Neutron Absorbers - Exploiting Additive Manufacturing for Better Instruments

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Environment in Uppsala

Centre for Neutron Scattering

https://neutronscattering.uu.se

Additive Manufacturing

https://www.additivemanufacturing.se

Overall Aims

Motivation

- Develop and improve neutron instrumentation and sample environment equipment
- Understand and improve modern materials
- Exploit and improve additive manufacturing

Activities

Themes

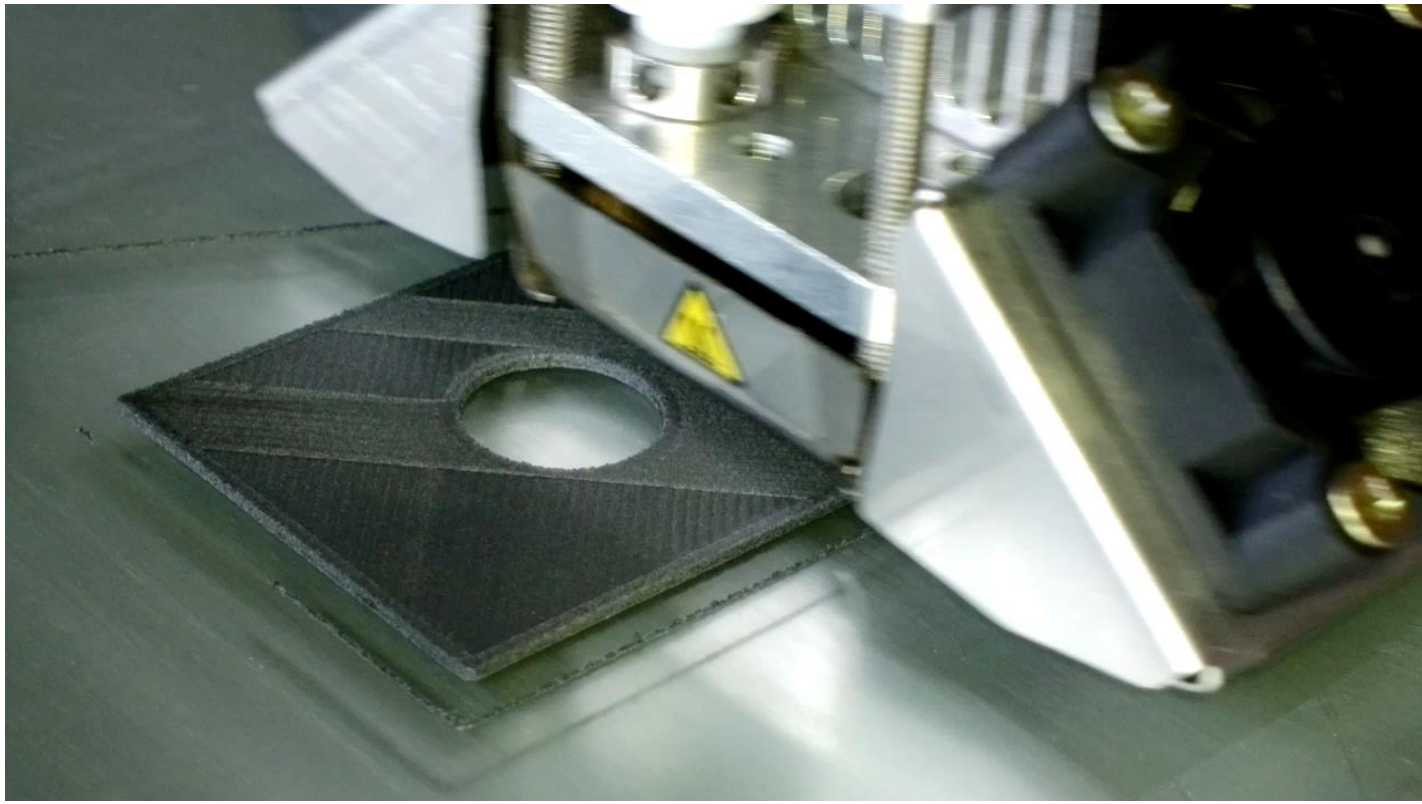
Motivation

- Exploit optimised design
- Use knowledge of materials

Composites / Metamaterials

- Combination of properties
- Many components possible

Printing



Some Needs for Absorbers with Neutron Instruments

- Apertures
- Collimators
- Shielding components
- Calibration masks
- etc.

