Microscopic calculations of the photon strength functions in magic and semi-magic nuclei

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Plan

- Aims of work
- Microscopic self-consistent calculations of photon strength functions (PSFs) in magic and semi-magic nuclei to account for phonon coupling (PC) effects
- Calculations of radiative neutron capture cross sections and average radiative widths with EMPIRE 3.1 using our microscopic PSFs
- Conclusion

Aims of calculations:

We want to investigate the specificity of the radiative characteristics in magic and semi-magic nuclei:

- To take self-consistency into account.
  (such an approach has a higher predictive power as compared with phenomenological approaches (SLO, MLO, EGLO etc.))
- To describe structures of E1 photon strength functions (PSFs) microscopically with both QRPA and phonon coupling effects
- To compare (^{3}He, ^{3}He' γ) Oslo exp. data, the (γ, γ') and (p, p') results for ^{208}Pb
- To calculate radiative neutron capture cross sections and average radiative widths for corresponding nuclei

Extended Theory of Finite Fermi Systems in the QTBA approximation

ETFFS(QTBA) contains:

1.(Q)RPA

2. Phonon coupling

3.Single-particle continuum (in discretized form)

4. Self-consistency

and uses the known Skyrme forces to calculate simultaneously the mean field, effective interaction and phonon characteristics self-consistently

No new parameters !

Method:

Kamerdzhiev *et al.*, Phys. Rep. **393**, 1, (2004)

Tselyaev, Rhys. Rev. C **75**, 024306 (2007)

Some our articles:

Avdeenkov *et al.*, Phys. Rev. C **83**, 064316 (2011)

Achakovskiy *et al.*, Phys. Rev. C **91**, 034620 (2015)

Kamerdzhiev *et al.*, JETP Lett., **101**, No. 11, 725 (2015)

Kamerdzhiev *et al.*, Phys. Atom. Nucl., **79**, 567 (2016)

Achakovskiy *et al.*, JETP Lett., **104,** No.6 (2016)

Features of the self-consistent approaches

- Self-consistency:
  Mean field (ground state) is determined by the first derivative of the **density functional.**
  Effective ph- and pp-interactions for phonons are the second derivative of the **same functional**
- Individual approach to each nucleus due to its single-particle and phonon spectra. Therefore, the individual PSF structures can be described
- Parameters of the Skyrme forces or functional are universal for all nuclei except for light ones ("first principle" approach)
- Great predictive power

Continuum TBA

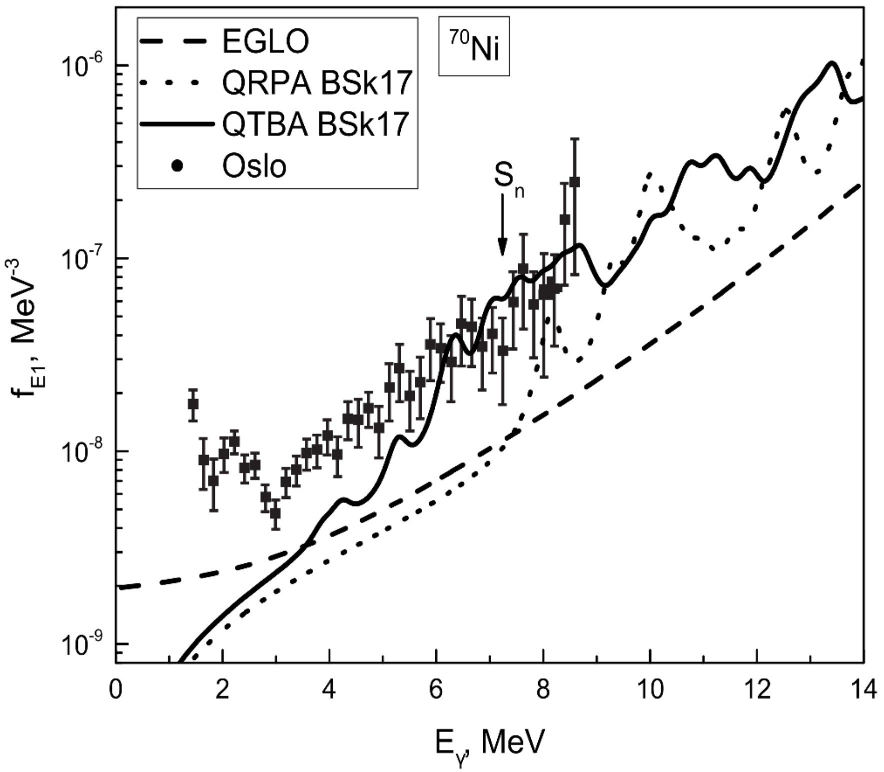
N. Lyutorovich, *et al.*, Phys. Lett B 749, 292 (2015)
V. Tselyaev, *et al.*, arXiv:1704.08560v1 (2017)

