SELF-SHIELDING AND NEUTRON MULTIPLE SCATTERING CORRECTIONS FOR NEUTRON CAPTURE YIELD IN THE UNRESOLVED RESONANCE REGION

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- Calculation of correction coefficient
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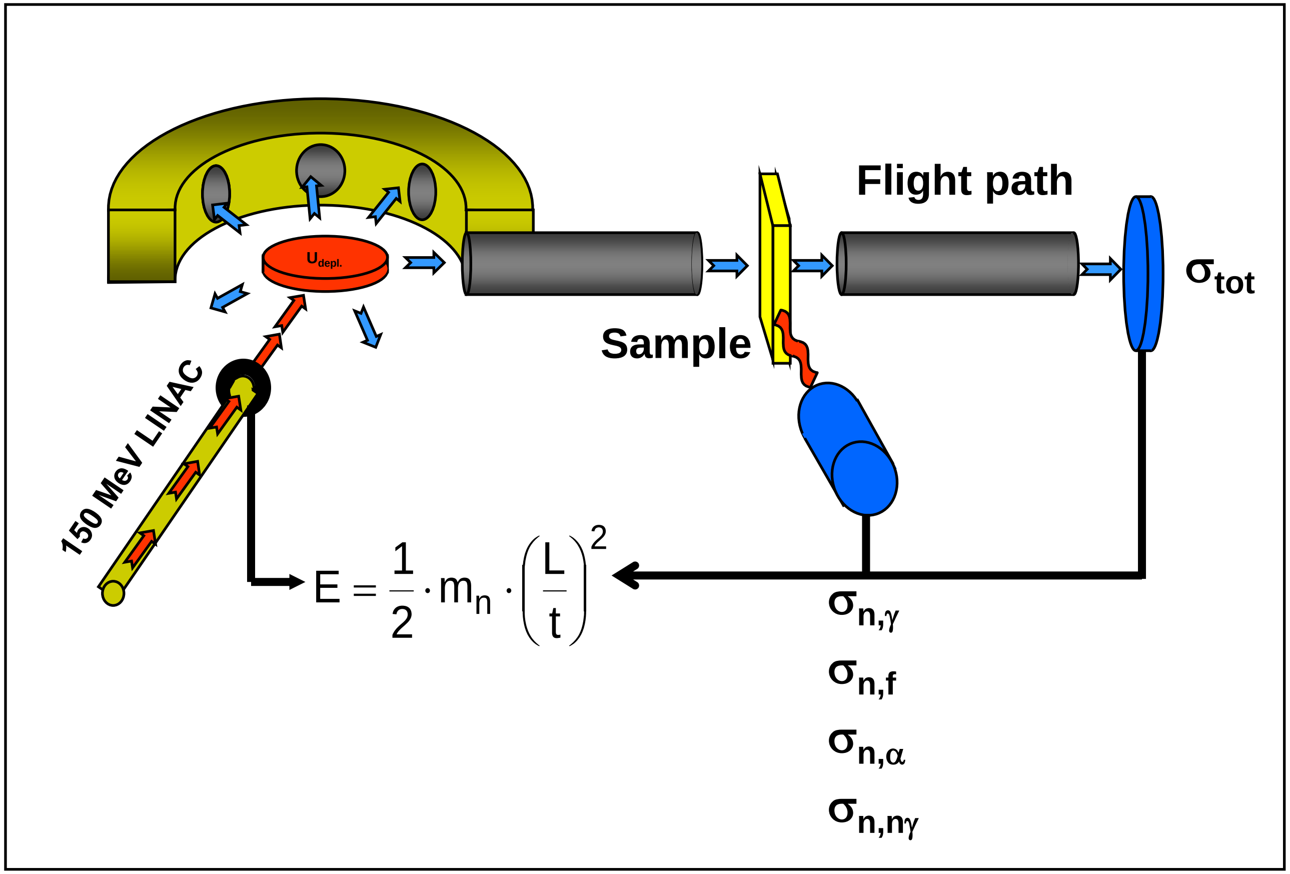
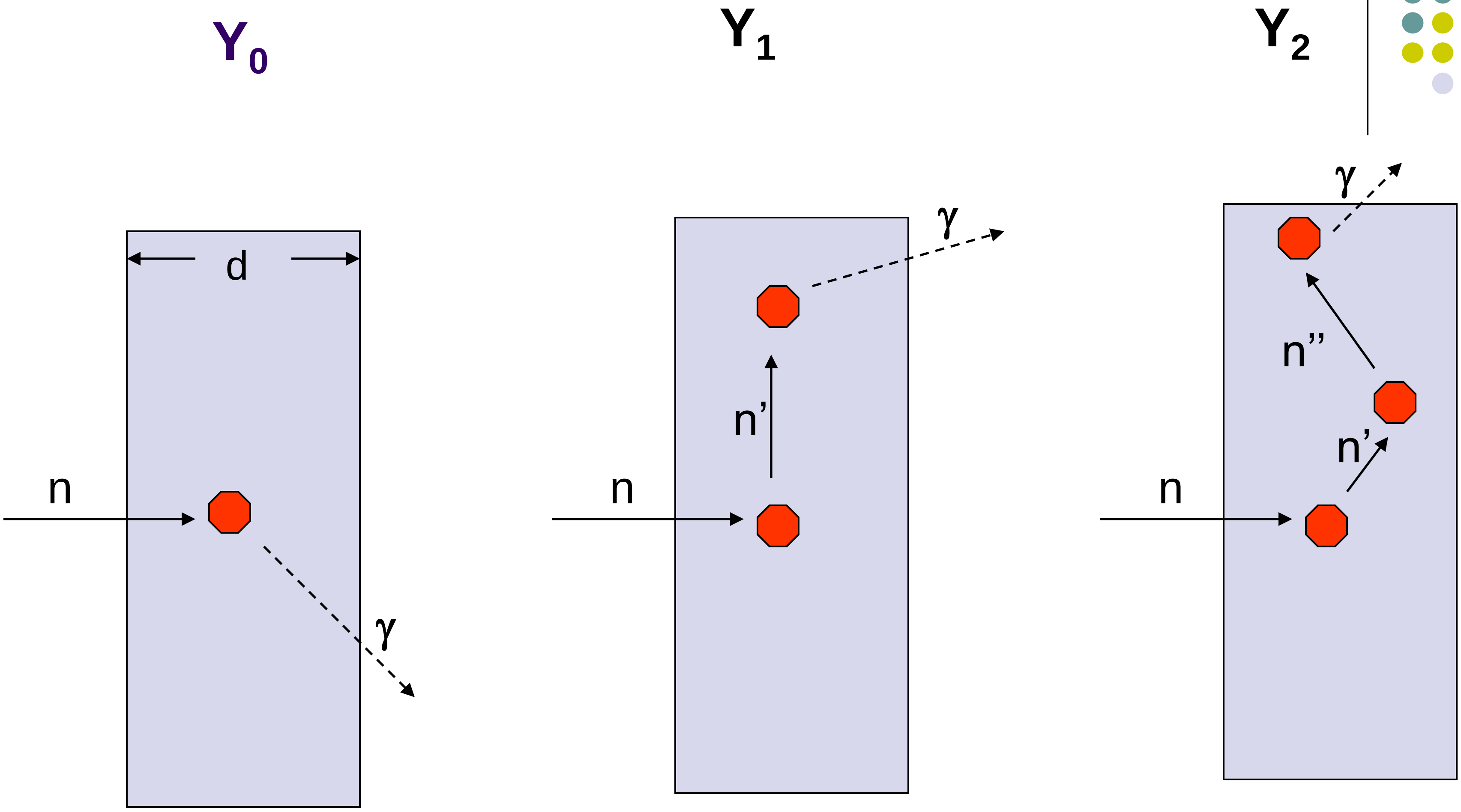
Cross section measurements



