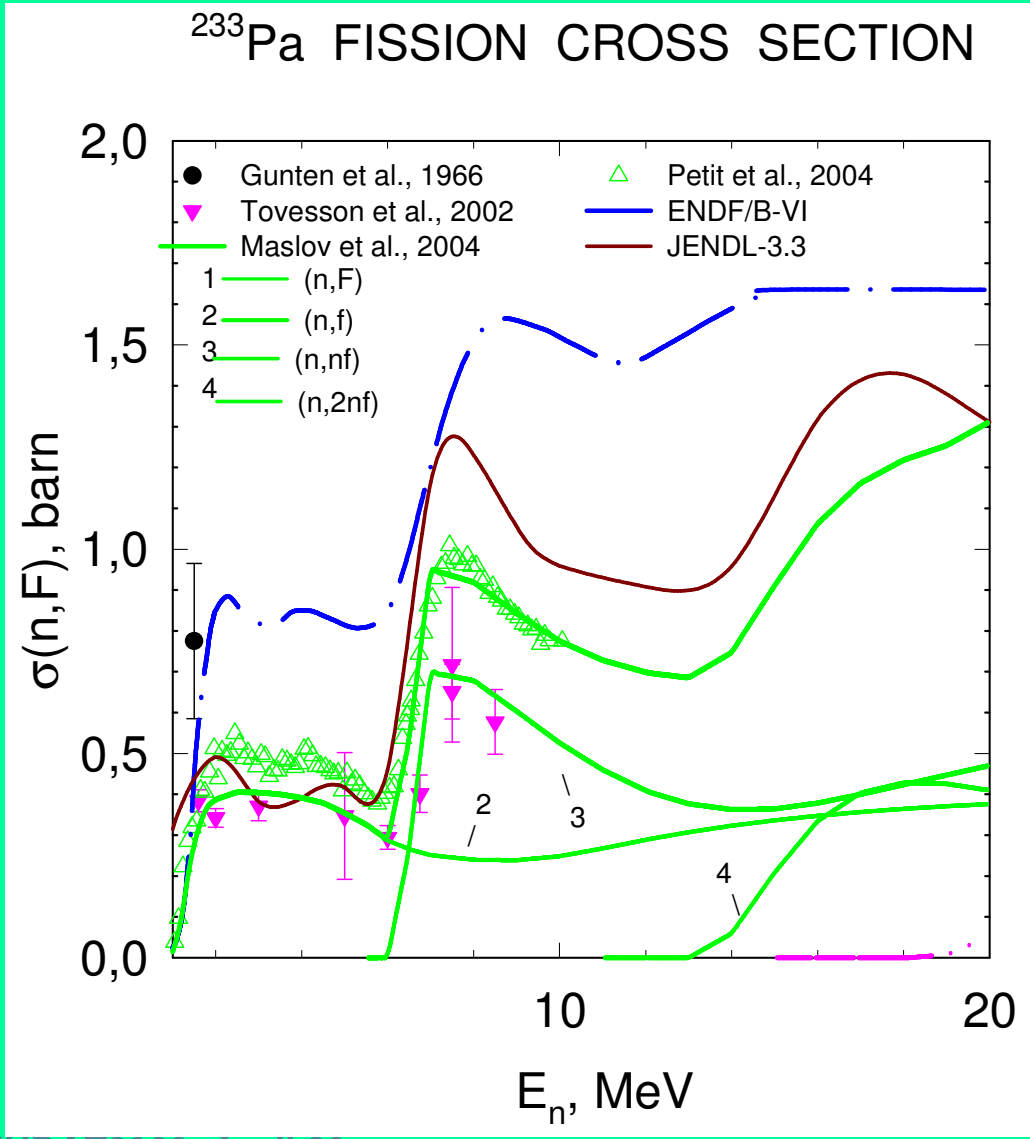
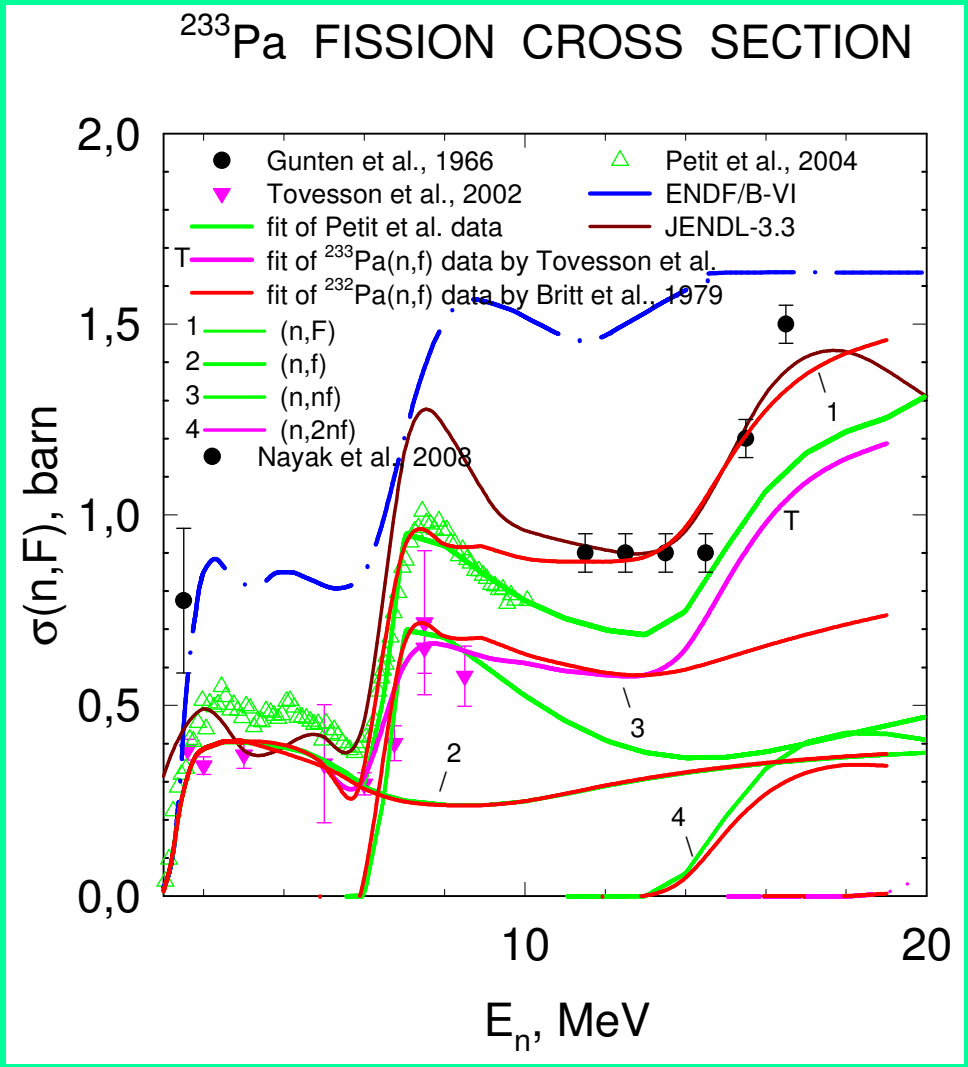
PROTACTINIUM NEUTRON-INDUCED FISSION UP TO 20 MeV

VLADIMIR MASLOV

Joint Institute for Nuclear & Energy Research,
220109, Minsk-Sosny, Belarus


^{233}Pa FISSION CROSS SECTION
Gunten et al., 1966
Tovesson et al., 2002
Maslov et al., 2004
Petit et al., 2004
ENDF/B-VI
JENDL-3.3
1 (n,F)
2 (n,f)
3 (n,nf)
4 (n,2nf)
σ(n,F), barn
2,0
1,5
1,0
0,5
0,0
10
20
E$_n$, MeV


^{233}Pa FISSION CROSS SECTION
Gunten et al., 1966
Tovesson et al., 2002
fit of Petit et al. data
fit of ^{233}Pa(n,f) data by Tovesson et al.
fit of ^{232}Pa(n,f) data by Britt et al., 1979
1 (n,F)
2 (n,f)
3 (n,nf)
4 (n,2nf)
Nayak et al., 2008
Petit et al., 2004
ENDF/B-VI
JENDL-3.3
T
σ(n,F), barn
E$_n$, MeV
2,0
1,5
1,0
0,5
0,0
10
20

Fission CS model or surrogate/ratio surrogate method deficiency

^{232}Th(^{3}He,p)^{234}Pa-Petit e.a., 2004. (n,F)

^{232}Th(^{3}He,d)^{233}Pa, Britt e.a.,1979 Petit e.a., 2004

^{232}Th(^{3}He,t)^{232}Pa Petit e.a., 2004 (n,F)

^{231}Pa(d,p)^{232}Pa,Britt e.a., 1979 (n,F)

