^{232}Th fission fragment angular distributions

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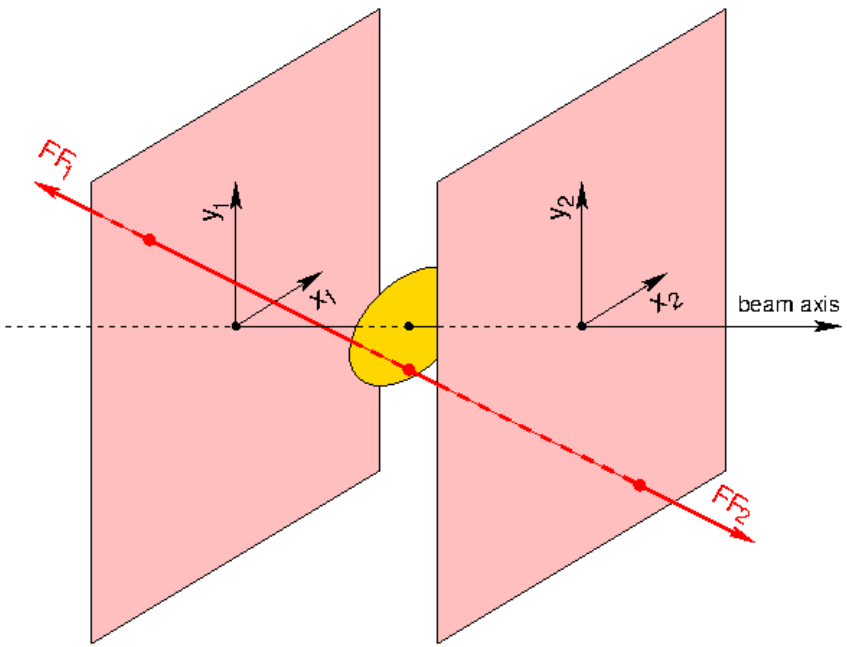
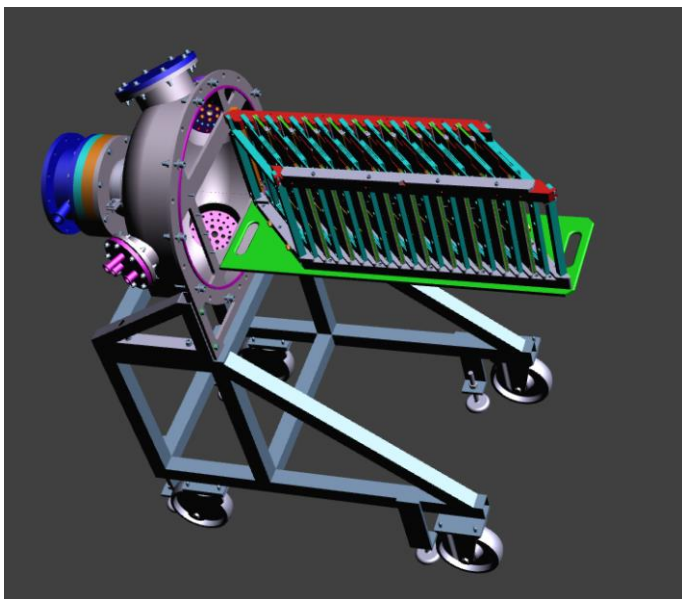
^{232}Th fission fragment angular distribution (FFAD)

- Detection of the 2 fission fragments
- Fission direction given by the positions of the 2 fragments

