Beyond-mean-field calculations of transfermium nuclei

Benjamin Bally

in collaboration with M. Bender

Colloque GANIL - 29/09/2021

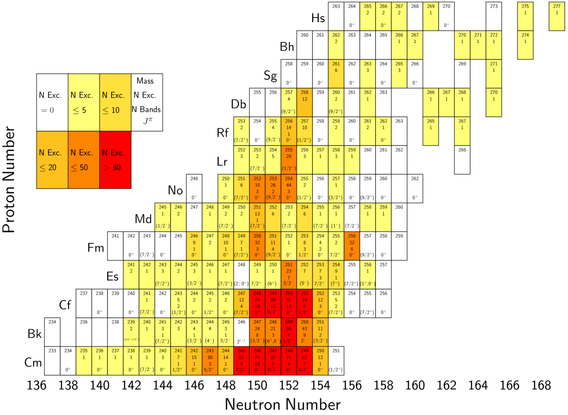
Universidad Autónoma de Madrid

Marie Skłodowska-Curie Actions

TAURUS (ID:839847)

Need for beyond-mean-field (BMF) calculations

- Great experimental progress
  - ◇ Spectroscopy possible
  - ◇ New facilities
- Need to improve the theory!
  - ◇ Effective interactions
  - ◇ BMF calculations → correlations



Theisen *et al.*, NPA 944, 388 (2015)

Recent experimental results on Nobelium isotopes

Universidad Autónoma de Madrid

- Electromagnetic moments (^{253}No) and differential charge radii

  Raeder *et al.*, PRL 120, 232503 (2018)

- Study of isomers for ^{254,255,256}No

  → talks by M. Forge and K. Kessaci

Theoretical model

- Variational method: $\delta \frac{\langle \Theta | H_{\text{phen}} | \Theta \rangle}{\langle \Theta | \Theta \rangle} = 0$

Theoretical model

Universidad Autónoma de Madrid

- Variational method: $\delta \frac{\langle \Theta | H_{\text{phen}} | \Theta \rangle}{\langle \Theta | \Theta \rangle} = 0$

- Mean-field step: minimization under constraints $\rightarrow \{|\Phi_i\rangle\}$
  example of constraints: deformation (β, γ), rotational frequency (ω), ...

Theoretical model

Universidad Autónoma de Madrid

- Variational method: $\delta \frac{\langle\Theta|H_{\text{phen}}|\Theta\rangle}{\langle\Theta|\Theta\rangle} = 0$

- Mean-field step: minimization under constraints $\rightarrow \{|\Phi_i\rangle\}$
  example of constraints: deformation (β,γ), rotational frequency (ω), ...

- Beyond-mean-field step: minimization for $|\Psi\rangle = \sum_{iK} f_{iK} P^J_{MK} P^N P^Z |\Phi_i\rangle$
  $\Rightarrow$ Projected Generator Coordinate Method (PGCM)

Theoretical model

- Variational method: $\delta \frac{\langle \Theta | H_{\text{phen}} | \Theta \rangle}{\langle \Theta | \Theta \rangle} = 0$

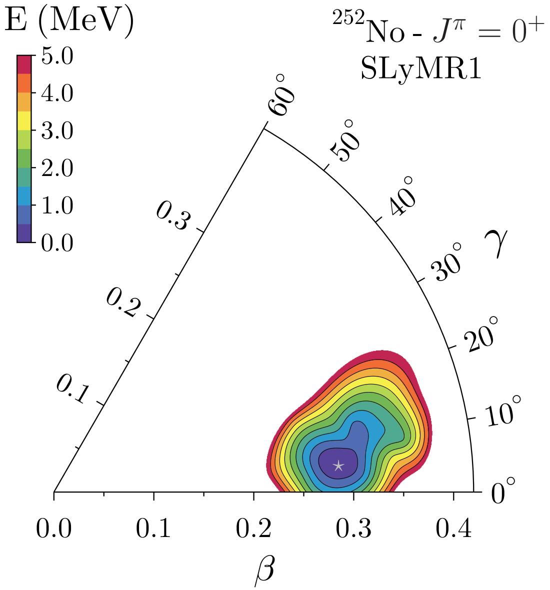
- Mean-field step: minimization under constraints $\rightarrow \{|\Phi_i\rangle\}$
  example of constraints: deformation (β, γ), rotational frequency (ω), ...

