

Experimental study on reactions in URANIUM AND TRANSURANIUM ISOTOPES IN THE NEUTRON FIELD OF THE QUINTA TARGET

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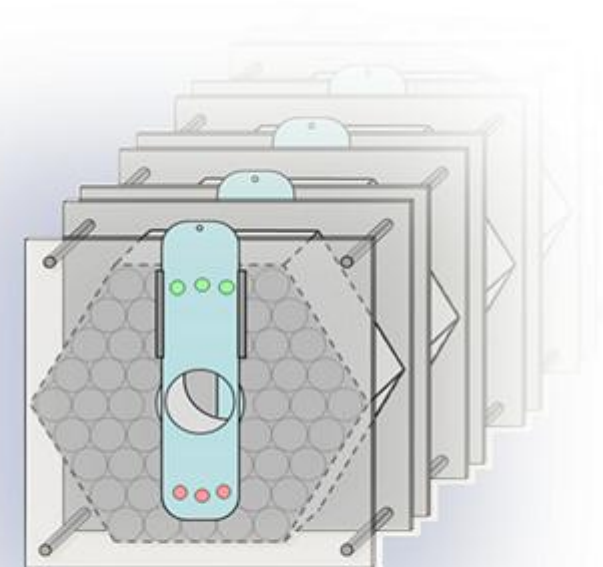
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«Energy and Transmutation - RAW»

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Objectives of the presentation

- Results of the experiment in Dec 2012
- Experimental samples:
 $^{127,129}\text{I}$, $^{\text{nat}}\text{Th}$, $^{\text{nat},233,235}\text{U}$, ^{237}Np ,
 $^{238,239}\text{Pu}$, ^{241}Am
- $E_d = 1, 2, 4 \text{ GeV/A}$

Transmutation reactions

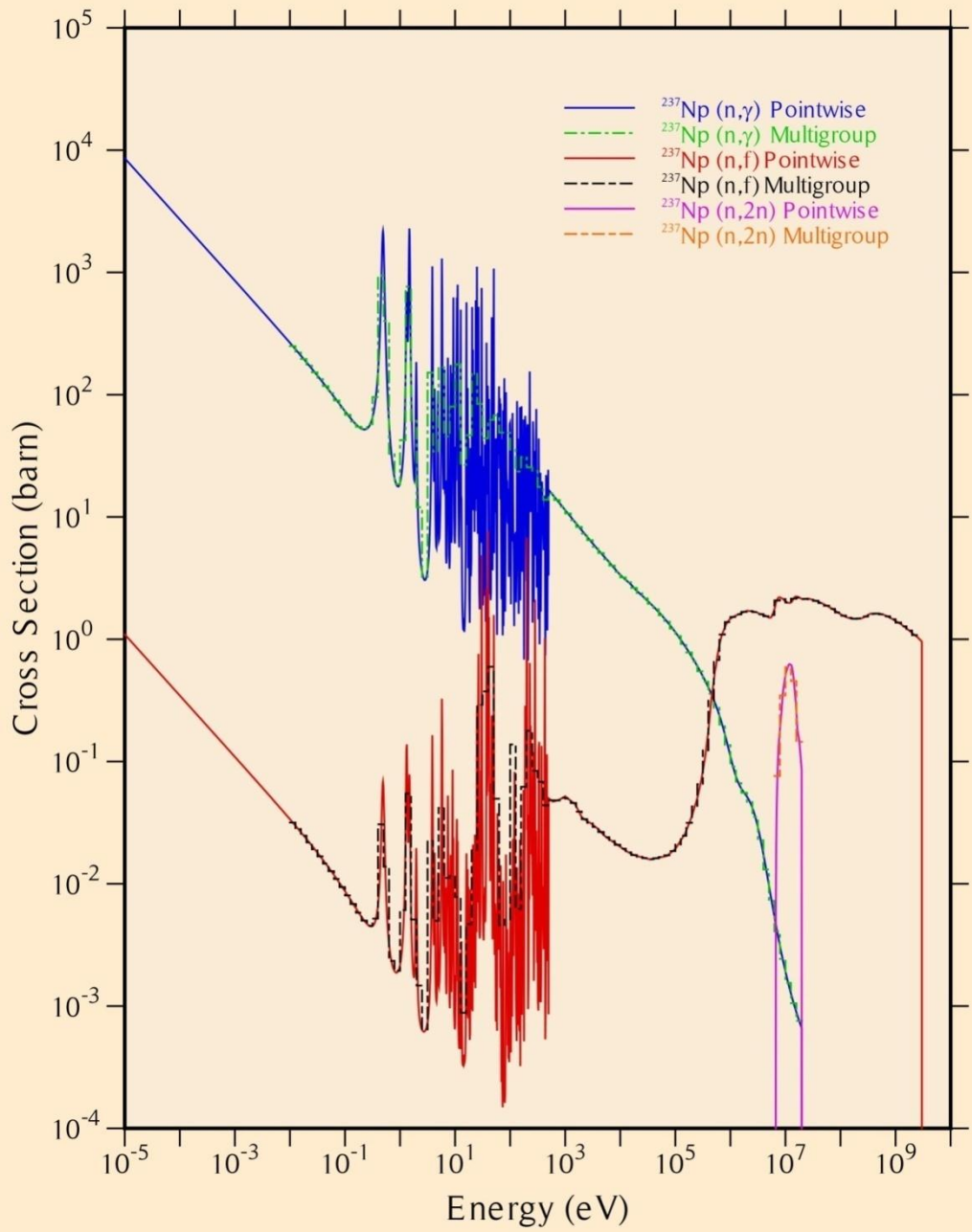
- Long-lived FP and TRU into short-lived or stable isotopes
- spallation reaction
- (n,f) fission
- (n,xn) nonelastic reaction
- (n, γ) radiative capture

Transmutation reactions

- Long-lived FP and TRU into short-lived or stable isotopes
- spallation reaction
- (n,f) fission
- (n,xn) nonelastic reaction
- (n, γ) radiative capture !
neutron consuming, \rightarrow higher TRU

