Quantum phase transitions via two-neutron transfer

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Meeting in honour of Edoardo Lanza

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

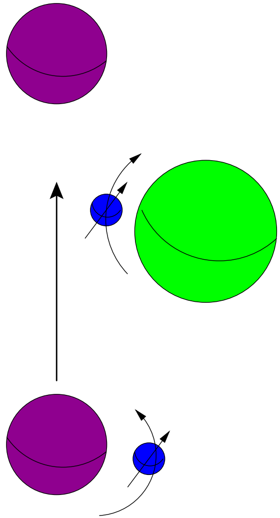
Motivation

⇒ One and two-neutron transfer is a subtle peripheral process

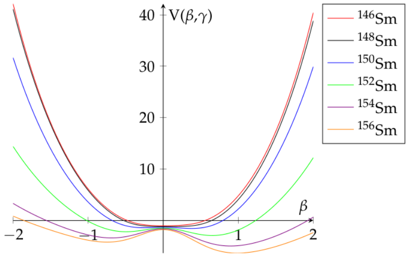
- × small cross sections
- ✓ selectivity

⇓

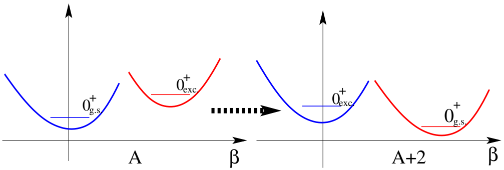
⇒ A and $A+2$ nuclei should present similar deformations ⇒ good for shape-phase transitions



⇒ Shape-phase transition



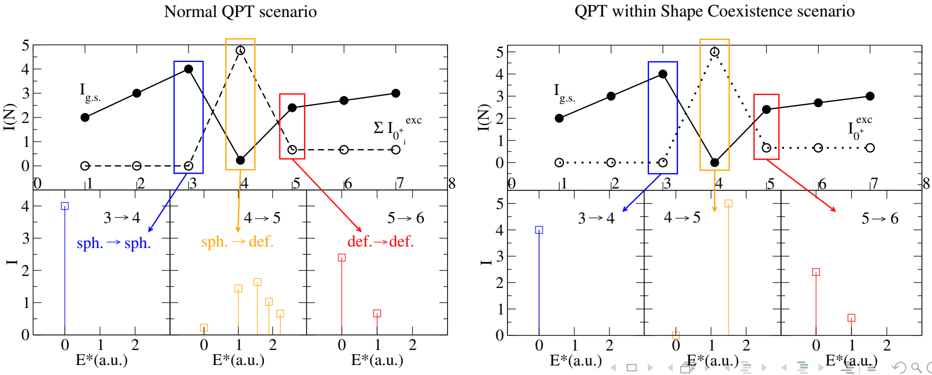
⇒ Transition driven by Shape Coexistence



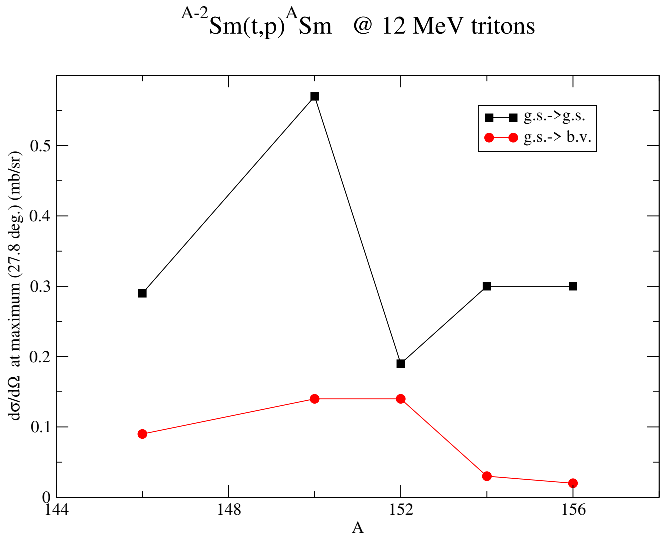
Let start from IBM as a benchmark model for considering all possible deformations

