Nuclear Physics Mid Term Plan in Italy

LNL – Session

Legnaro, April 11th-12th 2022

Nuclear Structure:
Deformation and Collective States

Fabio Crespi
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Composition of the (active) working group

Fabio CRESPI **(UNIMI / INFN)** – *Experimental (Convener)*

Deniz SAVRAN **(GSI)** - *Experimental*

Giovanna BENZONI **(INFN)** - *Experimental*

Johann ISAAK **(TU Darmstadt)** - *Experimental*

Kazuhito MIZUYAMA (**Duy Tan University**) - *Theoretical*

Luna PELLEGRI (**WITS & iTL South Africa**) - *Experimental*

Marcus SCHECK (**University of West Scotland**) - *Experimental*

Maria KMIECIK (**IFJ PAN Krakow**) - *Experimental*

Mark SPIEKER (**Florida State University**) - *Experimental*

Oliver WIELAND (**INFN**) - *Experimental*

Shinsuke OTA (**RCNP Osaka University**) - *Experimental*

Volker WERNER (**TU Darmstadt**) - *Experimental*

Xavier ROCA MAZA (**UNIMI / INFN)** - *Theoretical*

Yi Fei NIU (**Lanzhou University)** - *Theoretical*

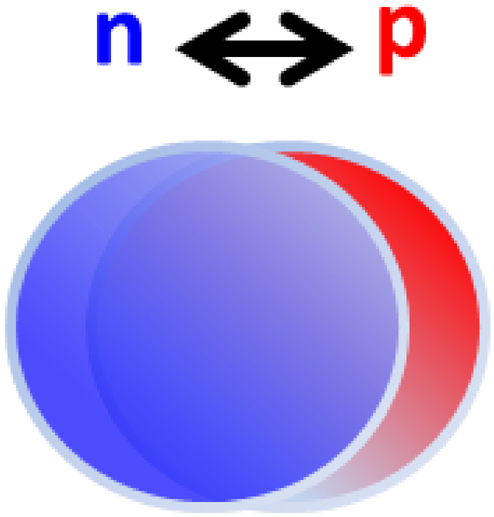
Giuseppe CARDELLA (external collaborator, convener of similar Working Group at **LNS-INFN Catania**)

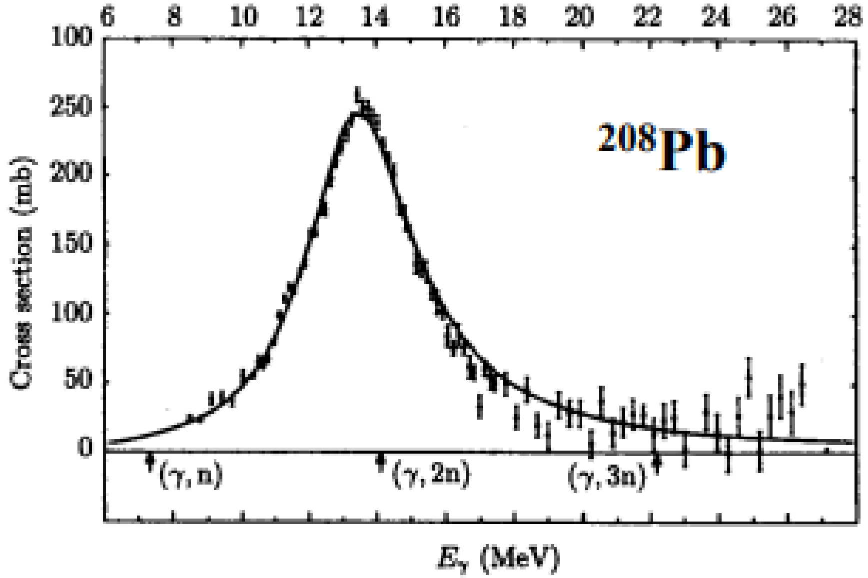
Outline

- General Introduction
- Selected Theoretical Methods
- Summary Table-List of the Experiments
- Available Experimental Instrumentation
- Detailed Physics Cases (SPES beams)
- Detailed Physics Cases (stable beams)
- Conclusions and Perspectives

Resonances and Nuclear Structure

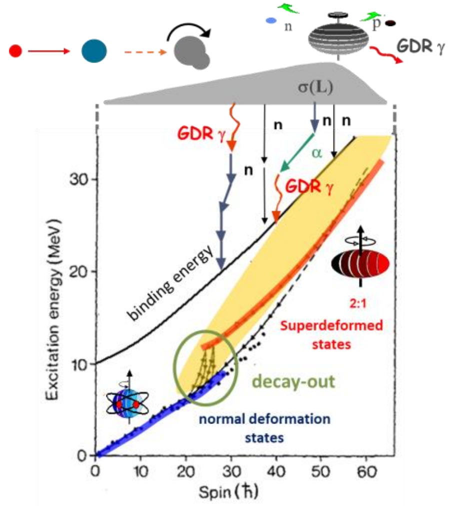
- One of the best examples of *collective modes* in nuclei is the Isovector Electric Giant Dipole Resonance (**IVGDR**), that can be understood as a density oscillation of neutrons against protons
- *This is also a perfect example of how a complex quantum system like the atomic nucleus can exhibit very simple collective configurations*



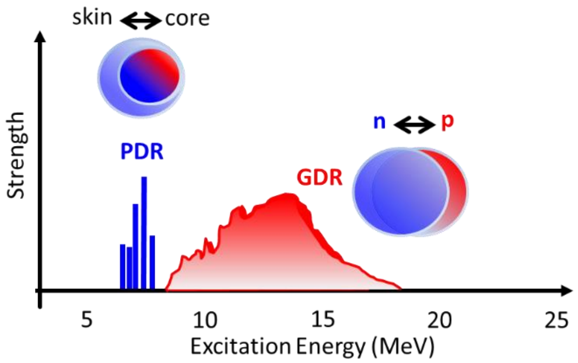


Lorentzian-Type Shape

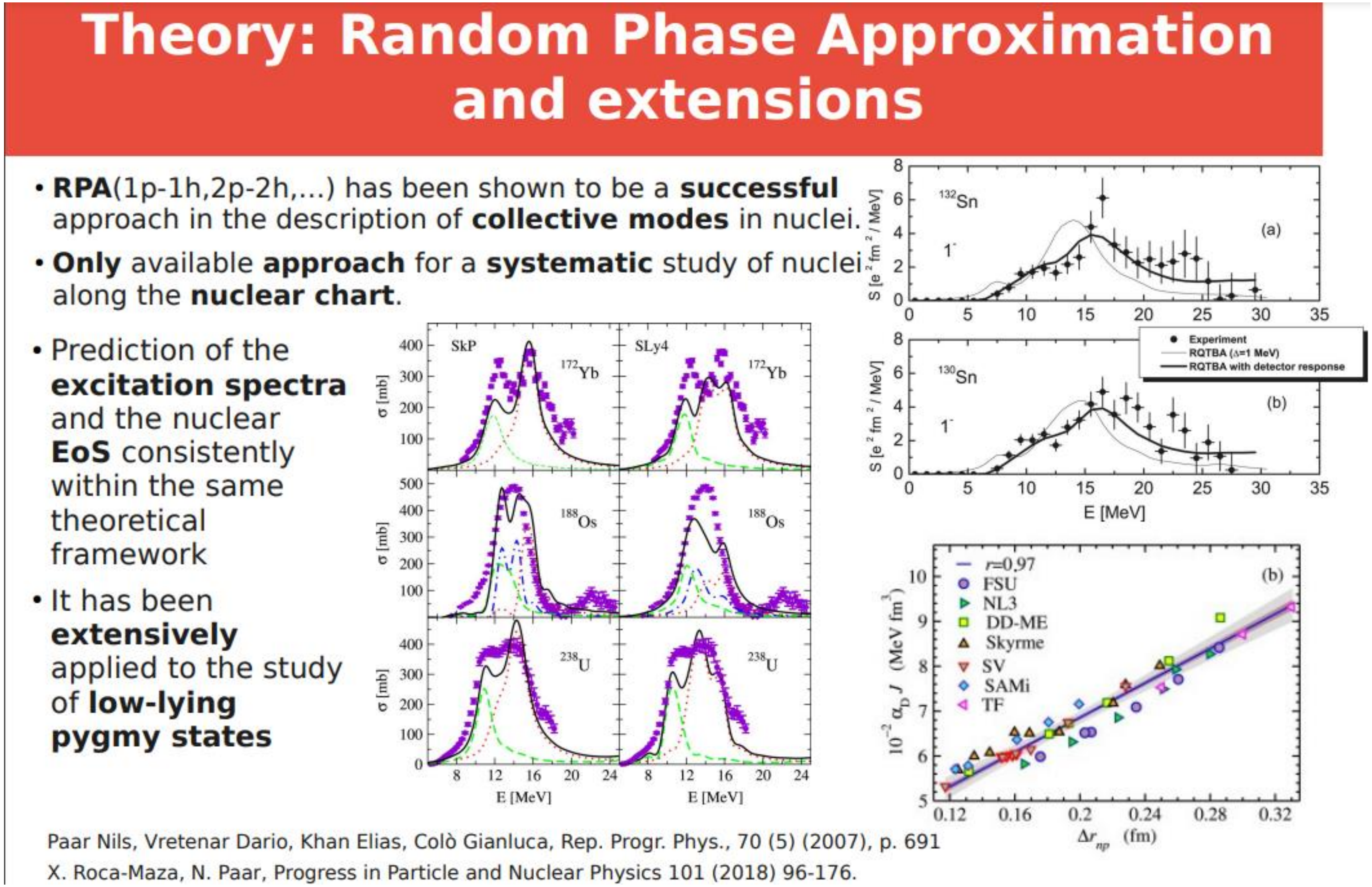
Resonances and Nuclear Structure



- ✓ This phenomenological “simplicity” out of the “nuclear complexity” has been used to extract valuable information on the nuclear structure (*IVGDR reflects the bulk properties of nuclear matter*)
- ✓ In particular, the IVGDR has been widely studied in the past, both at zero and finite temperature, however, some interesting aspects are still subject of present important scientific research, like the understanding of its evolution as a function of isospin and of the low-lying dipole strength (**Pygmy Dipole Resonance**)
- ➢ *In this respect experiments performed with **SPES radioactive neutron rich beams** are important. In addition, also experiments using **stable beams** have still an important role as will be outlined in the following example cases.*



Selected theoretical methods



Theory: Random Phase Approximation and extensions

- **RPA**(1p-1h,2p-2h,...) has been shown to be a **successful** approach in the description of **collective modes** in nuclei.
- **Only** available **approach** for a **systematic** study of nuclei along the **nuclear chart**.
- Prediction of the **excitation spectra** and the nuclear **EoS** consistently within the same theoretical framework
- It has been **extensively** applied to the study of **low-lying pygmy states**

Paar Nils, Vretenar Dario, Khan Elias, Colò Gianluca, Rep. Progr. Phys., 70 (5) (2007), p. 691

