Advances in the analysis of resonance cross section data

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Topics

URR (I. Sirakov visitor 2 x 3 months)

- ENDF-6 compatible evaluation procedures optical model calculation
- Self shielding and multiple scattering corrections

RRR (M. Moxon visitor 1.5 month)

- Varying Weighting function according to resonance strength
- Corrections for powder samples
- Investigation of Multiple Scattering Corrections (collaboration with KIT)

URR Cross Section

$$\bar{\sigma}_{cc'} = \bar{\sigma}^{se}_{cc'}\delta_{cc'} + \frac{\pi}{k_c^2} g_c \frac{T_c T_{c'}}{T} F_{cc'}$$

$F_{cc'}$ Fluctuation factor

$\bar{\sigma}^{se}_{cc'}$ Shape elastic scattering cross section
ENDF-6 compatibility lead to approximations

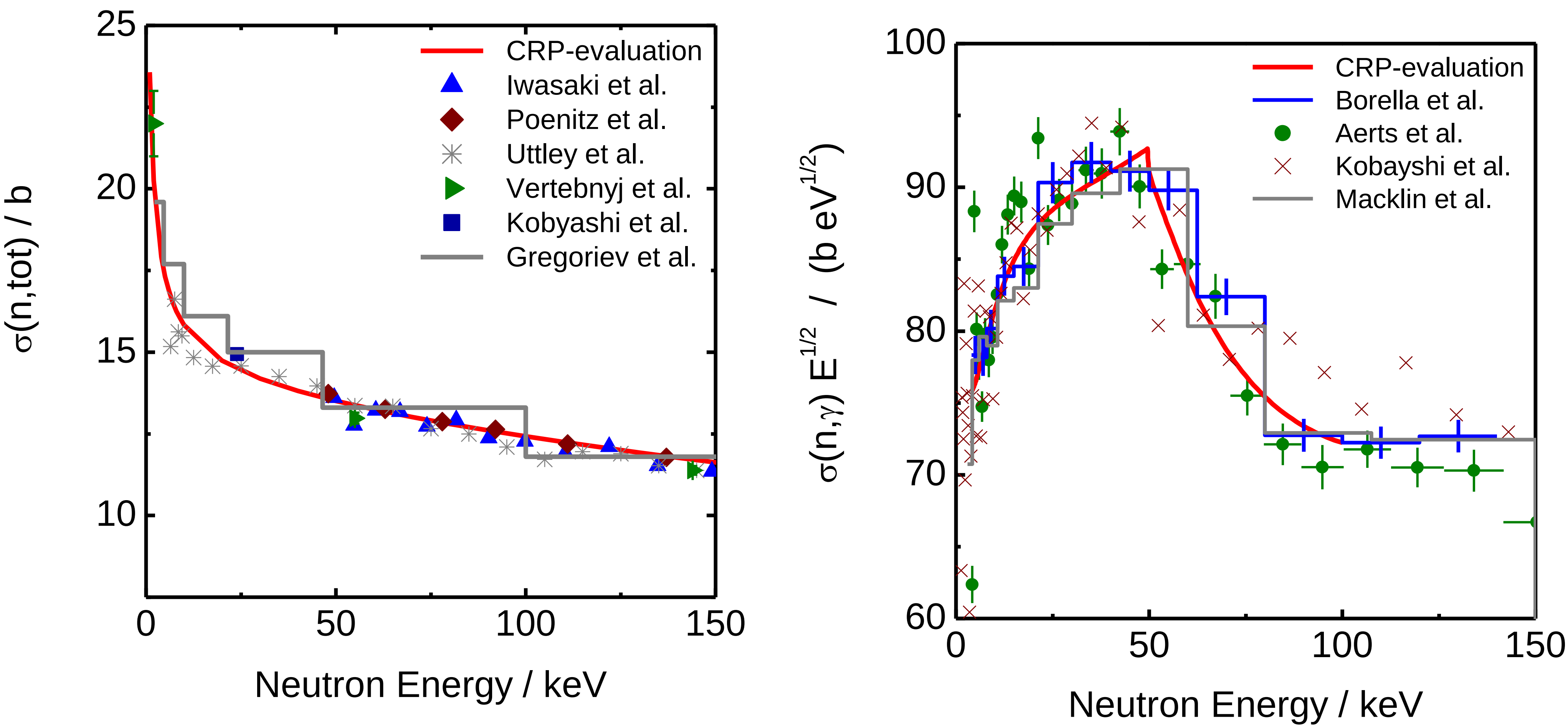
$T_c, T_{c'}$ Transmission coefficient $T_\gamma^{J^\pi}(E) = T_{\gamma^0}^{J^\pi} f_{T_\gamma}^{J^\pi}(E)$

