Quelle est la structure et la dynamique des systèmes faiblement liés (noyaux exotiques)

Contributors

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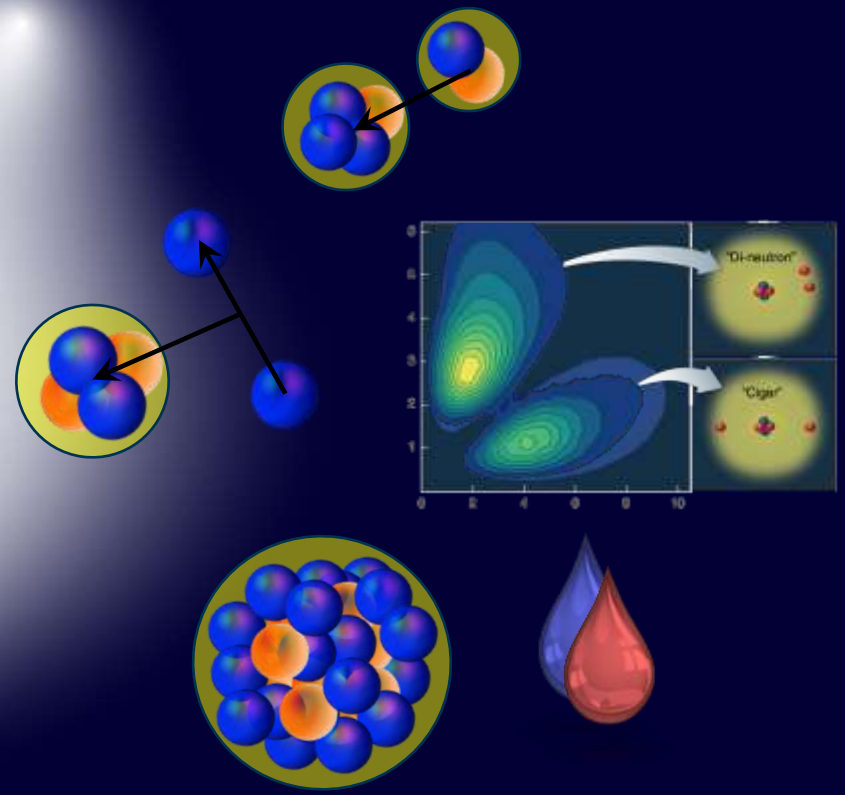

Rapporteurs du GT:

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Topics addressed in GT1 (physics at the drip lines)

1. Shell evolution towards the continuum (respective role of 3body, continuum effects).
2. Evolution of pairing towards the drip line / proton neutron forces close to continuum.
3. Clustering towards the drip line (di-proton, di-neutron, quasi-molecular states).
4. Study of in-medium clustering.
5. Emergence of halo & Borromean states and related properties.
6. Broken mirror symmetries.
7. Quenching of SF towards drip line or between systems involving haloes & cluster nuclei.
8. Giant and pigmy modes in exotic nuclei.
9. Synergy with other quantum systems.

Équipes IN2P3 concernées

CEA

J.P.	Ebran
A.	Corsi
M.	Vandebrouck

CENBG

J.	Giovinazzo
S.	Grévy
B.	Blanck

IPHC Strasbourg

R.	Lazauskas
N.	Novacki
S.	Courtin

GANIL

O.	Sorlin
F.	De Oliveira
G.	Verde
M.	Ploszajczak
A.	Chbihi

IP2I

J.	Margueron

- Strong theory support
- Topics covered vast area of phenomenon
- Strong internationalization (expt. abroad in GSI/RIKEN)

LPC caen

F.M.	Marqués
A.	Matta
F.	Flavigny
N.	Orr
J.	Gibelin
O.	Lopez
N.	Leneindre
D.	Gruyer
F.	Gulminelli

IJCLab Orsay

D.	Lacroix
M.	Grasso
E.	Khan
J.	Carbonell
P.	Schuck
M.	Assié
D.	Beaumel
Y.	Blumenfeld
I.	Stefan

Actions de « management » réalisées

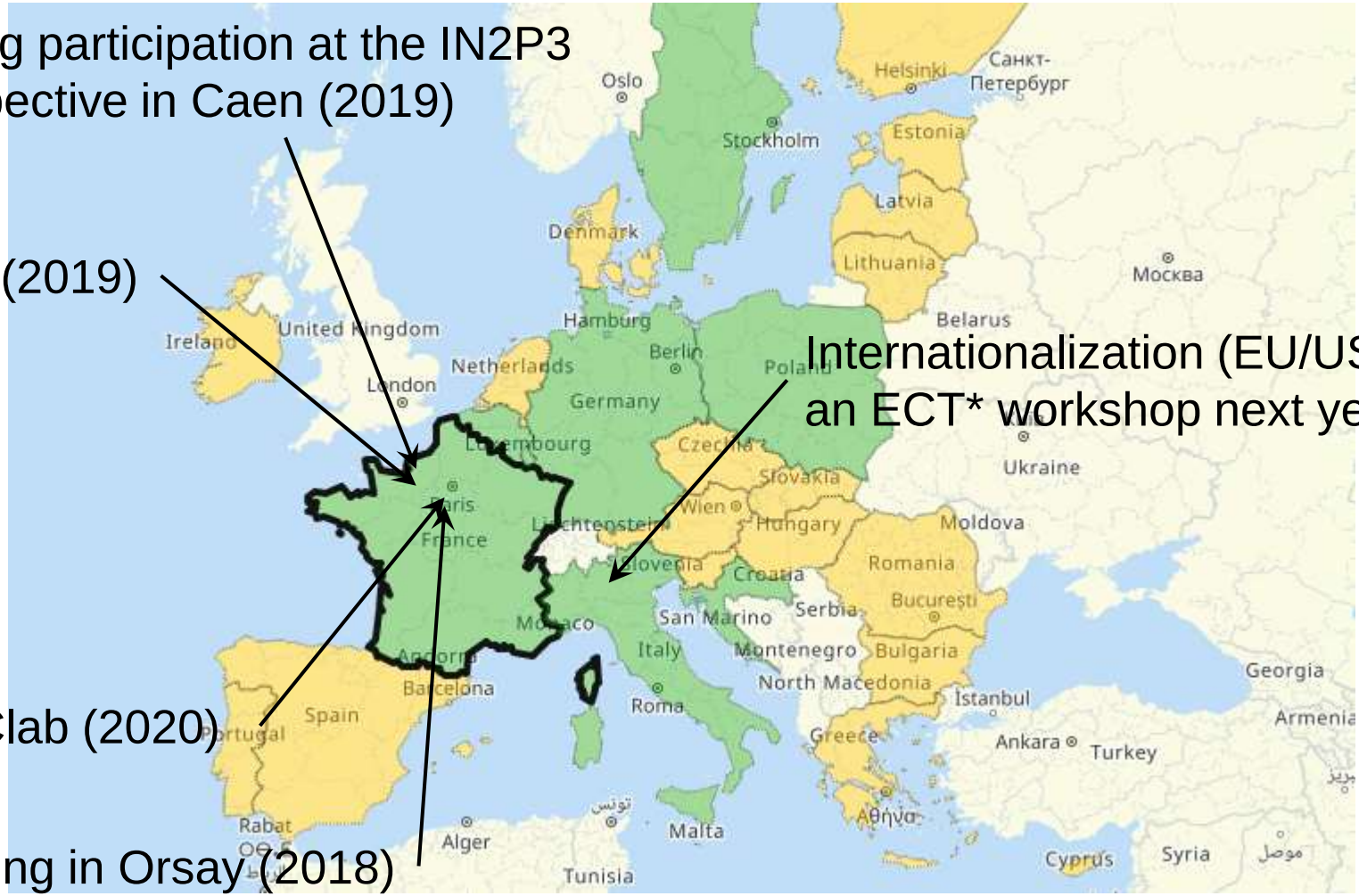
Strong participation at the IN2P3 perspective in Caen (2019)

Workshop in GANIL (2019)

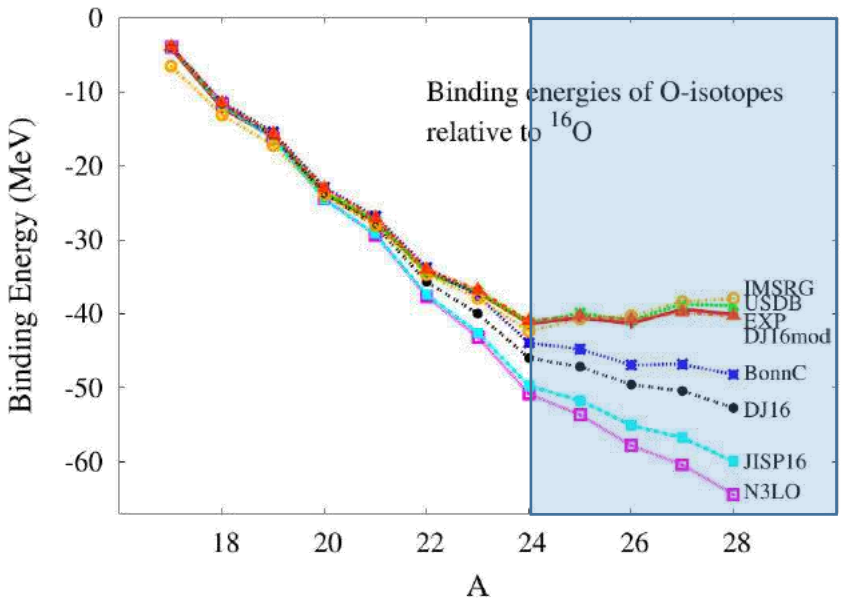
Internationalization (EU/US) with an ECT* workshop next year

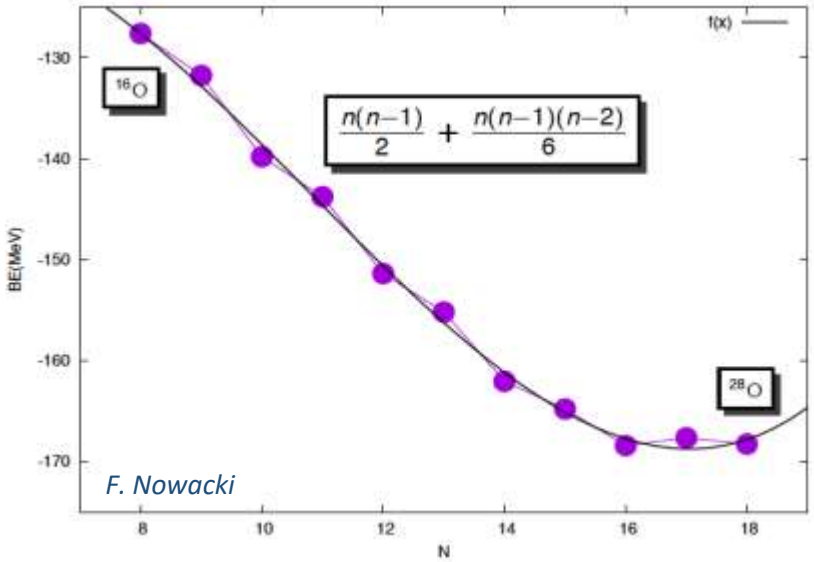
Workshop GMR at IJClab (2020)

