Proton Drip-Line Neighbouring Nuclei and Nuclear Structure

N. Laouet and F. Benrachi

LPMPS Laboratory-Frères Mentouri Constatine 1 University, Algeria

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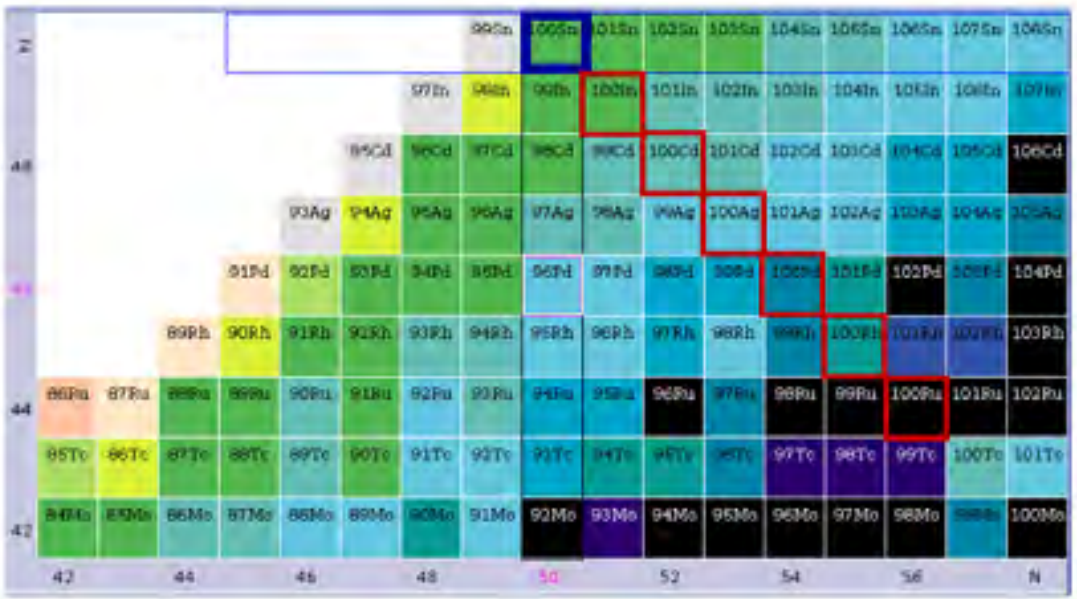
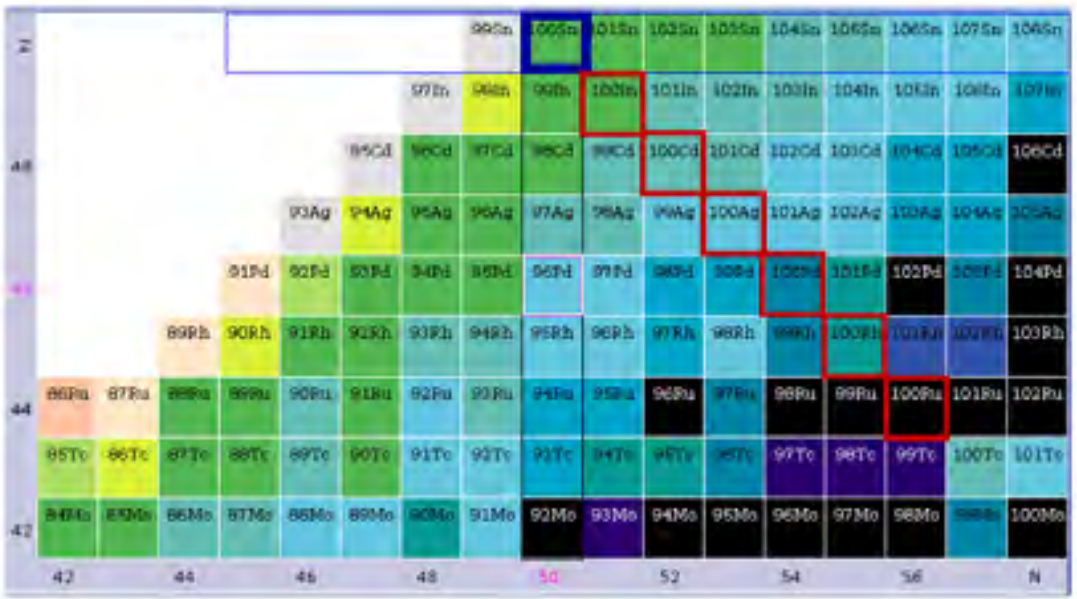
Nuclear Physics



- Proton rich nuclei
- Shell evolution in this region?!!!!
- Close to the proton drip line
- Close to rp-process path
- Few experimental data about nuclei in this region

Nuclear Physics



- Proton rich nuclei
- Shell evolution in this region?!!!!
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- Few experimental data about nuclei in this region

$\Rightarrow$ In this study:

- Monopole effect
- Investigation of nuclear properties of $A = 100$ isobars

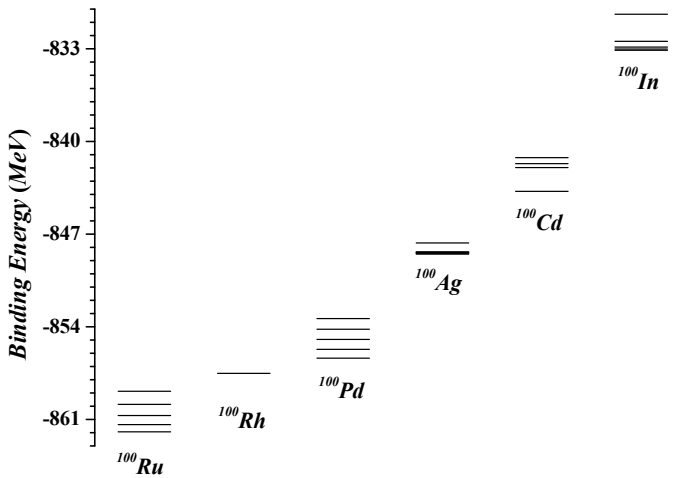


Figure: Yrast states up to 8^+ for $A = 100$ isobars.

- $A = 100$ nuclei lie in proton drip-line neighbourhood.
- Some of $A = 100$ nuclei lie close to *rp-process* path.

