WAYS TO PROBE DOUBLE BETA MATRIX ELEMENTS BY INDEPENDENT DATA

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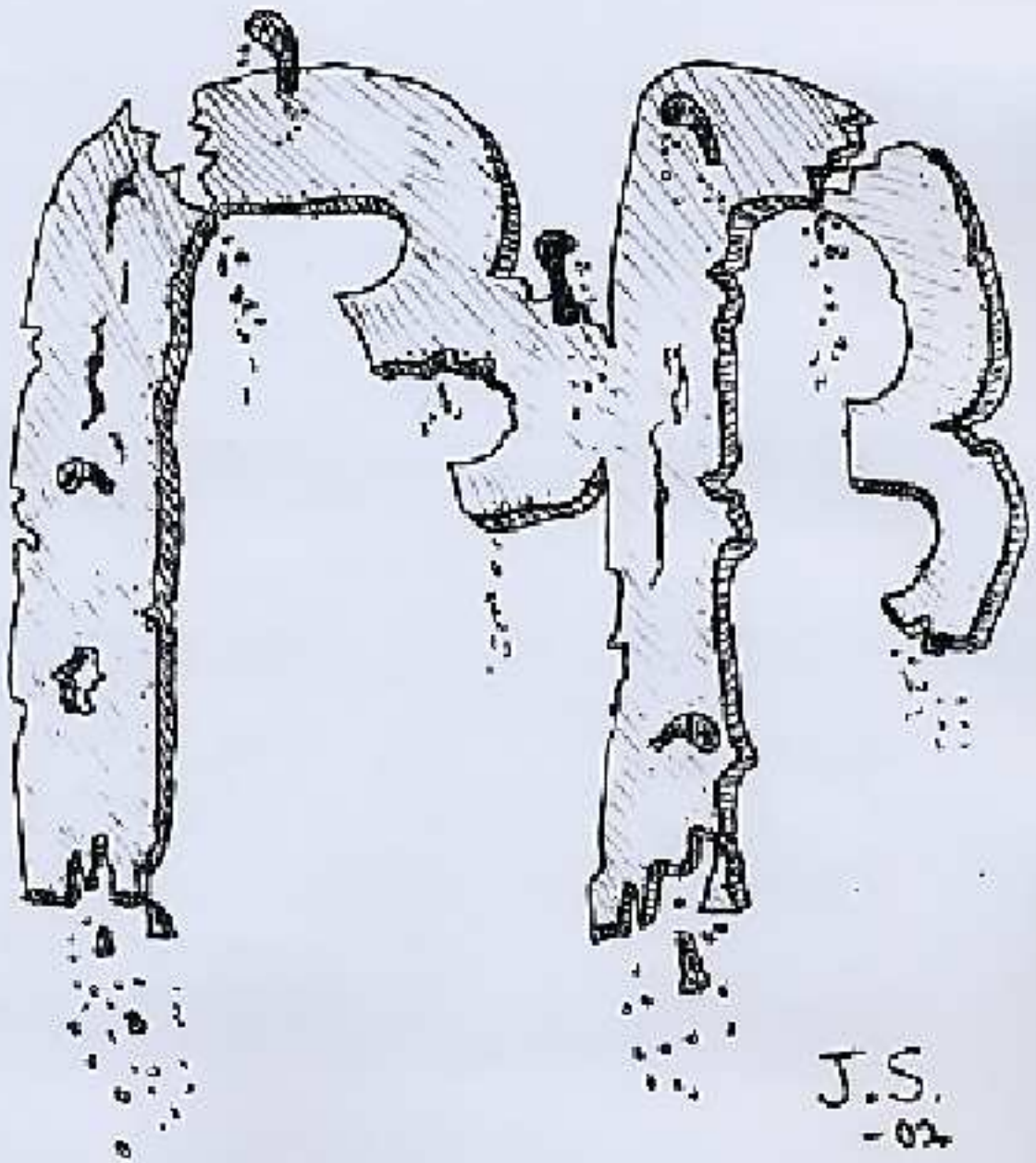
CONTENTS

- $0\nu\beta\beta$ m.e.'s from $2\nu\beta\beta$- or β-decay data ?
- Decomposition of the $0\nu\beta\beta$ m.e. $\leftrightarrow$ dedicated experiments

↑

charge exchange

μ^- capture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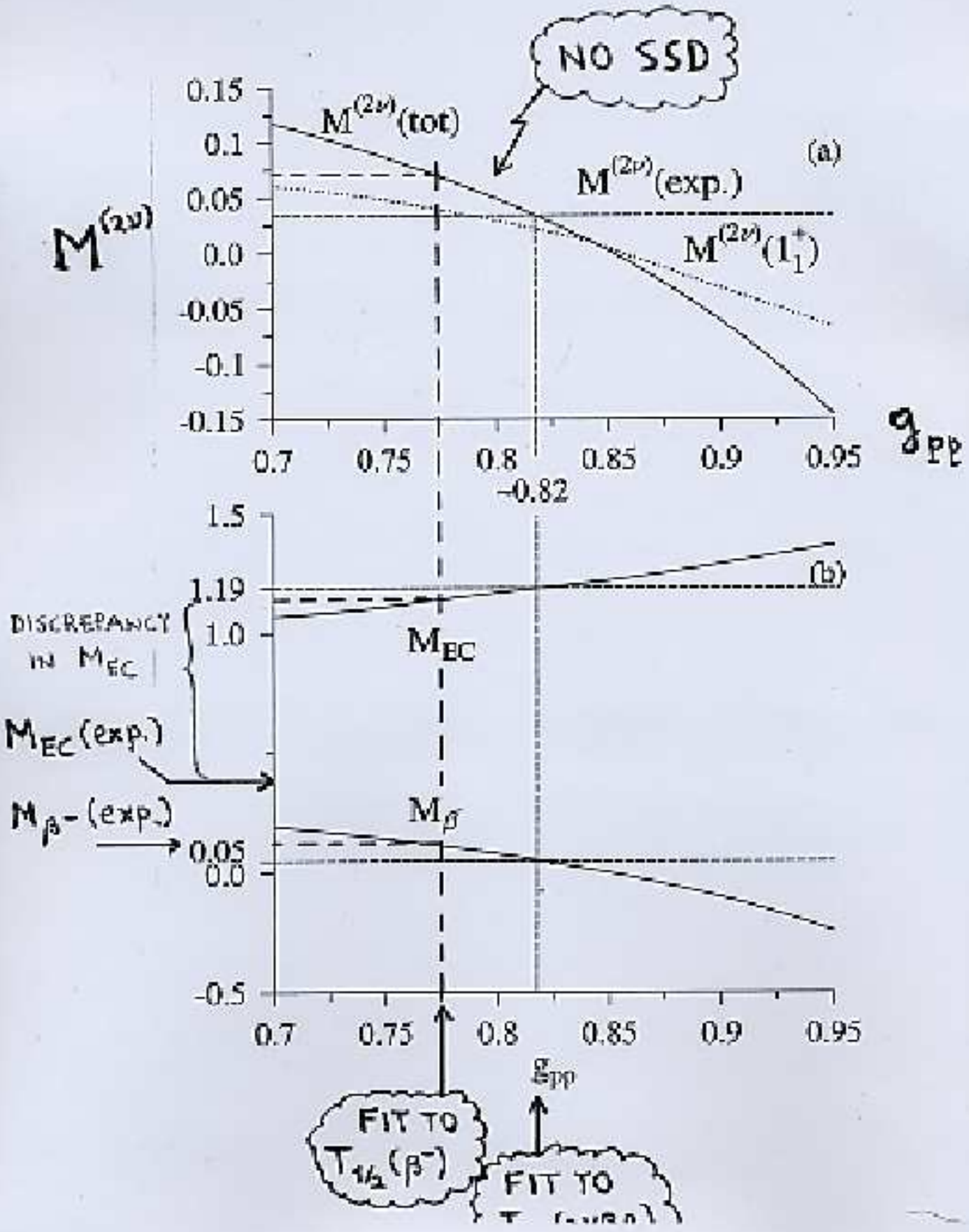
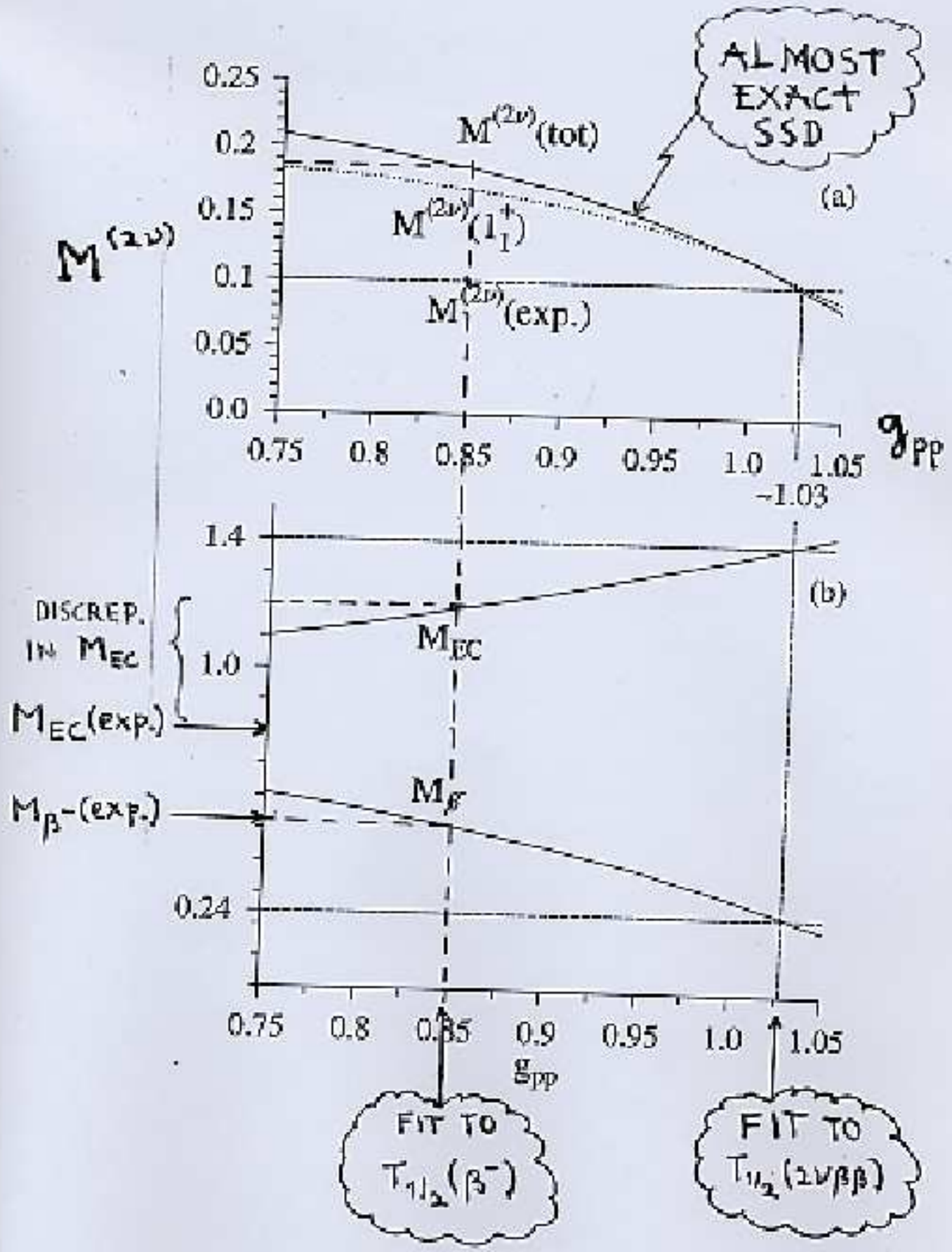
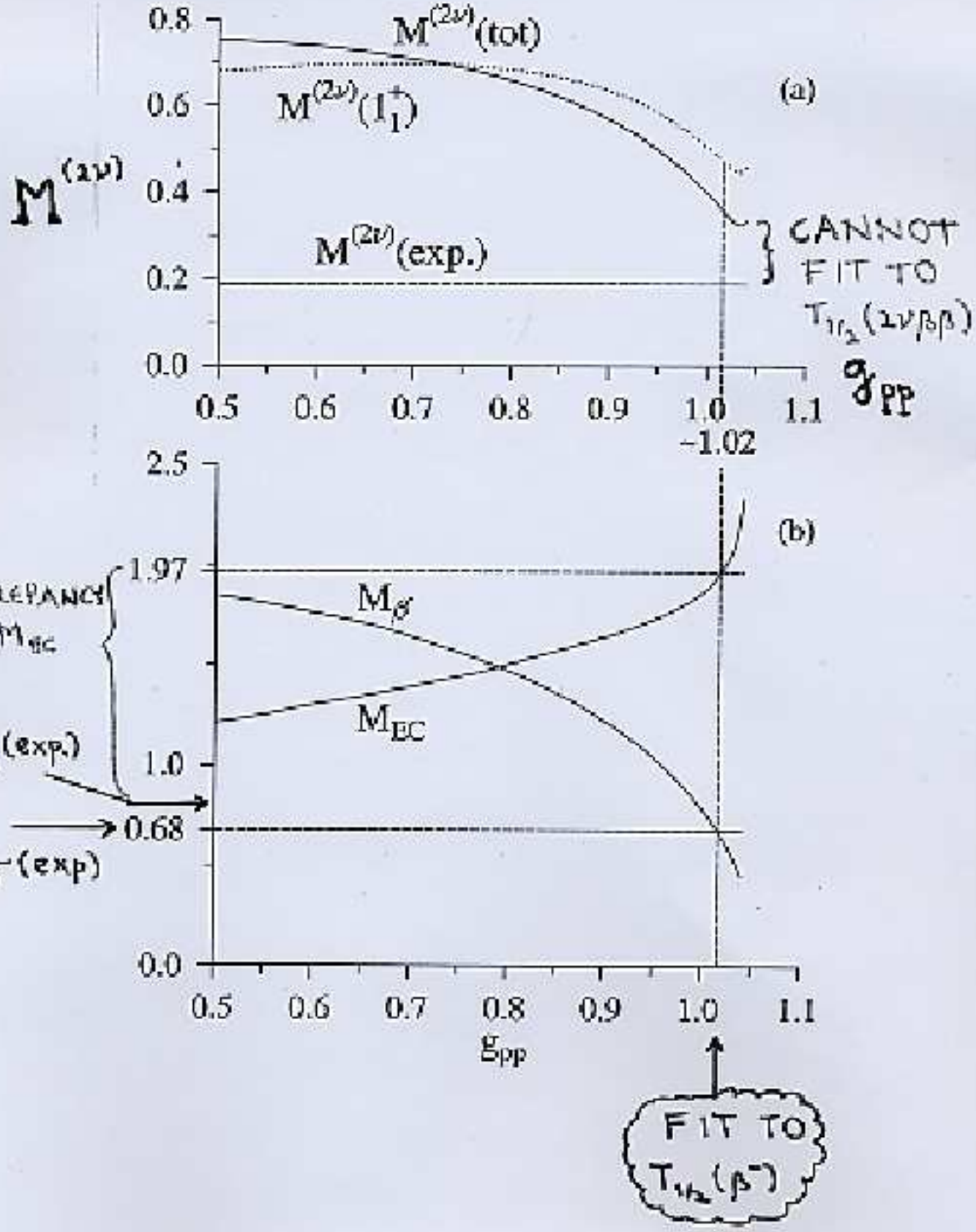
$^{128}Te \xrightarrow{2\nu\beta^-\beta^-} {}^{128}Xe$



