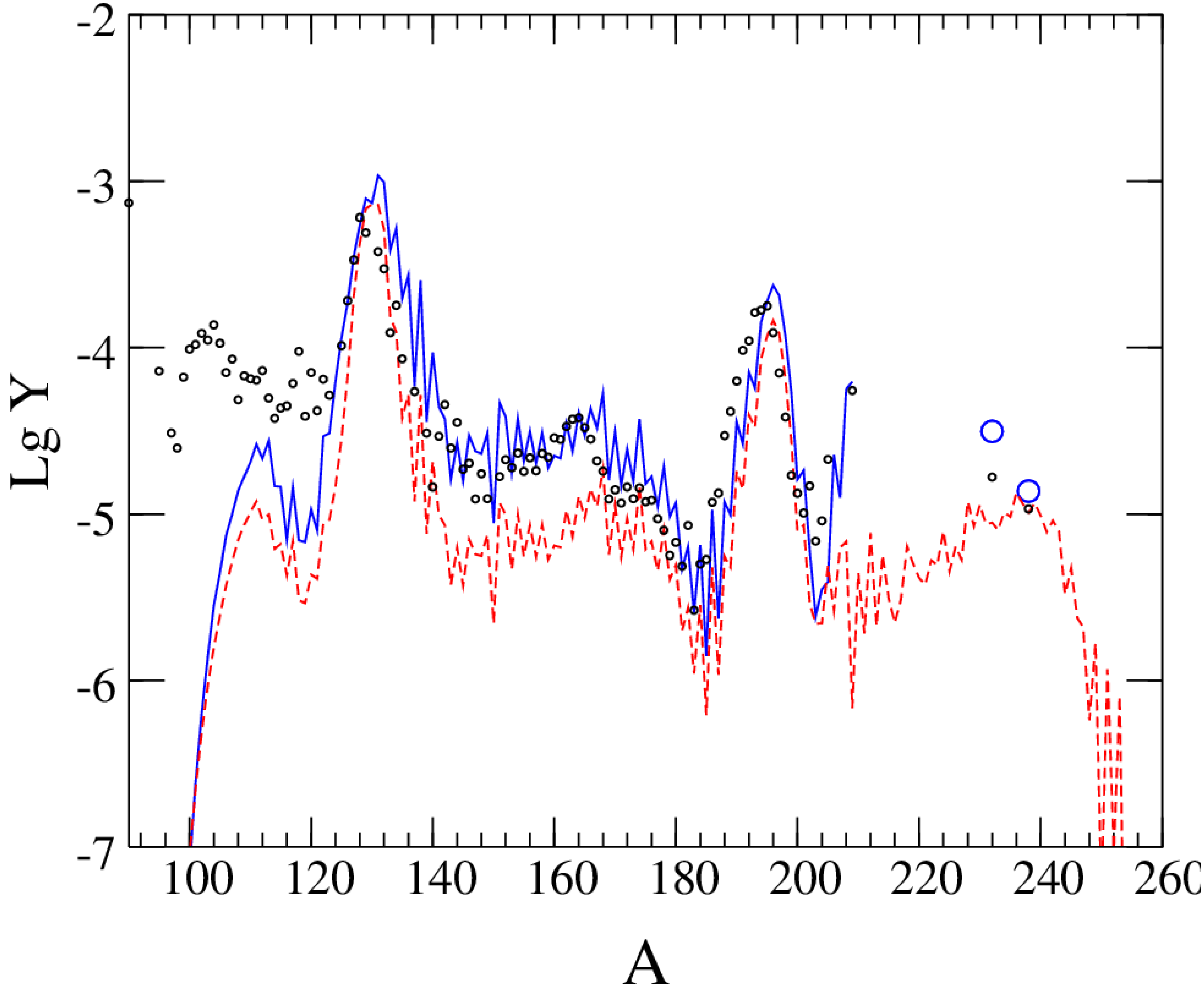
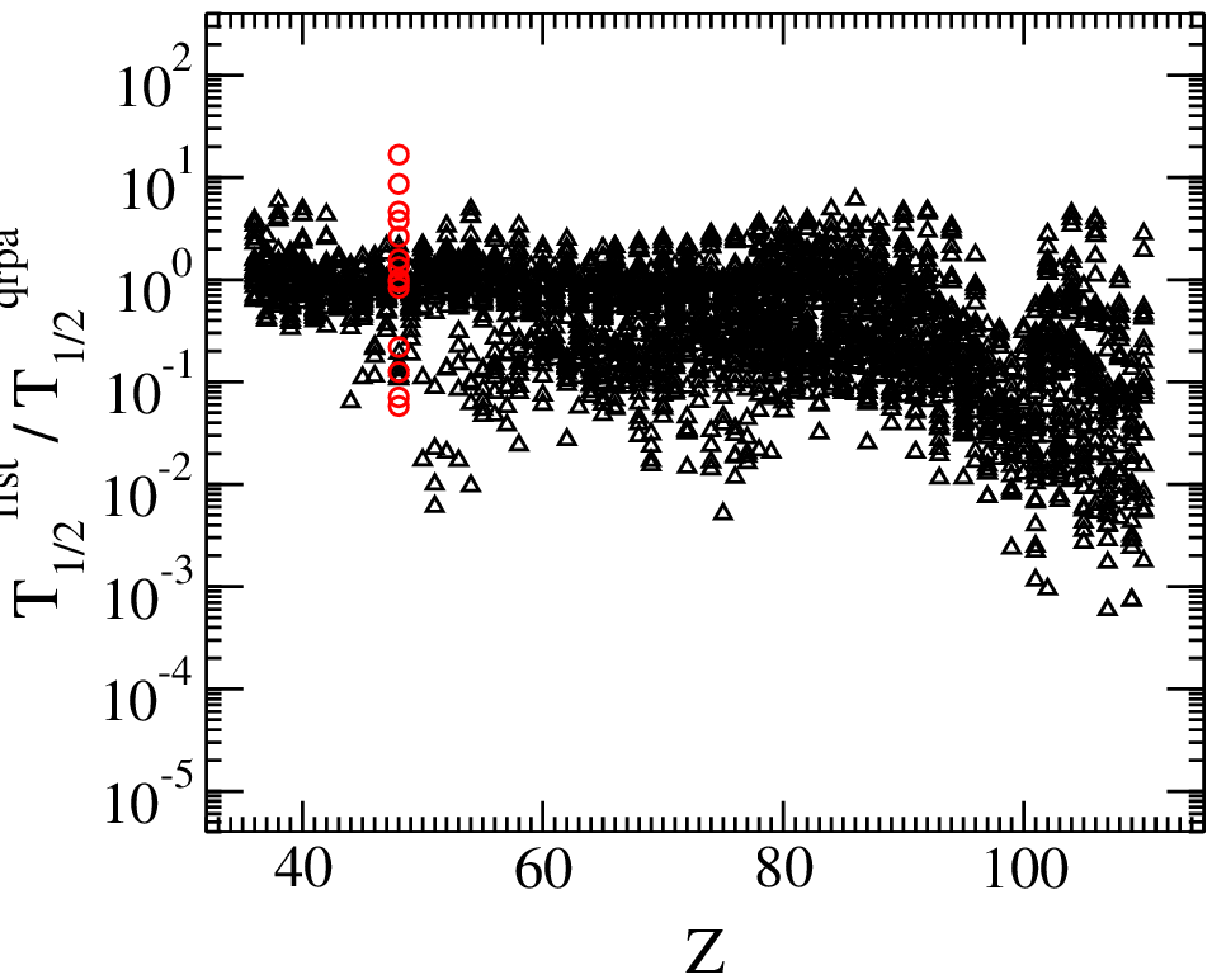
BETA-DECAY RATES OF SHORT-LIVED NEUTRON-RICH NUCLEI, INVOLVED INTO THE R-PROCESS.

- Panov, I. V.; Lutostansky, Yu. S.; Thielemann, F.-K. Half-life of short-lived neutron-excess nuclei that participate in the r-process. 2015 BRASP..79..437P
- Eichler, M.; Arcones, A.; Kelic, A.; Korobkin, O.; Langanke, K.; Marketin, T.; Martinez-Pinedo, G.; Panov, I.; Rauscher, T.; Rosswog, S.; Winteler, C.; Zinner, N. T.; Thielemann, F.-K.
  The Role of Fission in Neutron Star Mergers and Its Impact on the r-Process Peaks. 2015 ApJ...808...30E

