AGATA at GANIL

Final report

ACC November 2021

2020 ….. All the facility was shut-down after the e775s AGATA experiment

(Irene almost trapped forever in GANIL, the experiment was stopped 36h and teams put in quarantine due to a new Italian visitor …)

Half of AGATA was warmed-up in a controlled way

2021 ….. Beam started on the 9th of March with re-scheduling of e793s ^{47}K(d,p) MUGAST (UK/Fr experiment)

Heavy Ions Mode

^{238}U+^{238}U D. Ackerman [20-29 May]

Xe + Pt Y. Kim [19 June – 2 July]

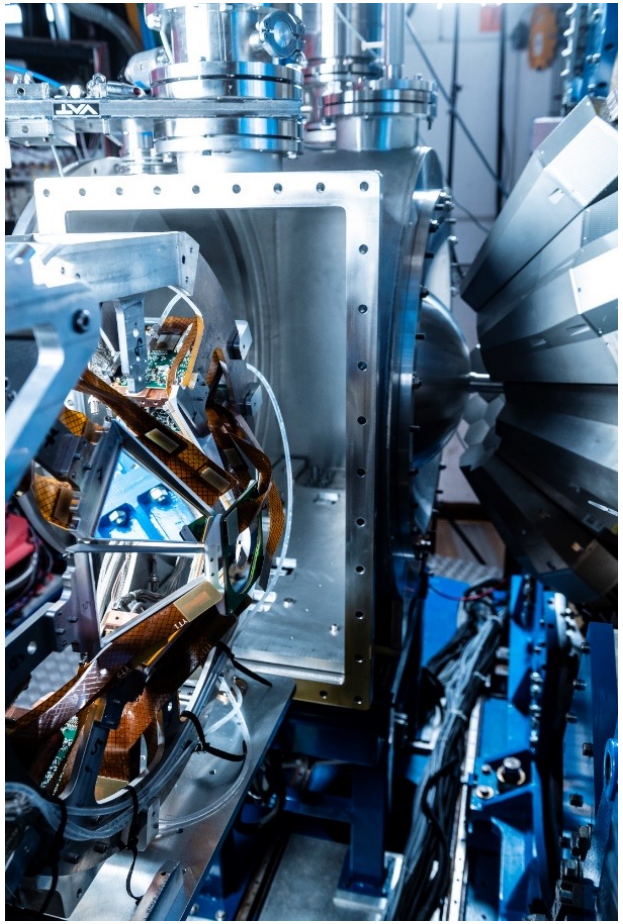
Experimental conditions a bit complicated

50% GH closed
Restaurant is open
GH kitchen is closed
Couvre feu 18h

- GANIL DAQ in VNC via VPN
- AGATA DAQ in x2go via lxagata0

→ 36 capsules back in operation for the data taking

MUGAST campaign 2021



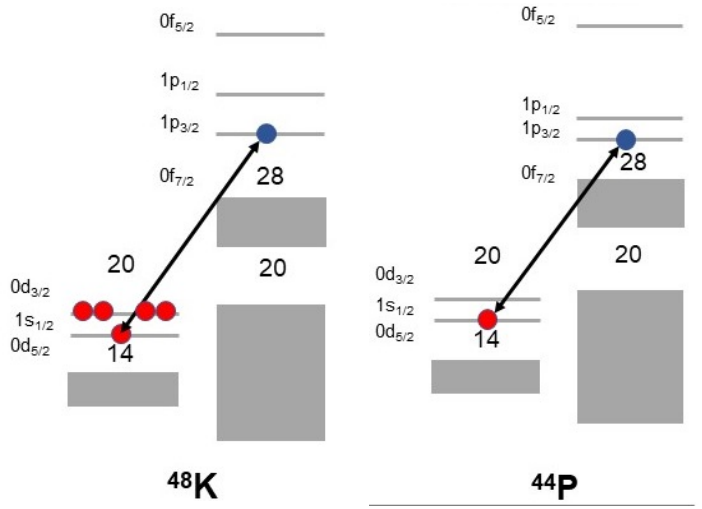
NUCLEAR STRUCTURE.

Proton-neutron interactions across the *N* = 28 shell closure via ^{47}K(*d*,*p*)^{48}K, and implications for the most neutron-rich phosphorus

(Spokespersons: W.N. Catford, G. Lotay and A. Matta)

SPIRAL1 post-accelerated RIB

MUGAST-AGATA-VAMOS setup



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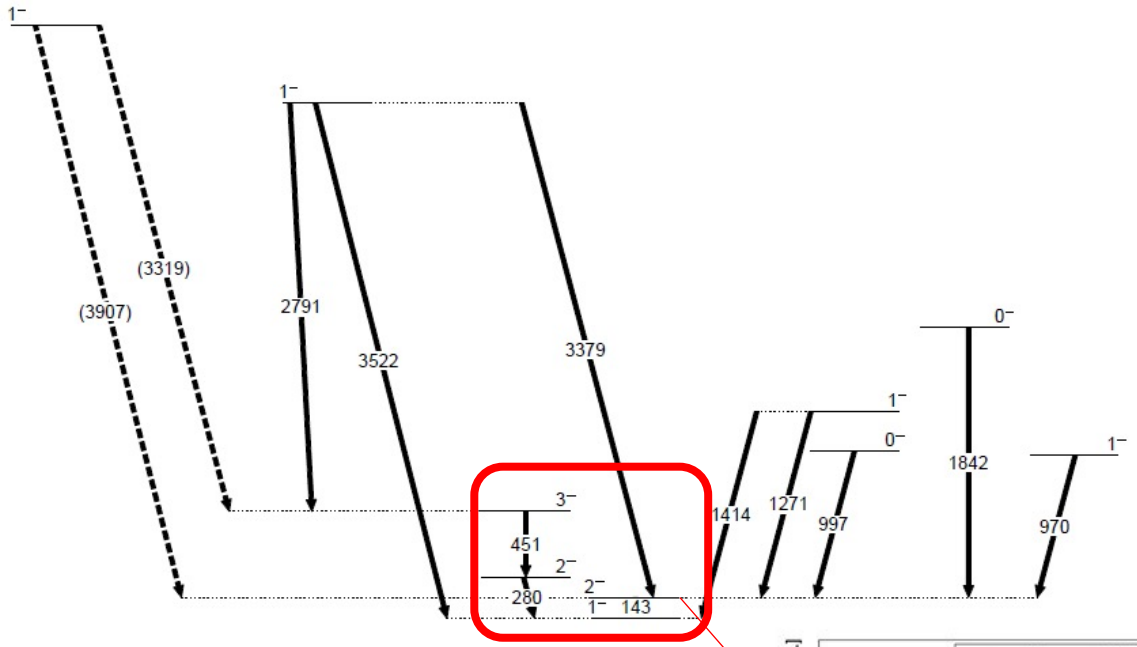
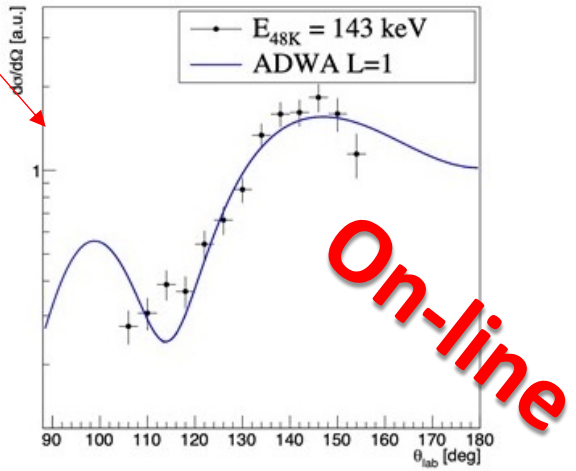


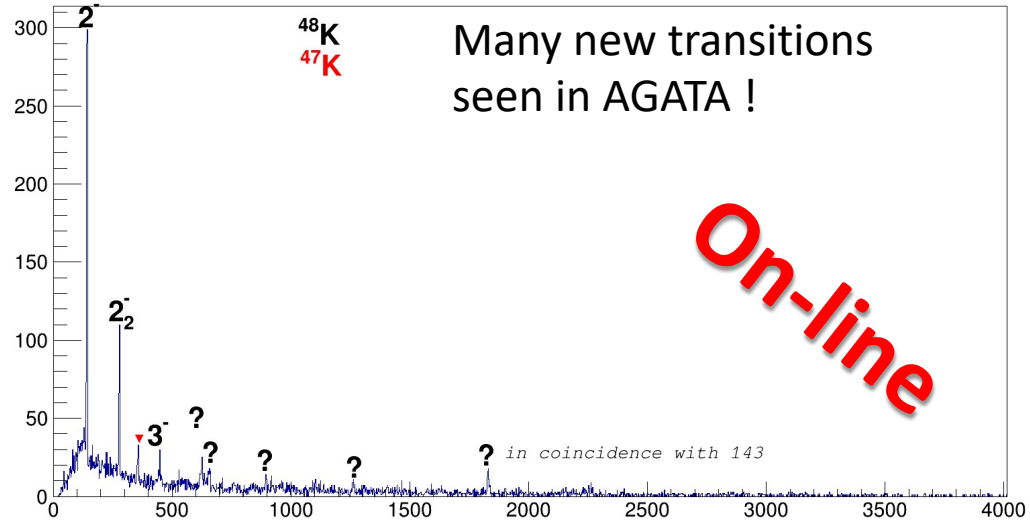
Known-



On-line

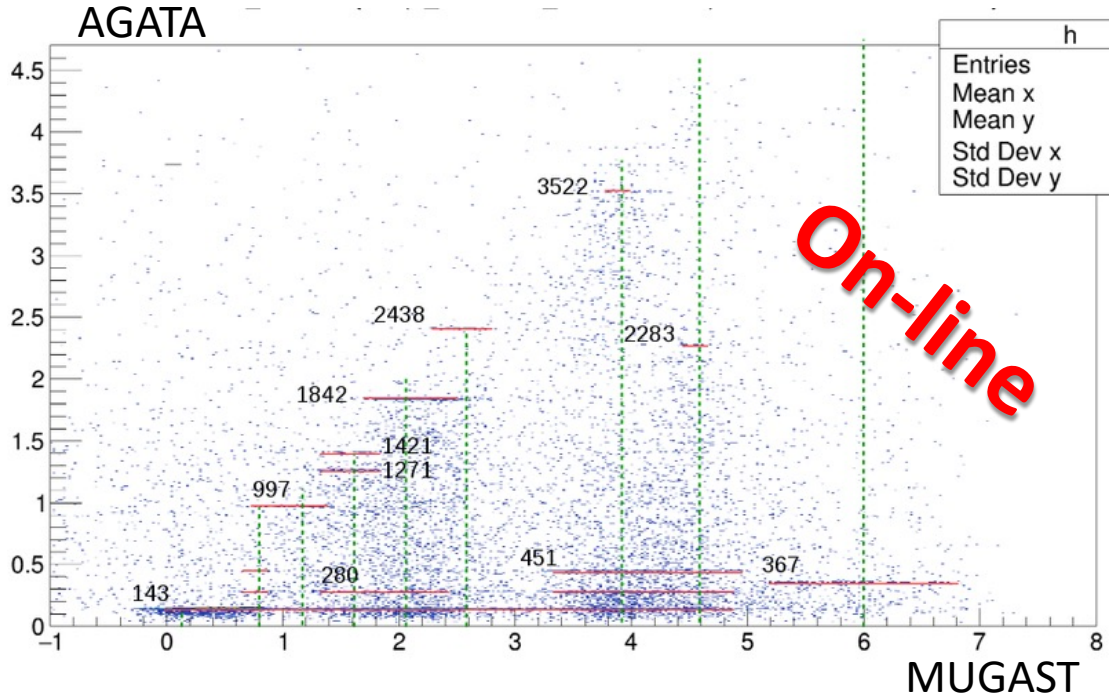
Very successful experiment

MUGAST angular distribution
AGATA Gated



Many new transitions seen in AGATA !

