WAYS TO PROBE DOUBLE BETA MATRIX ELEMENTS BY INDEPENDENT DATA

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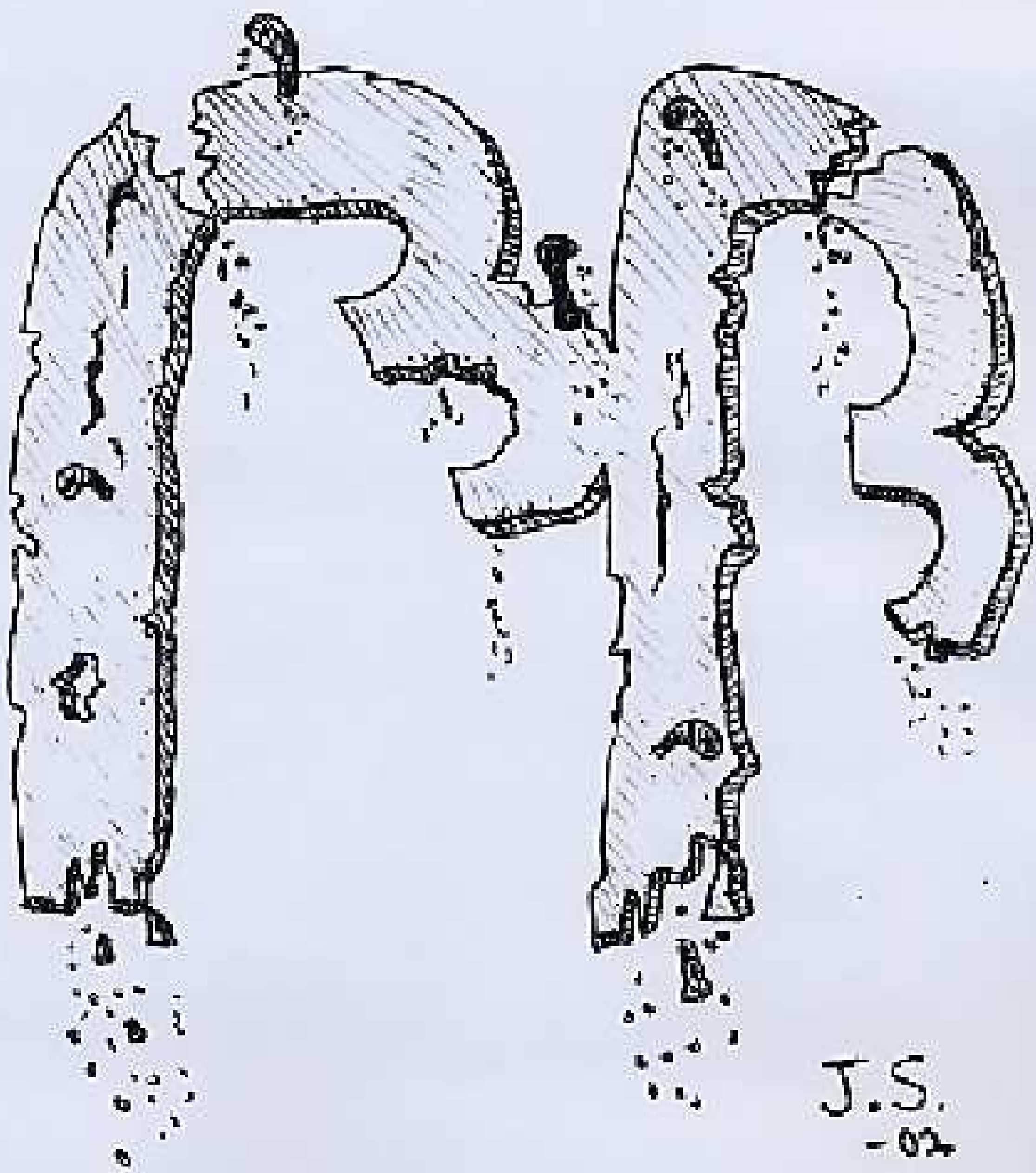
CONTENTS

- $0\nu\beta\beta$ 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

$\boxed{\mu^- \text{ capture}}$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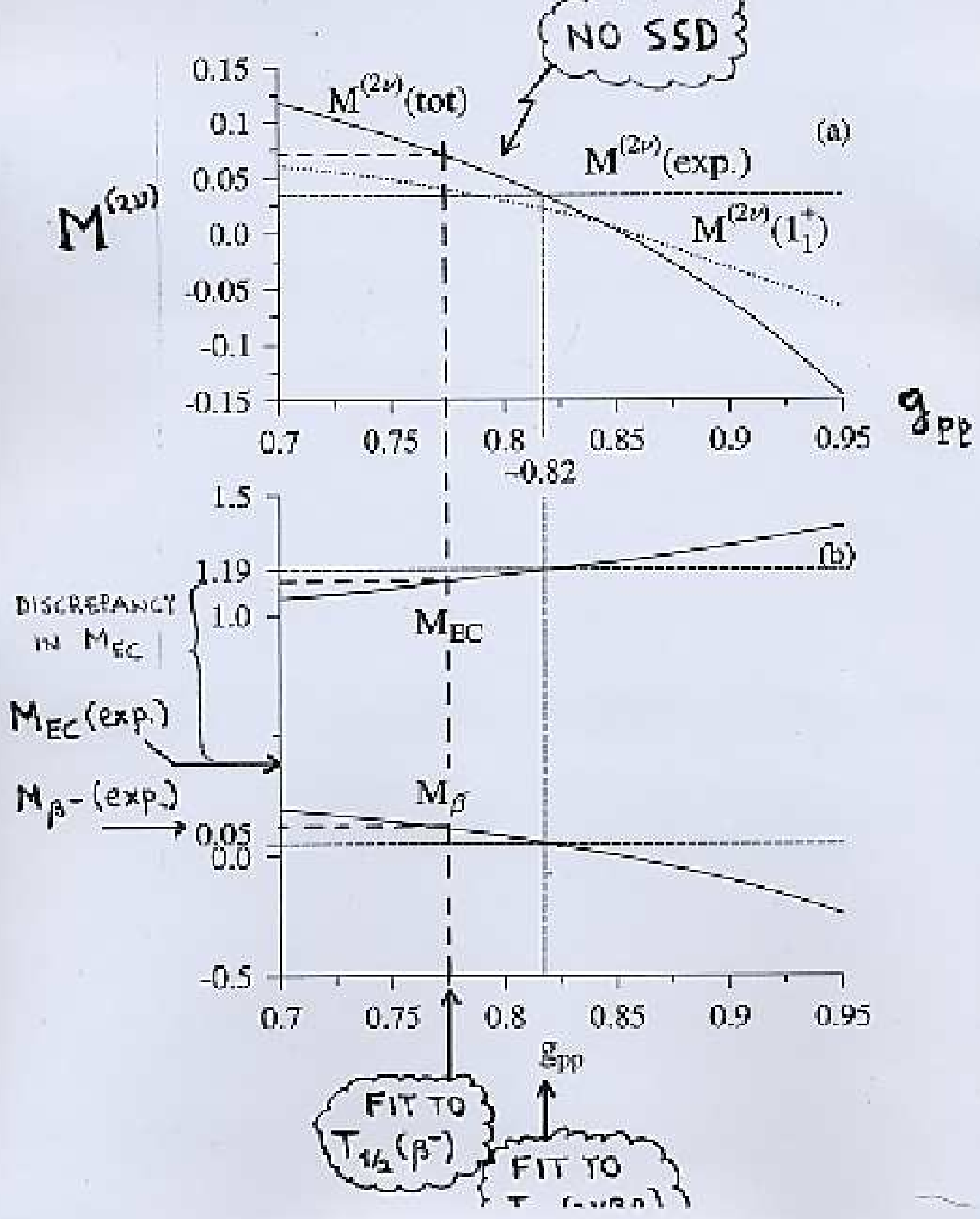
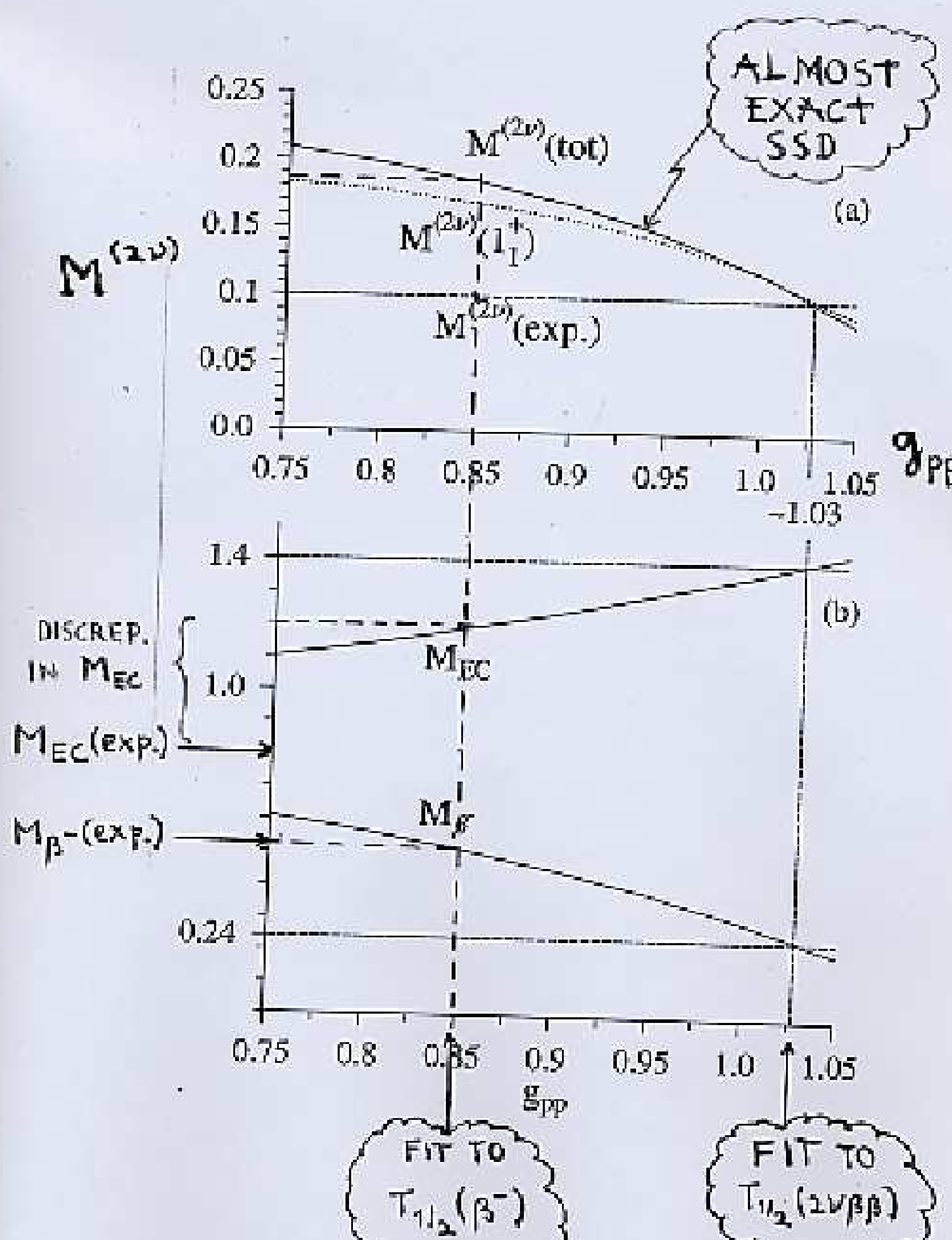
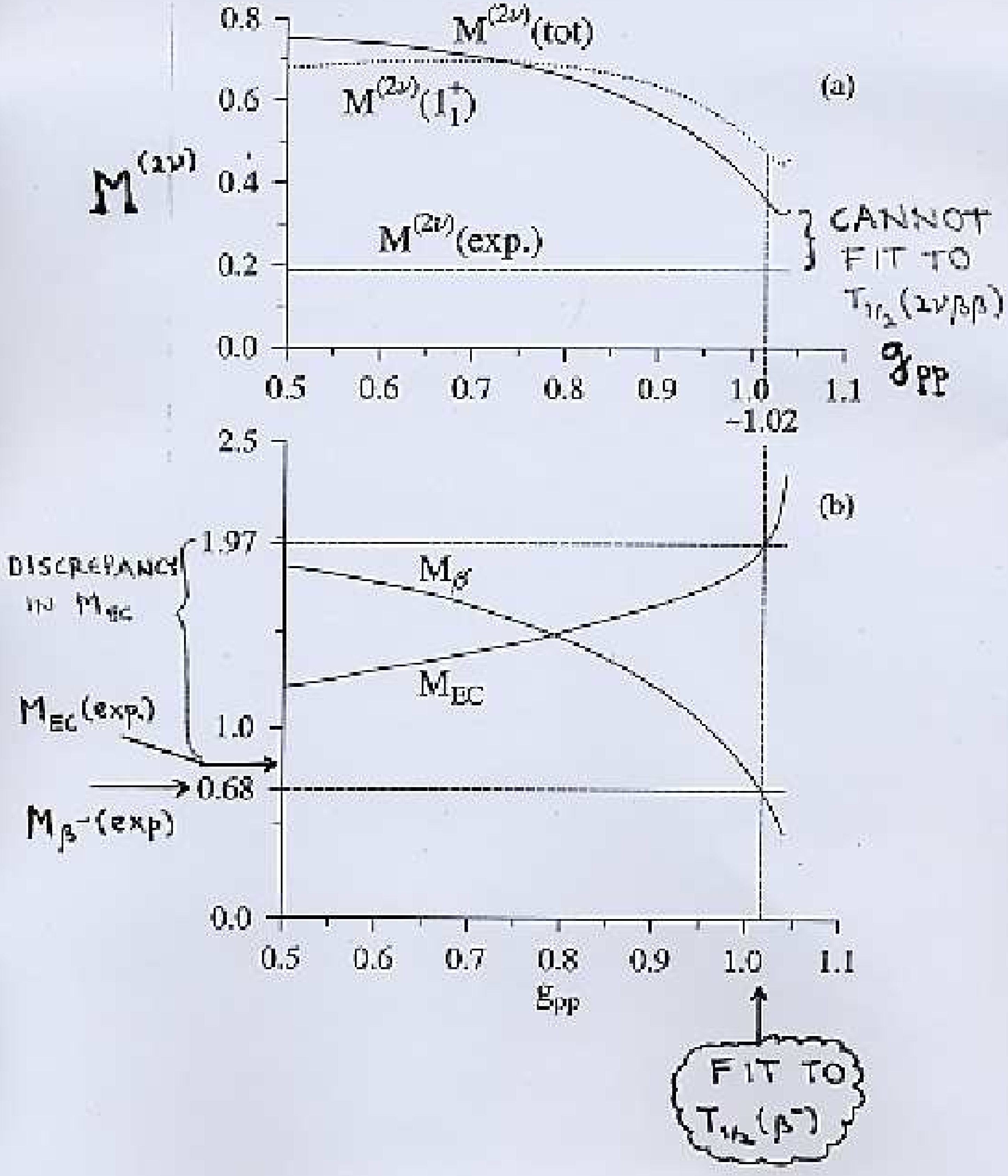
$^{128}Te \xrightarrow{2\nu\beta^-\beta^-} {}^{128}Xe$



