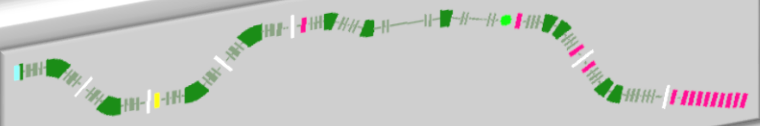
Oleg B. Tarasov
NCSL / MSU, USA

LISE^{++} development, Production mechanism, PID

Expert Fragment-Separator Meeting

October 2, 2019



LISE++

LISE++

1. Version 12
2. Development review
3. Abrasion-Fission
4. Abrasion-Ablation
5. ^{198}Pt beam: fragment-separator + spectrometer
6. PID: Cleaning from charge states
7. ~~Production of super neutron-rich Ca isotopes~~
8. Summary

LISE^{++} version 12

Will be released soon!
(October 2019)

Number of versions

Correction	fixed buges	37
Development	new	94
Modification	no changes in output results	54
Update	Revision, Improvement	56
total		241

- Last three years – a lot of experimental activity, data analysis
- Main part of LISE^{++} modifications related with development and improvement of LISE++ reactions models

- High-Z Abrasion-Fission production cross sections
- Initial Fissile Nuclei (IFN) Analyzer
- Plotting and passing two fission fragments simultaneously
  - Two Fission Fragments registration efficiency BATCH
- Abrasion-Ablation minimization to describe user cross-sections
- Momentum distribution: Universal parameterization
  - Projectile Isospin and Velocity fragment
- Fragment deformation at the Scission point
- New configurations: **ARIS**, AIRIS, **ISLA**, **HRS**…
- FRIB rates v 1.08
- “Loading A1900 settings” utility
- Mass tables in LISE^{++}
- Production of super neutron-rich Ca isotopes

Let’s rock-n-roll! (152 slides) No… ☺ Less

The main point to mention new features to find it later in documentation

Still pending… Sorry

2017
100% dialogs been ported to Qt
100% Mathematics and physics
10% dialogs been connected
no graphics…

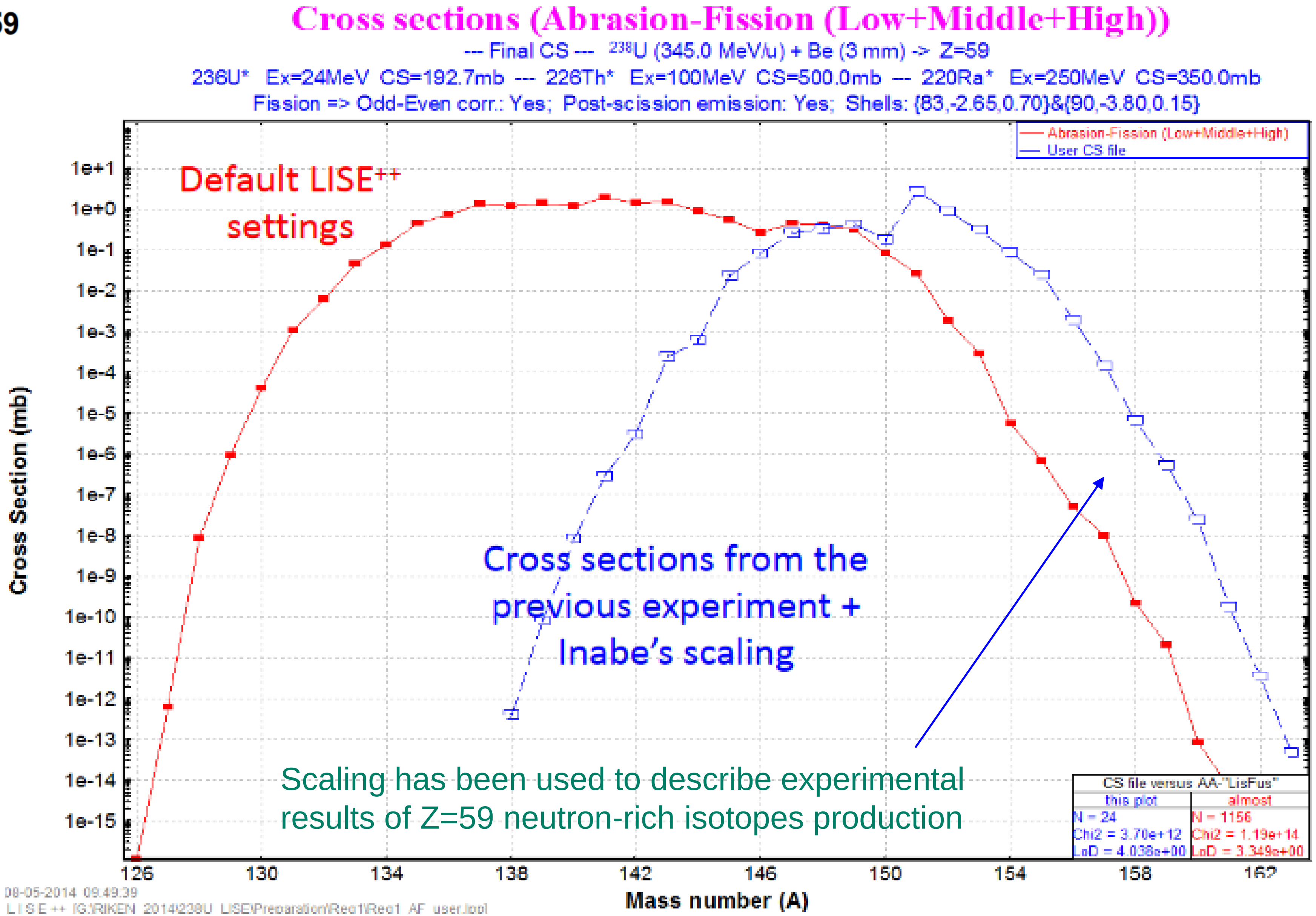
- LISE^{++} porting to a modern framework
- ATIMA 1.4 -- time is needed to convert from C++11
- LISE for Excel -- MS “support”, LISE^{++} porting to 64-bit
- ETACHA4 -- Still stiffness problem
- Range Optimizer at high energies ------------ It required some time…

Looking for more people to overcome it!

High-Z Abrasion-Fission production cross sections

High-Z Abrasion-Fission production cross sections

Cross sections Z=59

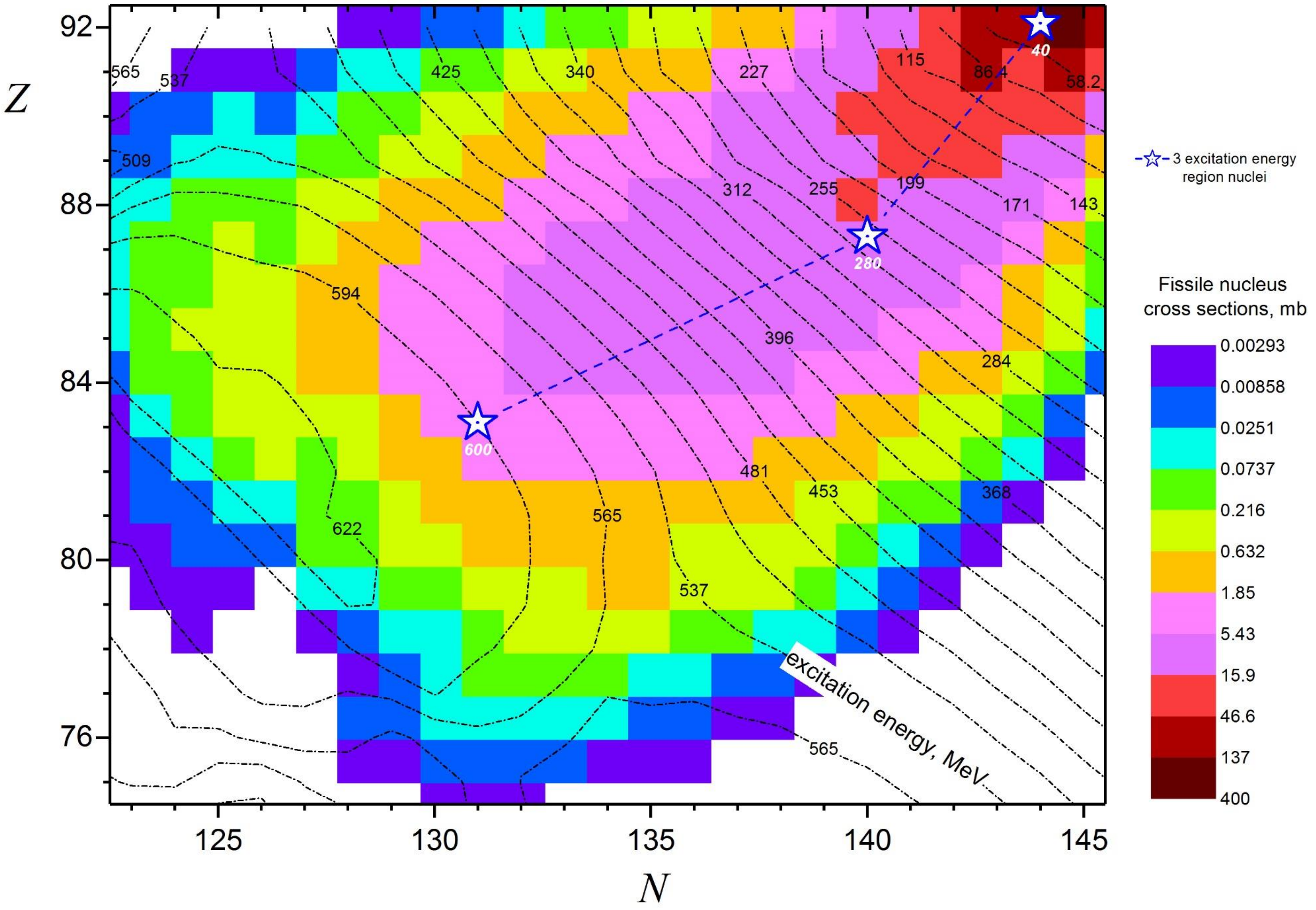


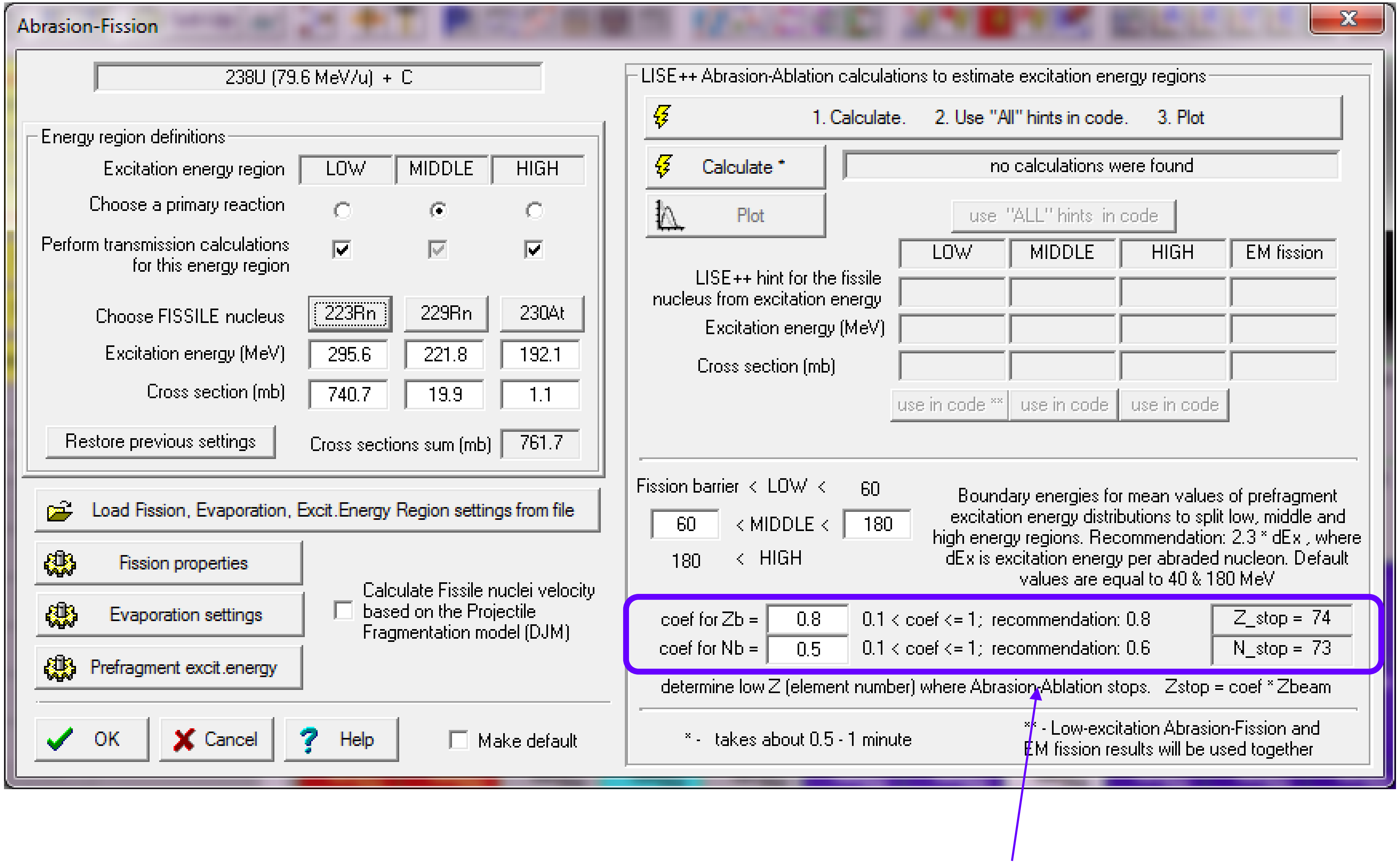
Scaling has been used to describe experimental results of Z=59 neutron-rich isotopes production

LISE++ Abrasion-Fission 3EER model

1. Fast Analytical model

2. Averaging → substitution of more than 1000 fissile nuclei by **3** nucleus





The user can specify the fissile nuclei region in the new version

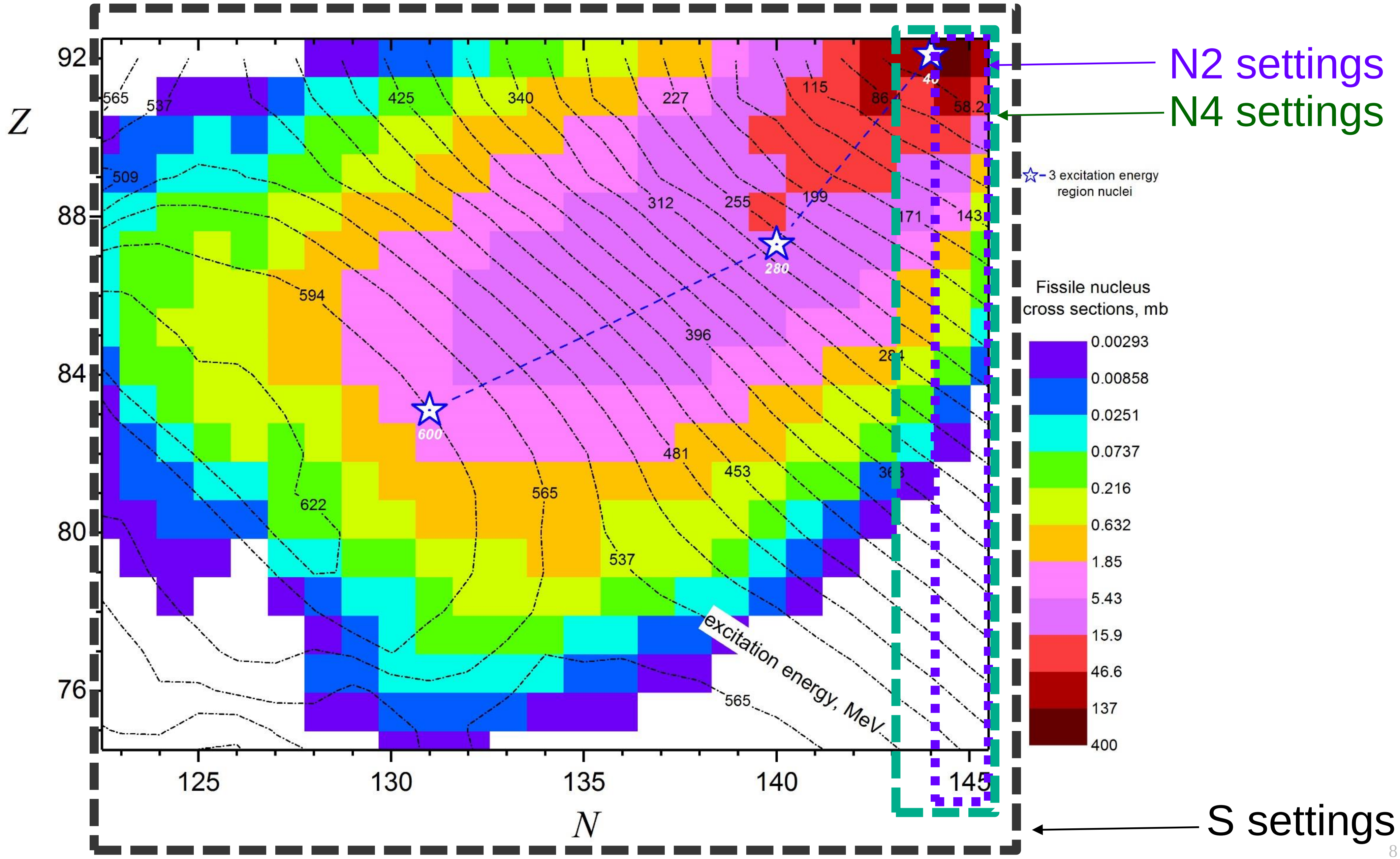
Let's consider 3 different rectangle areas : S, N2, N4

Where

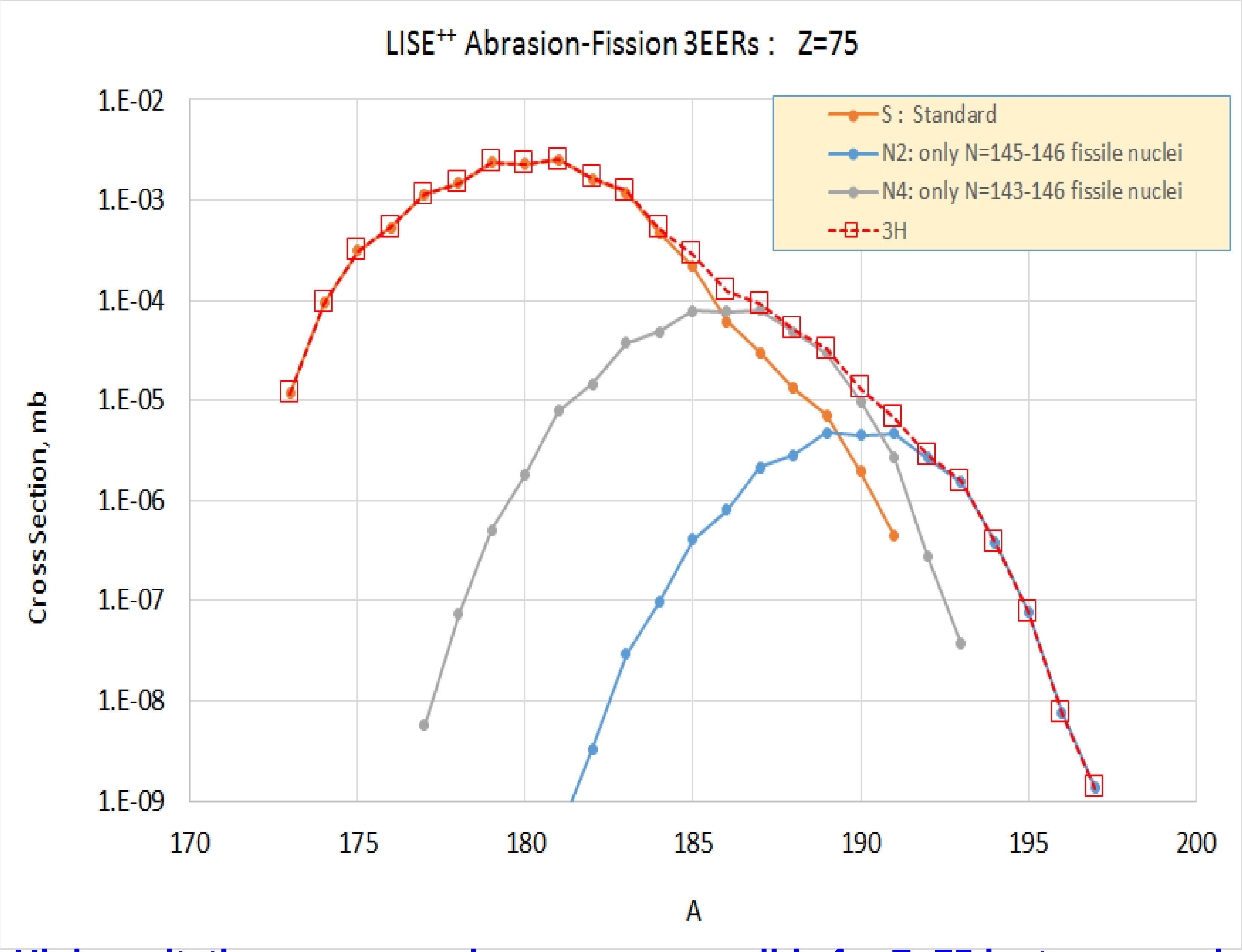
S : standard

N2 : not more than 2 abraded neutrons

N4 : not more than 4 abraded neutrons



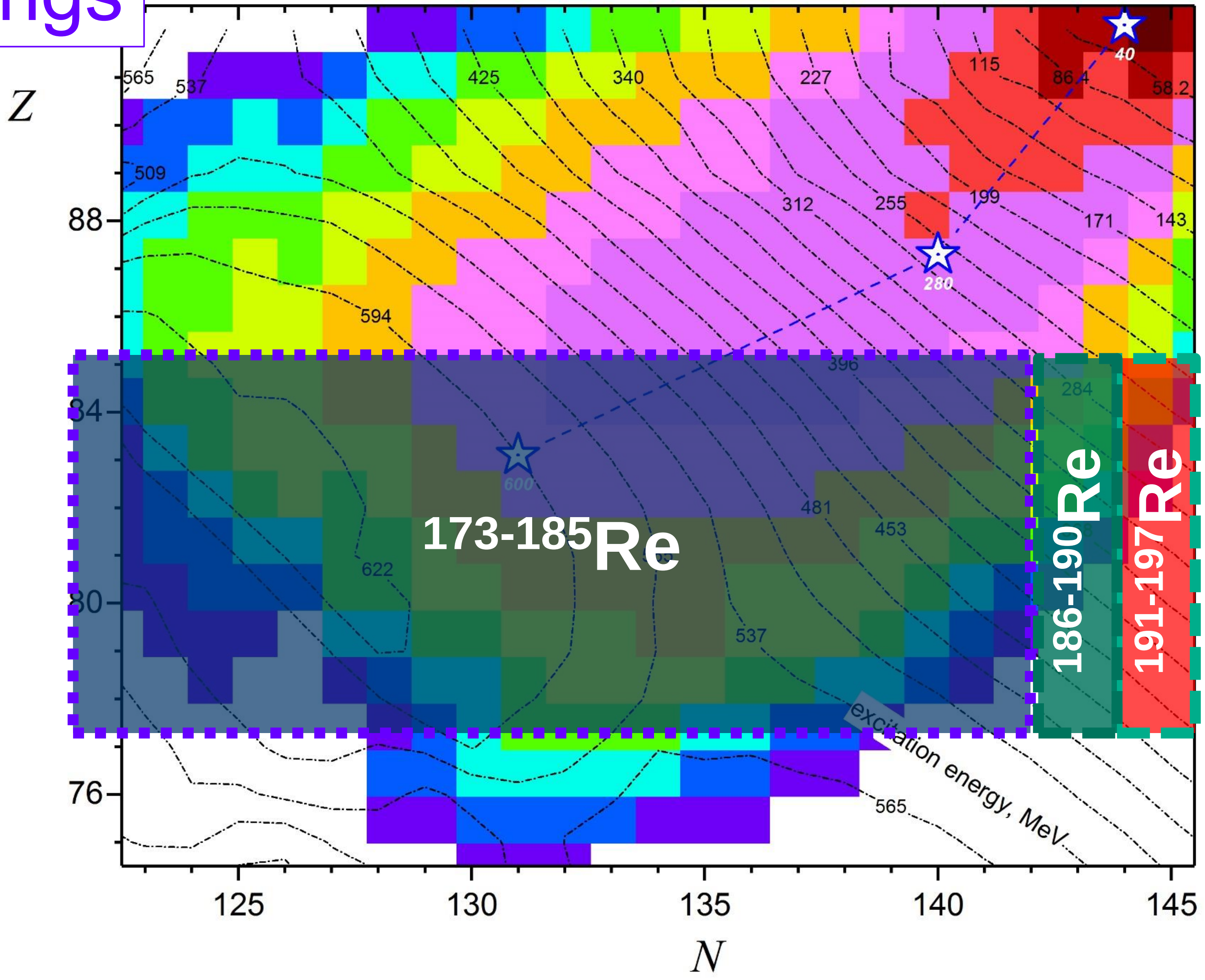
“3H“ settings for Z=75



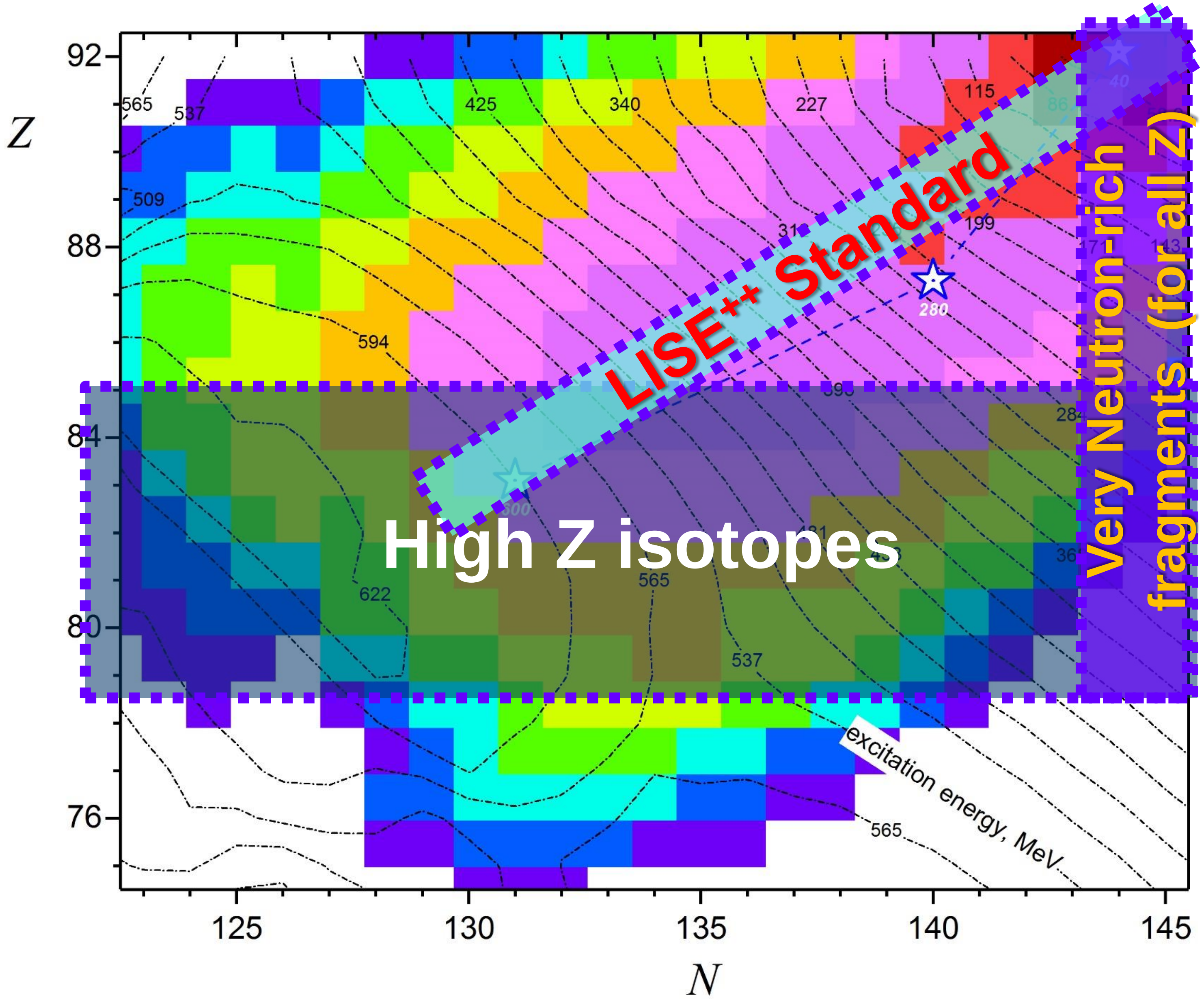
High excitation energy regions are responsible for Z=75 isotopes production!

Fissile nuclei topology for Z=75 isotopes production

"3H" settings



Fissile nuclei topology



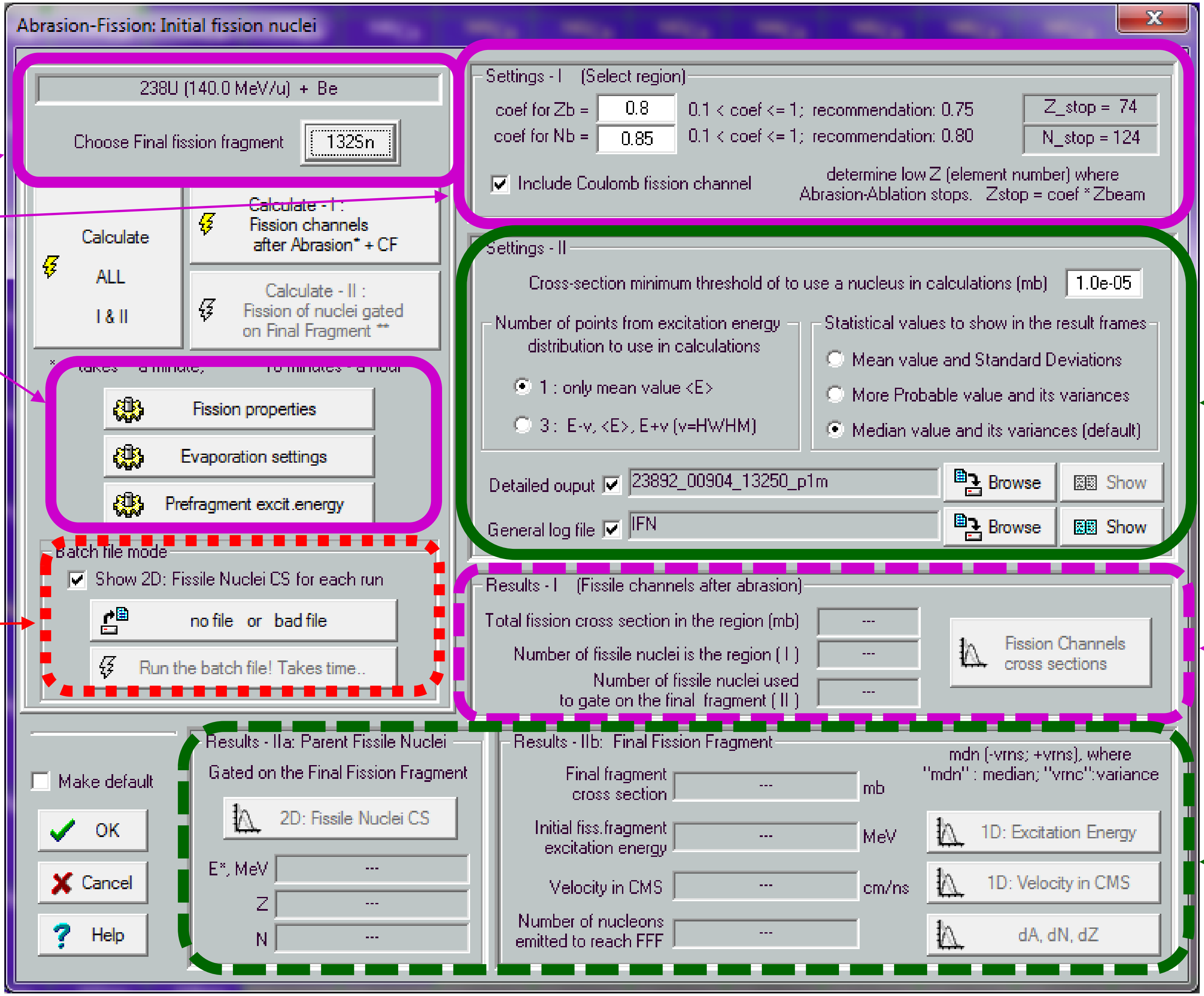
Only special high excitation energy region settings should be used for high Z isotopes production!

Initial Fissile Nuclei (IFN) Analyzer

Initial Fissile Nuclei (IFN) dialog

1st step settings

Batch mode settings and run



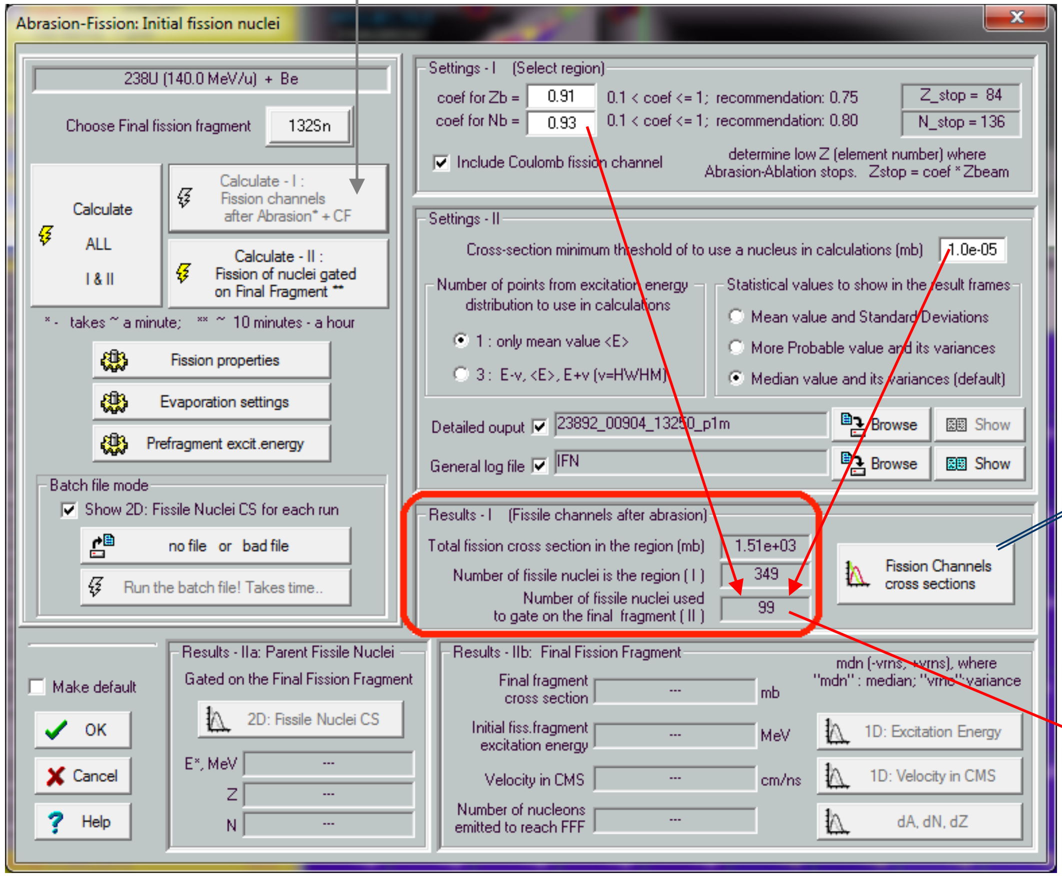
2nd step settings

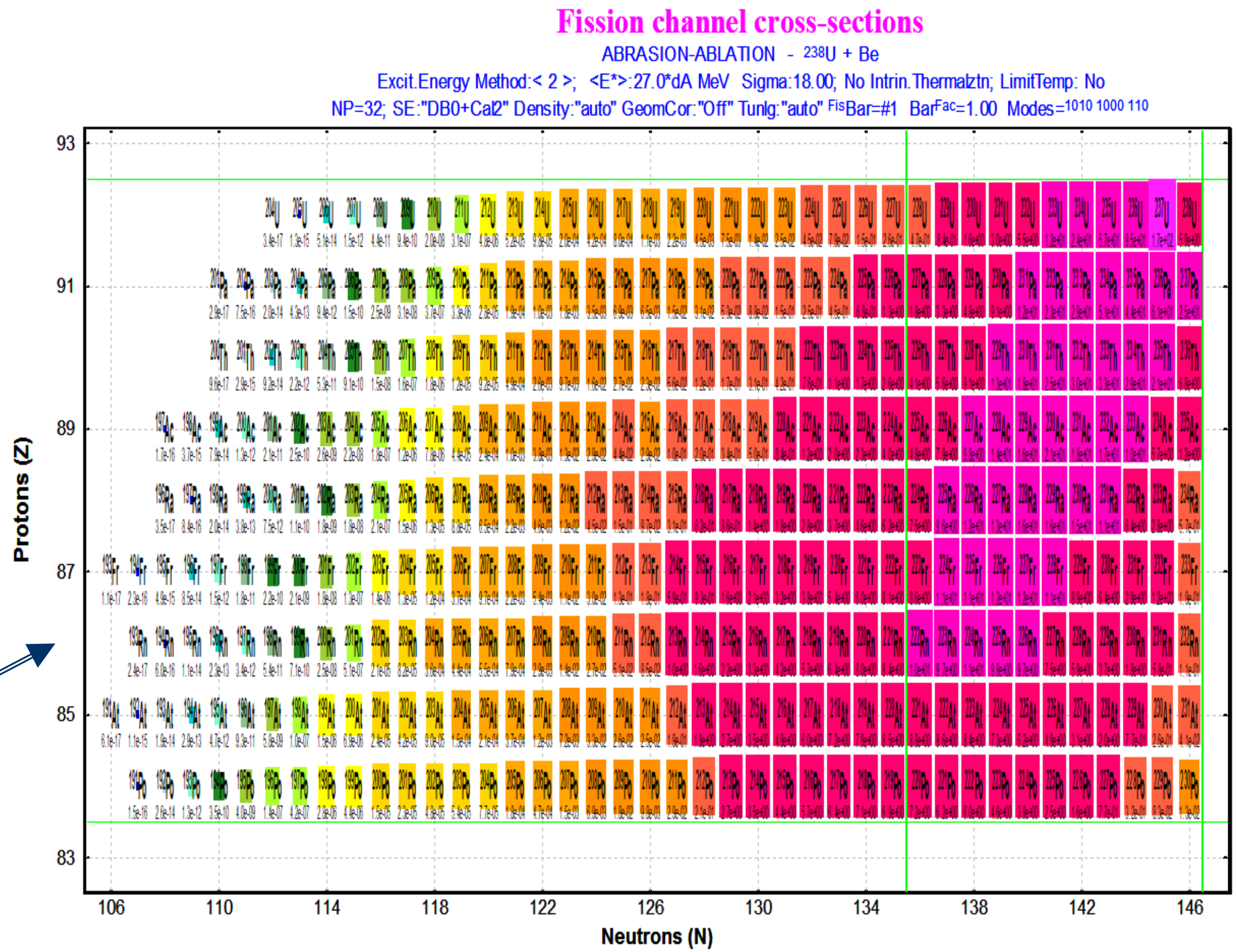
1st step results

2nd step results

1st step calculation results

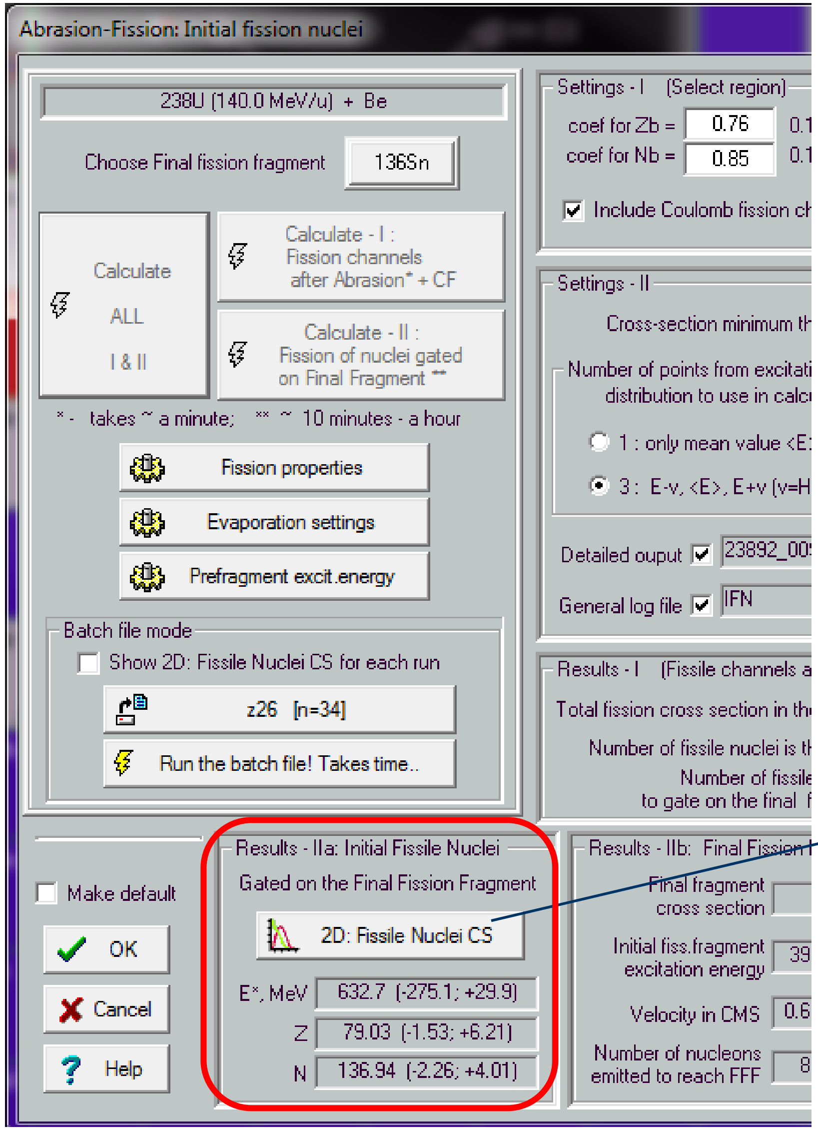
Not enable (gray color)



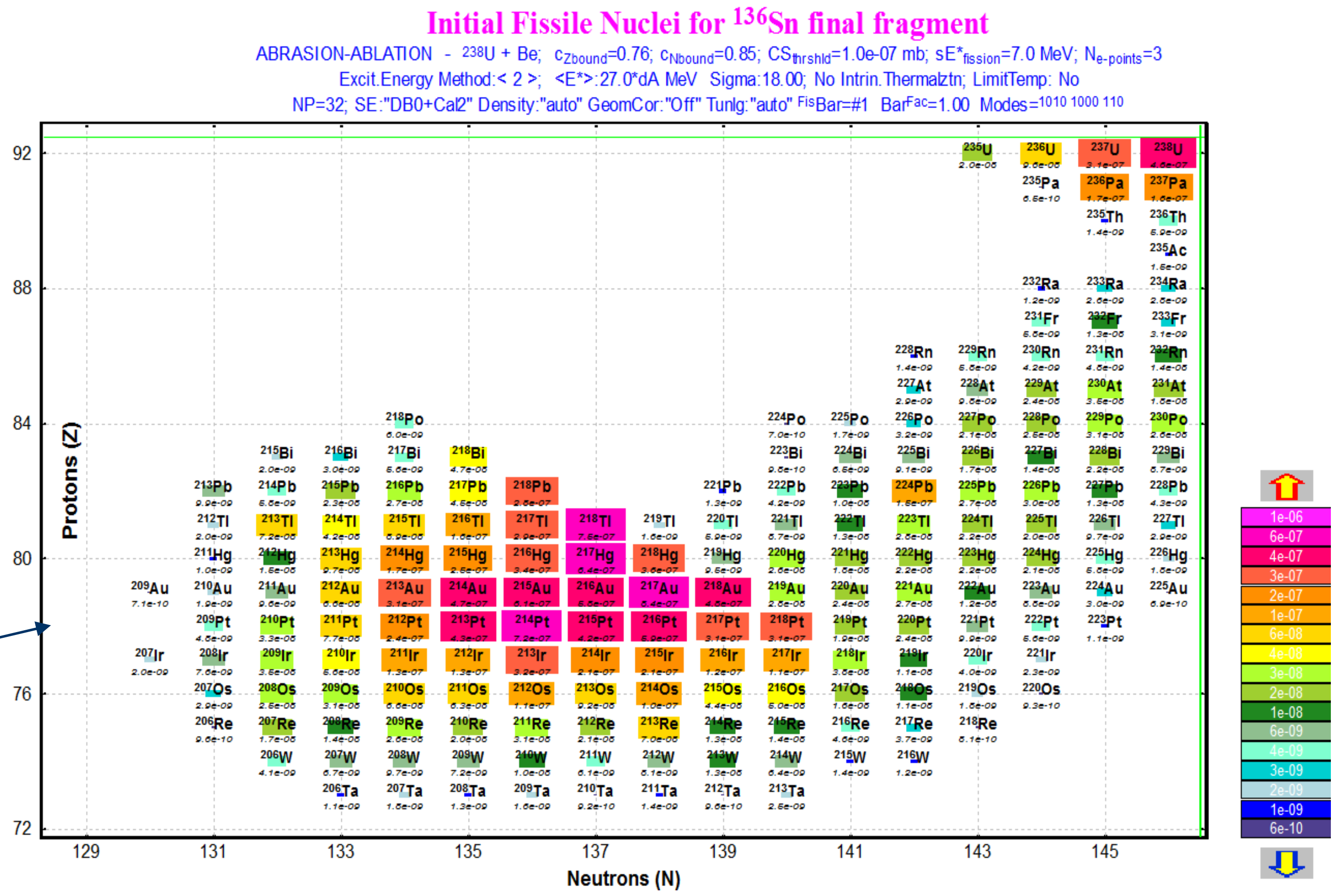


99 isotopes will be used for the 2nd step calculations gated by the selected region (Z_stop, N_stop) and the cross-section threshold value (2nd step settings) from 349 isotopes calculated at Step #1.

