Isospin nature of

Nature of Pygmy Dipole Excitation in ^{74}Ge

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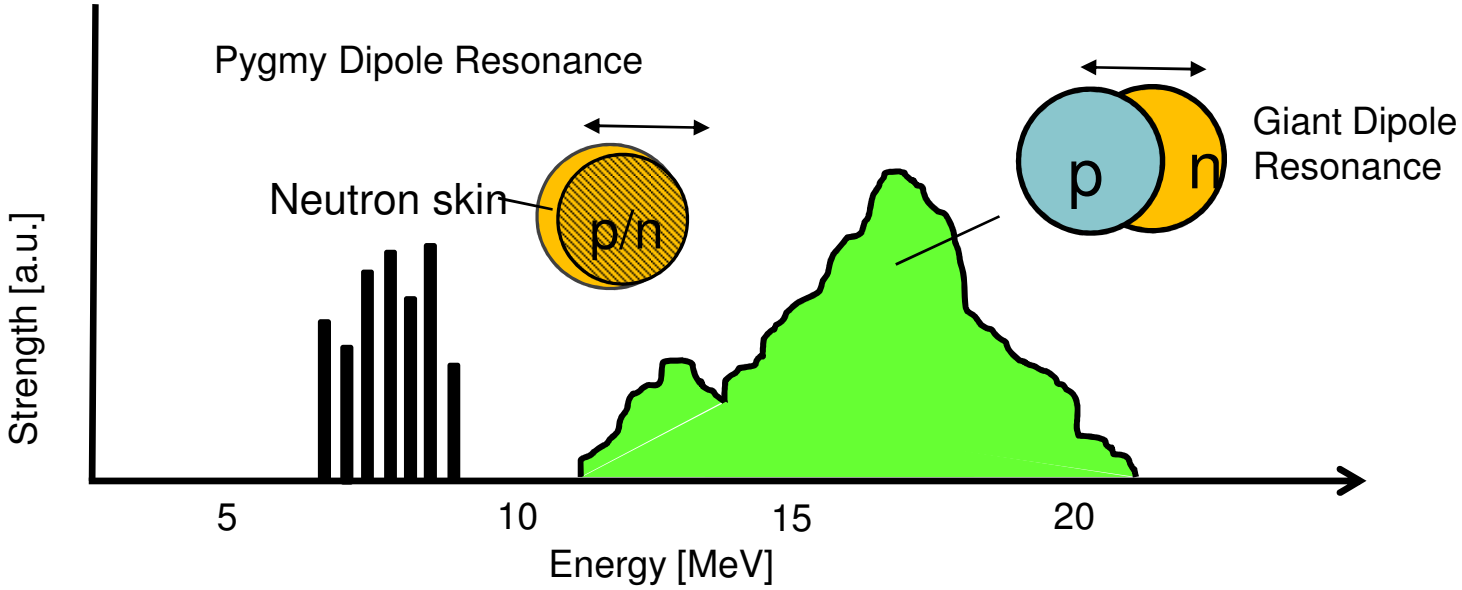
The Pygmy Dipole Resonance



- Enhanced strength at the low energy tail of GDR
  (exhaust ~ 1-2 % of EWSR)
- Between *Ex* = 5 to 10 MeV
- Macroscopically Oscillation of neutron skin against core (isospin saturated) R. Mohan, M. Danos, L.C. Biedenharn, Phys. Rev. C 3 (1971) 1740.
- First observed in late 1950's .
  G.A. Bartholomew, Annu. Rev. Nucl. Sci. 11 (1961) 259

The Pygmy Dipole Resonance

Relevance in other areas

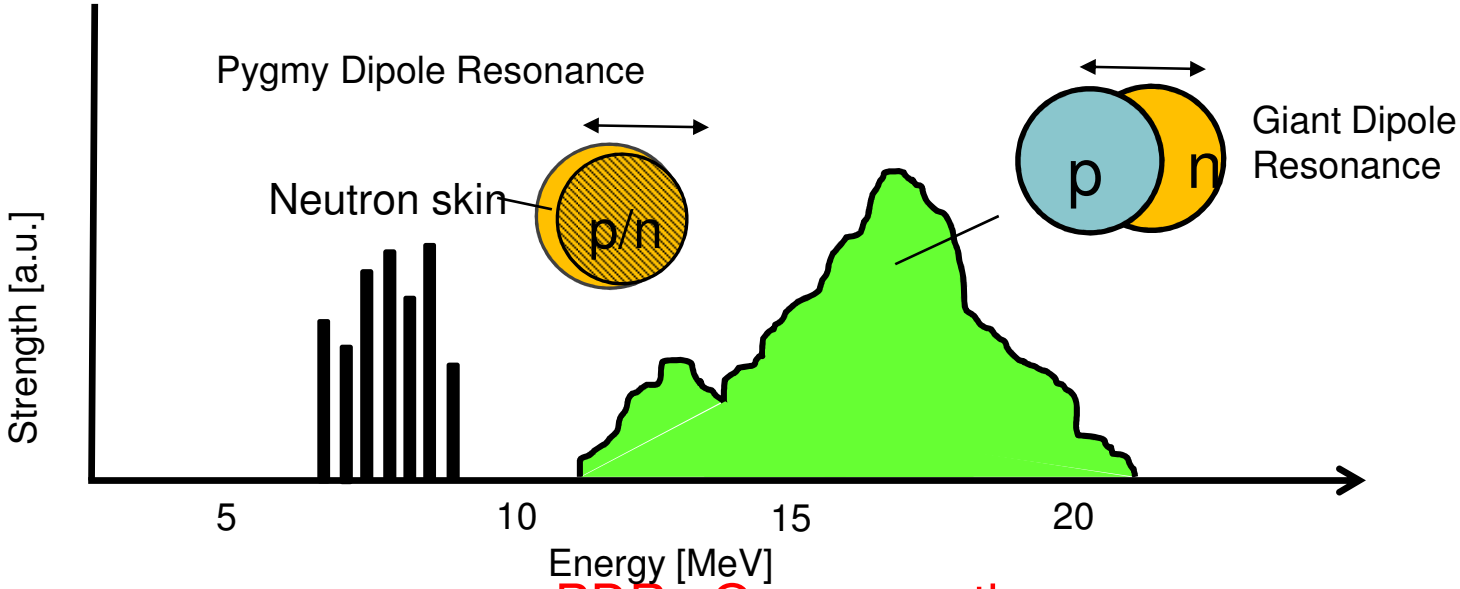
- Determination of neutron skin thickness (rn-rp)
  A Klimkiewicz et al., Phys. Rev. C 76 (2007) 051603(R)