- Reports at Int. Conf. 1) Nuclear Physics and astrophysics; 2) Nucleus-2015

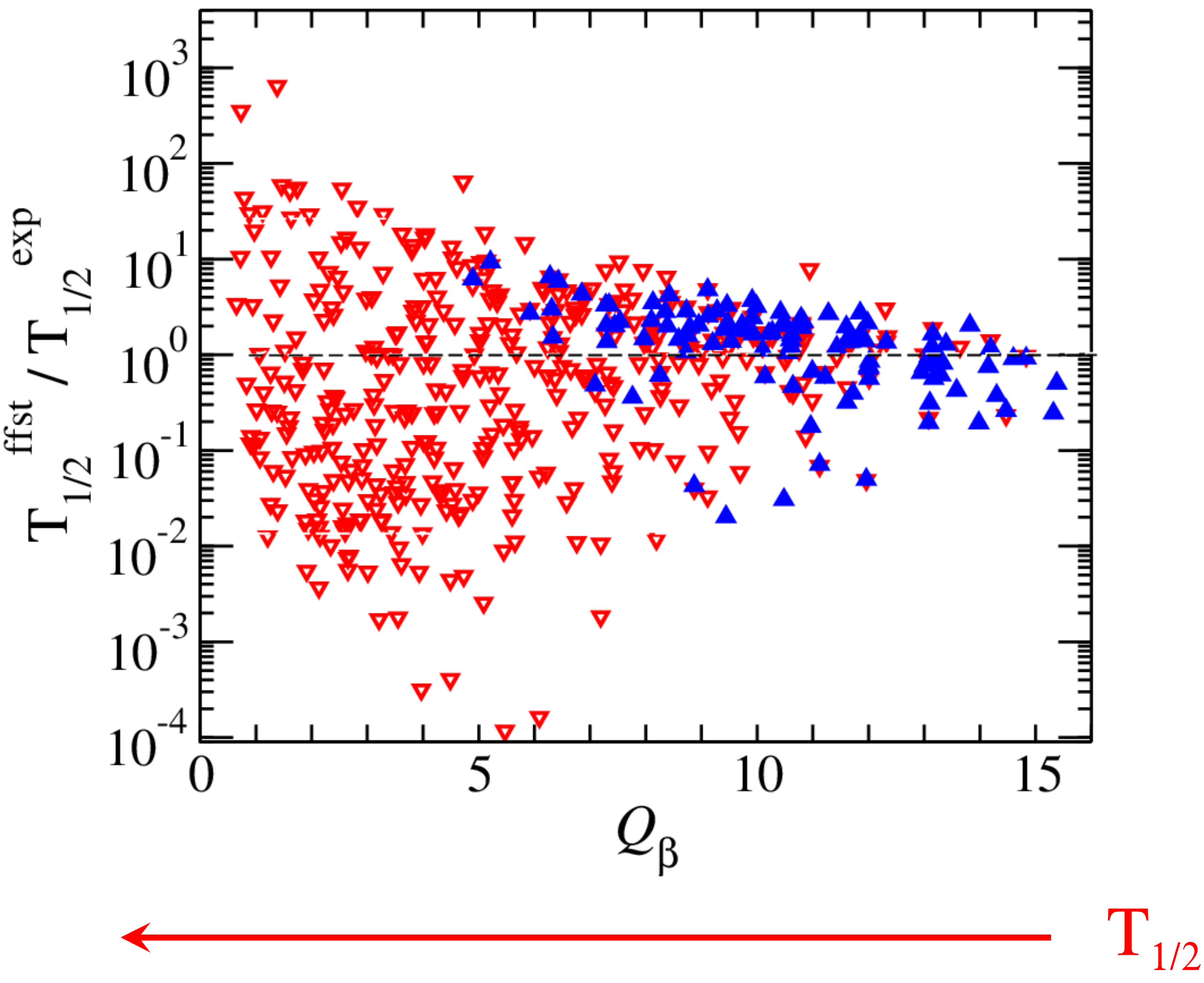
o - Solar abundance of the r-elements (small circles) and model calculations Y_A in the model of Neutron star merger (in red). Blue line – after alpha-decay when β-decay rates for Z>80 were increased in 3 times. им **(Panov et al. Astronomy Letters, 2008;)**

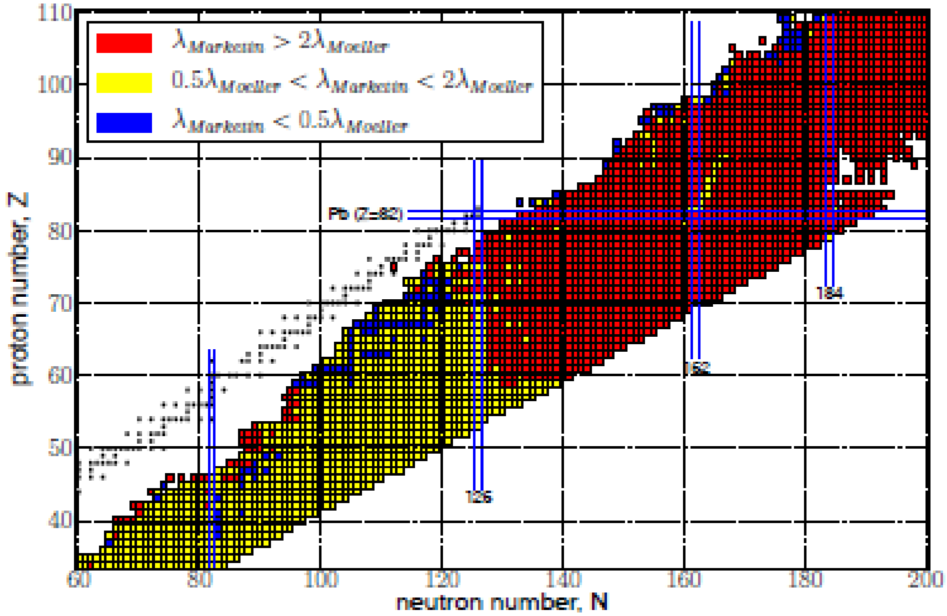




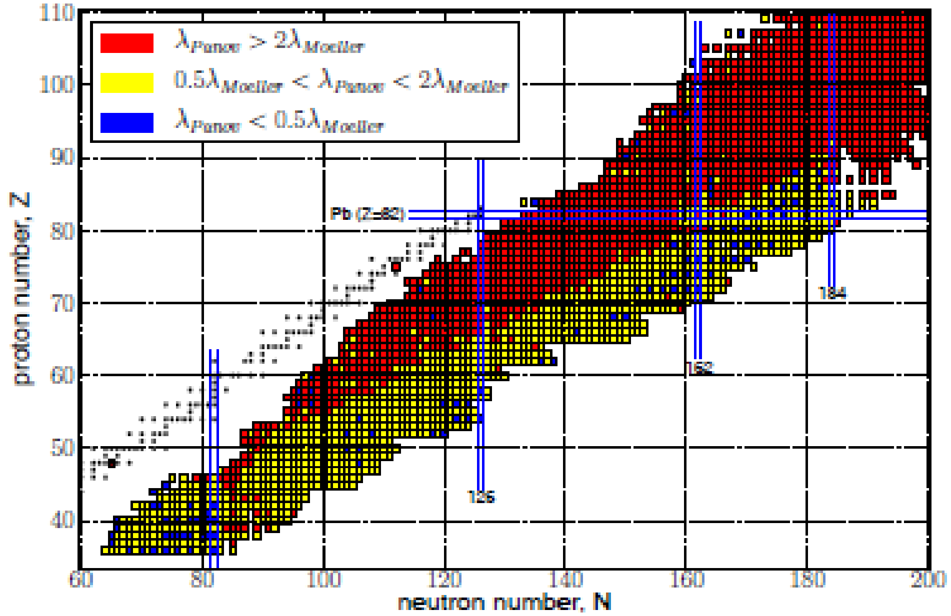
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
40
60
80
100
Z
$T_{1/2}^{ffst} / T_{1/2}^{qrpa}$