^{230}Th(^{3}He,d)^{231}Pa, Britt e.a., 1979

^{230}Th(^{3}He,t)^{230}Pa, Britt e.a., 1979

^{230}Th(^{3}He, ^{4}He)^{231}Th, Petit e.a., 2004 (n,F)

$$\sigma_{\mathrm{nf}}(\mathrm{E_n}) = 3.1\mathrm{P_f^{exp}},$$

$$\sigma_{\mathrm{nf}}(\mathrm{E_n}) = \mathrm{q(E_n)}\frac{\pi\lambda^2}{2(2I+1)}\sum_{\mathrm{lJ}\pi}(2\mathrm{J}+1)\mathrm{T}_{\mathrm{lj}\pi}(\mathrm{E_n})\mathrm{P_f^{exp}}(\mathrm{E_n}),$$

(n,F)=(n,f)+(n,xnf)

$$\sigma_{\mathrm{nF}}(E_n) = \sigma_{\mathrm{nf}}(E_n) + \sum_{x=1}^{X}\sigma_{\mathrm{n,\,xnf}}(E_n)$$

$$\sigma_{\mathrm{n,xnf}}(E_n) = \sum_{J\pi}^{J}\int_0^{U_{\max}} W_{x+1}^{J\pi}(U)\,P_{f\,(x+1)}^{J\pi}(U)\,dU$$

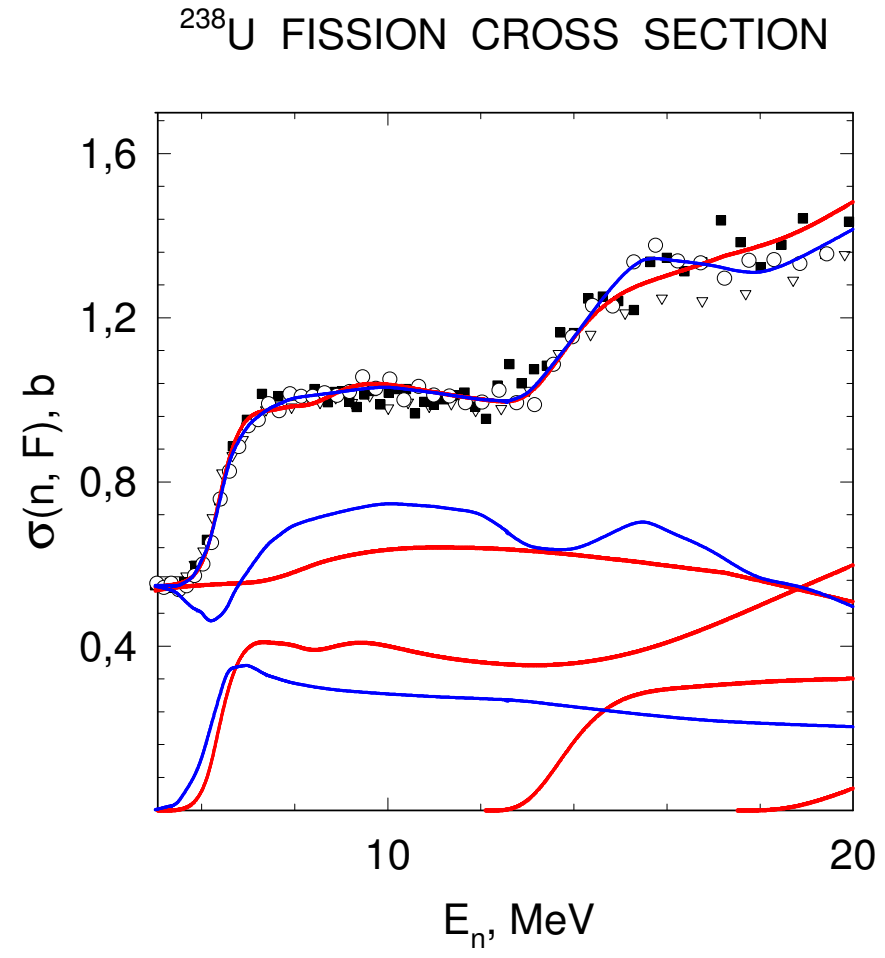
^{237}U(n,F),compatible with surrogate ratio data

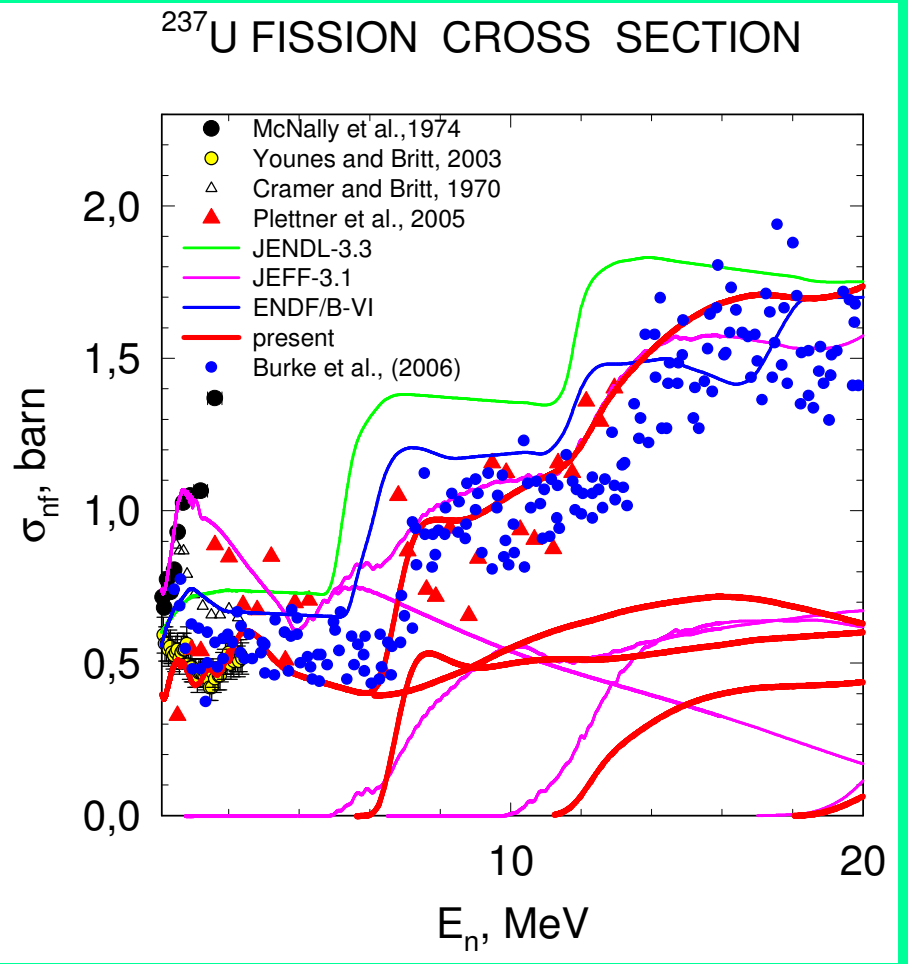
$$U(d,d'f)/^{236}U(d,d'f)\_Plettner\_e.a.,2005$$

$$^{38}U(\alpha,\alpha'f)/^{236}U(\alpha,\alpha'f)\_Burke\_e.a.,2006$$

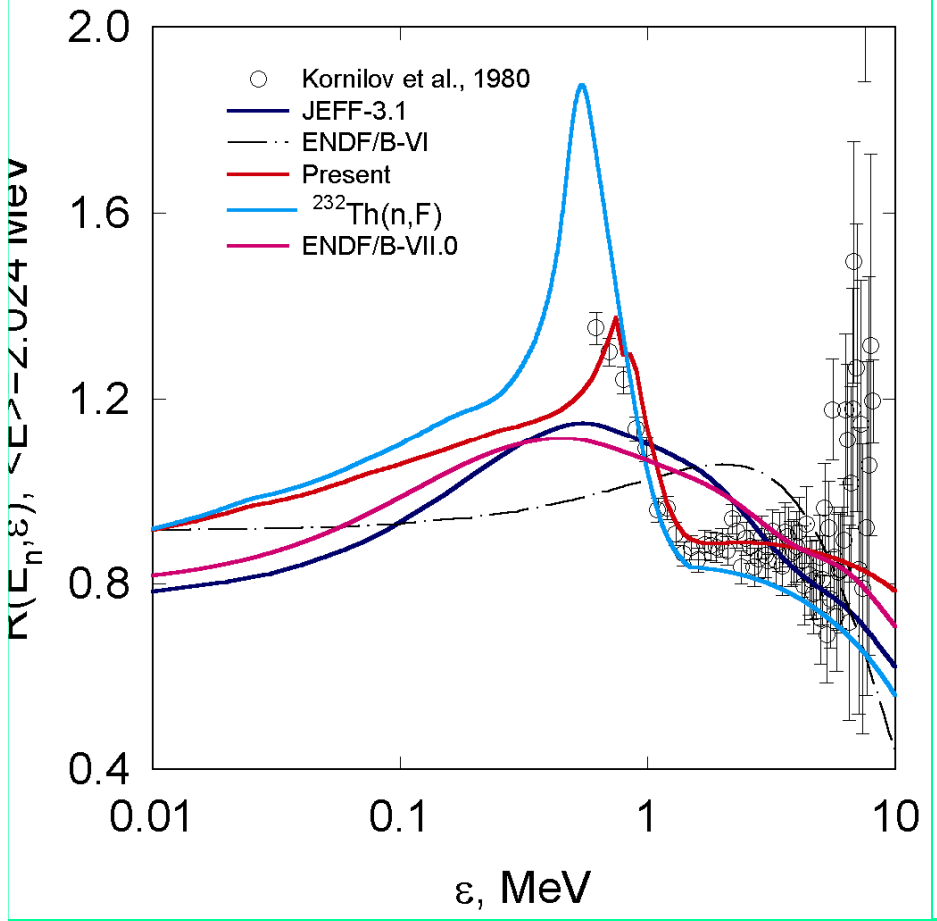
$$Th(^{6}Li,^{4}He)^{234}Pa/^{232}Th(^{6}Li,d)^{236}\_Nayak\_e.a.,2008$$

