Can β-decay populate PDR states ?

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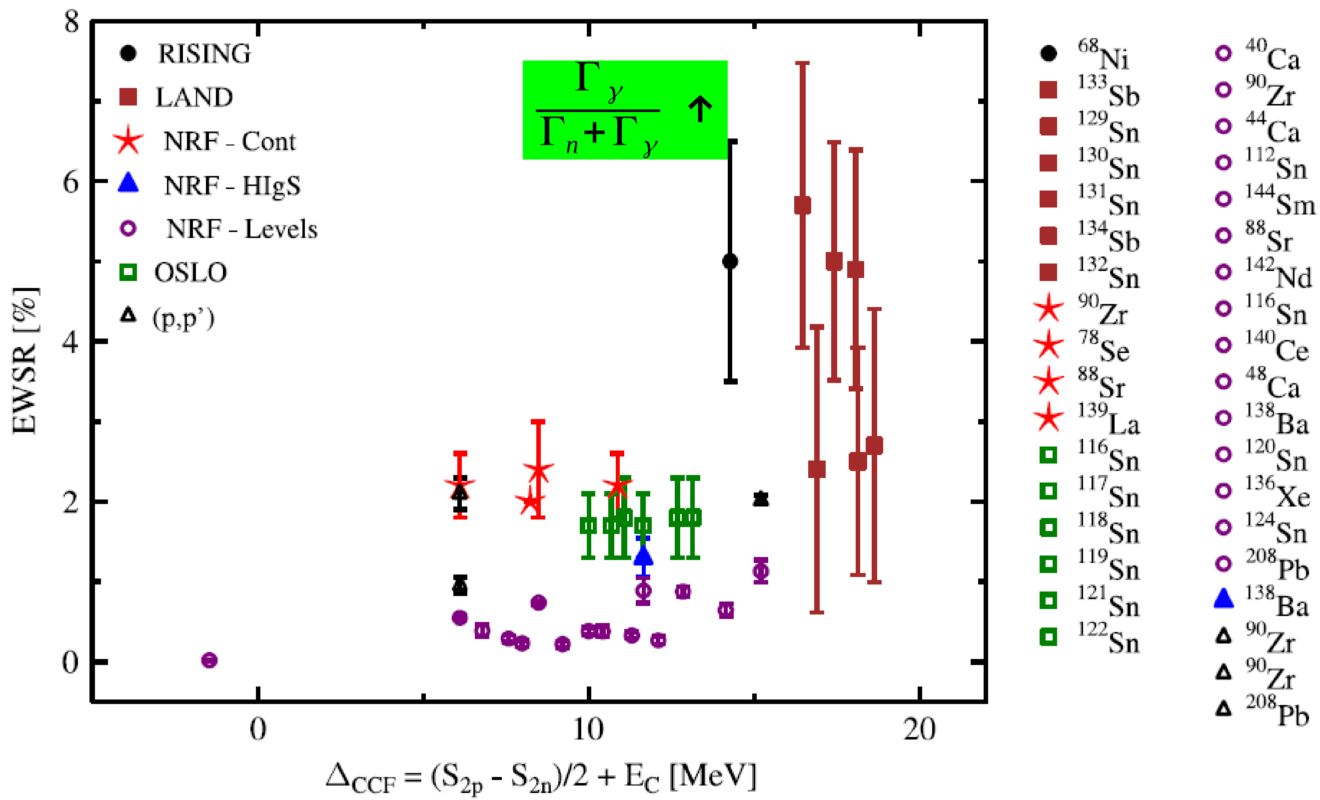
Experimental and theoretical PDR work : concentrated around proton closed shells : Z=20, 28, 50, 82

(review: D. Savran et al. / PPNP 70 (2013) 210–245)



- Different (complementary) experimental techniques : NRF, (relat) COULEX, hadron scattering, ion induced reactions (probing also the PDR structure)

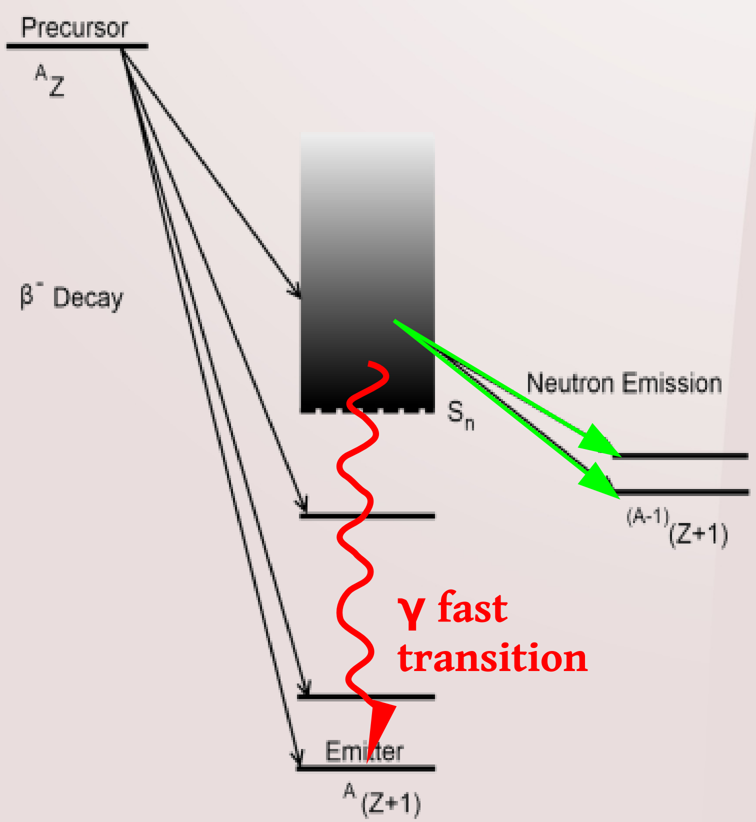
- NRF – stable nuclei; all others are produced in reactions and used on secondary targets (need intensities > 10^3 – 10^4 part/sec)

