Recent Developments in the CONRAD Code regarding Experimental Corrections

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Needs for Time-of-Flight measurements in CONRAD

Before in CONRAD:

Measurements had to be given in energy, why?

- because theoretical models work with energy,
- because there are less experimental corrections when analysis are carried out in the URR and the continuum energy regions.

Needs for Time-of-Flight measurements in CONRAD

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- because theoretical models work with energy,
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Now in CONRAD:

Measurements can be given both in energy and in ToF:

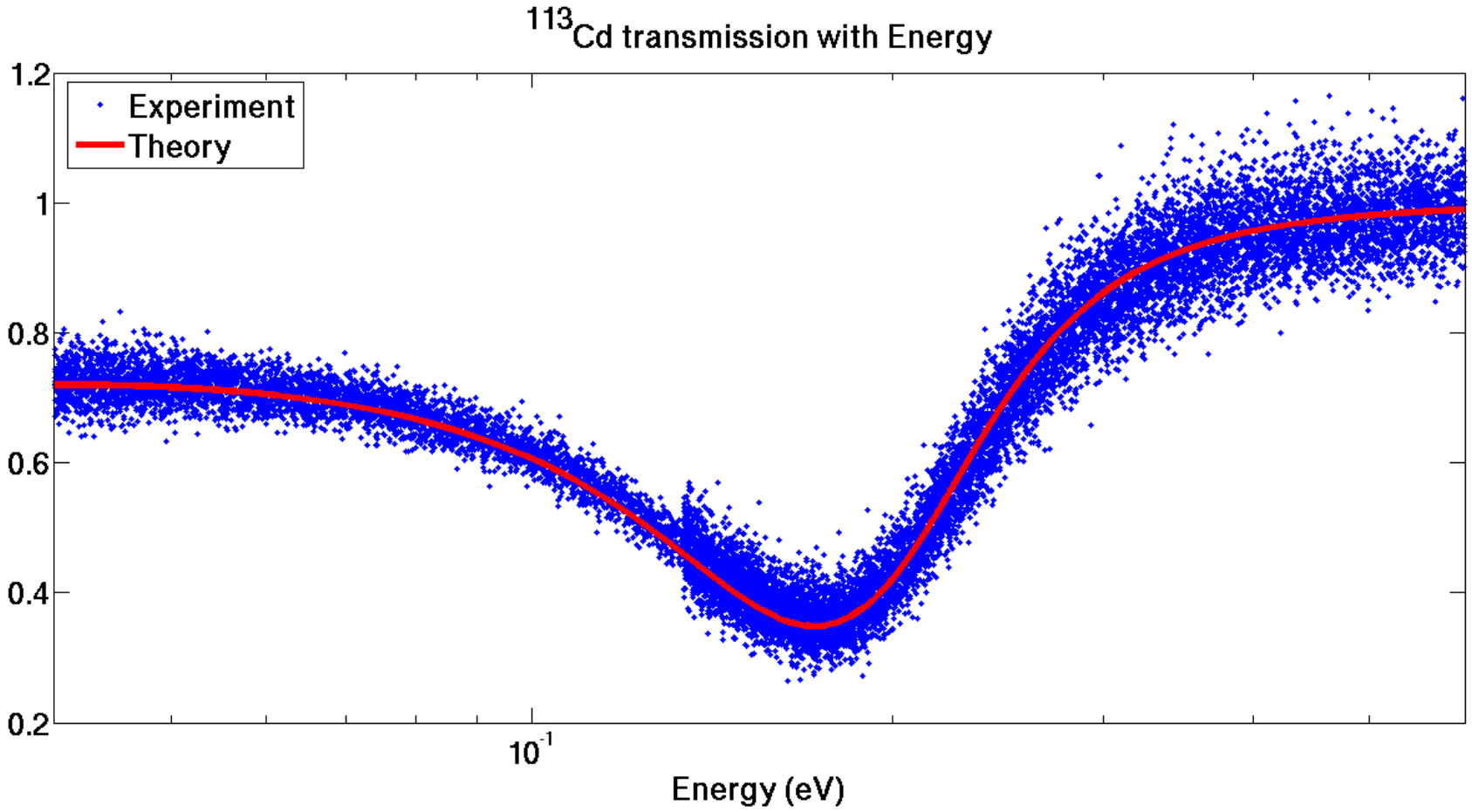
- because most experiments for the resonance range use the ToF technique,
- because it goes naturally when one has to use resolution functions, in time/distance (see next section).

