Covariant density functional Theory:

a) The impact of pairing correlations on the fission barriers

b) The role of pion

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b) The role of pion

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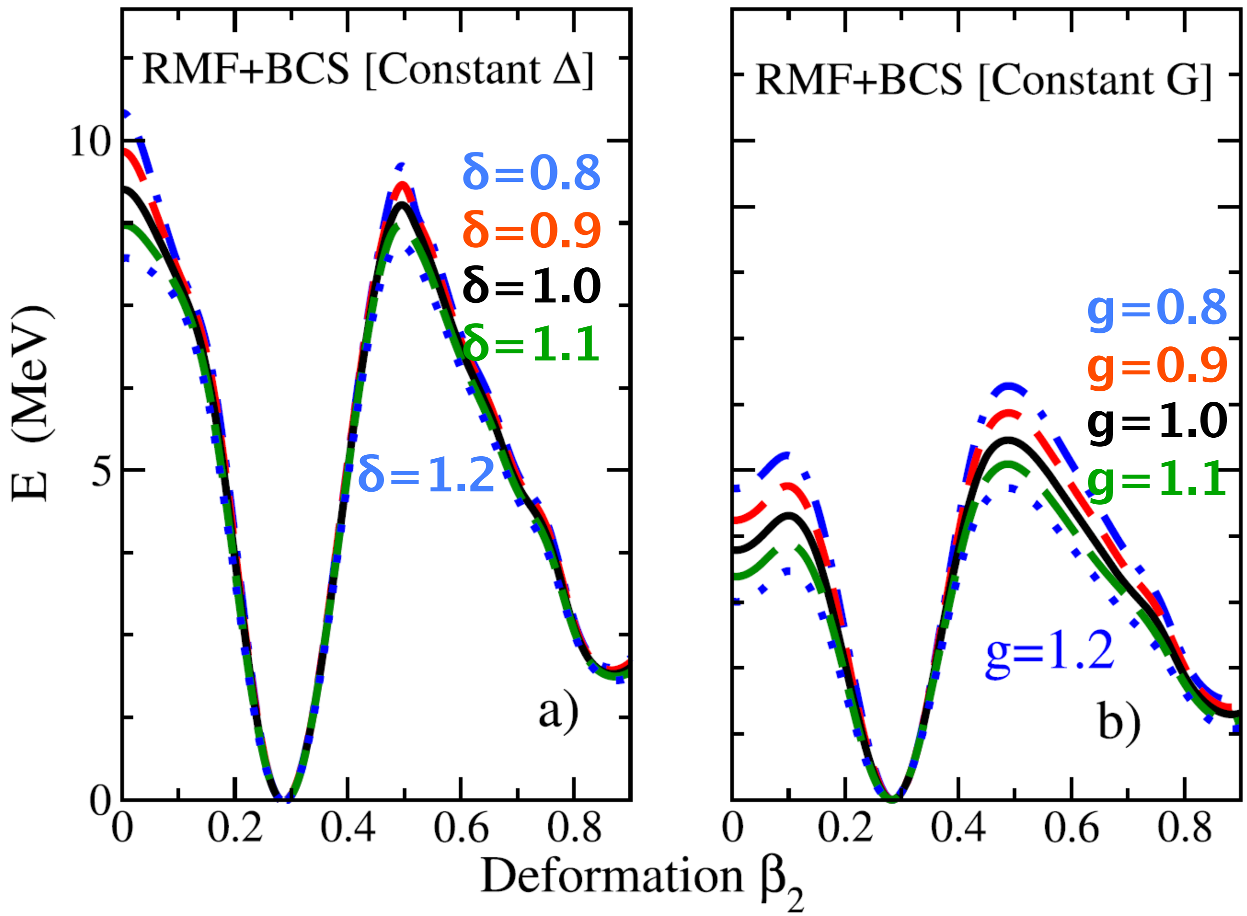


