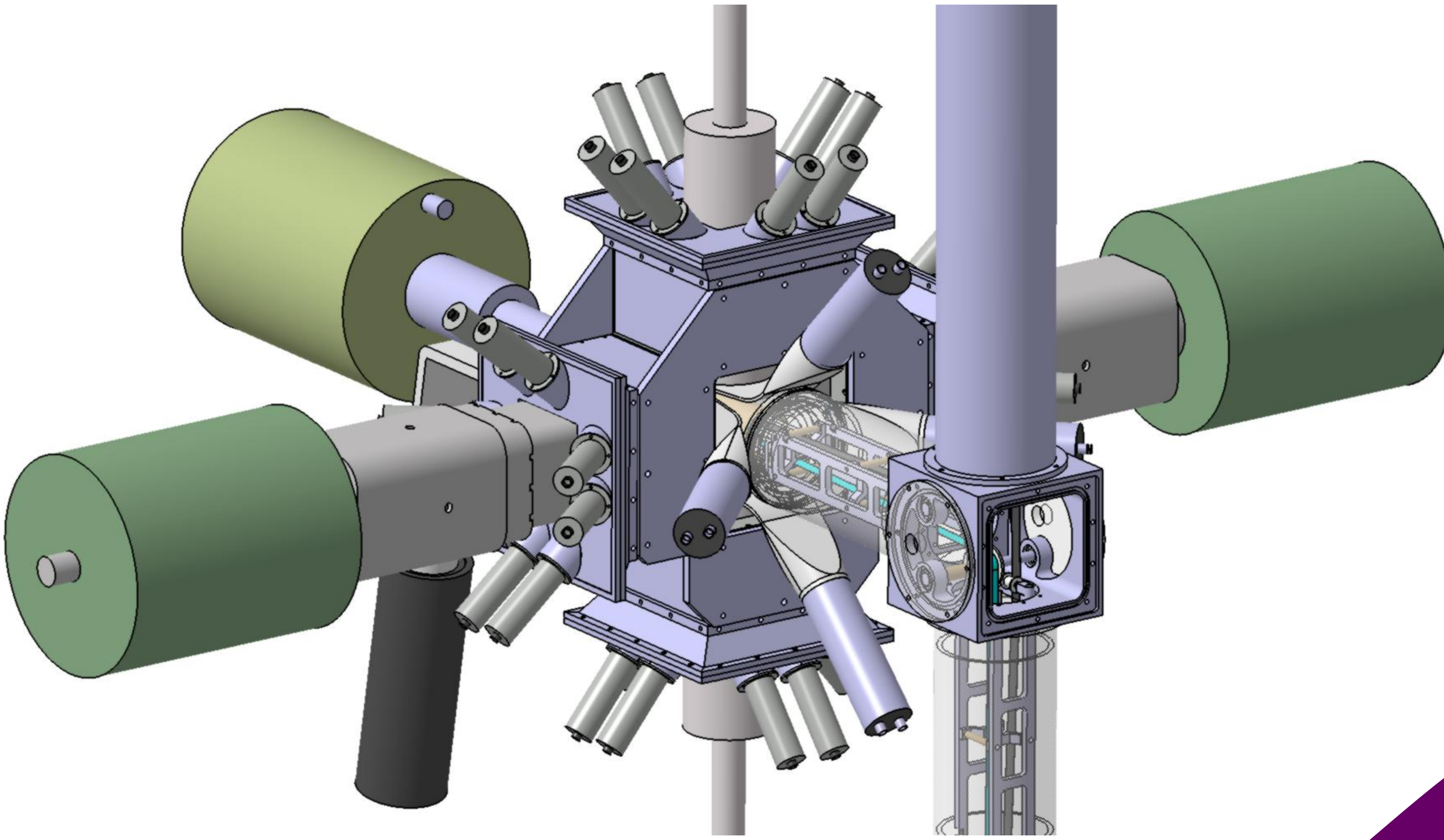


Detection system for

γ-spectroscopy following β-decay

