

B-1108 ISTC PROJECT PROPOSAL
Neutron multiplicities and cross sections up to 200
MeV

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SCOPE

Prompt fission neutron spectra and $\bar{\nu}$
232-Th, 235-U, 238-U, 239-Pu + minor actinides

Th, U, Pu, Np, Am, Cm (n,tot),(n,f),(n,xn),(n,n'),(n, γ) css.

Symmetric vis. asymmetric fission of
Th, U, Np, Pu, Am, Cm up to 200 MeV

Prompt Fission Neutron Spectra

**CEA/DAM-LANL measurements of $\langle E \rangle$ of PFNS for
 $^{235}\text{U}(\text{n},\text{F}), ^{238}\text{U}(\text{n},\text{F}), 0.4 < E_n < 200 \text{ MeV}$**

Ethvignot et al., Phys. Rev. Let. Vol. 94, 052701, 2005

Ethvignot et al., Phys. Lett. B575, 221, 2003

New U, Np, Pu measurements are planned

JINER(Minsk) Prompt fission neutron spectra (PFNS) analysis

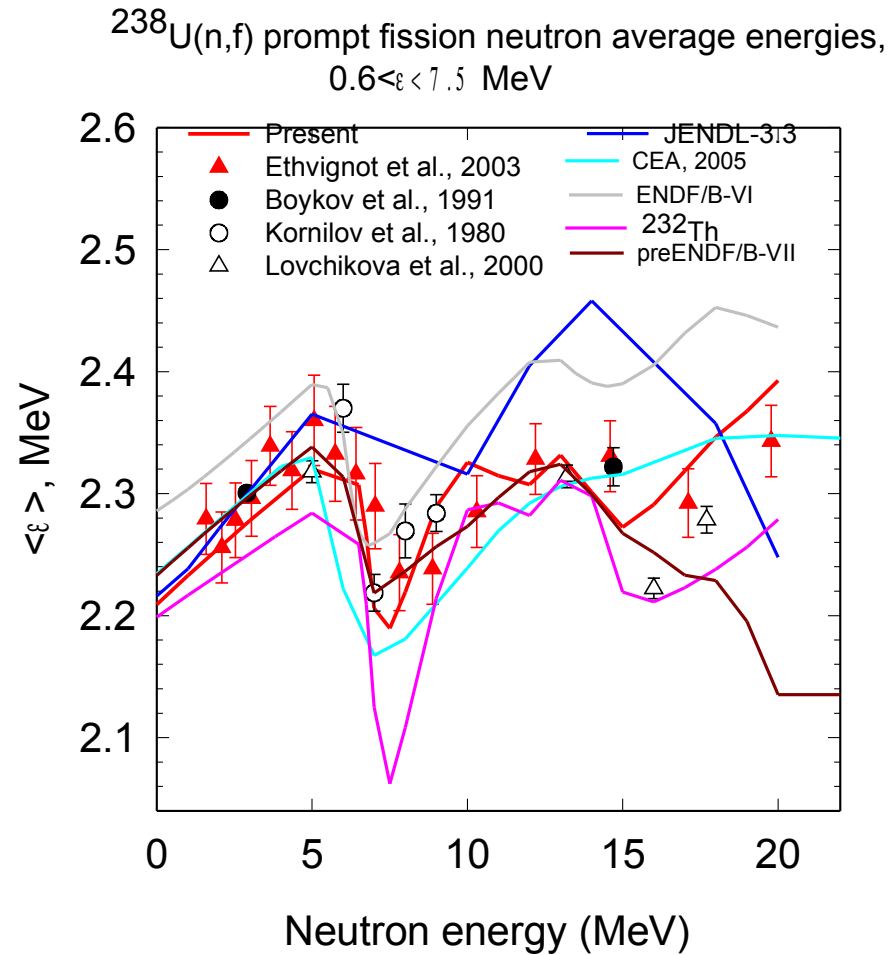
$^{238}\text{U}(\text{n},\text{f}), ^{232}\text{Th}(\text{n},\text{f})$ at $E_n < 20 \text{ MeV}$,

Maslov et al. Phys.Rev. C69, 034607, 2003

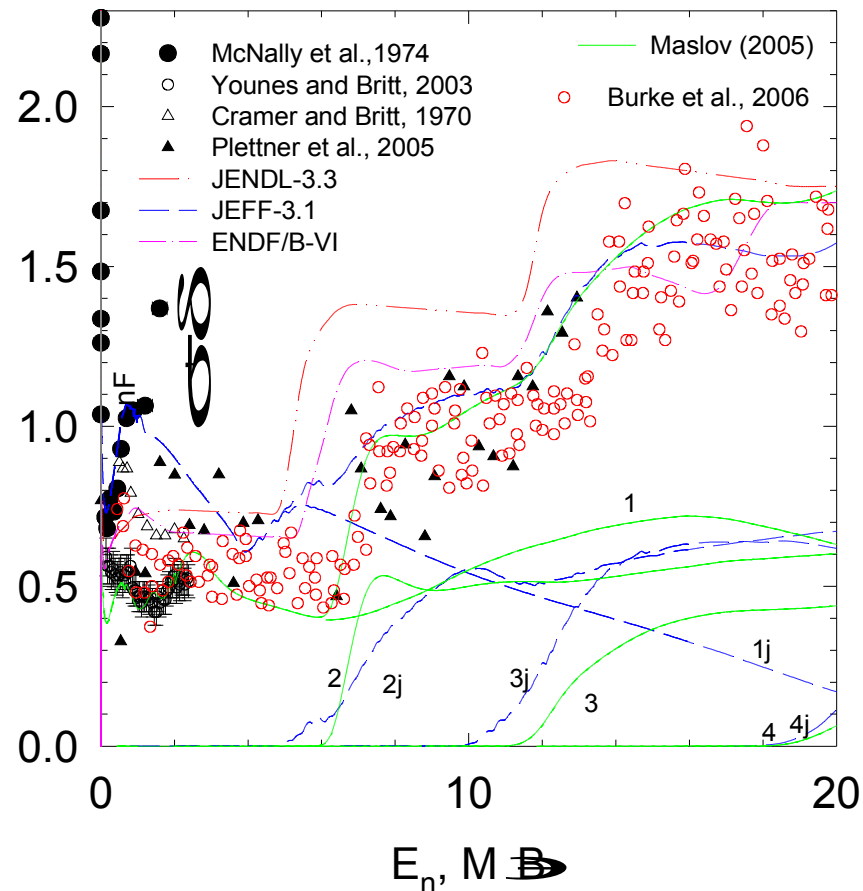
$^{235}\text{U}(\text{n},\text{f})$, Maslov et al. Nucl. Phys. A760, 274, 2005