Test case with ^{113}Cd transmission

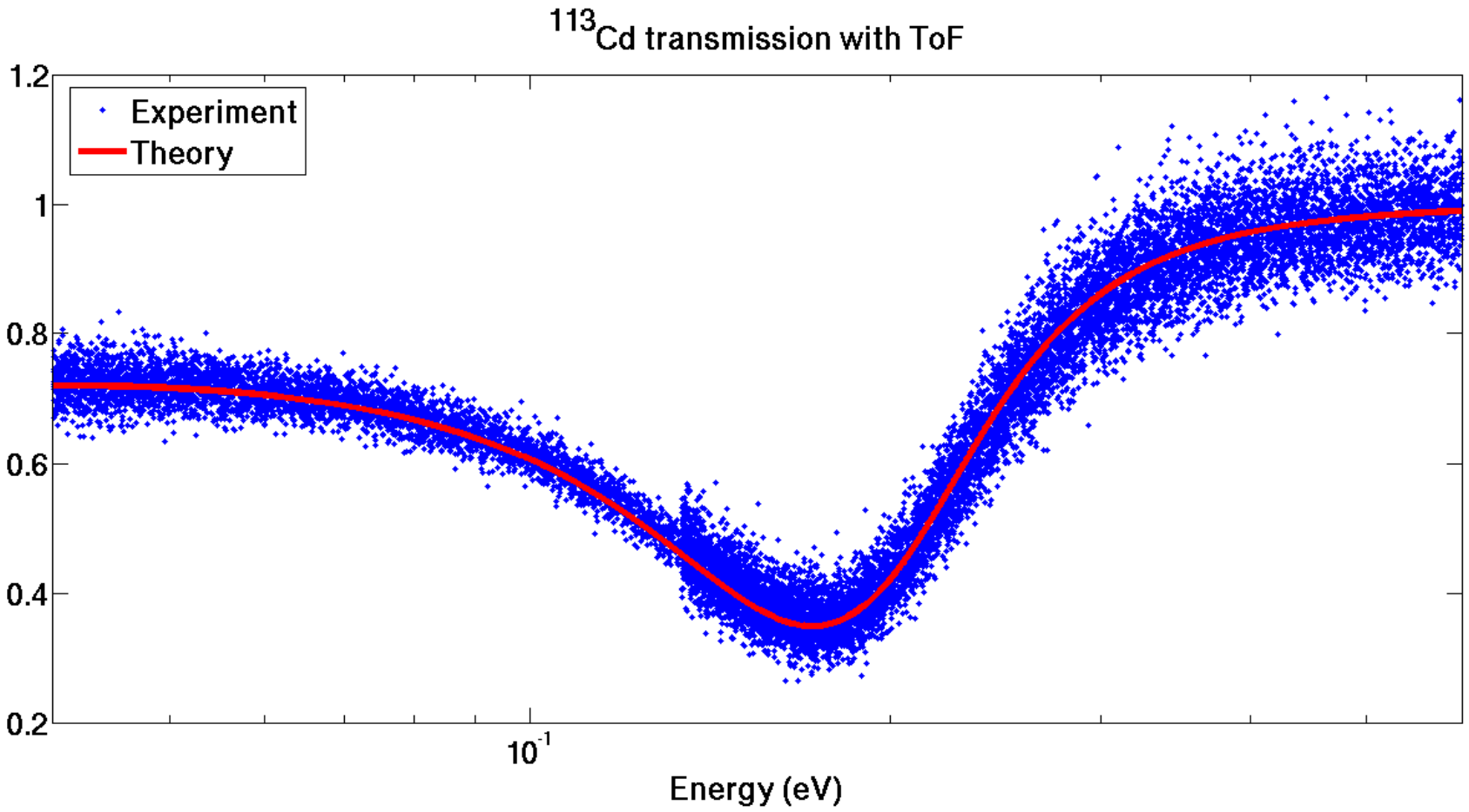
Transmission data (S. Kopecky)

- Analysis between 0.04 eV and 0.6 eV (first resonance of ^{113}Cd)
- Areal density: $1.3643.10^{-4}$ at./b
- ^{113}Cd abundance: 0.1222
- Doppler: FreeGas model, effective temperature: 298.5 K
- Flight Path: 26.464 m
- Time Offset: -684 ns

Test case with ^{113}Cd transmission



Test case with ^{113}Cd transmission



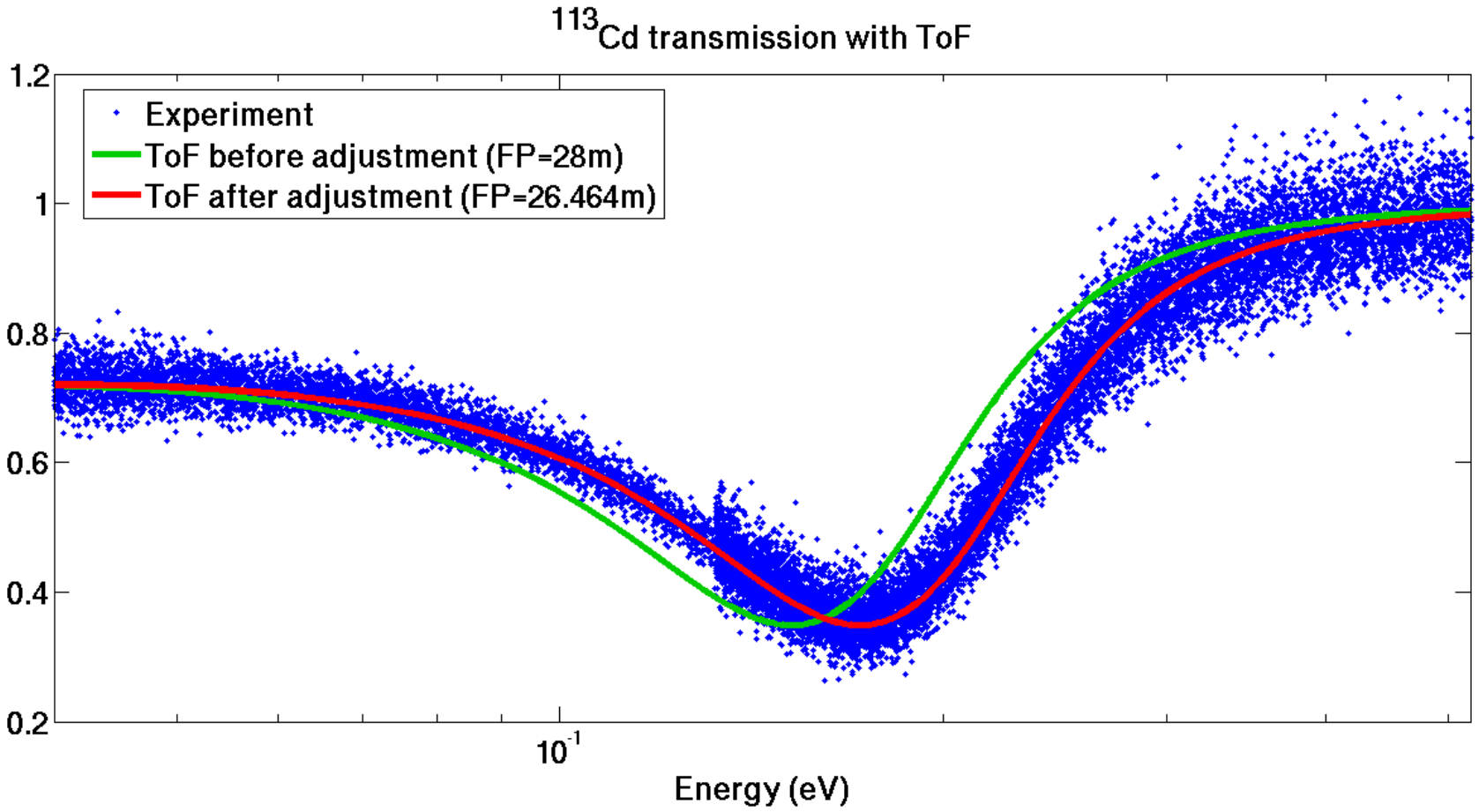
Test case with ^{113}Cd transmission

Wrong flight path...

