laboratoire commun CEA/DRF — CNRS/IN2P3

Efforts on angular distributions and correlations with AGATA

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GANIL, France

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Legnaro, Italy

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Angular correlation & distribution: a power tool for gamma spectroscopy

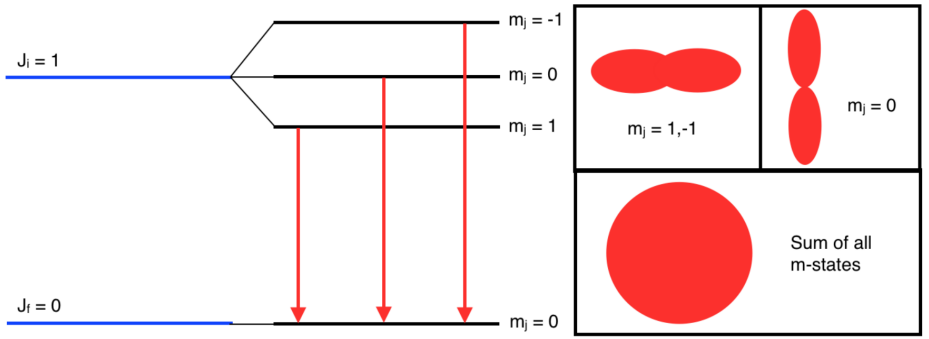
- Relation between gamma angular distribution and multipolarity of transition

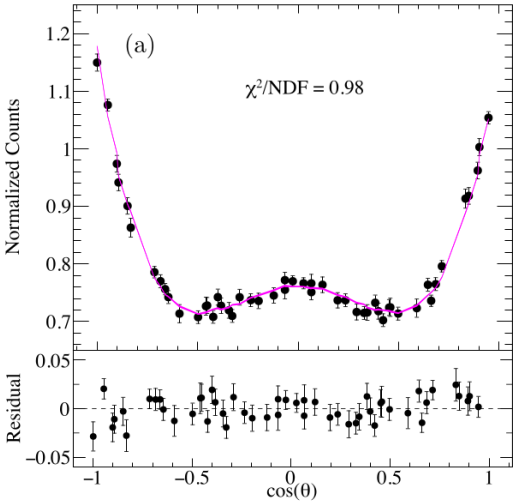
- Accessible experimentally in two cases:
  - Polarization of emitting nuclei
    (magnetic field, reaction...)
  - Gamma cascade

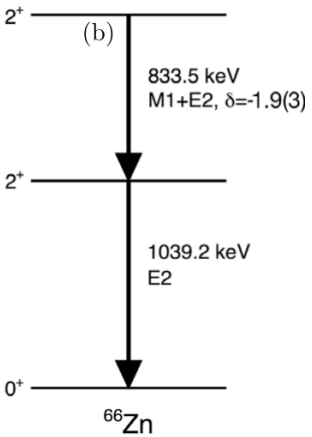
- Case of gamma cascade the relative angle $\theta(\gamma_{ini}\text{-}\gamma_{fin})$ contains the information

$$W(\theta) = \sum_{i=0,even}^{\infty} A_{ii} P_i(\cos(\theta))$$

$$W(\theta) \sim A_{00}(1 + a_2 P_2(\cos(\theta)) + a_4 P_4(\cos(\theta)))$$







Smith et al. NIMA 922 2019

Angular γ-γ correlations with a advance gamma ray tracker

AGATA provides high efficiency and tracking resolution

Ideal tool for angular distribution study ?

Angular γ-γ correlations with a advance gamma ray tracker

AGATA provides high efficiency and tracking resolution

→ **Ideal tool for angular distribution study ?**

What is the AGATA response function on angular distribution ?

Two main filters affecting angular correlation studies:

- PSA algorithm
- Tracking algorithm

→ **To investigate**

Reference work on ^{60}Co angular correlations: what to expect

Starting point: ^{60}Co beta decay

Well known transition in ^{60}Ni:

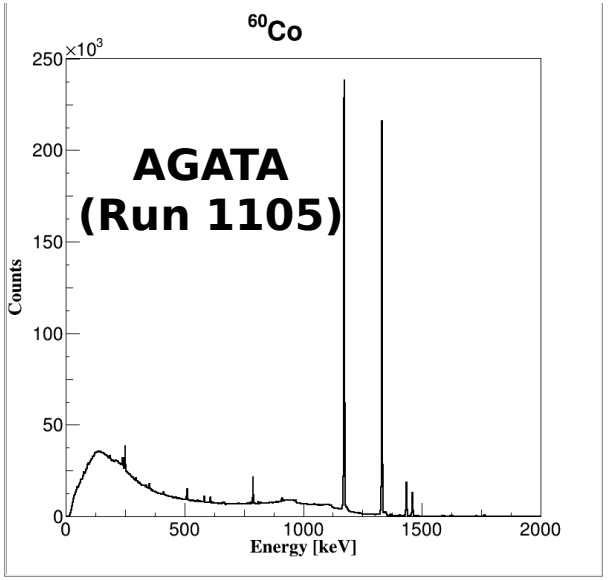
$4^+ \rightarrow 2^+ \rightarrow 0^+$

$E\gamma_1$[1173.23 keV] → $E\gamma_2$ [1332.50 keV]

Angular correlation characterised (E2/M1):

a2 = 0.1005(22) a4 = 0.0094(3)

$$W(\theta) \sim (1 + a_2 P_2(\cos(\theta)) + a_4 P_4(\cos(\theta)))$$



Huge data set available for AGATA.

