Nuclear structure studies with the neutron detector NEDA: fusion evaporation and transfer reactions

Jose Javier Valiente Dobón

Laboratori Nazionali di Legnaro (INFN), Italy.

Overview

- NEDA neutron detector
- Fusion evaporation reactions
  - Octupole correlations in the neutron deficient Xe
- Transfer reactions (^{3}He,n)
  - The Colossal MED in ^{36}Ca-^{36}S
- Summary

What is NEDA?

- Versatile neutron detector to be coupled to gamma-ray arrays, ex. AGATA
- Neutron detection is based on the liquid scintillator EJ301 with good neutron-gamma discrimination capabilities.
- Single hexagonal detector FEE fully digital system:
  - 200 MHz and ENOB 11,3
  - Global Trigger System - GTS

Nuclear Inst. and Methods in Physics Research, A 927 (2019) 81–86

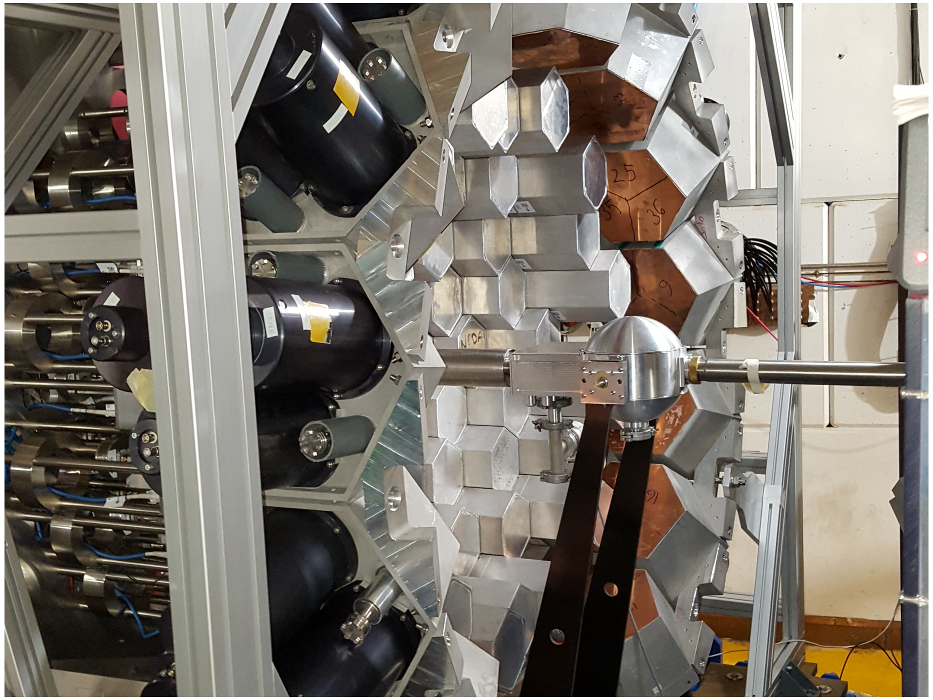
Contents lists available at ScienceDirect

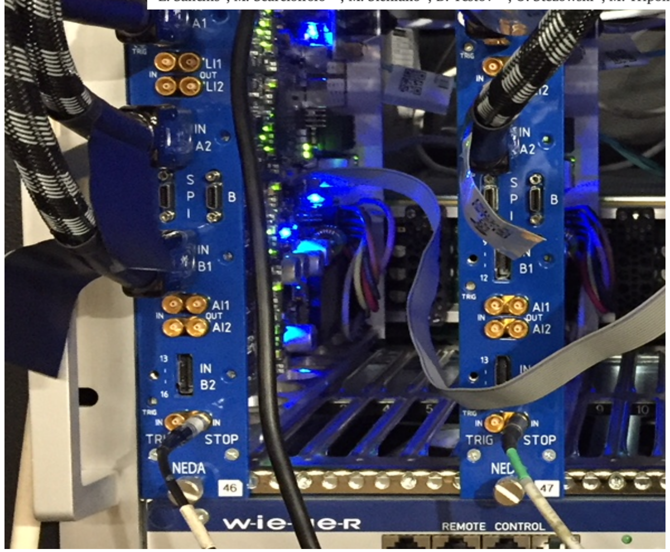
Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima

NEDA—NEutron Detector Array

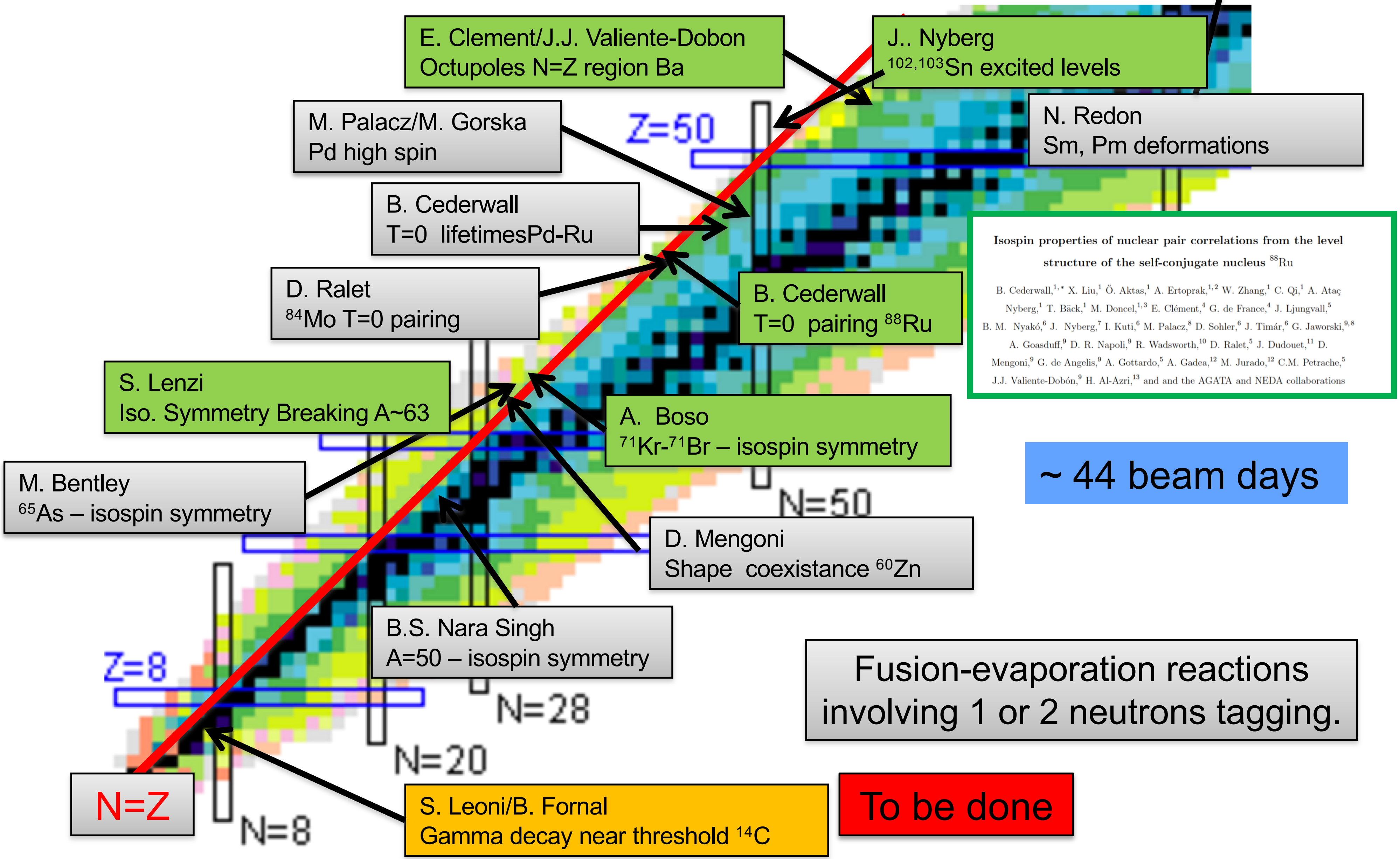
J.J. Valiente-Dobón [a,*], G. Jaworski [a], A. Goasduff [a,b,c], F.J. Egea [a,b,c,d], V. Modamio [a,e], T. Hüyük [d], A. Triossi [b,c,f], M. Jastrząb [g], P.A. Söderström [h], A. Di Nitto [i], G. de Angelis [a], G. de France [j], N. Erduran [k], A. Gadea [d], M. Moszyński [l], J. Nyberg [m], M. Palacz [n], R. Wadsworth [o], R. Aliaga [d], C. Aufranc [q], M. Bézard [j], G. Baulieu [q], E. Bissiato [a], A. Boujrad [j], I. Burrows [p], S. Carturan [a,b], P. Cocconi [a], G. Colucci [b,c], D. Conventi [a], M. Cordwell [p], S. Coudert [j], J.M. Deltoro [a], L. Ducroux [j], T. Dupasquier [q], S. Ertürk [r], X. Fabian [q], V. González [s], A. Grant [p], K. Hadyńska-Klęk [a,t], A. Illana [a], M.L. Jurado-Gomez [d], M. Kogimtzis [p], I. Lazarus [p], L. Legeard [j], J. Ljungvall [u], G. Pasqualato [b,c], R.M. Pérez-Vidal [d], A. Raggio [a], D. Ralet [j], N. Redon [q], F. Saillant [j], B. Sayğı [v], E. Sanchis [s], M. Scarcioffolo [b,c], M. Siciliano [a], D. Testov [b,c], O. Stezowski [q], M. Tripon [j], I. Zanon [a]





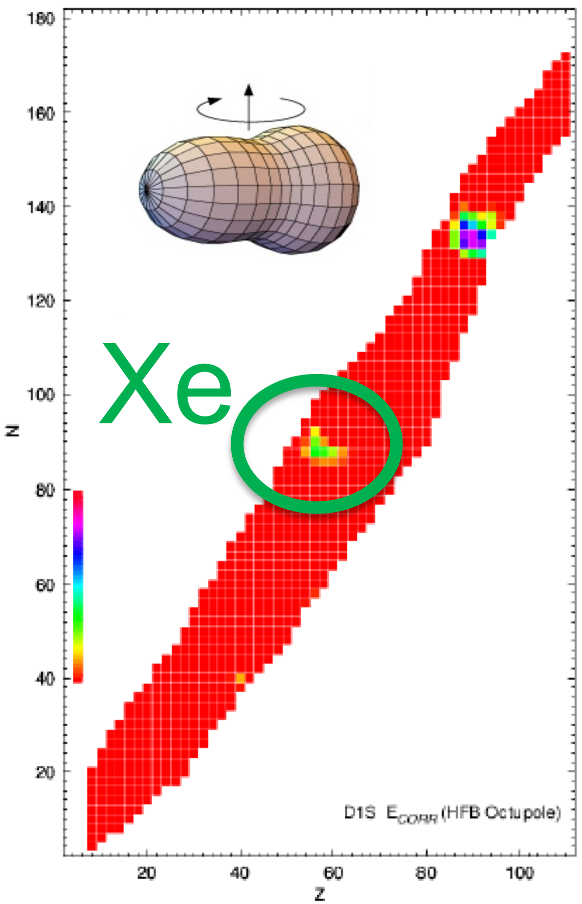
First physics campaign with NEDA

18th of april until 29th of July 2018



Fusion evaporation reactions

Octupoles in the Segré chart



Mean field correlation energies of 1.5 MeV at most, while id quadrupole deformed nuclei can reach up to 20 MeV.