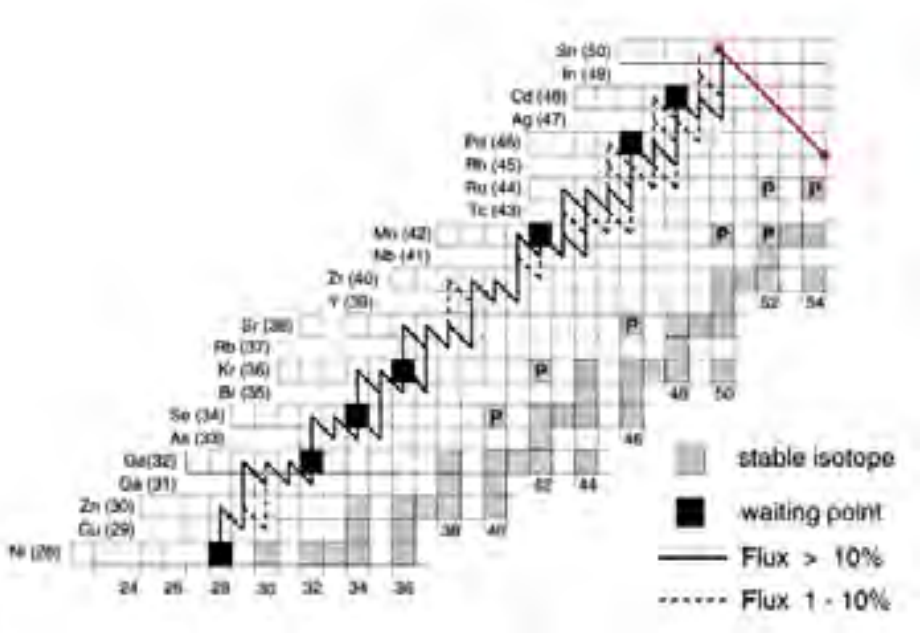


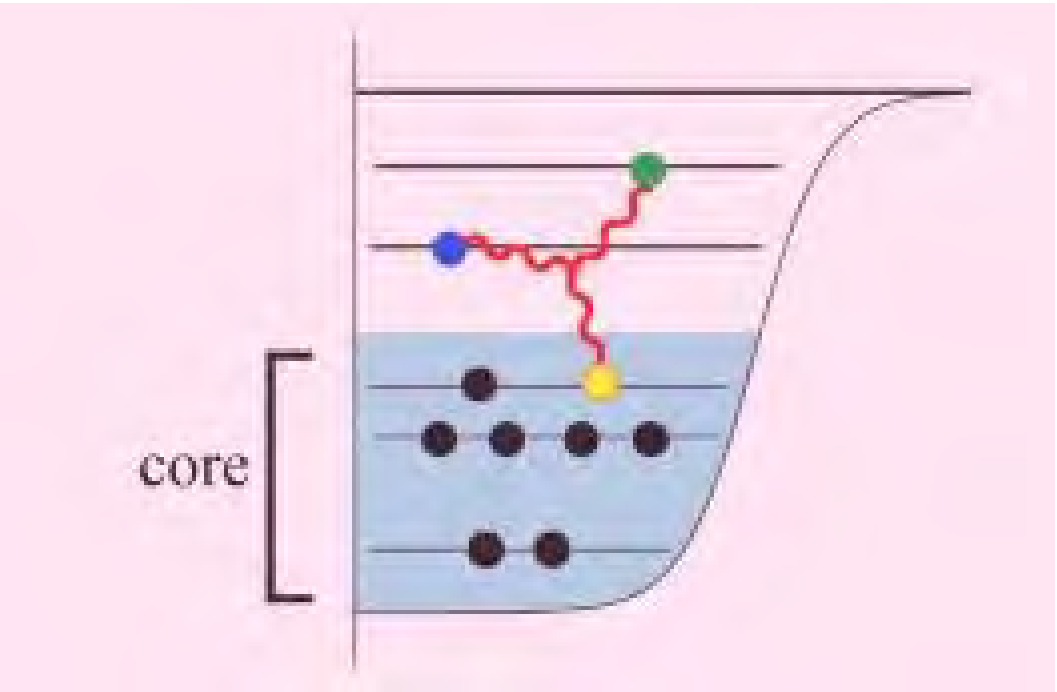
Figure: Studied $A = 100$ isobars near rp-process reaction path bellow ^{100}Sn mass region. [1].

[1] Wiescher and Schatz, Prog. Theor. Phys. Supp. 140, 11 (2000)

- Monopole Effect

Monopole Effect

- Nuclear Shell Model: Nucleus $\Rightarrow$ Inert Core + n Valence Particles $\longrightarrow$ Failure of reproducing nuclear properties A$>$ 20



The Hamiltonian of a system can be expressed in terms of monopole and Multipole parts

$$H = H_m + H_M$$

$$H_m = \sum_s n_s \varepsilon_s + \sum_{s \leq t} \left(a_{st} n_{st} + b_{st} T_{st} \right) \tag{1}$$

$$V_{j_\tau j_{\acute{\tau}}}^{\tau \acute{\tau}} = \frac{\sum_J (2J+1) V_J \left(j_\tau j_{\acute{\tau}} \right)}{\sum_J (2J+1)}$$

- ε_s is the *SPE*
- n_s and T_{st} are occupation and isospin operators
- a_{st} and b_{st} can be expressed in terms of the centroid $V_J \left(j_\tau j_{\acute{\tau}} \right)$
  - Subshell s with spin j_τ
  - Subshell t with spin $j_{\acute{\tau}}$

NuShellX@MSU code

NuShellX is a set of computer codes

Written by Bill Rae[2]
Used to obtain nuclear structure properties
Used J coupled pn basis
100 million matrix dimension can be considered

NuShellX@MSU is a set of computer codes

Written by Alex Brown[2]
Used data files to generate input for NuShellX
Convert NuShellX output to generate figures and tables

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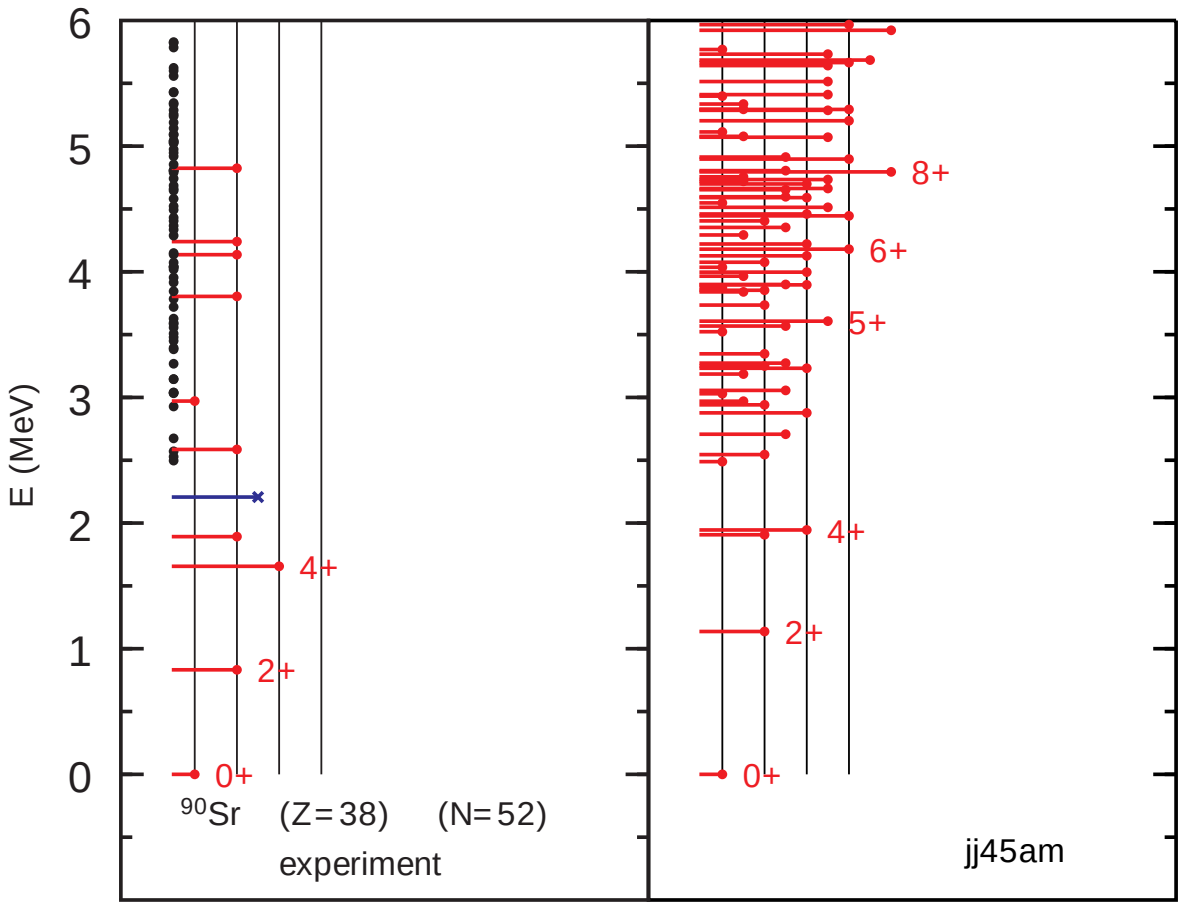
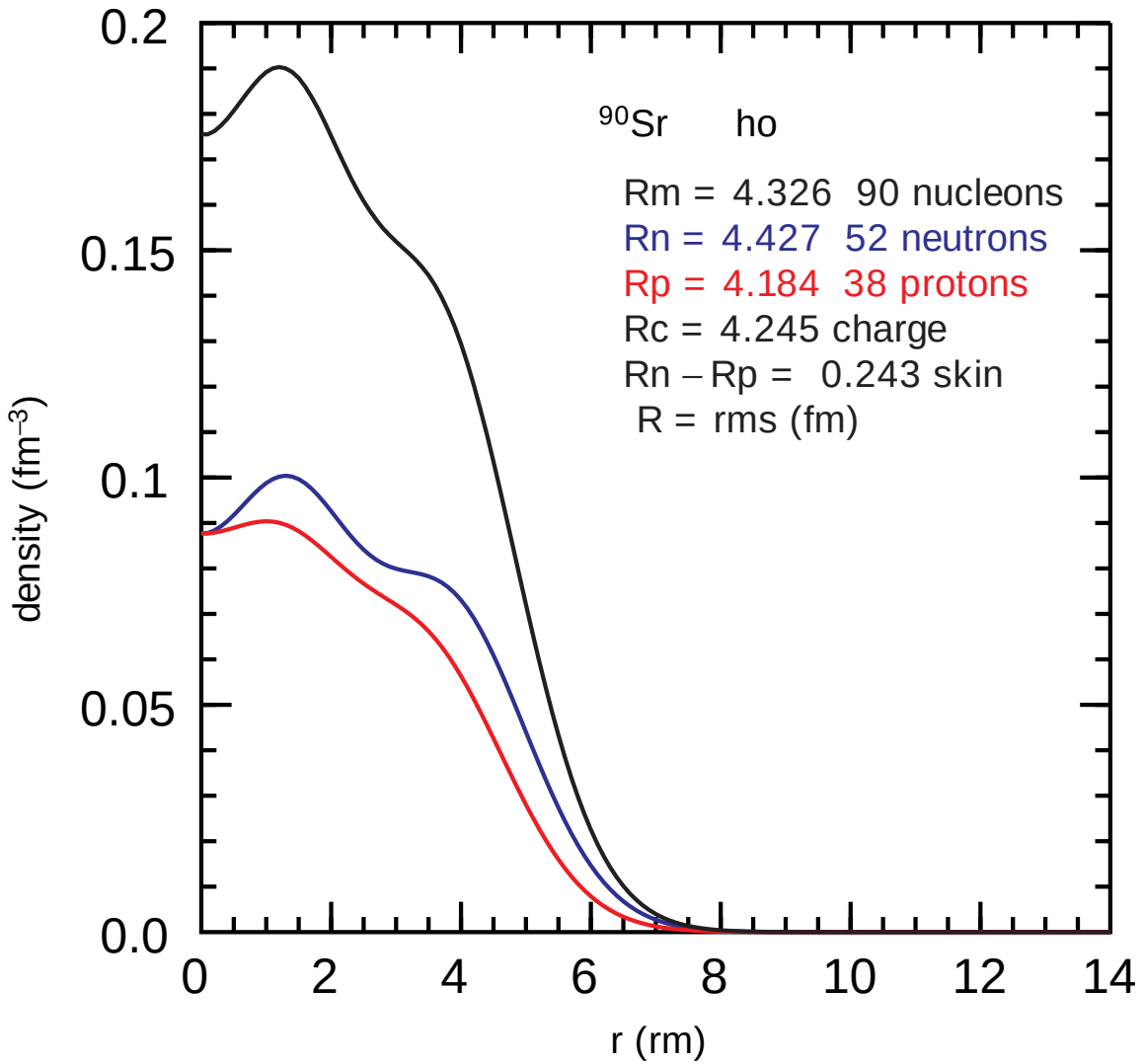
[2] B.A. Brown and W.D.M. Rae, Nuclear Data Sheets 120 (2014)

