



The AGATA γ -ray tracking array at the LNL TANDEM-ALPI-PIAVE facility

Giorgia Pasqualato

With the courtesy of:

Daniele Brugnara

Laboratori Nazionali di Legnaro – INFN (Italy)

Magda Zielinska

CEA Saclay (France)

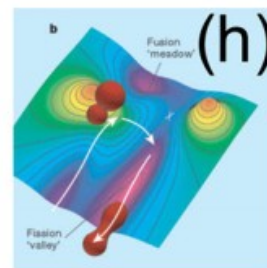
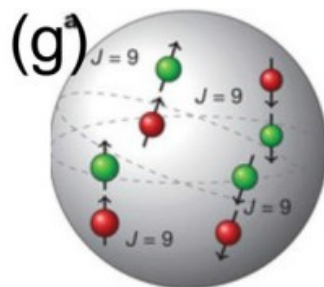
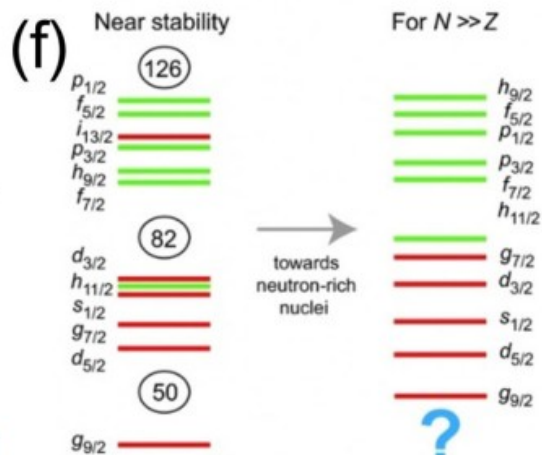
Demi-journee AGATA 03/07/2023



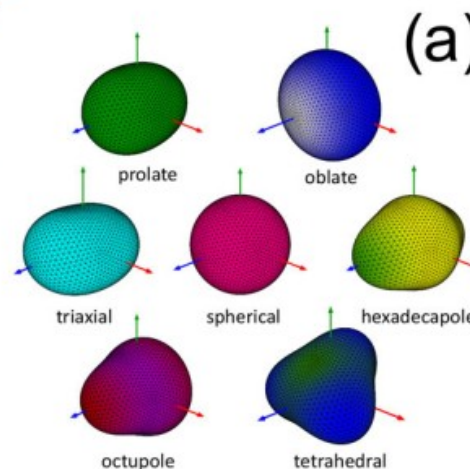
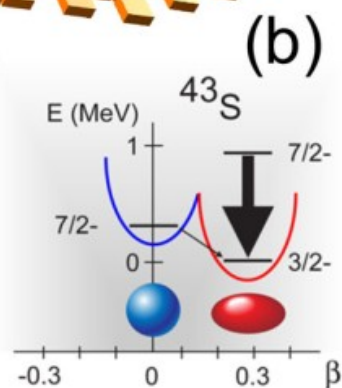
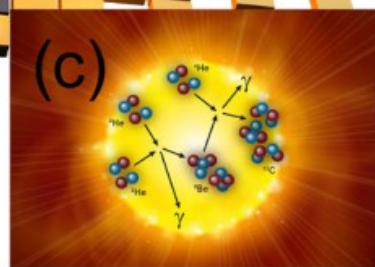
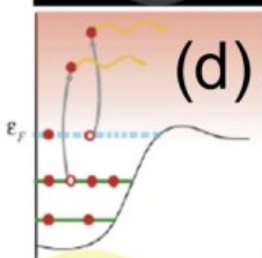
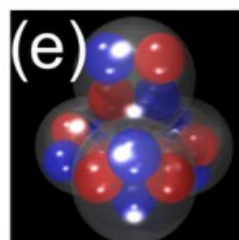
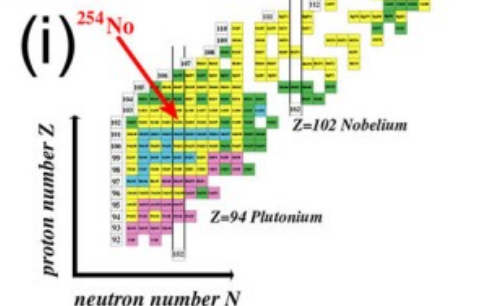
Physics opportunities with AGATA



Nuclear Shell Structure



superheavy elements



- (a) Nuclear shapes
- (b) Shape coexistence
- (c) Nuclear astrophysics
- (d) Coupling to continuum
- (e) Clustering
- (f) Shell evolution
- (g) Pairing correlations
- (h) Fusion and fission dynamics
- (i) Super-heavy elements

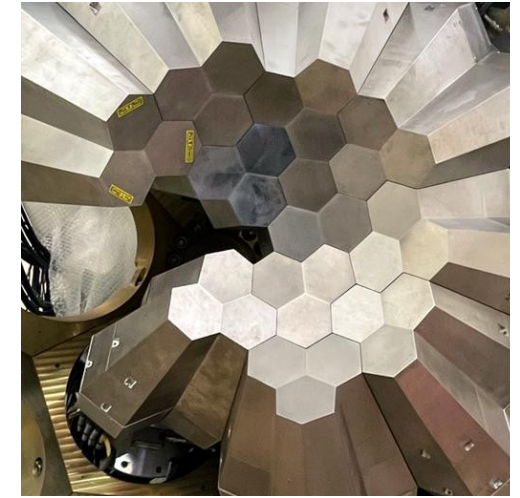
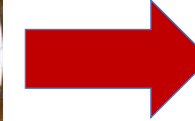
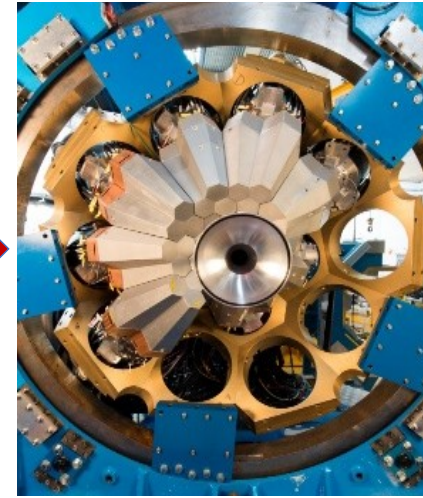
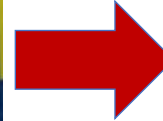
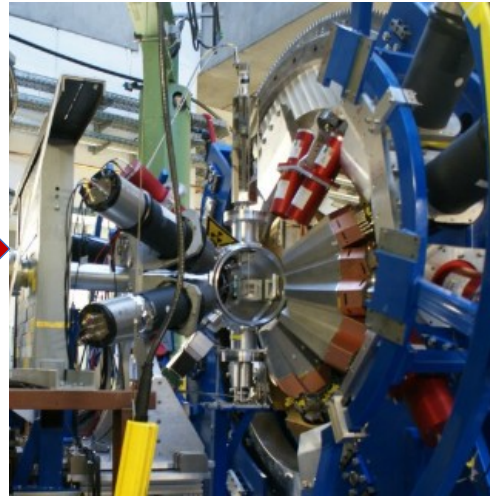
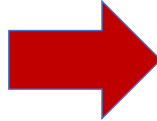
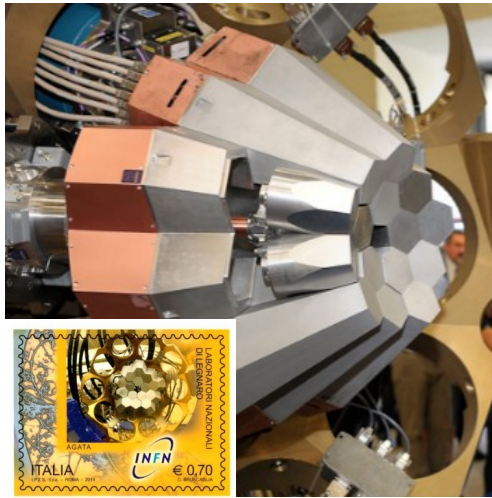
Celebrating 10 years of science: back to LNL

LNL

GSI

GANIL

LNL



2010

2012

2015

2021-2025

Demonstrator

Phase 1

Phase 2: up to 2π



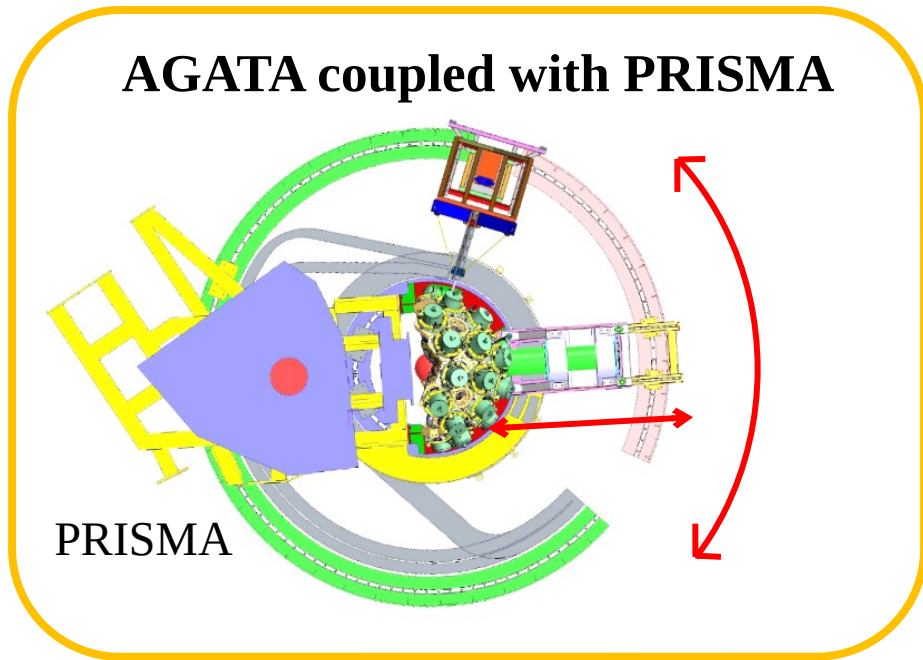
M. Zielinska physics coordinator
J. J. Valiente Dobon local coordinator



