UNIVERSITÀ DEGLI STUDI DI MILANO

DIPARTIMENTO DI FISICA

INFN

Study of Nuclear Collective Modes Using High-Resolution Gamma-Ray Spectroscopy

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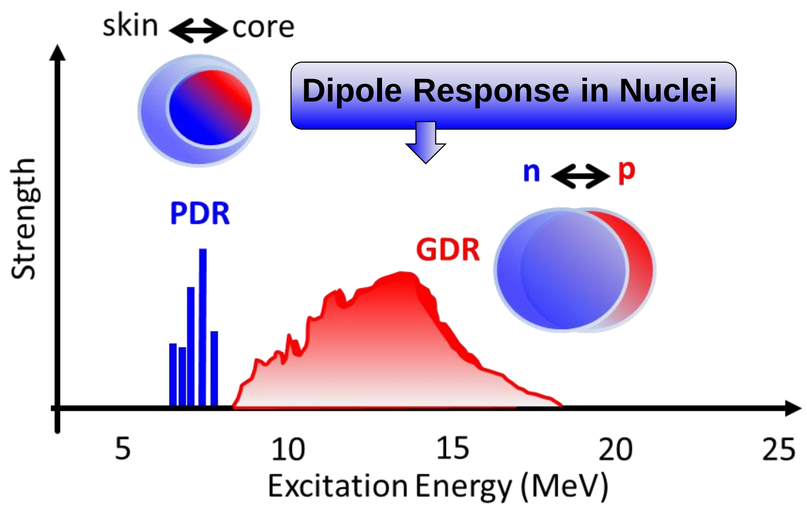
*On Behalf of the Gamma Milano Collaboration**

❑ Giant and Pygmy Resonances

Collective phenomena are a common feature of strongly interacting many-body quantum systems and atomic nuclei also show collective behavior. A prime example of this is given by the giant resonances.

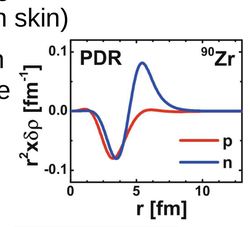


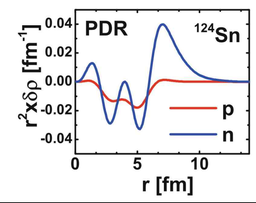
Giant resonances can be seen as vibrations of the density or shape of the nuclear system around an equilibrium value. The best studied giant resonance is the so-called **Isovector Giant Dipole Resonance (IVGDR), which is a collective dipole oscillation of protons versus neutrons**.

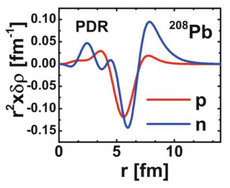
We aim at studying a new collective mode (called **pygmy dipole resonance, PDR**), originating from an oscillation of the N=Z core against the neutron skin in neutron rich nuclei.

❑Peculiar Features of the PDR States:

- originated in nuclei with N/Z > 1 by the excitation of the neutron excess (their strengths are more intense in the exotic nuclei with neutron skin)
- *n* and *p* **transition densities** in phase inside the nucleus, at the surface only the neutron part survive
- strong mixing of isoscalar and isovector character







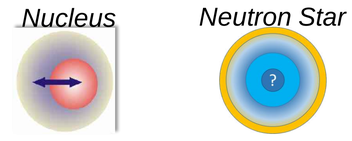
Implications beyond nuclear structure

The derivative of the symmetry energy at saturation is related to the slope parmeter ***L***

$$S(\rho) = J + \frac{L}{3\rho_0}(\rho-\rho_0) + \frac{K_{sym}}{18\rho_0^2}(\rho-\rho_0)^2 + \dots$$

"*L*" is related to the *Pressure* from the symmetry energy for pure neutron matter in neutron stars

