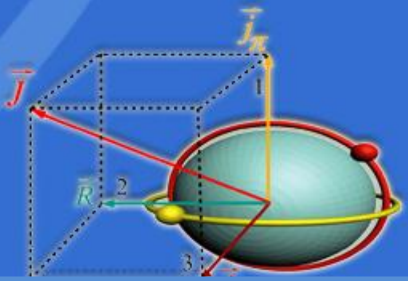
Search for the chiral doublet bands in ^{78}Br

- Speaker: C. Liu
- Supervisor: Prof. S. Y. Wang
- Shandong University, Weihai



Oct. 28, 2013

Beijing

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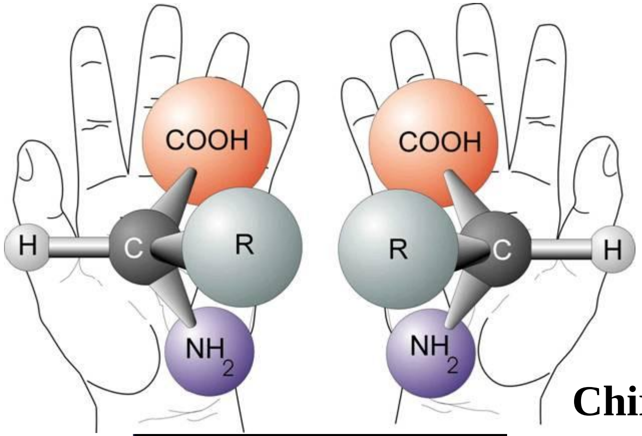
Introduction

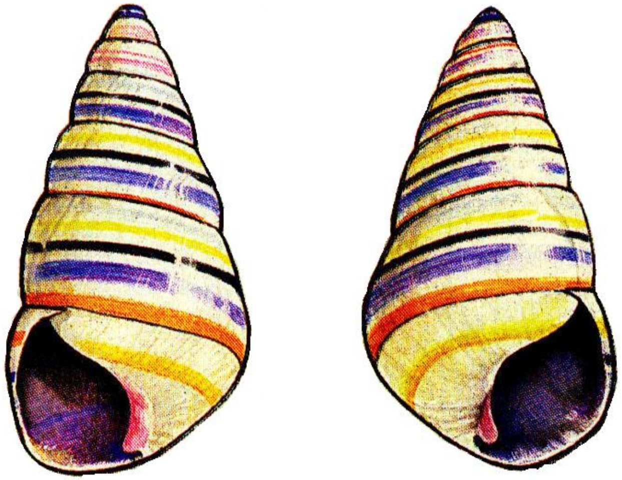
Chirality exists commonly in nature.



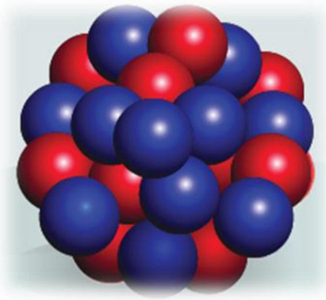
Chiral Molecules

DNA

Left- **Right-**

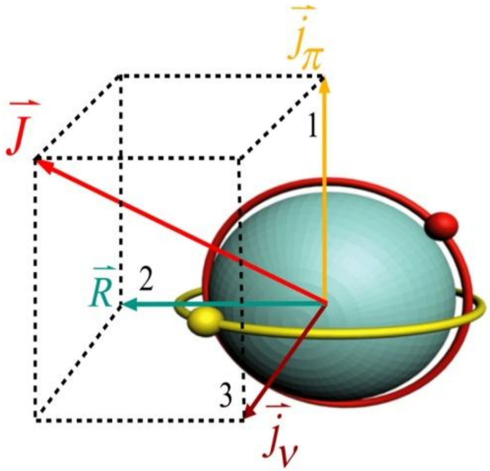


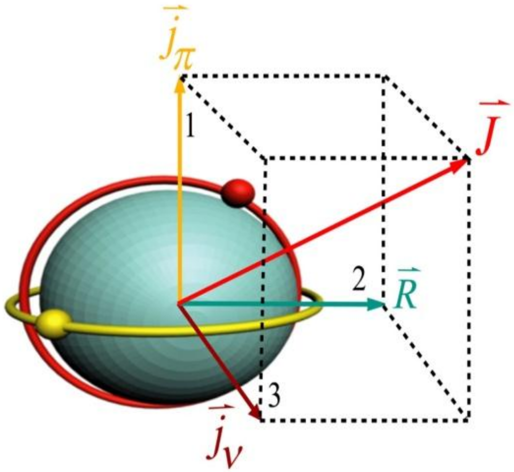
Snail Shells



Is Chirality in Nuclear World ???

Introduction





"chiral rotation"

Left-handed $|\mathcal{L}\rangle$ **Right-handed** $|\mathcal{R}\rangle$

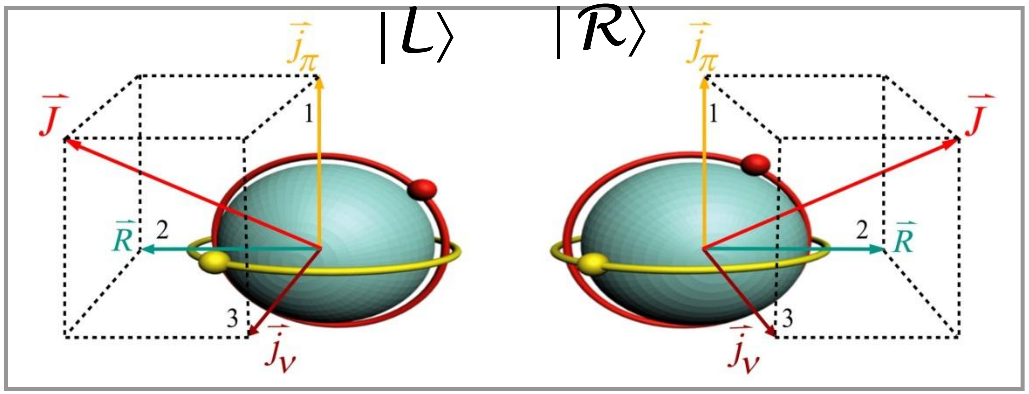
In 1997, Frauendorf and Meng pointed out that the rotation of triaxial nuclei may attain a chiral character -- chiral doublet bands.

Frauendorf and Meng NPA617, 131(1997)

Introduction

Intrinsic frame

Frauendorf and Meng NPA617, 131(1997)



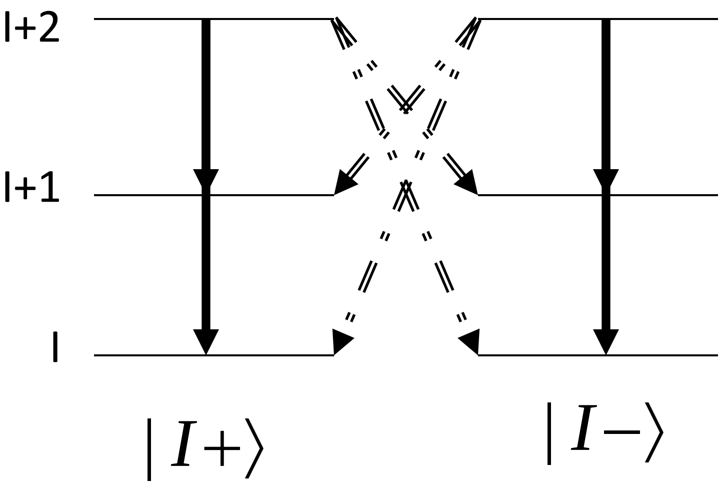
chiral symmetry breaking

Lab. frame:

restoration of symmetry breaking

$$|IM+\rangle = \frac{1}{\sqrt{2}}(|\mathcal{R}\rangle + |\mathcal{L}\rangle),$$

$$|IM-\rangle = \frac{i}{\sqrt{2}}(|\mathcal{R}\rangle - |\mathcal{L}\rangle),$$



Expected exp. signal:

Two near degenerate ΔI =1 bands, called chiral doublet bands

Introduction

VOLUME 86, NUMBER 6 PHYSICAL REVIEW LETTERS 5 FEBRUARY 2001

Chiral Doublet Structures in Odd-Odd $N = 75$ Isotones: Chiral Vibrations

K. Starosta,[1,*] T. Koike,[1] C. J. Chiara,[1] D. B. Fossan,[1] D. R. LaFosse,[1] A. A. Hecht,[2] C. W. Beausang,[2] M. A. Caprio,[2] J. R. Cooper,[2] R. Krücken,[2] J. R. Novak,[2] N. V. Zamfir,[2,†] K. E. Zyromski,[2] D. J. Hartley,[3] D. L. Balabanski,[3,‡] Jing-ye Zhang,[3] S. Frauendorf,[4] and V. I. Dimitrov[4,‡]

[1]*Department of Physics and Astronomy, SUNY at Stony Brook, Stony Brook, New York 11794*
[2]*Wright Nuclear Structure Laboratory, Yale University, New Haven, Connecticut 06520*
[3]*Department of Physics and Astronomy, University of Tennessee, Knoxville, Tennessee 37996*
[4]*Department of Physics, University of Notre Dame, Notre Dame, Indiana 46556*
and Institute for Nuclear and Hadronic Physics, Research Center Rossendorf, 01314 Dresden, Germany
(Received 24 July 2000)

New sideband partners of the yrast bands built on the $\pi h_{11/2} \nu h_{11/2}$ configuration were identified in $_{55}$Cs, $_{57}$La, and $_{61}$Pm $N = 75$ isotones of ^{134}Pr. These bands form with ^{134}Pr unique doublet-band systematics suggesting a common basis. Aplanar solutions of 3D tilted axis cranking calculations for triaxial shapes define left- and right-handed chiral systems out of the three angular momenta provided by the valence particles and the core rotation, which leads to spontaneous chiral symmetry breaking and the doublet bands. Small energy differences between the doublet bands suggest collective chiral vibrations.

