Karlsruher Institut für Technologie

Update on MMC analysis

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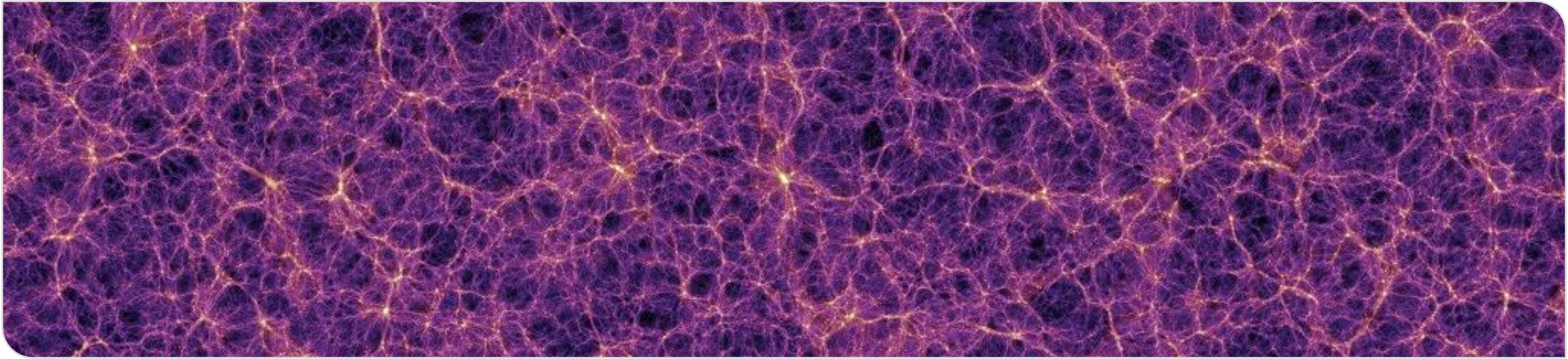
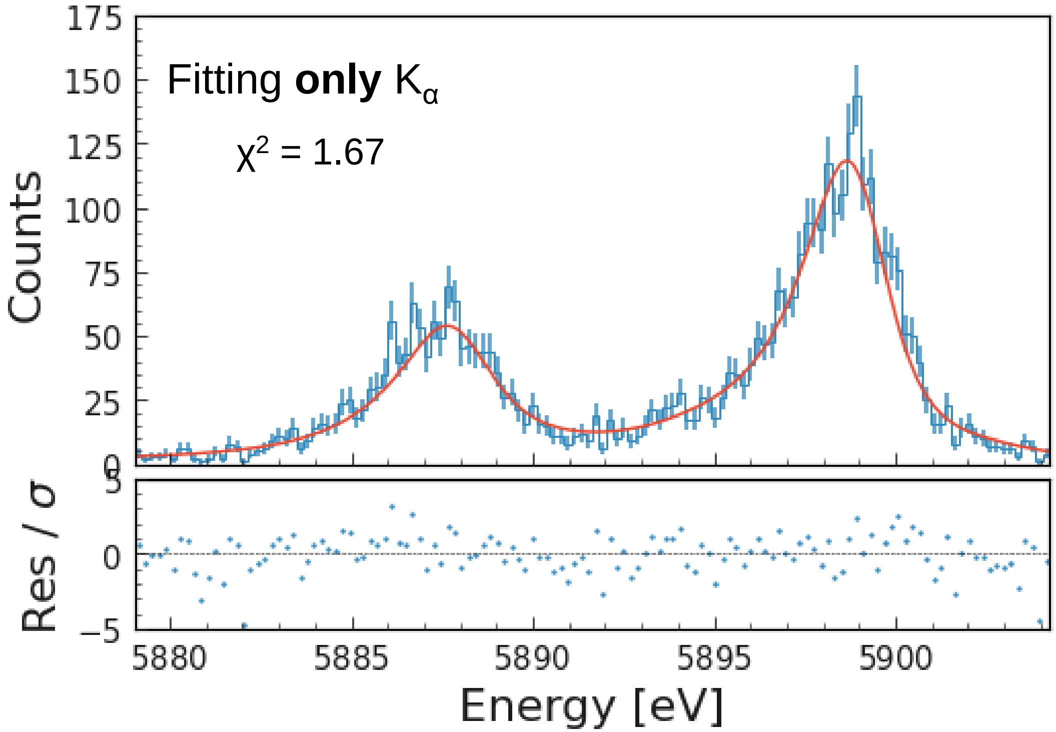
DELight meeting, 08.08.2023

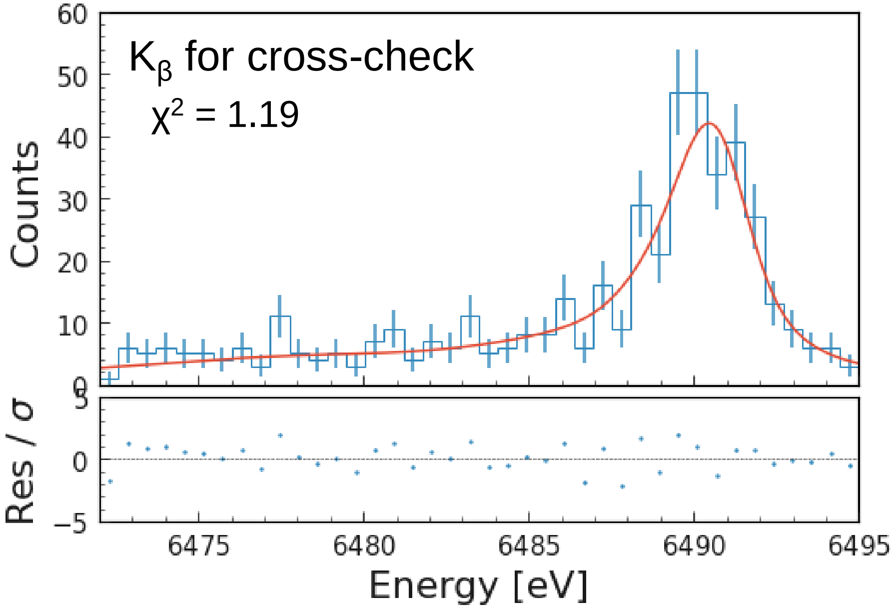


Where were we?