Monopole pairing

$$G = \Delta \Big/ \sum_k u_k v_k .$$

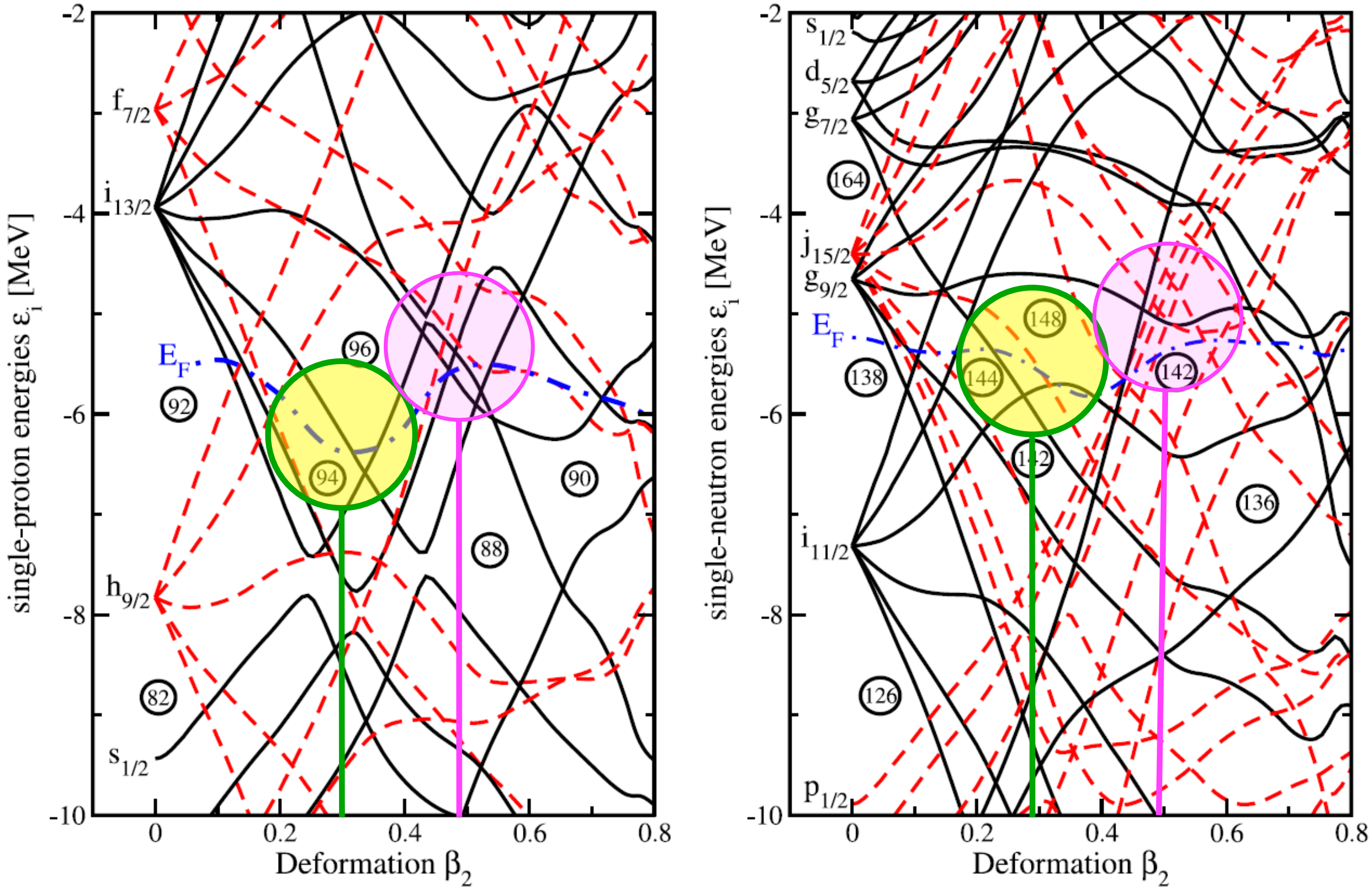
^{240}Pu

- Constant Δ:
  the gap $\Delta = \delta * \Delta_0$ is kept constant along the fission path (not selfconsistent)

- Constant G:
  the interaction $G = g * G_0$ is kept constant, i.e. the gap changes (self-consistent)

(Karatzikos et al, PLB 689, 72 (2010))

The level density changes along the fission path:



^{240}Pu

groundstate: low level density

top of barrier: high level density

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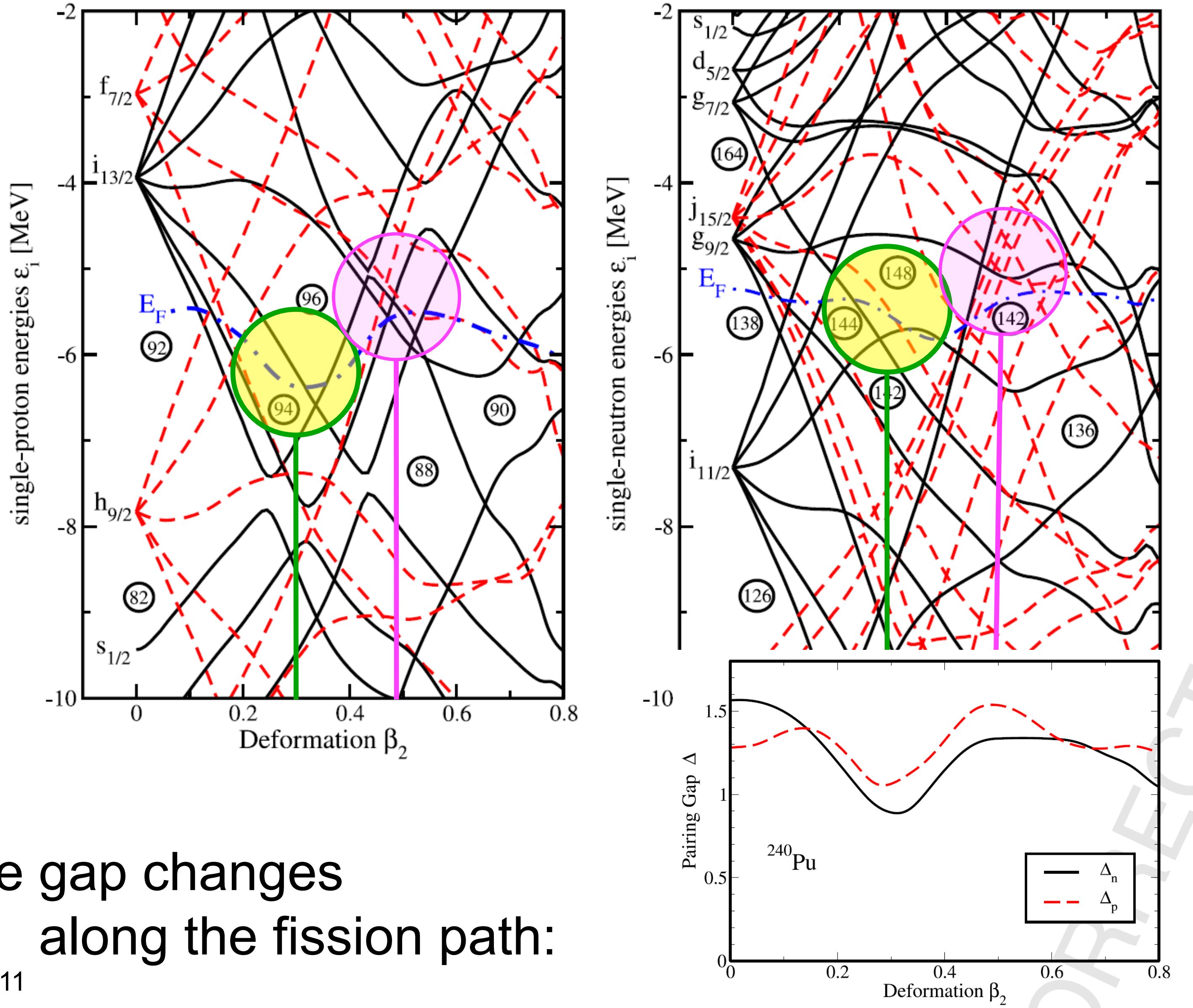
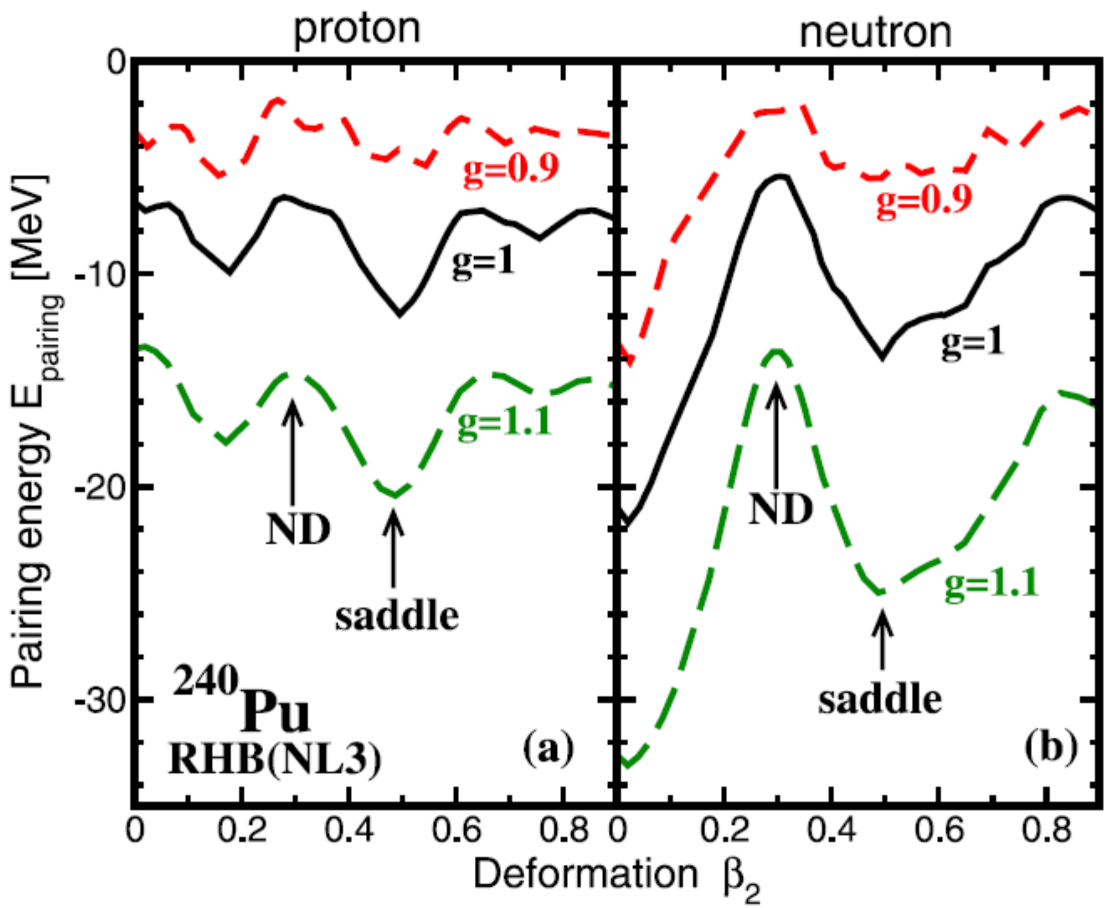
The level density changes along the fission path