First meeting in Orsay (2018)



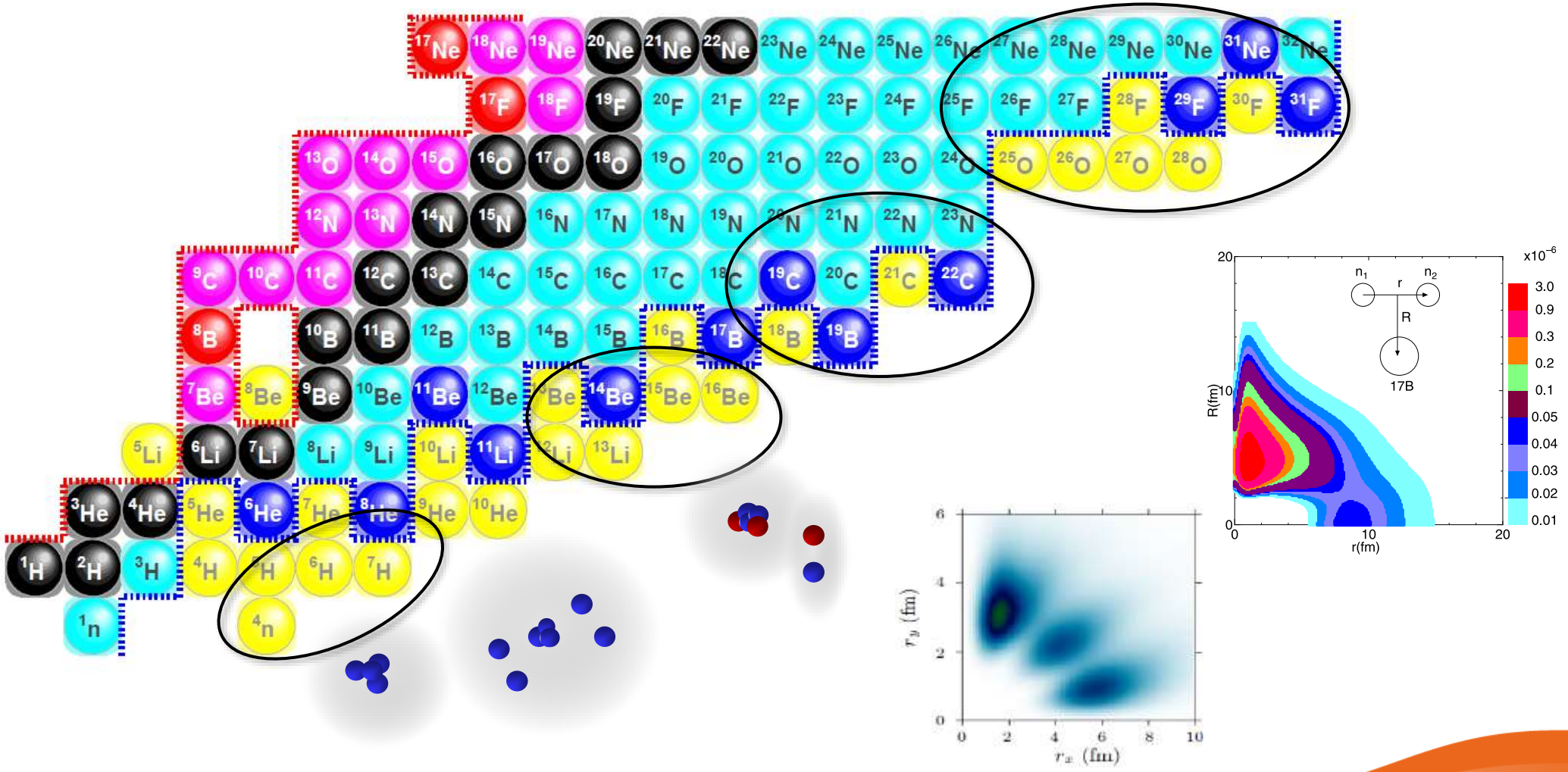
Shell evolution in the O chain: 3N forces viz continuum ?





- Curvature of BE in O chain accounted for by effective 2-body or ‘realistic’ 3-body forces.
- But the proximity of the continuum is expected to produce non-linear effects as well.

Shell evolution in the O chain: 3N forces viz continuum ?



Ongoing work!

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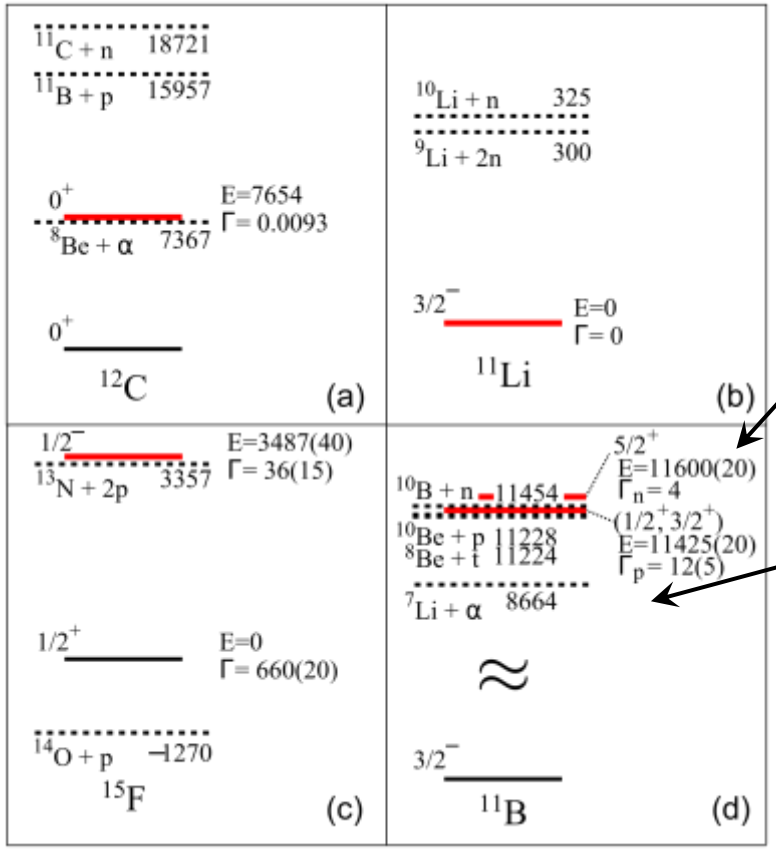
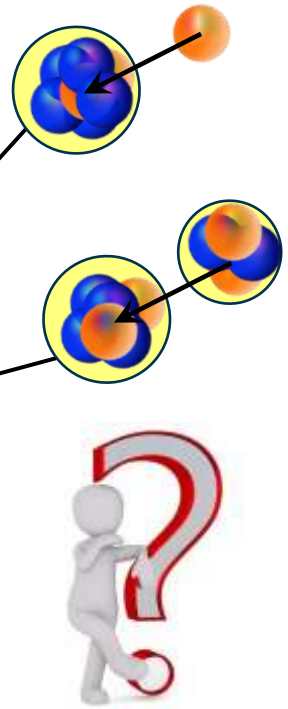
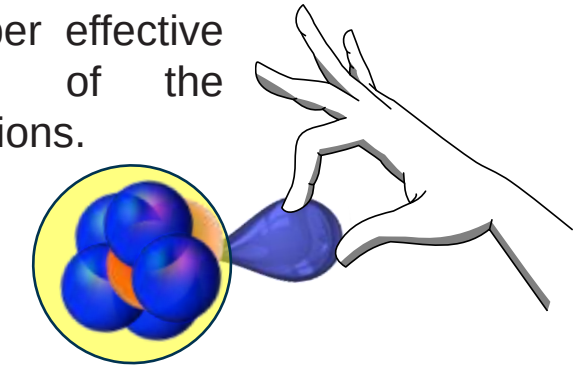
Life in the continuum (one example)

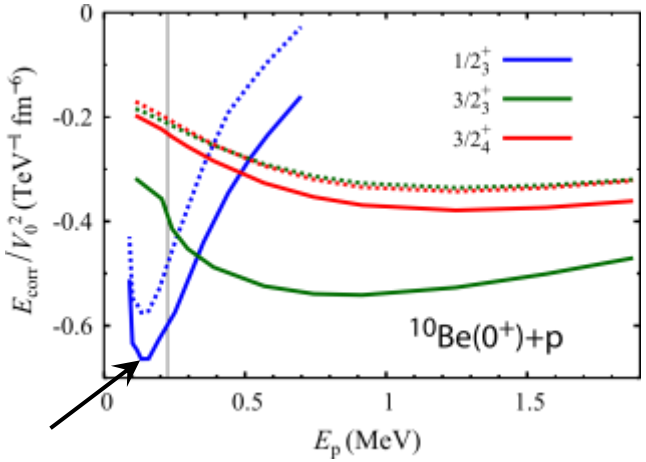




Motivation : On which decay channel lies the 2nd excited state of ^{11}B ?

Method : Shell model embedded in the continuum with proper effective interaction. Exploration of the different decay configurations.