FFST predictions vs experimental data



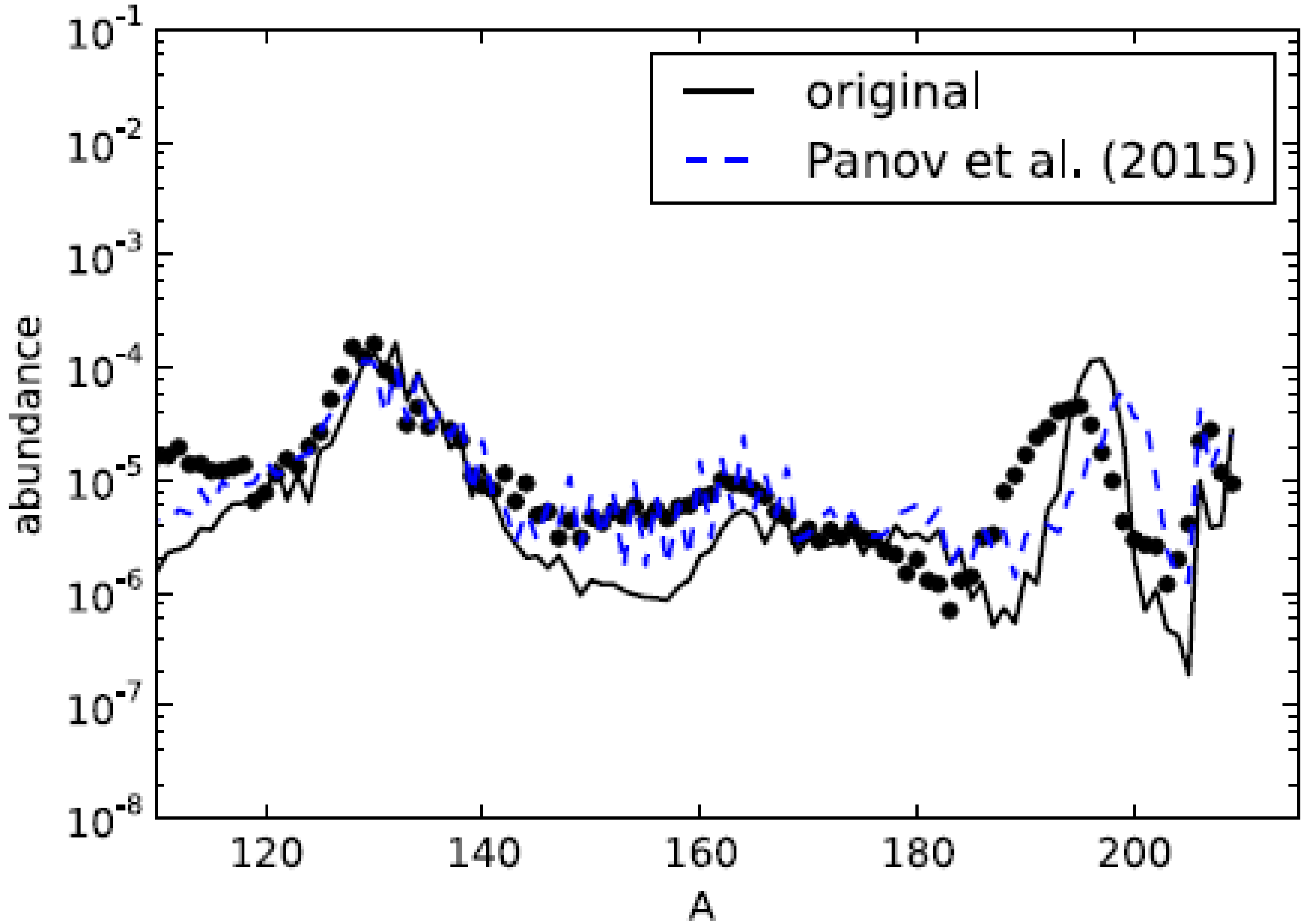


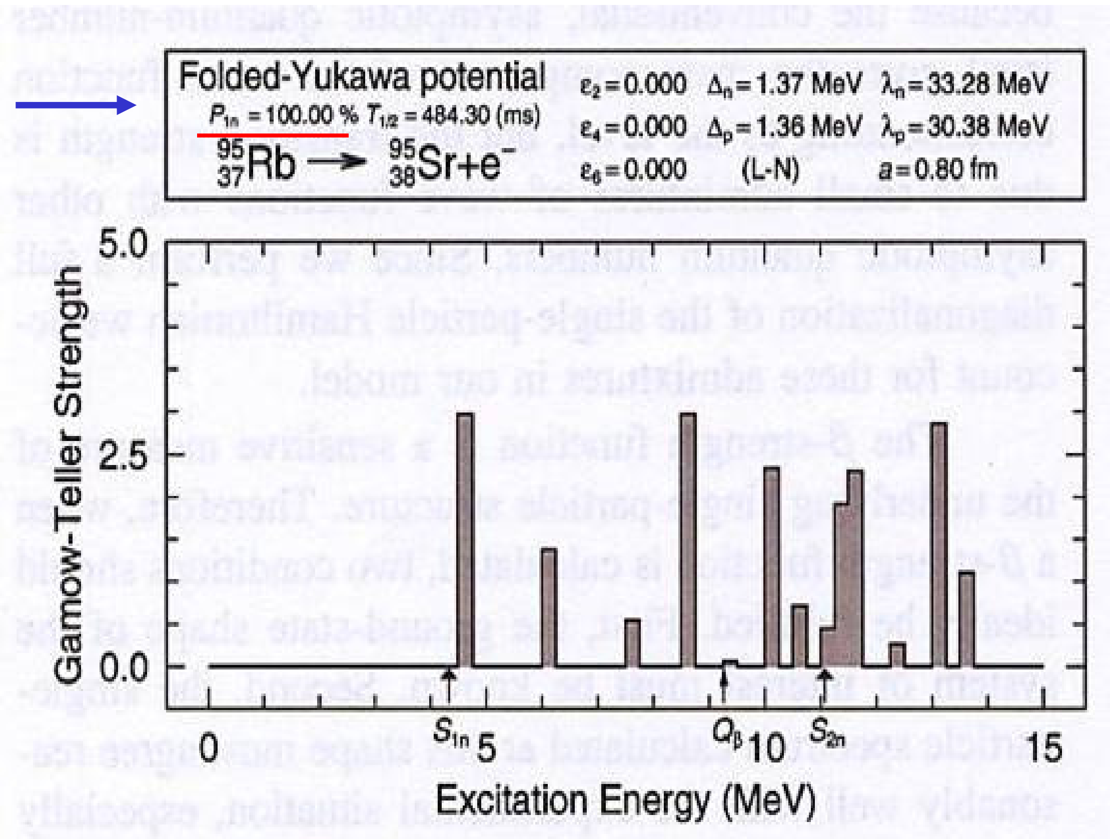
T.Marketin et al. 2015



Panov, Lutostansky, Thielemann 2015

Влияние скоростей β-распада на Y_A Eichler et al. 2015;





T1/2 = 0.484

Pn=100%

S_β(E)

<=QRPA

Kratz et al 1997

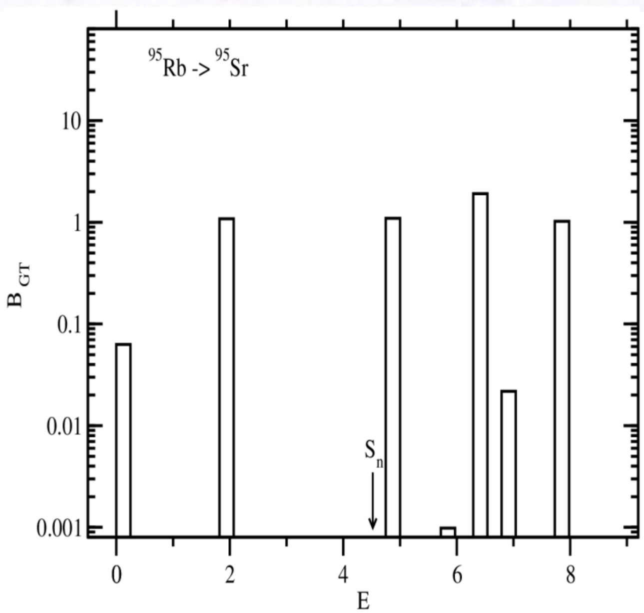
+ 1st fbd in Moller et al.

2003(P_n=32,$T_{1/2}$=0.31)

QRPA(GT)+ff(GT)

Pn(exp)= 26.6%

$T_{1/2}^{exp}$ = 0.384



Most strong ICCS

E, Mev	**J^π**	**V(r)**
E_x = 1.41	1+	2
E_x = 1.94	1+	1
E_x = 4.87	1+	1
E_x = 6.40	1+	0
E_x = 7.85	1+	1

