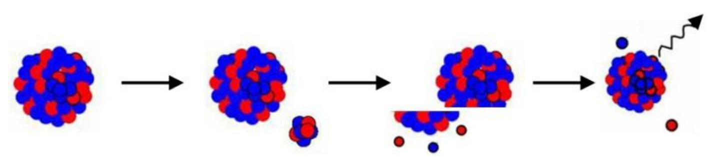
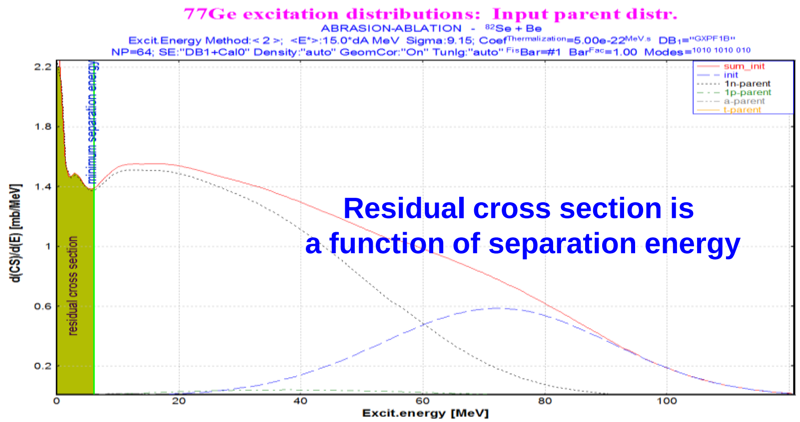
Projectile fragmentation

Abrasion-ablation model



Ablation step (Evaporation cascade) uses a mass table to obtain separation energies!!



Nuclear Physics A531 (1991) 709–745
North-Holland

A REEXAMINATION OF THE ABRASION–ABLATION MODEL FOR THE DESCRIPTION OF THE NUCLEAR FRAGMENTATION REACTION*

J.-J. GAIMARD[1] and K.-H. SCHMIDT

We propose the following approach for calculating the excitation energy of the prefragment: The nucleons are bound in the potential well of the nucleus. During the abrasion, the orbits of the nucleons not removed are preserved. This is suggested by the short time span of the abrasion, in the order of $(2\text{–}5)\times10^{-23}$ s. By the abrasion, a certain number of single-particle levels is vacated, and the excitation energy is given by the sum of the energies of these holes with respect to the Fermi surface. For a quantitative estimate we take a Woods–Saxon potential with an average depth of −47.4 MeV for neutrons and protons [29]). We neglect that the density reduction caused by the abrasion decreases the potential depth because it is reestablished after the contraction to normal nuclear density. The energy generated by one hole varies between 0 and 40 MeV depending on its position if we assume a Fermi energy around −7.4 MeV. In order to calculate the mean energy induced by one hole in the potential well below the Fermi surface, we use the single-particle level density $g(\varepsilon)$ of the Woods–Saxon potential which can be described approximately by $g\sim\varepsilon$ [ref. [30])] if ε is the single-particle energy counted from the bottom of the potential well, and we assume that the probability for generating the hole is the same for each level. This statistical hole-energy model gives an average excitation energy of 13.3 MeV per hole.

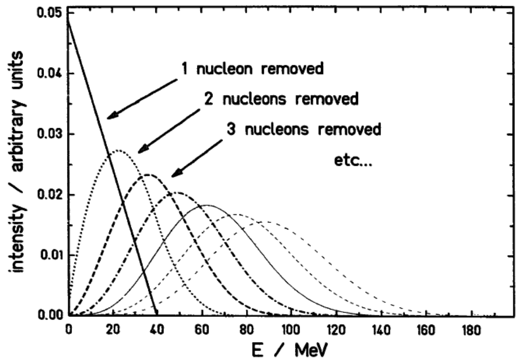


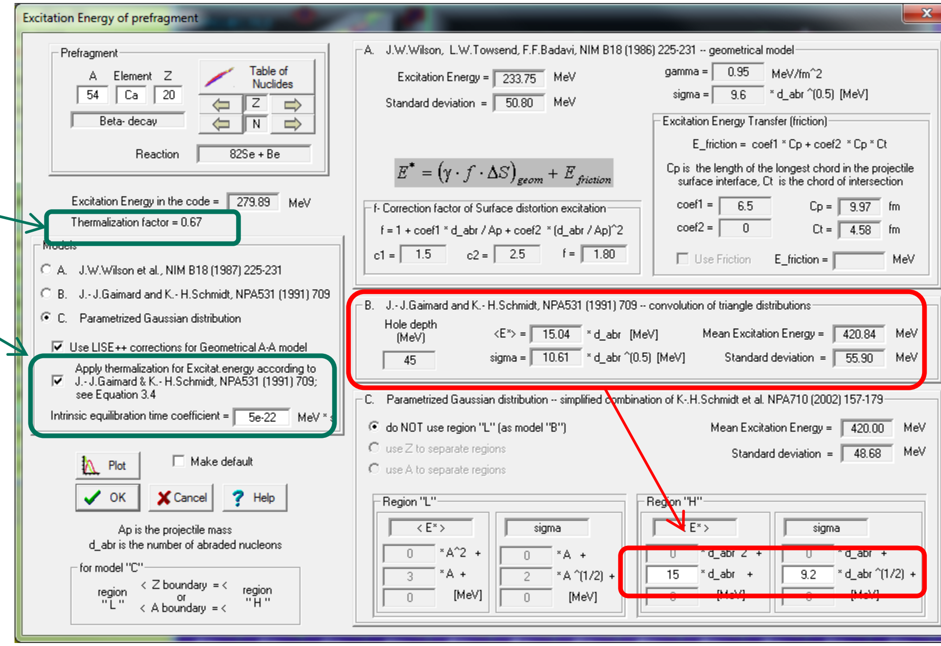
Fig. 2. Excitation-energy distributions as calculated with the diabatic model (this work) for different prefragments, after the abrasion of 1–8 nucleons from the projectile nucleus.

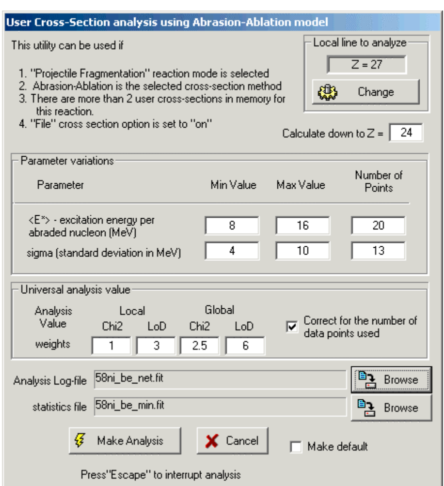
Abrasion-Ablation : Excitation energy

v. 9.4.44 06/09/12
thermalization
of excitation energy

In the following we will investigate whether the basic assumption of our proposed model is justified, namely that the orbits of the nucleons of the prefragment are untouched by the abrasion process, that means whether the abrasion process at relativistic energies is diabatic. For this purpose we will estimate the part of the excitation energy which is thermalized during the abrasion, that means the part which is equilibrated and modifies the orbits of the nucleons of the prefragment. According to calculations of Bertsch [31]), Nörenberg [32]) estimated an intrinsic thermalization time, also called intrinsic equilibration time, by the following relation:

$$\tau_{intr}(t) = 2 \times 10^{-22}\ \mathrm{MeV \cdot s}/e^{*}(t)\,, \qquad (3.1)$$





User cross-section analysis using Abrasion-Ablation model

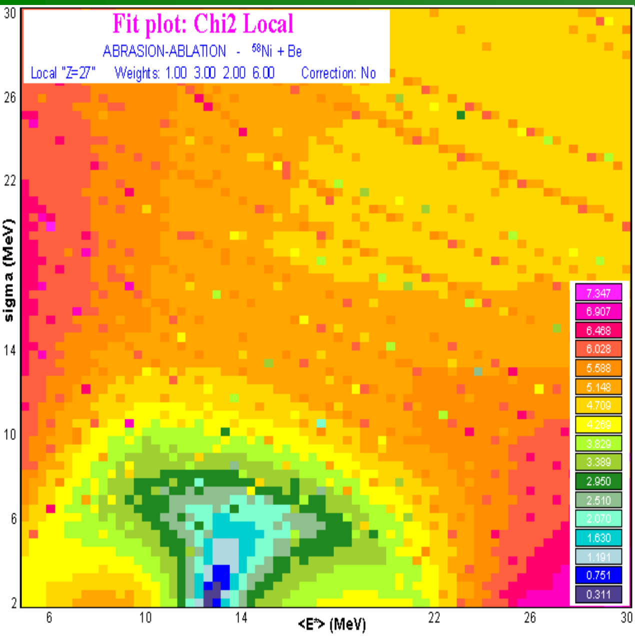
http://lise.nscl.msu.edu/7_5/lise++_7_5.pdf#page=85

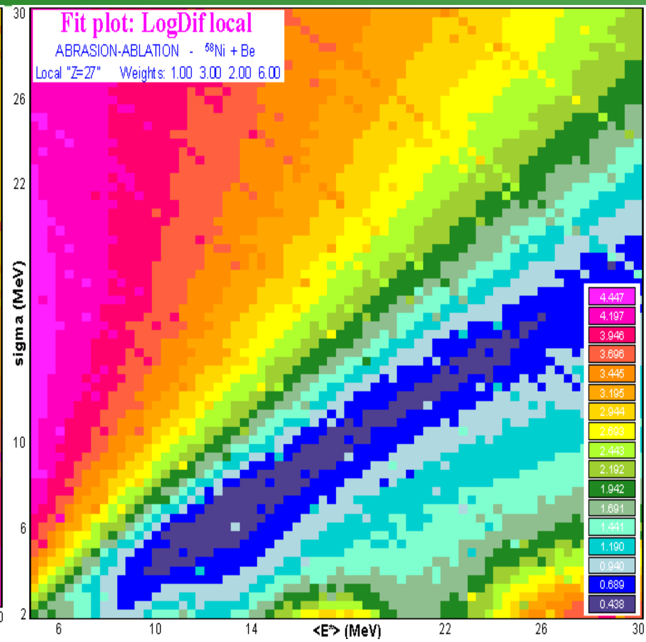
$$Final = w_1 \cdot Lo\chi 2_{\,local} + w_2 \cdot LoD_{\,local} + w_3 \cdot Lo\chi 2_{\,total} + w_4 \cdot LoD_{\,total}$$

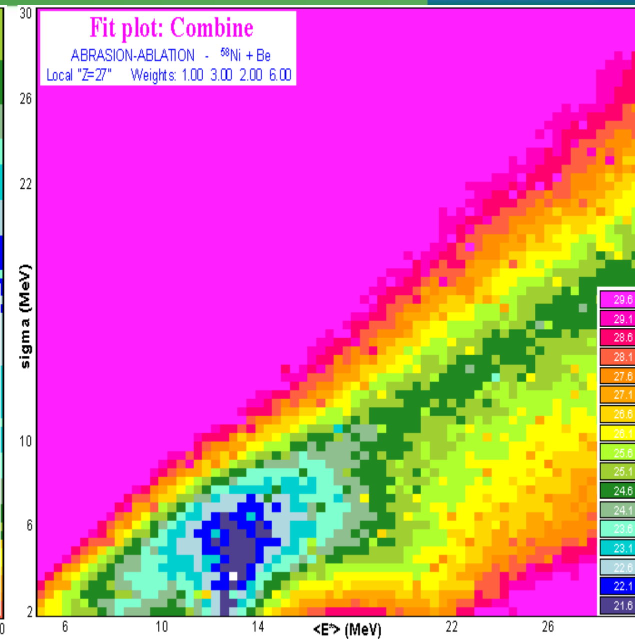
$$\text{where } Lo\chi 2 = \ln(\chi^2) \text{ and } LoD = \sum_{i=1}^{N} \left| \log 10(y_{exp}) - \log 10(y_{calc}) \right| / N$$

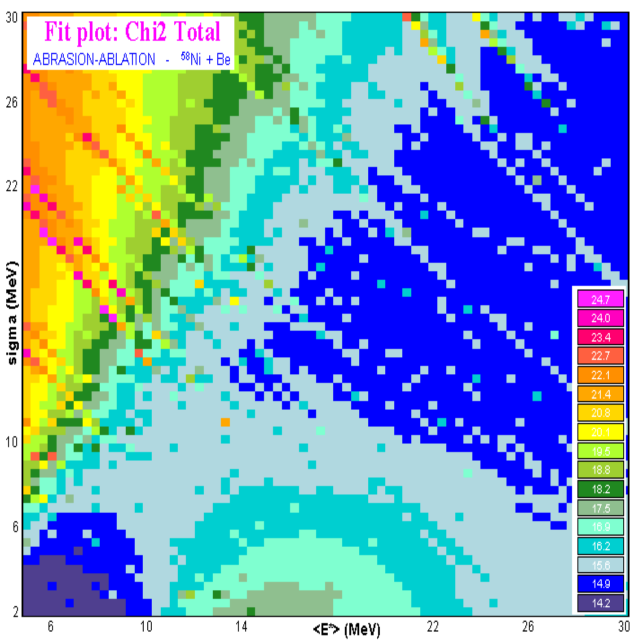
Global fit by AA for all CSs obtained in the experiment allows to deduce the excitation energy parameters

