СКОРОСТЬ БЕТА-РАСПАДА КАК ВАЖНЫЙ ФАКТОР ОБРАЗОВАНИЯ ТЯЖЕЛЫХ ЯДЕР В R-ПРОЦЕССЕ

BETA-DECAY RATE IS AN IMPORTANT FACTOR OF HEAVY NUCLEI NUCLEOSYNTHESIS IN THE R-PROCESS

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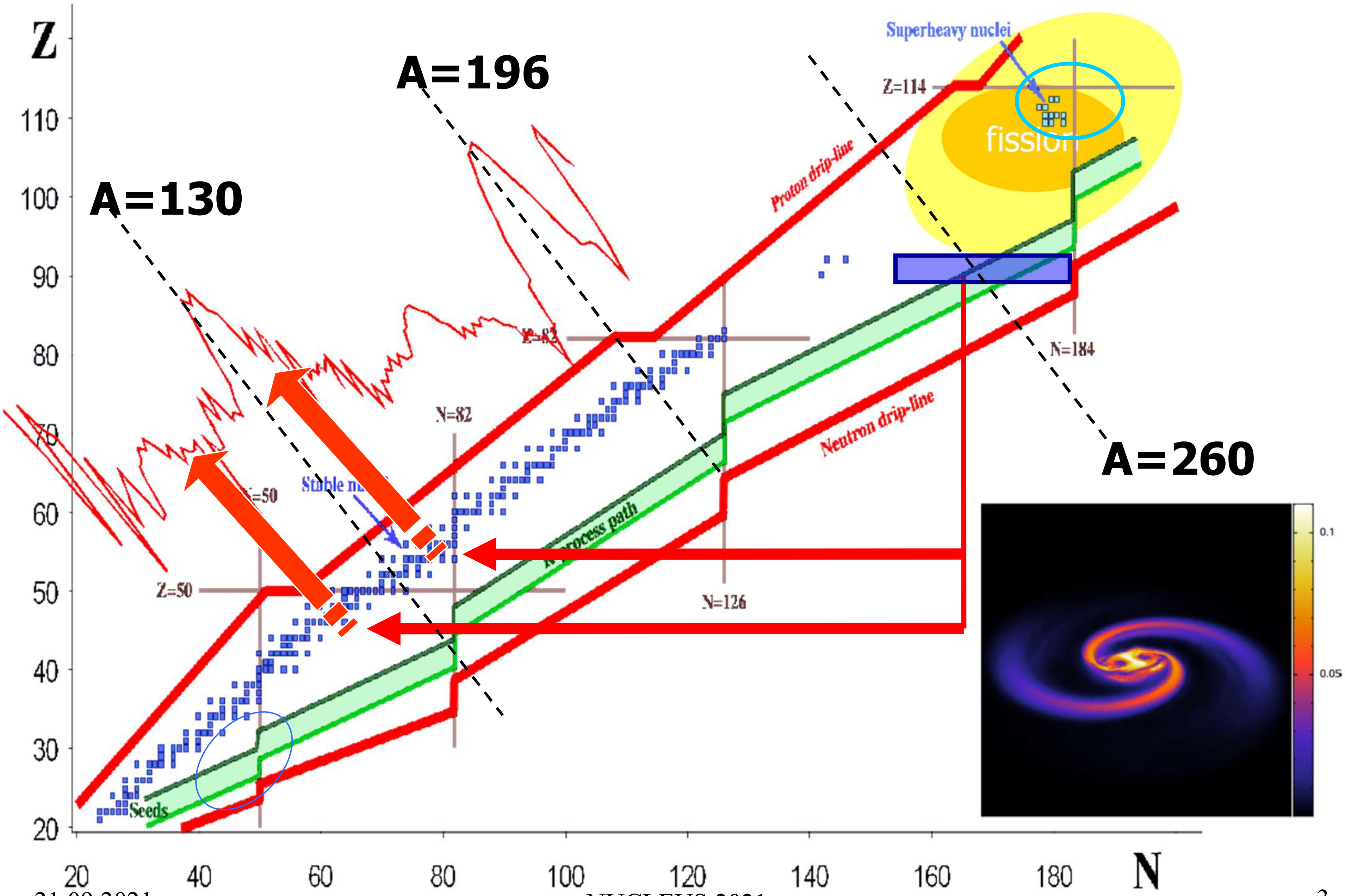
- Introduction and motivation
- Nuclear data for the r-process
- Beta-decay rates on the basis of QRPA and pnRQRPA
- r-process calculations and abundances of heavy nuclei in Neutron Star Merger (NSM) scenario
- Conclusion: discussion and problems

