^{238}U Neutron Capture with the Total Absorption Calorimeter

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Outline

- Introduction
- Background contributions
- Pile up effect
- Neutron scattering correction
- Resonance analysis
- Kernel comparison
- Conclusions

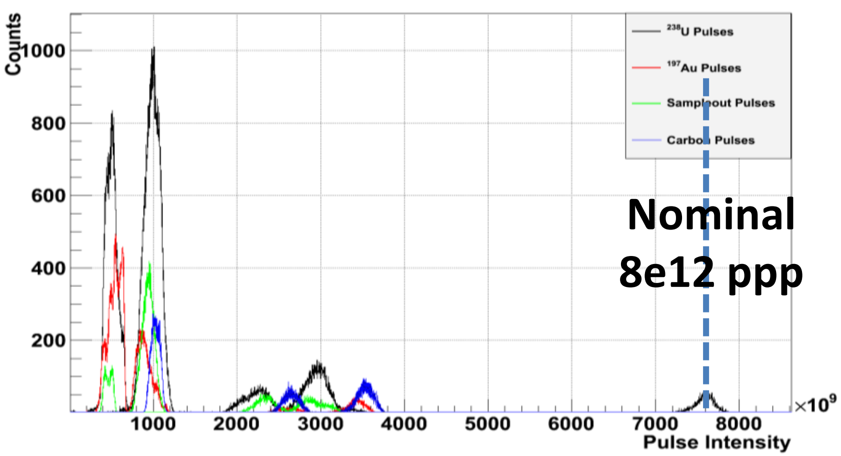
Introduction

Features on the NEA high priority request list

Requested uncertainties:

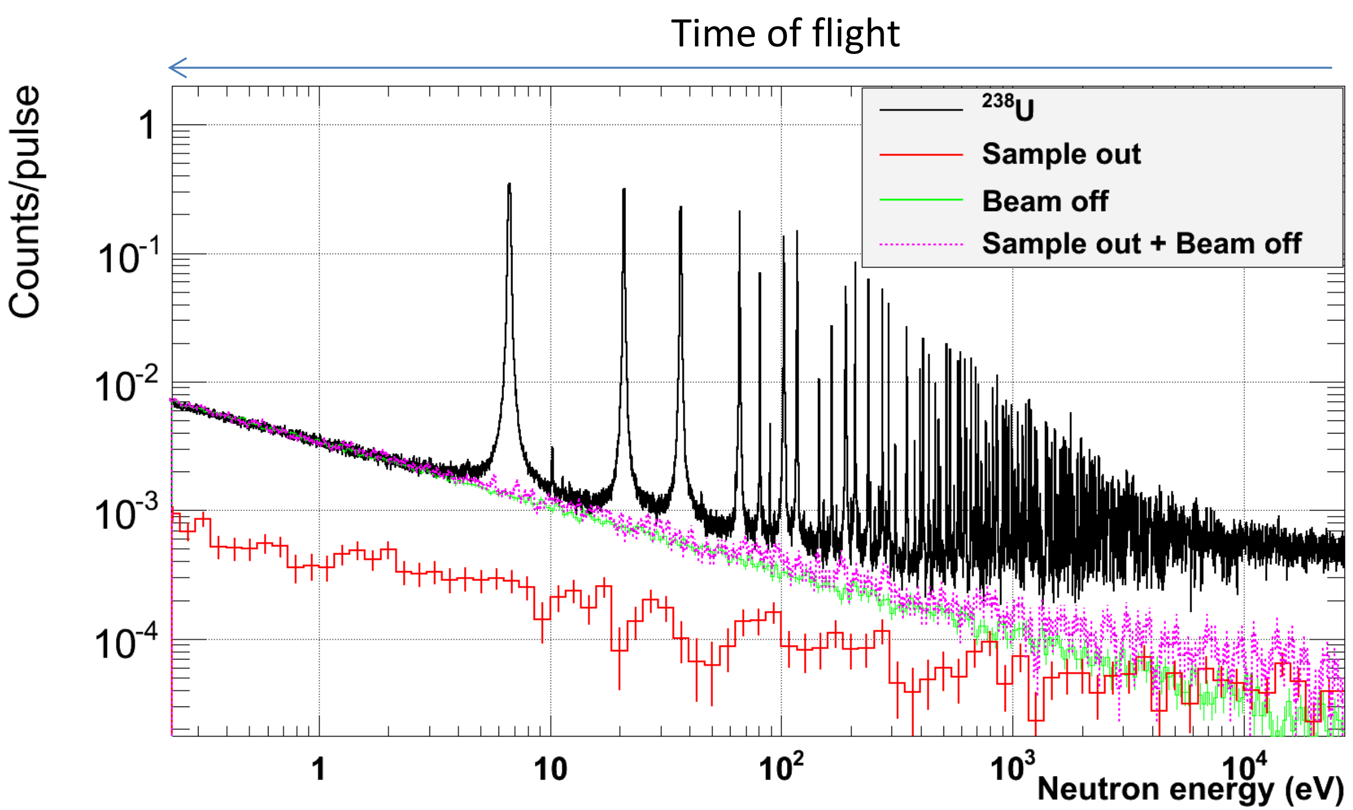
- 0.01 -1 keV **1%** (currently 2%)
- 1-10keV **1%** (currently 3%)
- 10-25keV **3%** (currently 9%)

- 6.125 g ^{238}U sample was measured for 41 days
- The same sample was measured with the C_6D_6 detectors at n_TOF and GELINA
- To reach maximum precision, the data analysis of the three separate measurements will be combined in the final stage



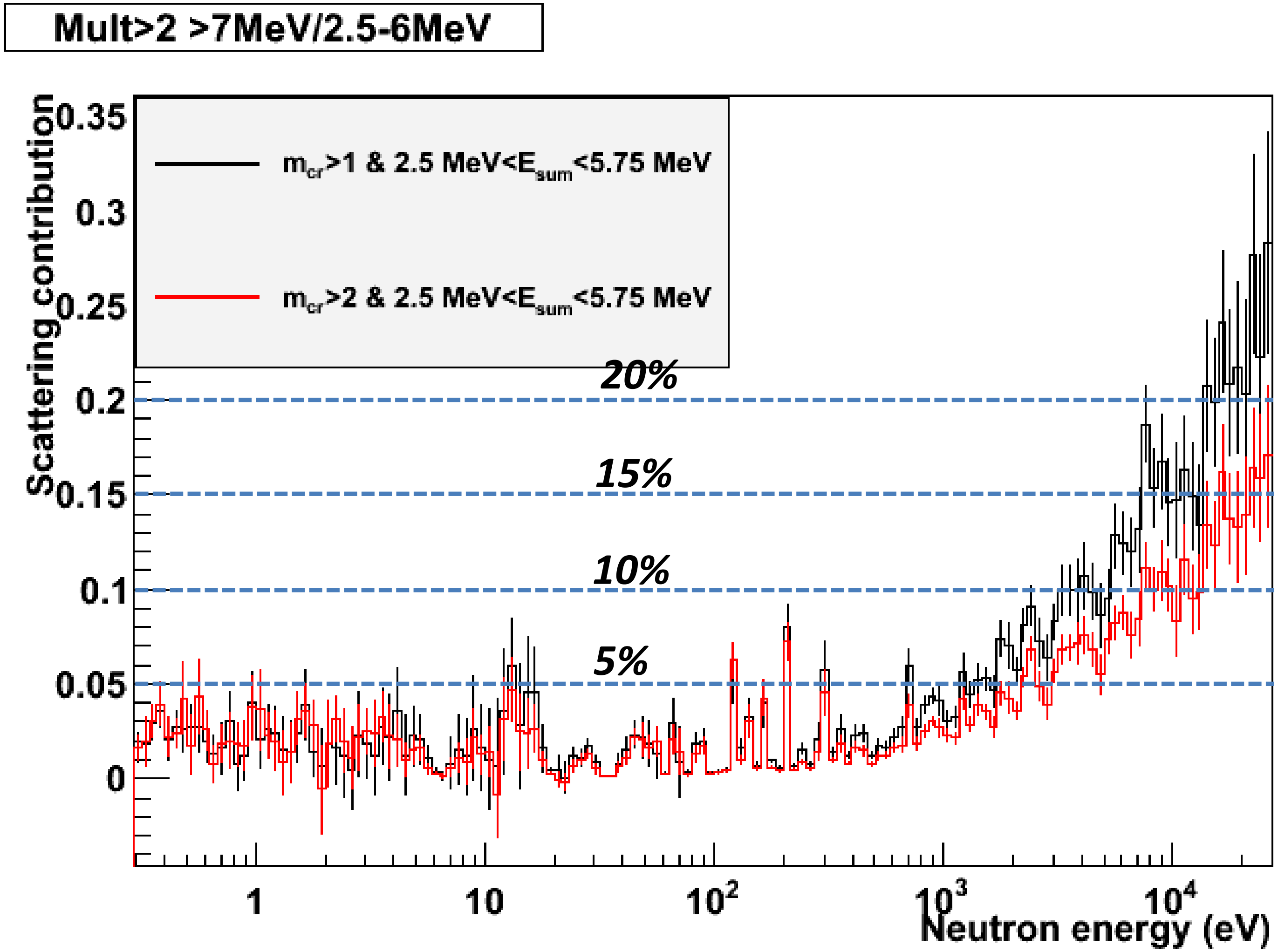
- Three main pulse intensities used, all lower than the nominal intensity to avoid large pile up problems due to the sample mass
- ANDES deliverable – joint report submitted end of October from C_6D_6 and TAC at n_TOF and C_6D_6 at GELINA
- Main previous outstanding issues – pile up not correctly corrected for and the first resonance could not be correctly fitted with SAMMY

Background contributions



- Beam off background fitted using a linear function on a log-log scale
- No sample canning
- Sample out background smoothed by re-binning, then interpolating between adjacent bins
- So the background contribution remains below 15%
- Here, the neutron scattering background will dominate
- Above 10 keV, we will be unable to analyse due to the gamma flash

