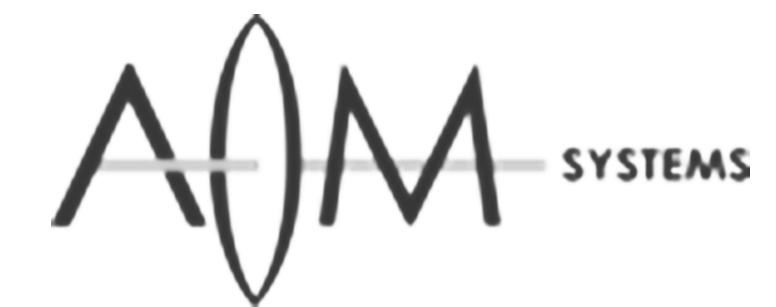
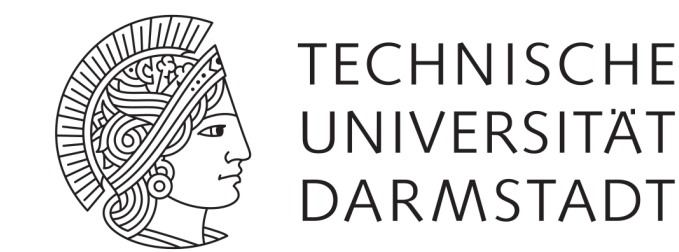


Light Scattering from a Drop with an Embedded Spherical Particle for the Time-Shift Technique

L. Li ¹, C. Tropea ¹ and W. Schäfer ^{2,3}**1** TU Darmstadt **2** AOM-Systems **3** ai-quanton

[1] L. Li, S. Rosenkranz, W. Schaefer, and C. Tropea, "Light scattering from a drop with an embedded particle and its exploitation in the time-shift technique," *J. Quant. Spectrosc. Radiat. Transfer*, vol. 227, pp. 20–31, 2019, doi: [10.1016/j.jqsrt.2019.01.022](https://doi.org/10.1016/j.jqsrt.2019.01.022)



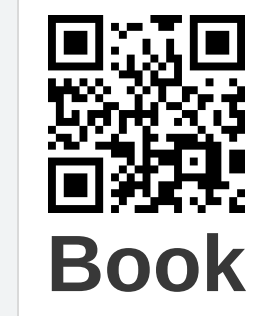
Paper

[2] W. Schäfer and C. Tropea, "Time-shift technique for simultaneous measurement of size, velocity, and relative refractive index of transparent droplets or particles in a flow," *Appl. Opt.*, vol. 53, pp. 588–597, 2014, doi: [10.1364/AO.53.000588](https://doi.org/10.1364/AO.53.000588)



Paper

[3] W. Schäfer, *Time-Shift Technique for Particle Characterization in Sprays*. Ph.D. diss., TU Darmstadt, 2012; book ed., Berlin, 2013, ISBN 979-8161309988. <https://amzn.eu/d/08dPYjDf>



Book

[4] P. Laven, "Simulation of rainbows, coronas, and glories by use of Mie theory," *Appl. Opt.*, vol. 42, pp. 436–444, 2003, doi: [10.1364/AO.42.000436](https://doi.org/10.1364/AO.42.000436)



Paper

This study is devoted to **light scattering from drops with an embedded particle**, as expected in encapsulation and coating processes or with the spraying of metallic paints. A 3D ray-tracing model computes the trajectories of a large number of rays of an incident plane wave and superimposes all rays scattered in a given direction to obtain the scattering diagram [1, 3].

1 3-Dimensional Ray Tracing Technique (3DRT)