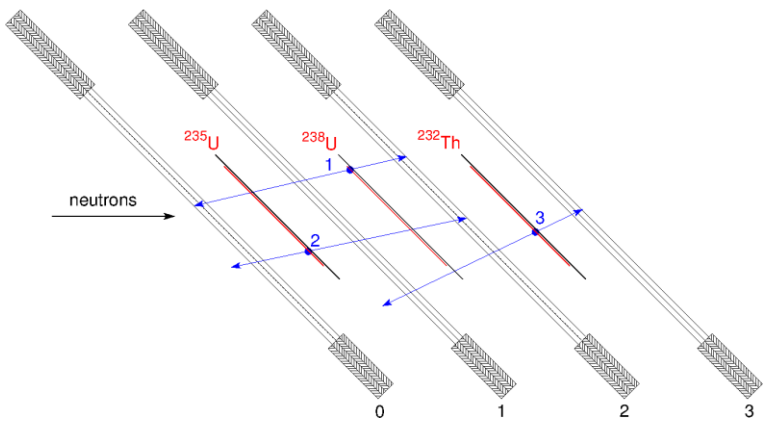


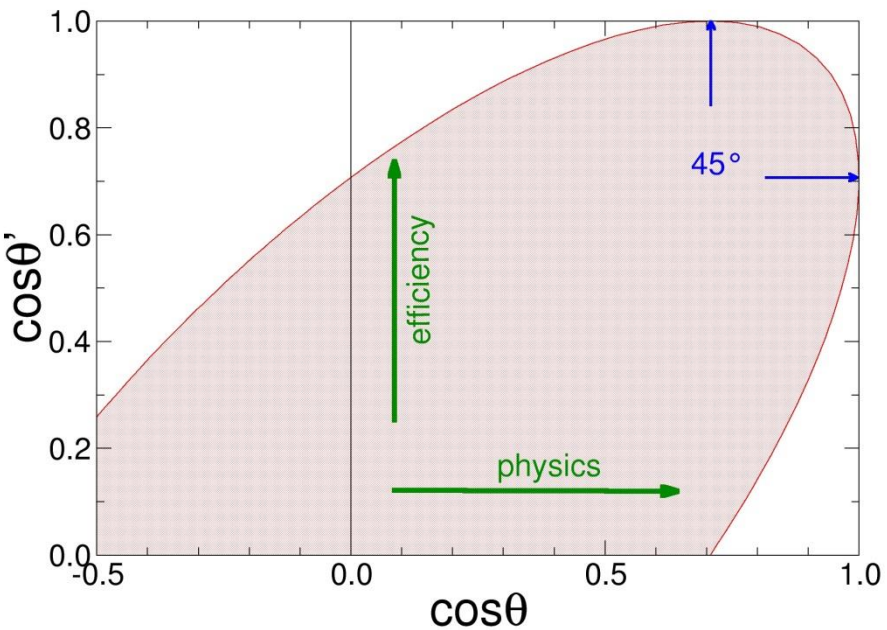


- 9 Targets and 10 detectors tilted by 45°
- 1x^{235}U 1x^{238}U 1x^{237}Np 6x^{232}Th

Detection efficiency (angle dependent)

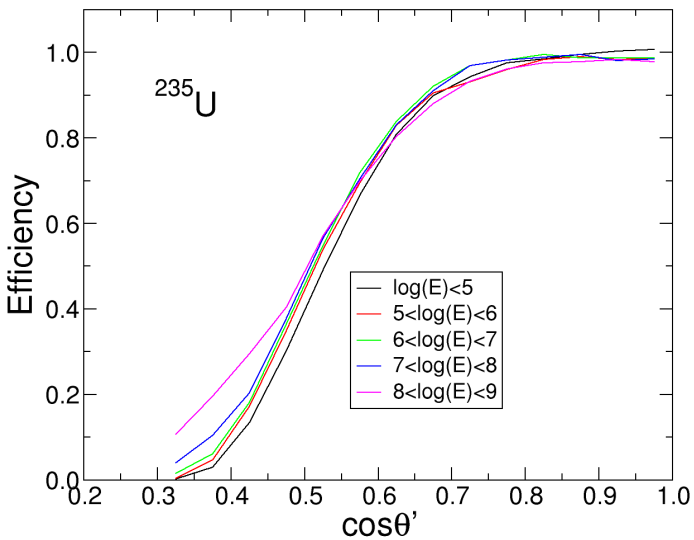
Efficiency governed by the stopping of the fission fragments at large angles relative to the normal to detectors

