

Shape phase transitions and shape coexistence through two-neutron transfer

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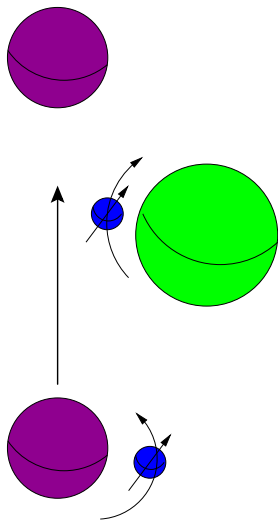
Dubrovnik, 14th July 2022



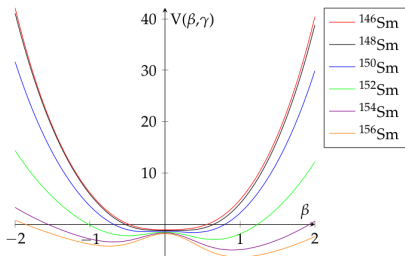
- 1 Motivation
- 2 Type I Quantum Phase Transition (QPT): Sm
- 3 Type II QPT, driven by shape-coexistence: Zr
- 4 Reaction framework and error sources
- 5 Conclusions

Motivation

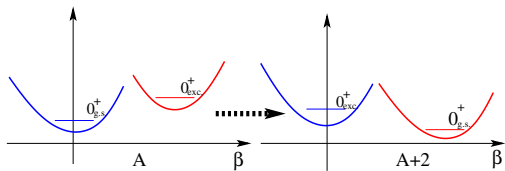
- ⇒ One and two-neutron transfer is a subtle peripheral process
 - ✗ small cross sections
 - ✓ selectivity
- ⇓
- ⇒ A and $A + 2$ nuclei should present similar deformations ⇒ good for shape-phase transitions



⇒ Shape-phase transition



⇒ Transition driven by Shape Coexistence

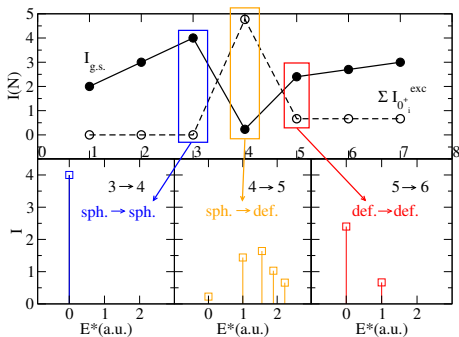


Let start from IBM as a benchmark model for considering all possible deformations

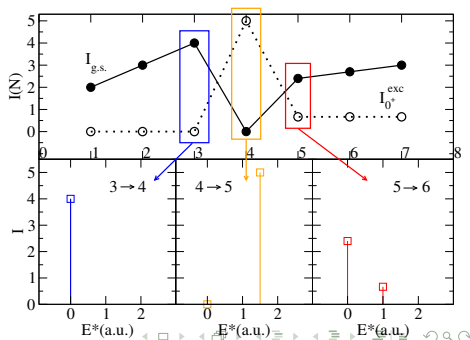
⇒ Fossion et al. PRC76, 014316 (2007), Two neutron transfer intensities:

$$I(N, i \Rightarrow N + 1, j) = |\langle N + 1, 0_j^+ || P^+ || N, 0_i^+ \rangle|^2$$

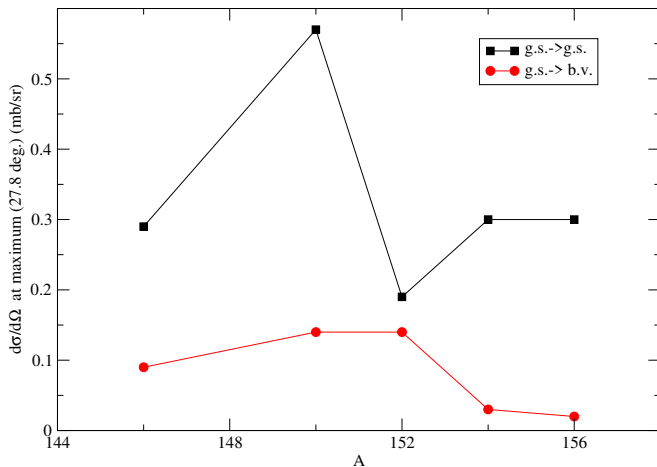
Normal QPT scenario



QPT within Shape Coexistence scenario



Sm as a well-known case of Type I QPT

 $A^{-2} \text{Sm}(t,p)^A \text{Sm}$ @ 12 MeV tritonsJ. H. Bjerregaard *et al.* Nucl. Phys. 86 (1966) 145