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

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



Sm as a well-known case of Type I QPT



J. 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:

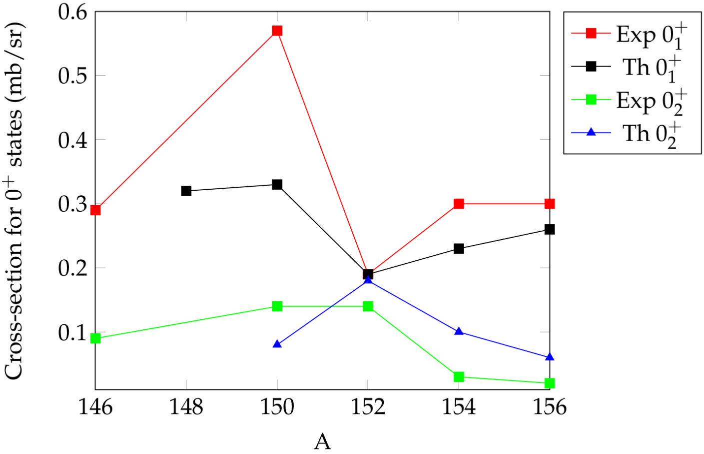
Y. Zang and F. Iachello PRC95, 034306 (2017)
J. E. García-Ramos, J. M. Arias, and A. Vitturi CPC44, 124101 (2020)

+ 2nd-order DWBA calculation of transfer cross sections

- x We need information about the orbital
- ⇒ Therefore we fit one reaction to data and keep relative strengths to look at the rest of isotopes

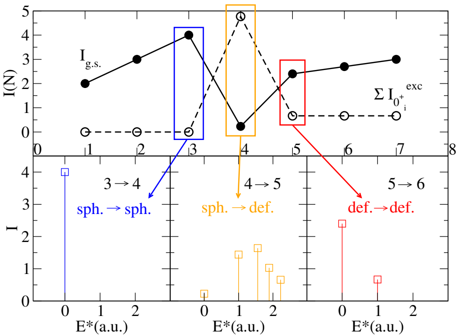
Sm as a well-known case of Type I QPT

$^{A-2}$Sm$(t,p)^{A}$Sm

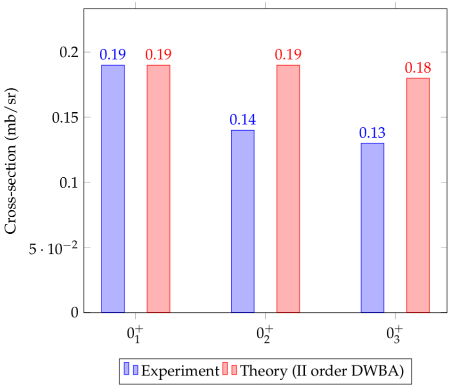


P. Jodidar (Master thesis)

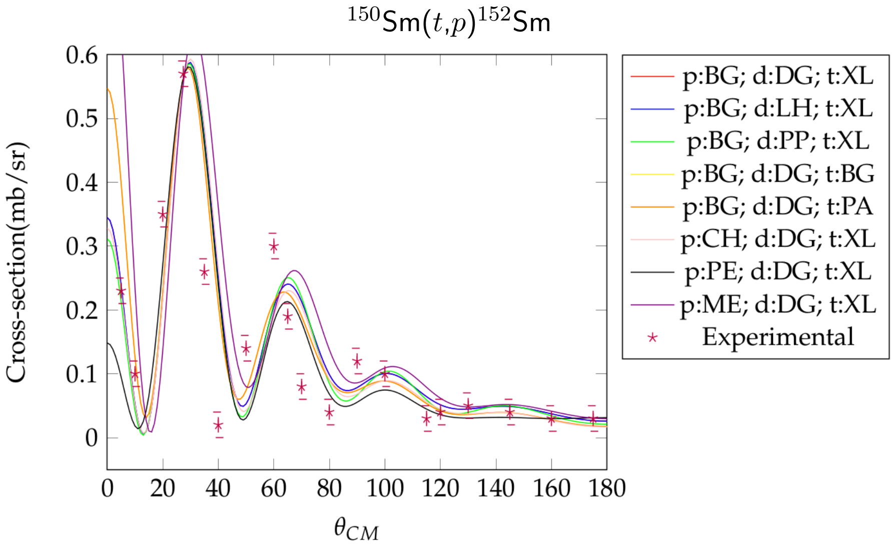
Fragmentation as signature of Type I QPT