^{240}Pu

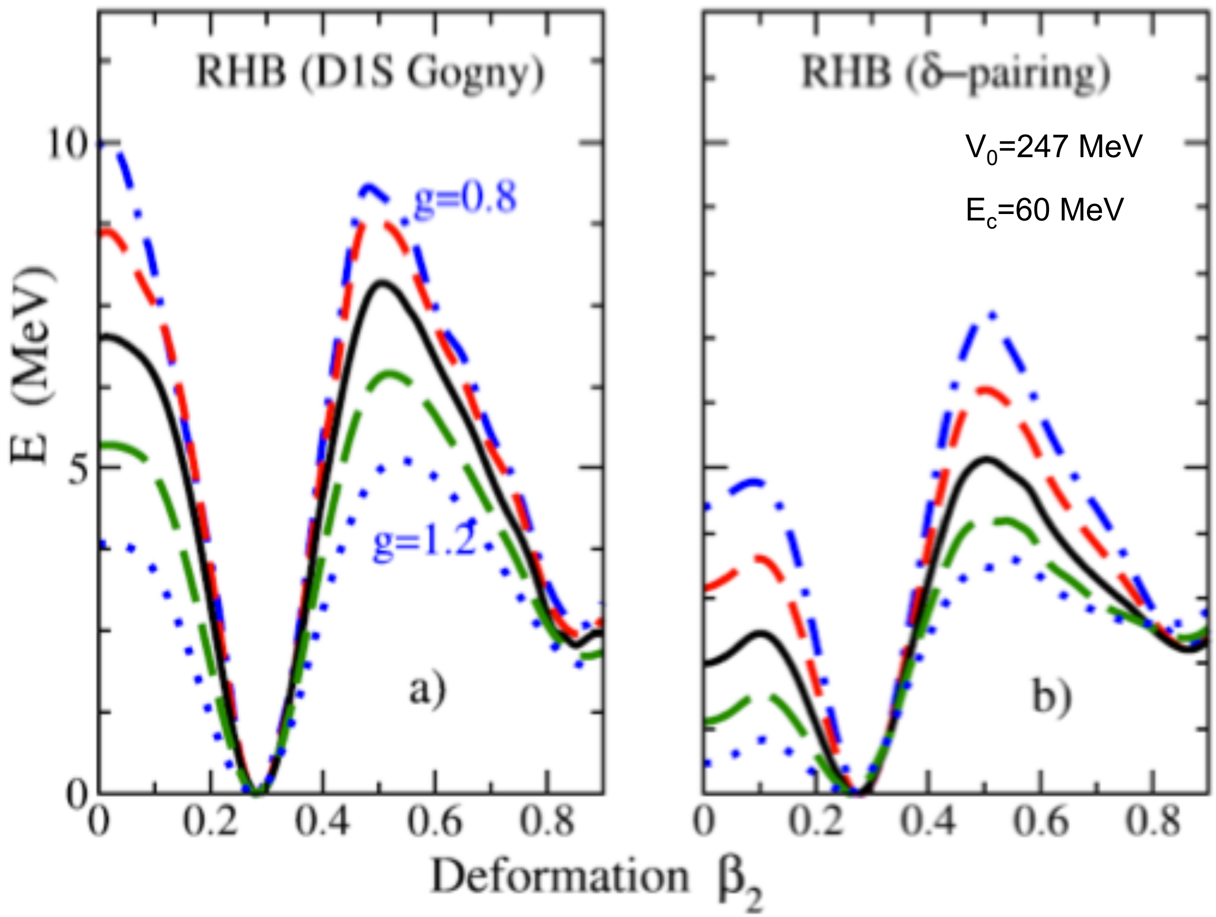
the gap changes
along the fission path:

The pairing energy changes along the fission path:



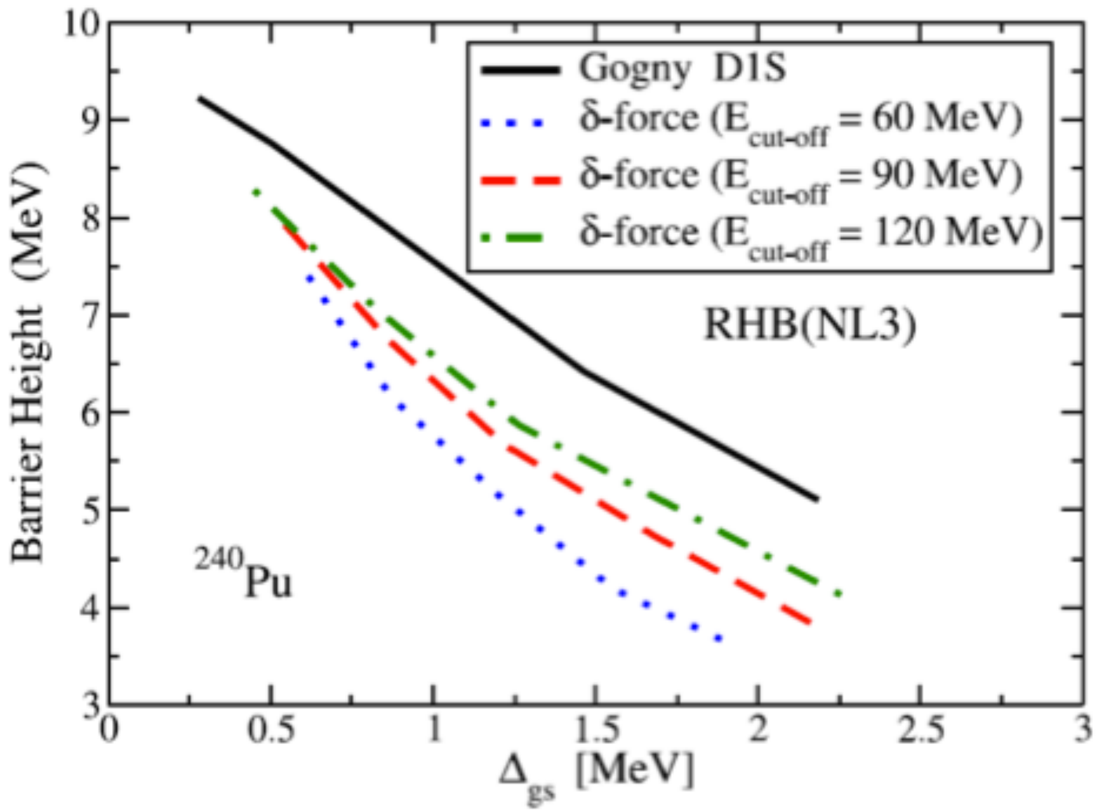
$$V^{\mathrm{pp}}(1,2) \rightarrow g V^{\mathrm{pp}}(1,2)$$