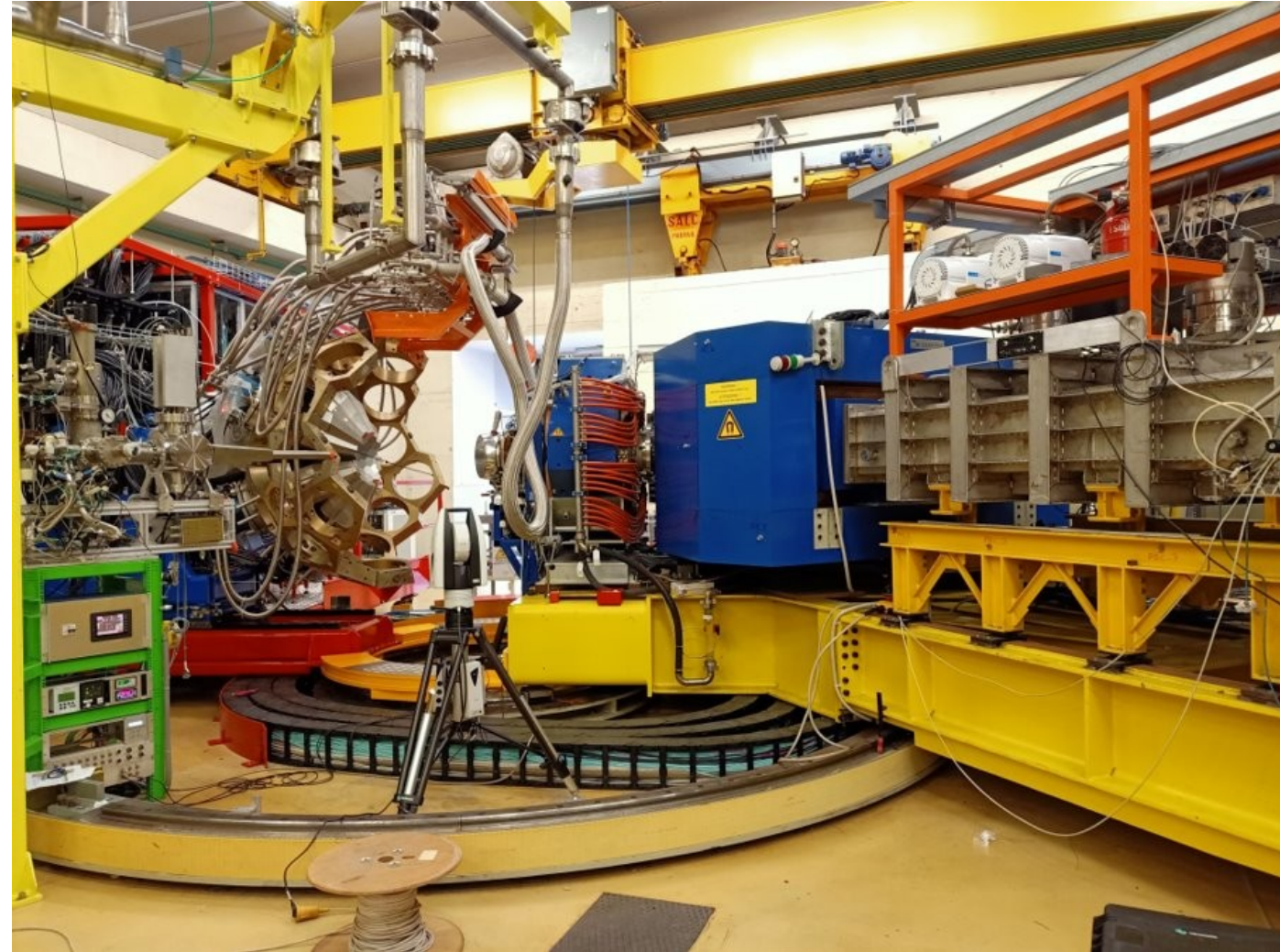
2022

CELEBRATION FOR THE 10(+2) YEARS OF SCIENCE ACTIVITIES OF AGATA

Current configuration



- PRISMA (large-acceptance magnetic spectrometer):
 - **Multi-nucleon transfer**
 - **Fusion-Fission**
- SPIDER, EUCLIDES, DANTE (silicon detectors):
 - **Coulomb Excitation**
 - **Direct reactions**
 - **Fusion-evaporation**



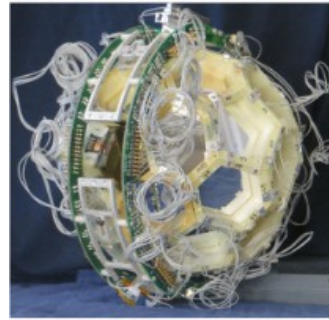
J. J. Valiente-Dobòn, R. Menegazzo, A. Goasduff et al.,
Nucl. Instr. Meth. A **1049** (2023) 168040

Coupling with different detectors and devices

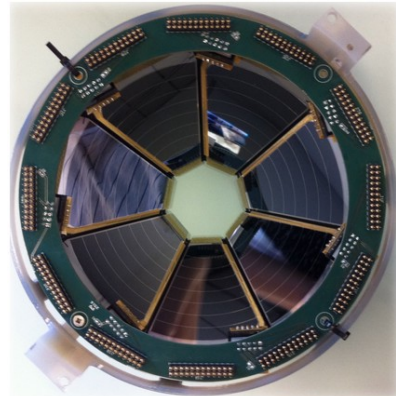
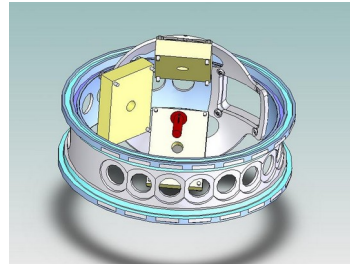
PRISMA
heavy ions



EUCLIDES
light charged particles



DANTE
heavy ions



SPIDER
light and heavy ions

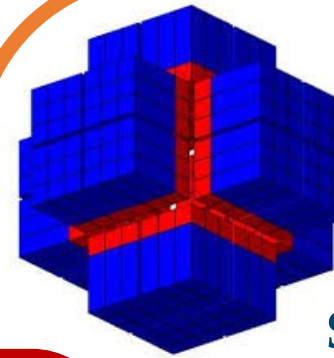
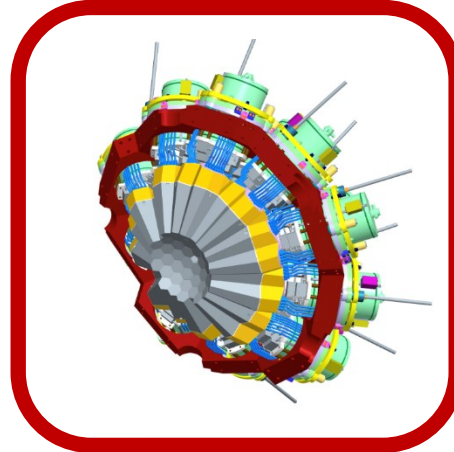


LaBr3

Lifetime measurements



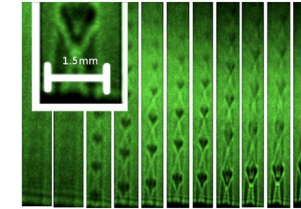
PLUNGER



PARIS
 γ -rays

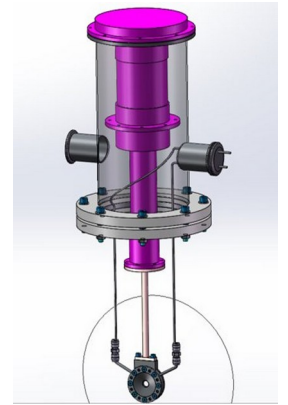


SUGAR
gas-jet target

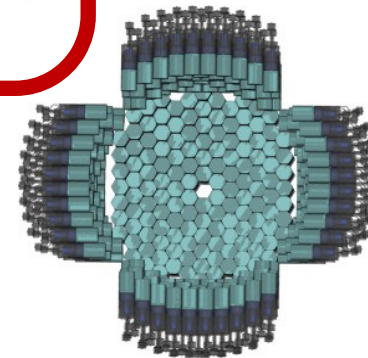
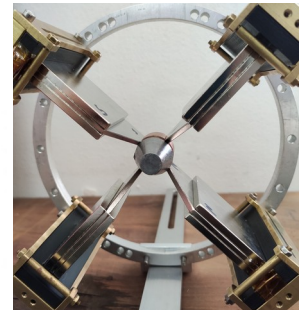


1.0 1.2 1.4 1.9 2.3 2.5 2.8 3.7 4.4 4.7 5.3
Schlieren images of the jet at different pressures, indicated under each flow.

