Status of ^{235}U evaluation in the high energy region

P. Romain, B. Morillon, H. Duarte
CEA,DAM,DIF
F-91297 Arpajon, France
1 2

CEA/DAM/DIF

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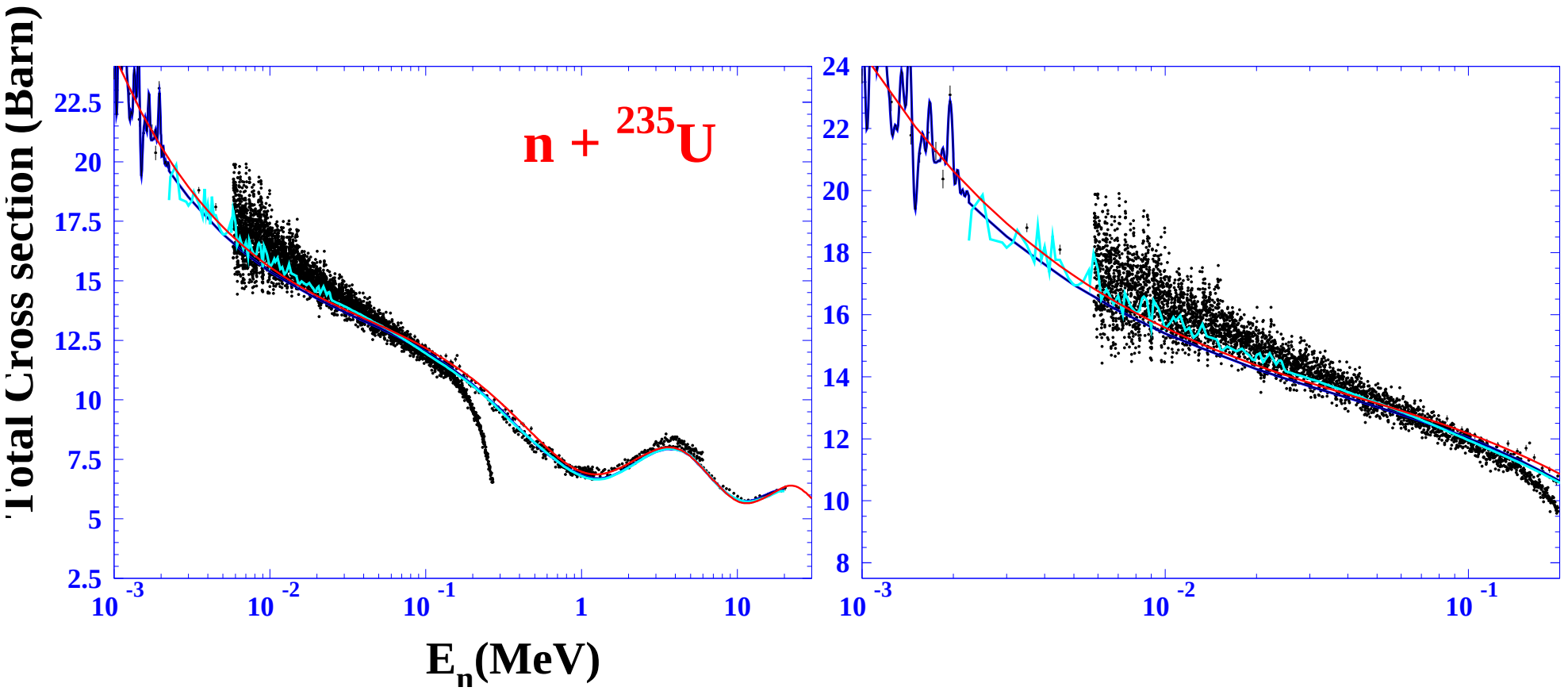
1. **All the calculations presented here were done with the TALYS code**
2. **and benchmarking with the MCNP5 code**

Modeling : OM + SM calculations ...

For ^{235}U isotope,

Just to show the results ...

