

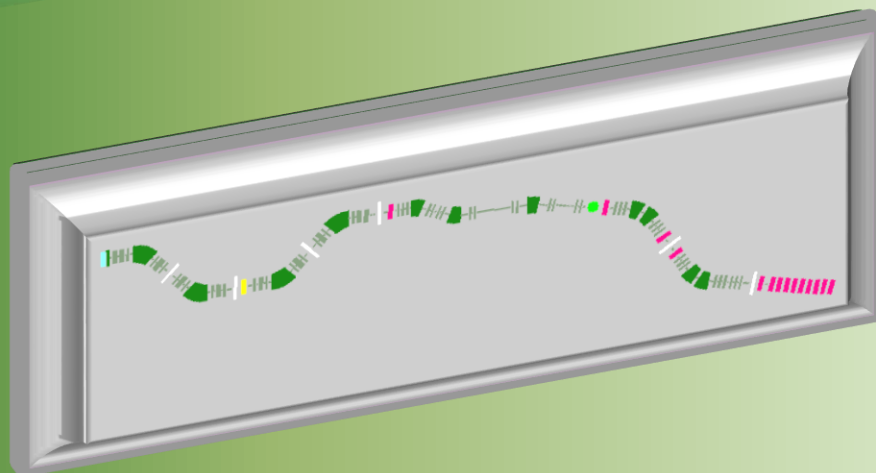
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NCSL / MSU, USA

October 2, 2019


**LISE++ development,
Production mechanism,
PID**

*Expert Fragment Separator Meeting
Expert Fragment-Separator Meeting*

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 Ga isotopes~~
 8. Summary
- 

Will be released soon!
(October 2019)

Number of versions

Correction	fixed bugs	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

- LISE⁺⁺ porting to a modern framework
- ATIMA 1.4 -----
- LISE for Excel -----
- ETACHA4 -----
- Range Optimizer at high energies -----

2017

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

time is needed to
convert from C++11

MS “support”, LISE⁺⁺ porting to 64-bit

Still stiffness problem

It required some time...

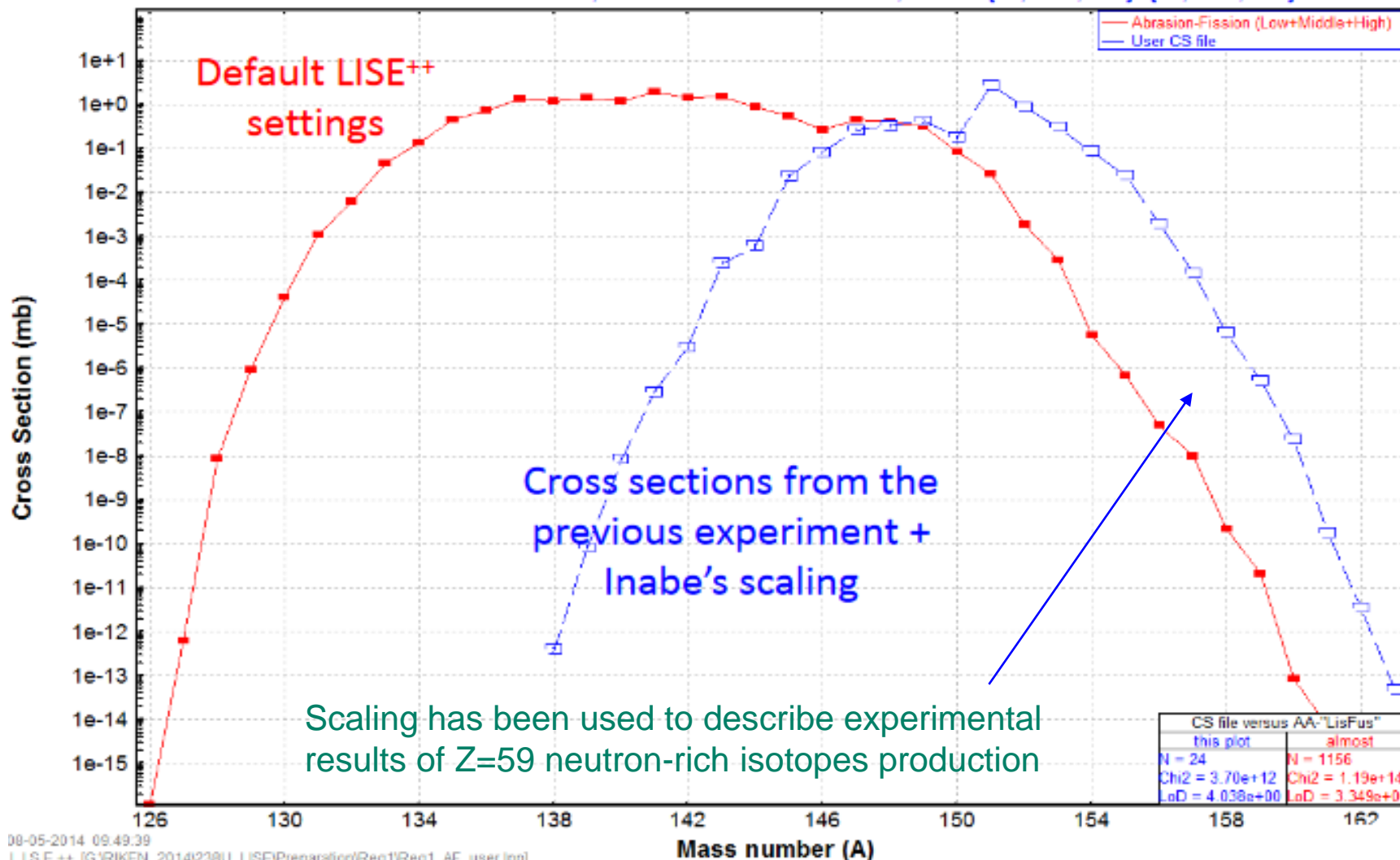
Looking for more people to overcome it!

High-Z Abrasion-Fission production cross sections

Cross sections Z=59

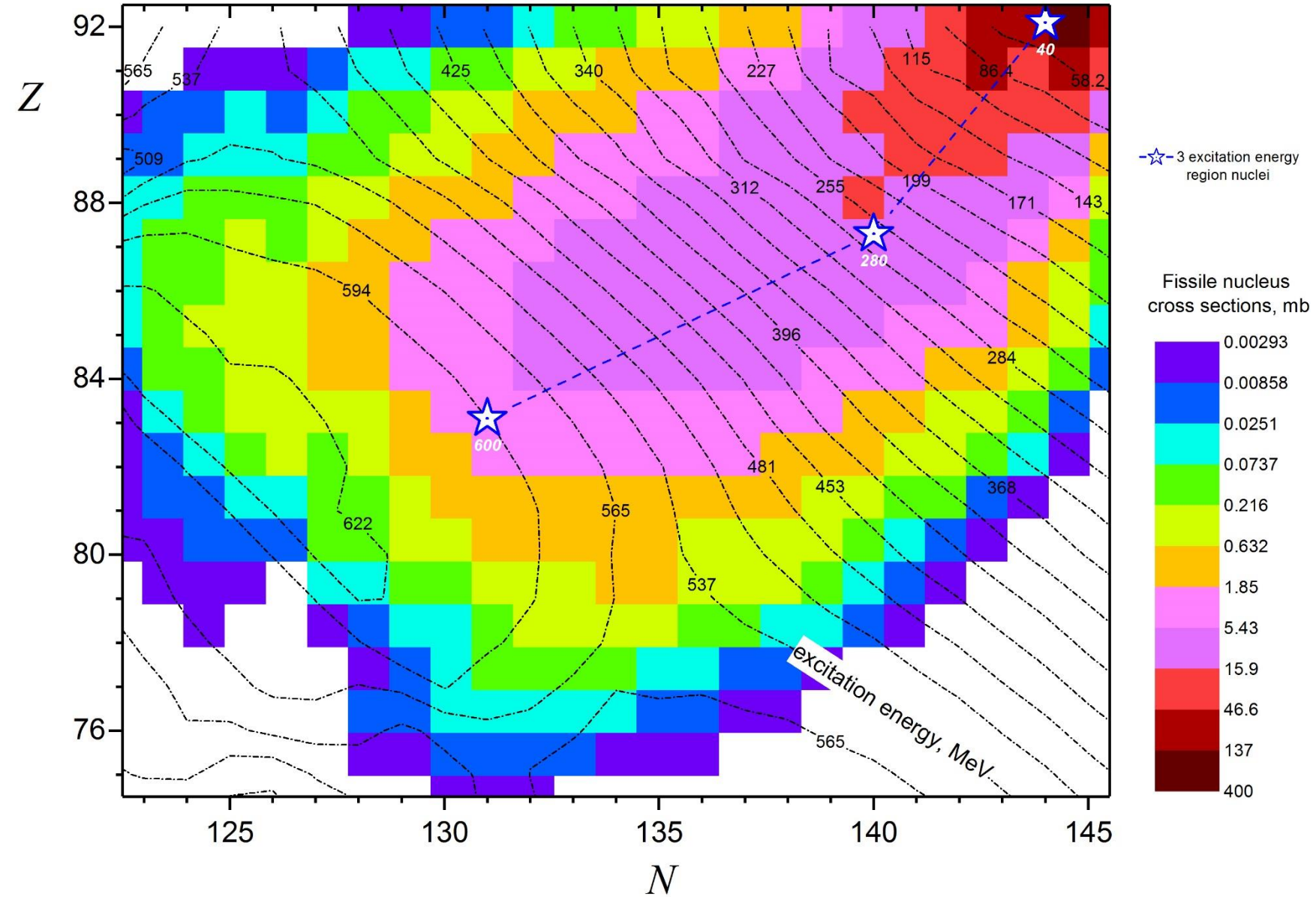
Cross sections (Abrasion-Fission (Low+Middle+High))

-- Final CS -- ^{238}U (345.0 MeV/u) + Be (3 mm) \rightarrow Z=59
 $^{236}\text{U}^*$ Ex=24MeV CS=192.7mb -- $^{226}\text{Th}^*$ Ex=100MeV CS=500.0mb -- $^{220}\text{Ra}^*$ Ex=250MeV CS=350.0mb
 Fission => Odd-Even corr.: Yes; Post-scission emission: Yes; Shells: {83,-2.65,0.70}&{90,-3.80,0.15}



00-05-2014 09:49:39
 LISE++ (G:\RIKEN 2014\238U LISEPreparation\Rec1\Rec1_AF user.lol)

1. Fast Analytical model
2. Averaging → substitution of more than 1000 fissile nuclei by 3 nuclei



Abrasion-Fission

238U (79.6 MeV/u) + C

Energy region definitions

Excitation energy region	LOW	MIDDLE	HIGH
Choose a primary reaction	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>
Perform transmission calculations for this energy region	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Choose FISSILE nucleus	223Rn	229Rn	230At
Excitation energy (MeV)	295.6	221.8	192.1
Cross section (mb)	740.7	19.9	1.1

Restore previous settings Cross sections sum (mb) 761.7

Load Fission, Evaporation, Excit. Energy Region settings from file

Fission properties Calculate Fissile nuclei velocity based on the Projectile Fragmentation model (DJM)

Evaporation settings

Prefragment excit. energy

OK Cancel Help Make default

LISE++ Abrasion-Ablation calculations to estimate excitation energy regions

1. Calculate. 2. Use "All" hints in code. 3. Plot

Calculate * no calculations were found

Plot use "ALL" hints in code

	LOW	MIDDLE	HIGH	EM fission
LISE++ hint for the fissile nucleus from excitation energy				
Excitation energy (MeV)				
Cross section (mb)				
	use in code **	use in code	use in code	

Fission barrier < LOW < 60 Boundary energies for mean values of prefragment excitation energy distributions to split low, middle and high energy regions. Recommendation: $2.3 * dEx$, where dEx is excitation energy per abraded nucleon. Default values are equal to 40 & 180 MeV

60 < MIDDLE < 180

180 < HIGH

coef for Zb = 0.8 0.1 < coef <= 1; recommendation: 0.8 Z_stop = 74

coef for Nb = 0.5 0.1 < coef <= 1; recommendation: 0.6 N_stop = 73

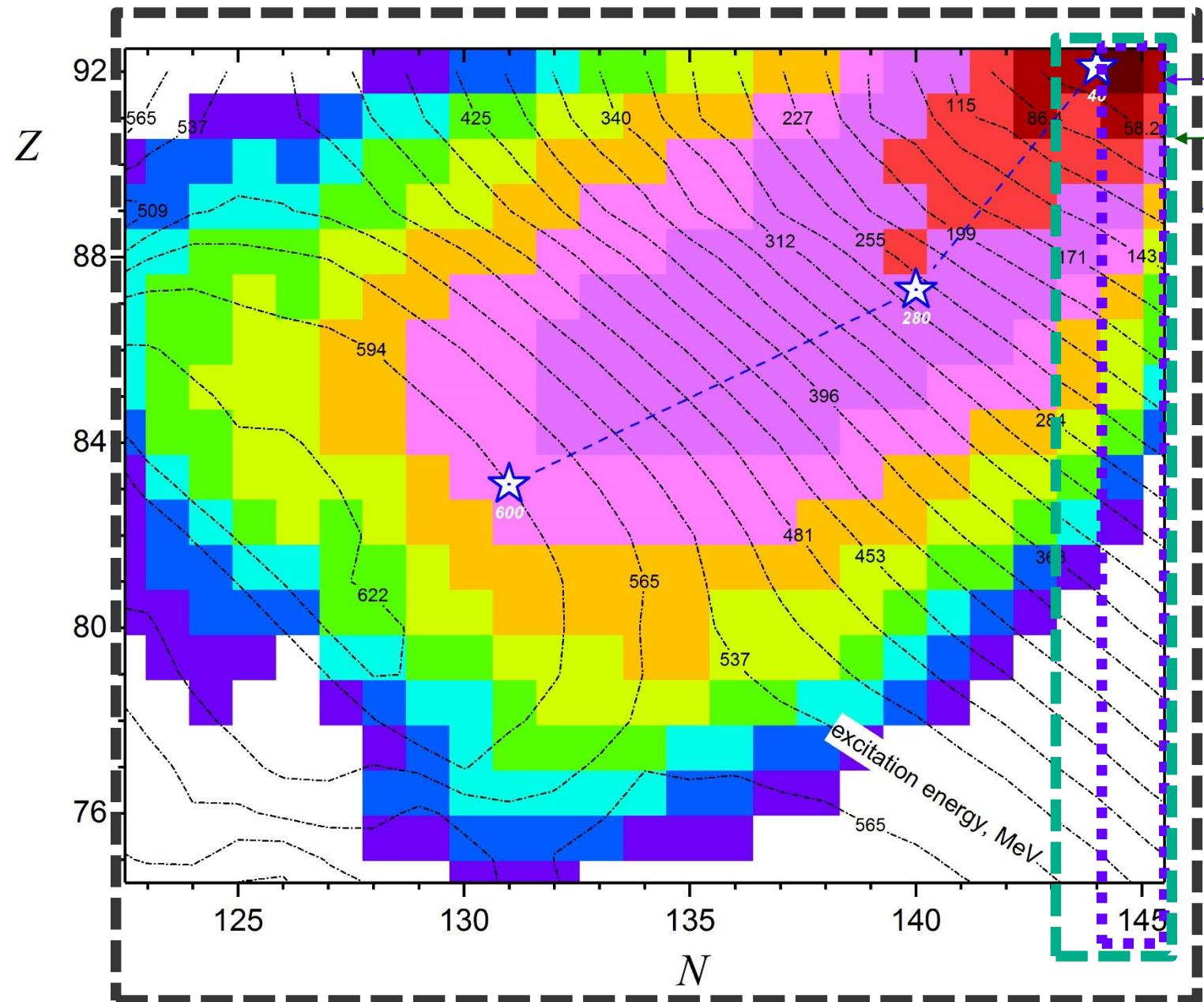
determine low Z (element number) where Abrasion-Ablation stops. $Z_{stop} = coef * Z_{beam}$

* - takes about 0.5 - 1 minute ** - Low-excitation Abrasion-Fission and EM fission results will be used together

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

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

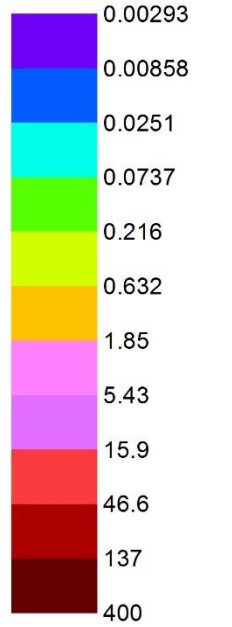
Where
 S : standard
 N2 : not more than 2 abraded neutrons
 N4 : not more than 4 abraded neutrons



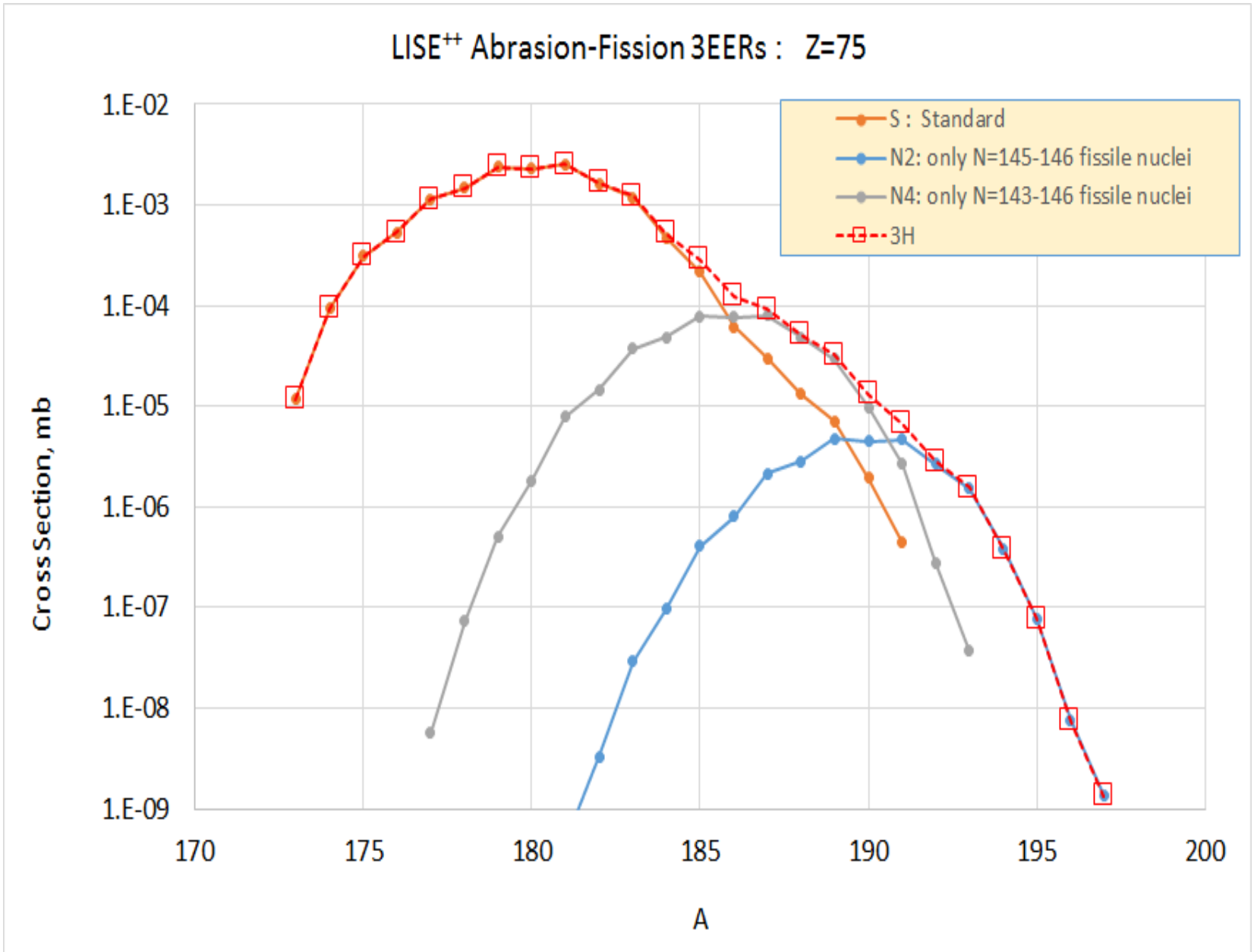
N2 settings
 N4 settings

☆ - 3 excitation energy region nuclei

Fissile nucleus cross sections, mb

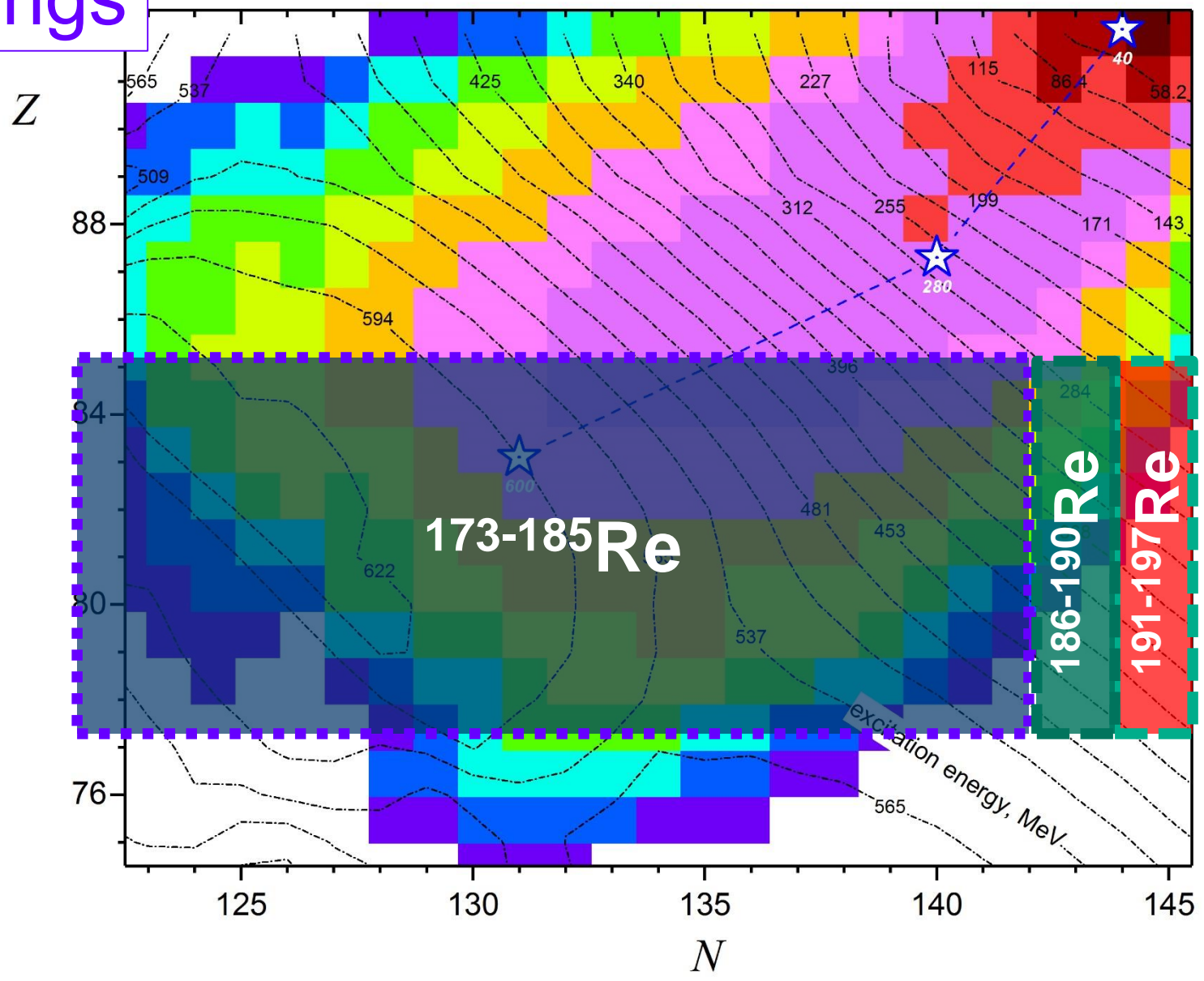


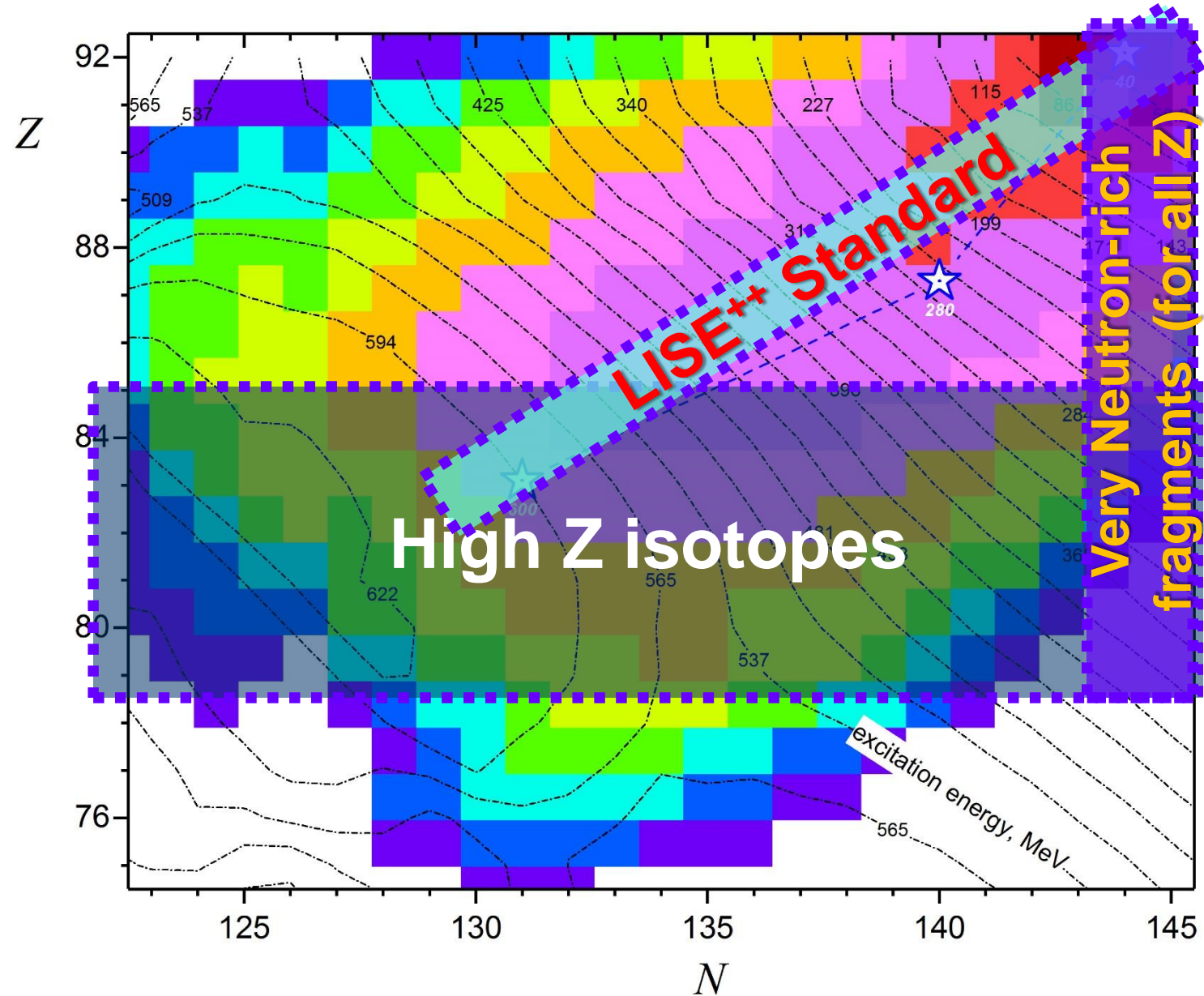
S settings



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

“3H” settings





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

Initial Fissile Nuclei (IFN) Analyzer

1st step settings

Batch mode settings and run

Abrasion-Fission: Initial fission nuclei

238U (140.0 MeV/u) + Be

Choose Final fission fragment: 132Sn

Calculate ALL

Calculate - I : Fission channels after Abrasion* + CF

Calculate - II : Fission of nuclei gated on Final Fragment**

Fission properties

Evaporation settings

Prefragment excit. energy

Batch file mode

Show 2D: Fissile Nuclei CS for each run

no file or bad file

Run the batch file! Takes time..

Settings - I (Select region)

coef for Zb = 0.8 0.1 < coef <= 1; recommendation: 0.75 Z_stop = 74

coef for Nb = 0.85 0.1 < coef <= 1; recommendation: 0.80 N_stop = 124

Include Coulomb fission channel determine low Z (element number) where Abrasion-Ablation stops. Zstop = coef * Zbeam

Settings - II

Cross-section minimum threshold of to use a nucleus in calculations (mb) 1.0e-05

Number of points from excitation energy distribution to use in calculations

Statistical values to show in the result frames

1: only mean value <E>

Mean value and Standard Deviations

More Probable value and its variances

3: E-v, <E>, E+v (v=HWHM)

Median value and its variances (default)

Detailed output 23892_00904_13250_p1m Browse Show

General log file IFN Browse Show

Results - I (Fissile channels after abrasion)

Total fission cross section in the region (mb) ...

Number of fissile nuclei in the region (I) ...

Number of fissile nuclei used to gate on the final fragment (II) ...

Fission Channels cross sections

Results - IIa: Parent Fissile Nuclei Gated on the Final Fission Fragment

2D: Fissile Nuclei CS

E*, MeV ...

Z ...

N ...

Results - IIb: Final Fission Fragment

Final fragment cross section ... mb

Initial fiss. fragment excitation energy ... MeV

Velocity in CMS ... cm/ns

Number of nucleons emitted to reach FFF ...

mdn (-vrns; +vrns), where "mdn": median; "vrnc": variance

1D: Excitation Energy

1D: Velocity in CMS

dA, dN, dZ

OK Cancel Help

2nd step settings

1st step results

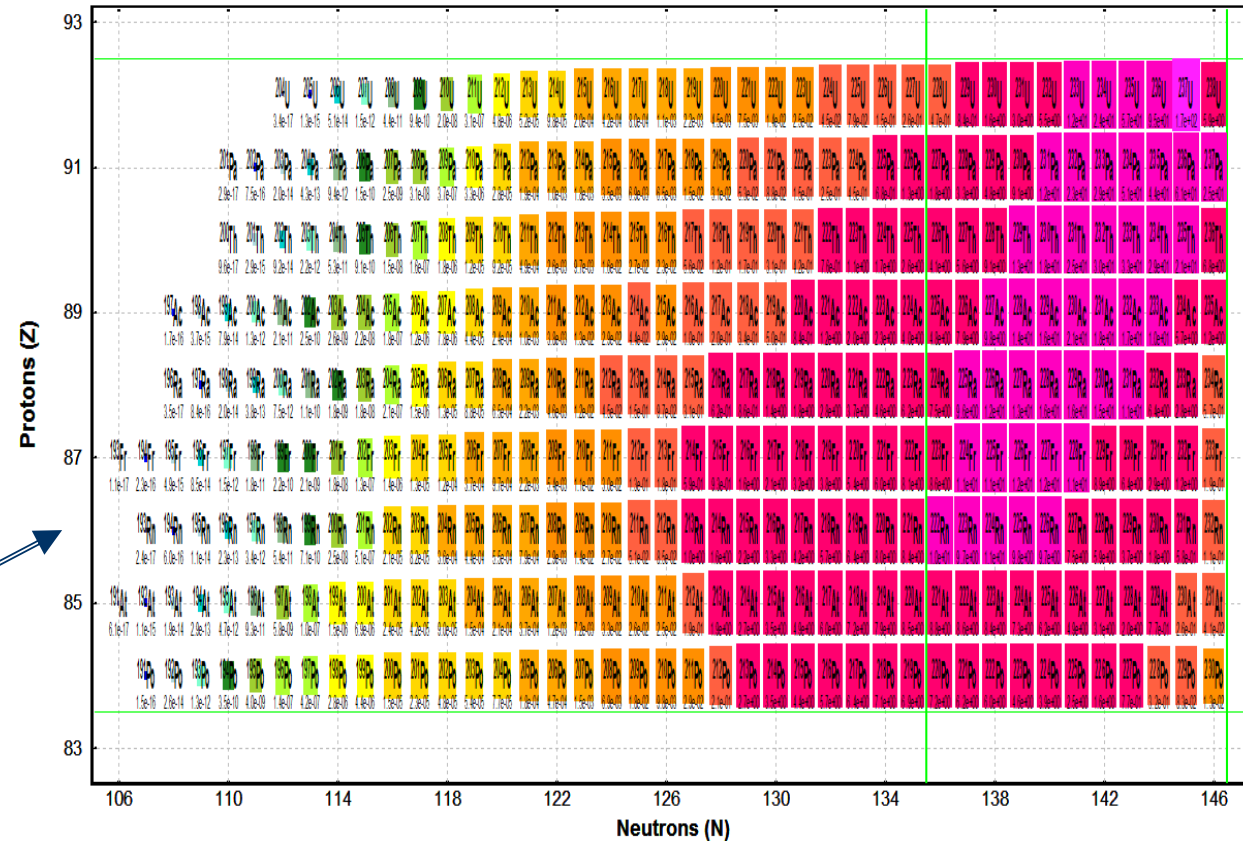
2nd step results

Not enable
(gray color)

Fission channel cross-sections

ABRASION-ABLATION - ²³⁸U + Be

Excit.Energy Method:< 2 >; <E*>:27.0*dA MeV Sigma:18.00; No Intrin.Thermatzn; LimitTemp: No
NP=32; SE:"DB0+Ca2" Density:"auto" GeomCor:"Off" Tunlg:"auto" FisBar=#1 BarFac=1.00 Modes=1010 1000 110



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

Abrasion-Fission: Initial fission nuclei

238U (140.0 MeV/u) + Be

Choose Final fission fragment: 136Sn

Calculate ALL I & II

Settings - I (Select region): coef for Zb = 0.76, coef for Nb = 0.85

Settings - II: Cross-section minimum threshold, Number of points from excitation distribution to use in calculation

Results - I (Fissile channels and total fission cross section in the region): Total fission cross section in the region: 1.0e-07

Results - IIa: Initial Fissile Nuclei Gated on the Final Fission Fragment

2D: Fissile Nuclei CS

E*, MeV: 632.7 (-275.1; +29.9)

Z: 79.03 (-1.53; +6.21)

N: 136.94 (-2.26; +4.01)

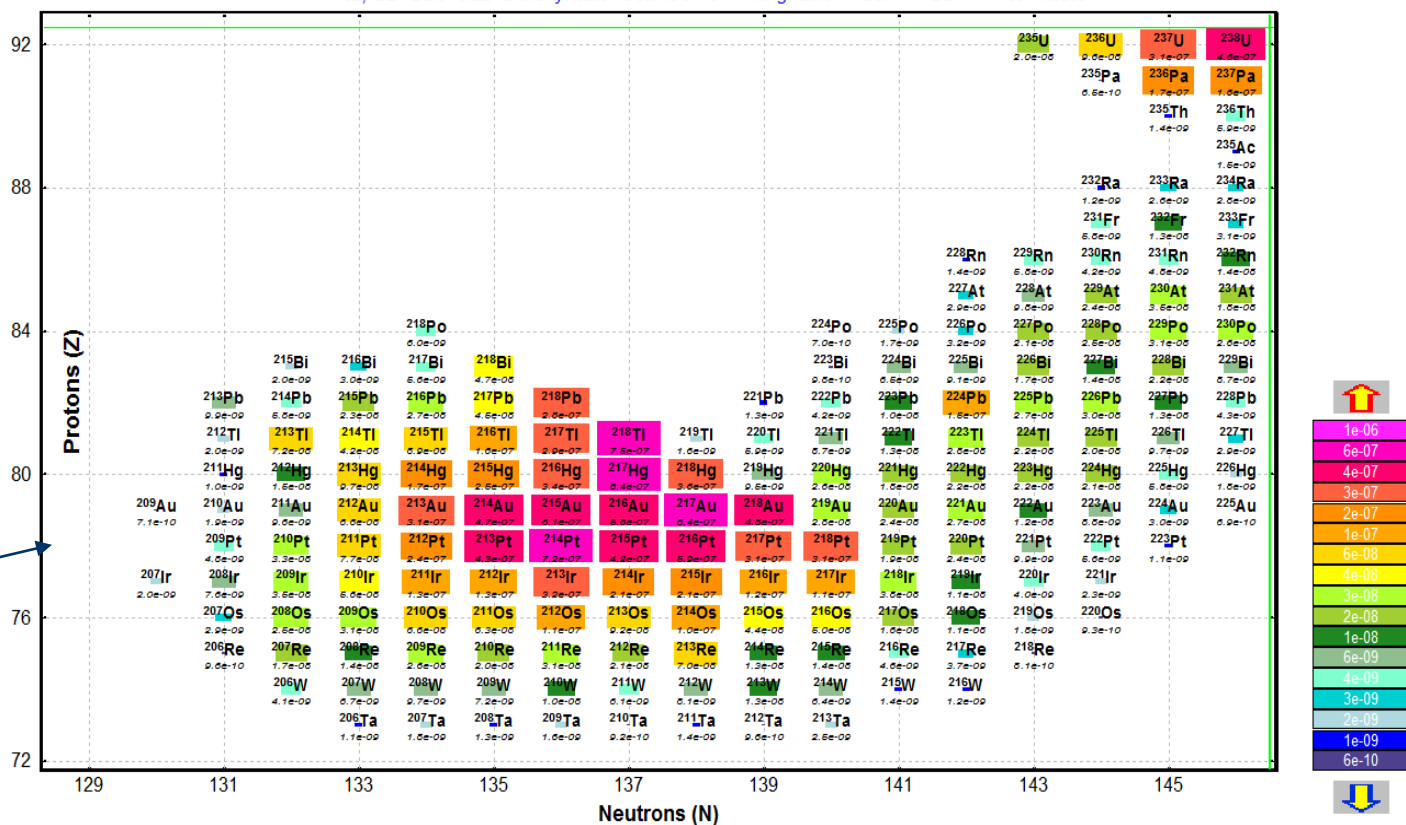
FFF=¹³⁶Sn, N_p=3; Large IFN region (489)

Initial Fissile Nuclei for ¹³⁶Sn final fragment

ABRASION-ABLATION - 238U + Be; C_Zbound=0.76; C_Nbound=0.85; CS_{thrshld}=1.0e-07 mb; sE*_{fission}=7.0 MeV; N_e-points=3

Excit.Energy Method:< 2 >; <E*>:27.0*dA MeV Sigma:18.00; No Intrin.Thermatztn; LimitTemp: No

NP=32; SE:"DB0+Ca2" Density:"auto" GeomCor:"Off" Tung:"auto" FisBar=#1 BarFac=1.00 Modes=1010 1000 110



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

Evaporation settings
Prefragment excit.energy

Batch file mode
 Show 2D: Fissile Nuclei CS for each run
 z26 [n=34]
 Run the batch file! Takes time..

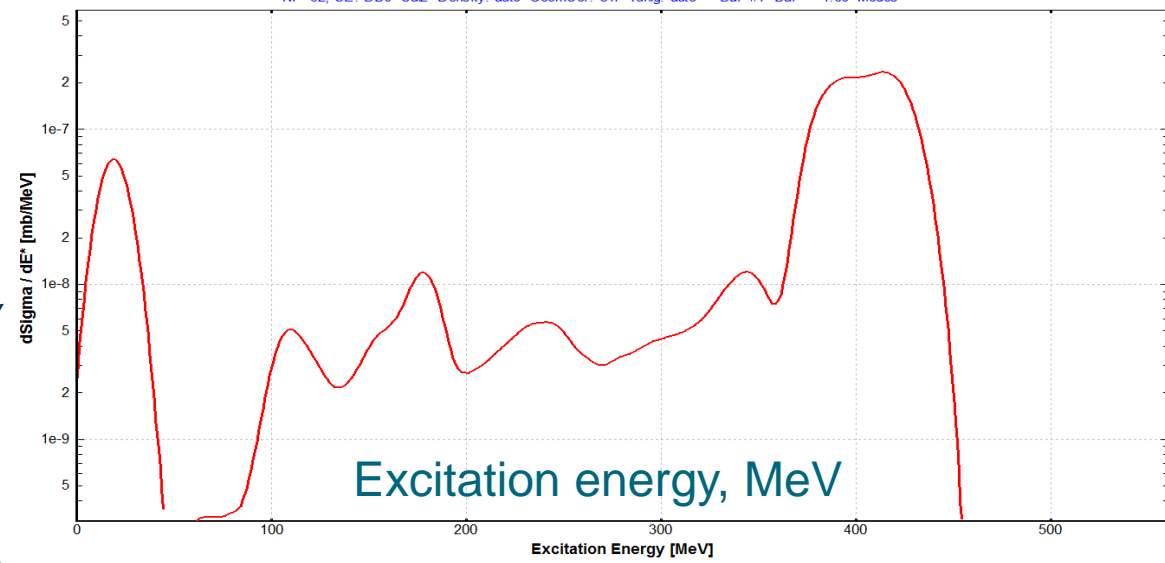
Detailed output: 23892_00904_13650_p3m
 General log file: IFN

Results - I (Fissile channels after abrasion)
 Total fission cross section in the region (mb): 1.60e+03
 Number of fissile nuclei in the region (I): 1029
 Number of fissile nuclei used to gate on the final fragment (II): 489

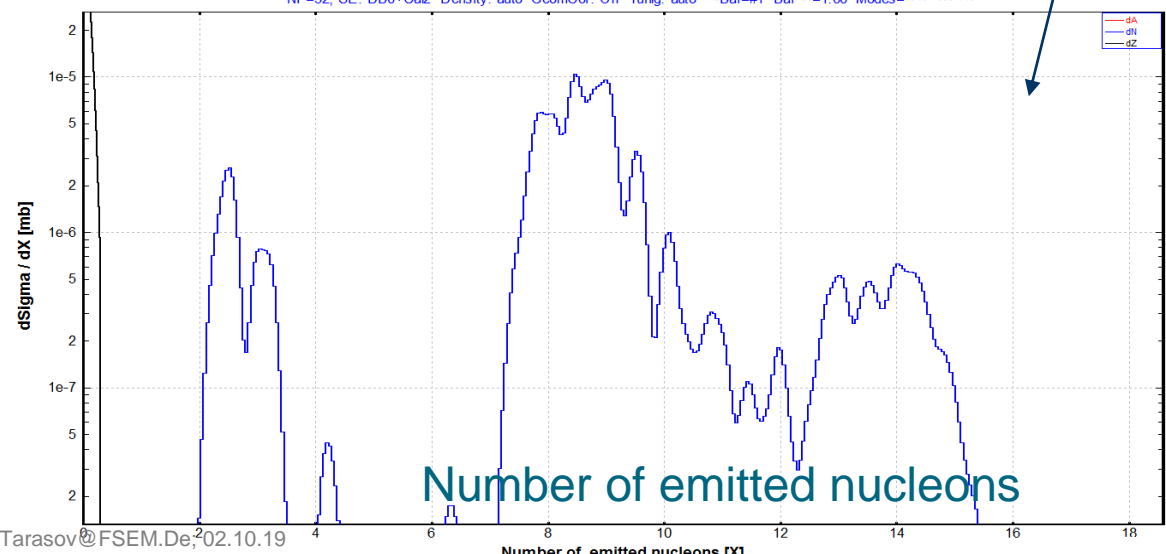
Results - IIa: Initial Fissile Nuclei
 Gated on the Final Fission Fragment
 2D: Fissile Nuclei CS
 E*, MeV: 632.7 (-275.1; +29.9)
 Z: 79.03 (-1.53; +6.21)
 N: 136.94 (-2.26; +4.01)

Results - IIb: Final Fission Fragment
 Final fragment cross section: 1.47e-05 mb
 Initial fiss.fragment excitation energy: 399.0 (-175.2; +20.1) MeV
 Velocity in CMS: 0.623 (-0.043; +0.133) cm/ns
 Number of nucleons emitted to reach FFF: 8.60 (-2.49; +1.99)

