Terzo Incontro Nazionale di Fisica Nucleare
INFN2016

Study of Quadrupole Correlations in Neutron-Deficient Sn Isotopes via Lifetime Measurements

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INTRODUCTION

NUCLEAR DEFORMATION

The Hamiltonian used to describe the nuclei can be separated in two parts:

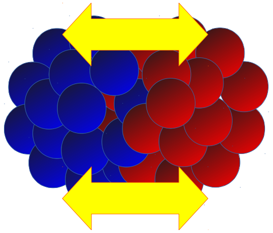
$$\hat{H} = \hat{H}_m + \hat{H}_M$$

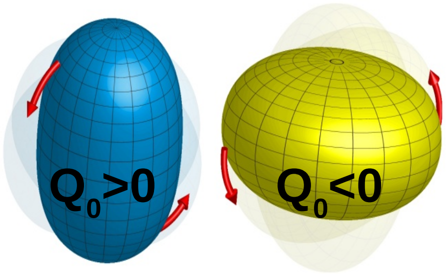
Monopolar Hamiltonian:

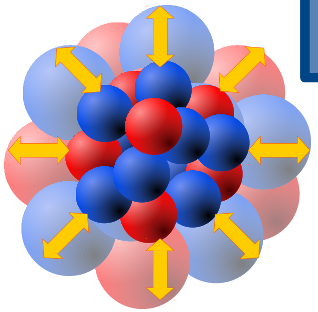
- Spherical mean field extracted from the interacted shell model
- Responsible of the shell evolution as function of the neutron/proton number

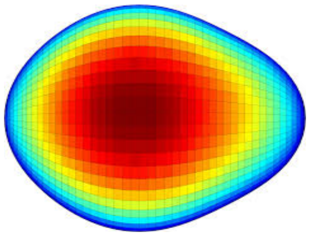
Multipole Hamiltoninan:

- Pairing force causes the superfluidity behaviour and drives the nuclear surface to a spherical shape
- Strong correlations between nucleons entails collective motions.









In the multipole hamiltonian H_M the balance between the proton-neutron correlations and the pairing force determine the **nuclear shape**.

QUADRUPOLE CORRELATIONS

The nuclear quadrupole moment gives information on the **nuclear shape** (Q=0 spherical, Q>0 prolate, Q<0 oblate).

$$Q_0 = \sqrt{\frac{4\pi}{5}} \langle \psi_i | r^2 Y_0^2 | \psi_f \rangle$$

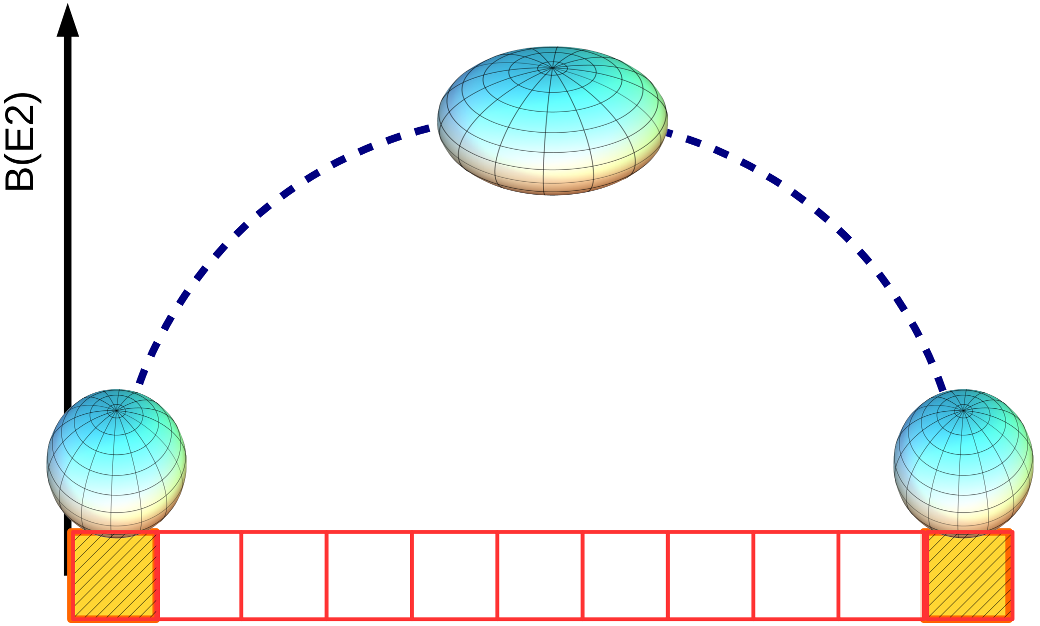
Experimentally the quadrupole moment can be deduced by measuring the **reduced transition probability** $B(E2; I_i \rightarrow I_f) \propto e^2 Q_0^2$.

→ Coulomb excitation reactions

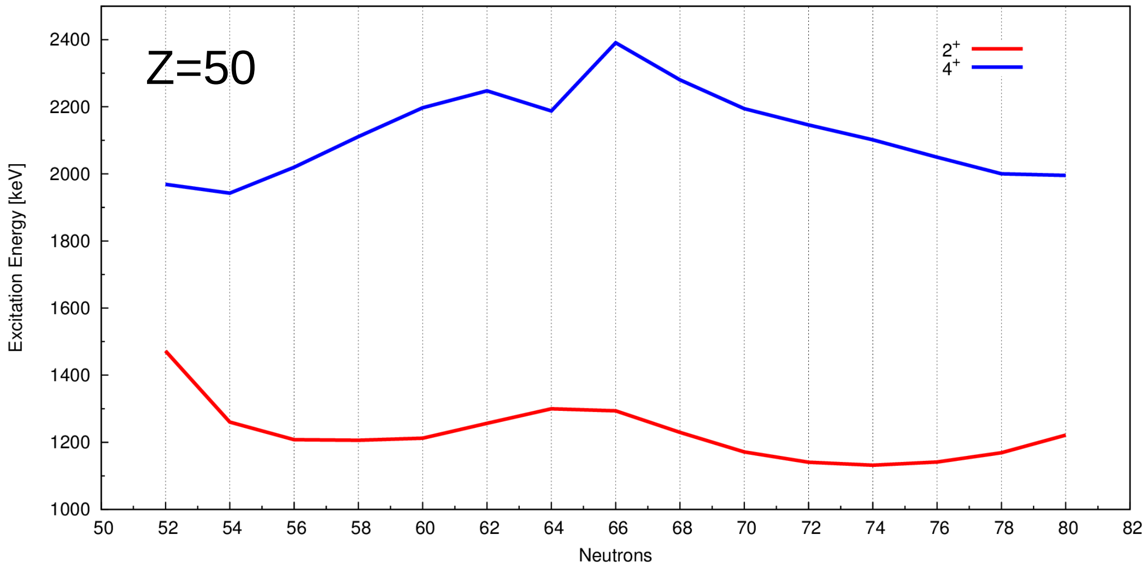
$$\boxed{\sigma_{Coulex} \propto B(E2)}$$