Some problems with IBM

IBM1 calculations with parameters from PRC56 (1997) 829

⇒ Previous comparisons to the level of intensities:

Y. Zang and F. Iachello PRC95, 034306 (2017)

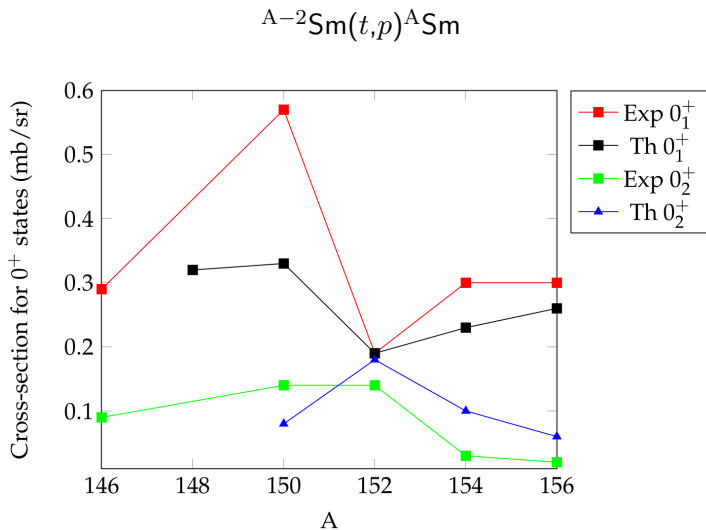
J. E. García-Ramos, J. M. Arias, and A. Vitturi CPC44, 124101 (2020)

+ 2nd-order DWBA calculation of transfer cross sections

× We need information about the orbital

⇒ Therefore we **fit one** reaction to data and keep relative strengths to **look at the rest** of isotopes

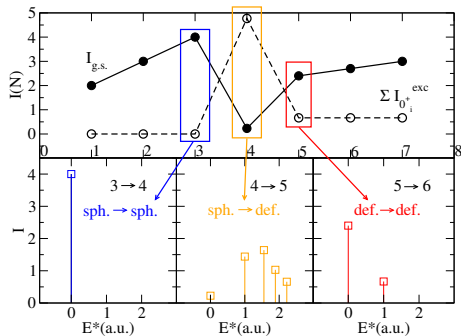
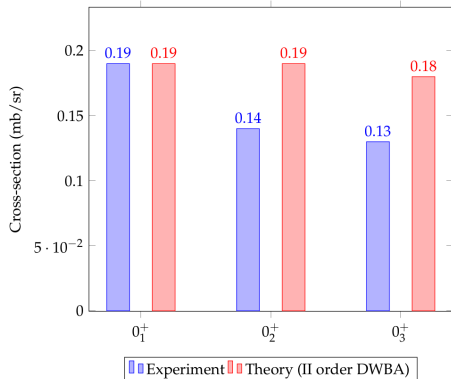
Sm as a well-known case of Type I QPT



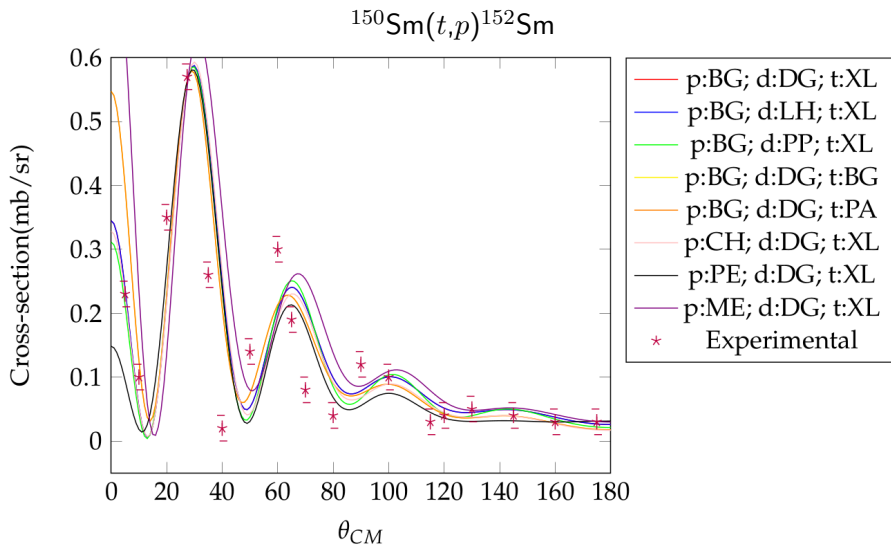
P. Jodidar (Master thesis)

