Istituto Nazionale di Fisica Nucleare
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AGATA week workshop 2023

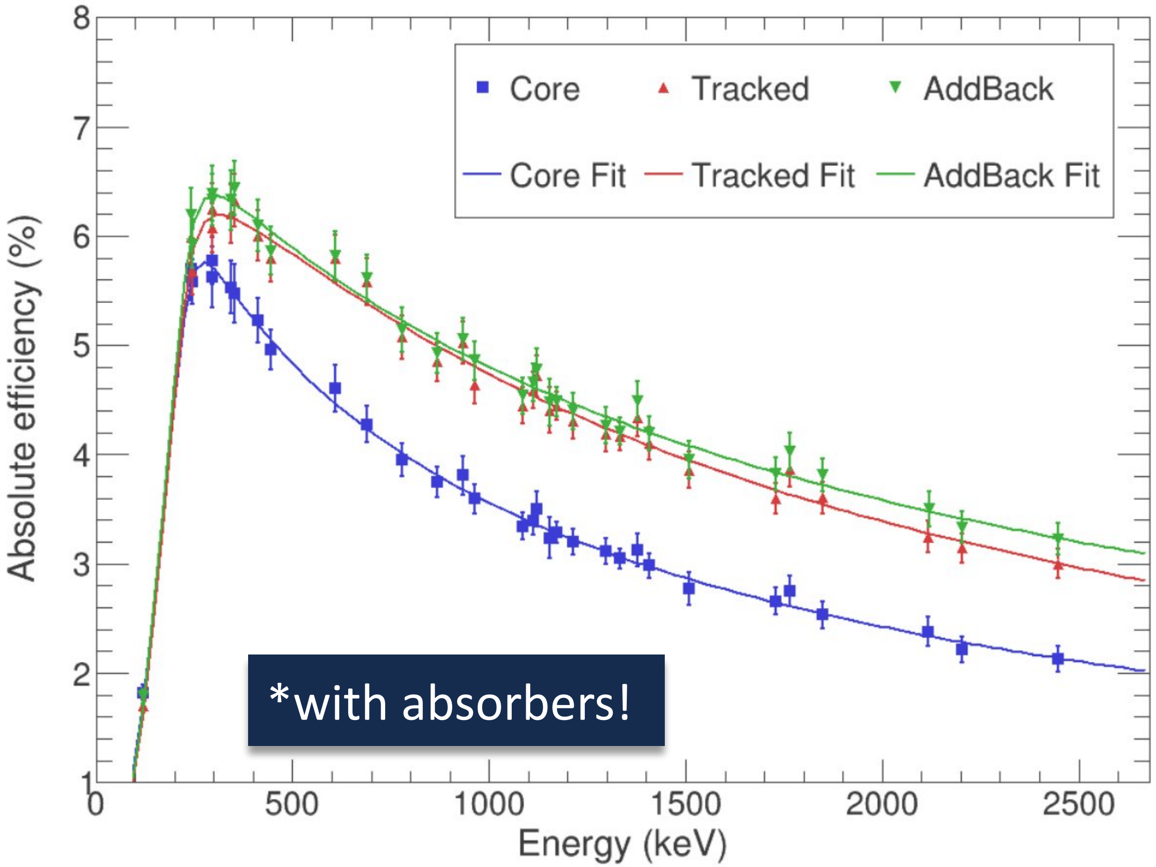
Performance of AGATA at higher energies

M. Balogh, S. Bottoni, R.M. Peréz-Vidal, S. Pigliapoco, Md.S.R. Laskar

Performance of AGATA

- absolute efficiency
- resolution
- peak-to-total ratio
- angular correlations

Analysis mode: **core, tracked, addback**



*with absorbers!

@ 1.3 MeV

Analysis mode	Efficiency	P/T
Core	3.05(9) %	16.8(6) %
Tracked	4.16(12) %	32.9(9) %
Addback	4.21(13) %	28.6(8) %

R.M. Pérez-Vidal et al., INFN-LNL Annual reports, vol. **56**, 2022.