DOI: 10.1103/PhysRevLett.86.971 PACS numbers: 21.10.Re, 23.20.Lv, 23.90.+w, 27.60.+j

Static chirality exists in molecules composed of four different atoms and is common for biological and pharmaceutical molecules with important consequences. In particle physics, chirality is a dynamic property which distinguishes for massless fermions the parallel or antiparallel orientation

$\pi h_{11/2} \nu h_{11/2}$ configuration with the Fermi level near the bottom of the $\pi h_{11/2}$ subshell and near the top of the $\nu h_{11/2}$ subshell. Previous experimental information on the $Z = 59$ ^{134}Pr isotone [3] revealed a nearly degenerate sideband feeding into the $\Delta I = 1$ $\pi h_{11/2} \nu h_{11/2}$ yrast band

Introduction

VOLUME 86, NUMBER 6 PHYSICAL REVIEW LETTERS 5 FEBRUARY 2001

Chiral Doublet Structures in Odd-Odd $N = 75$ Isotones: Chiral Vibrations

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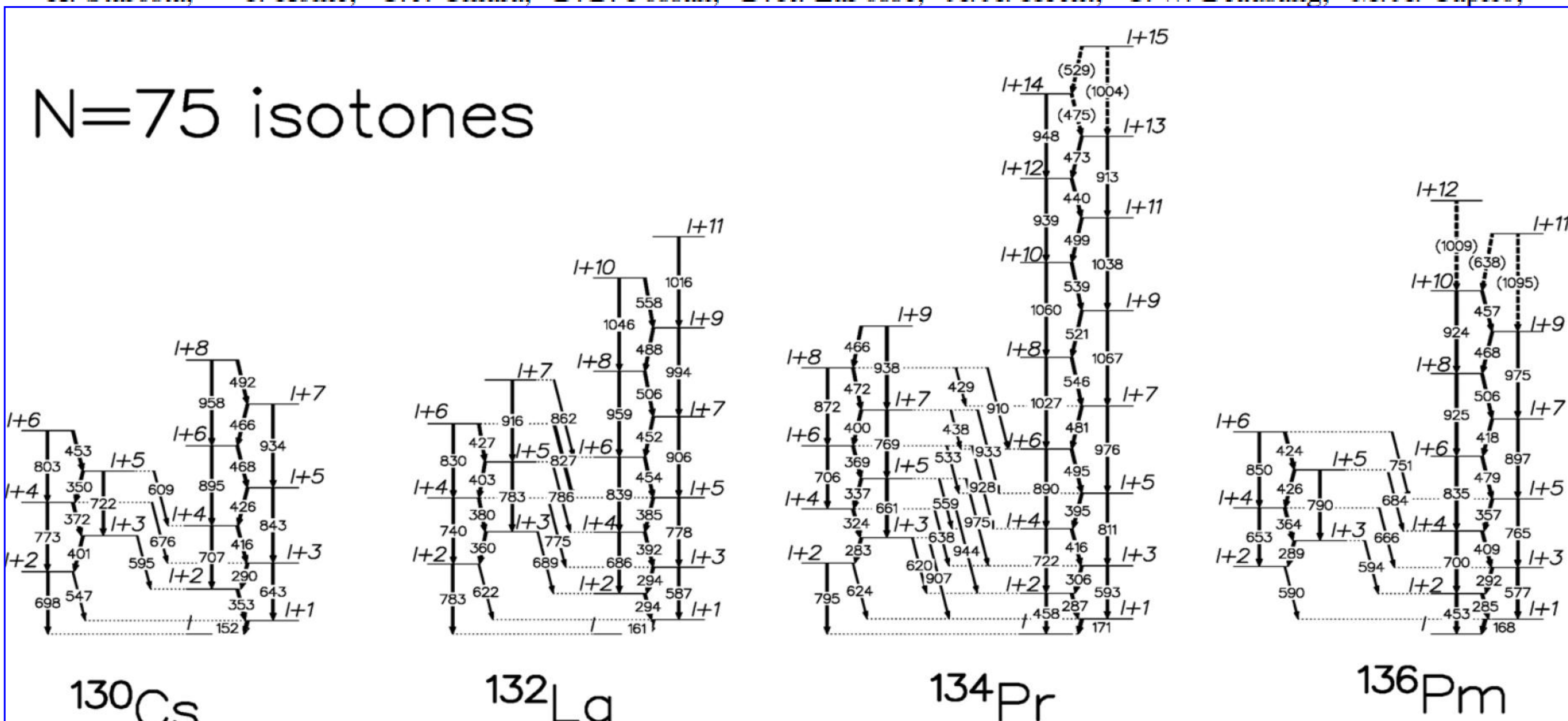
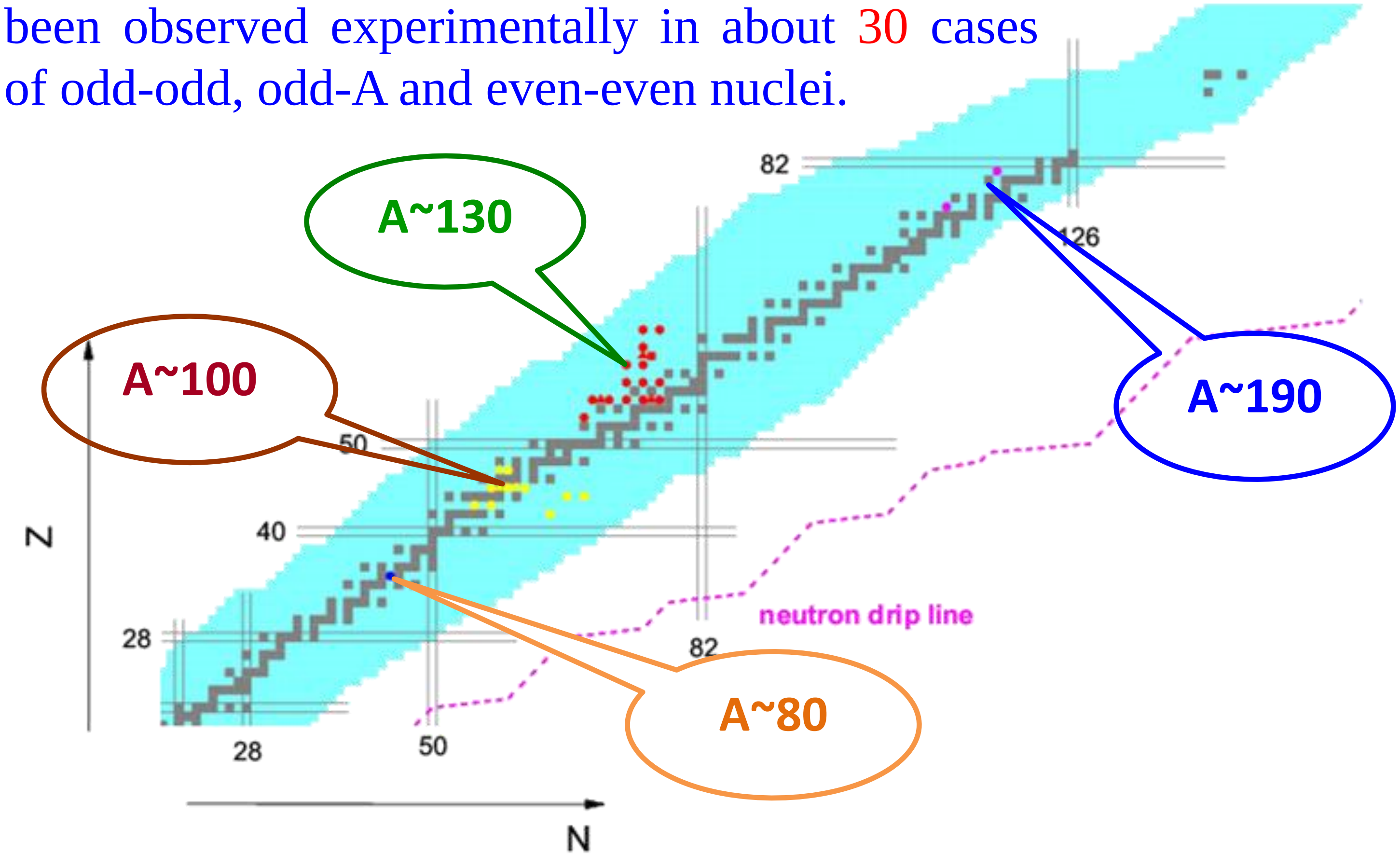


