Edge On Study

Dashboard

Is it possible to use the MD3 in edge on mode?

To compare the theoretical attenuation with the real data the theory model should combine:

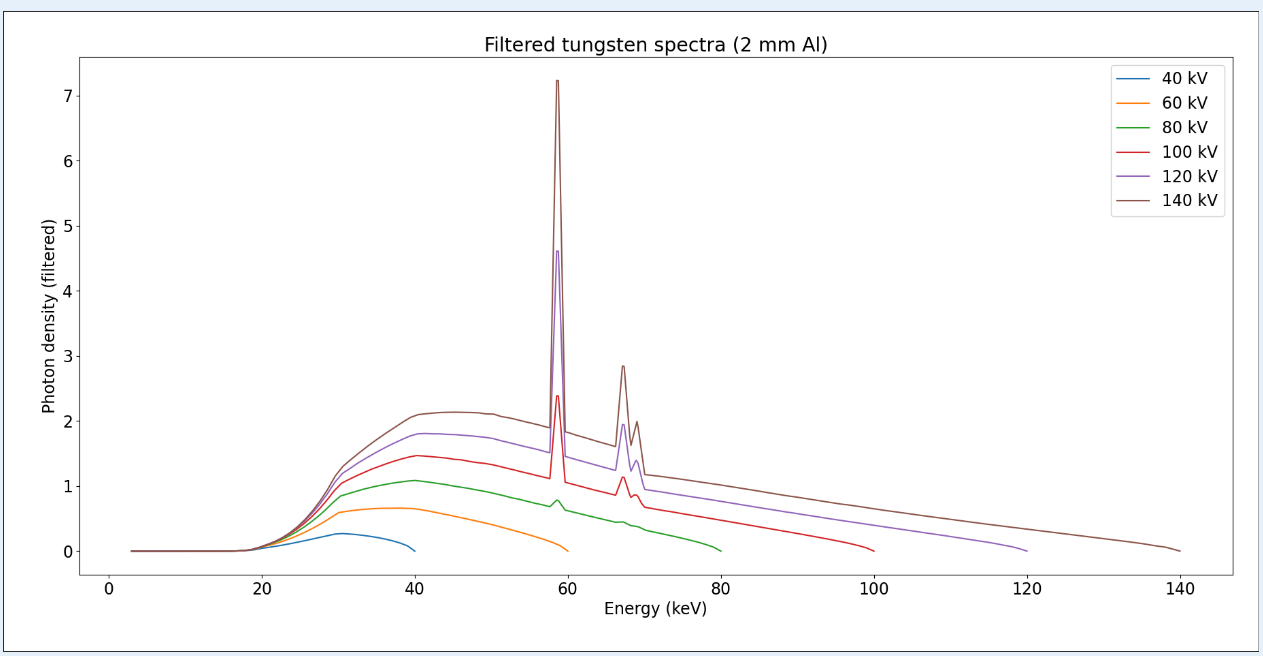
- Tungsten spectrum
- Attenuation of photons in aluminum filter
- Distance from the source
- Eventually a correction for the detector tilt