Starting point of study:

Run 1105 from e673 (2017)

More than 10h

^{60}Co source (~7000 Bq) centred

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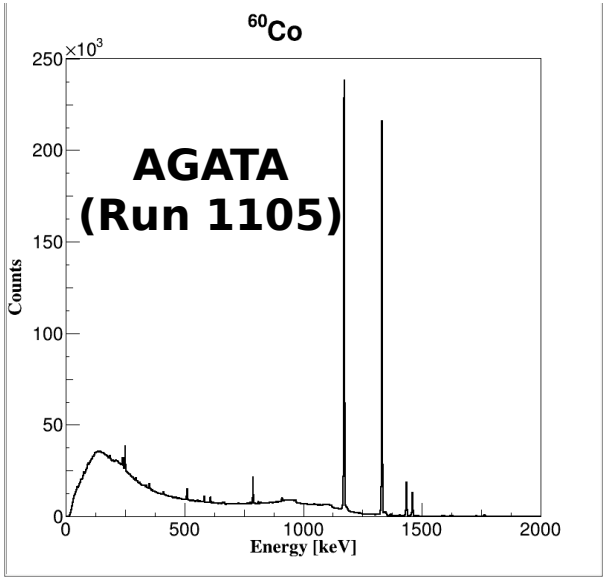

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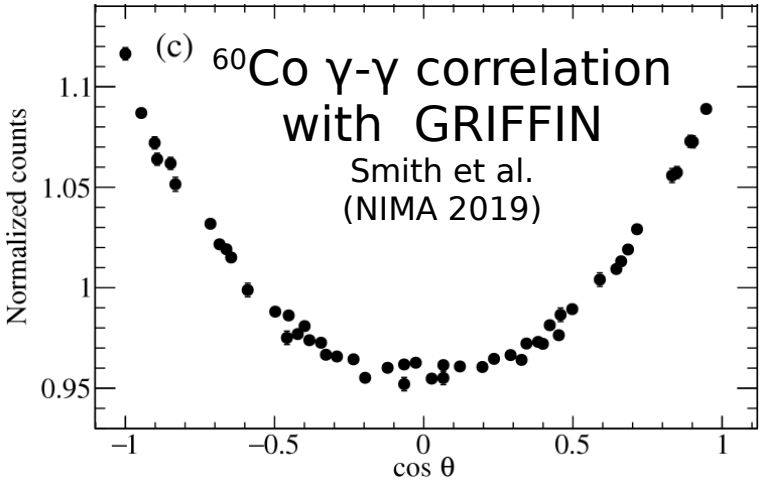

If AGATA was not a tracking array: back to basic crystal information

Using AGATA as **simple HpGe array**

- No PSA
- No tracking

Looking for ^{60}Ni γ-γ events:

- Using core energy
- Interaction position is the middle of the triggered crystal

Finite number of detectors:

- Minimum angle ~ 14°
- Maximum angle ~ 108°

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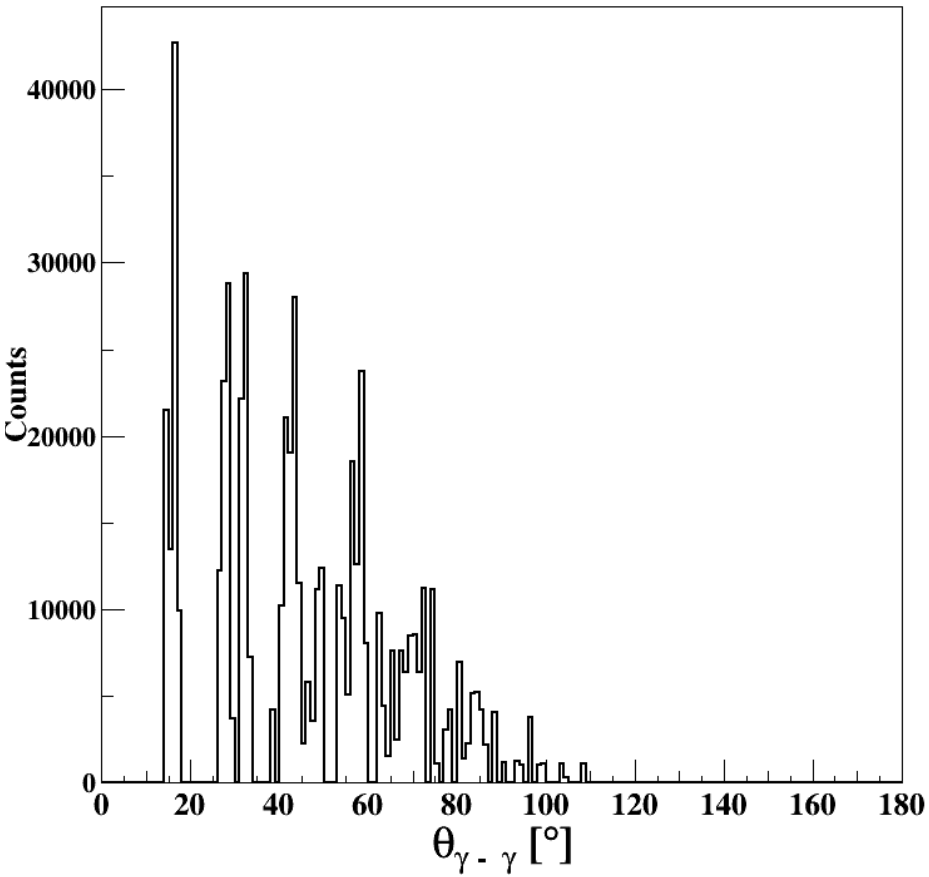
Sensitive to AGATA angular response