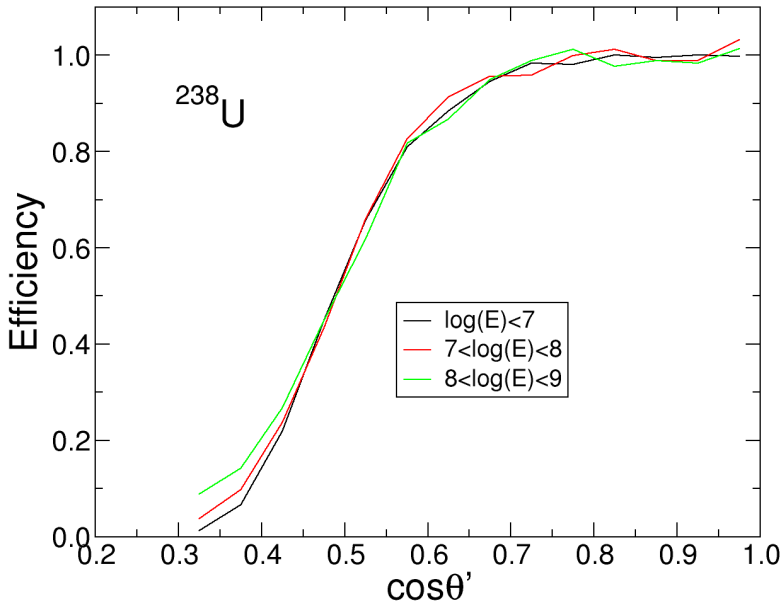


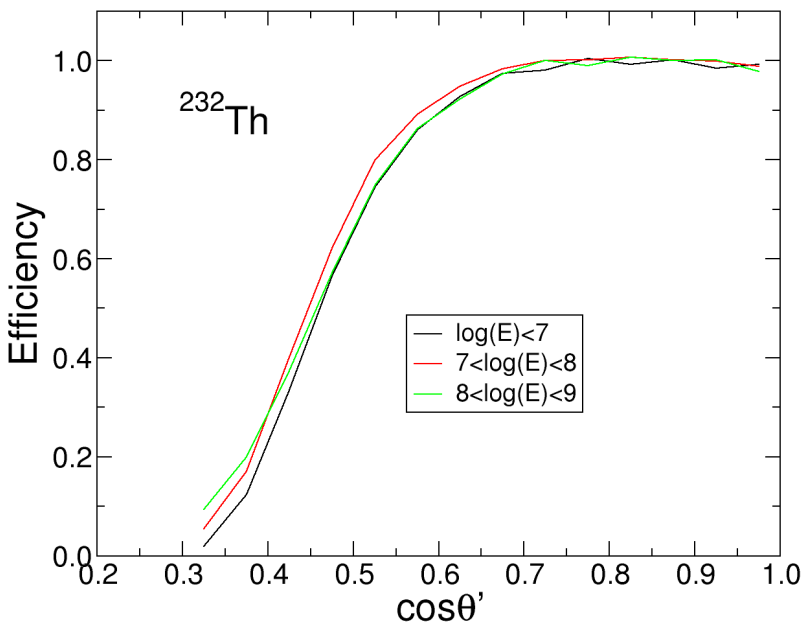


Efficiency ε(cosθ') reconstructed from cosθ'=1 for intervals of neutron energy

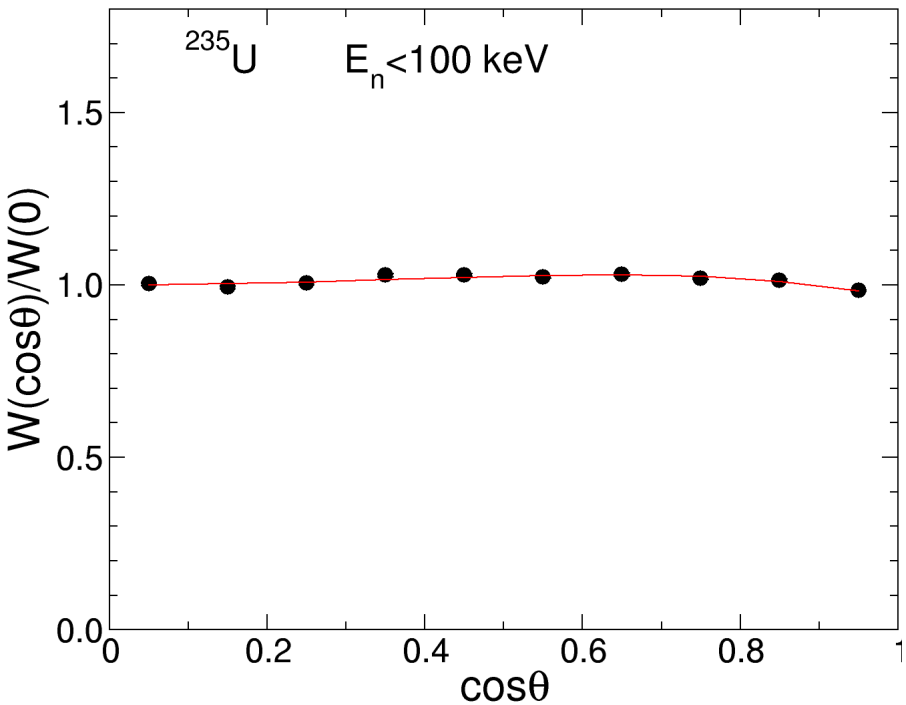
