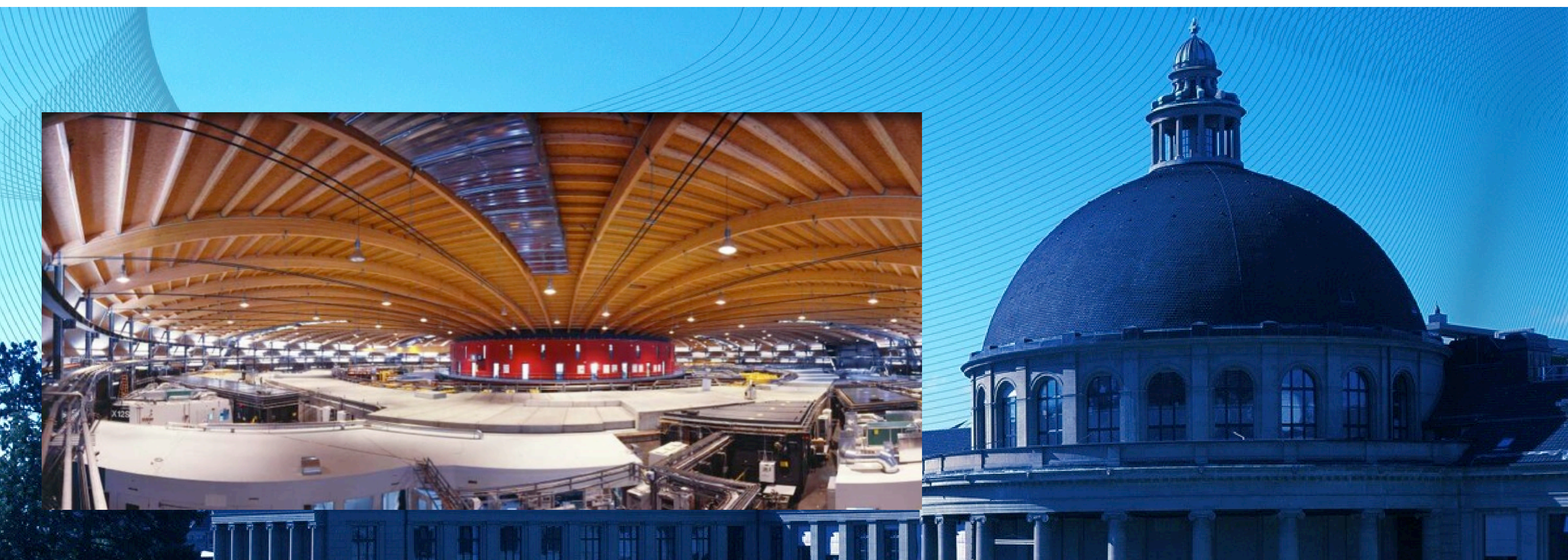
Dark field and transmission in the Compton regime

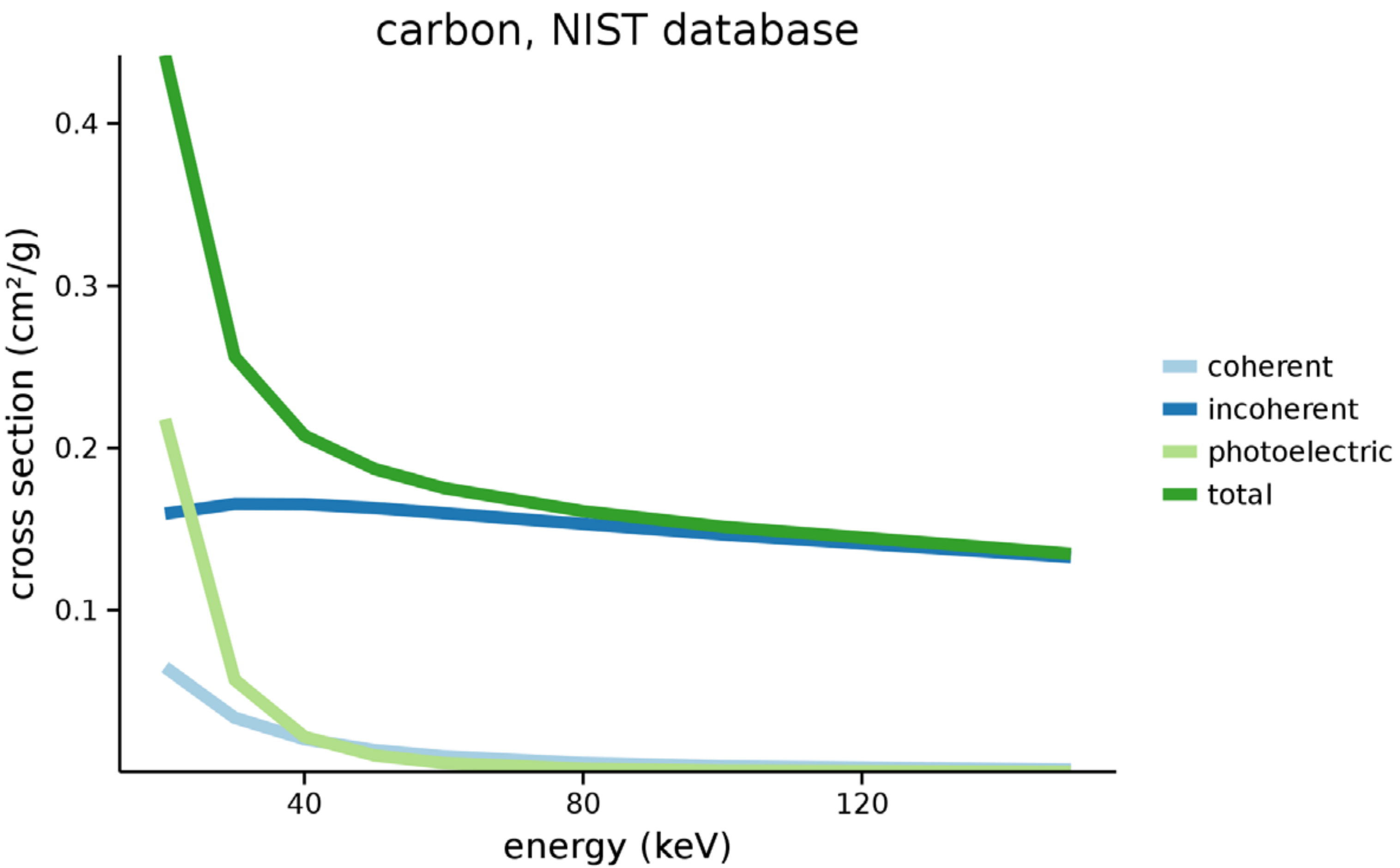
Matteo Abis, Pablo Villanueva Perez, Zhentian Wang, Marco Stampanoni