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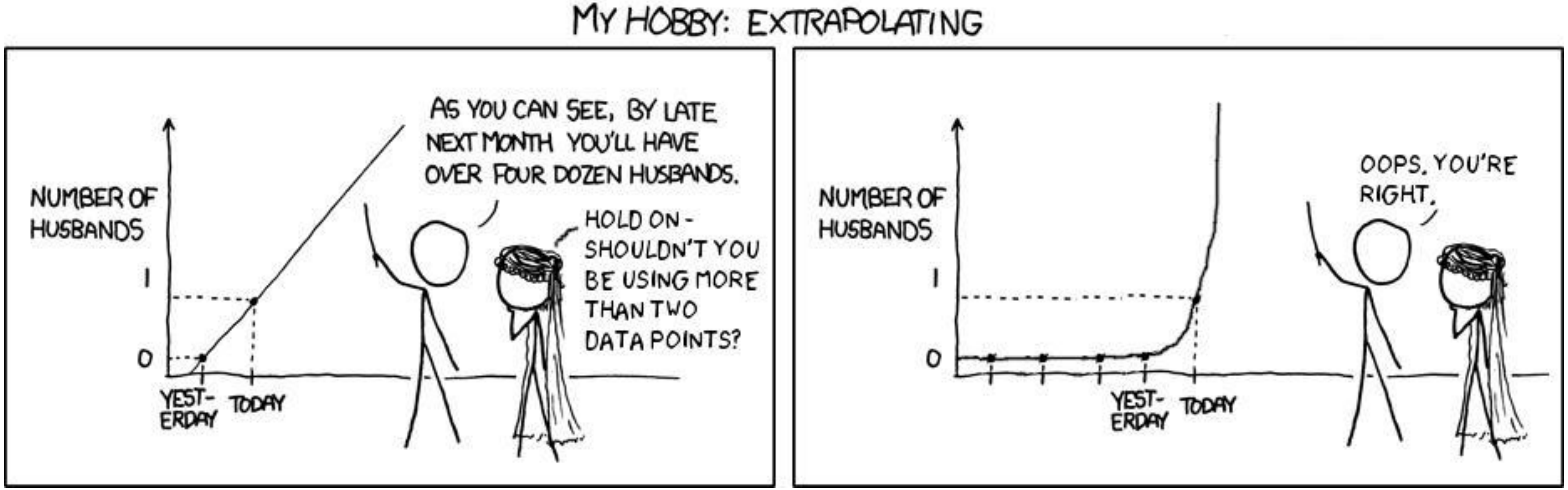
Performance of AGATA

- Analyses of γ-ray spectroscopic data



Performance of AGATA at higher energies

Scientific motivation

The experiment

1^{st} PHASE ^{56}Co

2^{nd} PHASE $^{66}Zn(p,n)$

Summary

Performance of AGATA

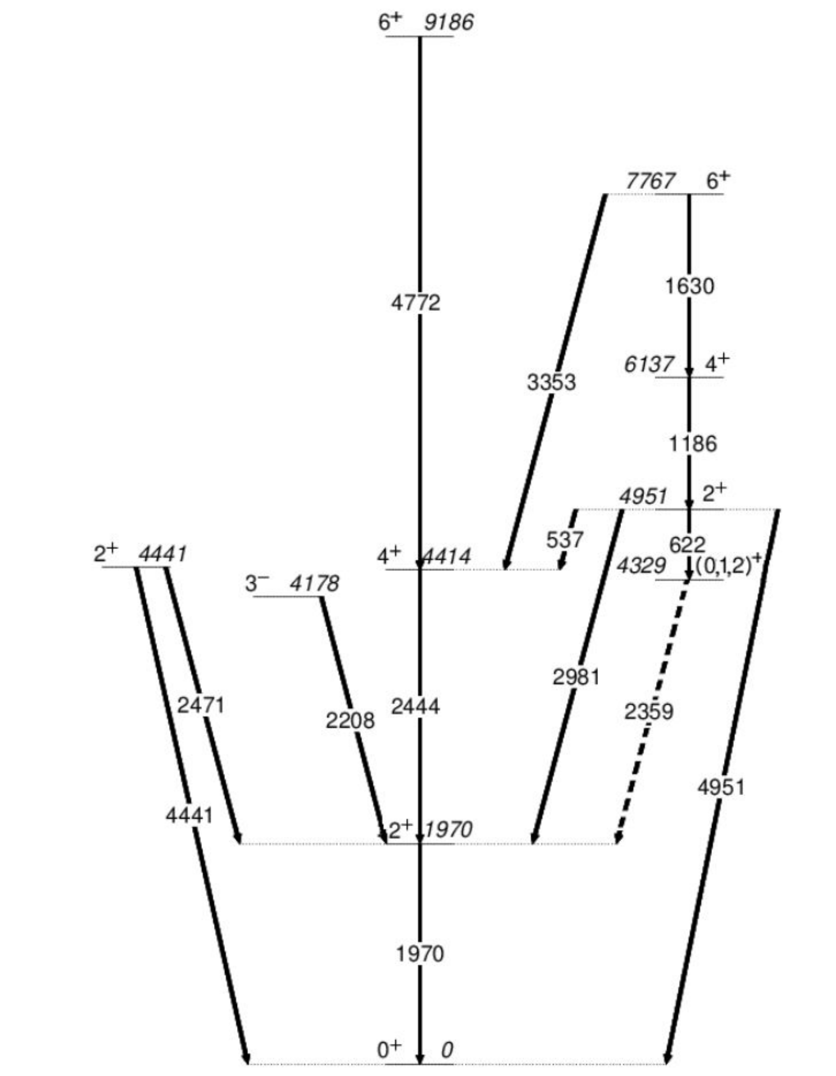
- Analyses of γ-ray spectroscopic data
- Preparation of experimental proposals

