PLANS FOR THEORETICAL AND EXPERIMENTAL STUDY OF ABRASION - FISSION

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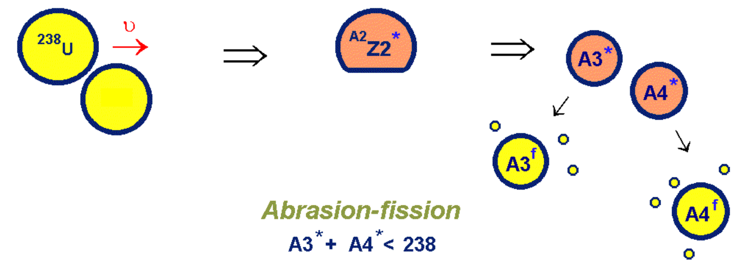
Introduction

In-flight fission is one main production mechanism at new generation of rare isotopes beam facilities as RIKEN, FRIB, FAIR. Models (such as LISE^{++} 3EER[1], PROFI[2]) based on the geometrical abrasion approach[3] and excitation energy formalism [4] are used for fast calculation of production yield in Abrasion-Fission. These models do not take into account primary beam energy, do not consider energy dissipation processes important for intermediate energies and heavy targets. In this work more sophisticated JQMD Ver.2 [5] in the PHITS 2.88 package[6], which simulates dynamical system of colliding nuclei, has been used to calculate fissile pre-fragment mass and excitation energy distributions. These calculations show drastic importance of input channels as primary beam energy and target choice comparing to the geometrical abrasion approach, and indicate on necessity on theoretical development suitable for fast calculations.

Abrasion-Fission



The basic complexity in the case of Abrasion-Fission is the fact that there are more than 1000 fissile nuclei (see Figure) after abrasion of a fast heavy projectile by a target compared to only one fissile nucleus in the case of Coulomb fission.

To overcome this problem, the 3EER model has been developed in the framework of LISE^{++} for fast calculations of Abrasion-Fission fragment production.

The model suggests just three fissile nuclei for different excitation energy regions, which are calculated by using LISE^{++} Abrasion-Ablation model based on the geometrical abrasion approach[3] and excitation energy formalism[4]. The excitation region (low, middle, high) is determined by three parameters: excitation energy, cross-section, and fissile nucleus (A,Z). But this model does not take into account primary beam energy, do not consider energy dissipation processes important for heavy targets.

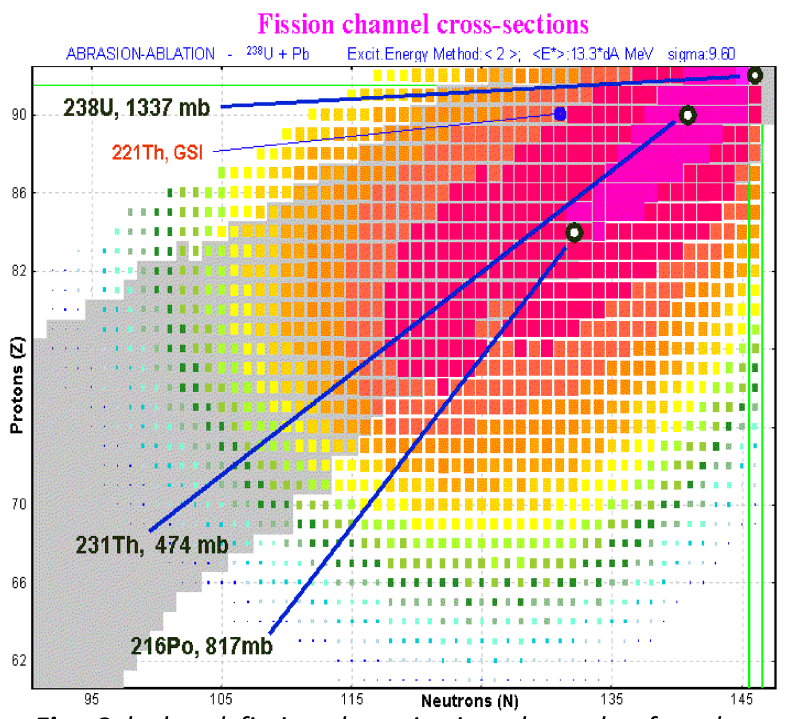
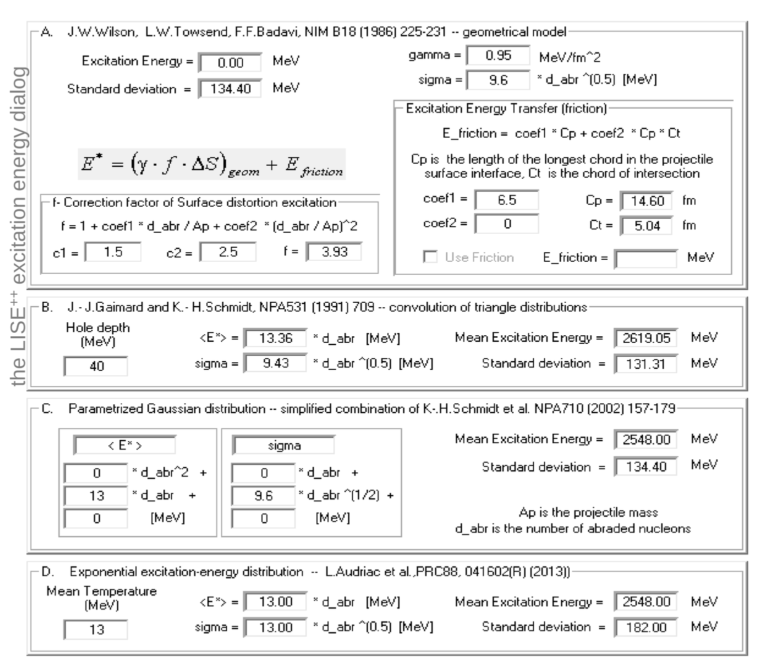