Detection efficiency

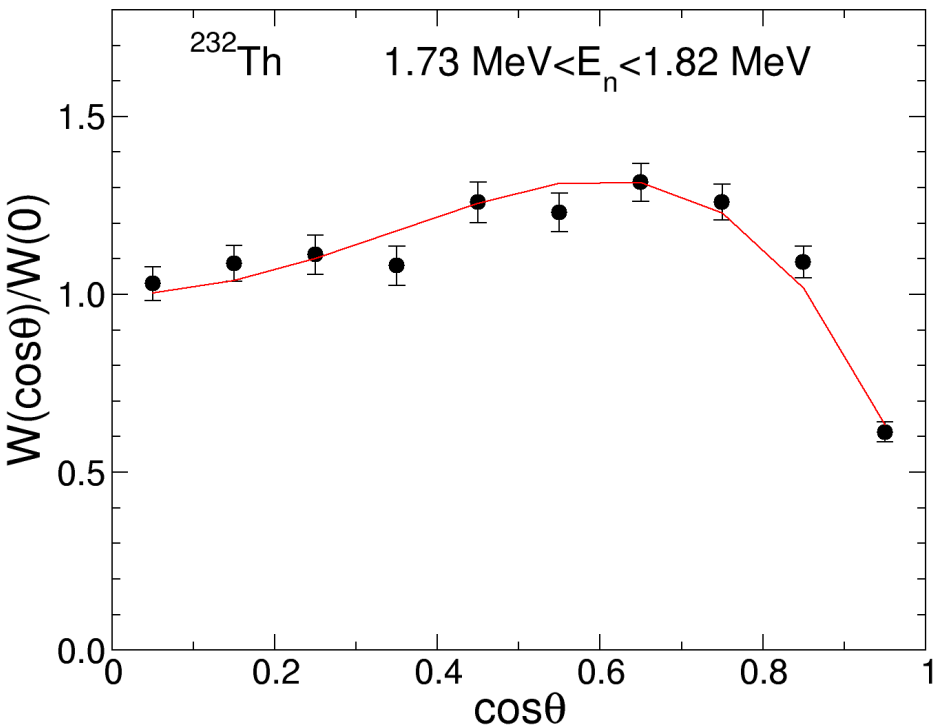


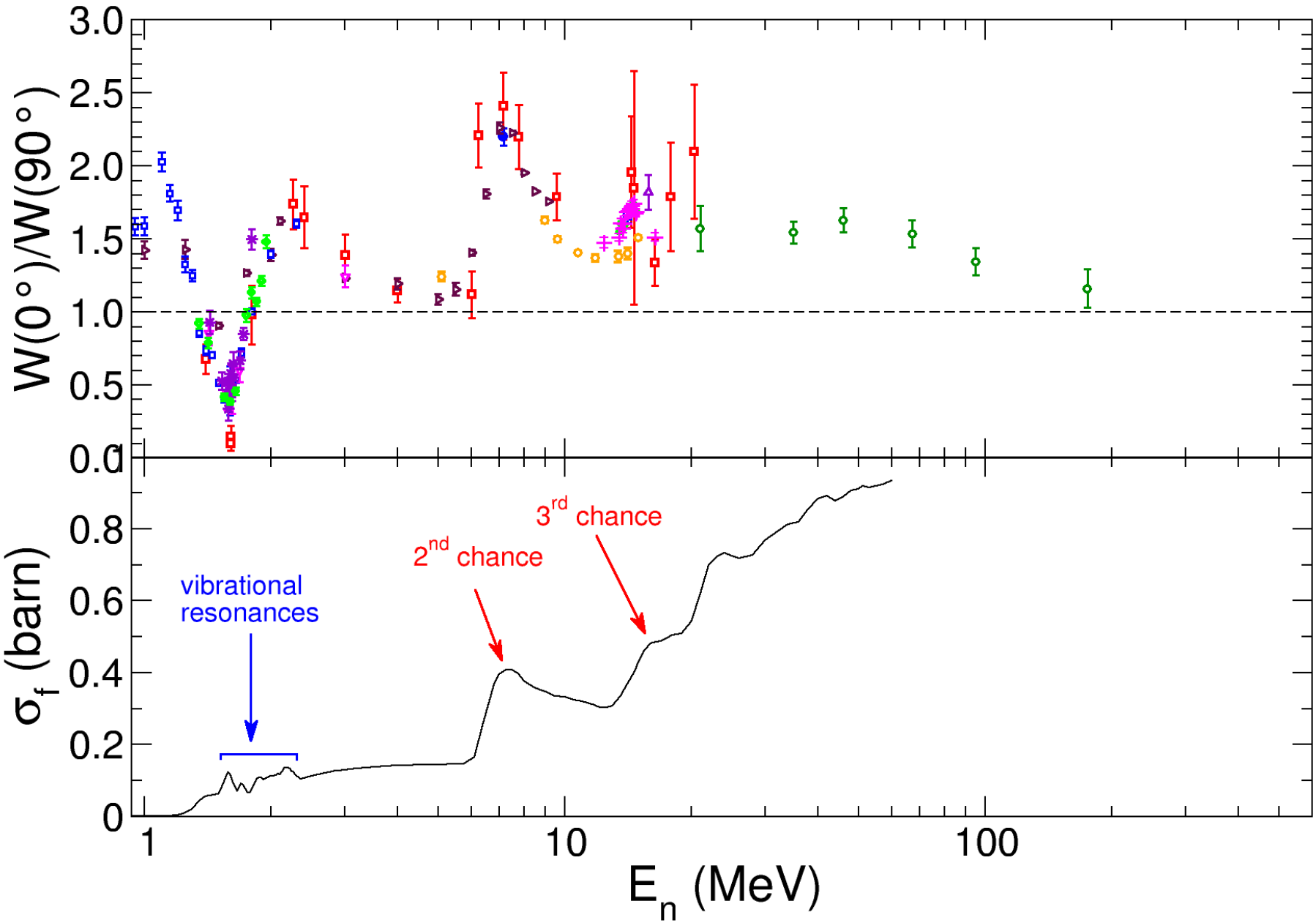




Examples of angular distributions

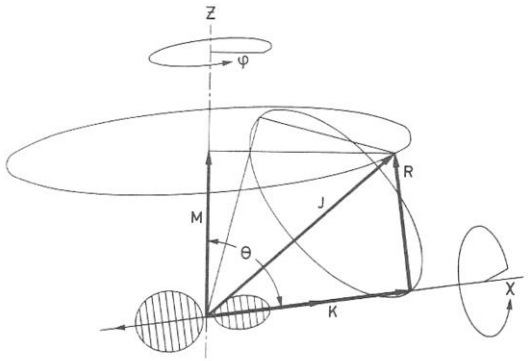


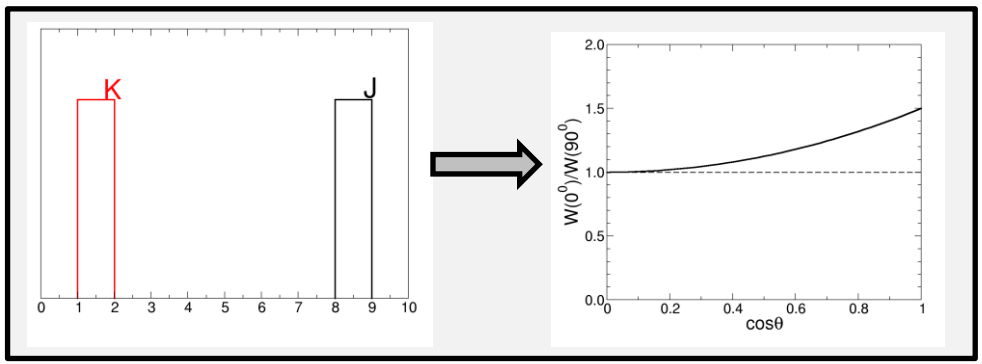


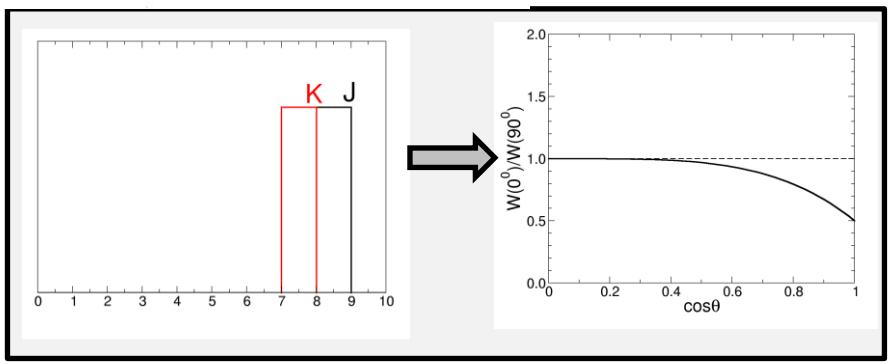

W(0°)/W(90°)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
σf (barn)
0.8
0.6
0.4
0.2
0
vibrational
resonances
2nd chance
3rd chance
1
10
100
En (MeV)