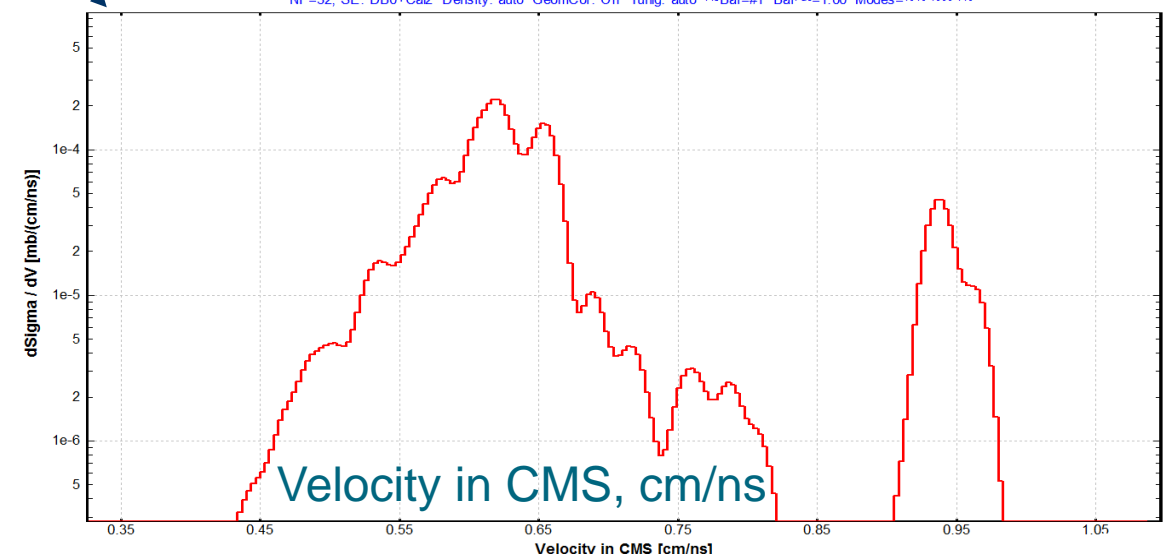
Excitation energy of initial fission fragments coming to ¹³⁶Sn final fragment
 ABRASION-ABLATION - ²³⁸U + Be; C_{zbound}=0.76; C_{nbound}=0.85; CS_{thrshid}=1.0e-07 mb; sE_{fission}=7.0 MeV; N_{a-points}=3
 Excit.Energy Method:< 2 >; <E*>:27.0*dA MeV Sigma:18.00; No Intrin.Thermalztn; LimitTemp: No
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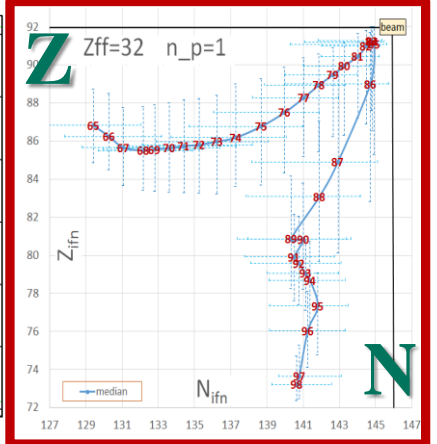
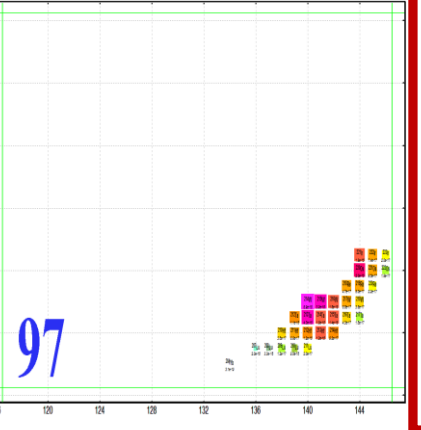
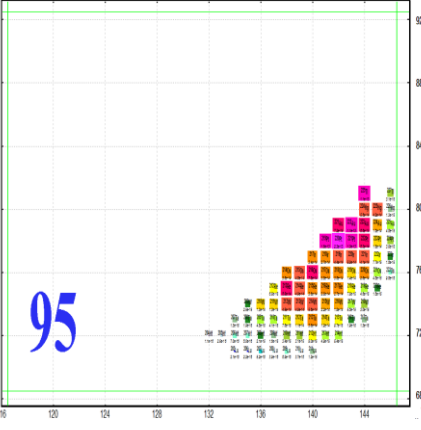
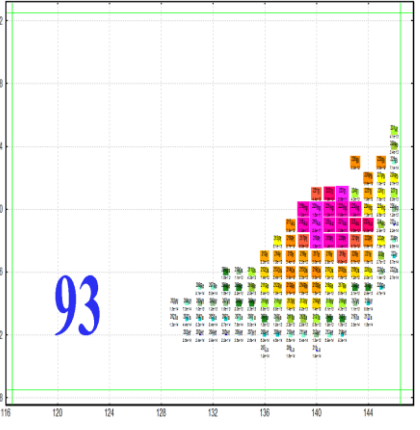
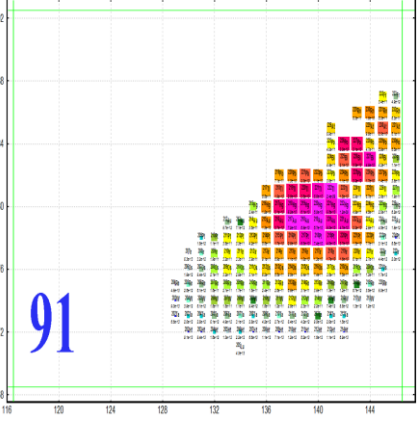
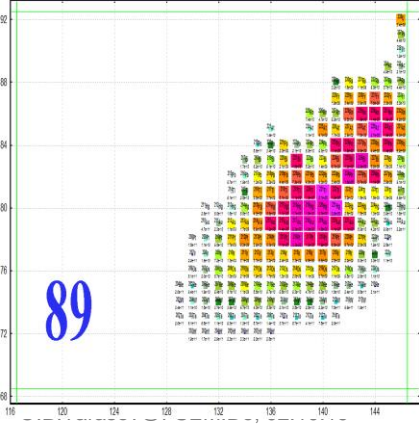
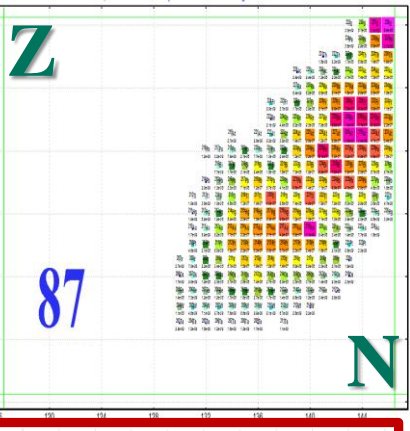
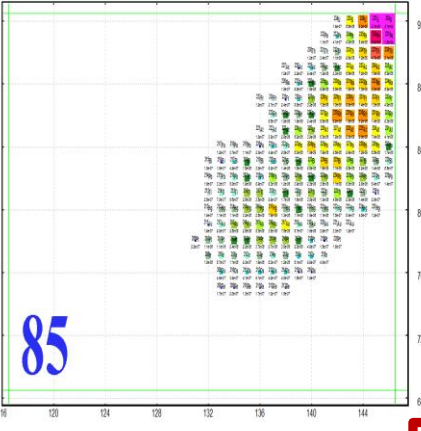
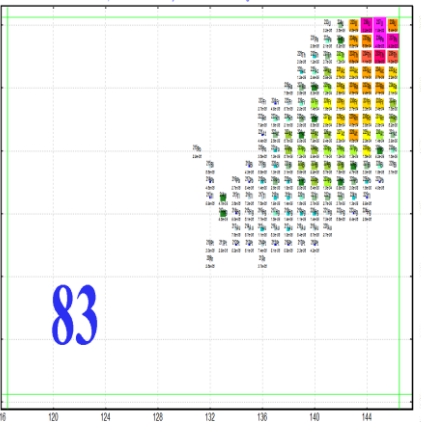
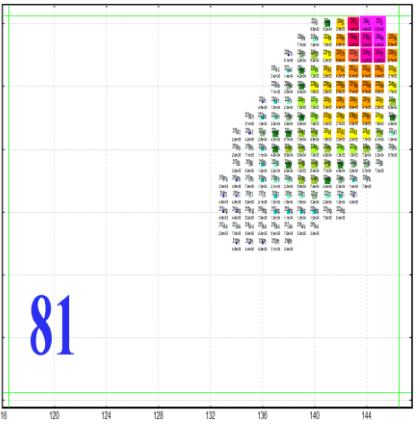
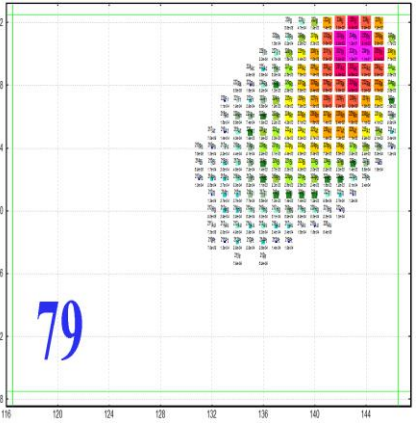
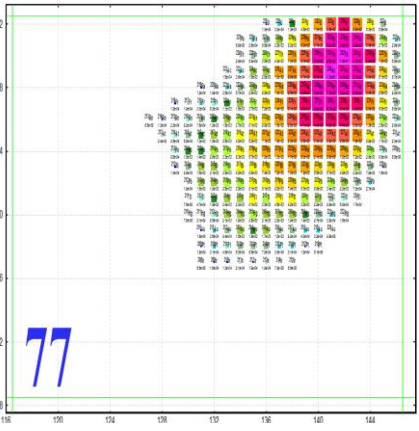
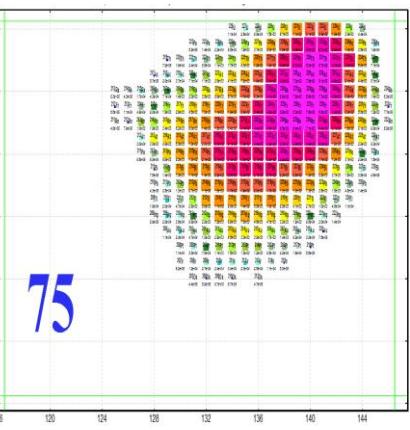
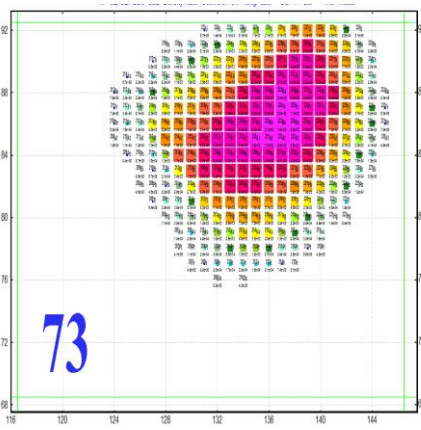
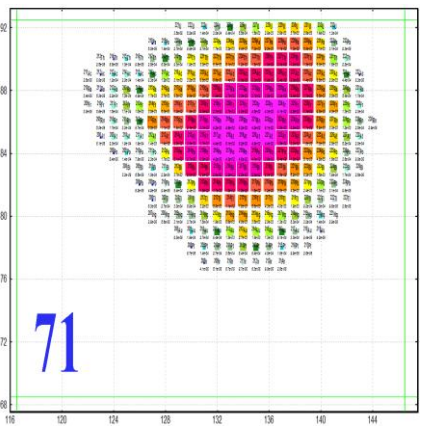
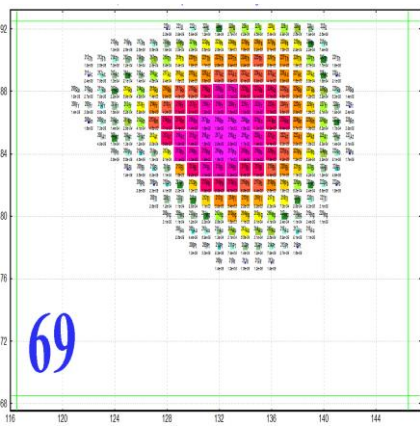
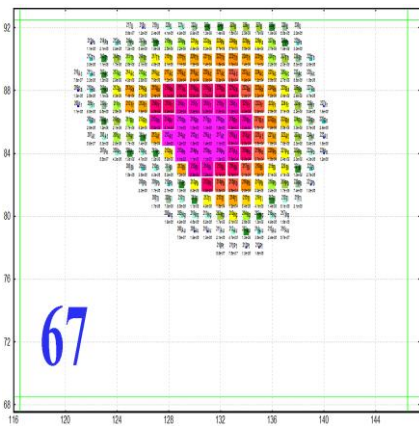
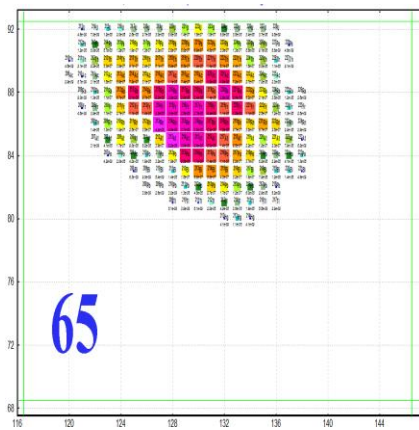
Emitted nucleons from initial fission fragment coming to ¹³⁶Sn
 ABRASION-ABLATION - ²³⁸U + Be; C_{zbound}=0.76; C_{nbound}=0.85; CS_{thrshid}=1.0e-07 mb; sE_{fission}=7.0 MeV; N_{a-points}=3
 Excit.Energy Method:< 2 >; <E*>:27.0*dA MeV Sigma:18.00; No Intrin.Thermalztn; LimitTemp: No
 NP=32; SE:"DB0+Ca2" Density:"auto" GeomCor:"Off" Tunlg:"auto" F_{is}Bar=#1 Bar_{f³c}=1.00 Modes=1010 1000 110

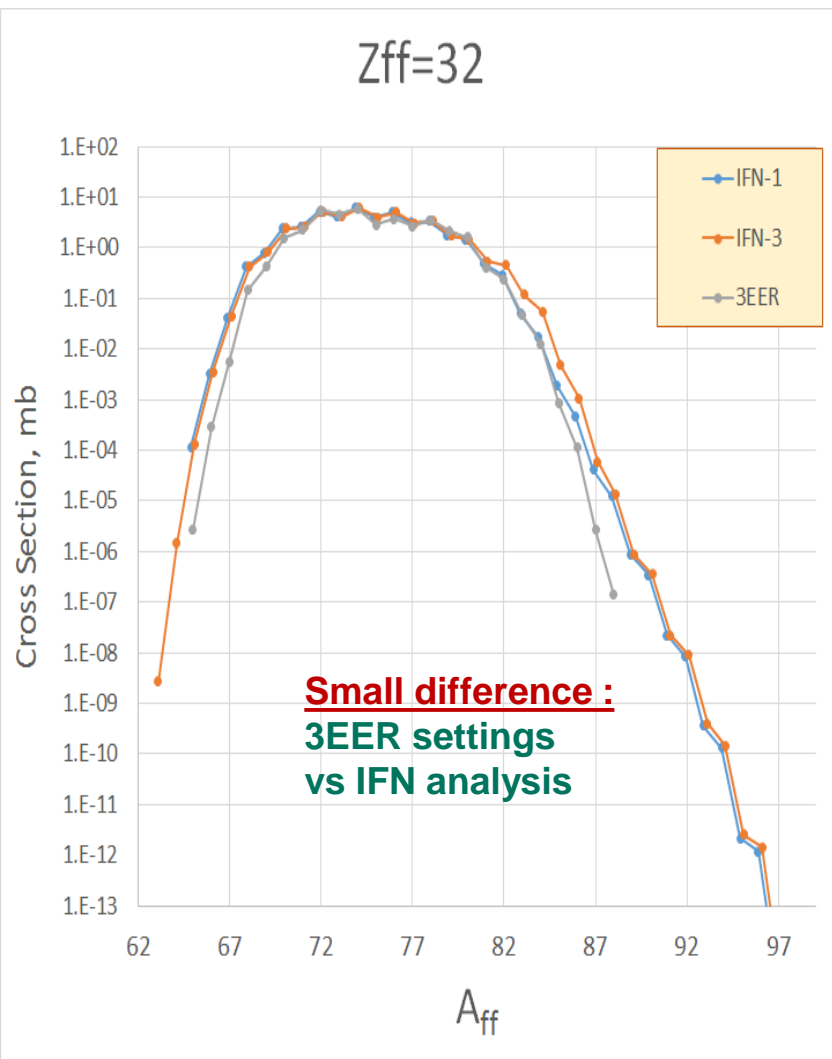


¹³⁶Sn final fragment velocity in CMS
 ABRASION-ABLATION - ²³⁸U + Be; C_{zbound}=0.76; C_{nbound}=0.85; CS_{thrshid}=1.0e-07 mb; sE_{fission}=7.0 MeV; N_{a-points}=3
 Excit.Energy Method:< 2 >; <E*>:27.0*dA MeV Sigma:18.00; No Intrin.Thermalztn; LimitTemp: No
 NP=32; SE:"DB0+Ca2" Density:"auto" GeomCor:"Off" Tunlg:"auto" F_{is}Bar=#1 Bar_{f³c}=1.00 Modes=1010 1000 110

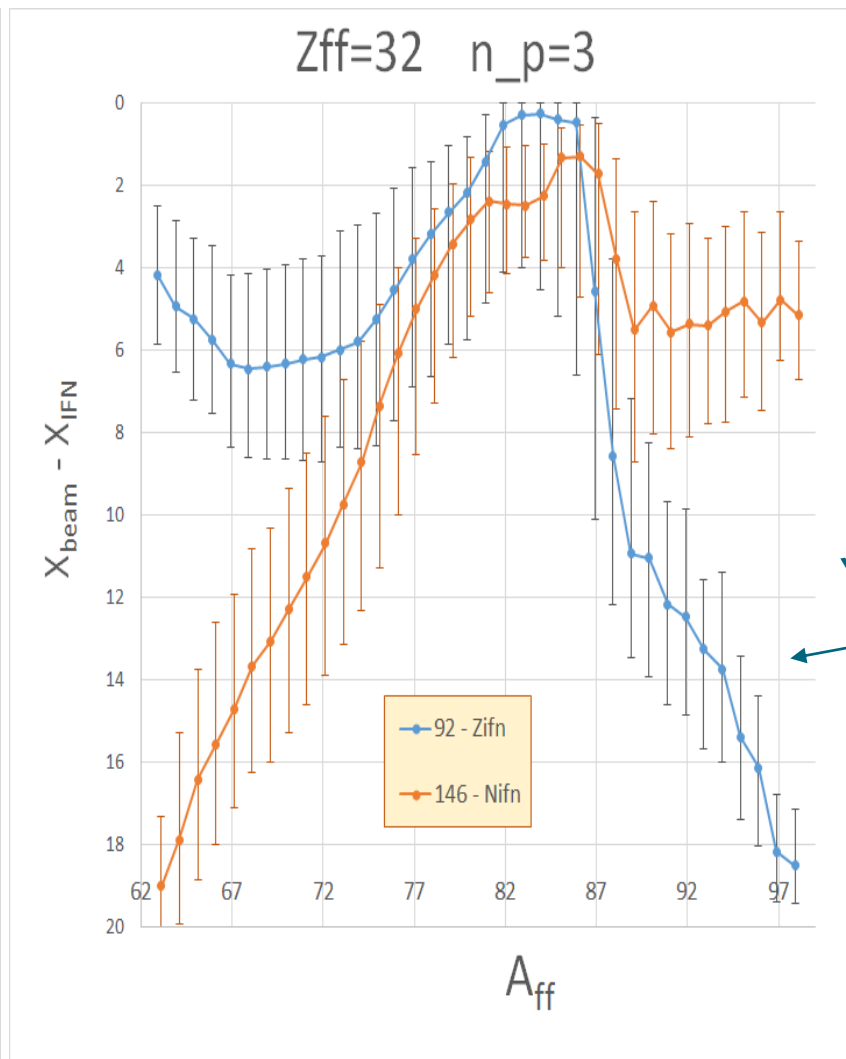


Initial Fissile Nuclei (IFN) for final Ge-isotopes (Z=32)

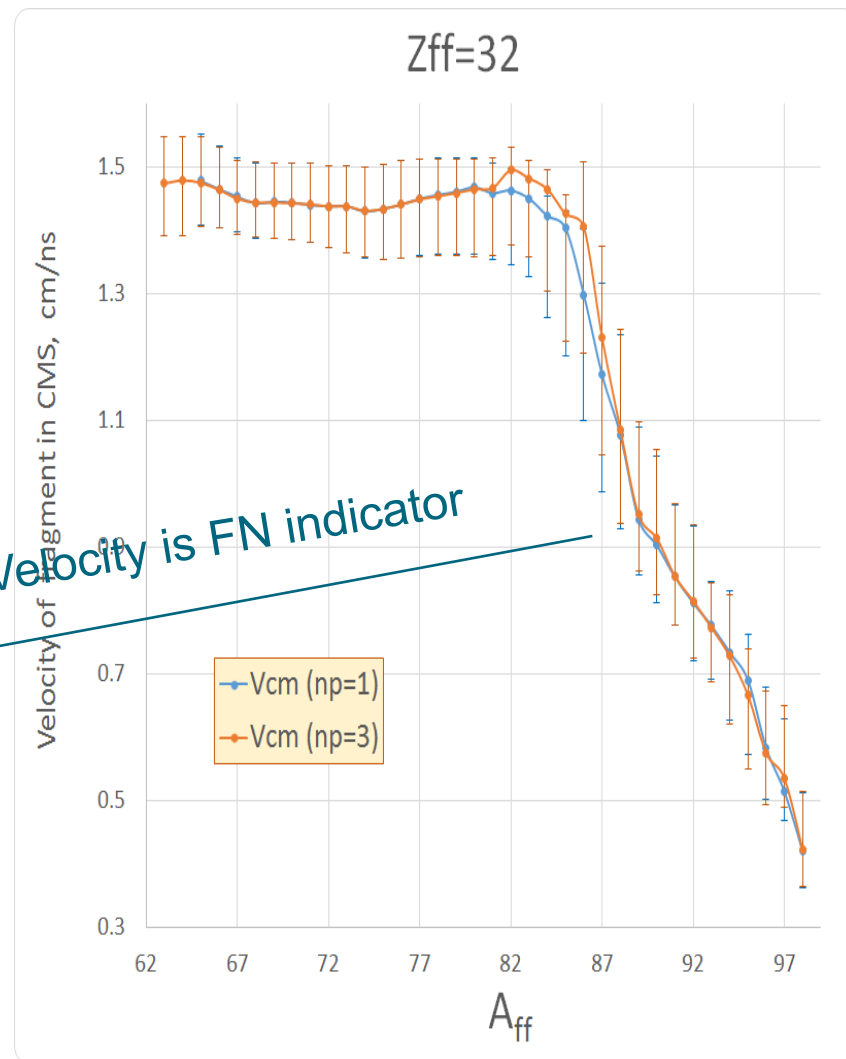




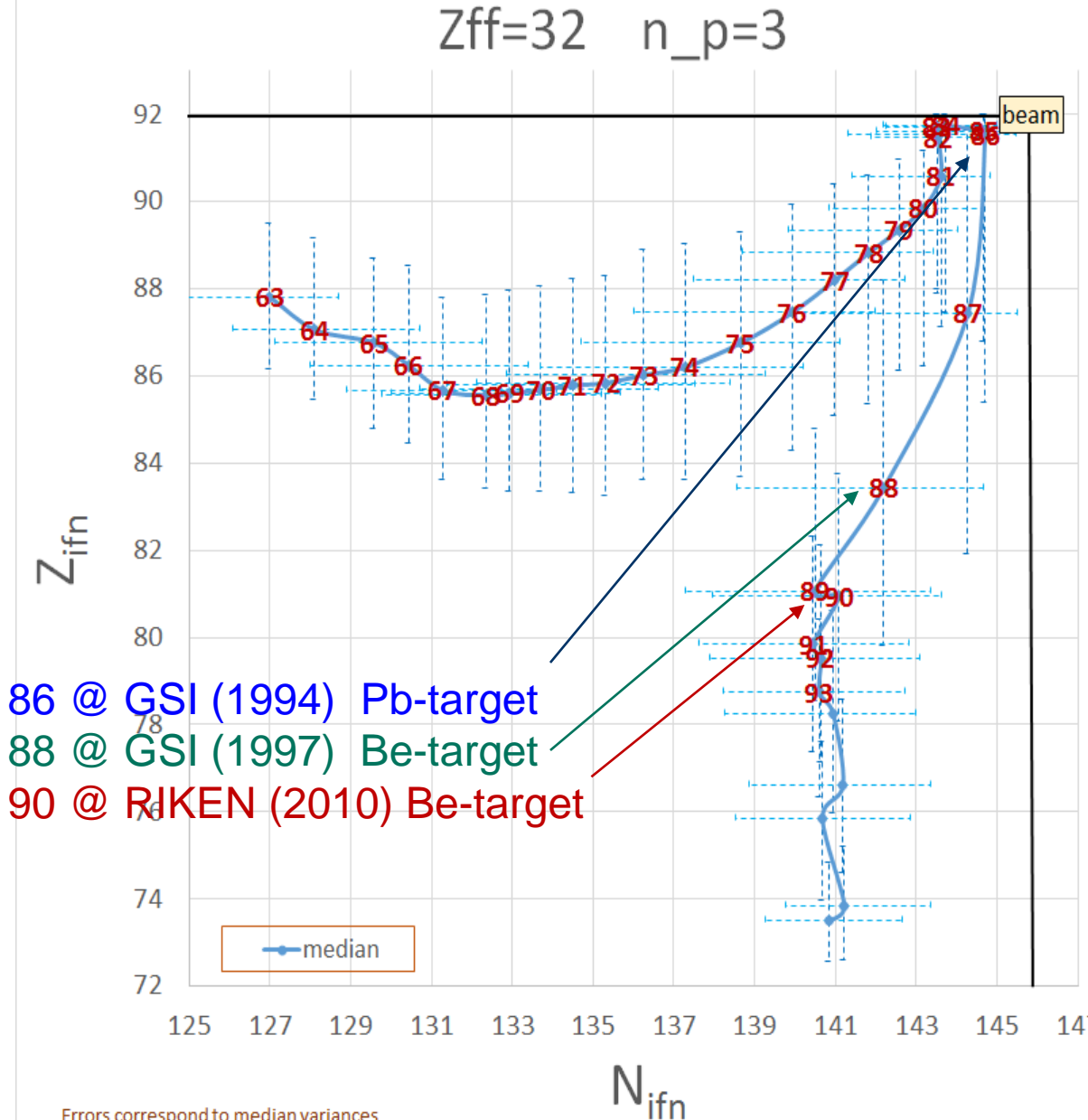
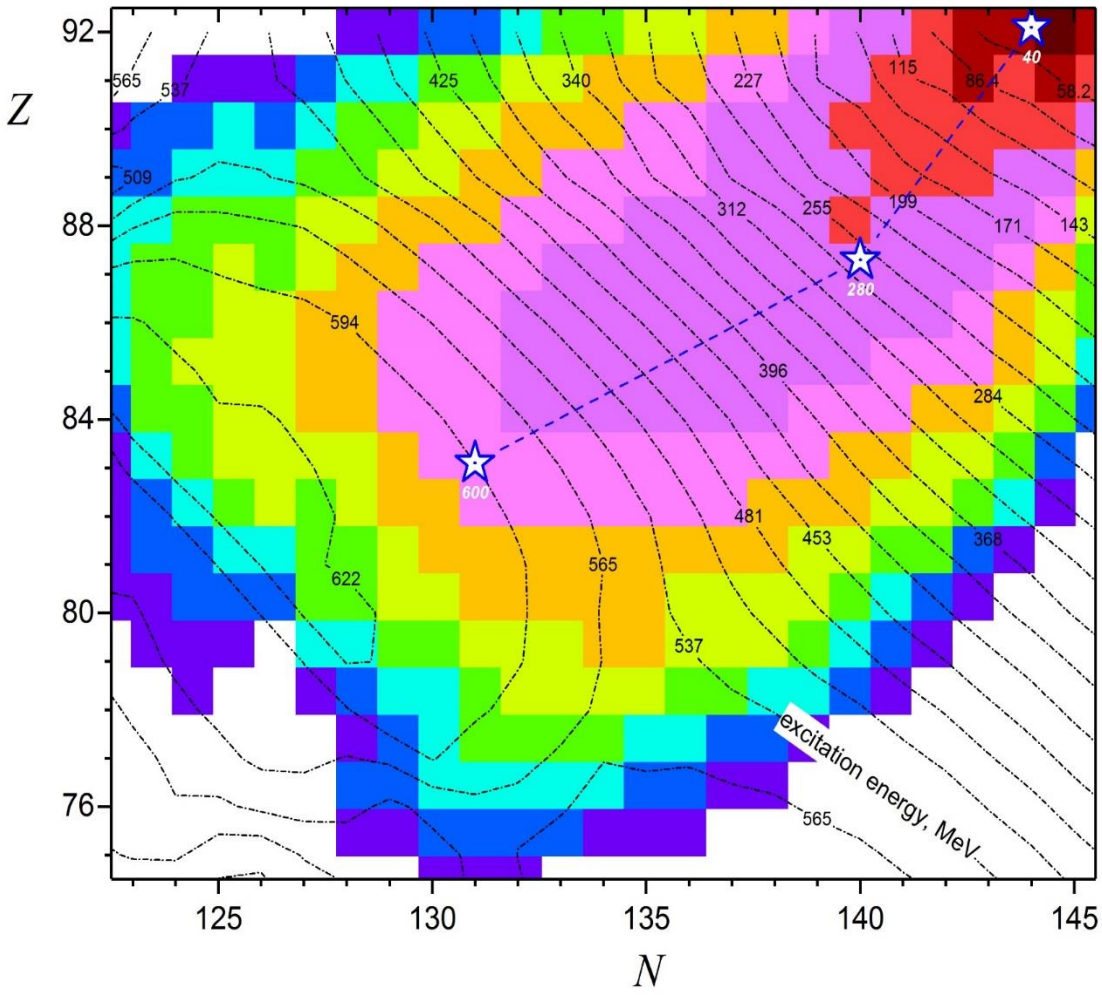
Cross-sections



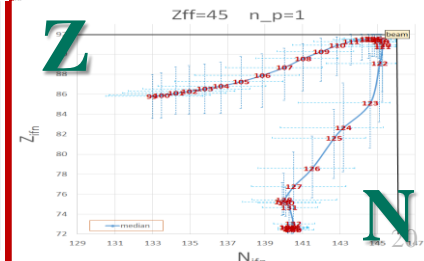
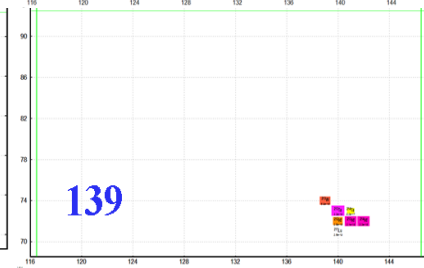
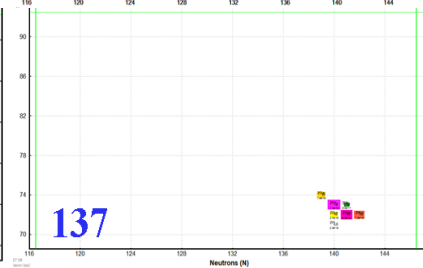
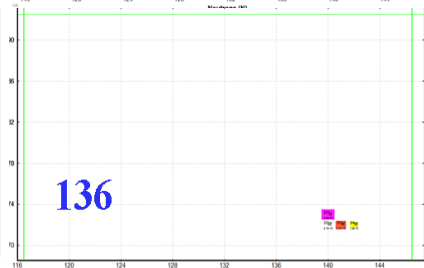
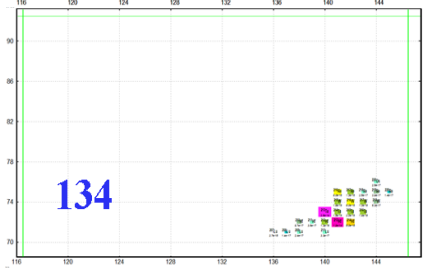
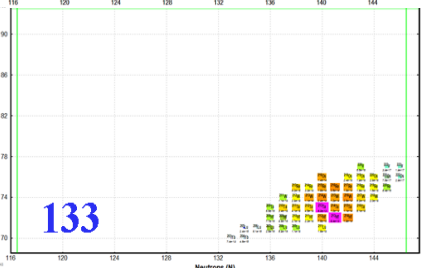
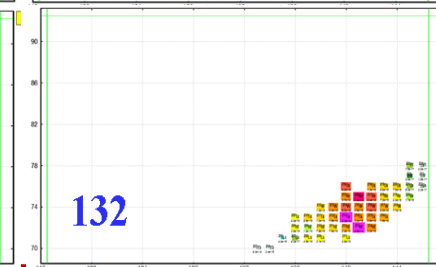
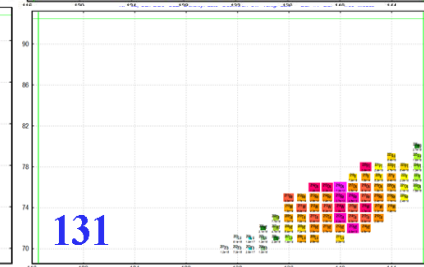
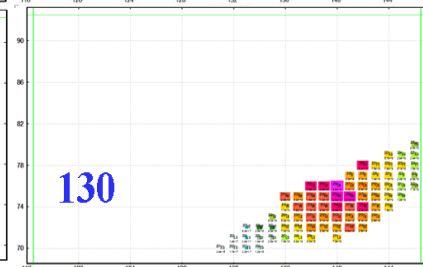
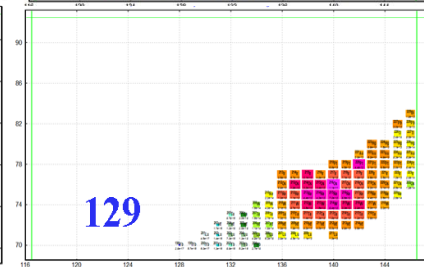
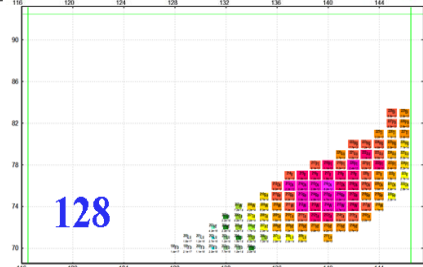
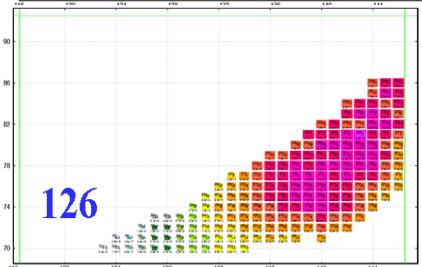
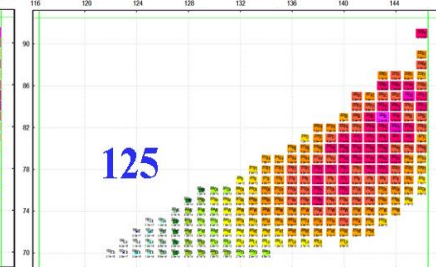
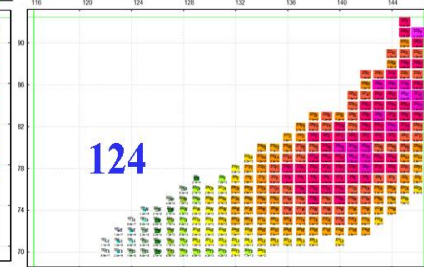
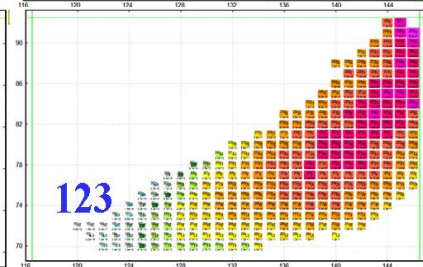
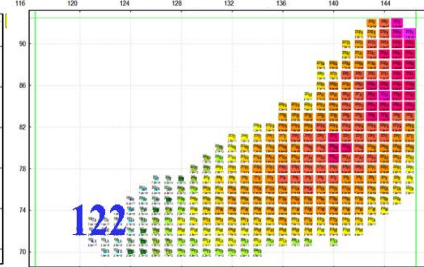
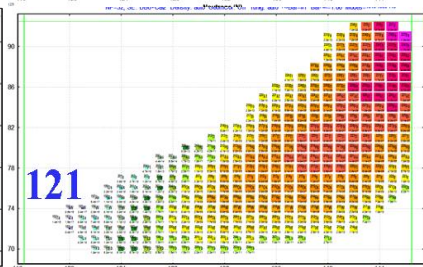
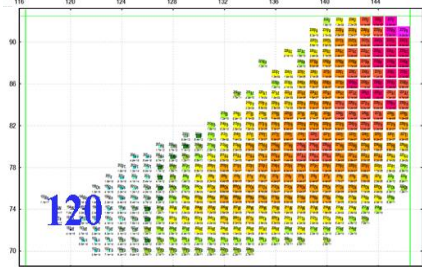
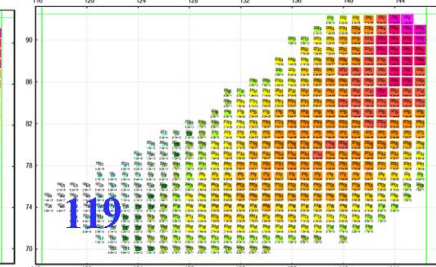
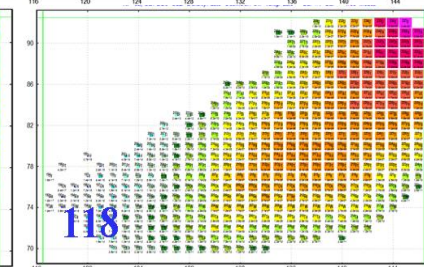
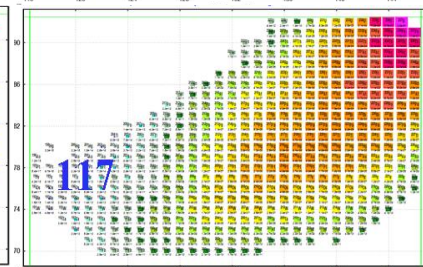
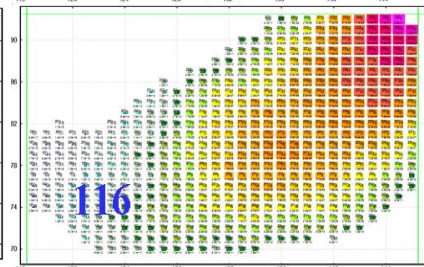
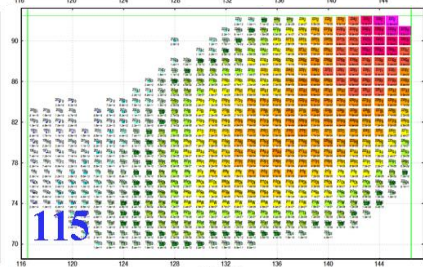
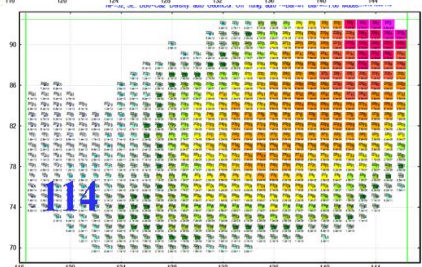
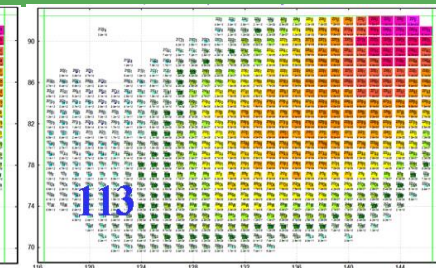
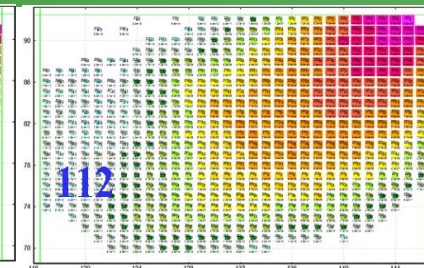
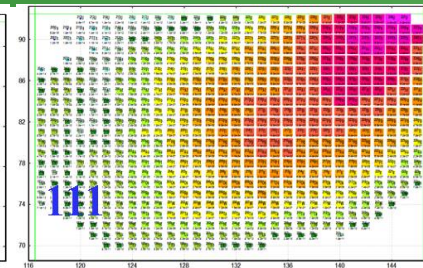
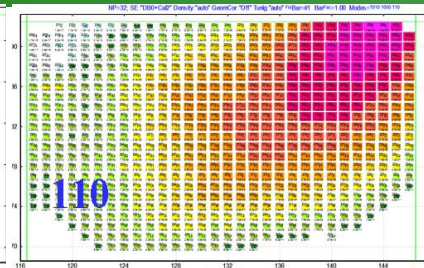
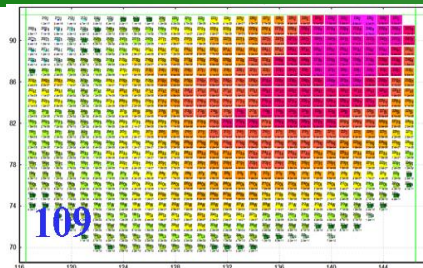
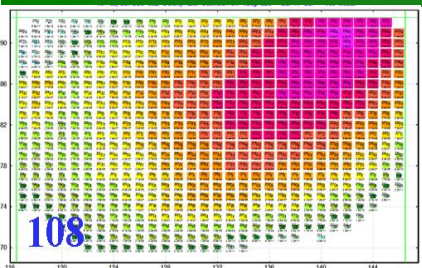
$Z(N)_{beam} - Z(N)_{FisNucl}$

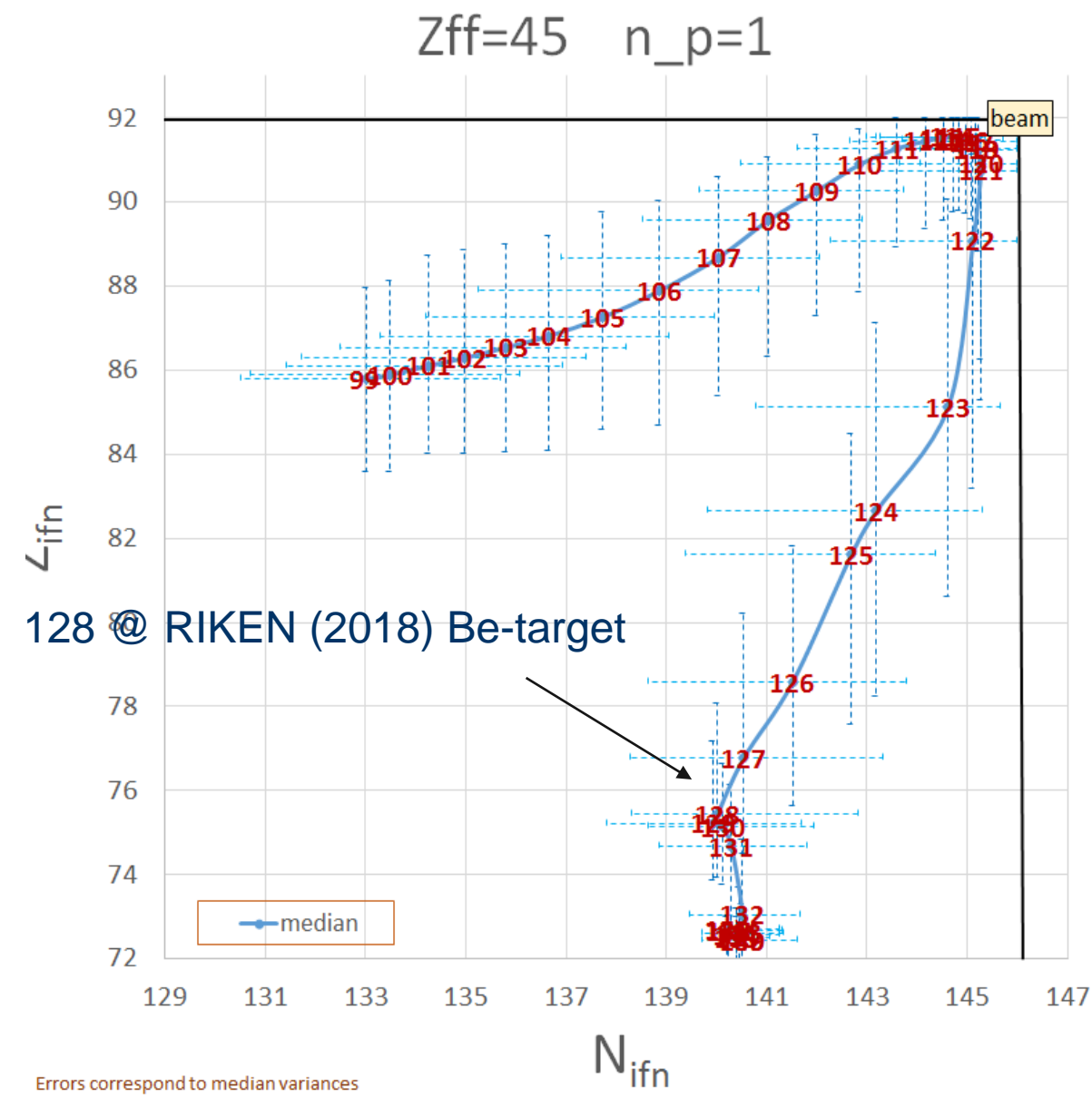
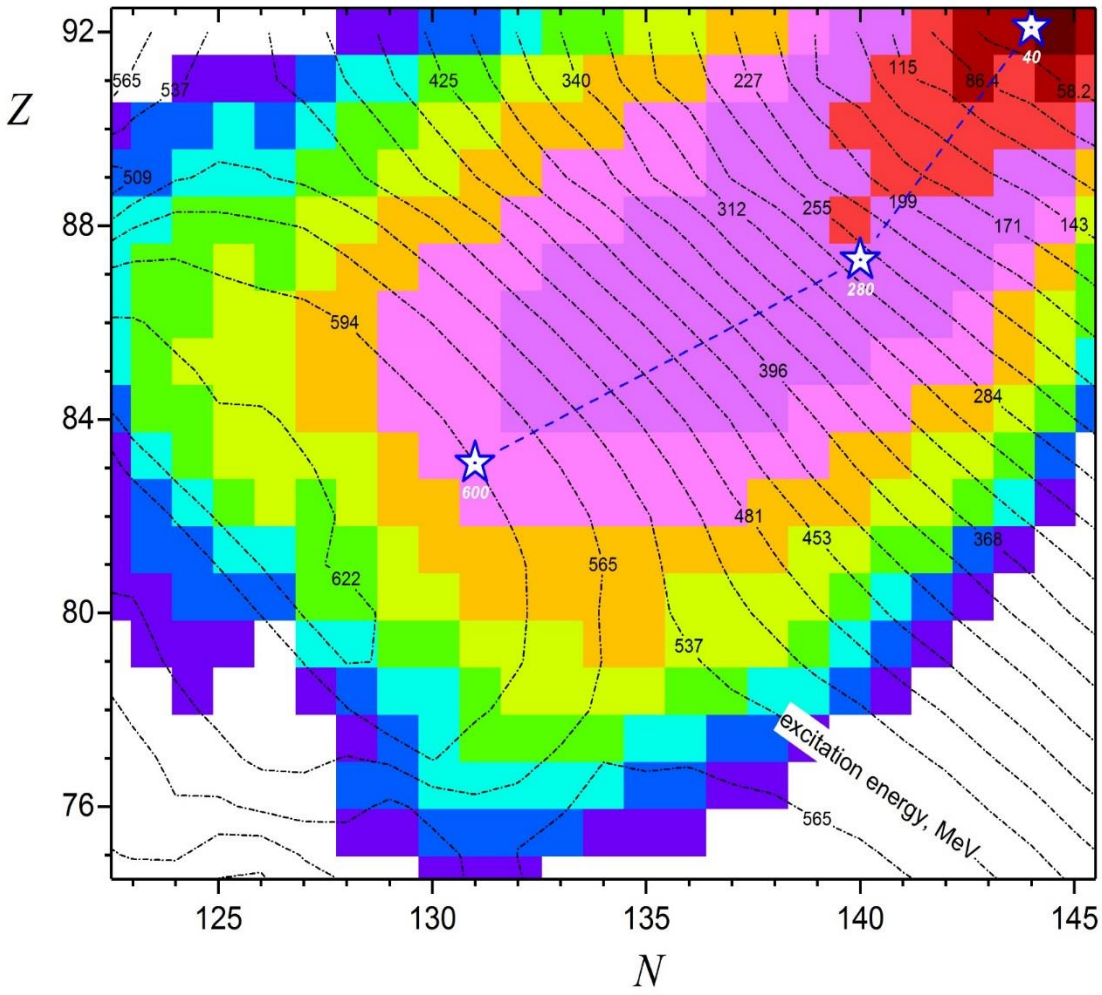


