Experimental proof of chirality by absolute transition probabilities

Julian Srebrny, Heavy Ion Laboratory, University of Warsaw, Poland

“Chirality and Wobbling in Atomic Nuclei” (CWAN’23), Huizhou, China, July 10-14, 2023

Dedicated to the memory of S.G. Rohozinski,
our great teacher and friend,
who passed away 2 years ago.

Experimental proof of chirality by absolute transition probabilities

OUTLINE

1. DSAM mesurements of picosecond life-time – eight cases
2. B(M1)/B(E2) could be misleading ?
3. S-symmetry , core symmetry P_α and particle symmetry $C_{\pi\nu}$
4. $^{124,126,128,130}Cs$ example of B(M1) and B(E2) of *2qp:* $\pi h_{11/2} \otimes \nu^{-1} h_{11/2}$
5. $^{76,80}Br$ B(M1) and B(E2): *2qp:* $\pi g_{9/2} \otimes \nu^{-1} g_{9/2}$
6. Many quasiparticle cases : *3 qp and 4 qp* ^{135}Nd , ^{194}Tl
7. DSAM: thin and thick target, software A.A. Pasternak and J.C. Well, N. Johnson

Absolute values of electromagnetic transition probabilities in partner bands provide a stringent test of nuclear chirality.

Up to now, chirality was confirmed by DSAMethod only in eight nuclei:

^{128}Cs, ^{126}Cs, ^{124}Cs, ^{130}Cs, ^{135}Nd, ^{76}Br, ^{80}Br and ^{194}Tl,

The reason is very short, 0.1-1.5 ps, lifetime of studied levels.

Such data could be obtained only through lifetime measurements using the Doppler Shift Attenuation Method.

^{128}Cs, ^{126}Cs, ^{124}Cs,	**studied by Warsaw team using heavy ion cyclotron at HIL, UW**
^{124}Cs	**studied by Kolkata team in 15UD Pelletron accelerator at IUAC, New Delhi**
^{130}Cs	**Beijing HI13 Tandem,**
^{76}Br	**Shandong team in Beijing,**
^{80}Br	**Heidelberg MP tandem, Shandong- Rossendorf team,**
^{135}Nd	**ATLAS, GAMMASPHERE, Notre Dame-Argonne team,**
^{194}Tl	**iThemba team Afrodite**

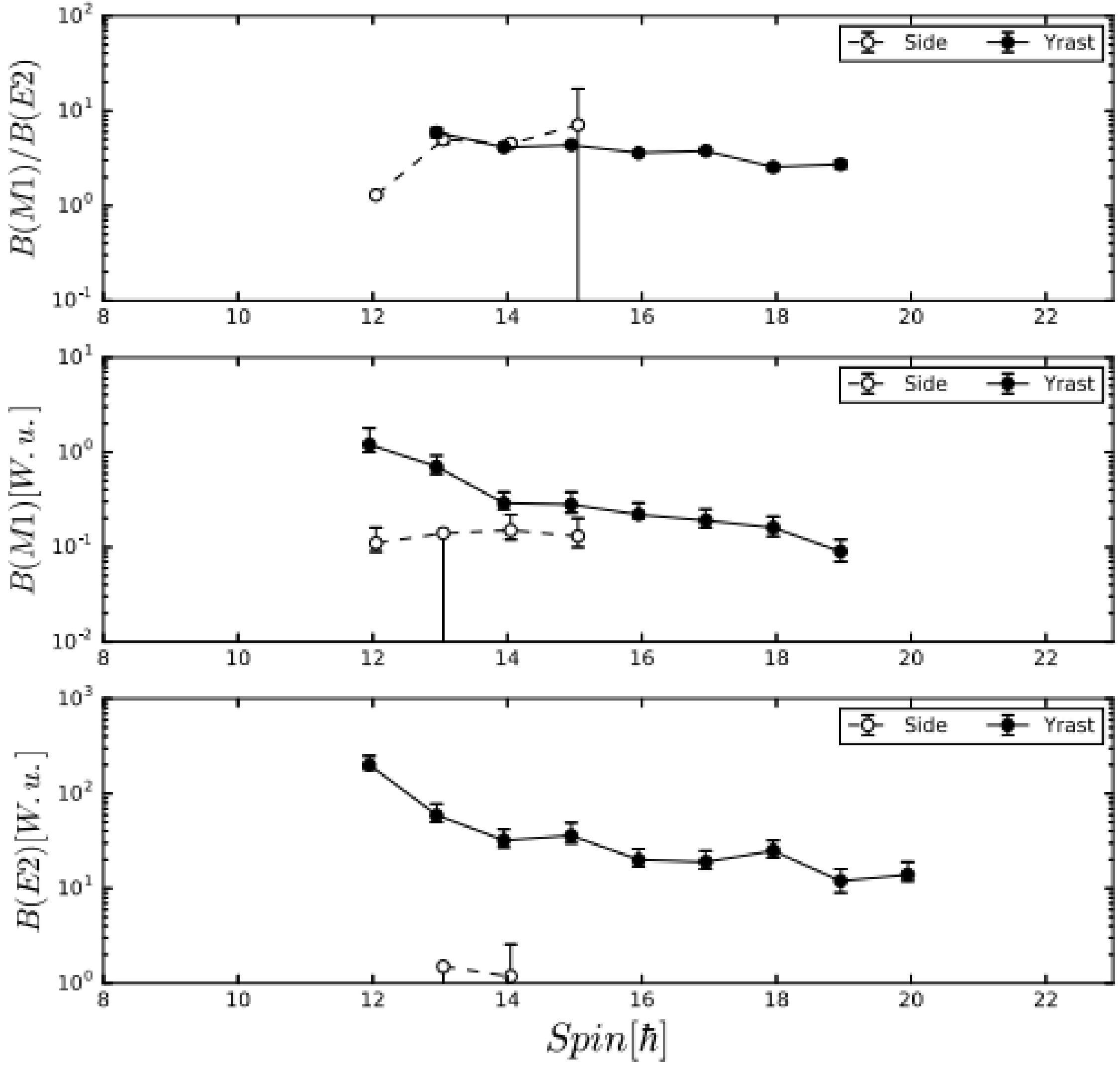
B(M1)/B(E2) could be misleading ?