Fragmentation as signature of Type I QPT

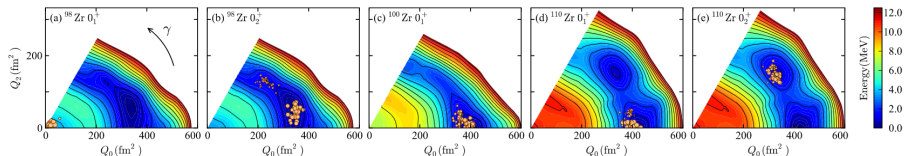
Normal QPT scenario

 $^{150}\text{Sm}(t,p)^{152}\text{Sm}$ 

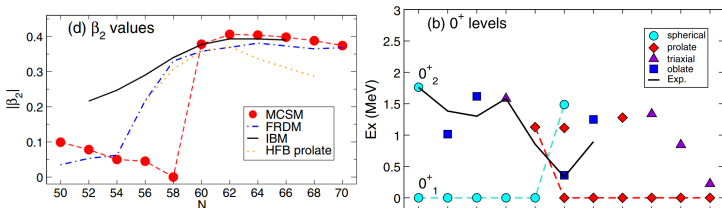
Sensitivity to optical potentials



Zr as a case of shape-coexistence

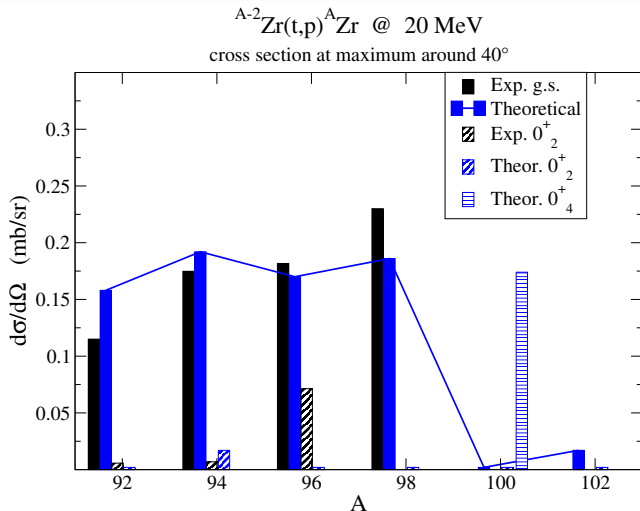


⇒ Monte Carlo Shell Model calculations from
T. Togashi, Y. Tsunoda, T. Otsuka, *et al.* [PRL117 (2016) 172502]



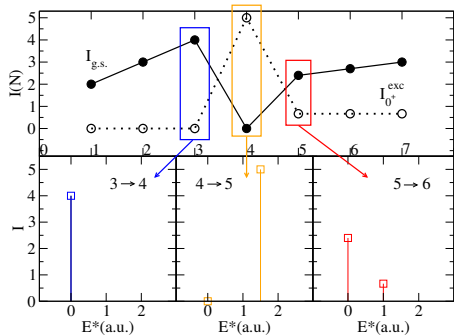
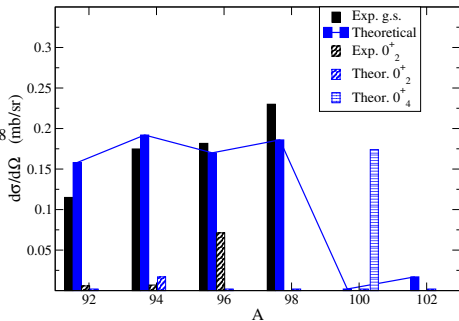
⇒ Two Neutron Amplitudes $\langle A + 2 || [a_j^\dagger a_j^\dagger]^0 || A \rangle$

