Pygmy Dipole Resonance experiments @FRIB

NUSDAF 2025 - 1st Collaboration Meeting

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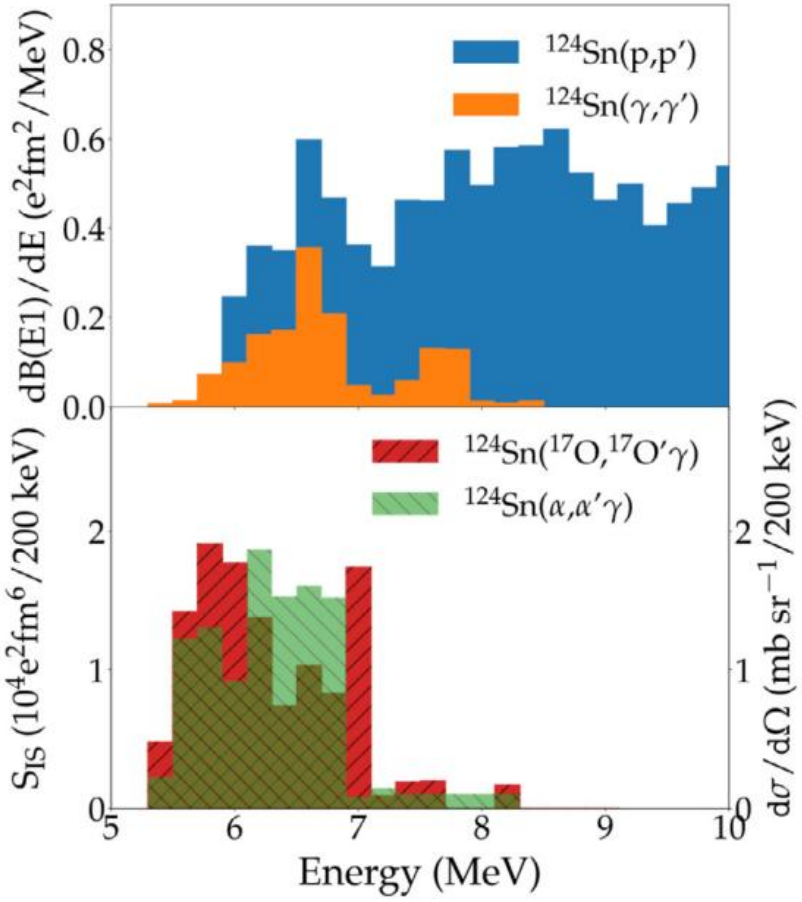
INFN-Sezione di Catania
SAMOTHRACE & CHIRONE collaboration

24-10-2025

Outline

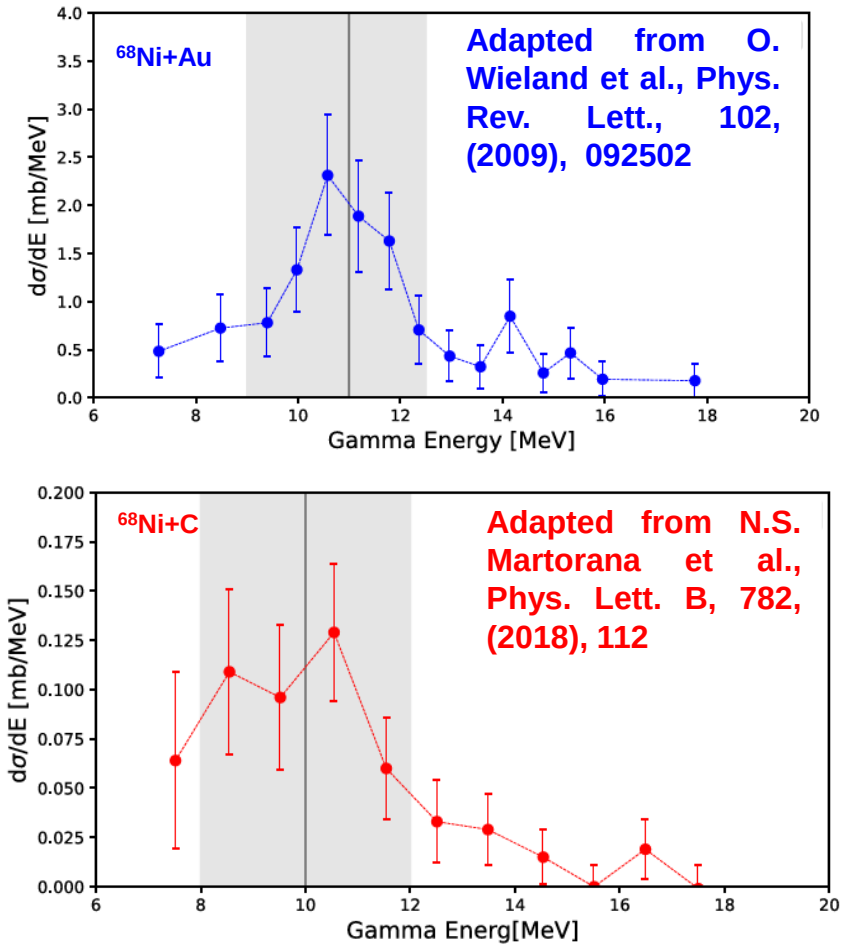
- Measurement performed in Catania @INFN-LNS
    - Pygmy Dipole Resonance in ^{68}Ni using an isoscalar probe
    - ɣ decay channel with CHIMERA & FARCOS
- New measurements @FRIB