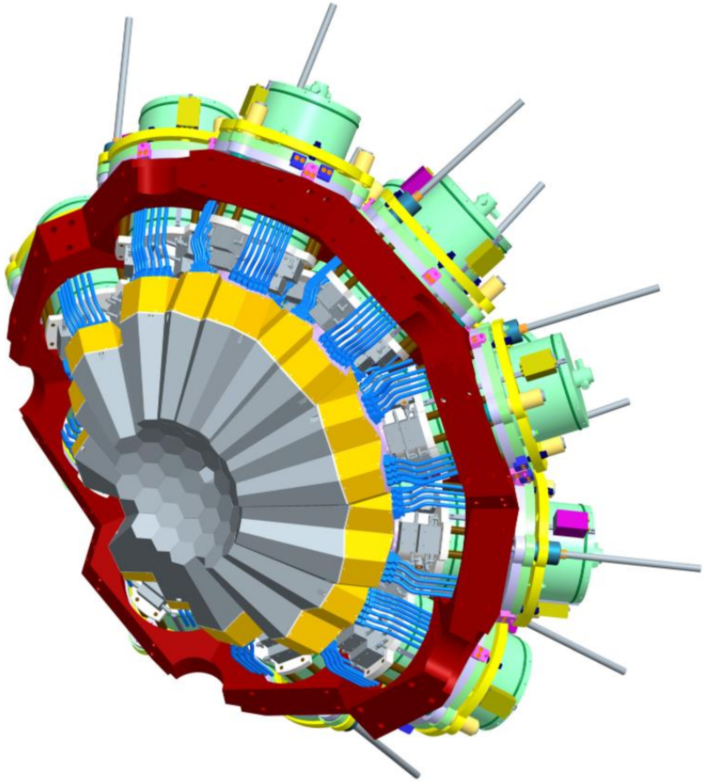
X. Roca-Maza, N. Paar, Progress in Particle and Nuclear Physics 101 (2018) 96-176.

Summary table

Experimental Ideas for the Deformation and collective states Working Group - Legnaro Mid Term Plan											
						Detection of γ rays			Detection of Particles		
PHYSICS TOPIC	BEAM (1)	BEAM (2)	BOMBARDING ENERGY	TARGET	REACTION	**AGATA**	**PARIS/HECTOR+**	**CLYC**	**TRACE**	**EUCLIDES**	**Other**
PDR	STABLE and SPES	different	10 MeV /A	p, alpha	inel. scattering	**X**	**X**				**CTADIR**
PDR	STABLE and SPES	different	Coulomb barrier	deuteron	(d, p) or (d, t)	**X**	**X**		X		**CTADIR**
Hot GDR / Jacobi Shape	STABLE and SPES	different	different	different	fusion-evaporation	**X**	**X**			**X**	
Octupole def B(E3)	SPES	146Ba	4.5 MeV /A	208Pb	Coulex	**X**					Coulex Silicon
BETA DECAY PDR	SPES	146Cs	STOPPED	-	beta decay to 146Ba						Ge+Si+CLYC(?)
PQR	STABLE and SPES	different	10 MeV /A	p, alpha	inel. scattering	**X**	**X**		X		**CTADIR**
GQR / GDR	STABLE	17O	20 MeV/A	40Ca, Heavier	inel. scattering	**X**	**X**		**X**		
Hot GDR /Isospin Mixing	STABLE	24Mg	40-80 MeV	28Si,30Si	fusion-evaporation	**X**	**X**	**X**			

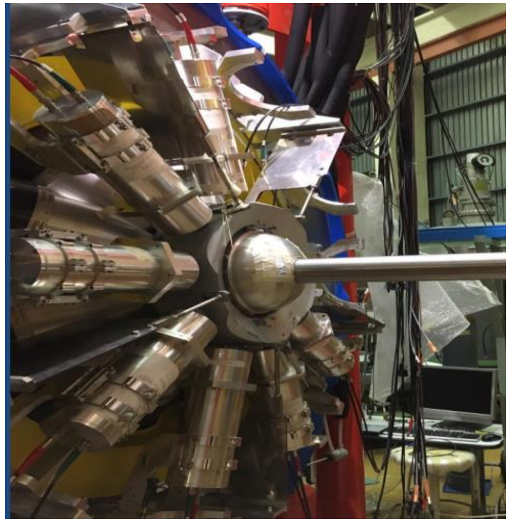
Detection of Gamma-rays

The Advanced GAmma Tracking Array (**AGATA**)

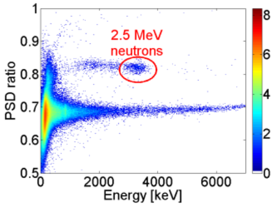


PARIS : A versatile detection array for low and high energy gamma-rays

HECTOR+ / Large volume LaBr3:Ce

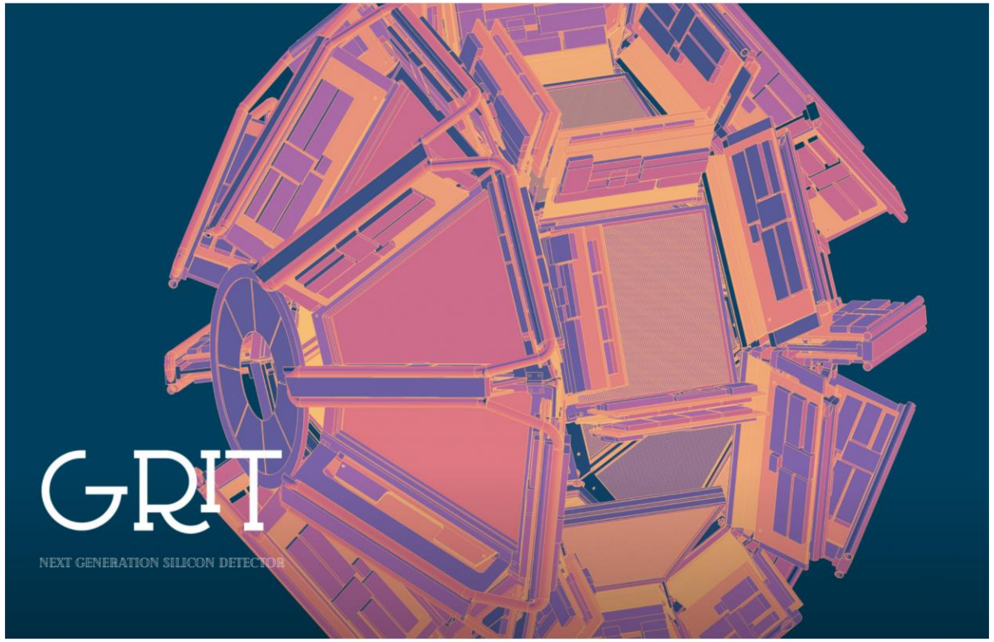


CLYC scintillators

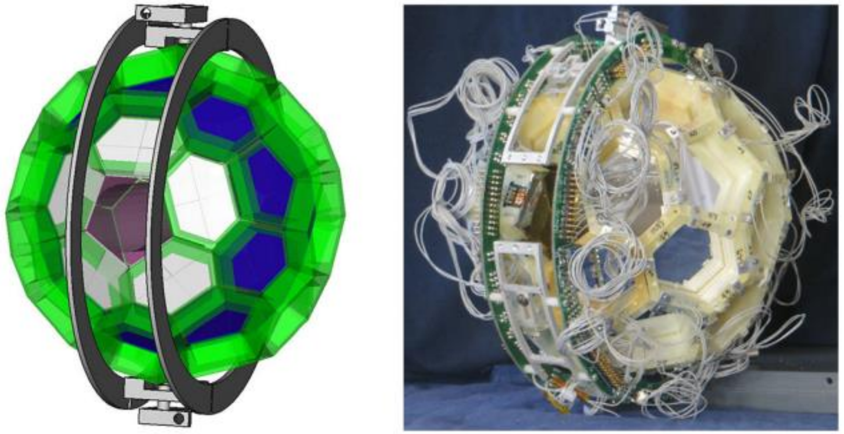


Detection of Charged Particles

GRIT stands for "Granularity, Resolution, Identification, Transparency". It is a **new generation silicon array** for low energy nuclear physics

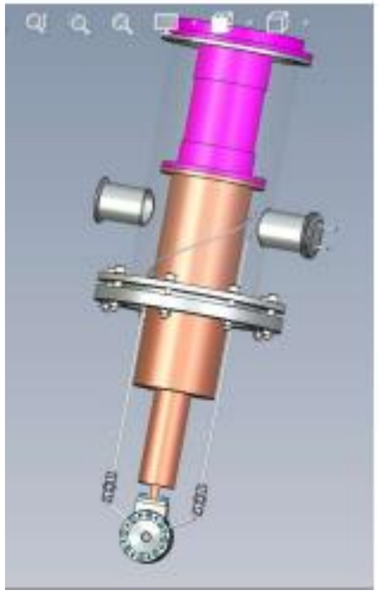


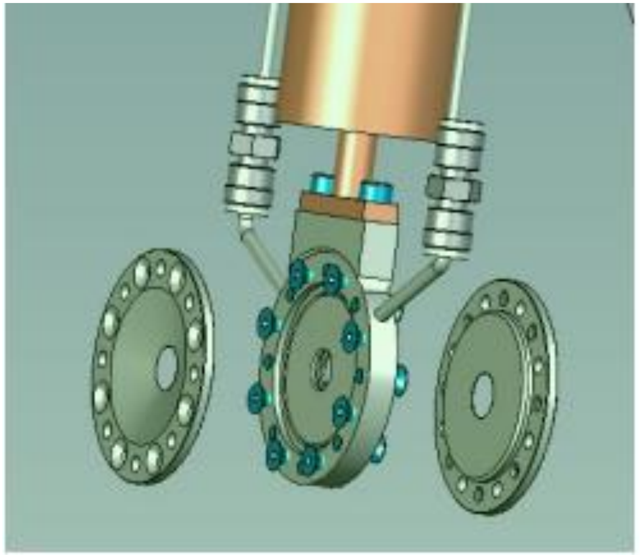
The 4π highly-efficient light-charged-particle detector EUCLIDES

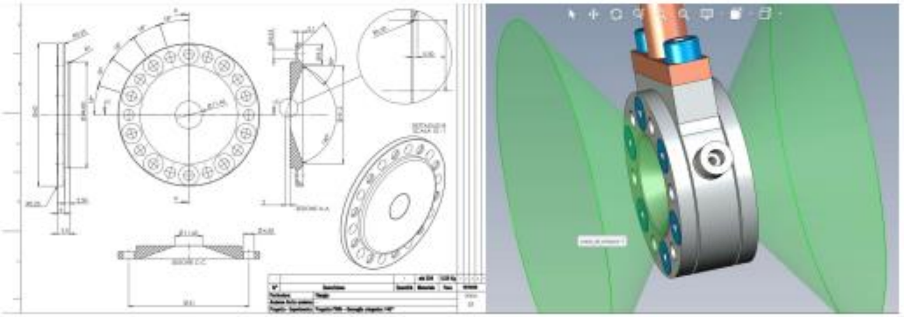


Other Complementary Instrumentation

The Cryogenic Target for Direct Reactions (CTADIR)