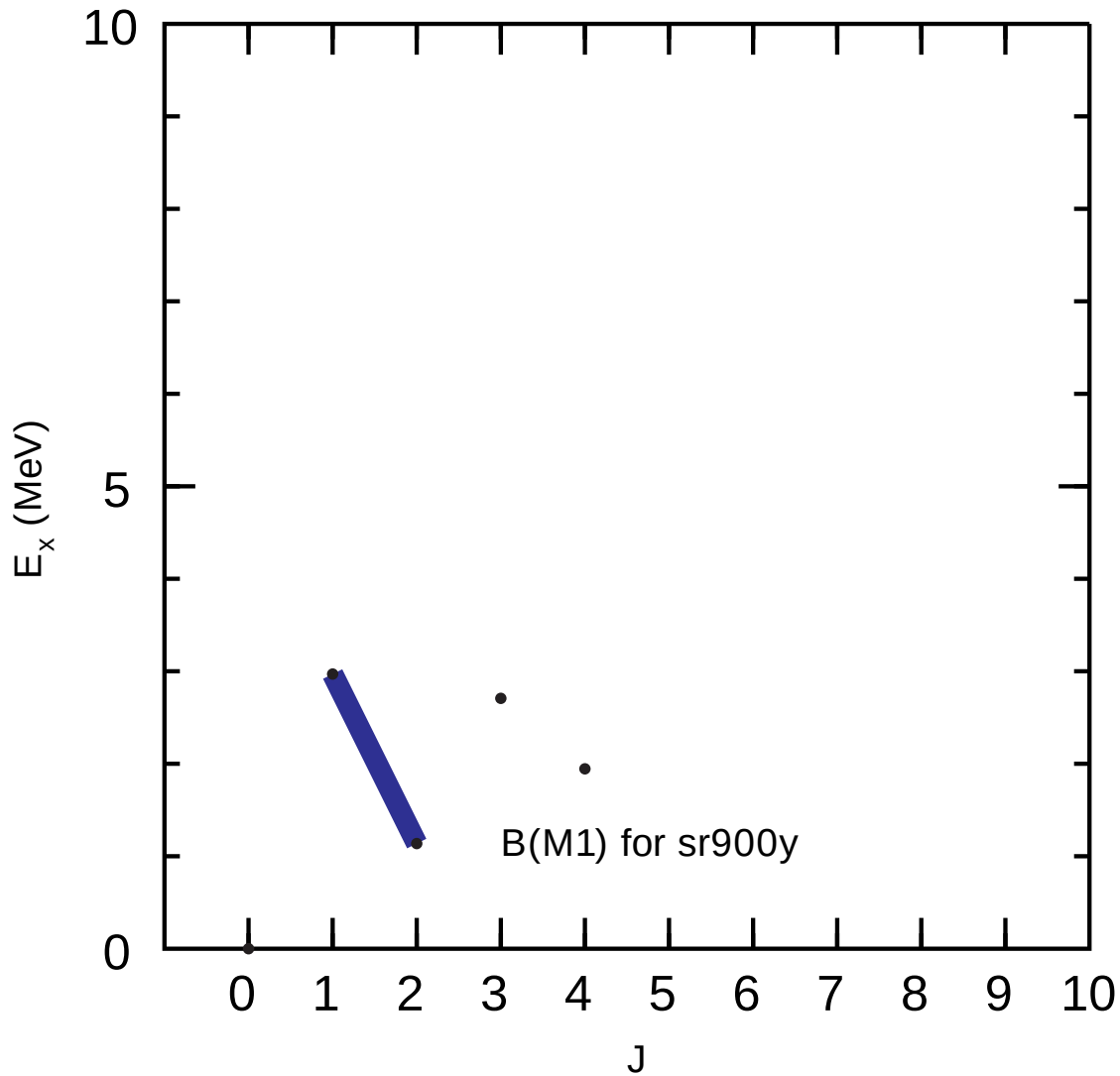
NuShellX@MSU code



NuShellX@MSU code



NuShellX@MSU code



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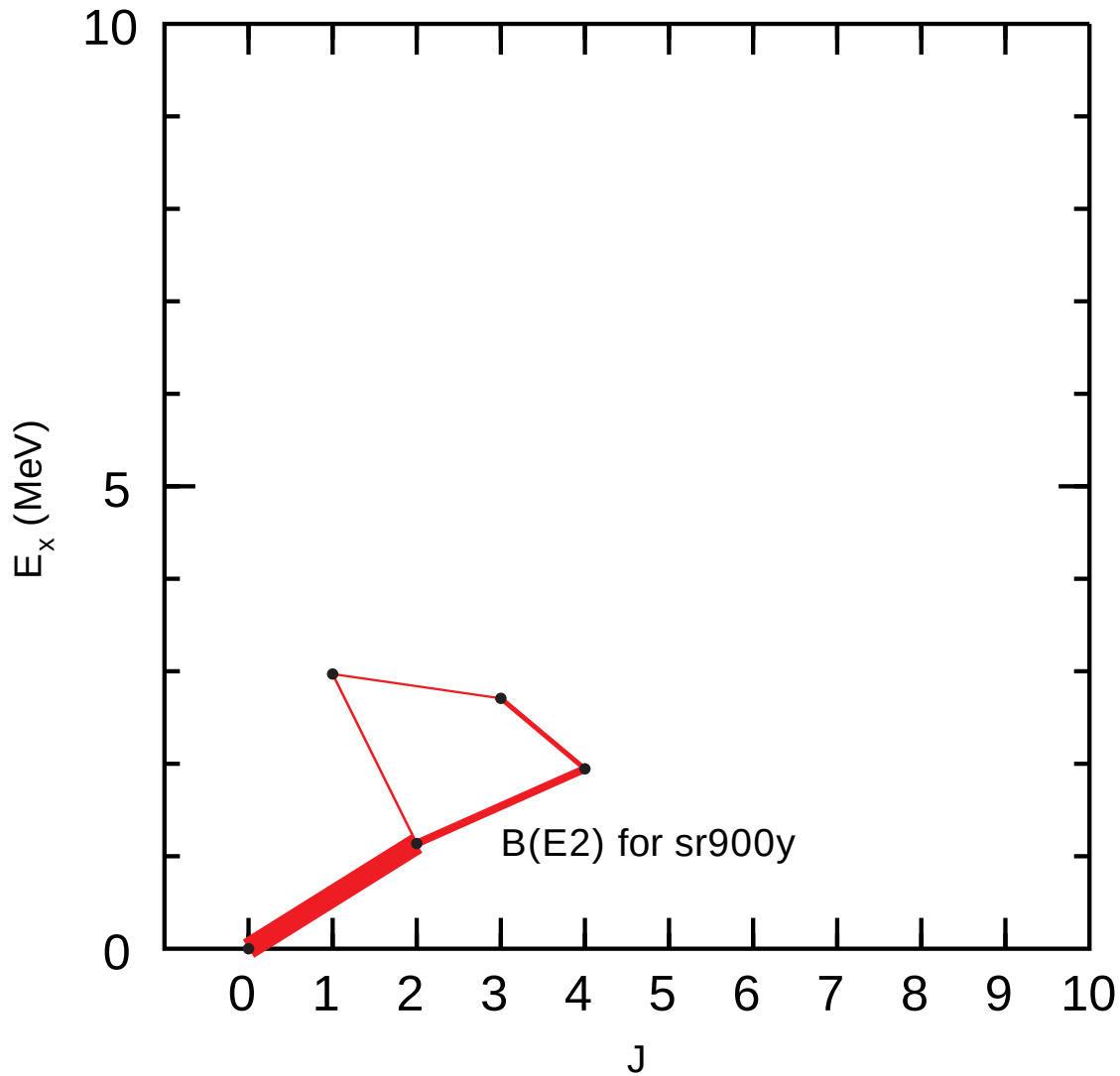