- Equation of state of neutron rich matter
  J. Piekarewicz, Phys. Rev. C 73 (2006) 044325

- Influence on nucleosynthesis processes
  S. Goriely, Phys. Lett. B 436 (1998) 10

- Supernova explosion mechanism
  J. Piekarewicz, Phys. Rev. C 73 (2006) 044325

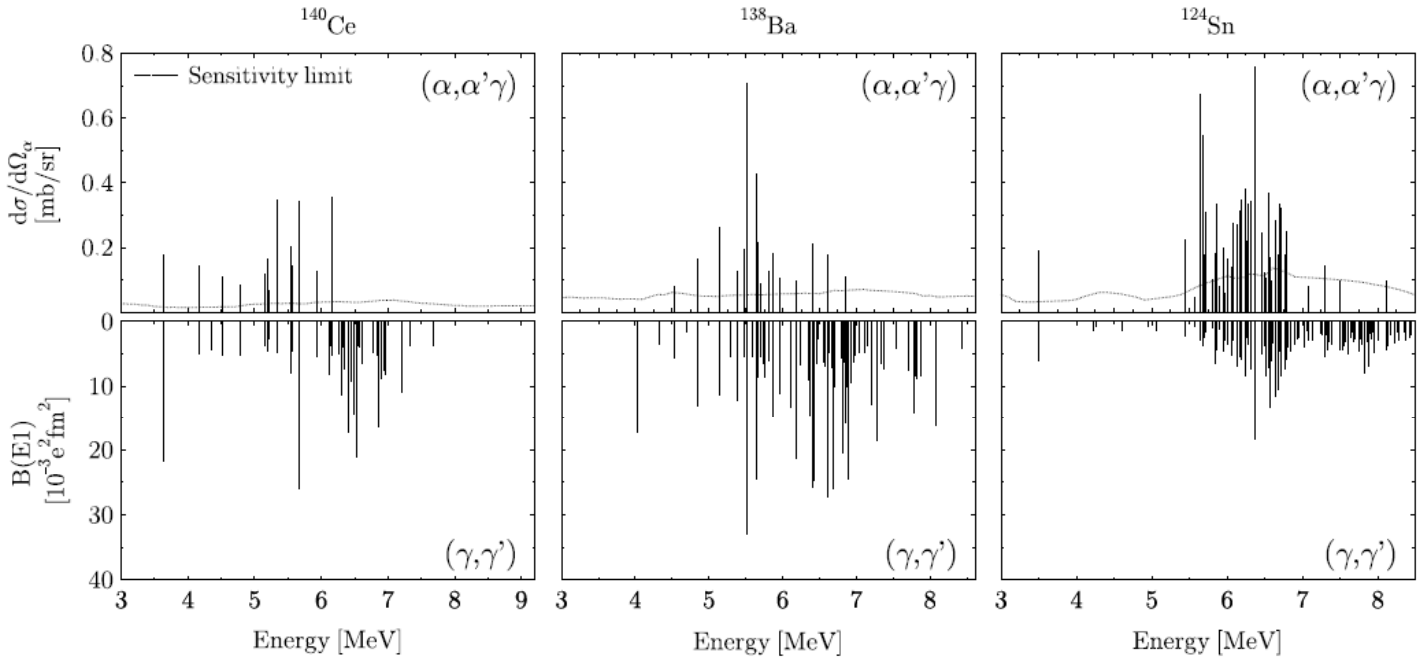
The Pygmy Dipole Resonance



PDR : Open questions

- How collective it is ?
  (different predictions from different theoretical approaches)
- What is the macroscopic picture ?
  (skin oscillation or toroidal motion)
- Does PDR depends on N/Z ?
  (increasing strength for more neutron rich Nuclei expected)
- Does proton pygmy really exists ?
- Nature of Isoscalar –isovector splitting ?

E1 Strength distribution in ^{40,48}Ca, ^{58}Ni, ^{90}Zr, ^{94}Mo, ^{140}Ce, ^{138}Ba, ^{124}Sn, ^{208}Pb (study of isospin nature)



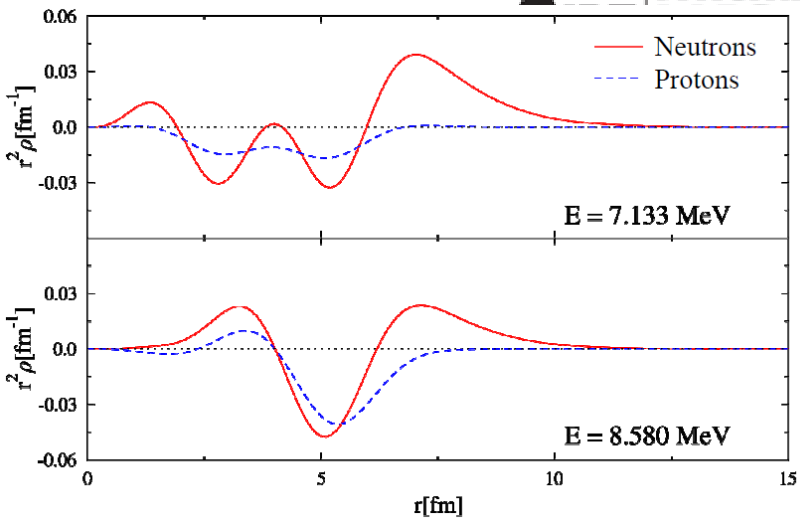
D. Savran et. al., Prog. Part. Nucl. Phys. 70, 210 (2013)

- Excitation by complementary probes : α, γ ,^{17}O
- Separation of excitation in two regions
- Higher excitation region not populated in (α, α'γ) reactions mostly pure isovector nature
- Lower energy part populated in both the reaction mixed isospin nature