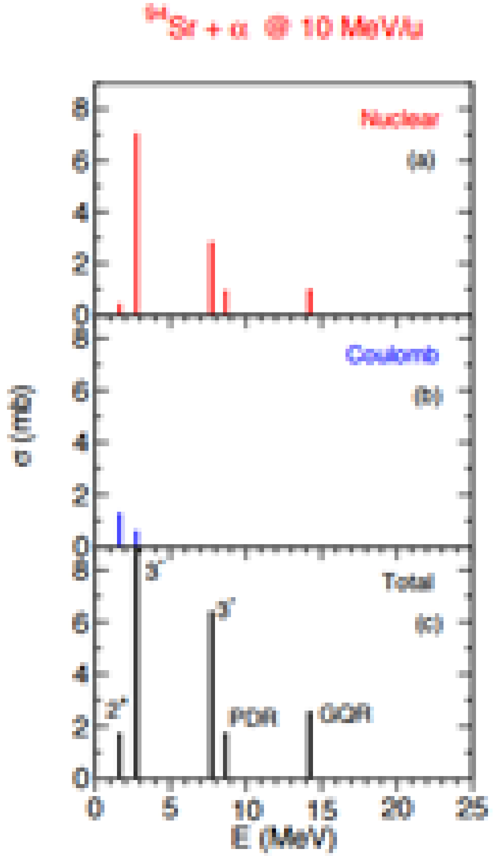
PRIN 2017

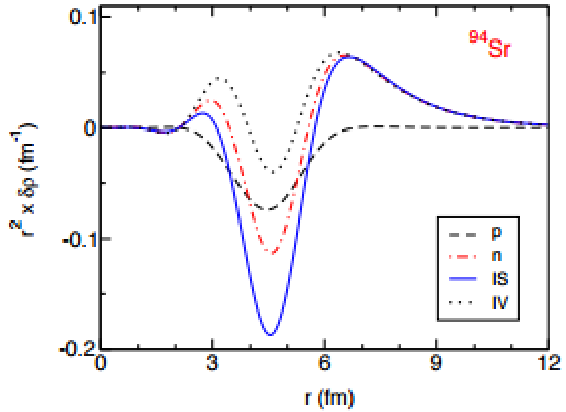
CTADIR

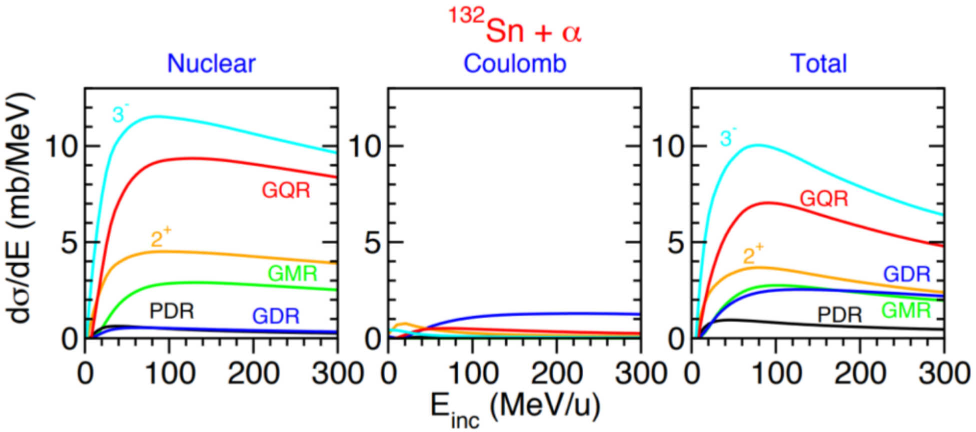
**Possibility of nuclear resonance studies also with Active Targets (ATS)
See e.g. presentation of S. Bottoni (Light to medium-mass exotic nuclei)

SPES Beams - Pygmy Dipole Resonance (1)

- Inelastic scattering in inverse kinematics + gamma-rays in coincidence
- **Beam Energy**: 10 MeV / u **Possibly Studied nuclei**: ^{94}Sr, ^{132}Sn, ^{140}Xe, ^{142}Ba, ^{134}Te + STABLE**
- **Setup**: Cryogenic target CTADIR (p or alpha) + AGATA + PARIS/LaBr3:Ce + GRIT
- SPES Letter of intent already submitted







Calculations by E. Lanza (INFN Catania)

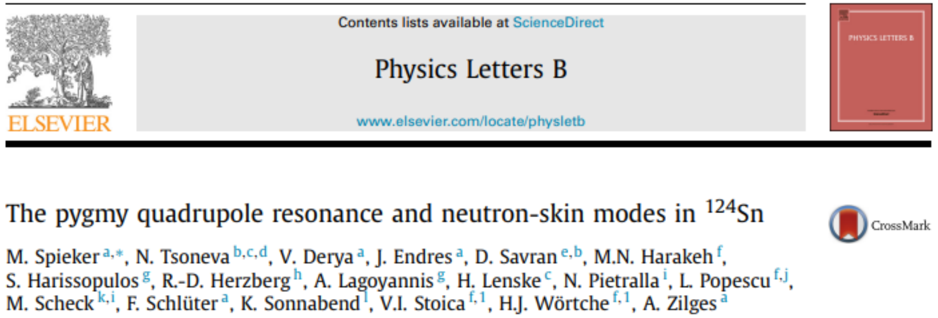
LNL-NS-DCS-co

LNL-NS-DCS-bo

mainly involved working group participants: F. Crespi UNIMI/INFN, L. Pellegri WITS & iTL

SPES Beams - Pygmy Quadrupole Resonance

- Inelastic scattering in inverse kinematics + gamma-rays in coincidence
- **Beam Energy**: 10 MeV / u **Possibly Studied nuclei**: ^{94}Sr, ^{132}Sn, ^{140}Xe, ^{142}Ba, ^{134}Te + STABLE**
- **Setup**: Cryogenic target CTADIR (p or alpha) + AGATA + PARIS/LaBr3:Ce + GRIT
- SPES Letter of intent already submitted


Contents lists available at ScienceDirect

Physics Letters B

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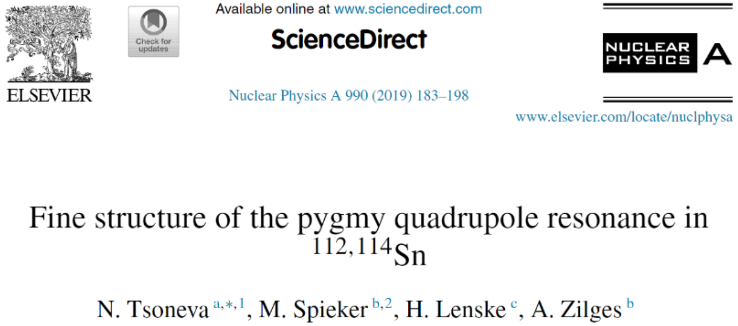
ELSEVIER

The pygmy quadrupole resonance and neutron-skin modes in ^{124}Sn

M. Spieker[a,*], N. Tsoneva[b,c,d], V. Derya[a], J. Endres[a], D. Savran[e,b], M.N. Harakeh[f], S. Harissopulos[g], R.-D. Herzberg[h], A. Lagoyannis[g], H. Lenske[c], N. Pietralla[i], L. Popescu[f,j], M. Scheck[k,i], F. Schlüter[a], K. Sonnabend[l], V.I. Stoica[f,1], H.J. Wörtche[f,1], A. Zilges[a]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Nuclear Physics A 990 (2019) 183–198

NUCLEAR PHYSICS A

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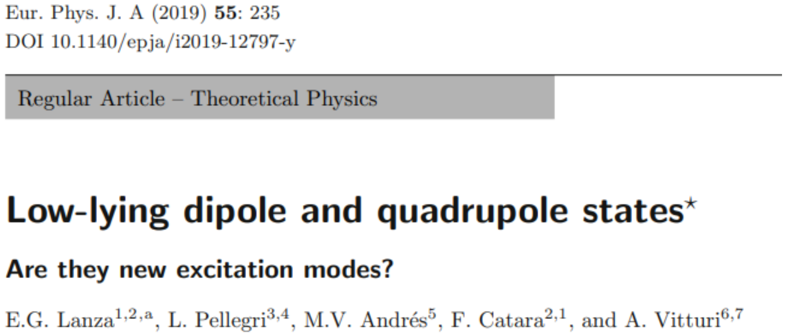
Fine structure of the pygmy quadrupole resonance in ^{112,114}Sn

N. Tsoneva[a,*,1], M. Spieker[b,2], H. Lenske[c], A. Zilges[b]

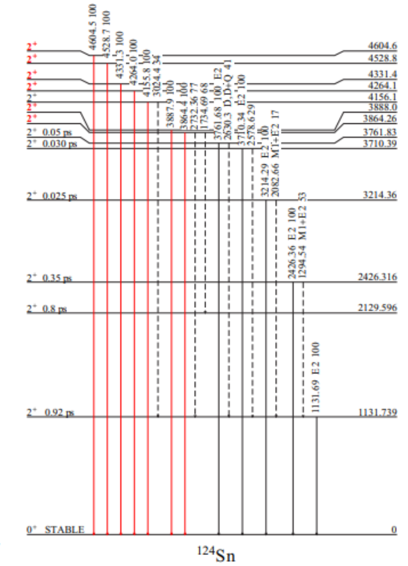

Eur. Phys. J. A (2019) **55**: 235
DOI 10.1140/epja/i2019-12797-y

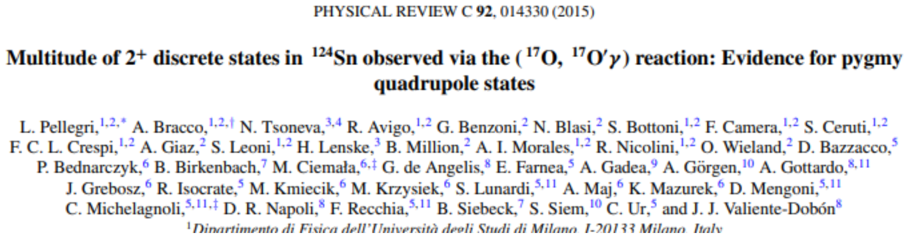
Regular Article – Theoretical Physics

Low-lying dipole and quadrupole states*

Are they new excitation modes?