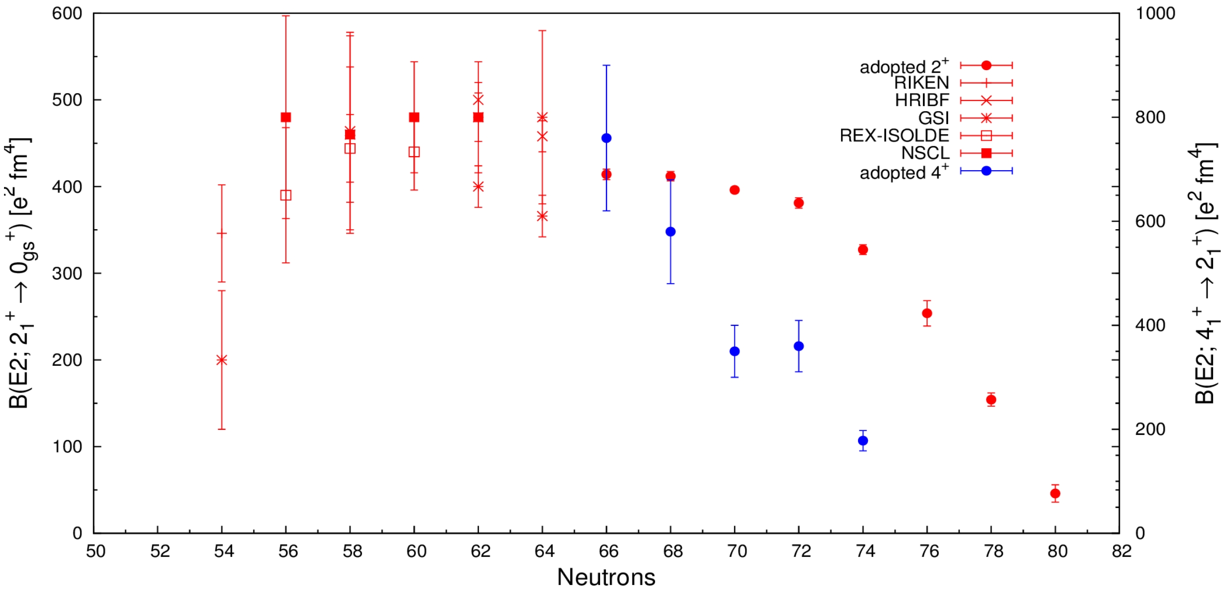
→ **Lifetime measurement**

$$\boxed{B(E2; L \rightarrow L+2) \propto \tau^{-1} E_\gamma^{-5}}$$



Z=50 ISOTOPES





The systematic of the first 2^+ state excitation energy is well known for Sn isotopes and its behaviour is rather constant.

For neutron-deficient isotopes the information on the reduce transition probability suffers from **large experimental uncertainties** (~20%).

The neutron-deficient region has been investigated via Coulomb excitation reactions.

MOTIVATIONS

- Study of nuclear structure close to Z=N=50 shell closure.
  Examine the robustness of the proton shell closure when N=50 is approached.

- Reduced transition probabilities B(E2; $0^+ \rightarrow 2^+$) and B(E2; $2^+ \rightarrow 4^+$) of $^{106-108}$Sn, via direct lifetime measurement.
  Complementary information to previous Coulomb excitation experiments.

- First lifetime measurement with plunger device in this region.

