LUND UNIVERSITY

Properties of rotational bands from symmetry breaking and restoration

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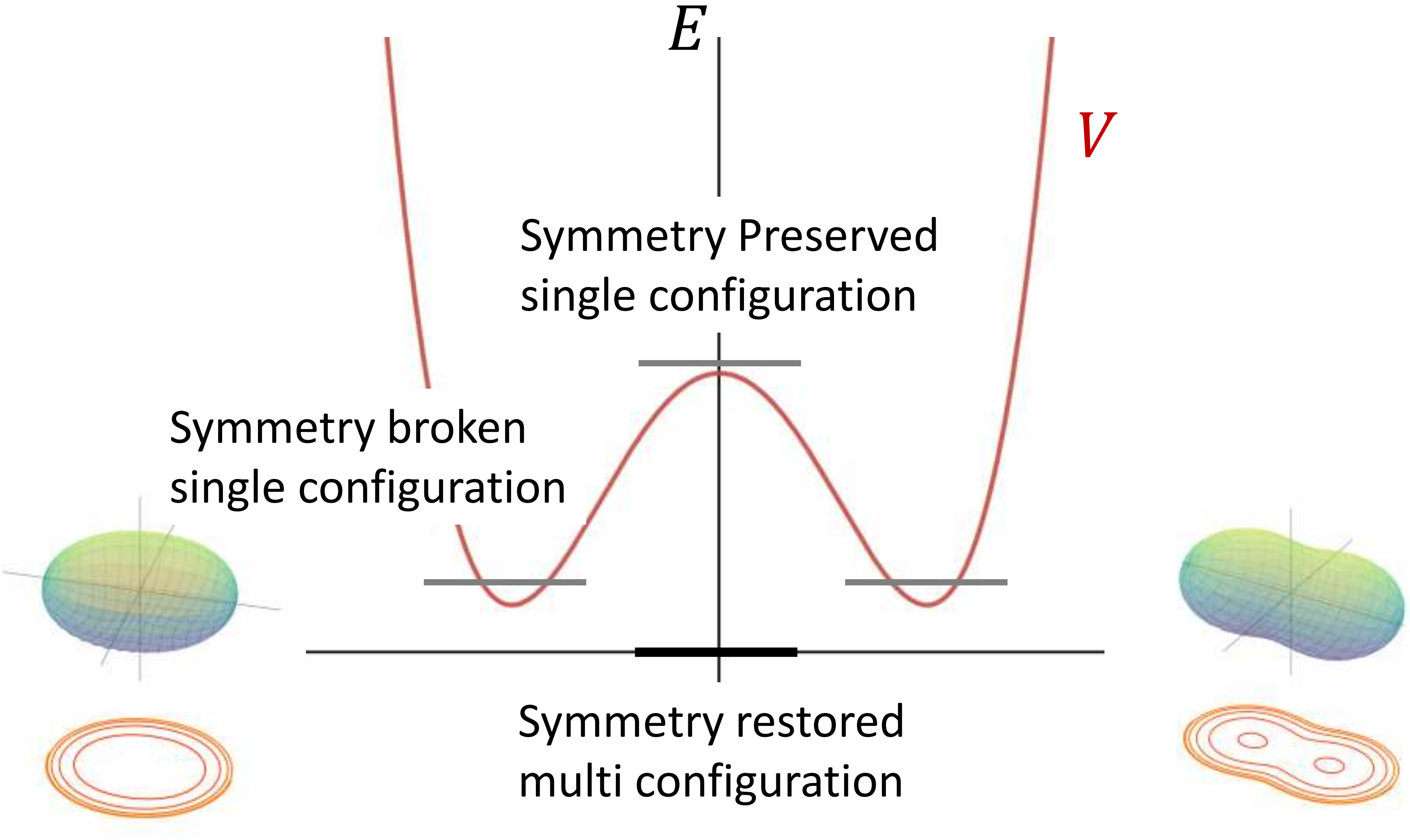
COMEX7

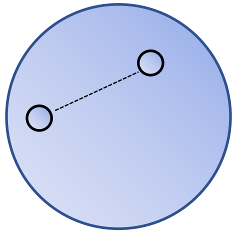
Catania, 12 June 2023

Symmetry Breaking



Nuclear Correlations

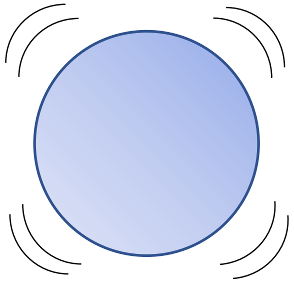
Pairing



Bogoliubov basis

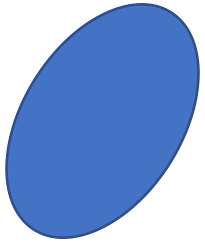
Particle number symmetry breaking

Vibrations



RPA

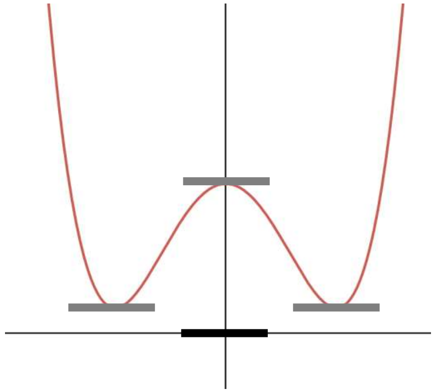
Rotations



Constrained variation

Dynamic and static deformation symmetry breaking

Projection to restore “good” symmetries of the Hamiltonian



Generator Coordinate Method

weight function

generating states

$$|\Psi\rangle = \int \mathrm{d}a\, f(a) |\Phi(a)\rangle$$

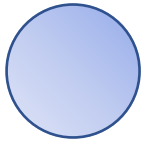
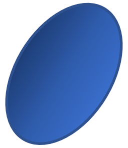
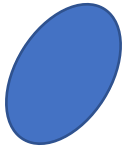
generator Coordinate

In our case

$$|\psi\rangle = \sum f(\cdot)|\Phi(\beta, \gamma, g_n, g_p, j_x)\rangle$$

Generating states as constrained HFB

Project to good number of particles and angular momentum

$$|\Psi\rangle = P^N P^Z P^I_{MK}(h_1|\Phi($$

$$)\rangle + h_2|\Phi($$

$$)\rangle + h_3|\Phi($$

$$)\rangle + \ldots)$$

Hill Wheeler Equation

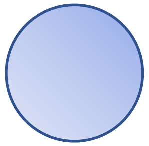
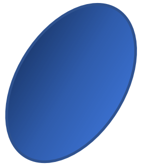
$$H|\psi_i\rangle = E_i|\psi_i\rangle$$ Schroedinger Equation

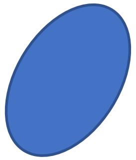
However, $|\psi_i\rangle$ are described in a non-orthogonal $|\Phi(\cdot)\rangle$

$$Hh = EOh$$

Hill-Wheeler $O_{IJ}^{KK'} = \left\langle \phi_I \left| \hat{P}^I_{KK'} \hat{P}_Z \hat{P}_N \right| \phi_J \right\rangle$

$$H_{IJ}^{KK'} = \left\langle \phi_I \left| \hat{H} \hat{P}^I_{KK'} \hat{P}_Z \hat{P}_N \right| \phi_J \right\rangle$$

$|\Psi(I)\rangle = \sum_{KM} P^N P^Z P^I_{MK} (h_1 |\Phi($  $)\rangle + h_2 |\Phi($  $)\rangle$

$+ h_3 |\Phi($  $)\rangle + \ldots)$

Construction of the effective Hamiltonian

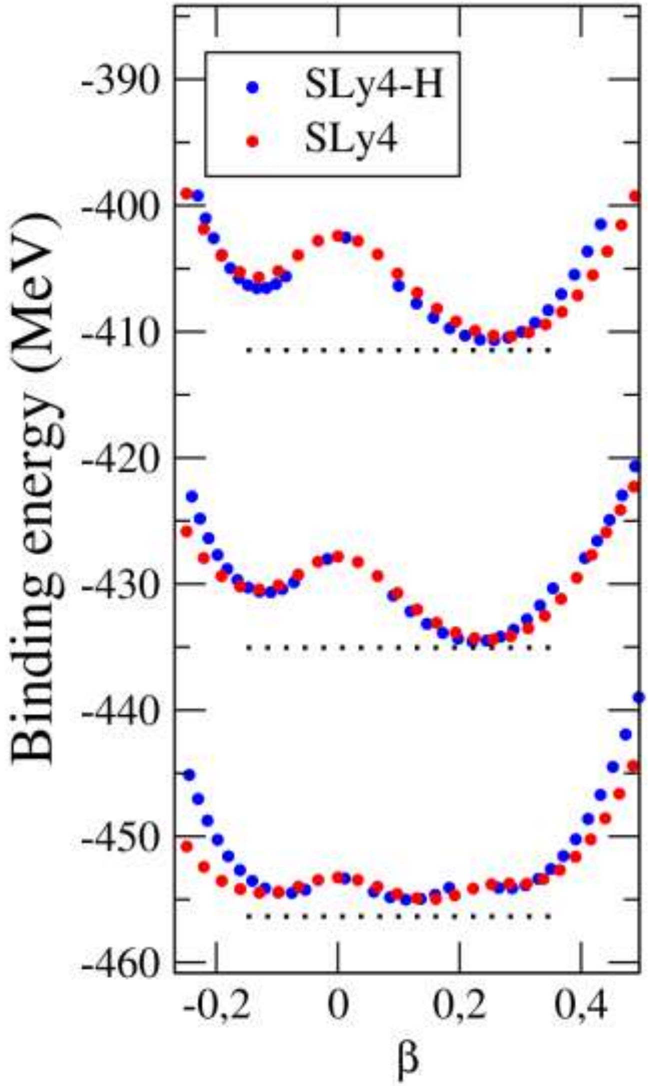
$$\hat{H} = \hat{H}_0 + \hat{H}_Q + \hat{H}_P$$

Single particle “mean field”