- Performance
- Cost (per absorption length)
- Ease of fabrication
- Safety (chemical hazards, secondary radiation, …)
- Rapid production

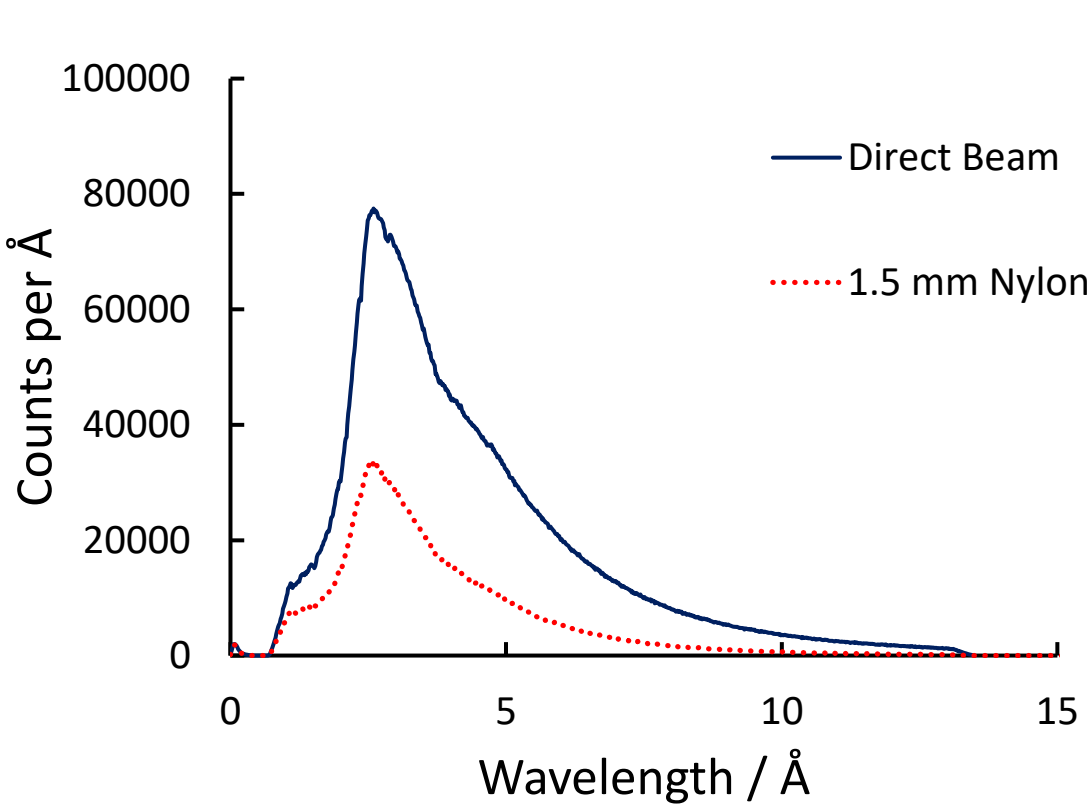
I will discuss fused filament fabrication – techniques used elsewhere include powder processing (Binder jet) and reverse additive manufacturing
Wear of nozzle with hard material (B_4C) is mostly solved problem

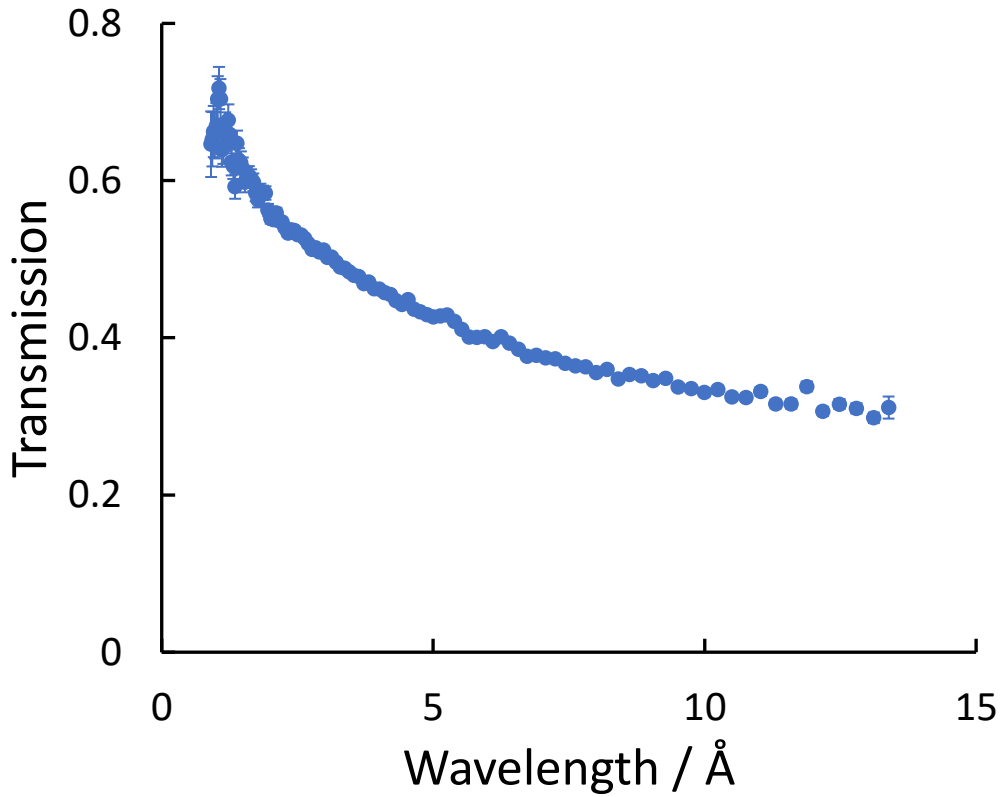
A. Olsson, M. S. Hellsing, A. R. Rennie 'New possibilities using additive manufacturing with materials that are difficult to process and with complex structures' *Physica Scripta* **92**, (2017), 053002. https://doi.org/10.1088/1402-4896/aa694e