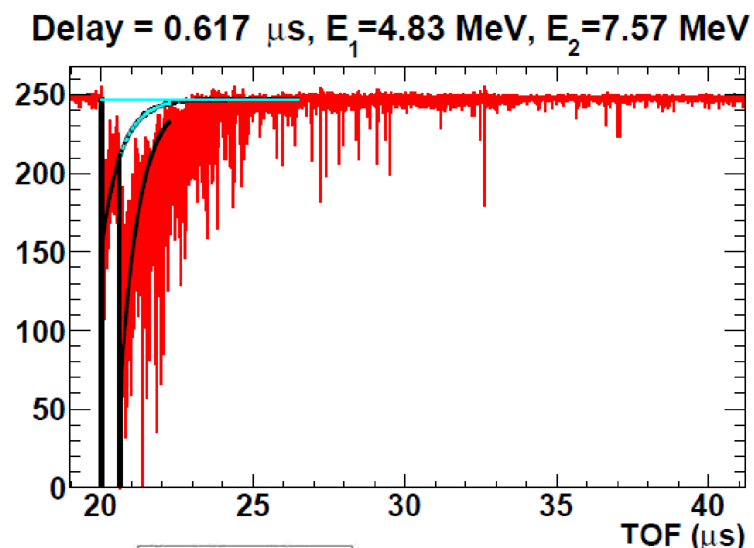
Neutron scattering correction

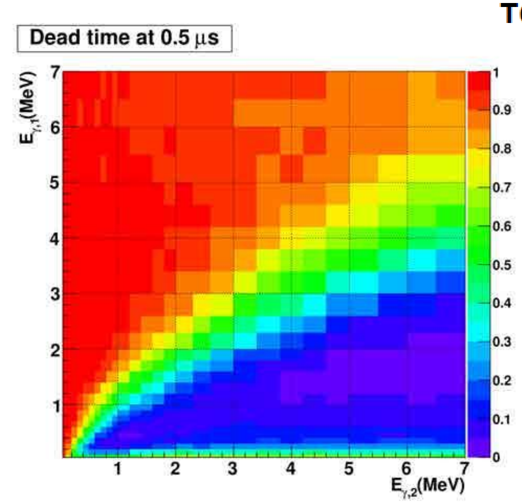


- At higher neutron energies, the background contribution from neutron scattering is larger
- Here the histogram is re-binned to 100bins/decade

Pile up

- The slow component of BaF_2 is around 630 ns, thus subsequent signals within a few µs can be difficult to identify
- The probability of detecting a second (or third..) signal depends on the energy of the first signal, E_1, the energy of the second signal E_2 and the time between the two signals, t.
- This probability is found by taking many, many examples from the raw data.

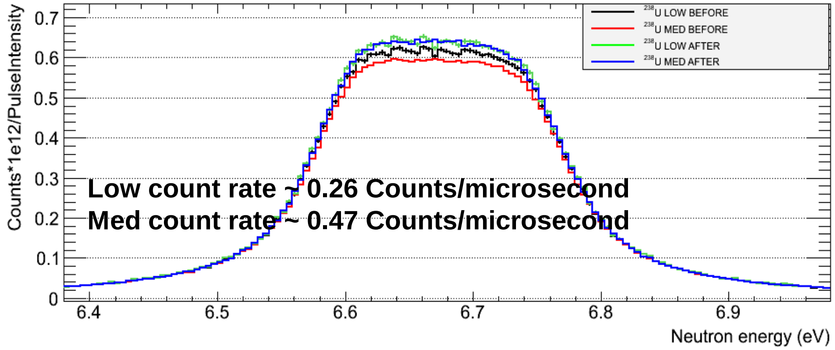


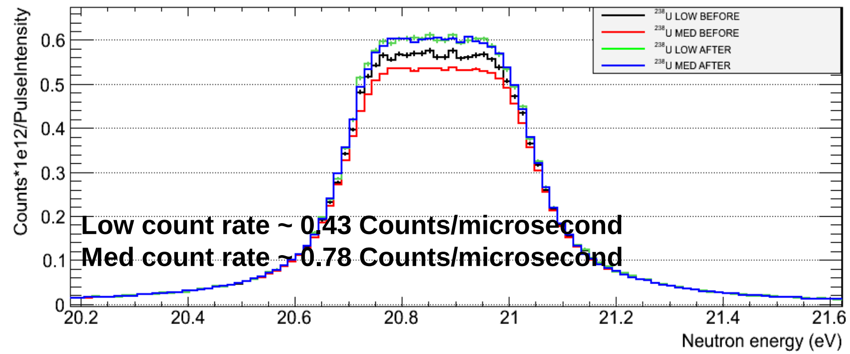


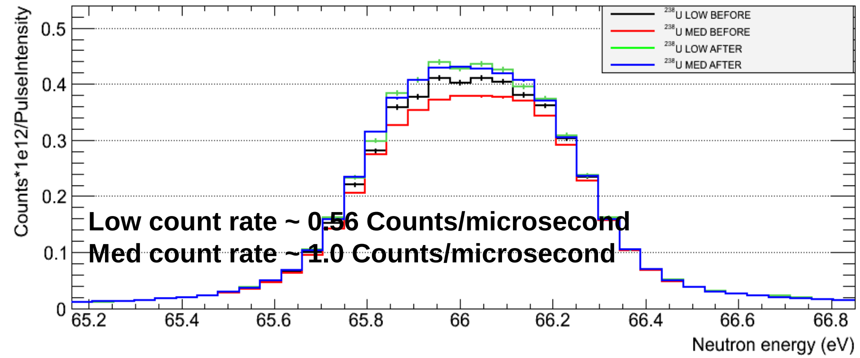
Thanks to C. Guerrero, E. Mendoza and D. Cano Ott

Pile up

- Take the (n,γ) cascades from a low count rate, e.g. in the tail of a resonance
- Randomly sample these cascades depending on the measured count rate and determine the probability of killing a signal.
- From this you can estimate the true count rate, and thus the magnitude of the pile up correction



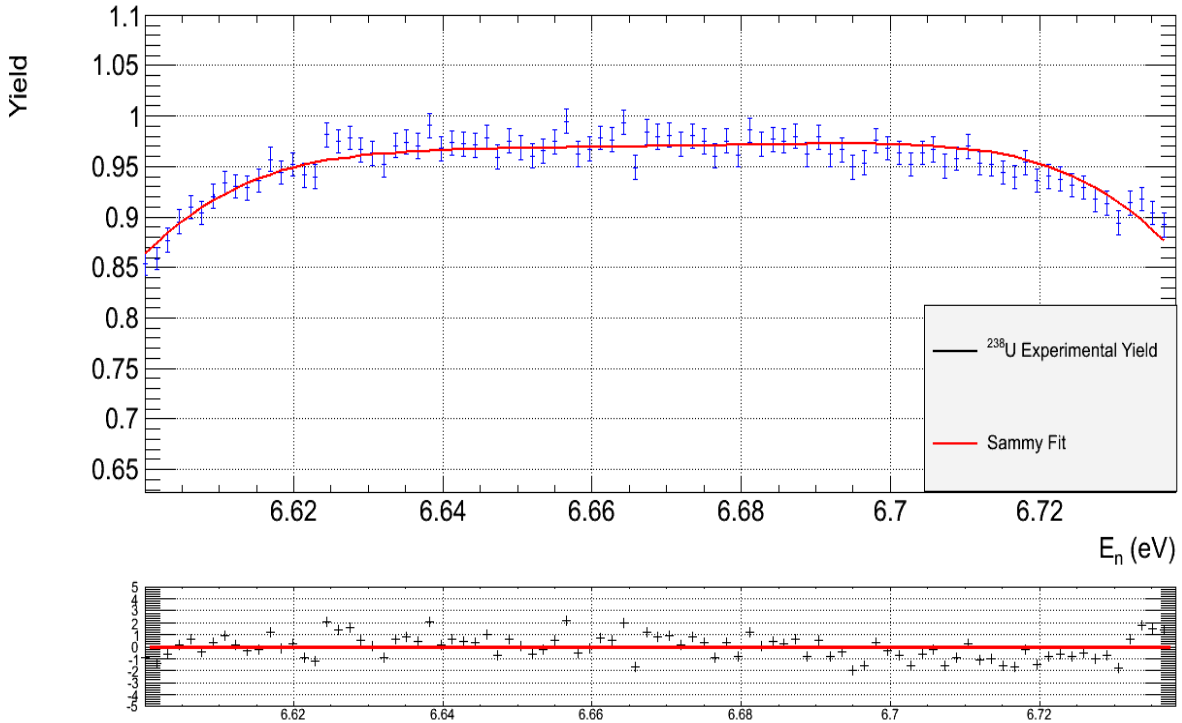




- A comparison between different count rate data sets show the correction works for count rates as high as 1 count/µs with a 1% accuracy.
- The asymmetric resonance shape caused pile up is lost when you apply the correction, showing it's powerful use with a variable count rate

Yield calculation

Normalised in the peak of the first resonance. $N_{bif} \cdot \varepsilon$ = 0.67 for our chosen analysis conditions, m_{cr}>1 & 2.5 < *Esum (MeV)* < 5.75