Total Coss Sections

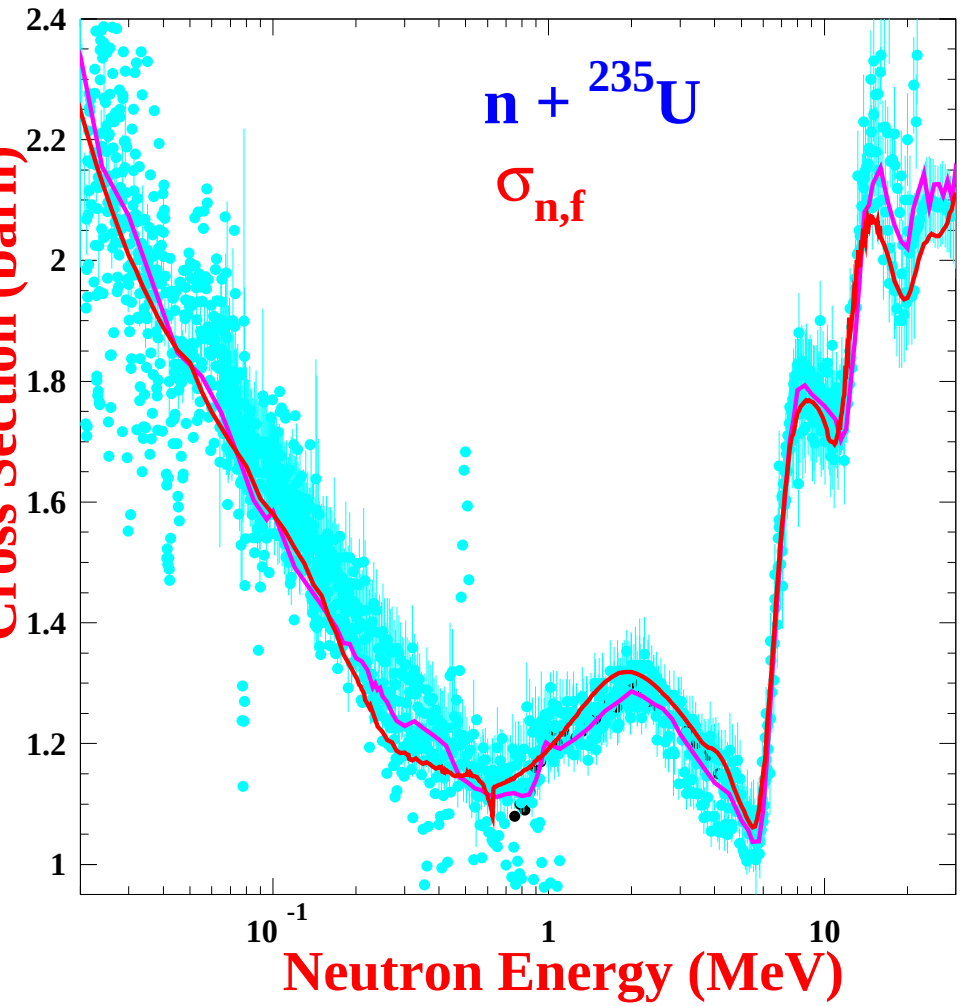


ENDF/B-VII.1

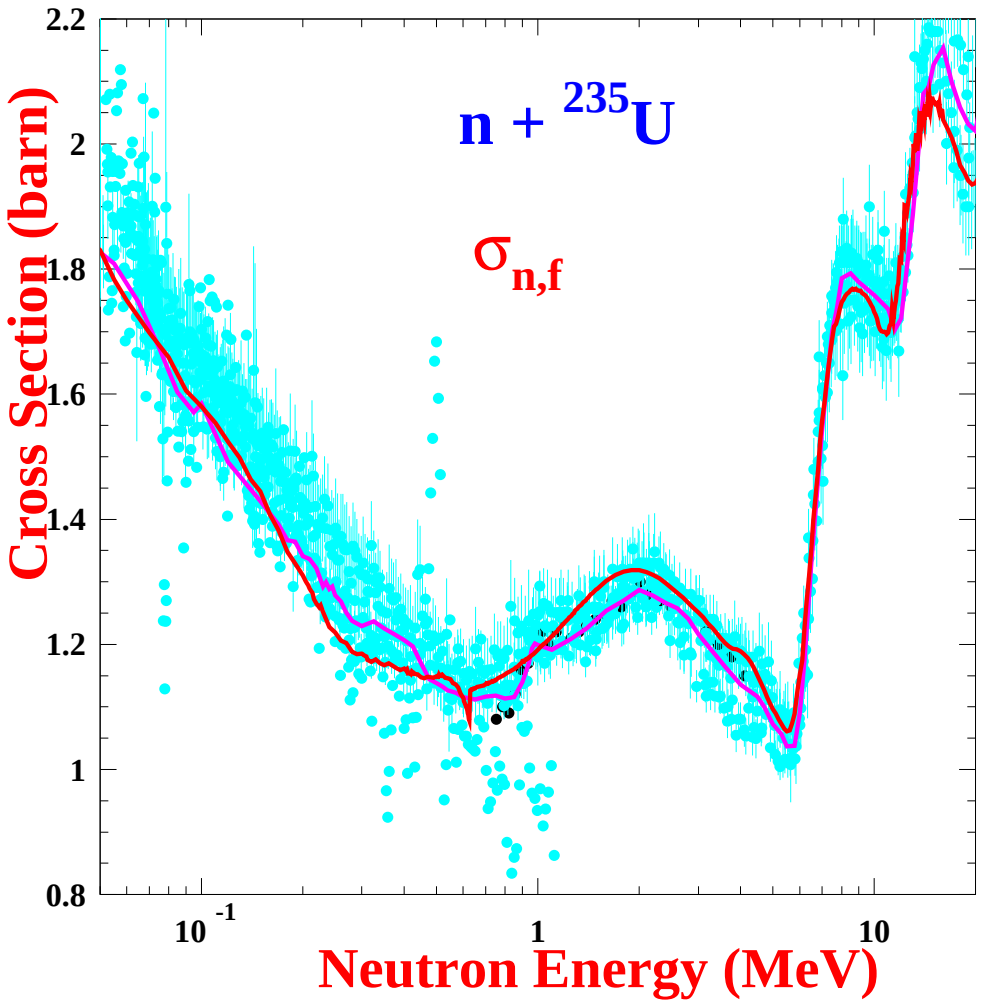
JENDL4.0

BRCweek38

Fission Coss Sections

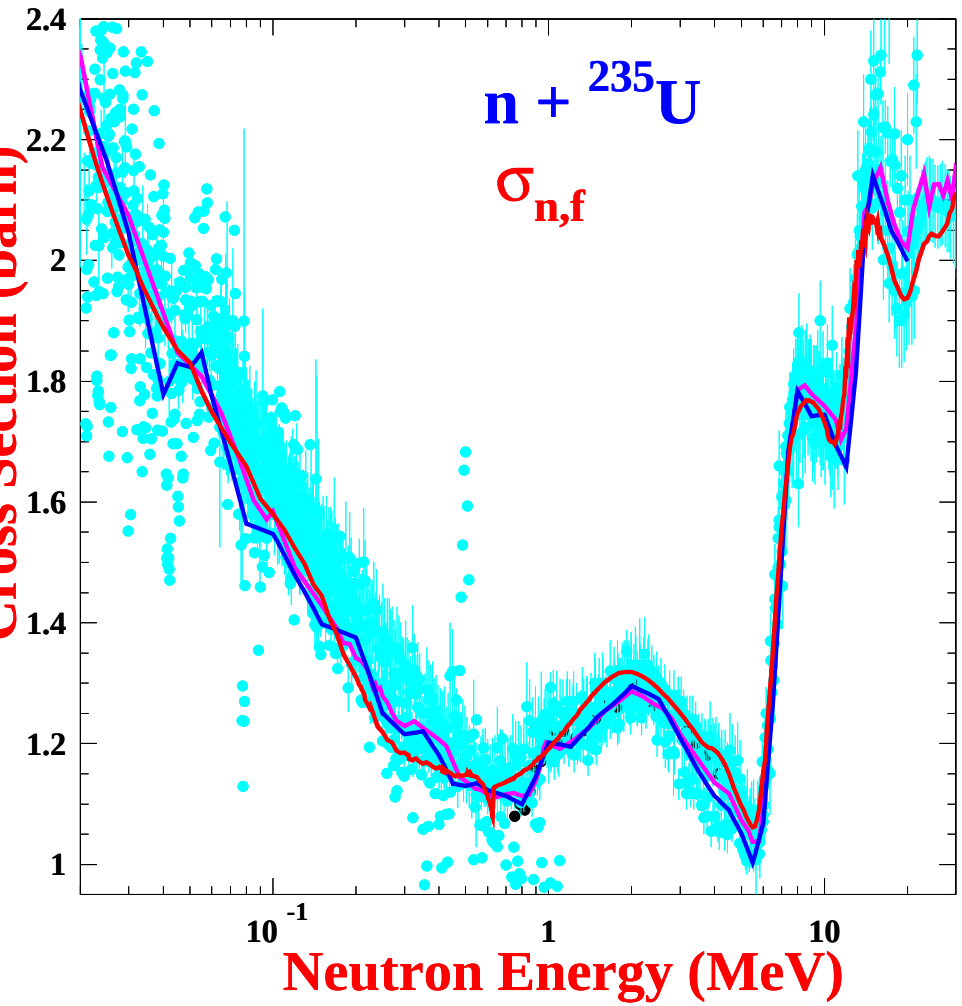


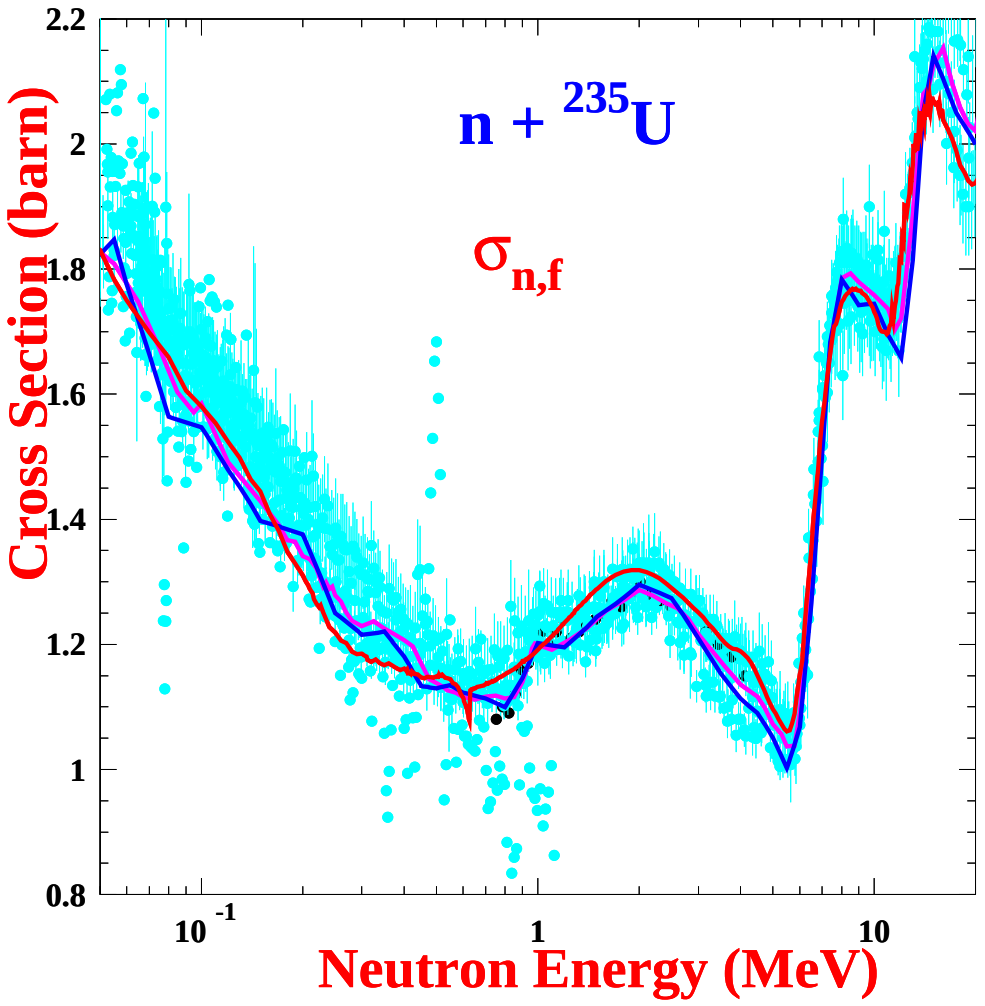
IAEA's standard



BRCweek38

Fission Coss Sections

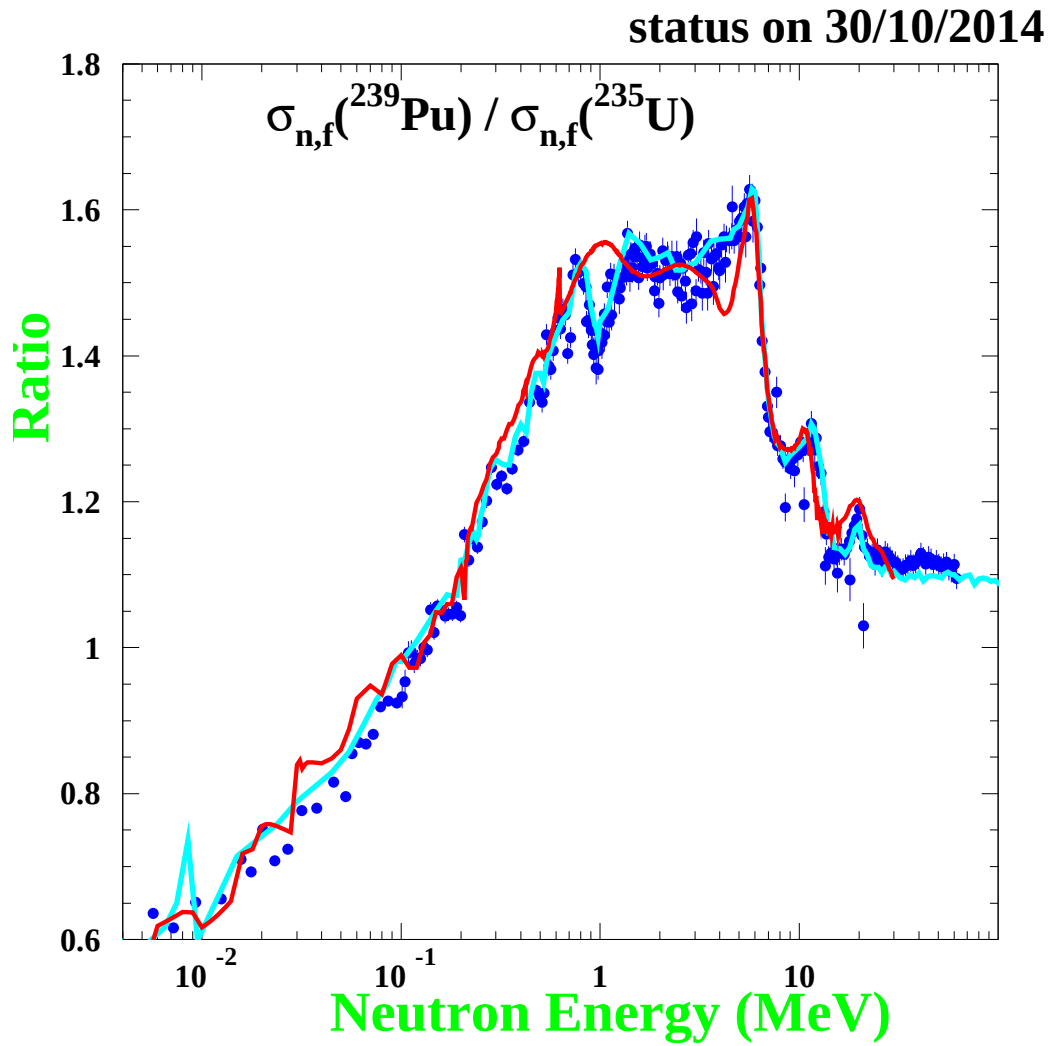




IAEA's standard BRCweek38

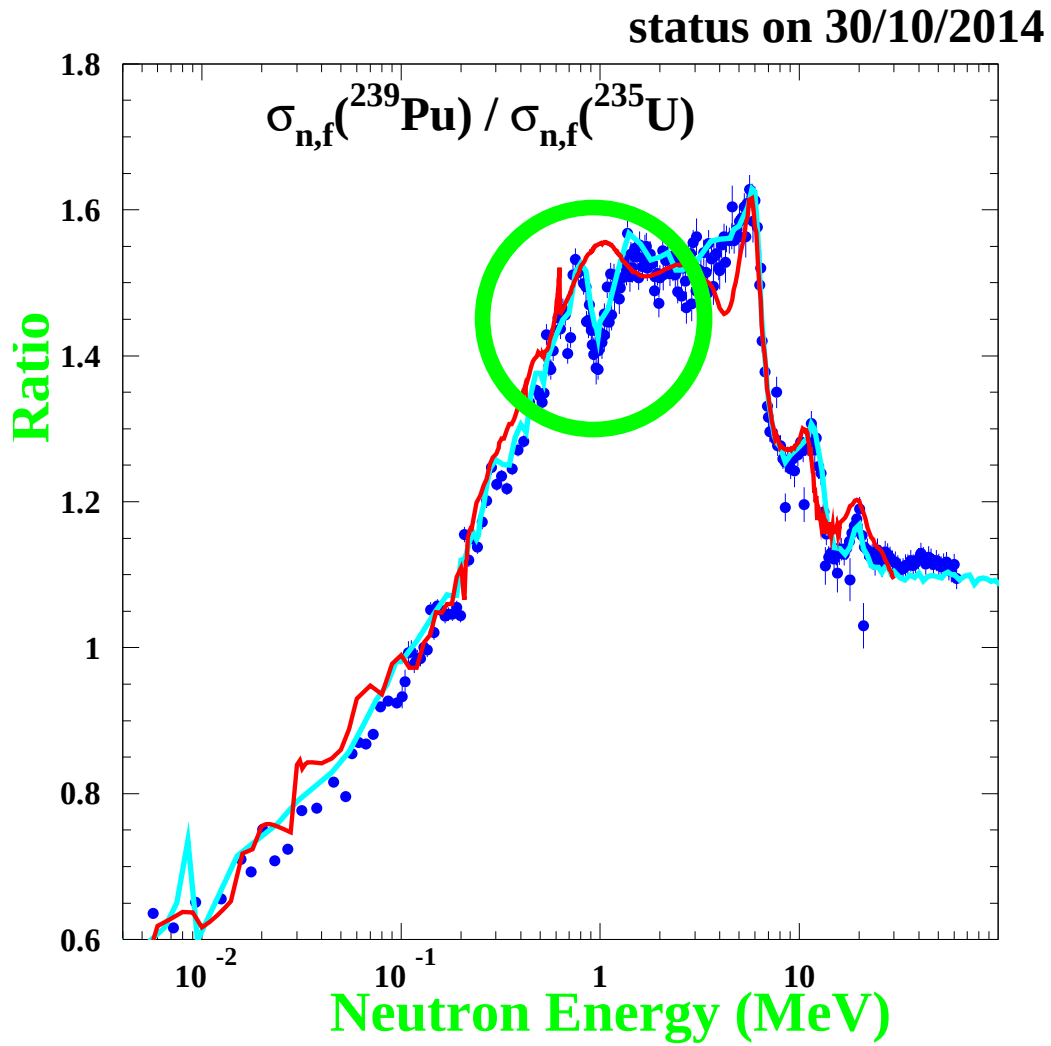
JENDL4.0

Fission Coss Sections



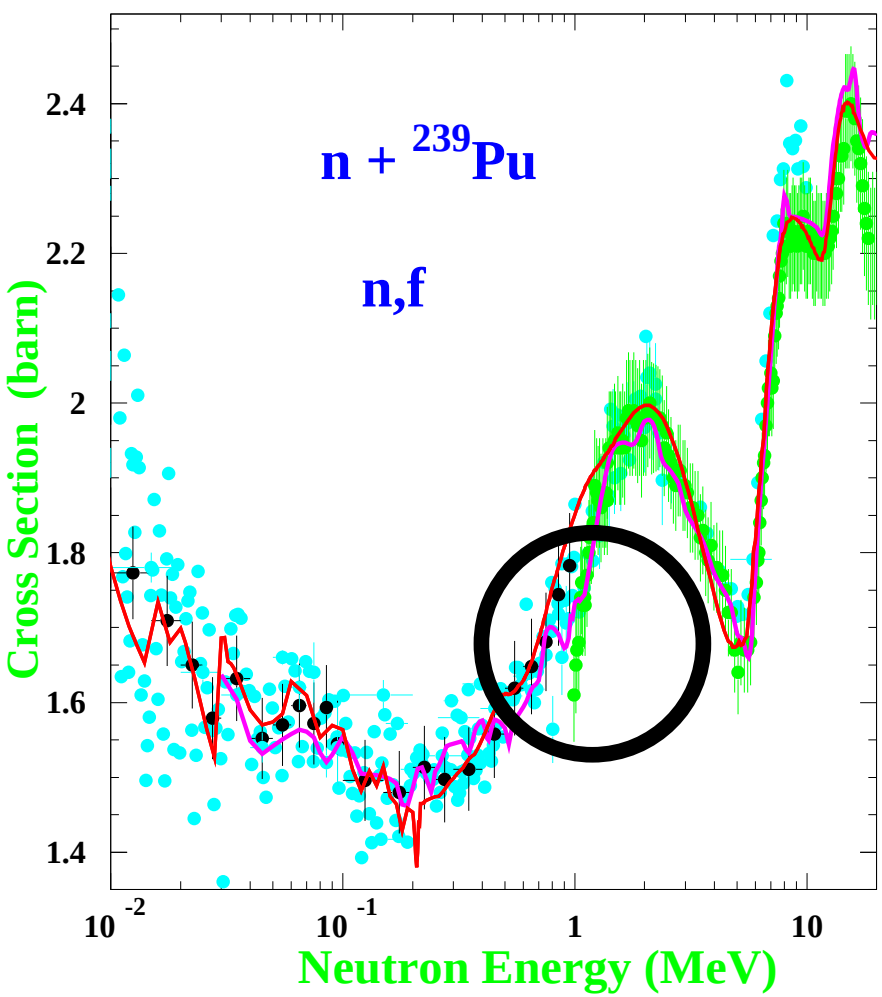
IAEA's standards BRCweek38

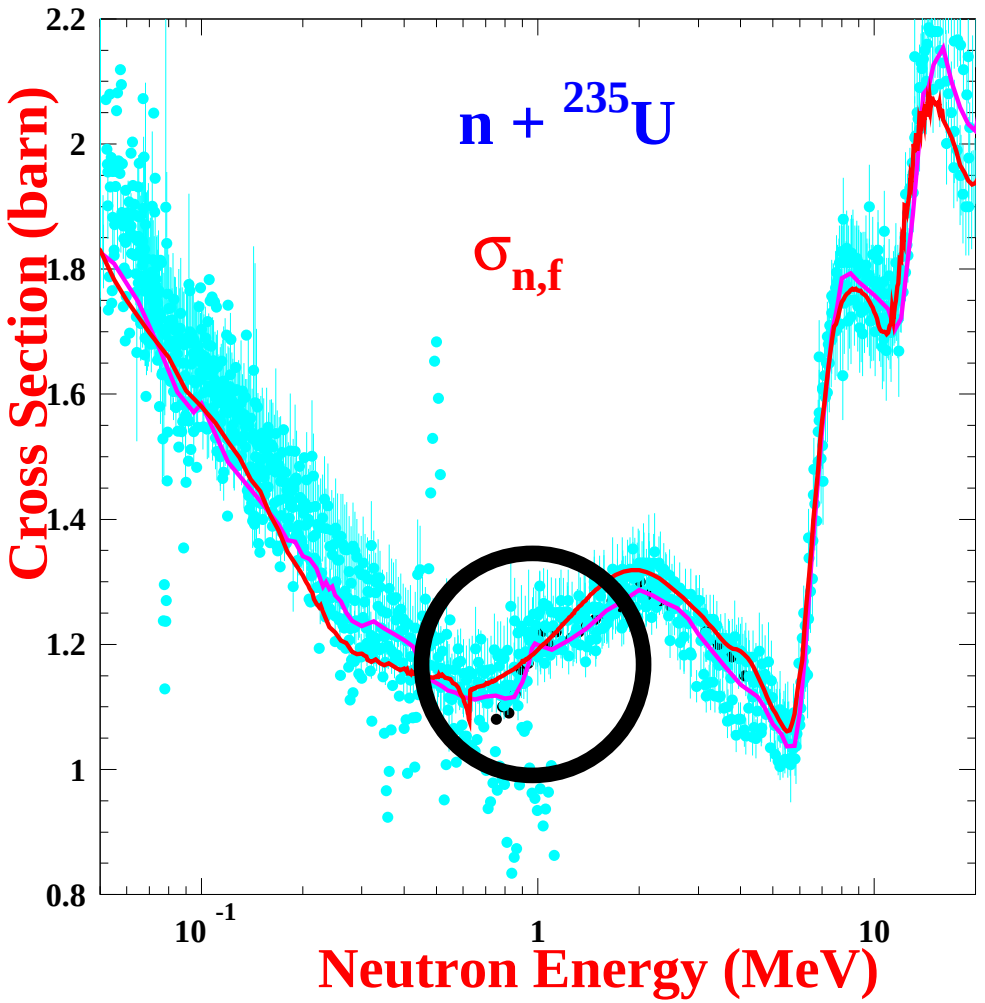
Fission Coss Sections



IAEA's standards BRCweek38

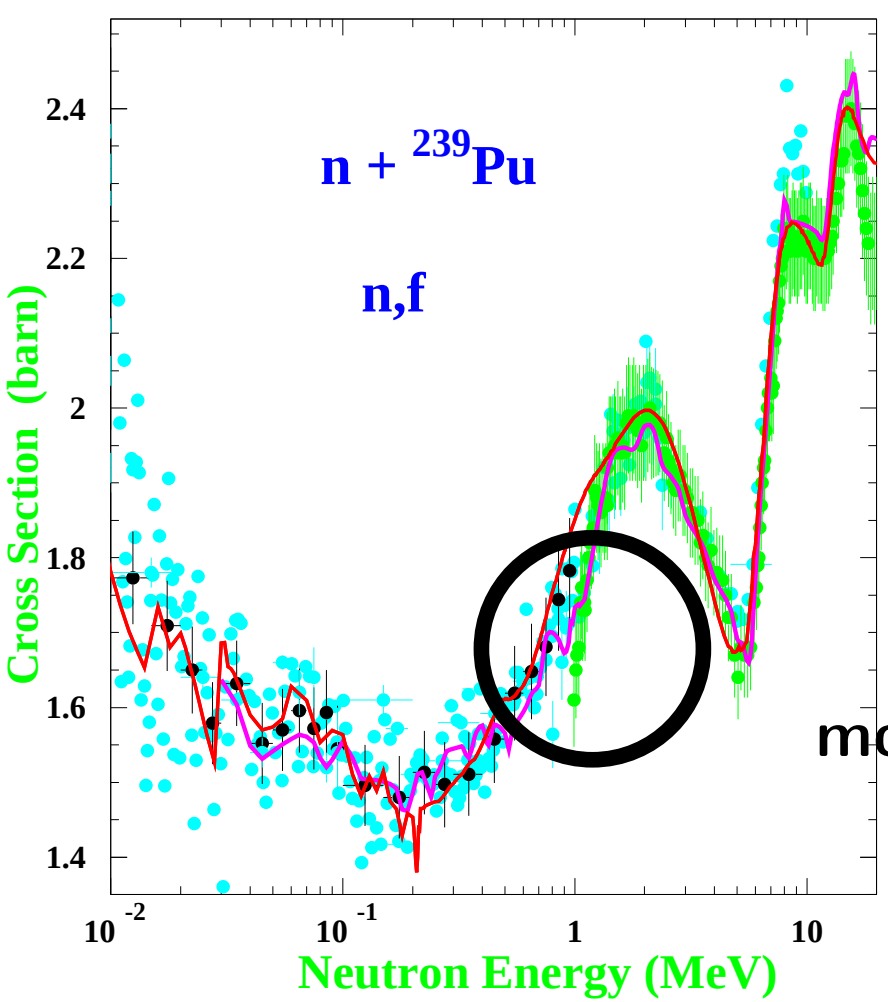
Fission Coss Sections

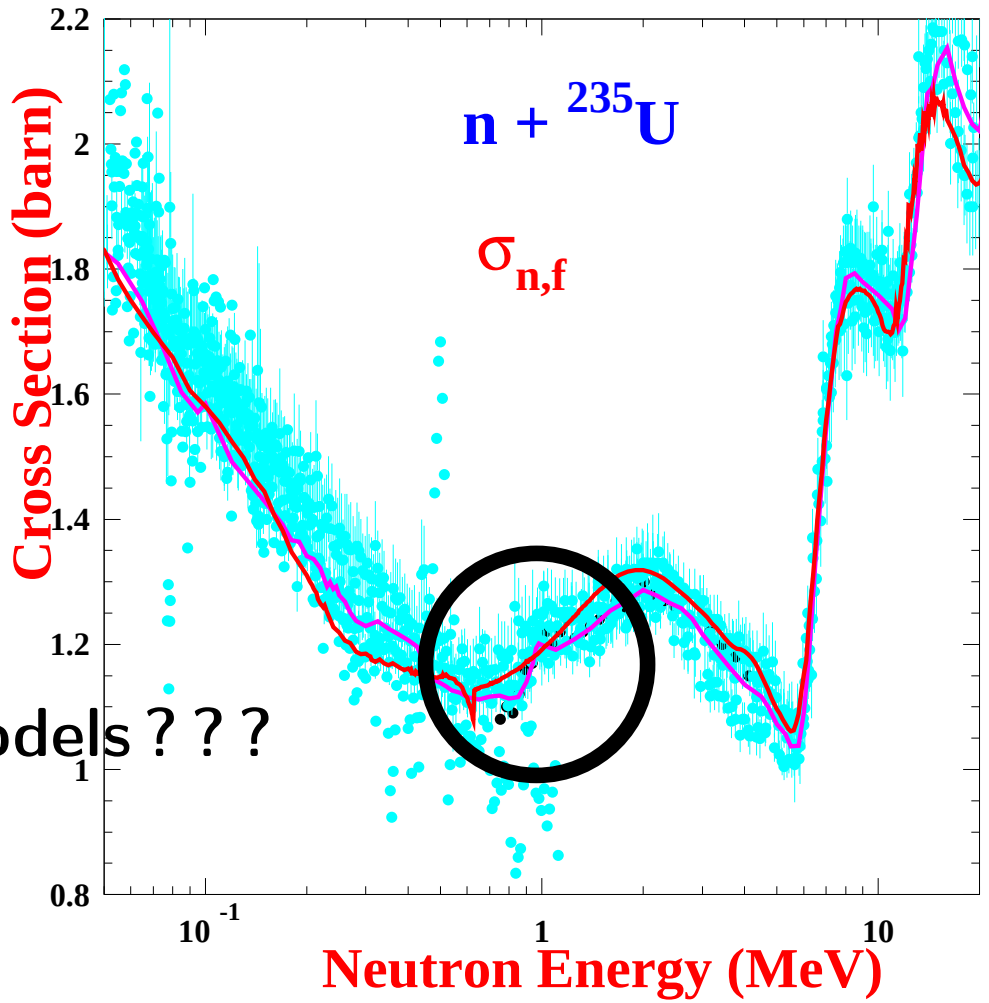




IAEA's standard BRCweek38

Fission Coss Sections

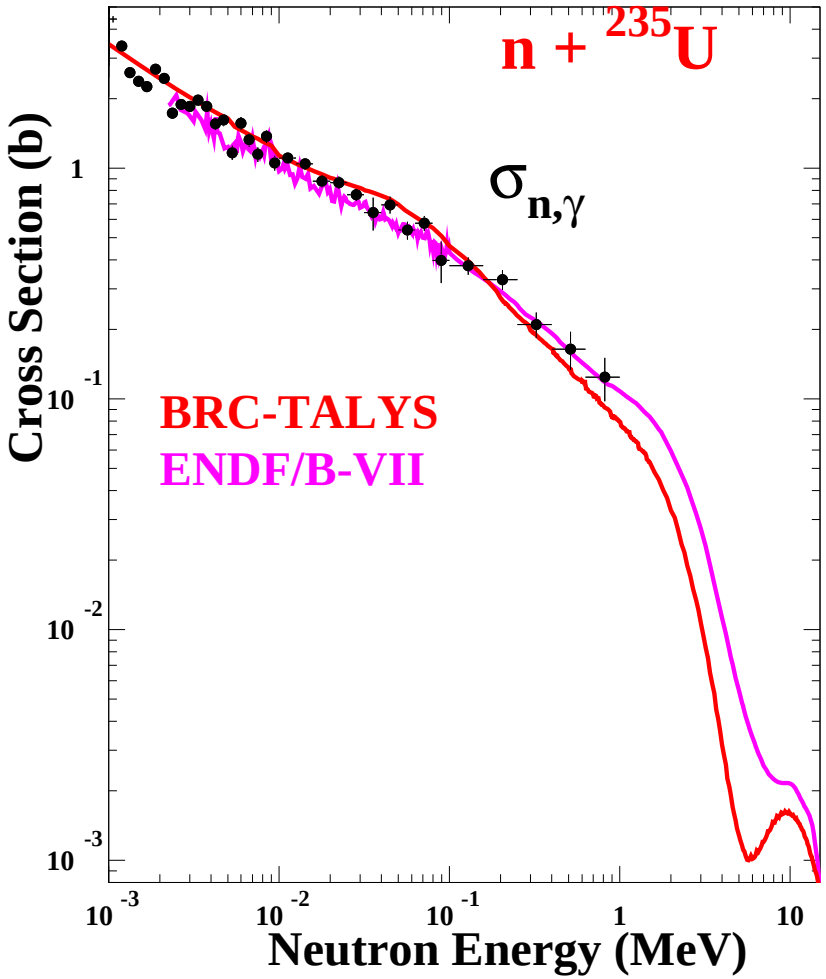




models ? ? ?

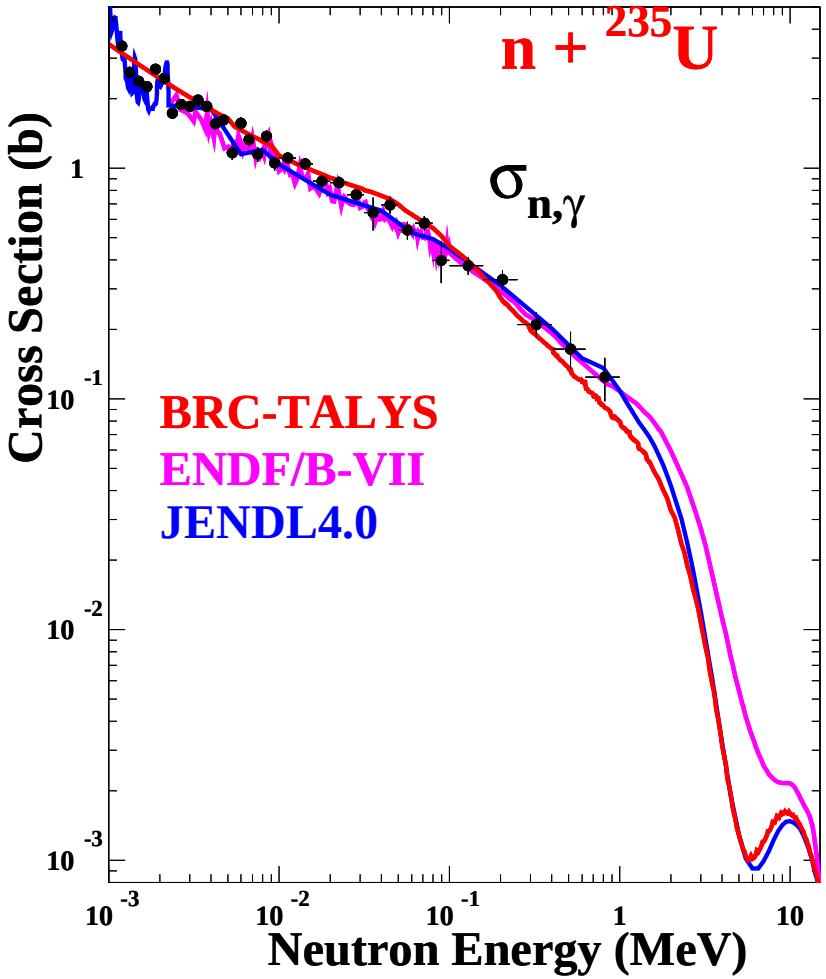
IAEA's standard BRCweek38

Capture Coss Sections



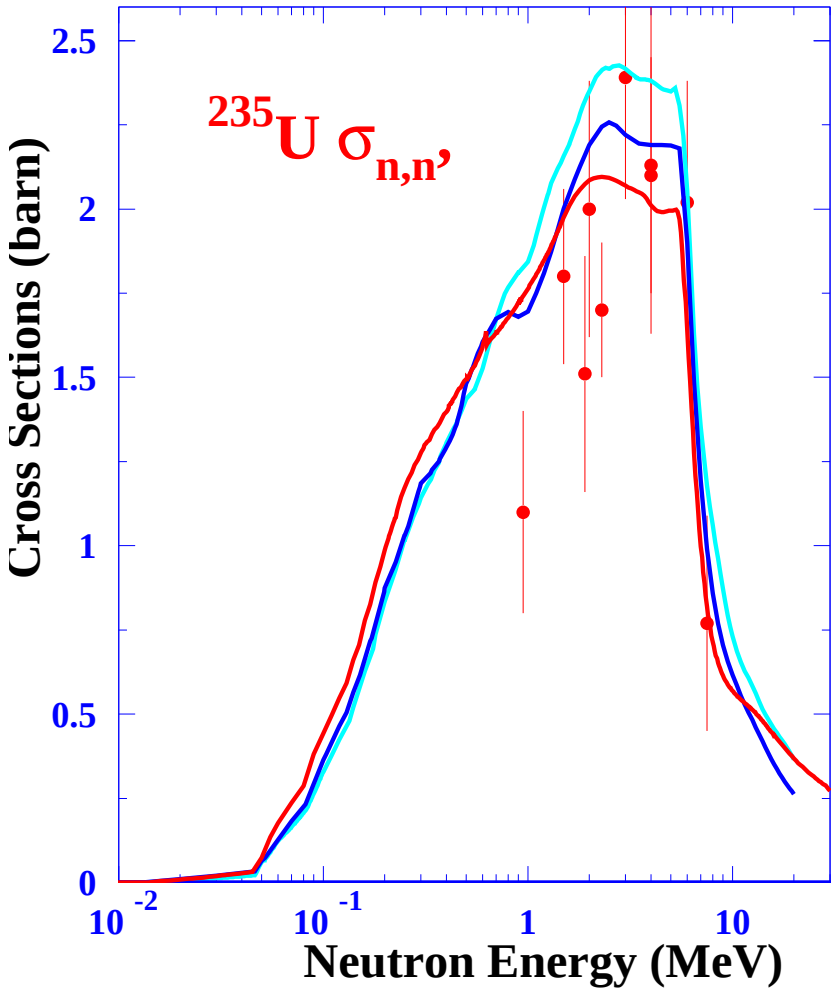
JANDEL et al. 2012

Capture Coss Sections



JANDEL et al. 2012

Inelastic Coss Sections



ENDF/B-VII.1

JENDL4.0

BRCweek38

Prompt fission neutron spectra [1] (center of mass)

$$\phi_{C.M.}(\epsilon) = \int_0^\infty \frac{\sigma_c(\epsilon)\,\epsilon\,e^{-\epsilon/T}}{\int_0^\infty \sigma_c(\epsilon)\,\epsilon\,e^{-\epsilon/T}\,d\epsilon} P(T)\,dT$$

- $\epsilon\, e^{-\epsilon/T}$: Weisskopf spectrum [2].
- $P(T)$: temperature distribution of fission-fragment
  Terrell $\rightarrow$ triangular distribution :
  $P(T) = 2T/T_M^2,\ T \leq T_M = \sqrt{E_M^*/a}$
- $< E_M^* > = < E_r > + B_n + E_n - < E_F^{tot} >$
- σ_c : cross section for the inverse process of compound nucleus formation
  $(n + (A-1)_{FF} \rightarrow A_{FF})$.

1. D.G.Madland,J.R.Nix, NSE, 81, (1982)
2. V.Weisskopf, Phys. Rev. 52, (1937)

Transformation to laboratory system [1]

$$\phi_{L.}(E, E_F) = \frac{1}{4\sqrt{E_F}} \int_{(\sqrt{E}-\sqrt{E_F})^2}^{(\sqrt{E}+\sqrt{E_F})^2} \frac{\phi_{C.M.}(\epsilon)}{\sqrt{\epsilon}}\, d\epsilon$$

$\phi_{L.}(E, E_F)$: neutrons emitted isotropically from a fission fragment with average kinetic energy per nucleon E_F.

1. D.G.Madland,J.R.Nix, NSE, 81, (1982)

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Madland Nix

$$\phi_{L.}(E) = \frac{(\phi_{L.}(E, E_F^H) + \phi_{L.}(E, E_F^L))}{2}$$

$x_H + x_L = 1$

1. D.G.Madland,J.R.Nix, NSE, 81, (1982)

Transformation to laboratory system [1]

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$\phi_{L.}(E, E_F)$: neutrons emitted isotropically from a fission fragment with average kinetic energy per nucleon E_F. In this model, two fragments :

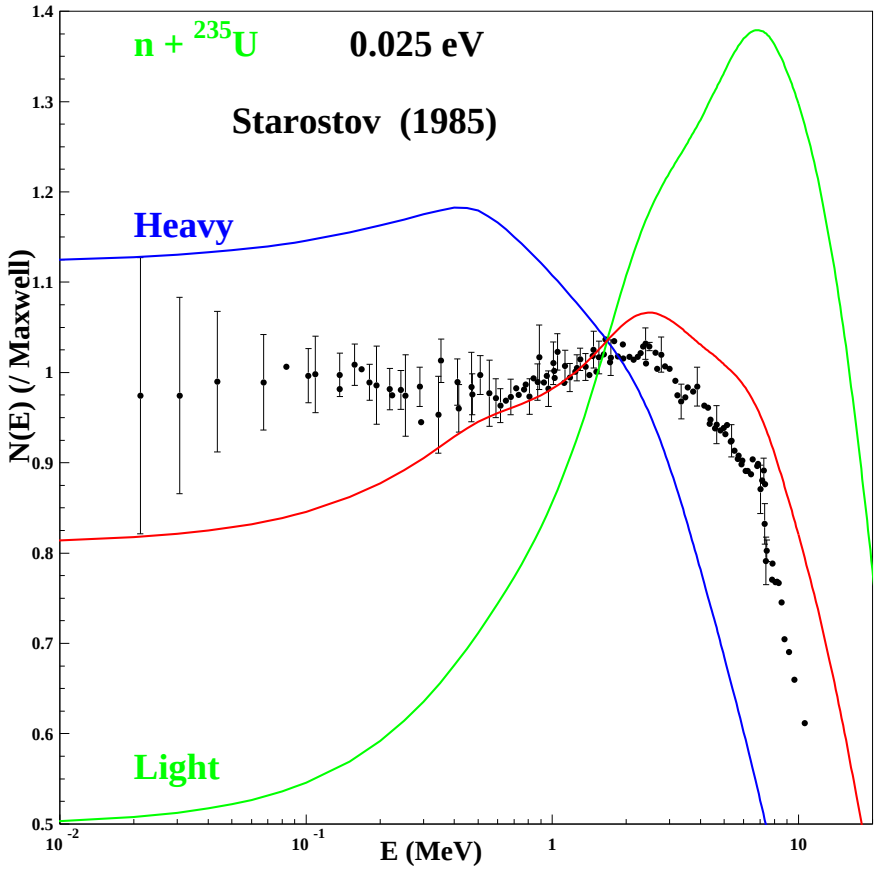
Modified Madland Nix

$$\phi_{L.}(E) = \frac{(x_H \phi_{L.}(E, E_F^H) + x_L \phi_{L.}(E, E_F^L))}{2}$$

$x_H + x_L = 1$

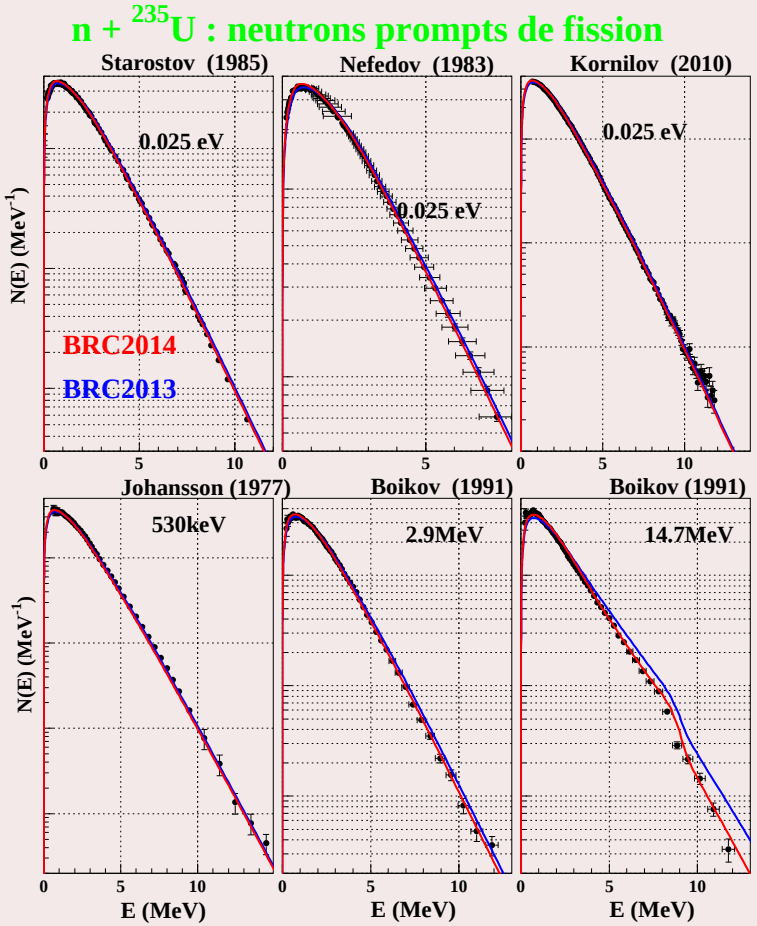
1. D.G.Madland,J.R.Nix, NSE, 81, (1982)

Neutron emitted from Light and Heavy fragments



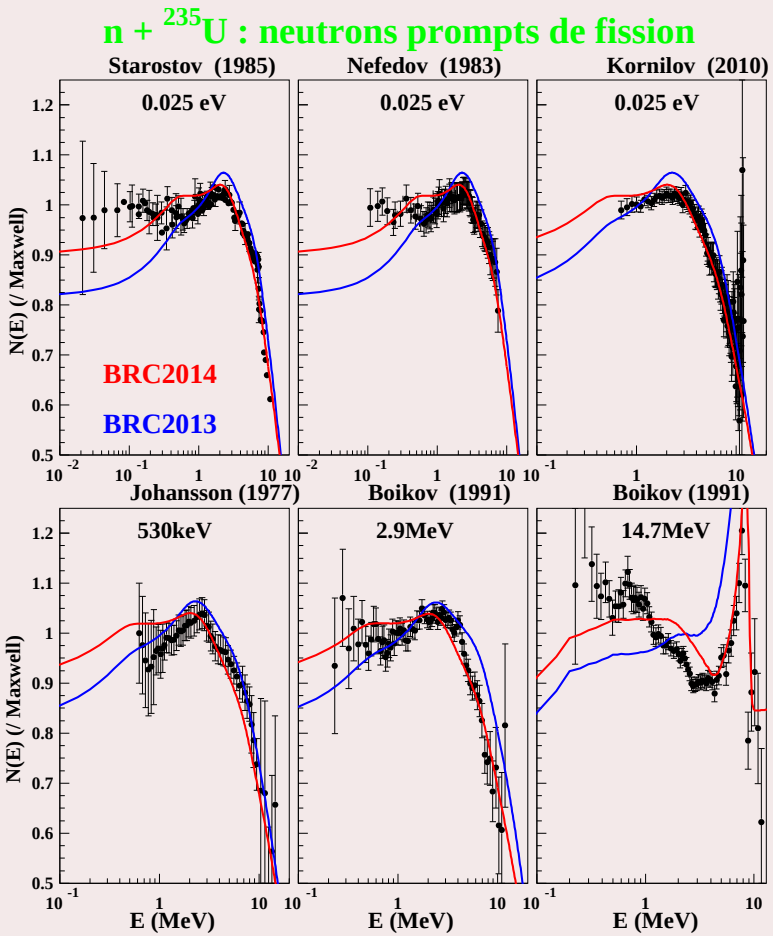
^{235}U(n,f) : prompt fission neutron spectra (0.025 eV, 530 keV, 2.9 MeV, 14.7 MeV)

BRC2013 - BRC2014



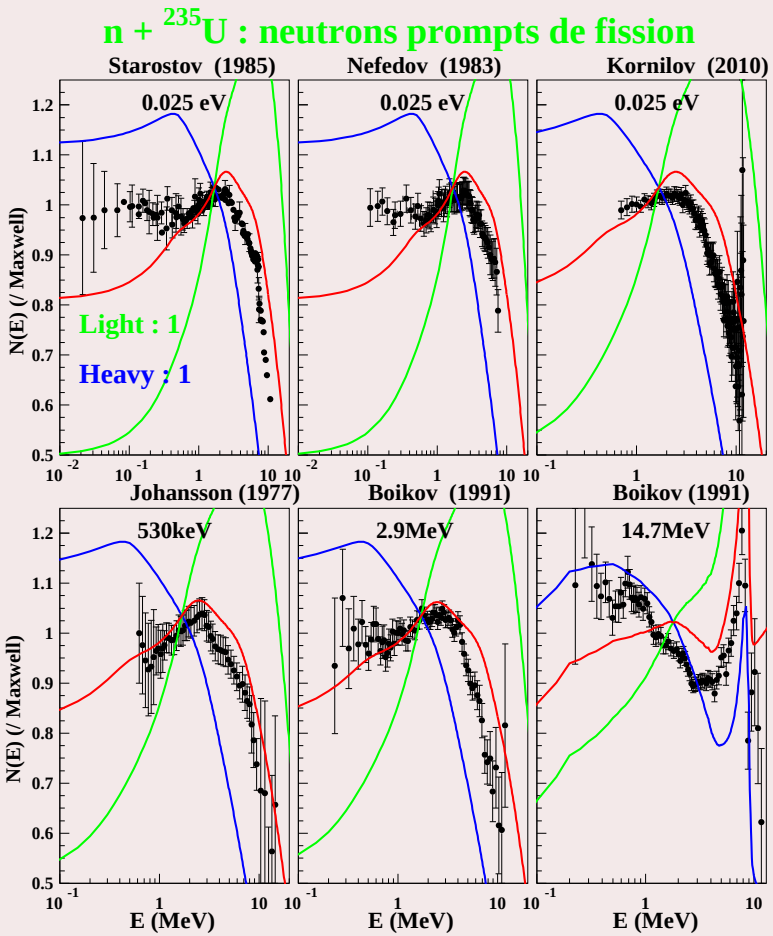
^{235}U(n,f) : prompt fission neutron spectra (0.025 eV, 530 keV, 2.9 MeV, 14.7 MeV)

BRC2013 - BRC2014 / Maxwell



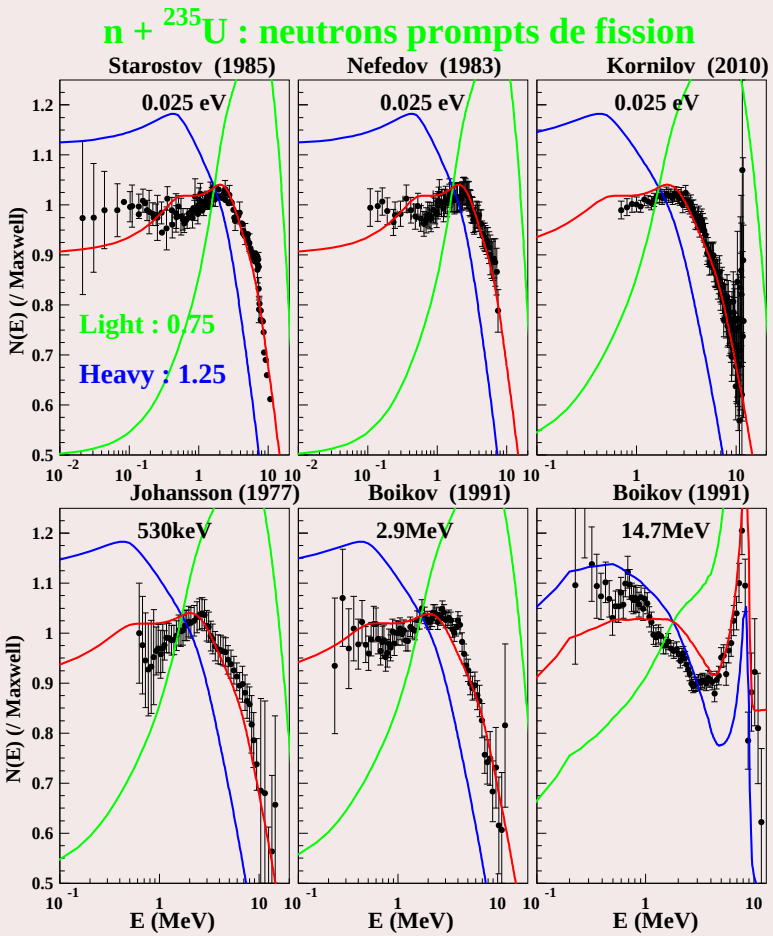
^{235}U(n,f) : prompt fission neutron spectra (0.025 eV, 530 keV, 2.9 MeV, 14.7 MeV)

Heavy (1.) and Light (1.) Fragment



^{235}U(n,f) : prompt fission neutron spectra (0.025 eV, 530 keV, 2.9 MeV, 14.7 MeV)

Heavy (1.25) and Light (0.75) Fragment



Status of ^{235}U evaluation in the high energy range

TESTs!!!