- Beyond-mean-field step: minimization for $|\Psi\rangle = \sum_{iK} f_{iK} P^J_{MK} P^N P^Z |\Phi_i\rangle$
  $\Rightarrow$ Projected Generator Coordinate Method (PGCM)

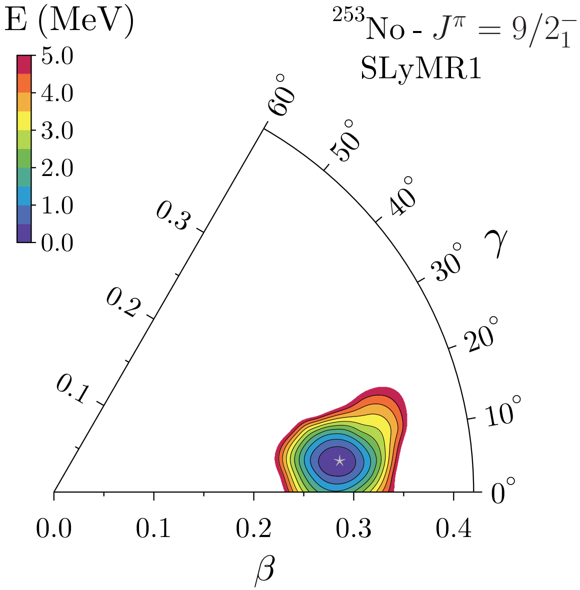
Advantages (of our implementation)

- Beyond-mean-field correlations
- Good quantum numbers (JM, N, Z, P)
- No-core calculations
- Triaxial deformations (β, γ)
- Cranking (ω)
- Skyrme parametrization: SLyMR1

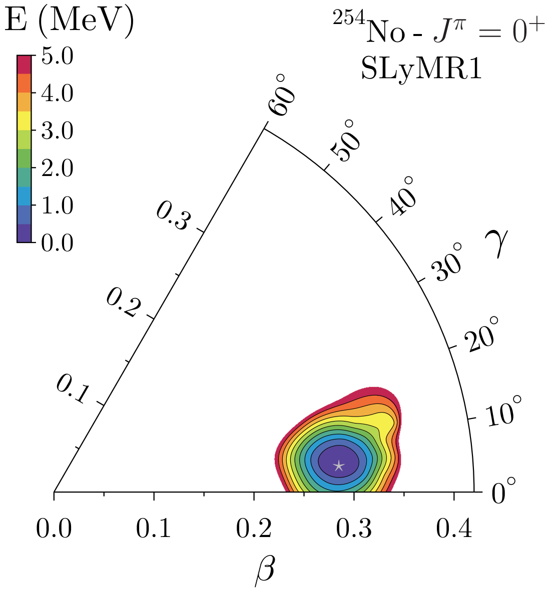
Triaxial energy (AMPNP) surface of ^{252}No



Triaxial energy (AMPNP) surface of ^{253}No



Triaxial energy (AMPNP) surface of ^{254}No



Ground state properties of ^{253}No

	J^π	E (MeV)	Q_s (eb)	μ (μ_N)
Experiment	$9/2^-$	-1877.885(7)	+5.9(1.4)(0.9)	-0.527(33)(75)
PGCM-SLyMR1	$9/2^-$	-1871.415	+7.0	-0.96

Raeder *et al.*, PRL 120, 232503 (2018)
AME2020, CPC 45, 030002 (2021)