$$\Sigma d << 1$$

$$Y(E) = J(E)\, n\, \Sigma_{\gamma}(E)$$



$$Y = Y_0 + Y_1 + Y_2 + ...$$

$$Y(d,E) = C(d,E)\,\Sigma_\gamma(E)$$

Correction coefficient C

The correction coefficient C allows for self-shielding and multiple reactions of neutrons in the volume sample - *thickness effects;*

$$C(d,E)=\frac{\int Y(d,E)dE}{\int Y(E)dE}=C1+C2$$

$$Y(d,E)=\frac{Y(d,E)}{Y(E)}\Sigma_{\gamma}(E) \Longrightarrow Y(E)=J(E)n\Sigma_{\gamma}(E)$$

C1

C1 (90%);

accounts for first collision of the incident neutron with nuclei of the sample (self-shielding effect), followed with n-capture or n-scattering with loosing energy (slowing dawn).

This effect decreases the number of neutrons in the neutron flux and tends to lower absorption yield.

C2

C2 (10%);

relates to the neutrons slowing down in the sample. Those are the neutrons which have already had a collision in the target and loosing energy after inelastic scattering enter in the resonance.

This effect increases the number of neutrons in the neutron flux and tends to higher absorption yield.

Calculation of C

two ways for calculation the correction coefficient

- Monte-Carlo simulation ; codes- SESH,
  SAMMY -(SAMSMC), MCNP

- analytical solution - in multilevel resonance analysis codes REFIT (RRR) and SAMMY

Analytical solution of *C1*

Coefficient *C1* is considered in terms of self shielding effect and ***it can be exactly calculated*** ***using appropriate nuclear models for the resonant cross sections description***.

$$C_1 = \int \frac{\Sigma_\gamma(E)}{\Sigma(E)} \left(1 - exp[\Sigma(E)d]\right) dE \Big/ d \int \Sigma_\gamma(E) dE$$

Analytical solution of *C2*

For calculation of C2 some schemes from theory of the neutron resonance capture in a heterogeneous reactor medium are borrowed;

- Narrow Resonance Approximations (NRA)
- Flat Flux (FF) approximation for space distribution of neutrons out of resonance

$$C_2(d,E)=\frac{1-e^{-d\Sigma_p}}{1-P(d\Sigma_p)}\int_{\Delta E_\lambda}\frac{\Sigma_\gamma(E)}{\Sigma(E)}P[d\Sigma(E)]dE \Bigg/ d\int_{\Delta E_\lambda}\Sigma_\gamma(E)dE$$

Appropriate nuclear model

Unresolved Resonance Region

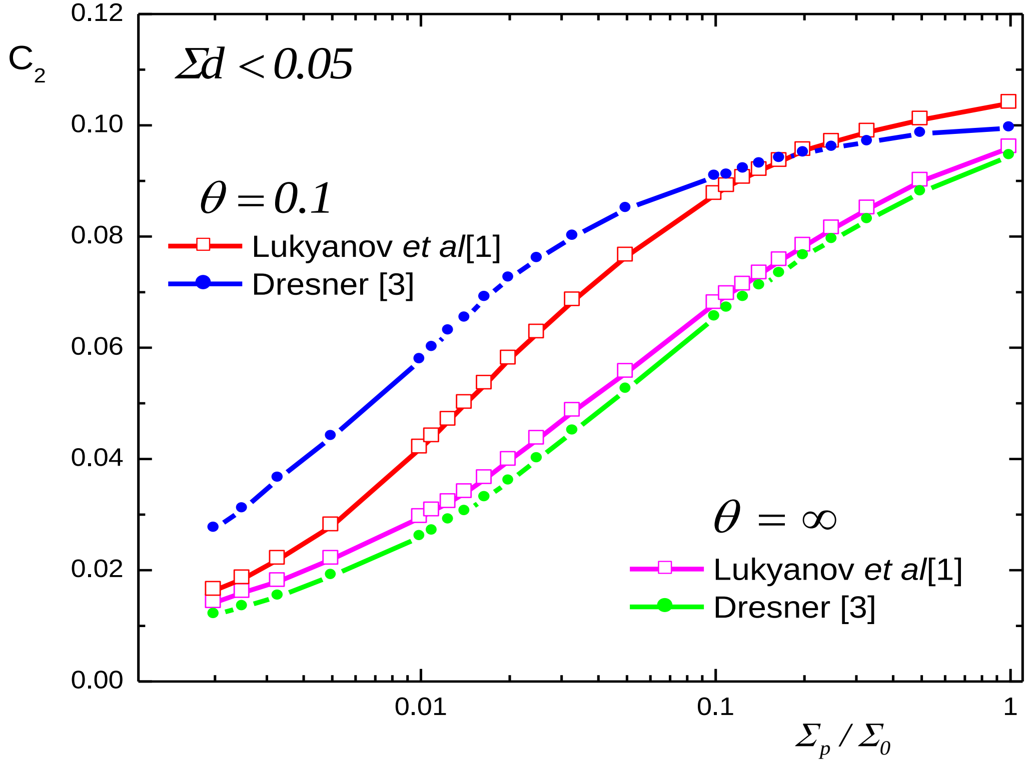
- Periodical resonance cross sections structure
- One-channel - model of characteristic function