Status of ^{235}U evaluation in the high energy range

vers2 = MF2MT151(Luiz LEAL) + MF1,3,4,5,6(JENDL4.0)

vers3 = MF2MT151(Luiz LEAL) + MF1,3,4,5,6(BRC$_{week38}$)

Status of ^{235}U evaluation in the high energy range

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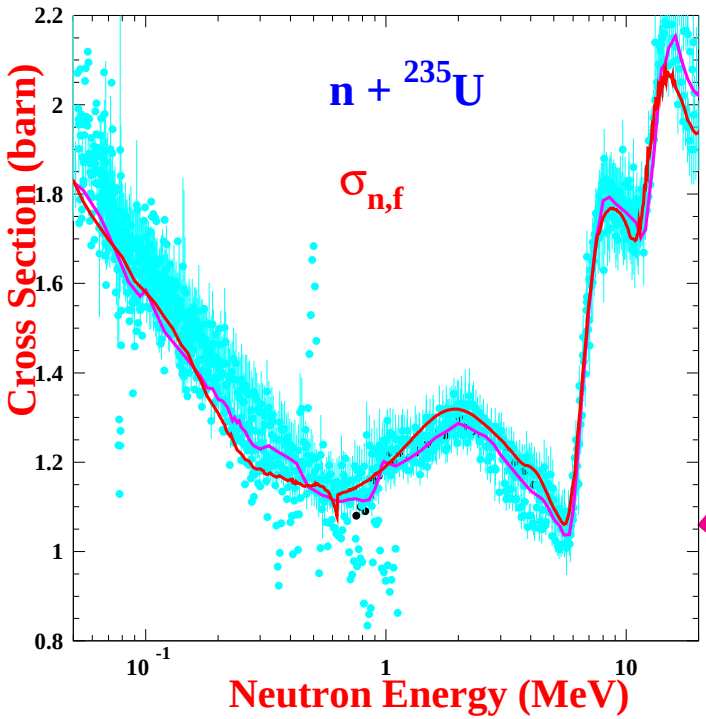
with



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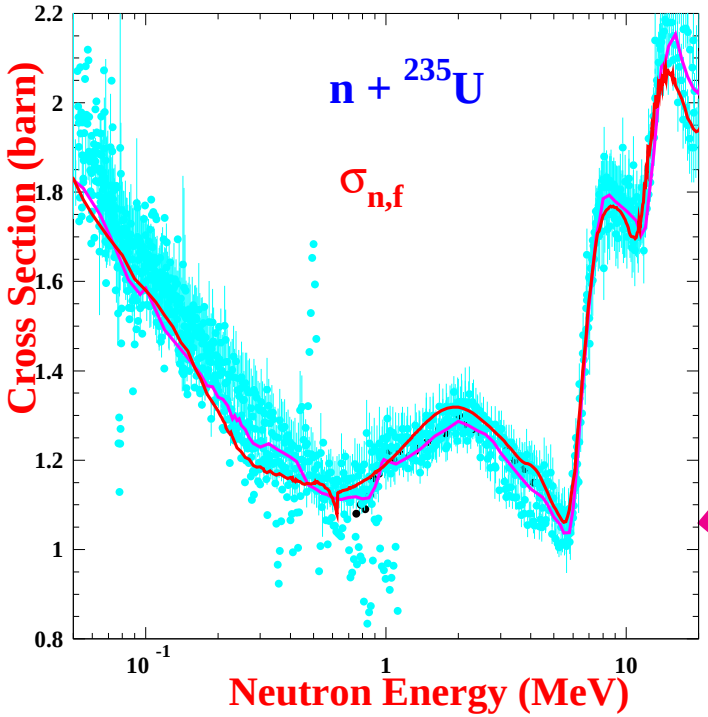
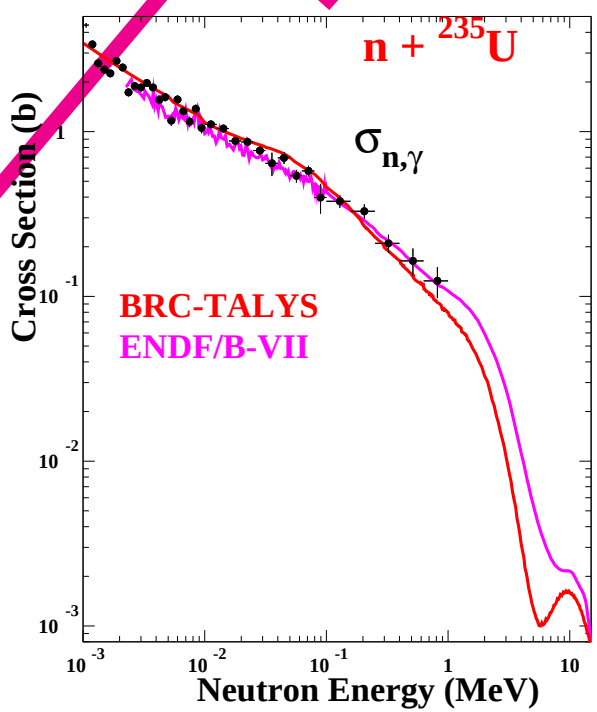
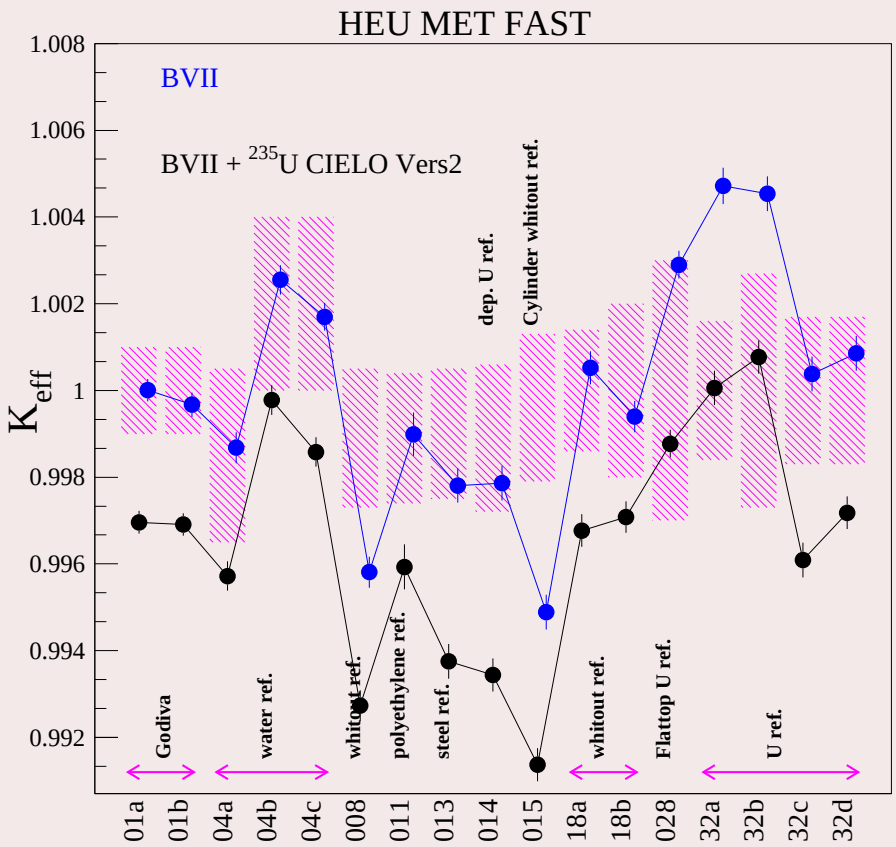




Differences reported on Total Elasctic XS

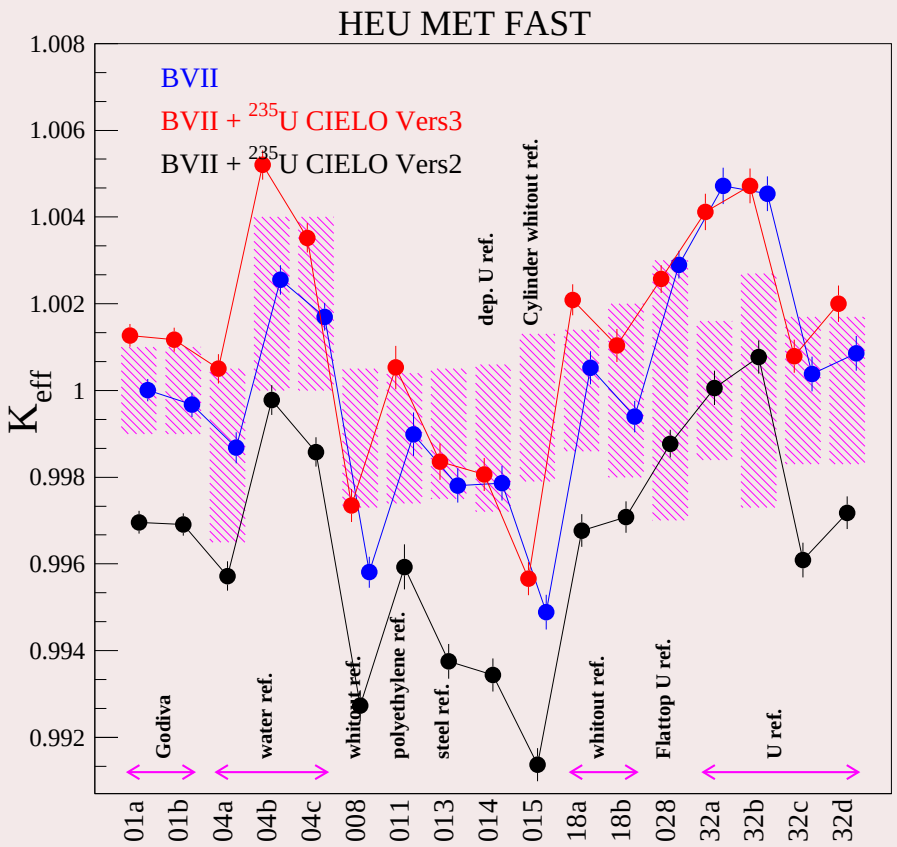
^{235}U : ENDFB7, CIELO : Vers2 and Vers3

HEU MET FAST

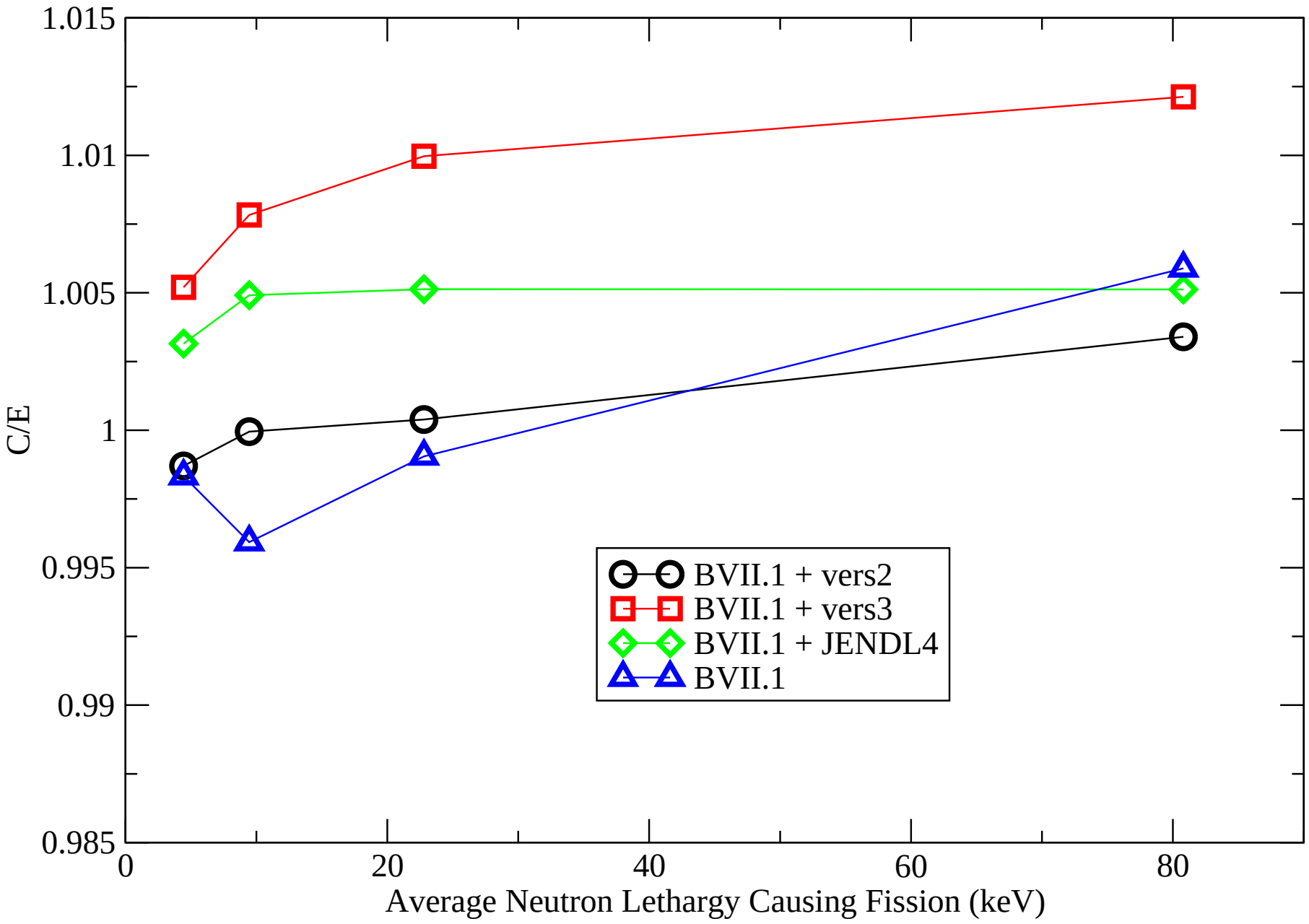


^{235}U : ENDFB7, CIELO : Vers2 and Vers3

HEU MET FAST



HEU-MEU-INTER-006 (ZEUS)

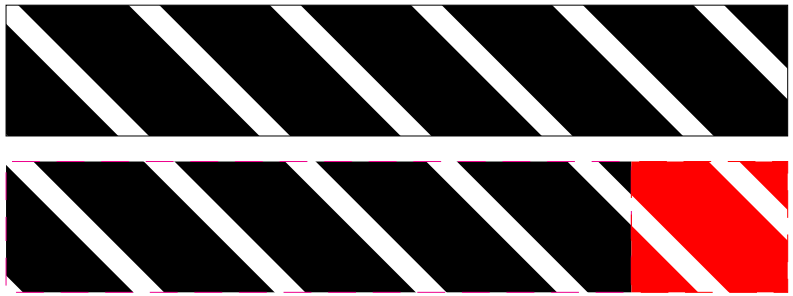


De-re-construction

vers2

De-re-construction

vers2



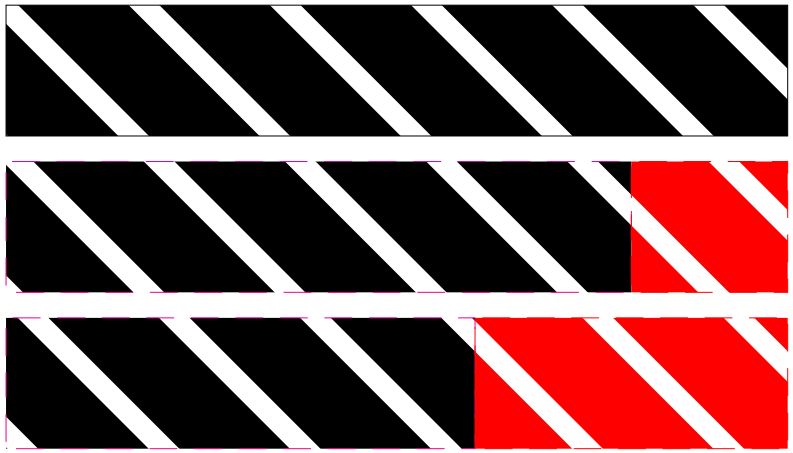
vers2 ← part-1 vers3

De-re-construction

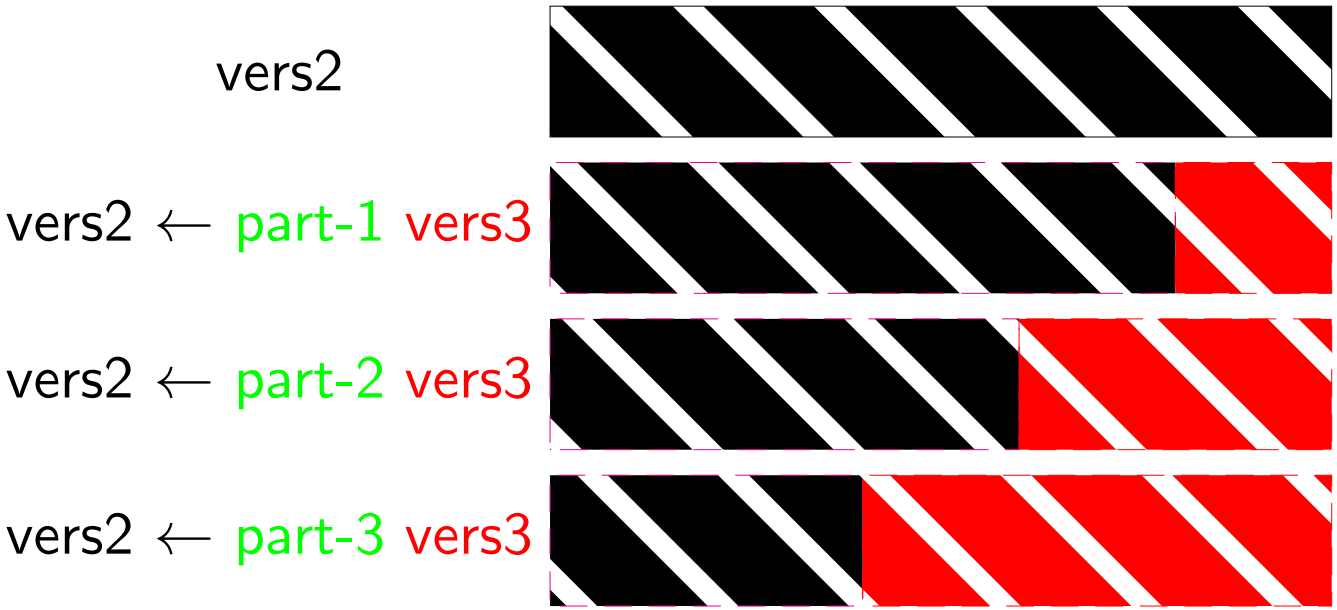
vers2

vers2 ← part-1 vers3

vers2 ← part-2 vers3



De-re-construction



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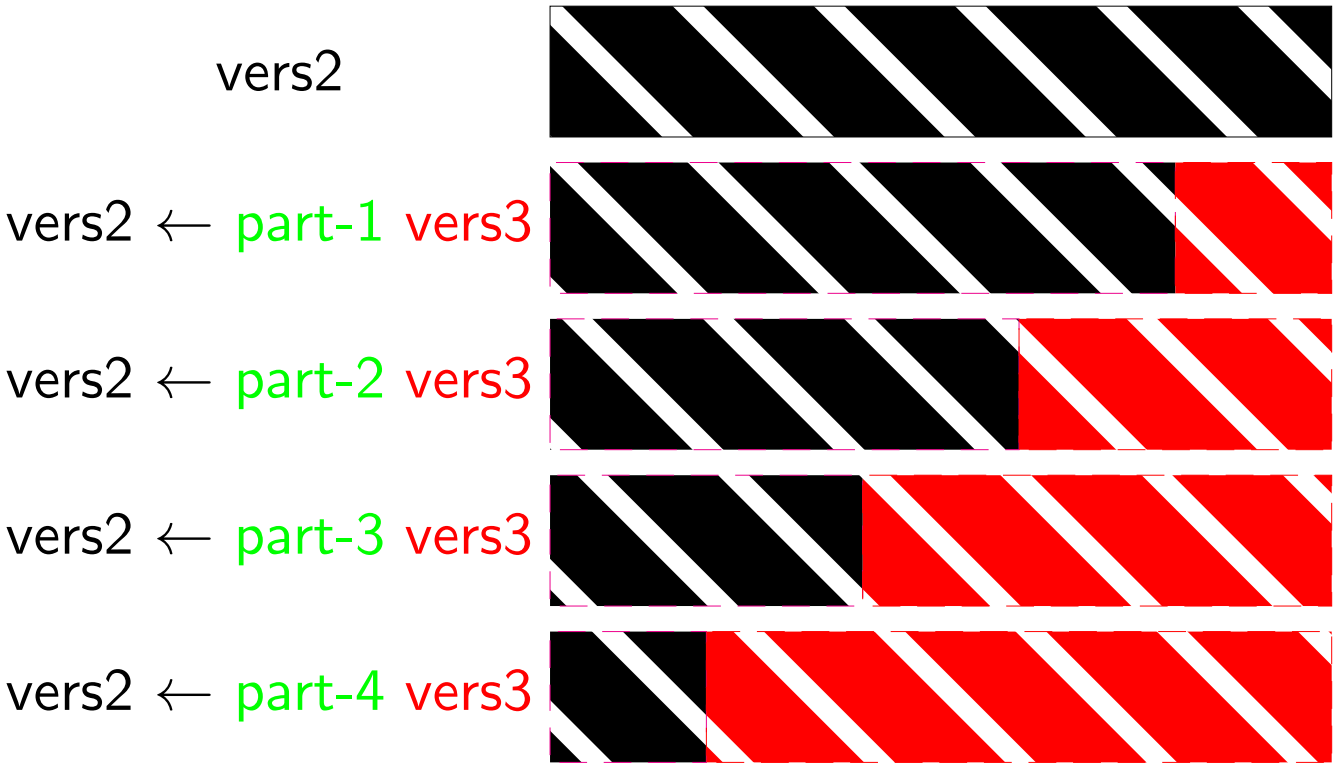

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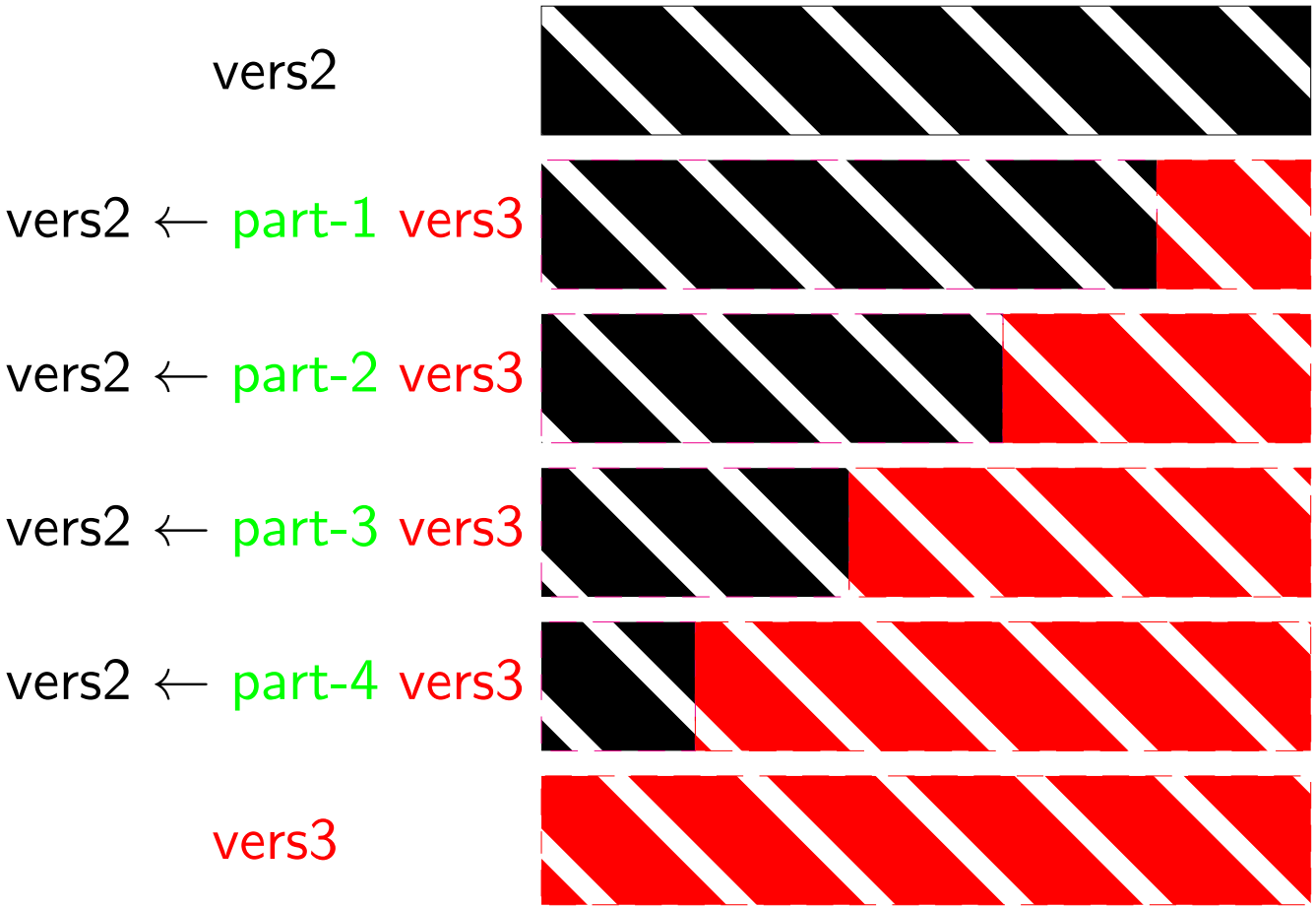
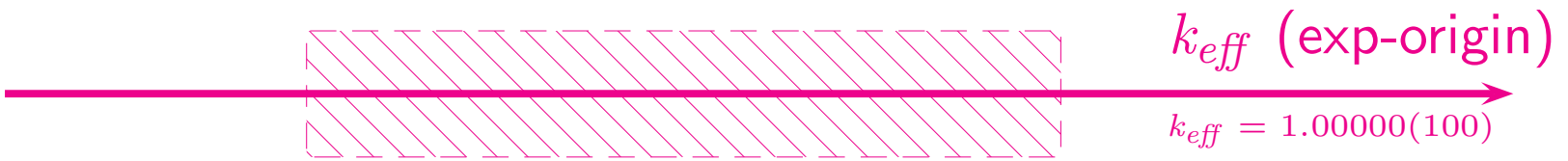
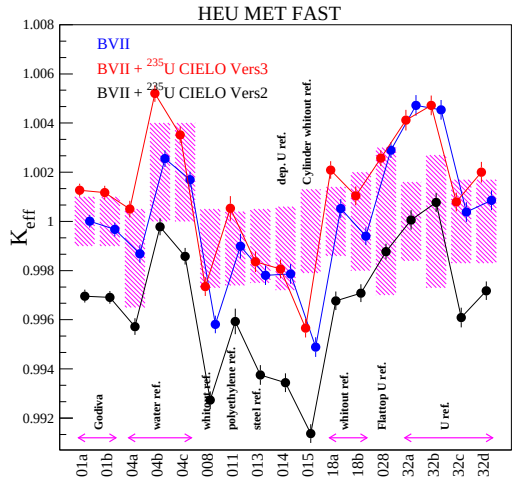


Fresnel Representation - ^{235}U eval. DE-RE-construction

MCNP study of the GODIVA critical benchmark

$k_{eff}\,(vers2) = 0.99689(13)$ $k_{eff}\,(vers3) = 1.00135(13)$





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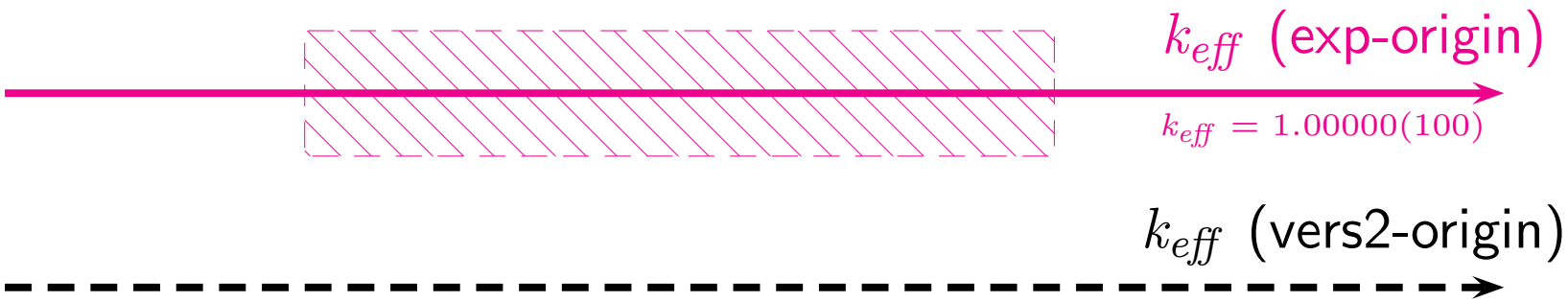

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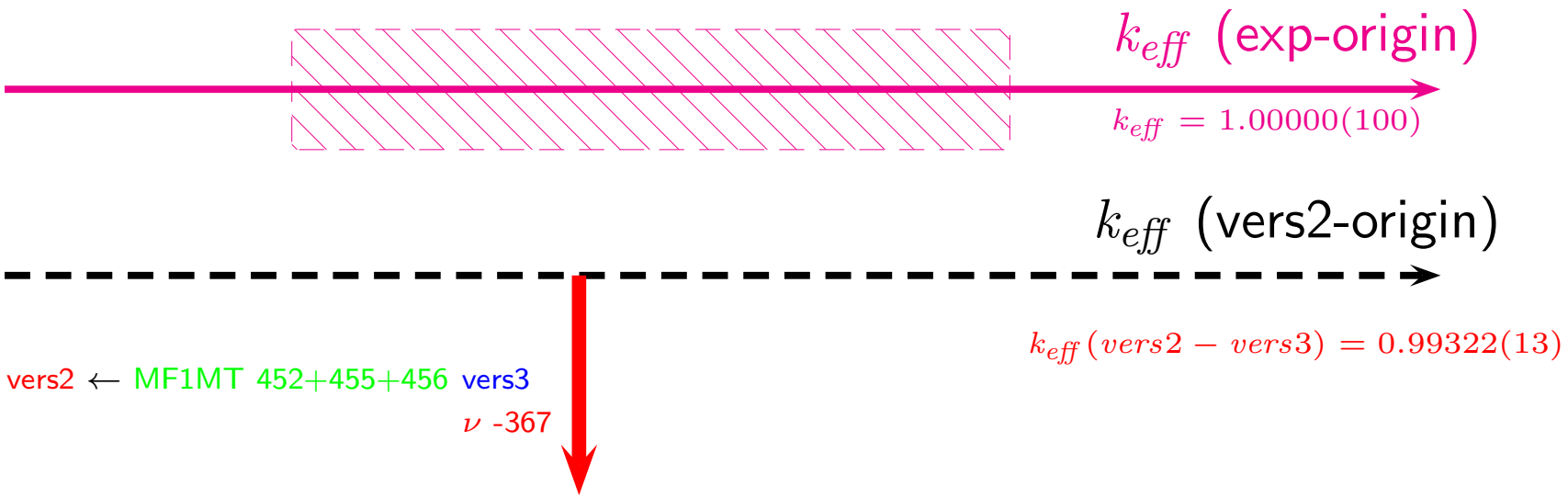

Fresnel Representation - ^{235}U eval. DE-RE-construction

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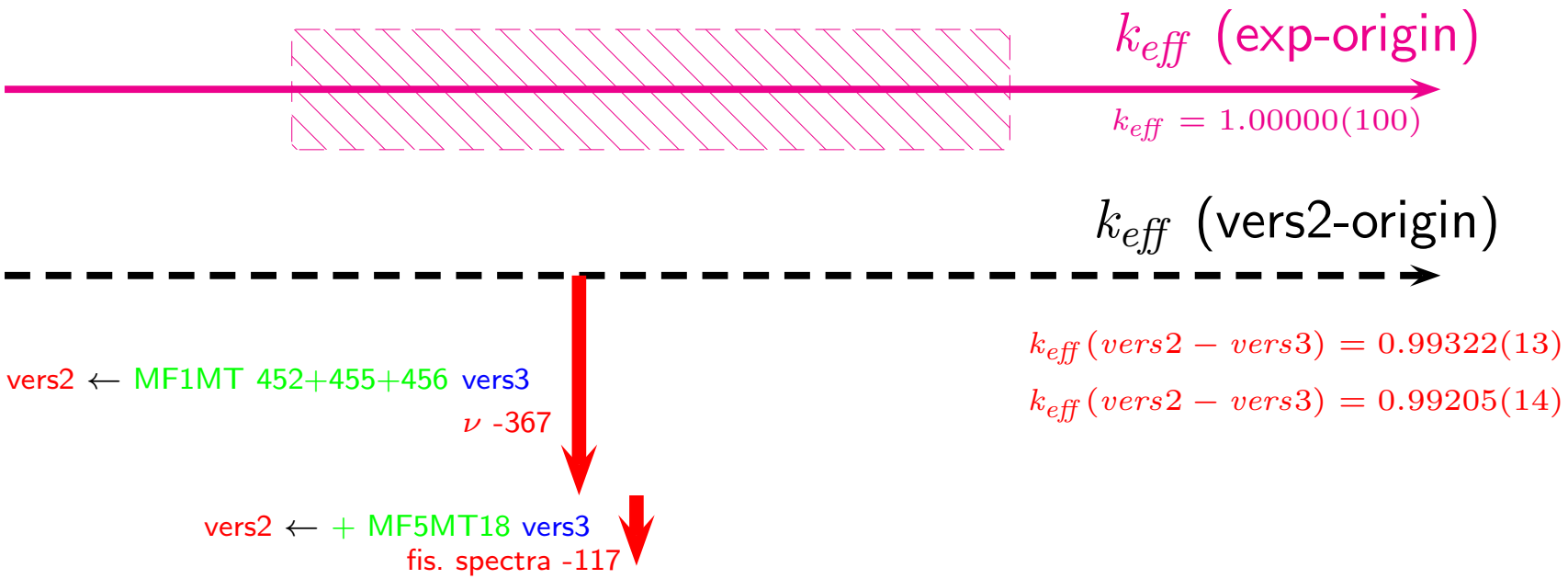