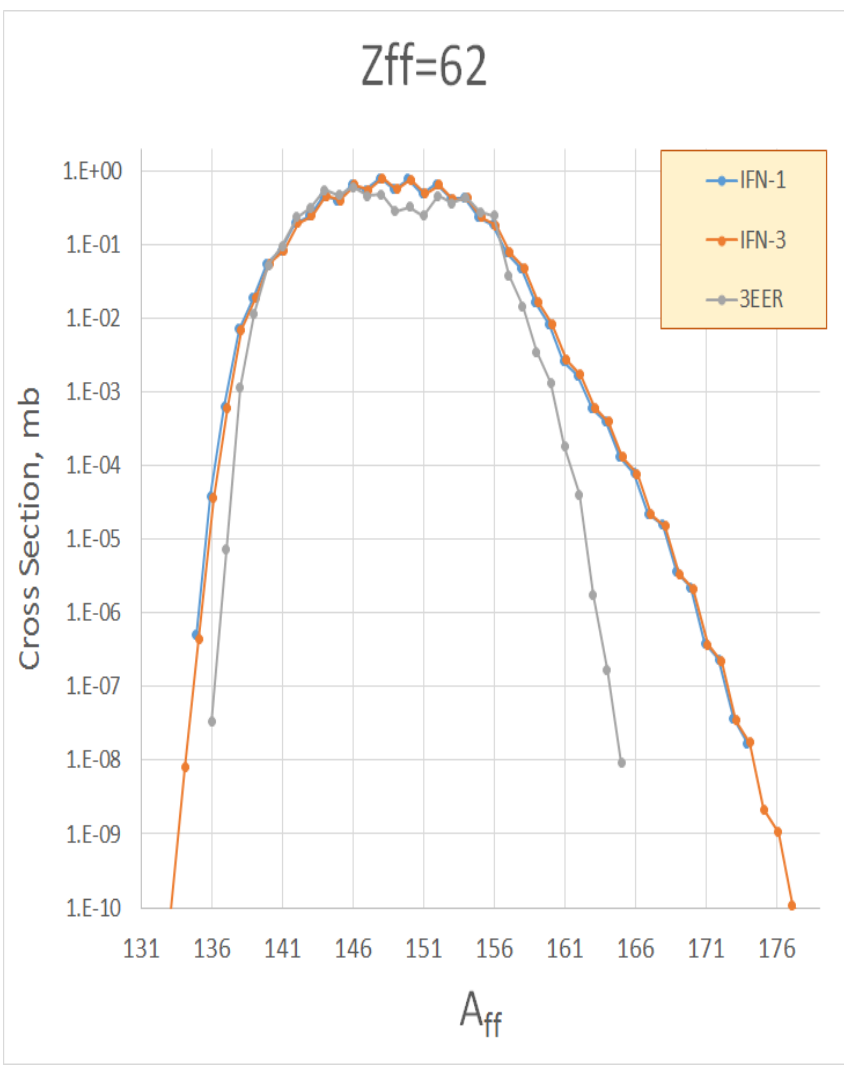
Fragment velocity (CMS – cm/ns)



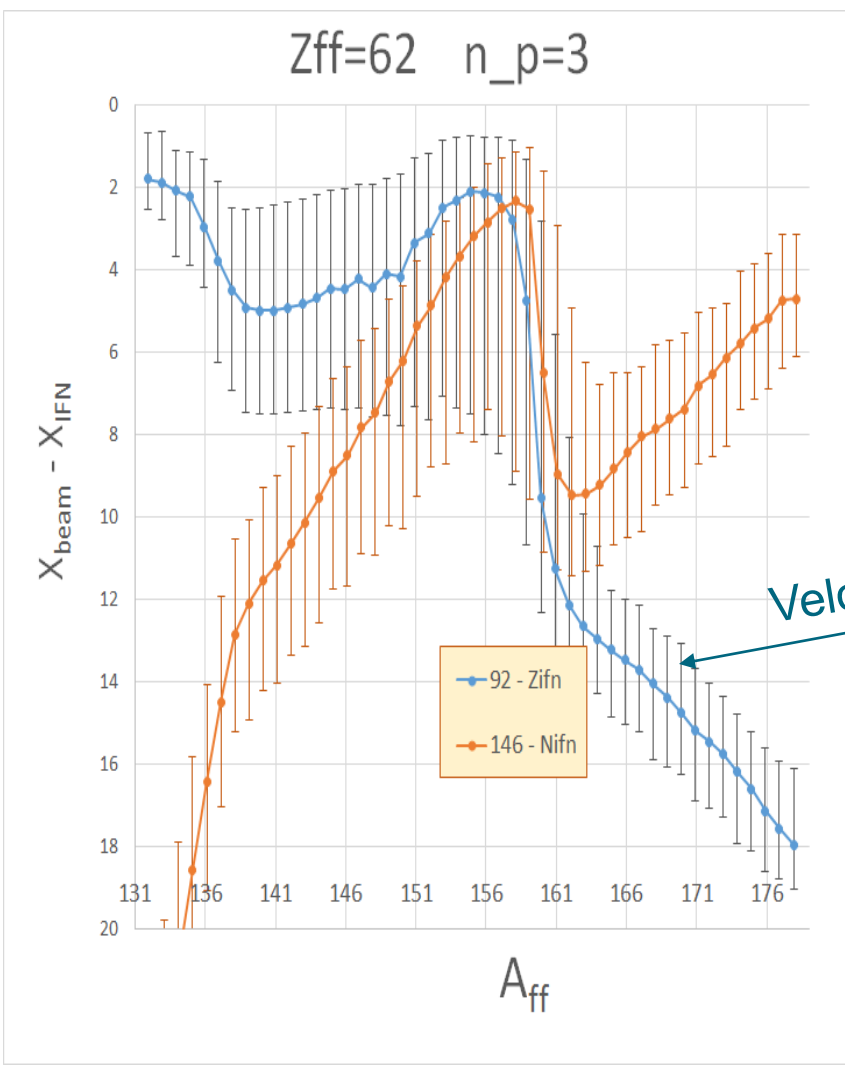
Initial Fissile Nuclei (IFN) for final Rh-isotopes (Z=45)



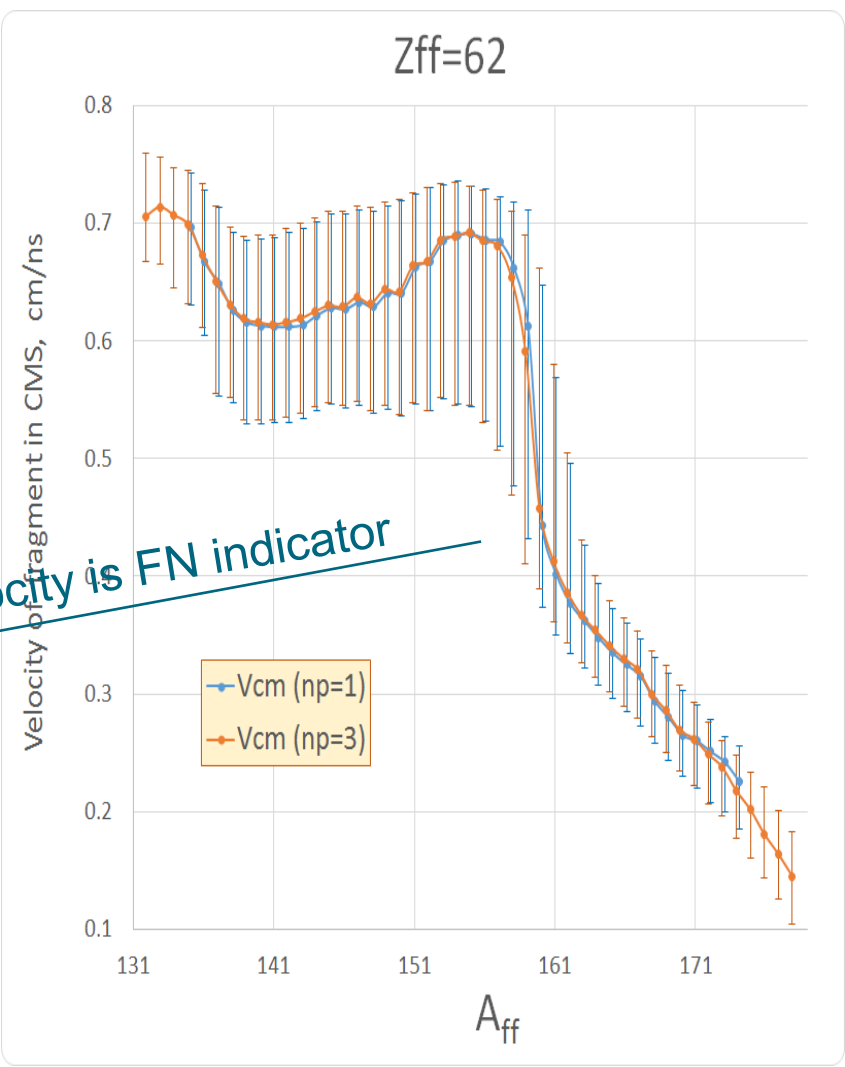




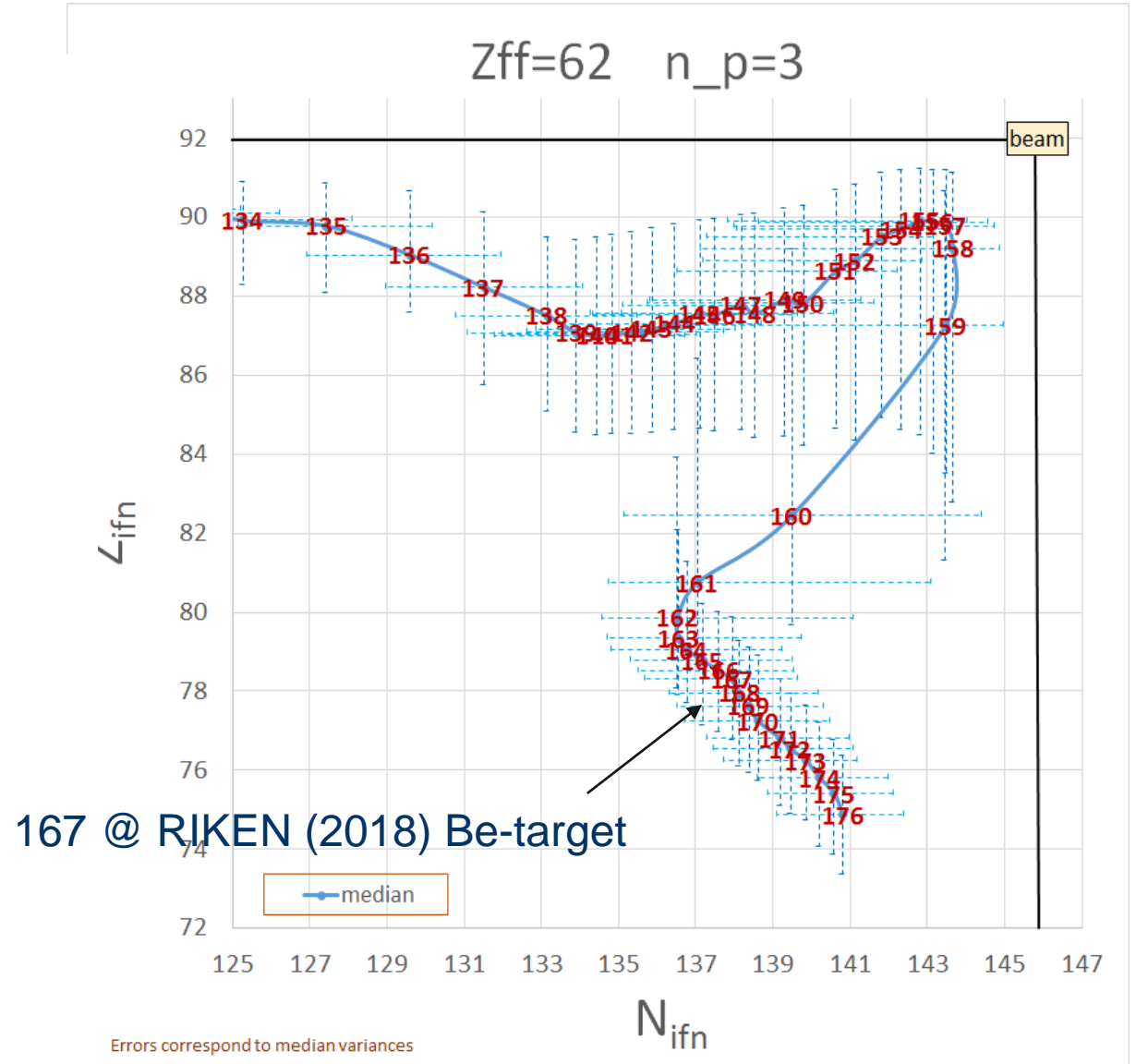
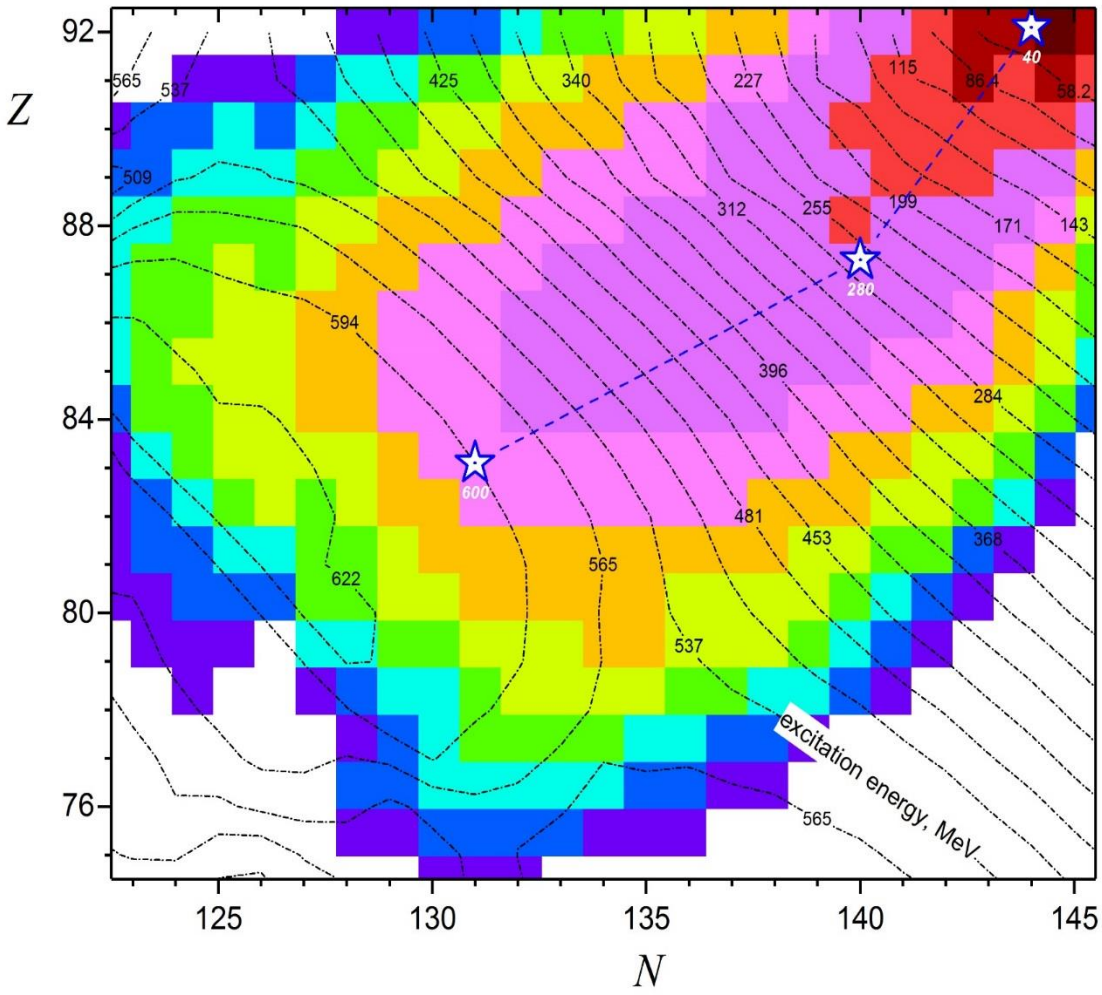
Cross-sections

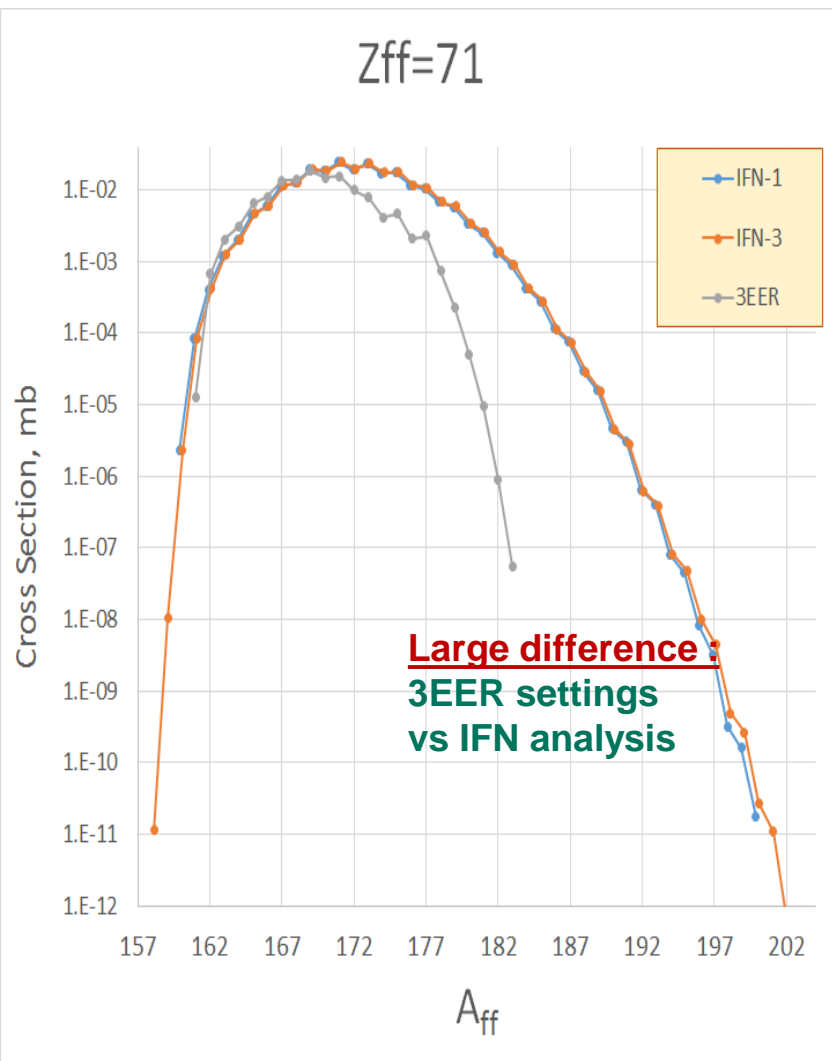


$Z(N)_{\text{beam}} - Z(N)_{\text{FisNucl}}$

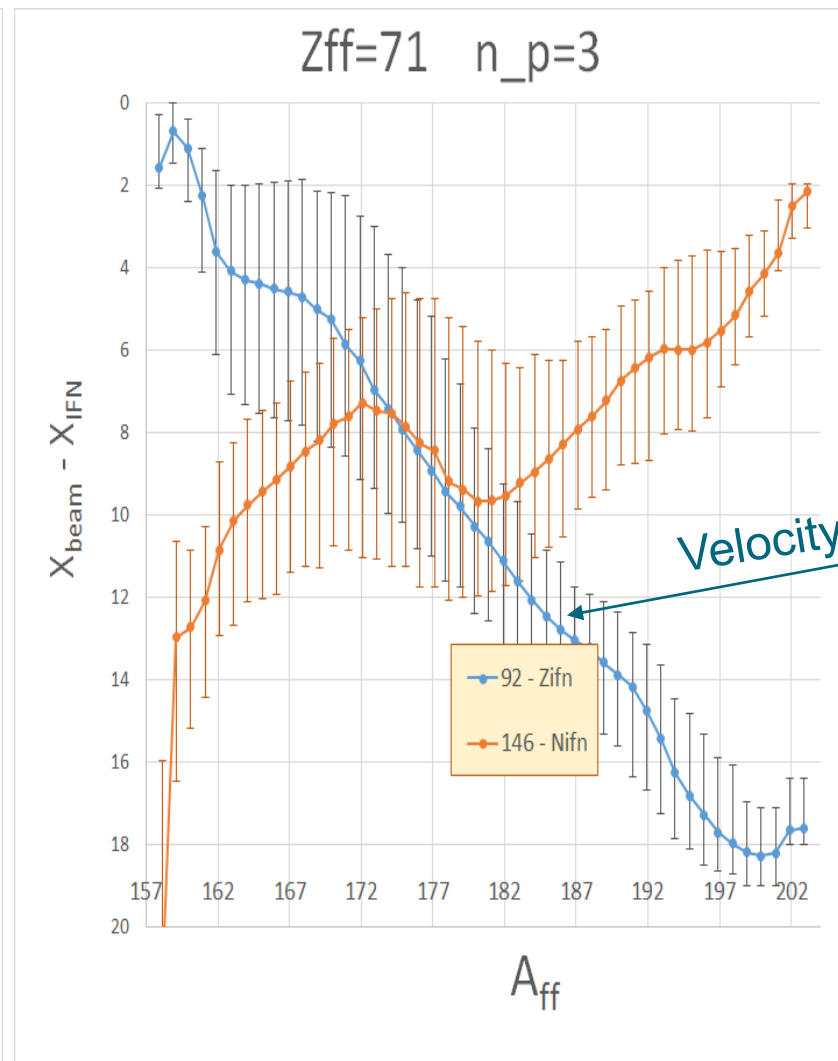


Fragment velocity (CMS – cm/ns)

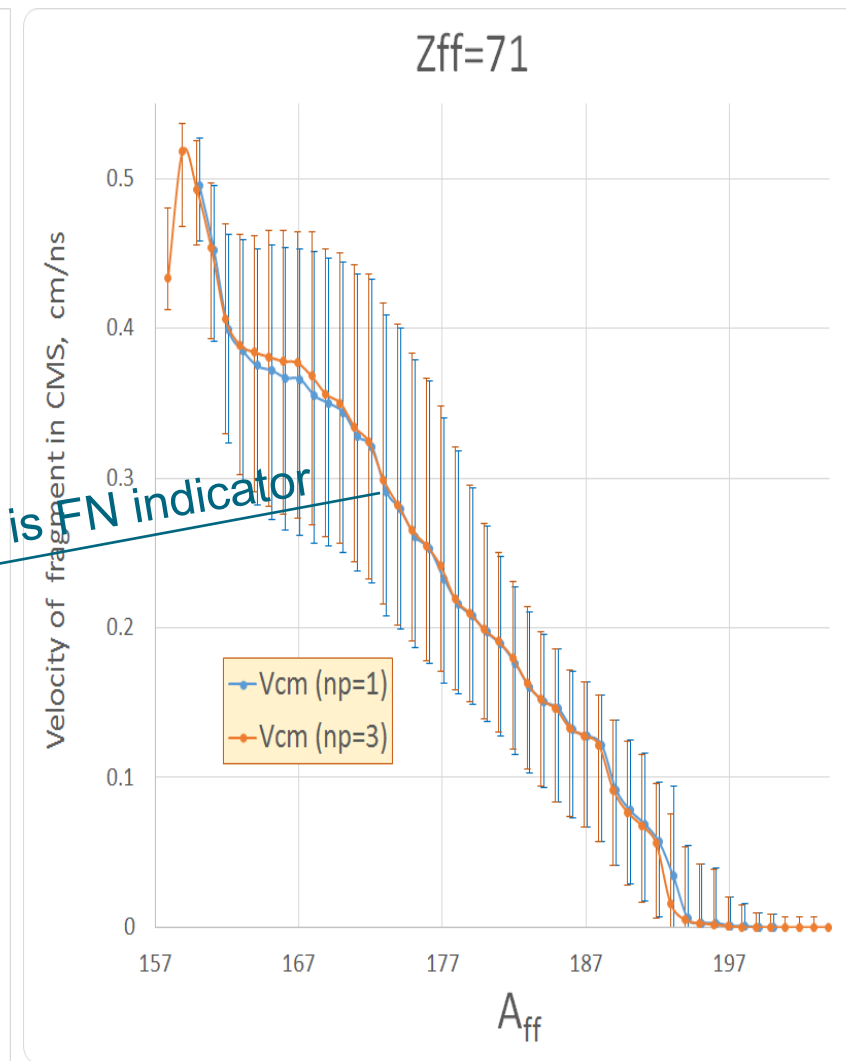




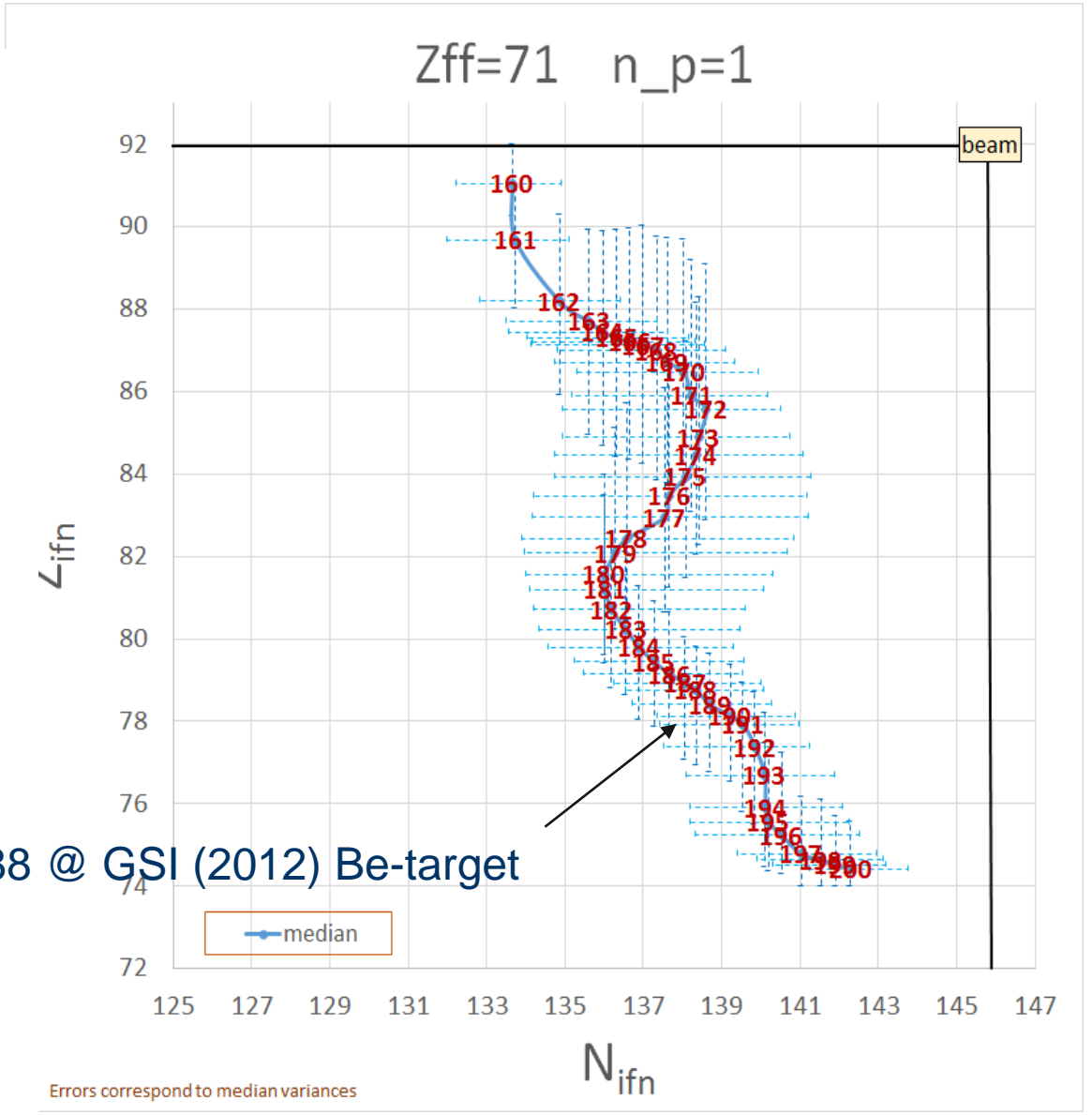
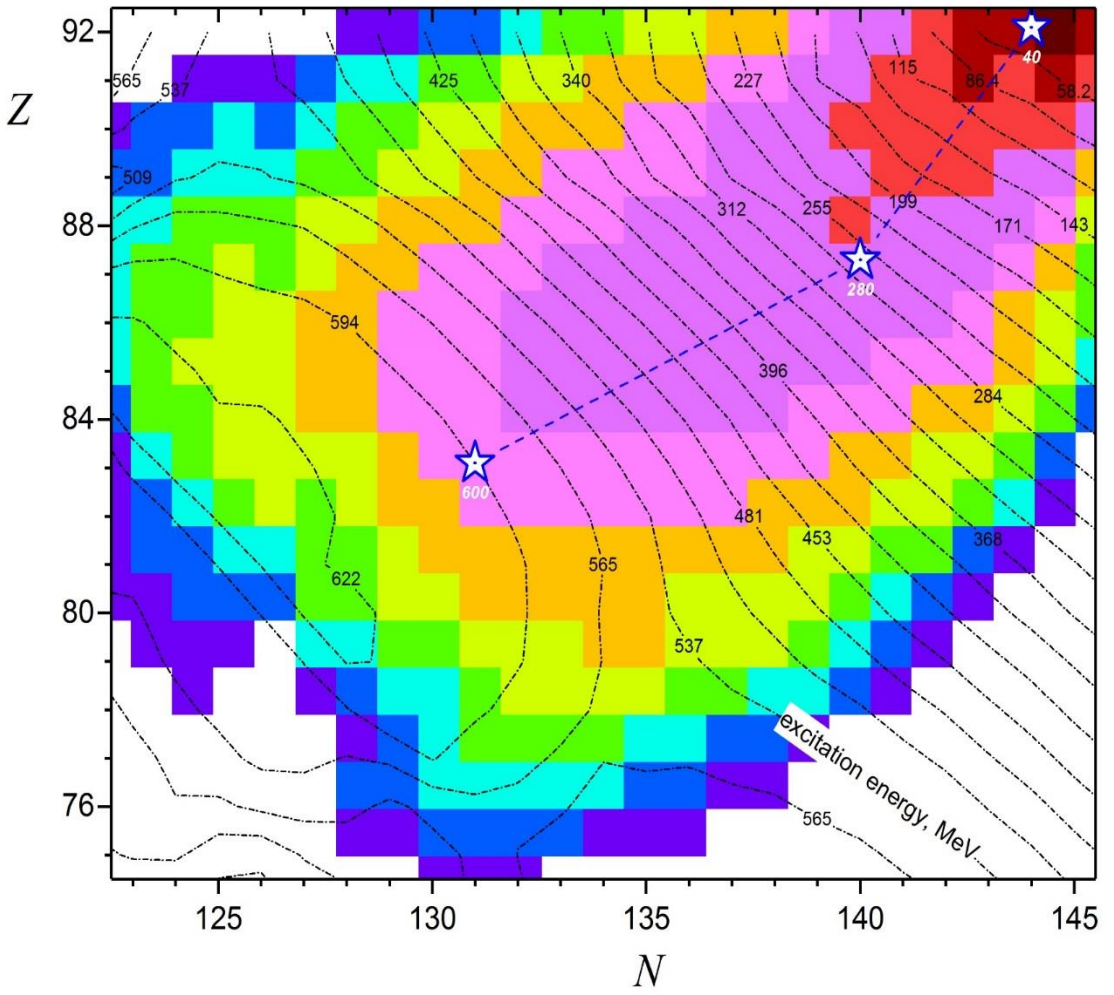
Cross-sections



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



Fragment velocity (CMS – cm/ns)



188 @ GSI (2012) Be-target

Errors correspond to median variances

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.*

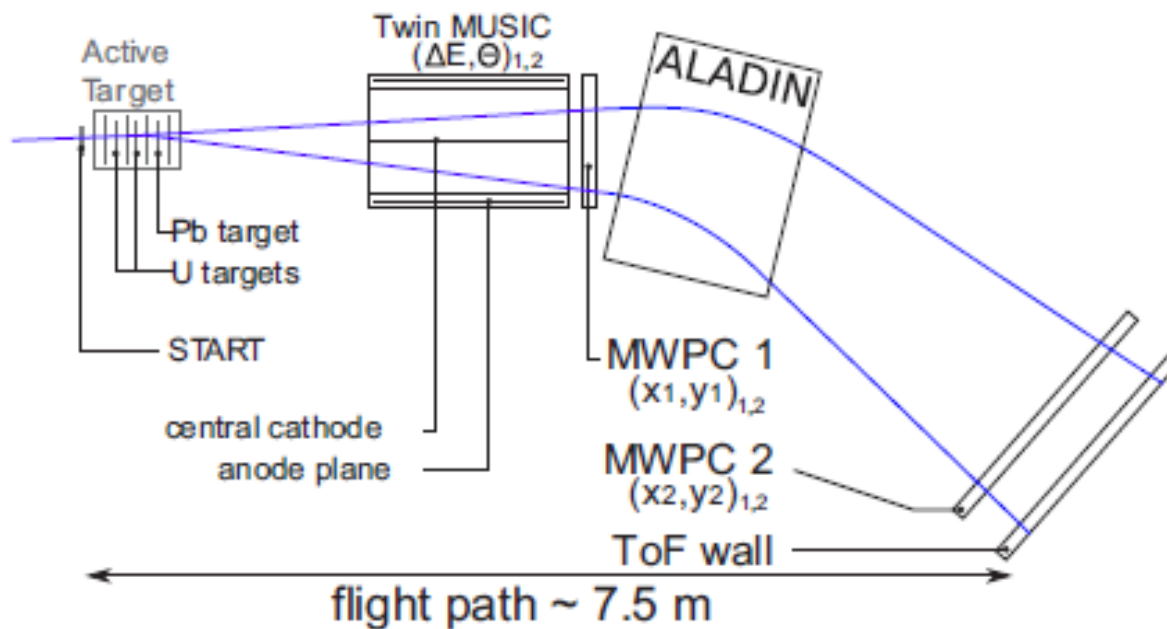


FIG. 4. Schematic view of the SOFIA setup to identify the nuclear mass and charge of both fission fragments in coincidence (top view, not on scale).

BREAKUP (FISSION)

Projectile: 238U (200.0 MeV/u)
Target: 9Be

Fragment (C *): 97Rb, Ex. energy: 18.39
Residual (D *): 141Cs, Ex. energy: 22.51
Q-value (MeV): 159.88 MeV

Excitations

take from systematics
 set manually in Kinematics calculator

Acceptances (in case of C_final fragment plot)

Angular Acceptance shape: Ellipse Rectangle

	Value	Variance
Horizontal ±	3000	0.5 mrad
Vertical ±	3000	0.5 mrad

Momentum acceptance: Setting Brho: 5.612 T*m, Acceptance ±: 1000 %

Expected final fragments

C_final: 95Rb: 49.5% <dn> 2.51
D_final: 138Cs: 48.2% <dn> 2.85

TKE(CM) from systematics: 161.87
TKE(CM) from calculations: 156.52

Fragment to plot

Excited (C *)
 Expected final (C_final)
 add conjugated fragment (D)

Plots

Lab: Vz & Vx E & A Brho (q=Z) & A
 Vz & Vxy E & Ax Brho (q=Z) & Ax
 Vz & Ax E & Ay Brho (q=Z) & Ay
 Vz & Ay Vz & phi Ax & Ay

CM: Vz & Vx
 Vz & Vxy
 Ax & Ay
 A & phi

Energy variation after the reaction due to straggling: 0.1 MeV/u

* Warning: it takes a lot of computing time if this value is more than 0

Initial emittance: Horizontal Angular ±: 0 mrad, Vertical Angular ±: 0 mrad, Energy** ±: 0 MeV/u

Broadening due to particle emission: Angular ±: 0.79 mrad, Energy ±: 0.02 MeV/u

Angular Distribution (CM): ISOTROPIC

Momentum acceptance instead the previous pseudo-energy acceptance

"Brho" plots

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

add conjugated fragment (D)

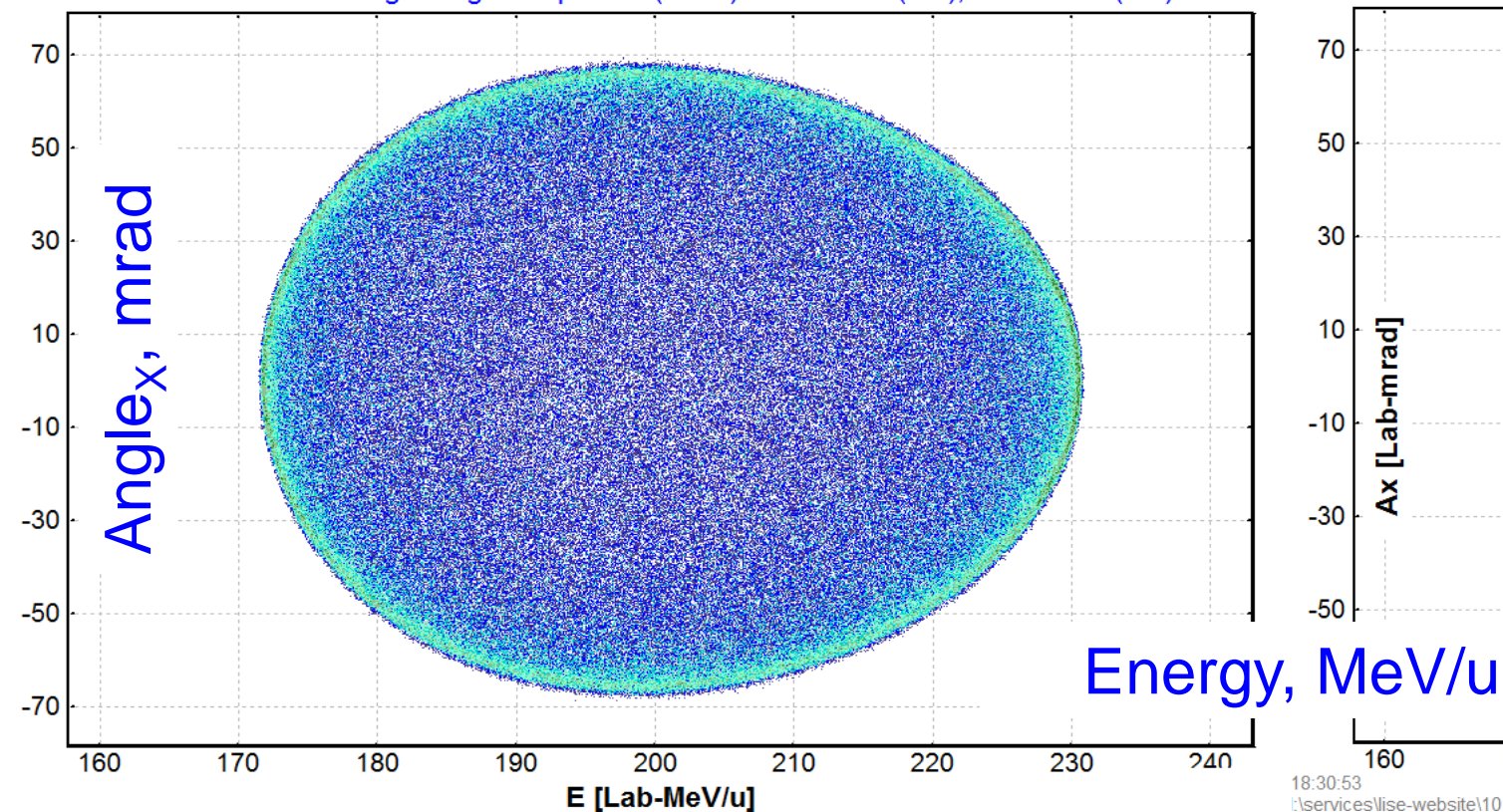
add conjugated fragment (D)

^{95}Rb fragment kinematics (expected final)

$^{238}\text{U} \Rightarrow ^{95}\text{Rb}(^{97}\text{Rb}^*) + ^{138}\text{Cs}(^{141}\text{Cs}^*)$ (Projectile Energy : 200.00 MeV/u)

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

Rectangle Ang.Acceptance (mrad): H = 3000.0(0.5); V = 3000.0(0.5)

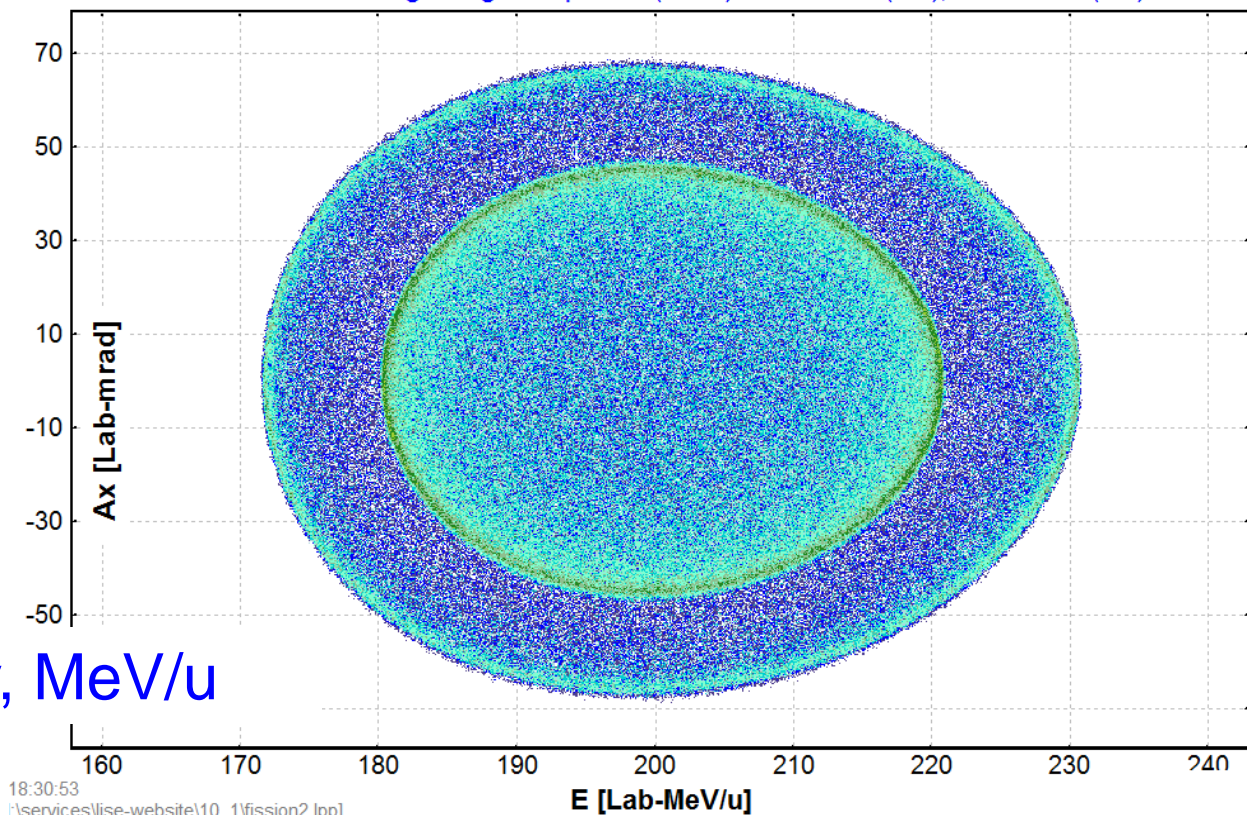


^{95}Rb & ^{138}Cs fragment kinematics (expected final)

$^{238}\text{U} \Rightarrow ^{95}\text{Rb}(^{97}\text{Rb}^*) + ^{138}\text{Cs}(^{141}\text{Cs}^*)$ (Projectile Energy : 200.00 MeV/u)

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

Rectangle Ang.Acceptance (mrad): H = 3000.0(0.5); V = 3000.0(0.5)



Acceptances (in case of C_final fragment plot)

Angular Acceptance

Angular acceptance shape

Ellipse Rectangle

	Value	Variance
Horizontal ±	150	0.5 mrad
Vertical ±	50	0.5 mrad

Momentum acceptance

Setting Brho 5.612 T*m

Acceptance ± 1000 %

BOTH fragments should pass Angular and Momentum Acceptances

Acceptances (in case of C_final fragment plot)

Angular Acceptance

Angular acceptance shape

Ellipse Rectangle

	Value	Variance
Horizontal ±	150	0.5 mrad
Vertical ±	50	0.5 mrad

Momentum acceptance

Setting Brho 5.612 T*m

Acceptance ± 1000 %

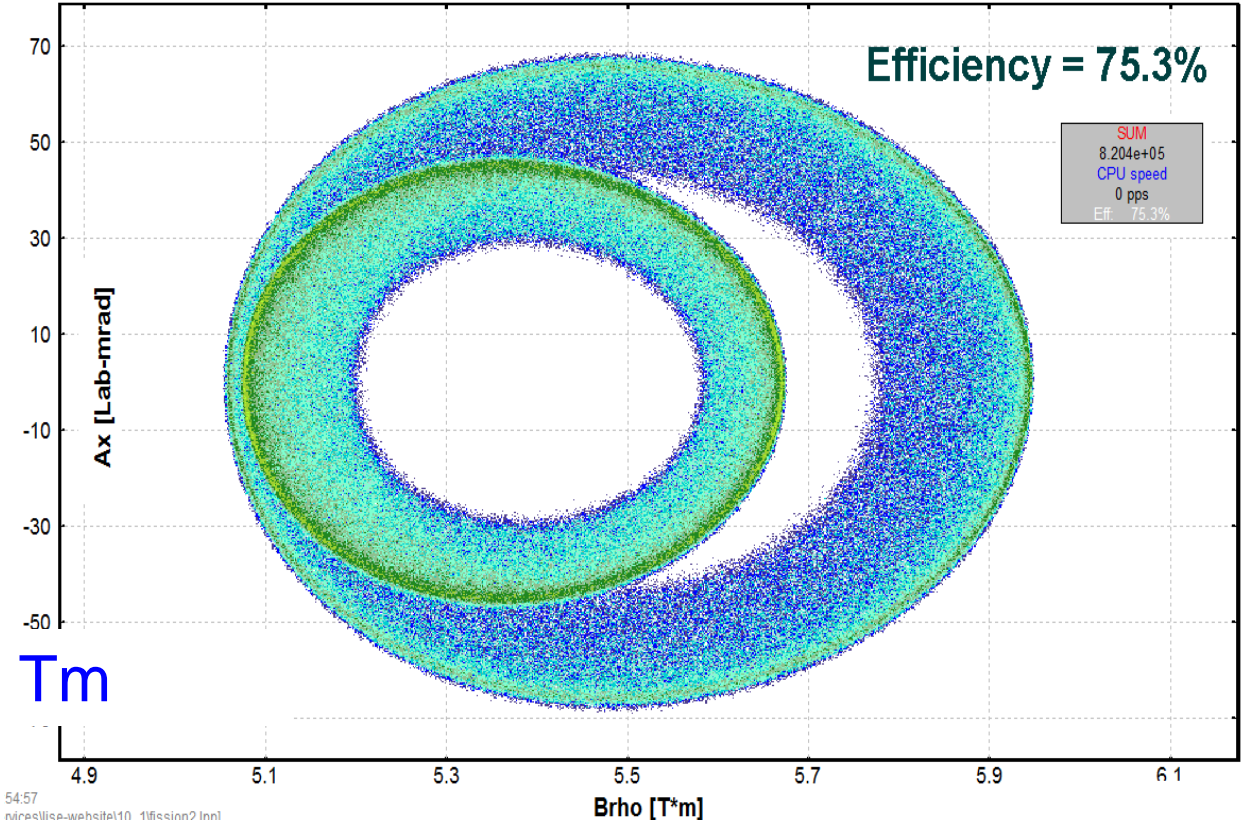
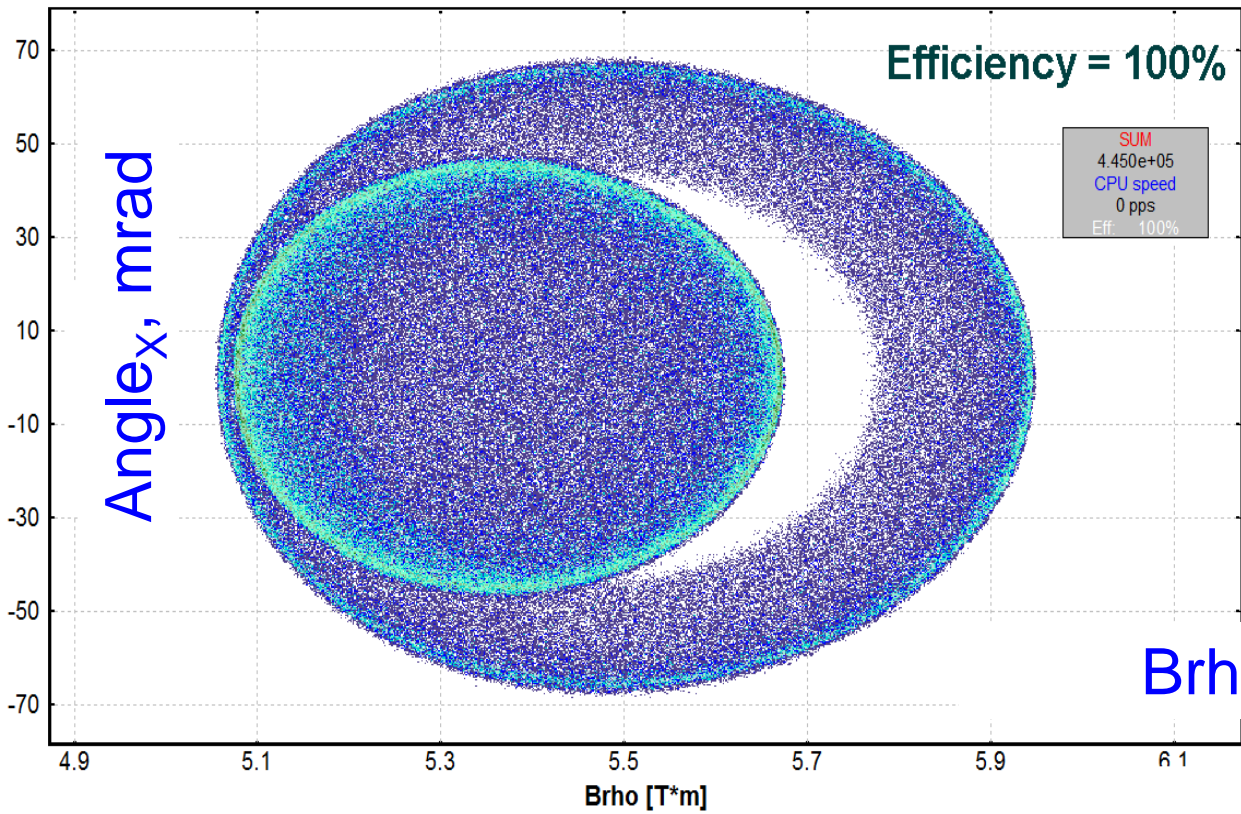
BOTH fragments should pass Angular and Momentum Acceptances

