Nuclear Matrix Elements for Weak Decays

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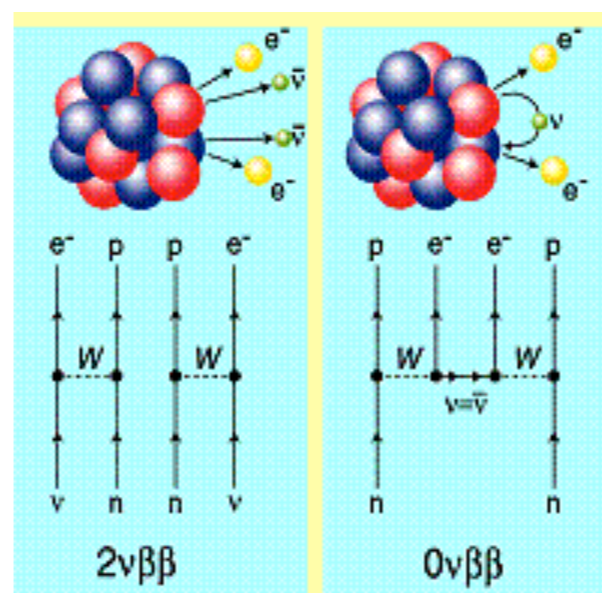
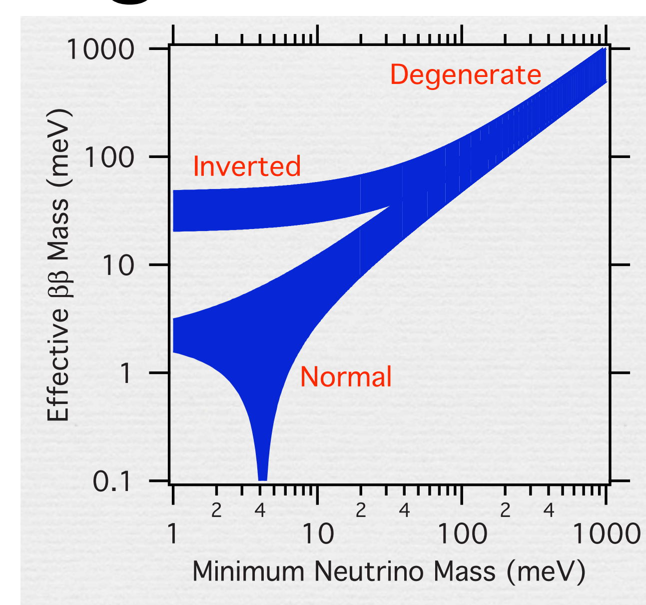
In collaboration with B. A. Brown

Motivation

- Neutrinoless double beta decay has key importance on understanding the nature of neutrino





- Accurate calculations of nuclear matrix elements for these process are crucial

Methods

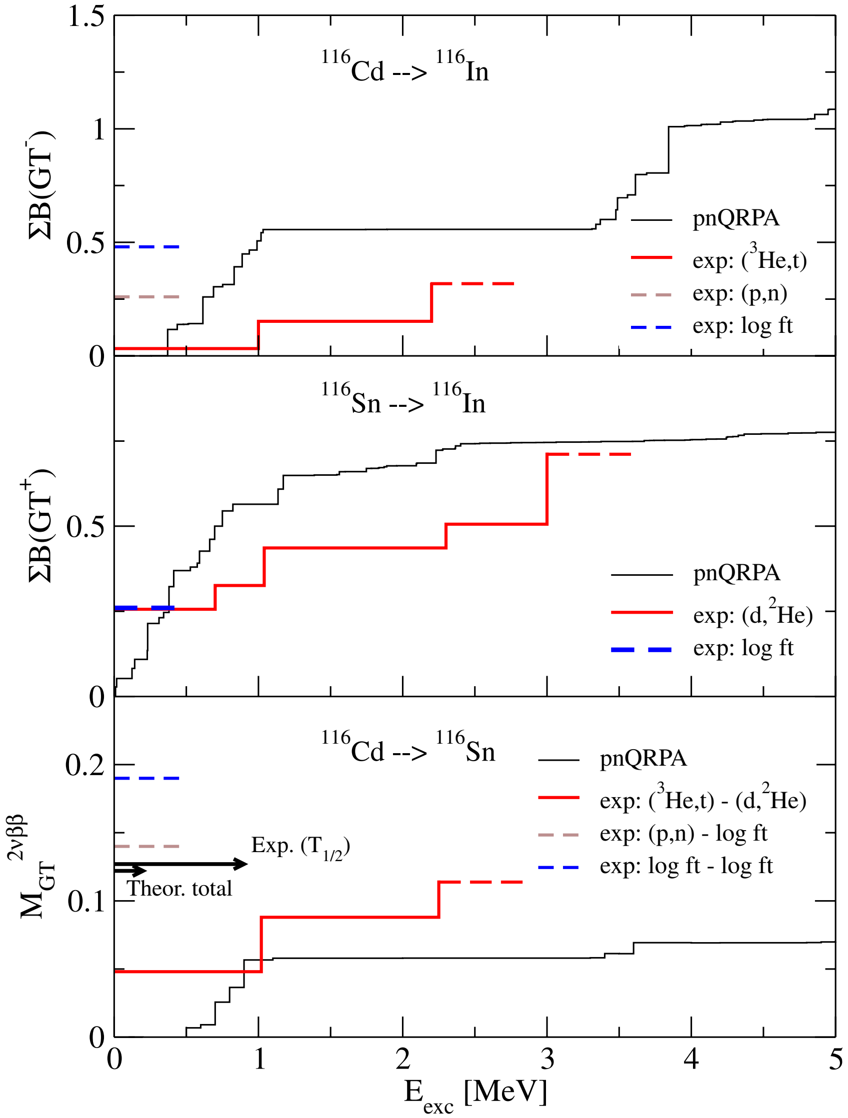
- Methods for NME calculations
  - Shell Model(Configuration-Interactions)
    - limited nuclei
  - QRPA
    - most nuclei but accuracy limited
  - PHBF, IBM, GCM etc.

Running Sum

- Controversy over the hypothesis of Single-State-Dominance (SSD) or Lowlying-State-Dominance (LSD) for $2\nu\beta\beta$ decay
- With the validation of SSD or LSD, the Configuration-Interaction may set the limit over the Matrix elements

Running Sum

- Negative results for SSD or LSD



O. Moreno *et al*, J. Phys. G36(2009)015106

Running Sum

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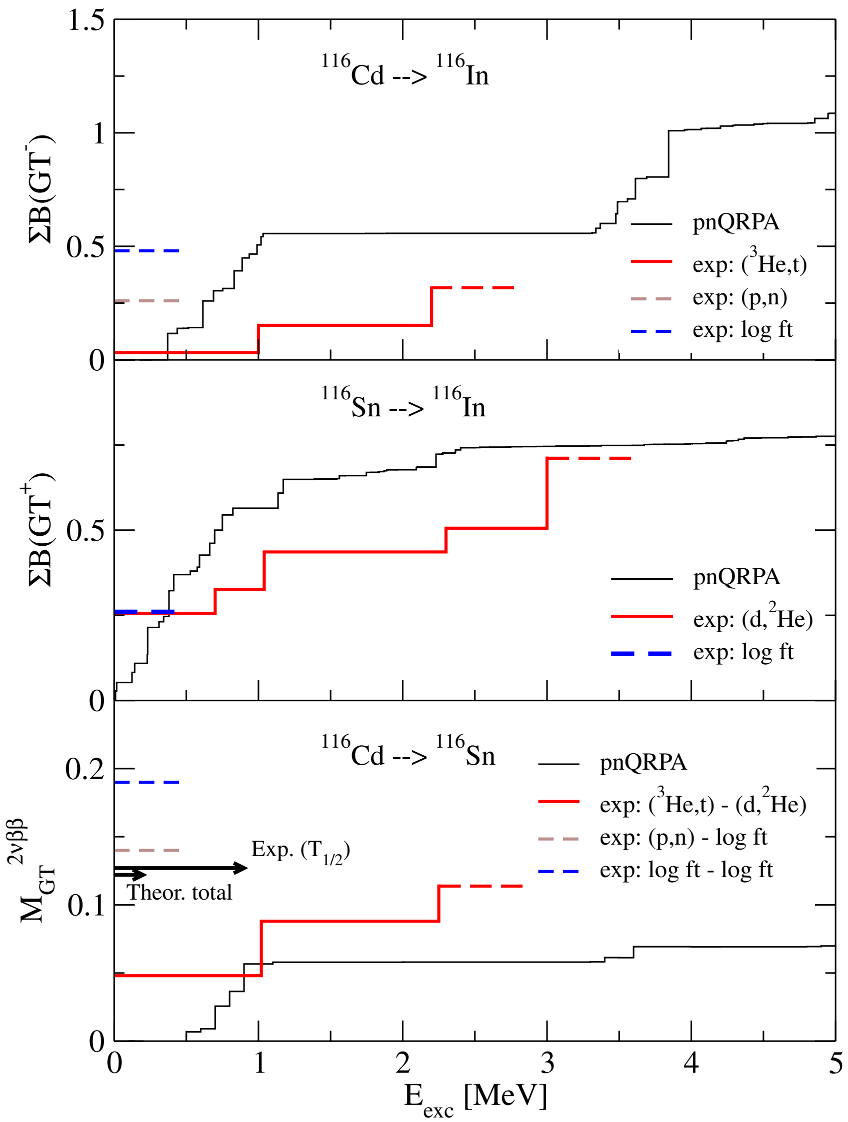