- Athermal phonons escape modeled as error function
- Minimizing chi-square with binned fit

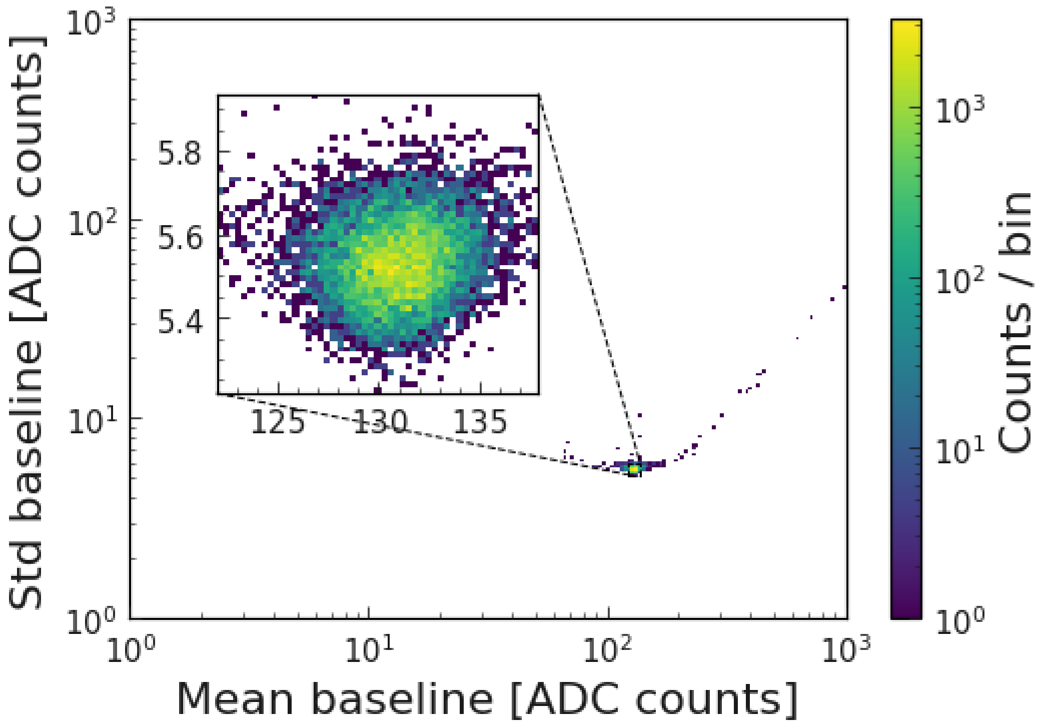


FWHM = **(1.242 ± 0.152) eV**



Optimization of cuts

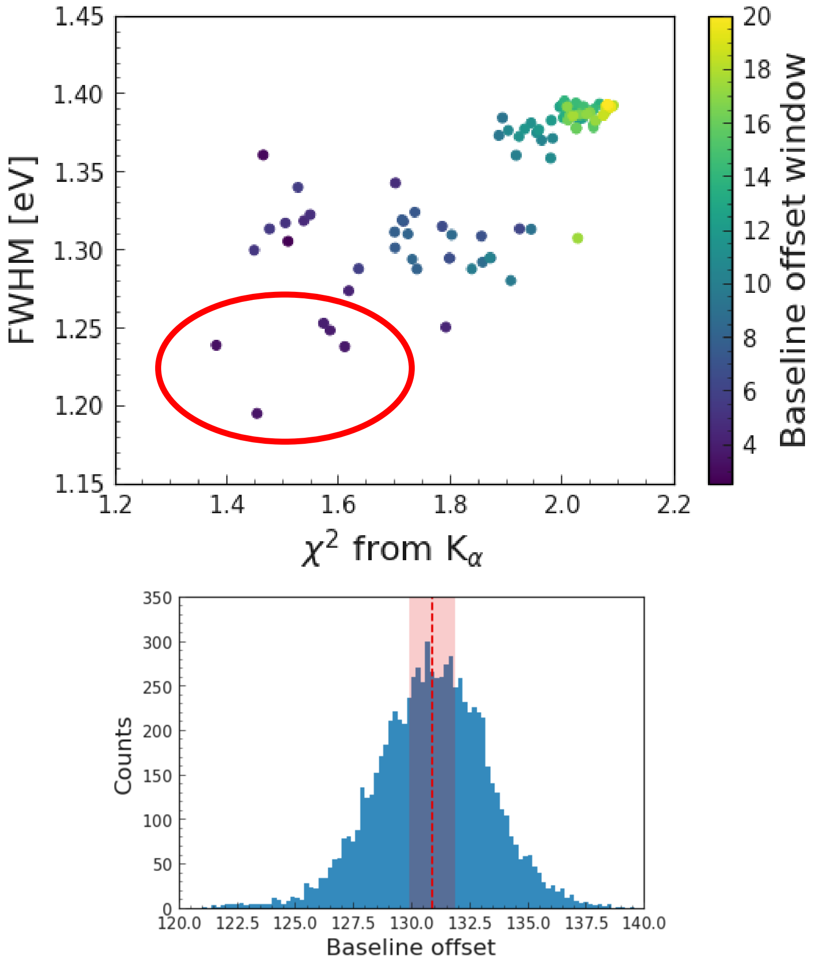
- *„Basic" cuts* throwing away very bad traces,
- *Quality cuts* selecting best traces based on baseline.




```
mask_mean_baseline = df['mean_baseline'] < 138 #132.45
mask_mean_baseline &= df['mean_baseline'] > 122 #129.6
mask_baseline_offset = df['baseline_offset'] > 129
mask_baseline_offset &= df['baseline_offset'] < 133
mask_std_baseline = df['std_baseline'] < 6
mask_temperature = df['temperature'] > 3e4
mask_amplitude = (df['OF_ampl_0'] > 0)&(df['OF_ampl_1'] > 0)
mask_mean = df['mean'] < 20000
mask_chi2_TF = df['TF_chi2'] < 1000
mask_rise_time = df['rise_time'] > 0.00001
```