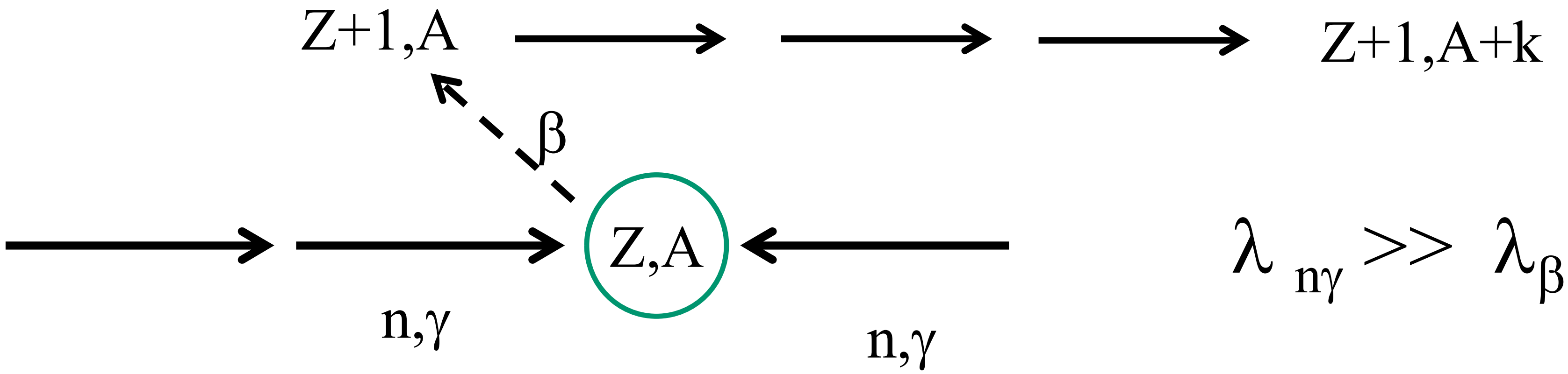
- Introduction and motivation – the main conditions of r-process nucleosynthesis and connected astrophysical scenario – neutron star merger of two neutron stars of equal masses will be briefly overviewed.
- The important for the r-process Nuclear data will be listed
- Beta-decay rates prepared on the basis of global models - QRPA and pnRQRPA will be considered.
- The results of r-process calculations and abundances of heavy nuclei in Neutron Star Merger (NSM) scenario with utilization of global beta-decay models will be shown.
- Conclusion: discussion and problems left

Nuclear map and r-process path



Nuclear data for the r-process: n/seeds >100;

In full r-process from 3000 till 6000 nuclei are involved and ~ tens thousand of different reactions.