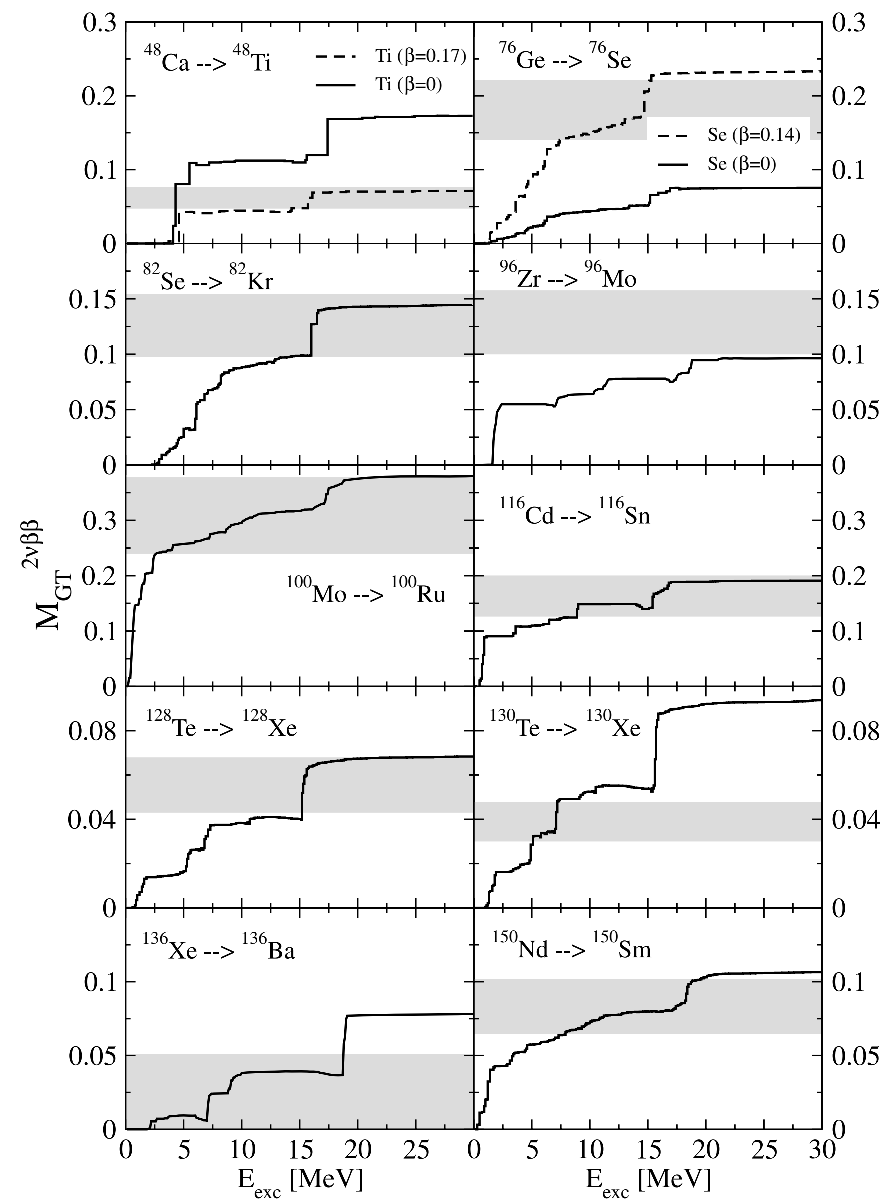

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Running Sum

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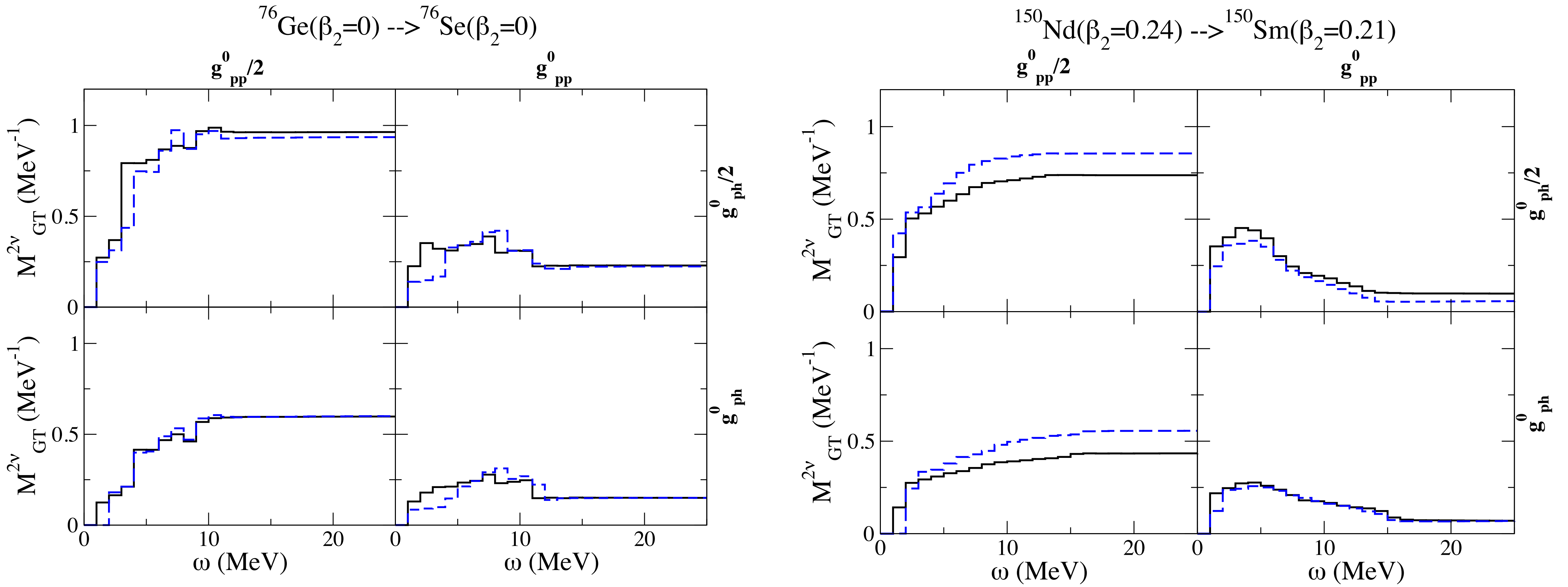


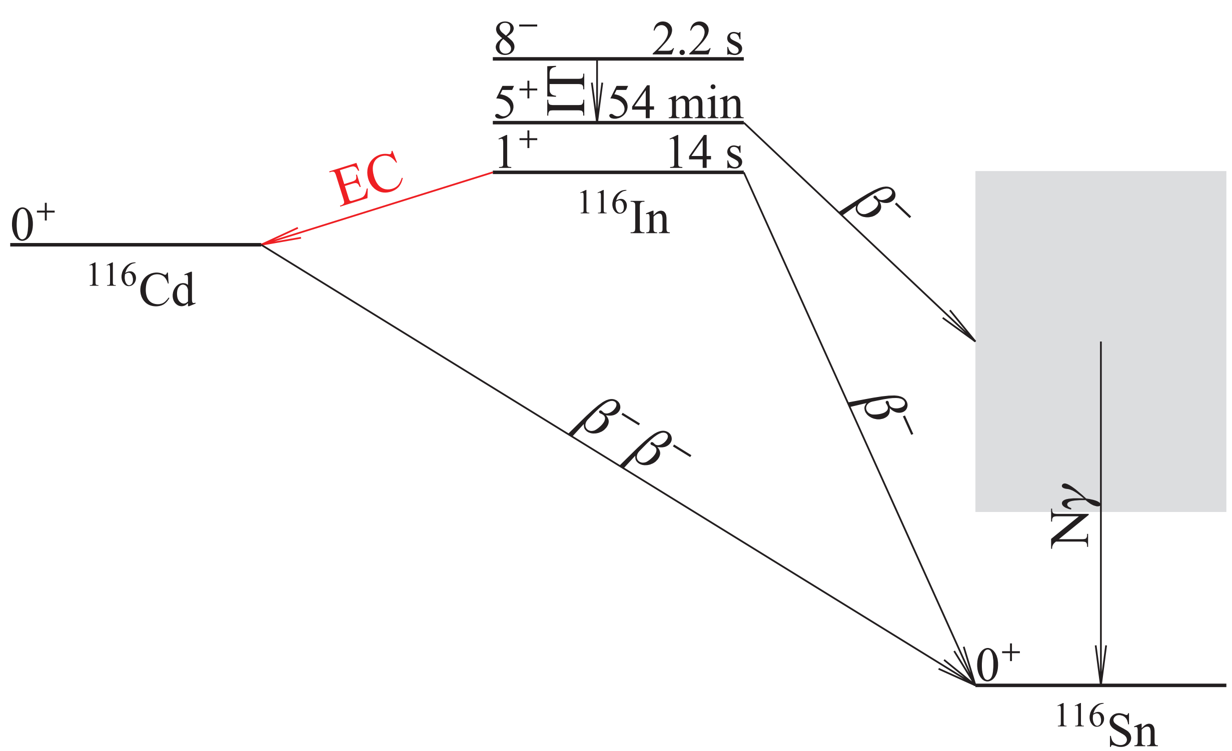
DLF, A. Faesler, V. Rodin, M. S. Yousef and F. Simkovic, PRC81,037303(2009)

Parameters

- The normal procedure of choosing parameters (QRPA with realistic forces)
  - g_{ph} (the position of GTR)
  - g_{pp} (The $2\nu\beta\beta$ matrix element)
  - g_A (Experimental quenching if available)

Parameters

- the decay scheme for intermediate states



Parameters

- Combination of g_A and g_{pp} to connect matrix elements of β^-/EC and $\beta\beta$ when all are experimentally available
  - I. The same g_A and g_{pp} to reproduce the matrix element of β^-/EC and $\beta\beta$ A. Faessler *et al* JPG 35,075104(2008)
  - II. g_{pp} being the same for β^-/EC and $\beta\beta$, but different g_A
  - III. g_A the same for the β^-/EC and $\beta\beta$, but different g_{pp}