What about PDR along closed neutron shell isotonic chains ?

N=50 : R. Schwengner et al, PRC87 (2013)
N = 82 : D. Savran et al, PRC84 (2011)
Theoretical calculations: N. Tsoneva et al, Journal of Physics G: Nuc. Part. Phys. 35 (2008)
...

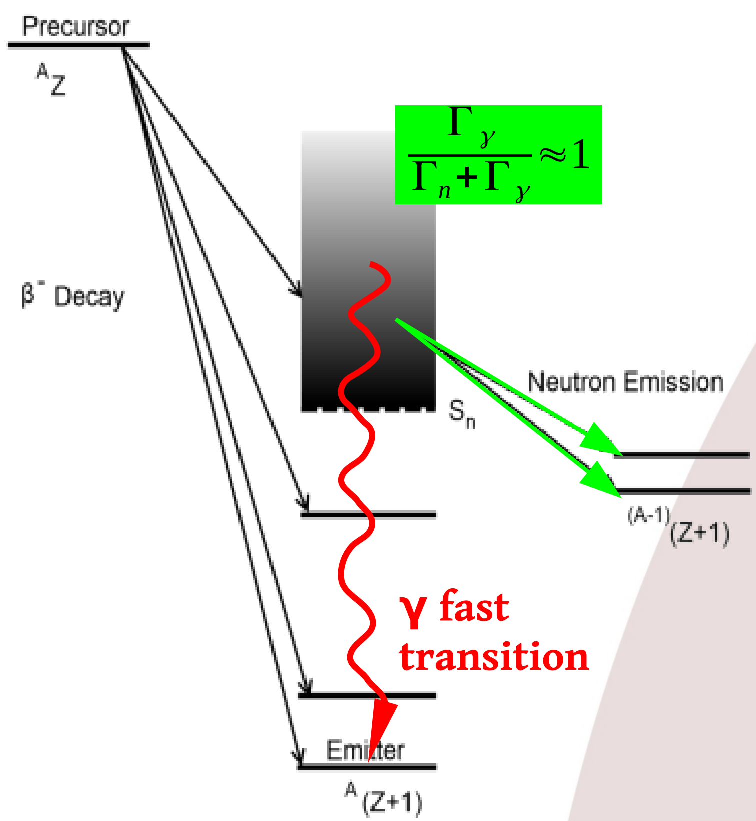
Limited to stable nuclei !

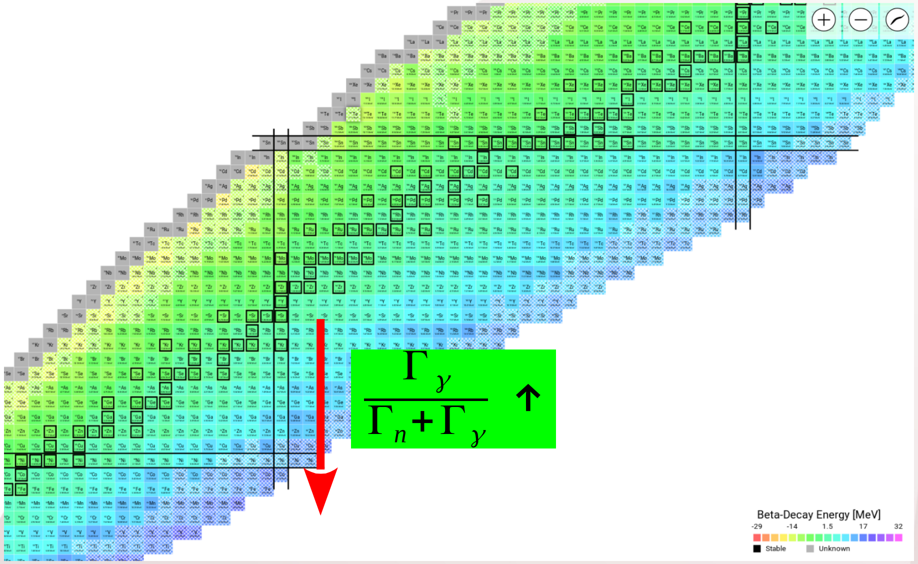
Along an isotonic chain systems become faster exotic that along an isotopic chain
→ experimentally challenging !