Calculation method

SPS

$\pi\{1f_{5/2}, 2p_{3/2}, 2p_{1/2} \quad and \quad 1g_{9/2}\}^{Z=28-50}$
$\nu\{1g_{7/2}, 2d_{5/2}, 2d_{3/2}, 3s_{1/2} \quad and \quad 1h_{11/2}\}^{N=50-82}$

SPE

For protons and neutrons, taken from experimental data and from Grawe 2007 [a]

[a] H. Grawe, K. Langanke and G Martinez-Pinedo, Rep. Prog. Phys. 70, 1525, 2007

Calculation method

TBME

$$\langle j_\tau j_{\tau'} | V_{mkh} | j_\tau j_{\tau'} \rangle = \langle j_\tau j_{\tau'} | V_{kh5082} | j_\tau j_{\tau'} \rangle + \quad \textit{Monopole} \quad \textit{Term}$$

[a]

$$\langle j_\tau j_{\tau'} | V_{mkh78} | j_\tau j_{\tau'} \rangle = \langle j_\tau j_{\tau'} | V_{mkh} | j_\tau j_{\tau'} \rangle + \quad \textit{Region} \quad \textit{Transformation}$$

[b]

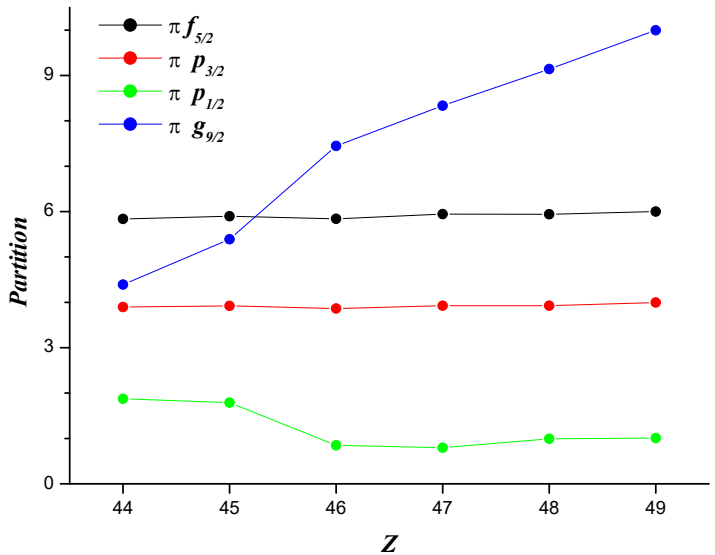
[a] Laouet and Benrachi, Cum. Sci. Jour. 37, 66 (2016)
[b] Chou and Warburton, Phys. Rev. C 45, 1720 (1992)

- $V_{\pi\pi} \longmapsto$ is taken from TBMEs
- $V_{\nu\nu} \longmapsto$ is taken from TBMEs
- $V_{\pi\nu} \longmapsto$ is taken from TBMEs

Application

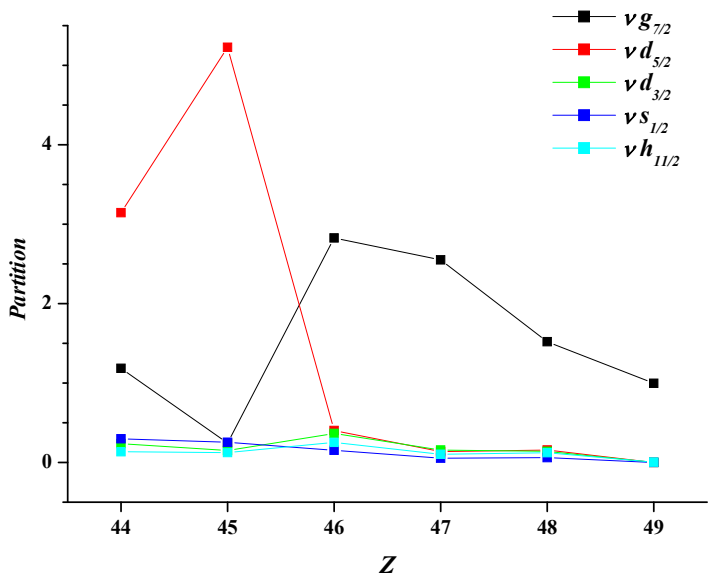
- Theory $\Leftrightarrow$ Nuclear Shell Model
- Inert Core $\Leftrightarrow$ ^{100}Sn
- Phenomenon $\Leftrightarrow$ Monopole effect for $\pi\pi$ and $\nu\nu$ and $\pi\nu$
- Nuclei $\Leftrightarrow$ $A = 100$ Isobars
- Investigated nuclei $\Leftrightarrow$ ^{100}Ru, ^{100}Rh, ^{100}Pd, ^{100}Ag, ^{100}Cd and ^{100}In
- Code $\Leftrightarrow$ NuShellX@MSU
- Calculation $\Leftrightarrow$ Energetic Spectra

Proton partition



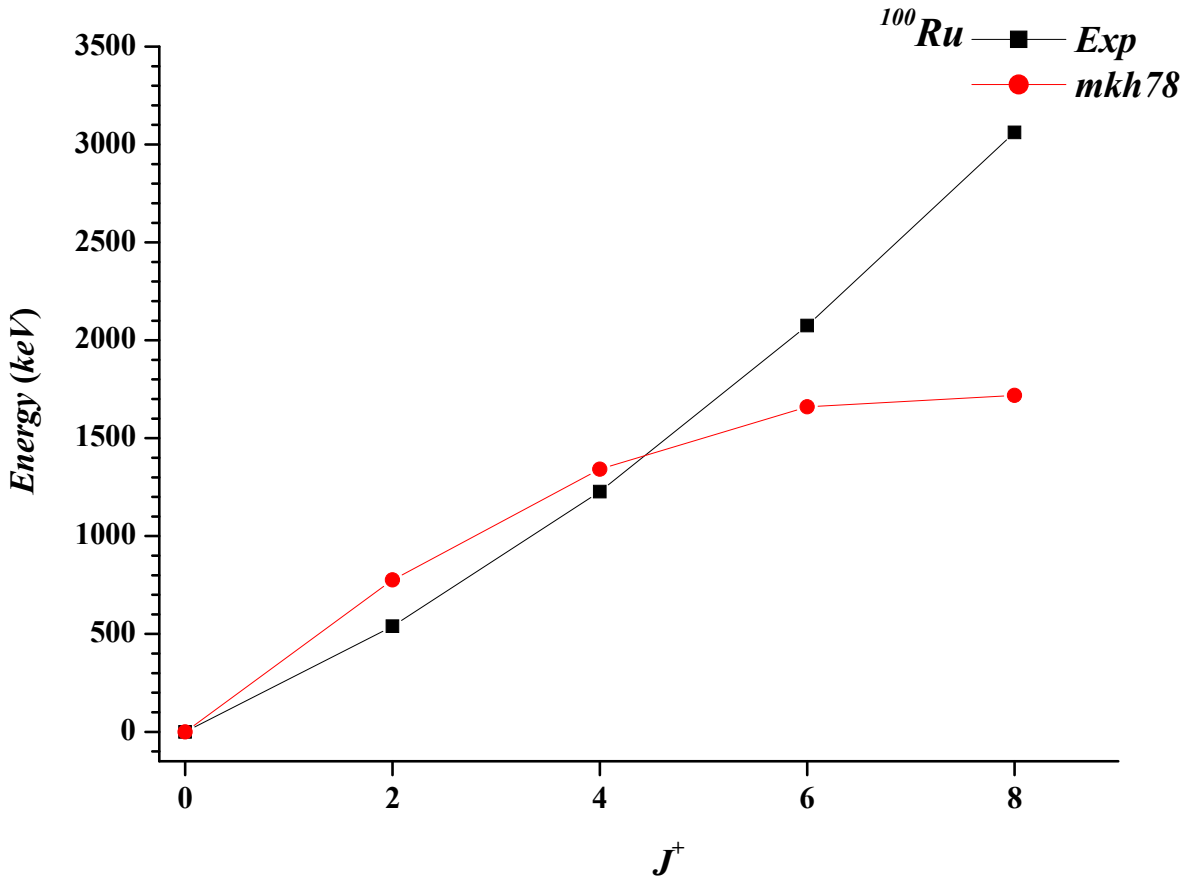
- Calculation carried out in the full proton space for ^{100}Pd, ^{100}Ag, ^{100}Cd and ^{100}In
  - $\pi f_{5/2}$, $\pi p_{3/2}$ and $\pi p_{1/2}$ partitions are almost constant
  - $\pi g_{9/2}$ partition increases with increasing proton number
  - $\Rightarrow$ Truncate proton space