Institute for Biomedical Engineering, University and ETH Zürich, Zürich, Switzerland
Swiss Light Source, Paul Scherrer Institut, Villigen, Switzerland



What is the Compton regime?

Energy > 40-50 keV for biomedical applications



Signals from phase stepping curves

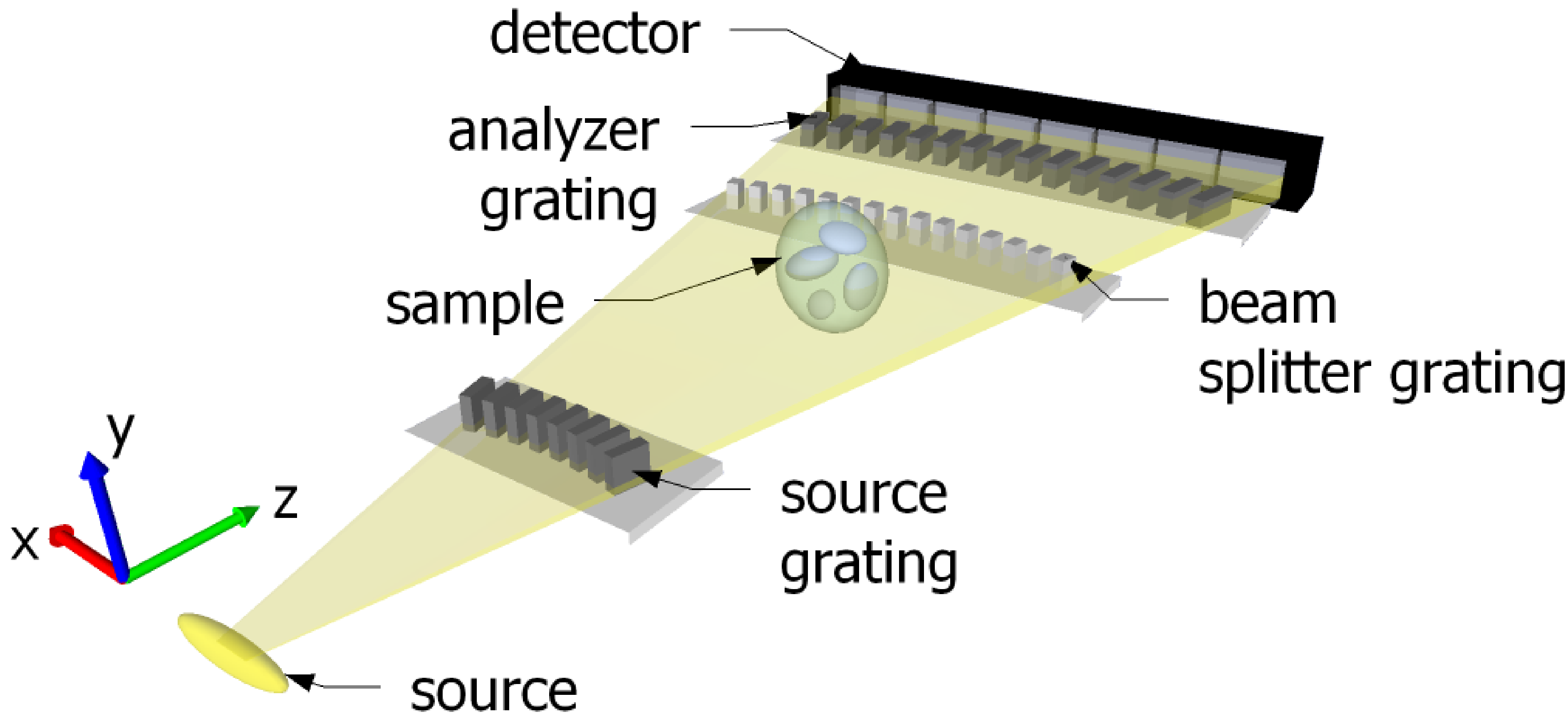
- Moduli of the first two Fourier coefficients a_0, a_1
- Transmission $A = \frac{a_{0,s}}{a_{0,f}}$
- Dark field $B = \frac{a_{1,s}}{a_{1,f}} \frac{a_{0,f}}{a_{0,s}}$
- Ratio $R = \frac{\log B}{\log A}$