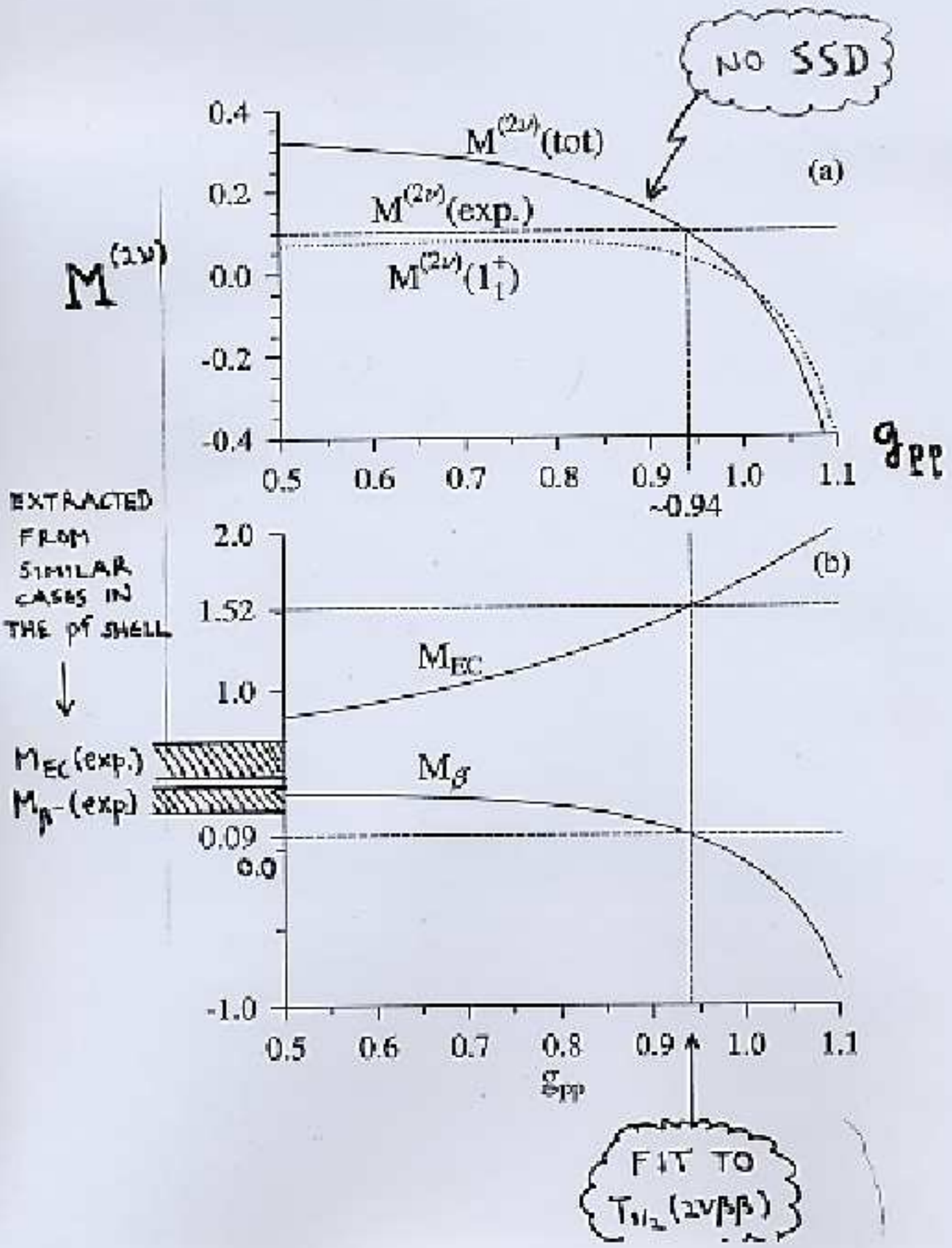
$^{116}Cd \xrightarrow{2\nu\beta^-\beta^-} {}^{116}Sn$



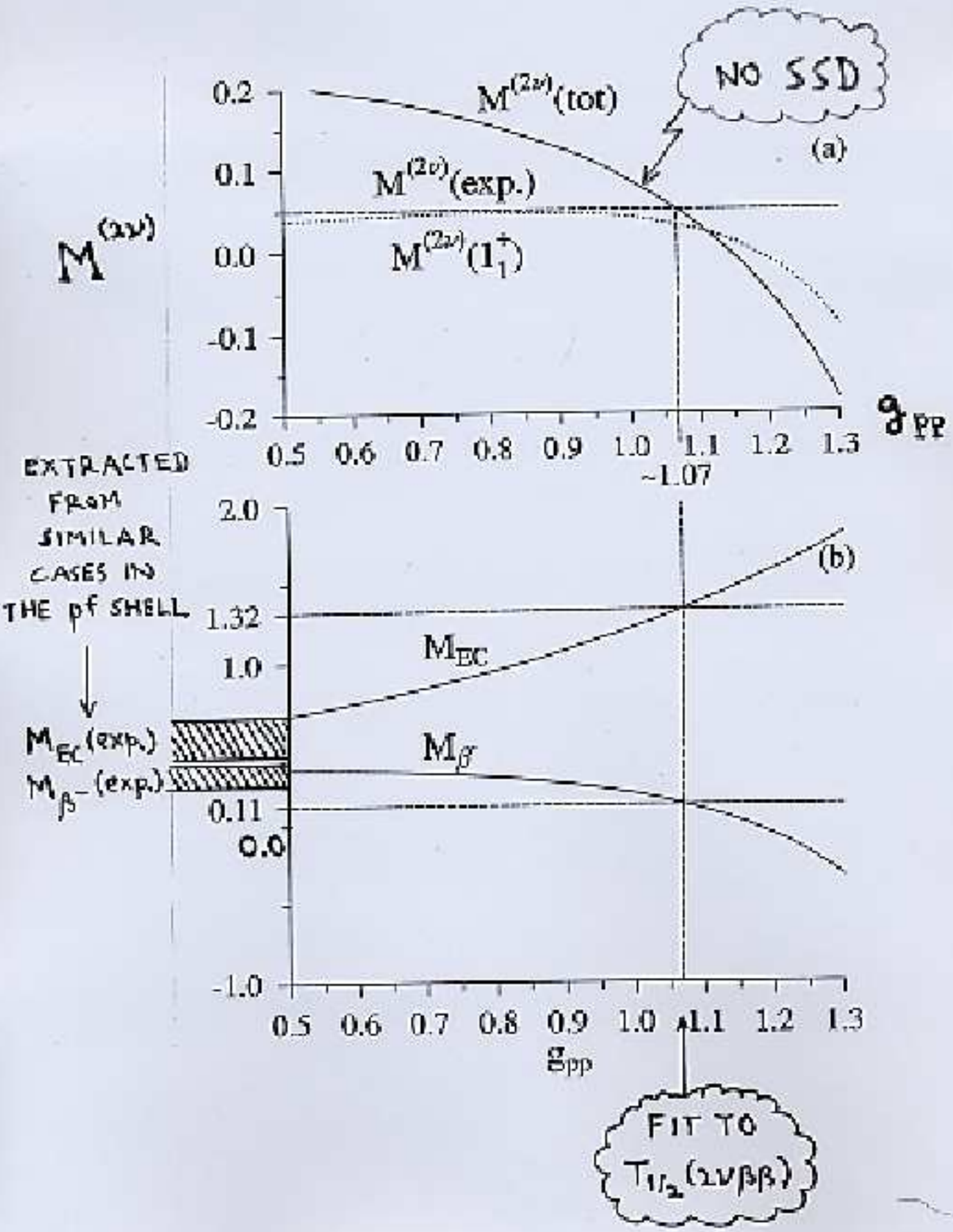
$^{100}Mo \xrightarrow{2\nu\beta\beta^-} {}^{100}Ru$