2nd step calculation results: Initial Fissile Nuclei (IFN) gated to the selected Final Fission Fragment (FFF) - b

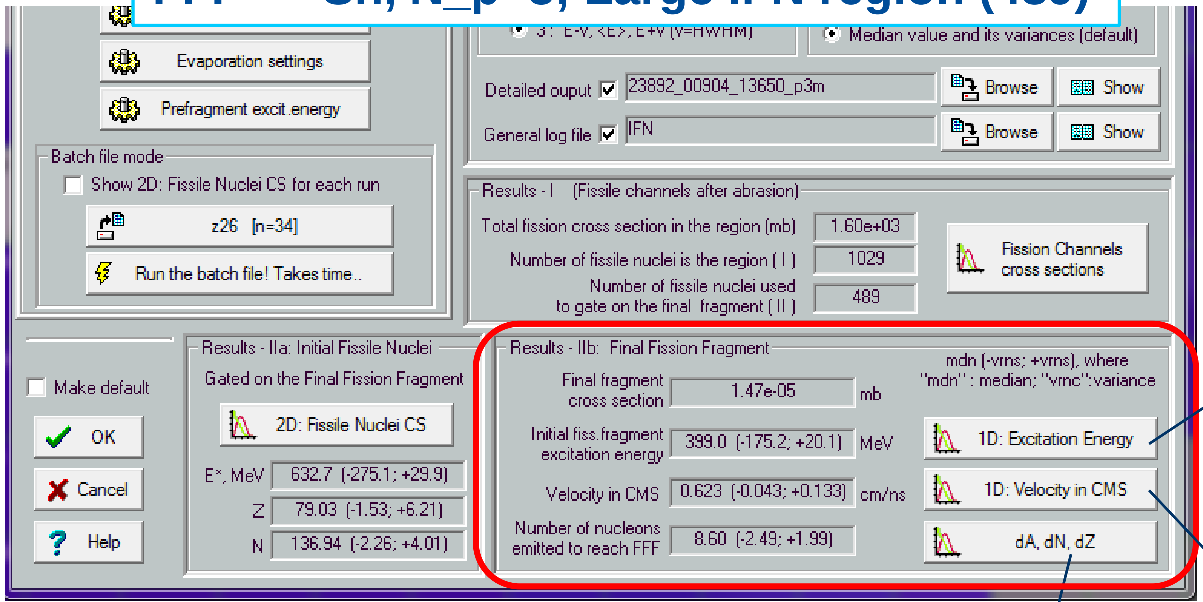


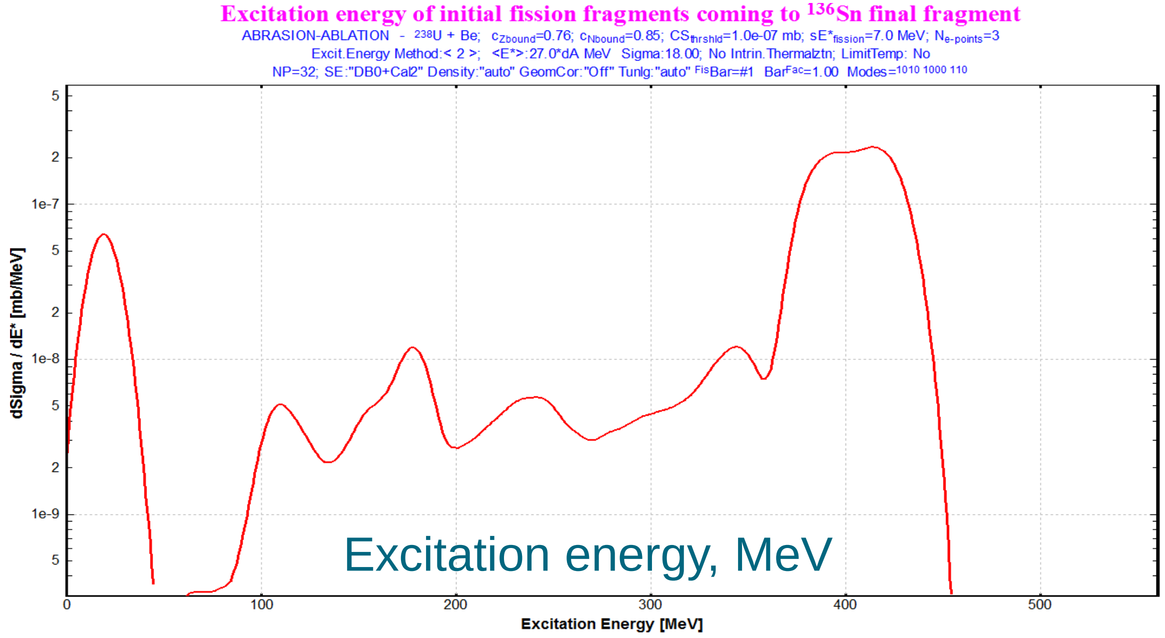
FFF=^{136}Sn, N_p=3; Large IFN region (489)

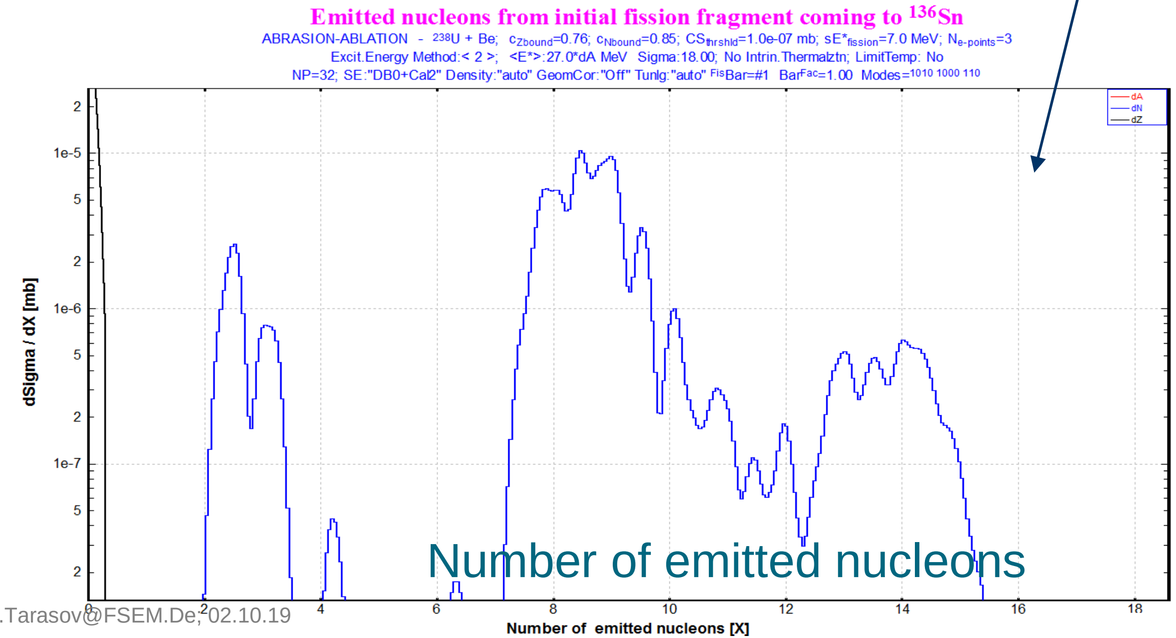


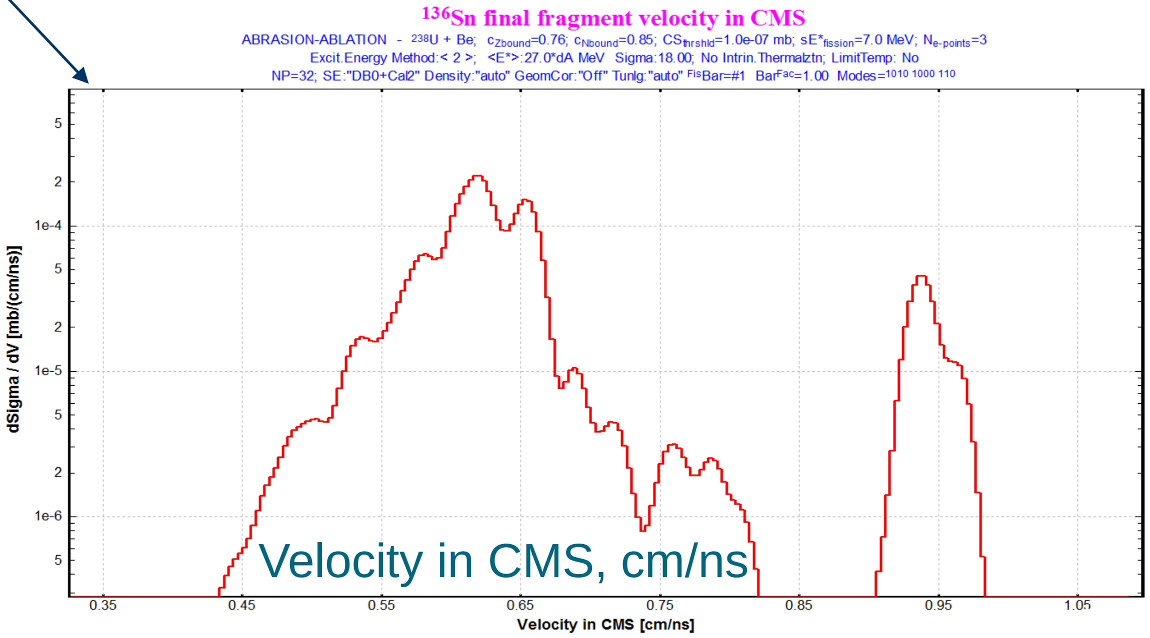
2^{nd} step calculation results: Final Fission Fragment (FFF)

FFF=^{136}Sn, N_p=3; Large IFN region (489)

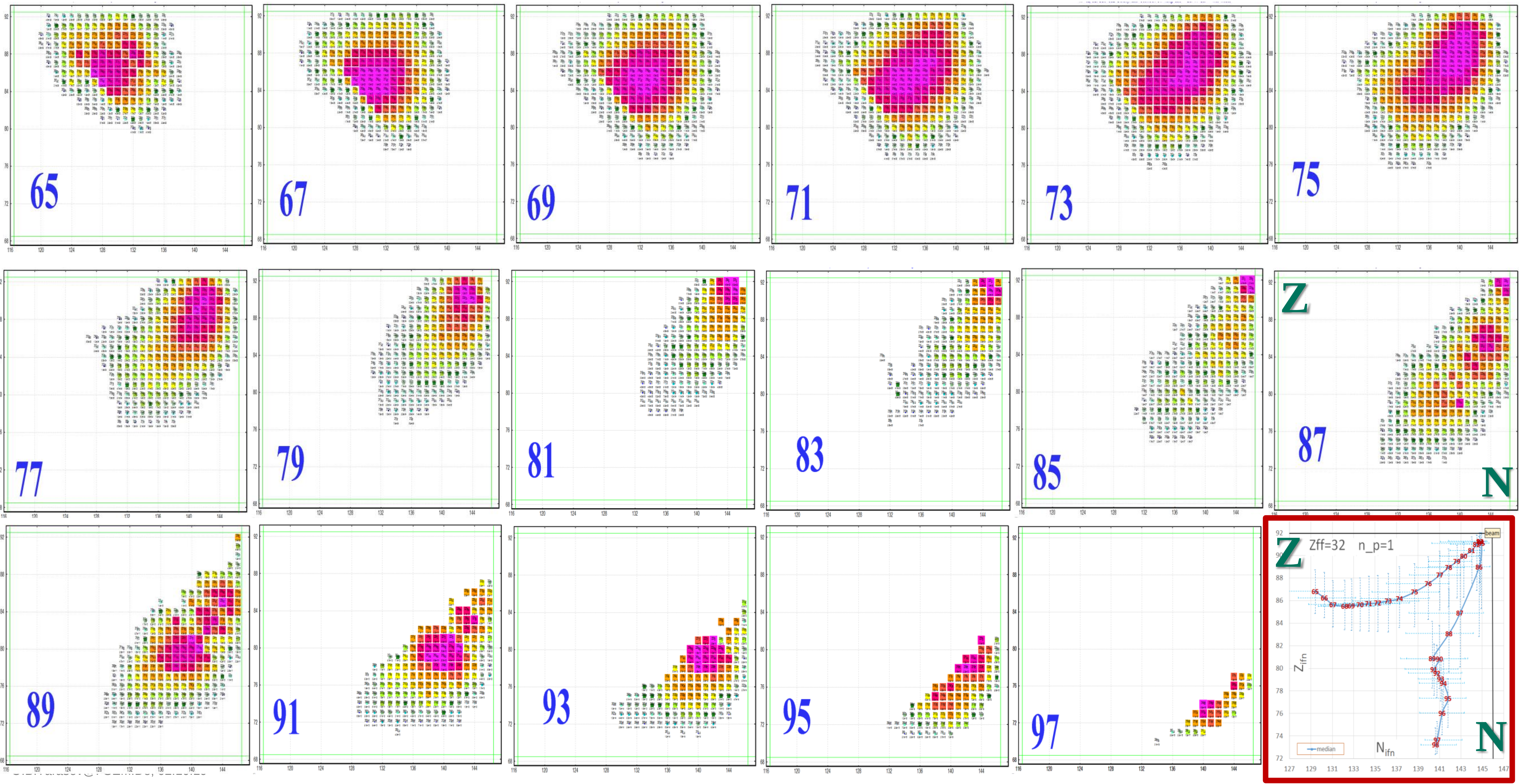




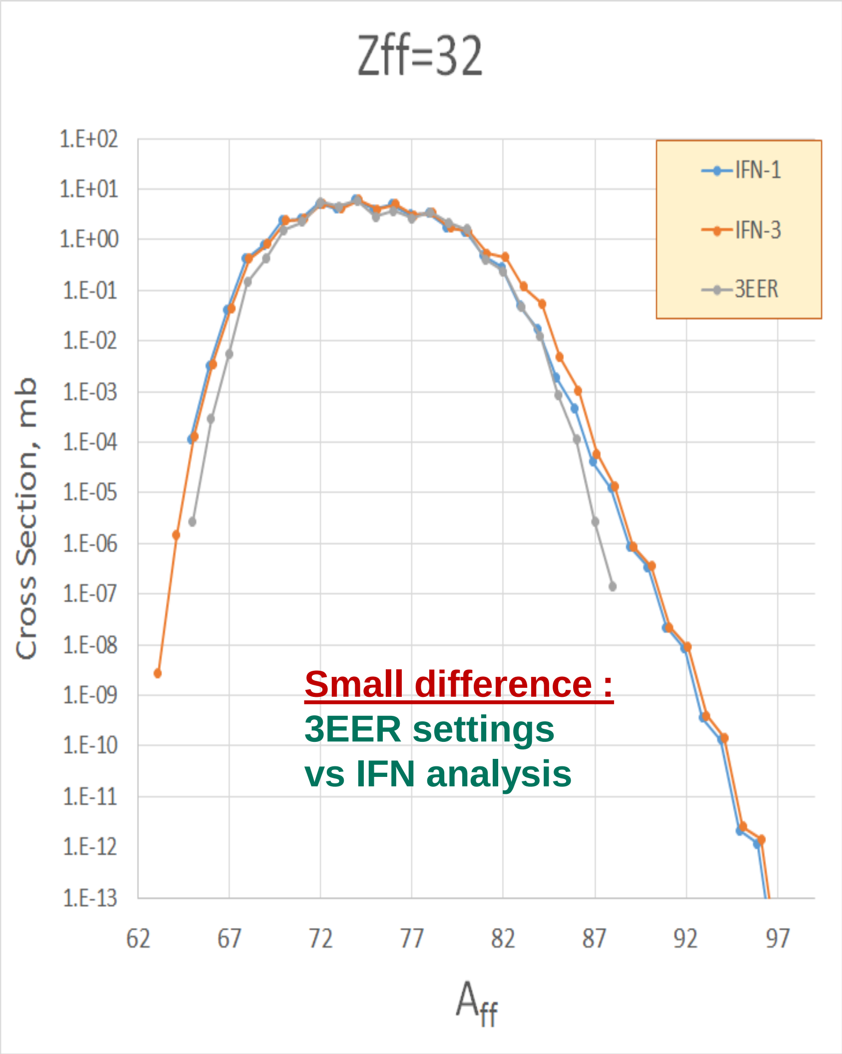


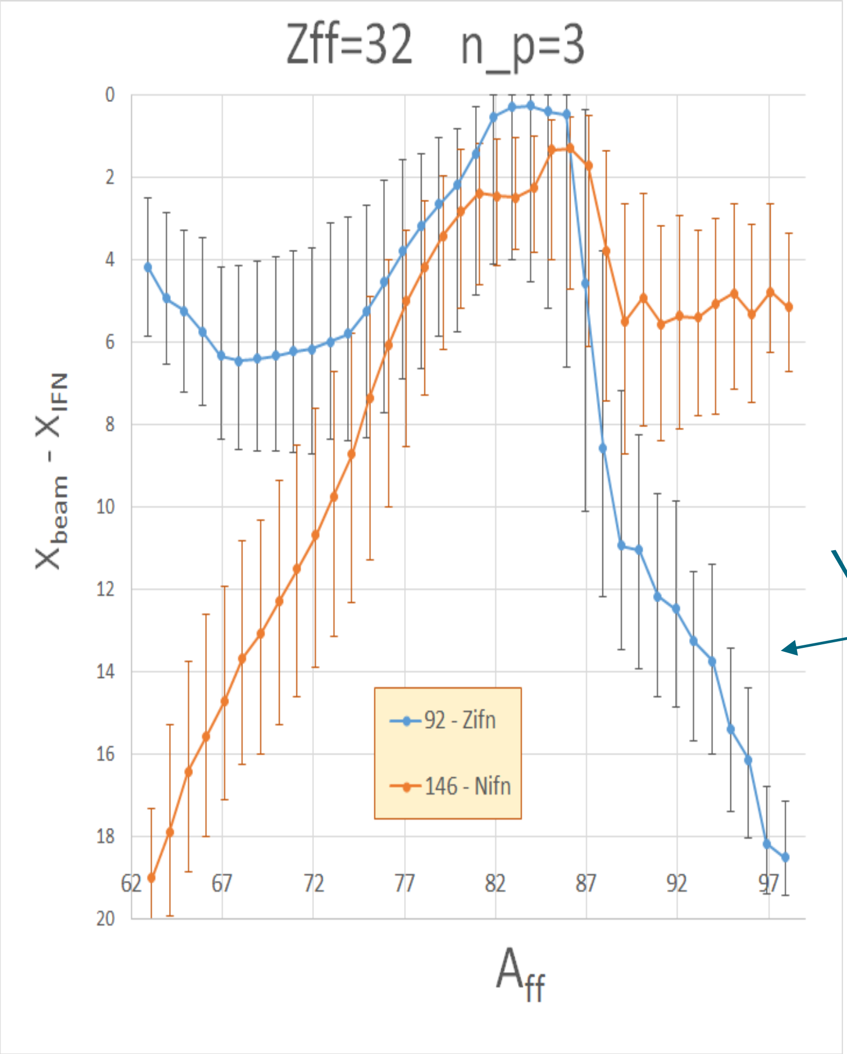


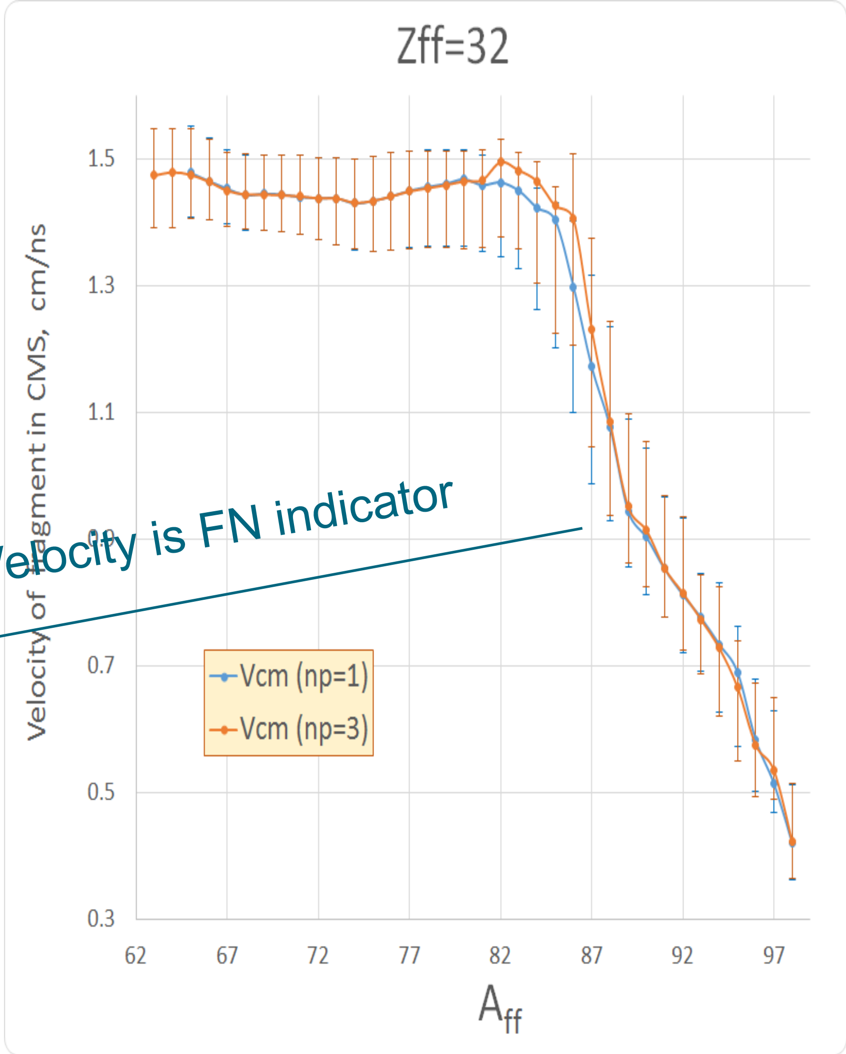
Initial Fissile Nuclei (IFN) for final Ge-isotopes (Z=32)



IFN-analysis for final Ge-isotopes (Z=32) : a







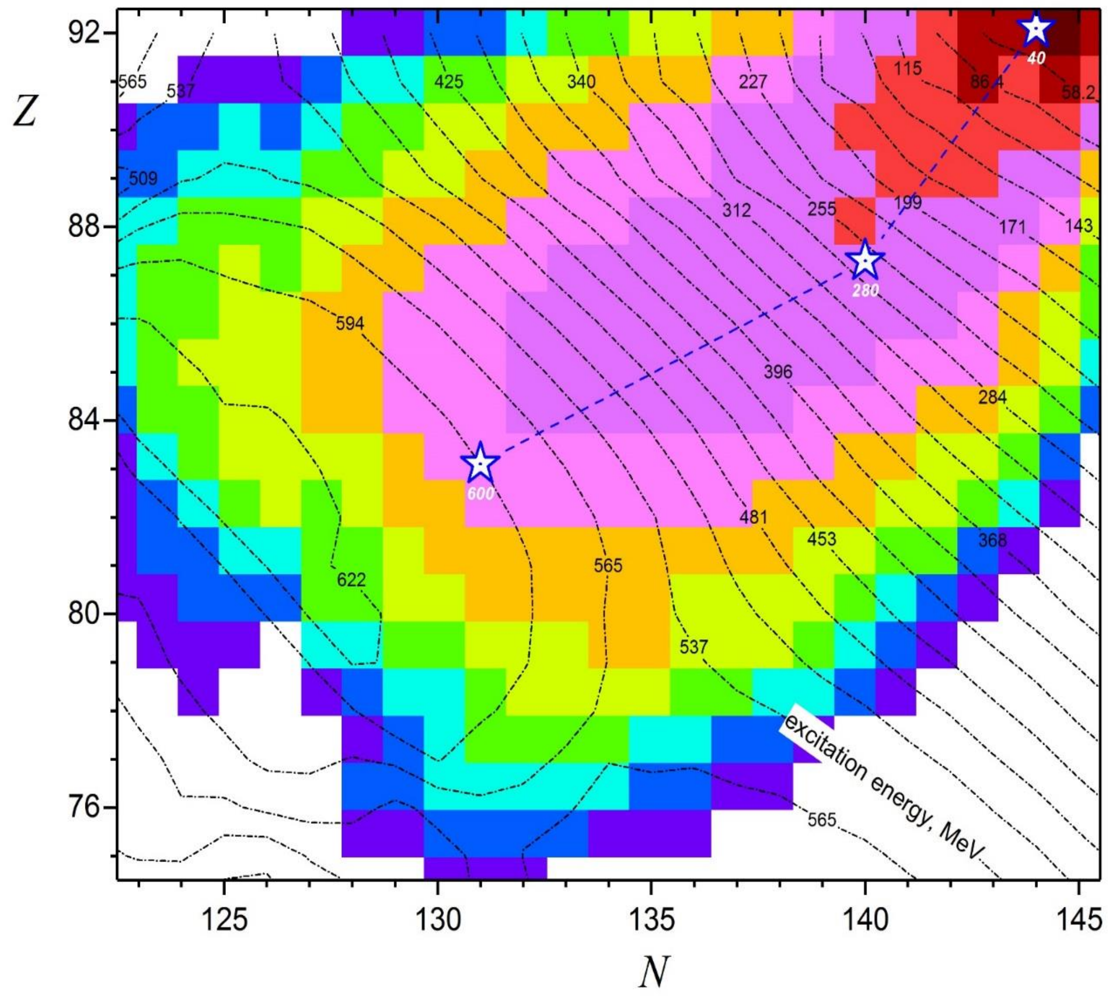
Velocity is FN indicator

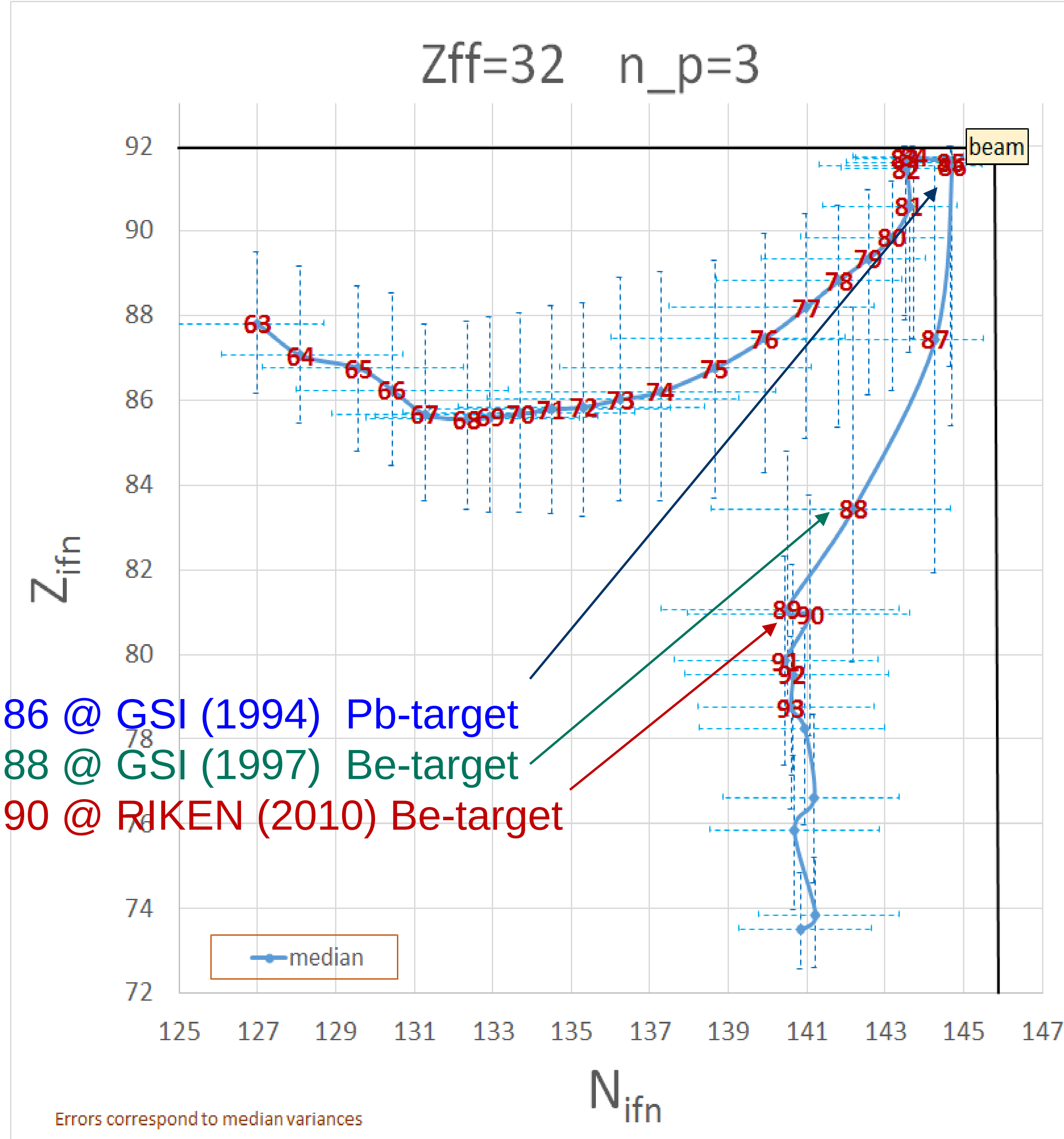
Cross-sections

$Z(N)_{beam} - Z(N)_{FisNucl}$

Fragment velocity
(CMS – cm/ns)

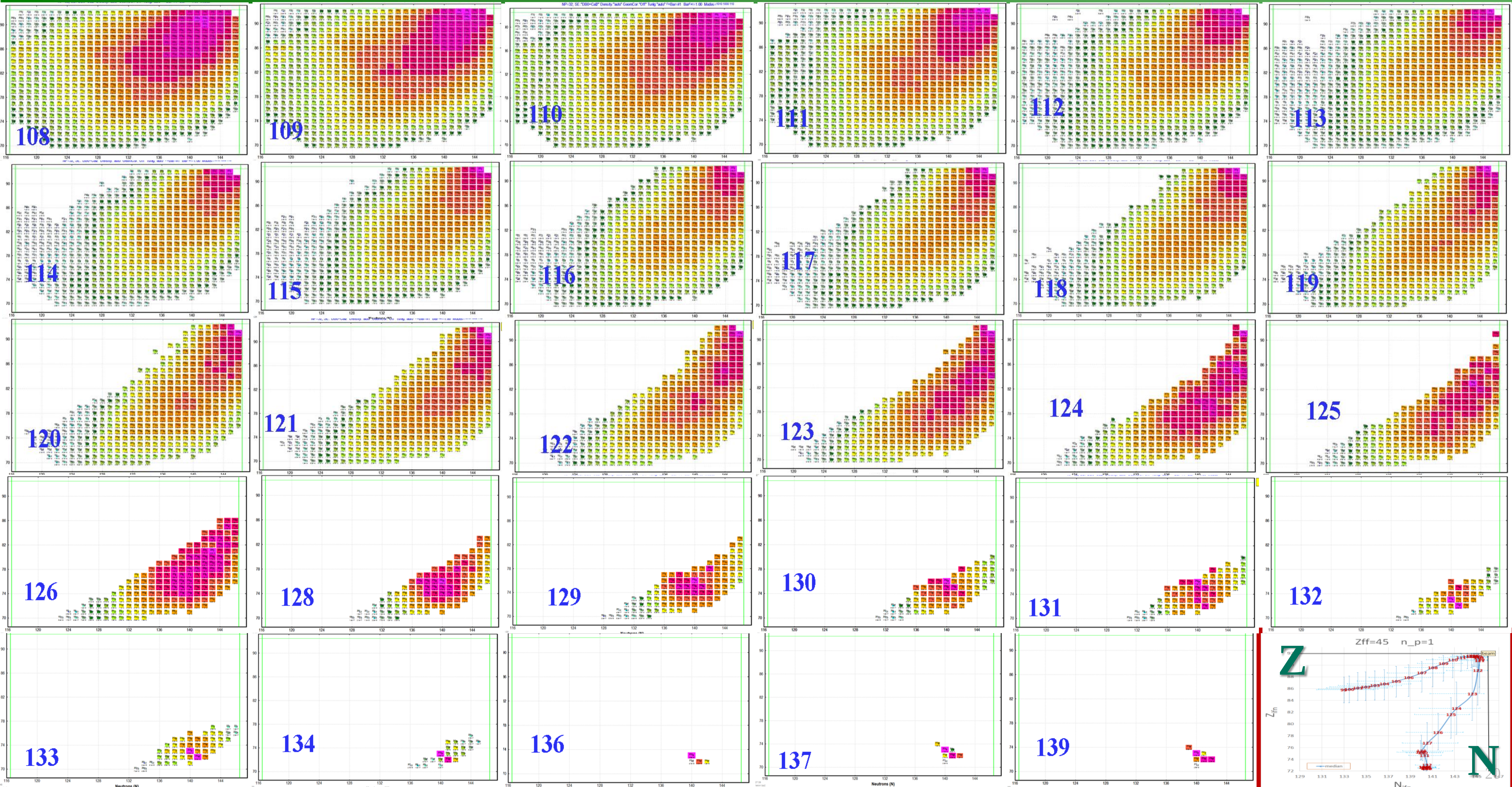
IFN-analysis for final Ge-isotopes (Z=32)



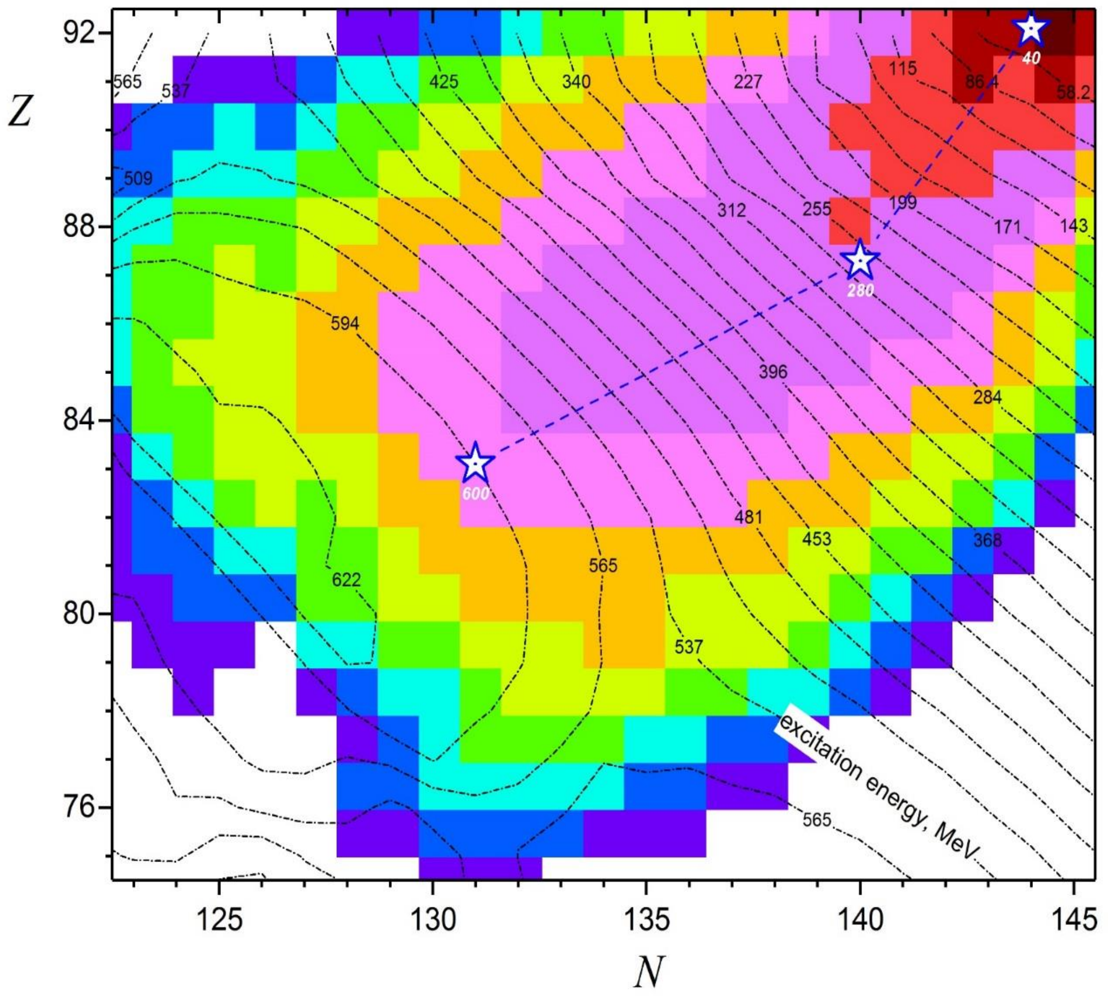


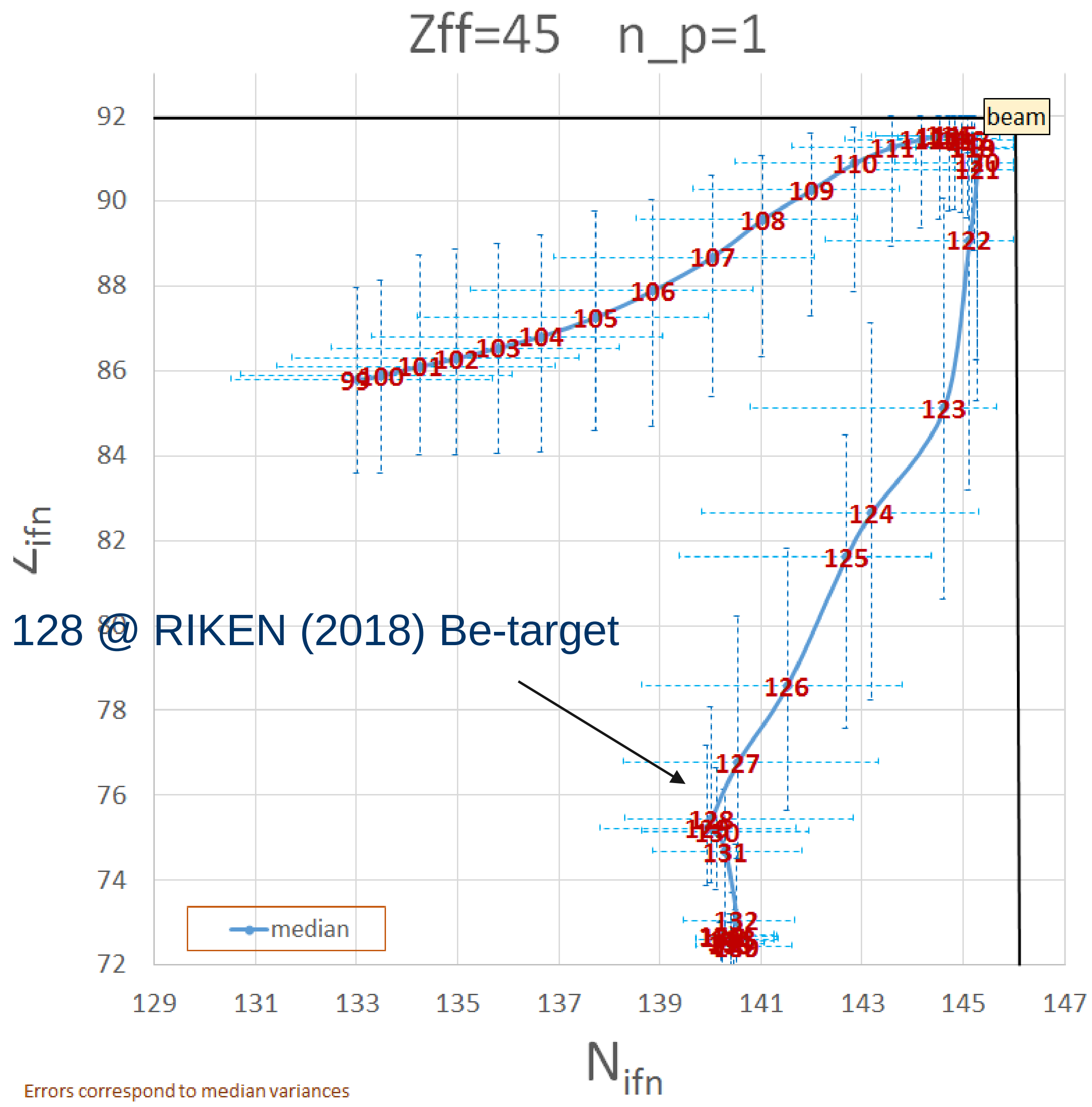
86 @ GSI (1994) Pb-target
88 @ GSI (1997) Be-target
90 @ RIKEN (2010) Be-target

Initial Fissile Nuclei (IFN) for final Rh-isotopes (Z=45)

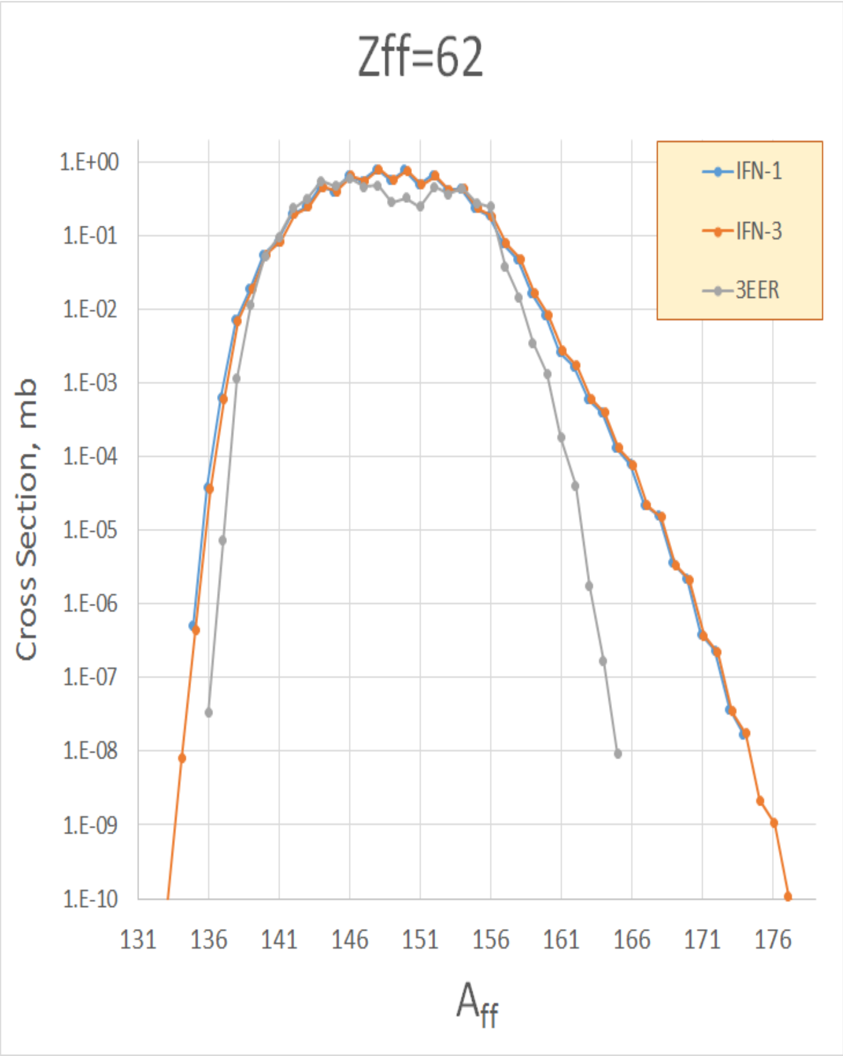


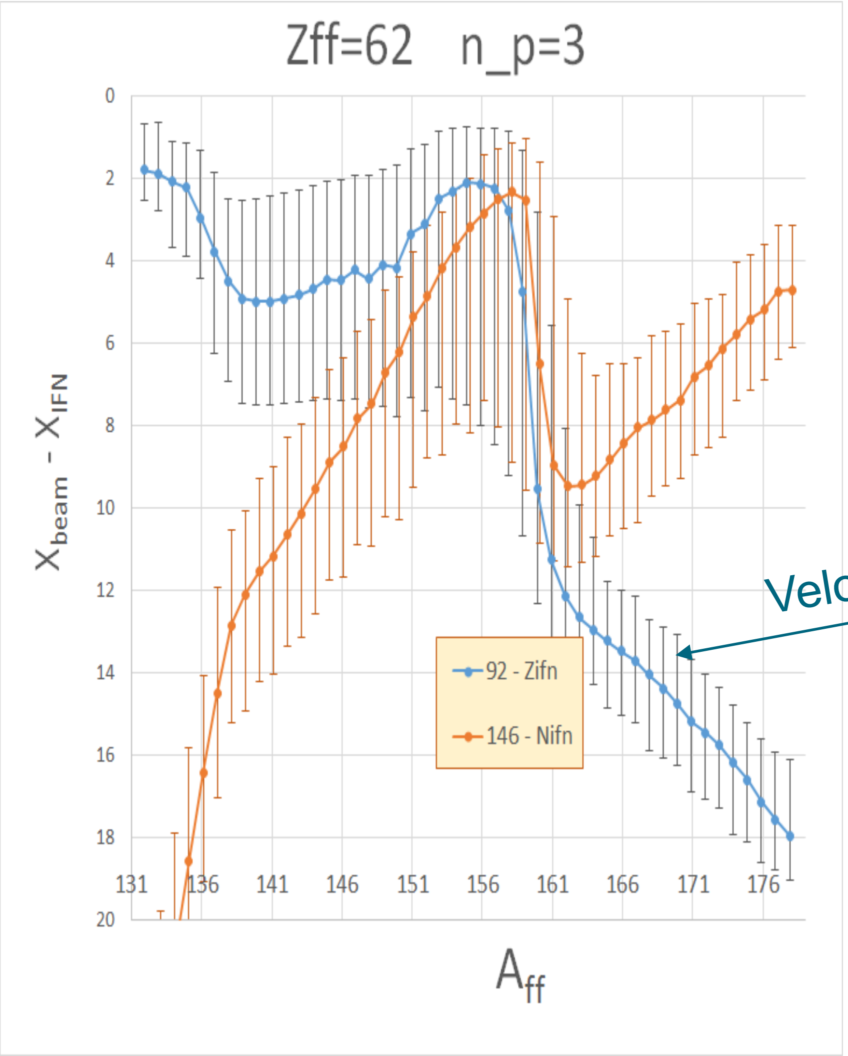
IFN-analysis for final Rh-isotopes (Z=45)

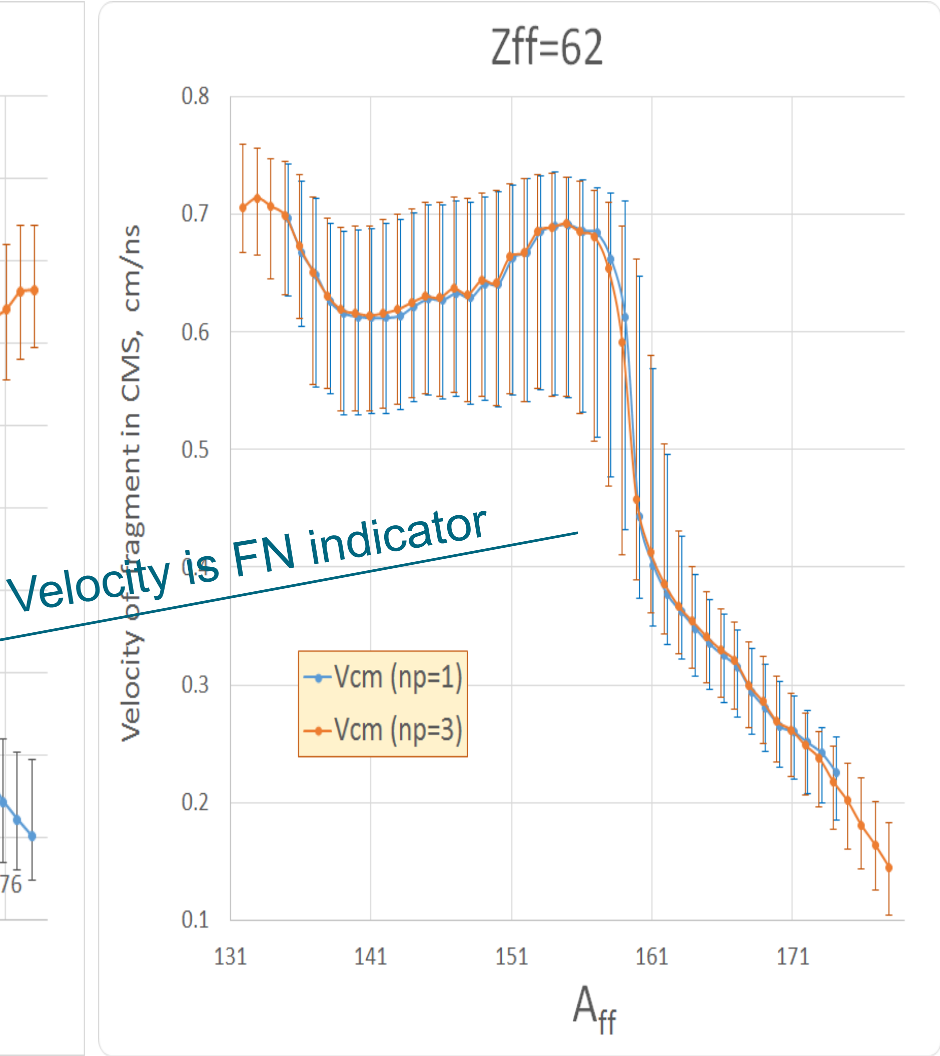




IFN-analysis for final Sm-isotopes (Z=62) : a





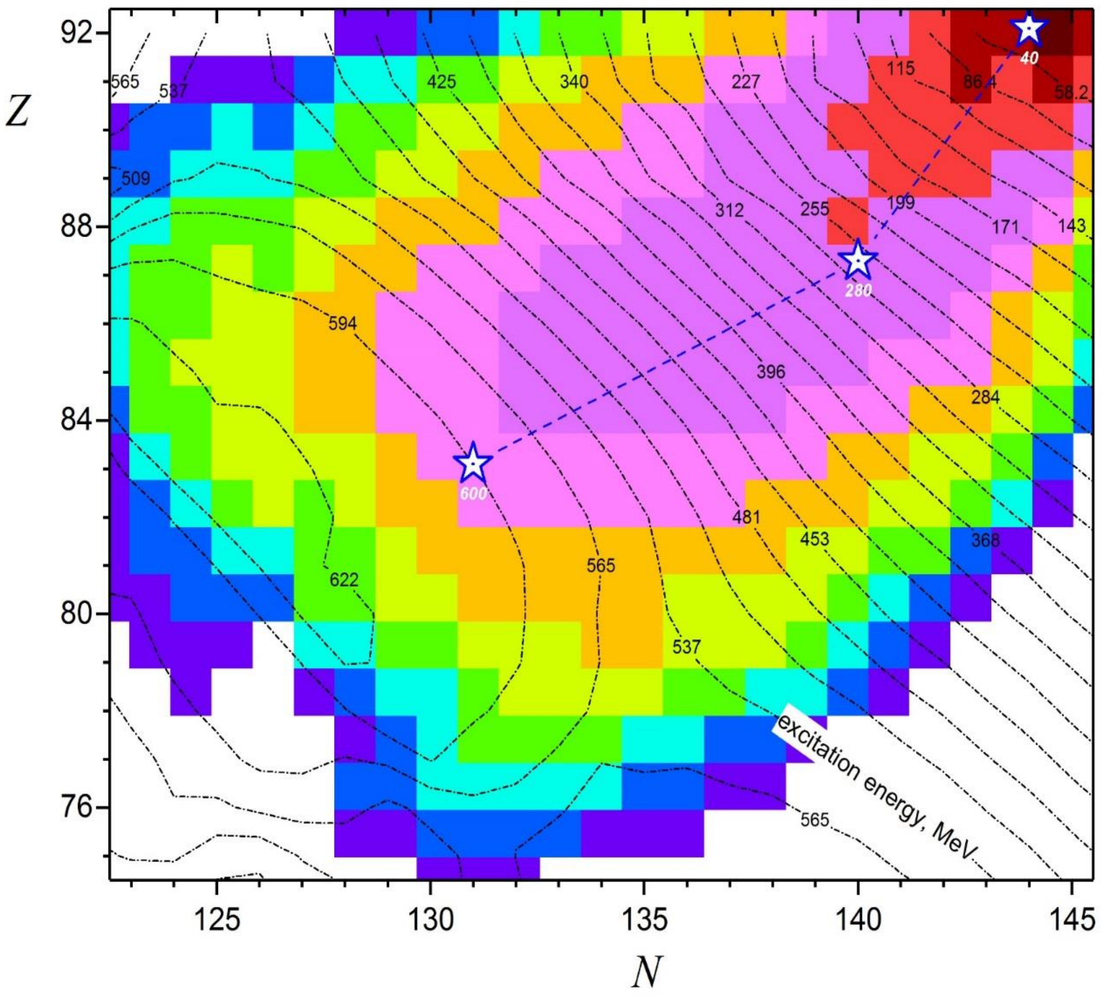


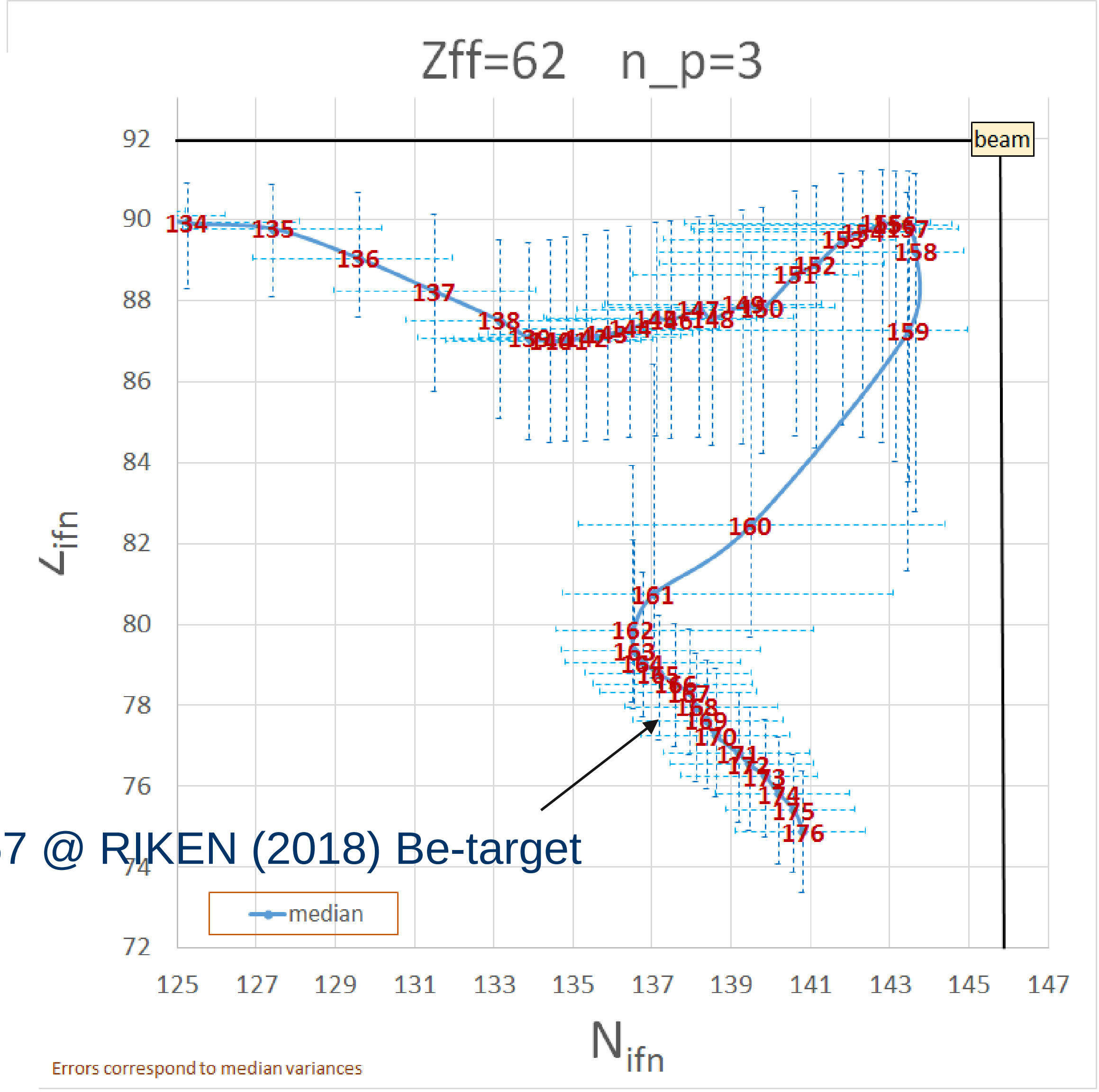
Cross-sections

$Z(N)_{beam} – Z(N)_{FisNucl}$

Fragment velocity (CMS – cm/ns)

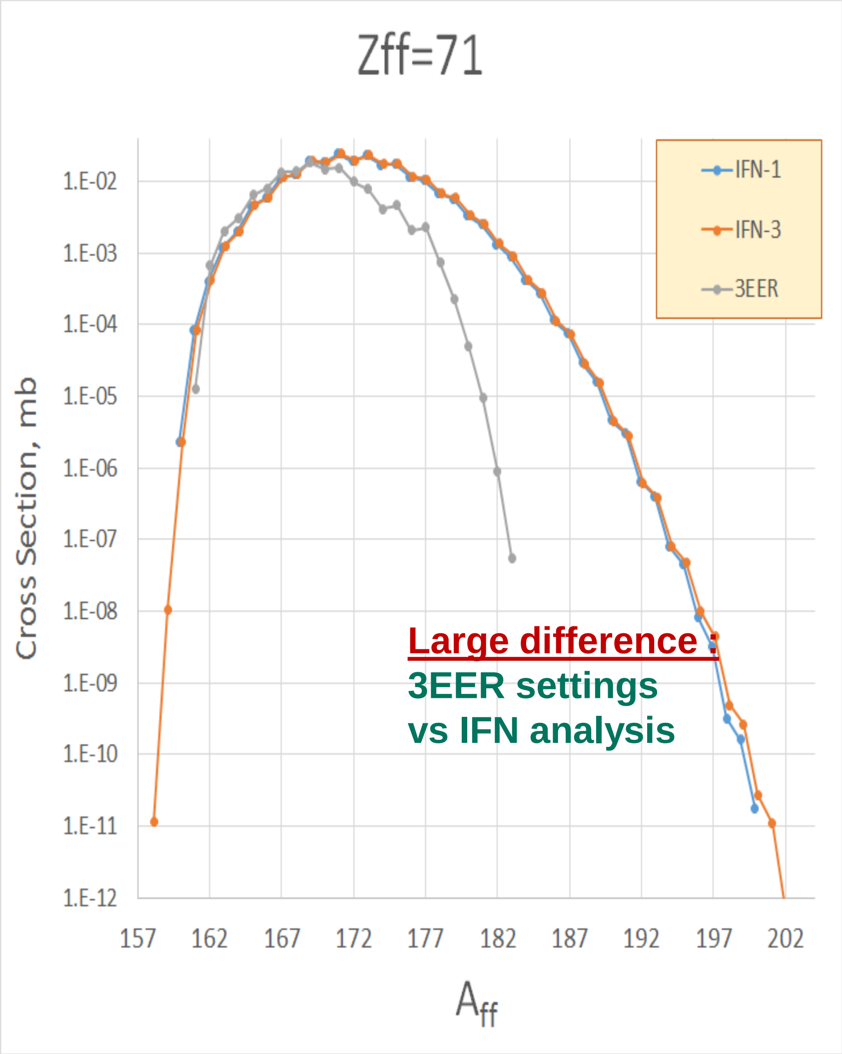
IFN-analysis for final Sm-isotopes (Z=62)