Transmission factors and shape elastic cross section calculated by optical model

$S_l(E)$ Strength function
R’(E) scattering radius

Adjustment of $S_l(0)$ and T_γ to experimental cross section data

URR Th-232



⇒σ(n,tot) & σ(n,γ) + covariance matrix in ENDF/B-VII

Sirakov et al., Annals of Nuclear Energy 35 (2008) 128

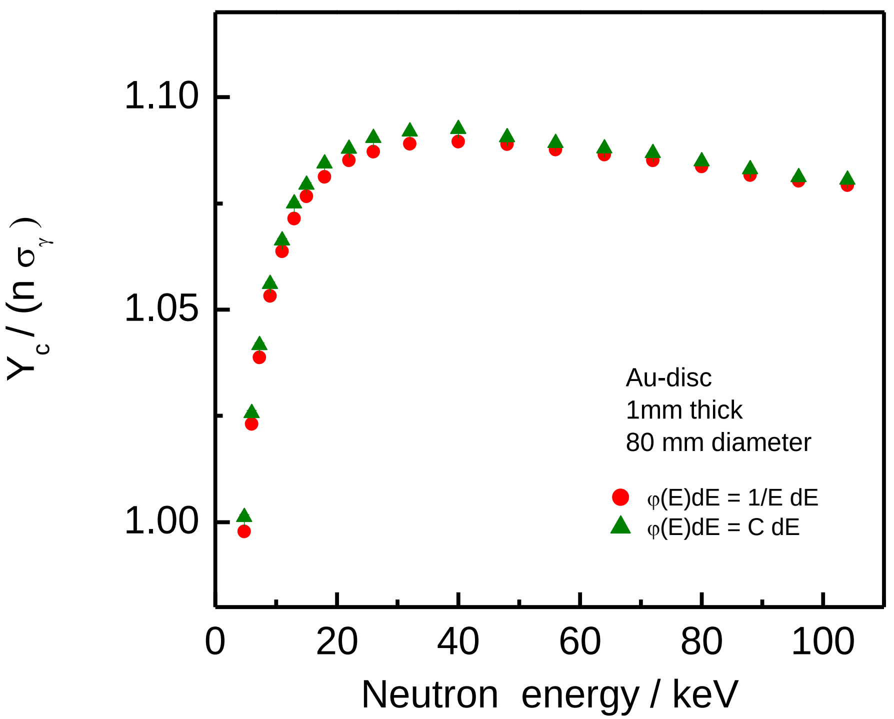
URR – ENDF-6

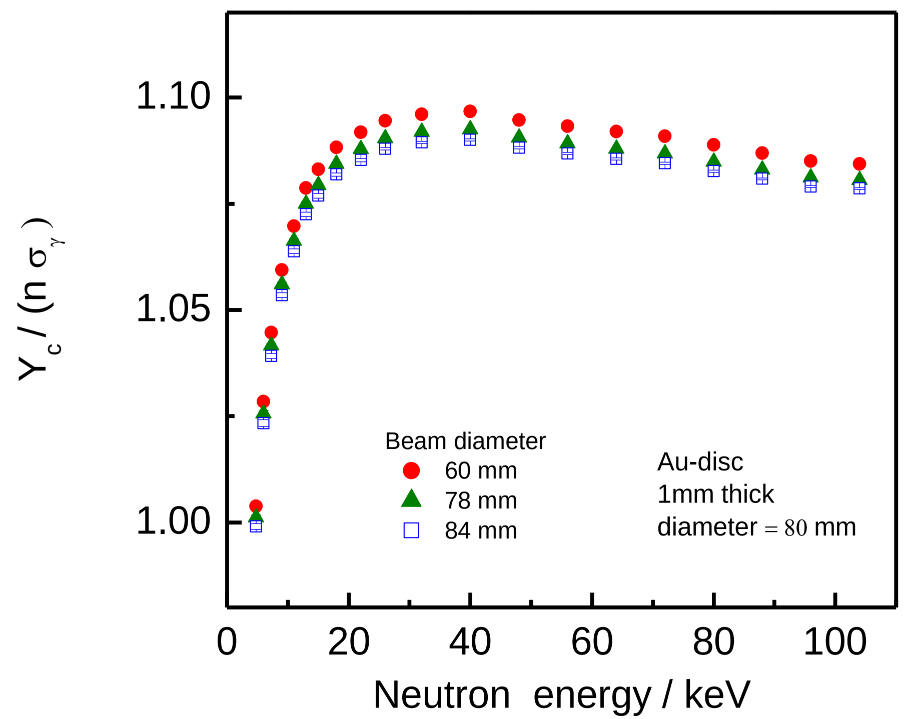
⇒ **Programs & Procedures to determine average parameters and their covariance matrix**

⇒ **Derive cross sections linked to optical model calculations**

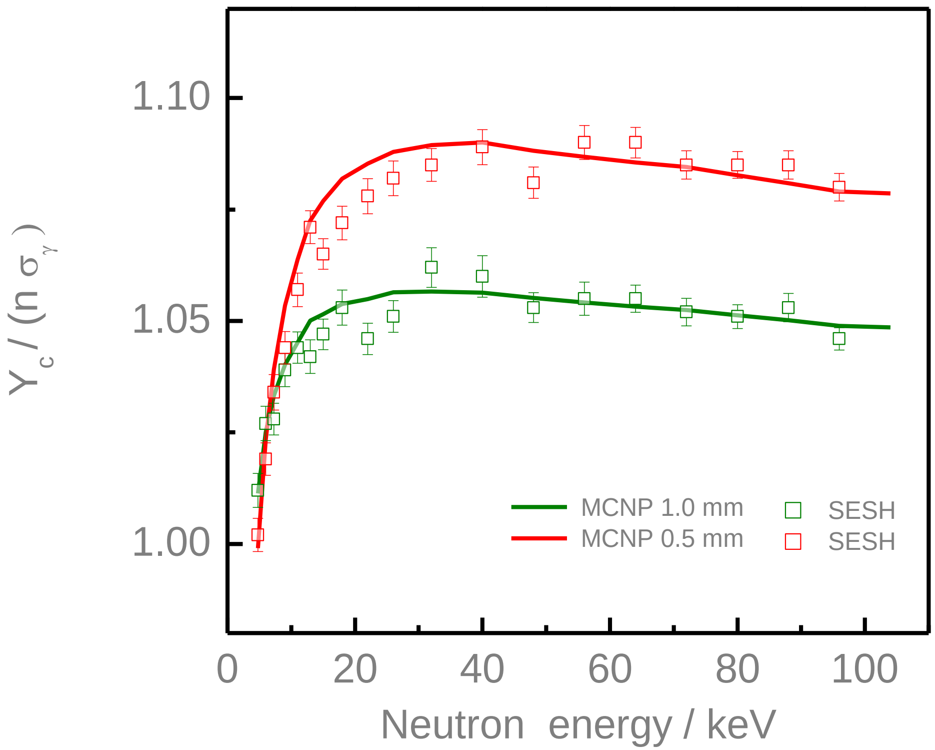
⇒ **NJOY has been modified to accommodate energy dependent R’**

URR - MCNP-Flux Geometry





Comparison SESH-MCNP



⇒ **Tested influence of experimental conditions on shelf-shielding and multiple scattering**

⇒ **SESH & MCNP similar results**

⇒ **Procedures established to derive corrections and fitting of average parameters**

Weighting Function

Reliable WF's can be obtained by Monte Carlo simulations provided that the geometry input reflects the experimental conditions, i.e. accounts for γ–ray transport in sample (started with Perey et al. at ORELA)

⇒ Weak resonance : WF1

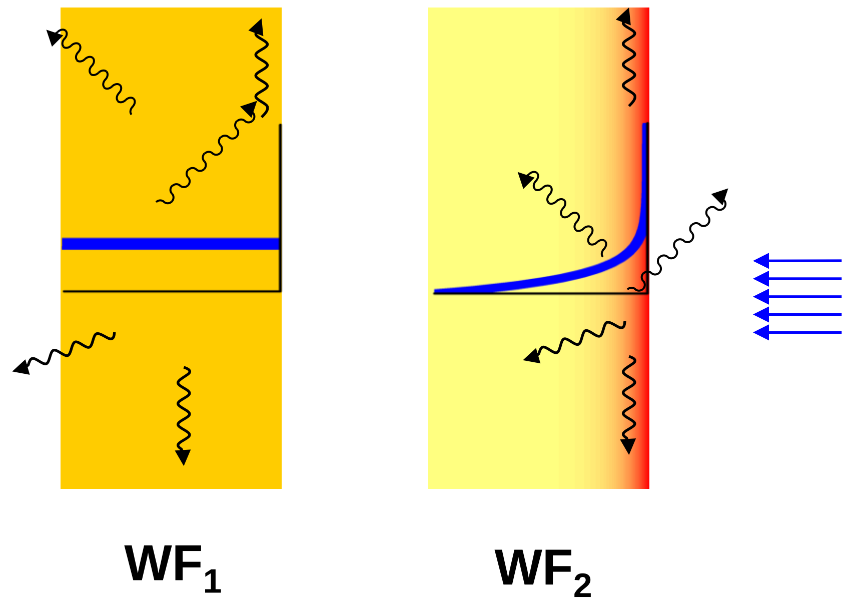
⇒ Strong resonance : WF2

(Affects also the observed shape)

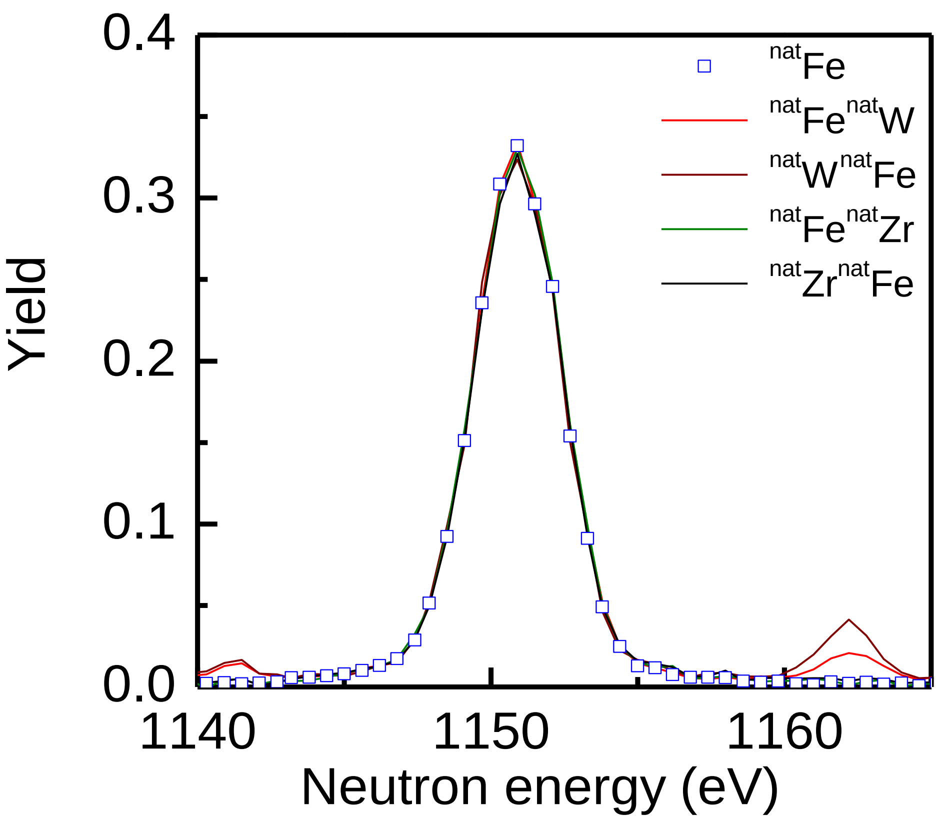
Procedure :