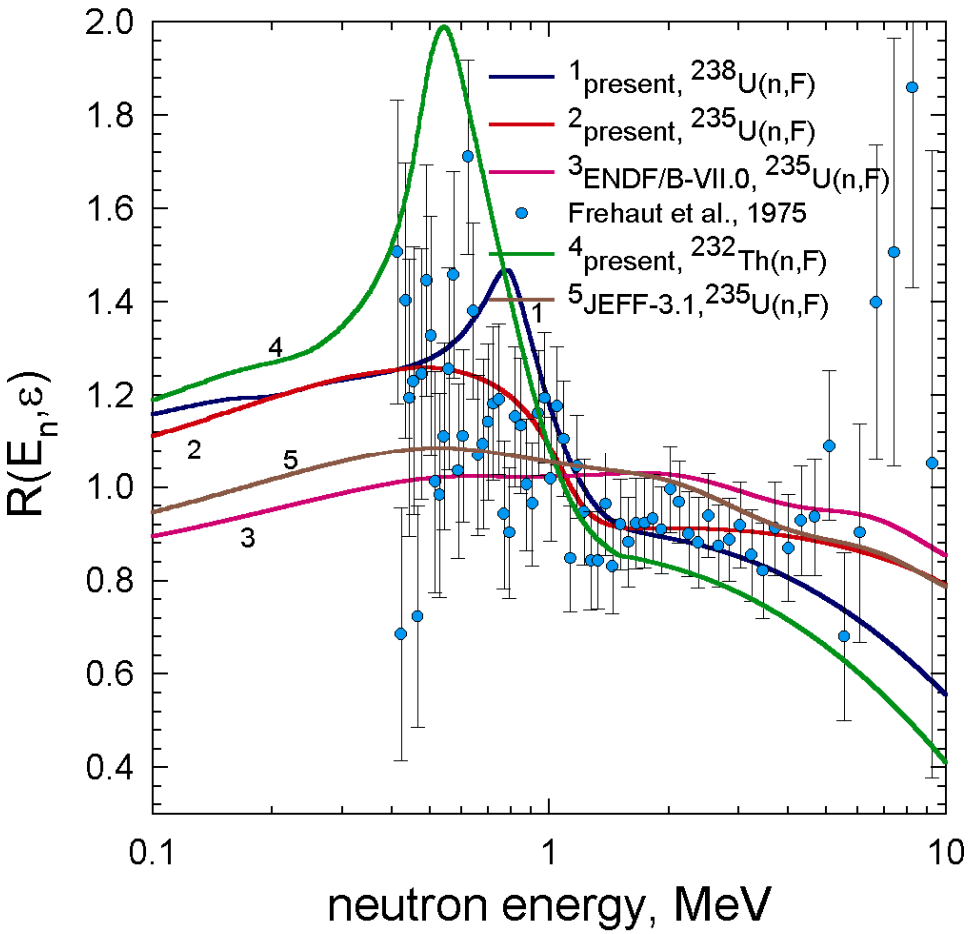
Surrogate vis. direct data for ^{237}U



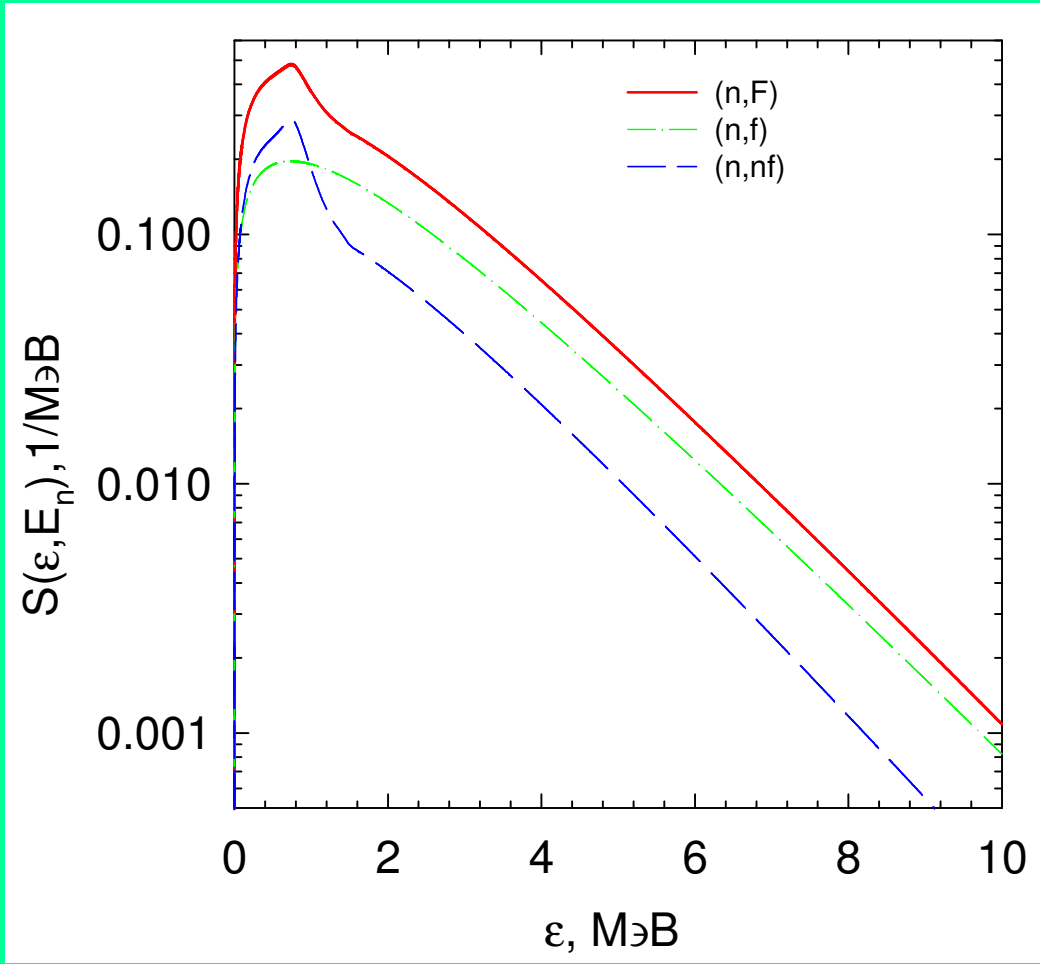


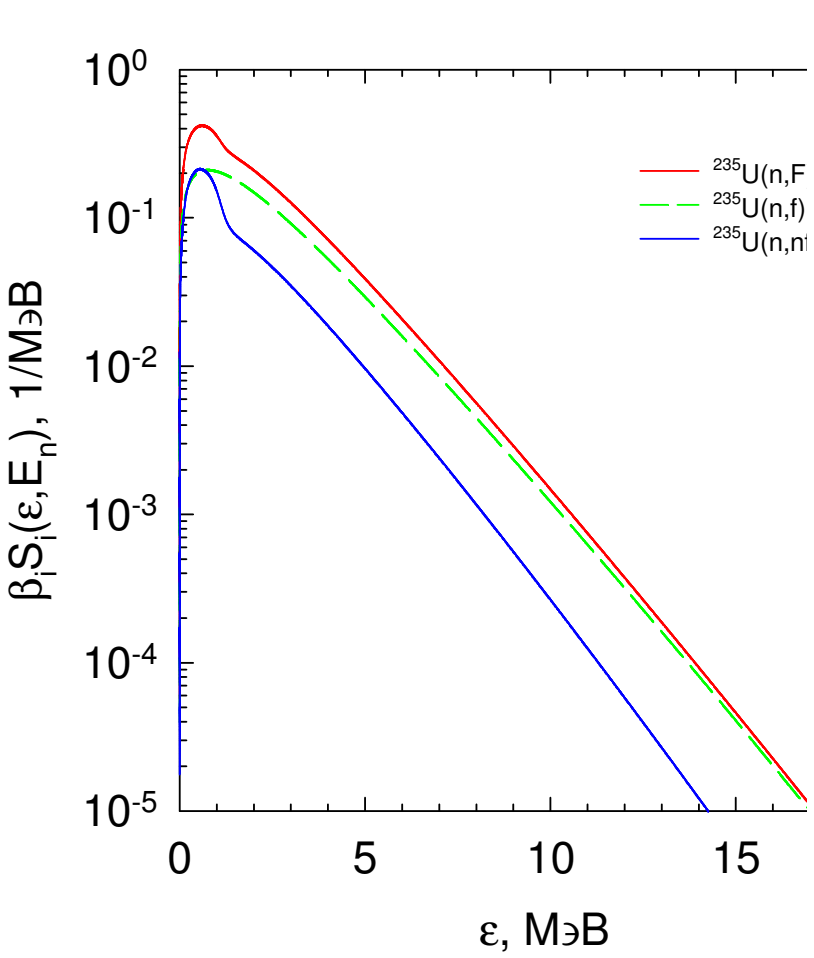