  This scheme for C has been already applied;

  Borrela et al., NSE 152 (2006) “Determination of the Th-232(n,g) Cross Section from 4 to 140 keV at GELINA"

- Currently it is also applicable for few open neutron and fission channels

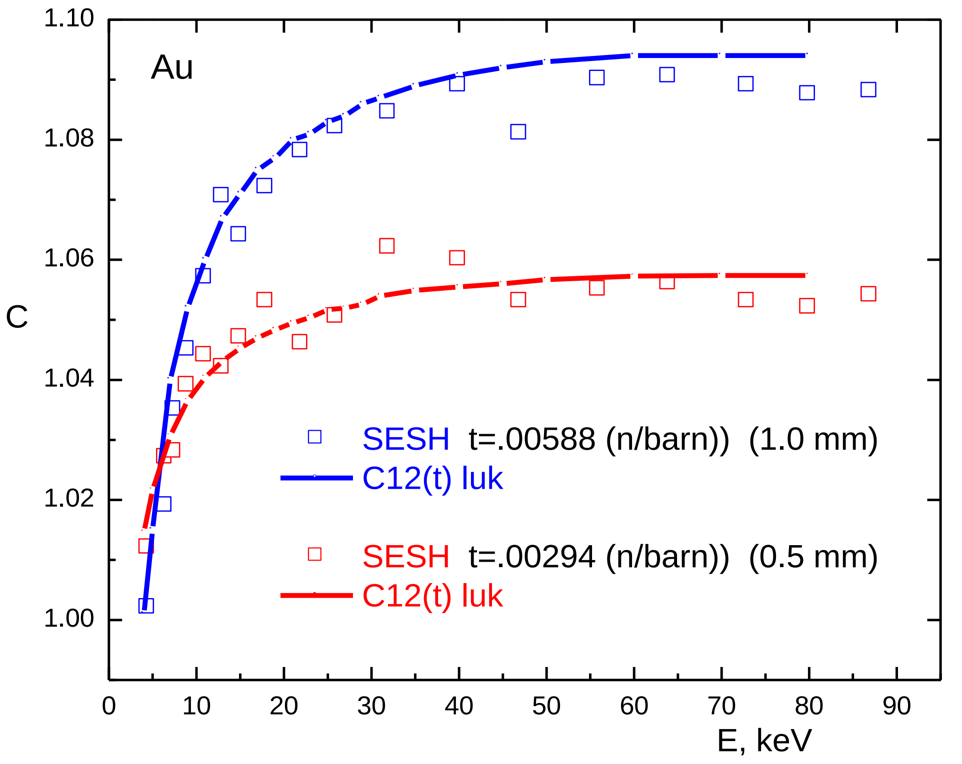
Results - C2



C2; calculated for two effective temperatures $\theta = \frac{\Gamma}{(4E_0 kT/A)^{1/2}}$