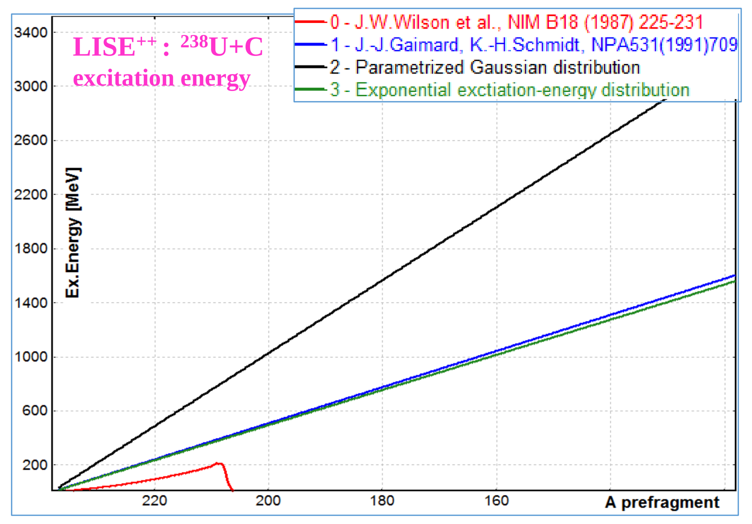
Fig. Calculated fission de-excitation channels after the abrasion of ^{238}U(1AGeV) by a lead target. The most probable fissile nuclei in the excitation energy regions are shown in the figure

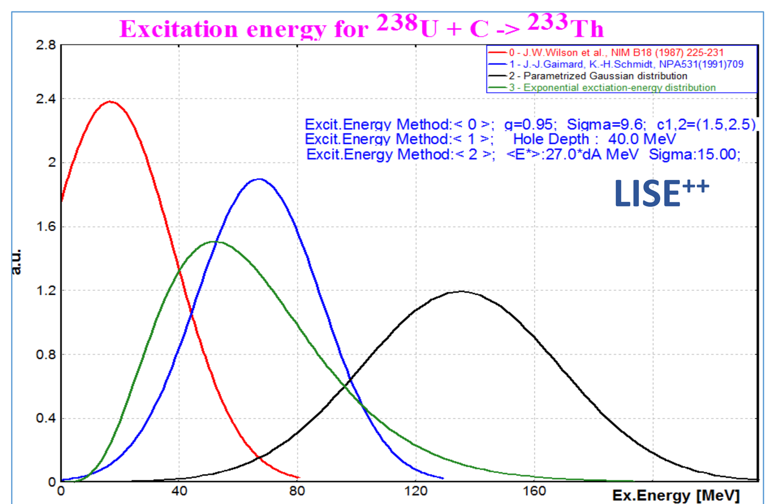
Characteristics (<E>, $\sigma(E)$, shape) of excitation energy distribution of abraded projectiles are not well studied or measured as function of primary beam energy and target material, and they appear more crucial uncertainty contribution in Abrasion-Fission calculations.