⁹⁵Rb & ¹³⁸Cs fragment kinematics (expected final)

$^{238}\text{U} \Rightarrow ^{95}\text{Rb}(^{97}\text{Rb}^*) + ^{138}\text{Cs}(^{141}\text{Cs}^*)$ (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)

⁹⁵Rb & ¹³⁸Cs fragment kinematics (expected final) **BOTH fragments should**

$^{238}\text{U} \Rightarrow ^{95}\text{Rb}(^{97}\text{Rb}^*) + ^{138}\text{Cs}(^{141}\text{Cs}^*)$ (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)



Acceptances (in case of C_final fragment plot)

Angular Acceptance

Angular acceptance shape

Ellipse Rectangle

	Value	Variance	Unit
Horizontal ±	3000	0.5	mrad
Vertical ±	3000	0.5	mrad

Momentum acceptance

Setting Brho T*m

Acceptance ± %

BOTH fragments should pass Angular and Momentum Acceptances

"A" - angle, "V" - velocity, "E" - energy
 "CM" - center of mass, "LAB" - laboratory
 "z" corresponds to the beam direction.
 No events with Vz<0 in the case of non-zero target thickness

Acceptances (in case of C_final fragment plot)

Angular Acceptance

Angular acceptance shape

Ellipse Rectangle

	Value	Variance	Unit
Horizontal ±	3000	0.5	mrad
Vertical ±	3000	0.5	mrad

Momentum acceptance

Setting Brho T*m

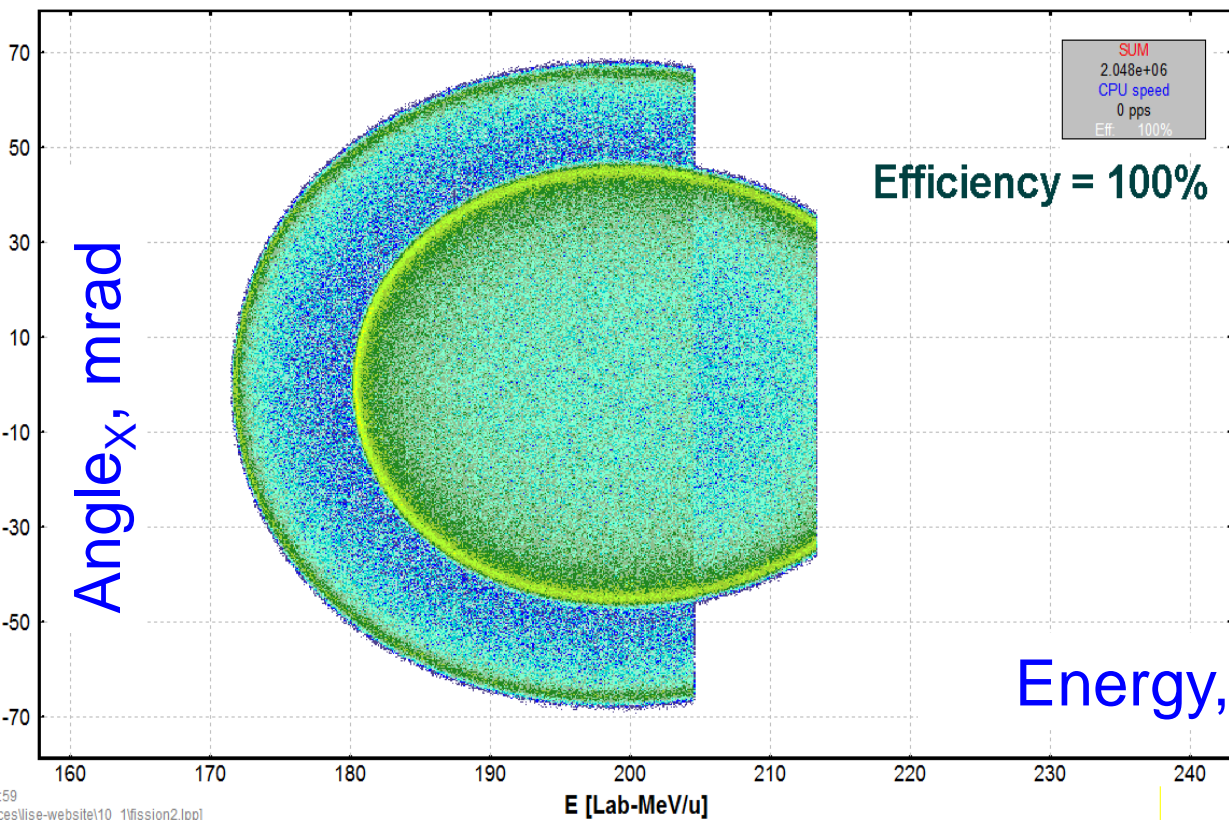
Acceptance ± %

BOTH fragments should pass Angular and Momentum Acceptances

"A" - angle, "V" - velocity, "E" - energy
 "CM" - center of mass, "LAB" - laboratory
 "z" corresponds to the beam direction.
 No events with Vz<0 in the case of non-zero target thickness

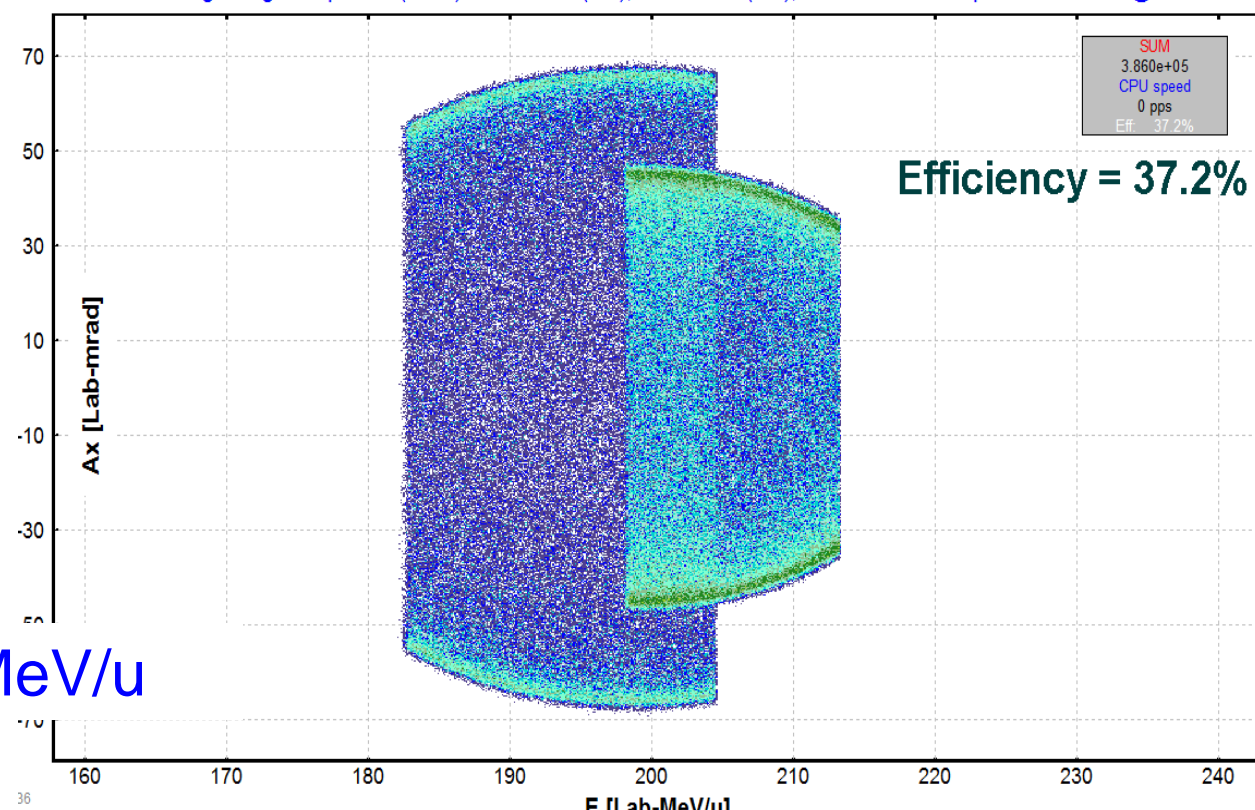
⁹⁵Rb & ¹³⁸Cs fragment kinematics (expected final)

$^{238}\text{U} \Rightarrow ^{95}\text{Rb}(^{97}\text{Rb}^+) + ^{138}\text{Cs}(^{141}\text{Cs}^*)$ (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 = 3000.0(0.5); V = 3000.0(0.5); Momentum Acceptance : 5.00 % @ Brho = 5.30



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

$^{238}\text{U} \Rightarrow ^{95}\text{Rb}(^{97}\text{Rb}^+) + ^{138}\text{Cs}(^{141}\text{Cs}^*)$ (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 = 3000.0(0.5); V = 3000.0(0.5); Momentum Acceptance : 5.00 % @ Brho = 5.30



2D fragment plot (Monte Carlo)

BREAKUP (FISSION)

Projectile: 238U (200.0 MeV/u)

Target: **9Be (1 mm)**

Ex. energy

Fragment (C *) 97Rb 18.39

Residual (D *) 141Cs 22.51

Q-value (MeV) 159.88 MeV

Excitations

take from systematics

set manually in Kinematics calculator

TKE plot

Acceptances (in case of C_final fragment plot)

Angular Acceptance

Angular acceptance shape

Ellipse Rectangle

	Value	Variance
Horizontal ±	150	0.5 mrad
Vertical ±	50	0.5 mrad

Momentum acceptance

Setting Brho 5.612 T*m

Acceptance ± 200 %

BOTH fragments should pass Angular and Momentum Acceptances

Take into account a target thickness

No (fast) **Yes**

Initial emittance

Horizontal Angular ± 0 mrad

Vertical Angular ± 0 mrad

Energy** ± 0 MeV/u

Broadening due to particle emission

Angular ± 0.81 mrad

Energy ± 0.02 MeV/u

Angular Distribution (CM)

ISOTROPIC

Energy loss and energy straggling inclusion

Ok Cancel

Plots

Lab

Vz & Vx E & A Brho (q=Z) & A

Vz & Vxy E & Ax Brho (q=Z) & Ax

Vz & Ax E & Ay Brho (q=Z) & Ay

Vz & Ay Vz & phi Ax & Ay

CM

Vz & Vx Vz & Vxy Ax & Ay A & phi

Expected final fragments

C_final 95Rb: 49.5% <dn> 2.51

D_final 138Cs: 48.2% <dn> 2.85

TKE(CM) from systematics 161.87

TKE(CM) from calculations 156.52

Fragment to plot

Excited (C *)

Expected final (C_final)

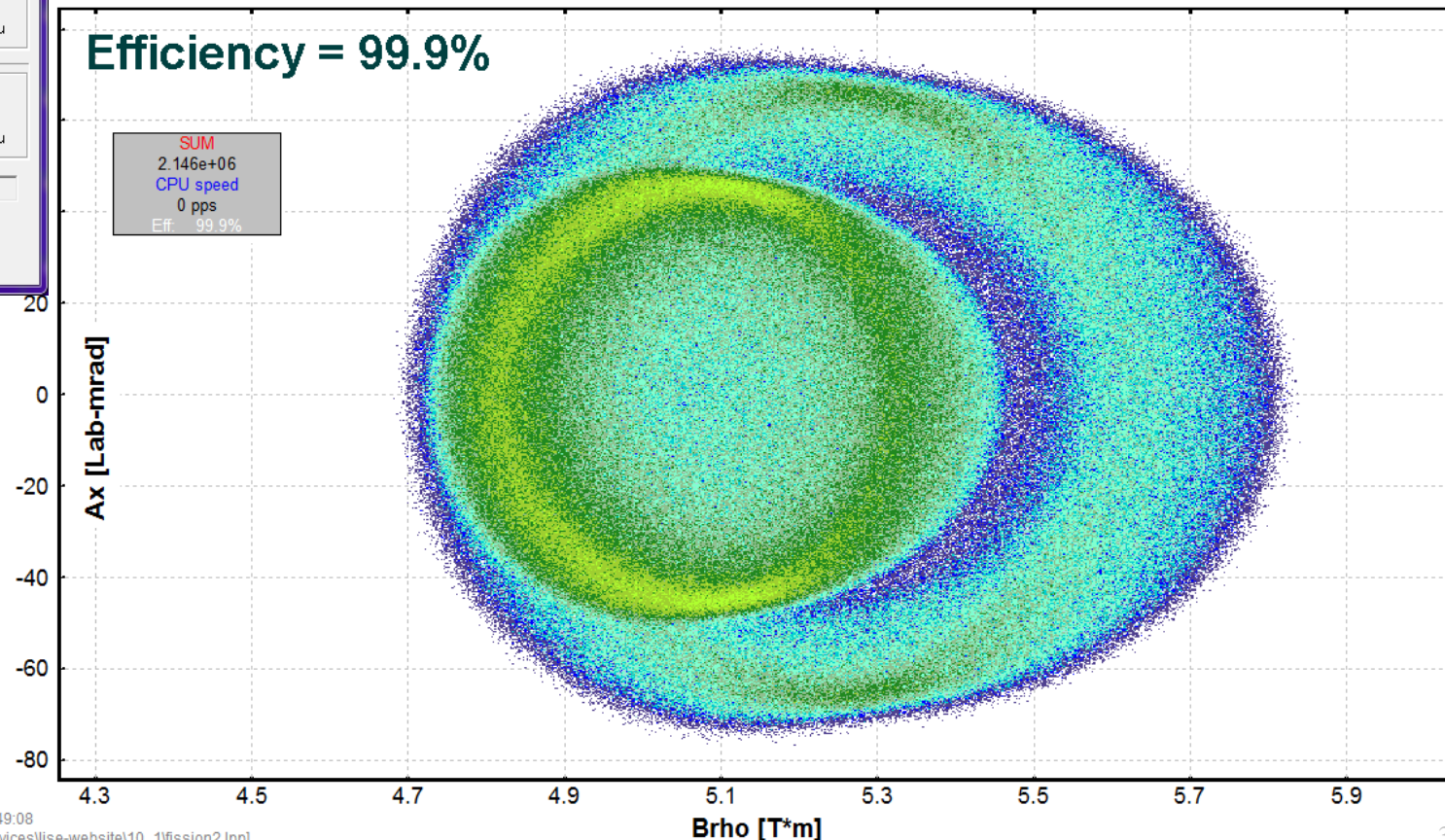
add conjugated fragment (D)

⁹⁵Rb & ¹³⁸Cs fragment kinematics (expected final)

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

Target: Be (1 mm); Q reaction: 159.88 MeV (Excitations 20.0=>18.4+22.5); Angular Distribution (CM): Isotrop
 Rectangle Ang.Acceptance (mrad): H = 150.0(0.5); V = 50.0(0.5)

Efficiency = 99.9%



Acceptances and non-zero target thickness

Acceptances (in case of C_final fragment plot)

Angular Acceptance

Angular acceptance shape

Ellipse Rectangle

	Value	Variance	
Horizontal ±	150	0.5	mrad
Vertical ±	50	0.5	mrad

Momentum acceptance

Setting Brho T*m

Acceptance ± %

BOTH fragments should pass Angular and Momentum Acceptances

Acceptances (in case of C_final fragment plot)

Angular Acceptance

Angular acceptance shape

Ellipse Rectangle

	Value	Variance	
Horizontal ±	150	0.5	mrad
Vertical ±	50	0.5	mrad

Momentum acceptance

Setting Brho T*m

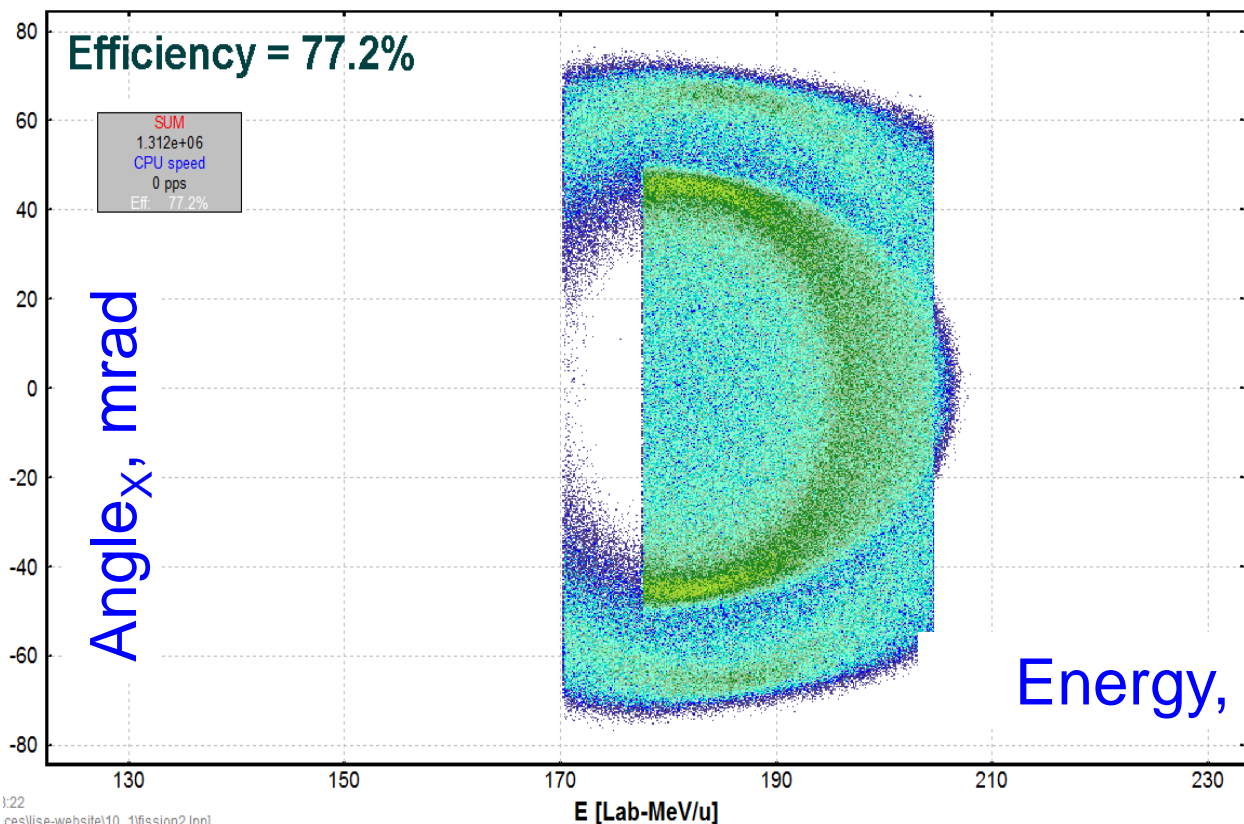
Acceptance ± %

BOTH fragments should pass Angular and Momentum Acceptances

⁹⁵Rb & ¹³⁸Cs fragment kinematics (expected final)

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

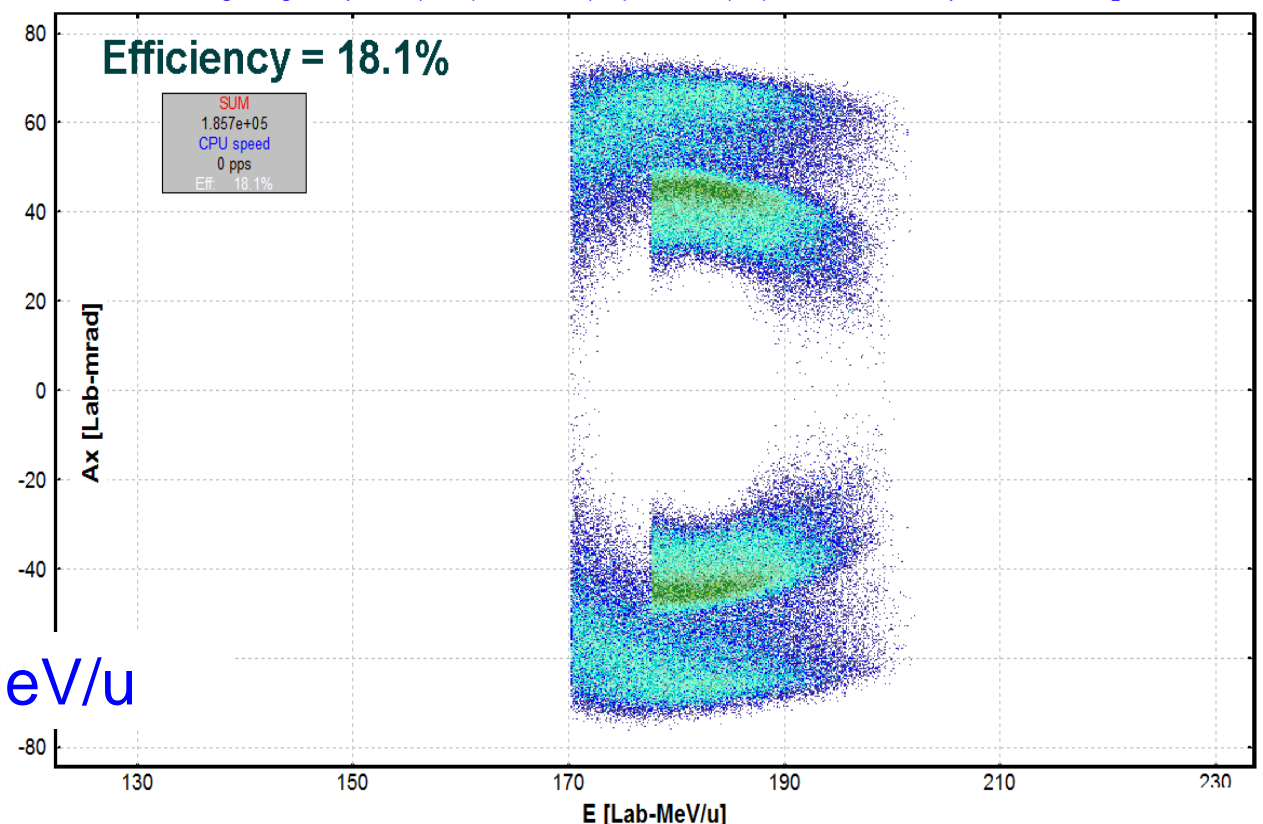
Target: Be (1 mm); Q reaction: 159.88 MeV (Excitations 20.0=>18.4+22.5); Angular Distribution (CM): Isotrop
 Rectangle Ang.Acceptance (mrad): H = 150.0(0.5); V = 50.0(0.5); Momentum Acceptance : 5.00 % @ Brho = 5.300f



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

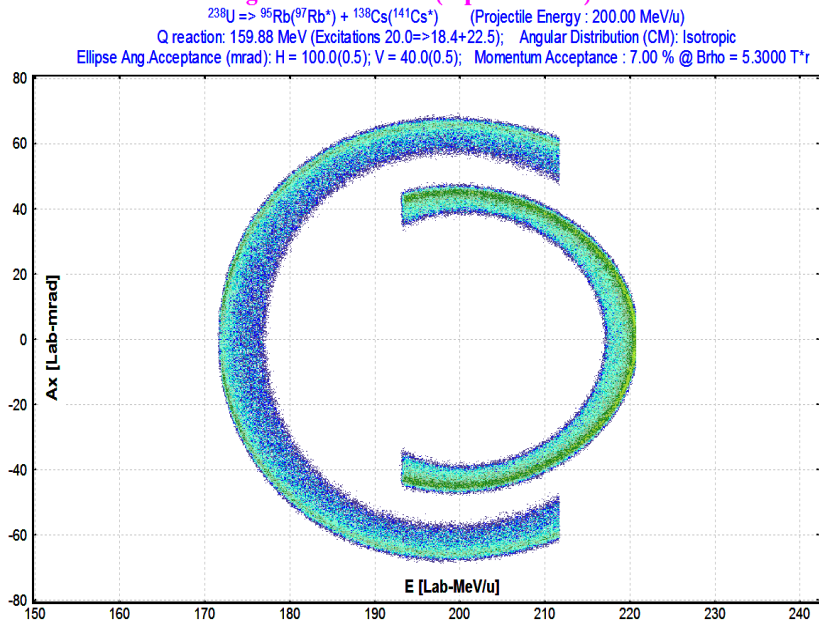
²³⁸U => ⁹⁵Rb(⁹⁷Rb*) + ¹³⁸Cs(¹⁴¹Cs*) (Projectile Energy : 200.00 MeV/u)

Target: Be (1 mm); Q reaction: 159.88 MeV (Excitations 20.0=>18.4+22.5); Angular Distribution (CM): Isotrop
 Rectangle Ang.Acceptance (mrad): H = 150.0(0.5); V = 50.0(0.5); Momentum Acceptance : 5.00 % @ Brho = 5.300f

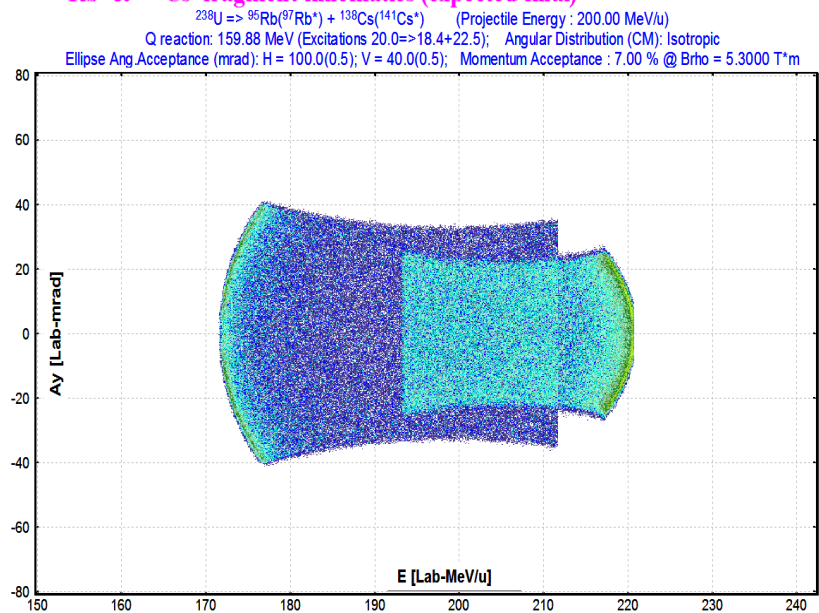


Some other plots.....

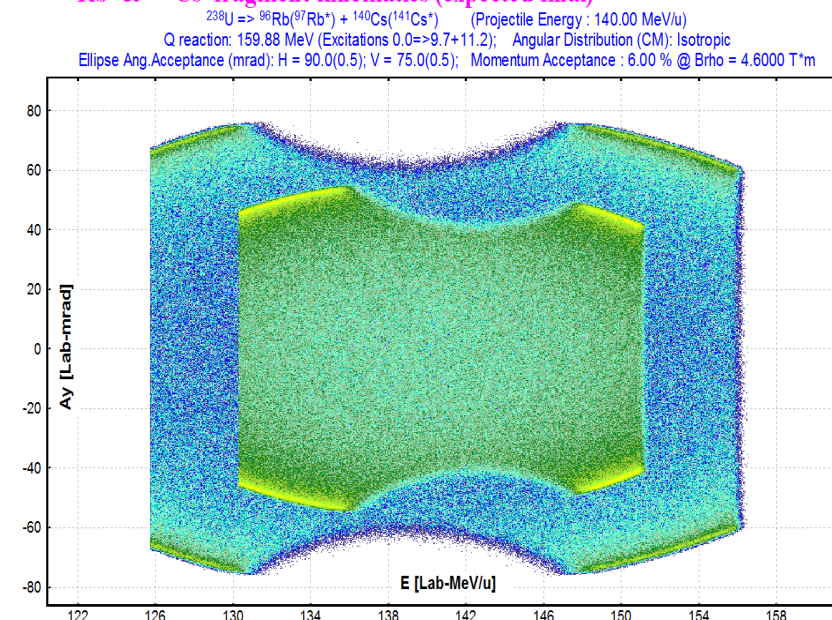
⁹⁵Rb & ¹³⁸Cs fragment kinematics (expected final) BOTH fragments should pass



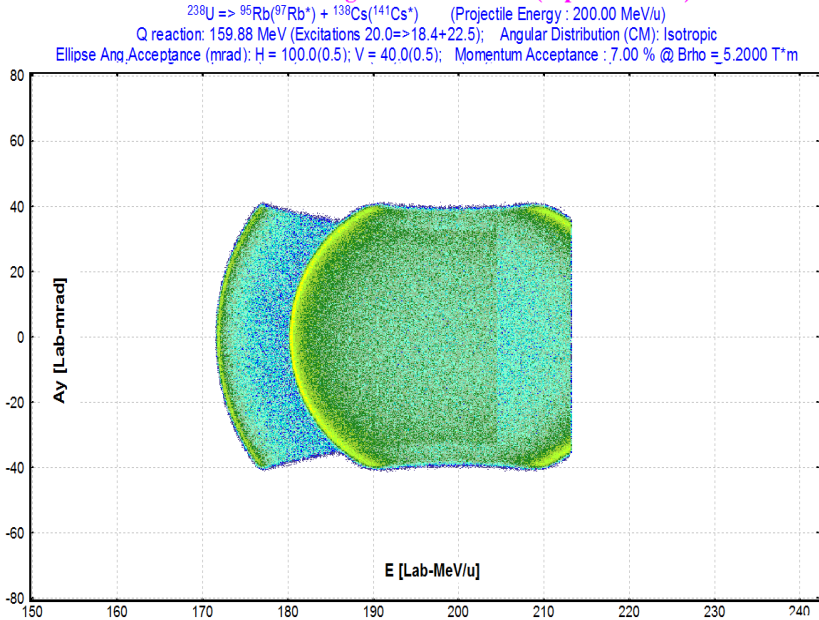
⁹⁵Rb & ¹³⁸Cs fragment kinematics (expected final) BOTH fragments should pass



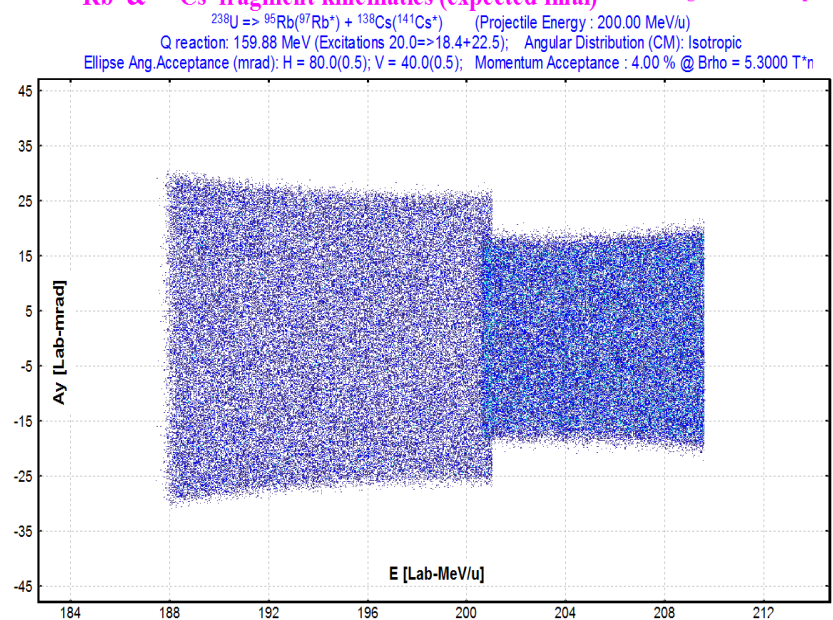
⁹⁶Rb & ¹⁴⁰Cs fragment kinematics (expected final) BOTH fragments should pass



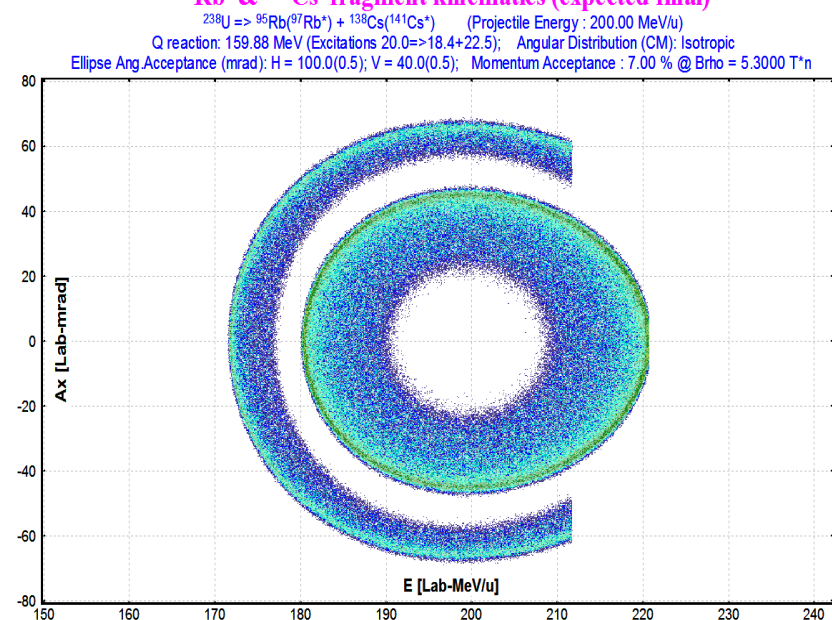
⁹⁵Rb & ¹³⁸Cs fragment kinematics (expected final)



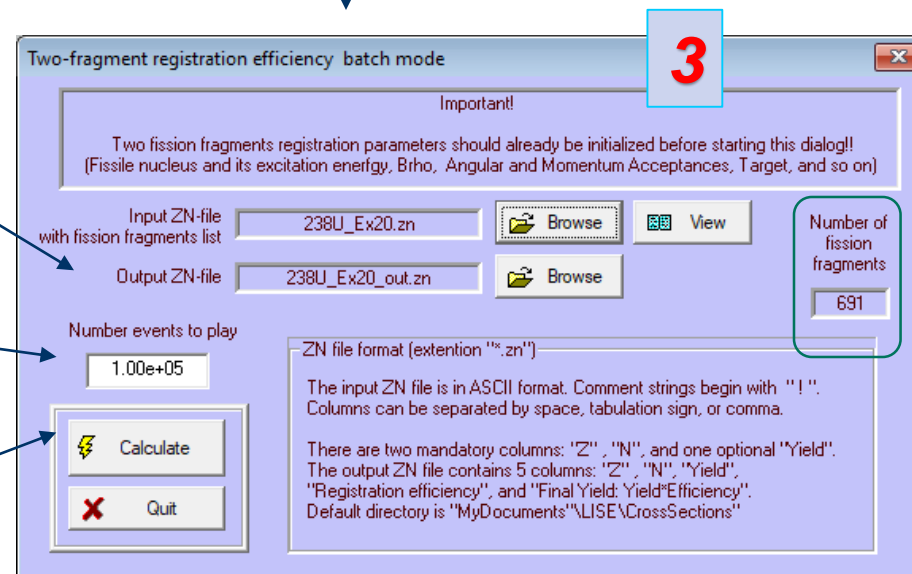
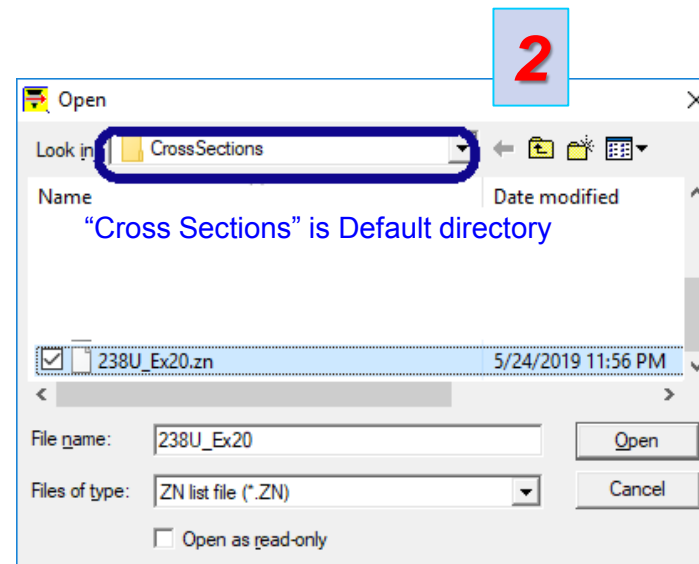
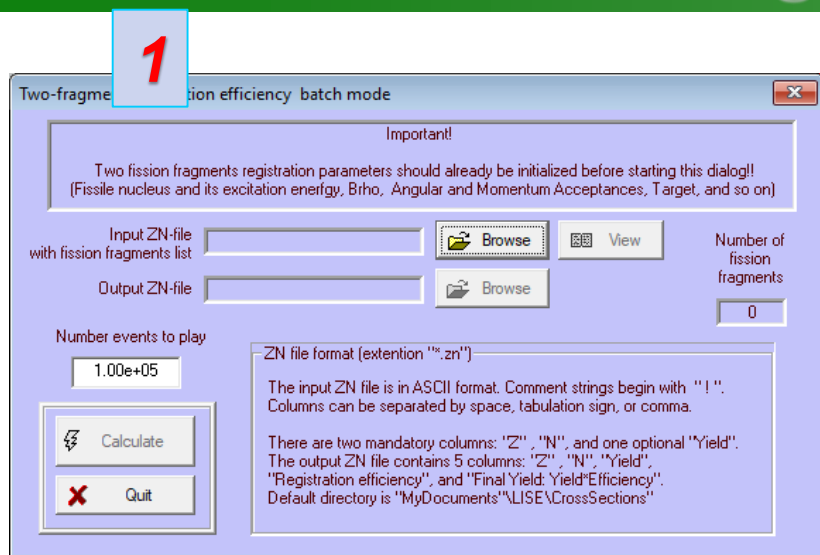
⁹⁵Rb & ¹³⁸Cs fragment kinematics (expected final) BOTH fragments should pass



⁹⁵Rb & ¹³⁸Cs fragment kinematics (expected final)



Two Fission Fragments registration efficiency BATCH mode



LISE++ automatically proposes output file 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)

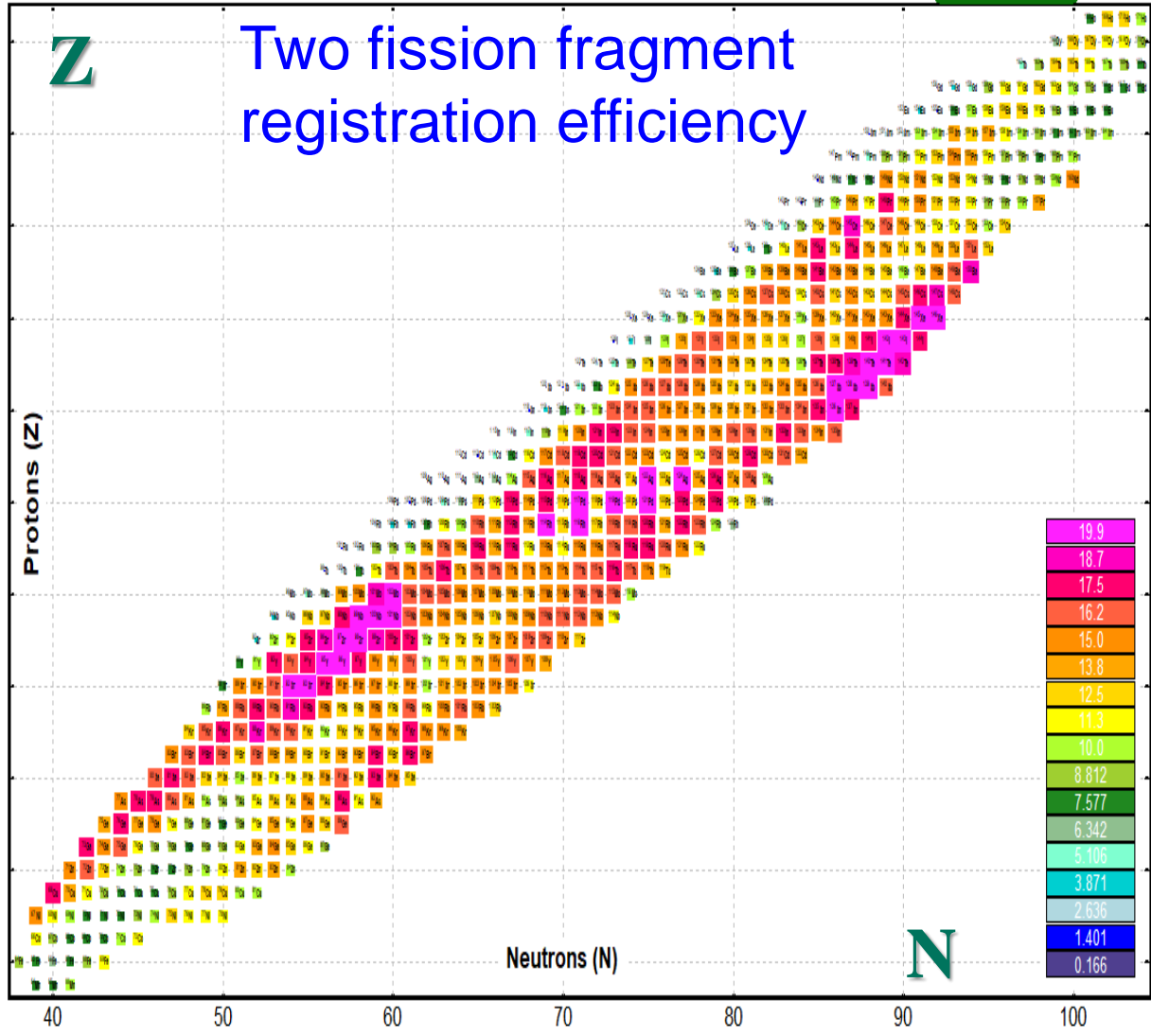
Fission fragment registration efficiency

Input ZN batch file: C:\user\c\lise_pp_11\CrossSections\238U_Ex20.zn

Projectile ²³⁸U (E=200.00 MeV/u; E*=20.00); kinematics of two fragment(s)(expected final) BOTH fragments should pass

Rectangle Ang.Acc.(mrad): H = +60.0(0.5); V = +80.0(0.5); Momentum Acc.: +3.00 % @ Brho = 4.900 Tm