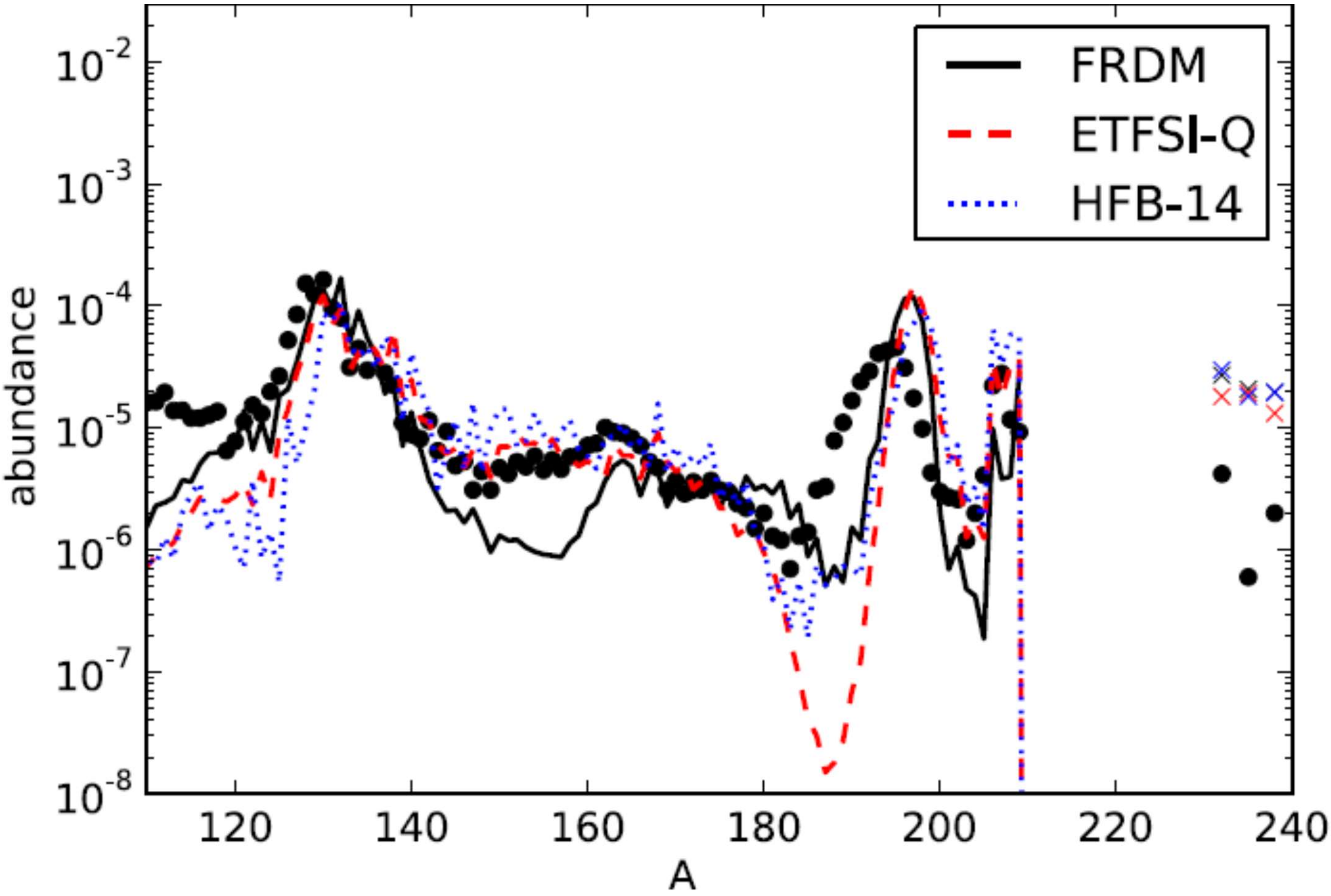


$\lambda_{n\gamma} >> \lambda_\beta$

- **mass-excess predictions**
- **(n,γ)- cross-sections** (neutron rates)
- **Beta-decay-rates** $\lambda_\beta \sim \ln 2/T_{1/2}$
- and $P_{\beta i}$
- And Fission …
- Other data …