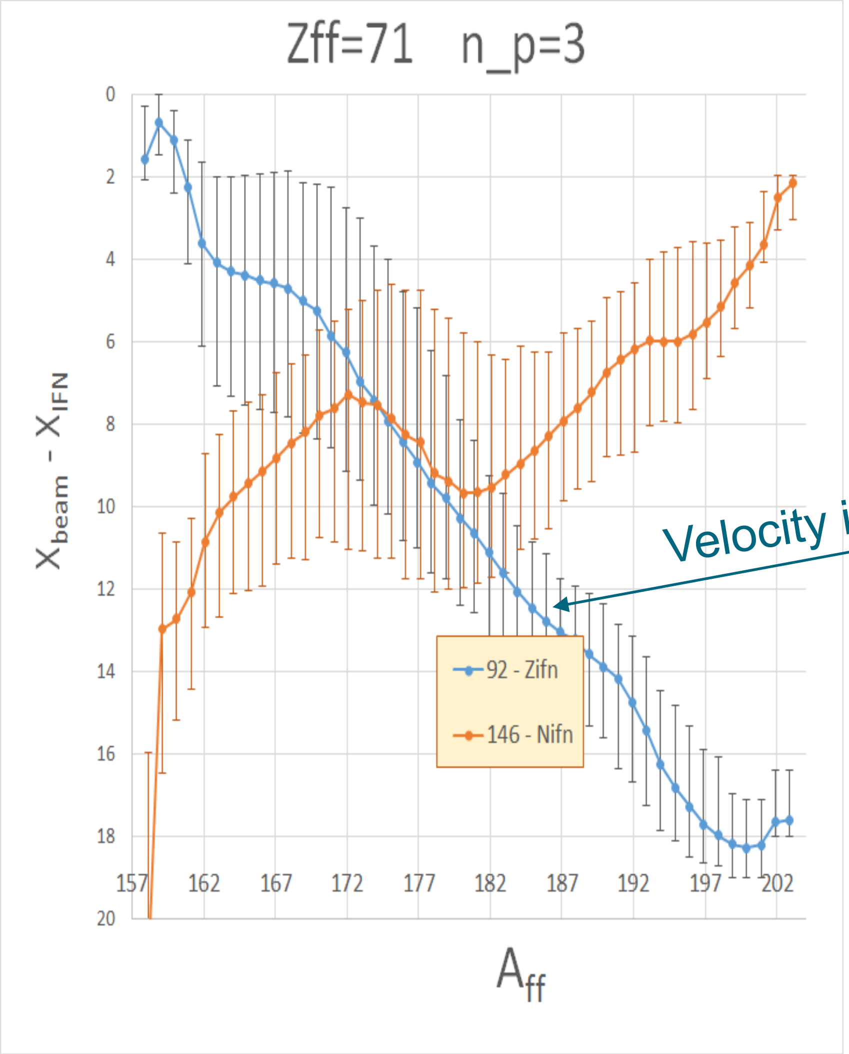


167 @ RIKEN (2018) Be-target

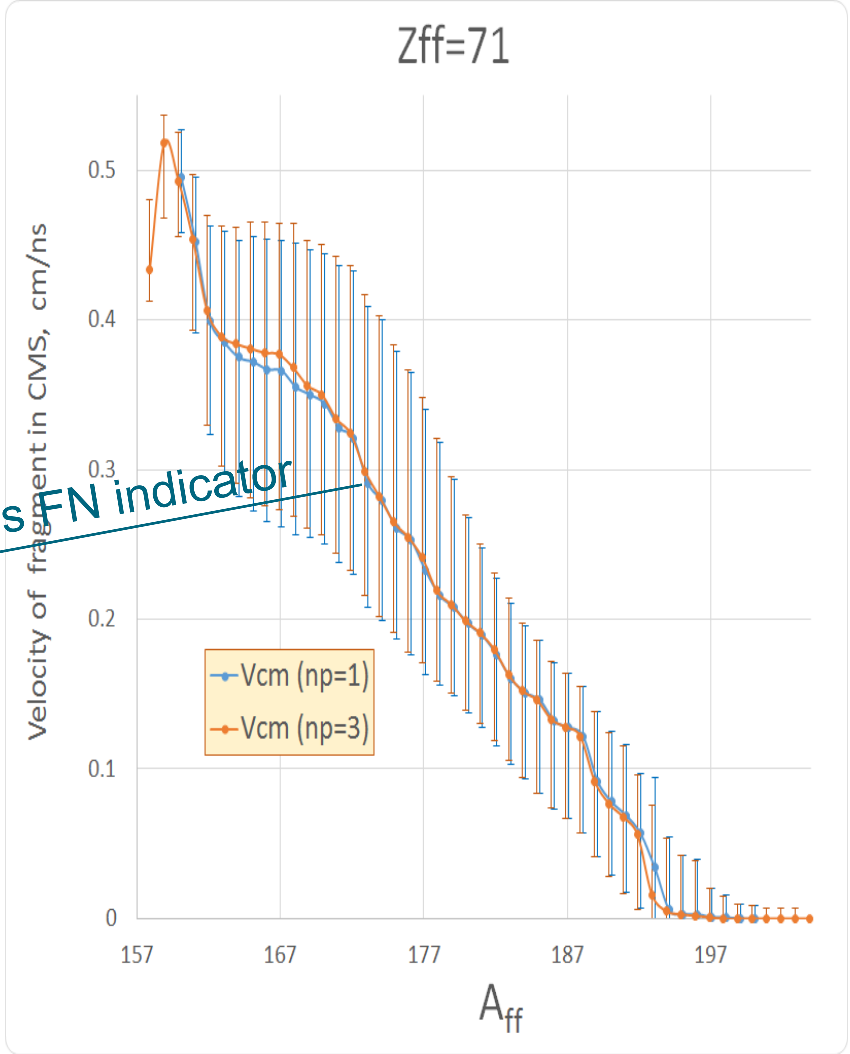
IFN-analysis for final Lu-isotopes (Z=71) : a



Cross-sections

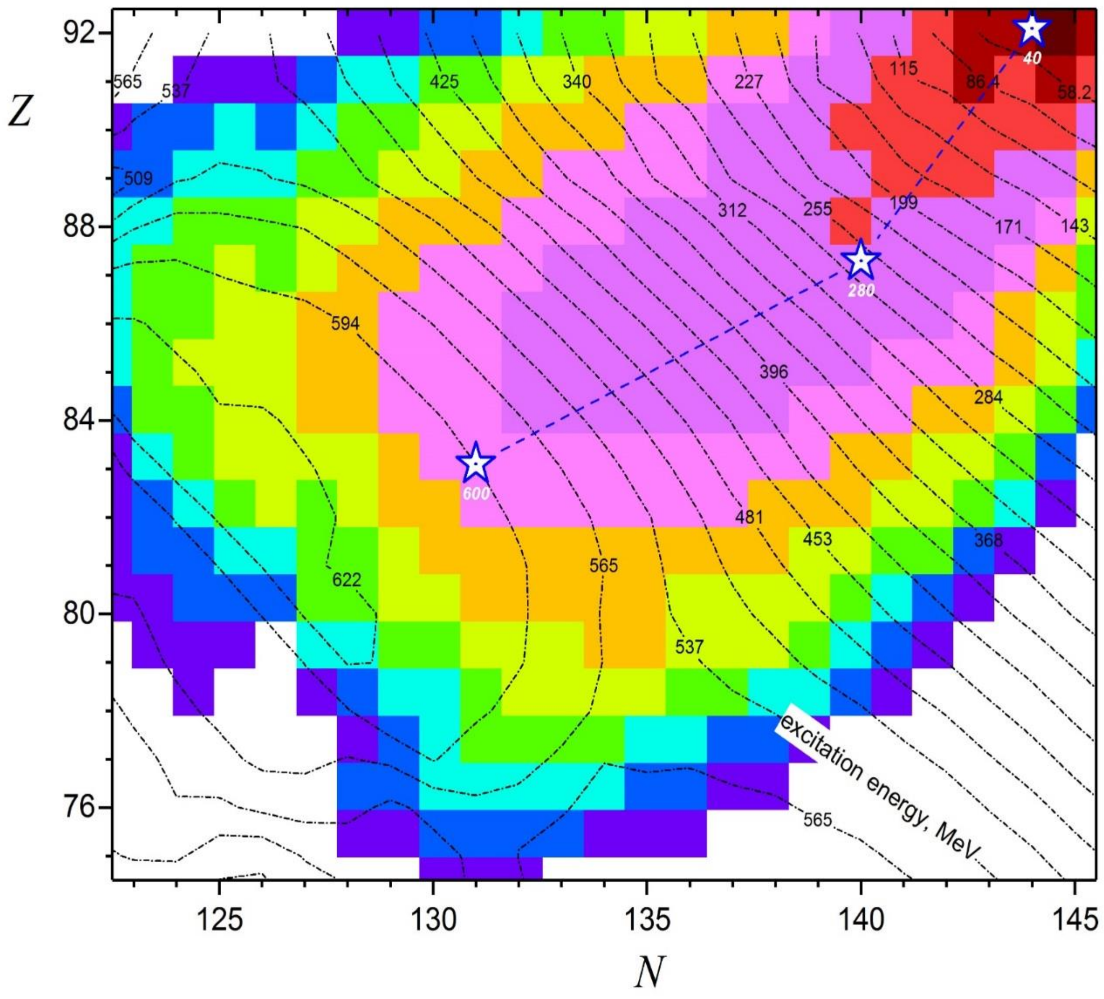


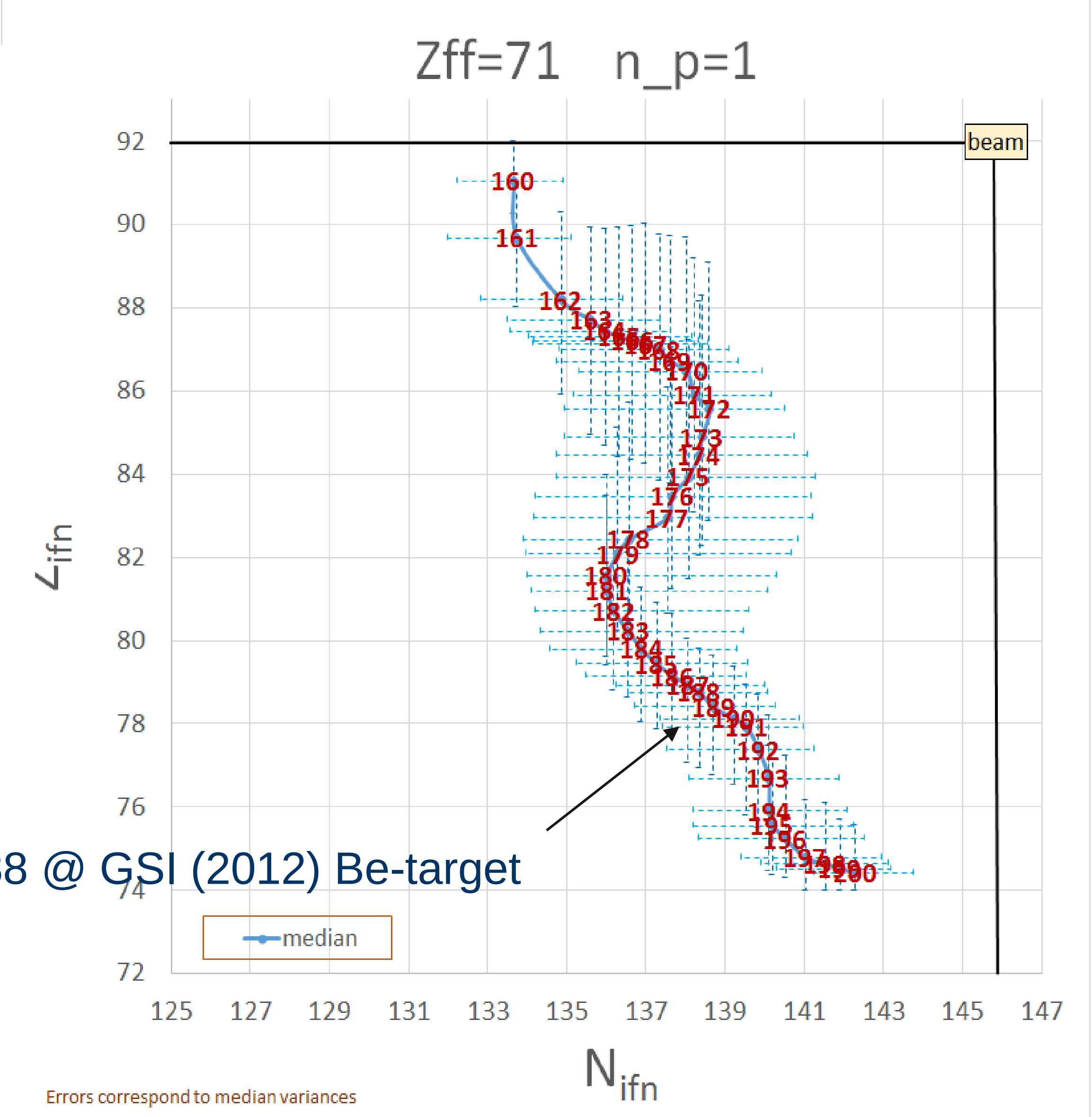
$Z(N)_{beam} – Z(N)_{FisNucl}$



Fragment velocity (CMS – cm/ns)

IFN-analysis for final Lu-isotopes (Z=71) : b





188 @ GSI (2012) Be-target

Conclusions and Next steps

This analysis allows to understand
what reaction mechanism involved → choice of target

- Utility calculation speed optimization

- Using the new utility try to define Fission, Evaporation, AA excitation energy parameters for best agreement with experimental data

- **Generate Z-full range IFN1 and IFN3 tables for different targets** (and energies?)

- Develop new Abrasion-Fission mode to use IFN tables, that provides more fast and qualitative yield calculations

Plotting and passing two fission fragments simultaneously

- Passing and plotting two fission fragments **simultaneously**
  - Angular Acceptance
  - Momentum Acceptance
  - Using non-zero target thickness

Two-fission registration setups (SOFIA, SAMURAI, HRS in future) use a wide aperture magnet : large A_X angular acceptance, moderate A_Y (vertical gap), and large Brho-acceptance

E. PELLEREAU *et al.*

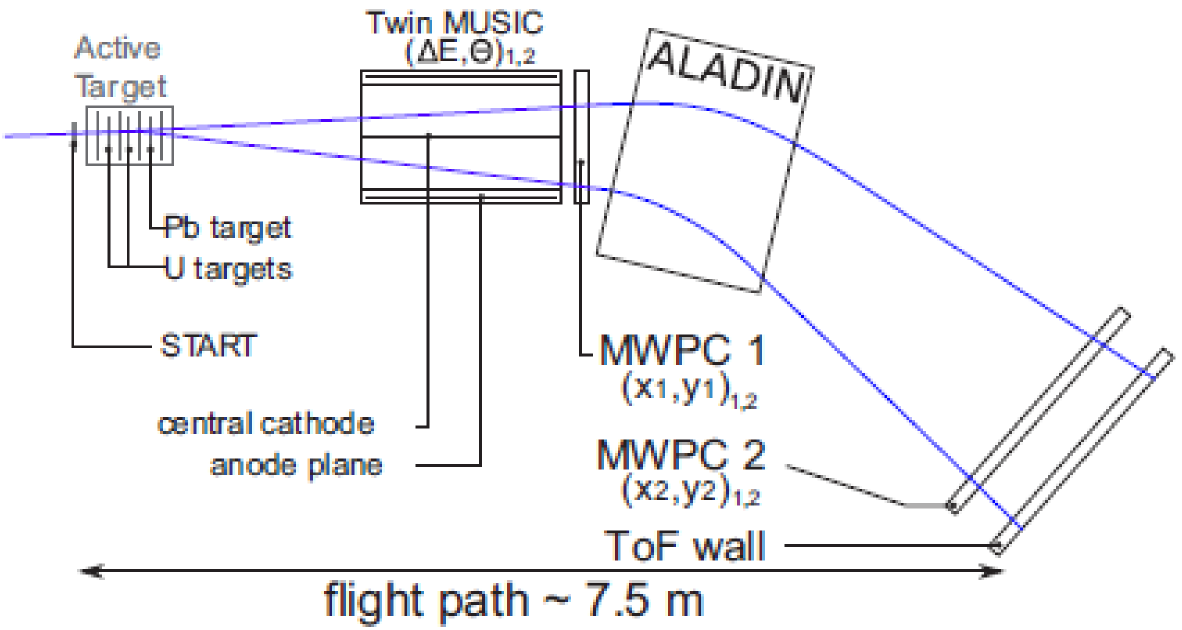
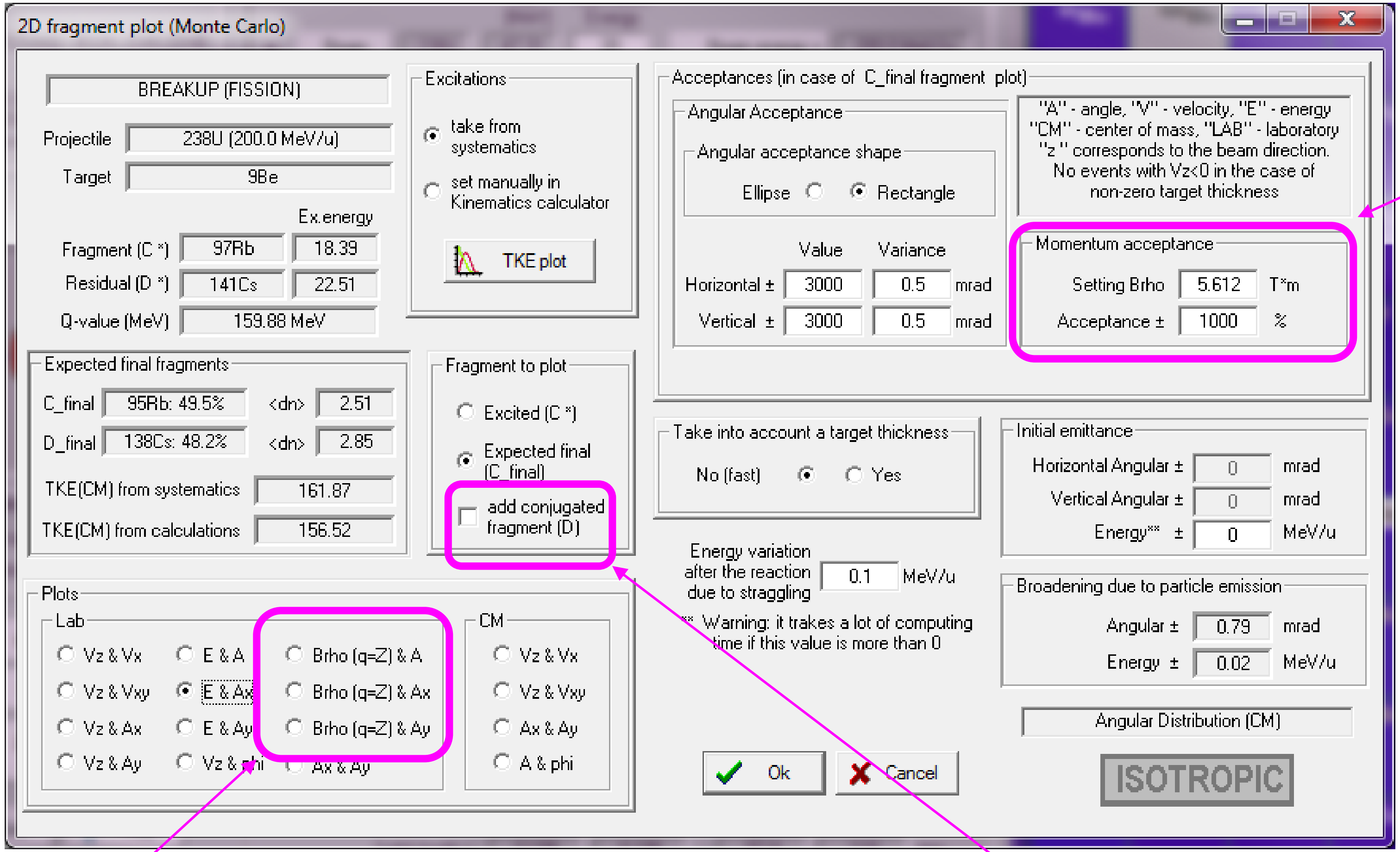


FIG. 4. Schematic view of the SOFIA setup to identify the nuclear mass and charge of both fission fragments in coincidence (top view, not on scale).

New features of the Fission Kinematic MC Calculator



Momentum acceptance instead the previous pseudo-energy acceptance

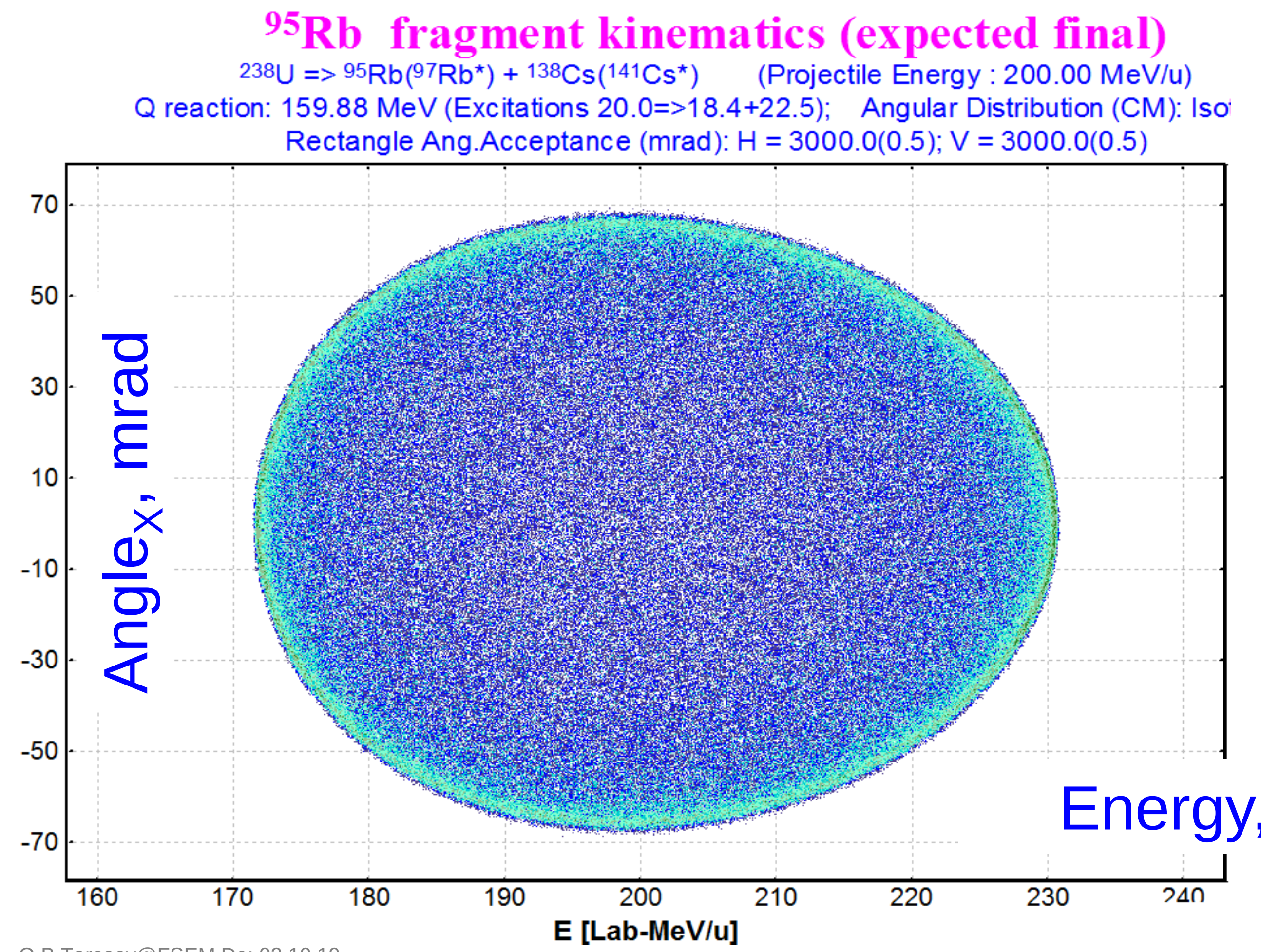
"Brho" plots

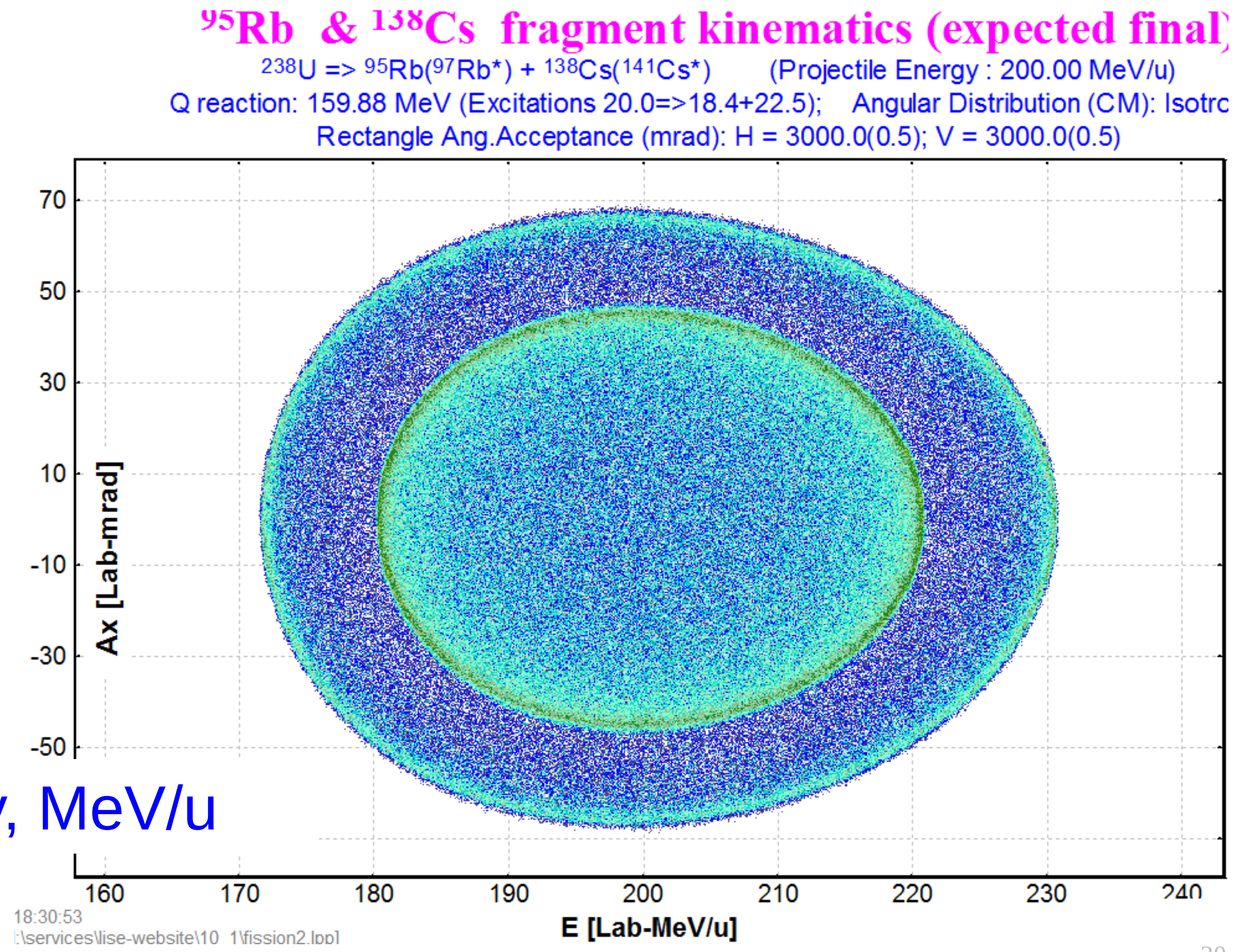
Main new feature to start plotting and passing two fission fragments simultaneously

Plotting two fission fragments simultaneously (A_X vs. Energy)

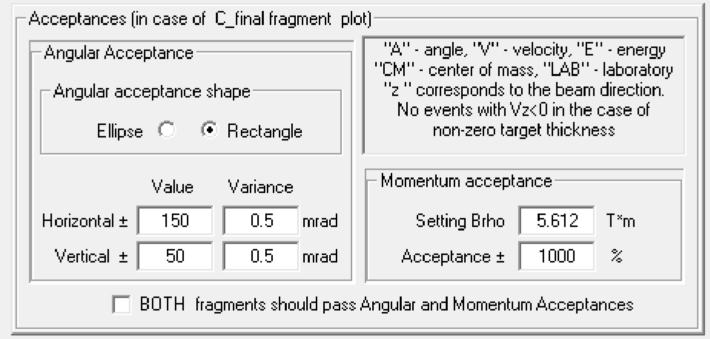
☐ add conjugated fragment [D]

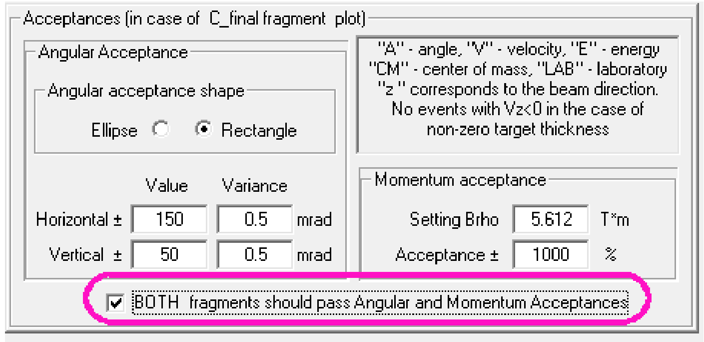
☑ add conjugated fragment [D]





Passing two fission fragments simultaneously (Angular acceptance)



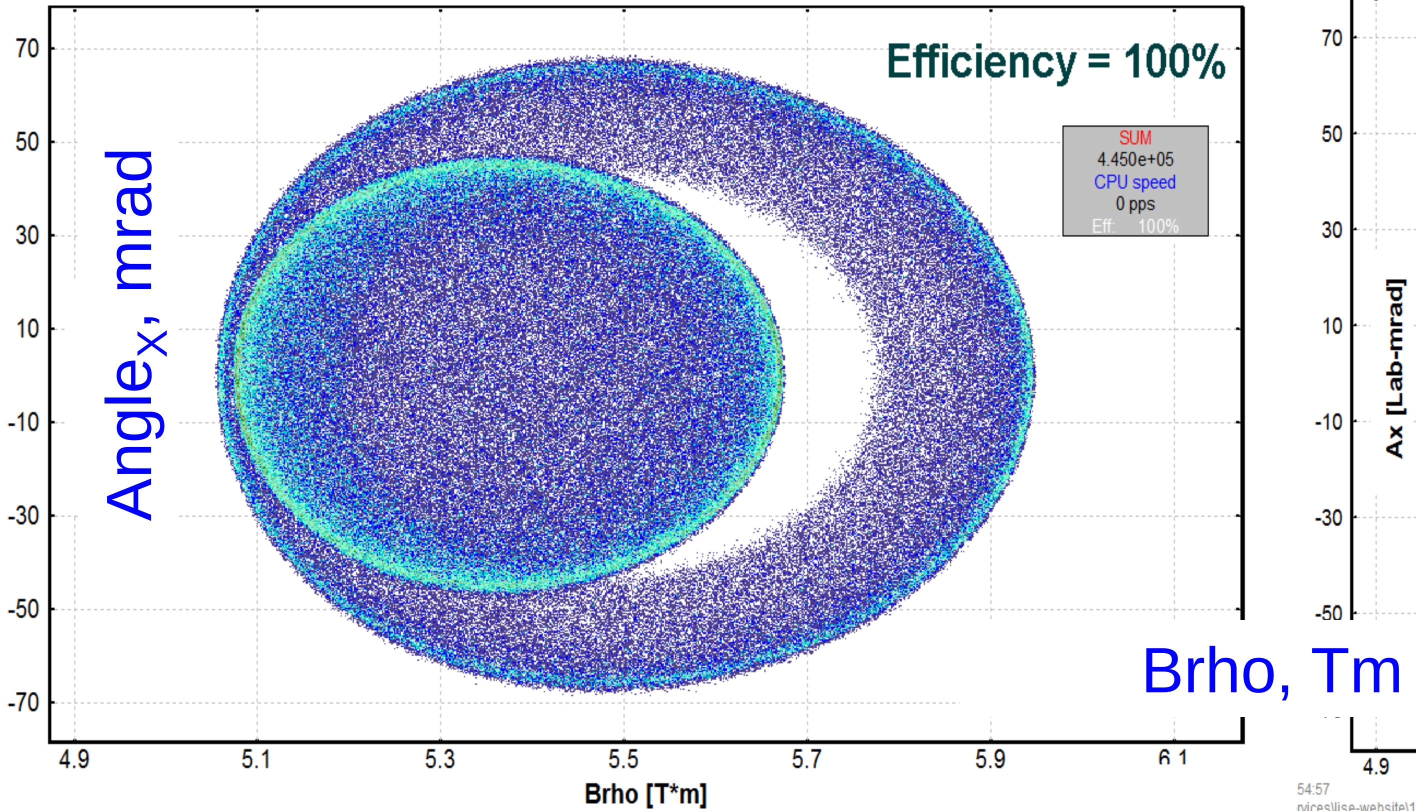


^{95}Rb & ^{138}Cs fragment kinematics (expected final)

^{238}U => ^{95}Rb(^{97}Rb*) + ^{138}Cs(^{141}Cs*) (Projectile Energy : 200.00 MeV/u)

Q reaction: 159.88 MeV (Excitations 20.0=>18.4+22.5); Angular Distribution (CM): Isotropic

Rectangle Ang.Acceptance (mrad): H = 150.0(0.5); V = 50.0(0.5)



^{95}Rb & ^{138}Cs fragment kinematics (expected final) (BOTH fragments should)

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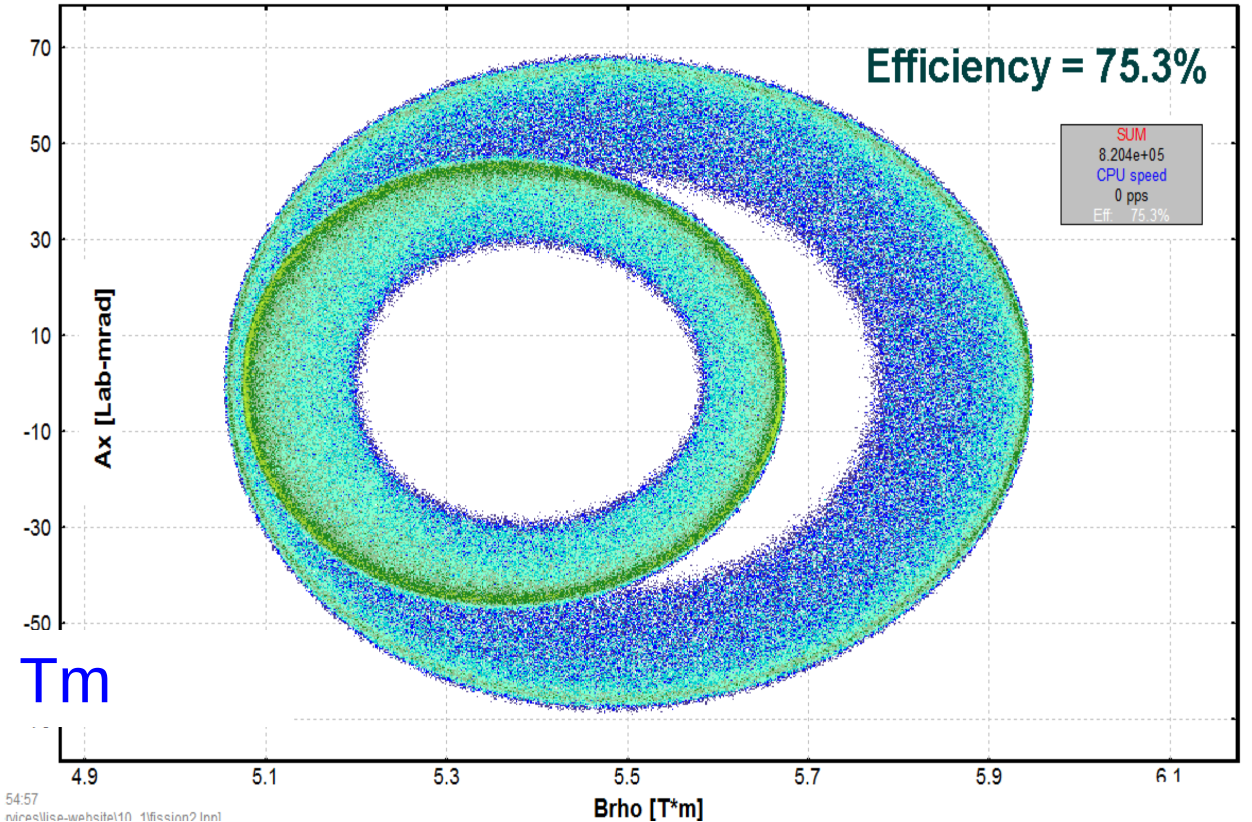
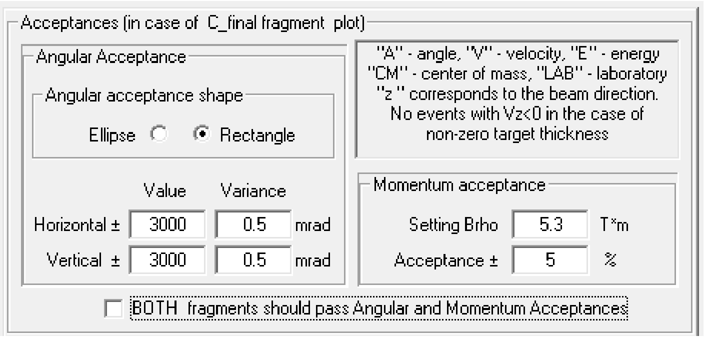
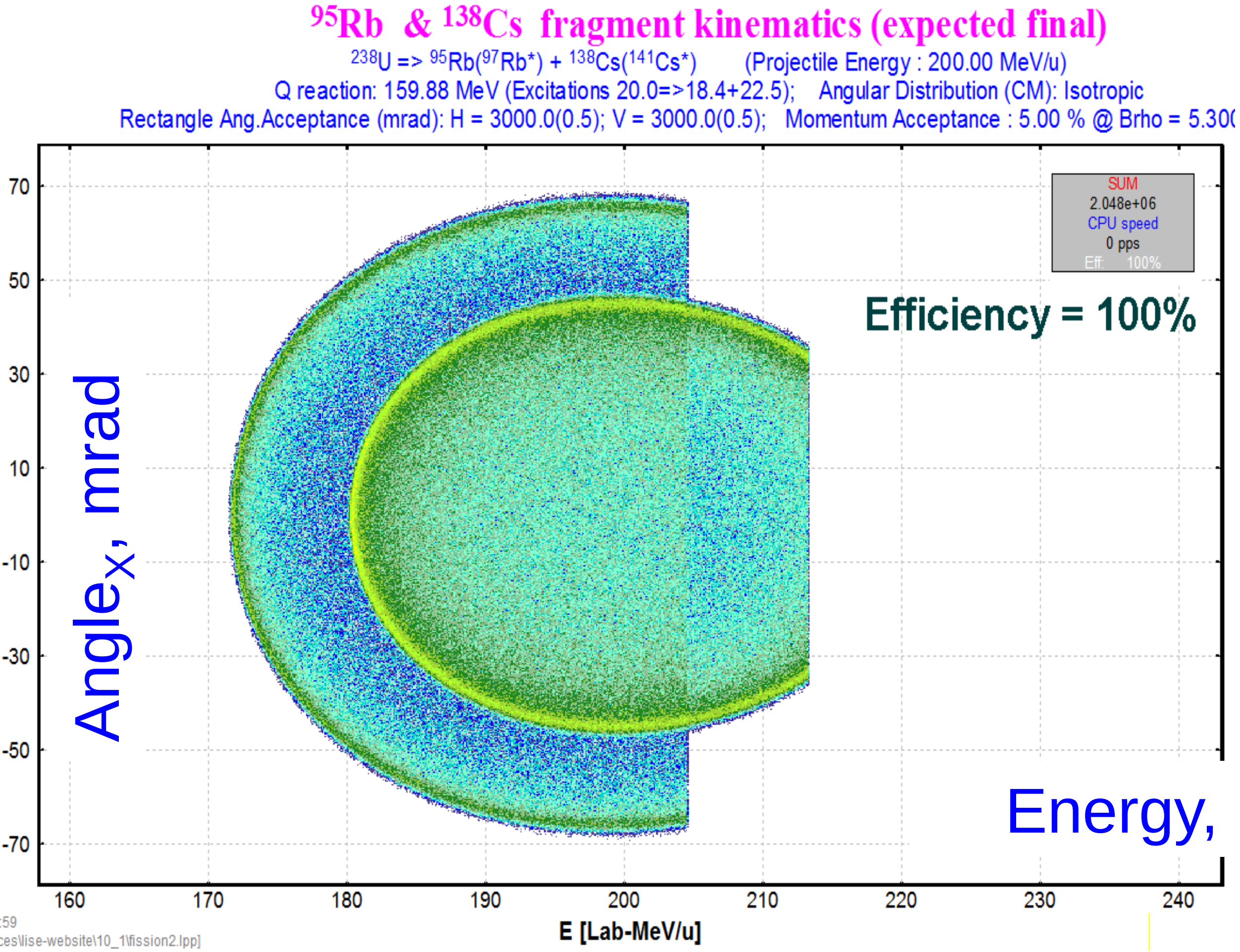
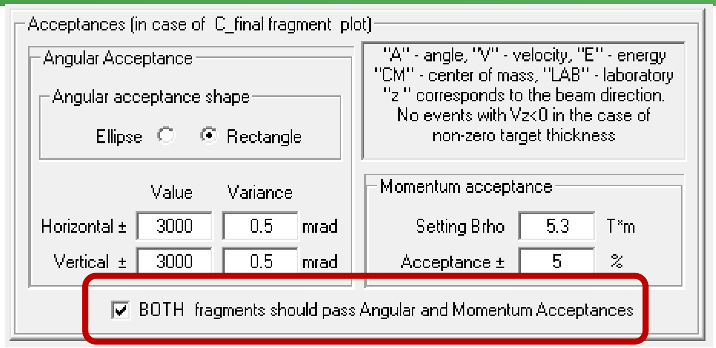
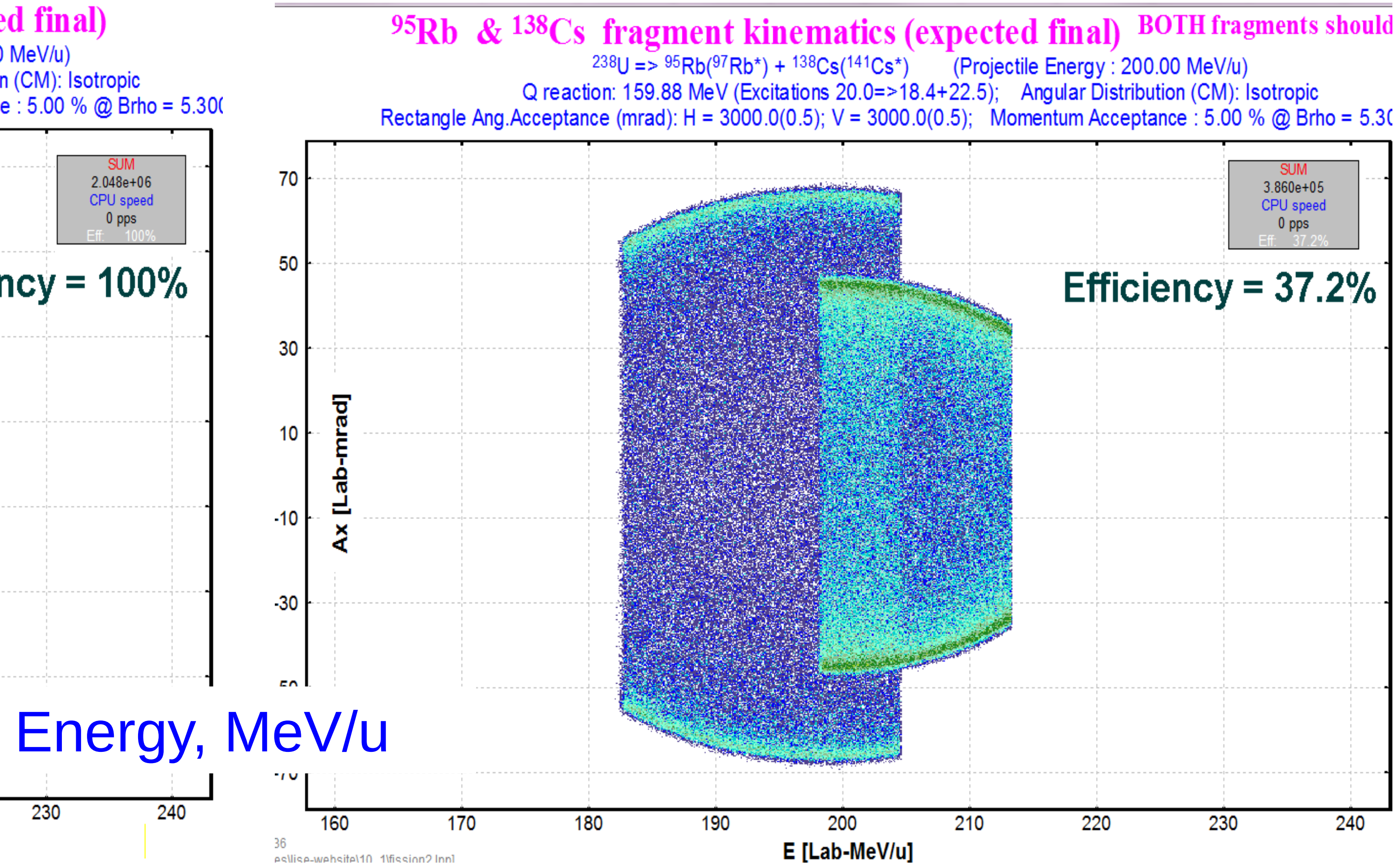