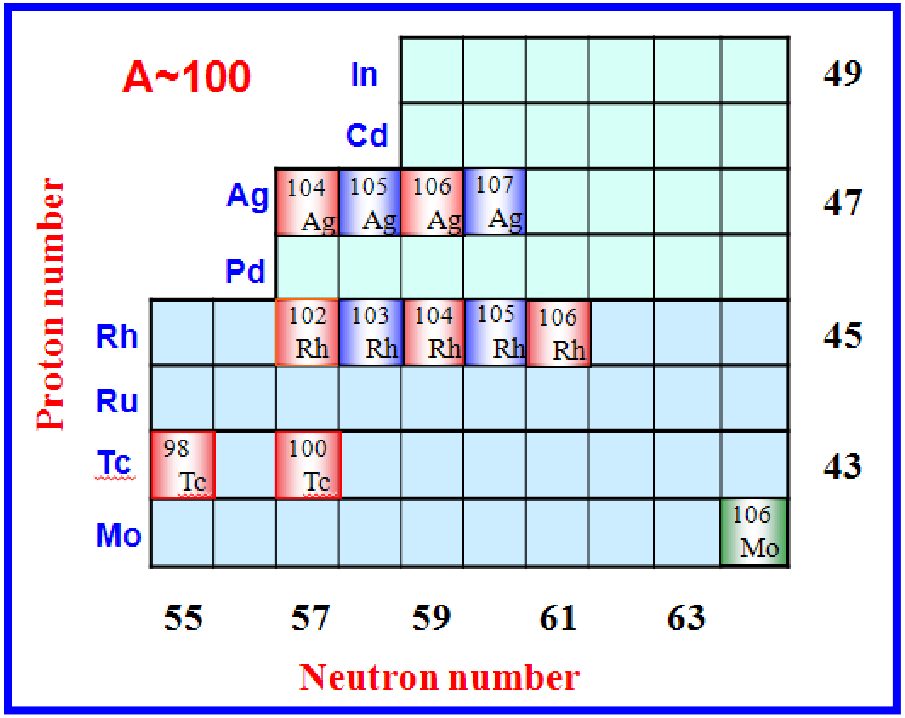
Introduction

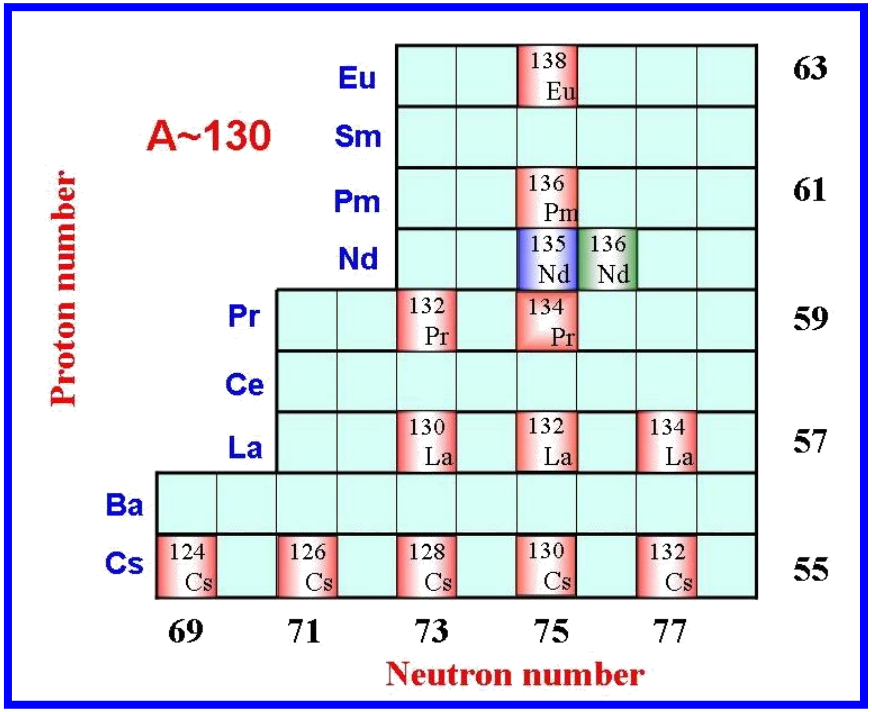
So far, candidates for chiral doublet bands have been observed experimentally in about 30 cases of odd-odd, odd-A and even-even nuclei.



J.Meng and S. Q. *Zhang*, J. Phys. G: Nucl. Part. Phys. 37 (2010) 064025

Introduction





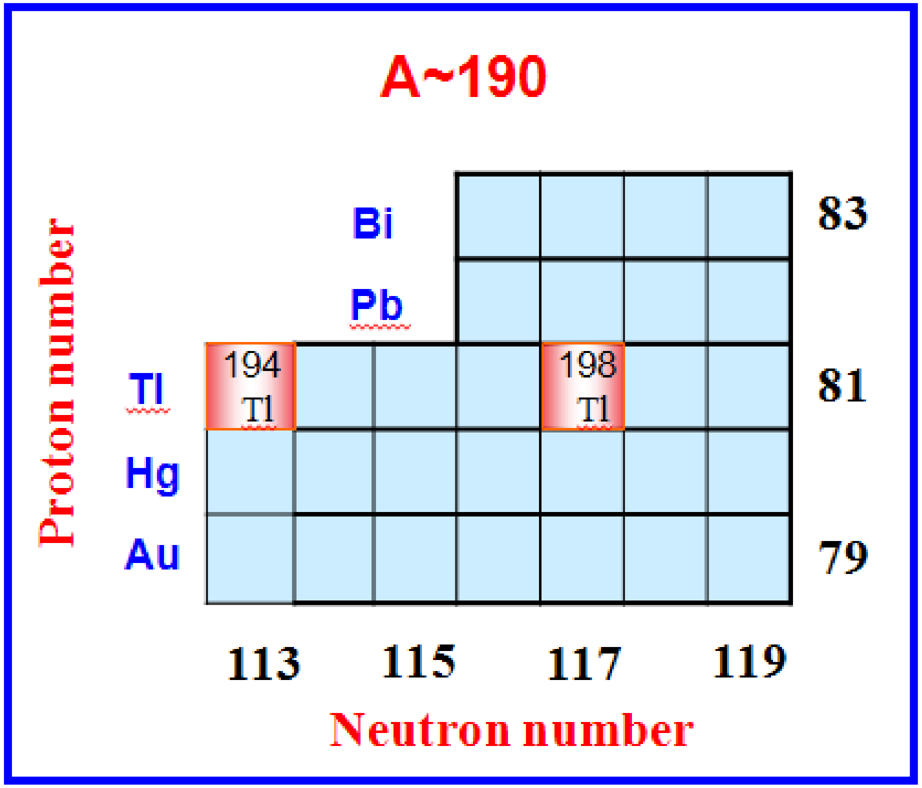
Most studies on nuclear chirality have focused on the 100 and 130 mass regions.

J.Meng and S. Q. *Zhang*, J. Phys. G: Nucl. Part. Phys. 37 (2010) 064025

Introduction

- It is necessary to search for more candidates in other mass regions to show that these chiral symmetry properties are of a general nature and not related only to a specific nuclear mass region.

- Recently, the negative-parity partner bands in ^{194,198}Tl have been suggested as candidate chiral bands.



Lawrie *et al.*, PRC 78,021305(R) (2008)

P.L.Masiteng *et al.*, Phys.Lett. B 719, 83 (2013)

- Very recent work on ^{80}Br performed at iThemba LABS has provided the first evidence for chirality in the A~80 mass region.

Physics Letters B 703 (2011) 40–45

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PHYSICS LETTERS B

The first candidate for chiral nuclei in the $A \sim 80$ mass region: ^{80}Br

S.Y. Wang [a], B. Qi [a], L. Liu [a], S.Q. Zhang [b,*], H. Hua [b], X.Q. Li [b], Y.Y. Chen [b], L.H. Zhu [c], J. Meng [b,c,d,*], S.M. Wyngaardt [d], P. Papka [d], T.T. Ibrahim [d,e,f], R.A. Bark [e], P. Datta [e], E.A. Lawrie [e], J.J. Lawrie [e], S.N.T. Majola [e], P.L. Masiteng [e], S.M. Mullins [e], J. Gál [g], G. Kalinka [g], J. Molnár [g], B.M. Nyakó [g], J. Timár [g], K. Juhász [h], R. Schwengner [i]

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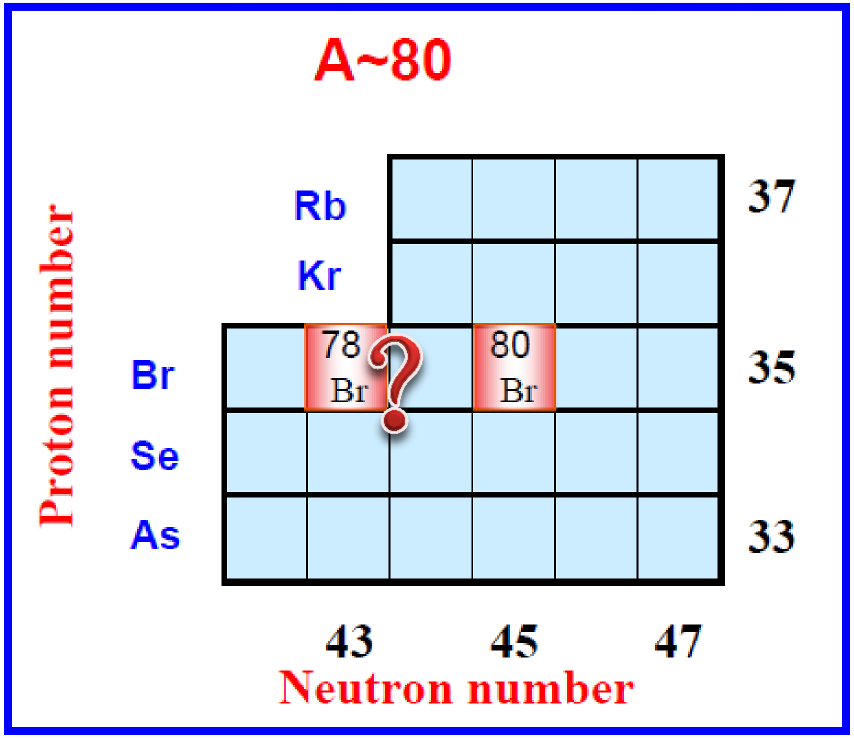
[b] *State Key Lab Nucl. Phys. & Tech., School of Physics, Peking University, Beijing 100871, China*
[c] *School of Physics and Nuclear Energy Engineering, Beihang University, Beijing 100191, China*
[d] *Department of Physics, University of Stellenbosch, Matieland 7602, South Africa*
[e] *iThemba LABS, 7129 Somerset West, South Africa*
[f] *Department of Physics, University of Ilorin, PMB 1515, Ilorin, Nigeria*
[g] *Institute of Nuclear Research of the Hungarian Academy of Sciences (ATOMKI), H-4001 Debrecen, P.O. Box: 51, Hungary*
[h] *Department of Information Technology, University of Debrecen, Egyetem tér 1, Debrecen, Hungary*
[i] *Institut für Strahlenphysik, Helmholtz-Zentrum Dresden-Rossendorf, D-01314 Dresden, Germany*

