Study of deformed and spherical 2^+ states via Coulomb excitation and first time measurement of PDR in ^{34}Si

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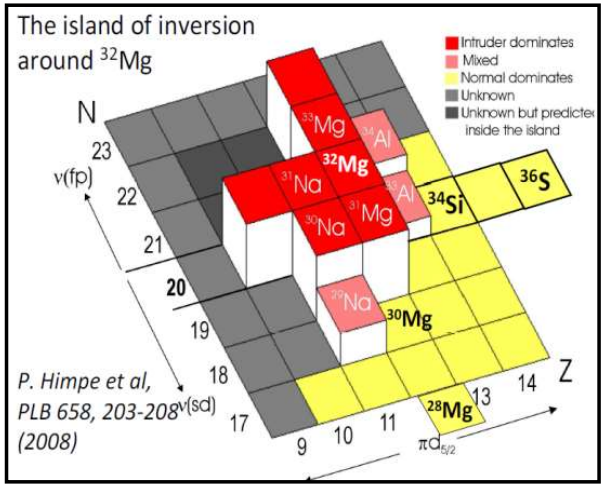
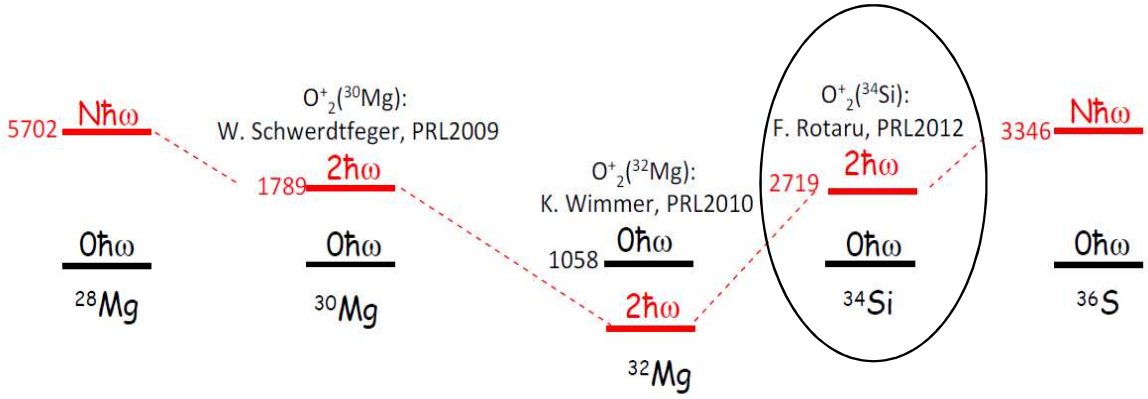
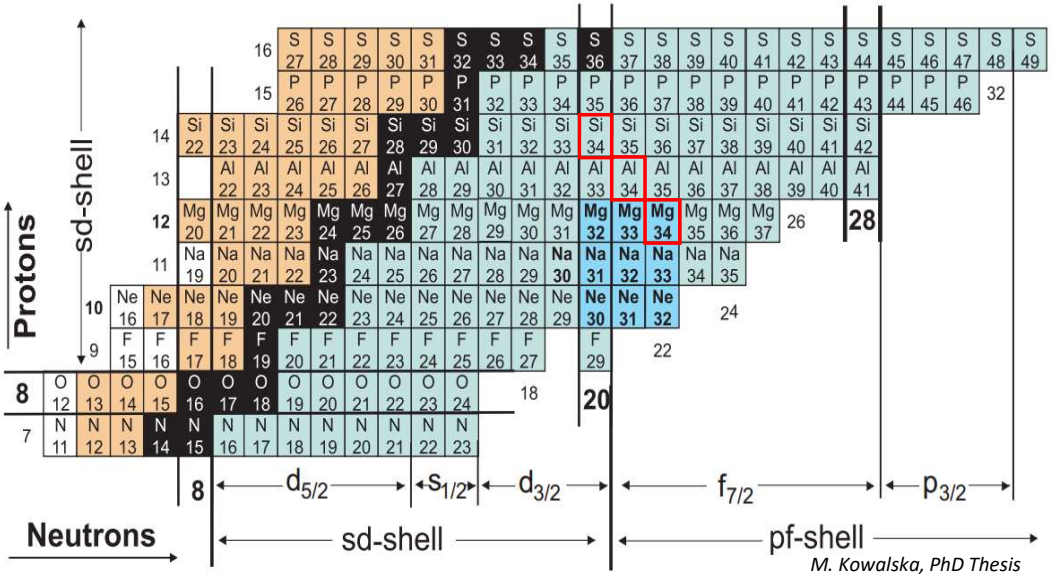
GANIL laboratoire commun CEA/DRF SPIRAL2 CNRS/IN2P3

PROPOSAL FOR AN EXPERIMENT

The physics case of ^{34}Si



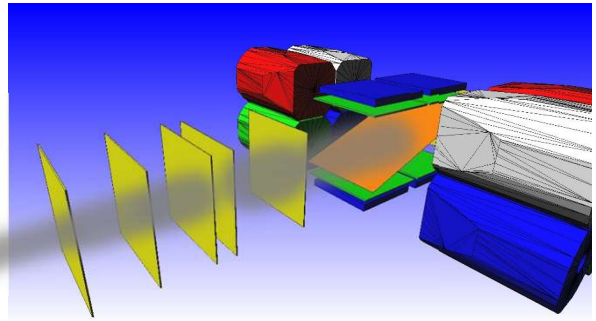




- The recent experimental results on the $0^{+}_{1,2}$ states in ^{32}Mg [1] and ^{34}Si [2] has brought further credit to the description in which a crossing between normal and intruder regime occurs between these two nuclei.
- ^{34}Si is at the verge of the IoI and deformed structures were found in its level scheme [2, 3].

[1] K. Wimmer et al. PRL 105, 252501 (2010).
[2] F. Rotaru et al. PRL 109, 092503 (2012).
[3] R. Lica et al. PRC 100, 034306 (2019).