Two fission fragment registration efficiency



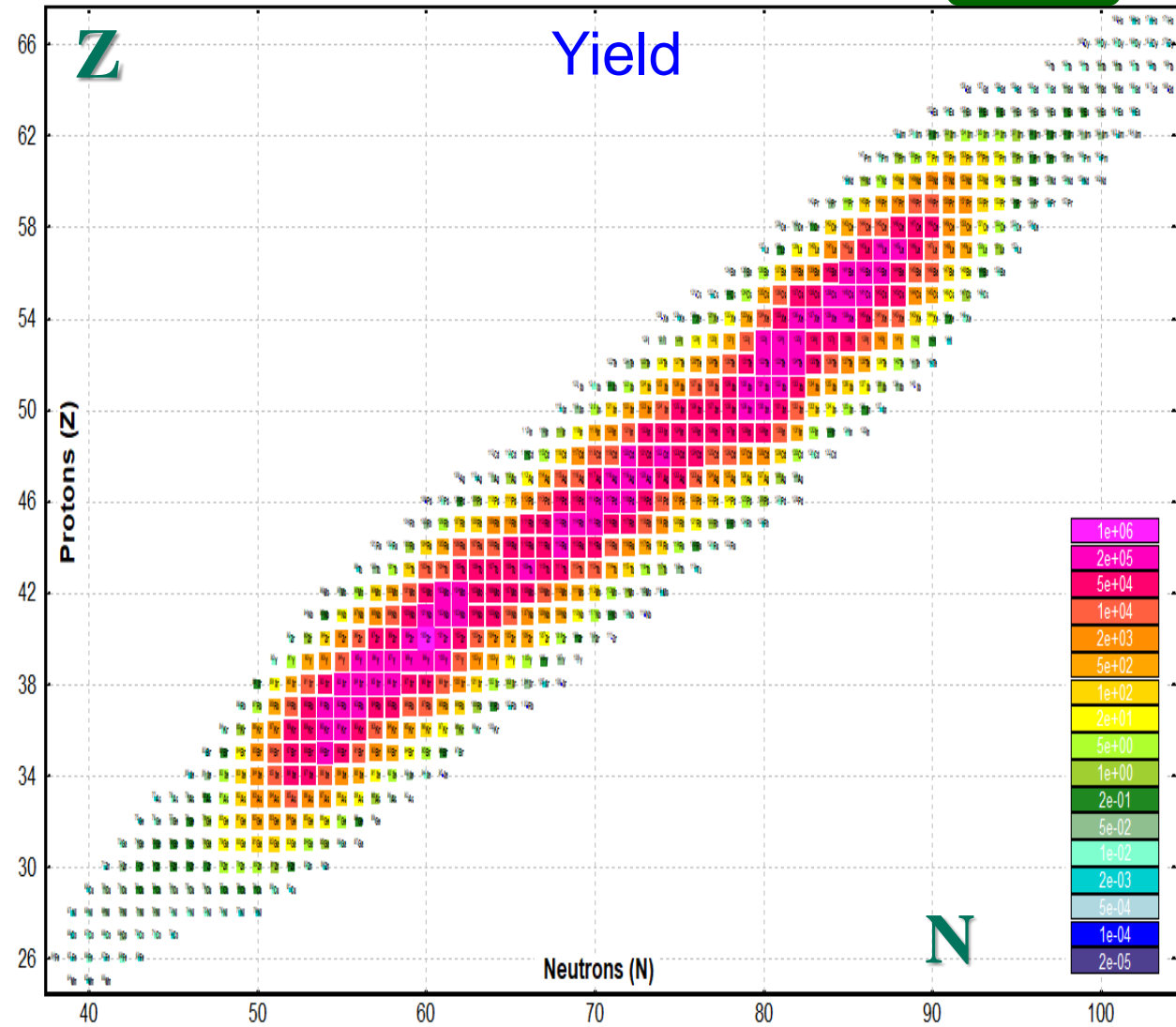
Final Fission Fragment Yields

Input ZN batch file: C:\user\c\lise_pp_11\CrossSections\238U_Ex20.zn; Target: Be (300 mg/cm²)

Projectile ²³⁸U (E=200.00 MeV/u; E*=20.00); kinematics of two fragment(s)(final) BOTH fragments should pass

Rectangle Ang.Acc.(mrad): H = +60.0(0.5); V = +80.0(0.5); Momentum Acc.: +3.00 % @ Brho = 4.900 Tm

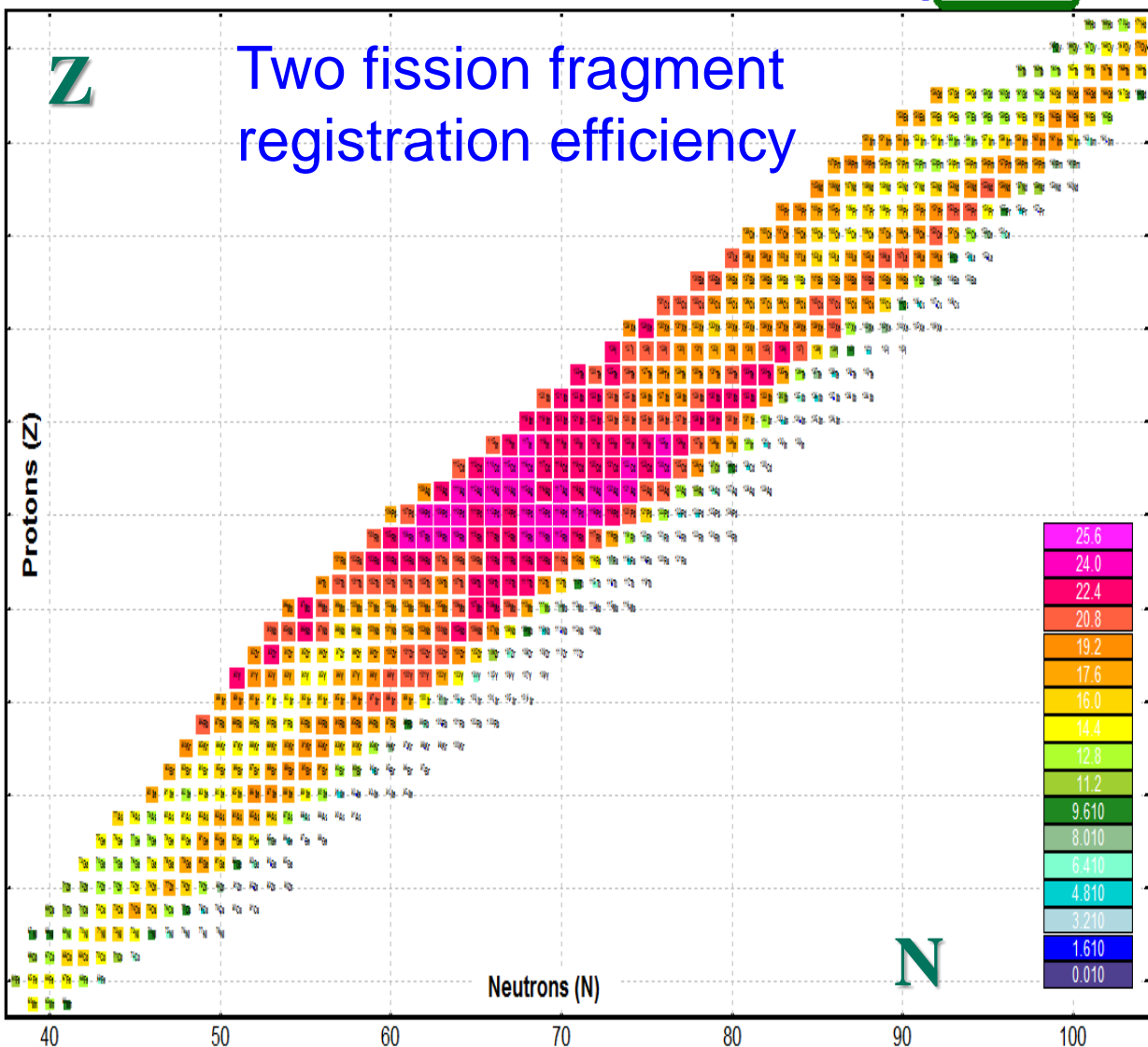
Yield



Fission fragment registration efficiency

Input ZN batch file: C:\user\c\lise_pp_11\CrossSections\238U_Ex20.zn; Target: Be (300 mg/cm²)
 Projectile ²³⁸U (E=200.00 MeV/u; E*=-20.00); kinematics of two fragment(s)(final) BOTH fragments should pass
 Rectangle Ang.Acc.(mrad): H = +60.0(0.5); V = +80.0(0.5); Momentum Acc.: +3.00 % @ Brho = 5.000 Tm

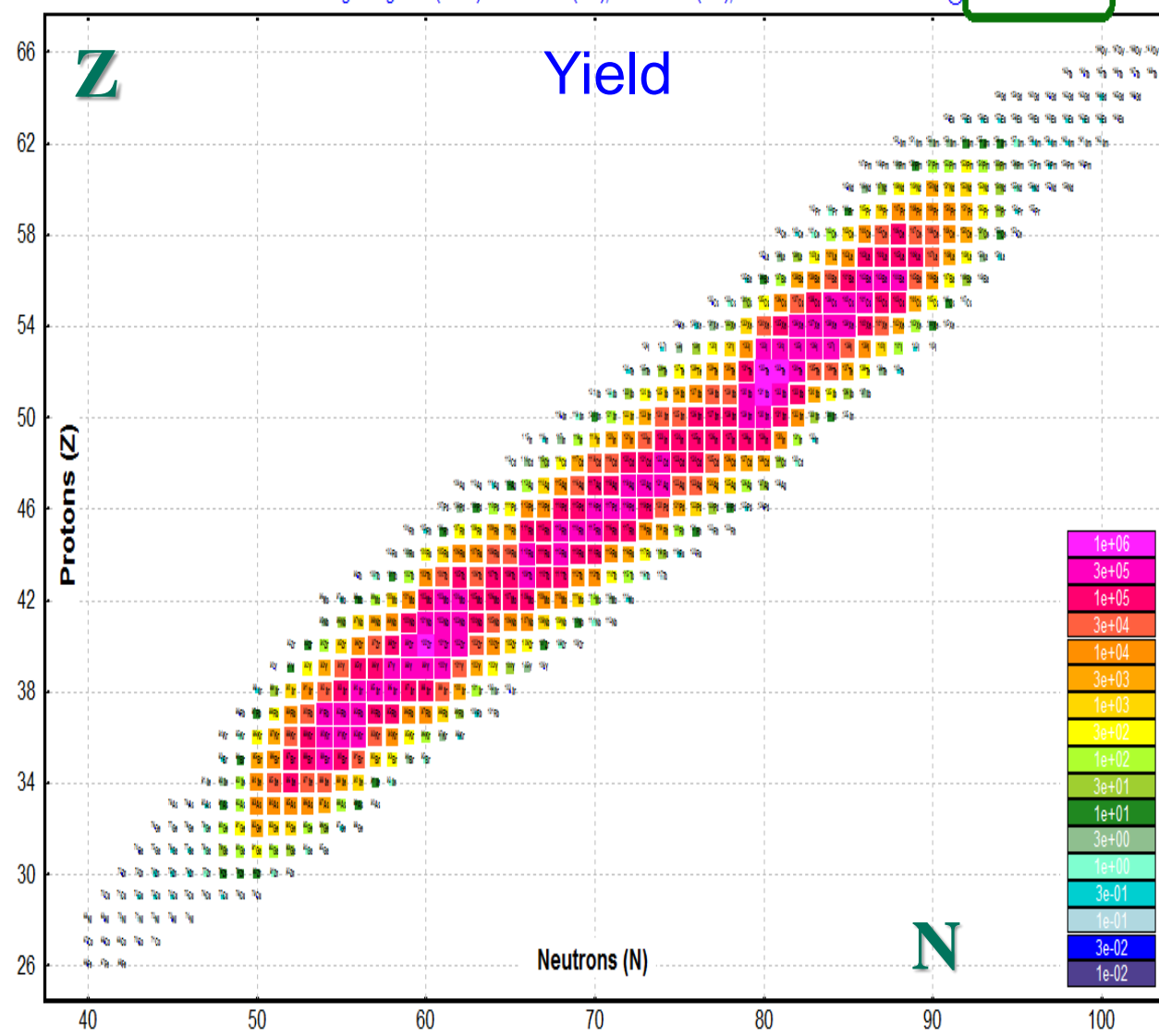
Two fission fragment registration efficiency



Final Fission Fragment Yields

Input ZN batch file: C:\user\c\lise_pp_11\CrossSections\238U_Ex20.zn; Target: Be (300 mg/cm²)
 Projectile ²³⁸U (E=200.00 MeV/u; E*=-20.00); kinematics of two fragment(s)(final) BOTH fragments should pass
 Rectangle Ang.Acc.(mrad): H = +60.0(0.5); V = +80.0(0.5); Momentum Acc.: +3.00 % @ Brho = 5.000 Tm

Yield



Abrasion-Ablation minimization to describe user cross-sections

C. Parametrized Gaussian distribution -- simplified combination of K.-H.Schmidt et al. NPA710 (2002) 157-179

< E* >		sigma		Mean Excitation Energy = <input type="text" value="1484.00"/> MeV
<input type="text" value="0"/>	* d_abr ² +	<input type="text" value="0"/>	* d_abr +	Standard deviation = <input type="text" value="98.84"/> MeV
<input type="text" value="14"/>	* d_abr +	<input type="text" value="9.6"/>	* d_abr ^(1/2) +	
<input type="text" value="0"/>	[MeV]	<input type="text" value="0"/>	[MeV]	

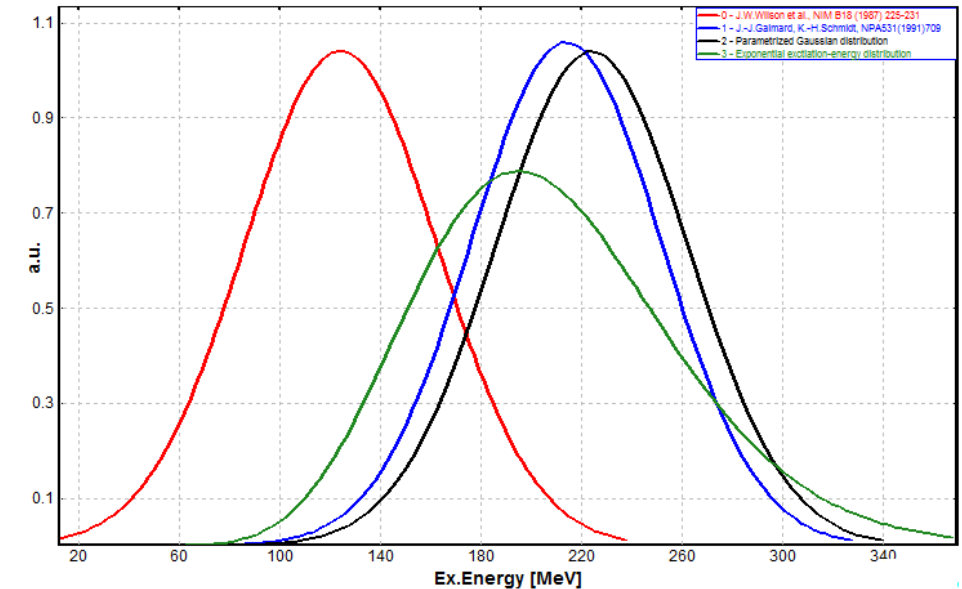
A_p is the projectile mass
 d_{abr} is the number of abraded nucleons

Excitation energy for $76\text{Ge} + \text{Be} \rightarrow 60\text{Ca}$: Ex.Energy distribution

Excit.Energy Method:< 0 >; g=0.95; Sigma=9.6; c1,2=(1.5,2.5) Friction:"Off"

Excit.Energy Method:< 1 >; Hole Depth : 40.0 MeV

Excit.Energy Method:< 2 >; <E*>:14.0*dA MeV Sigma:9.60; No Intrin.Thermalztn; LimitTemp: No



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

v.7.5 09/2005

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

User Cross-Section analysis using the Abrasion-Ablation model: MATRIX

This utility can be used if

- "Projectile Fragmentation" reaction mode is selected
- Abrasion-Ablation is the selected cross-section method
- "File" cross section option is set to "on"
- There are more than 2 user cross-sections in memory for this reaction.

Local line to analyze
Z = 18
Change

Calculate down to Z = 18

Parameter variations

Parameter	Min Value	Max Value	Number of Points
<E*> - excitation energy per abraded nucleon (MeV)	10	30	11
sigma (standard deviation in MeV)	5	17	23

Universal analysis value

Analysis Value	Local		Global		<input checked="" type="checkbox"/> Correct for the number of data points used
	Chi2	LoD	Chi2	LoD	
weights	1	2	2	4	

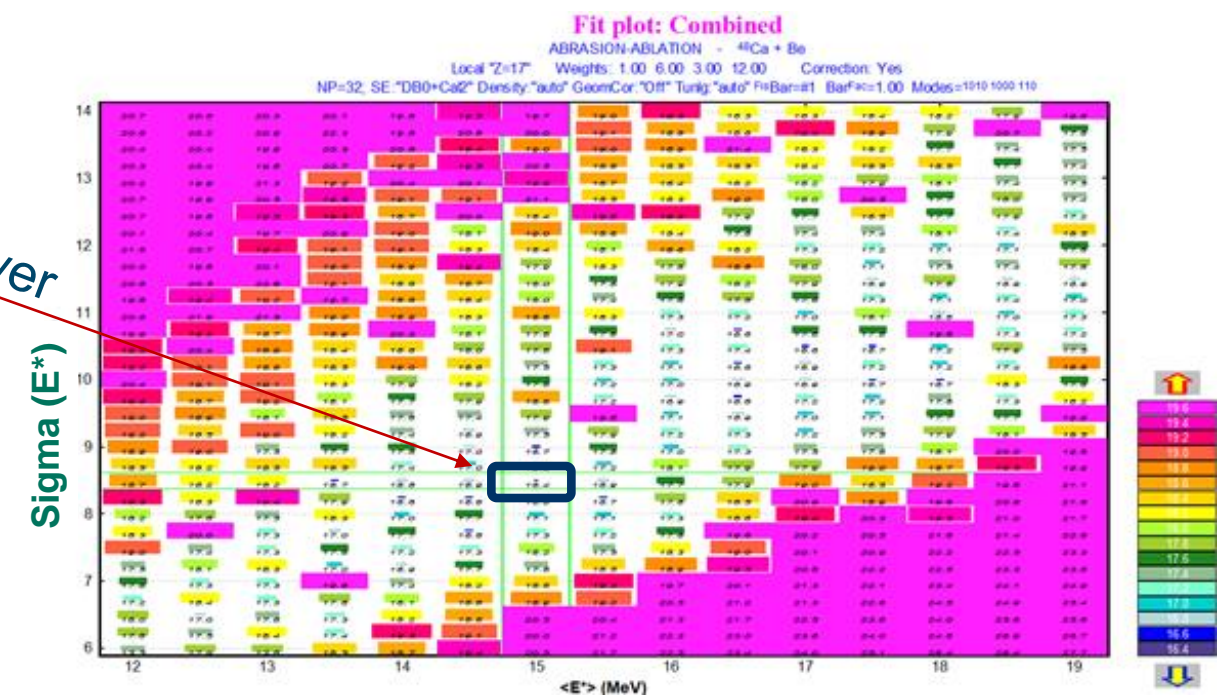
Analysis Log-file: MinimizationCS_net.fit
statistics file: MinimizationCS_min.fit

Make Analysis Cancel Help Make default

Press "Escape" to interrupt analysis

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

answer



Excitation Energy per Abraded Nucleon (MeV)

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

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

Levmar minimization settings

Options: Maximum number of iterations = 4
 Use Lower & Upper bounds

LevMar package samples: Choose example = 4 (0-15)
 Run minimization

Options	Value	Stopping threshold	Default value
tau	1.00e-03	$\mu/\max(J^T J)_i$	1e-03
epsilon 1	1.00e-15	$\ J^T e\ _{inf}$	1e-15
epsilon 2	1.00e-15	$\ Dp\ _2$	1e-15
epsilon 3	1.00e-20	$\ e\ _2$	1e-20
delta	1.00e-06	approximation step *	1e-06

LevMar package info: LEVMAR: Levenberg-Marquardt nonlinear least squares algorithms by M.I.A. Lourakis
 levmar link

Make default
 Ok Cancel

* delta - difference approximation step, used only in the Bounds mode
 If delta=0, the Jacobian is approximated with central differences which are more accurate (but slower) compared to the forward differences employed by default.

User Cross-Section analysis using the Abrasion-Ablation model : MINIMIZATION

This utility can be used if:
 1. "Projectile Fragmentation" reaction mode is selected
 2. Abrasion-Ablation is the selected cross-section method
 3. "File" cross section option is set to "on"
 4. There are more than 2 user cross-sections in memory for this reaction.
 Make items 1-3

Local line to analyze: Change Z = 18

Calculate down to Z = 18

Universal analysis value:
 Analysis Value: Local Chi2, LoD, Global Chi2, LoD
 weights: 1, 2, 2, 4
 Correct for the number of data points used

Save Settings, Load Settings, Evaporation settings, Prefragment excit.energy

Press "Escape" to interrupt analysis

E^* : quadratic polynomial
 $\langle E^* \rangle$ - excitation energy per abraded nucleon (MeV)
 2.03776 + 17.90092 * d_{abr} - 0.61537 * d_{abr}^2
 Use in Fitting process: 0, 1, 2
 Use Bounds constraints: 0, 1, 2
 Lower bound: 0, 10, -2
 Upper bound: 15, 30, 2

$\sigma(E^*)$: quadratic polynomial
 Sigma (standard deviation)
 0 + 9.68991 * $d_{abr}^{1/2}$ + 0 * d_{abr}
 Use in Fitting process: 0, 1, 2
 Use Bounds constraints: 0, 1, 2
 Lower bound: 0, 4, -2
 Upper bound: 10, 20, 2

Fitting: N iterations = 4
 Fit Options, Show initial conditions, Target value = --, N CS points = --, Restore previous values, FIT

Analysis Log-file: Browse, LISE_net.fit

Make default
 Ok Cancel Help

Press it to get initial values:

Target value = 1.15e+01
 N CS points = 11(29)

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

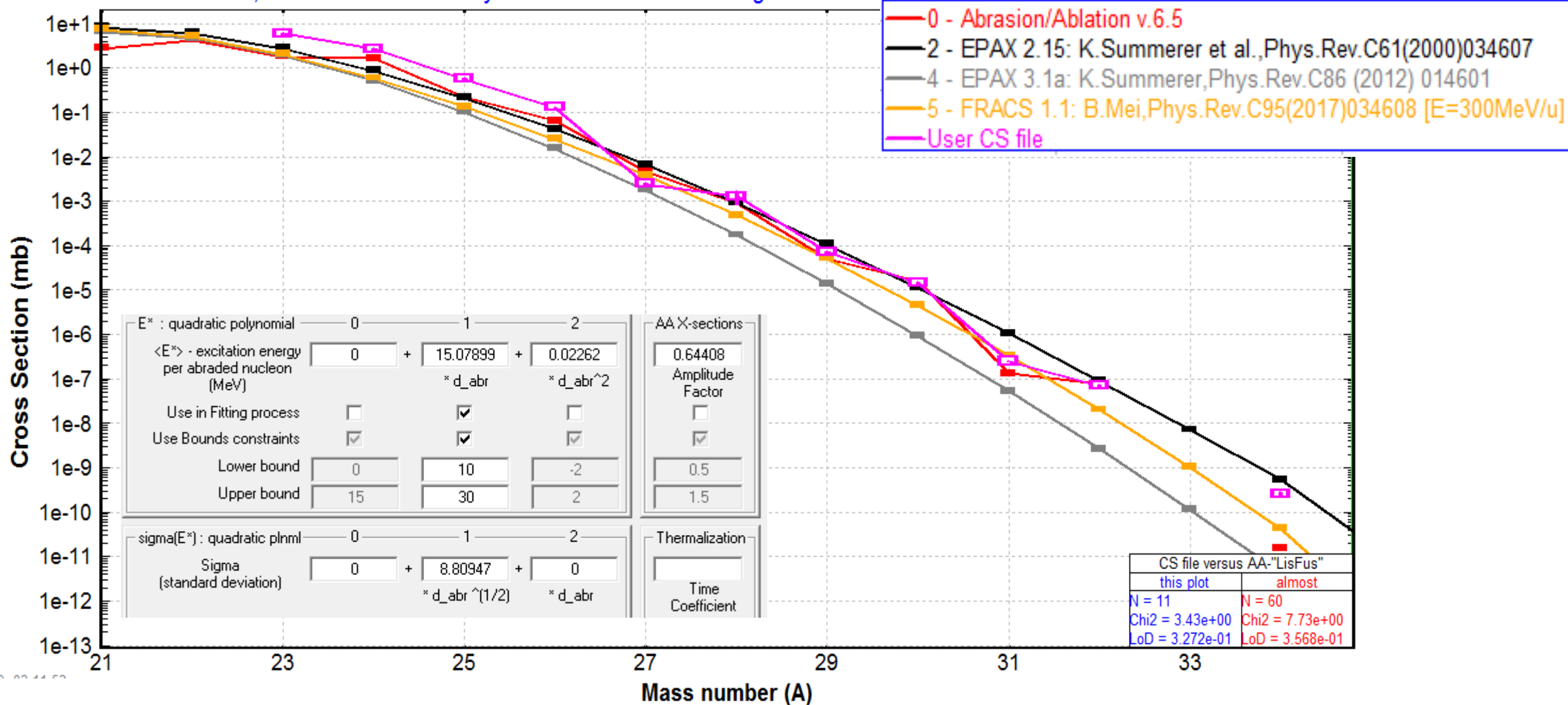
Applying the new utility to analyze the recent RIEKN experimental data obtained with ^{132}Sn , ^{70}Zn , ^{78}Kr and ^{48}Ca beams using different mass tables.

Cross sections (Projectile Fragmentation)

$^{48}\text{Ca} + \text{Be} \rightarrow Z=10$

Excit.Energy Method:< 2 >; <E*>:15.1*dA MeV Sigma:8.81; No Intrin.Thermalztn; LimitTemp: No; DB₁="AME2016"

NP=32; SE:"DB1+Cal1" Density:"auto" GeomCor:"On" Tunlg:"auto" FisBar=#1 Bar^{Fac}=1.00 Modes=1010 1000 110

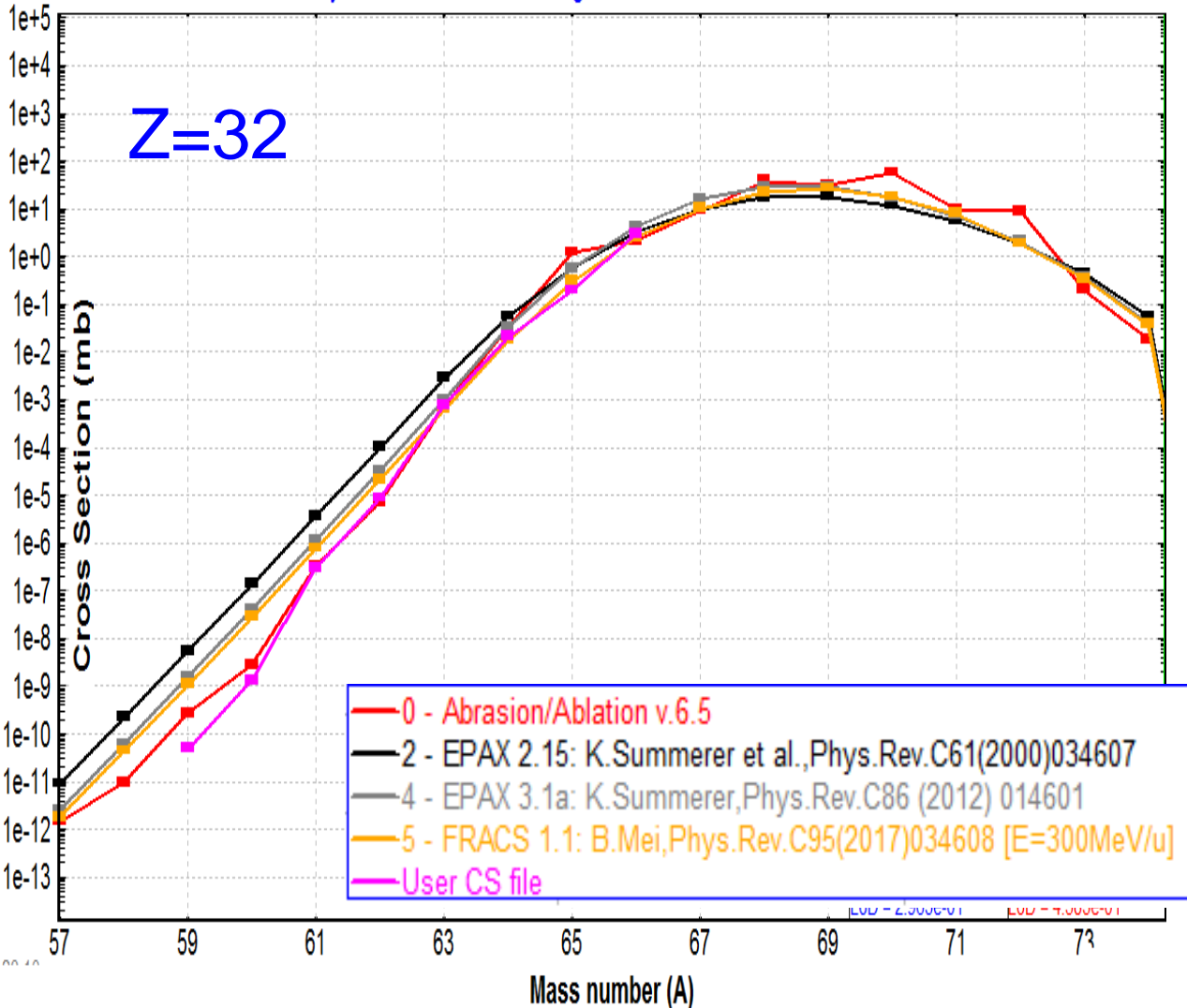


Cross sections (Projectile Fragmentation)

$^{78}\text{Kr} + \text{Be} \rightarrow Z=32$

Excit.Energy Method:< 2 >; <E*>:19.2*dA MeV Sigma:7.19; No Intrin.Thermalztn; LimitTemp: No; DB₁="AME2016"

NP=32; SE:"DB1+Cal1" Density:"C" GeomCor:"On" Tunlg:"On" dR=5.0fm FisBar=#1 BarFac=1.00 Modes=1010 1000 110

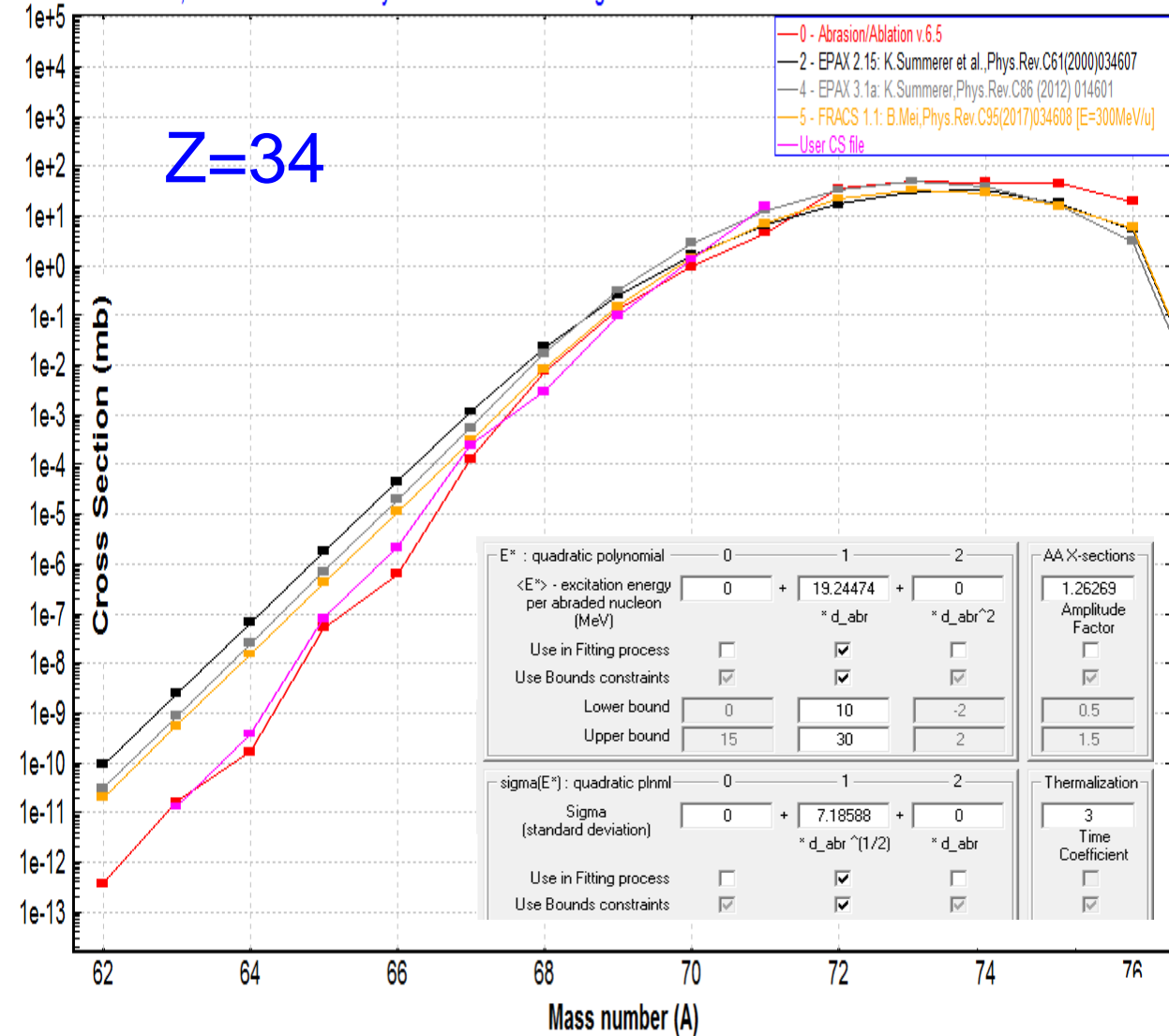


Cross sections (Projectile Fragmentation)

$^{78}\text{Kr} + \text{Be} \rightarrow Z=34$

Excit.Energy Method:< 2 >; <E*>:19.2*dA MeV Sigma:7.19; No Intrin.Thermalztn; LimitTemp: No; DB₁="AME2016"

NP=32; SE:"DB1+Cal1" Density:"C" GeomCor:"On" Tunlg:"On" dR=5.0fm FisBar=#1 BarFac=1.00 Modes=1010 1000 110

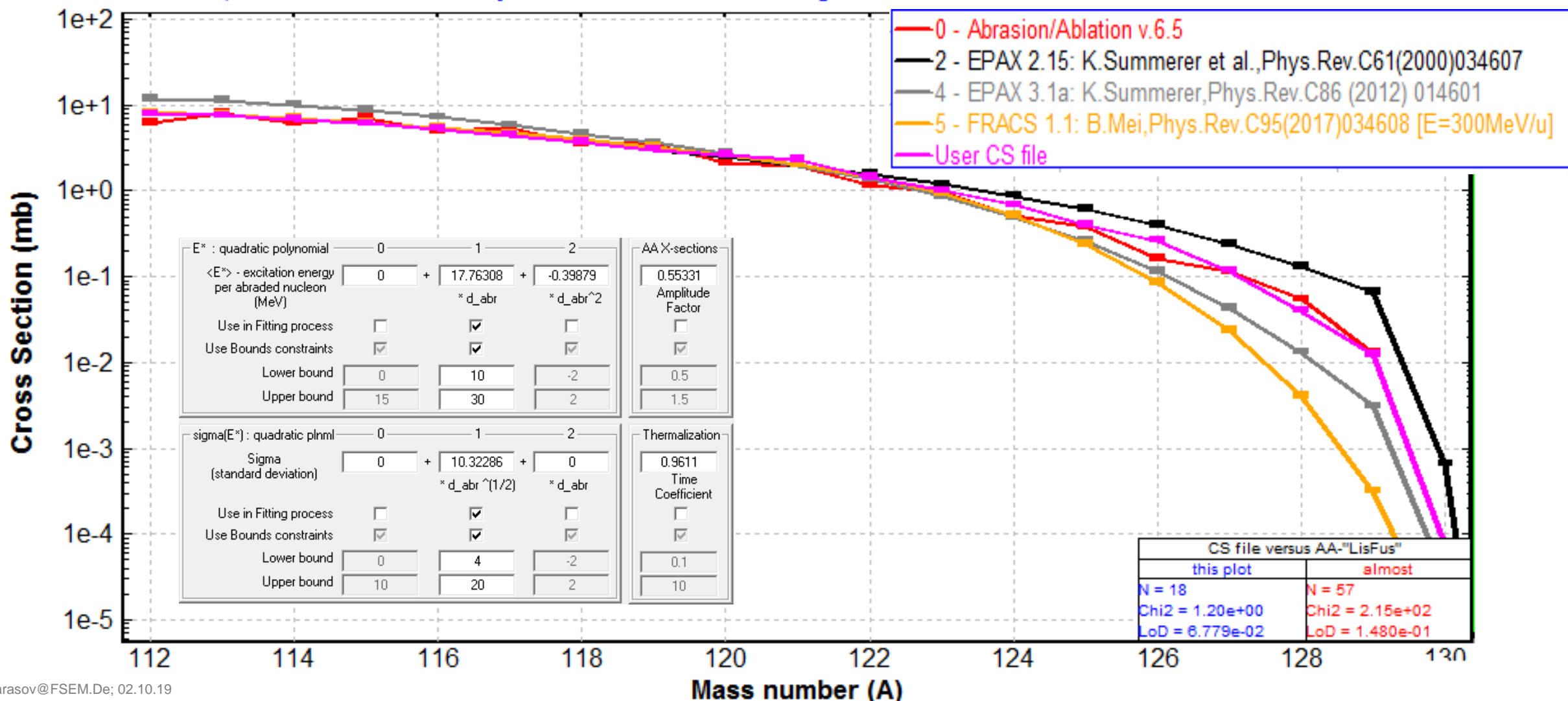


Z=47

Cross sections (Projectile Fragmentation)

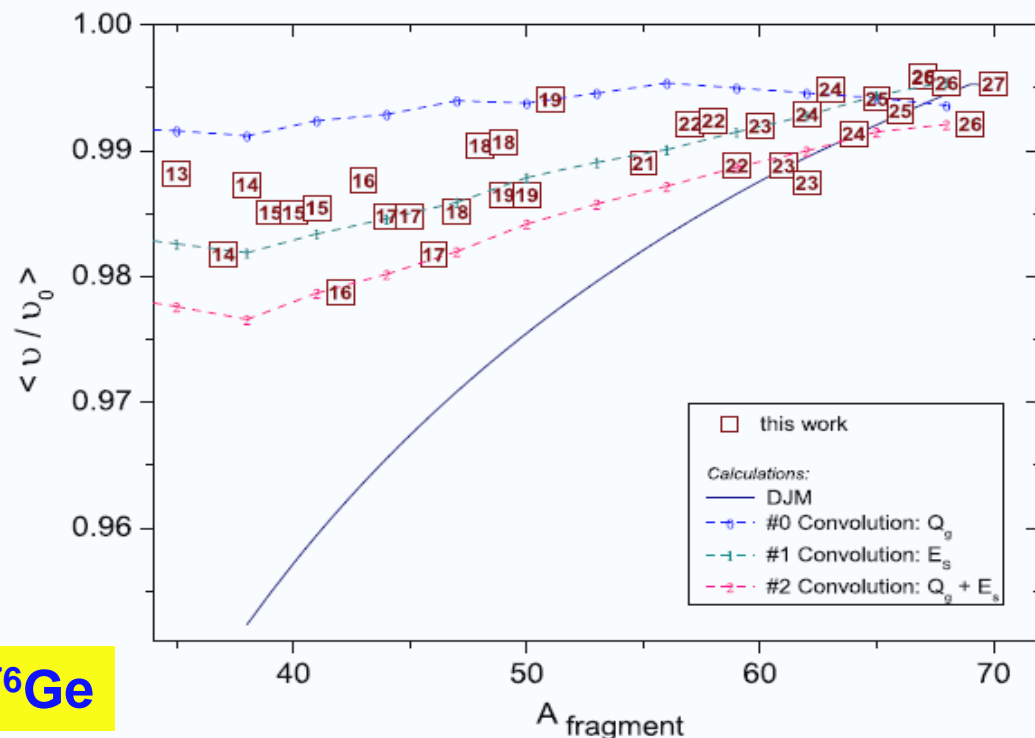
$^{132}\text{Sn} + \text{Be} \rightarrow Z=47$

Excit. Energy Method: < 2 >; < E* >: 17.8*dA MeV Sigma: 10.32; Coef^{Thermalization}=9.61e-01 MeV.s; LimitTemp: No; DB₁="WS4_RB
 NP=64; SE:"DB1+Cal1" Density:"auto" GeomCor:"Off" Tunlg:"auto" FisBar=#1 BarFac=1.00 Modes=1010 1000 110



Momentum distribution: Universal parameterization

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



^{76}Ge

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 ($\sigma_0 = 87 \text{ MeV}/c$, $E_S = 8 \text{ MeV}$). See text for details. The dashed lines represent the convolution model results with separation energy modes as listed in Table 4.

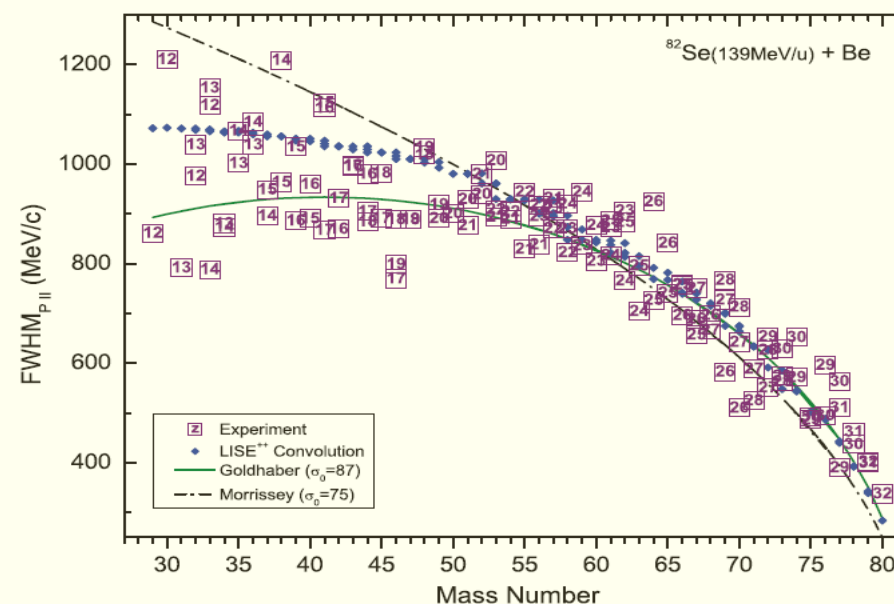
the separation energy parameter for nuclei observed in the present work in the region $A_p/2 \leq A_f \leq A_p$ exhibits a linear decrease with the number of removed nucleons:

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

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

for DJM

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



^{82}Se

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.

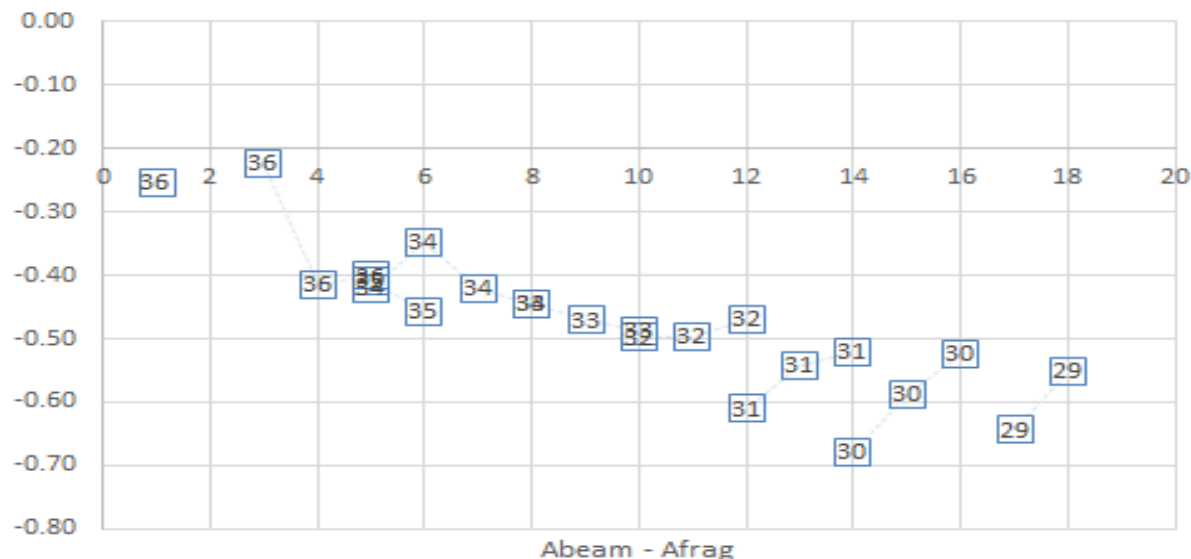
$$\text{for DJM} \quad E_S = 8 - 9.2\Delta A/A_p,$$

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.