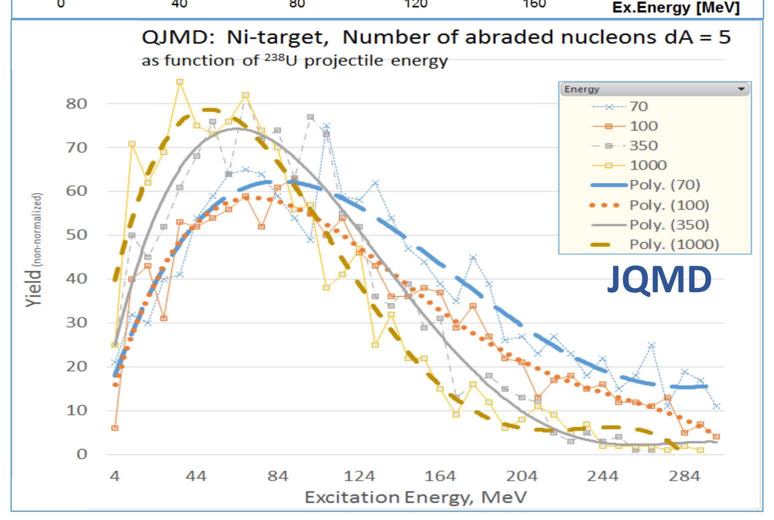
LISE^{++} : excitation energy models

Four prefragment excitation energy models are implemented in LISE^{++}. There is not observed agreement for "Geometrical" model with experimental and other models calculations, though this model has some corrections based on beam & target masses, and beam energy. All other models in LISE^{++} depend only on number of abraded nucleons.