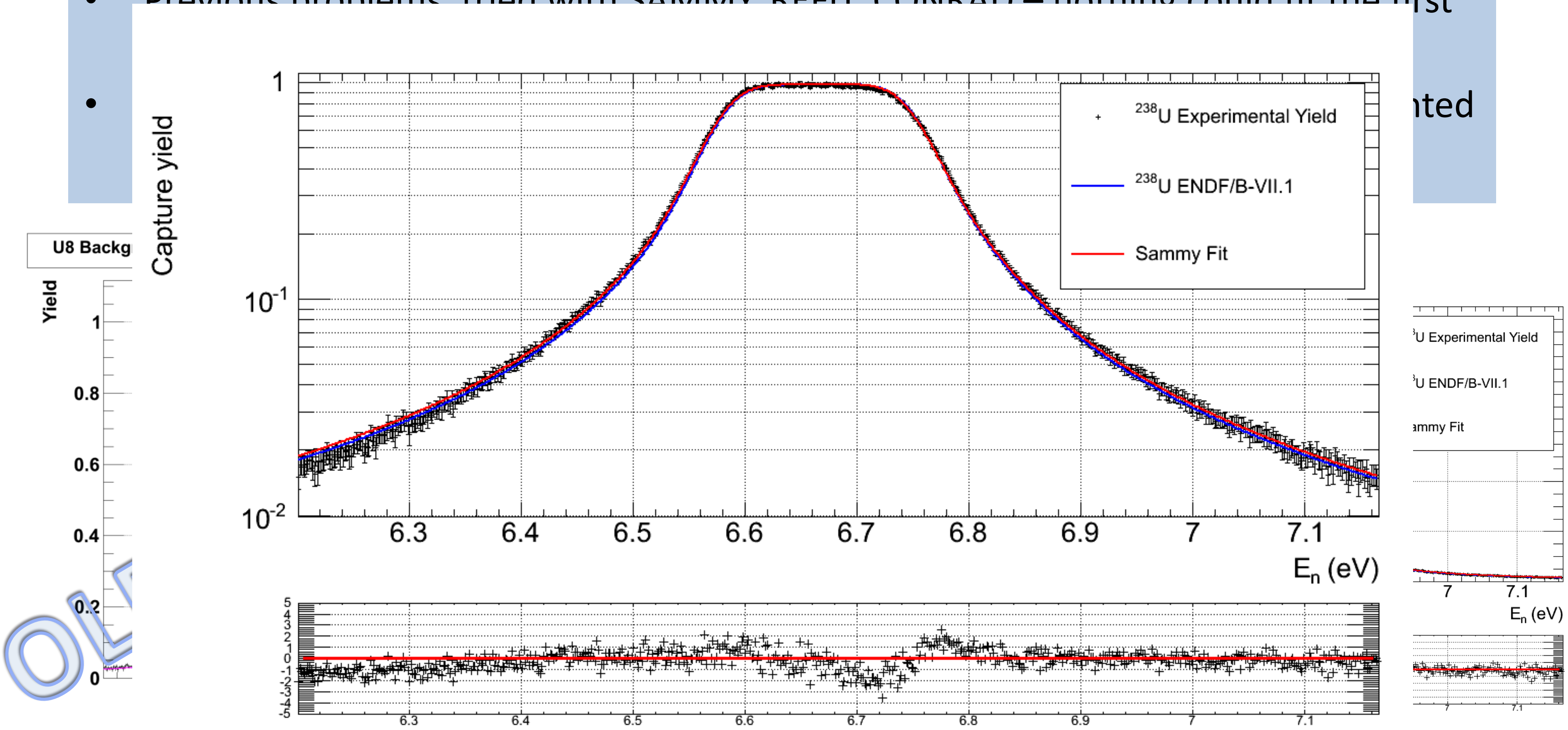


$$Y(E_n) = \frac{C_{tot}(E_n) - C_{back}(En)}{N_{bif} \cdot \varepsilon \cdot \varphi(En)}$$

The first **three** resonances are saturated, allowing three normalisation points to be used.
They all agree within 1 %.

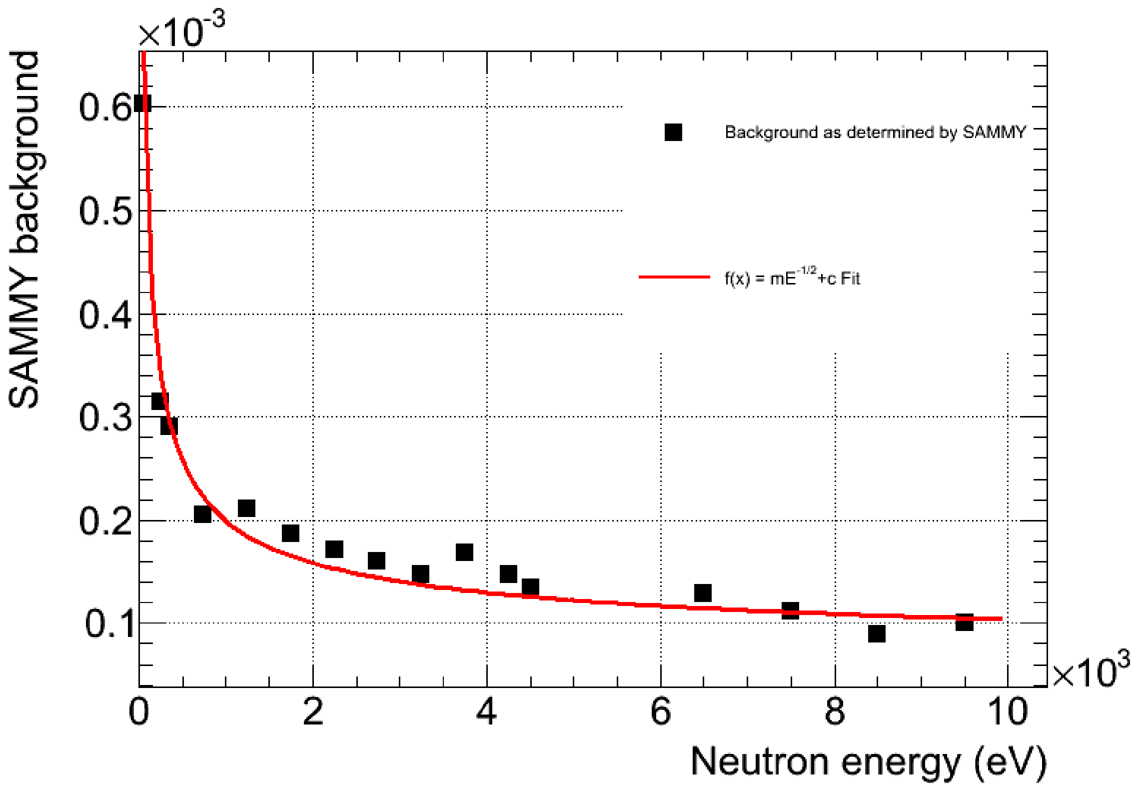
Resonance analysis – First resonance

- Previous problems, tried with SAMMY, REFIT, CONRAD – nothing could fit the first
- nted



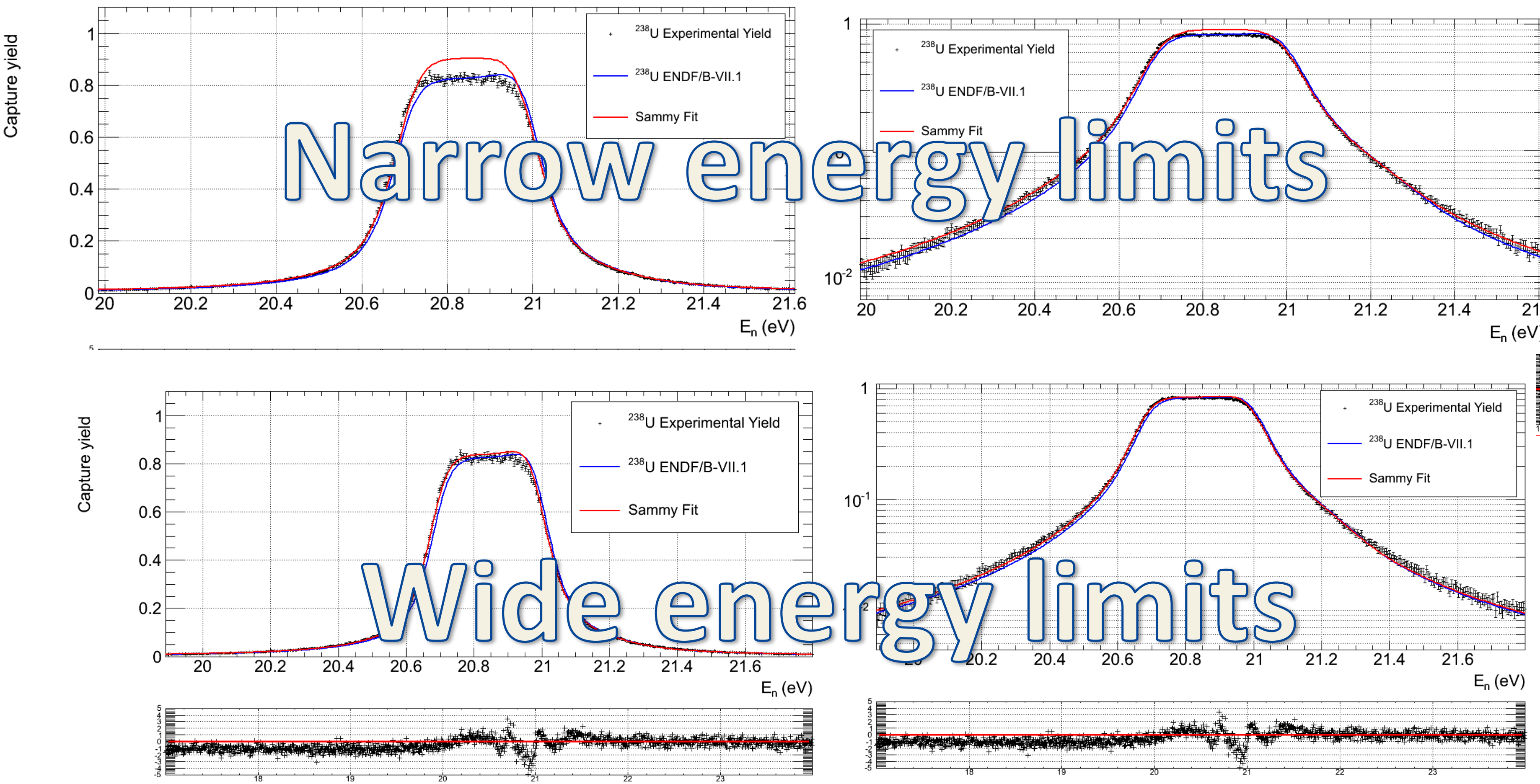
Resonance analysis – Background

- SAMMY shows there is some background present in the data
- By leaving the constant background free in different energy regions the shape of the background was found