E.G. Lanza[1,2,a], L. Pellegri[3,4], M.V. Andrés[5], F. Catara[2,1], and A. Vitturi[6,7]

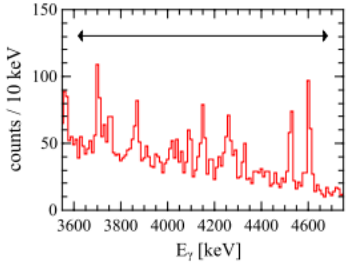



PHYSICAL REVIEW C **92**, 014330 (2015)

Multitude of 2$^+$ discrete states in ^{124}Sn observed via the (^{17}O, ^{17}O′γ) reaction: Evidence for pygmy quadrupole states

L. Pellegri,[1,2,*] A. Bracco,[1,2,†] N. Tsoneva,[3,4] R. Avigo,[1,2] G. Benzoni,[2] N. Blasi,[2] S. Bottoni,[1,2] F. Camera,[1,2] S. Ceruti,[1,2] F. C. L. Crespi,[1,2] A. Giaz,[2] S. Leoni,[1,2] H. Lenske,[3] B. Million,[2] A. I. Morales,[1,2] R. Nicolini,[1,2] O. Wieland,[2] D. Bazzacco,[5] P. Bednarczyk,[6] B. Birkenbach,[7] M. Ciemała,[6,‡] G. de Angelis,[8] E. Farnea,[5] A. Gadea,[9] A. Görgen,[10] A. Gottardo,[8,11] J. Grebosz,[6] R. Isocrate,[5] M. Kmiecik,[6] M. Krzysiek,[6] S. Lunardi,[5,11] A. Maj,[6] K. Mazurek,[6] D. Mengoni,[5,11] C. Michelagnoli,[5,11,‡] D. R. Napoli,[8] F. Recchia,[5,11] B. Siebeck,[7] S. Siem,[10] C. Ur,[5] and J. J. Valiente-Dobón[8]

[1] Dipartimento di Fisica dell'Università degli Studi di Milano, I-20133 Milano, Italy



LNL-NS-DCS-b0

LNL-NS-DCS-c0

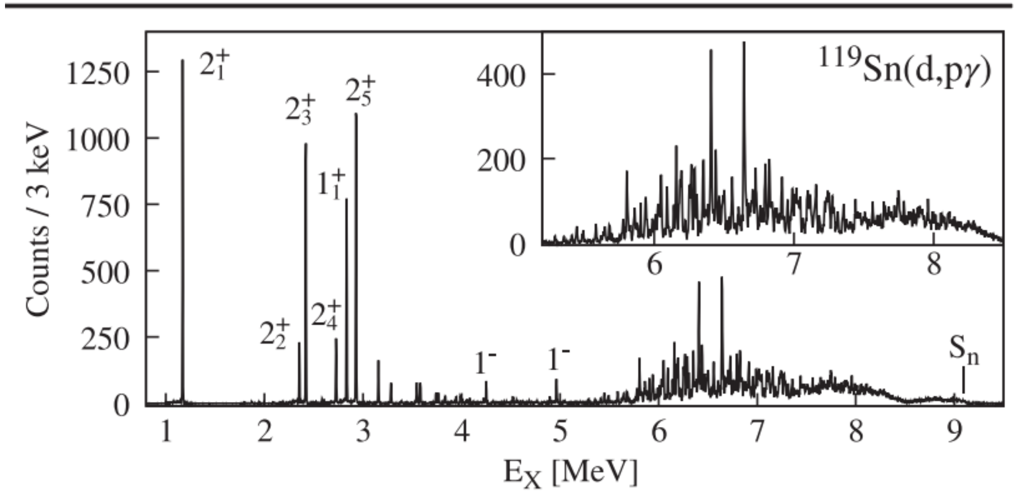
mainly involved working group participants:
F. Crespi UNIMI/INFN, L. Pellegri WITS & iTL, M. Spieker FSU

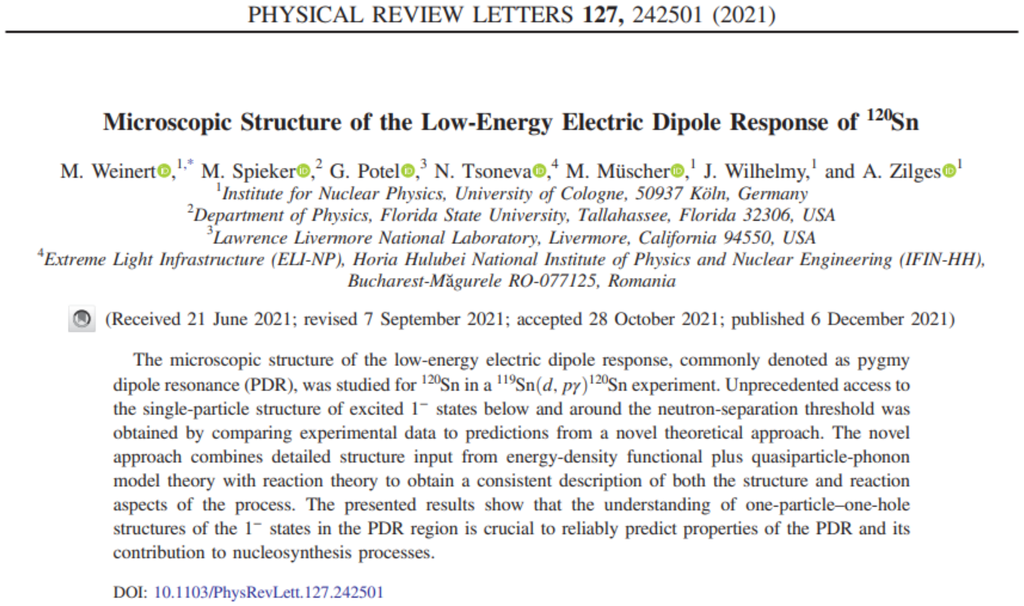
SPES Beams - Pygmy Dipole Resonance (2)

- Transfer reactions in inverse kinematics + gamma-rays in coincidence
- **Beam Energy**: sub-Coulomb, few MeV/u above Coulomb barrier
- **Reactions**: ^{131}Sn(d,p)^{132}Sn* ^{133}Sn(d,t)^{132}Sn* + STABLE**
- **Setup**: Cryogenic target CTADIR (deuteron) + AGATA + PARIS/LaBr3:Ce + GRIT

Example: **^{119}Sn(d,pγ)^{120}Sn @ 8.5 MeV**

Institute for Nuclear Physics in Cologne




PHYSICAL REVIEW LETTERS **127,** 242501 (2021)

Microscopic Structure of the Low-Energy Electric Dipole Response of ^{120}Sn

M. Weinert,[1,*] M. Spieker,[2] G. Potel,[3] N. Tsoneva,[4] M. Müscher,[1] J. Wilhelmy,[1] and A. Zilges[1]
[1] *Institute for Nuclear Physics, University of Cologne, 50937 Köln, Germany*
[2] *Department of Physics, Florida State University, Tallahassee, Florida 32306, USA*
[3] *Lawrence Livermore National Laboratory, Livermore, California 94550, USA*
[4] *Extreme Light Infrastructure (ELI-NP), Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH), Bucharest-Măgurele RO-077125, Romania*

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The microscopic structure of the low-energy electric dipole response, commonly denoted as pygmy dipole resonance (PDR), was studied for ^{120}Sn in a ^{119}Sn$(d, p\gamma)^{120}$Sn experiment. Unprecedented access to the single-particle structure of excited 1^- states below and around the neutron-separation threshold was obtained by comparing experimental data to predictions from a novel theoretical approach. The novel approach combines detailed structure input from energy-density functional plus quasiparticle-phonon model theory with reaction theory to obtain a consistent description of both the structure and reaction aspects of the process. The presented results show that the understanding of one-particle–one-hole structures of the 1^- states in the PDR region is crucial to reliably predict properties of the PDR and its contribution to nucleosynthesis processes.

DOI: 10.1103/PhysRevLett.127.242501

mainly involved working group participants:
F. Crespi UNIMI/INFN, L. Pellegri WITS & iTL, M. Spieker FSU

LNL-NS-DCS-c1

LNL-NS-DCS-b1

SPES Beams - Jacobi shape (hot GDR)

<u>^{142}La</u>

Beam: 420 MeV 94Rb - radioactive/re-accelerated

Target: 48Ca

Fusion-evaporation, E* = 109MeV, Lmax=98 h

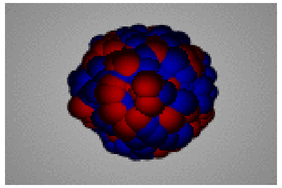
Measured: high-energy γ rays, discrete transitions and multiplicity (PARIS)

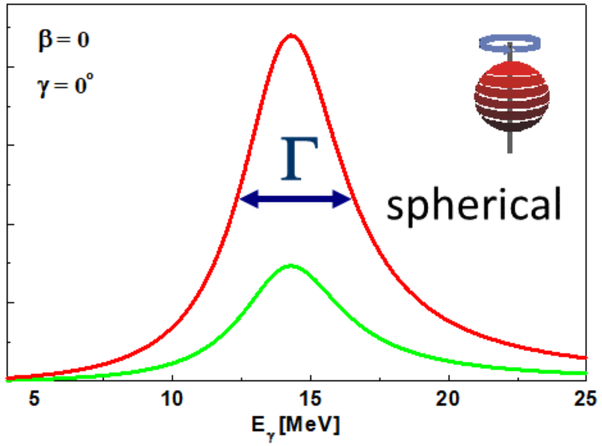
Detectors: PARIS, AGATA

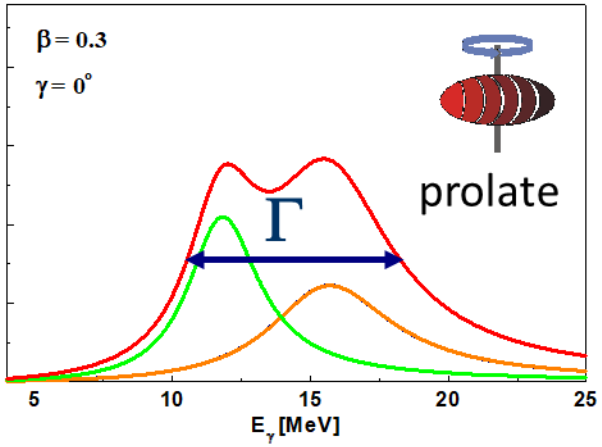
LNL-NS-DCS-c2

GDR - nuclear shape probe

GDR







mainly involved working group participants: M. Kmiecik, IFJ-PAN Krakow

SPES Beams - Jacobi shape (hot GDR)

142La

Beam: 420 MeV 94Rb

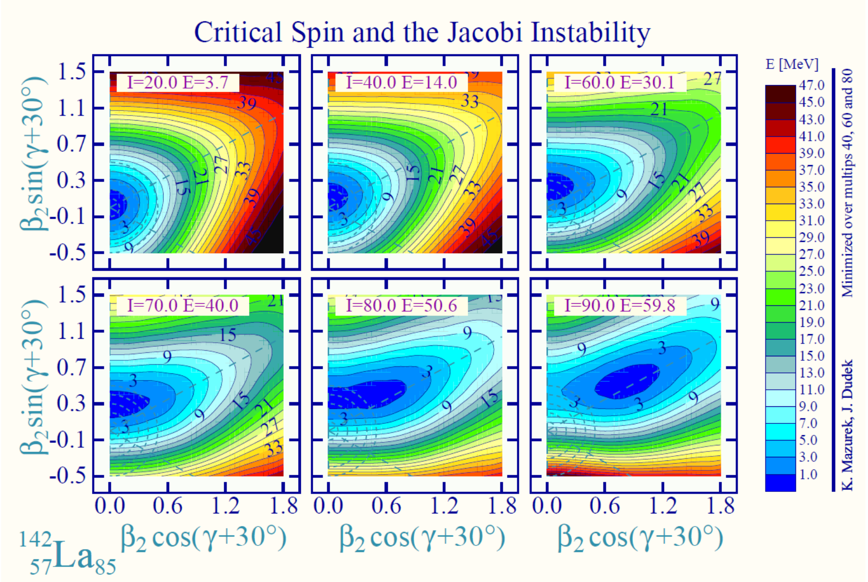
Target: 48Ca

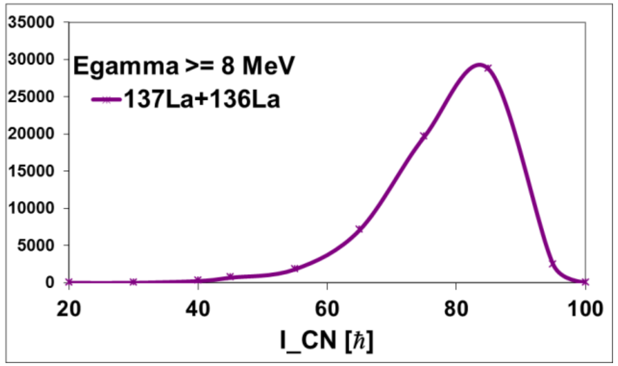
Fusion-evaporation, E* = 109MeV, Lmax=98 h,