This method

- is improved fully self-consistent **method TBA**
- uses the additional (to QTBA) Coulomb and spin-orbital forces
- automatically takes into account the spurious 1^- state
- account more consistently the single–particle spectrum
- was developed recently **only for double-magic nuclei**

Comparison of these two methods with experiment for double-magic nuclei allows to check and choose the method

Predictions of PDR for ^{70}Ni (QTBA)



All Ni isotopes are calculated with Skyrme forces BSk17

$S_n = 7.31\ MeV$ $\Delta = 200$ keV

For energy interval 4–8 MeV

QRPA: $\langle E \rangle$ = 6.74 MeV, 0.24 % of EWSR,

QTBA: $\langle E \rangle$ = 6.92 MeV, 1.0 % of EWSR.

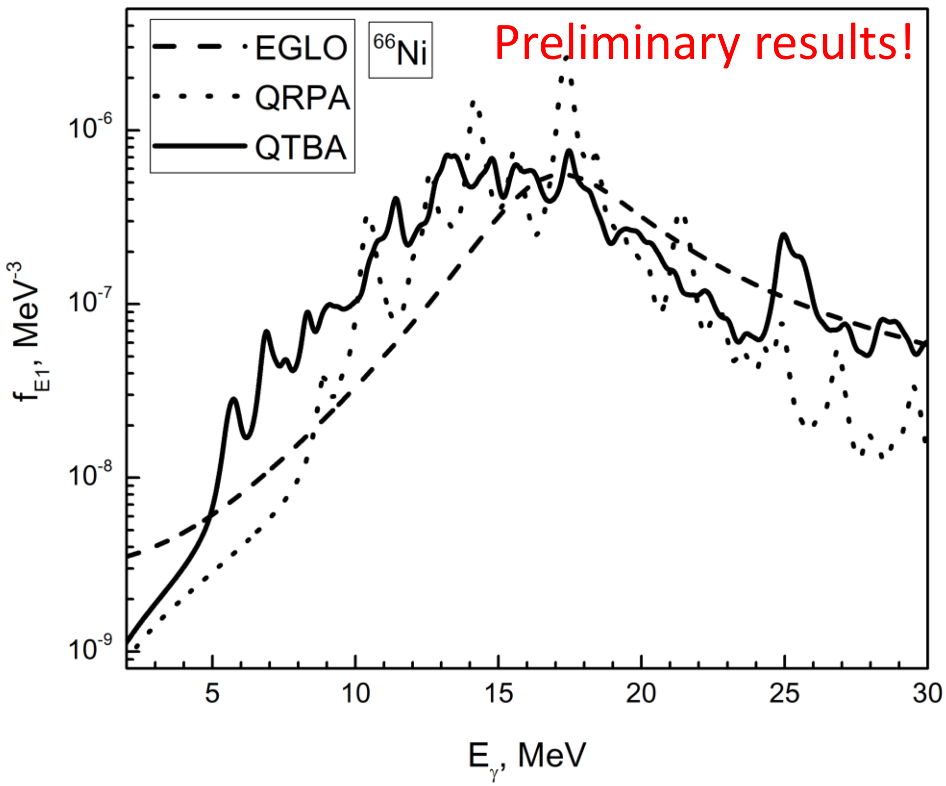
For energy interval 8–14 MeV

QRPA : $\langle E \rangle$ = 12.3 MeV, 20.6 % of EWSR,

QTBA : $\langle E \rangle$ = 12.2 MeV, 27.7 % of EWSR.