^{132}La

Study of Chirality in odd-odd Cs Isotopes;
Search for Critical Frequency

T. Marchlewski, J. Srebrny, E. Grodner

Acta Physica Polonica B 11 (2018)89



CPHC theoretical model and S-symmetry

The symmetry operation **S** is a combination of the α-parity of the core $\mathbf{P_\alpha}$,
and the exchange of the proton and neutron states $\mathbf{C_{\pi\nu}}$

$$\mathbf{S = P_\alpha C_{\pi\nu}}$$

The inversion $\mathbf{P_\alpha}$ transforms the intrinsic collective variables of the core Hamiltonian $(\beta,\gamma,\Omega) \rightarrow (\beta,\gamma \pm \pi,\Omega)$,

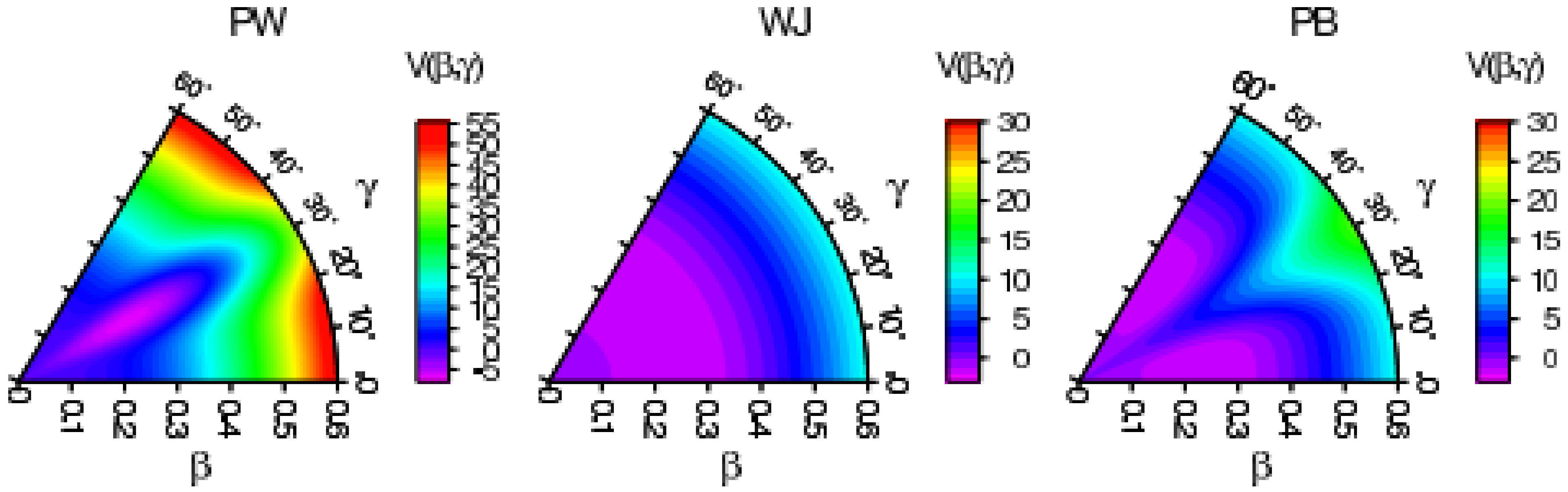
The exchange operator $\mathbf{C_{\pi\nu}}$ in the proton–neutron space is defined as

$$C_{\pi\nu}|(\pi, j_\pi m_\pi)(\nu, j_\nu m_\nu)i = |(\pi, j_\nu m_\nu)(\nu, j_\pi m_\pi)i.$$

We conclude from our investigation that the three-body systems with the S-symmetry show the characteristics which are usually treated as the "chirality fingerprints" discussed in the literature.

Odd-odd nuclei as the core-particle-hole systems and chirality
S.G. Rohozinski, L. Prochniak, K. Starosta, and Ch. Droste ***European Physical J. A 47 (2011)*** *90*

A symmetry of the CPHC model of odd-odd nuclei and its consequences
for properties of M1 and E2 transitions
L. Próchniak S.G. Rohoziński, Ch. Droste, K. Starosta ***Acta Physica Polonica B42(2011) 465***