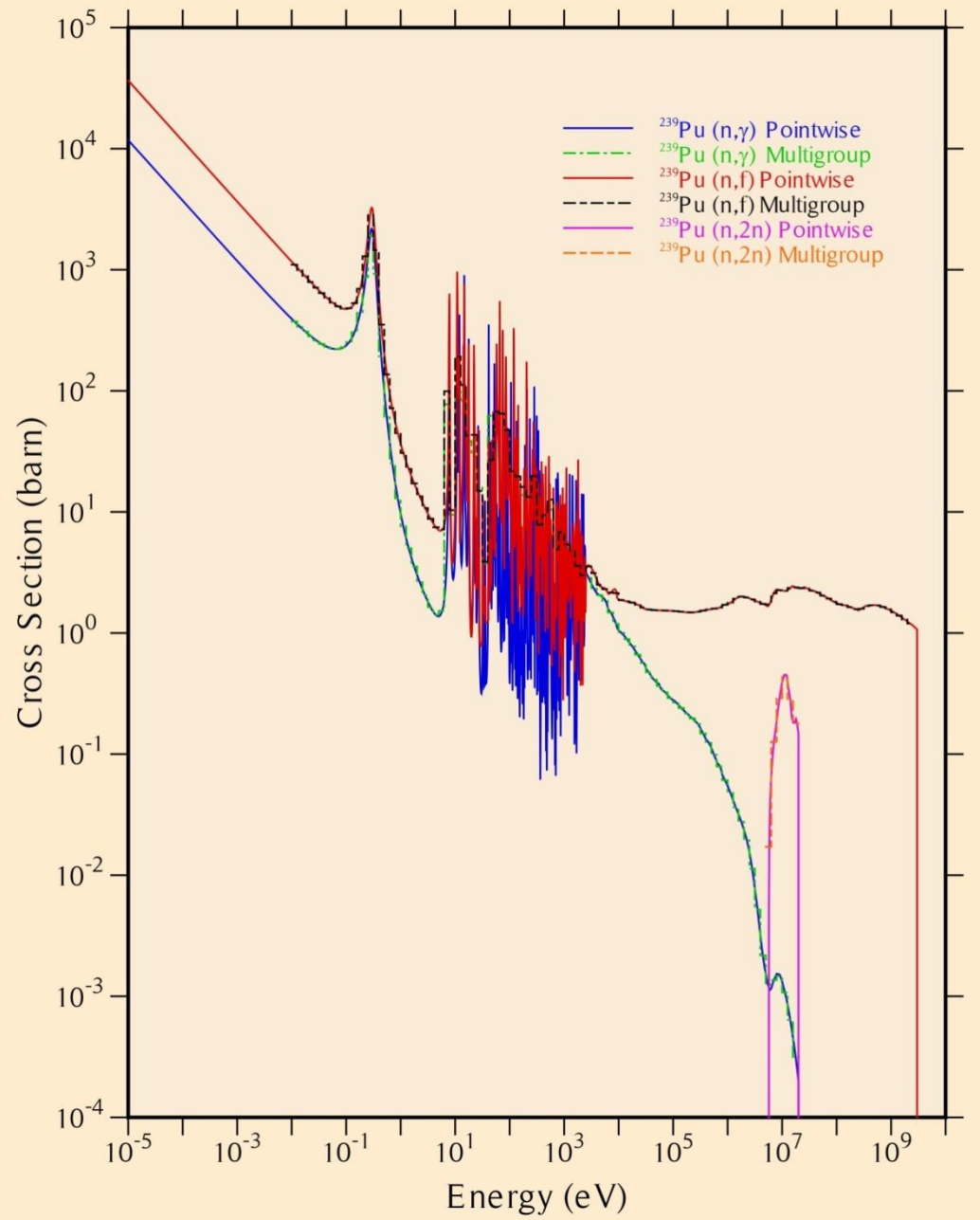
JENDL/HE-2007 Cross-Section Comparison

²³⁷Np (n,γ), (n,f), and (n,2n) XS

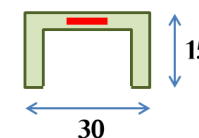
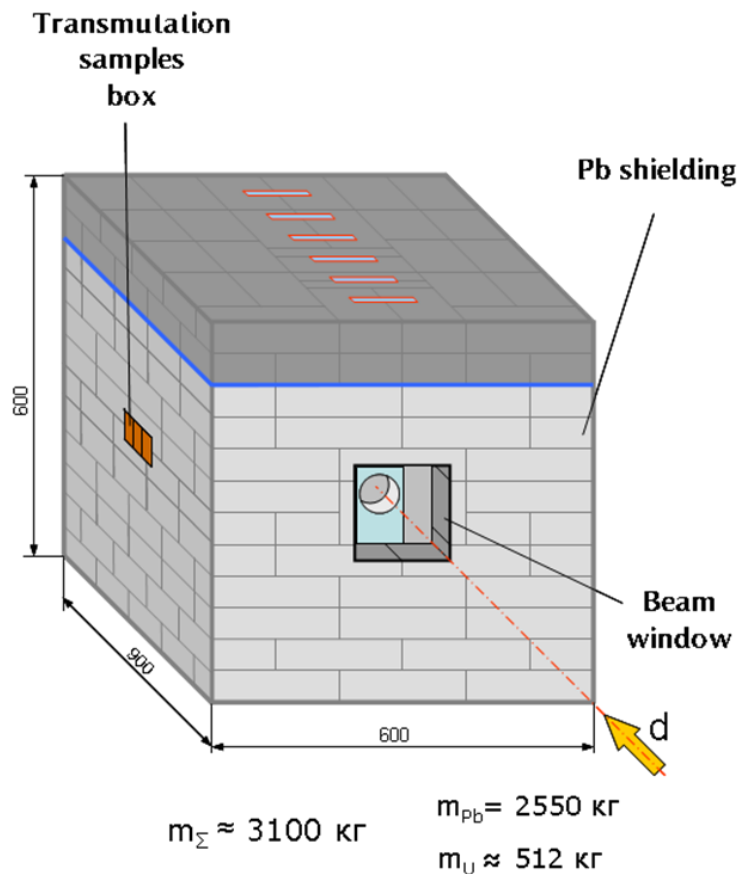


JENDL/HE-2007 Cross-Section Comparison

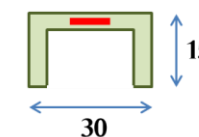
²³⁹Pu (n,γ), (n,f), and (n,2n) XS



46th Nuclotron run
December 2012



1 GeV/n
4 GeV/n



2 GeV/n



Experimental methods

- **Activation measurement technique**
- **Gamma spectroscopy with the use of HPGe detectors Canberra and ORTEC (20%, resp. 30% relative efficiency)**
Calibrated with standards made in 2011;
FEP improved by MCNPX simulation

Isotope identification

- **Half-life (≥ 10 measurements)**
- **Energy and intensity of gamma line**
- **Reaction rates calculated from measured activity**
- **Included corrections:**

decay during irradiation, cooling and measurement, dead time, detector efficiency, nonlinearity, beam instability, gamma line intensity, self-absorption, gamma coincidence summing, nonpoint-like source

²³⁵U Results

R-factor:

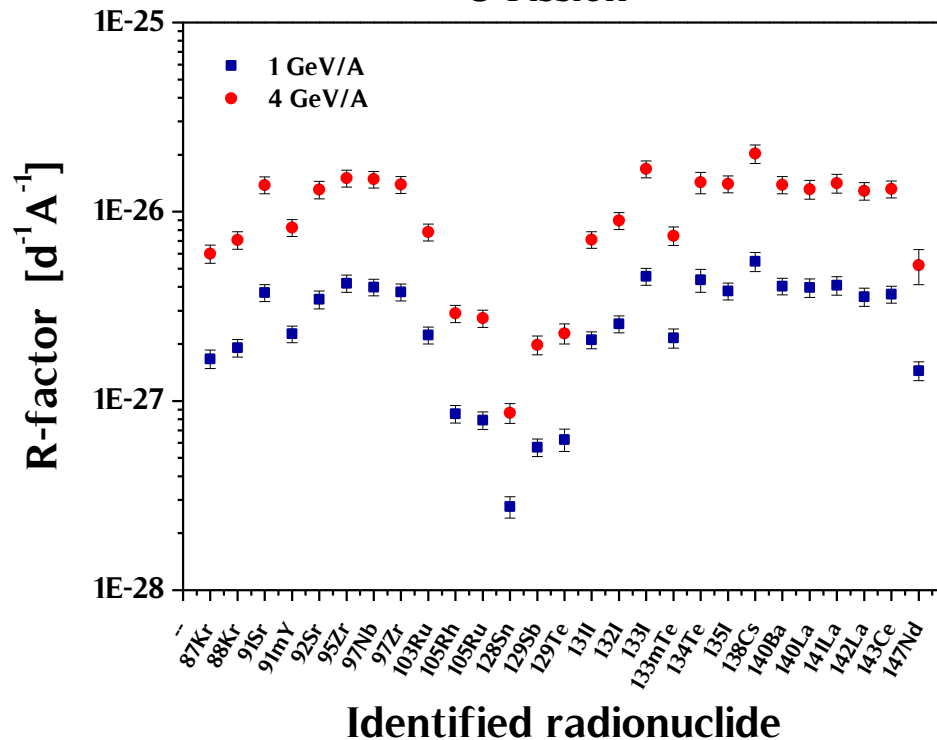
$$R(A_r, Z_r) = \frac{Q_a(A_r, Z_r)}{N_t \cdot N_d}$$