$^{76}Ge \xrightarrow{2\nu\beta^-\beta^-} {}^{76}Se$



$^{82}Se \xrightarrow{2\nu\beta^-\beta^-} {}^{82}Kr$

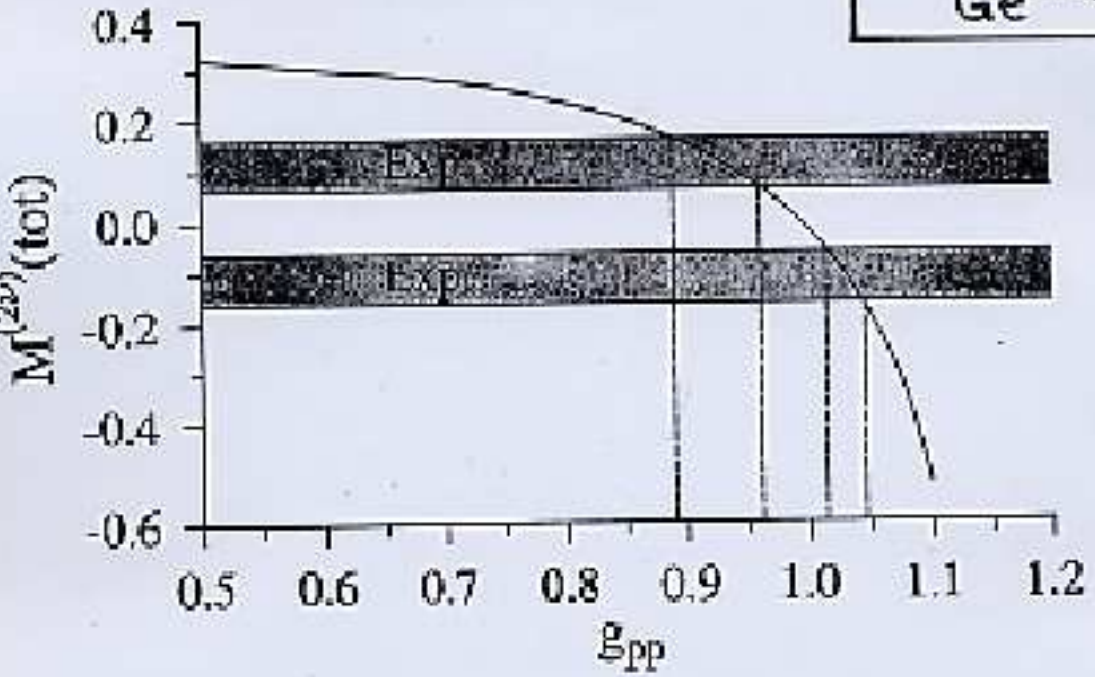


β Decay vs. $2\nu\beta\beta$ Decay in Fitting g_{pp}

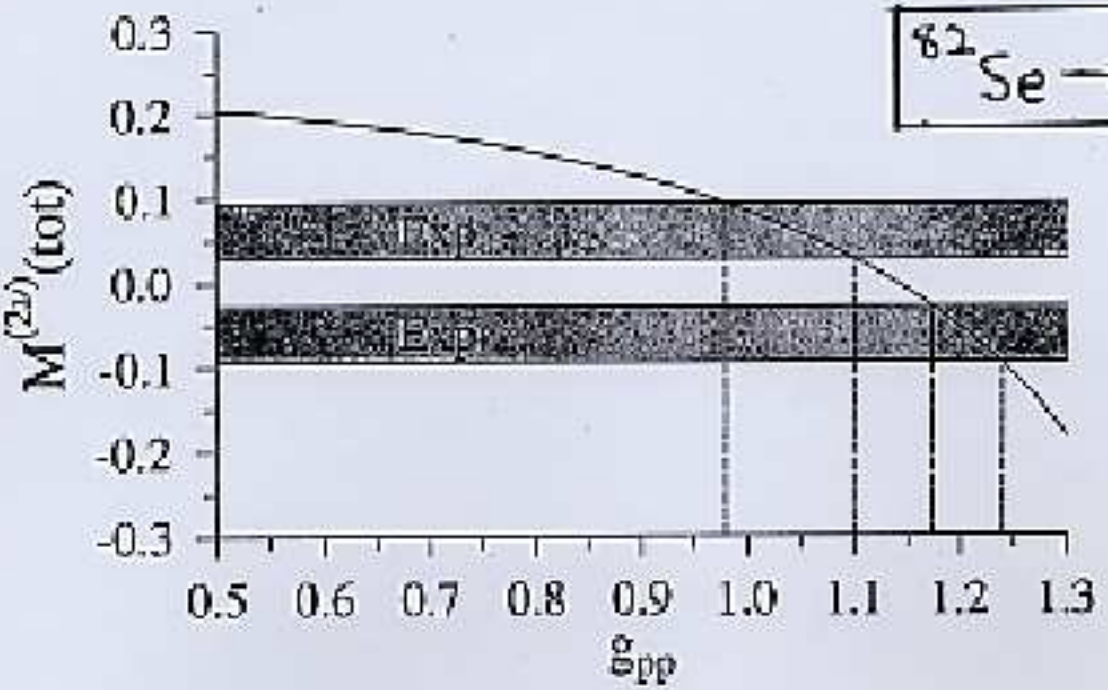
Point	Fit to β^- and/or EC decay(s)	Fit to $2\nu\beta^-\beta^-$ decay
1	One, two or more observables can be used for the fit (+)	Only one observable can be used for the fit (−)
2	Direct access to grass-root-level deficiencies of a nuclear model (+)	Two or more compensating errors may conspire to produce a good $2\nu\beta^-\beta^-$ decay rate (−)
3	The beta-decay properties better reproduced (+)	The $2\nu\beta^-\beta^-$ decay properties better reproduced (+)
4	Error limits from comparison of the experimental and computed $2\nu\beta^-\beta^-$ decay rate (+)	Advisable to check against data on β^- decays
5	Largely eliminates the model-space dependence of the computed $0\nu\beta^-\beta^-$ decay rates (+)	Largely eliminates the model-space dependence of the computed $0\nu\beta^-\beta^-$ decay rates (+)
6	Can be extended to study of forbidden contributions, e.g. 2^-, in $0\nu\beta^-\beta^-$ decay (+)	No access to a possible variation of g_{pp} from multipole to multipole (−)
7	Can access $\beta\beta$ decays where no $2\nu\beta\beta$ data exists, see Table 2 (+)	Can access $\beta\beta$ decays where no direct β-decay data exists (^{76}Ge and ^{82}Se) (+)
Balance	7 × (+)	3 × (+) and 3 × (−)