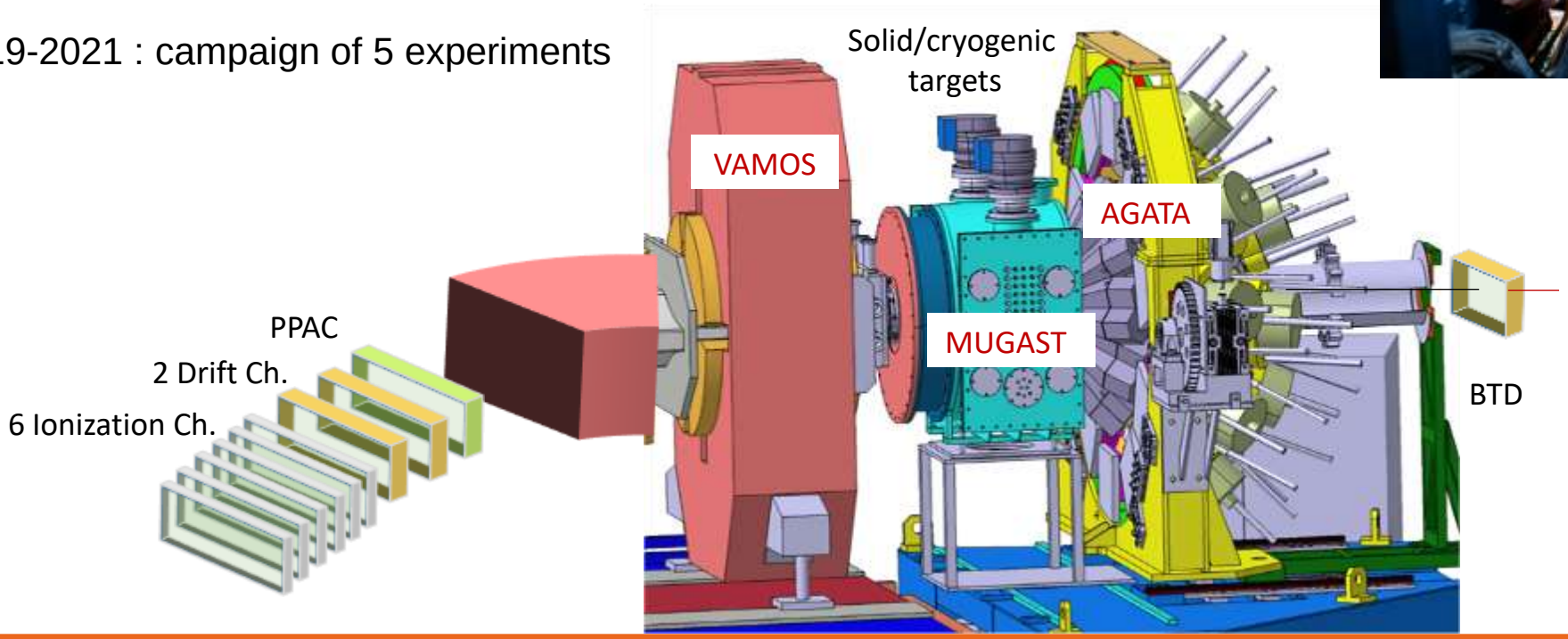
Minimum configuration at the physical energy

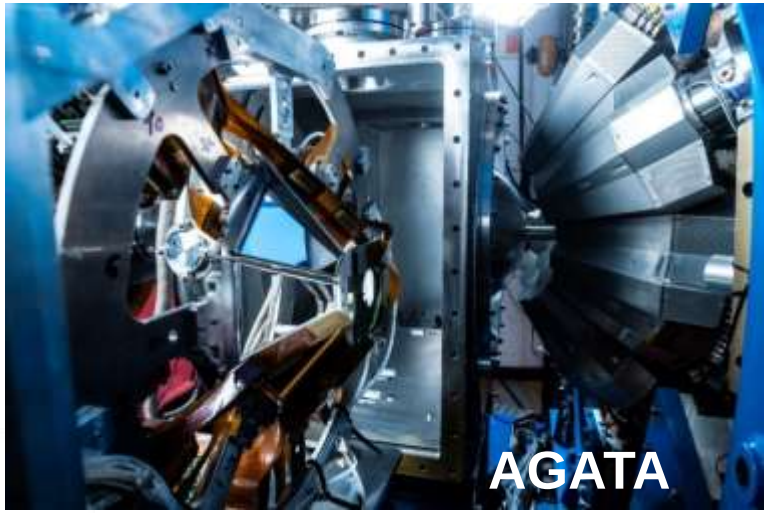
Competitive setup for direct reactions : MUGAST–AGATA-VAMOS

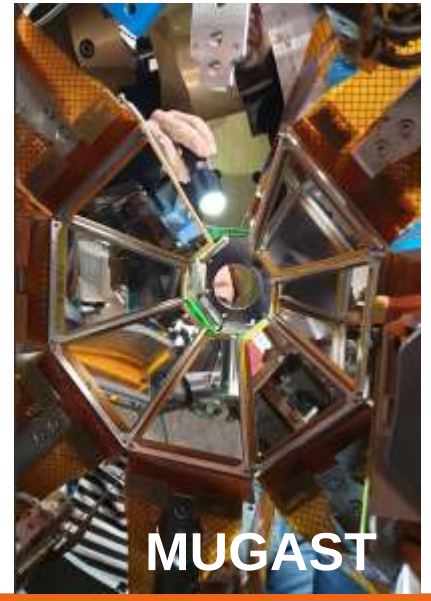
- Transfer reactions induced by **SPIRAL1 radioactive ions beams @ GANIL**
- Unique installation for **high resolution studies** to probe the structure of exotic nuclei combining :
  - ***VAMOS*** **:** large acceptance magnetic spectrometer for **recoiling Ions**
  - ***AGATA*** **:** high resolution **γ-ray** spectrometer,
  - ***MUGAST*** **: light charged particles** (p, d, t and α) angular distributions (J^{π})

  ⇒ High efficiency and selectivity from **triple coincidence measurements :**

- 2019-2021 : campaign of 5 experiments

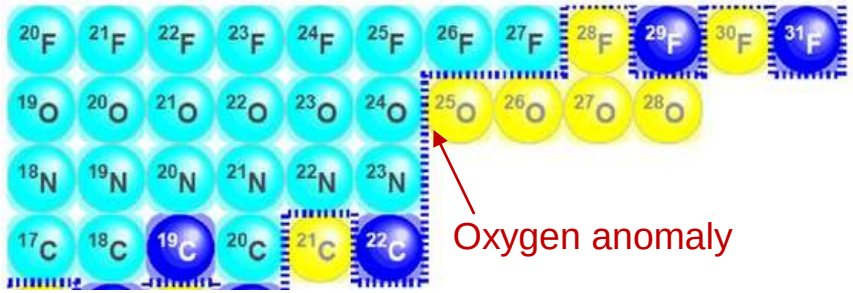




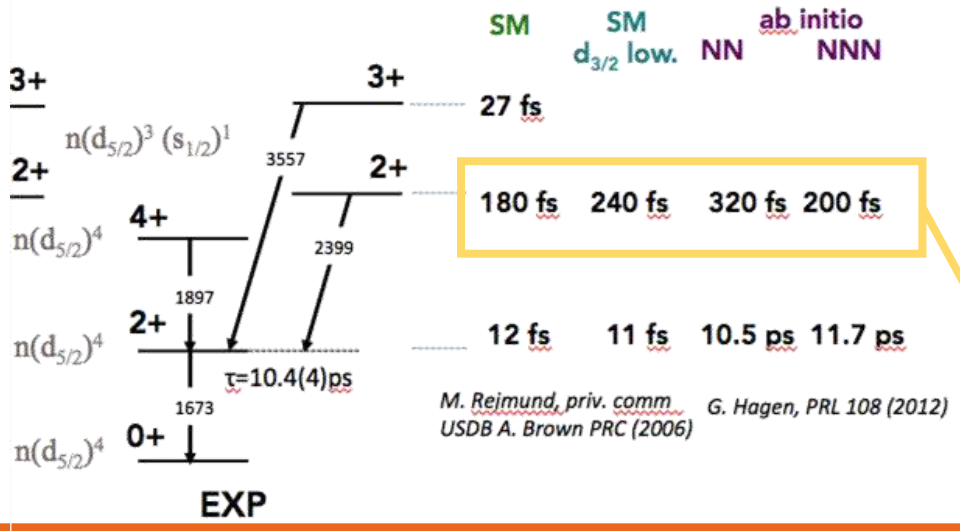


Benchmarking 3-body interactions from controlled lifetime measurement

Motivation : Oxygen drip-line anomaly explained microscopically by including three-nucleon force contribution in the nuclear interaction.



Predictions : from Shell model and ab-initio (2N and 3N forces)

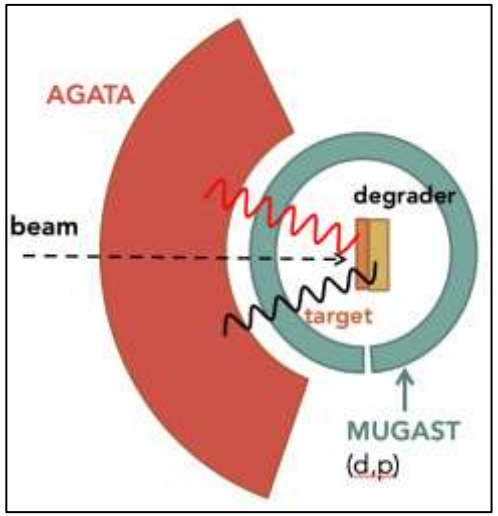


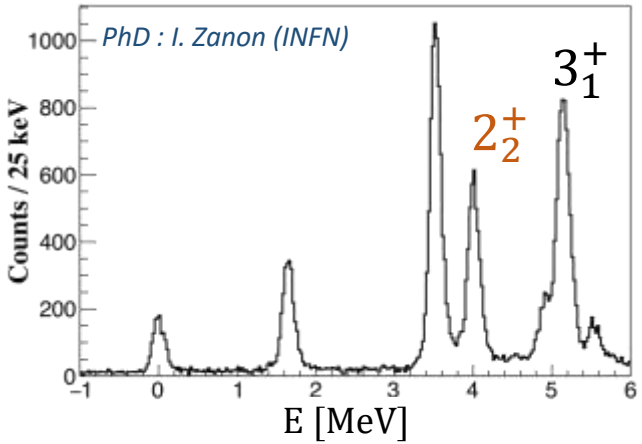
Experiment SP: E. Clément (GANIL), A. Goasduff (INFN)

Method : Exclusive lifetime measurement in the femto-sec. scale (DSAM) using $^{19}O(d,p)^{20}O$

First time in inverse kinematics !

