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From projections to small-angle scattering : Artifacts induced by polychromatic cone-beams

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Context and objectives

Small-angle scattering (SAS - X-ray, neutron) is a technique for the investigation of the structure of disordered materials at the 1nm - 100nm scale. It delivers, in Fourier space, the two-point correlations of the electron density within the material.

For isotropic materials, the SAS pattern $I(q)$ depends on the norm q of the wave-vector only, and the covariance function $\gamma(r)$ depends on the norm r of the lag-vector only.

$$I(q) \propto \int_0^{+\infty} 4\pi r^2 \text{sinc}(qr) \gamma(r) dr$$

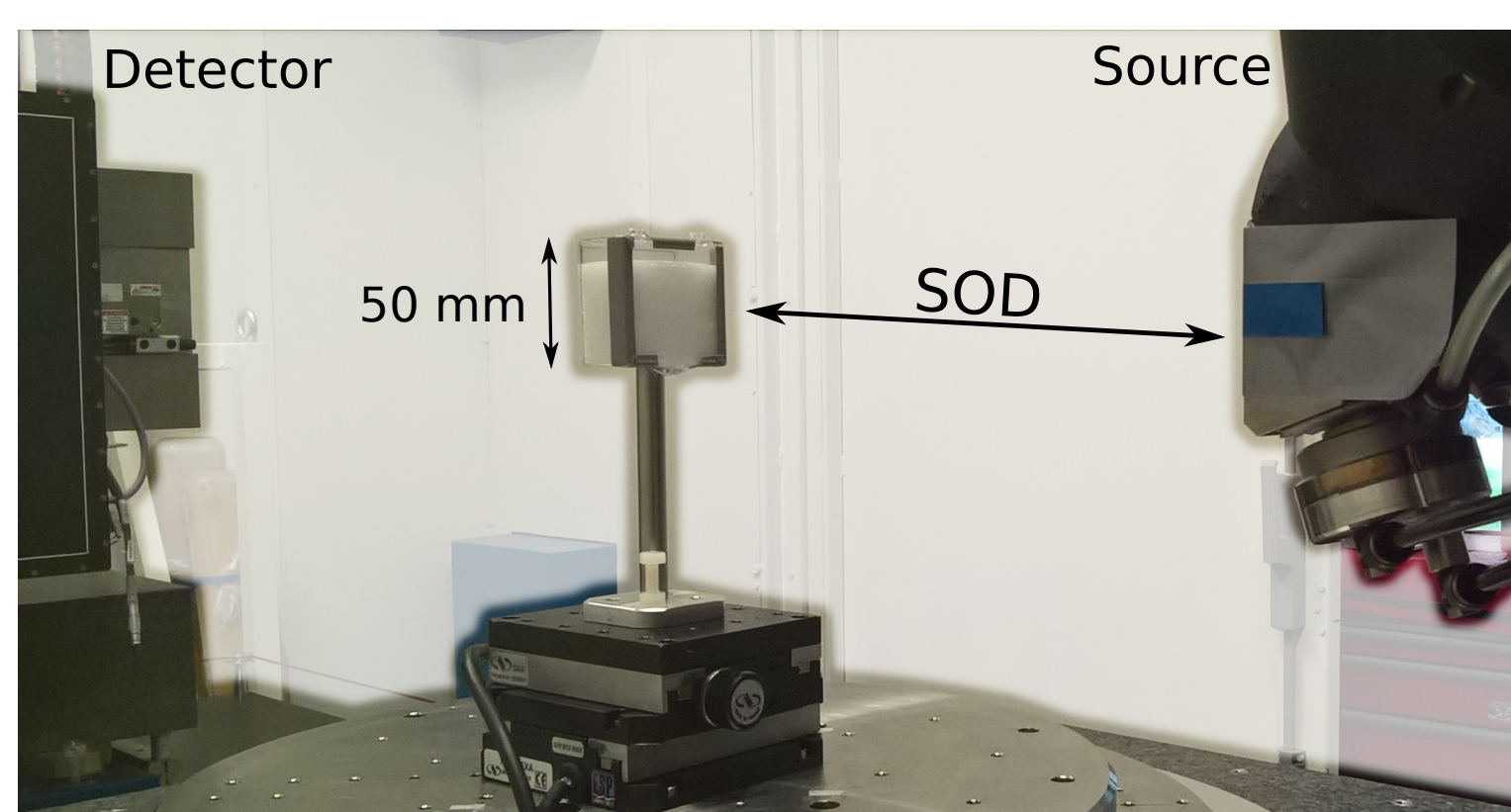
- ▶ The sample preparation is kept to a minimum.
- ▶ The 3d structural information [$\gamma(r)$] is limited, but quantitative: volume fraction, specific surface area, particle-size distribution...
- ▶ Applications from biology [1] to geomaterials [2-3].