$^{239}\text{Pu}(\text{n},\text{f})$ PFNS predictions

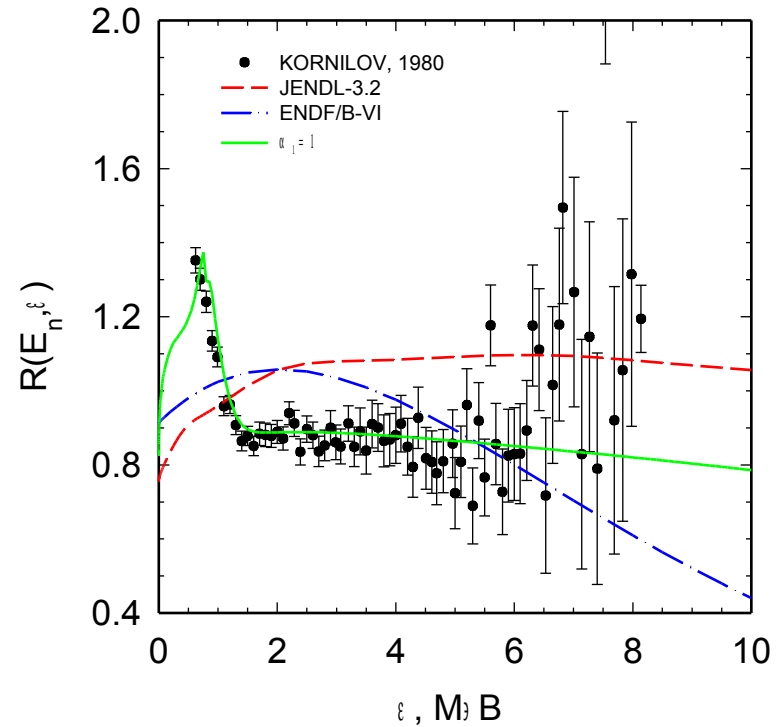
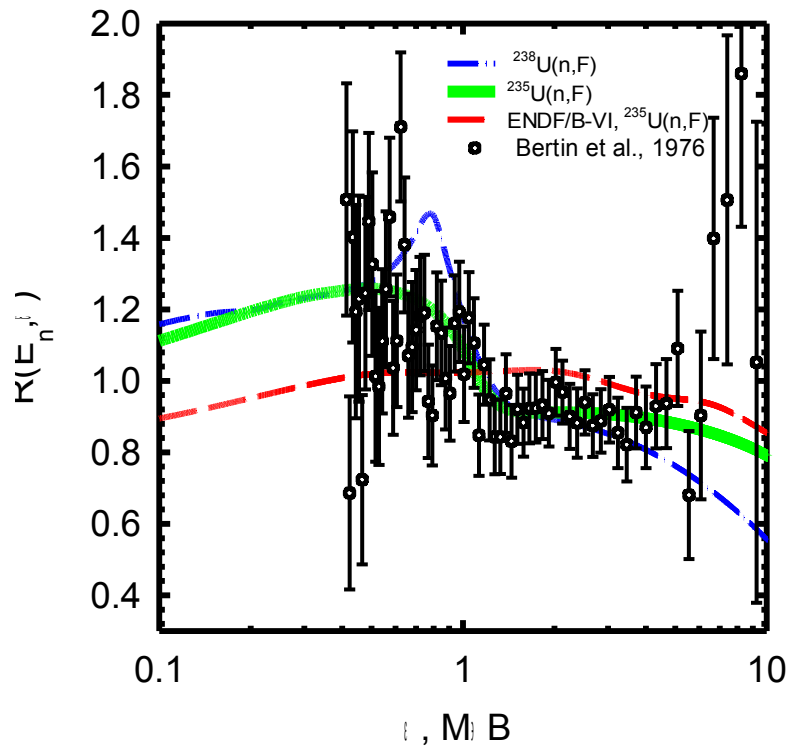
Pres. calculation best describes CEA/DAM-LANL $^{238}\text{U}(n,f)$ data



^{238}U PFNS&CSS data fix 2-chance contribution, i.e.
 $^{237}\text{U}(n,F); ^{238}\text{U}(d,d'f)/^{236}\text{U}(d,d'f); ^{238}\text{U}(\alpha,\alpha'f)/^{236}\text{U}(\alpha,\alpha'f)$

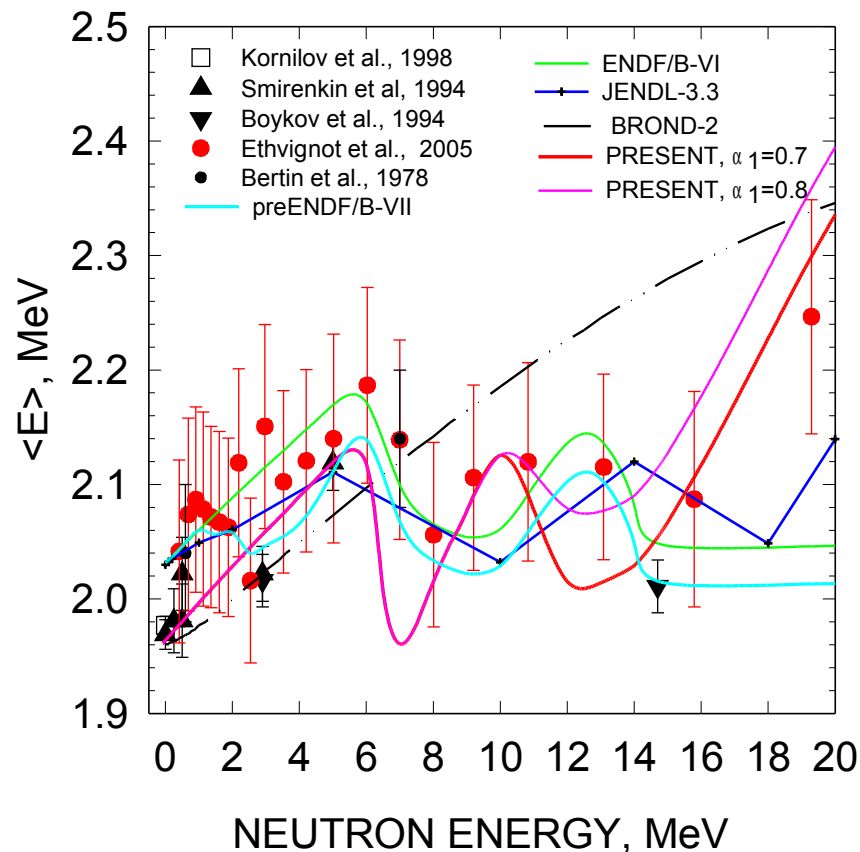


(n,nf) evidence in CEA/DAM(^{235}U)&IPPE(^{238}U) PFNS,
 $^{235}\text{U}(n,F)$ & $^{238}\text{U}(n,F)$, $E_n = 7 \text{ MeV (M}\bar{\text{e}}\text{B)}$