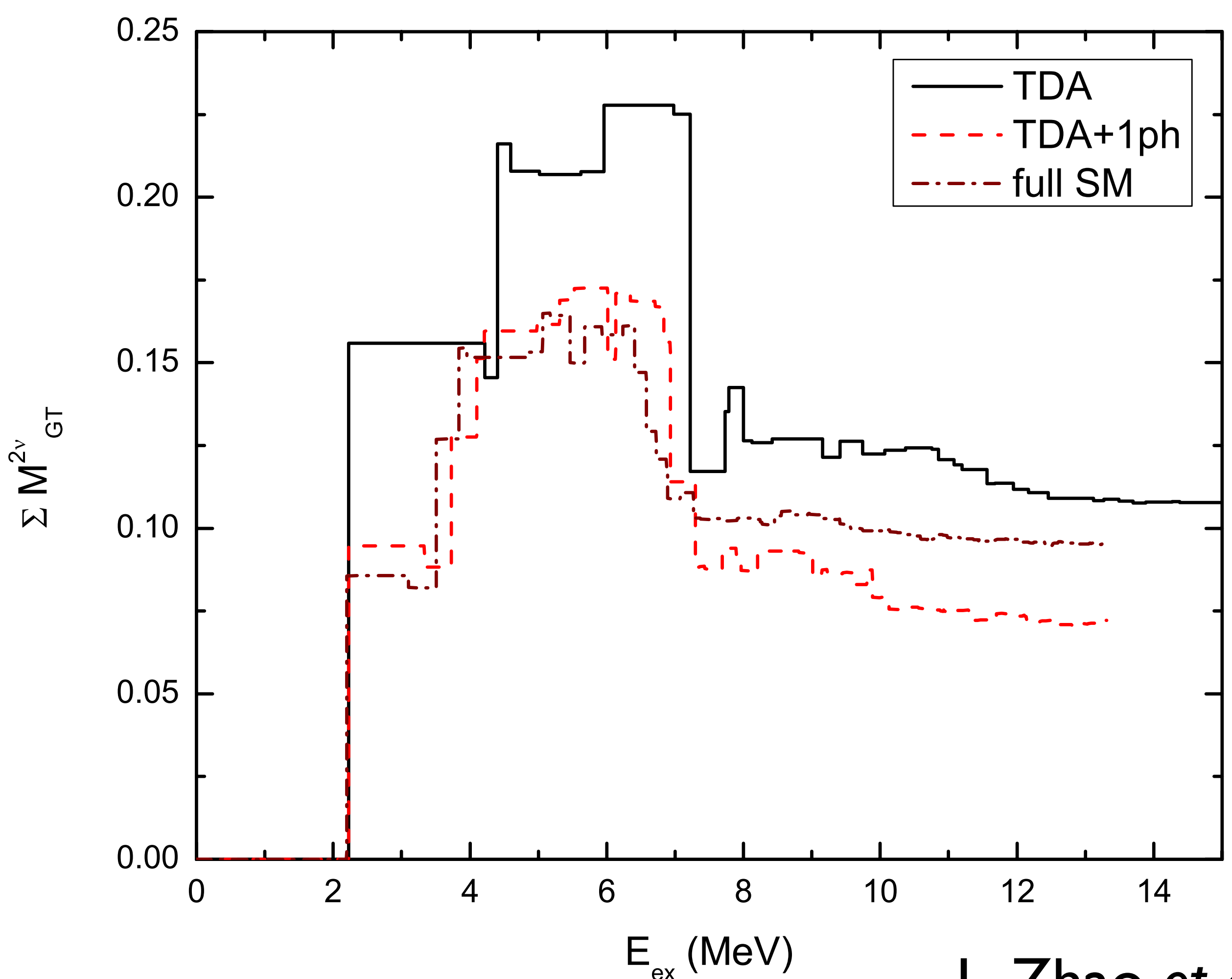
J. Suhonen *et al* PLB725,153(2013)

Parameters

- Are these choices arbitrary?
  - We should be aware of the fact that QRPA is kind of approximation
  - Shell Model as exact soultion on the other hand with proper Hamiltonian could give us some hints
  - However, Shell Model is not available for most ββ isotopes currently except ^{48}Ca

Results

- Running sum for ^{48}Ca



L. Zhao *et al.* PRC**47**,2461(1993)
M. Horoi *et al.* PRC**75,**034303(2007)

Results

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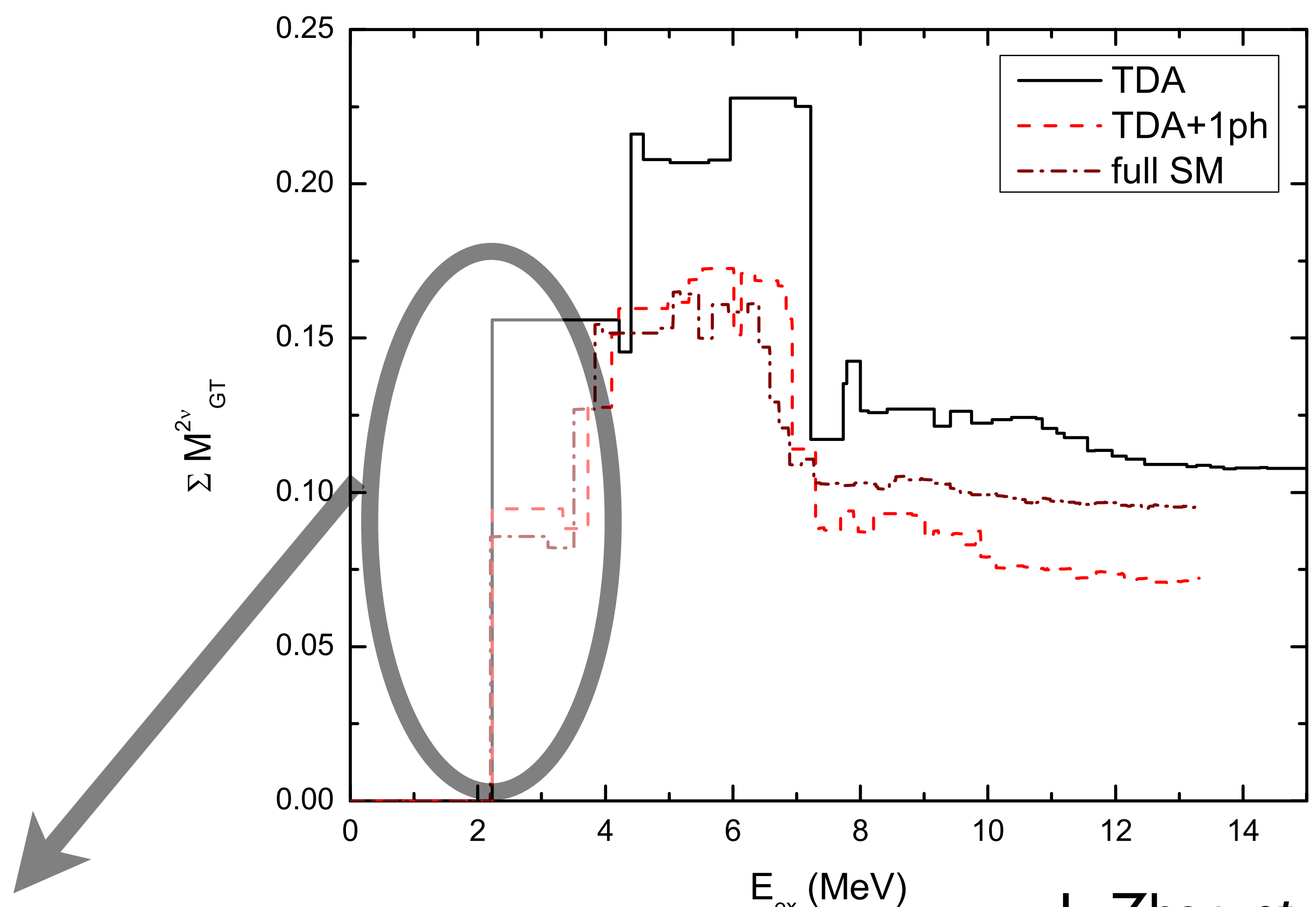