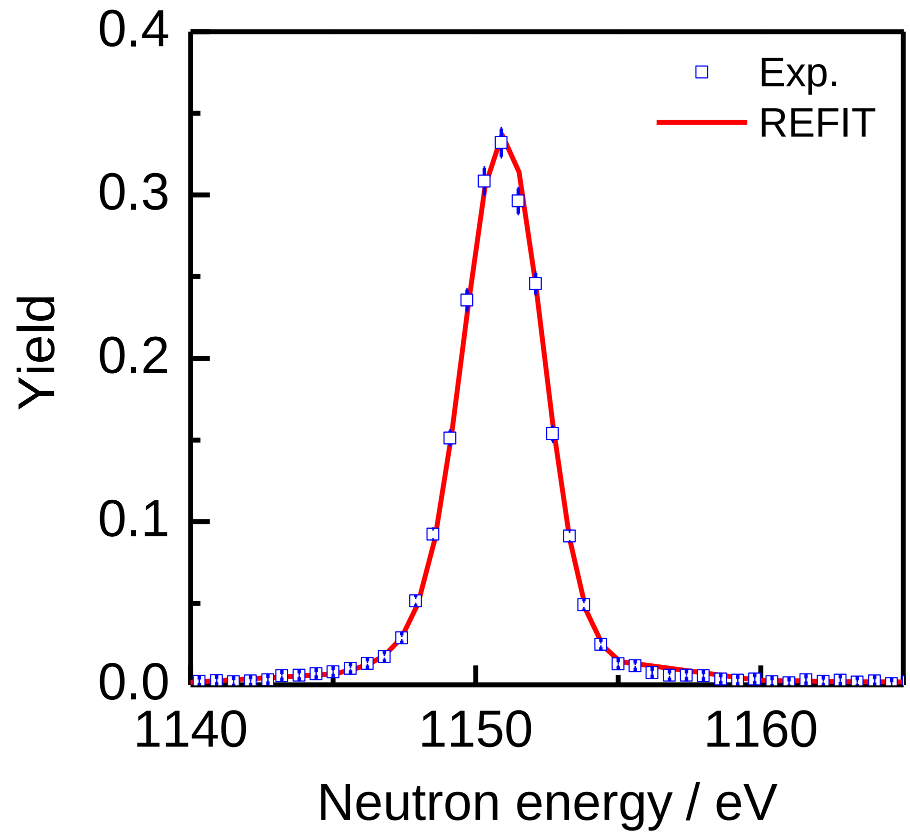
(1) Apply WF1 on experimental data

(2) Correction factor on calculated yield



Verification of WF and normalization by experiment 1.15 keV of $^{56}Fe + n$



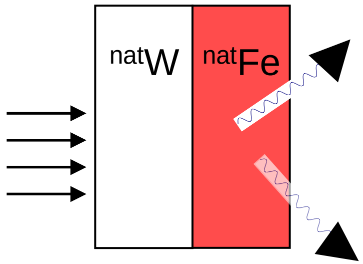


Γ_n = 61.7 ± 0.9 meV

Γ_γ = 574 meV

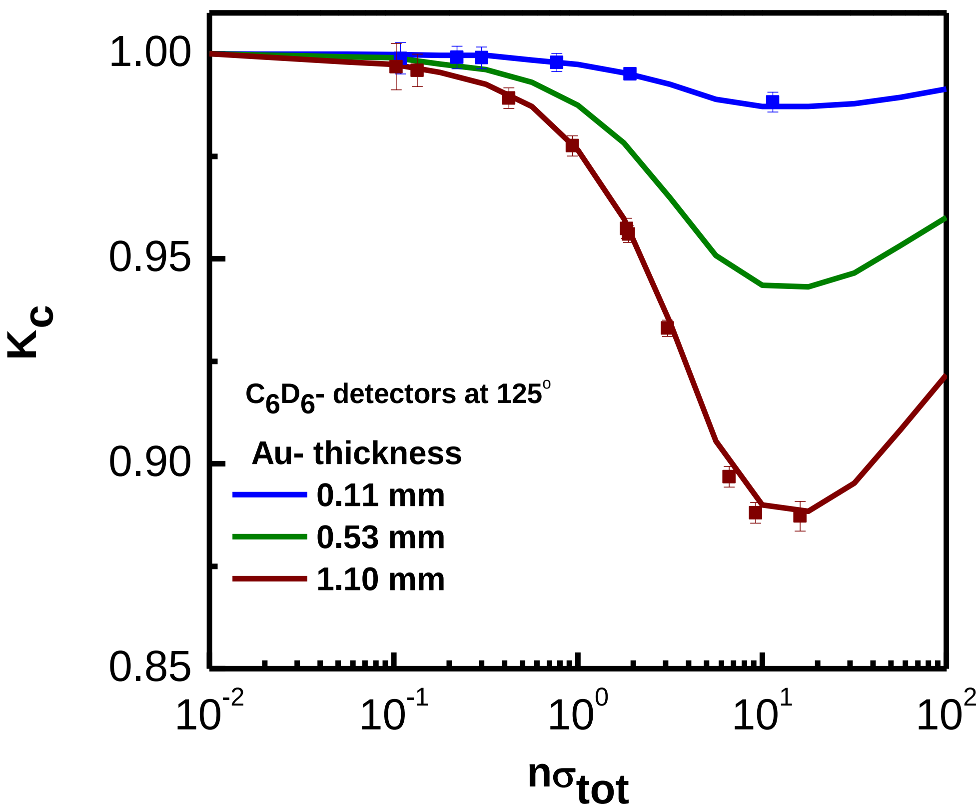
Normalization capture data: 1.15 keV of $^{56}Fe + n$

Sample	Length / m	Normalization	
	REFIT MCNP resolution	REFIT MCNP resolution	SAMMY Analytical resolution
^{nat}Fe	58.5660 ± 0.0004	28.16 ± 0.25	27.80 ± 0.25
^{nat}Fe / ^{nat}W	58.5670 ± 0.0004	27.88 ± 0.25	28.50 ± 0.25
^{nat}Fe / ^{nat}Zr	58.5671 ± 0.0004	27.68 ± 0.25	28.10 ± 0.25
^{nat}W / ^{nat}Fe	58.5678 ± 0.0004	27.41 ± 0.25	28.30 ± 0.25
^{nat}Zr / ^{nat}Fe	58.5674 ± 0.0004	27.19 ± 0.25	27.70 ± 0.25
Average	58.5671	27.67	28.08
Stdev	0.0007	0.38	0.34
Stdev (%)	0.0011	1.4	1.2