$\langle |\cos 3\gamma| \rangle \approx 0$

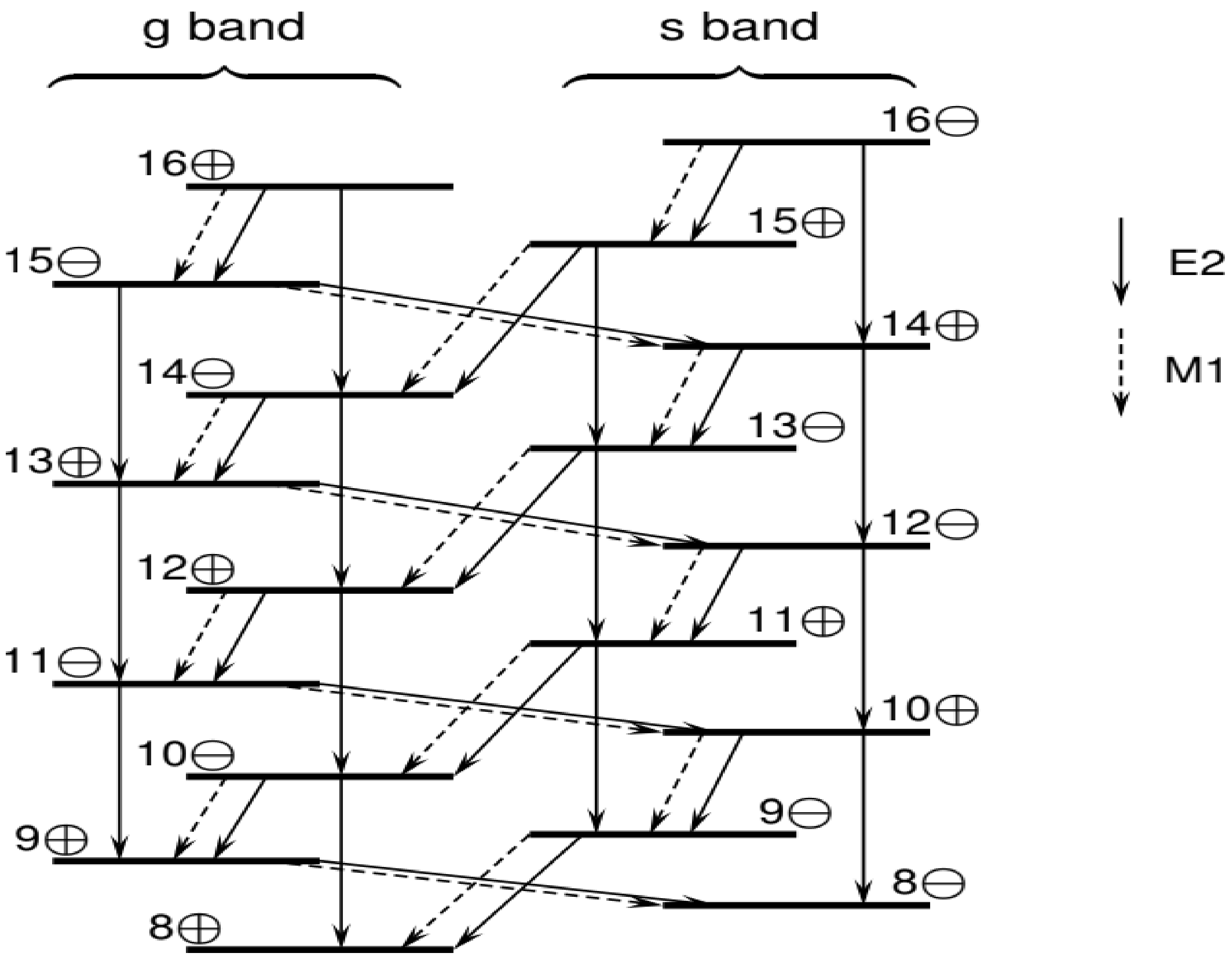
The inversion P_α transforms the intrinsic collective variables

$(\beta,\gamma,\Omega) \rightarrow (\beta,\gamma \pm \pi,\Omega)$,

when γ is restricted to one sextant $0 \leq \gamma \leq \pi/3$,

$(\beta,\gamma,\Omega) \rightarrow (\beta,\pi/3 - \gamma,R_x(\pi/2)\Omega)$,

S-symmetry B(M1), B(E2) selection rules



Warsaw HIL cyclotron data, our best cases by DSAM

2qp: $\pi\, h_{11/2} \otimes \nu^{-1}\, h_{11/2}$

Partner bands of ^{126}Cs – first observation of chiral electromagnetic selection rules