238_U(n,F) E_n=7 MeV 235_U(n, F),



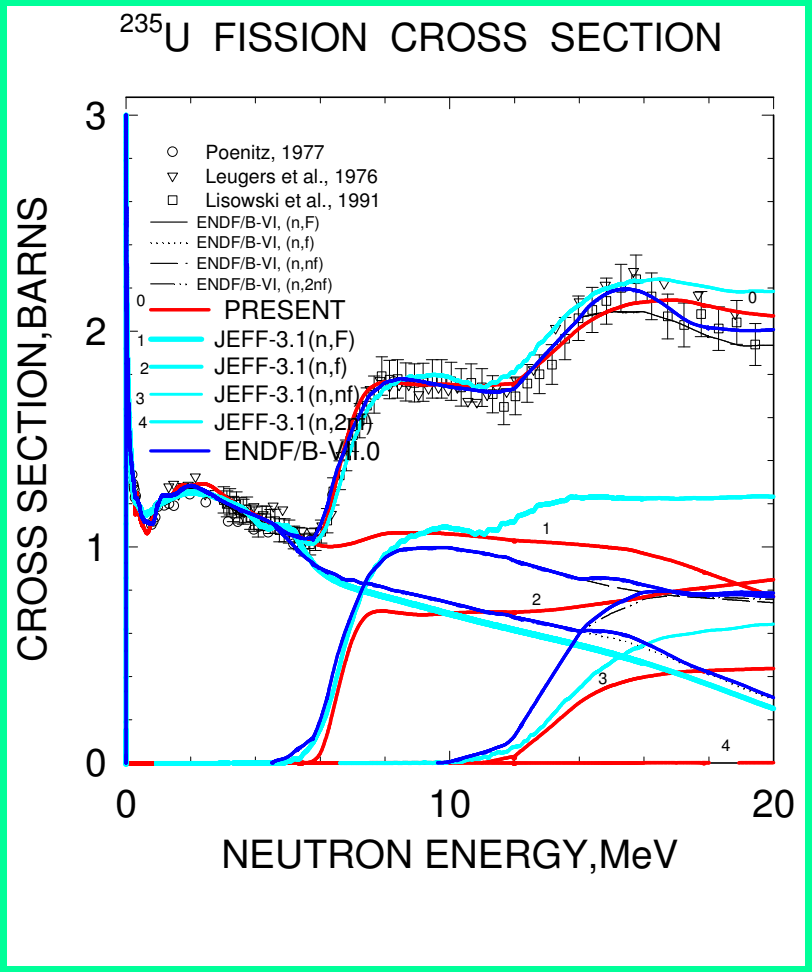


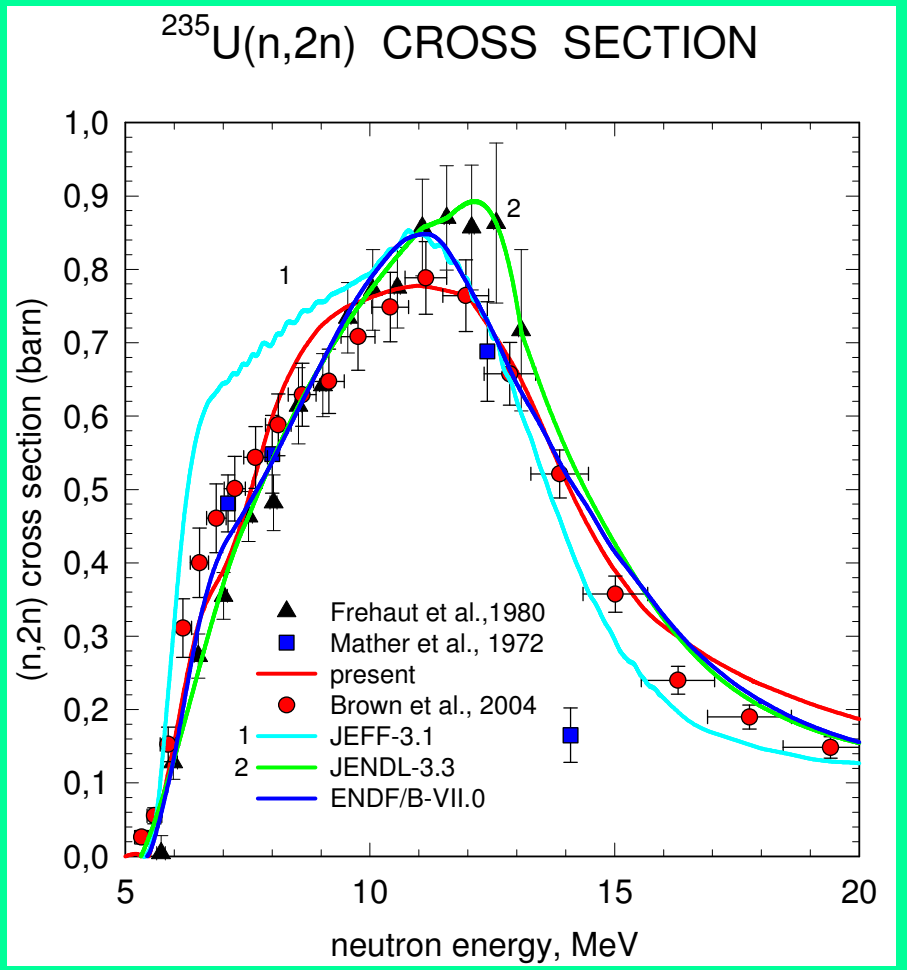
^{238}U(n,F) [PFNS E_n=7 MeV] ^{235}U(n,F)