But this also opens the Q-beta window and lowers the Sn !

Result: high energy exited states are populated (PDR region ~ 7-10 MeV) and high energy gamma transitions compete with n-decay (signature of E1 type)





TAS technique

Tain et al PRL 115, 062502 (2015)

"Enhanced γ-ray emission from neutron unbound states populated in β decay"

$^{87,88}Br$; $^{93,94}Rb$

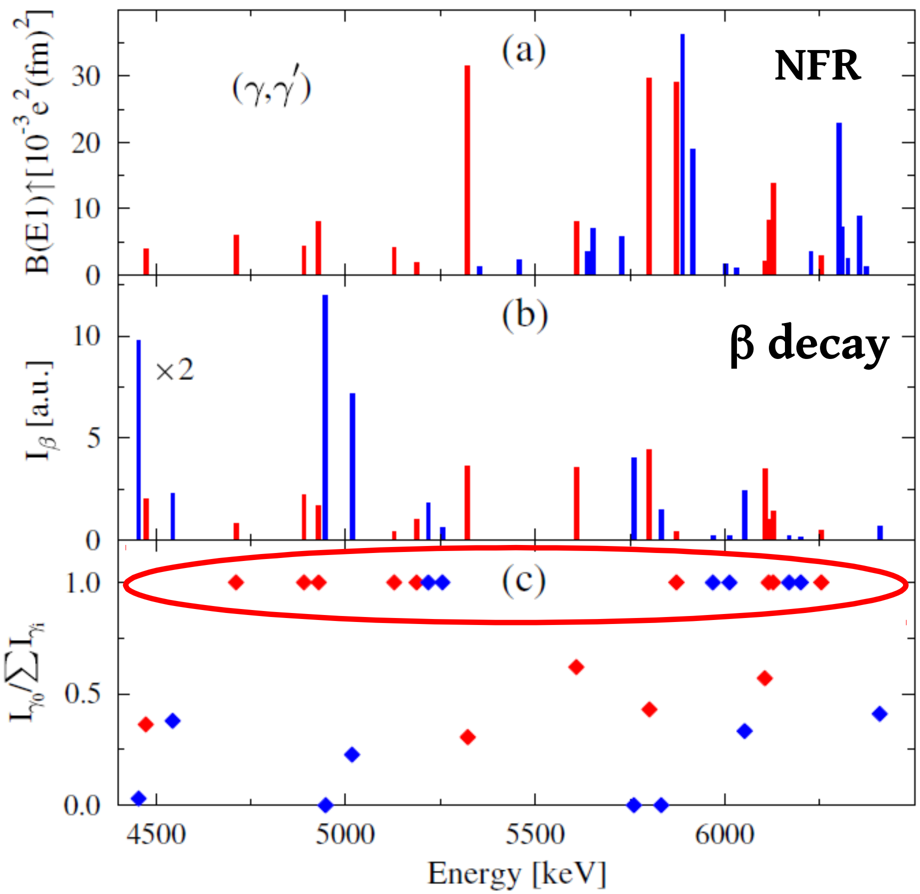
enhancement of Γ_γ → consequence on (n,γ) cross sections → impact on r-process calculations

Example 1: $^{136}I \rightarrow ^{136}Xe$(stable), N=82

(Scheck et al, PRL116 (2016))

Mother	J^π	Daughter	S_n [keV]	Q_β [keV]	$P_{\beta n}$ [%]
^{48}K	(2^-)	^{48}Ca	9945	12090	1.1
^{50}K	$(0^-, 1^-, 2^-)$	^{50}Ca	6353	14220	22.5
^{84}Ga	(0^-)	^{84}Ge	5243	12900	42.5
^{86}Br	(1^-)	^{86}Kr	9857	7626	
^{96}Y	0^-	^{96}Zr	7856	7096	
^{98}Y	$(0)^-$	^{98}Zr	6415	8824	0.33
^{130}In	$1^{(-)}$	^{130}Sn	7596	10249	0.92
^{136}I	(1^-)	^{136}Xe	8084	6930	
^{140}Cs	1^-	^{140}Ba	6428	6220	
^{142}Cs	0^-	^{142}Ba	6181	7325	0.09
^{144}Cs	$1^{(-)}$	^{144}Ba	5901	8500	2.9
^{146}Cs	1^-	^{146}Ba	5495	9370	12.4

Red – transitions seen in both



Ingredients:

- High Qbeta, low Sn

- Jᵖ selection rules compatible between GT transitions and E1 decays

Conclusions:

- only a fraction of PDR levels are populate in β-decay

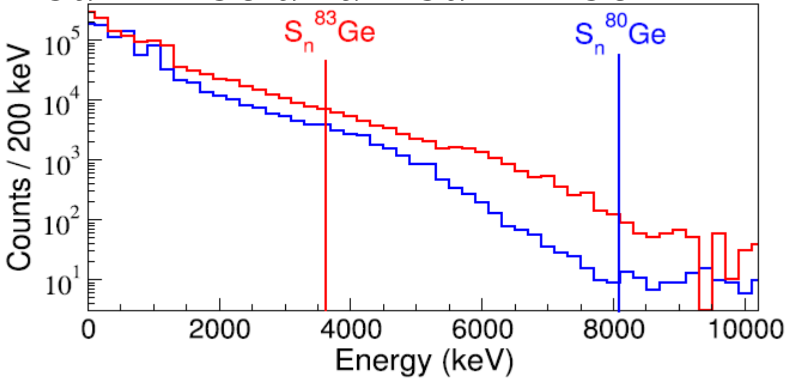
- Comparison with QPM (quasi-particle phonon model) indicate that β-decay dominantly populates complex configurations

Example 2 : ALTO-RIB experiment
^{83}Ga: can GT trigger low-lying nuclear dipole oscillations ?

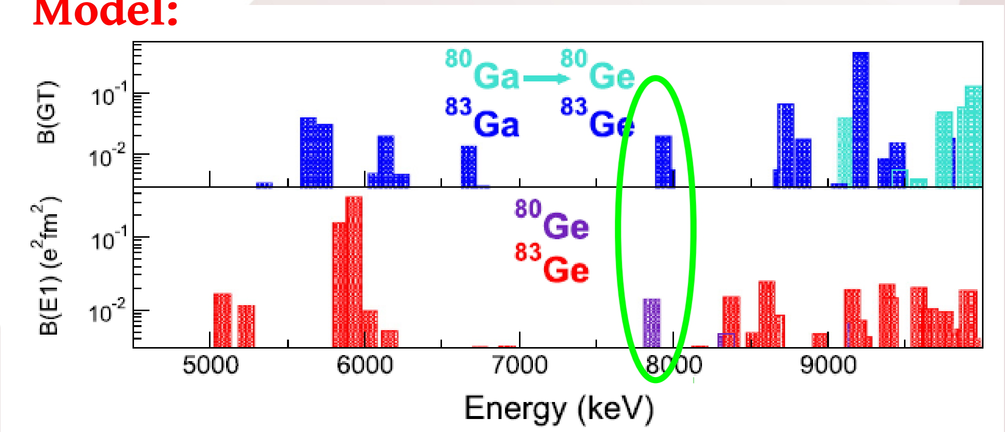
A.Gottardo et al., PLB772 (2017)

Measurement (1 single LaBr3 2x2x4):

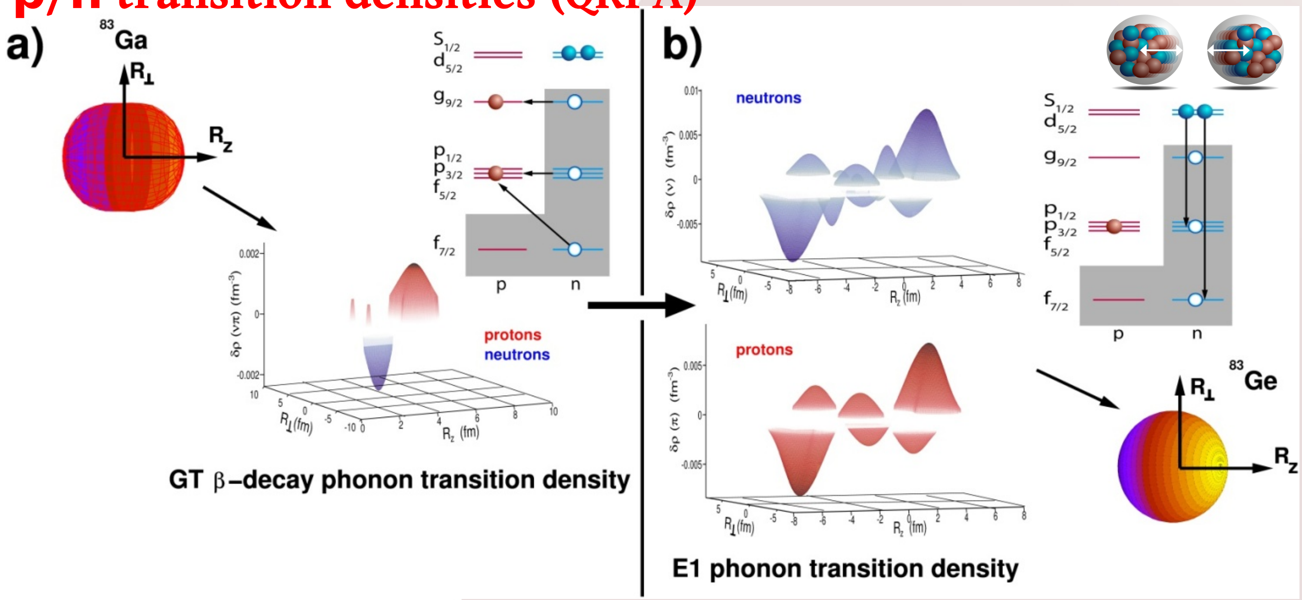
^{80}Ga → ^{80}Ge and ^{83}Ga → ^{83}Ge



Model:



p/n transition densities (QRPA)