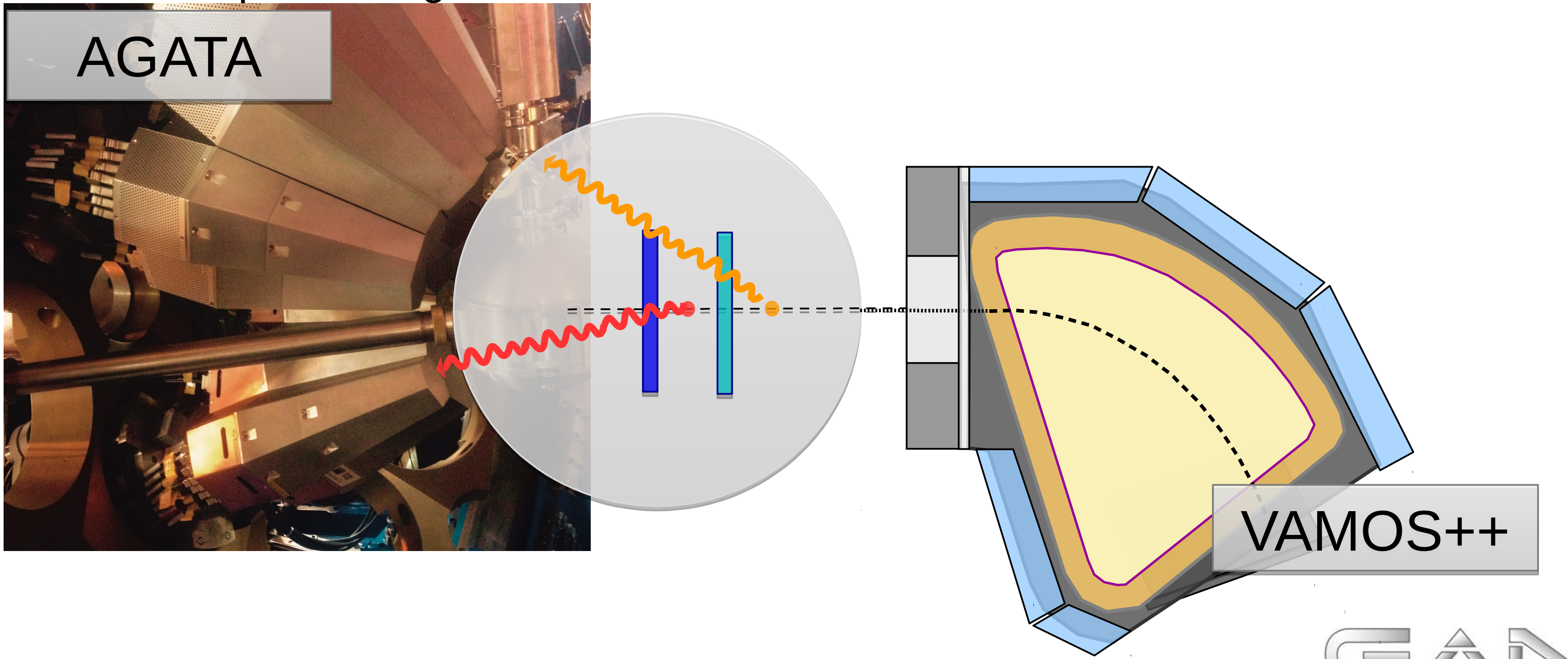
EXPERIMENTAL DETAILS

MULTI-NUCLEON TRANSFER REACTION

Beam: ^{106}Cd @ 770 MeV

Target: ^{92}Mo 0.715 mg/cm^2
Degrader: ^{24}Mg 1.6 mg/cm^2

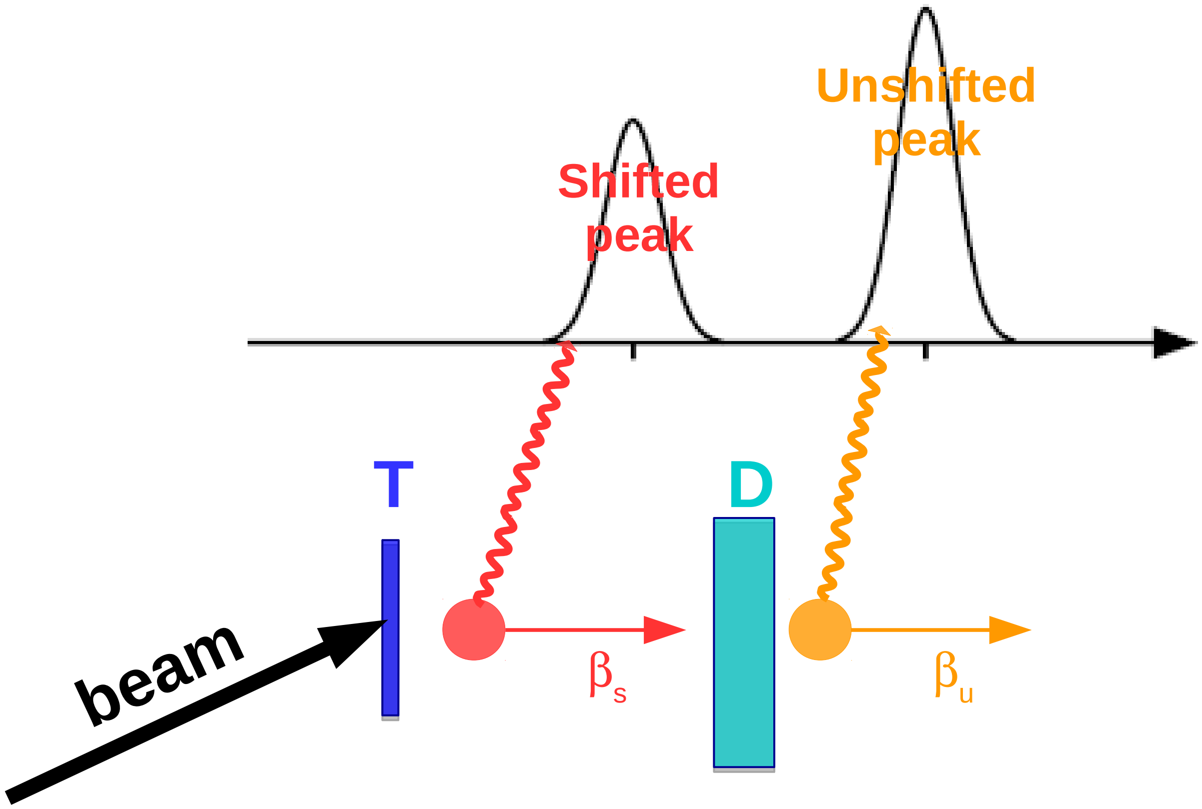
AGATA compact configuration

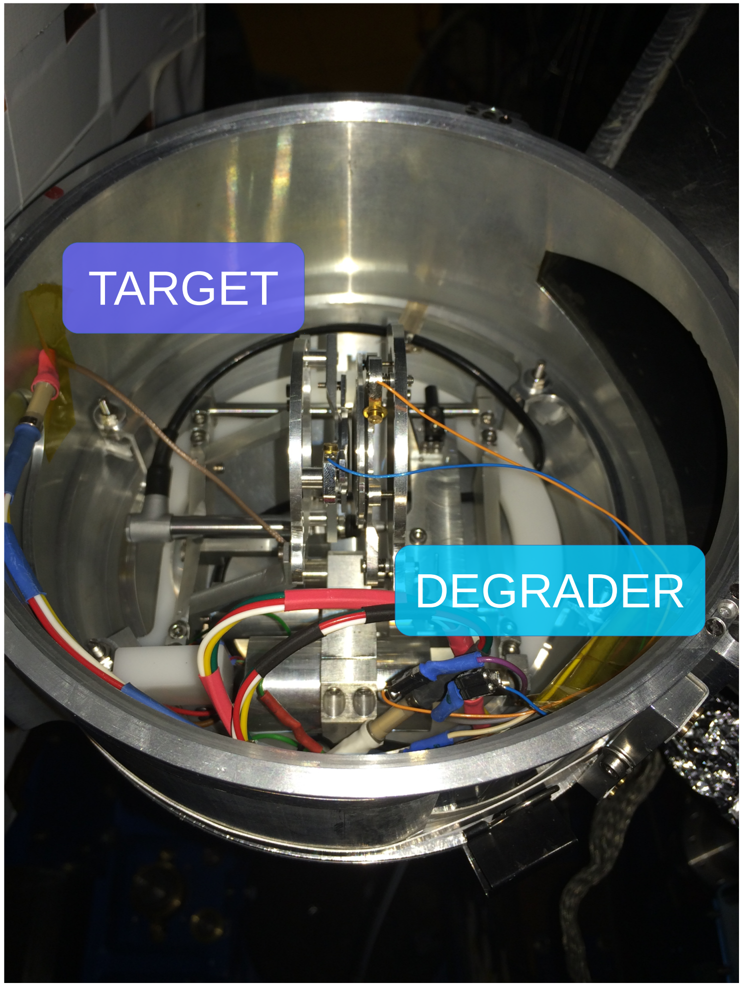


GANIL spiral2

Differential Plunger

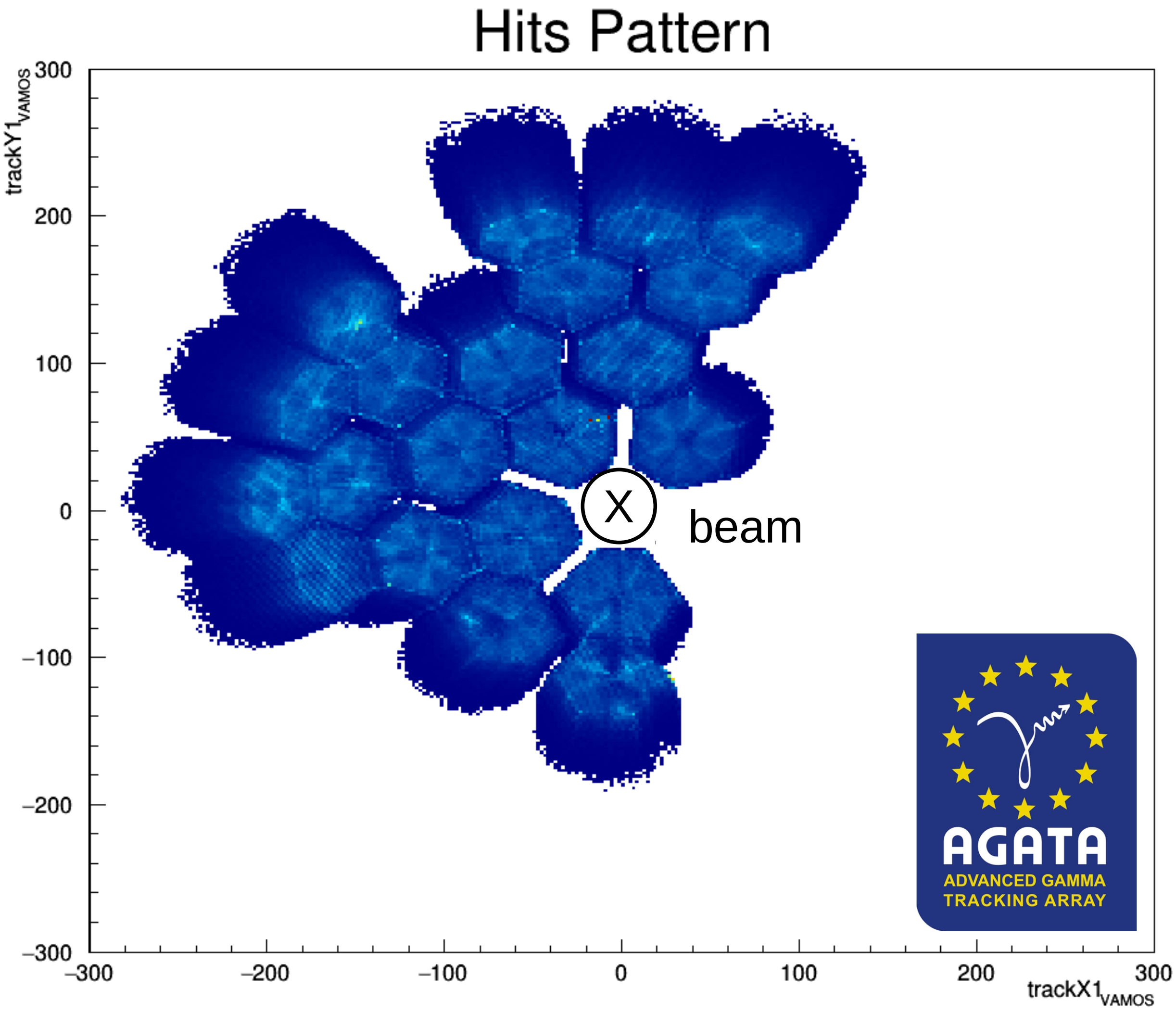
The γ–ray energy is Doppler corrected for β_u, so in the spectrum a second under-corrected shifted peak appears.





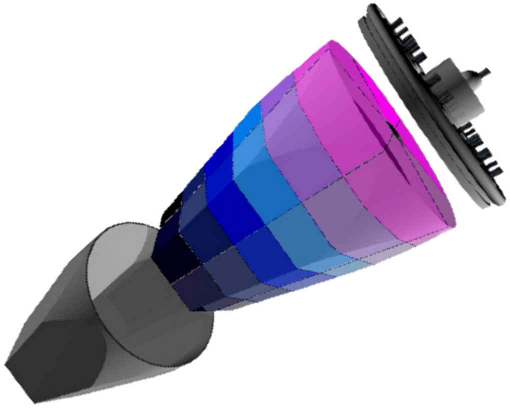
The relative intensity of the two peaks depends on the TOF between target and degrader (β_s,distance) and lifetime.