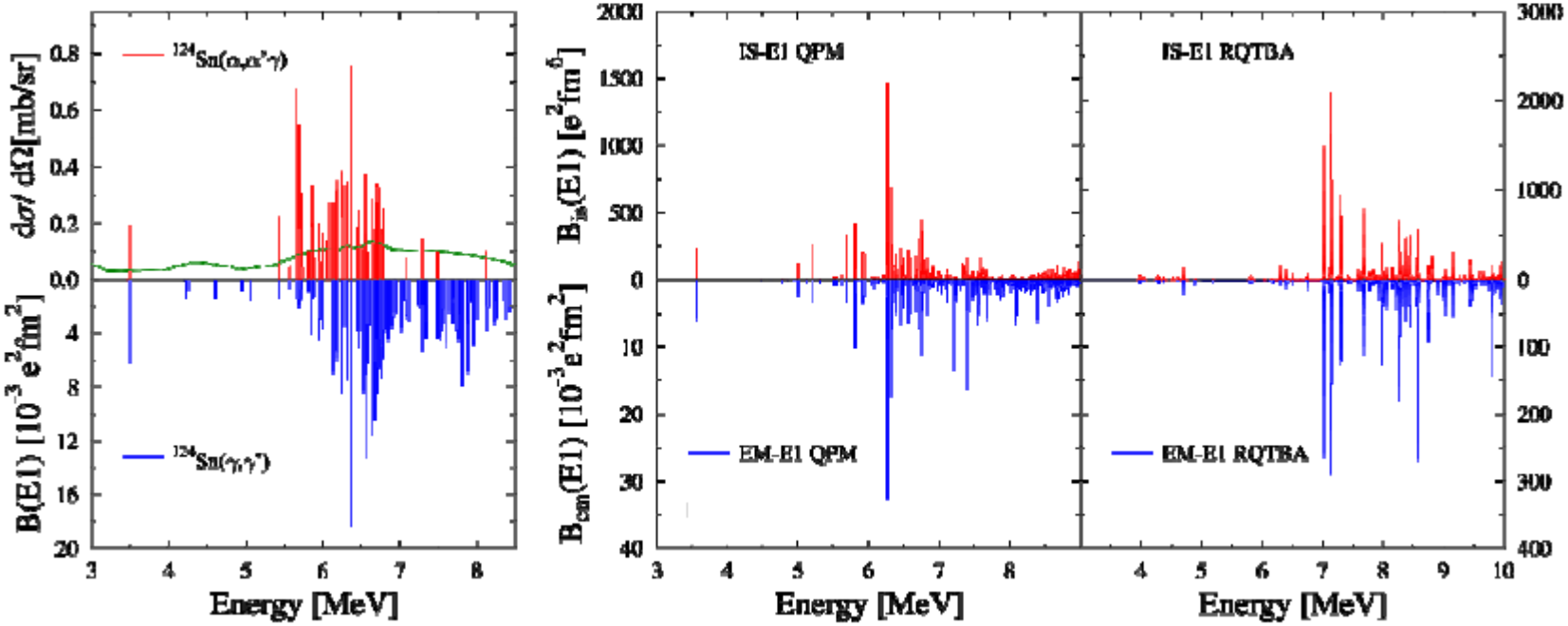
Comparison of theory and experiment

Relativistic Quasiparticle Time Blocking Approximation
Relativistic Random Phase Approximation + RHB

E. Litvinova et. al., PRC 78, 014312 (2008)
N. Paar et. al., PRL 103, 032502 (2010)



Transition densities in RQTBA



Experiments in new domain

- The study is limited to few nuclei in the nuclear chart
- Mostly limited to nuclei large charge asymmetry
- Explore nuclei closer to N/Z =1
- ^{74}Ge chosen as a test case
  - (γ, γ') experiment performed at Dresden, Germany.
  - (α,α') scattering experiment performed at iThemba LABS

The Pygmy Dipole Resonance

Probing isospin nature

α scattering versus real photon scattering

Use of complementary probes to reveal details of structure

.

Photon scattering : (electromagnetic interaction)	- dominant isovector excitation - interaction with whole nucleus (kR << 1)
α scattering : (hadronic interaction)	- dominant isoscalar excitation - interaction dominant at the surface

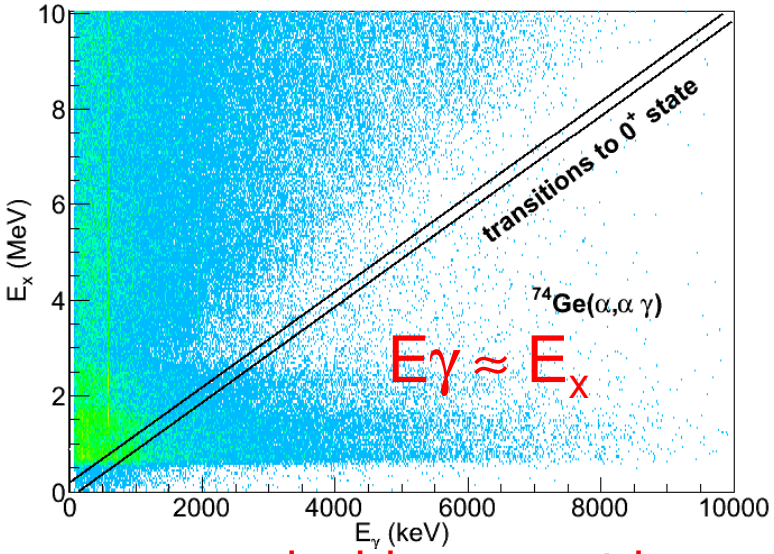
Recent advances in experimental techniques

Scattered particle detection + Gamma array of Ge detectors
(Magnetic spectrometer/Si telescope detectors)

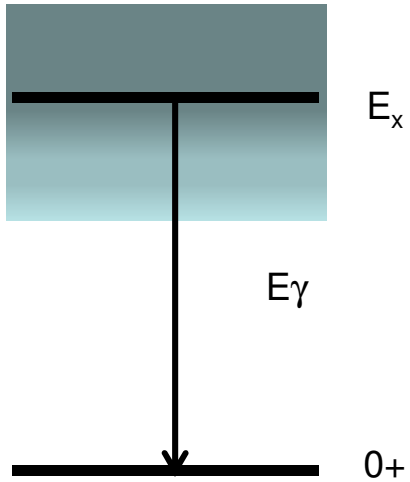
D. Savran et. al., NIM 564, 267(2006)

Experimental technique for the study of Pygmy dipole resonance

- Excitation energy of the system from the inelastically scattered alpha particles.
- Simultaneous detection of γ decaying to the ground state.