Experiments performed on **stable nuclei** below the neutron emission threshold reveal a property known as isospin splitting



S. Bassauer, et al., Phys. Rev. C 102 (2020) 034327
Lanza E. et al., Prog. Part. Nucl. Phys., 129 (2023) 104006

The isospin splitting is not observed for **unstable nuclei** above the neutron emission threshold



Lanza E. et al., Prog. Part. Nucl. Phys., 129 (2023) 104006

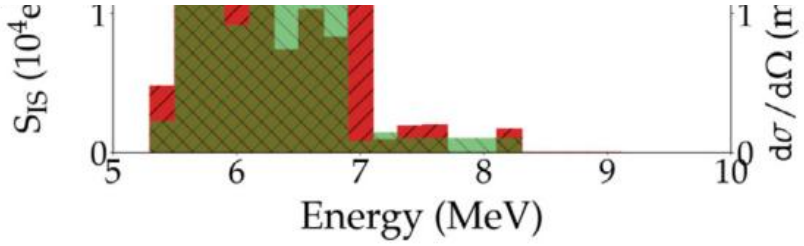
Experiments performed on **stable nuclei** below the neutron emission threshold reveal a property known as isospin splitting

The isospin splitting is not observed for **unstable nuclei** above the neutron emission threshold

Several features of the PDR are well described by the theoretical approaches and there are many experimental investigations→ **open questions remain to be clarified** (*see also E. G. Lanza et al., Progr. in Part. and Nucl. Phys., Vol 129, 2023, 104006, and references therein*)

- isospin splitting (*N.S. Martorana et al., Phys. Lett. B, 782, (2018), 112 - O. Wieland et al., Phys. Rev. Lett., 102, (2009), 092502)*
- collectivity of the PDR *(M. Spieker et al., Phys. Rev. C, 108, (2023), 014311)*
- relation of neutron excess and PDR strenght
- ….

new measurements are needed with different probes, energies, and target/projectile



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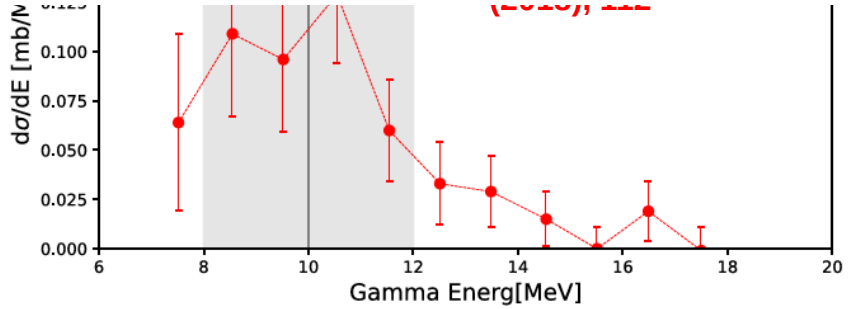
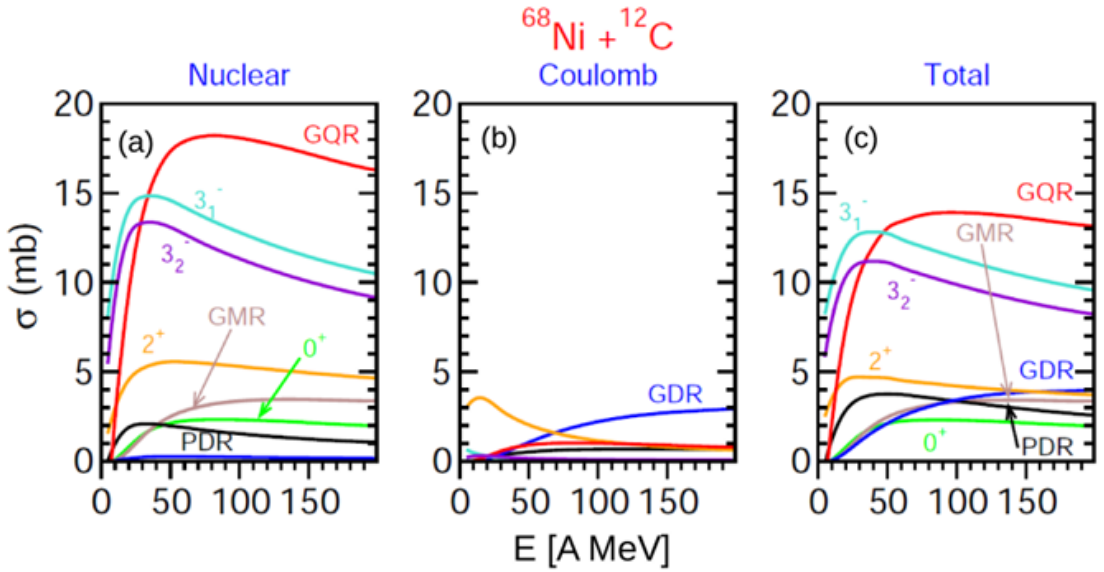


Lanza E. et al., Prog. Part. Nucl. Phys., 129 (2023) 104006

At INFN-LNS→ experiment to excite the PDR in the ^{68}Ni through an isoscalar probe, i.e. a natural carbon target

