AGATA@GANIL.2

M. Assié, E. Clément

MoHo 2024

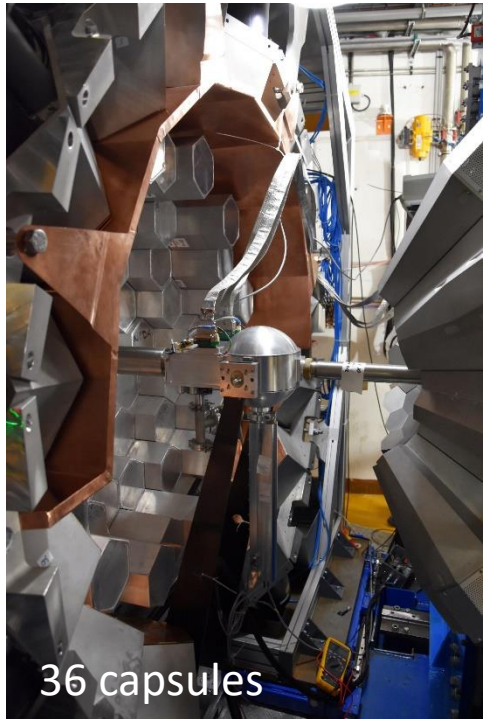
AGATA@GANIL.1 were many sub-campaigns

2015-2017

AGATA coupled to VAMOS, FATIMA, PARIS

Exotic nuclei spectroscopy by MNT transfer and fission reaction

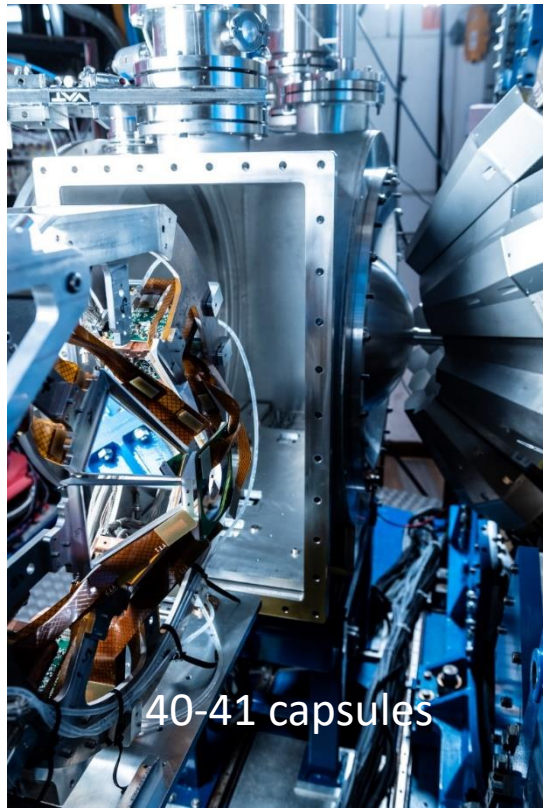
2018



AGATA coupled to NEDA- DIAMANT

N~Z nuclei spectroscopy by fusion evaporation

2019-2021

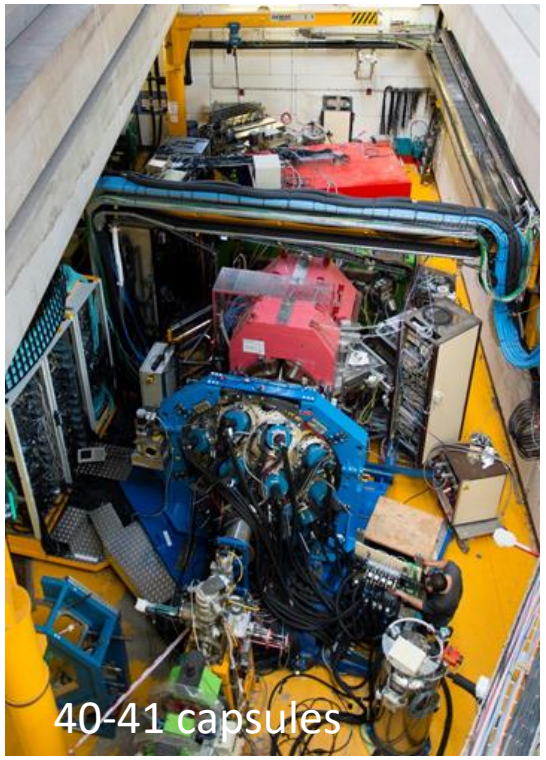


AGATA coupled to VAMOS MUGAST

40-41 capsules

Exotic nuclei spectroscopy by transfer reaction using RIB

2021



AGATA coupled to VAMOS, EXOGAM, 2nd Arm, LEPS

Exotic nuclei spectroscopy by MNT transfer

927 UT have been approved
821 UT have been performed over 29 experiments (90 % done)

AGATA campaign #1 at GANIL

After 7 years [2014-2021], the AGATA@GANIL campaign was completed

29 experiments

558 To of data

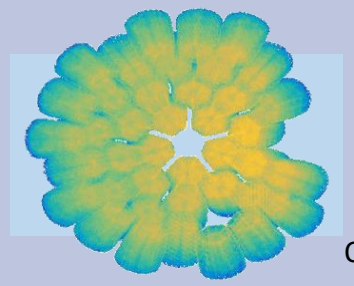
6568 hours beam on target

14 034 elog entries

2386 days of LN2 surveillance

11,5 Tons of scientific equipment

Experiments performed in 2015-2021 at GANIL with AGATA



RIB *with MUGAST*

SHE Cross section $^{238}U+^{238}U$ in MNT

Search for Double Gamma decay in ^{137}Cs source

Reaction mechanism : Fission of Light Hg

Octupole – Quadrupole correlation in ^{112}Xe

^{208}Pb

Studies of excited states in $^{102,103}Sn$

Octupole correlation in ^{207}Pb

Evolution of collectivity around N=50: lifetime measurements $^{104,106}Sn$

Exploration of alpha-cluster : the unique case of ^{212}Po (^{208}Pb + α)

N=126 Xe+Pt spectroscopy after MNT

Evolution of collectivity around N=50: lifetime measurements ^{94}Ru

Shape transition in the neutron-rich W isotopes

Transition Quadrupole Moments in $^{166,168}Dy$.

Search for isoscalar pairing in the N=Z nucleus ^{88}Ru

^{100}Sn

$i_{13/2}$ single particle state in ^{133}Sn and high spin in ^{108}Zr

Isospin Symmetry Breaking in the A=63,71 mirror nuclei

^{132}Sn

Shape evolution in neutron rich fission fragments in the mass A~100 region

Above barrier narrow resonances in ^{15}F

^{68}Ni

^{78}Ni

Shell evolution around N=50: ^{81}Ga spectroscopy

Deter. the $\alpha+^{15}O$ radiative capture rate

Evolution of collectivity around N=52: lifetime measurements in $^{83,84}Ge$

Evolution of collectivity around N=40: lifetime measurements in $^{73,75}Ga$

^{48}Ca

Evolution of collectivity around N=40: lifetime measurements in ^{64}Fe

Proton-neutron interactions across the N = 28 shell closure via $^{47}K(d,p)^{48}K$

Lifetime measurements of excited states in neutron-rich C and O isotopes

Evolution of the shell structure in the region of neutron-rich Ti isotopes

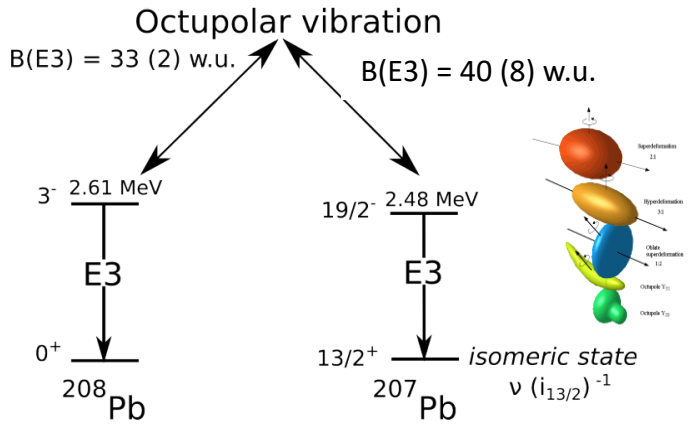
The lifetime in ^{23}Mg as a probe for classical novae models

3-body contribution in ^{20}O structure

Is there a problem with protons in N=28 nucleus ^{46}Ar ?