Characterising the 0_2^+ in ^{34}Si at GANIL



GANIL/LISE projectile fragmentation ^{36}S at 77.5 MeV/A

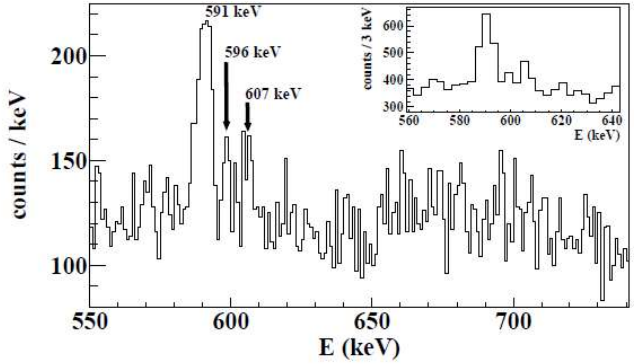
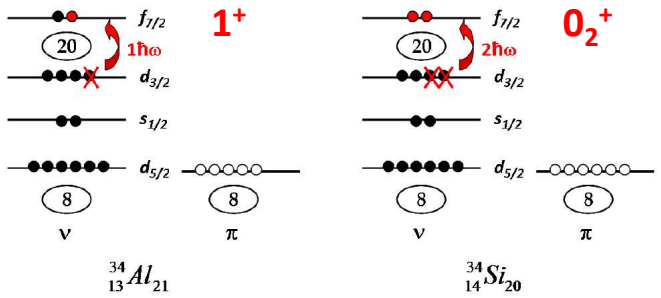


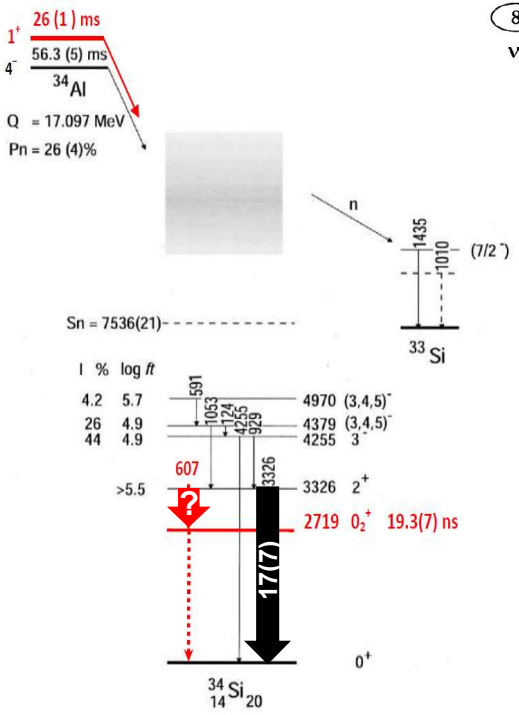
FIG. 3. Part of the gamma energy spectrum following the implantation of ^{34}Si nuclei. The main peak corresponds to the known 591 keV transition in ^{34}Si. Peaks at 607 keV and 596 keV correspond to the $2_1^+ \rightarrow 0_2^+$ decay and the (n,n'γ) reactions on the ^{74}Ge nuclei of EXOGAM, respectively. A zoom with 3 keV/bin is presented in the inset.

PRL 109, 092503 (2012) PHYSICAL REVIEW LETTERS week ending 31 AUGUST 2012

Unveiling the Intruder Deformed 0_2^+ State in ^{34}Si

F. Rotaru,[1] F. Negoita,[1] S. Grévy,[2,*] J. Mrazek,[3] S. Lukyanov,[4] F. Nowacki,[5] A. Poves,[6] O. Sorlin,[2] C. Borcea,[1] R. Borcea,[1] A. Buta,[1] L. Cáceres,[2] S. Calinescu,[1] R. Chevrier,[7] Zs. Dombrádi,[8] J. M. Daugas,[7] D. Lebhertz,[2] Y. Penionzhkevich,[4] C. Petrone,[1] D. Sohler,[8] M. Stanoiu,[1] and J. C. Thomas[2]





B(E2:$2^+_1 \rightarrow 0^+_2$) from:

- B(E2; 3326 keV $2^+_1 \rightarrow 0^+_1$) = 17(7) e^2fm^4
  Coulex : Ibbotson, PRC80(1998)2081

- $I\gamma$(3326 keV)/$I\gamma$(606 keV) = 1380(717)

Improved at IDS

B(E2:$2^+_1 \rightarrow 0^+_2$) = 61(40) e^2fm^4

IS530 experiment in 2015 at the ISOLDE Decay Station

- 42 transitions placed in the ^{34}Al level scheme
- **Clear identification of the 4$^-$ ground state and 1$^+$ isomer at 46.6 keV**