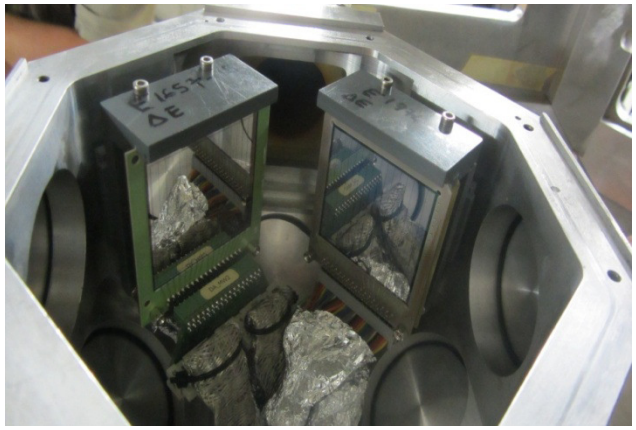
$\alpha - \gamma$ coincidence matrix



Good selection of $J^{\pi} = 1^-$ states
(for $E_x > 5$ MeV in even-even nucleus)

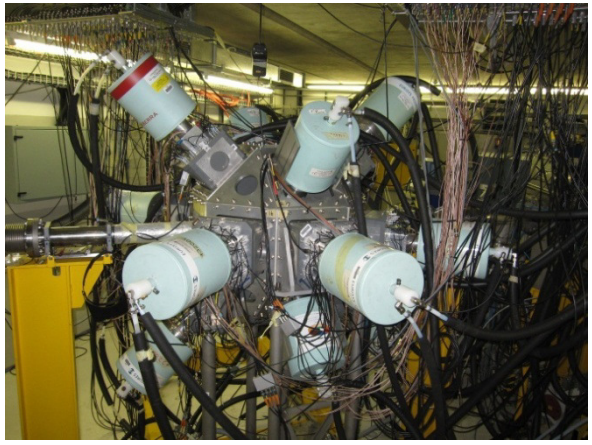
Experimental details

Population of excited states via inelastic scattering of ^{74}Ge using the following reaction $^{74}Ge(^{4}He, ^{4}He')^{74}Ge$ @ 48 MeV

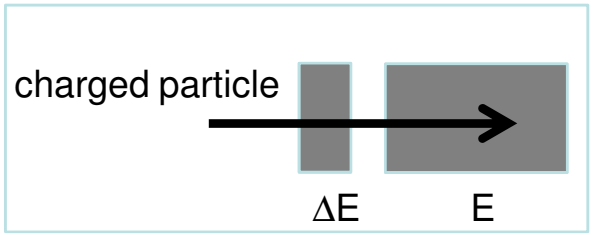


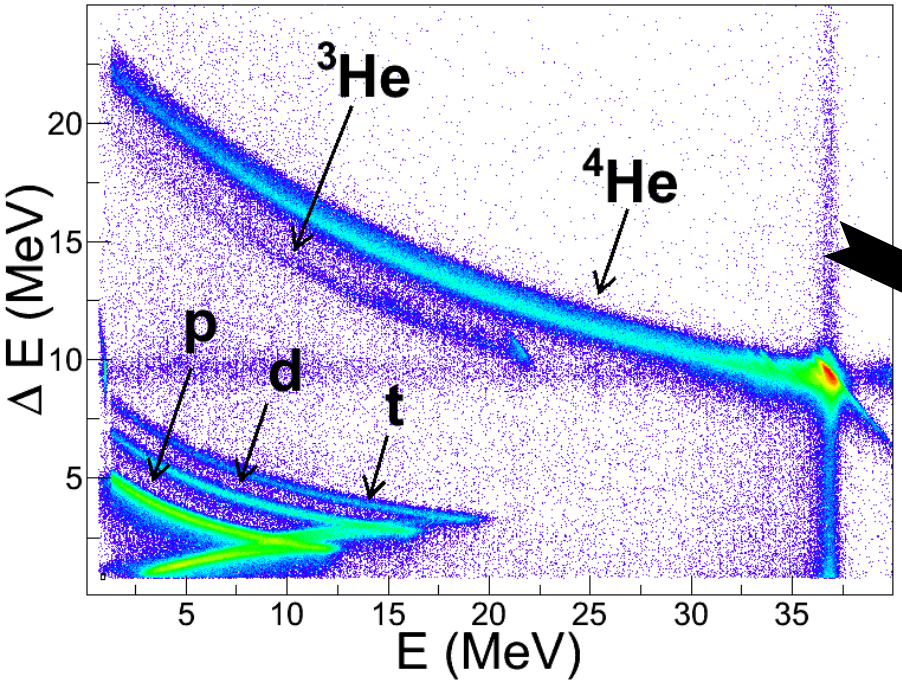
For the detection of
charged particles
Telescope counters
(Double sided) Silicon Strip Detectors
Two Counters
Thickness (ΔE) = 284 μm
Thickness (E) = 980 μm
At ± 45 degrees with respect to the beam axis

For the detection of γ-rays
HPGe detectors in Clover arrangement
Nine Clover detectors.
(AFRODITE Array at iThemba LABS)