Passing two fission fragments simultaneously : Brho = 5.3 Tm

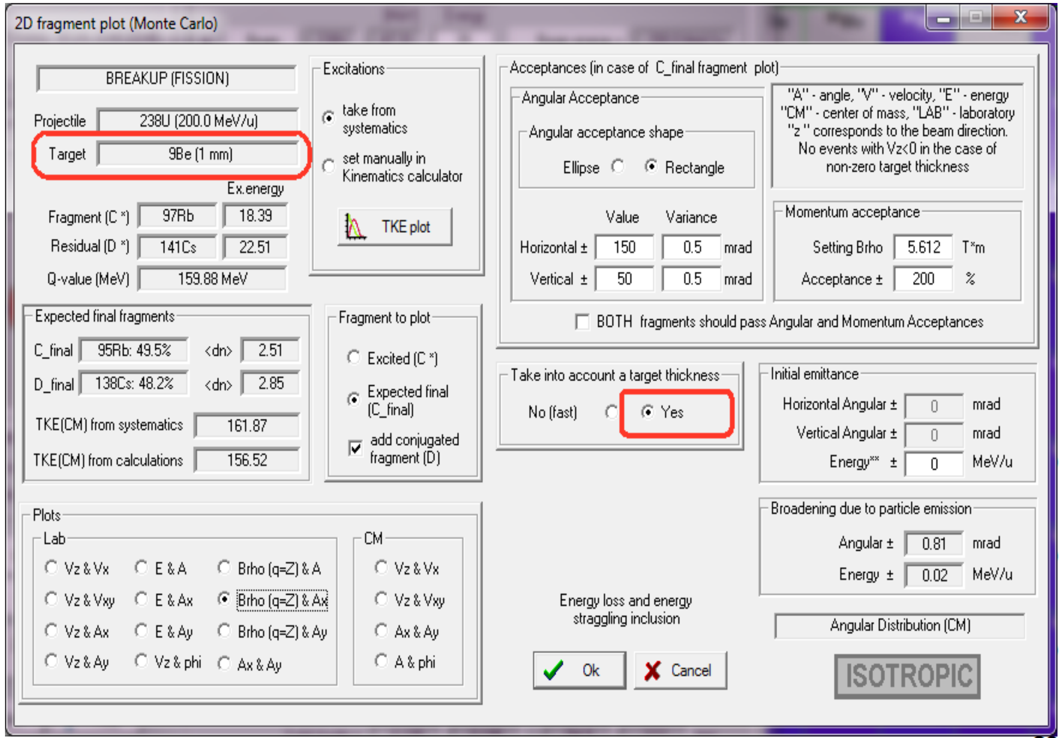


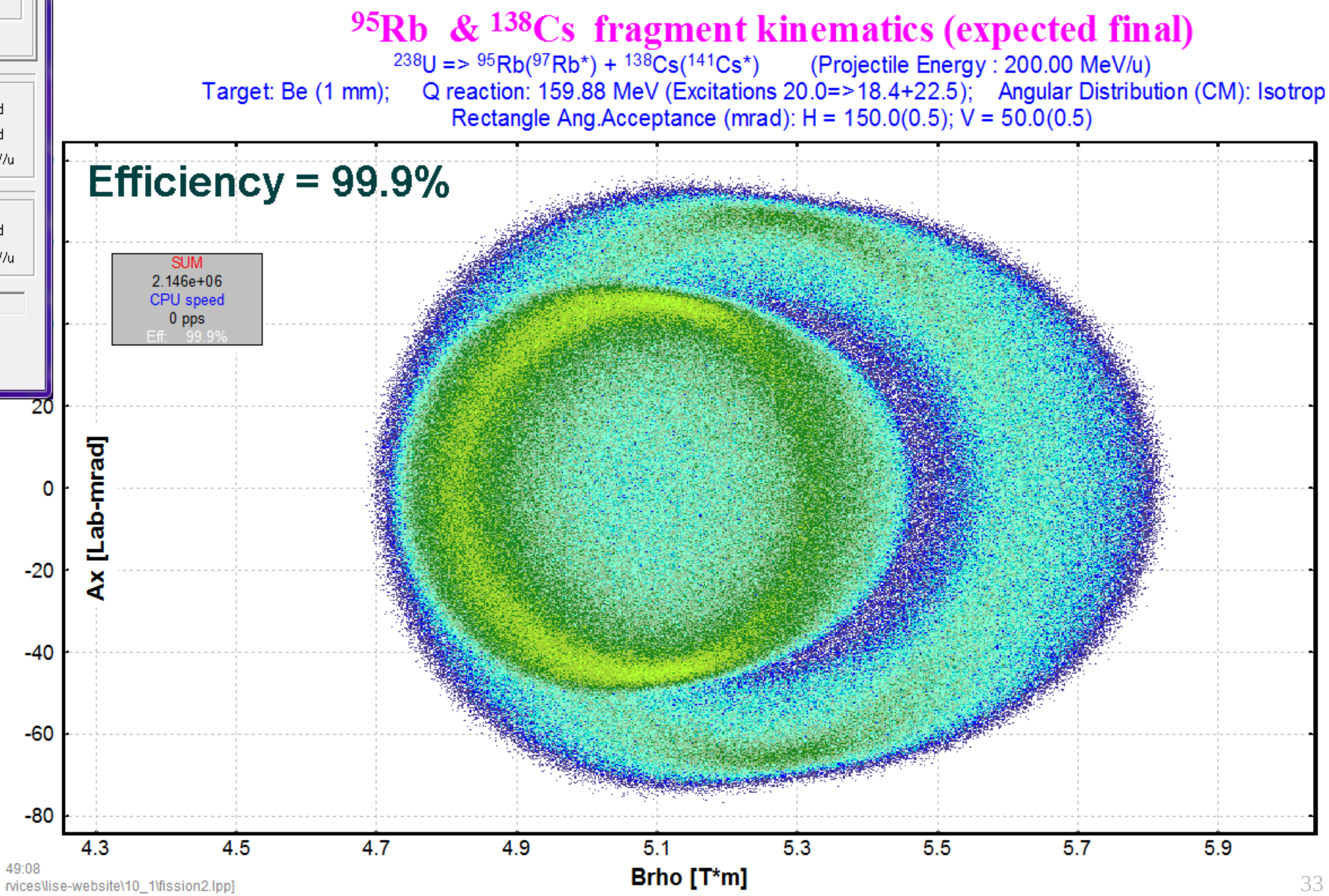




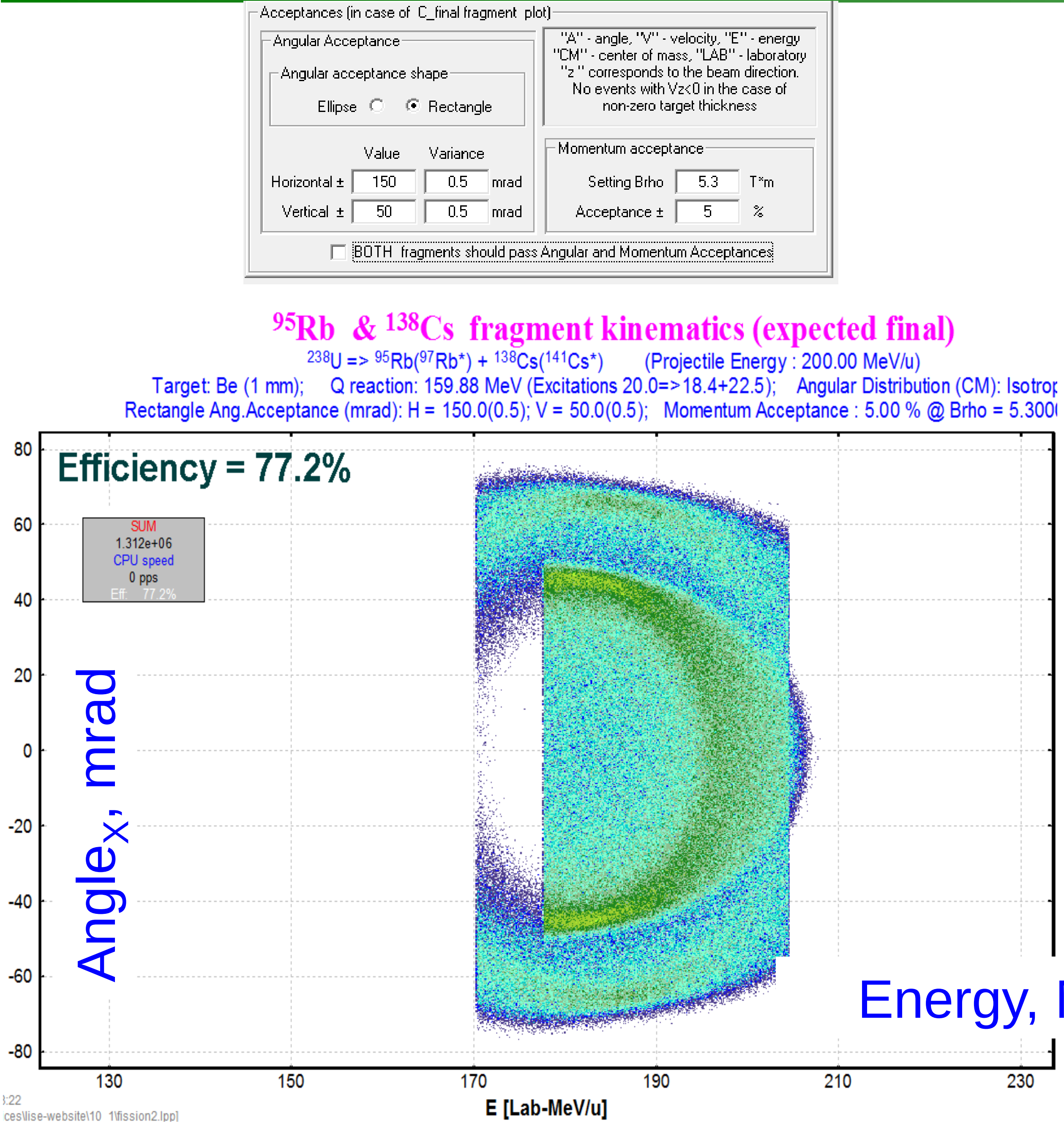


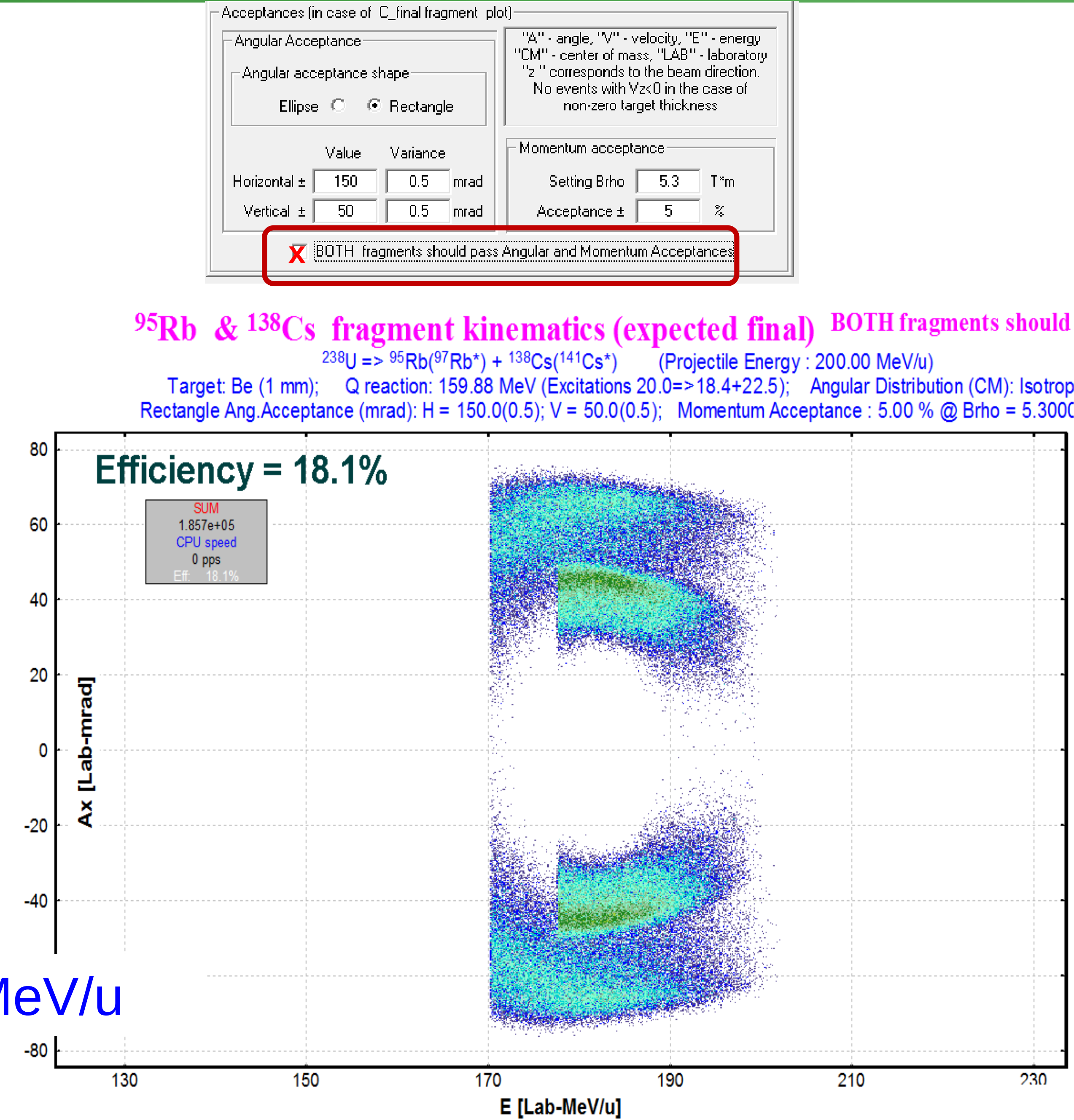
Using non-zero target thickness



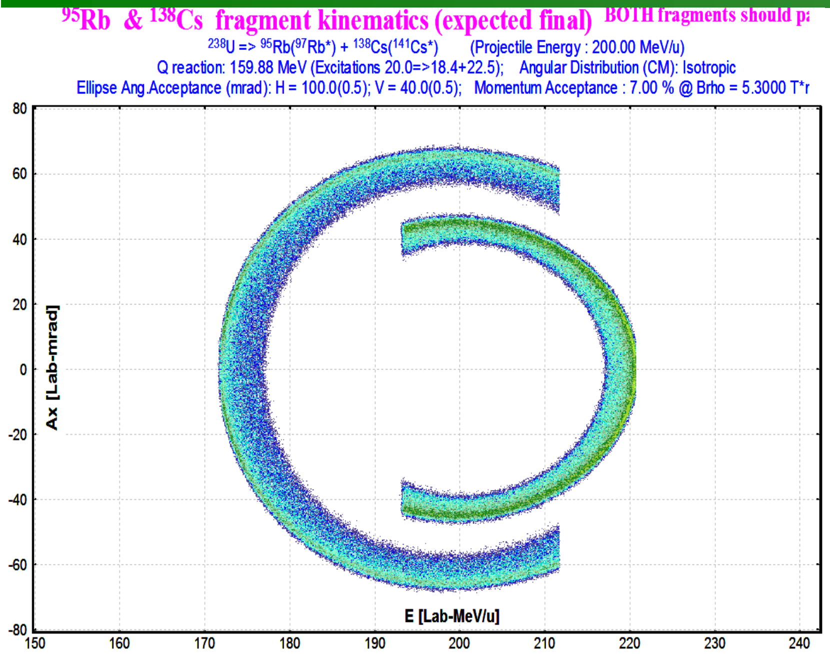


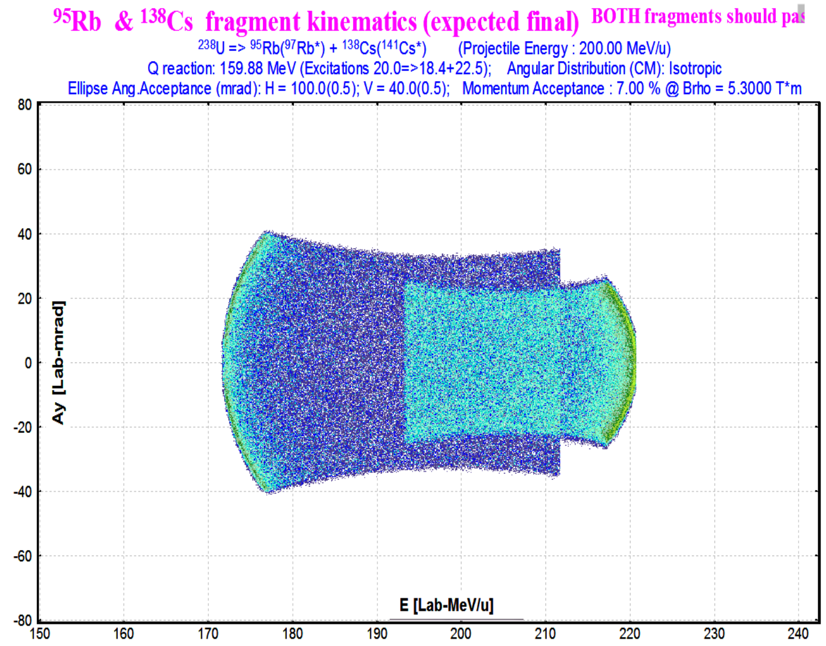
Acceptances and non-zero target thickness

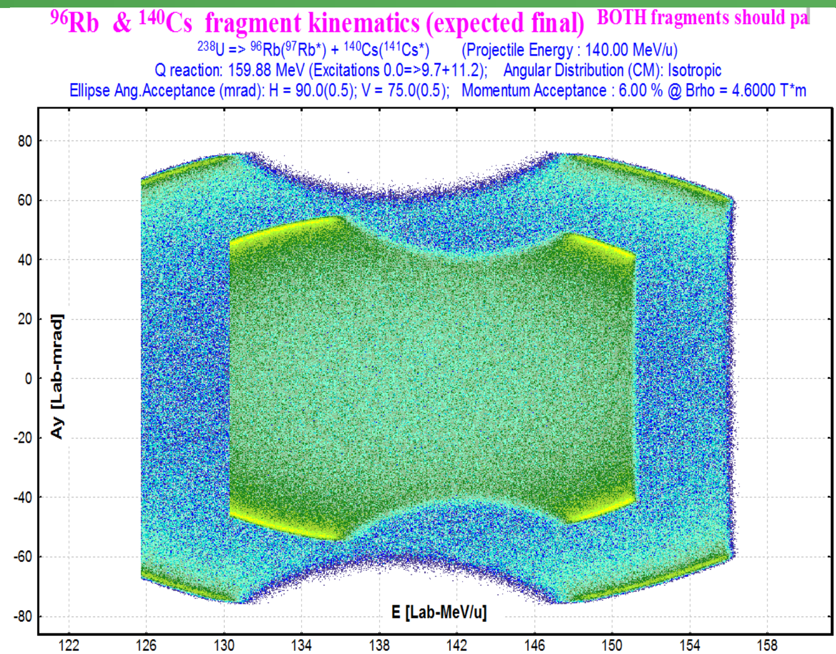


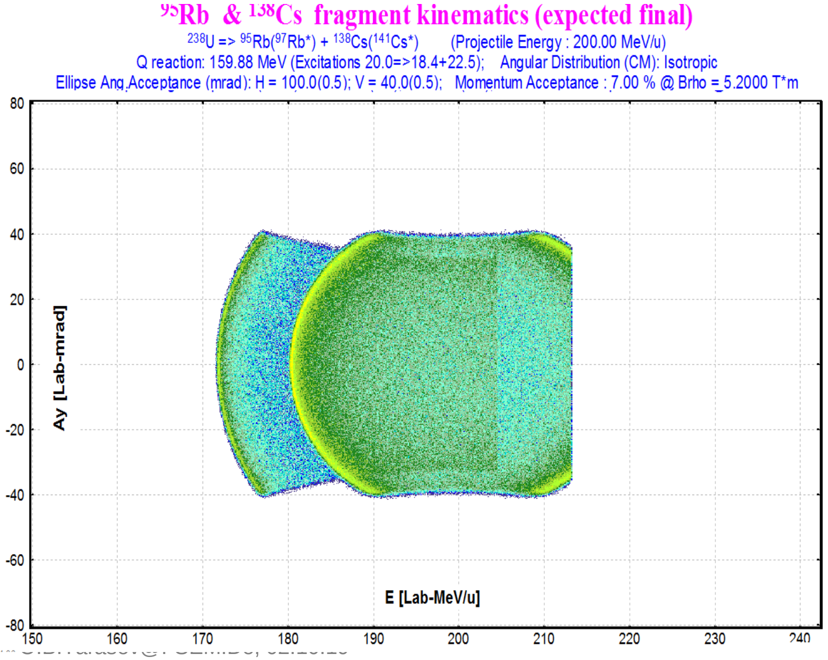


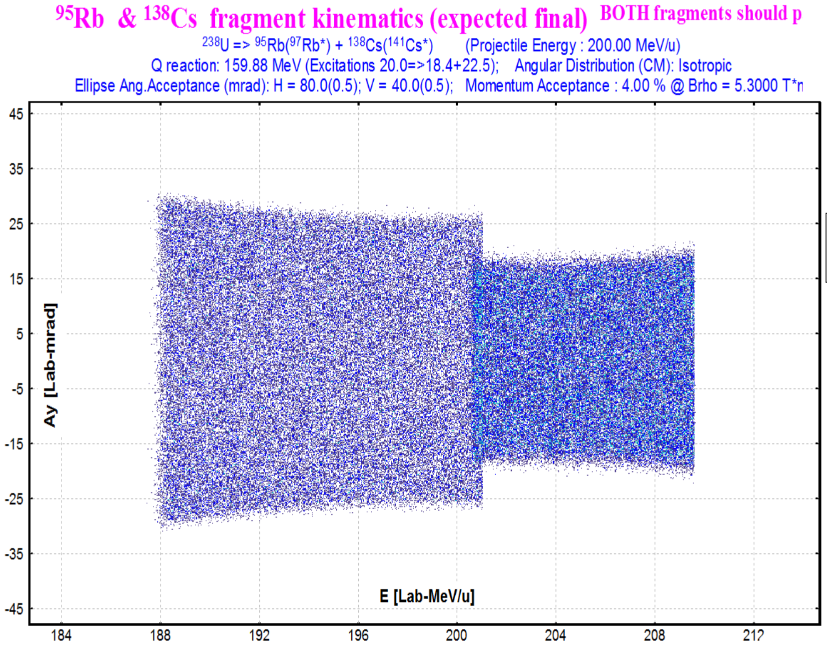
Some other plots…..

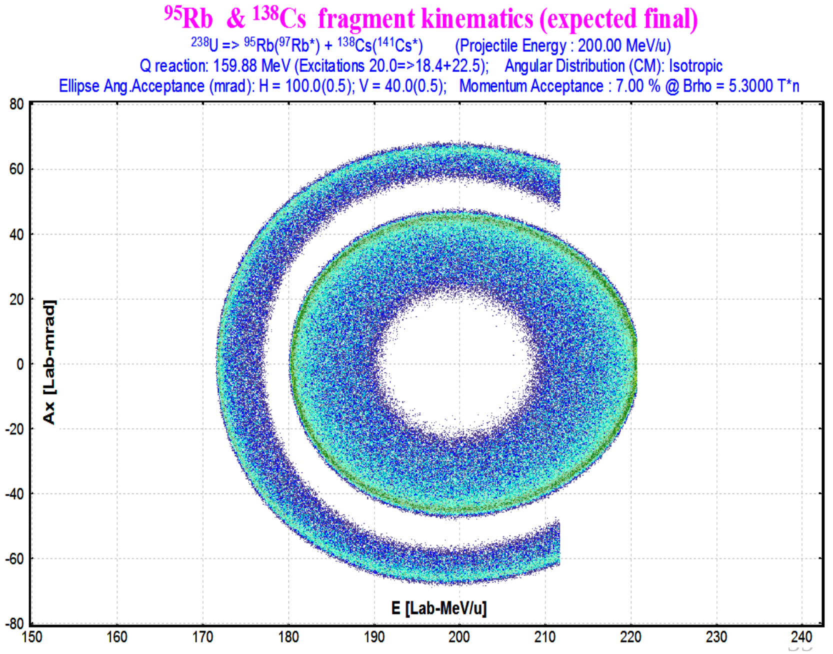








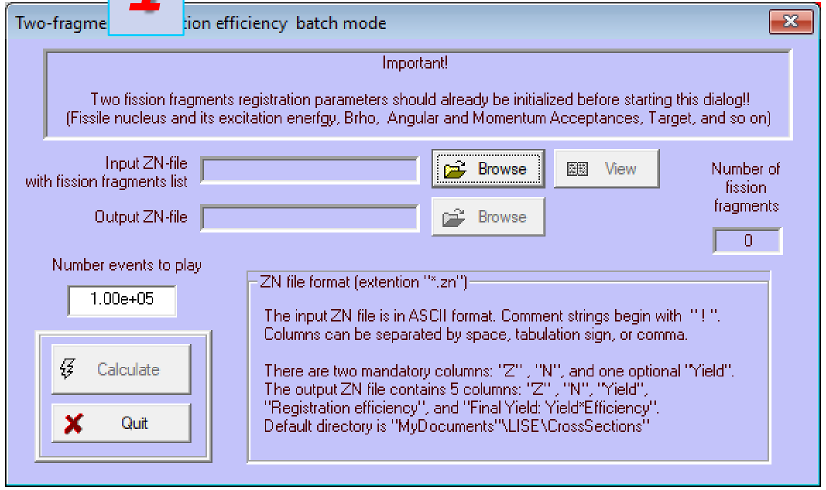




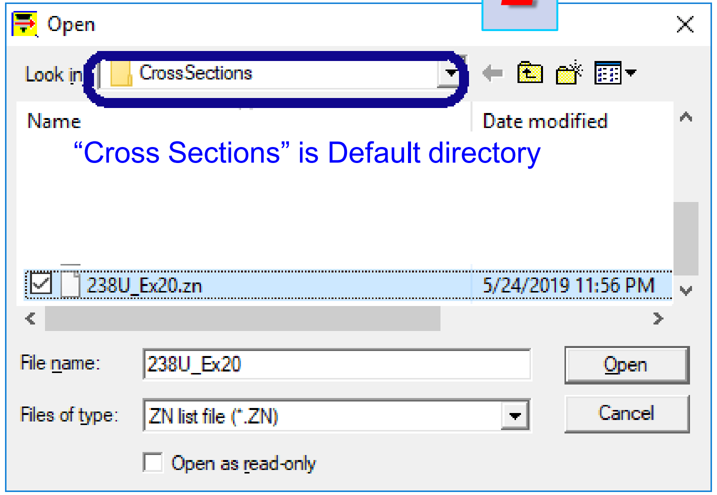
Two Fission Fragments registration efficiency BATCH mode

Fission Fragment Batch Mode dialogue

1

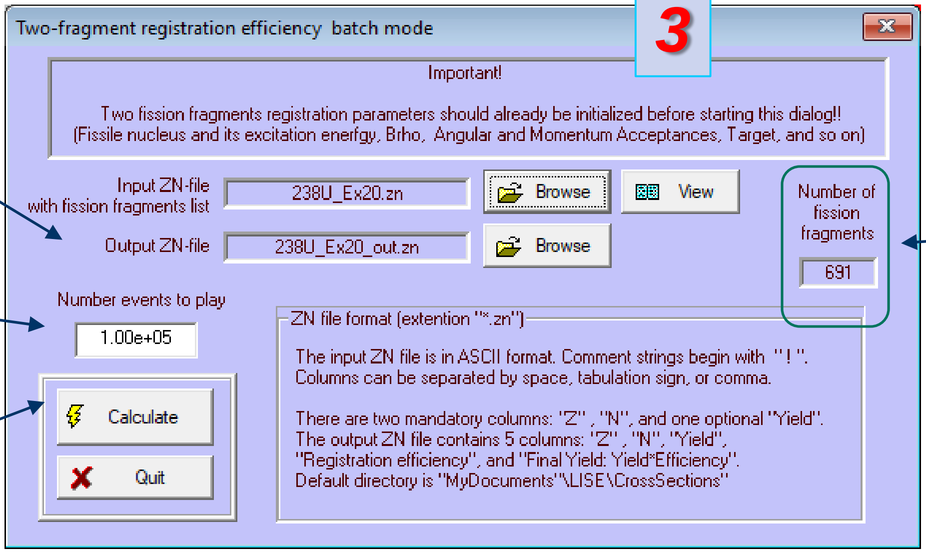


2



"Cross Sections" is Default directory

3



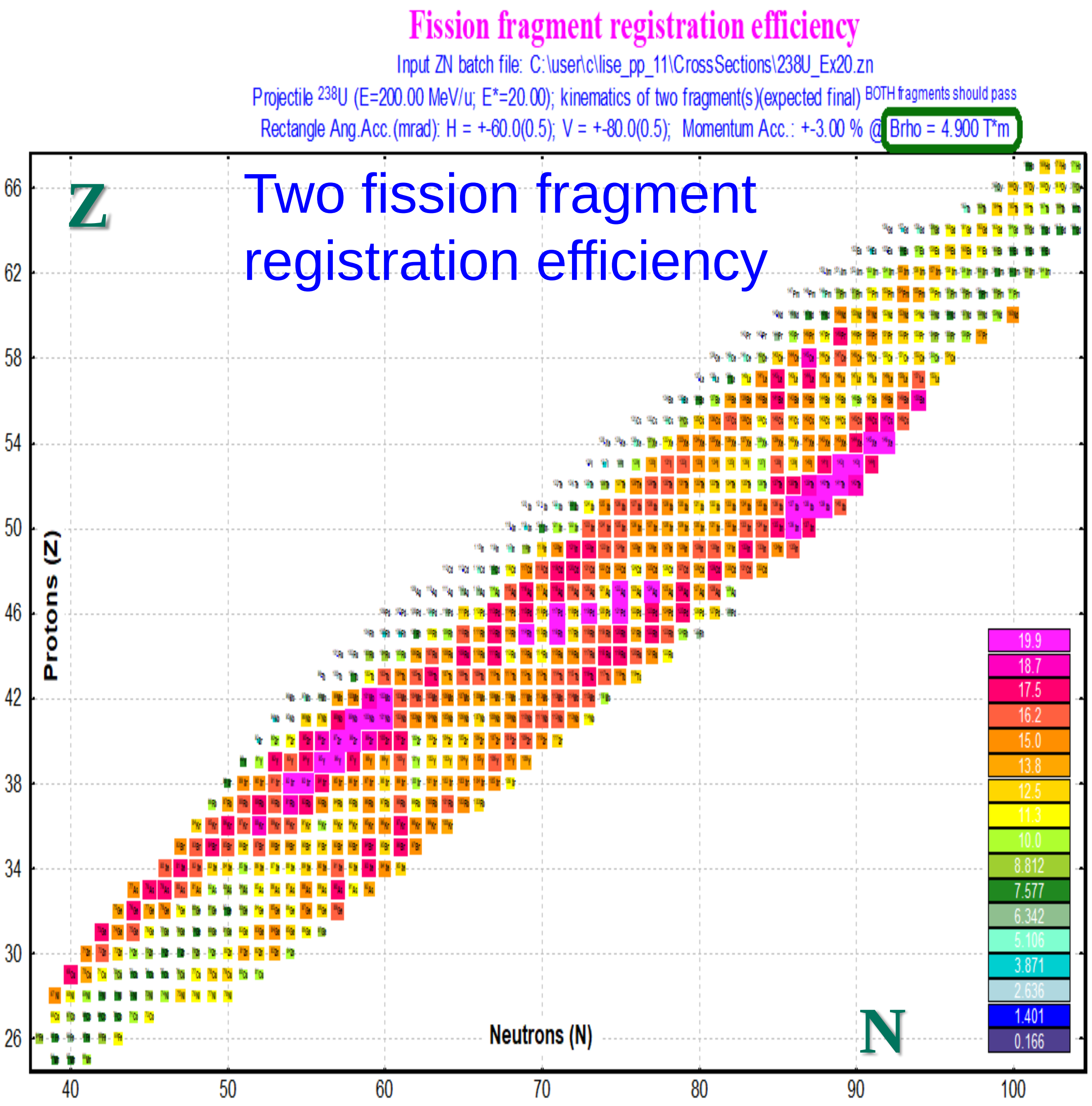
LISE^{++} automatically proposes output fil name. The user can rename it.

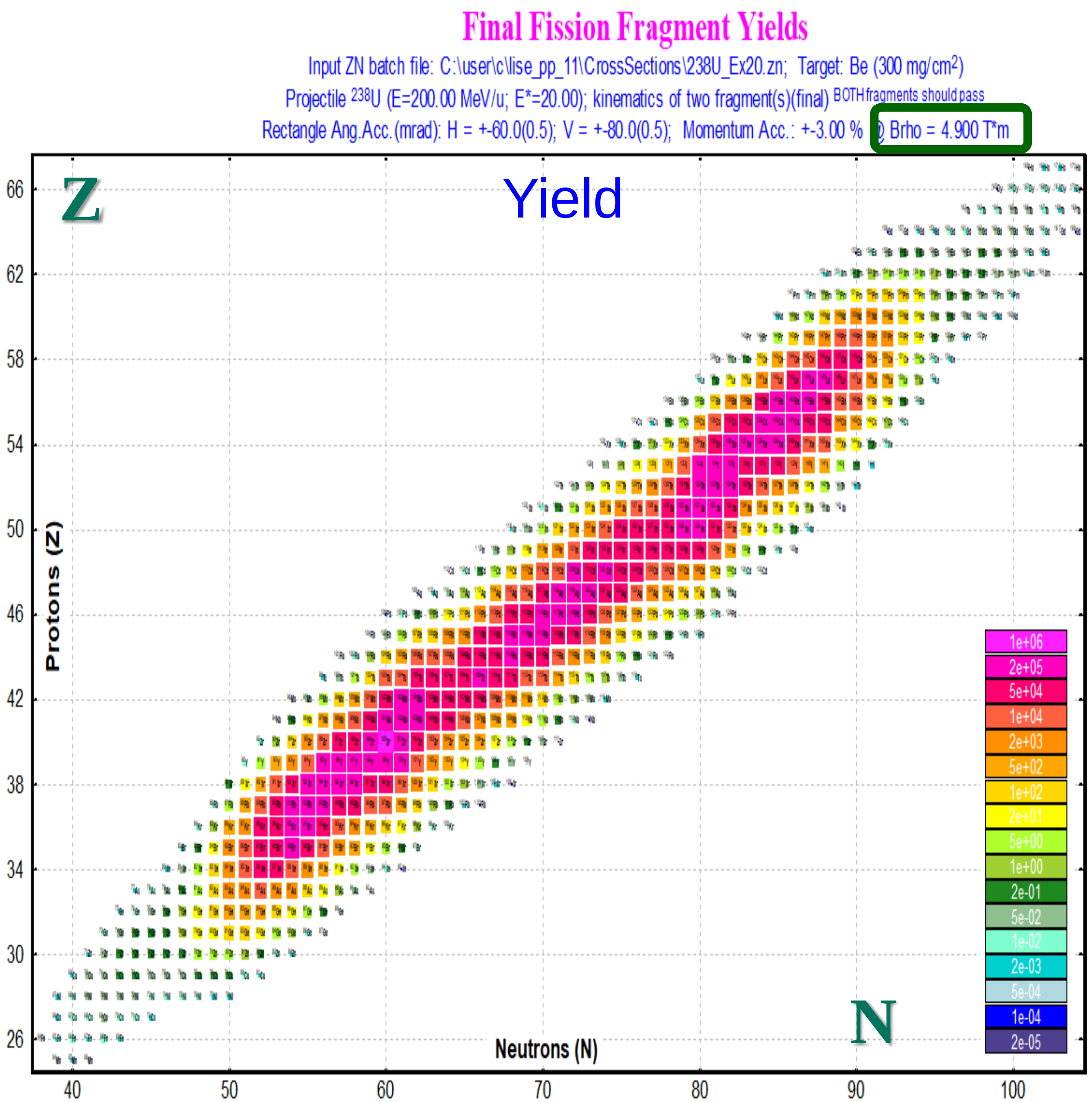
Calculations will be stop reaching this set number of events.
Default value is equal to 1e5, that correspond of 1 event registration to 0.001% efficiency

Run Calculations

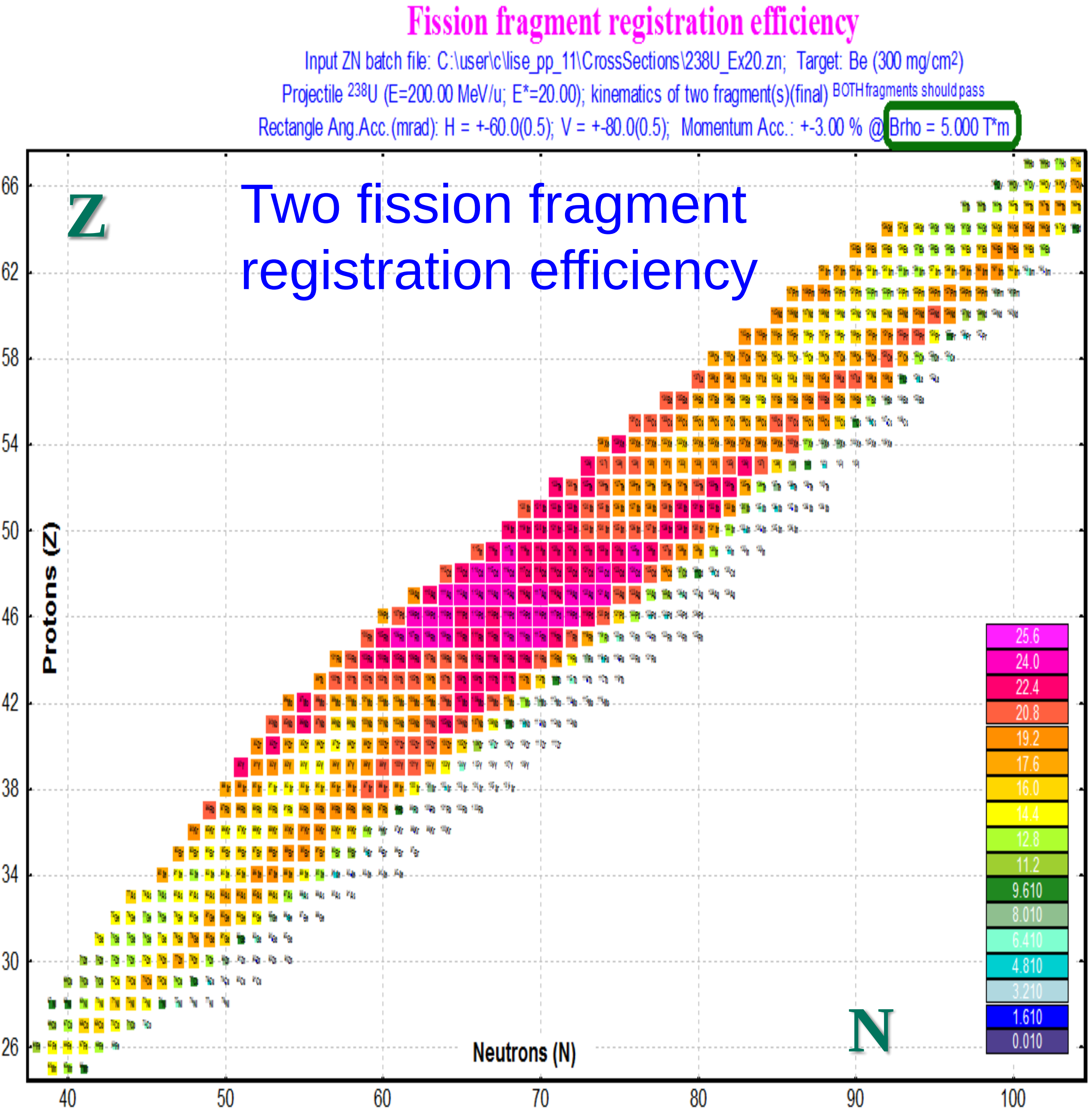
Pay attention for the number of lines corresponding to number of fission fragments (Z, N, Yield after target)

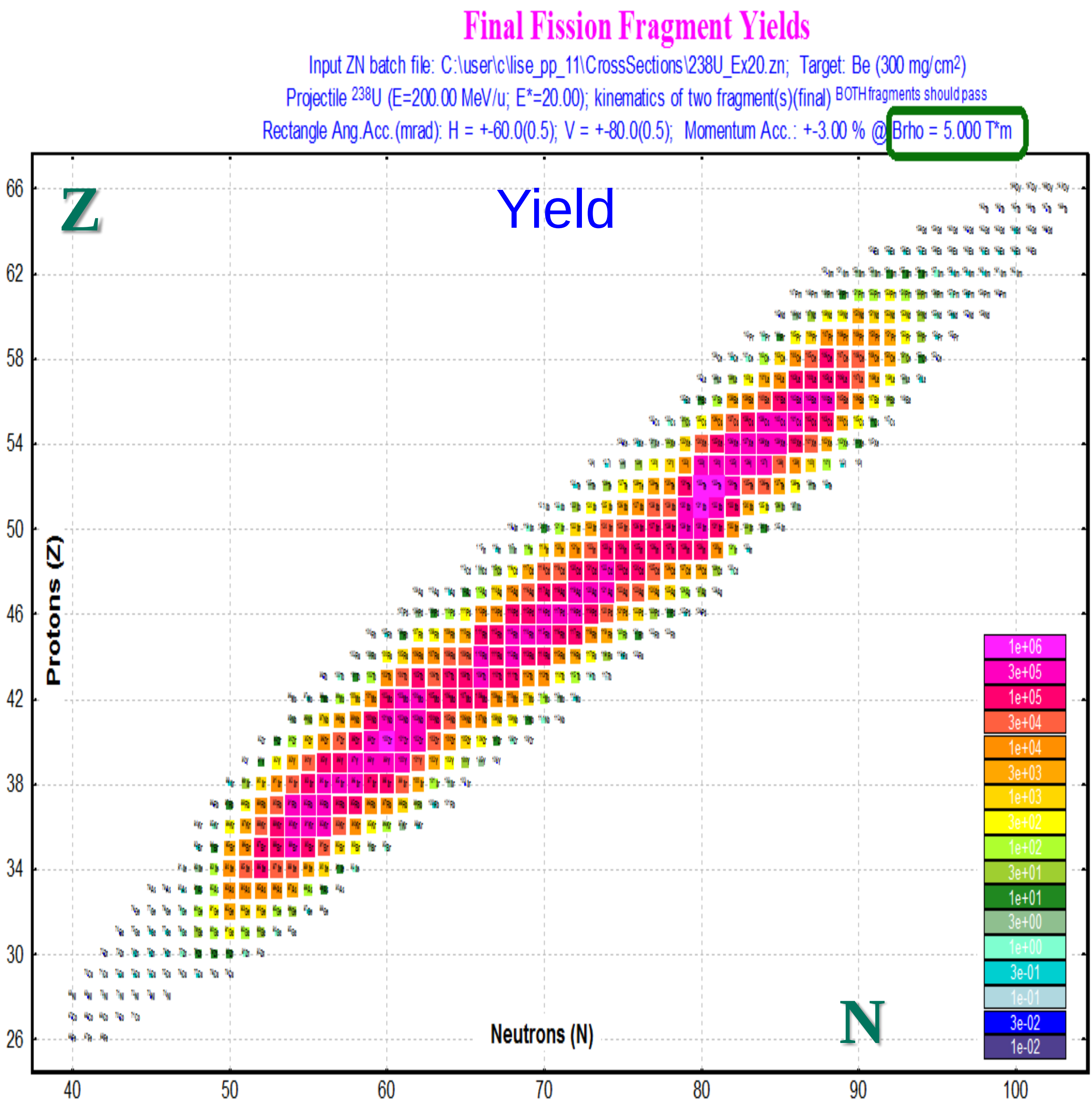
Results : with energy loss in a target → Brho = 4.9 Tm





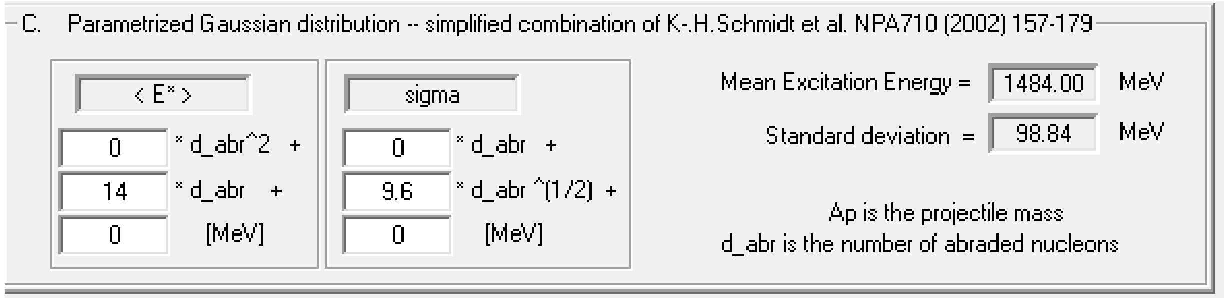
Results : with energy loss in a target → Brho = 5.0 Tm

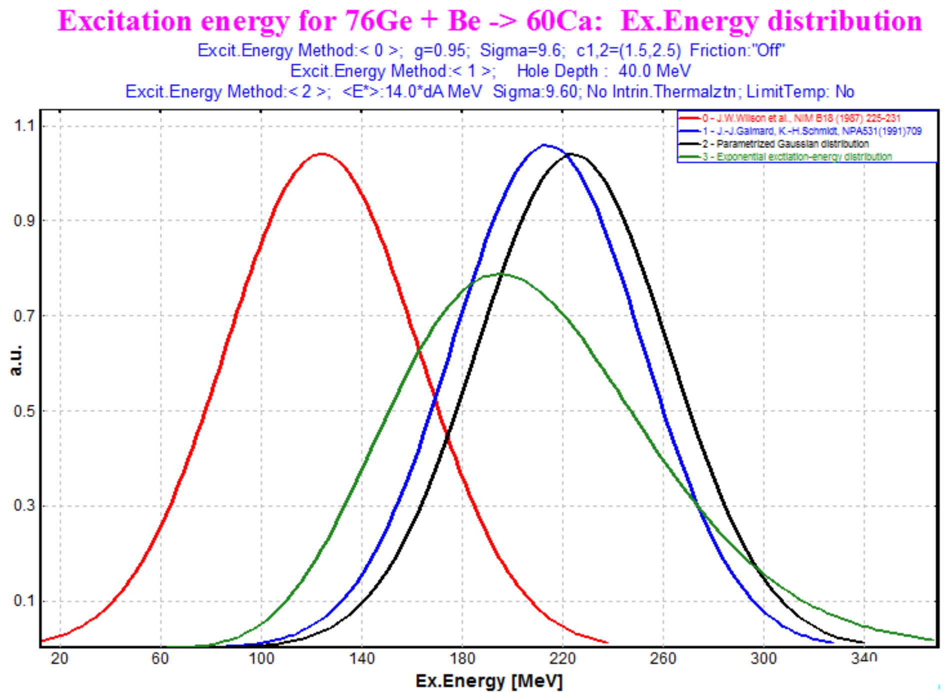




Abrasion-Ablation minimization to describe user cross-sections

Abrasion-Ablation minimization to describe user cross-sections

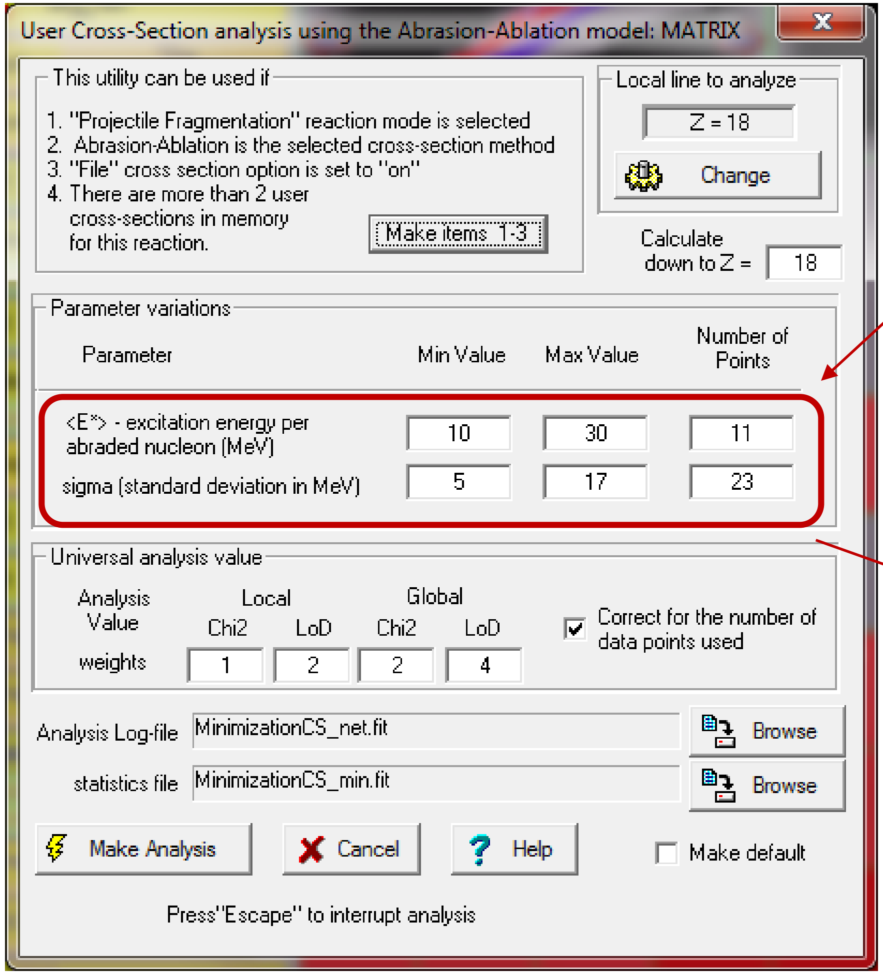




The new utility allows to minimize Abrasion-Ablation excitation energy <u>polynomials</u> (up to 2nd order) to describe user (experimental) cross-sections

v.7.5 09/2005

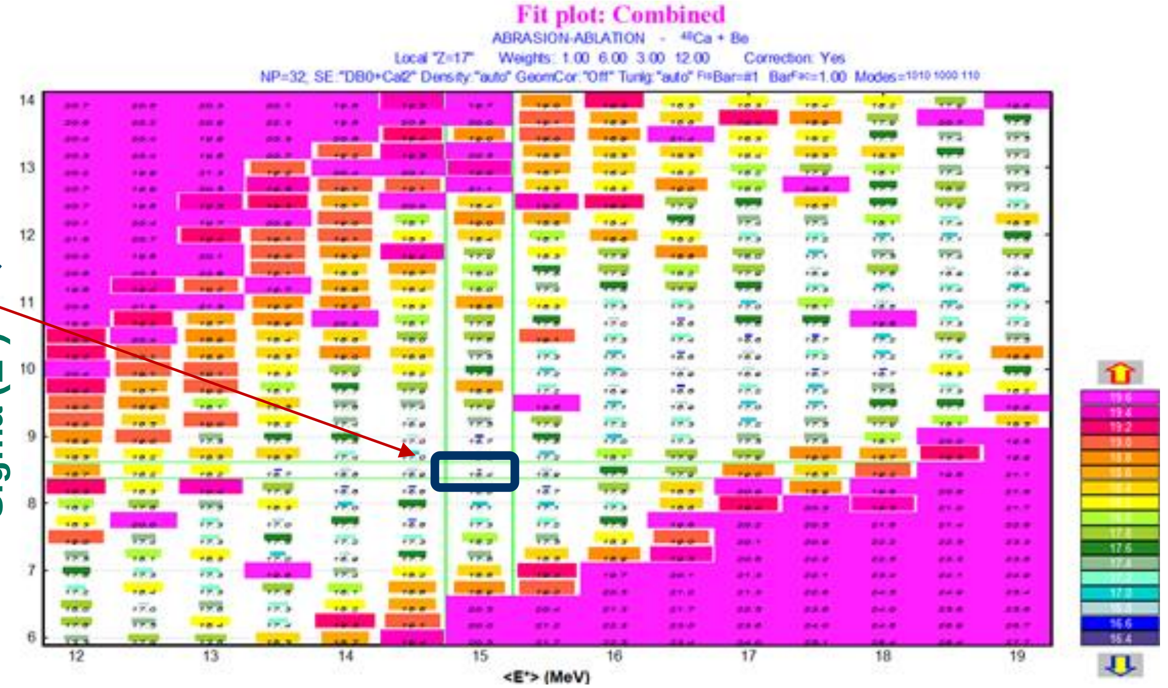
http://lise.nscl.msu.edu/7_5/lise++_7_5.pdf#page=85



The user defines dimensions of the matrix **E* vs Sigma**

answer

Sigma (E*)

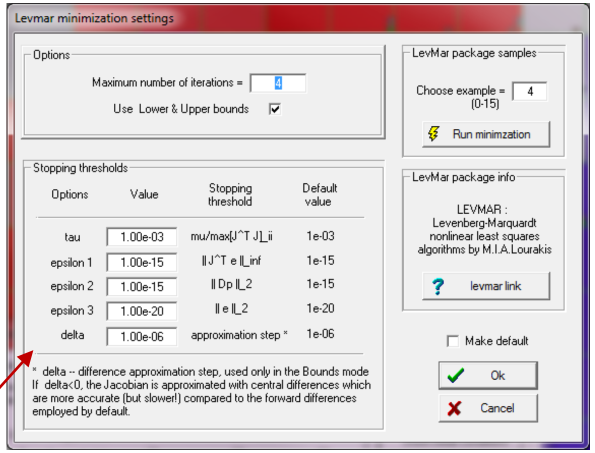


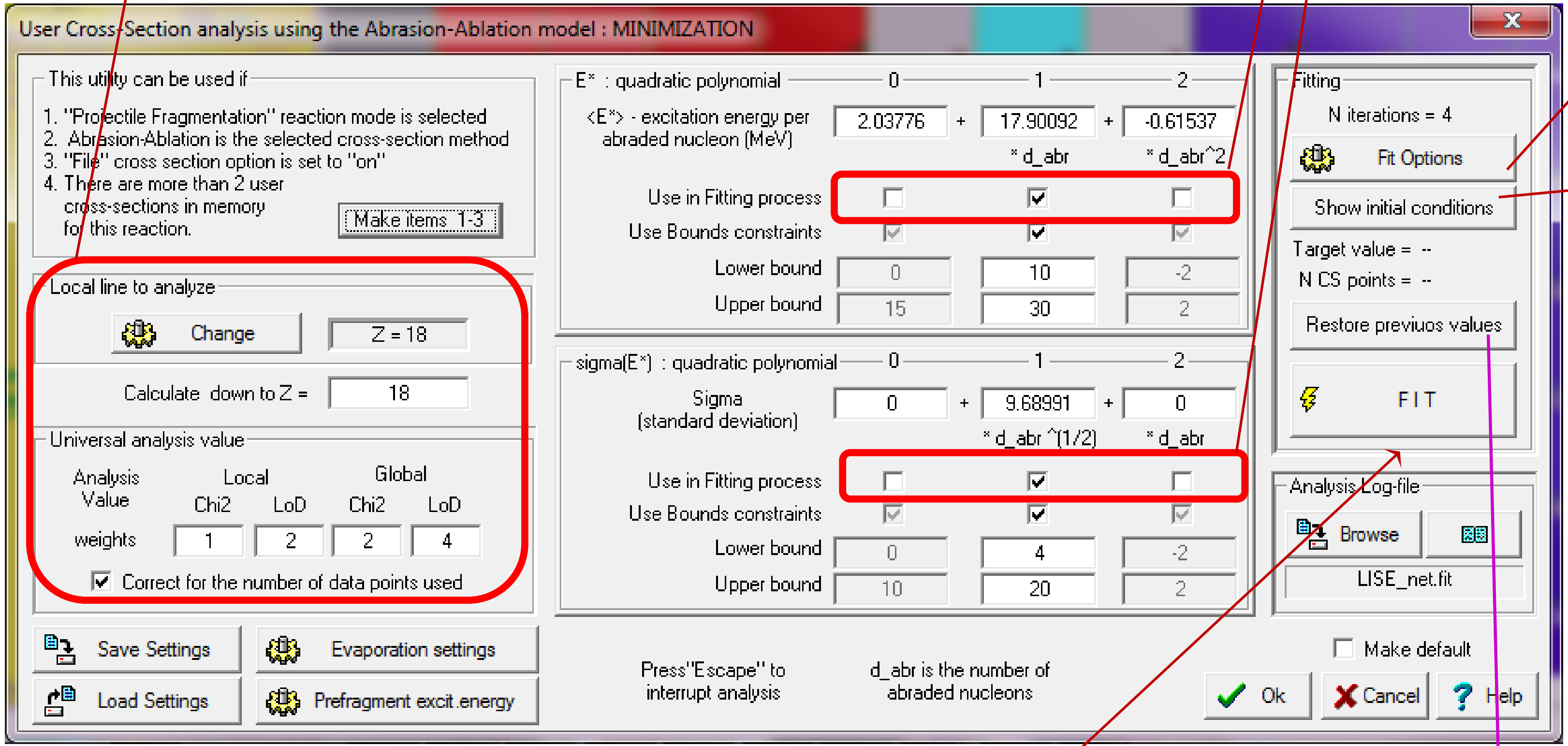
Excitation Energy per Abraded Nucleon (MeV)

Abrasion-Ablation minimization dialog

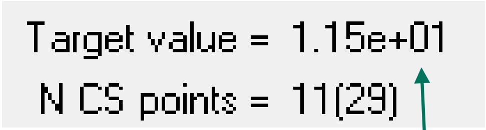
The same approach as
@ Abrasion-Ablation "MATRIX" dialog
http://lise.nscl.msu.edu/7_5/lise++_7_5.pdf#page=85

2 parameters from 8 possible will be varied in the current settings





Press it to get initial values:



11 CS points at the local line (Z=18)
29 CS points total down to Z=18

Value to minimize

Minimization start

Restore previous values if the minimization process has been canceled

Next steps

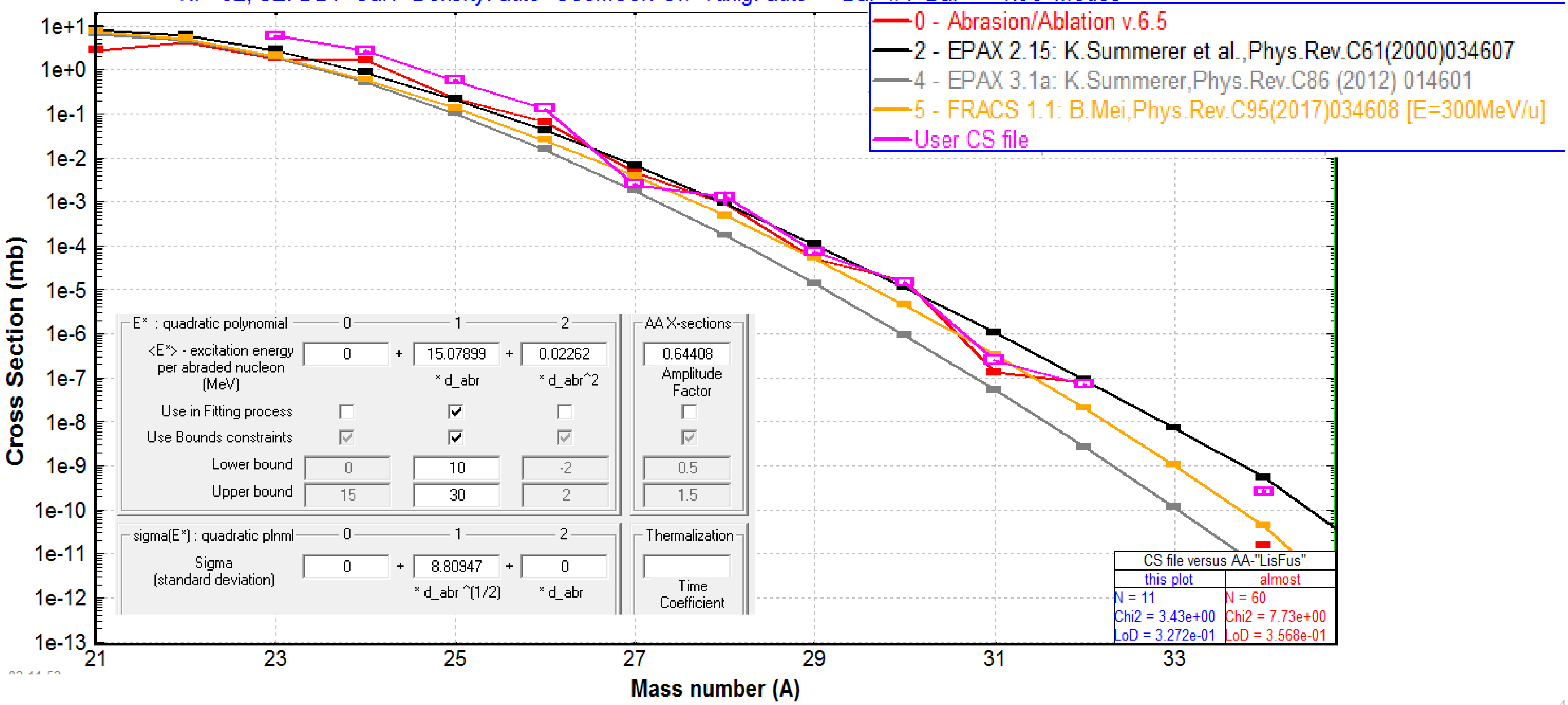
Applying the new utility to analyze the recent RIEKN experimental data obtained with ^{132}Sn, ^{70}Zn, ^{78}Kr and ^{48}Ca beams using different mass tables.