- Triple coincidences in high resolution mode
- Control entry point through transfer reaction



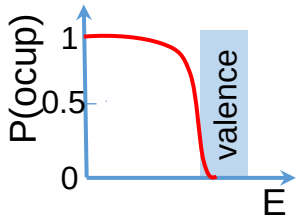


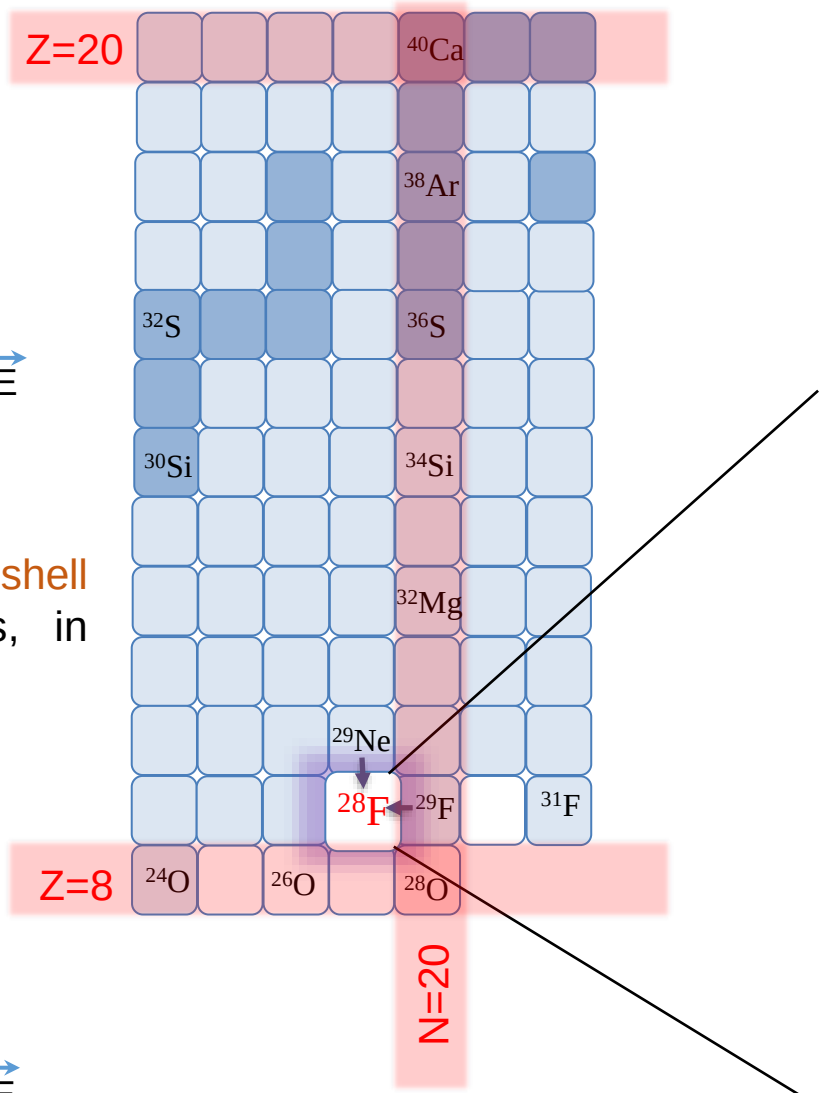
Feeding free 2_2^+ lifetime measurement and
First measurement of 3^+ lifetime
➟ constraint on recent 3-body interactions

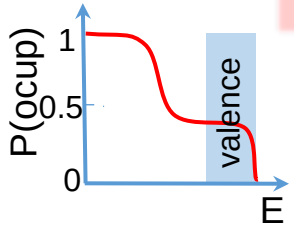
Previous measurement : M. Ciemala et al, PRC 101, 021303(R) (2020), support from ERP in2p3-Cracovie

Hints of disappearance of shell gaps around ^{28}O

Motivation : Evolution of shell structure, magic numbers, in very exotic nuclei.

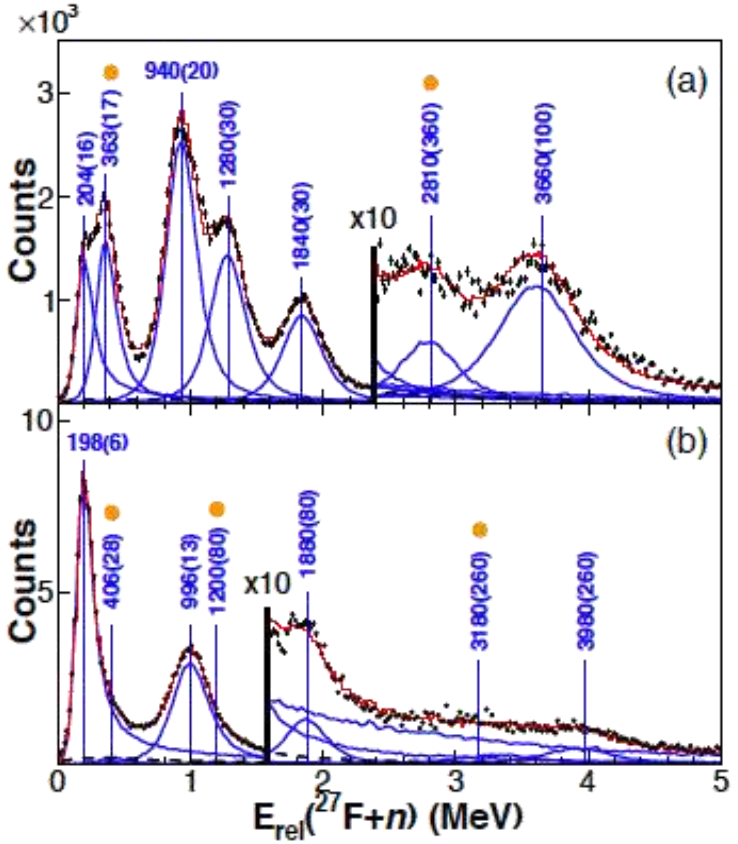




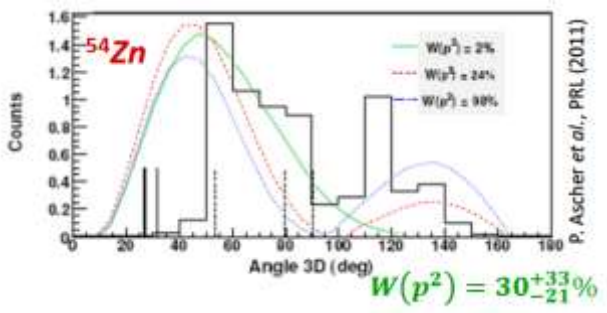


Method : Infer shell evolution from neighboring nuclei.

Results : Mostly p-wave (intruder), very diffuse fermi surface not hint of shell closure and extra stability in ^{28}O.



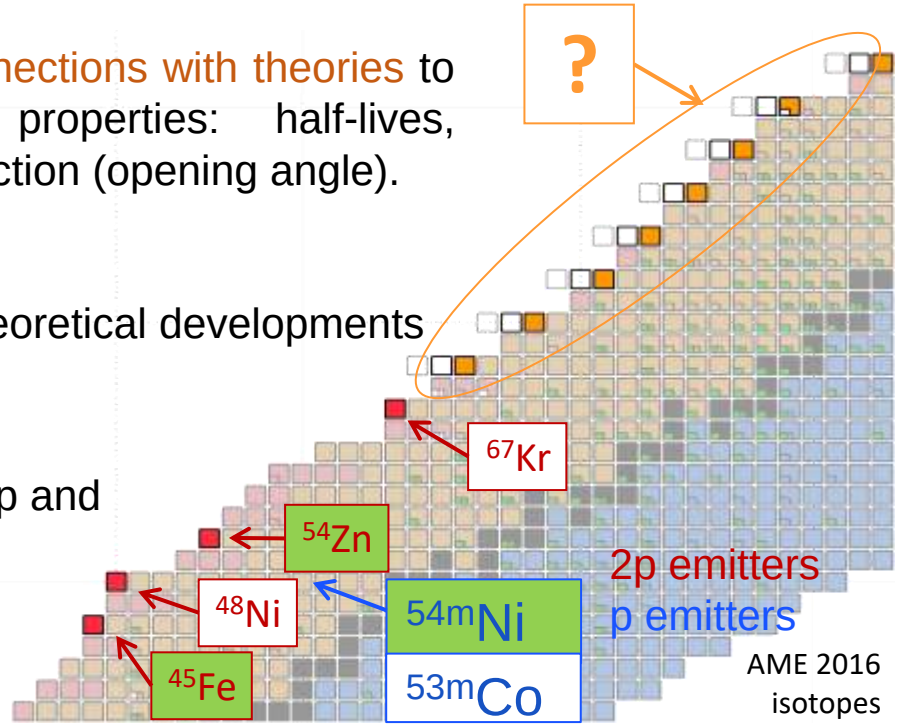
1p radioactivity imaging : first step towards a 2p decay telescope



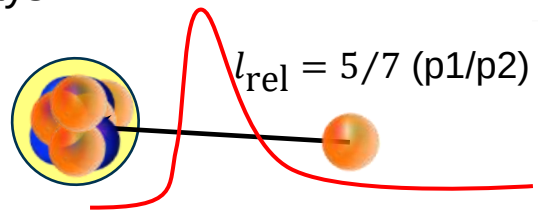
Motivation : Strong connections with theories to interpret the decay properties: half-lives, branching ratio, cross-section (opening angle).

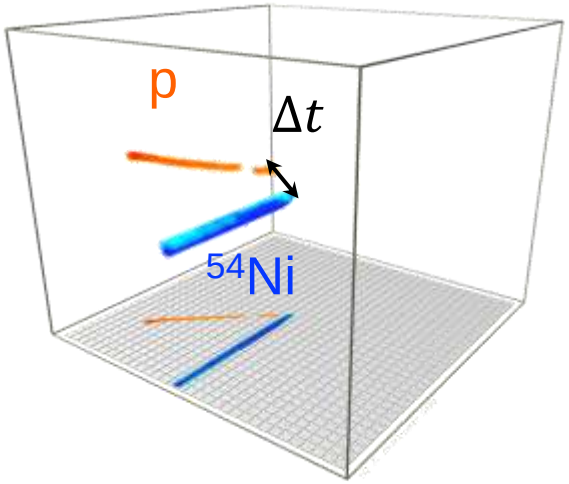
Before :

- Discrepancies with theoretical developments
- Few counts



^{54m}Ni produced by fragmentation : γ,p and 2p decays





Method : New 3D imaging of charged particle radioactivity adapted for rare isotope beams.