User cross-section analysis using Abrasion-Ablation model









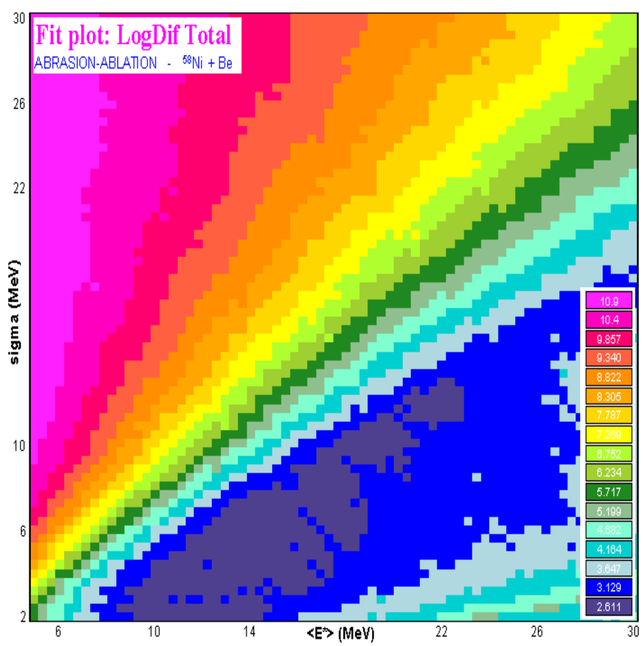
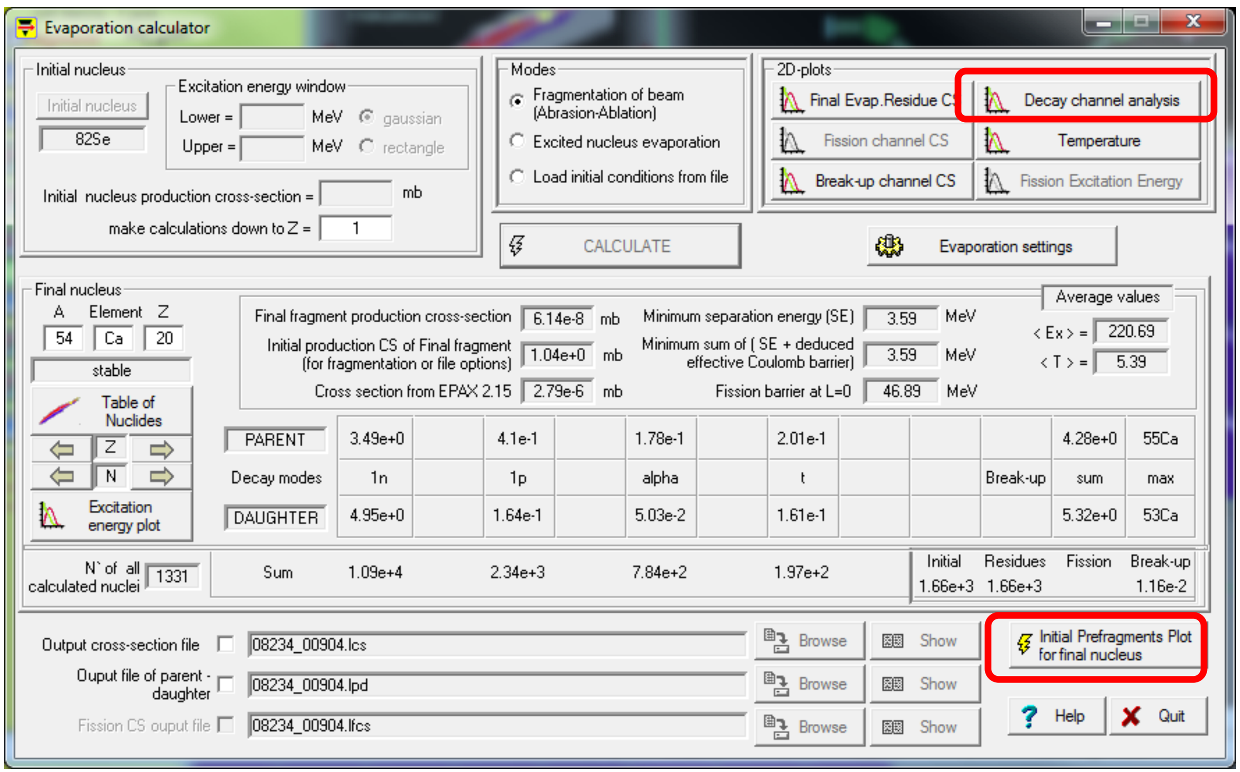
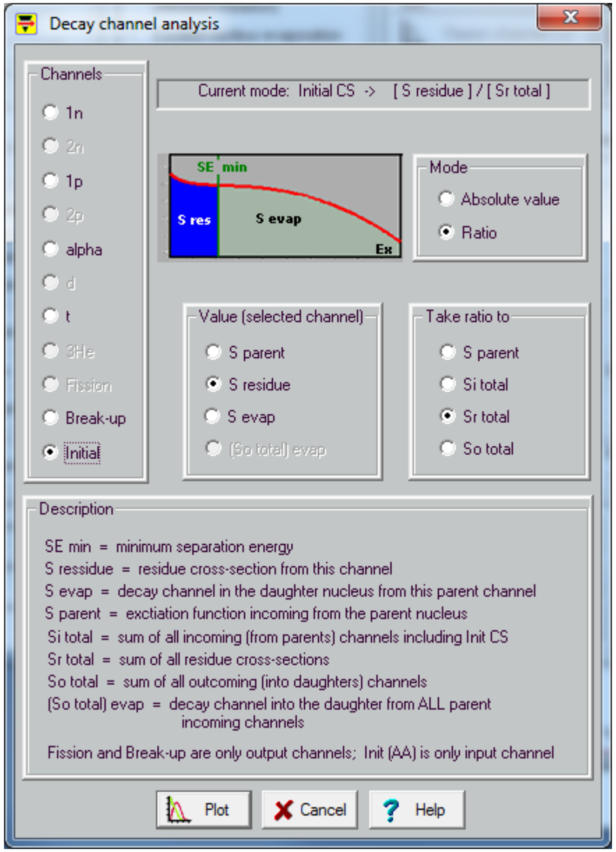


Figure. *Comparisons of experimental data [Bla94] and Abrasion-Ablation calculations for the ^{58}Ni(650AMeV)+Be reaction. Left top and middle top plots represent comparisons for a Local line, which was set to Z=27. Left bottom and middle bottom plots are done for the global data set. The right top plot shows the sum of all four models, using coefficients 1,3,2,6 (see insertions in plots).*
Using this analysis it is possible to conclude that the best parameters to use in the AA model to describe these experimental data are <E>=13 and sigma=4 MeV.*

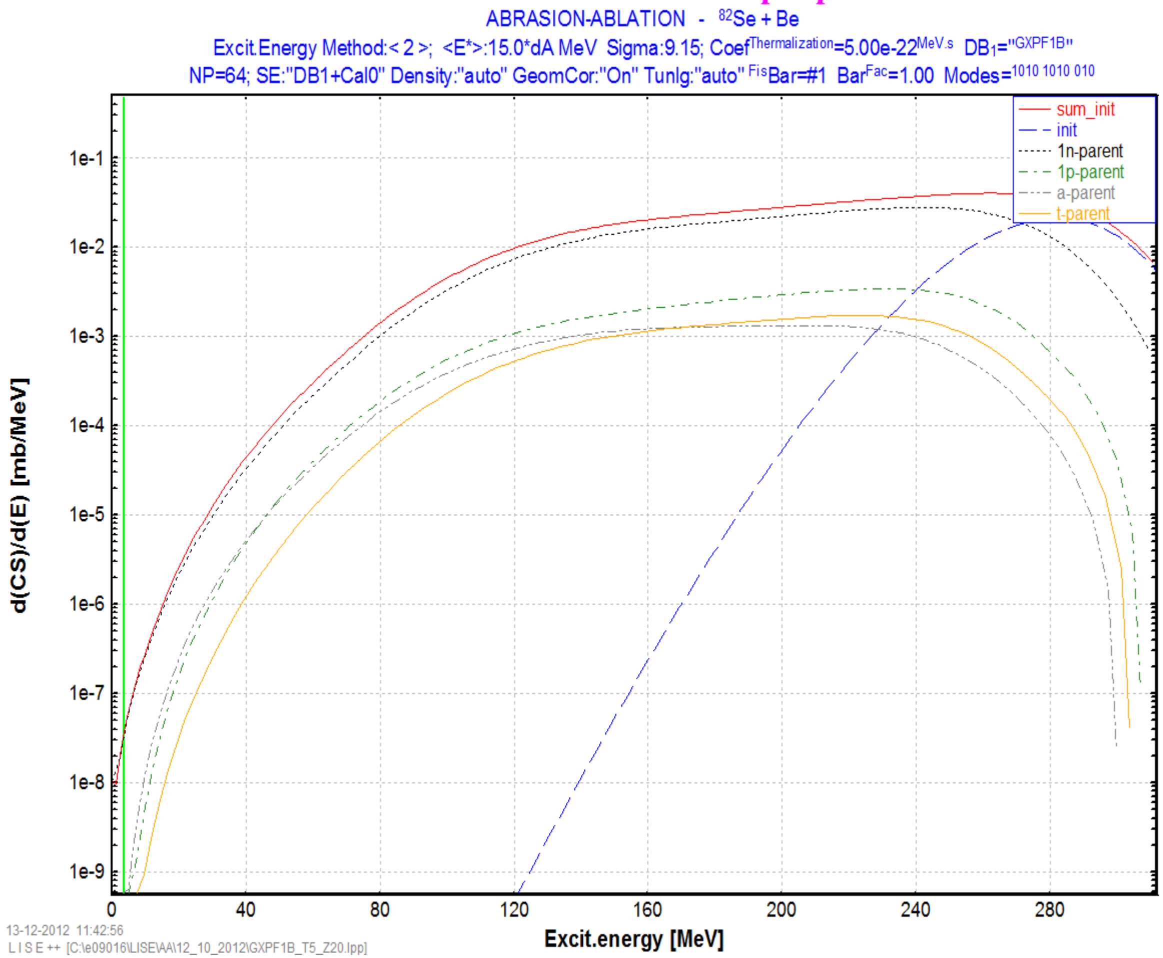
During analysis of GSI's ^{238}U, RIKEN's ^{238}U, MSU's ^{82}Se experiments there was significant modification of LISE++ AA:

- **Improving/Fixing problems (interpolation, new methods),**
- **new properties (excitation energy thermalization and etc),**
- **new utility: Initial prefragments plot, Decay Analysis utility update,**
- **new mass tables (AME2011, GXPF1B), unknown masses extrapolation procedure update and so on**





54Ca excitation distributions: Input parent distr.



GXPF1B5 + LDM0, E* = 15.0 & 9.15

(deduced from ^{82}Se experimental data)

LISE++ Abrasion-Ablation: Decay Analysis

MICHIGAN STATE UNIVERSITY LISE++

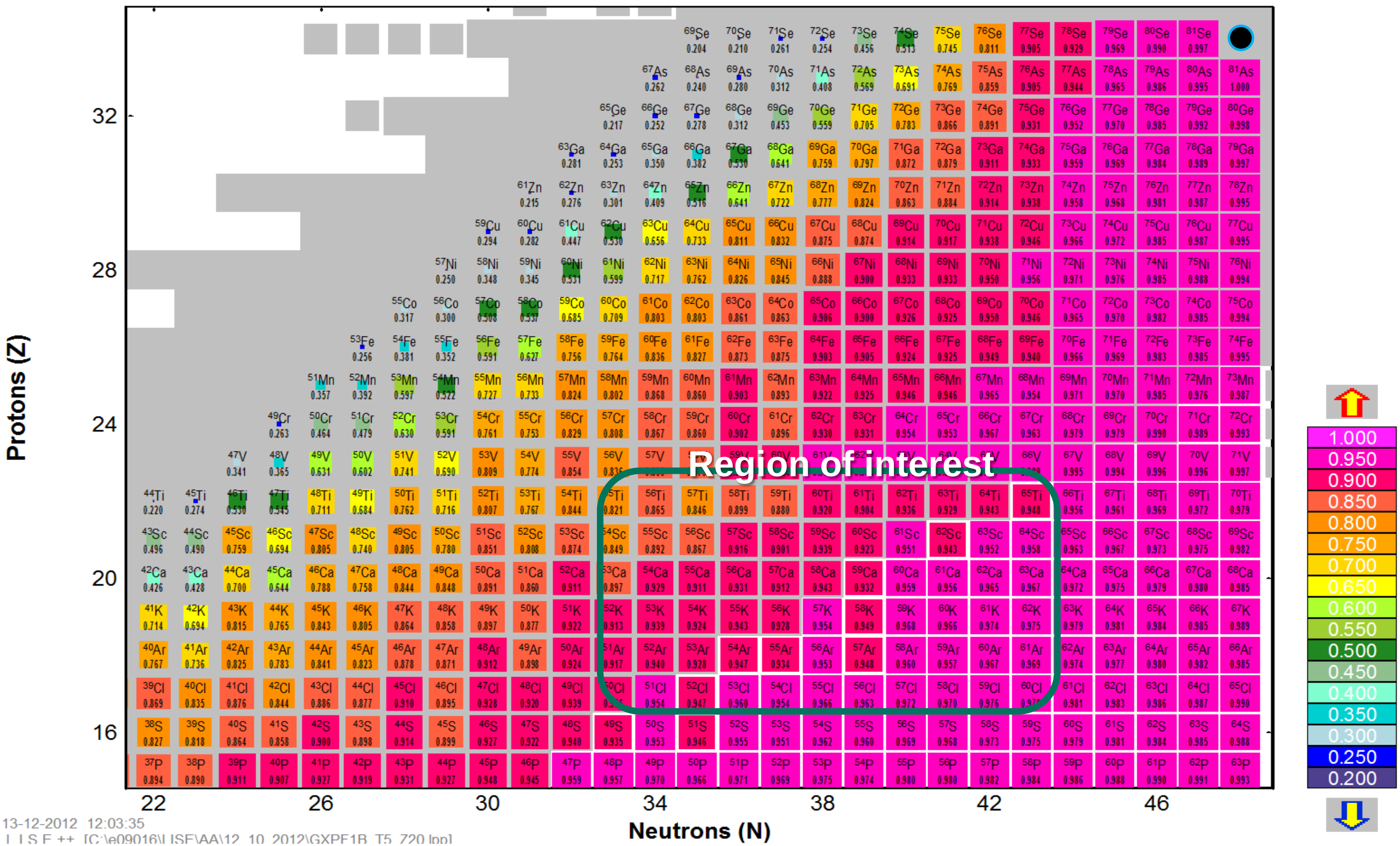
NSCL

Current mode: 1n -> [(So total) evap] / [So total]

ABRASION-ABLATION - ^{82}Se + Be

Excit.Energy Method:< 2 >; <E*>:15.0*dA MeV Sigma:9.15; Coef^{Thermalization}=5.00e-22$^{MeV.s}$ DB$_1$="GXPF1B"

NP=64; SE:"DB1+Cal0" Density:"auto" GeomCor:"On" TunIg:"auto" ^{Fis}Bar=#1 Bar^{Fac}=1.00 Modes=$^{1010\ 1010\ 010}$



13-12-2012 12:03:35

L I S E ++ [C:\e09016\LISE\AA\12_10_2012\GXPF1B_T5_720.lpp]