[deuteron⁻¹ atom⁻¹]

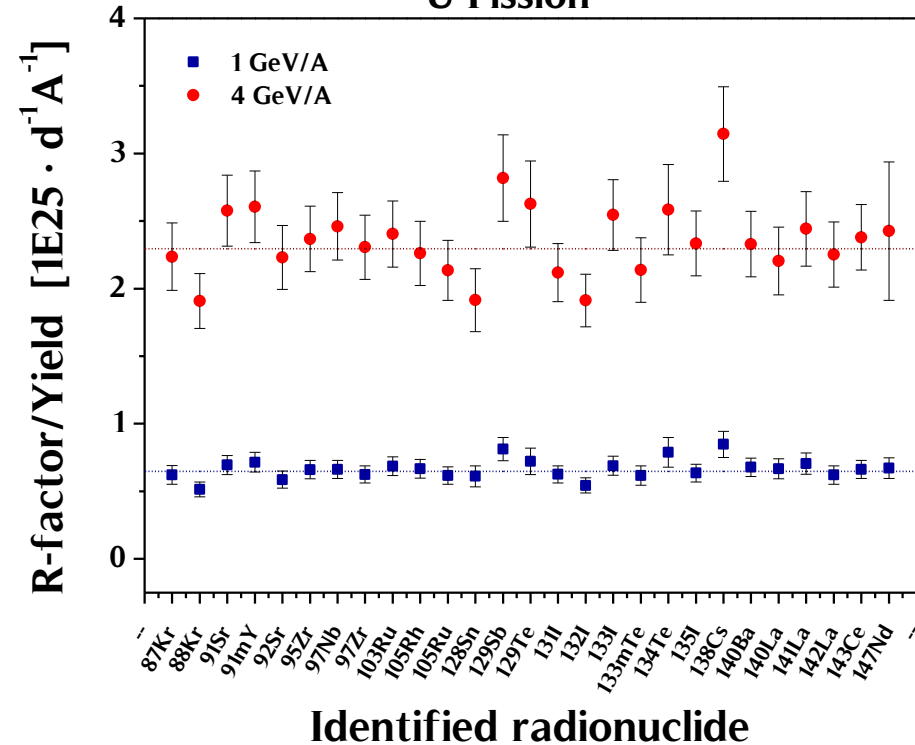
Cumulative yields:

ENDF/B-VII.1 500 keV

²³⁵U Fission



²³⁵U Fission



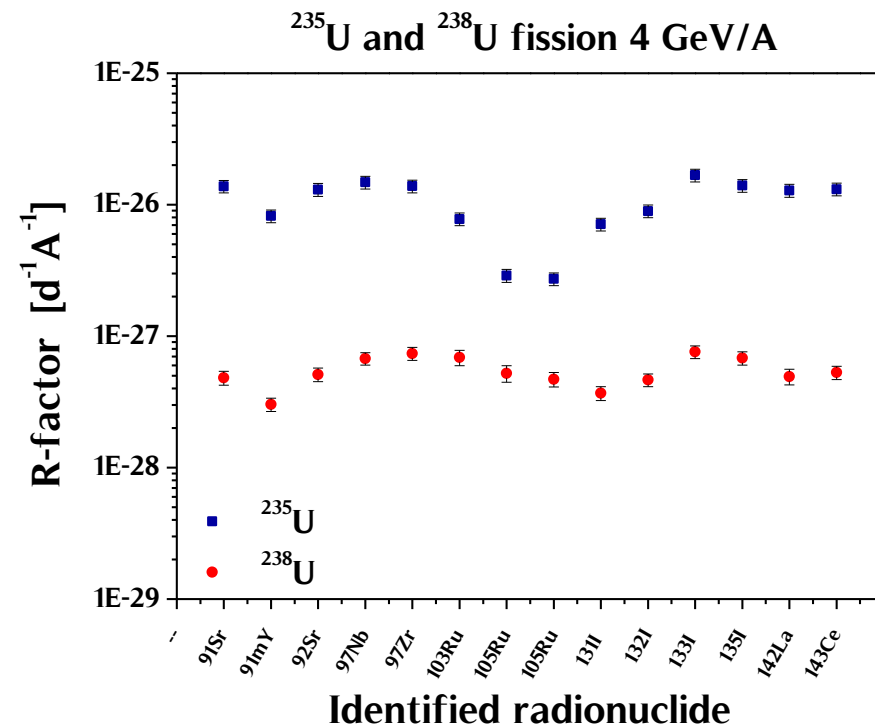
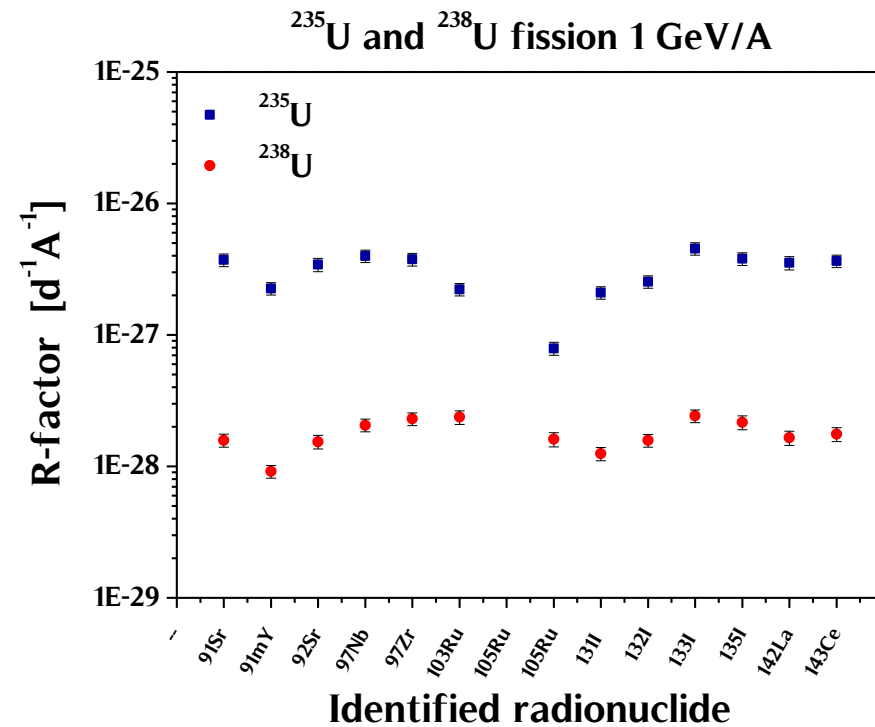
⁸⁷Kr
⁸⁸Kr
⁹¹Sr
^{91m}Y
⁹²Sr
⁹⁵Zr
⁹⁷Nb
⁹⁷Zr
¹⁰³Ru
¹⁰⁵Rh
¹⁰⁵Ru
¹²⁸Sn
¹²⁹Sb
¹²⁹Te
¹³¹I
¹³²I
¹³³I
^{133m}Te
¹³⁴Te
¹³⁵I
¹³⁸Cs
¹⁴⁰Ba
¹⁴⁰La
¹⁴¹La
¹⁴²La
¹⁴³Ce
¹⁴⁷Nd