CTADIR
cryogenic target

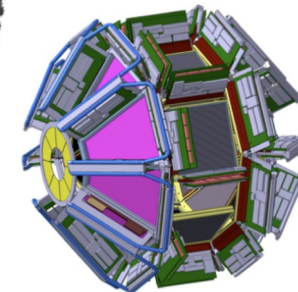


SLICES
Internal conversion electrons detector



NEDA
neutrons

GRIT
light charged particles



PAC@LNL 21-23 February 2022

28 proposals submitted

- 10 (+3 commissioning) priority A
- 5 priority B

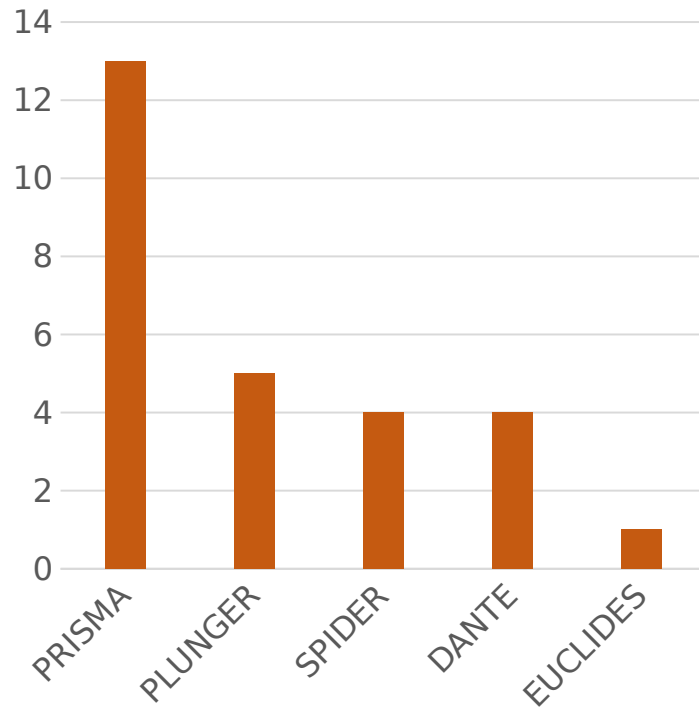
PAC@LNL 05-06 December 2022

24 proposals submitted

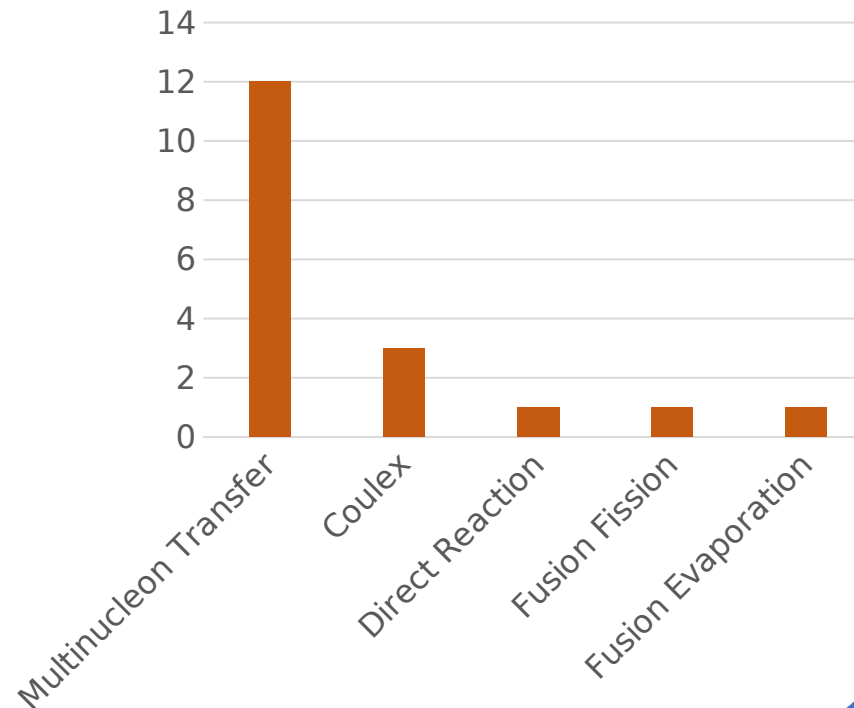
- 6 priority A
- 10 priority B

15 experiments performed!

Detectors



Reactions



April 2022 - May 2023
physics @ LNL

Exploring the nuclear chart

Pr. A

Pr. B

Search for octupole structures in the light U, Th and Pa isotopes via multi-nucleon transfer reactions
(A. Goasduff, G. De Angelis)

Understanding the nature of 0^+ states in ^{110}Sn and ^{112}Sn and ^{108}Cd
(N. Marginean, M. Ciemala, F. Crespi)

Probing Multiple Shape Coexistence in ^{110}Cd with Coulomb Excitation
(M. Zielinska, K. Wrzosek Lipska, A. Nannini, P. Garrett)

Pathway to nuclear structure in heavy neutron rich nuclei in the vicinity of $N=126$ and nuclei northwest of ^{132}Sn via multi-nucleon transfer reactions
(P. Reiter)

Lifetimes in the ^{196}Os region populated with multi-nucleon transfer reactions
(D. Brugnara, M. Sedlak, J. Pellumaj)

Search for a Josephson like effect in the $^{116}\text{Sn}+^{60}\text{Ni}$ system
(L. Corradi, S. Szilner)

Probing nucleon nucleon correlations in the $^{48}\text{Ca}+^{208}\text{Pb}$ system below the Coulomb barrier
(T. Mijatovic, L. Corradi)

Coexisting Shapes in ^{96}Zr
(D. Doherty, N. Marchini, M. Zielinska)

Fusion-fission for gamma-ray spectroscopy of neutron rich nuclei around $N=50$
(A. Gottardo, M. Caamano, D. Ramos, J.J. Valiente Dobon)

Shape Coexistence Coulex of ^{74}Se
(W. Korten, K. Wrzosek Lipska, E. Clement)

Nuclear structure in the vicinity of the $Z=28$ neutron rich isotopes with AGATA and PRISMA
(R.M. Perez Vidal, S. Bottoni, E. Sahin, A. Illan)

Study of shape coexistence in ^{60}Fe via lifetime measurement of excited 0^+ states
(G. Pasqualato, J. Jungvall)

Lifetime measurements around ^{48}Ca
(C. Fransen, A. Gottardo, D. Mengoni)

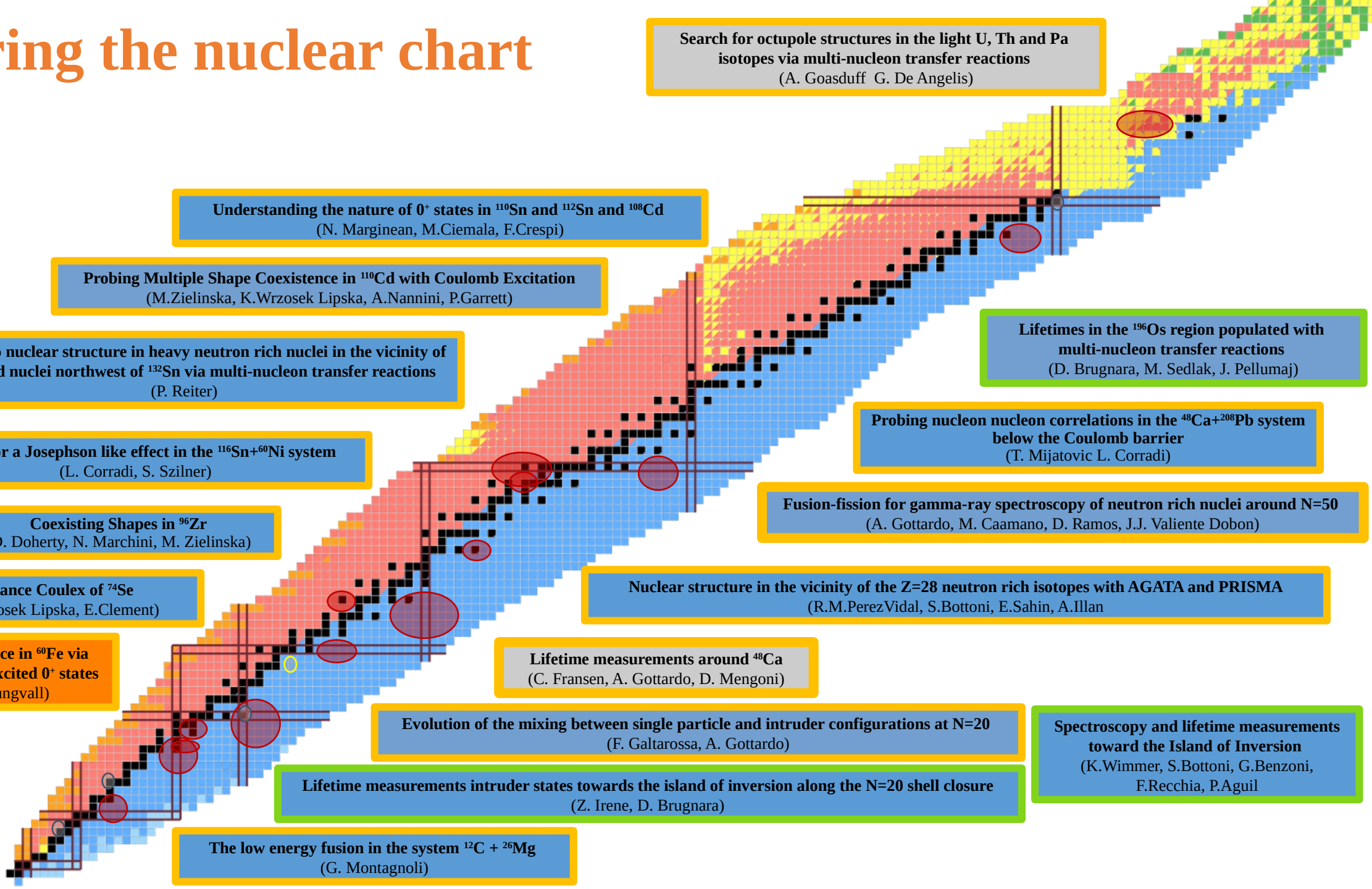
Test of the CKM unitarity and the existence of Fierz interference through the measurement of superallowed beta decay of light nuclei
(J. Ha, F. Recchia)

Evolution of the mixing between single particle and intruder configurations at $N=20$
(F. Galtarossa, A. Gottardo)

Spectroscopy and lifetime measurements toward the Island of Inversion
(K. Wimmer, S. Bottoni, G. Benzoni, F. Recchia, P. Aguil)

Lifetime measurements intruder states towards the island of inversion along the $N=20$ shell closure
(Z. Irene, D. Brugnara)

The low energy fusion in the system $^{12}\text{C} + ^{26}\text{Mg}$
(G. Montagnoli)