The flight path can be fitted in CONRAD:

- test with a bad FP = 28 m (instead of 26.464 m)
- ask the code to “find” the correct flight path

Test case with ^{113}Cd transmission



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Resolution Functions?

All experimental data are resolution broadened:

The true observables are

$$T_{eff}(E) = \int R(E', E)\, T(E)\, dE' \tag{1}$$

$$Y_{eff}(E) = \int R(E', E)\, Y(E)\, dE' \tag{2}$$

Deviation in Time-of-Flight

- Accelerator burst width t_b
- Time channel width t_c
- Target-moderator assembly L_{mod}
- Lithium glass detector L_{det} (for transmission)
- ...

Analytical Resolution Function: χ^2 with n degrees of freedom

Analytical distribution used for moderator

$$R(t) \propto \left(\frac{t}{\lambda}\right)^{\left(\frac{n}{2}-1\right)} \cdot \exp\left(-\frac{t}{\lambda}\right) \tag{3}$$

with λ, the mean free time (or mean free path) of neutrons in the moderator.

Implementation in CONRAD

- you can choose if you want a distribution in time (ns) or in distance (m)
- λ is currently constant with the incident neutron energy, whereas it can be energy-dependant in REFIT and SAMMY

Numerical Resolution Function (User Defined RF)

Distributions given by the user

Most of the time calculated with Monte-Carlo codes (MCNP, ...)

- They can describe a part (moderator, detector...) or the whole experimental setup
- Each distribution is given for a given incident neutron energy

Implementation in CONRAD

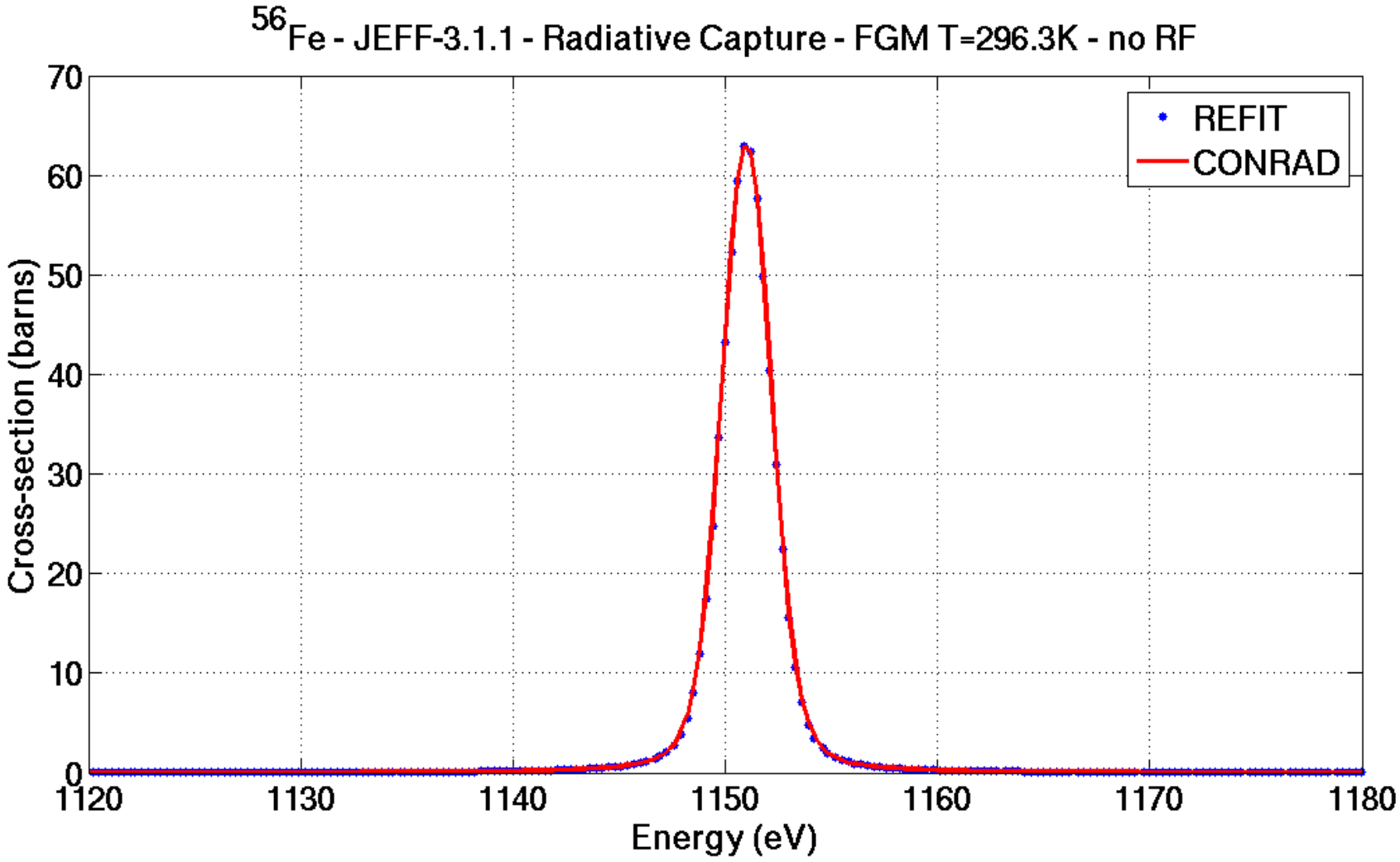
- you can have distributions in time (ns) or in distance (m)
- we use a log-lin interpolation for neutron energies between two distributions