RESULTS

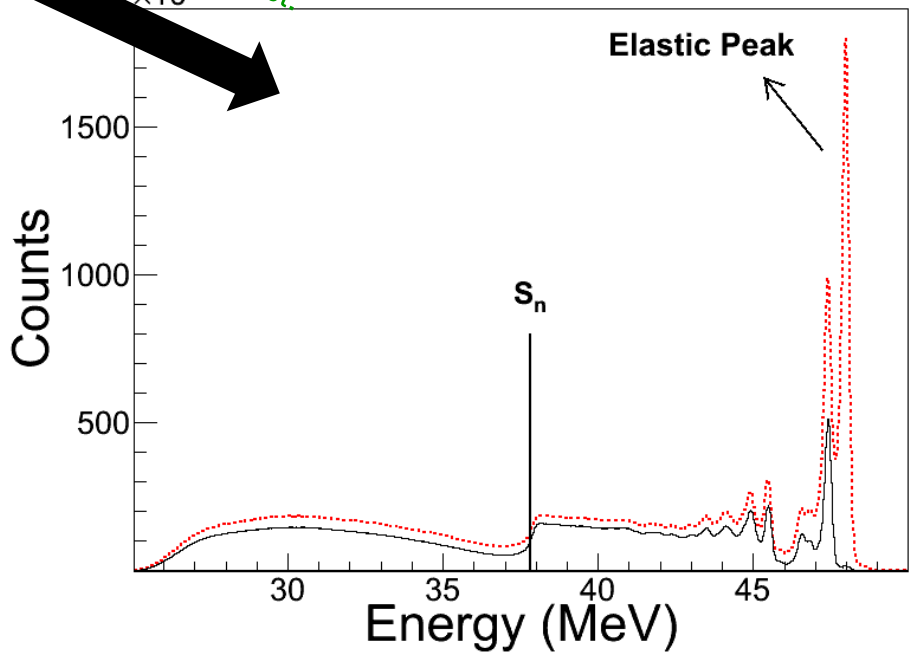




Raw Particle Identification plot

Kinematic corrections.
Energy loss corrections
in absorbers and target.

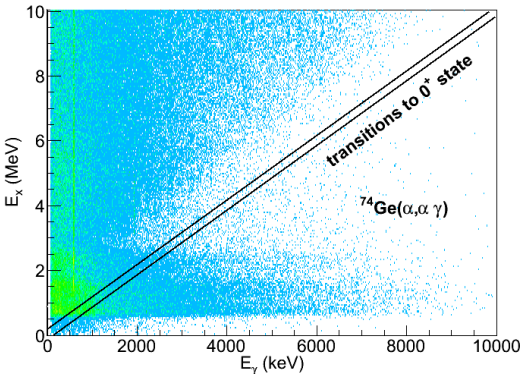
α particle spectrum
(with γ in coincidence)



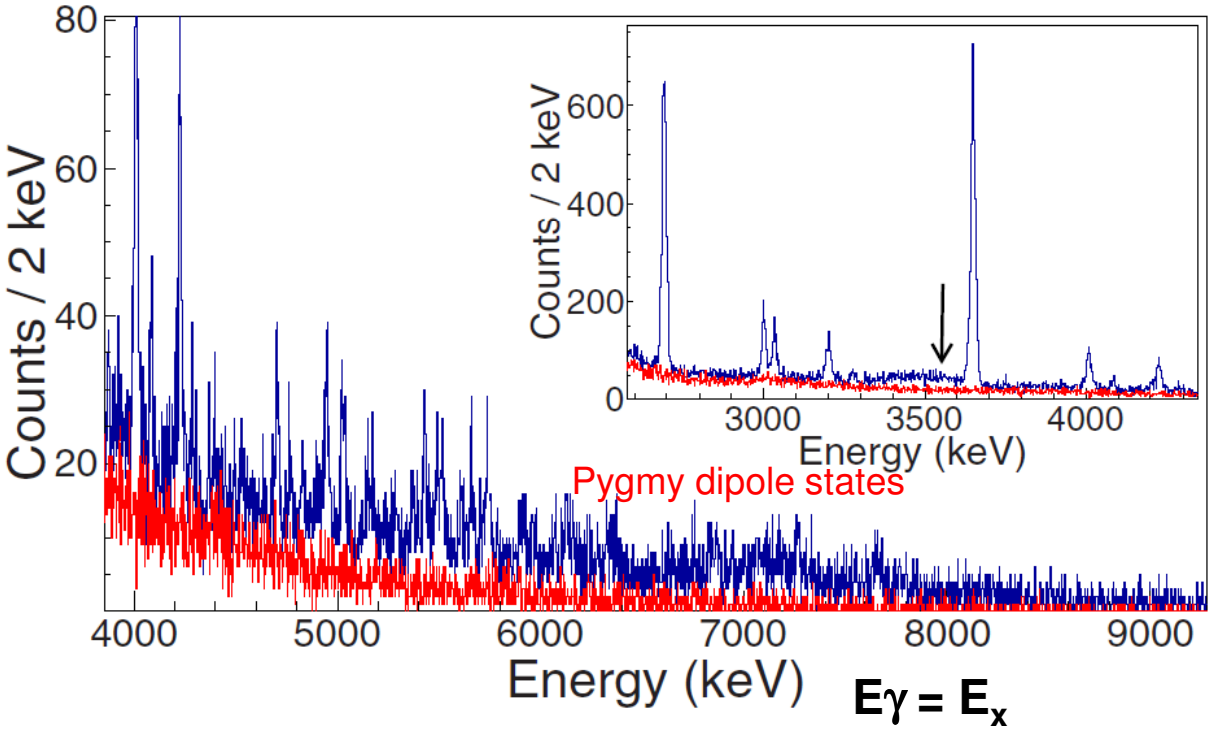
Red data are random events
Blue data are after random subtraction
Energy resolution ~ 250 keV

RESULTS cont....