**Shape coexistence in ^{60}Fe :
lifetime measurements of 0^+ excited states**
(G. Pasqualato, J. Ljungvall)

Onset of deformation in Fe and Cr isotopes

- Study shape coexistence in ^{60}Fe

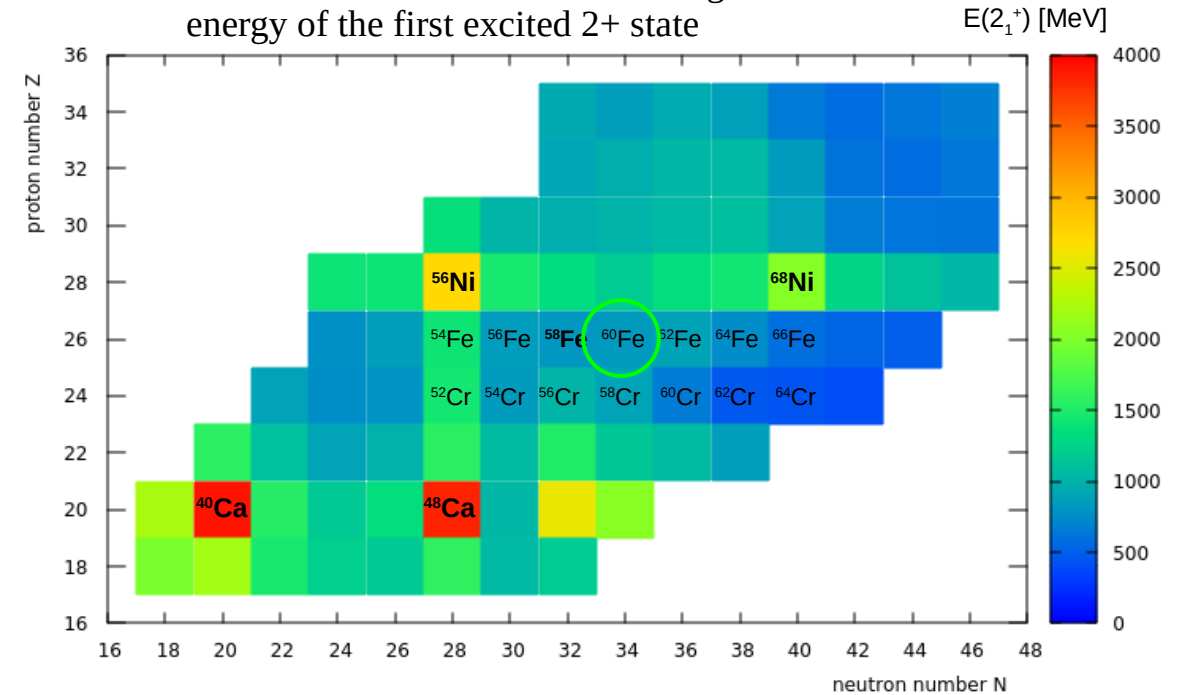
why ?

- Onset of deformation just below the doubly-magic ^{68}Ni

how ?

- Study the structure of excited 0^+ states, band-head of possible deformed band

- Onset of deformation visible through the energy of the first excited 2^+ state



Low-lying excited 0^+ states in the iron isotopes

- direct measurement of nuclear properties sensitive to shape and deformation (lifetimes \rightarrow transition probabilities)
- comparison with the model predictions:

$$\tau(0^+_2) = 110 \text{ ps}$$

$$\tau(0^+_2) = 5 \text{ ps}$$

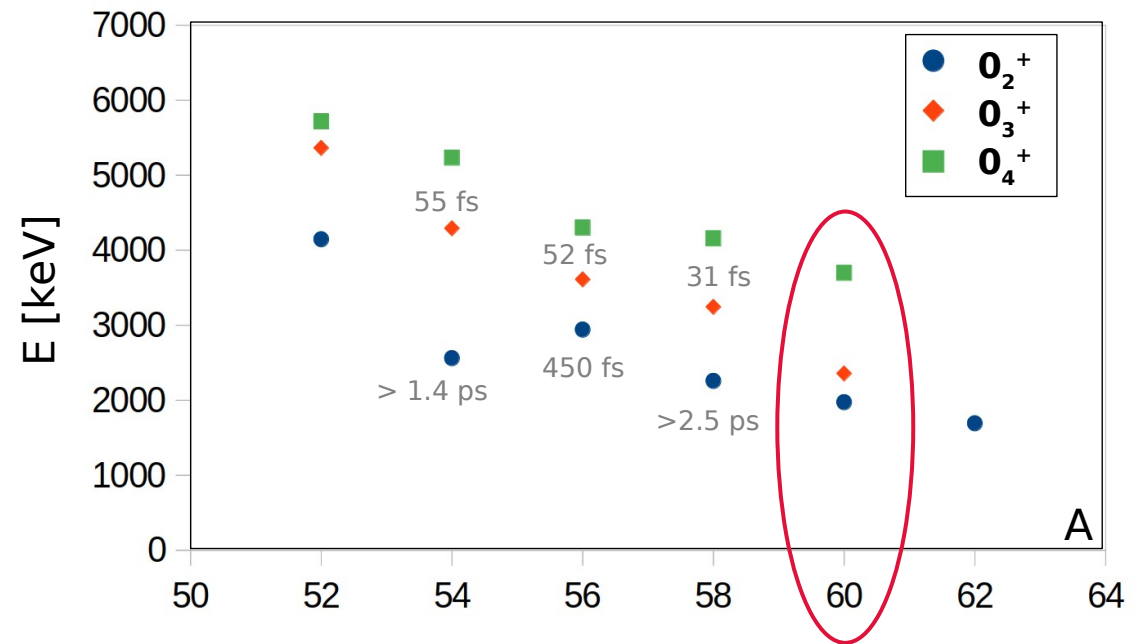
$$\tau(0^+_3) = 400 \text{ ps}$$

$$\tau(0^+_3) = 2 \text{ ps}$$

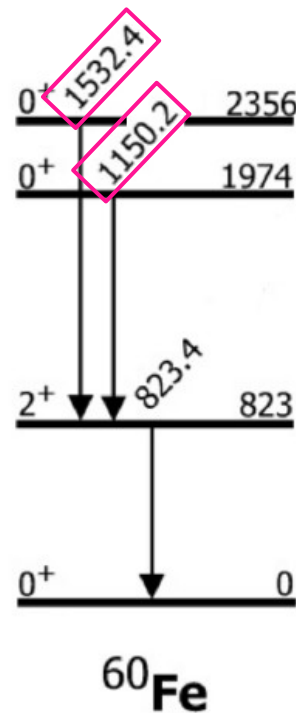
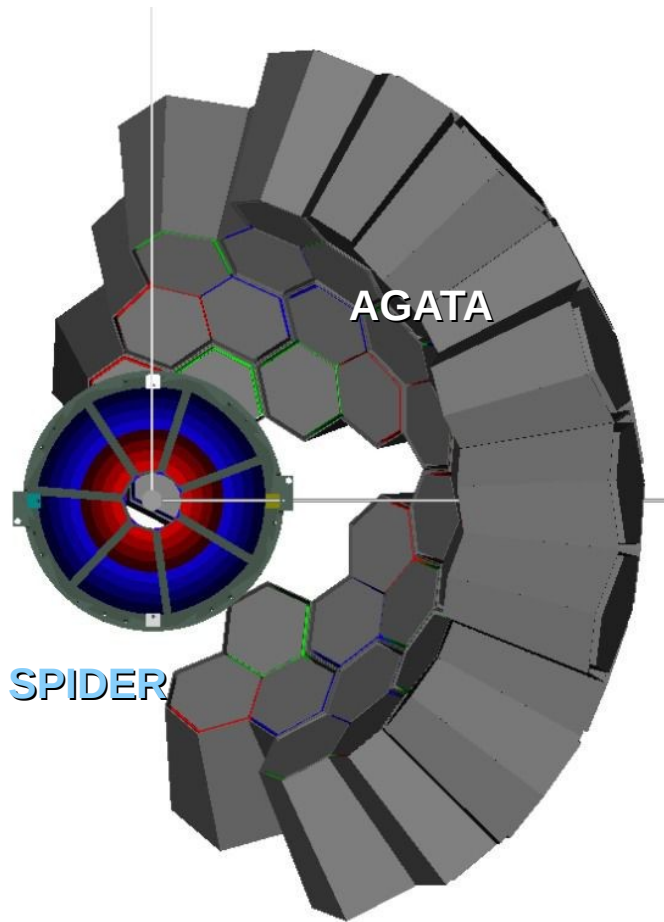
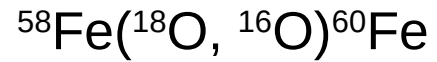
LSSM