Comparisons between CONRAD and REFIT

Capture cross-section

- ^{56}Fe radiative capture
- Analysis between 1120 eV and 1180 eV
- Doppler: FreeGas model, effective temperature: 296.3 K
- Flight path: 28.419 m

Comparisons between CONRAD and REFIT



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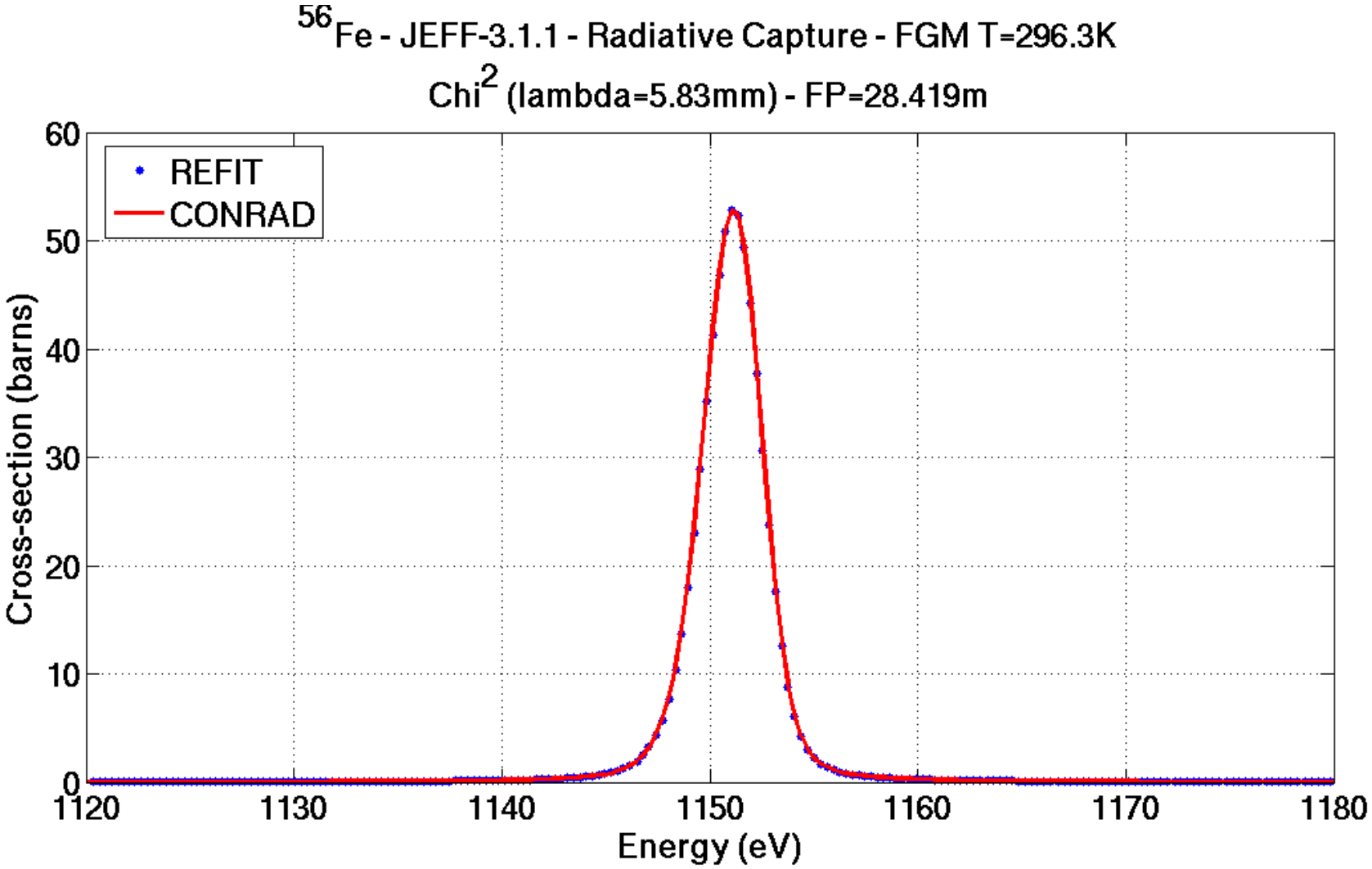