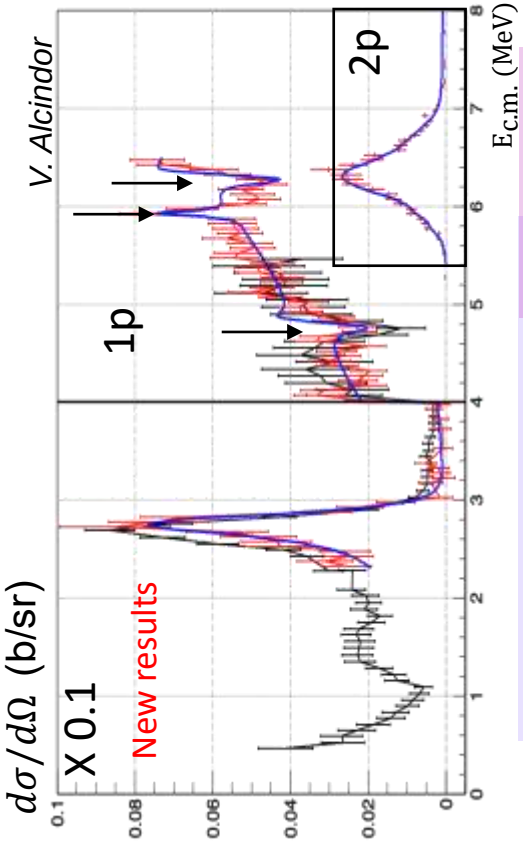
Now :

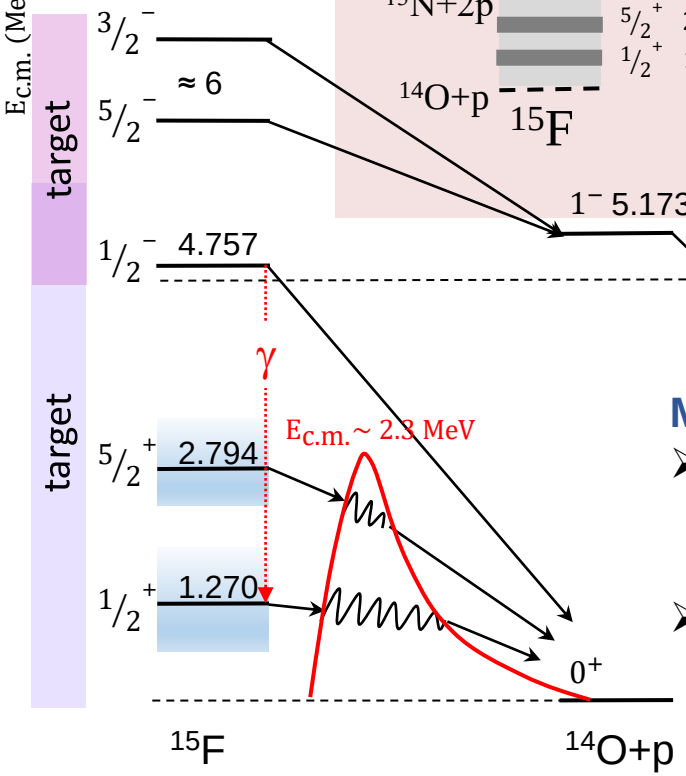
- Better resolution/less dead time

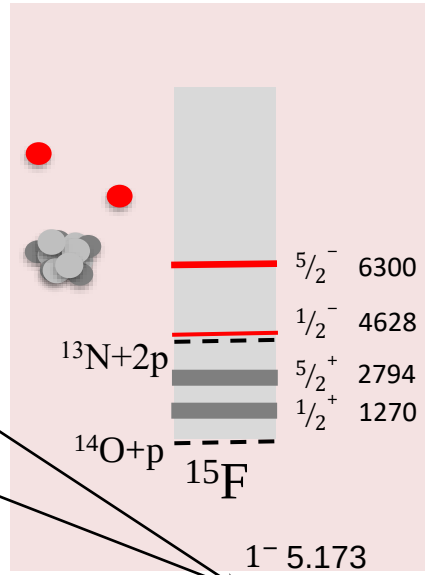
GANIL, RIKEN, GSI

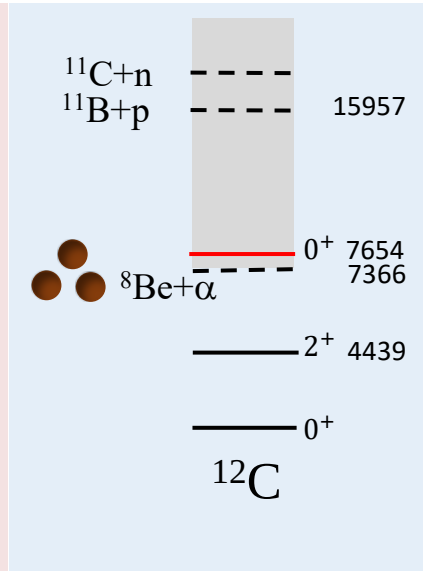
Search for 2p cluster configurations around S_{2p} threshold

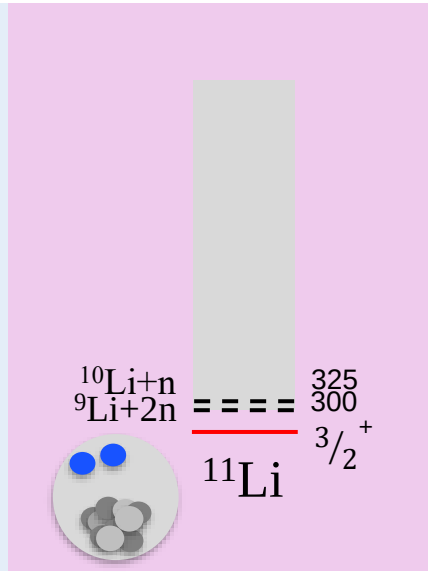
Motivation : Searching for resonances with a xp structure. Spatial properties of 2p resonance at threshold through γ decay.

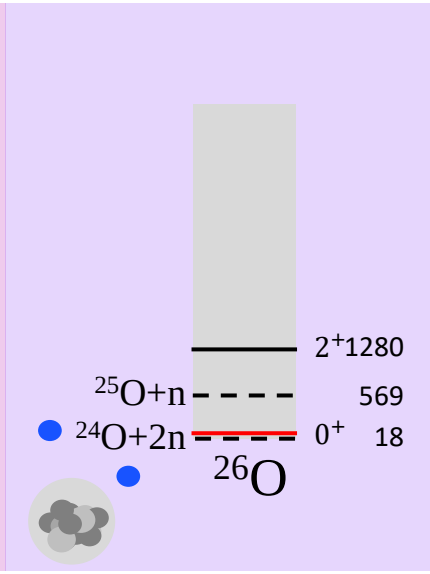






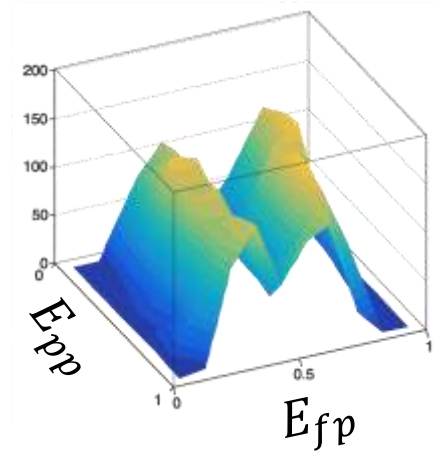






Method :

- Search for E1 fast γ decay signature of cluster state (strong change of spatial distribution).
- Search for others 2p decays and characterize their decays.



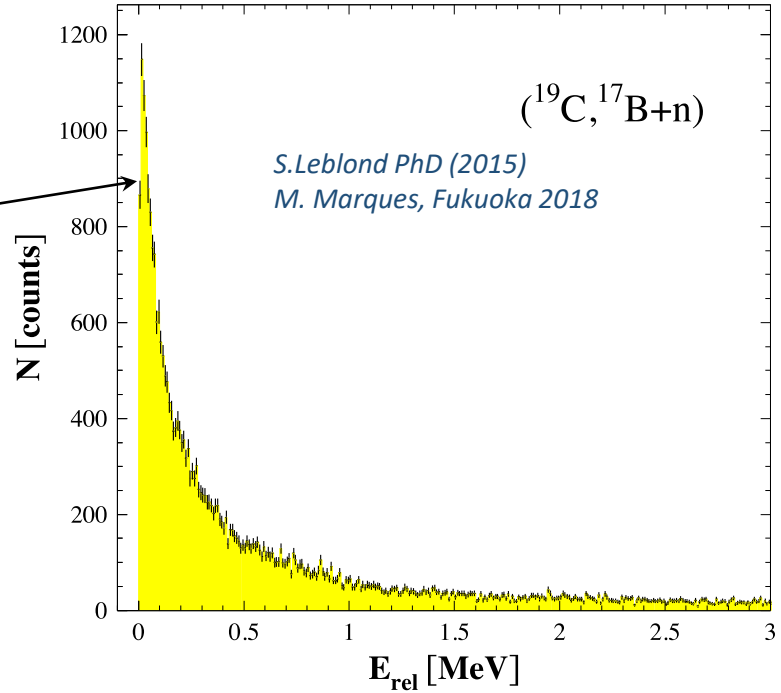
^{17}B-n-n three-body system almost at the unitary limit

Motivation : Nuclear systems at/close to unitarity do not exist, np has the highest isoscalar s-wave scattering length.