^{48}Ca+Be @ RIKEN, UNEDF0 mass

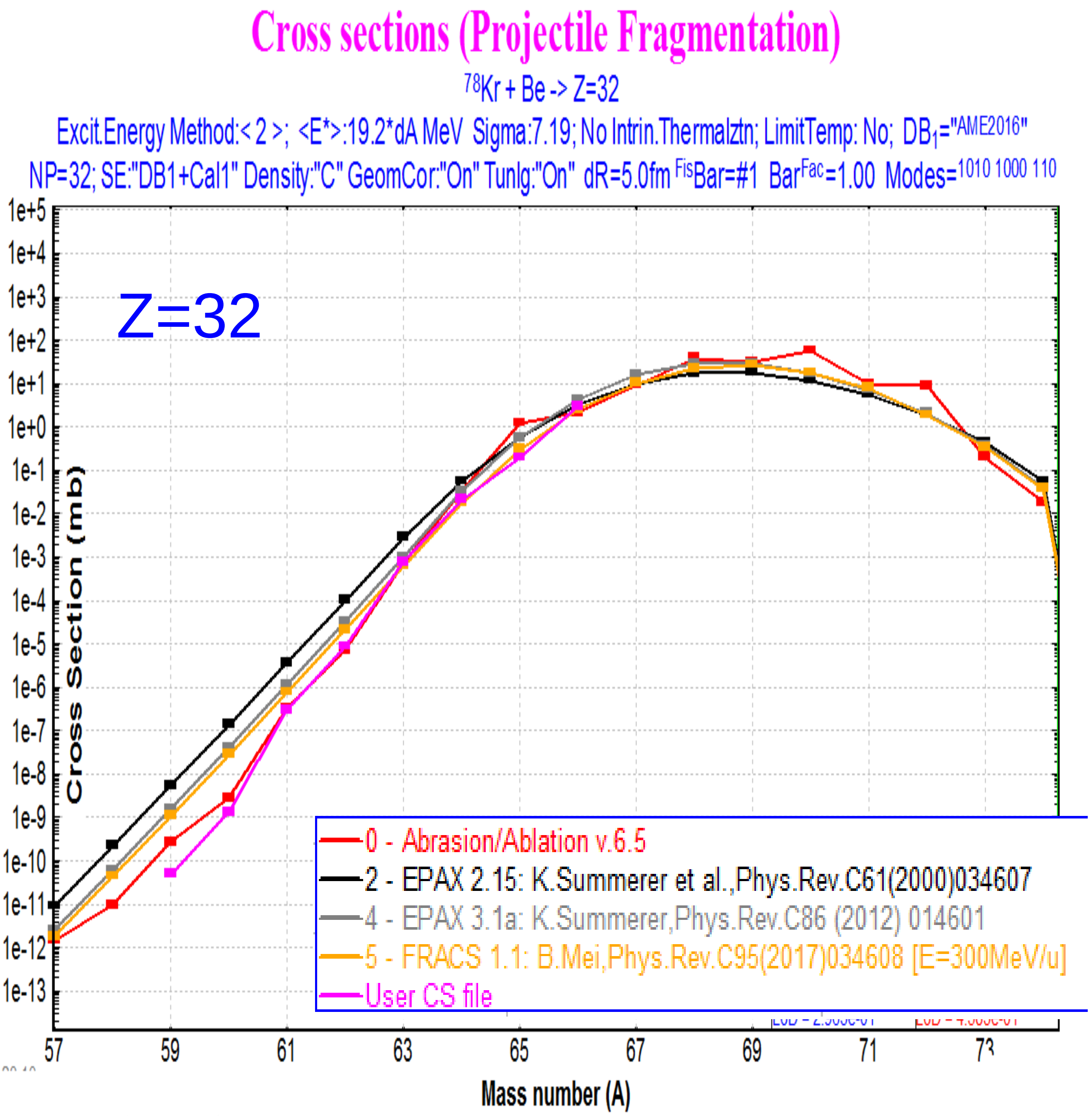
Cross sections (Projectile Fragmentation)

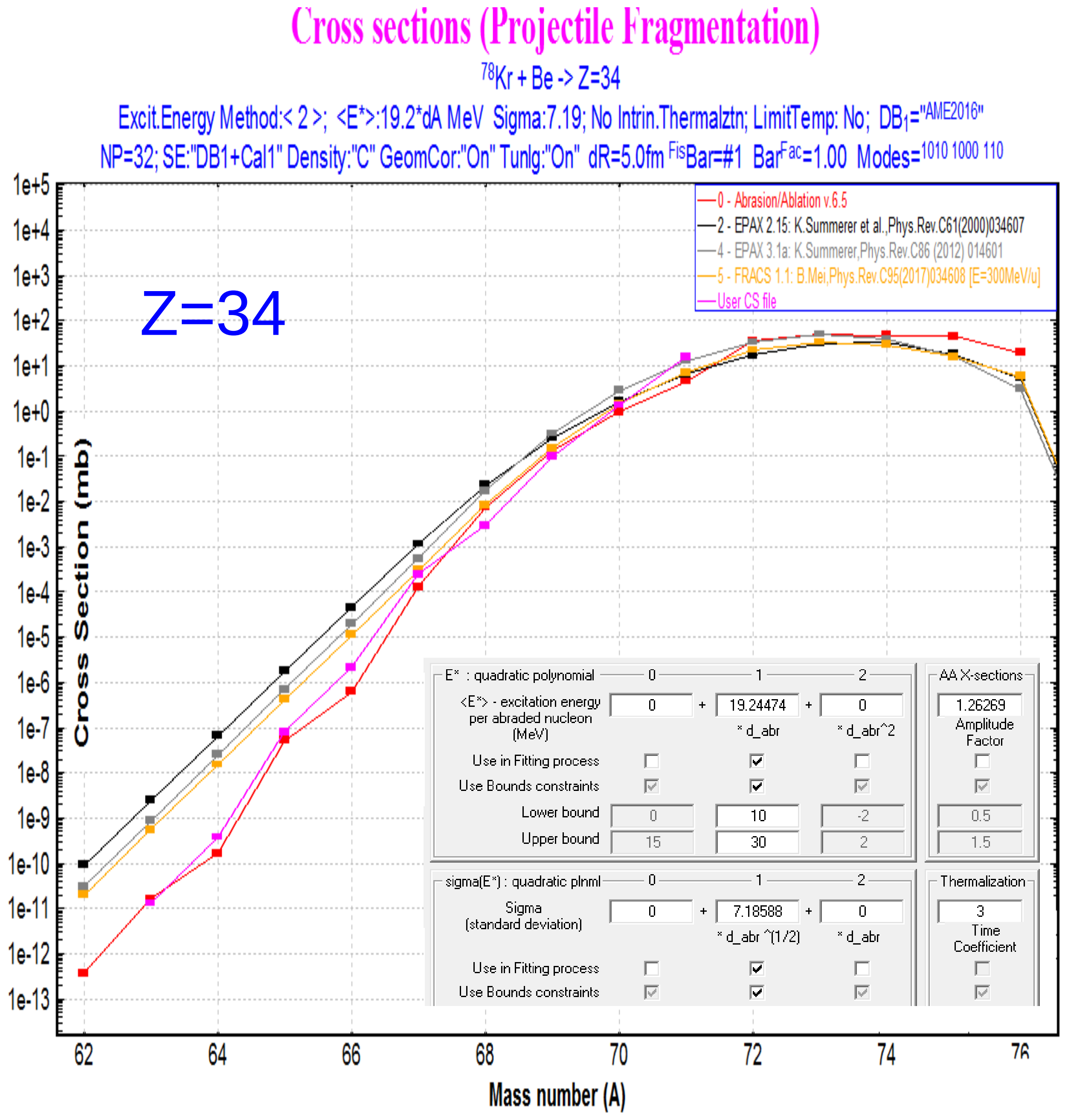
^{48}Ca + Be -> Z=10

Excit.Energy Method:< 2 >; <E*>:15.1*dA MeV Sigma:8.81; No Intrin.Thermalztn; LimitTemp: No; DB_1="AME2016"
NP=32; SE:"DB1+Cal1" Density:"auto" GeomCor:"On" Tunlg:"auto" ^{Fis}Bar=#1 Bar^{Fac}=1.00 Modes=1010 1000 110



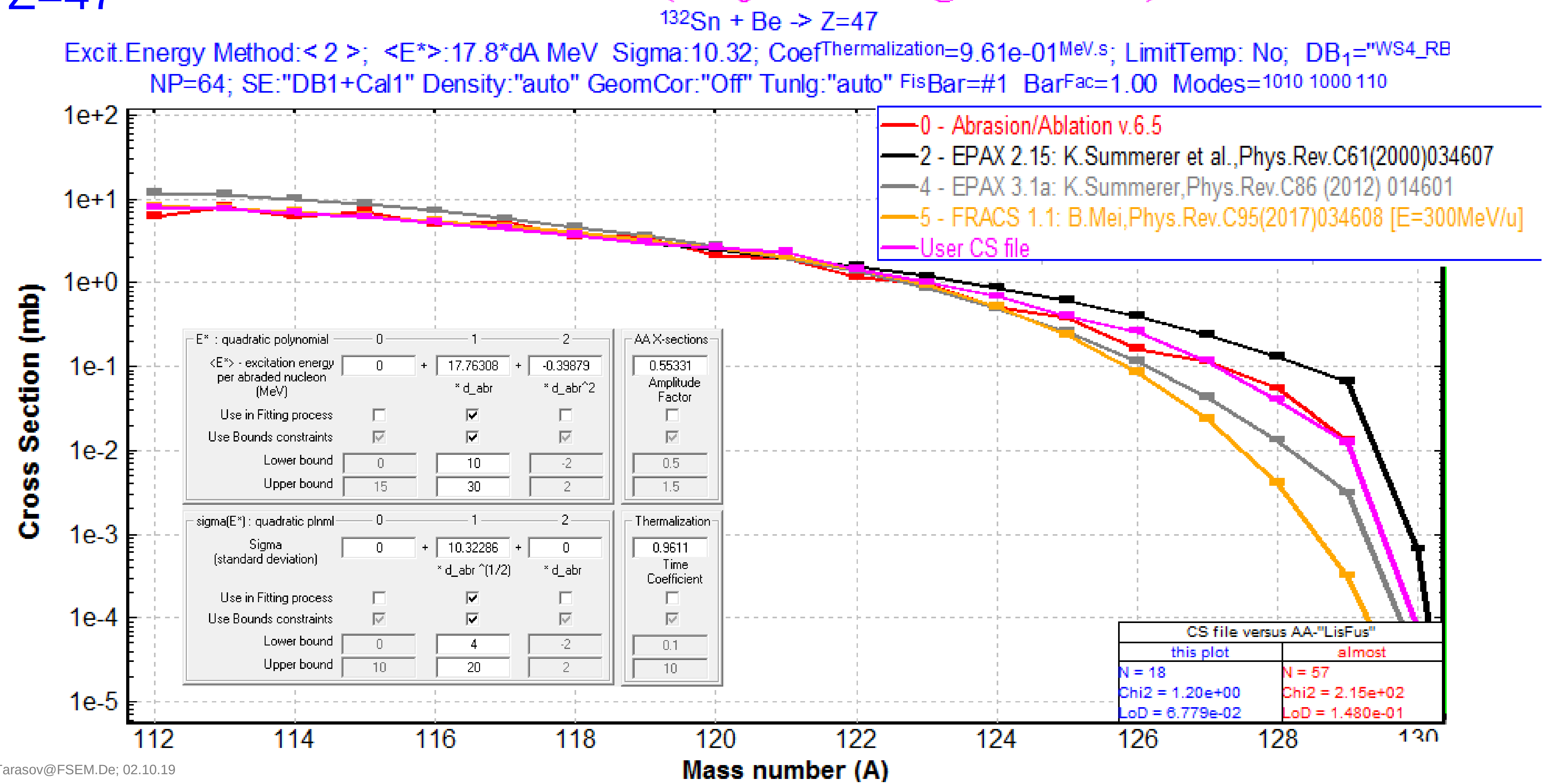
^{78}Kr+Be @ RIKEN, AME2016 mass





Z=47

Cross sections (Projectile Fragmentation)



Momentum distribution: Universal parameterization

Velocity of fragments : neutron-rich region

O.B. Tarasov et al. / Nuclear Instruments and Methods in Physics Research A 620 (2010) 578–584

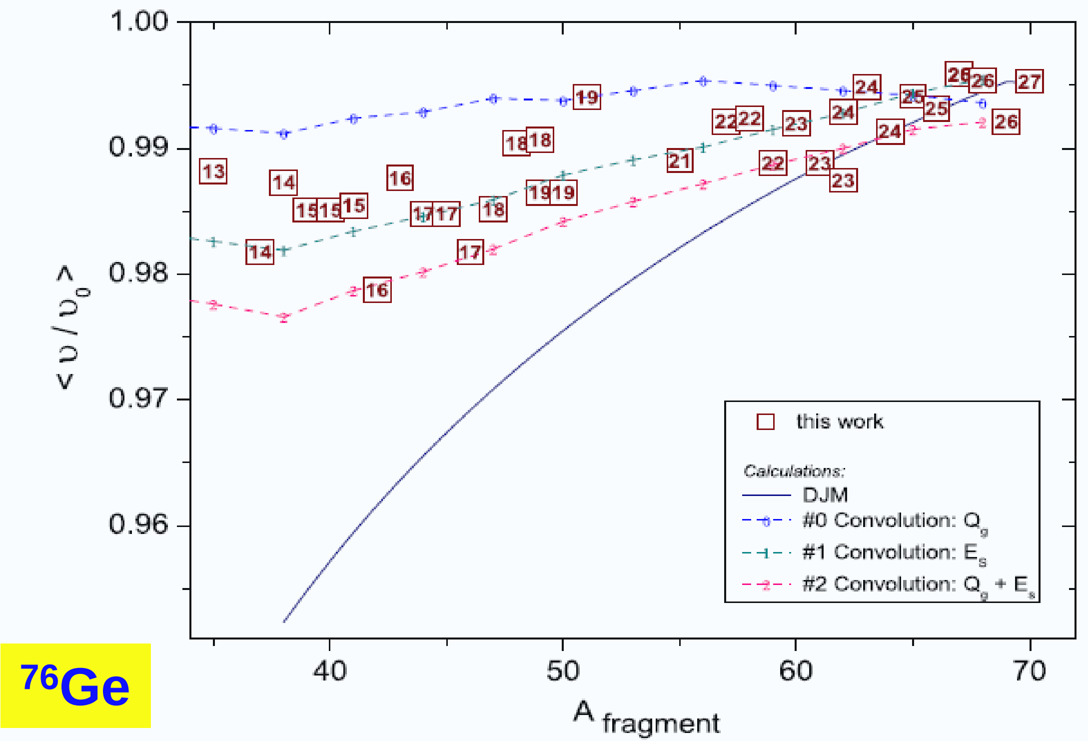


Fig. 4. (Color online) Experimental mean ratios of the fragment velocities to the projectile velocity for neutron-rich isotopes (located along the line $A=2.56q+1.6$) produced by fragmentation of a ^{76}Ge beam at 132 MeV/u with beryllium targets. The atomic numbers are shown inside of rectangles. The solid line represents calculations using Morrissey's model [2] with default settings ($\sigma_0=87$ MeV/c, $E_S=8$ MeV). See text for details. The dashed lines represent the convolution model results with separation energy modes as listed in Table 4.

the separation energy parameter for nuclei observed in the present work in the region $A_P/2 \le A_F \le A_P$ exhibits a linear decrease with the number of removed nucleons:

for DJM

$$E_S = 8 - 11.2\Delta A/A_P$$

where $\Delta A = A_P - A_F$, A_P is the projectile mass number, and A_F is the fragment mass number.

OT et al., PHYSICAL REVIEW C **87**, 054612 (2013)

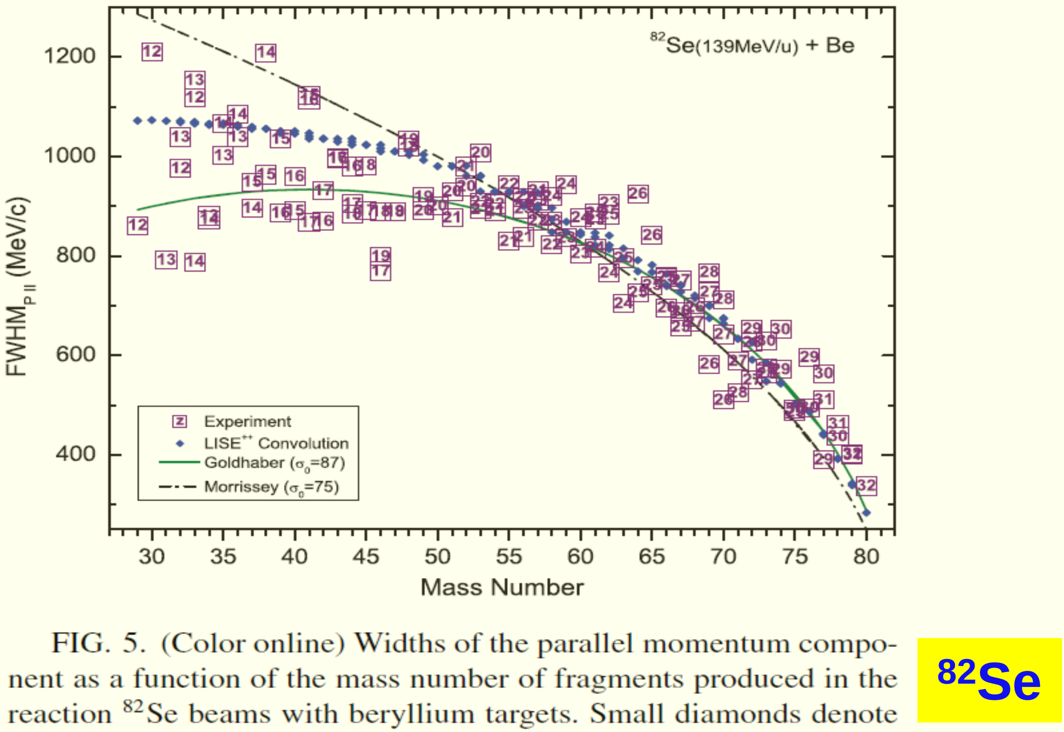


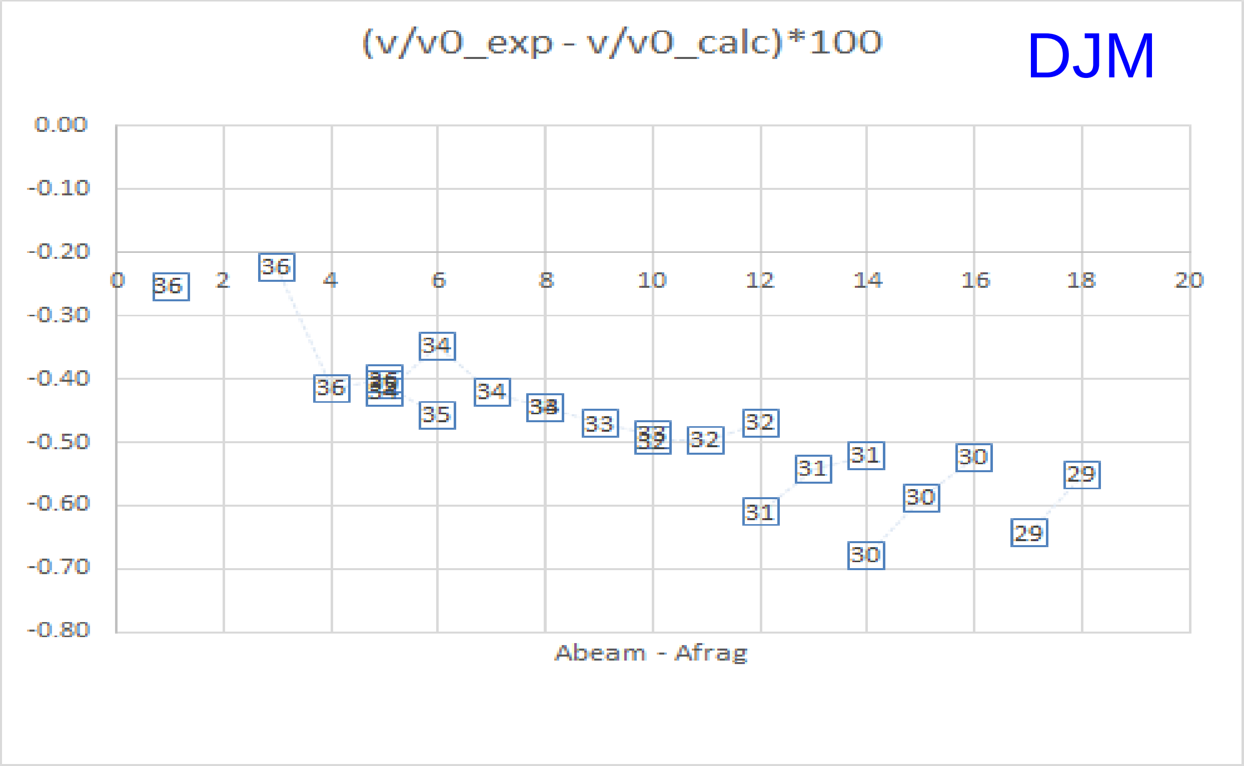
FIG. 5. (Color online) Widths of the parallel momentum component as a function of the mass number of fragments produced in the reaction ^{82}Se beams with beryllium targets. Small diamonds denote calculations by the convolution model [38] with default settings for separation energy (E_s) option #1 in LISE^{++}. Solid green and dot-dashed black lines represent the best fit to the data for the Goldhaber [35] and Morrissey [36] models, respectively.

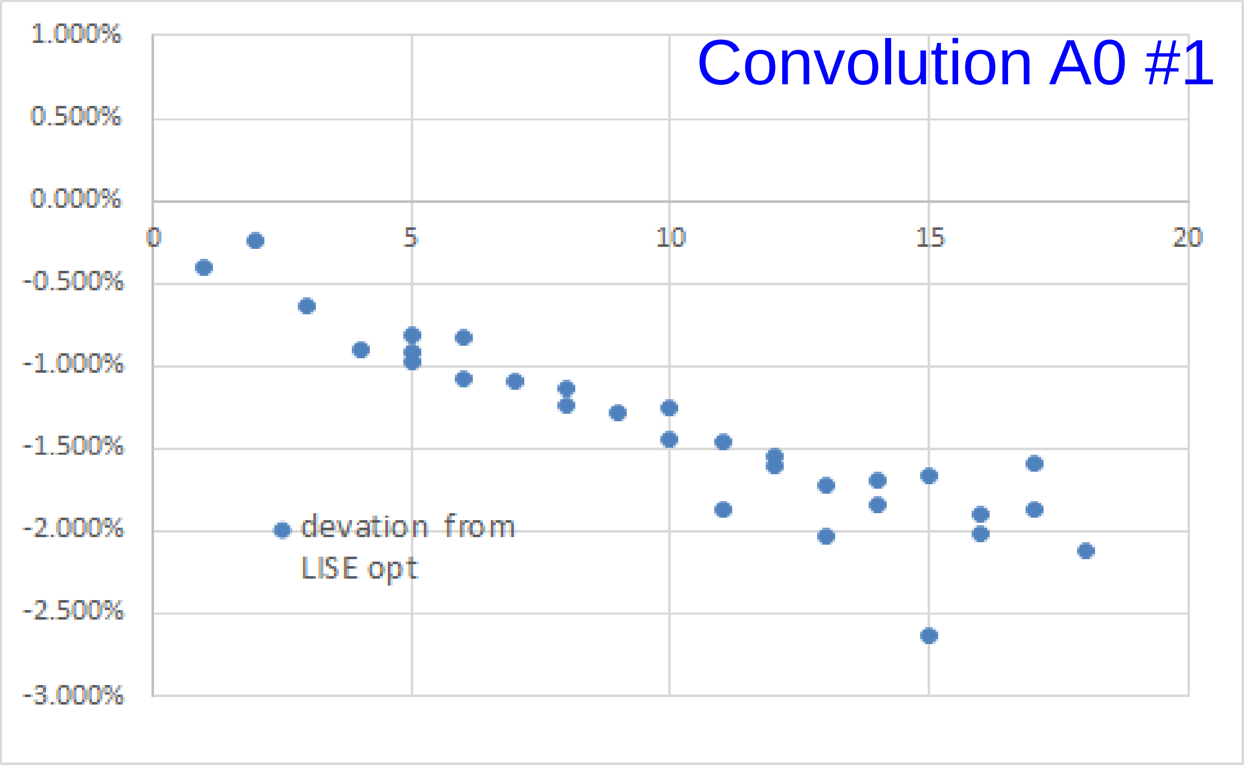
for DJM $E_S = 8 - 9.2\Delta A/A_P,$

The Universal parameterization fairly describes mean values and widths of velocity distributions in a neutron-rich region, whereas fragments are faster and distributions are narrow comparing to the DJM parameterization with default parameters.

Velocity of fragments : proton-rich region

^{78}Kr (150 MeV/u) + Be(374 mg/cm^2) @ NSCL





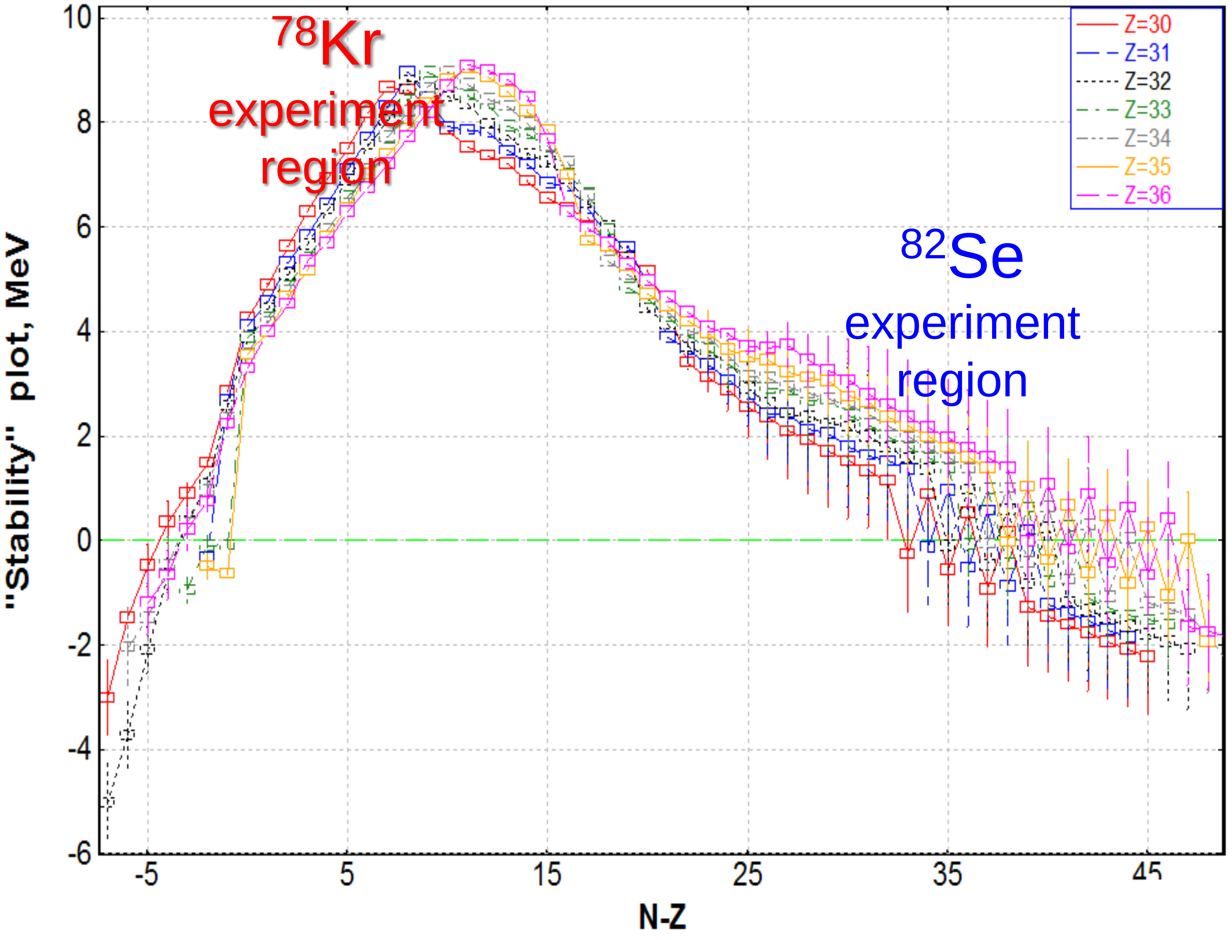
http://lise.nscl.msu.edu/paper/velocity/2019_05_17_78Kr_results.pdf

Both models with default parameters predict significantly faster fragments.
DJM with E_s parameter equal to 10 (instead default 8) reproduce experimental data

Binding energies changes from west to east

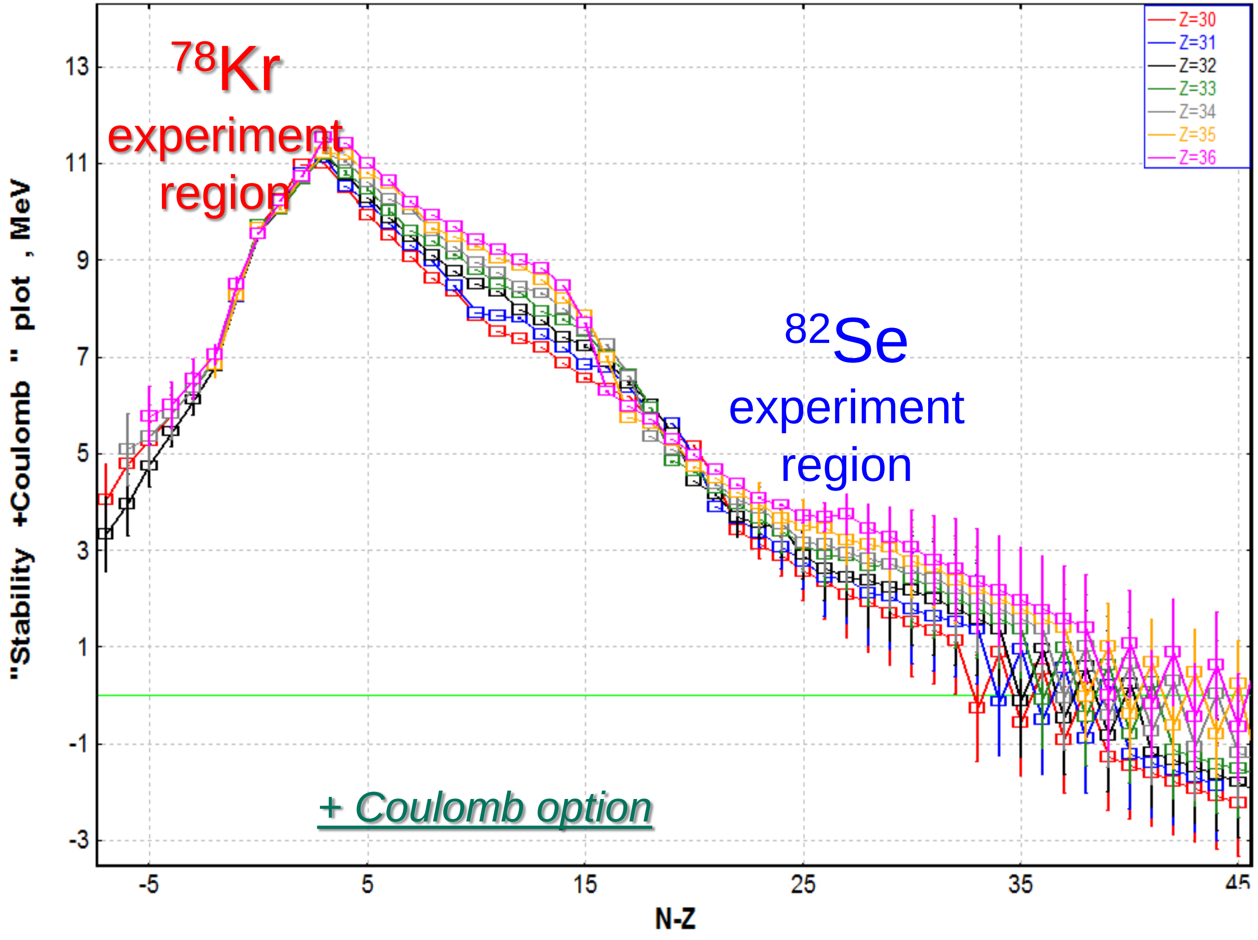
"Stability" plot

<Database: AME2016 (database) + LDM2>
Z=30-36
Reduced value based on from S_{1n}, S_{2n}, S_{1p}, S_{2p}, Barrier $_{Fission}$ -1



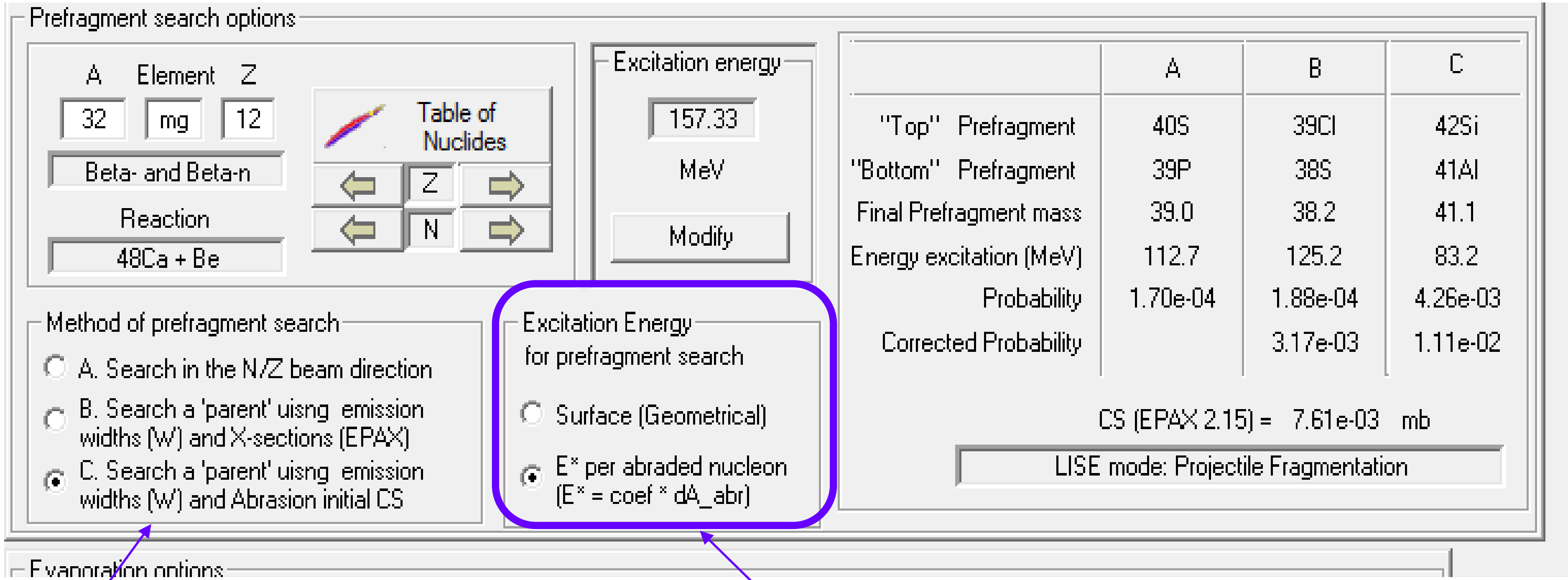
"Stability$^{+Coulomb}$" plot

<Database: AME2016 (database) + LDM2>
Z=30-36
Reduced value based on from S_{1n}, S_{2n}, $S_{1p}+CB_p$, $S_{2p}+CB_{2p}$, Barrier $_{Fission}$ -1



http://lise.nscl.msu.edu/9_8/LISE_stability_plot.pdf

New excitation energy model (#1) to use in prefragment search

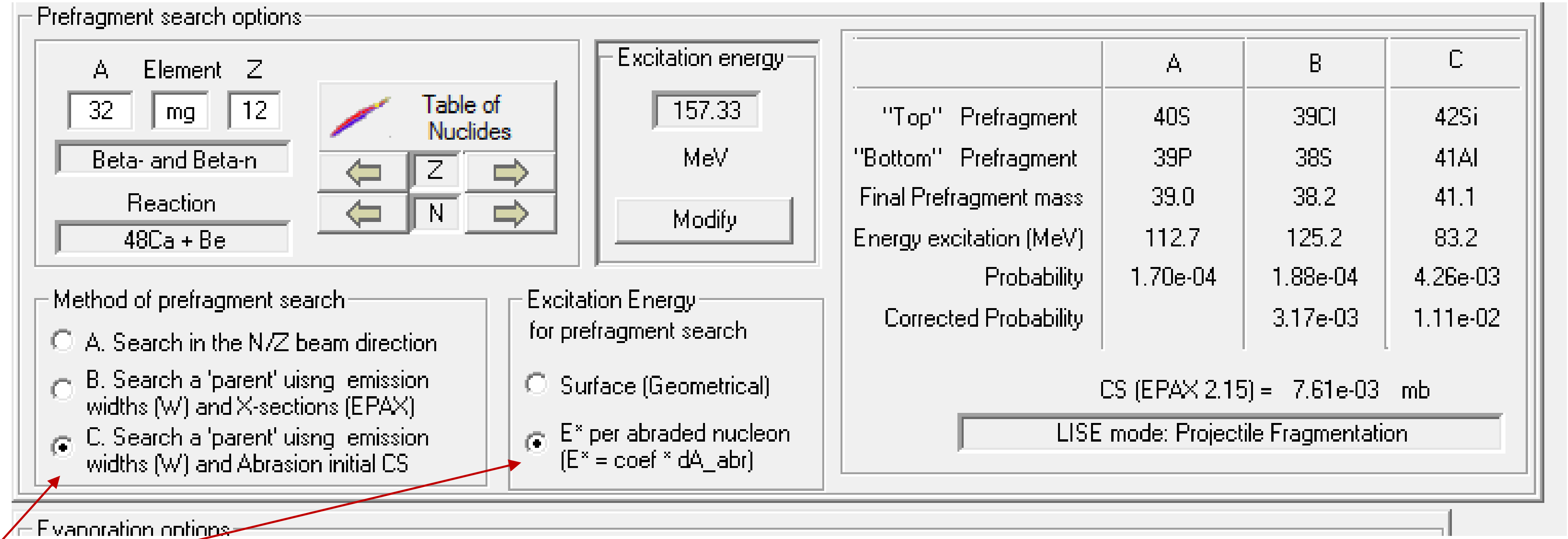


new search option :
$P = W * CS_{geom} * \text{factorial}$

New radiobutton frame with new search option: “E* per abraded nucleon”. The Previous search version was based only on the “dSurface” energy.

CS_{geom} – geometrical cross section to for production of prefragment with A-nucleons,
factorial – probability for Z-protons and N-protons after projectile abrasion

Prefragment calculation settings



New default
Settings **“C1”**

What is already out of date? [3]

- Momentum distribution "Convolution" model
  - separation energy models

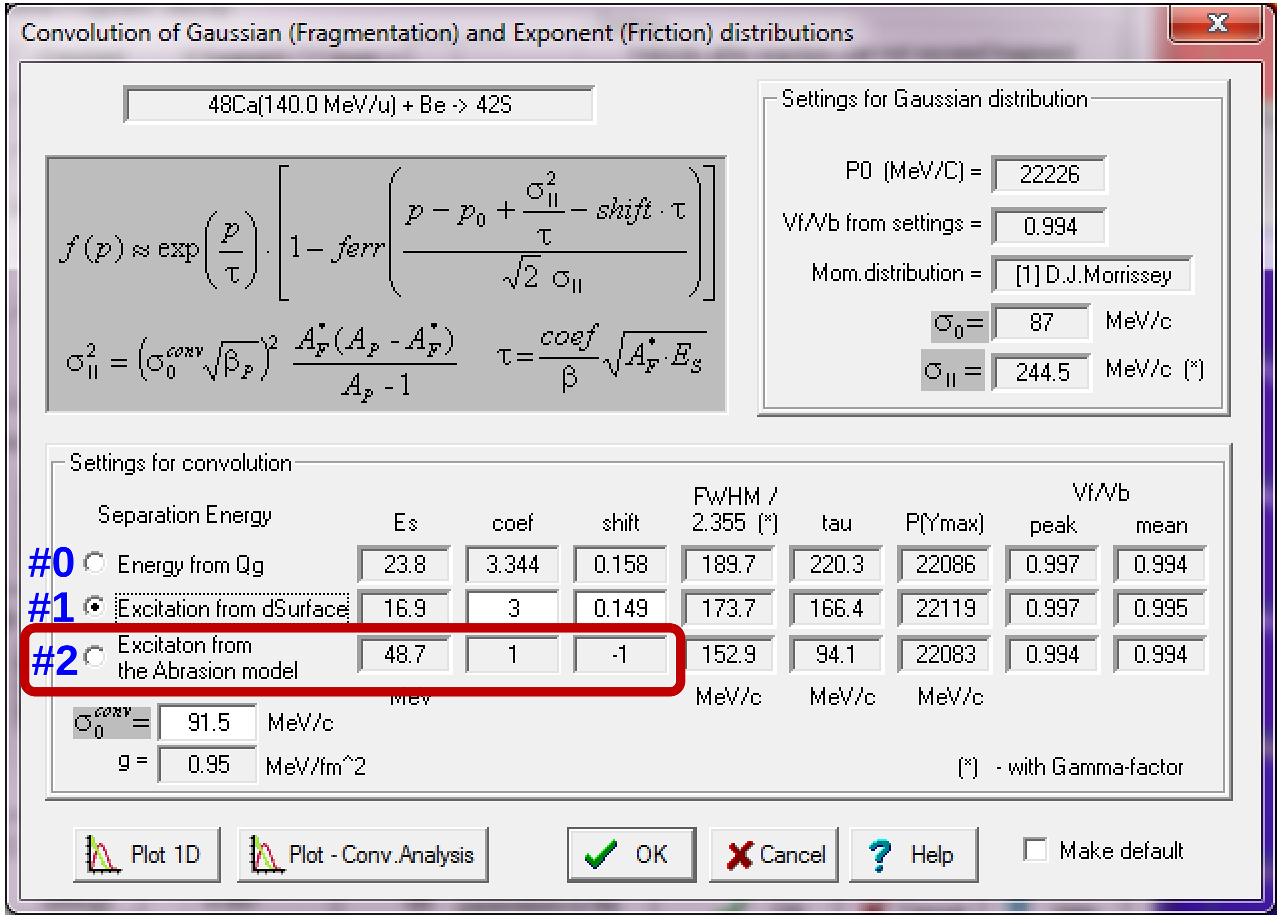
Update of the Convolution method dialog

$$E_S = E_0 * dA$$

dA - number of abraded nucleons calculated by a module set in the Prefragment search dialog

E0 – currently set to 14 Mev

New version



Old version

^{78}Kr (150 MeV/u) + Be(374 mg/cm^2) experiment @ NSCL

NSCL FRIB MICHIGAN STATE UNIVERSITY

A0

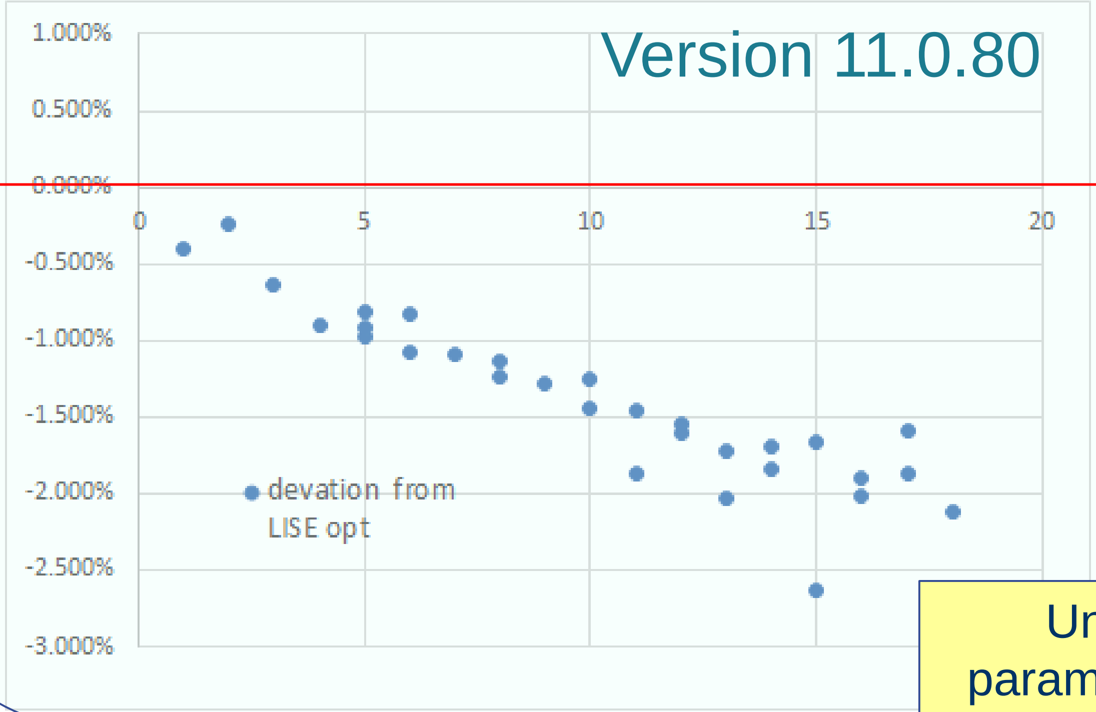
Method of prefragment search
- (•) A. Search in N/Z beam direction
- ( ) B. Search a 'parent' nucleus uisng emission widths and cross-sections

Exc.Energy to prefragment search
- (•) Surface (Geometrical)
- ( ) E* per abraded nucleon E* = c * dAabr

#1

Separation Energy	coef	shift
( ) Energy from Qg	3.344	0.158
(•) Excitation from dSurface	3	0.149
( ) Excitaton from the Abrasion model	1	-1

σ_0^{conv} = 91.5 MeV/c



Universal parameterization

C1

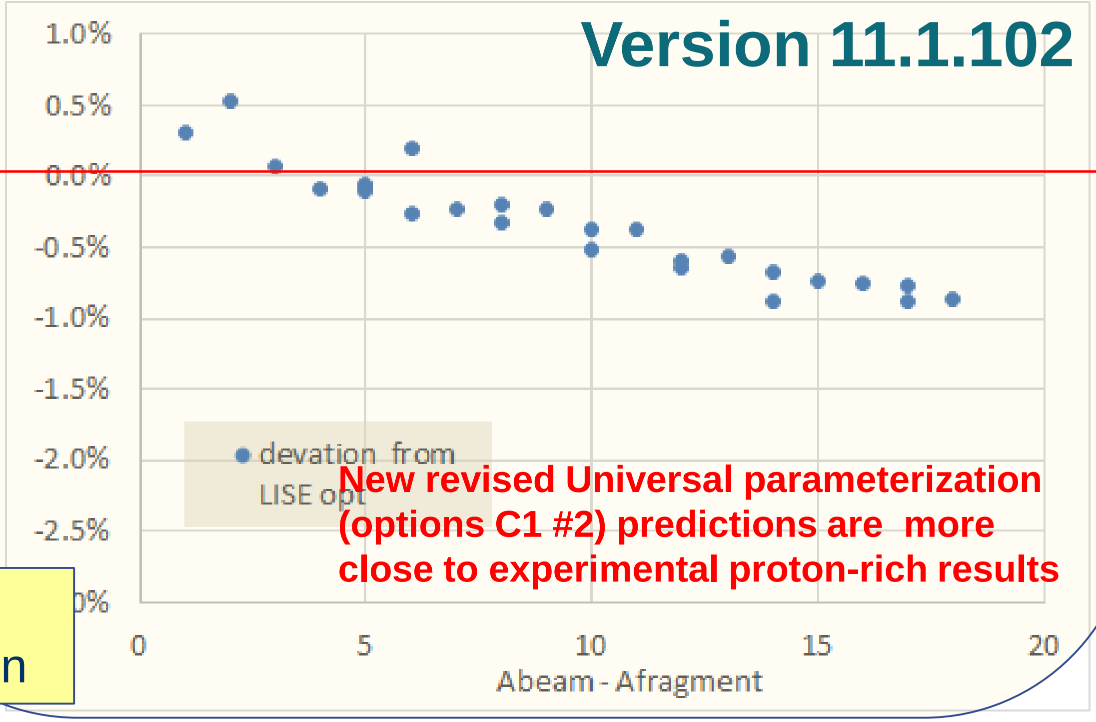
Method of prefragment search
- ( ) A. Search in the N/Z beam direction
- ( ) B. Search a 'parent' uisng emission widths (W) and X-sections (EPAX)
- (•) C. Search a 'parent' uisng emission widths (W) and Abrasion initial CS

Exc.Energy to prefragment search
- ( ) Surface (Geometrical)
- (•) E* per abraded nucleon E* = c * dAabr

#2

Separation Energy	coef	shift
( ) Energy from Qg	3.344	0.158
( ) Excitation from dSurface	3	0.149
(•) Excitaton from the Abrasion model	1	-1

σ_0^{conv} = 120 MeV/c

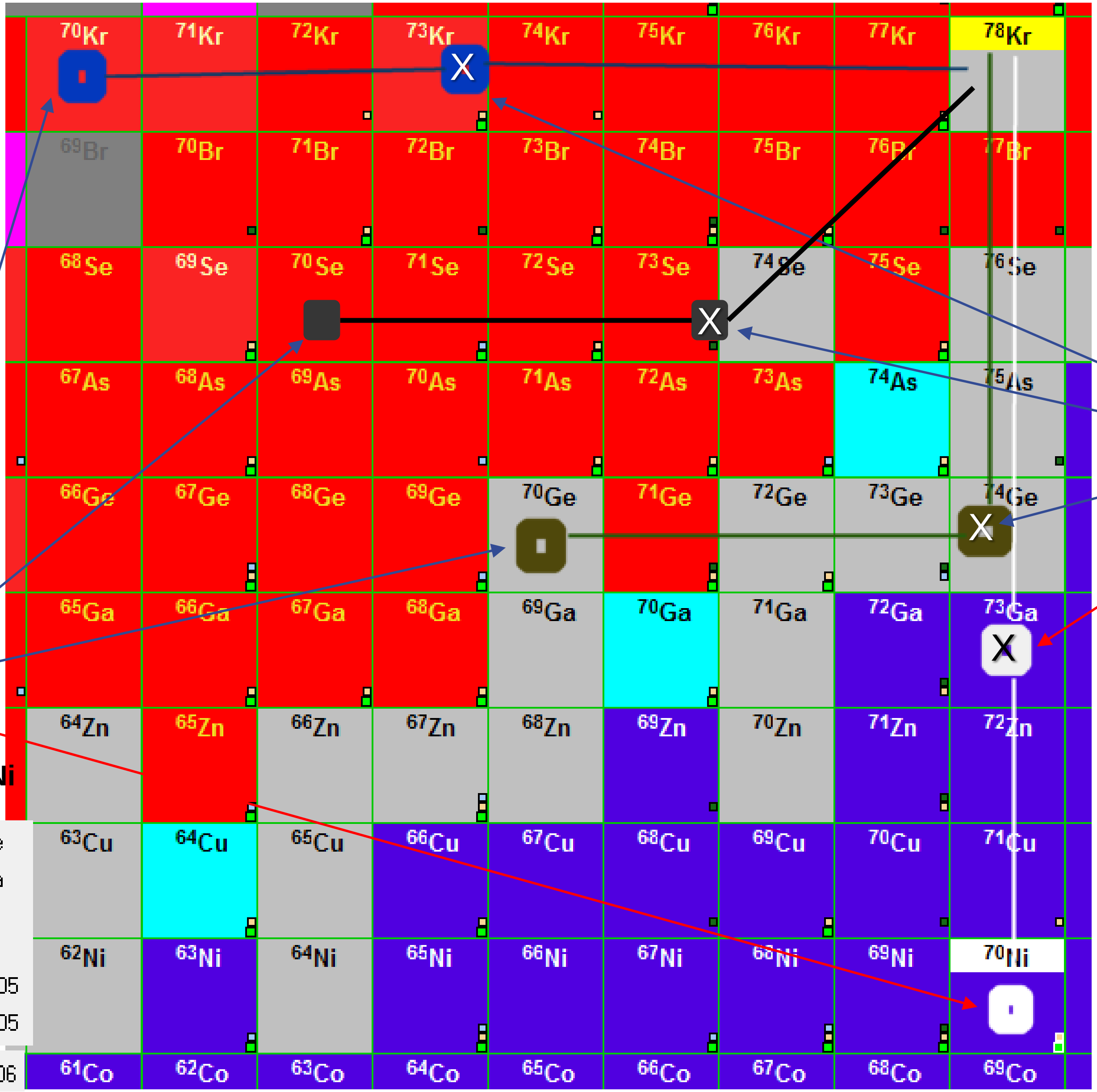


New revised Universal parameterization (options C1 #2) predictions are more close to experimental proton-rich results

X-axis: A_{beam} - $A_{fragment}$

LISE_opt → Brho-value corresponding to maximum yield from the convolution model

^{78}Kr (140 MeV/u) → A=70 : Prefragment search "C1"



Prefragments

Final fragments

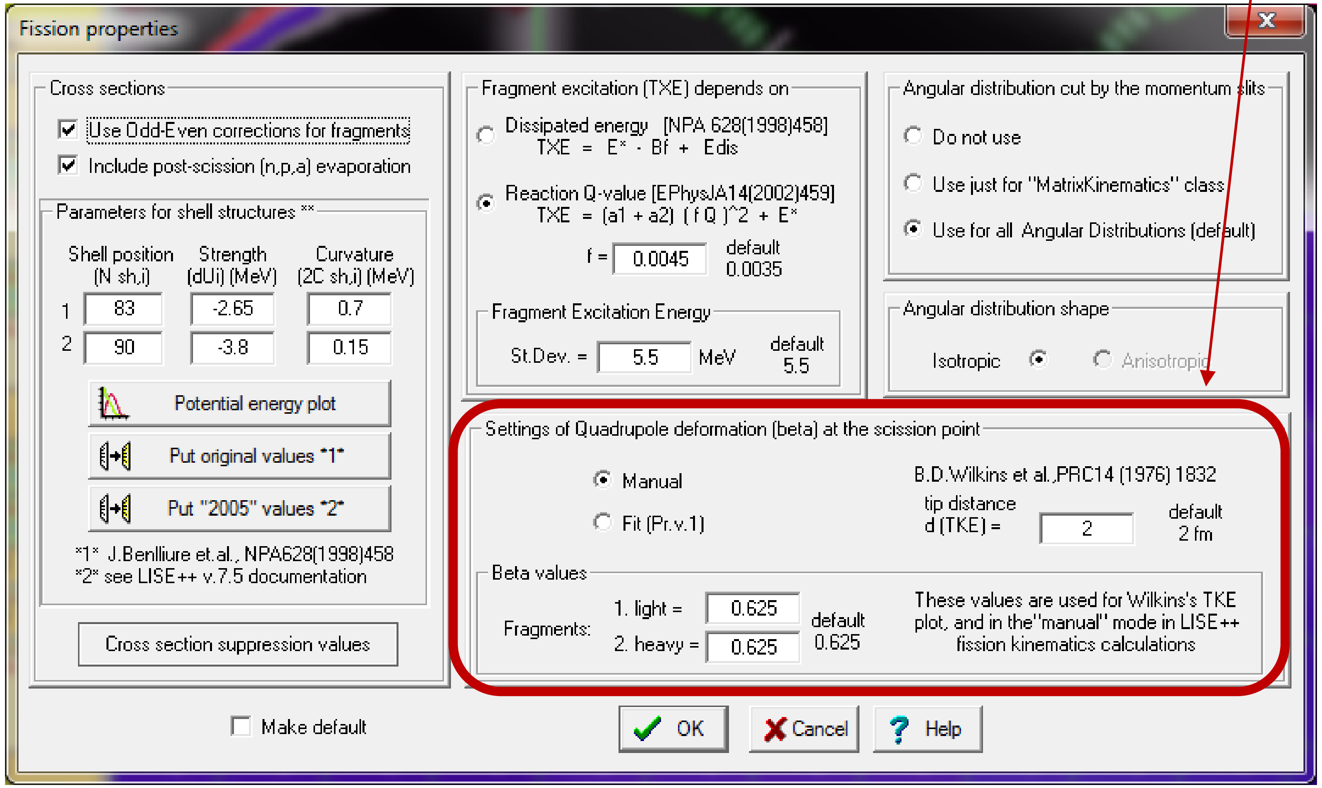
	70Kr	70Se	70Ge	70Ni
"Top" Prefragment	74Kr	74Se	75As	74Ge
"Bottom" Prefragment	73Kr	73Se	74Ge	73Ga
Final Prefragment mass	73.2	73.7	74.0	73.0
Energy excitation (MeV)	54.6	54.6	52.2	57.8
Probability	8.10e-04	5.92e-02	3.98e-01	2.93e-05
Corrected Probability	8.10e-04	4.82e-01	4.16e+00	2.93e-05
EPAX2	7.48e-06	1.64e+00	1.16e+01	2.25e-06

Fragment deformation at the Scission point

Update of the Fission Properties dialog

Discussions with Prof.J.Benlliure are appreciated.