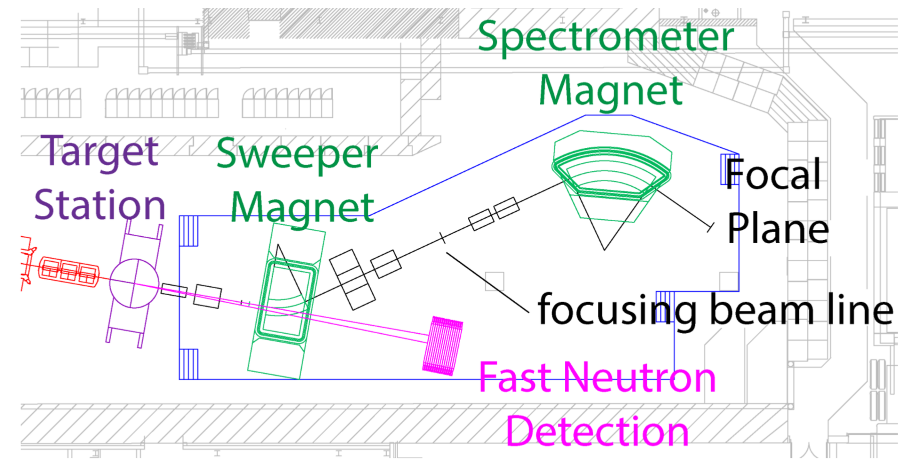






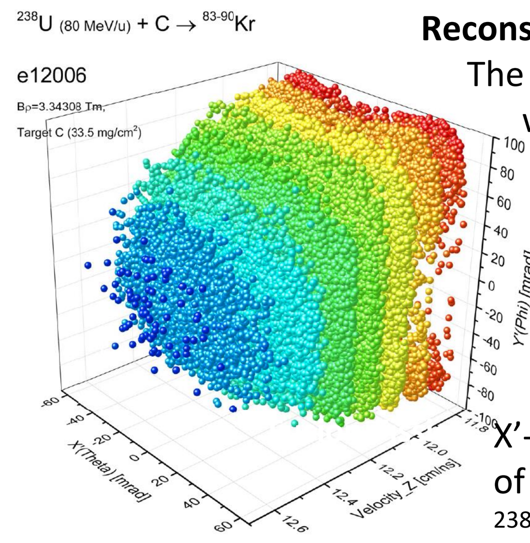
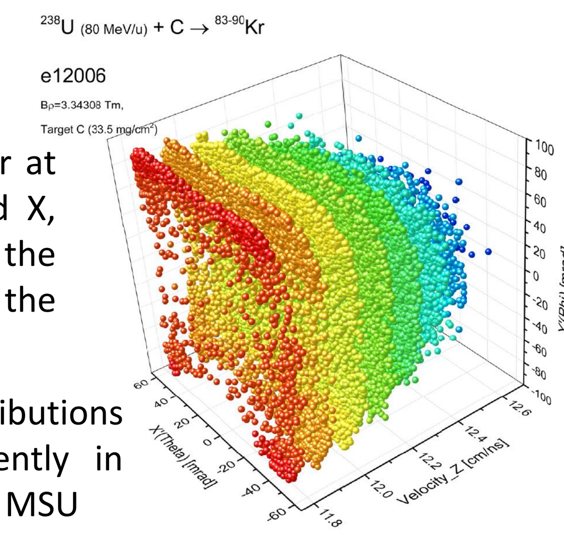
Fission study using backtracking in HRS

Abrasion-Fission is very complicated mechanism for experimental study to compare with theoretical predictions due to a large number of fissile nuclei. It is necessary to **identify simultaneously both fission fragments** (A,Z,q) in the focal final plane of a spectrometer with succeeding backtracking up to target to deduce their momentum vectors. Obtained information can be used to reestablish parent fissile nucleus (A,Z,E^*). The High Rigidity Spectrometer (HRS) proposed for construction at FRIB is considered in the context of **in-flight fission study**. Correlations between fission outputs and full spectral shapes will be available for experimental testing. In particular, experimental information regarding low-lying states in the produced fission fragments will be used whenever possible, and in the continuum, a level density is assumed based on systematics.