Some highlights of AGATA@GANIL.1

Evidence of octupole-phonon at high spin in ^{207}Pb : Study of the octupole phonon in the ^{208}Pb region.

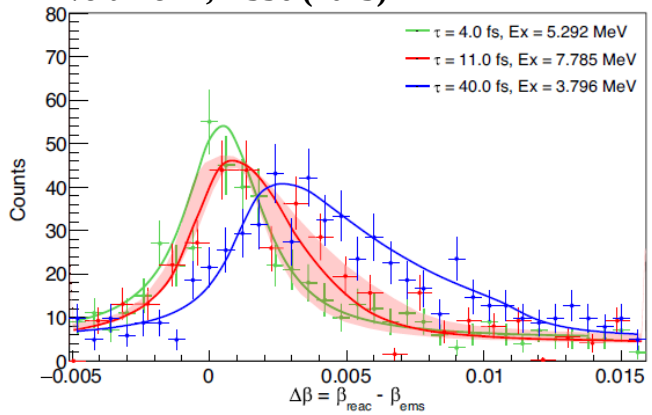


D. Ralet et al Phys. Lett. B 797, 134797 (2019),

Search for ^{22}Na in novae supported by a novel method for measuring femtosecond nuclear lifetimes

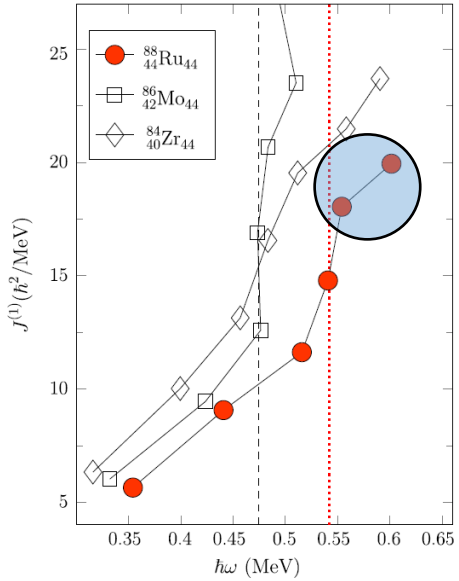
Constraining the ^{22}Na(p, γ)^{23}Mg reaction from the spectroscopy of the 7785.0(7) keV resonance in ^{23}Mg.

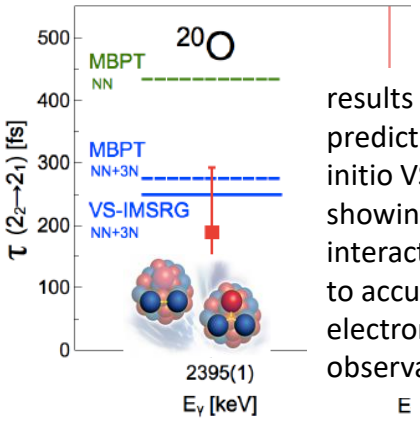
Ch. Fougère et al Nature Communications volume 14, 4536 (2023)



Direct observation of a "delayed" rotational alignment in a deformed N = Z nucleus (^{88}Ru), in agreement with theoretical predictions related to the presence of strong isoscalar neutron-proton pair correlations.

B. Cederwall et al, Phys. Rev. Lett. 124,062501 (2020)





results agree well with predictions from ab initio VS-IMSRG for ^{20}O. showing that 3N interactions are nee(to accurately describ electromagnetic observables

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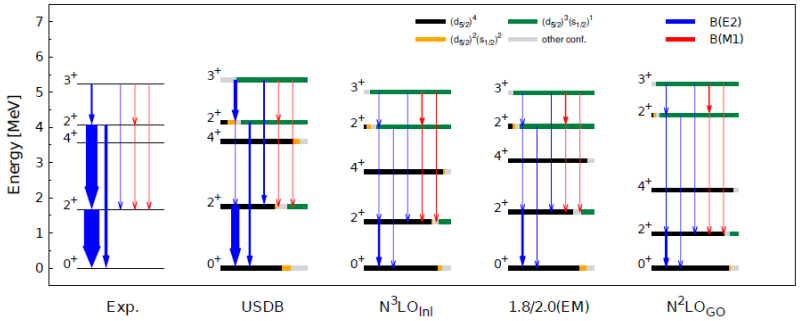
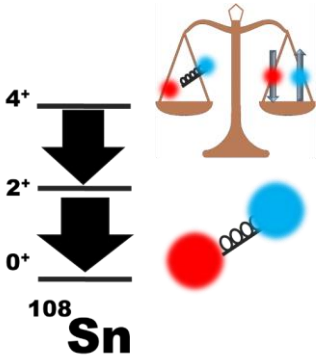
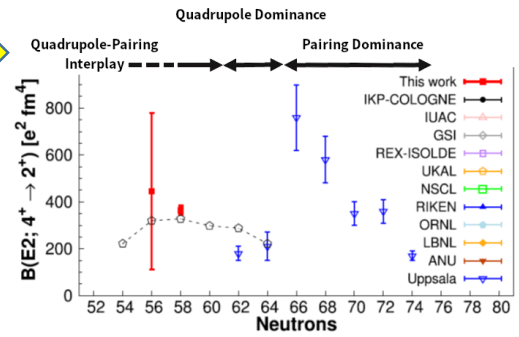
M. Ciemala et al, Phys. Rev. C101, 021303(R) (2020)

More accurate and holistic description from MUGAST-AGATA data, **Phys. Rev. Lett. 131, 262501 (2023), I. Zanon, E. Clément, et al.**







M.Siciliano et al, Physics Letters B 806 (2020) 135474

- 2^+ wave function is dominated by the p-n quadrupole interaction
- 4+ wave function is a balance between p-n quadrupole and pairing interactions
- Revisit our predictions on the ^{100}Sn structure to be investigated at S3

Investigation of the Seniority Conservation in the $\pi g_{9/2}$ shell
R.M. Pérez-Vidal et al, Phys. Rev. Lett 129, 112501 (2022)

AGATA opportunities @GANIL :

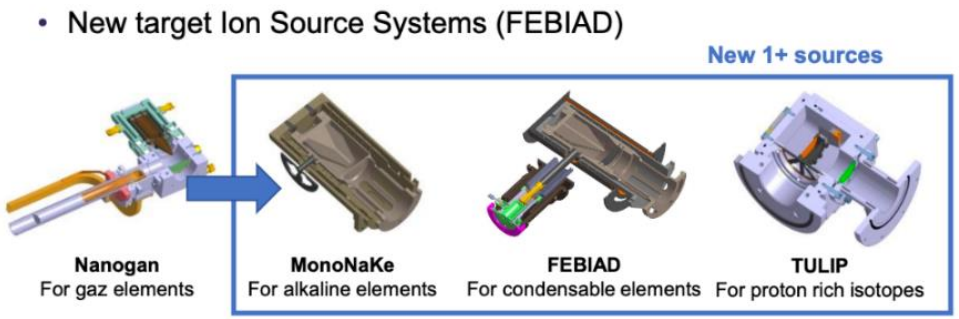
SUMMARY

- Very successful previous campaign with high-impact publications
- GANIL staff trained and operational on AGATA duties
  Most of the campaign#1 infrastructures are still available
- High-quality and new RIB from SPIRAL1
- High-intensity and high-quality stable heavy-ion beams
- State-of-the-art spectrometer and instrumentation
- Surrounding collaborations with active and cryogenic targets (ATRACT) or particle detectors (MUGAST/GRIT)
- *Commitment of the GANIL management to dedicate at least 50% of the CYCLOTRON beam-time (when approved by PAC) : ~ 100 UT yearly : 2500 hours of beam on target !*

AGATA@GANIL.2 Proposal : 0° degree campaign using the SPIRAL1 beams with GRIT and VAMOS