235,238U results

235U fission in natU:

	r = 20		r = 0
	EXP	CALC	CALC
1 GeV/A	0.13(4)	0.14	0.03
4 GeV/A	0.15(5)	-	0.04
AVG:	0.13(4)	0.14	0.04

MCNPX: **Very good agreement**



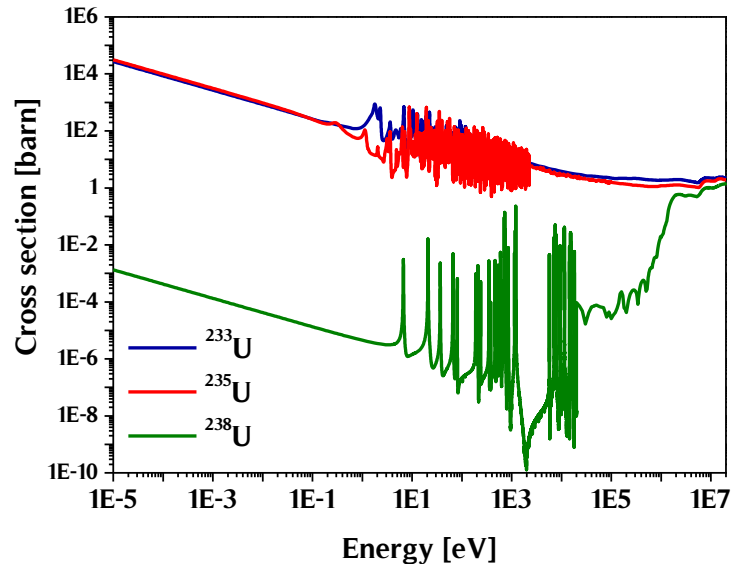
- ⁹¹Sr
- ^{91m}Y
- ⁹²Sr
- ⁹⁷Nb
- ⁹⁷Zr
- ¹⁰³Ru
- ¹⁰⁵Rh
- ¹⁰⁵Ru
- ¹³¹I
- ¹³²I
- ¹³³I
- ¹³⁵I
- ¹⁴²La
- ¹⁴³Ce

^{233}U Results

FISSION / 1 GeV in ^{233}U

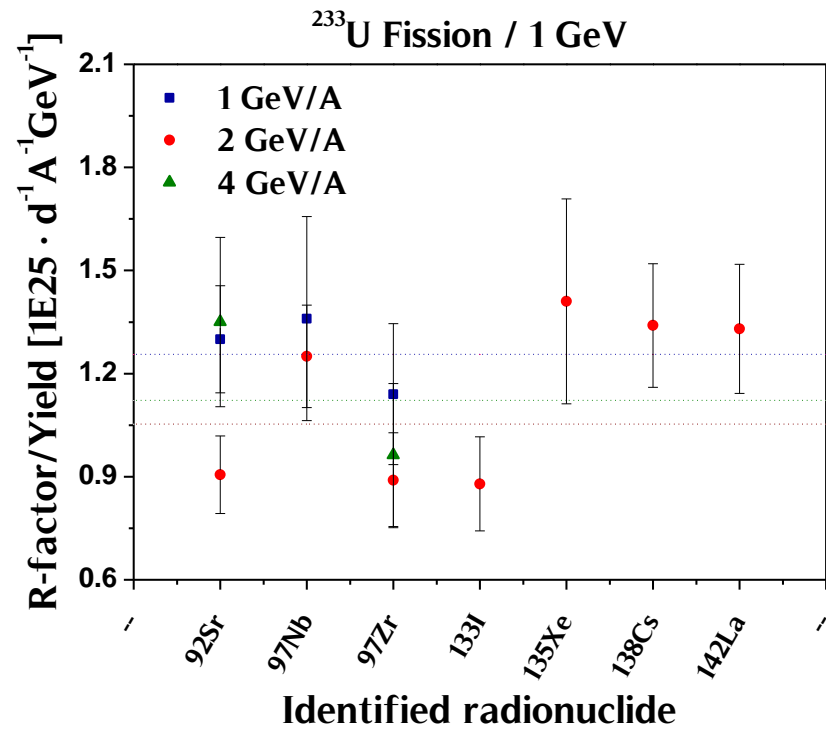
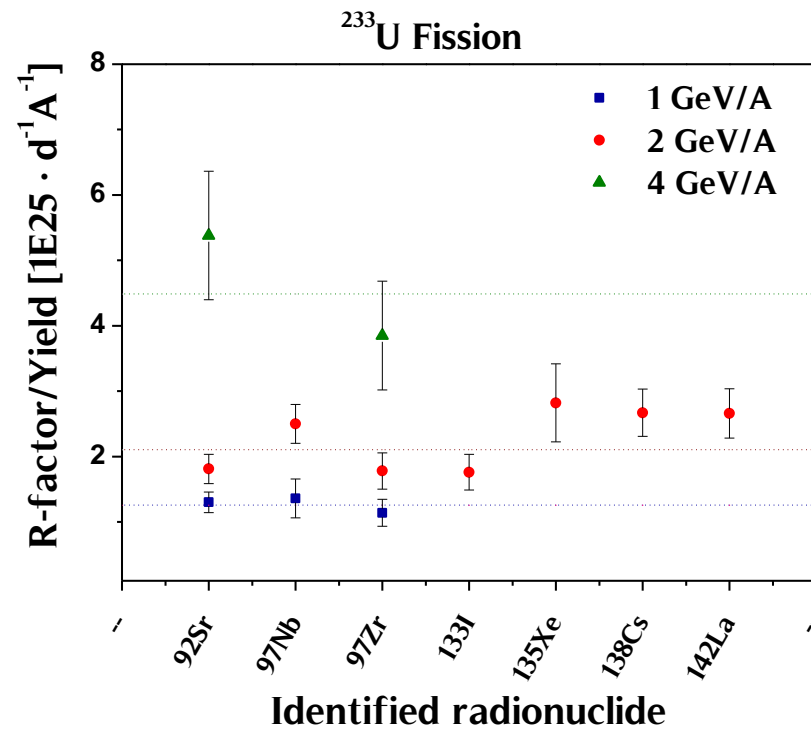
	R·1E27
1 GeV/A	125(19)
2 GeV/A	105(16)
4 GeV/A	112(22)