SCCM

\rightarrow RDDS technique

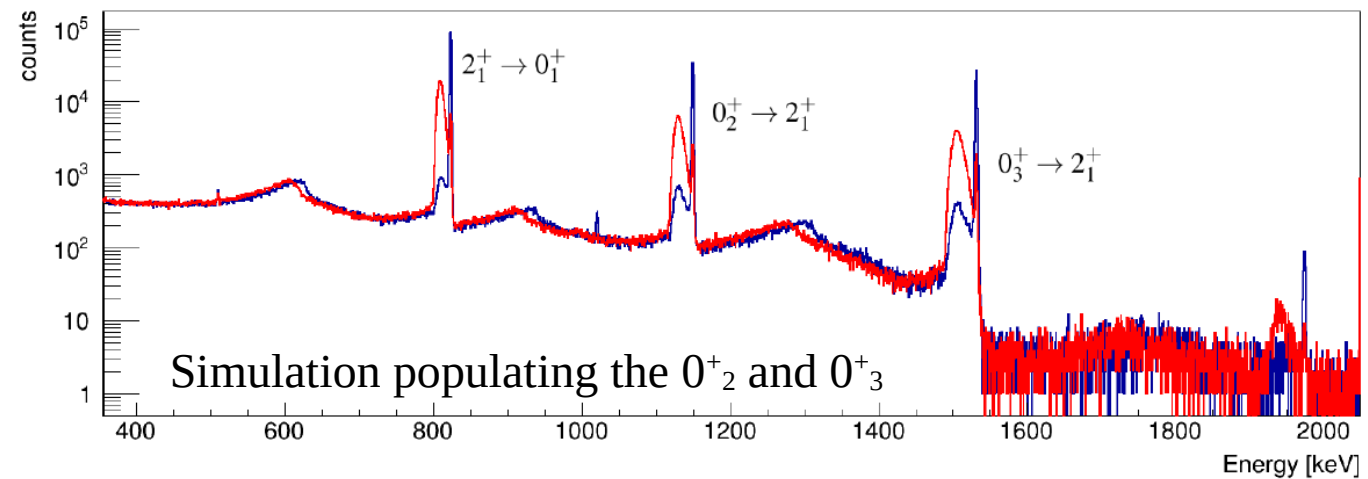


The experiment



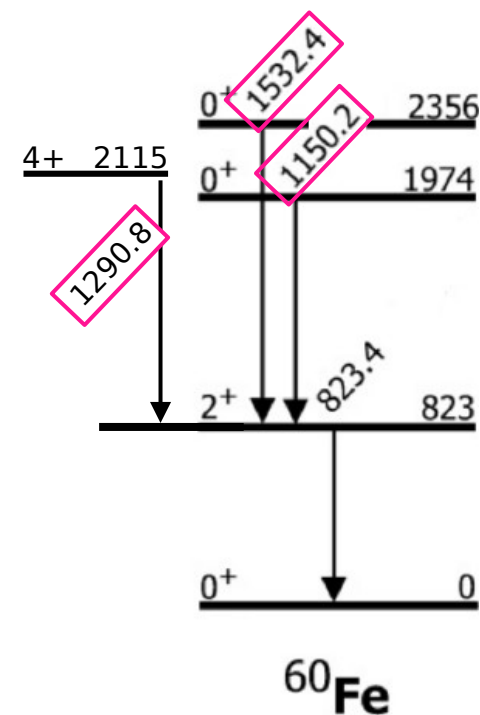
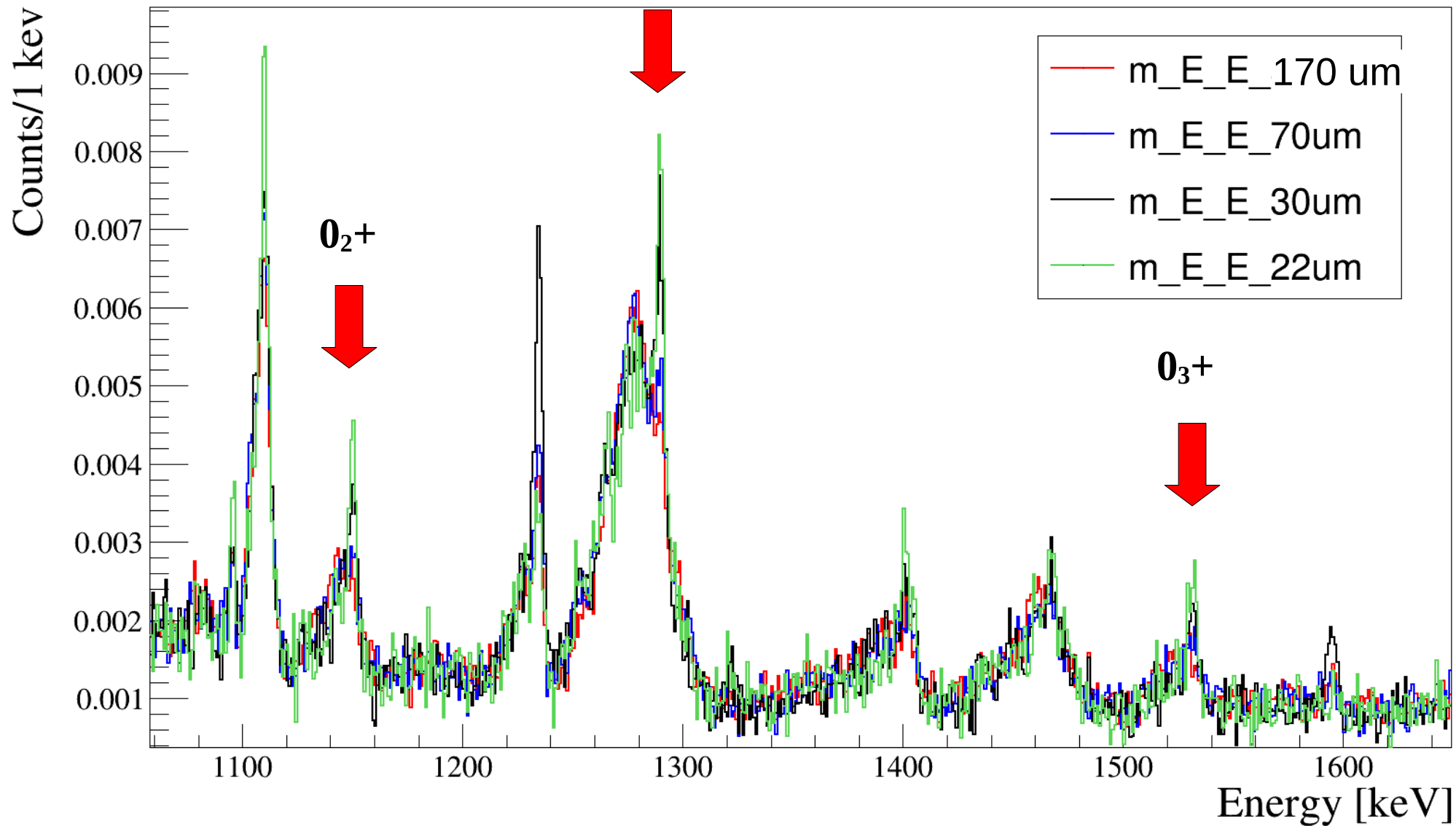
- 0^+ levels expected to be in the range **1-500 ps** → **RDDS**
- ^{18}O beam at 40 MeV
- Target: 1 mg/cm² of ^{58}Fe + Stopper: 3.8 mg/cm² of Nb
- beam-like fragments ^{16}O detected in SPIDER at 124-161 degrees angles: selection of ^{58}Fe in forward direction
- Control on Ex → selection of iron isotopes over possible FE events or reactions on the stopper

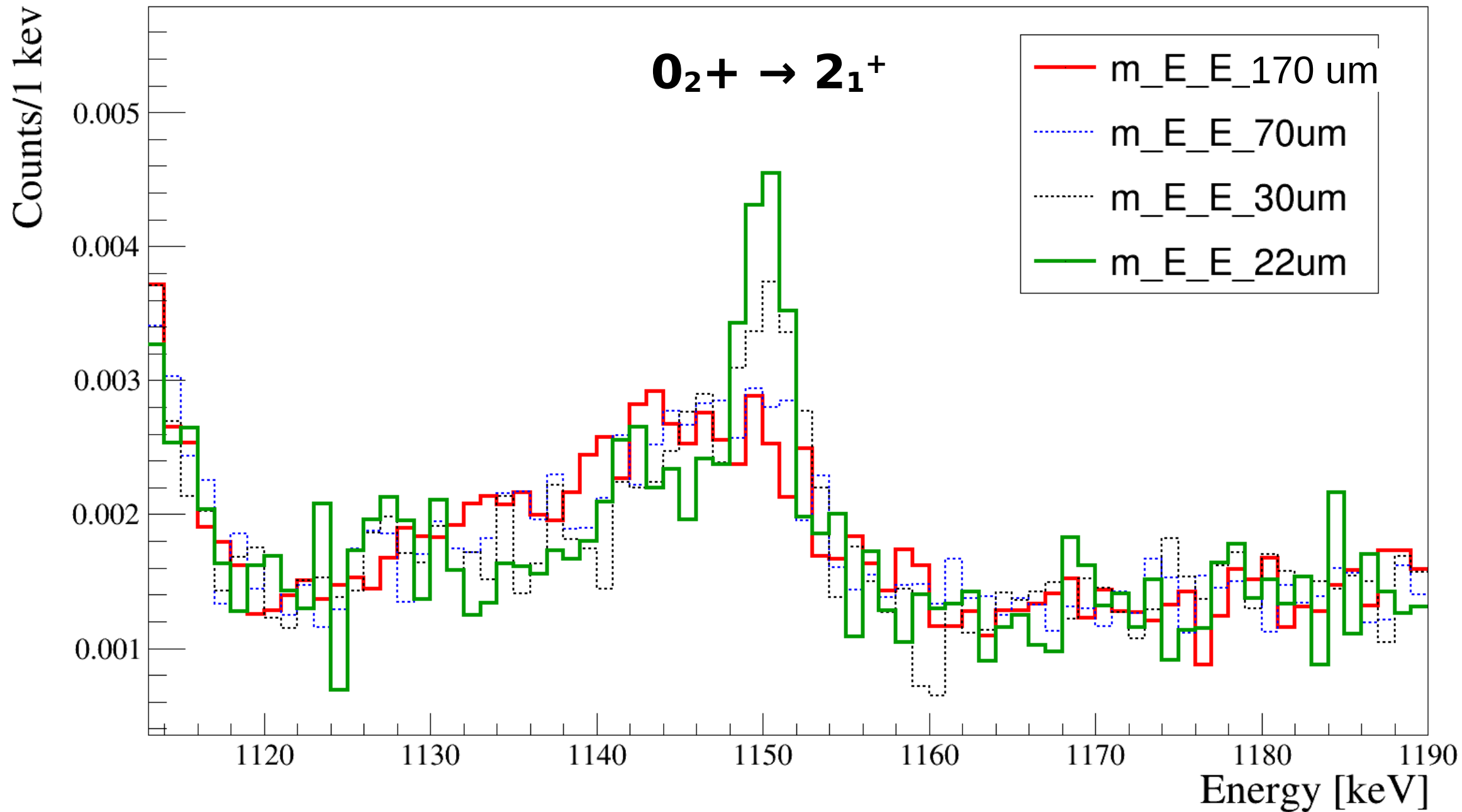
GEANT4 simulations show peak separation given angular coverage of Spider and no DC