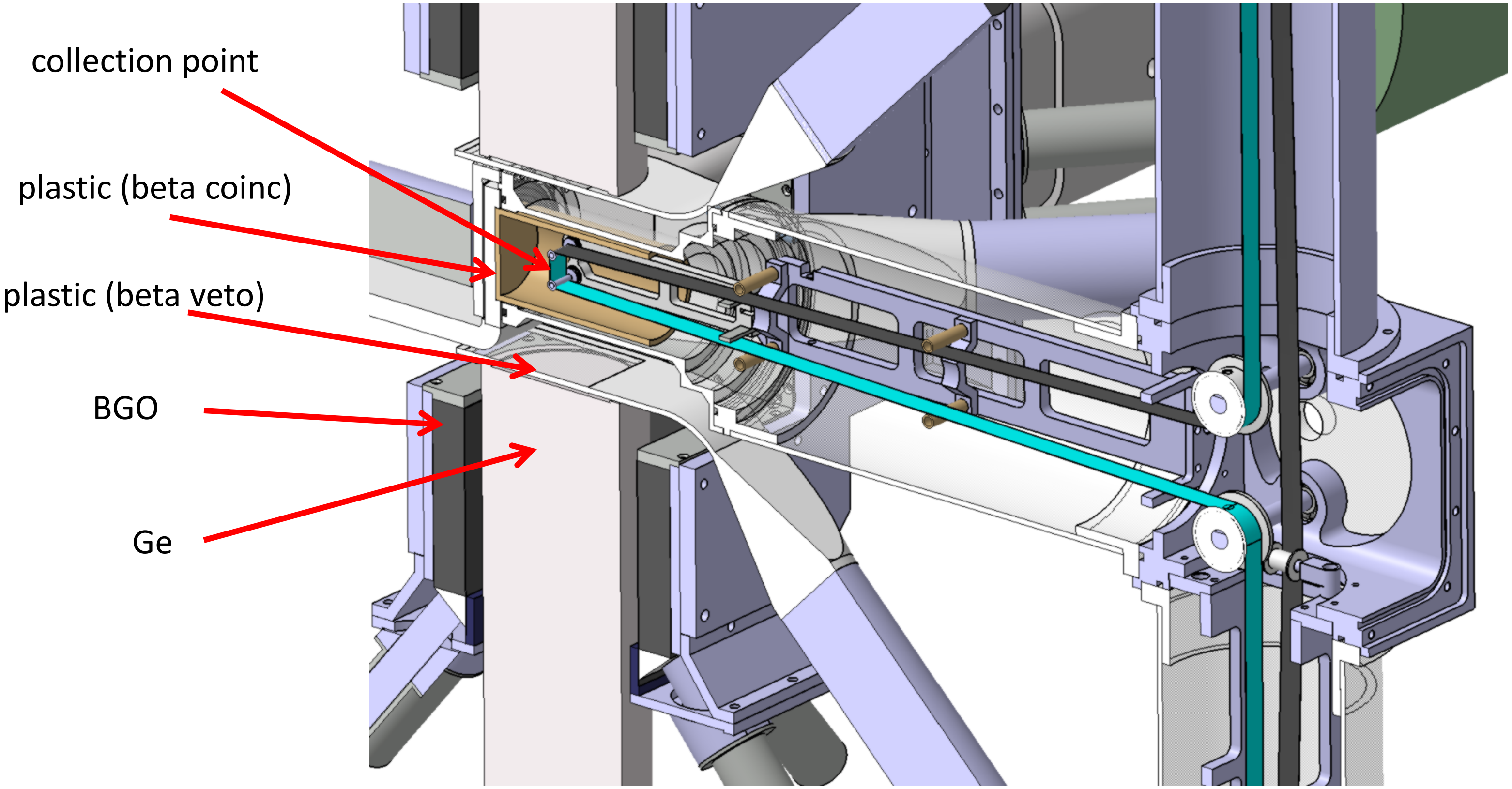
Detection system for

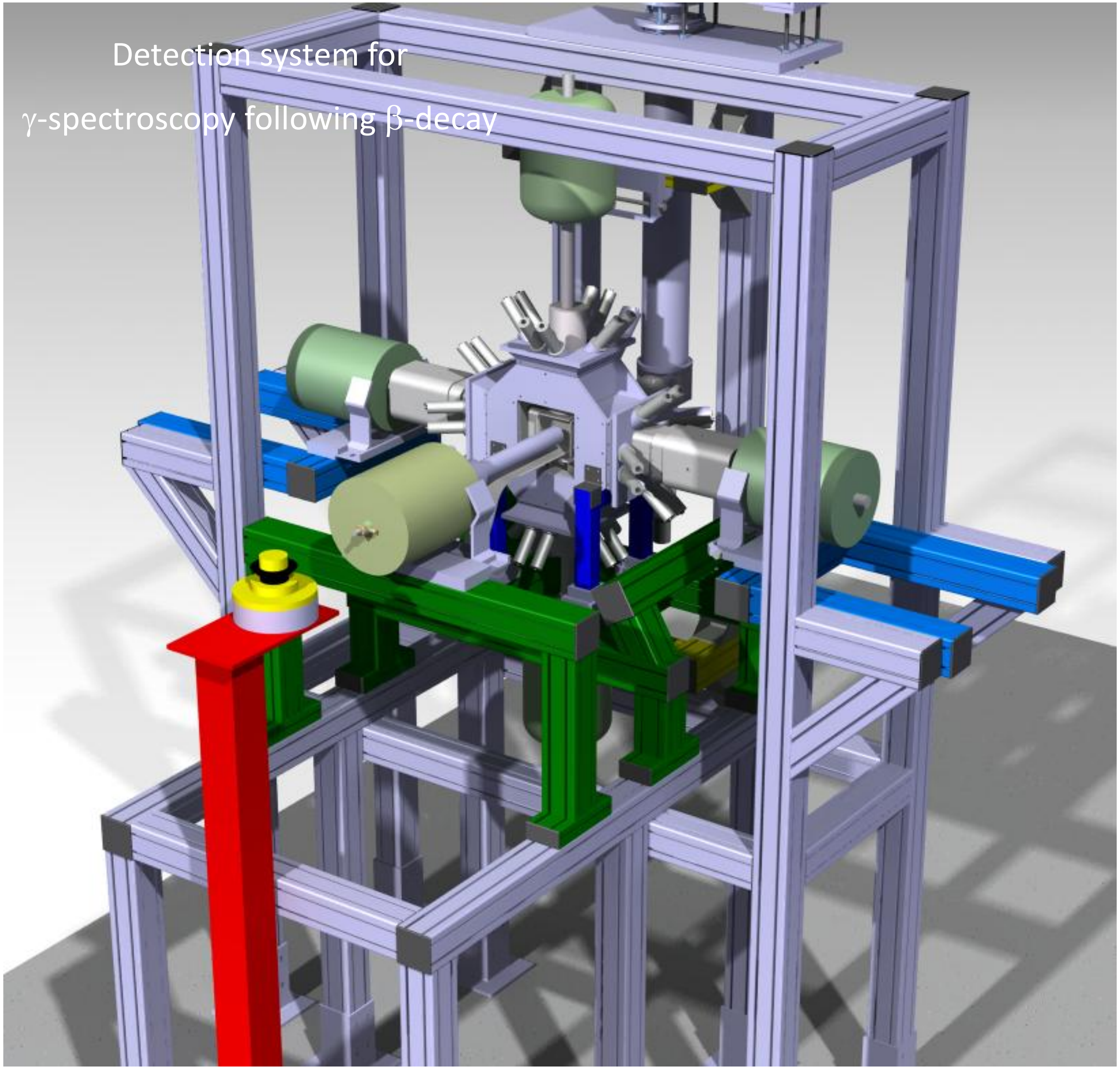
γ-spectroscopy following β-decay