Geometrical effect, Individual efficiency

➡ Uncorrelated contribution

How to normalize data ?



If AGATA was not a tracking array: Pair counting & efficiency

Using AGATA as **simple HpGe array**

AGATA angular mainly affected by:

- Geometrical acceptance
- Individual detector efficiency

Normalisation procedure:

- Counting number of crystal pairs per angle
- Weight each event by individual detector efficiency

Look simple procedure

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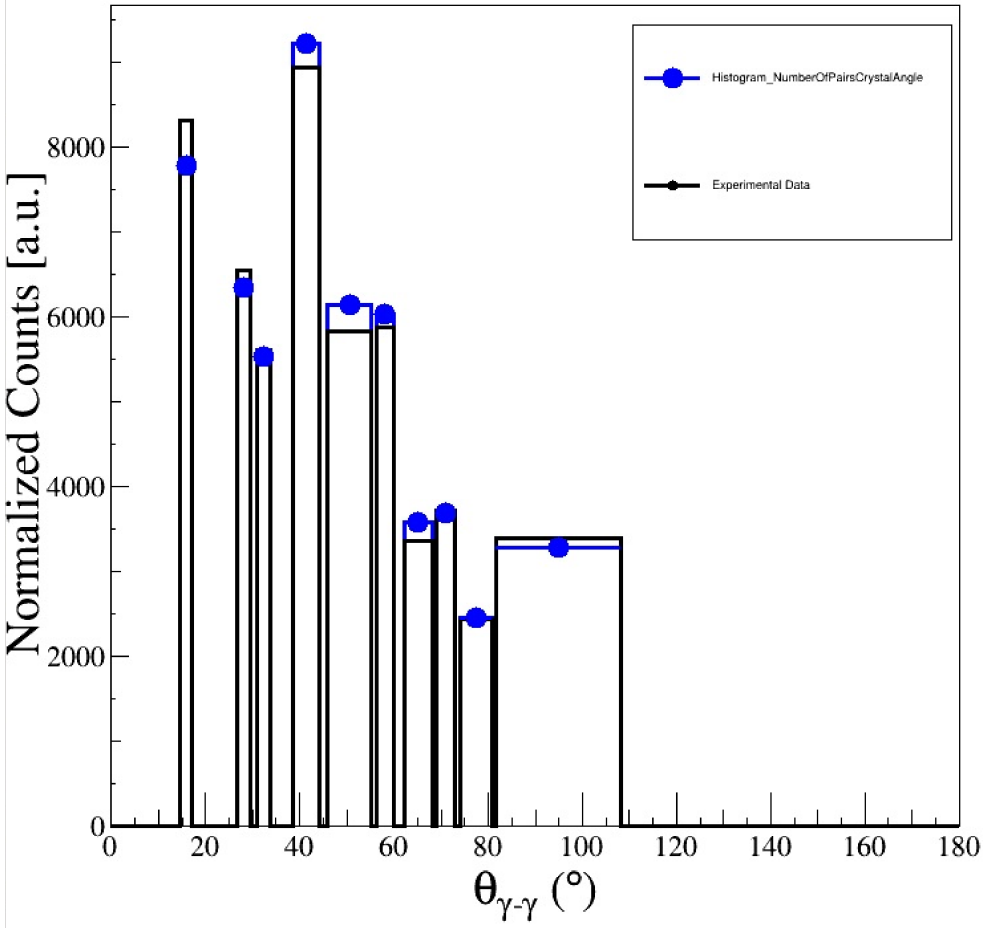