AGATA


Hits Pattern

8 ATC mounted = 24 not Compton-suppressed HPGe

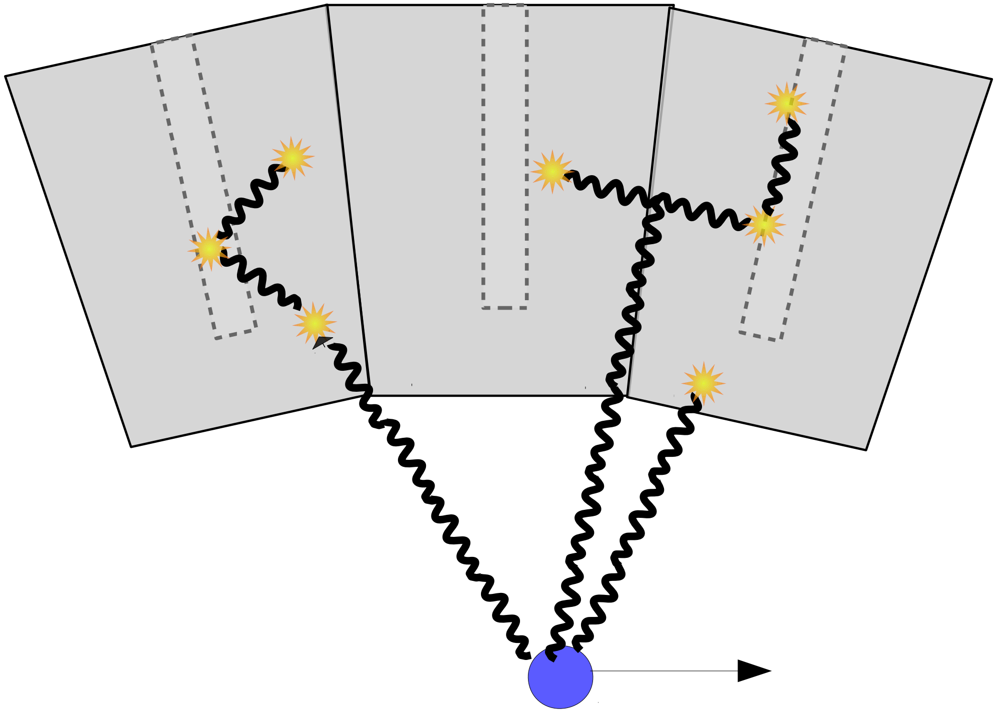
- 36 segments per crystal
- 2 cores per crystal



Comparing segments and cores signals:

- ✔ dead segments correction
- ✔ neutron damage correction
- ✔ Pulse-Shape Analysis
- ✔ gamma tracking

AGATA Tracking



The interaction positions from PSA are used for reconstructing the tracked γ-ray.

- **Photo-electric absorption** process has large probability in the range 90-250 keV
  \+ distance to next interaction point more than 4cm
- For **Compton scattering** interaction points belonging to the same photon are clustered in a limited angular range
- **Pair-production** events occur for high energy γ rays
  \+ at least 3 interaction points with total energy more than 1022 keV

Tracking parameters have been optimized by improving the peak-to-total ratio without rejecting good events (reducing the integral of the peak).

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AGATA Efficiency

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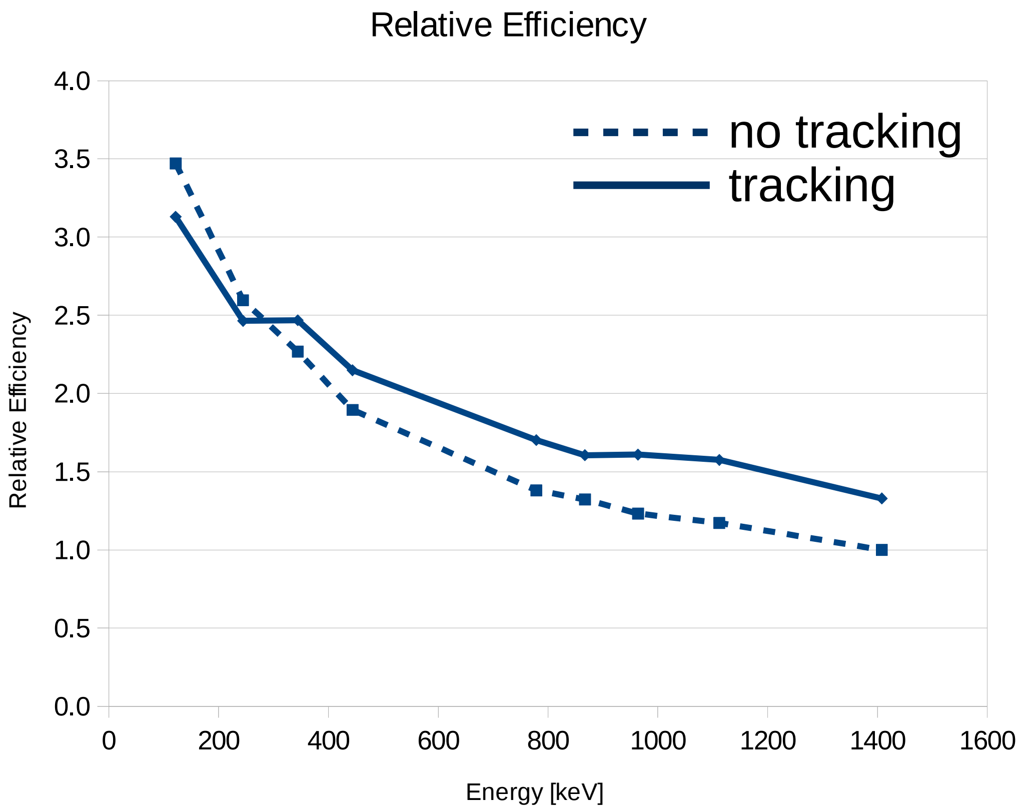
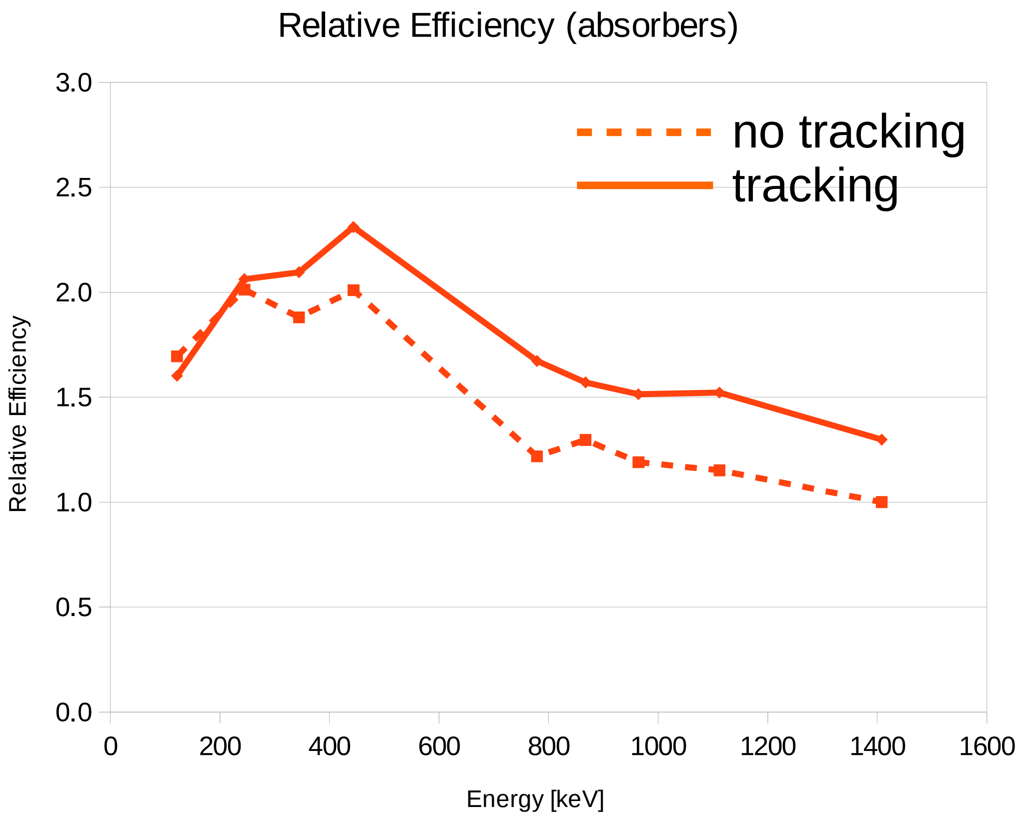
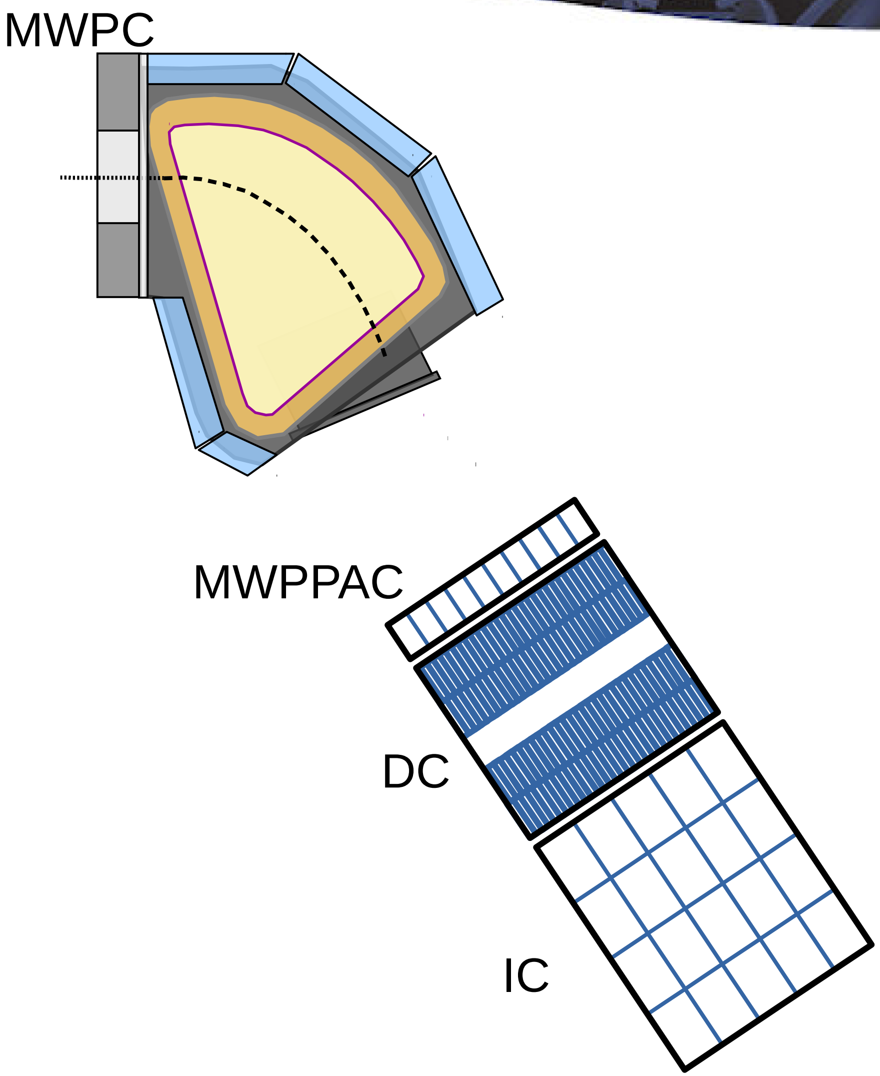
Energy Resolution: 3.92 keV @ 1408 keV
2.78‰