On-line



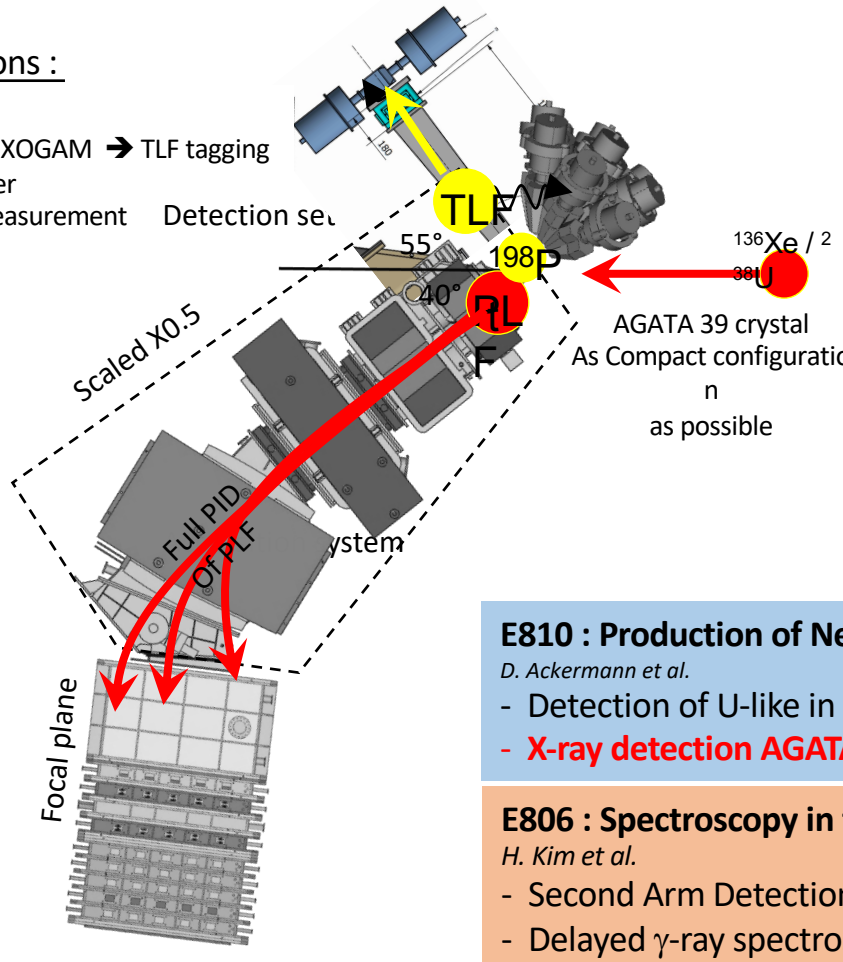
On-line

AGATA + VAMOS 2021 – Heavy Ions

laboratoire commun CEA/DRF CNRS/IN2P3

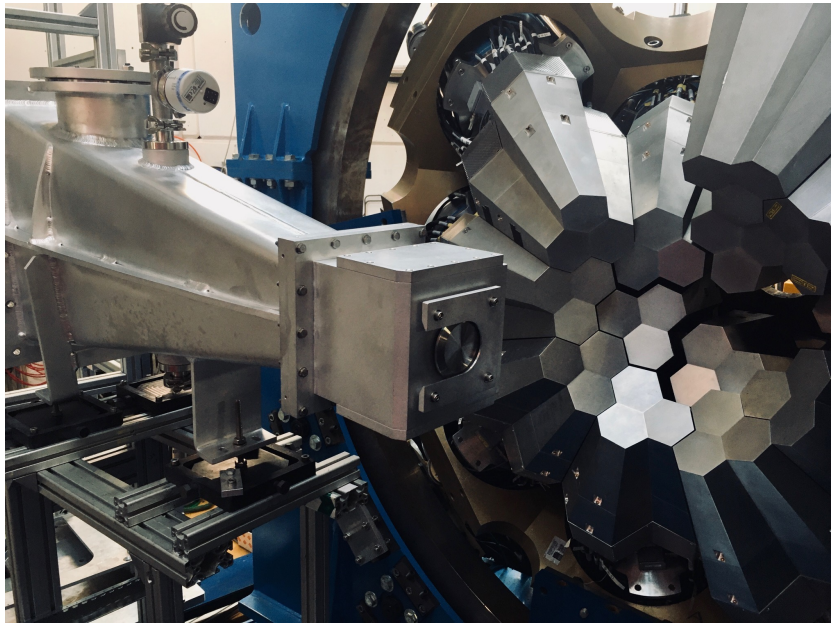
Motivations :

2nd arm + EXOGAM ➔ TLF tagging
- µs Isomer
- A, E* measurement Detection se



Courtesy A. Lemasson

2nd arm

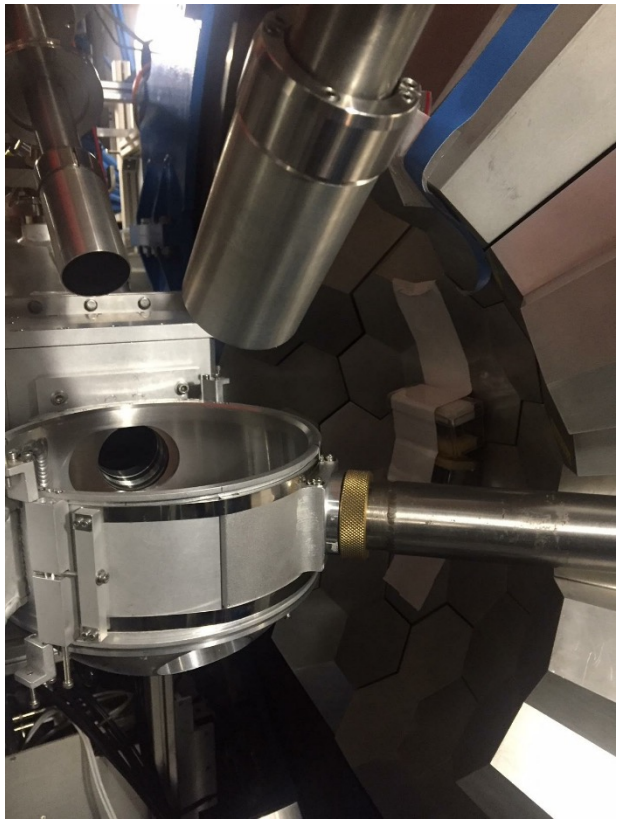


AGATA

E810 : Production of Neutron rich nuclei using MNT $^{238}U+^{238}U$.
D. Ackermann et al.
- Detection of U-like in VAMOS
- **X-ray detection AGATA** + LEPS **AGATA response function < 100 keV**

E806 : Spectroscopy in the vicinity of N=126 from MNT $^{136}Xe+^{198}Pt$
H. Kim et al.
- Second Arm Detection
- Delayed γ-ray spectroscopy

2nd Arm LEPS



AGATA

VAMOS

E810 : Production of Neutron rich nuclei using MNT $^{238}U+^{238}U$.

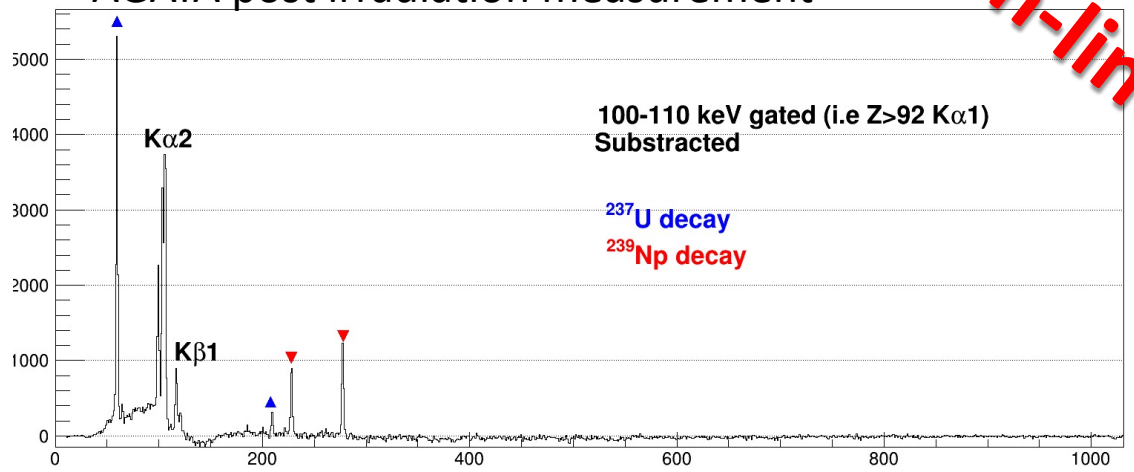
D. Ackermann et al.

- Detection of U-like in VAMOS
- **X-ray detection AGATA** + LEPS

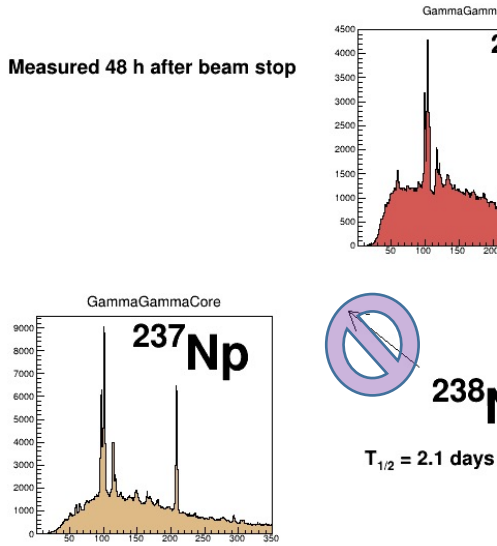
- R&D on low energy γ and Tracking
- No obvious sign of transfer seen on-line in VAMOS M/Q
- Offline measurement with long-lived isotopes
- Neutron channel seen but no proton channel

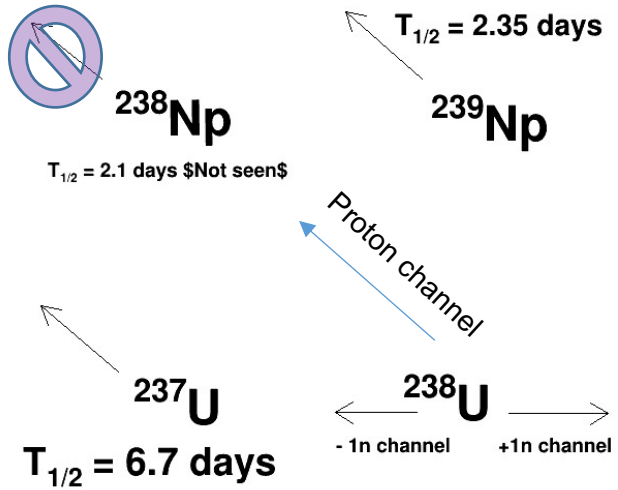
  A. Utepov PhD GANIL

AGATA post irradiation measurement



On-line



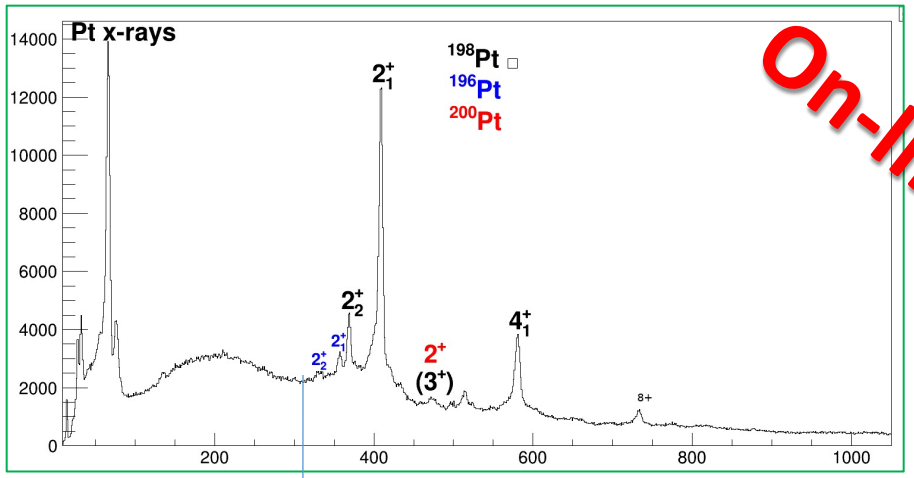


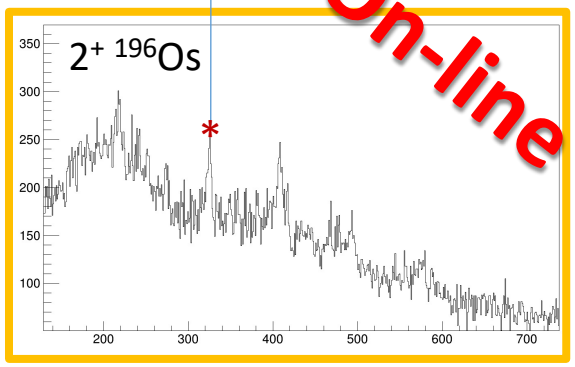
E806 : Spectroscopy in the vicinity of N=126 from MNT $^{136}Xe+^{198}Pt$