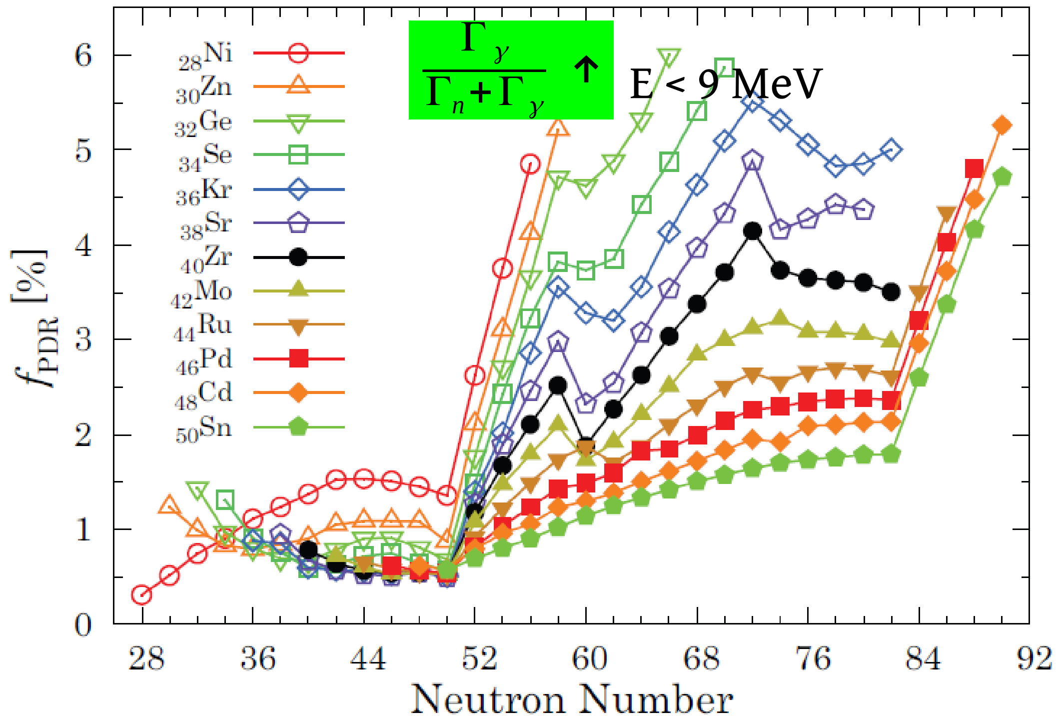
a) GT decay create a depletion of neutron density in the core

b) The excited ^{83}Ge states can then decay via E1 γ emission with a «PDR-like» transition density

Motivations from theoretical field

(S. Ebata, T. Nakatsukasa, and T. Inakura, Phys. Rev. C 90 (2014))

- Canonical basis time-dependent Hartree-Fock-Bogoliubov (CbTDHFB) with Skyrme force