Ca → Sn

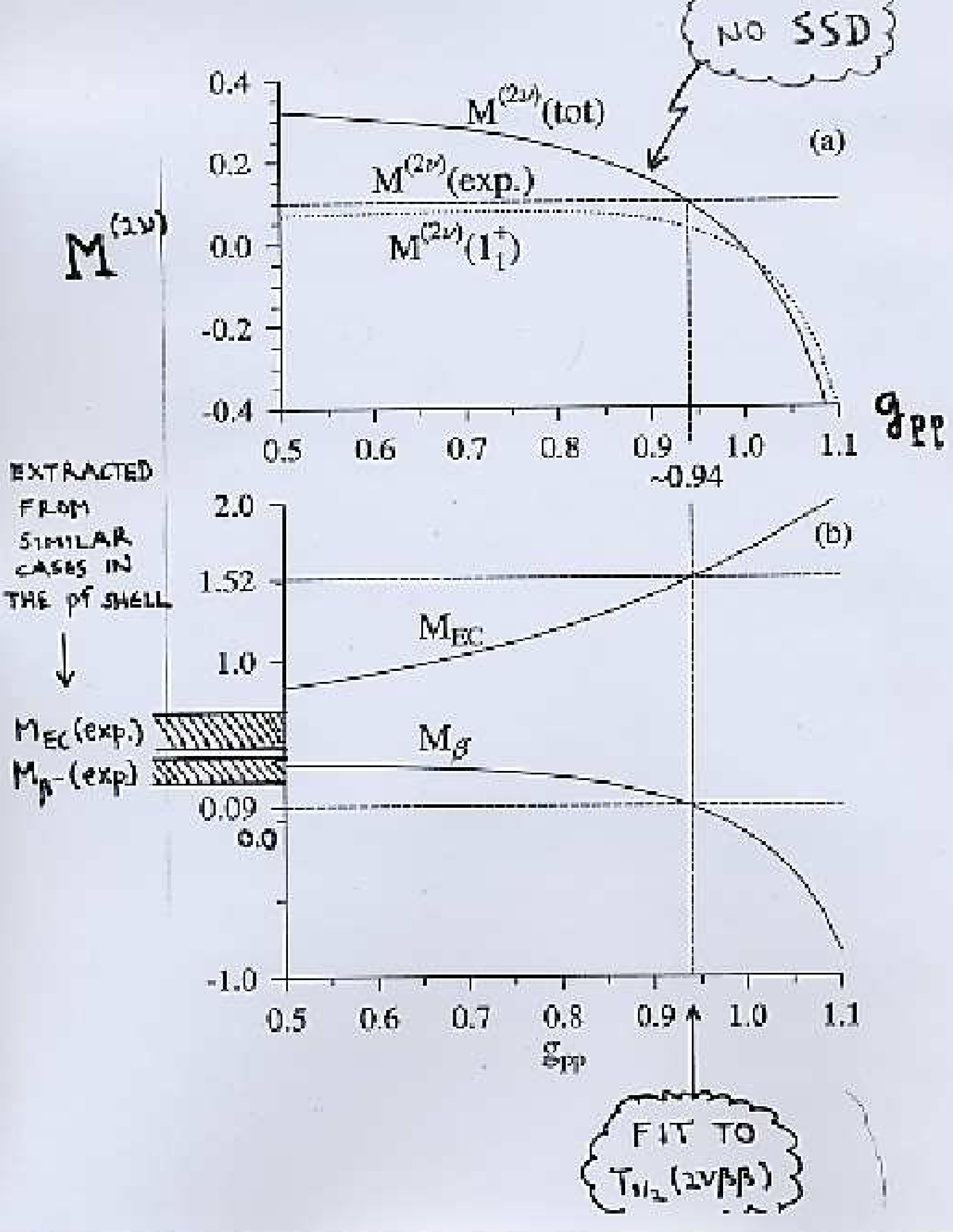

ALMOST EXACT SSD
M^(2ν)
M^(2ν)(tot)
M^(2ν)(1+1)
M^(2ν)(exp.)
(a)
0.25
0.2
0.15
0.1
0.05
0.0
0.75
0.8
0.85
0.9
0.95
1.0
1.05
gpp
~1.03
1.4
1.0
0.24
(b)
DISCREP. IN MEC
MEC(exp.)
Mβ-(exp.)
MEC
Mβ
gpp
FIT TO T1/2(β-)
FIT TO T1/2(2νββ)