Fresnel Representation - ^{235}U eval. DE-RE-construction

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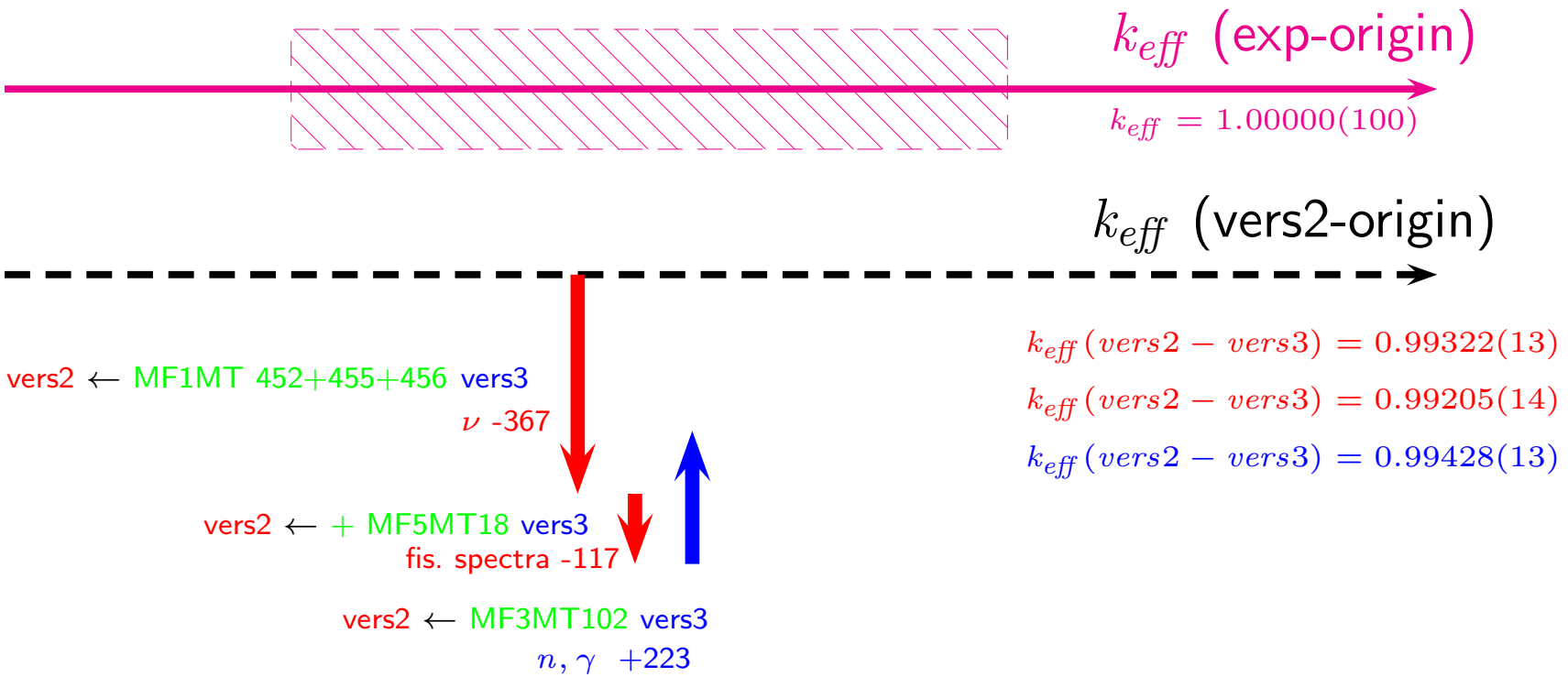

Fresnel Representation - ^{235}U eval. DE-RE-construction

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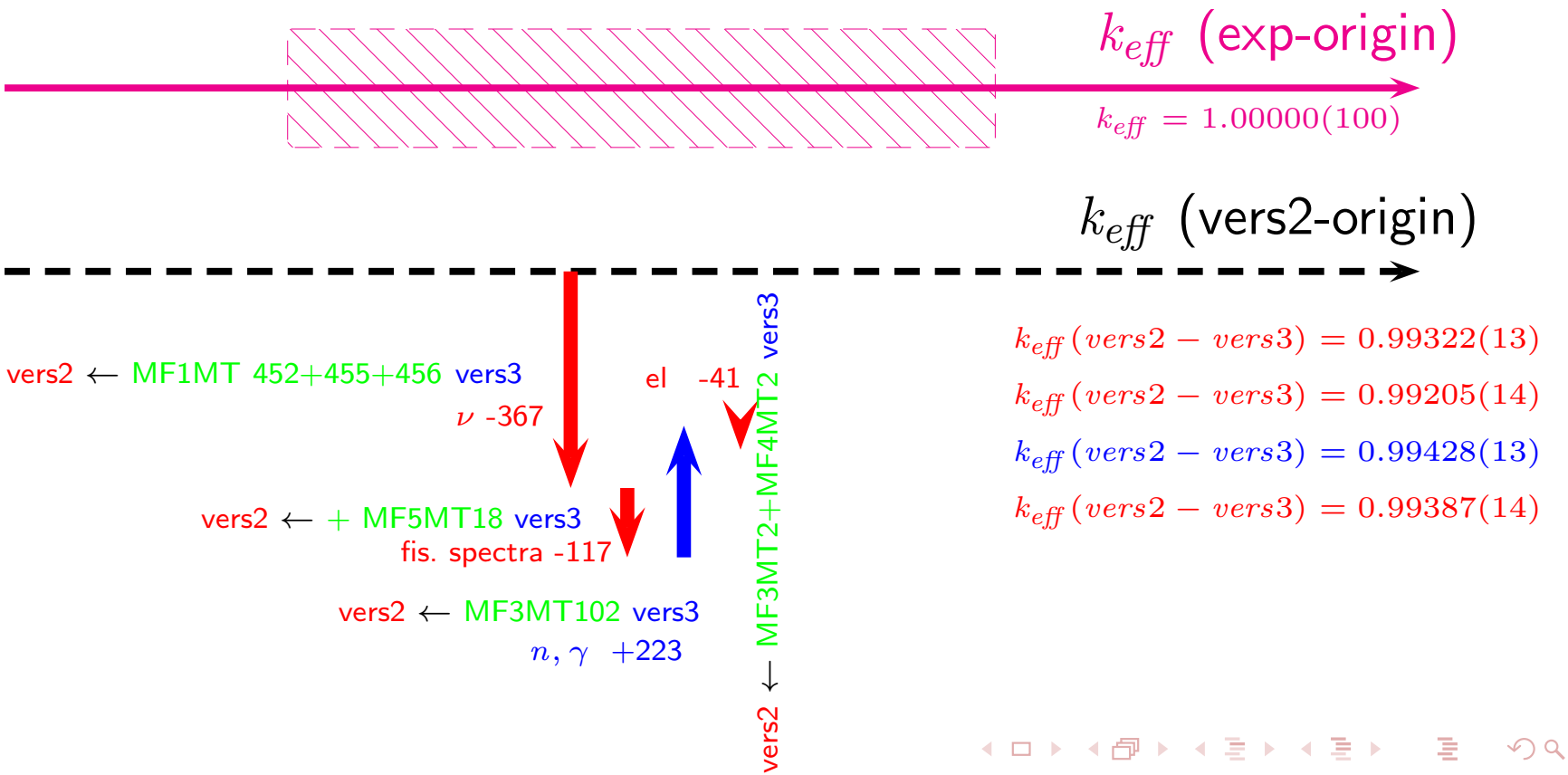

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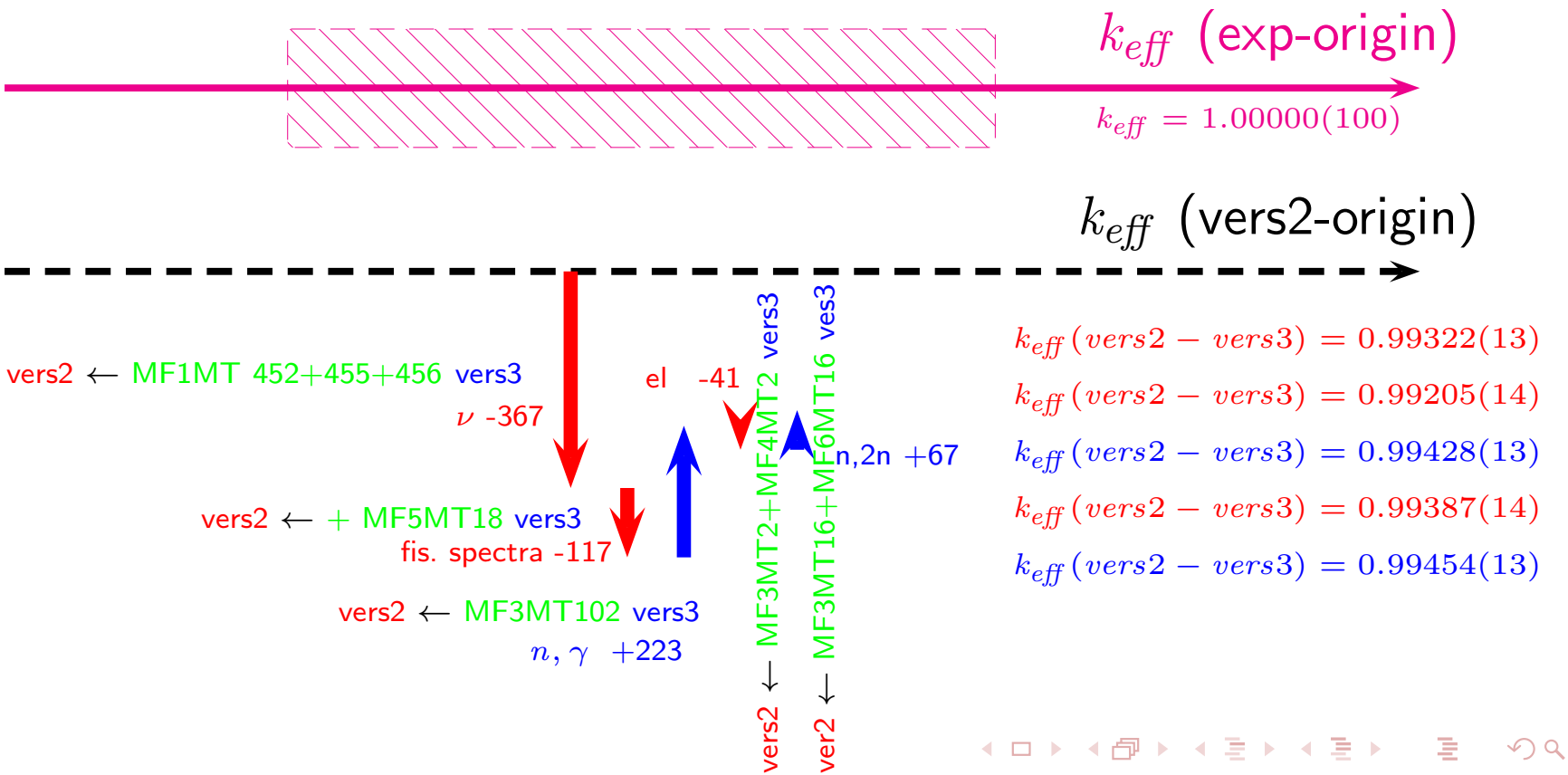

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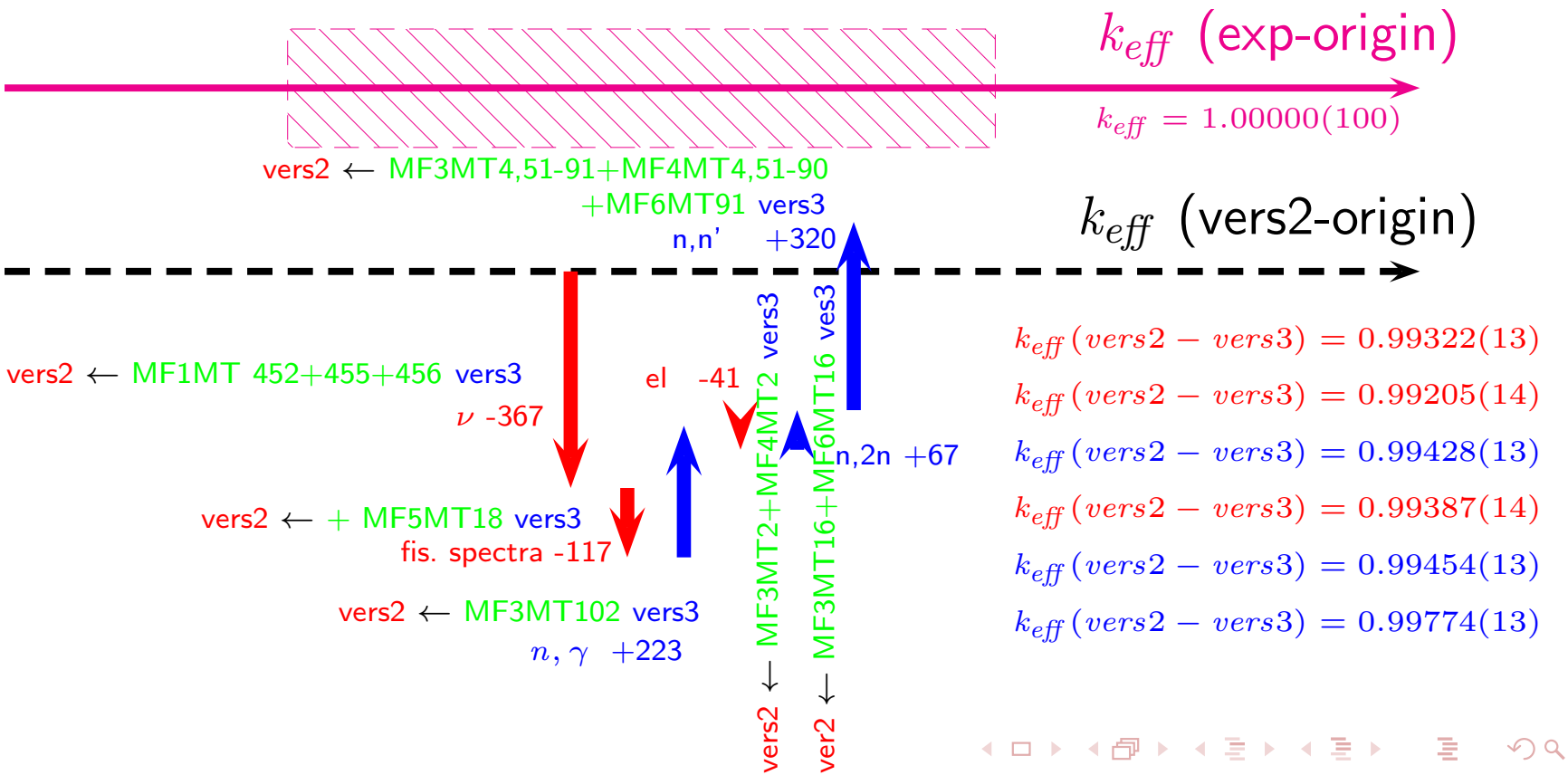

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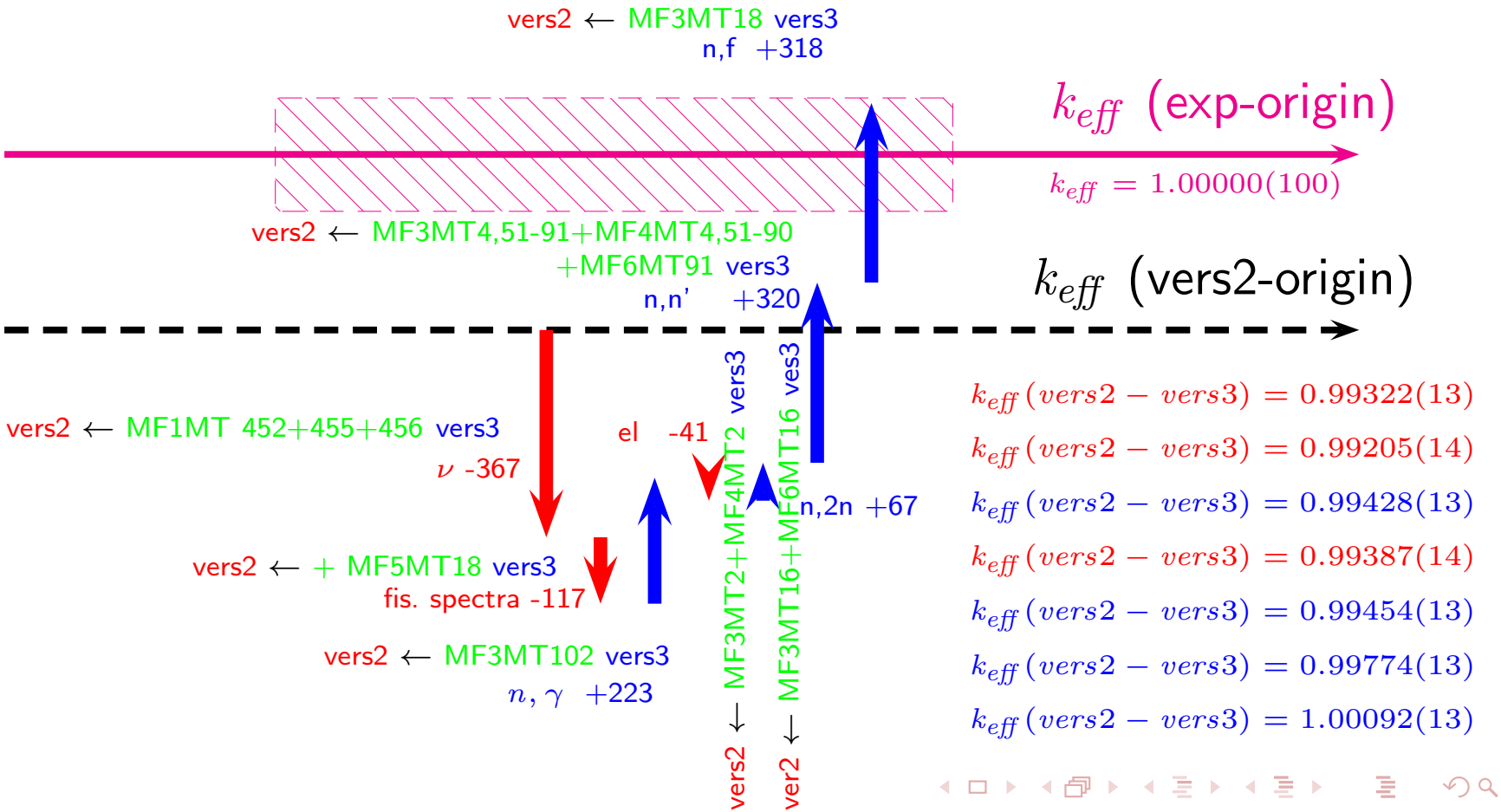

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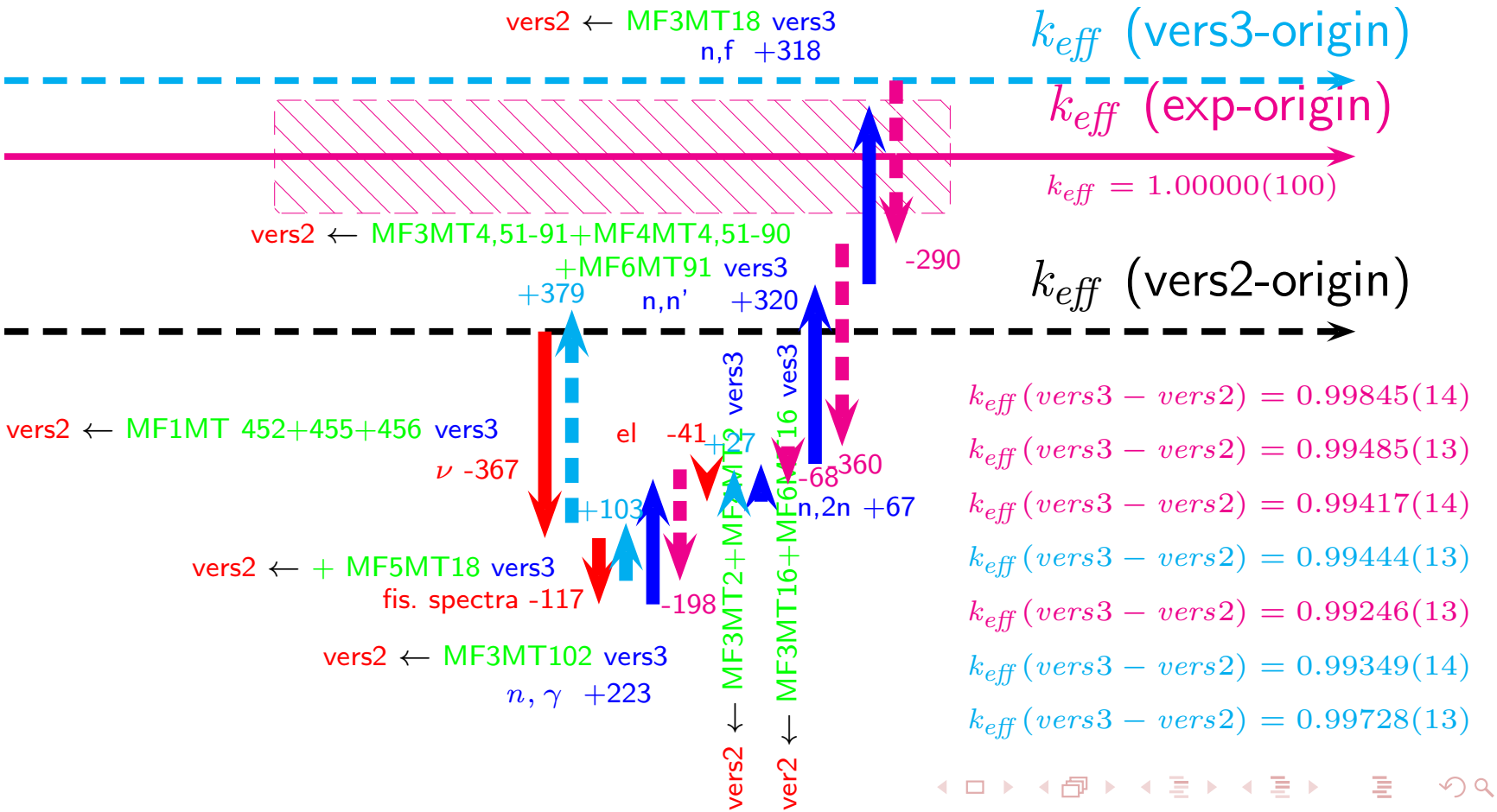
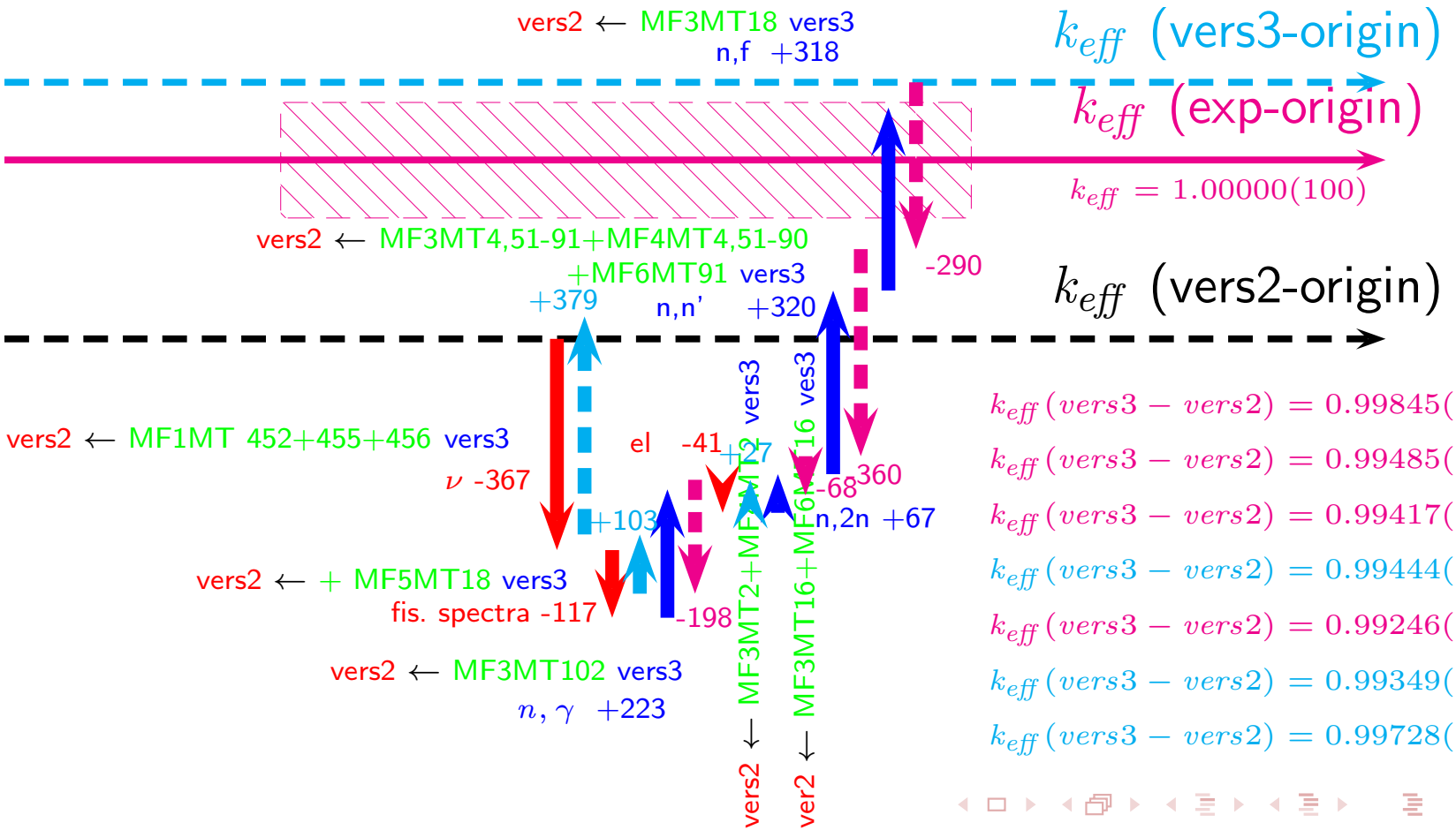


MCNP study of the GODIVA critical benchmark

$k_{eff}\,(vers2) = 0.99689(13)$ $k_{eff}\,(vers3) = 1.00135(13)$

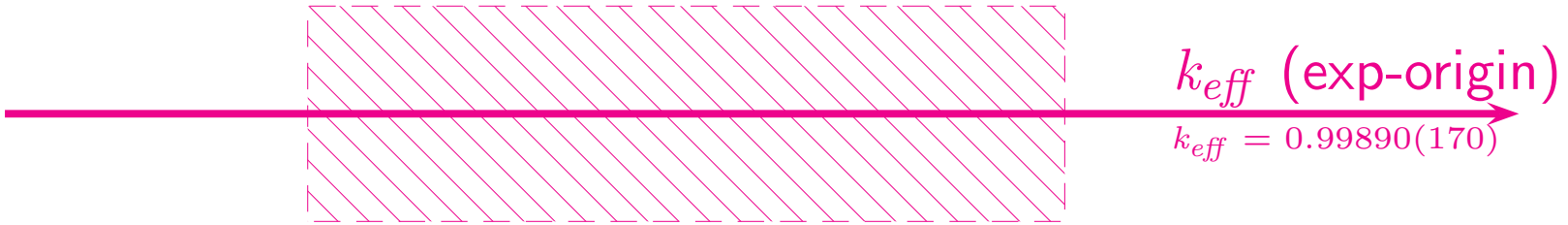
Direct and Reverse paths equivalent

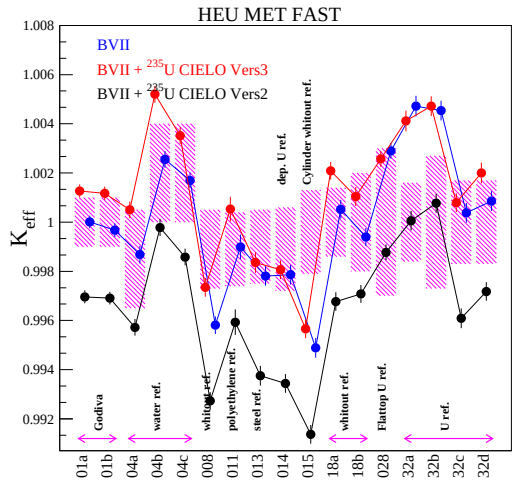


Fresnel Representation - ^{235}U eval. DE-RE-construction

MCNP study of the HMF014 critical benchmark

$k_{eff}\,(vers2) = 0.99352(20)$ $k_{eff}\,(vers3) = 0.99806(19)$

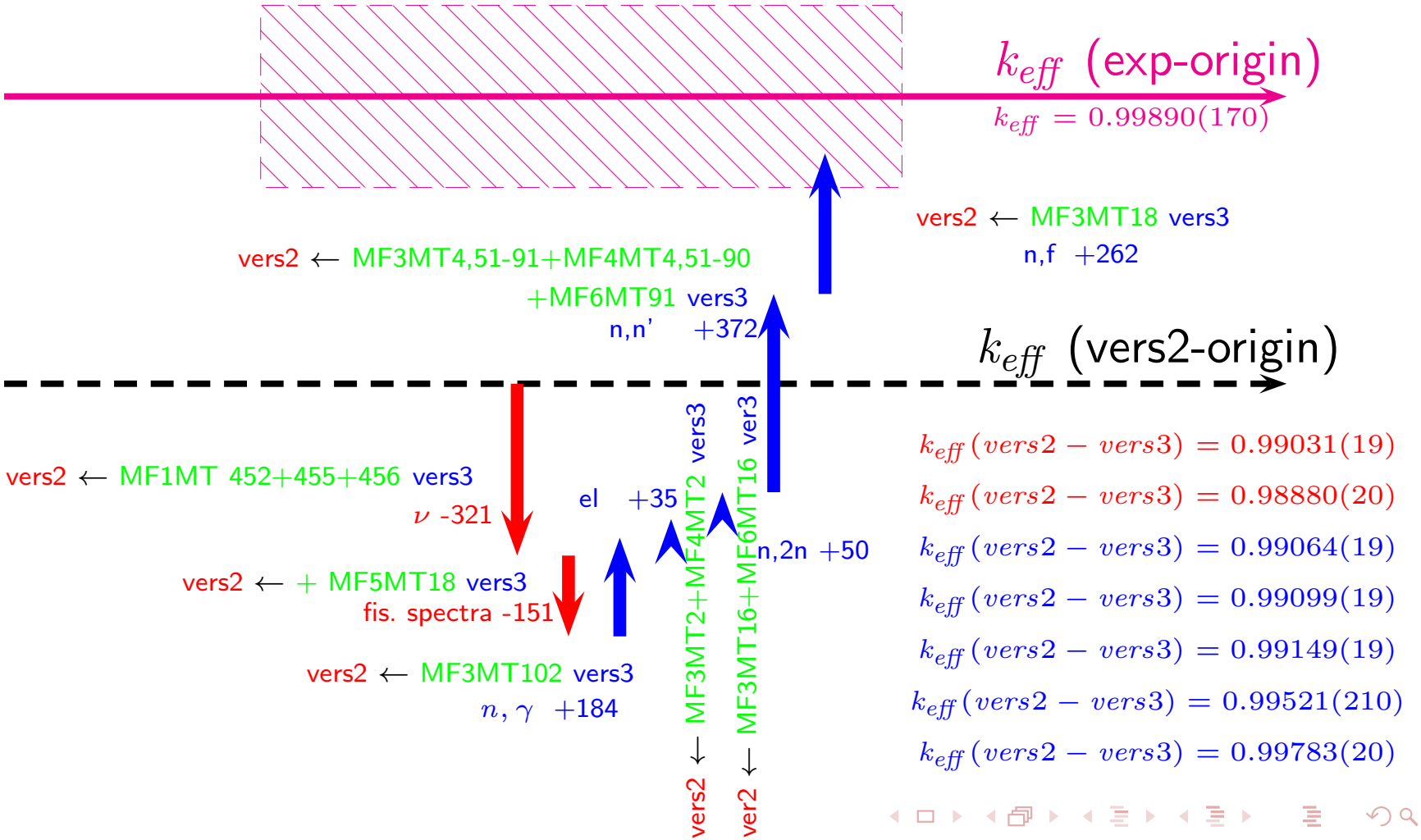




Fresnel Representation - ^{235}U eval. DE-RE-construction

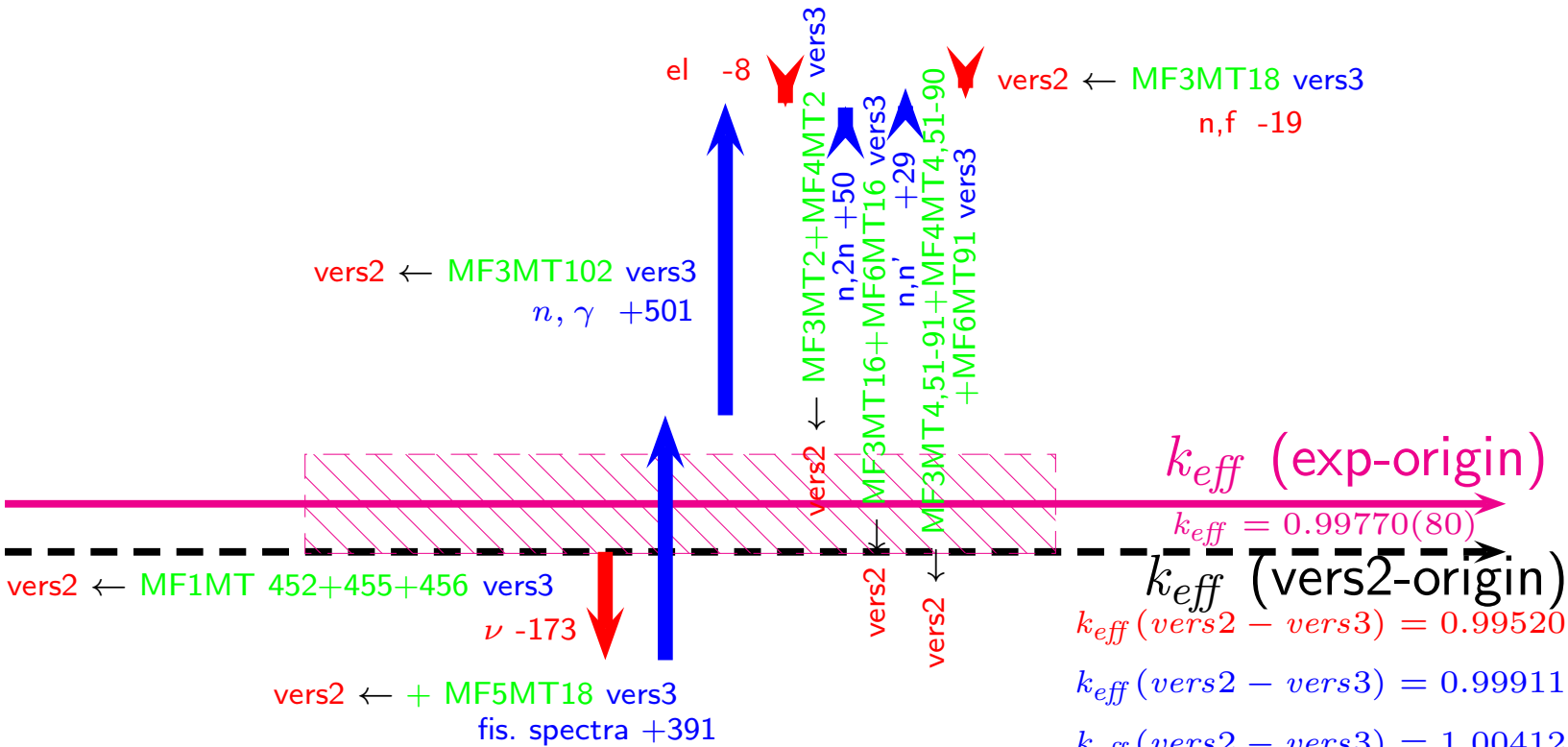
MCNP study of the HMF014 critical benchmark