Theor. calc.: Achakovskiy *et al.,* JETP Lett., **104,** No.6 (2016)
Exp. data: S. N. Liddick *et al.,* PRL **116**, 242502 (2016)

Predictions of PSF for ^{66}Ni (QTBA)



PC give additional (as compared with QRPA) PSF structures and allow us to describe structures in PDR energy region

$S_n = 8.95$ MeV $\Delta = 200$ keV

For energy interval 4–8 MeV

QRPA: $\langle E \rangle = 6.49$ MeV, 0.14 % of EWSR,

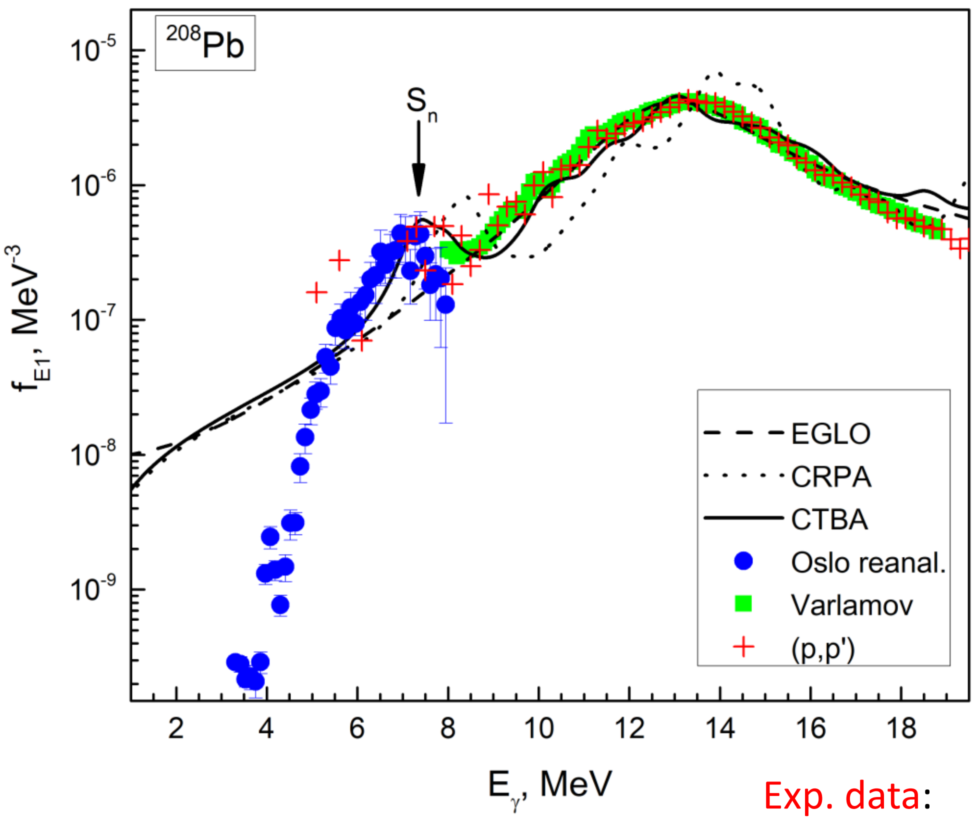
QTBA: $\langle E \rangle = 6.75$ MeV, 0.84 % of EWSR.

For energy interval 8–14 MeV

QRPA : $\langle E \rangle = 12.26$ MeV, 16.5 % of EWSR,

QTBA : $\langle E \rangle = 12.14$ MeV, 23.9 % of EWSR.