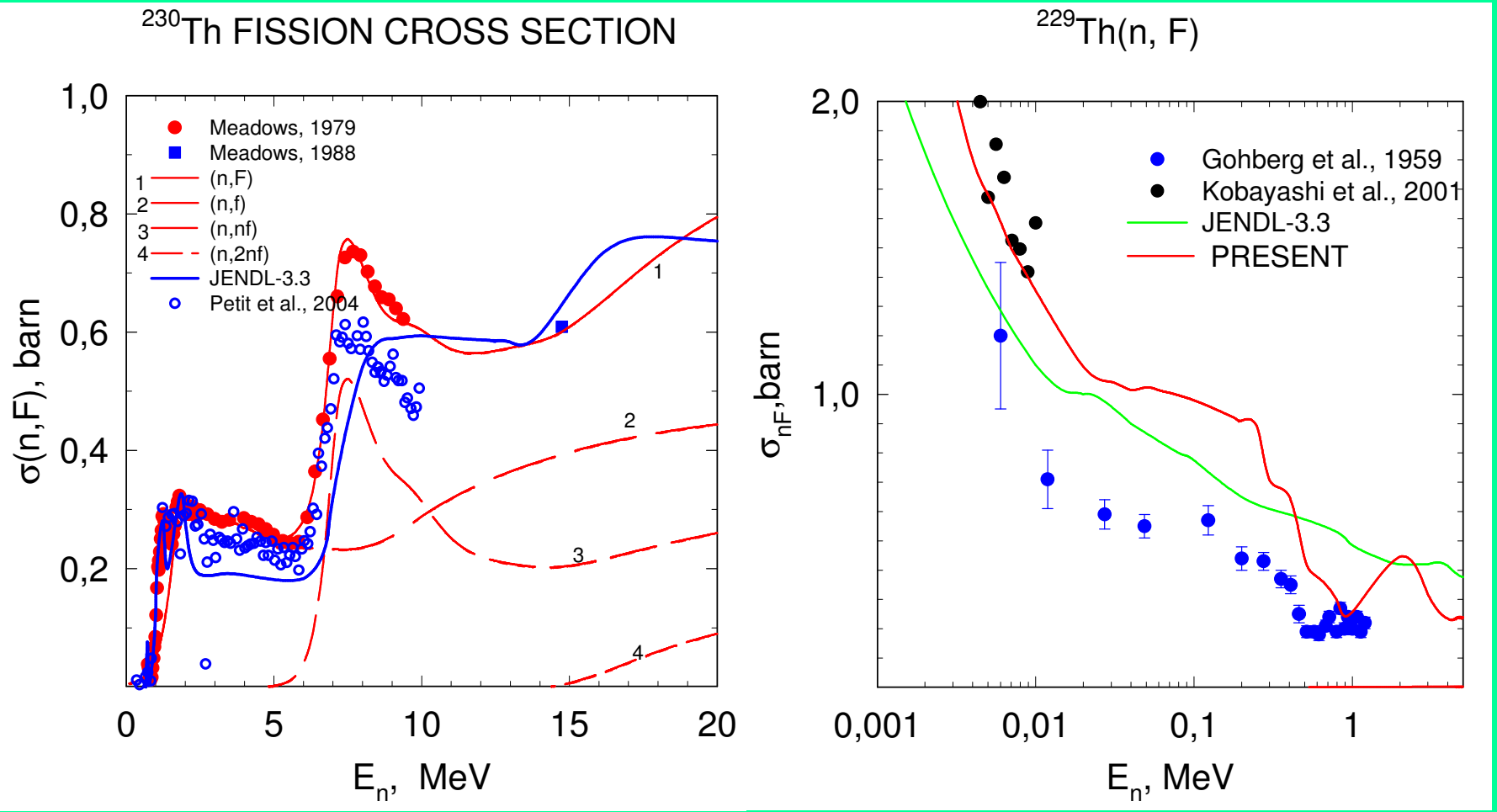


First chance fission CS for ^{235}U(n, F)

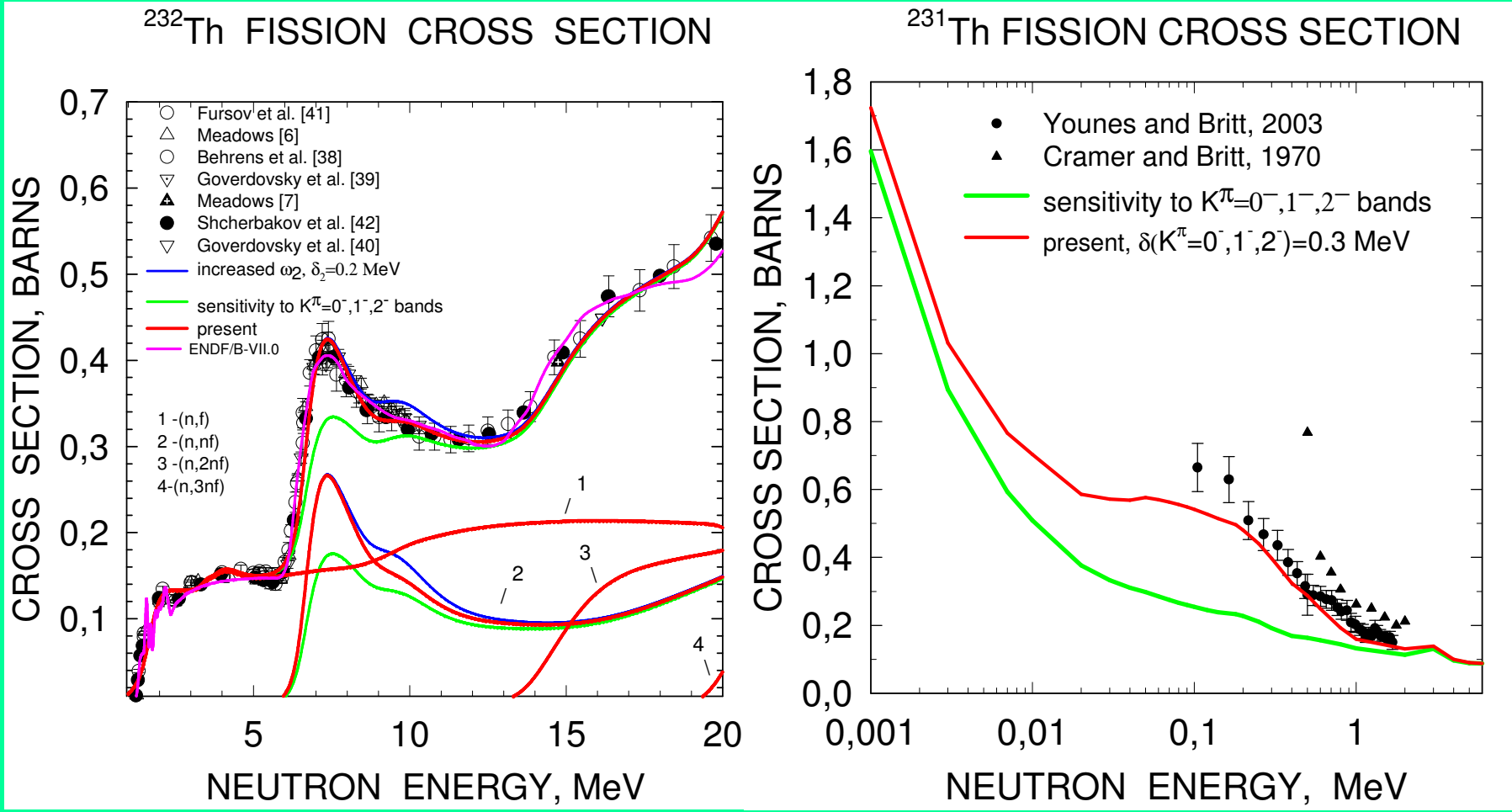




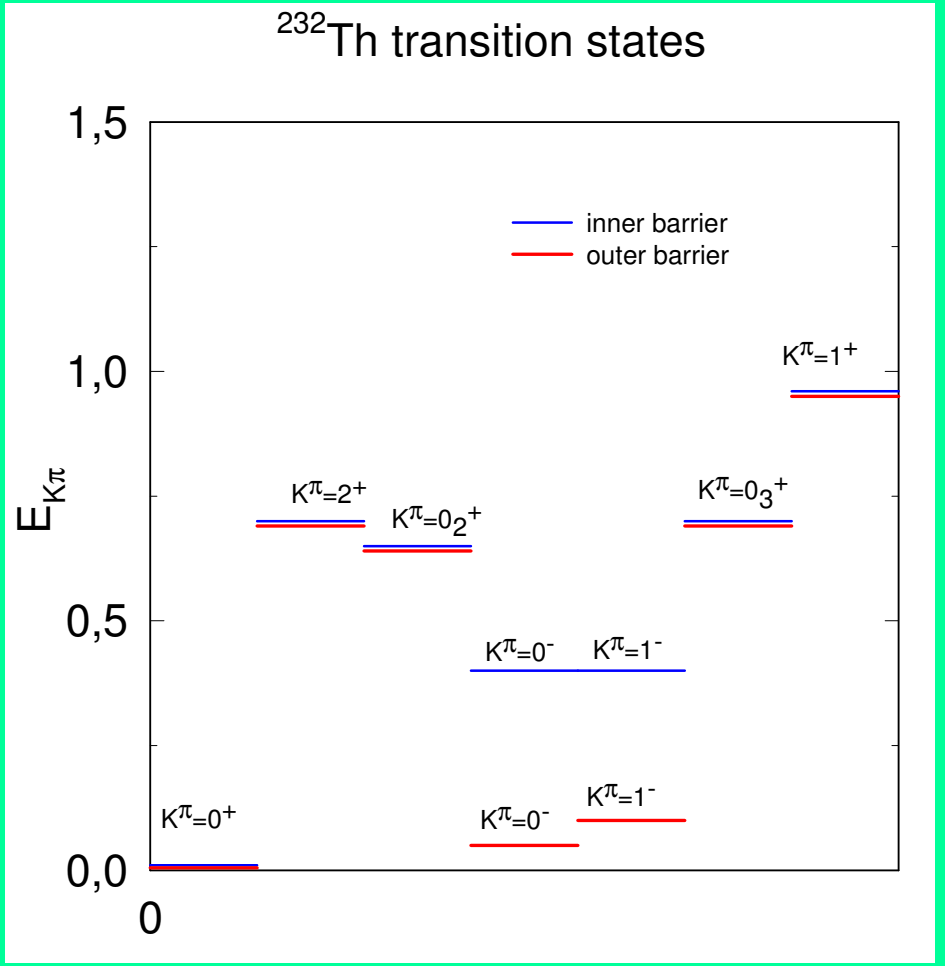
Surrogate vis. direct data for ^{230}Th(n,F)& ^{229}Th(n,F)

