Optimization of conversion factors

Calculation of the dose

Given a matrix $\hat{N}$ containing taken energy spectra for a source emitting a certain dose as their rows. Each row consists of 16 bins where the histogram itself was made by previously specified bin edges (see section 'Optimization of bin edges').

The doses $\vec{D}$ for all spectra are calculated from the measured data $\hat{N}$ using a set of conversion factors $\vec{\alpha}$ via

$$\vec{D} = \hat{N} \cdot \vec{\alpha}.$$

EPD vs. Dosepix (Thilo)

$\vec{\alpha}$ was fitted using simulations made by Thilo (see file and table below for conversion factors). Notice that Slot 1 is free field, Slot 2 is aluminium (Al) and Slot 3 is tin (Sn).

Slot 1	Slot 2	Slot 3
0.002171	0.007387	0.000285
0.002262	0.005770	-0.001509
0.002392	0.002779	-0.001899
0.001639	0.003638	-0.000502
0.000773	0.002092	-0.000011
0.001357	0.001789	0.001386
0.000683	0.001132	0.002413
0.000445	0.000682	0.001704
0.000182	0.000377	0.001879
0.000101	0.000358	0.001899
0.000034	0.000223	0.001869
0.000027	0.000182	0.001653
0.000024	0.000145	0.001263
0.000024	0.000137	0.000992
0.000029	0.000113	0.000967
0.000018	0.000341	0.000757

Keep in mind that the fit itself also took negative factors into consideration (unphysical, since in extreme cases the resulting dose might be negative).

Measurements with the EPD were taken and its dose is set as reference. The dose ratio $R_i = \frac{D_{\text{DPX},i}}{D_{\text{EPD},i}}$ was optimized where $R_i = 1$ is the best value to be achieved. Here, $\vec{\alpha}$ is used as start parameter $\vec{p}$ for the fit. At the same time, the parameter boundaries are set to $\vec{p}_{\text{low},i}, \vec{p}_{\text{high},i} = (f \cdot \alpha_i, (1 + (1 - f)) \cdot \alpha_i)$, where f is a factor between 0.5 and 1. This is set to only slightly vary the values of $\vec{\alpha}$ instead of performing a free fit as the initial $\vec{\alpha}$ was determined by simulations. If α_i is negative, the boundaries are set to $\vec{p}_{\text{low},i}, \vec{p}_{\text{high},i} = (0, \infty)$. This in the end results in the execution of a NNLS (**N**on **N**egative **L**east **S**quares) fit.

Fit w/o error

The fit optimizes

$$\|\hat{N} \cdot \alpha - \vec{D}_{\text{EPD}}\|.$$

The error of $\hat{N}$ is not considered during the fit. The resulting curves for differnt values of f are shown in the figure below. Here, the dose ratio R_i is shown as a function of the mean energy E_i. The resulting conversion factors for $f = 0.9$ can be found here.