New panel



B. D. Wilkins, E. P. Steinberg, and R. R. Chasman., Phys. Rev. C **14**, 1832 (1976).

$$\mathrm{TKE} = \frac{Z_1 \cdot Z_2 \cdot e^2}{D},$$

where e is the electron charge and Z_1 and Z_2 refer to the charge of the two fission fragments. The distance D between the two uniformly charged spheroids that constitute the fission fragments is given by:

$$D = r_0 A_1^{1/3}\left(1 + \frac{2\beta_1}{3}\right) + r_0 A_2^{1/3}\left(1 + \frac{2\beta_2}{3}\right) + d$$

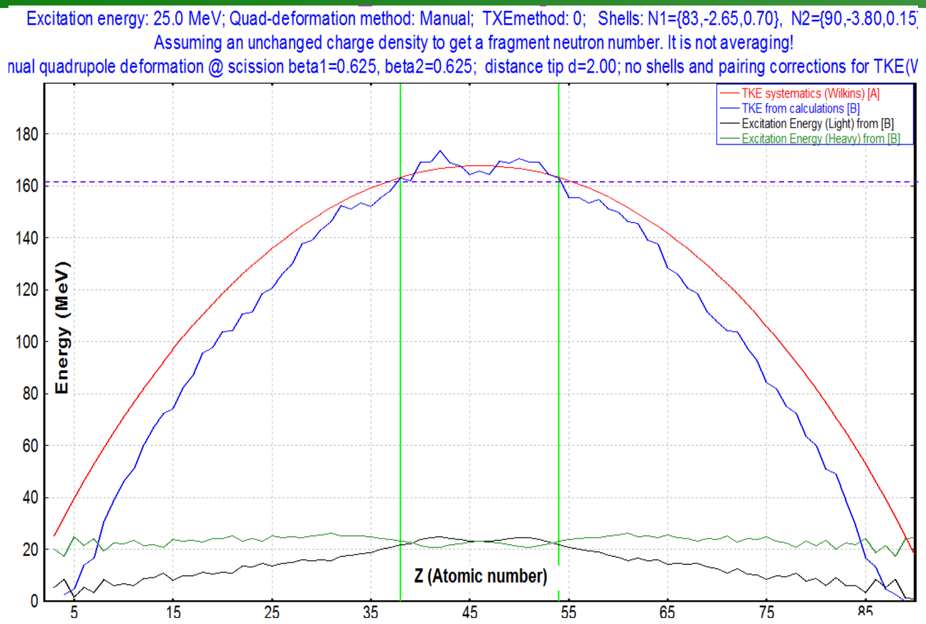
the parameters proposed by Wilkins *et al.* for the macroscopic version of their model, corresponding to high-energy fission: $r_0 = 1.16$ fm, $d = 2$ fm, and $\beta_1 = \beta_2 = 0.625$.

NOTE: For Cross Sections and transmission calculations the LISE^{++} code uses the **internal Four-momentum relativistic apparatus**, where deformation energy is taken into account in excitation energy balance in TXE #0 mode. TKE of fission fragments is a by-product result of these calculations.

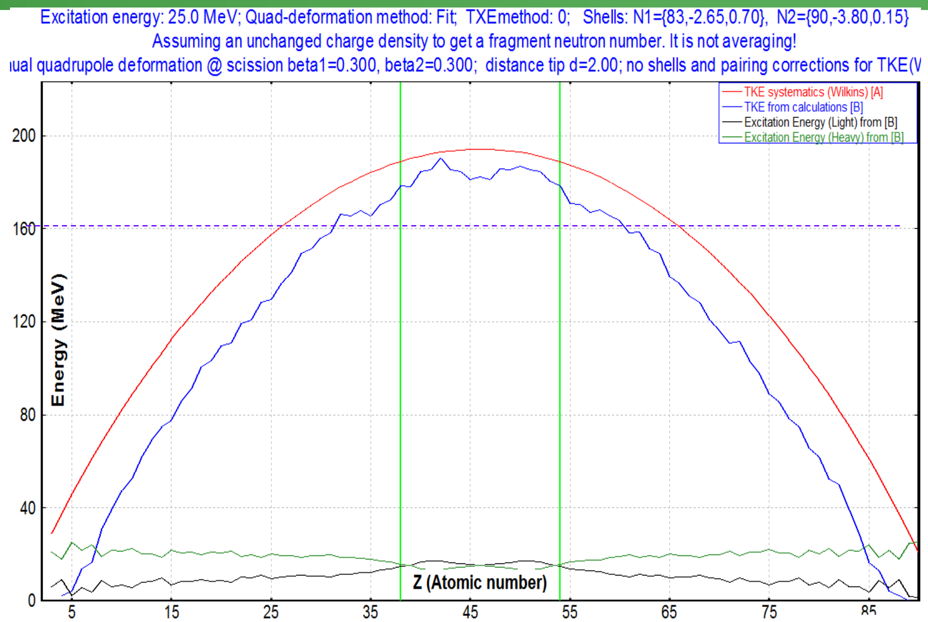
Previous versions LISE^{++} values are “Fit” mode and default Wilkins’s parameters

Excitation energy mode TXE #0

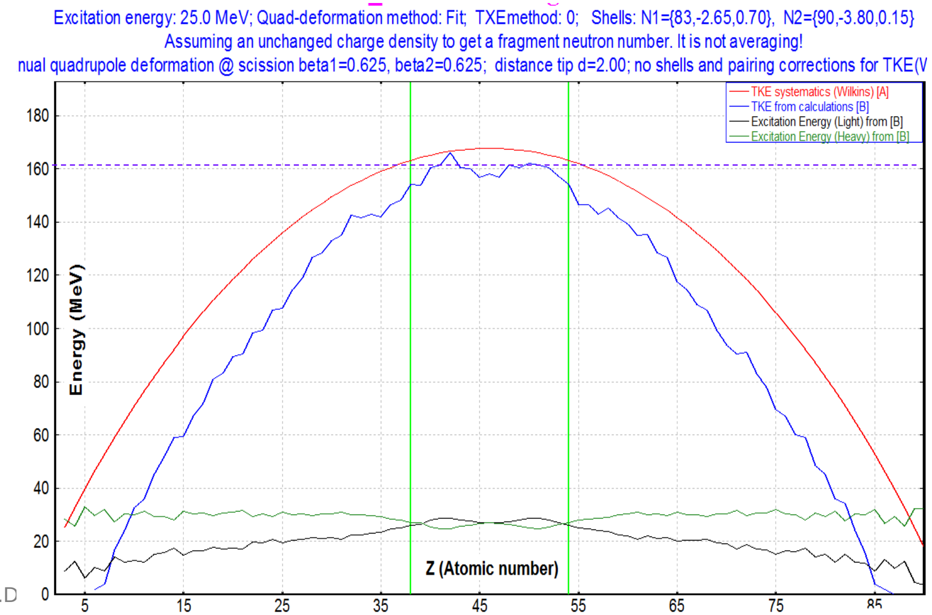
“Fit” mode



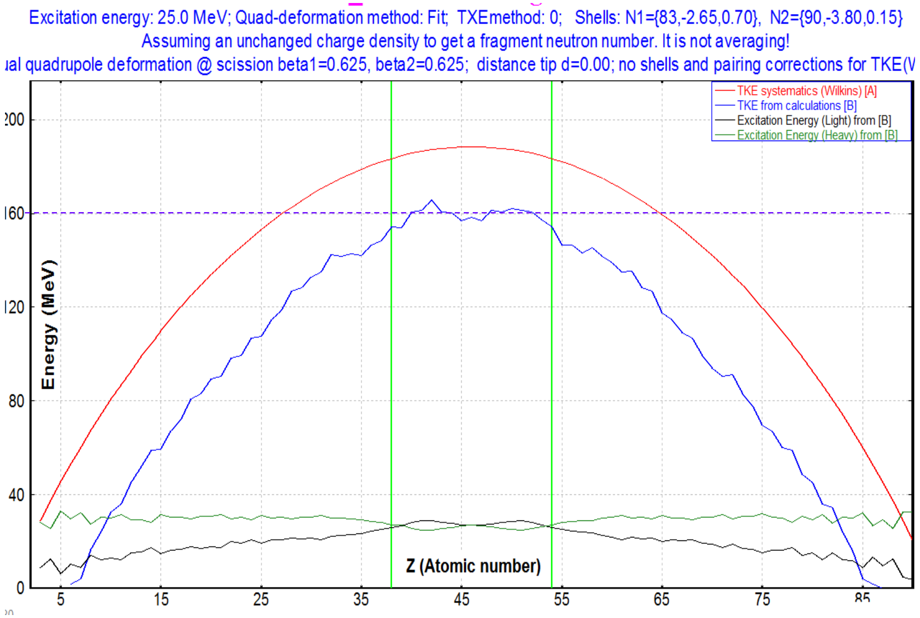
beta=0.3, d=2 fm



beta=0.625, d=2 fm
“Manual” mode

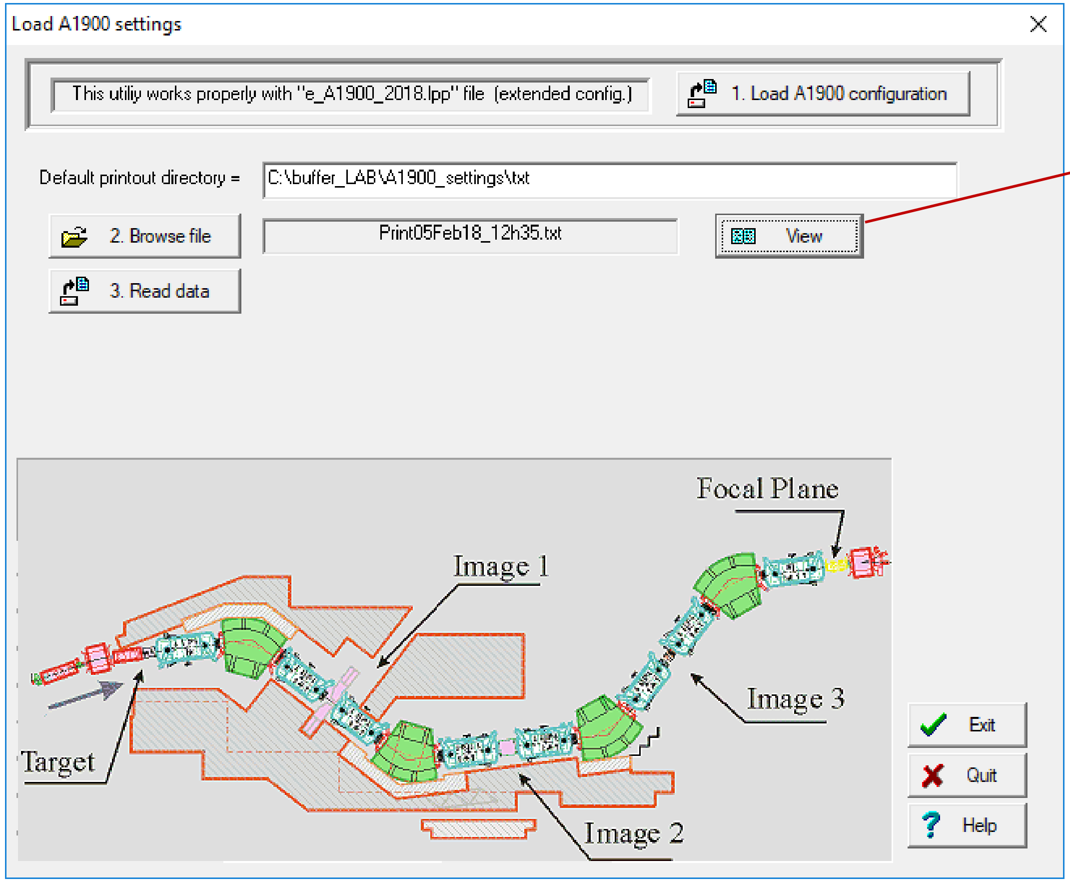


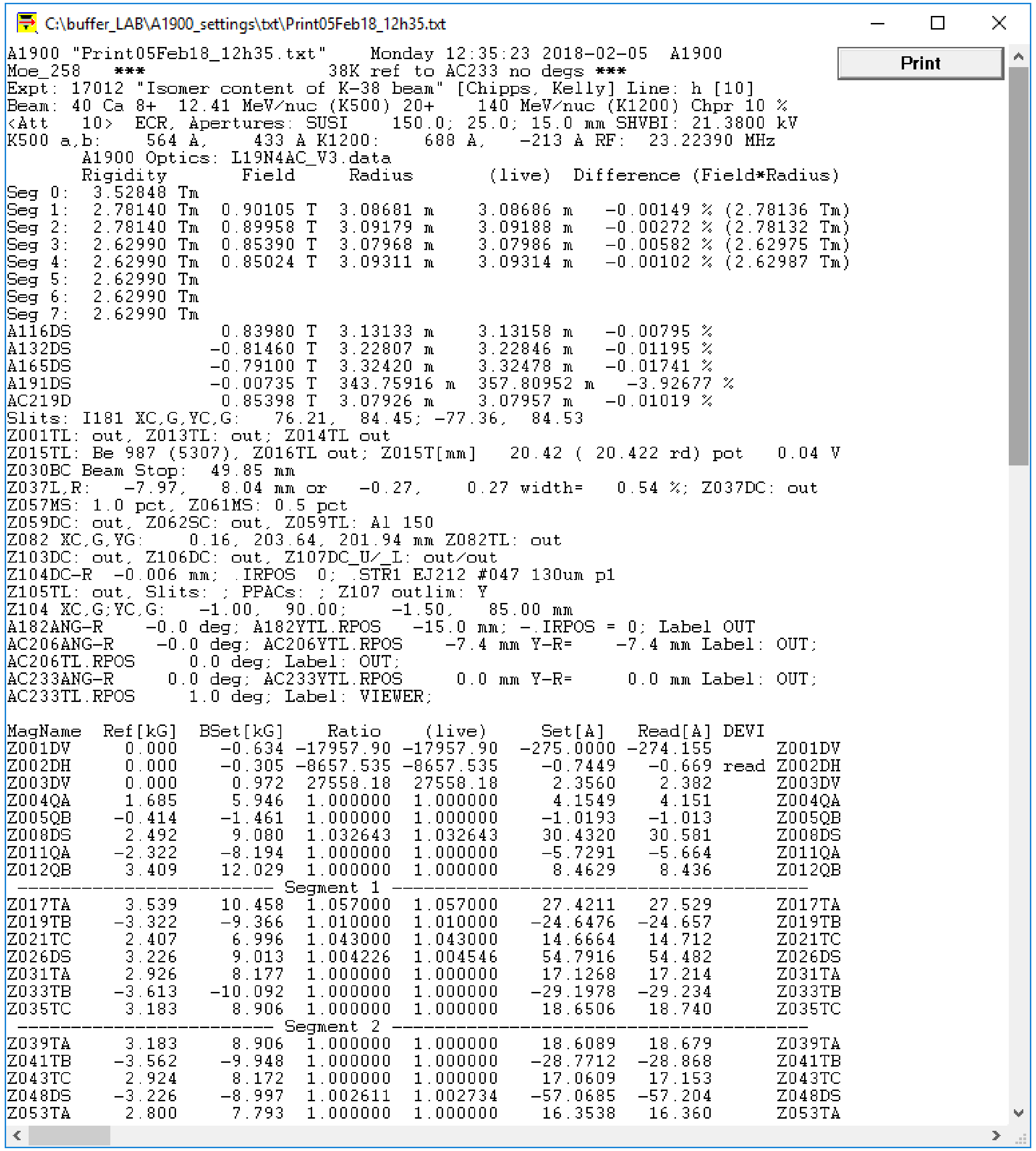
beta=0.625, d=0 fm



“Loading A1900 settings” utility

Browse file and view of A1900 settings





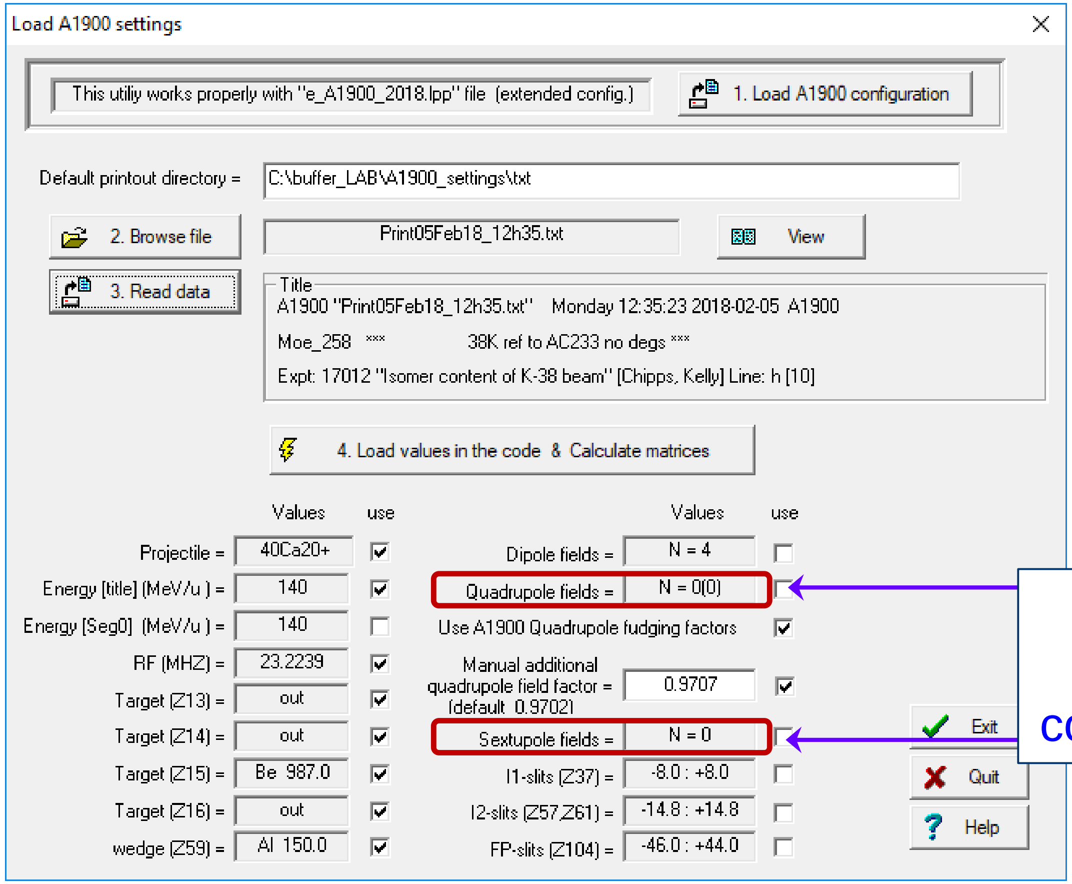

```
A1900 "Print05Feb18_12h35.txt"    Monday 12:35:23 2018-02-05  A1900
Moe_258   ***                   38K ref to AC233 no degs ***
Expt: 17012 "Isomer content of K-38 beam" [Chipps, Kelly] Line: h [10]
Beam: 40 Ca 8+  12.41 MeV/nuc (K500) 20+    140 MeV/nuc (K1200) Chpr 10 %
<Att   10>  ECR, Apertures: SUSI    150.0; 25.0; 15.0 mm SHVBI: 21.3800 kV
K500 a,b:     564 A,    433 A K1200:    688 A,   -213 A RF:  23.22390 MHz
       A1900 Optics: L19N4AC_V3.data
       Rigidity        Field      Radius        (live)  Difference (Field*Radius)
Seg 0:  3.52848 Tm
Seg 1:  2.78140 Tm  0.90105 T  3.08681 m    3.08686 m   -0.00149 % (2.78136 Tm)
Seg 2:  2.78140 Tm  0.89958 T  3.09179 m    3.09188 m   -0.00272 % (2.78132 Tm)
Seg 3:  2.62990 Tm  0.85390 T  3.07968 m    3.07986 m   -0.00582 % (2.62975 Tm)
Seg 4:  2.62990 Tm  0.85024 T  3.09311 m    3.09314 m   -0.00102 % (2.62987 Tm)
Seg 5:  2.62990 Tm
Seg 6:  2.62990 Tm
Seg 7:  2.62990 Tm
A116DS              0.83980 T  3.13133 m    3.13158 m   -0.00795 %
A132DS             -0.81460 T  3.22807 m    3.22846 m   -0.01195 %
A165DS             -0.79100 T  3.32420 m    3.32478 m   -0.01741 %
A191DS             -0.00735 T  343.75916 m  357.80952 m   -3.92677 %
AC219D              0.85398 T  3.07926 m    3.07957 m   -0.01019 %
Slits: I181 XC,G,YC,G:   76.21,  84.45; -77.36,  84.53
Z001TL: out, Z013TL: out; Z014TL out
Z015TL: Be 987 (5307), Z016TL out; Z015T[mm]   20.42 ( 20.422 rd) pot   0.04 V
Z030BC Beam Stop:  49.85 mm
Z037L,R:   -7.97,   8.04 mm or   -0.27,    0.27 width=   0.54 %; Z037DC: out
Z057MS: 1.0 pct, Z061MS: 0.5 pct
Z059DC: out, Z062SC: out, Z059TL: Al 150
Z082 XC,G,YG:    0.16, 203.64, 201.94 mm Z082TL: out
Z103DC: out, Z106DC: out, Z107DC_U/_L: out/out
Z104DC-R  -0.006 mm; .IRPOS  0; .STR1 EJ212 #047 130um p1
Z105TL: out, Slits: ; PPACs: ; Z107 outlim: Y
Z104 XC,G;YC,G:   -1.00,  90.00;    -1.50,   85.00 mm
A182ANG-R    -0.0 deg; A182YTL.RPOS   -15.0 mm; -.IRPOS = 0; Label OUT
AC206ANG-R    -0.0 deg; AC206YTL.RPOS    -7.4 mm Y-R=    -7.4 mm Label: OUT;
AC206TL.RPOS     0.0 deg; Label: OUT;
AC233ANG-R     0.0 deg; AC233YTL.RPOS     0.0 mm Y-R=     0.0 mm Label: OUT;
AC233TL.RPOS     1.0 deg; Label: VIEWER;

MagName  Ref[kG]  BSet[kG]    Ratio     (live)      Set[A]    Read[A] DEVI
Z001DV     0.000    -0.634 -17957.90 -17957.90  -275.0000 -274.155       Z001DV
Z002DH     0.000    -0.305 -8657.535 -8657.535    -0.7449   -0.669 read Z002DH
Z003DV     0.000     0.972  27558.18  27558.18     2.3560    2.382       Z003DV
Z004QA     1.685     5.946  1.000000  1.000000     4.1549    4.151       Z004QA
Z005QB    -0.414    -1.461  1.000000  1.000000    -1.0193   -1.013       Z005QB
Z008DS     2.492     9.080  1.032643  1.032643    30.4320   30.581       Z008DS
Z011QA    -2.322    -8.194  1.000000  1.000000    -5.7291   -5.664       Z011QA
Z012QB     3.409    12.029  1.000000  1.000000     8.4629    8.436       Z012QB
 ------------------------ Segment 1 ---------------------------------------
Z017TA     3.539    10.458  1.057000  1.057000    27.4211   27.529       Z017TA
Z019TB    -3.322    -9.366  1.010000  1.010000   -24.6476  -24.657       Z019TB
Z021TC     2.407     6.996  1.043000  1.043000    14.6664   14.712       Z021TC
Z026DS     3.226     9.013  1.004226  1.004546    54.7916   54.482       Z026DS
Z031TA     2.926     8.177  1.000000  1.000000    17.1268   17.214       Z031TA
Z033TB    -3.613   -10.092  1.000000  1.000000   -29.1978  -29.234       Z033TB
Z035TC     3.183     8.906  1.000000  1.000000    18.6506   18.740       Z035TC
 ------------------------ Segment 2 ---------------------------------------
Z039TA     3.183     8.906  1.000000  1.000000    18.6089   18.679       Z039TA
Z041TB    -3.562    -9.948  1.000000  1.000000   -28.7712  -28.868       Z041TB
Z043TC     2.924     8.172  1.000000  1.000000    17.0609   17.153       Z043TC
Z048DS    -3.226    -8.997  1.002611  1.002734   -57.0685  -57.204       Z048DS
Z053TA     2.800     7.793  1.000000  1.000000    16.3538   16.360       Z053TA
```

Reading and Analysis of A1900 settings

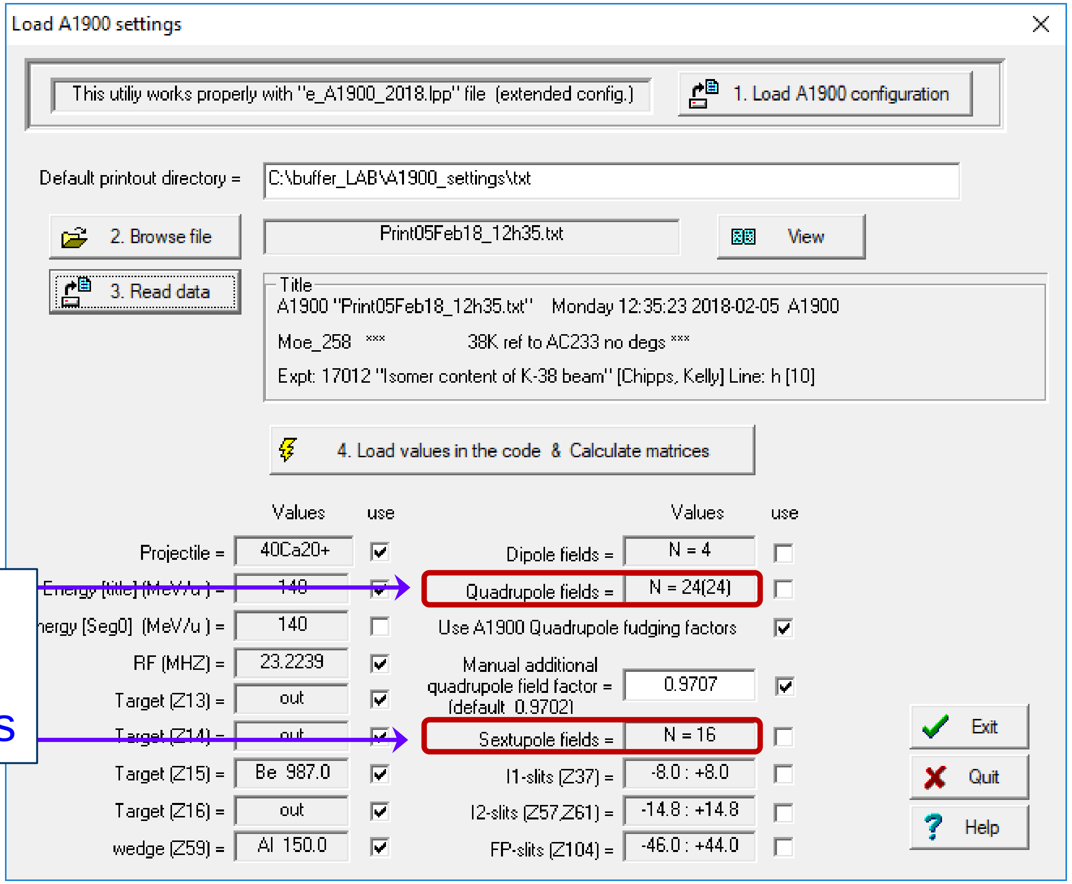
press the “3. Read data” button

default A1900_2016 (**segmented**)



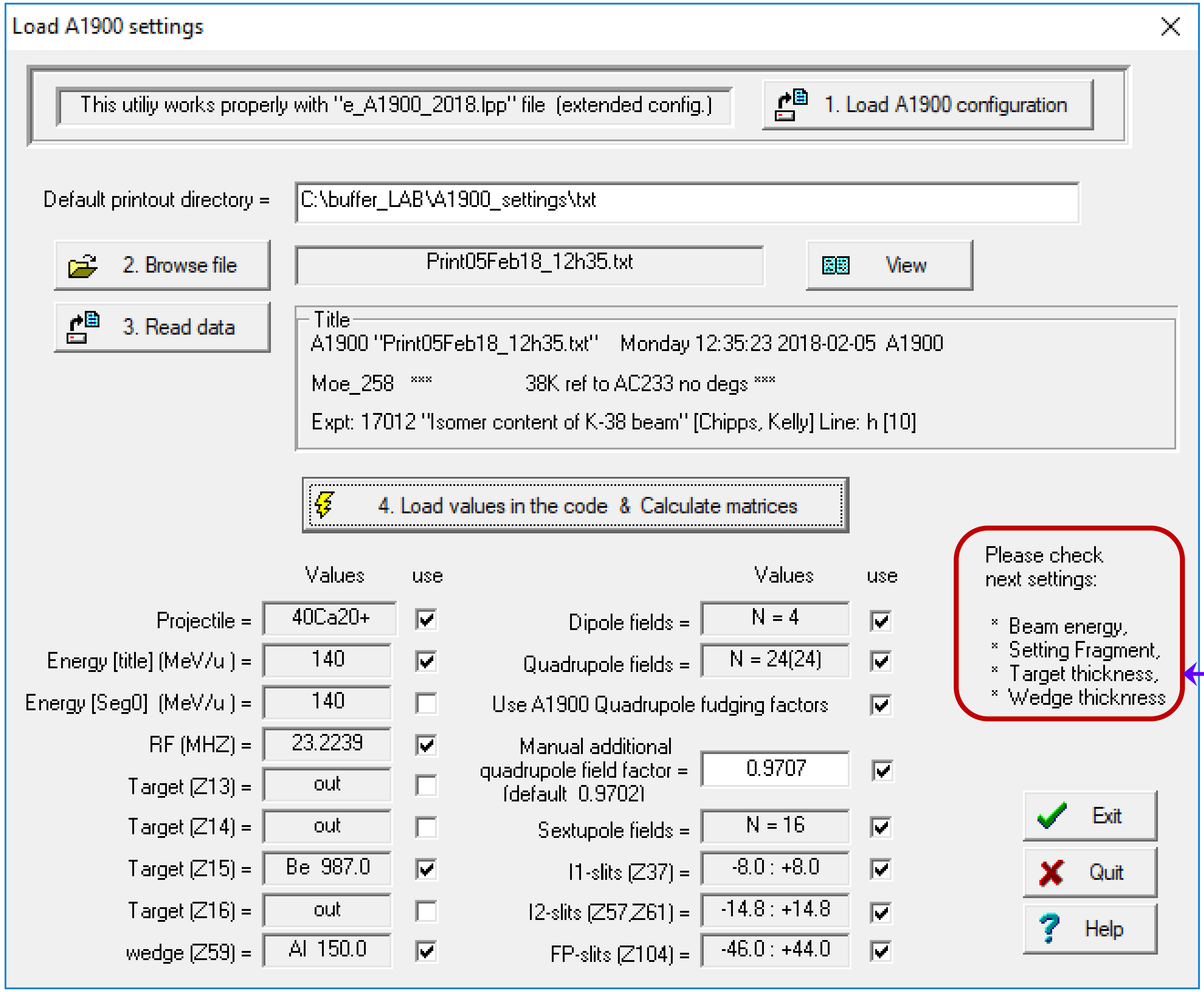
Difference between configurations

e_A1900_2018.lpp (**extended**)

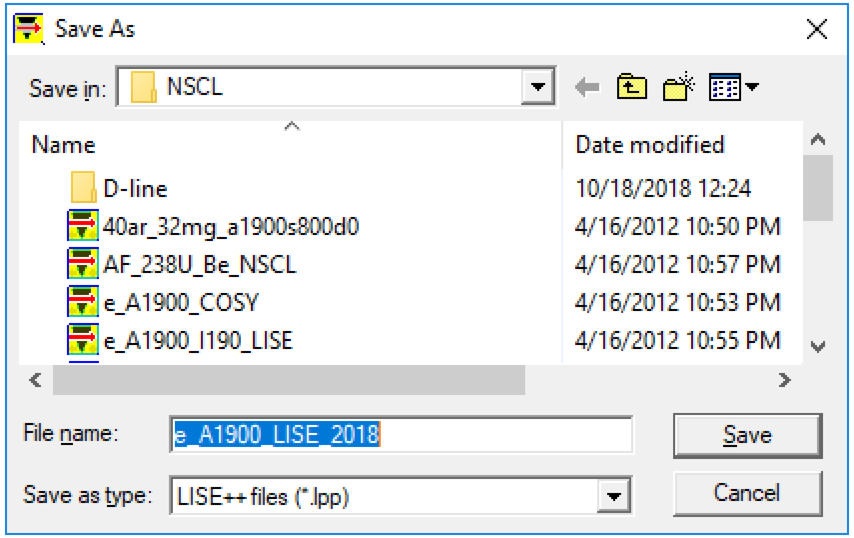


Loading values into the code and matrix recalculation

press the “4. Load values into the code & Calculate matrices” button



LISE^{++} automatically proposes you to save the modified file.
Please, do not overwrite the original e_A1900_LISE_2018.lpp file



Important!

Matrices are recalculated by LISE^{++} based on the TRANSPORT approach using dipole and quad settings of e_A1900_LISE_2018.lpp file

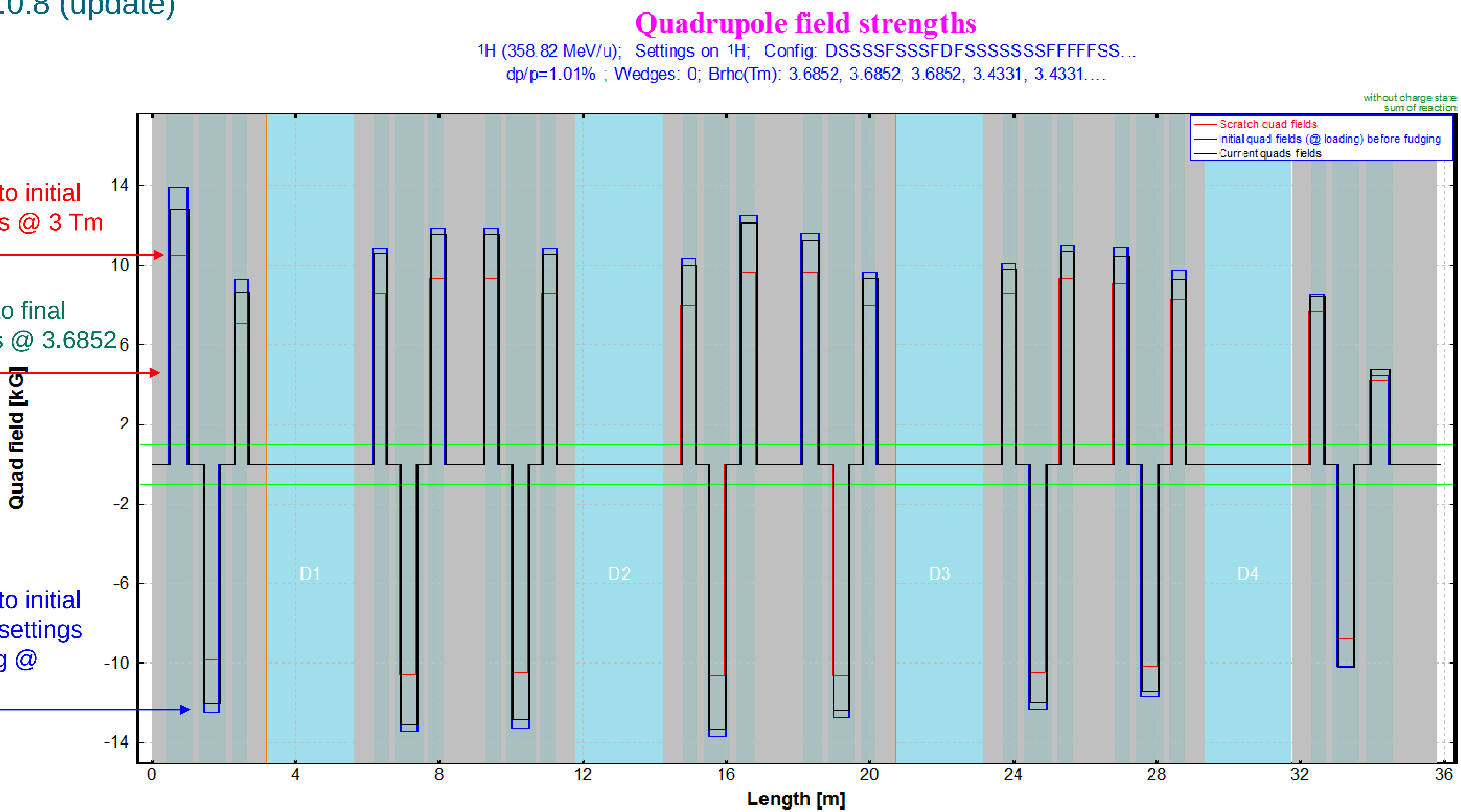
Plot quad (scratch, final, initial $_{\text{before fudging}}$) field values

Version 11.0.8 (update)
11/13/18

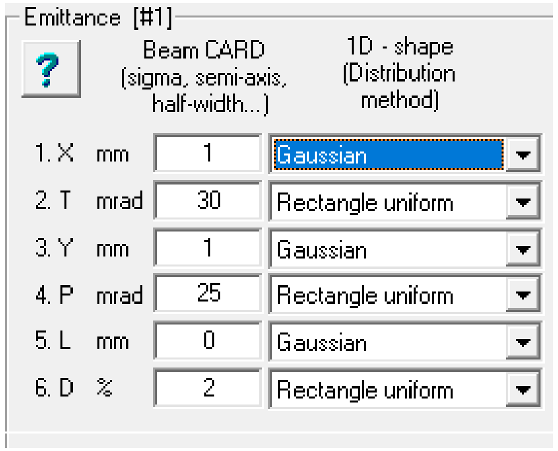
Corresponds to initial e_a1900 fields @ 3 Tm

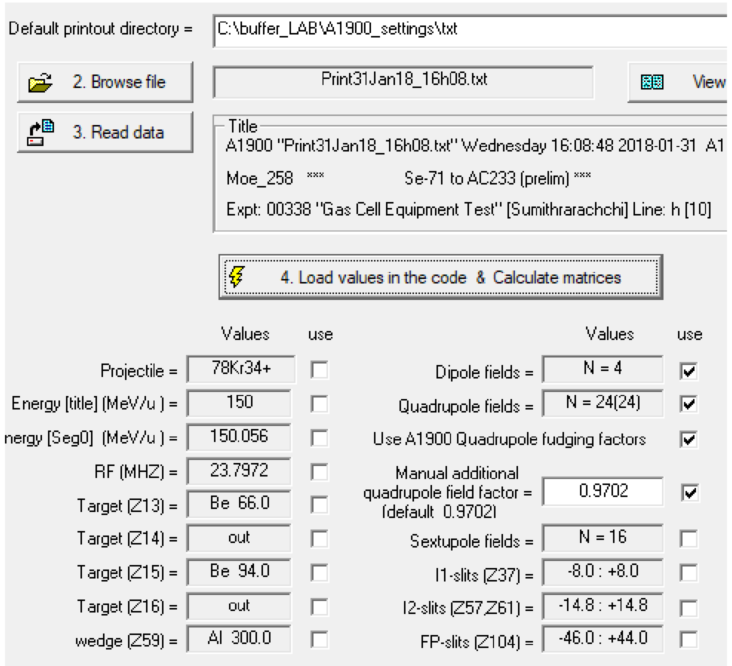
Corresponds to final (current) fields @ 3.6852

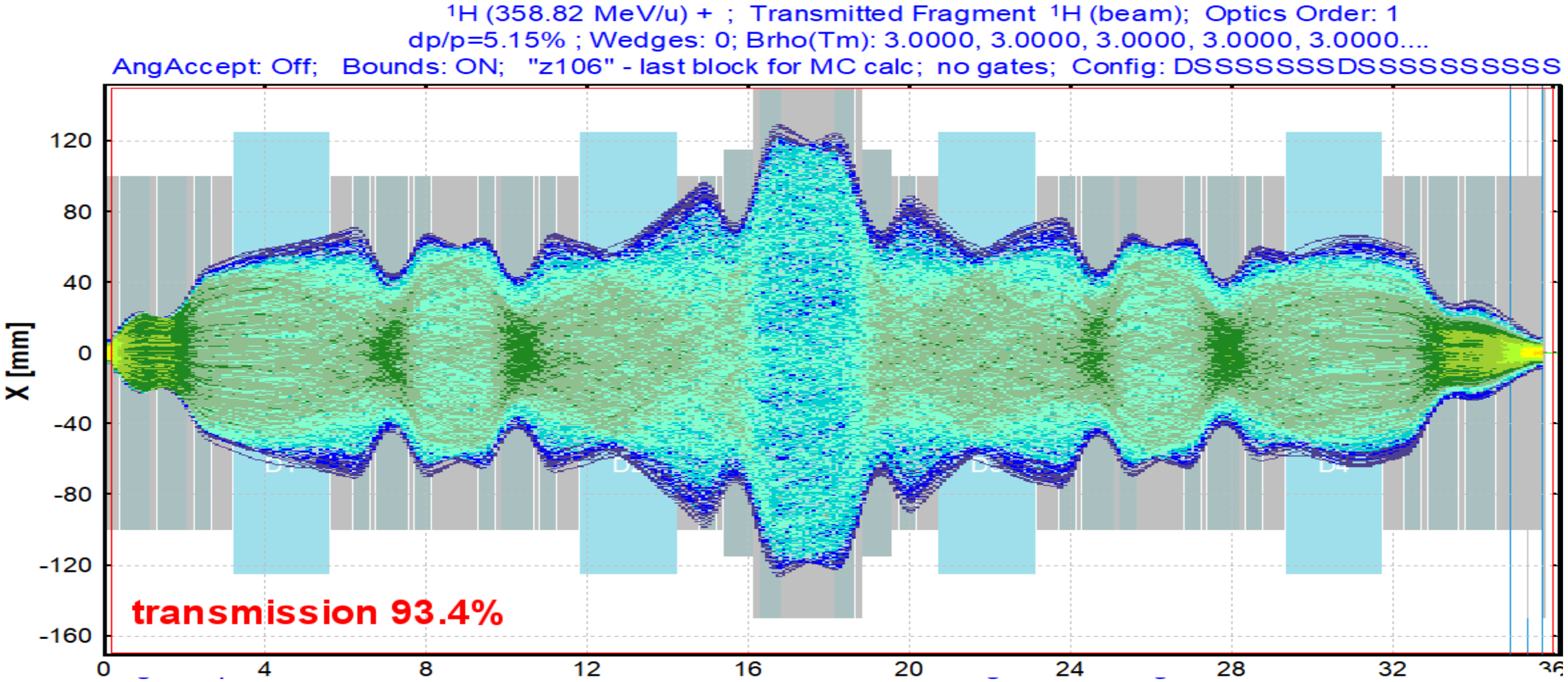
Corresponds to initial experimental settings before fudging @ 3.6852 Tm