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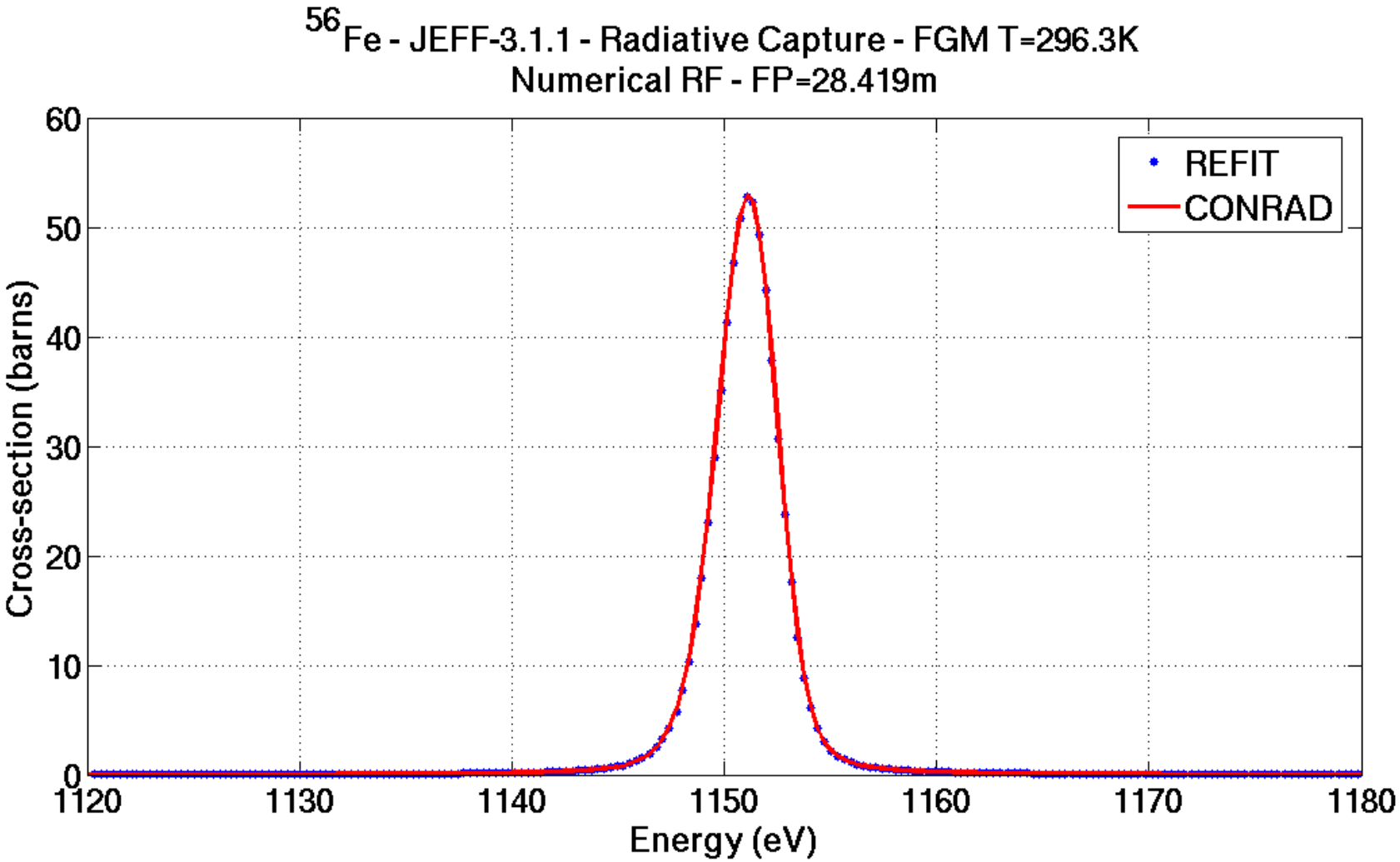

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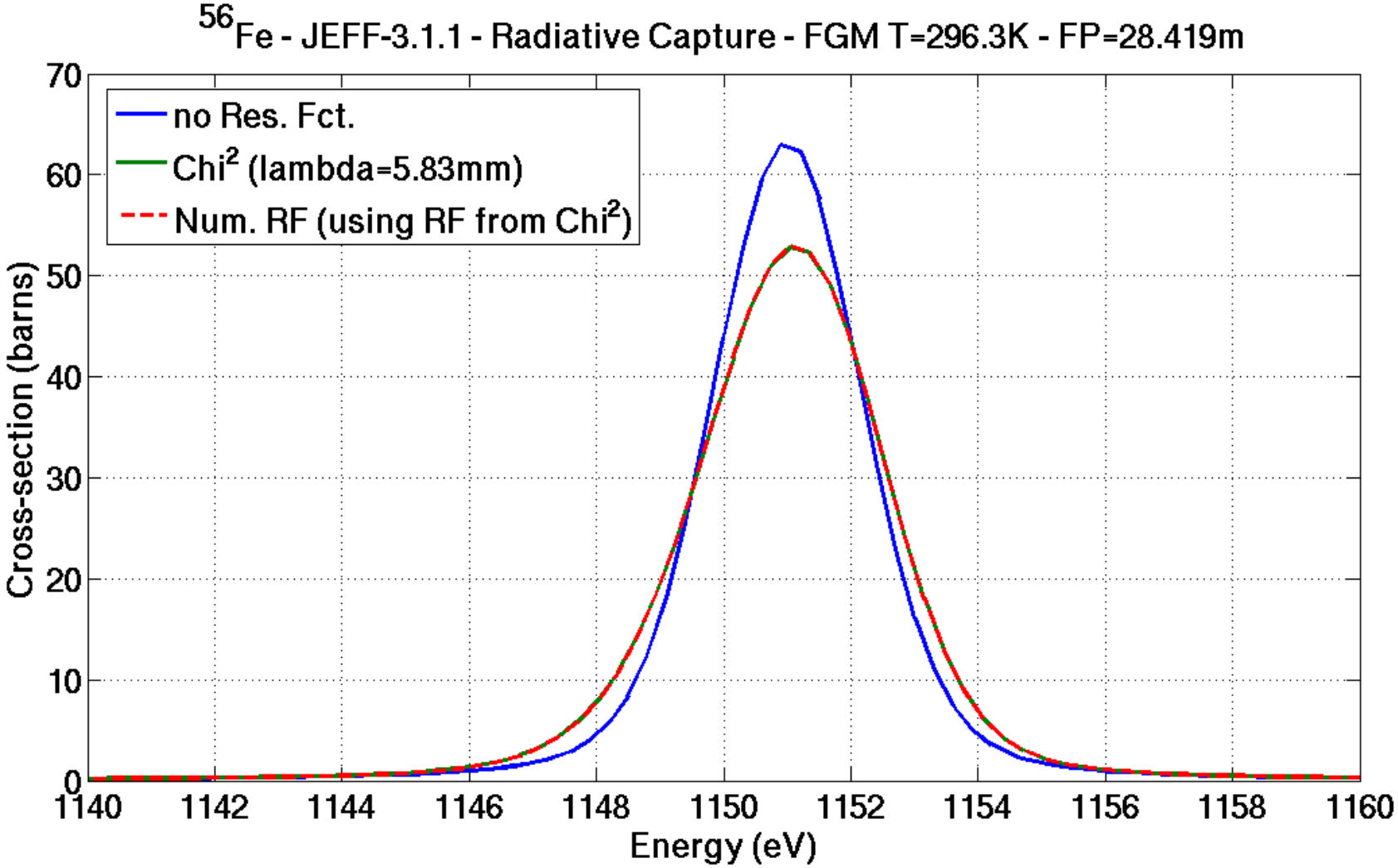

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Inhomogeneities

For thin powder sample, such as U/Pu oxydes

- Large porosity (holes)
- Thickness of the sample is not constant

From the paper of S. Kopecky in ND2007

- A log-normal distribution has been used to describe the thickness in the sample,
- This model can be used in REFIT to account for those inhomogeneities.