H. Kim et al.

- Second Arm Detection
- Delayed γ-ray spectroscopy

- Successful experiment
- A lot to be analyzed
- Complementary devices analysis

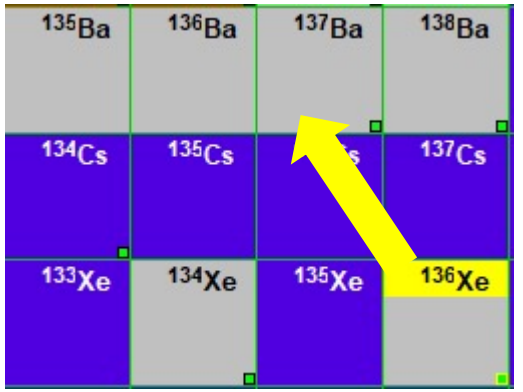




Low Q-reaction selection from Δv – Δθ correlation between VAMOS and 2nd arm

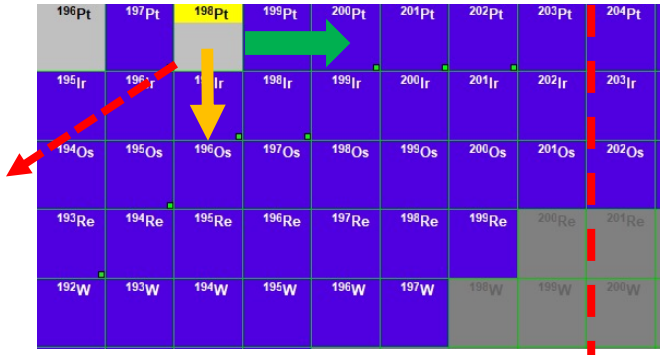
AGATA prompt DC for heavy partner in 2nd arm

* P. R. John et al. Phys. Rev. C 90, 021301(R) – (2014) AGATA PRISMA

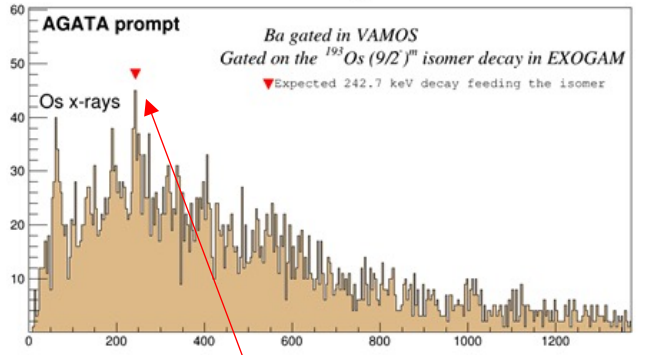


Identified in VAMOS

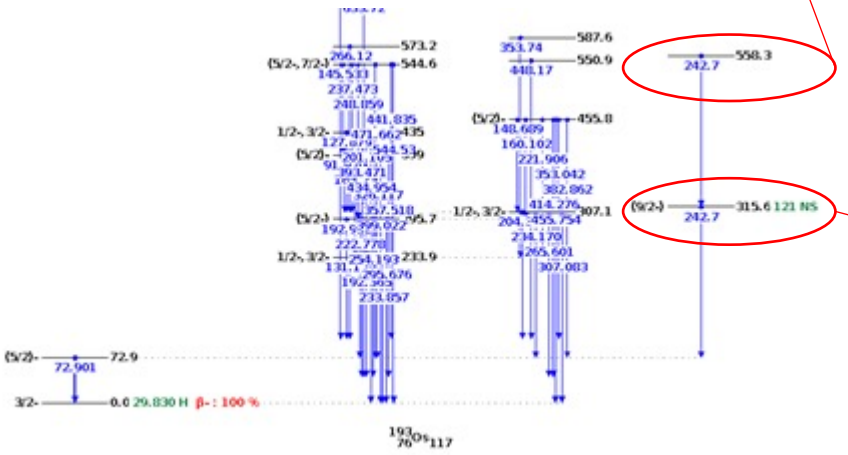
In the 2nd arm

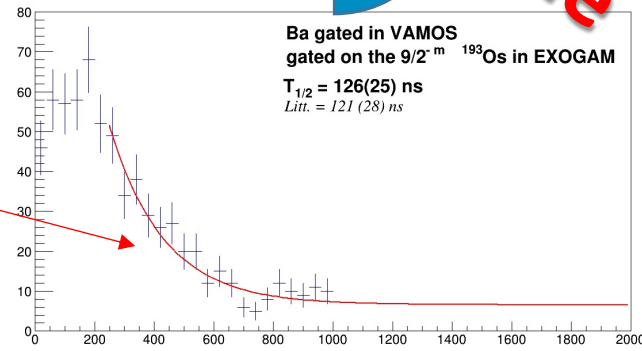


N=126



On-line

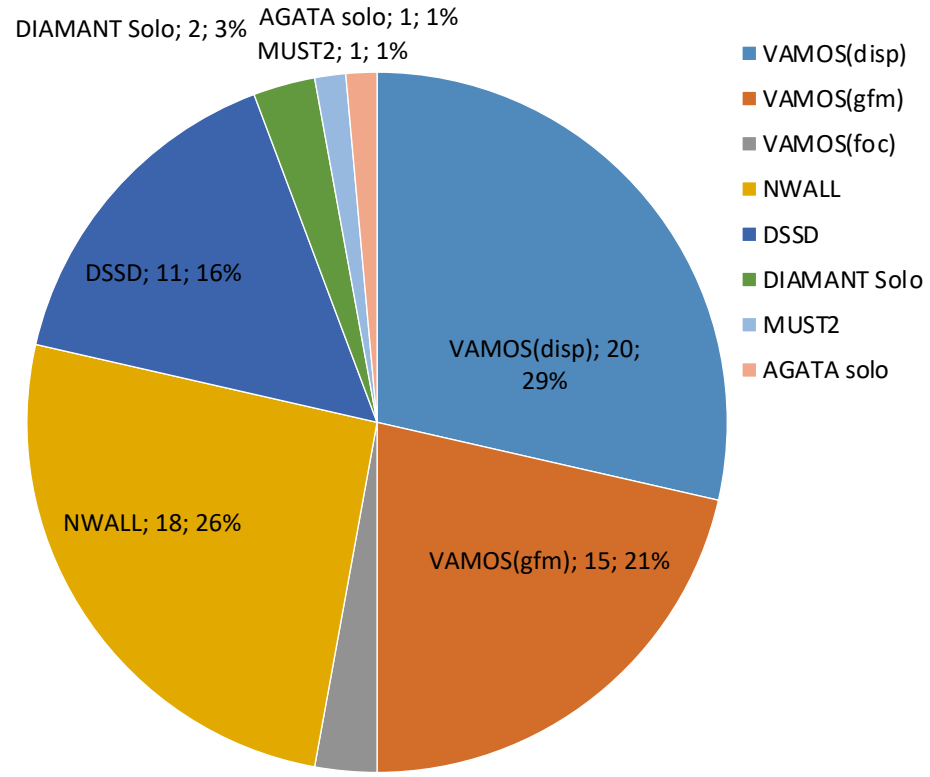


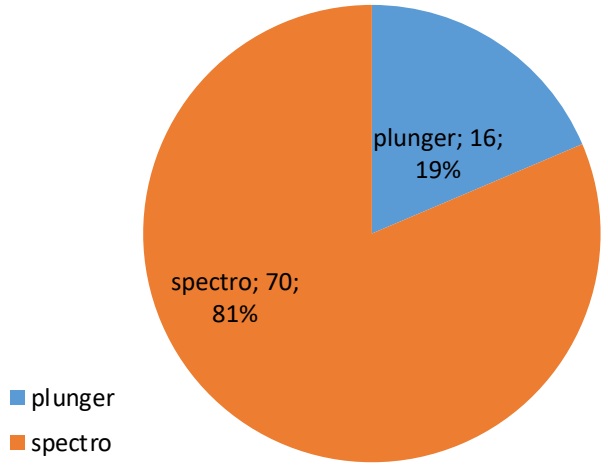


EXOGAM delayed in 2nd arm by 242 kev

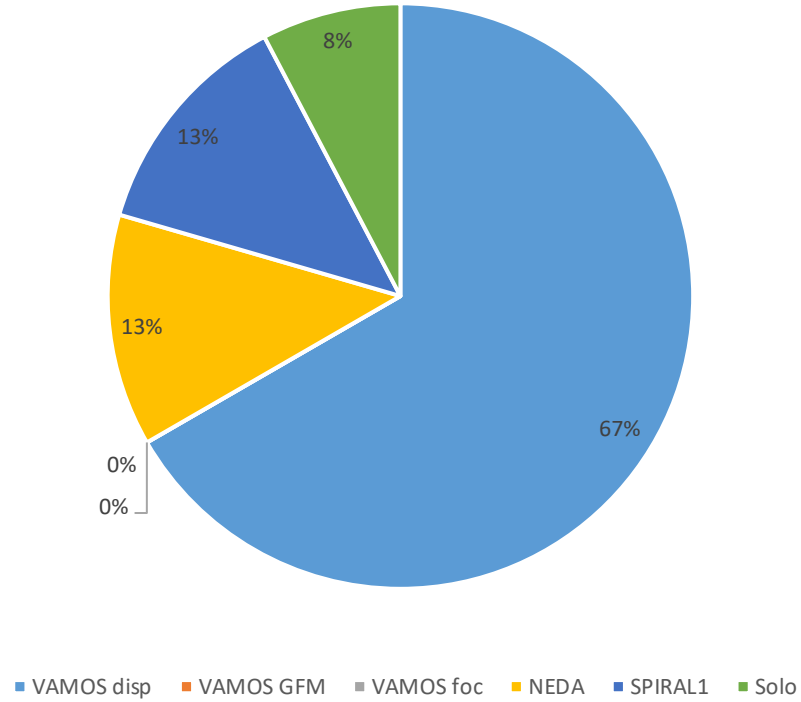
18th -20th of February 2013
Campaign spokesperson : Silvia Lenzi

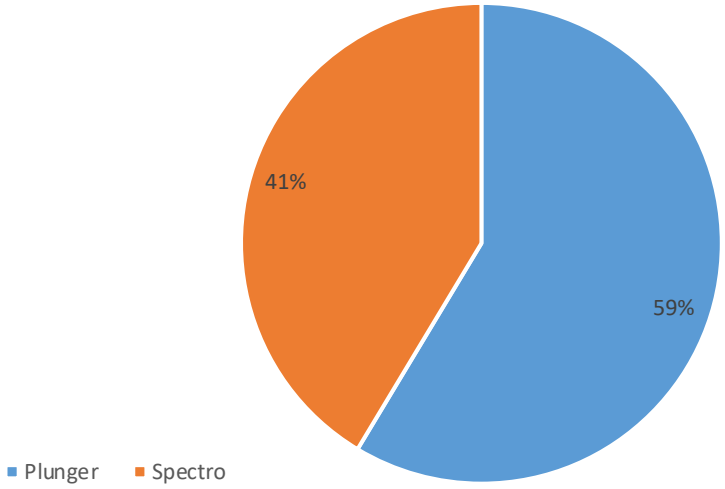
A document summarizing the outcome of the workshop has been distributed to the collaboration and the participants





LoI in 2013 Workshop





The Campaign

The GANIL Campaign organization

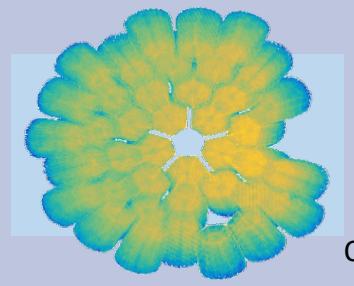
The AGATA campaign at GANIL has been extend (4 times) to end of June 2021

Each GANIL PAC had a “PrePac” workshop with a specific call ***without filters*** : ***AGATA Collaboration Meeting***

- 1st PAC in 2014 : VAMOS (10 experiments approved)
- 2nd PAC in 2015 : VAMOS || NEDA (10 experiments approved)
- 3rd PAC in 2016 : NEDA (6 experiments approved)
- 4th PAC in 2017: Fully opened : 2(1) VAMOS (MUGAST) approved
- 5th PAC in 2018 : MUGAST (2 experiments approved)
- 6th PAC in 2019 : MUGAST (1 experiment approved)
- 7th PAC in 2020 : VAMOS heavy ions (2 experiments re-approved)
- PAC in 2021 : call in February –without AGATA