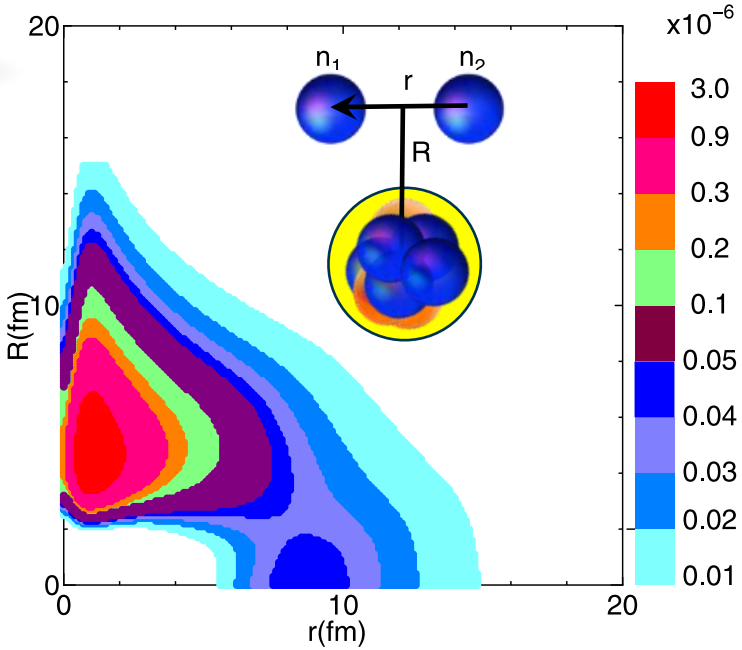
Sym	J	a-	a+
p	½+	**-23.71**	+5.41
n	½+	**-18.59**	
^{2}H	1-	+0.65	+6.35
^{3}He	½+	+6.6-3.7i	+3.5
^{3}H	½+	+3.9	+3.6
^{4}He	0+	+2.61	
^{6}Li	1+	+4.0	+0.57
^{7}Li	3/2^{-}	+0.87	**-3.63**
^{8}He	0+	**-3.17**	
^{9}Li	3/2^{-}	**-14**	

Methods : Observation reports anomalous cross-section at threshold.

$$\sigma(0) = 4\pi a^2$$



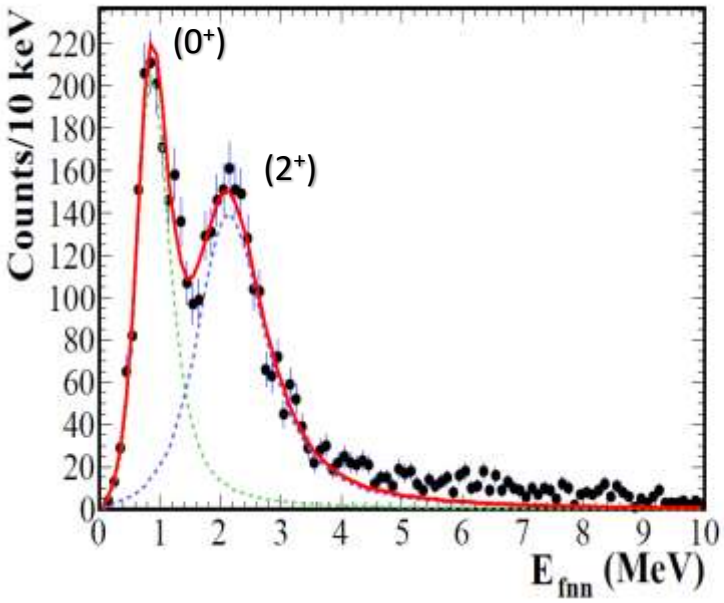
Spatial probability amplitude fixing a_s=-100 fm (not yet experimentally known)

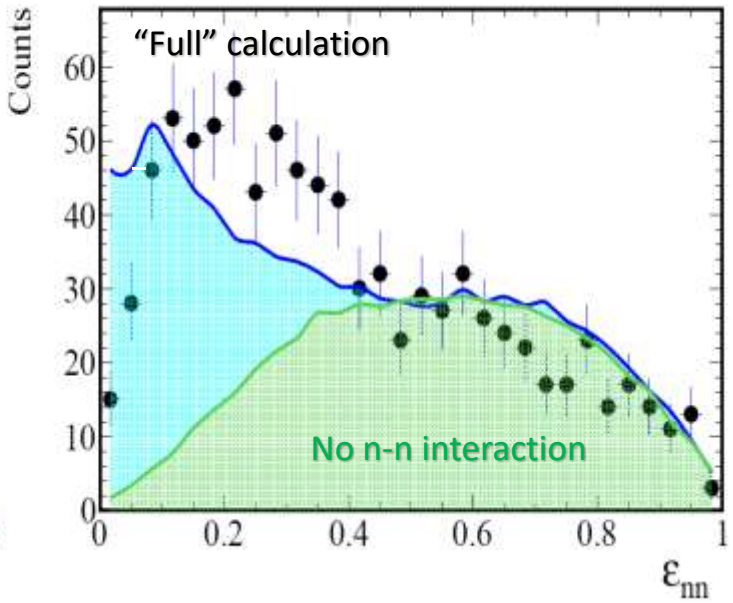


Pre/Postdiction : Genuine three-body calculation with effective n-^{17}B potential and microscopic V_{nn}. Very simple and successful model: local S-wave potential, no 3-body force, one single parameter.

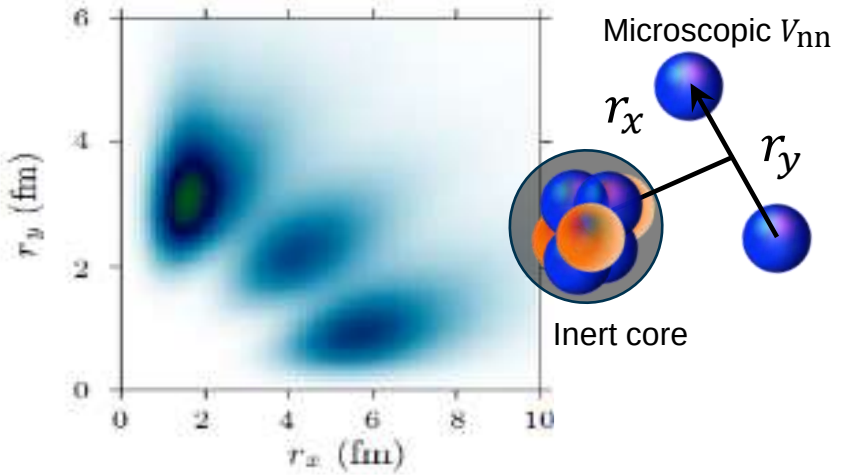
Spectroscopy & neutron-neutron correlations in ^{16}Be

H(^{17}B,^{14}Be+n+n)2p @ 250 MeV/nucleon





B. Monteagudo et al., NP1306 SAMURAI18

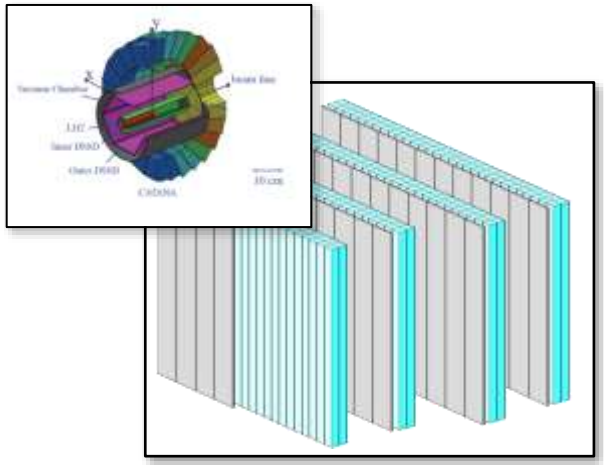


J. Casal et al., PRC (2019)

Motivation : Detect neutron with high efficiency and good angular/energy resolution. Study the structure of neutron halos, based on models.

Method : Improve detection systems

1. Projet "Strasse" (~2020-22)
2. Upgrade "Nebula"

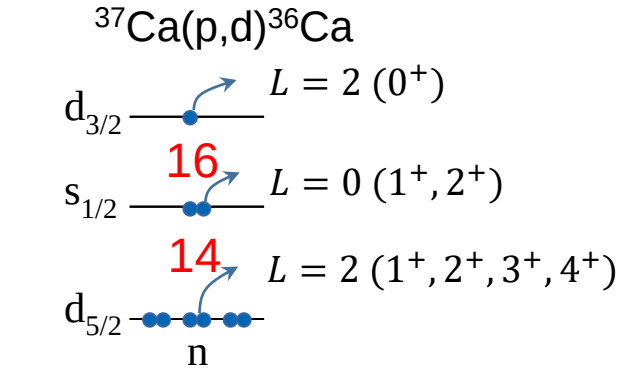


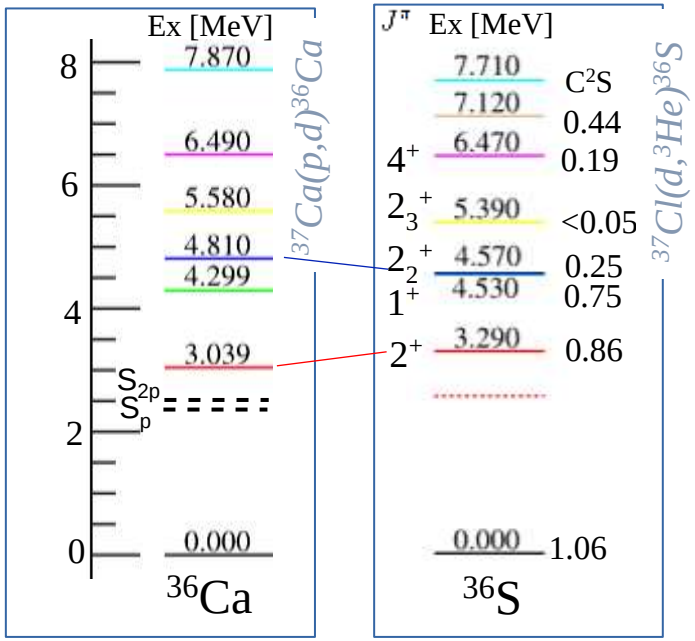
Spectroscopy of ^{36}Ca : mirror symmetry and stellar implications

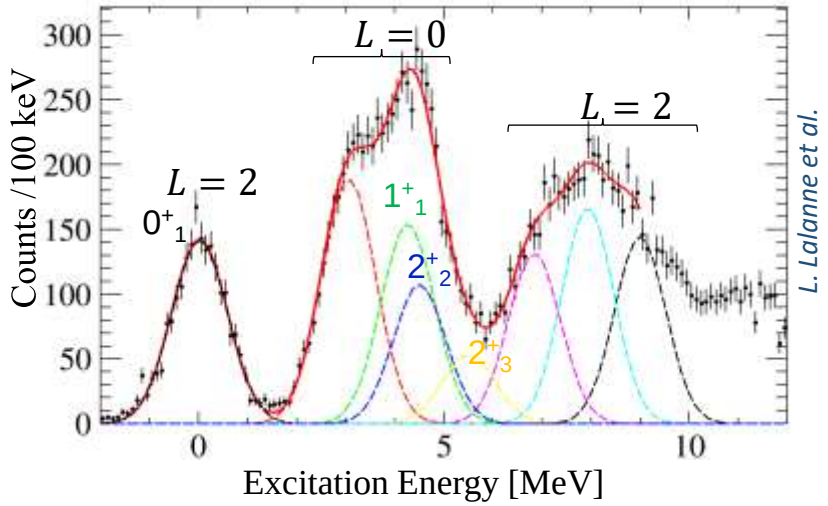
Motivation :

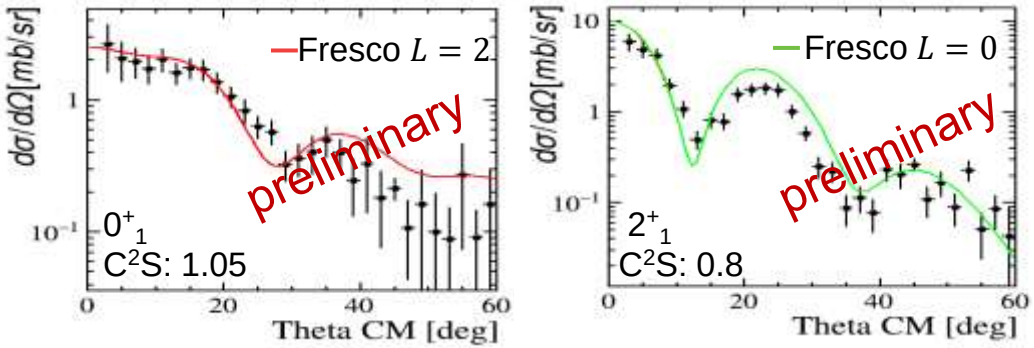
- Determination of the N=16 and N=14 shell gaps.
- Constrain reaction rates through 2^+ and 1^+ resonant states.
- Study of mirror structure and mirror reactions, mixing of states into the continuum in ^{36}Ca.