Quadrupole-Quadrupole

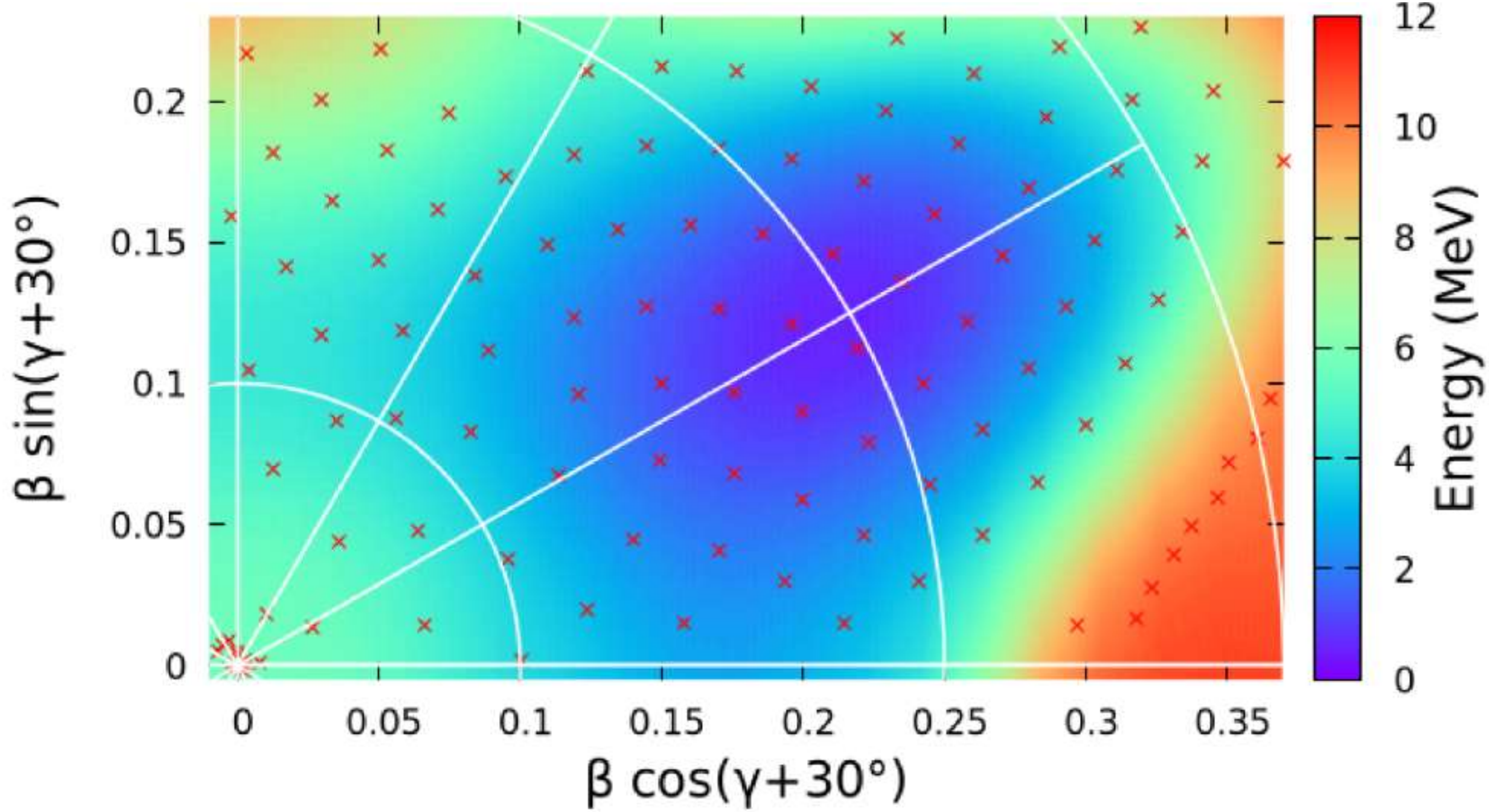
Seniority Pairing

$$H^{eff} = \sum_i \epsilon_i a_i^\dagger a_i - \frac{1}{4}\chi \sum_{\mu,ijkl} [Q_{ij}^{2\mu} Q_{kl}^{2\mu *} - Q_{ik}^{2\mu} Q_{jl}^{2\mu *}] a_i^\dagger a_j^\dagger a_k a_l + G \sum_{ijkl} P_{ij} P_{kl} a_i^\dagger a_j^\dagger a_k a_l$$



Construction of the basis states

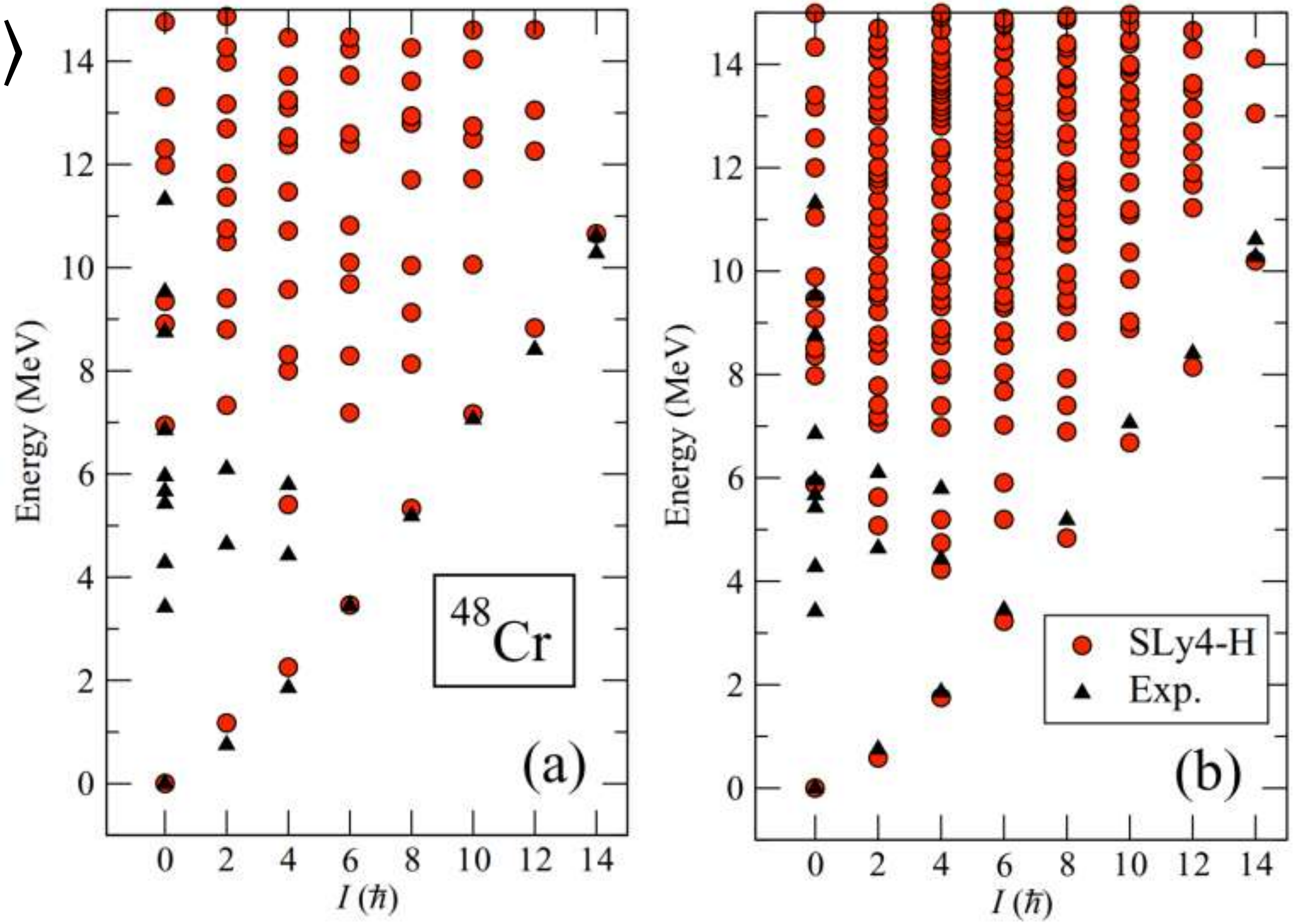
^{48}Cr SLy4-H, N_{max}=11



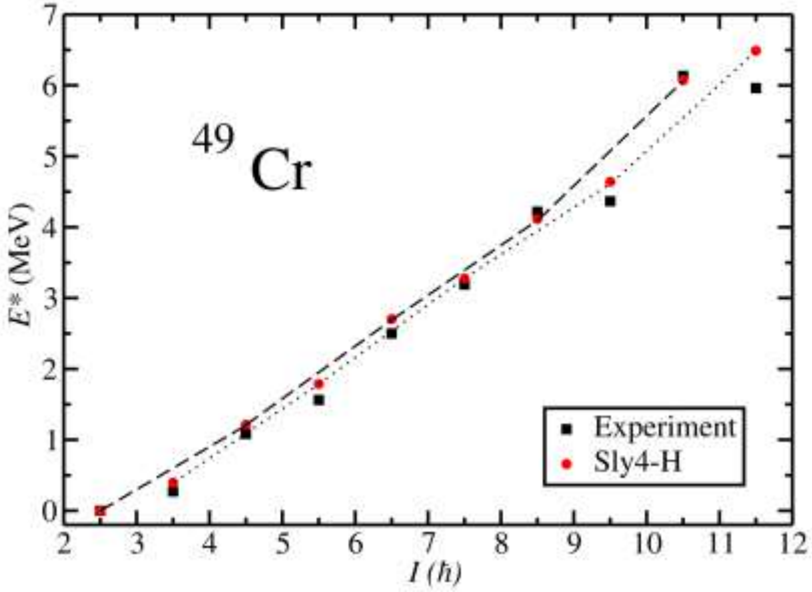
Excitation mixing

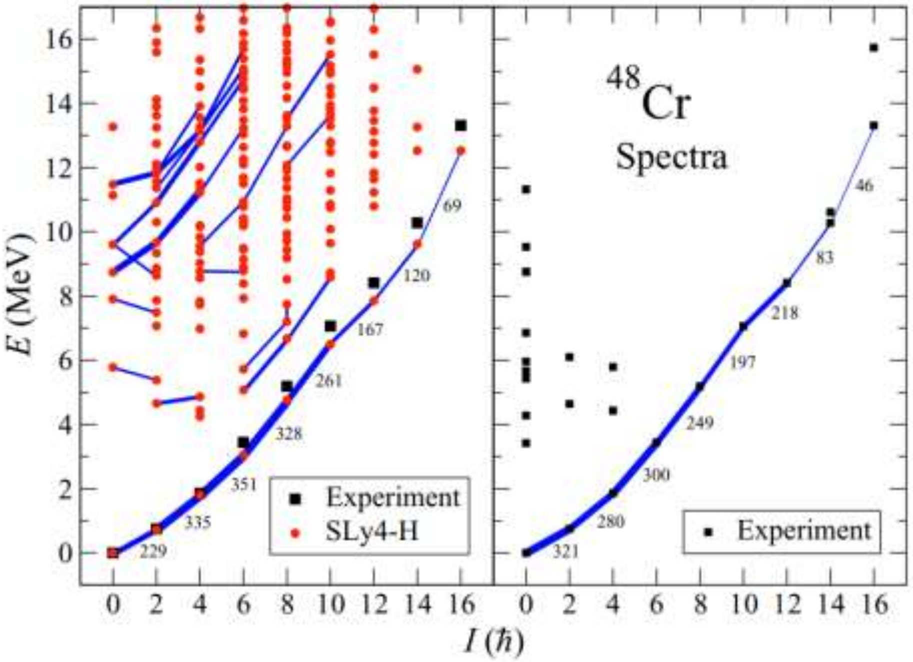
$$|\psi'(\cdot)\rangle = e^{\sum z\beta^+\beta^+}|\psi(\cdot)\rangle$$