Mo Ru

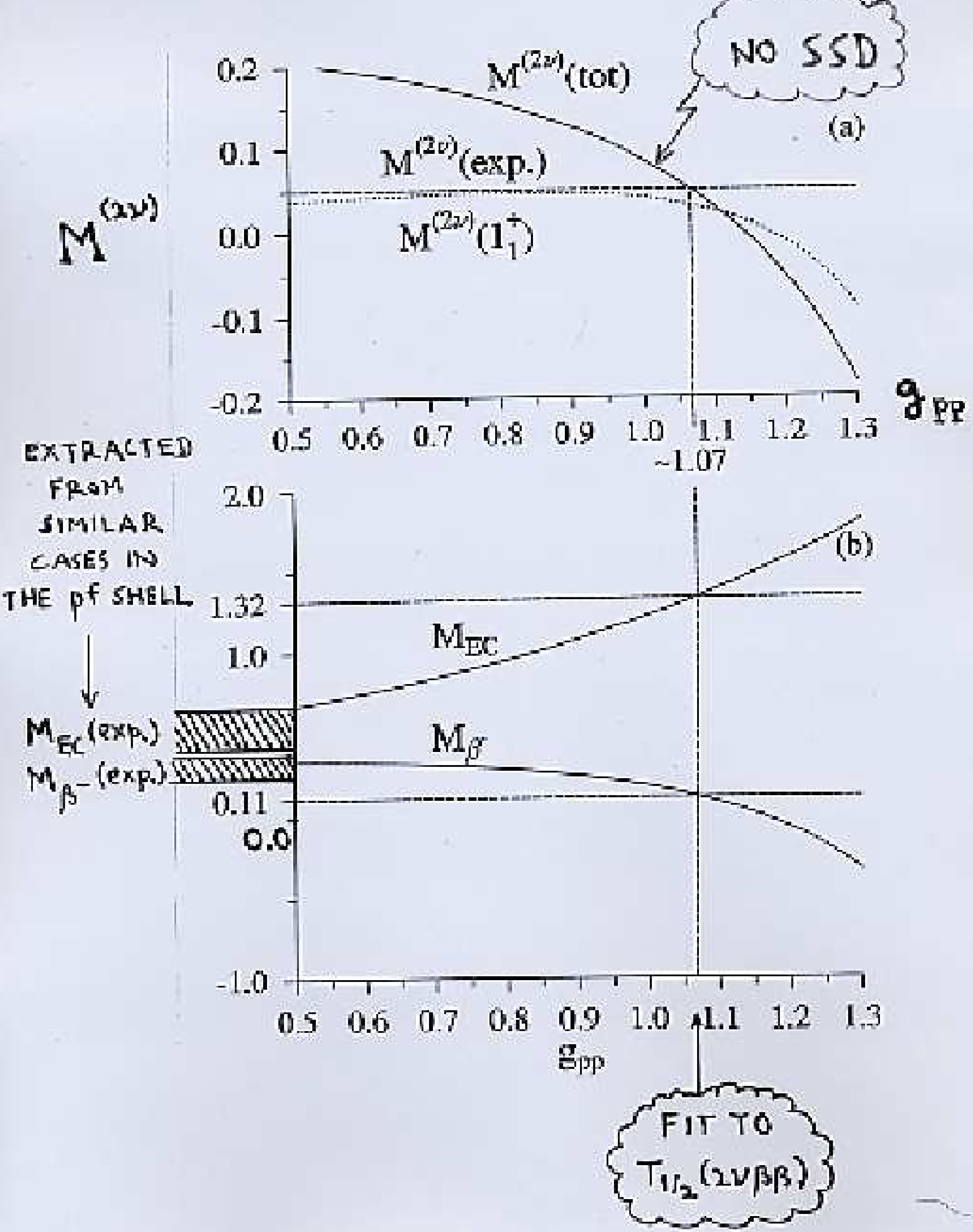


$M^{(2\nu)}$
$M^{(2\nu)}$(tot)
$M^{(2\nu)}(1_1^+)$
$M^{(2\nu)}$(exp.)
(a)
CANNOT FIT TO $T_{1/2}(2\nu\beta\beta)$
g_{pp}
~1.02
(b)
DISCREPANCY IN M_{EC}
1.97
M_{β^-}
M_{EC}
M_{EC}(exp.)
0.68
M_{β^-}(exp)
g_{pp}
FIT TO $T_{1/2}(\beta^-)$

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



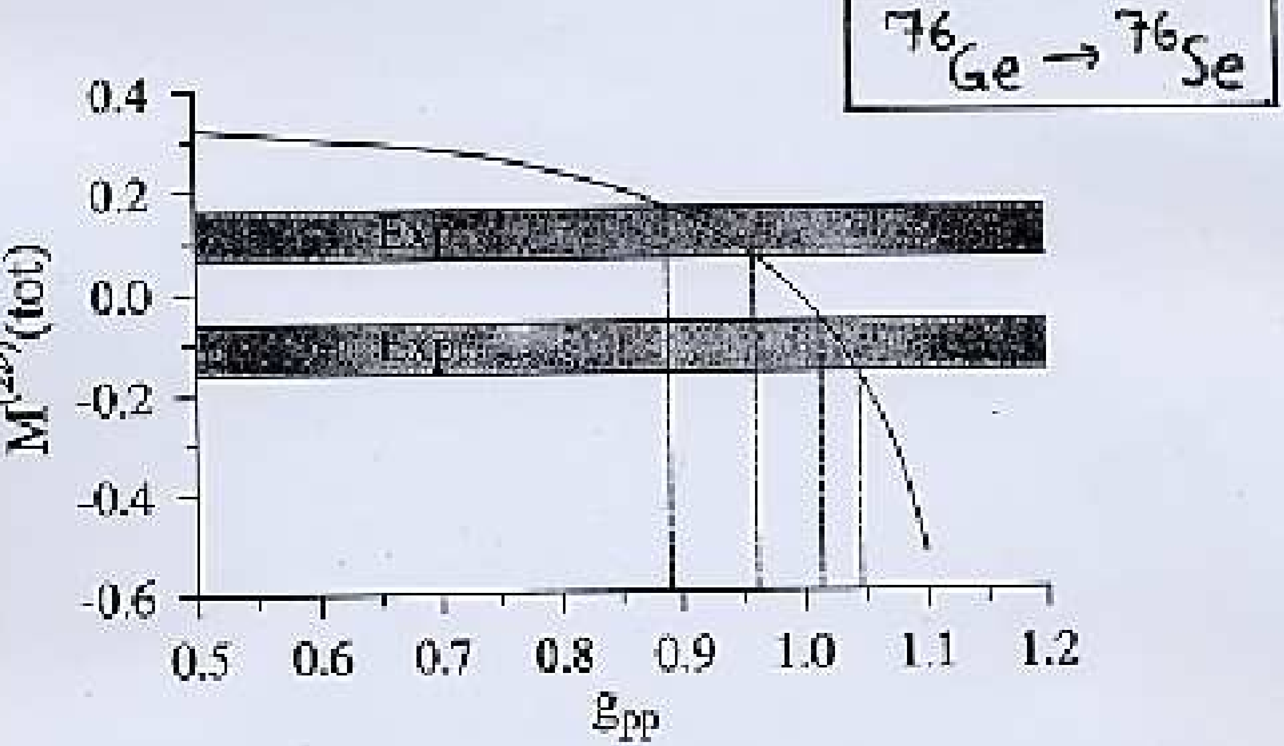
$^{82}Se \xrightarrow{2\nu\beta^-\beta^-} {}^{82}Kr$

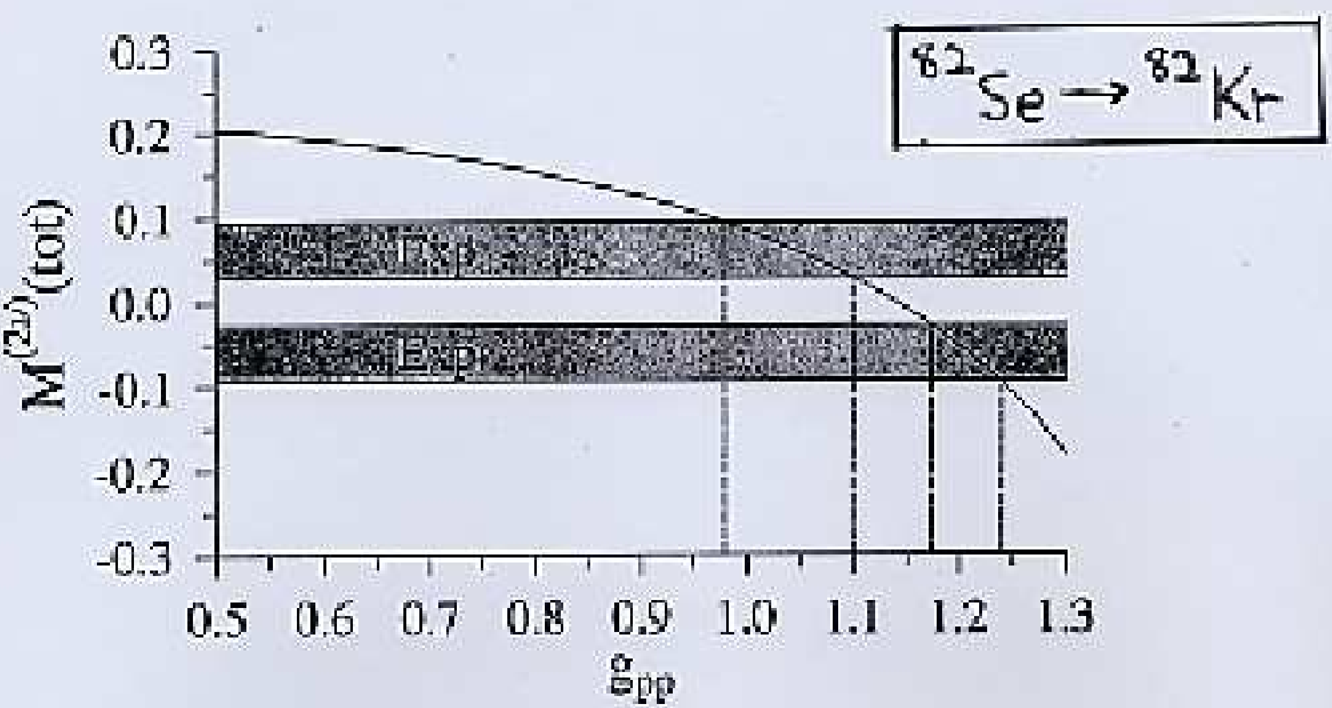


β Decay vs. $2\nu\beta\beta$ Decay in Fitting g_{pp}

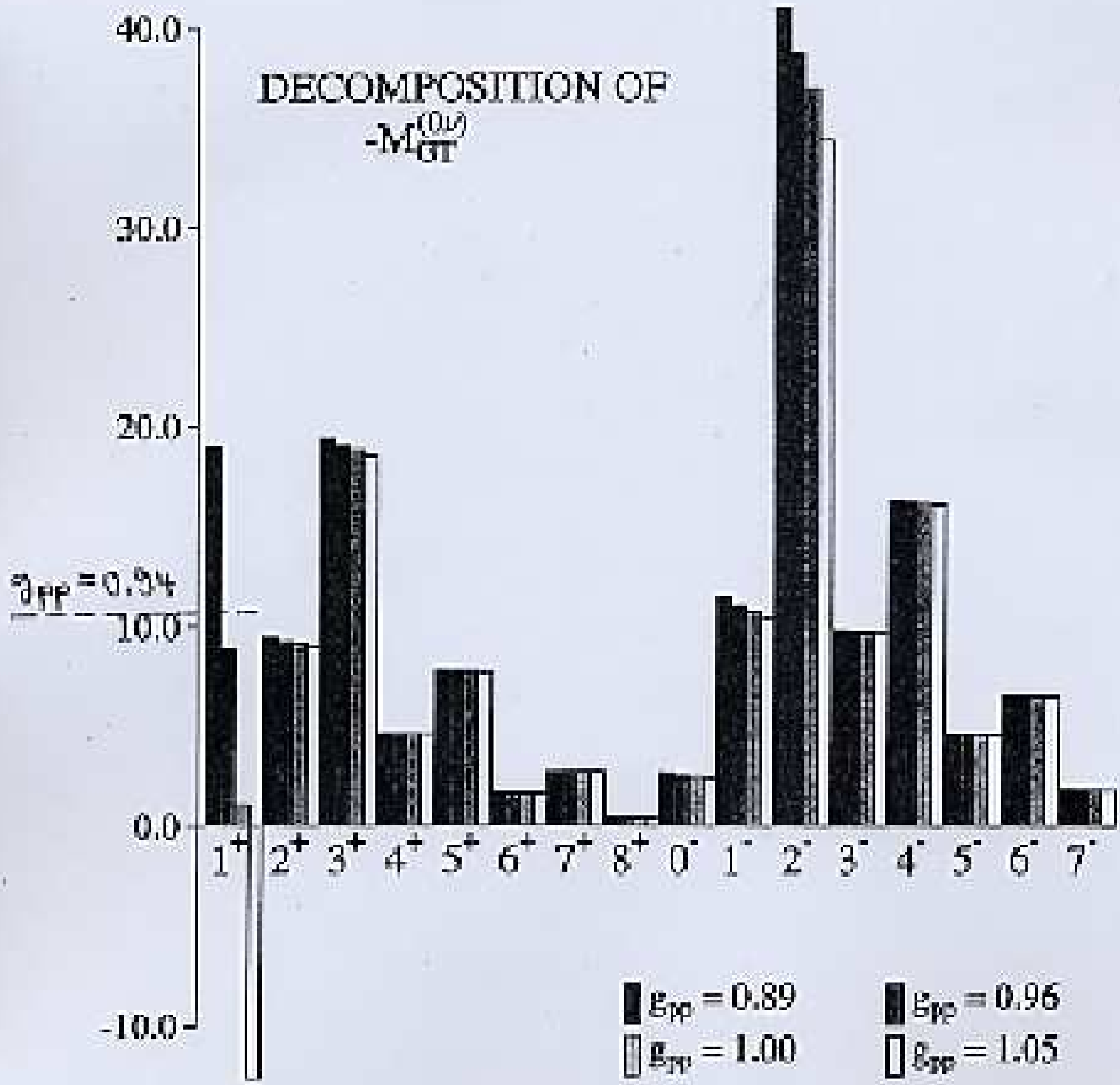
Point	Fit to β^- and/or EC decay(s)	Fit to $2\nu\beta^-\beta^-$ decay
1	One, two or more observables can be used for the fit (+)	Only one observable can be used for the fit (−)
2	Direct access to grass-root-level deficiencies of a nuclear model (+)	Two or more compensating errors may conspire to produce 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 Ge and Se