- Z~34, 56, 88
- N~34, 56, 88,134

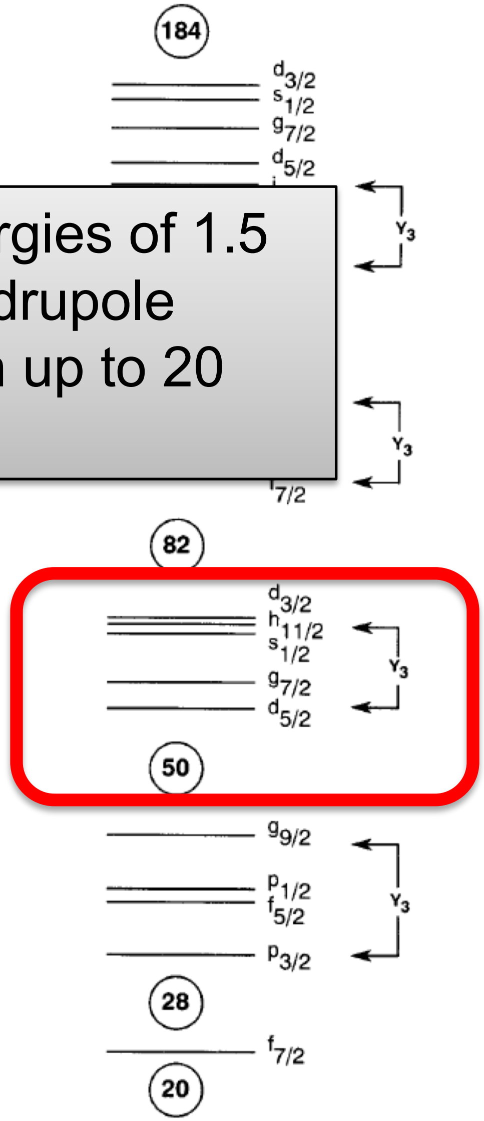
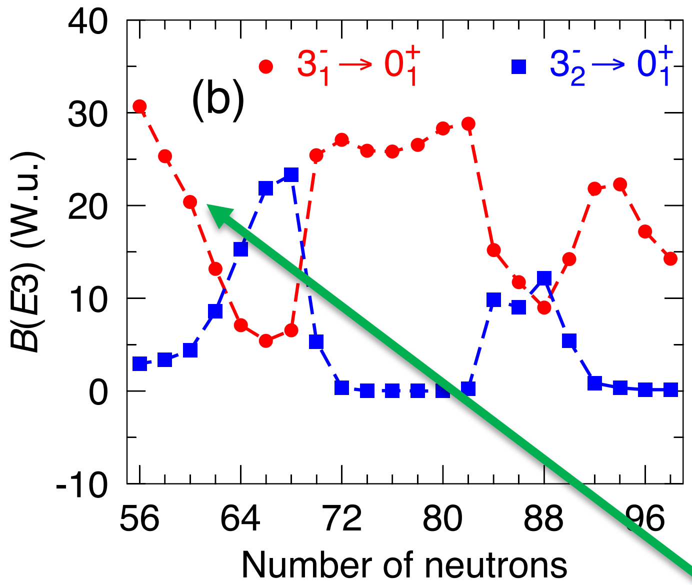


FIG. 4. Nuclear spherical single-particle levels. The most important octupole couplings are indicated.

L.M. Robledo (private communication)

Octupole correlations in ^{114}Xe

Symmetry Conserving Configuration Mixing → T. Rodriguez



Coherent proton–neutron contribution to octupole correlations in the neutron-deficient ^{114}Xe nucleus

G. de Angelis[a], A. Gadea[a], E. Farnea[a], R. Isocrate[b], P. Petkov[c,d], N. Marginean[a], D.R. Napoli[a], A. Dewald[c], M. Bellato[b], A. Bracco[e], F. Camera[e], D. Curien[f], M. De Poli[a], E. Fioretto[a], A. Fitzler[c], S. Kasemann[c], N. Kintz[f], T. Klug[c], S. Lenzi[b], S. Lunardi[b], R. Menegazzo[b], P. Pavan[b], J.L. Pedroza[g], V. Pucknell[h], C. Ring[f], J. Sampson[i], R. Wyss[j]

[a] *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Legnaro, I-35020 Legnaro, Italy*
[b] *Dipartimento di Fisica dell'Università, and Istituto Nazionale di Fisica Nucleare, Sezione di Padova, I-35131 Padova, Italy*
[c] *Institut für Kernphysik der Universität zu Köln, D-50937 Köln, Germany*
[d] *Bulgarian Academy of Sciences, Institute for Nuclear Research and Nuclear Energy, 1784 Sofia, Bulgaria*
[e] *Dipartimento di Fisica dell'Università, and Istituto Nazionale di Fisica Nucleare, Sezione di Milano, I-20133 Milano, Italy*
[f] *Institut de Recherches Subatomiques, F67037 Strasbourg, France*
[g] *Centre D'Etudes Nucleaires de Bordeaux, Bordeaux, France*
[h] *Daresbury Laboratory, Warrington WA44AD, United Kingdom*
[i] *University of Liverpool, PO Box 147, Liverpool L69 3BX, United Kingdom*
[j] *KTH-Kärnfysik, Frescativ. 24, S-104 05 Stockholm, Sweden*

Received 13 December 2001; received in revised form 8 April 2002; accepted 8 April 2002

Editor: J.P. Schiffer

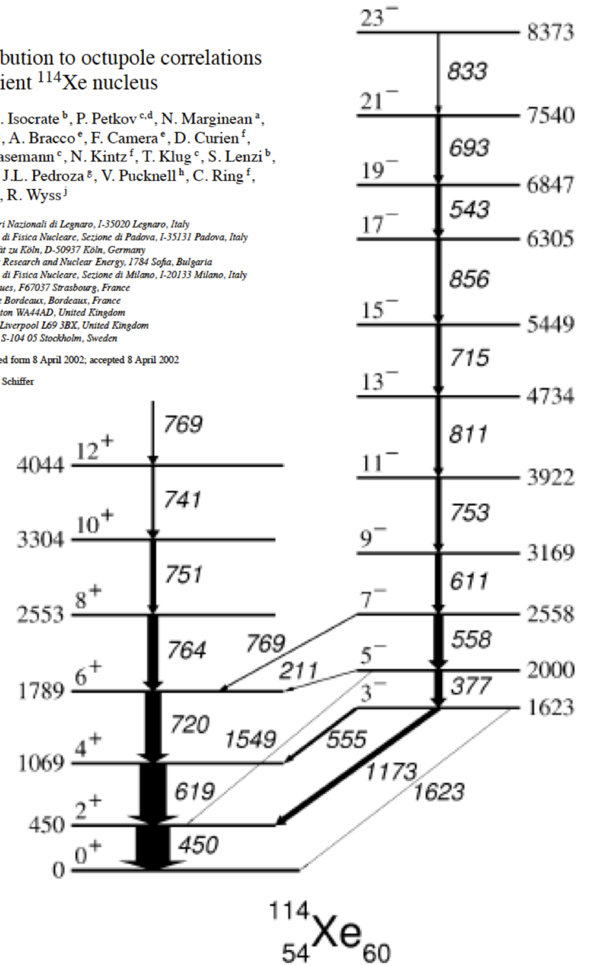


Fig. 2. Partial level scheme for ^{114}Xe. The energies are given in keV. The widths of the arrows are proportional to the relative intensities.