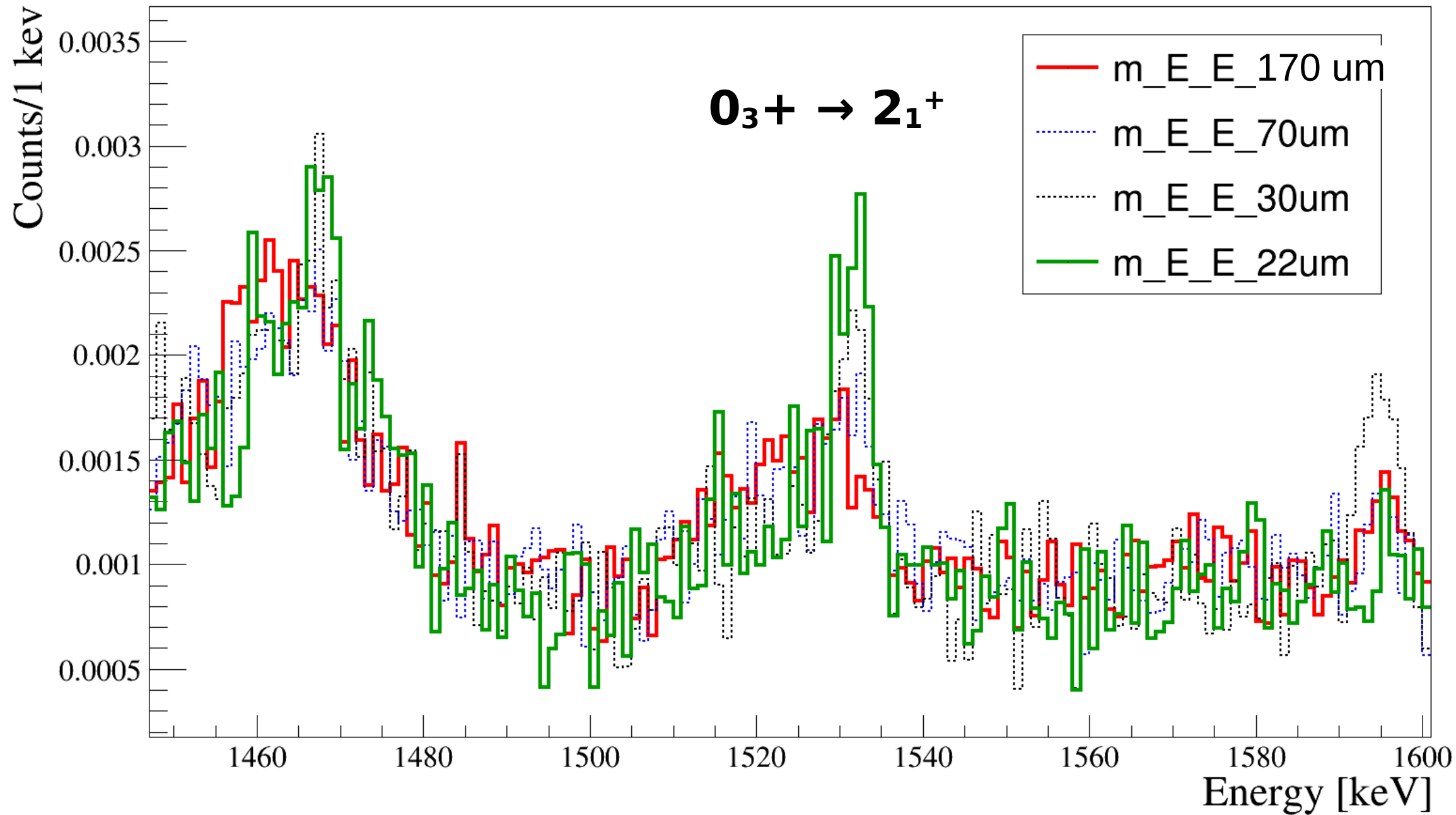


Preliminary results

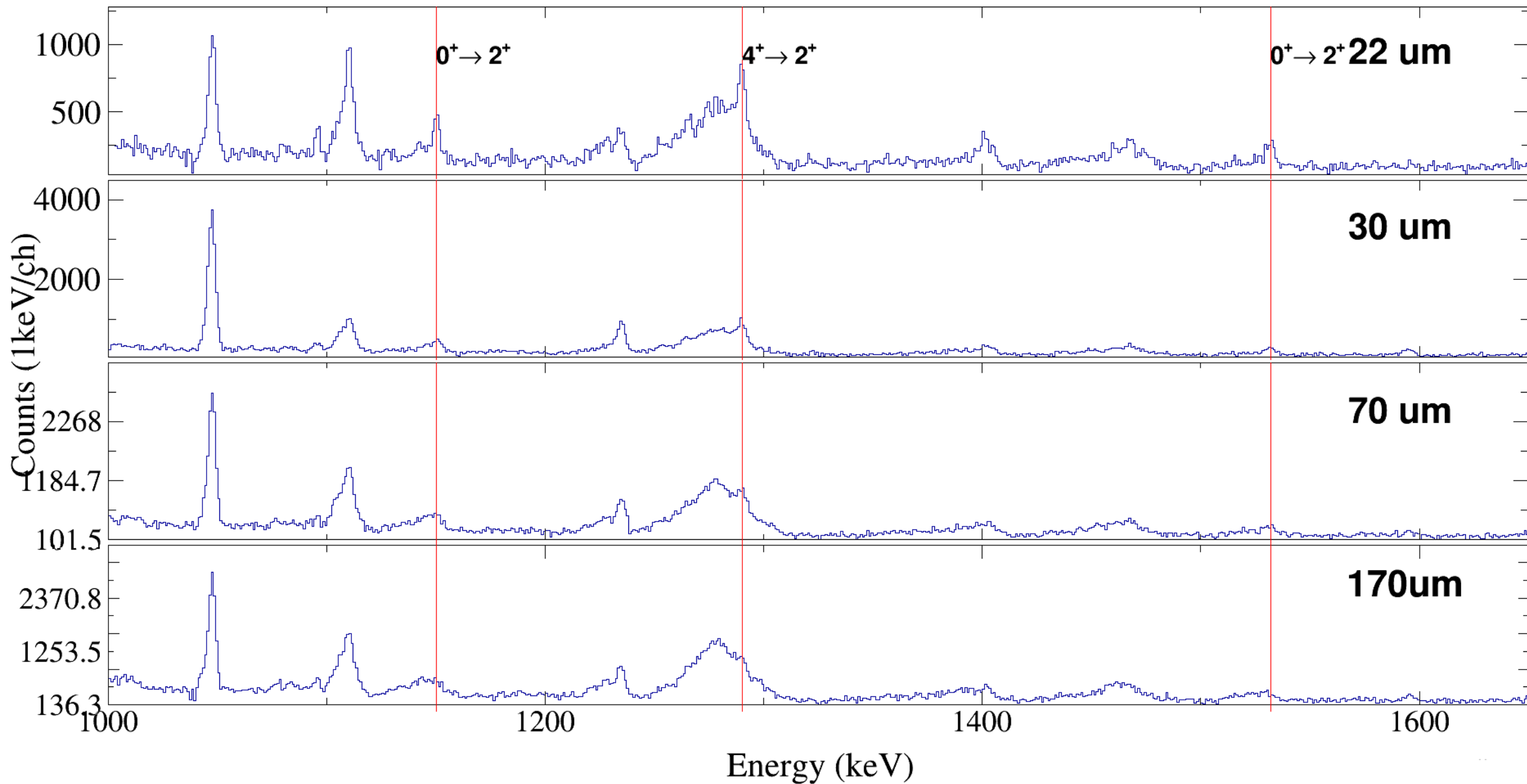
- Gamma-gamma coincidence spectra at different distances.
- Gate in the ground-state transition @ 823 keV.
- No coincidence with particles.







Preliminary results

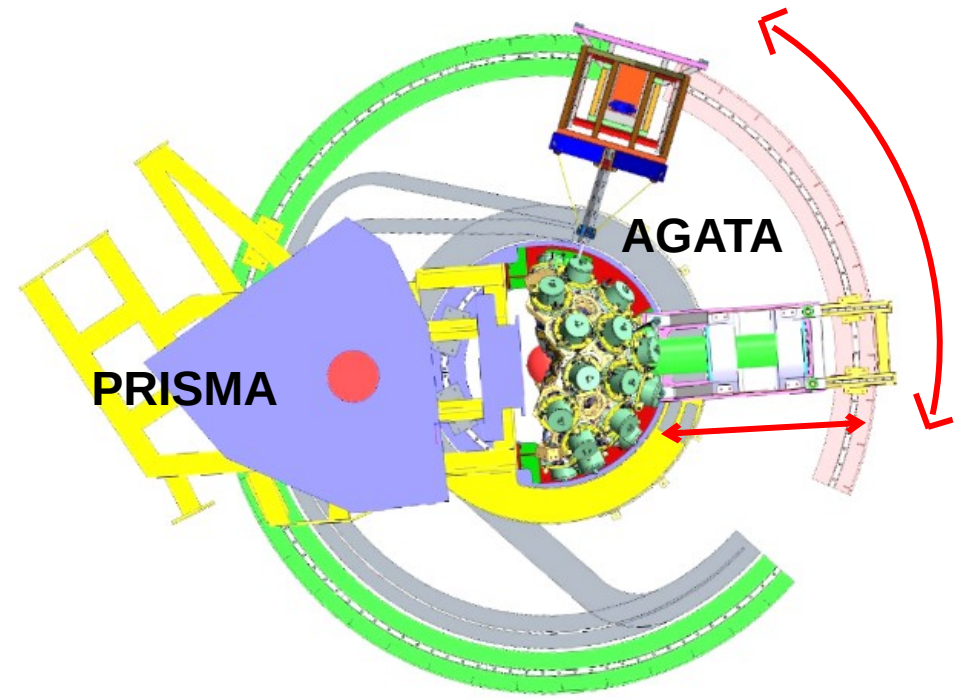


What's next?

Switching to the Zero-degree configuration

2021 – 2024?