$2\nu\beta\beta$ DECAYS OF ^{76}Ge and ^{82}Se

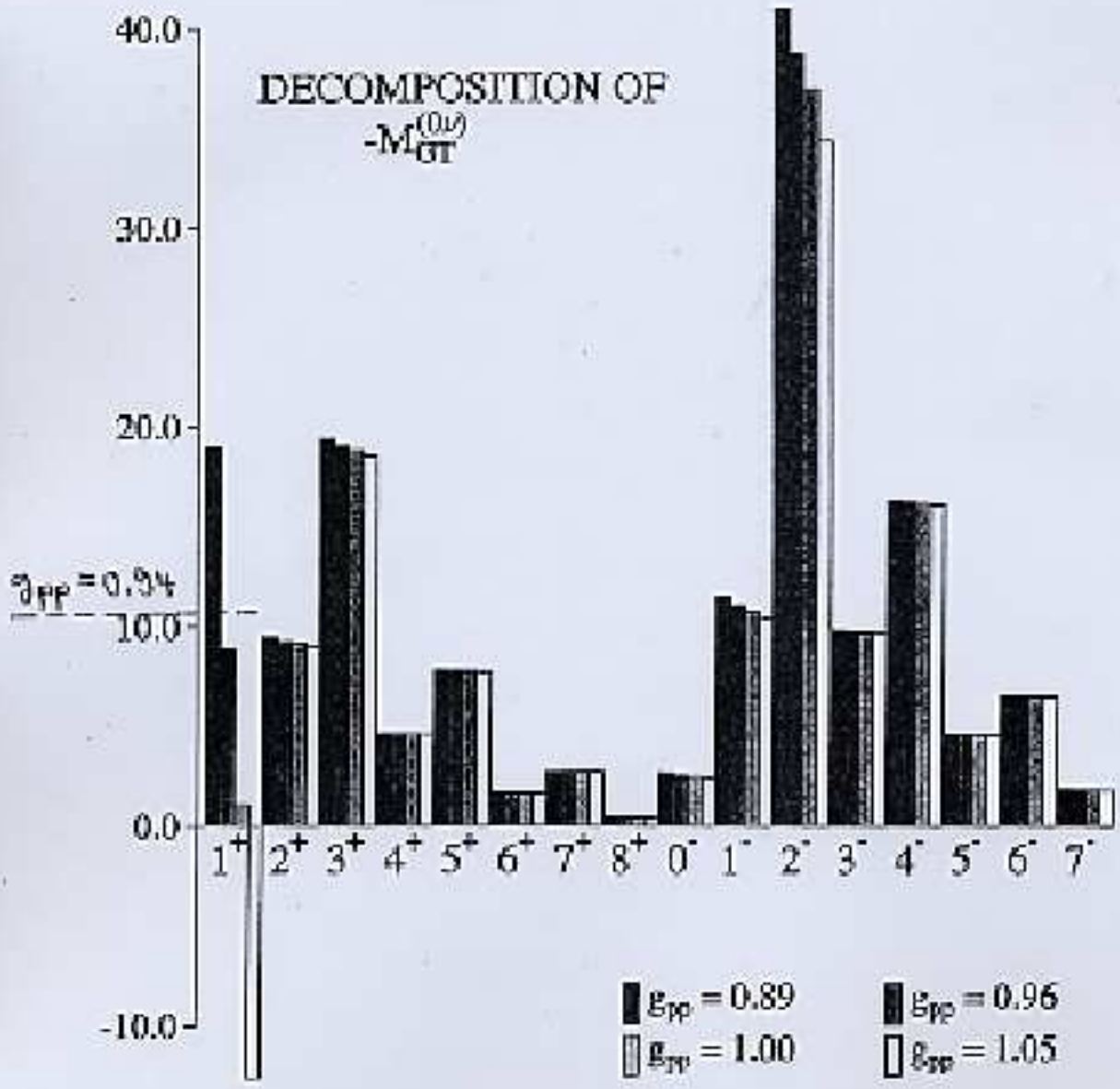
$^{76}Ge \rightarrow {}^{76}Se$



$^{82}Se \rightarrow {}^{82}Kr$

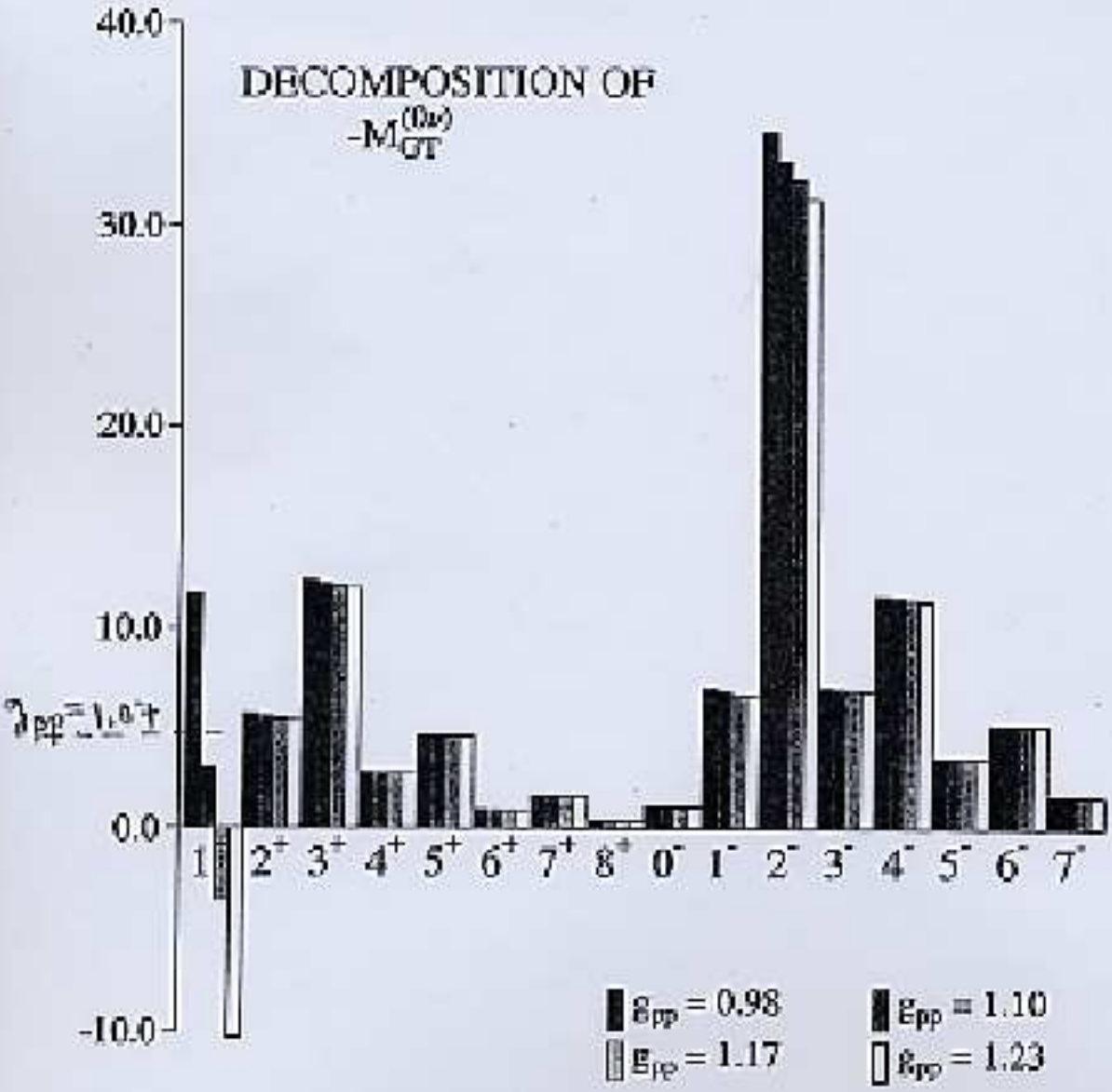


$^{76}Ge \longrightarrow {}^{76}Se$



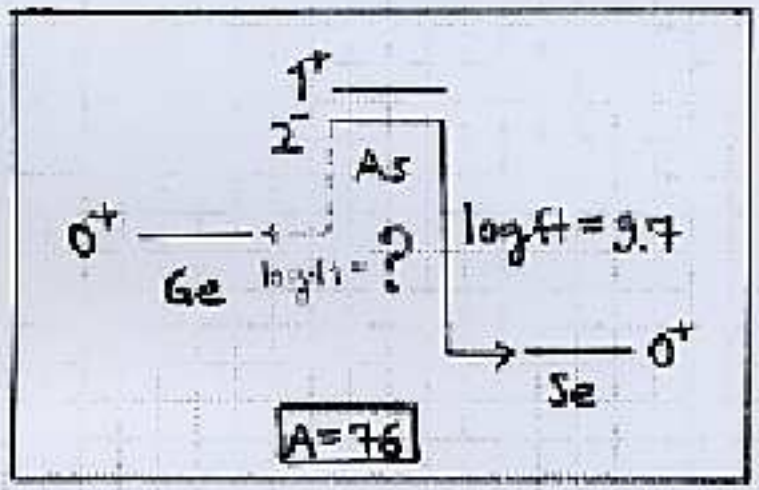
From fit to central value: $g_{pp} = 0.34$

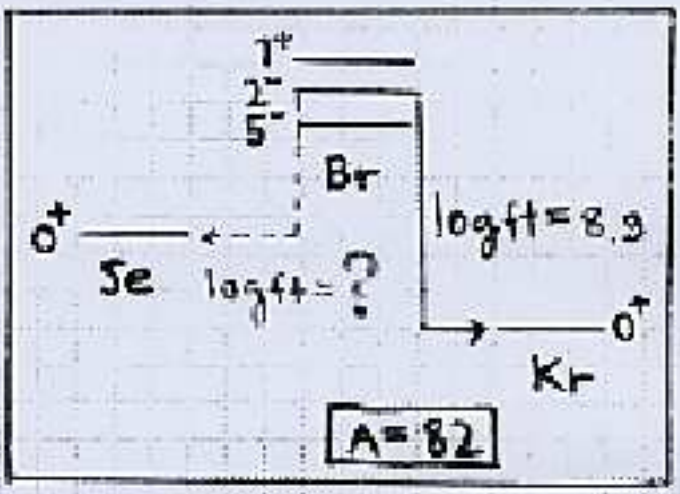
$^{82}Se \longrightarrow {}^{82}Kr$

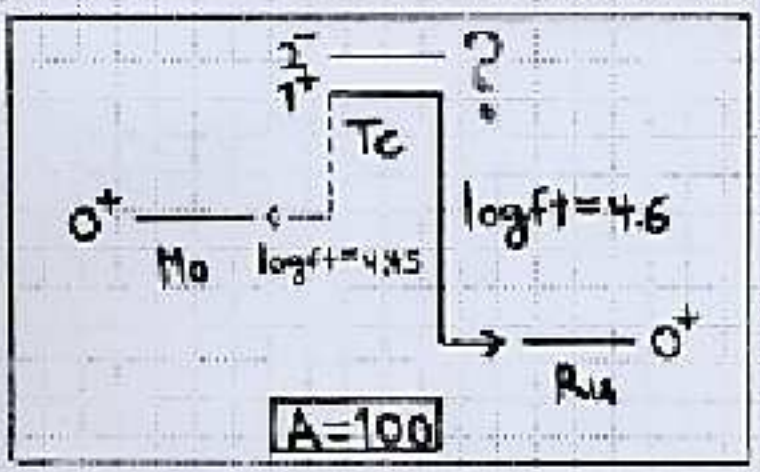


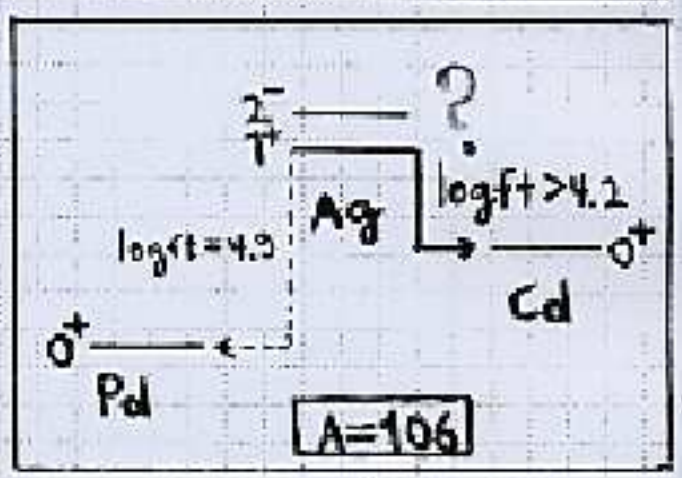
From fit to central value: $g_{pp} = 1.07$