WF calculated with γ-rays distributed in Fe

Correction Factor



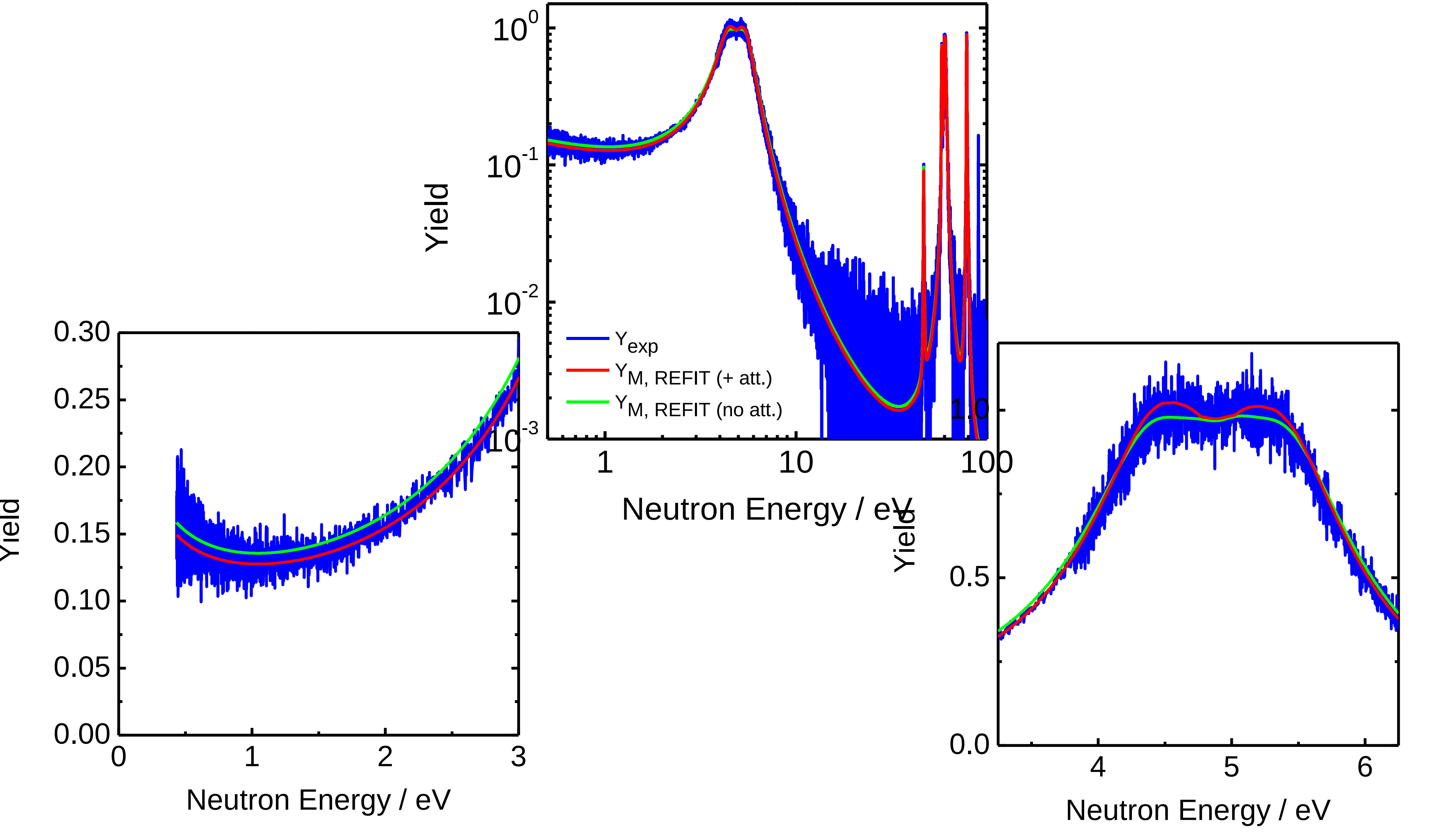
DICE-box for gamma spectrum
Fold calculated spectrum with WF

⇨ Derive Correction Factor

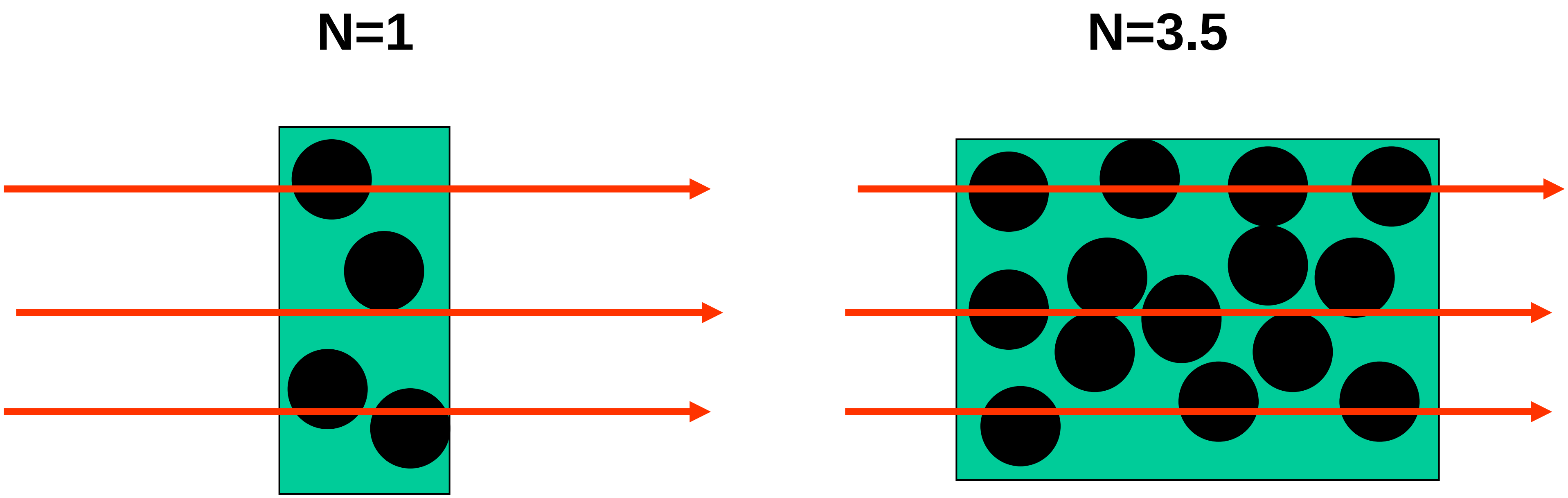
$$K_c(n\sigma_t) = \frac{< WF_1 >}{< WF_2 >}$$

$$Y_{exp} = N \int R(T_n, E_n)\,(K_c \varepsilon_{cw} Y_c + \varepsilon_{nw} Y_n)\, dE_n$$