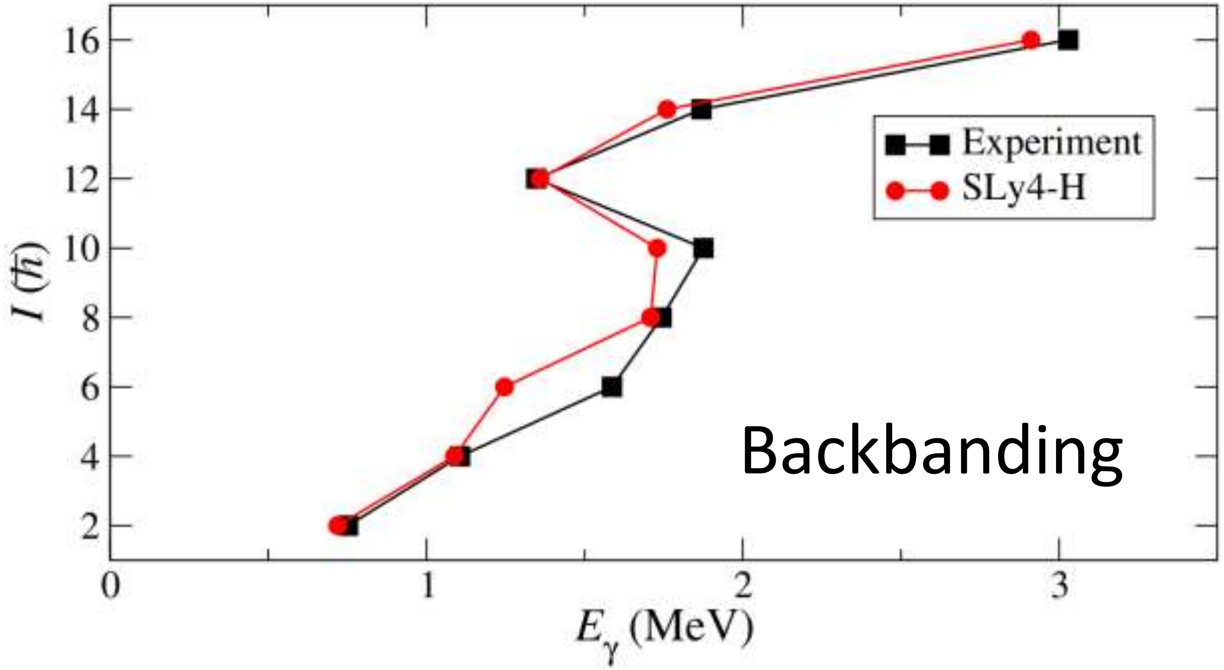
z "temperature like"
random coefficient



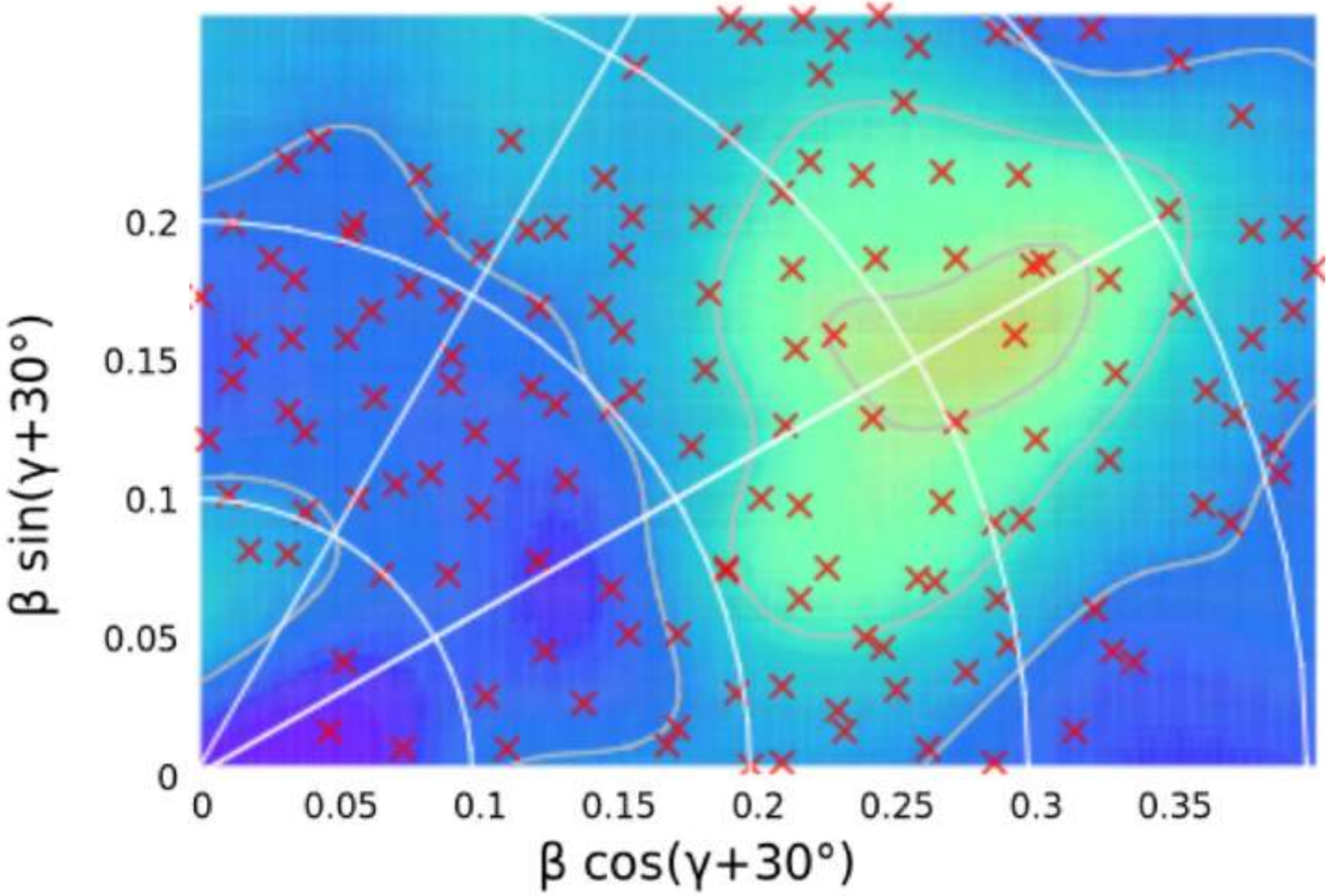
Results:
States and transitions

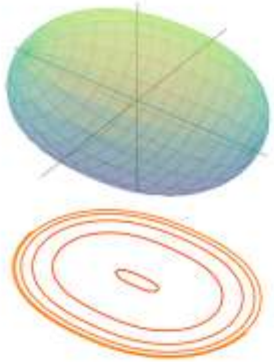




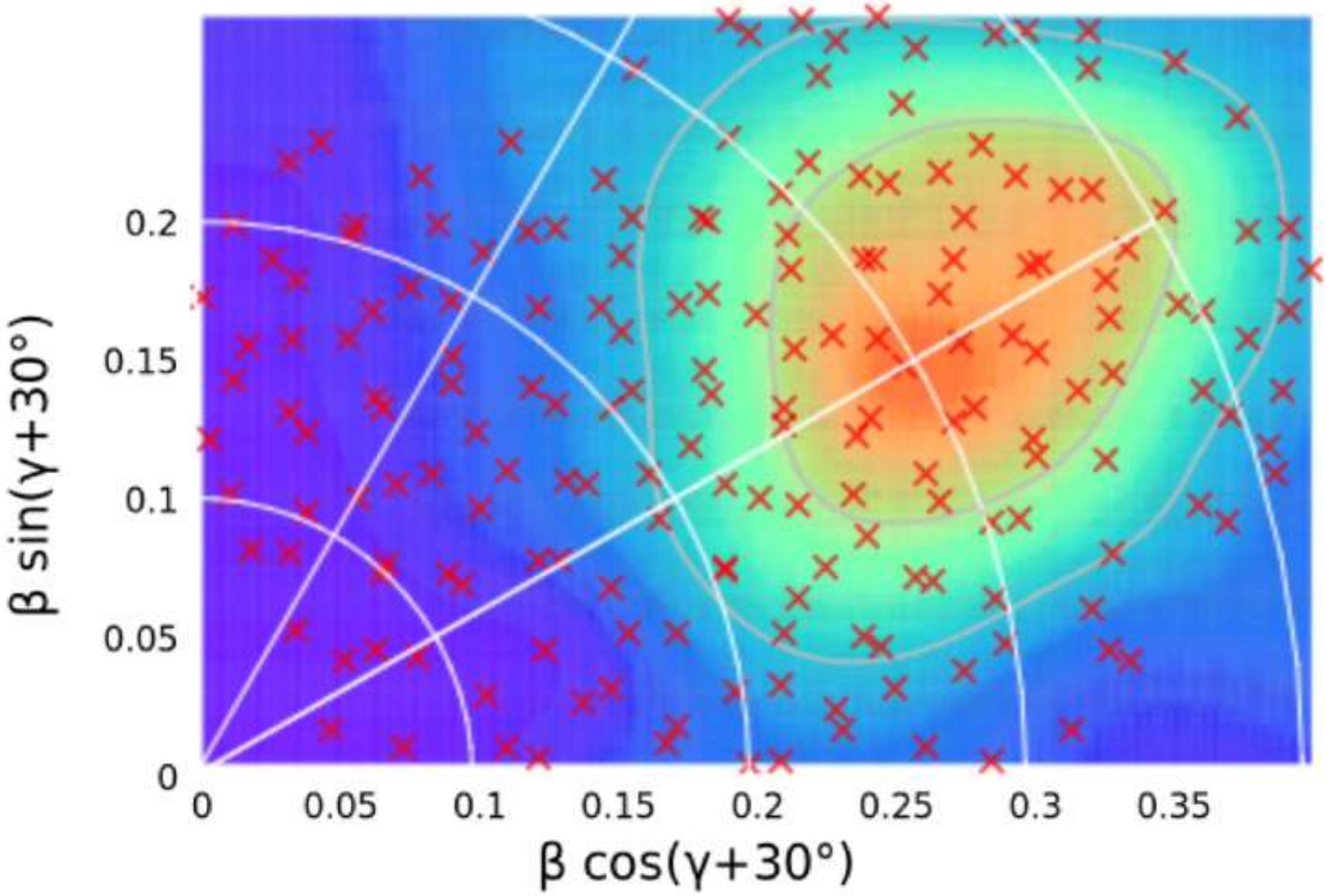


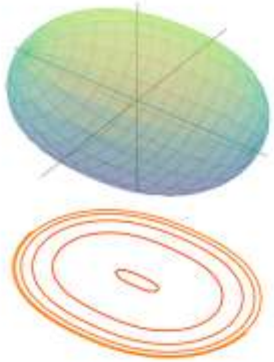
Amplitudes of HFB-states for ^{48}Cr; $I = 0$