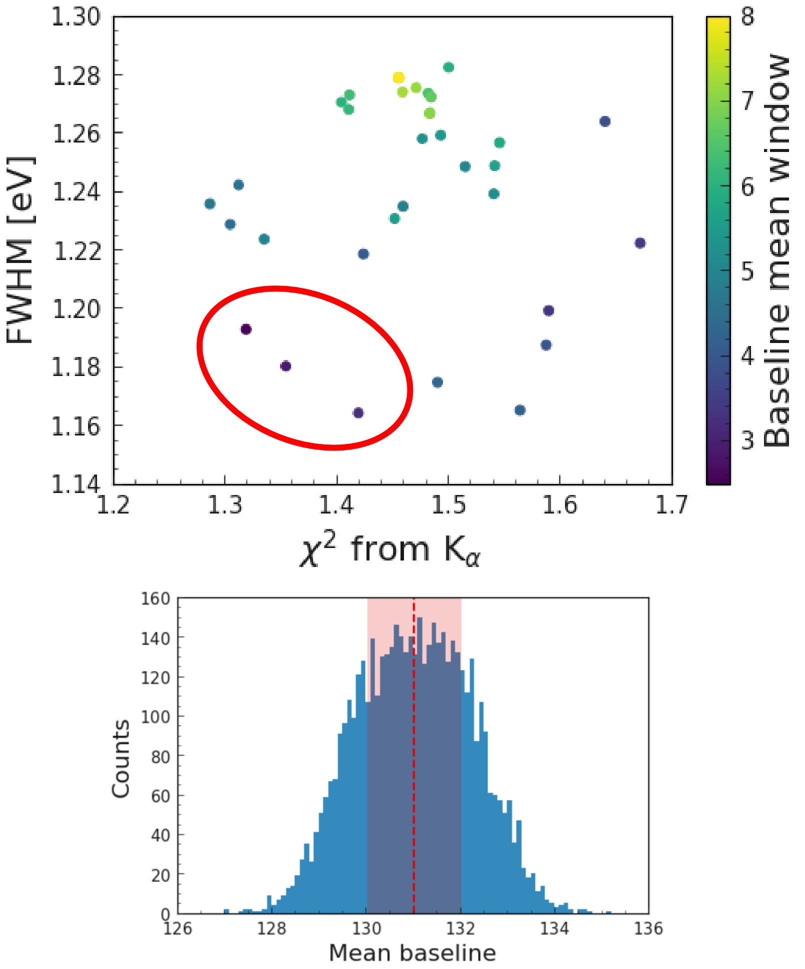
Optimization of cuts

Baseline offset
(already optimized by Benedikt)

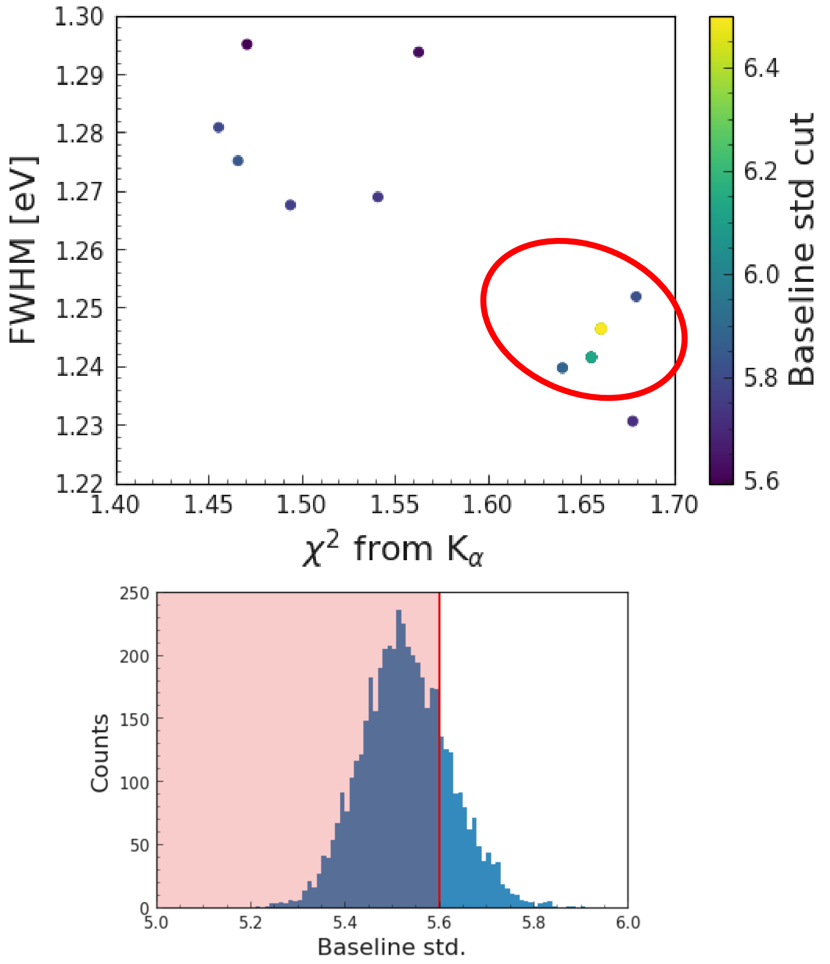


[129.6, 132.45]

Baseline mean



Baseline standard dev.