The ratio R in literature below 40 kVp

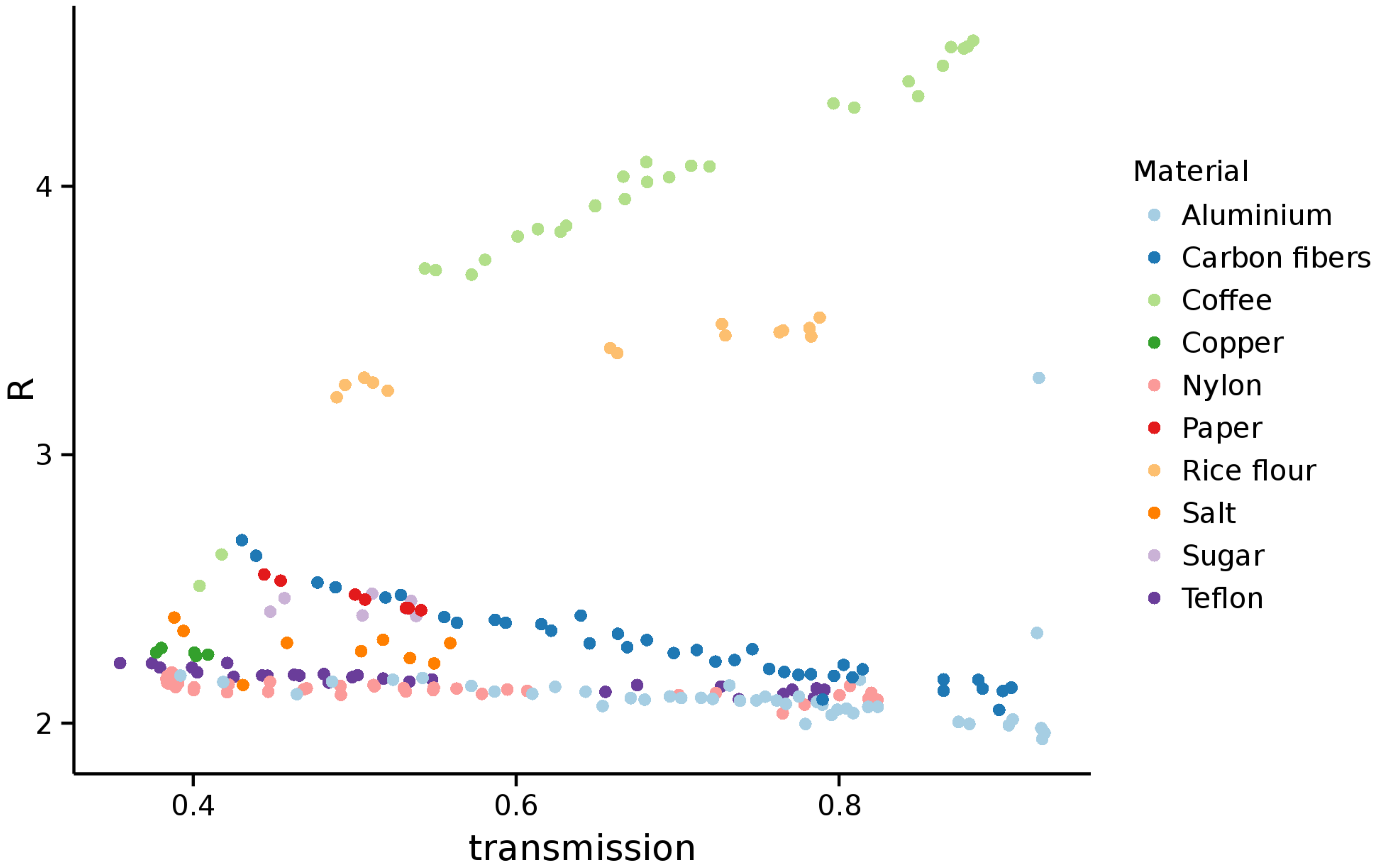
- Independent of thickness
- Depends on atomic number
- Depends on microstructure size

Wang and Stampanoni, Quantitative x-ray radiography using grating interferometry: a feasibility study, Phys. Med. Biol., 2013
Scherer et al., Non-invasive Differentiation of Kidney Stone Types using X-ray Dark-Field Radiography, Sci. Rep., 2015

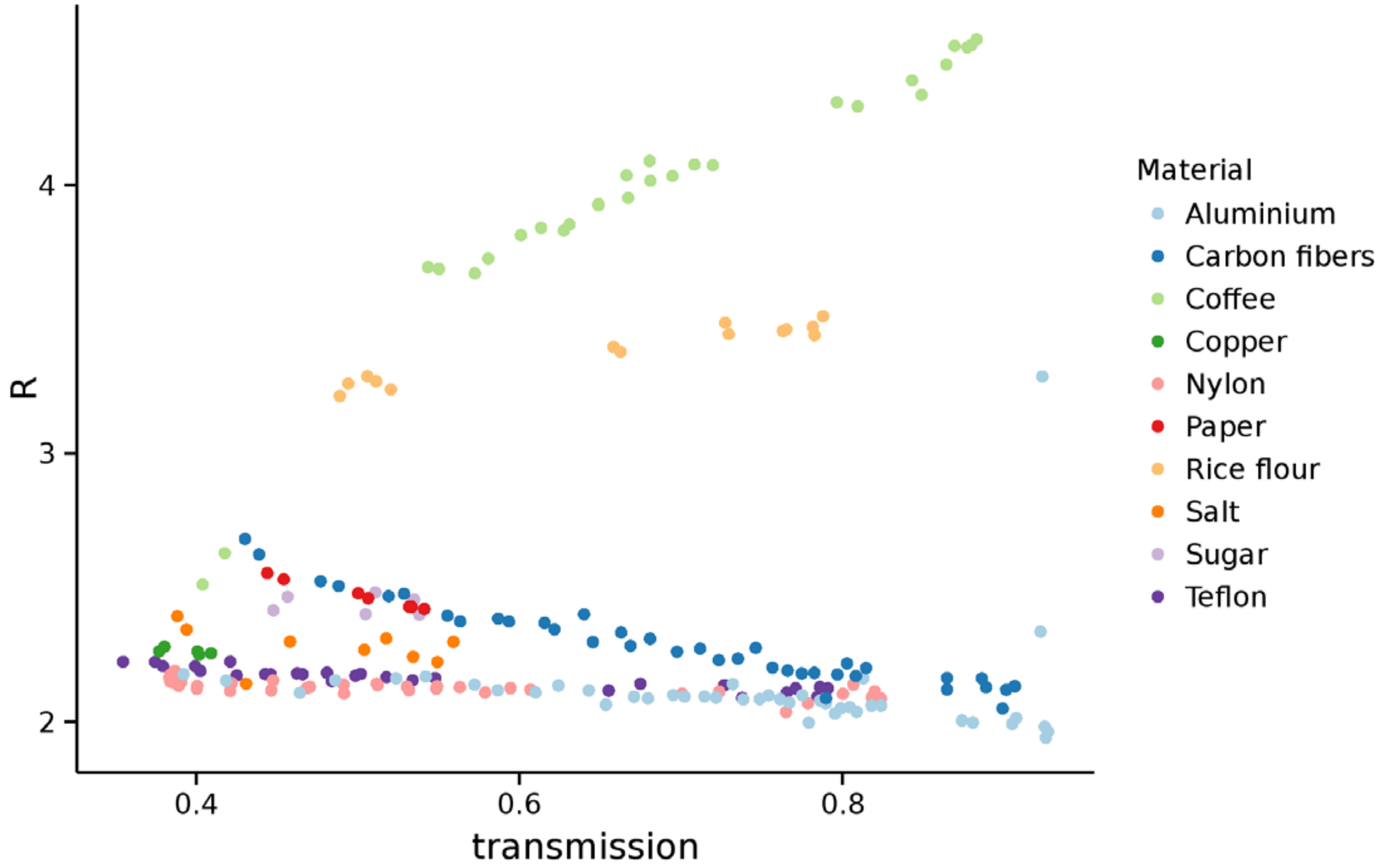
Edge-on illumination for experiments at 160 kVp