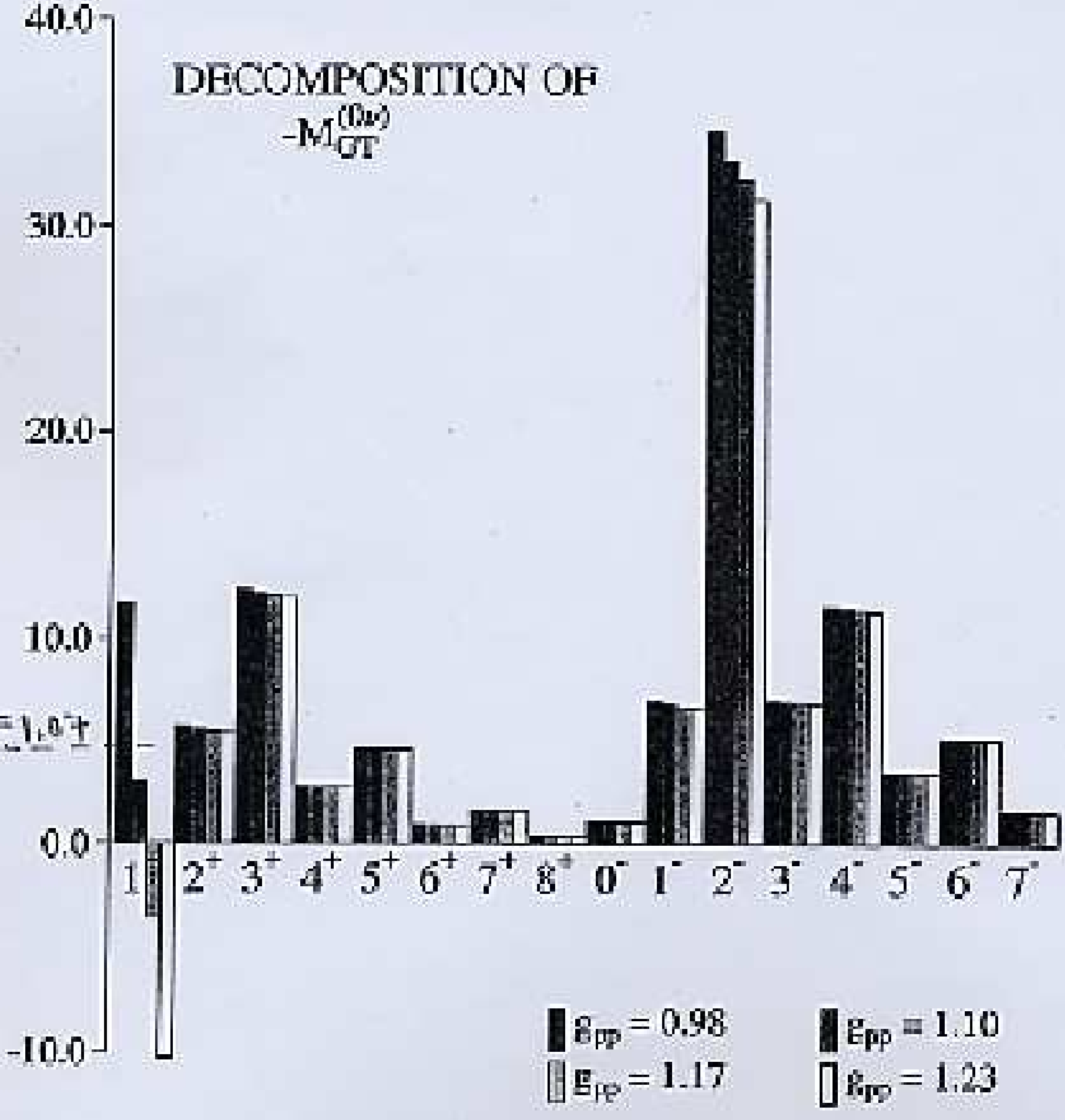


$^{76}Ge \longrightarrow {}^{76}Se$



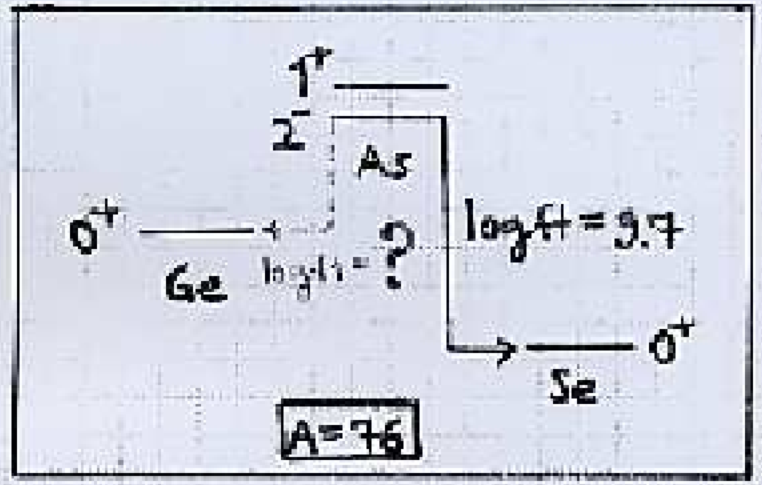
From fit to central value: $g_{pp} = 0.94$

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

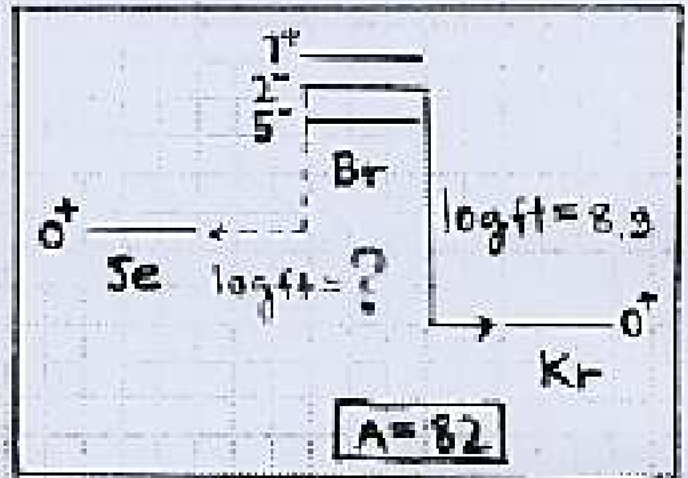


From fit to central value: $g_{pp} = 1.07$

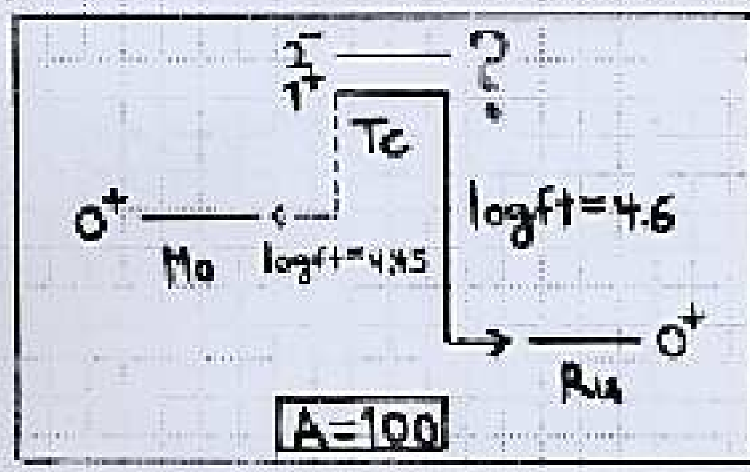
$0\nu\beta\beta$ ^{82}Se



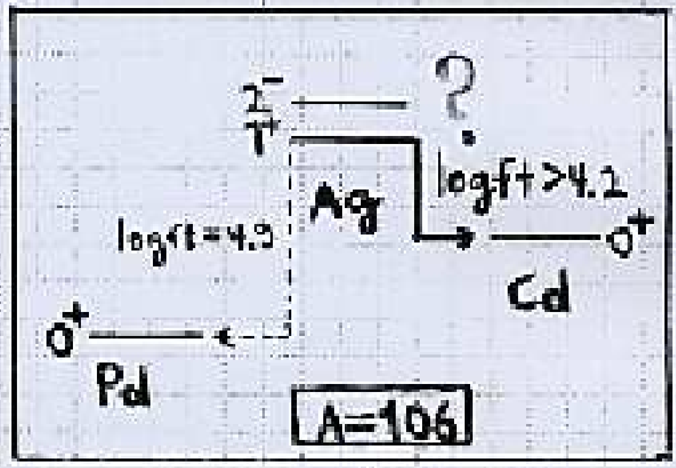
1+
2-
As
0+
Ge
logft=?
logft=9.7
0+
Se
A=76



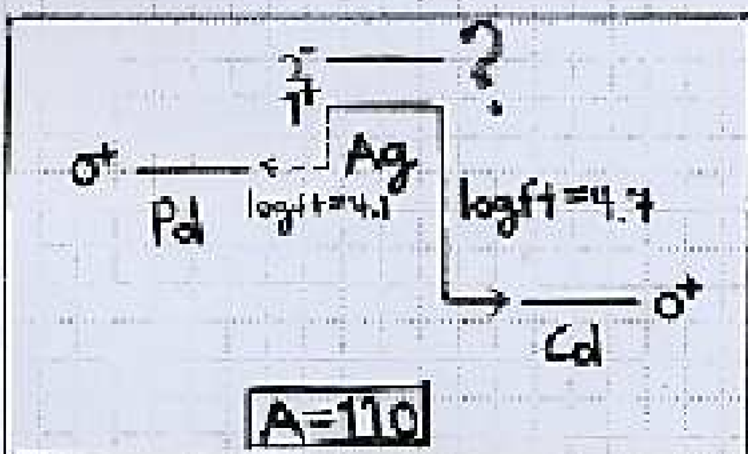
1+
2-
5-
Br
0+
Se
logft=?
logft=8.9
0+
Kr
A=82