Method : Study level scheme with transfer reaction (MUST2).



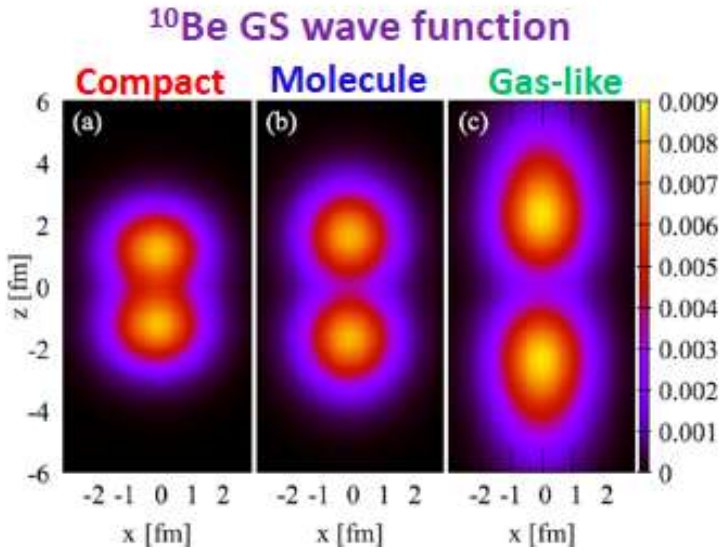






Probing cluster structures using knockout and transfer reactions

Motivation : Observe clustering in nuclei, particularly the type of clustering (d, t, α, ^{6}He, ^{9}Li etc..).



Method : High sensitivity of the α knockout cross section to the extension of the cluster.

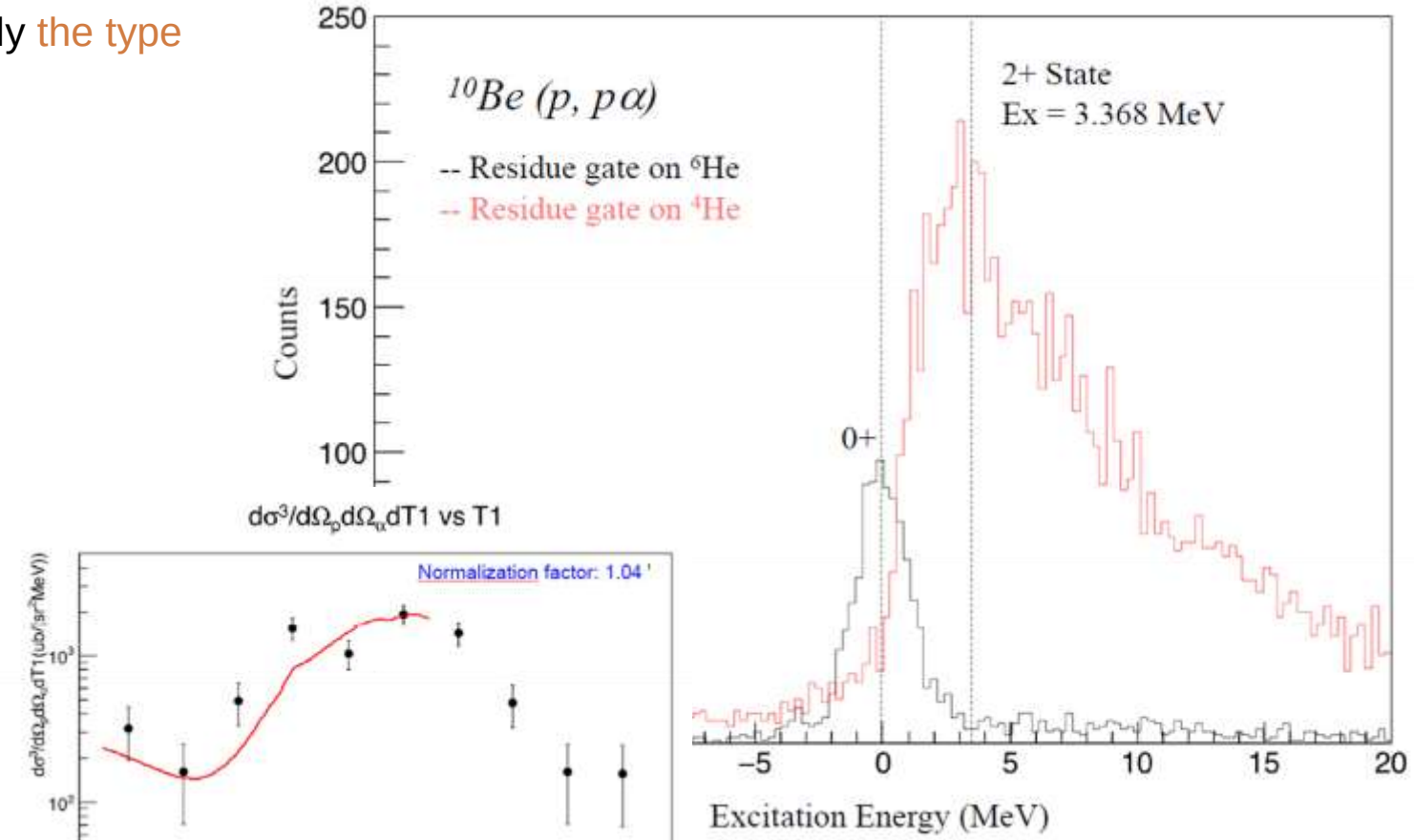


Fig.2 : TDX for ^{10}Be(p,pα)^{6}He^{GS} (Lab frame)

- Good agreement with DWIA

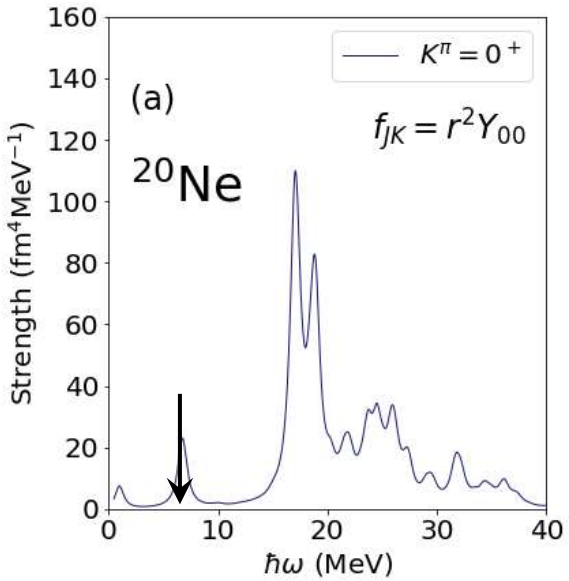
Cluster states in relativistic EDF

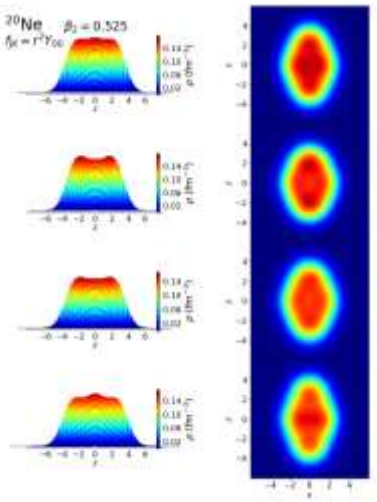
Motivation : Properties of α-clustering, energy, half-life, excitation mode etc...

Method : Relativistic EDF

1. QFAM method for multipole response function.
2. Minimization integral on 3D potential energy surface.

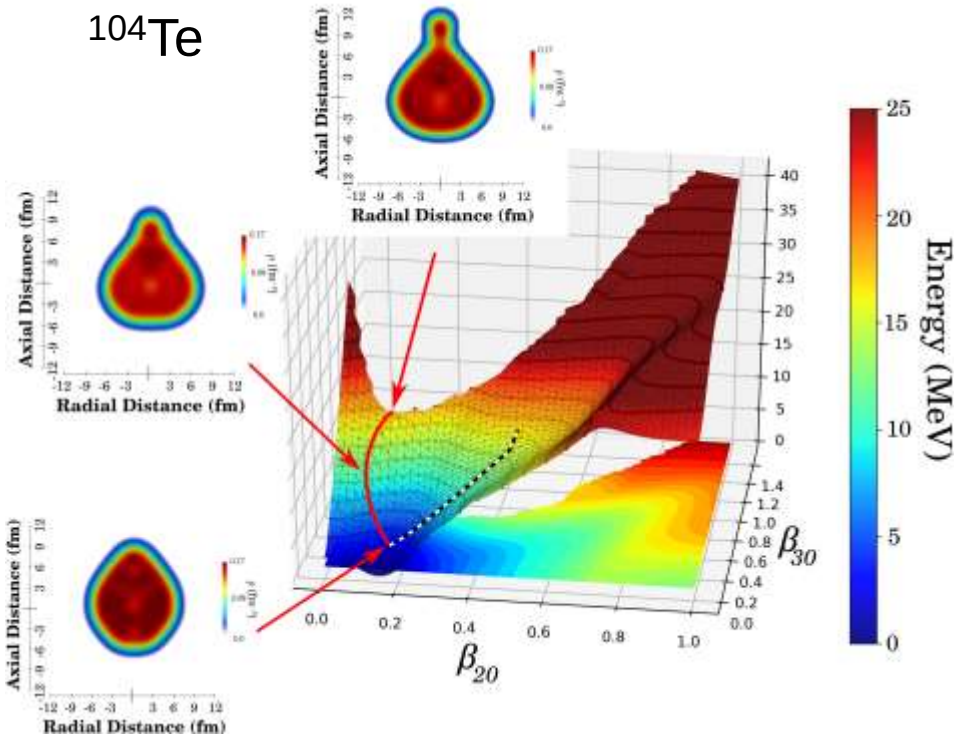
1)





Monopole made of 2α oscillation with respect to ^{12}C core.