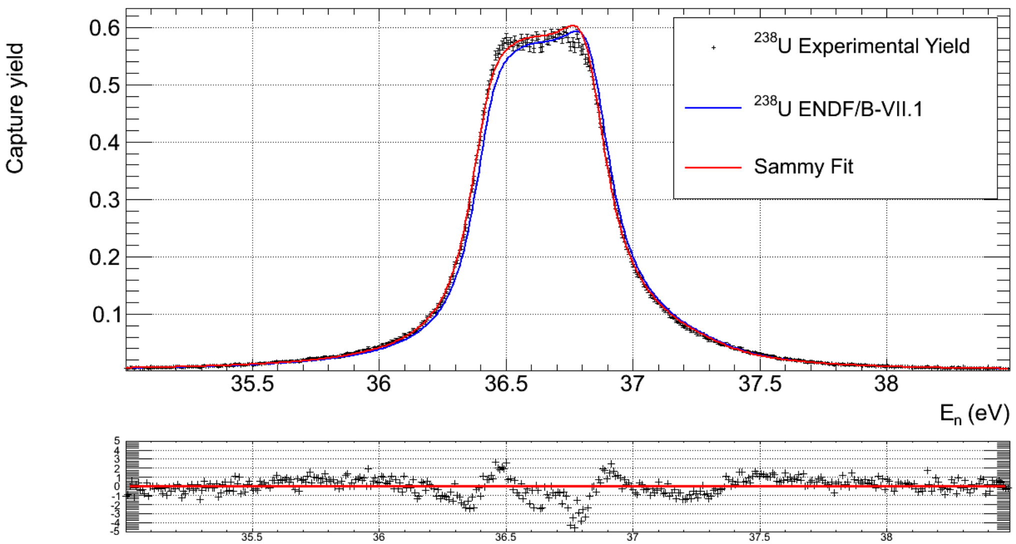


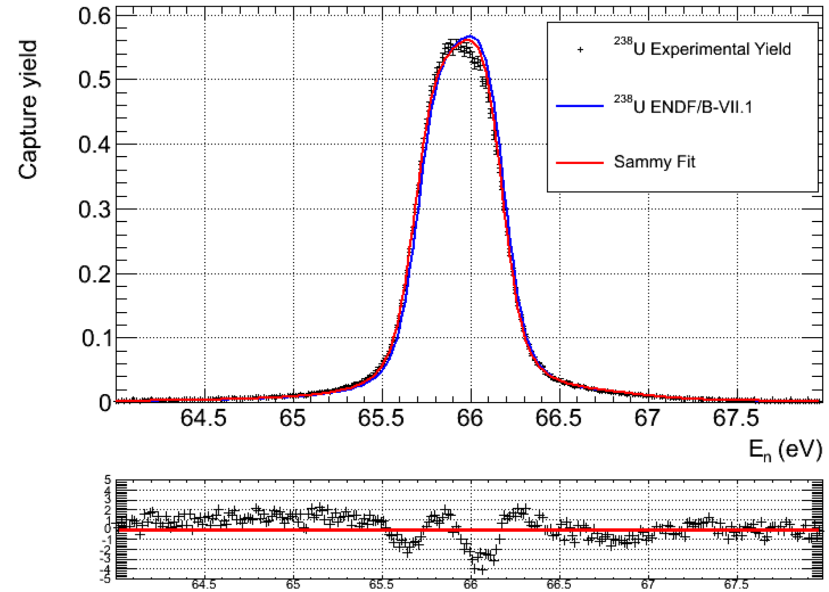
The background has both a constant component:
c = 6.00433 x 10^{-5}
and a $E_n^{-1/2}$ component:
m = 4.40615 x 10^{-3}

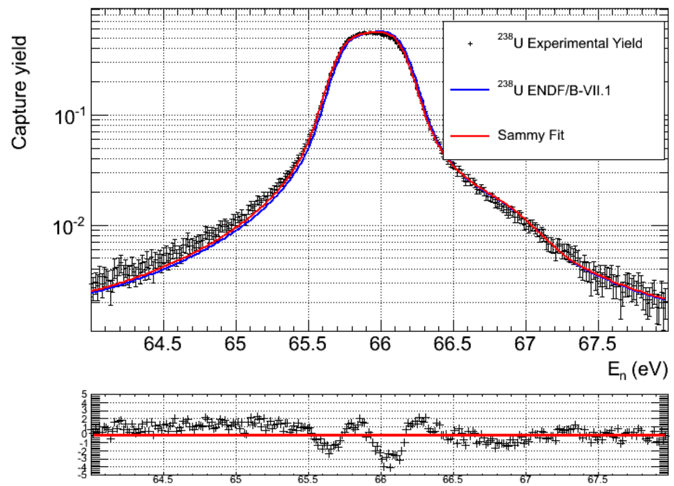
Resonance analysis – Second resonance



Resonance analysis – Third and fourth resonances

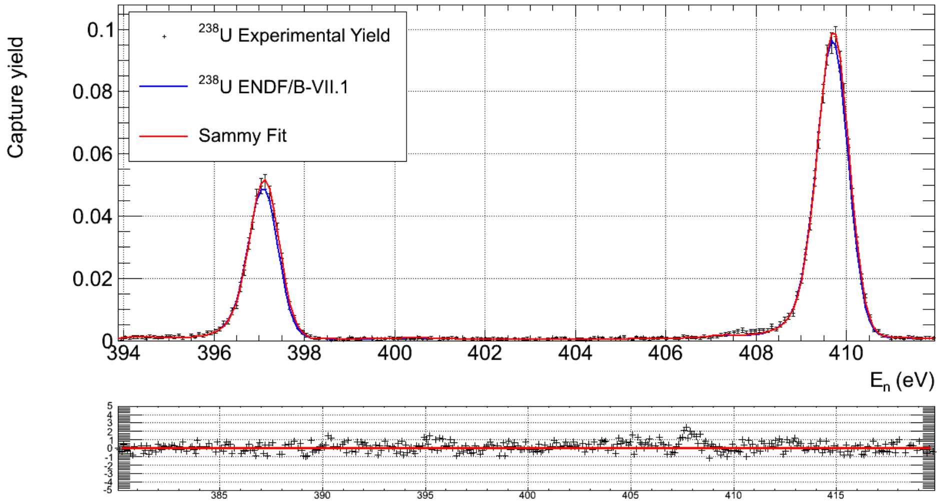




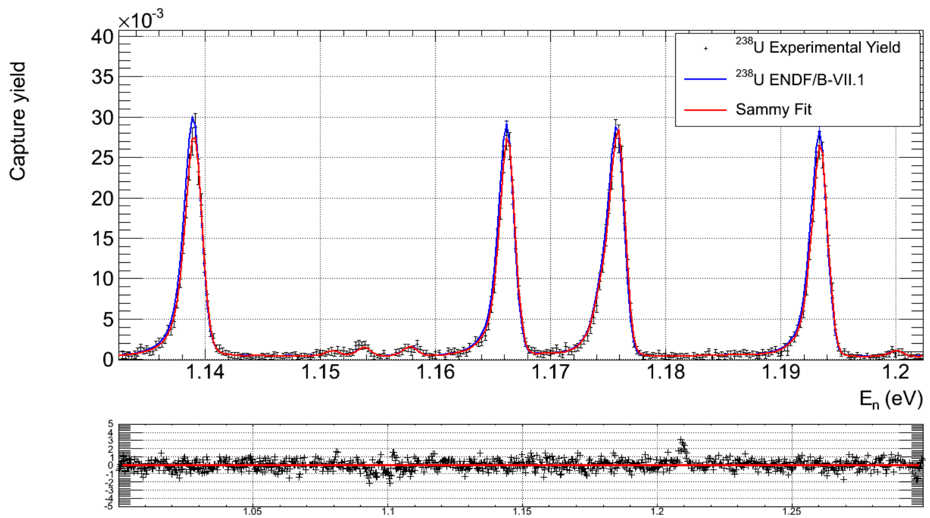


- Problems with fitting resonances up to 100 eV
- Here the uncertainty should already be 2 %
- May have to leave some specific resonances out of the analysis?
- Comparison with the C_6D_6 data will be done