LISE++ Abrasion-Ablation: Decay Analysis

MICHIGAN STATE UNIVERSITY LISE++

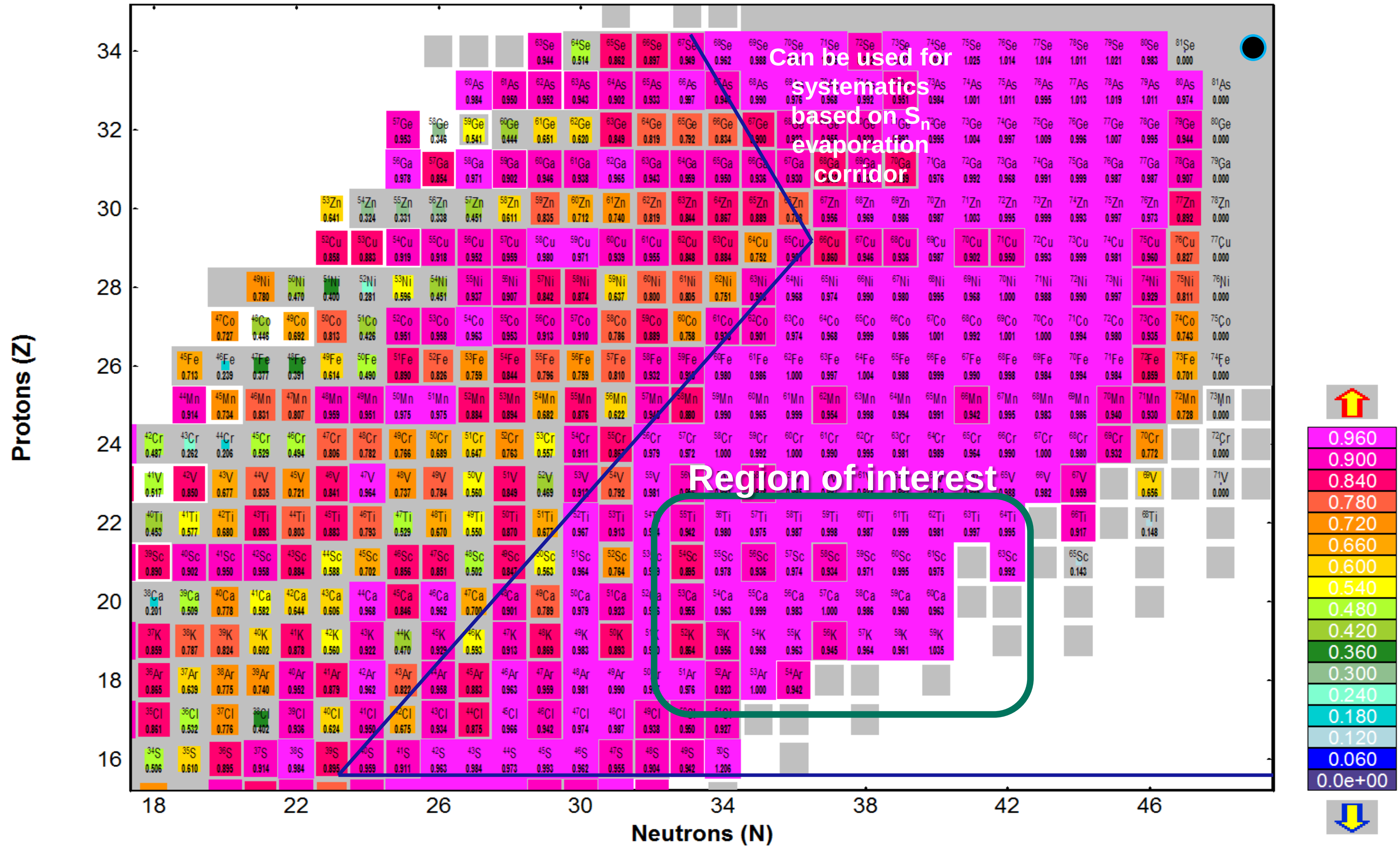
NSCL

Current mode: 1n -> [S residue] / [Sr total]

ABRASION-ABLATION - ^{82}Se + Be

Excit.Energy Method:< 2 >; <E*>:15.0*dA MeV Sigma:9.15; Coef^{Thermalization}=5.00e-22$^{MeV.s}$ DB$_1$="GXPF1B"

NP=64; SE:"DB1+Cal0" Density:"auto" GeomCor:"On" TunIg:"auto" ^{Fis}Bar=#1 Bar^{Fac}=1.00 Modes=$^{1010\ 1010\ 010}$



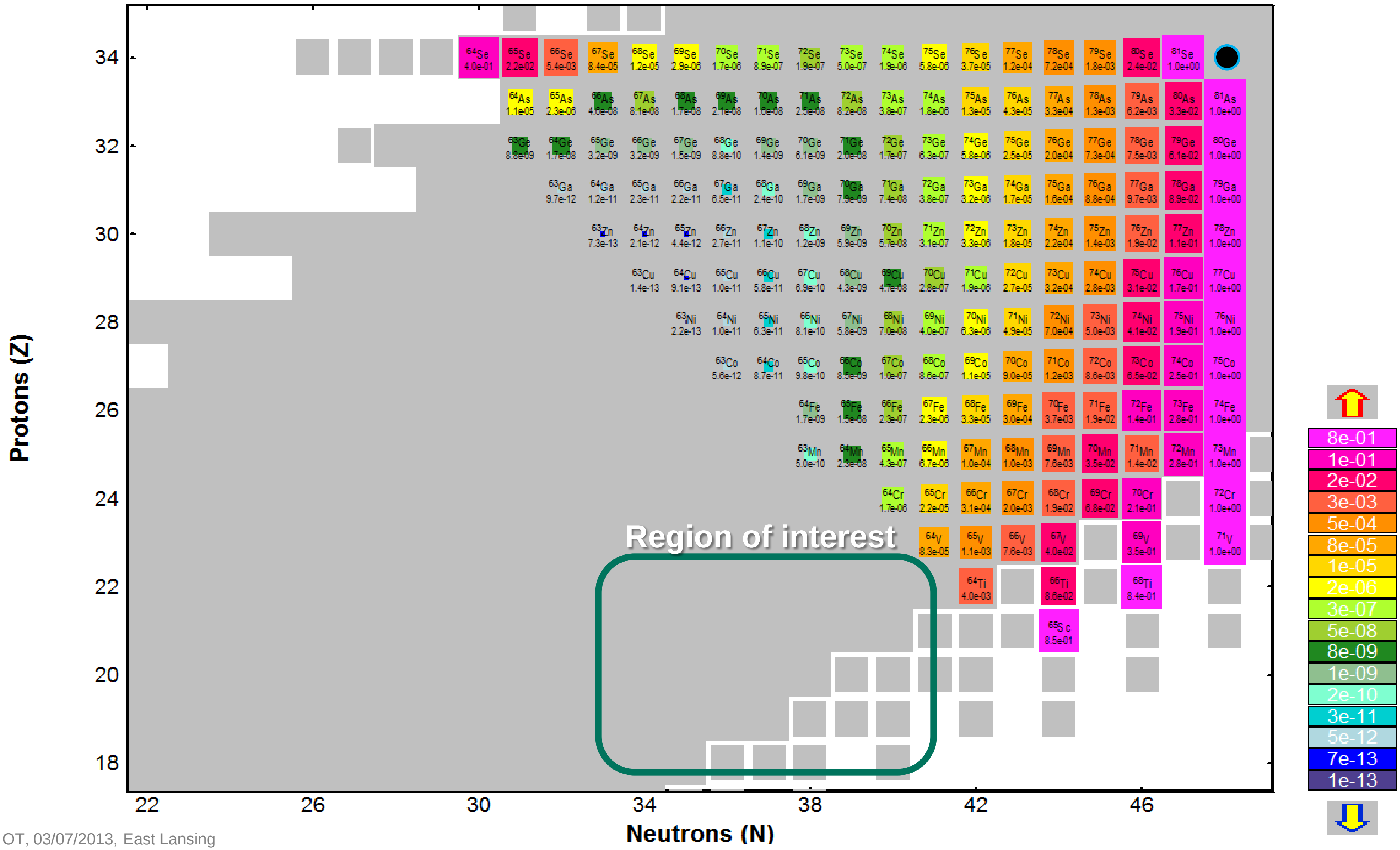
MICHIGAN STATE UNIVERSITY LISE++ NSCL

Current mode: Initial CS -> [S residue] / [Sr total]

ABRASION-ABLATION - ^{82}Se + Be

Excit.Energy Method:< 2 >; <E*>:15.0*dA MeV Sigma:9.15; Coef^{Thermalization}=5.00e-22$^{MeV.s}$ DB$_1$="GXPF1B"

NP=64; SE:"DB1+Cal0" Density:"auto" GeomCor:"On" TunIg:"auto" ^{Fis}Bar=#1 Bar^{Fac}=1.00 Modes=$^{1010\ 1010\ 010}$

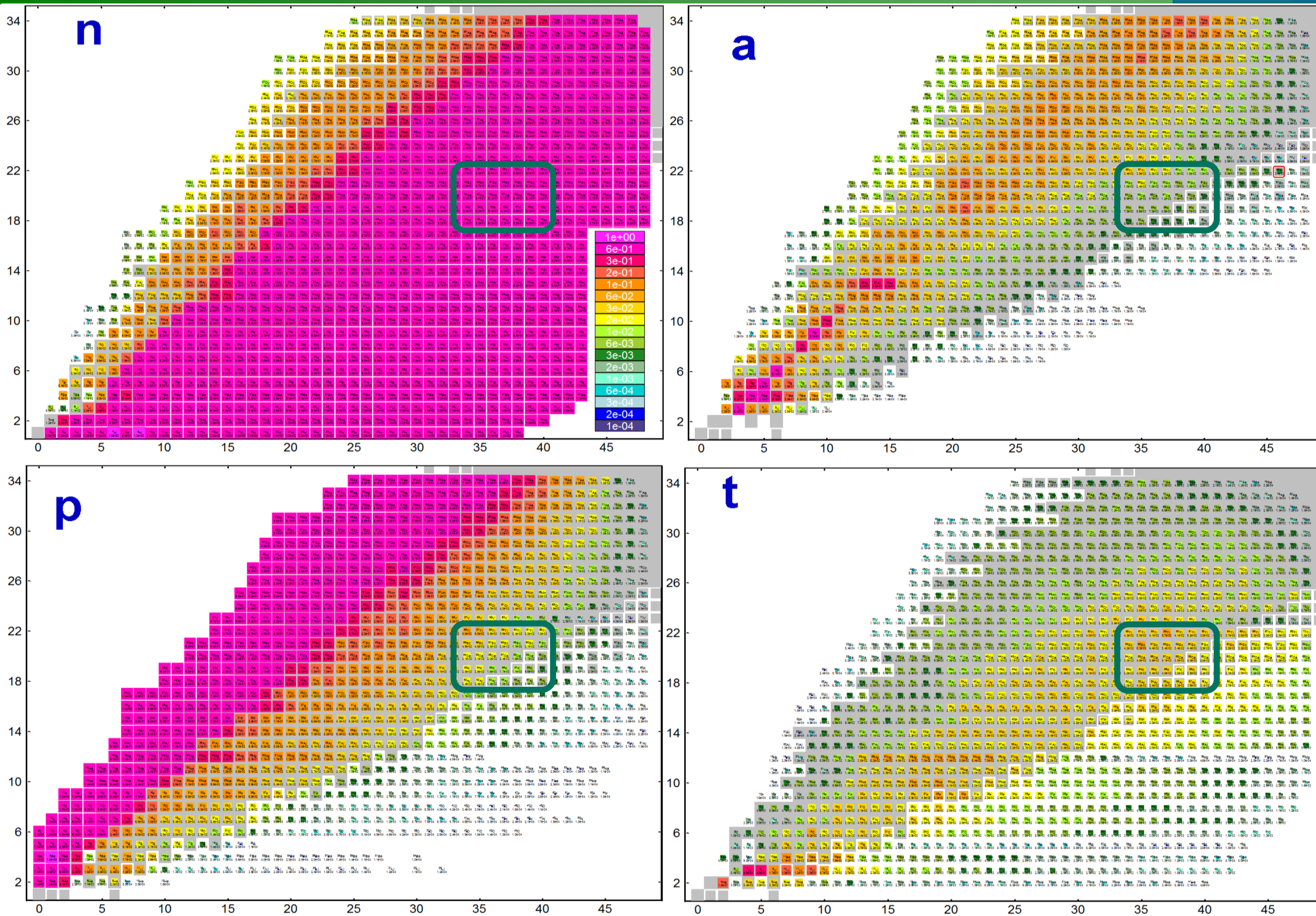


NSCL

So evap-channel / So evap-total (one scale for all plots)

MICHIGAN STATE UNIVERSITY

LISE++



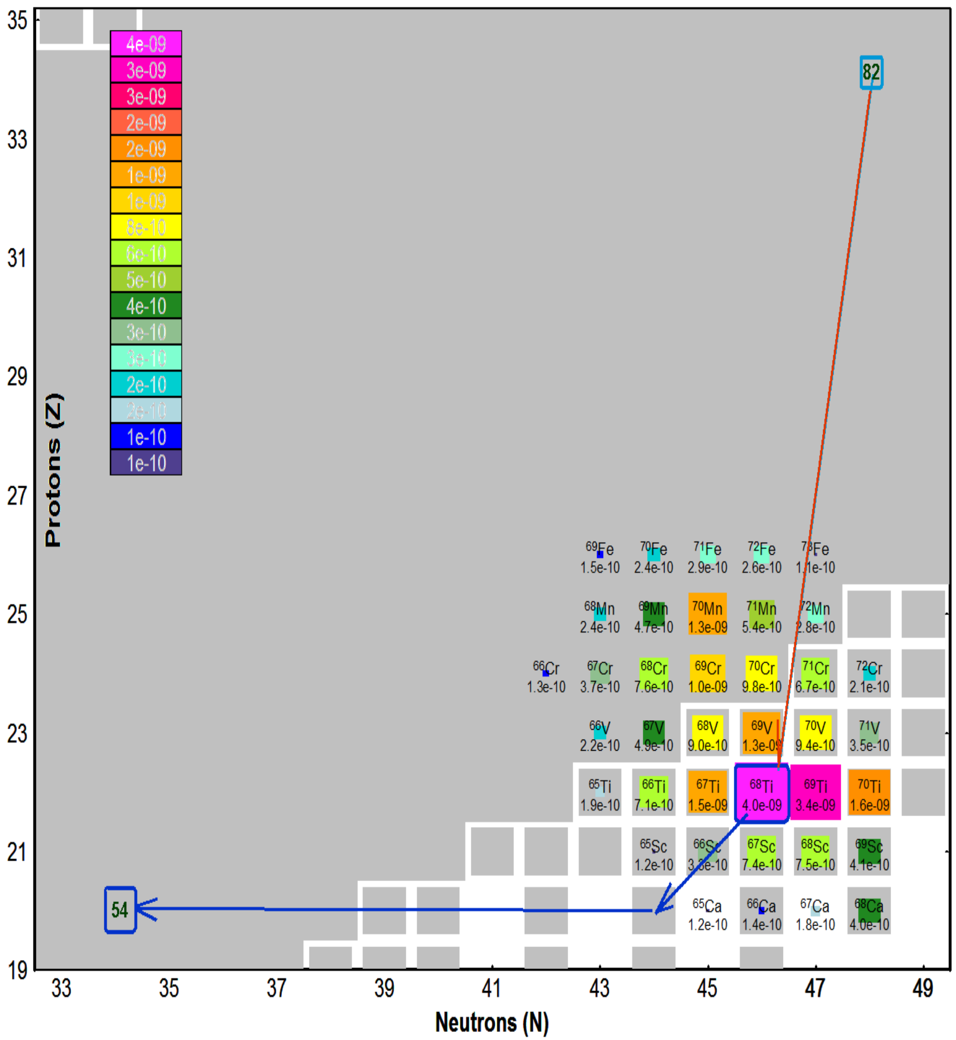
LISE++ Abrasion-Ablation: Initial prefragments plot (^{82}Se)

Initial Prefragments Plot for ^{54}Ca (2.78e-08 mb)

ABRASION-ABLATION - ^{82}Se + Be: more probable ^{68}Ti(4.02e-09 mb); <-dZ>=2.88 <-dN>=11.78

Excit.Energy Method:< 2 >; <E*>:15.0*dA MeV sigma:9.20; Thermal.Intr.Coef. = 5.00e-22 MeV*s

NP=64; SE:"DB1+Cal0" Density:"auto" Geom.Corr:"On" TunIg:"auto" FisBar=#1 BarFac=1.00 Modes=1010 1010 01(