PSF for ^{208}Pb (CTBA)



Calculated with CTBA with new Skyrme SV-m56k6

N. Lyutorovich, *et al.*, Phys. Lett B 749, 292 (2015)

$S_n = 7.37$ MeV $\quad \Delta = 400\ keV$

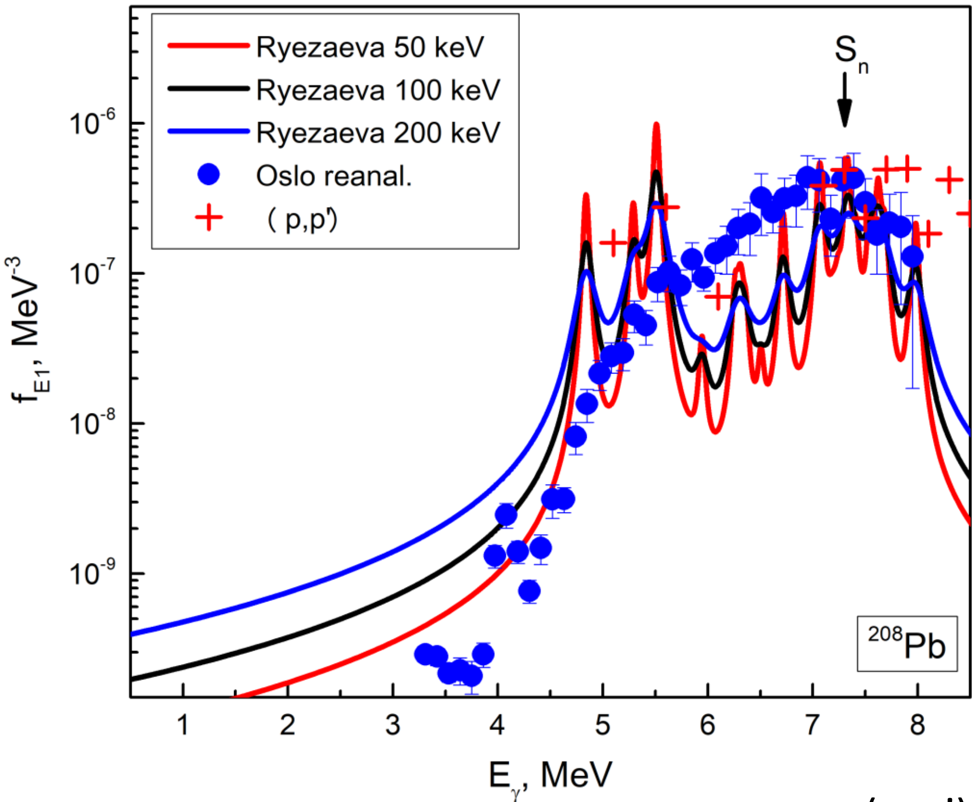
The improved approach describes the reanalyzed data better at E>5 MeV

Exp. data:

Oslo group - N.U.H.Syed *et al.,* PRC **79**, 024316 (2009), private communication (reanalyzed data)

