Problem with gradual absorption in MSD/MSC calculations

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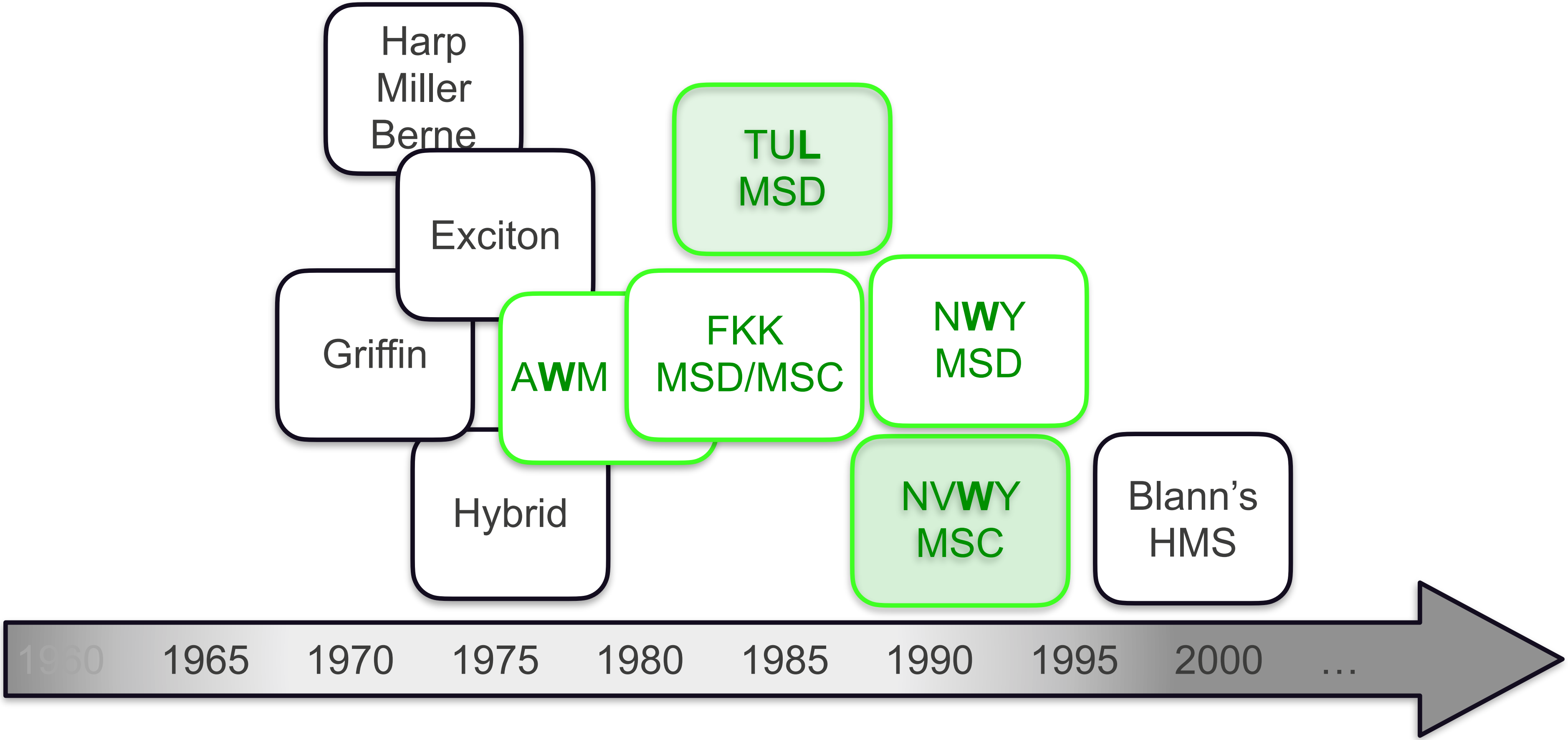
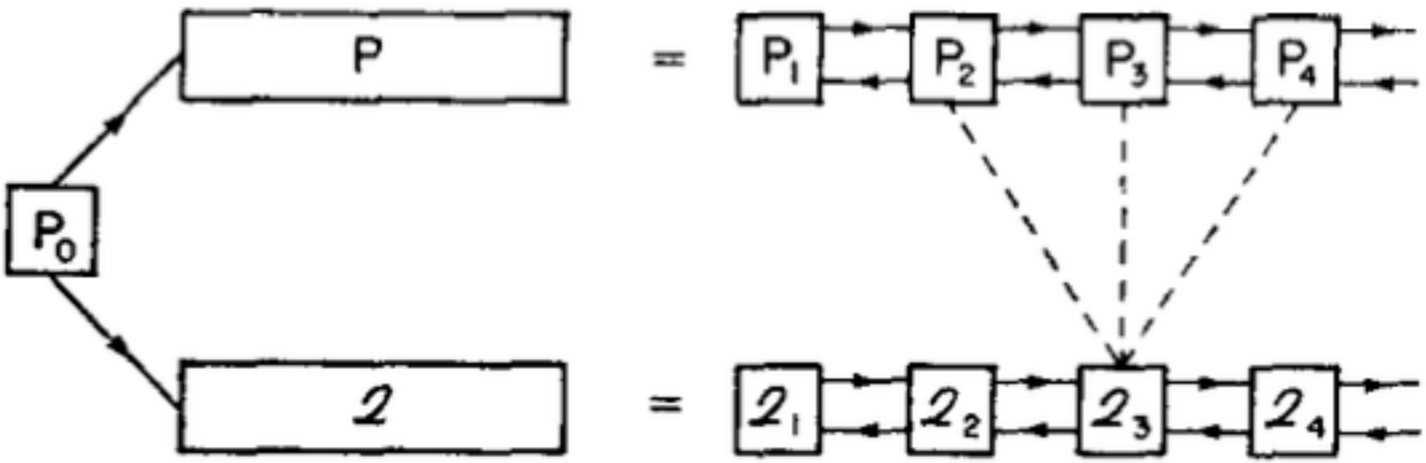
Simplified timeline of Multistep…