Fit systematics

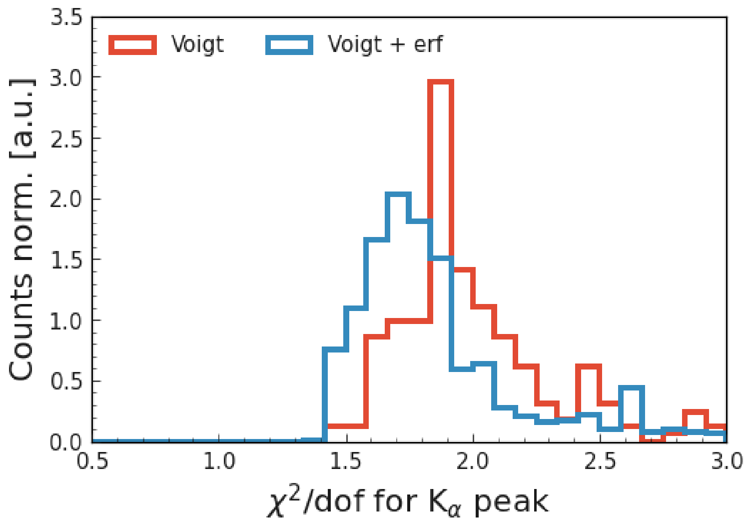
- Checking the fit for different initial values and binning → **systematics**
  - Define 2000 initial values (distribution based on experience)

```
ESC_K = np.random.uniform(0, 0.15, N_params)
KAs = np.random.uniform(6, 15, N_params)
SIGMA_0 = np.random.uniform(0.1, 0.7, N_params)
E2s = np.random.normal(3.26315e-06, 2e-6, N_params)
E1s = np.random.normal(0.532509, 0.3, N_params)
```

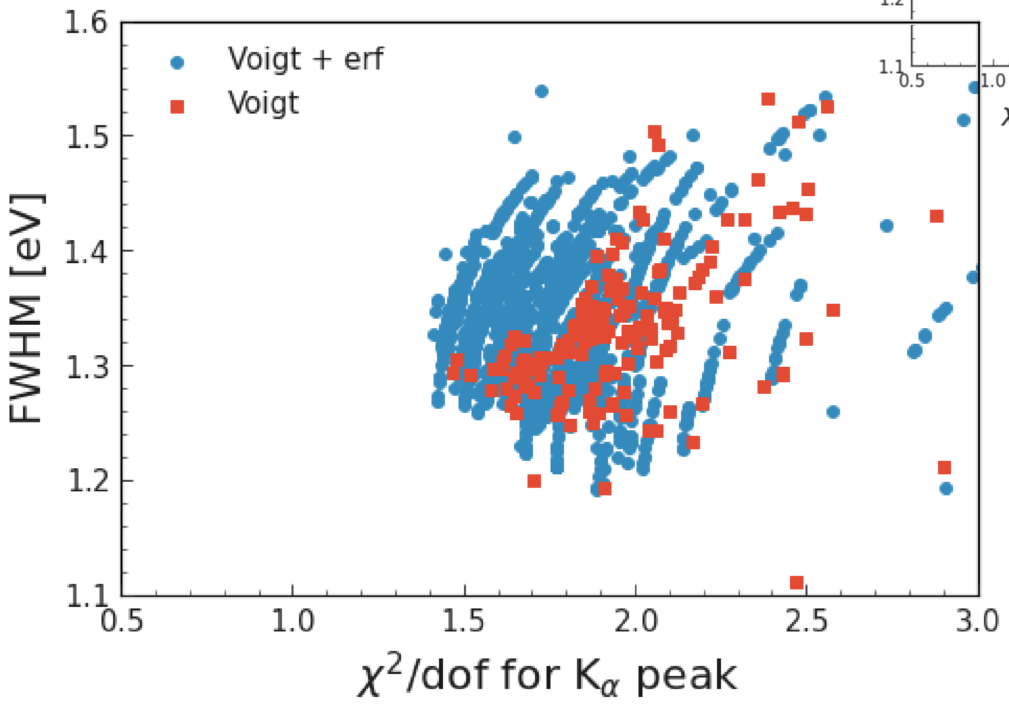
  - Minimize chi-square of K_α using different binnings
  - Estimate chi-square of K_β
  - Repeat for:
    - looser and tighter cuts of *mean_baseline*
    - fit with and without escaping factor

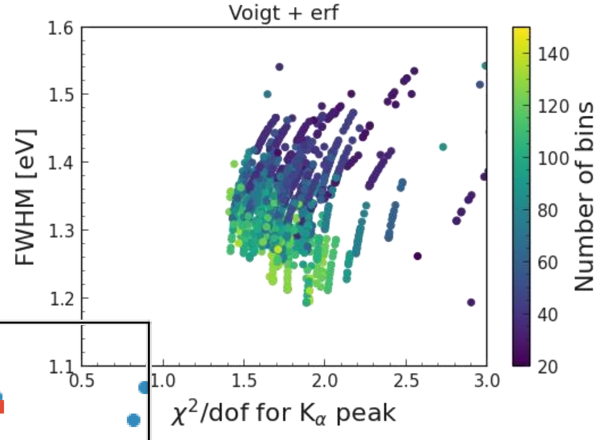
Fit systematics – loose cut

How many fits failed?	Voigt (w/o escape)	Voigt + erf (w/ escape)
Acceptance	0.37%	1.91%