Coulomb excitation of the super-deformed structure in ^{36}Ar

AGATA + SPIDER + DANTE

Spokespersons: K. Hadyńska-Klęk, M. Matejska-Minda

Transition	E_γ [keV]	Counts / 7 days (AGATA + SPIDER) $124\text{-}161^\circ_{LAB}$	Counts/ 7 days (AGATA + DANTE) $15\text{-}75^\circ_{LAB}$
$2_1^+ \rightarrow 0_1^+$	1970	$8{\cdot}10^6$	$2{\cdot}10^7$
$4_1^+ \rightarrow 2_1^+$	2444	$3{\cdot}10^3$	$2{\cdot}10^3$
$0_2^+ \rightarrow 2_1^+$	2359	$1{\cdot}10^3$	100
$2_2^+ \rightarrow 2_1^+$	2981	150	120
$2_2^+ \rightarrow 0_1^+$	4951	50	50
$2_3^+ \rightarrow 0_1^+$	4441	110	100
$2_3^+ \rightarrow 2_1^+$	2471	70	90
$3_1^- \rightarrow 2_1^+$	2208	$3{\cdot}10^3$	$3{\cdot}10^3$



AGATA week workshop
October 2023

Performance of AGATA at higher energies

Scientific motivation

The experiment

1^{st} PHASE ^{56}Co

2^{nd} PHASE $^{66}Zn(p,n)$

Summary

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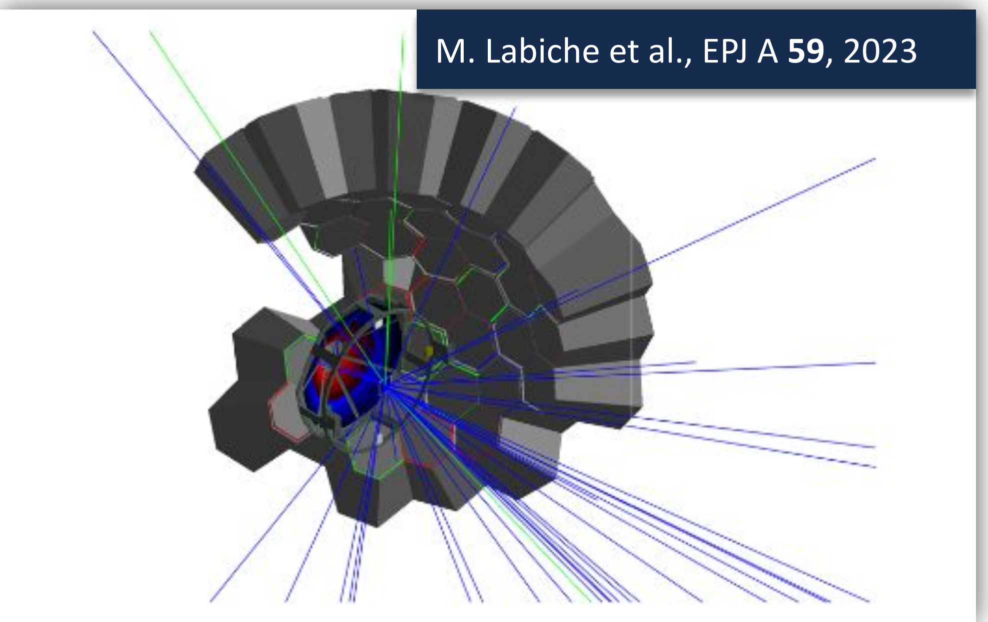
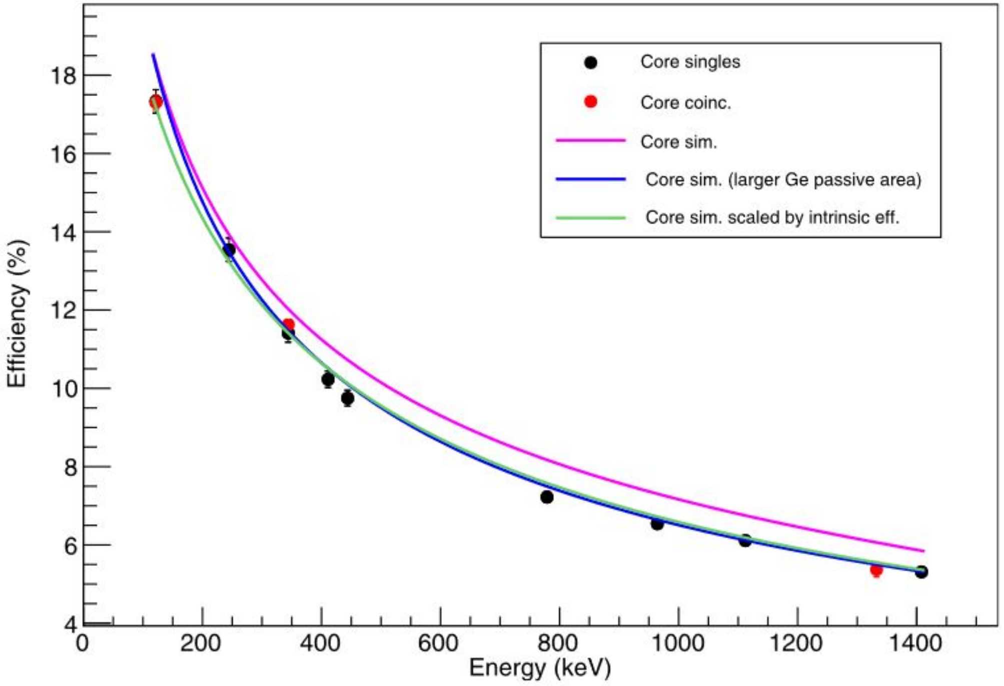
Performance of AGATA