- **SPIRAL1** experiments have a **strong impact** (1 PRL and 1 Nature Comm. with AGATA+MUGAST under referee procedure at the moment)

  He, Ne, Ar, Kr, O, N, F, K beams are operational. Several tests have been performed in 2021-2023 leading to a list of **50 new isomers/isotopes** with intensities suitable for acceleration using CIME



https://www.ganil-spiral2.eu/scientists/ganil-spiral-2-facilities/available-beams/

- **SPEFICITIES of the combination of GRIT-AGATA-VAMOS**

AGATA: - high resolution and P/T ratio

- high efficiency

- high resolving power

2π simulation at 23 cm

Tracked ε@1.3 MeV ^{60}Co = 13%, P/T = 42% *(EXOGAM -12 clovers same distance ~3%)*

Resolving power of AGATA 2π is order of magnitude better than EXOGAM in singles and without comparison at higher energies or for DSAM measurement

GRIT: - High granularity --> Doppler correction from 2-body kinematics *(Resolution 7 keV)*

--> Improved excitation energy resolution *(depending on reaction kinematics)*

- PSA for particle identification (upstream particularly)

VAMOS: - full background rejection

--> “uniqueness” experiments using transfer reactions in the fields of nuclear structure, astrophysics and dynamic.

Workshop AGATA at GANIL 2

https://indico.in2p3.fr/event/32436/

AGATA at GANIL 2

Wednesday 22 May 2024, 11:00 → 18:30 Europe/Paris

Maison d'Hotes (GANIL)

Description The goal of this one day meeting organized at GANIL (GuestHouse) is to construct the physics case of the second AGATA campaign at GANIL by the end of the present decade.

The participants are invited to post during their registration Letters of Intents for the use of AGATA phase 2 at GANIL, which will be used to define the physics objectives and framework of this second campaign.

The workshop is in HYBRIDE mode ; if nedded the remote connection :

https://cnrs.zoom.us/j/95703300317?pwd=aFRsL3l6bEMx0XhaMy9qU2c2U1l0QT09

The present meeting is a satellite of the 2024 LISE workshop : https://indico.in2p3.fr/event/32295/

Registration to both event is recommanded.

Stable and radioactive beams available at GANIL, including 2023 updates, can be found at https://www.ganil-spiral2.eu/scientists/ganil-spiral-2-facilities/available-beams/

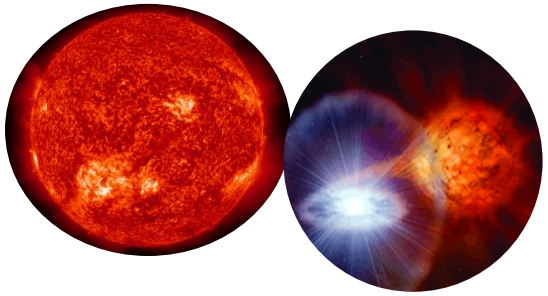
The use of RIB using the "Batch-mode" technique will be also discussed (^{7,10}Be ; ^{20}Al ; ^{32}Si ; ^{44}Ti ; ^{73}As)

		Emmanuel CLEMENT
		Pierre Chauveau 11:20 - 12:05
		Direction GANIL 12:05 - 12:45
13:00	**Lunch** *Maison d'Hotes, GANIL*	12:45 - 13:30
	16 - Spectroscopy of unbound states in light nuclei	*Dr Gheorghe STEFAN*
14:00	**5 - Coulomb excitation of 44Ti and 62Zn - a need for the beam development at GANIL**	*Dr Kasia Hadynska-Klek*
	13 - Spectroscopy of proton-rich nuclei using charge-exchange reactions with a 3He target	*Beatriz Fernandez Dominguez*
	6 - Attacking the quasi-continuum with AGATA: Study of super-deformed and hyper-deformed nuclei	*Amel KORICHI*
15:00	**9 - Study of neutron-proton pairing in fp-shell through two-nucleon addition reactions (3He,p)**	*Marlene Assie*
	7 - Probing mixed-spin np pairing in the super-collective Z~60 and A~130 region	*Dr Jérémie Dudouet*
	8 - Can AGATA extract an average lifetime of multiple states?	*Dr Shuya Ota*
16:00	**Break**	
	10 - Clustering in medium-mass proton-rich nuclei studied through Li-induced stripping reactions	*Didier Beaumel*
	11 - Studying X-ray Bursts with the AGATA-GRIT-VAMOS Setup	*Gavin Lotay*
17:00	**17 - Study of the Heavy Fragment survival in Multi Nucleon Tranfer reaction**	*Dr Gheorghe STEFAN*
	4 - Lifetime measurements of excited states in 24Ne populated by direct nucleon transfer	*Emmanuel CLEMENT*
	15 - Spectroscopic prospects of 19Ne above the alpha-particle threshold	*François de Oliveira*
	14 - Conclusion	*Emmanuel CLEMENT*

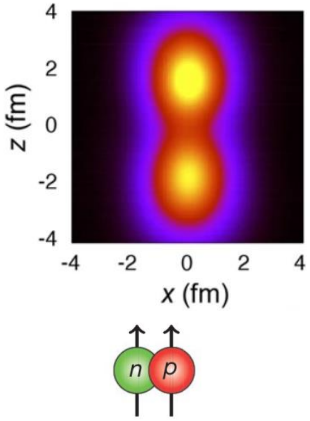
Overview of the perspectives with AGATA-GRIT-VAMOS @GANIL-Spiral1

Nuclear astrophysics

- Studying X-ray Bursts with the AGATA-GRIT-VAMOS Setup G. Lotay et al



(New) clustering and pairing



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Shell model & collectivity

- Ab-Initio test ^{23}Ne(d,p)^{24}Ne by DSAM on the 2^+_2, E. Clément et al
- Coulomb excitation of ^{44}Ti and ^{62}Zn, K. Hadynska-Klek et al
- Can AGATA extract an average lifetime of multiple states? S. Ota et al

Hyper-Deformation

- Attacking the quasi-continuum & the entry distribution with AGATA hyperdeformation hunting Superdeformation revisiting, A. Korichi et al
- Study of the Heavy Fragment survival in Multi Nucleon Transfer reaction I. Stefan et al

Unbound nuclei

- Spectroscopic prospects for ^{19}Ne above the a-particle threshold, F. De Oliveira *et al*
- Spectroscopy of unbound states in light nuclei. I Stefan et al
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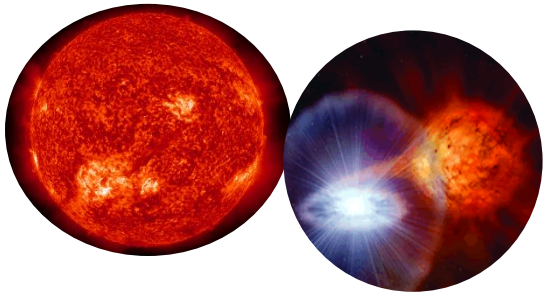

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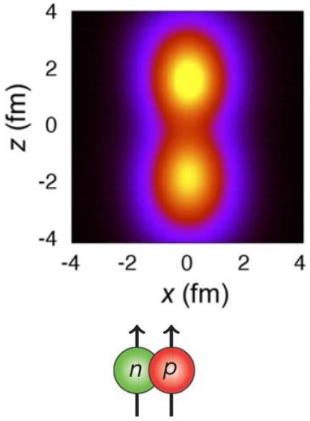