Resonance analysis - RRR

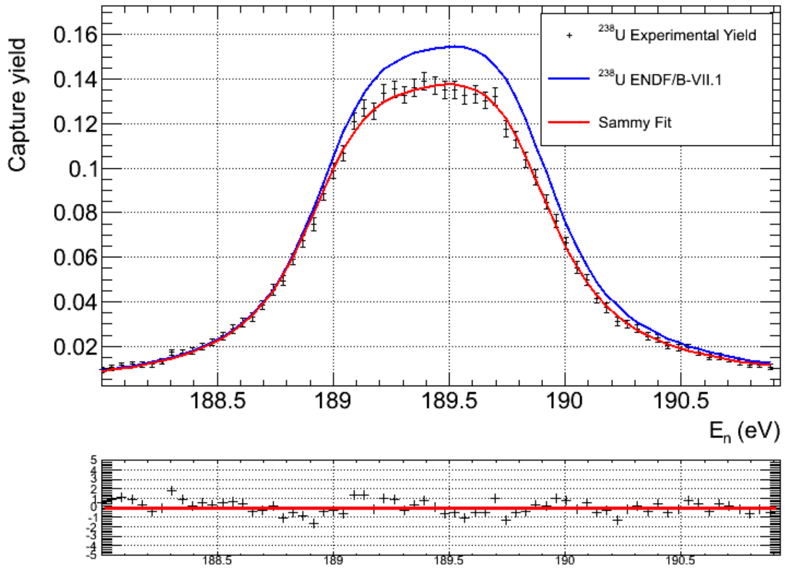


- Here we seem slightly higher than ENDF



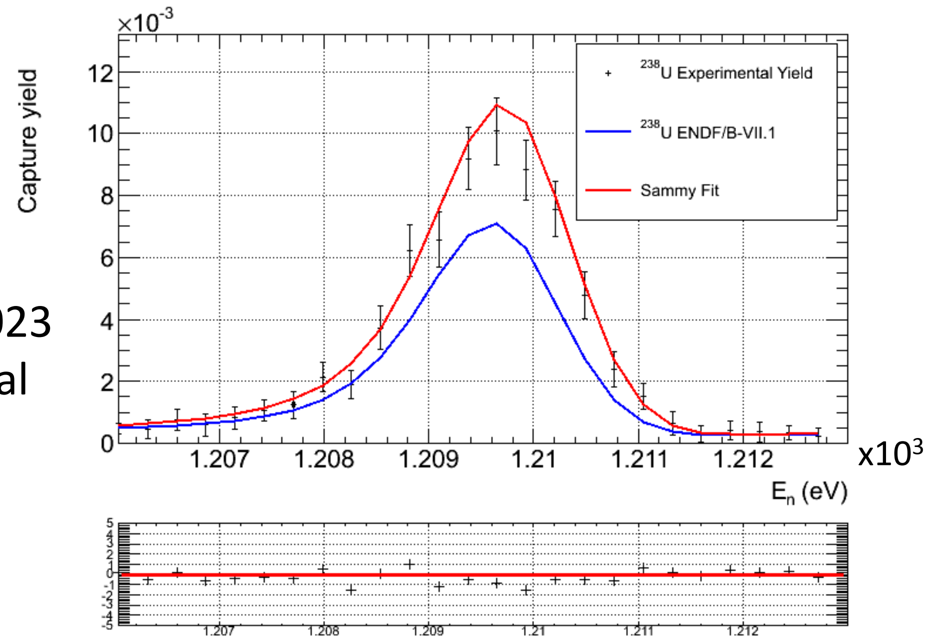
- Here we seem slightly lower than ENDF

Resonance analysis - RRR



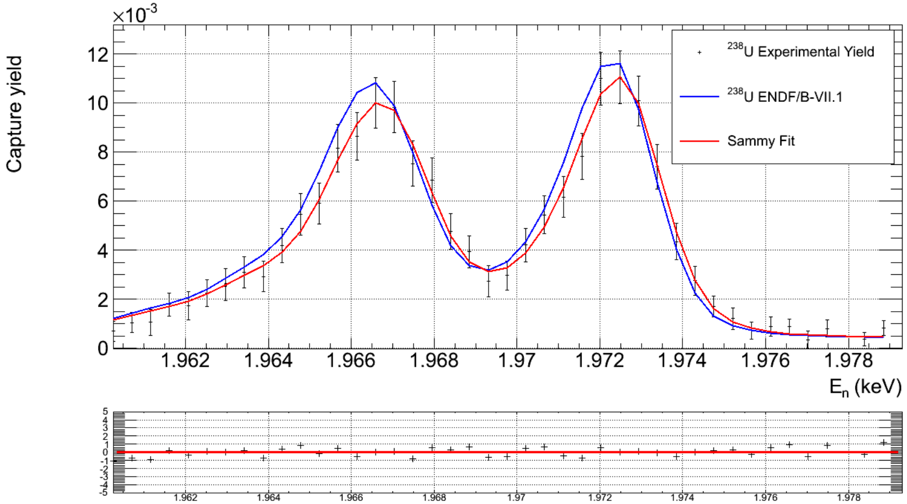
We seem some major differences between individual resonances

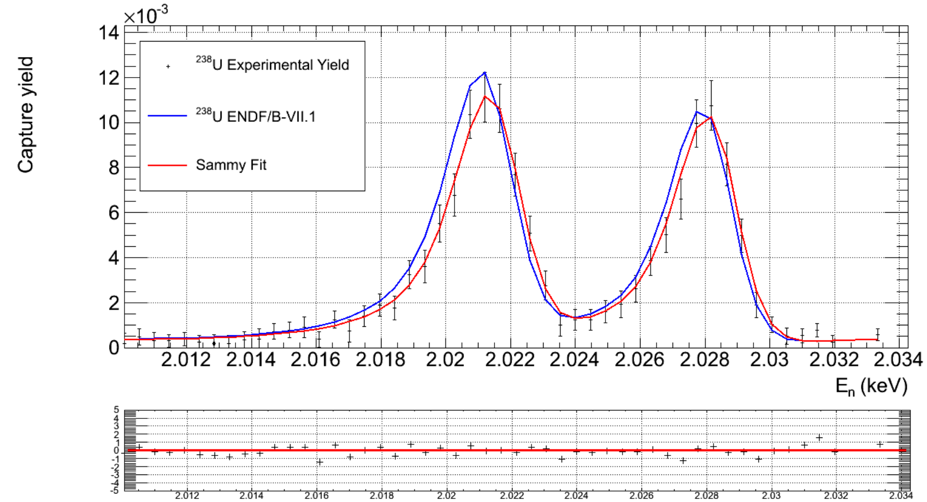
Here, Γ_n is approximately 7 times bigger than Γ_γ.
But surely we would expect to be above ENDF if we were confusing extra counts from neutron scattering?

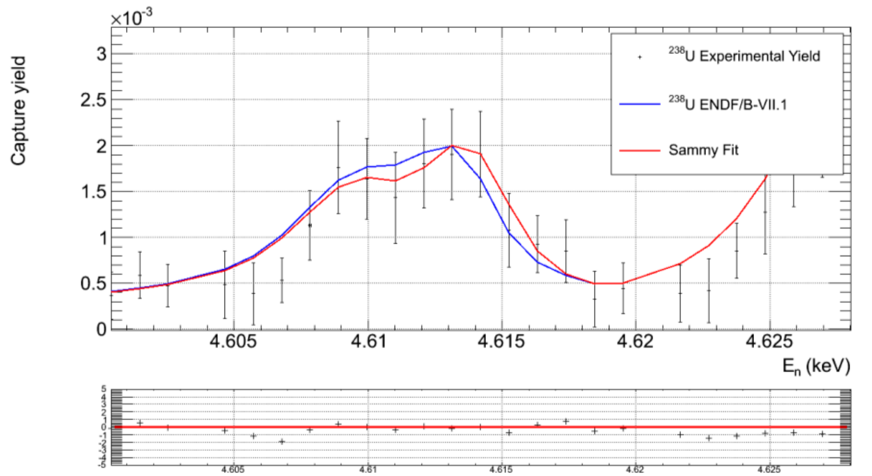


Here, Γ_γ = 0.0066 compared to the usual 0 .023 but has , Γ_f = 0.000472 compared to the usual 0.

Resonance analysis - RRR







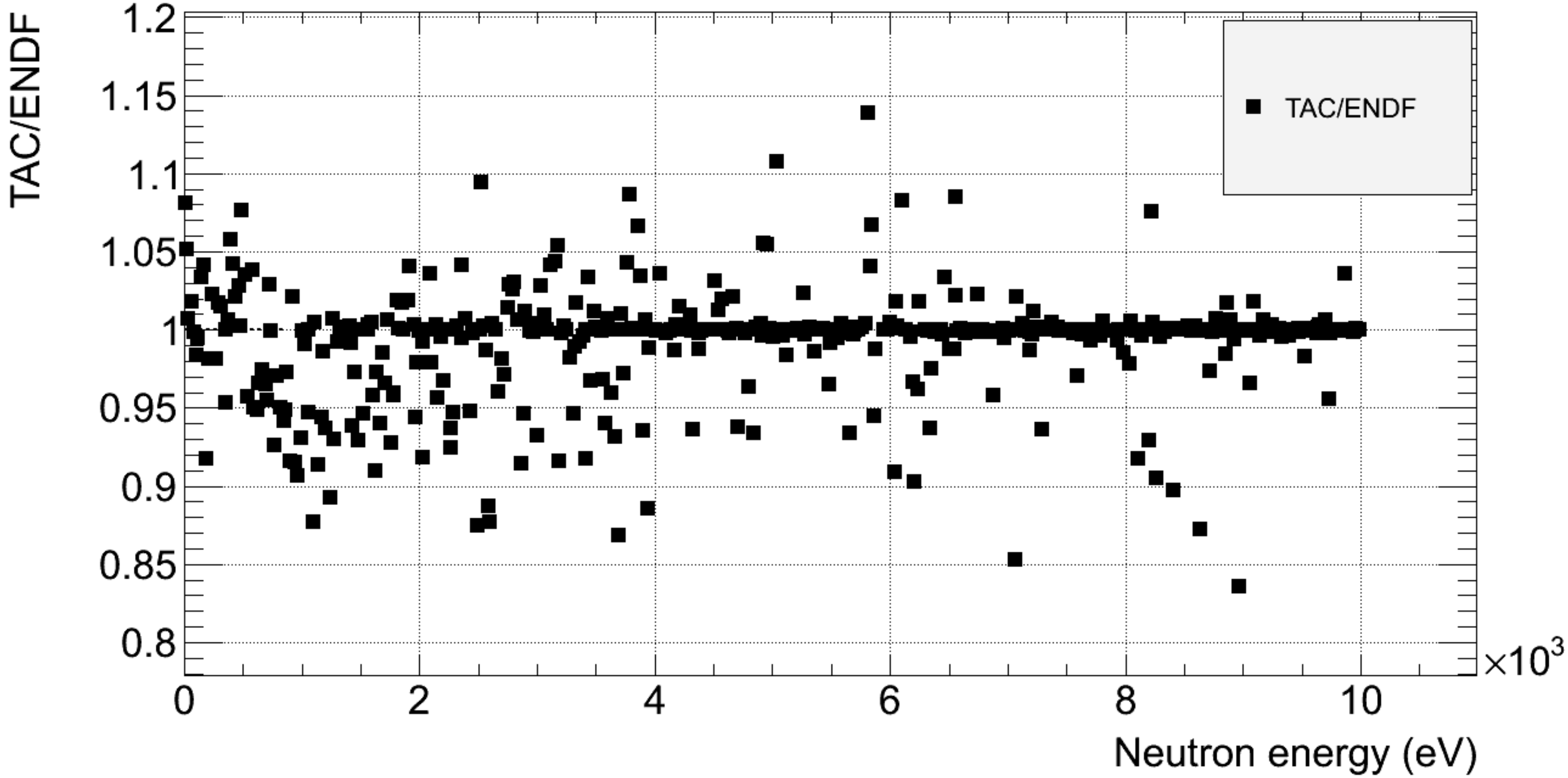
Perhaps the energy calibration isn't perfect

As we reach 5 keV, statistics start to be limiting

Let's look at the resonance kernels and compare to ENDF to see if we can see any systematics

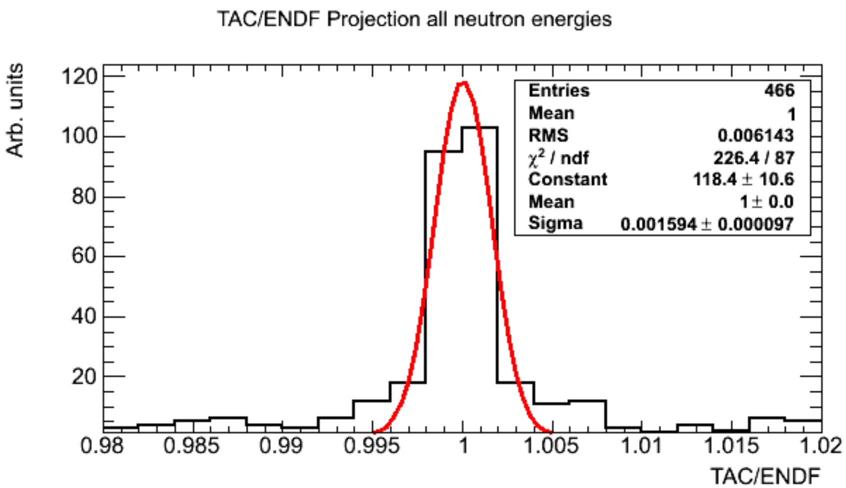
$$RK = \frac{\Gamma_n \cdot \Gamma_\gamma}{\Gamma_n + \Gamma_\gamma}$$