JEFF 3.1.1 (n,f) Cross section



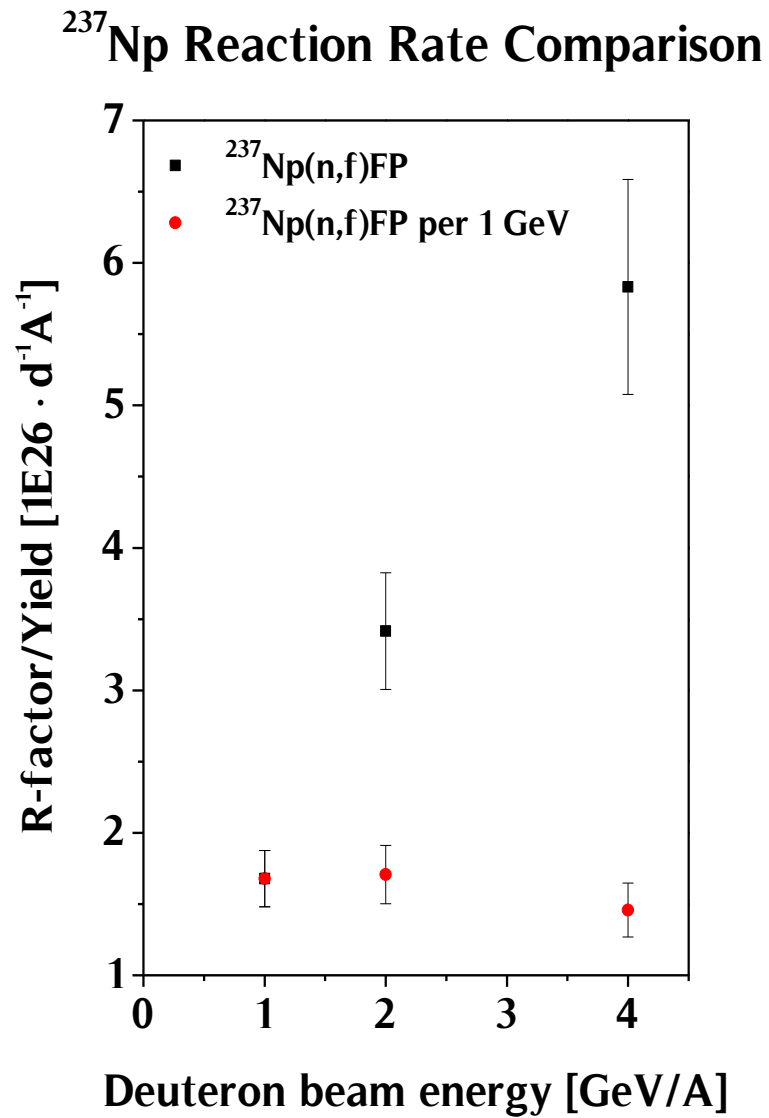
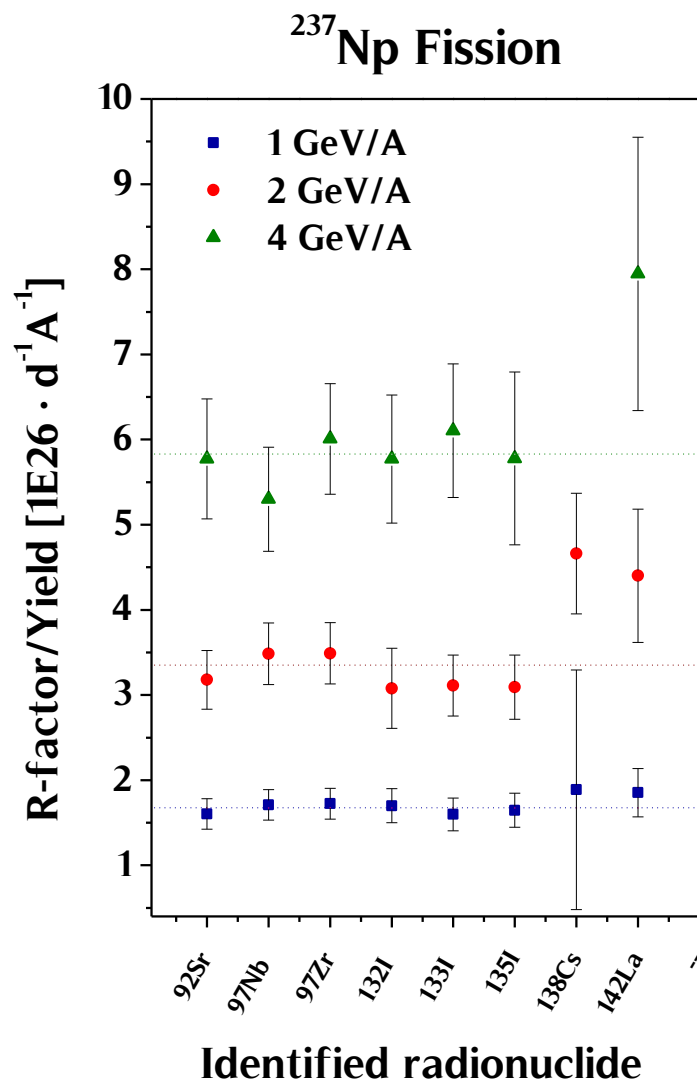
FISSION / 1 GeV in URANIUM

R·1E27	^{233}U	^{235}U	^{238}U
1 GeV/A	125(19)	65(7)	3.7(5)