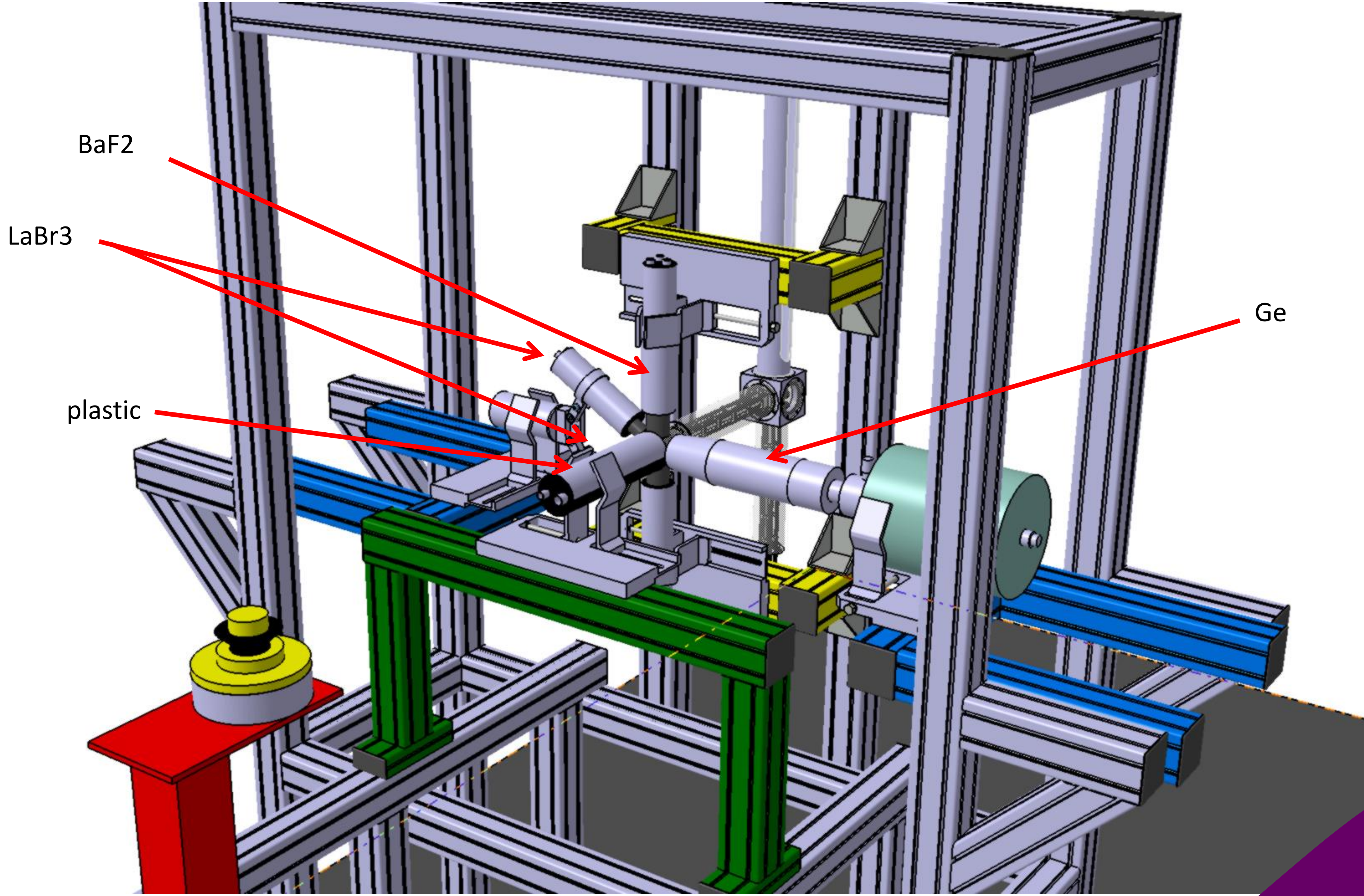
Detection system for

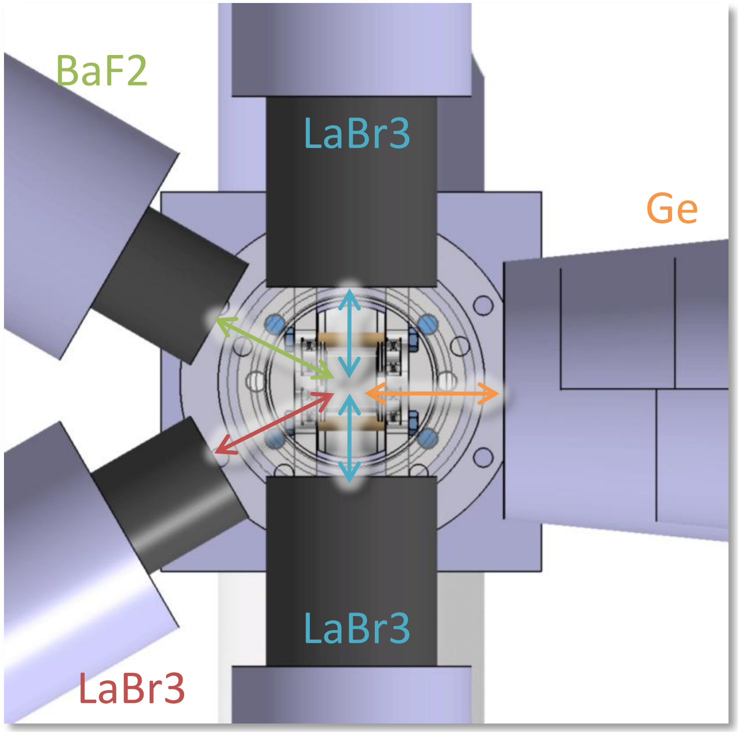