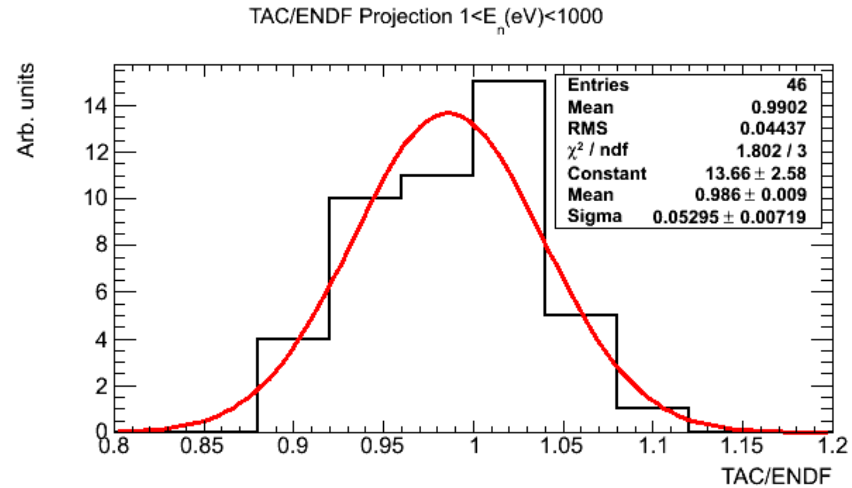
Kernel comparison

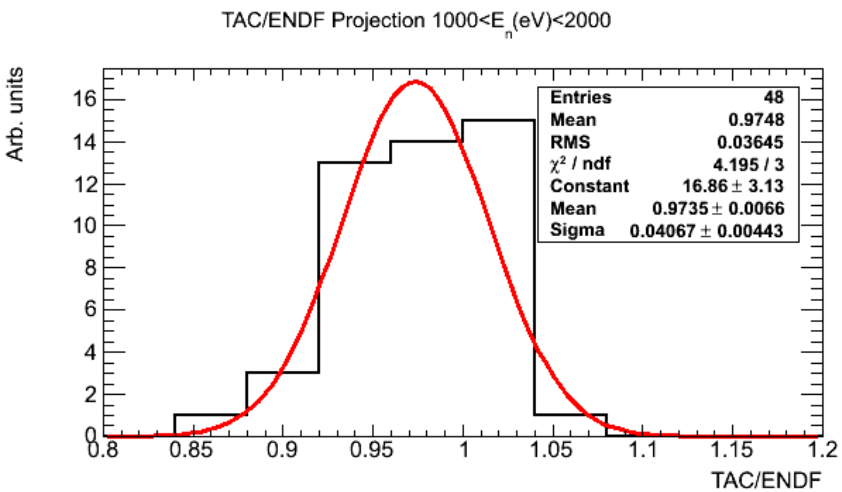


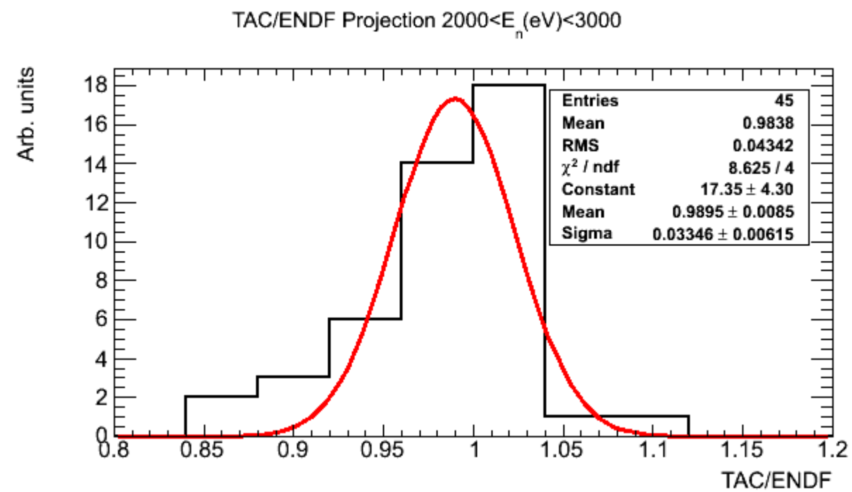
Unfortunately no error bars yet, as it is not trivial….

Projections









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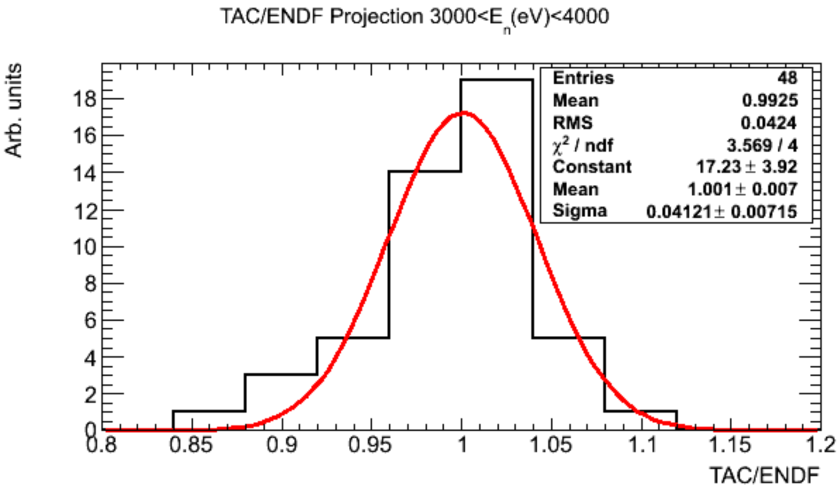