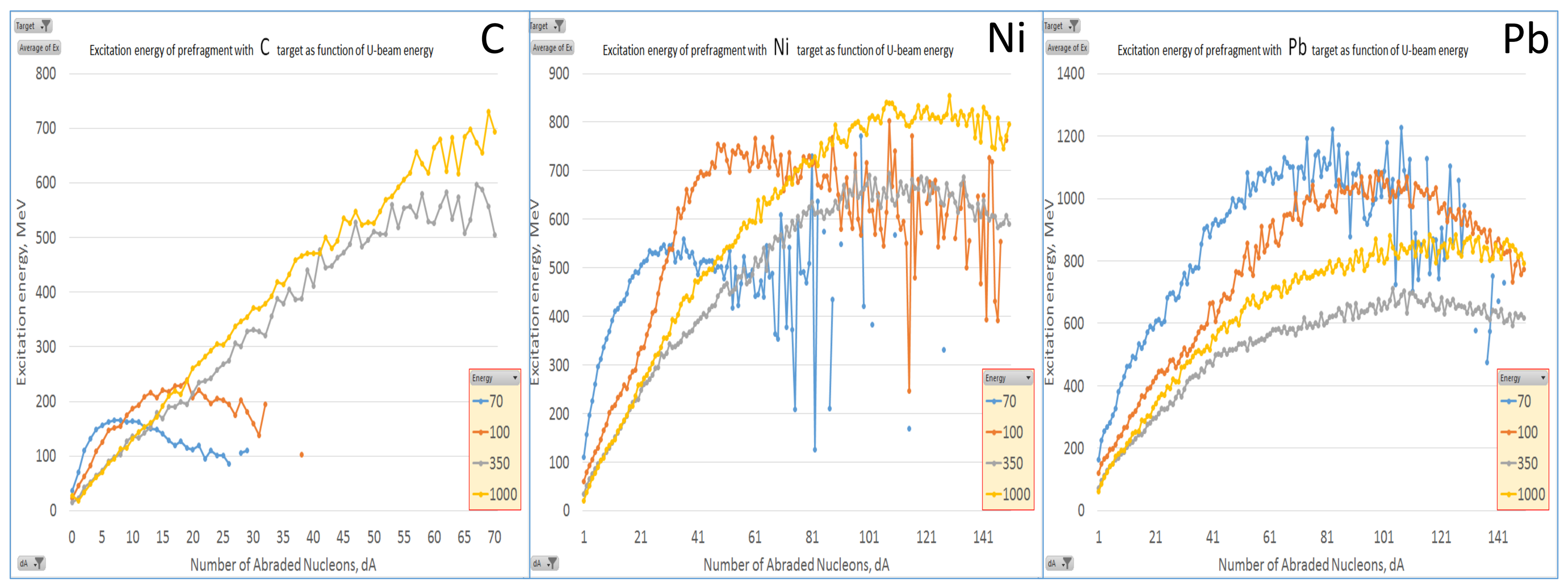
Reconstruction

The backtracking technique is widely used in spectrographs to get a momentum vector at the target using measured X, X', Y, Y', E ion values in the focal final plane and the inverse spectrograph map.

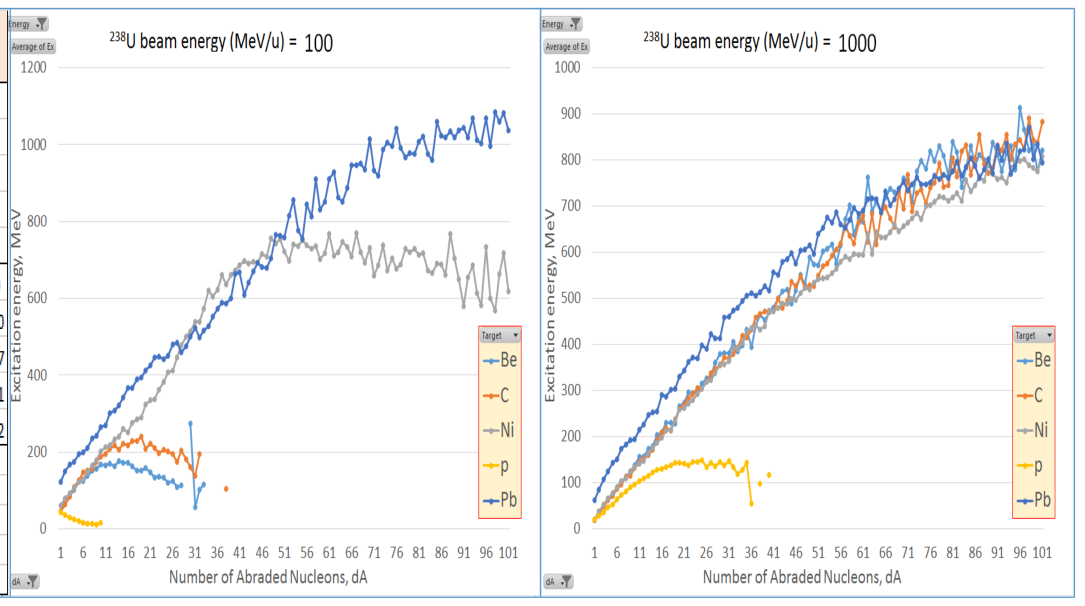



X'-Y'-velocity after target distributions of Kr isotopes produced recently in ^{238}U(80MeV/u) in-flight fission @ MSU