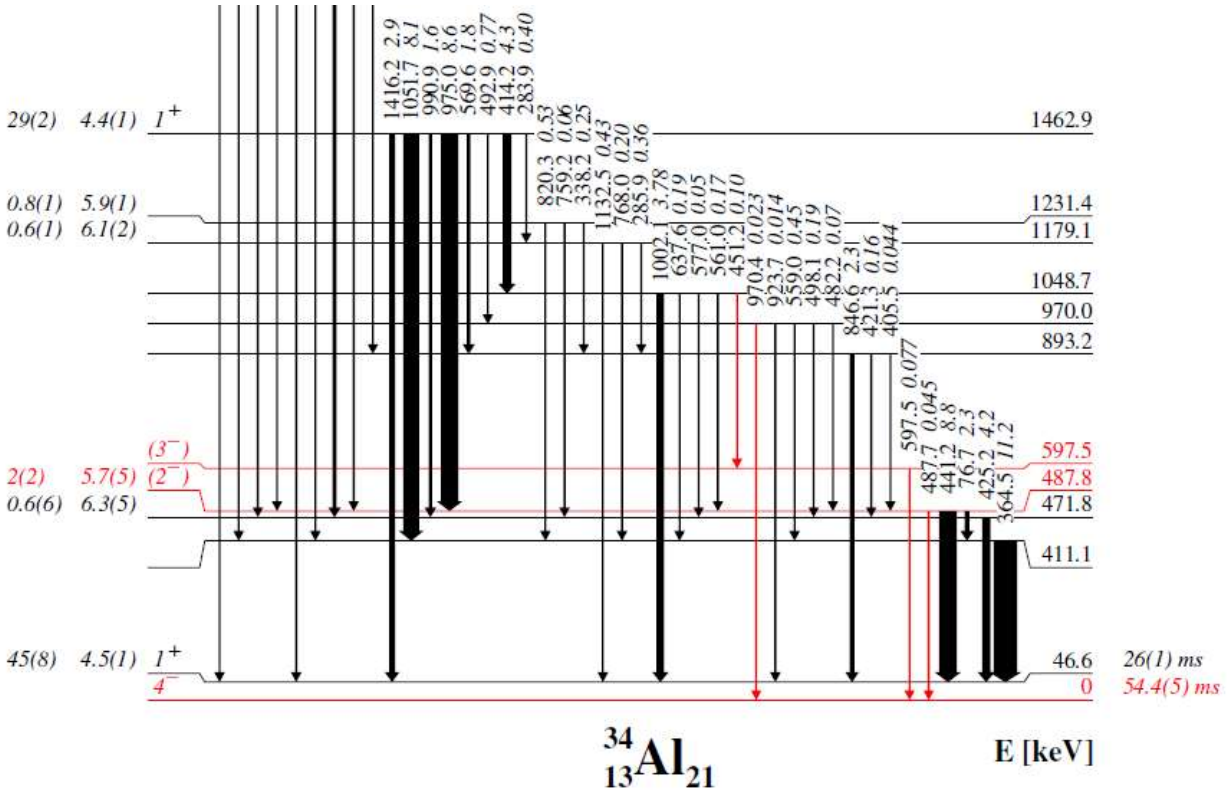
RAPID COMMUNICATIONS

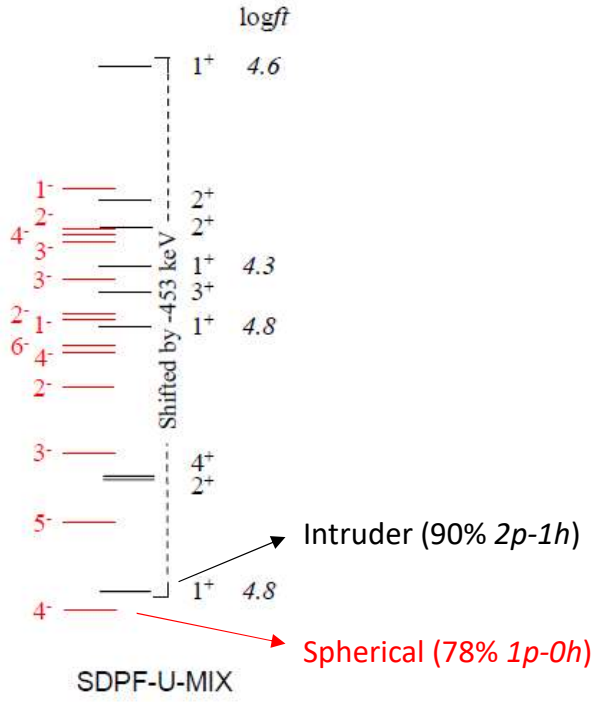
PHYSICAL REVIEW C **95**, 021301(R) (2017)

Identification of the crossing point at $N = 21$ between normal and intruder configurations

R. Lică,[1,2] F. Rotaru,[2] M. J. G. Borge,[1,3] S. Grévy,[4,5] F. Negoiță,[2] A. Poves,[6,7] O. Sorlin,[4] A. N. Andreyev,[8] R. Borcea,[2] C. Costache,[2] H. De Witte,[9] L. M. Fraile,[10] P. T. Greenlees,[11,12] M. Huyse,[9] A. Ionescu,[2] S. Kisyov,[2,13] J. Konki,[11,12] I. Lazarus,[14] M. Madurga,[1] N. Mărginean,[2] R. Mărginean,[2] C. Mihai,[2] R. E. Mihai,[2] A. Negret,[2] R. D. Page,[15] J. Pakarinen,[11,12] S. Pascu,[2] V. Pucknell,[14] P. Rahkila,[11,12] E. Rapisarda,[1] A. Şerban,[2] C. O. Sotty,[2] L. Stan,[2] M. Stănoiu,[2] O. Tengblad,[3] A. Turturică,[2] P. Van Duppen,[9] R. Wadsworth,[8] and N. Warr[16] (IDS Collaboration)

^{34}Al

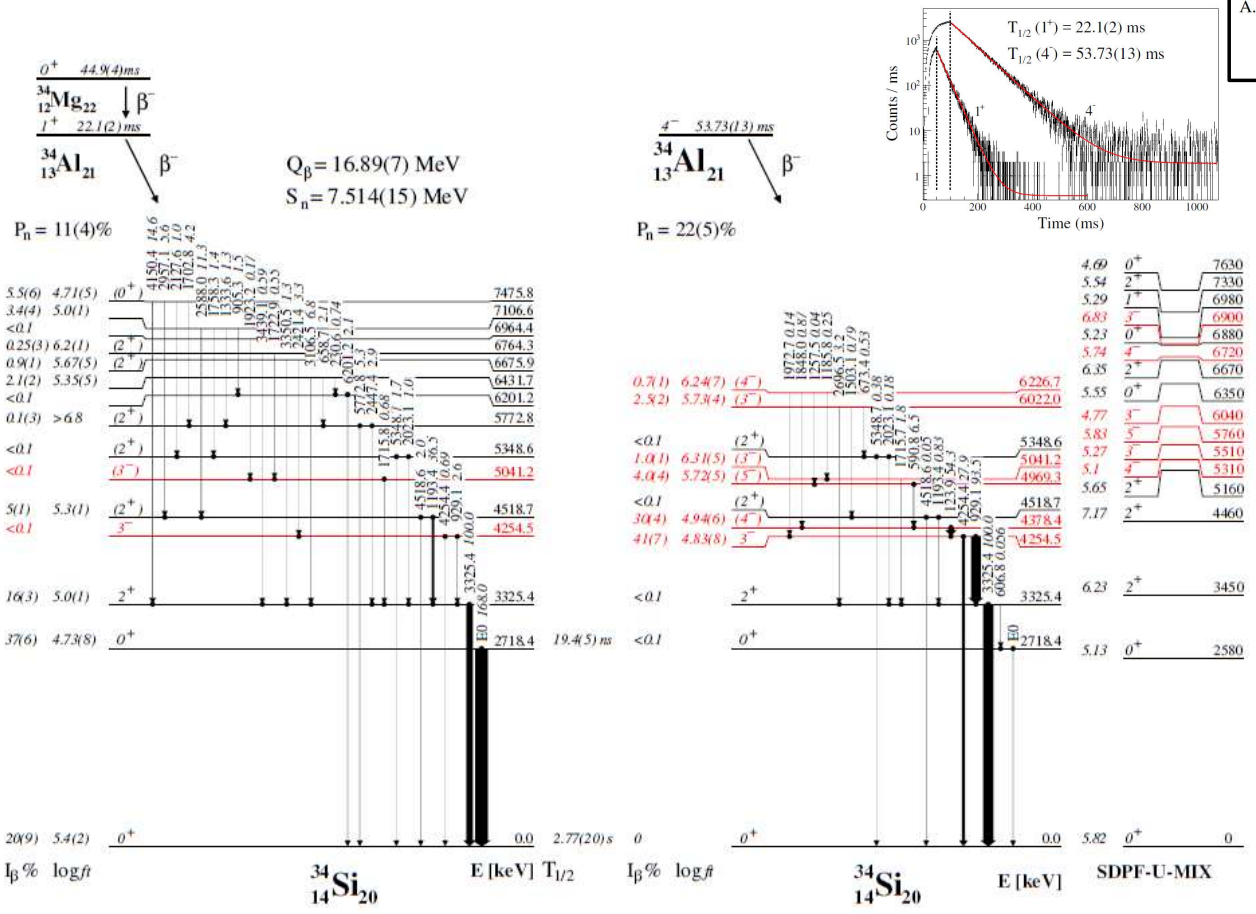




ISOLDE Decay Station

IS530 experiment in 2015 at the ISOLDE Decay Station

^{34}Si populated from separately implanted ^{34}Mg → ^{34}Al(1$^+$) and ^{34}Al(4$^-$,1$^+$)