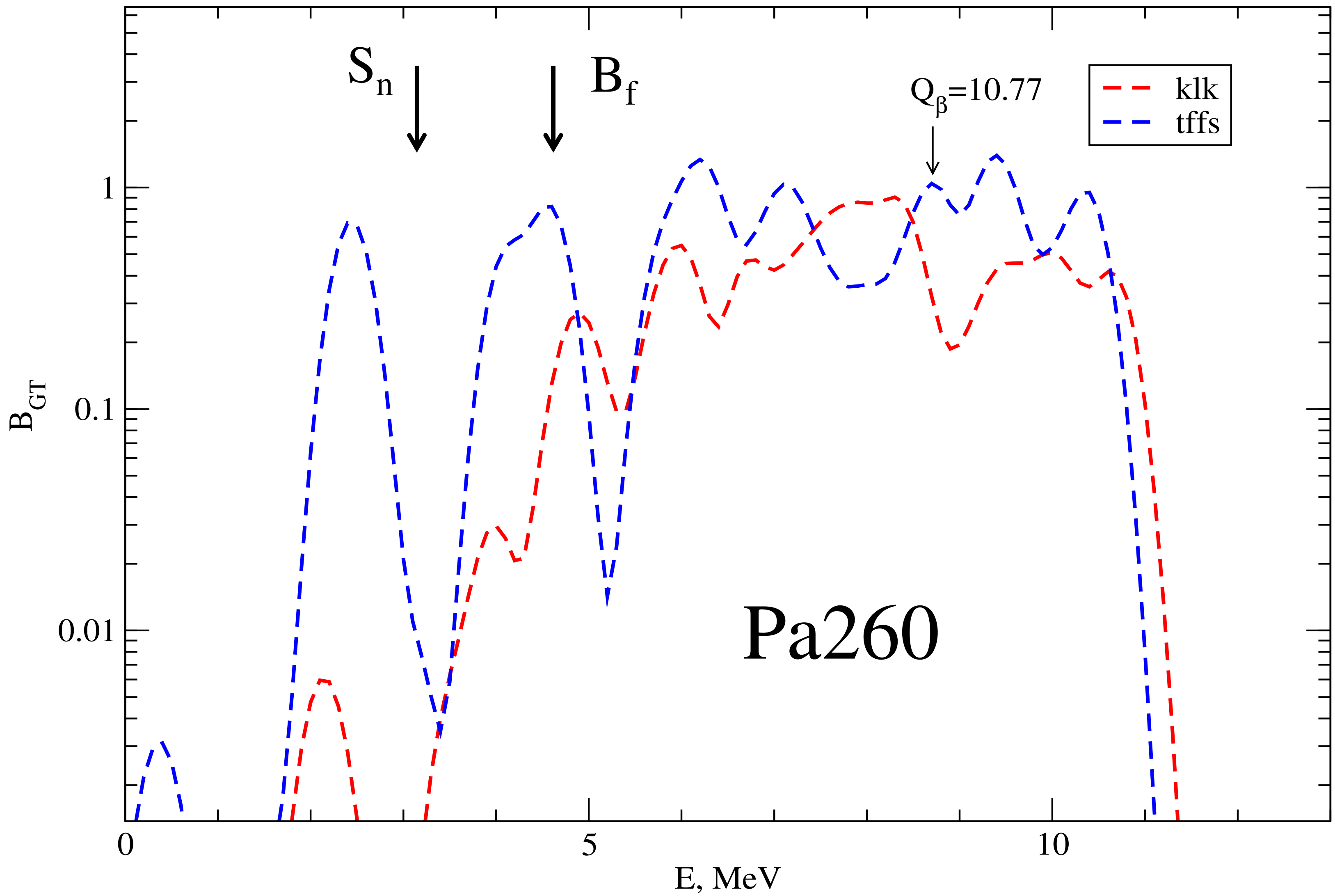
Pn=14.03%

<=TFFS

$T_{1/2}$ (etfsi)= 0.654

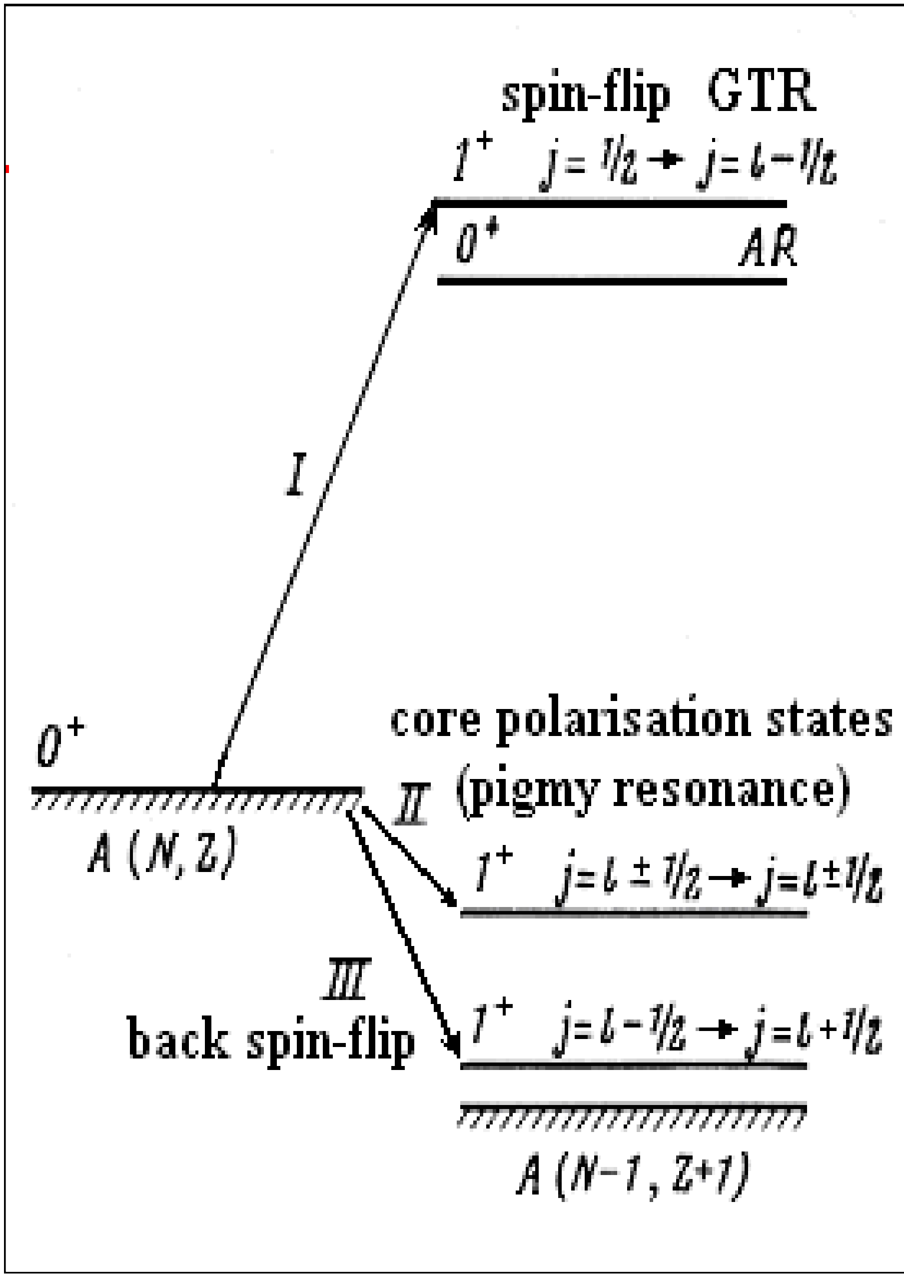
$T_{1/2}$ (frdm)= 0.684

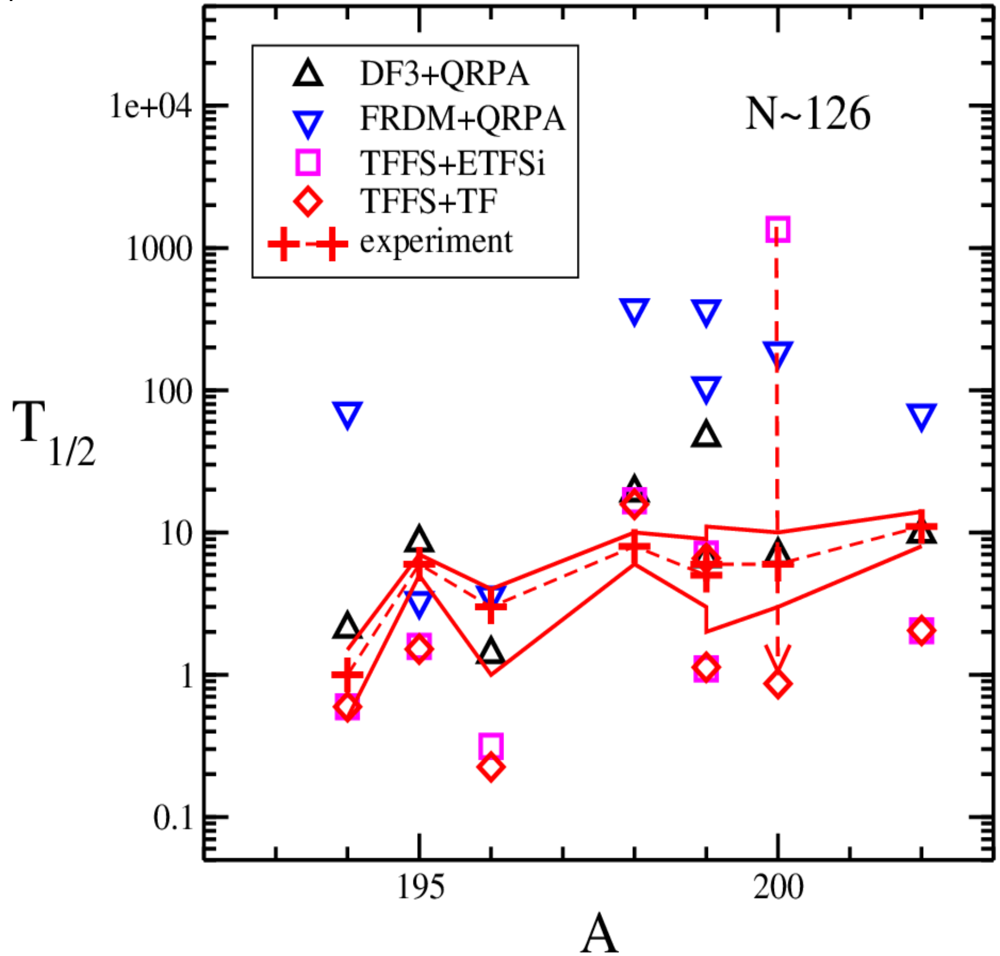
Comparison of beta-strenght functions derived on the framework of ETFSI+QRPA (klk) and ETFSI+FFST (ТКФС)



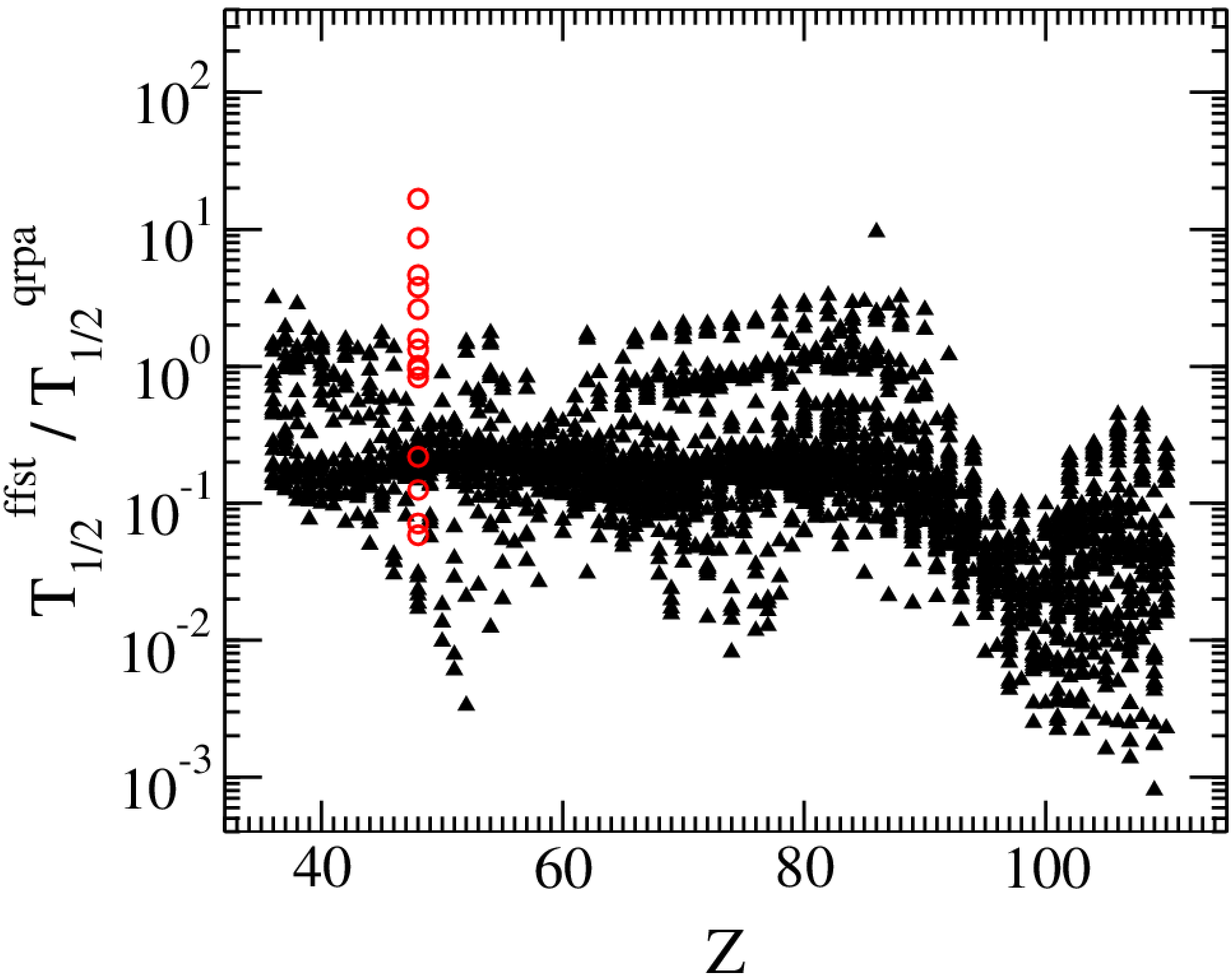
Resonances in low energy region lead to not only decreasing of $T_{1/2}$ и P_{in}, but and also $P_{\beta df}$, very important for formation of nuclei cosmochronometers and SHE

Beta Strength function model for spherical nuclei, TFFS





Yu. Gaponov, Yu. S. Lyutostanskii, I. V. Panov.
Proc. Of Conf. Nuclear Spectroskopy, 1979
V. G. Aleksankin, Yu. S. Lyutostanskii, I. V. Panov,
Yad. Fiz. **34**, 1451 (1981)
Kurtukian-Nieto et al. Nuclear Physics A 2009


$T_{1/2}^{ffst} / T_{1/2}^{qrpa}$
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
40
60
80
100
Z

Beta-decay-rates

- $T_{1/2} \sim (Q_\beta)^m$ Tasaka K. JAERI 1975
- Gross K. Takahashi, M. Yamada, T. Kondoh, ADNDT (1973)
  T. Tachibana, M. Yamada, N. Yoshida, PTPhys. 84 (1992)
- RPA(SM+BB) Petrow, Naumow, H.-V. Klapdor. Z. Phys. A 1978   Klapdor-…-Thielemann Z.Phys.A 299 (**1981**)
- qRPA Klapdor et al. **1990/1992**
- RPA   P. Moller, B. Pfeifer, K.-L. Kratz et al. **1997**--
  Krumlinde, Moller,Rundrup 1984-1990;
  P. Moller, B. Pfeifer, K.-L. Kratz **2003** --
- FFST Migdal A.(1967);
  Gaponov Yu. V., Lyutostanskii Yu. S et al. 1972-**1981**; 1986-1988
- cQRPA+DF3   Borzov, Fayans, Trykov et al. 1994- 2014
- (pn-RQRPA) T.Nikˇsi´c, T.Marketin, D.Vretenar, N.Paar PRC
- FFST Lyutostanskii Yu. et al. **2010-2015**
- FFST-BETA Panov & Lyutostanskii Yu. S et al. **2013-2015**
  ceFFST ~to pnQRPA 1)Birbrair NPA 108 (1968);
  2)Borzov et al. (2008)