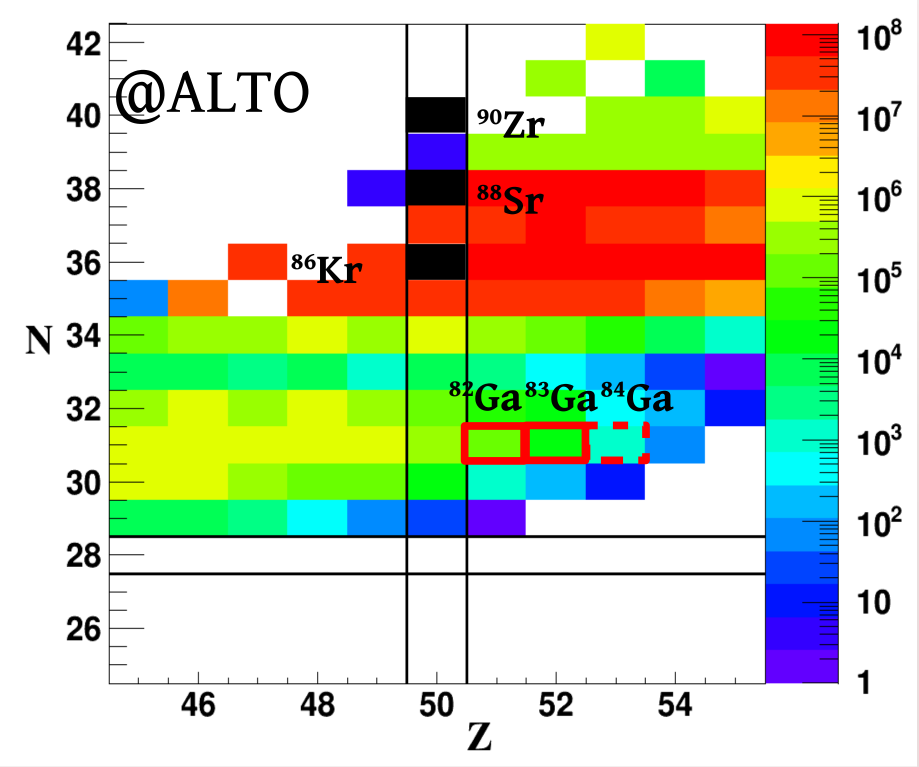


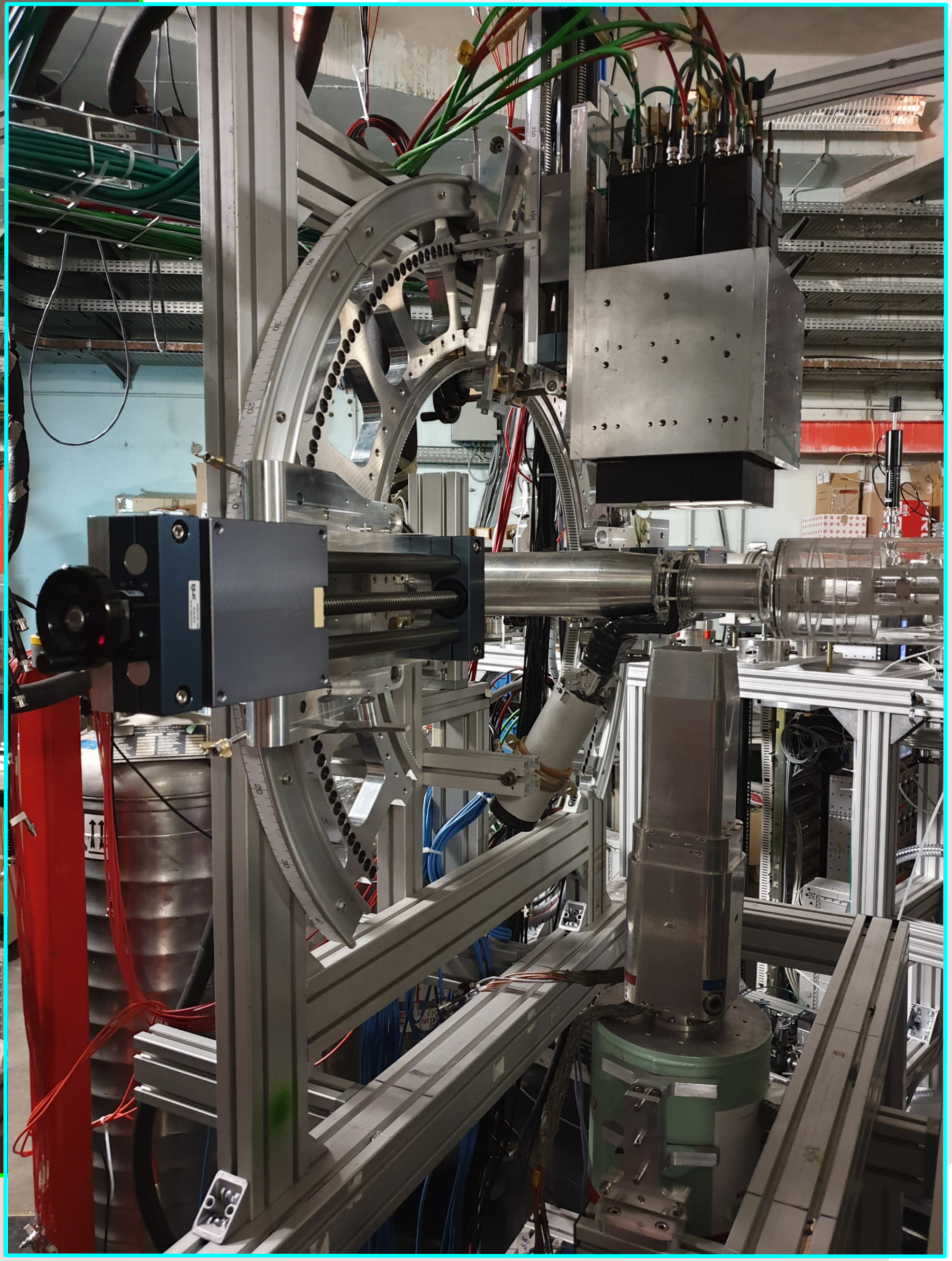
- higher slope from N=50 to N=52 for most exotic isotopes