γ-spectroscopy following β-decay




Detection system for
γ-spectroscopy following β-decay

Detection system for fast-timing measurements

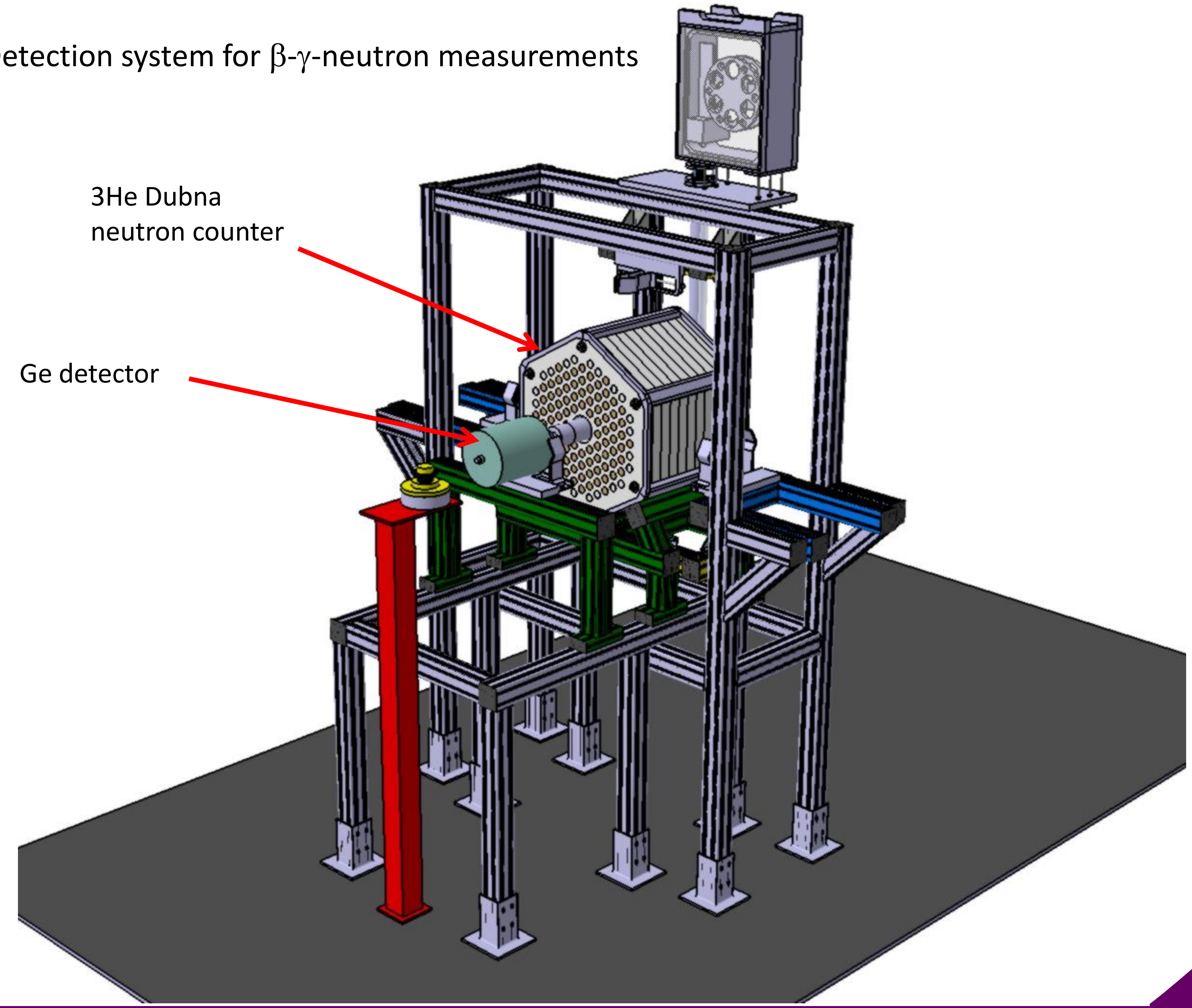




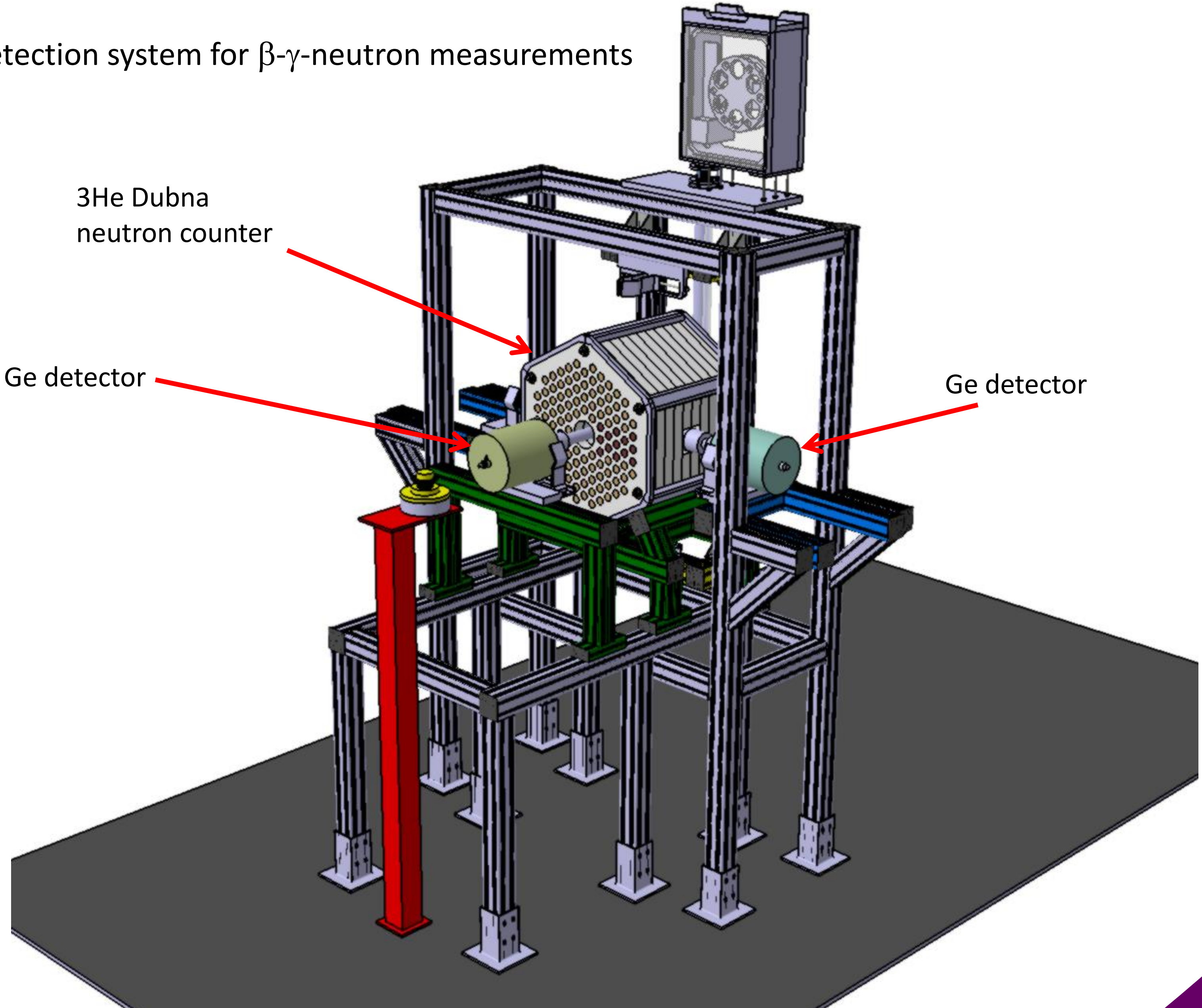
Distances / source :