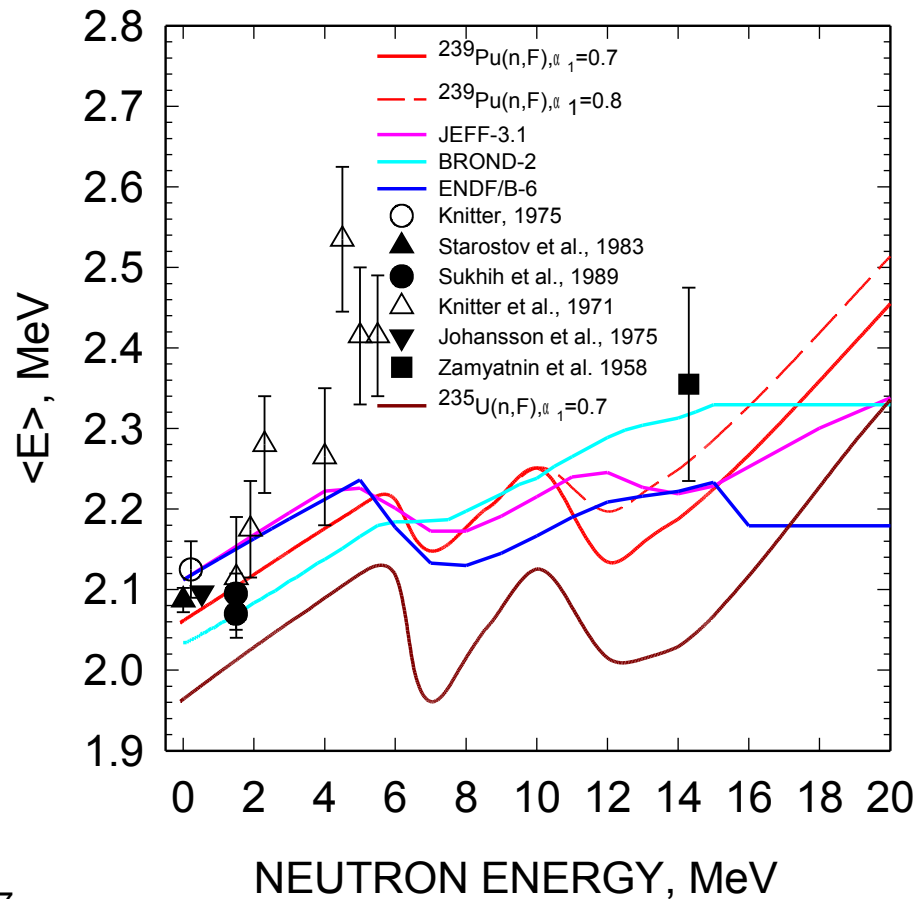


(n,nf) and (n,2nf) evidence in $\langle E \rangle$ of $^{235}\text{U}(n,F)$ CEA/DAM-LANL data and JINER analysis

^{235}U : AVERAGE ENERGY OF PFNS

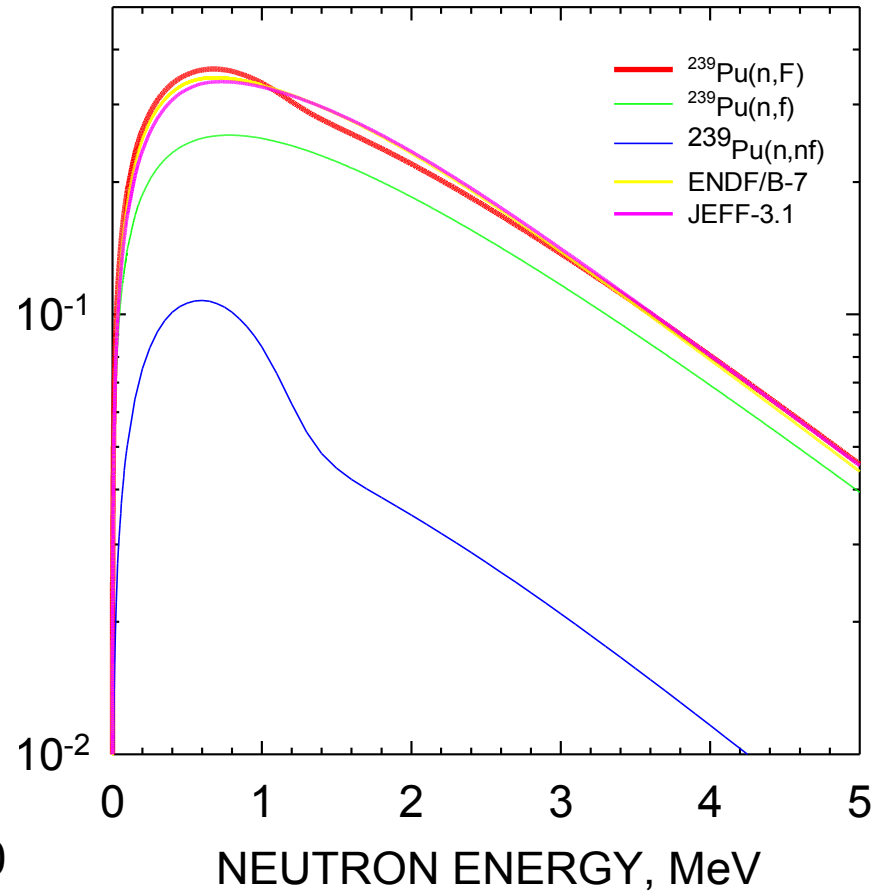
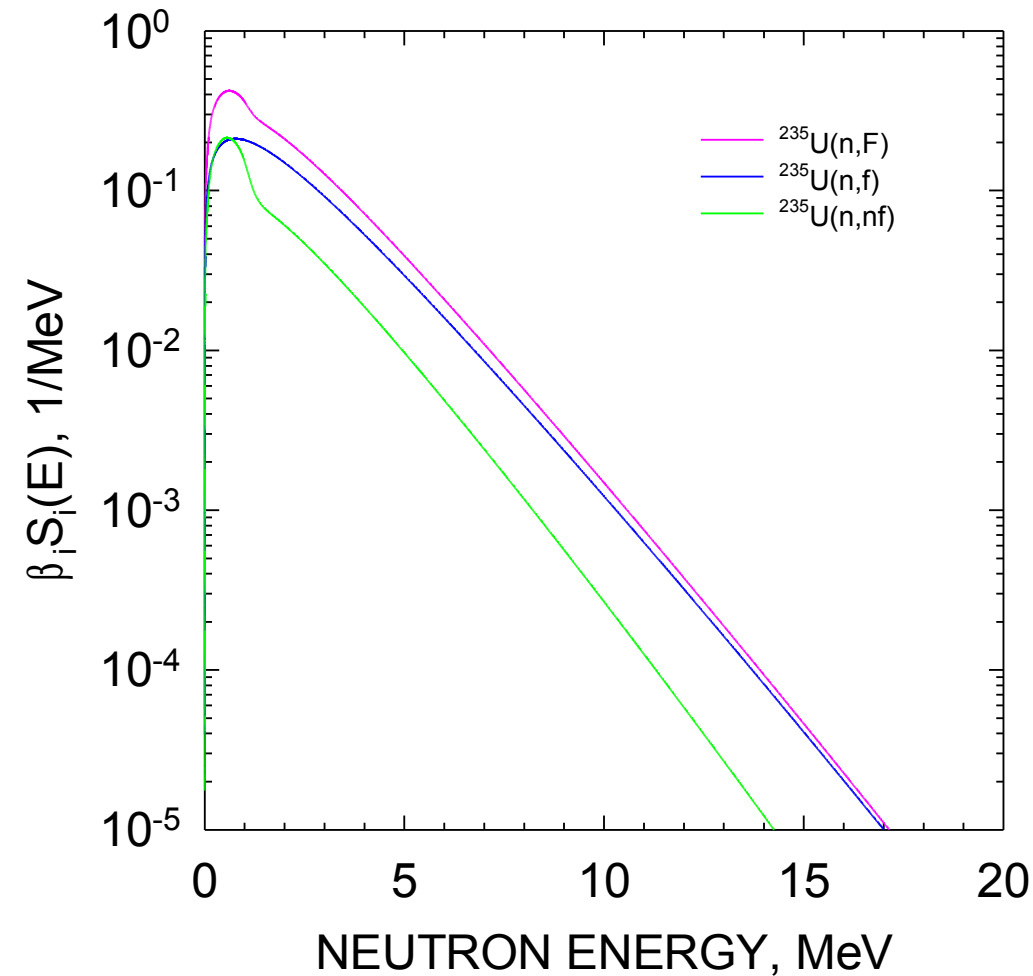