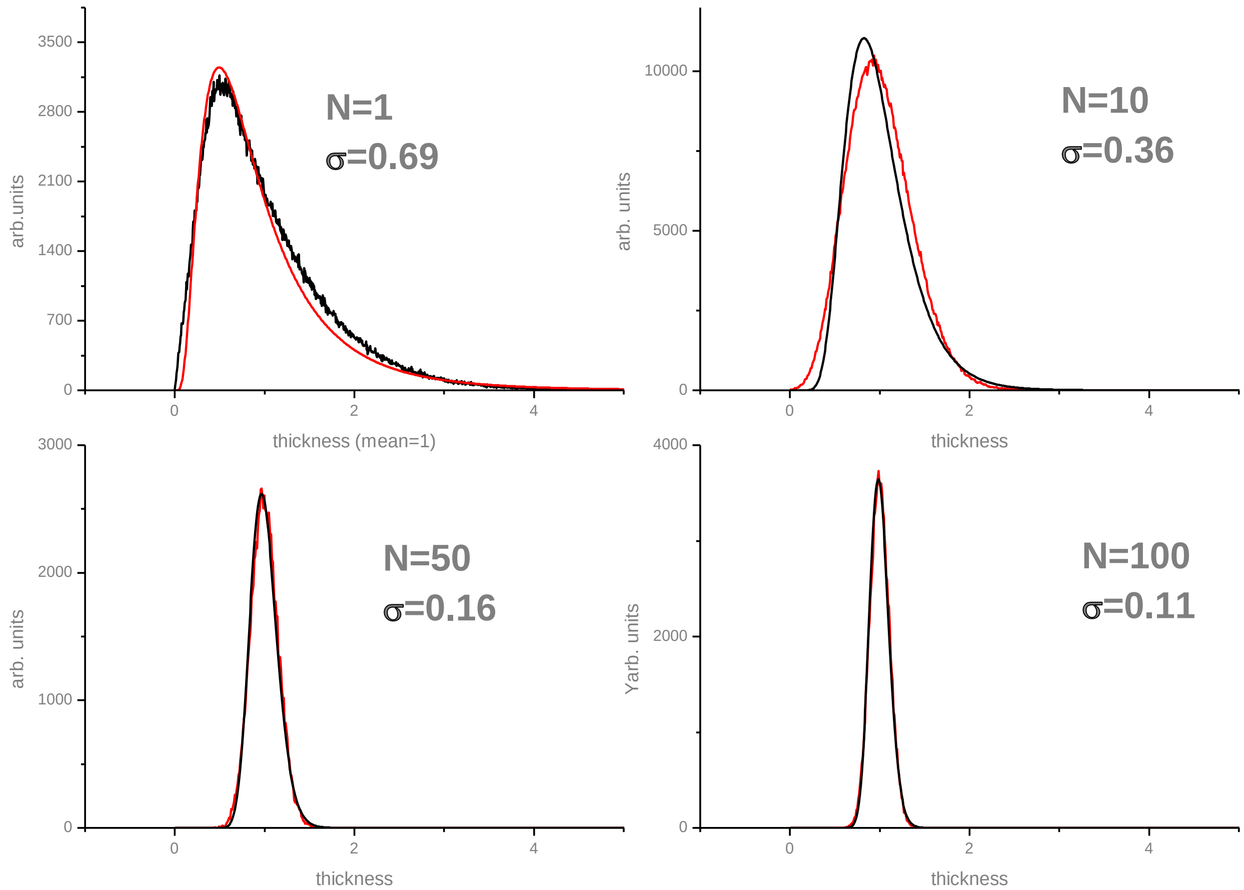
Influence of K_c on normalization



Powder sample

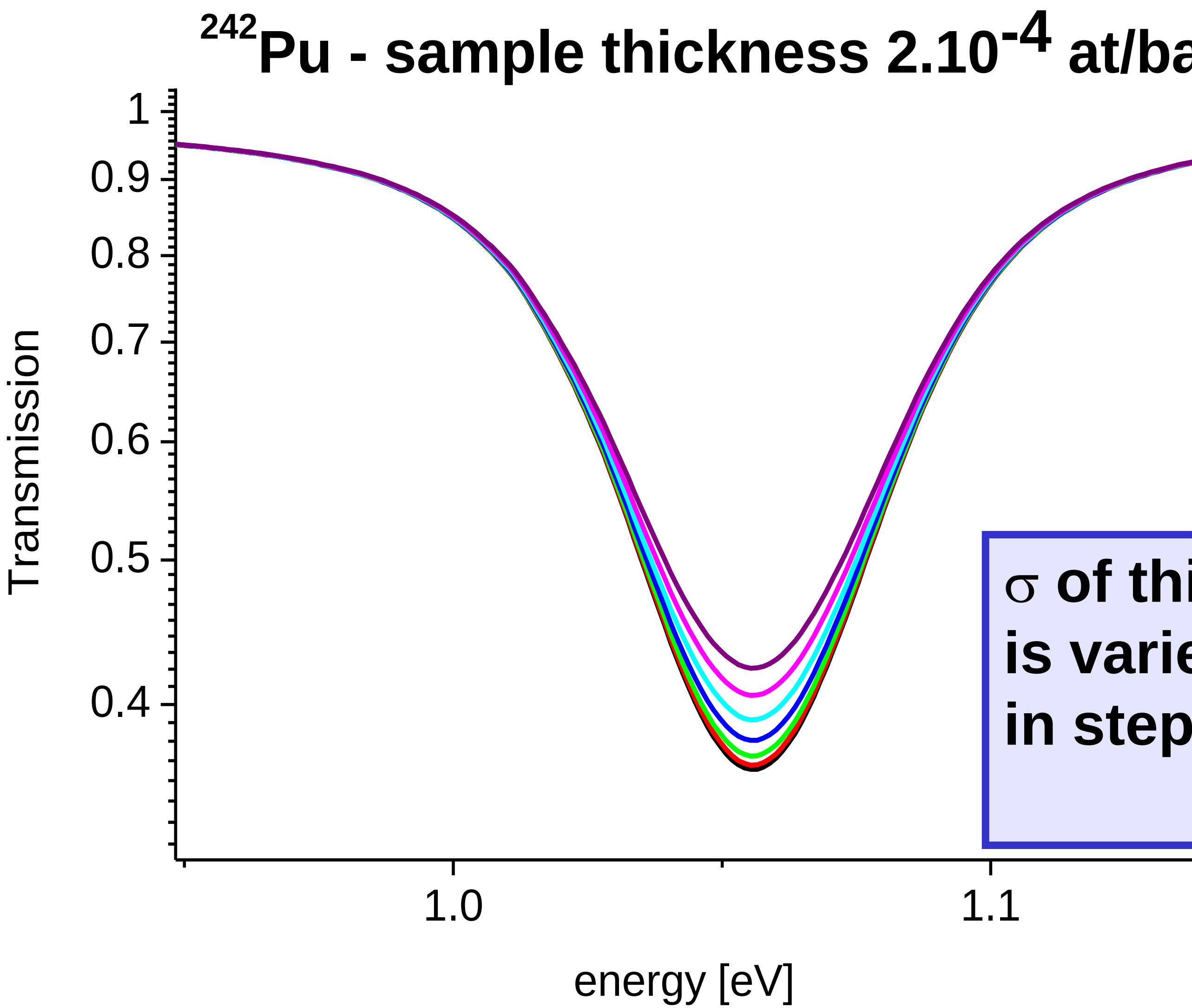


Probability that a neutron “sees” n particle, given by Poisson-statistics



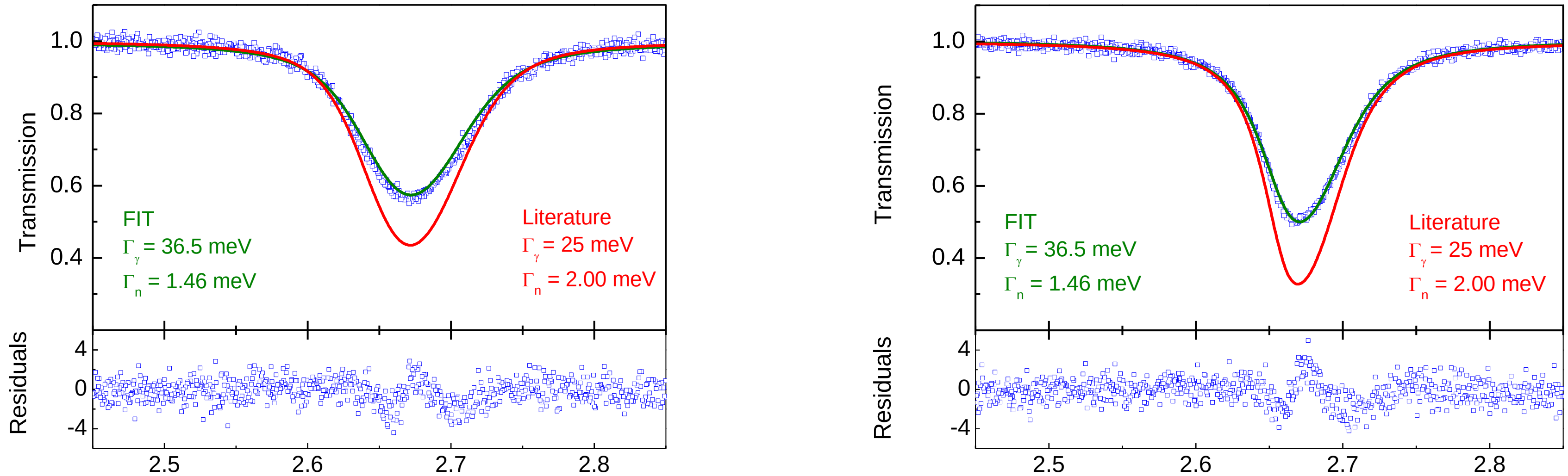
- **Poisson distribution**
- **Spheres**
- **Radius lognormal**
- **Black line MC**
- **Red line lognormal fit**