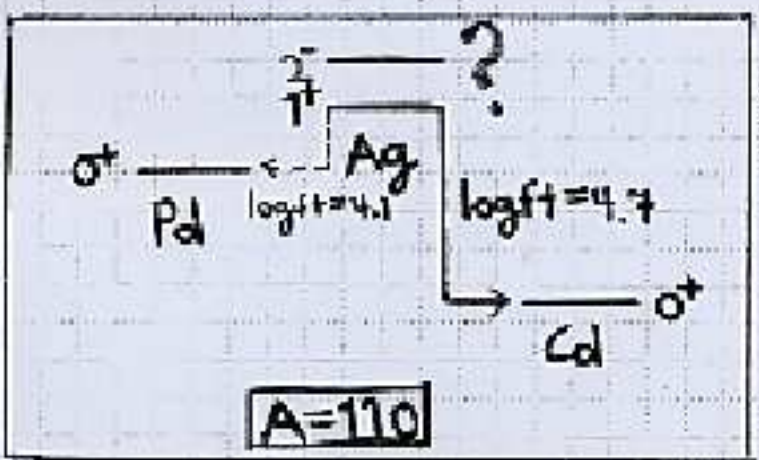
STUDIED CASES

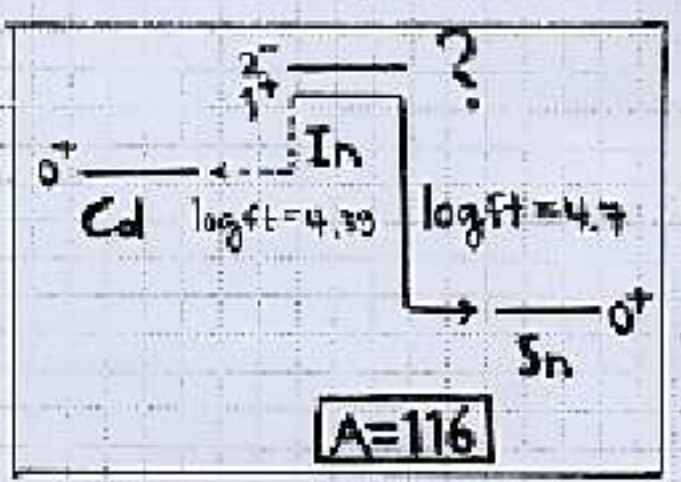


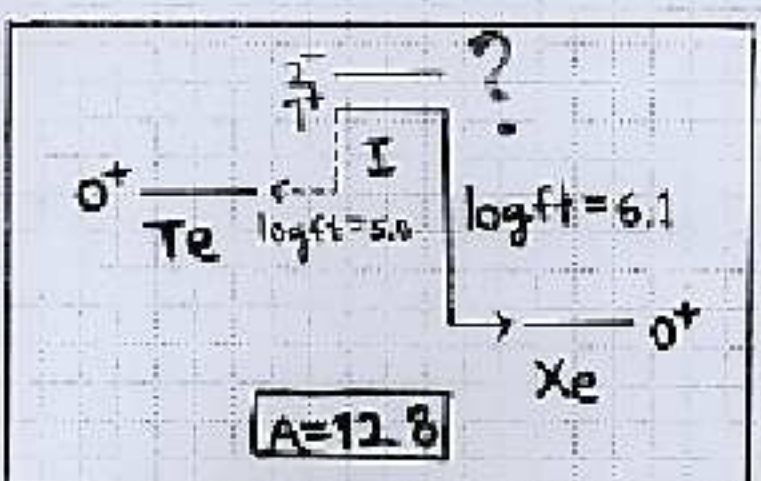


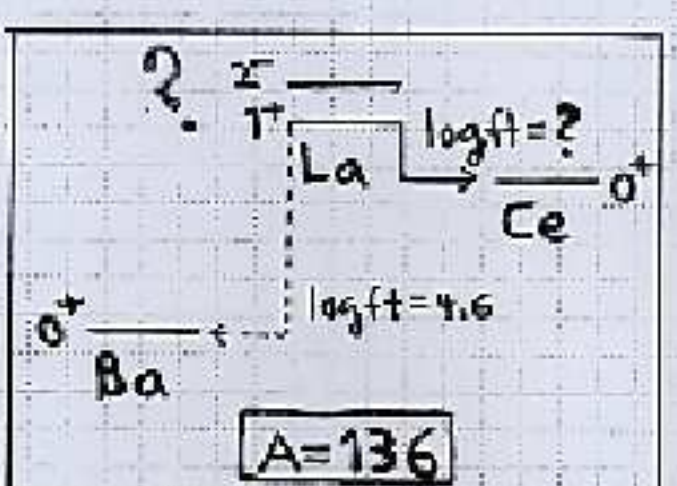


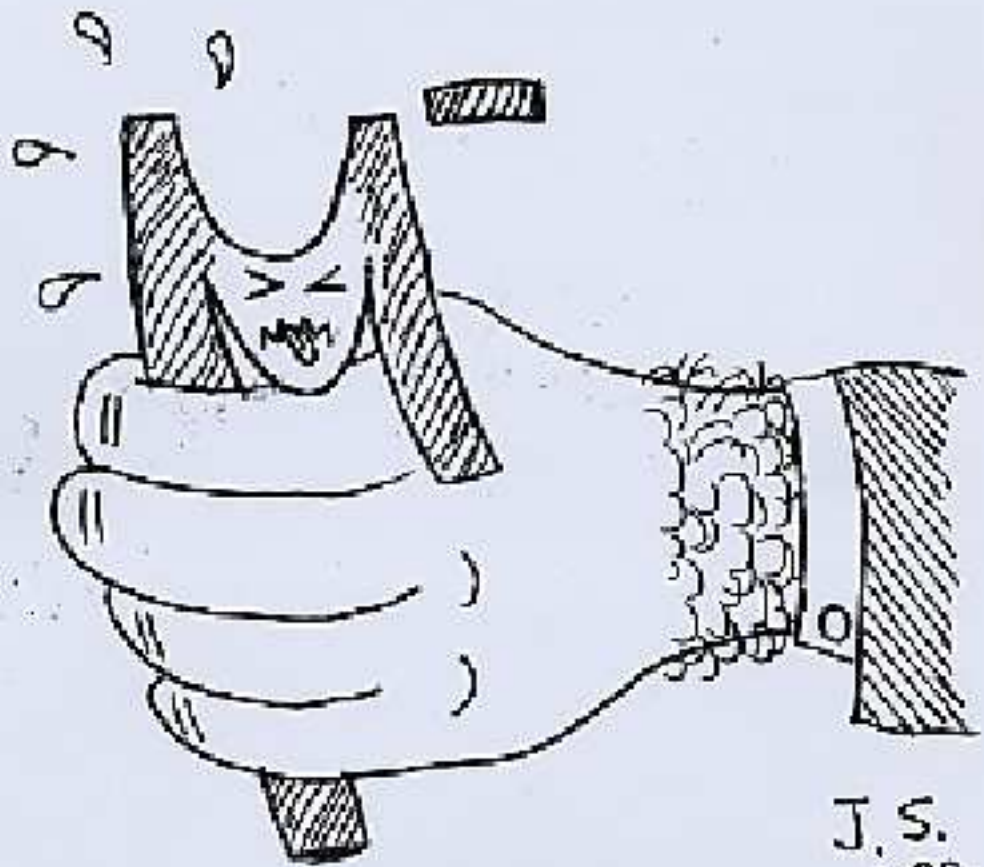












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MUONIC PROCESSES

The muon disappears from the atomic 1s orbit by

① MUON DECAY ($t_{1/2} \sim 10^{-6}$ s):

$$\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu \quad \text{(OMD)}$$
$$\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu + \gamma \quad \text{(RMD)}$$

② CAPTURE by the nucleus:

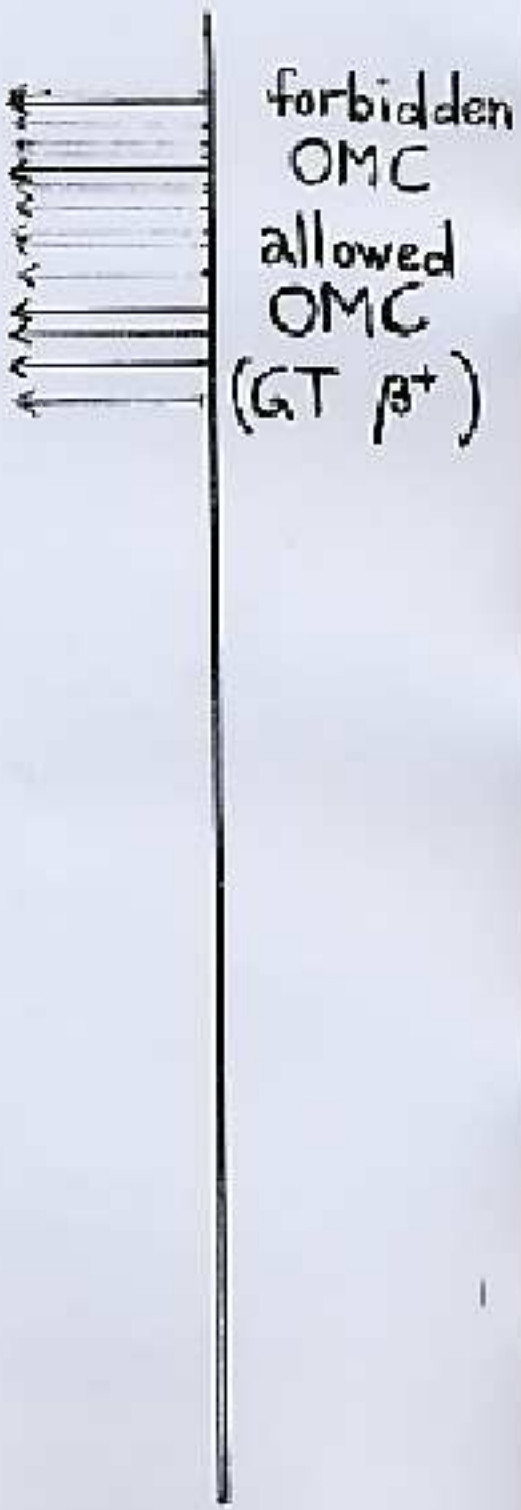
$$\mu^- + (A,Z) \rightarrow (A,Z-1) + \nu_\mu \quad \text{(OMC)}$$
$$\mu^- + (A,Z) \rightarrow (A,Z-1) + \nu_\mu + \gamma \quad \text{(RMC)}$$

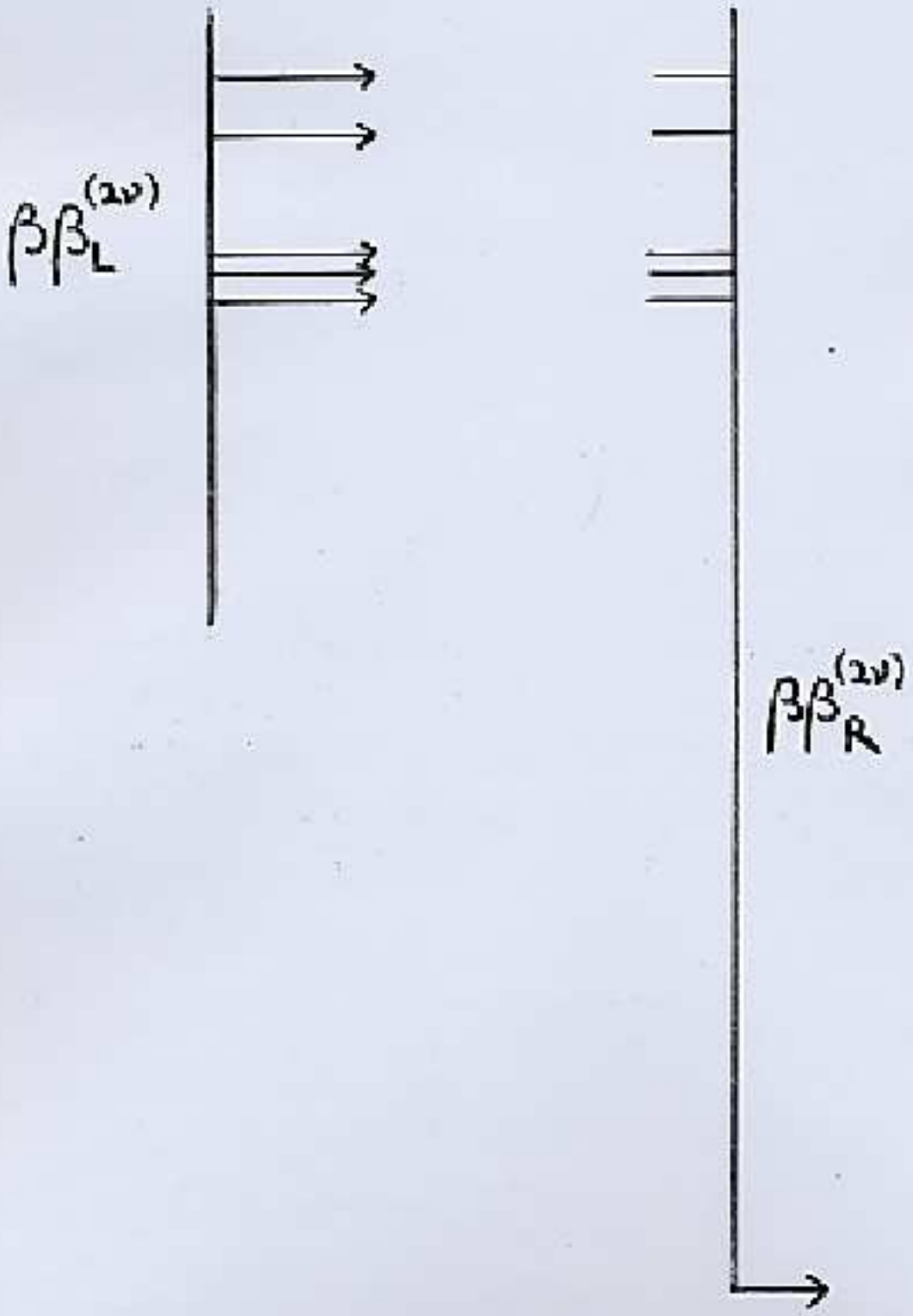
③ CONVERSION processes:

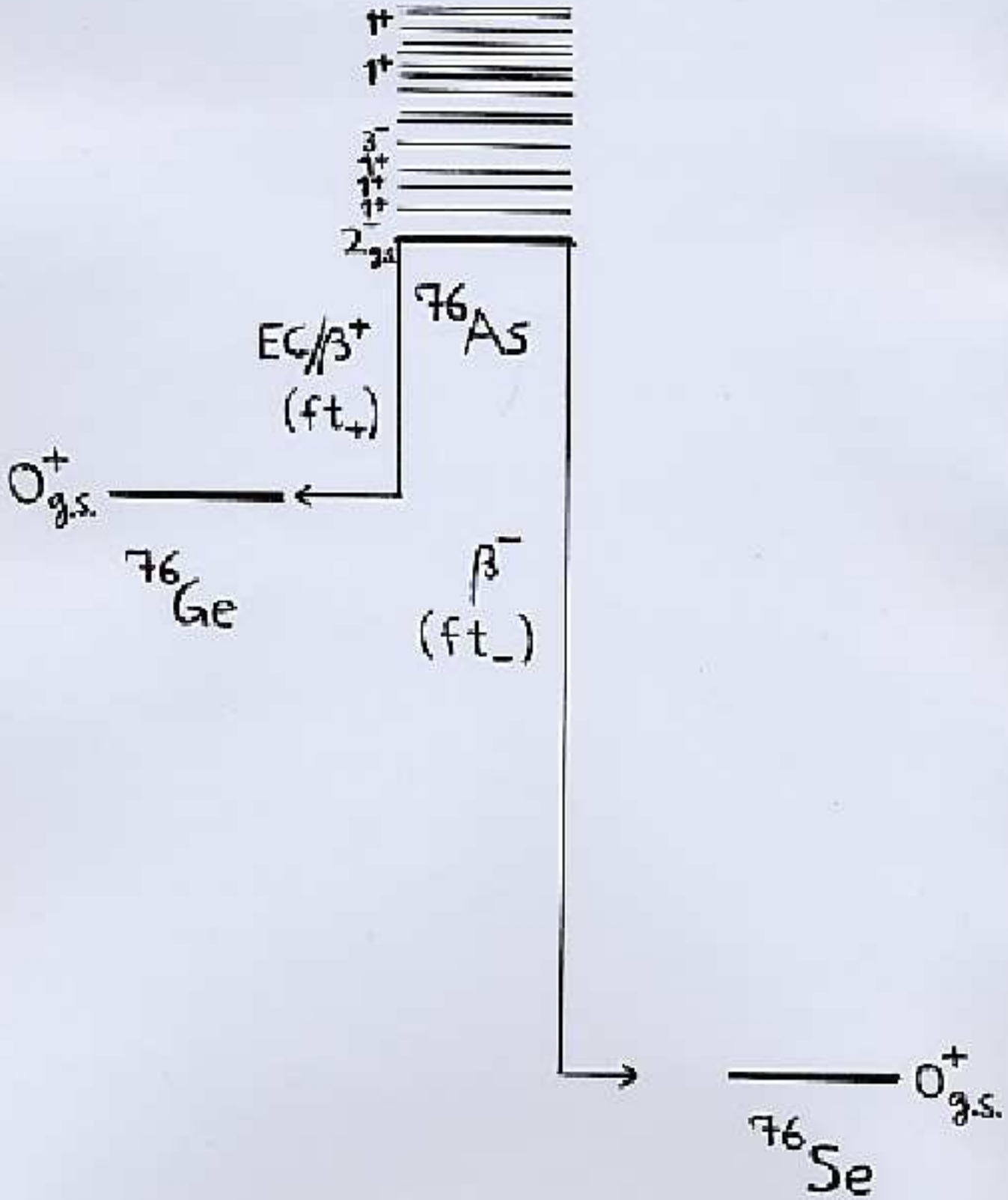
$$\mu^- + (A,Z) \rightarrow e^- + (A,Z)$$

$$\mu^- + (A,Z) \rightarrow e^+ + (A,Z-2)$$

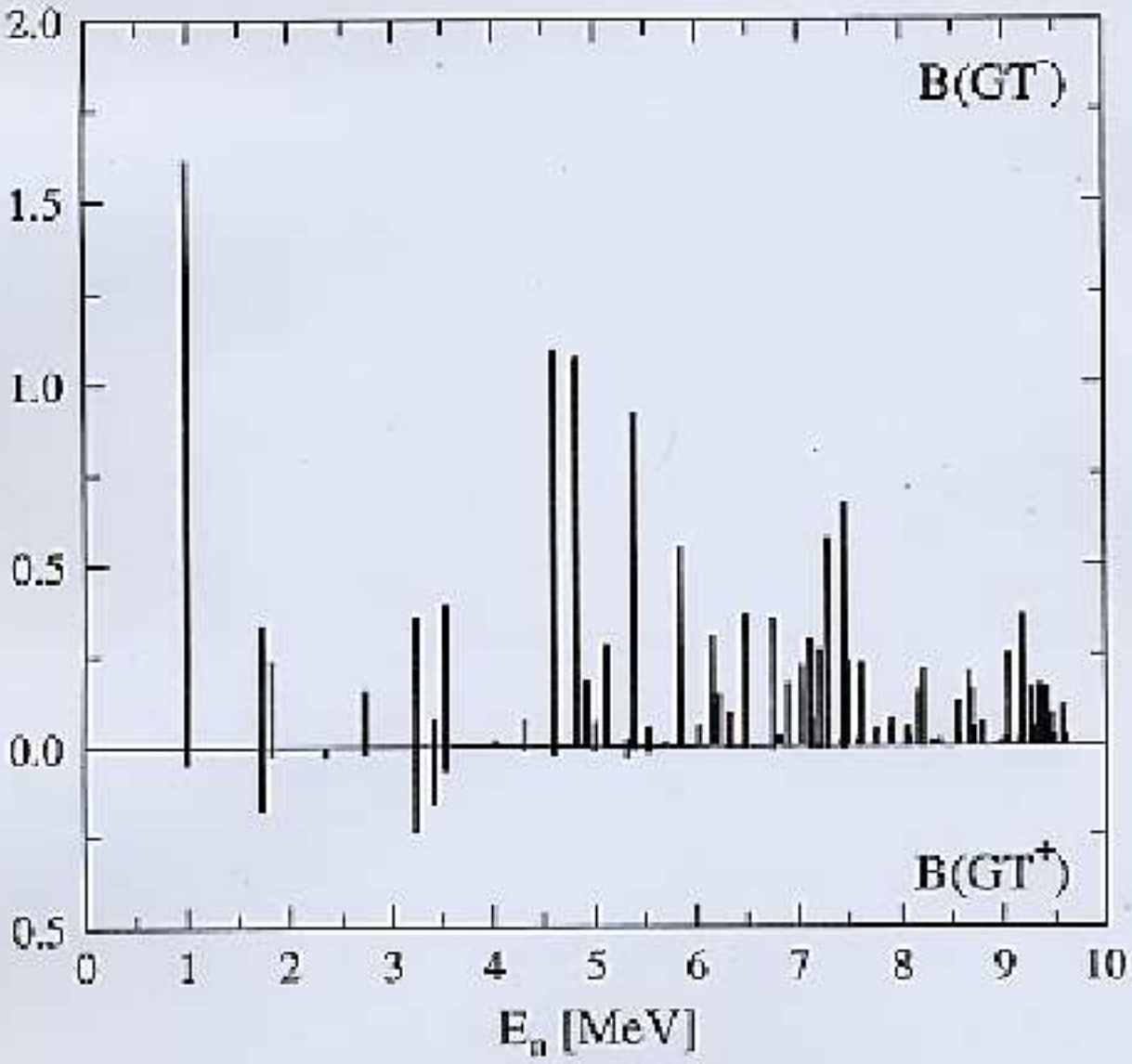
(lepton-flavour violating)


forbidden
OMC
allowed
OMC
(GT β+)

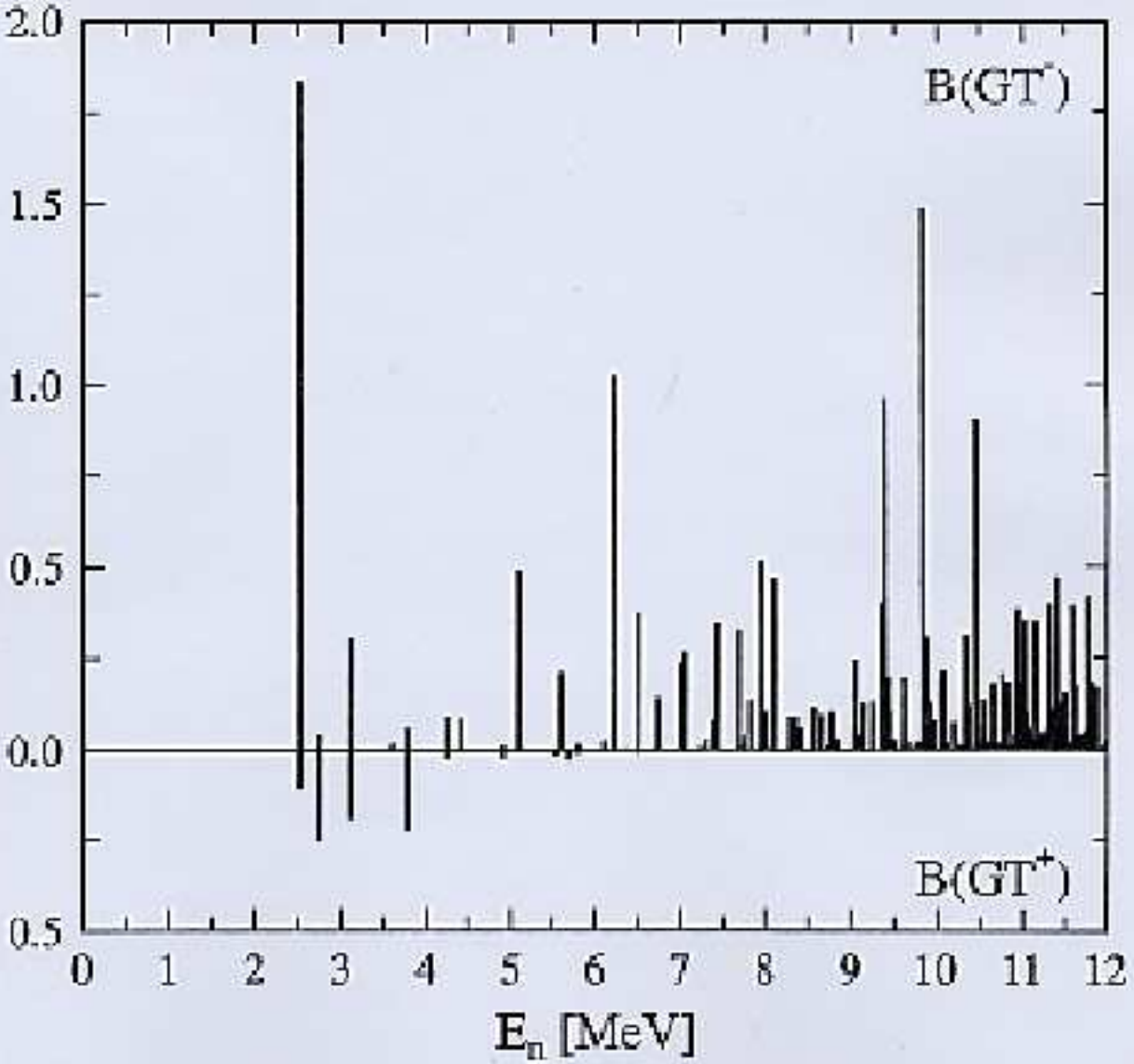

$\beta\beta_L^{(2\nu)}$
$\beta\beta_R^{(2\nu)}$


1^+
1^+
3^-
1^+
1^+
1^+
$2^-_{g.s.}$
^{76}As
EC/β^+
(ft_+)
$0^+_{g.s.}$
^{76}Ge
β^-
(ft_-)
$0^+_{g.s.}$
^{76}Se