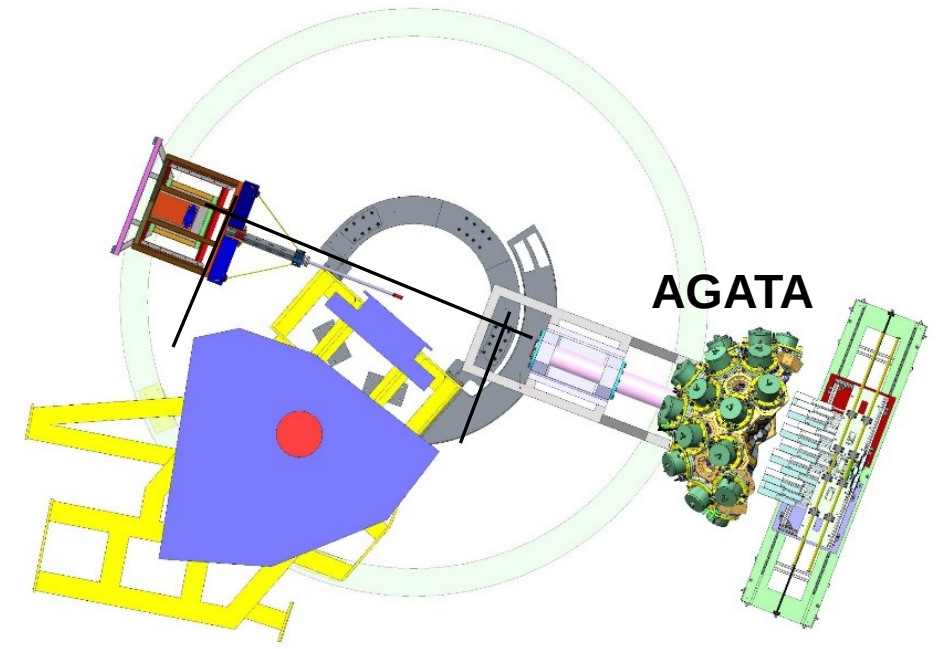
AGATA coupled with PRISMA



Current configuration

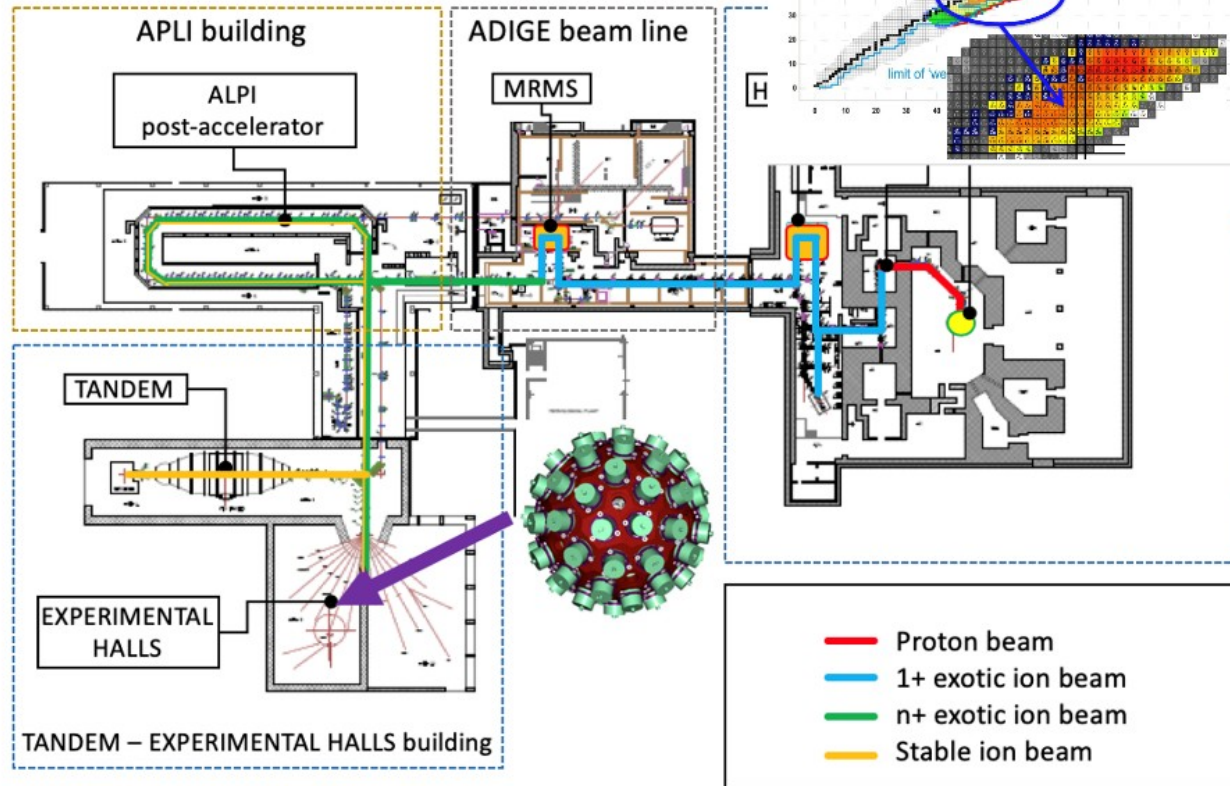
2024?, 2025?

AGATA zero degrees



The SPES project: ISOL radioactive beams @ LNL

40 MeV - 200 μ A of protons \rightarrow production of re-accelerated neutron-rich exotic beams **10^{13} fission/s in-target production, and re-acceleration at 10^*A MeV ($A=132$)**



DayOne SPES beams.

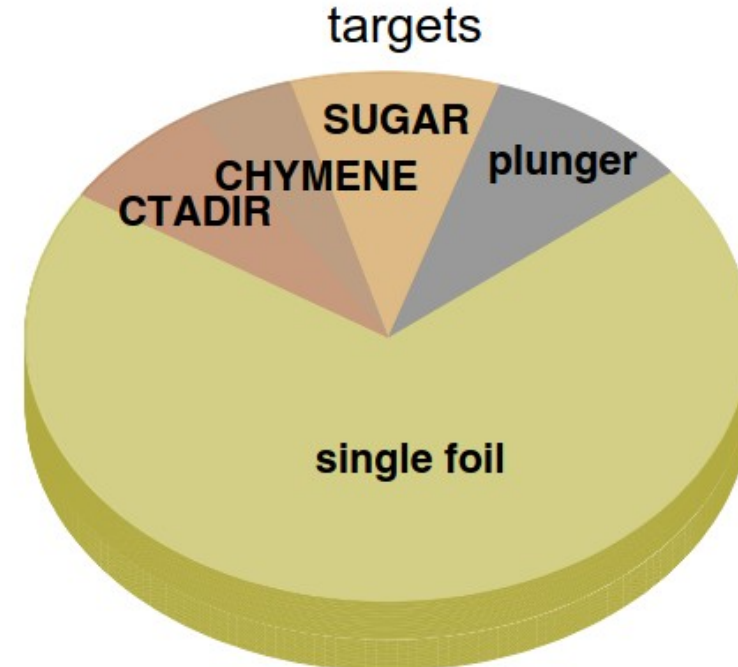
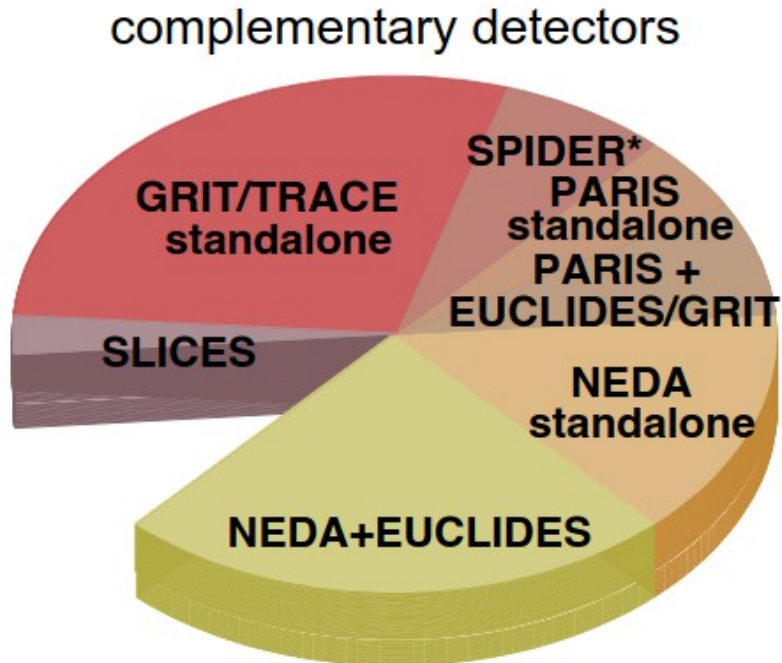
List of possible first SPES beams:

Primary target	Beam	Intensity (pps)	Max energy (MeV/A)
TiC	43Sc	2,40E+07	10
TiC	44Sc	2,25E+08	10
TiC	42K	3,70E+07	10
UCx	130Sn	3,95E+06	10
UCx	132Sn	7,70E+05	10
UCx	132Te	2,11E+07	10
UCx	132Sb	9,50E+05	10
UCx	134Te	1,50E+04	10
UCx	94Rb	6,80E+06	10
UCx	75Ga	1,10E+05	10