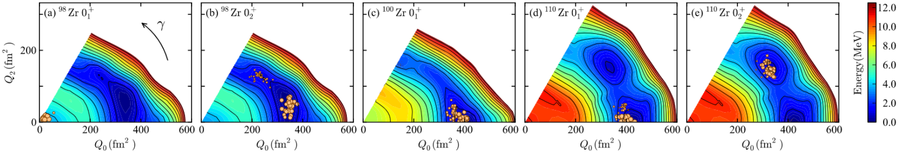
^{150}Sm$(t,p)^{152}$Sm



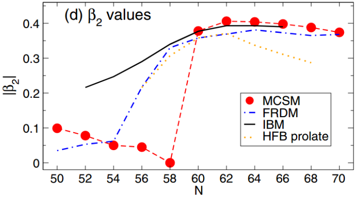
Sensitivity to optical potentials

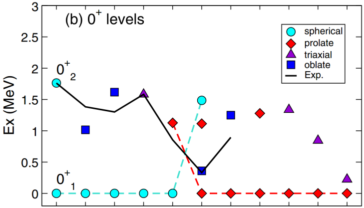


Zr as a case of shape-coexistence



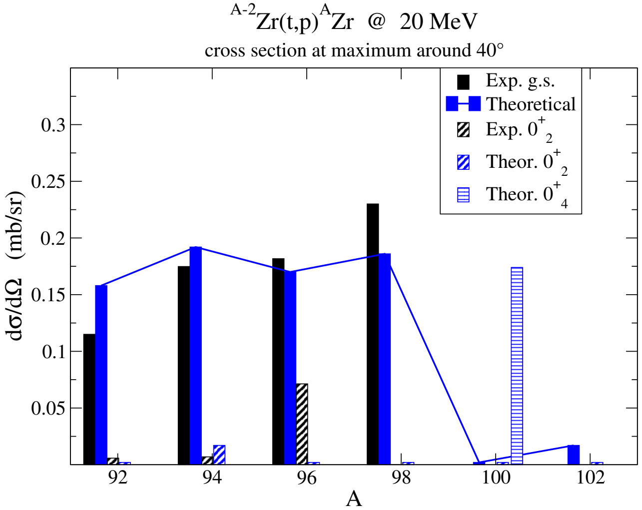
⇒ Monte Carlo Shell Model calculations from
T. Togashi, Y. Tsunoda, T. Otsuka, *et al.* [PRL117 (2016) 172502]