Neutron partition

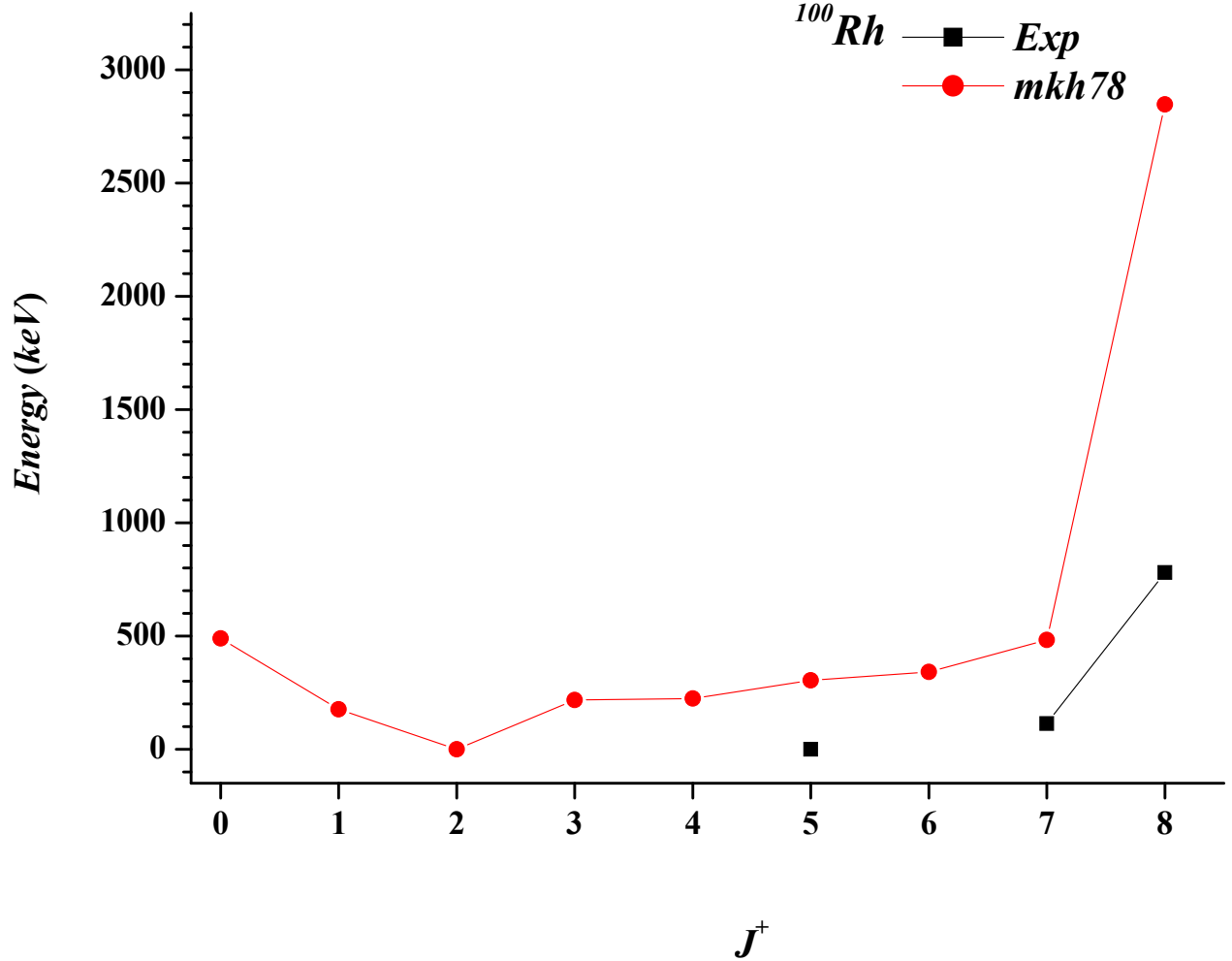


- Calculation carried out in the full neutron space for ^{100}Pd, ^{100}Ag, ^{100}Cd and ^{100}In
  - $\nu d_{3/2}$, $\nu s_{1/2}$ and $\nu h_{11/2}$ partitions are almost constant
  - $\nu g_{7/2}$ and $\nu d_{5/2}$ partition decrease with increasing neutron number
  - $\Rightarrow$ Truncate neutron space