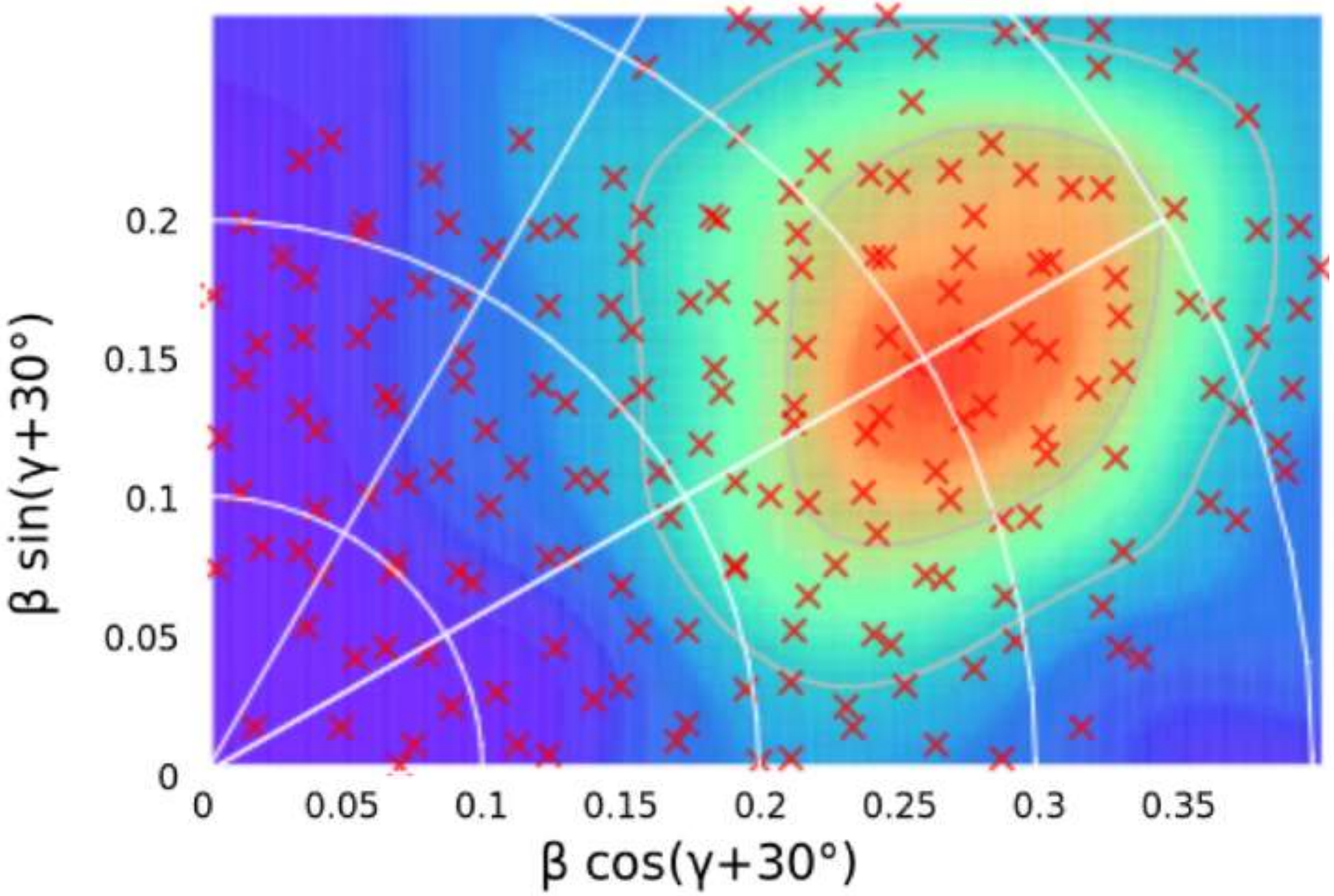


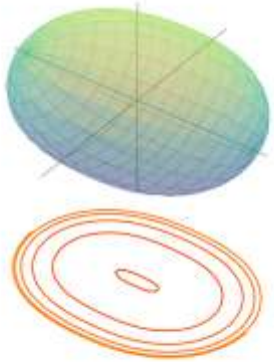
Amplitudes of HFB-states for ^{48}Cr; $I = 2$



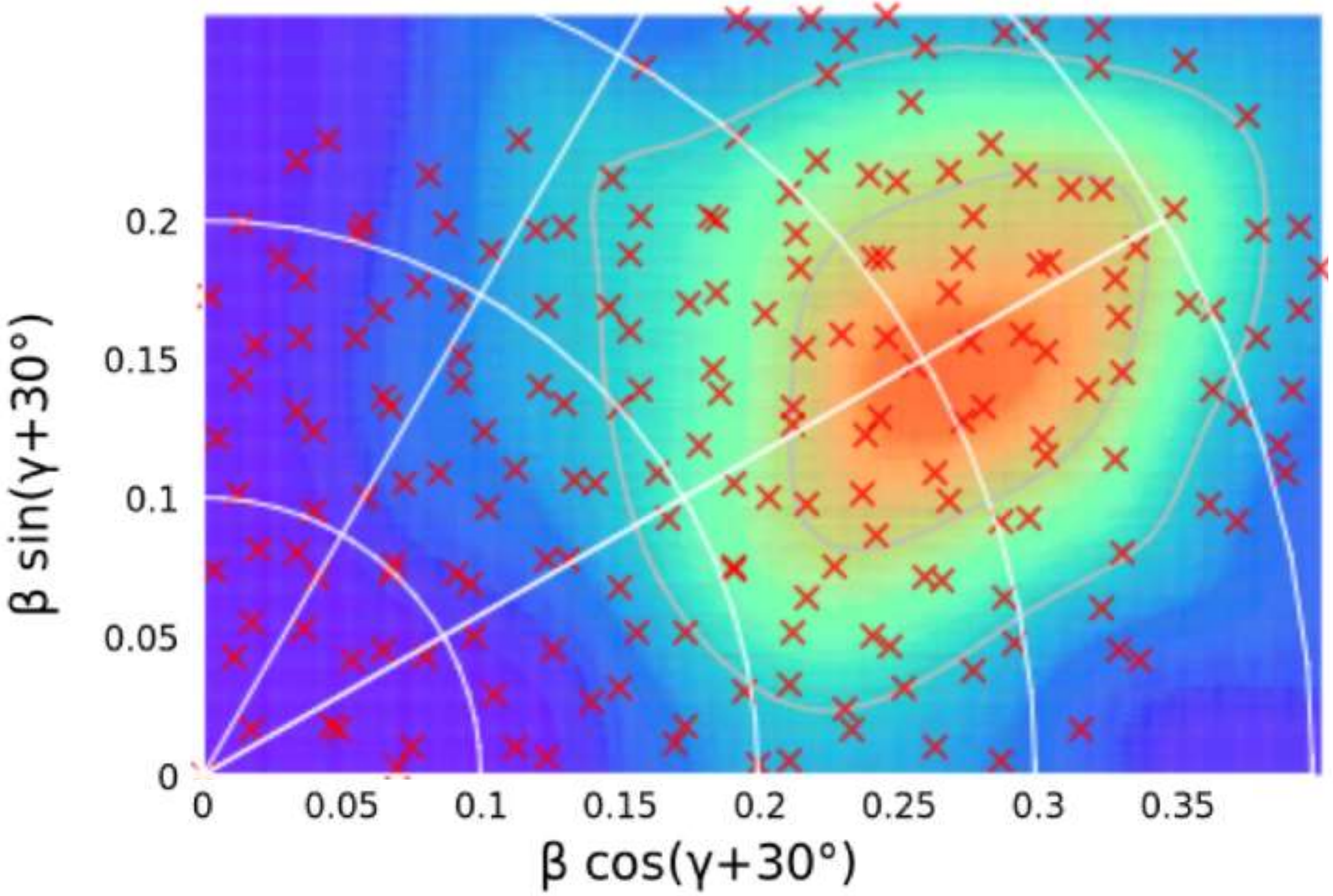


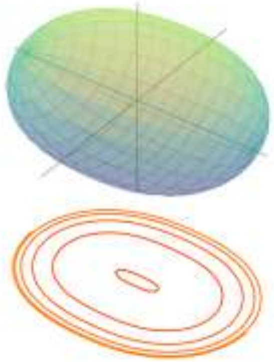
Amplitudes of HFB-states for ^{48}Cr; $I = 4$



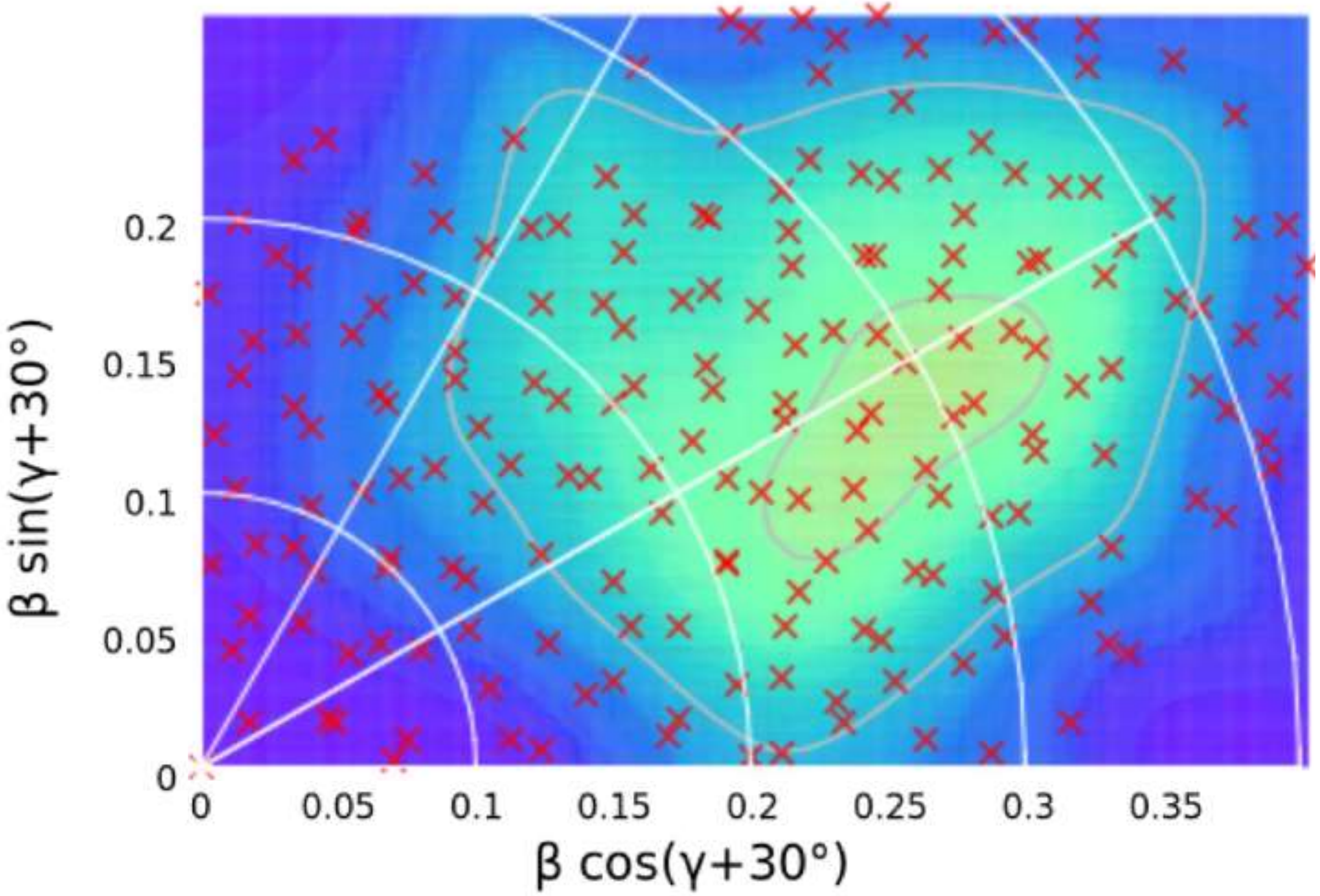


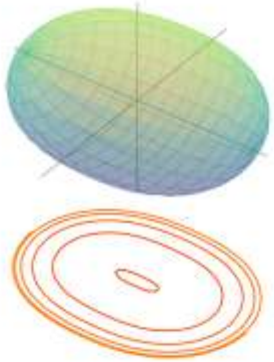
Amplitudes of HFB-states for ^{48}Cr; $I = 6$