$g_A^{\beta} g_A^{EC}/(g_A^{SM})^2 \sim 0.77$

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L. Zhao *et al.* PRC**47**,2461(1993)
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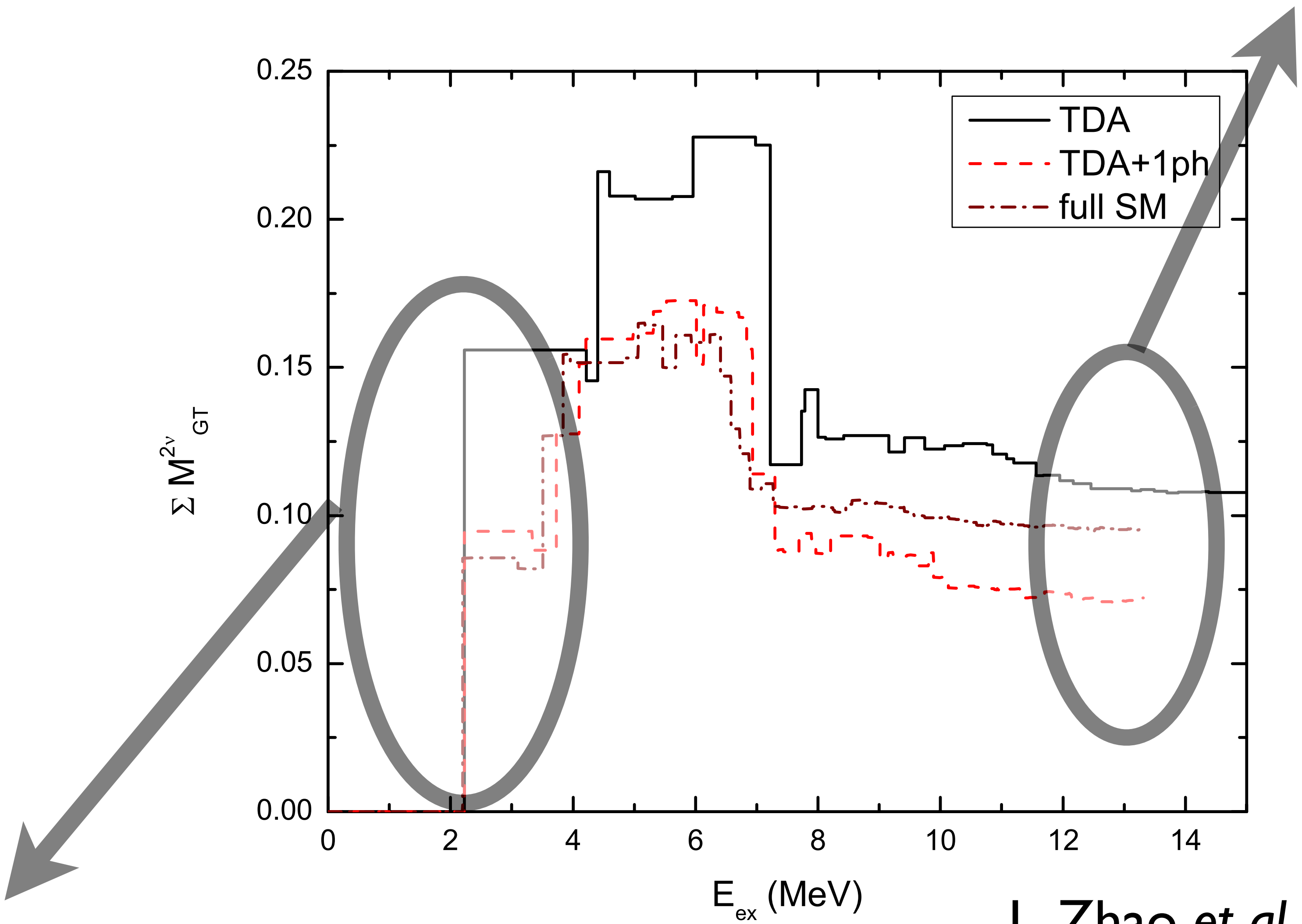
Results

- Running sum for ^{48}Ca

$(g_A^{\beta\beta})^2/(g_A^{SM})^2 \sim 0.90$



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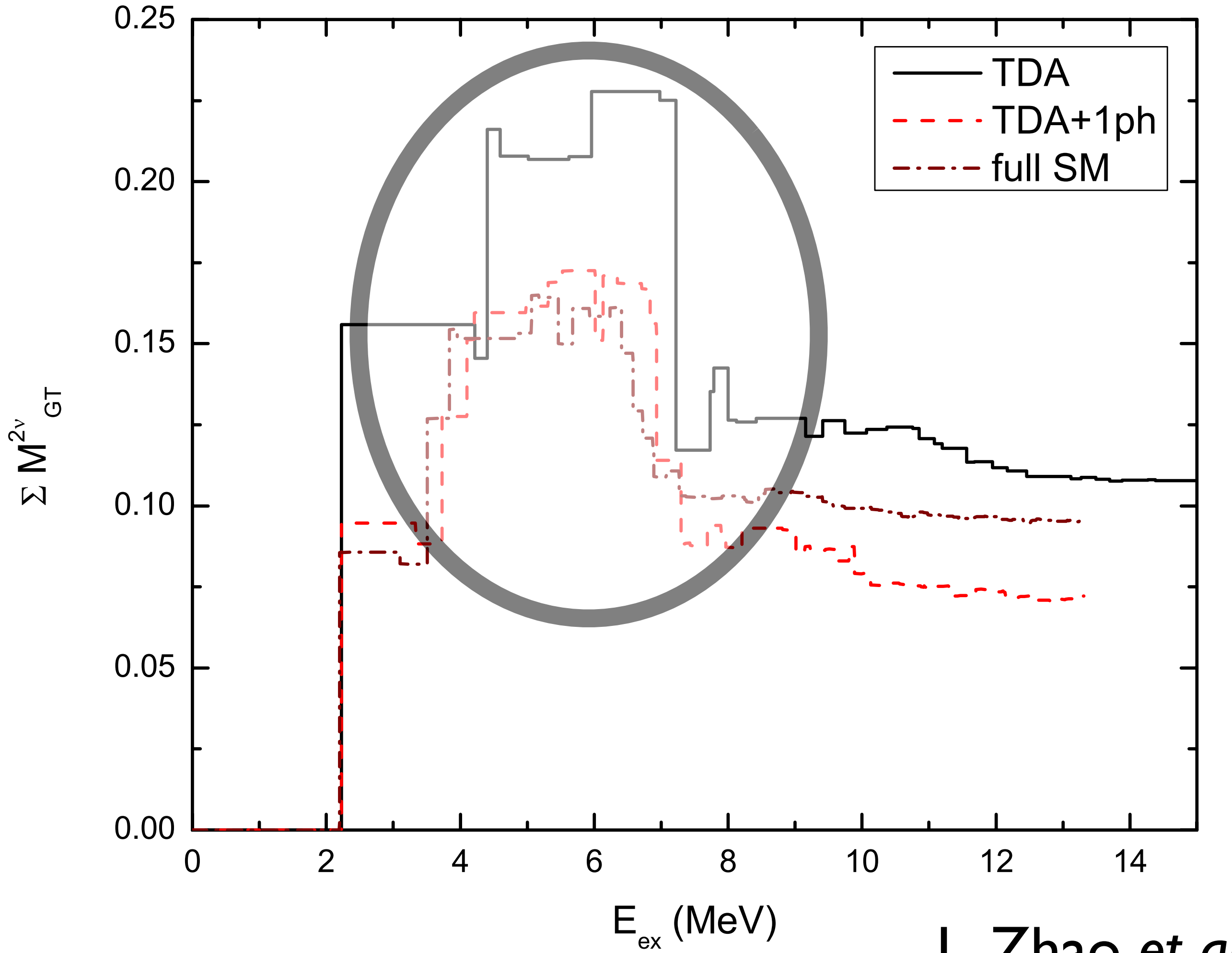

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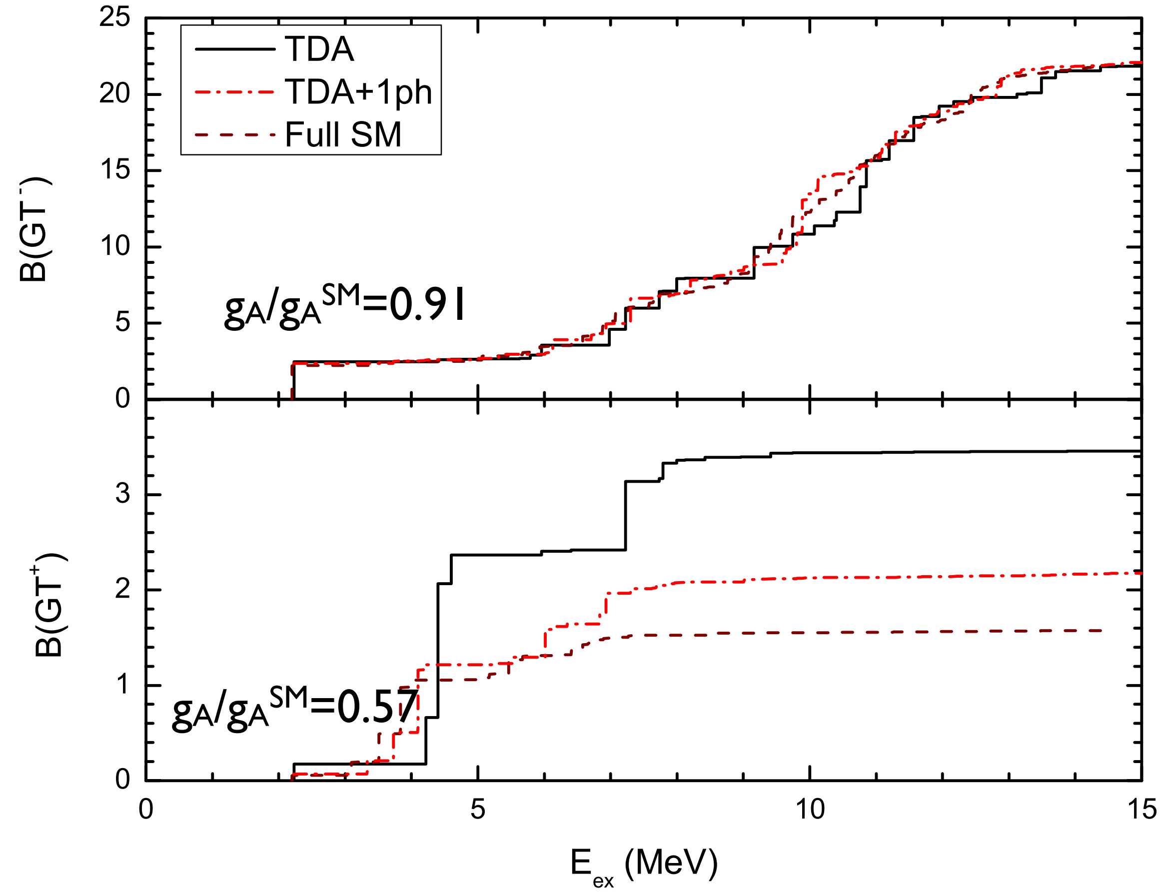
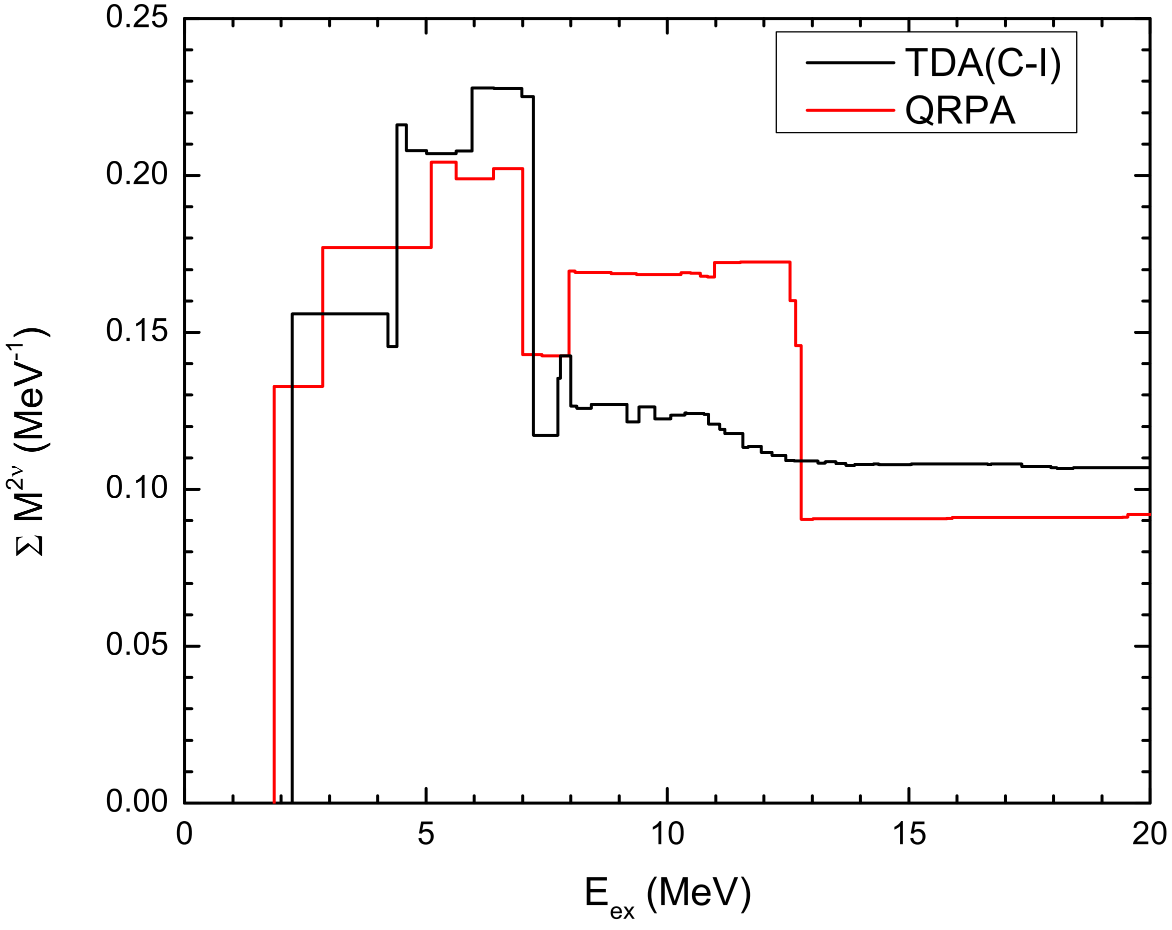
Results