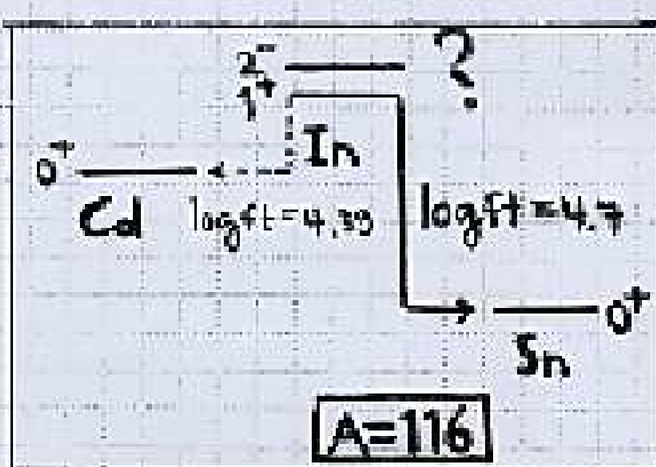
2-
1+
?
Tc
0+
Mo
logft=4.45
logft=4.6
0+
Ru
A=100



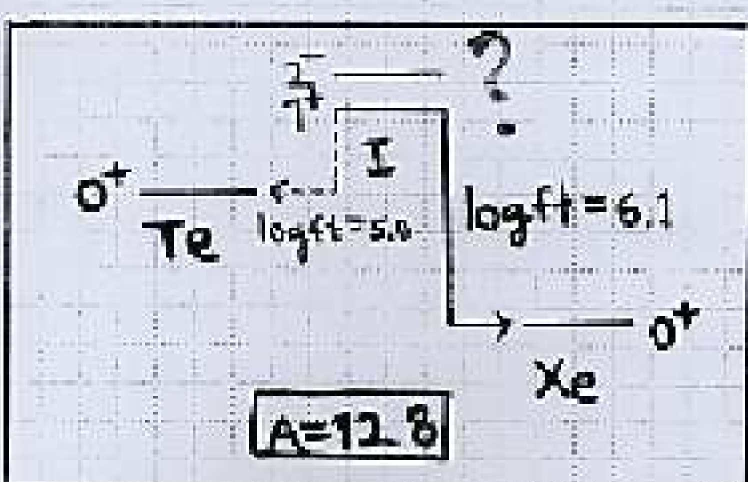
2-
1+
?
logft>4.2
Ag
logft=4.9
0+
Cd
0+
Pd
A=106



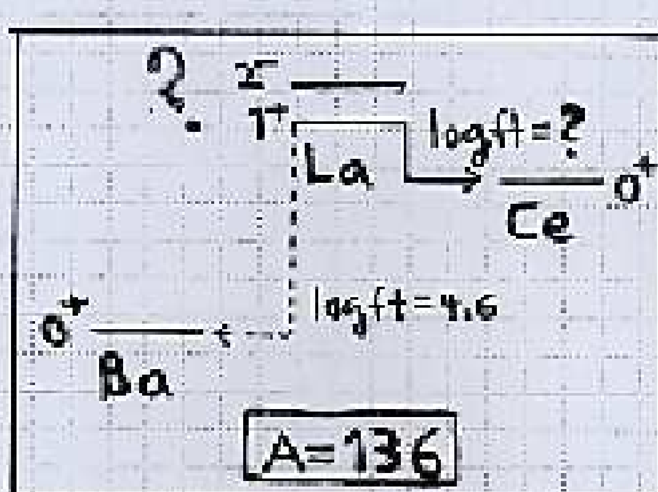
2-
1+
?
0+
Ag
Pd
logft=4.1
logft=4.7
0+
Cd
A=110



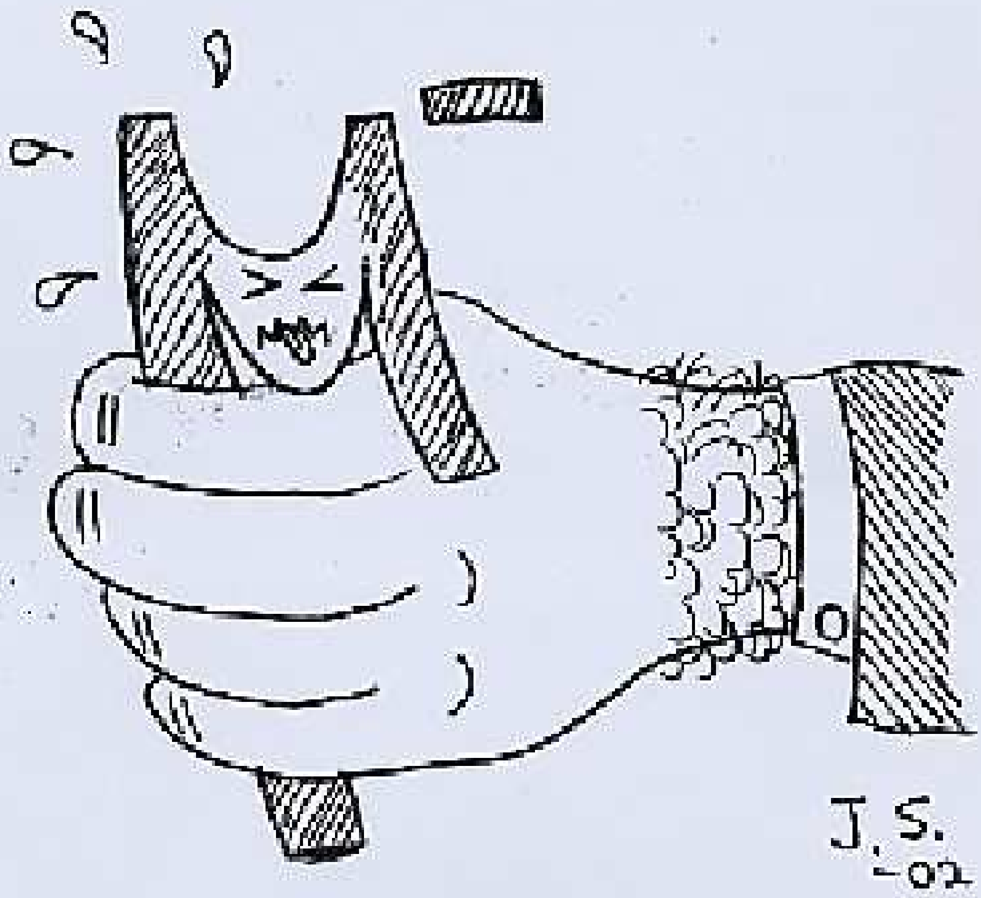
2-
1+
?
0+
In
Cd
logft=4.39
logft=4.7
0+
Sn
A=116



2-
1+
?
I
0+
Te
logft=5.0
logft=6.1
0+
Xe
A=128



?
2-
1+
logft=?
La
0+
Ce
logft=4.6
0+
Ba
A=136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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:

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

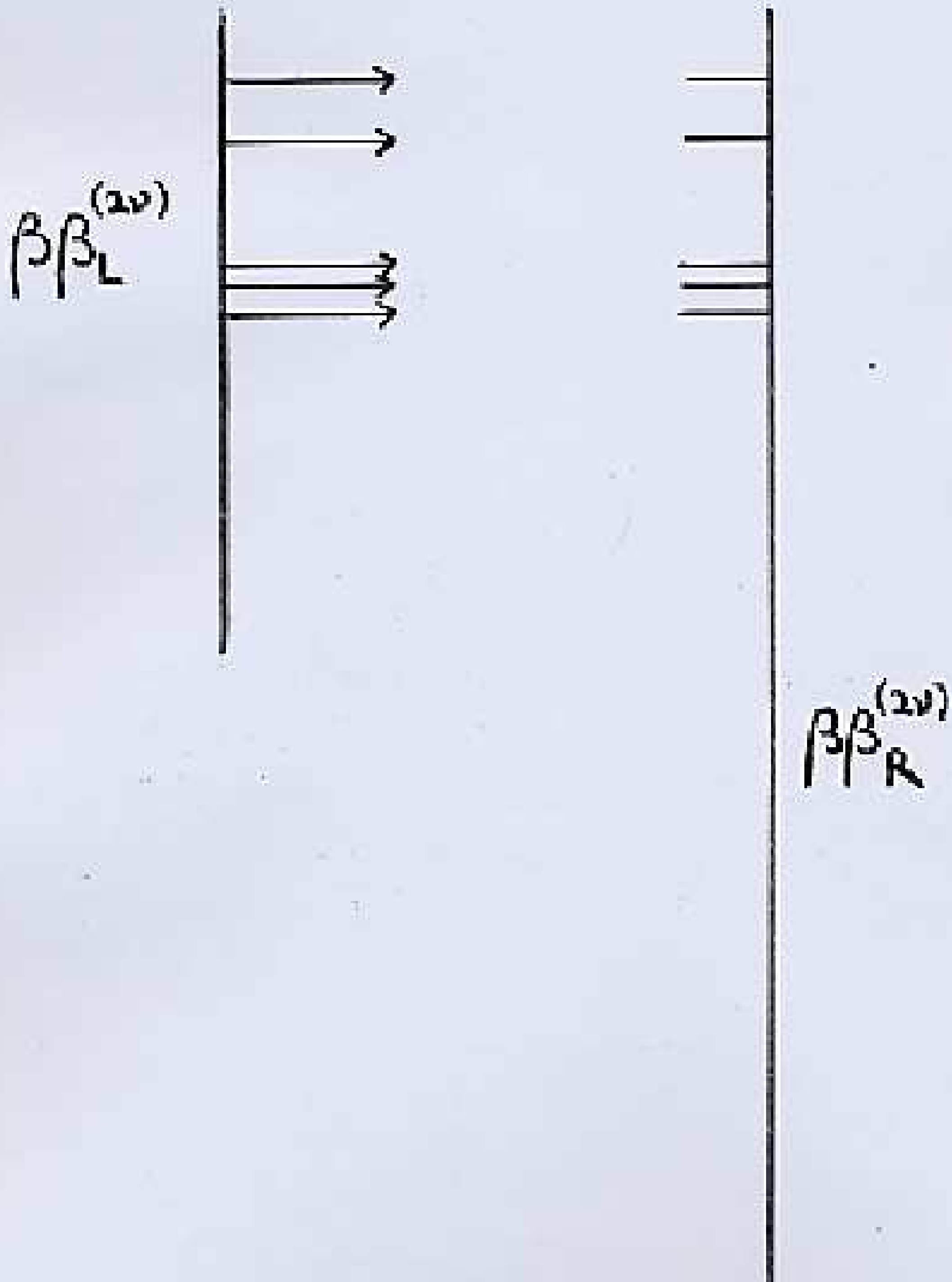
③ CONVERSION processes:

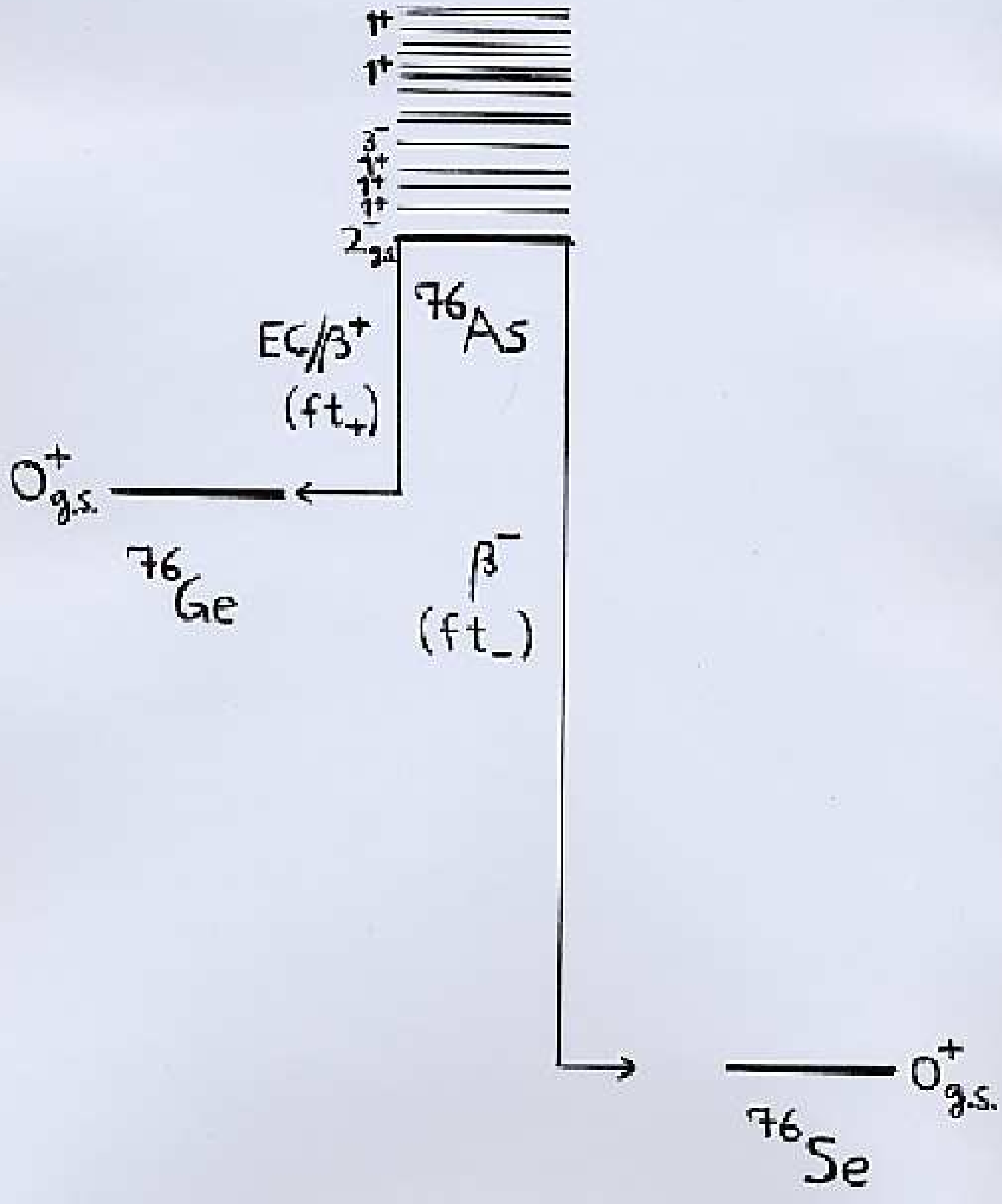
$$\mu^- + (A,Z) \rightarrow e^- + (A,Z)$$

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

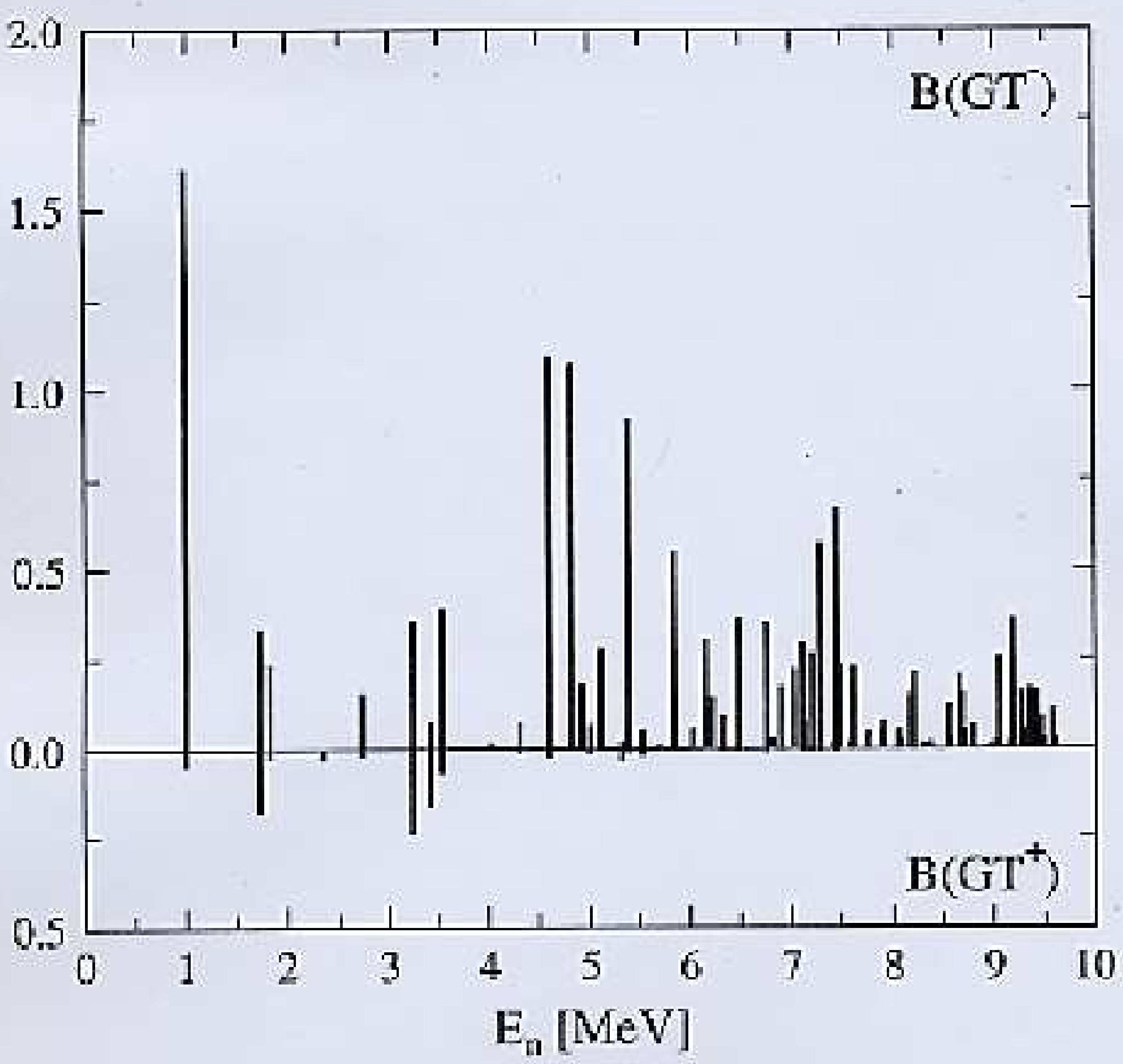
(lepton-flavour violating)


forbidden
OMC
allowed
OMC
(GT β+)

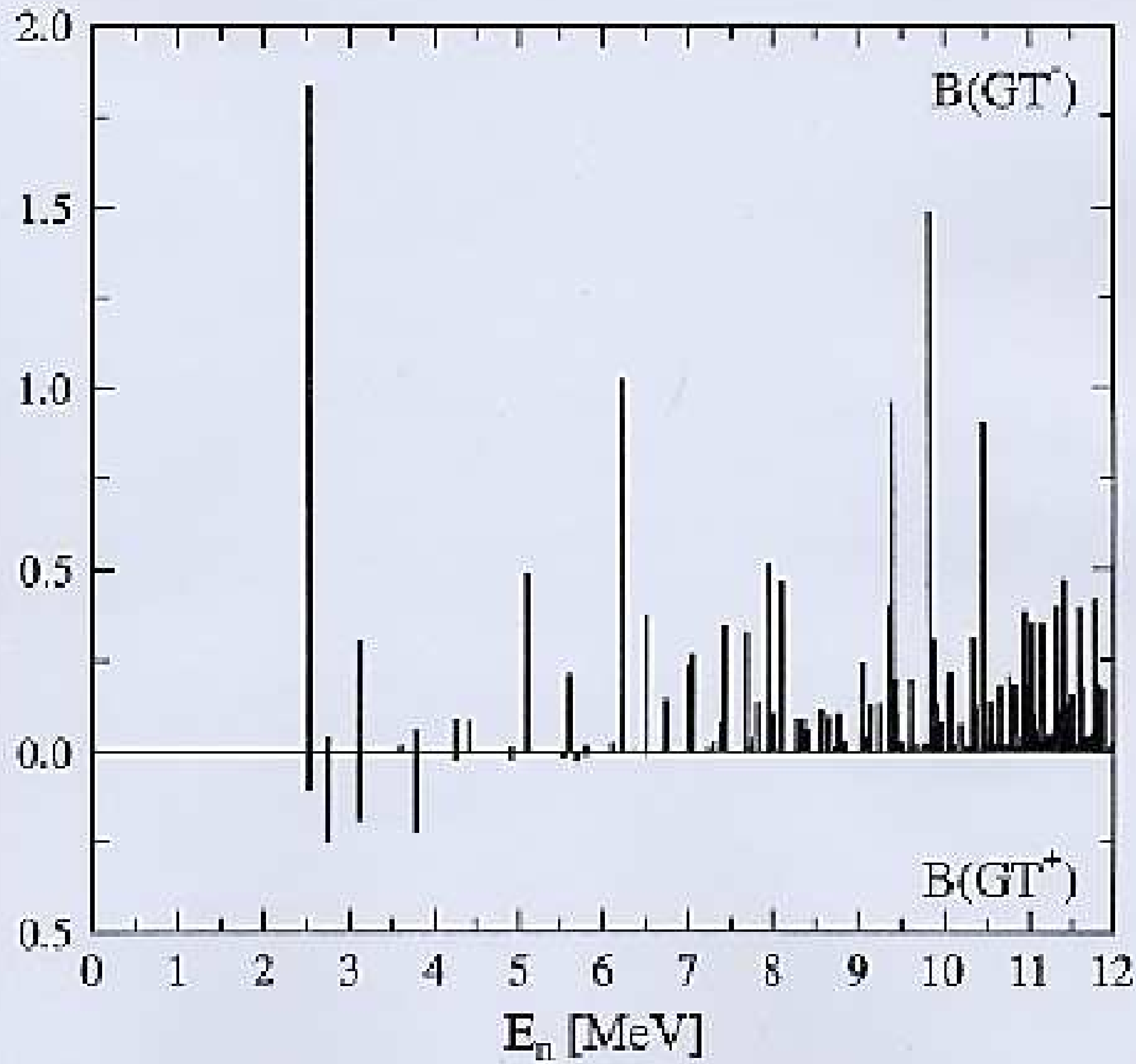

$\beta\beta_L^{(2\nu)}$
$\beta\beta_R^{(2\nu)}$


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)