The same behavious is found for Gogny- or δ-pairing:



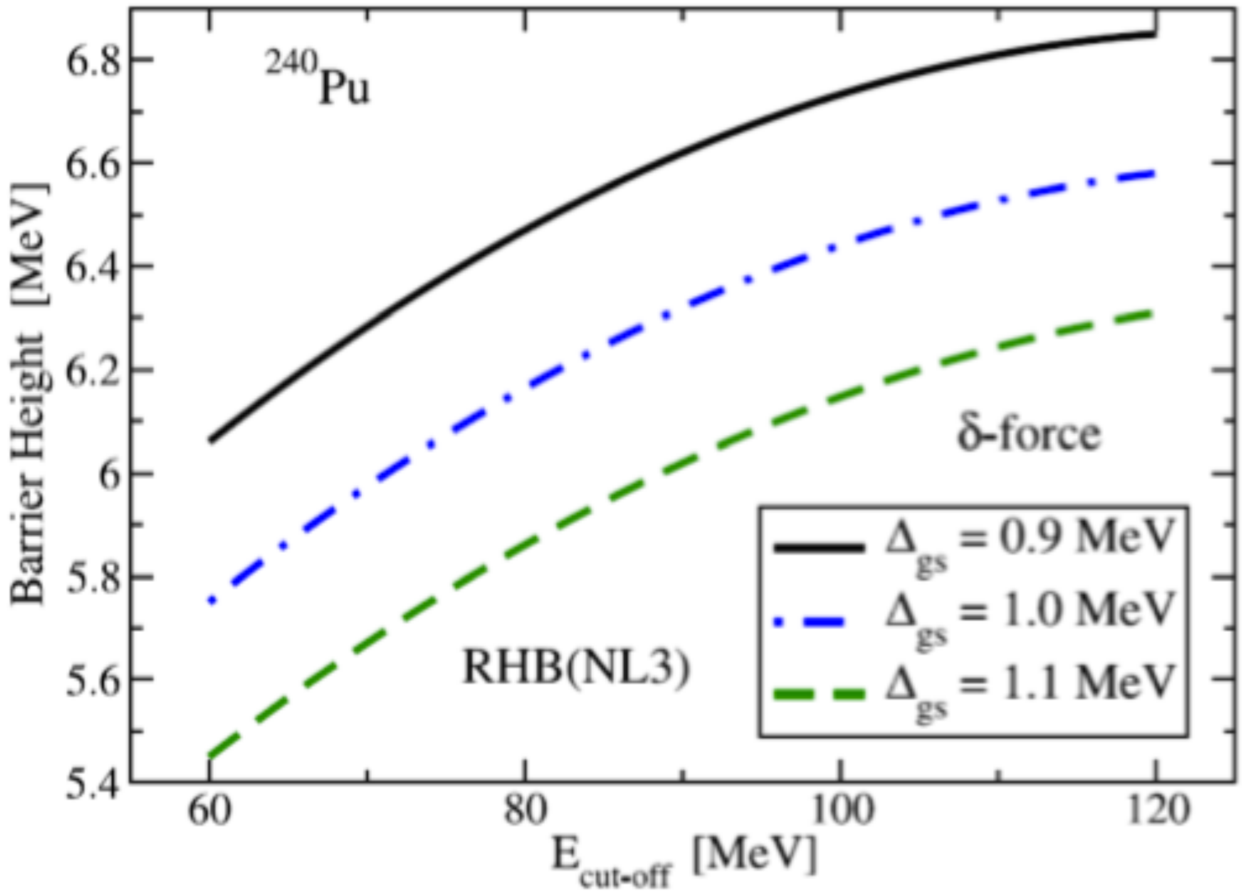
The gap parametes for both forces at the ground state are nearly identical.
This is no longer the case on the top of the barrier
It all depends on the cut-off energy Ec of the δ-force

The barrier height as a function of the gap at the ground state:



The change of pairing energy between the top of the barrier the ground state decreases with increasing pairing correlations.