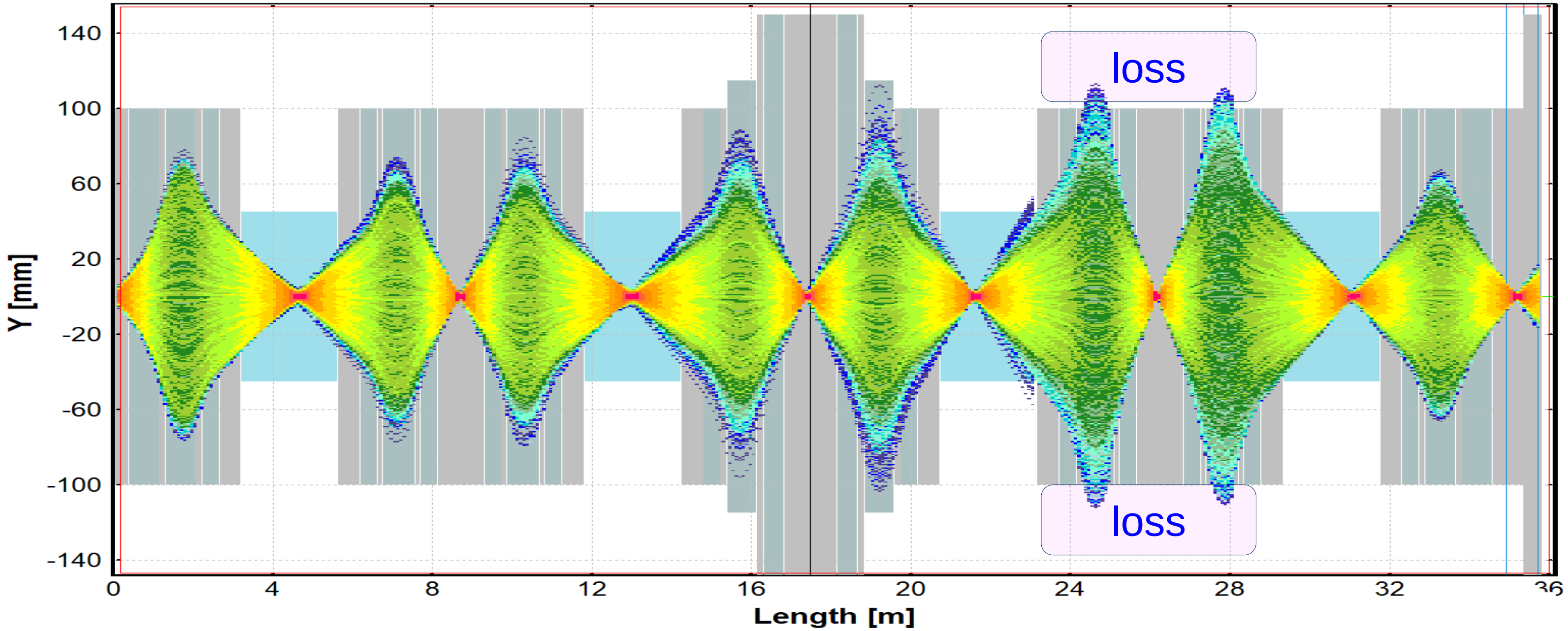


MC envelopes for imported A1900 data settings in LISE^{++}



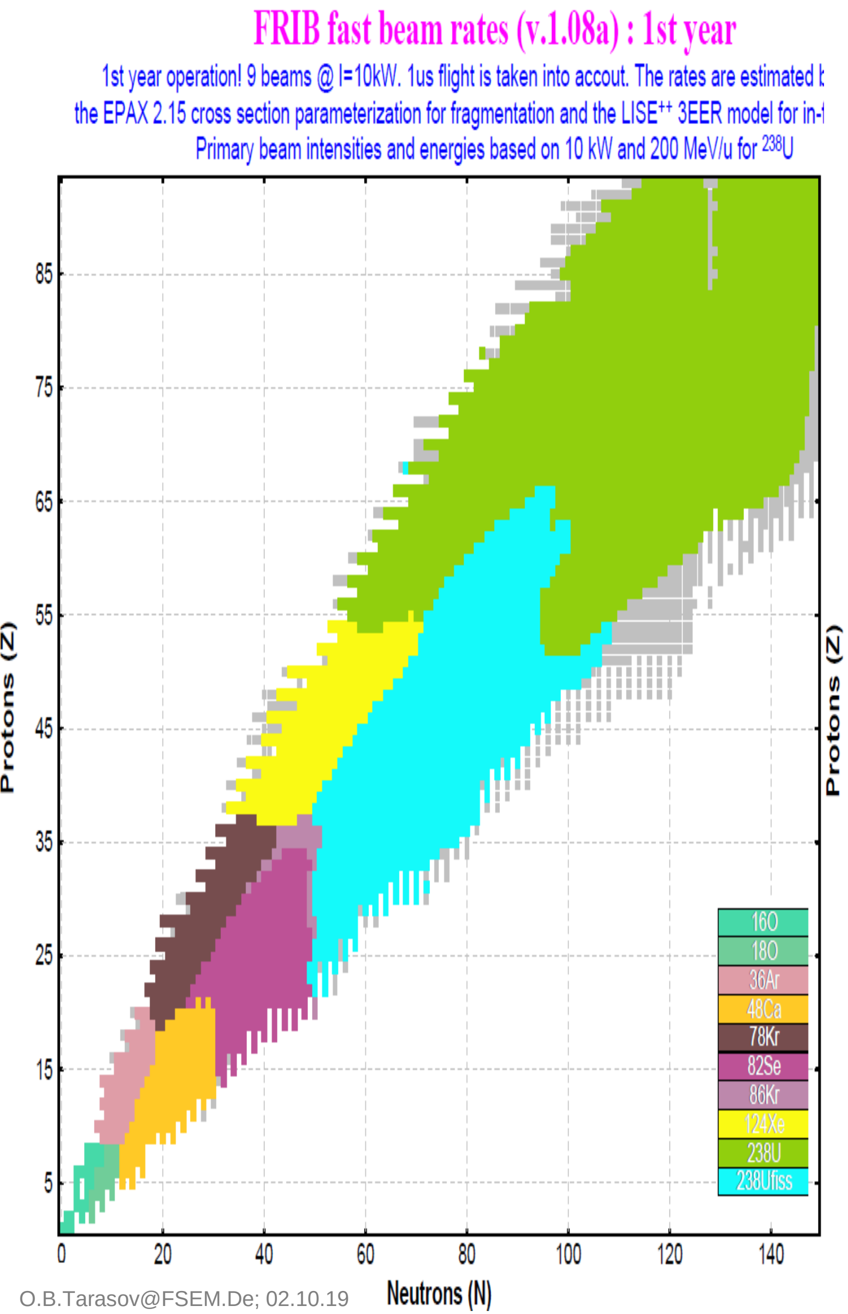


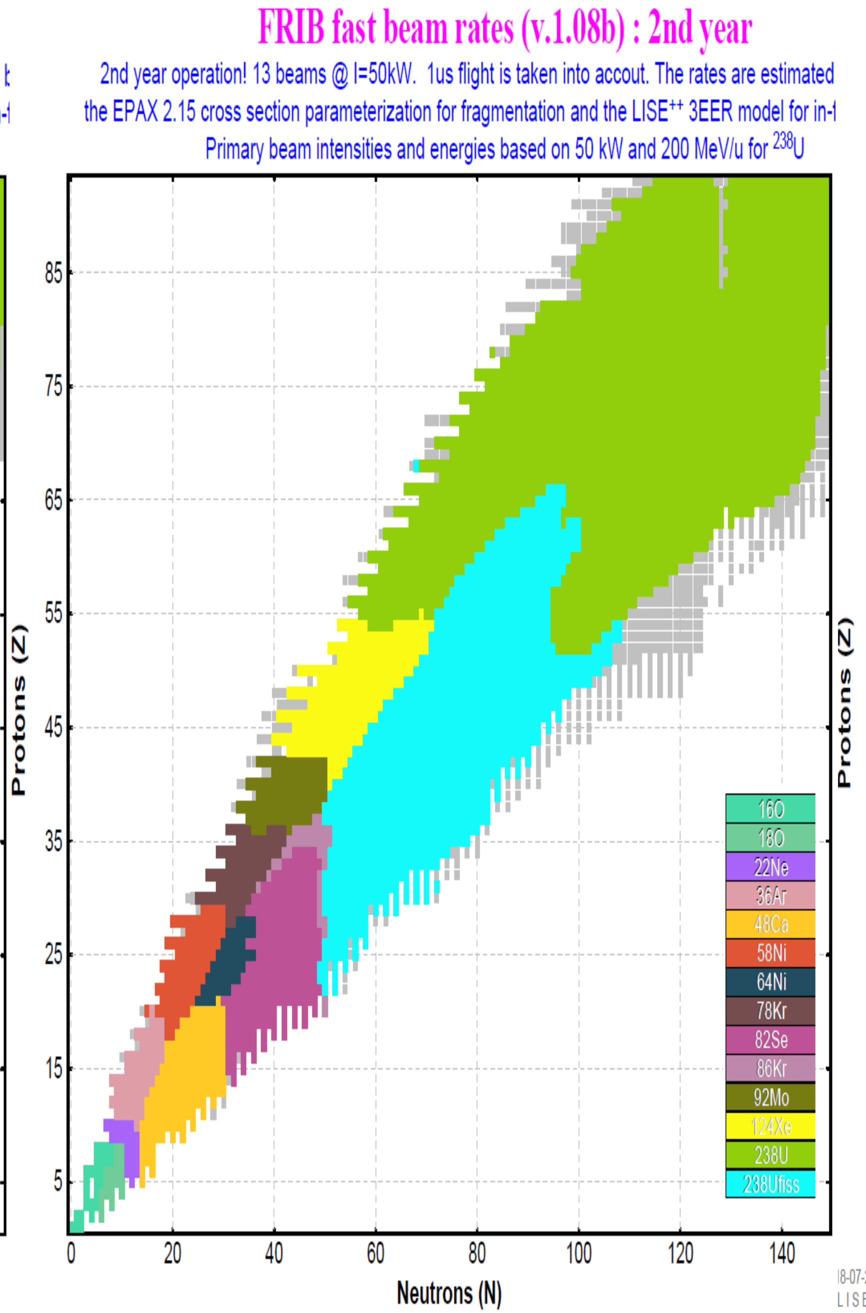


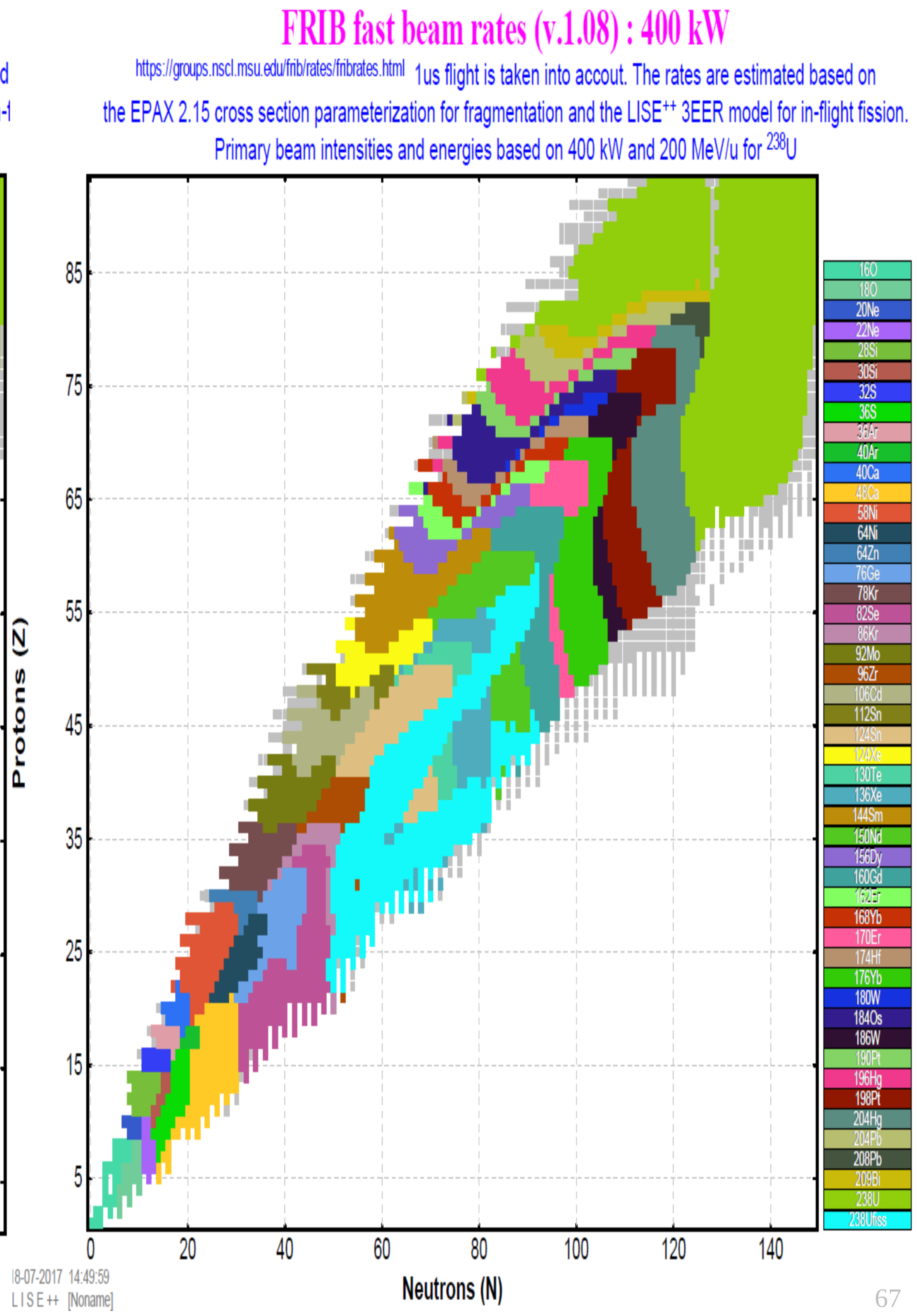


FRIB rates 1.08

FRIB beams to for best isotope production



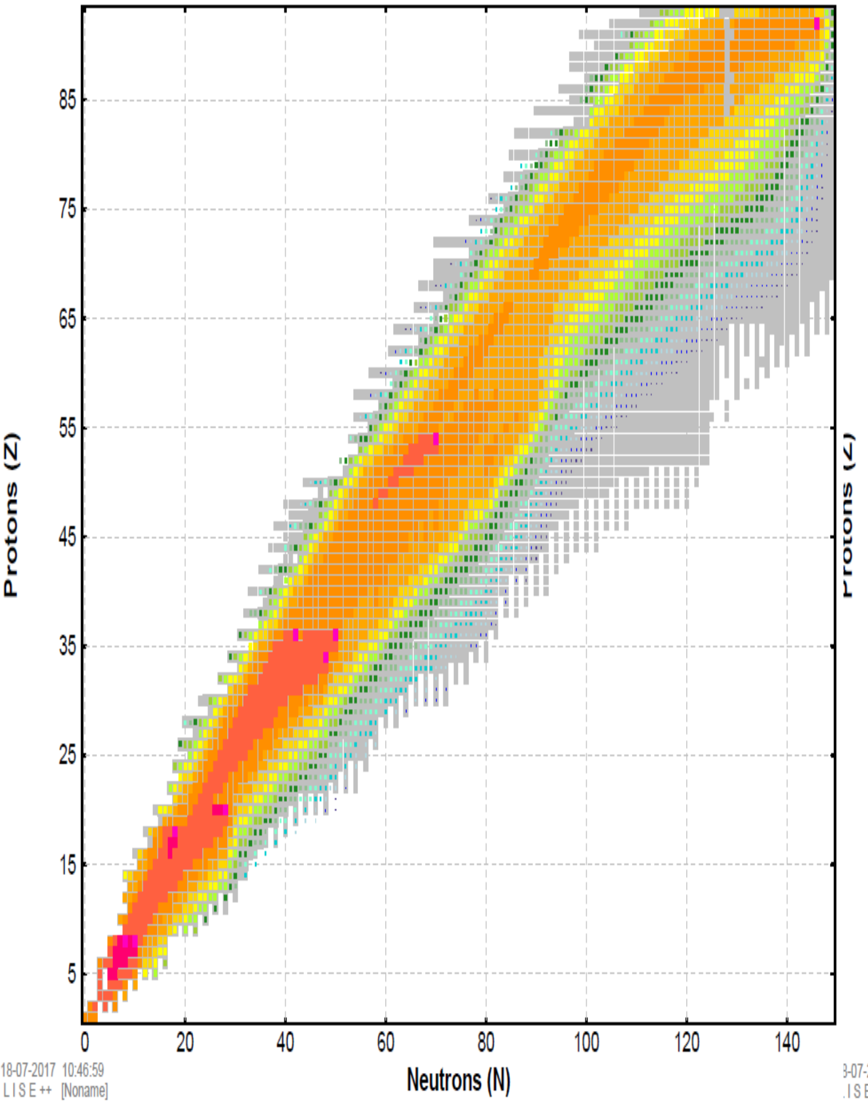




FRIB rates

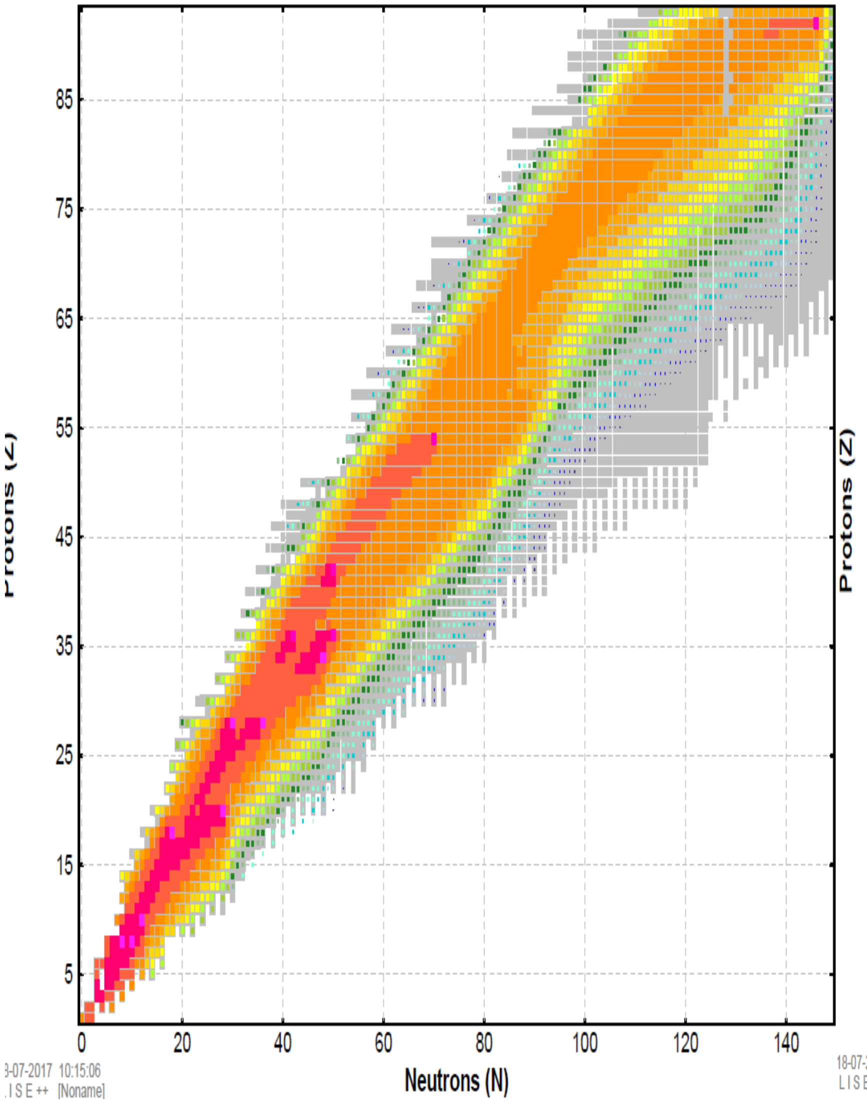
FRIB fast beam rates (v.1.08a) : 1st year

1st year operation! 9 beams @ I=10kW. 1us flight is taken into accout. The rates are estimated b
the EPAX 2.15 cross section parameterization for fragmentation and the LISE++ 3EER model for in-fl
Primary beam intensities and energies based on 10 kW and 200 MeV/u for ^{238}U



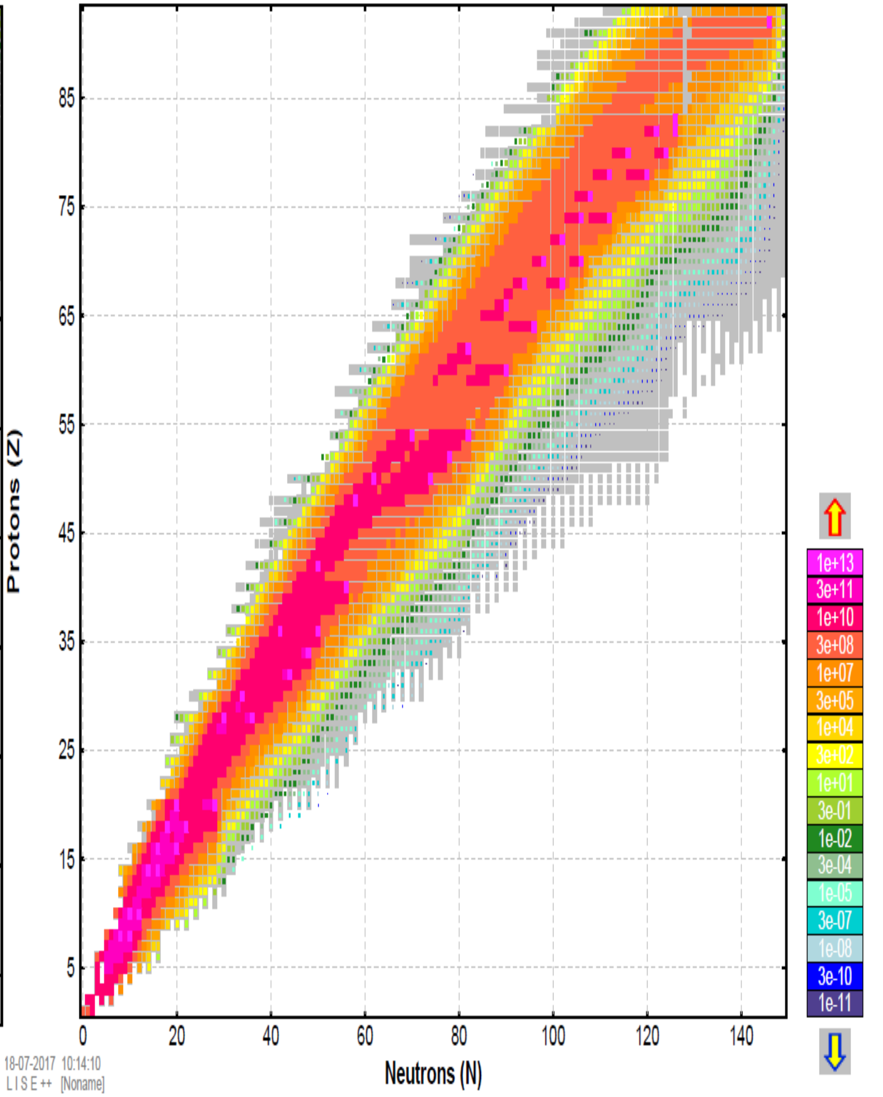
FRIB fast beam rates (v.1.08b) : 2nd year

2nd year operation! 13 beams @ I=50kW. 1us flight is taken into accout. The rates are estimated
the EPAX 2.15 cross section parameterization for fragmentation and the LISE++ 3EER model for in-
Primary beam intensities and energies based on 50 kW and 200 MeV/u for ^{238}U



FRIB fast beam rates (v.1.08) : 400 kW

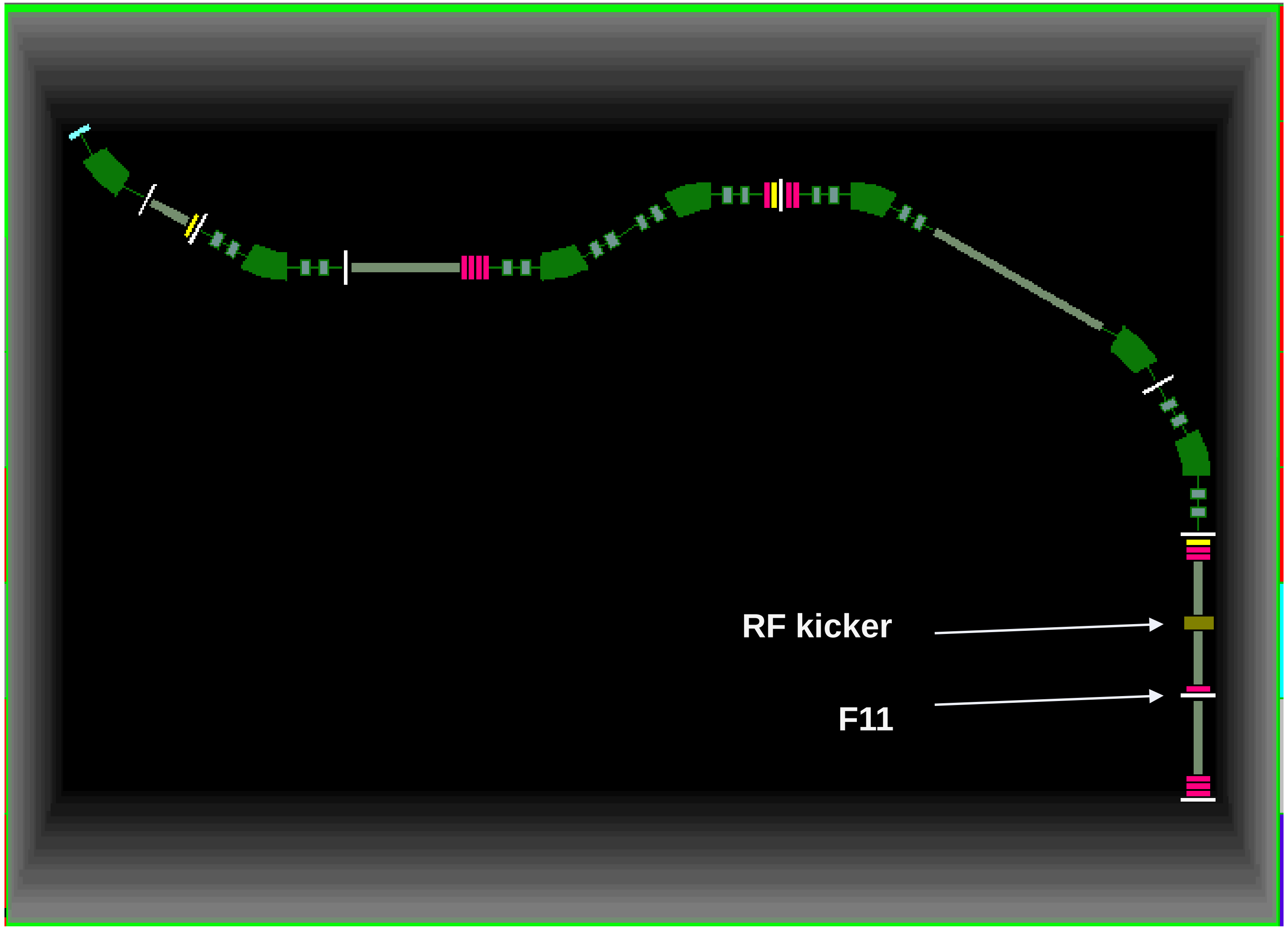
https://groups.nscl.msu.edu/frib/rates/fribrates.html 1us flight is taken into accout. The rates are estimated based on
the EPAX 2.15 cross section parameterization for fragmentation and the LISE++ 3EER model for in-flight fission
Primary beam intensities and energies based on 400 kW and 200 MeV/u for ^{238}U



RF-kicker update

Toshiyuki Sumikama's request (OEDO)

Modification of the exit angle of a particle passing a RF-kicker due to spatial shift



v.10.0.26 : Monte Carlo solution

v.10.0.27 : Analytical solution

Optics

Global matrix in front of the RF-kicker

Global matrix

-0.13972	1.95362	0	0	0	-21.75481	[mm]
-0.51235	6.819e-3	0	0	0	3.77646	[mrad]
0	0	12.67801	0.33856	0	0	[mm]
0	0	1.10516	0.10839	0	0	[mrad]
1.14542	-0.75236	0	0	1	57.61709	[mm]
0	0	0	0	0	1	[%]
/[mm]	/[mrad]	/[mm]	/[mrad]	/[mm]	/[%]	

Local matrix of the RF-kicker

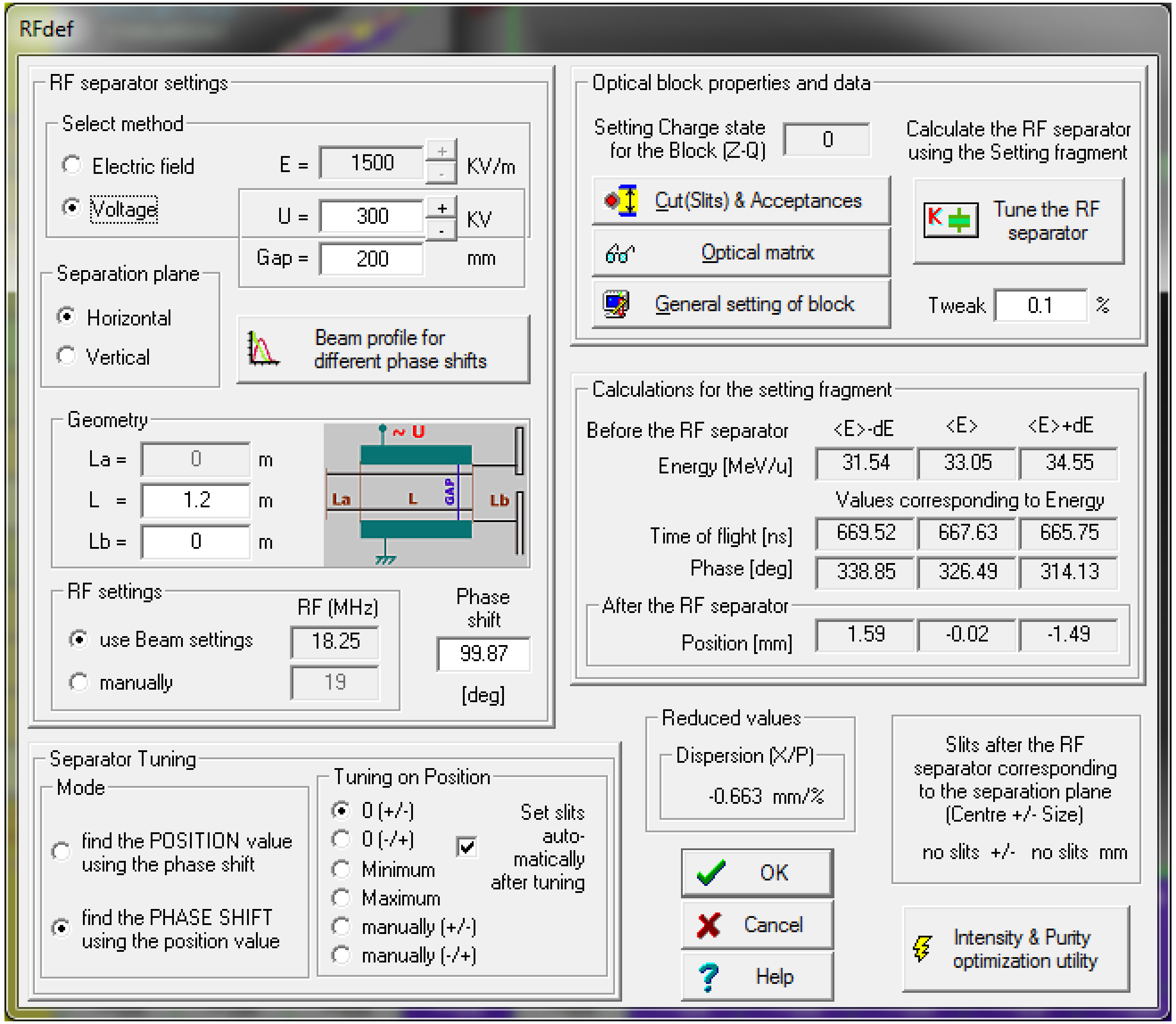
Block matrix

1. X	1	1.2	0	0	0	0
2. T	0	1	0	0	0	0
3. Y	0	0	1	1.2	0	0
4. P	0	0	0	1	0	0
5. L	0	0	0	0	1	0
6. D	0	0	0	0	0	1
	/[mm]	/[mrad]	/[mm]	/[mrad]	/[mm]	/[%]

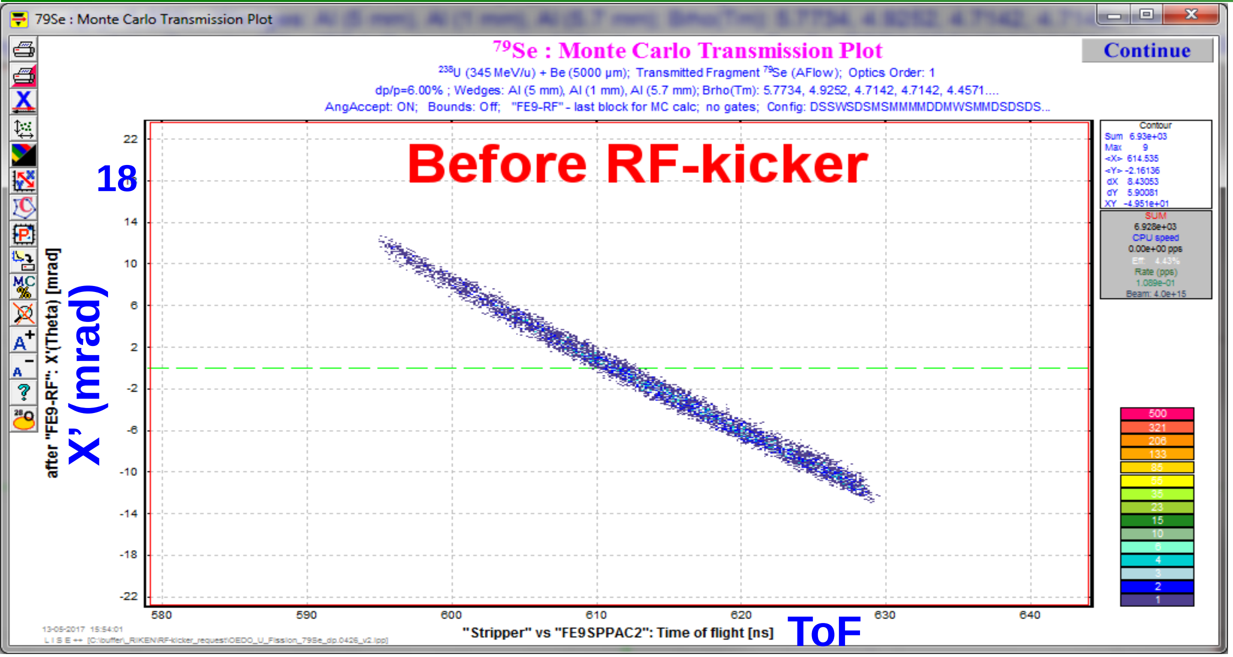
F11 Global matrix

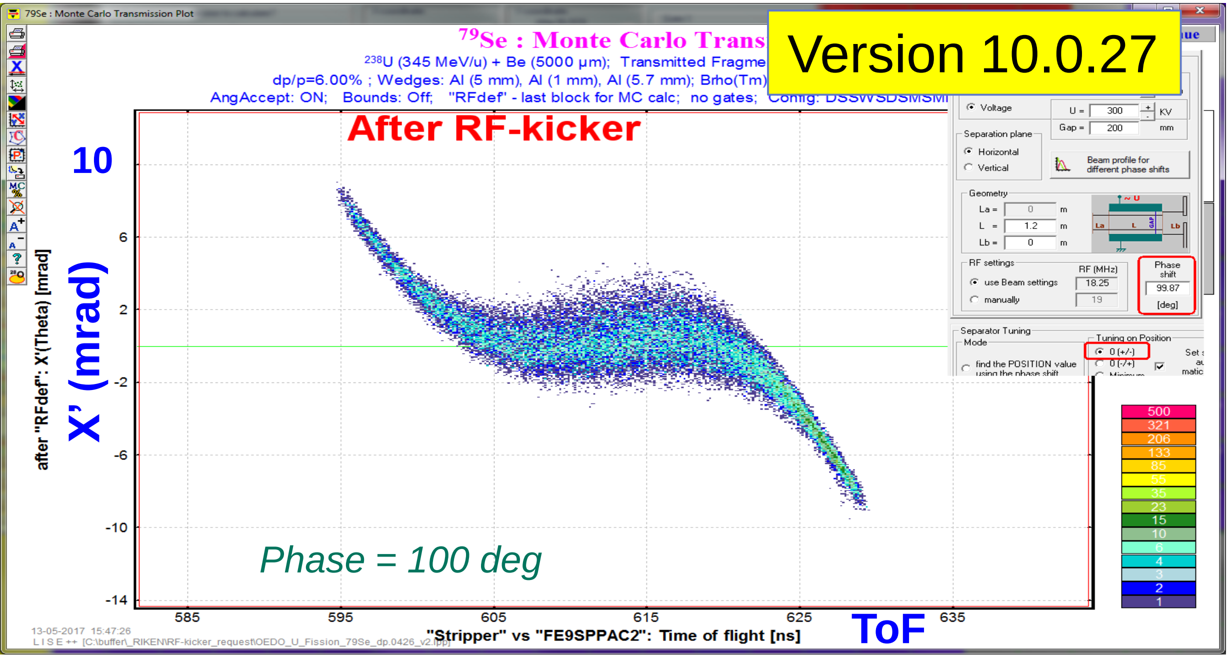
Global matrix

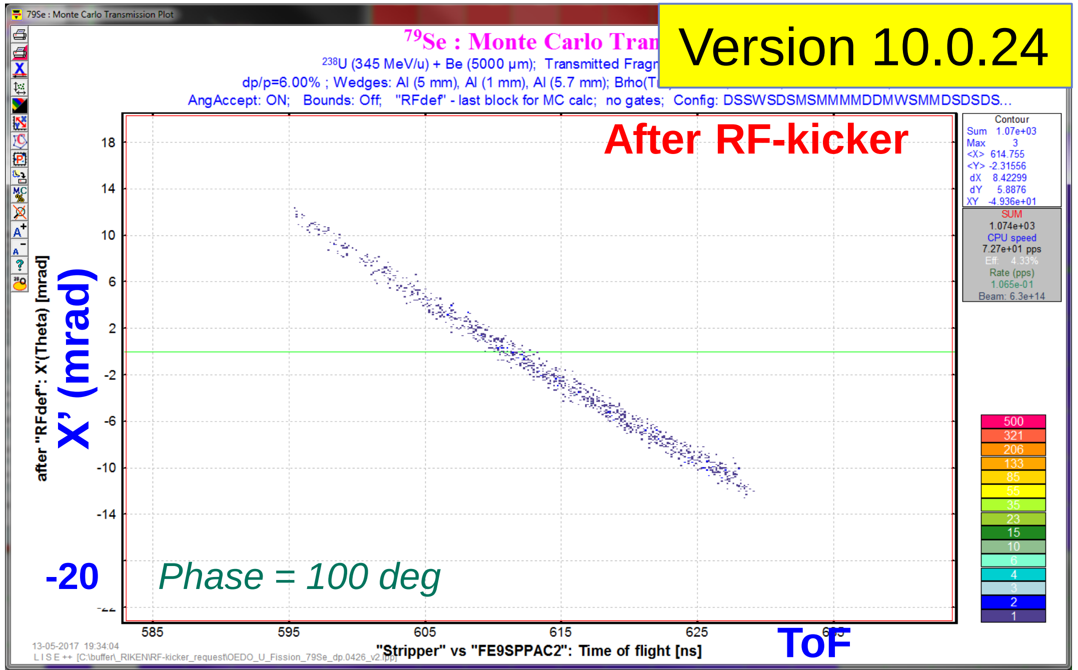
-1.84902	0.02449	0	0	0	13.63026	[mm]
0.20887	-0.54359	0	0	0	4.77385	[mrad]
0	0	-0.25146	0.11675	0	0	[mm]
0	0	-7.94658	-0.28726	0	0	[mrad]
1.14542	-0.75236	0	0	1	49.65549	[mm]
0	0	0	0	0	1	[%]
/[mm]	/[mrad]	/[mm]	/[mrad]	/[mm]	/[%]	



Monte Carlo solution (after RF-kicker) : Versions

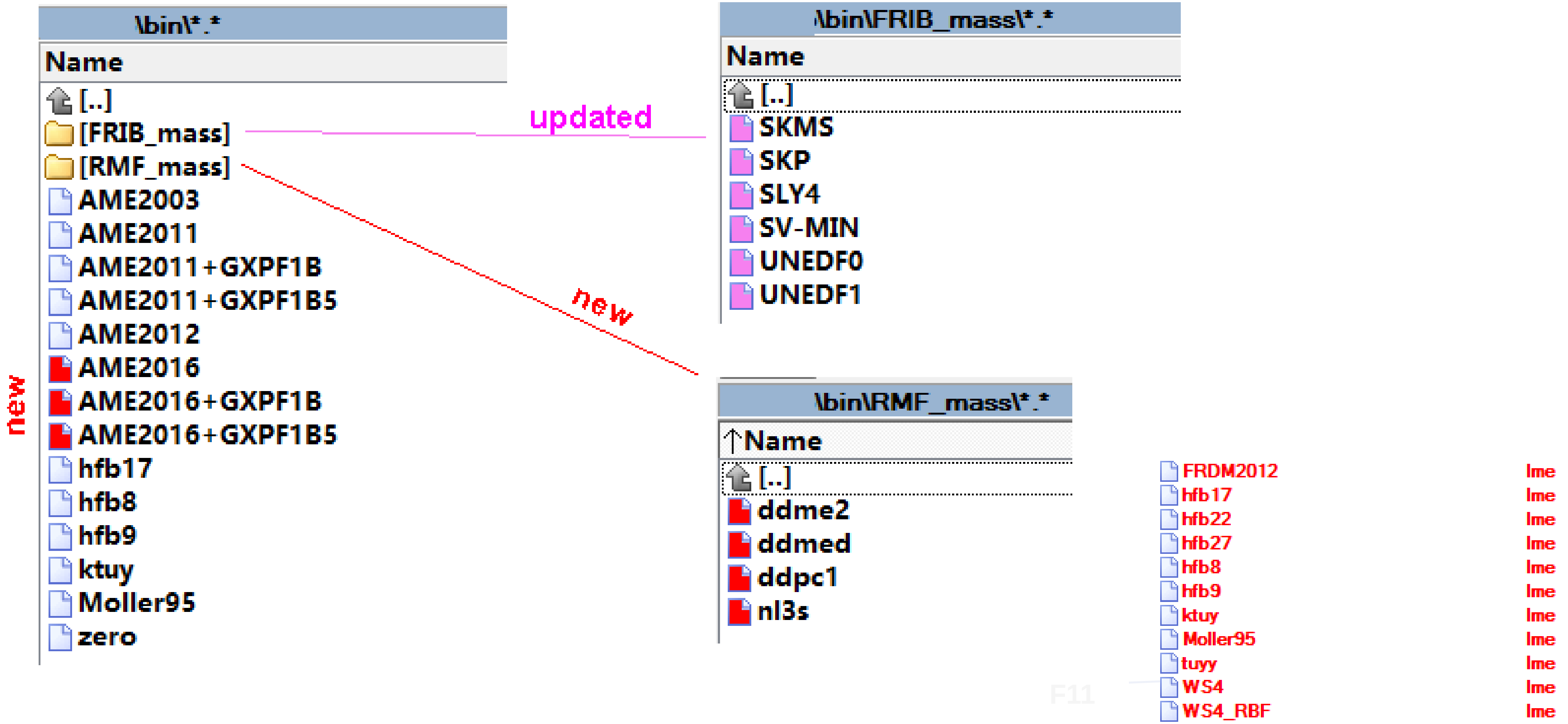






Mass tables in LISE^{++}

2018 : New mass tables in LISE^{++}



You can use own mass tables. LISE mass file extension is “lme”.

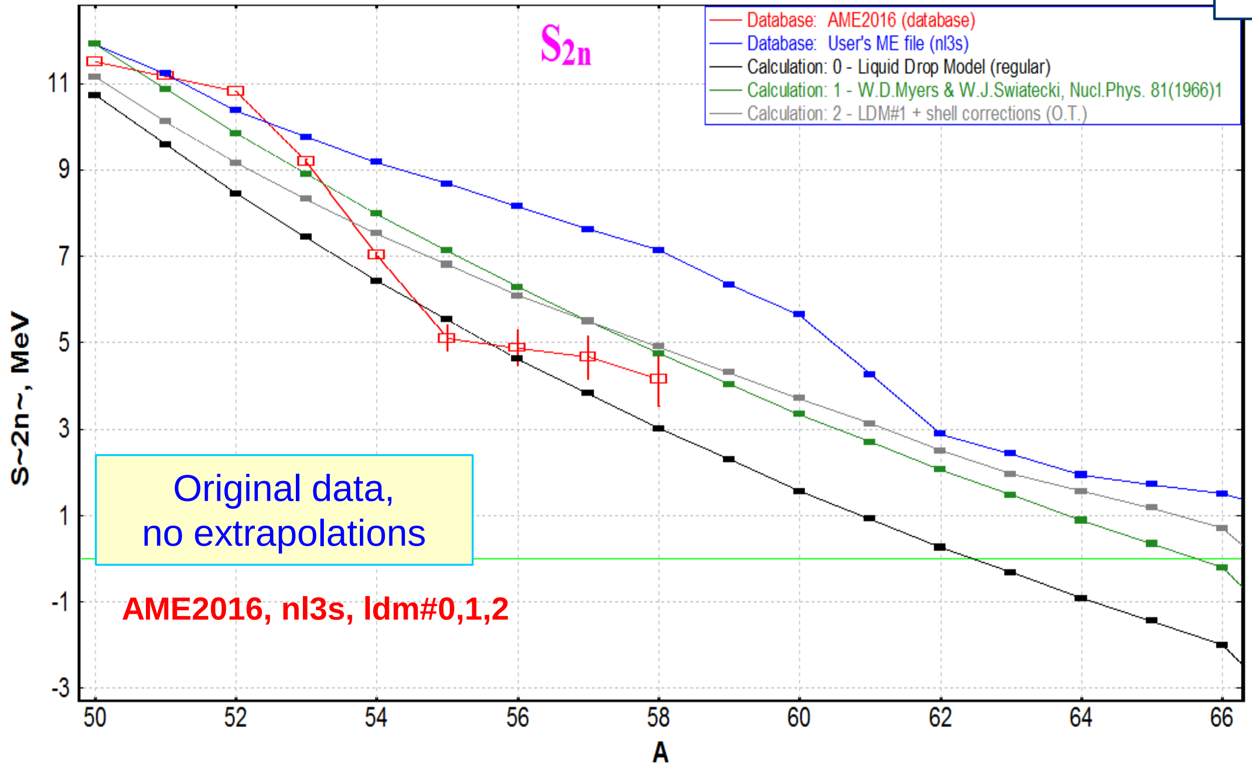
Line Format : Index *<separator>* ME (+ optional → *<separator>* dME),

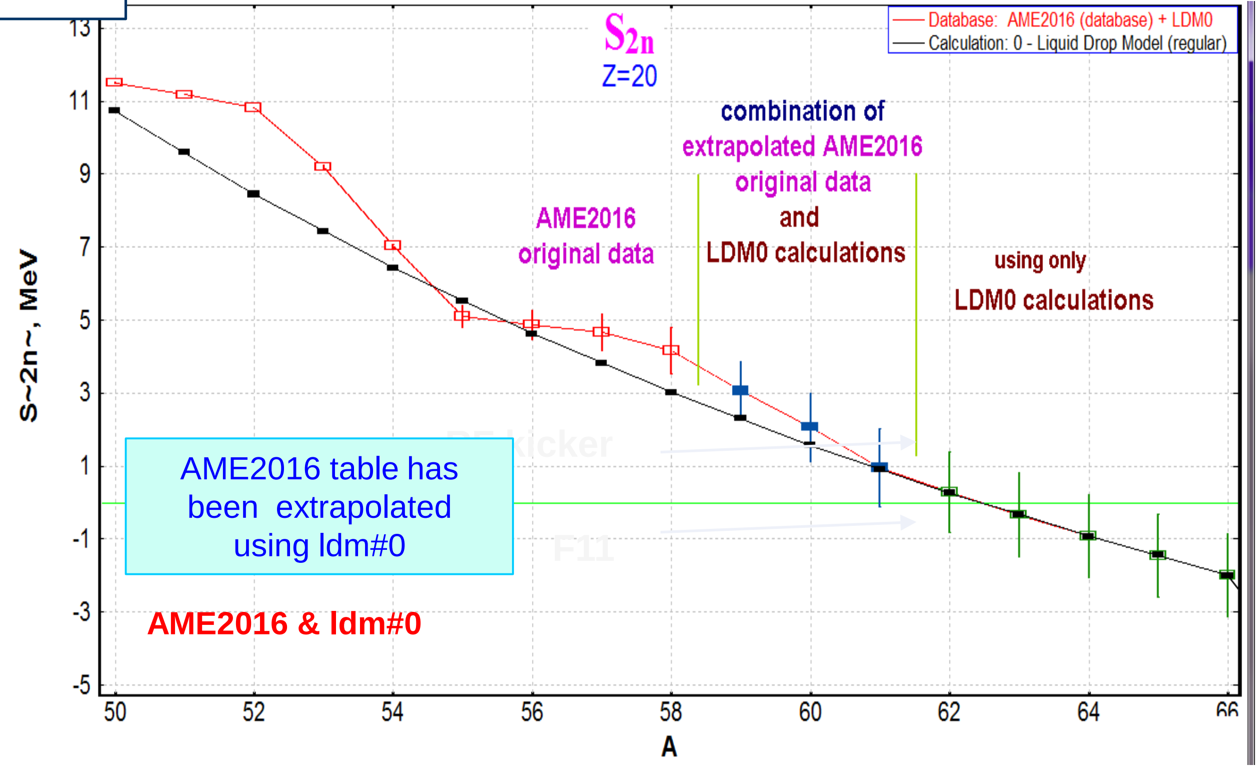
Where “Index” is *Z**1000+*N*, *<separator>* can be space, comma, or tab, “ME” is Mass Excess in MeV, “dME” is Mass Excess Error in MeV.

Modification of the mass excess extrapolation in LISE^{++}

S_{2n} plots for Z=20 (corresponds to the previous Mass Excess page)

Z=20





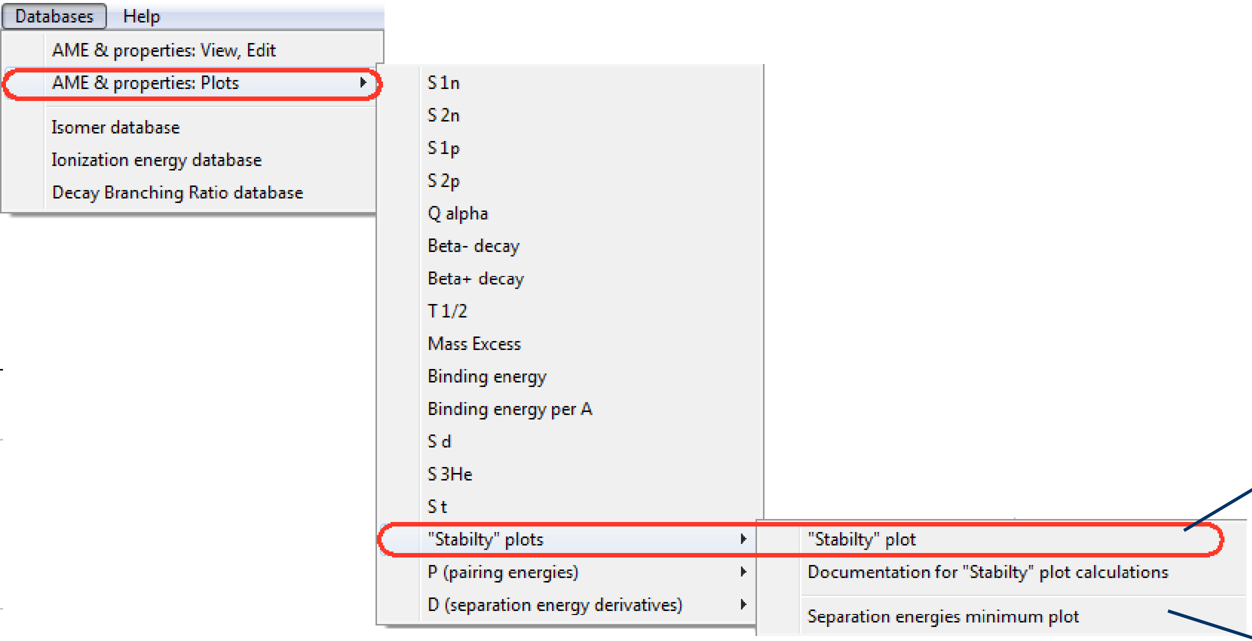
Where LDM #0,1,2 are [Liquid Droplet Models in LISE^{++}](http://lise.nscl.msu.edu/6_1/lise++_6.htm#_Toc26162476)

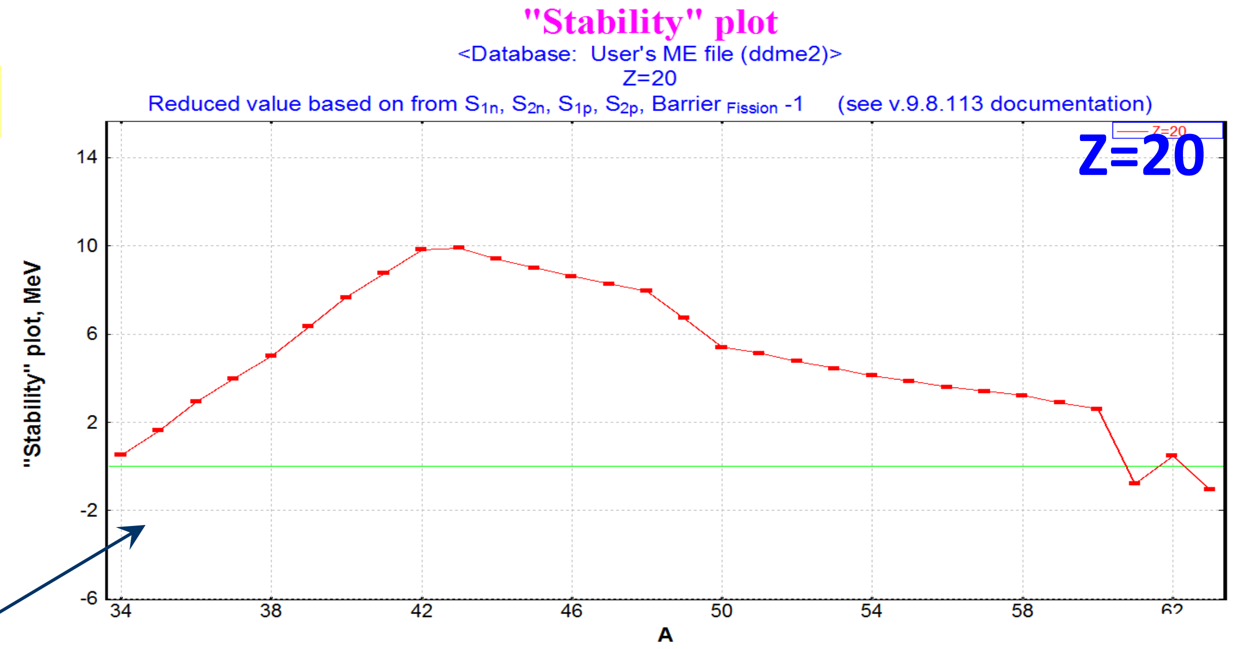
http://lise.nscl.msu.edu/6_1/lise++_6.htm#_Toc26162476

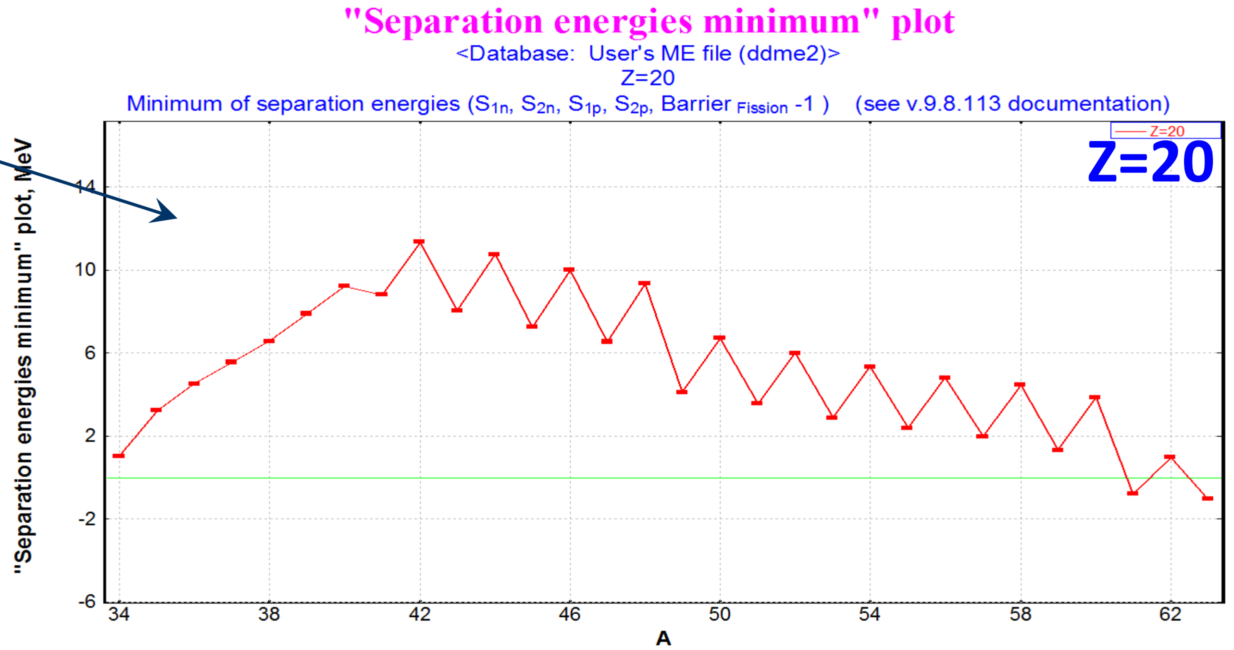
“Stability” plots

More information can be find at

http://lise.nscl.msu.edu/9_8/LISE_stability_plot.pdf







The Purpose is to deduce and plot a minimum value from the set of S1n, S2n, S1p, S2p, Fission Barrier in order to

- Show particle bound isotopes
- Avoid “saw” structure due to odd-even corrections in separation energy

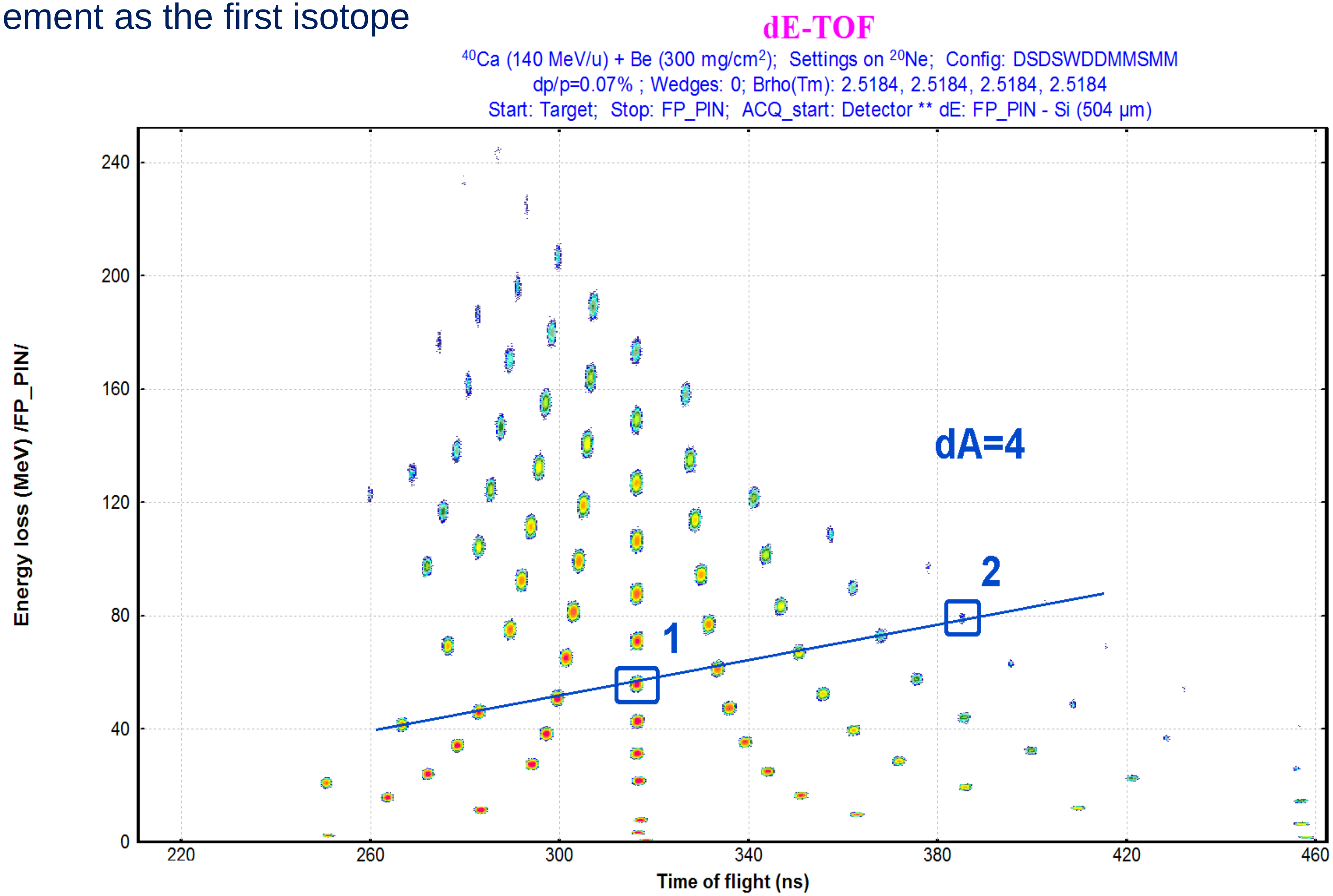
Fission barrier is a maximum value obtained from Fission barrier models in LISE^{++}, including experimental information. BarFac=1, L=0. Fission barrier is decrease by 1.0,roughly assuming that at Fission Barrier =1 a nucleus is not particle bound against fission