Nucleus *Neutron Star*

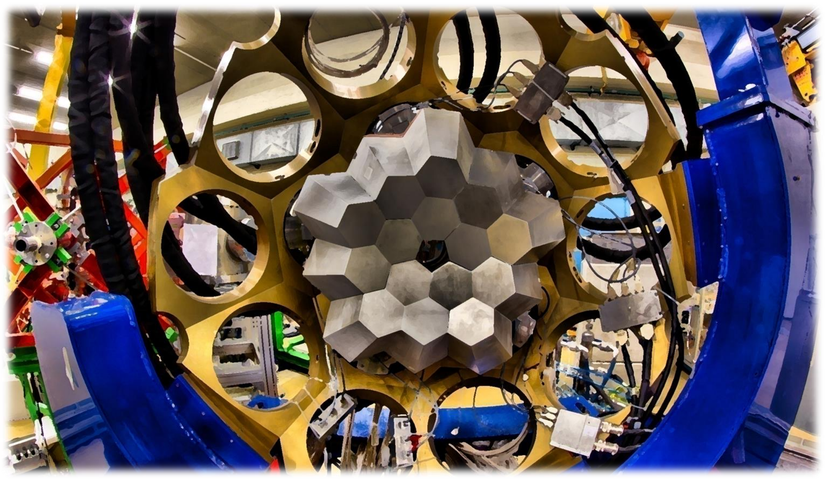


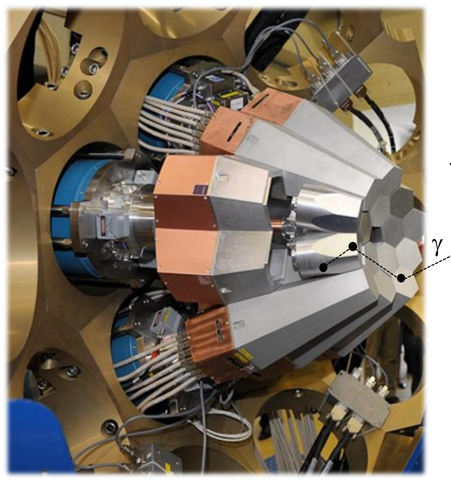
In both cases the radius depends on the knowledge of equation of state of neutron rich matter.

❑ The Advanced GAmma-ray Tracking Array (AGATA)

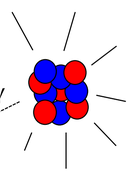
The progress in nuclear structure studies has always been closely related to the development of new generation gamma-ray spectrometers

➢ Gamma spectroscopy experiments with radioactive beams are performed in difficult conditions (low beam intensities, relevant Doppler broadening and large amount of background radiation) } *Need for New Generation γ-ray Detectors!*



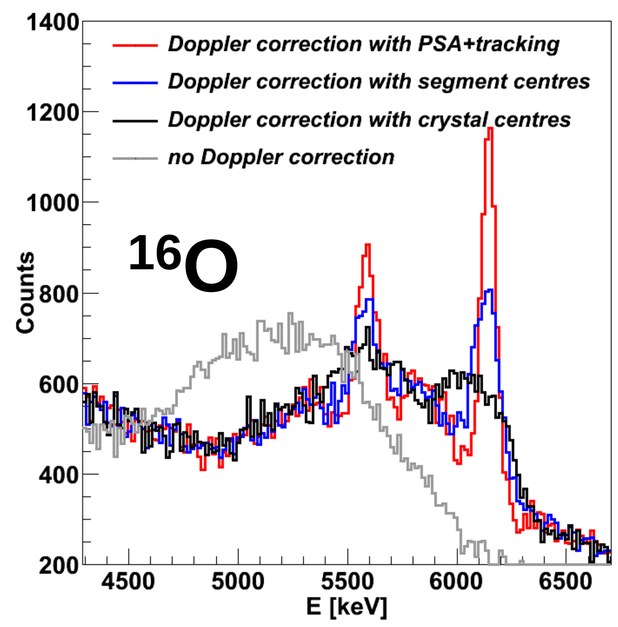


Position Sensitive, Segmented Semiconductor HPGe detectors



AGATA ADVANCED GAMMA TRACKING ARRAY

These detectors are capable of reconstructing the track of the gamma rays (gamma-ray tracking).