^{46}Ca (fpbp)



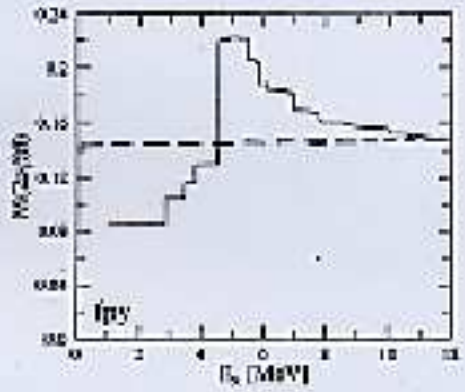
^{48}Ca (fpbp)

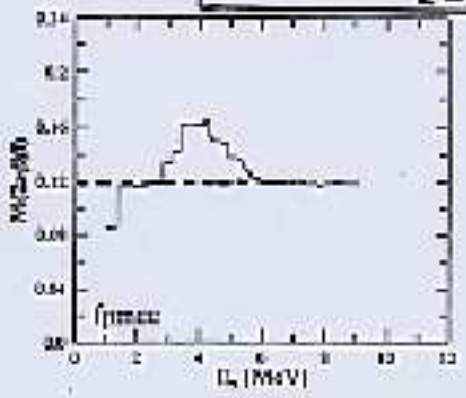


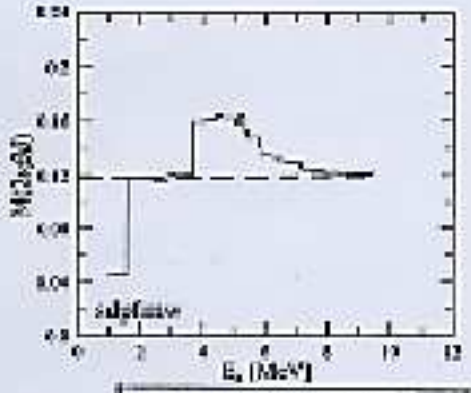
$^{46}_{20}Ca_{26} \xrightarrow{2\nu\beta^-} {}^{46}_{22}Ti_{24}$

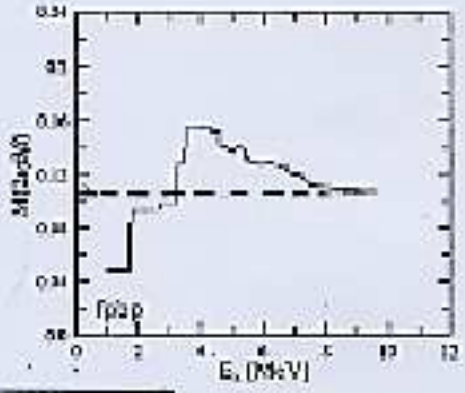
CUMULATIVE SUM:

$$M_{GT}^{2\nu}(E_x) = \sum_{E \le E_x} \frac{M_L M_R}{DENOM(E_x)}$$

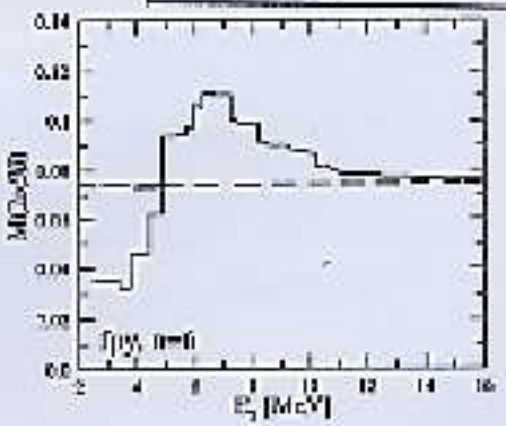


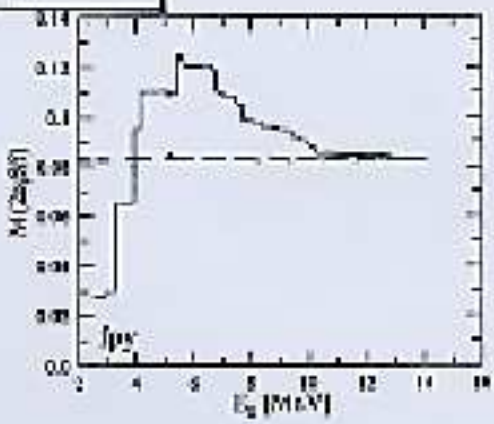


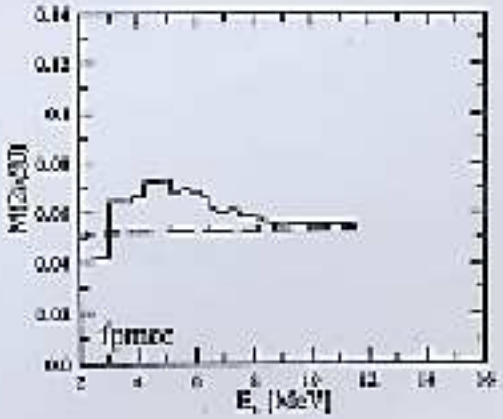


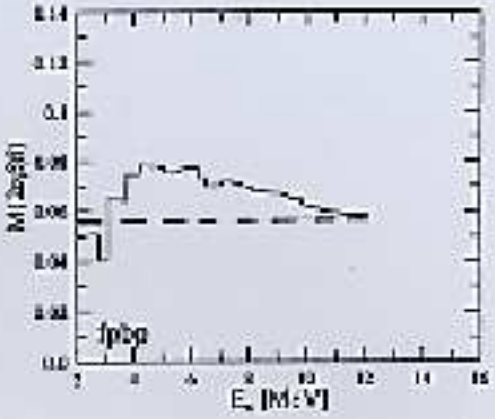


$^{48}_{20}Ca_{28} \xrightarrow{2\nu\beta^-} {}^{48}_{22}Ti_{26}$





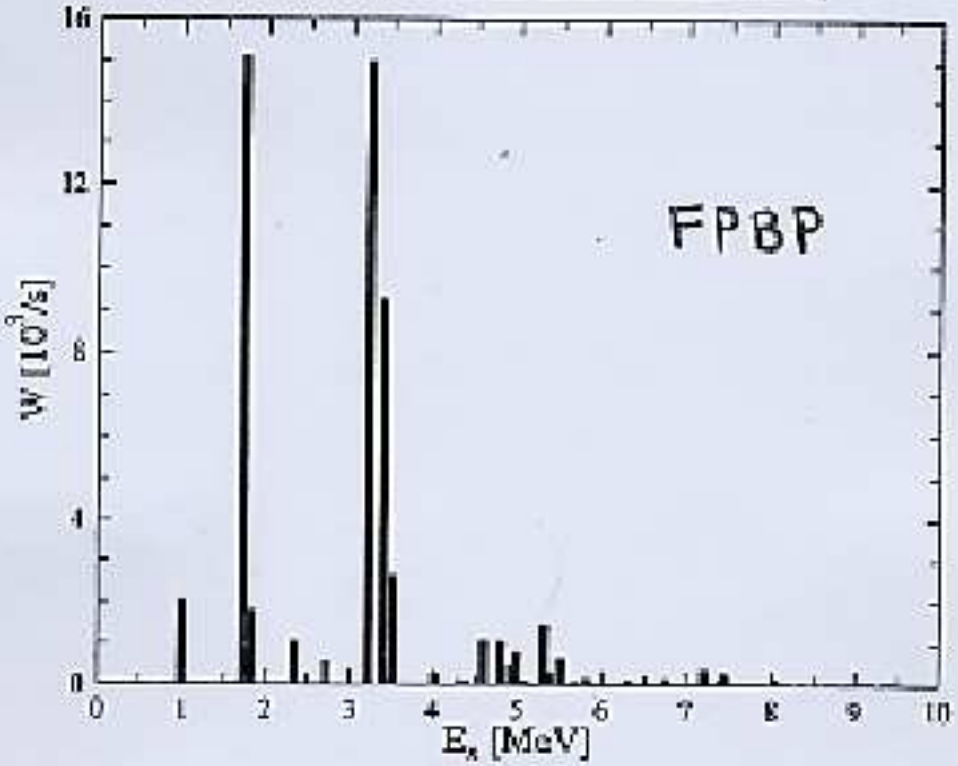


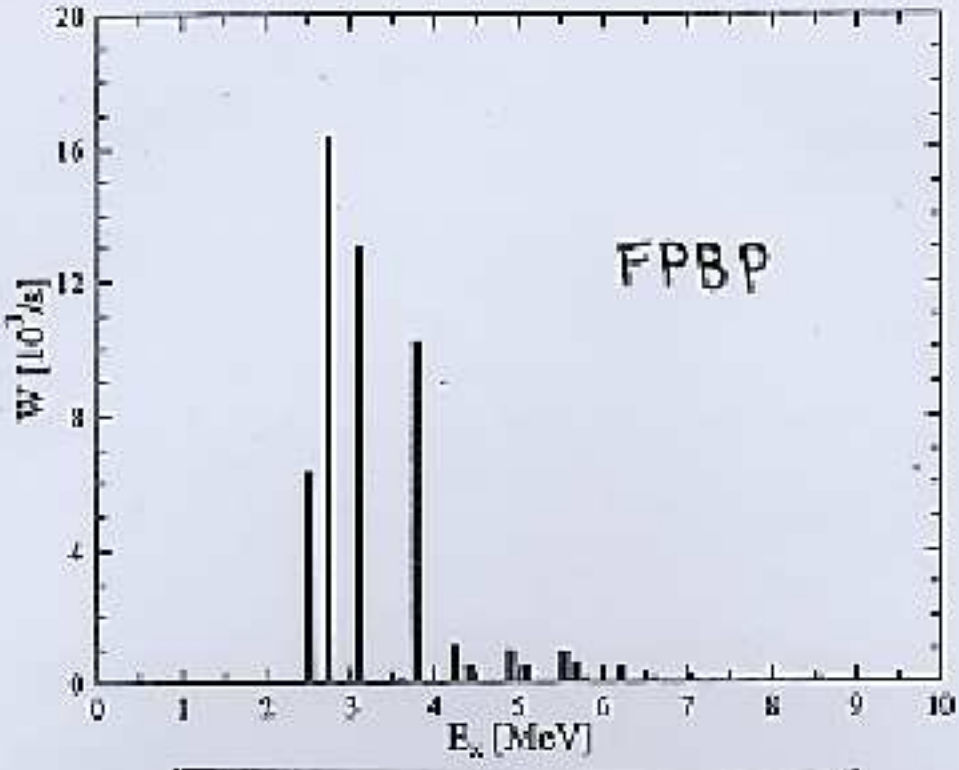


^{48}Ca: $M_{GT}^{2\beta}(exp) = (0.034 - 0.115)\,MeV^{-1}$

MUON-CAPTURE RATES

$^{46}Ti(0^+_{gs}) \xrightarrow{OMC} {}^{46}Sc(1^+_n)$



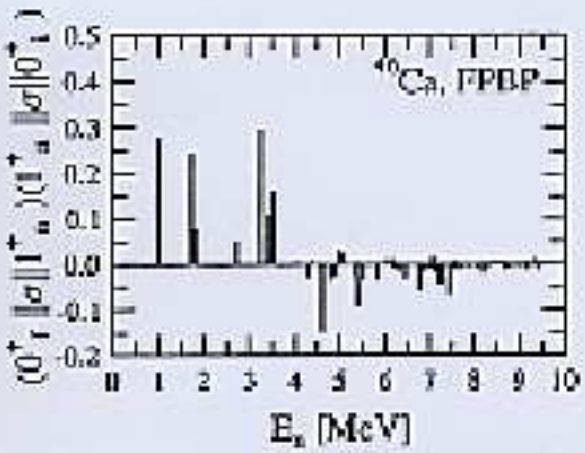


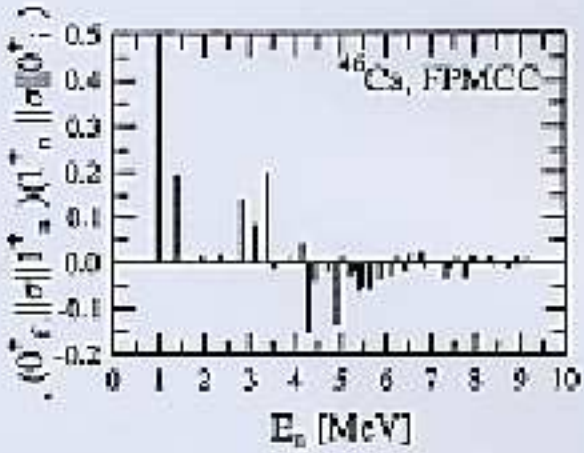
$^{48}Ti(0^+_{gs}) \xrightarrow{OMC} {}^{48}Sc(1^+_n)$