χ^2 preference for Voigt+erf





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How many fits failed?	Voigt (w/o escape)	Voigt + erf (w/ escape)
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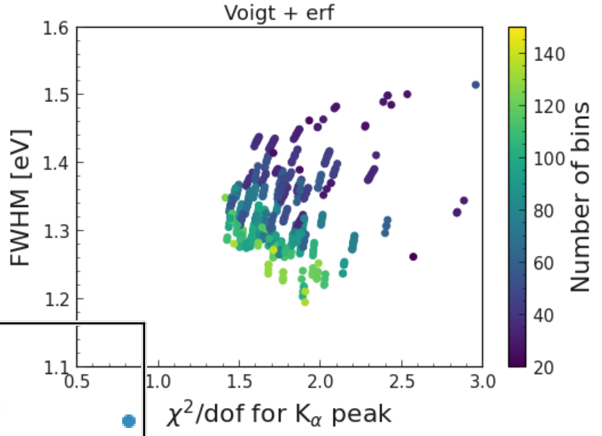
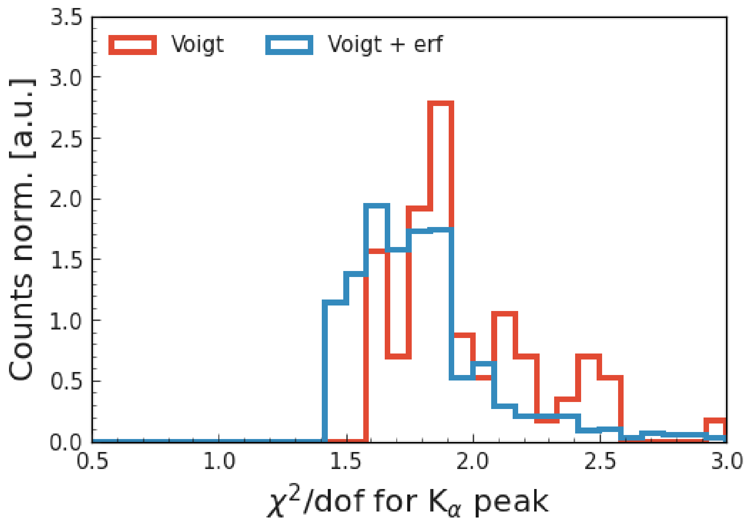
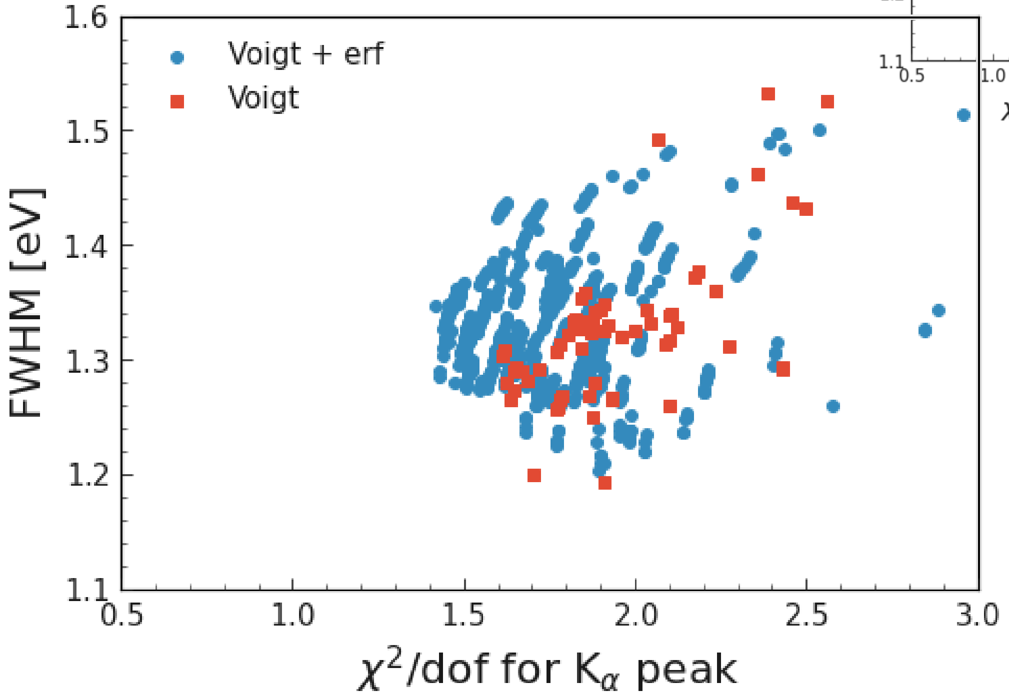