Relative Efficiency


Relative Efficiency (absorbers)

VAMOS++

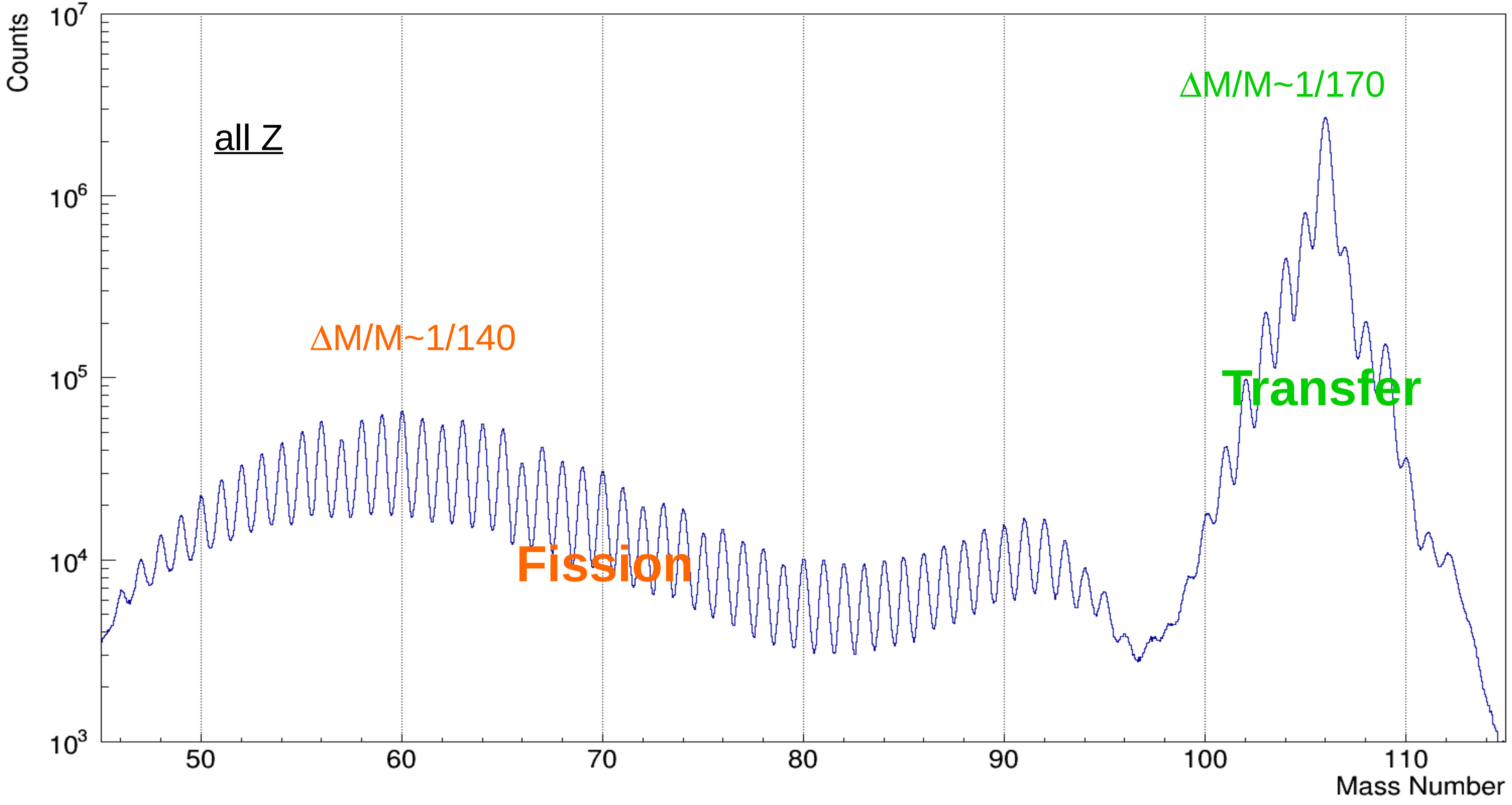


VAMOS++, large angular acceptance magnetic spectrometer, gives a complete identification (Z, A, β) of the recoils event-by-event.