Experiment at 160 kVp



Experiment at 160 kVp



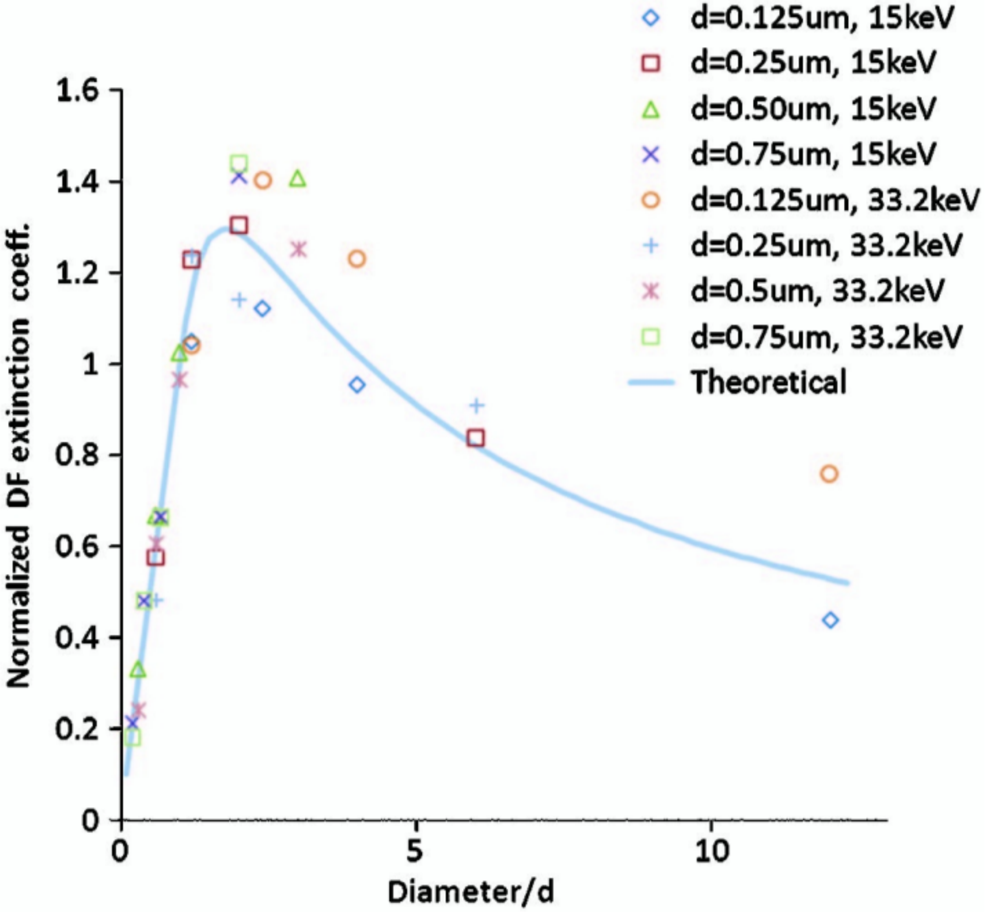
- R independent of thickness
- R depends on atomic number
- R depends on microstructures

No Z information

- Given by photoelectric absorption $\propto Z^{3-4}$
- Irrelevant above 50 keV for low-Z materials