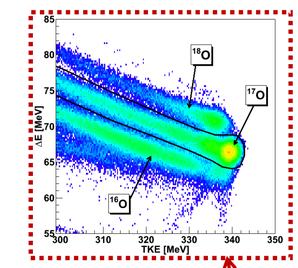


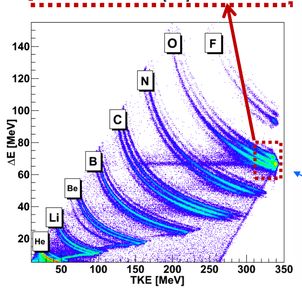
The AGATA array has been hosted in different European laboratories: Laboratori Nazionali di Legnaro (LNL-INFN), GSI (Darmstadt, Germany), GANIL (Caen, France)

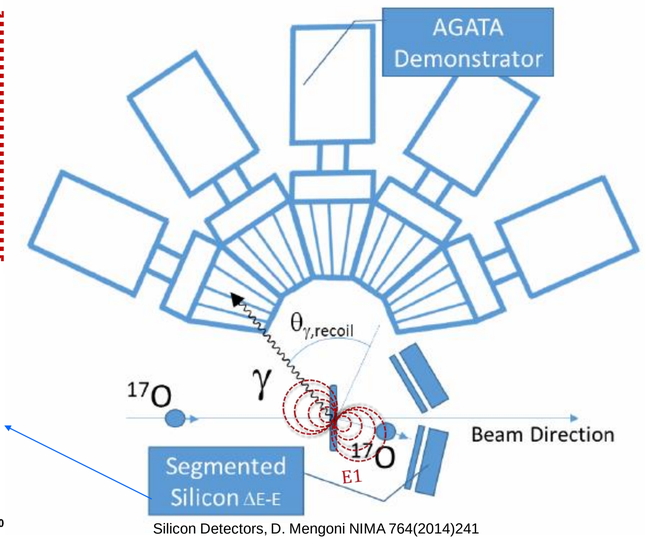
❑Gamma Decay of Pygmy Dipole Resonance (PDR) States from Inelastic Scattering of Ions

➢ *Experiments performed at Laboratori Nazionali di Legnaro (LNL-INFN)*

➢ *Inelastic scattering of ^{17}O @ 20 MeV/u on different targets + γ-rays in coincidence*





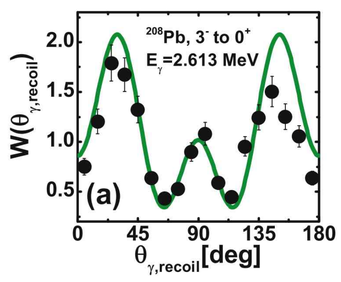


Silicon Detectors, D. Mengoni NIMA 764(2014)241

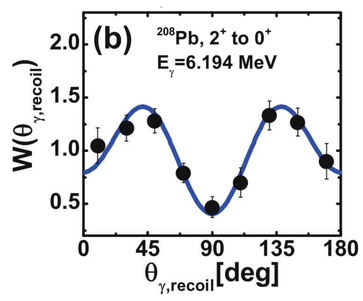
❑Angular Correlation Plots (Different Multipolarity of the Gamma Radiation)

Thanks to the position sensitivity of the AGATA detectors it was possible to obtain for the most intense transitions almost continuous angular correlation of the emitted gamma-rays relative to the direction of the recoiling nucleus