V. V. Varlamov, *et al.,* Vop. At. Nauki i Tekhn., Ser. Yadernye Konstanty 1-2 (2003)

PSF for ^{208}Pb: comparison of experimental data sets

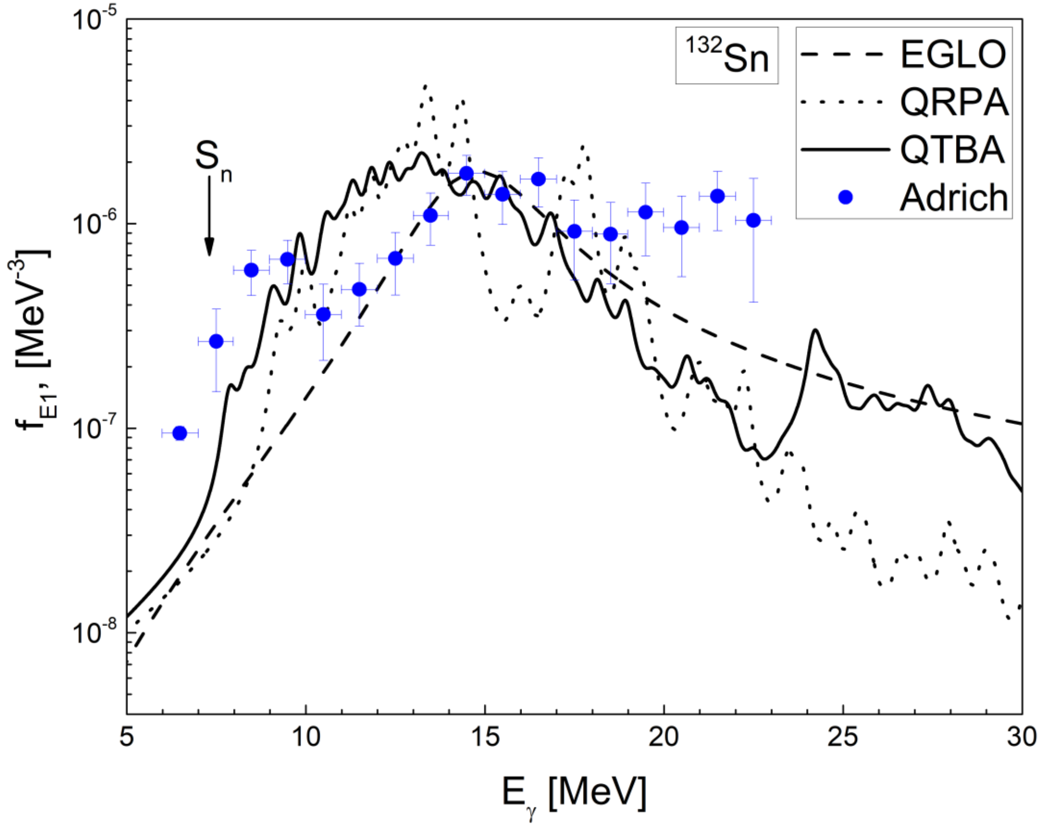


The PSF structures at E<4.84 MeV may be only caused by the (M1?) transitions between excited states.

Some additional transitions between excited states at E>5 Mev ?

(γ, γ') - N. Ryezaeva, *et al.*, PRL **89**, 272502 (2002)
(p, p') - S. Bassauer, *et al.*, PRC **94**, 054313 (2016)
(^{3}He, ^{3}He' γ) - N.U.H. Syed, *et al.*, PRC **79**, 024316 (2009), private communication (reanalyzed data)

PSF for ^{132}Sn (QTBA)