- **IC** measures the energy loss and gives information about the **Z** of the recoils
- **DC** allows the trajectory reconstruction for **A** identification
- dual position sensitive **MWPC** gives the recoil entrance velocity vector **β**, crucial for the Doppler-correction

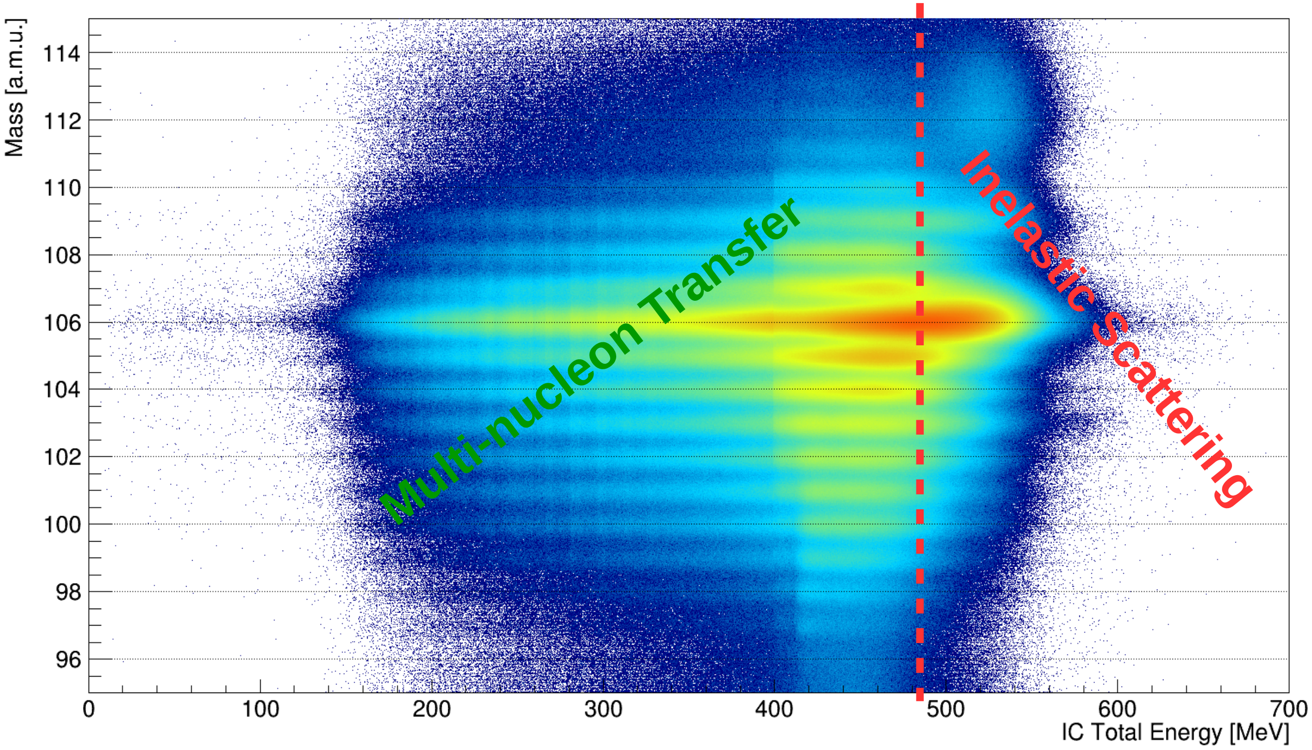
PRELIMINARY RESULTS

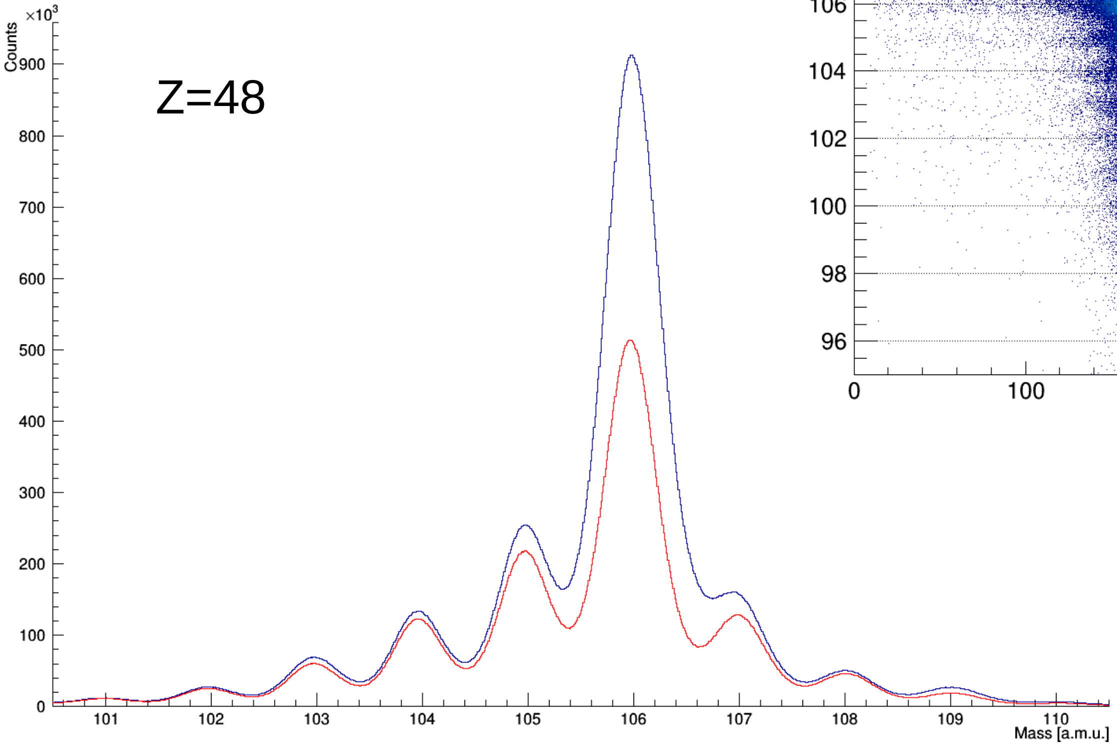
PID – Mass


Counts
10^7
10^6
10^5
10^4
10^3
all Z
ΔM/M~1/140
Fission
ΔM/M~1/170
Transfer
50
60
70
80
90
100
110
Mass Number

PID – Mass

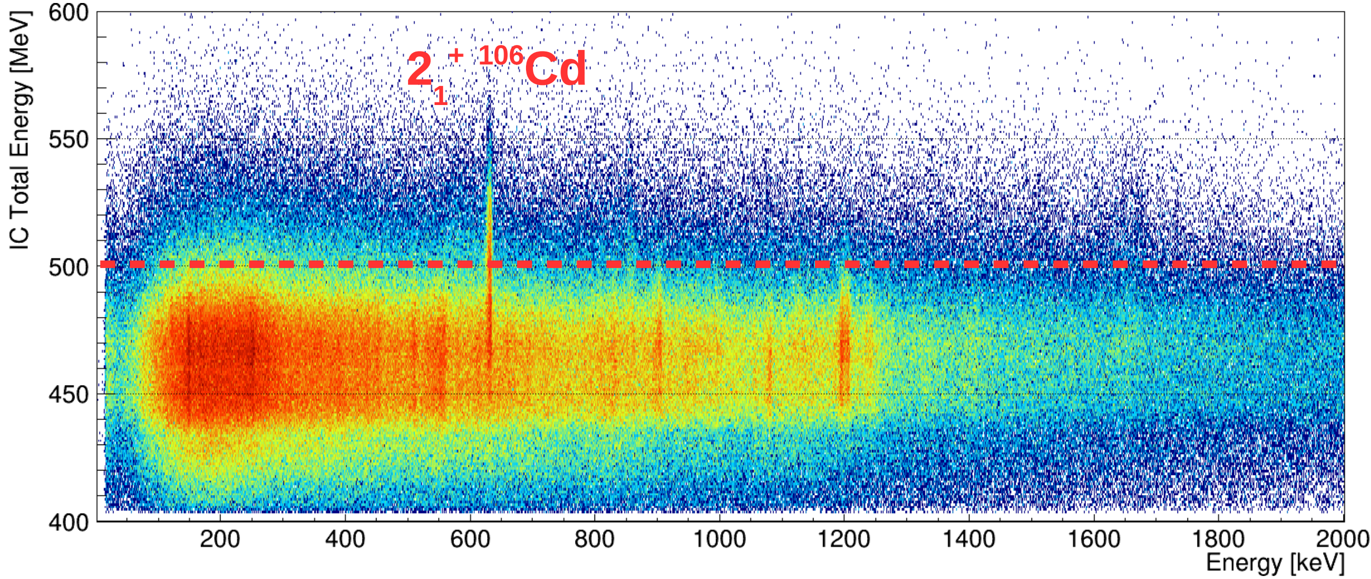
Events from the inelastic scattering of the beam overwhelm the ±1n peaks in the mass identification.