E. Grodner, I. Sankowska, T. Morek, S.G. Rohozinski , Ch. Droste, J. Srebrny, A.A. Pasternak,

M. Kisielinski, M. Kowalczyk, J. Kownacki, J. Mierzejewski, A. Król, K. Wrzosek.

Physics Letters B703,(2011)46

^{128}Cs as the Best Example Revealing Chiral Symmetry breaking

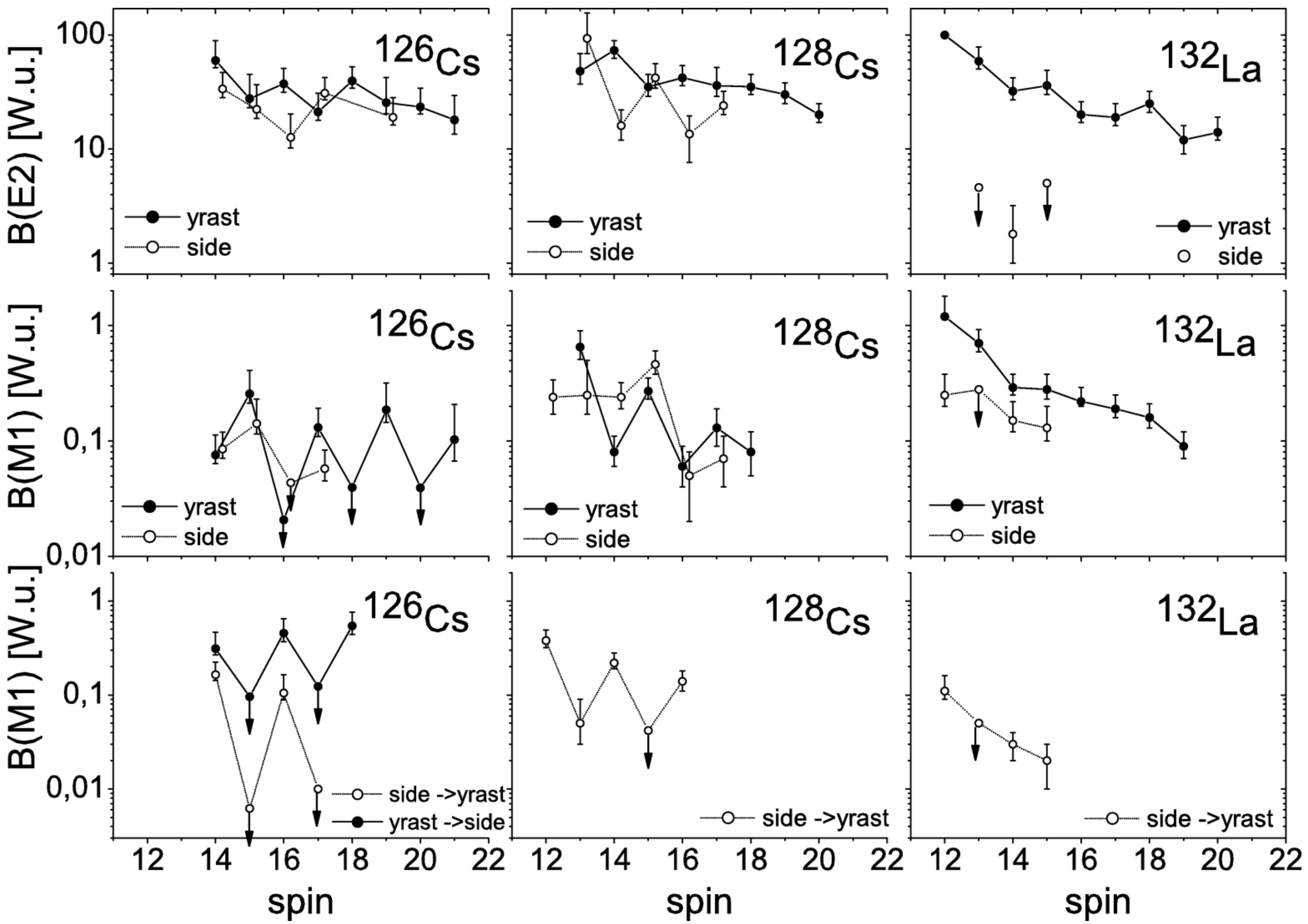
E. Grodner, J. Srebrny, A. A. Pasternak, I. Zalewska, T. Morek, Ch. Droste, J. Mierzejewski, M. Kowalczyk,

J. Kownacki, M. Kisielinski, S. G. Rohozinski, T. Koike, K. Starosta, A. Kordyasz, P. J. Napiorkowski,

M. Wolinska-Cichocka, E. Ruchowska, W. Płociennik, and J. Perkowski

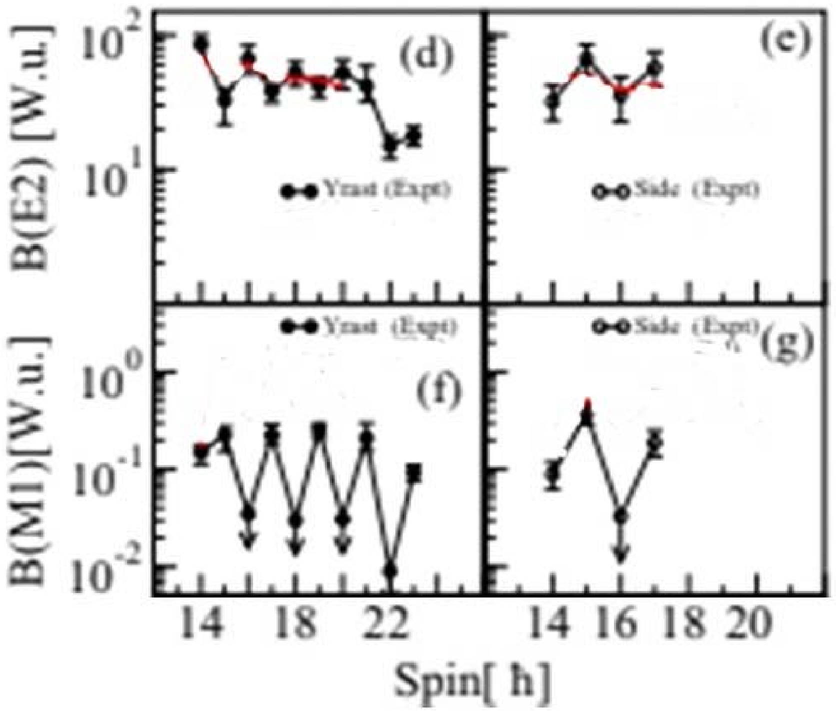
Physical Review Letters 97, 172501 (2006)