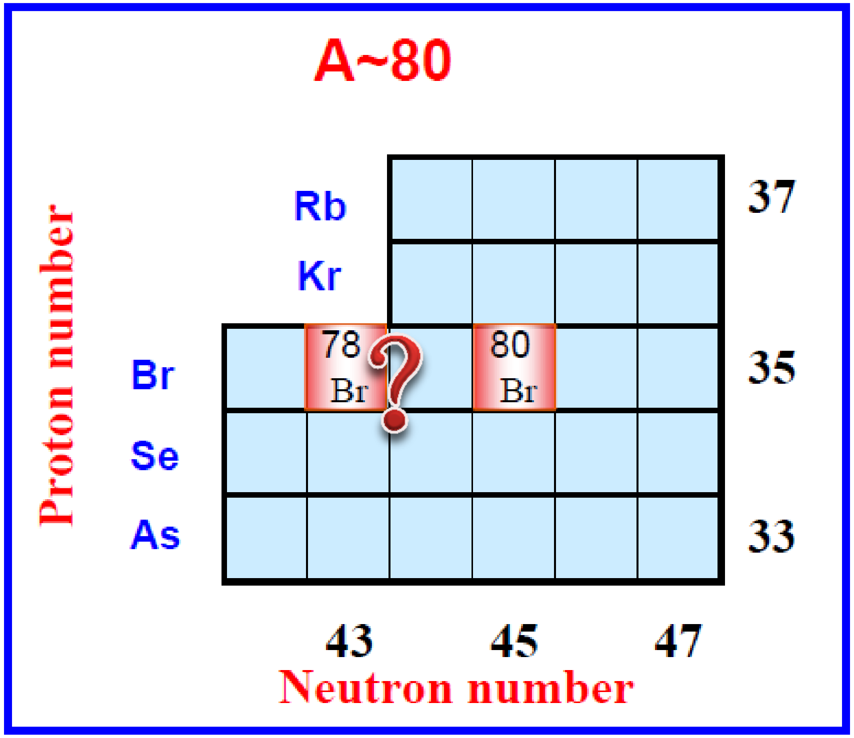
Introduction



- For this mass region, total Routhian surfaces (TRS) calculations suggest that ^{78}Br exhibits a triaxial shape with $\gamma=21.3^\circ$ and $\beta=0.32$ for a rotational band with configuration $\pi g_{9/2} \otimes \nu g_{9/2}^{-1}$.
- The deformation parameters are suitable for the construction of chiral doublet bands.

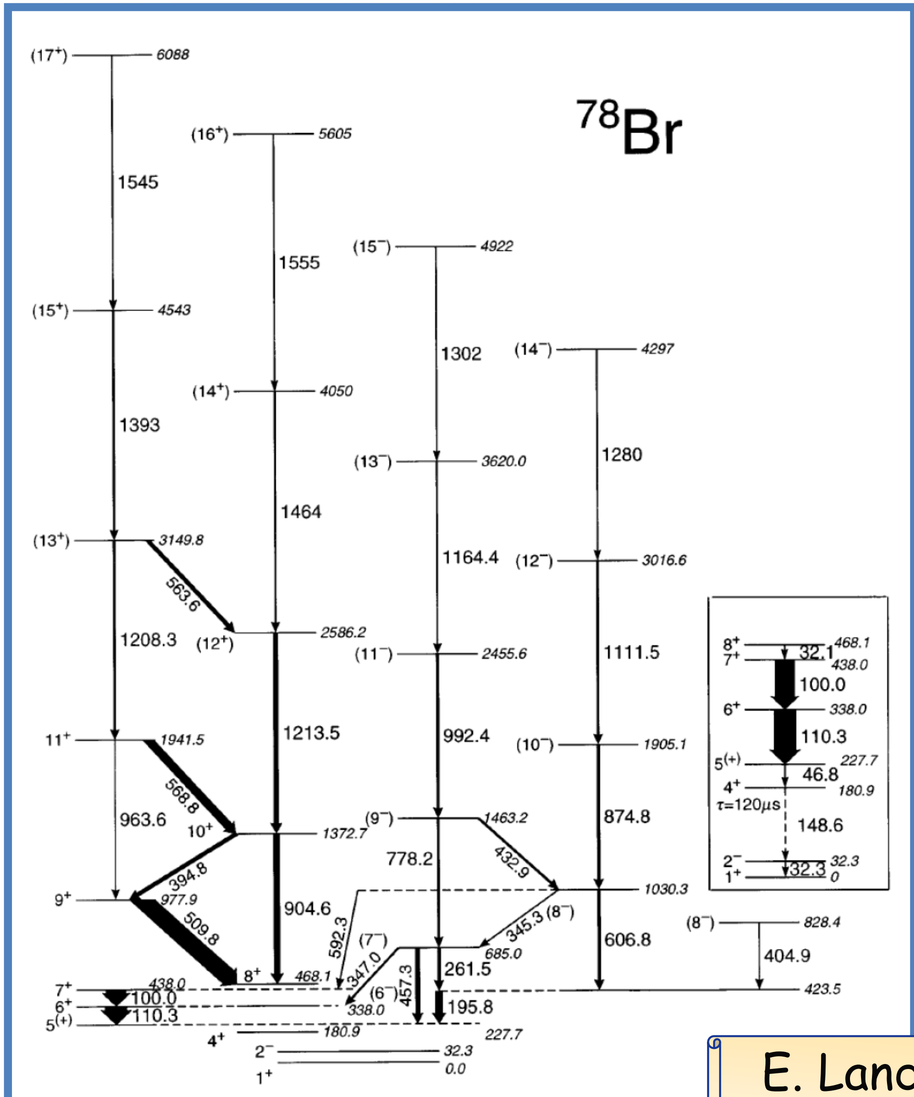
E. Landulfo et al., Phys. Rev. C 54, 2 (1996).

Introduction



- Hence, it is interesting to populate high-spin states of ^{78}Br and to search for chiral doublet bands.
- It is also important to establish whether chirality exists in more than one odd-odd nuclei in the A~80 mass region in order to provide systemic survey on the chiral interpretation.

Previous study of ^{78}Br



- Previous investigation on high-spin states of ^{78}Br was preformed at the Florida State University with ^{70}Zn (^{11}B, 3n) at 45 MeV beam energy.

- No sideband of the yrast band was observed.

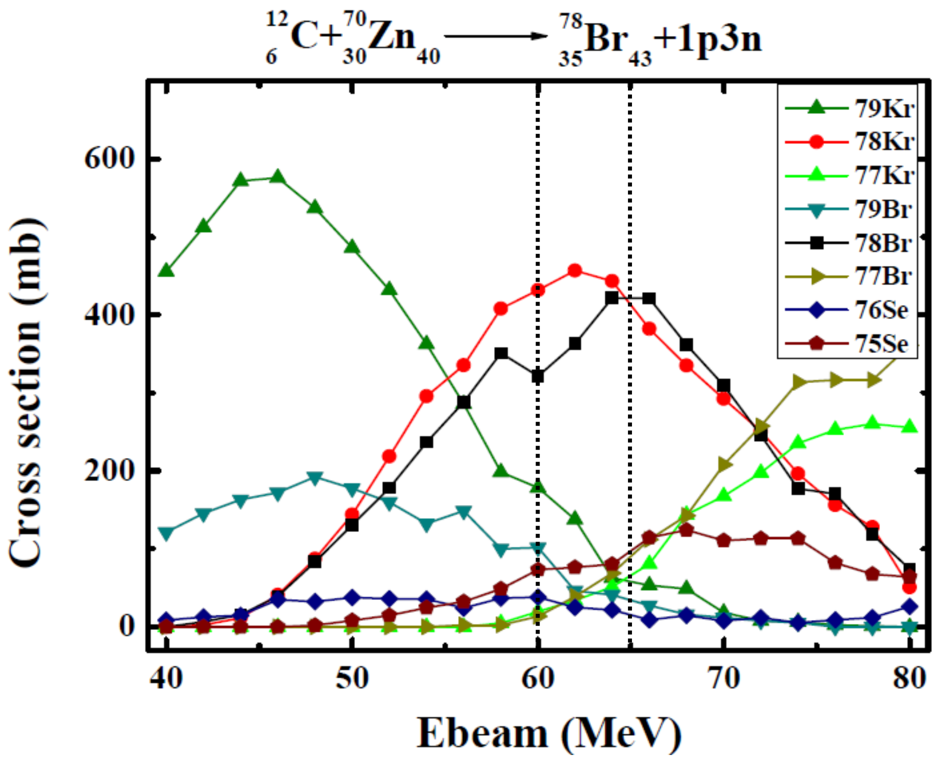
E. Landulfo et al., Phys. Rev. C 54, 626 (1996).

Contents

Experiment Details

- The experiment was carried out at the iThemba LABS in South Africa in Feb. 2012.