- Different quenching for β^- and EC indicated by Shell Model calculations



Results

- Has it anything to do with QRPA calculations?



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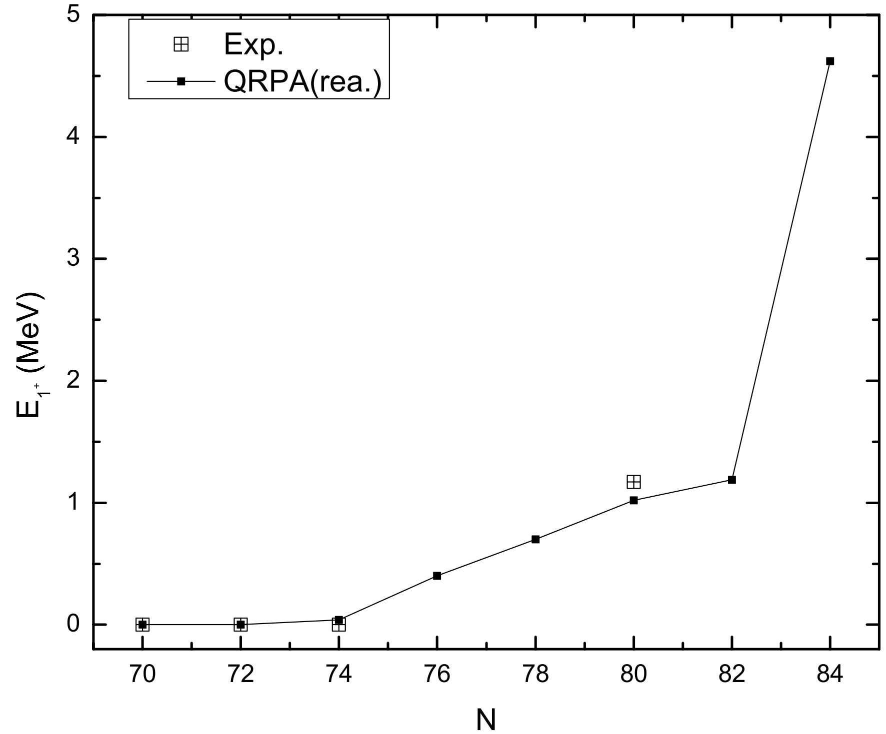
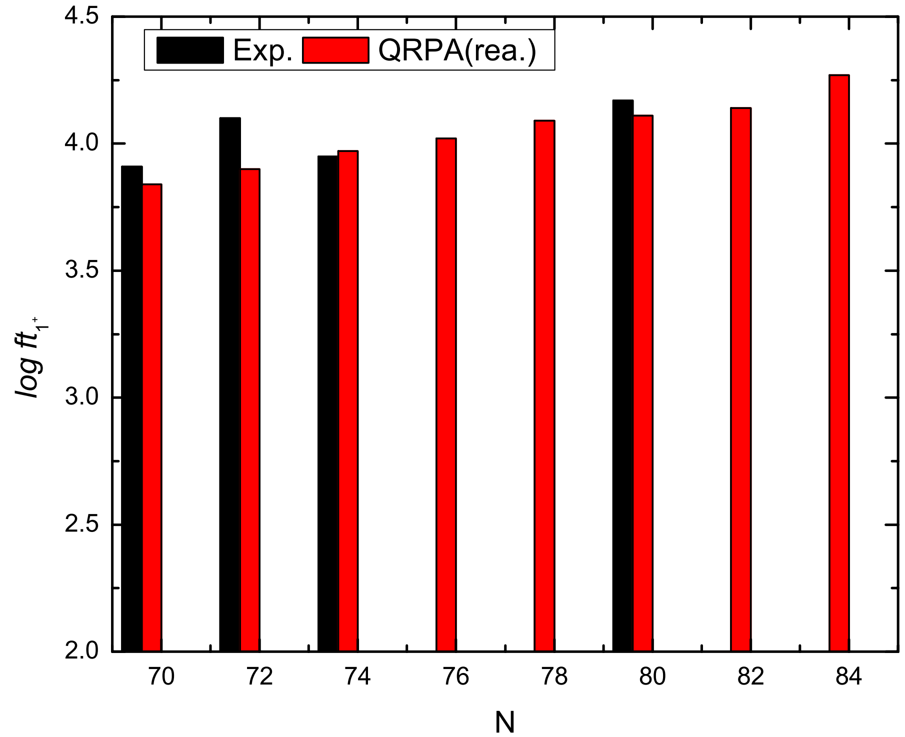
Results

- What have we learnt from Shell Model study
  - effective quenching arising from the fact that QRPA or TDA are approximations to Shell Model
  - experimental quenching which still is a puzzle should be accounted
  - these two quenching mechanisms should be distinguished
  - g_{pp} should be the same or very similar for the grandparent and granddaughter nuclei