2) ^{104}Te



$\tau_{\frac{1}{2}} = 197$ ns (expt. < 18 ns)

Results : Good agreement with expt. and elucidation of the cluster nature of multipole response.

F. Mercier et al. PRC 102, 011301(R) and arXiv:2007.13358

Soft breathing (E0) and PDR (E1) modes in the N=20, N=40 nuclei

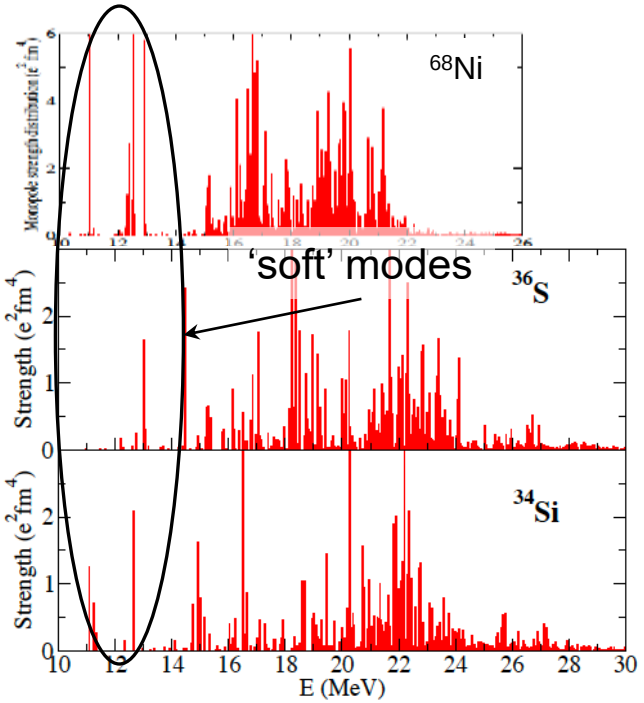
Predictions/motivations:

1. Soft mode of a pure neutron nature in ^{34}Si, ^{36}S and ^{68}Ni.
2. IS and IV components contribution calculated in ^{68}Ni and ^{34}Si PDR.

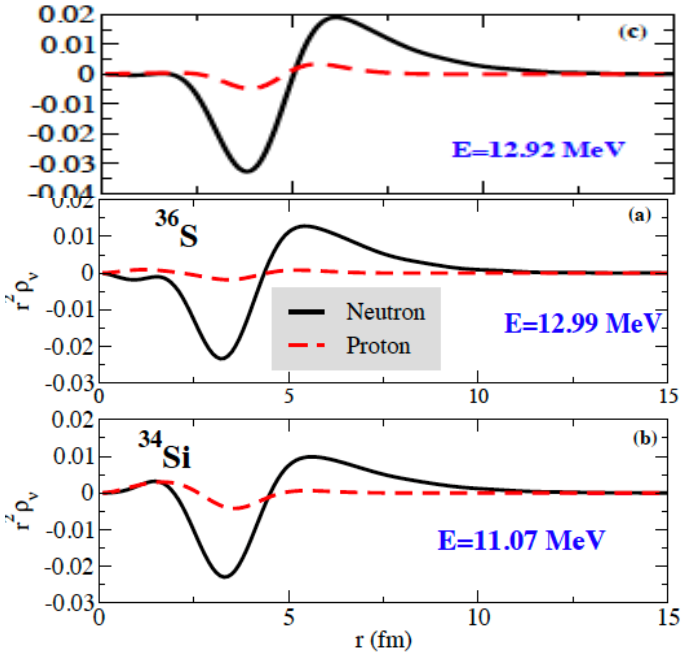
Method :

- Unstable ^{34}Si and ^{68}Ni with ACTAR-TPC @ LISE GANIL.
- Stable ^{36}S with K600 zero degree spectrometer @ Ithemba-Labs.
- Different probes are needed to answer these questions : Coulomb and nuclear excitations.

1)



Almost pure neutron oscillations

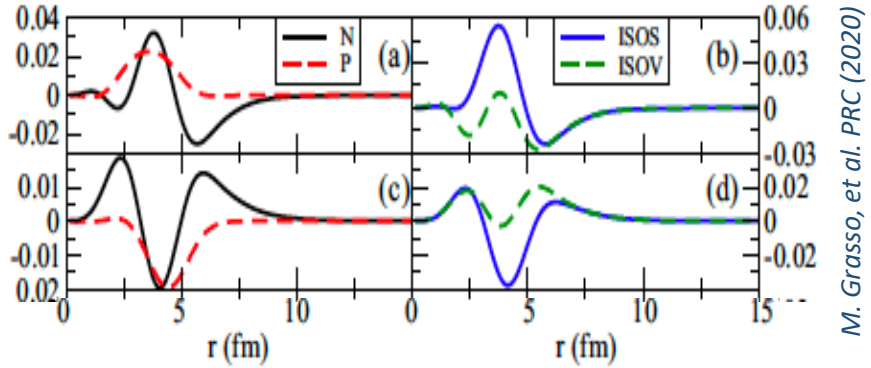


D. Gambacurta et al. PRC (2019)

2) ^{68}Ni PDR

9.14 MeV

9.70 MeV



M. Grasso, et al. PRC (2020)

Proposals !

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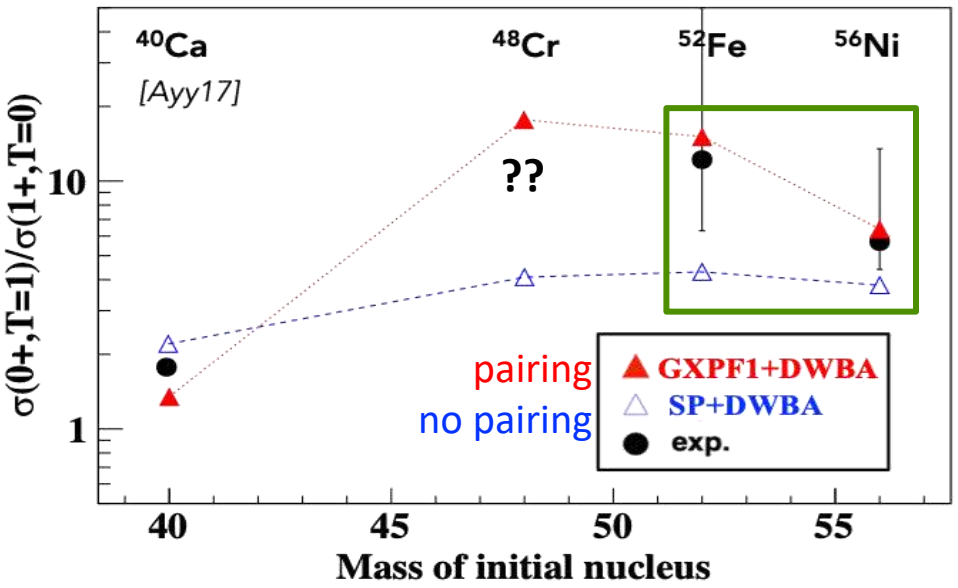
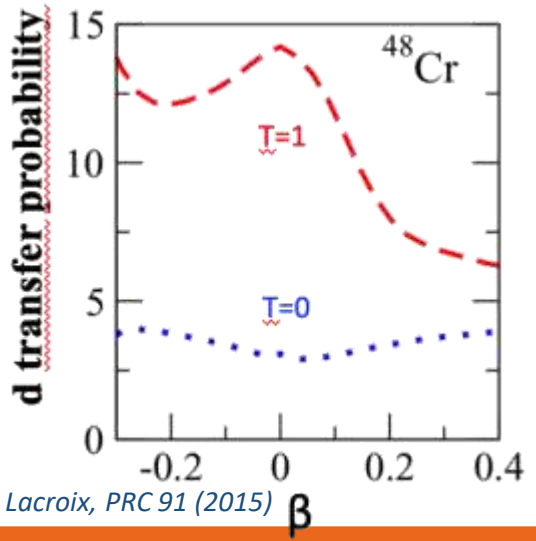
91405 Orsay cedex

Neutron-proton pairing in ^{48}Cr



Le Crom, M. A. et al, submitted



D. Gambacurta, D. Lacroix, PRC 91 (2015)

T=1

T=0

- np pairing occurs in 2 different states:
  T=1 (isovector)
  T=0 (isoscalar) <-- unique in np pairs
- The question we want to address is whether or not the T=0 pairing can create a correlated state in analogy with the BCS superfluid phase.

Which method ?

2N transfer reaction (p,^{3}HeX)

Where to search for np pairing ?

np pairing mostly (only) in N=Z nuclei, stronger in high-j orbitals

Approved experiment at GANIL to study the mid-shell nucleus of f-shell 48Cr, via the (p,3He) reaction.

^{48}Cr is also a **good rotor** so that the interplay between np pairing and deformation will be investigated.

En « vrac »

Thèses

- Search for neutral nuclei : investigation of the 6-neutron system
- Systematic studies of the continuum-coupling correlations in near-threshold states

Physics cases/Projets

- PARIS-EXOGAM2 coulex., inelastic scattering for EM transitions studies.
- MUGAST-EXOGAM2 transfer reaction at drip line or clustering and quasi molecular state.
  ANR for the future of Chymène towards more cryogenic targets.
- ACTAR-TPC in TANDEM setup. Campaign at RIKEN on RIBF SAMOURAI/Nebula spectroscopy of dripline nuclei.
  Projet “Strasse” (~2020-22)
  Upgrade “Nebula”
- Campaign at RIKEN on quasimolecular states.
- Campaign at GSO on R3B evolution of superfluidity towards dripline.
- ANR on Gamow-Teller, beta-decay, and double beta decay without quenching within subtracted SRPA.
- ANR+projet IN2P3 on Quantum computing.
- Multi-configuration TDHFB. *D. Lacroix PRL. 125, 230502 (2020)*