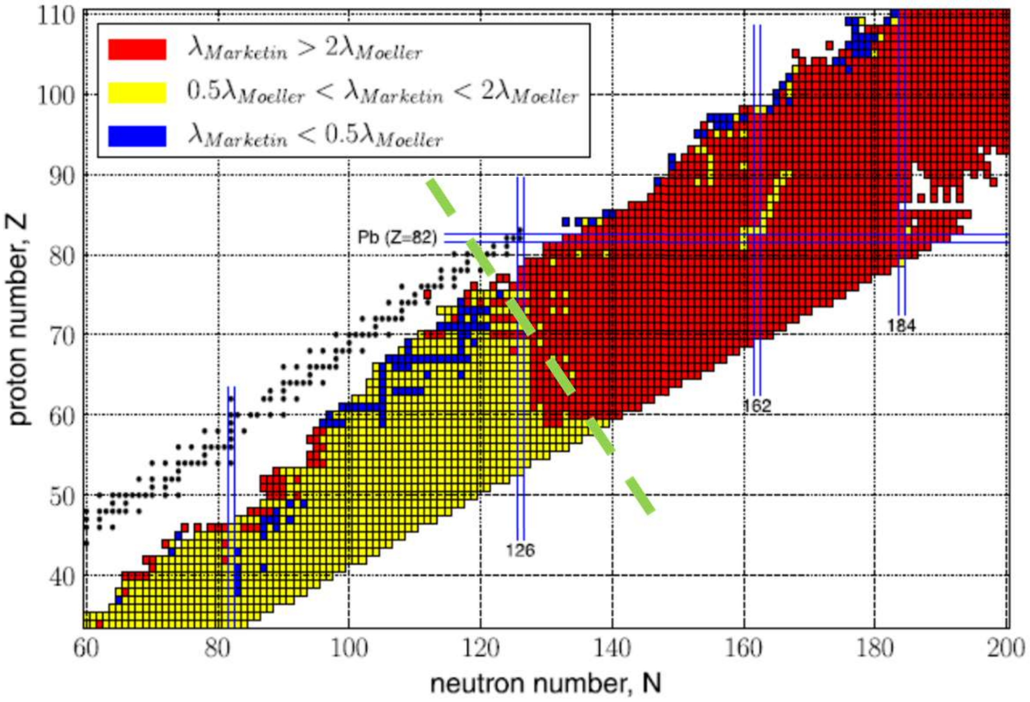
2. r-процесс. Ядерные данные

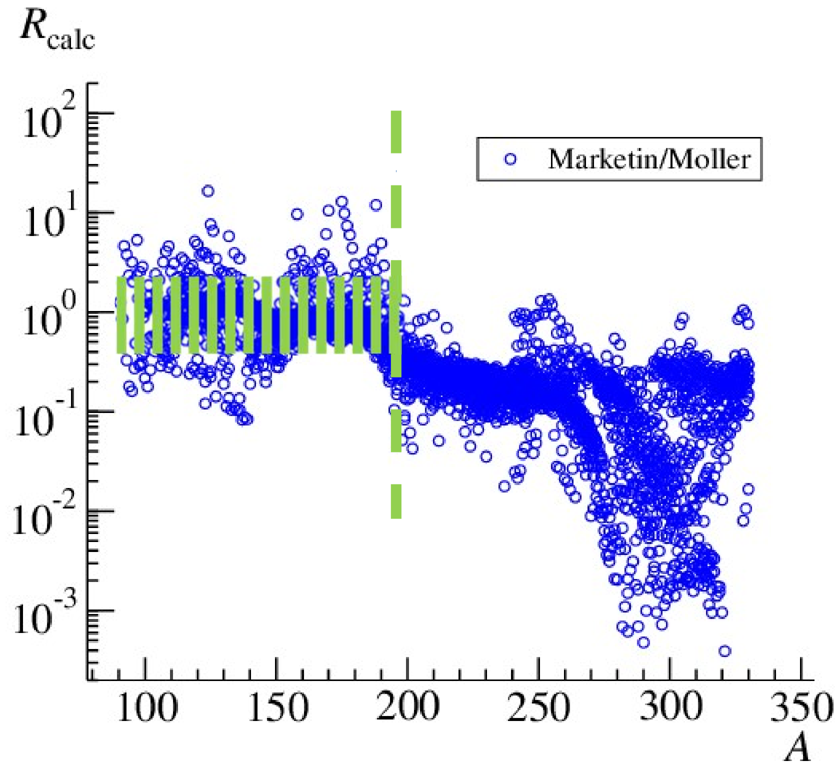
- Nuclear masses and fission barriers
- Cross-sections and reaction rates, (n,g),….. (n,f), :
  $<\sigma_{n\gamma}v>$, $<\sigma_{nf}v>$ for: TF, (ETFSI), FRDM, HFB
- Beta-decay, $T_{1/2}$
- and delayed processes P_{in}, $P_{\beta df}$
- Strength function of beta-decay – E_x, M^2
- Spontaneous neutron-induced and delayed fission
- Fission fragments mass distribution
- alpha-decay


FRDM
ETFSI-Q
HFB-14
abundance
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
120
140
160
180
200
220
240
A

3. Beta-decay-rates

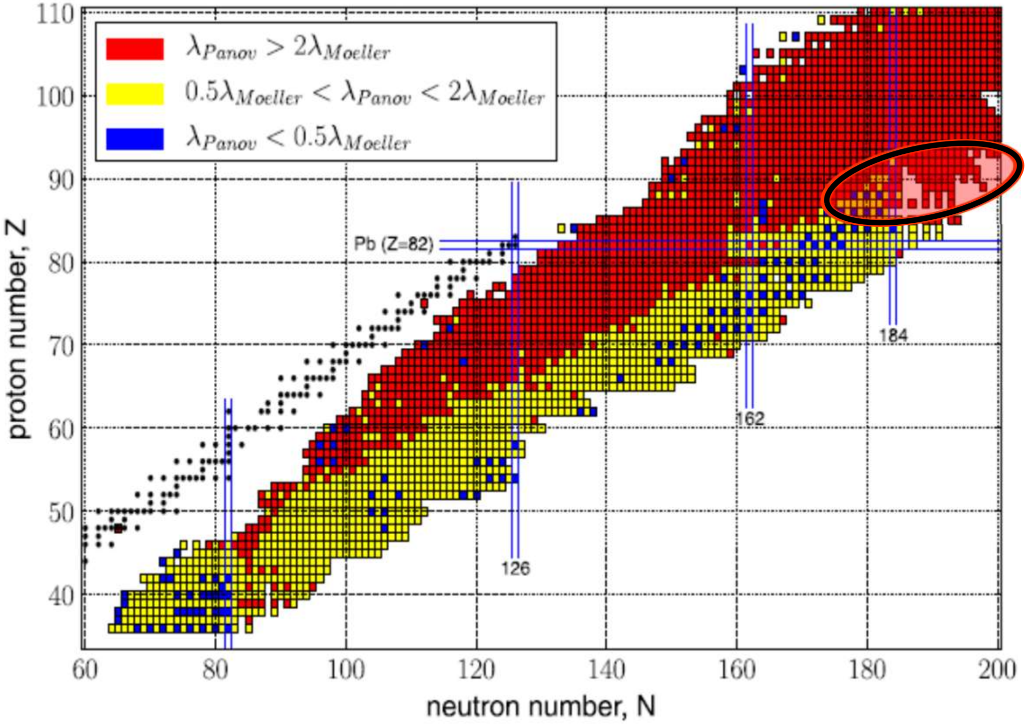
- RPA Petrow, Naumow, H.-V. Klapdor. Z. Phys. A 1978; Klapdor-…-Thielemann Z.Phys.A 299 (**1981**); qRPA Klapdor et al. **1992**
- QRPA+FRDM P. Moller, B. Pfeifer, K.-L. Kratz et al. **1997**
  QRPA+ff P. Moller, B. Pfeifer, K.-L. Kratz 2003
- FFST Migdal A.(1967); Alexankin V., Lyutostanskii Yu. S., Panov I.V. BETA-model, **1981-1988;**
- **FFST-BETA Panov & Lyutostanskii Yu. S** et al. **2013-2016**
- cQRPA+DF3, Borzov, Fayans, Trykov, 1994; Borzov **2008-2019-** Fully self-consistent framework of **Density Functional plus Continuum Quasi particle Random Phase Approximation (DF + CQRPA) for ground and excited states.**
- **T.Nikˇsi´c, T.Marketin, D.Vretenar, N.Paar 2015-2017**; self-consistent covariant density functional theory (CDFT); g.s. - relativistic Hartree-Bogoliubov (RHB) model, and ex.s. - proton-neutron relativistic quasiparticle phase approximation (pn-RQRPA).