Results

Cd Isotopes





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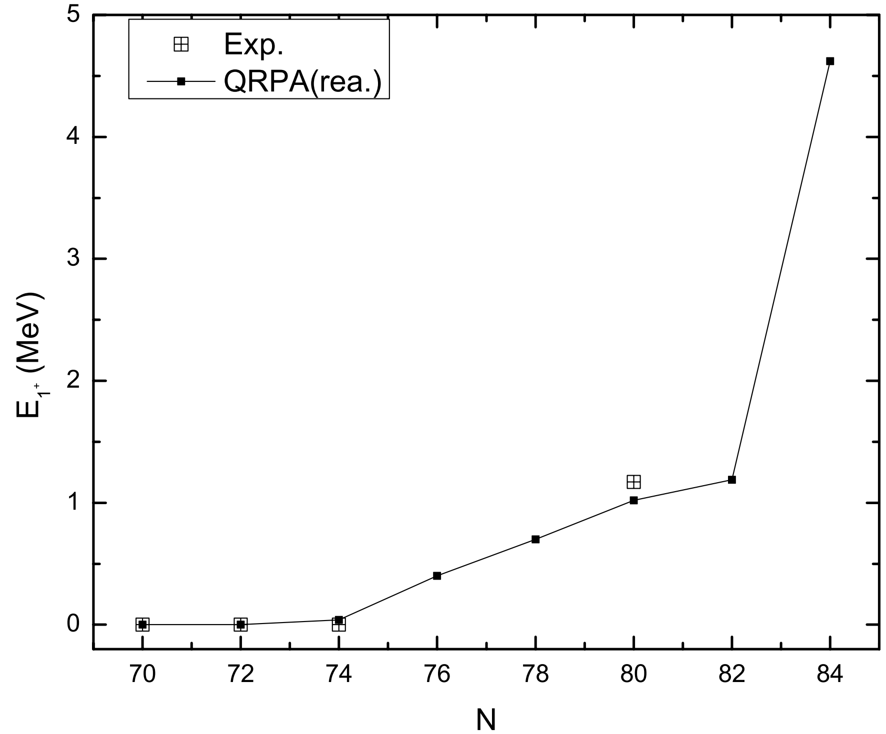
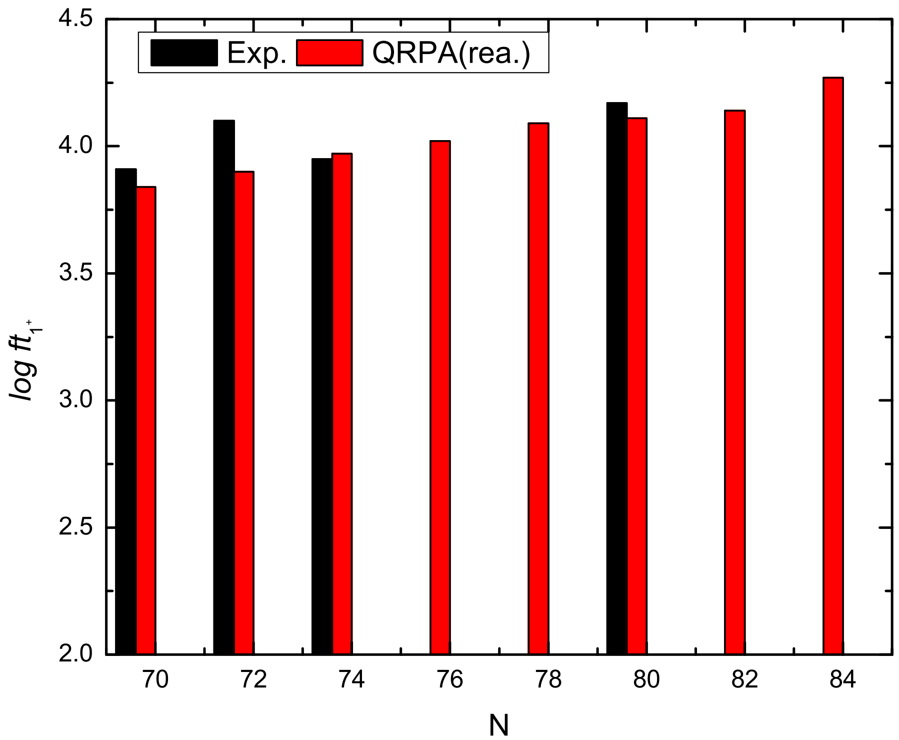
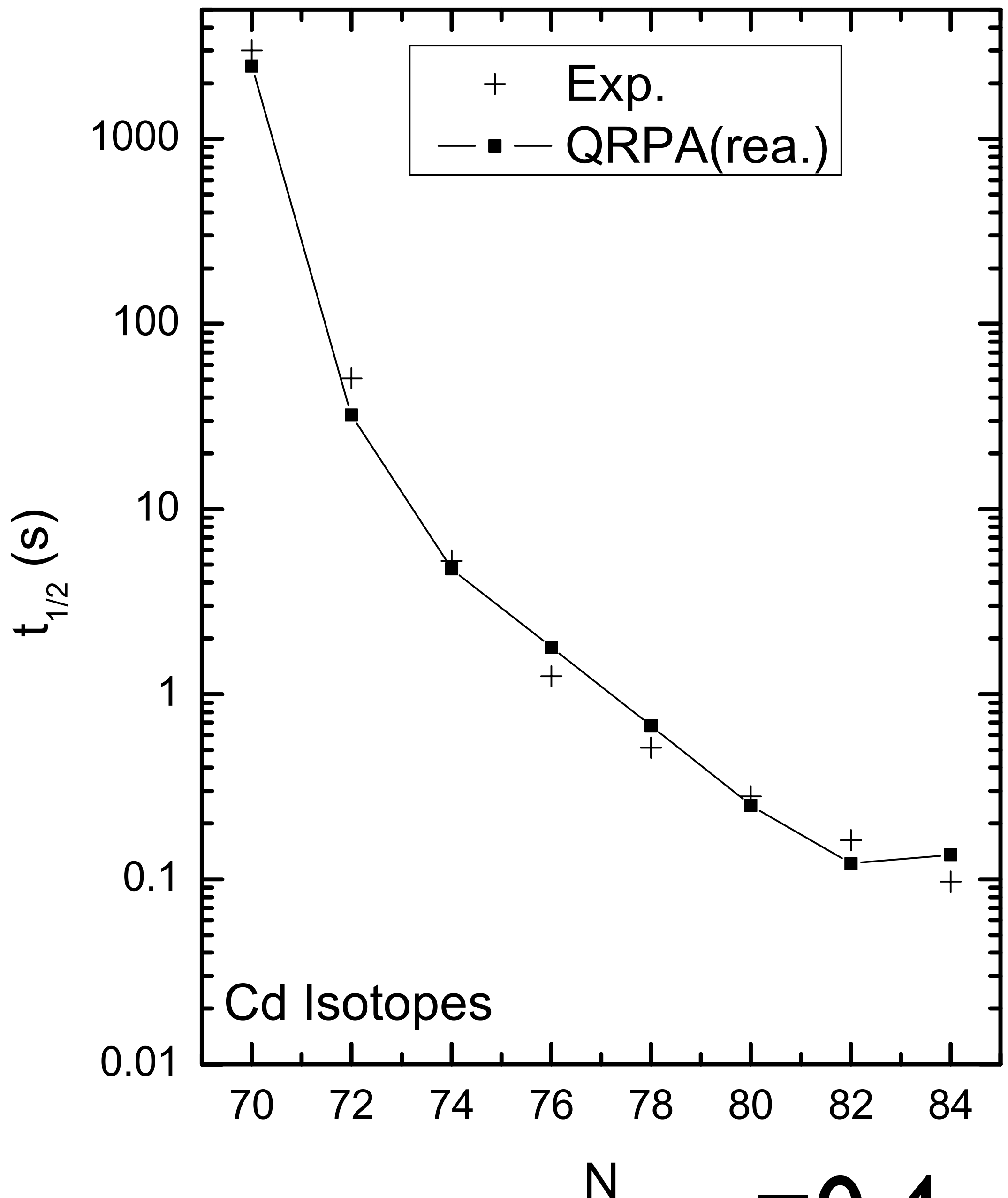
$g_A=0.4,\ g_{pp}=0.8$

Results

Cd Isotopes







g_A=0.4, g_{pp}=0.8

Results

- Results concerning the matrix elements for ^{116}Cd ββ process

Process	Res.	Ref.
(3He,t) $B(GT^{-})1$	0.03	Akimune *et al* PLB394,23(1997)
(p,n) $B(GT^{-})2$	0.26	Sasano *et al* NPA778,76c(2007)
logft (EC) $B(GT^{-})3$	0.39	Bhattacharya *et al* PRC58,1247(1998)
logft (EC) $B(GT^{-})4$	0.402	Wrede *et al* PRC87,031303(2013)
logft (β^{-}) $B(GT^{+})1$	0.25	Blachot NDS92,455(2001)
$M^{2\nu\beta\beta}$	0.128	Barabash PRC81,035501(2010)

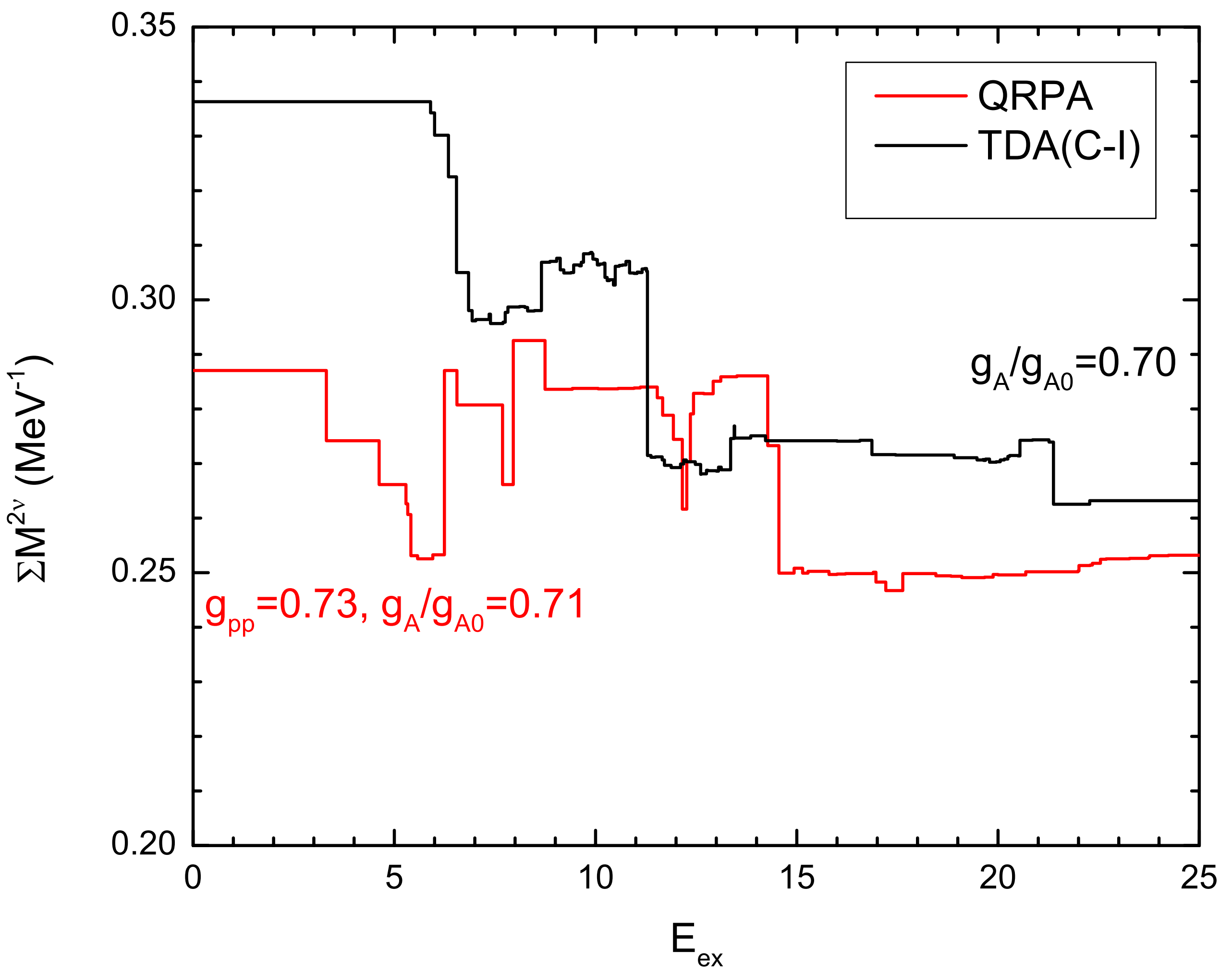
Results

- The SSD hypothesis tested from above data

(-,+)	$M^{2\nu}$ (SSD)	M(SSD)/M(Exp)
1,1	0.046	0.36
2,1	0.136	1.06
3,1	0.167	1.30
4,1	0.170	1.33