1. Evaluate the Spectra

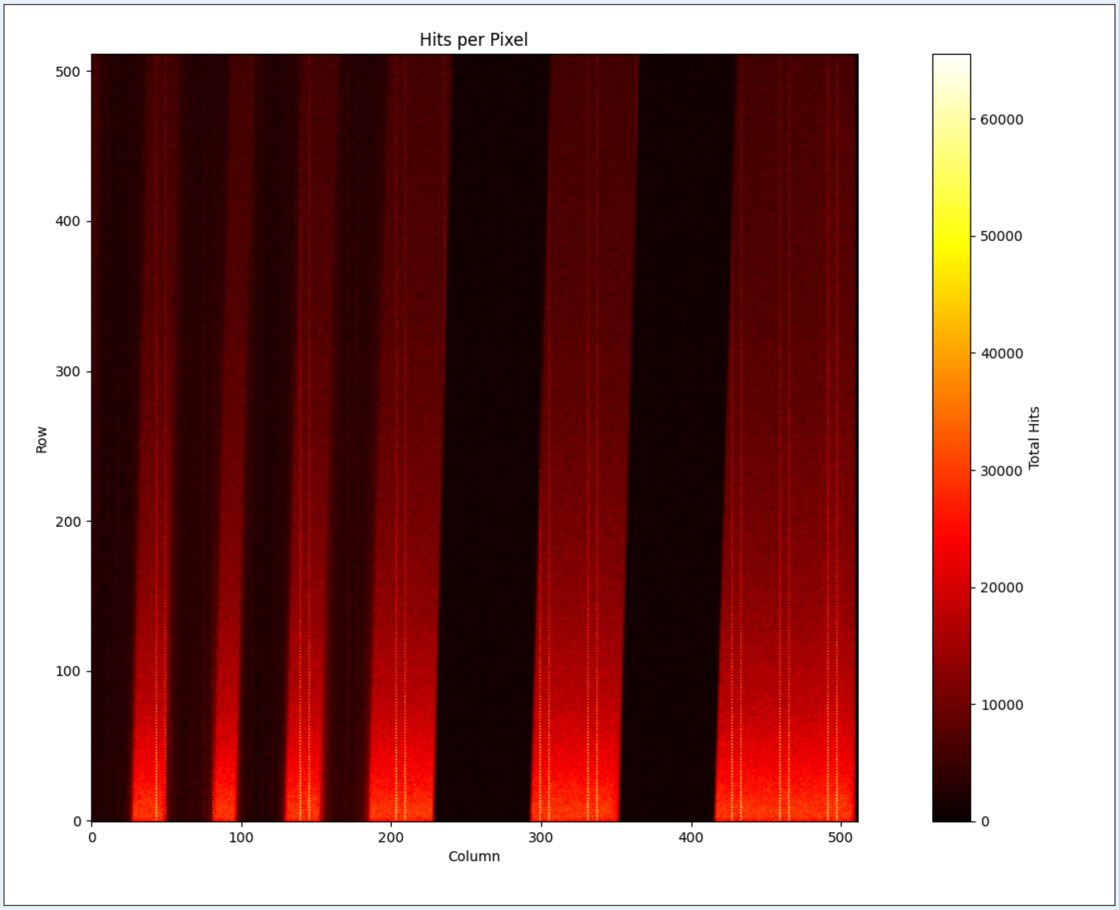
Input Data

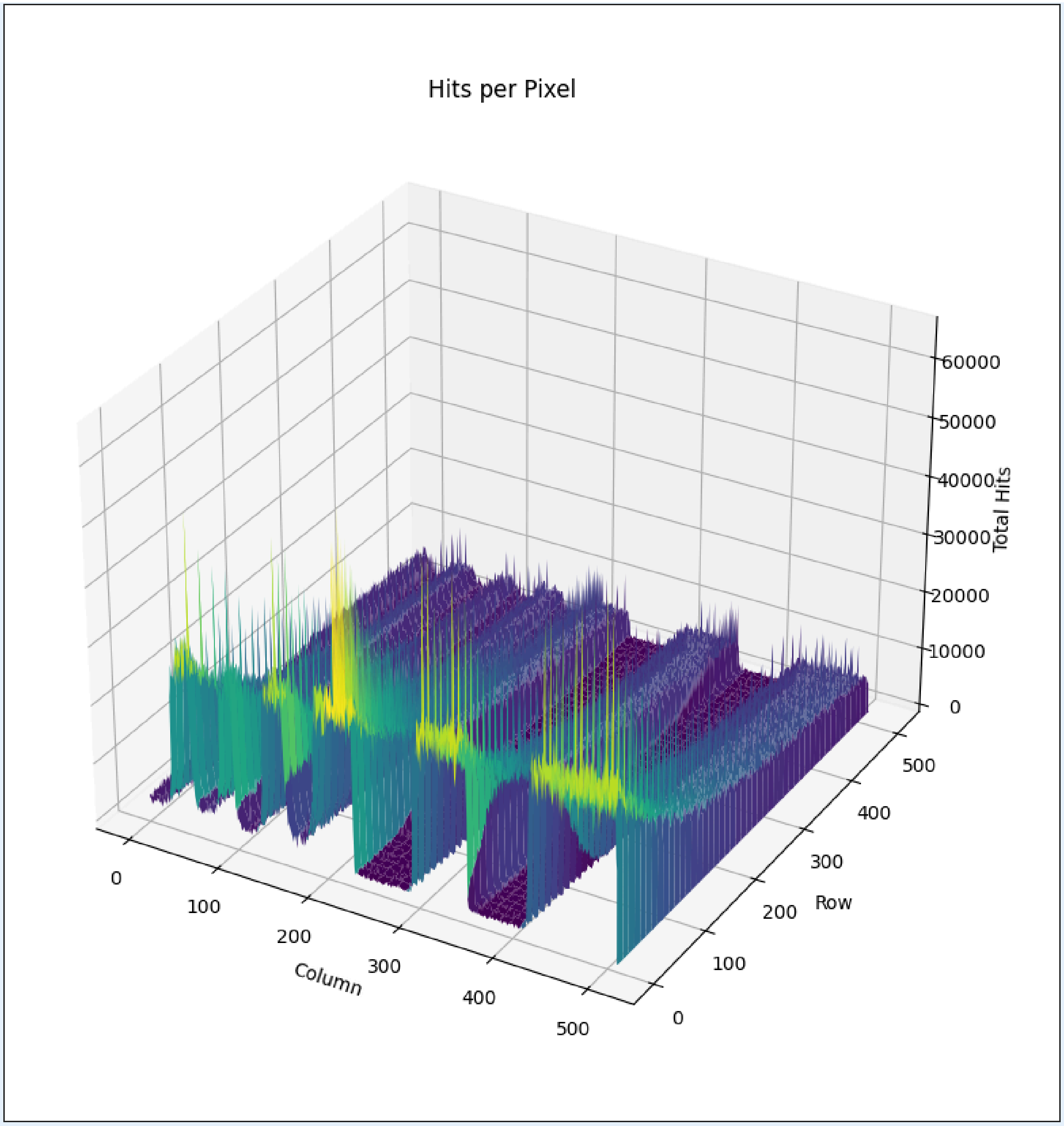
- NIST mass attenuation data for silicon (μ/ρ)
- Discretized tungsten X-ray emission spectrum (energy vs relative probability) (calculated with link accounting for a 2mm aluminum filter and 150 cm of air)