$k_{eff}\,(vers2) = 0.99352(20)$ $k_{eff}\,(vers3) = 0.99806(19)$



MCNP study of the ZEUS-1 critical benchmark

$k_{eff}\,(vers2) = 0.99693(20)$ $k_{eff}\,(vers3) = 1.00417(19)$



$k_{eff}\,(vers2 - vers3) = 0.99520(19)$

$k_{eff}\,(vers2 - vers3) = 0.99911(20)$

$k_{eff}\,(vers2 - vers3) = 1.00412(19)$

$k_{eff}\,(vers2 - vers3) = 1.00404(19)$

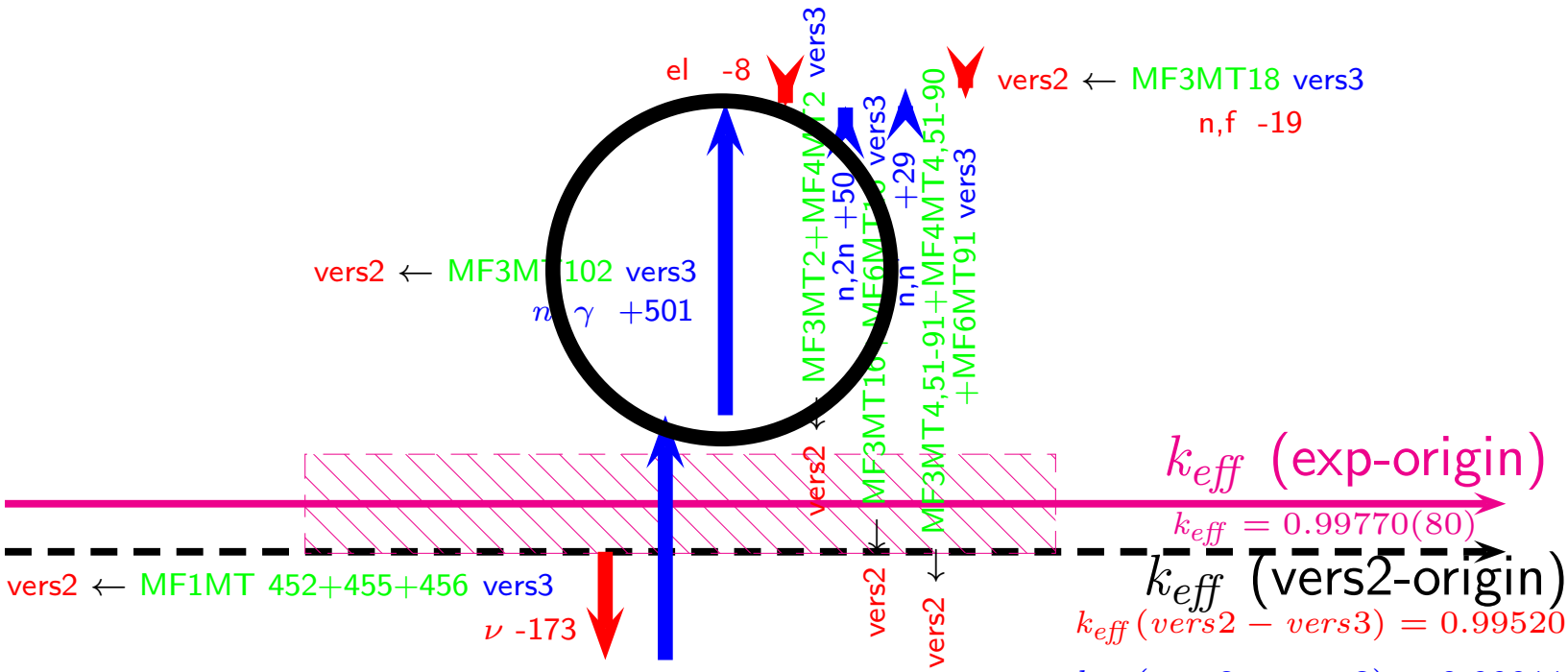
$k_{eff}\,(vers2 - vers3) = 1.00407(19)$

$k_{eff}\,(vers2 - vers3) = 1.00436(210)$

$k_{eff}\,(vers2 - vers3) = 1.00391(20)$

MCNP study of the ZEUS-1 critical benchmark

$k_{eff}\,(vers2) = 0.99693(20)$ $k_{eff}\,(vers3) = 1.00417(19)$



$k_{eff}\,(vers2 - vers3) = 0.99520(19)$

$k_{eff}\,(vers2 - vers3) = 0.99911(20)$

$k_{eff}\,(vers2 - vers3) = 1.00412(19)$

$k_{eff}\,(vers2 - vers3) = 1.00404(19)$

$k_{eff}\,(vers2 - vers3) = 1.00407(19)$

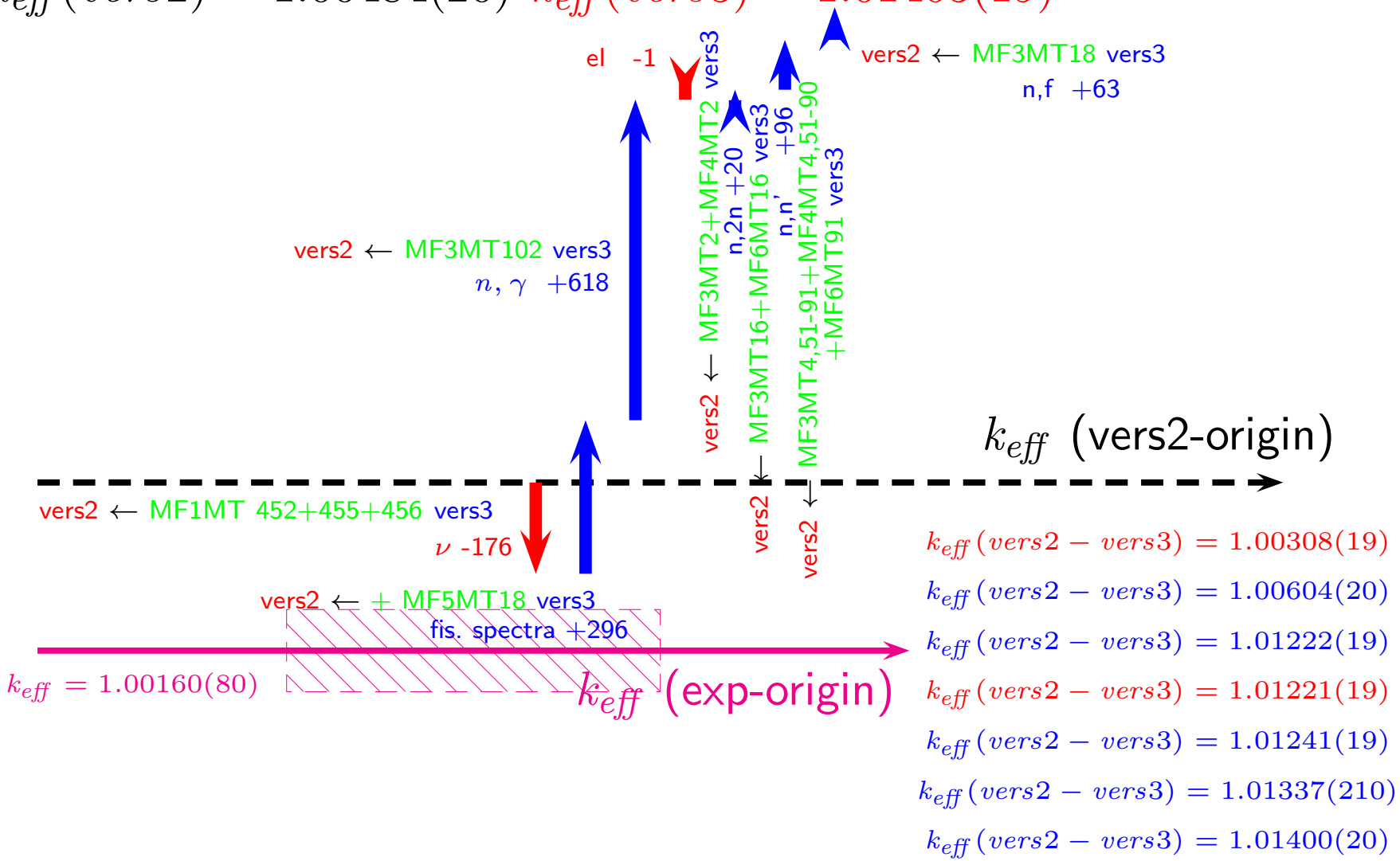
$k_{eff}\,(vers2 - vers3) = 1.00436(210)$

$k_{eff}\,(vers2 - vers3) = 1.00391(20)$

Fresnel Representation - ^{235}U eval. DE-RE-construction

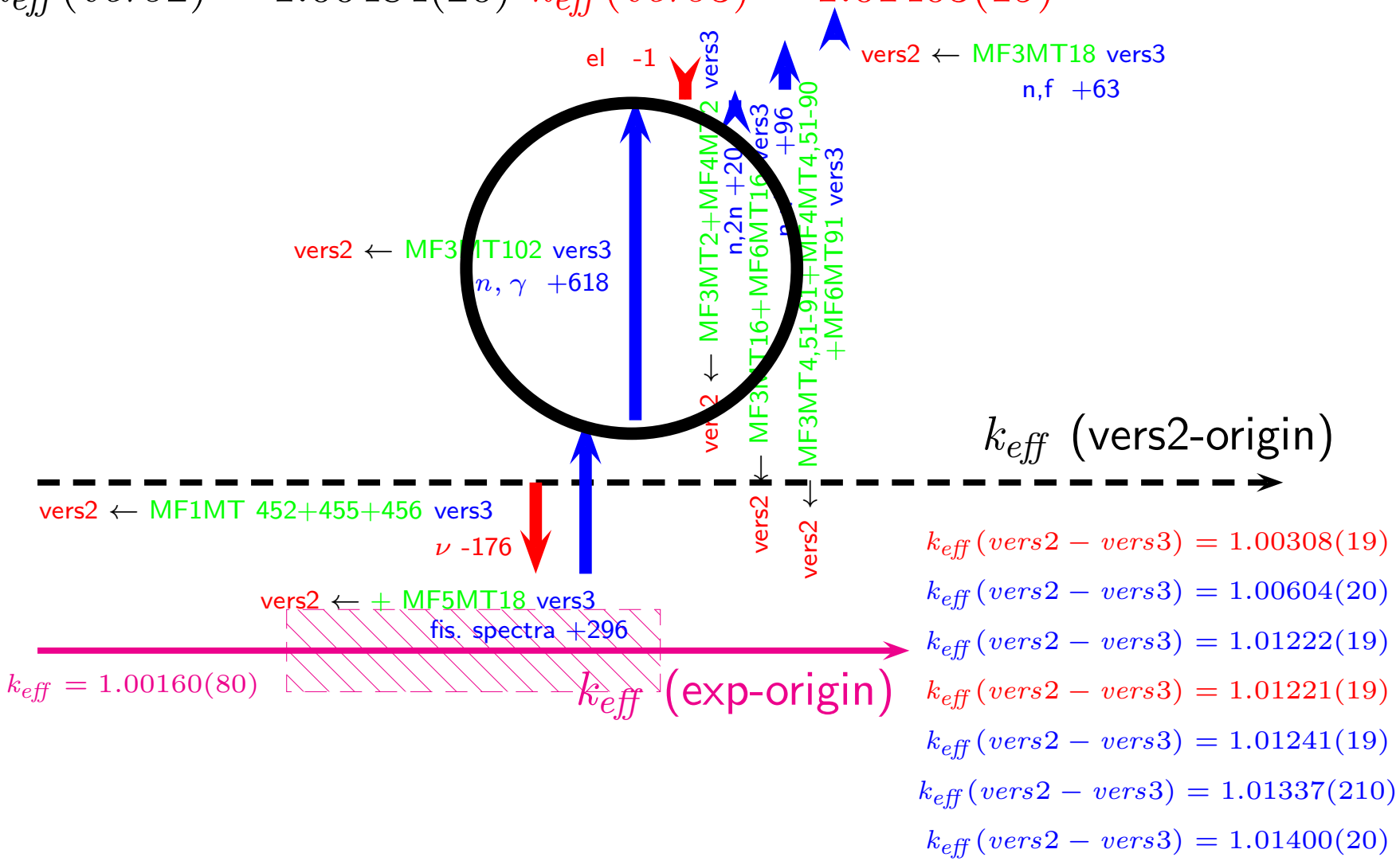
MCNP study of the ZEUS-4 critical benchmark

$k_{eff}(vers2) = 1.00484(20)$ $k_{eff}(vers3) = 1.01403(19)$



MCNP study of the ZEUS-4 critical benchmark

$k_{eff}\,(vers2) = 1.00484(20)$ $k_{eff}\,(vers3) = 1.01403(19)$



$k_{eff}\,(vers2 - vers3) = 1.00308(19)$

$k_{eff}\,(vers2 - vers3) = 1.00604(20)$

$k_{eff}\,(vers2 - vers3) = 1.01222(19)$

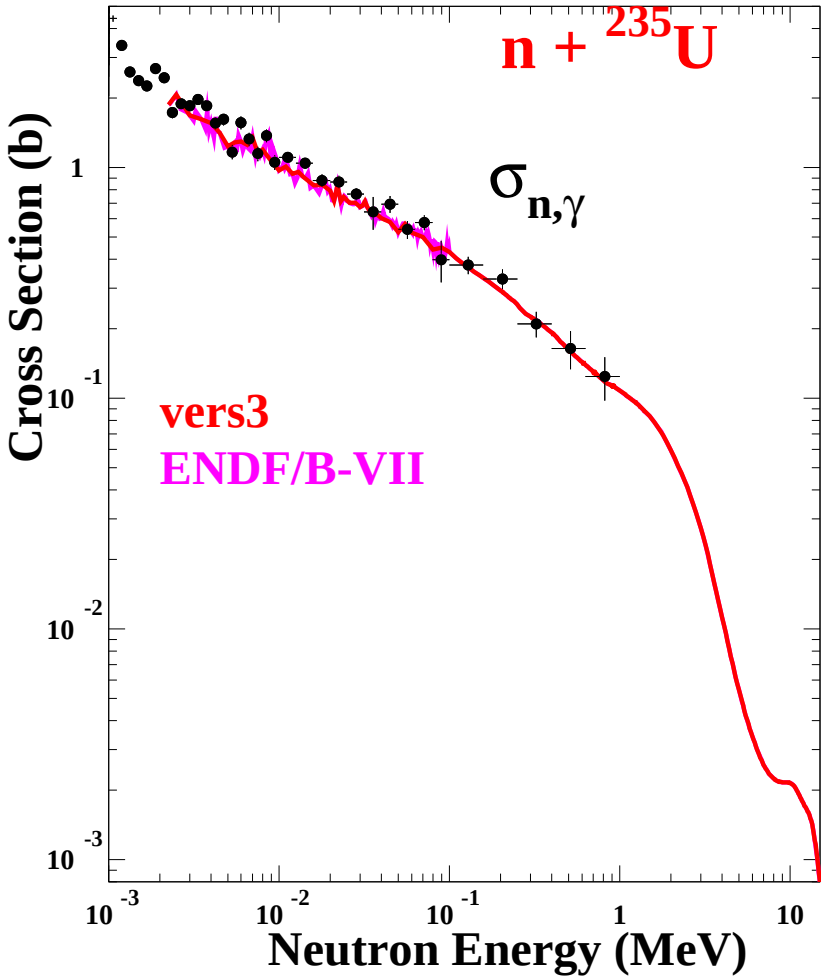
$k_{eff}\,(vers2 - vers3) = 1.01221(19)$

$k_{eff}\,(vers2 - vers3) = 1.01241(19)$

$k_{eff}\,(vers2 - vers3) = 1.01337(210)$

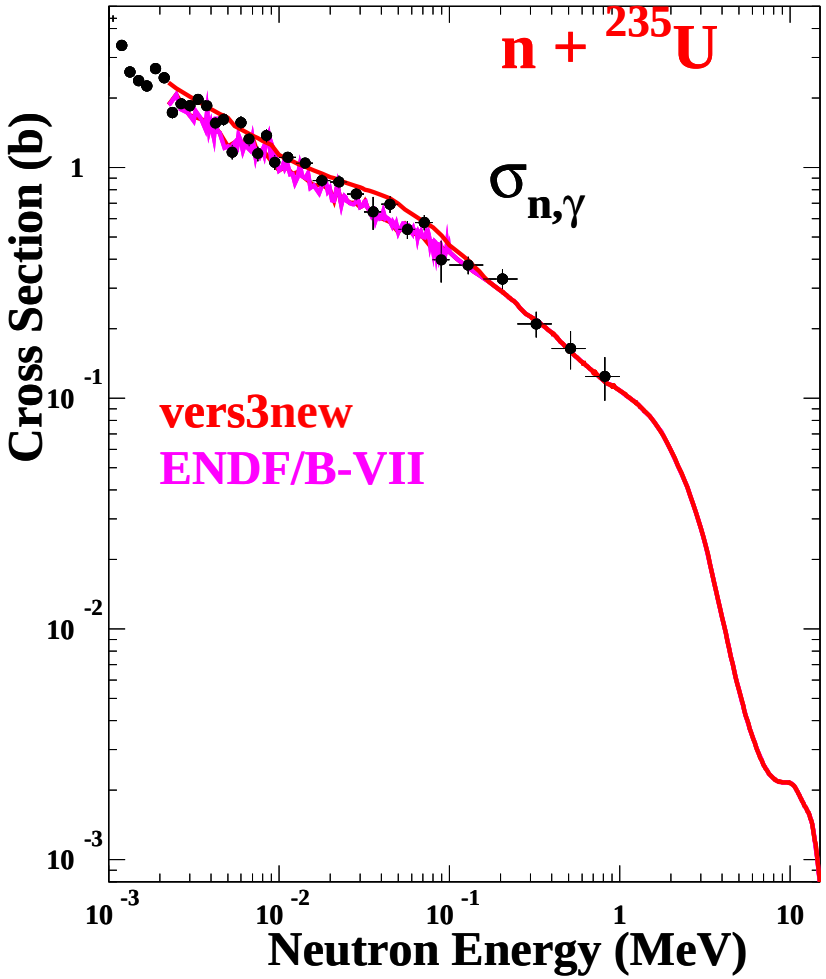
$k_{eff}\,(vers2 - vers3) = 1.01400(20)$

Capture Cross Sections



JANDEL et al. 2012

Capture Cross Sections



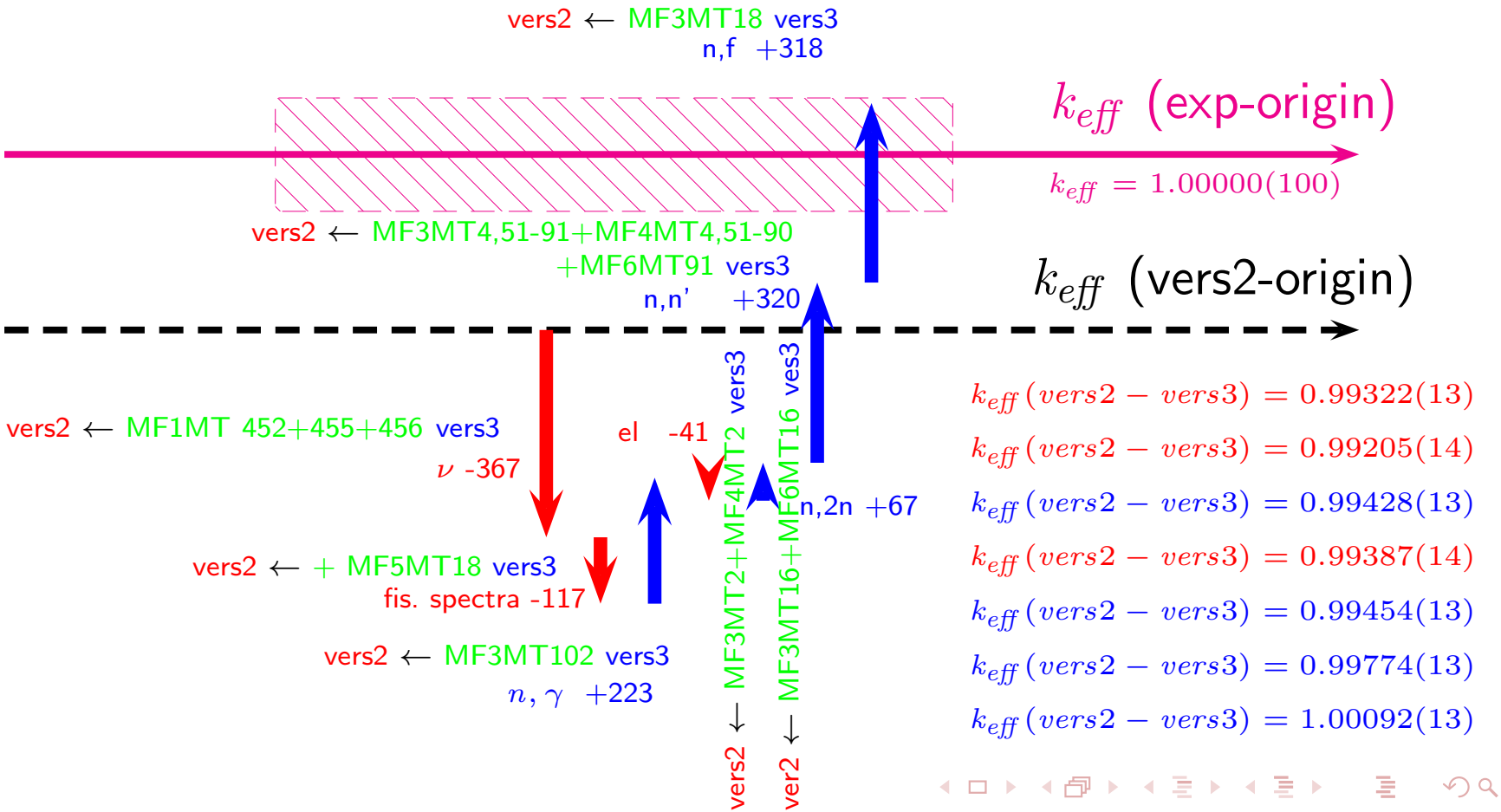
JANDEL et al. 2012

(n, γ) $2.25 < E < 170$ **keV**

ENDF/BVII.1 ⟵ BRC-TALYS

MCNP study of the GODIVA critical benchmark

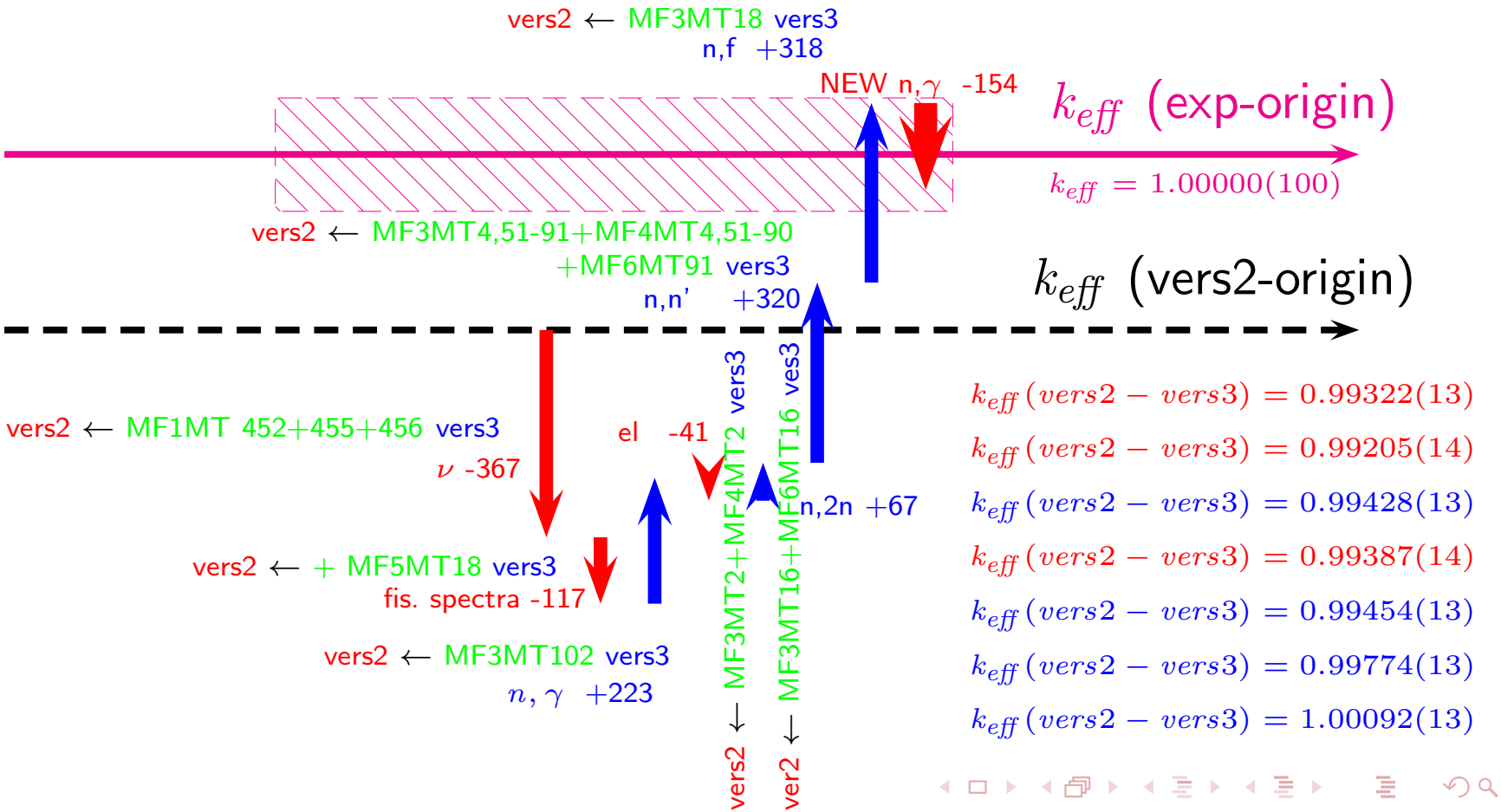
$k_{eff}\,(vers2) = 0.99689(13)$ $k_{eff}\,(vers3) = 1.00135(13)$