- Analyses of γ-ray spectroscopic data
- Preparation of experimental proposals
- Comparison with GEANT4 simulations



M. Labiche et al., EPJ A **59**, 2023



J. Ljungvall et al., NIM A **955**, 2020

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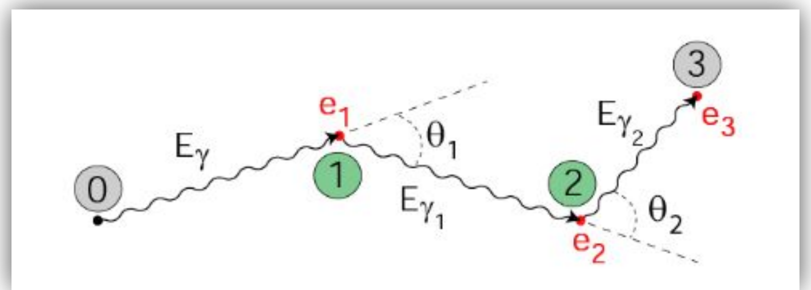
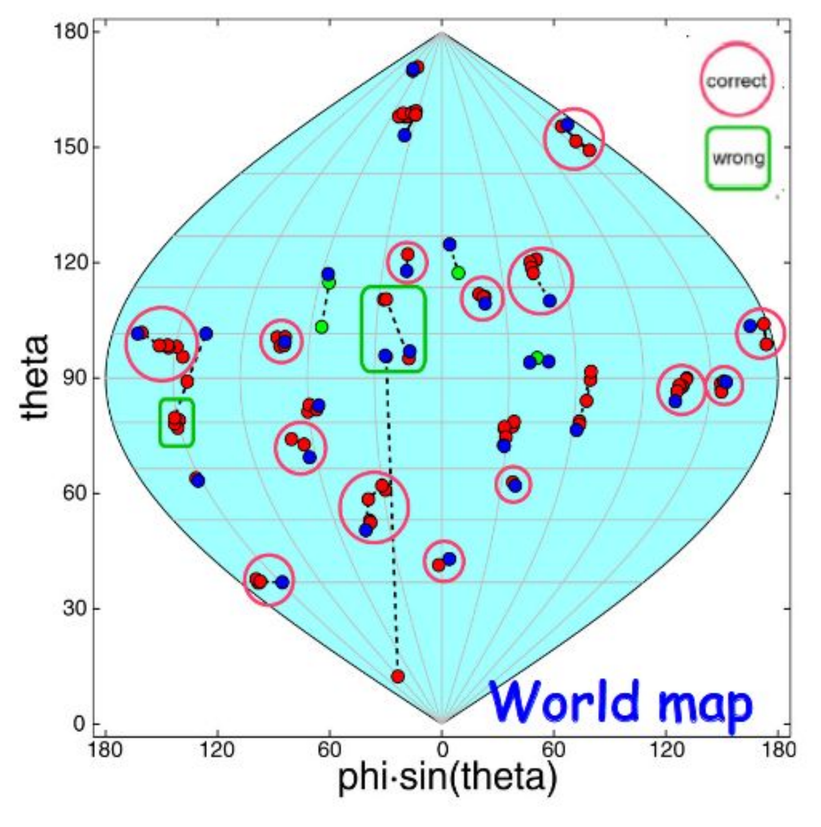
Performance of AGATA

- Analyses of γ-ray spectroscopic data
- Preparation of experimental proposals
- Comparison with GEANT4 simulations
- Optimization of the tracking parameters for E>3 MeV





Previous performance reviews

LNL 2013

F.C.L. Crespi, NIM A **705**, 2013

- 6 crystals
- resolution, hit multiplicity, tracking
- Am-Be-Fe source + in-beam

GSI 2016

N. Lalović, NIM A **806**, 2016

- 21 crystals
- efficiency, P/T, tracking
- calibration sources, up to 3.4 MeV (^{152}Eu, ^{60}Co, ^{56}Co)

GANIL 2020

J. Ljungvall et al., NIM A **955**, 2020

- 30 crystals
- efficiency, tracking, P/T, angular correlations
- calibration sources (^{152}Eu, ^{60}Co) and in-beam (^{92}Mo)