Microstructures

- Lynch et al. 2011, synchrotron experiment and analytical description



$$\mu_{\mathrm{d}} = \frac{3\pi^2}{\lambda^2} f |\Delta\chi|^2 d \begin{cases} D' - \sqrt{D'^2 - 1}(1 + D'^{-2}/2) + \\ (D'^{-1} - D'^{-3}/4) \\ \ln[(D' + \sqrt{D'^2 - 1})/ \\ (D' - \sqrt{D'^2 - 1})], \quad \text{for } D > d; \\ \\ D', \quad \text{for } D \leq d; \end{cases}$$

$$\mu_d = \frac{-\log B}{t} = R\mu$$

Microstructures on polychromatic sources

- Compute the contribution as in Lynch et al for each energy $\rightarrow R(E)$

- Sum over spectral weights $w(E)$

- Our model, with 2 parameters R_0 and C:

$$R = R_0 + C \sum_E w(E) R(E)$$

Spectral weights

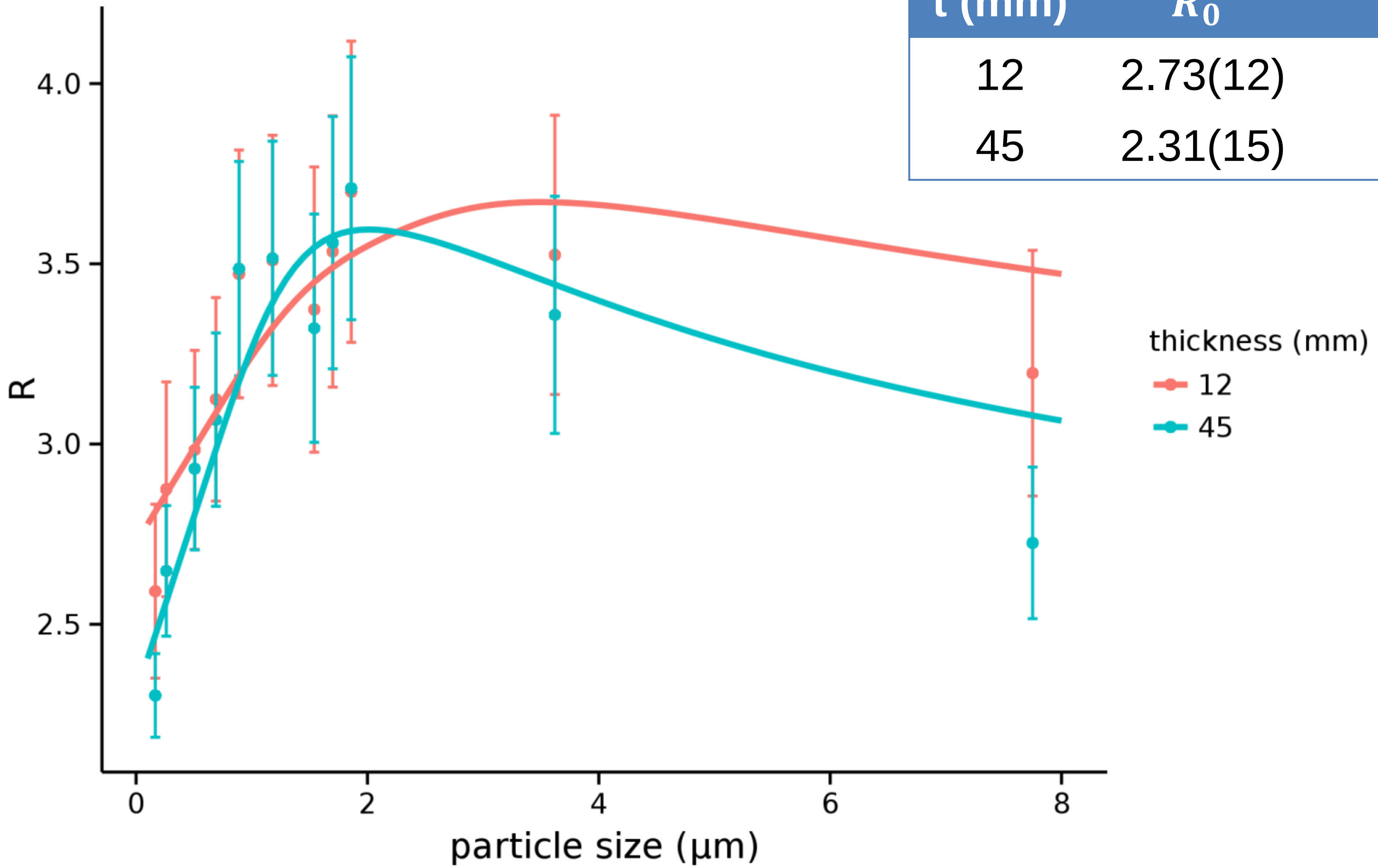
$w(E) = \text{source} \times \text{visibility} \times \text{detector efficiency} \times \text{sample abs.}$

- Simulated source (SpekCalc)
- Detector efficiency and sample abs. from NIST coefficients
- Visibility as a function of energy from Thüring et al., *Performance and optimization of X-ray grating interferometry*, 2014

Silica microspheres 0.16 to 7.75 µm

- Fit the two parameters R_0 and C:
- Samples with two different thicknesses

t (mm)	R_0	C
12	2.73(12)	5(1)
45	2.31(15)	11(2)