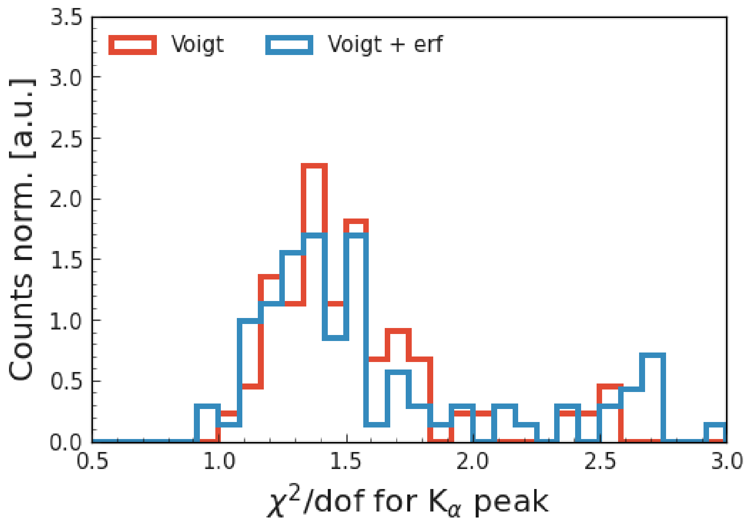


χ^2 preference for Voigt+erf

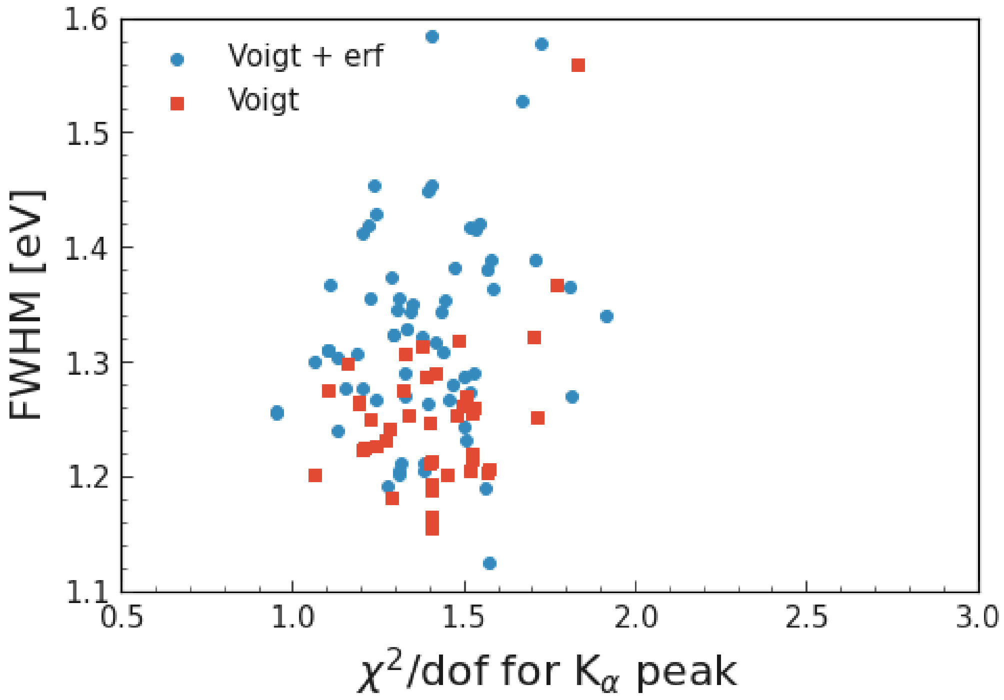
⚠ $\chi_\beta^2/\mathrm{dof} < 2$

Fit systematics – tight cut

How many fits failed?	Voigt (w/o escape)	Voigt + erf (w/ escape)
Acceptance	0.31%	0.34%



No clear preference:
losing statistics, losing information?



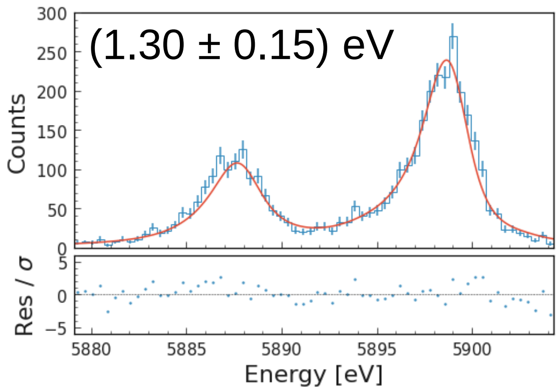
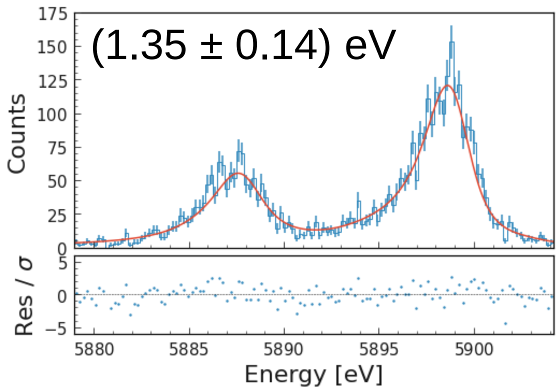
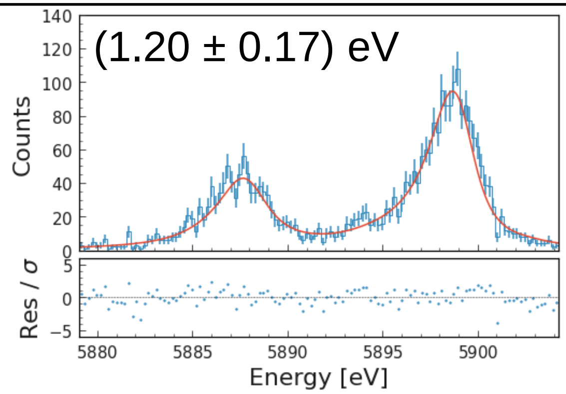
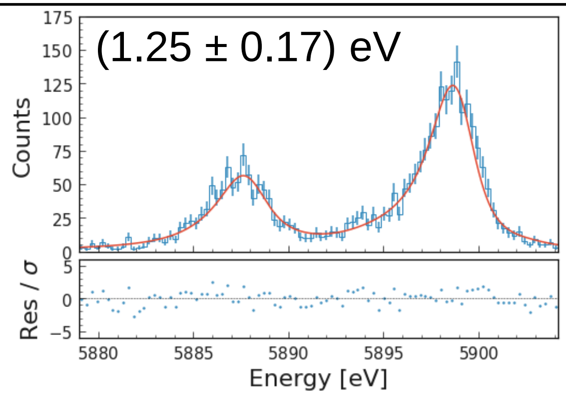
⚠ χ_β^2/dof < 2

Picking minimum chi-square

$\chi_\beta^2/\mathrm{dof} < 2$

ATHERMAL PHONONS ESCAPE

THERMAL FLUCTUATIONS

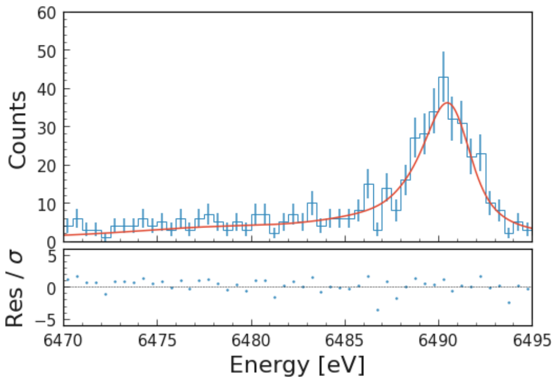
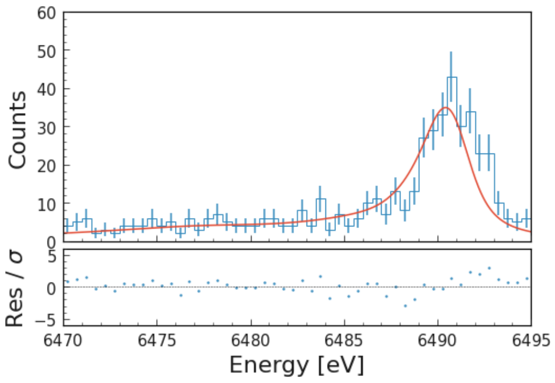
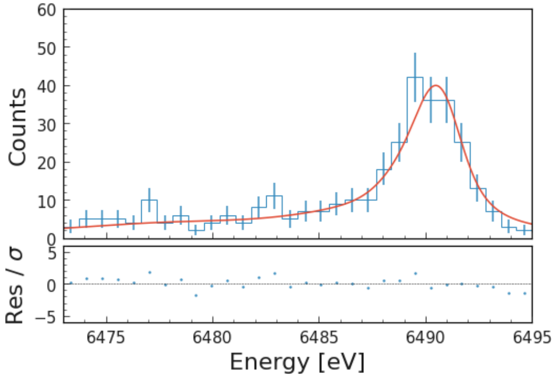
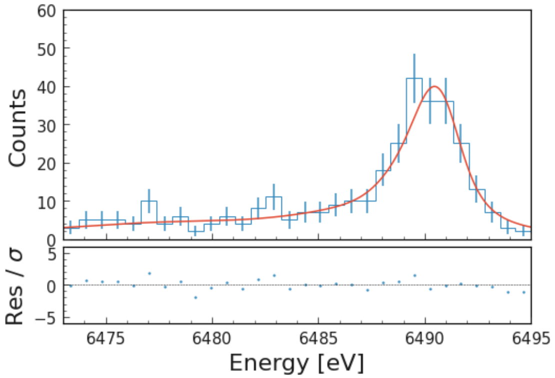
	Voigt		Voigt + erf	
Loose cut		$\chi^2 = 1.61$		$\chi^2 = 1.42$
Tight cut		$\chi^2 = 1.06$		$\chi^2 = 0.95$