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Efficiencies up to 3.4 MeV

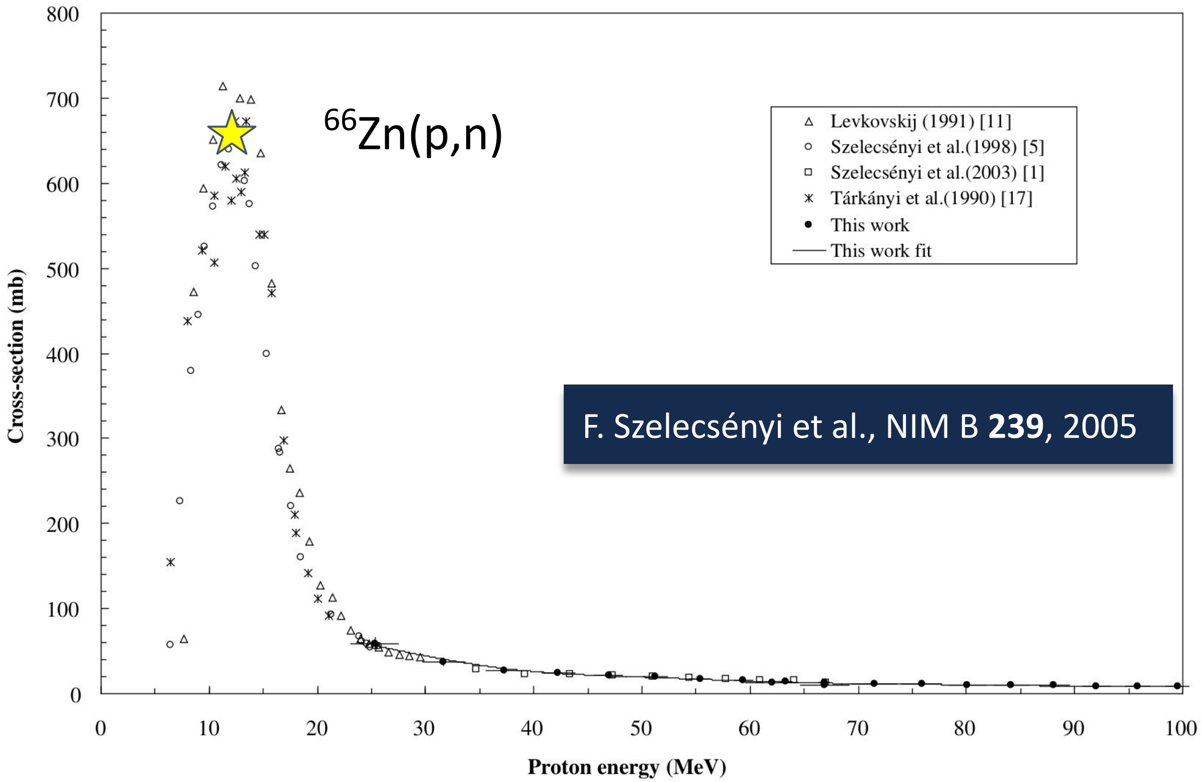
- measured with a ^{56}Co γ-ray source
- 2-3 days measurement (^{56}Co, ^{60}Co, ^{152}Eu, ^{241}Am, ^{226}Ra)

TABLE I: ^{56}Co γ rays with intensity >0.95 %. Data taken from NNDC database.

Energy [keV]	Intensity [%]	Rel. uncertainty [%]
846.77	100.00	0.02
977.37	1.42	0.42
1037.84	14.06	0.28
1175.10	2.25	0.27
1238.29	66.50	0.18
1360.21	4.29	0.28
1771.36	15.42	0.39
2015.22	3.02	0.40
2034.79	7.77	0.39
2598.50	16.98	0.24
3009.65	1.04	1.25
3202.03	3.21	0.37
3253.50	7.93	0.27
3273.08	1.88	0.11
3451.23	0.95	0.53

Efficiencies up to 4.8 MeV

- above 4 MeV estimated via the $^{66}Zn(p,n)$ reaction
- ^{66}Zn enriched target to limit the neutron flux on AGATA
- E_p=13 MeV ⟶ **σ≈680 mb**
- thickness ~ **2.5 mg/cm²**
- **Al backing** for preventing recoils to exit the target



F. Szelecsényi et al., NIM B **239**, 2005

Efficiencies up to 4.8 MeV

- above 4 MeV estimated via the ^{66}Zn(p,n) reaction
- ^{66}Zn enriched target to limit the neutron flux on AGATA
- E_p=13 MeV ⟶ **σ≈680 mb**
- thickness ~ **1.5 mg/cm^2**
- **Al backing** for preventing recoils to exit the target

TABLE II: γ rays with intensity >0.8 % produced in ^{66}Zn(p,n) reaction and expected number of fully-absorbed tracked γ ray events per crystal for the duration of the measurement. Data taken from NNDC database.