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

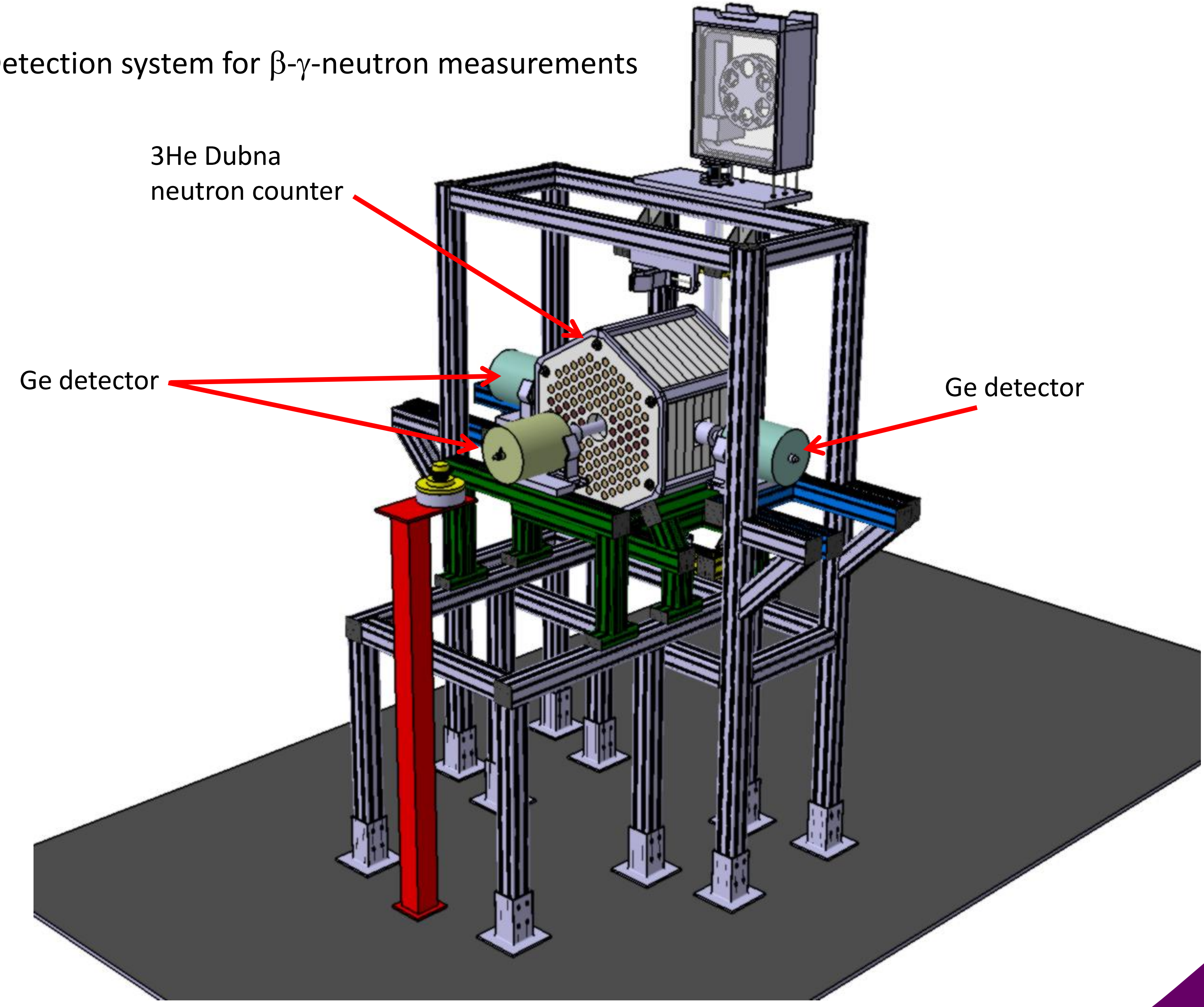
Detection system for β-γ-neutron measurements