Influence of Power Sample on Transmission

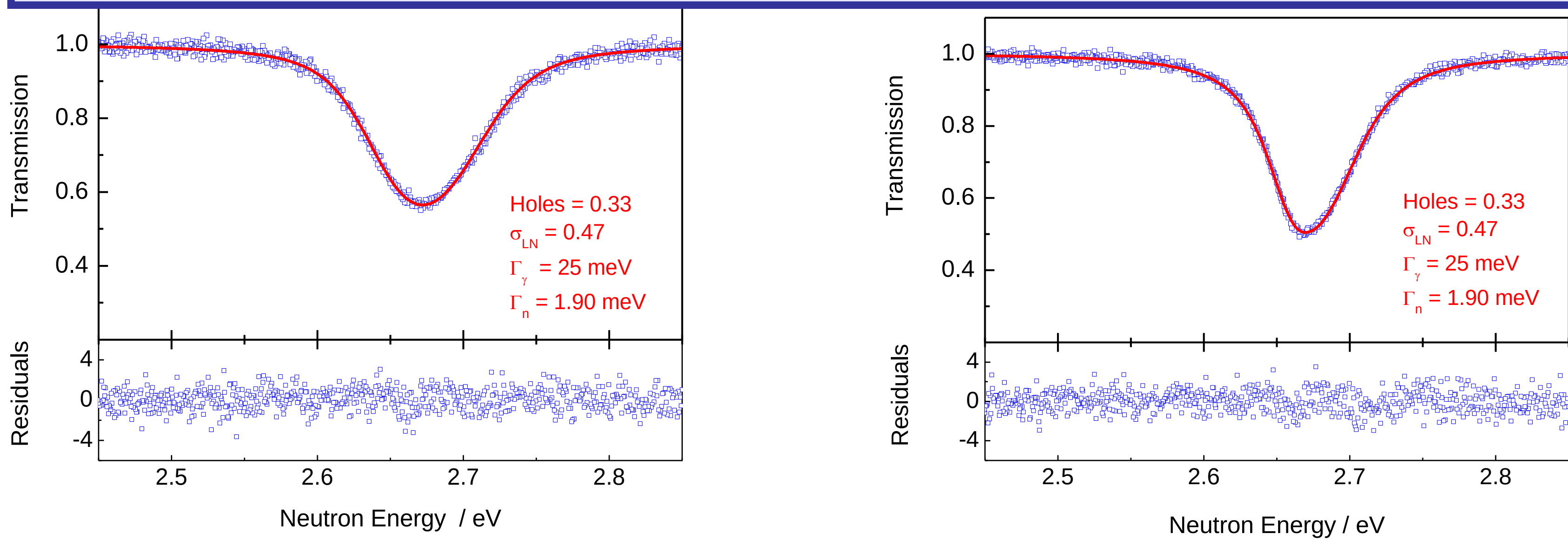


σ of thickness distribution is varied between 0 to 0.6 in steps of 0.1

Experminentally observed effects



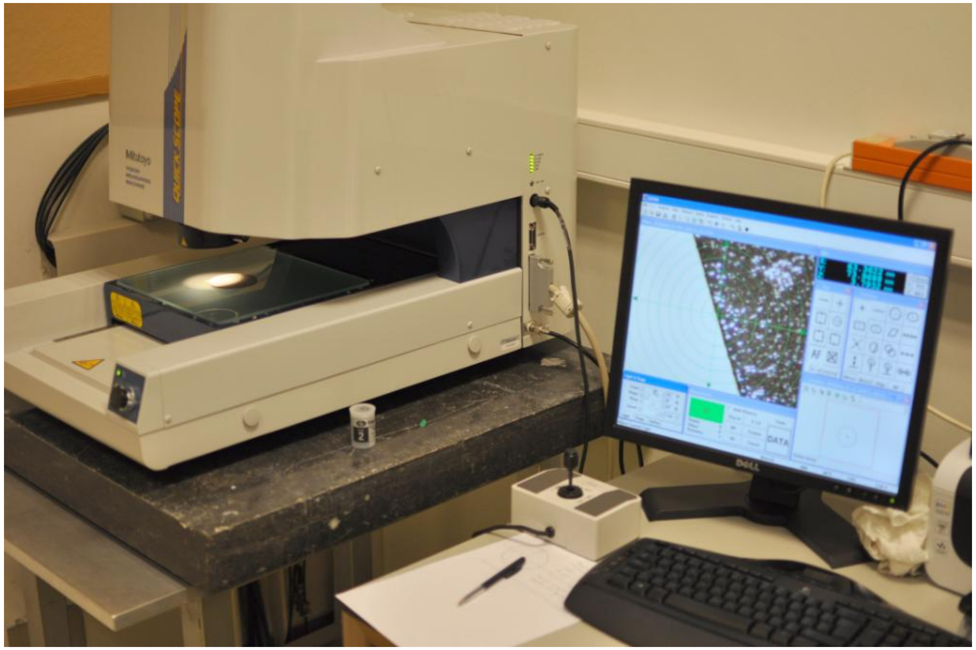
REFIT: accounting for the powder grain size (EFNUDAT project : IRMM - Moxon)



Sample characterization: discs and foils

Sample dimensions are determined by a 2D-optical scanning system including a height measurement

- ⇒ Area (also for irregular shapes)
- ⇒ Circularity of a disc
- ⇒ Height profile



$$T_{exp} \leftrightarrow e^{-n\sigma_{tot}}$$

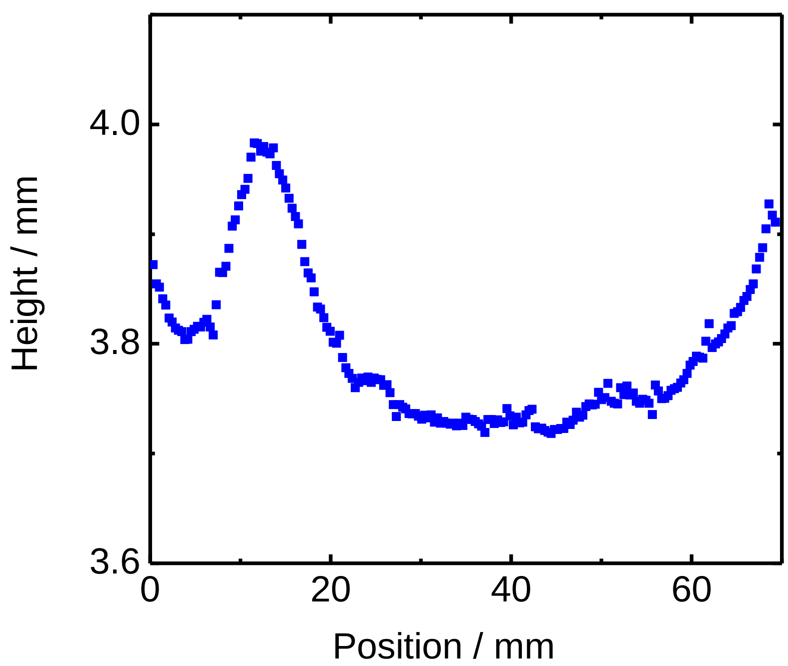
$$Y_{exp} \leftrightarrow \left(1-e^{-n\sigma_{tot}}\right)\frac{\sigma_\gamma}{\sigma_{tot}} + \dots$$