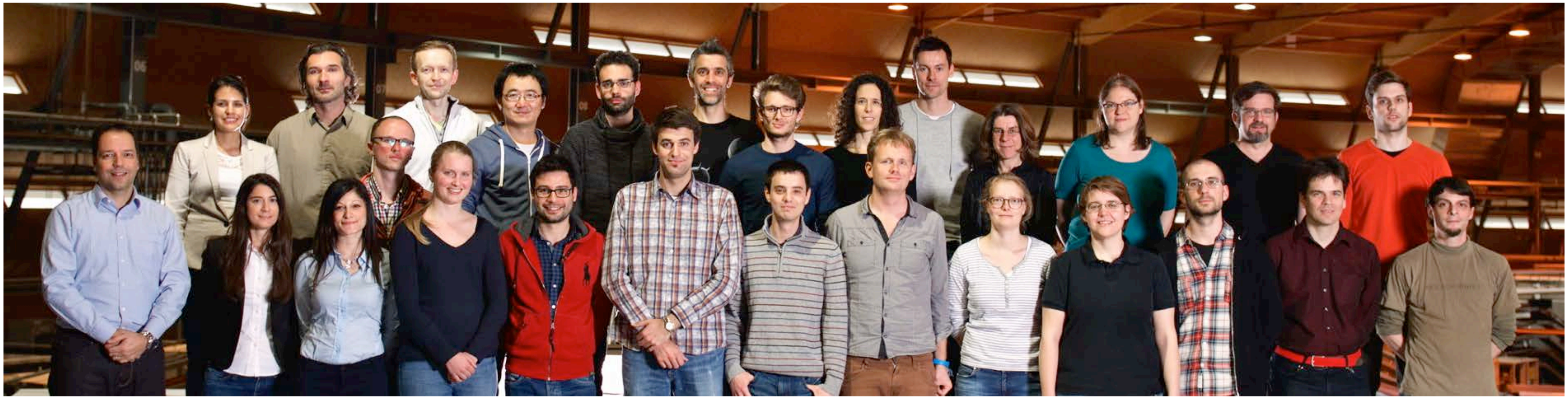


Conclusions

- Good model for dark field above 50 keV on polychromatic sources
- Effective Z information is lost
- Fully complementary information on microstructures can be retrieved with R
- $R_0 > 1$ means that the phase signal is very difficult to recover

Acknowledgements

TOMCAT Team



CIBM

FNSNF
Fonds national suisse
Schweizerischer Nationalfonds
Fondo nazionale svizzero
Swiss National Science Foundation