- Linear polarization
- Lifetimes

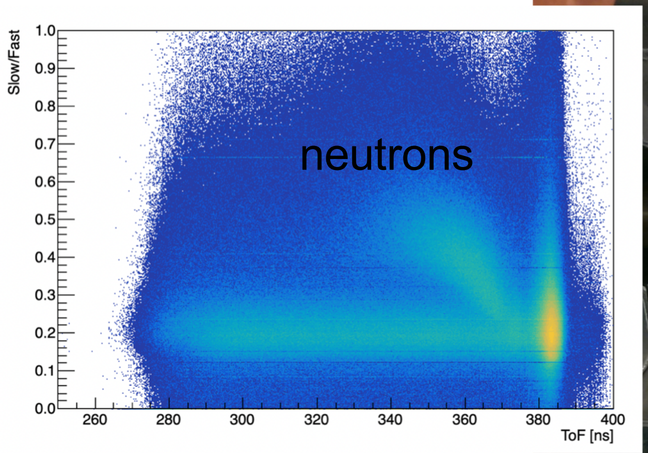
} $B(E3{:}3^- \rightarrow 0^+) = 77$ W.u.

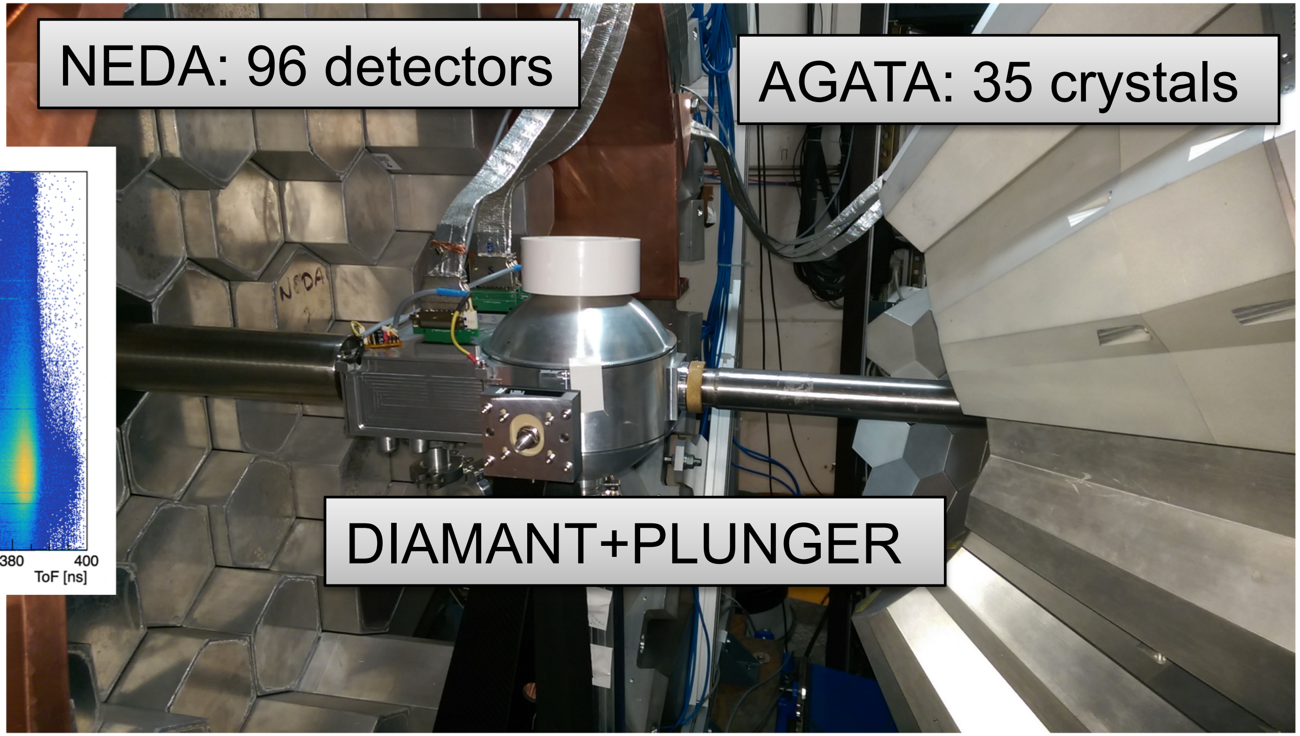
^{114}Xe is not expected to be a static octupole.
The large B(E3) might be understood in terms of dynamical coupling of the proton-neutron type
$\pi(\nu)\ d_{5/2} - \nu\ (\pi)\ h_{11/2}$

NEDA+AGATA GANIL exp.

Fusion-evaporation reaction ^{58}Ni(^{58}Ni, 2n2p)^{112}Xe 250 MeV
Plunger technique for lifetimes