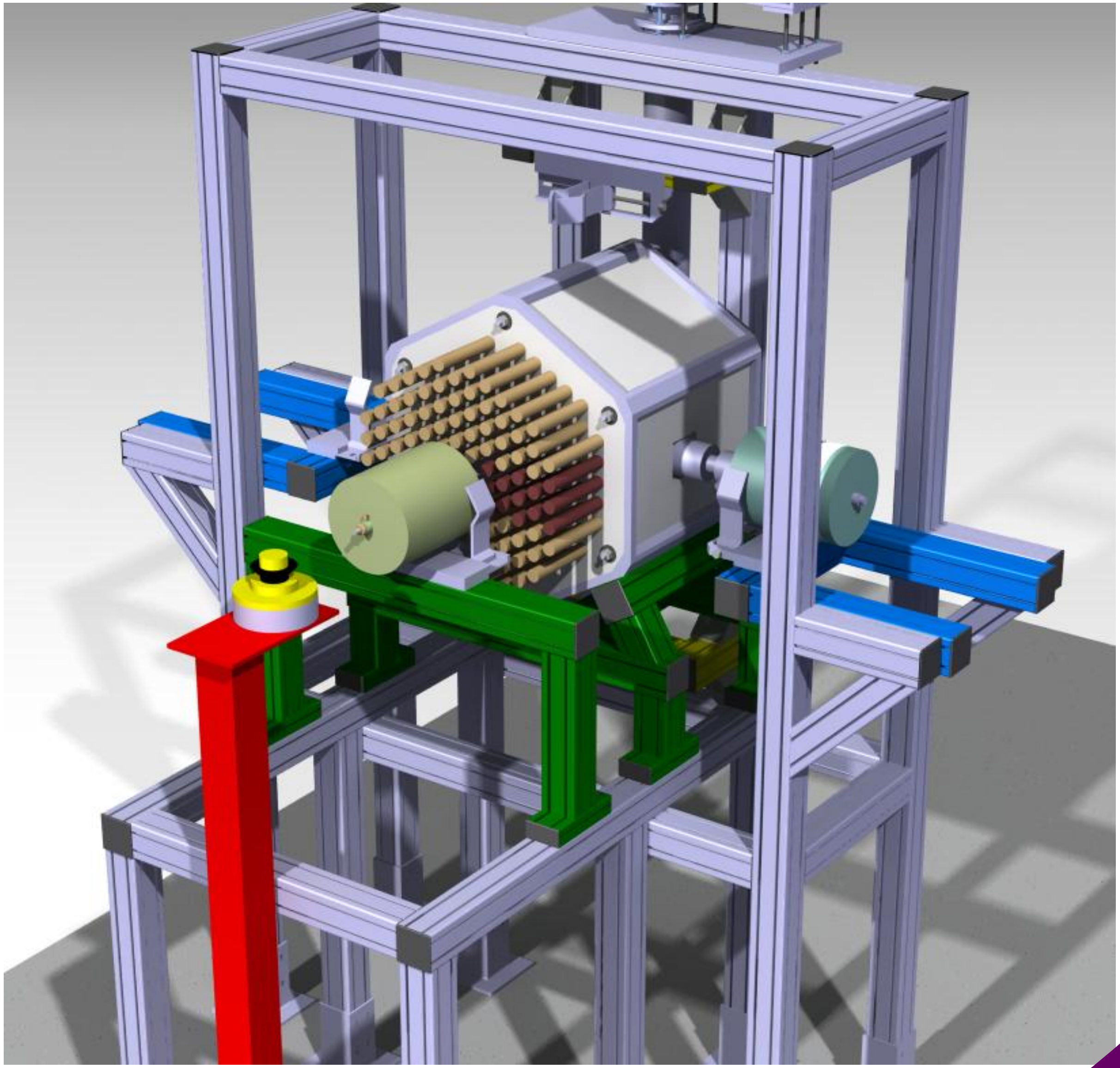


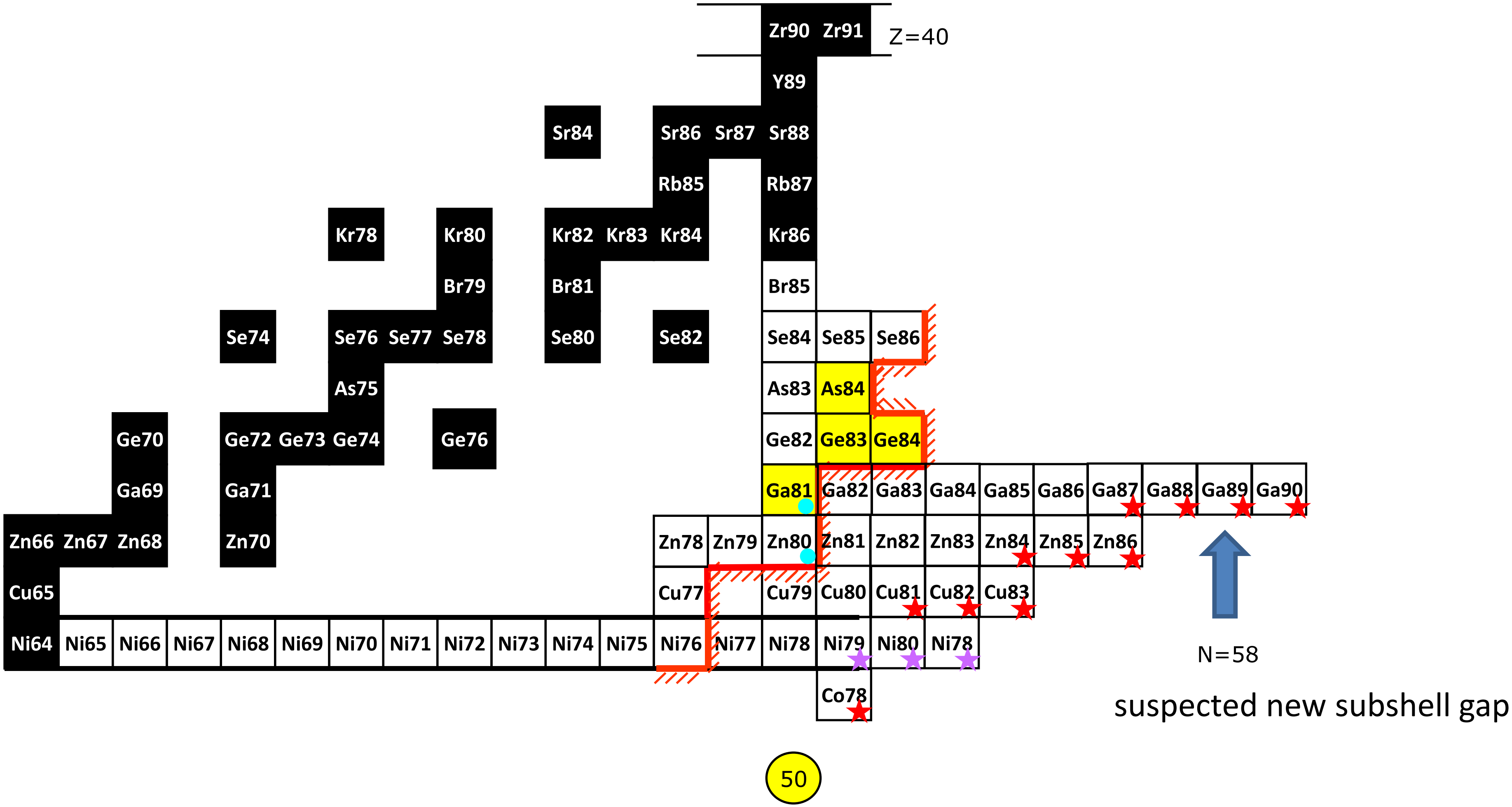
Detection system for β-γ-neutron measurements



Detection system for β-γ-neutron measurements






Zr90 Zr91
Z=40
Y89
Sr84 Sr86 Sr87 Sr88
Rb85 Rb87
Kr78 Kr80 Kr82 Kr83 Kr84 Kr86
Br79 Br81 Br85
Se74 Se76 Se77 Se78 Se80 Se82 Se84 Se85 Se86
As75 As83 As84
Ge70 Ge72 Ge73 Ge74 Ge76 Ge82 Ge83 Ge84
Ga69 Ga71 Ga81 Ga82 Ga83 Ga84 Ga85 Ga86 Ga87 Ga88 Ga89 Ga90
Zn66 Zn67 Zn68 Zn70 Zn78 Zn79 Zn80 Zn81 Zn82 Zn83 Zn84 Zn85 Zn86
Cu65 Cu77 Cu79 Cu80 Cu81 Cu82 Cu83
Ni64 Ni65 Ni66 Ni67 Ni68 Ni69 Ni70 Ni71 Ni72 Ni73 Ni74 Ni75 Ni76 Ni77 Ni78 Ni79 Ni80 Ni78
Co78
50
N=58
suspected new subshell gap