^{68}Ni (10^5 pps) + ^{nat}C (75 μm) @ 28A MeV N.S. Martorana et al., Phys. Lett. B, 782, (2018), 112



computed cross section as a function of the beam energy

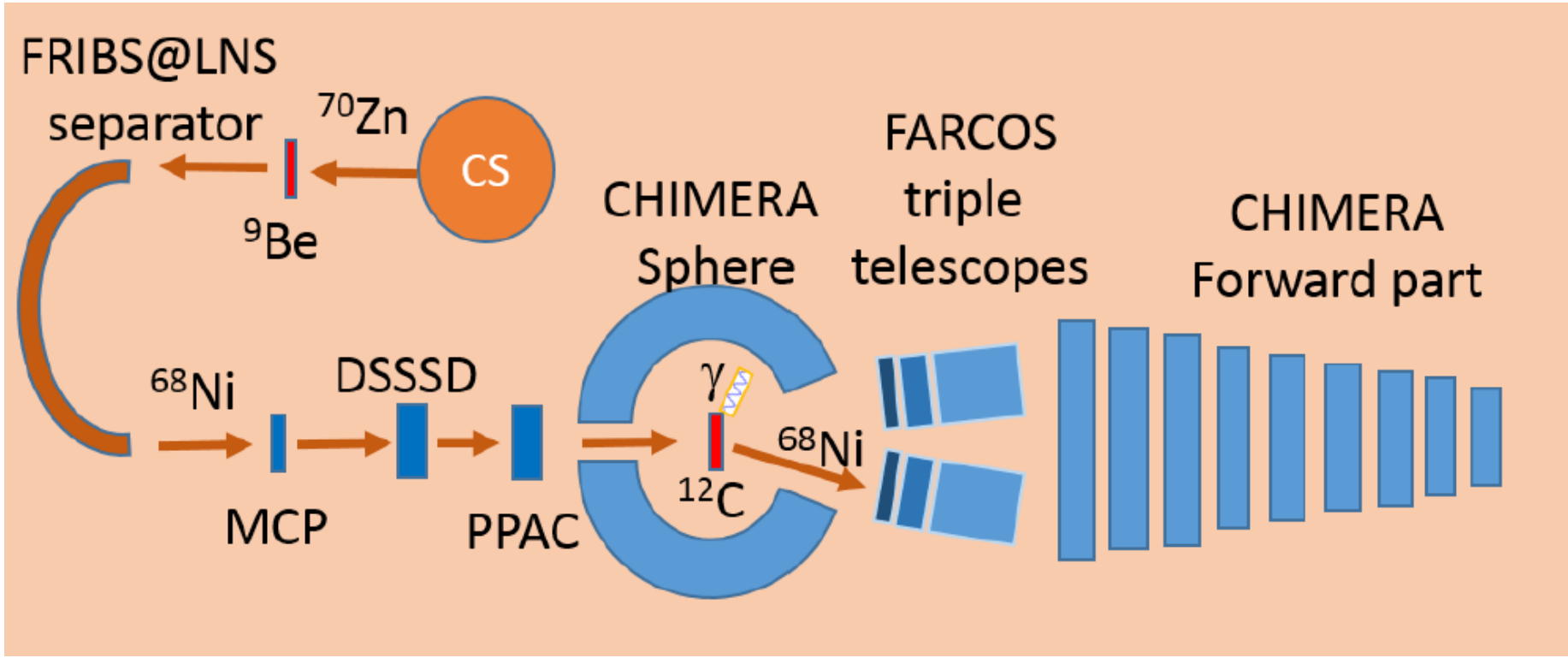
E.G. Lanza et al., Phys. Rev. C , 91, (2015), 54606

Semiclassical calculations show that at 28A MeV:

- Most of the total inelastic PDR cross section ≈ 60 % is due to the pure nuclear interaction
- Coulomb contribution amounts at 9 %
- ≈ 30 % is given by the interference between nuclear and Coulomb contributions

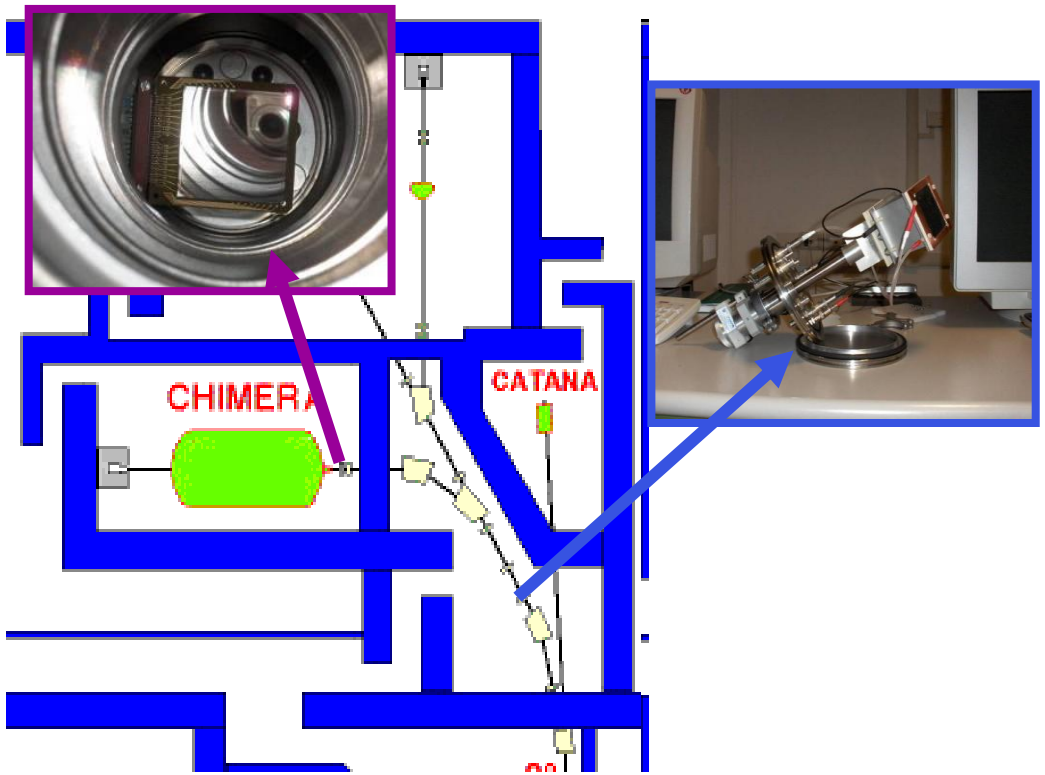
^{68}Ni radioactive beam →^{70}Zn @ 40 MeVA accelerated by CS on a ^{9}Be target using the FRIBs@LNS