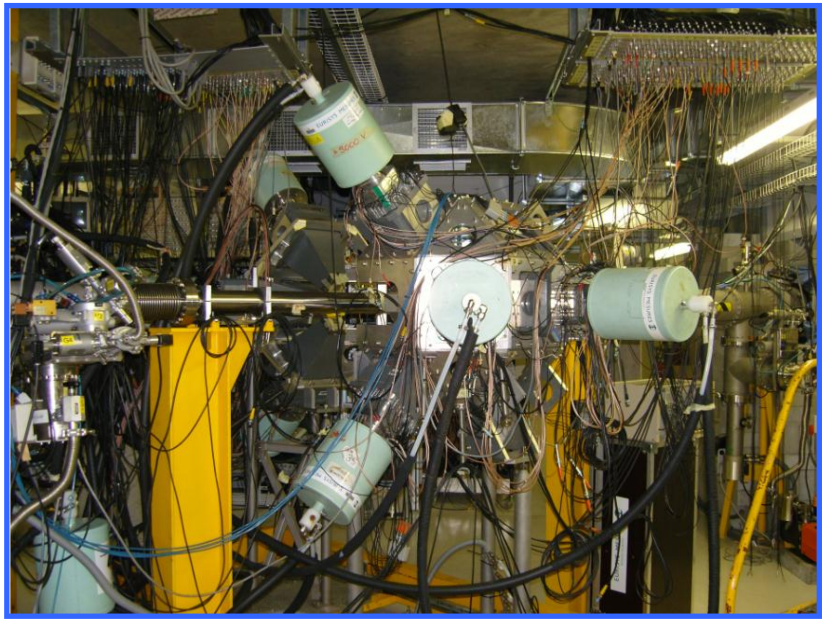
Experiment Details

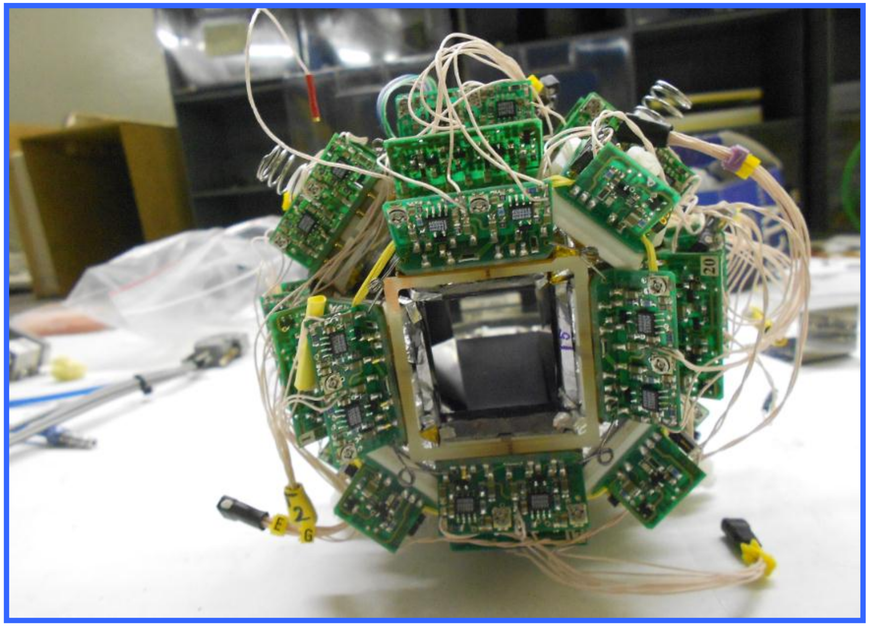


Cross sections have been calculated with the PACE2 program.

The ^{70}Zn (^{12}C, 1p3n) reaction is used to populated the high spin states of ^{78}Br at a beam energy of 65&60 MeV.

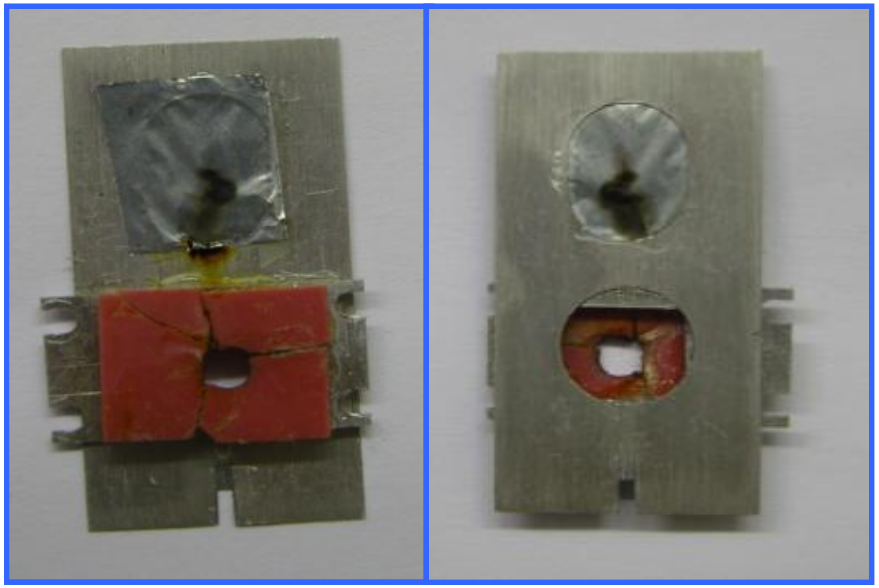
Experiment Details





- The γ-rays were measured with the detector array AFRODITE, which consists of 8 Compton Suppressed Clover detectors.
- The DIAMANT array of CsI particle detectors were also used to select reaction channels.

Experiment Details



- The Zn target is a 0.85 mg/cm^2 self-supported metallic foil.

Experiment Details

- The experiment lasted 145 hours.

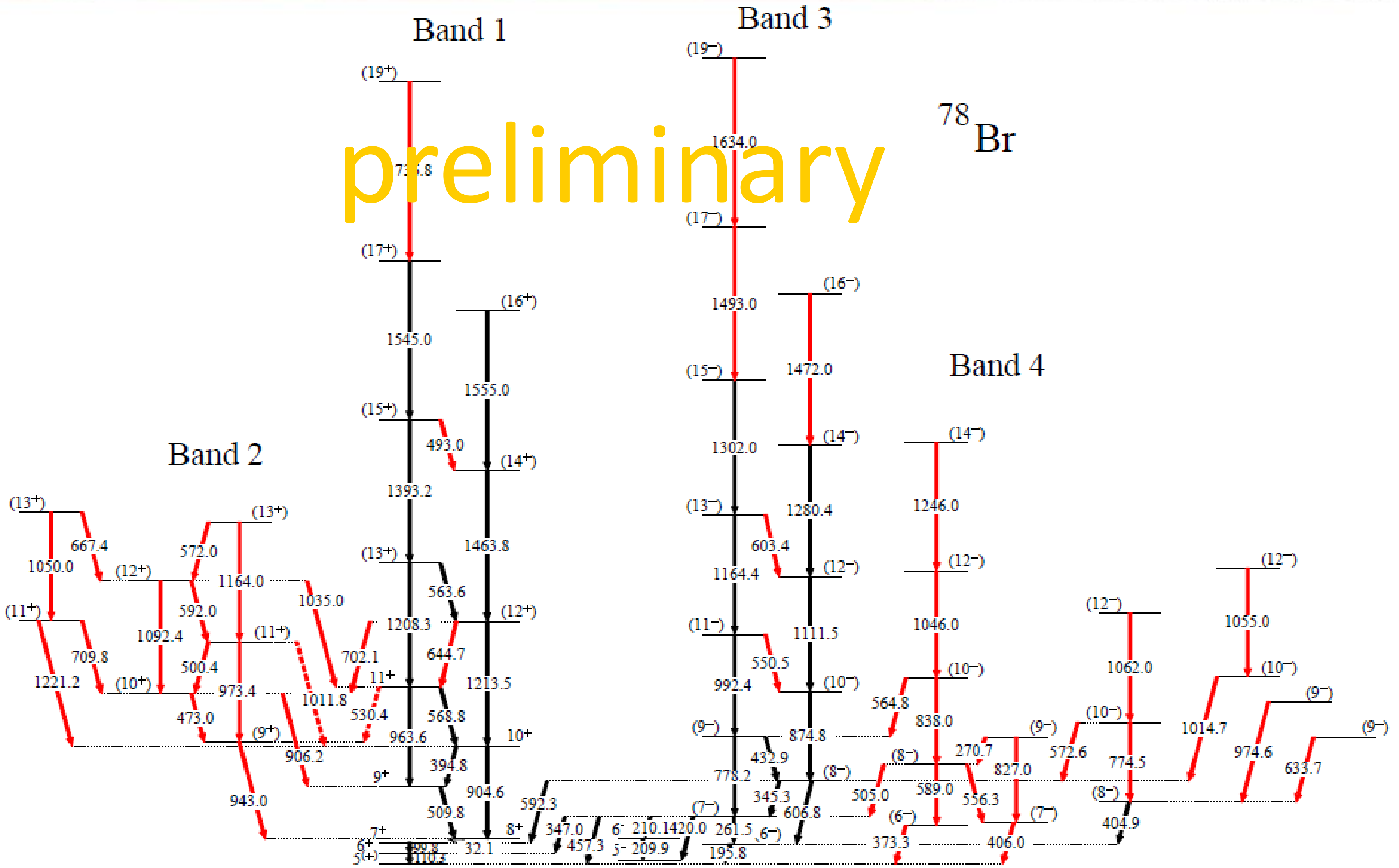
- A total of 1.5×10^9 γ-γ coincidence events were collected in the experiment and sorted into Eγ-Eγ matrix as well as Eγ-Eγ-Eγ cube.

- The γ-γ coincidence events were picked out in the one-proton and α emission channels using DIAMANT, respectively.

- A p-Eγ-Eγ matrix was sorted.