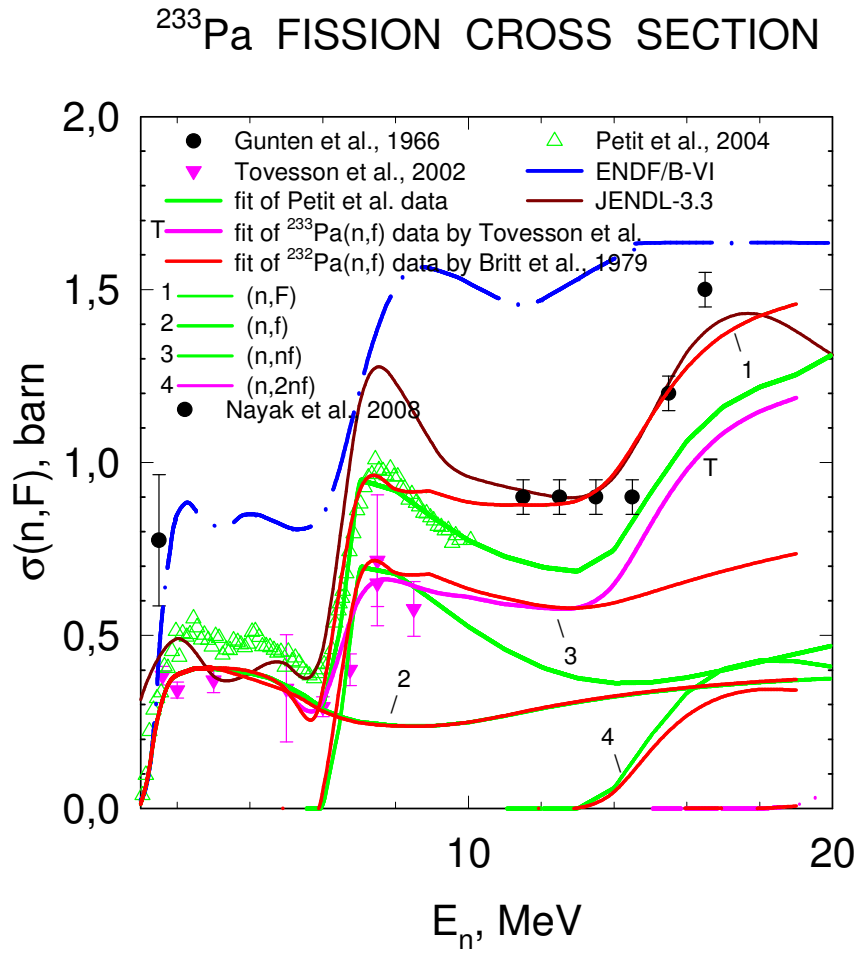


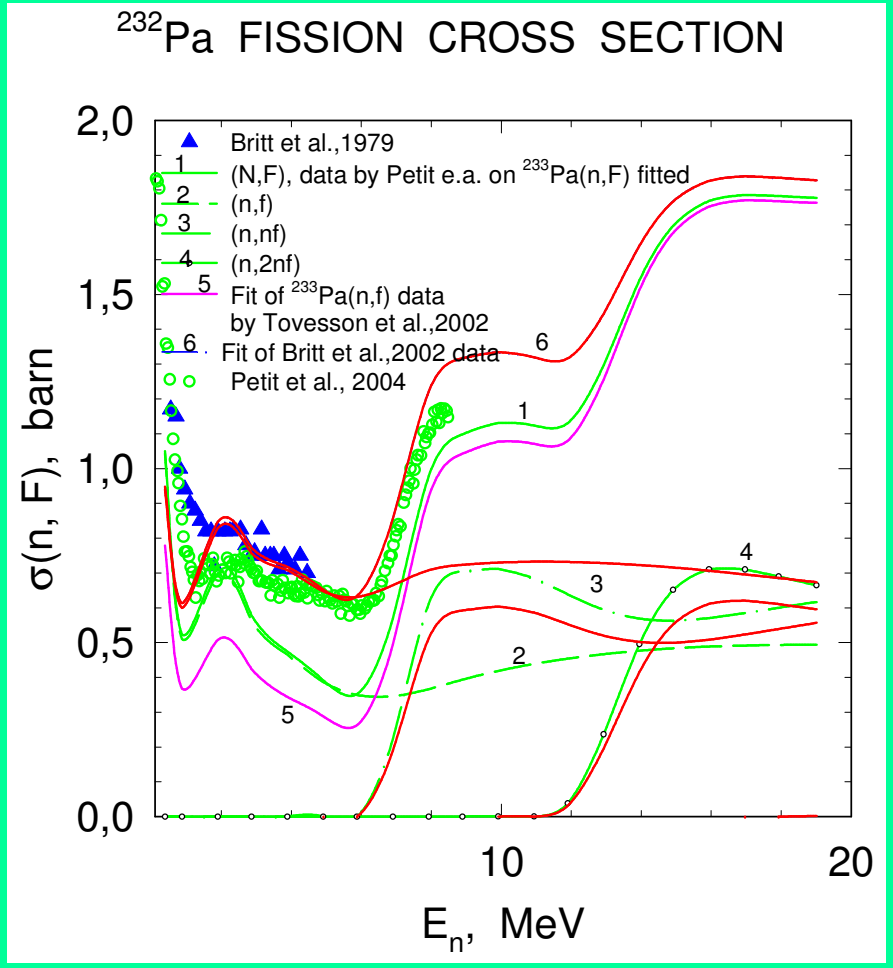
Surrogate vis. direct data for ^{231}Th(n,F)