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

Experiments performed in 2015-2021 at GANIL with AGATA



RIB

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

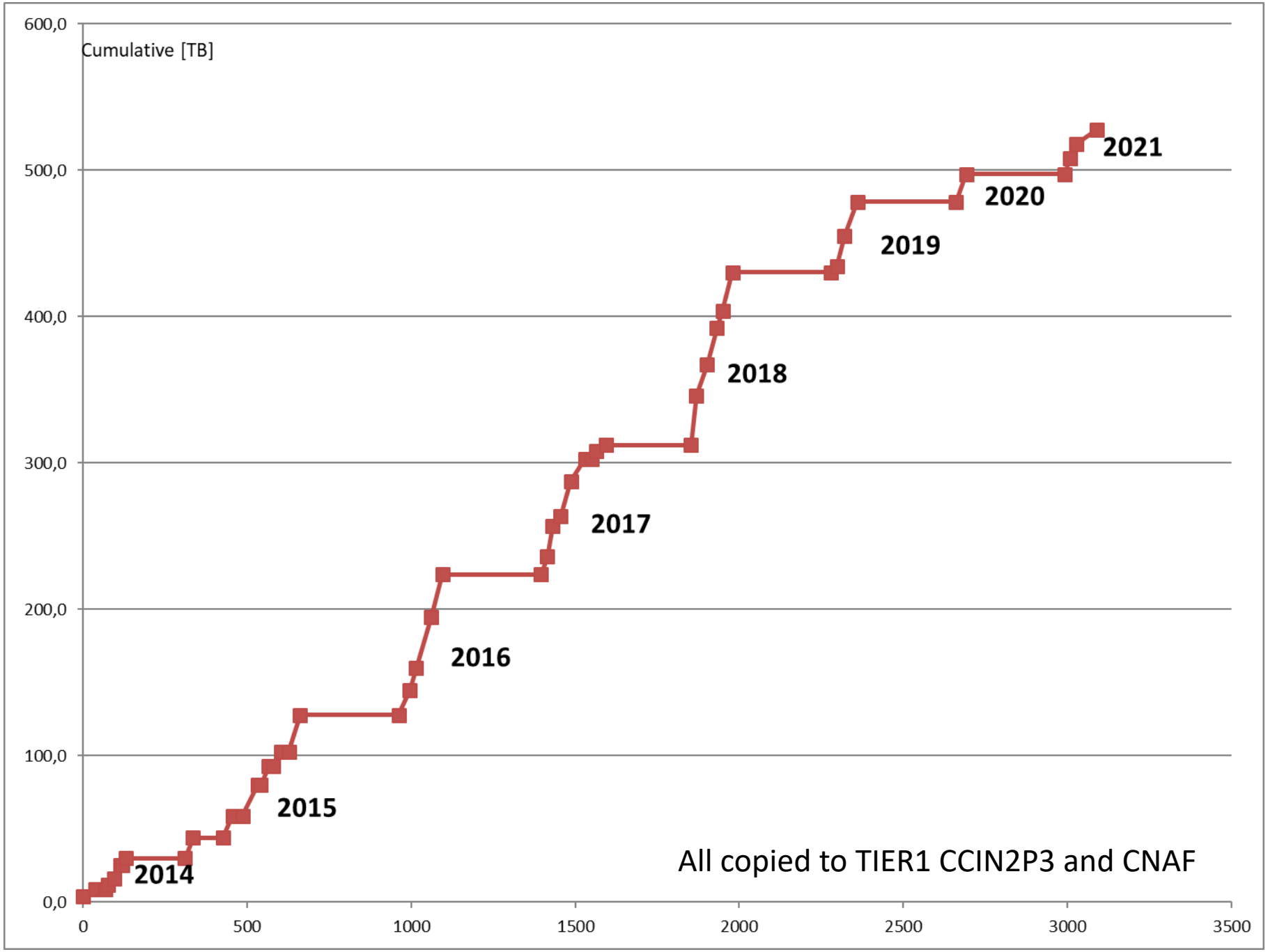
Evolution of the shell structure in the region of neutron-rich Ti isotopes

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

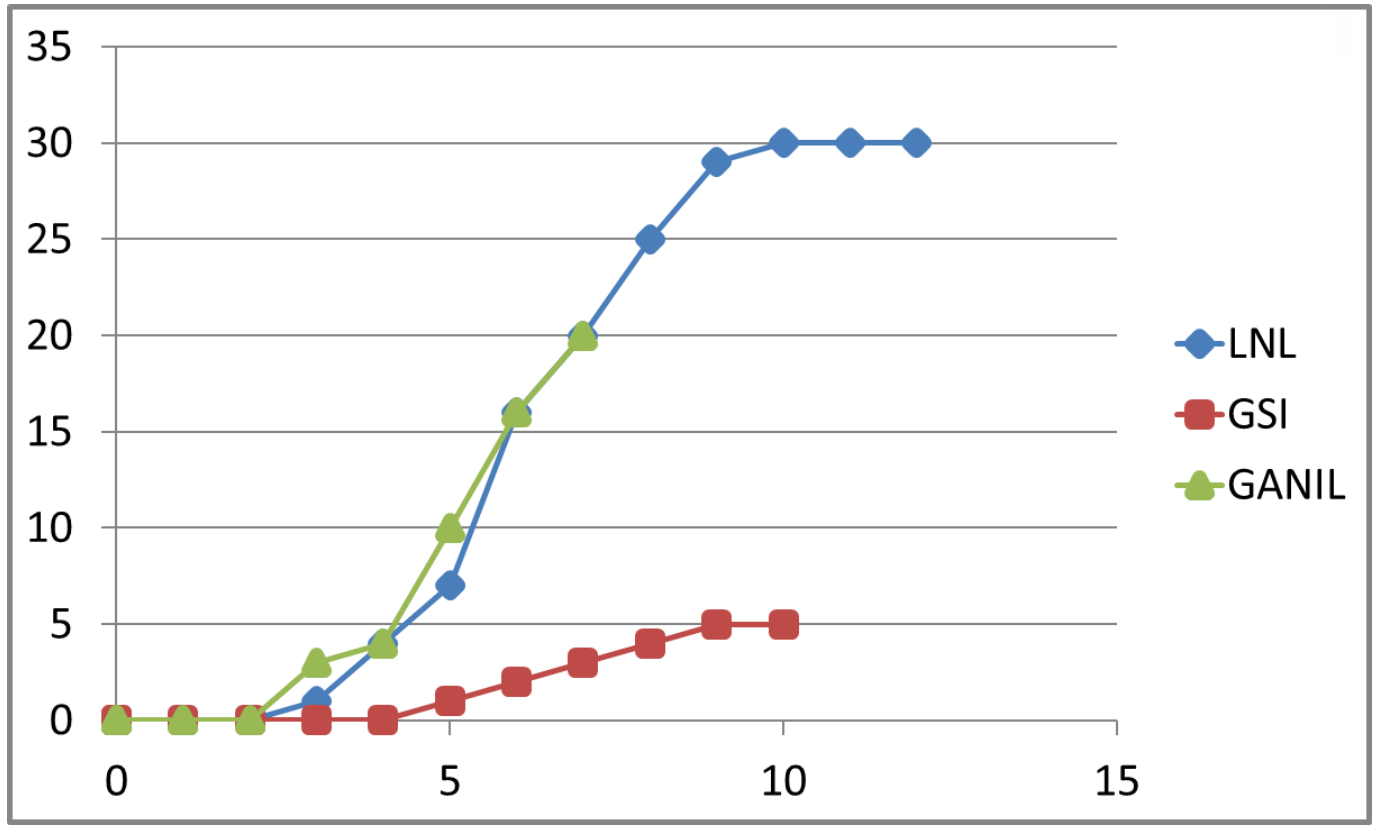
3-body contribution in ^{20}O structure

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

Data production



Integrated number of scientific papers

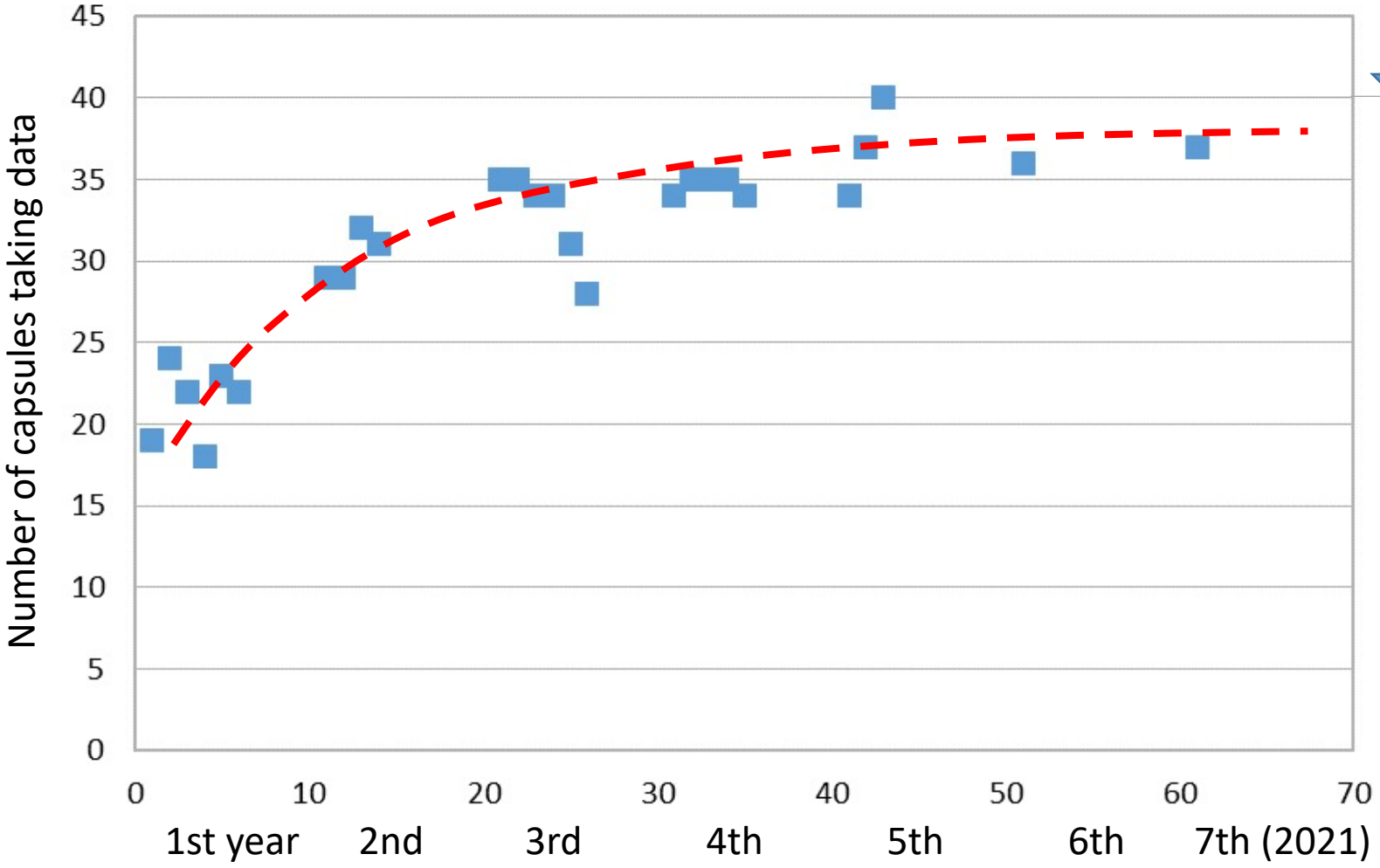


From [2015,2016,2017] fully analyzed experiments, we get 1.35 paper / experiment in average

In the corresponding years [2019, 2020, 2021], 40-50 % of the GANIL Nuclear Physics publication is AGATA

- Complete set of bound negative-parity states in the neutron-rich nucleus ^{18}N S. Ziliani *et al.* Phys. Rev. C 104, L041301 – (2021) (AGATA-VAMOS-PARIS)
- Accessing tens-to-hundreds femtoseconds nuclear state lifetimes with low-energy binary heavy-ion reactions M. Ciemała Eur. Phys. J. A (2021) 57:156 (AGATA-VAMOS-PARIS)
- Lifetime measurements in the even-even $^{102–108}$Cd isotopes M. Siciliano *et al.* Phys. Rev. C 104, 034320 – (2021) (AGATA-VAMOS)
- Evidence for enhanced neutron-proton correlations from the level structure of the N=Z+1 nucleus ^{87}Tc X. Liu *et al.* Phys. Rev. C 104, L021302 – (2021) (AGATA-NEDA-DIAMANT)

GANIL Campaign efficiencies



LNL Day 1 objective

Like a β-decay, new detectors compensated the detectors under maintenance

Rapid increase after the maintenance done post-GSI during the first 3 years

Saturated after ~5 years for simple failures like core FET broken or more rarely problems with cryostat due to the long operating time (some 7 years in a row)