^{92}Sr
 ^{97}Nb
 ^{97}Zr
 ^{133}I
 ^{135}Xe
 ^{138}Cs
 ^{142}La

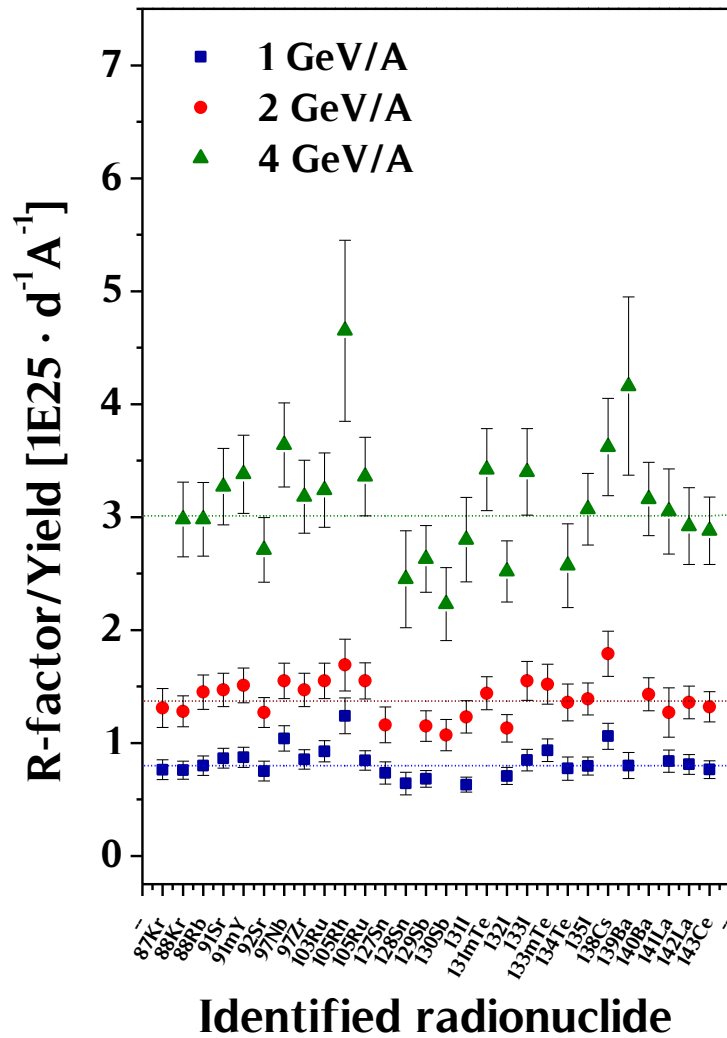
^{237}Np Results



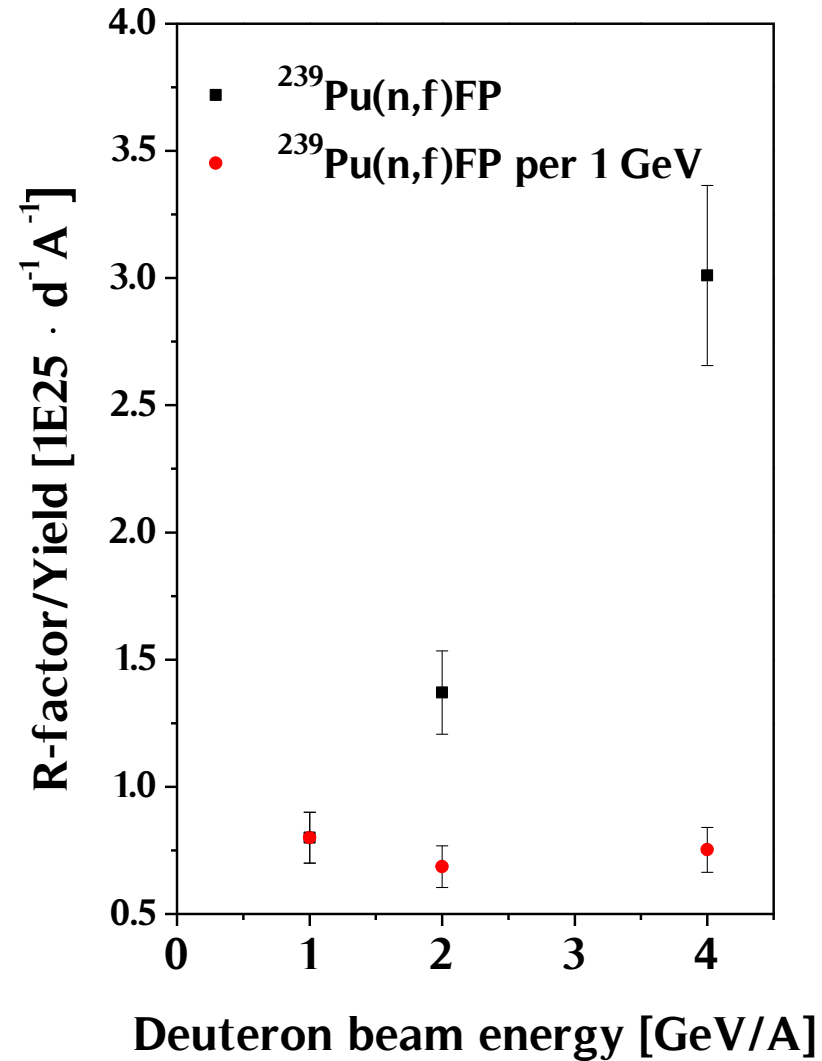
^{92}Sr
 ^{97}Nb
 ^{97}Zr
 ^{132}I
 ^{133}I
 ^{135}I
 ^{138}Cs
 ^{142}La