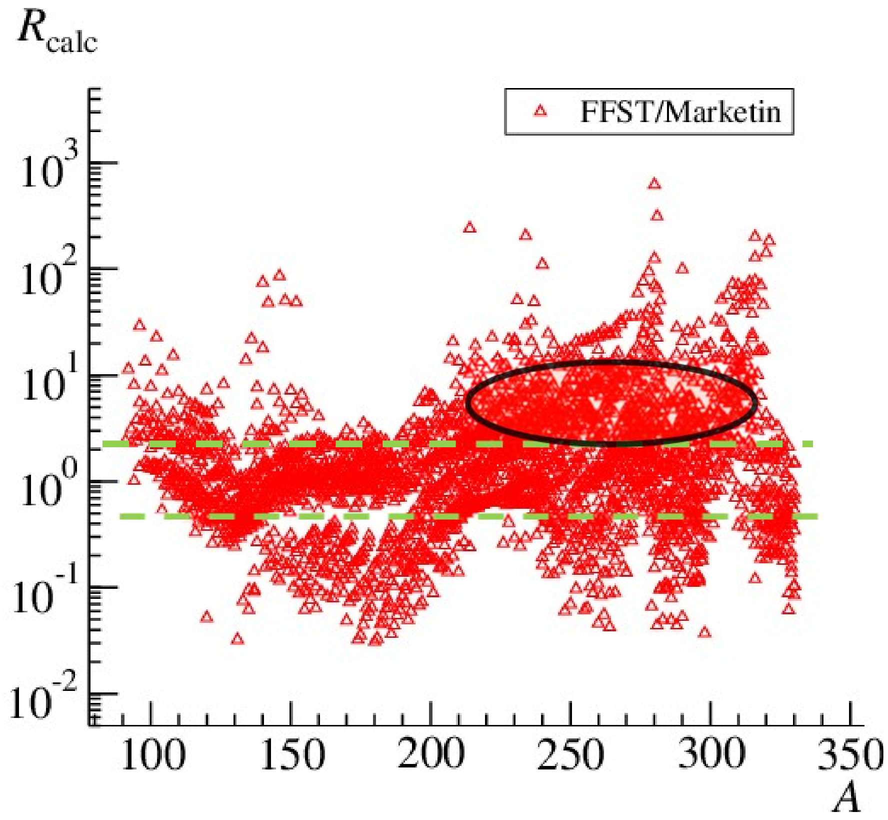




Eichler, Arcones, Kelic, Korobkin, Langanke, Marketin, Martinez-Pinedo, I. Panov et. al. AJ,2015