Results are compared with ***Dresner,*** *Nucl.Instr.Meth.,* ***16*** *(1962)*

Results-C (many open channels)



^{197}Au ; *C* calculated for d= 0.5 mm and d=1.0 mm.
Results are compared with SESH *Schillebeeckx et al., Nuclear Data Sheets, 113 (2012)*

Integral formula for C /new/

C1 and *C2* are calculated through self-indication functions for neutron capture ;

$$T_c(t) = \int \Sigma_c(E) e^{-\Sigma(E)t} dE \Big/ \int \Sigma_c(E) dE$$

$$C_1(d) = \frac{1}{d} \int_0^d T_c(t') dt'$$

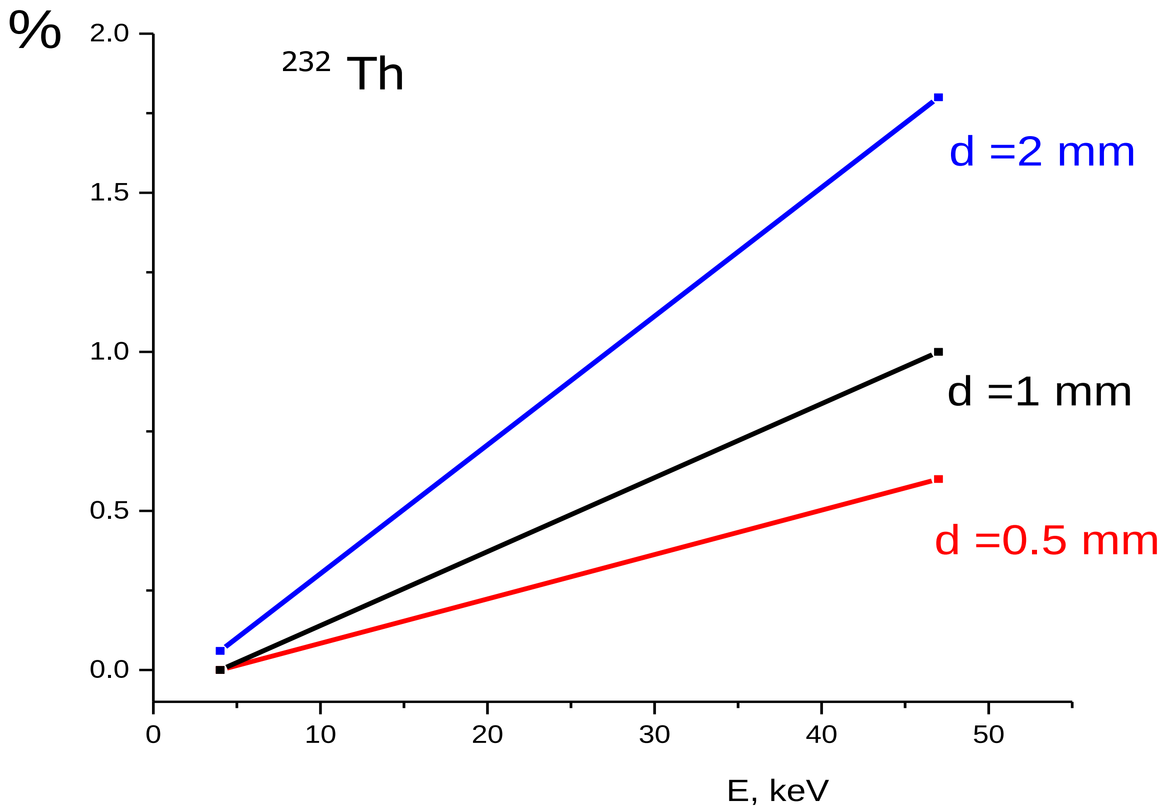
$$C_2(d) = f_0 \left[C_1(d) + \frac{1}{2} \int_d^\infty \frac{dt}{t} T_c(t) - \frac{1}{2d^2} \int_0^d t\, T_c(t) dt' \right]$$