This difference depends also on the cut-off energy zero-range pairing: barrier height depends on the cut-off:



This can change the barrier height B_f by 0.6 – 0.8 MeV

Conclusions:

- pairing has a strong influence on the barrier height

- changes of the level density along the fission path produce changes of pairing

- the constant gap approximation fails completely

- with increasing pairing the barrier height decreases

- monopole-pairing and zero-range pairing need cut-off

- barrier height B_f depends on the cut-off energy

The role of pion
Facts to the tensor force:

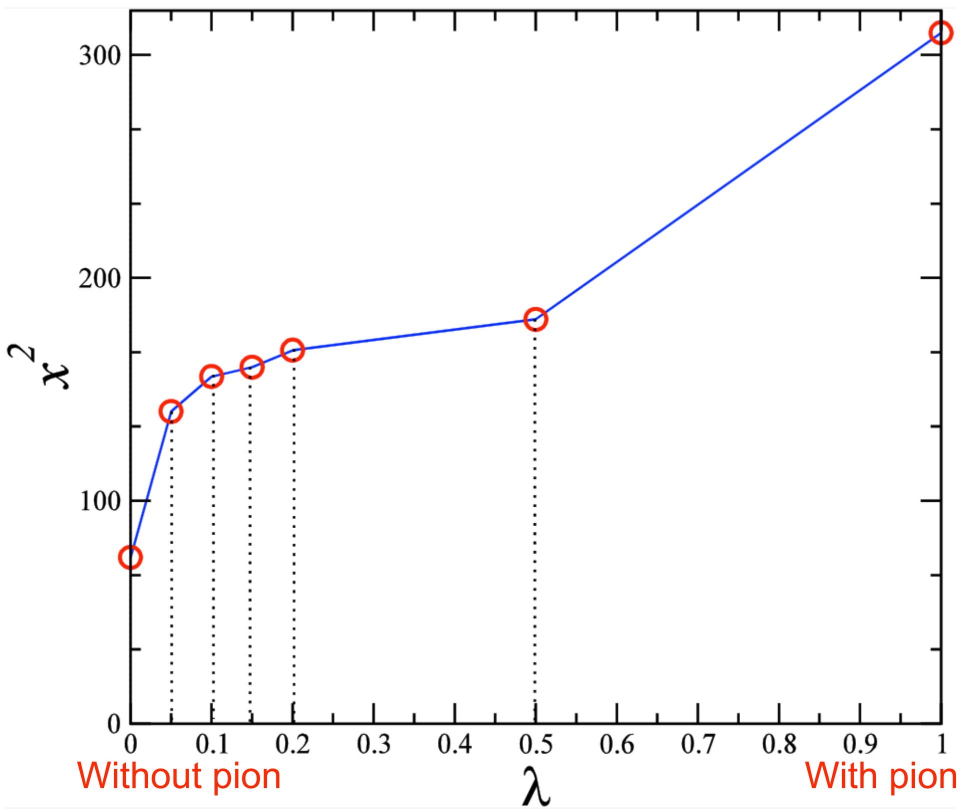
- The bare nuclear force has a strong tensor component (pion exchange)
- Brueckner calculations show a reduced, but not vanisching tensor force in the nuclear medium
- second order tensor is responsible for intermediate nuclear attraction (σ-meson)
- all present successful mean field calculations do not need tensor explicitly
- Usual fits to masses and radii do not like tensor
- relativistic Hartree-Fock calculations with pion have tensor strength has to be reduced (density dependent) (V. Giai)

Further observations :

- effective single particle energies in shell-model calculations show specific trends due to the tensor force, which agrees with many data (Otsuka, Schiffer, Greavy)

- the same trend can be found qualitatively if one added a the pion with an effective coupling constant in fully selfconsistent RHF calculations (Giai)

- particle-vibrational coupling is also important (Colo)