CONTRIBUTIONS FROM VIRTUAL TRANSITIONS

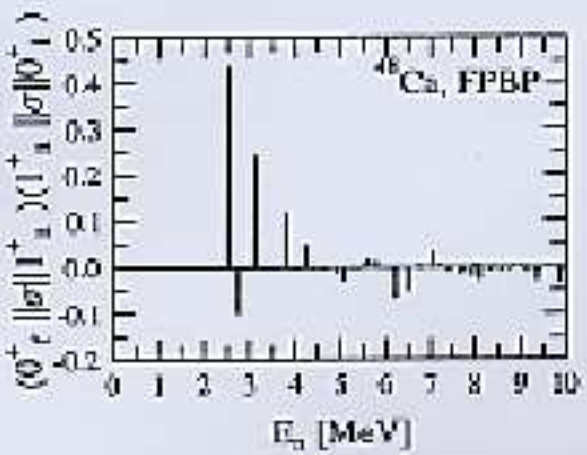
$$M^{(2\nu)}_{DGT} = \sum_n \frac{\langle 0^+_f \| \delta \| 1^+_n \rangle \langle 1^+_n \| \delta \| 0^+_i \rangle}{(\frac{1}{2} Q_{\beta\beta} + E_n - M_i)/m_e + 1}$$

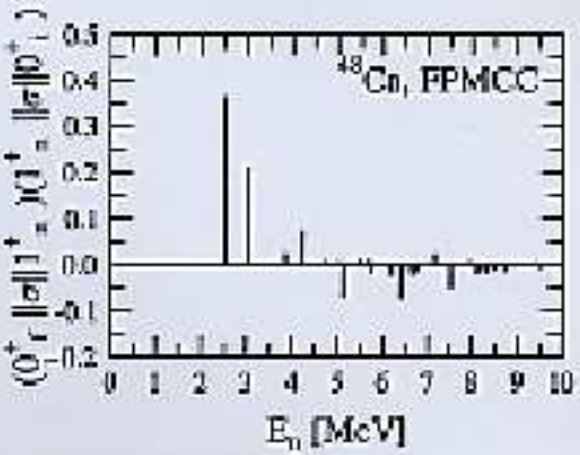
pf model space





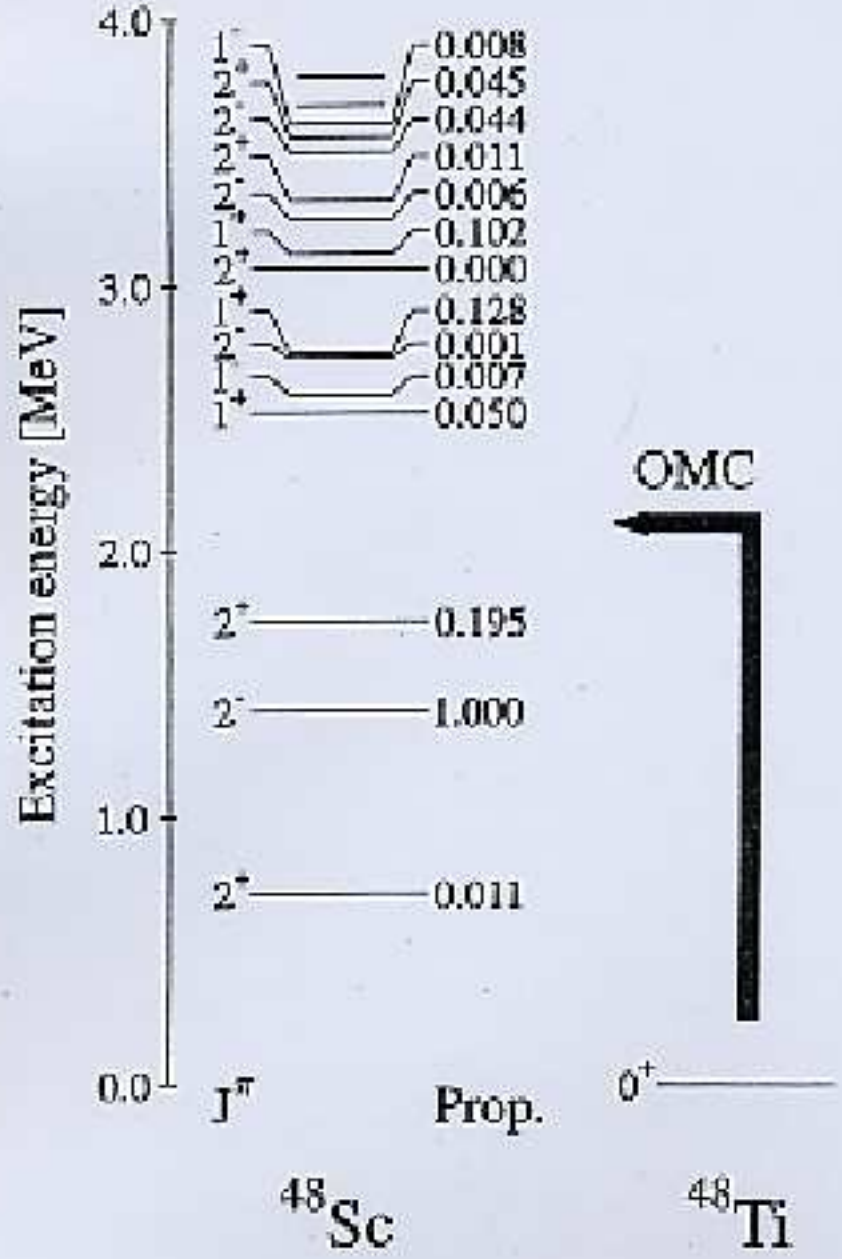
$$^{46}_{20}Ca_{26} \xrightarrow{2\nu\beta^-\beta^-} {}^{46}_{22}Ti_{24}$$





$$^{48}_{20}Ca_{28} \xrightarrow{2\nu\beta^-\beta^-} {}^{48}_{22}Ti_{26}$$

MUON-CAPTURE RATES IN ^{48}Ti



μ^- CAPTURE & $\beta\beta$ DECAY: CONCLUSIONS

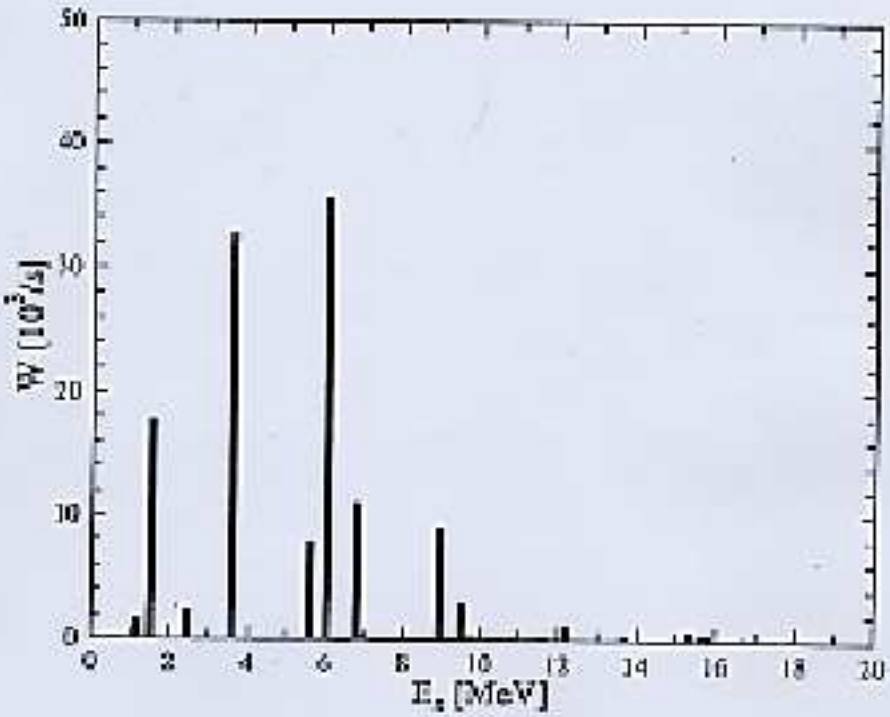
- μ^- CAPTURE RATE TO THE 1^+_1 STATE VERY SENSITIVE TO g_{pp} (pn ple-ple int. action) $\leftrightarrow$ LINK IN THE $2\nu\beta\beta$ DECAY!

- GOOD POSSIBILITY TO CONSTRAIN THE WAVE FUNCTIONS OF THE $\beta\beta$ INTERMEDIATE NUCLEUS

- POSSIBILITY TO CONSTRAIN THE MAGNITUDE OF THE INDUCED PSEUDO-SCALAR COMPONENT OF THE HADRONIC CHARGED WEAK-INTERACTION CURRENT

- PRESENT STATUS:
  - ANALYSIS OF THE PSI EXPERIMENT(S) GOING ON
  - SHELL-MODEL CALCULATIONS FOR THE SYSTEMS

$$^{36}Ar \xrightarrow{2\nu ECEC} {}^{36}S \quad , \quad {}^{36}Ar \xrightarrow{\mu^- C} {}^{36}Cl$$
$$^{46}Ca \xrightarrow{2\nu\beta^-\beta^-} {}^{46}Ti \quad , \quad {}^{46}Ti \xrightarrow{\mu^- C} {}^{46}Sc$$
$$^{48}Ca \xrightarrow{2\nu\beta^-\beta^-} {}^{48}Ti \quad , \quad {}^{48}Ti \xrightarrow{\mu^- C} {}^{48}Sc$$
$$^{50}Cr \xrightarrow{2\nu ECEC} {}^{50}Ti \quad , \quad {}^{50}Ti \xrightarrow{\mu^- C} {}^{50}V$$


W [10^3/s]
E_x [MeV]
0
10
20
30
40
50
0
2
4
6
8
10
12
14
16
18
20