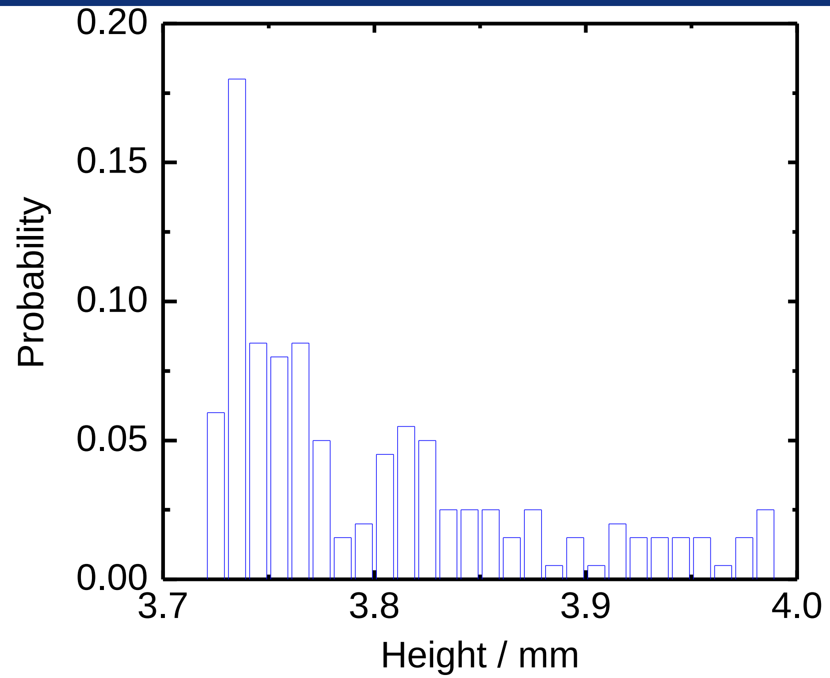
n : areal density

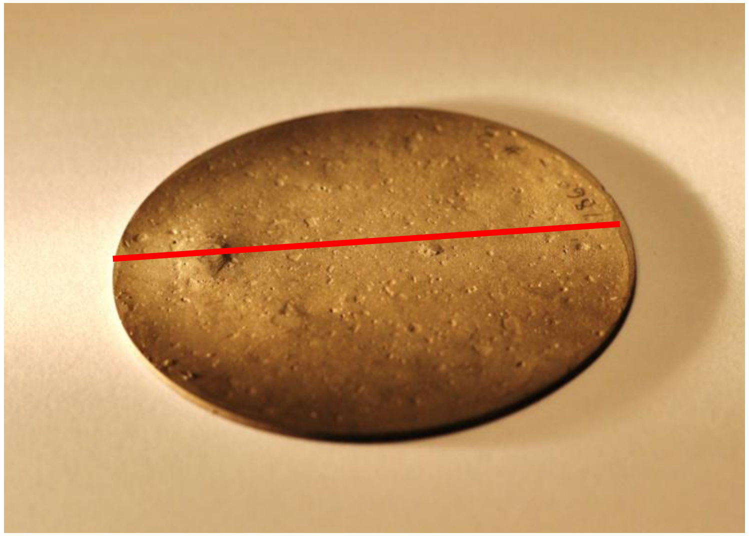
$$n = \frac{N_A}{m_X}\frac{weight}{area}$$

⇒ sample dimensions

Sample characterization : homogeneity ^{186}W (metal disc)