Energy [keV]	Intensity [%]	Rel. uncertainty [%]	Number of tracked γ rays [1/crystal/day]
833.53	5.90	5.08	305 000
1039.22	37.00	5.41	1 860 000
1333.11	1.17	5.13	56 500
1918.33	1.99	5.53	89 800
2189.62	5.30	5.66	233 000
2422.53	1.88	5.32	80 800
2751.84	22.70	5.29	950 000
3228.80	1.61	5.30	61 000
3380.85	1.47	5.44	58 700
3422.04	0.86	5.81	34 300
3791.00	1.09	5.50	42 400
4085.85	1.27	5.51	48 500
4295.19	3.81	5.51	144 000
4461.20	0.84	5.95	31 435
4806.01	1.86	5.38	68 000

Estimated rate ~**2kHz/crystal** assuming
- flat P/T = 30%
- 2.67 average hits per track
- 1% extrapolated efficiency
- 24 hours of measurement

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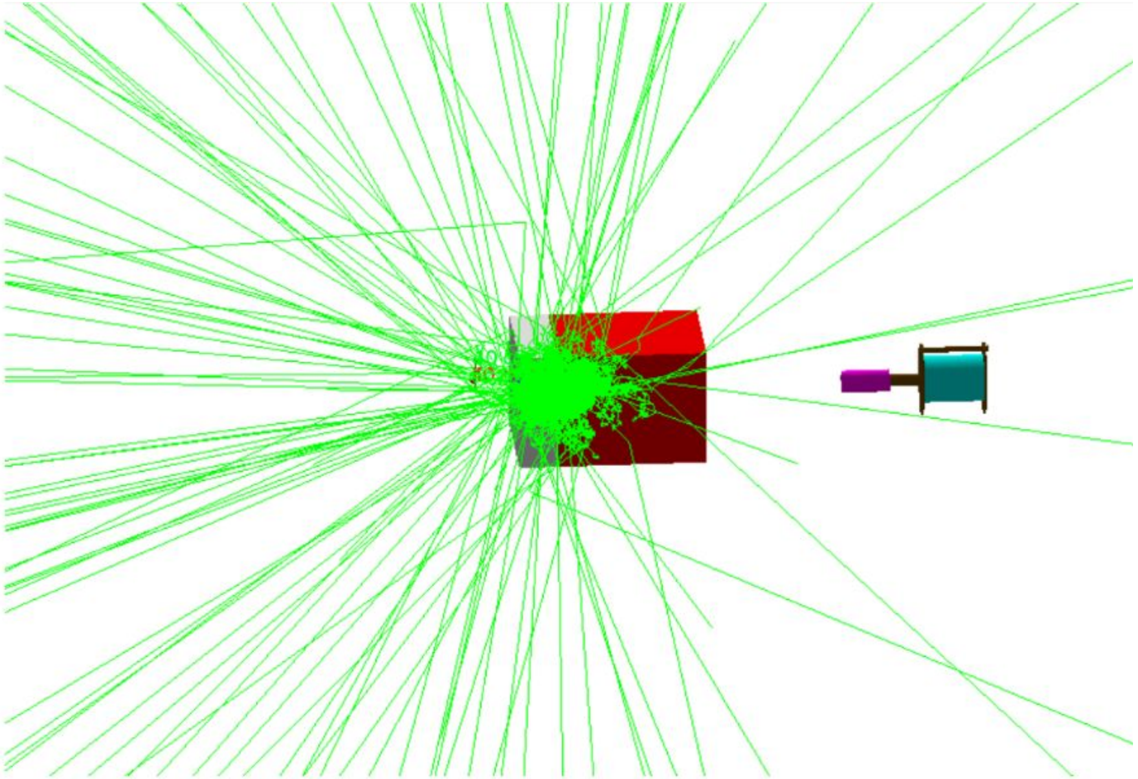
Neutron flux

- estimated using PACE4
- lowest neutron flux - backward angles (PRISMA@20°)
- AGATA backward
- average **8 neutrons/s/crystal** (24 hour measurement)

- neutron shielding 10cm polyethylene + 38cm paraffine
- flux decrease **> 1/100**



Summary

1st PHASE:

^{56}Co γ-ray source measurement:

- Efficiencies up to 3.4 MeV

2nd PHASE:

^{66}Zn(p,n) reaction:

- Efficiencies up to 5 MeV
- σ≈ 680 mb
- 5 pnA proton beam @13MeV, **24 hours**
- AGATA @ **back-most**
  - **$144x10^3$** counts/ crystal x day @ 4.3 MeV
  - **~$70x10^3$** counts/ crystal x day @ 4.8 MeV

PHASE	BEAM TIME Requested
^{56}Co+others sources	2-3 days
^{66}Zn(p,n)	1 day

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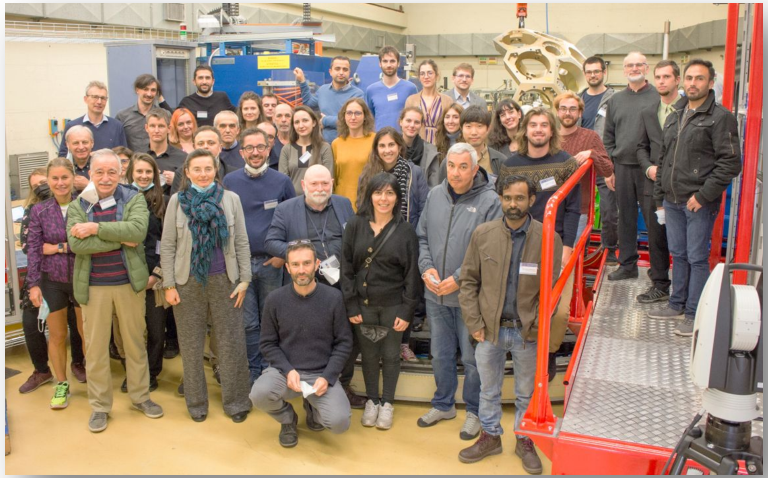
Collaboration