$| E_x - E_\gamma | \; < \; 130$ keV



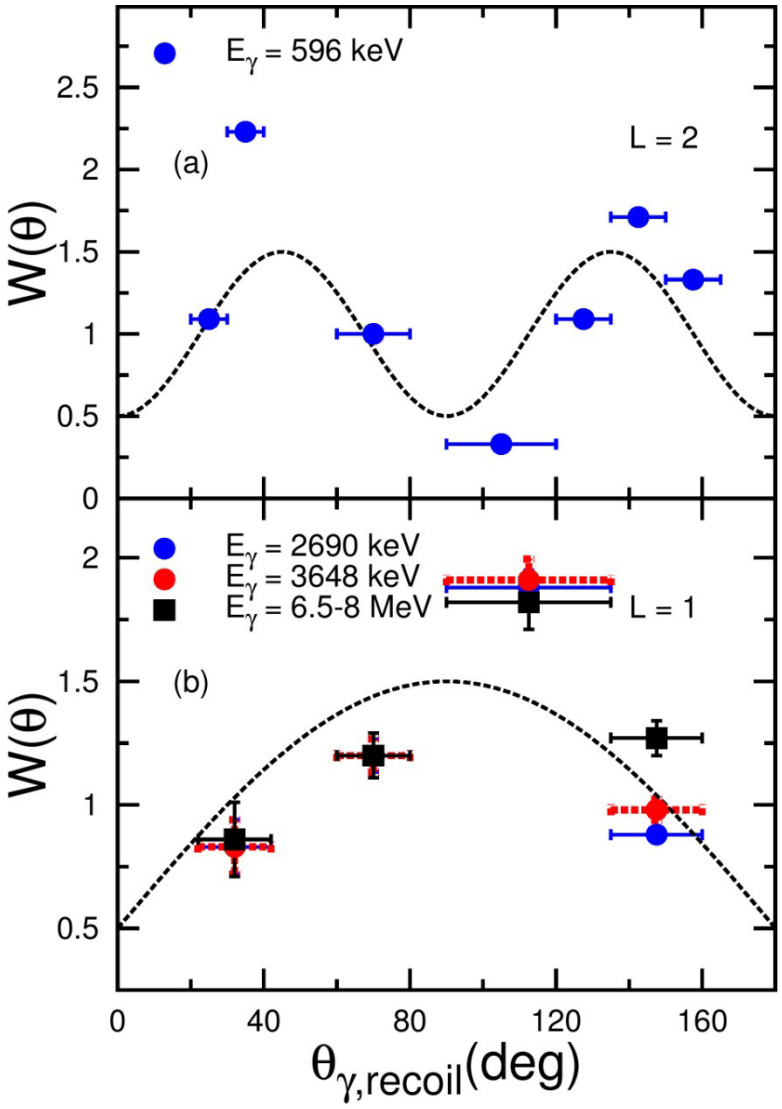
α – γ coincidence matrix



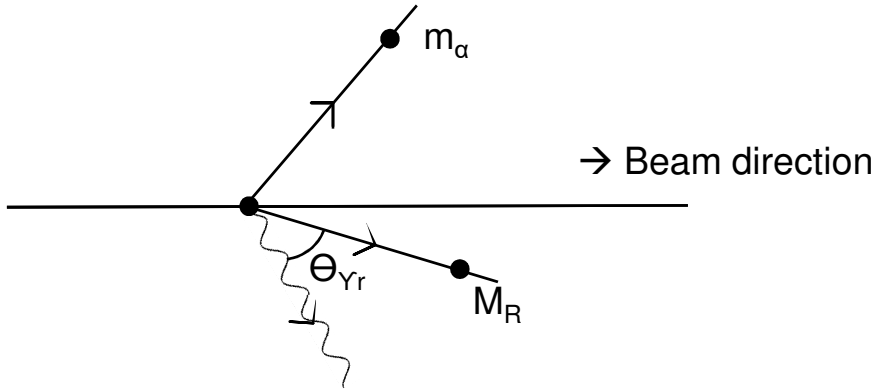
Eγ = E_x

Red spectrum is from uncorrelated events
Blue spectrum is contains both correlated and uncorrelated events.
"↓" indicate position of an absent transition observed in (γ , γ ') data

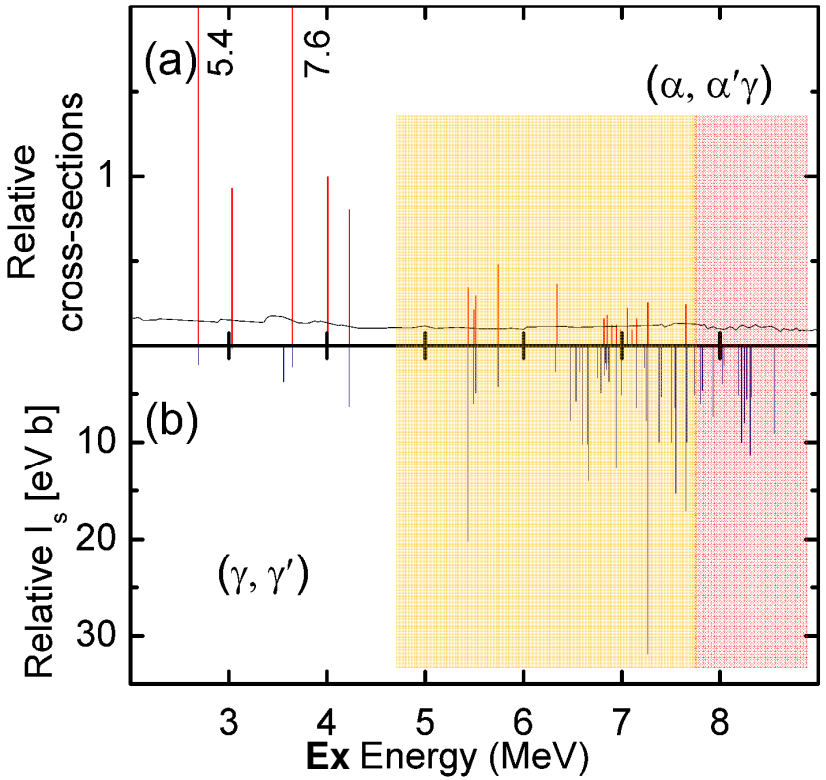
Angular distribution of the Dipole transitions



Similar angular distribution of Pygmy Dipole Excitations with the known dipole transitions



Comparison with (γ, γ')data



(a,a'γ) data from D. Negi et al., Phys. Rev. C 94 (2016) 024322.
(γ,γ') data taken from R. Massarczvk et al., Phys. Rev. C 92 (2015) 044309.