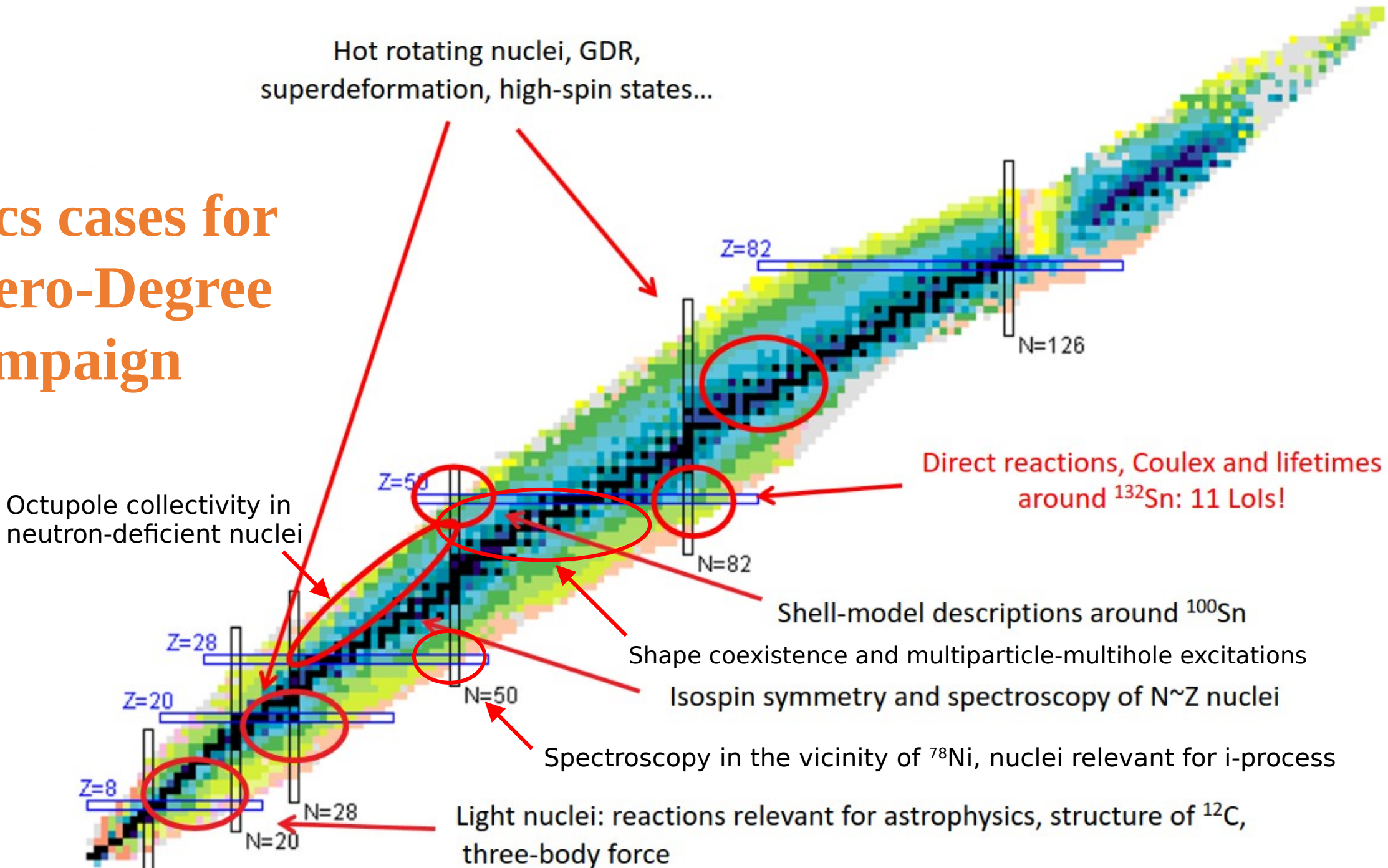
Third pre-PAC and Zero-Degree campaign workshop

19-21 April 2023

- stable beams from the Tandem-ALPI-PIAVE complex or first SPES beams
- complementary set-ups compatible with AGATA at zero degrees: NEDA, PARIS, GRIT, TRACE, gas/cryogenic targets (SUGAR, CTADIR, CHYMENE)
+ detectors used in the present campaign: EUCLIDES, SPIDER, DANTE
- overwhelming response from the community: 42 “physics” LoIs + 4 umbrella proposals

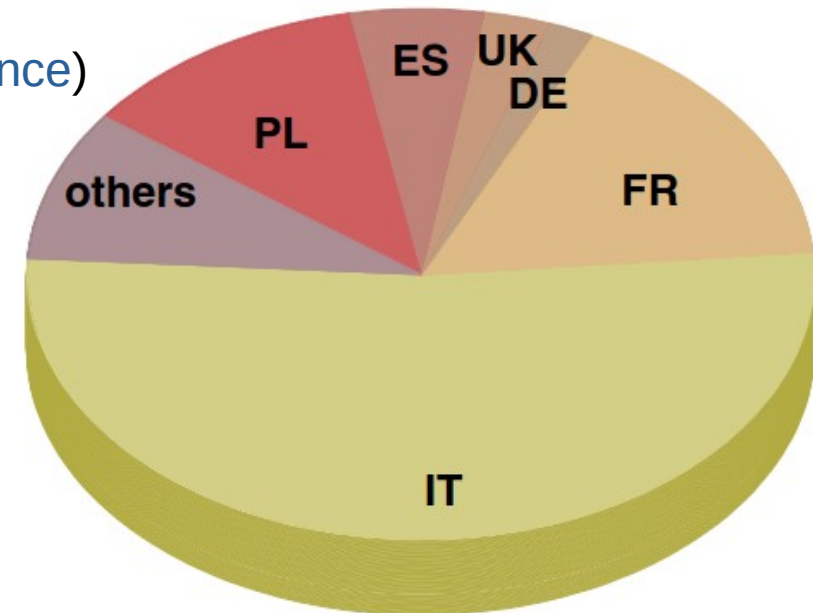


Physics cases for the Zero-Degree campaign



French involvement in the Zero-Degree Lol

- DSAM measurement in ^{132}Sn using direct reaction (E. Clément, M. Assié, F. Flavigny, A. Matta, I. Zanon)
- Investigation of the microscopic structure of Pygmy Dipole Resonances in ^{132}Sn using transfer reactions (D. Beaumel)
- Nuclear structure studies around ^{132}Sn with a tritium target (S. Bottoni, F. Galtarossa, M. Assié)
- Excitation energy, spin and parity determination in identical superdeformed bands via the search and placement of linking transitions. The case of the identical bands of ^{151}Tb and ^{152}Dy (G. Duchêne)
- Structure of neutron-rich Ge isotopes in vicinity of the double-magic ^{78}Ni nucleus (F. Didierjean, G. Duchêne, A. Gottardo, M. Moukaddam, D. Verney)
- Spectroscopy in $^{102,103}\text{Sn}$ and lifetime measurements in ^{103}Sn to investigate nuclear structure toward 100Sn (G. Pasqualato, A. Gottardo)
- Octupole and non-Yrast states in ^{80}Zr (A. Gadea, R. Perez Vidal, G. de France)
- + umbrella proposals:
 - Study of direct reactions using the CHyMENE target (I. Zanon, A. Gillibert, A. Gottardo, A. Corsi)
 - Umbrella Lol for GRIT (D. Beaumel, D. Mengoni)
 - High-spin studies with AGATA – a physics campaign (G. Duchêne)
 - Coupling PARIS with AGATA (A. Maj, F. Camera, M. Lewitowicz)



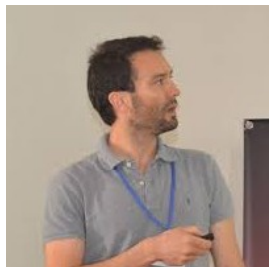
Conclusion and future perspectives

- AGATA has concluded the first year at LNL, carrying out a total of 15 experiments, 3 commissioning and a long acquisition for improvements on the generation of the PSA bases
- In its first configuration it is coupled with PRISMA and other detectors to exploit the stable beams provided by the TANDEM-ALPI-PIAVE facility
- The community response in terms of proposals and LOI has been overwhelming

- In its second phase AGATA will be in the Zero-Degree configuration coupled with the neutron-detector array NEDA.
- As SPES ISOL radioactive beams are foreseen within the time frame of AGATA@LNL, new exciting physics cases are expected.

New results coming soon!

Special thanks to the LNL-Padova local group



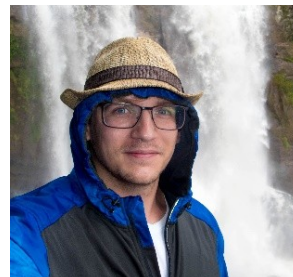
J.J. Valiente-Dobón



A. Ertoprak



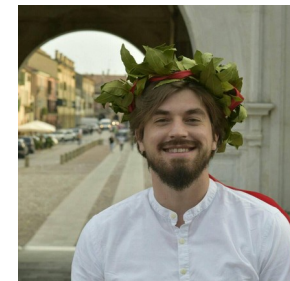
D. Mengoni



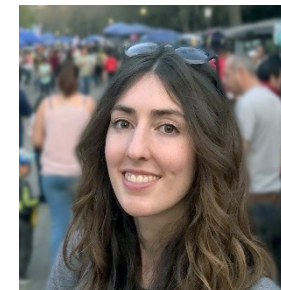
M. Balogh



P. Aguilera



J. Pellumaj



R.M. Pérez-Vidal



F. Angelini



M. Sedlák



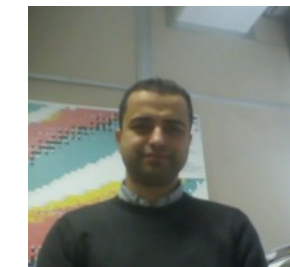
A. Goasduff



S. Pigliapoco



E. Pilotto



A. Gottardo



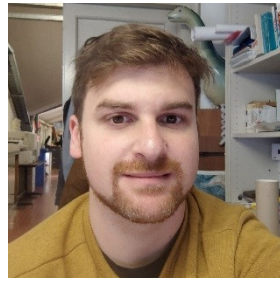
R. Escudeiro



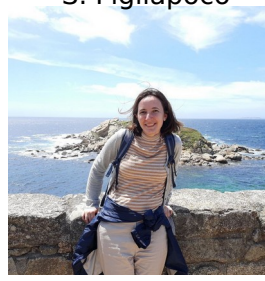
M. Polettini



D. Brugnara



J. Benito



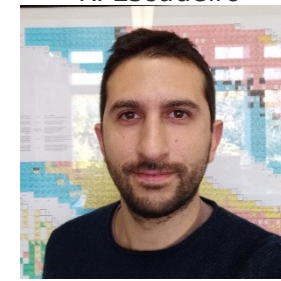
I. Zanon



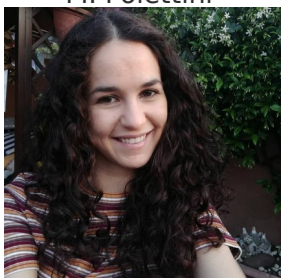
L. Zago



B. Góngora



F. Galtarossa



S. Carollo



R. Menegazzo



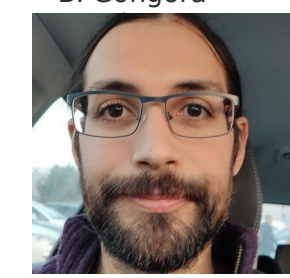
K. Rezynkina



F. Recchia



S. Lenzi



J. Collado



G. De Angelis