Integral formula for C - results

^{232}Th sample ; d=0.5 mm , R=4 cm

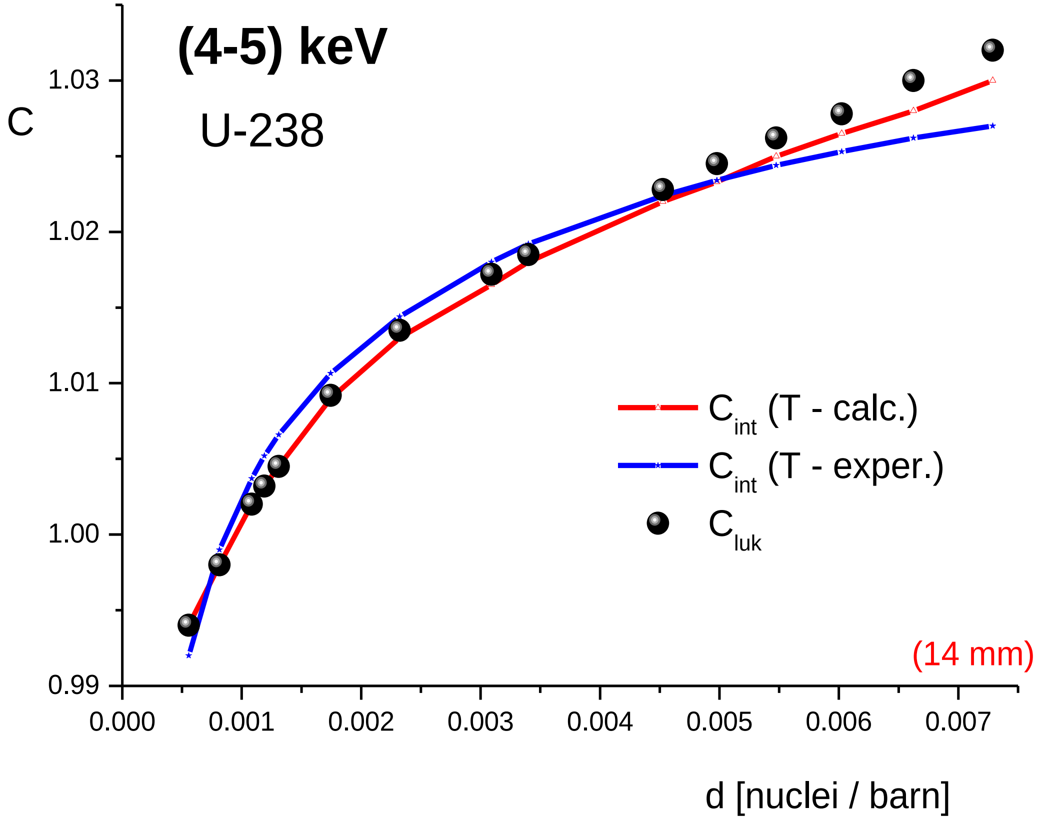
E, keV	C (luk)	C (int)	(a-b)/a; %
4.5	1.017	1.017	0.0
6.5	1.024	1.024	0.0
8.5	1.028	1.027	0.1
10.5	1.0307	1.0289	0.17
15.5	1.036	1.032	0.38
17.5	1.037	1.032	0.48
21	1.0372	1.0324	0.46
25	1.0385	1.0328	0.54
29	1.039	1.033	0.56
32.5	1.039	1.033	0.57
42.5	1.0398	1.0335	0.58
47.5	1.0399	1.0336	0.6