Measure Material Properties

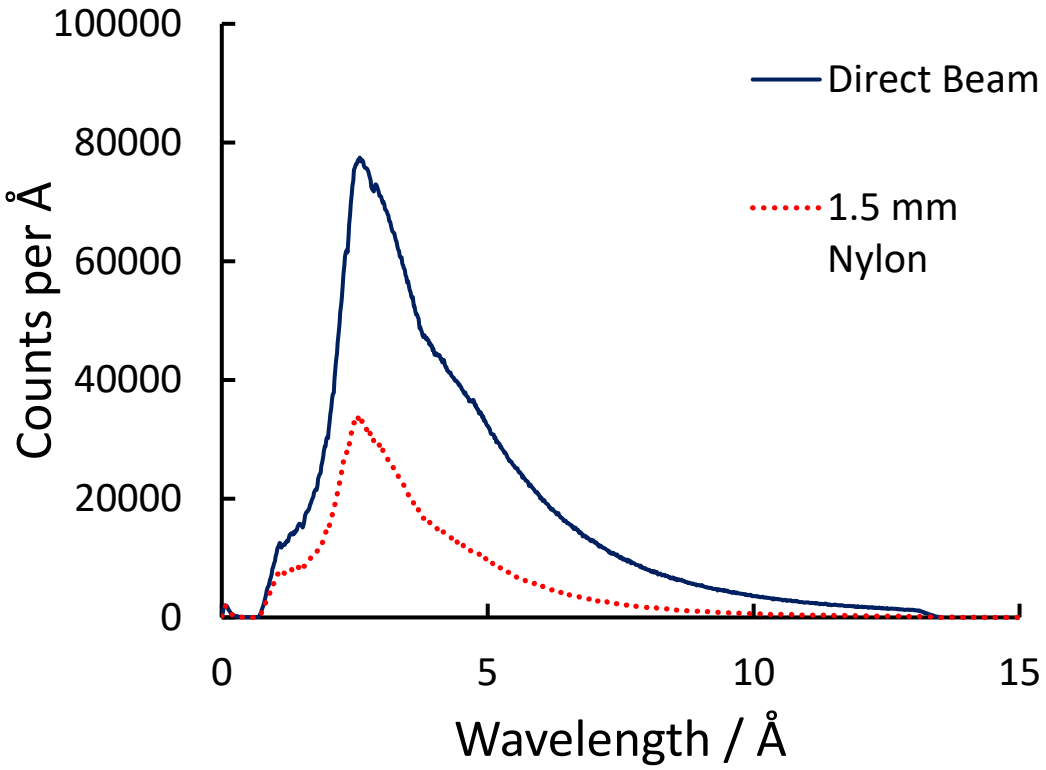
Larmor at ISIS facility. Sample with different thicknesses up to 0.6 mm. 25%wt B_4C in nylon