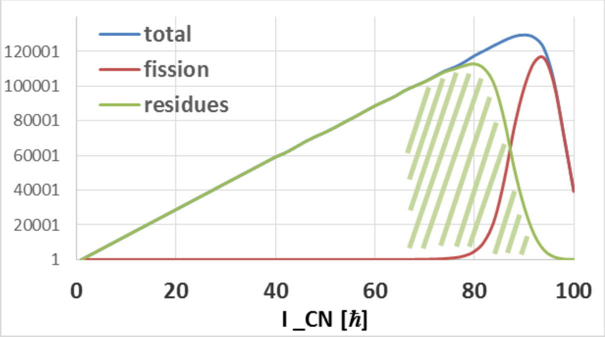
Gated on discrete transitions (137La, 136La) – if beam intensity > 10^{10}

Detectors: PARIS, AGATA,

Measured: high-energy γ rays and multiplicity (PARIS) – if beam intensity > 10^{8}-10^{9}







Calculations: M. Kmiecik and K. Mazurek

mainly involved working group participants: M. Kmiecik, IFJ-PAN Krakow

SPES Beams - Octupole Deformation in ^{146}Ba

- Coulomb excitation in inverse kinematics + gamma-rays in coincidence
- Beam Energy: 4.5 MeV/A
- Reactions: ^{146}Ba(^{208}Pb,^{208}Pb)^{146}Ba*
- ^{146}Ba(^{48}Ti, ^{48}Ti)^{146}Ba*
- ^{146}Ba(^{58}Ni, ^{58}Ni)^{146}Ba*
- Silicon Det. + AGATA

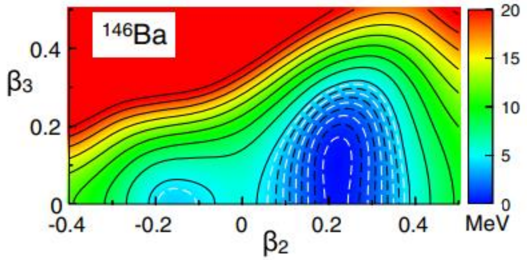
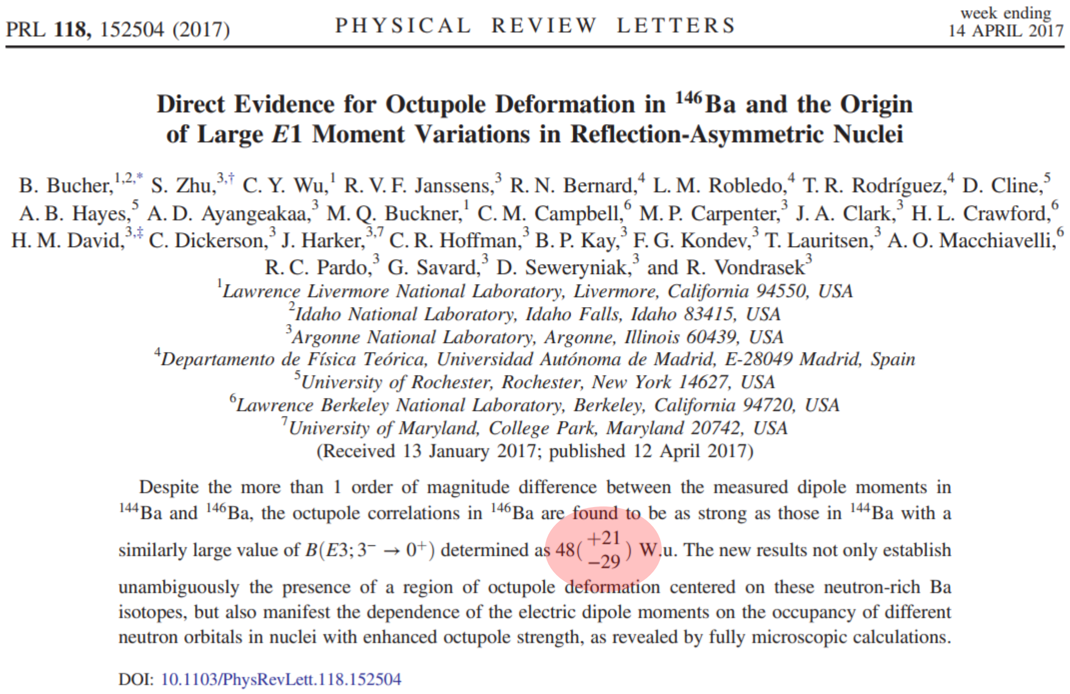


FIG. 3. The HFB potential energy surface. Axial quadrupole (β_2) and octupole (β_3) deformation parameters are defined as $\beta_\lambda \equiv 4\pi\langle \mathbf{q}|r^\lambda Y_{\lambda 0}|\mathbf{q}\rangle/(3r_0^\lambda A^{\lambda/3+1})$ with $r_0 = 1.2$ fm and A being the mass number. Dashed (solid) contour lines are separated by 0.5 (2.0) MeV.



PRL **118,** 152504 (2017) PHYSICAL REVIEW LETTERS week ending 14 APRIL 2017

Direct Evidence for Octupole Deformation in ^{146}Ba and the Origin of Large *E*1 Moment Variations in Reflection-Asymmetric Nuclei

B. Bucher,[1,2,*] S. Zhu,[3,†] C. Y. Wu,[1] R. V. F. Janssens,[3] R. N. Bernard,[4] L. M. Robledo,[4] T. R. Rodríguez,[4] D. Cline,[5] A. B. Hayes,[5] A. D. Ayangeakaa,[3] M. Q. Buckner,[1] C. M. Campbell,[6] M. P. Carpenter,[3] J. A. Clark,[3] H. L. Crawford,[6] H. M. David,[3,‡] C. Dickerson,[3] J. Harker,[3,7] C. R. Hoffman,[3] B. P. Kay,[3] F. G. Kondev,[3] T. Lauritsen,[3] A. O. Macchiavelli,[6] R. C. Pardo,[3] G. Savard,[3] D. Seweryniak,[3] and R. Vondrasek[3]

[1]*Lawrence Livermore National Laboratory, Livermore, California 94550, USA*
[2]*Idaho National Laboratory, Idaho Falls, Idaho 83415, USA*
[3]*Argonne National Laboratory, Argonne, Illinois 60439, USA*
[4]*Departamento de Física Teórica, Universidad Autónoma de Madrid, E-28049 Madrid, Spain*
[5]*University of Rochester, Rochester, New York 14627, USA*
[6]*Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA*
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(Received 13 January 2017; published 12 April 2017)

Despite the more than 1 order of magnitude difference between the measured dipole moments in ^{144}Ba and ^{146}Ba, the octupole correlations in ^{146}Ba are found to be as strong as those in ^{144}Ba with a similarly large value of $B(E3; 3^- \rightarrow 0^+)$ determined as $48(^{+21}_{-29})$ W.u. The new results not only establish unambiguously the presence of a region of octupole deformation centered on these neutron-rich Ba isotopes, but also manifest the dependence of the electric dipole moments on the occupancy of different neutron orbitals in nuclei with enhanced octupole strength, as revealed by fully microscopic calculations.

DOI: 10.1103/PhysRevLett.118.152504

LNL-NS-DCS-c3

mainly involved working group participants: M. Scheck UWS, M. Spieker FSU

SPES Beams - PDR Beta decay

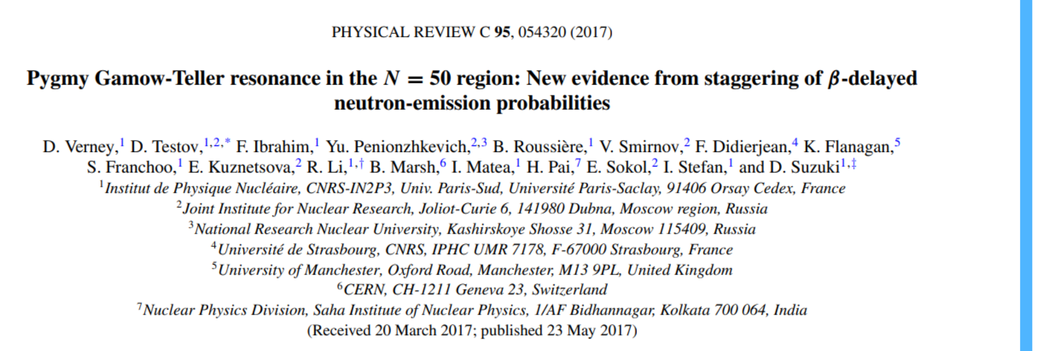
- Decay spectroscopy

SPES Beta decay station

-> *setup shown in the next slide*

- + possibility of adding a neutron detector array under consideration

Orsay-ALTO 83Ga decay, N=50



PHYSICAL REVIEW C **95**, 054320 (2017)

Pygmy Gamow-Teller resonance in the $N = 50$ region: New evidence from staggering of β-delayed neutron-emission probabilities

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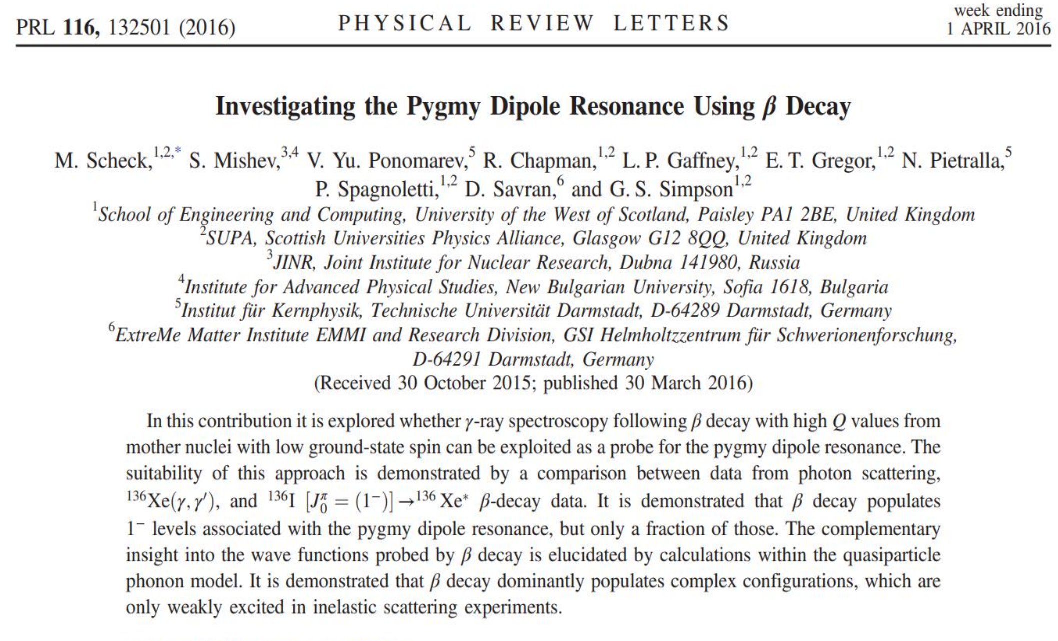
(Received 20 March 2017; published 23 May 2017)