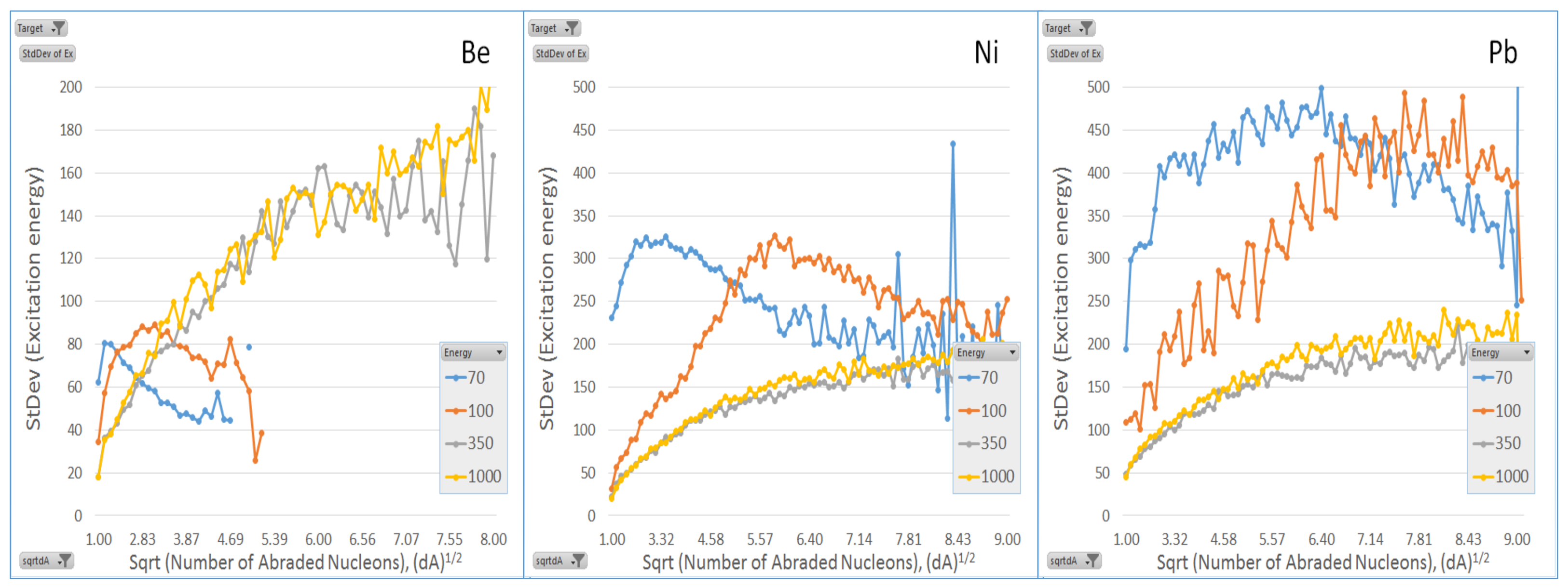
JQMD: mean excitation energy



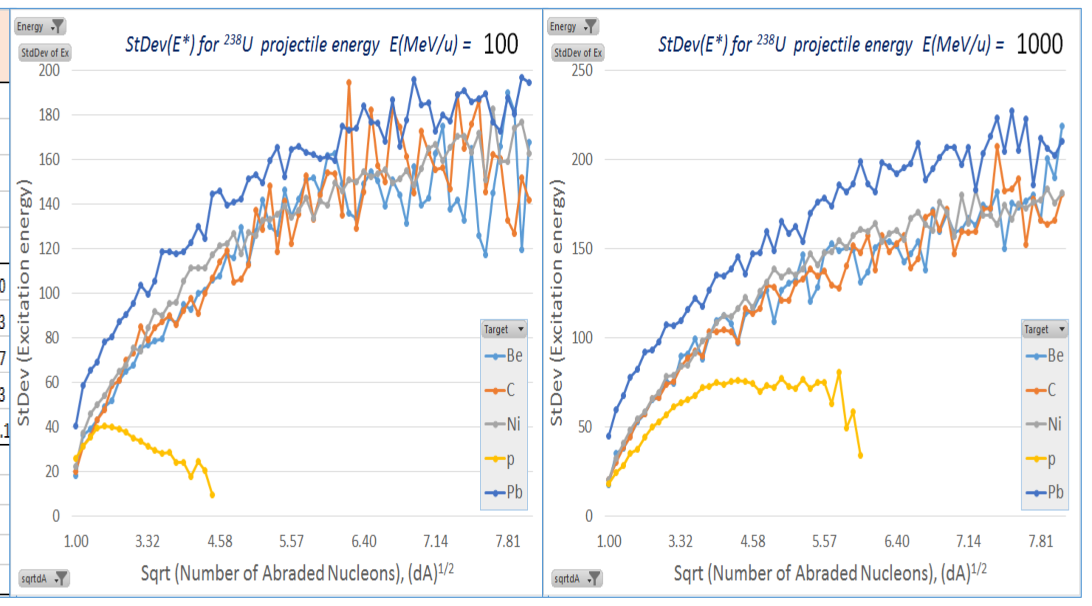
x=dA	target	^{238}U beam energy (MeV/u) 70	100	350	1000
linear trendline with 0-intercept	p			12.9x	9.5x
	Be	38.1x	19.3x	11.2x	12.8x
	C	37.5x	19.0x	11.1x	12.4x
	Ni	48.5x	16.7x	11.5x	12.3x
	Pb	36.4x	19.3x	14.0x	16.0x
linear trendline	p	-5.5x + 35.7	-5.7x + 47.7	7.6x + 23.0	8.0x + 14.0
	Be	20.4x + 53.1	12.9x + 44.3	10.3x + 20.9	12.2x + 14.0
	C	20.8x + 61.3	13.9x + 45.7	9.9x + 24.5	11.9x + 12.7
	Ni	32.0x + 93.3	14.9x + 38.4	9.9x + 34.3	11.5x + 17.1
	Pb	22.5x + 180.	13.0x + 132.	9.9x + 88.2	12.6x + 73.2
number of points used for trend	p	5	6	6	14
	Be	4	10	32	32
	C	5	13	31	32
	Ni	8	31	32	32
	Pb	19	31	32	32