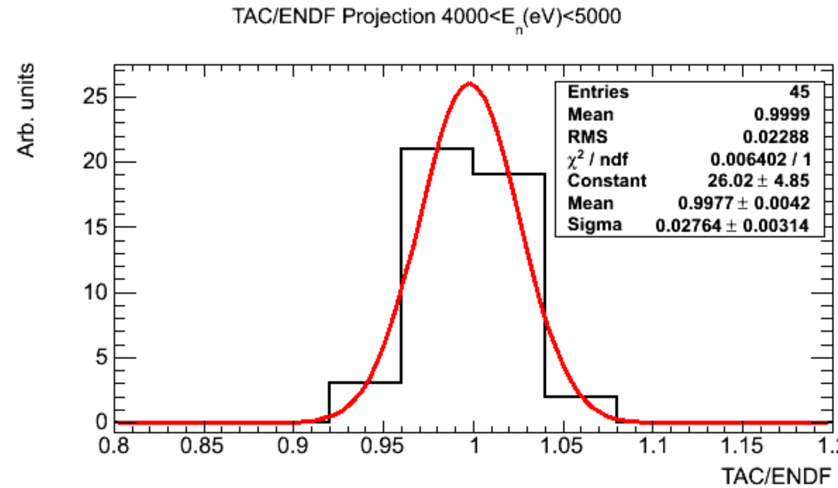

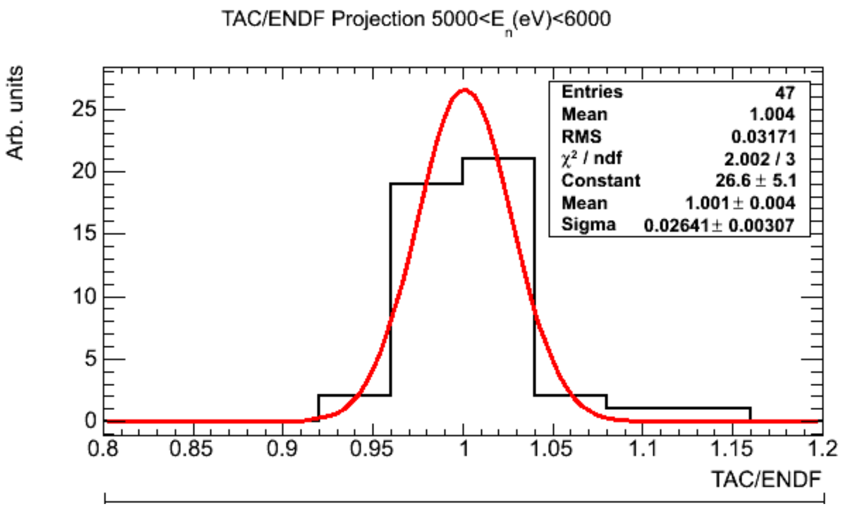

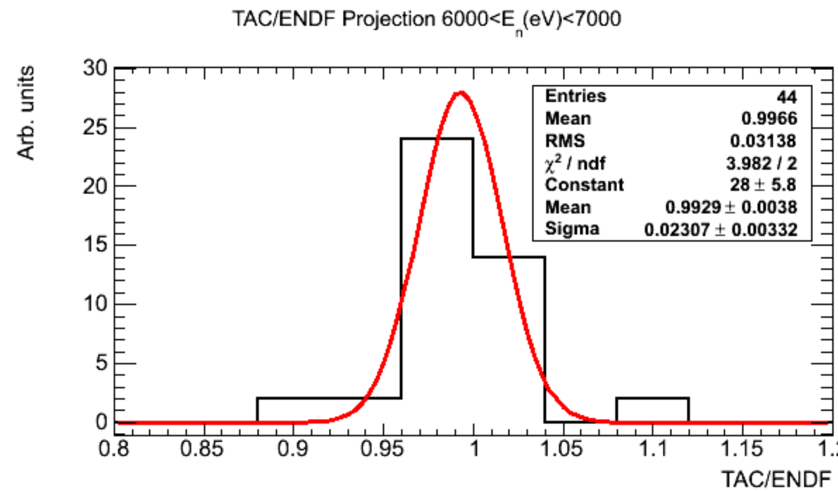

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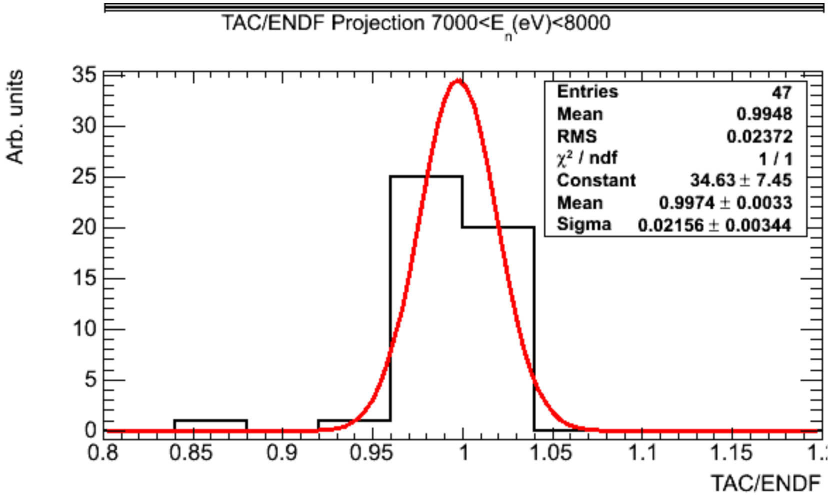
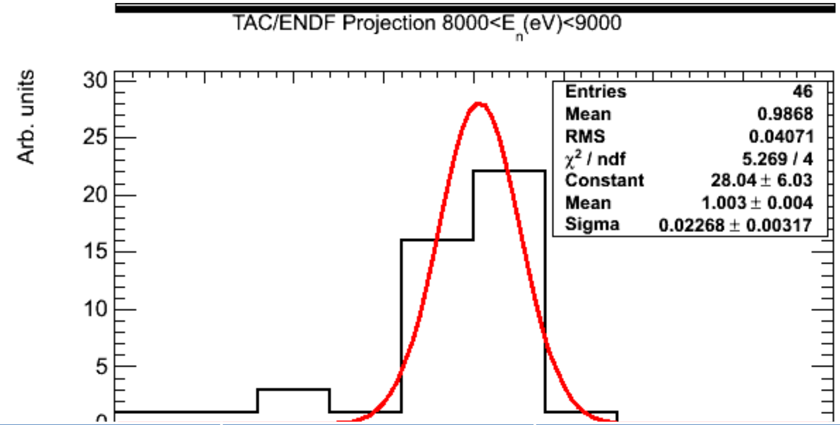
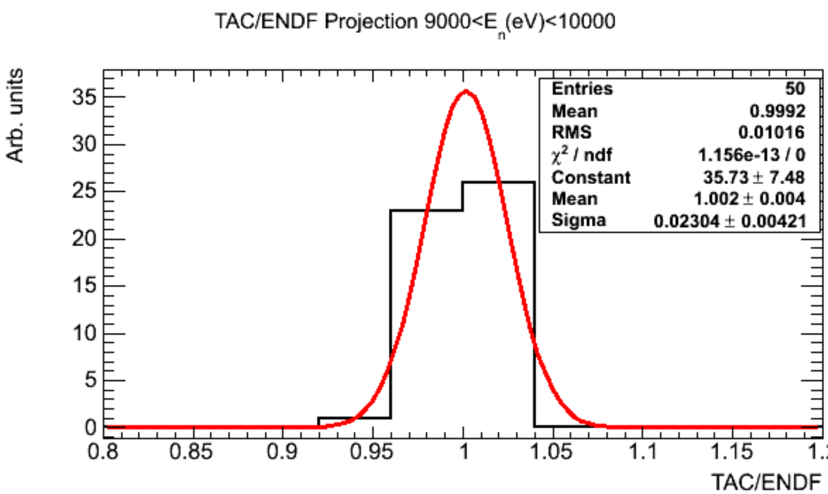
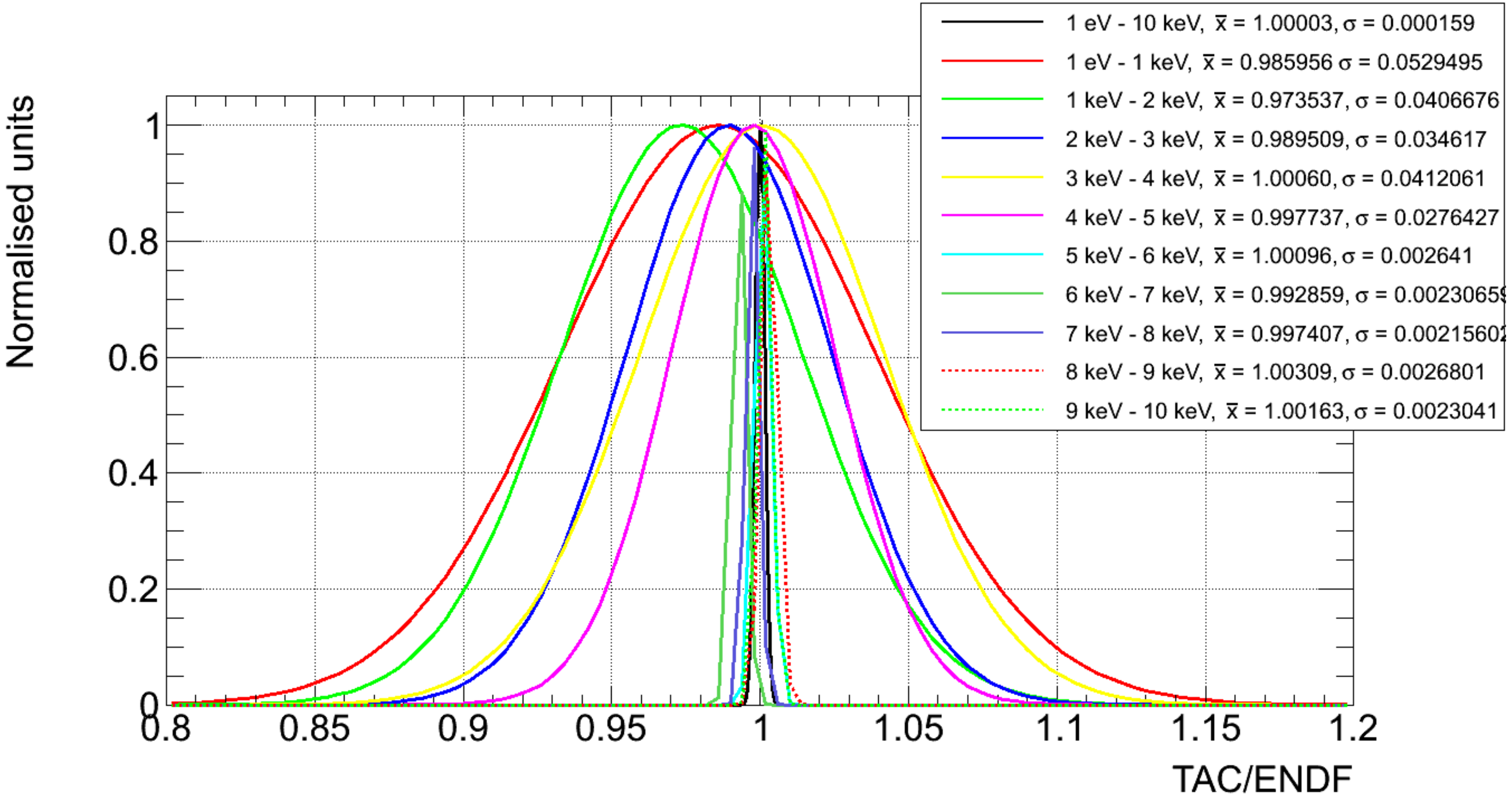




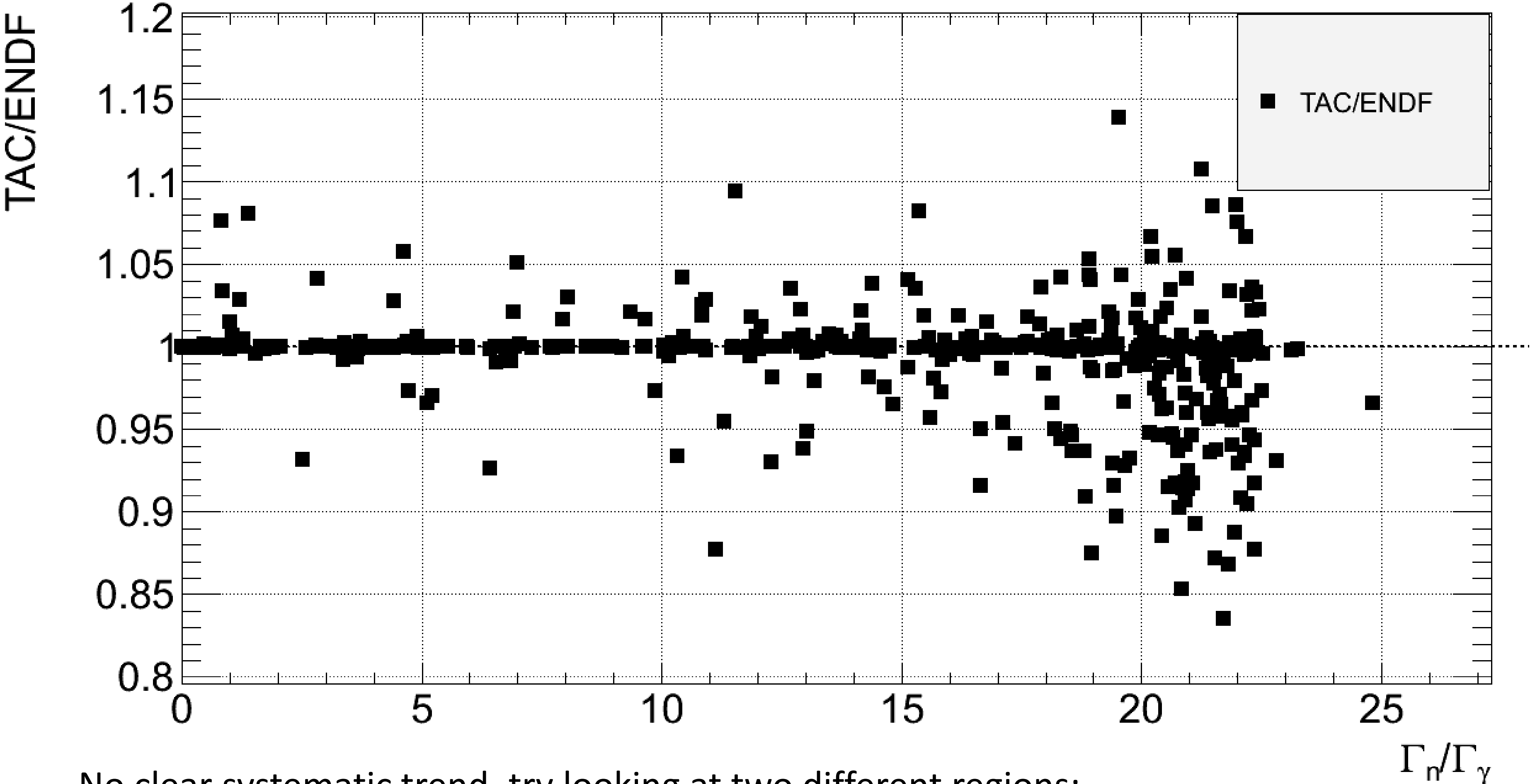


Energy range (eV)	Mean	Sigma
All	1.000	0.00159
1-1000	0.986	0.0529
1000-2000	0.974	0.0407
2000-3000	0.990	0.0346
3000-4000	0.998	0.0412
4000-5000	1.001	0.02764
5000-6000	0.993	0.002641