PRL **116,** 132501 (2016) PHYSICAL REVIEW LETTERS week ending 1 APRIL 2016

Investigating the Pygmy Dipole Resonance Using β Decay

M. Scheck,[1,2,*] S. Mishev,[3,4] V. Yu. Ponomarev,[5] R. Chapman,[1,2] L. P. Gaffney,[1,2] E. T. Gregor,[1,2] N. Pietralla,[5] P. Spagnoletti,[1,2] D. Savran,[6] and G. S. Simpson[1,2]
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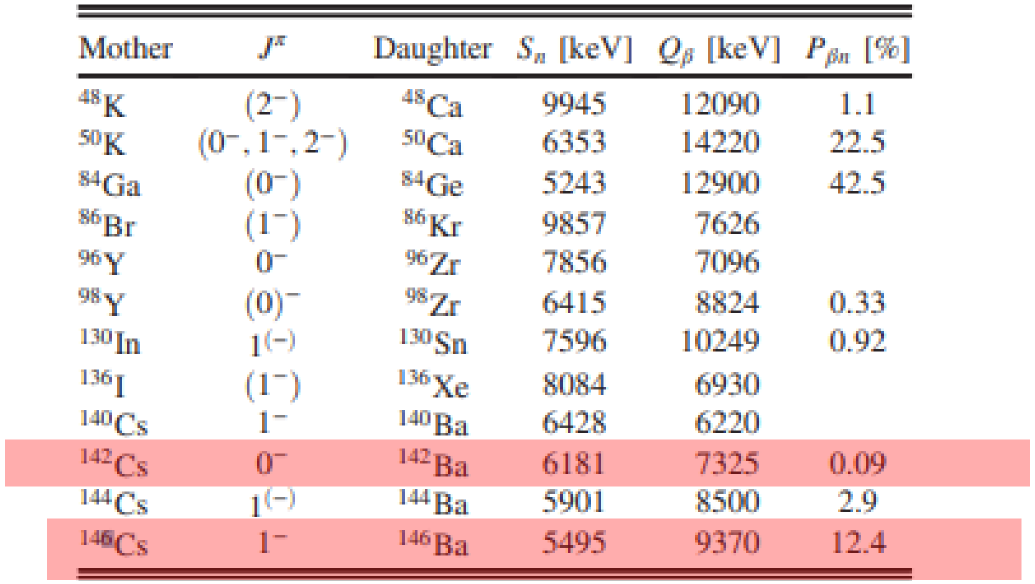
(Received 30 October 2015; published 30 March 2016)

In this contribution it is explored whether γ-ray spectroscopy following β decay with high Q values from mother nuclei with low ground-state spin can be exploited as a probe for the pygmy dipole resonance. The suitability of this approach is demonstrated by a comparison between data from photon scattering, ^{136}Xe(γ,γ'), and ^{136}I $[J_0^\pi = (1^-)] \rightarrow {}^{136}$Xe* β-decay data. It is demonstrated that β decay populates 1^- levels associated with the pygmy dipole resonance, but only a fraction of those. The complementary insight into the wave functions probed by β decay is elucidated by calculations within the quasiparticle phonon model. It is demonstrated that β decay dominantly populates complex configurations, which are only weakly excited in inelastic scattering experiments.

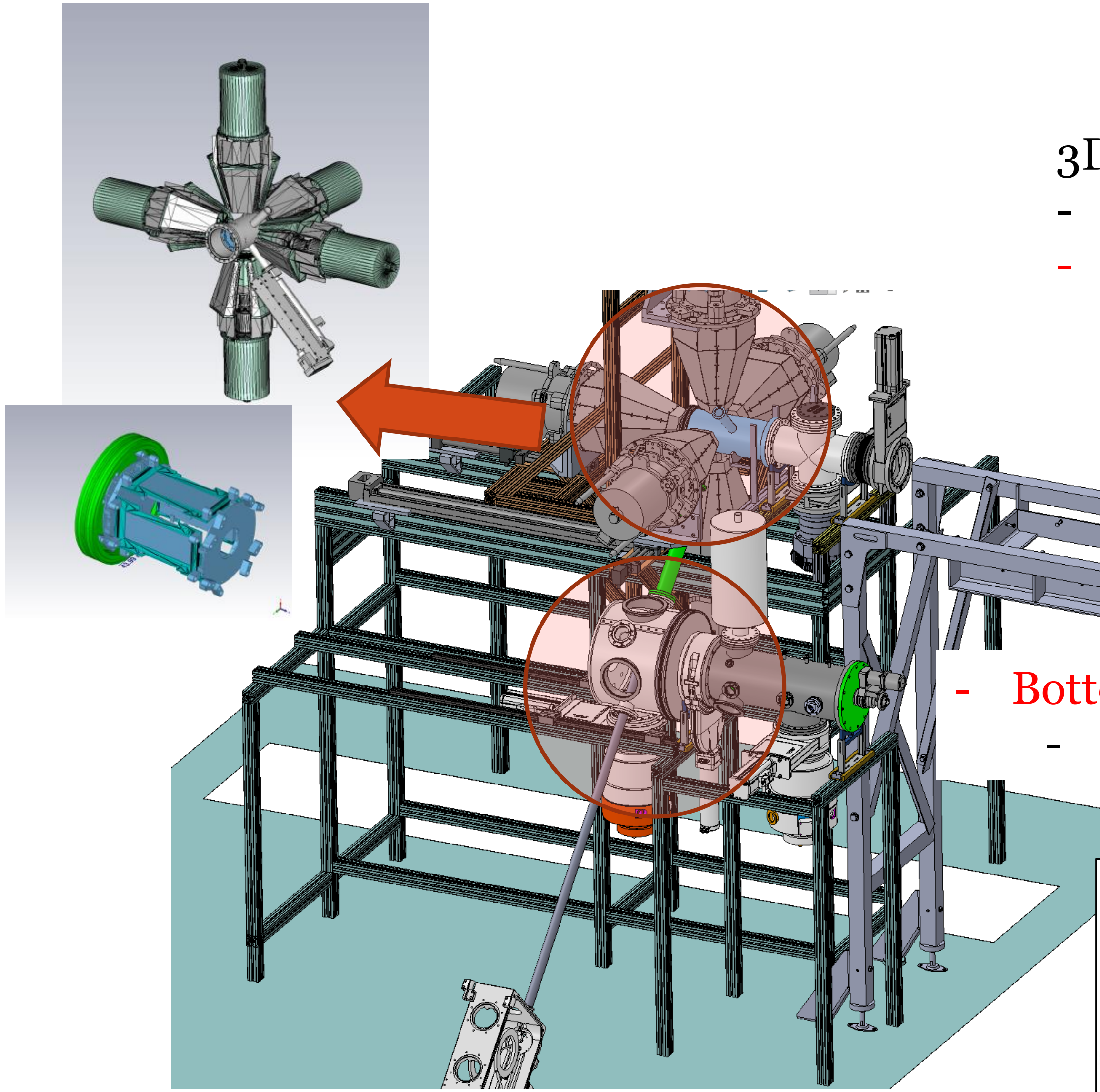


Mother	J^π	Daughter	S_n [keV]	Q_β [keV]	$P_{\beta n}$ [%]
^{48}K	(2^-)	^{48}Ca	9945	12090	1.1
^{50}K	$(0^-,1^-,2^-)$	^{50}Ca	6353	14220	22.5
^{84}Ga	(0^-)	^{84}Ge	5243	12900	42.5
^{86}Br	(1^-)	^{86}Kr	9857	7626	
^{96}Y	0^-	^{96}Zr	7856	7096	
^{98}Y	$(0)^-$	^{98}Zr	6415	8824	0.33
^{130}In	$1^{(-)}$	^{130}Sn	7596	10249	0.92
^{136}I	(1^-)	^{136}Xe	8084	6930	
^{140}Cs	1^-	^{140}Ba	6428	6220	
^{142}Cs	0^-	^{142}Ba	6181	7325	0.09
^{144}Cs	$1^{(-)}$	^{144}Ba	5901	8500	2.9
^{146}Cs	1^-	^{146}Ba	5495	9370	12.4

LNL-NS-DCS-c3

mainly involved working group participants: G. Benzoni INFN Mi, F. Crespi UNIMI-INFN , M. Scheck UWS

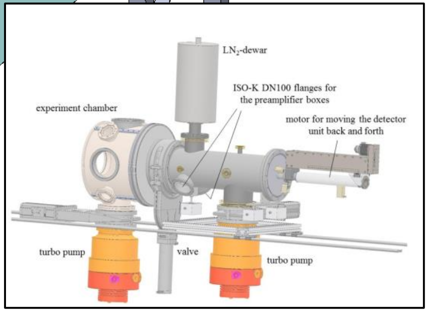
b-DS @SPES

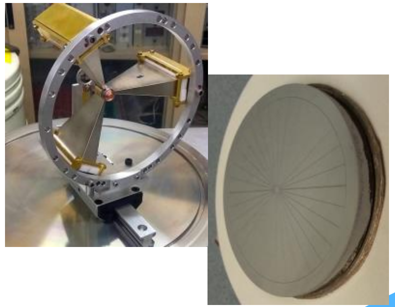


3D rendering of the structure:

- 2 chambers connected via same tape system
- Top chamber dedicated to decay studies:
    - Plastic det. for betas with SiPM readout
    - HPGe (Galileo Triple Clusters) for gamma rays

- Bottom chamber for E0 and EC measurements:
    - MOS system coupled to cooled Si(Li)