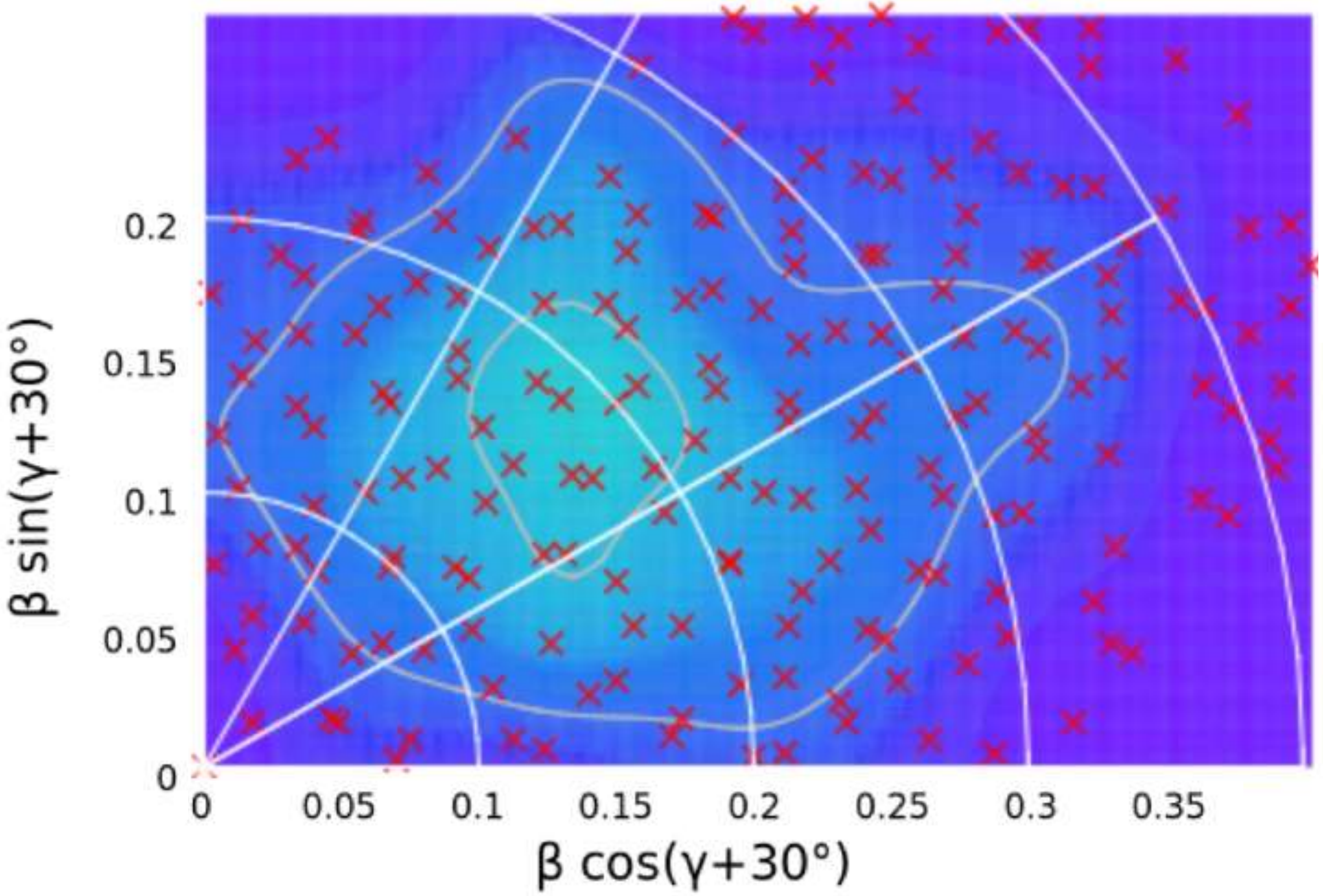


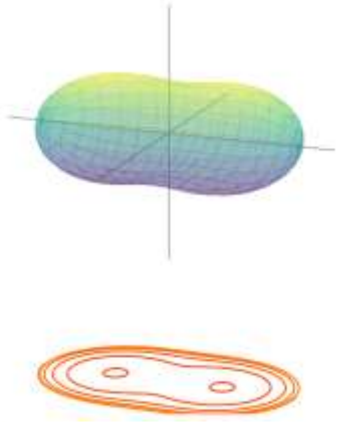
Amplitudes of HFB-states for ^{48}Cr; $I = 8$