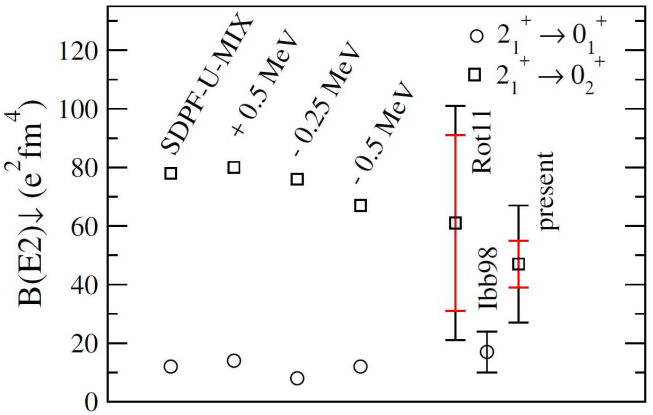


PHYSICAL REVIEW C **100**, 034306 (2019)

Normal and intruder configurations in ^{34}Si populated in the β^- decay of ^{34}Mg and ^{34}Al

R. Lică,[1,2] F. Rotaru,[1] M. J. G. Borge,[2,3] S. Grévy,[4,5] F. Negoiță,[1] A. Poves,[6,7] O. Sorlin,[4] A. N. Andreyev,[8] R. Borcea,[1] C. Costache,[1] H. De Witte,[9] L. M. Fraile,[10] P. T. Greenlees,[11,12] M. Huyse,[9] A. Ionescu,[1,13] S. Kisyov,[14,1] J. Konki,[11,12,2] I. Lazarus,[15] M. Madurga,[2] N. Mărginean,[1] R. Mărginean,[1] C. Mihai,[1] R. E. Mihai,[1] A. Negret,[1] F. Nowacki,[16,17] R. D. Page,[18] J. Pakarinen,[11,12] V. Pucknell,[15] P. Rahkila,[11,12] E. Rapisarda,[2,19] A. Şerban,[1] C. O. Sotty,[1] L. Stan,[1] M. Stănoiu,[1] O. Tengblad,[3] A. Turturică,[1] P. Van Duppen,[9] N. Warr,[20] Ph. Dessagne,[21] T. Stora,[22] C. Borcea,[1] S. Călinescu,[1] J. M. Daugas,[23] D. Filipescu,[1] I. Kuti,[24] S. Franchoo,[25] I. Gheorghe,[1] P. Morfouace,[25,23] P. Morel,[23] J. Mrazek,[26] D. Pietreanu,[1] D. Sohler,[27] I. Stefan,[25] R. Şuvăilă,[1] S. Toma,[1] and C. A. Ur[1,28]
(IDS Collaboration)