Absolute transition probabilities as chirality and S-symmetry proof



^{124}Cs

2qp: $\pi\, h_{11/2} \otimes \nu^{-1}\, h_{11/2}$



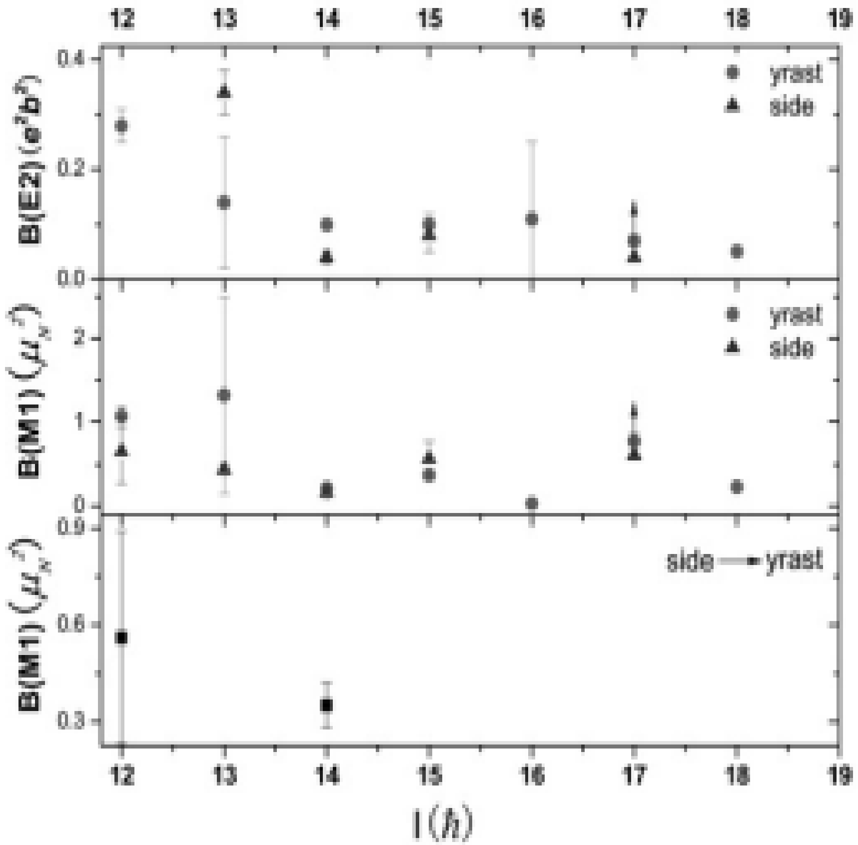
Evidence for octupole correlation and chiral symmetry breaking in ^{124}Cs

K. Selvakumar, A. K. Singh, Chandan Ghosh, Purnima Singh,A. Goswami, R. Raut, A. Mukherjee, U. Datta, P. Datta S. Roy, G. Gangopadhyay S. Bhowal, S. Muralithar, R. Kumar, R. P. Singh , M. Kumar Raju ***Physical Review C 92, 064307 (2015)***

Electromagnetic Propertiese of Chiral Bands in ^{124}Cs

T. Marchlewski, R. Szenborn, J. Samorajczyk, E. Grodner , J. Srebrny, Ch. Droste , L. Próchniak, A.A. Pasternak , M. Kowalczyka, M. Kisielińskia T. Abraham , J. Andrzejewski , P. Decowski, K. Hadyńska-Klęk, Ł. Janiak , M. Komorowska, J. Mierzejewski , P. Napiorkowski , J. Perkowski, A. Stolarz ***Acta Physica Polonica 46(2015)689***

^{130}Cs



2qp: $\pi\, h_{11/2} \otimes \nu^{-1}\, h_{11/2}$

Good chirality of the Yrast and side bands.

Probably the S-symmetry not exact

Test of Chirality in Nucleus ^{130}Cs

WU Xiaoguang, WANG Lielin, ZHU Lihua, LI Guangsheng, HAO Xin, ZHENG Yun, HE Chuangye, LI Xueqin, PAN Bo, LIU Ying, WANG Lei, ZHAO Yanxin, LI Zhongyu, DING Huaibo

Plasma Science and Technology, Vol.14, 526(2012)

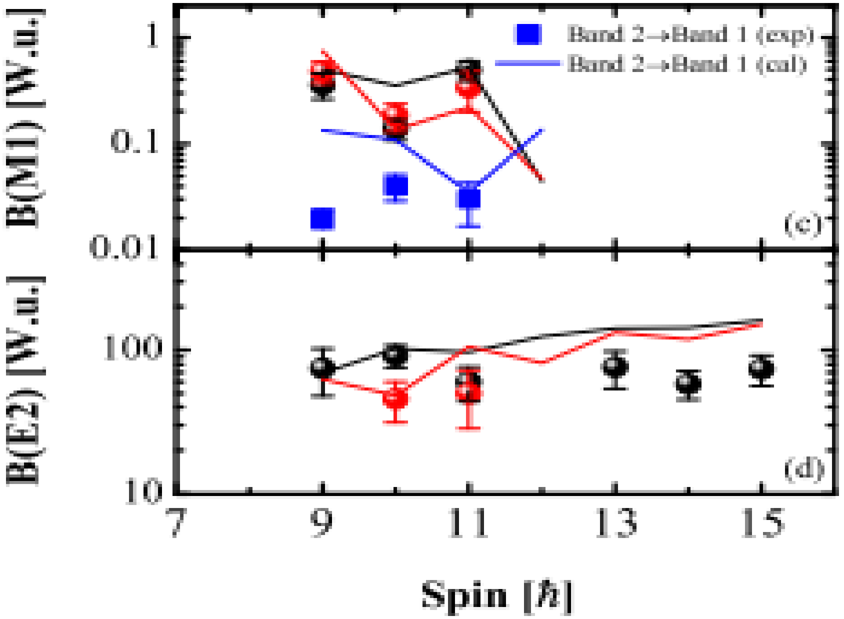
Interplay between nuclear chiral and reflection symmetry breakings revealed by the lifetime measurements in ^{76}Br W.Z. Xu, S.Y. Wang, C. Liu, X.G. Wu, R.J. Guo, B.Qi, J.Zhao, A.Rohilla, H. Jia, G.S.Li, Y. Zheng, C.B. Li, X.C. Han, L. Mu, X. Xiao, S. Wang, D.P. Sun, Z.Q. Li, Y.M. Zhang, C.L. Wang, Y. Li