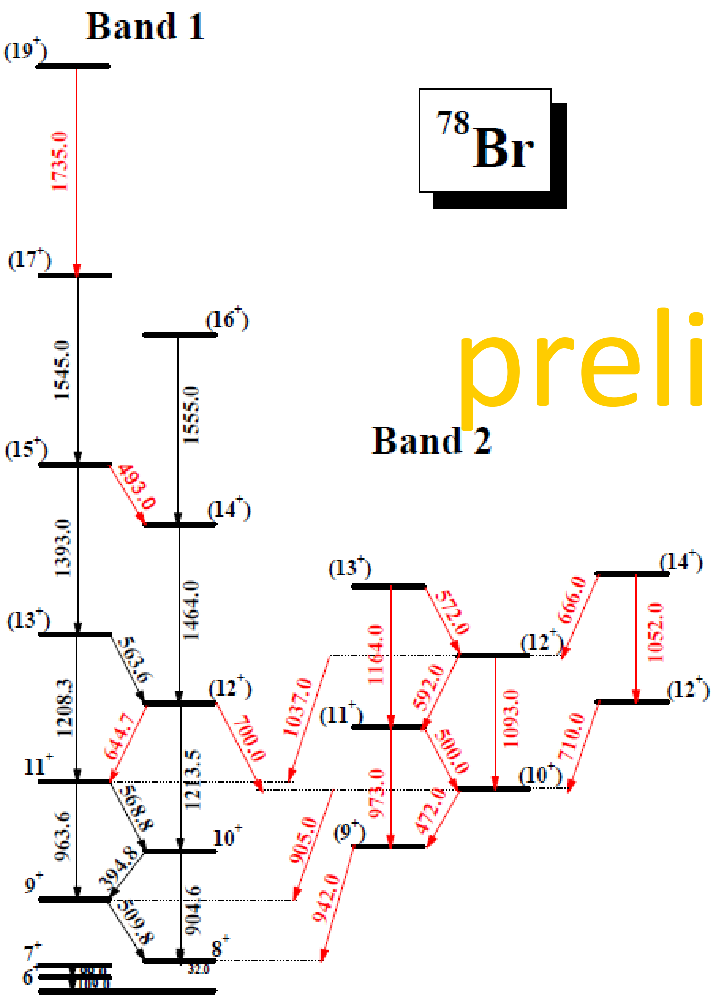
Contents

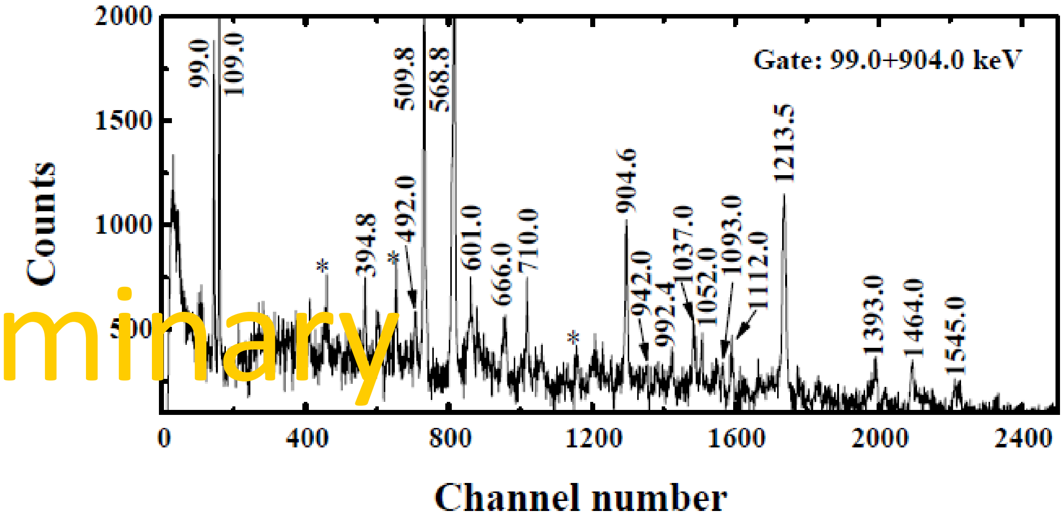
Level Scheme of ^{78}Br



Level scheme of ^{78}Br deduced from the present work.

Results and Discussions



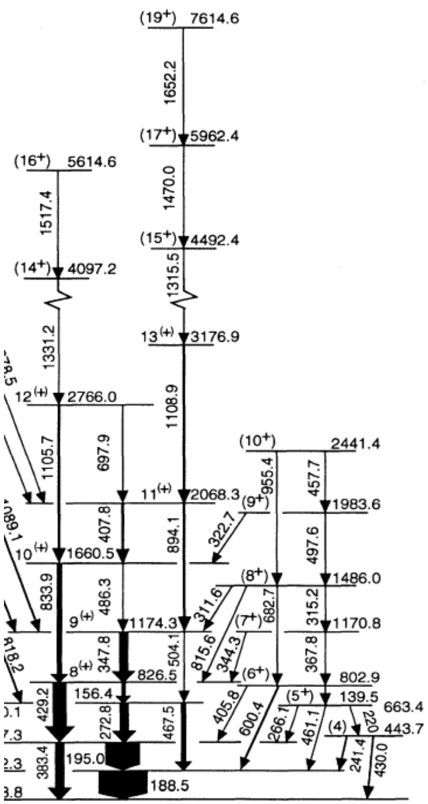


preliminary

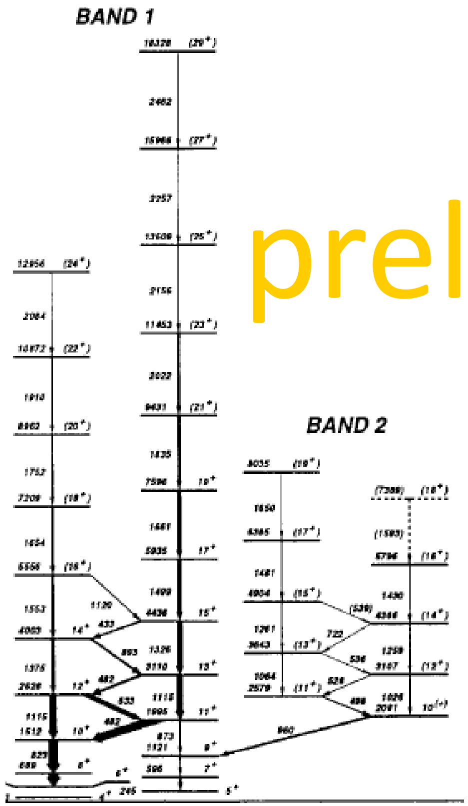
- There is an overlap of the wavefunctions in the two bands, so the two bands might based on the same configuration.