Motivation

1. $T_{1/2}$, P_{1n}, P_{2n}, P_{3n} $P_{\beta df}$ in the same approach for the r-process
2. Systematics $T_{1/2}$(RPA) > $T_{1/2}$(TFFS) =>
   Panov et al. Astronomy Letters, 2008
3. P_{in}(RPA-1997) -> 100%
4. $\sum P_{ik} < 100$ %

P_n overestimation in QRPA

Z=92

A	$P^{a}_{\beta dn}$	$P^{b}_{\beta df}$	$P_{\beta dn} + P_{\beta df}$
261	74.58	94	168.58
262	67.12	47	114.12
263	82.93	96	178.93
264	65.96	55	120.96
265	59.49	62	121.49

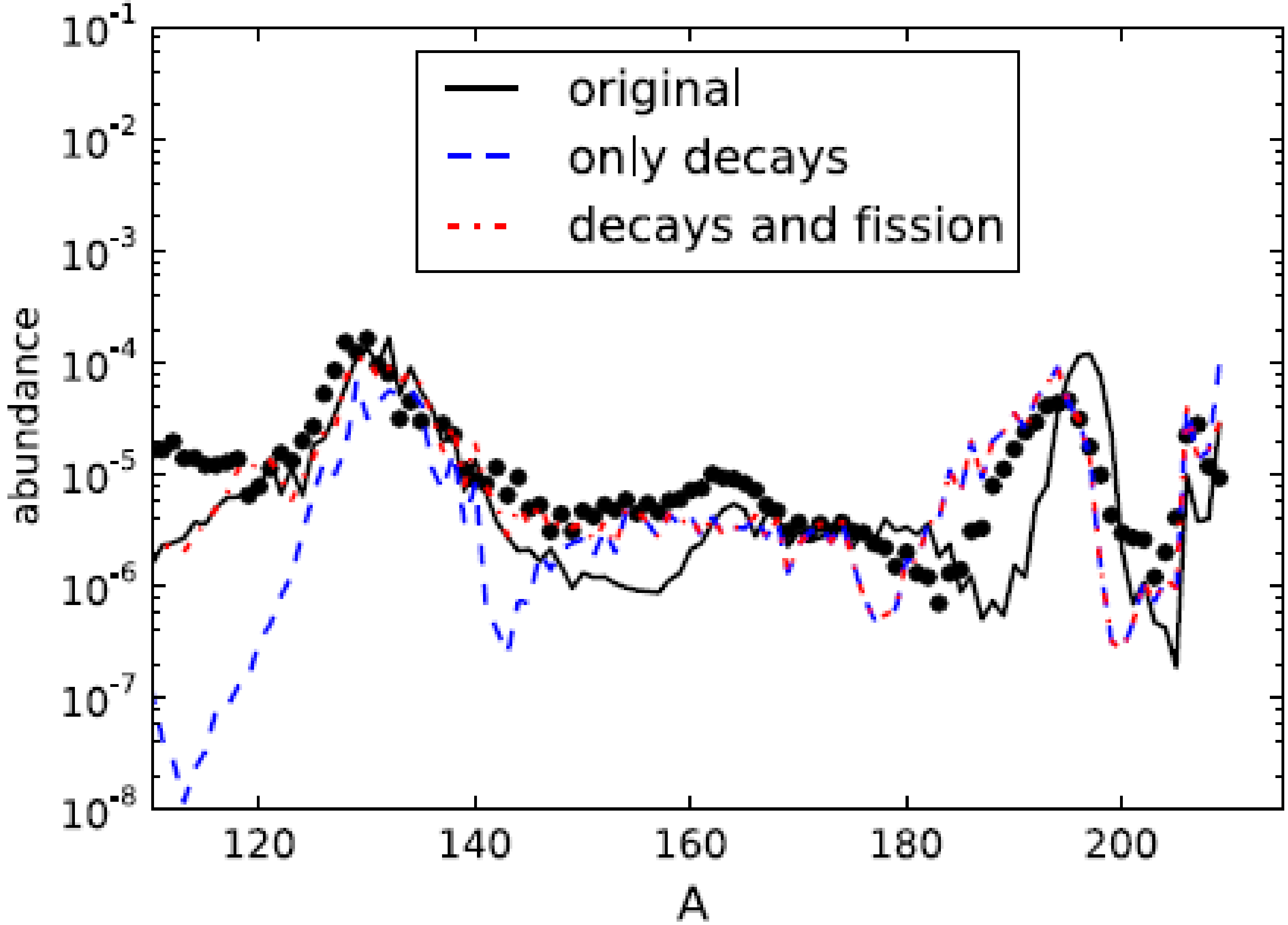
1. Systematics $T_{1/2}$(RPA)> $T_{1/2}$(TFFS) =>
   Panov et al. Physics of Atomic Nuclei, 2013, Vol. 76, p. 88

$P_{\beta di}$ in FFST

Z=92

A	P_0	$P_{\beta dn}$	$P_{\beta df}$(ETFSI)
261	29.0	2.8	68.2
262	25.1	9.5	15.6
263	31.1	3.4	65.5
264	80.1	8.7	11.2
265	54.2	6.2	39.6
266	74.5	25.5	0.0
267	54.0	44.7	1.3
268	66.2	33.8	0.0