- fPDR for N=50 increases when going towards Nickel isotopes

N = 50 : dipole strength distribution studies towards neutron rich isotopes

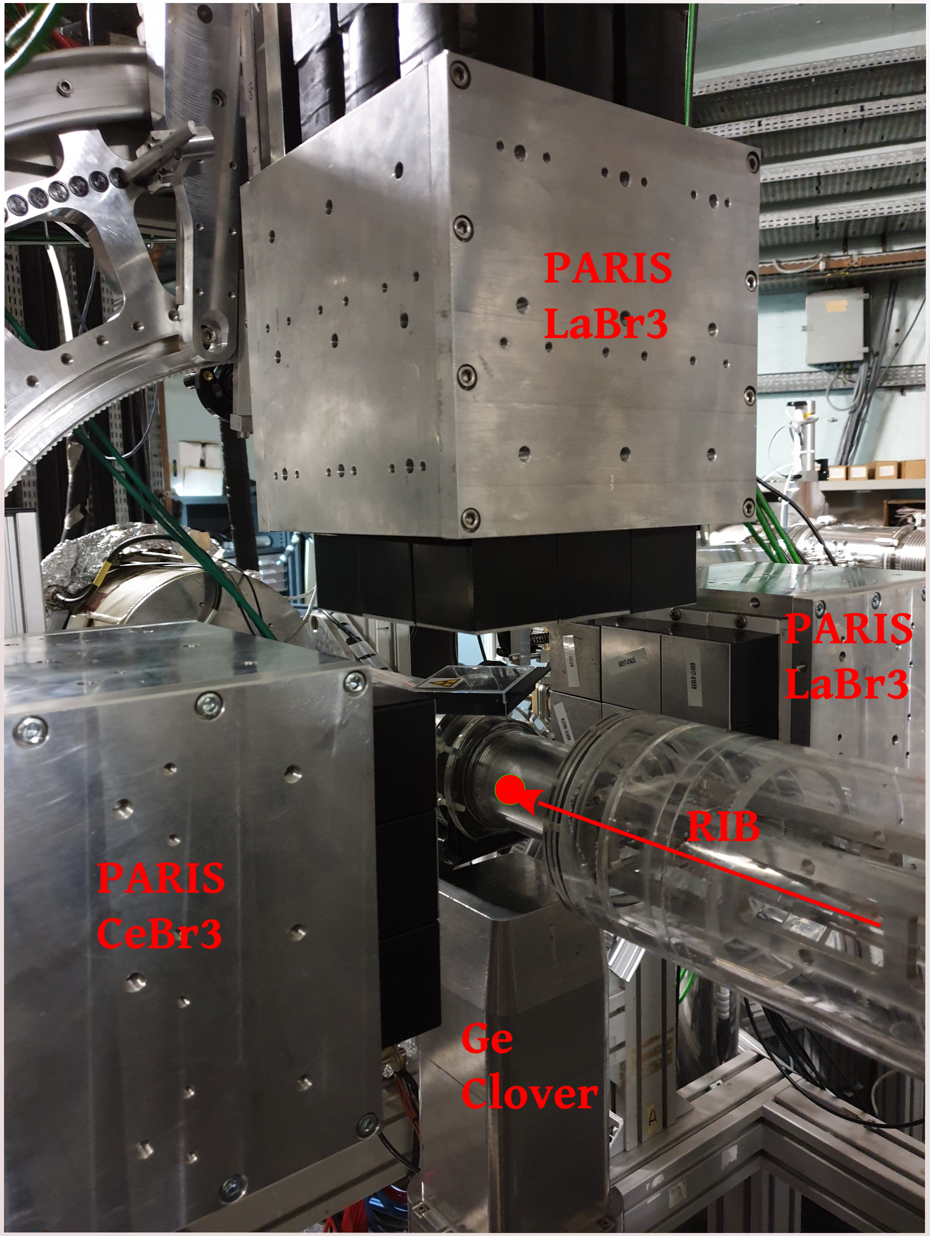
So, there is an increasing PDR strength below 9 MeV above a shell closure → energetically, they are then accessible by beta decay