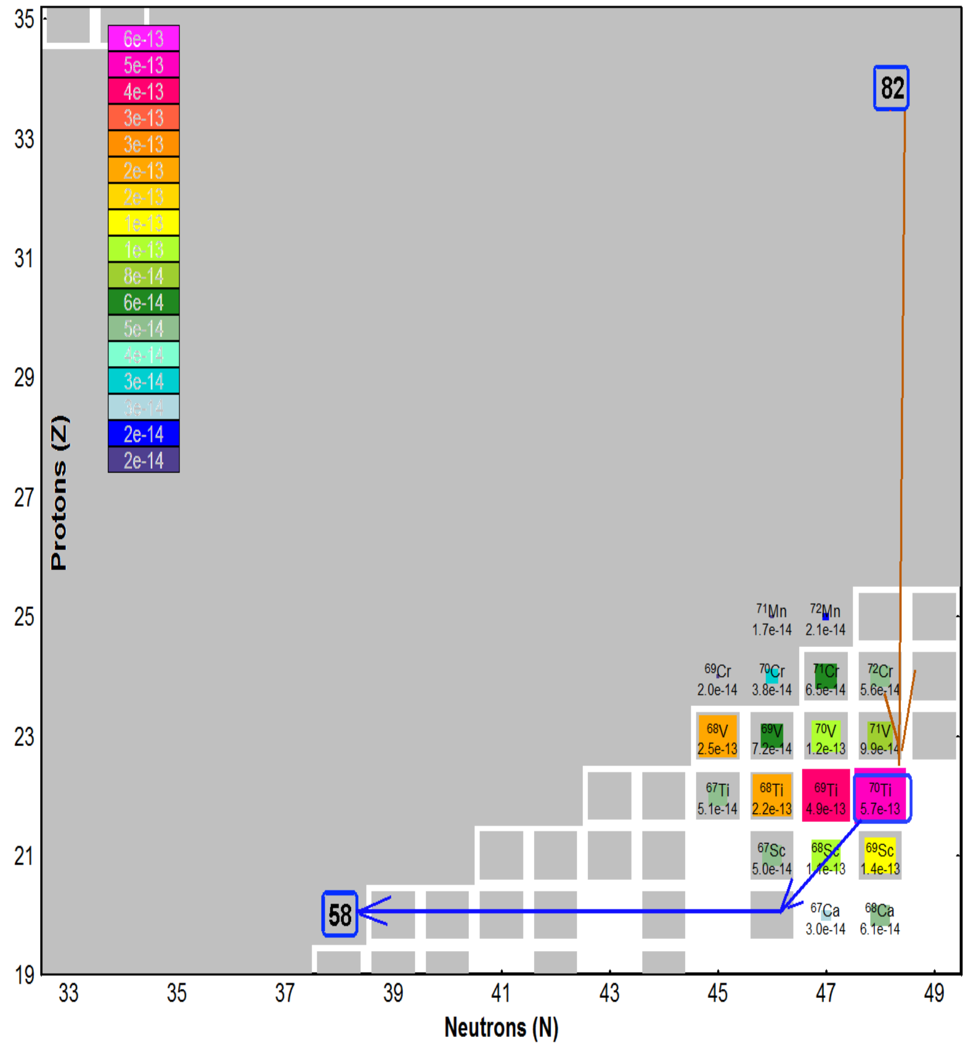


Initial Prefragments Plot for ^{58}Ca (2.57e-12 mb)

EVAPORATION - Compound nucleus ^{68}Ti: more probable ^{70}Ti(5.73e-13 mb); <-dZ>=2.27 <-dN>=8.89

Excit.Energy: 149.0-207.0 MeV; Fus.CS: 0.0 mb; Fus.Barrier: 10.82 fm; h_omega = 2.0 MeV

NP=64; SE:"DB1+Cal0" Density:"auto" GeomCor:"On" TunIg:"auto" FisBar=#1 BarFac=1.00 Modes=1010 1010 010



More probable prefragments are Ti-isotopes (dZ=2)

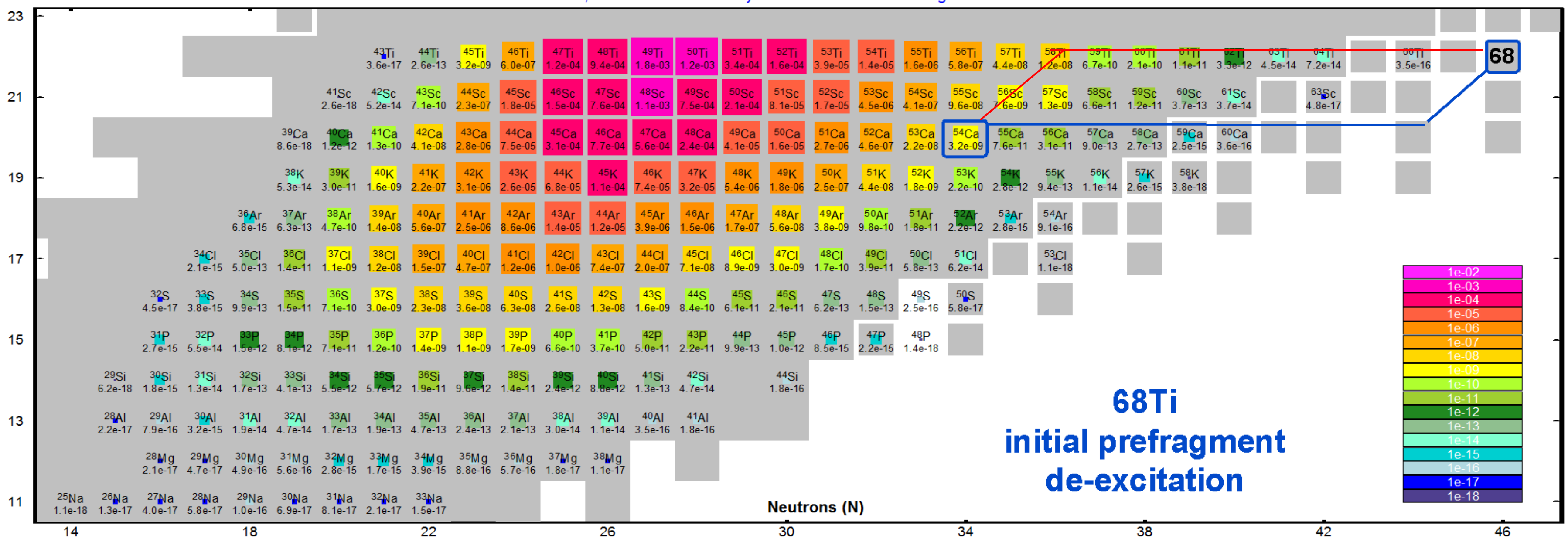
$^{82}Se \rightarrow {}^{68}Ti^* \rightarrow {}^{54}Ca$

Final Evaporation Residue cross-sections (LisFus)

EVAPORATION - Compound nucleus ^{68}Ti

Excit.Energy: 149.0-207.0 MeV; Fus.CS: 0.0 mb; Fus.Barrier: 10.82 fm; h_omega = 2.0 MeV

NP=64; SE:"DB1+Cal0" Density:"auto" GeomCor:"On" Tunl g:"auto" FisBar=#1 BarFac=1.00 Modes=1010 1010 010



Probabiltiy for 68Ti*(Ex=180MeV)

t = 2.6e-2

a = 3.6e-3

p =9.2e-3

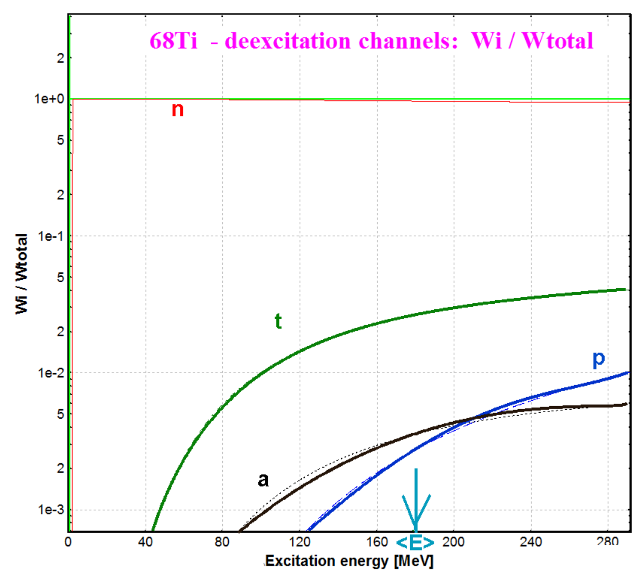
Probabiltiy (dZ=2)

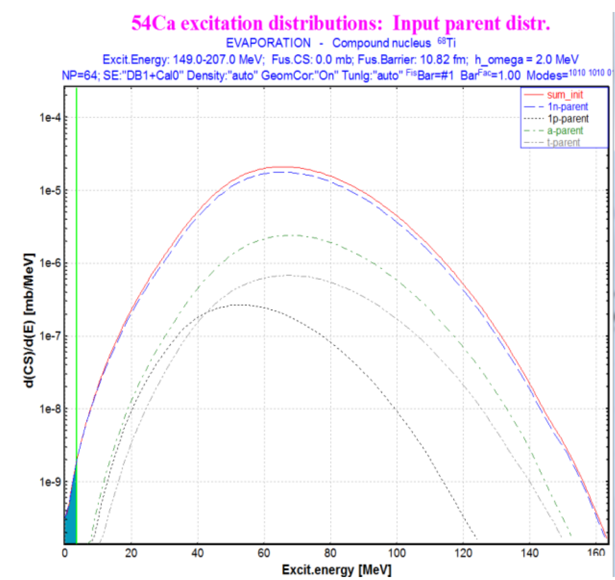
t^2 = 6.8e-4

a = 3.6e-3

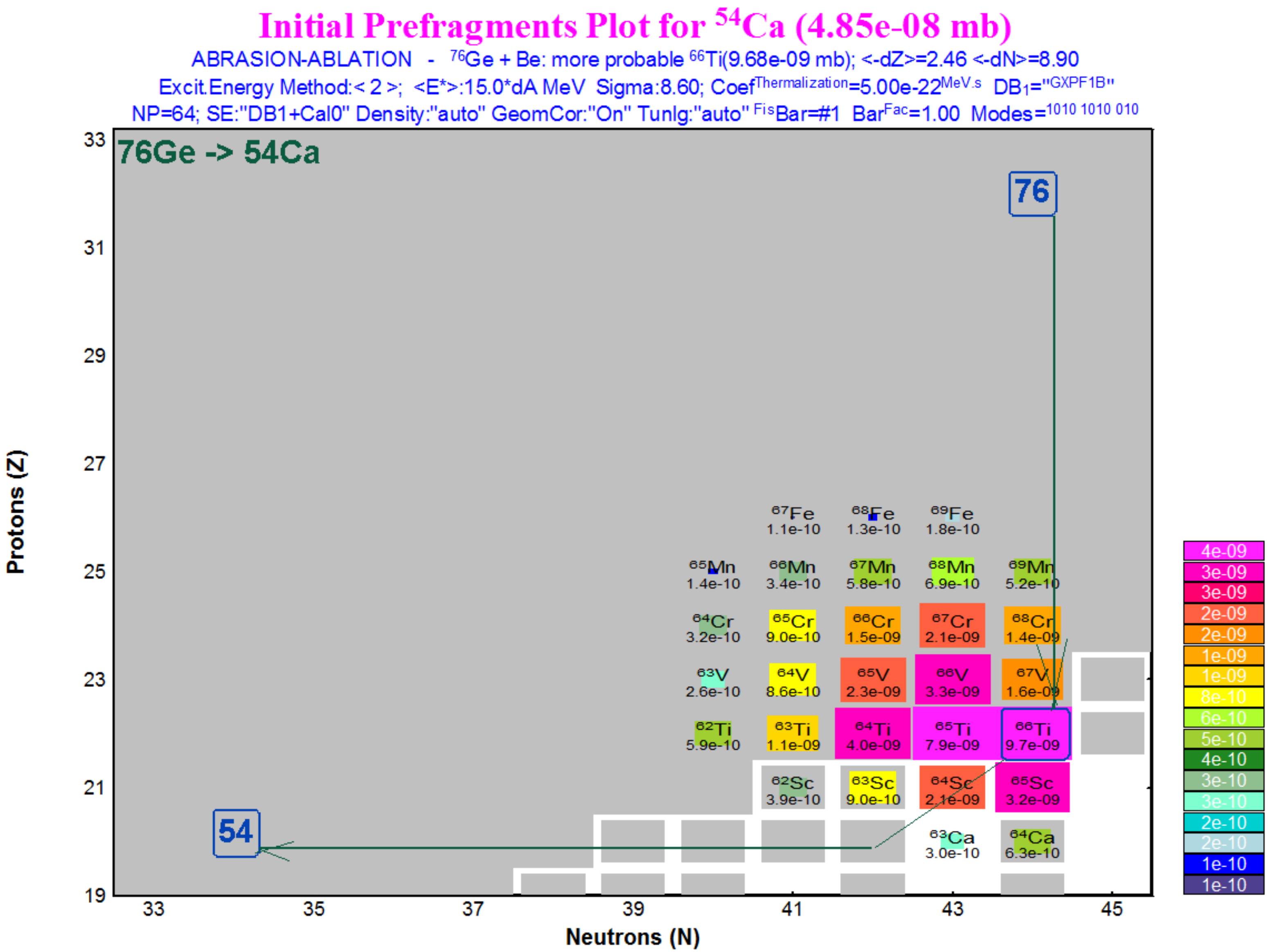
p^2 =8.7e-5

It is necessary to create the MC version to gate for ^{54}Ca residual in order to answer where (Ti → **-^{4}Ca) alpha de-excitation is more probable**