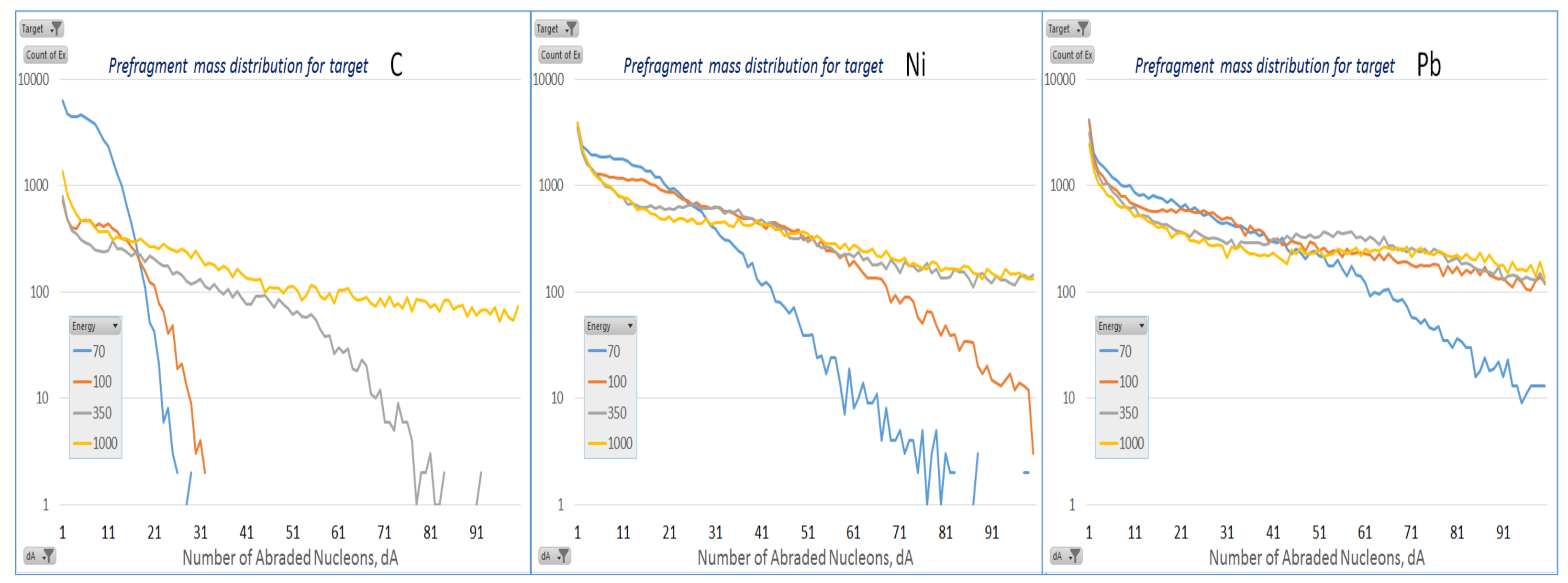
JQMD: excitation energy standard deviation