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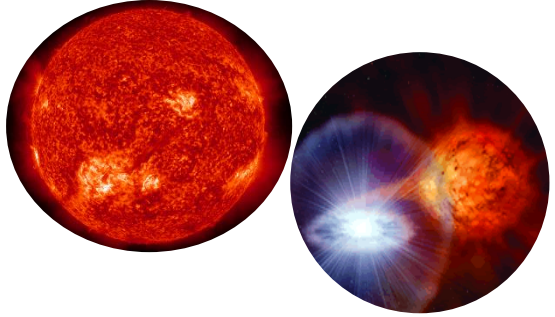
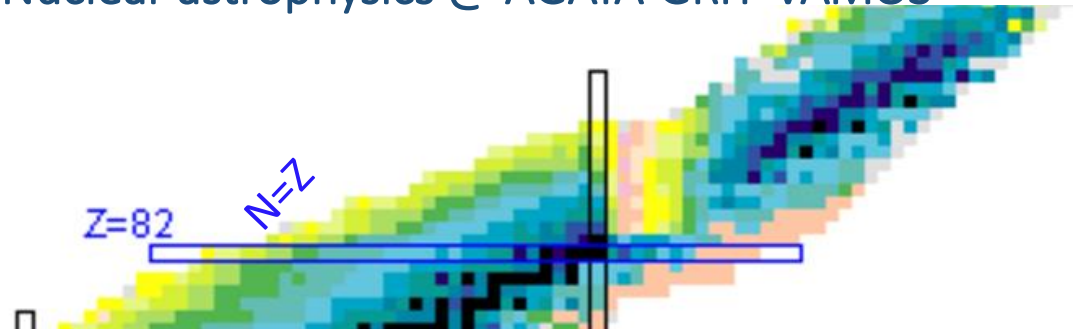
Selected cases

Nuclear astrophysics @ AGATA-GRIT-VAMOS

- Studying X-ray Bursts with the AGATA-GRIT-VAMOS set-up, G. Lotay et al





-- **Type I X-ray bursts**

. Sensitive study --> few tens of reactions play an important role

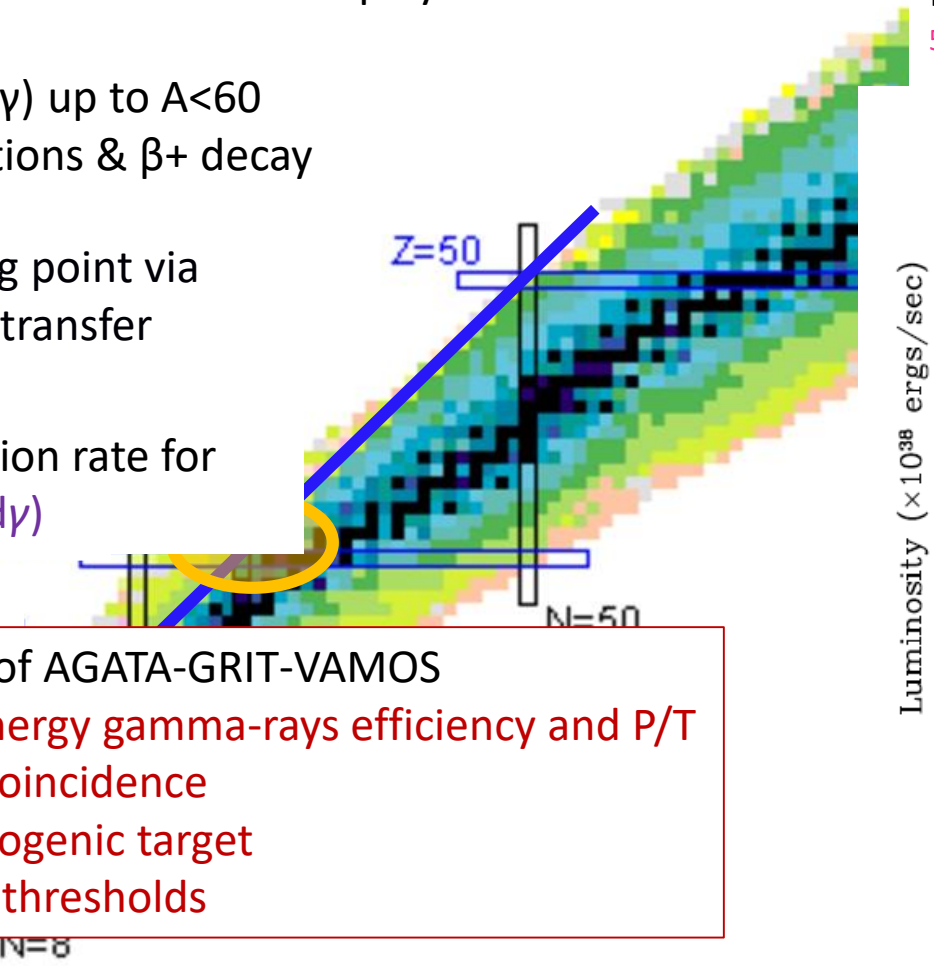
➟ (α,p) process: (α,p)(p,γ) up to A<60

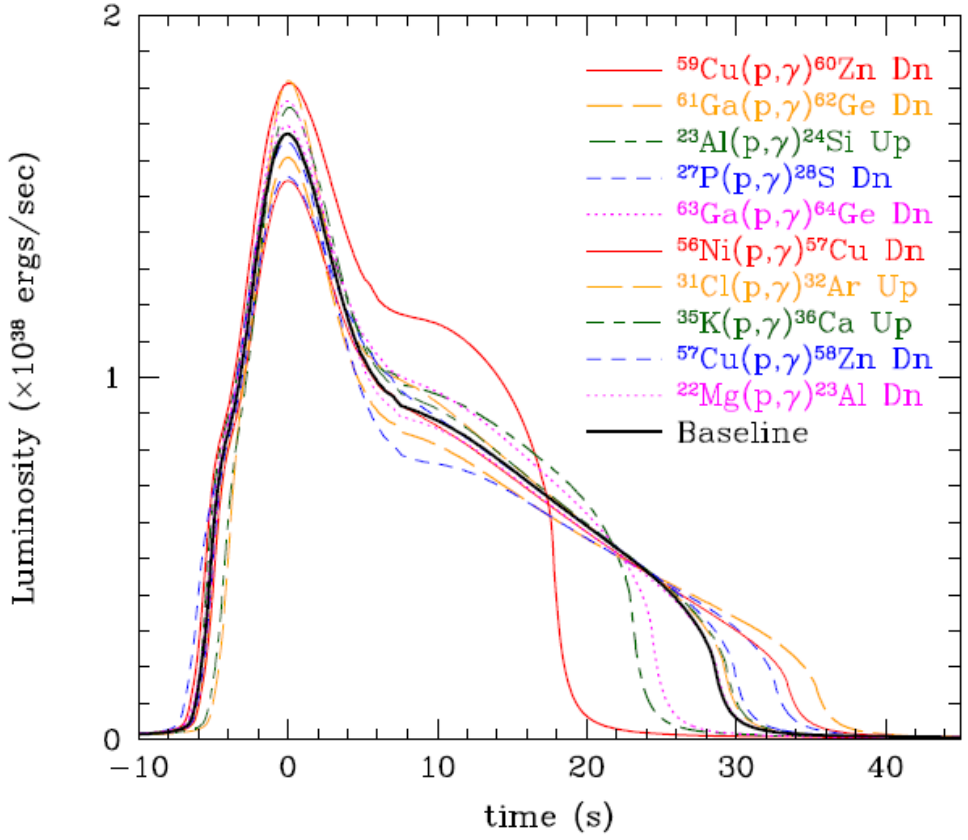
➟ rp-process: (p,γ) reactions & β+ decay

Most important effect on the light curve :

^{59}Cu(p,γ)^{60}Zn, ^{56}Ni(p, γ)^{57}Cu and ^{57}Cu(p, γ)^{58}Zn

- Probing the ^{56}Ni waiting point via ^{55}Co(*d,p*) and ^{57}Ni(*d,p*) transfer (mirror reactions)
- Determination of reaction rate for ^{59}Cu(p,*γ*) via ^{59}Cu(^{3}He,d*γ*)





Assets of AGATA-GRIT-VAMOS

High energy gamma-rays efficiency and P/T

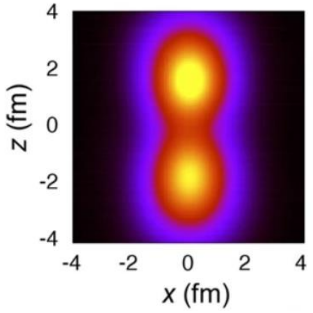
Triple coincidence

^{3}He cryogenic target

Energy thresholds

New Clustering @ AGATA-GRIT-VAMOS

- Clustering in medium-mass proton-rich nuclei (Ar) studied through Li-induced stripping reactions, D. Beaumel et al