P & Q spaces make quantum theories different from classical ones



FKK ANNALS OF PHYSICS 125, 429-476 (1980)

NVWY MSC implementation essentials

NVWY MSC cross section

$$U_n^a = \rho_n^b < W_{n,a} >$$

$$\frac{d\sigma_{ab}}{dE} = (1+\delta_{ab}) \sum_{n,m} T_n^a \Pi_{n,m} T_m^b \qquad T_n^a = \frac{4\pi^2 U_n^a}{(1+\pi^2 \sum_m U_m^a)^2}$$

$$(\Pi^{-1})_{nm} = \delta_{nm}(2\pi\rho_n^b)(\Gamma_n^{\downarrow} + \Gamma_n^{ext}) - (1-\delta_{nm}) 2\pi\rho_n^b \overline{V_{n,m}^2} 2\pi\rho_m^b$$

$$\Gamma_n^{\downarrow} = 2\pi \sum_m \overline{V_{n,m}^2} \rho_m^b \qquad \Gamma_n^{ext} = (2\pi\rho_n^b)^{-1} \sum_a T_n^a$$

$$\overline{V_{n,m}^2} \leftarrow \Gamma_n^{\downarrow} = 2W(\epsilon)$$

$$< W_{n,a} > \leftarrow T_n^a$$

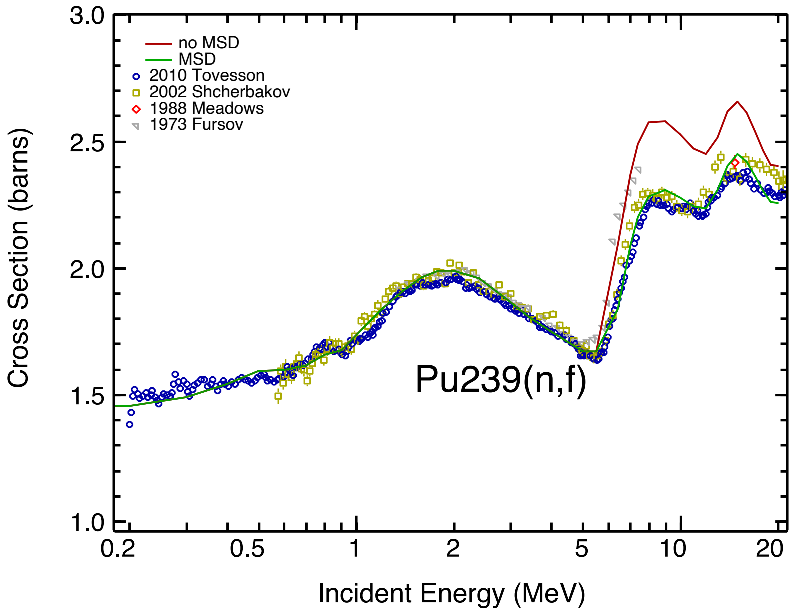
Two microscopic quantities derived from the macroscopic ones