M. Balogh[1], S. Bottoni[2,3], R.M. Pérez-Vidal[1], S. Pigliapoco[4,5], Md. S. R. Laskar[3], G. Benzoni[3], D. Brugnara[1], F. Camera[2,3], F.C.L. Crespi[2,3], A. Ertoprak[1], F. Galtarossa[5], A. Goasduff[1], A. Gottardo[1], R. Menegazzo[5], D. Mengoni[4,5], B. Million[3], J. Pellumaj[1], J.J. Valiente Dobón[1], O. Wieland[3], L. Zago[1,4],

[1] *INFN, Laboratori Nazionali di Legnaro, Legnaro, Italy.*
[2] *Dipartimento di Fisica dell'Università degli Studi di Milano, Milano, Italy*
[3] *INFN, Sezione di Milano, Milano, Italy.*
[4] *Dipartimento di Fisica dell'Università di Padova, Padova, Italy.*
[5] *INFN, Sezione di Padova, Padova, Italy.*



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Thank you for your attention!

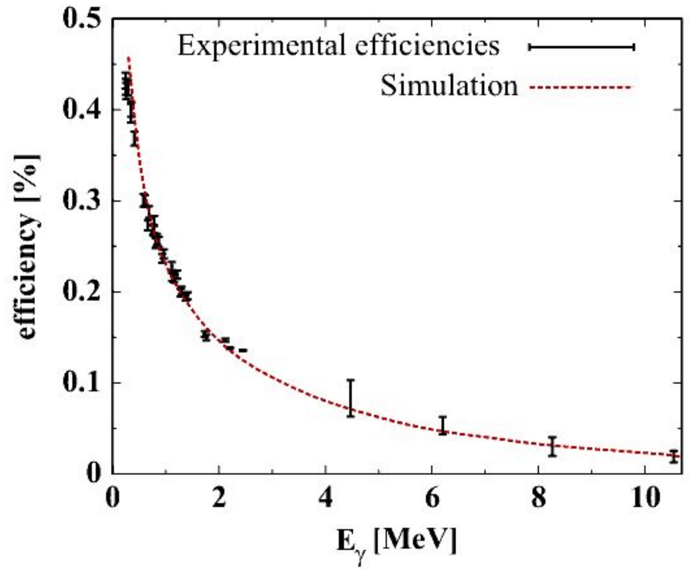
Better ideas?

Table 1
Parameters of the (p, γ) reactions, energies (E_γ) and relative intensities (I_γ) of the γ-rays emitted by product nucleus [9,11,12].

Reaction	E_{res} (keV)	Q value (keV)	E_p (keV)	E_γ (keV)	I_γ	Target and its thickness (μg/cm²)
$^{23}Na(p,\gamma)^{24}Mg$	1318.1	11 693	1323	1368.6(1)	1.000(2)	Na_2WO_4
				11 584.9(6)	0.960(2)	20
$^{23}Na(p,\gamma)^{24}Mg$	1416.9	11 693	1422	2754.0(1)	1.000(1)	Na_2WO_4
				8925.2(6)	0.985(1)	20
$^{27}Al(p,\gamma)^{28}Si$	767.2	11 585	770	2838.7(1)	1.0000(14)	Al
				7706.5(2)	0.9810(14)	15
$^{39}K(p,\gamma)^{40}Ca$	1346.6	8328	1351	3904.4(1)	1.000(1)	K_2SO_4
				5736.5(1)	0.965(1)	20
$^{11}B(p,\gamma)^{12}C$	675	15 957	676	4438.0(3)	1.0000(7)	$LiBO_2$
				12 137.1(3)	1.0000(7)	75
$^{7}Li(p,\gamma)^{8}Be$	441	17 255	450	17 619.0(6)	–	$LiBO_2$, 75

Nuclear data are taken from ENSDF [13]. Q values calculated by QCalc from NNDC [14].