Skyrme forces – SLy4

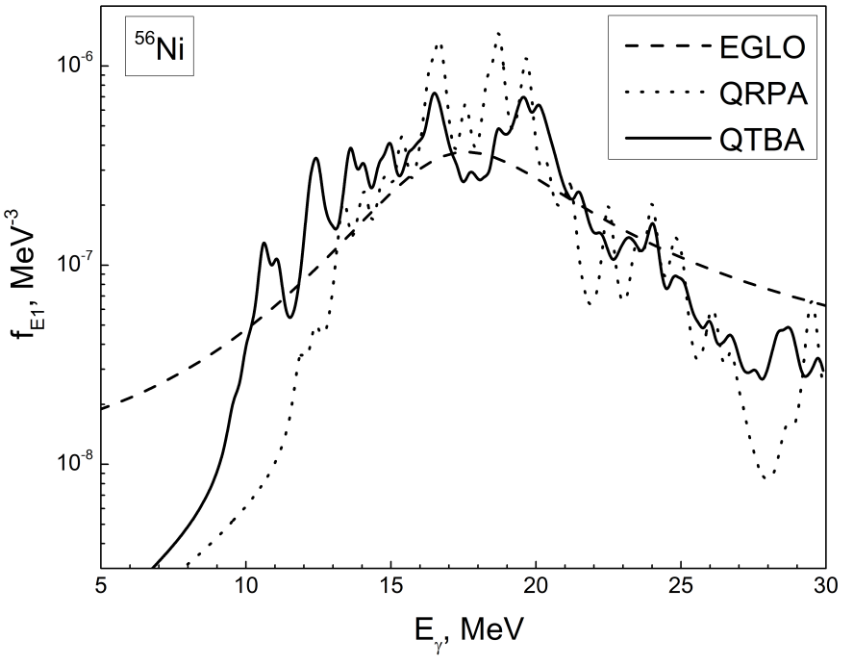
S_n=7.34 MeV

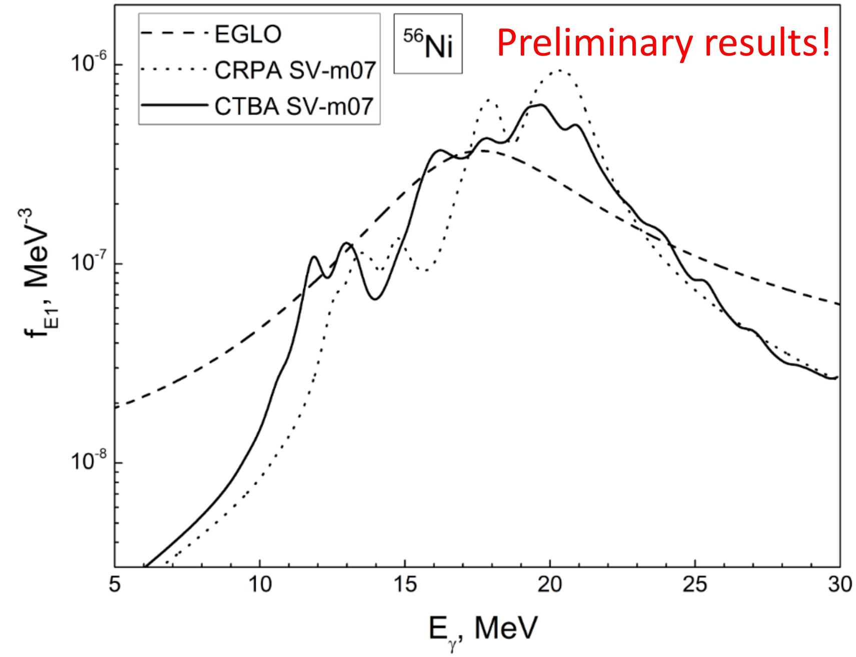
$\Delta = 200\ keV$

Exp. data: P. Adrich *et al.,* PRL **95**, 132501 (2005)

PSF for ^{56}Ni (QTBA and CTBA)