TUL & NVWY calculations

EMPIRE code

- Dispersive CC potential for incident channel
- Multistep Direct for (n,n') - (TUL, ORION+TRISTAN by **H. Lenske**)
- Multistep Compound for (n,n'), (n,p), (n,γ) - (NV**W**Y)
- Exciton model for (n,a), (n,d), (n,t), (n,^{3}He) - (PCROSS)
- Compound nucleus (Hauser-Feshbach with width fluctuation)

Effect of MSD on fission calculations



Calculations - MSC options

- Transmission coefficients calculated using matrix elements determined in the incident channel
- Gamma down calculated using matrix element determined from the optical model imaginary part
- 3-initial excitons: neutrons = 1.2, protons = 0.80 (σ_{nn}/σ_{np} = 4)
- Ratio of unbound-bound to unbound-unbound matrix elements = **1.0**
- 4-stage MSC calculations followed by the Hauser-Feshbach
- single-particle lev. dens. = **A/13**

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NUCLEAR PHYSICS A

MULTISTEP-COMPOUND CONTRIBUTION TO PRECOMPOUND REACTION CROSS SECTION

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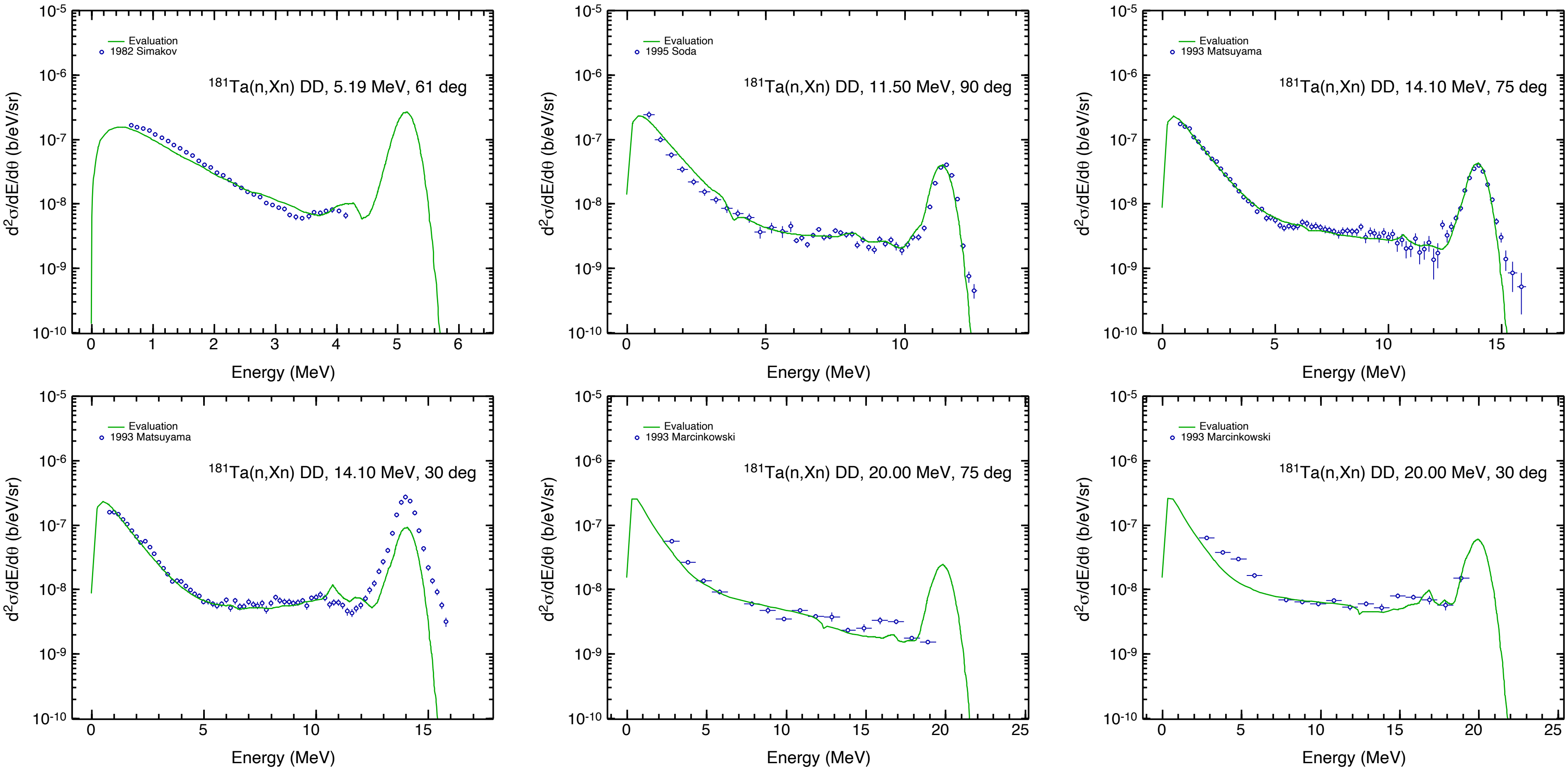
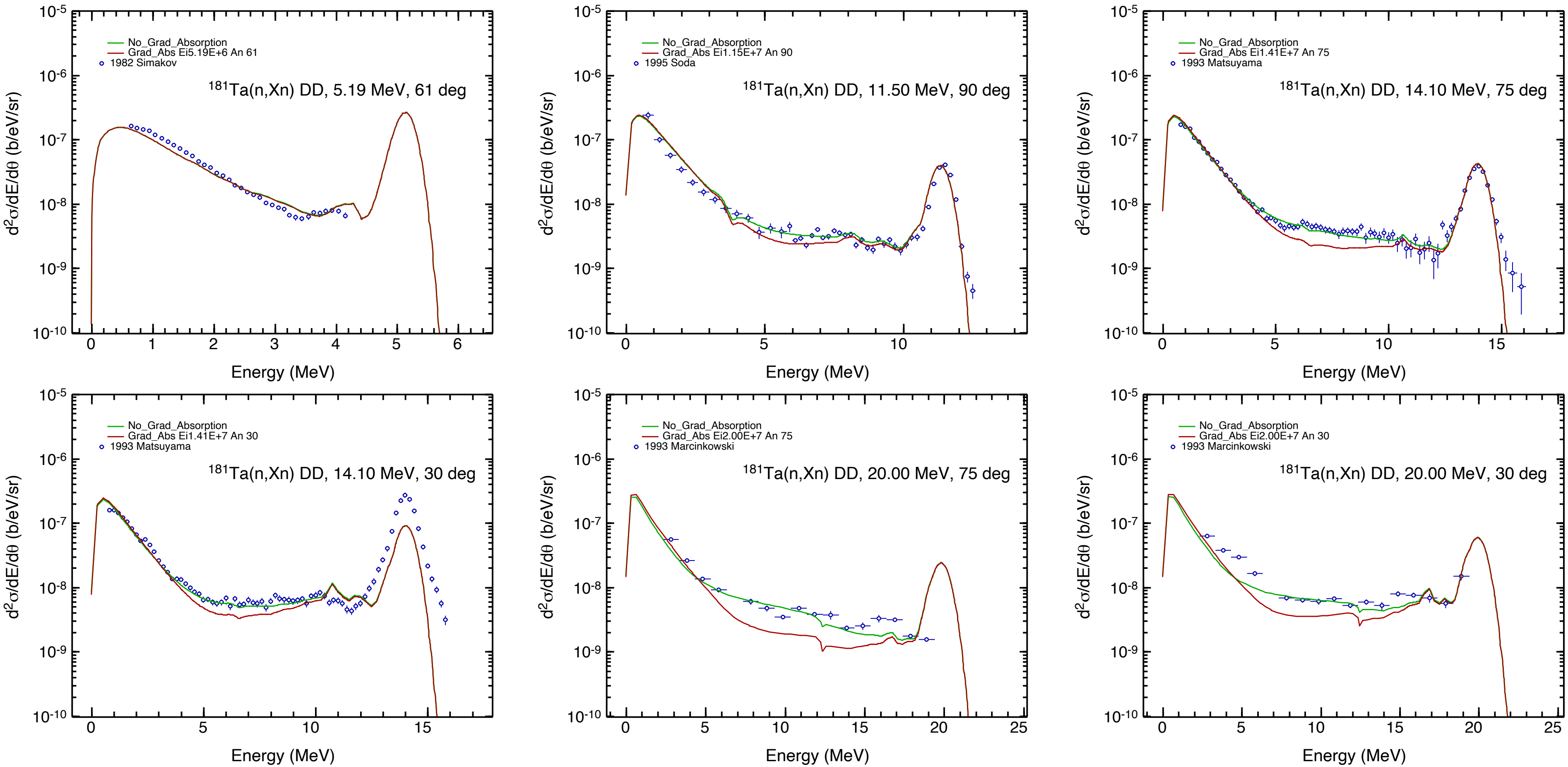
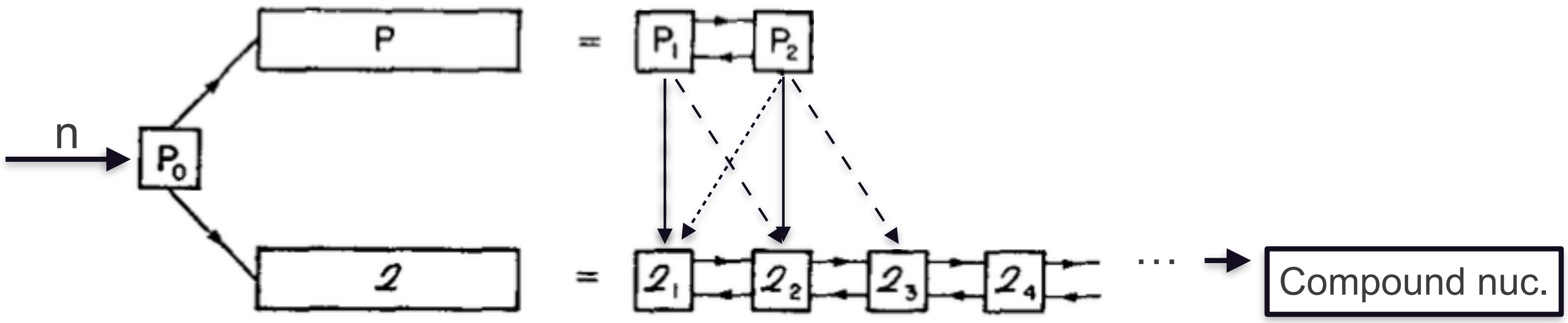
MSD+MSC performance (n+Ta181 evaluation)