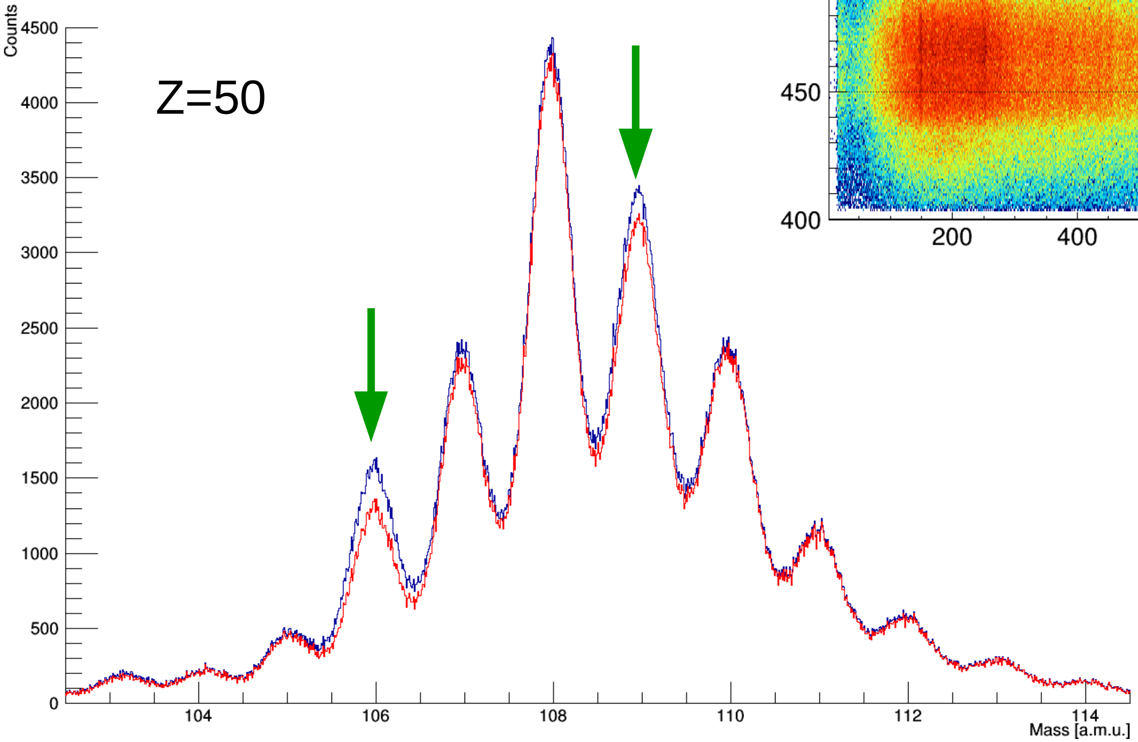




By gating on E_{TOT}, it separates the multi-nucleon transfer event from the inelastic scattering ones.