***Physics Letters B833*, (2022) 137287**

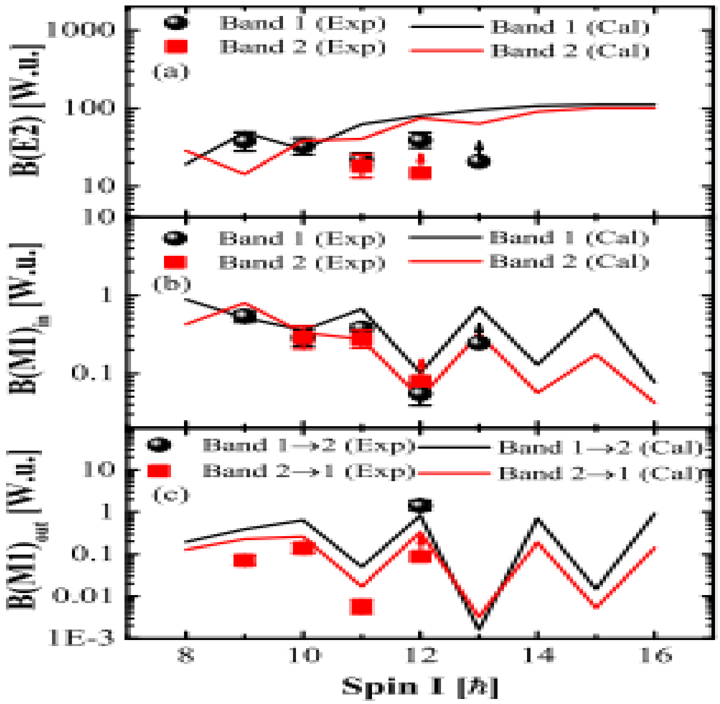
Lifetime measurements in ^{80}Br and a new region for observation of chiral electromagnetic selection rules R.J. Guo, S.Y. Wang, R. Schwengner, W.Z. Xu, B. Qi, C. Liu, A. Rohilla, F. Dönau, T. Servene, H. Schnare, J. Reif, G. Winter, L. Käubler, H. Prade, S. Skoda, J. Eberth, H.G. Thomas, F. Becker, B. Fiedler, S. Freund, S. Kasemann, T. Steinhardt, O. Thelen, T. Härtlein, C. Ender, F. Köck, P.Reiter, D. Schwalm
Physics Letters B 833 (2022) 137344