F.C.L. Crespi, NIM A **705**, 2013



L. Netterdon, NIM A **754**, 2014

AGATA week workshop
October 2023

Performance of AGATA at higher energies

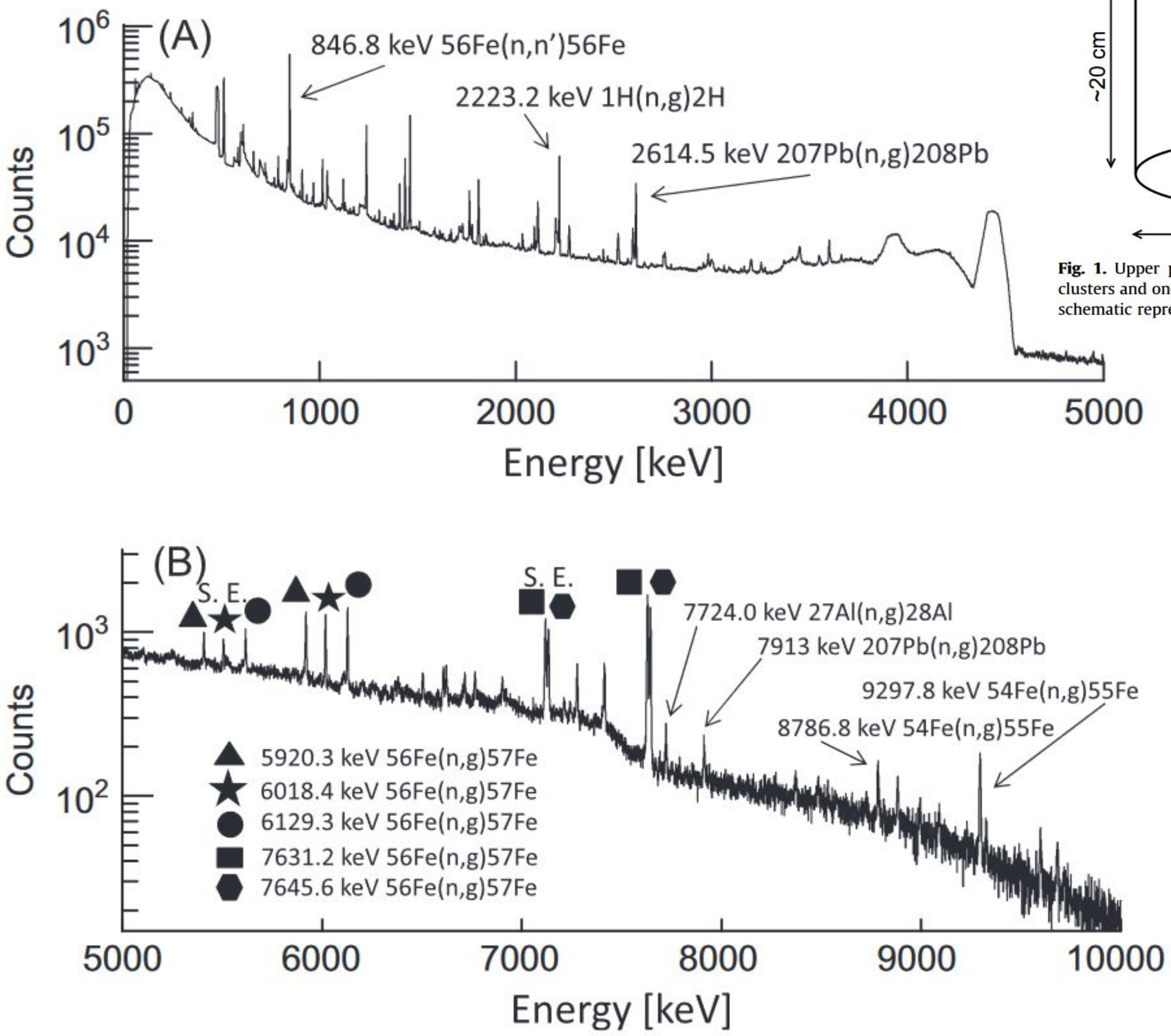
Scientific motivation

The experiment

1st PHASE ^{56}Co

2nd PHASE ^{66}Zn(p,n)

Summary



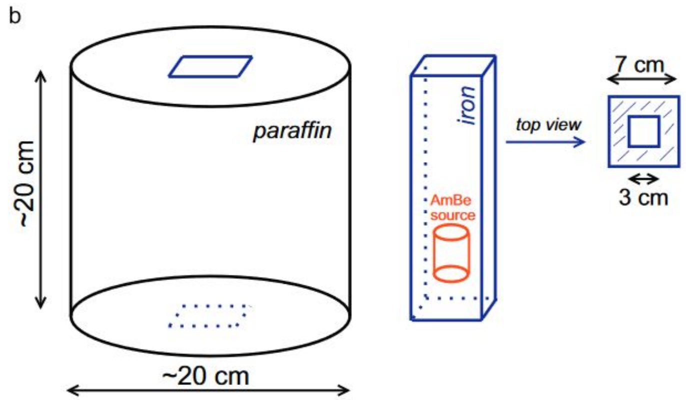


Fig. 1. Upper panel: The experimental set-up consisting of two AGATA triple clusters and one 3.5" × 8" cylindrical $LaBr_3$:Ce scintillation detector. Lower panel: schematic representation of the Am–Be–Fe source.

F.C.L. Crespi, NIM A **705**, 2013

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Single ATC characterization

- Possibility of sending one AGATA ATC to ILL to be tested with (n,g) in the future