INFN Milano, Firenze, Perugia, Uni. Camerino

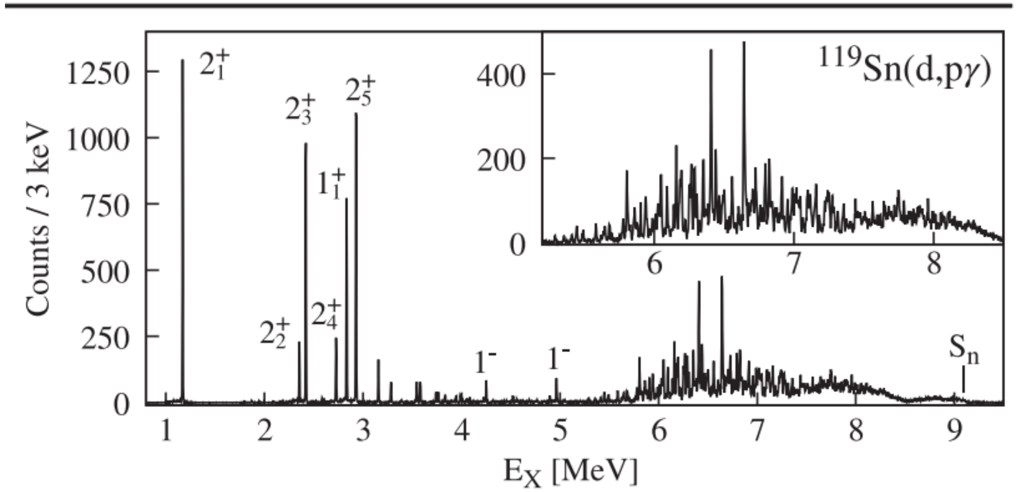
Courtesy of G. Benzoni

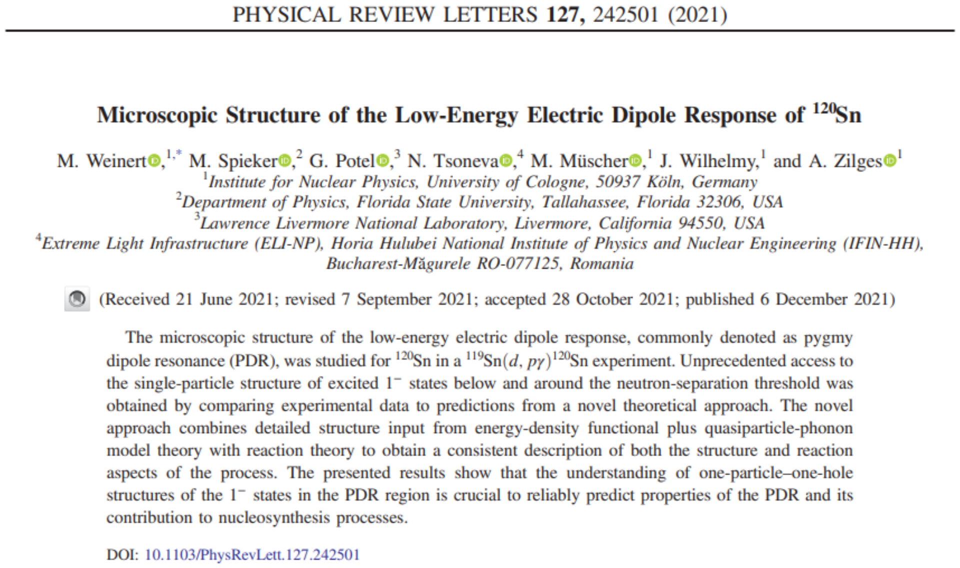
Stable Beams - PDR and PQR

- Inelastic scattering and transfer reactions (also in inverse kinematics) + gamma-rays in coincidence
- **Setup:** Cryogenic target CTADIR (p or alpha) (AGATA and PARIS/LaBr3:Ce) (TRACE)
- **Reactions:** ^{91}Zr(p,d)^{90}Zr* also Sn and Te
- *neutron removal* (investigation of hole states)

Example: ^{119}Sn(d,pγ)^{120}Sn @ 8.5 MeV

Institute for Nuclear Physics in Cologne





PHYSICAL REVIEW LETTERS **127,** 242501 (2021)

Microscopic Structure of the Low-Energy Electric Dipole Response of ^{120}Sn

M. Weinert,[1,*] M. Spieker,[2] G. Potel,[3] N. Tsoneva,[4] M. Müscher,[1] J. Wilhelmy,[1] and A. Zilges[1]
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(Received 21 June 2021; revised 7 September 2021; accepted 28 October 2021; published 6 December 2021)

The microscopic structure of the low-energy electric dipole response, commonly denoted as pygmy dipole resonance (PDR), was studied for ^{120}Sn in a ^{119}Sn$(d, p\gamma)^{120}$Sn experiment. Unprecedented access to the single-particle structure of excited 1^- states below and around the neutron-separation threshold was obtained by comparing experimental data to predictions from a novel theoretical approach. The novel approach combines detailed structure input from energy-density functional plus quasiparticle-phonon model theory with reaction theory to obtain a consistent description of both the structure and reaction aspects of the process. The presented results show that the understanding of one-particle–one-hole structures of the 1^- states in the PDR region is crucial to reliably predict properties of the PDR and its contribution to nucleosynthesis processes.

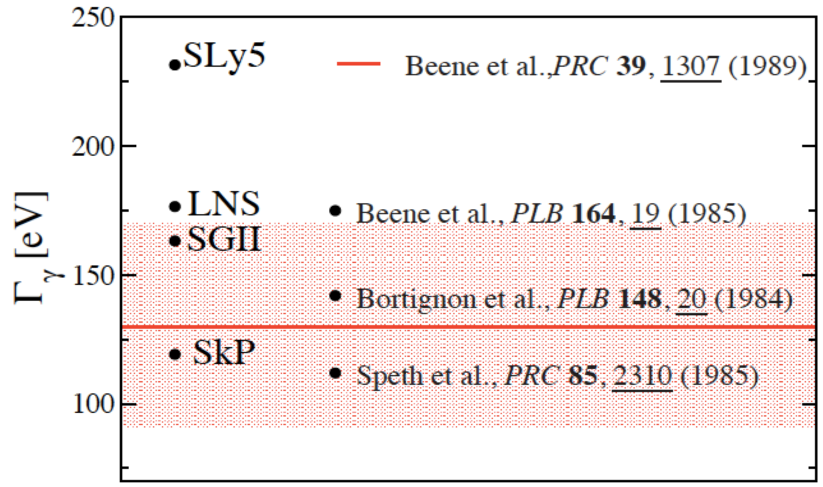
DOI: 10.1103/PhysRevLett.127.242501

mainly involved working group participants:
F. Crespi UNIMI/INFN, L. Pellegri WITS & iTL, M. Spieker FSU

LNL-NS-DCS-a0

LNL-NS-DCS-b0

Stable Beams - GDR / GQR



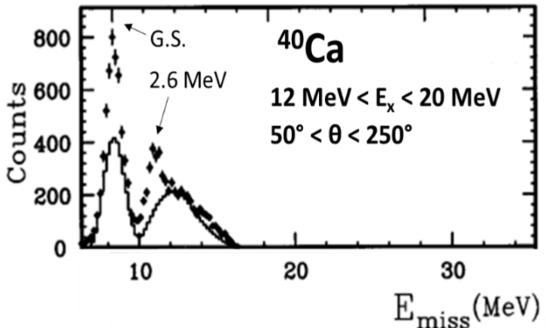
Gamma and Particle Decay of Giant Resonances Excited by Inelastic Scattering of ^{17}O ions at 20 MeV/A

- The gamma-decay width is a small fraction (≈ 10^{-3}) of the total width
- A microscopic model based on Skyrme functionals has been [*] developed

The particle decay from GR states

[*] M. Brenna, G. Colò, and P.F. Bortignon, Phys. Rev. C85, 014305 (2012)

- in past experiments main limitation was due to the detection of the low energy charge particles
  - ➢ decay was mainly measured for the ground state and the first excited state
- We would like to measure the GR particle decay via detection of gamma rays from residual nuclei (high efficiency of AGATA allows to determine the entry point after particle emission)
  - *Better energy resolution and no problems for detection of low energy particles*



LNL-NS-DCS-a1

Interesting nuclear systems to study first are ^{40}Ca, ^{24}Mg and Ni isotopes

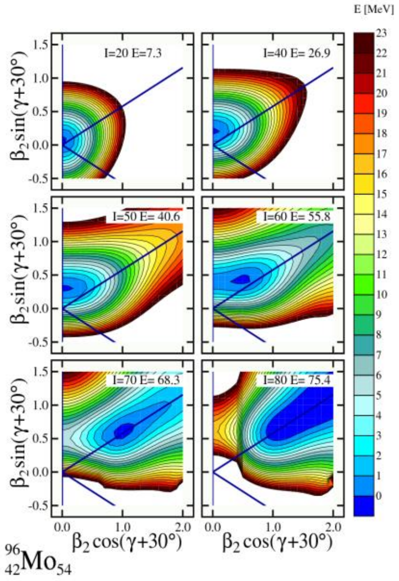
**Learning about the structure of giant resonances from their γ decay, W. L. Lv, Y. F. Niu, and G. Colo, Phys. Rev. C 103, 064321 (2021).

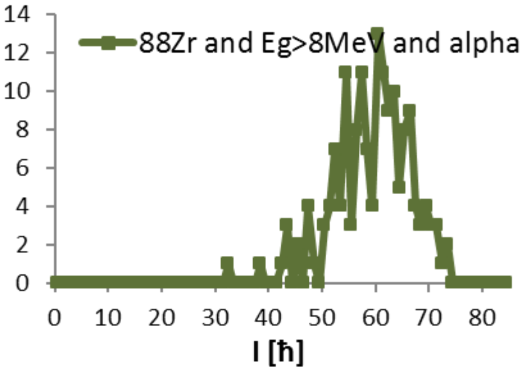
mainly involved working group participants: F. Crespi UNIMI-INFN

Stable Beams - Jacobi shape (hot GDR)

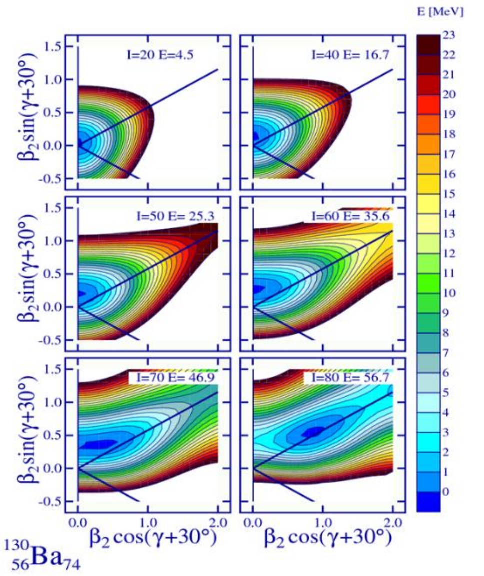
LNL-NS-DCS-a2

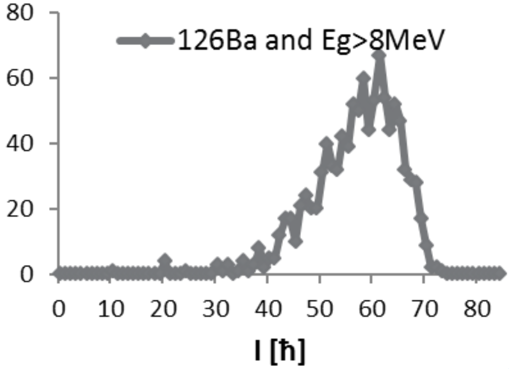
^{96}Mo
Beam: 250 MeV ^{48}Ca - stable
Target: ^{48}Ti
Fusion-evaporation, E* = 121MeV, Lmax=80 h
Measured: high-energy γ rays, discrete transitions and α particles
Detectors: PARIS, AGATA, Euclides