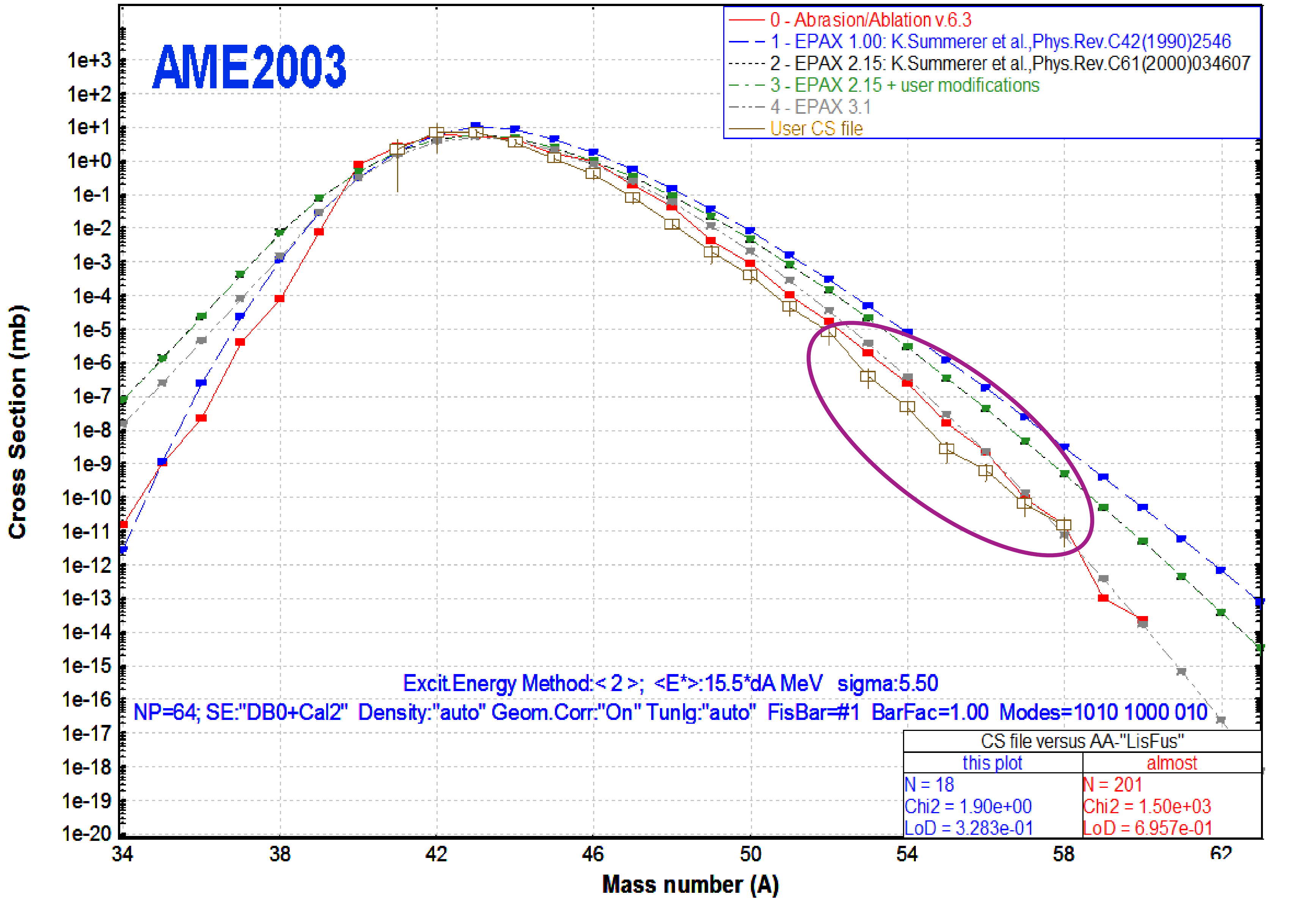


LISE++ Abrasion-Ablation: Initial prefragments plot (^{76}Ge)



More probable prefragments are Ti-isotopes (dZ=2)

Attempt to reproduce "Calcium anomaly"



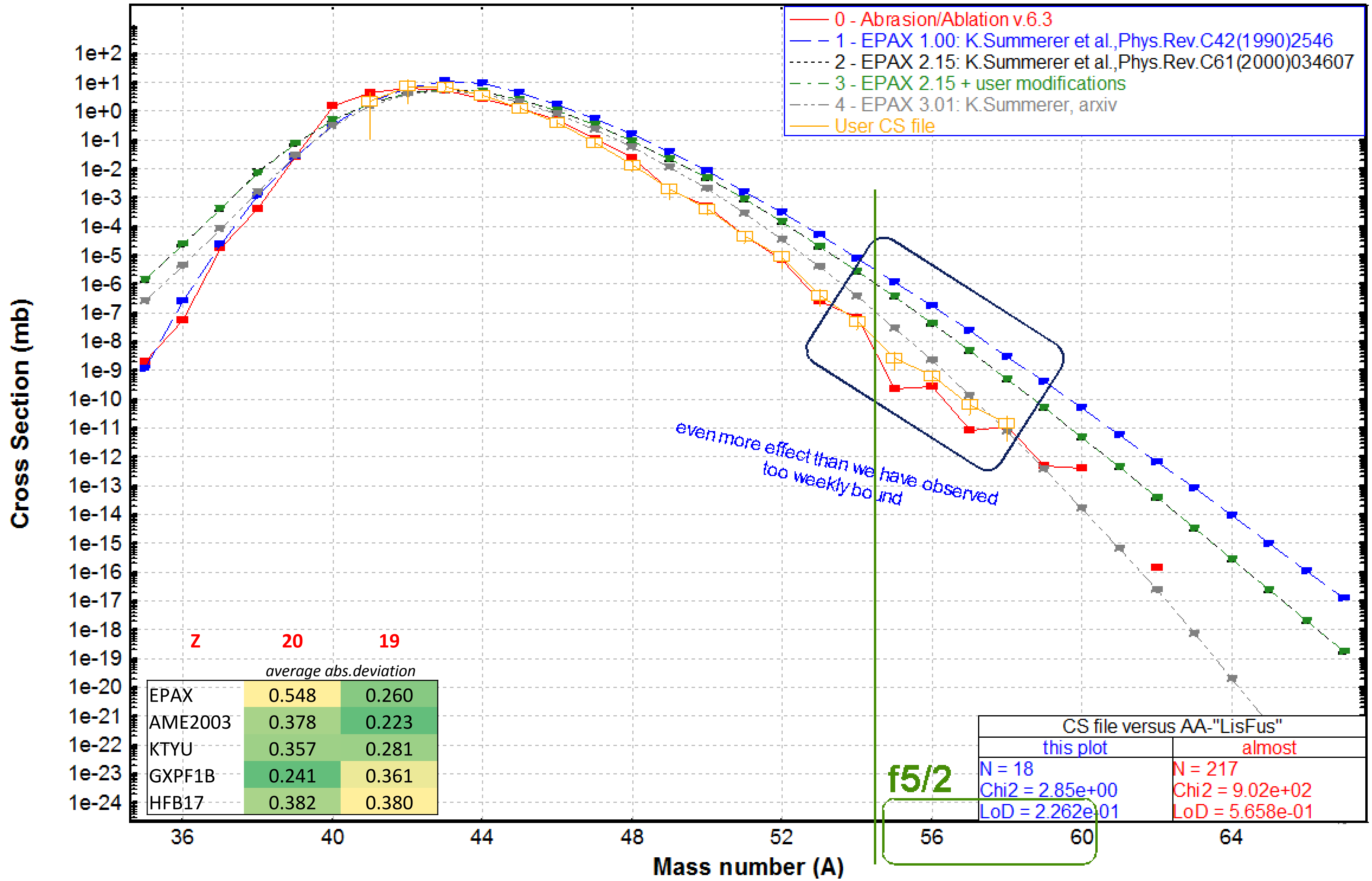
GXPF1B vs. AA : Z=20

Cross sections (Projectile Fragmentation)

^{82}Se + Be -> Z=20

Excit.Energy Method:< 2 >; <E*>:15.0*dA MeV Sigma:9.20; Coef^{Thermalization}=5.00e-22$^{MeV.s}$ DB$_1$="GXPF1A_d000"

NP=64; SE:"DB1+Cal0" Density:"auto" GeomCor:"On" TunIg:"auto" ^{Fis}Bar=#1 Bar^{Fac}=1.00 Modes=$^{1010\ 1010\ 010}$



Z	20	19
EPAX	0.548	0.260
AME2003	0.378	0.223
KTYU	0.357	0.281
GXPF1B	0.241	0.361
HFB17	0.382	0.380

this plot	almost
N = 18	N = 217
Chi2 = 2.85e+00	Chi2 = 9.02e+02
LoD = 2.262e-01	LoD = 5.658e-01

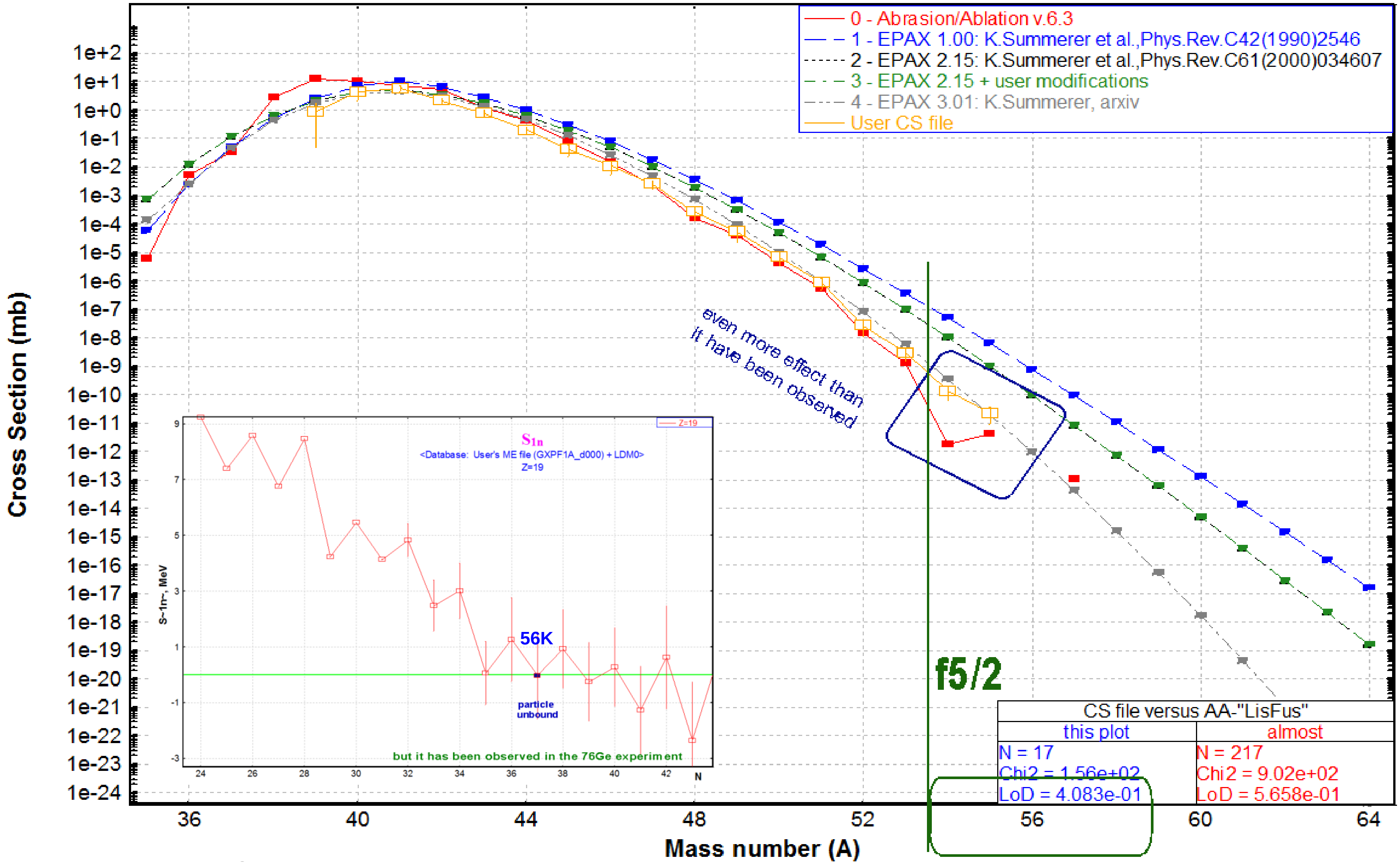
GXPF1B vs. AA : Z=19

Cross sections (Projectile Fragmentation)

^{82}Se + Be -> Z=19

Excit.Energy Method:< 2 >; <E*>:15.0*dA MeV Sigma:9.20; Coef^{Thermalization}=5.00e-22$^{MeV.s}$ DB$_1$="GXPF1A_d000"

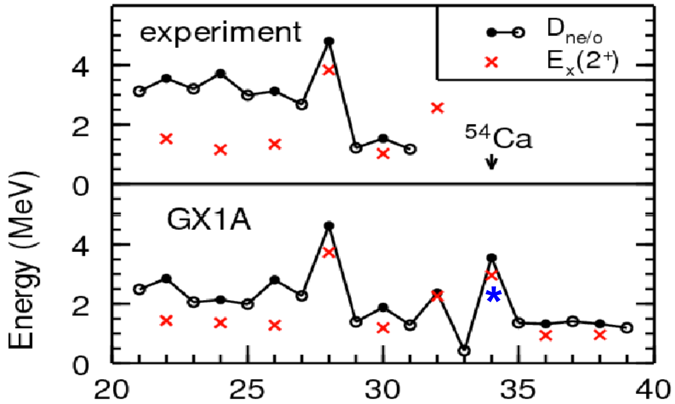
NP=64; SE:"DB1+Cal0" Density:"auto" GeomCor:"On" TunIg:"auto" ^{Fis}Bar=#1 Bar^{Fac}=1.00 Modes=$^{1010\ 1010\ 010}$



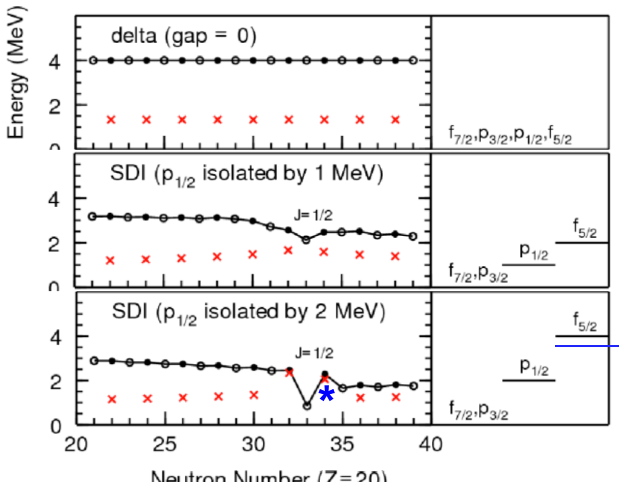
"GXPF1B5"