Picking minimum chi-square

⚠ $\chi_\beta^2/\text{dof} < 2$

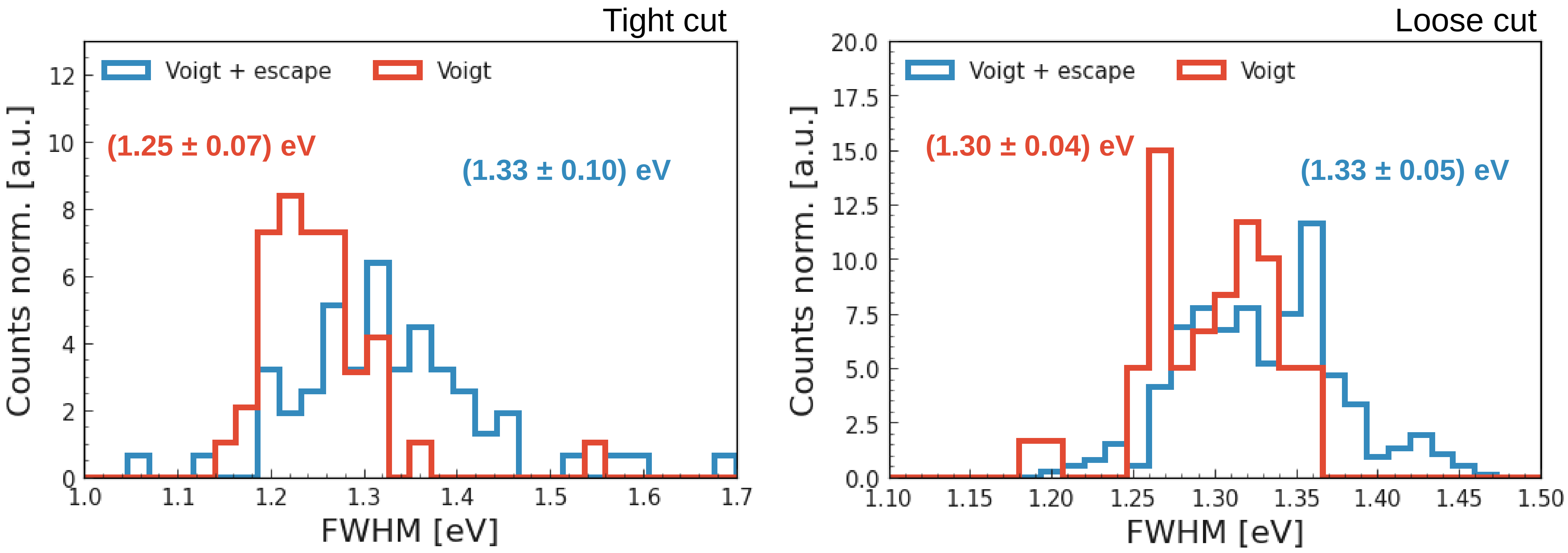
ATHERMAL PHONONS ESCAPE

THERMAL FLUCTUATIONS

	Voigt		Voigt + erf	
Loose cut		$\chi^2 = 1.19$		$\chi^2 = 1.27$
Tight cut		$\chi^2 = 0.78$		$\chi^2 = 0.66$

FWHM distribution

- χ_β^2/dof < 2 and χ_α^2/dof < 2 (similar results with stricter χ_β^2/dof < 1.2)



Baseline resolution

- After talking with Sebastian, he pointed that it is possible to calculate the optimal energy resolution for a given OF (<u>thermal equilibrium</u>).