Predicted (n,nf) and (n,2nf) evidence in $\langle E \rangle$ of PFNS for $^{239}\text{Pu}(n,f)$, CEA/DAM-LANL meas.planned

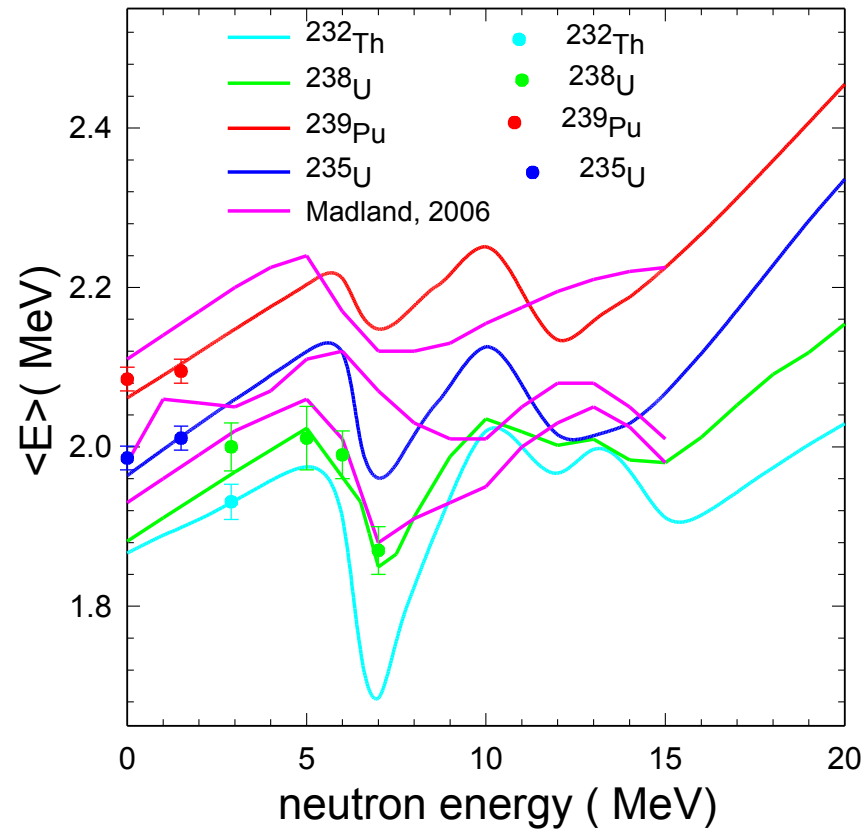


fission chance structure is different in case of $^{235}\text{U}(n,F)$ and $^{239}\text{Pu}(n,F)$, hence
 PFNS are different too. PFNS, $E_n=7$ MeV