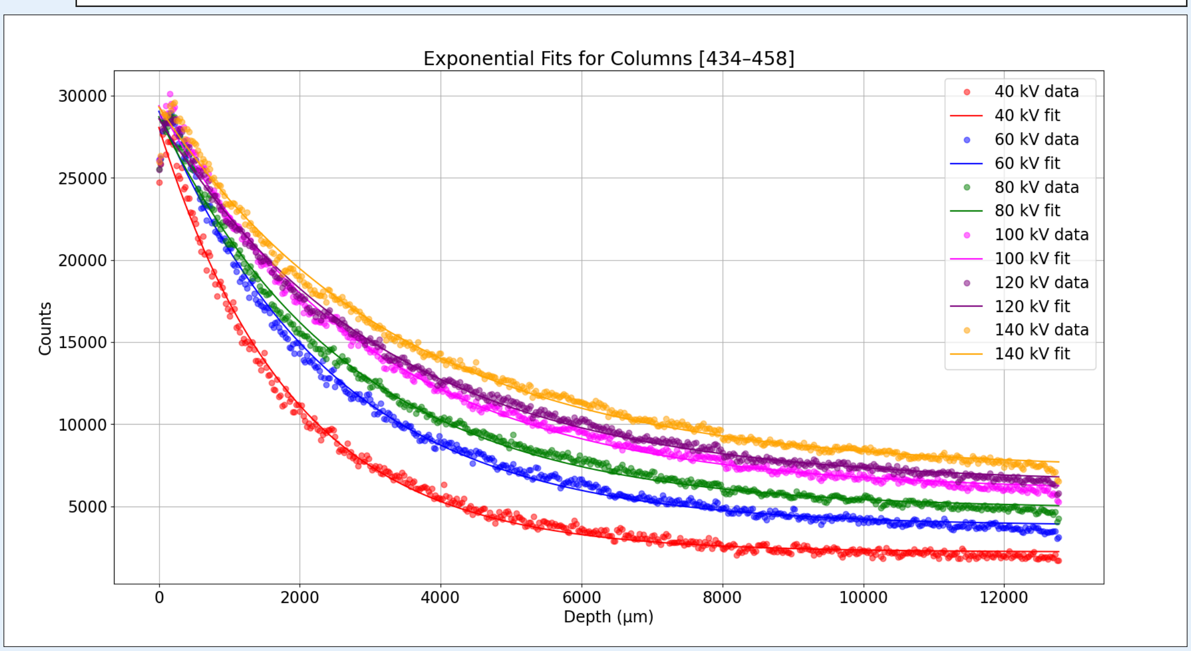
xpecgen



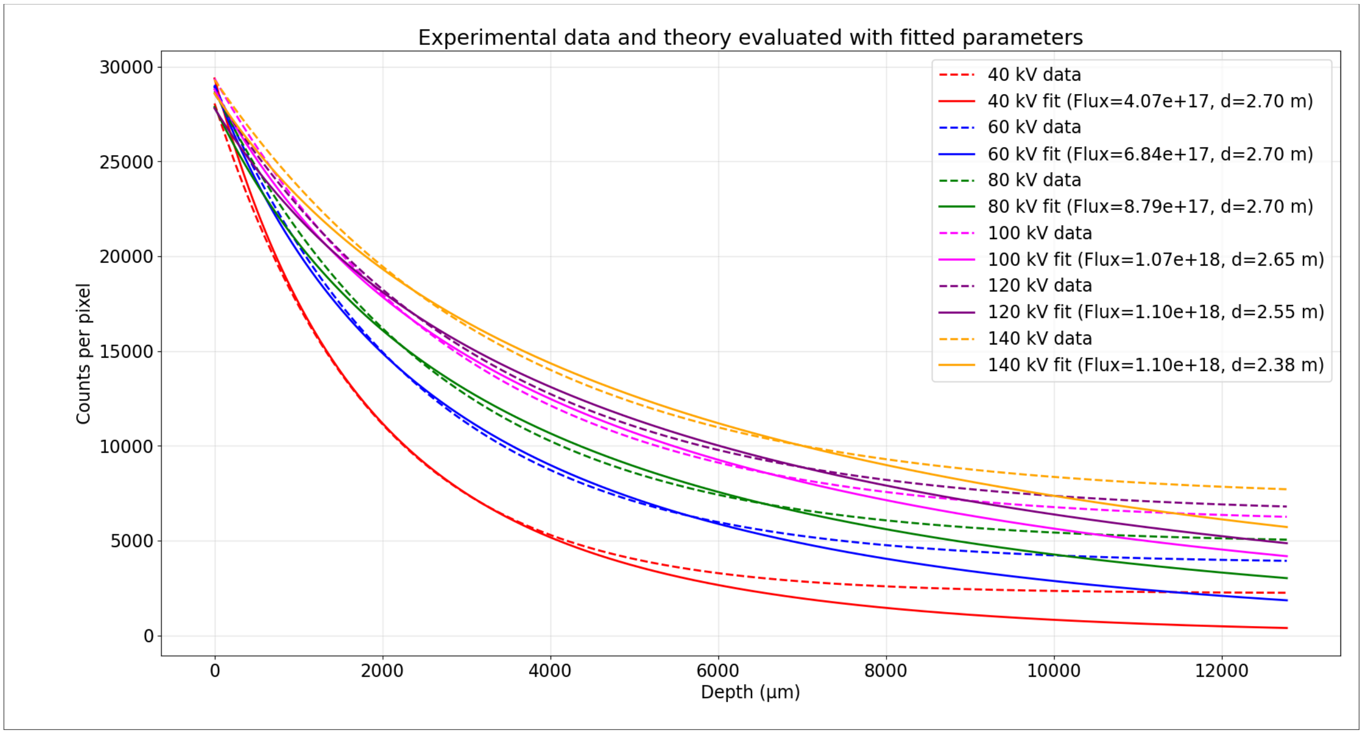
- Empirical fit parameter on the lab data (`a`,`b`,`c` $a \cdot exp(b \cdot x) + c$)

> **Data taken in lab**
>
> - Scan at multiple kVp [40, 140]kV
> - Current at 40uA
> - Mean of multiple illuminated columns
>   - avoided shadow areas in the matrix
>   - 
>