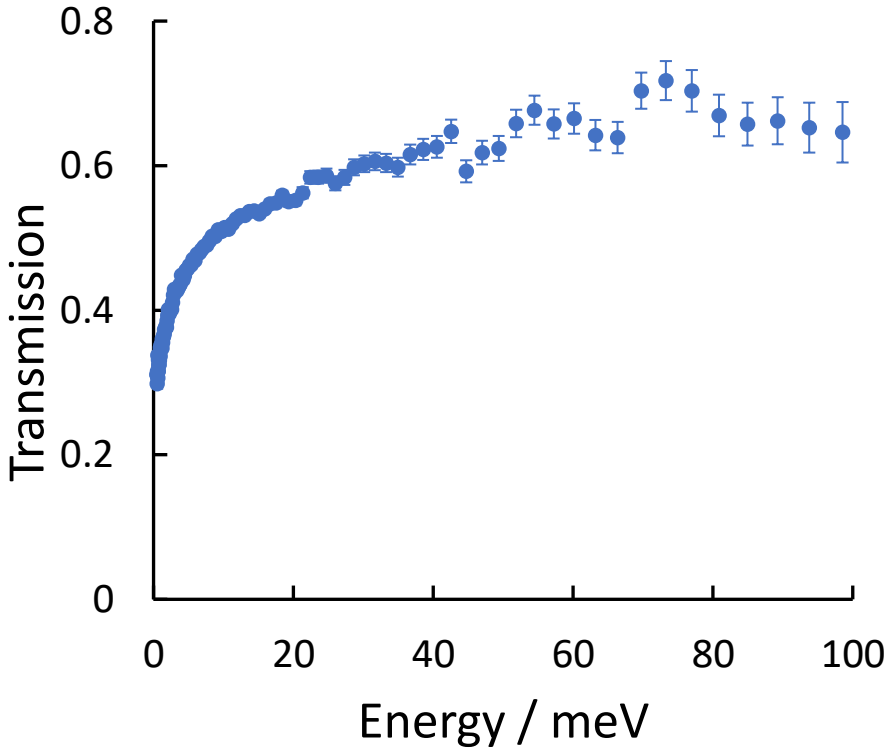
Determine Transmission





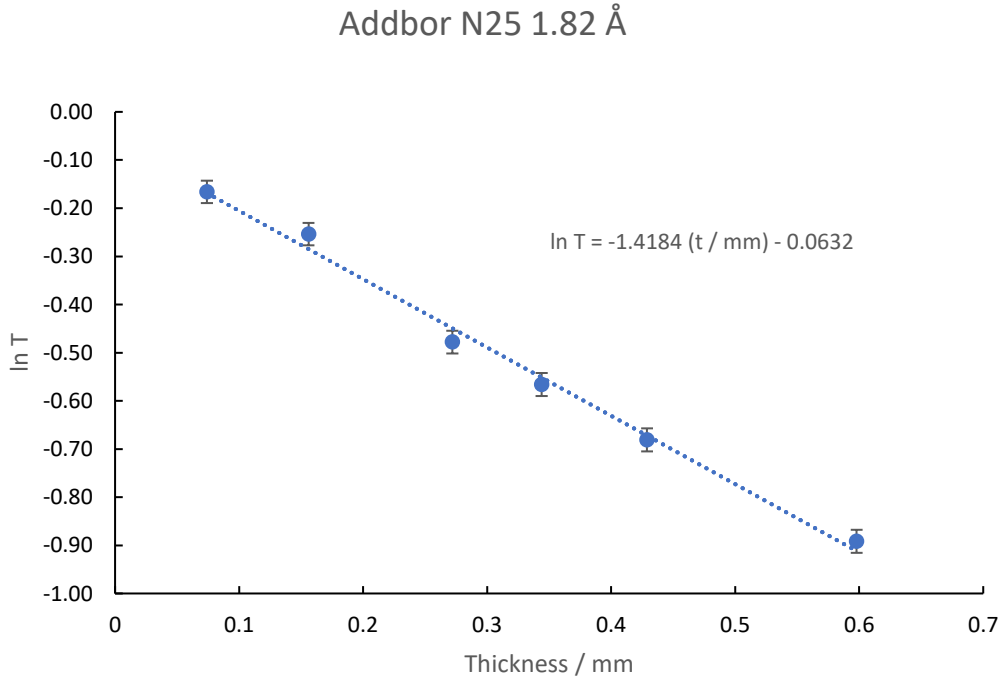
Determine Transmission



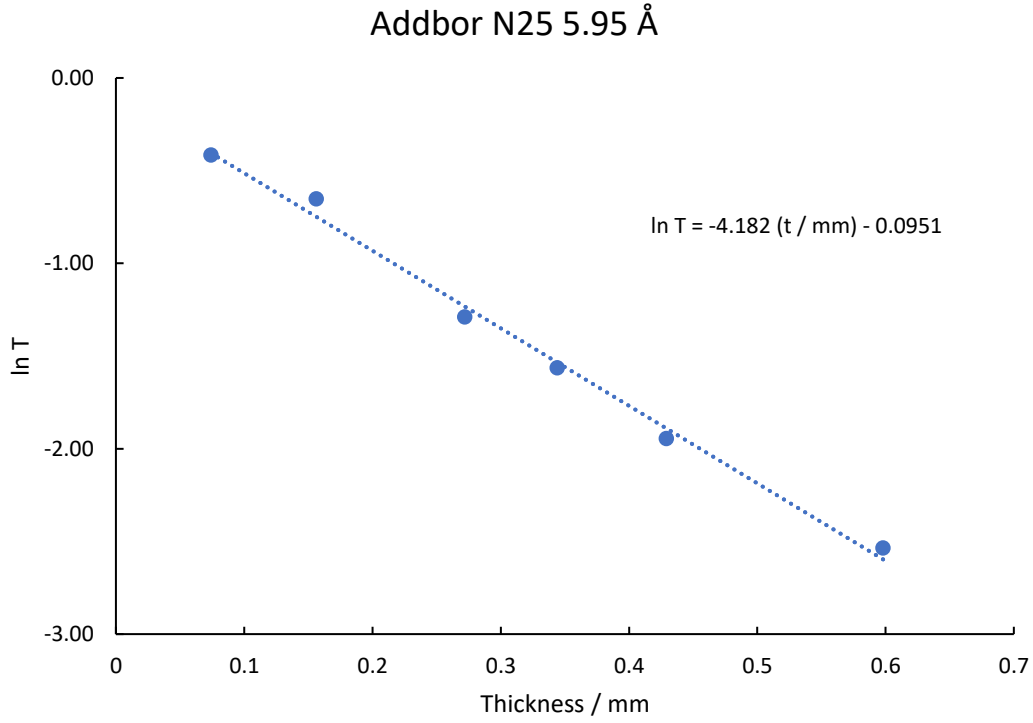


Measured Transmissions 25%wt B_4C in Nylon

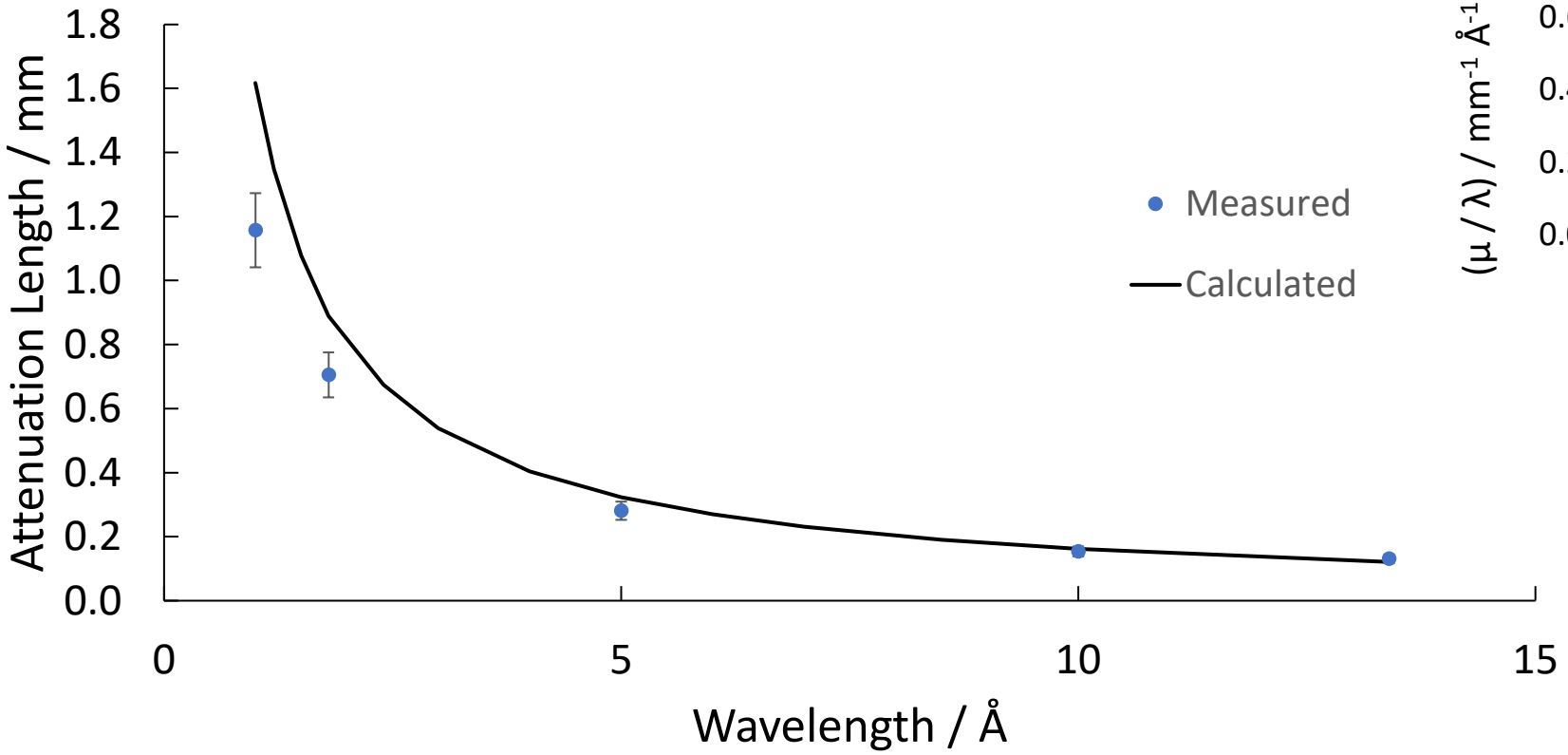
Wavelength 1.82 Å

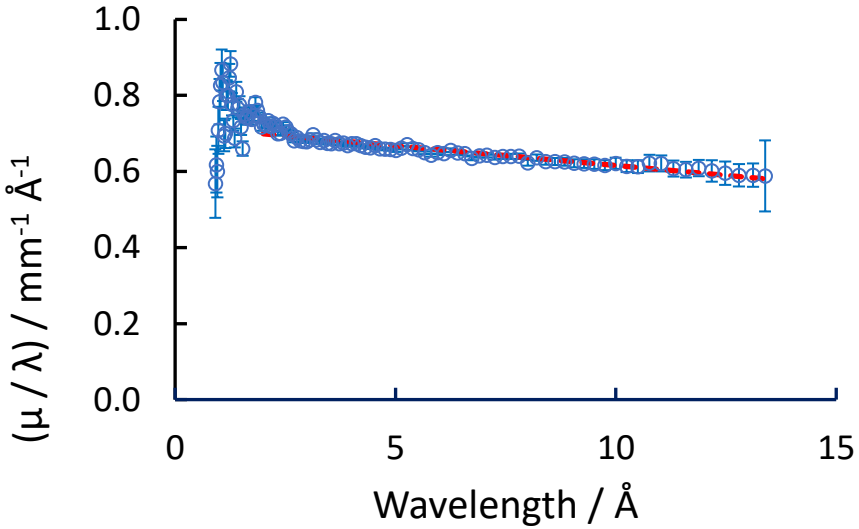