PID resolution calculator

Elaine's formula

$(A/q)_1$ isotope – should be belong to A/q line as 2, 2.5 or 3
$(A/q)_2$ isotope – should be the element as the first isotope
ΔA – isotope mass difference

$$Z = \frac{\Delta A}{(A/q)_1 - (A/q)_2}$$



LISE for Excel : PID resolution calculator

$(A/q)_1$ isotope

Ion	
A =	56
Z =	28
q =	28
M_isotope =	55.94213
M_ion =	55.92677
M_ion/q =	1.997385

Set-up				
Energy =	120.00	MeV/u		
Flight Length =	35.500	m		
1st(Z) detector material =	14			
1st(Z) detector thickness =	40	mg/cm2	172.325	um

coef_Aq =	3.10713
Eloss_option =	2
dA_shift=	5

$(A/q)_2$ isotope
Where ΔA – isotope mass difference

Resolution	sigma		systematical (calibration)	
TOF =	0.100	ns	0.01	%
Eloss =	0.20	%	1.11	% (straggling)
TKE =	0.20	%	0.10	%
Z =			0.2	%
Momentum (Brho) =	0.0771	%	0.01	%

Momentum Resolution		
X-image at target =	1.0	mm
X-magnification @ disp.plane =	2.0	
X-dispersion =	29.0	mm/%
Detector resolution =	1.0	mm
Momentum Resolution =	0.0771	%

Measured values			error (σ)	%
TOF =	255.2603	ns	0.103	0.040
Brho =	3.2501	T*m	0.003	0.078
E1_loss =	161.46	MeV	1.82	1.127
TKE =	6711.21	MeV	15.01	0.224

Deduced values			error (σ)	%		Brho	Beta	TKE	E1_loss	Zsyst	A/q	Z
						contribution in error						
beta =	0.463921		0.00019	0.040								
gamma =	1.128825		0.00046	0.040								
velocity =	13.9074	cm/ns	0.00562	0.040								
A / q =	1.997385		0.00224	0.112		0.078%	0.081%					
A/q (2)=	2.17556		0.002657	0.122	A/q 2	0.085%	0.088%					

PID values		error (σ)	%	Brho	Beta	TKE	E1_loss	Zsyst	A/q	Z
Z(Eloss) =	28	0.167	0.60		0.084%		0.56%	0.20%		
Z(A/q)=	28.062	0.547	1.95	1.352%	1.406%					
Z(Aint/q)=	28.480	0.431	1.51	1.049%	1.091%				0.131%	
q =	28.000	0.101	0.36	0.078%	0.272%	0.224%				
A (from TKE) =	55.9268	0.234	0.42		0.353%	0.224%				
A (from [A/q]*q_integer) =	55.9268	0.063	0.11						0.112%	
A (from [A/q]*q_measur) =	55.9268	0.211	0.38	0.078%	0.081%	0.361%				
A-2q =	-0.07	0.063		0.04	0.04	0.00				
A-3q =	-28.07	0.096		0.07	0.03	0.06				

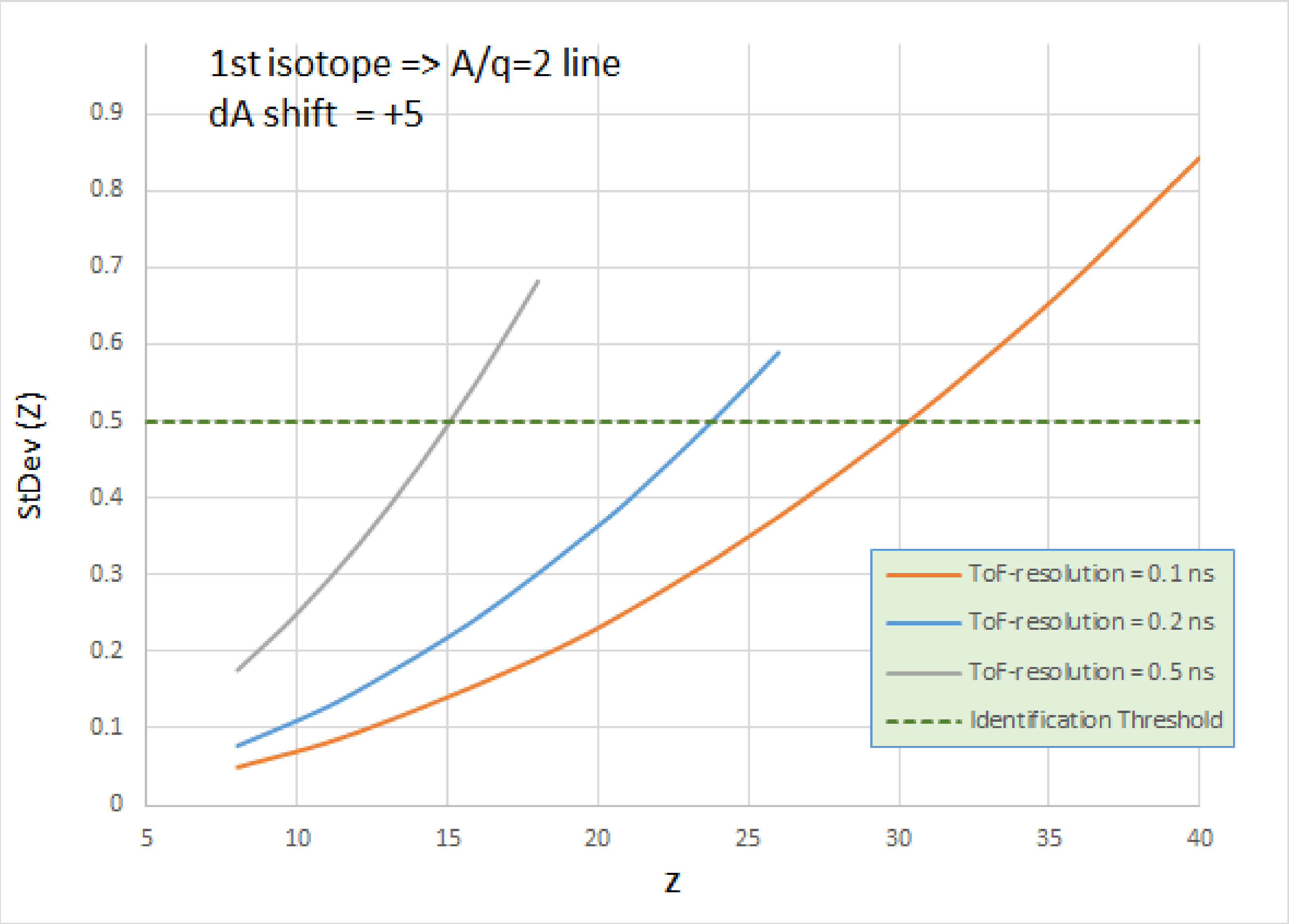
Base | Global | ChargeStates -> MeanValue | **PID resolution calculator** | ReactionCalculation | List of LISE.xlsm functions | work

Z(A/q) -> when ion masses are used for both isotope A/q ratios

Z(Aint/q) -> when integer A-value is used to define a/q value (Elaine's case)

New PID capabilities and features : timing resolution

All calculations were done for
- A1900 separator
- No wedge
- E(1st fragment)=120 MeV/u
- I1_slits = ± 1mm



Under current conditions, the identification above Calcium is possible

^{198}Pt experiment :
fragment-separator & spectrometer

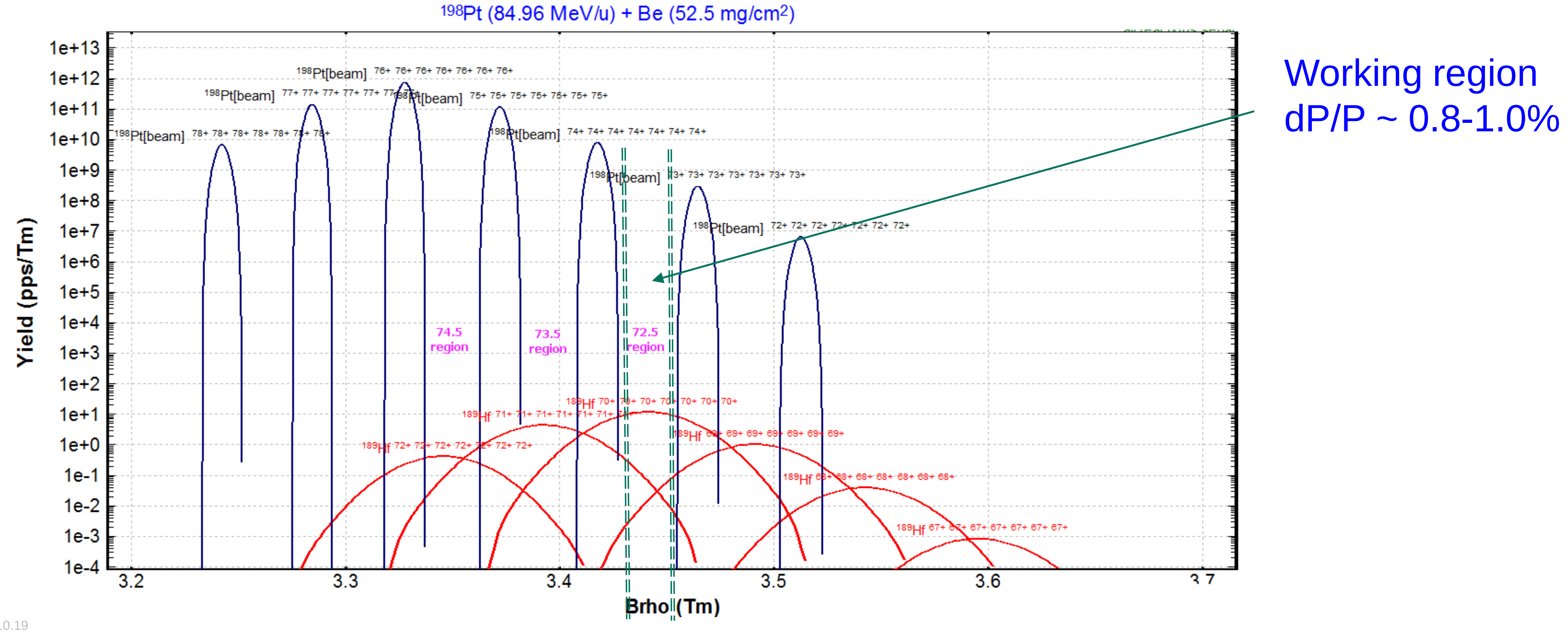
Working in High-Z region at intermediate energies

07 / 2019

NSCL E15130
"Search for isotopes and isomers in the Hf region"

PIs:
- Partha Chowdhury (UML)
- Oleg Tarasov (MSU)
- Andrew Rogers (UML)

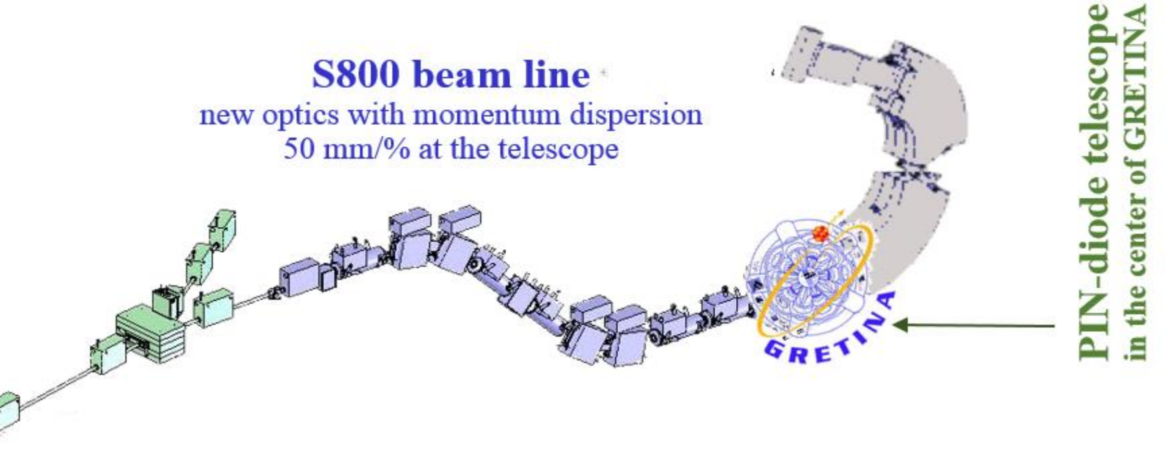
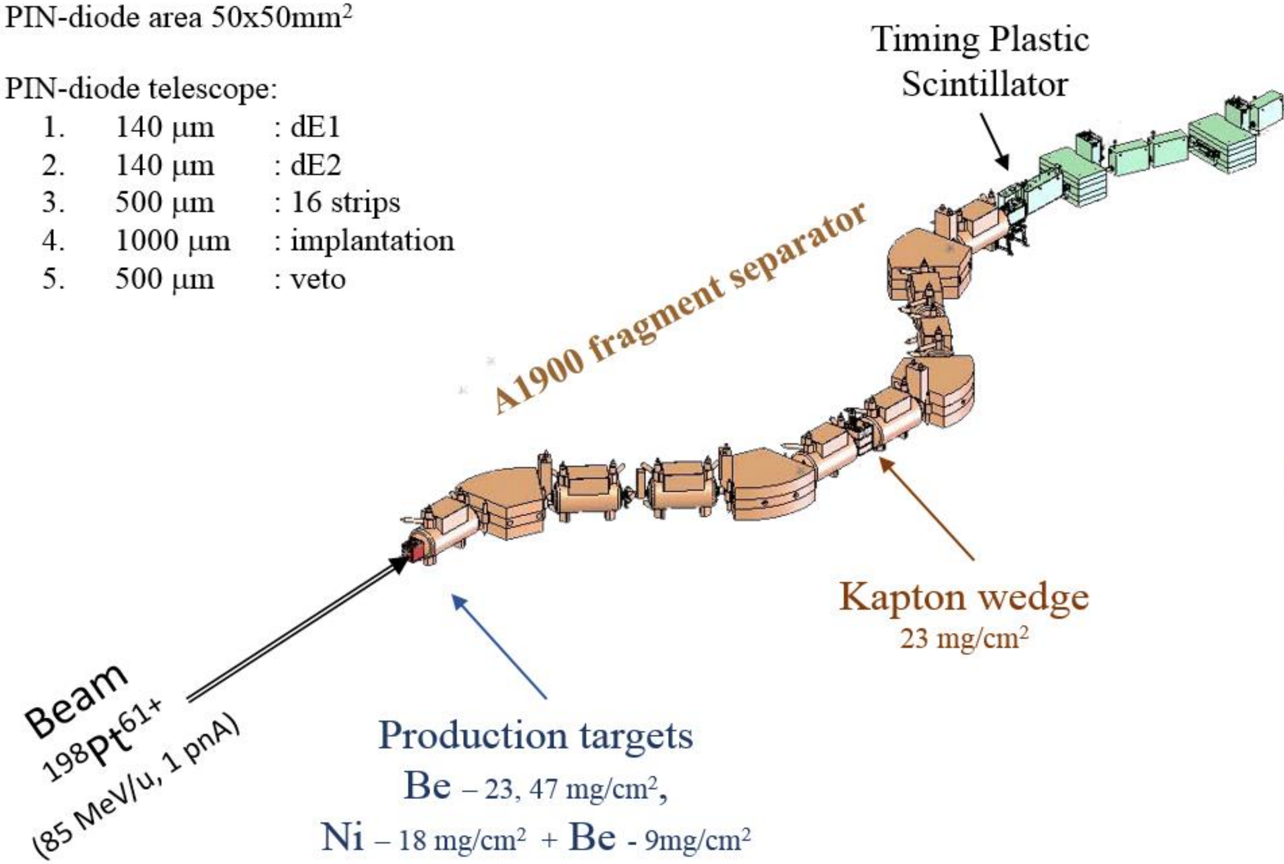
- Working between primary beam charge states
- Try to avoid in-flight detectors (charge state production)
- No in-flight detectors in Dispersive plane ("wedge" property)
- "Separator + *Long* Spectrometer" method

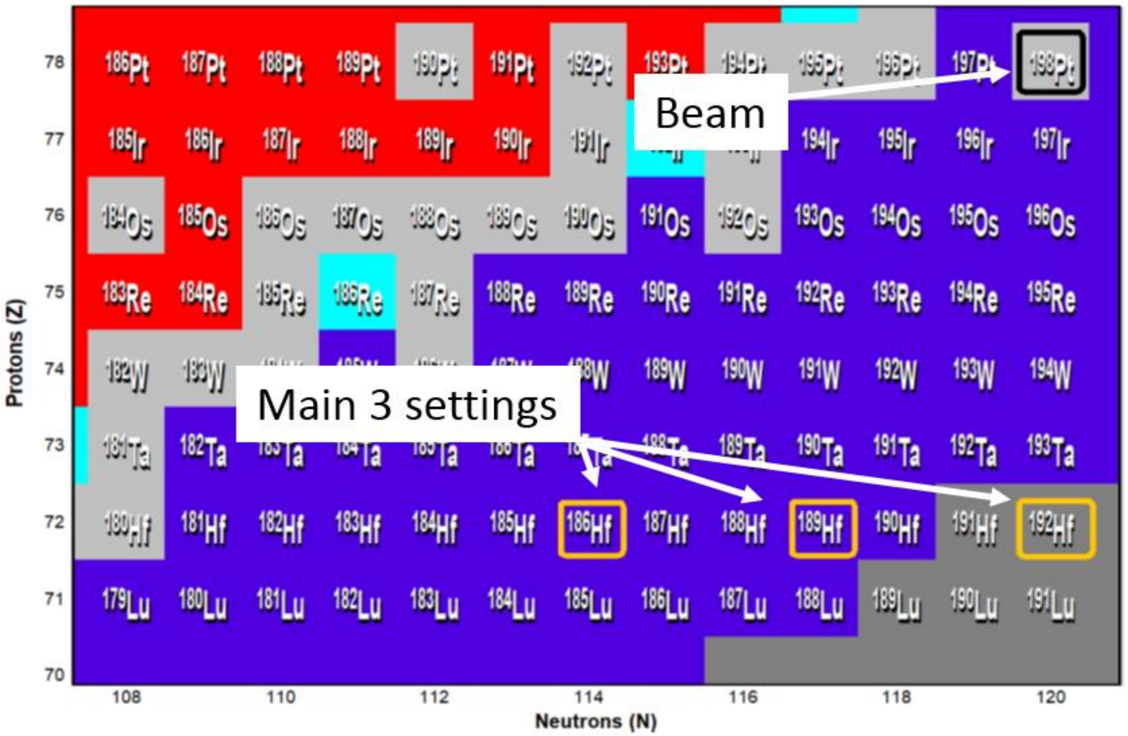


Layout of the e15130 experiment at NSCL / MSU (07/2019):

"Search for isotopes and isomers in the Hf region"

- Working between primary beam charge states ($\Delta p/p \leq 1\%$)
- Distance between the A1900 XFP Sci & the PIN-diode telescope ~ 46.5 m
- PIN-diode area 50x50mm²
- PIN-diode telescope:
  1. 140 μm : dE1
  2. 140 μm : dE2
  3. 500 μm : 16 strips
  4. 1000 μm : implantation
  5. 500 μm : veto

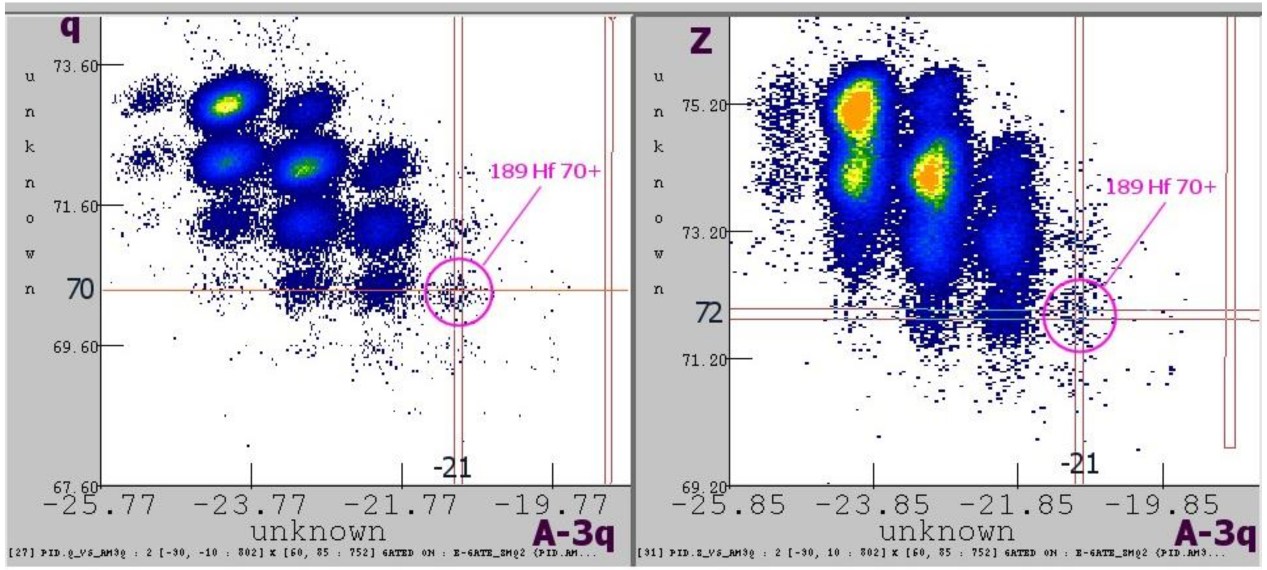





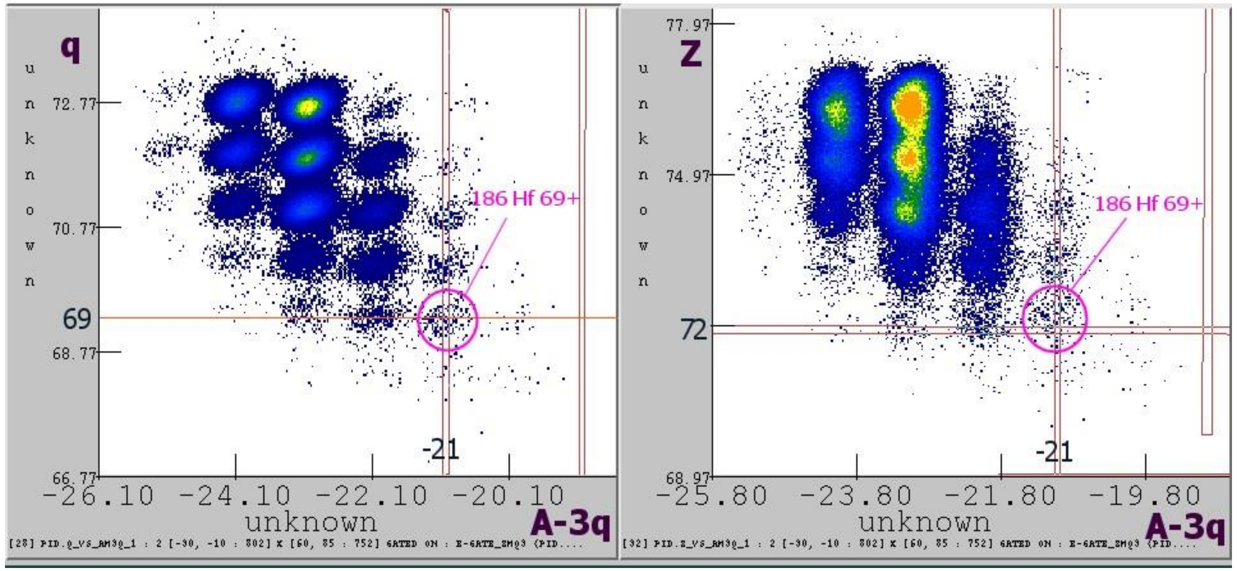
Experiment #e15130; July 2019 @ NSCL/MSU

^{198}Pt (85 MeV/u) + Be (47 mg/cm^2) -> Wedge -> $^{189}Hf^{70+}$

selection Z-q=2



selection Z-q=3



- New isotopes have been observed in the $^{192}Hf^{70+}$ settings
- Similar experiment (High-Z beam, working between charge states, dispersion at the FP detectors) will be held in RIKEN (11/2019)

e12022
Charge states “cleaning”

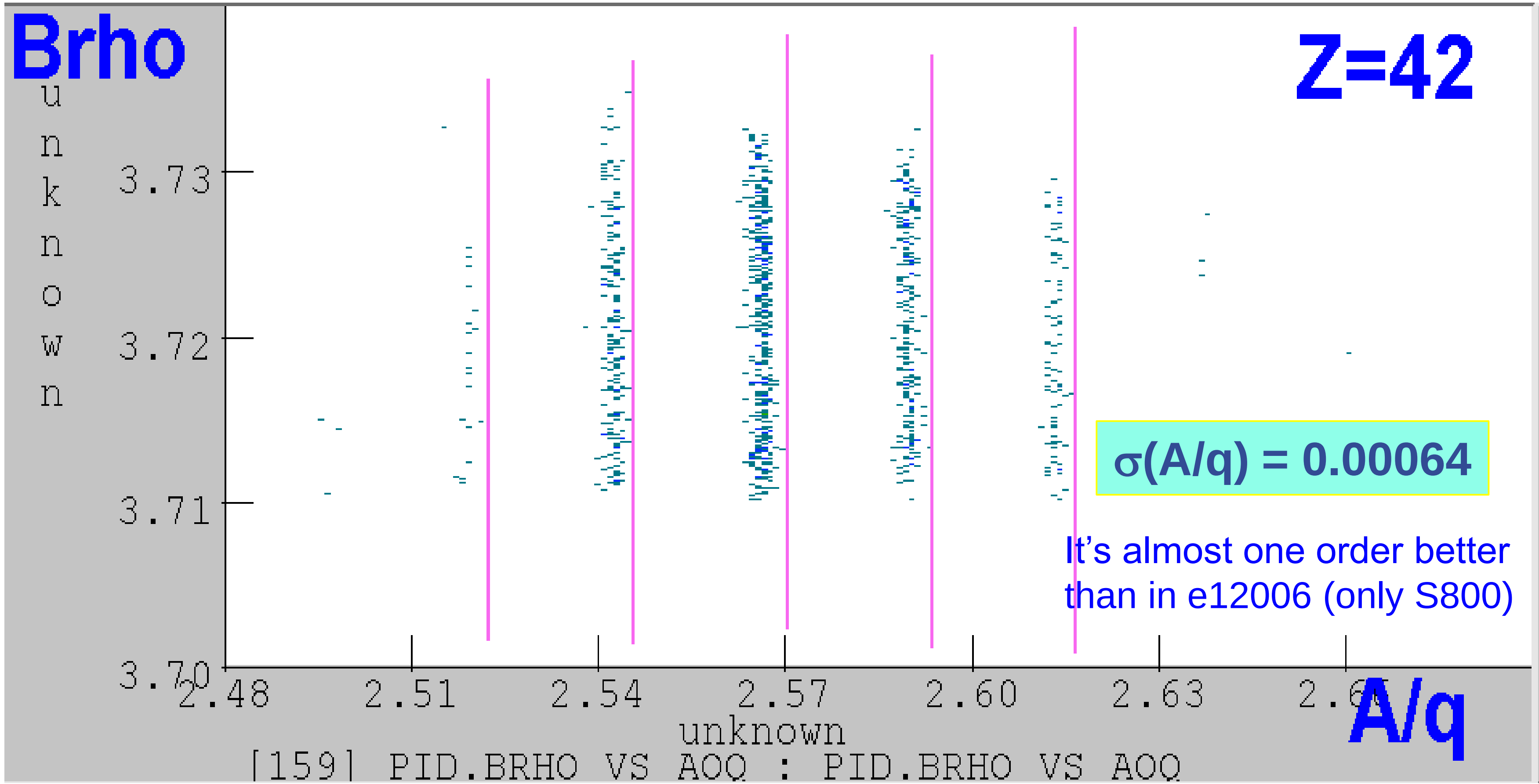
E12022 : PID

PI: M.Famiano

- Mass measurement
- Disperse mode
- PIN-telescope at the S800 FP
- Bhro measurement at the S800 TP by MCP

Dispersion12= 112.00000	mm/%
user.mcpm_x1_a3	-19.399
user.mcpm_x1_a2	-3.38656
user.mcpm_x1_a1	-26.62532
user.mcpm_x1_a0	-4.11869

Good



σ(A/q) = 0.00064

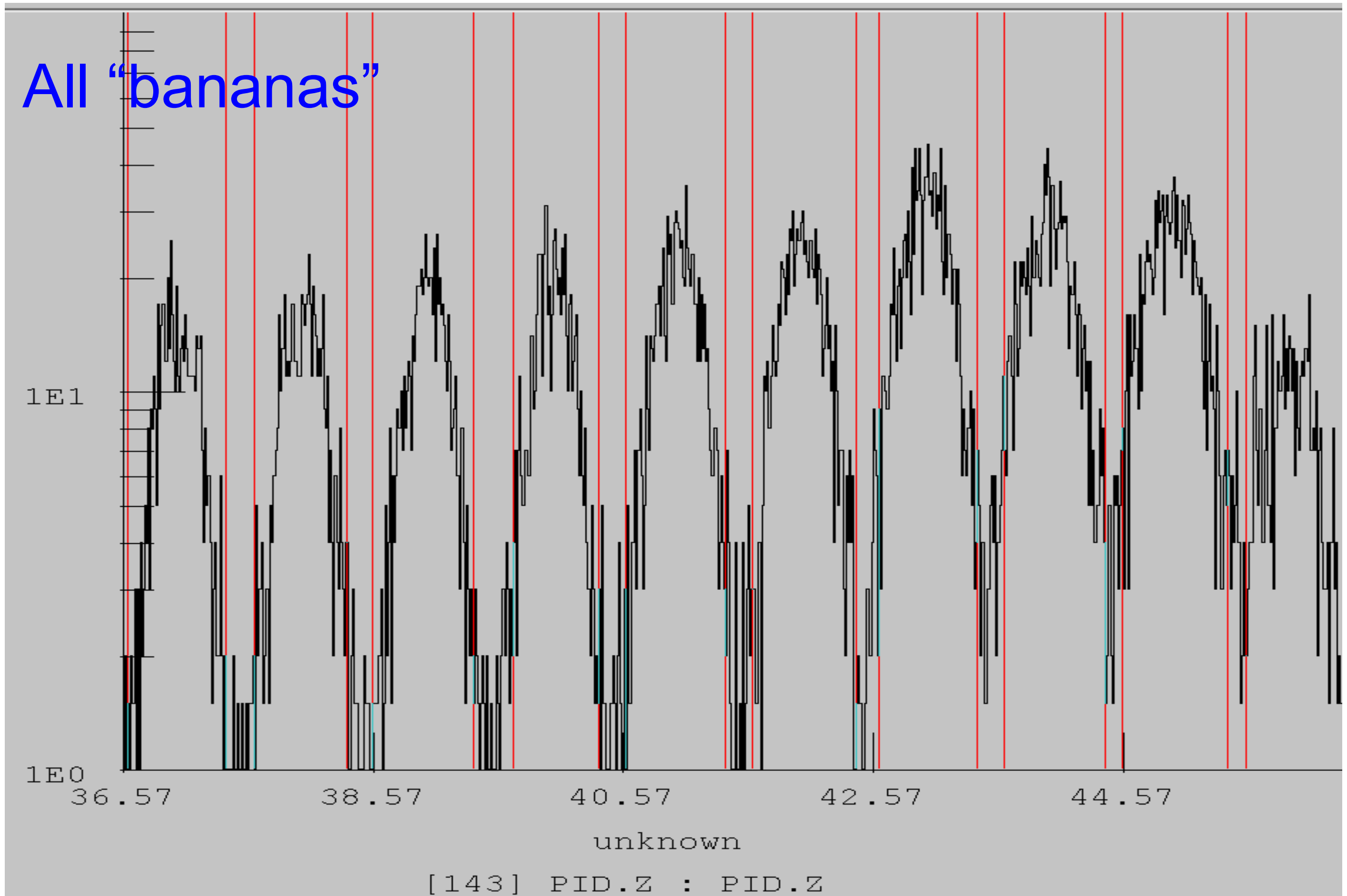
It's almost one order better than in e12006 (only S800)

Resolution : Z

Good

Average of $|Z_{calc} - Z_{peak}| = 0.057$ in Z=32-50 region

$\sigma(Z) = 0.157$ for all Z=42 isotopes, $\sigma(Z) = 0.153$ for ^{108}Mo



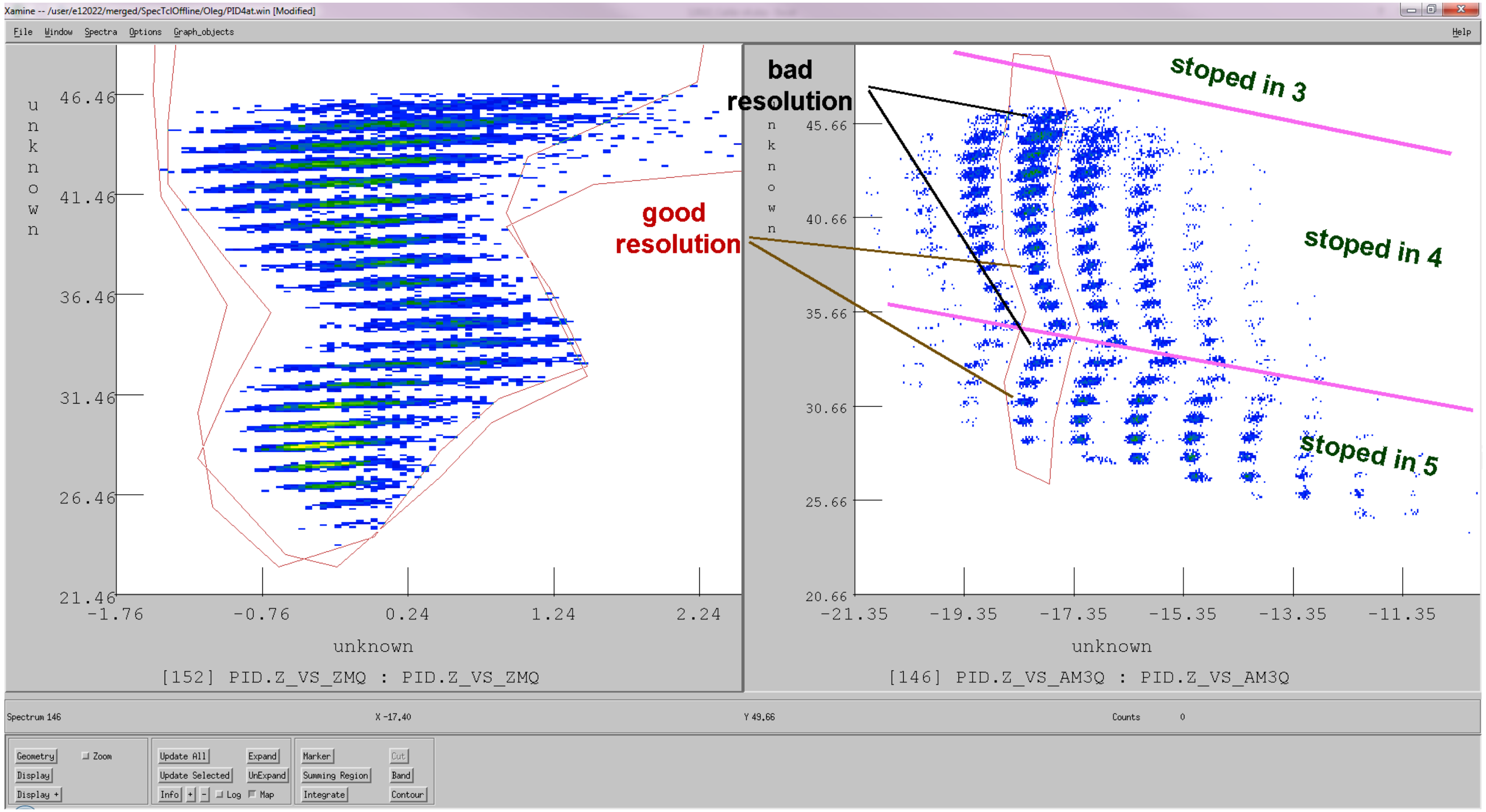
Resolution : TKE & Q

BAD !

3rd and 4th PIN-diodes **not well** depleted

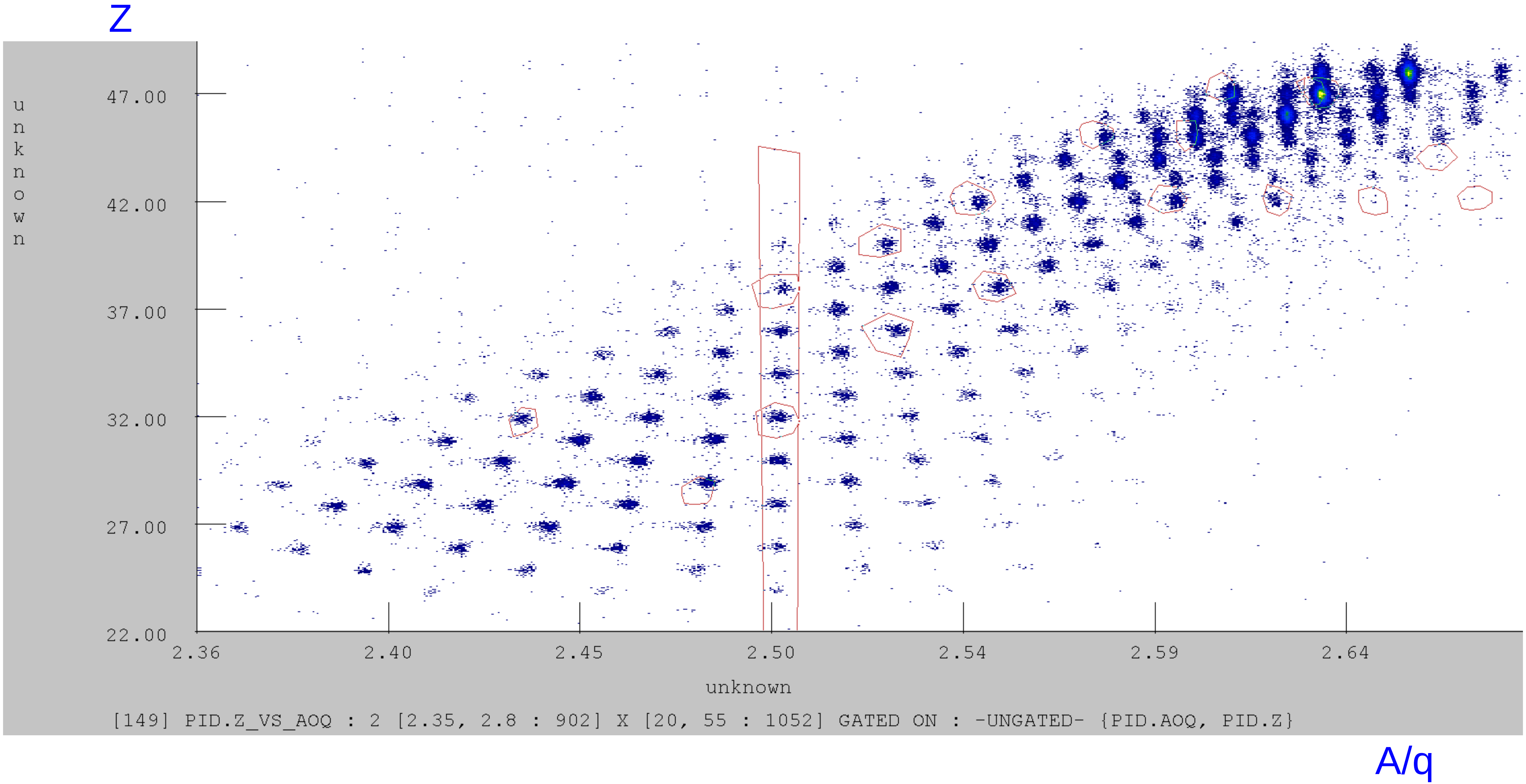
Average of $|Q_{calc} - Q_{peak}|$ = **0.29 (!)** in Z=32-50 region

$Q_{measured}$ = 42.24 with σ(Q) = 0.27 for $^{108}Mo^{42+}$, for all Z=42 full-stripped isotopes σ(Q) = 0.274*



Actually σ(Q) is not so bad, but charge state overlapping was observed in the Z-q plot. So, the "banana" selection method can help.
See next slides

PID plot without filtering



Charge state separation with “A-3Z” integer values

This method can be used only in the case of

- perfect Z and A/q resolution
- far from integer values of A/Z (2,3) ***(see last slide for details)*
- Only to separate Z-q =0 and Z-q=1.

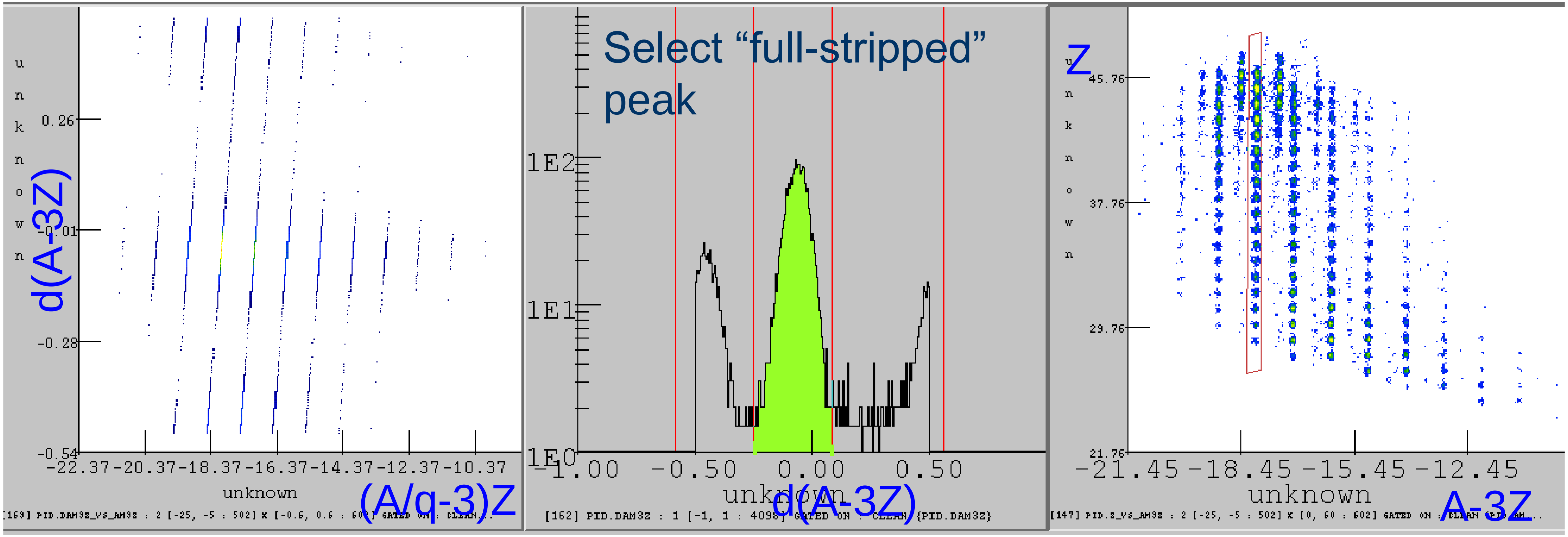
So, in our case we are working around 2.5, and no helium-like products

Zi = int(Z+0.5)

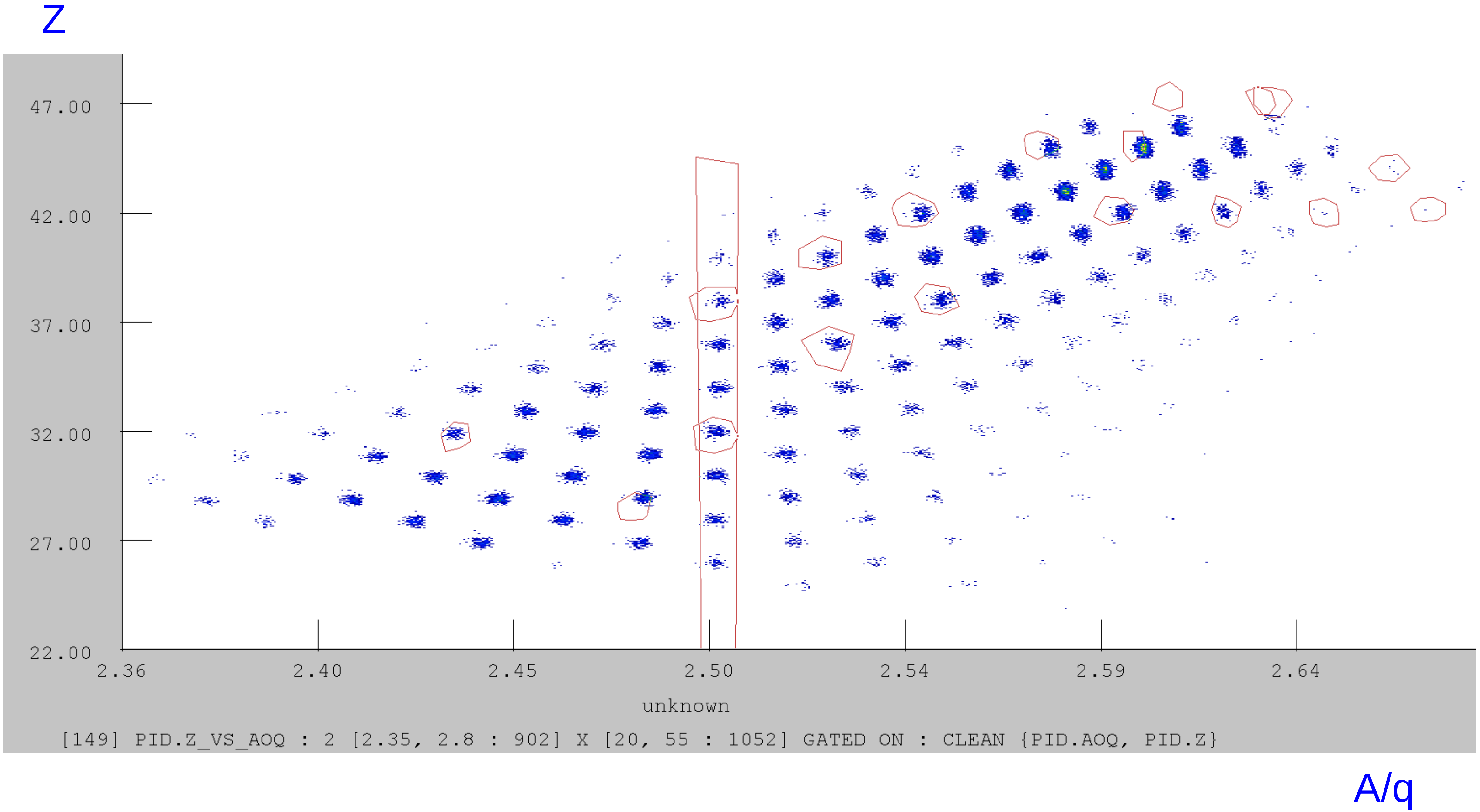
Am3Z = (A/q – 3) * Zi

Am3Zi = int(Am3Z + 1.5)

dA3mZ = Am3Z - Am3Zi



Final PID plot of full-stripped ions passed to the 4th detector



Region to cut charge states using the "integer" method

The red color shows that charge states will be cut for specific isotope of Z=42

Z = 42

A	Z-q 1	Z-q 2	Z-q 3	Z-q 4
80	0.049	0.000	0.154	0.421
81	0.024	0.050	0.231	0.474
82	0.000	0.100	0.308	0.368
83	0.024	0.150	0.385	0.263
84	0.049	0.200	0.462	0.158
85	0.073	0.250	0.462	0.053
86	0.098	0.300	0.385	0.053
87	0.122	0.350	0.308	0.158
88	0.146	0.400	0.231	0.263
89	0.171	0.450	0.154	0.368
90	0.195	0.500	0.077	0.474
91	0.220	0.450	0.000	0.421
92	0.244	0.400	0.077	0.316
93	0.268	0.350	0.154	0.211
94	0.293	0.300	0.231	0.105
95	0.317	0.250	0.308	0.000
96	0.341	0.200	0.385	0.105
97	0.366	0.150	0.462	0.211
98	0.390	0.100	0.462	0.316
99	0.415	0.050	0.385	0.421

A	Z-q 1	Z-q 2	Z-q 3	Z-q 4
100	0.439	0.000	0.308	0.474
101	0.463	0.050	0.231	0.368
102	0.488	0.100	0.154	0.263
103	0.488	0.150	0.077	0.158
104	0.463	0.200	0.000	0.053
105	0.439	0.250	0.077	0.053
106	0.415	0.300	0.154	0.158
107	0.390	0.350	0.231	0.263
108	0.366	0.400	0.308	0.368
109	0.341	0.450	0.385	0.474
110	0.317	0.500	0.462	0.421
111	0.293	0.450	0.462	0.316
112	0.268	0.400	0.385	0.211
113	0.244	0.350	0.308	0.105
114	0.220	0.300	0.231	0.000
115	0.195	0.250	0.154	0.105
116	0.171	0.200	0.077	0.211
117	0.146	0.150	0.000	0.316
118	0.122	0.100	0.077	0.421
119	0.098	0.050	0.154	0.474

Region to cut charge states using the "integer" method

The red color shows that charge states will be cut for specific isotope of Z=50

For example for A=132 (A-3q =18), main problem to clean will be Z-q=3 (A=124)

				Z	50					
							real banana			
1	2	3	4		A	0	1	2	3	4
0.041	0.167	0.383	0.304		100	-50.0	-48.0	-45.8	-43.6	-41.3
0.061	0.208	0.447	0.217		101	-49.0	-46.9	-44.8	-42.6	-40.2
0.082	0.250	0.489	0.130		102	-48.0	-45.9	-43.8	-41.5	-39.1
0.102	0.292	0.426	0.043		103	-47.0	-44.9	-42.7	-40.4	-38.0
0.122	0.333	0.362	0.043		104	-46.0	-43.9	-41.7	-39.4	-37.0
0.143	0.375	0.298	0.130		105	-45.0	-42.9	-40.6	-38.3	-35.9
0.163	0.417	0.234	0.217		106	-44.0	-41.8	-39.6	-37.2	-34.8
0.184	0.458	0.170	0.304		107	-43.0	-40.8	-38.5	-36.2	-33.7
0.204	0.500	0.106	0.391		108	-42.0	-39.8	-37.5	-35.1	-32.6
0.224	0.458	0.043	0.478		109	-41.0	-38.8	-36.5	-34.0	-31.5
0.245	0.417	0.021	0.435		110	-40.0	-37.8	-35.4	-33.0	-30.4
0.265	0.375	0.085	0.348		111	-39.0	-36.7	-34.4	-31.9	-29.3
0.286	0.333	0.149	0.261		112	-38.0	-35.7	-33.3	-30.9	-28.3
0.306	0.292	0.213	0.174		113	-37.0	-34.7	-32.3	-29.8	-27.2
0.327	0.250	0.277	0.087		114	-36.0	-33.7	-31.3	-28.7	-26.1
0.347	0.208	0.340	0.000		115	-35.0	-32.7	-30.2	-27.7	-25.0
0.367	0.167	0.404	0.087		116	-34.0	-31.6	-29.2	-26.6	-23.9
0.388	0.125	0.468	0.174		117	-33.0	-30.6	-28.1	-25.5	-22.8
0.408	0.083	0.468	0.261		118	-32.0	-29.6	-27.1	-24.5	-21.7
0.429	0.042	0.404	0.348		119	-31.0	-28.6	-26.0	-23.4	-20.7
0.449	0.000	0.340	0.435		120	-30.0	-27.6	-25.0	-22.3	-19.6
0.469	0.042	0.277	0.478		121	-29.0	-26.5	-24.0	-21.3	-18.5
0.490	0.083	0.213	0.391		122	-28.0	-25.5	-22.9	-20.2	-17.4
0.490	0.125	0.149	0.304		123	-27.0	-24.5	-21.9	-19.1	-16.3
0.469	0.167	0.085	0.217		124	-26.0	-23.5	-20.8	-18.1	-15.2
0.449	0.208	0.021	0.130		125	-25.0	-22.4	-19.8	-17.0	-14.1
0.429	0.250	0.043	0.043		126	-24.0	-21.4	-18.75	-16.0	-13.0
0.408	0.292	0.106	0.043		127	-23.0	-20.4	-17.71	-14.9	-12.0
0.388	0.333	0.170	0.130		128	-22.0	-19.4	-16.7	-13.8	-10.9
0.367	0.375	0.234	0.217		129	-21.0	-18.37	-15.6	-12.8	-9.8
0.347	0.417	0.298	0.304		130	-20.0	-17.35	-14.6	-11.7	-8.7
0.327	0.458	0.362	0.391		131	-19.0	-16.3	-13.5	-10.6	-7.6
0.306	0.500	0.426	0.478		132	-18.0	-15.3	-12.5	-9.6	-6.5
0.286	0.458	0.489	0.435		133	-17.0	-14.3	-11.5	-8.5	-5.4
0.265	0.417	0.447	0.348		134	-16.0	-13.3	-10.4	-7.4	-4.3
0.245	0.375	0.383	0.261		135	-15.0	-12.2	-9.4	-6.4	-3.3
0.224	0.333	0.319	0.174		136	-14.0	-11.2	-8.3	-5.3	-2.2
0.204	0.292	0.255	0.087		137	-13.0	-10.2	-7.3	-4.3	-1.1
0.184	0.250	0.191	0.000		138	-12.0	-9.2	-6.3	-3.2	0.0
0.163	0.208	0.128	0.087		139	-11.0	-8.2	-5.2	-2.1	1.1
0.143	0.167	0.064	0.174		140	-10.0	-7.1	-4.2	-1.1	2.2

Summary

LISE++ summary

Thank you for choosing our company!

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