Trigger: at least 1 neutron (PSA) in coincidence with γ-rays is required

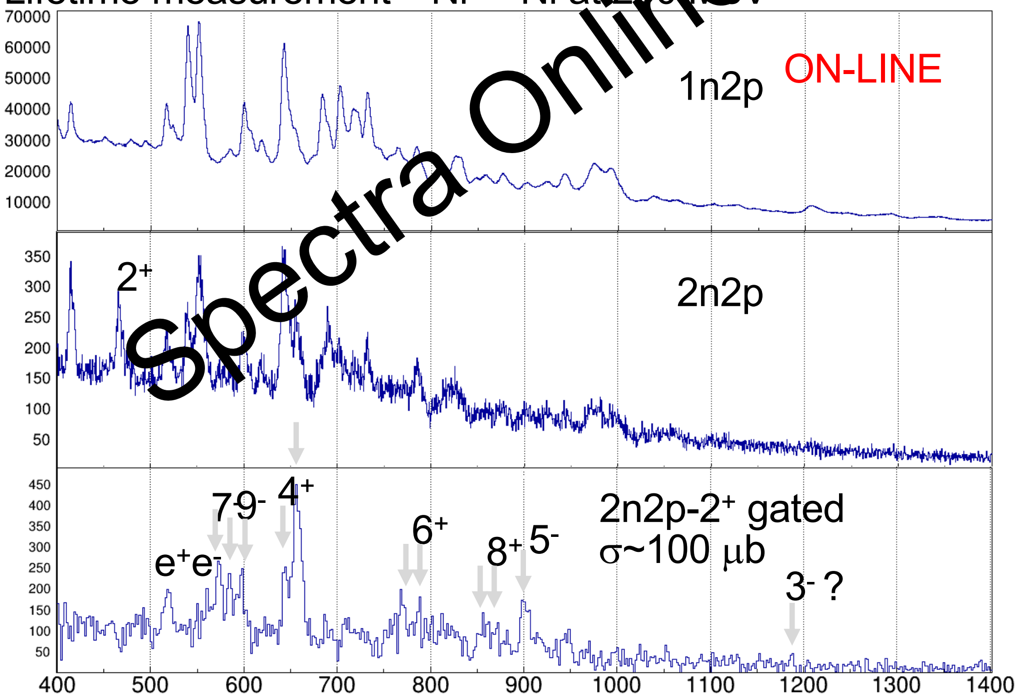




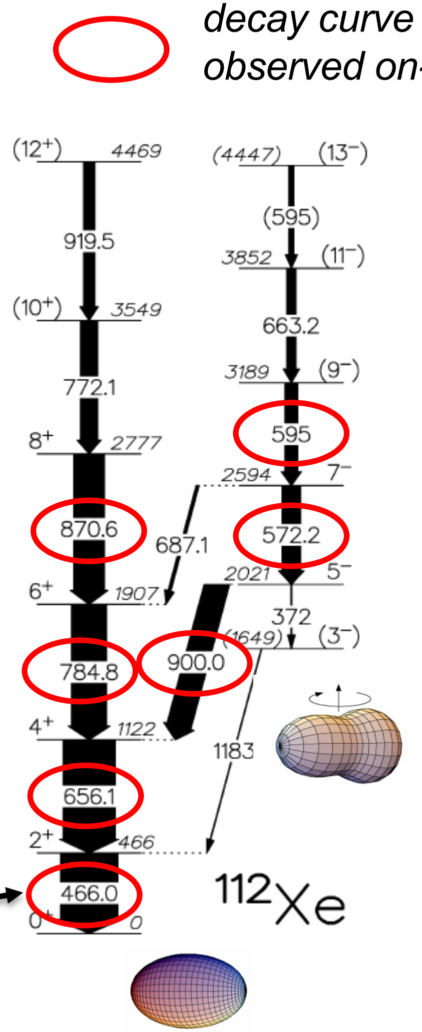
PhD thesis: M.L. Jurado (U. of Valencia and Padova)
Spokepersons: E. Clement, A. Gadea & JJVD

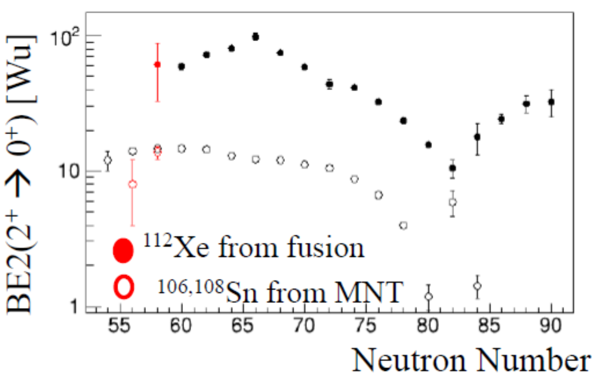
Lifetimes in ^{112}Xe

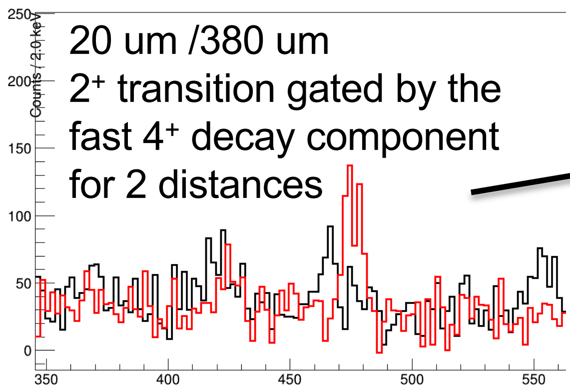
Lifetime measurement ^{58}Ni+^{58}Ni at 250 MeV