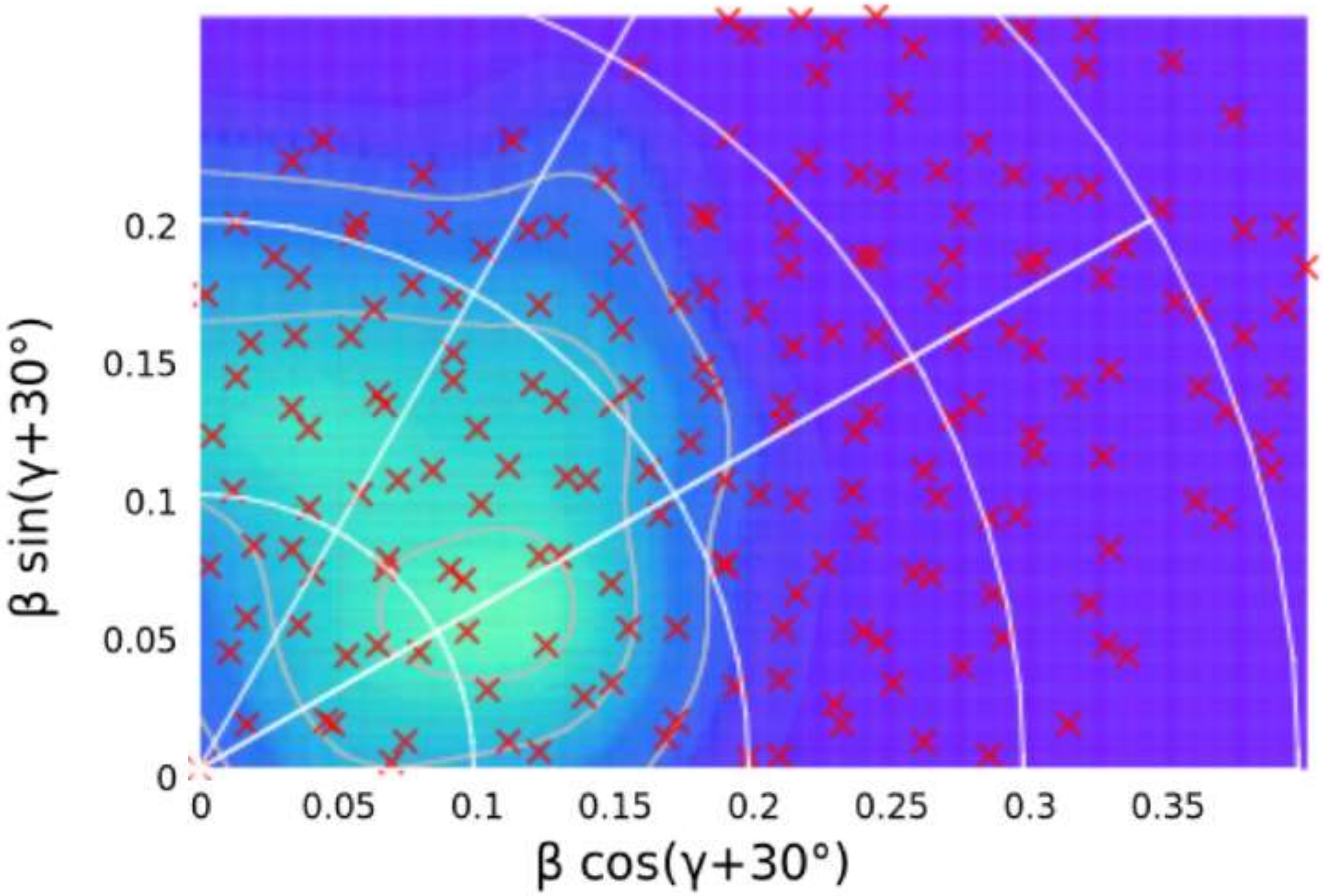


Amplitudes of HFB-states for ^{48}Cr; $I = 10$

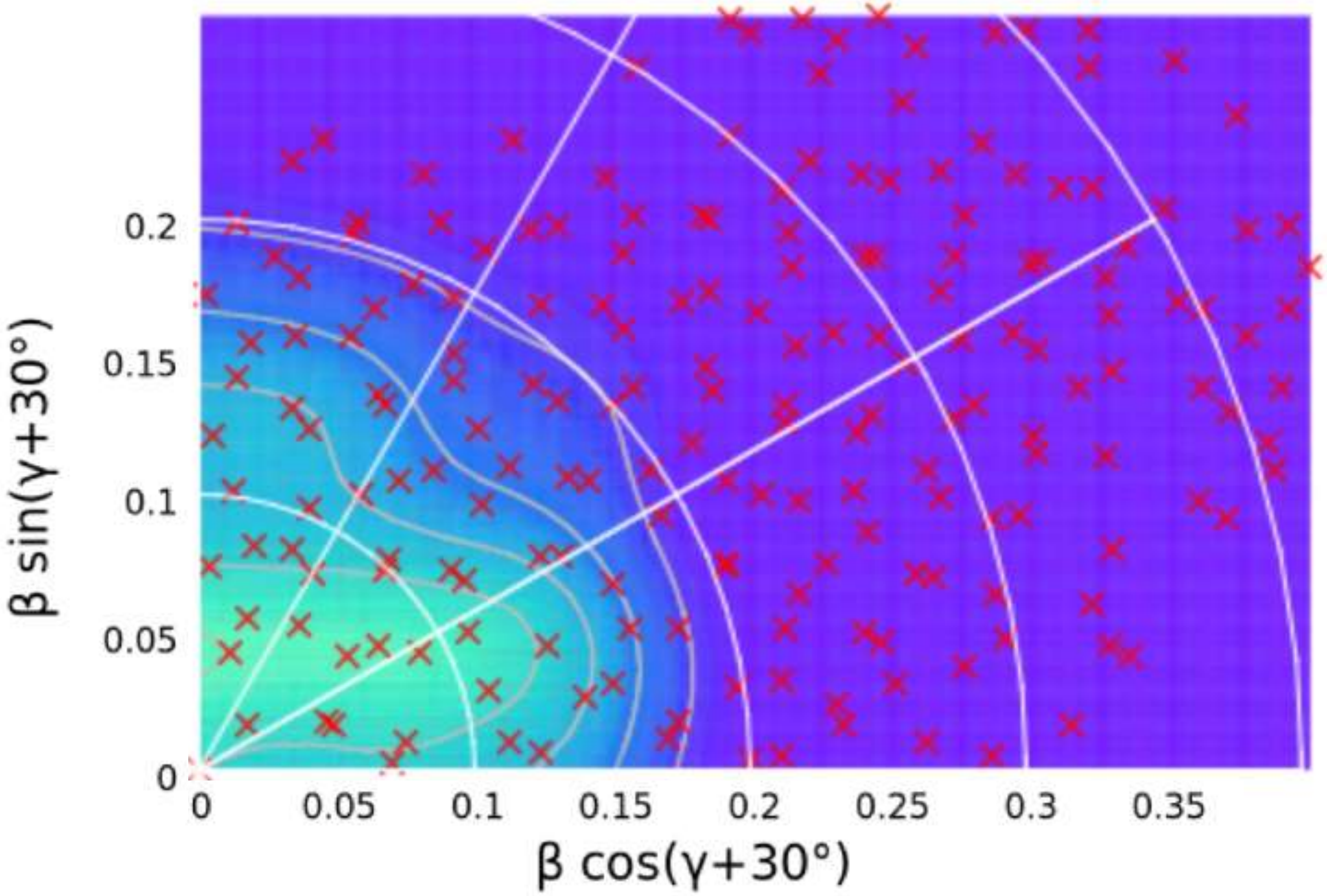




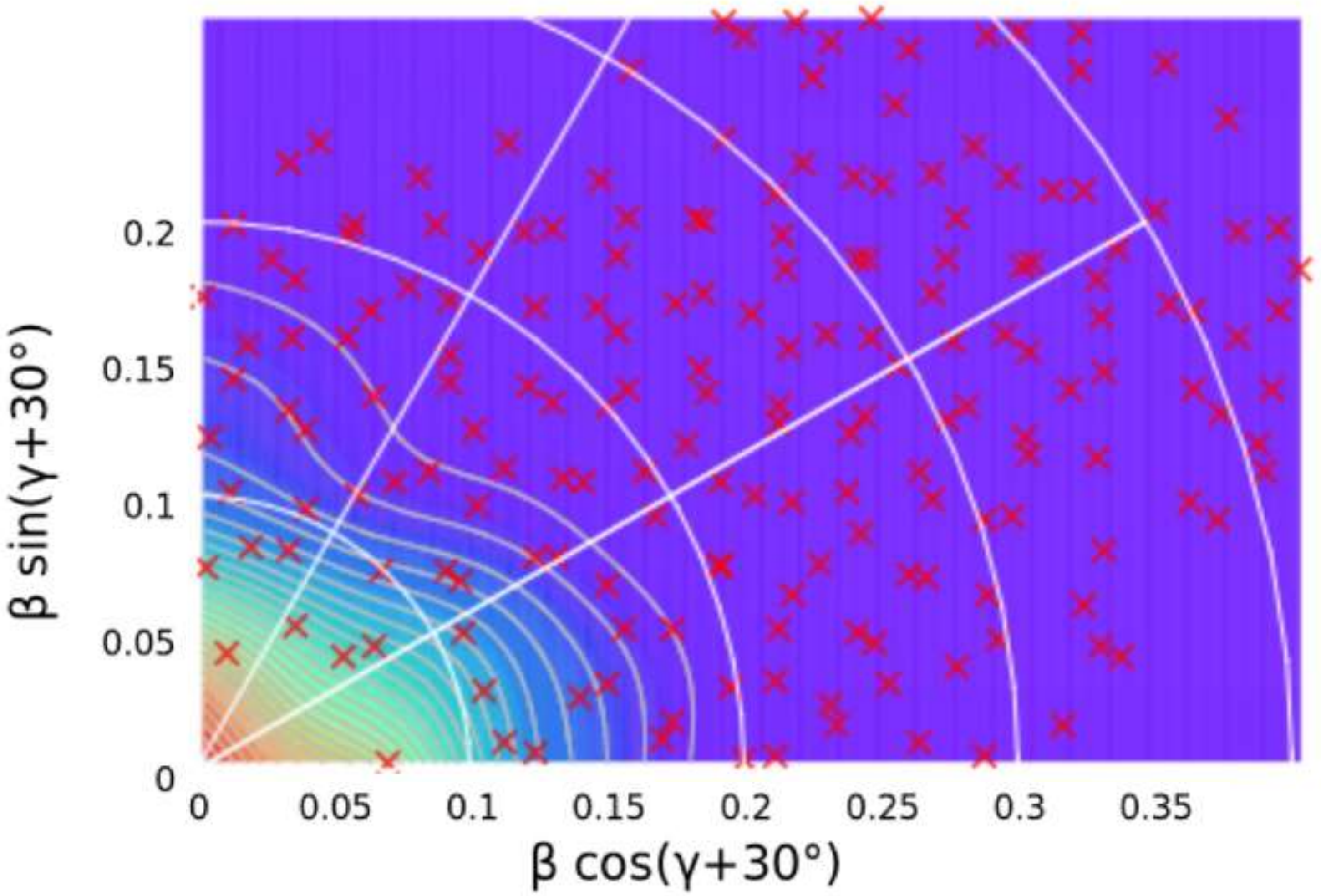
Amplitudes of HFB-states for ^{48}Cr; $I = 12$

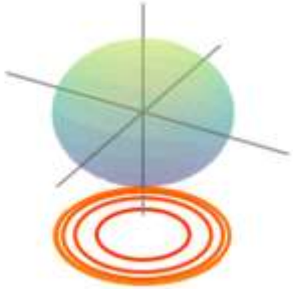


Amplitudes of HFB-states for ^{48}Cr; $I = 14$

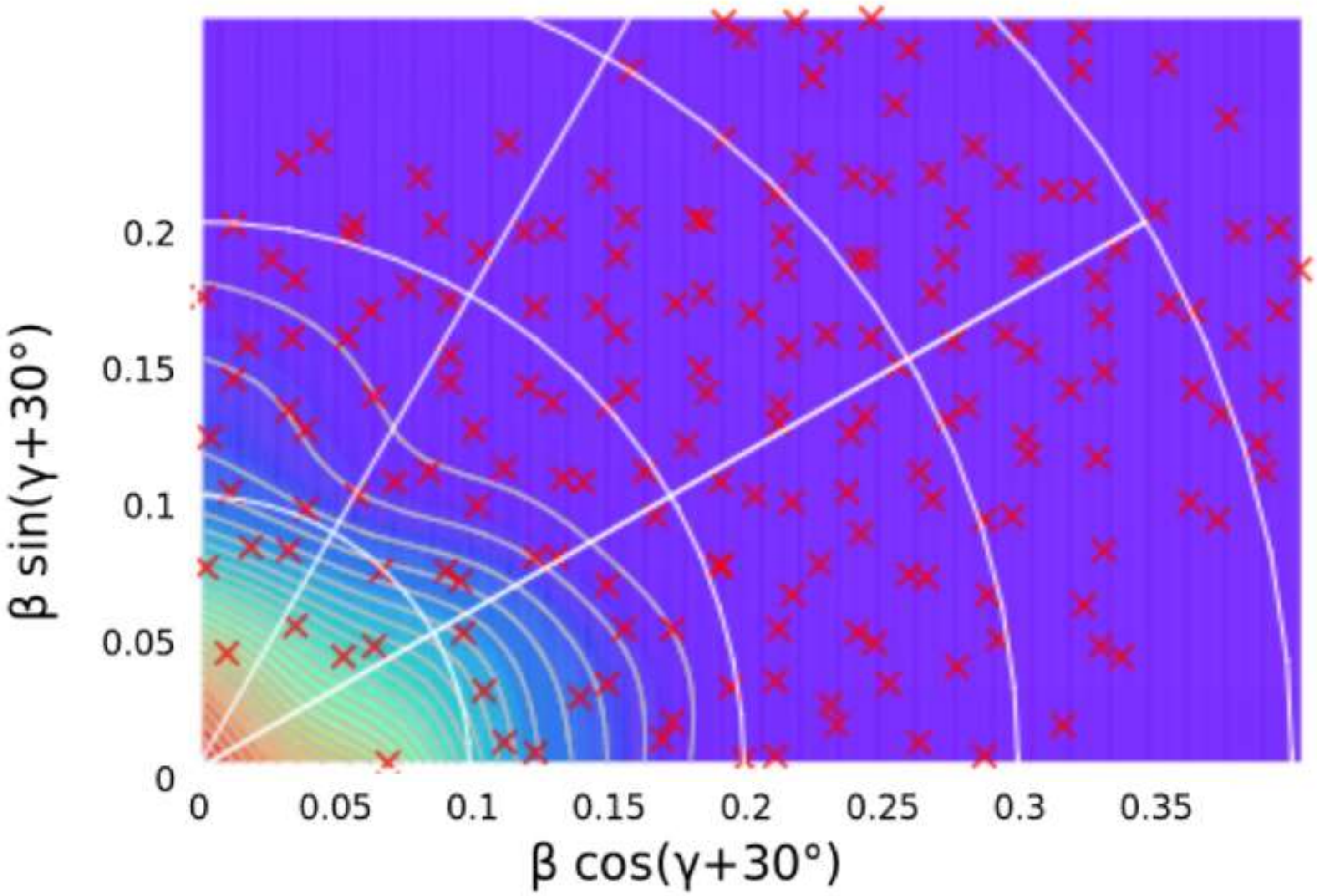


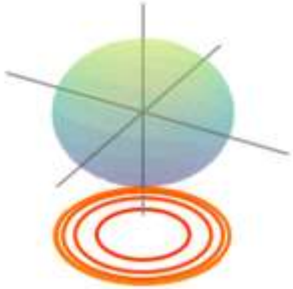
Amplitudes of HFB-states for ^{48}Cr; $I = 16$