Time domain

$$S(t) = aA(t) + n(t)$$

Frequency domain

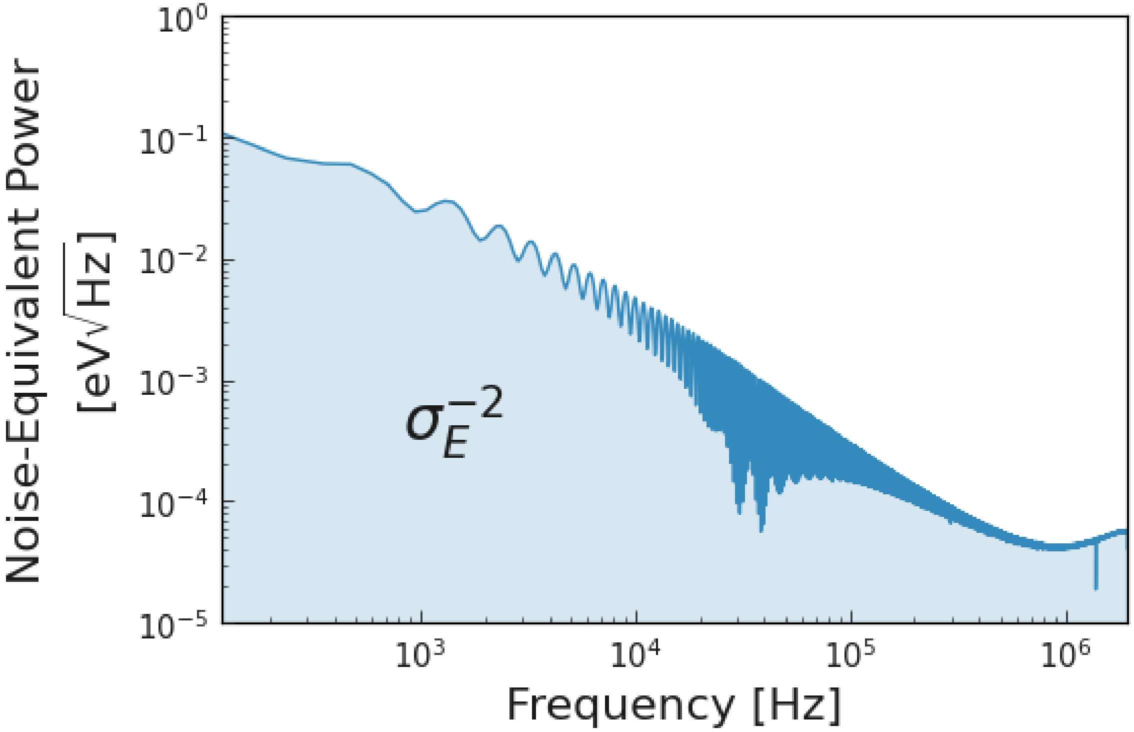
$$\tilde{S}(\omega) = a\tilde{A}(\omega) + \tilde{n}(\omega)$$

Optimum Filter

$$\chi^2 = \sum_n \frac{\left(\tilde{S}_n - a\tilde{A}_n\right)^2}{J_n}, \text{ where } J_n = \langle \tilde{n}_n^2 \rangle$$

$$\frac{\partial \chi^2}{\partial a} = 0 \rightarrow \hat{a} = \frac{\sum_n \frac{\tilde{A}_n^* \tilde{S}_n}{J_n}}{\sum_n \frac{|\tilde{A}_n|^2}{J_n}}$$

$$\sigma_a^2 = -\frac{1}{2}\left(\frac{\partial^2 \chi^2}{\partial a^2}\right)^{-1} = \left(\sum_n \frac{|\tilde{S}_n|^2}{J_n}\right)^{-1}$$



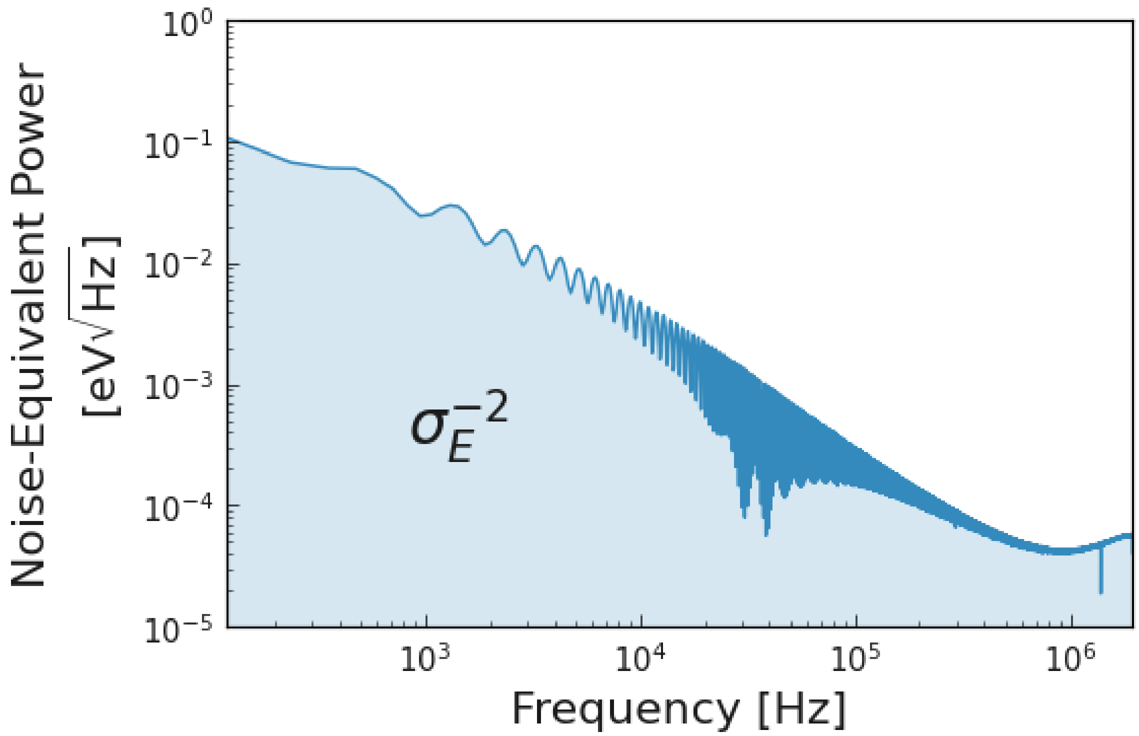
Baseline resolution

- After talking with Sebastian, he pointed that it is possible to calculate the optimal energy resolution for a given OF (<u>thermal equilibrium</u>).

ΔE_{FWHM} = 1.09 eV

- Based on Krantz thesis, the theoretical resolution is 0.64 eV (FWHM), but no active temperature stabilization during data taking (T ~ 7 mK), hence possible impact of temperature fluctuations.

- Considering a noise PSD + template using the same cut, we get same resolution → maybe T fluctuations do not impact PSD/templ.?



Summary of discussion with Sebastian

- Tighter baseline = less temperature fluctuations
  - This indicates that we are affected by T fluctuations
  - We cannot distinguish between athermal phonons escaping and T fluctuations, indeed chi-square shows no preference between the two models

- For the paper show the entire story (different fits with different cuts), as it shows that we are affected by T fluctuations
  - For DELight we need to have better temperature control/stability

Back-up slides

Correlation FWHM – esc_k