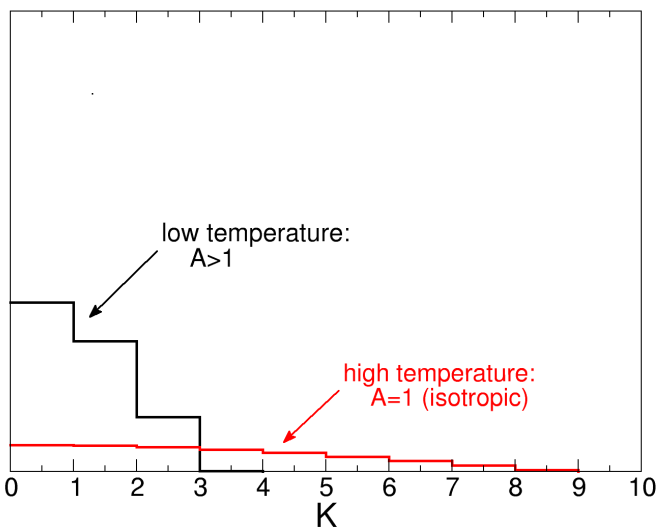
Rules of thumb for FFADs

$$W(\theta) = \left| d^{J}_{K,M}(\theta) \right|^2$$



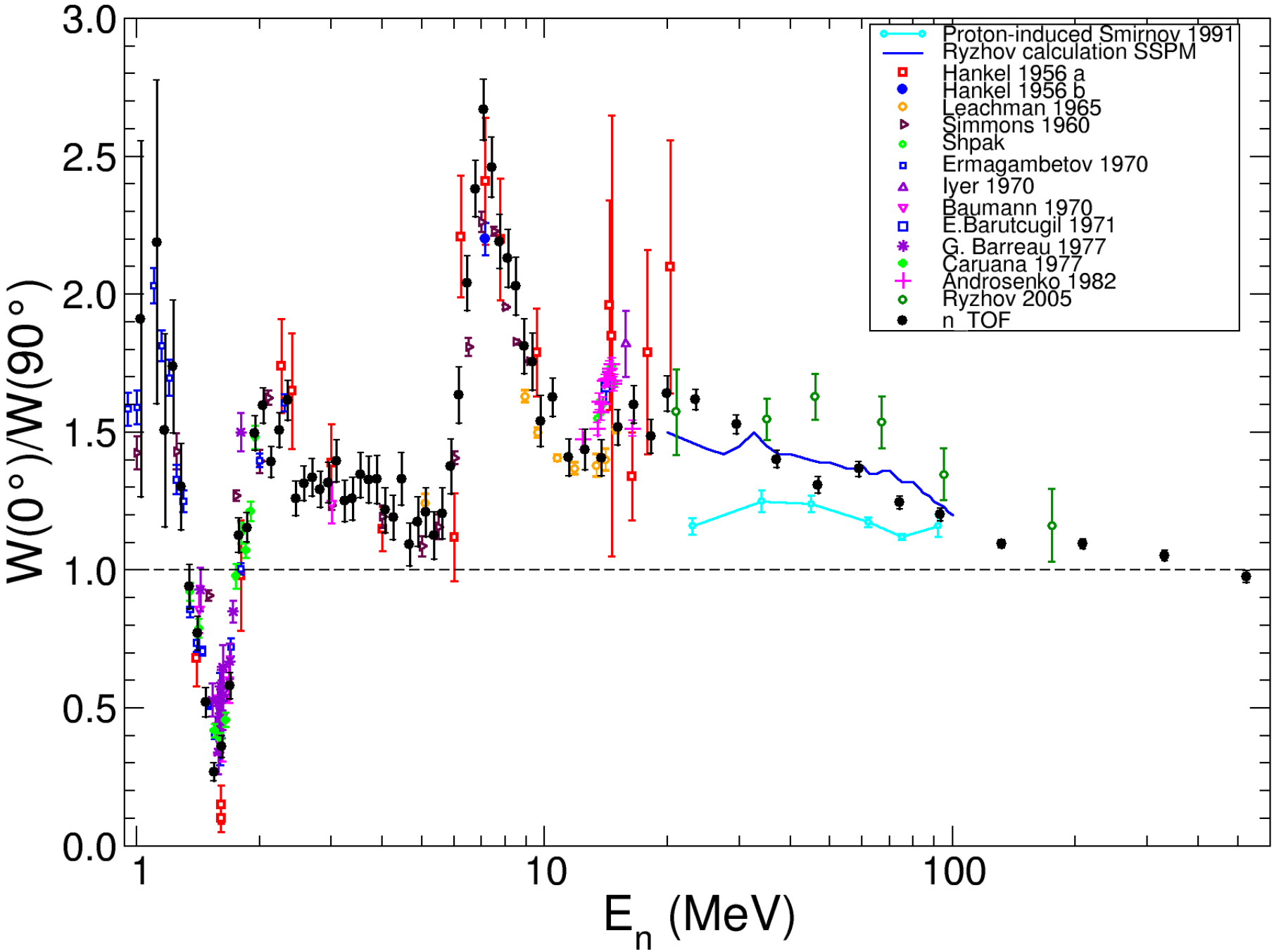




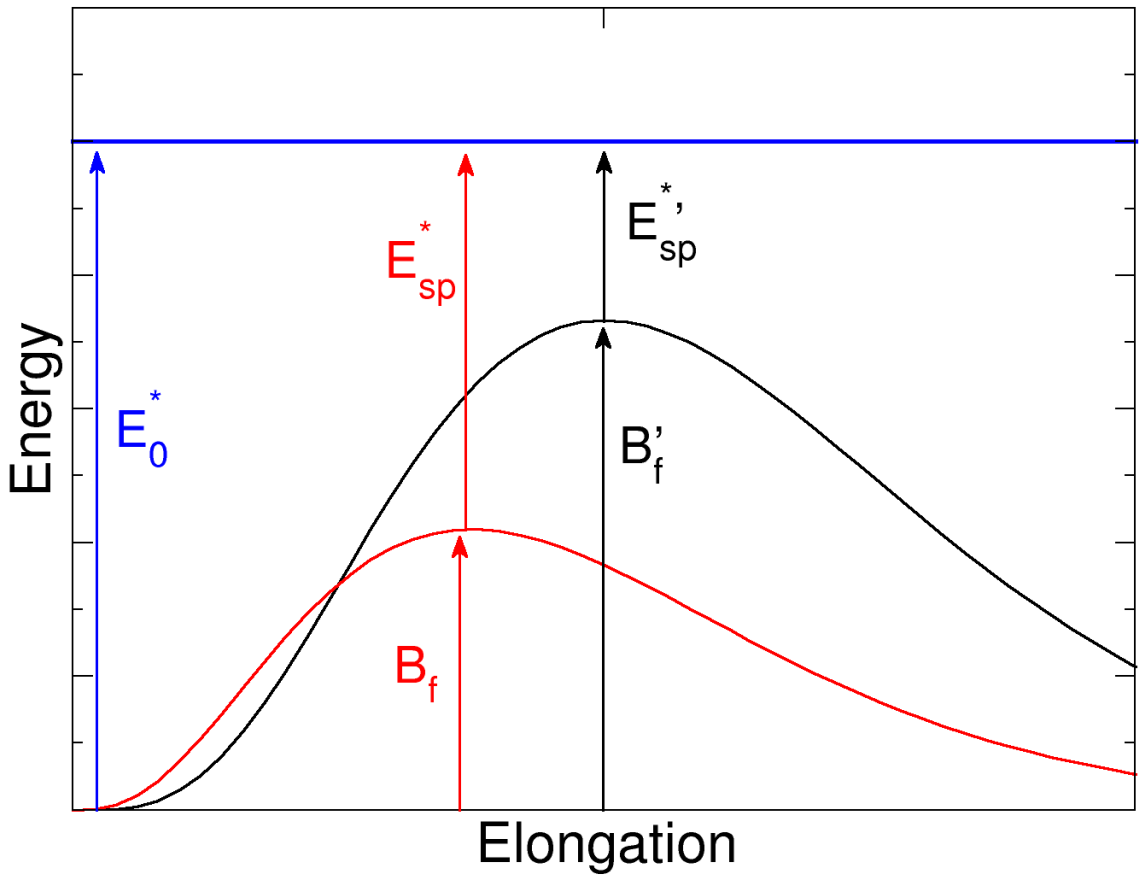


$$P(K) \sim \exp\left(-\frac{K^2}{K_0^2}\right)$$

$$K_0^2 = \frac{J_{eff} T}{\hbar^2}$$