Observations :

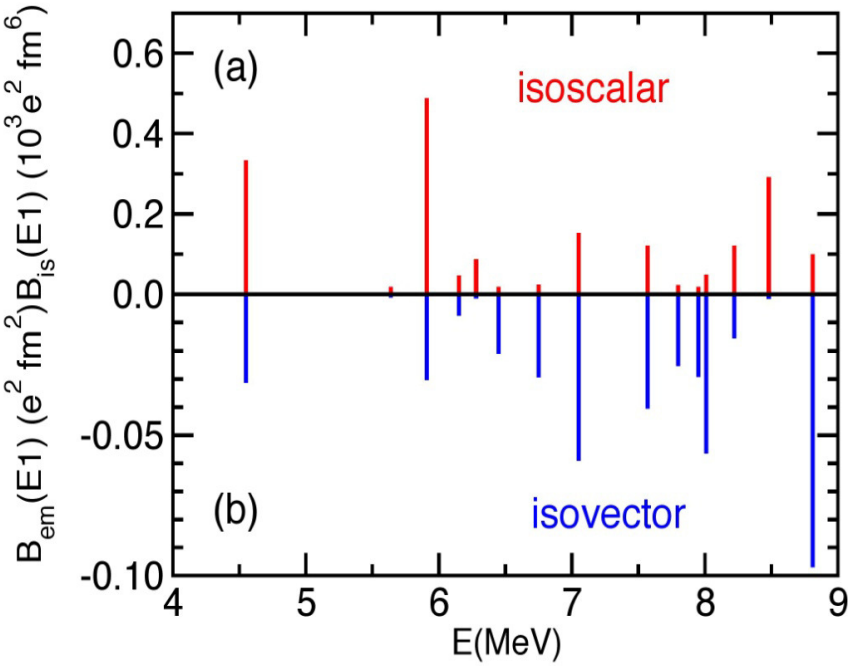
- Presence of different regions
- Dipole excitation Ex > 5.5 MeV splits into two distinctive parts
- Ex > 7.5 MeV no observable excitations in (α, α 'γ) reaction.
- Ex < 7.5 MeV observable excitations in both (α, α 'γ) and (γ, γ') reactions.

Inference :

(since alpha is isoscalar probe)

- Low energy part --> strong isospin mixing
- High energy part --> predominantly isovector

Comparison with theory



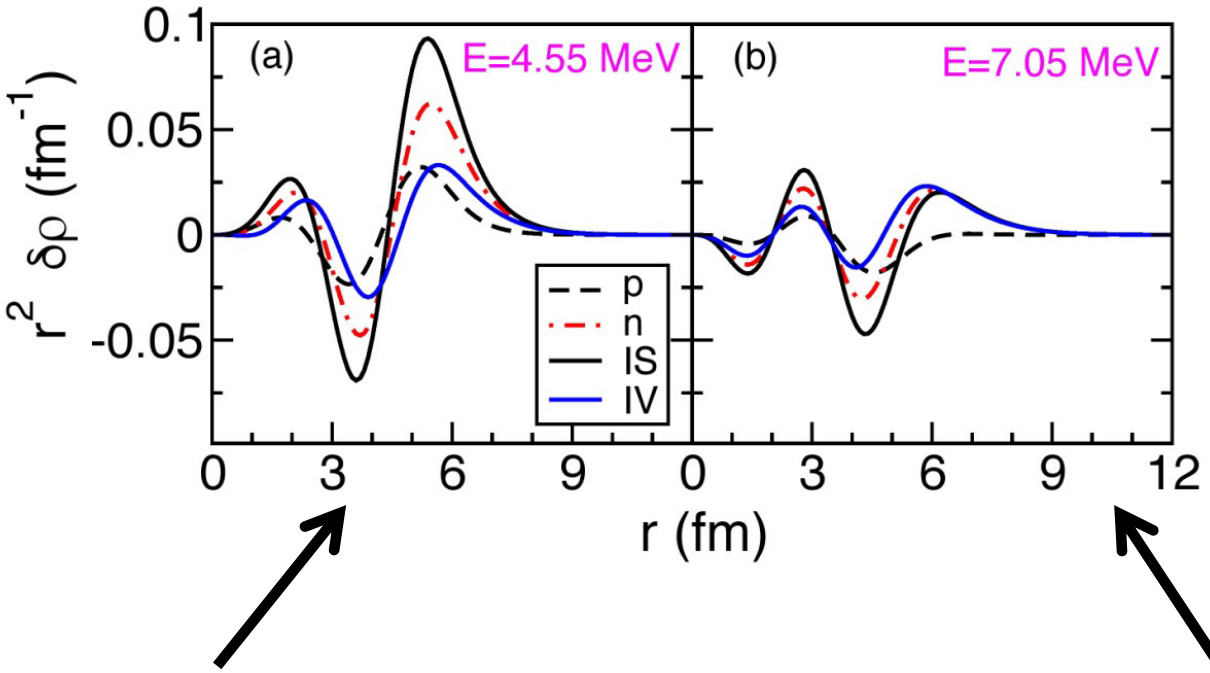
General agreement with theoretical calculation done within RQTBA
(relativistic random phase approximation)

For RQTBA calculations see
E. Litvinova et. al., PRC 78, 014312 (2008)

Thanks to E. Litvinova
NSCL, Michigan, USA

Comparison with theory

Behaviour of transition densities

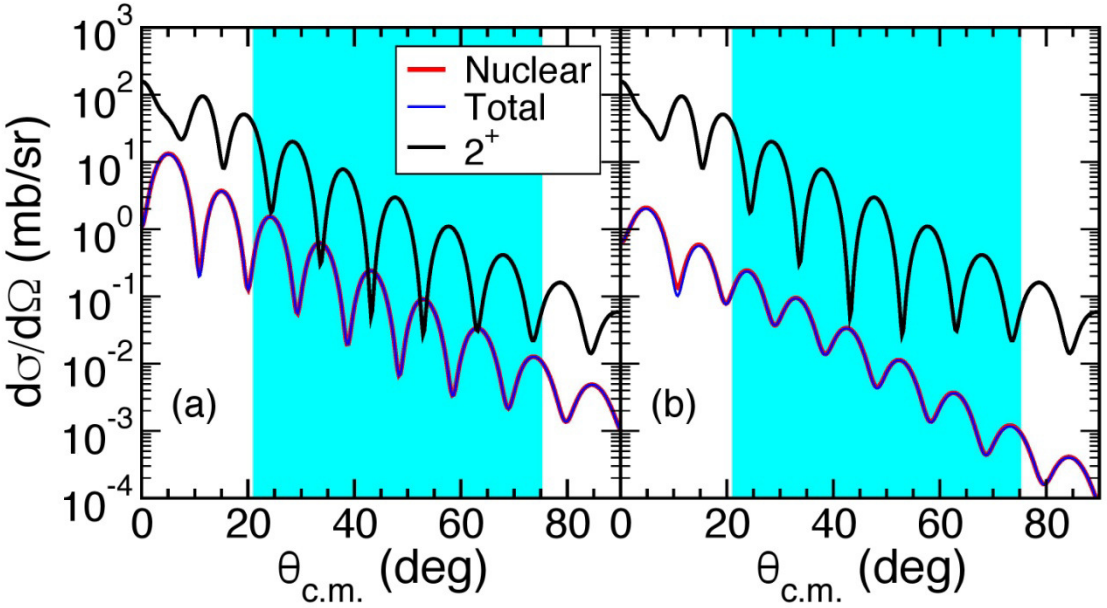


Neutron and proton transition densities are in phase both inside and at the nuclear surface (Compression mode)

Neutron and proton transition densities are in phase only in inside Contribution only from neutron at the surface (Pygmy mode)

Thanks to EG.Lanza , E.Litvinova
INFN Catania, Italy
NSCL, Michigan, USA

Contribution of Coulomb interaction



Ex = 4.55 MeV Ex = 7.05 MeV

DWBA Calculations (FRESCO code) using microscopic transition densities from RQTBA calculations.