A technique was proposed to simulate the SAS pattern of a material from a **single X-ray radiography** [4], which:

- ▶ bridges the length scales explored by SAS and by microtomography,
- ▶ opens the door to time-resolved, quantitative experiments,
- ▶ was successfully used in various applications [3, 5, 6].

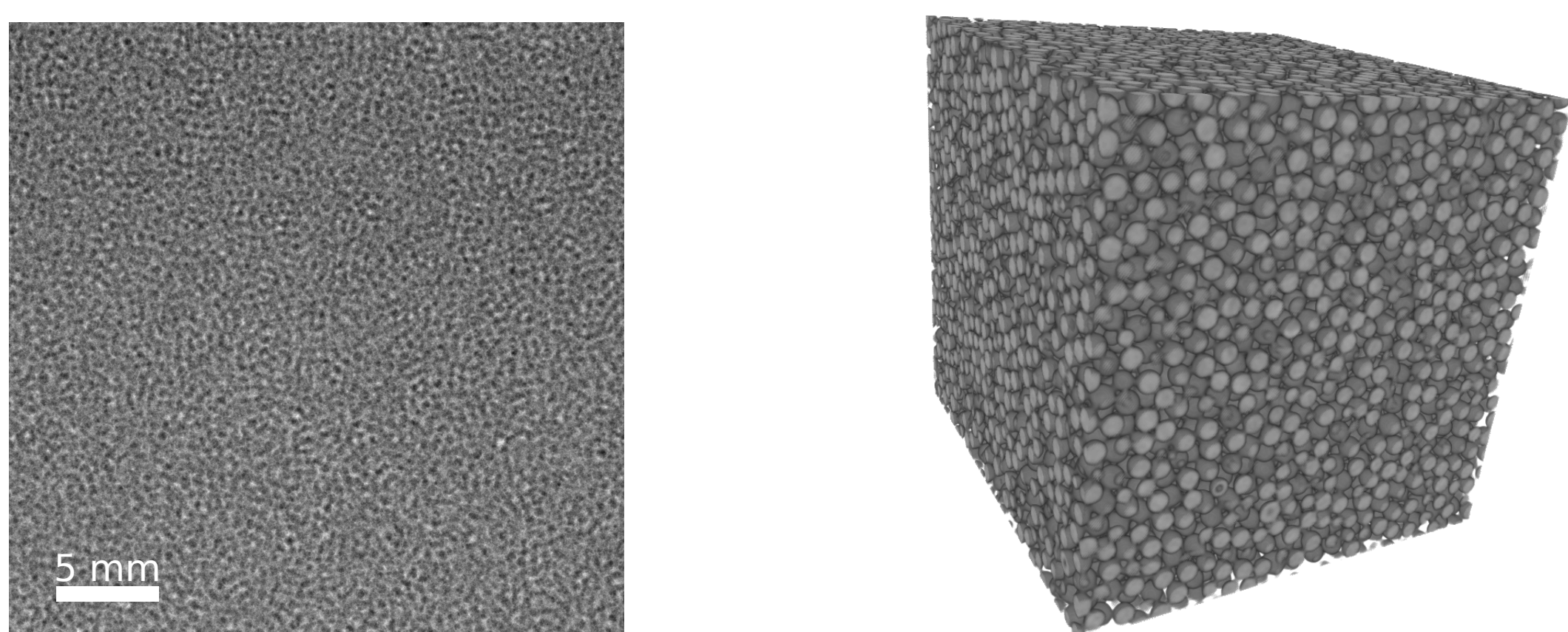
However, it is mathematically correct (and fully validated) for parallel beams only. In order to **extend this technique to cone-beam geometries**, our goal in this project is to quantify the distortions induced by non paraxial rays.