2qp: $\pi\, g_{9/2} \otimes \nu^{-1} g_{9/2}$

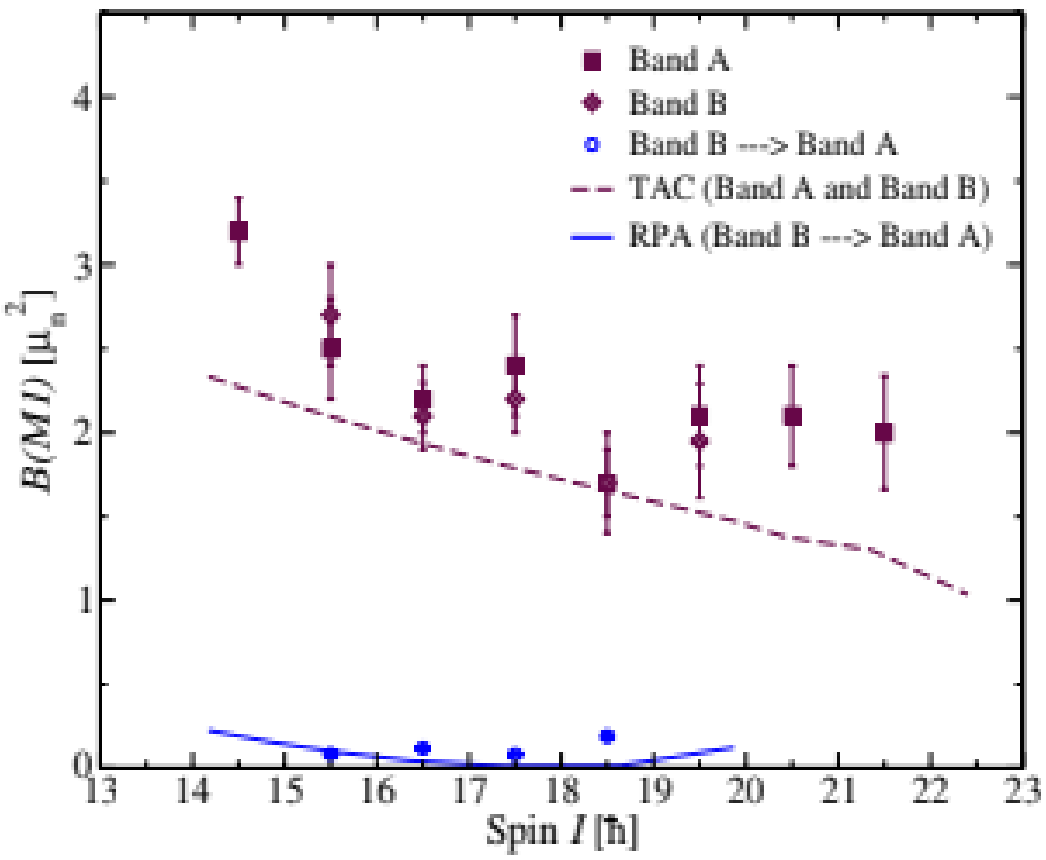
^{76}Br



^{80}Br



^{135}Nd



3qp: $\pi h_{11/2} \otimes \nu^{-2} h_{11/2}$

Not S-symmetry, but chiral

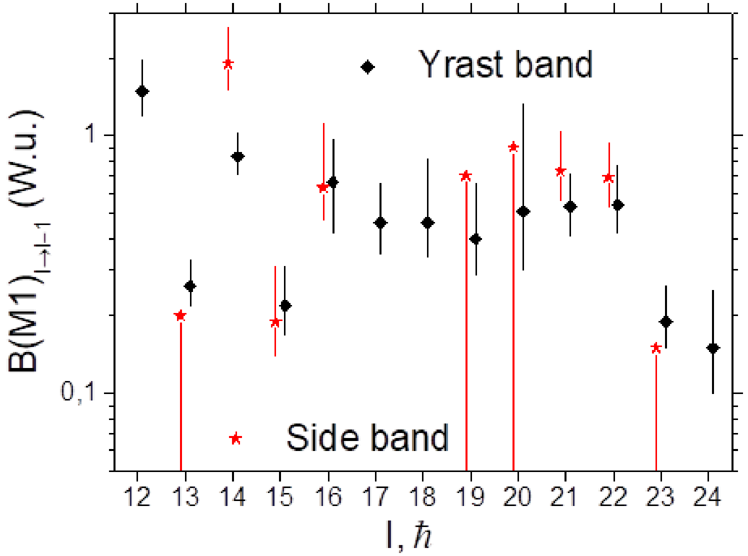
From Chiral Vibration to Static Chirality in ^{135}Nd

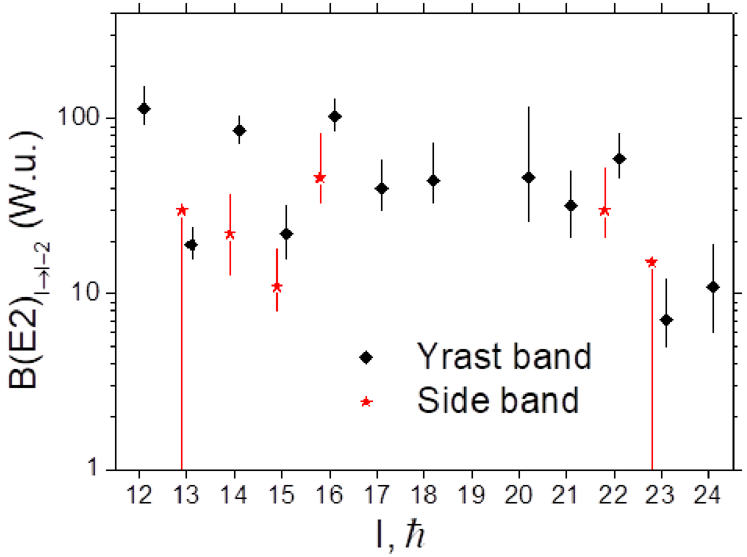
S. Mukhopadhyay, D. Almehed, U. Garg, S. Frauendorf, T. Li, P. V. Madhusudhana Rao, X. Wang,

S. S. Ghugre, M. P. Carpenter, S. Gros, A. Hecht, R. V. F. Janssens, F. G. Kondev, T. Lauritsen, D. Seweryniak, and S. Zhu ***Phys. Rev. Let. 99, 172501 (2007)***

^{194}Ta B(M1) and B(E2) in *4 qp* $\pi h_{9/2} \otimes \nu i^{-3}_{13/2}$

chiral partners – yrast and side band





not S-symmetry in particle part

DSAM lifetime measurements for the chiral pair in ^{194}Tl

P.L. Masiteng, A.A. Pasternak, E.A. Lawrie, O. Shirinda, J.J. Lawrie, R.A. Bark, S.P. Bvumbi, N.Y. Kheswa, R. Lindsay, E.O. Lieder, R.M. Lieder, T.E. Madiba, S.M. Mullins, S.H.T. Murray, J. Ndayishimye, S.S. Ntshangase, P. Papka, and J.F. Sharpey-Schafer *The European Physical Journal A52(2016) 28*

DSAM: experimental methods and data analysis

Mainly two DSAM software were used:

J.C. Well, N. Johnson thin target, thick backing(Pb orAu,..)

dE/dx J. F.Ziegler- SRIM code

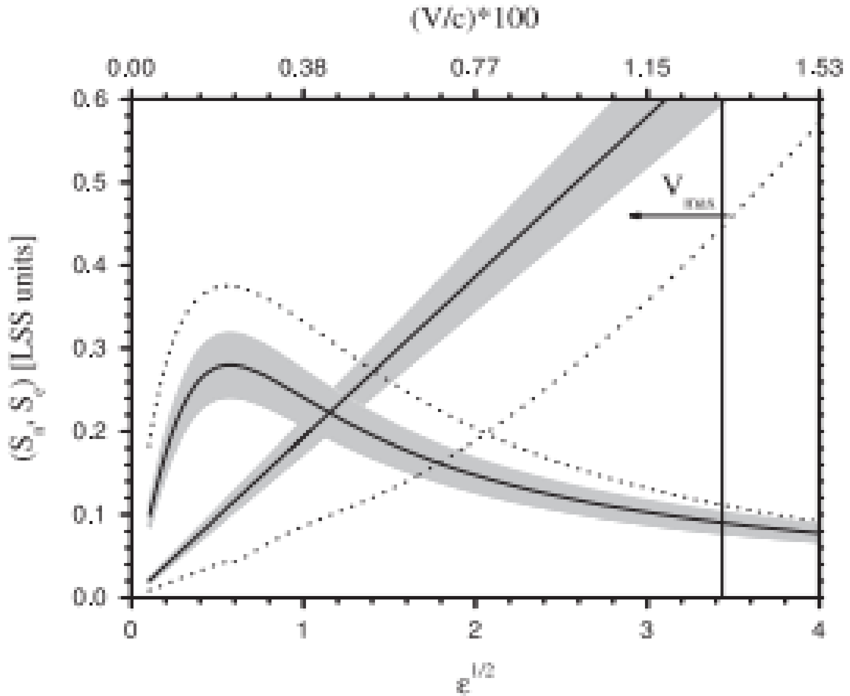
^{76}Br, ^{80}Br, ^{124}Cs, ^{130}Cs, ^{135}Nd,