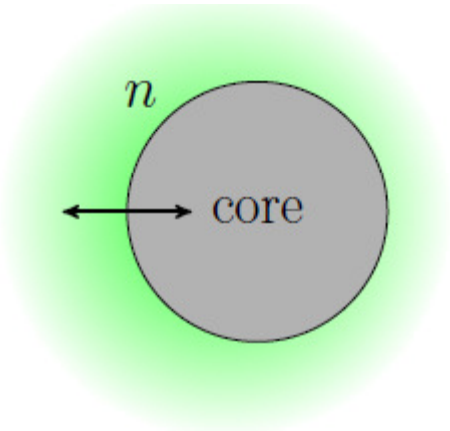
Red Curve : Only nuclear interaction
Blue curve : Nuclear + Coloumb interaction

Negligible contribution from the Coulomb interaction at both the low and high energies : Coloumb contribution is important for higher beam energies (> 30 MeV/u).

Thanks to E. Lanza and A Vitturi
INFN, Catania, Italy

Conclusions :

- We adhered to the recent findings of isospin splitting of dipole excitations in ^{74}Ge.
- Extended this our to nuclei with lower charge asymmetry.
- Scenario of neutron skin oscillation against the core is supported by RQTBA calculations.
- Possibility of using Si Telescopes for these measurements has been explored.



Collaboration

South Africa

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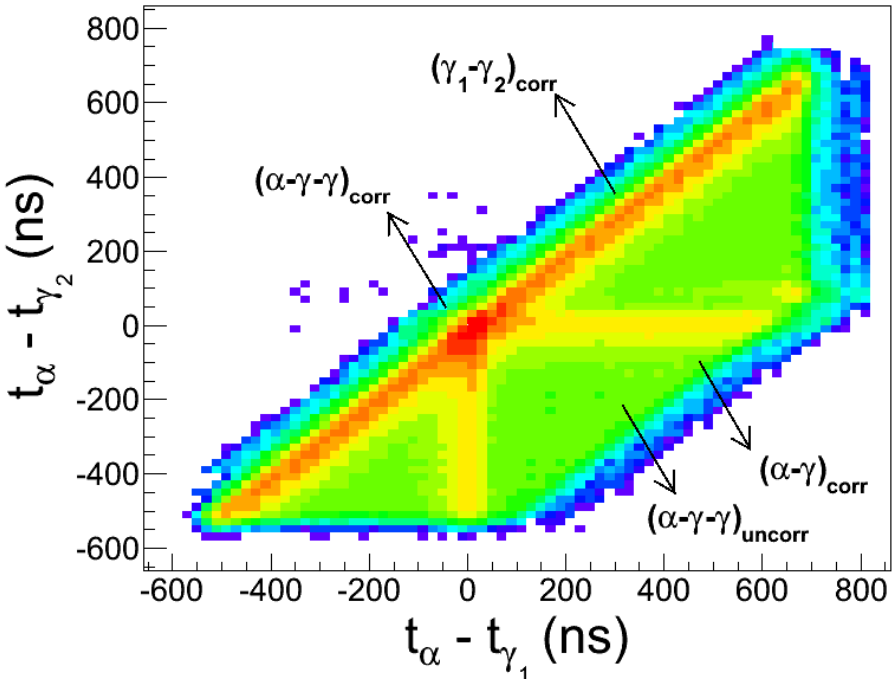
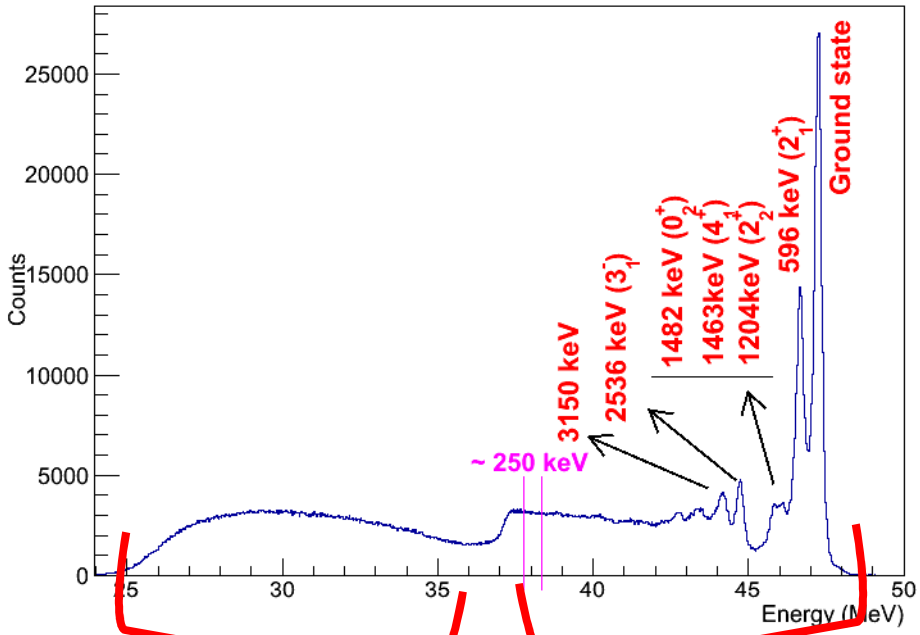
Thank You

- Time relationships



RESULTS cont....

Particle Spectrum with α banana gate



γ-ray Spectrum