MCNP study of the GODIVA critical benchmark

$k_{eff}\,(vers2) = 0.99689(13)$ $k_{eff}\,(vers3) = 1.00135(13)$

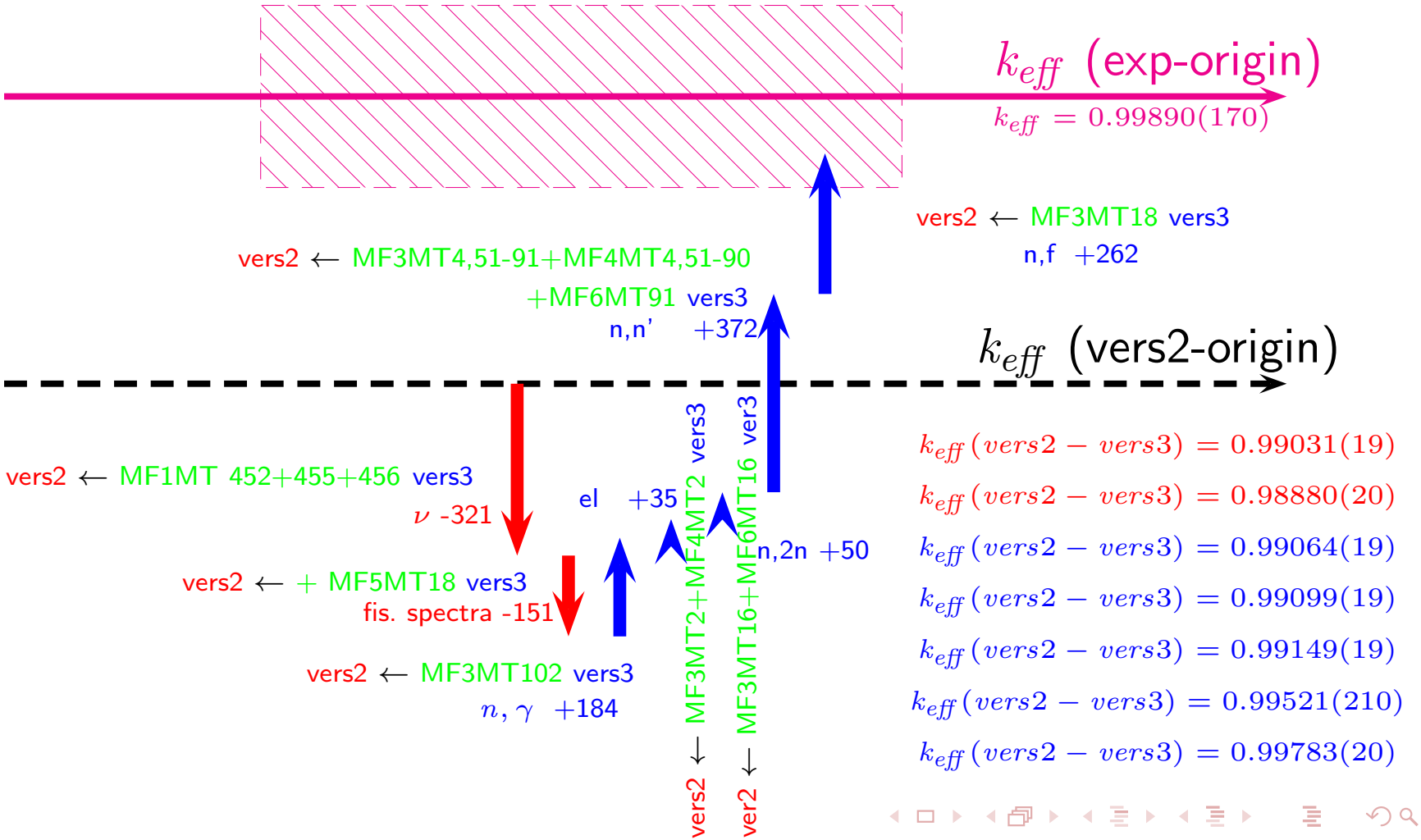
k_{eff} **(vers3new)=** $0.99938(14)$



Fresnel Representation - ^{235}U eval. DE-RE-construction

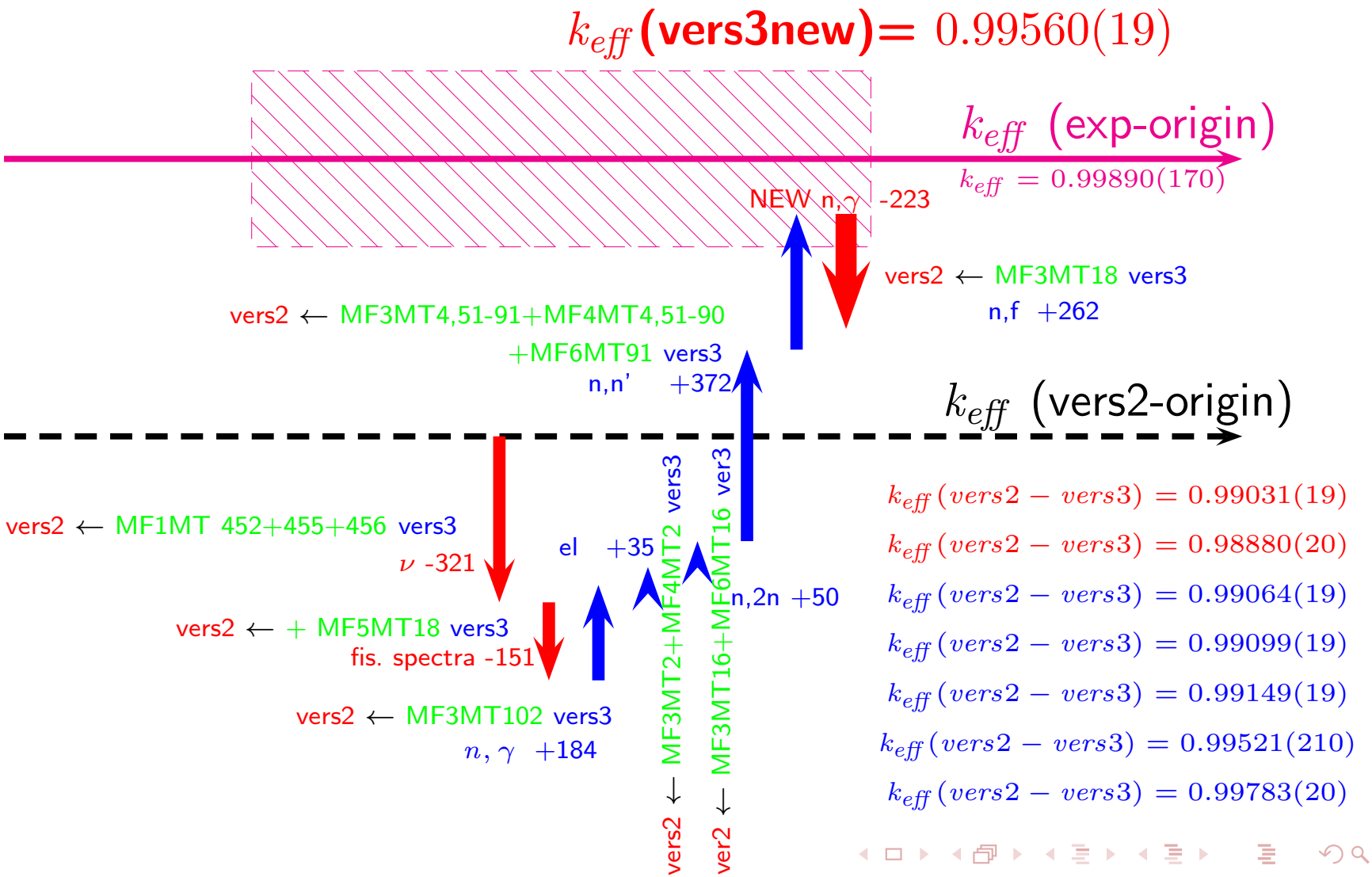
MCNP study of the HMF014 critical benchmark

$k_{eff}\,(vers2) = 0.99352(20)$ $k_{eff}\,(vers3) = 0.99806(19)$



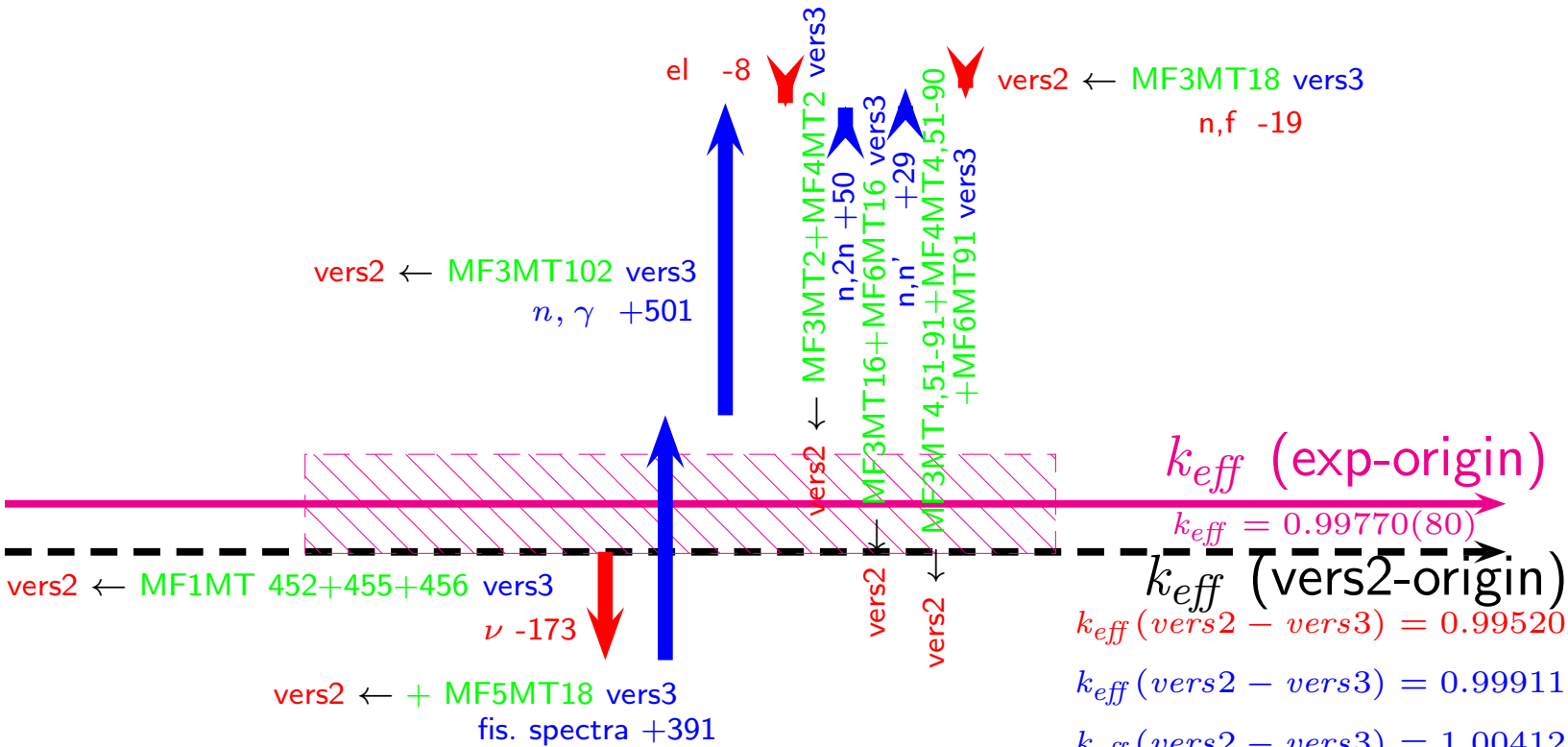
MCNP study of the HMF014 critical benchmark

$k_{eff}\,(vers2) = 0.99352(20)$ $k_{eff}\,(vers3) = 0.99806(19)$



MCNP study of the ZEUS-1 critical benchmark

$k_{eff}\,(vers2) = 0.99693(20)$ $k_{eff}\,(vers3) = 1.00417(19)$



$k_{eff}\,(vers2 - vers3) = 0.99520(19)$

$k_{eff}\,(vers2 - vers3) = 0.99911(20)$

$k_{eff}\,(vers2 - vers3) = 1.00412(19)$

$k_{eff}\,(vers2 - vers3) = 1.00404(19)$

$k_{eff}\,(vers2 - vers3) = 1.00407(19)$

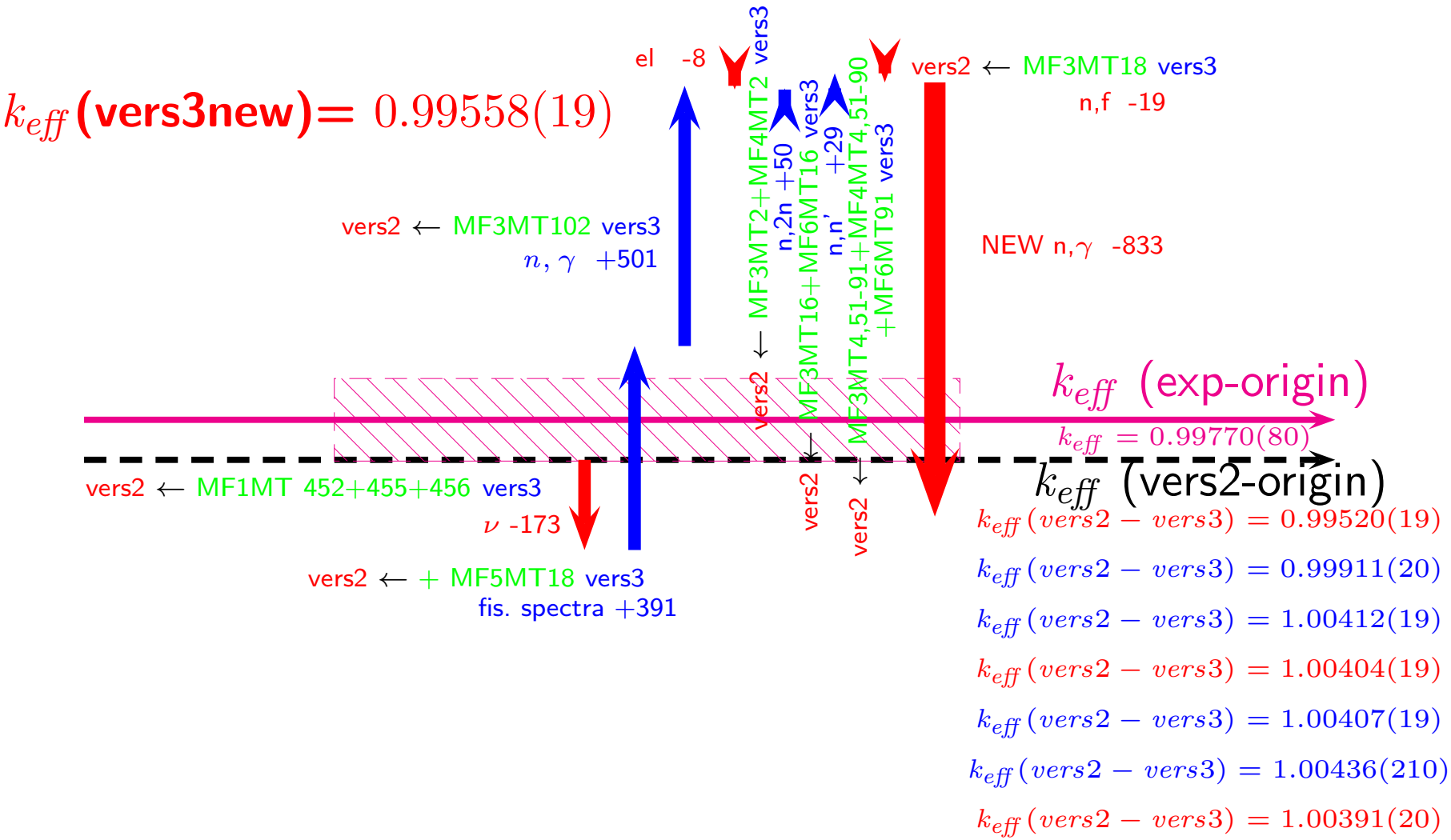
$k_{eff}\,(vers2 - vers3) = 1.00436(210)$

$k_{eff}\,(vers2 - vers3) = 1.00391(20)$

Fresnel Representation - ^{235}U eval. DE-RE-construction

MCNP study of the ZEUS-1 critical benchmark

$k_{eff}\,(vers2) = 0.99693(20)$ $k_{eff}\,(vers3) = 1.00417(19)$



$k_{eff}\,(vers2 - vers3) = 0.99520(19)$

$k_{eff}\,(vers2 - vers3) = 0.99911(20)$

$k_{eff}\,(vers2 - vers3) = 1.00412(19)$

$k_{eff}\,(vers2 - vers3) = 1.00404(19)$

$k_{eff}\,(vers2 - vers3) = 1.00407(19)$

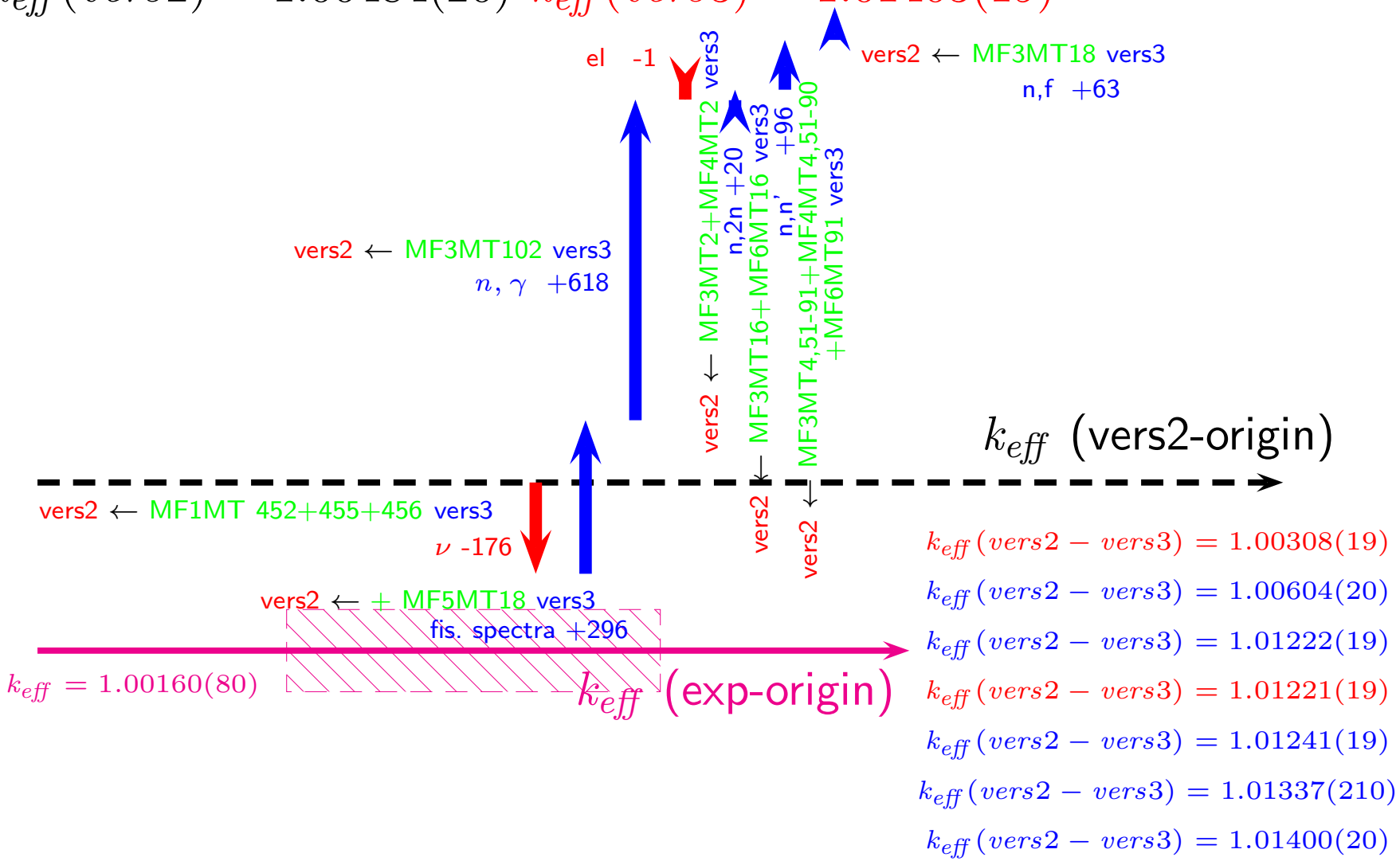
$k_{eff}\,(vers2 - vers3) = 1.00436(210)$

$k_{eff}\,(vers2 - vers3) = 1.00391(20)$

Fresnel Representation - ^{235}U eval. DE-RE-construction

MCNP study of the ZEUS-4 critical benchmark

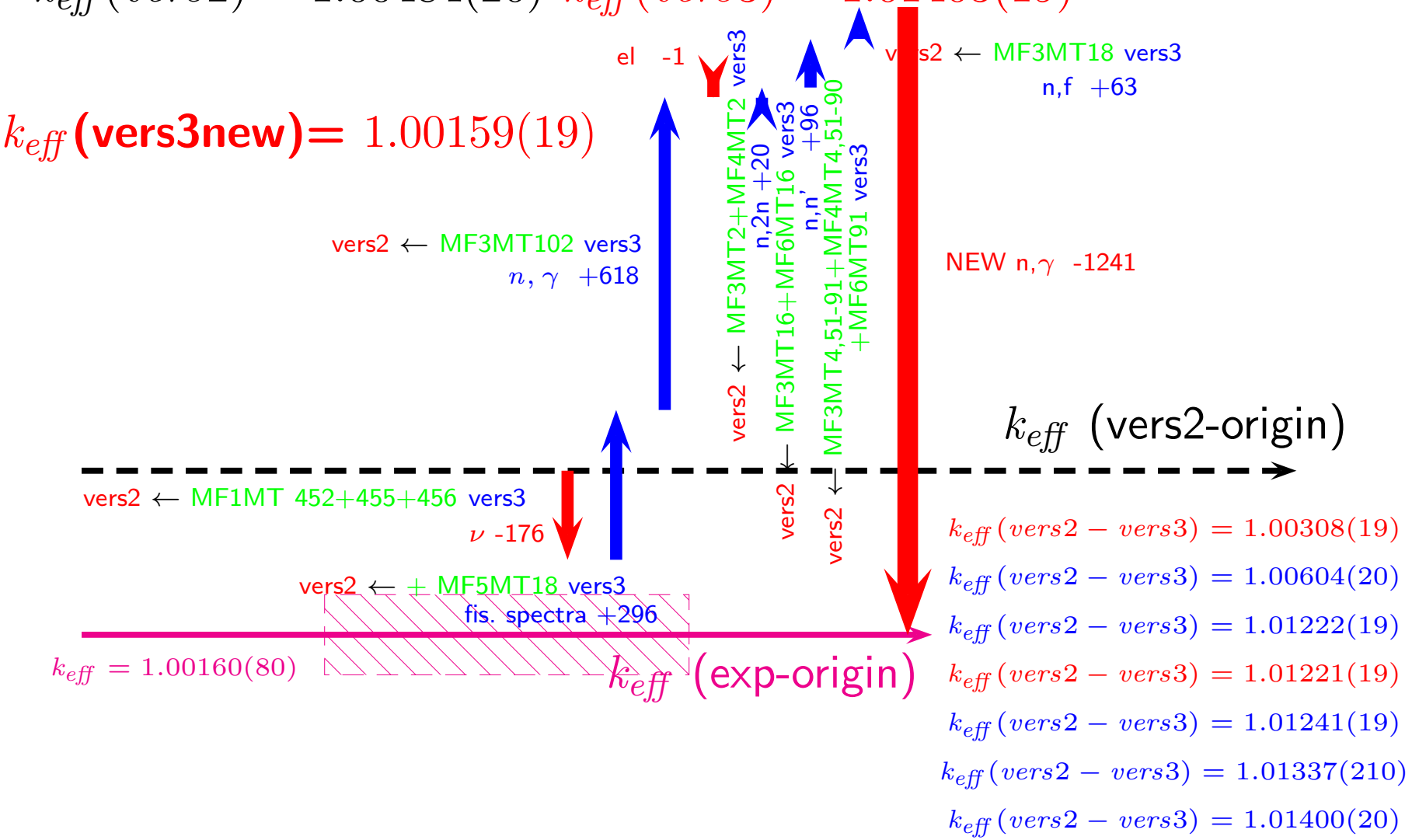
$k_{eff}(vers2) = 1.00484(20)$ $k_{eff}(vers3) = 1.01403(19)$



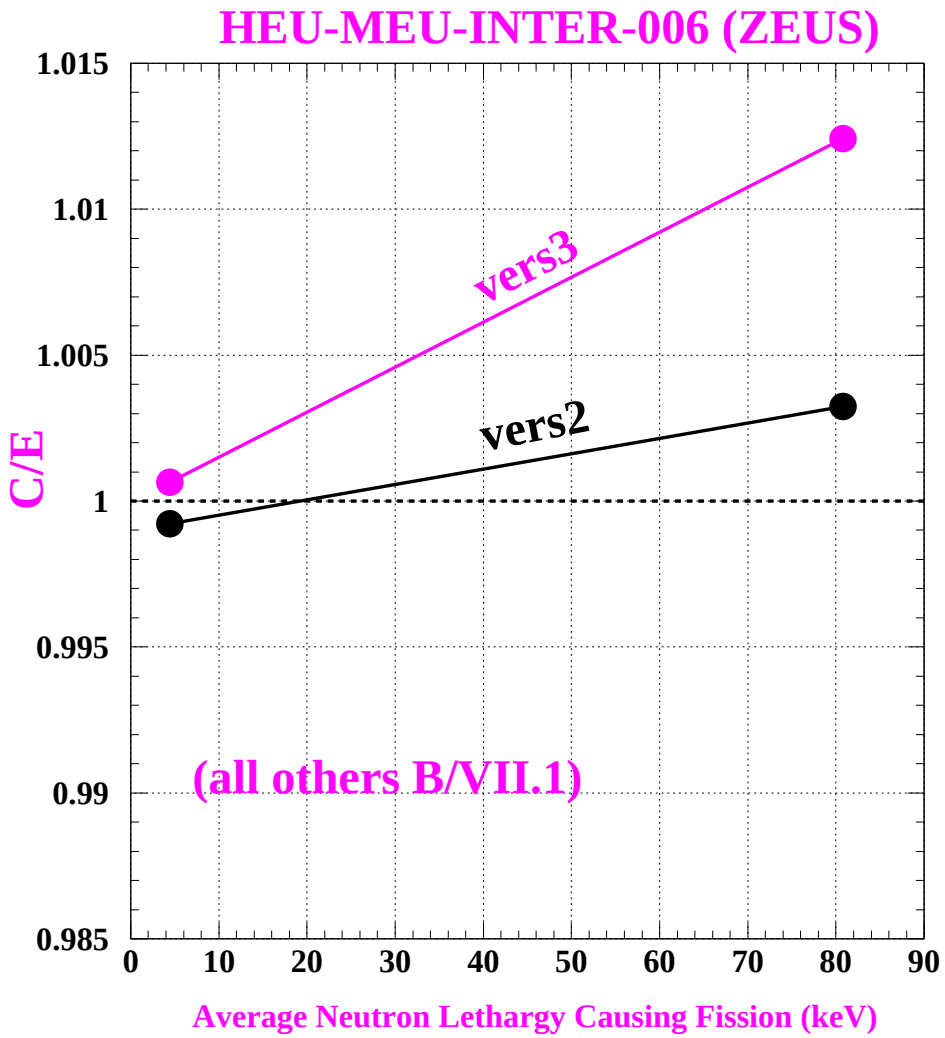
Fresnel Representation - ^{235}U eval. DE-RE-construction

MCNP study of the ZEUS-4 critical benchmark

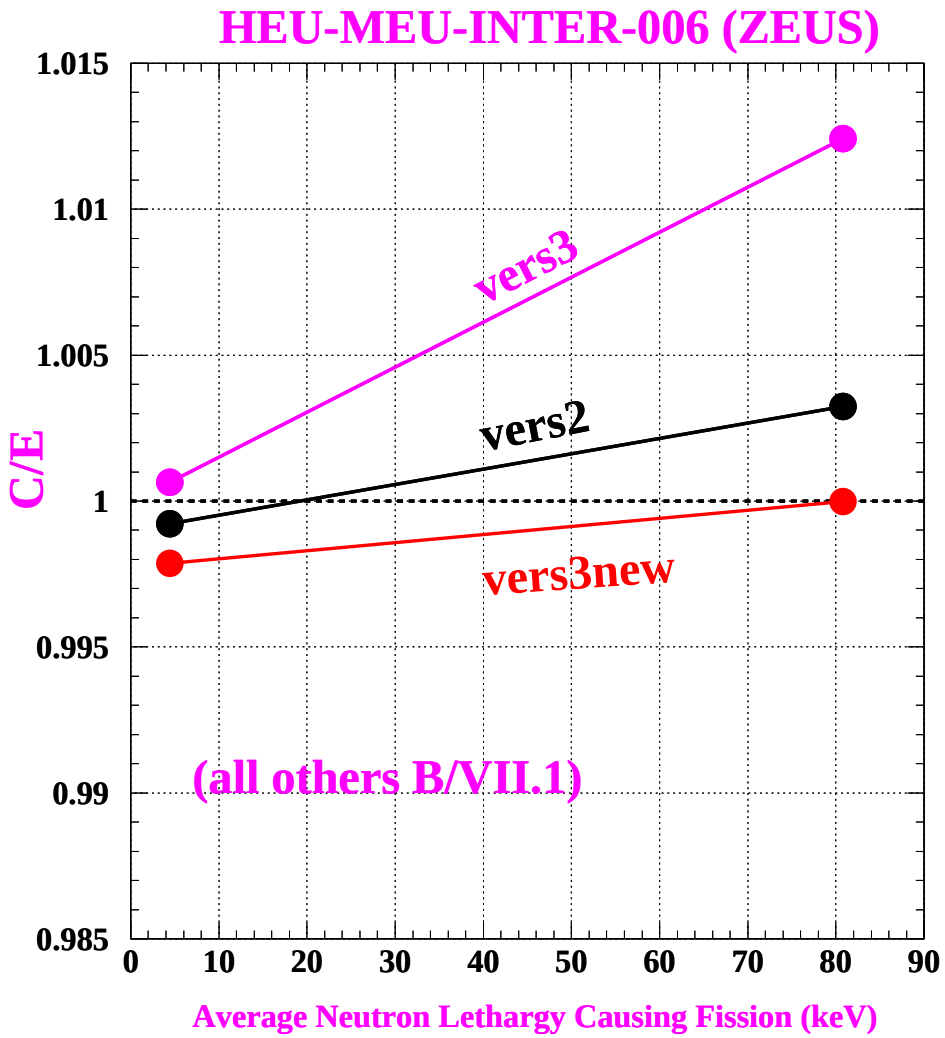
$k_{eff}(vers2) = 1.00484(20)$ $k_{eff}(vers3) = 1.01403(19)$