Results

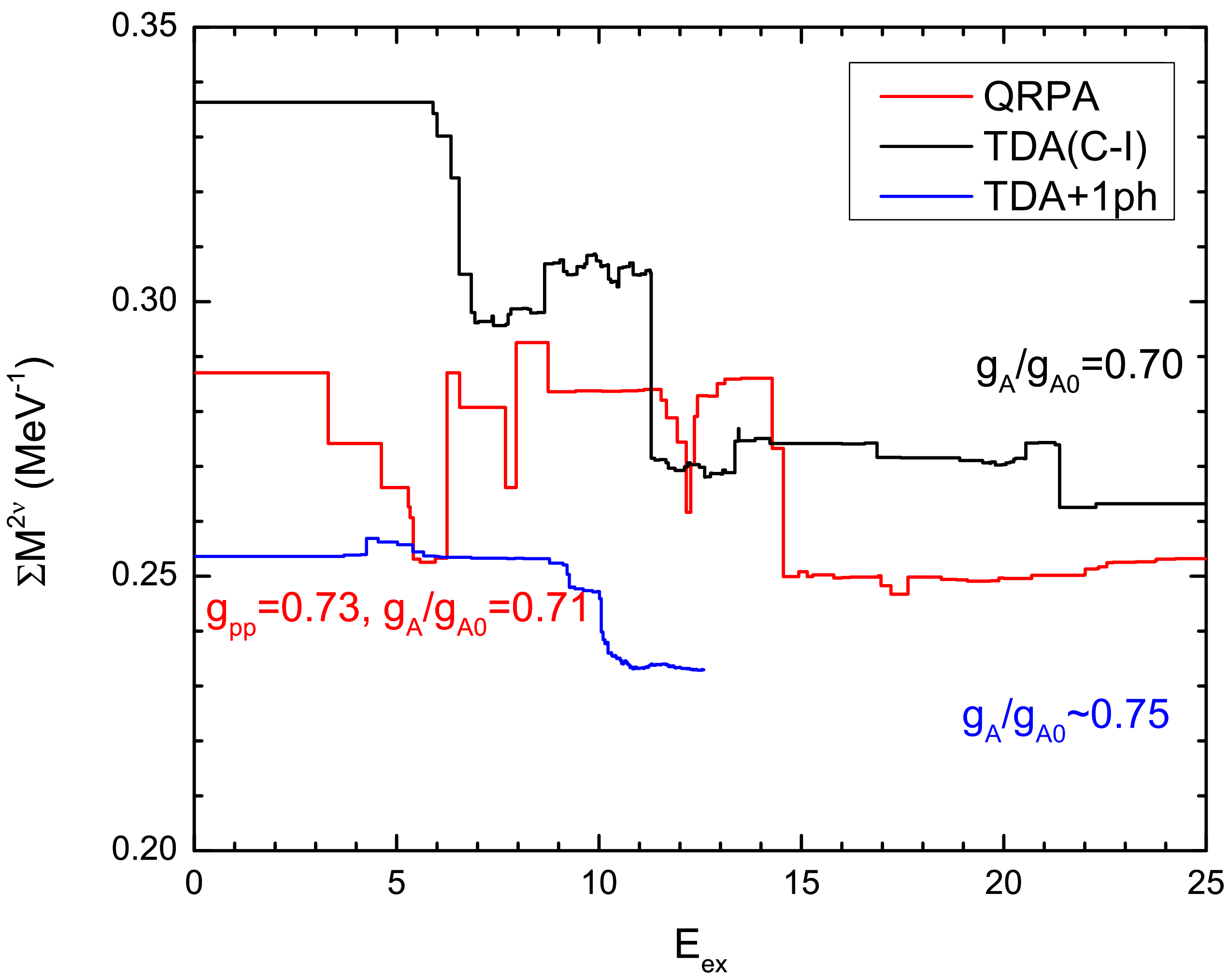
- Running Sum for $2\nu\beta\beta$ decay of ^{116}Cd



M. Horoi and B. A. Brown, PRL110,222502(2013)

Results

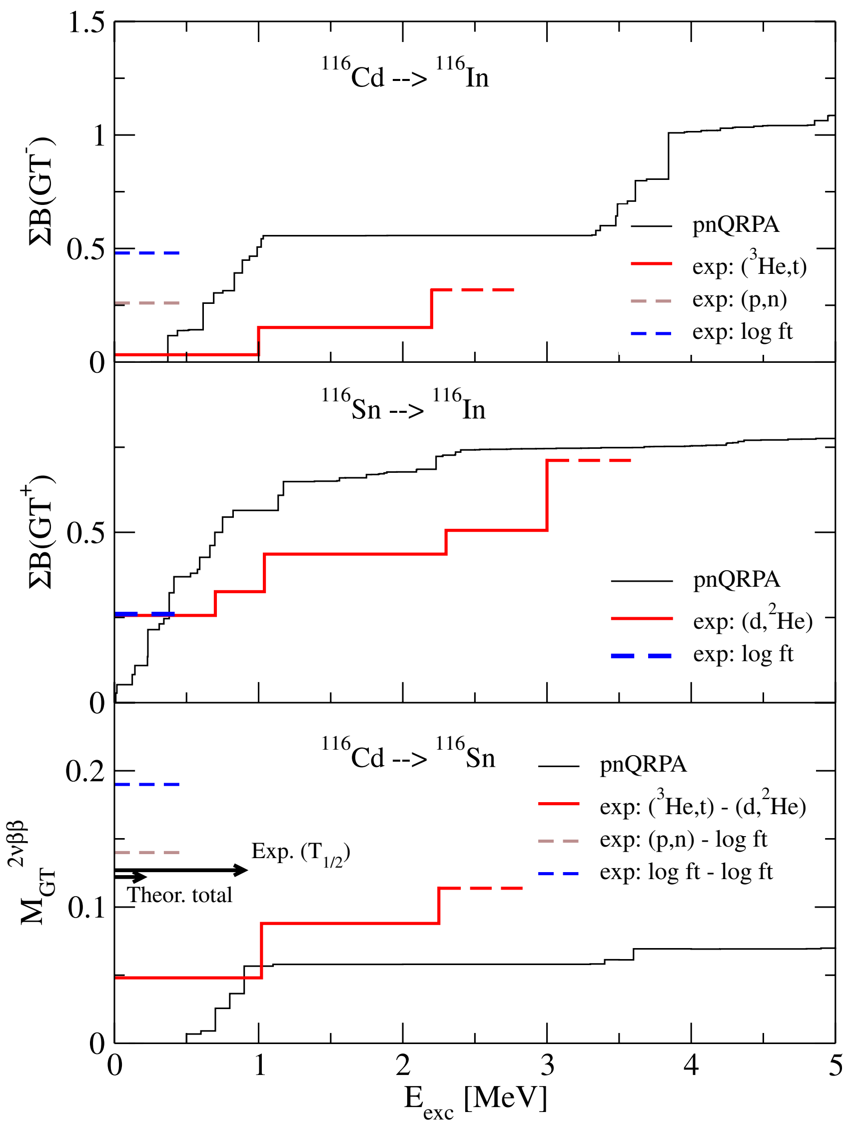
- Running Sum for 2νββ decay of ^{116}Cd