Alex Brown, ENSFN, October 11, 2012

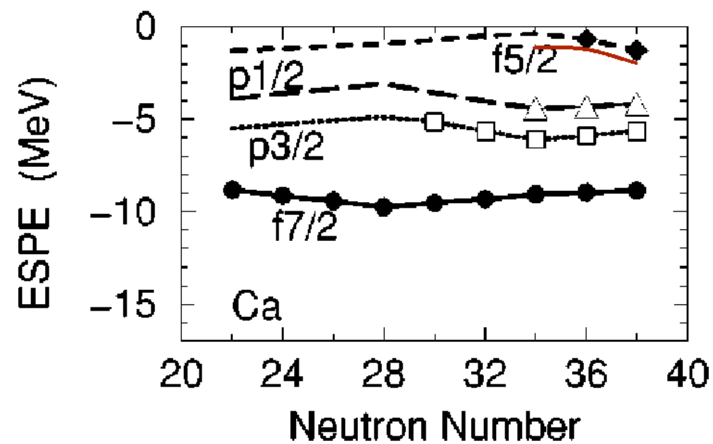
Pairing and Shell Gaps



$$D_n(N) = (-1)^N[S_n(Z,N+1) - S_n(Z,N)]$$



RIKEN Experiment: $E_x(2^+) \rightarrow$ 0.5 MeV below predictions



$^{55-60}$Ca are more particle bound then GXPF1B predicted

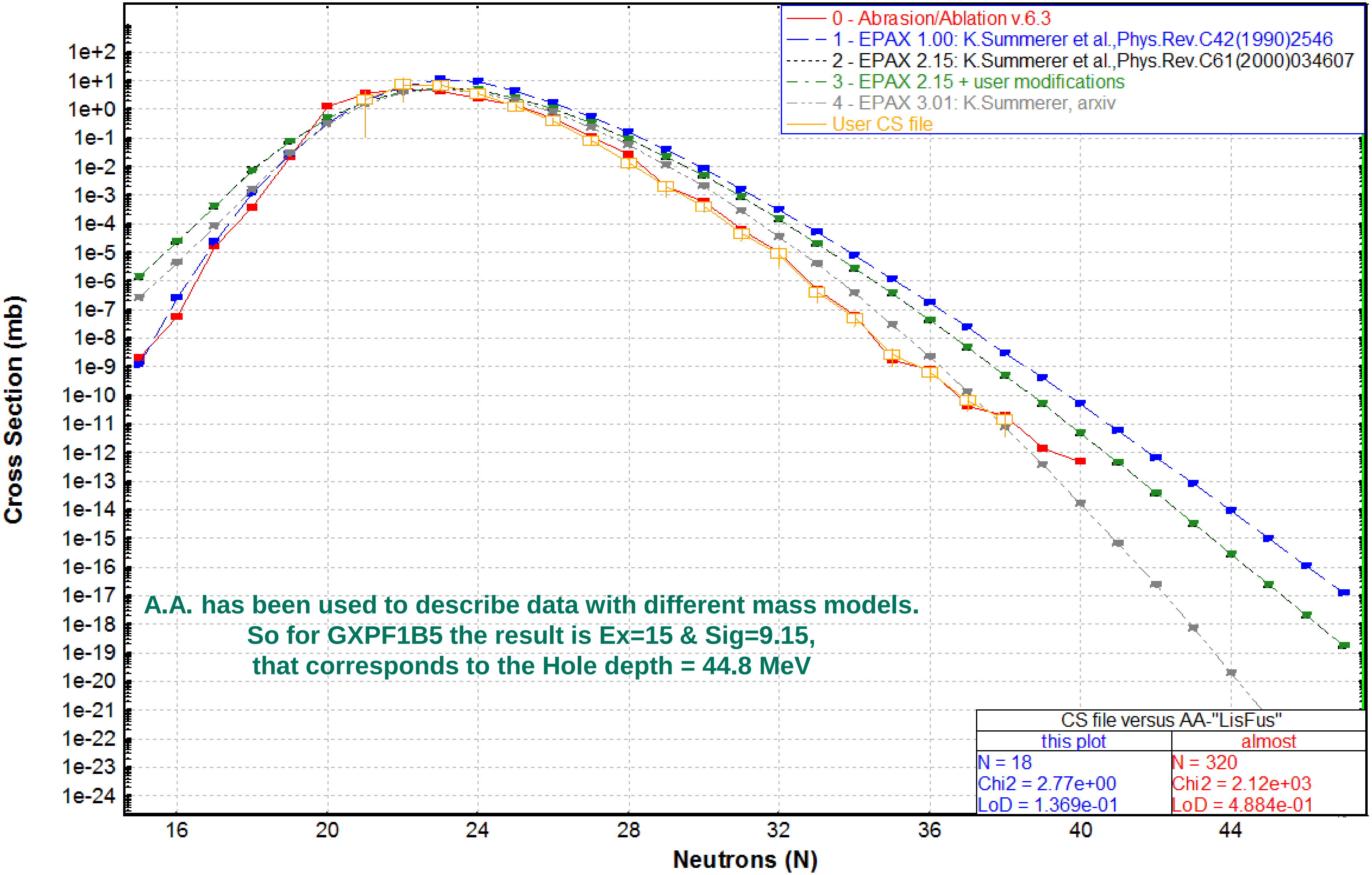
GXPF1B5 vs. AA : Z=20

Cross sections (Projectile Fragmentation)

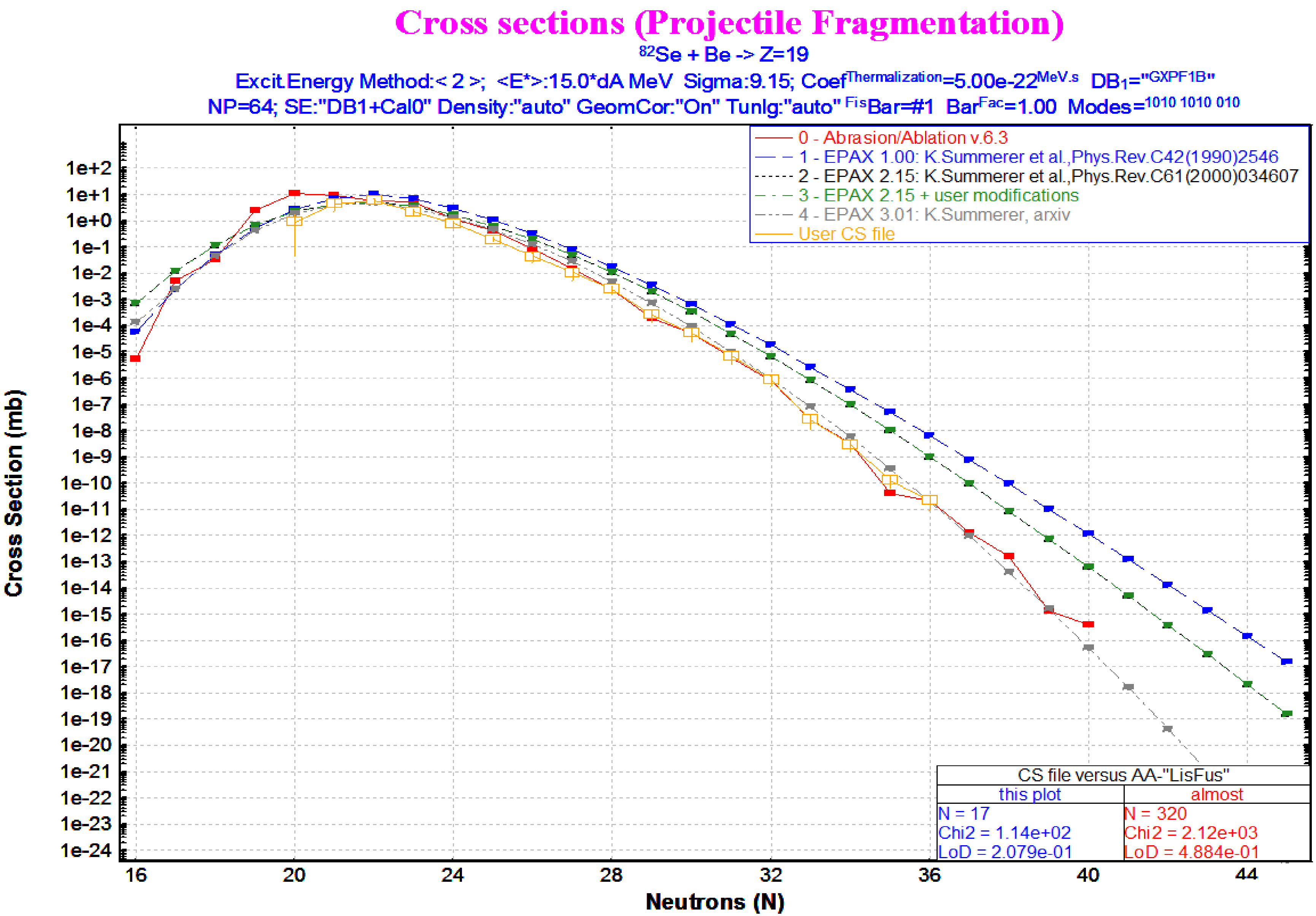
^{82}Se + Be -> Z=20

Excit.Energy Method:< 2 >; <E*>:15.0*dA MeV Sigma:9.15; Coef^{Thermalization}=5.00e-22$^{MeV.s}$ DB$_1$="GXPF1B"

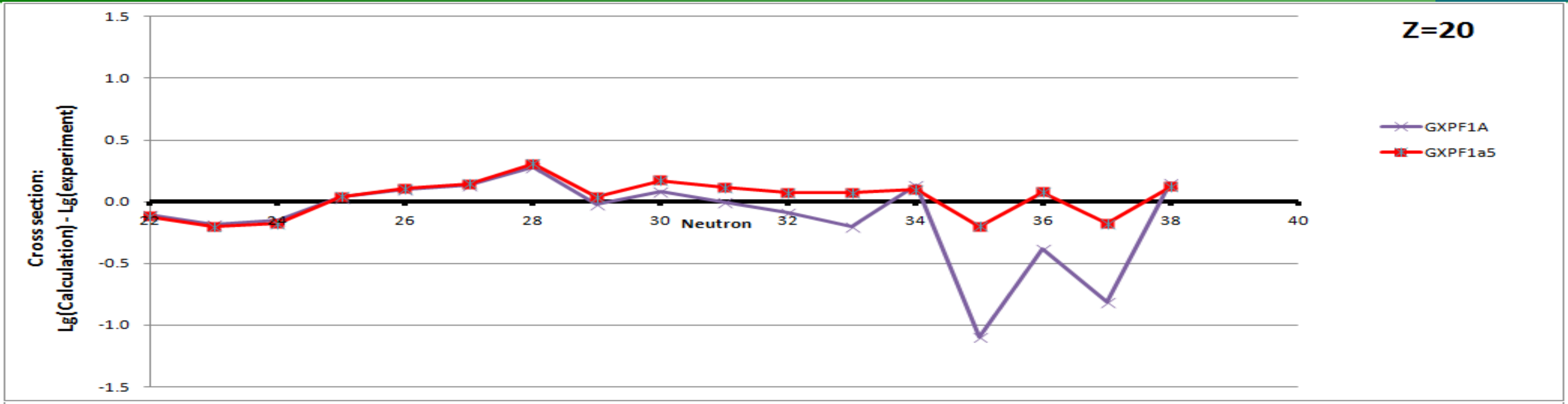
NP=64; SE:"DB1+Cal0" Density:"auto" GeomCor:"On" TunIg:"auto" ^{Fis}Bar=#1 Bar^{Fac}=1.00 Modes=$^{1010\ 1010\ 010}$