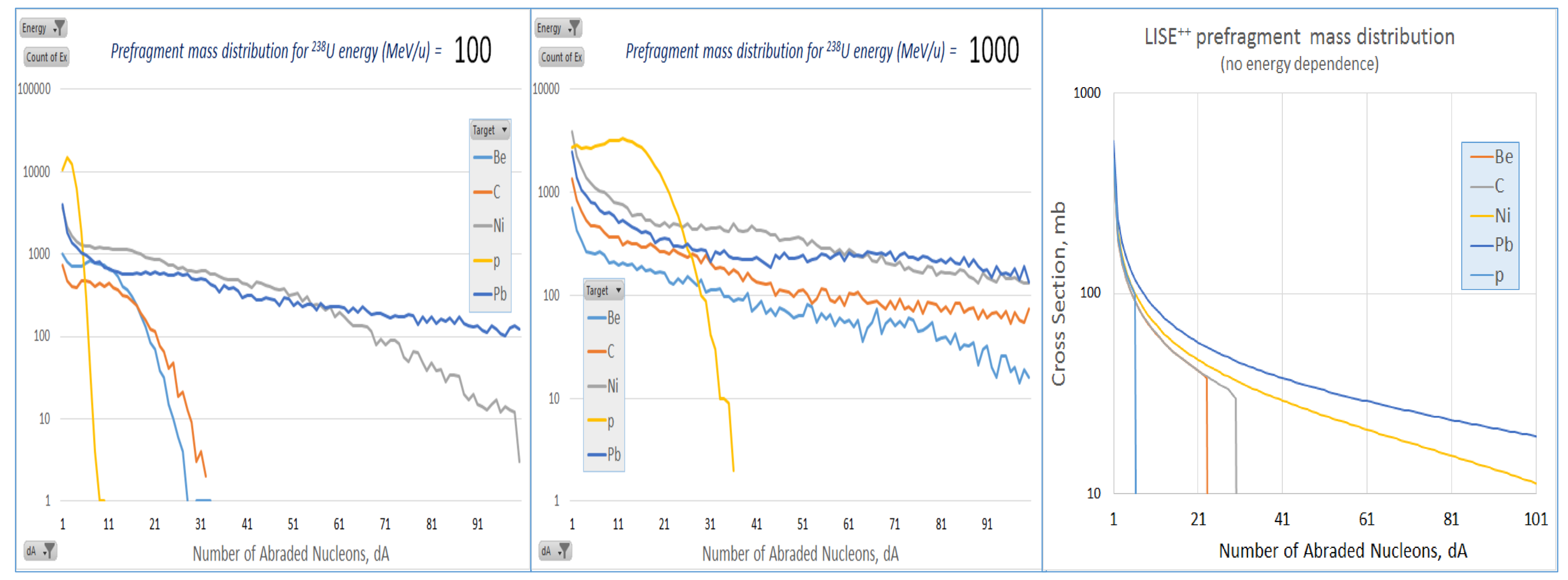


x=sqrt(dA)	target	^{238}U beam energy (MeV/u) 70	100	350	1000
linear trendline with 0-intercept	p			20.1x	18.7x
	Be		34.5x	24.2x	25.3x
	C		38.8x	23.9x	24.8x
	Ni	145.7x	40.3x	25.3x	26.4x
	Pb	98.5x	56.4x	30.4x	32.6x
linear trendline	p	-6.2x + 19.8	-8.0x + 29.0	12.8x + 13.1	20.1x - 4.0
	Be	-12.3x + 96.0	23.7x + 23.9	26.2x - 8.6	26.5x - 5.3
	C	-12.1x + 114.3	34.7x + 9.8	24.9x - 4.1	25.7x - 3.7
	Ni	80.6x + 126.2	41.8x - 4.8	25.1x + 0.9	28.3x - 8.3
	Pb	43.5x + 235.5	47.0x + 40.4	25.8x + 19.7	27.4x + 21.1
number of points used for trend	p	5	8	5	16
	Be	17	8	32	32
	C	22	9	32	32
	Ni	6	17	32	
	Pb	32	32	32	32



JQMD: prefragment mass distribution





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