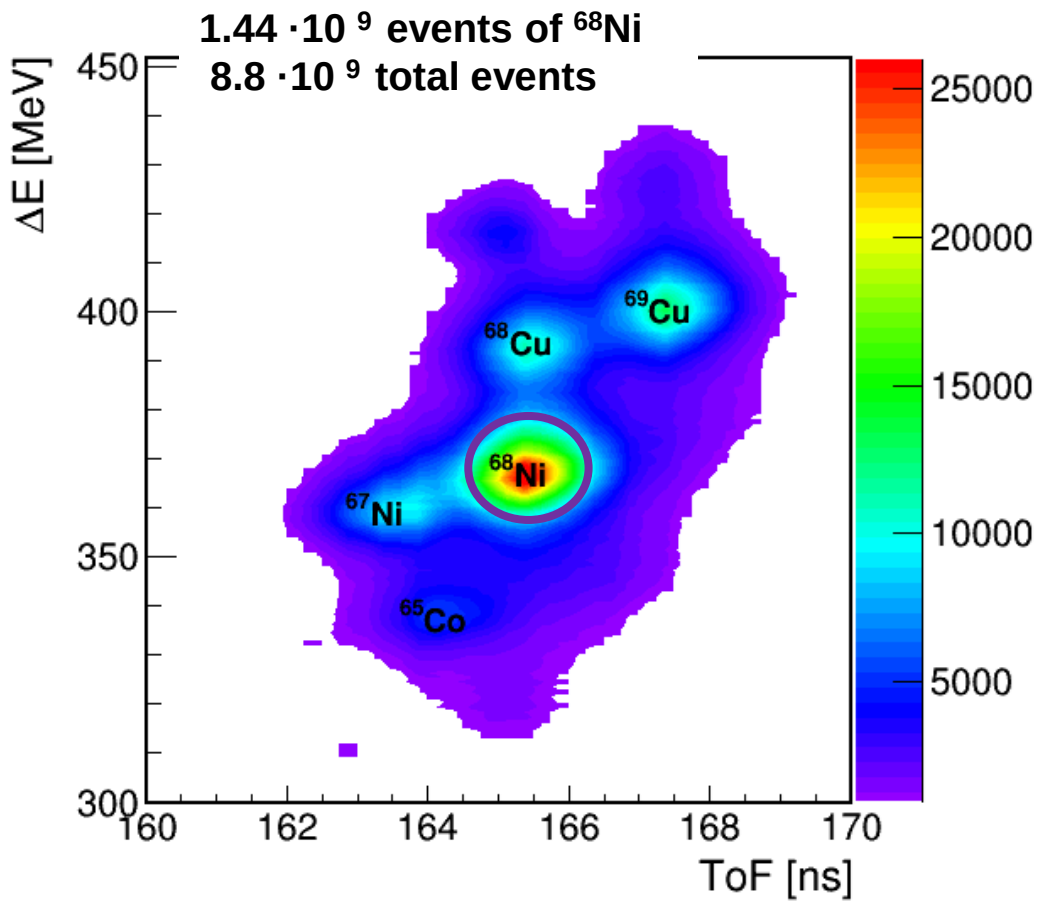
(P. Russotto et al., Jour. Phys.: Conf. Ser., 1014, (2018), 012016)



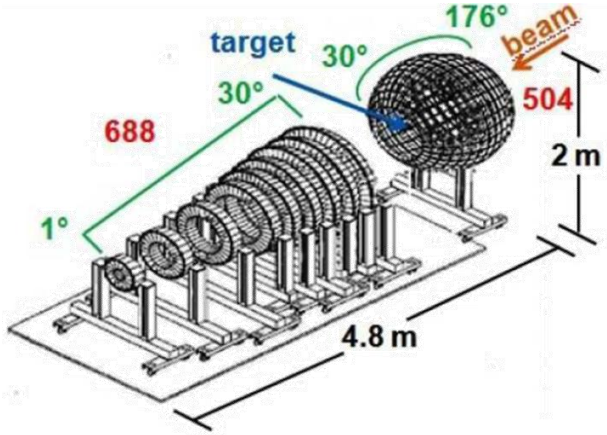
Tagging device for the CHIMERA beam line→ event-by-event identification of the cocktail beam via ΔE-ToF