Present calculations of ratio $R=T_{1/2}(pnRQRPA)/T_{1/2}(RPA)$

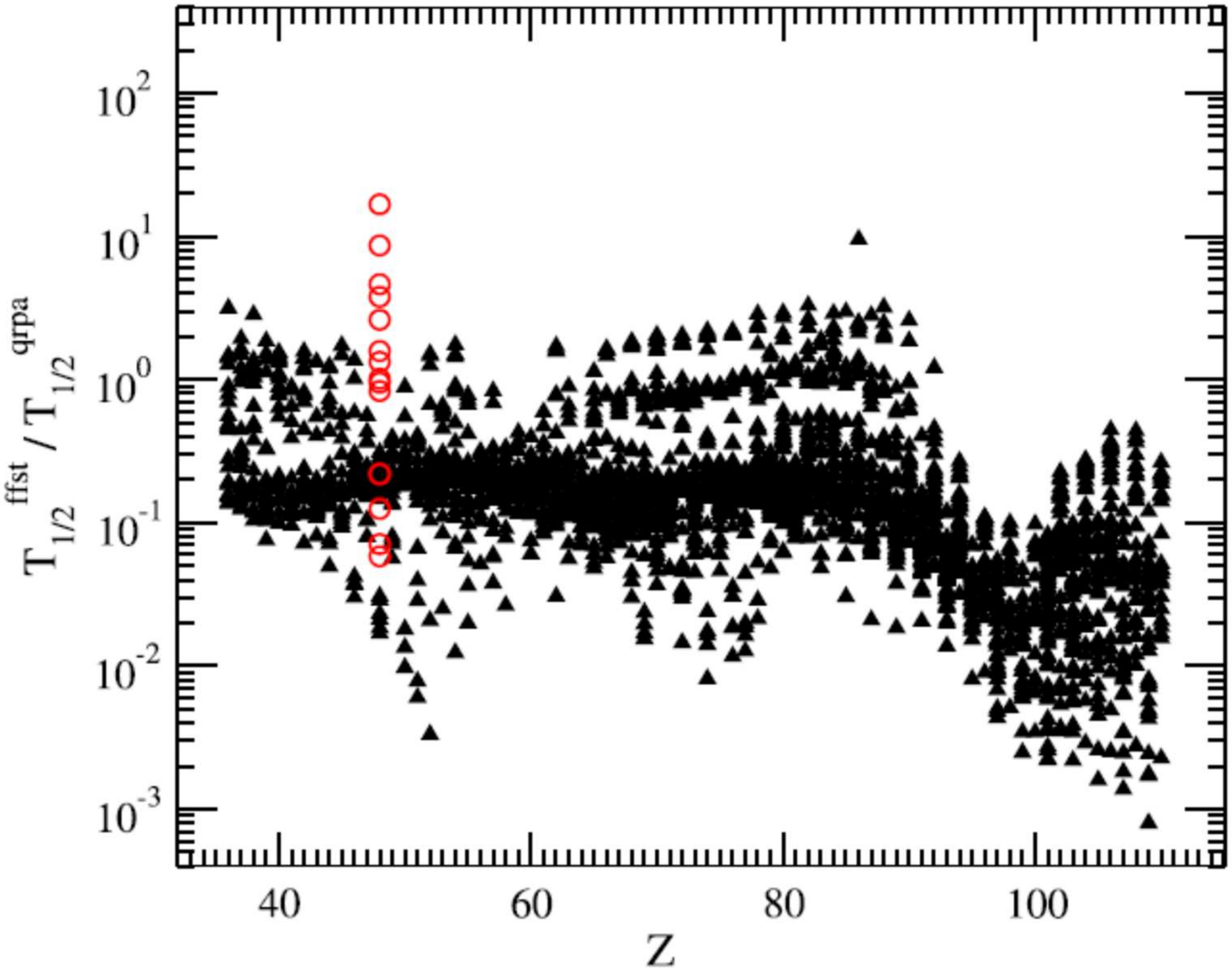




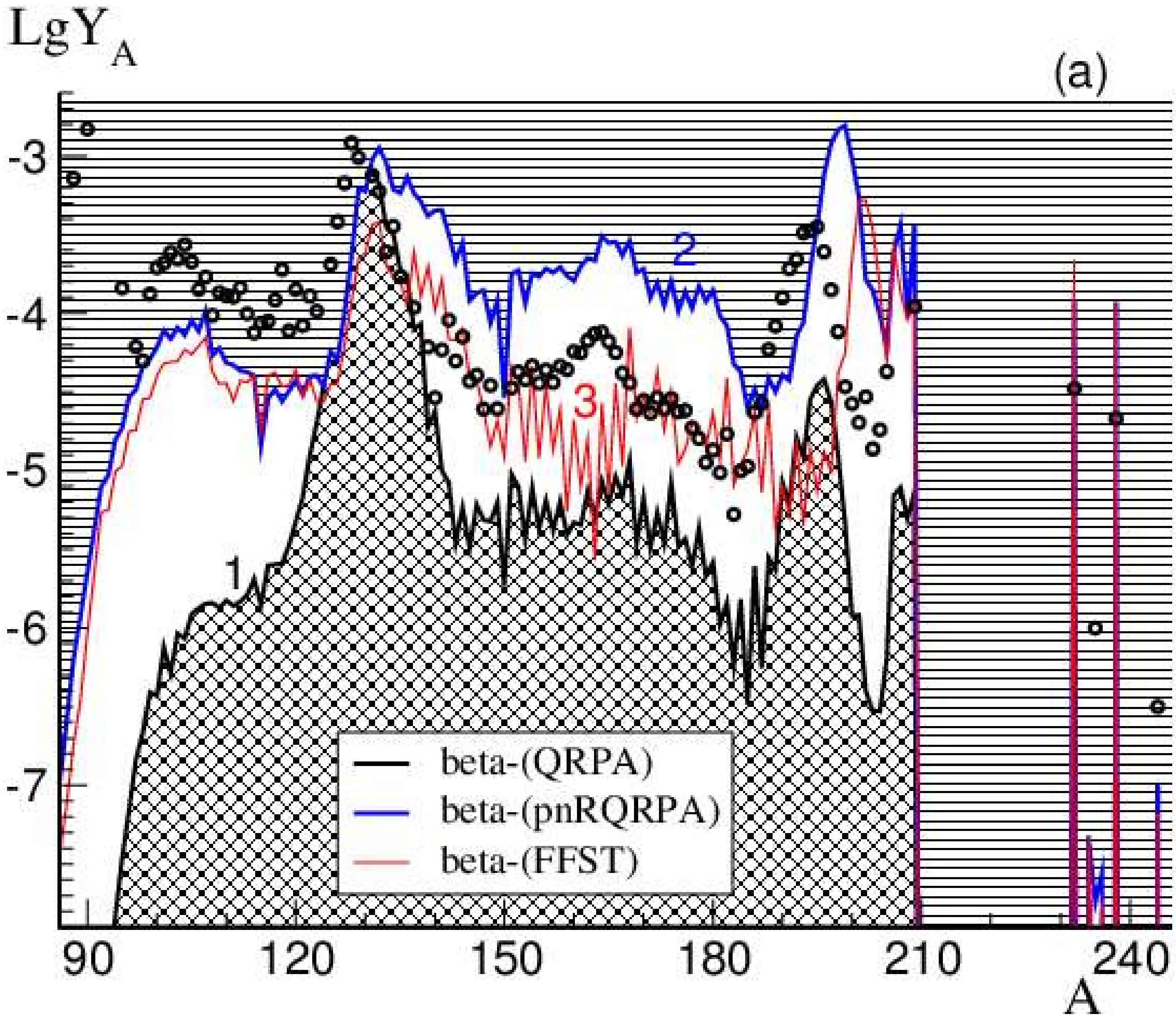
Eichler, Arcones, Kelic, Korobkin, Langanke, Marketin, Martinez-Pinedo, I. Panov et. al. AJ,2015