^{34}Si

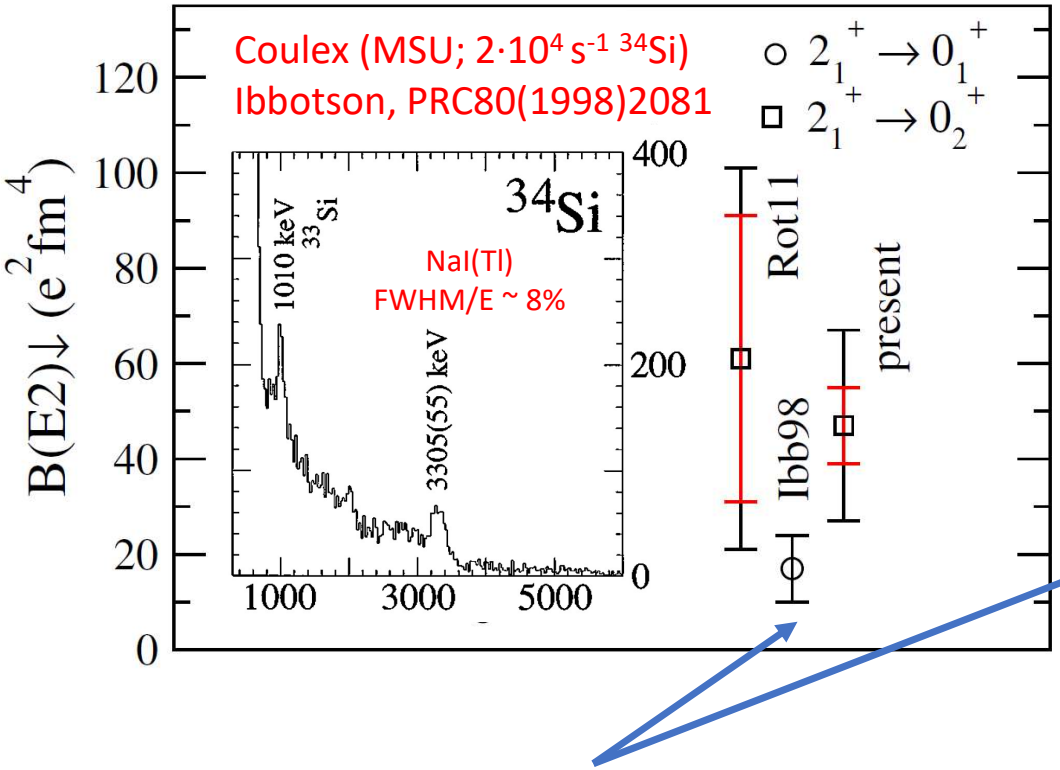


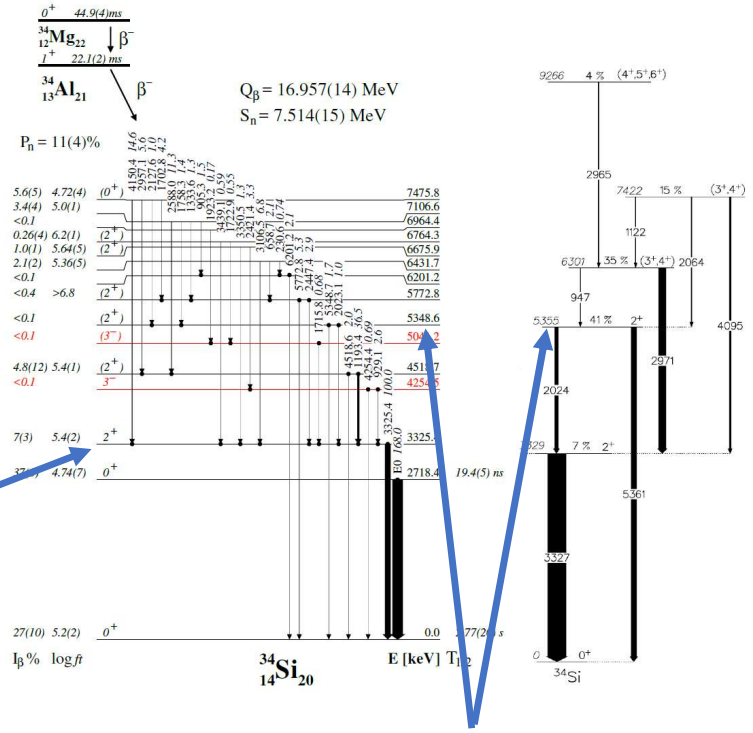
$$B(E2; 607keV; 2_1^+ \rightarrow 0_2^+)\downarrow = \frac{4939 \cdot B(E2; 0_1^+ \rightarrow 2_1^+)\uparrow}{5 \cdot B_r} = 47(20)e^2fm^4 = 7.2(31)W.u.$$

B_r=1779(182)

- Deformed configurations (*2p-2h*) dominate the 0_2^+ and 2_1^+ states – 86 - 89%
- The 0_1^+ ground state is dominated by the spherical (*0p-0h*) configuration – 90%
- The 2_3^+ state corresponds to the *0p–0h* nature (spherical), dominated by the π(1d5/2)−1(1s1/2)1 configuration with N = 20 closed

Proposed measurement at LISE: ^{34}Si Coulomb excitation





(1) Deformed 3.3 MeV 2^+ state identified in ^{34}Al decay

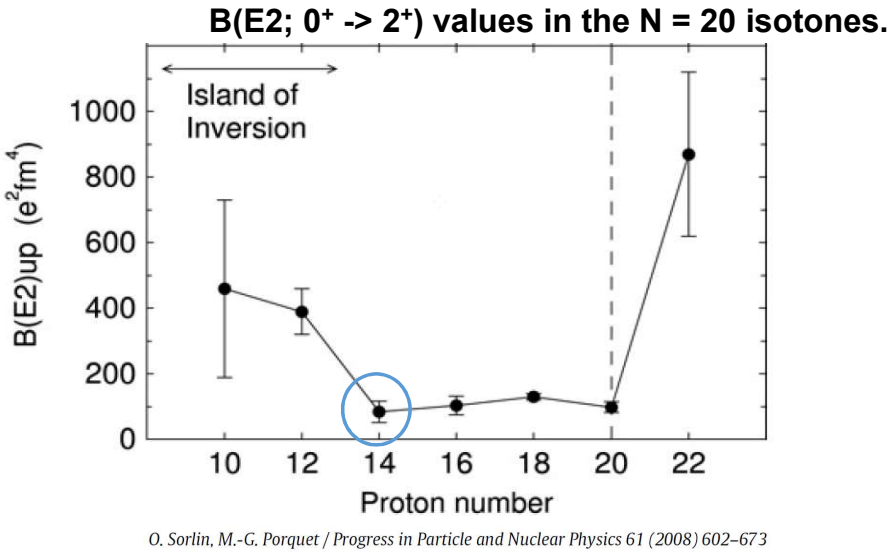
B(E2; 3.3 MeV $0^+_1 \rightarrow 2^+_1$) = 85(33) e²fm⁴

(2) Spherical 5.3 MeV 2^+ state identified in ^{34}Al decay and well produced (41%) in ^{35}P(-1p)^{34}Si [D. Sohler et al. to be published

B(E2; 5.3 MeV $0^+_1 \rightarrow 2^+_3$) = 100 e²fm⁴ (Shell-Model)

Proposed measurement at LISE: ^{34}Si Coulomb excitation

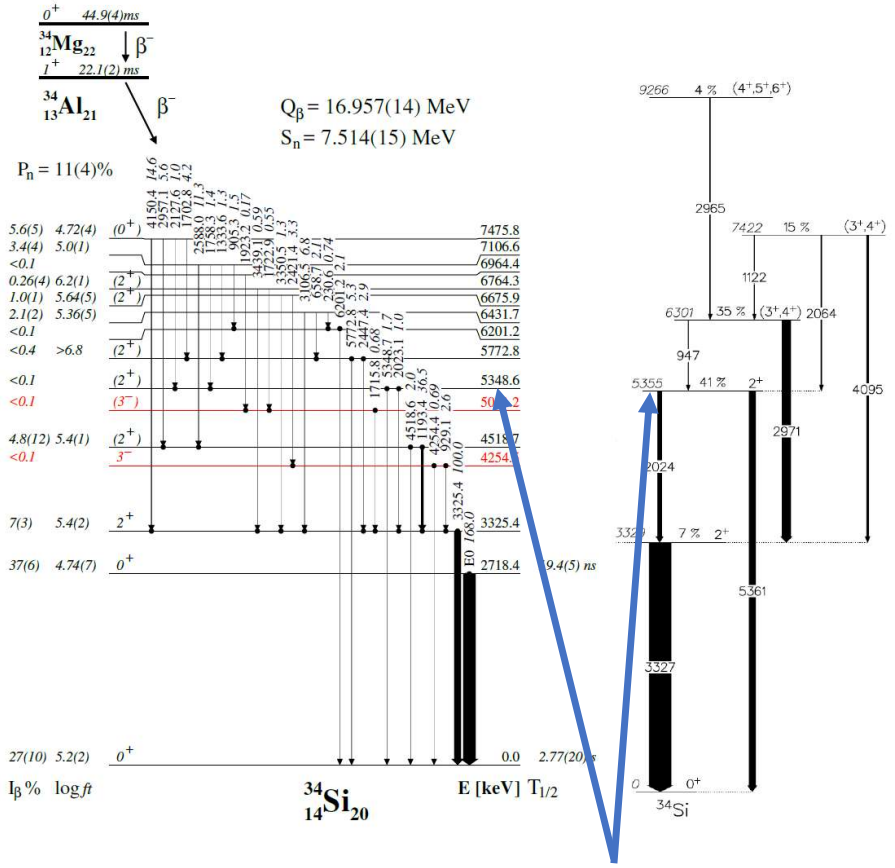
Objectives



O. Sorlin, M.-G. Porquet / Progress in Particle and Nuclear Physics 61 (2008) 602–673

(1) Remeasure the B(E2:0_1^+ -> 2_1^+) value as the previous error bar was large and we suspect some contamination from the feeding of an upper 2^+ state.