Results and Discussions

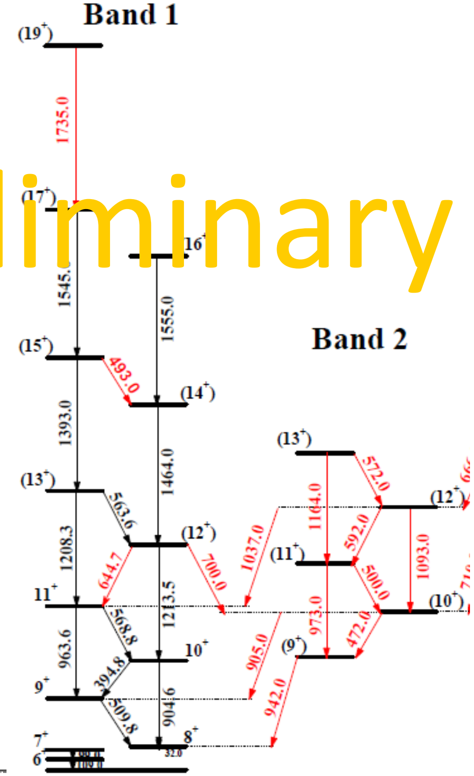
^{74}Br



^{76}Br

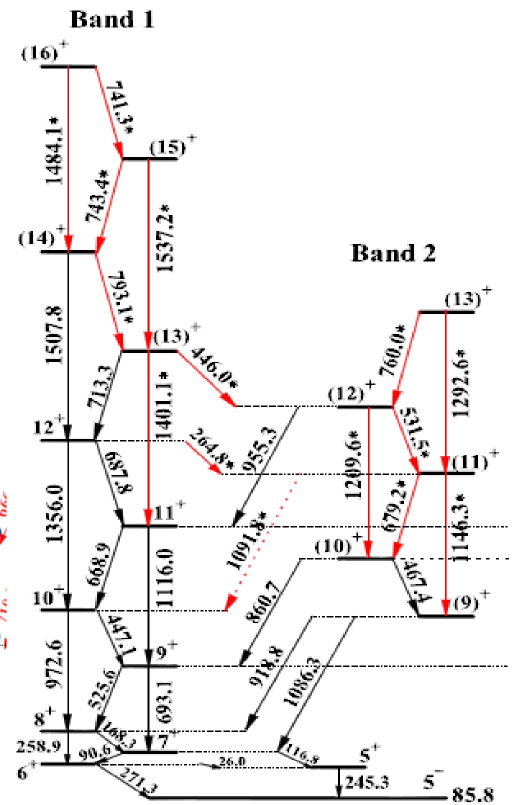


^{78}Br

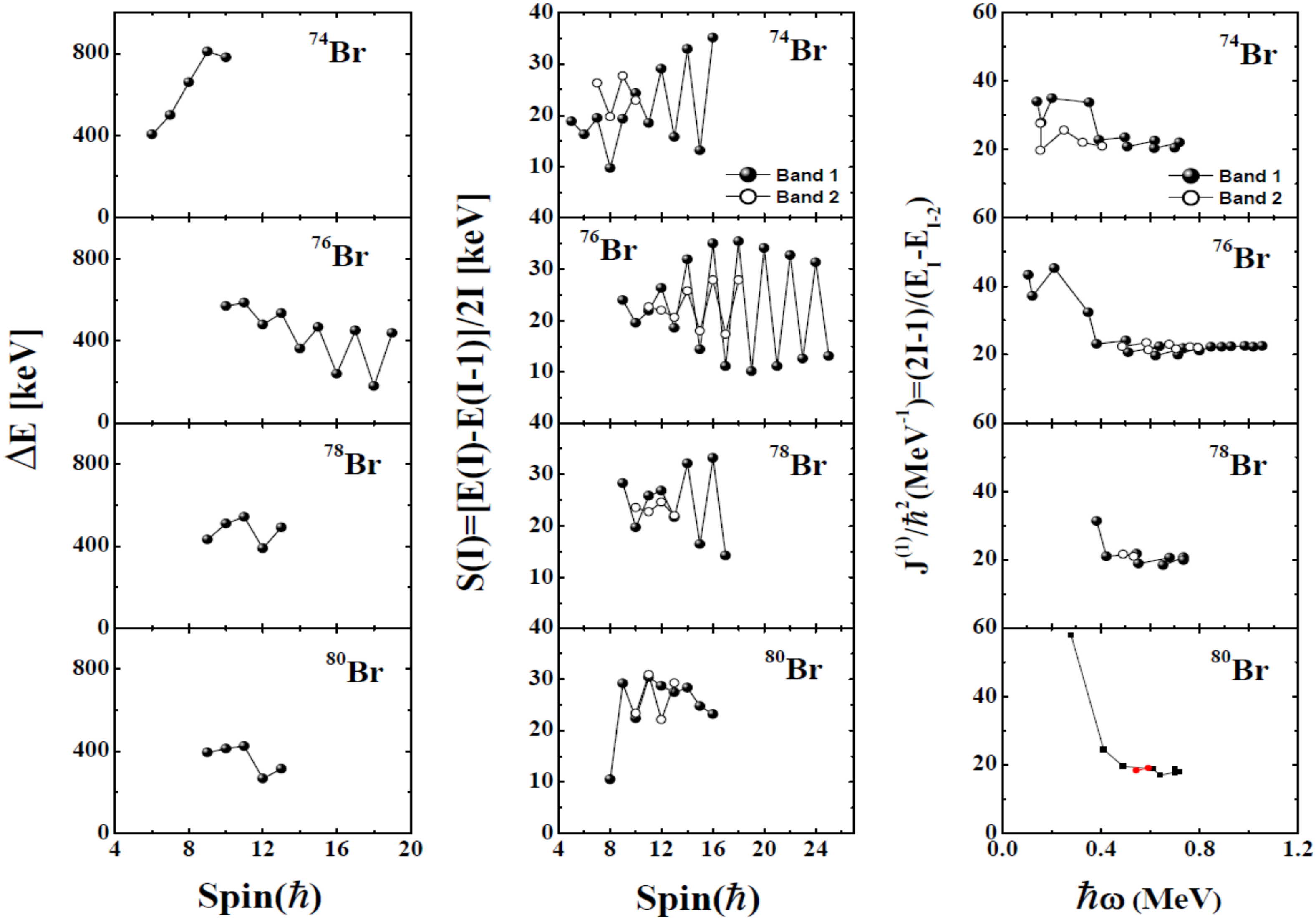


preliminary

^{80}Br



Results and Discussions



Results and Discussions

- In ^{78}Br, The two bands maintain an energy difference around 500 keV within the observed spin interval.
- The experimental values of S(I) have an almost constant value of ~ 25 keV/ħ in those nuclei.
- The two bands in ^{78}Br has similar S(I) values.
- The two bands in ^{78}Br have similar $J^{(1)}$ values, which infer those bands have similar deformations.

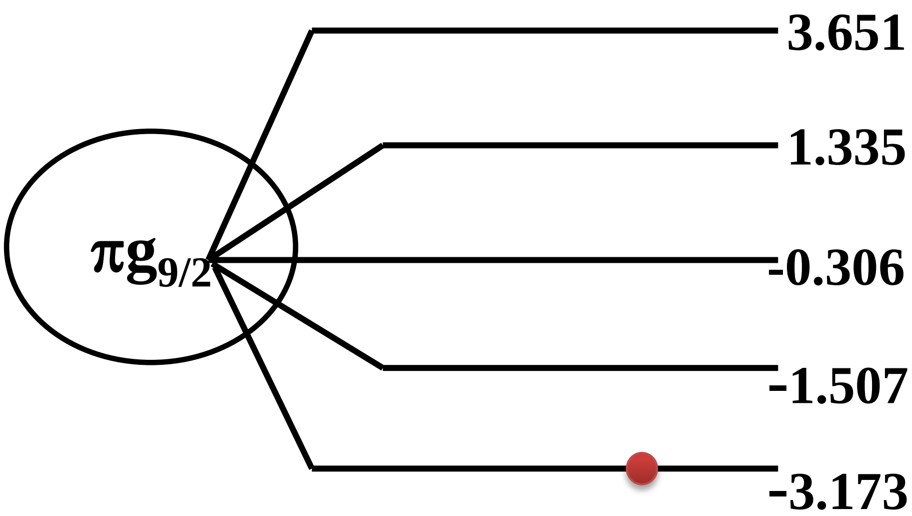
PRM(Particle Rotor Model)[1,2] calculation

Parameter	Calculation method	Value	Note
C_p/C_n	$C=\frac{38.8(N+3/2)}{J(J+1)}A^{-1/3}\beta$ [3]	0.646/0.646	Coupling parameter
Gamma	Ref. [4]	21.3°	Deformation parameter
$\mathfrak{J}$		12	
$2j_p+1/2j_n+1$	$\pi g_{9/2}\otimes\nu g_{9/2}$ [4]	10/10	
I_{sta}/I_{end}		1/24	
g_p-g_R/g_n-g_R	g_p/g_n $g_R\approx Z/A\approx 0.45$ [3]	0.811/-0.705	g factor
Q_0	$Q_0=\frac{3}{\sqrt{5\pi}}R^2Z\beta_2$ [3]	2.485	
Deltap/Deltan	$\Delta_p=\Delta_n=12/\sqrt{A}$ [3]	1.359/1.359	

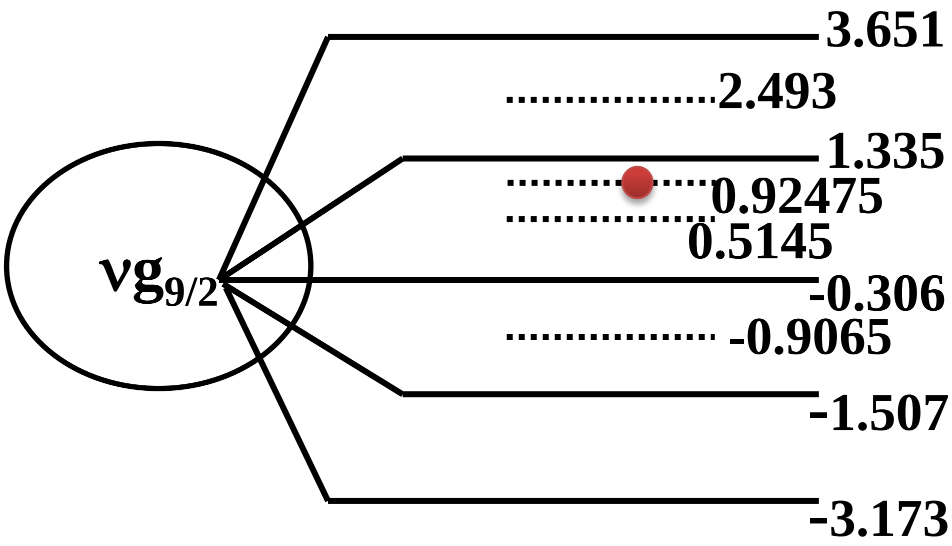
[1] S. Y. Wang *et al.*, Phys. Rev. C 75,024309 (2007).
[2] S. Q. Zhang et al., Phys. Rev. C 75, 044307 (2007).
[3]. S. Y. Wang et al., Phys. Rev. C 77, 034314 (2008)
[4]. E. Landulfo et al., Phys. Rev. C 54, 2 (1996).