Transitions for which a decay curve was observed on-line



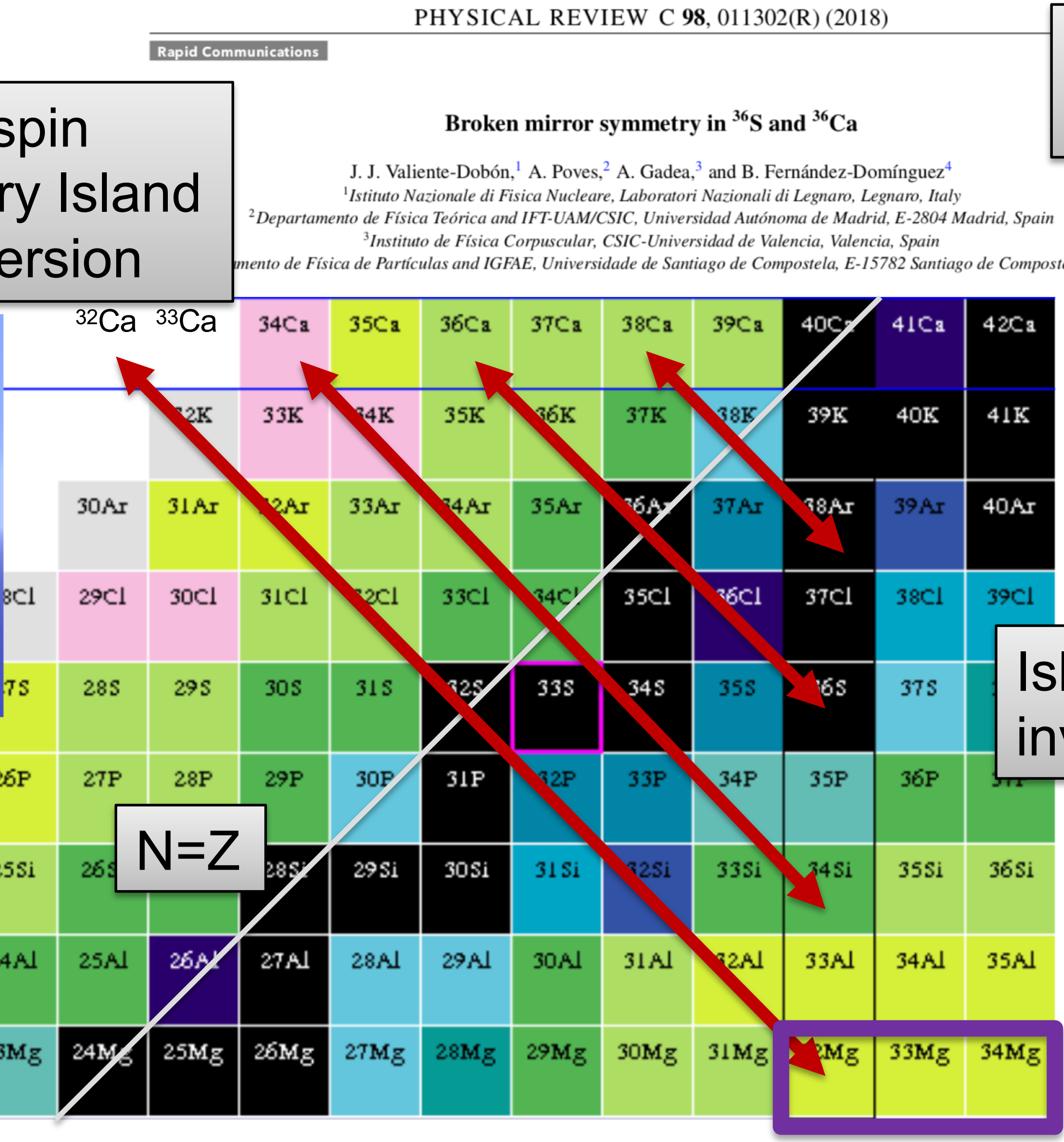




Transfer reactions (^3He,n)

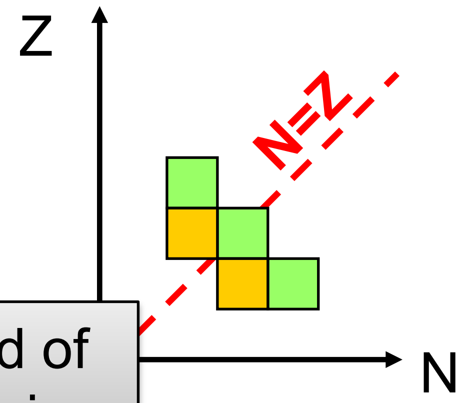
Broken mirrors: the ^{36}Ca-^{36}S case

Isospin symmetry Island of inversion



Mirror Energy Differences

$MED_J = E_{J,Z>} - E_{J,Z<}$



Island of inversion

LSSM calculations for ^{36}Ca-^{36}S

GANIL

PHYSICAL REVIEW C **86**, 064609 (2012)

Cross sections for one-neutron knock-out from ^{37}Ca at intermediate energy

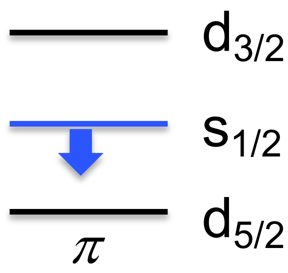
A. Bürger,[1,2,*] F. Azaiez,[3] A. Algora,[4] A. Al-Khatib,[1] B. Bastin,[5] G. Benzoni,[6] R. Borcea,[7] C. Bourgeois,[3] P. Bringel,[1] E. Clément,[2] J.-C. Dalouzy,[8] Z. Dlouhý,[9] Z. Dombrádi,[4] A. Drouart,[2] C. Engelhardt,[1] S. Franchoo,[3] Z. Fülöp,[4] A. Görgen,[2] S. Grévy,[8] H. Hübel,[1] F. Ibrahim,[3] W. Korten,[2] J. Mrázek,[9] A. Navin,[8] F. Rotaru,[7] P. Roussel Chomaz,[8] M.-G. Saint-Laurent,[8] G. Sletten,[10] D. Sohler,[4] O. Sorlin,[8] M. Stanoiu,[7] I. Stefan,[8] C. Theisen,[2] C. Timis,[11] D. Verney,[3] and S. Williams[11]

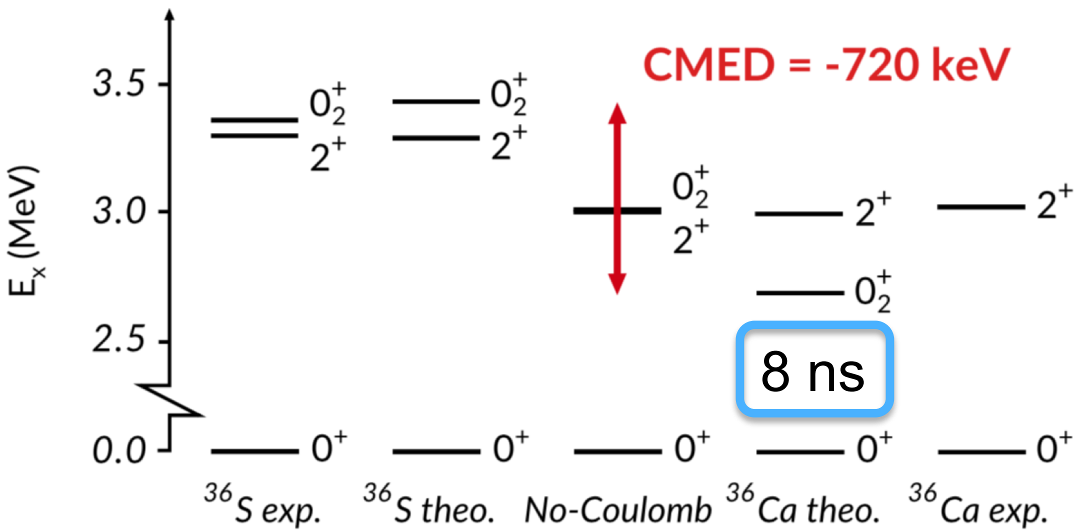
GSI

ELSEVIER
Available online at www.sciencedirect.com
ScienceDirect
Physics Letters B 647 (2007) 237–242
PHYSICS LETTERS B
www.elsevier.com/locate/physletb