…when we do it right (trick of the trade: ignore gradual absorption)



Gradual absorption (independent from MSD!)



$$T_1 = T_{om} \frac{< V_{ub}^2 > \rho_1^b(E)}{< V_{ub}^2 > \rho_1^b(E) + < V_{uu}^2 > \rho_1^u(E)} = T_{om} \frac{R}{(R-1) + \frac{\rho_1(E)}{\rho_1^b(E)}}$$

$R =< V_{ub}^2 > / < V_{uu}^2 >$

$$T_n = \left(T_{om} - \sum_{i=1}^{n-1} T_i \right) \frac{R}{(R-1) + \frac{\rho_n(E)}{\rho_n^b(E)}}$$

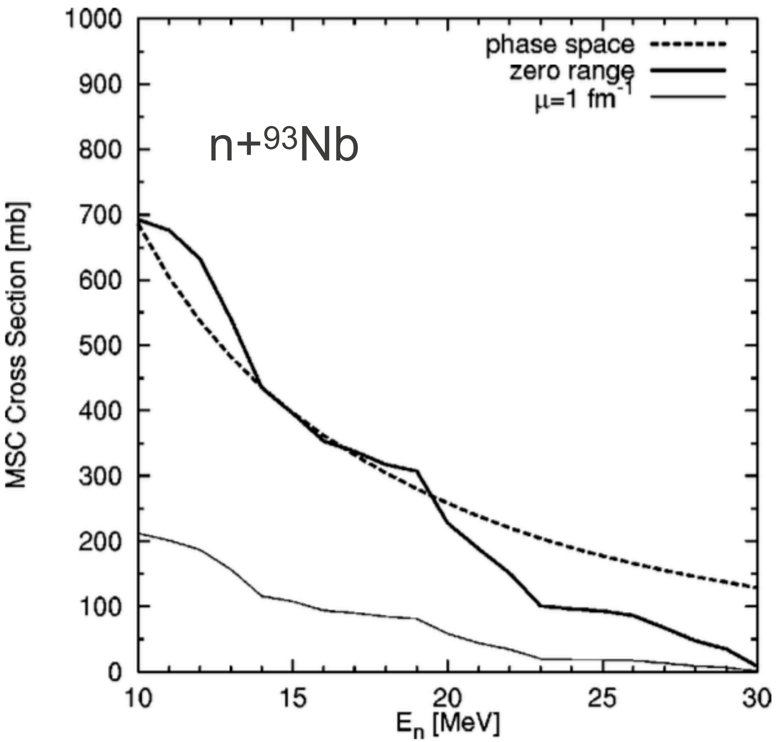
Gradual population of Q- stages

E (MeV)	Q1	Q2	Q3	Q4	Σ
5	0.60	0.35	0.04	0.001	0.991
11	0.26	0.38	0.27	0.08	0.99
14	0.19	0.30	0.30	0.16	0.95
20	0.11	0.18	0.24	0.23	0.76

Options to increase MSC

- Ratio unbound->bound to unbound->unbound (we assume 1) ?
  We would need ratio of ~2.5; is there any plausible explanation for this?
- Strong backward transition P_2 => Q_1?
  Practically impossible - convert 3p-2h with unbound particle into 2p-1h bound configuration.
- P_n => Q_{n+1} transition?
  Would increase total population of Q chain but would shift it to higher n.
- More steps in MSD?
  Very unlikely to help MSC.
- More steps in MSC (we use 4)?
  Unlikely to affect emission spectra in the middle-energy range.
- Explicit use of spin (and parity) distributions?

Kawano microscopic results confirm decrease of MSC with energy



Kawano, PRC 59 (1999) 865

Bonus - spin distribution in MSD

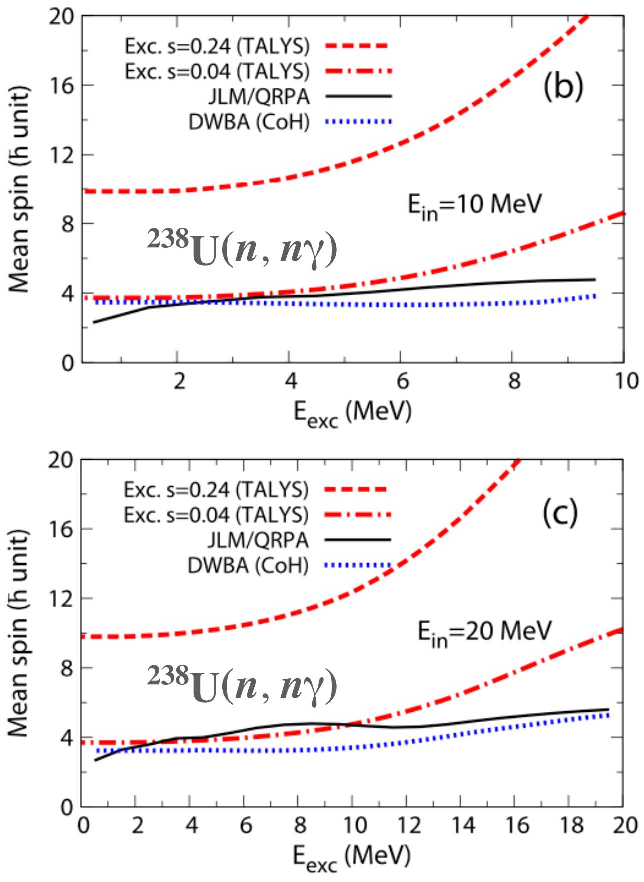
Typical spin-cut off parameter for p-h

$$\sigma^2(n) = cnA^{2/3}$$ with $c = 0.24$

Recent DWBA and QRPA calculations found for MSC calculations much smaller factor $c = 0.04$.