Wavelength 5.95 Å

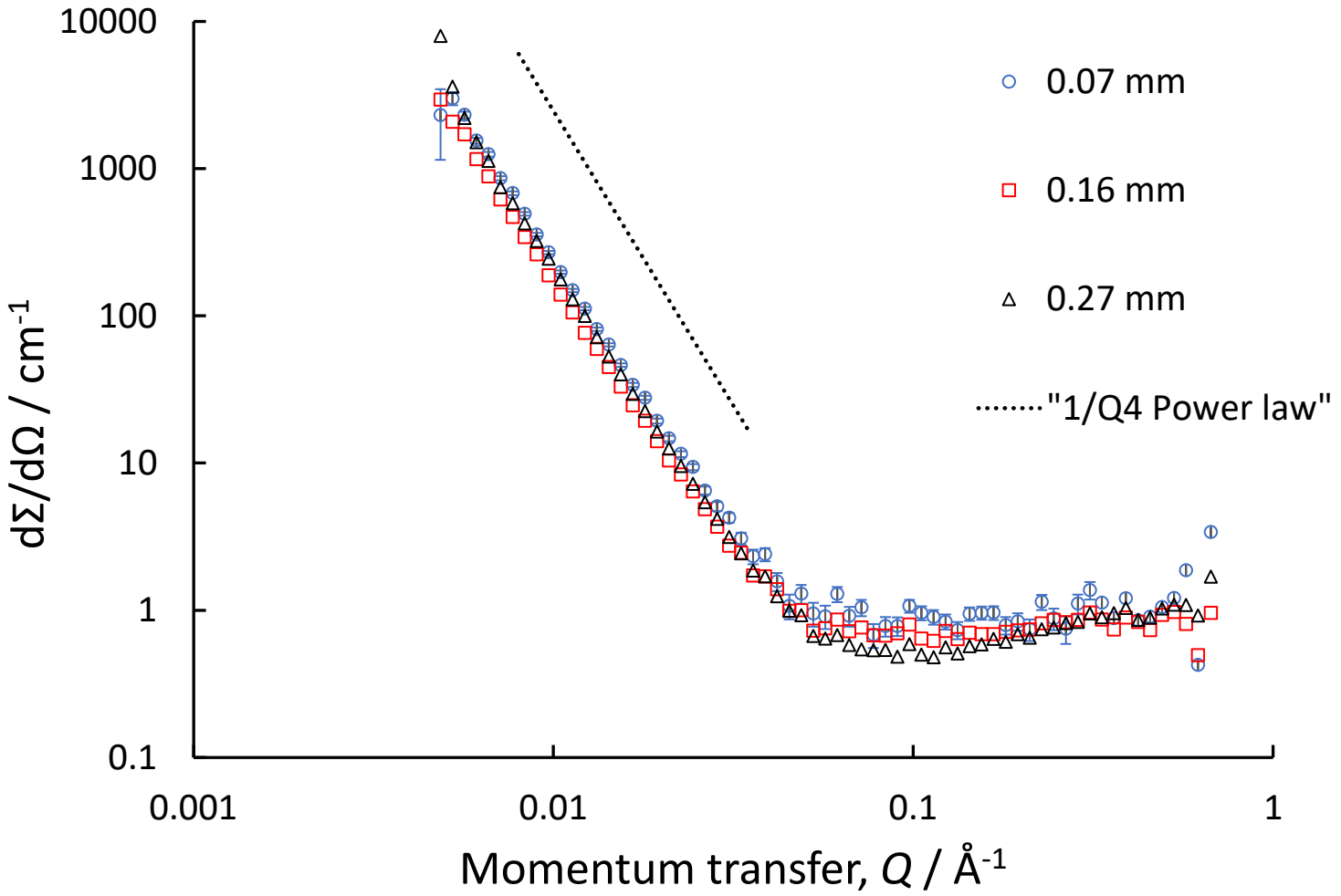


Attenuation Length
Comparison with calculation – Addbor N25





Scattering 25%wt B_4C in Nylon



- Large scattering Q is dominated by inelastic incoherent scattering – wavelength dependent
- Small Q – scattering is from surface of particles

- In practice, scattering is attenuated strongly by the composite itself .

Design Concepts

Exploit additive manufacturing

- Material where needed
- Shapes can be complex – tapered holes, curves,
- Multiple components
- Threaded components

- Allows non-toxic materials

Materials for FFM

Choice of polymer:

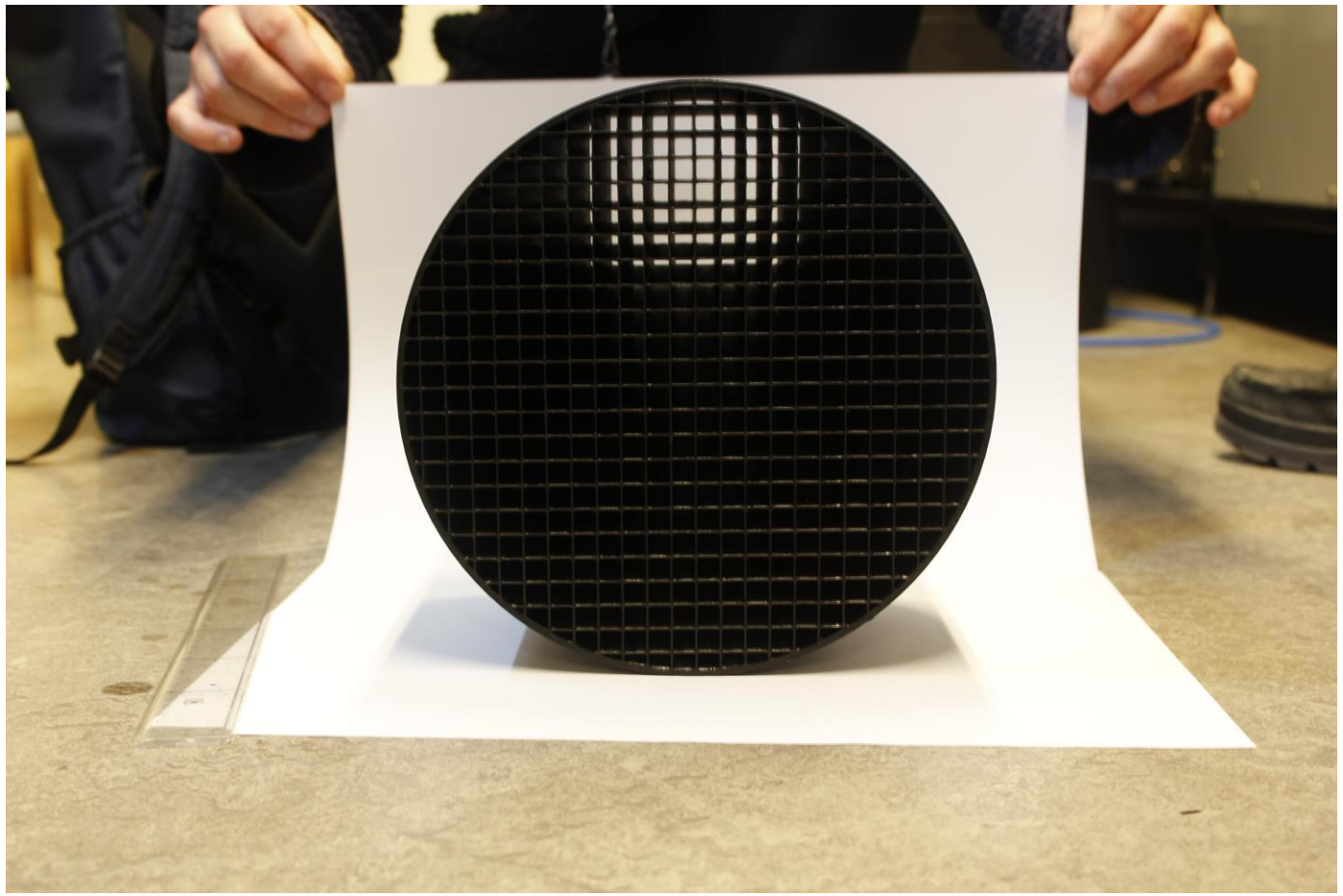
ABS, Nylon (polyamide), PLA …

Absorber:

B_4C, gadolinium oxide, $^{10}B_4C$ but also metals

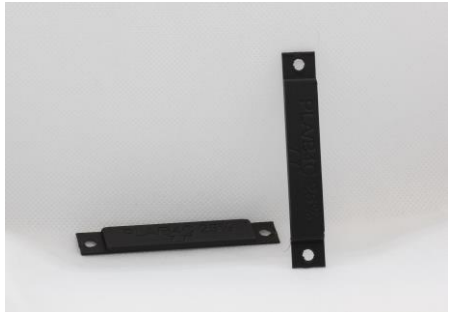
Tungsten for γ-radiation (can be included in fabrication)

Manufactured Products - Examples



½” (12.7 mm) aperture $^{10}B_4C/B_4C$

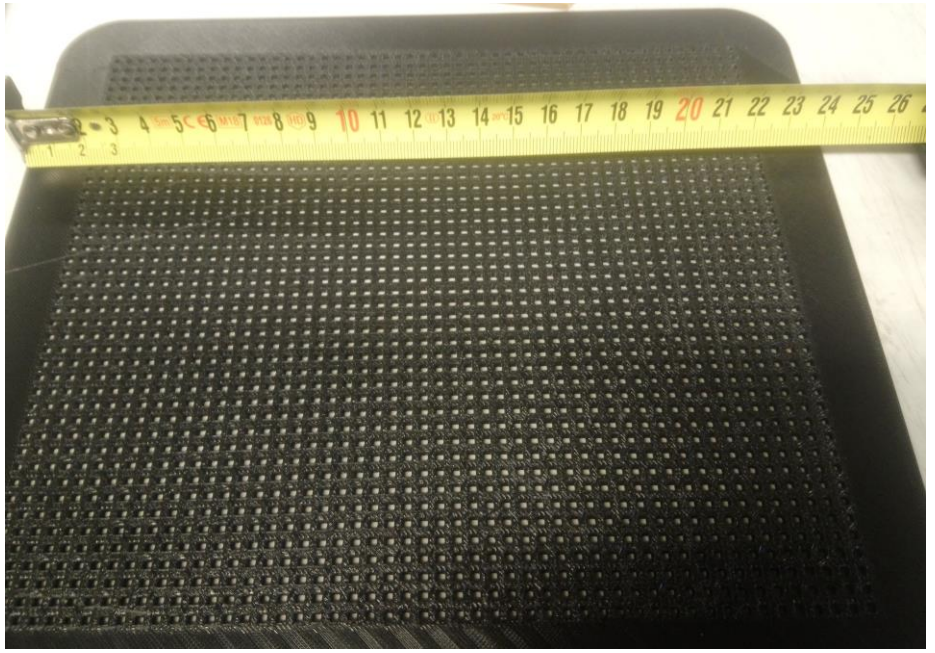
65 mm baffles for reflection cell



A. Olsson, A. R. Rennie ‘Boron carbide composite apertures for small-angle neutron scattering made by three-dimensional printing’ *J. Appl. Cryst*. **49,** (2016), 696-699. https://doi.org/10.1107/S1600576716000534

Manufactured Products - Examples

Bolt and Nut (M10)



Detector Calibration Mask

Conclusions

- Many advantages for additive manufacturing
- Consider at the design stage – instrument or facility as well as components
- New materials are possible – higher absorption & lower toxicity than Cd

A.R. Rennie, A. Engberg, O. Eriksson, R. M. Dalgliesh ‘Understanding neutron absorption and scattering in a polymer composite material’ *Nuclear Instruments and Methods in Physics Research Section A*: (2020), in press. https://doi.org/10.1016/j.nima.2020.164613