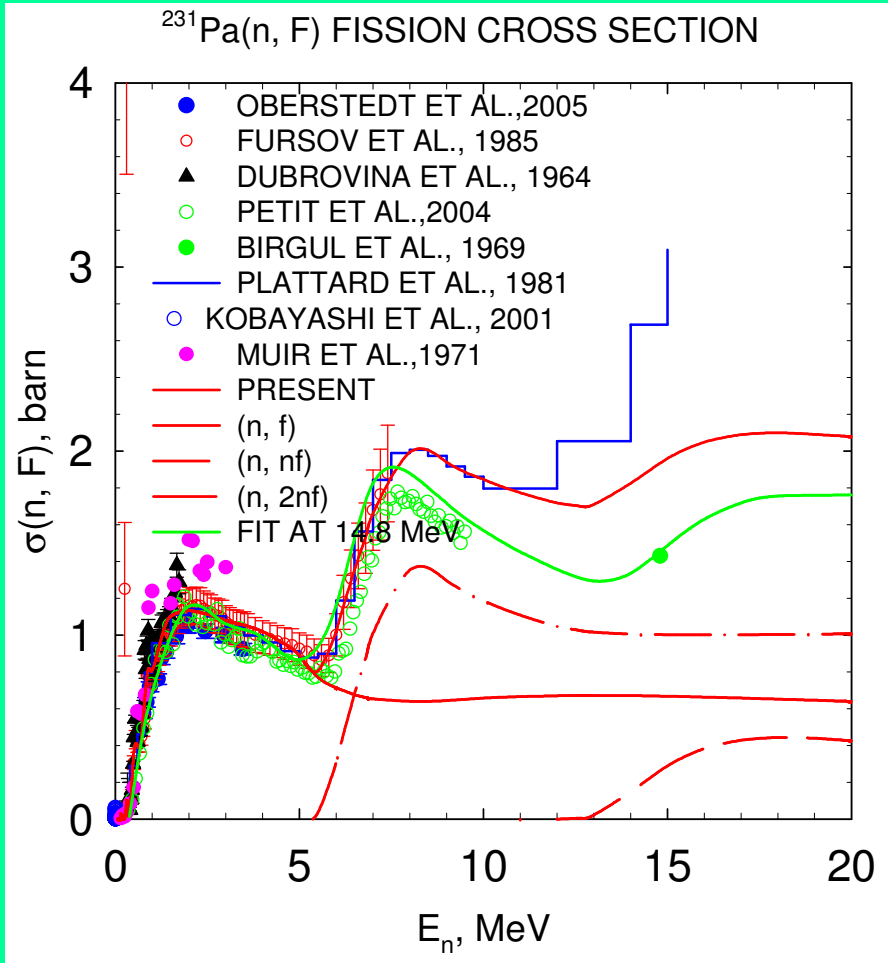


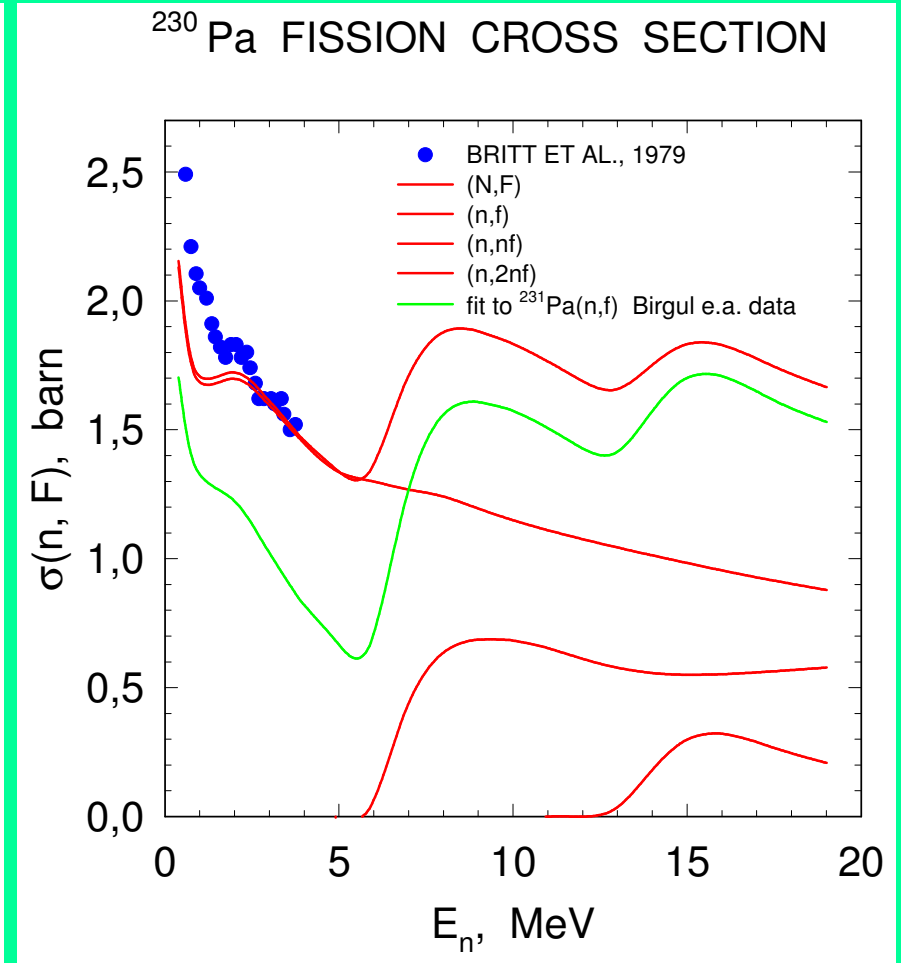
for mass-asym. shapes lowering of $K^{\pi}= 0_1^-$, $K^{\pi} =1_1^-$



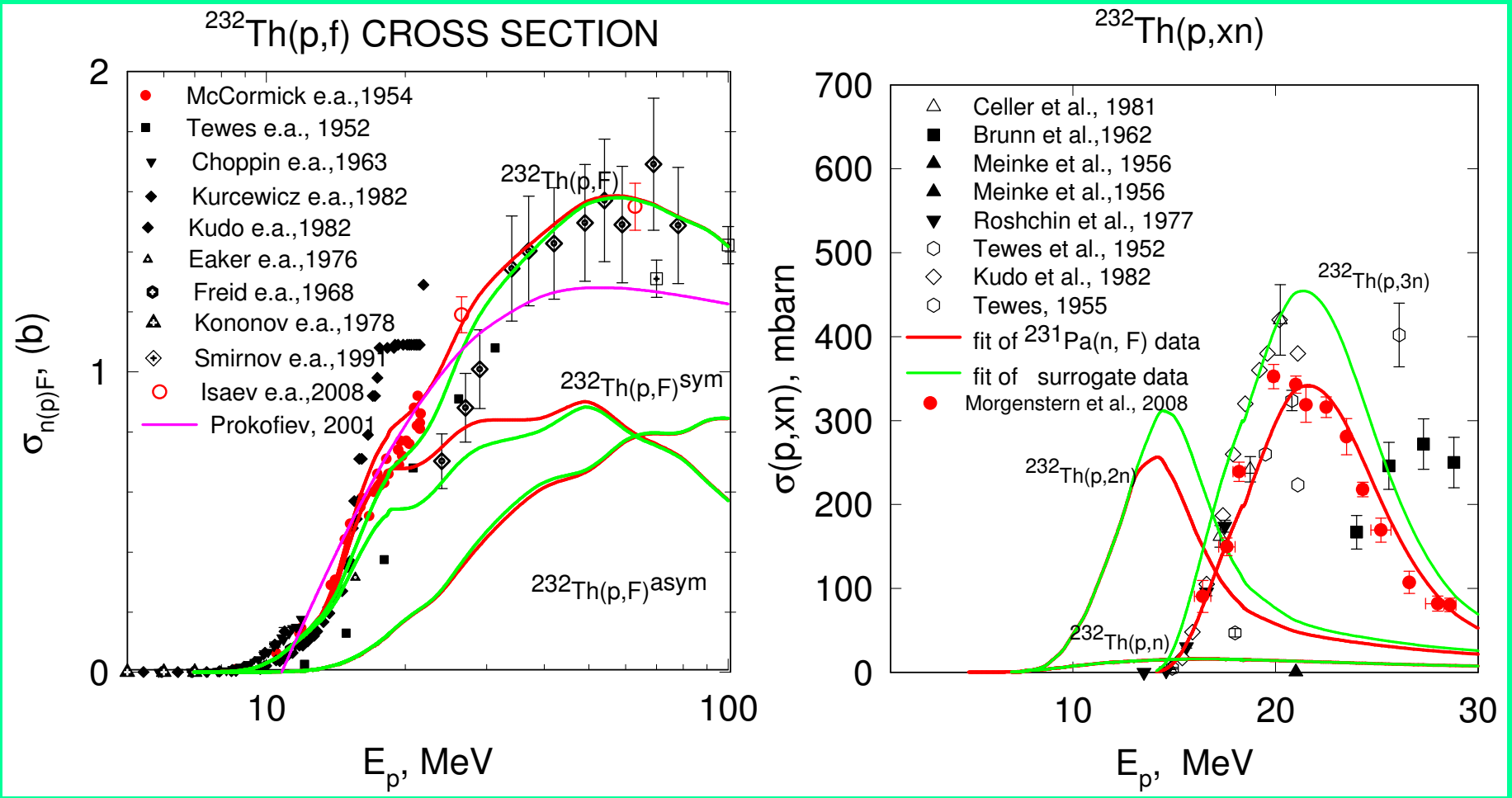

233Pa FISSION CROSS SECTION
Gunten et al., 1966
Tovesson et al., 2002
fit of Petit et al. data
fit of 233Pa(n,f) data by Tovesson et al.
fit of 232Pa(n,f) data by Britt et al., 1979
Petit et al., 2004
ENDF/B-VI
JENDL-3.3
1 (n,F)
2 (n,f)
3 (n,nf)
4 (n,2nf)
Nayak et al., 2008
T
σ(n,F), barn
E_n, MeV
2,0
1,5
1,0
0,5
0,0
10
20