The $T = 2$ mirrors ^{36}Ca and ^{36}S:
A test for isospin symmetry of shell gaps at the driplines

P. Doornenbal[a,b], P. Reiter[a,*], H. Grawe[b], T. Otsuka[c,d], A. Al-Khatib[e], A. Banu[b], T. Beck[b], F. Becker[b], P. Bednarczyk[b,f], G. Benzoni[g], A. Bracco[g], A. Bürger[e], L. Caceres[b,h], F. Camera[g], S. Chmel[e], F.C.L. Crespi[g], H. Geissel[b], J. Gerl[b], M. Górska[b], J. Grębosz[b,f], H. Hübel[e], M. Kavatsyuk[b,i], O. Kavatsyuk[b,i], M. Kmiecik[f], I. Kojouharov[b], N. Kurz[b], R. Lozeva[b,j], A. Maj[f], S. Mandal[k], W. Meczynski[f], B. Million[g], Zs. Podolyák[l], A. Richard[a], N. Saito[b], T. Saito[b], H. Schaffner[b], M. Seidlitz[a], T. Striepling[a], Y. Utsuno[c,d], J. Walker[b], N. Warr[a], H. Weick[b], O. Wieland[g], M. Winkler[b], H.J. Wollersheim[b]

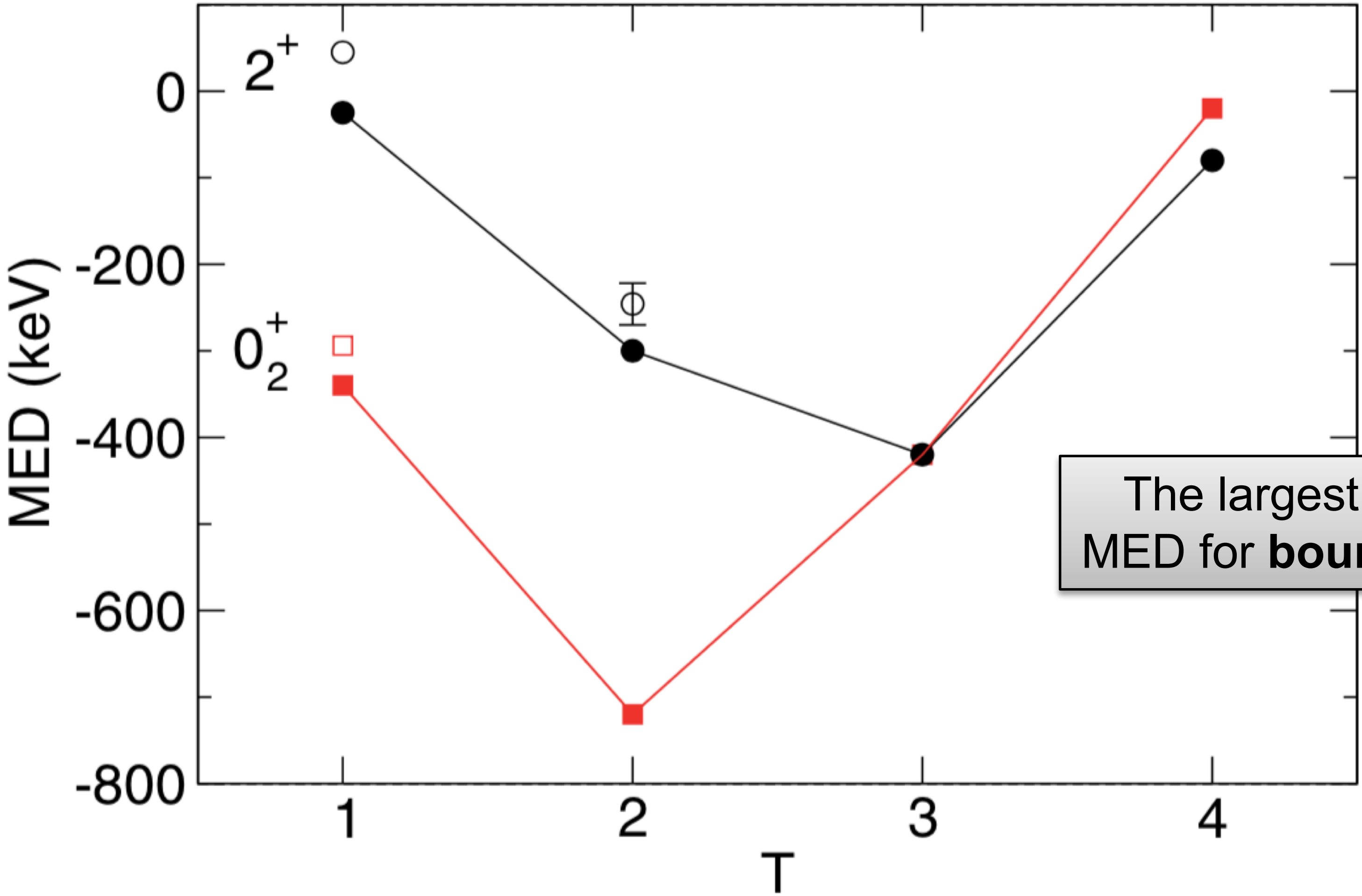




	^{36}Ca	
π		ν
$(sd)^{12}$		$d_{5/2}^{6}s_{1/2}^{1}d_{3/2}^{1}$
$d_{5/2}^{6}s_{1/2}^{2}d_{3/2}^{2}\ (pf)^{2}$		$d_{5/2}^{6}s_{1/2}^{1}d_{3/2}^{1}$
$(sd)^{12}$		$d_{5/2}^{6}s_{1/2}^{2}$

- Sdpfu-mix interaction: model space (sdpf)$\pi\nu$ and (sd) $\pi\nu$
- two-body matrix elements of the Coulomb potential

Colossal MED in ^{36}Ca-^{36}S



The largest known MED for **bound** states

How to measure the CMED in ^{36}Ca?