Amplitudes of HFB-states for ^{48}Cr; $I = 16$

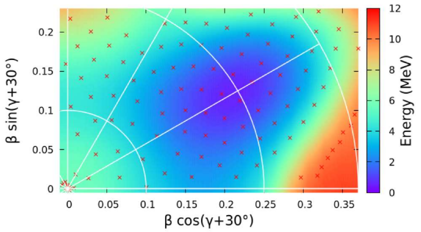


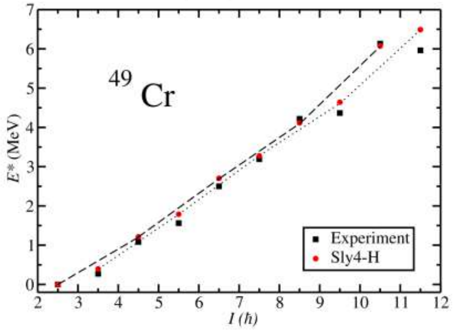


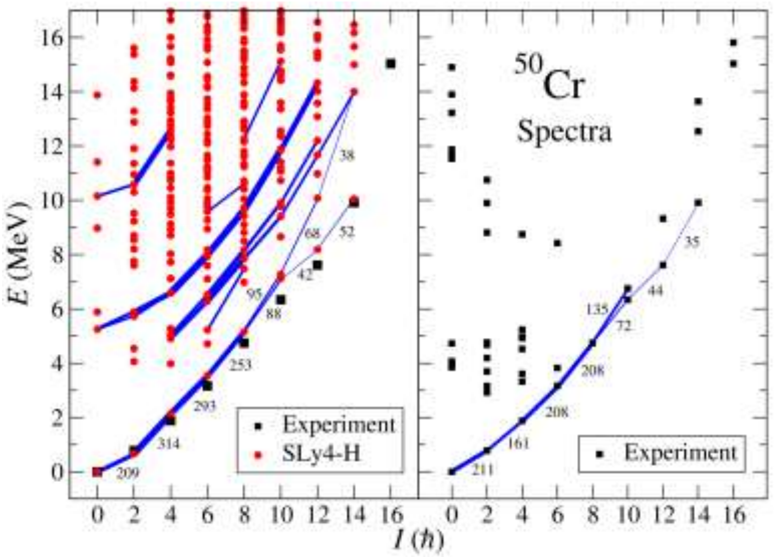
4×2 particles in $f_{7/2}$

Conclusions & Outlook

- GCM can describe low energy states with a great degree of collectivity within a consistent elegant framework.
- Working towards:
  - Generalizing the effective Hamiltonian
  - Additional observables (e.g. scattering)







Phys. Rev. C 106, 014314 (2022)
arXiv:2211.14263
arXiv:2212.07673

GCM

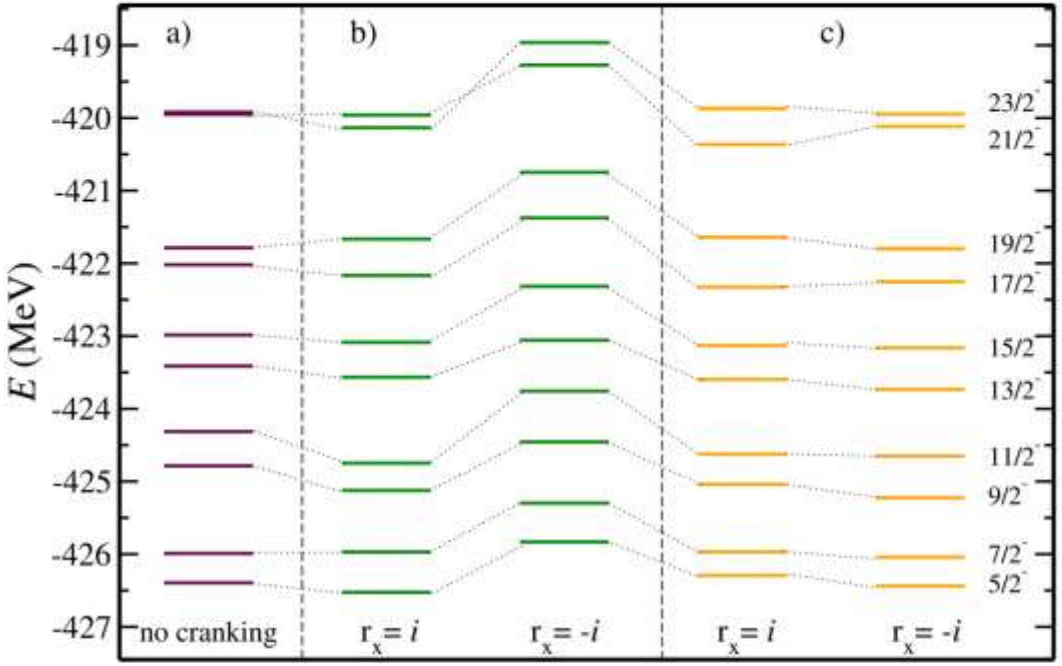


Figure 7: Energies of the g.s. rotational band in ^{49}Cr computed in different bases. In the panel a) the basis include 116 states and the cranking is switched off. In the panels b) and c), respectively, 114 and 156 states are included in the basis and the cranking is switched on. Results on the left (right) side of panels b) and c) are obtained in a basis with signature

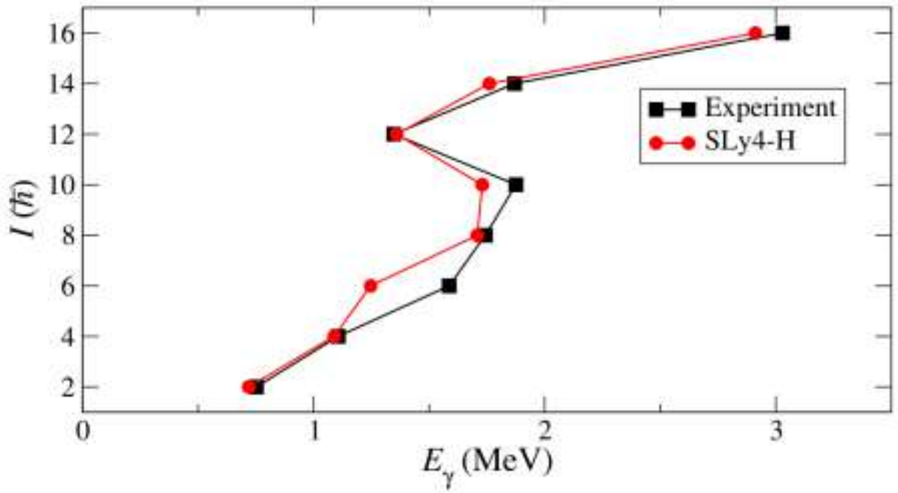
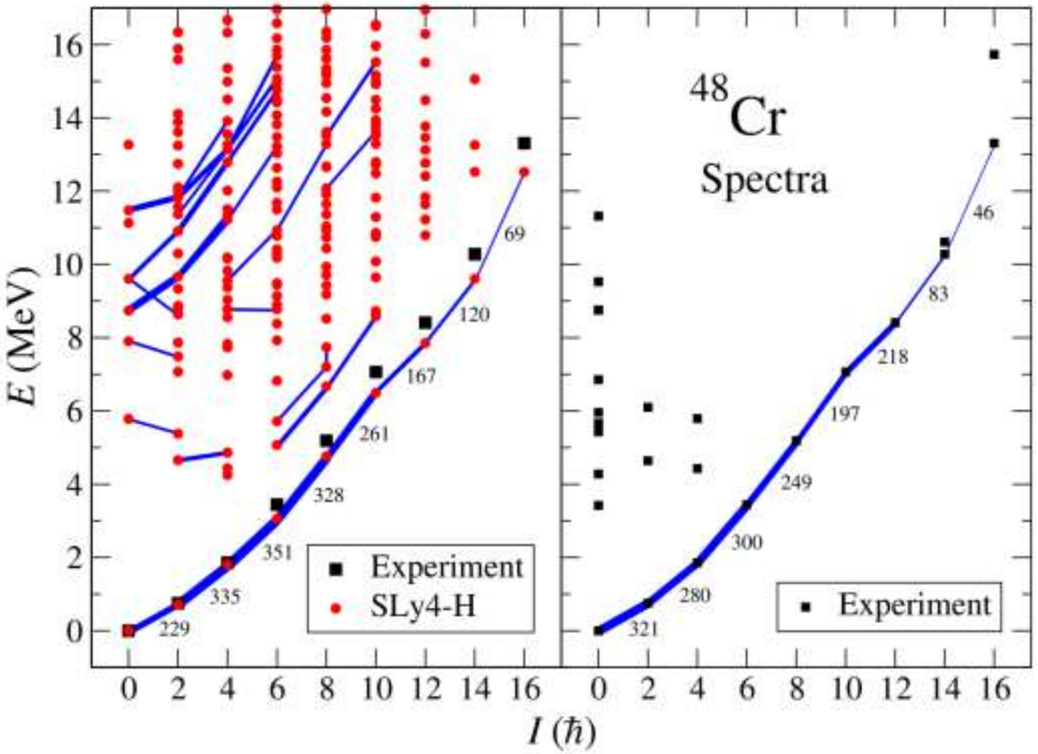
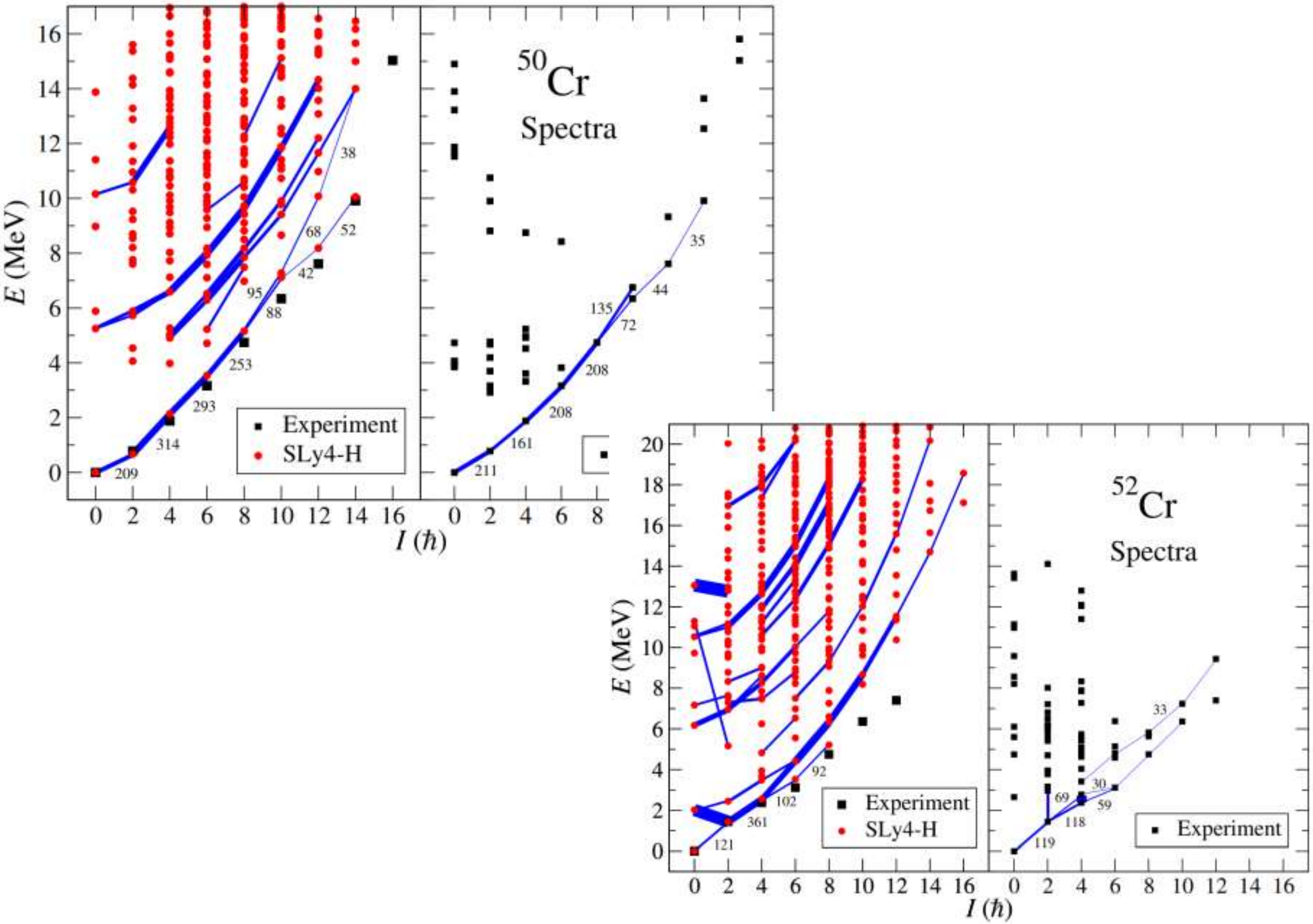
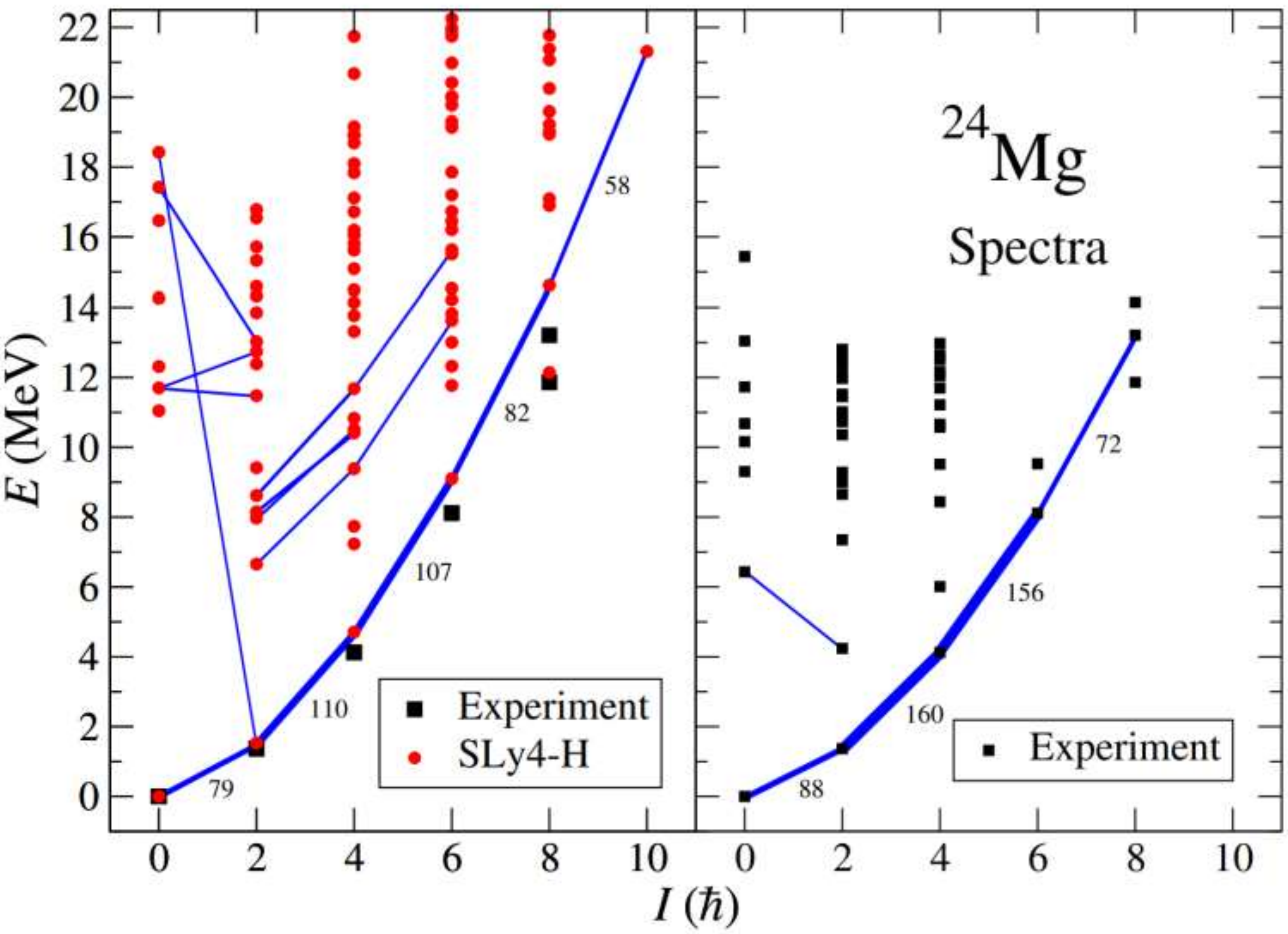