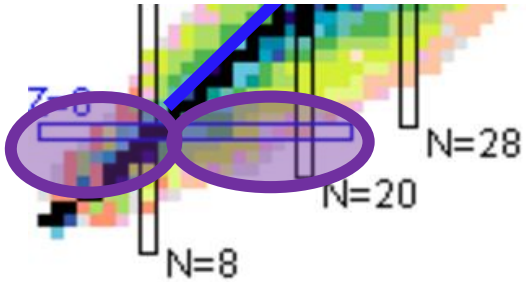


- Triton clustering in Be observed @ RIKEN via QFS *(D. Beaumel et al)*

→ further investigation by transfer (p,alpha) on Be *(experiment performed in 2024 with MUGAST-EXOGAM-LISE)*

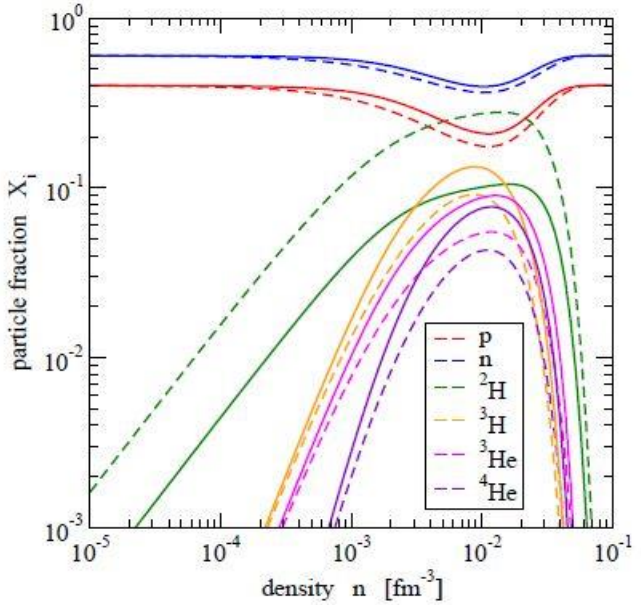
- Hint for ^{3}He clustering in N=2 isotones *(S. Koyama et al)*

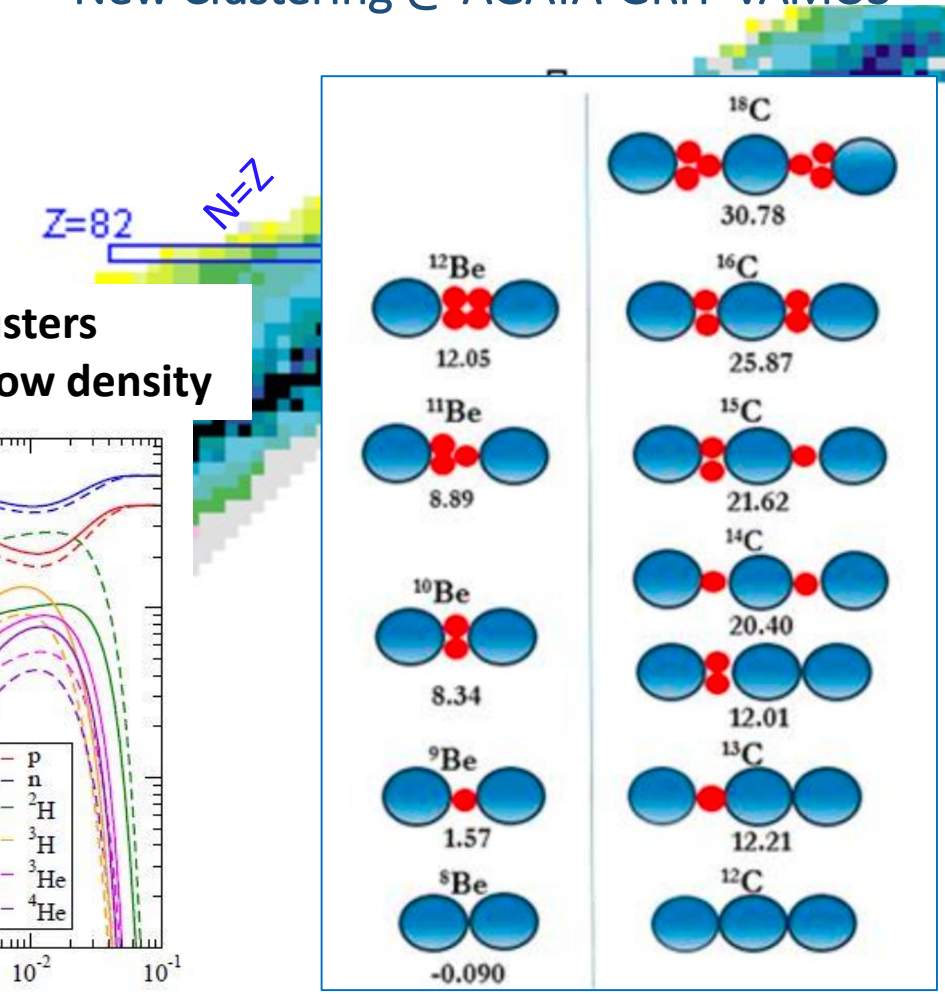
→ **Further experimental program: heavier nuclei (Ar) and ^{3}He clustering (proton-rich)**



S.Typel, J.Phys.Conf.Ser.420,012078(2013)

Theory: All kind of clusters should be formed at low density





Assets from AGATA-GRIT-VAMOS
Triple coincidence
Study of clustering in excited states
low CS --> efficiencies

- Ab-Initio test ^{23}Ne(d,p)^{24}Ne by DSAM on the 2^+_2, E. Clément et al

-- **3N forces**

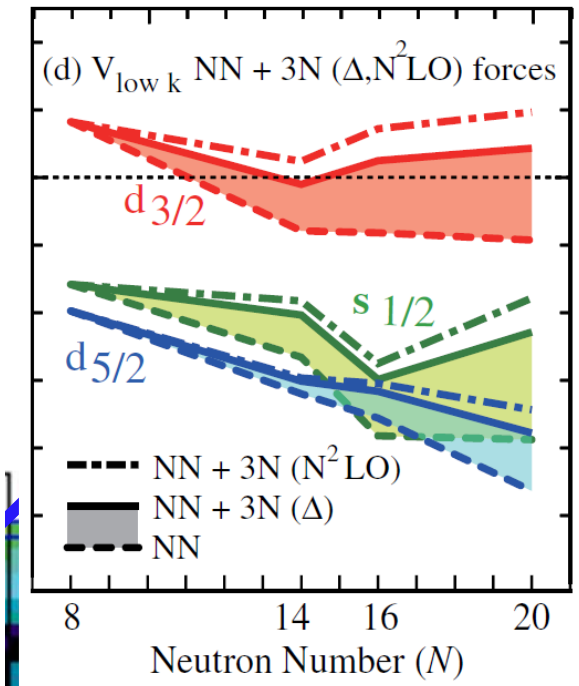
. ^{24}O is the last bound isotopes : striking anomaly !