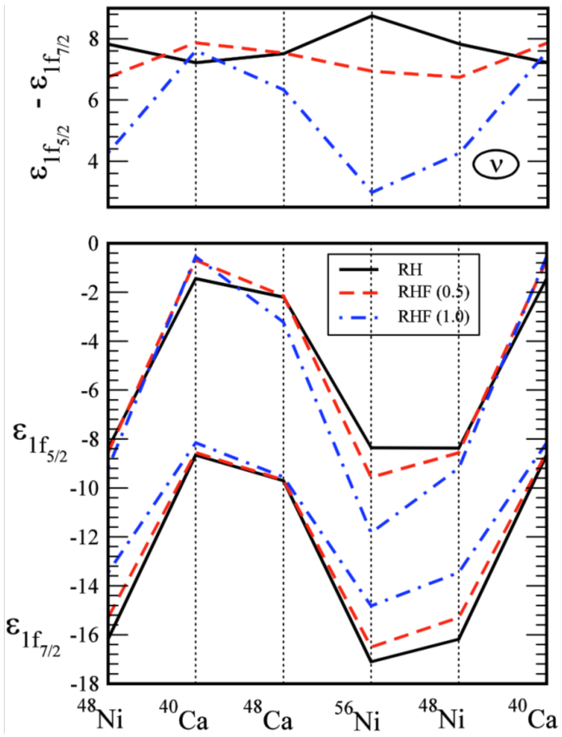


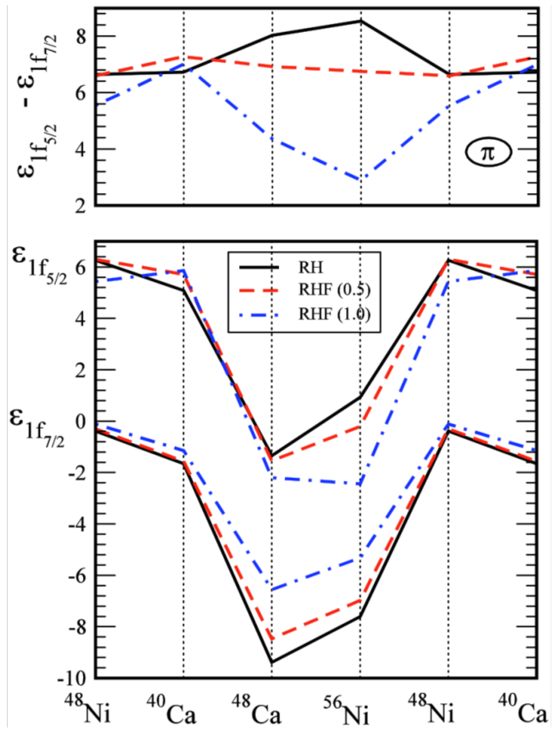
$E[\rho,\varphi]= E_{RMF}[\rho,\varphi]+E_{\pi}[\rho]$,
$\varphi_m = \sigma,\omega,\rho,A$

The parameters are adjusted for various coupling strength of the pion field ($f_{\pi}^2=\lambda f_{\pi}^{2(free)}$) by extensive multiparameter χ^2 minimization procedures to reproduce bulk properties of infinite nuclear matter and spherical nuclei.

The model does not favor the pion field

	RHF(1.0)	RHF(0.5)	RH
M (MeV)	939.000	939.000	939.000
$m_\pi (MeV)$	138.000	138.000	138.000
m_σ (MeV)	511.741	511.272	505.967
m_ω (MeV)	782.501	782.501	782.238
m_ρ (MeV)	763.000	763.000	763.000
g_σ	10.442	10.532	10.189
g_ω	13.677	13.588	12.899
g_ρ	3.606	4.222	4.589
g_2 (fm^{-1})	-7.192	-8.417	-10.209
g_3	-23.248	-26.468	-28.612
λ	1.00	0.50	0.00
χ^2	310.00	168.00	75.00





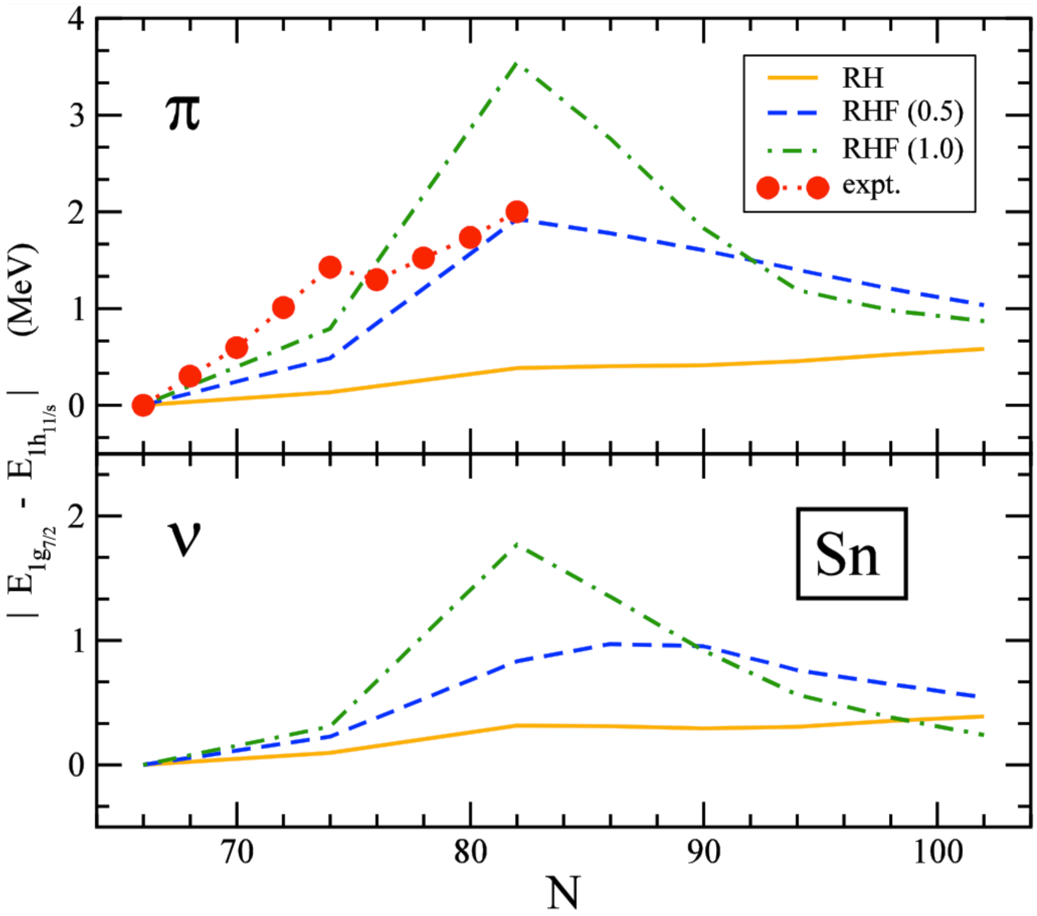
Tensor force: proton with $j_{>}=l_{\pi}+1/2$ and v.v
neutron with $j_{<}=l_{\nu}-1/2$

Strongly attractive

Tensor force: proton with $j_{>}=l_{\pi}+1/2$ or antiparallel
neutron with $j_{>}=l_{\nu}+1/2$