Zr as a case of shape-coexistence

E. R. Flynn *et al.* NPA218 (1974) 285J. A. Lay *et al.* arXiv:1905.12976

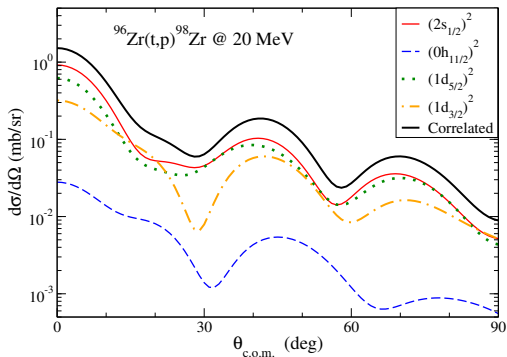
Absence of fragmentation

QPT within Shape Coexistence scenario

 $A^{-2}\text{Zr}(t,p)^A\text{Zr}$ @ 20 MeV
cross section at maximum around 40° 

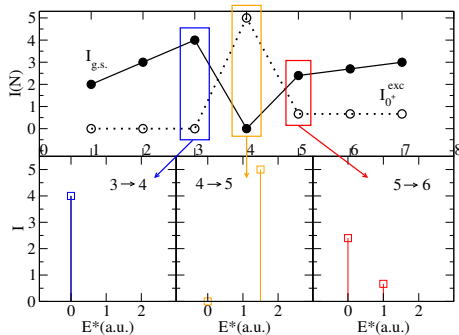
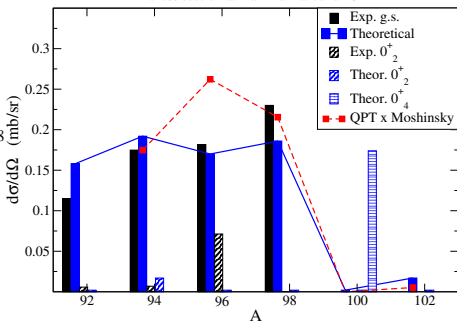
Decomposition of Two-Nucleon Amplitudes

	90-92gs	92-94gs	94-96gs	96-98gs	98-100gs	98-100(0_4^+)	100-102gs
$1d_{5/2}$	0.74	0.86	0.86	0.13	~ 0.0	0.16	0.08
$2s_{1/2}$	0.10	0.08	0.10	0.90	~ 0.0	0.16	0.05
$1d_{3/2}$	0.13	0.18	0.16	0.07	~ 0.0	0.90	0.04
$0h_{11/2}$	0.22	0.20	0.19	0.08	~ 0.0	0.14	0.55



J. E. García-Ramos and K. Heyde Phys. Rev. C 102, 054333 (2020)

QPT within Shape Coexistence scenario

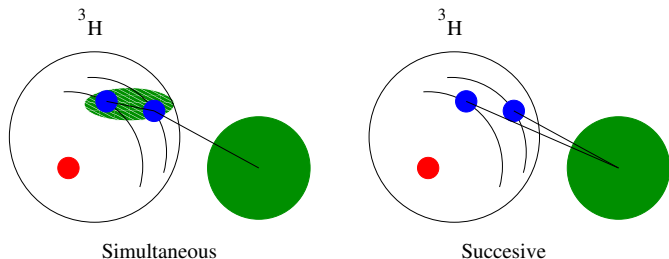

 $A^{-2}Zr(t,p)^AZr$ @ 20 MeV
 cross section at maximum around 40°


Few words on the reaction mechanism

2N transfer reaction

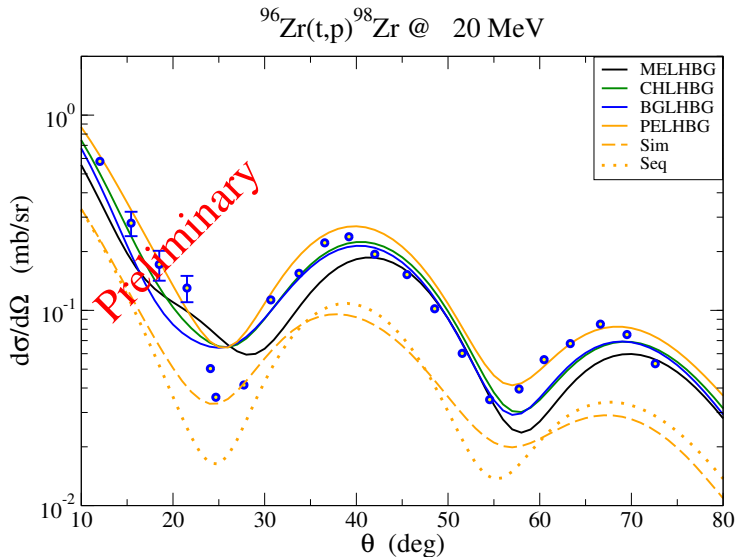
- 2^{nd} order DWBA can reproduce the total cross section
- ✗ We rely on Optical Potentials
- Relative cross sections for different states as more robust observables

~ Using SF \rightarrow Overlap $\langle {}^{98}\text{Zr} | {}^{96}\text{Zr} \rangle \approx \text{TNA} \cdot \text{s.p. Wavefunctions}$



✓ Includes Sim.+Seq.+ Non-Orthogonality terms

Sensitivity to optical potentials



Conclusions

Transfer with shape-phase transitions and shape coexistence

- ⇒ Transfer reactions are perfect probes to pinpoint critical points in QPT
- ⇒ Also a promising tool to disentangle shape-phase transitions and shape coexistence
- ⇒ Non critical sensitivity to optical potentials

Thank you!!



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