➟ need for **3N forces** to understand it

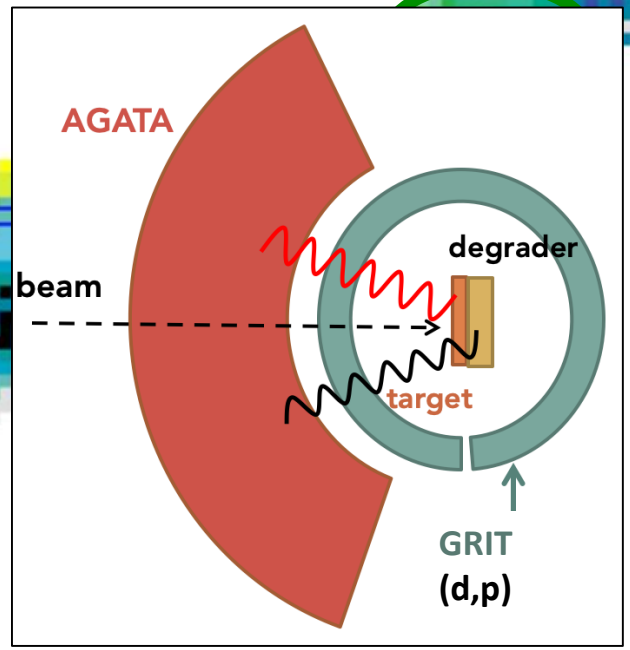
--> Constraining ab-initio models towards the dripline:

^{19}O(d,pγ)$_{DSAM}$measured at GANIL (*I. Zanon, et al. Phys. Rev. Lett. 131, 262501 (2023)*)

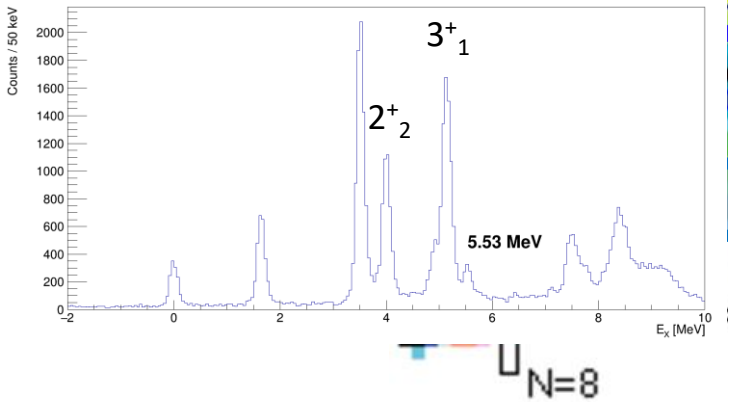
^{23}Ne(d,pγ) to be measured !

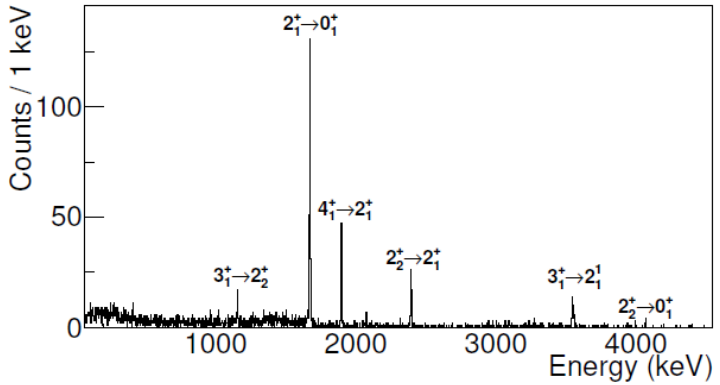


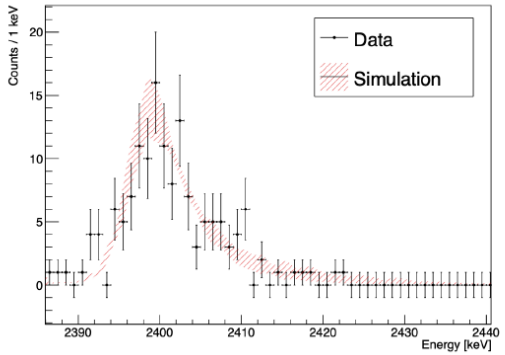
T. Otsuka et al, PRL 104, 012501 (2010)



Assets from AGATA-GRIT-VAMOS
Triple coincidence
Resolving power of AGATA
Entry point control (GRIT)







I. Zanon et al, PRL(2023)

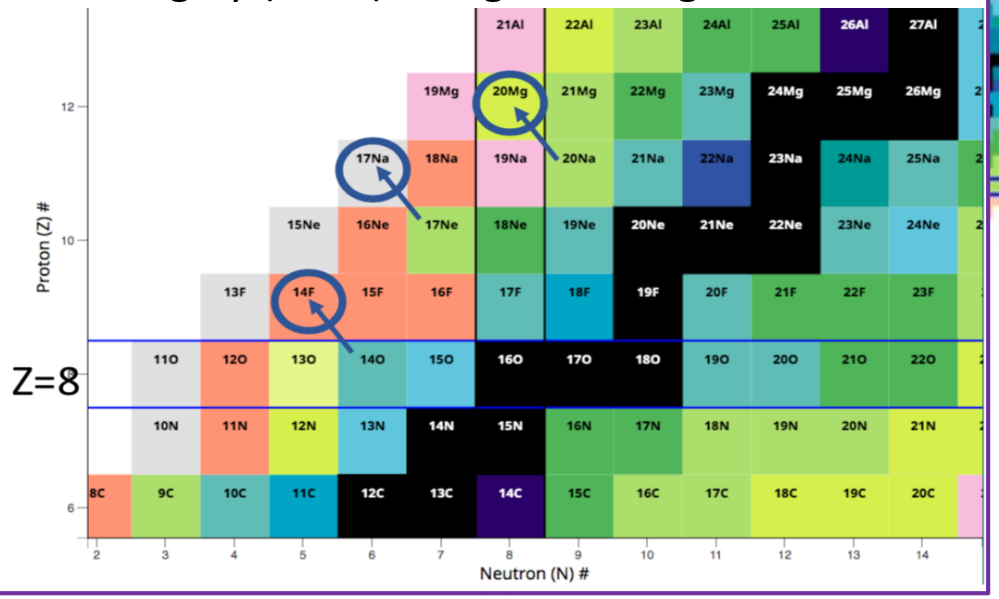
Unbound nuclei at the proton dripline with GRIT-AGATA-VAMOS

- Spectroscopy of proton-rich nuclei using charge-exchange reactions and proton adding with a ^{3}He target, B. Fernandez-Dominguez et al.,

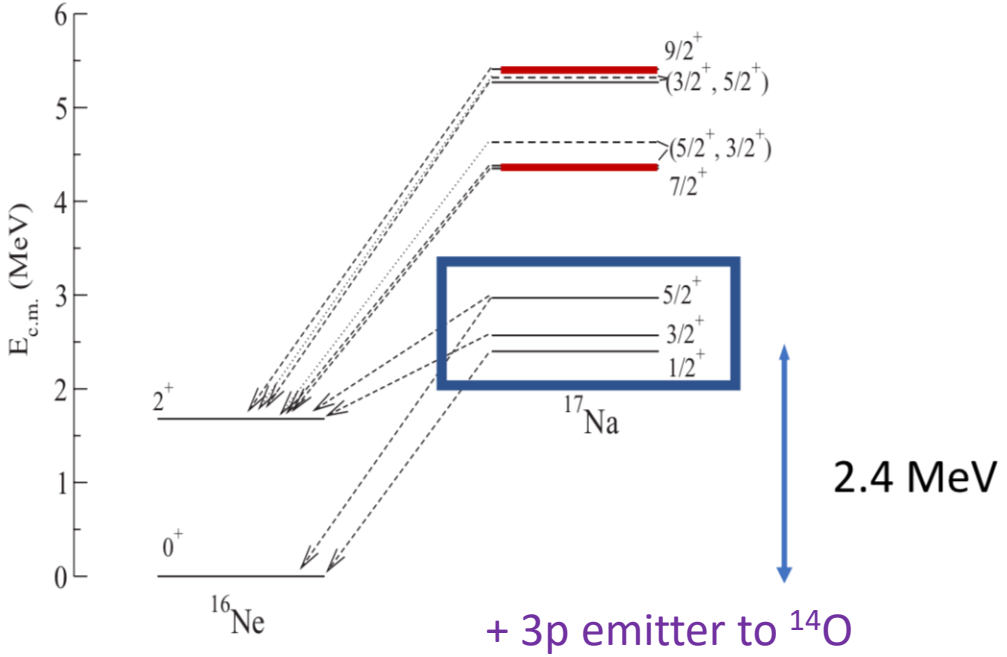
Nuclei at the confluence of shell gaps between standard Z=8, N=8

- *sd*- space with intruder presence
- Effects of 3N-body forces
- Influence of the continuum
- Test of INC- Hamiltonians in the *sd*-shell