These experimental corrections have been implemented in CONRAD in the case of powder sample analysis

Experimental modeling of transmission

Transmission without correction

$$T_{eff}(E) = \exp\left[-n \cdot \sigma_{tot}(E)\right] \tag{4}$$

with n the areal density or thickness (at./barn).

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Transmission with porosity

$$T_{eff}(E) = (1-p) \cdot \exp\left[-\frac{n}{(1-p)} \cdot \sigma_{tot}(E)\right] + p \tag{5}$$

with p, the porosity or holes in the sample (in %).

Experimental modeling of transmission

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with p, the porosity or holes in the sample (in %).

Transmission with porosity and an areal density distribution

$$T_{eff}(E) = (1-p) \cdot \int_0^{\infty} pdf(x) \exp\left[-\frac{n \cdot x}{(1-p)} \cdot \sigma_{tot}(E)\right] dx + p \tag{6}$$

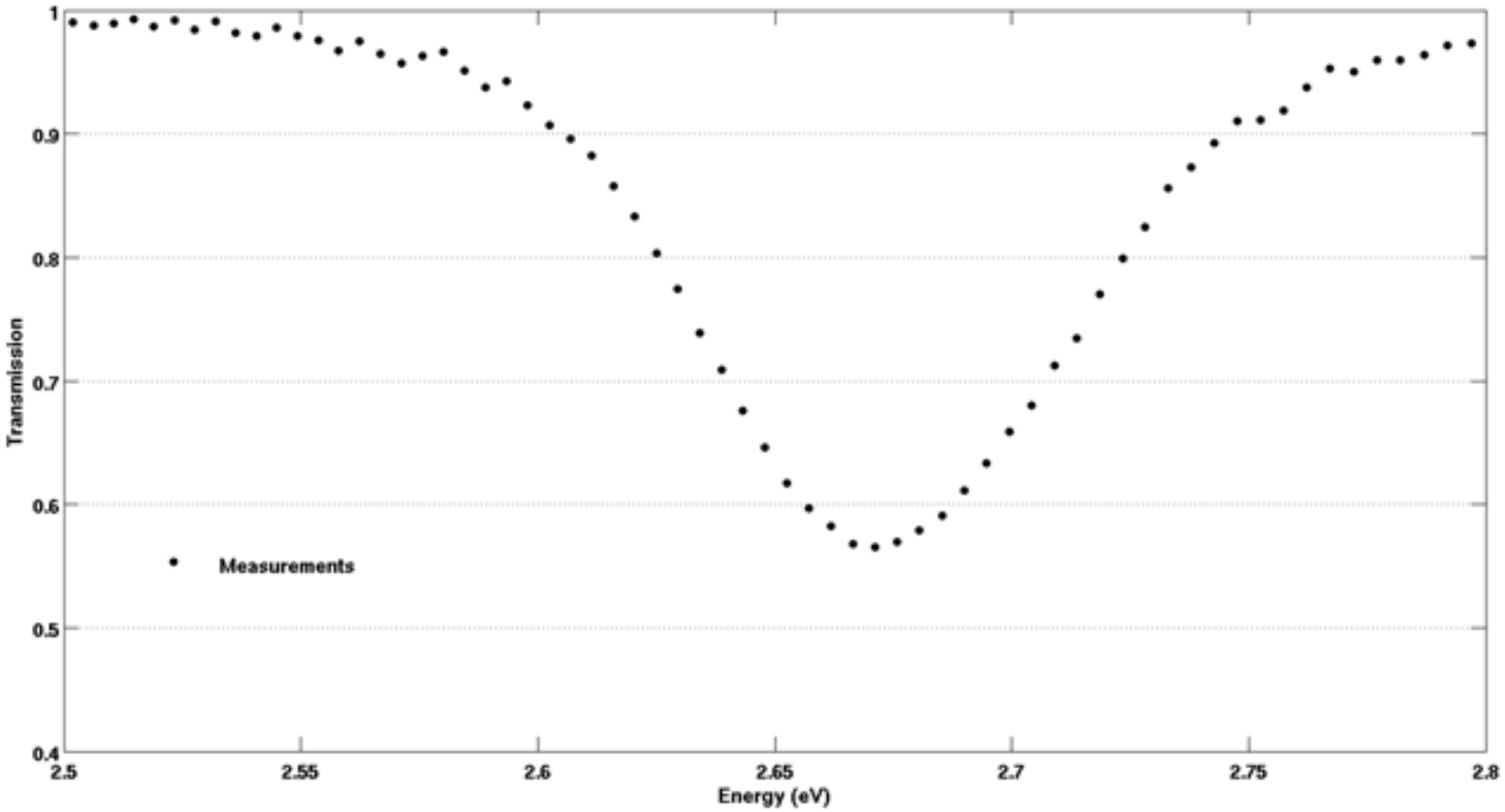
with $pdf(x)$, a probability density function (log-Normal in this case)