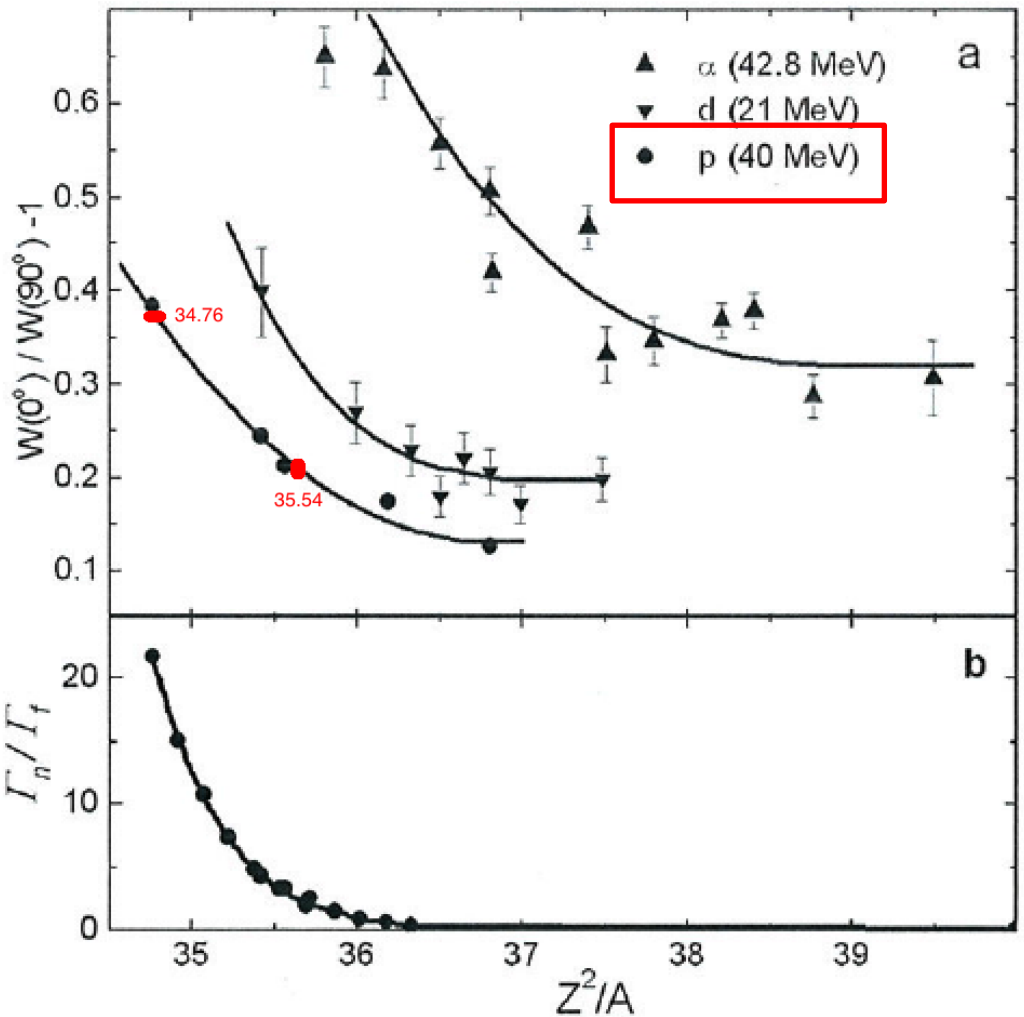

W(0°)/W(90°)
E$_n$ (MeV)
Proton-induced Smirnov 1991
Ryzhov calculation SSPM
Hankel 1956 a
Hankel 1956 b
Leachman 1965
Simmons 1960
Shpak
Ermagambetov 1970
Iyer 1970
Baumann 1970
E.Barutcugil 1971
G. Barreau 1977
Caruana 1977
Androsenko 1982
Ryzhov 2005
n_TOF