If AGATA was not a tracking array: Pair counting normalisation

Using AGATA as **simple HpGe array**

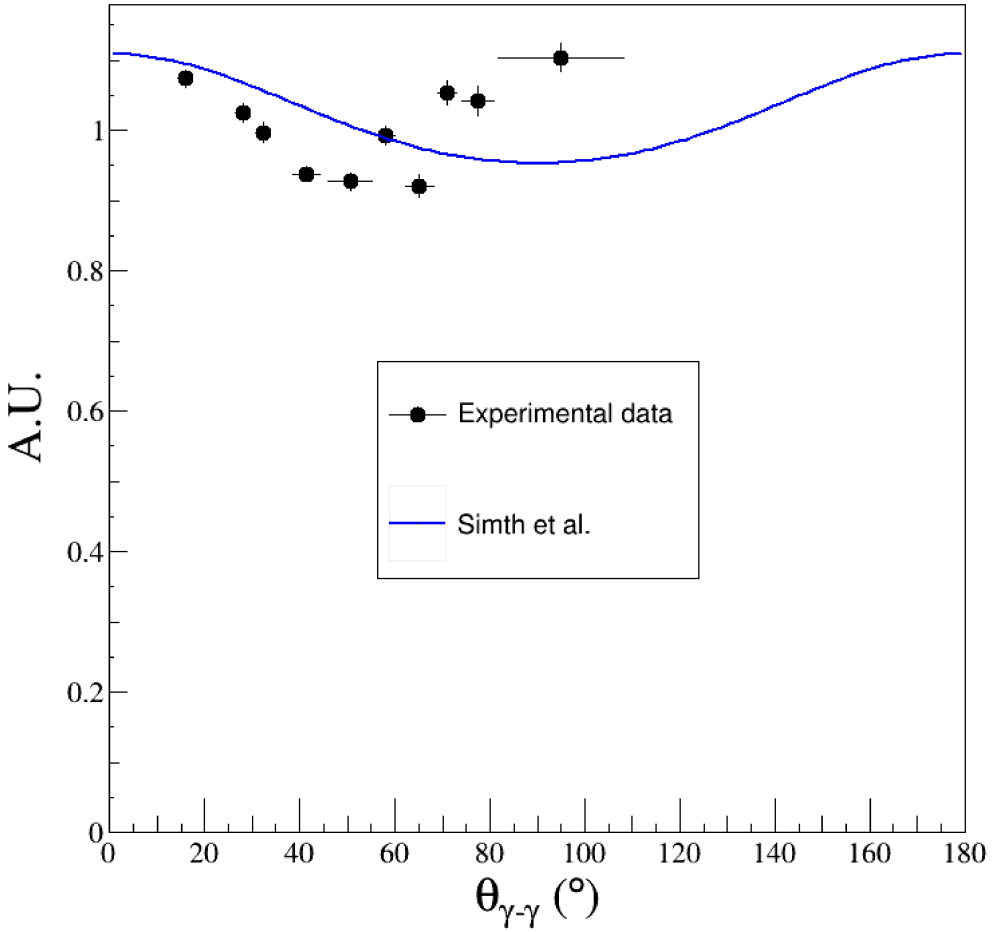
Normalisation procedure:

- Counting number of crystal pairs per angle
- Weight each event by individual detector efficiency

Results & comments

- Shape is not correct
- Minimum of distribution is not observed at 90°

Not working !!
Something missing ?

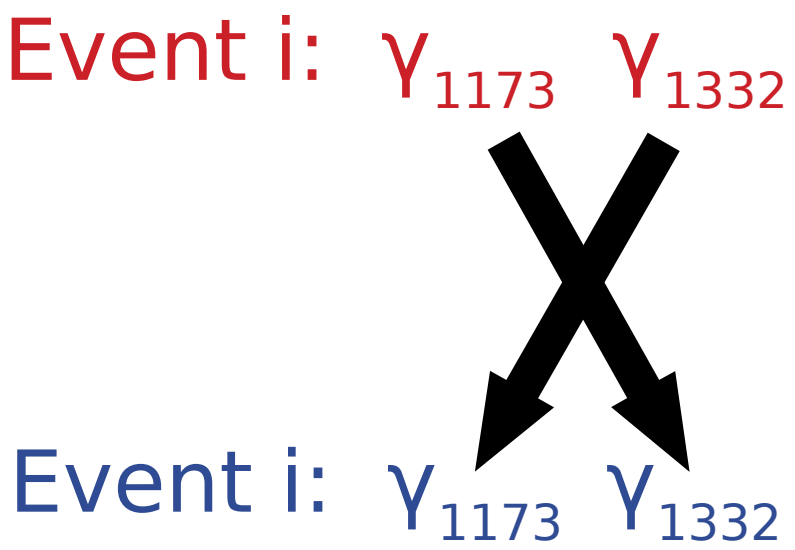


If AGATA was not a tracking array: Event mixing

Using AGATA as **simple HpGe array**

Basic concept:
Detected γ in data are affected by the AGATA response function

Idea: Event mixing
construct the uncorrelated distribution from artificial γ-γ pairs



Normalizing Procedure:

- Loop over all data
- Find two random γ-γ events e1 & e2
- Reconstruct artificial angles:
  $\theta(e1_{1333} - e2_{1173})$
  $\theta(e1_{1333} - e2_{1173})$
  ≠ Crystal ID !
- Normalize by obtained distribution

If AGATA was not a tracking array: Event mixing normalisation

Using AGATA as **simple HpGe array**

Normalizing Procedure:

- Loop over all data
- Find two random γ-γ events e1 & e2
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  $\theta(e1_{1333} - e2_{1173})$
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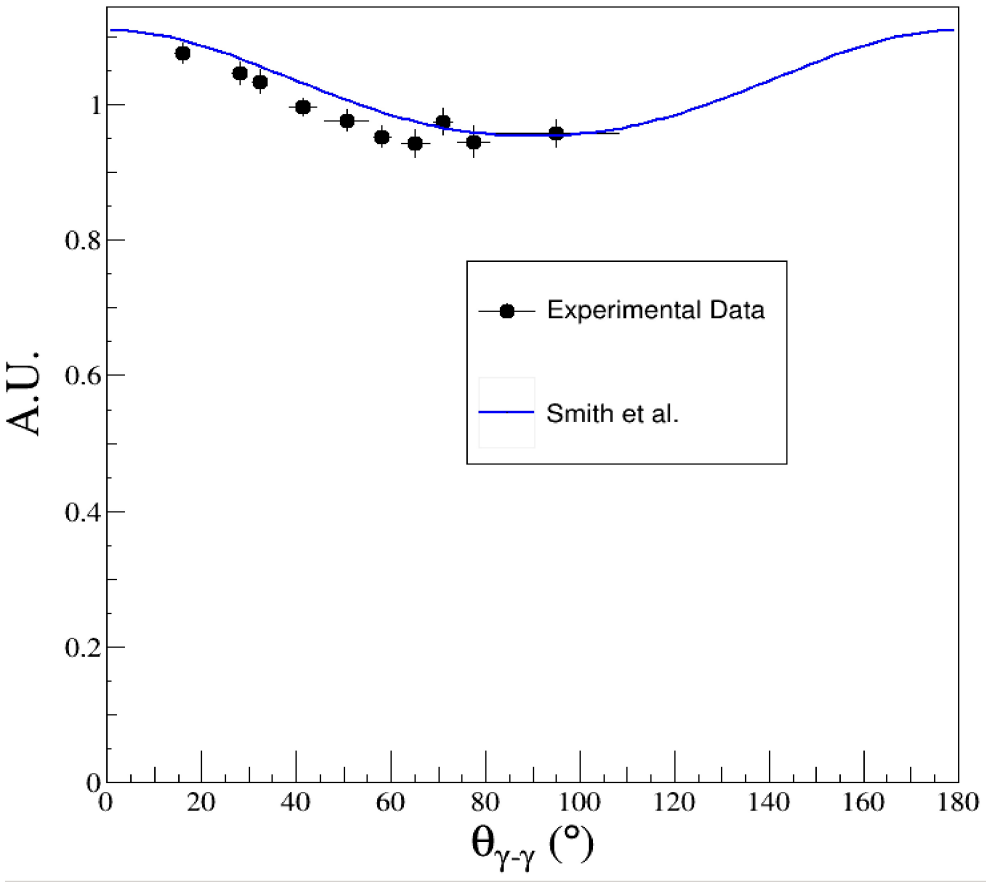


Results & comments

- Trend is well reproduced
- Slight offset in amplitude (depends on normalization range)

Success ?

If AGATA was not a tracking array: Normalisation comparison

Using AGATA as **simple HpGe array**

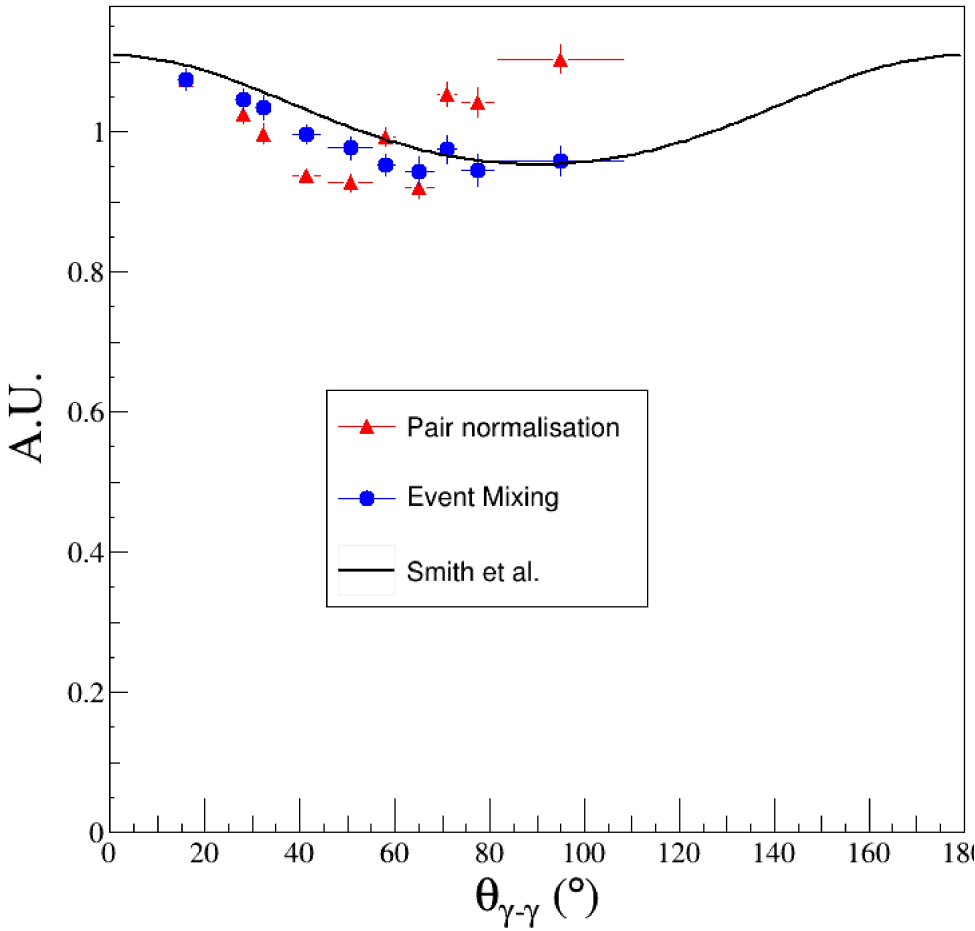
Two normalisation procedures:

- Number of Pair / angle + individual efficiency
- Event mixing

Overall results

- Pair normalisation is not working
- Mixing seems to provide reasonable results, expecting for the normalisation

Can we apply to same method to AGATA working as a tracking array ?



AGATA as tracking array: Angular distribution with PSA + tracking

Using AGATA with **all filters**

- PSA
- Tracking

Looking for ^{60}Ni γ-γ events:

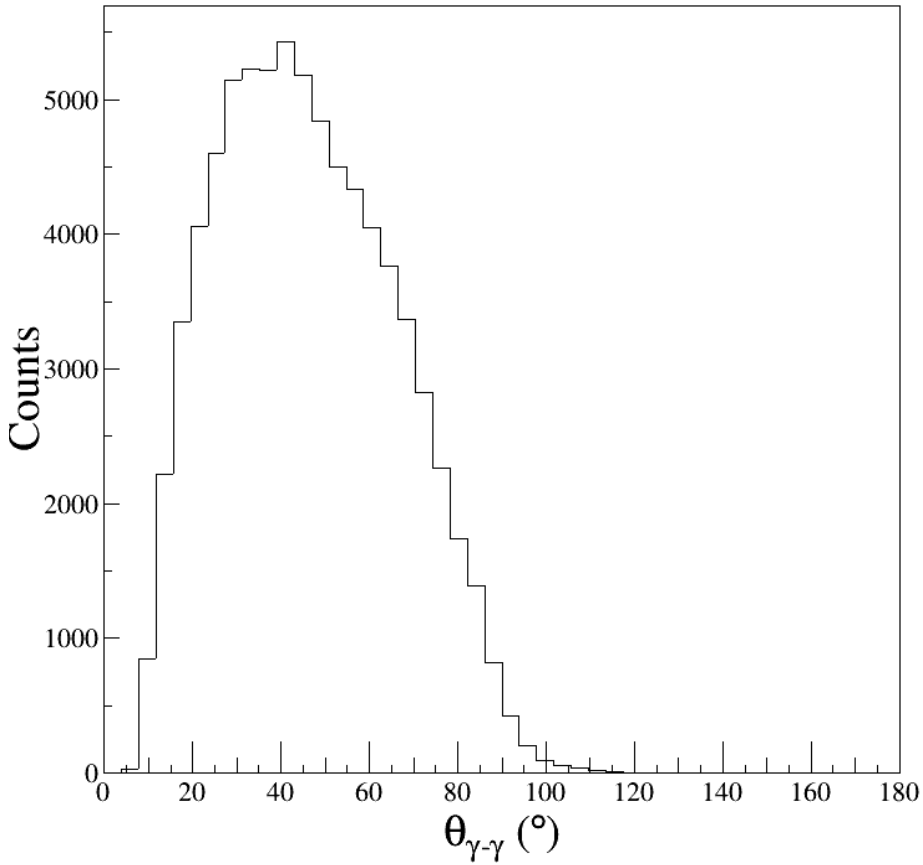
- Using tracked energy
- Interaction position is given by the tracking