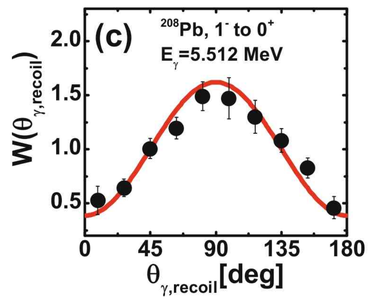
OCTUPOLE



QUADRUPOLE

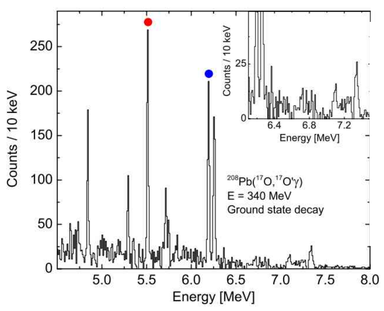


DIPOLE

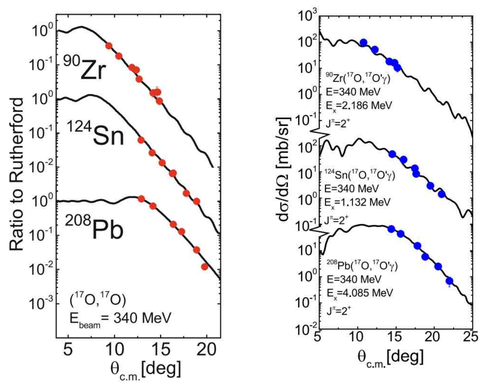


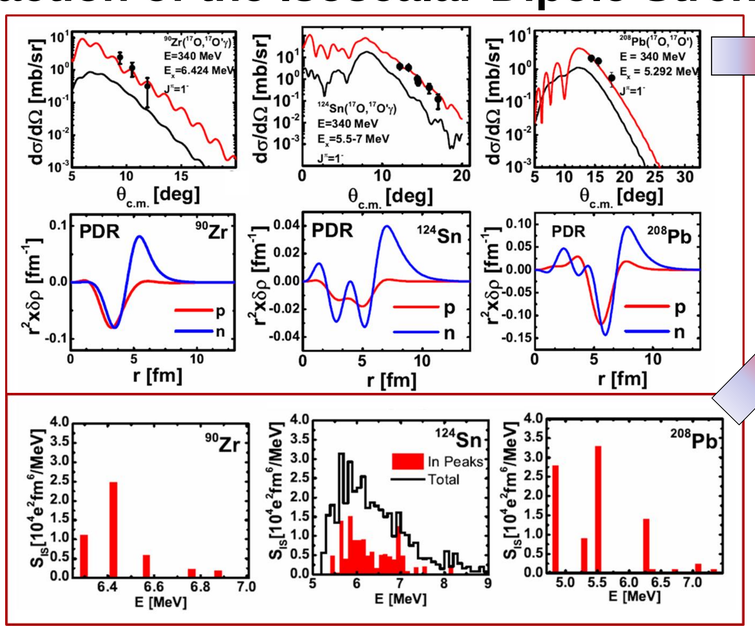
❑Differential Cross Measurements and the Extraction of the Isoscalar Dipole Strength for the PDR states

The intensities of the peaks in the **gamma spectra**, measured as a function of the ^{17}O scattering angle, were used to deduce the differential cross sections



The data analysis with the distorted wave Born approximation approach gives a good description of the **elastic scattering** and of the **inelastic excitation of the 2⁺ and 3⁻ states**





➢ predictions obtained with form factors deduced from *microscopic transition densities which incorporate the main features of these 1⁻ states*

➢ This has allowed us to extract the ***isoscalar component of the PDR states***

❑ References

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The work is done also in collaboration with several other institutions (see references): Università degli Studi di Padova-INFN Sezione di Padova, INFN Laboratori Nazionali di Legnaro, INFN Sezione di Catania, The Niewodniczanski Institute of Nuclear Physics PAN (Krakow, Poland), Institut für Kernphysik, Universität zu Köln (Germany).