^{235}U PARTIAL FISSION NEUTRON
 SPECTRA, $E_n=7$ MeV



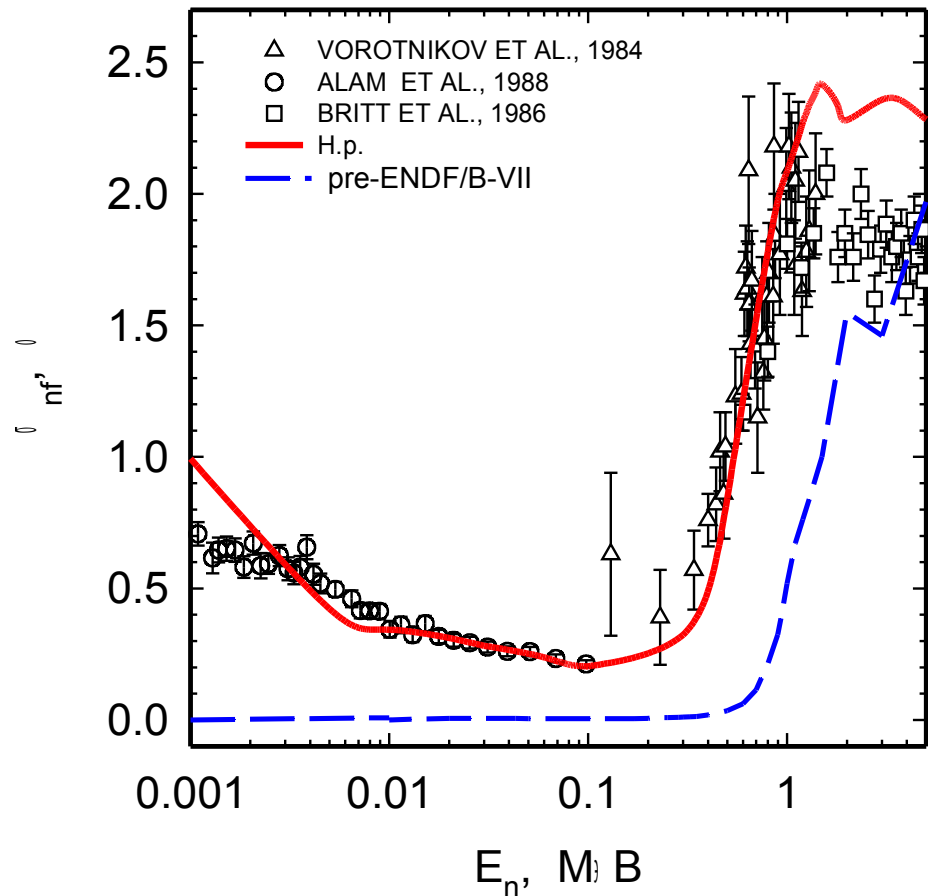
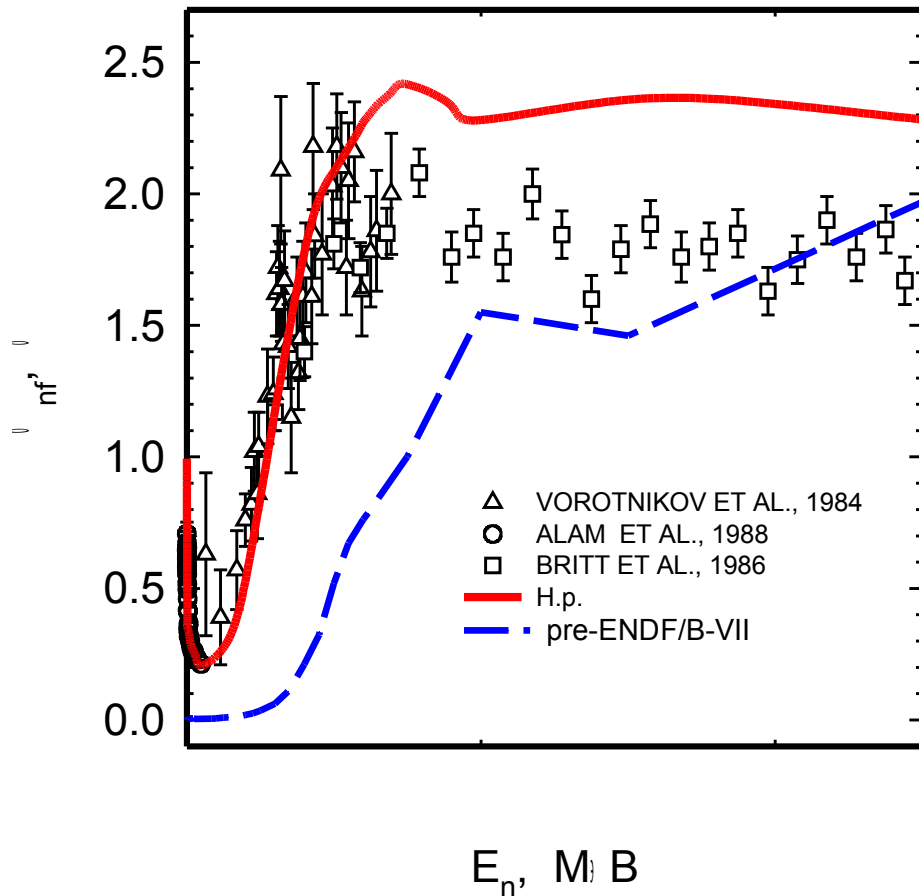
Dependence of PFNS $\langle E \rangle$ on (n,xf) contrib. to (n,F)



Conclusions

- 1. Pre-fission (n,xnf) spectra+ neutrons from the fission fragments - a number of peculiarities in $^{235}\text{U}(n,f)$ are interpreted as for $^{238}\text{U}(n,f)$ and $^{232}\text{Th}(n,f)$ PFNS for $E_n < 20$ MeV**
- 2. Predicted multiple-chance fission contributions of $^{239}\text{Pu}(n,F)$ PFNS are correlated with the (n,f), (n,2n) and (n,3n) data description**
- 3. The energy balance model for the multi-chance fission is validated for $E_n < 20$ MeV describing fission cross sections, PFNS, and neutron multiplicities, would be extended to minor actinides and to higher E_n**