X-ray Absorption Fitting



The fit exponential curves from the lab data are now fitted with the expected trend from theory

Verify correctness

The initial photon flux emitted by the source:

$$\Phi_{\text{surface}}(E) = \Phi_{\text{source}} \cdot f(E)$$

- Φ_{source}: total flux
- $f(E)$: normalized spectral fraction of photons at energy E

The aluminum attenuation is already evaluated by the `xpecgen` library which does this:

- The tungsten spectrum is filtered by aluminum (2 mm):

$$\Phi_{\text{filtered}}(E) = \Phi_{\text{surface}}(E) \cdot \exp[-\mu_{\text{Al}}(E) \cdot t_{\text{Al}}]$$

- $\mu_{\text{Al}}(E)$: mass attenuation coefficient of Al (cm^{-1})
- t_{Al}: filter thickness in cm
  Given the distance from the xray source the flux is attenuated like:

$$\Phi_{\text{geom}}(E, z) = \frac{\Phi_{\text{filtered}}(E)}{4\pi(x_0 + z)^2}$$

- x_0: source-to-detector distance (cm)
- z: depth in detector (cm)

The expected number of counts is evaluated.
Photon absorption in a thin pixel layer:

$$N_{\text{abs}}(E, z) = \Phi_{\text{geom}}(E, z) \cdot \left(1 - e^{-\mu_{\text{Si}}(E)\, \Delta x}\right) \cdot A_{\text{pixel}}$$

- $\mu_{\text{Si}}(E)$: linear attenuation coefficient of Si (cm^{-1})
- Δx: pixel thickness (cm)
- A_{pixel}: pixel area (cm^2)
- $\Phi_{\text{geom}}(E, z)$: photon flux **at the front of the pixel**, including geometry and attenuation up to depth z:

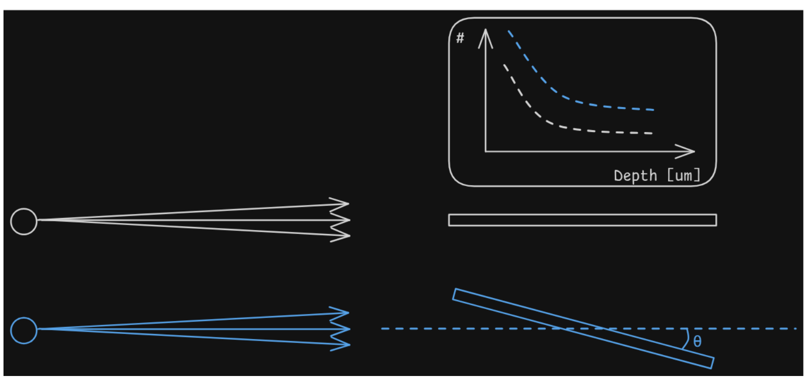
$$\Phi_{\text{geom}}(E, z) = \Phi_{\text{geom}}(E, z) \cdot e^{-\mu_{\text{Si}}(E)\, z}$$

- $\left(1 - e^{-\mu_{\text{Si}}(E)\, \Delta x}\right)$:
  1. **Survival to pixel front**: $e^{-\mu_{\text{Si}}(E) z}$
  2. **Absorption in pixel layer**: $1 - e^{-\mu_{\text{Si}}(E) \Delta x}$

Total counts per pixel:

$$N_{\text{pixel}}(z) = \sum_E N_{\text{abs}}(E, z)$$

Top-illumination (Tilt) Contribution?



The tilt can contribute in some photons hitting directly on the front of the matrix instead of the edge.
For small tilt angle θ:

$$N_{\text{tilt}}(z) = \sin(\theta) \cdot \Phi_{\text{filtered}}(E) \cdot A_{\text{pixel}} \cdot \left(1 - e^{-\mu_{\text{Si}}(E)\, t_{\text{wafer}}}\right)$$

- t_{wafer}: wafer thickness in cm
- Fraction $\sin(\theta)$ scales top-illumination relative to edge-on absorption

Thus the final counts at depth z including tilt:

$$N_{\text{total}}(z) = (1 - f_{\text{top}})\, N_{\text{edge-on}}(z) + f_{\text{top}}\, N_{\text{tilt}}(z)$$

- $f_{\text{top}} = \sin(\theta)$