Fit of conversion factors to measured data using different factors of f.
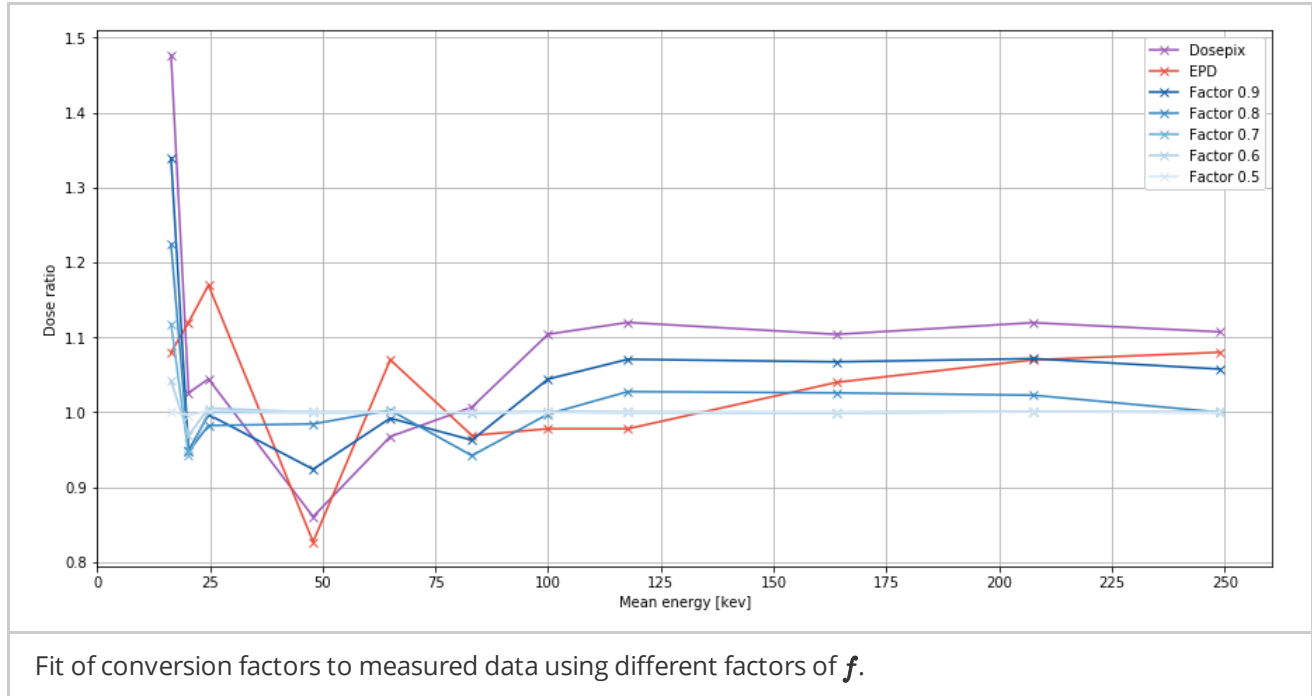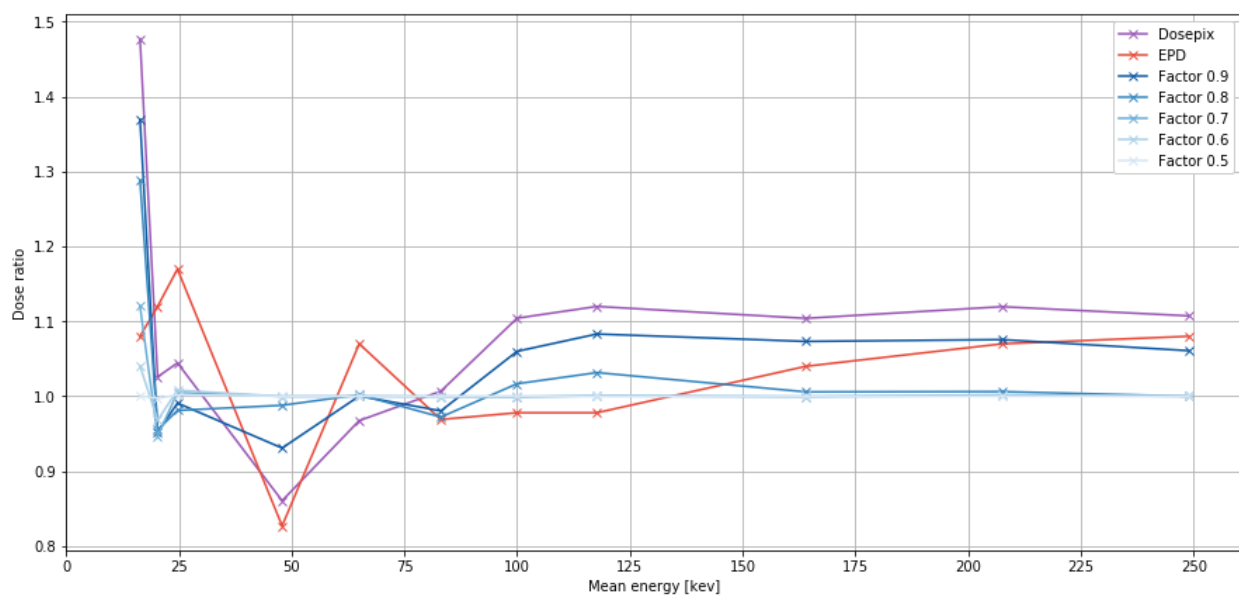
Fit w error

The fit considers the error of $\hat{N}$ and optimizes

$$\left\|\frac{1}{\Delta \alpha_j} (N_{ij} \cdot \alpha_j - \vec{D}_{\text{EPD},j})\right\|$$

with

$$\Delta \alpha_i = \sqrt{\Delta N_{ij}^2 \cdot \alpha_j^2},$$
$$\Delta N_{ij} = \sqrt{N_{ij}}.$$

Fit of conversion factors to measured data using different factors of f under the consideration of errors of $\hat{N}$.