illustration how latest $^{242}\text{Cm}(n,f)$ evals. could be improved

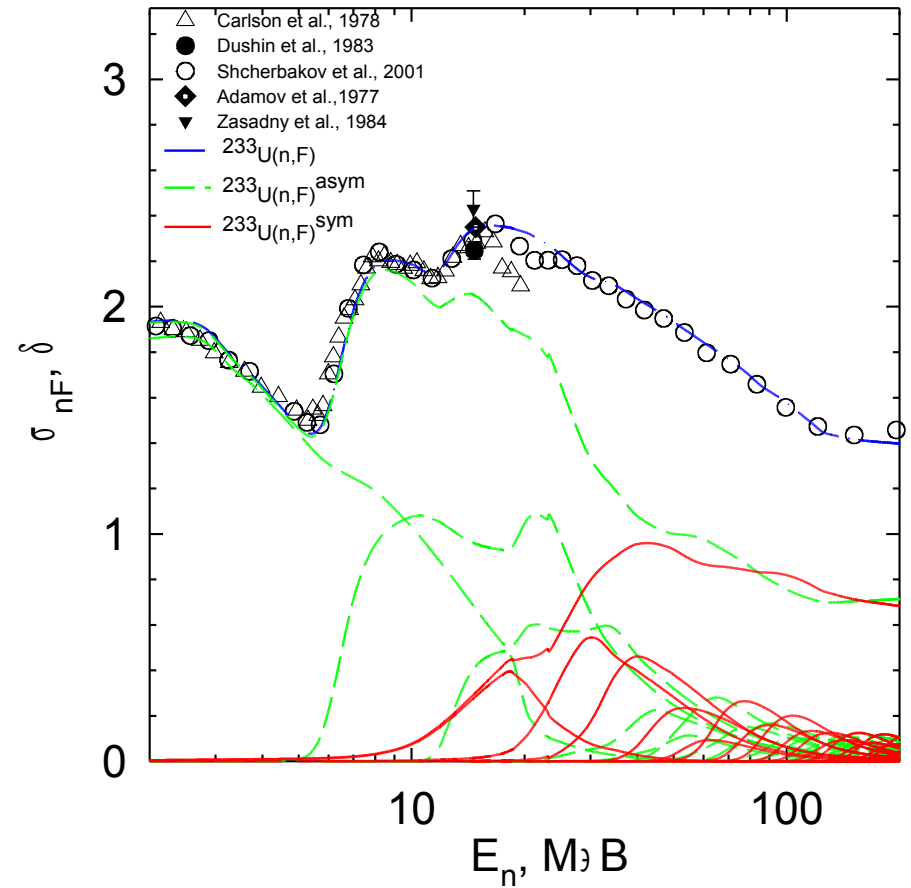
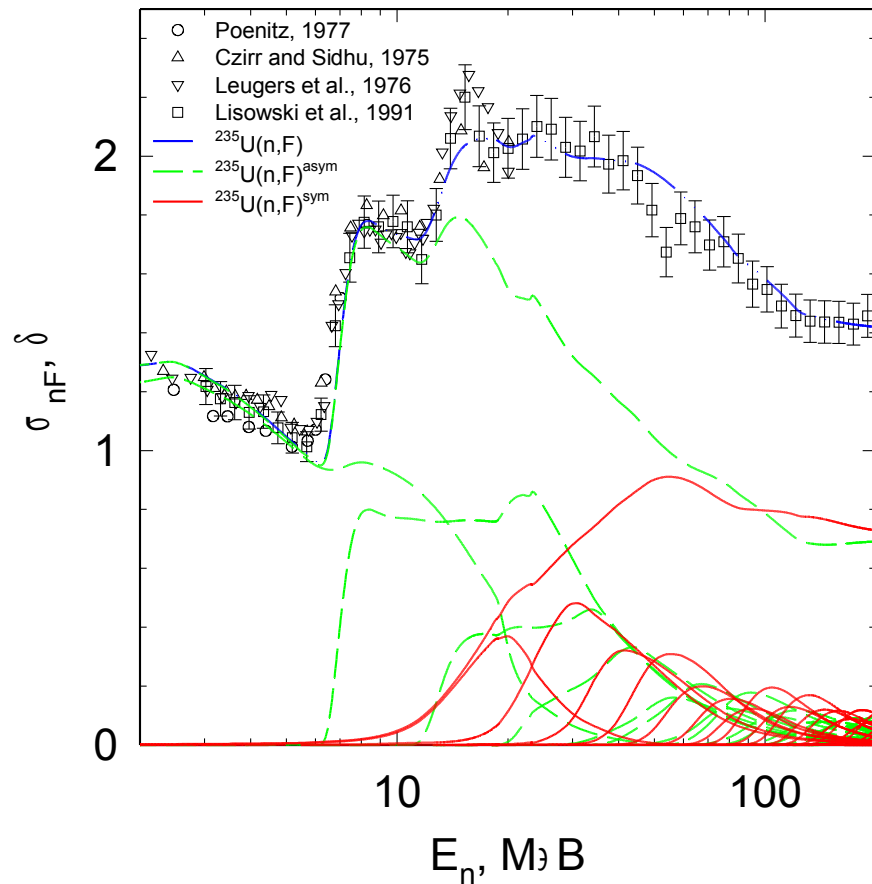


**KEY- analysis of $^{238}\text{U}(\text{n},\text{F})$, $^{238}\text{U}(\text{p},\text{F})$, $^{232}\text{Th}(\text{n},\text{F})$,
 $^{232}\text{Th}(\text{p},\text{F})$
SYMMETRIC/ASYMMETRIC NEUTRON-
INDUCED FISSION UP TO 200 MeV**

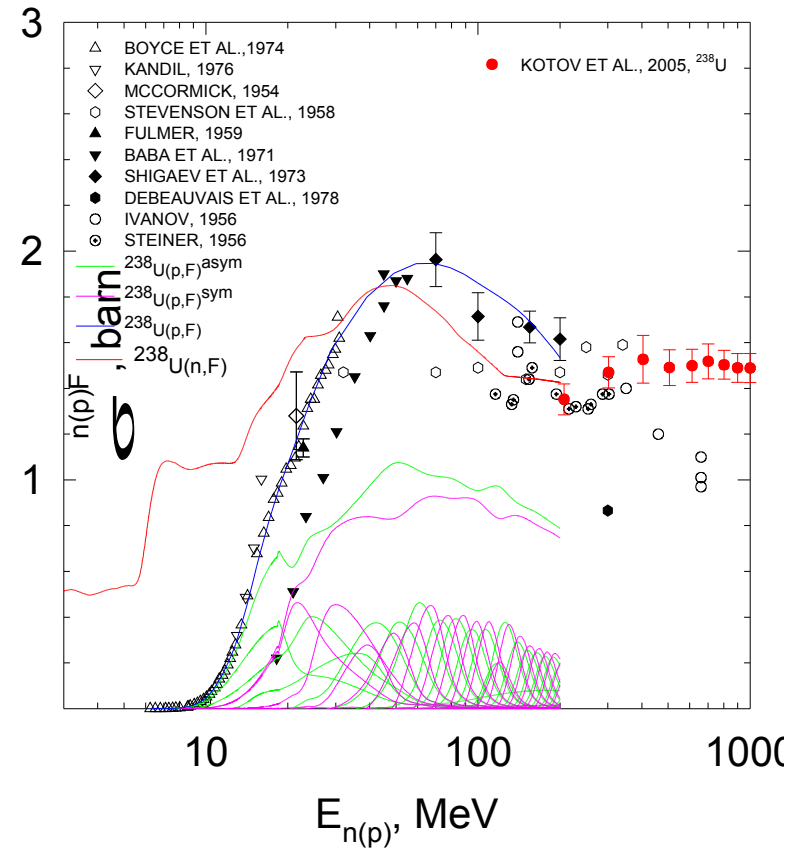
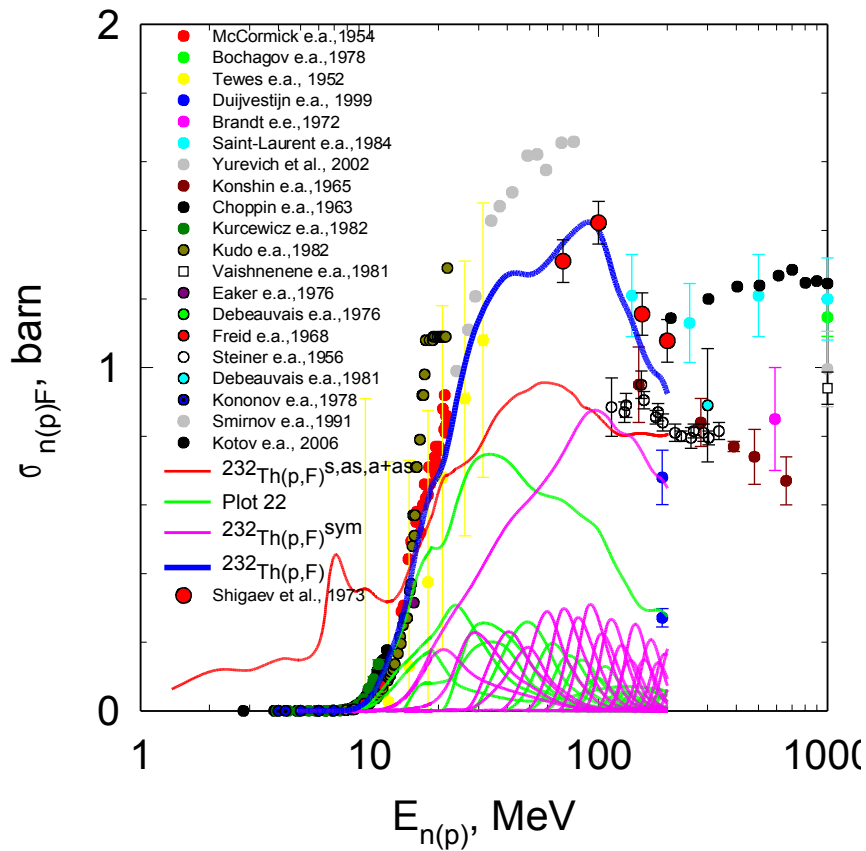
(n,xnf) and sym/asym. Structure