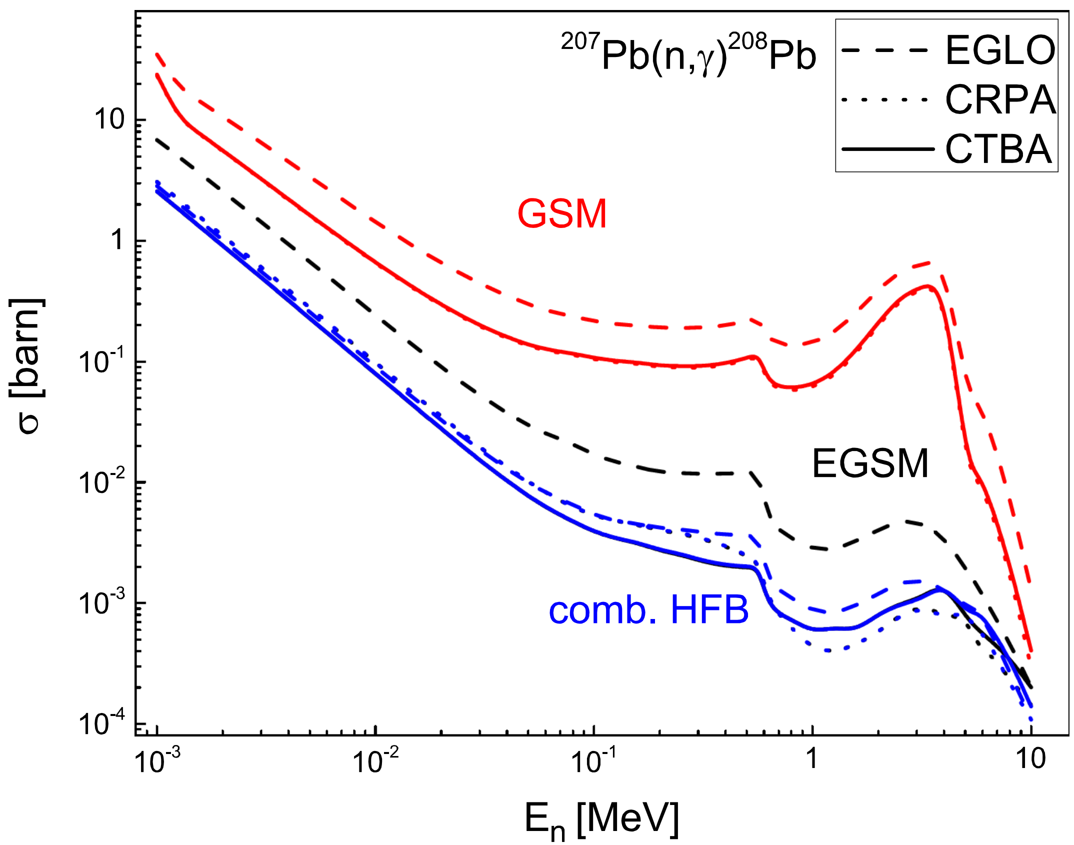
$$S_n = 16.64\ MeV$$





Skyrme parametrization SV-m07:
V. Tselyaev, N. Lyutorovich, J. Speth, P.-G. Reinhard; arXiv:1704.08560v1 (2017)