Test case with ^{242}Pu transmission measurements

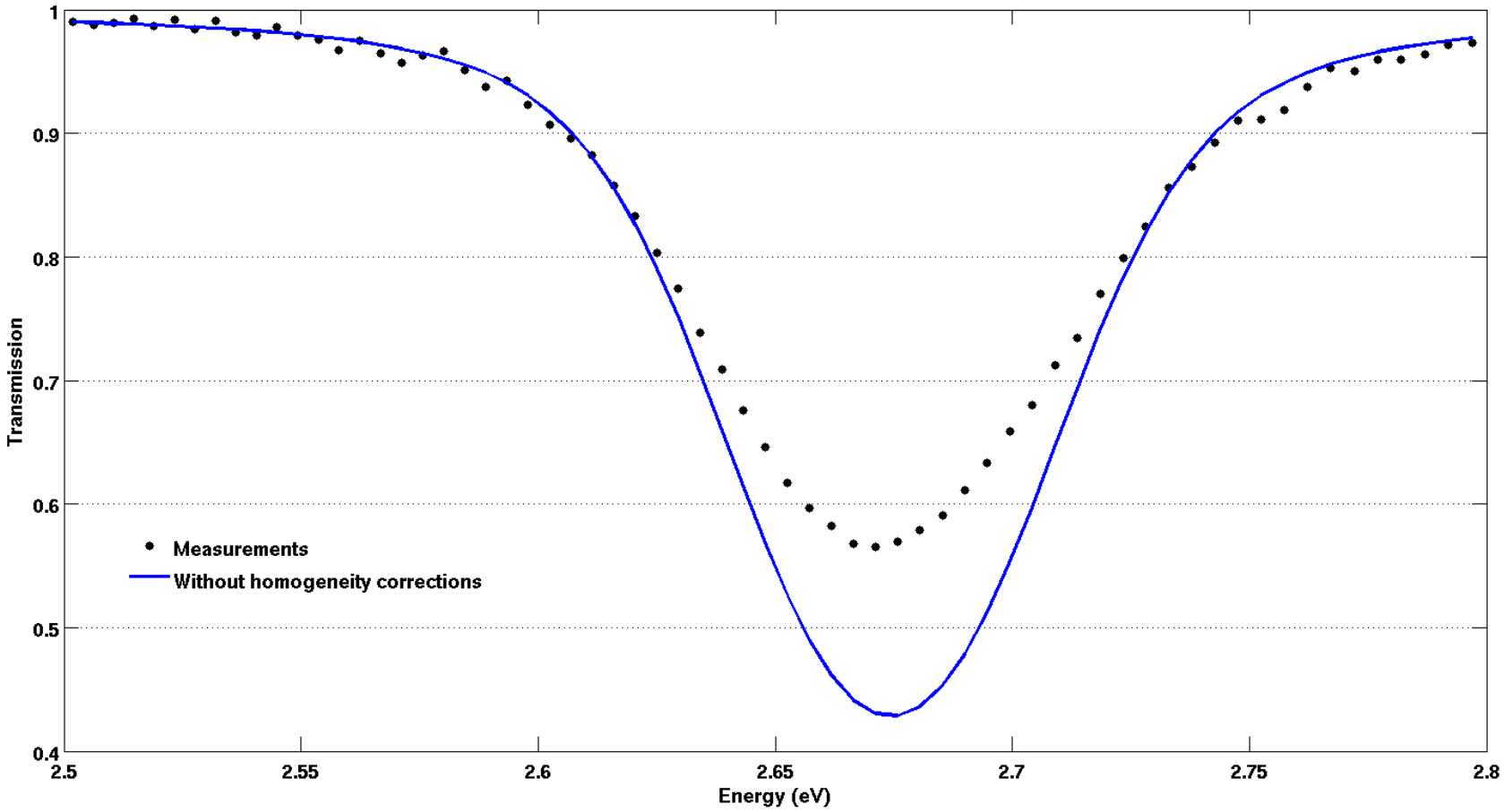
Transmission data (S. Kopecky)

- Analysis between 1 eV and 3.5 eV
- Areal density: $2.51.10^{-5}$ at./b
- Doppler: FreeGas model, effective temperature: 295.45K

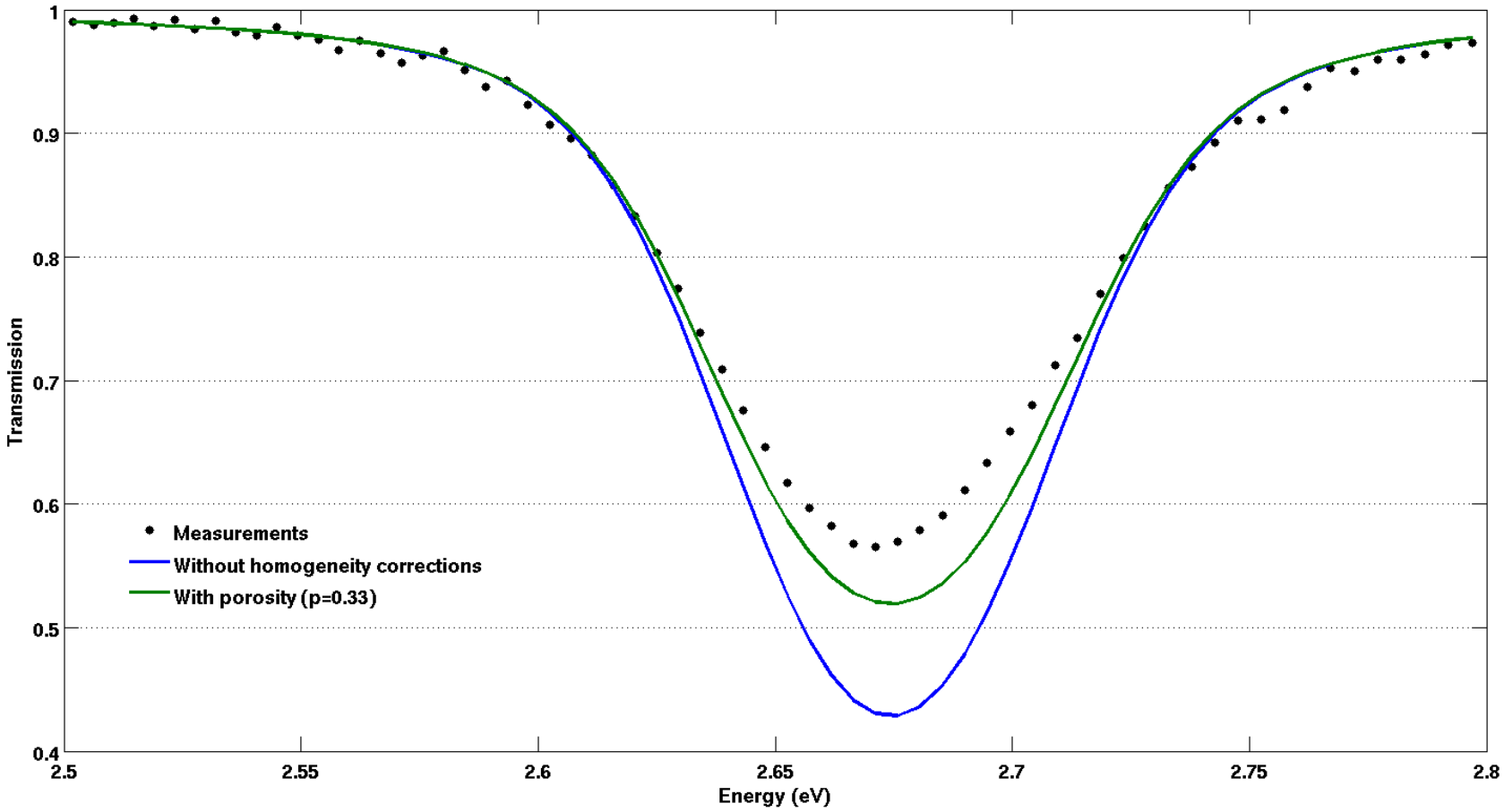
Test case with ^{242}Pu transmission measurements