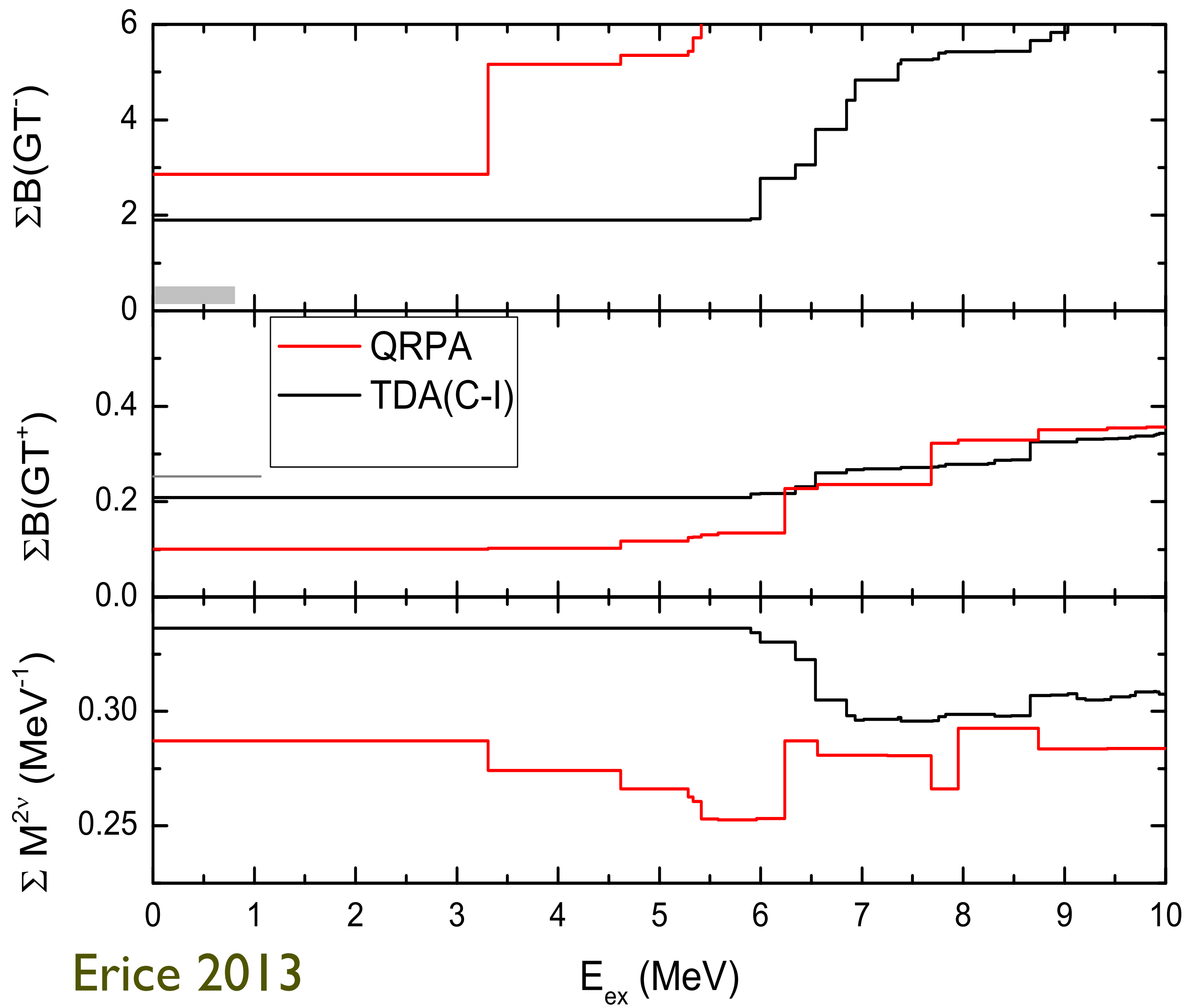


M. Horoi and B. A. Brown, PRL110,222502(2013)

Results

- B(GT) for ^{116}Cd





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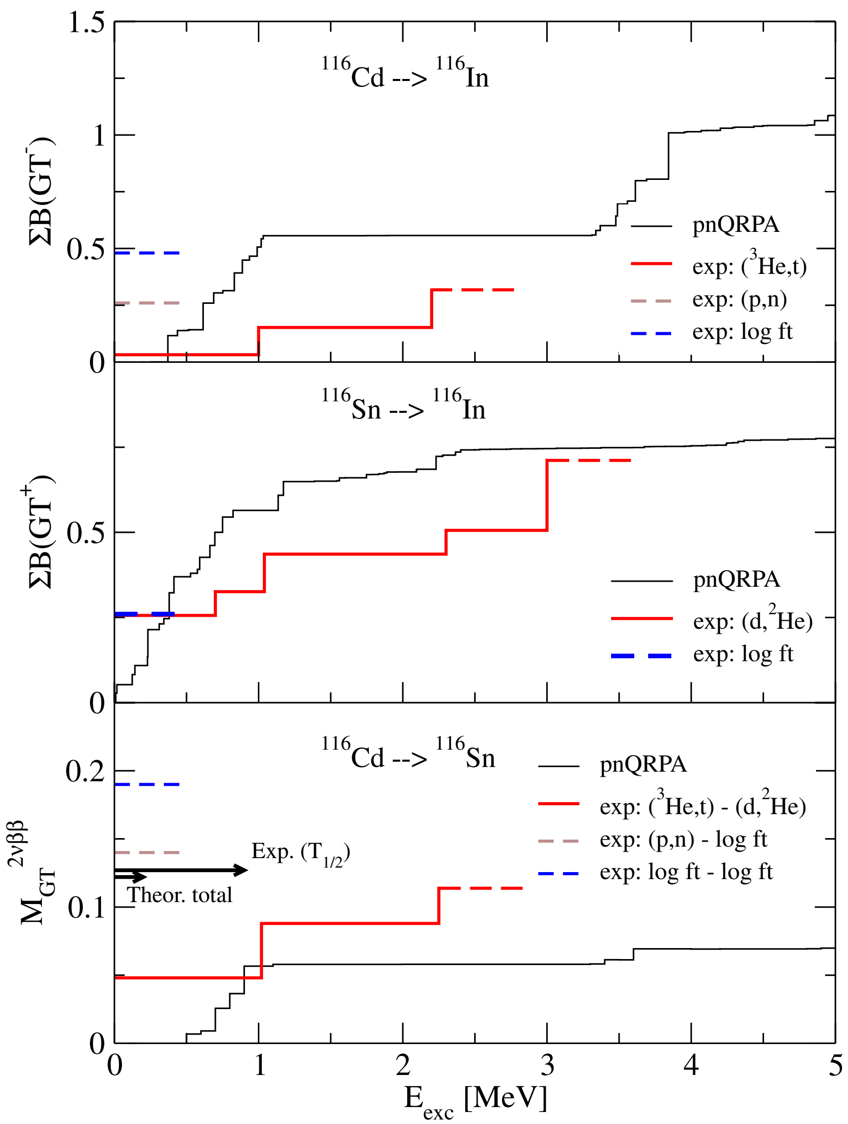

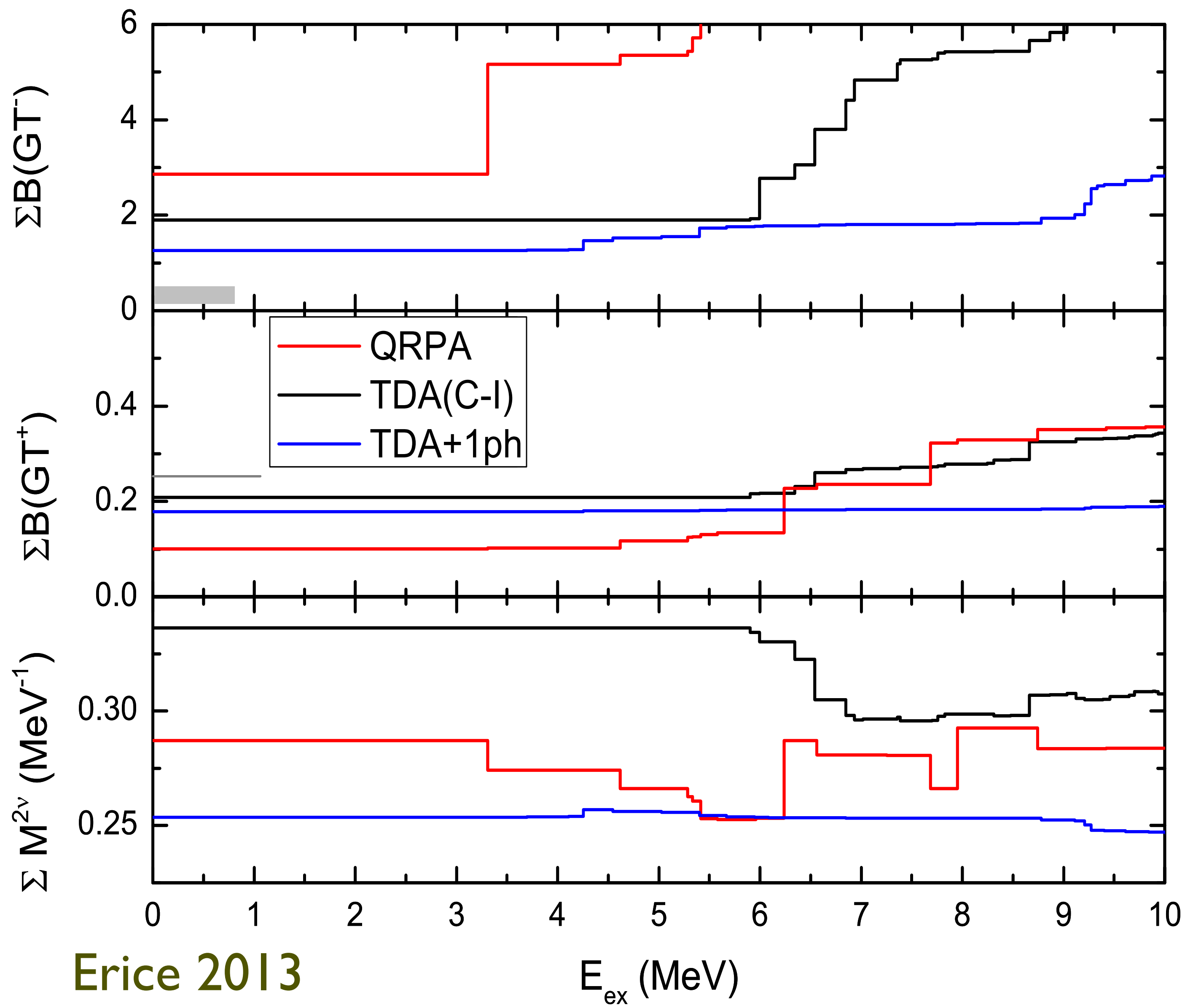

Conclusion

- The origins of different g_A's in β^-/EC and $\beta\beta$ are clarified with the help of Shell Model
- The running sum of ^{116}Cd for $2\nu\beta\beta$ is calculated with SSD or LSD observed
- The running sum of $0\nu\beta\beta$ will be checked in the near future

Thanks!