Present calculations of ratio $R=T_{1/2}(FFST)/T_{1/2}(pnRQRPA)$

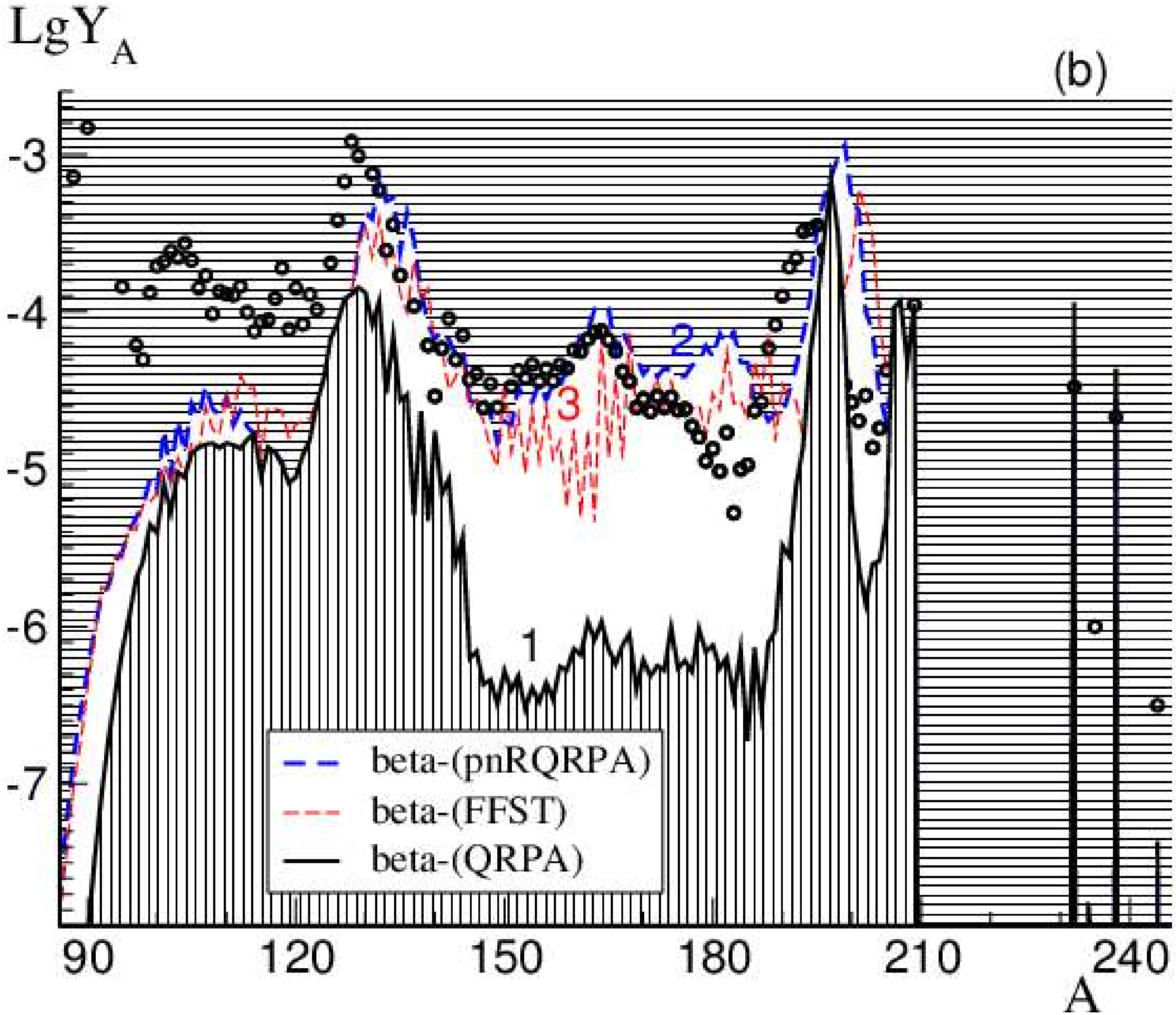
RPA versus FFST (Beta-model)