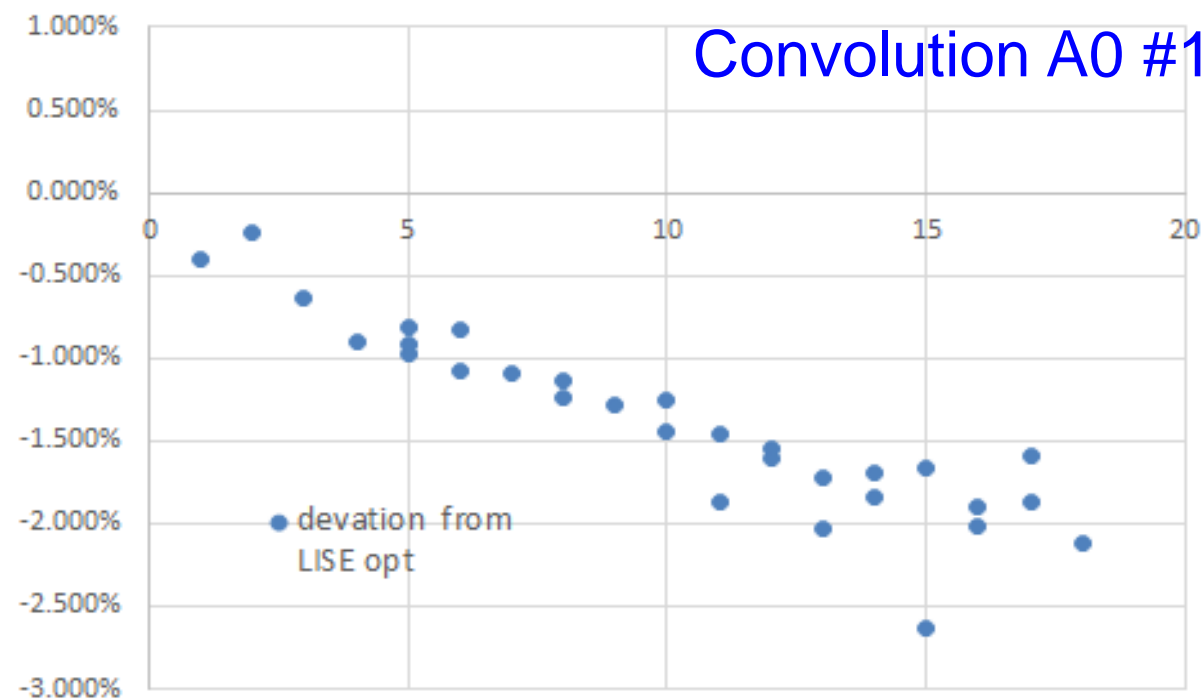
^{78}Kr (150 MeV/u) + Be(374 mg/cm²) @ NSCL

$(v/v0_exp - v/v0_calc)*100$

DJM



Convolution A0 #1



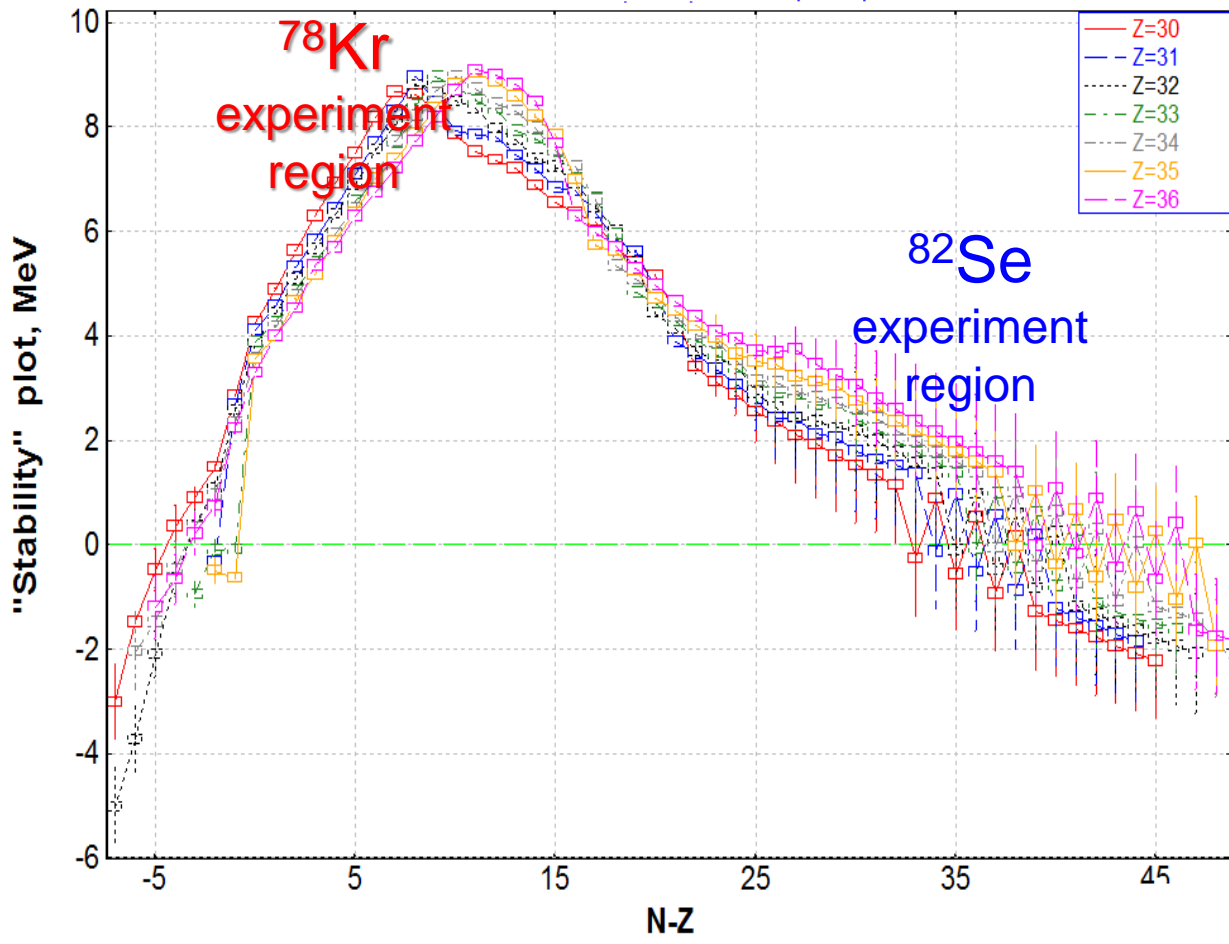
http://lise.nsl.msu.edu/paper/velocity/2019_05_17_78Kr_results.pdf

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

"Stability" plot

<Database: AME2016 (database) + LDM2>
Z=30-36

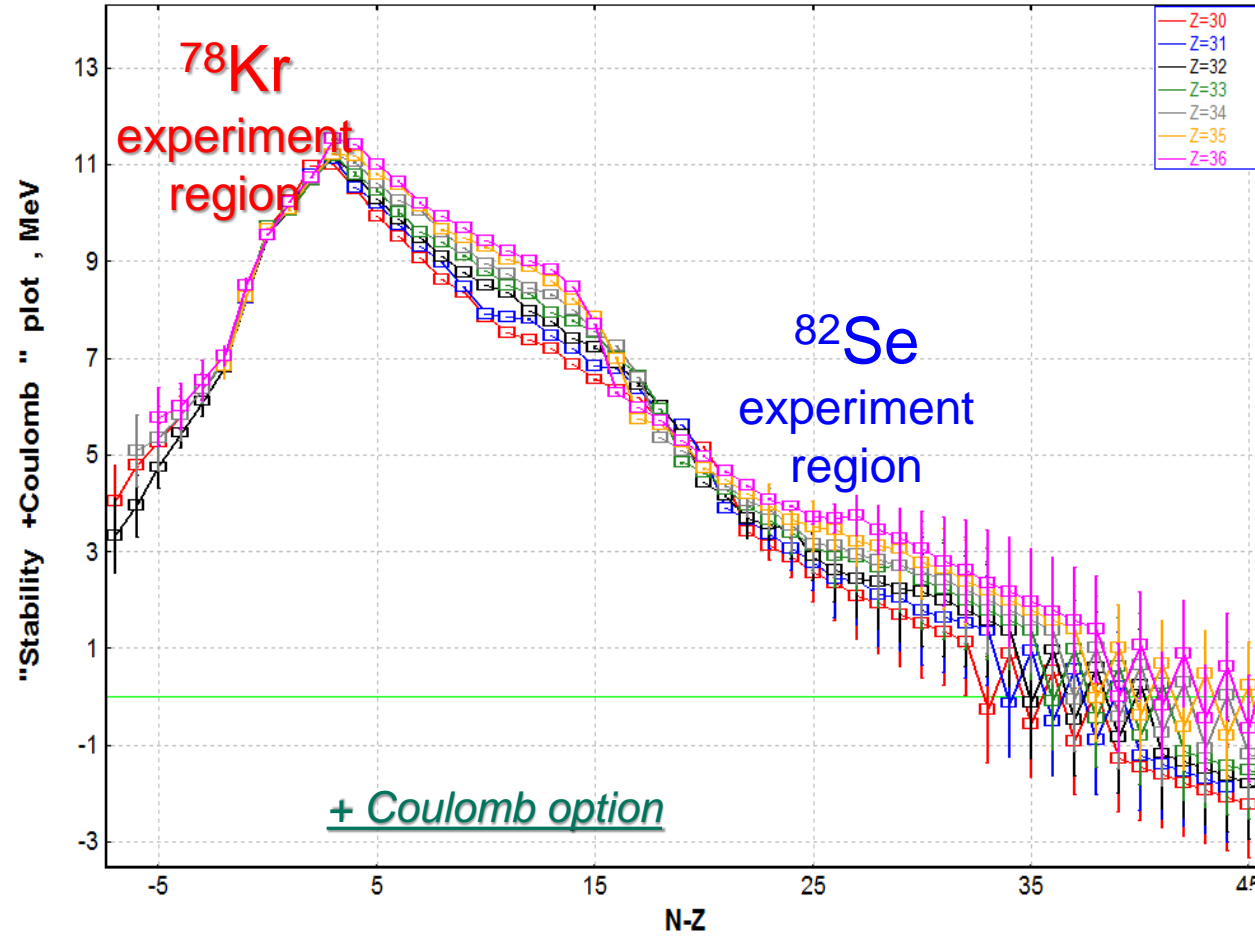
Reduced value based on from S_{1n} , S_{2n} , S_{1p} , S_{2p} , Barrier_{Fission} -1



"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.nsl.msui.edu/9_8/LISE_stability_plot.pdf

Prefragment search options

A: 32, Element: mg, Z: 12

Reaction: 48Ca + Be

Excitation energy: 157.33 MeV

Method of prefragment search:

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

Excitation Energy for prefragment search:

- Surface (Geometrical)
- E* per abraded nucleon (E* = coef * dA_abr)

	A	B	C
"Top" Prefragment	40S	39Cl	42Si
"Bottom" Prefragment	39P	38S	41Al
Final Prefragment mass	39.0	38.2	41.1
Energy excitation (MeV)	112.7	125.2	83.2
Probability	1.70e-04	1.88e-04	4.26e-03
Corrected Probability		3.17e-03	1.11e-02

CS (EPAX 2.15) = 7.61e-03 mb

LISE mode: Projectile Fragmentation

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

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

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

Prefragment search options

A: 32, Element: mg, Z: 12

Beta- and Beta-n

Reaction: 48Ca + Be

Table of Nuclides

Excitation energy: 157.33 MeV

Modify

Method of prefragment search

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

Excitation Energy for prefragment search

- Surface (Geometrical)
- E* per abraded nucleon ($E^* = \text{coef} * dA_{\text{abr}}$)

	A	B	C
"Top" Prefragment	40S	39Cl	42Si
"Bottom" Prefragment	39P	38S	41Al
Final Prefragment mass	39.0	38.2	41.1
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Probability	1.70e-04	1.88e-04	4.26e-03
Corrected Probability		3.17e-03	1.11e-02

CS (EPAX 2.15) = 7.61e-03 mb

LISE mode: Projectile Fragmentation

New default Settings "C1"

- ❖ Momentum distribution
- “Convolution” model
 - separation energy models

$$E_s = E_0 * dA$$

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

Update of the Convolution method dialog

Convolution of Gaussian (Fragmentation) and Exponent (Friction) distributions

48Ca(140.0 MeV/u) + Be -> 42S

$$f(p) \approx \exp\left(\frac{p}{\tau}\right) \cdot \left[1 - \text{ferr} \left(\frac{p - p_0 + \frac{\sigma_{||}^2}{\tau} - \text{shift} \cdot \tau}{\sqrt{2} \sigma_{||}} \right) \right]$$

$$\sigma_{||}^2 = \left(\sigma_0^{\text{conv}} \sqrt{\beta_p} \right)^2 \frac{A_F^* (A_P - A_F^*)}{A_P - 1} \quad \tau = \frac{\text{coef}}{\beta} \sqrt{A_F^* \cdot E_s}$$

Settings for Gaussian distribution

P0 (MeV/C) = 22226

Vf/Vb from settings = 0.994

Mom. distribution = [1] D.J.Morrissey

σ_0 = 87 MeV/c

$\sigma_{||}$ = 244.5 MeV/c (*)

Settings for convolution

Separation Energy	Es	coef	shift	FWHM / 2.355 (*)	tau	P(Ymax)	peak	mean
#0 Energy from Qg	23.8	3.344	0.158	189.7	220.3	22086	0.997	0.994
#1 Excitation from dSurface	16.9	3	0.149	173.7	166.4	22119	0.997	0.995
#2 Excitation from the Abrasion model	48.7	1	-1	152.9	94.1	22083	0.994	0.994

σ_0^{conv} = 91.5 MeV/c

g = 0.95 MeV/fm²

(*) - with Gamma-factor

Plot 1D Plot - Conv. Analysis OK Cancel Help Make default

#2 Qg + dSurface 42.9 2.936 0.153 222.7 255.2 22062 0.996 0.993

A0

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

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

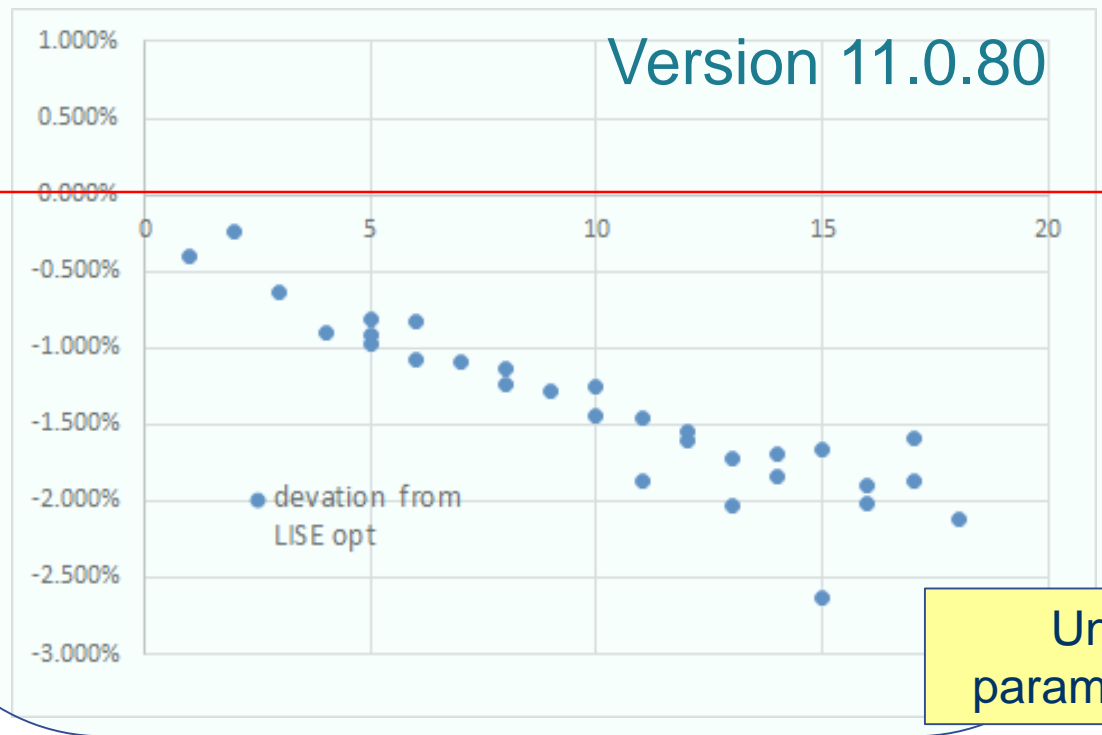
Separation Energy

- Energy from Qg
- Excitation from dSurface
- Excitation from the Abrasion model

	coef	shift
Energy from Qg	3.344	0.158
Excitation from dSurface	3	0.149
Excitation from the Abrasion model	1	-1

$\sigma_0^{\text{conv}} = 91.5$ MeV/c

#1



C1

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

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

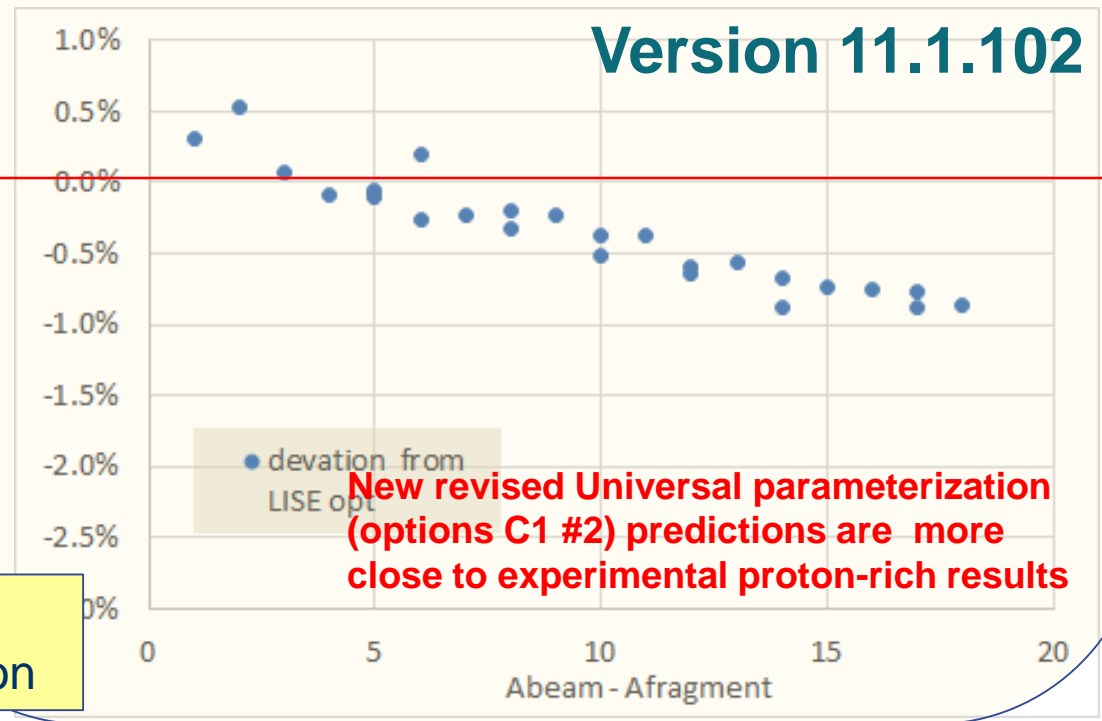
Separation Energy

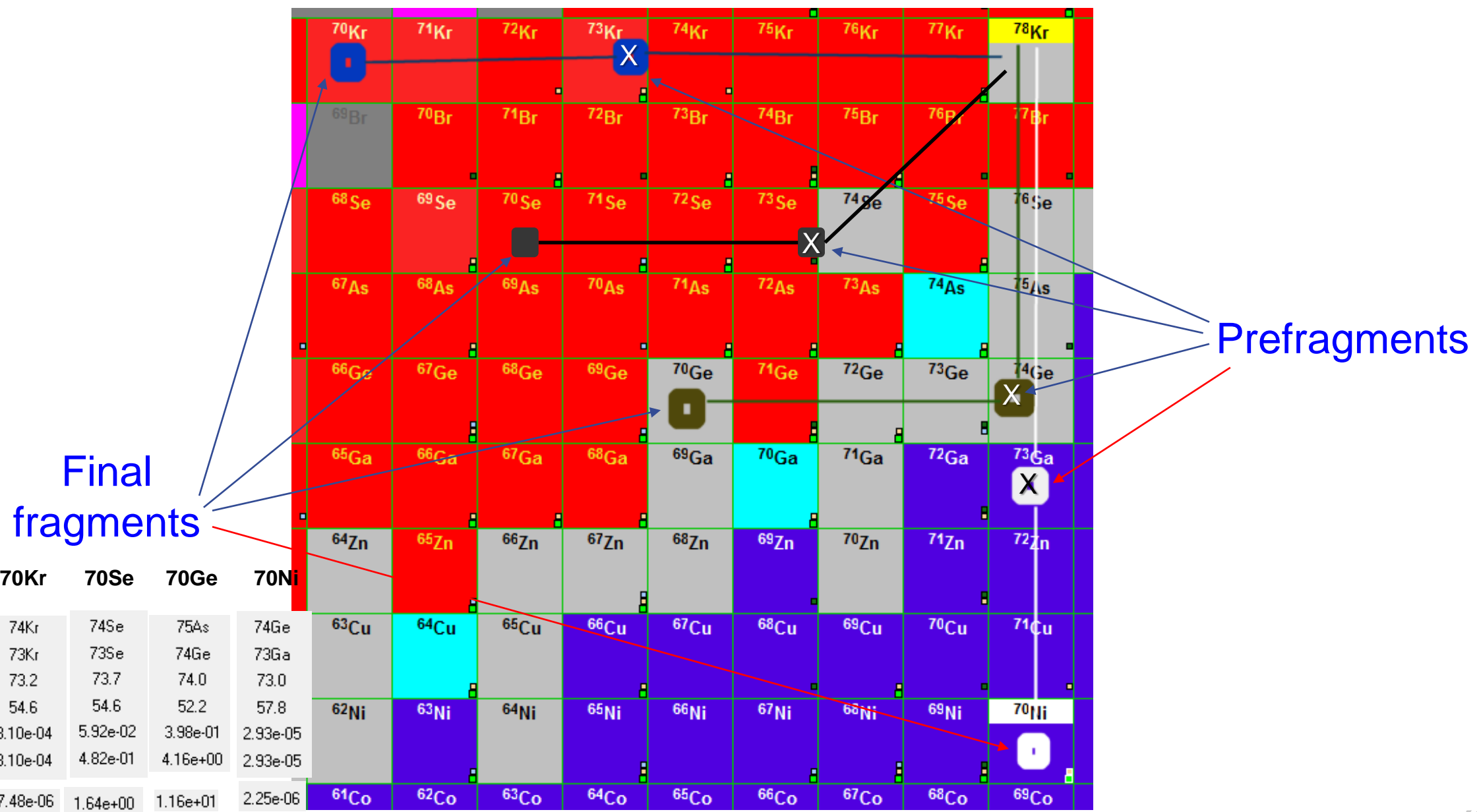
- Energy from Qg
- Excitation from dSurface
- Excitation from the Abrasion model

	coef	shift
Energy from Qg	3.344	0.158
Excitation from dSurface	3	0.149
Excitation from the Abrasion model	1	-1

$\sigma_0^{\text{conv}} = 120$ MeV/c

#2

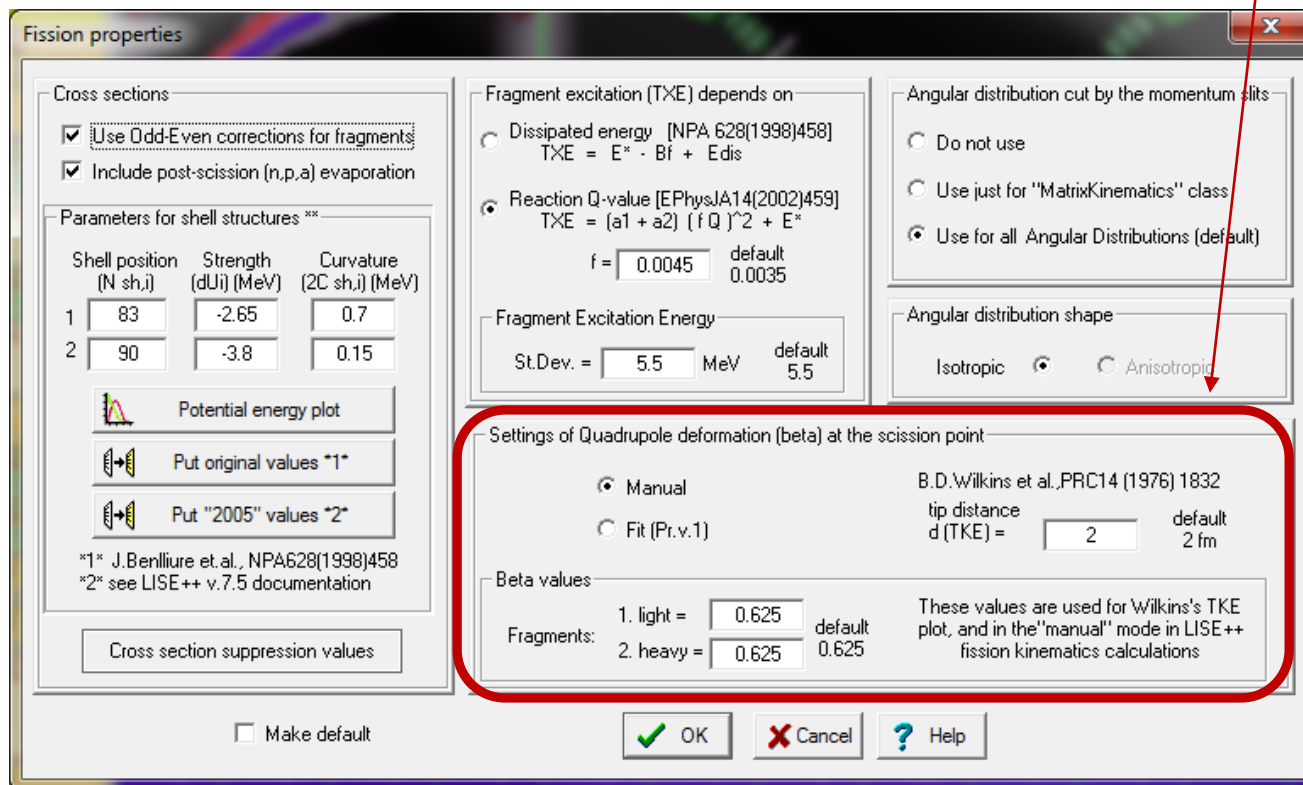




Fragment deformation at the Scission point

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).

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

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:

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

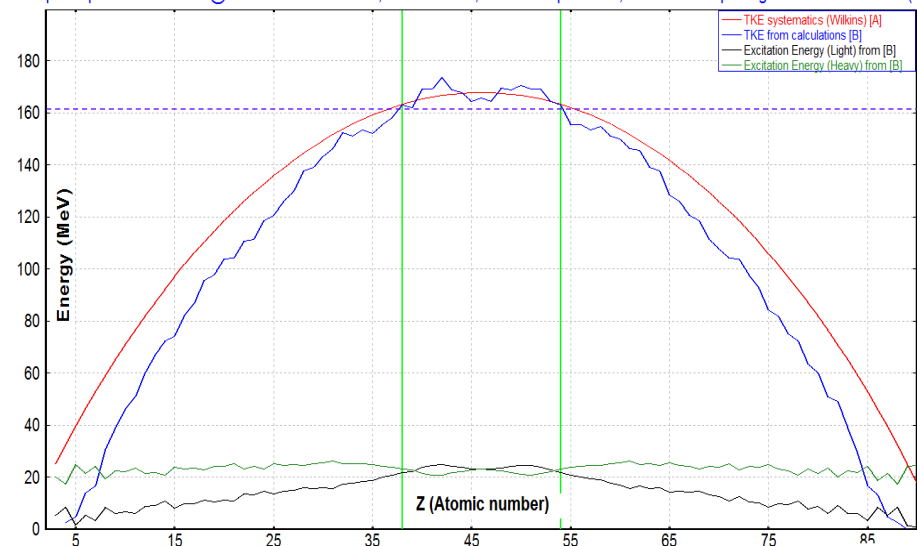
the parameters proposed by Wilkins *et al.* for the macroscopic version of their model, corresponding to high-energy fission: $r_0 = 1.16$ fm, $d = 2$ fm, and $\beta_1 = \beta_2 = 0.625$.

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

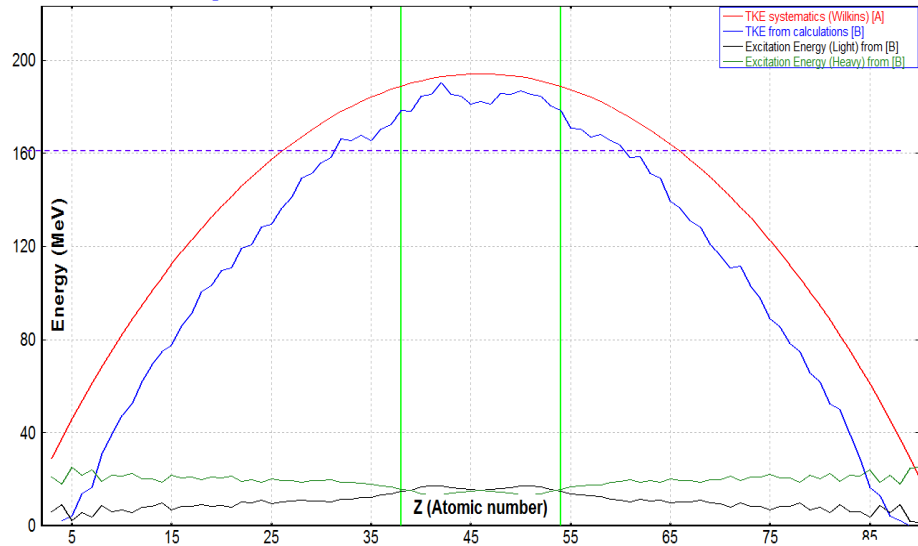
Excitation energy: 25.0 MeV; Quad-deformation method: Manual; TXEmethod: 0; Shells: N1={83,-2.65,0.70}, N2={90,-3.80,0.15}
 Assuming an unchanged charge density to get a fragment neutron number. It is not averaging!
 nual quadrupole deformation @ scission beta1=0.625, beta2=0.625; distance tip d=2.00; no shells and pairing corrections for TKE(V)

“Fit” mode



Excitation energy: 25.0 MeV; Quad-deformation method: Fit; TXEmethod: 0; Shells: N1={83,-2.65,0.70}, N2={90,-3.80,0.15}
 Assuming an unchanged charge density to get a fragment neutron number. It is not averaging!
 nual quadrupole deformation @ scission beta1=0.300, beta2=0.300; distance tip d=2.00; no shells and pairing corrections for TKE(V)

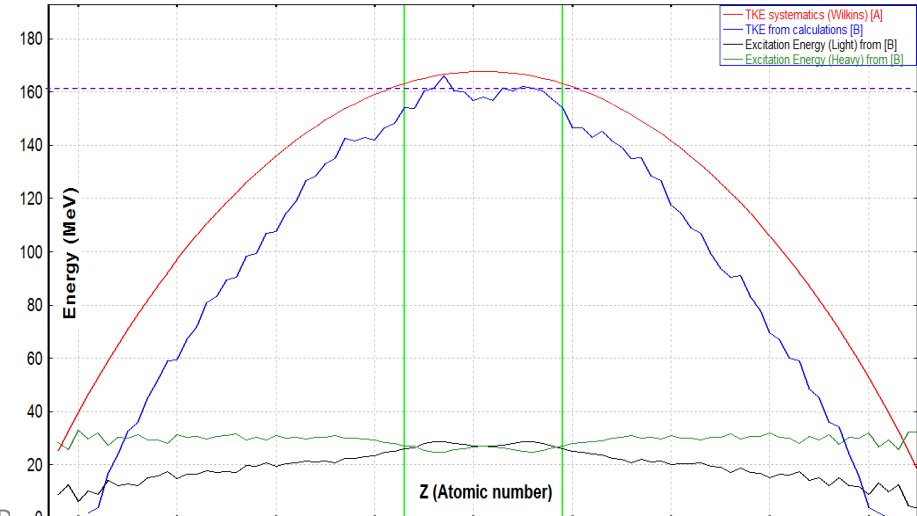
beta=0.3, d=2 fm



Excitation energy: 25.0 MeV; Quad-deformation method: Fit; TXEmethod: 0; Shells: N1={83,-2.65,0.70}, N2={90,-3.80,0.15}
 Assuming an unchanged charge density to get a fragment neutron number. It is not averaging!
 nual quadrupole deformation @ scission beta1=0.625, beta2=0.625; distance tip d=2.00; no shells and pairing corrections for TKE(V)

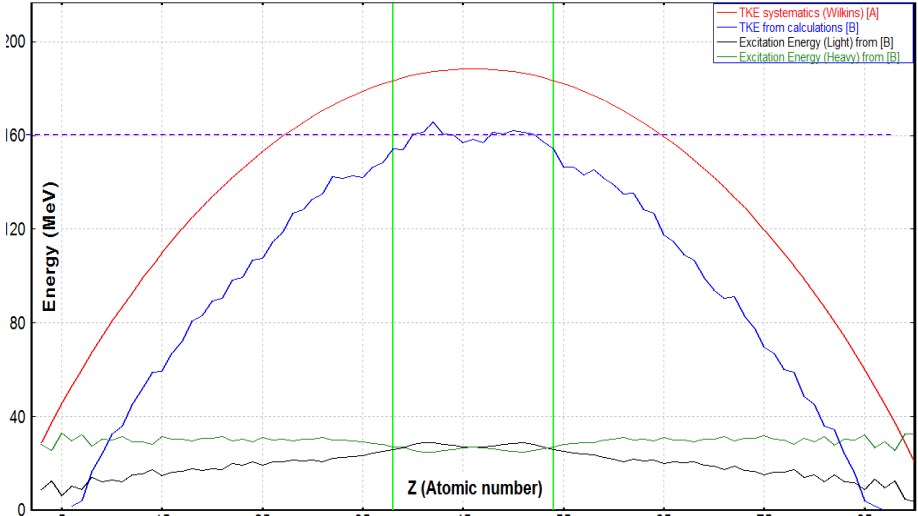
beta=0.625, d=2 fm

“Manual” mode



Excitation energy: 25.0 MeV; Quad-deformation method: Fit; TXEmethod: 0; Shells: N1={83,-2.65,0.70}, N2={90,-3.80,0.15}
 Assuming an unchanged charge density to get a fragment neutron number. It is not averaging!
 nual quadrupole deformation @ scission beta1=0.625, beta2=0.625; distance tip d=0.00; no shells and pairing corrections for TKE(V)

beta=0.625, d=0 fm



“Loading A1900 settings” utility

Load A1900 settings


This utility works properly with "e_A1900_2018.lpp" file (extended config.)

1. Load A1900 configuration

Default printout directory = C:\buffer_LAB\A1900_settings\txt

2. Browse file View

3. Read data



Exit Quit Help

C:\buffer_LAB\A1900_settings\txt\Print05Feb18_12h35.txt

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" [Chippis, 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

Seg	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					

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: A1 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 pl

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

MagName	Ref[kG]	BSet[kG]	Ratio	(live)	Set[A]	Read[A]	DEVI
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

MagName	Ref[kG]	BSet[kG]	Ratio	(live)	Set[A]	Read[A]	DEVI
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

press the "3. Read data" button

default A1900_2016 (segmented)

e_A1900_2018.lpp (extended)

Load A1900 settings

This utility works properly with "e_A1900_2018.lpp" file (extended config.) 1. Load A1900 configuration

Default printout directory = C:\buffer_LAB\A1900_settings\txt

2. Browse file Print05Feb18_12h35.txt View

3. Read data

Title
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]

4. Load values in the code & Calculate matrices

Values	use	Values	use
Projectile = 40Ca20+	<input checked="" type="checkbox"/>	Dipole fields = N = 4	<input type="checkbox"/>
Energy [title] (MeV/u) = 140	<input checked="" type="checkbox"/>	Quadrupole fields = N = 0(0)	<input type="checkbox"/>
Energy [Seg0] (MeV/u) = 140	<input type="checkbox"/>	Use A1900 Quadrupole fudging factors	<input checked="" type="checkbox"/>
RF (MHZ) = 23.2239	<input checked="" type="checkbox"/>	Manual additional quadrupole field factor = 0.9707	<input checked="" type="checkbox"/>
Target [Z13] = out	<input checked="" type="checkbox"/>	Sextupole fields = N = 0	<input type="checkbox"/>
Target [Z14] = out	<input checked="" type="checkbox"/>	11-slits [Z37] = -8.0 : +8.0	<input type="checkbox"/>
Target [Z15] = Be 987.0	<input checked="" type="checkbox"/>	12-slits [Z57,Z61] = -14.8 : +14.8	<input type="checkbox"/>
Target [Z16] = out	<input checked="" type="checkbox"/>	FP-slits [Z104] = -46.0 : +44.0	<input type="checkbox"/>
wedge [Z59] = Al 150.0	<input checked="" type="checkbox"/>		

Exit Quit Help

Load A1900 settings

This utility works properly with "e_A1900_2018.lpp" file (extended config.) 1. Load A1900 configuration

Default printout directory = C:\buffer_LAB\A1900_settings\txt

2. Browse file Print05Feb18_12h35.txt View

3. Read data

Title
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]

4. Load values in the code & Calculate matrices

Values	use	Values	use
Projectile = 40Ca20+	<input checked="" type="checkbox"/>	Dipole fields = N = 4	<input type="checkbox"/>
Energy [title] (MeV/u) = 148	<input checked="" type="checkbox"/>	Quadrupole fields = N = 24(24)	<input type="checkbox"/>
Energy [Seg0] (MeV/u) = 140	<input type="checkbox"/>	Use A1900 Quadrupole fudging factors	<input checked="" type="checkbox"/>
RF (MHZ) = 23.2239	<input checked="" type="checkbox"/>	Manual additional quadrupole field factor = 0.9707	<input checked="" type="checkbox"/>
Target [Z13] = out	<input checked="" type="checkbox"/>	Sextupole fields = N = 16	<input type="checkbox"/>
Target [Z14] = out	<input checked="" type="checkbox"/>	11-slits [Z37] = -8.0 : +8.0	<input type="checkbox"/>
Target [Z15] = Be 987.0	<input checked="" type="checkbox"/>	12-slits [Z57,Z61] = -14.8 : +14.8	<input type="checkbox"/>
Target [Z16] = out	<input checked="" type="checkbox"/>	FP-slits [Z104] = -46.0 : +44.0	<input type="checkbox"/>
wedge [Z59] = Al 150.0	<input checked="" type="checkbox"/>		

Exit Quit Help

Difference between configurations

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

Load A1900 settings

This utility works properly with "e_A1900_2018.lpp" file [extended config.] 1. Load A1900 configuration

Default printout directory = C:\buffer_LAB\A1900_settings\txt

2. Browse file Print05Feb18_12h35.txt View

3. Read data

Title
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]

4. Load values in the code & Calculate matrices

	Values	use		Values	use
Projectile =	40Ca20+	<input checked="" type="checkbox"/>	Dipole fields =	N = 4	<input checked="" type="checkbox"/>
Energy [title] (MeV/u) =	140	<input checked="" type="checkbox"/>	Quadrupole fields =	N = 24(24)	<input checked="" type="checkbox"/>
Energy [Seg0] (MeV/u) =	140	<input type="checkbox"/>	Use A1900 Quadrupole fudging factors		<input checked="" type="checkbox"/>
RF (MHZ) =	23.2239	<input checked="" type="checkbox"/>	Manual additional quadrupole field factor = (default 0.9702)	0.9707	<input checked="" type="checkbox"/>
Target [Z13] =	out	<input type="checkbox"/>	Sextupole fields =	N = 16	<input checked="" type="checkbox"/>
Target [Z14] =	out	<input type="checkbox"/>	l1-slits [Z37] =	-8.0 : +8.0	<input checked="" type="checkbox"/>
Target [Z15] =	Be 987.0	<input checked="" type="checkbox"/>	l2-slits [Z57,Z61] =	-14.8 : +14.8	<input checked="" type="checkbox"/>
Target [Z16] =	out	<input type="checkbox"/>	FP-slits [Z104] =	-46.0 : +44.0	<input checked="" type="checkbox"/>
wedge [Z59] =	Al 150.0	<input checked="" type="checkbox"/>			

Please check next settings:

- * Beam energy,
- * Setting Fragment,
- * Target thickness,
- * Wedge thickness

Exit
Quit
Help

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

Save As

Save in: NSCL

Name	Date modified
D-line	10/18/2018 12:24
40ar_32mg_a1900s800d0	4/16/2012 10:50 PM
AF_238U_Be_NSCL	4/16/2012 10:57 PM
e_A1900_COSY	4/16/2012 10:53 PM
e_A1900_I190_LISE	4/16/2012 10:55 PM

File name: e_A1900_LISE_2018 Save

Save as type: LISE++ files (*.lpp) Cancel

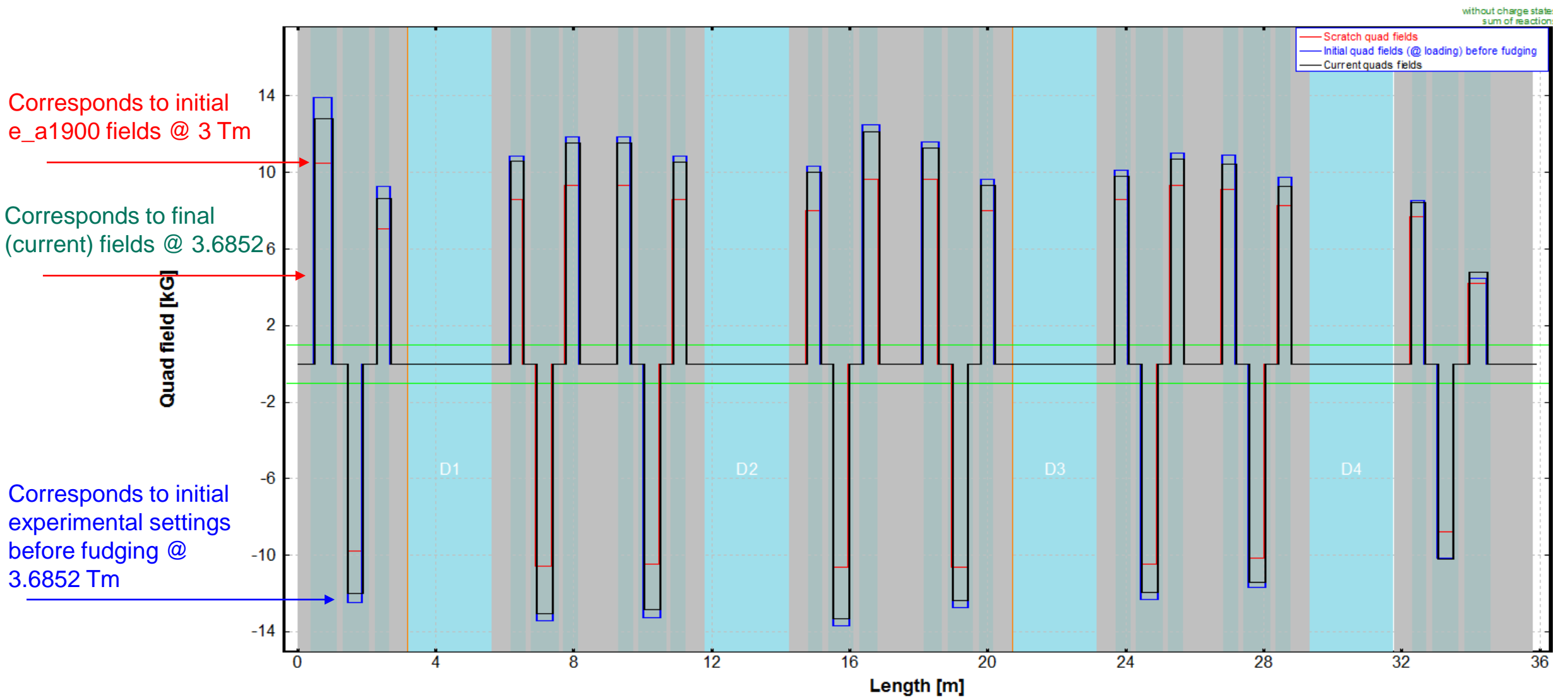
Important!

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

Version 11.0.8 (update)
11/13/18

Quadrupole field strengths

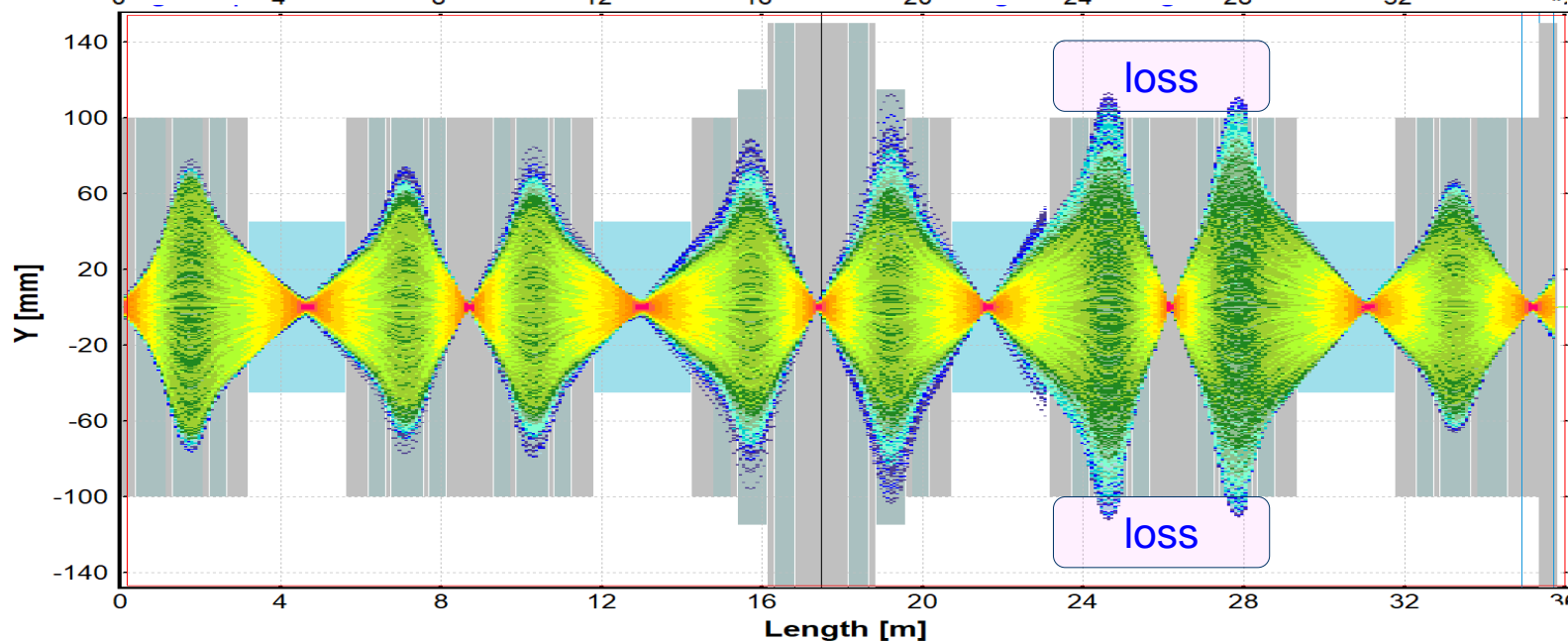
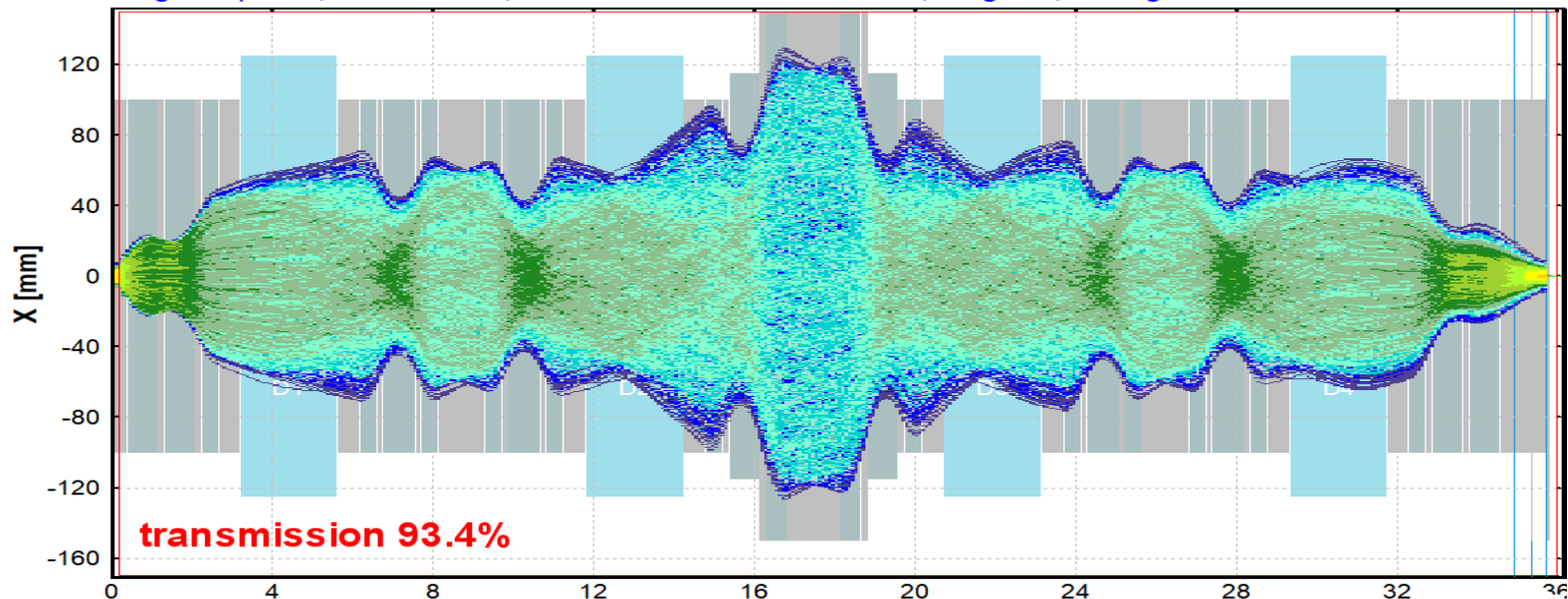
^1H (358.82 MeV/u); Settings on ^1H ; Config: DSSSFSSSFDFSSSSSSFFFFSS...
dp/p=1.01% ; Wedges: 0; Brho(Tm): 3.6852, 3.6852, 3.6852, 3.4331, 3.4331....