A similar fast increase should be observed in the first years at LNL

GANIL Campaign achievements

- No failure of the cryogenic part
- Complete change of technology in the data storage to CEPH (/agatadisks/)
- Data acquisition system major upgrade Narval → DCOD – Ready for phase 2
- Continues integration of femul and agapro
- New tools to make the data more « accessible » (AGASpy, femul::TreeBuilder, documentation)
- Phase 0 stabilization (ATCA fuses, no more LINCO1, cooling plates)
- Phase 1 (GGP) put on-line successfully
- Improved PCIe readout libraries (Crystal Producer) for both GGP and LINCO2
- Great progresses in the global understanding of the response function of the array (efficiencies, performances, data rate, angular correlation)
- New trigger processor
- Coupled to NEDA – DIAMANT (GTS based), VAMOS (VME→GTS/numexo), MUGAST, PARIS, DSSD …
- Successful integration of NUMEXO2 and its TP in AGATA via the GTS and the DCOD/TM/RCC systems
- GRID transfer is a routine
- Topology Manager
- Documentation (yes !)
- Data analysis schools

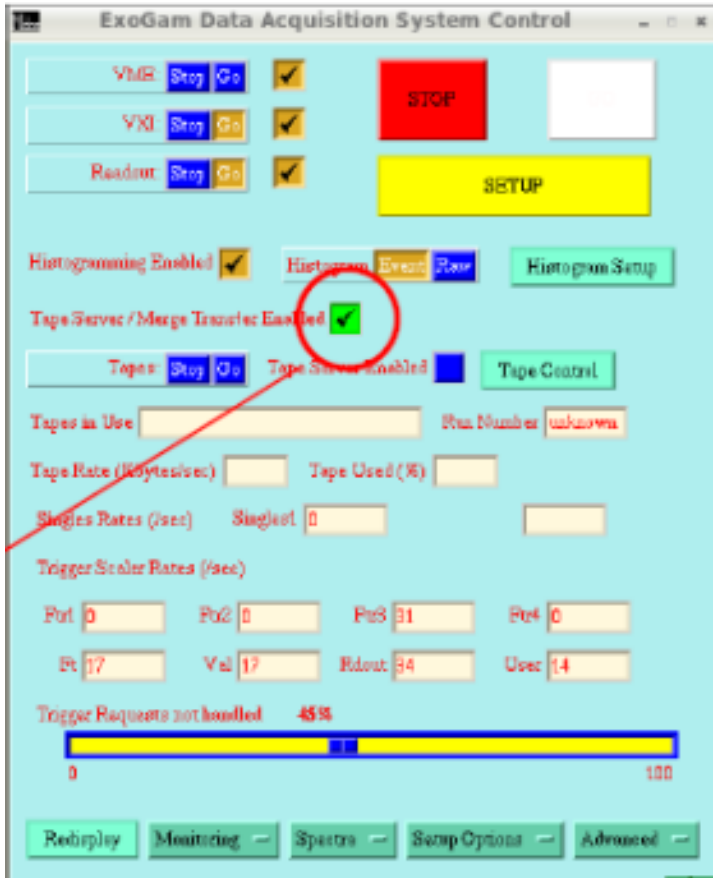
Some regrets

- We never reached the efficiency we promised for the 1st PAC meeting
- We did not improve at all the PSA algorithms in the on-line processing
- AGATA remain “complex” to start and of expert duties (can we dream to a “SETUP”, “STOP”, “START” Midas exogam like panel ?)
- And for problems at expert level, cooking recipies are not very useful

- SPIRAL1 did not delivered all expected beams.
- Stable beams accelerator are what they are. Should we run longer experiment to make indeed a breakthrough ?
- The Gas-filled mode of VAMOS was never developed
- Angular distribution/correlation and polarization measurements

- There was clearly an opportunity to make a very long fission run (spectroscopy and plunger)
- ^{48}Ca-based experiment never done due to the target production

- The amount of data is huge ! … and probably under-evaluated.



By-products

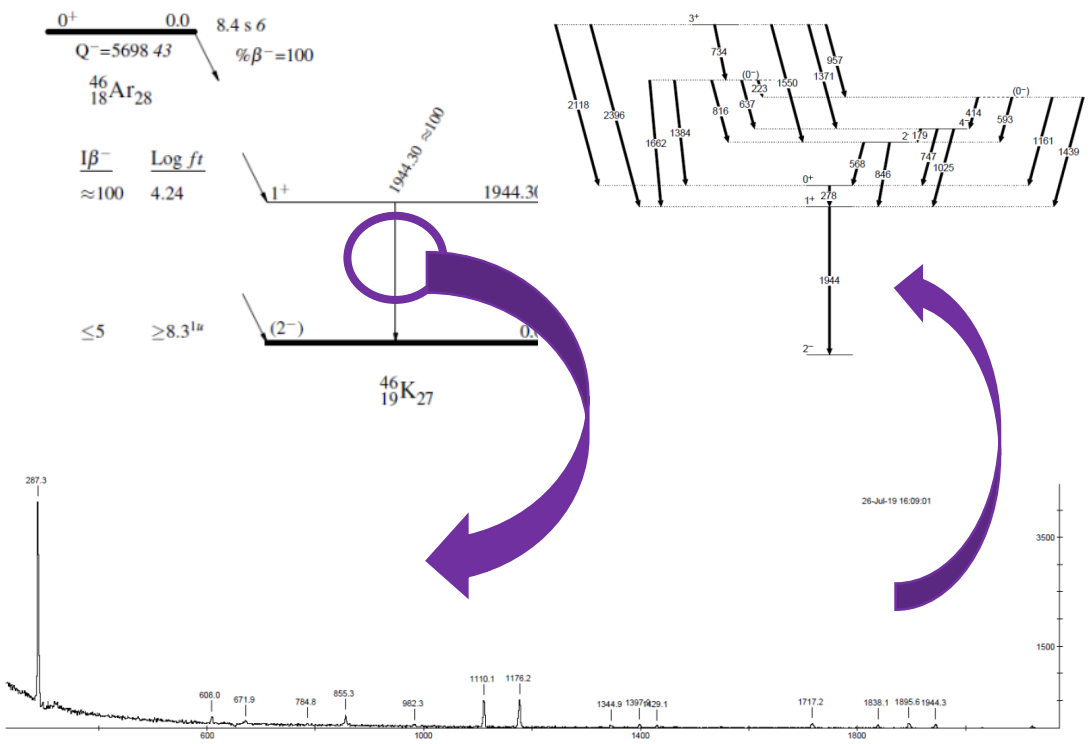
β-decay of ^{46}Ar

E. Clément[1] and for the AGATA collaboration
[1]GANIL, CEA/DRF-CNRS/IN2P3, Bd. Henri Becquerel, BP 55027, F-14076 Caen, France
(Dated: November 8, 2021)

^{46}Ar β^- decay 1980Hu01,1978Pe04

Decay Scheme

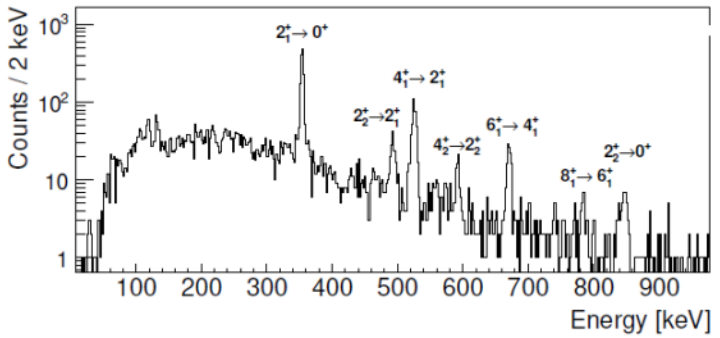
Intensities: I_γ per 100 parent decays

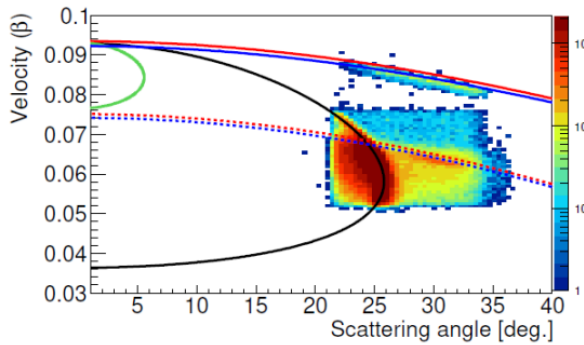


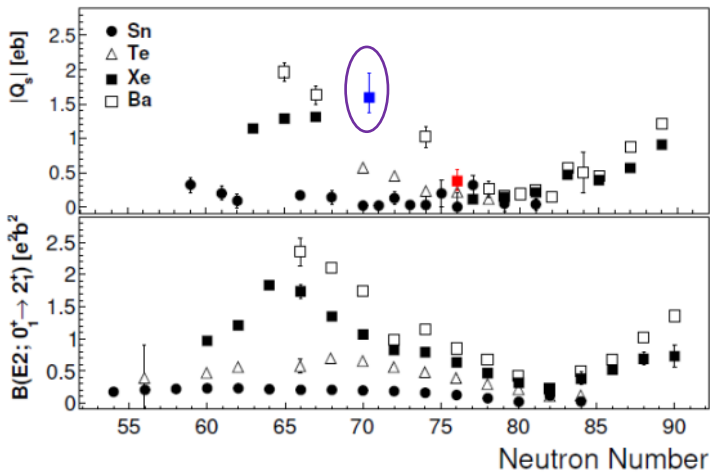
All SPIRAL1 experiments have been run trigger-less
[To] of β-decay of the beam have been recorded
Exemple from the e786s, ^{46}Ar beam
Applying γγγ on the decay of the beam reveal a lot new states in ^{46}K

Spectroscopic quadrupole moments in ^{124}Xe

E. Clément,[1] P. Van Isacker,[1] M. Rejmund,[1] C. Schmitt,[2] A. Lemasson,[1] B. Jacquot,[1]
D. Ralet,[3,1] G. de France,[1] M. Zielińska,[4] and for the AGATA collaboration
[1]GANIL, CEA/DRF-CNRS/IN2P3, Bd. Henri Becquerel, BP 55027, F-14076 Caen, France
[2]IPHC/CNRS-University of Strasbourg, F-67037 Strasbourg, France
[3]IJCLAB, Université Paris-Saclay, CNRS/IN2P3, IJCLab, 91405 Orsay, France
[4]IRFU, CEA/DRF, Centre CEA de Saclay, F-91191 Gif-sur-Yvette Cedex, France







In e667, the Fe target was fund to be contaminated by W^{nat}

Safe Coulex of ^{124}Xe on heavy target (for the first time)

GOSIA analysis

Qs for the first 2$^+$ extracted

By-products

On the AGATA performances at low γ-ray energies

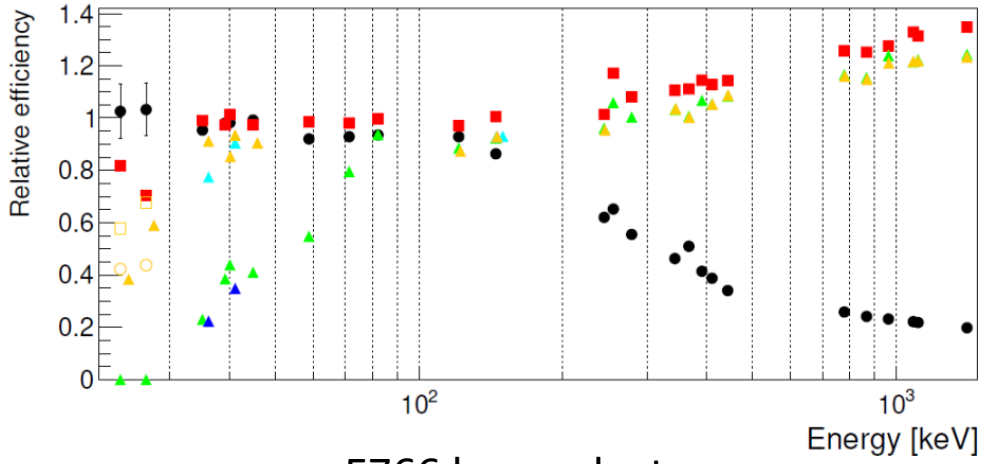
E. Clément [a] R. M. Pérez-Vidal [b] J. Dudouet [c] J. Ljungvall [d]
A. Lopez-Martens [d] A. Korichi [d] J. Piot [a]

[a] *Grand Accélérateur National d'Ions Lourds (GANIL), CEA/DRF-CNRS/IN2P3, F-14076 Caen Cedex 05, France*

[b] *INFN Laboratori Nazionali di Legnaro, IT-35020 Legnaro, Italy*

[c] *Université Lyon, CNRS/IN2P3, IPN-Lyon, F-69622, Villeurbanne, France*

[d] *Laboratoire de Physique des 2 infinis Irène Joliot-Curie, CNRS / Université Paris-Saclay / Université de Paris 91405 Orsay cedex, France*