^{239}Pu Results

^{239}Pu Fission



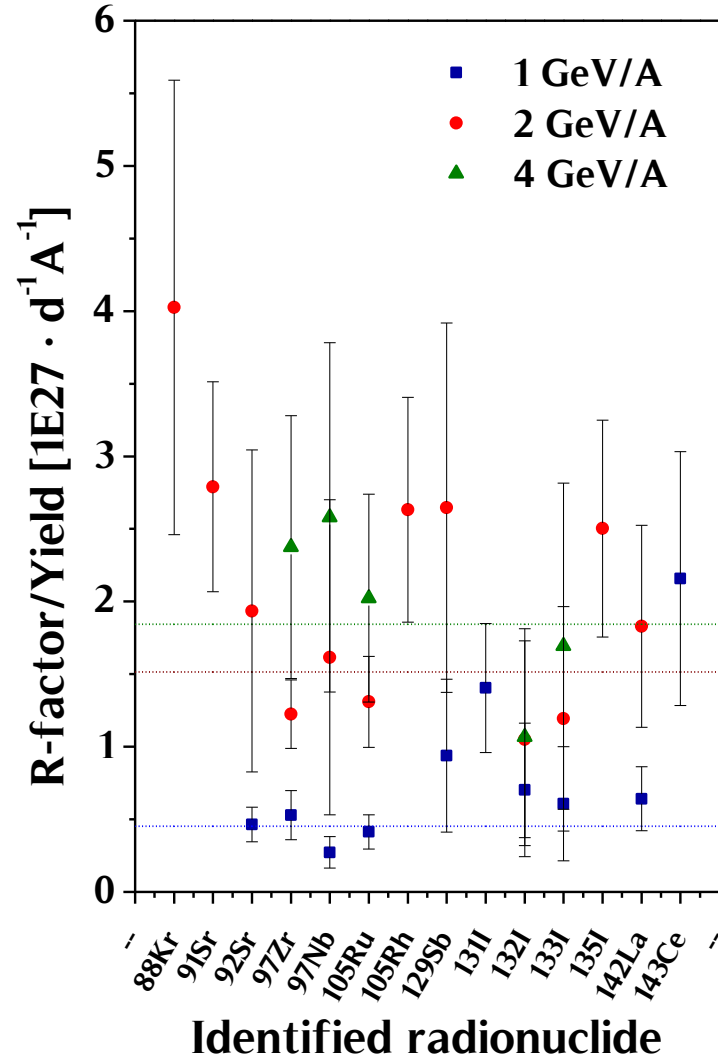
^{239}Pu Reaction Rate Comparison



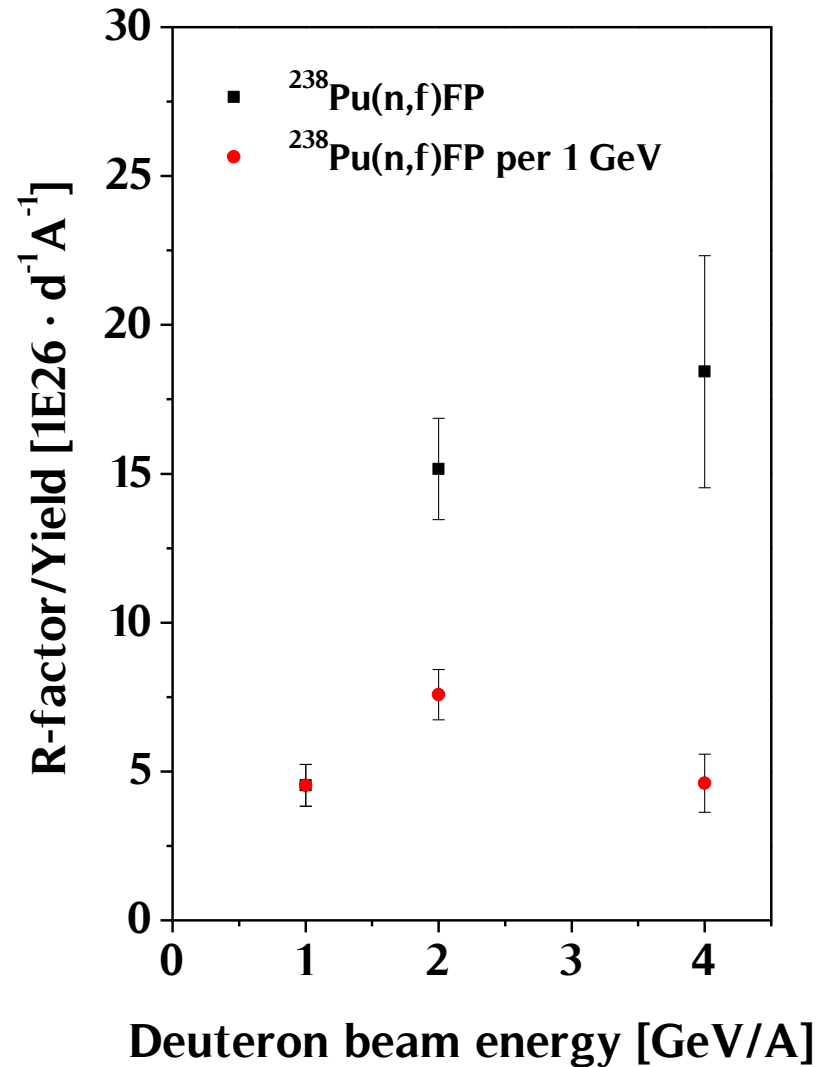
- ^{87}Kr
- ^{88}Kr
- ^{88}Rb
- ^{91}Sr
- $^{91\text{m}}\text{Y}$
- ^{92}Sr
- ^{92}Zr
- ^{103}Ru
- ^{105}Rh
- ^{105}Ru
- ^{128}Sn
- ^{129}Sb
- ^{130}Sb
- ^{131}I
- $^{131\text{m}}\text{Te}$
- ^{132}I
- ^{133}I
- $^{133\text{m}}\text{Te}$
- ^{134}Te
- ^{135}I
- ^{138}Cs
- ^{139}Ba
- ^{140}Ba
- ^{141}La
- ^{142}La
- ^{143}Ce

^{238}Pu Results

^{238}Pu Fission



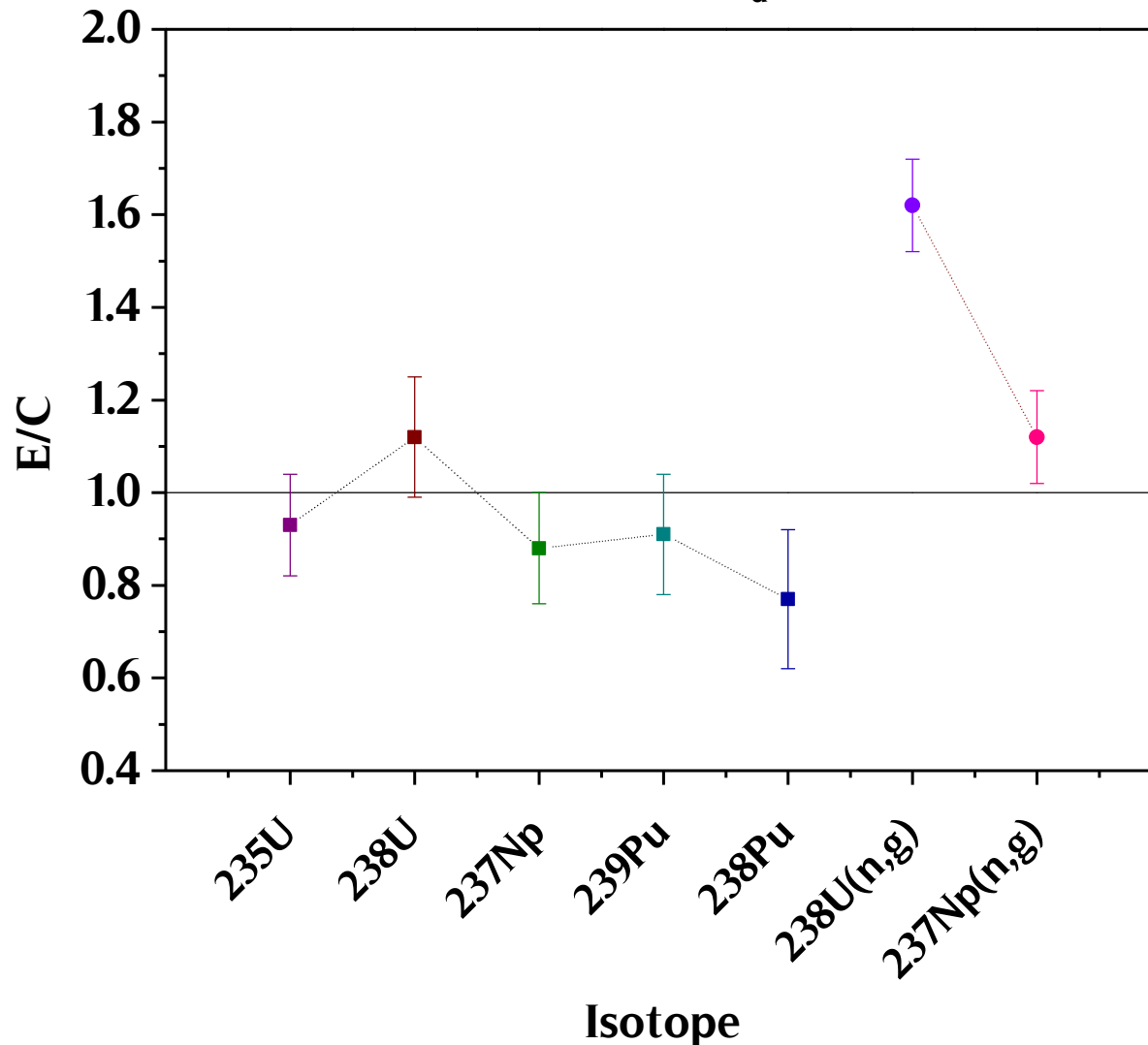
^{238}Pu Reaction Rate Comparison



^{88}Kr
 ^{91}Sr
 ^{92}Sr
 ^{97}Zr
 ^{97}Nb
 ^{105}Rh
 ^{105}Ru
 ^{129}Sb
 ^{131}I
 ^{132}I
 ^{133}I
 ^{135}I
 ^{142}La
 ^{143}Ce

Experiment vs. calculation

E/C Comparison $E_d = 1 \text{ GeV/A}$



$$R = \int_{E_0}^{E_{\max}} \sigma \cdot \phi \, dE$$

Neutron spectra:

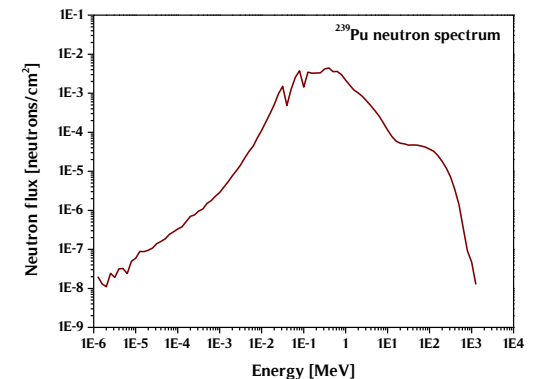
MCNPX 2.7

(INCL4/ABLA)