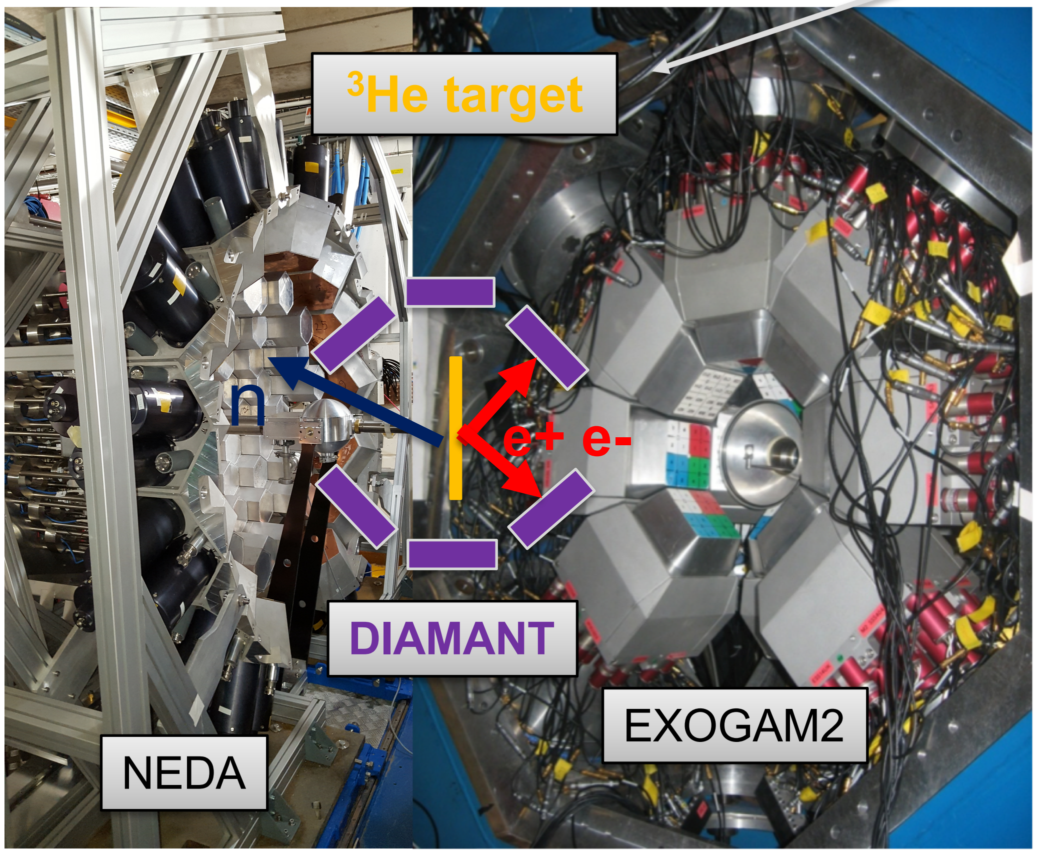
- Populate the 0_2^+ via **^{34}Ar (^{3}He,n) ^{36}Ca** 5 MeV.A
- Measure the $0^+ \rightarrow 0^+$ transition internal pair production e^+e^-.
- E_{e+e-} = 2700 – 1022 ~ 1700 keV (DIAMANT to measure)
- Solid ^{3}He target (patent)
- Exp. apparata: AGATA/EXOGAM2, DIAMANT, NEDA

Low gas consumption fabrication and testing of novel solid ^{3}He targets for Nuclear Reactions

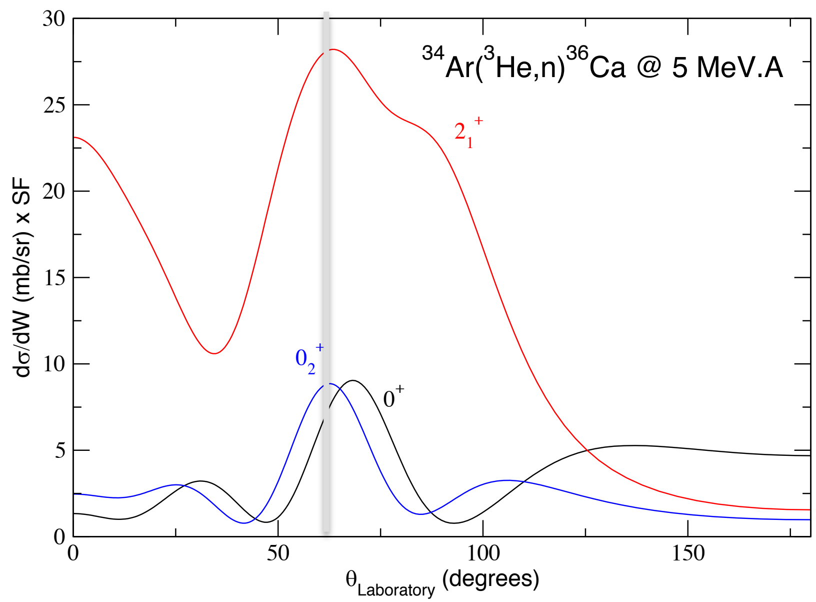
A. Fernández,*[a] D. Hufschmidt,[a] J.L. Colaux,[b1,b2] J.J. Valiente-Dobón,[c] V. Godinho,[a] M.C. Jiménez de Haro,[a] D. Feria,[a] A. Gadea,[d] S. Lucas.[b2]

[a] Instituto de Ciencia de Materiales de Sevilla, CSIC-Univ. Seville, Avda. Américo Vespucio 49, 41092-Sevilla, Spain.
[b1] Synthesis, Irradiation & Analysis of Ma... ue de Bruxelles, 5000 Namur, Belgium .
[b2] Laboratoire d'Analyse par Réactions N... atter (NISM), University of Namur, 61 Rue de
[c] INFN, Laboratori Nazionali di Legnaro,
[d] Instituto de Física Corpuscular, CSIC-Univ. Valencia, E-46980 Paterna, Spain

^{3}He target



DWBA calculations (Twofnr) – One step process – Abs value for evaluation normalized to ^{36}Ar (^{3}He,n) ^{38}Ca



NEDA angular coverage

Summary

- NEDA has been designed to be a multiplicty filter for fast neutrons from fusion-evaporation reactions, but not only …
- First campaign physics with NEDA+AGATA+DIAMANT finished in july 2018 (~44 days beam) → Fusion evaporation reactions
  - ^{112}Xe lifetimes to study quadrupole and octupole degrees of freedom
- NEDA will open new possibilities with transfer reactions where the emitted particle is a neutron. One case could be the study of the CMED in ^{36}Ca. There are other cases such as: ^{22}Mg (^{3}He,n) ^{24}Si – ^{78}Sr (^{3}He,n) ^{80}Zr

END