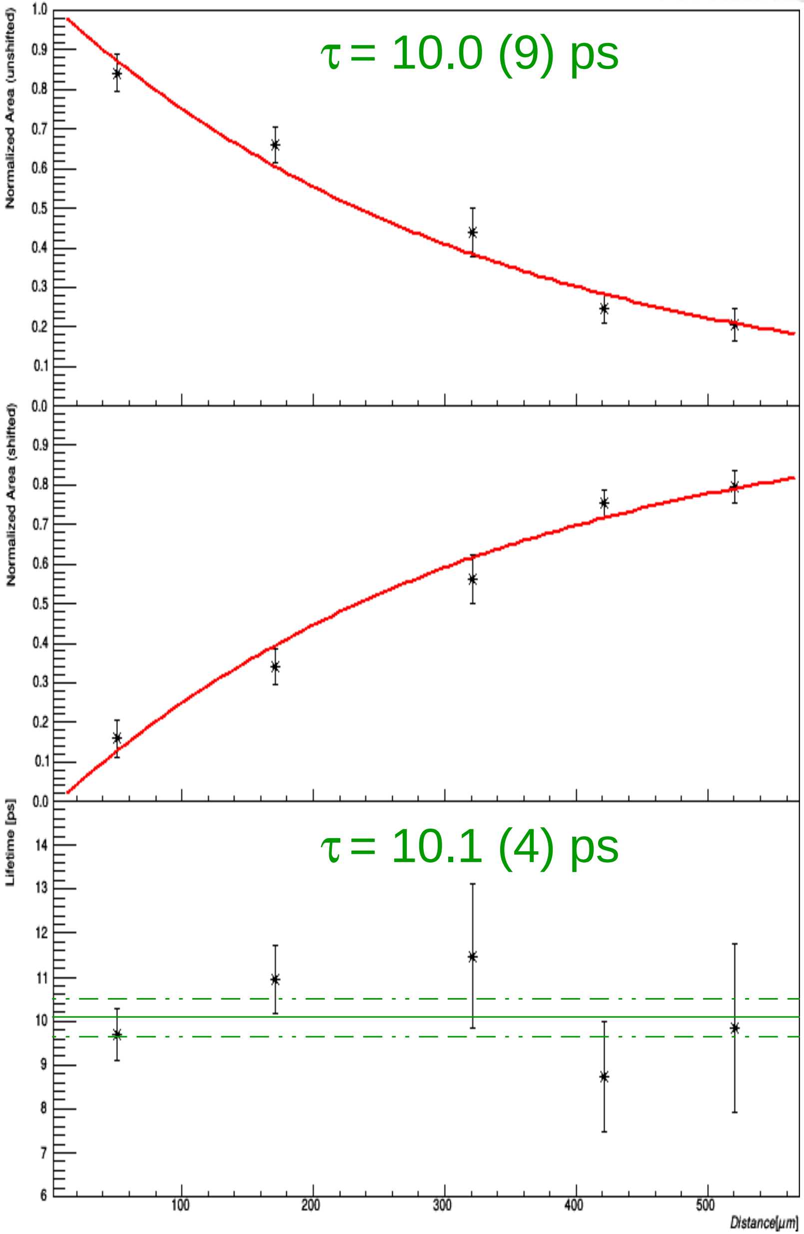
PID – Mass

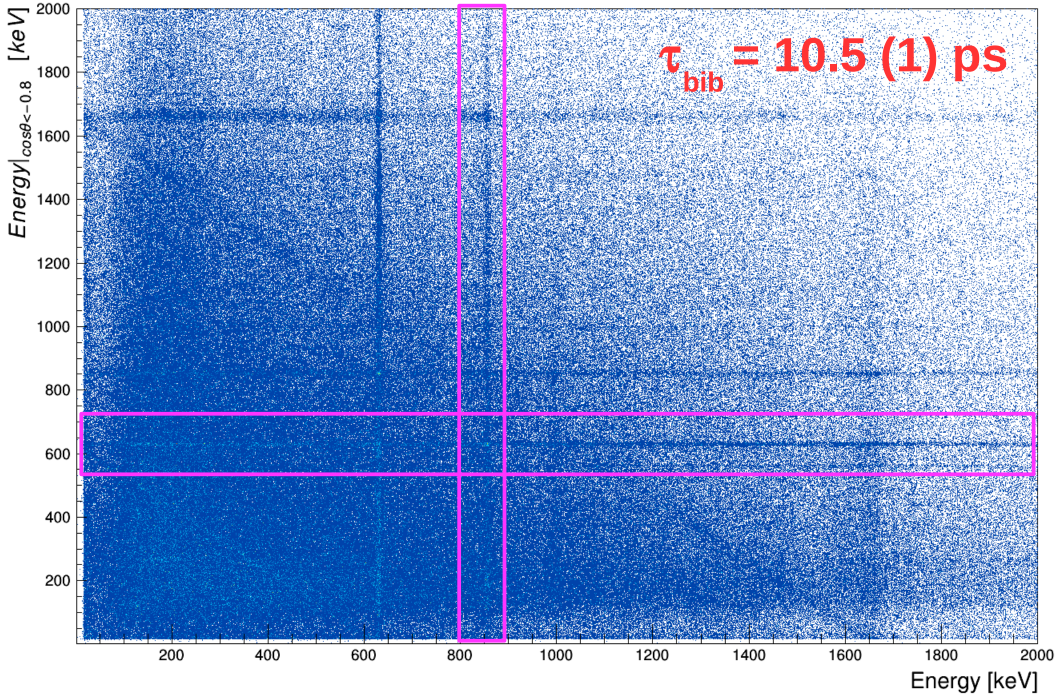




By gating on E_{TOT}, it is possible to reduce the contaminations from the inelastic-scattering events, without rejecting good events.

106Cd

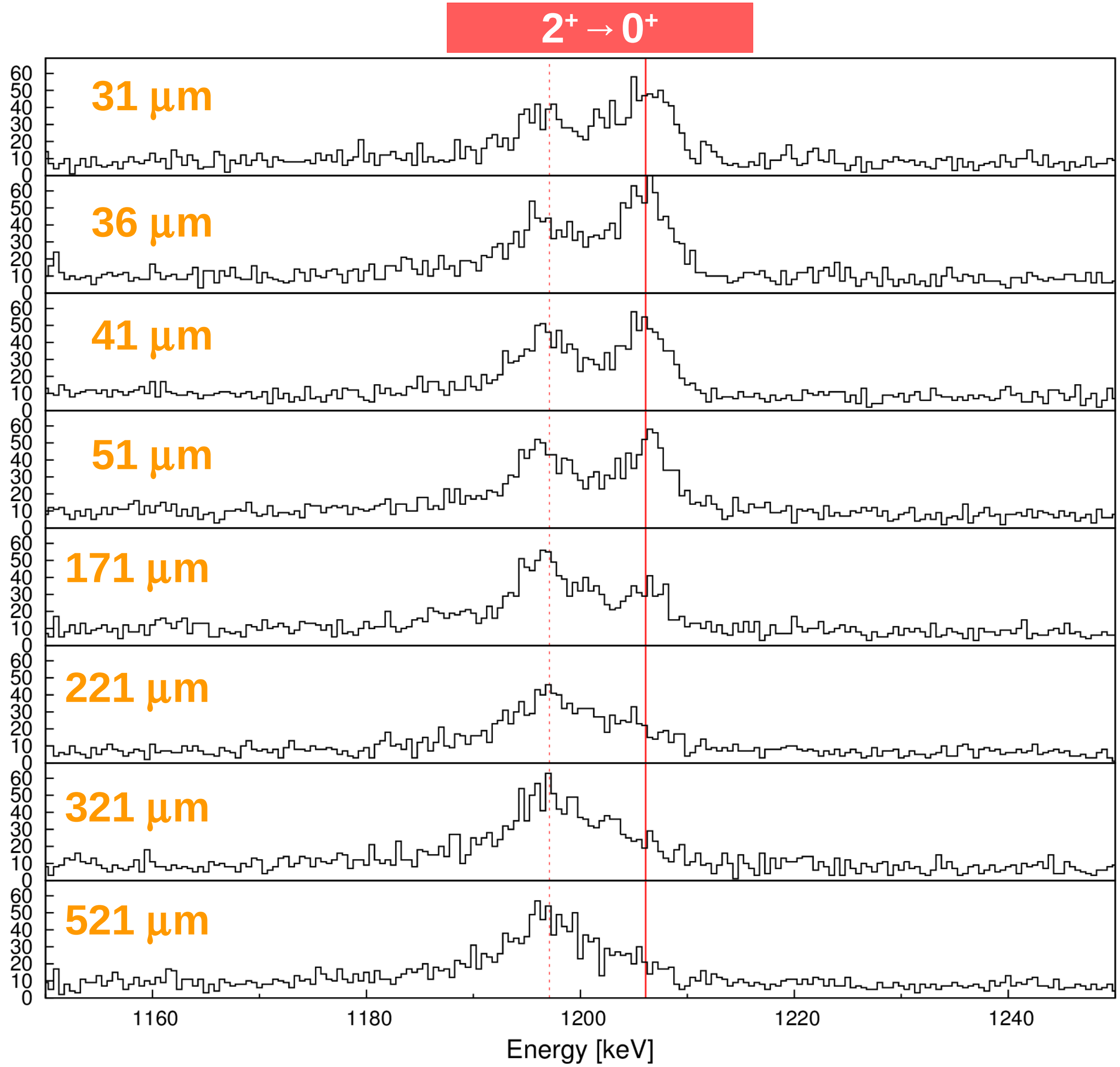




Gating on the shifted component of $4_1^+ \rightarrow 2_1^+$ transition, the lifetime of $2_1^+ \rightarrow 0_{gs}^+$ transition can be measured via Differential Decay Curve Method (DDCM).

$$\tau = \frac{I_A^u(x)}{\frac{d}{dx} I_A^s(x)} \cdot \frac{1}{v}$$

108Sn



The transition of interest $2^+ \rightarrow 0^+$ and $4^+ \rightarrow 2^+$ are clearly visible.

The energy of the $8^+ \rightarrow 6^+$ transition (1196 keV) is similar to the energy of the $2^+ \rightarrow 0^+$ shifted component: Qvalue gate is required to reduce the possible feeding from this state.

CONCLUSIONS

- Reduced transition probability provides information about the collective behaviour of the nucleus.

- The tracking in AGATA has been optimized in order to improve both the P/T and the efficiency

- VAMOS++ provides a complete identification of the recoils, giving informations on the velocity vector, the atomic number Z and the mass A.

- Coupling AGATA detectors with the mass spectrometer allows to select the channel of interest.
  Moreover, thanks to the unique performances of AGATA and VAMOS++ it is possible to apply a more precise event-by-event Doppler correction, which improves the sensibility of the lifetime measurement via Doppler-shift techniques.

- The lifetime of the first 2^+ of ^{106}Cd has been measured via DCM and DDCM in order to check plunger absolute distances and to validate the experimental method.

- ^{108}Sn clearly visible, but a Q-value gate may be necessary to reduce the feeding from higher excitation energy states. More work is required for ^{106}Sn because of the possible contamination from the inelastic beam.

M. Siciliano[1,2], J.J. Valiente-Dobón[2], A. Goasduff[2], D. Bazzacco[1,3], G. Benzoni[4], T. Braunroth[5], N. Cieplicka[4], F.C.L. Crespi[4,6], E. Clement[7], G. de France[7], M. Doncel[8], S. Ertürk[9], C. Fransen[5], A. Gadea[10], G. Georgiev[11], A. Goldkuhle[5], U. Jakobsson[12], G. Jaworski[2], P.R. John[1,3], I. Kuti[13], A. Lemasson[7], A. Lopez-Martens[11], H. Li[12], S. Lunardi[1,3], T. Marchi[2], D. Mengoni[1,3], C. Michelagnoli[7], T. Mijatovic[14], C. Müller-Gatermann[5], D.R. Napoli[2], A. Navin[7], J. Nyberg[15], M. Palacz[16], R.M. Pérez-Vidal[10], M. Rejmund[7], B. Sayği[2,17], D. Sohler[13], S. Szilner[14], D. Testov[1]

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