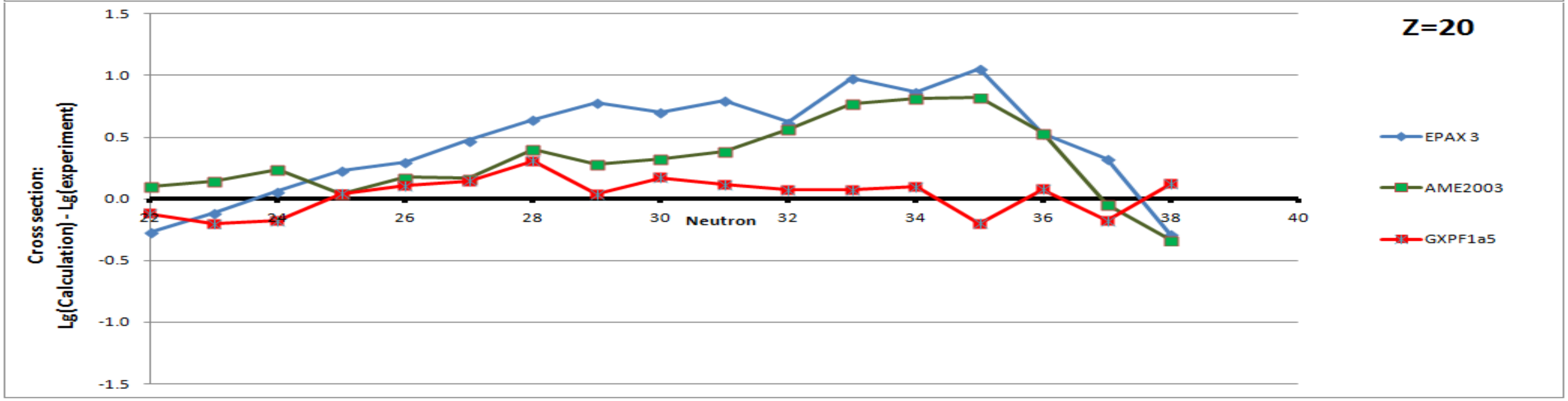


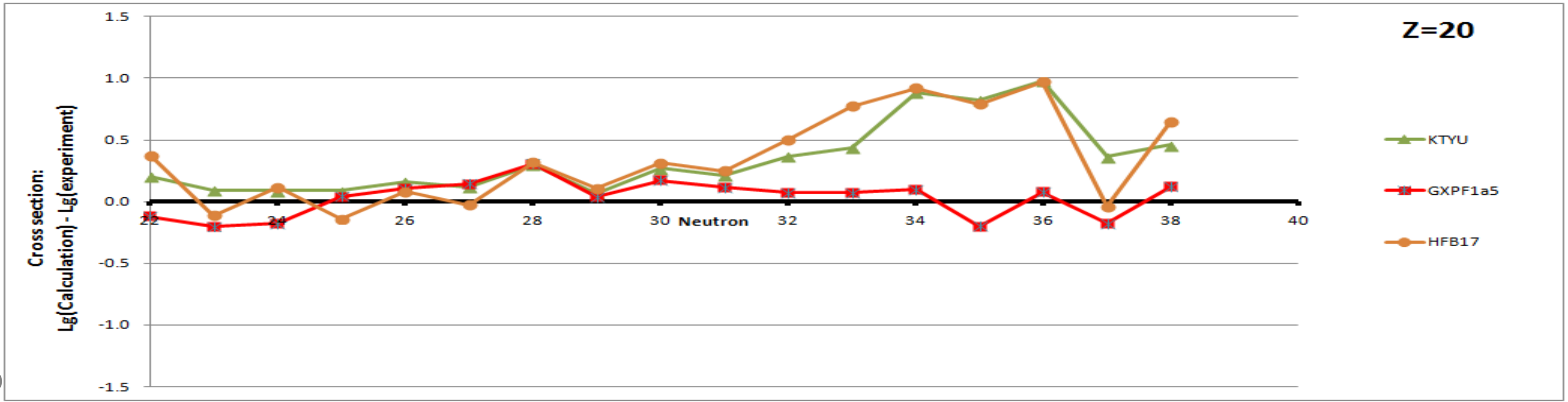
GXPF1B5 vs. AA : Z=19



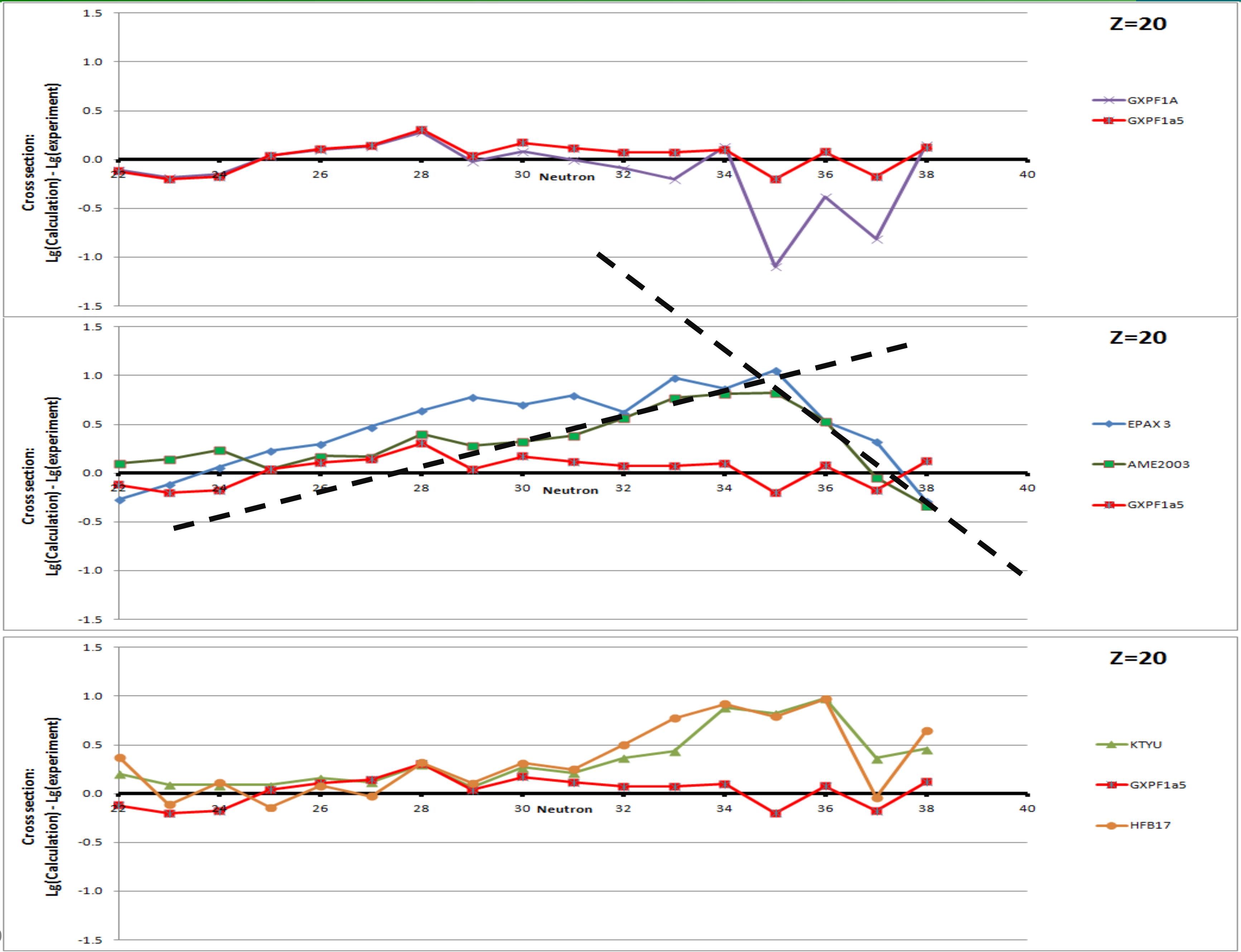
AA : Z=20


Z=20
Cross section:
Lg(Calculation) - Lg(experiment)
Neutron
GXPF1A
GXPF1a5

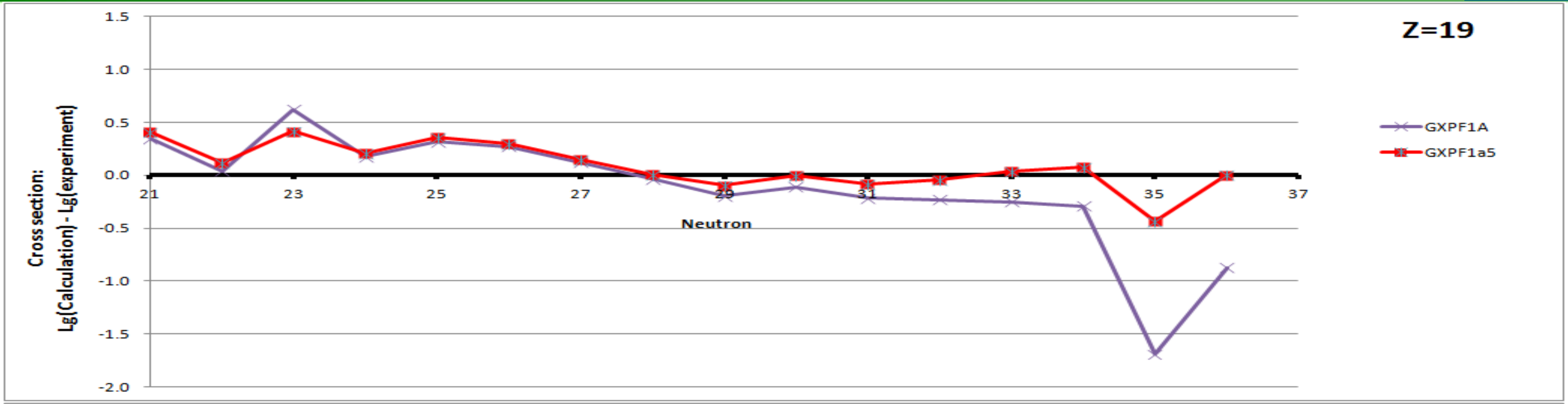

Z=20
Cross section:
Lg(Calculation) - Lg(experiment)
Neutron
EPAX 3
AME2003
GXPF1a5


Z=20
Cross section:
Lg(Calculation) - Lg(experiment)
Neutron
KTYU
GXPF1a5
HFB17

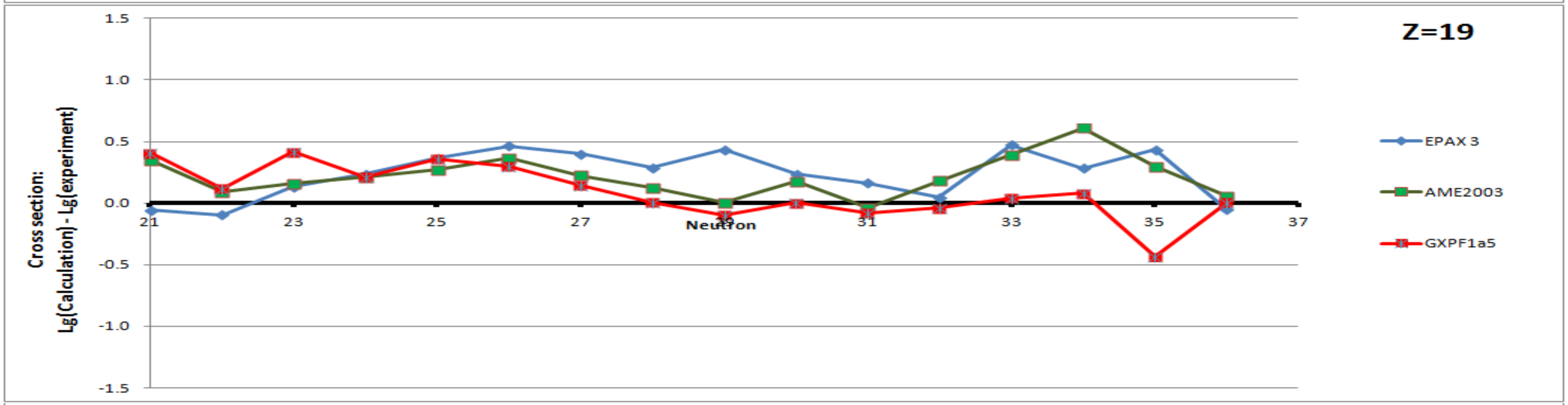
AA : Z=20 (with two lines for AME2003)



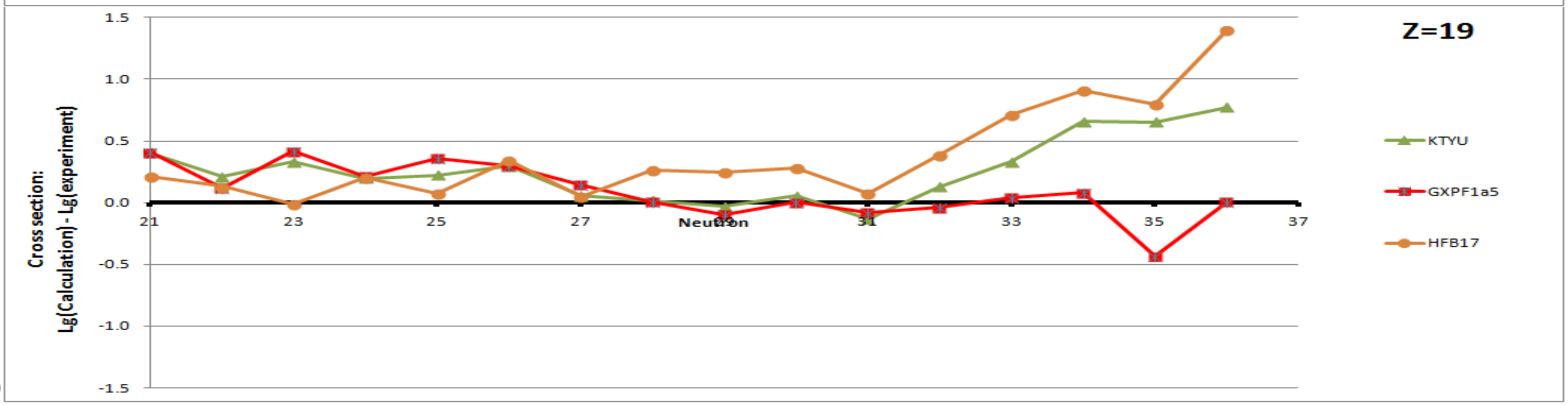
AA : Z=19



Z=19
Cross section:
Lg(Calculation) - Lg(experiment)
Neutron
GXPF1A
GXPF1a5

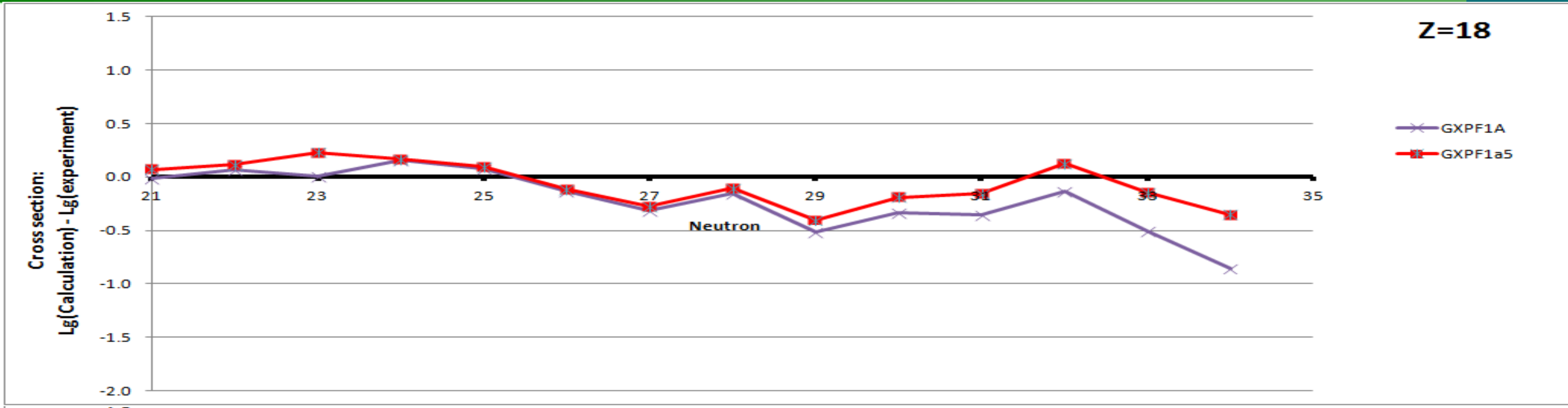


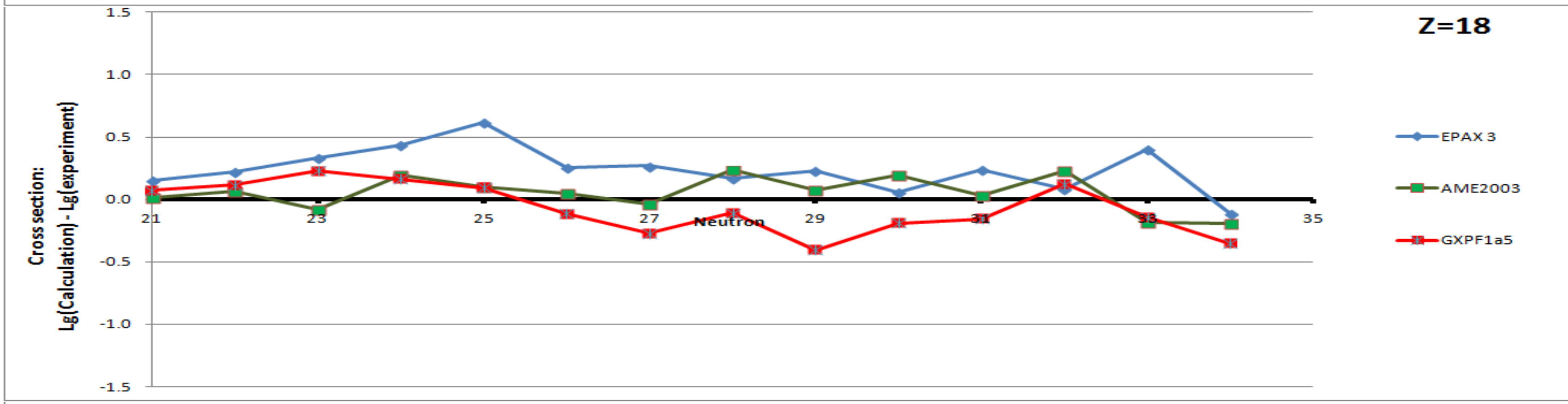
Z=19
Cross section:
Lg(Calculation) - Lg(experiment)
Neutron
EPAX 3
AME2003
GXPF1a5