Fitted Gaussians

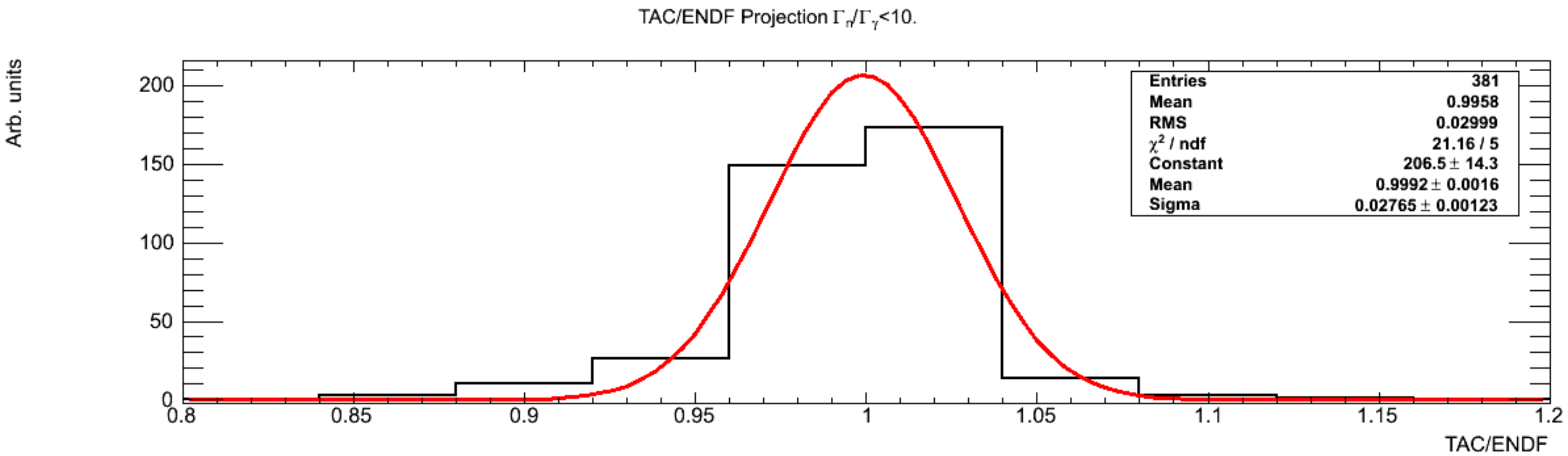


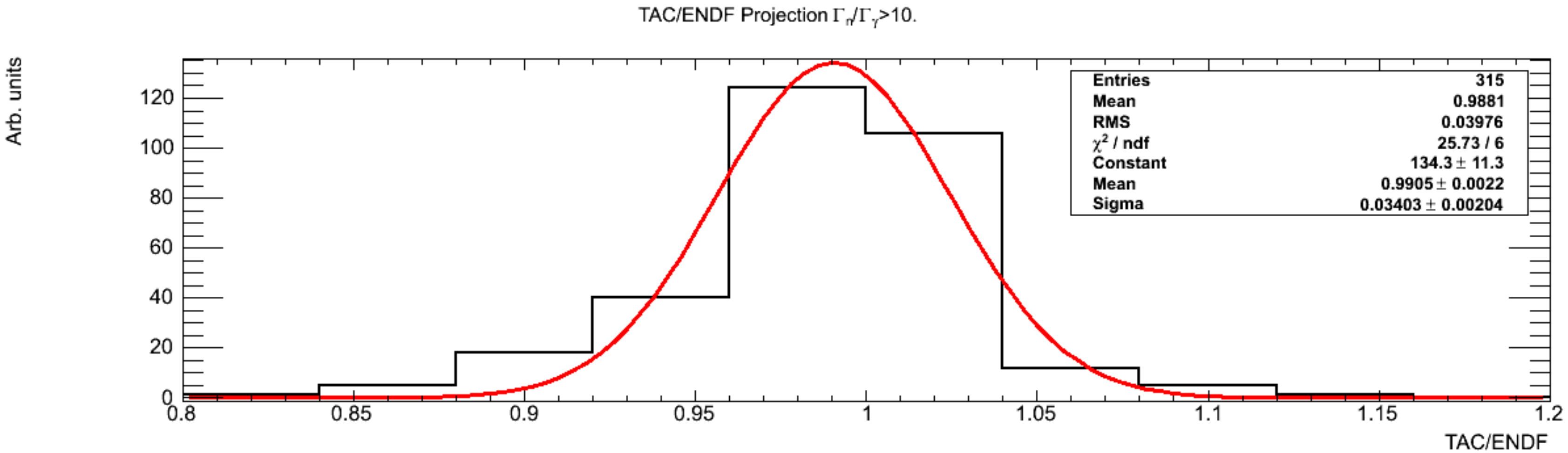
Kernel scattering comparison



No clear systematic trend, try looking at two different regions:
high scattering and low scattering

Projections





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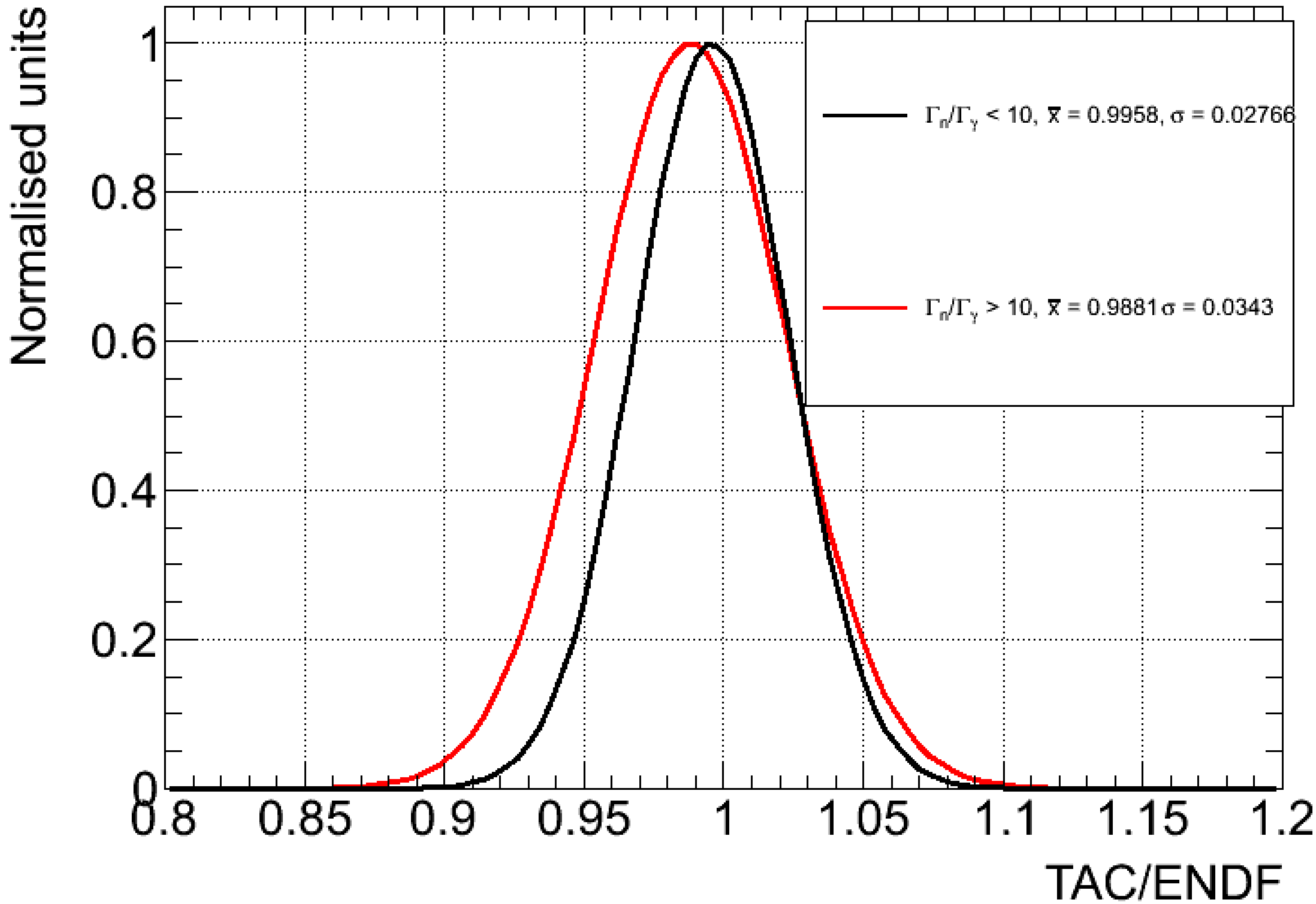

Conclusions

Dead-time and pile-up effects have been minimised and corrected for.

A combination of low pulse intensity and an innovative dead time correction method have been implemented to deal with this issue.

Normalisation to the first resonance must be accurate within 1%.

The first resonance is now fitted much better, and the normalisation to the first three resonances all agrees within 1 % giving confidence to this issue.

Final uncertainty of this individual measurement should be no larger than 3% up to 10 keV

This is achievable, the uncertainties related to each individual step in the analysis can be found in the ANDES report

Statistics must be sufficient

By choosing appropriate binning this is achieved

The TAC and C_6D_6 data sets should be compared in depth

This shall be done in the immediate future

The intial comparison with ENDF looks promising – the date should be useful in the upcoming ^{238}U evaluation as part of CIELO