Materials and Methods



Polystyrene beads were placed in a plastic container. Projections were acquired on a laboratory tomograph (RX Solutions) under various source-to-object distance (SOD) and a long source-to-detector distance.

For reference, a full tomography scan was also acquired (voxel-size 30 μ m).

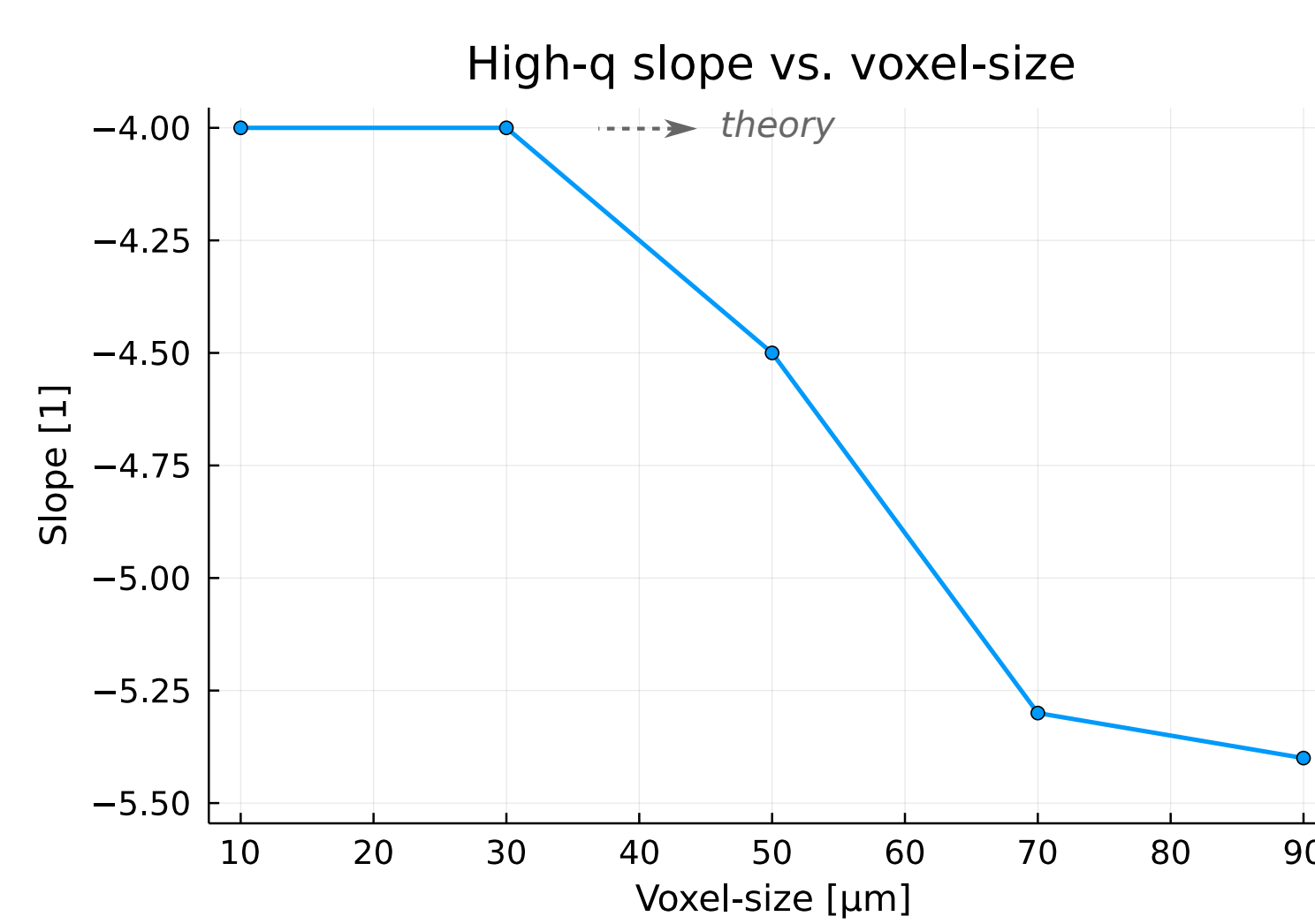
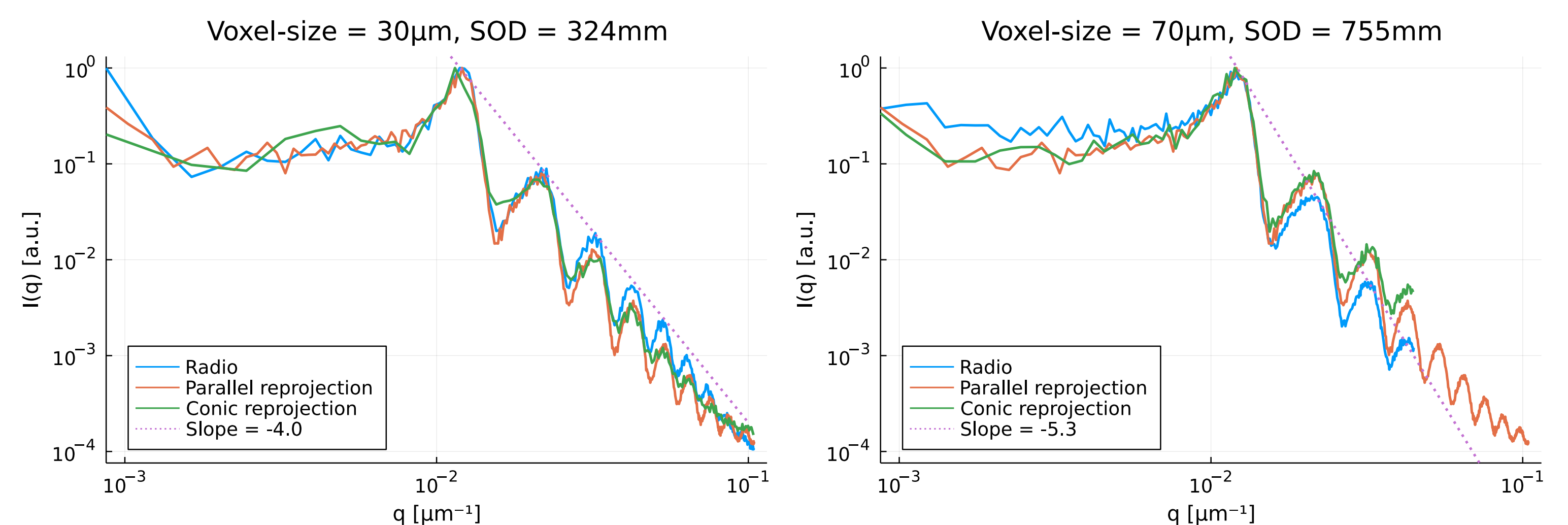