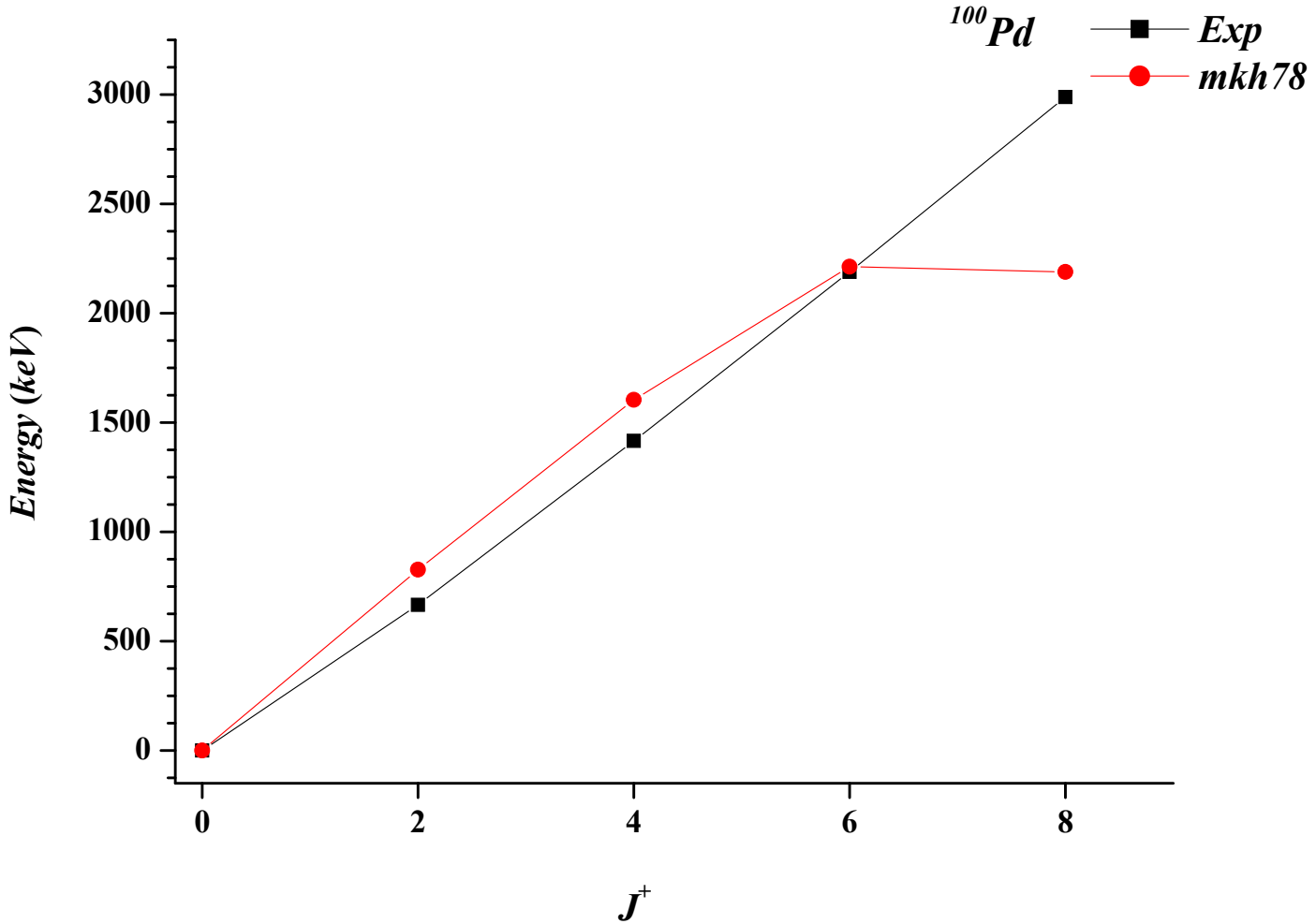
Energy spectra



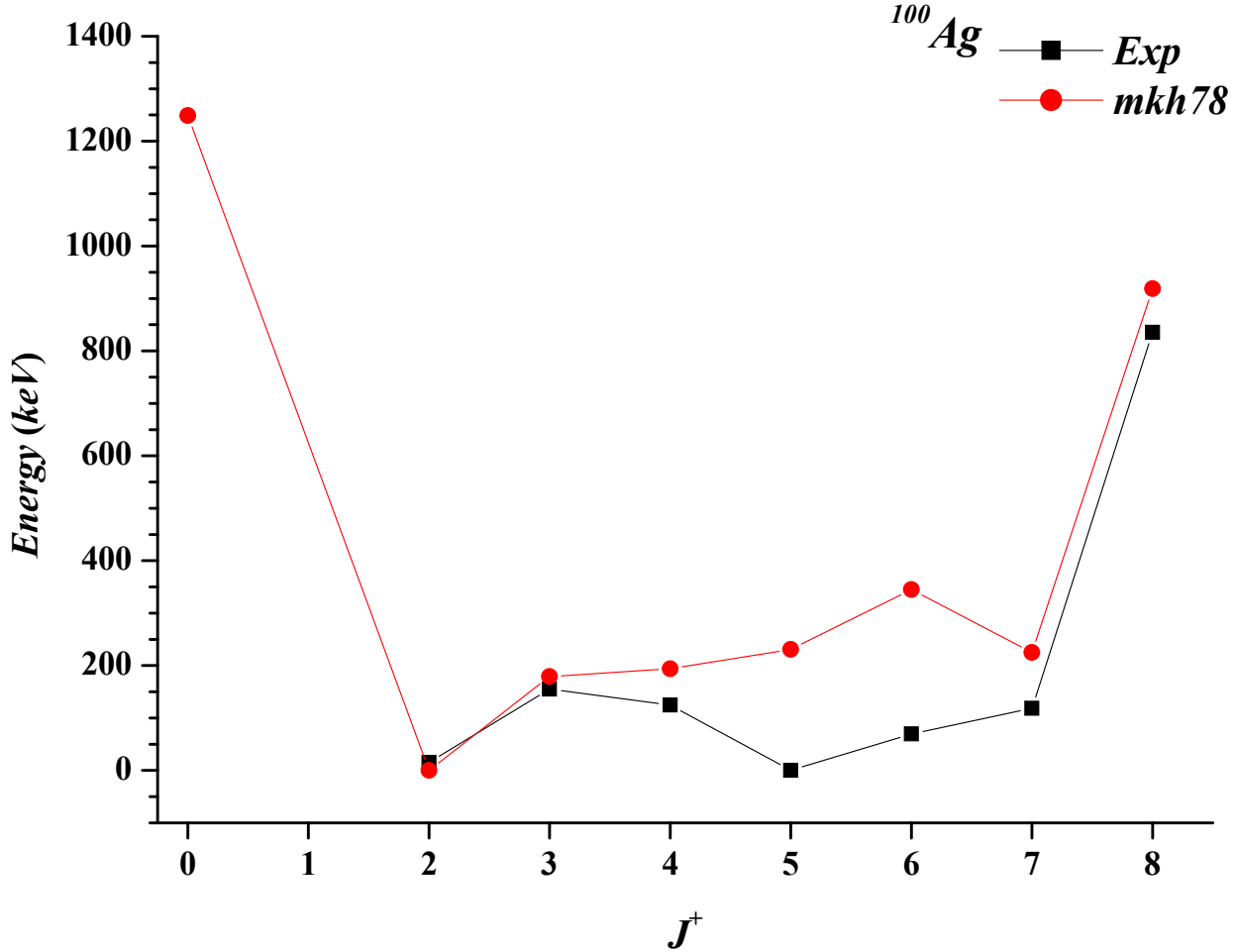
Energy spectra



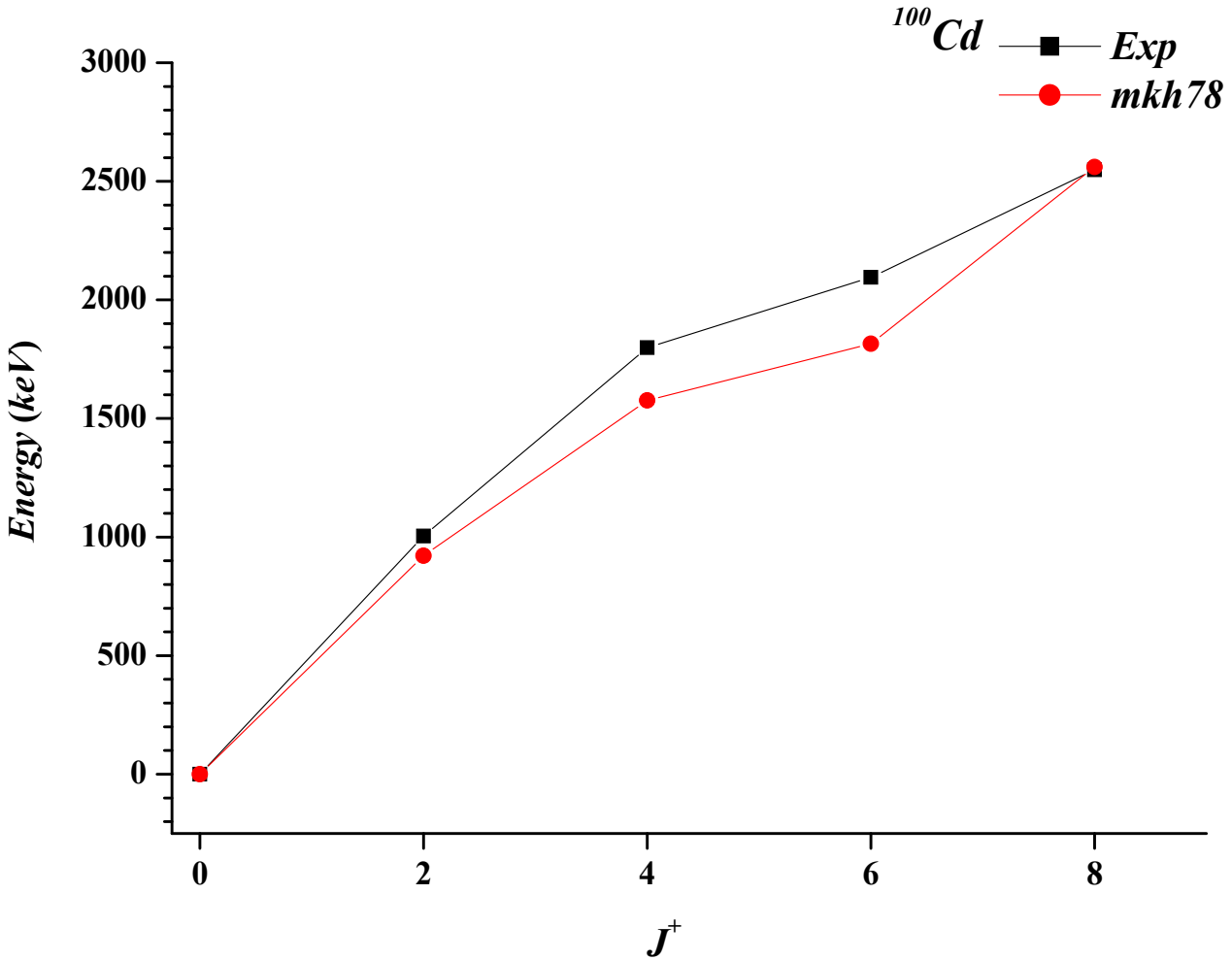
Energy spectra



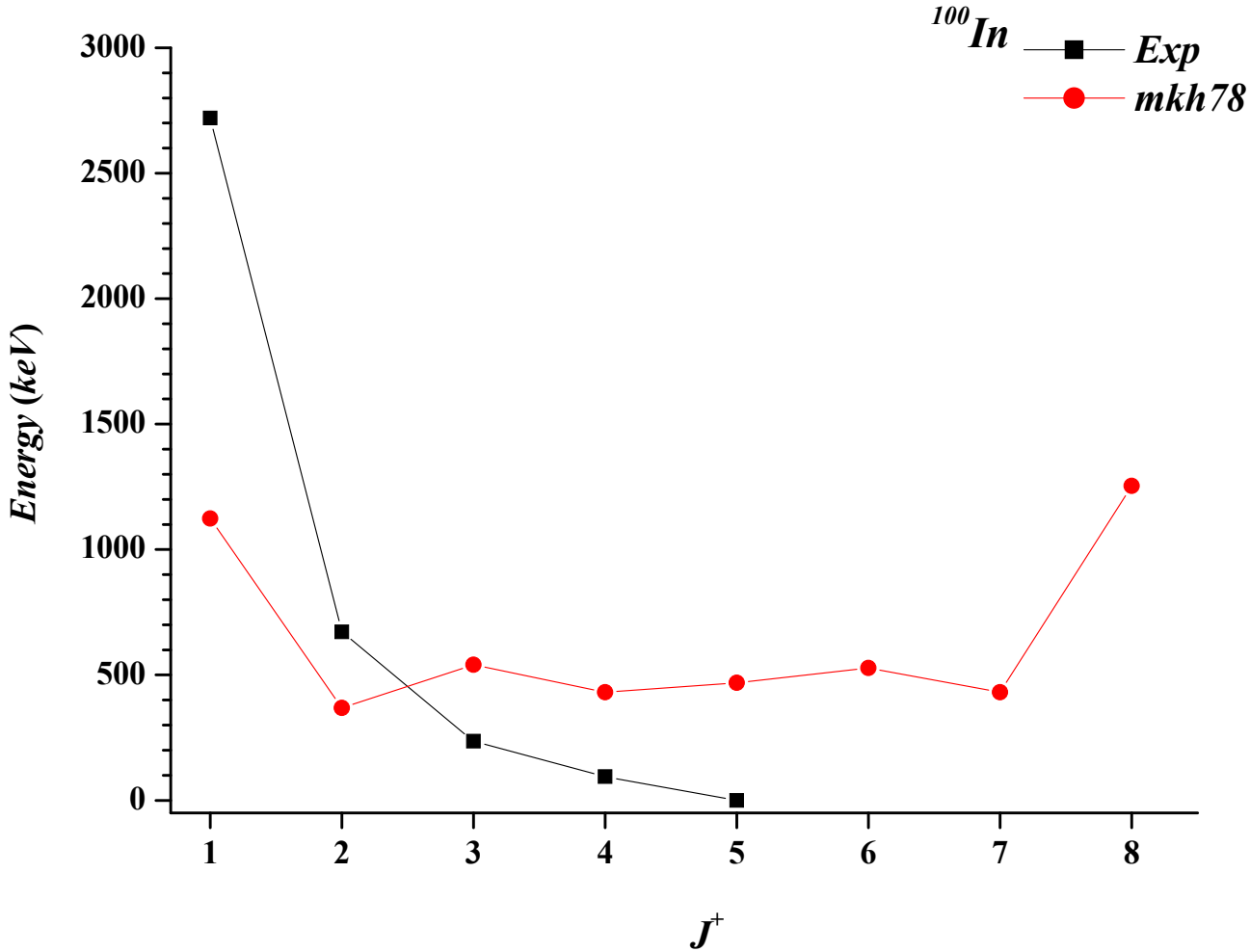
Energy spectra



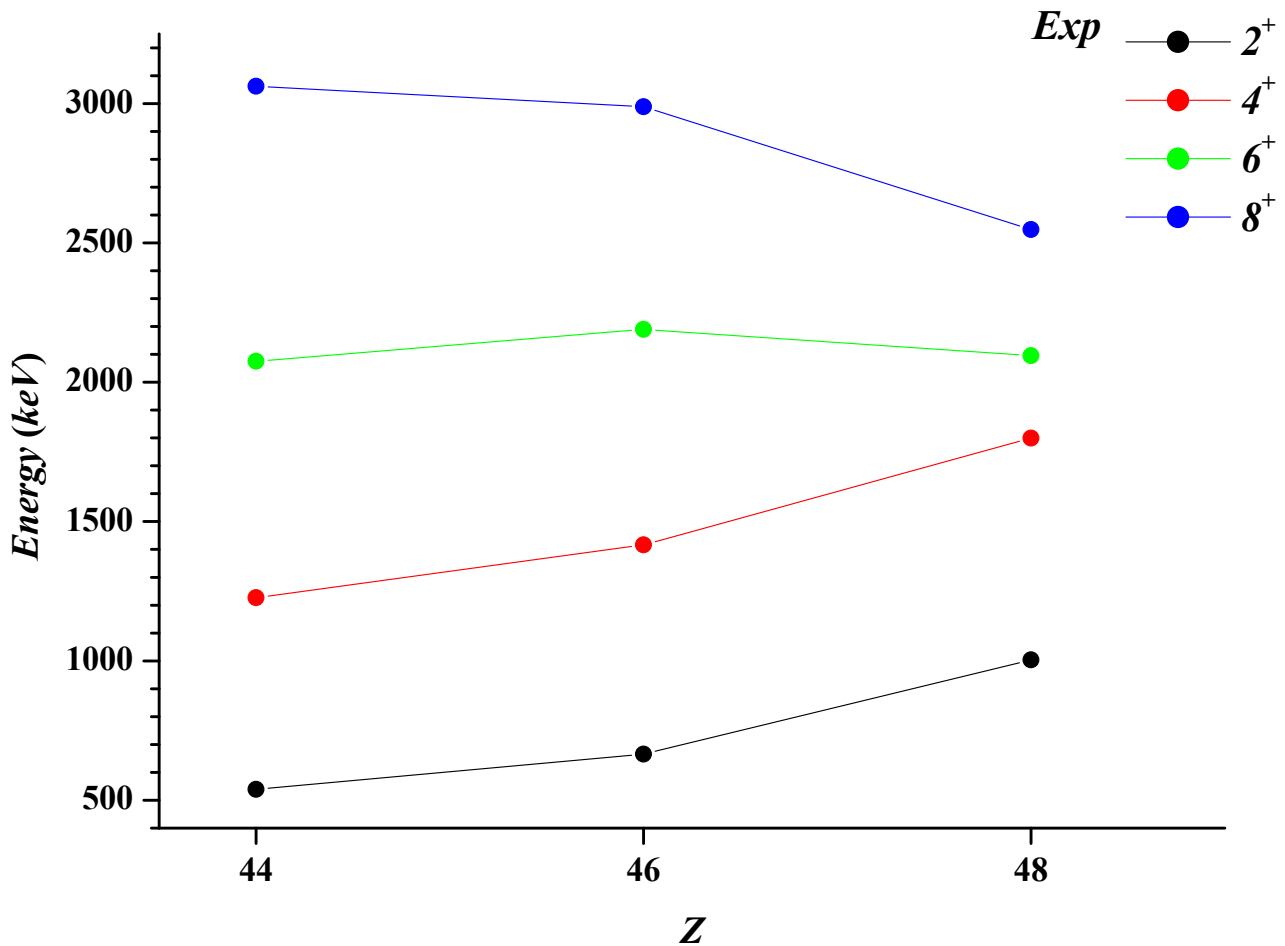
Energy spectra



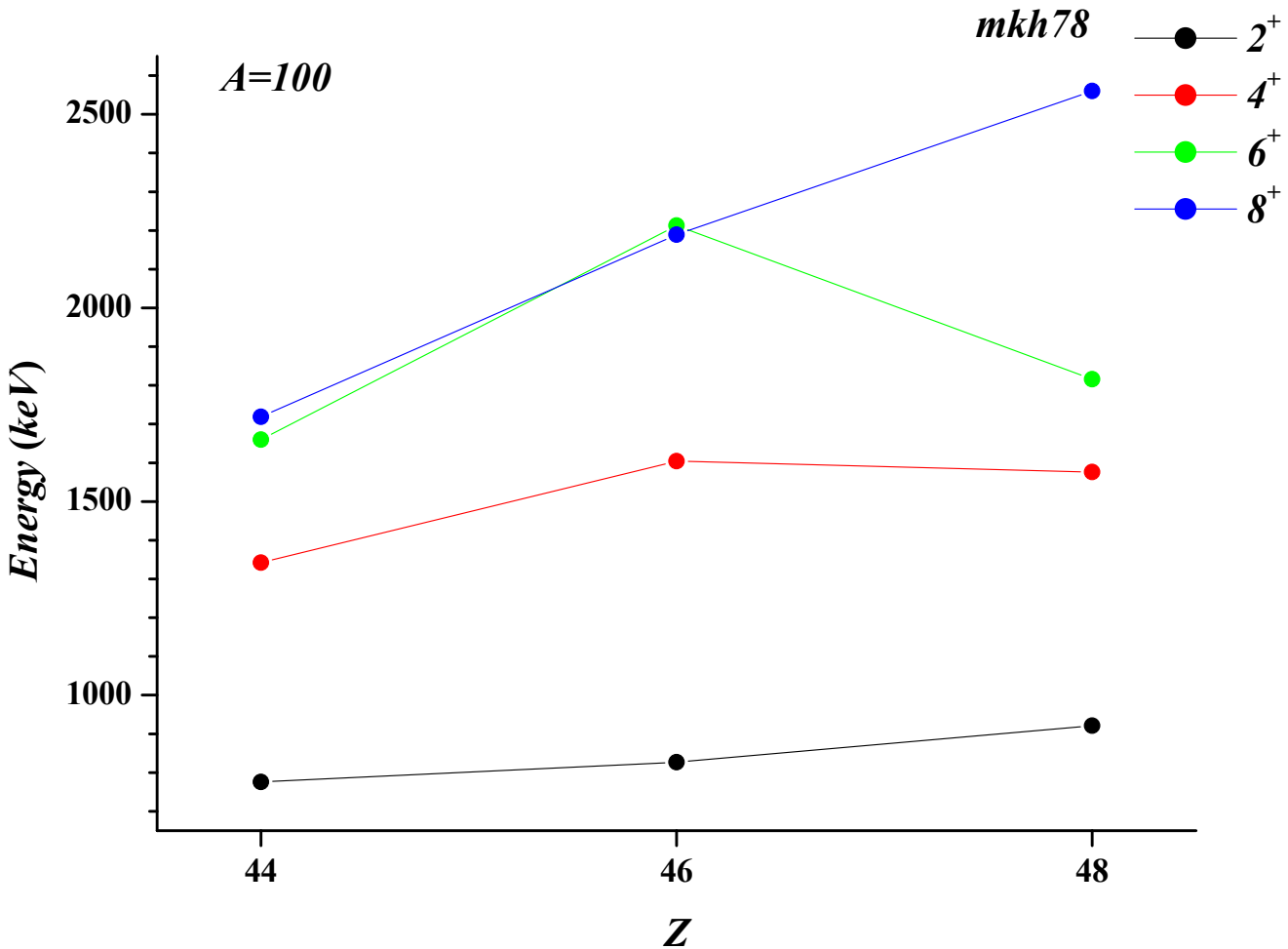
Energy spectra



Discussion



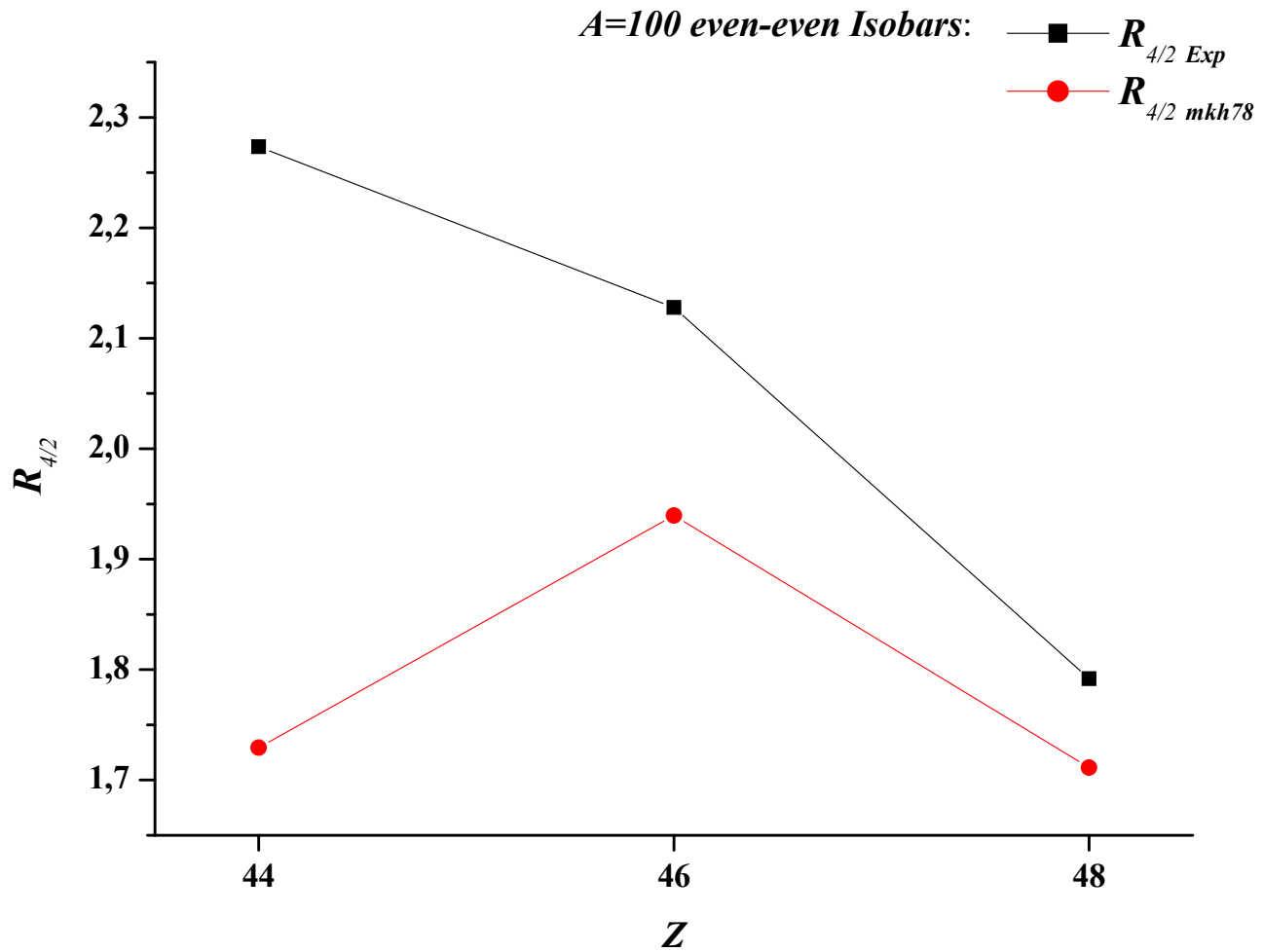
Discussion



Discussion

- The experimental energy systematics and the *calculated* ones show close behaviours.
- The calculated spectra are close to the experimental ones.

Discussion


A=100 even-even Isobars:
R 4/2 Exp
R 4/2 mkh78
R4/2
2,3
2,2
2,1
2,0
1,9
1,8