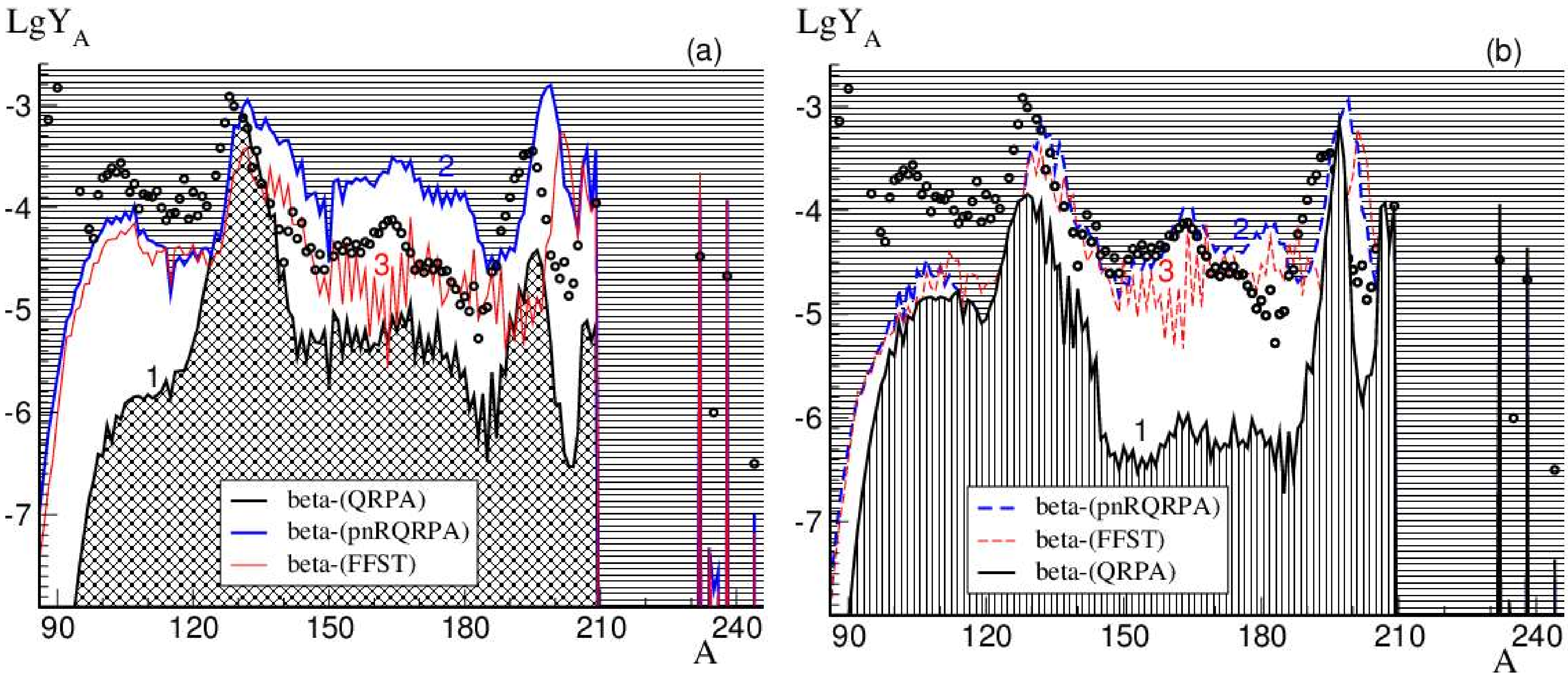
Masses: Extended Thomas Fermi+SI(ETFSi)



Finite Range Drop Model (FRDM)



NSM scenario for main r-process in extremely neutron-rich environments with fission cycling:



ETFSI FRDM

$n_c = \mathrm{Log}_2(\sum Y^{fin}_i / \sum Y^0_i)$

ETFSI	FRDM
1 – n_c = 2	1 – n_c = 1.6
2 – n_c =1	2 – n_c =0.15
3 – n_c =1.6	3 – n_c =1.4

DISCUSSION

1. The agreement between abundance calculations and observations is rather well – Both pnRQRPA and qRPA models in a whole describe well the resonance structure of abundance curve between 130 and 196 peaks.
2. The nucleosynthesis rate with pnRQRPA predictions used are in 2-4 times higher (number of nuclear due to fission cycling increased more than in 4 times), than with RPA-prediction (the number of seeds is increased in approximately ~ 0.1 -1.5 times, depending to other data).
3. The 3d peak problem – all models do not change significantly the position of the peaks, the reason of the shift are beyond the beta-decay rates' accuracy .

CONCLUSIONs, or
WHAT we understand from comparison done?

1) We should compare only the COMPATIBLE results, in our presentation 5 curves were derived for $n_c \sim 1$, when quasi-equilibrium between peaks <A>=130 and <A>=136 have been reached.
2) Even in the case of (1) the original trajectories can not give the sufficient information whether one or another nuclear model is better, only more detailed understanding of the scenario details with more detailed knowledge of different trajectories' contributions and more prominent nuclei models can help us in the question.

Thank you for attention!

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