The SAS spectra were computed from the projections P (log of radios) at each SOD.

$$I(q_x, q_y, q_z = 0) = \left| \hat{P}(q_x, q_y) \right|^2$$

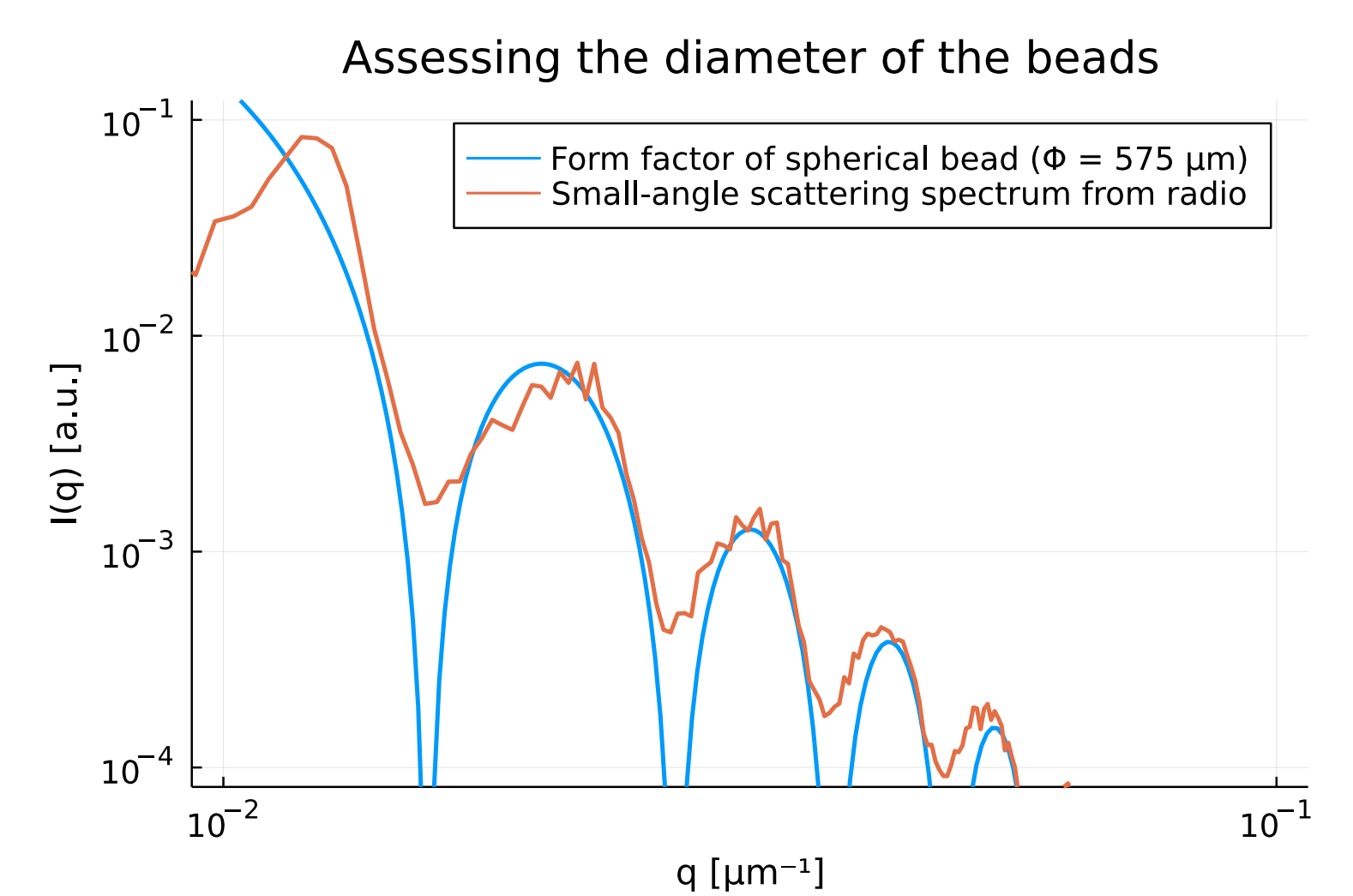
The SAS spectra were also computed from the **parallel reprojection** and **conic reprojection** of the 3D reconstructed + thresholded volume. Both reprojections are monochromatic.