(*Lombardo I. et al., Nucl. Phys. B Proc. Suppl., 215 (2011) 272)*



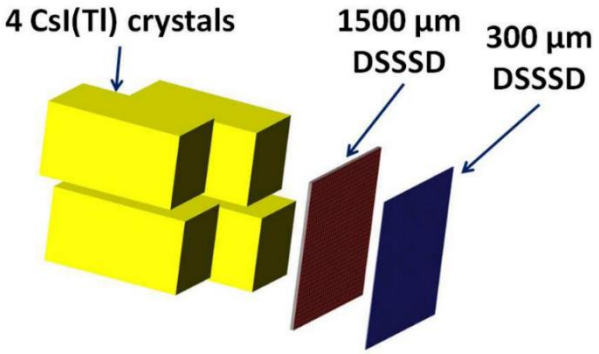


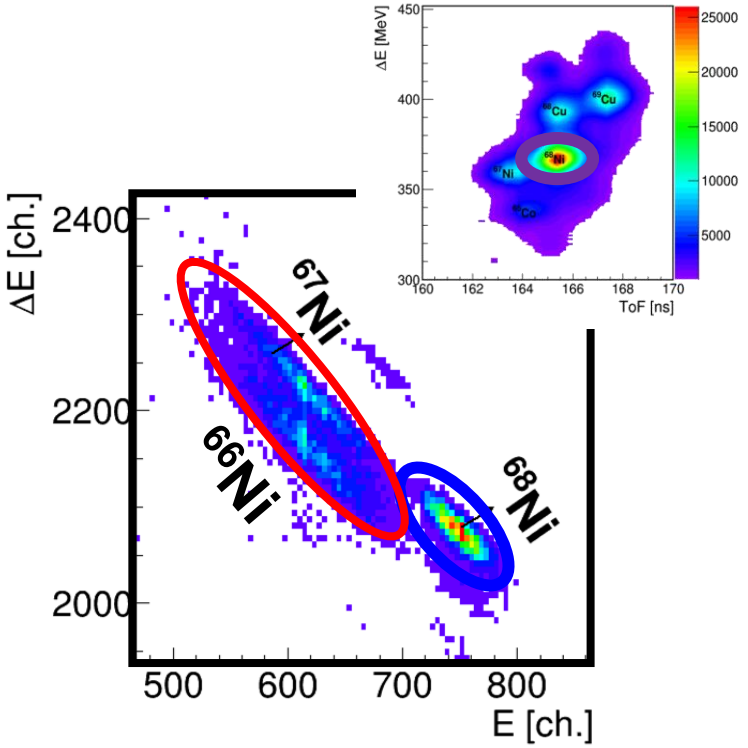
Start of ToF→ **MCP (43 mm x 63 mm)** 13 m away from the **DSSSD**
Stop & ΔE → **DSSSD (32 x 32 strips, 2 mm wide, 100-150 μm)** 2 m away from reaction target



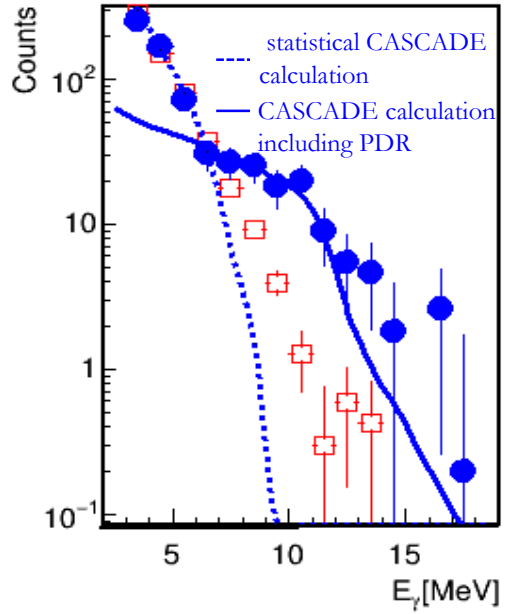
γ rays dedected by CHIMERA CsI(Tl) *(G. Cardella et al., NIM A, 799 , (2015), 64)*

^{68}Ni and other fragments detected by four telescopes of the FARCOS array

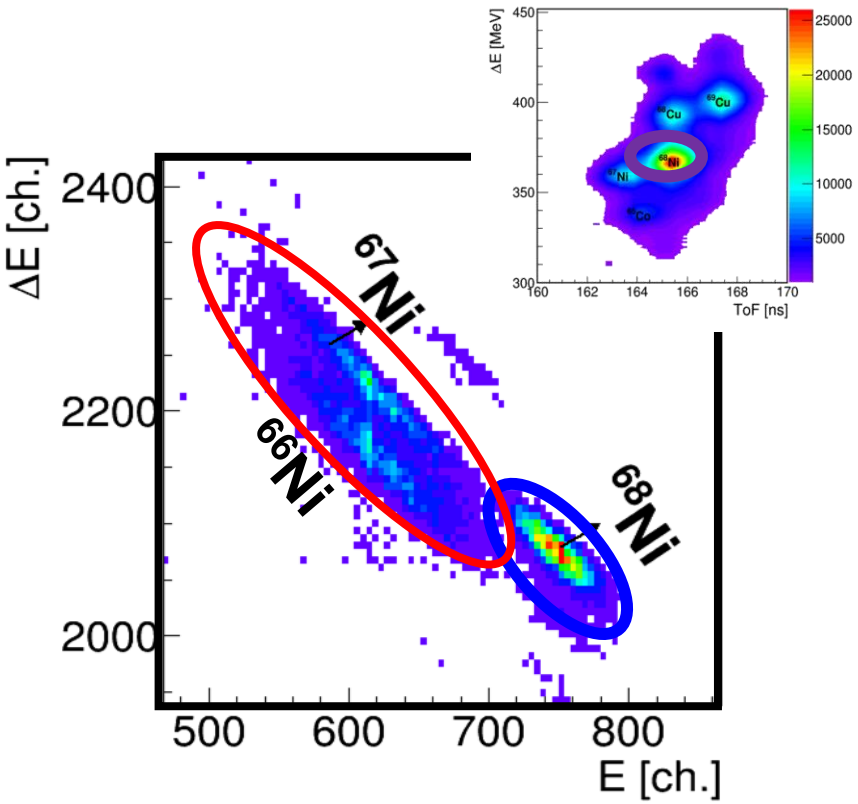




ΔE-E plot as obtained with FARCOS in coincidence with ^{68}Ni beam



γ-rays spectra as detected with CHIMERA in coincidence with ^{68}Ni and ^{66,67}Ni