1H (358.82 MeV/u) + ; Transmitted Fragment 1H (beam); Optics Order: 1
 dp/p=5.15% ; Wedges: 0; Brho(Tm): 3.0000, 3.0000, 3.0000, 3.0000, 3.0000...
 AngAccept: Off; Bounds: ON; "z106" - last block for MC calc; no gates; Config: DSSSSSSSDSSSSSSSSSS

Emittance [#1]

	Beam CARD (sigma, semi-axis, half-width...)	1D - shape (Distribution method)
1. X	mm 1	Gaussian
2. T	mrad 30	Rectangle uniform
3. Y	mm 1	Gaussian
4. P	mrad 25	Rectangle uniform
5. L	mm 0	Gaussian
6. D	% 2	Rectangle uniform



Default printout directory = C:\buffer_LAB\A1900_settings\txt

2. Browse file: Print31Jan18_16h08.txt

3. Read data

Title: A1900 "Print31Jan18_16h08.txt" Wednesday 16:08:48 2018-01-31 A1
 Moe_258 *** Se-71 to AC233 (prelim) ***
 Expt: 00338 "Gas Cell Equipment Test" [Sumithrarachchi] Line: h [10]

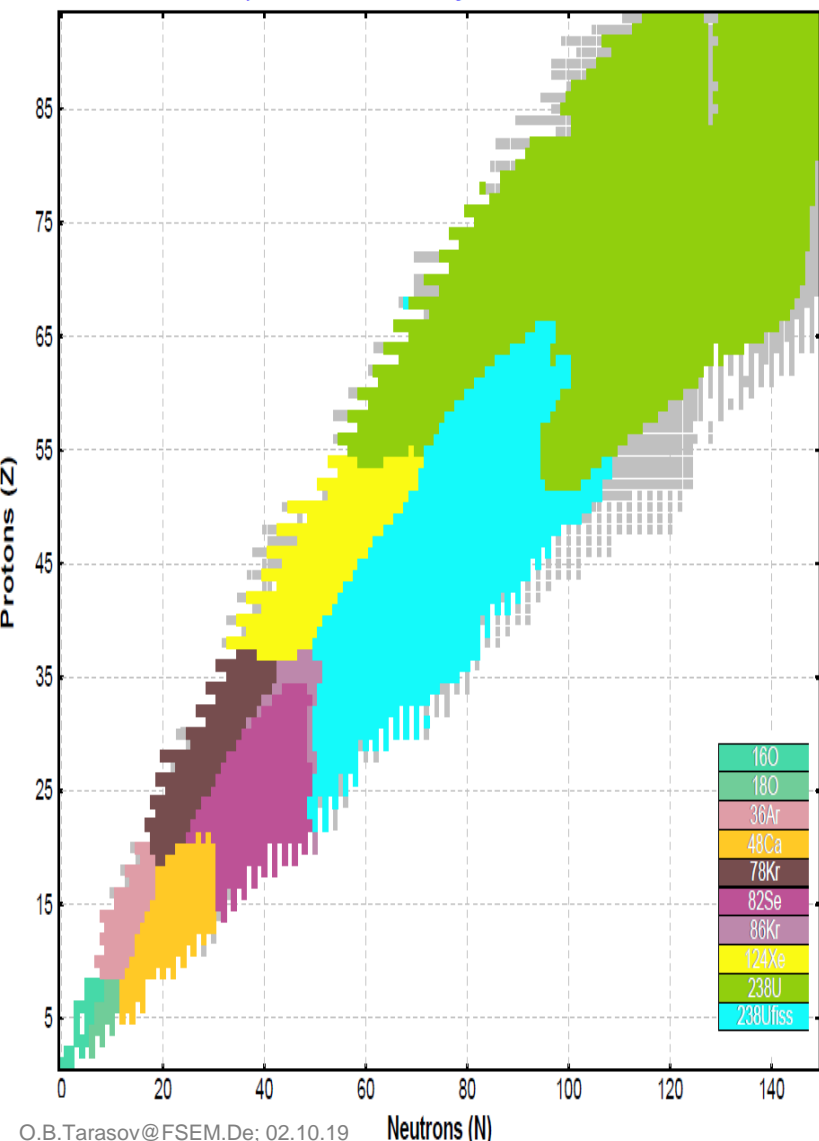
4. Load values in the code & Calculate matrices

Values	use	Values	use
Projectile = 78Kr34+	<input type="checkbox"/>	Dipole fields = N = 4	<input checked="" type="checkbox"/>
Energy [title] [MeV/u] = 150	<input type="checkbox"/>	Quadrupole fields = N = 24(24)	<input checked="" type="checkbox"/>
Energy [Seg0] [MeV/u] = 150.056	<input type="checkbox"/>	Use A1900 Quadrupole fudging factors	<input checked="" type="checkbox"/>
RF [MHZ] = 23.7972	<input type="checkbox"/>	Manual additional quadrupole field factor = (default 0.9702)	<input checked="" type="checkbox"/>
Target [Z13] = Be 66.0	<input type="checkbox"/>	Sextupole fields = N = 16	<input type="checkbox"/>
Target [Z14] = out	<input type="checkbox"/>	l1-slits [Z37] = -8.0 : +8.0	<input type="checkbox"/>
Target [Z15] = Be 94.0	<input type="checkbox"/>	l2-slits [Z57,Z61] = -14.8 : +14.8	<input type="checkbox"/>
Target [Z16] = out	<input type="checkbox"/>	FP-slits [Z104] = -46.0 : +44.0	<input type="checkbox"/>
wedge [Z59] = Al 300.0	<input type="checkbox"/>		

FRIB rates 1.08

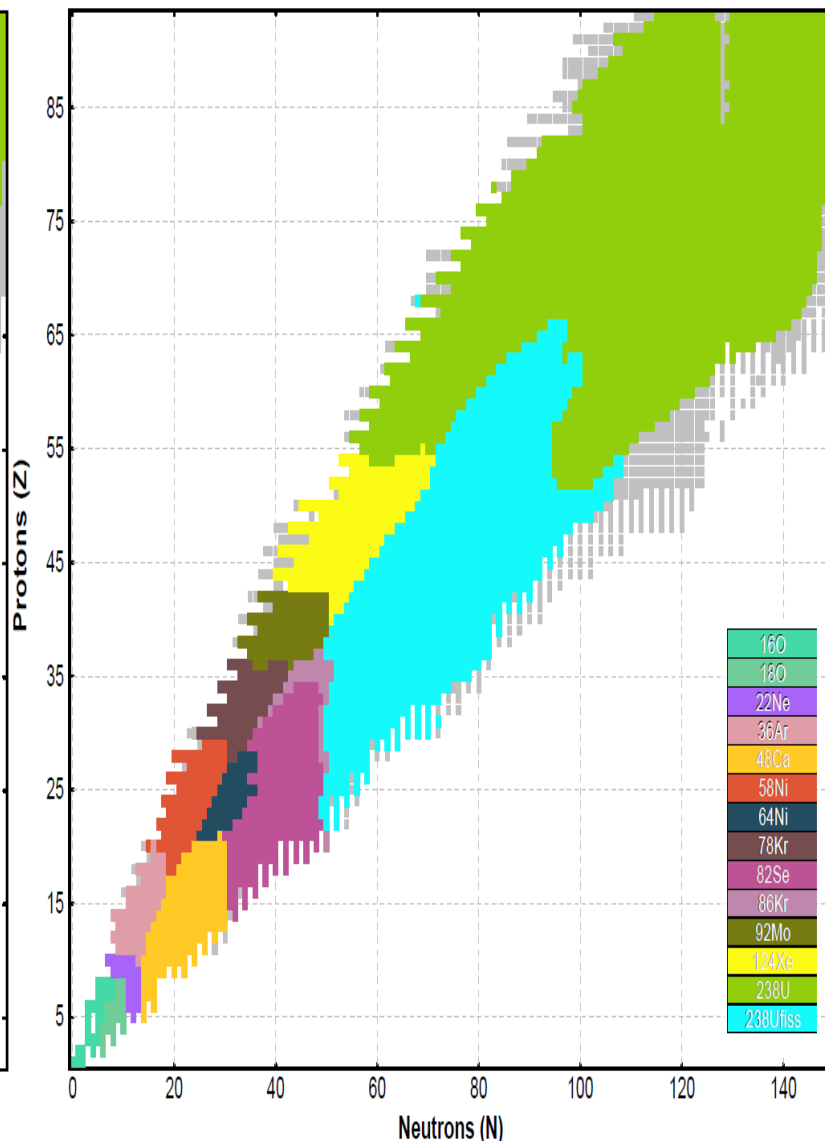
FRIB fast beam rates (v.1.08a) : 1st year

1st year operation! 9 beams @ I=10kW. 1us flight is taken into account. 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 10 kW and 200 MeV/u for ^{238}U



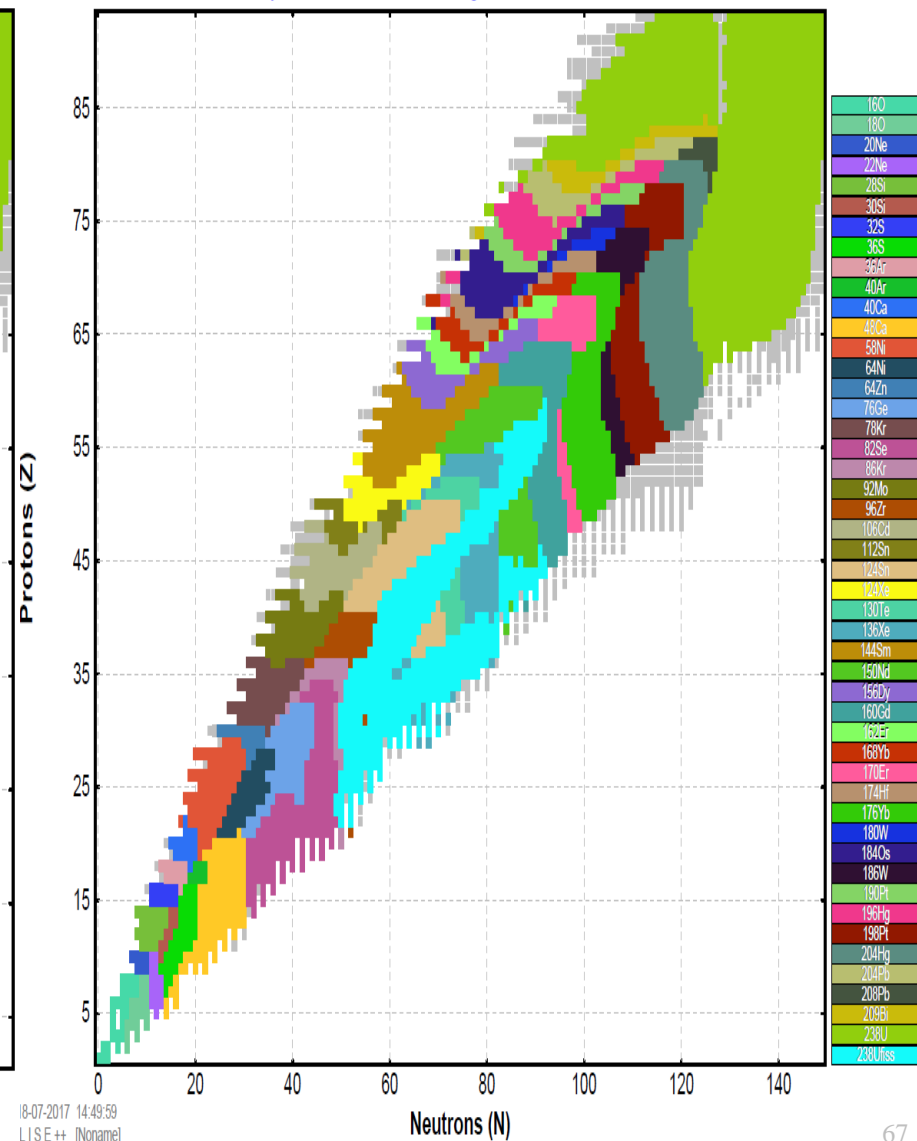
FRIB fast beam rates (v.1.08b) : 2nd year

2nd year operation! 13 beams @ I=50kW. 1us flight is taken into account. 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 50 kW and 200 MeV/u for ^{238}U



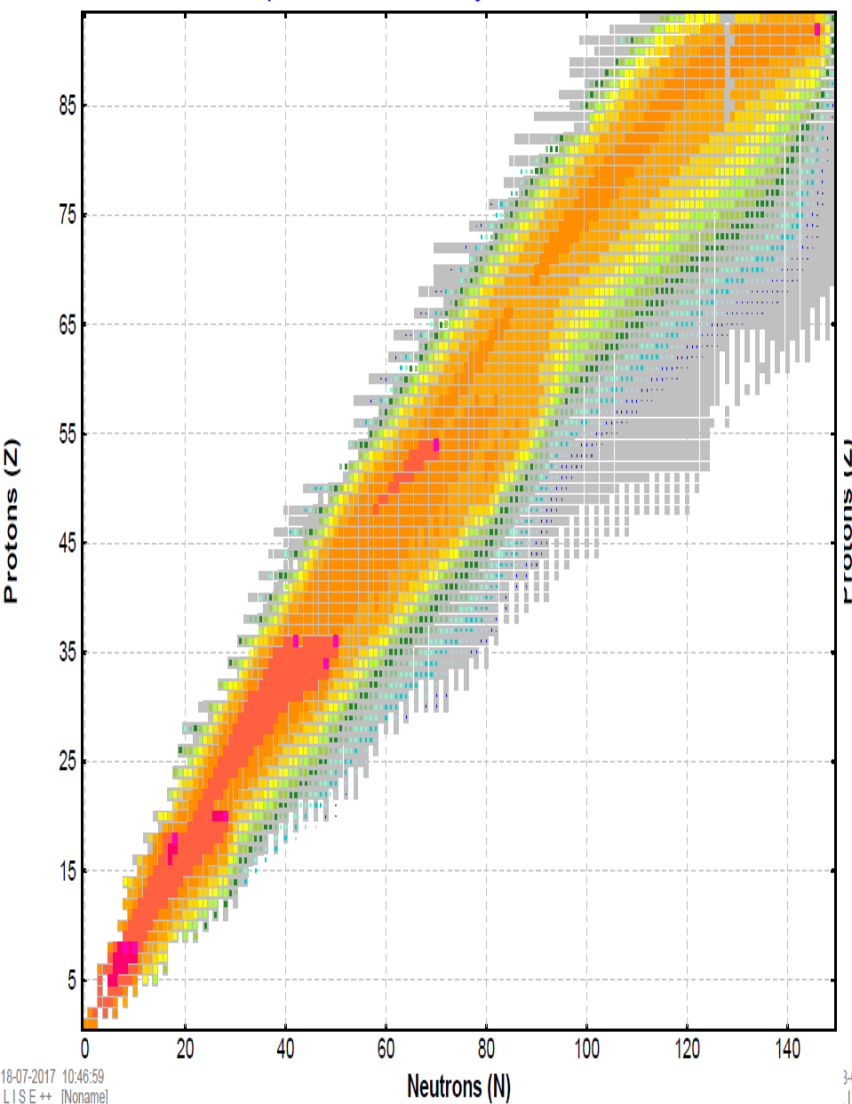
FRIB fast beam rates (v.1.08) : 400 kW

<https://groups.nsl.msu.edu/frib/rates/fribrates.html> 1us flight is taken into account. 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



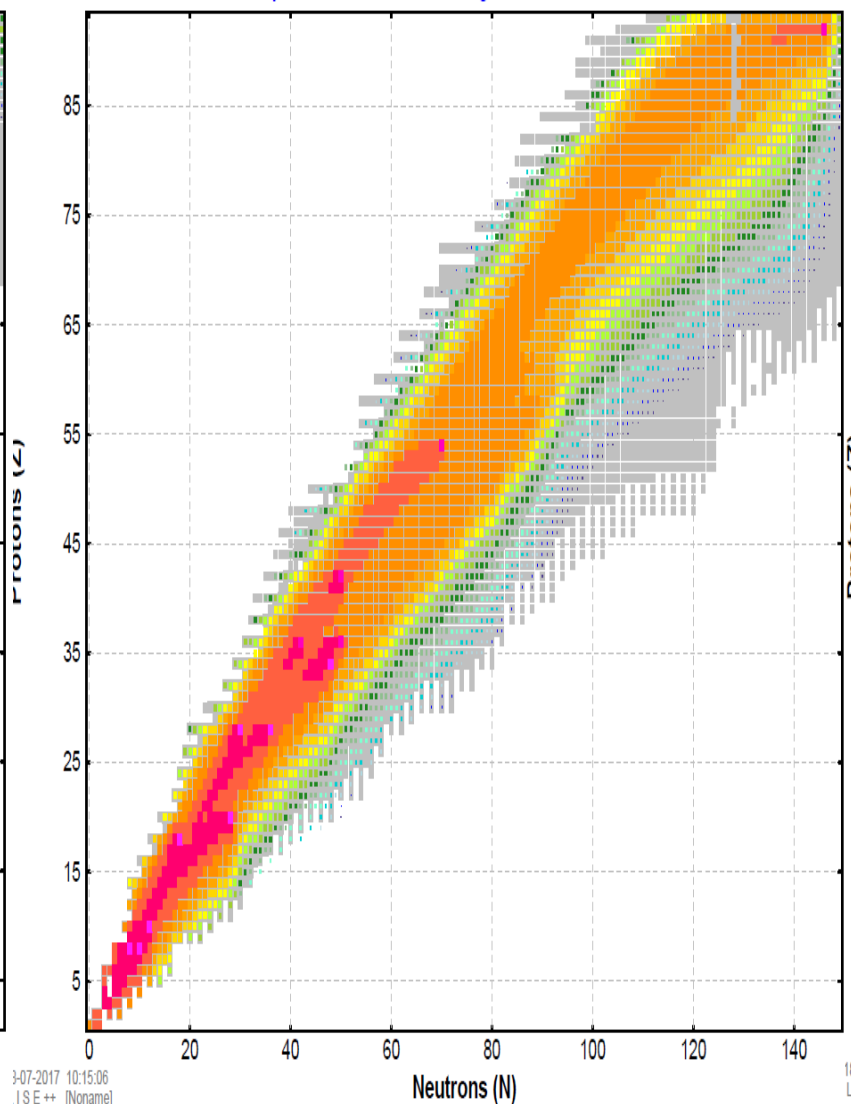
FRIB fast beam rates (v.1.08a) : 1st year

1st year operation! 9 beams @ I=10kW. 1 μ s flight is taken into account. The rates are estimated by 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 10 kW and 200 MeV/u for ^{238}U



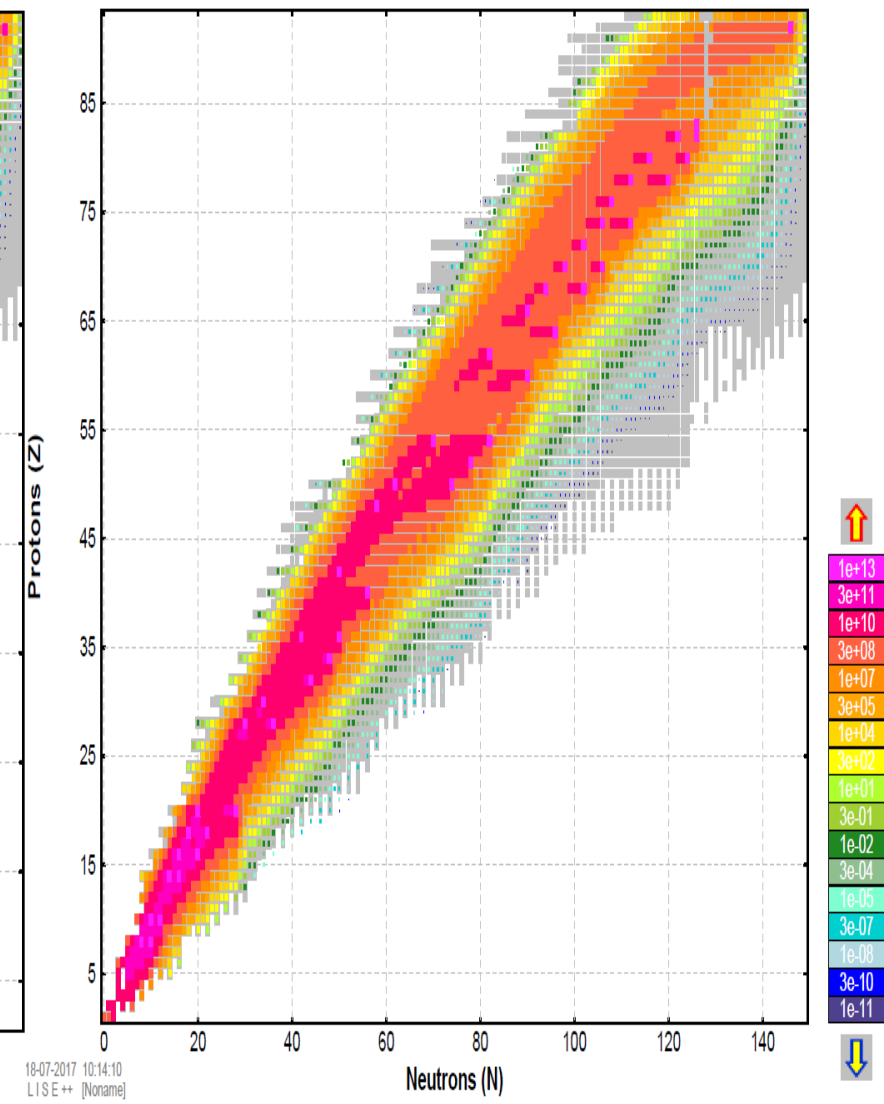
FRIB fast beam rates (v.1.08b) : 2nd year

2nd year operation! 13 beams @ I=50kW. 1 μ s flight is taken into account. The rates are estimated by 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 50 kW and 200 MeV/u for ^{238}U



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

<https://groups.nsl.msui.edu/fribrates/fribrates.html> 1 μ s flight is taken into account. The rates are estimated by 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



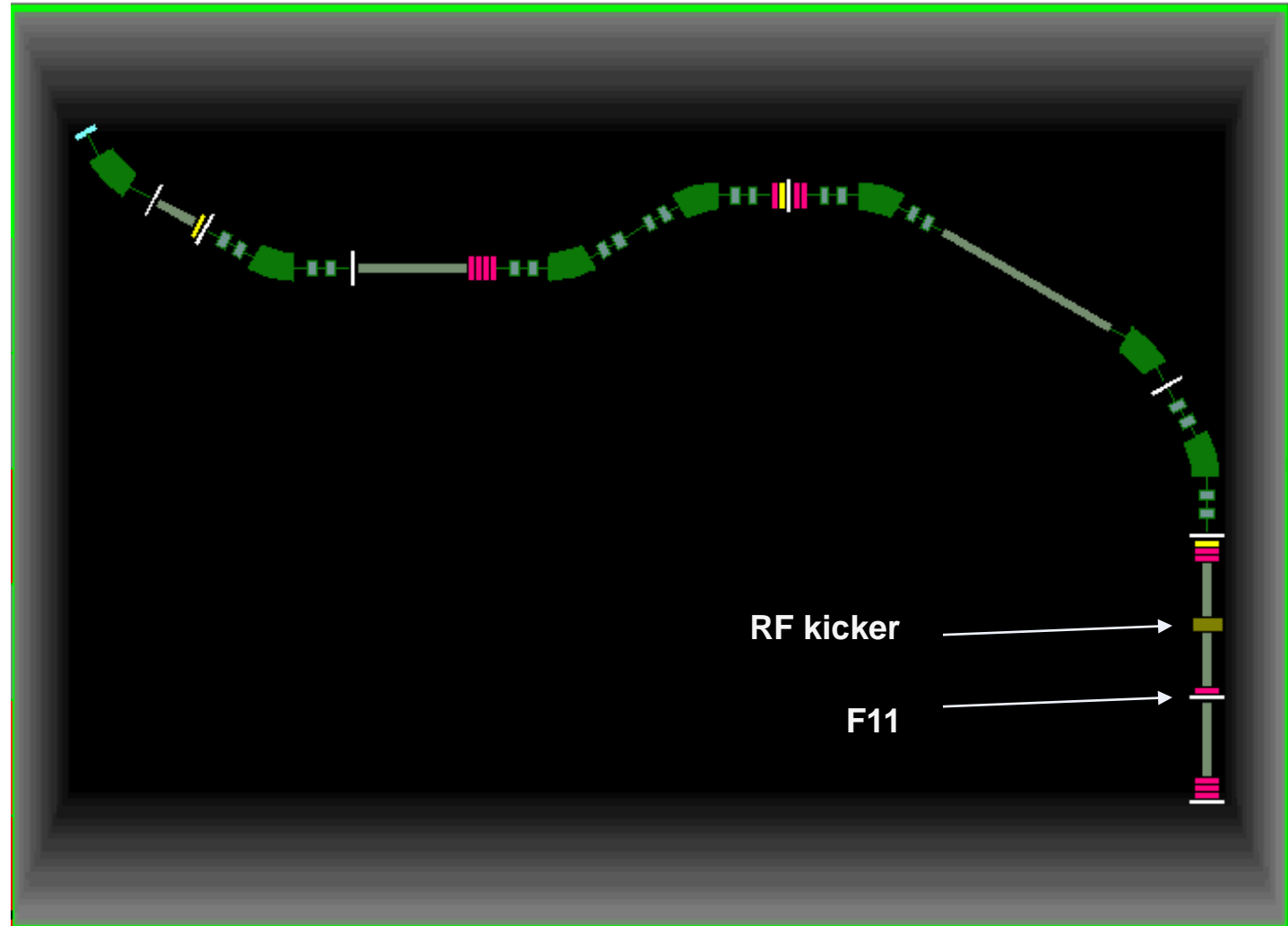
RF-kicker update

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



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]	/[%]	

RFdef

RF separator settings

Select method

Electric field $E = 1500$ KV/m

Voltage $U = 300$ KV

Gap = 200 mm

Separation plane

Horizontal

Vertical

Beam profile for different phase shifts

Geometry

$La = 0$ m

$L = 1.2$ m

$Lb = 0$ m

RF settings

use Beam settings $RF (MHz) = 18.25$ Phase shift 99.87

manually 19 [deg]

Separator Tuning

Mode

find the POSITION value using the phase shift

find the PHASE SHIFT using the position value

Tuning on Position

0 (+/-)

0 (-/+)

Minimum

Maximum

manually (+/-)

manually (-/+)

Set slits automatically after tuning

Optical block properties and data

Setting Charge state for the Block (Z-Q) 0 Calculate the RF separator using the Setting fragment

Cut(Slits) & Acceptances

Optical matrix

General setting of block

Tweak 0.1 %

Tune the RF separator

Calculations for the setting fragment

Before the RF separator	$\langle E \rangle - dE$	$\langle E \rangle$	$\langle E \rangle + dE$
Energy [MeV/u]	31.54	33.05	34.55
Values corresponding to Energy			
Time of flight [ns]	669.52	667.63	665.75
Phase [deg]	338.85	326.49	314.13

After the RF separator

Position [mm]	1.59	-0.02	-1.49
---------------	------	-------	-------

Reduced values

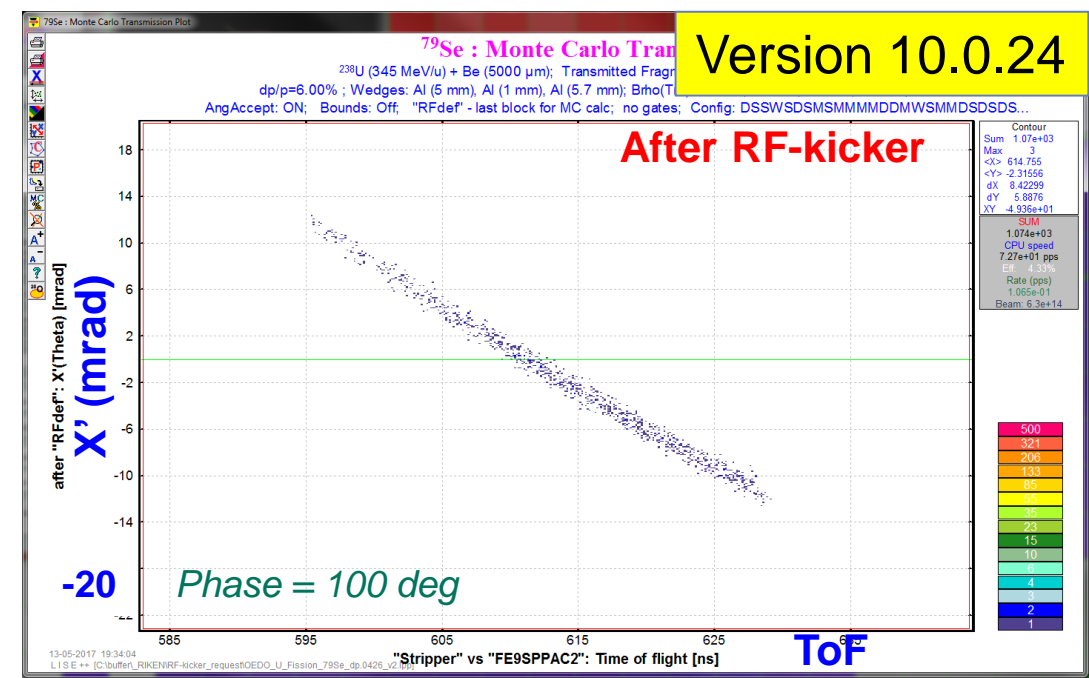
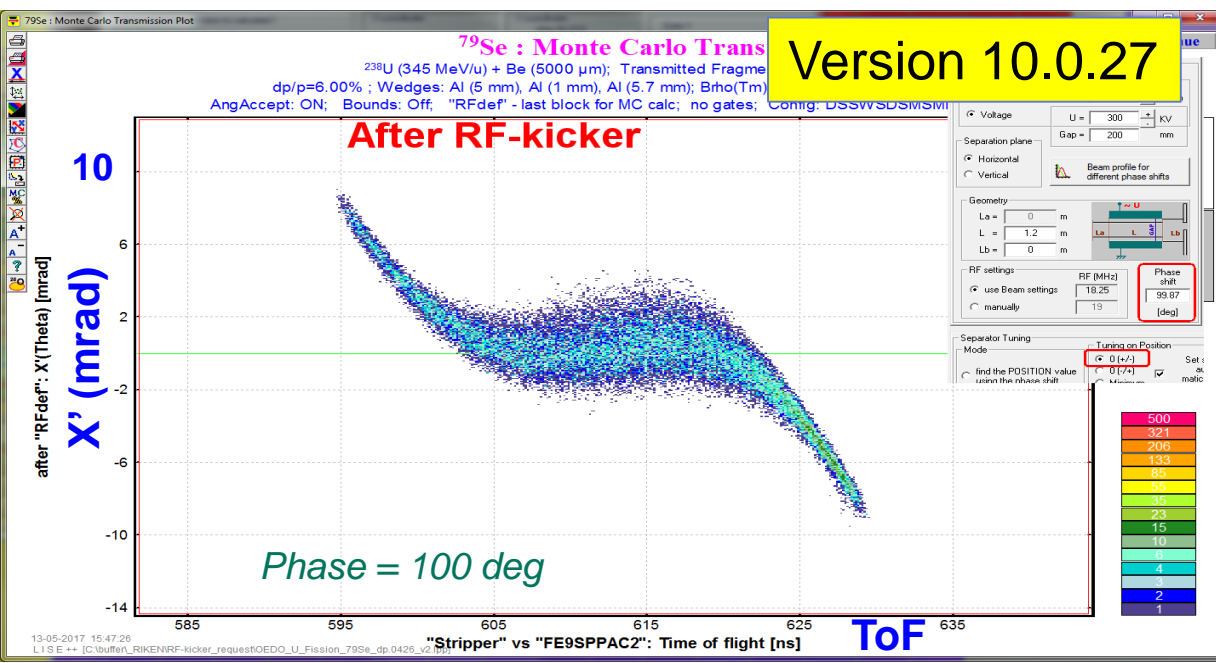
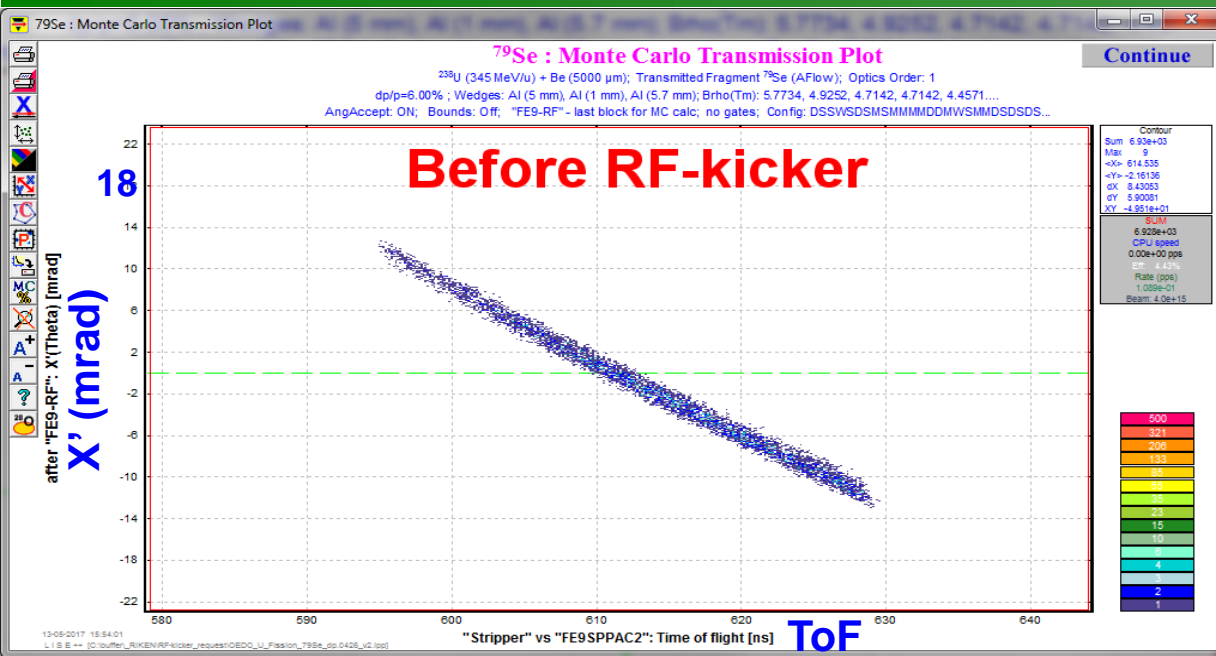
Dispersion (X/P) -0.663 mm/%

Slits after the RF separator corresponding to the separation plane (Centre +/- Size)

no slits +/- no slits mm

OK Cancel Help

Intensity & Purity optimization utility



Mass tables in LISE⁺⁺

The image shows a file explorer interface with three panes:

- Left Pane (\bin*.*):** Lists files and folders. Files AME2016, AME2016+GXPF1B, and AME2016+GXPF1B5 are marked with red icons and labeled "new". Folders [FRIB_mass] and [RMF_mass] are marked with pink lines and labeled "updated".
- Top Right Pane (\bin\FRIB_mass*.*):** Lists files SKMS, SKP, SLY4, SV-MIN, UNEDF0, and UNEDF1.
- Bottom Right Pane (\bin\RMF_mass*.*):** Lists files ddme2, ddmed, ddpc1, and nl3s.

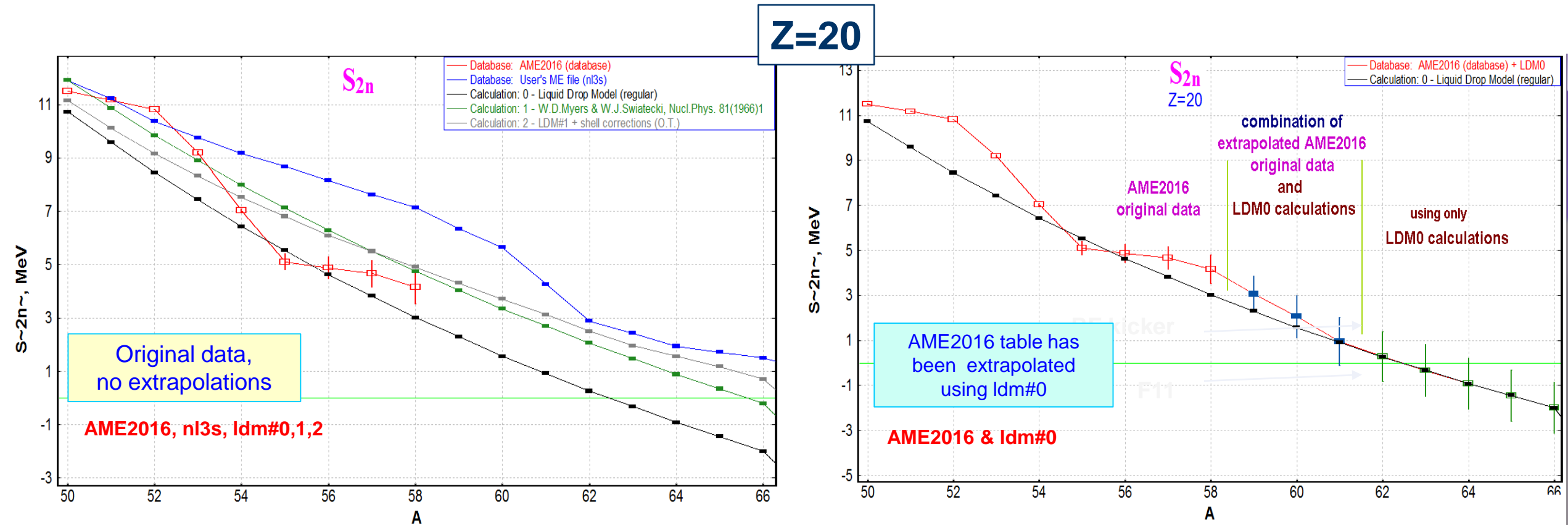
Additional files listed on the far right include FRDM2012, hfb17, hfb22, hfb27, hfb8, hfb9, ktuy, Moller95, tuyy, WS4, and WS4_RBF, each with a red icon and labeled "lme".

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.

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



Where LDM #0,1,2 are Liquid Droplet Models in LISE++

http://lise.nsl.msui.edu/6_1/lise++_6.htm#_Toc26162476

More information can be find at

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

Databases Help

- AME & properties: View, Edit
- AME & properties: Plots
- Isomer database
- Ionization energy database
- Decay Branching Ratio database

S1n
S2n
S1p
S2p
Q alpha
Beta- decay
Beta+ decay
T 1/2
Mass Excess
Binding energy
Binding energy per A
S d
S 3He
S t

"Stability" plots
P (pairing energies)
D (separation energy derivatives)

"Stability" plot
Documentation for "Stability" plot calculations
Separation energies minimum plot

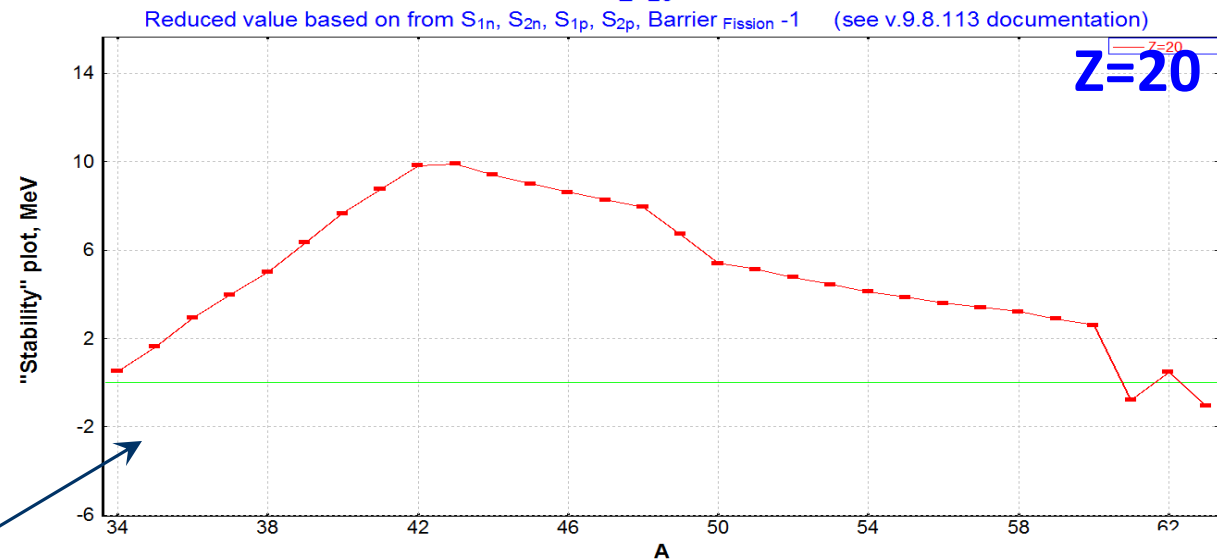
The Purpose is to deduce and plot a minimum value from the set of S1n, S2n, S1p, S2p, Fission Barrier in order to

- 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

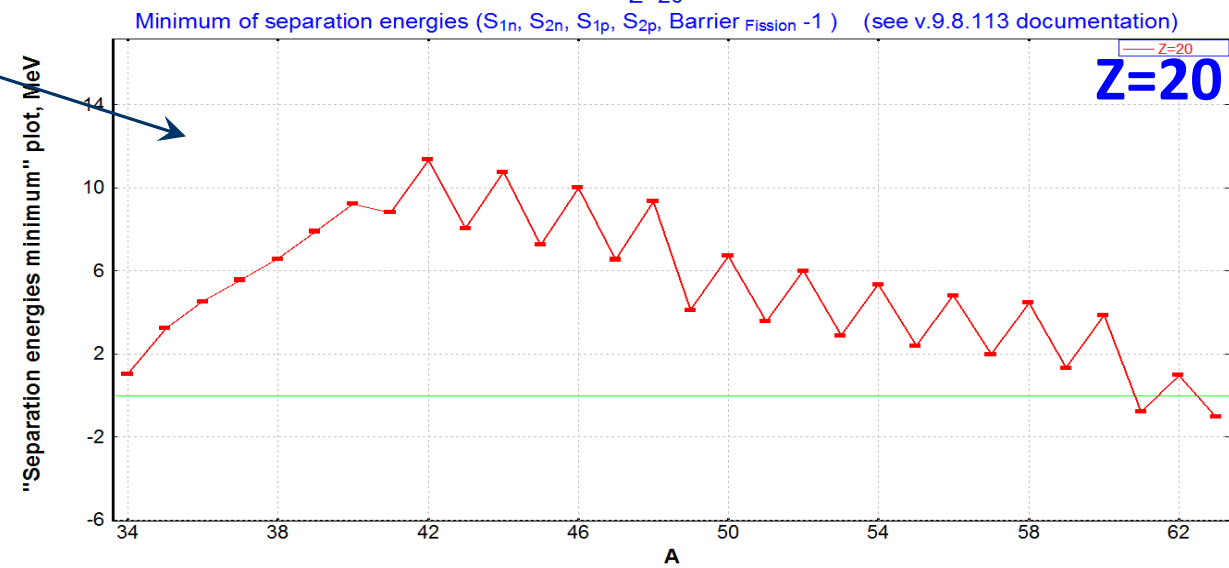
"Stability" plot

<Database: User's ME file (ddme2)>
Z=20



"Separation energies minimum" plot

<Database: User's ME file (ddme2)>
Z=20



PID resolution calculator

$(A/q)_1$ isotope – should belong to A/q line as 2, 2.5 or 3

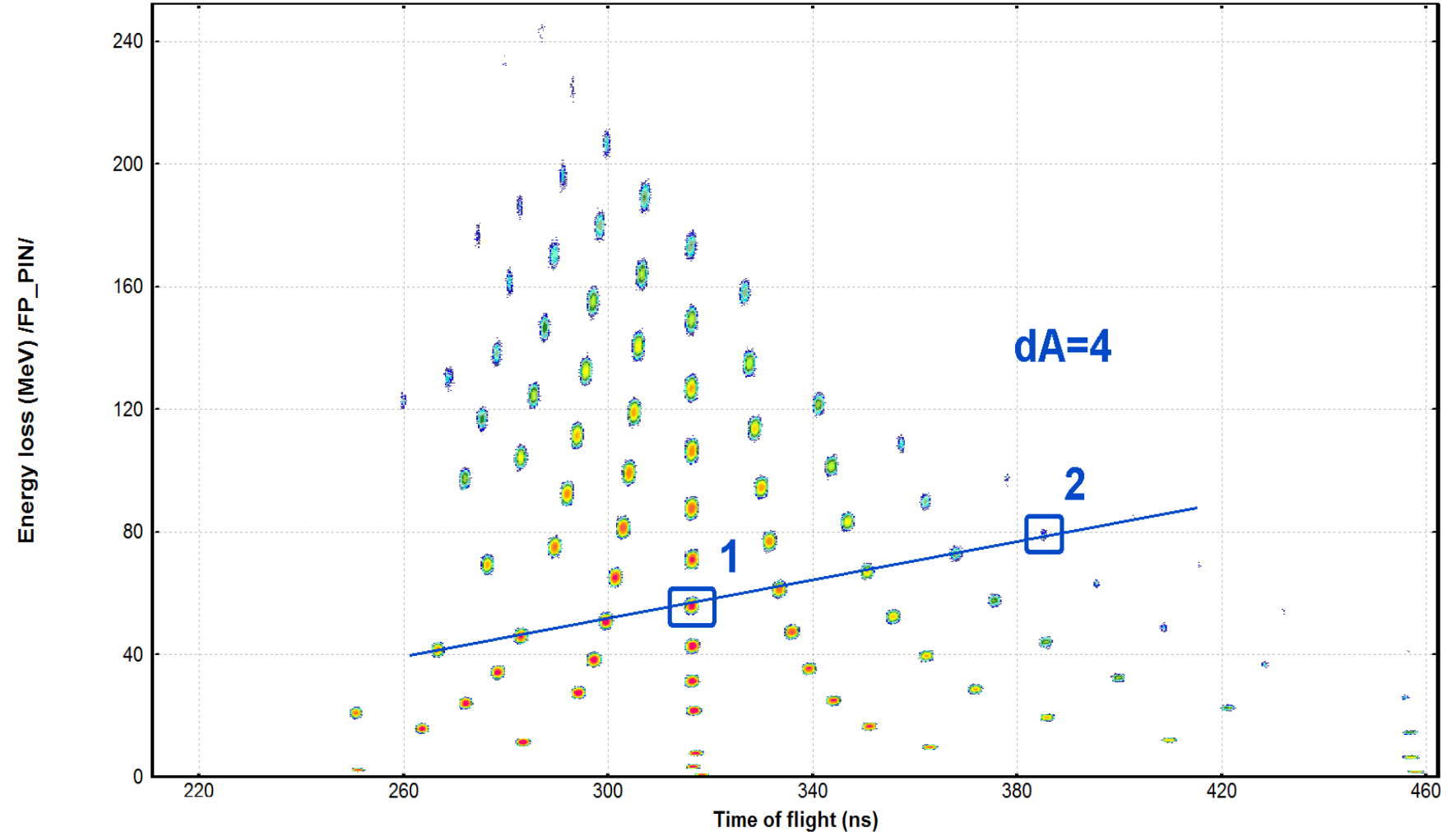
$(A/q)_2$ isotope – should be the element as the first isotope