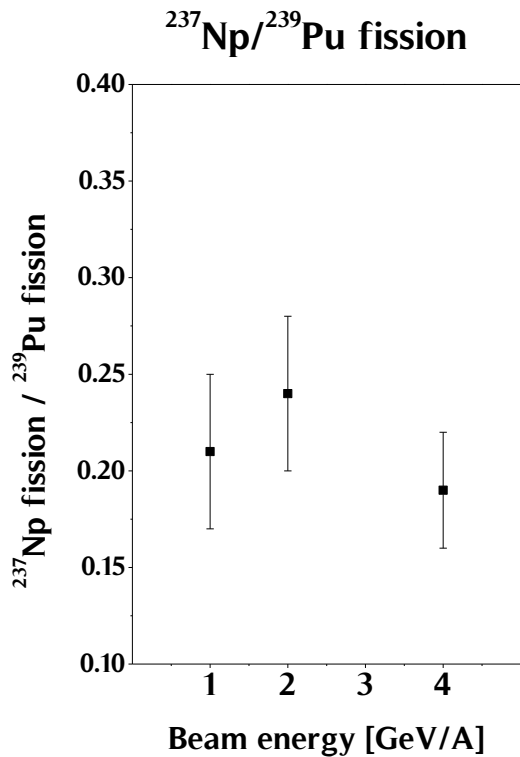
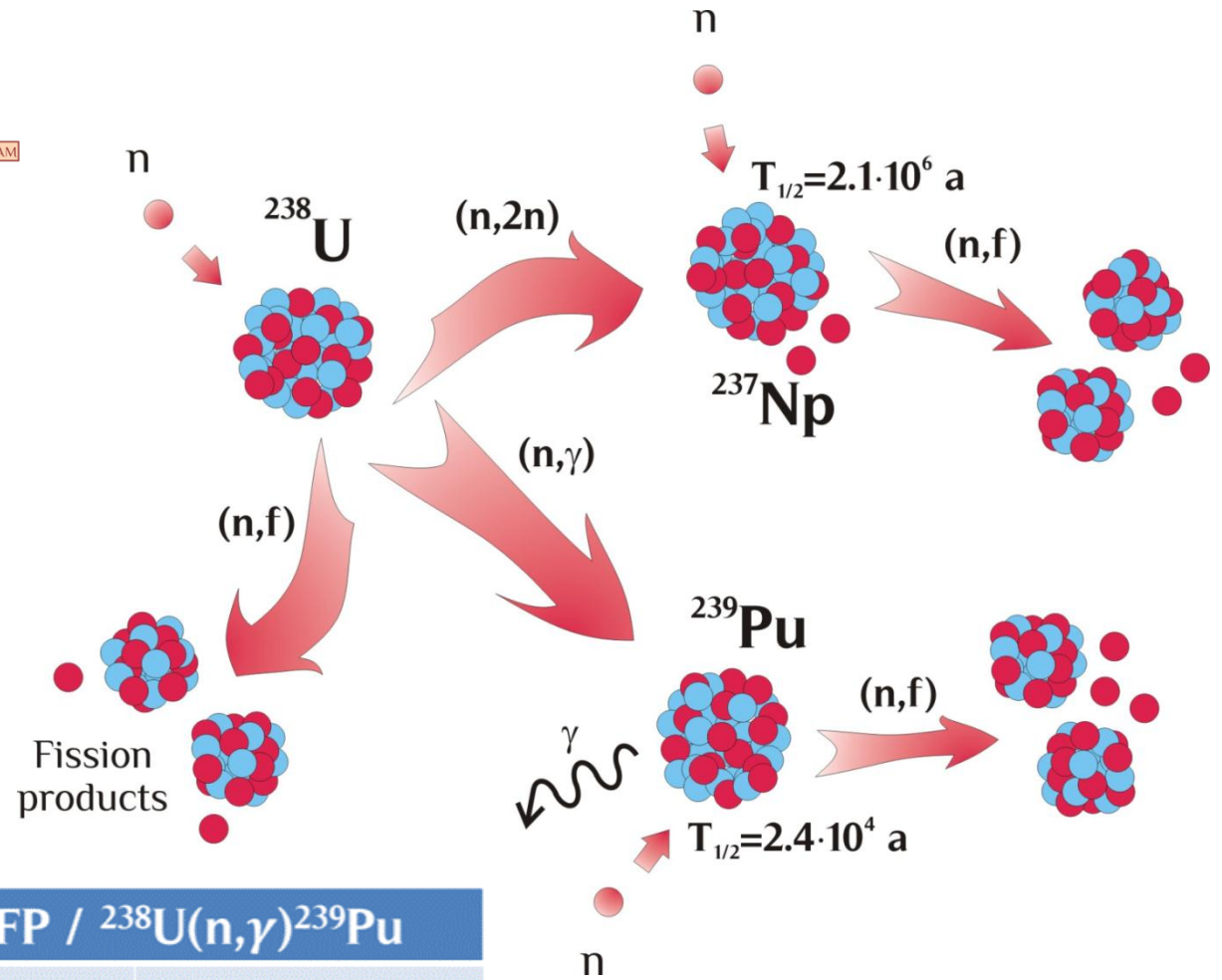
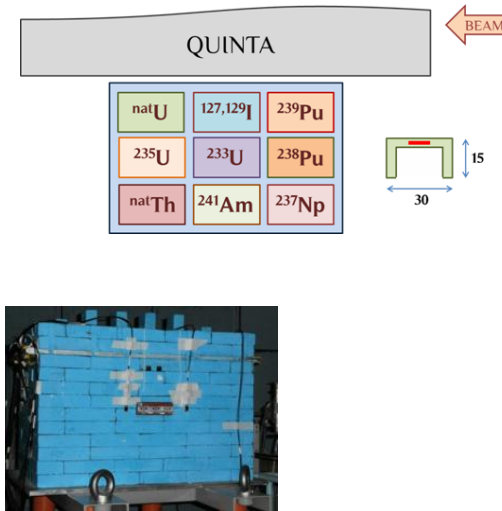
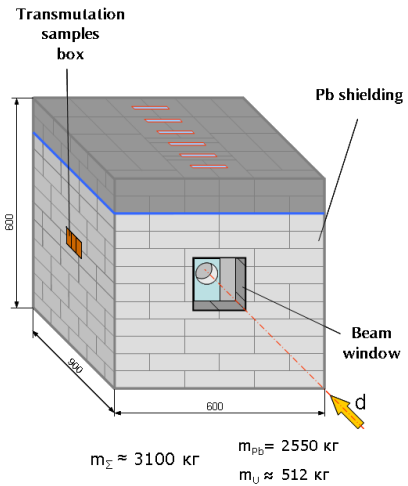
Cross section:

NJOY 99.112

(JENDL/HE-2007)



Conclusion



$^{239}\text{Pu}(n,f)\text{FP} / ^{238}\text{U}(n,\gamma)^{239}\text{Pu}$	
1 GeV/A	5.8(8)
2 GeV/A	6.8(10)
4 GeV/A	7.1(11)

FISSION / 1 GeV in URANIUM, NEPTUNIUM, and PLUTONIUM						
R · 1E27	^{233}U	^{235}U	^{238}U	^{237}Np	^{238}Pu	^{239}Pu
1 GeV/A	125(19)	65(7)	3.7(5)	17(2)	45(15)	80(10)

**Thank you for
your attention.**