NCCBI
National Competence Center for Biomedical Imaging

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Established by the European Commission
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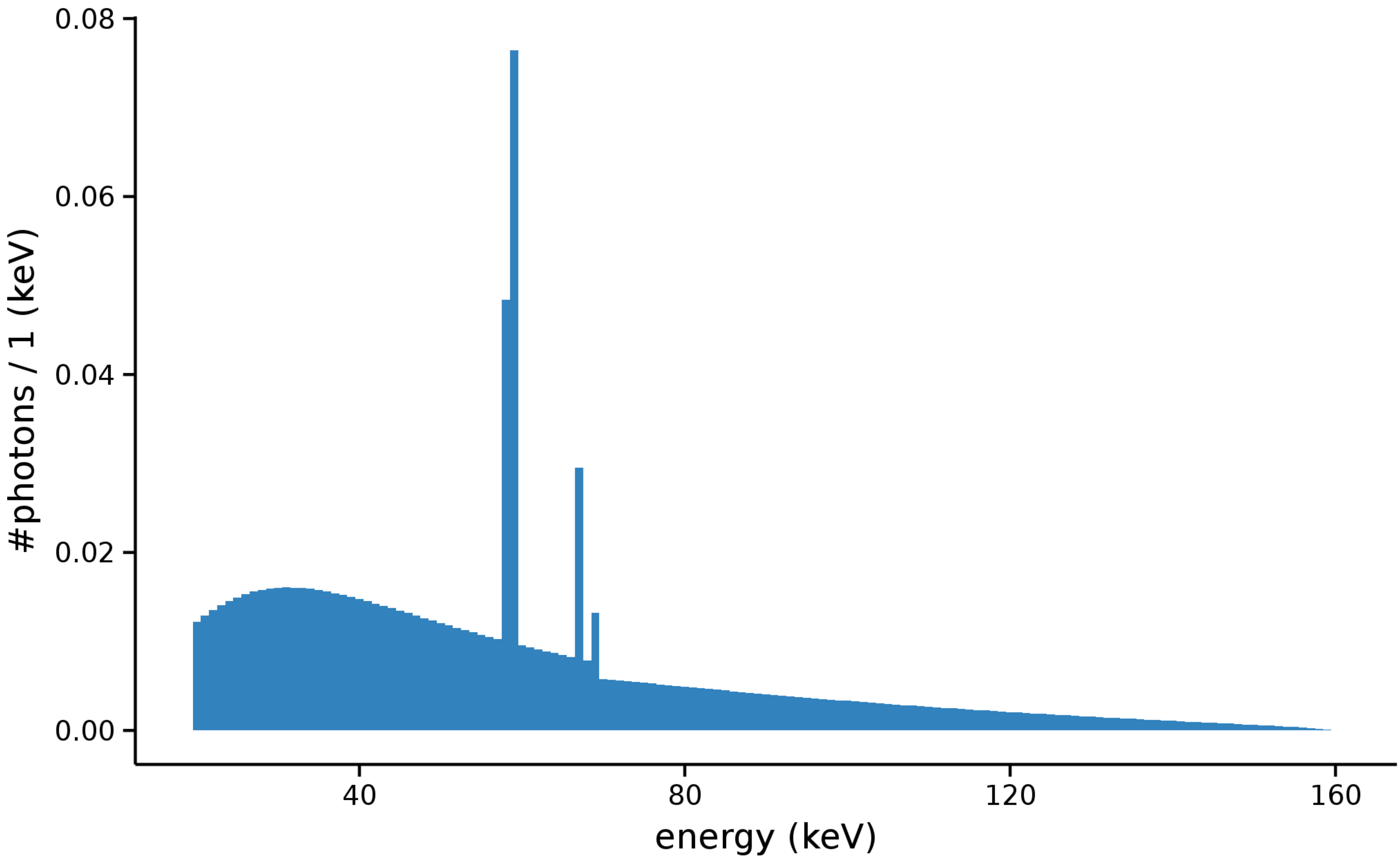
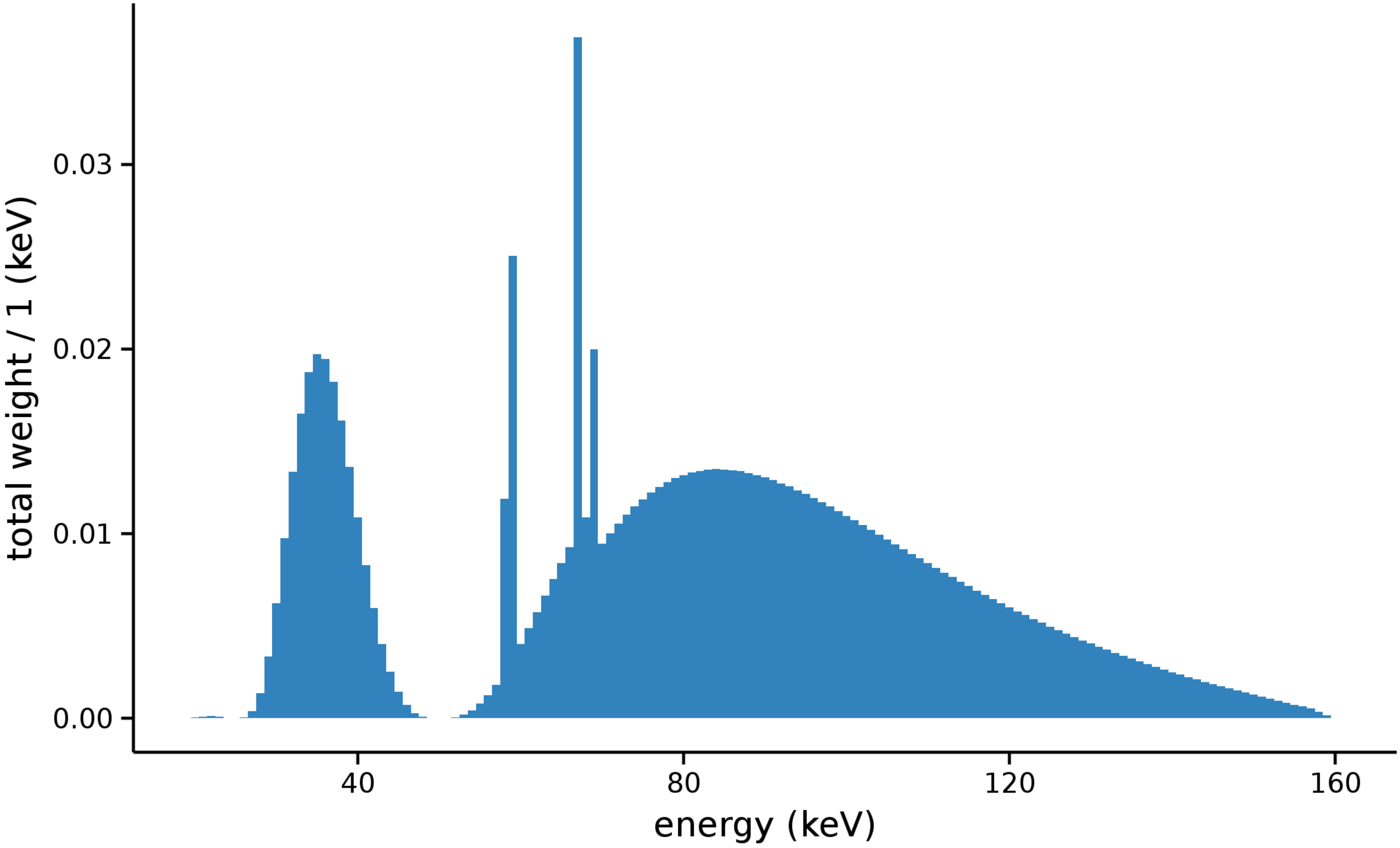
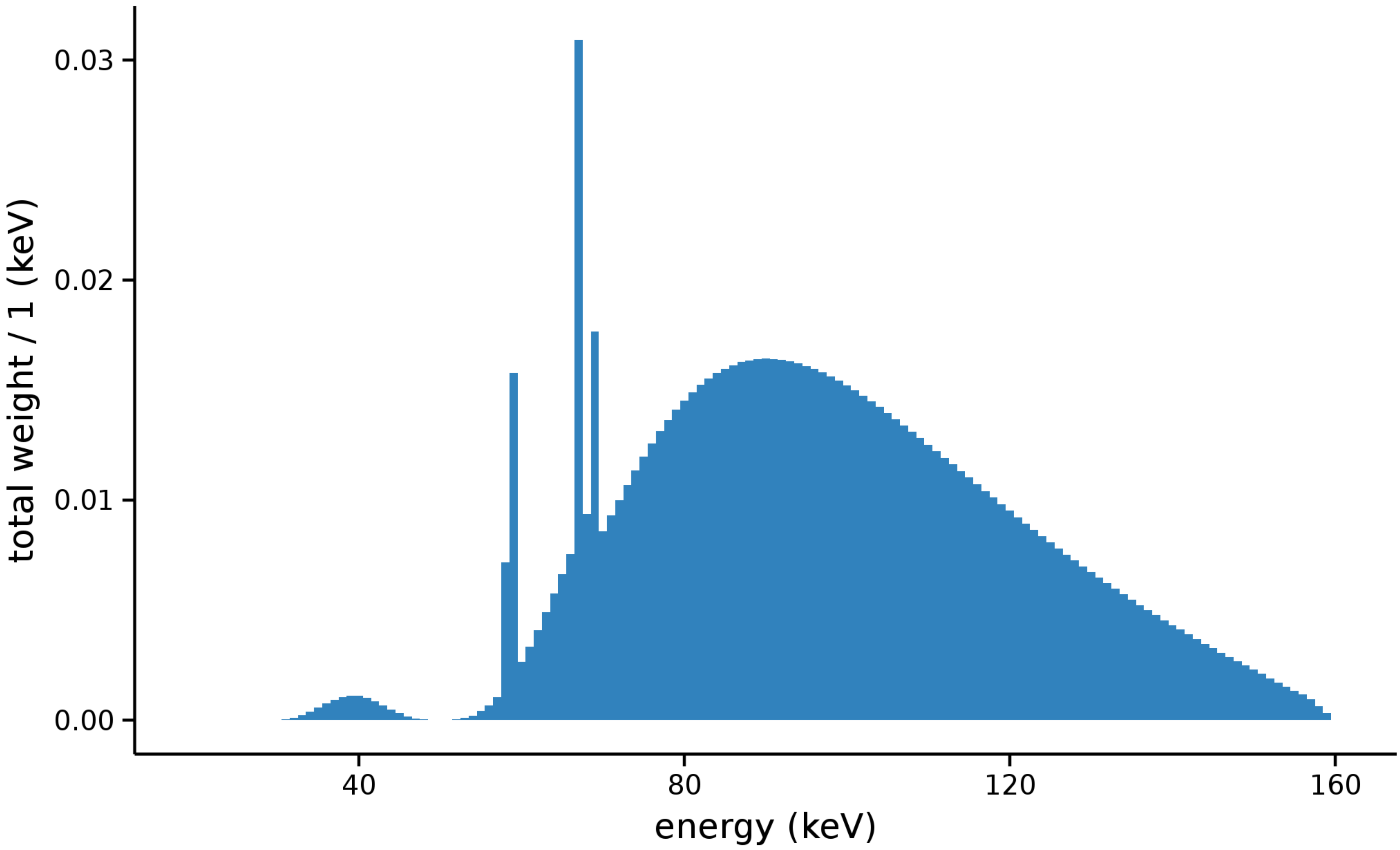