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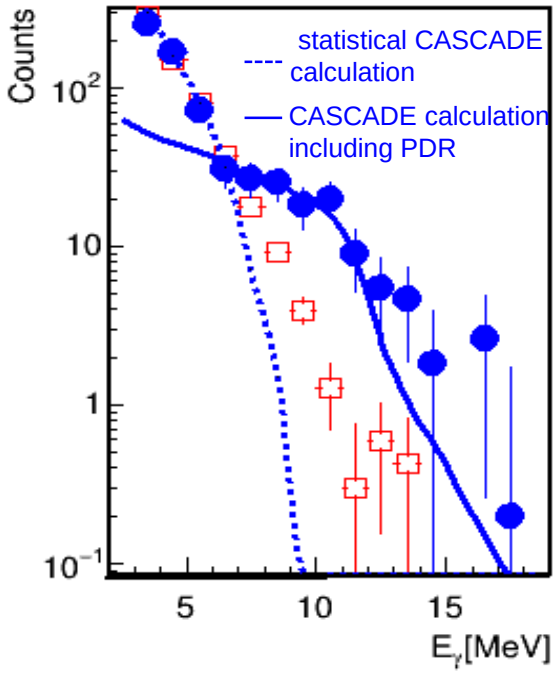
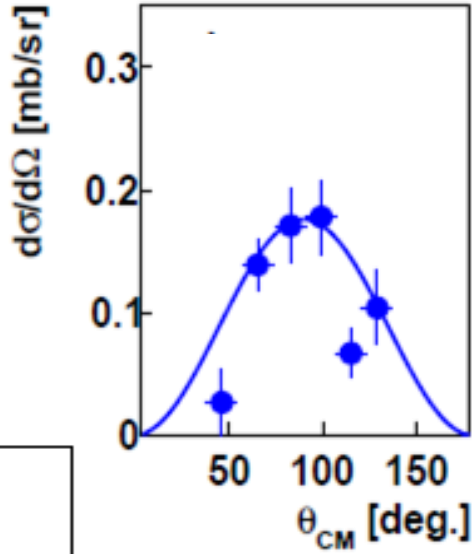
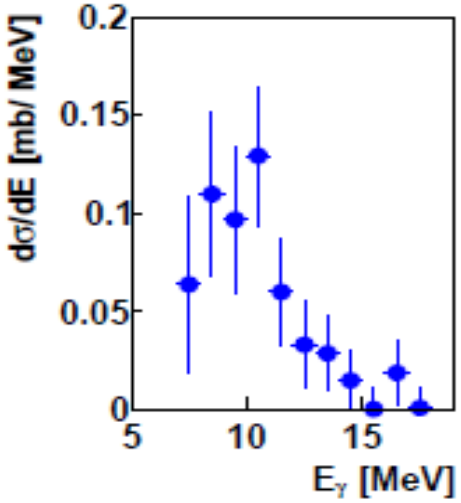


γ-rays spectra as detected with CHIMERA in coincidence with ^{68}Ni and ^{66,67}Ni

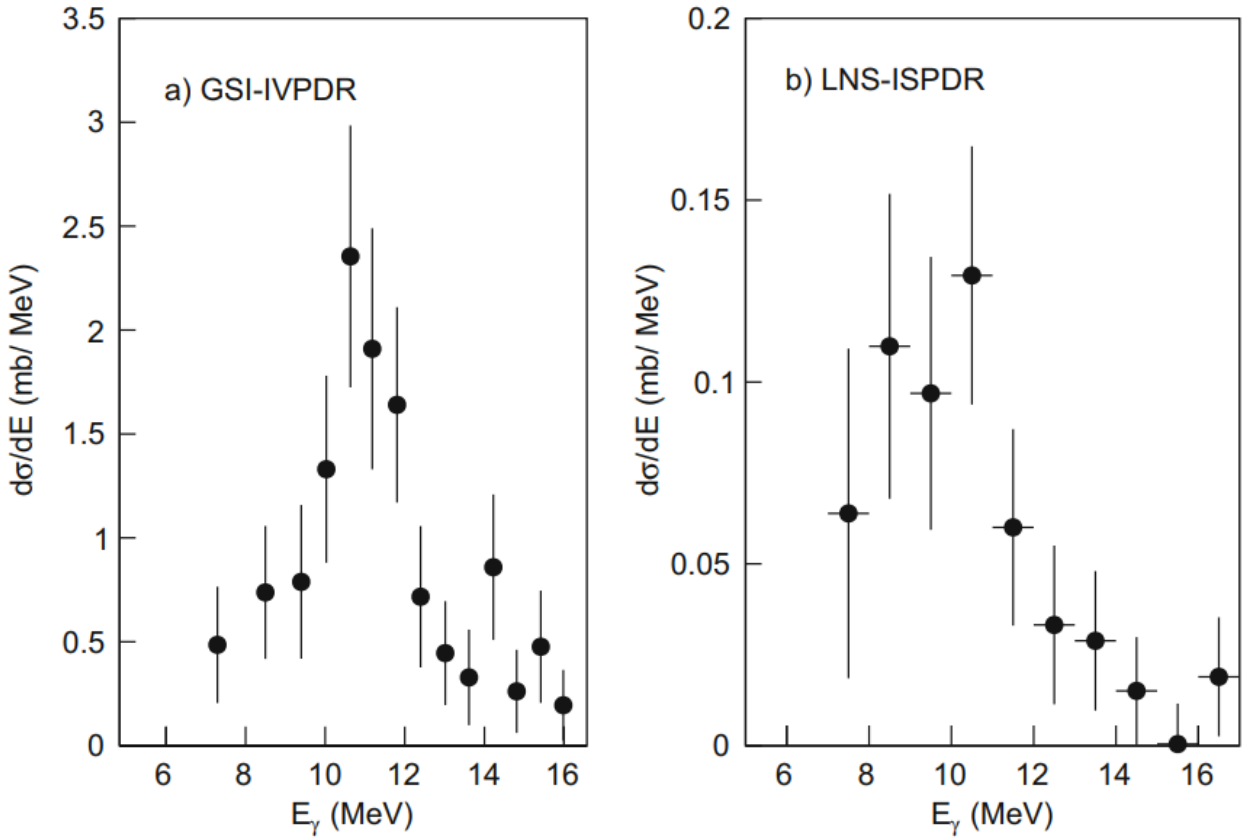
Blue dots → angular distribution in the center of mass frame
Blue line → typical distribution expected for a dipole transition with a maximum at 90°