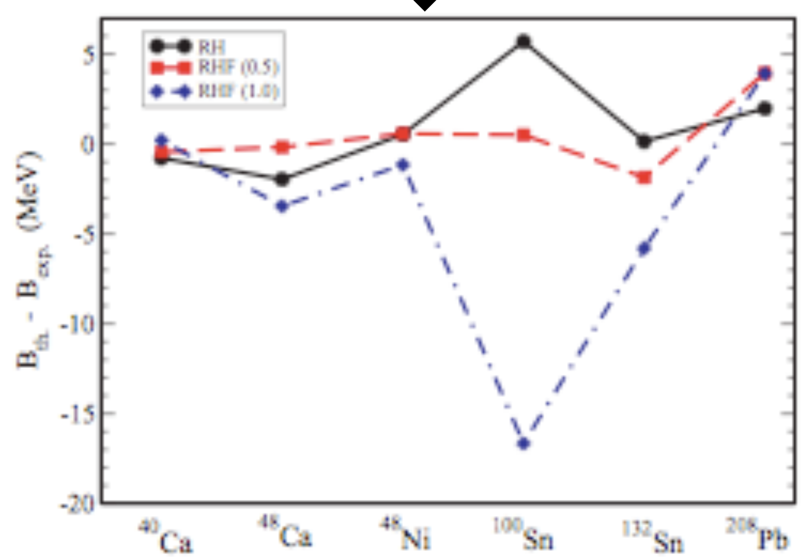
Strongly repulsive

Otsuka et al P.R.L 95,232502, (2005)



The energy difference between $\pi 1h_{1/2}$ and $\pi 1g_{7/2}$ orbits observed in Sn(a,t) in Argonne can be reproduced for roughly half the strength of the tensor force produced by the free pion.

Influence of the tensor force on the binding energies in close shell nuclei where only one of the spin partners is occupied.



G.L, S. Karatzikos, M. Serra, T. Otsuka and P. Ring
Phys. Rev. C80 041301 (R) (2009)

- The conventional RMF model is extended including the pion degree of freedom on the Hartree-Fock level

- The inclusion of pion does not destroy the overall description of the bulk properties

- The noncentral contribution of the pion (tensor part) does have effects on s.p energies and on binding energies of certain nuclei

So far on the mean field level
No coupling to low lying surface phonos
Much work is left !

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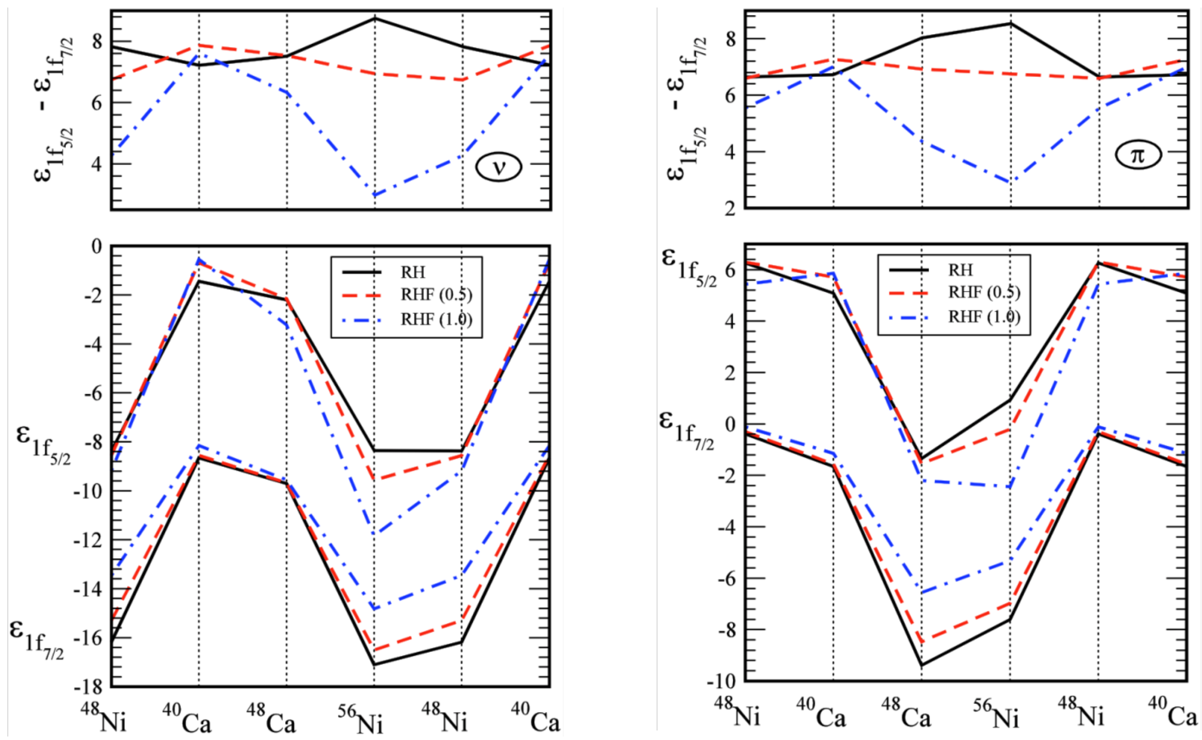
- particle-vibrational coupling is also important

Much work is left !



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neutron with $j_{<}=l_{\nu}-1/2$

Strongly attractive

Tensor force: proton with $j_{>}=l_{\pi}+1/2$ or antiparallel

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