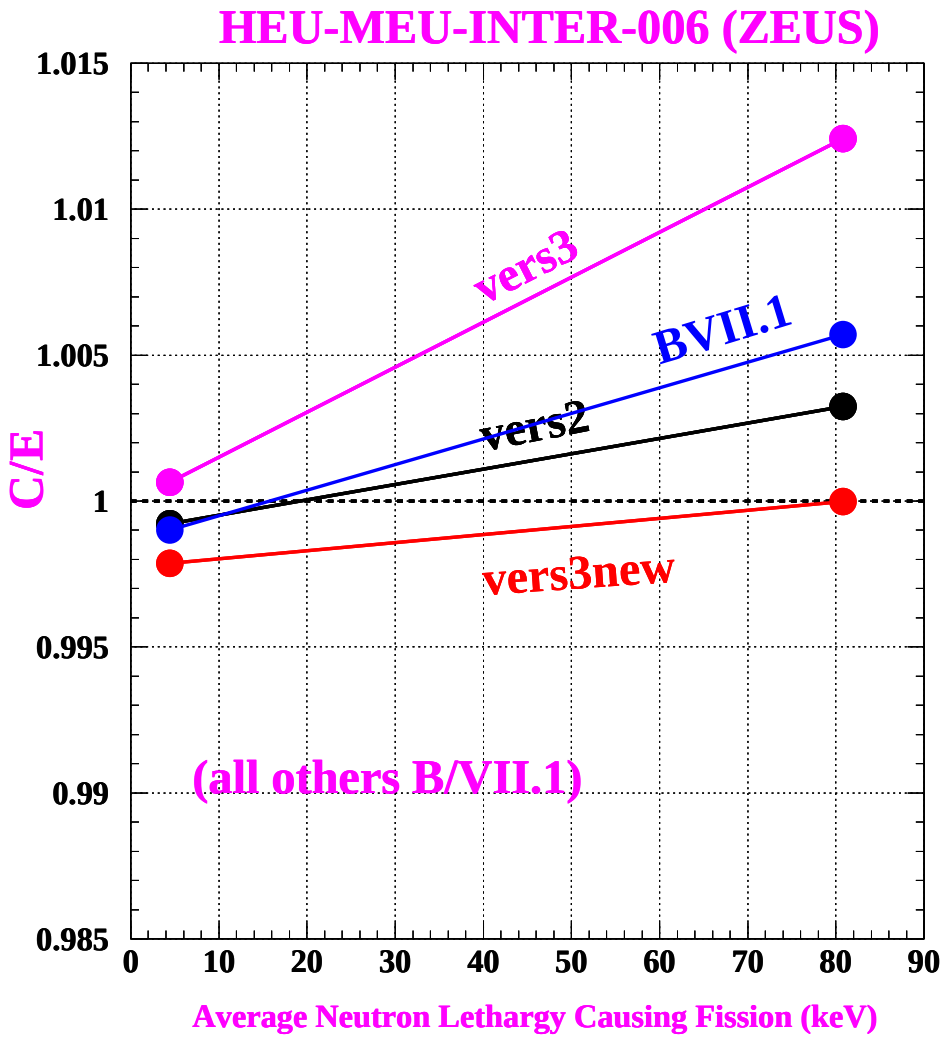
Improvements on the ZEUS-1 and ZEUS-4 benchmarks



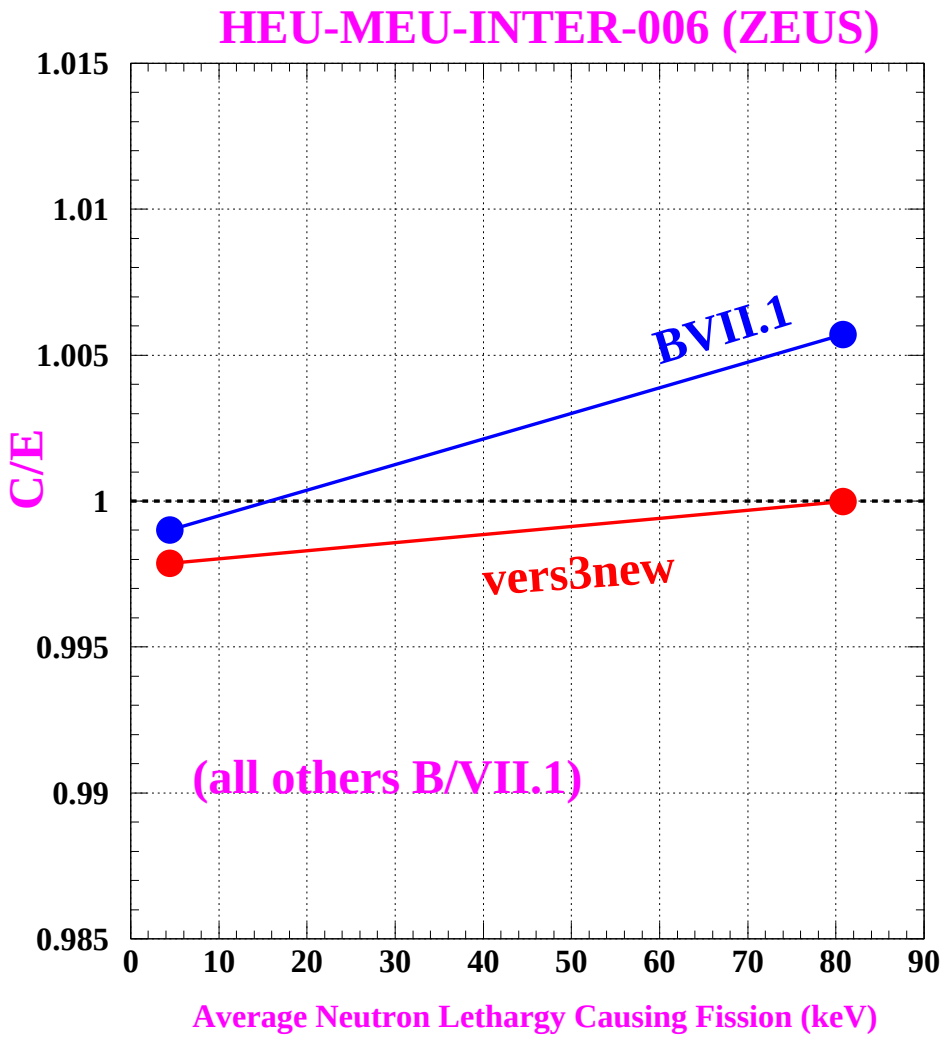
Improvements on the ZEUS-1 and ZEUS-4 benchmarks



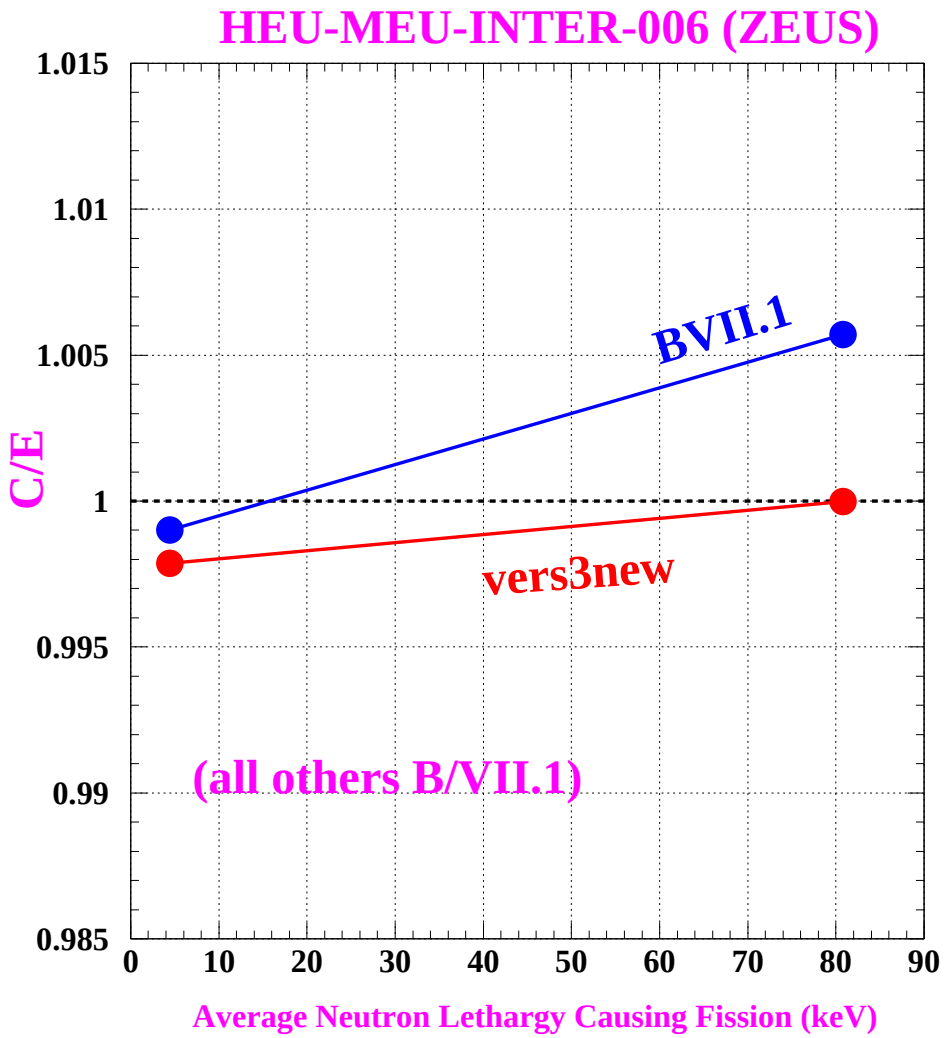
Improvements on the ZEUS-1 and ZEUS-4 benchmarks



Improvements on the ZEUS-1 and ZEUS-4 benchmarks



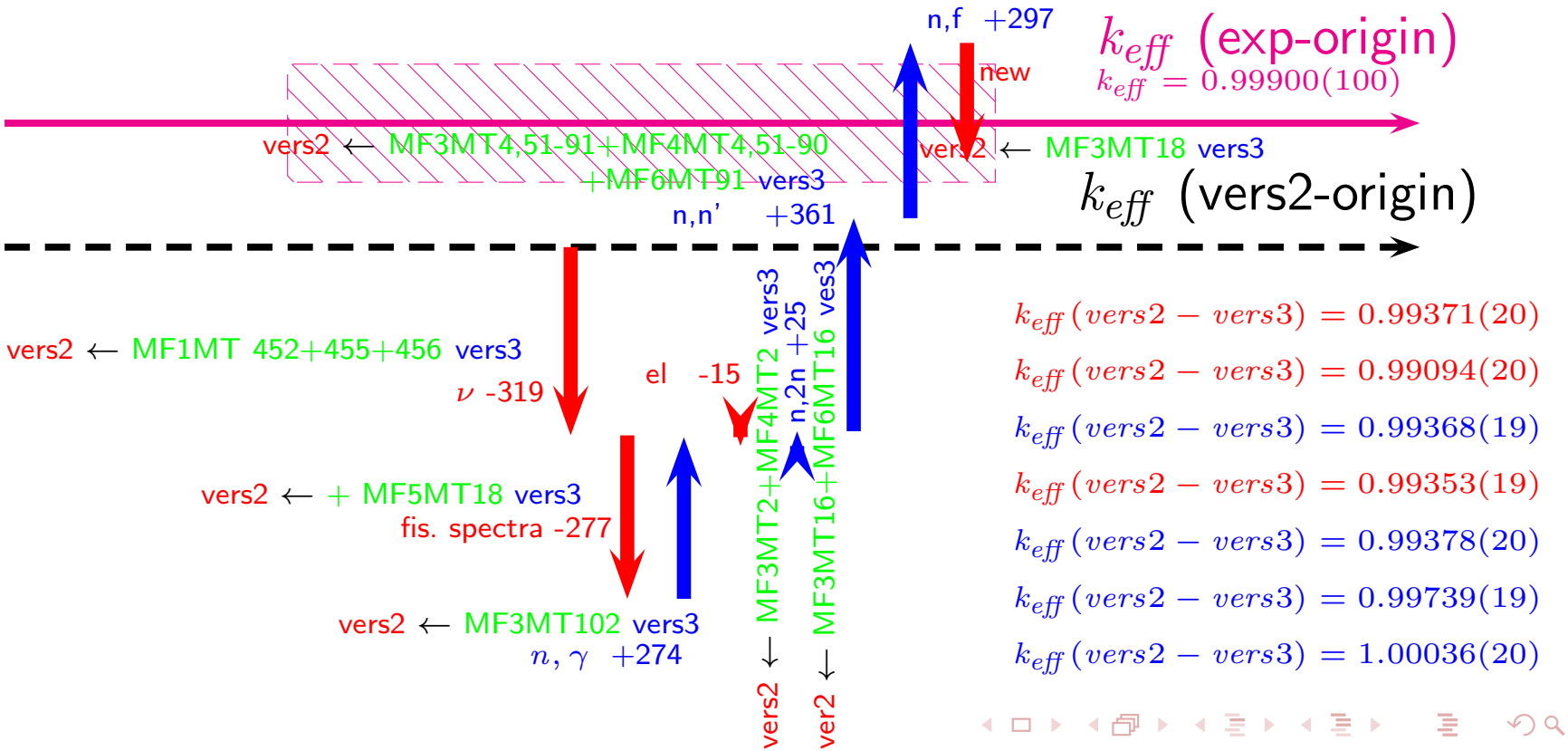
Improvements on the ZEUS-1 and ZEUS-4 benchmarks



BUT
What about
JEMIMA ?
BIGTEN ?

MCNP study of the JEMIMA (IMF001a) critical benchmark

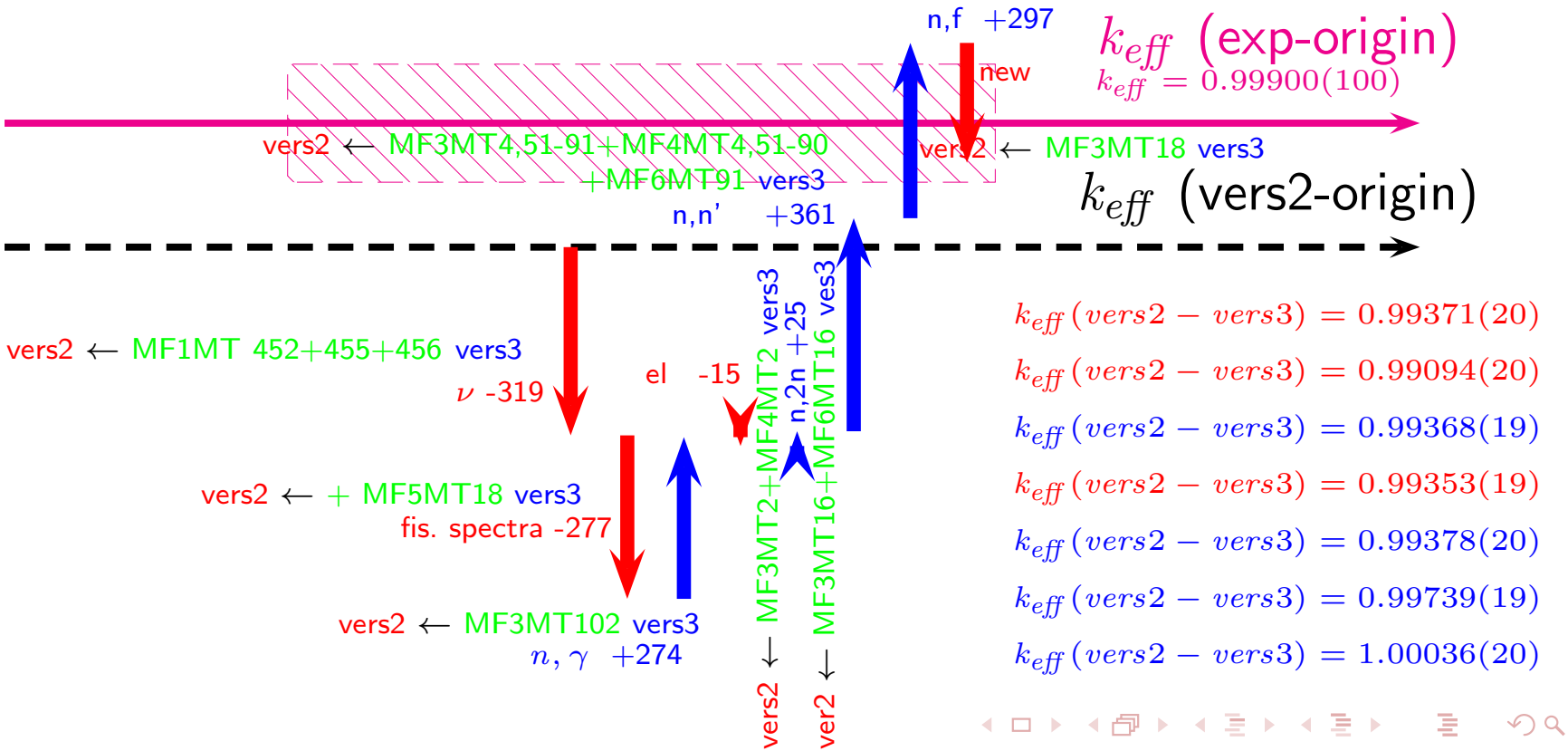
$k_{eff}(vers2) = 0.99690(17)$ $k_{eff}(vers3new) = 0.99833(20)$



MCNP study of the JEMIMA (IMF001a) critical benchmark

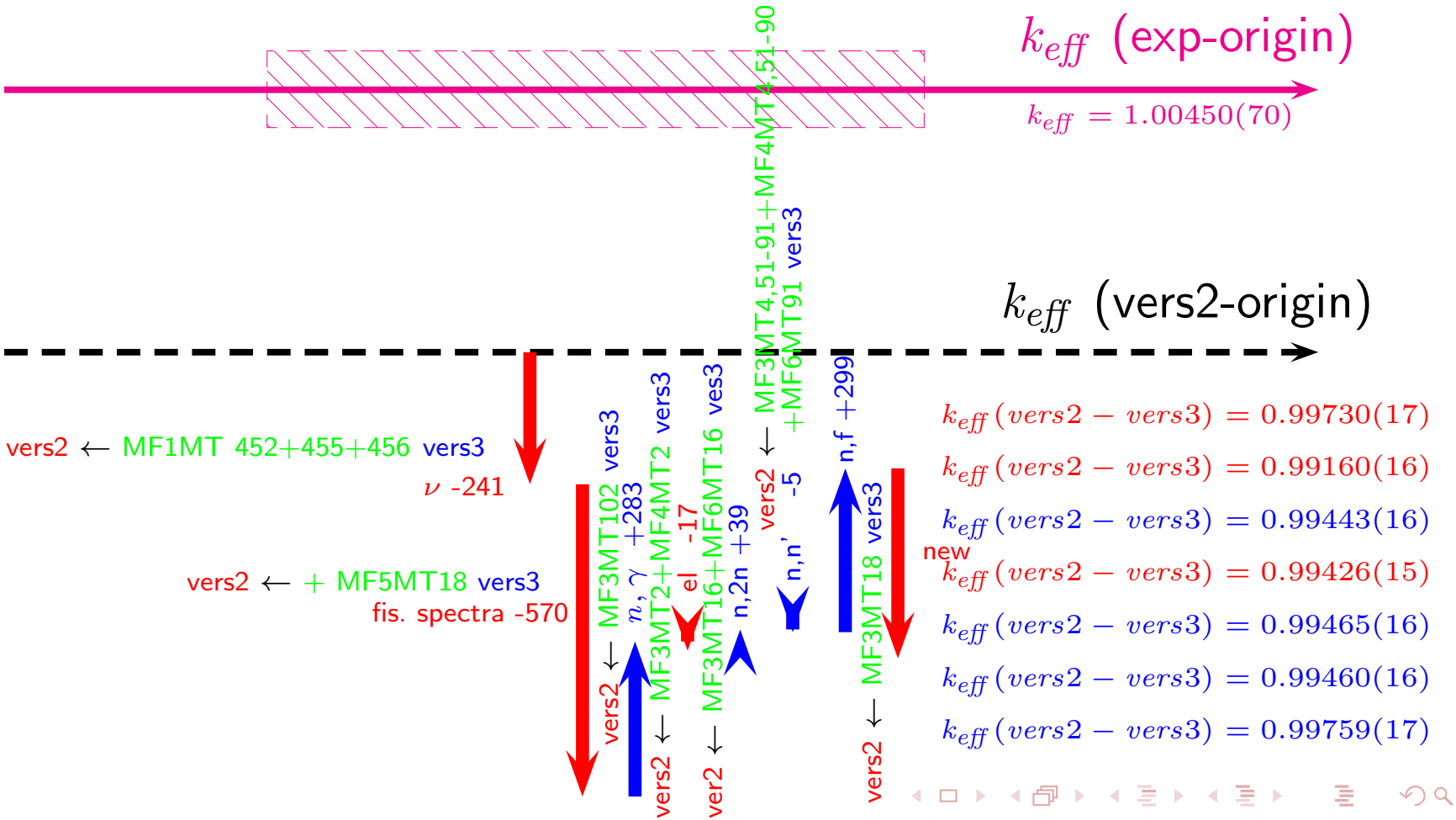
$k_{eff}(vers2) = 0.99690(17)$ $k_{eff}(vers3new) = 0.99833(20)$

$\sim$ OK



MCNP study of the BIGTEN (IMF007a) critical benchmark

$k_{eff}(vers2) = 0.99971(17)$ $k_{eff}(vers3new) = 0.99334(16)$

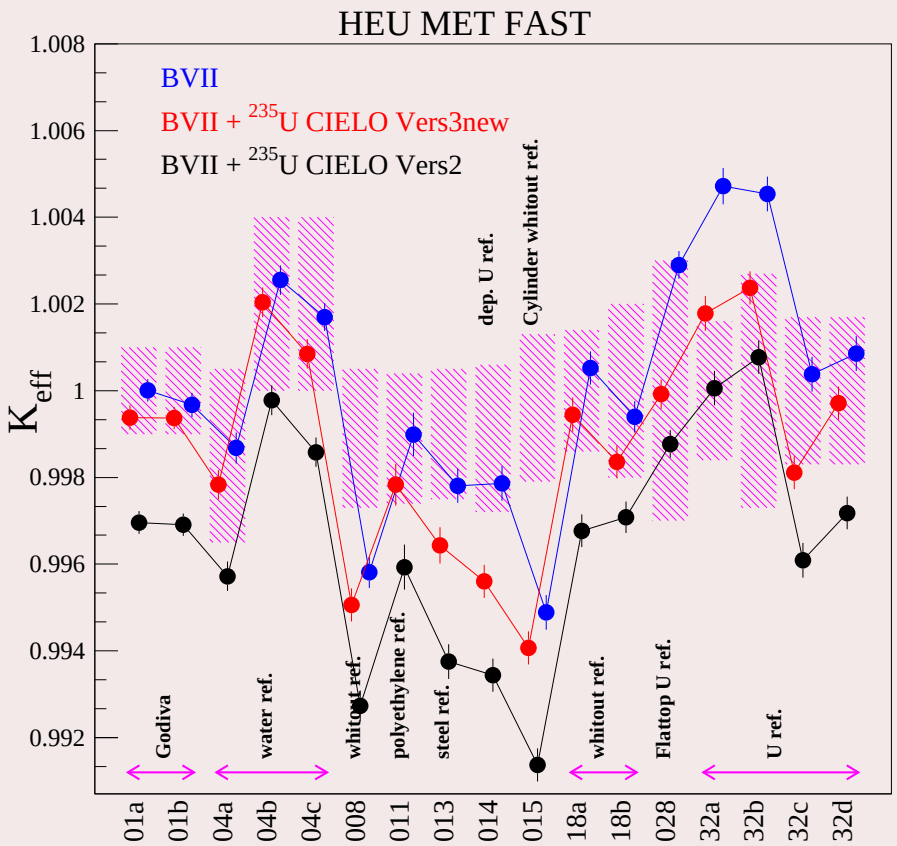


Status of ^{235}U evaluation in the high energy range

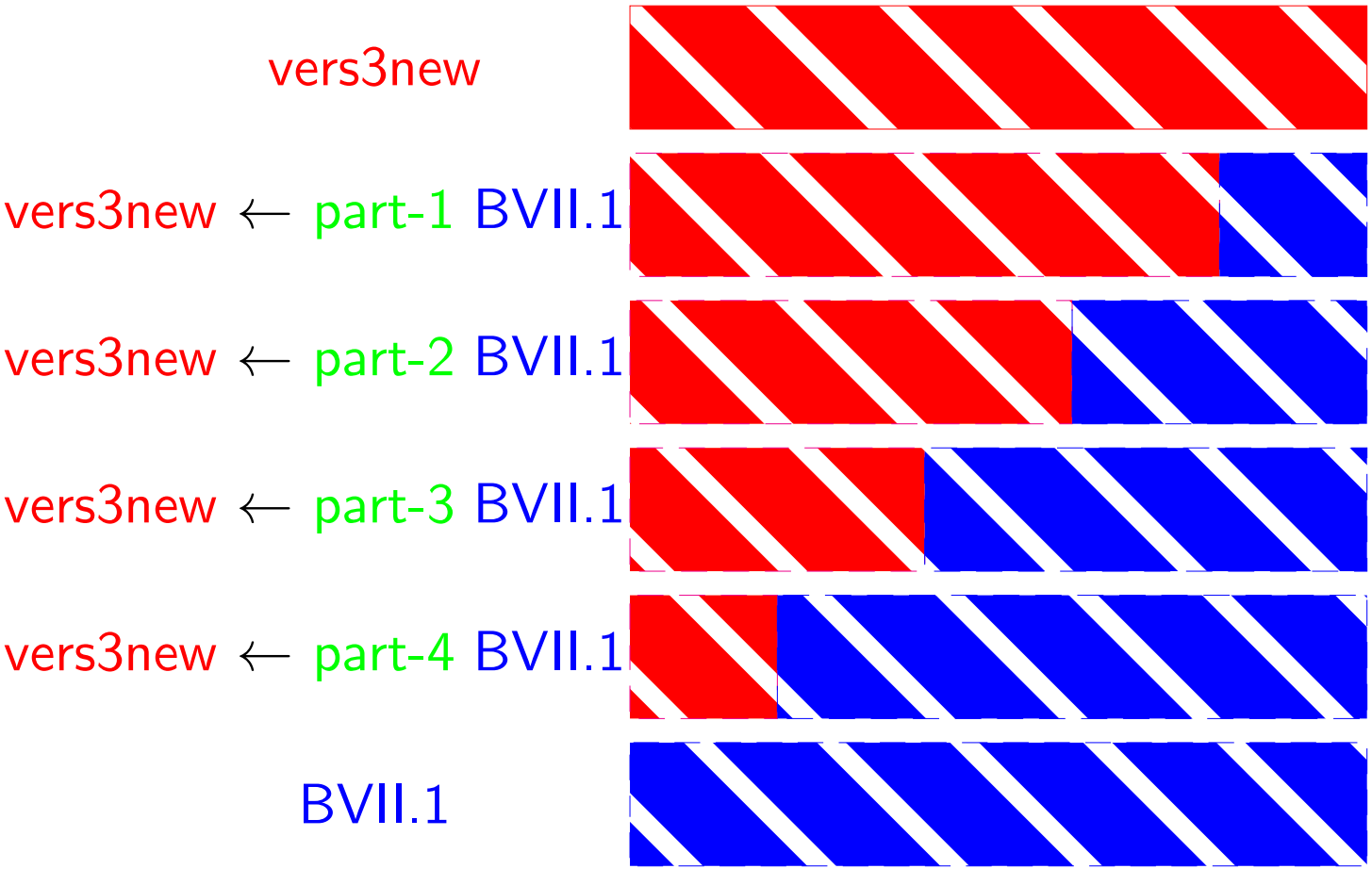
BIGTEN ? ? ? ?

BUT nevertheless ...