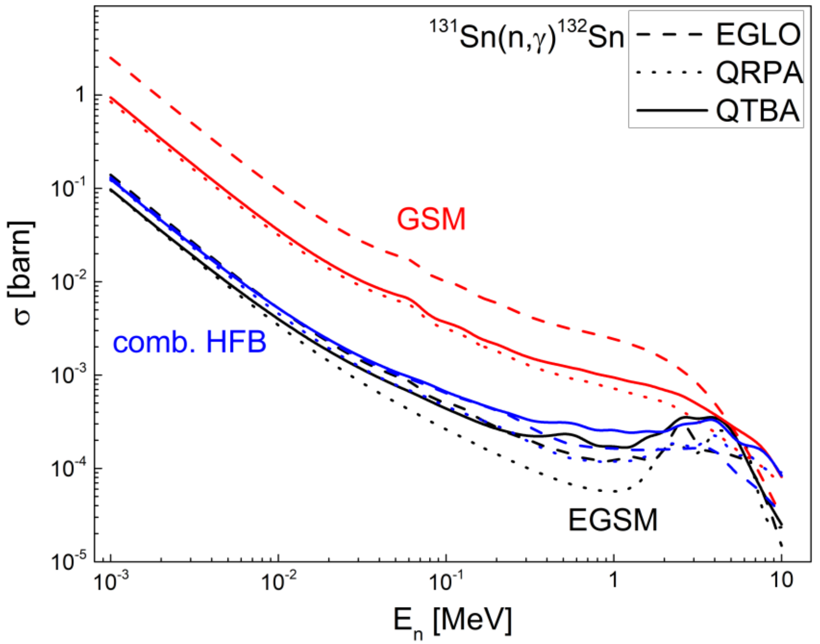
Neutron capture for ^{207}Pb

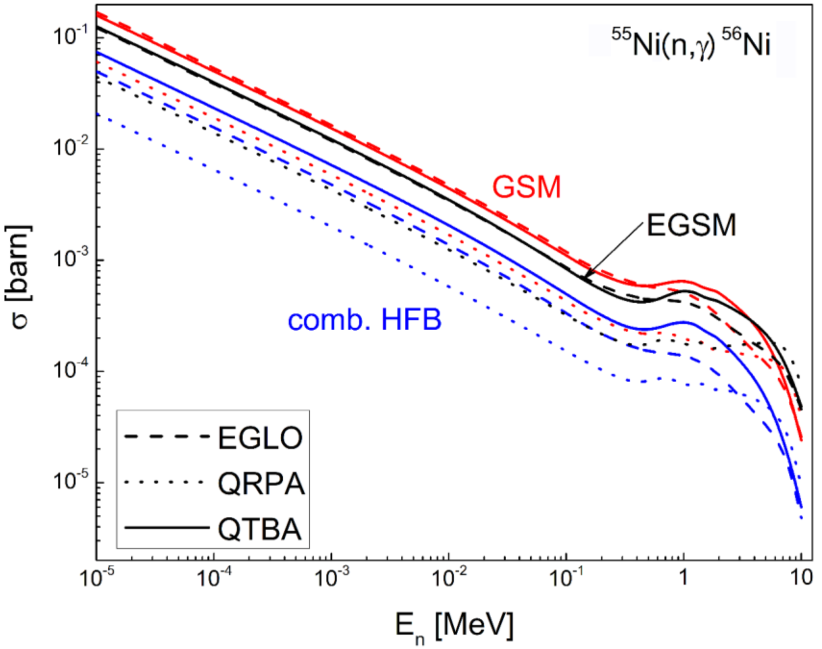


Very large difference between the results obtained with the traditional GSM and others NLD models (Enhanced GSM and combinatorial HFB)

Difference between the results obtained with CRPA and CTBA for one NLD model is much smaller than for different NLD models

Neutron capture for ^{131}Sn and ^{55}Ni





Average radiative width

Nuclei	NLD model	EGLO	RPA	TBA	System.	M1 contrib.
^{208}Pb	GSM	10,56	4,44	4,61	5070 3770	0,79
	EGSM	6292	2562	2109		6,56
	Comb. HFB	2734	2973	2448		5,25
^{132}Sn	GSM	398	133	148		40,9
	EGSM	7340	4675	5186		515,3
	Comb. HFB	4444	4279	4259		340,7
^{56}Ni	GSM	2279	270	656	2800	73,0
	EGSM	8073	1790	4160		201,7
	Comb. HFB	3132	647	1794		128,1

System. data: S. F. Mughabghab, *Atlas of Neutron Resonances, Resonance Parameters and Thermal Cross Sections Z = 1–100* (Elsevier, Amsterdam, 2006)

For ^{208}Pb:
D_0(GSM) = 0.00441 keV
D_0(EGSM) = 32.0 keV
D_0(HFB) = 37.6 keV
<u>D_0(exp) = 30 (8) keV</u>

For double magic nuclei contribution of PC to radiative characteristics is not so noticeable as compared with the semi-magic nuclei

It turned out that the contribution of the **M1 resonance** (Bohr model) is rather small

Conclusions

- **Our results showed <u>the necessity of inclusion both the QRPA and PC effects</u> for description of radiative nuclear data for magic and semi-magic nuclei, first of all for PSFs.** A reasonable agreement with experiment due to PC has been already obtained for ^{208}Pb and Sn isotopes.
- We have more pronounced PSF structure for double magic nuclei than for semi-magic nuclei
- For ^{208}Pb and ^{132}Sn the contribution of PC to radiative neutron capture cross sections and average radiative widths is not so noticeable as compared with the semi-magic nuclei
- For ^{208}Pb in PDR region transitions between excited states also could be measured by Oslo group
- GSM NLD model in EMPIRE is not suitable for description of characteristics in double-magic nuclei

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Thanks you for your attention !