0.08
0.06
0.04
0.02
0.00
#photons / 1 (keV)
40
80
120
160
energy (keV)



0.03
0.02
0.01
0.00
total weight / 1 (keV)
40
80
120
160
energy (keV)



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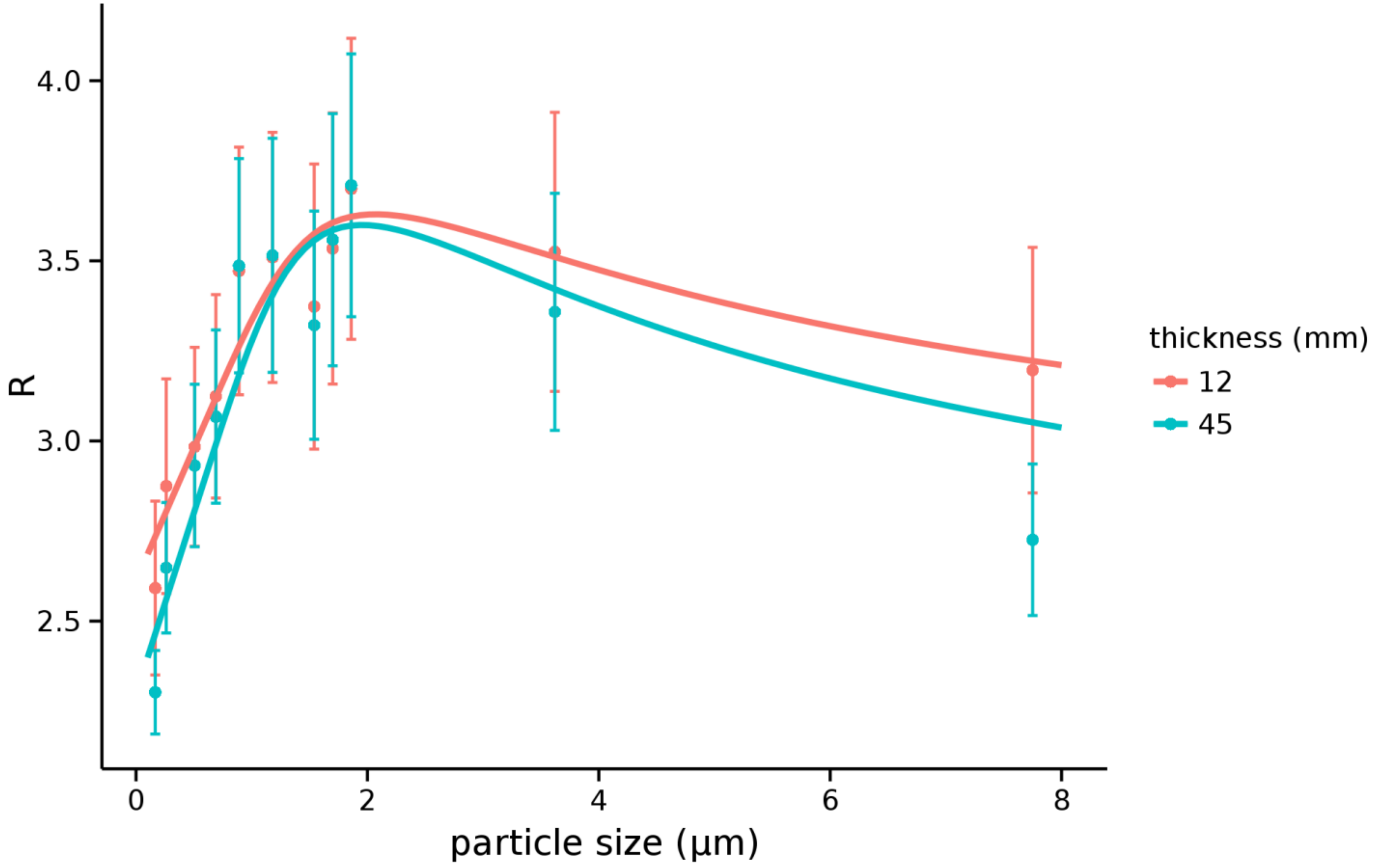
4.0
3.5
3.0
2.5
R
0
2
4
6
8
particle size (μm)
thickness (mm)
12
45