Results



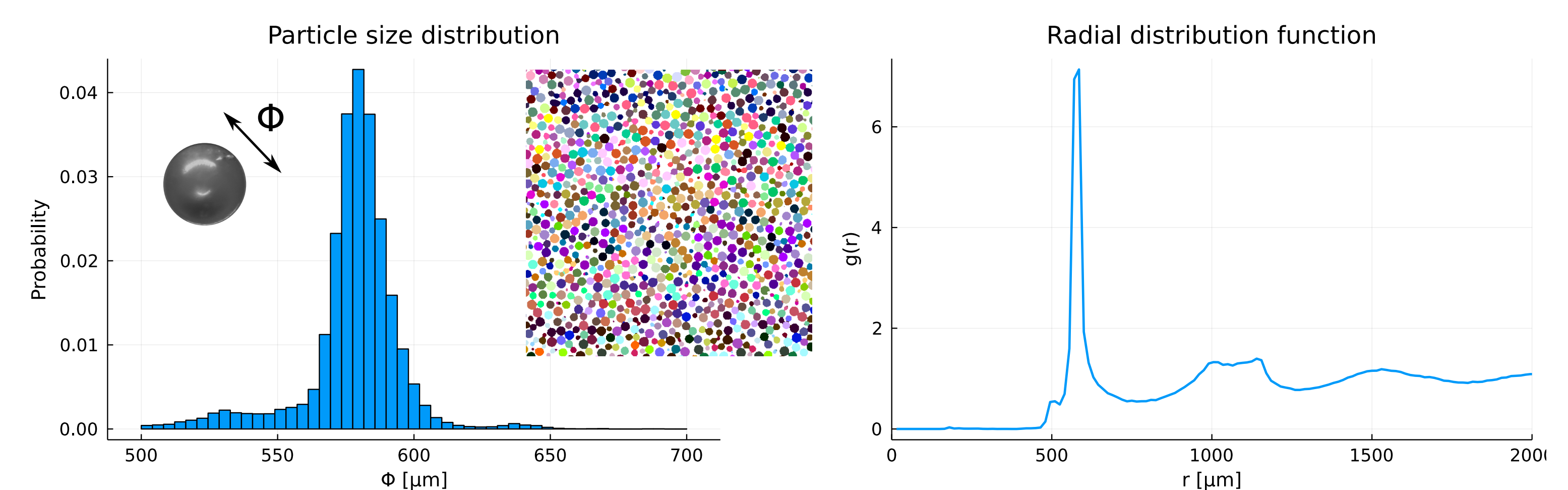
Maximizing the source-to-object distance minimizes the distortions induced by the conic geometry. Our results therefore suggest that there is at least one more source of distortions.

Comparison of **radio** and **conic reprojection** shows that beam-hardening cannot be neglected.



Despite these distortions, the proposed method is **quantitative**. We were able to measure the average radius of the spherical beads from one single radio.

The resulting value was confirmed by a more costly analysis of the 3D reconstructed volume (PSD + RDF [8]).



Perspectives

- ▶ New experimental setup, with a more controlled sample (dimensions, ...)
- ▶ Quantification of other descriptors: volume fraction, specific surface area ...
- ▶ Analytical model of geometric, noise-induced and beam-hardening distortions → deconvolution
- ▶ Extension to $N > 2$ phases: vary source kV and/or use photon-counting, dual energy, XC-Thor sensor from DirectConversion
- ▶ "Sub-pixel" accuracy?

References

- [1] A. Thureau et al., *J. Appl. Crystallogr.* (54) 2021 - doi : 10.1107/S1600576721008736
- [2] C. Hotton et al., *J. Colloid Interface Sci.* (604) 2021 - doi : 10.1016/j.jcis.2021.07.010
- [3] Brisard et al., *J. Am. Ceram. Soc.* (102, 5) 2019 - doi : 10.1111/jace.16059
- [4] Brisard et al., *Am. Min.* (97, 2-3) 2015 - doi : 10.2138/am.2012.3985
- [5] Odin et al., *Foss. Rec.* (20, 95-103) 2017 - doi : 10.5194/fr-20-95-2017
- [6] Geng et al., *Cem. Concr. Res.* (111) 2018 - doi : 10.1016/j.cemconres.2018.06.002
- [7] Brisard & Levitz, *Phys. Rev. E* (87) 2013 - doi : 10.1103/PhysRevE.87.013305
- [8] Yildirim & Brown, *Zenodo*, by256/rdfpy: rdfpy-v1.0.0, 2021 - doi : 10.5281/zenodo.4625675

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