Our MSD calculations for ^{181}Ta indicated dominance of the l=0 transfer that leads to population of levels with low spins.

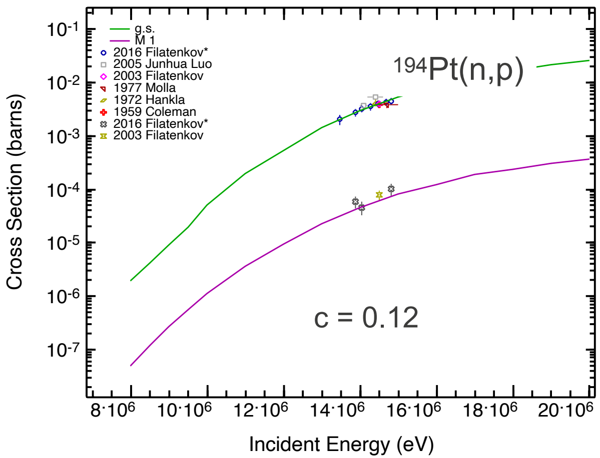
While 0.24 is probably valid for spin distribution of p-h states the MSD populates only low spin part of them.

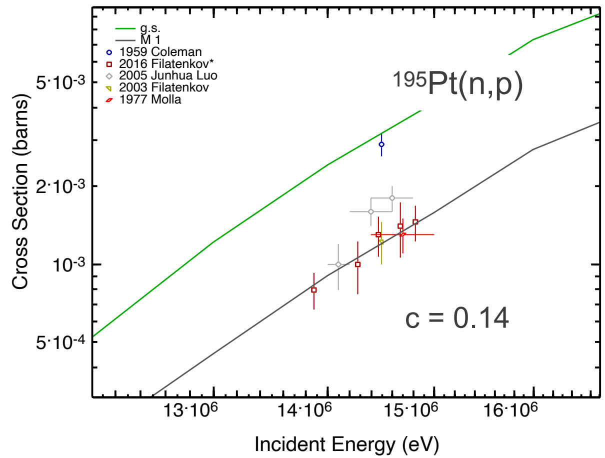


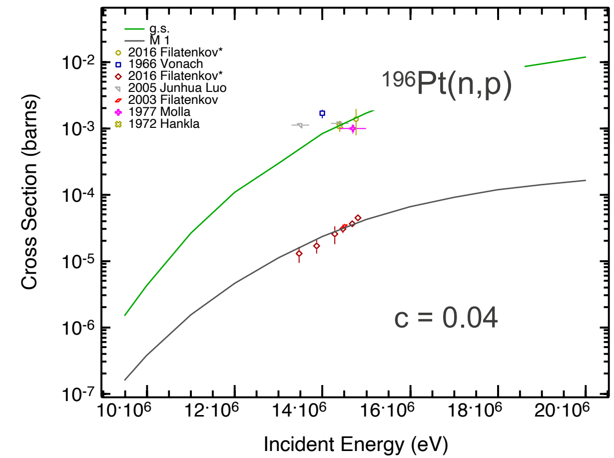
M. Kerveno+, PRC 104 (2021) 044605

Spin distribution in Pt(n,p) reactions

- Exciton model used (simulation of MSD + MSC) since MSC was underestimating (n,p)
- Isomeric ratios require “c” values much lower than 0.24







Fact that MSC underestimates (n,p) x-sec and that c-factors needed to reproduce isomeric x-sec are lower than 0.24 may point to MSD mechanism.

Humble requests in place of conclusions

- Experimental spectra suggest higher MSC. Current theory does not leave much space for it. More microscopic approach to coupling between P and Q chains could help? If so, it should be incorporated into MSD/MSC framework.

- We might need MSD for charge exchange reactions.

- Consistent treatment of angular momentum coupling in MSD/MSC should be coded.

- There are indications that in MSD we need to consider “population spin distribution” rather than “p-h level-density spin distribution”.