- If this side-feeding is confirmed the B(E2) value, ^{34}Si may have the smallest B(E2) among other N=20 isotones.
- Determine more precisely the mixing amplitude of the 0_1^+ and 0_2^+ states in ^{34}Si.

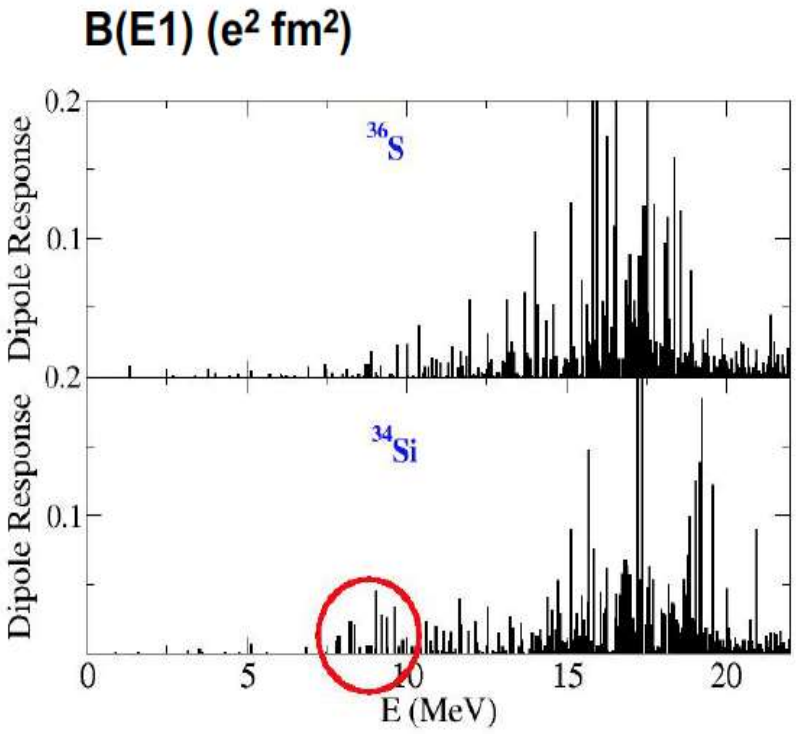


(2) Determine the B(E2:0_1^+- > 2_3^+), which is predicted to be of the same amplitude as the B(E2:0_2^+ -> 2_1^+)

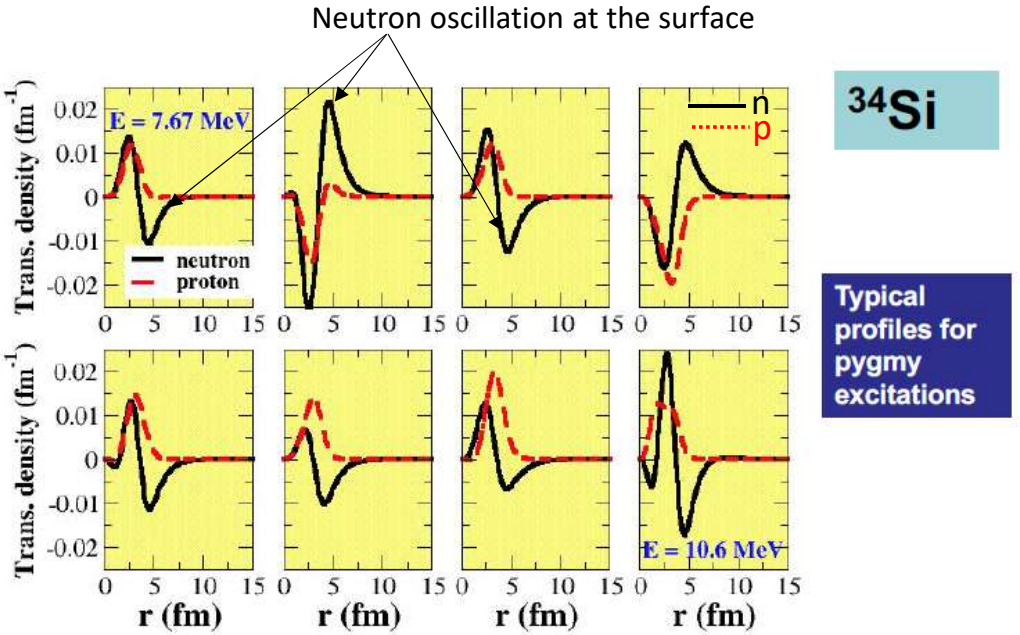
- Confirm the structure of the 2_3^+ in ^{34}Si dominated by a proton hole configuration which corresponds to the spherical band.

Proposed measurement at LISE: ^{34}Si PDR study

- ^{34}Si - presence of neutron oscillations at low excitation energy in (close or above Sn=7.5 MeV), that would give rise to E1 distribution.
- We propose the first time measurement of the PDR through isovector and isoscalar probes (^{208}Pb, ^{12}C).



Pygmy and giant dipole strength distribution in ^{34}Si using subtracted second random-phase approximation (SSRPA)



Transition density probability from 7.67 to 10.6 MeV, in which the presence of an almost pure neutron excitation is shown at the surface of the nucleus.

Calculations: Gambacurta, Grasso

Proposed measurement at LISE: ^{34}Si PDR study

- ^{34}Si - presence of neutron oscillations at low excitation energy in (close or above Sn=7.5 MeV), that would give rise to E1 distribution.
- We propose the first time measurement of the PDR through isovector and isoscalar probes (^{208}Pb, ^{12}C).

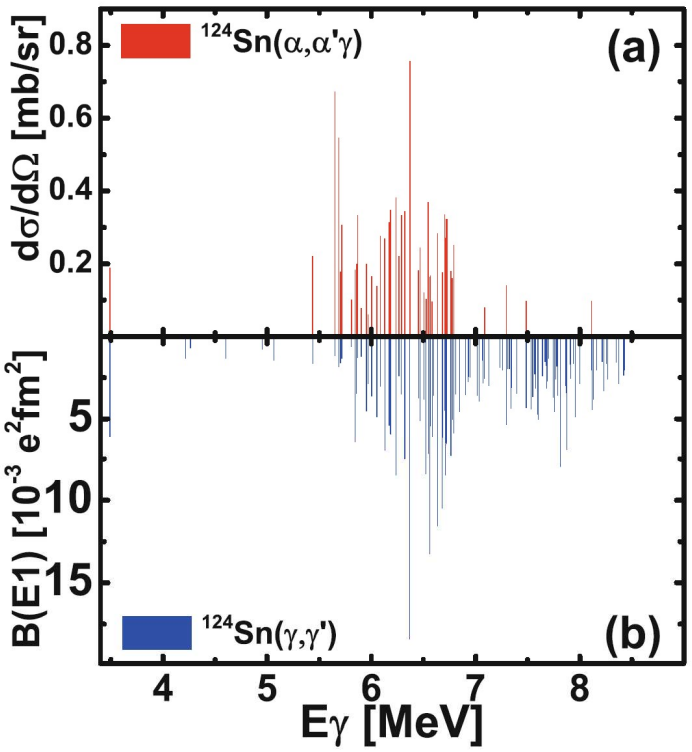


Fig. 8. (Color online) (a) Cross sections for the excitation of $J^\pi = 1^-$ in ^{124}Sn deduced from the $(\alpha, \alpha'\gamma)$ experiment. (b) The B(E1)↑ strength distribution, obtained in (γ, γ') [60]. Adapted from [61].