E766 by-product

Pseudospin Symmetry and Microscopic Origin of Shape Coexistence in the ^{78}Ni Region: A Hint from Lifetime Measurements

C. Delafosse *et al.*
Phys. Rev. Lett. **121**, 192502 – Published 9 November 2018

E669 : Lifetime Measurements Using RDDS Method in the Vicinity of ^{78}Ni
→ ^{84}Ge, ^{86}Se and ^{88}Kr 2^+ lifetime but more in the data

Acta Phys. Pol. B 50, 633 (2019)
https://tel.archives-ouvertes.fr/tel-01848718

^{A}X	$J^{\pi i} \to J^{\pi f}$	$B(E2\downarrow)$ [e^2 fm^4] This work	Exp. literature	SM:Ni78-II	HFB-5DCH
^{88}Kr	$2^+ \to 0^+$	274^{+244}_{-85}	262(38) [11]	371	389
^{86}Se	$2^+ \to 0^+$	456^{+124}_{-48}	438^{+259}_{-171} [12]/422(64) [11]	436	447
^{86}Se	$4_1^+ \to 2^+$	306^{+61}_{-42}	$\geq$ 140 [12]	329	—

E_γ [keV]	Ce travail τ [ps]	B(E2)$\downarrow$ [e^2fm^4]	B(M1)$\downarrow$ [μ_N^2]
1359	74^{+73}_{-67}	2^{+25}_{-1}	-
1238	$< 5.0(6)$	$> 56(8)$	$> 0.006(1)$
1248	$< 5.0(6)$	$> 54(7)$	$> 0.006(1)$
631	$< 5.0(6)$	$> 1625(222)$	$> 0.051(6)$

TABLE 8.6 – Résumé des des valeurs de durée de vie pour états excités de ^{83}Ge

$J_i^\pi \to J_f^\pi$	E_γ [keV]	Ce travail τ [ps]	B(E2)$\downarrow$ [e^2fm^4]	B(M1)$\downarrow$ [μ_N^2]	Littérature τ [ps]	B(E2)$\downarrow$ [e^2fm^4]
$2^+ \to 0^+$	704.0(1)	$10.3^{+1.2}_{-2.2}$	456^{+124}_{-48}	-	$10.8^{+6.9}_{-3.7-0.3}$ [65]	422(64) [111]
$4_1^+ \to 2^+$	864.1(3)	$5.5^{+0.9}_{-0.9}$	306^{+61}_{-42}	-	$<9.9^{+3.3}_{-2.2}$ [65]	-
$(4_2^+) \to 4_1^+$	504.2(5)	$3.2^{+0.6}_{-0.8}$	-	$0.13^{+0.05}_{-0.01}$	-	-
$(6^+) \to 4_1^+$	1279.3(9)	$\leq 3.9^{+1.2}_{-0.9}$	$\geq 88^{+44}_{-17}$	-	-	-
$(5^+) \to (4_2^+)$	990.7(9)	≤ 1.6	-	≥ 0.03	-	-

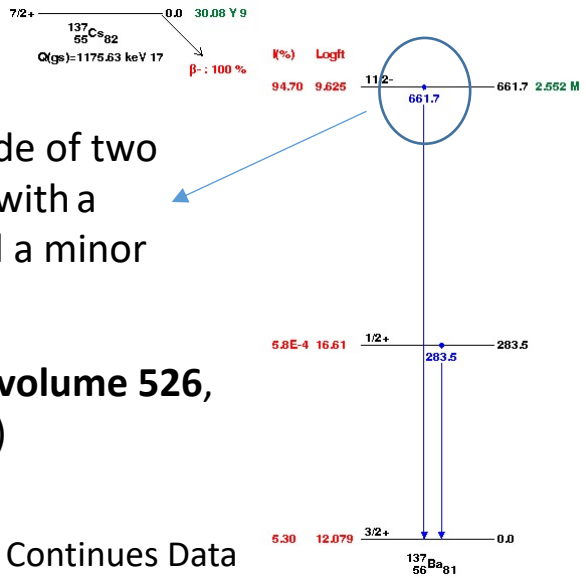
TABLE 8.2 – Résumé des valeurs de durée de vie obtenues pour les états excités de ^{86}Se

$J_i^\pi \to J_f^\pi$	E_γ [keV]	Ce travail τ [ps]	B(E2)$\downarrow$ [e^2fm^4]	B(M1)$\downarrow$ [μ_N^2]	Littératur τ [ps]
$\left(\frac{7}{2}^+\right) \to \left(\frac{5}{2}^+\right)$	1116(1)	$1.2^{+0.4}_{-0.3}$	391^{+130}_{-98}	$0.03^{+0.02}_{-0.01}$	<3(2) [42
$\left(\frac{9}{2}^+\right) \to \left(\frac{5}{2}^+\right)$	1437.8(5)	$0.7^{+1.3}_{-0.3}$	189^{+141}_{-122}	-	<3(2) [42
$\left(\frac{11}{2}^+\right) \to \left(\frac{9}{2}^+\right)$	540.0(6)	$2.8^{+0.8}_{-0.9}$	-	$0.12^{+0.06}_{-0.03}$	-

TABLE 8.4 – Résumé des valeurs de durée de vie obtenues pour des états excités de ^{85}Se

By-products

Double Gamma decay



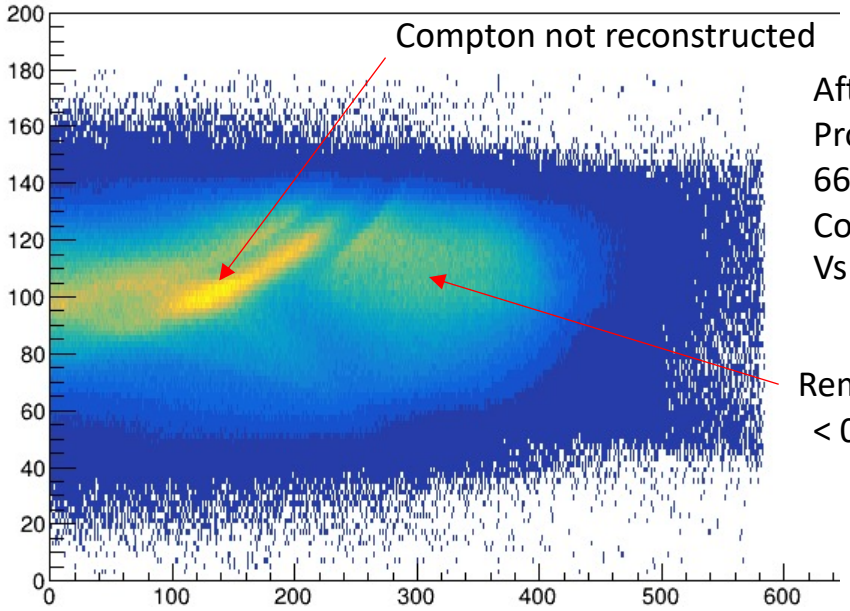
Can decay as a cascade of two gamma ($P \infty 2\ 10^{-6}$) with a dominant M2-E2 and a minor E3-M1 contribution

C. Walz et al., *Nature* **volume 526**, pages 406–409 (2015)

The main point is to discriminate the real double gamma event candidates on top of the "background" of the Compton scattering.

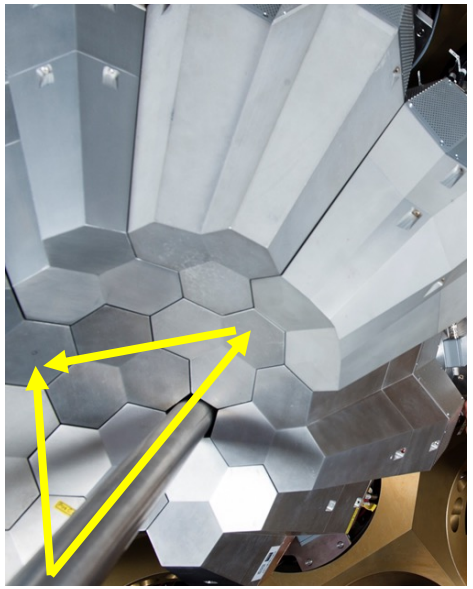
"Tracking" should be able to reconstruct the Compton scattering and leave only candidate for the double events … Proof of principle ?

30-31 May 2018 : 49h of Continues Data



After Tracking – OFT Std
Prompt Track1+Track2 =
661 ± 1.5 keV, nbTrack=2
Compton Angle (Track1,Track2)
Vs Diff (ETrack1, ETrack2)

Remain to be understood in details
< 0.007% of events



^{137}Cs

Open science, open data
Data Management Plan
for AGATA Phase 2

O.Stézowski
On behalf of the Data Processing Group
Work from dedicated DMP meetings March 2021 ☞ June 2021

Catalogue

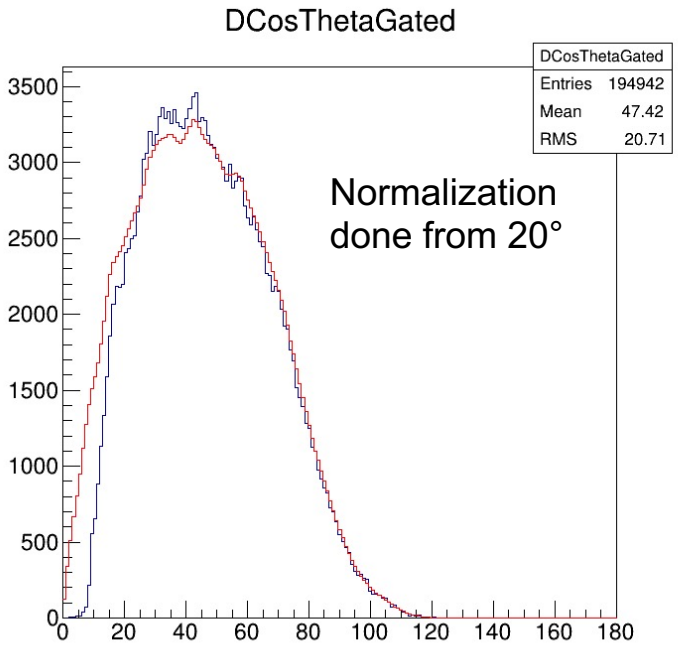
ANGULAR Correlation with 35 caps in Nominal – 2017 data

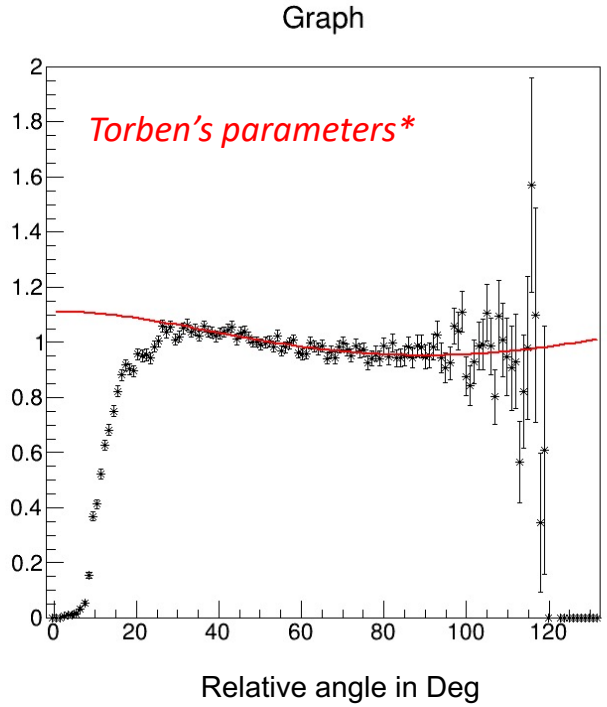
- part of the e673 report

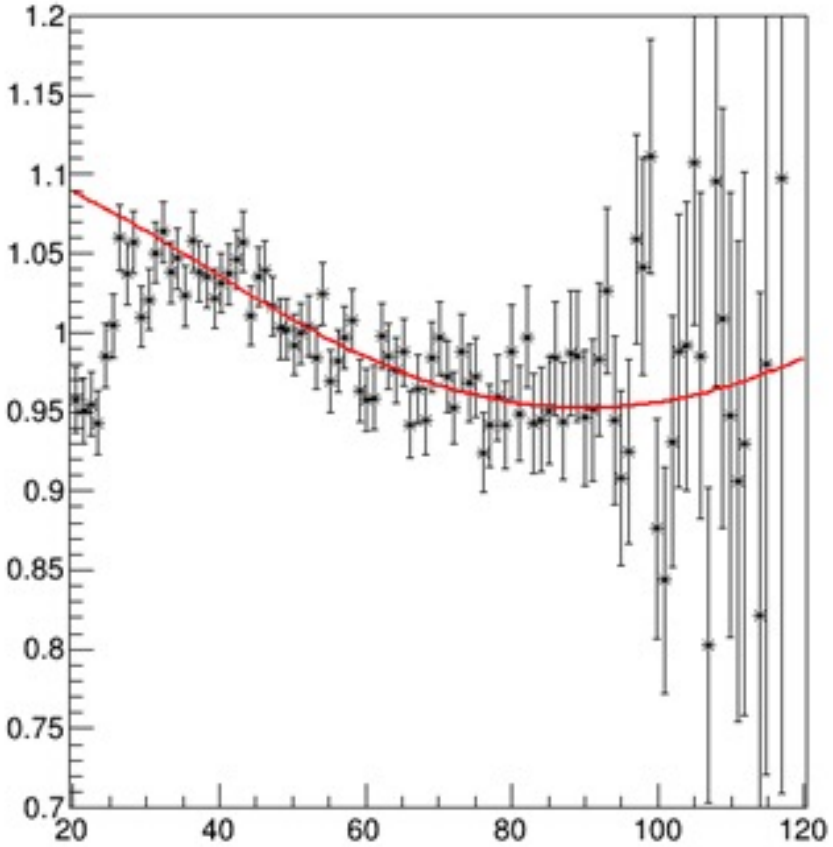
P.I : Ph. John

E673 - ^{60}Co centered at the target position. Nominal position
run 1105

Normalization done by grouping 100 tracked events and search for 1.1 – 1.3 coincidences with these 100 inter-events.
This ensures real random coincidence







What about real in-beam data ?