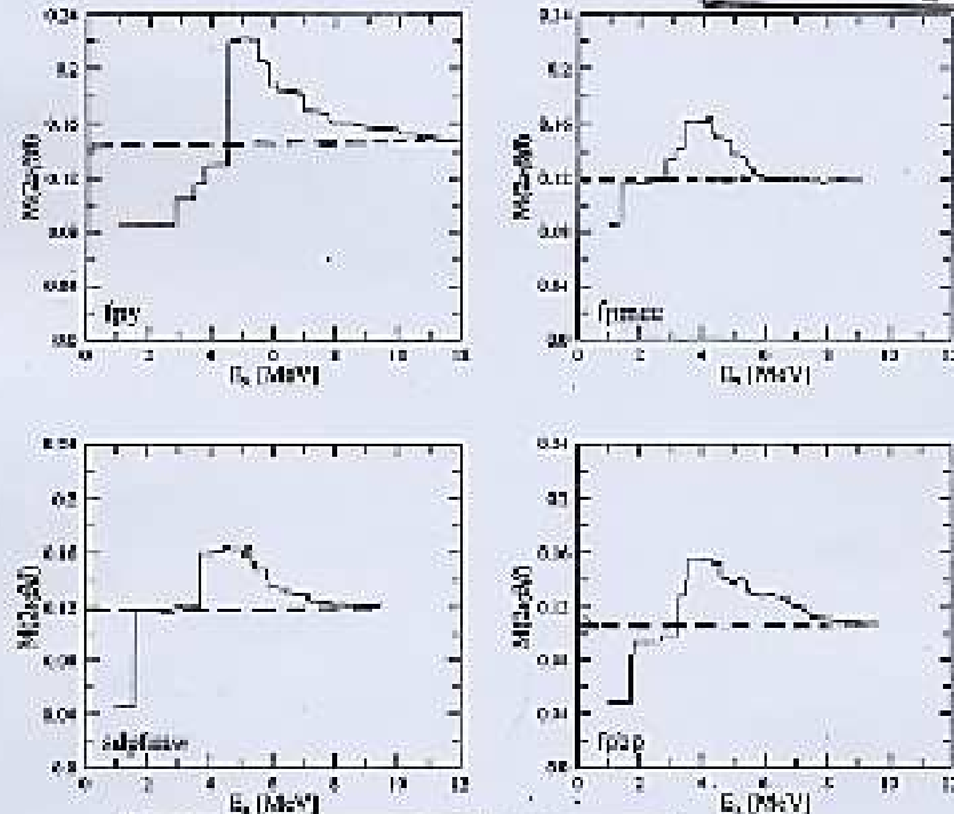


^{48}Ca (fpbp)

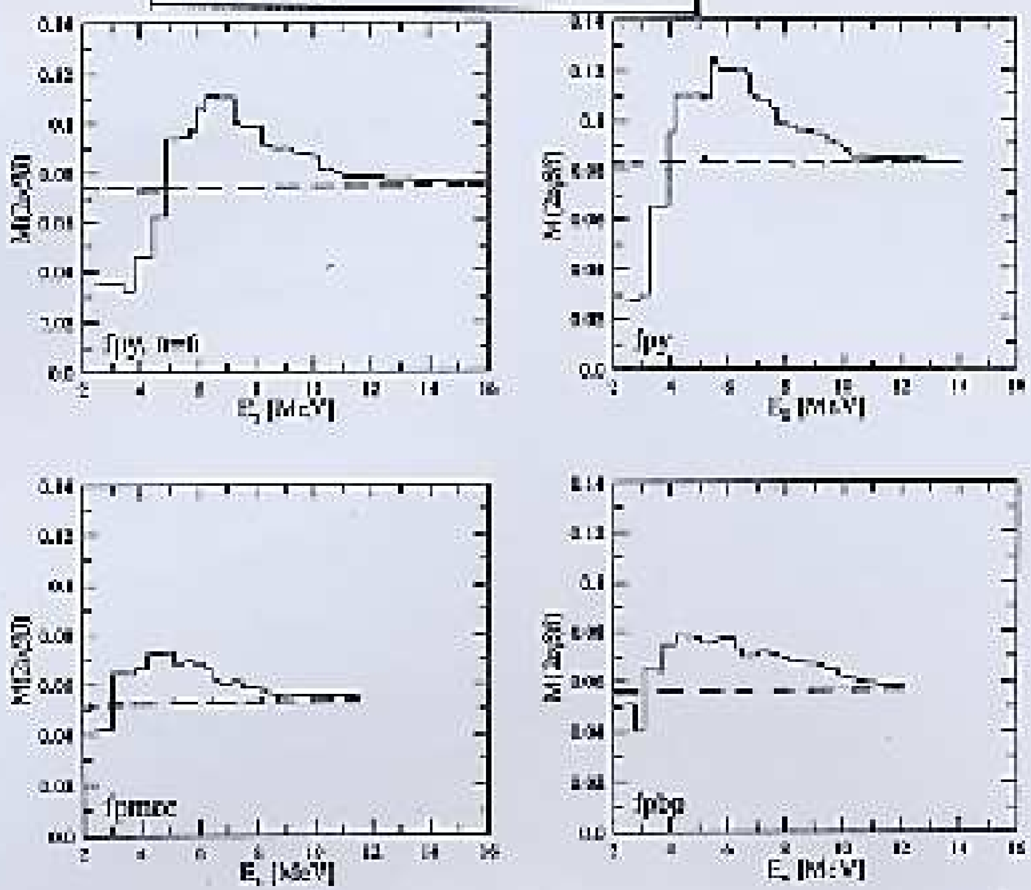


$_{20}Ca_{26} \longrightarrow {}_{22}Ti_{24}$

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



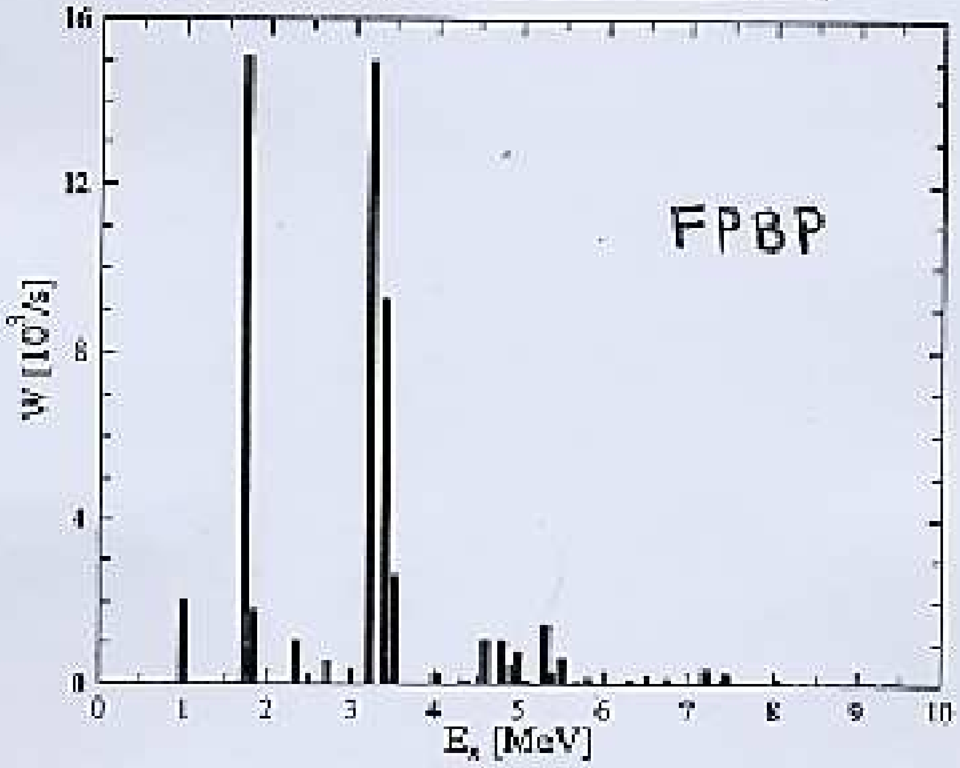
$$ {}^{48}_{20}Ca_{28} \xrightarrow{2\nu\beta^-\beta^-} {}^{48}_{22}Ti_{26} $$