Much higher energy and angle resolution

- Near-infinite number of angle pairs
- Large angle distribution

Normalisation algorithm

- Event mixing



AGATA as tracking array: Normalisation with event mixing

Using AGATA with **all filters**

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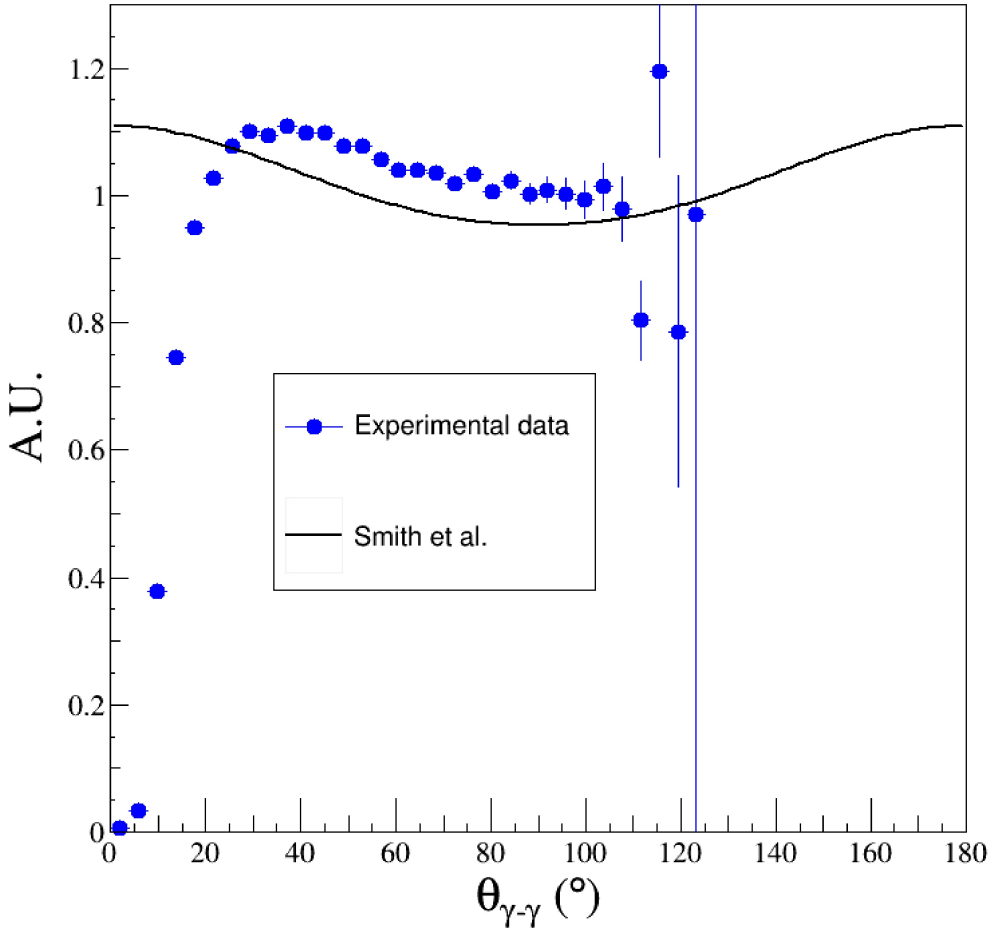

Results & comments

- Overall is well reproduced
- Failing at low angles
  → Mixing after tracking !!!
- Huge deviation at large angle

These deviations strongly affect the normalisation

AGATA as tracking array: Normalisation with event mixing

Using AGATA with **all filters**

Normalizing Procedure:

- Loop over all data
- Find two random γ-γ events e1 & e2
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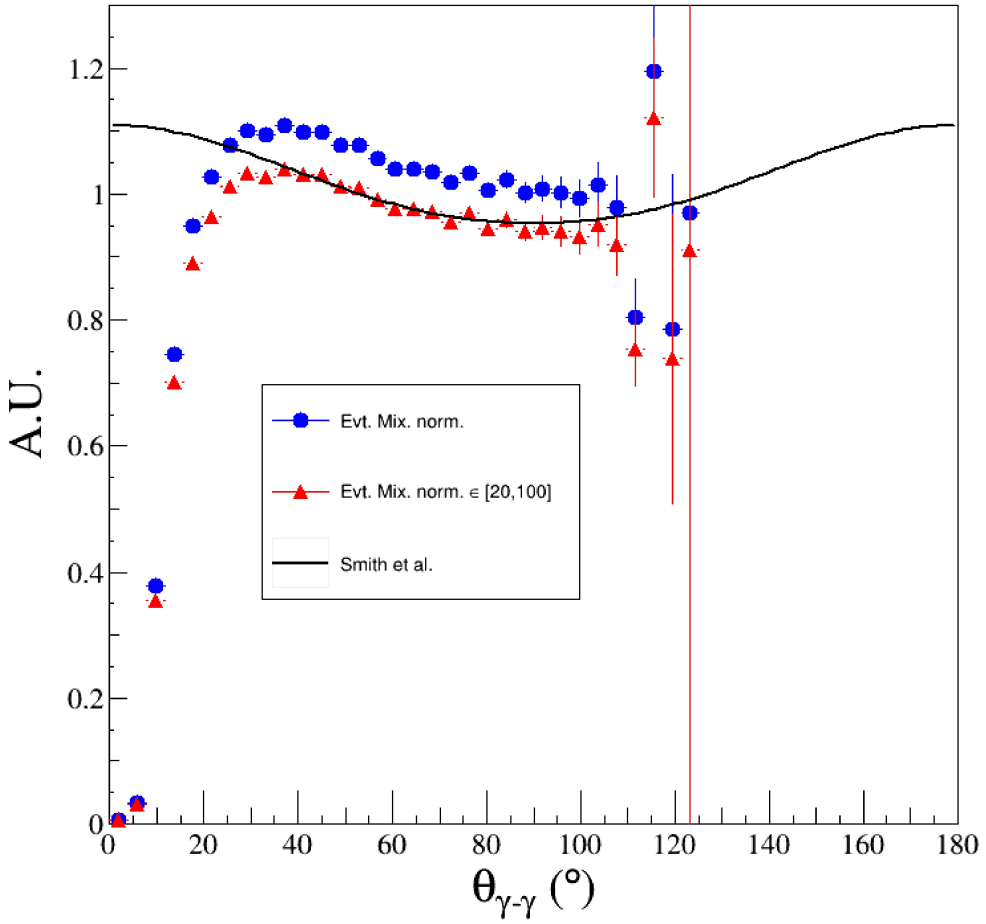