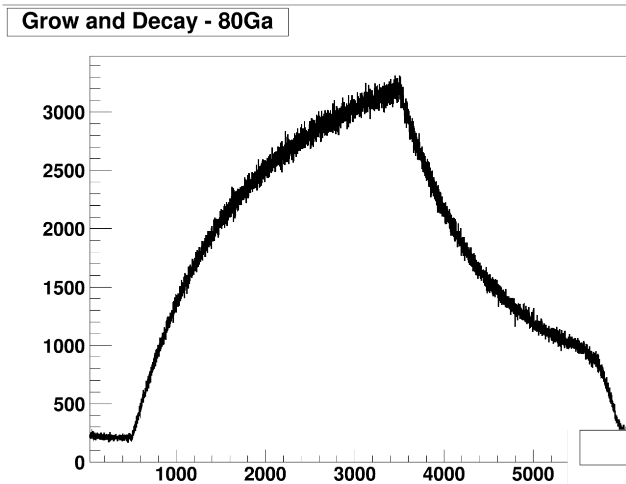


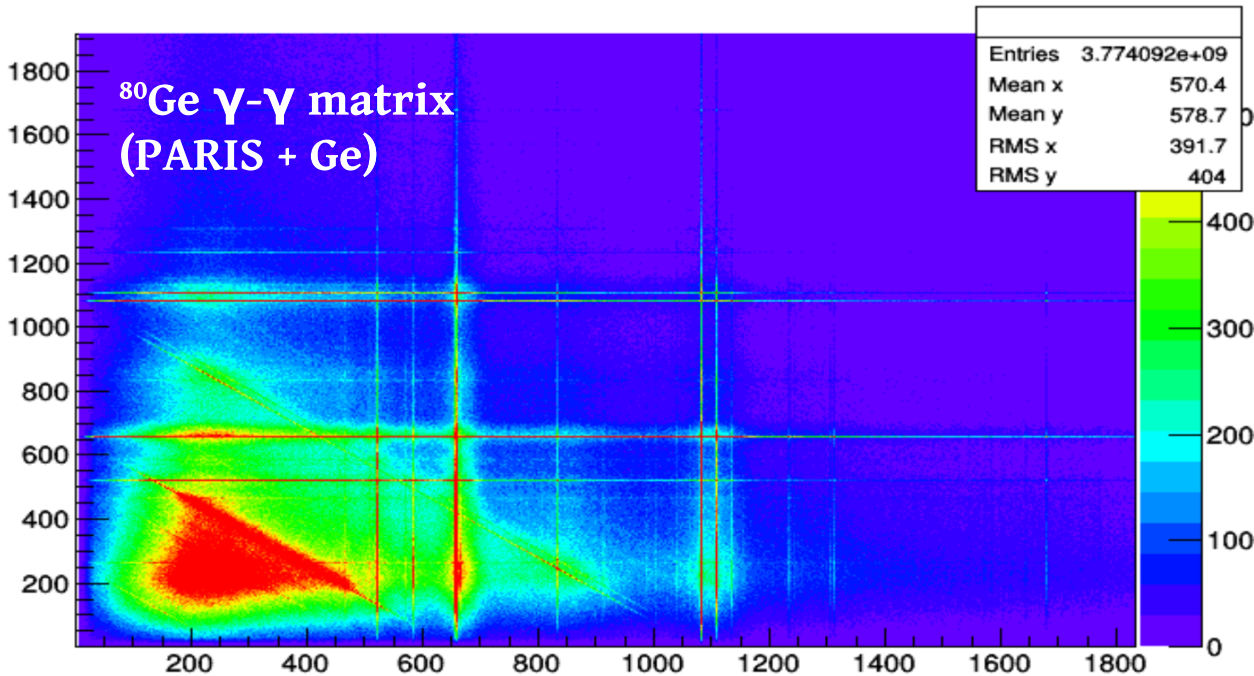


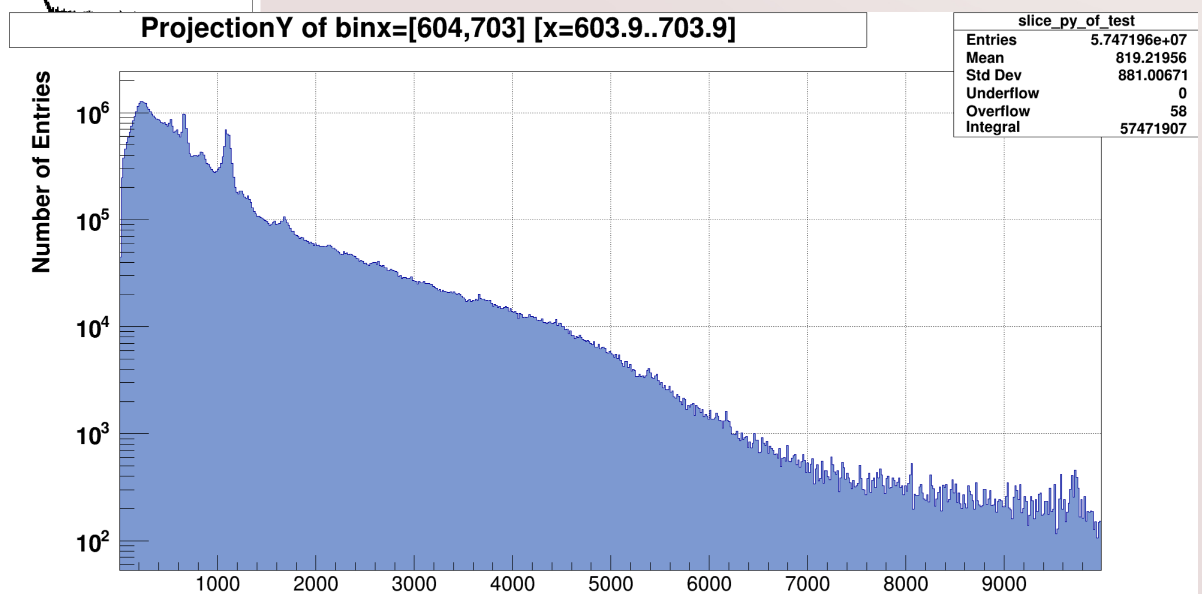
SETUP @ ALTO - BEDO:

- Tape implantation
- Beta detection : plastic (~70% eff)
- 3 PARIS clusters (13% @ 8 MeV)
- 1 HPGe Clover (~2% @ 1MeV)
- 1 Phase1 Ge detector









Very, very preliminary ...

Courtesy of Li Ren (IPN Orsay, PhD)

Thank you!