Eichler et al. 2015; сдвиг 3го пика за счет захвата нейтронов деления

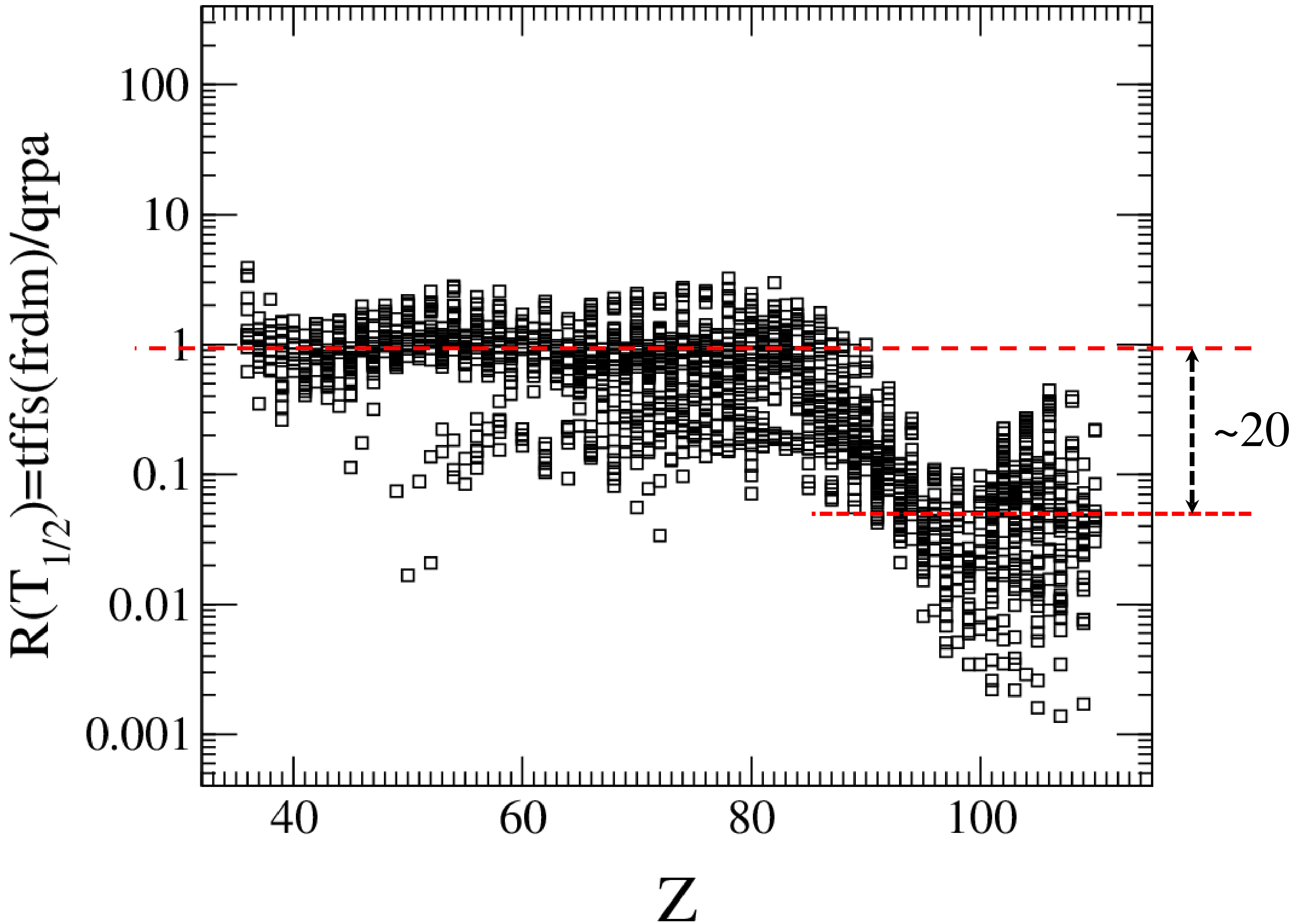


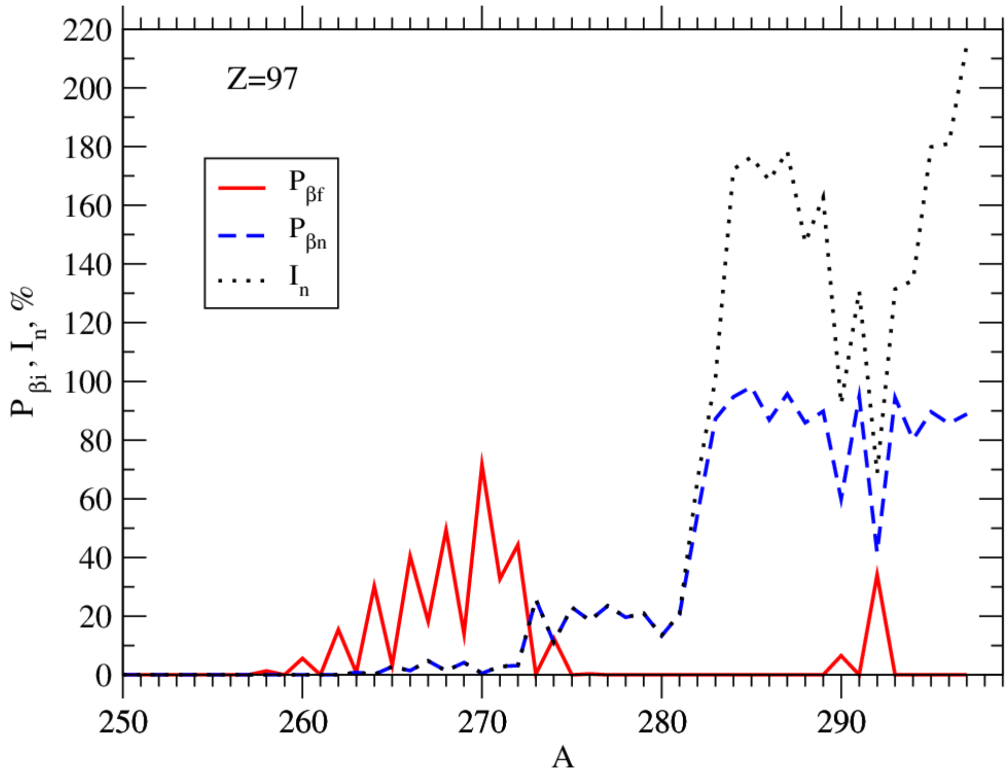
Conclusions

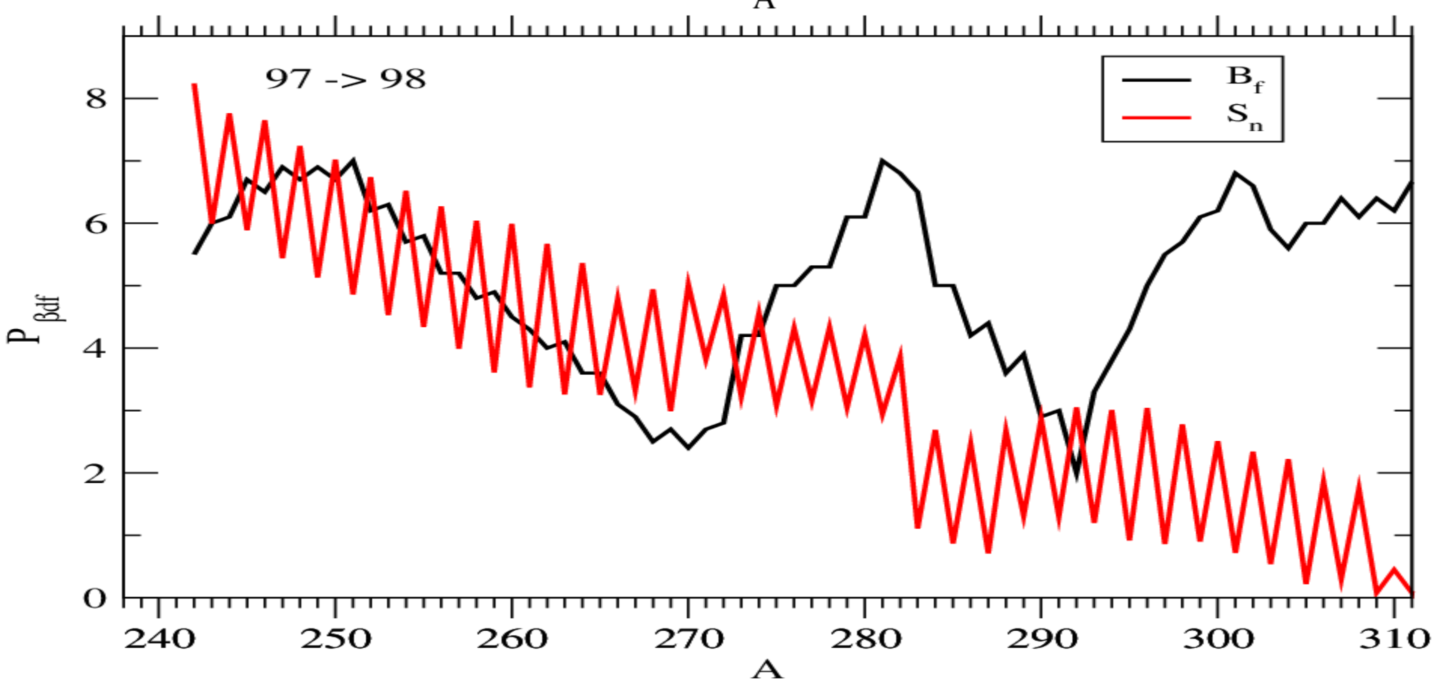
Opportunities of quasiclassical method:

- Consistent predictions of $T_{1/2}$ and P_{kn}
- Satisfactory agreement with experiment
- Small number of parameters
- Better agreement for nuclei with shorter $T_{1/2}$
- Full data base for the r-process modelling