*"Consequently, if one wants to learn about the underlying structure of pygmy states and about their isospin character it is important to compare the excitation cross section of these states with **isovector probes (as photons)** and **isoscalar probes** as, for example, alpha particles or heavier ions as C and O below 30MeV/u."*

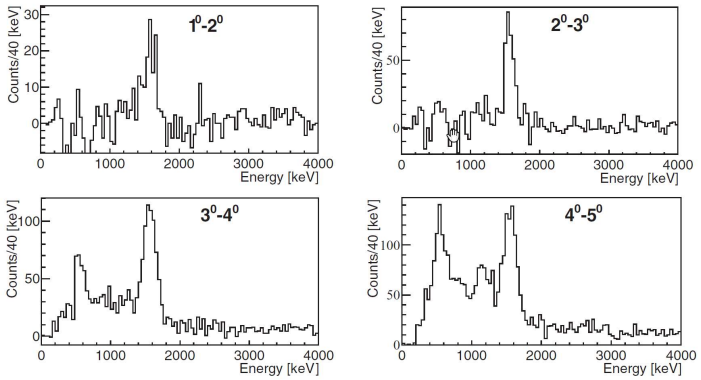
A. Bracco, F. Crespi, E. Lanza, Eur. Phys. J. A (2015) **51**: 99

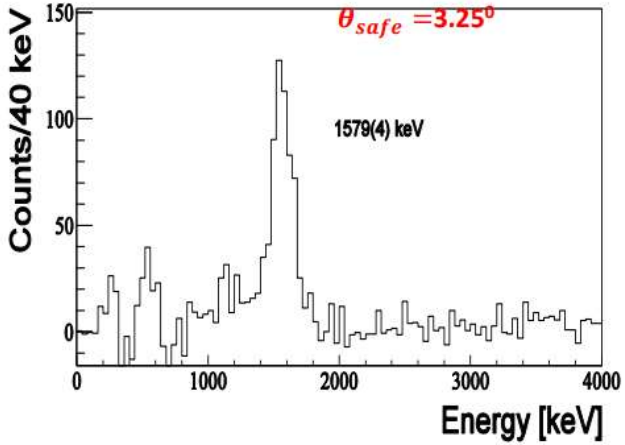
Proposed experiment at LISE

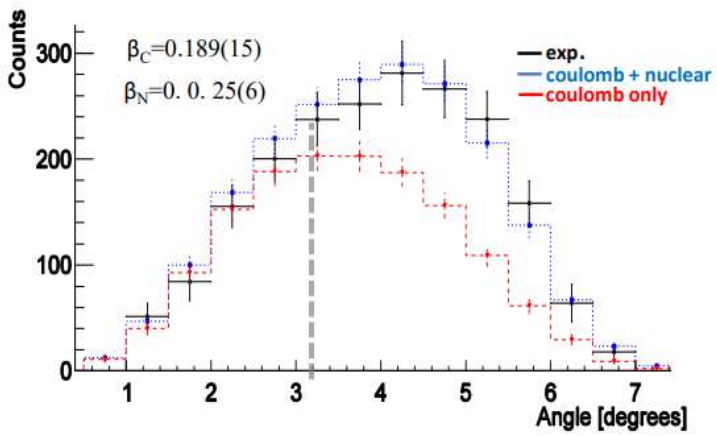
(similar to previous ^{44}Ca, ^{46}Ar experiment)

^{46}Ar @ 38.5 MeV/A + ^{208}Pb (200 mg/cm^2)

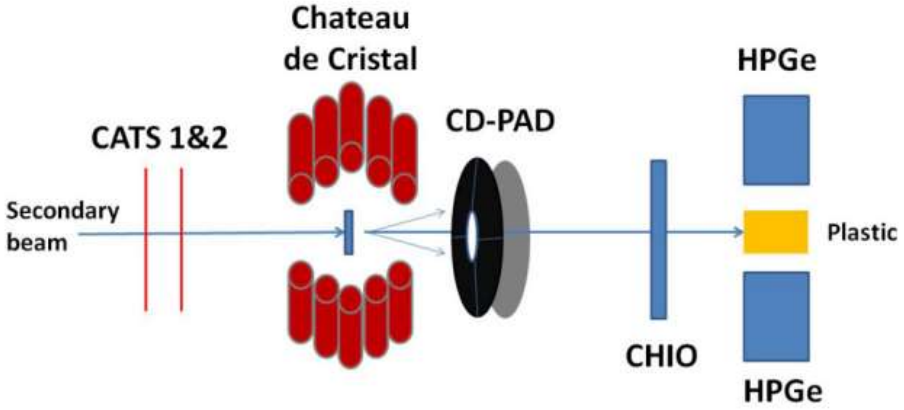
Extraction of B(E2:0_1^+->2_1^+) in ^{46}Ar from absolute cross section measurement and relative to the known B(E2) in ^{44}Ca







Doppler-corrected background subtracted γ -ray spectra displayed as a function of the scattering angle of ^{46}Ar, cast in fixed angular ranges of 1.