- The γ-rays angular distribution shows the E1 character of the transition
- The measured cross section was 0.32 mb with 18% of statistical error
- The strength of the PDR amount at 9 ± 2 % EWSR

The comparison with the experiment carried out at the GSI *O. Wieland et al., Phys. Rev. Lett., 102, (2009) 092502* does not show any significant difference in the shape of two distributions → **the isospin splitting is not observed for unstable nuclei above the neutron emission threshold**



New measurements are needed to better understand the nature of the PDR using both probes→ ^{20}O, ^{34}Si, ^{38}S, ^{48}Ar, ^{68}Ni, ^{70}Ni…

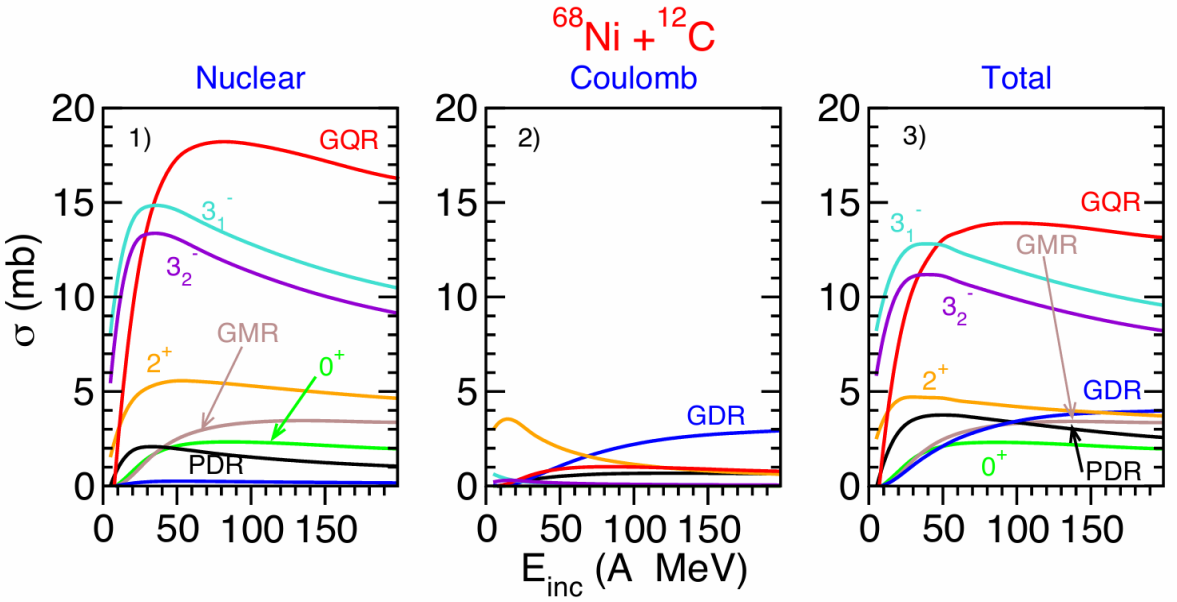
O. Wieland et al., Phys. Rev. Lett. 102, (2009), 092502