^{130}Ba
Beam: 350 MeV ^{82}Se - stable
Target: ^{48}Ti
Fusion-evaporation, E* = 90MeV, Lmax=78 h
Measured: high-energy γ rays, discrete transitions and multiplicity (PARIS)
Detectors: PARIS, AGATA,



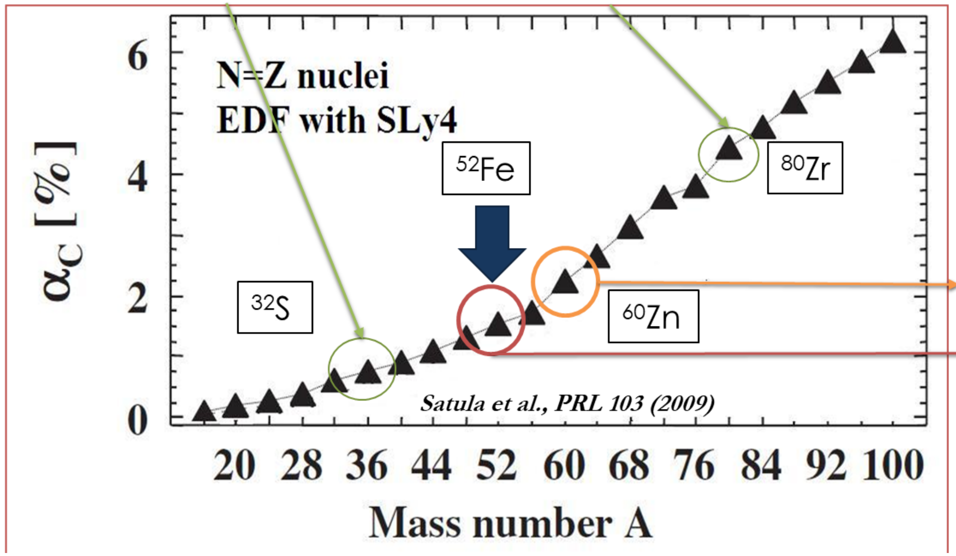


mainly involved working group participants: M. Kmiecik IFJ-PAN Krakow

Stable Beams - Isospin Mixing

D. Mondal et al.

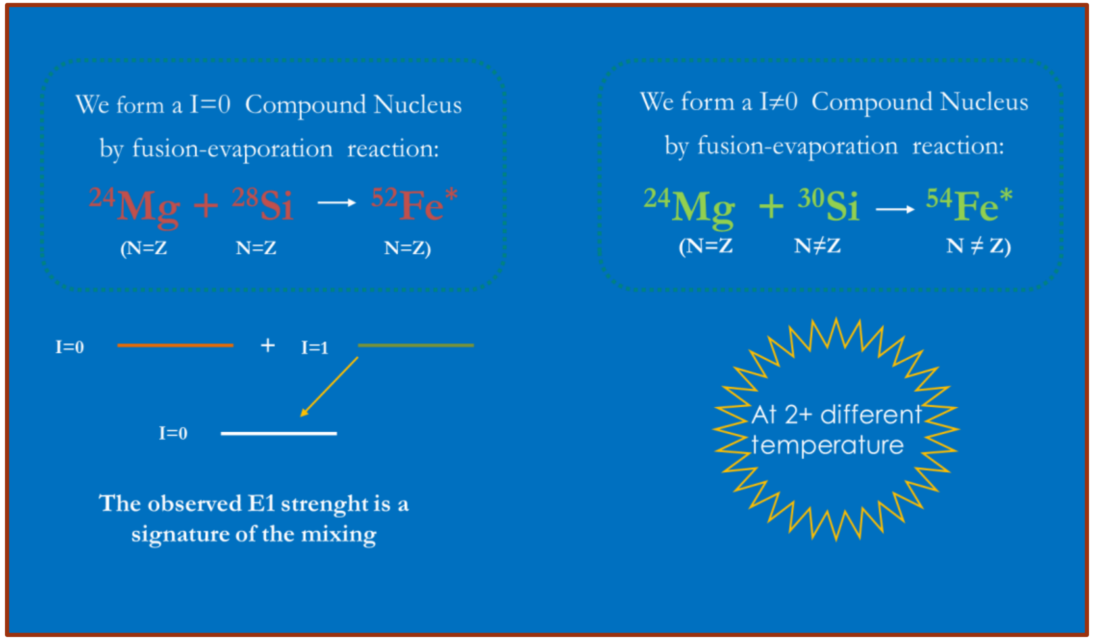
Ceruti et al. & Corsi at al.



Satula et al., PRL 103 (2009)

June 2016 and December 2018 @Laboratori Nazionali di Legnaro-INFN

Loi for Agata



We form a I=0 Compound Nucleus by fusion-evaporation reaction:

$^{24}\mathrm{Mg} + ^{28}\mathrm{Si} \rightarrow ^{52}\mathrm{Fe}^*$

(N=Z N=Z N=Z)

We form a I≠0 Compound Nucleus by fusion-evaporation reaction:

$^{24}\mathrm{Mg} + ^{30}\mathrm{Si} \rightarrow ^{54}\mathrm{Fe}^*$

(N=Z N≠Z N ≠ Z)

The observed E1 strenght is a signature of the mixing

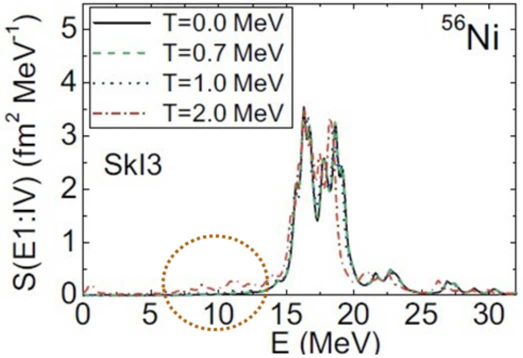
At 2+ different temperature

LNL-NS-DCS-a3

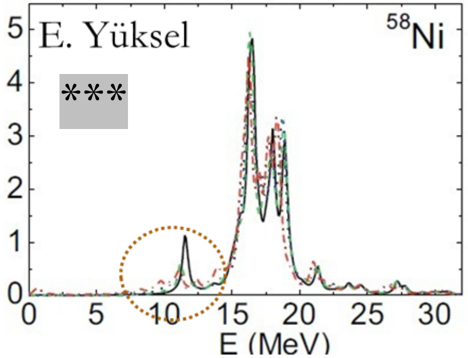
mainly involved working group participants: O. Wieland INFN Mi/ F. Camera UNIMI-INFN

Stable Beams – Hot-PDR (2022 experiment @IFIN-HH with ELIGANT)

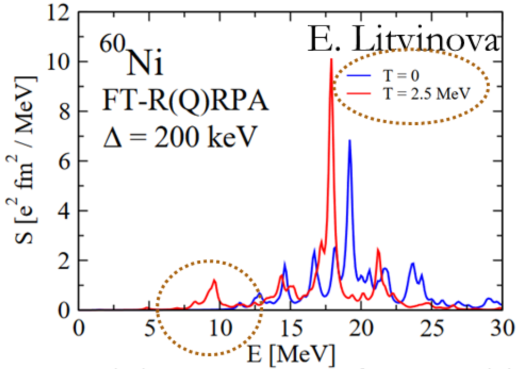
N=Z nucleus



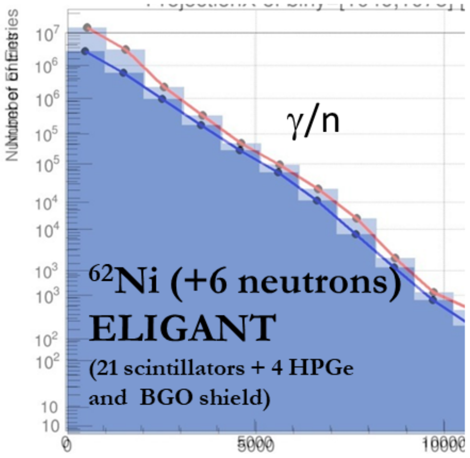
N=Z core + 2 neutrons



N=Z core + 4 neutrons ^{60}Ni



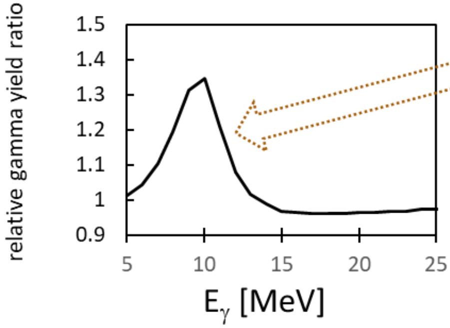
T=0 little PDR; T>0 growing of PDR strength !

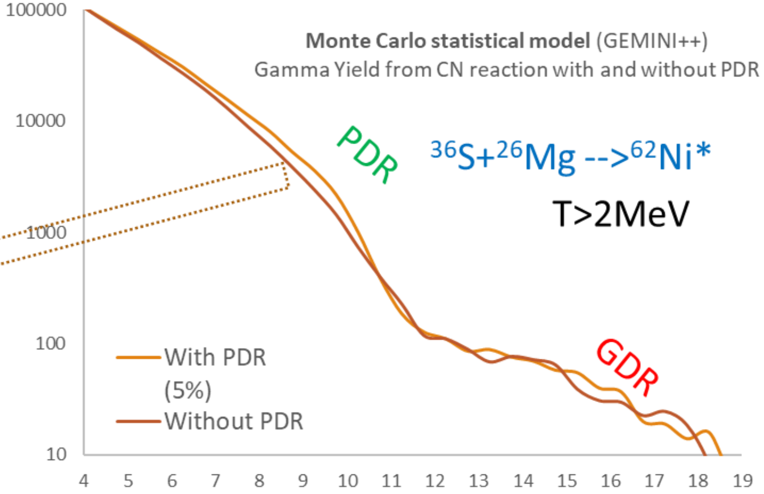


^{62}Ni (+6 neutrons)
ELIGANT
(21 scintillators + 4 HPGe and BGO shield)

difference measurement:

measure the HOT PDR in CN fusion in «difference» between γ-yield of nucleus with and without PDR





^{36}S+^{26}Mg -->^{62}Ni*

T>2MeV

We want now to answer to the open experimental never answered Question:
does the PDR state exist also at nuclear temperature >0
(excitation energy and spin) ?
impact on stellar processes,
neutron star collisions, mergers ??

Mid Term prospective:
Future measurements→ go to more n-rich systems

*** Low-energy monopole and dipole response in nuclei at finite temperature, Y. F. Niu, N. Paar, D. Vretenar, and J. Meng, Phys. Lett. B 681, 315 (2009)
Temperature effects on neutron-capture cross sections and rates through electric dipole transitions in hot nuclei, A. Berceanu, Y. Xu, and Y. F. Niu, Phys. Rev. C 104, 044332 (2021).

mainly involved working group participants: O. Wieland INFN Mi

LNL-NS-DCS-a4

Conclusions and Perspectives

- Lively discussions and significant work performed by the Deformation and Collective States Working Group, show the scientific vitality of this sub-field
- Several selected central physics cases that can be addressed taking advantage of the specific instrumentations and accelerators available at **LNL** (*presently and in the next few years, like* ***SPES***)
- Preparation of the paper…