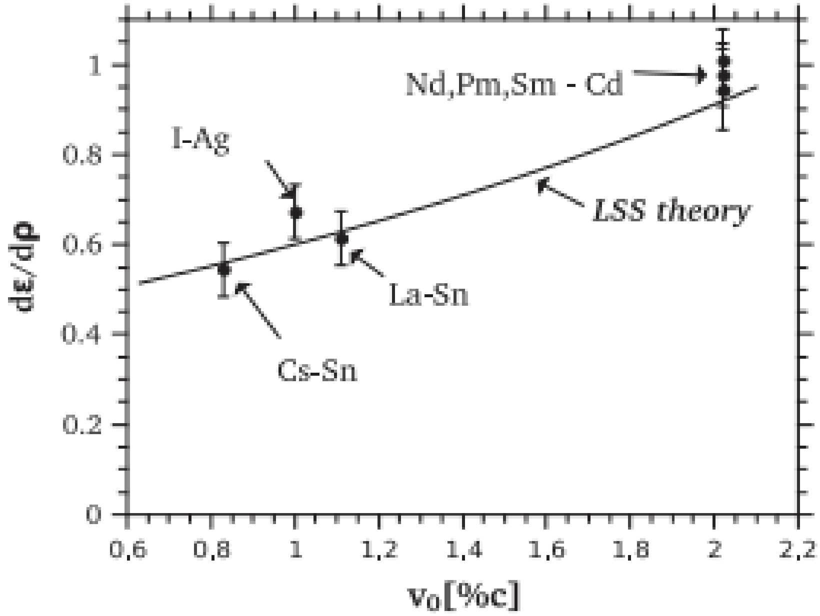
A.A. Pasternak thick target , COMPA, GAMMA, SHAPE

dE/dx J. Linhard, M. Sharf, H.E. Schiott - LSS

^{128}Cs, ^{126}Cs, ^{124}Cs, ^{194}Tl

dE/dx measurements by semi-thick target method





The stopping power of heavy ions for energies below 0.2 MeV/nucleon measured by the semi-thick target method

A.A. Pasternak, I. Sankowska, A. Tucholski, J. Srebrny, T. Morek, Ch. Droste, E. Grodner, M. Sałata, J. Mierzejewski, M. Kisieliński, M. Kowalczyk, J. Perkowski, L. Nowicki, R. Ratajczak, A. Stonert, J. Jagielski, G. Gawlik, J. Kownacki, A. Kordyasz, A.A. Korman, W. Płóciennik, E. Ruchowska, M. Wolińska-Cichocka ***Nuclear Instr. Methods A774(2015)82***

LAST NEWS FROM EAGLE - HIL UW

Search for transition from chiral to non-chiral configuration by PLUNGER lifetime measurement of I=10^+ state in 128Cs

A. Nałęcz-Jawecki, E. Grodner, J. Srebrny, Ch. Droste, L. Prochniak, Q. Chen, J.Samorajczyk-Pyśk, A. Stolarz, T. Abraham , M.Kowalczyk - ***HIL UW Cyclotron proposal 2022***

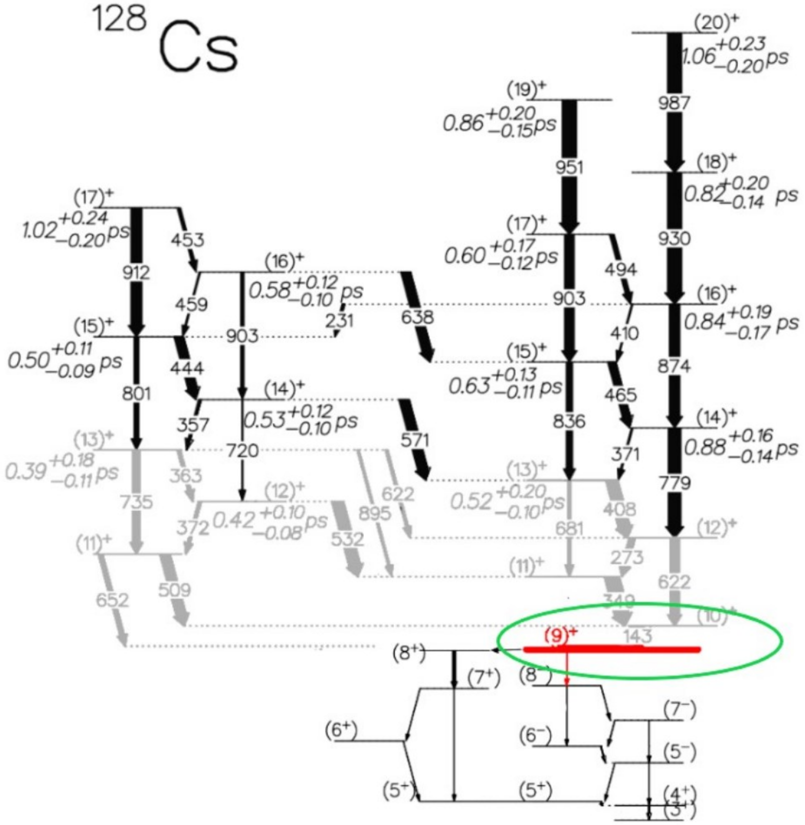
EAGLE + PLUNGER (Koln) RDM 10^+ life-time measurement - VII 2022

in ^{128}Cs: levels 13^+ up to 18^+ chiral by DSAM
level 9^+ nonchiral by g-factor

simplified evaluation of 10^+ level:
if chiral $T_{1/2} > 60$ ps
if nonchiral $T_{1/2} < 15$ ps

10^+ ? preliminary results – non chiral

phase transition or smooth evaluation ?



THANK YOU !