* T. Lauritsen et al NIM A 836, 46-56 (2016)

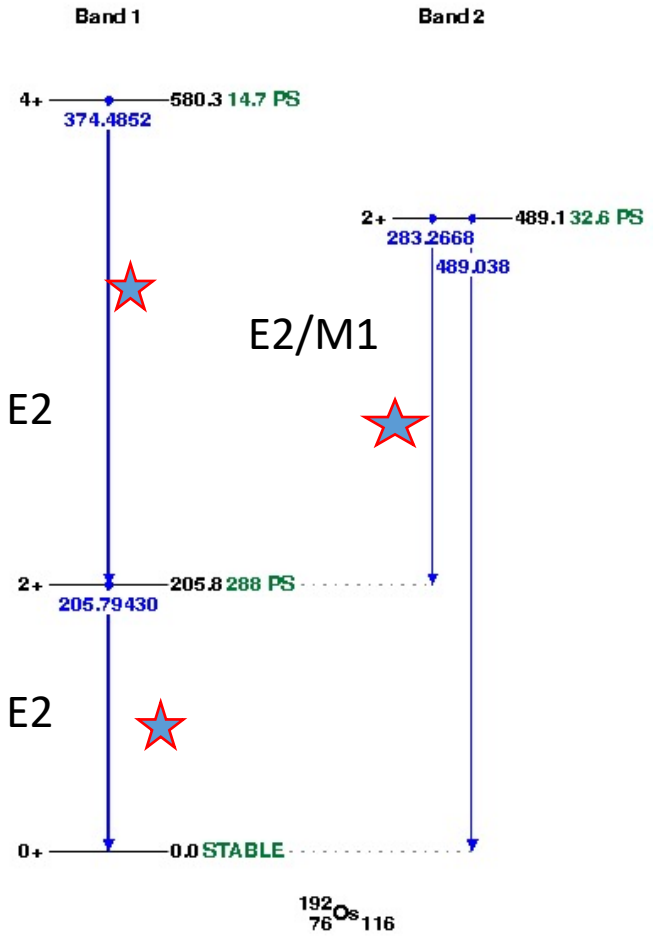
E.C for the AGATA collaboration
With the help of Amel and Torben

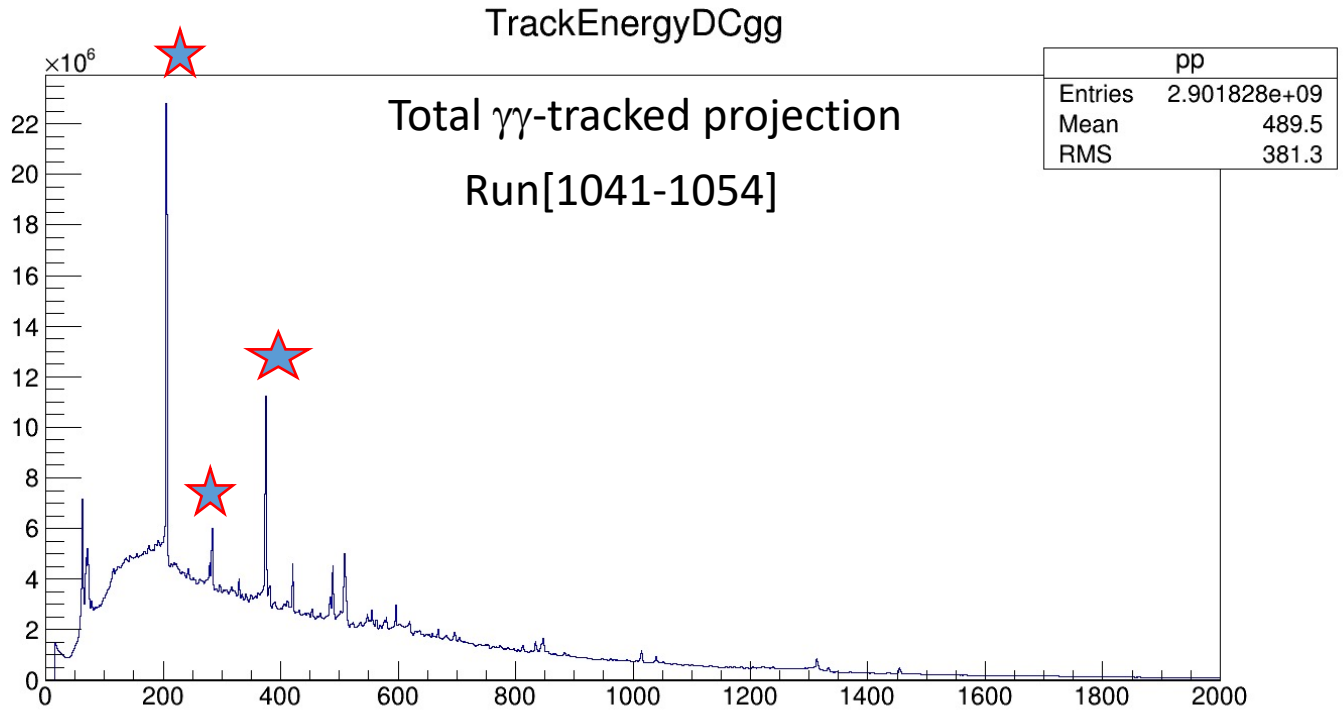
e673 : ^{136}Xe@ 897 MeV +^{192}Os – Tick Target. 2017

Trigger was AGATA-AGATA-FATIMA

All data are OFT tracked with standard Parameters

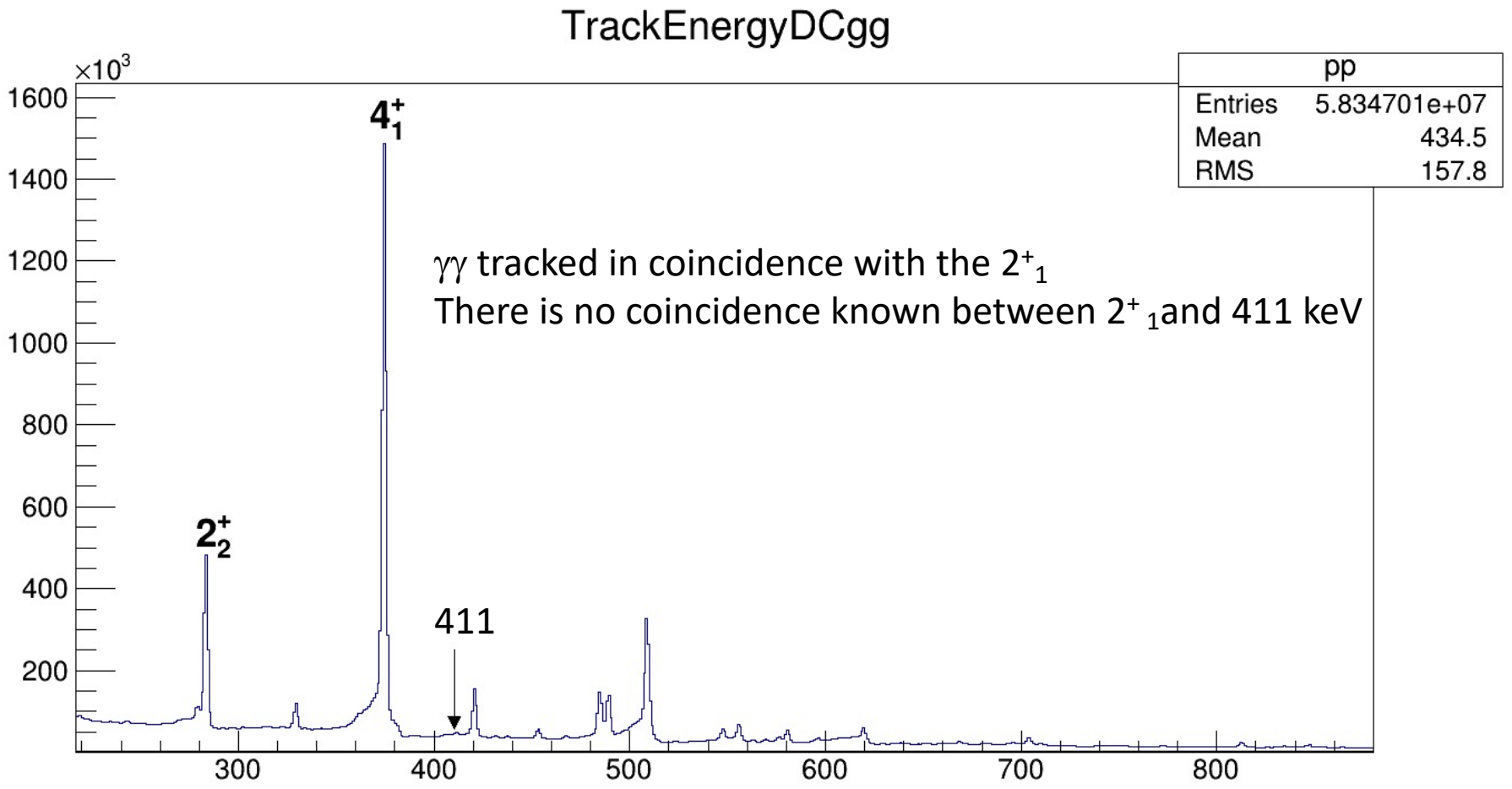
Nominal AGATA configuration





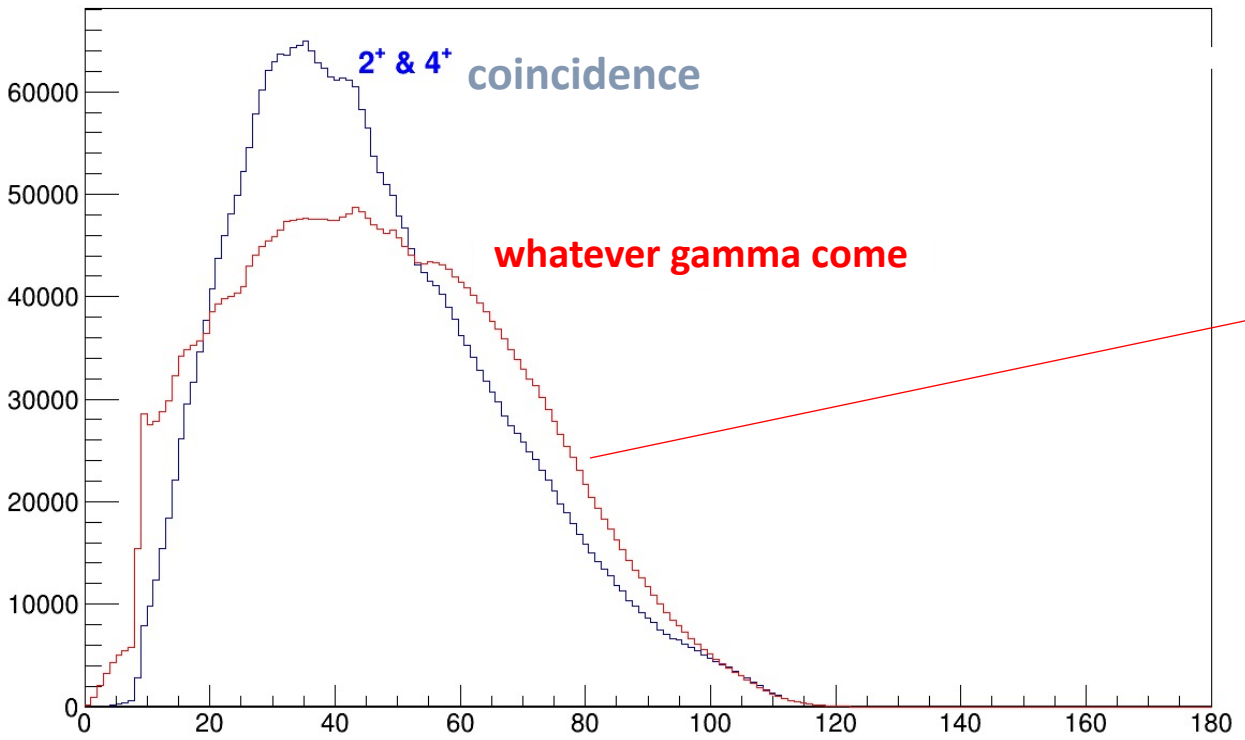
E.C for the AGATA collaboration
With the help of Amel and Torben