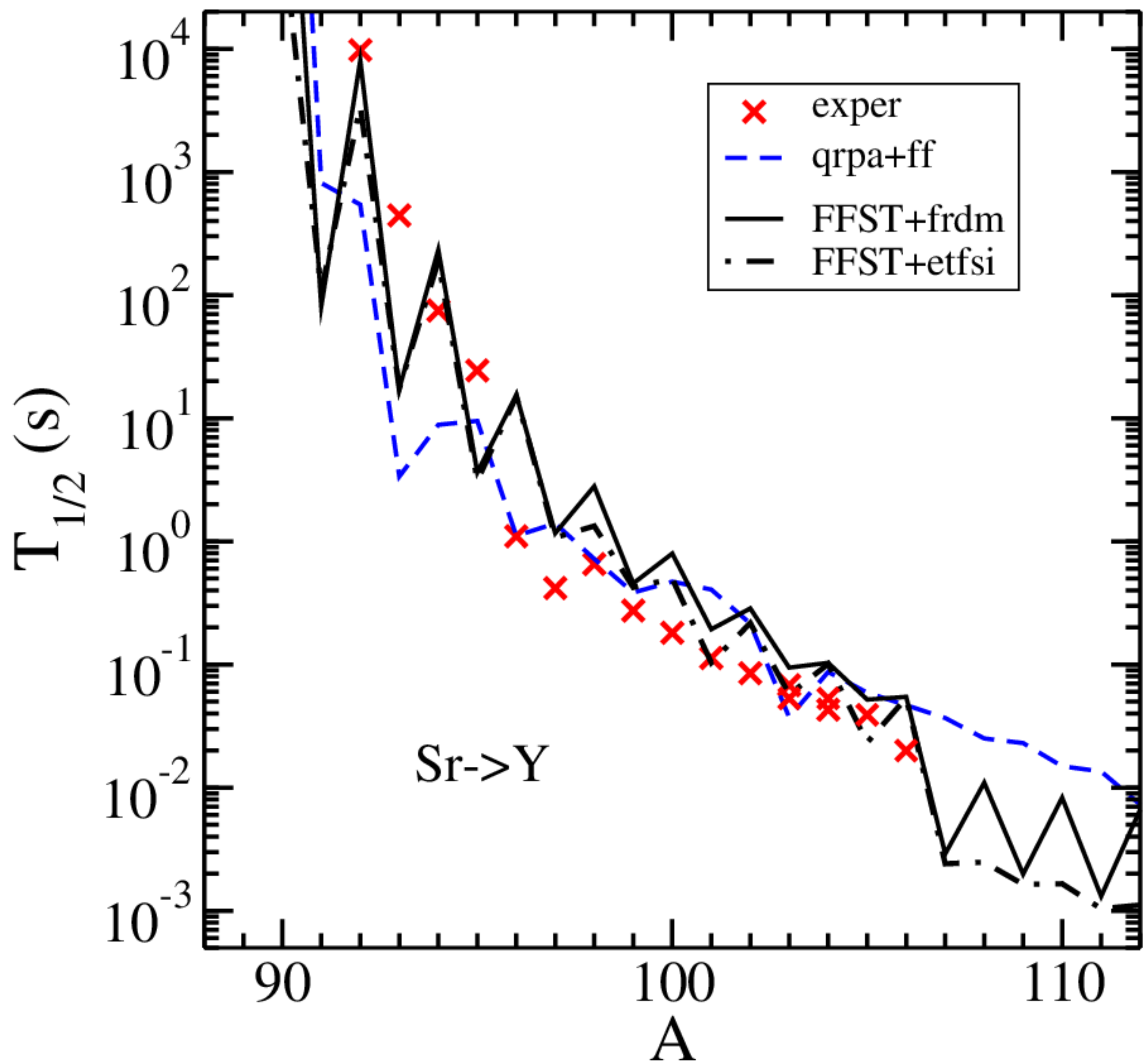
qrpa+frdm vs TFFS+frdm




Z=97
$P_{\beta f}$
$P_{\beta n}$
I_n
$P_{\beta i}$, I_n, %
A

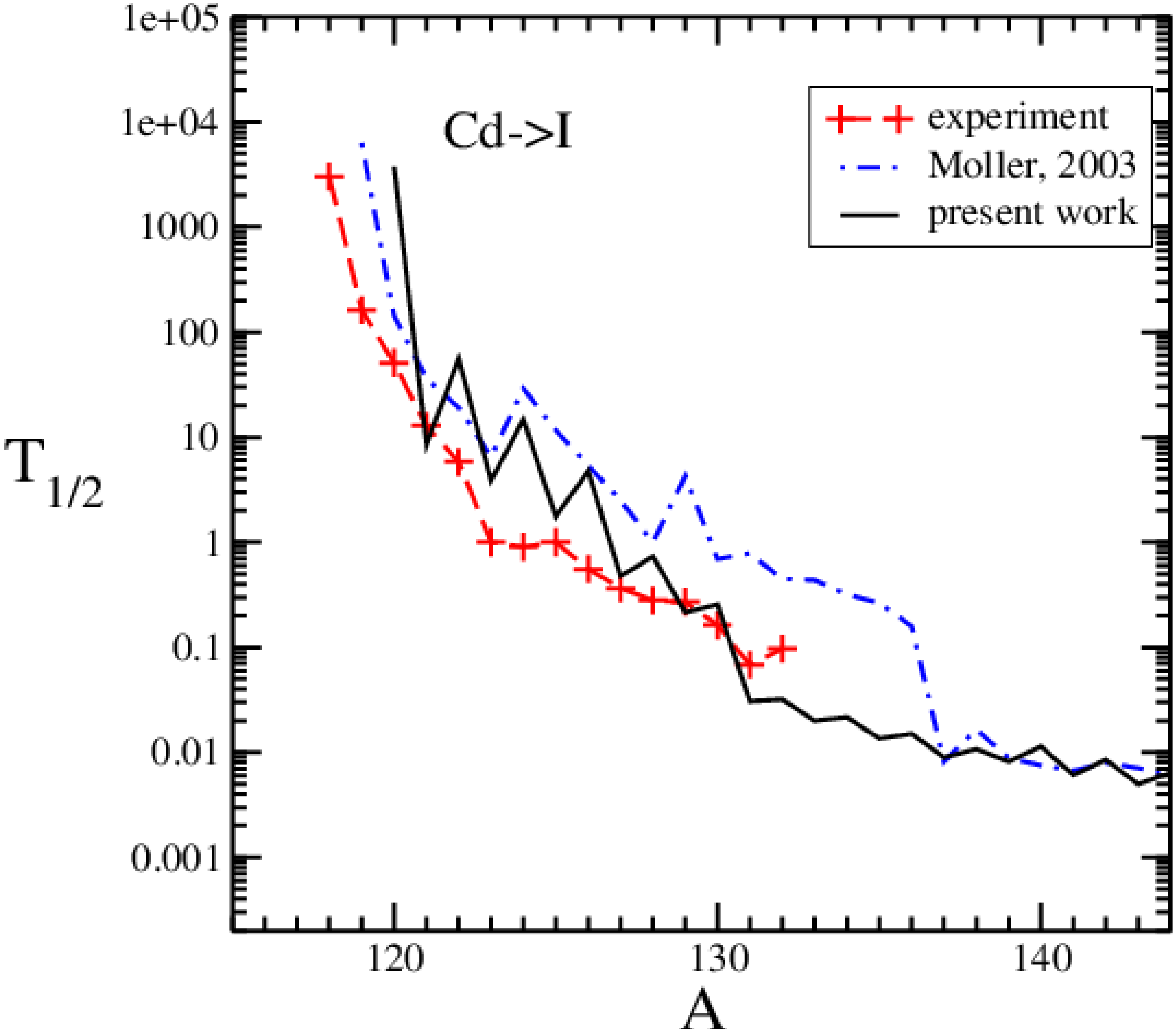

97 -> 98
B_f
S_n
$P_{\beta df}$
A

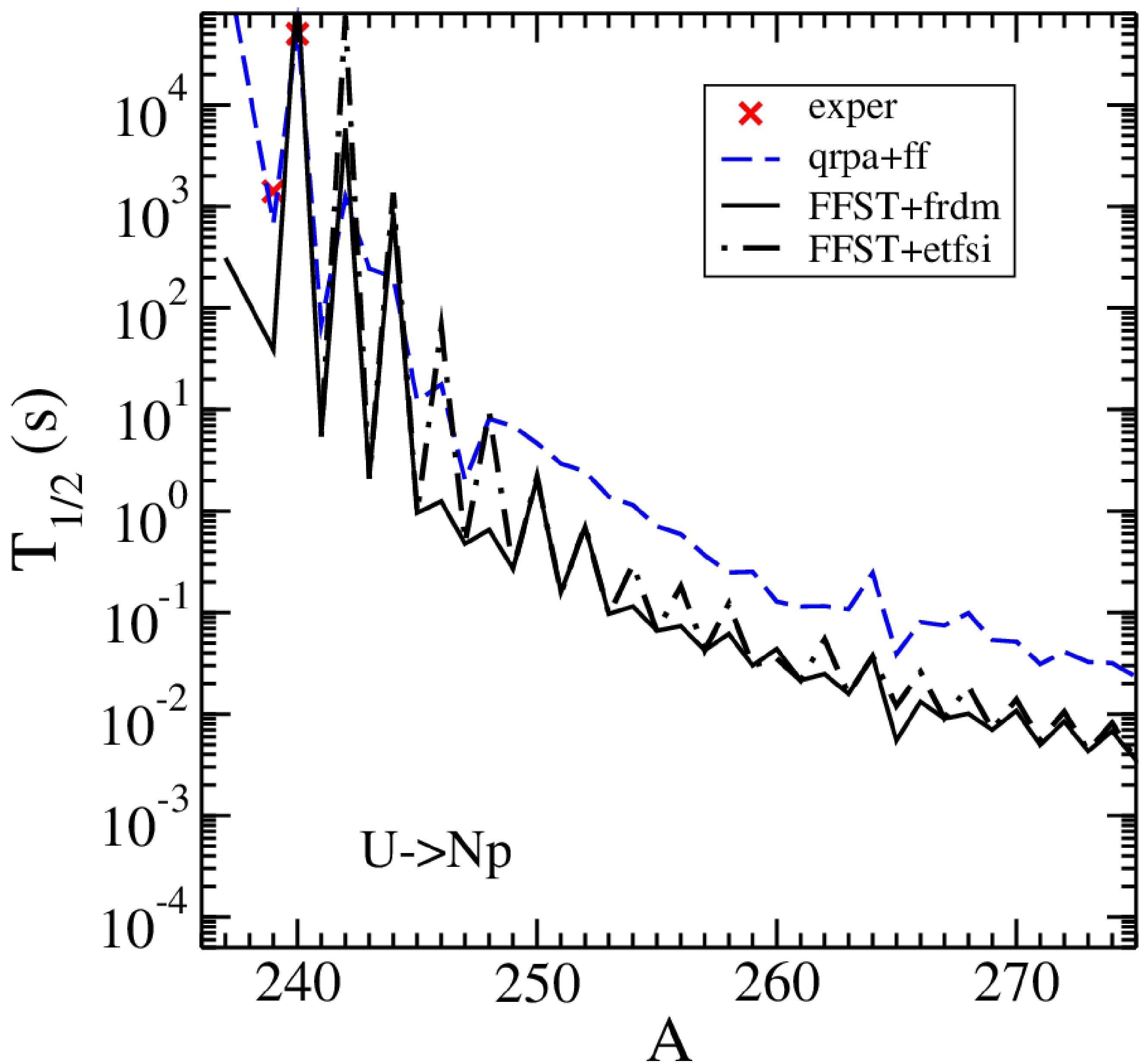
Beta-decay half-lives for Sr-isotopes in comparison with experiment (red) and other predictions (FRDM+QRPA, blue)



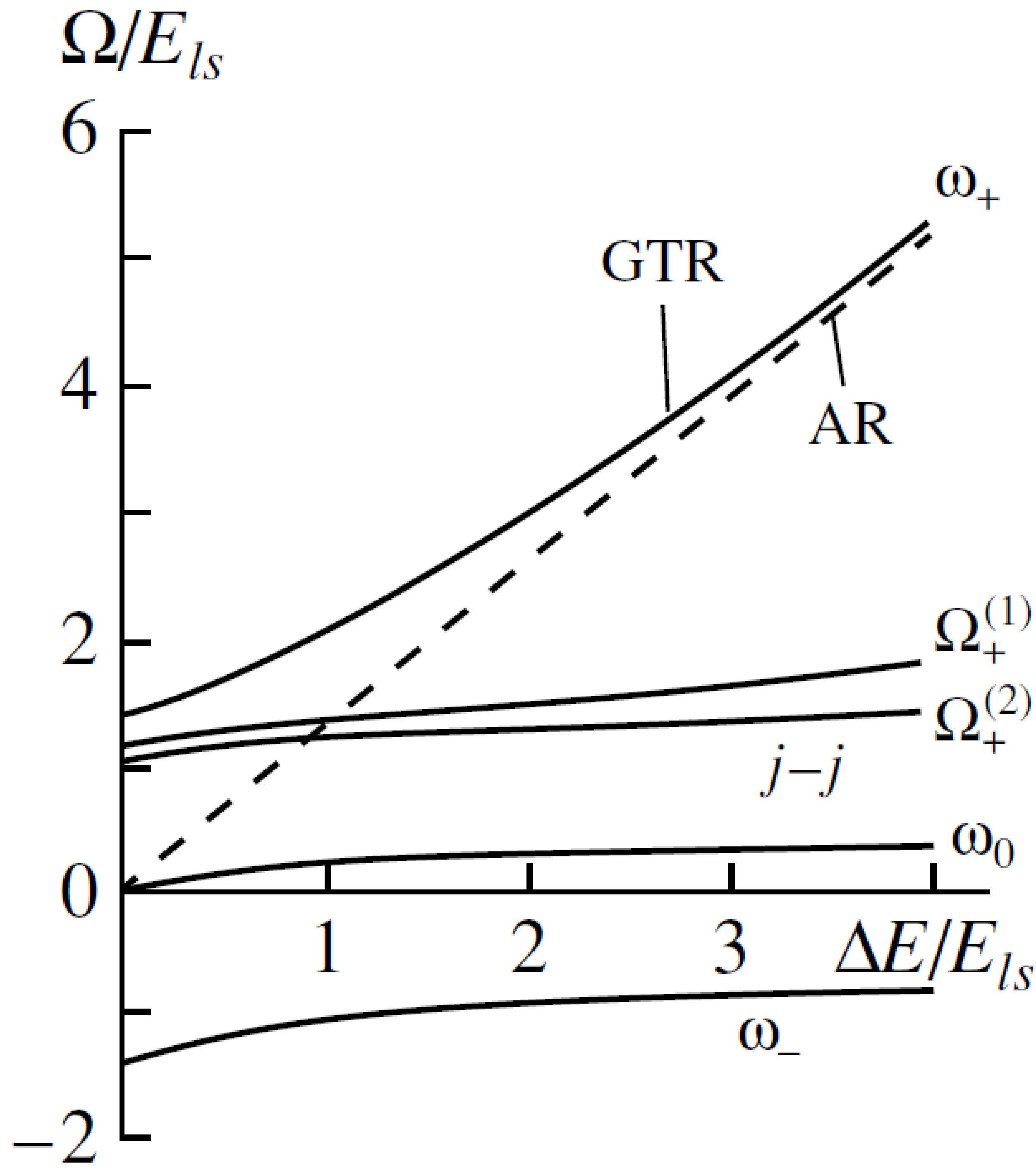
Beta-decay half-lives for Cd-isotopes

in comparison with experiment (red) and other predictions (blue)