1,7
44
46
48
Z

Discussion

- The experimental and the calculated $R_{4/2}$ give values in the same range for ^{100}Pd and ^{100}Cd.
- Both factors are in the range 2-2.3.
- Character close to a pure harmonic vibrator is observed for ^{100}Pd and ^{100}Cd isobars.
- Calculated $R_{4/2}$ ratio for ^{100}Ru is less then 2 [2].

[2] Heyde, Basic ideas and concepts on nuclear physics-An introductory approach,2nd edition, IOP Puplishing Ltd, 1999.

Conclusion

- This work is based on the energetic spectra calculations, for A=100 nuclei.
- The calculations are realized in the framework of the nuclear shell model, by means of NuShellX@MSU nuclear structure code.
- Using the mkh original interaction elaborated previously, we carried out some modifications based on the region transformation to get mkh78 one.
- All the calculated spin and parity of the studied nuclei are in agreement with the experimental ones.
- The excited states calculated using the elaborated interaction are close to the available experimental data and spectra show the same behaviour.

Conclusion

- The studied even-even isobars have a behaviour close to pure vibrator.
- Fact reproduced by the new interaction for ^{100}Pd and ^{100}Cd.
- $R_{4/2}$ is underestimated for ^{100}Ru.

شكرا على حسن الإصغاء

İlginiz için teşekkür ederiz

Thank you for your listening