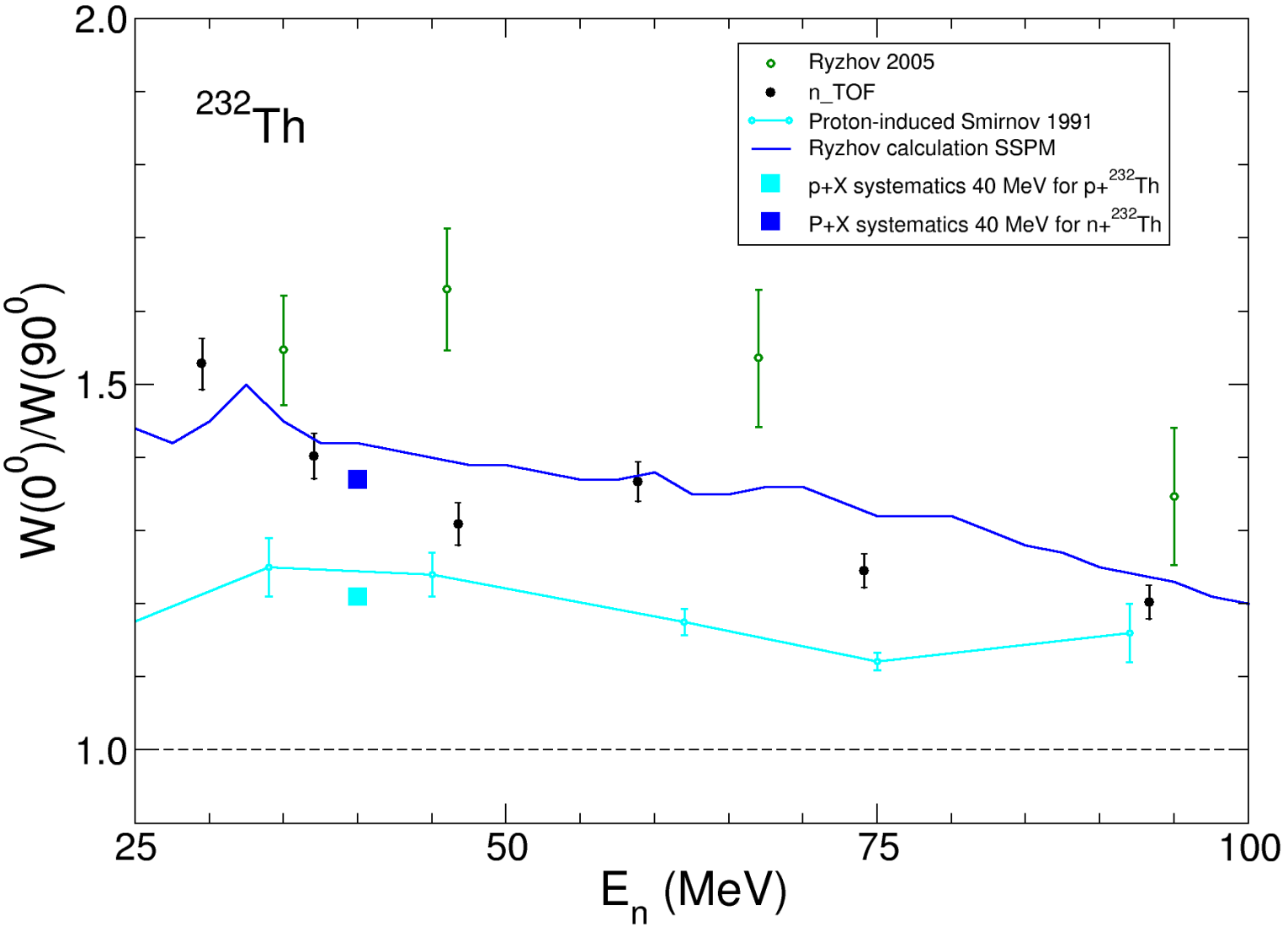
Fissility effect



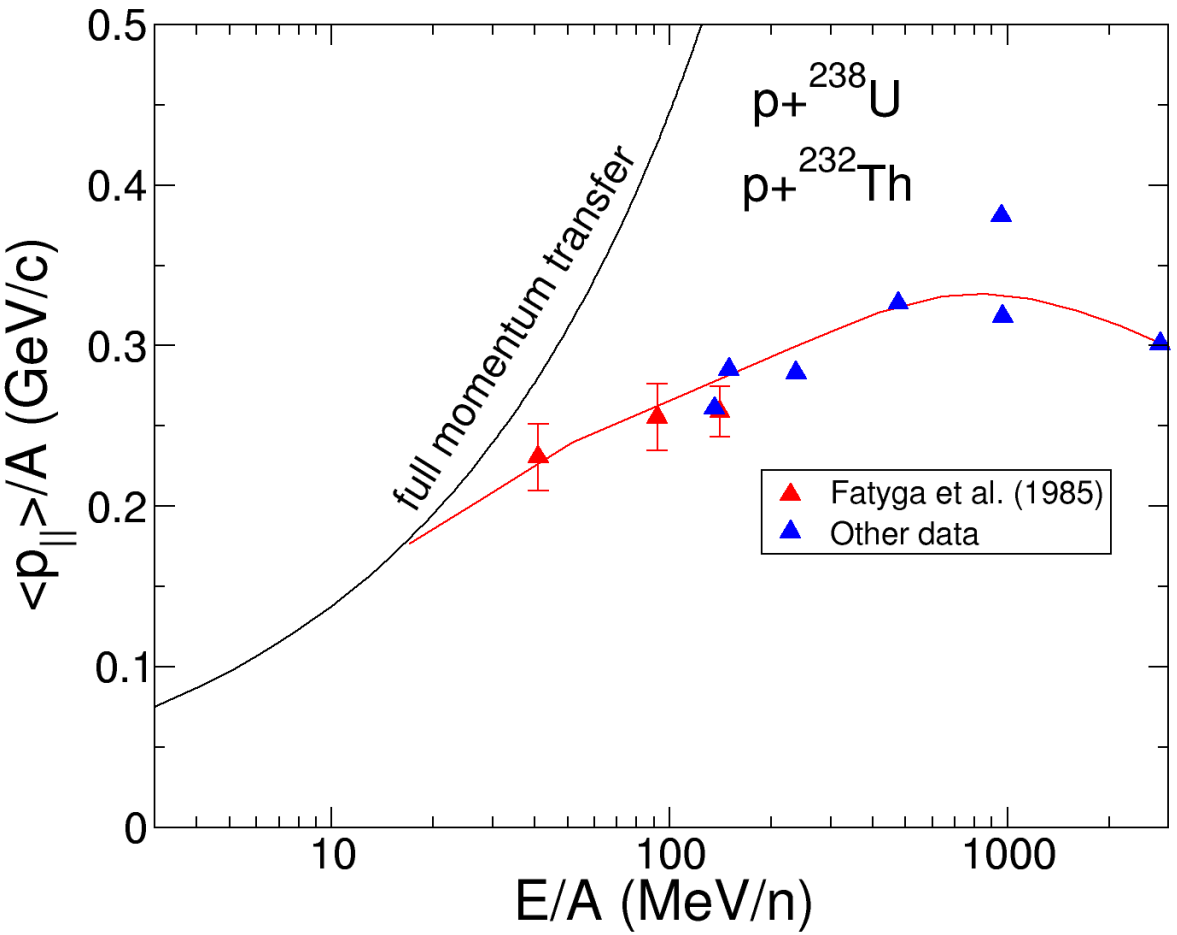
Lower fissility ➡ higher barrier ➡ lower temperature ➡ lower K_0
➡ lower K's ➡ higher positive anisotropy

Anisotropy for p+X at 40 MeV




232Th
Ryzhov 2005
n_TOF
Proton-induced Smirnov 1991
Ryzhov calculation SSPM
p+X systematics 40 MeV for p+232Th
P+X systematics 40 MeV for n+232Th
W(0°)/W(90°)
2.0
1.5
1.0
25
50
75
100
En (MeV)

Systematics of linear momentum transfer



At 40 MeV almost full momentum transfer: in most of the cases the proton is captured by the target nucleus

Conclusion

- We have measured the fission fragment angular distribution of ^{232}Th from threshold to 600 MeV
- Below 10 MeV we are in agreement with previous data and around 14 MeV a better accuracy is achieved
- Between 20 and 100 MeV we find a steeper drop of the anisotropy, compared to Ryzhov data and we are in agreement with his calculation
- The agreement with the fissility systematics indicates that the incoming neutron is captured at 40 MeV
- This is consistent with the systematics of linear momentum transfer