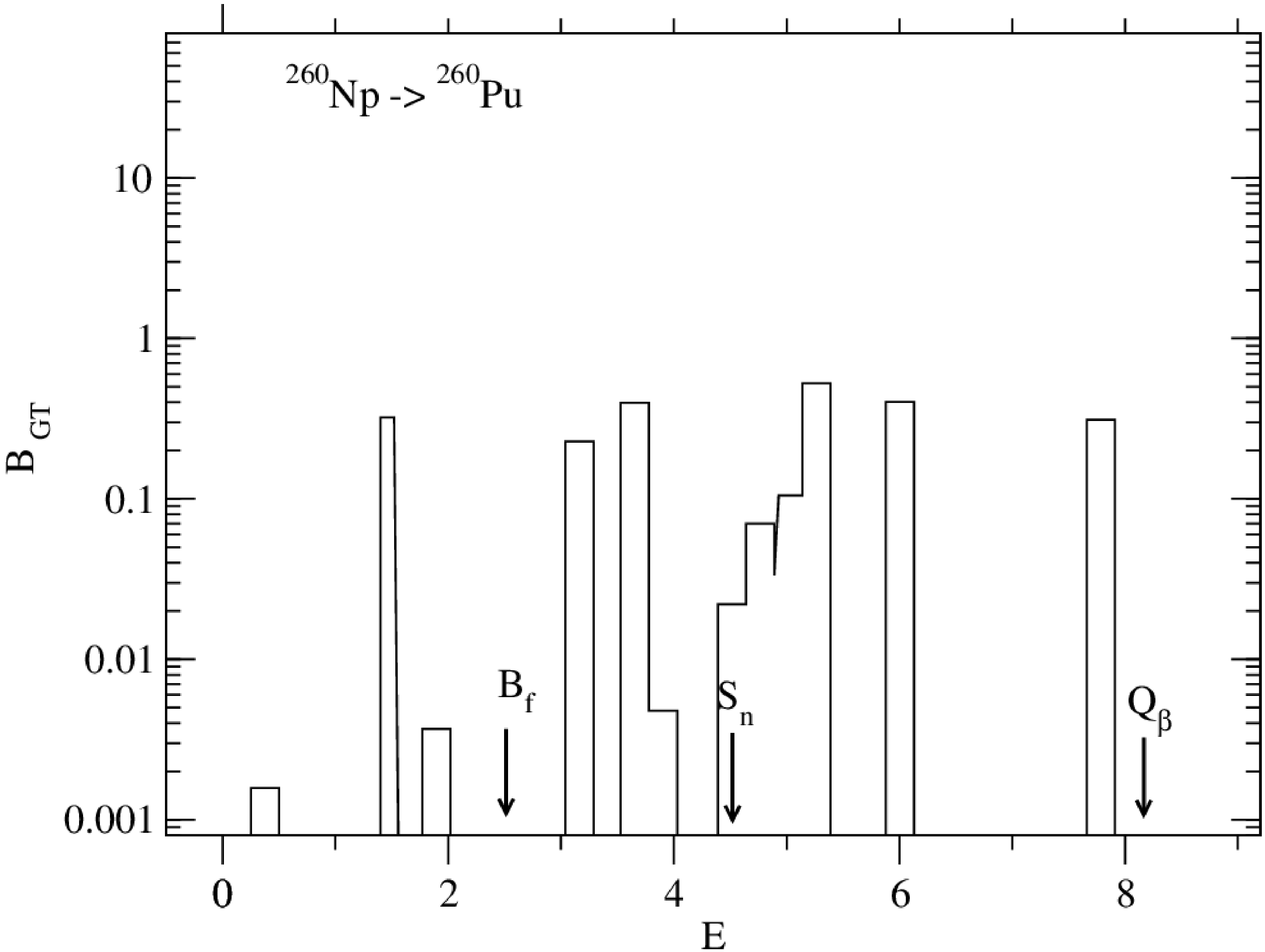


exper
qrpa+ff
FFST+frdm
FFST+etfsi
U->Np
$T_{1/2}$ (s)
A
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
240
250
260
270



Ω/E_ls
6
4
2
0
−2
ω+
GTR
AR
Ω+(1)
Ω+(2)
j–j
ω0
ω−
1
2
3
ΔE/E_ls

260Np -> 260 Pu



Model accuracy

- $\delta T_{1/2} \sim (\delta^2 T_g + \delta^2 T_{Q\beta\,+}\, \delta^2 T_{els\,+}\, \delta^2 T_\Gamma + \ldots)^{0.5} < 100\%$

  Lutostansky Panov Preprint ITEP № 32, 1986. M.

  average error $< \delta T_{1/2} > \sim 50\%$

$\delta g_0' \sim 10\% - 20\%$ -> $30 – 40\ \%$

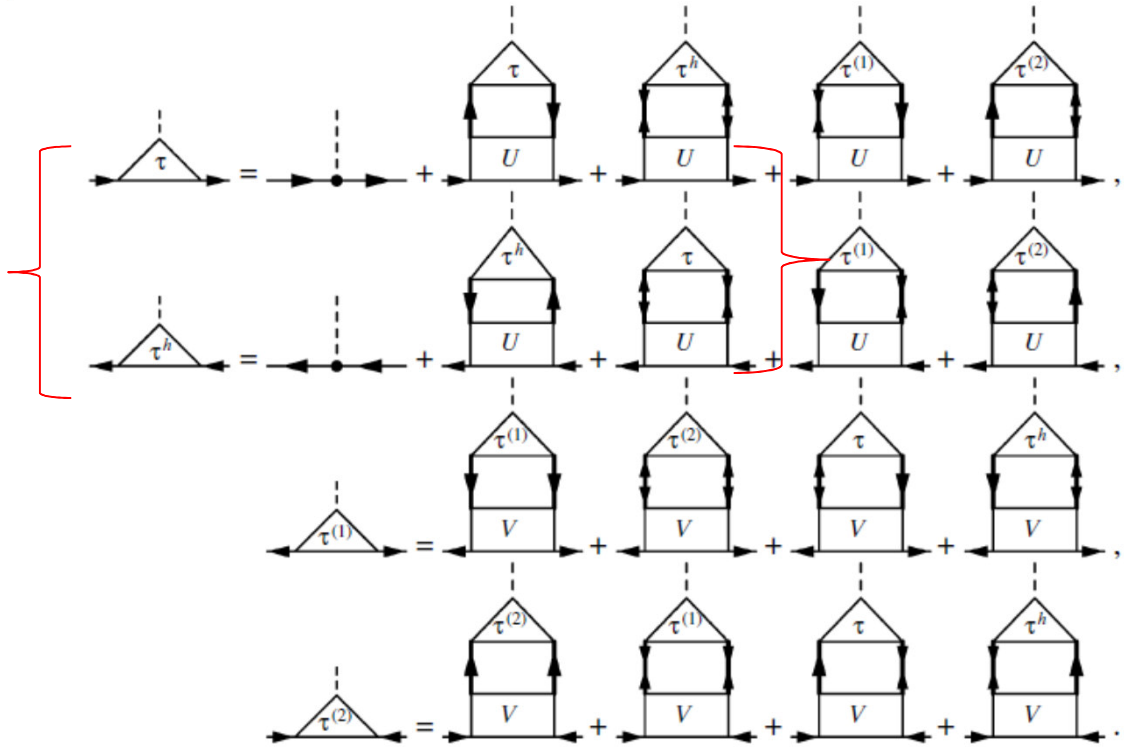
$\delta\ T_{Q\beta} \sim 0.5\text{-}1$ MeV -> $\sim 30\%$

$\delta\ T_{els} \sim 10\%$ -> $\sim 10\text{-}20\%$

$\delta\ T_\Gamma \sim \delta – 3$MeV -> $\sim 10\%$

……….

FFST pn QRPA eqns. *I.N. Borzov et al. NP A814 (2008)*



I.N. Borzov, S.A. Fayans, E.L. Trkov Nucl.Phys. A584 (1995) 335.

Here "τ" are the effective fields in the ph, hh and pp channels

The brakets show "cutted" QRPA matrix which leads to BCS+RPA eqns.
Thus the SO(8) symmetry of full QRPA eqns. is broken!
Such incomplete BCS+RPA eqns. has been used in the FRDM based approach:
P. Moeller, B. Pfeiffer, K.-L. Kratz.,Phys.Rev. C67, 055802 (2003)

Continuum pn-QRPA eqns. in FFST notations

$$[\hat{I} - \begin{pmatrix} F^{\omega} & -F^{\xi} & F^{\omega\xi} & F^{\xi\omega} \\ -F^{\xi} & F^{\omega} & F^{\xi\omega} & F^{\omega\xi} \\ F^{\omega\xi} & F^{\xi\omega} & F^{\xi} & -F^{\omega} \\ F^{\xi\omega} & F^{\omega\xi} & -F^{\omega} & F^{\xi} \end{pmatrix} \begin{pmatrix} L(\omega) & M(\omega) & N^1(\omega) & N^2(\omega) \\ M(\omega) & L(-\omega) & N^2(-\omega) & N^1(-\omega) \\ N^1(\omega) & N^2(-\omega) & K(\omega) & -M(\omega) \\ N^2(\omega) & N^1(-\omega) & -M(\omega) & K(-\omega) \end{pmatrix}] \begin{pmatrix} V \\ V^h \\ d^{(1)} \\ d^{(2)} \end{pmatrix} = \begin{pmatrix} e_q V_0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

Fττ' – charge changing effective NN-interactions

L,M,Ni,K - ph, pp, hh – propagators p(n)→n(p)

ph-propagator in continuum

$$L(r,r';\varpi) = A(r,r';\varpi) + \sum \left| L_{pn} - A^{\sim\sim}_{pn} \right| \varphi_p \varphi_n \varphi_{n*} \varphi_{p*}$$

Continuum, no pairing

pairing in the valence space

T=0 ***A.P. Platonov, E.E. Saperstein,***
Sov.J.Nucl.Phys 1987;
Nucl.Phys.A486(1988)63.

T=0 ***N. Van Giai,***
Nucl. Phys. A482 (1988) 473c.

|T|=1 ***I.N. Borzov, E.L. Trykov***
Izv.AN SSSR 53(1989) 2468:
I.N. Borzov, S.A.Fayans,E.L.Trykov
Sov.J.Nucl.Phys.52(1990) 33

$T_{1/2}$ predictions by different models and experimental data in the region of elements with N~196