$^{235}\text{U}(n,F)$

$^{233}\text{U}(n,F)$

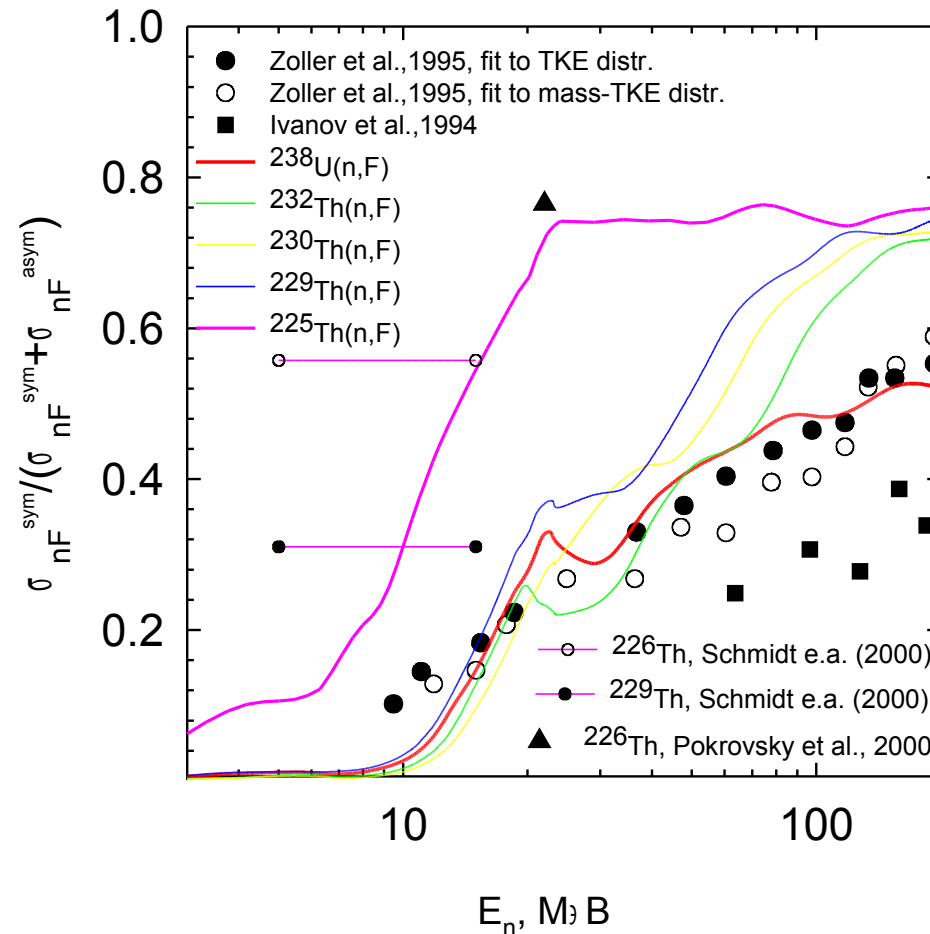


$^{232}\text{Th}(n,F)$ & $^{232}\text{Th}(p,F)$ $^{238}\text{U}(n,F)$ & $^{238}\text{U}(p,F)$