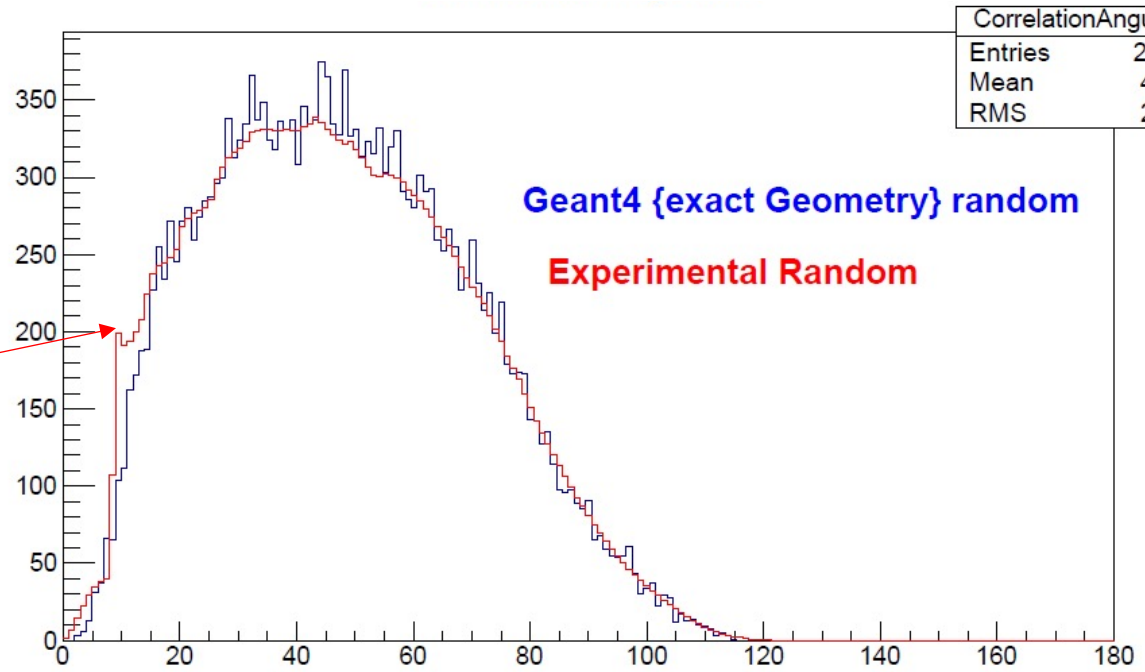
Angular correlation between the 2^+_1 decay and the 4^+_1, 2^+_2 and random(411 keV) ?



E.C for the AGATA collaboration
With the help of Amel and Torben

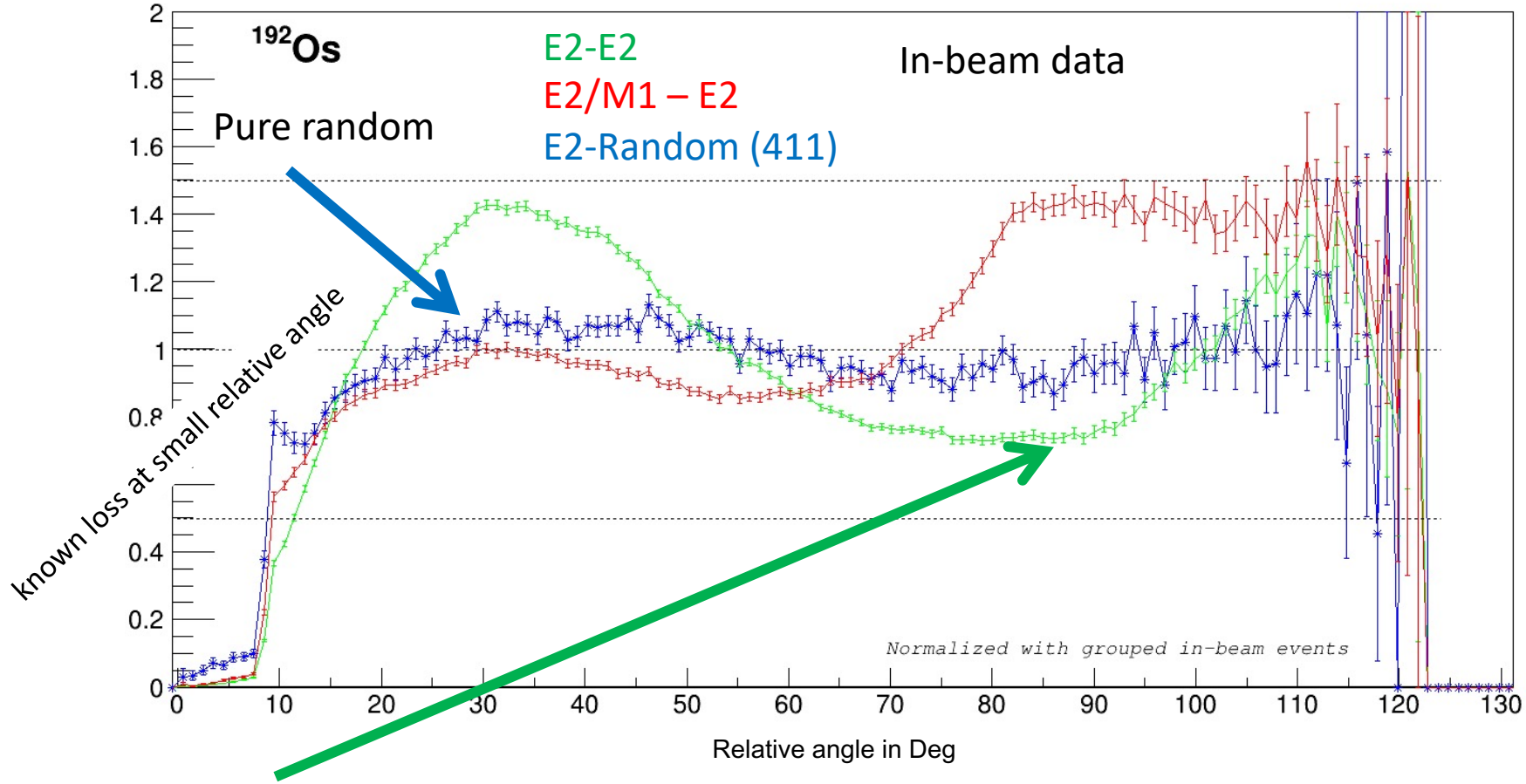
In-beam reconstructed random distribution (100 grouped events) vs Geant4 random distribution





E.C for the AGATA collaboration
With the help of Amel and Torben

Trend looks OK with a maximum around 90° and compatible with a strong M1 contribution



Trend looks OK with maximums toward 0° and 180° and a minimum close to 90°.
Not symmetric near the minimum and not EXACTLY at 90° (target to detector distance to be adjusted (?))

Angular correlation works.

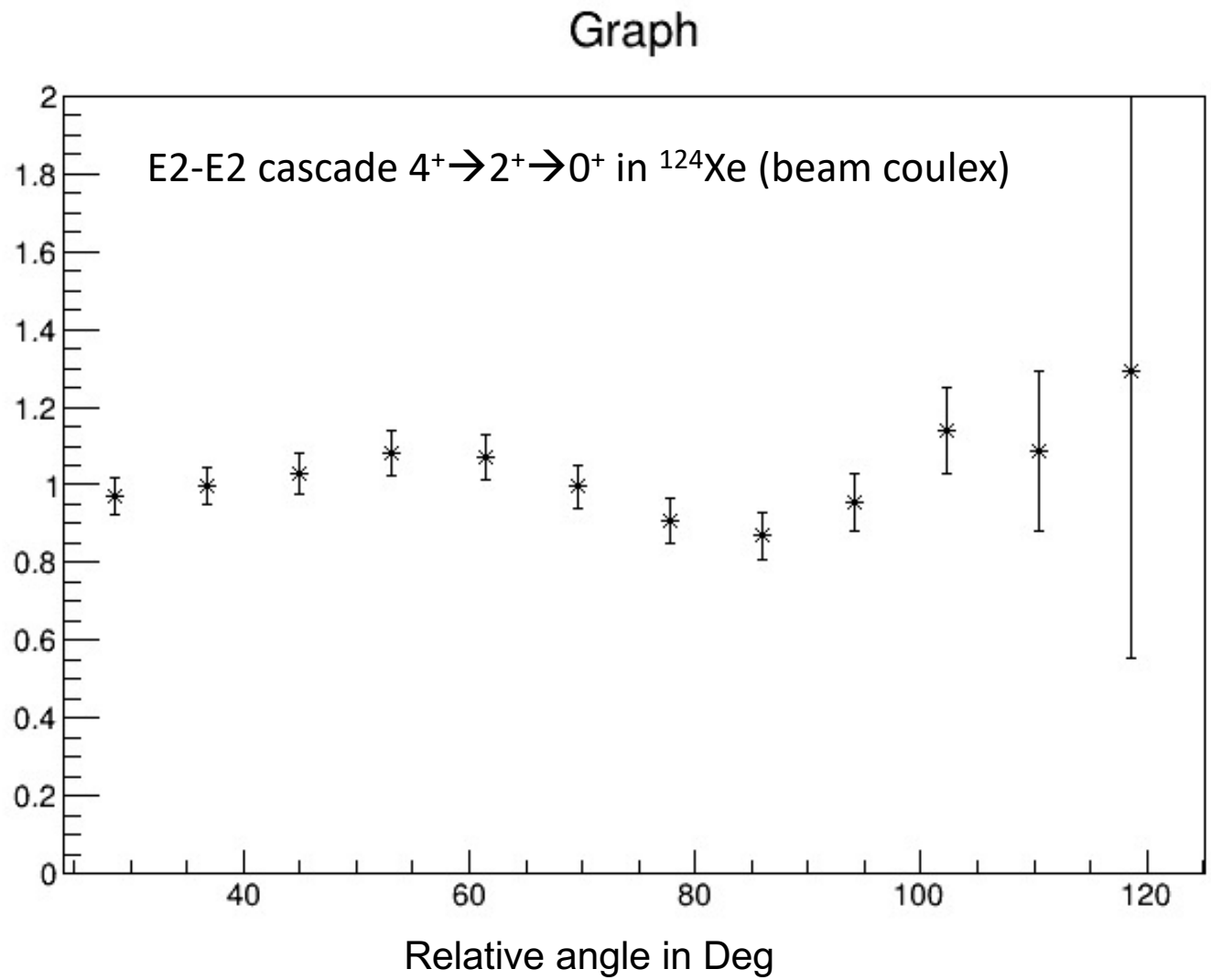
E.C for the AGATA collaboration
With the help of Amel and Torben

$^{124}Xe+^{54}Fe$ – Thin Target. e667 (2017)

Trigger is VAMOS

All data are OFT tracked with standard Parameters

Nominal AGATA configuration



E.C for the AGATA collaboration

With the help of Amel and Torben

Conclusion

- ✓ The AGATA campaign has been a real success
- ✓ Very challenging coordination efforts between experiments and setups
- ✓ Sub-campaign organization controlled the entropy (should we go even beyond ?)
- ✓ AGATA changed (part of) GANIL
- ✓ There are a lot of data ! → DMP !!!
- ✓ Many results have been published and more to come
- ✓ Some data are certainly under analyzed and could be listed → DMP !!!
- ✓ Thanks to all AGATA contributors
- ✓ Wishing the best to LNL !

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