Fit with new $\vec{\alpha}$

A new fit was performed using the energy spectra from Thilo's simulation while leaving the values of the bin edges as they were. Now, a NNLS is used so $\alpha_i \geq 0$ is guaranteed.

The resulting $\vec{\alpha}$ (see file) can be further optimized by performing fits under the consideration of errors.
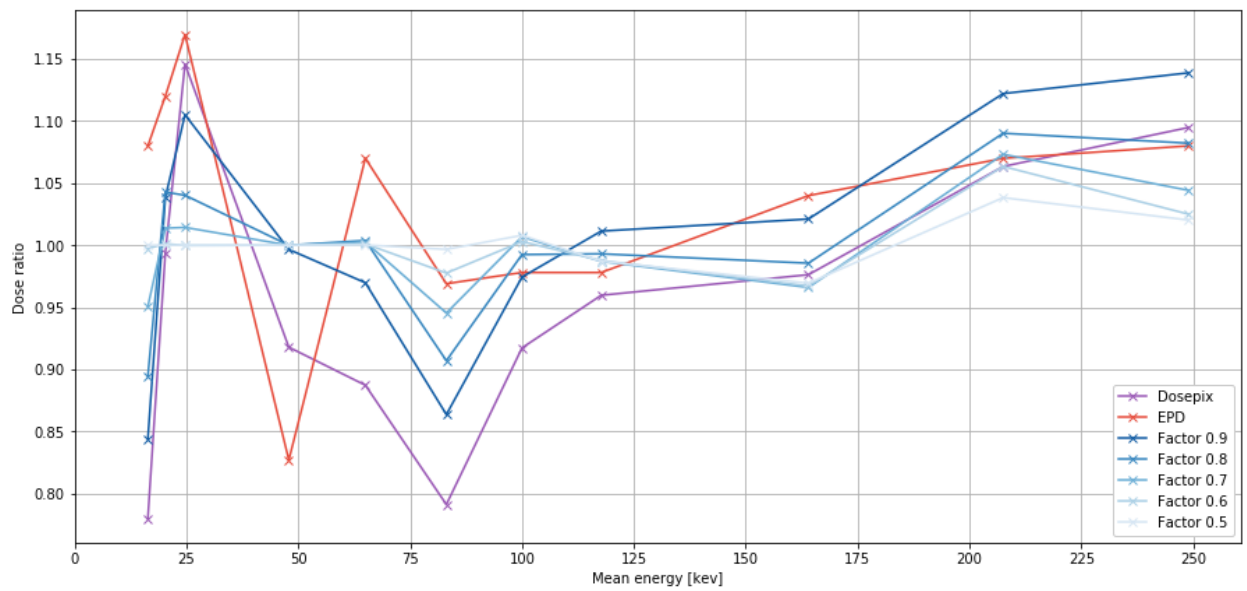
Fit of conversion factors to measured data using the $\vec{\alpha}$ estimated by a NNLS fit.

Optimization of bin edges

Definition of χ^2

Here, χ^2 is specified as follows:

$$\chi^2 = \sum_i (\hat{N} \cdot \alpha - \vec{D})^2$$

In this case, $\vec{D}$ is a theoretical input value of the simulation which generates $\hat{N}$ accordingly.

Optimization method

Optimization results

- Using data of folder '*runs_combined*'
- Fluence was slightly corrected to

$$\phi = \frac{1}{0.9} \cdot 5 \cdot 400000 \cdot 1000.0 \cdot \frac{1}{30^2}$$

- Current value of chi-squared (neglecting σ_i):

$$\chi^2 = 6.202$$

Optimization via genetic algorithm with a starting population of 30, running for 100 generations.
Result:

$$\chi^2 = 2.075$$

Bin edges (file):

Slot 1	Slot 2	Slot 3
12.1	12.1	9.3
23.7	36.2	33.4
55.2	53.1	67.6
59.9	82.6	114.1
78.6	109.9	118.7
96.2	144.1	141.8
97.5	172.4	153.6
121.7	211.1	161.3
149.8	222.4	216.7
160.1	238.7	258.2
210.0	265.6	262.2
256.8	282.7	266.4
313.9	317.6	294.5
366.6	343.9	344.9
374.1	388.0	366.6
416.9	409.3	400.1
425.3	424.4	414.0

Final fitness: 2.085