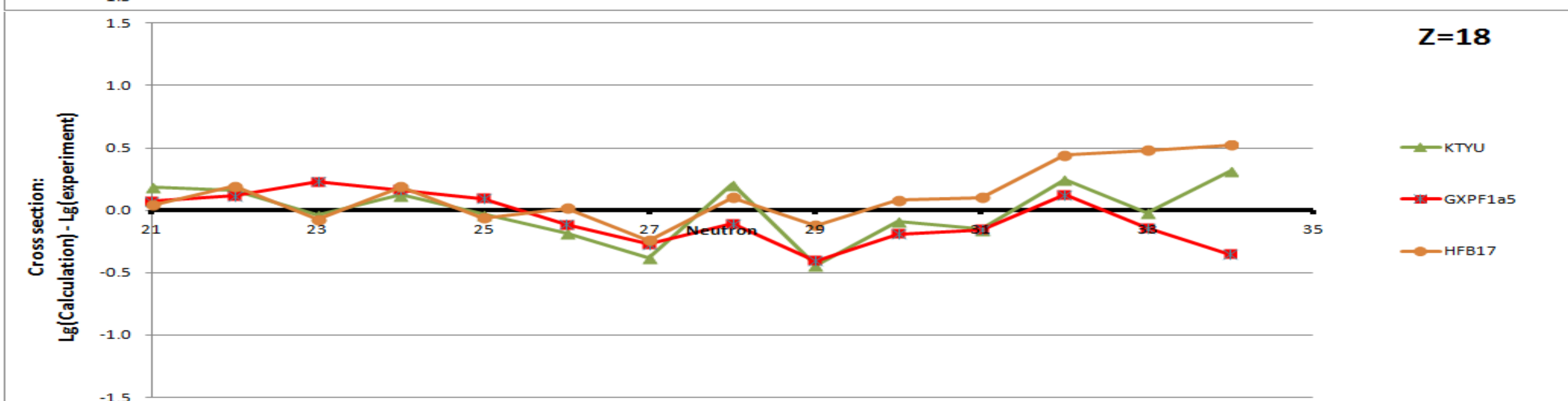


Z=19
Cross section:
Lg(Calculation) - Lg(experiment)
Neutron
KTYU
GXPF1a5
HFB17

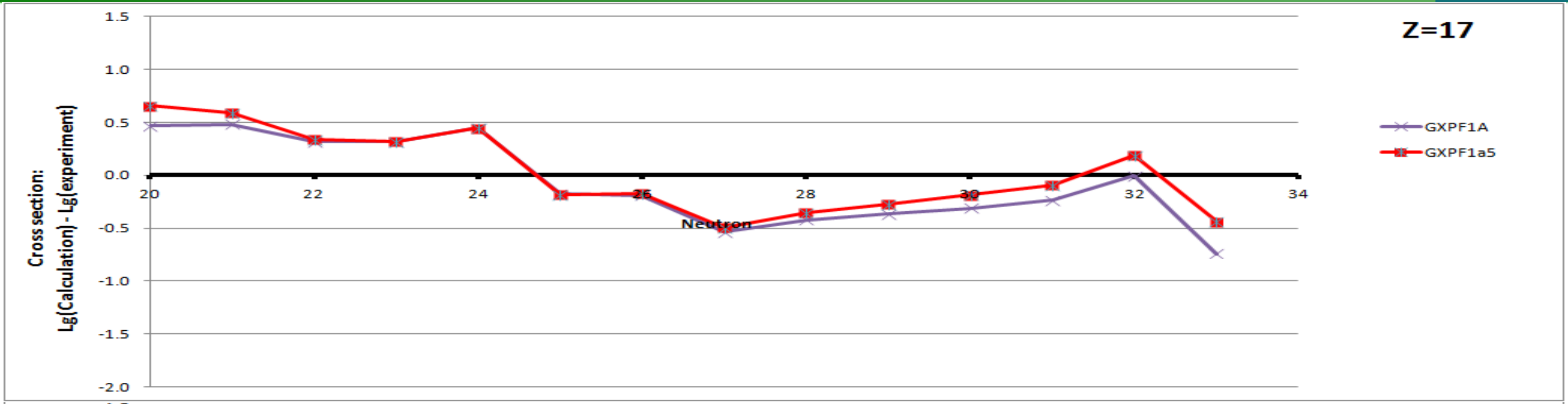
AA : Z=18

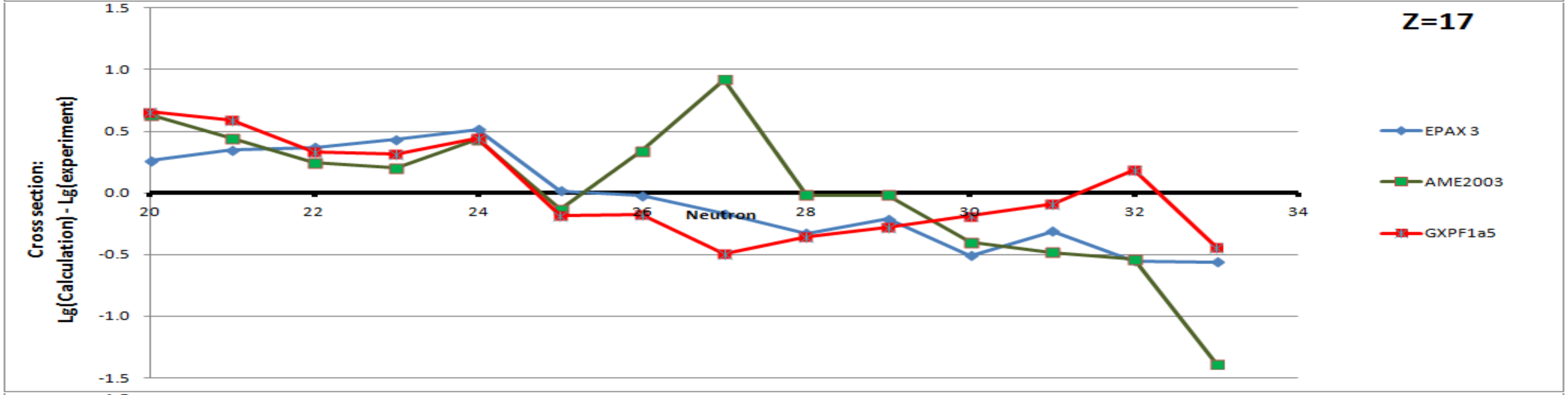

Z=18
Cross section:
Lg(Calculation) - Lg(experiment)
Neutron
GXPF1A
GXPF1a5

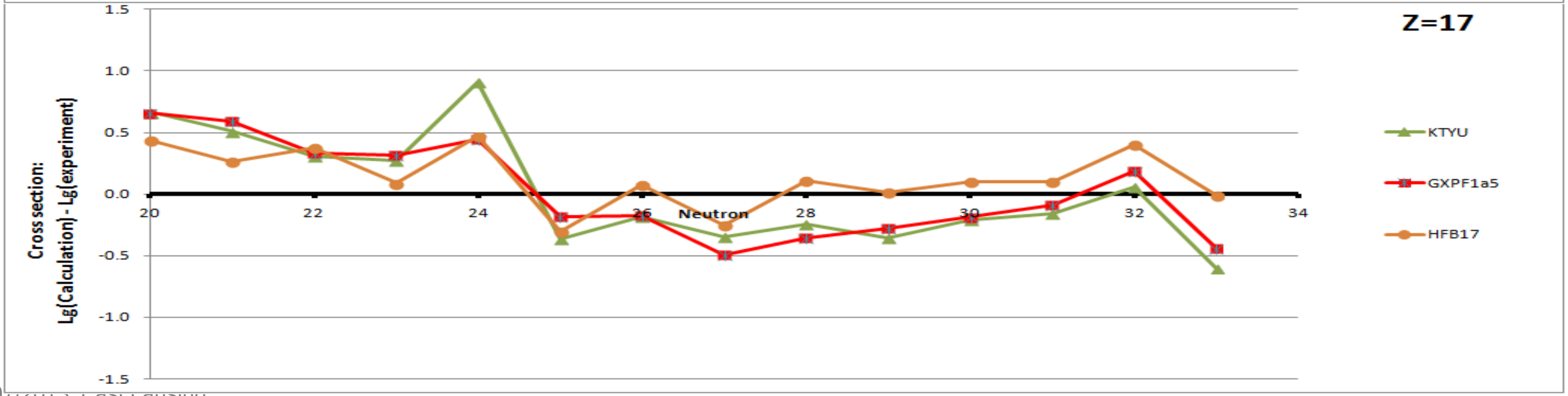

Z=18
Cross section:
Lg(Calculation) - Lg(experiment)
Neutron
EPAX 3
AME2003
GXPF1a5


Z=18
Cross section:
Lg(Calculation) - Lg(experiment)
Neutron
KTYU
GXPF1a5
HFB17

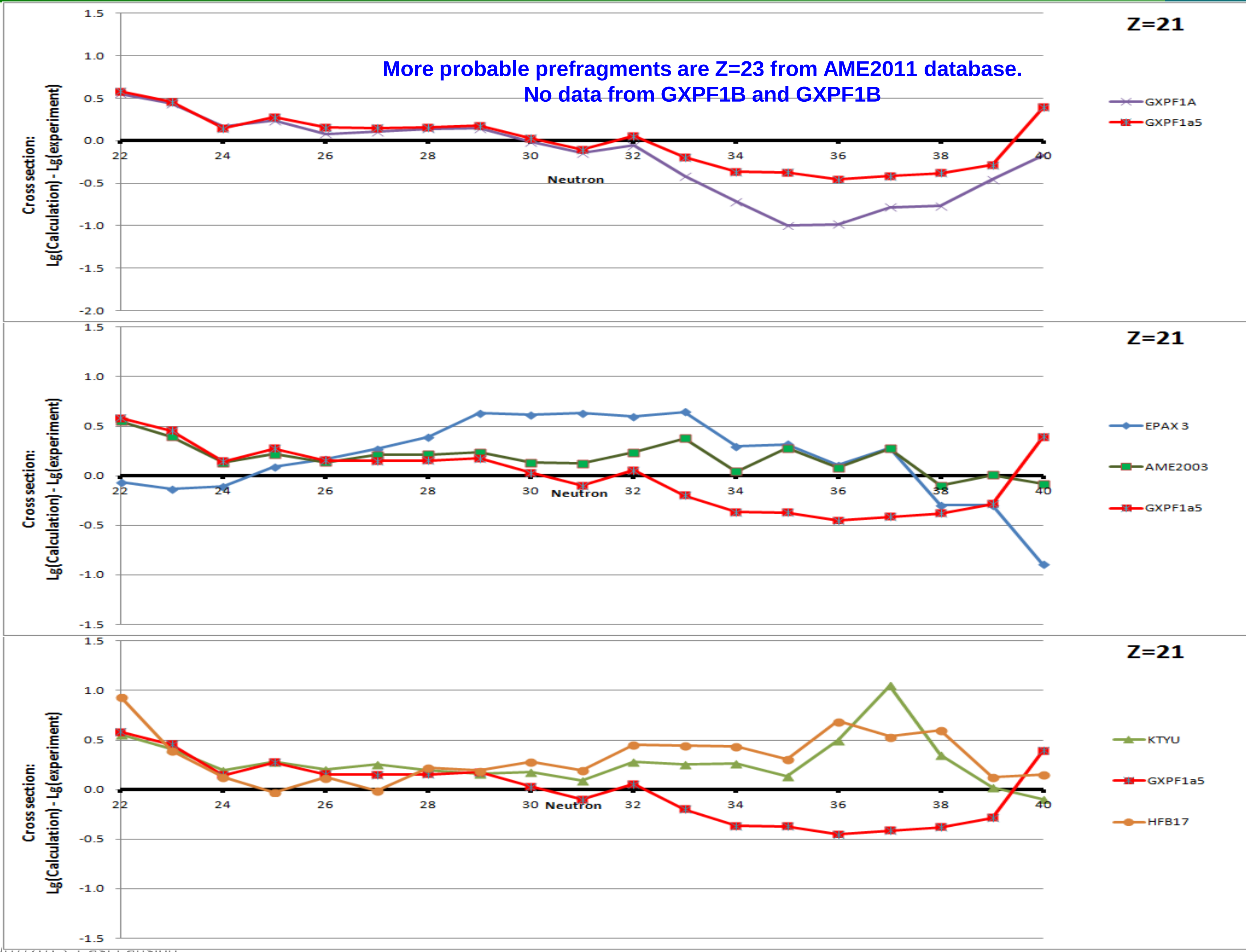
AA : Z=17


Z=17
Cross section:
Lg(Calculation) - Lg(experiment)
Neutron
GXPF1A
GXPF1a5

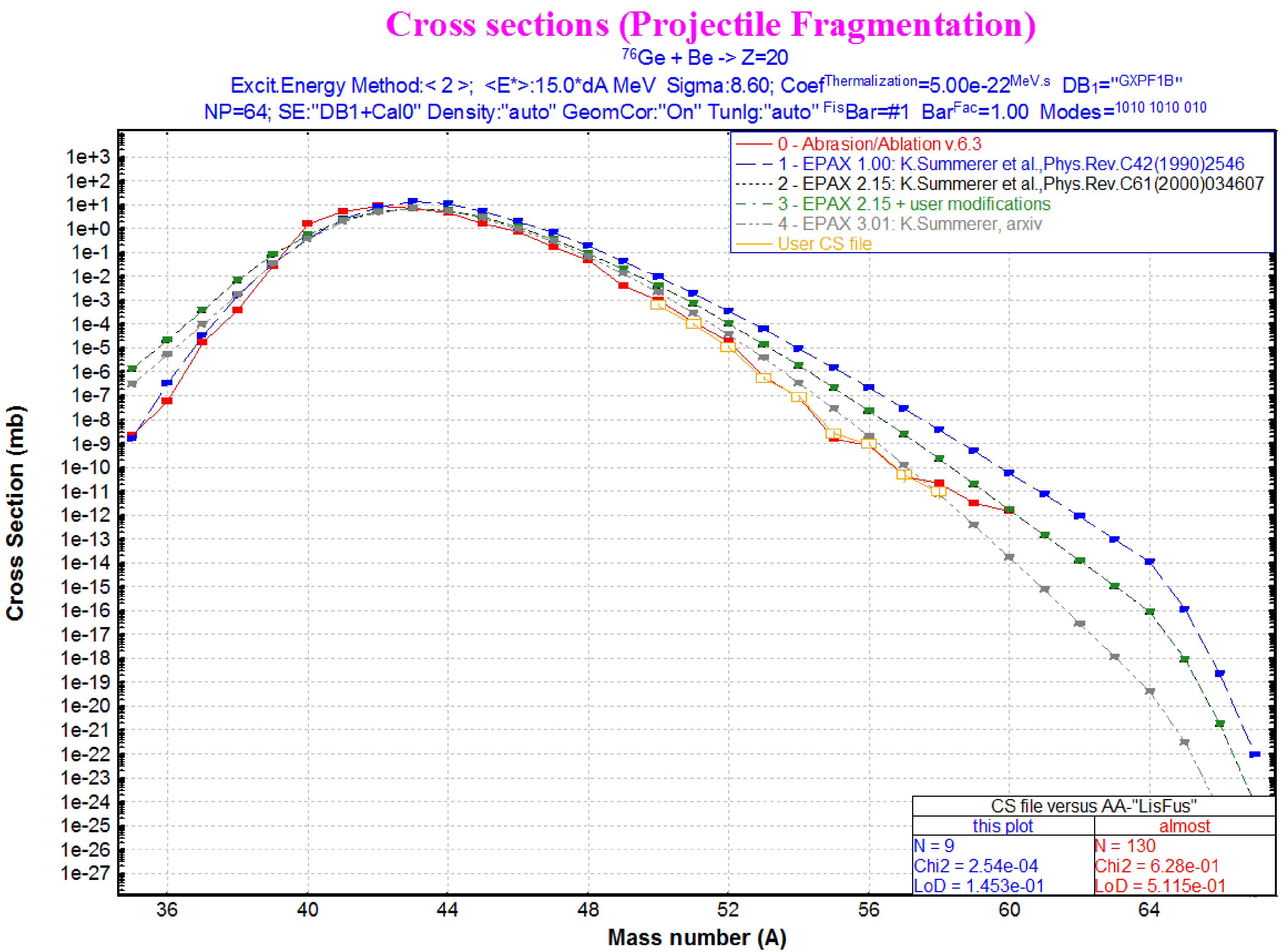

Z=17
Cross section:
Lg(Calculation) - Lg(experiment)
Neutron
EPAX 3
AME2003
GXPF1a5


Z=17
Cross section:
Lg(Calculation) - Lg(experiment)
Neutron
KTYU
GXPF1a5
HFB17

AA : Z=21


Z=21
More probable prefragments are Z=23 from AME2011 database.
No data from GXPF1B and GXPF1B
Cross section:
Lg(Calculation) - Lg(experiment)
Neutron
GXPF1A
GXPF1a5
Z=21
Cross section:
Lg(Calculation) - Lg(experiment)
Neutron
EPAX 3
AME2003
GXPF1a5
Z=21
Cross section:
Lg(Calculation) - Lg(experiment)
Neutron
KTYU
GXPF1a5
HFB17

Abrasion-Ablation vs. GXPF1B5 for the ^{76}Ge experiment



Abrasion-Ablation vs. GXPF1B5 for the ^{76}Ge experiment