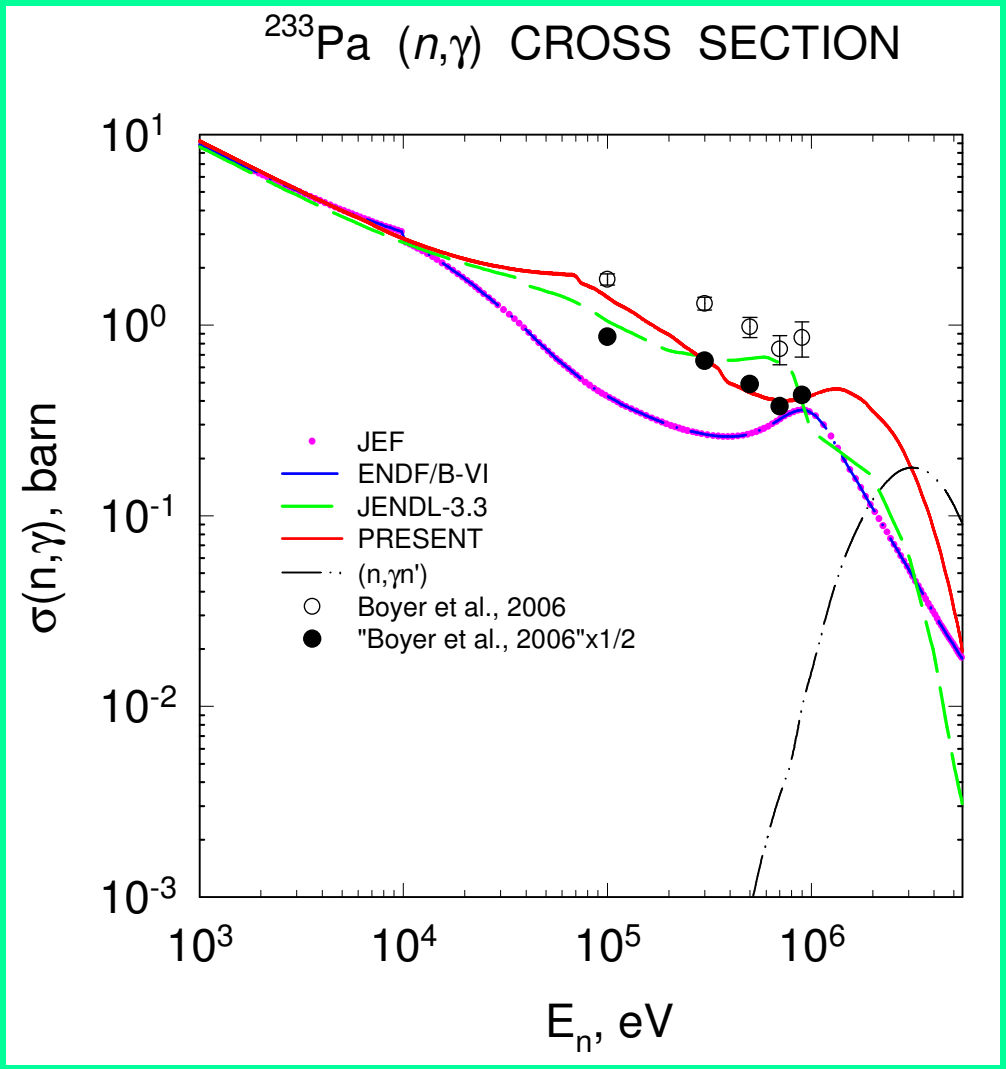

232Pa FISSION CROSS SECTION
Britt et al.,1979
1 (N,F), data by Petit e.a. on 233Pa(n,F) fitted
2 (n,f)
3 (n,nf)
4 (n,2nf)
5 Fit of 233Pa(n,f) data by Tovesson et al.,2002
6 Fit of Britt et al.,2002 data
Petit et al., 2004
σ(n, F), barn
E_n, MeV
2,0
1,5
1,0
0,5
0,0
10
20


231Pa(n, F) FISSION CROSS SECTION
OBERSTEDT ET AL.,2005
FURSOV ET AL., 1985
DUBROVINA ET AL., 1964
PETIT ET AL.,2004
BIRGUL ET AL., 1969
PLATTARD ET AL., 1981
KOBAYASHI ET AL., 2001
MUIR ET AL.,1971
PRESENT
(n, f)
(n, nf)
(n, 2nf)
FIT AT 14.8 MeV
σ(n, F), barn
E_n, MeV
0
1
2
3
4
0
5
10
15
20


230 Pa FISSION CROSS SECTION
BRITT ET AL., 1979
(N,F)
(n,f)
(n,nf)
(n,2nf)
fit to 231Pa(n,f) Birgul e.a. data
σ(n, F), barn
E_n, MeV
0,0
0,5
1,0
1,5
2,0
2,5
0
5
10
15
20

^{231}Pa, ^{230}Pa fissility check



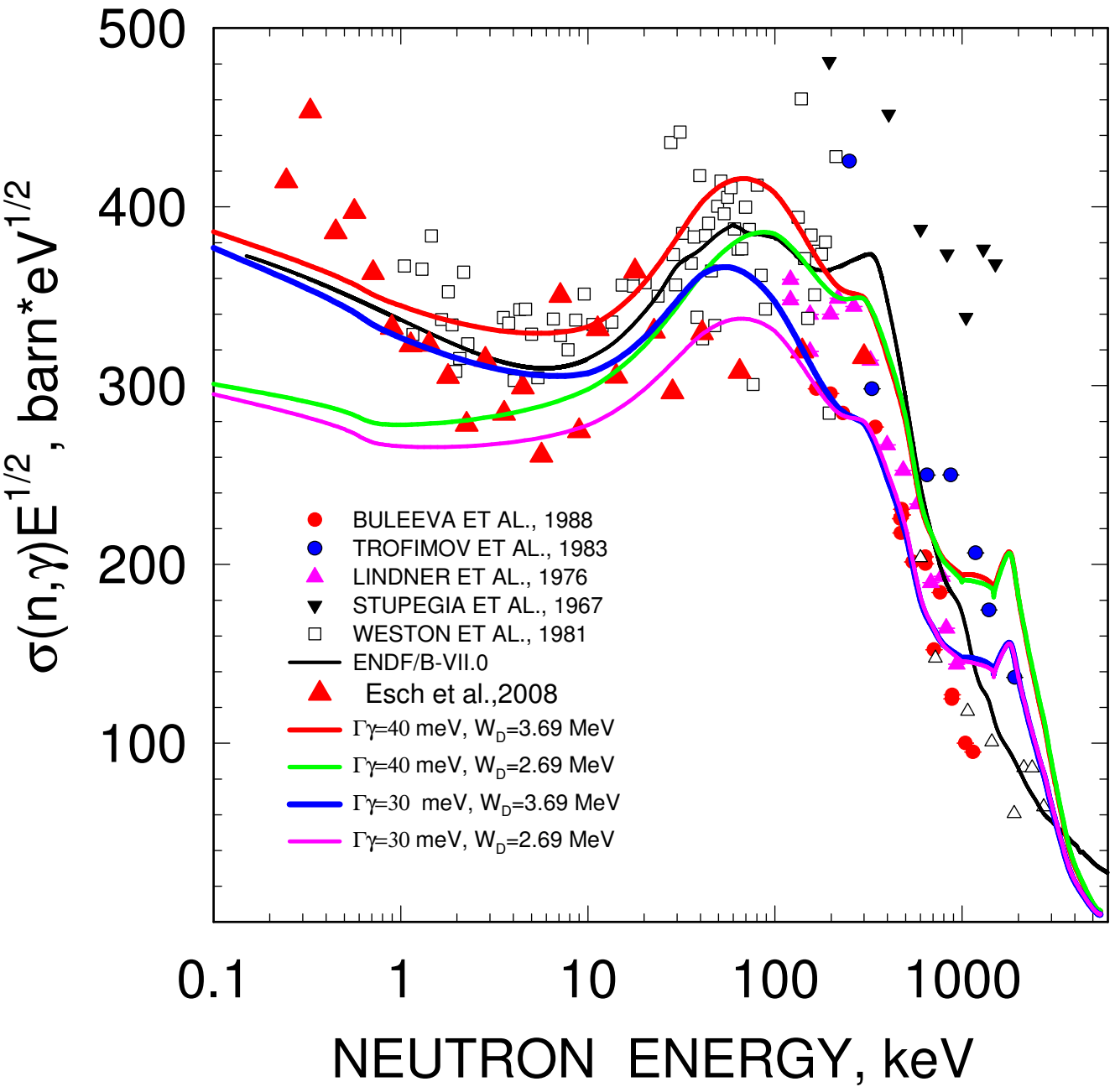

^{233}Pa (n,γ) CROSS SECTION
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^3
10^4
10^5
10^6
σ(n,γ), barn
E_n, eV
JEF
ENDF/B-VI
JENDL-3.3
PRESENT
(n,γn')
Boyer et al., 2006
"Boyer et al., 2006"x1/2

CAPTURE –model deficiency or URR+OMP uncertainties?

^{237}Np, ^{241,243}Am – tuning of model

$^{231\text{-}233}$Pa-model' prediction of capture css and uncertainty assessment

^{237}Np CAPTURE CROSS SECTION



- Improvements of the nuclear reaction modeling and nuclear parameter systematic for major actinides ^{232}Th, ^{233}U, ^{235}U, ^{238}U may provide a
- Sound basis for critical assessment and prediction of σ(n, F), σ(n, γ), σ(n, n'), σ(n,xn), PFNS of $^{230\text{-}233}$Pa
- $^{230\text{-}233}$Pa CSS uncertainties due to model deficiencies could lead to artificially large $\Delta\sigma$ for CSS

Conclusions

1. ^{230,231,232,233}Pa(n, F) evaluation based on first-chance fission probability data from transfer reactions.
2. Discrepancy of surrogate and (n, F) data for ^{230}Th target nuclide above (n, nf) emissive fission threshold is of systematic character, applicable for ^{231,233}Pa
3. Ratio surrogate data {d,d'f) &(α, α'F)} for the ^{237}U(n, F) reaction support present approach (PA).
4. Ratio surrogate data of ^{232}Th(^{6}Li,^{4}He)^{234}Pa and ^{232}Th(^{6}Li,d)^{236}U for the emissive fission, support PA
5. The predicted trend of ^{231}Pa(n, F) is similar to that of ^{233}Pa(n, F), is consistent with fissilities of ^{231,230}Pa (^{232}Th(p, F) and ^{232}Th(p,3n)).
5. See for ^{231,233} Pa evals at IAEA NDS web site