GOAL : proton-rich nuclei and 1p emitters: ^{14}F, ^{17}Na,^{20}Mg by (^{3}He,t) charge exchange reactions



^{17}Na predicted levels



Timofeyuk, Descouvemont, PRC (2010)

+ 3p emitter to ^{14}O

Assets from AGATA-GRIT-VAMOS

Triple coincidence

^{3}He cryogenic target

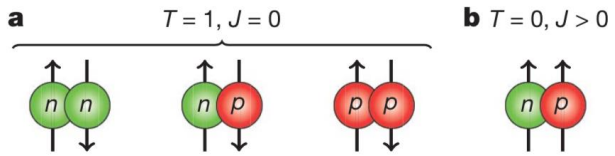
Granularity : 3p decay

background rejection (^{15}O)

Gamma decay from unbound states

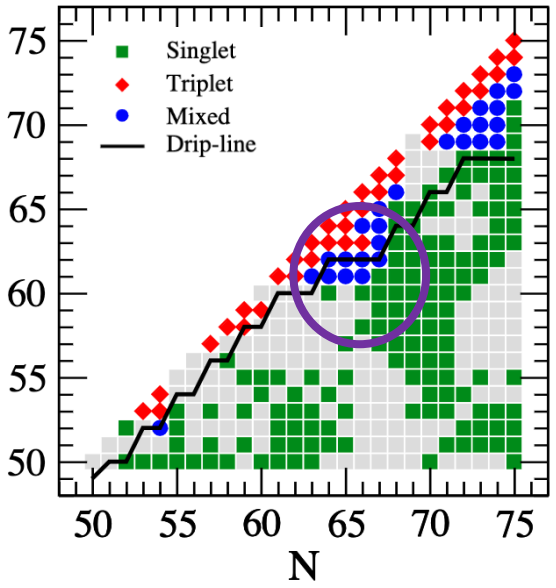
Mixed np pairing and super-cllecitivty by fusion evaporation with radioactive beams

- Probing mixed-spin np pairing in the super-collective Z~60 and A~130 region, J. Dudouet et al



Mixed pairing candidates :

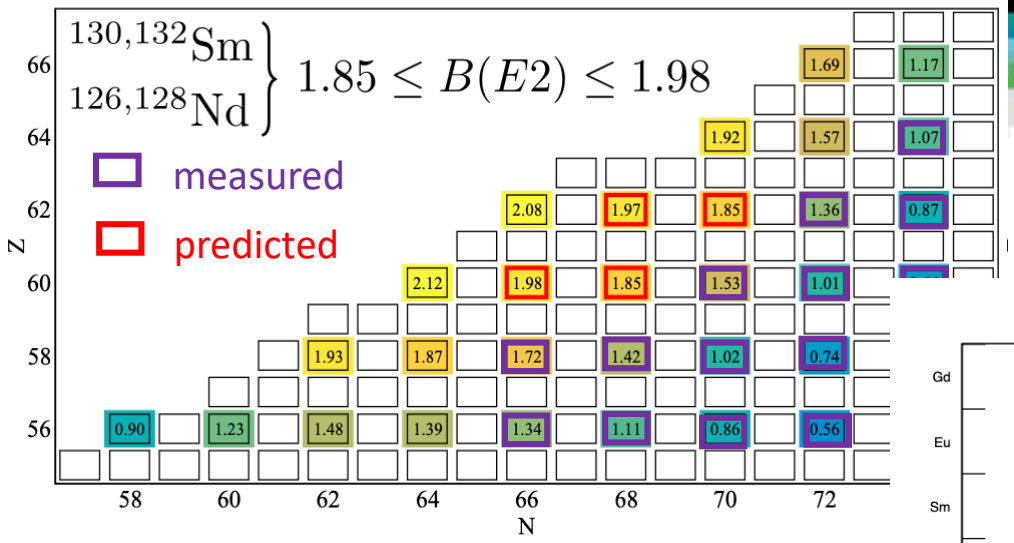
np pairing + realistic deformation

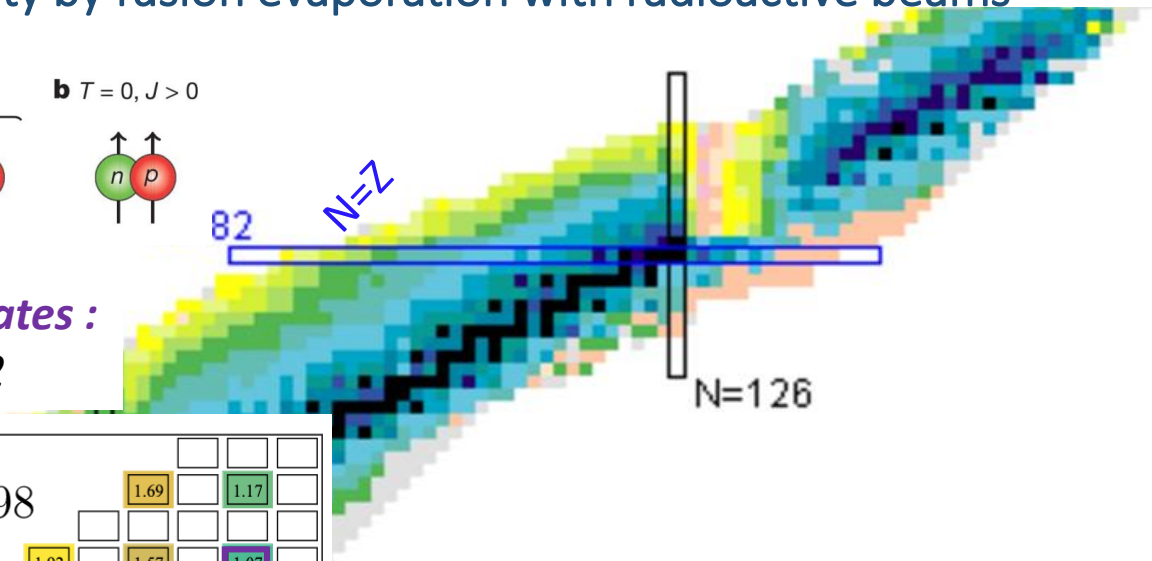


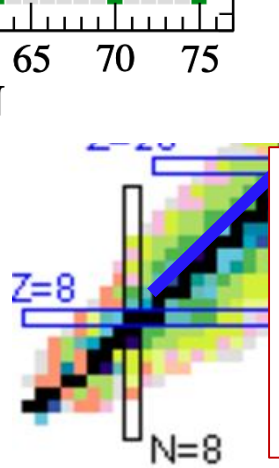
G. Palkanoglou ,A. Gezerlis, arXiv (2024)

Super-collectivity candidates :