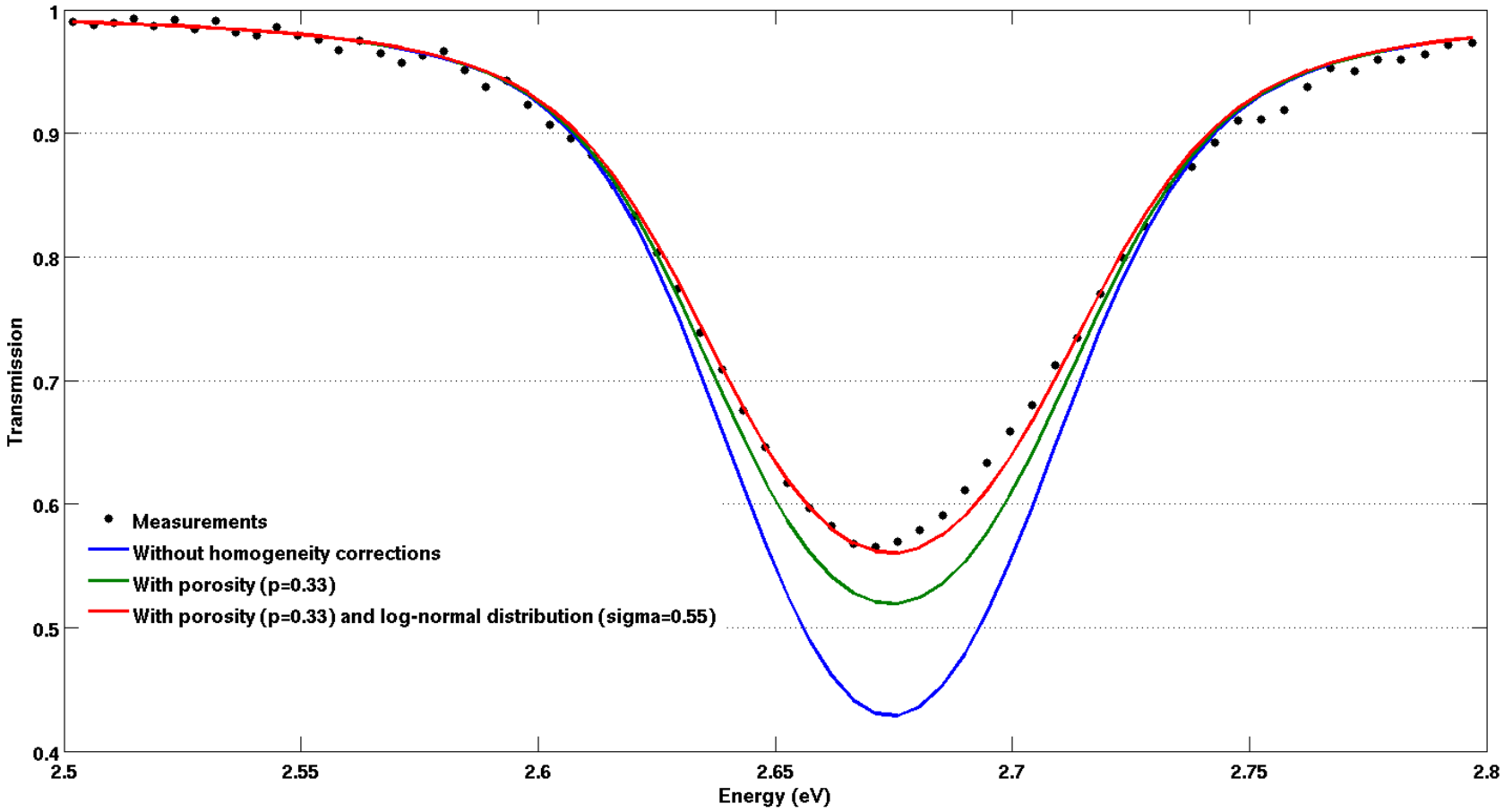
Test case with ^{242}Pu transmission measurements



Test case with ^{242}Pu transmission measurements



Test case with ^{242}Pu transmission measurements



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Realized in CONRAD for the moment:

- Implementation of both energy/Time-of-Flight measurements,
- Implementation of analytical (χ^2) and numerical resolution functions,
- Validation of the resolution functions versus REFIT and SAMMY codes,
- Implementation of sample inhomogeneities (porosity and log-normal distribution) for transmission experiments.

Conclusions

Further developments:

- Add new analytical resolution functions (gaussian, . . .),
- Add energy-dependancy for λ parameter,
- Add Crystal Lattice Model (almost ready!) to test on ^{242}Pu transmission data.

Conclusions

Acknowledgement

This work has been carried out in the framework of the ERINDA project and the CEA/IRMM collaboration.
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Thank you for your attention !