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

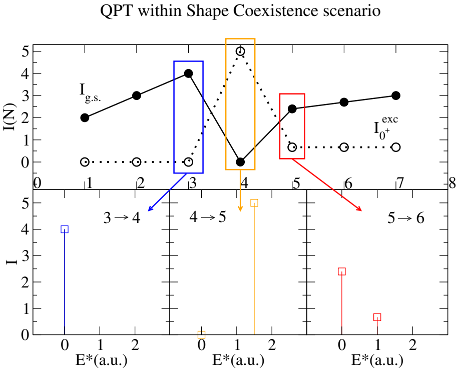
Zr as a case of shape-coexistence

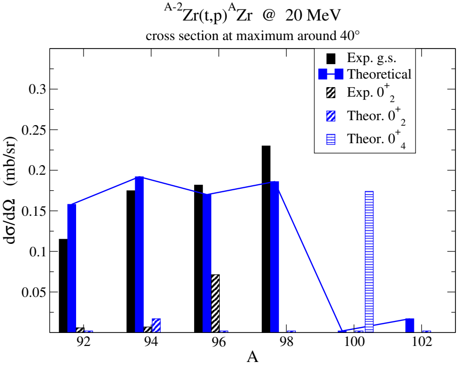


E. R. Flynn *et al.* NPA218 (1974) 285

J. A. Lay *et al.* arXiv:1905.12976

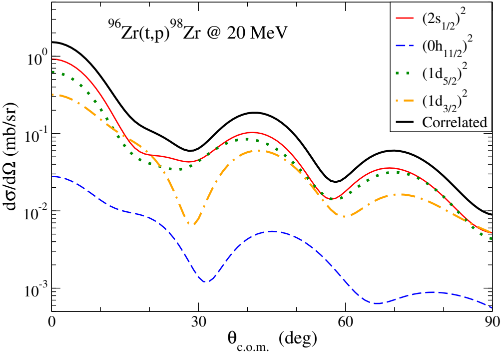
Absence of fragmentation



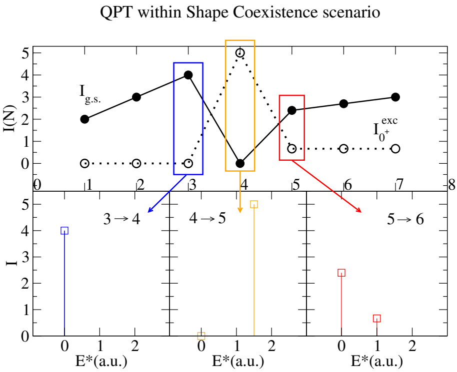


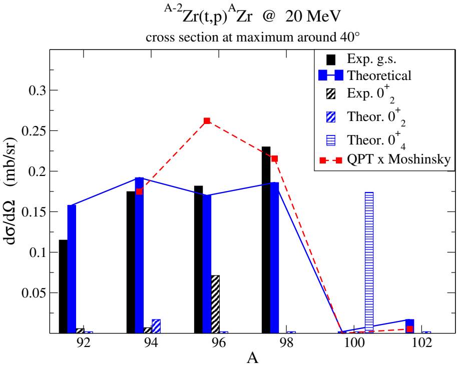
Decomposition of Two-Nucleon Amplitudes

	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	$\sim$ 0.0	0.16	0.08
$2s_{1/2}$	0.10	0.08	0.10	**0.90**	$\sim$ 0.0	0.16	0.05
$1d_{3/2}$	0.13	0.18	0.16	0.07	$\sim$ 0.0	**0.90**	0.04
$0h_{11/2}$	0.22	0.20	0.19	0.08	$\sim$ 0.0	0.14	**0.55**



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


QPT within Shape Coexistence scenario
I(N)
I g.s.
I 0+ exc
0
1
2
3
4
5
6
7
8
I
E*(a.u.)
3 → 4
4 → 5
5 → 6

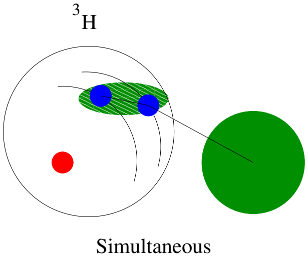

A-2Zr(t,p)AZr @ 20 MeV
cross section at maximum around 40°
dσ/dΩ (mb/sr)
A
Exp. g.s.
Theoretical
Exp. 0+2
Theor. 0+2
Theor. 0+4
QPT x Moshinsky
92
94
96
98
100
102

Few words on the reaction mechanism

2N transfer reaction

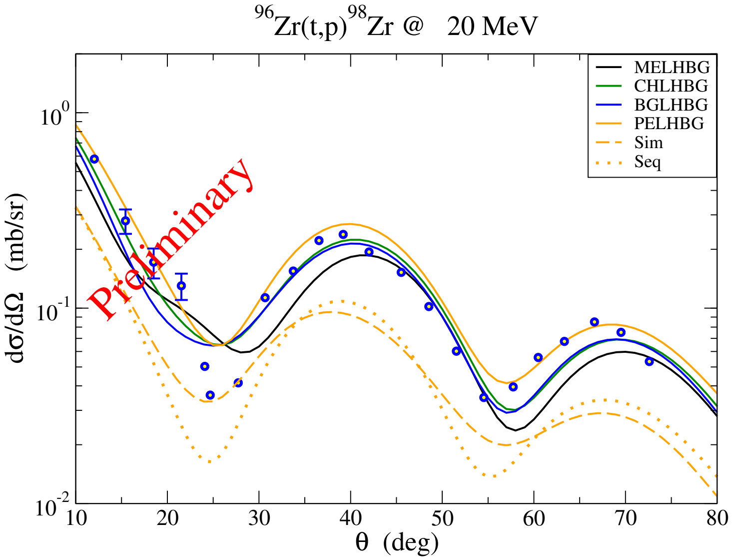
- 2^{nd} order DWBA can reproduce the total cross section
- X We rely on Optical Potentials
- Relative cross sections for different states as more robust observables

∼ Using SF → Overlap $\langle^{98}\text{Zr}|^{96}\text{Zr}\rangle \approx$ TNA · 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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