Z~60 and A~130, B(E2) ~2







Assets from AGATA-GRIT-VAMOS

Triple coincidence

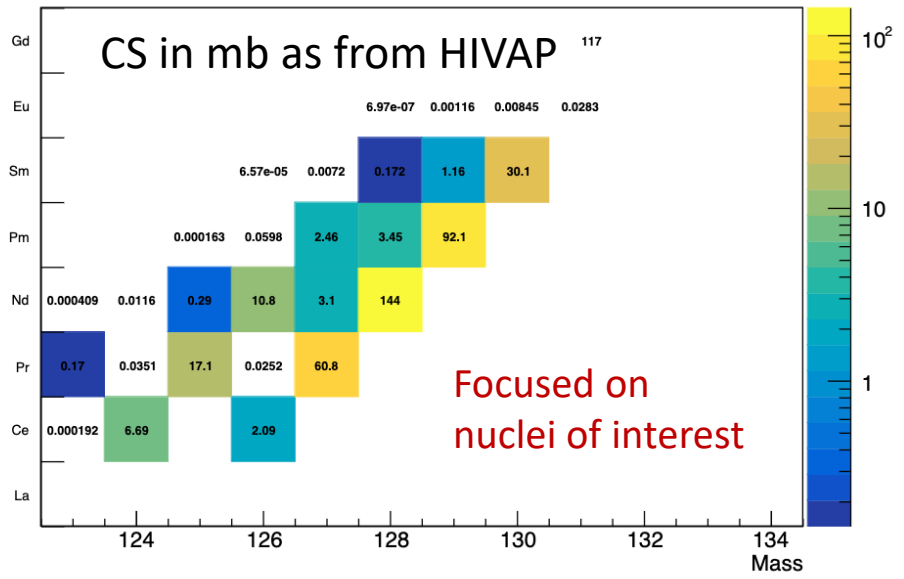
Vamos resolution

Combined Efficiencies

AGATA resolving power

Method: fusion-evaporation with radioactive beam ^{74}Kr + ^{58}Ni

^{74}Kr (1e4 pps) + ^{58}Ni @ 320 MeV



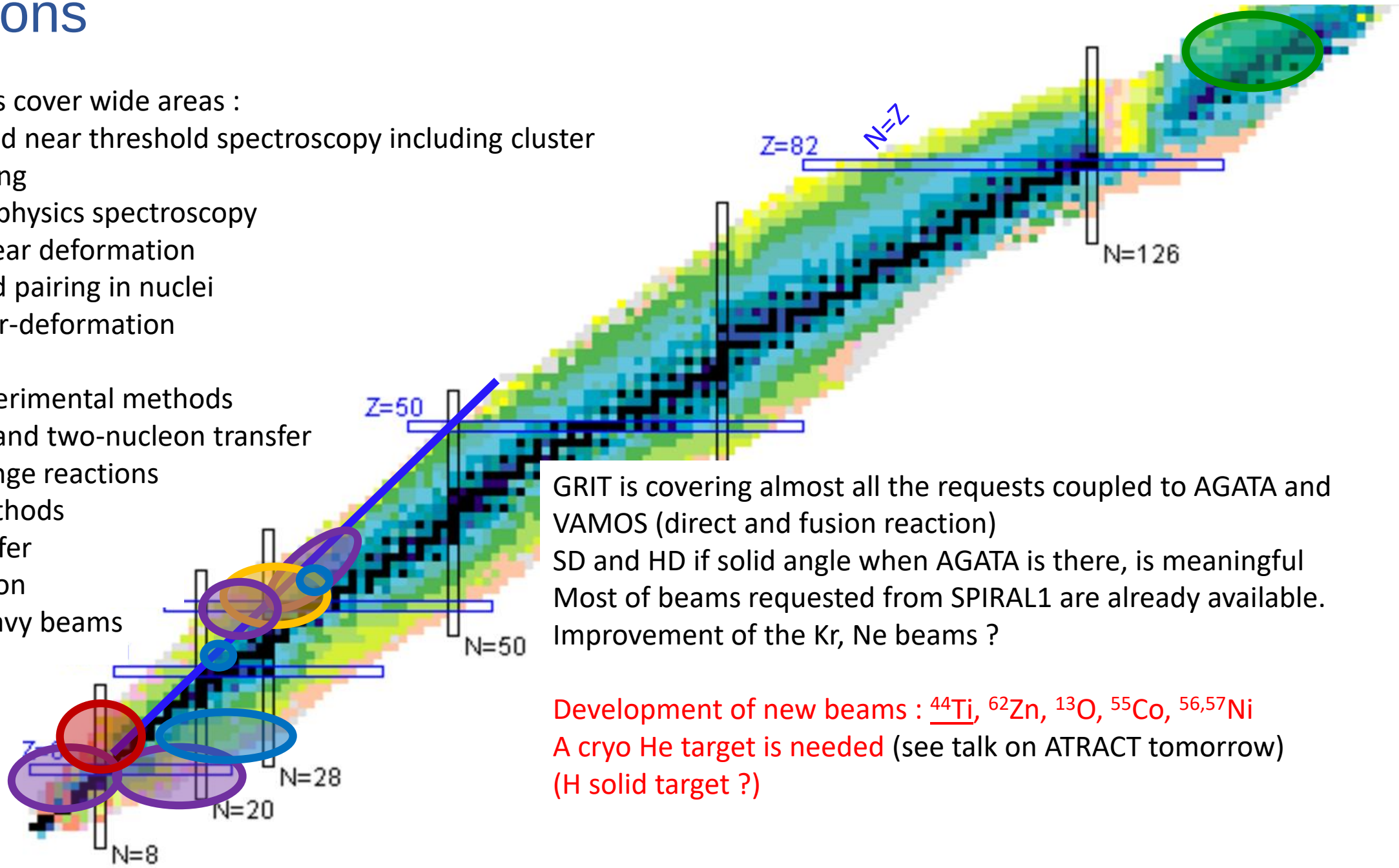
Conclusions

The physics cases cover wide areas :

- Resonance and near threshold spectroscopy including cluster
- Ab-initio testing
- Nuclear astrophysics spectroscopy
- Study of nuclear deformation
- Clustering and pairing in nuclei
- SHE and hyper-deformation

with various experimental methods

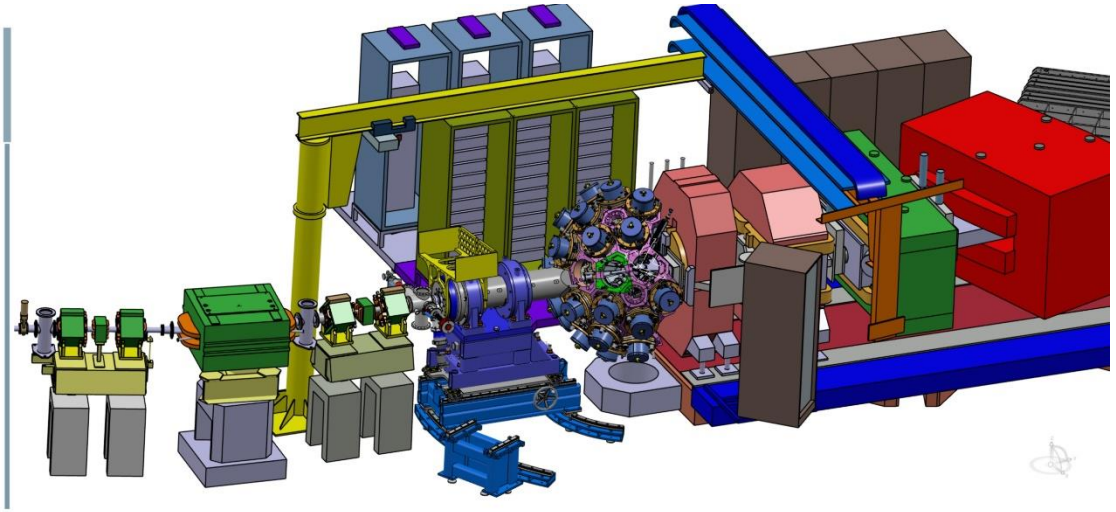
- one-nucleon and two-nucleon transfer
- charge exchange reactions
- surrogate methods
- DSAM + transfer
- coulex or fusion
- MNT with heavy beams



GRIT is covering almost all the requests coupled to AGATA and VAMOS (direct and fusion reaction)
SD and HD if solid angle when AGATA is there, is meaningful
Most of beams requested from SPIRAL1 are already available.
Improvement of the Kr, Ne beams ?

Development of new beams : ^{44}Ti, ^{62}Zn, ^{13}O, ^{55}Co, ^{56,57}Ni
A cryo He target is needed (see talk on ATRACT tomorrow)
(H solid target ?)

AGATA (2π) – GRIT – VAMOS – SPIRAL1



2nd of October 2024 – ASC meeting

To stay at LNL until mid 2028 to complete the zero-degree campaign.

Move to GANIL to start the campaign in March 2029 to have (at least) two campaigns with a minimum of 100UT per year dedicated to AGATA.

Formal decision on location after 2030 to be decided in 2027 once more information on SPES beams and FAIR timescales/funding become available.

DECISION: AGREED

→ Next steps :

- coming back in front of the community (GCM is part of the exercise)
- Preparing a more detailed white book detailing the precise needs in term of detection geometry to constrain the implementation and SPIRAL1 beams requiring development.
- Organizing this new collaboration in term of workload, PBS, milestone and collaboration between the partners