Integral formula for C - results



^{232}Th, comparison C(luk) with C(int) in (4-50) KeV for d=(0.5 – 2)mm

Integral formula for *C* - results



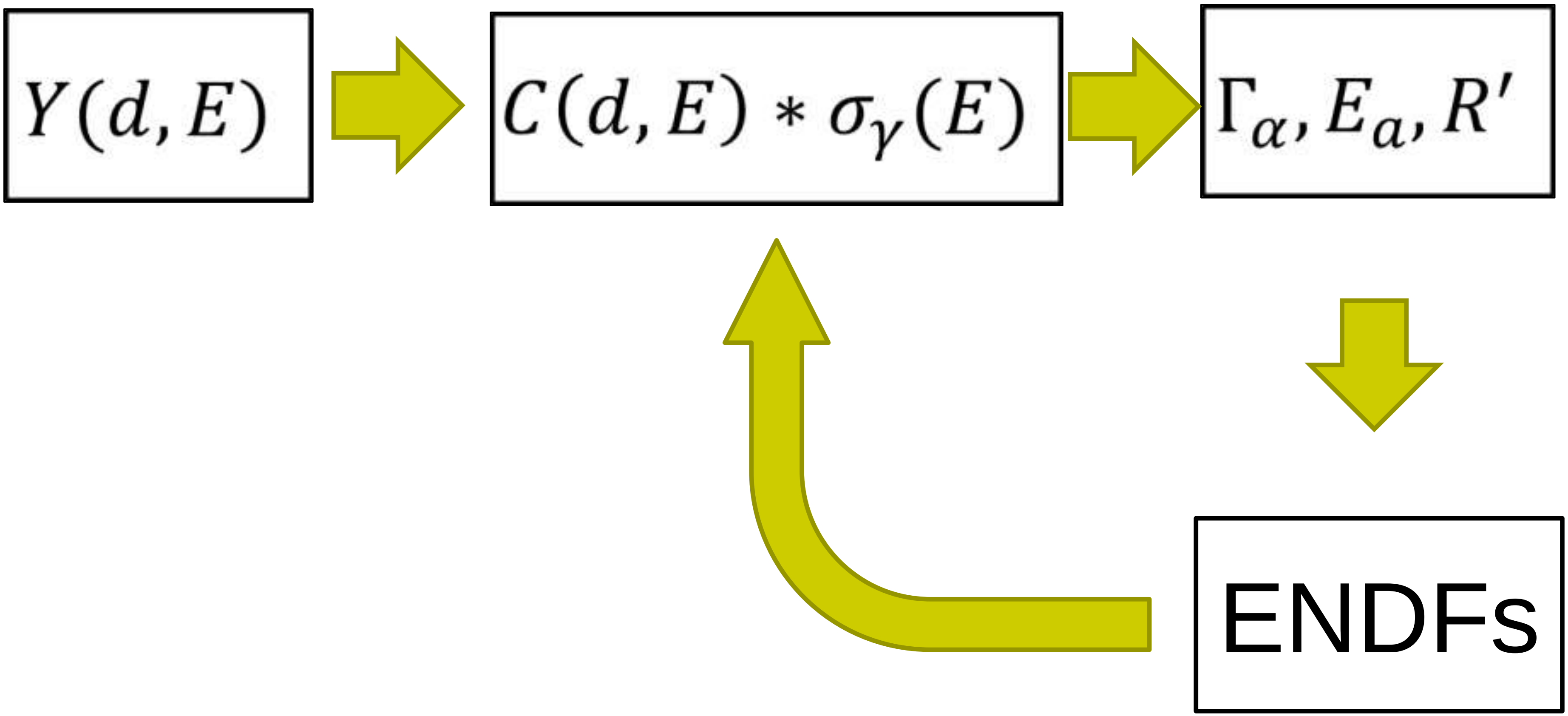
[238]U, comparison C(luk) with C(int) in (4-5) KeV for d=(0.5 – 14)mm, *experiment* Tc (t) ;*Oigawa et al., Nucl.Sci.Techn. 28 (1991)*

CONCLUSION

- Faster procedure for calculation the correction coefficient

- Applying the integral formulae ones no need of evaluated resonance parameters – source are only measured transmission function, that contain comprehensive information for detailed energy resonant cross sections structure

- Need of additional comparisons of these analytical results with Monte-Carlo calculations for thick samples


$Y(d,E)$
$C(d,E) * \sigma_\gamma(E)$
Γ_α, E_a, R'
ENDFs