Best fit for safe zone : B(E2) = 225(29) e²fm⁴

Relative to ^{44}Ca: B(E2) = $234(19)\ e^2fm^4$

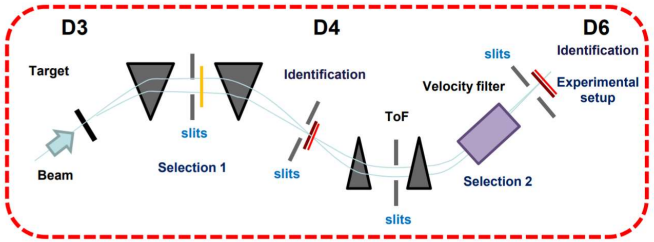
In agreement with previous Coulomb excitation measurements

Phys. Rev. C 93, 044333 (2016)

S. Calinescu, L. Caceres, S Grevy, O. Sorlin et al.

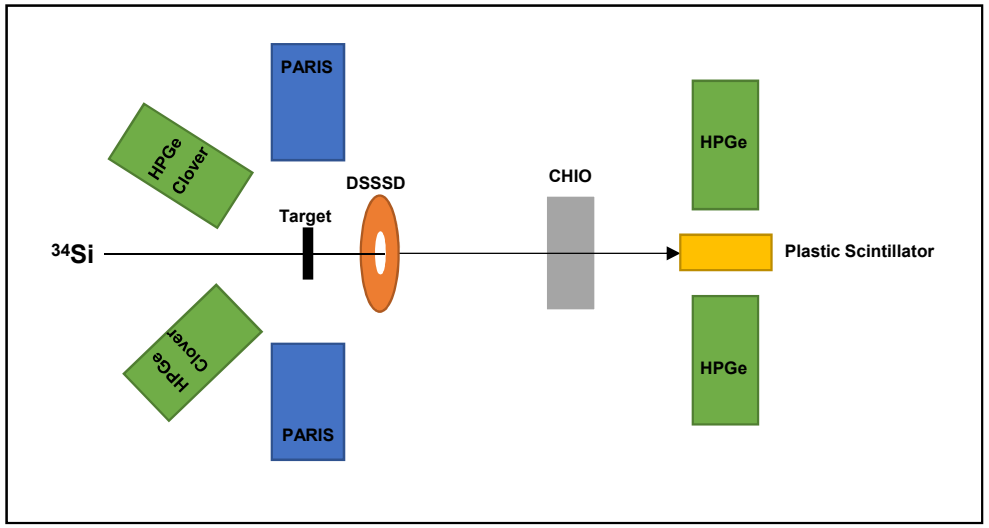
Proposed experiment at LISE

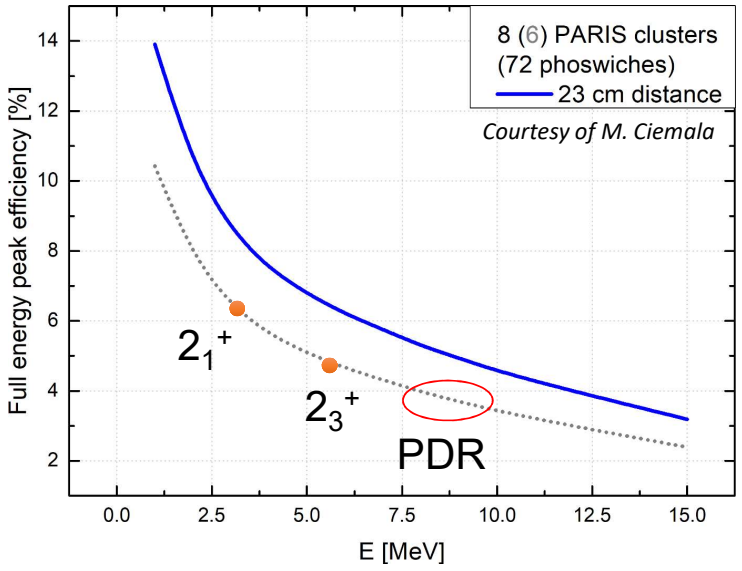
The GANIL/LISE spectrometer

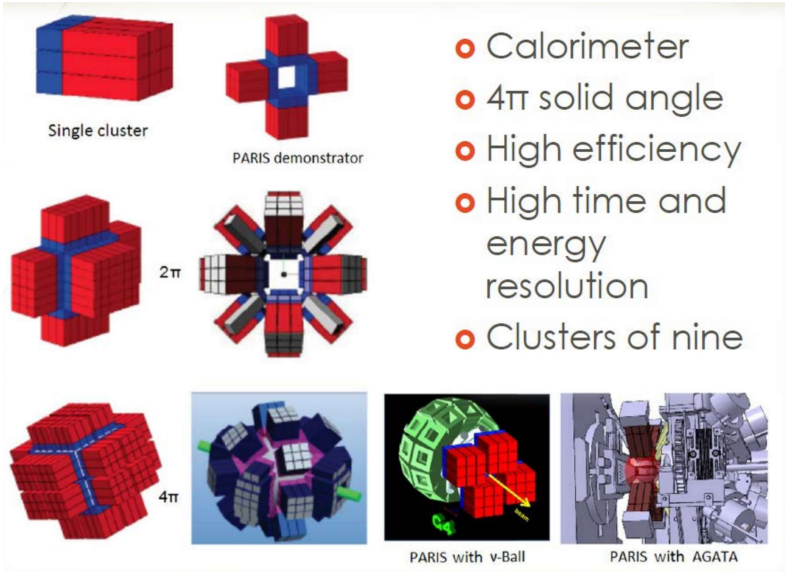


^{34}Si @ 55 MeV/A + ^{208}Pb / ^{12}C

+







PARIS array (5-6 clusters):

- Good energy resolution: FWHM/E = 4%
- Efficiency (**6 clusters** at **23 cm**):
  - ~ 6.5% at 3.3 MeV (2_1^+)
  - ~ 5% at 5.3 MeV (2_3^+)
  - ~ 4% at 8 MeV (PDR)
- Offline energy calibrations for high energies: ^{252}Cf source surrounded by Al and Ni samples producing γ-rays of of 7.7 and 8.9 MeV,

DWEIKO calculations - Safe angle up to 3°
(DSSSD coverage 1° – 6°)

Beamtime request

^{34}Si @ 55 MeV/A + ^{208}Pb / ^{12}C

Estimated ^{34}Si production: 10^5 s^{-1}

^{208}Pb target: 200 mg/cm^2 (electromagnetic probe)

^{12}C target: 146.4 mg/cm^2 (nuclear probe)

Rate estimations (DWEIKO, courtesy of S. Calinescu)

^{208}Pb target

2_1^+ : (18.3 mb; 4.5 mb safe) -> 2.7 x 10^3 evts / **18 UT**

2_3^+ : (14.3 mb; 2.3 mb safe) -> 1.1 x 10^3 evts / **18 UT**

PDR: (1.5 mb safe) -> 1.8 x 10^3 evts / **18 UT**

^{12}C target

2_1^+ : (26 mb) -> 3.1 x 10^5 evts / **4 UT**

2_3^+ : (17.4 mb) -> 2.0 x 10^5 evts / **4 UT**

PDR: (difficult to estimate) ~ 100-200 events / **4 UT**

Validation of the experimental method (3 UT) : ^{36}S beam (well known 2_1^+ at 3.29 MeV, B(E2)=2.83(24) W.u.)

Beam tuning and adjustments of the setup (4 UT)

Total number of requested UT's: **25 + 4 = 29**