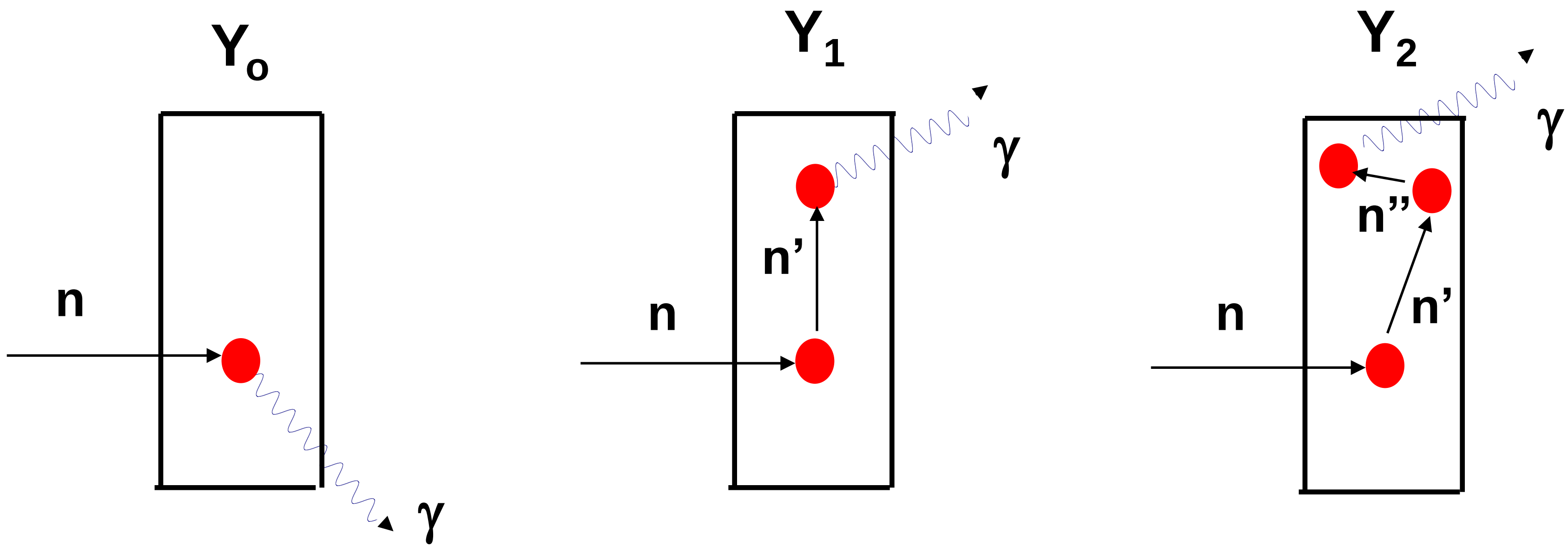




Probability distribution P(h)dh input to REFIT

Multiple Scattering

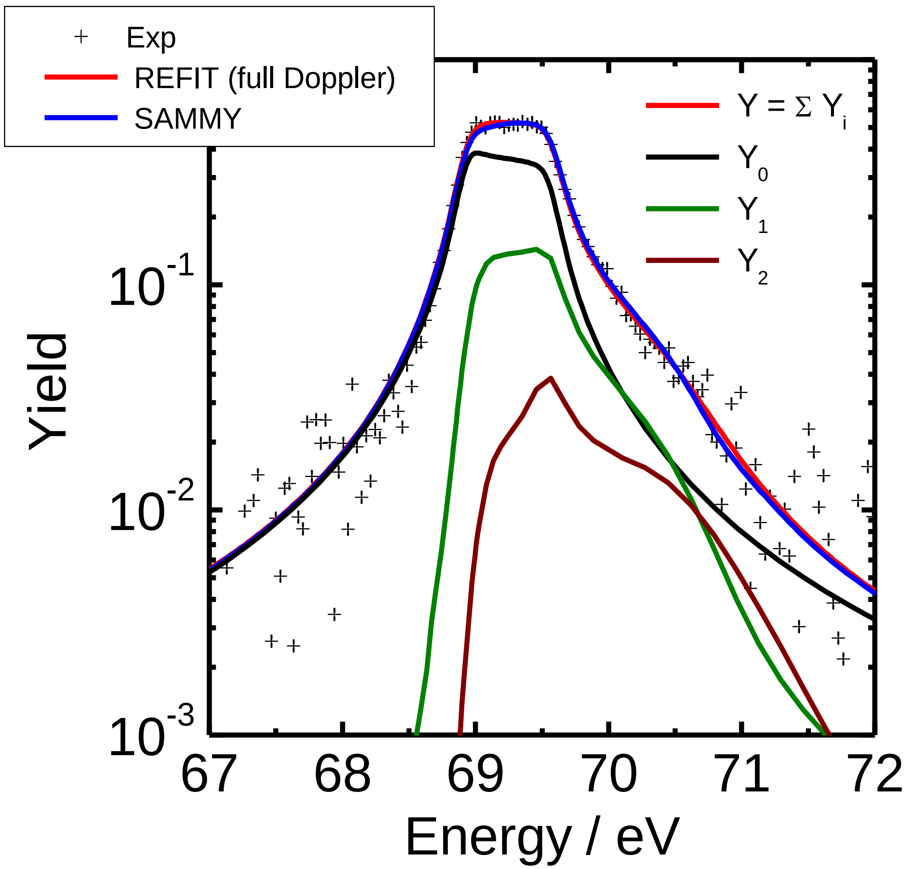
$$Y_m = \sum_j Y_j$$

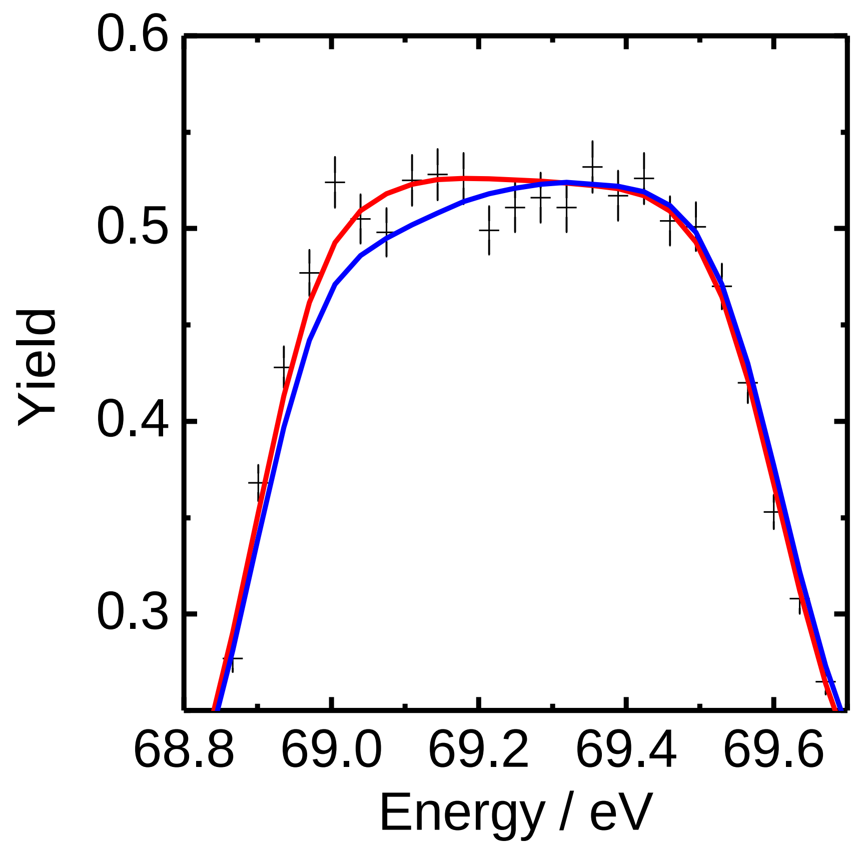


$$Y_o = \frac{\sigma_\gamma}{\sigma_{tot}}\left(1 - e^{-n\,\sigma_{tot}}\right)$$

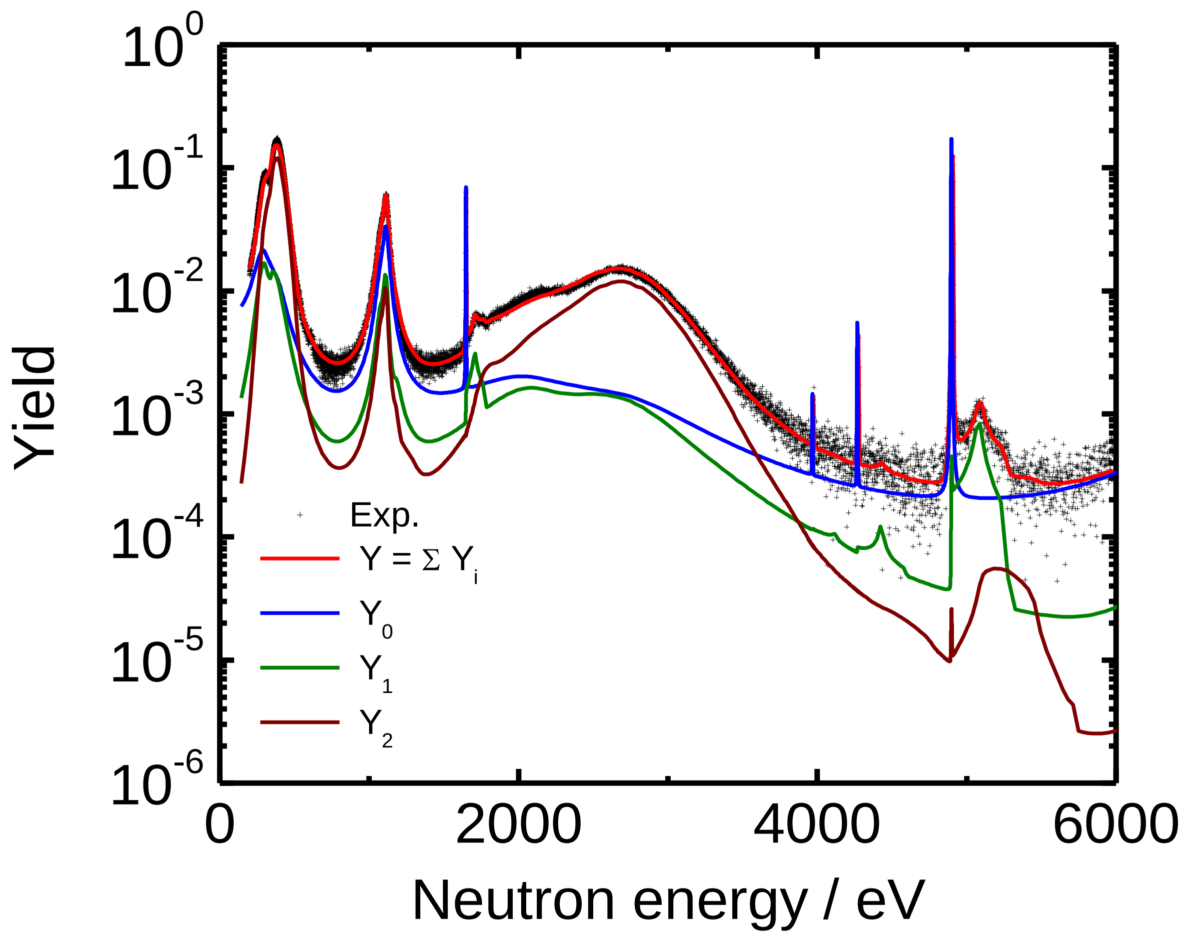
$$E_n' = E_n \left(\frac{m_n}{m_A + m_n}\right)^2 \left(\cos\theta + \sqrt{\left(\frac{m_A}{m_n}\right)^2 - \sin^2\theta}\right)^2$$

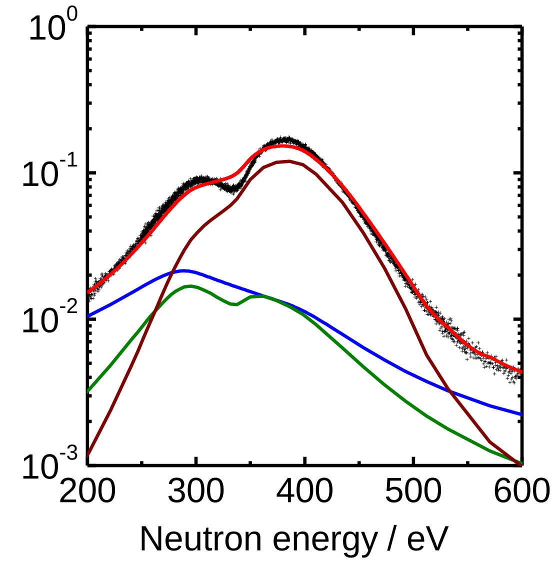
Multiple Scattering





Mn-55 Multiple Scattering





Mn sputtering target
77 mm diameter
3 mm thick

Conclusions

- ⇨ **Procedures and Programs to derive average parameters and their covariance matrix in the URR**
- ⇨ **Parameters are compatible with ENDF-6 procedures**
- ⇨ **NJOY has been modified to be ENDF-6 compatible**
- ⇨ **programs and procedures have been established to calculate self-shielding and multiple scattering in the URR**

Conclusions

- **Modification to RSA REFIT**
  - Corrections of WF depending on the resonance strength
  - Correction due to powder samples

- **Investigation of Multiple Scattering in RSA**
  - Started project to incorporate MC approach (EFNUDAT, Sept. 2010)