HEU MET FAST

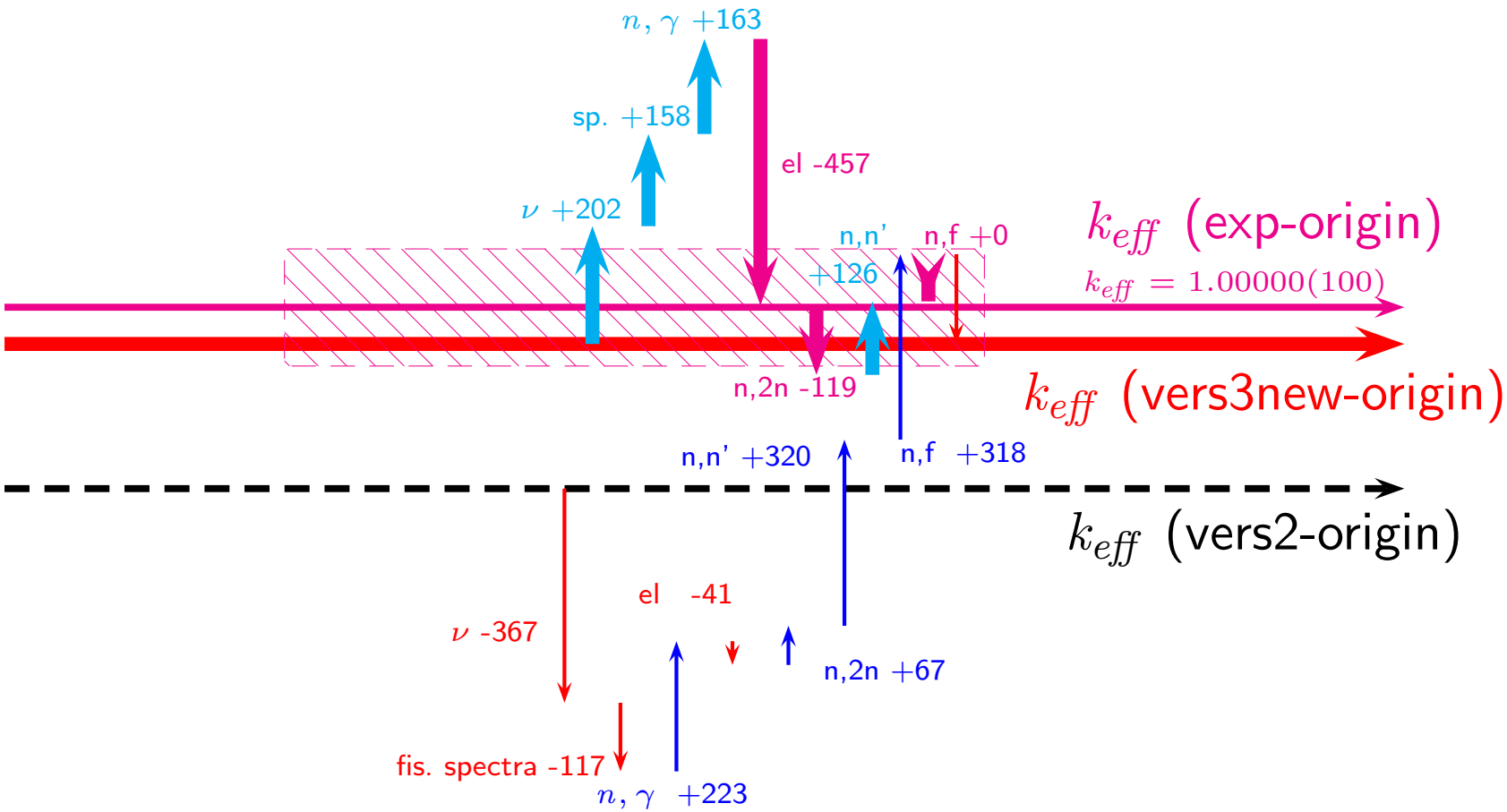

HEU MET FAST
BVII
BVII + 235U CIELO Vers3new
BVII + 235U CIELO Vers2
Keff
1.008
1.006
1.004
1.002
1
0.998
0.996
0.994
0.992
Godiva
water ref.
whitout ref.
polyethylene ref.
steel ref.
dep. U ref.
Cylinder whitout ref.
whitout ref.
Flattop U ref.
U ref.
01a
01b
04a
04b
04c
008
011
013
014
015
18a
18b
028
32a
32b
32c
32d

De-re-construction



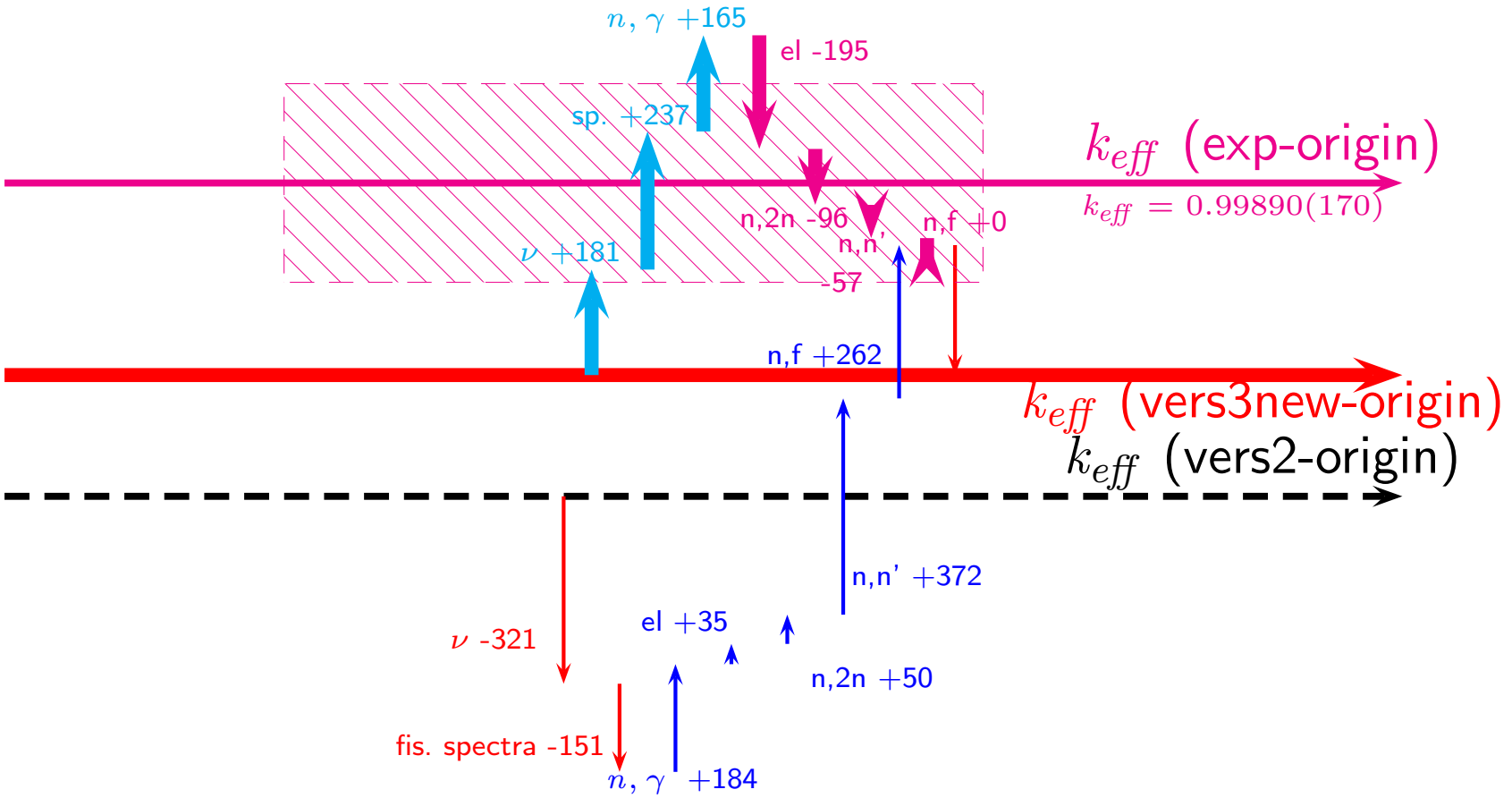
MCNP study of the GODIVA critical benchmark

$k_{eff}(BVII.1) = 1.00000(13)$ $k_{eff}(vers3new) = 0.99938(14)$



MCNP study of the HMF014 critical benchmark

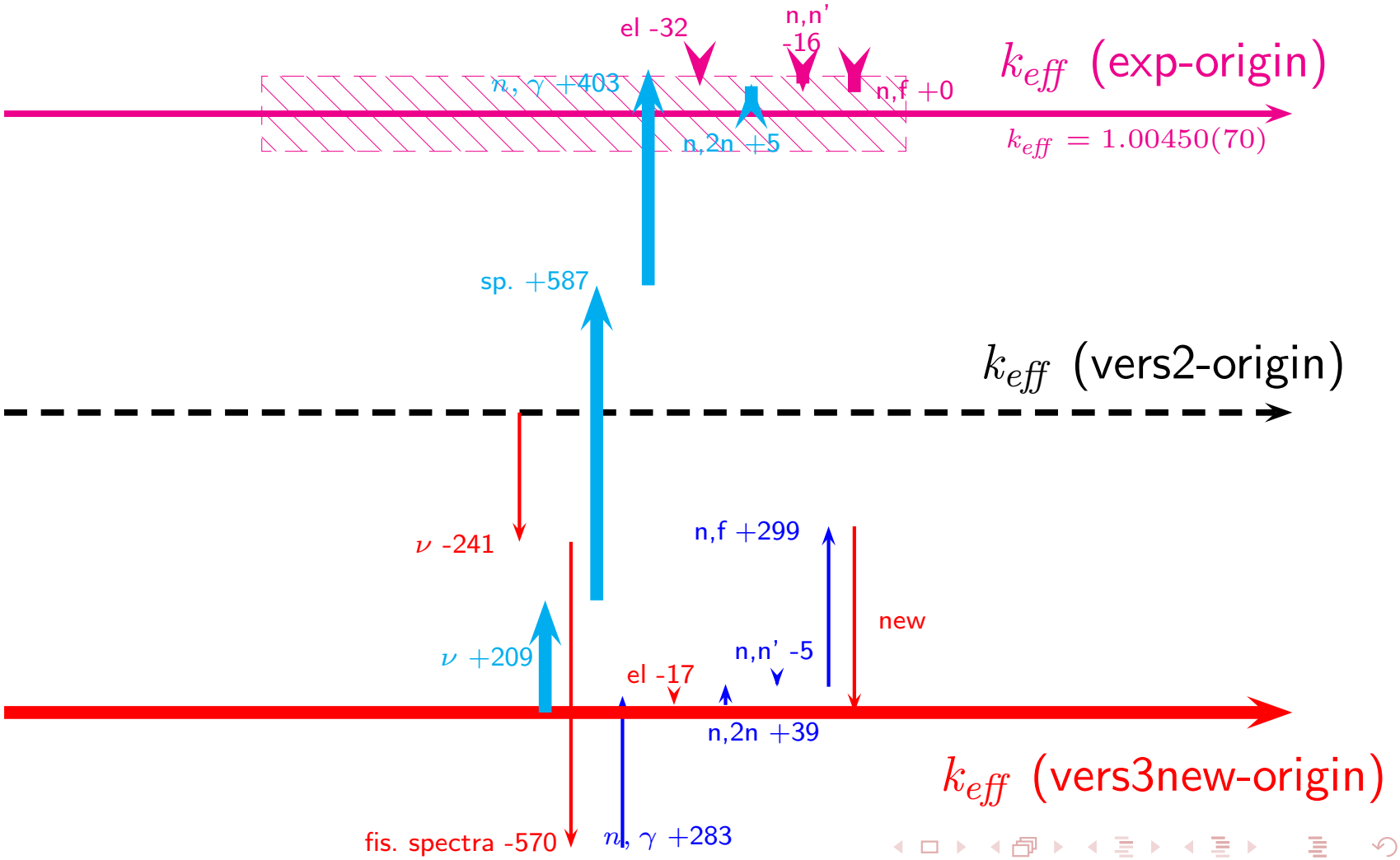
$k_{eff}(BVII.1) = 0.99778(20)$ $k_{eff}(vers3new) = 0.99560(19)$



Fresnel Representation - ^{235}U eval. DE-RE-construction

MCNP study of the BIGTEN (IMF007a) critical benchmark

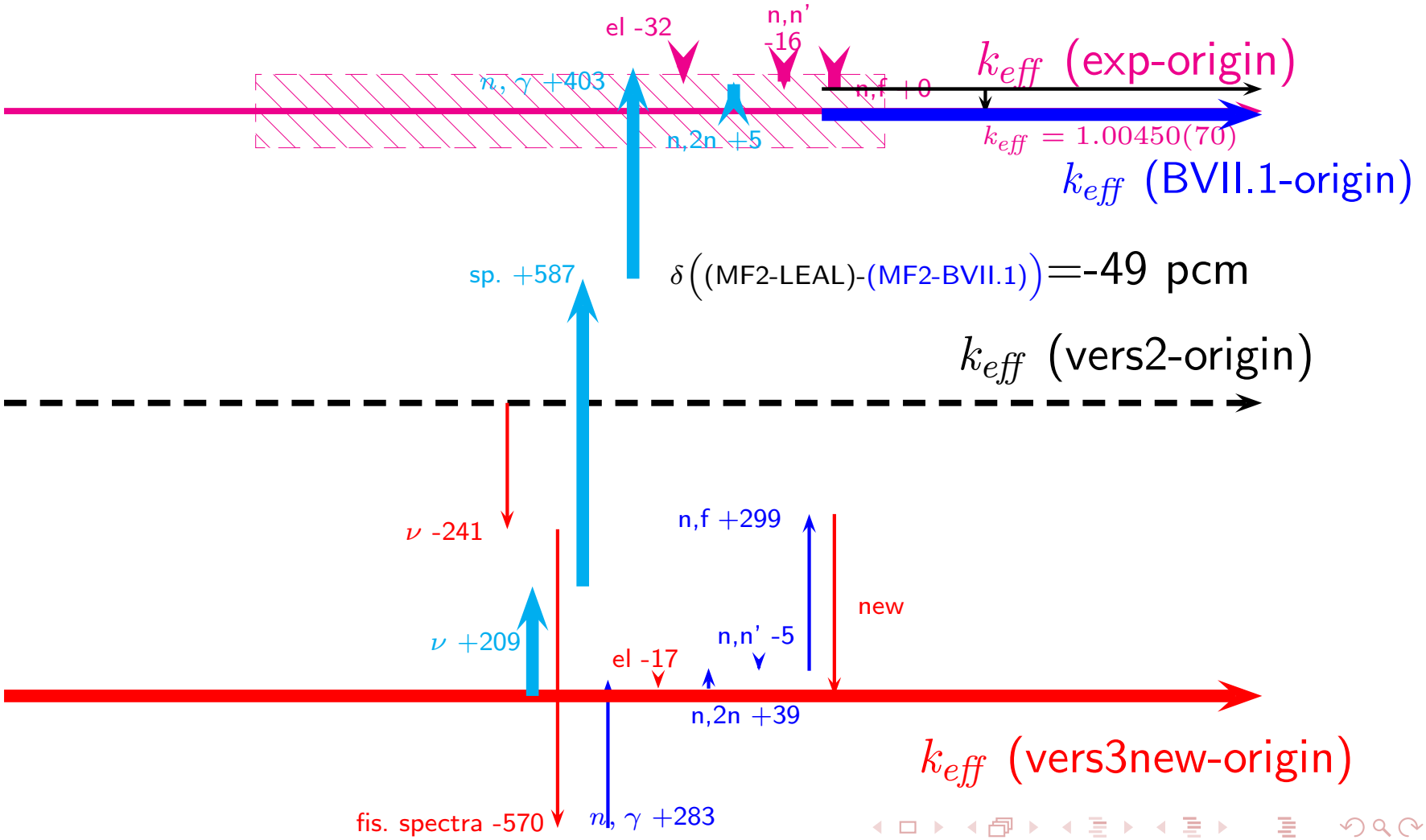
$k_{eff}(BVII.1) = 1.00441(17)$ $k_{eff}(vers3new) = 0.99334(16)$



Fresnel Representation - ^{235}U eval. DE-RE-construction

MCNP study of the BIGTEN (IMF007a) critical benchmark

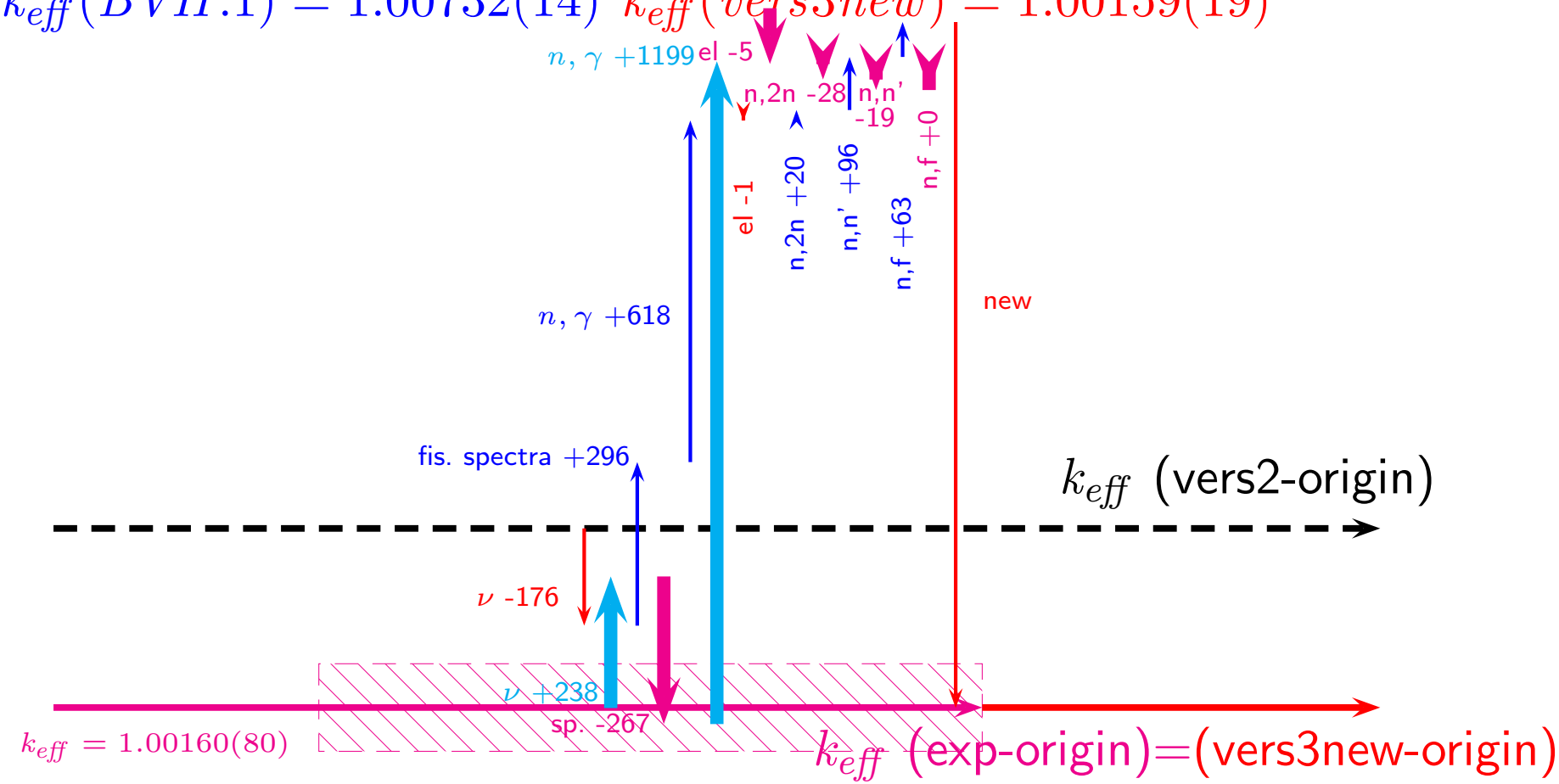
$k_{eff}(BVII.1) = 1.00441(17)$ $k_{eff}(vers3new) = 0.99334(16)$



Fresnel Representation - ^{235}U eval. DE-RE-construction

MCNP study of the ZEUS-4 critical benchmark

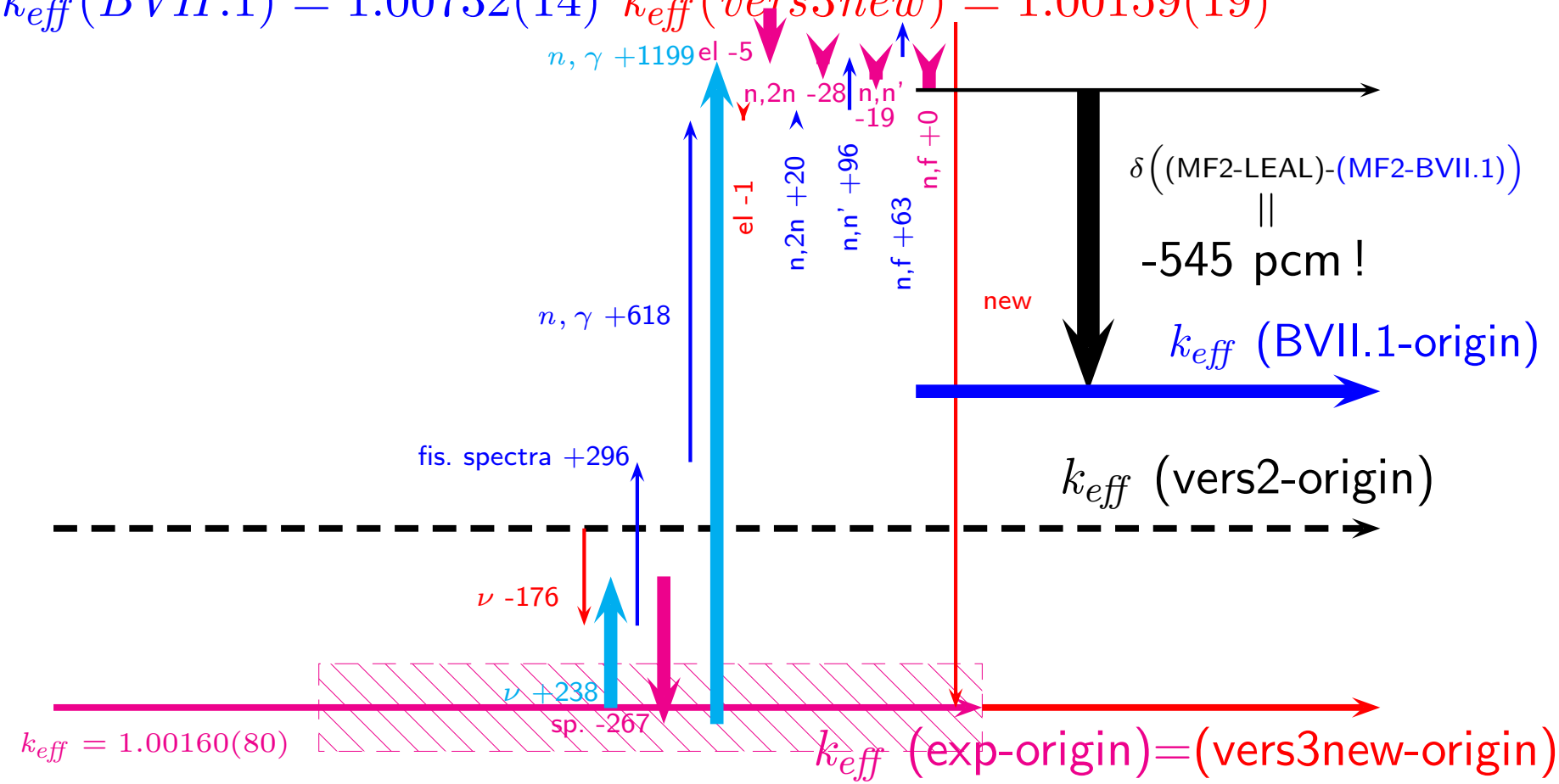
$k_{eff}(BVII.1) = 1.00732(14)$ $k_{eff}(vers3new) = 1.00159(19)$



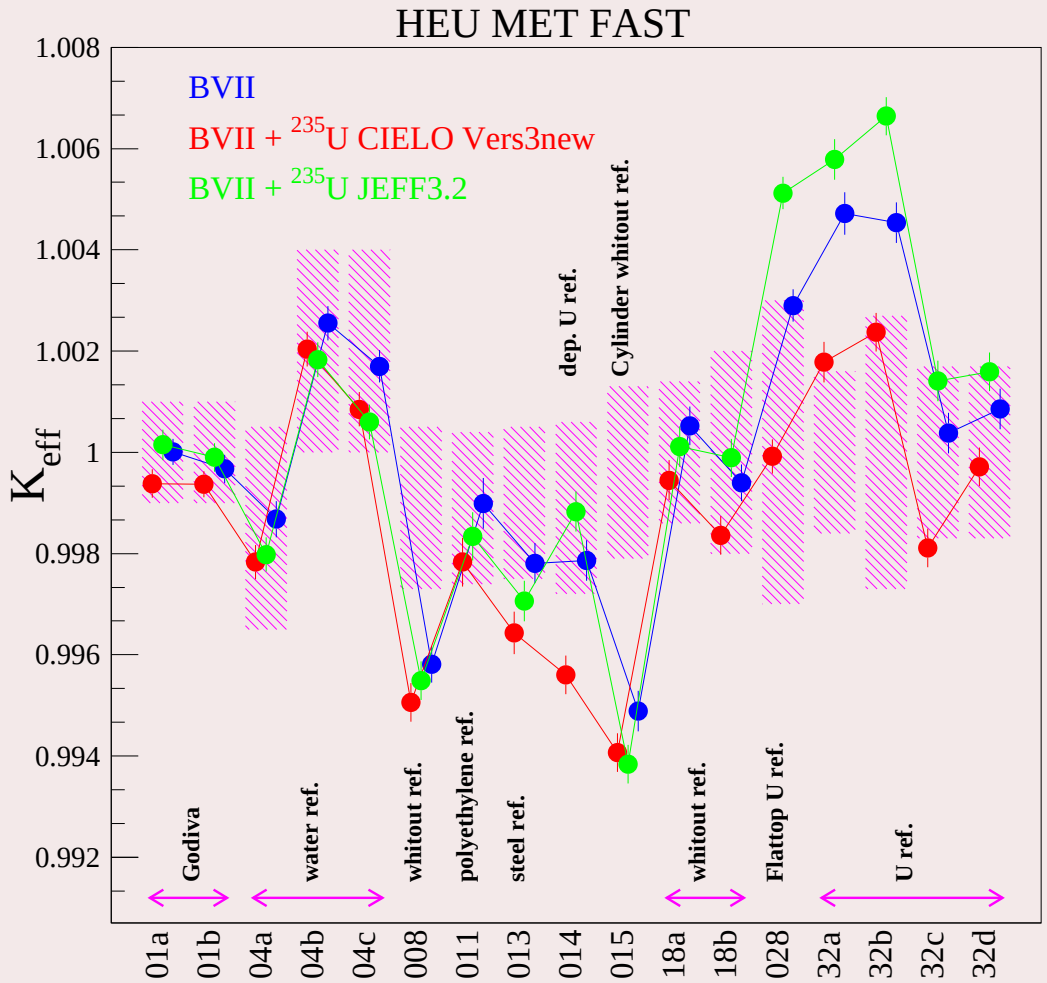
Fresnel Representation - ^{235}U eval. DE-RE-construction

MCNP study of the ZEUS-4 critical benchmark

$k_{eff}(BVII.1) = 1.00732(14)$ $k_{eff}(vers3new) = 1.00159(19)$

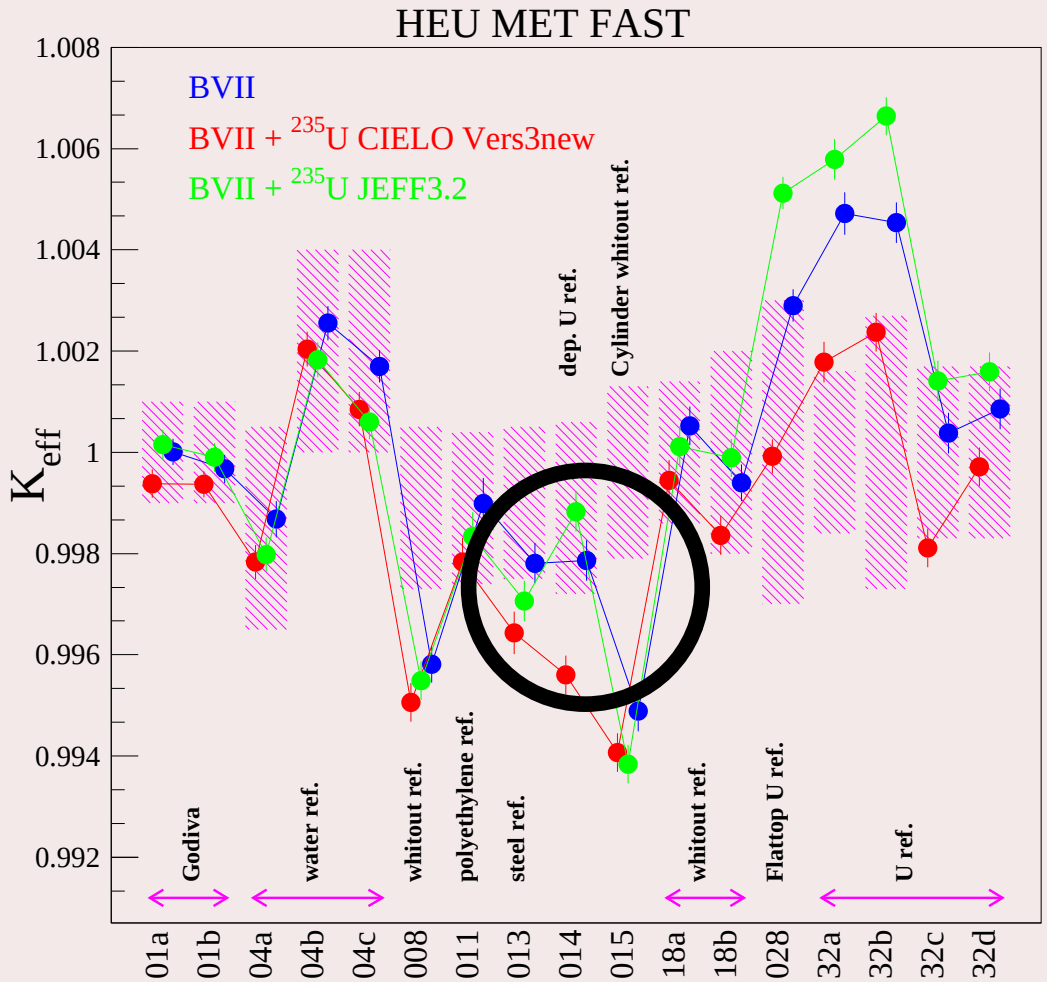


HEU MET FAST

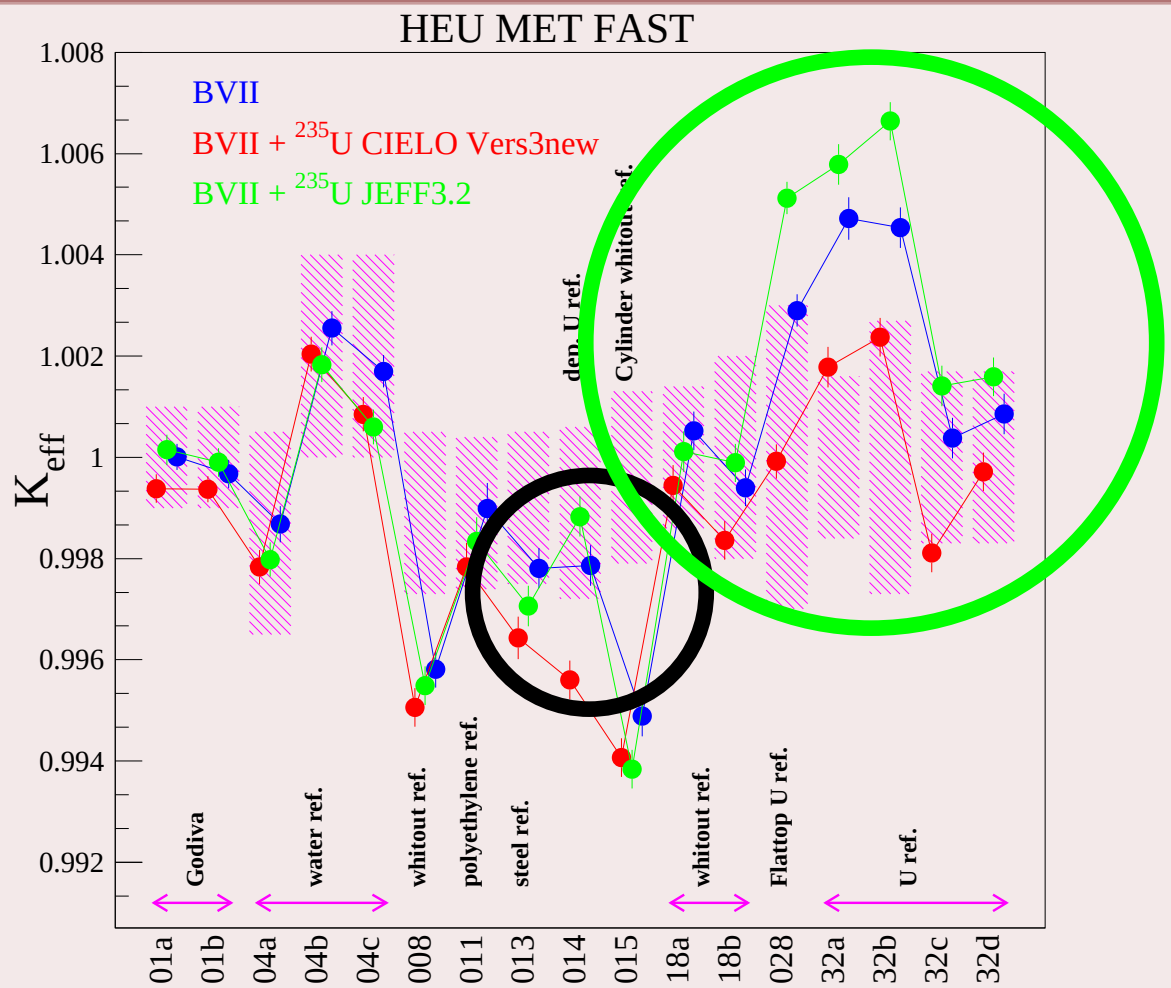

HEU MET FAST
BVII
BVII + 235U CIELO Vers3new
BVII + 235U JEFF3.2
Keff
1.008
1.006
1.004
1.002
1
0.998
0.996
0.994
0.992
Godiva
water ref.
whitout ref.
polyethylene ref.
steel ref.
dep. U ref.
Cylinder whitout ref.
whitout ref.
Flattop U ref.
U ref.
01a
01b
04a
04b
04c
008
011
013
014
015
18a
18b
028
32a
32b
32c
32d

^{235}U : ENDFB7, JEFF3.2 and Vers3new

HMF014 ? ? ? ?



IMPROVEMENTS



Status of the ^{235}U evaluation

vers3new $\longleftrightarrow$ vers4

some improvements on rapid benchmarks were performed,

but not enough,

this file has to be tested with many other benchmarks,

thermal ....