PRM(Particle Rotor Model) calculation

Parameter	Calculation method	Value	Note
Lamdap/Lamdan		-3.173/0.9248	Femi energy

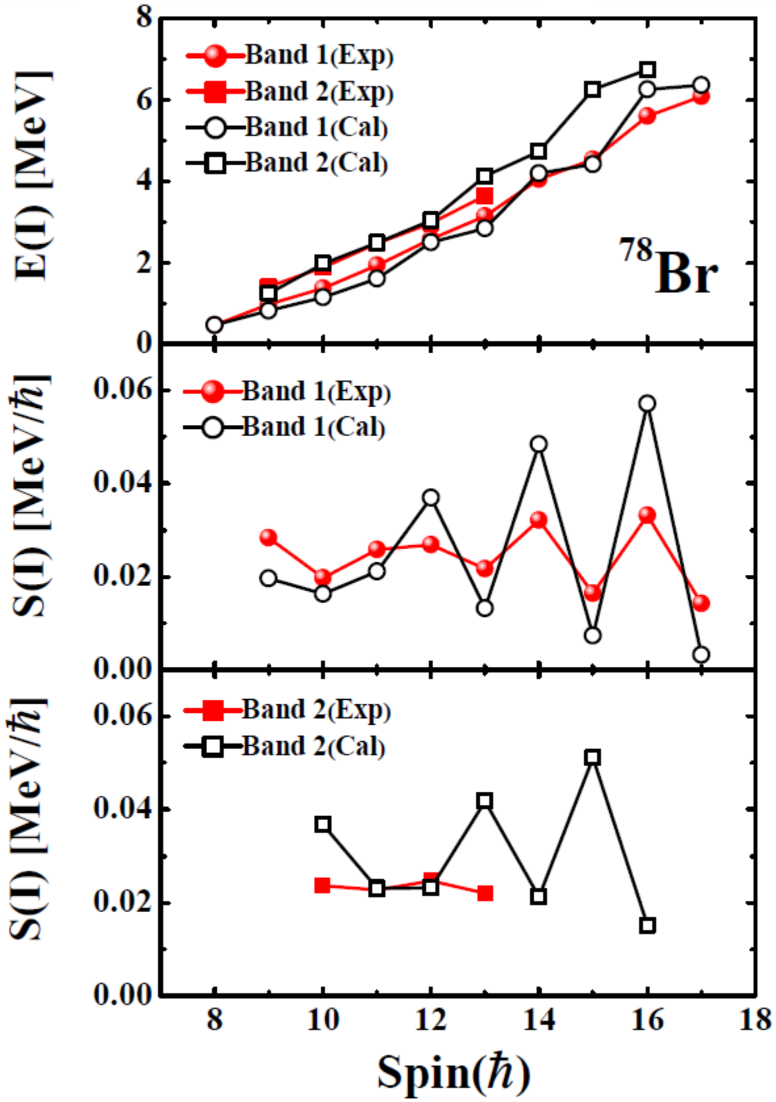


Z=35



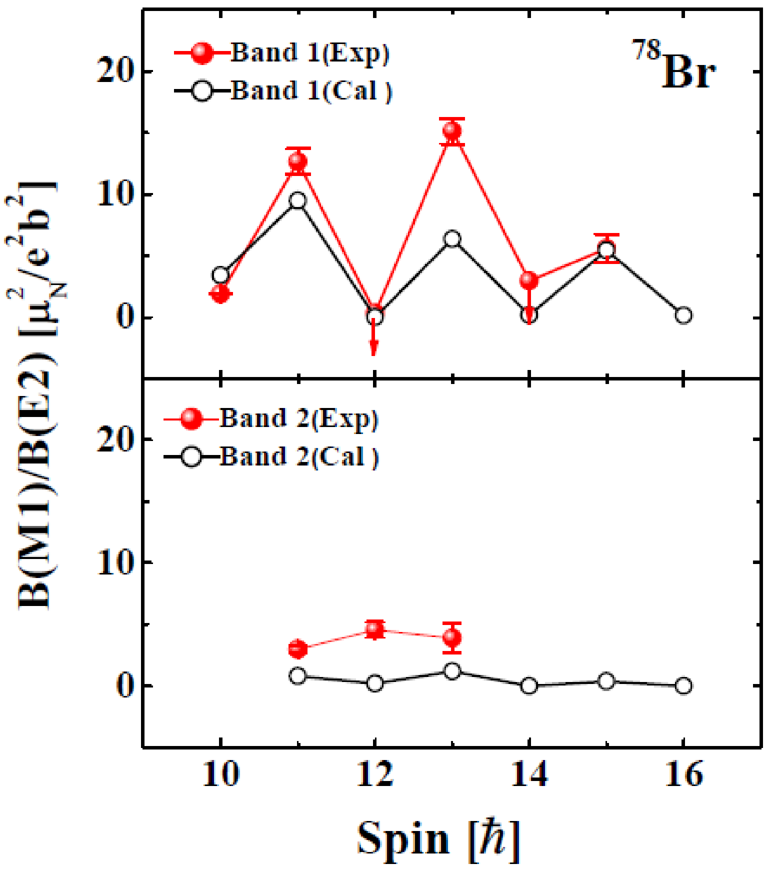
N=43

PRM(Particle Rotor Model) calculation



- the experimental energy spectra were well reproduced.
- The theoretical S(I) values have same magnitudes with the experimental values.

PRM(Particle Rotor Model) calculation



- The magnitude and trend of the ratios with spin are reproduced quite well.
- The B(M1)/B(E2) values of band 1 present obvious stagger during the spin interval, while band 2 have relatively smaller B(M1)/B(E2) values than band 1.

Contents

Conclusion

- High-spin states of ^{78}Br were populated using the ^{70}Zn(^{12}C, 1p3n) reaction at the iThemba LABS in South Africa.
- The previously known level scheme of ^{78}Br has been extended.
- The study of systematics in A~80 mass region show that the two positive-parity bands in ^{78}Br have similar characters with those in ^{80}Br.
- The observed energy levels and the ratio of the electromagnetic transition probabilities of the doublet bands in ^{78}Br are well reproduced by the particle rotor model.
- ^{78}Br might be another candidate of chiral nucleus in A~80 mass region . The further works are still on.

Acknowledgement

- I would like to thank the members of the iThemba LABS and Stellenbosch University for being friendly and helpful.
- the SA/CHINA research collaboration in science and technology
- the National Research Foundation of South Africa.
- This work is supported by the National Natural Science Foundation of China.

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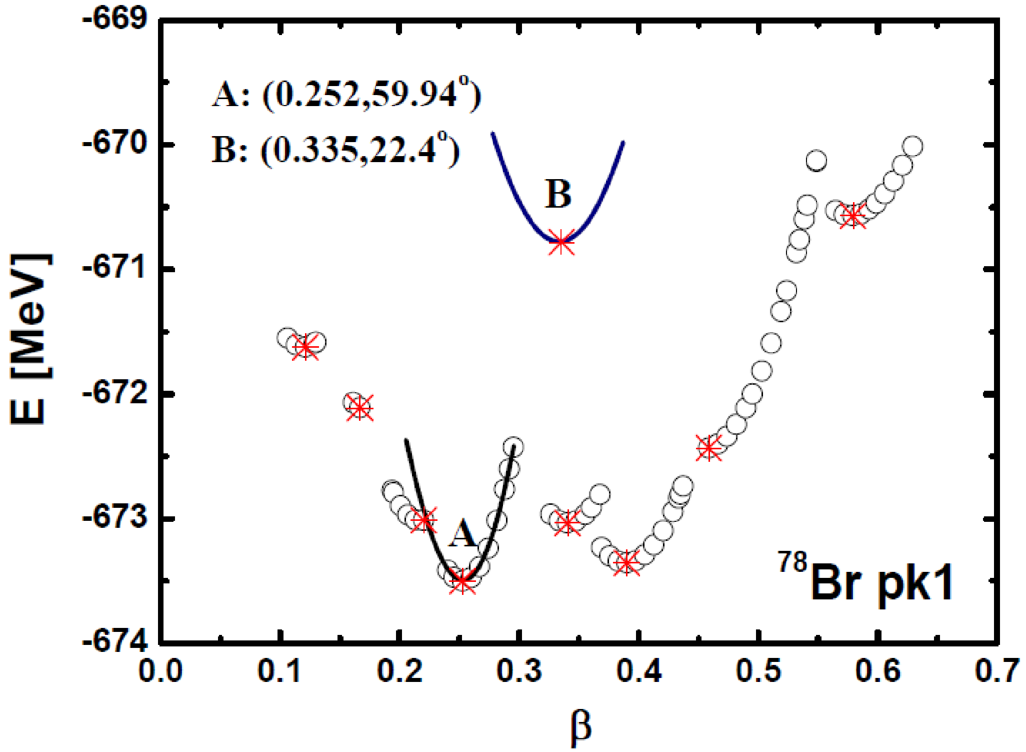
ATOMKI, Hungury: J. Gál, J. Molnár, B.M. Nyakó, K. Juhász

Peking Univ.: J. Meng, S.Q. Zhang, X.Q. Li, C. Xu

Tsinghua Univ.: H.J. Li

Supported by NSFC & NRF & China-SA collaboration!

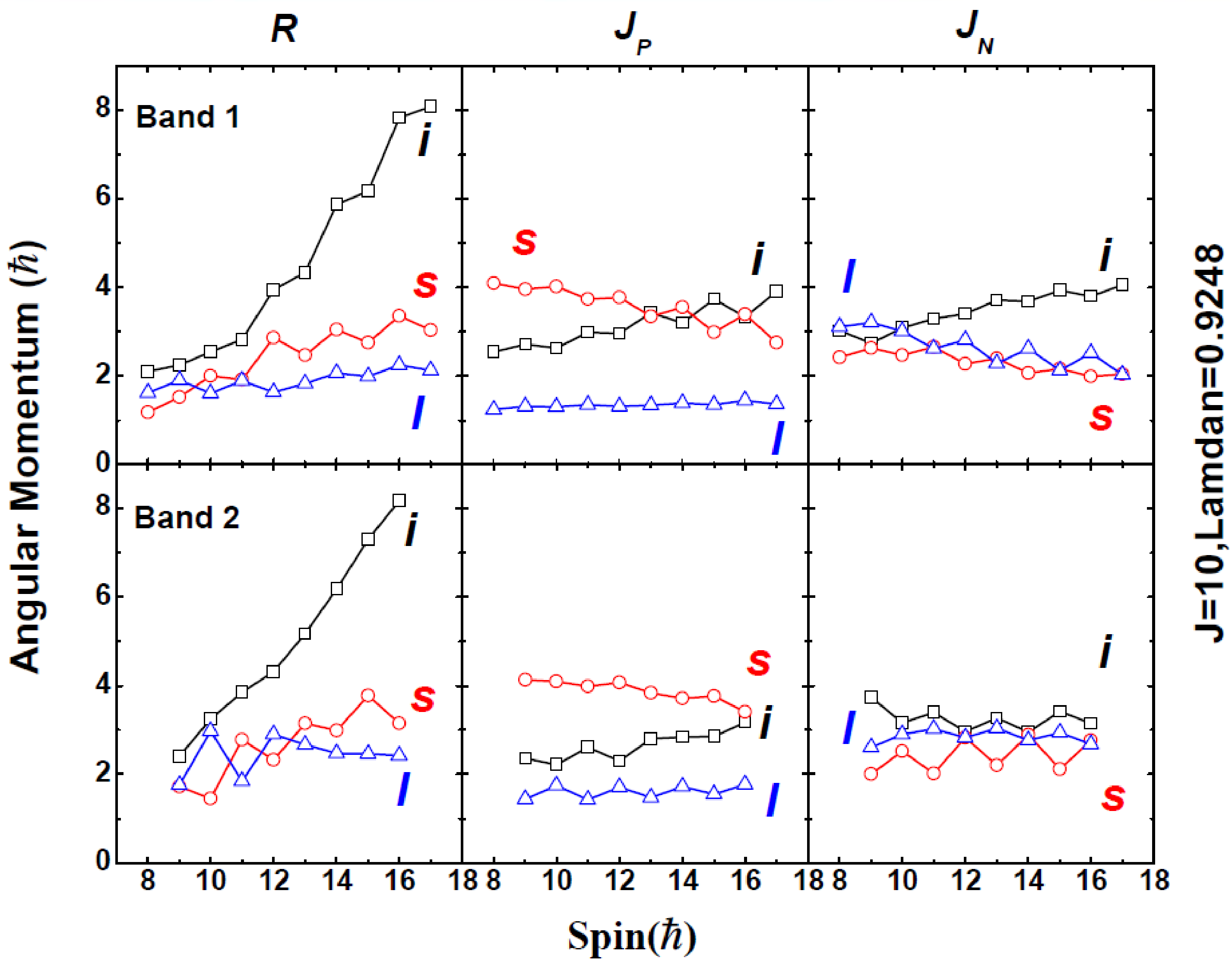
^{78}Br RMF计算结果



A为$\pi g_{9/2}^{1} \otimes \nu g_{9/2}^{-5}$组态

B为$\pi g_{9/2}^{3} \otimes \nu g_{9/2}^{-5}$组态

Results and Discussions



Results and Discussions