Figure 6: Released gamma ray energies for transit
I for the yrast band. The backbending at $I = 1$
a change in the internal structure.

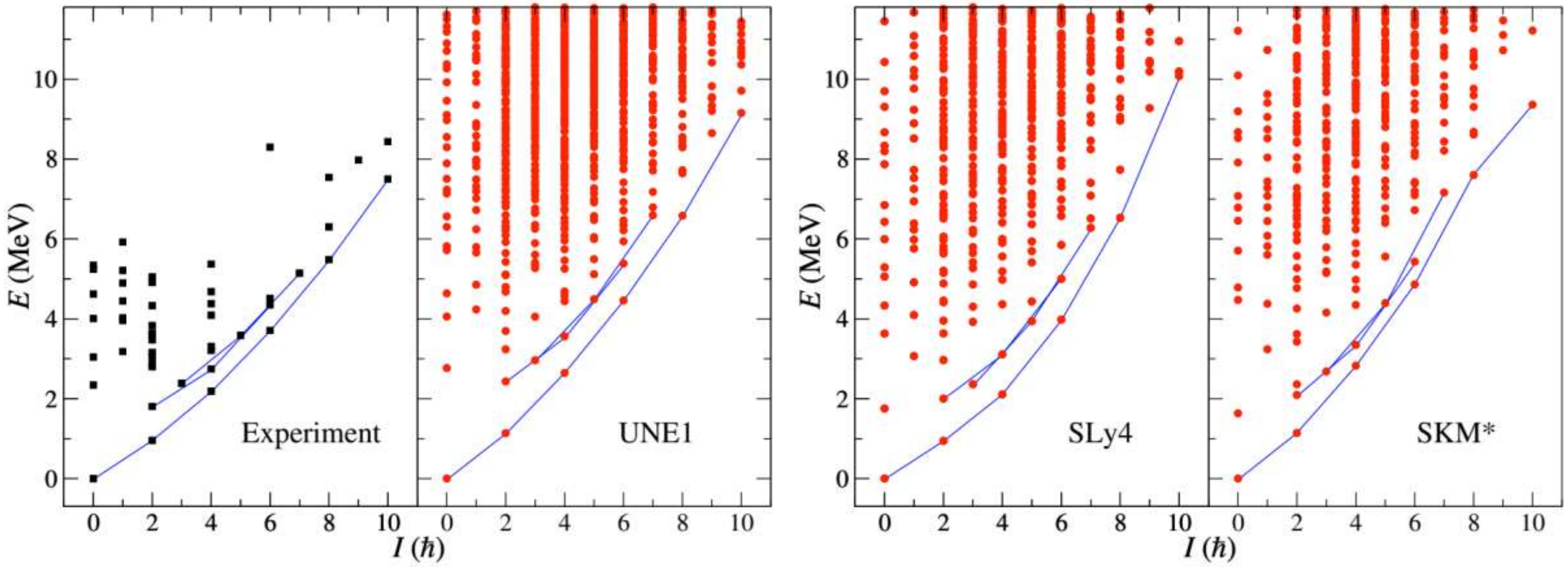




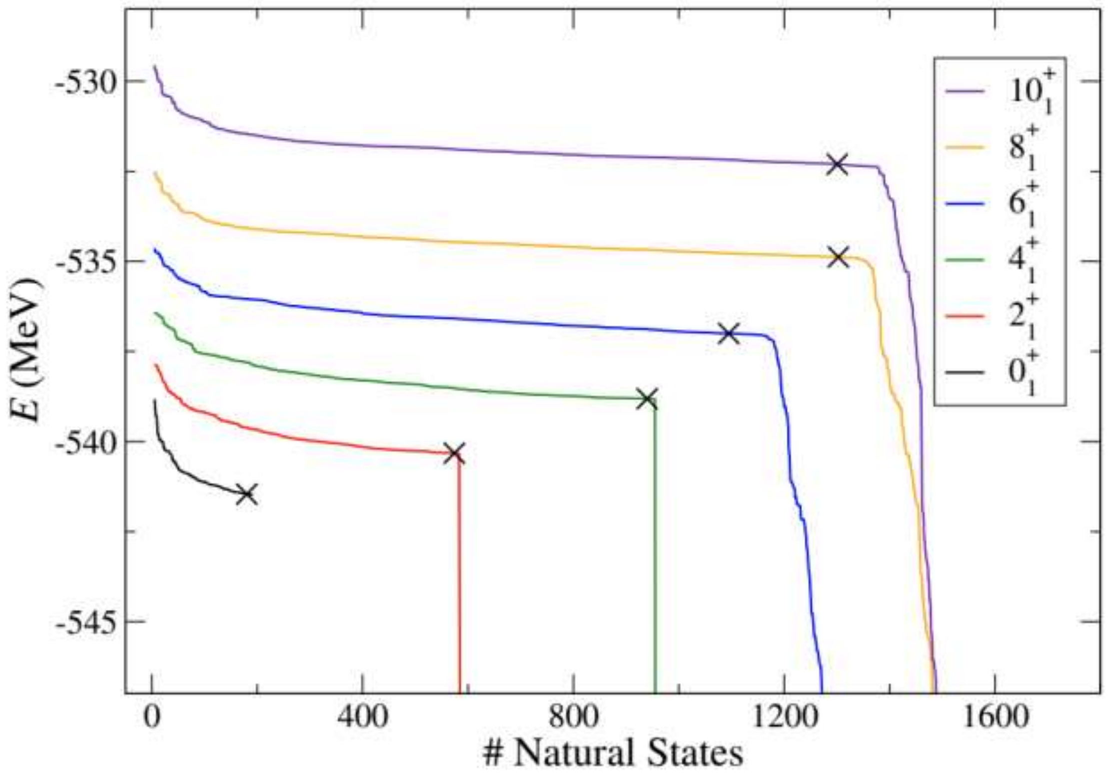
^{50}Cr
Spectra
Experiment
SLy4-H
E (MeV)
I (ħ)
^{52}Cr
Spectra
Experiment
SLy4-H
E (MeV)
I (ħ)



E (MeV)
I (ħ)
Experiment
SLy4-H
79
110
107
82
58
²⁴Mg
Spectra
88
160
156
72



^{62}Zn


-530
-535
-540
-545
E (MeV)
0
400
800
1200
1600
Natural States
10_1^+
8_1^+
6_1^+
4_1^+
2_1^+
0_1^+