ΔA – isotope mass difference

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

dE-TOF

^{40}Ca (140 MeV/u) + Be (300 mg/cm²); Settings on ^{20}Ne ; Config: DSDSWDDMMSMM
 dp/p=0.07% ; Wedges: 0; Brho(Tm): 2.5184, 2.5184, 2.5184, 2.5184
 Start: Target; Stop: FP_PIN; ACQ_start: Detector ** dE: FP_PIN - Si (504 μm)



$(A/q)_1$ isotope

Ion	Set-up	Resolution	Momentum Resolution	Measured values	Deduced values	PID values																																																																						
A = 56 Z = 28 q = 28 M_isotope = 55.94213 M_ion = 55.92677 M_ion/q = 1.997385	Energy = 120.00 MeV/u Flight Length = 35.500 m 1st(Z) detector material = 14 mg/cm2 1st(Z) detector thickness = 40 172.325 um	sigma TOF = 0.100 ns Eloss = 0.20 % TKE = 0.20 % Z = Momentum (Brho) = 0.0771 %	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 %	TOF = 255.2603 ns Brho = 3.2501 T*m E1_loss = 161.46 MeV TKE = 6711.21 MeV	beta = 0.463921 gamma = 1.128825 velocity = 13.9074 cm/ns A / q = 1.997385 A/q (2) = 2.17556	Z (Eloss) = 28 Z(A/q) = 28.062 Z(Aint/q) = 28.480 q = 28.000 A (from TKE) = 55.9268 A (from [A/q]*q_integer) = 55.9268 A (from [A/q]*q_measur) = 55.9268 A-2q = -0.07 A-3q = -28.07																																																																						
		systematical (calibration) 0.01 % 1.11 % (straggling) 0.10 % 0.2 % 0.01 %		error (sigma) % 0.103 0.040 0.003 0.078 1.82 1.127 15.01 0.224	error (sigma) % 0.00019 0.040 0.00046 0.040 0.00562 0.040 0.00224 0.112 0.002657 0.122 A/q 2	contribution in error <table border="1"> <thead> <tr> <th>Brho</th> <th>Beta</th> <th>TKE</th> <th>E1_loss</th> <th>Zsyst</th> <th>A/q</th> <th>Z</th> </tr> </thead> <tbody> <tr> <td>0.078%</td> <td>0.081%</td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>0.085%</td> <td>0.088%</td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td>0.56%</td> <td>0.20%</td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td>0.131%</td> <td></td> </tr> <tr> <td></td> <td></td> <td>0.224%</td> <td>0.224%</td> <td></td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td>0.353%</td> <td>0.224%</td> <td></td> <td></td> <td>0.112%</td> </tr> <tr> <td>0.078%</td> <td>0.081%</td> <td>0.361%</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>0.04</td> <td>0.04</td> <td>0.00</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>0.07</td> <td>0.03</td> <td>0.06</td> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table>	Brho	Beta	TKE	E1_loss	Zsyst	A/q	Z	0.078%	0.081%						0.085%	0.088%										0.56%	0.20%							0.131%				0.224%	0.224%						0.353%	0.224%			0.112%	0.078%	0.081%	0.361%					0.04	0.04	0.00					0.07	0.03	0.06				
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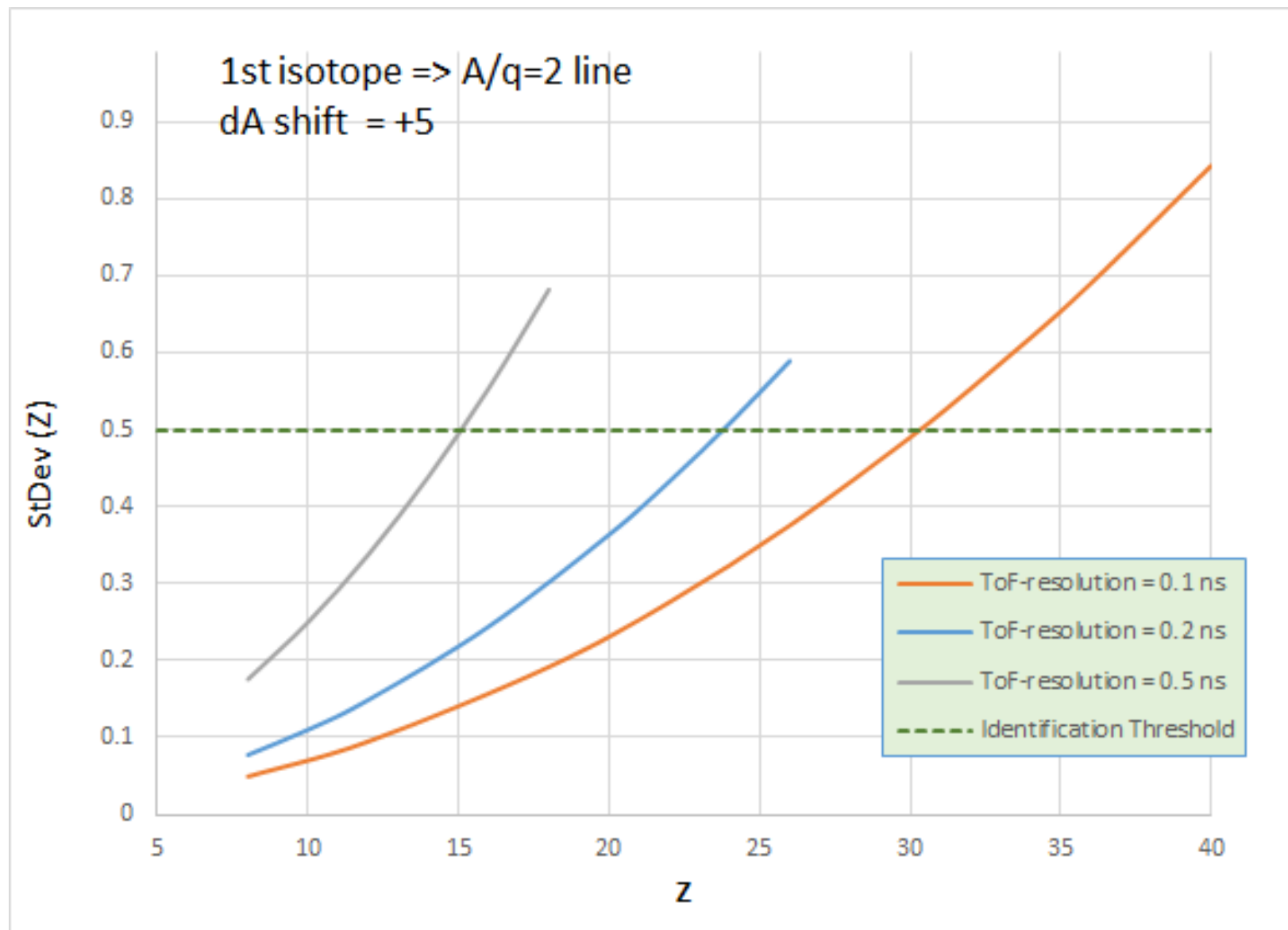
coef_Aq = 3.10713
~~Eloss_option = 2~~
 dA_shift = 5

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

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)

All calculations were done for

- A1900 separator
- No wedge
- $E(1^{\text{st}} \text{ fragment}) = 120 \text{ MeV/u}$
- $l1_slits = \pm 1 \text{ mm}$



Under current conditions,
the identification above
Calcium is possible

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

07 / 2019

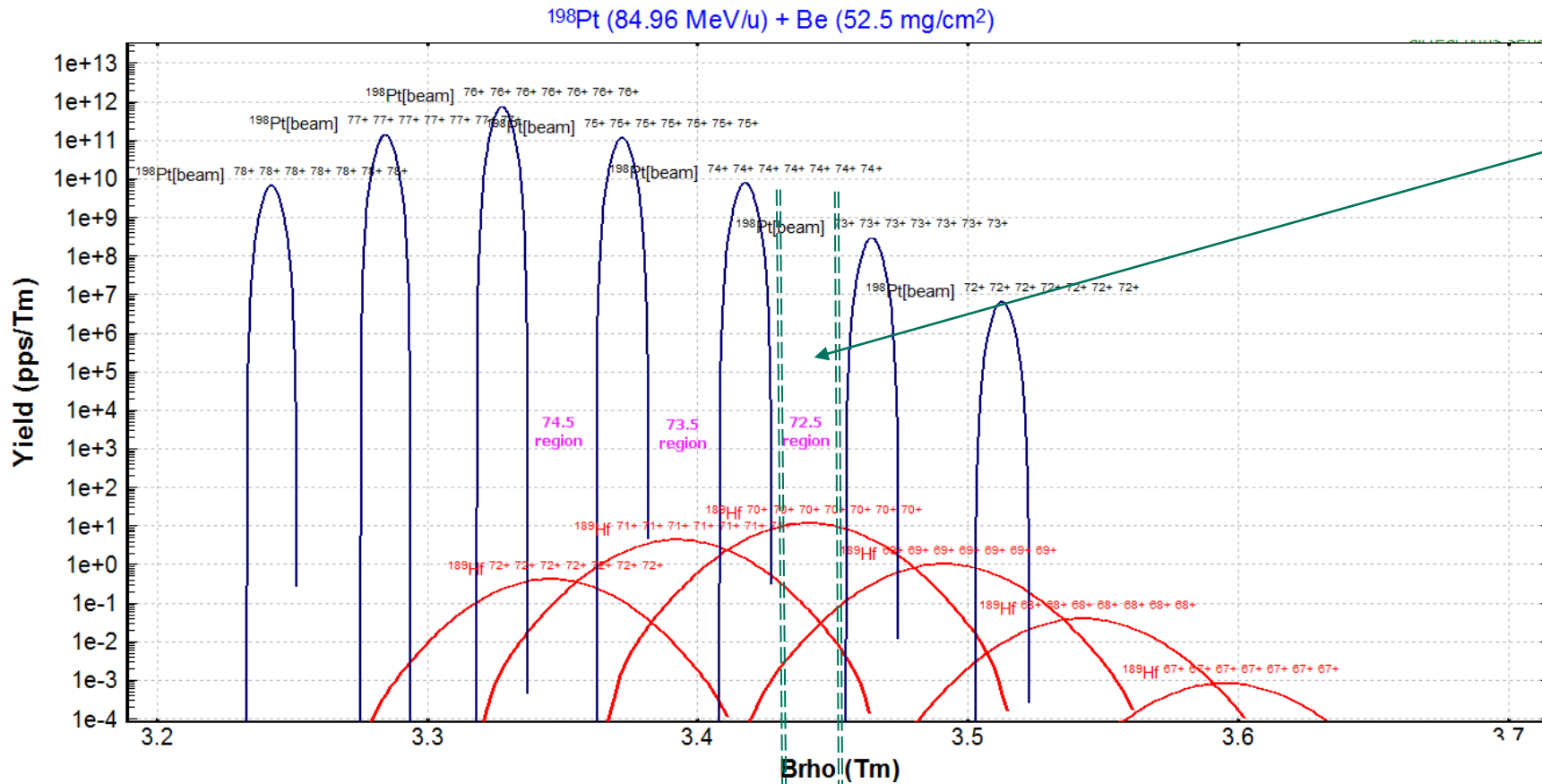
NSCL E15130

“Search for isotopes and isomers in the Hf region”

PIs:

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

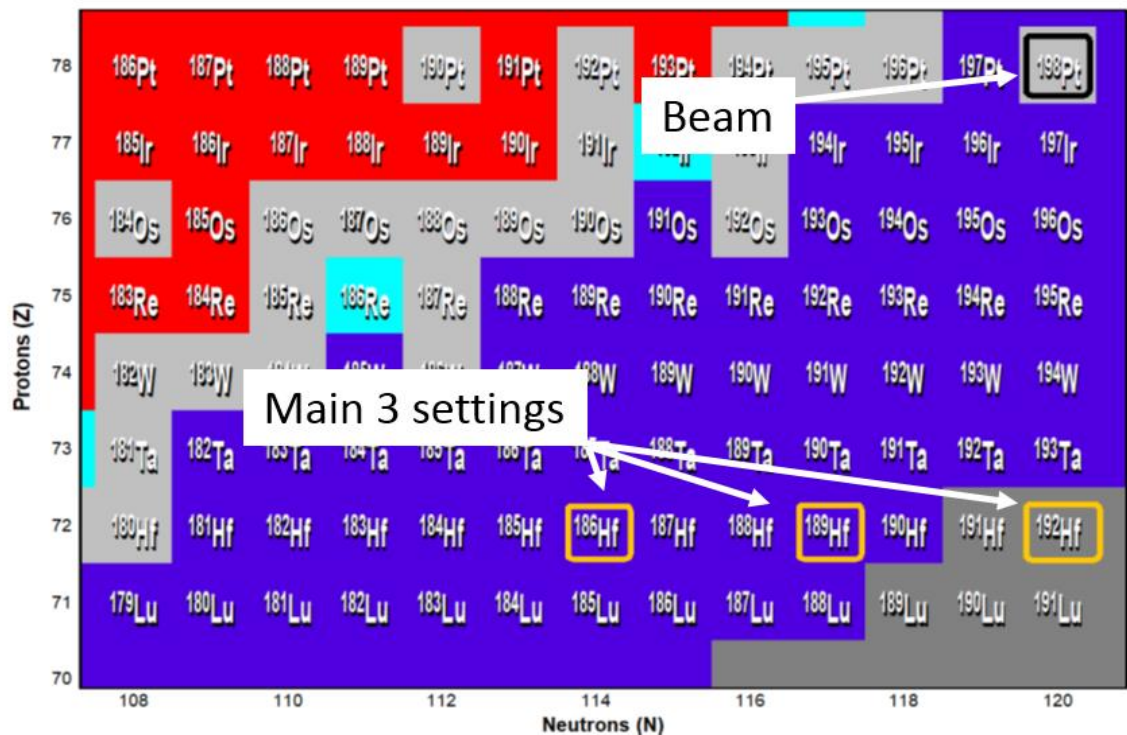
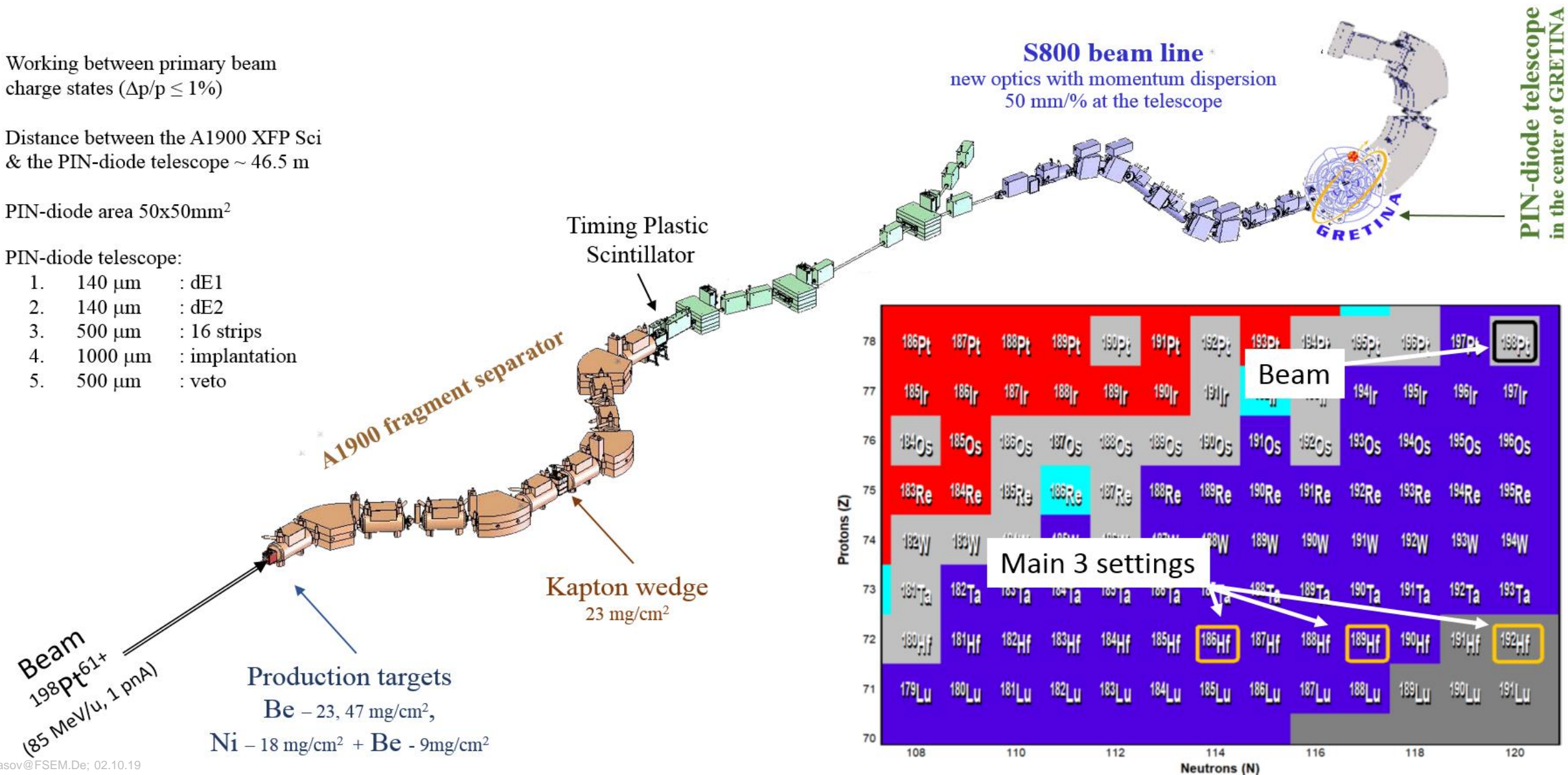
- Working between primary beam charge states
- Try to avoid in-flight detectors (charge state production)
- No in-flight detectors in Dispersive plane (“wedge” property)
- “Separator + Long Spectrometer” method



Working region
dP/P ~ 0.8-1.0%

"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 $50 \times 50 \text{ mm}^2$
- PIN-diode telescope:
 - $140 \mu\text{m}$: dE1
 - $140 \mu\text{m}$: dE2
 - $500 \mu\text{m}$: 16 strips
 - $1000 \mu\text{m}$: implantation
 - $500 \mu\text{m}$: veto

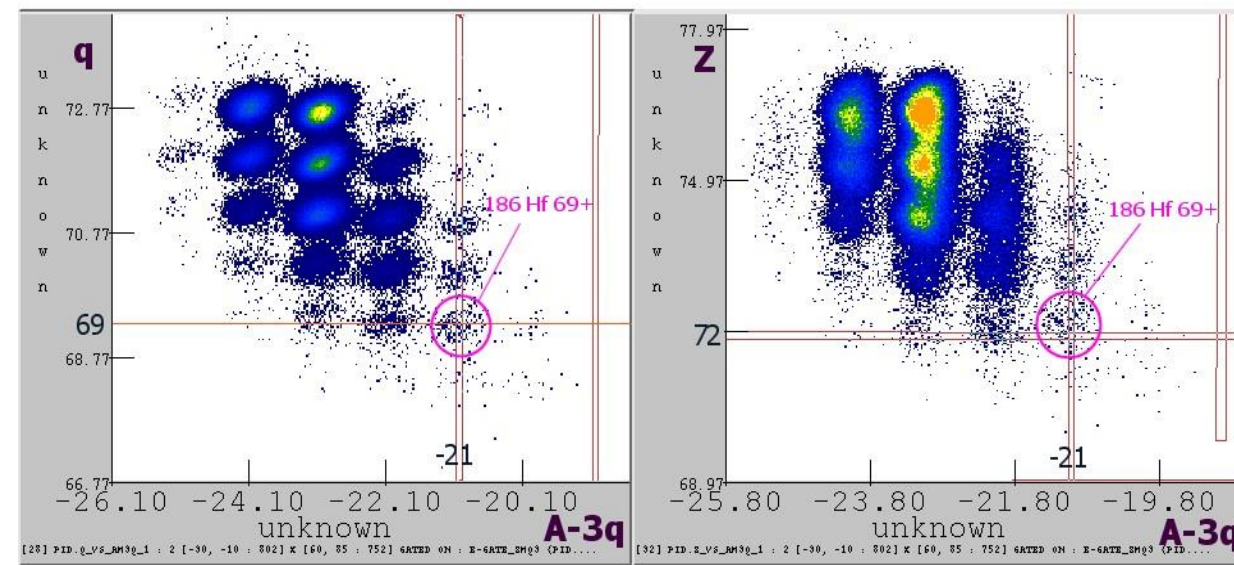
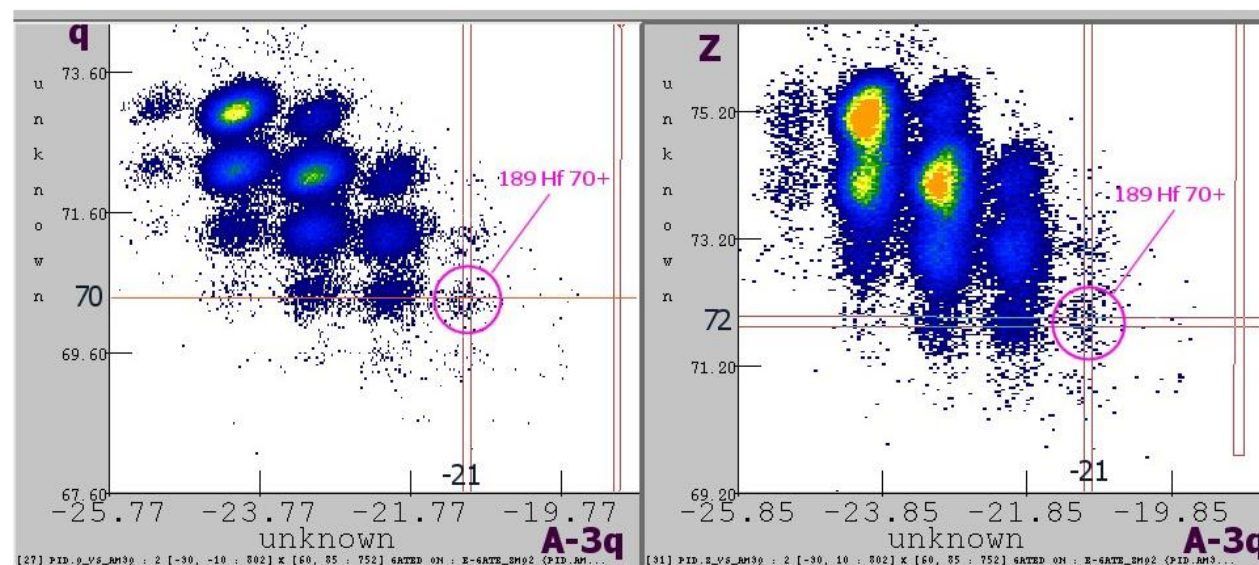


Experiment #e15130; July 2019 @ NSCL/MSU

^{198}Pt (85 MeV/u) + Be (47 mg/cm²) -> Wedge -> $^{189}\text{Hf}^{70+}$

selection Z-q=2

selection Z-q=3



- New isotopes have been observed in the $^{192}\text{Hf}^{70+}$ 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”

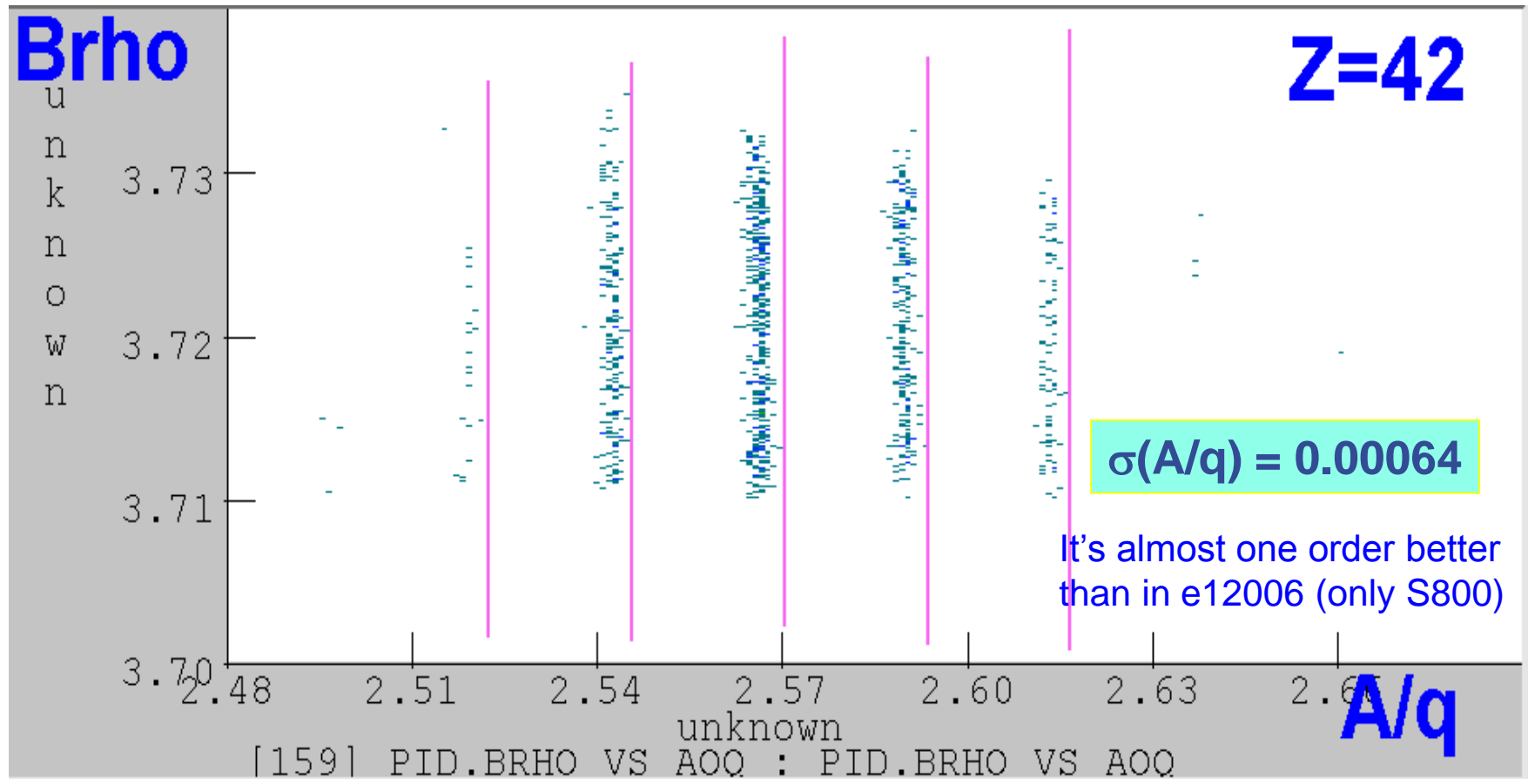
DispersionI2= 112.00000 mm/%

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

PI: M.Famiano

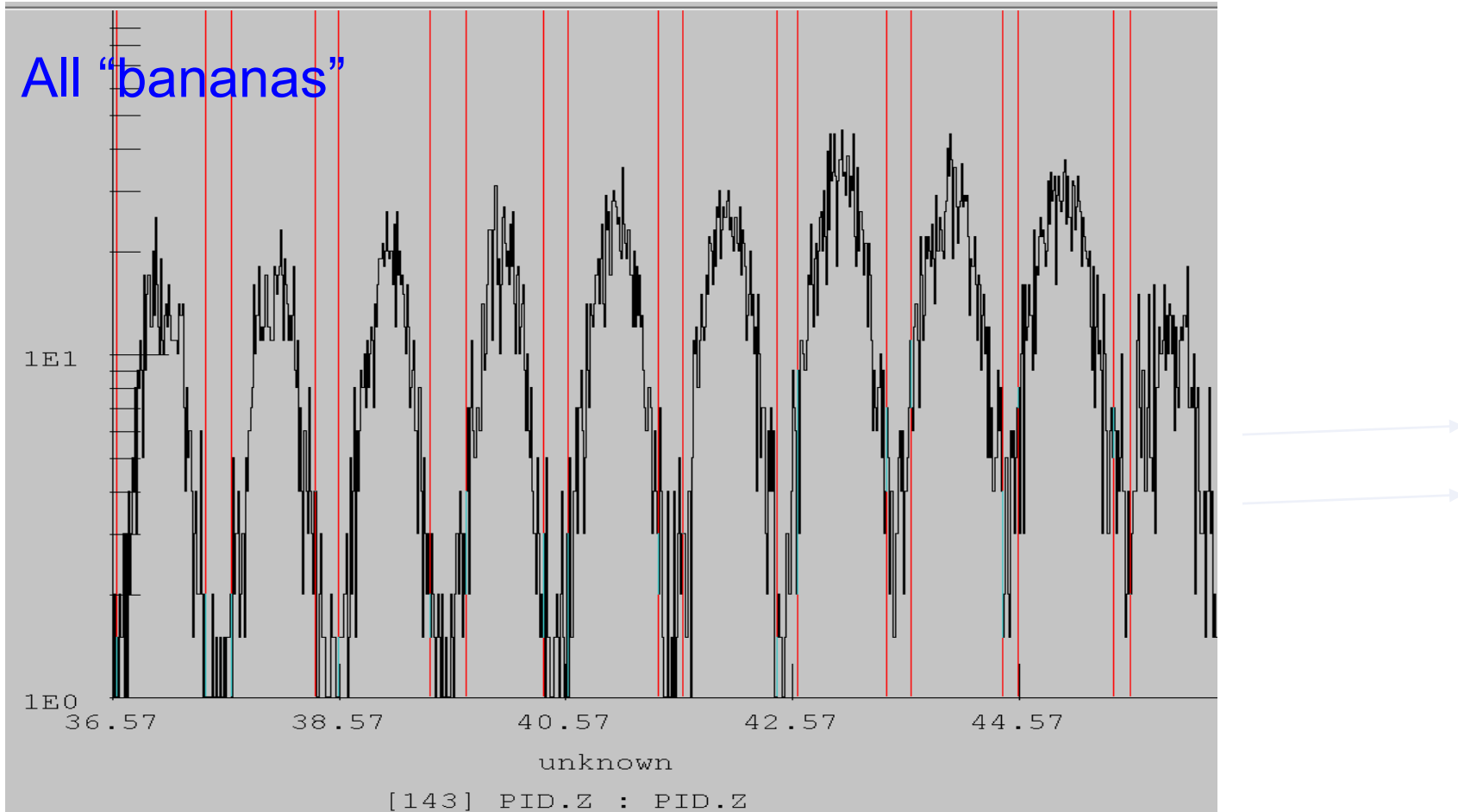
- Mass measurement
- Disperse mode
- PIN-telescope at the S800 FP
- Bhro measurement at the S800 TP by MCP



Good

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

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

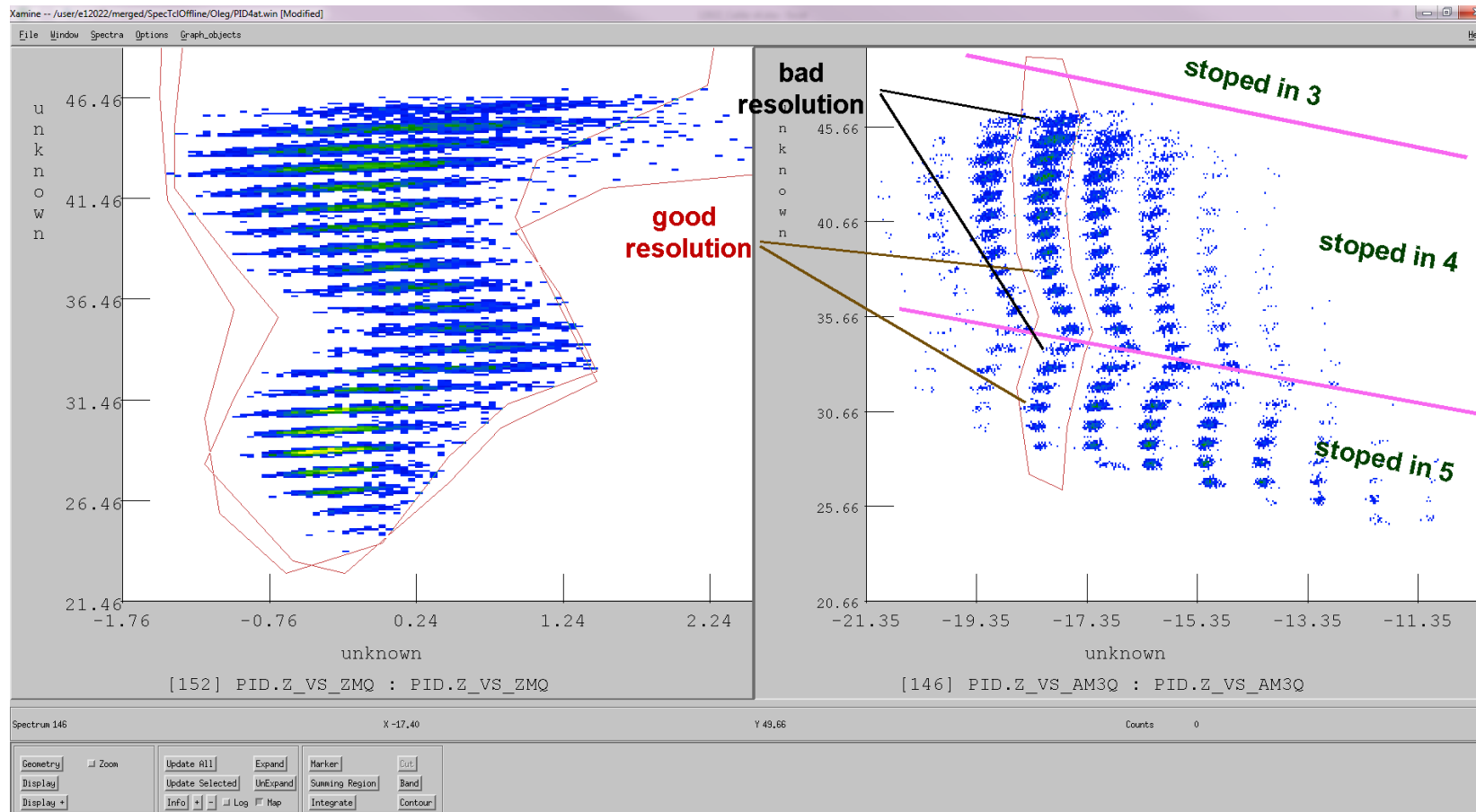


3rd and 4th PIN-diodes not well depleted

BAD !

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

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

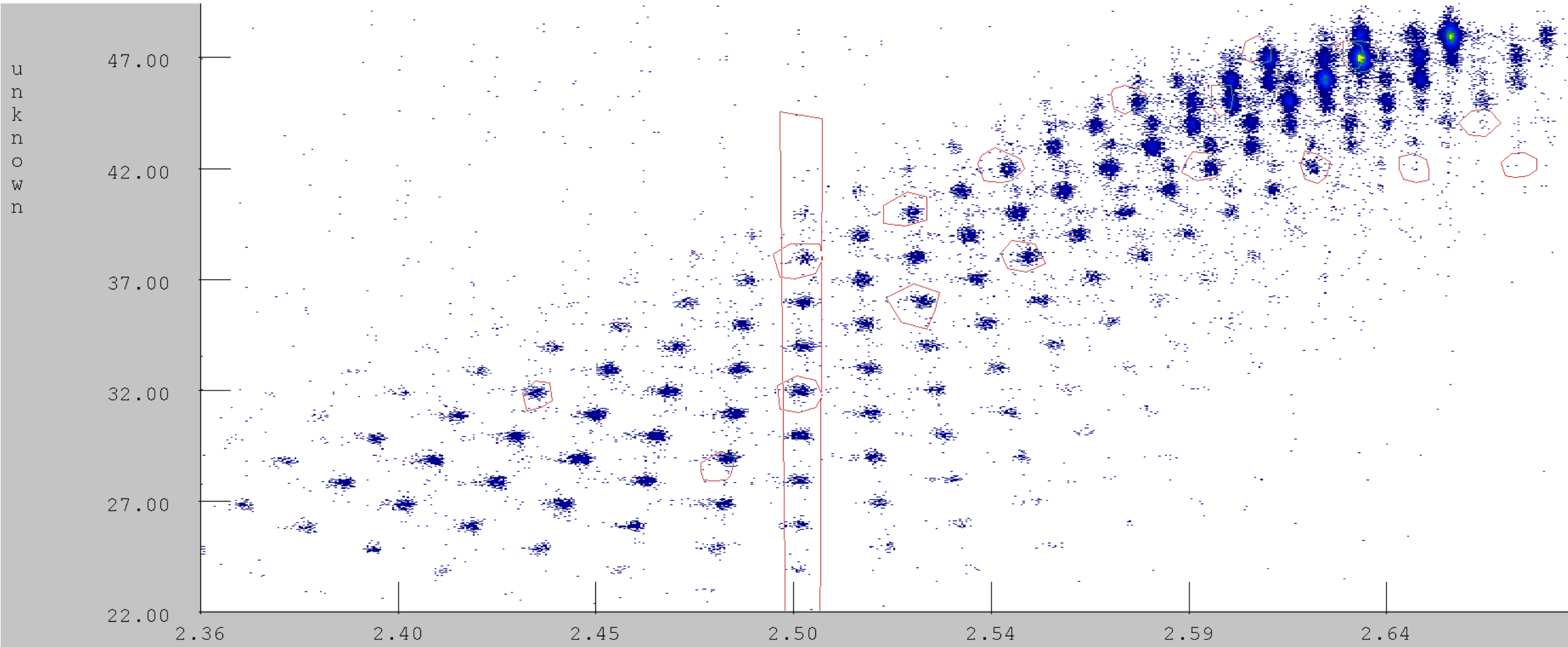


Actually $\sigma(Q)$ is not so bad, but charge state overlapping was observed in the Z-q plot. So, the “banana” selection method can help. See next slides

F11

PID plot without filtering

Z



unknown

[149] PID.Z_VS_AOQ : 2 [2.35, 2.8 : 902] X [20, 55 : 1052] GATED ON : -UNGATED- {PID.AOQ, PID.Z}

A/q

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.

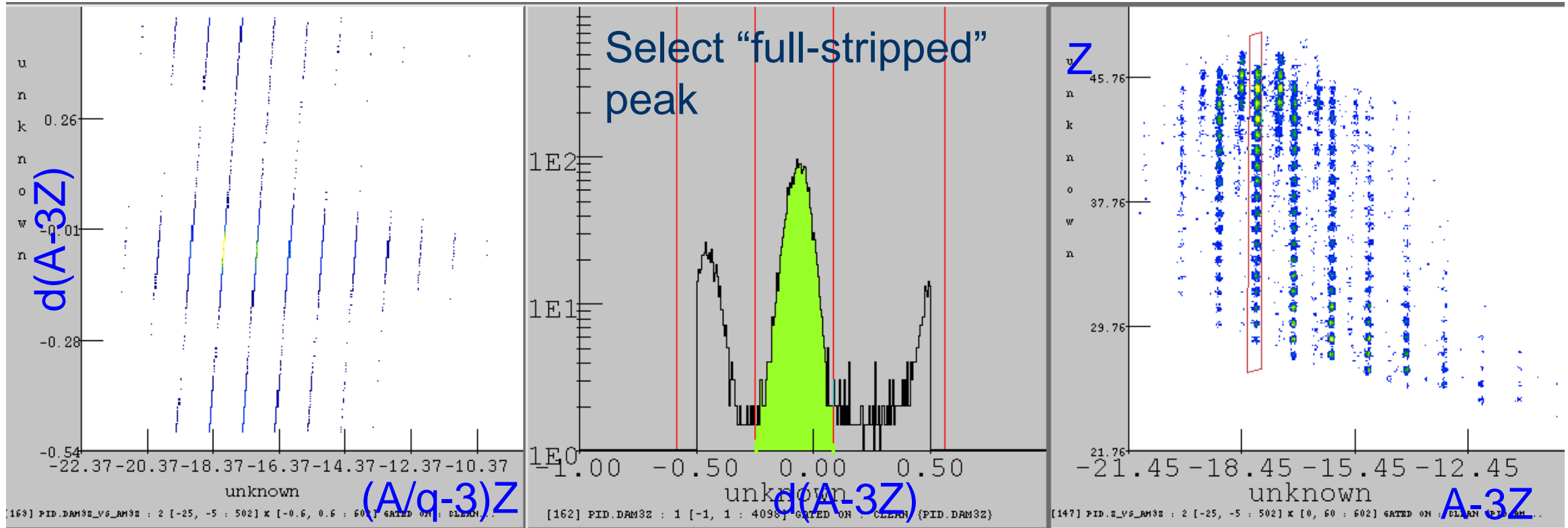
So, in our case we are working around 2.5, and no helium-like products

$$Z_i = \text{int}(Z+0.5)$$

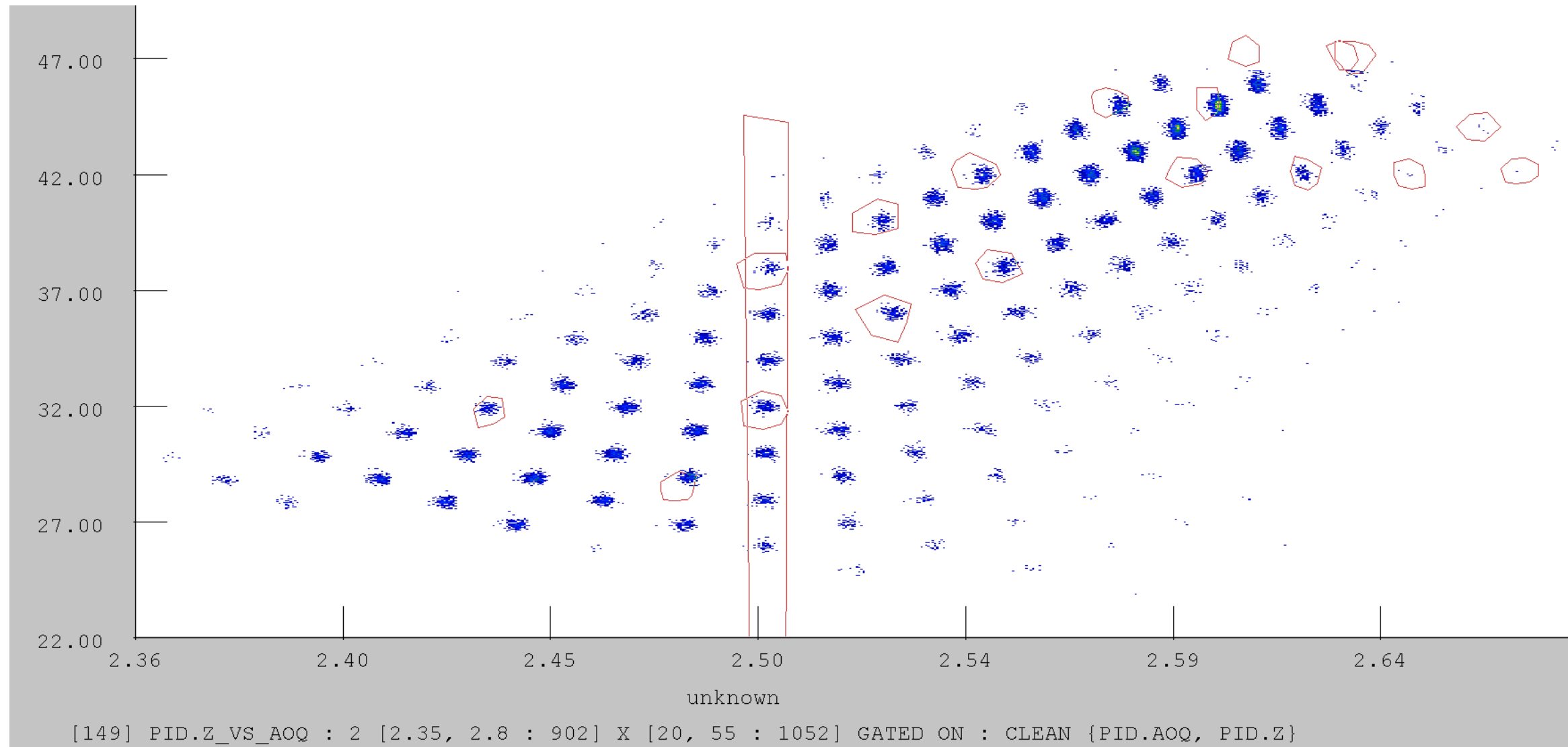
$$Am_{3Z} = (A/q - 3) * Z_i$$

$$Am_{3Z_i} = \text{int}(Am_{3Z} + 1.5)$$

$$dA_{3mZ} = Am_{3Z} - Am_{3Z_i}$$



Z



A/q

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

Z	42									
A	Z-q					A	Z-q			
	1	2	3	4			1	2	3	4
80	0.049	0.000	0.154	0.421		100	0.439	0.000	0.308	0.474
81	0.024	0.050	0.231	0.474		101	0.463	0.050	0.231	0.368
82	0.000	0.100	0.308	0.368		102	0.488	0.100	0.154	0.263
83	0.024	0.150	0.385	0.263		103	0.488	0.150	0.077	0.158
84	0.049	0.200	0.462	0.158		104	0.463	0.200	0.000	0.053
85	0.073	0.250	0.462	0.053		105	0.439	0.250	0.077	0.053
86	0.098	0.300	0.385	0.053		106	0.415	0.300	0.154	0.158
87	0.122	0.350	0.308	0.158		107	0.390	0.350	0.231	0.263
88	0.146	0.400	0.231	0.263		108	0.366	0.400	0.308	0.368
89	0.171	0.450	0.154	0.368		109	0.341	0.450	0.385	0.474
90	0.195	0.500	0.077	0.474		110	0.317	0.500	0.462	0.421
91	0.220	0.450	0.000	0.421		111	0.293	0.450	0.462	0.316
92	0.244	0.400	0.077	0.316		112	0.268	0.400	0.385	0.211
93	0.268	0.350	0.154	0.211		113	0.244	0.350	0.308	0.105
94	0.293	0.300	0.231	0.105		114	0.220	0.300	0.231	0.000
95	0.317	0.250	0.308	0.000		115	0.195	0.250	0.154	0.105
96	0.341	0.200	0.385	0.105		116	0.171	0.200	0.077	0.211
97	0.366	0.150	0.462	0.211		117	0.146	0.150	0.000	0.316
98	0.390	0.100	0.462	0.316		118	0.122	0.100	0.077	0.421
99	0.415	0.050	0.385	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

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Large Variety of
destinations



Would like to thank
colleagues

for Inspiring, discussions,
feedbacks, requests,
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