Results & comments

- Overall is well reproduced
- Failing at low angles
  ➡ Mixing after tracking !!!
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These deviations strongly affect the normalisation

AGATA as tracking array: Crystal VS PSA + Tracking

Two normalisation procedures:

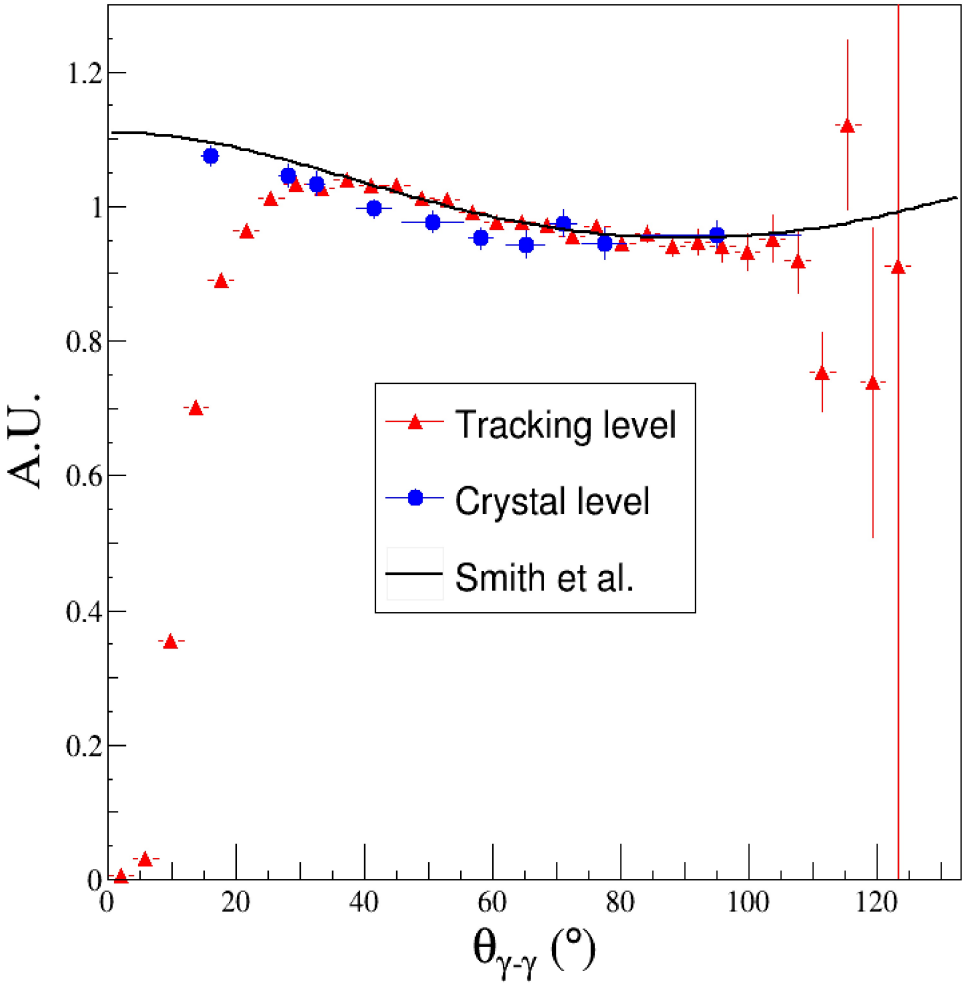
- Number of Pair / angle + individual efficiency
- Event mixing

Two angle reconstruction:

- Crystal level
- PSA + tracking

General:

- Event mixing seems to provide better normalisation
- Tracking provide better resolution but is not as good at low angles
- Understanding the response function is critical for normalisation



Conclusions & outlooks

I. Investigation of AGATA angular response function with ^{60}Co source

- AGATA as classical HPGe array
  - Normalization by number of crystal pairs
  - Normalization by event mixing
- AGATA as a tracking array
  - Normalization by event mixing

II. Preliminary observations

- Event mixing seems to provide reasonable results
- Clear evidence for effect of the tracking filter
- Understanding AGATA response function is critical to perform correctly the normalisation

III. Outlooks

- Perform properly the event mixing before the tracking
- Investigate effect of PSA ?
- Look at in-beam data