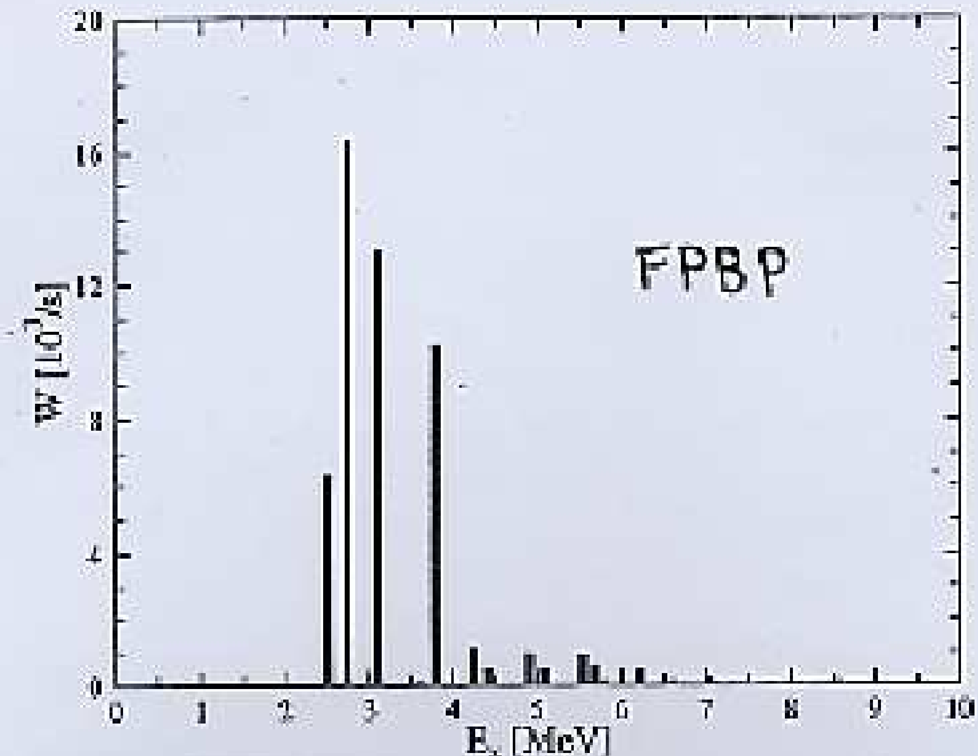


$$ {}^{48}Ca: \; M^{\beta\beta}_{GT}(exp) = (0.034 - 0.115)\, MeV^{-1} $$

MUON CAPTURE RATES

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

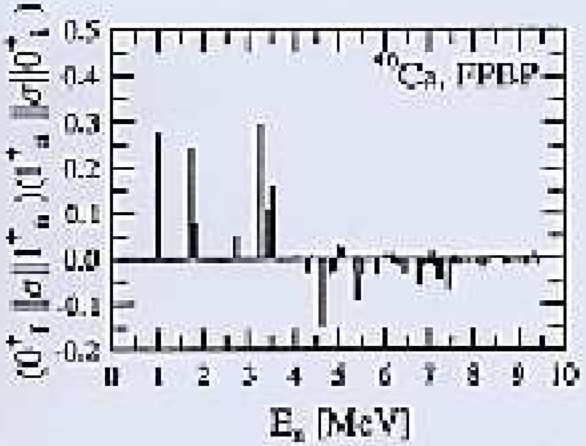


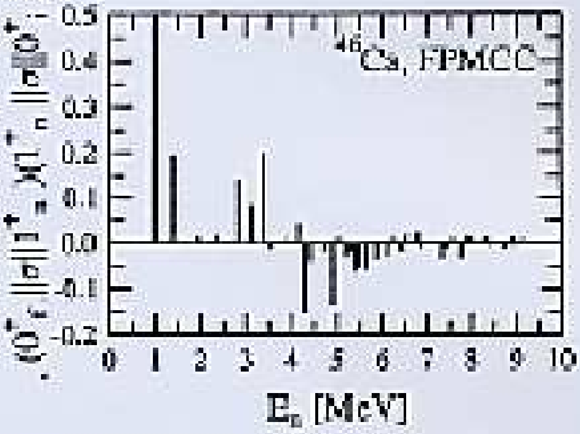


$^{48}\mathrm{Ti}(0^+_{gs}) \xrightarrow{\mathrm{OMC}} {}^{48}\mathrm{Sc}(1^+_n)$

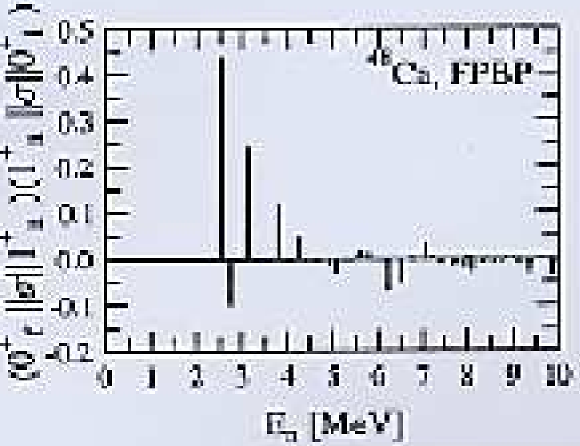
$$M^{(2\nu)}_{DGT} = \sum_n \frac{(0_f^+ \| \sigma \| 1_n^+)(1_n^+ \| \sigma \| 0_i^+)}{(\frac{1}{2} Q_{\beta\beta} + E_n - M_i)/m_e + 1}$$

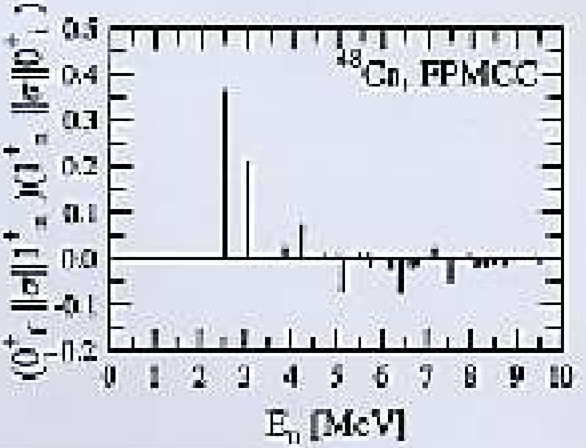
pf model space



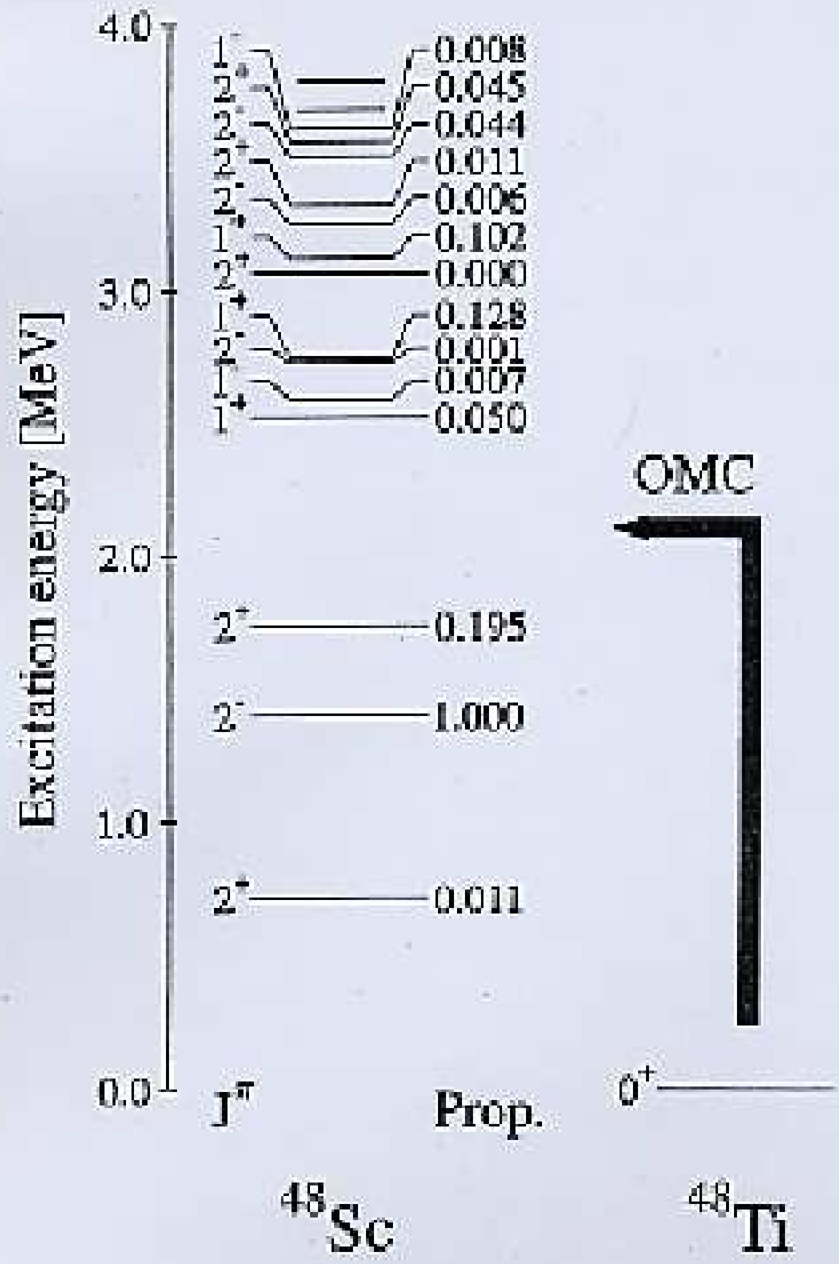


$$^{46}_{20}Ca_{26} \xrightarrow{2\nu\beta^-\beta^-} {}^{46}_{22}Ti_{24}$$





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



Excitation energy [MeV]
4.0
3.0
2.0
1.0
0.0
1⁻ 0.008
2⁺ 0.045
2⁻ 0.044
2⁺ 0.011
2⁻ 0.006
1⁺ 0.102
2⁺ 0.000
1⁺ 0.128
2⁻ 0.001
1⁻ 0.007
1⁺ 0.050
2⁺ 0.195
2⁻ 1.000
2⁺ 0.011
J^π
Prop.
OMC
0⁺
48Sc
48Ti

μ^- CAPTURE & $\beta\beta$ DECAY

CONCLUSIONS

- μ^- CAPTURE RATE TO THE 1^+_1 STATE VERY SENSITIVE TO g_{pp} (pn ple-ple int. action) $\longleftrightarrow$ LIKE 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

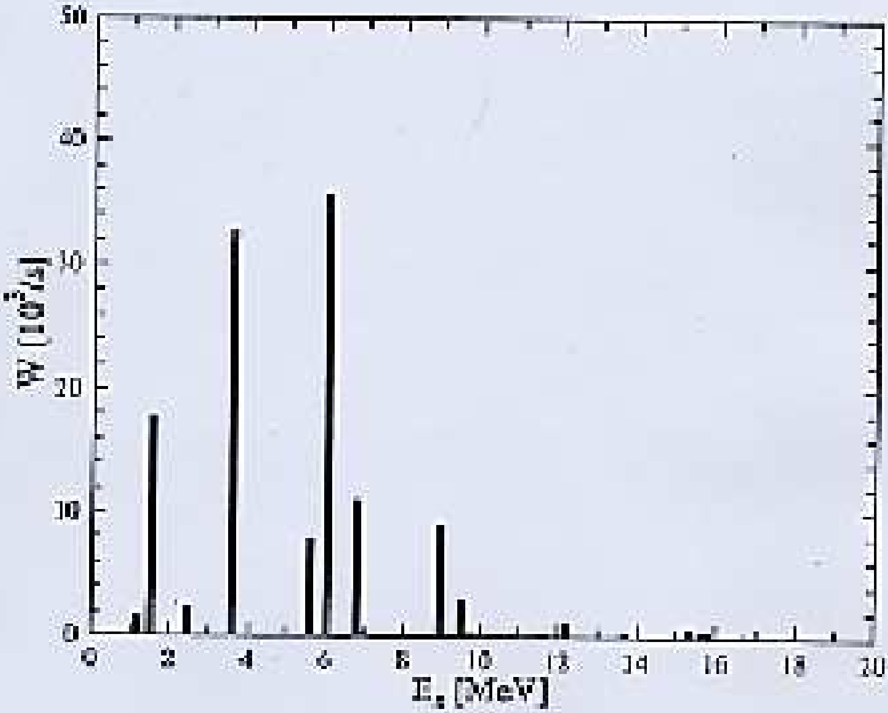
- PRESENT STATUS :
  - ANALYSIS OF THE PSI EXPERIMENT(S) GOING ON
  - SHELL-MODEL CALCULATIONS FOR THE SYSTEMS

$$^{36}Ar \xrightarrow{2\nu ECEC} {}^{36}S \ , \quad {}^{36}Ar \xrightarrow{\mu^- C} {}^{36}Cl$$

$$^{46}Ca \xrightarrow{2\nu\beta^-\beta^-} {}^{46}Ti \ , \quad {}^{46}Ti \xrightarrow{\mu^- C} {}^{46}Sc$$

$$^{48}Ca \xrightarrow{2\nu\beta\beta} {}^{48}Ti \ , \quad {}^{48}Ti \xrightarrow{\mu^- C} {}^{48}Sc$$

$$^{50}Cr \xrightarrow{2\nu ECEC} {}^{50}Ti \ , \quad {}^{50}Ti \xrightarrow{\mu^- C} {}^{50}V$$



W [10^3/s]
E_x [MeV]