increased symmetric fission yield in thoriums

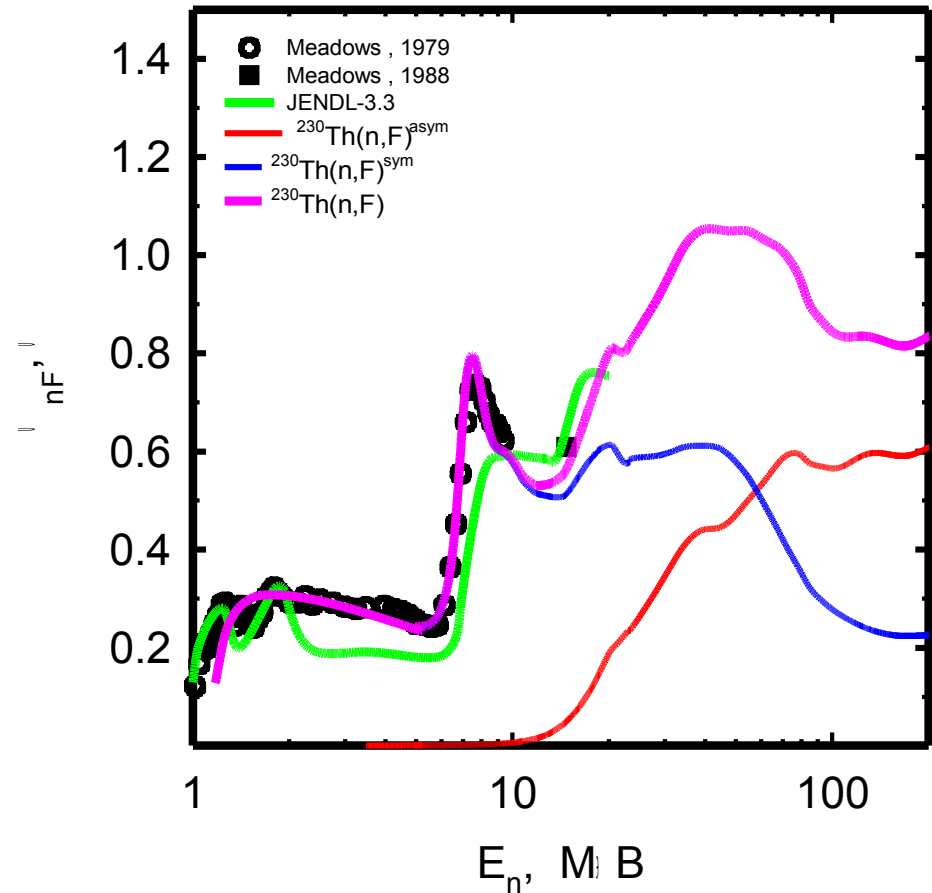
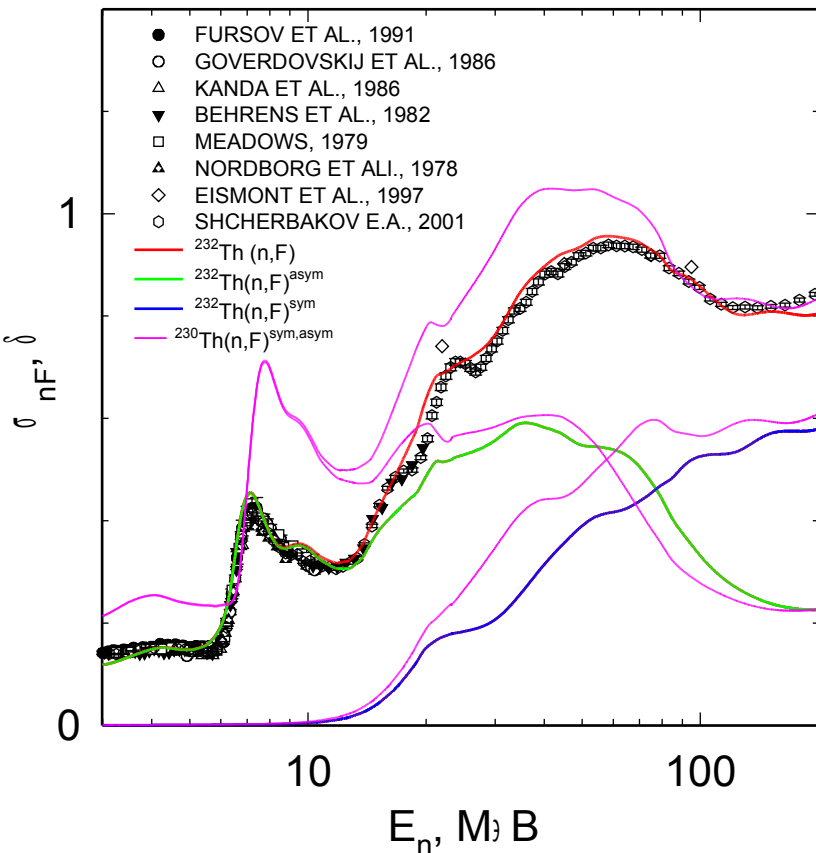
$${}^{232}\text{Th}(n,F)_{\text{sym}} / {}^{232}\text{Th}(n,F)$$



Symm./asymmetric contributions –target-dependent

$^{232}\text{Th}(n,F)$

$^{230}\text{Th}(n,F)$



CONCLUSIONS

- The description of $^{232}\text{Th}(n,F), ^{232}\text{Th}(p,F)$ ($^{238}\text{U}(n,F)$ $^{238}\text{U}(p,F)$) at $E_n \leq 200$ MeV - preferential contribution of fission of neutron-deficient Th,Pa (U,Np) nuclides.
- The fission chances distribution $^{238}\text{U}(n,F)$ + sym/asym. branching ratio
- Sharp increase of the sym. fission yield for $^{232}\text{Th}(n,F), ^{232}\text{Th}(p,F)$ at $E_n \geq 50$ MeV is predicted.
- $^{229,230,231,232}\text{Th}(n,F)$ at $E_n \geq 80$ MeV are virtually independent upon Z^2/A
- Symmetric/asymmetric fission competition at moderately high excitations are important for the analysis/prediction of fission cross sections for minor actinides of interest at $E_n \leq 200$ MeV .

Already available evaluated data files:

238-Np, 238-Pu, 242-Pu,
 241-Am, 242m-Am, 242g-Am, 243-Am, 243-Cm, 245-Cm, 246-Cm,
 232-Th, 238-U, 234-U, 233-U, 232-U, 231-Pa, 233-Pa

Adopted for ENDF/B-VI, ENDF/B-VII, JEFF-3.2, JENDL-3.2, JENDL-3.3,
 NDS IAEA <http://www-nds.iaea.org/minskact>

These files would be improved, extended to higher energies, several new (as negotiated) Th, Pa, U, Np, Pu, Am, Cm would be compiled

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2. V. M. Maslov, "Analysis of $n+^{232}\text{Th}$ interaction up to 200 MeV", **Nuclear Physics, Elsevier**, vol. 757, pp. 390-410, 2005.
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4. V.M. Maslov, Yu.V., Porodzinskij Tetereva, M. Baba, A. Hasegawa "Excitation of octupole, beta- and gamma-vibration band levels of ^{238}U by inelastic neutron-scattering" **Nuclear Physics, Elsevier**, A764, 212-245, 2006.
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7. V. M. Maslov, Yu. V. Porodzinskij, M. Baba, A. Hasegawa, N. V. Kornilov, A. B. Kagalenko, Tetereva N.A. "Prompt fission neutron spectra of $^{238}\text{U}(n,f)$ and $^{232}\text{Th}(n,f)$ above emissive fission threshold", **Physical Review C (Nuclear Physics)**, vol. 69, 034607, 2004, 14 стр., **American Physical Society, USA.**

8. V. M. Maslov, Yu. V. Porodzinskij, M. Baba, A. Hasegawa, Tetereva N.A. “ ^{238}U – Nucleon-Nucleus Optical Potential up to 200 MeV”, **Nuclear Physics A, 736,77-92 (2004), Elsevier, North Holland.**
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