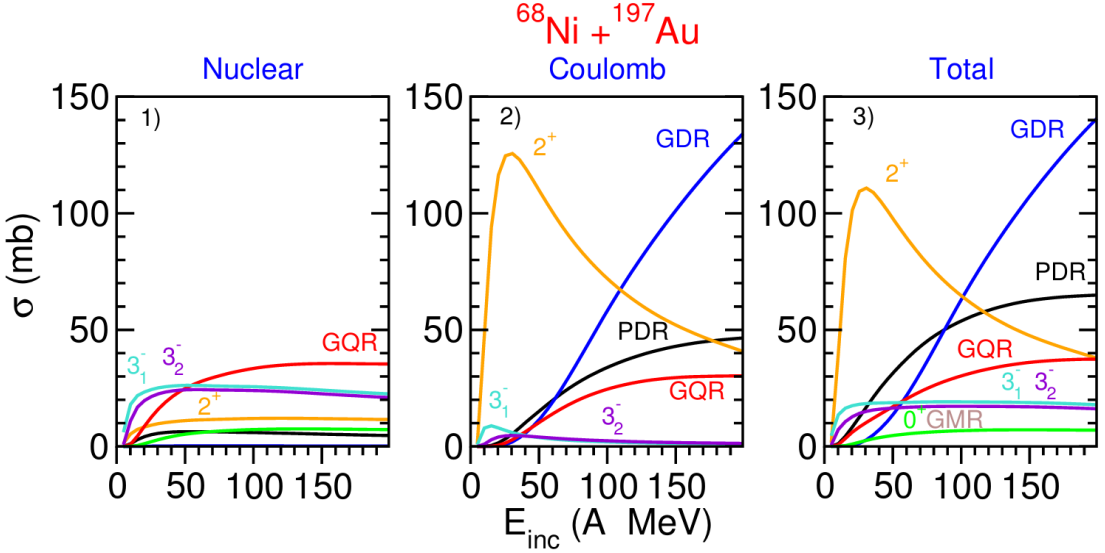
N.S. Martorana et al., Phys. Lett. B, 782, (2018) , 112

IDEA: Investigation of Pygmy Dipole Resonance in unstable nuclei as ^{68}Ni/^{70}Ni using both isoscalar and isovector probes with the same experimental setup

Experimental campaign to investigate PDR with radioactive ion beams:

- ✓ Using both probes alpha/carbon and Pb/Au targets
- ✓ Using different beam energies (30-80 AMeV or higher)





Courtesy of E. Lanza

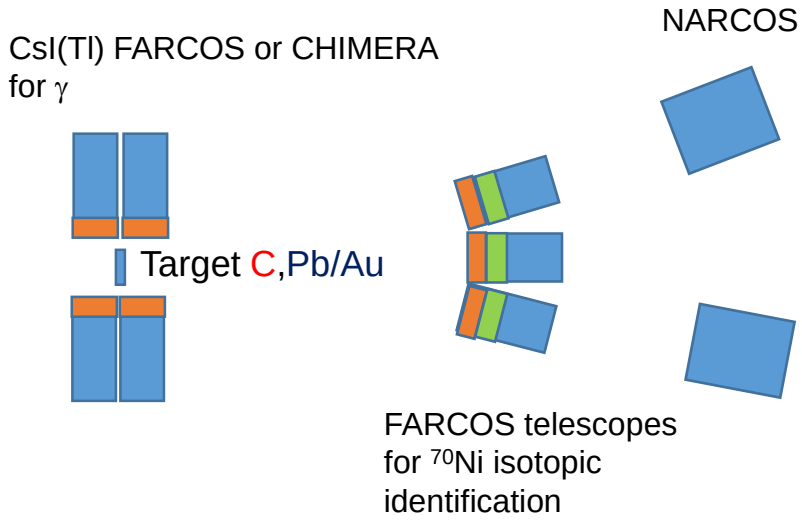
IDEA: Investigation of Pygmy Dipole Resonance in unstable nuclei as ^{68}Ni/^{70}Ni using both isoscalar and isovector probes with the same experimental setup

In order to determine the characteristics of the PDR:

- ✓ Perform isotopic identification of the scattered projectile allowing to separate the events in which the PDR decay by neutron emission (with detection of ^{69,68}Ni) and ɣ emission (with detection of ^{70}Ni)
- ✓ Measure with good resolution (ΔE=2-5 MeV) the beam energy in order to be able to measure the excitation energy of ^{70}Ni
- ✓ Measure in coincidence with the scattered projectile both ɣ rays and neutrons

Beams	Intensity	Targets	Energy range for Isoscalar part	Energy range for isovector part	Beam energy resolution	Purity of beam or possibility to select the RIBs
^{68}Ni	10^{4-5} pps	C/alpha + Pb/Au	30-40 AMeV (80 AMeV)	80-100 AMeV	2-5 MeV	Yes
^{70}Ni	10^{4-5} pps	C/alpha + Pb/Au	30-40 AMeV (80 AMeV)	80-100 AMeV	2-5 MeV	Yes

A possible experimental setup from the CHIRONE collaboration



- ✓ 8 FARCOS telescopes at forward angles 1°-8° to detect and isotopically identify scattered ^{70}Ni. Different configuration for isoscalar (2 stages 300 μm and 1500 μm) and isovector (2 stages 1500-1500 μm)
- ✓ 12 FARCOS telescopes around the target for ɣ ray detection or CHIMERA CsI(Tl)
- ✓ NARCOS to detect neutrons
- ✓ SiC array for the isotopic identification of the cocktail beam by the ΔE-TOF technique

We would like to employ FRIB capabilities/detectors:

- ✓ **Using the S800**
- ✓ **Employ different detectors for ɣ and neutrons**

Thank you for the attention

N.S. Martorana[1], G. Cardella[1], E.G. Lanza[1], A. Castoldi [2], E. De Filippo[1], E. Geraci[1,3,4], B. Gnoffo[1,3], C. Guazzoni[2], C. Maiolino[5], E.V. Pagano[5], S. Pirrone [1], G. Politi [1,3], F. Risitano[1,6], F. Rizzo[3,4,5], P. Russotto[5], M. Trimarchi[1,6], C. Zagami [3,4,5]

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