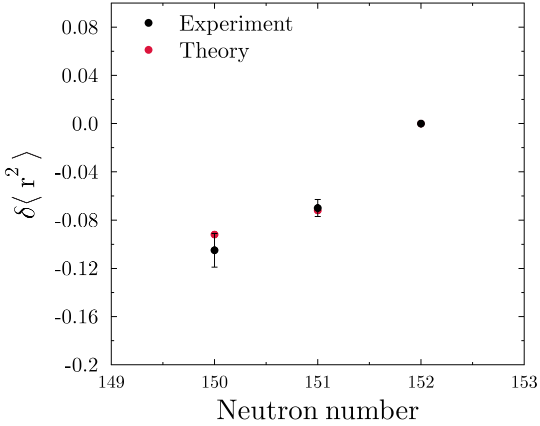
- PGCM(β, γ) with 15 states
- Good agreement (except the magnetic moment)

Difference of square charge radii for ^{252,253,254}No

Universidad Autónoma de Madrid

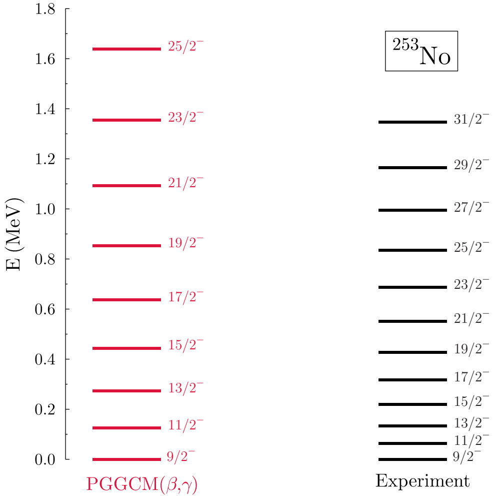
- Measurement of $\delta\langle r^2\rangle$ with respect to ^{254}No

Raeder *et al.*, PRL 120, 232503 (2018)



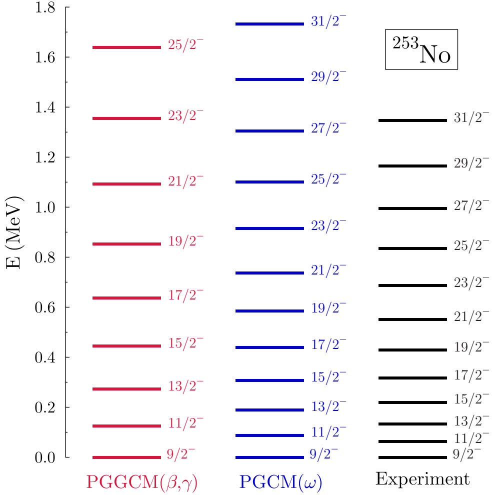
Ground-state rotational band of ^{253}No

◇ PGCM(β, γ) with 15 states



Improved moment of inertia

- Cranking: $\delta\langle\Phi|H_{\text{phen}} - \omega J_x|\Phi\rangle \longrightarrow$ PGCM(ω) with 7 states



Conclusion and outlook

Universidad Autónoma de Madrid

- Application of the PGCM method to very heavy nuclei
  - Spin-parity of low-lying states
  - Electromagnetic moments and transitions
  - Rotational bands
  - Isomers (e.g. for ^{254}No)

- Objectives
  - Calculations of ^{252,253,254,255}No
  - PGCM(β, γ, ω) → 1-2M CPU hours/nucleus

Collaborators

Universidad Autónoma de Madrid

T. R. Rodríguez
A. Sánchez-Fernández
J. Martínez-Larraz Torra
L. Robledo
A. Poves

Michigan State University

J. M. Yao
R. Wirth
H. Hergert

CEA

T. Duguet
M. Frosini
V. Somà
J.-P. Ebran
Y. Beaujeault-Taudière

The University of North Carolina at Chapel Hill

A. Márquez Romero
J. Engel

iP2i Les 2 Infinis Lyon

M. Bender
K. Bennaceur
J. Meyer

ULB

P.-H. Heenen
W. Ryssens

Technische Universität Darmstadt

A. Tichai

Axial energy (PNP) curve of ^{252}No

Universidad Autónoma de Madrid