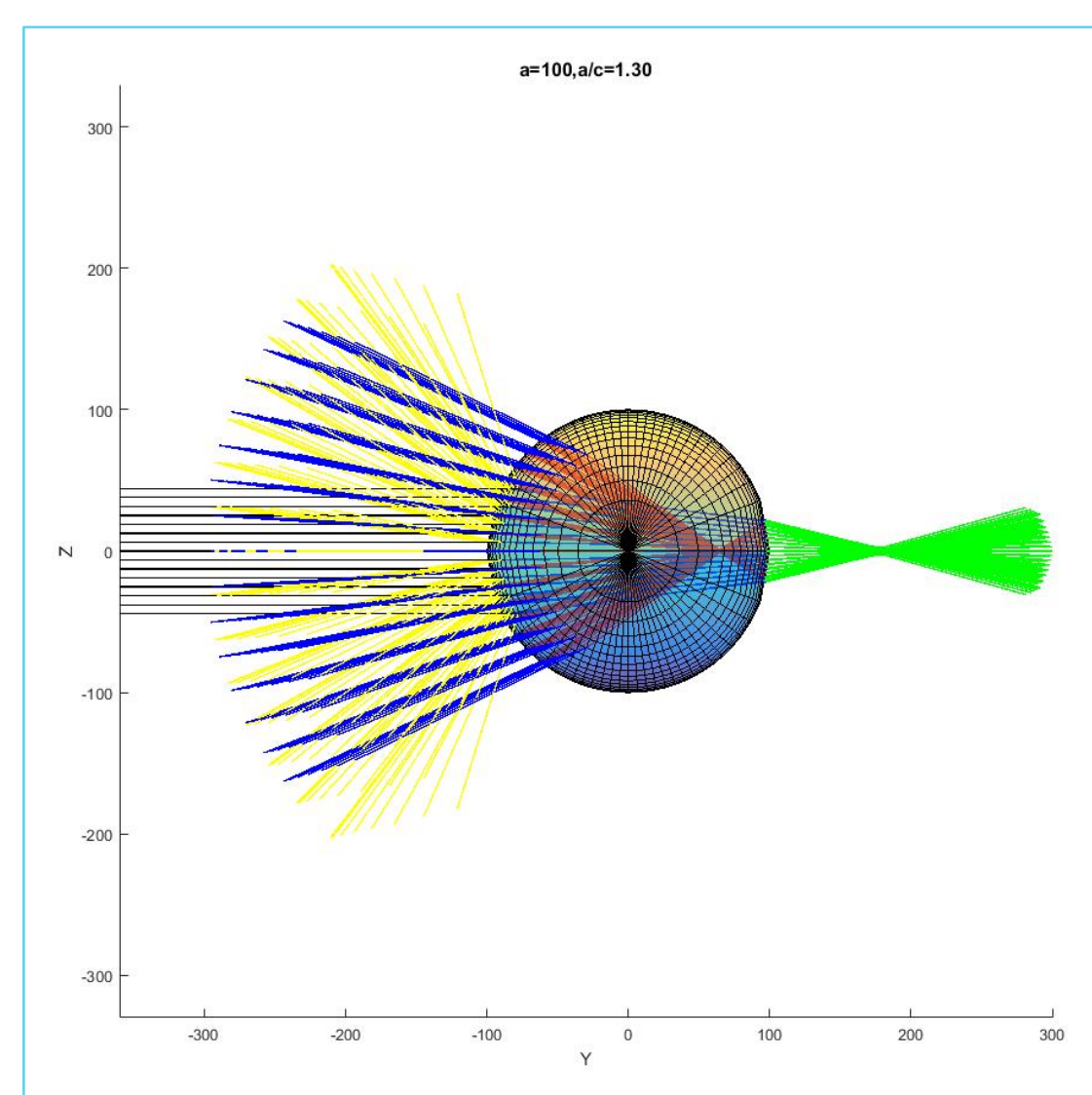


Fig. 1 Ray-tracing model of a drop with an embedded particle.

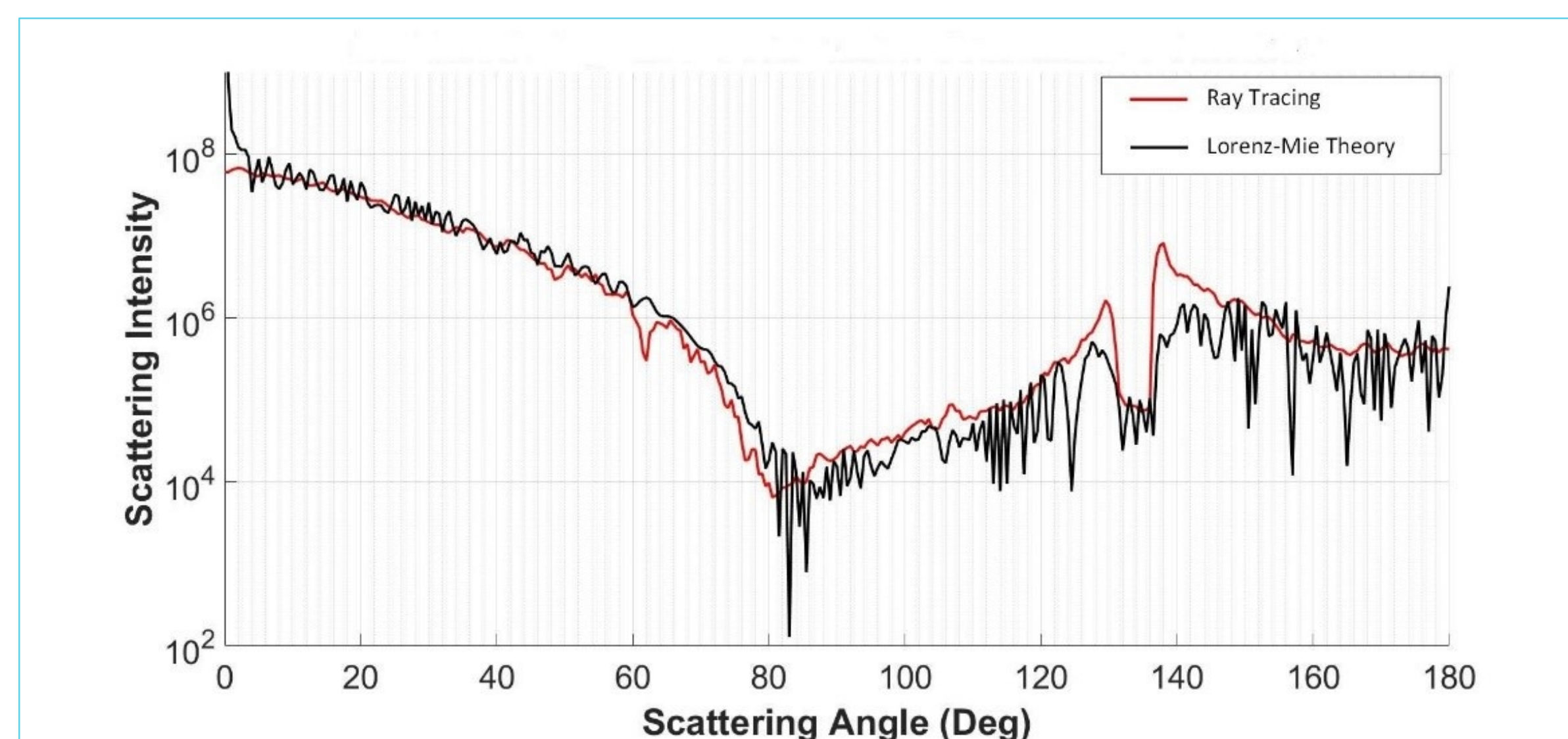


Fig. 2 Ray tracing (red) versus Lorenz-Mie theory (black) [4].

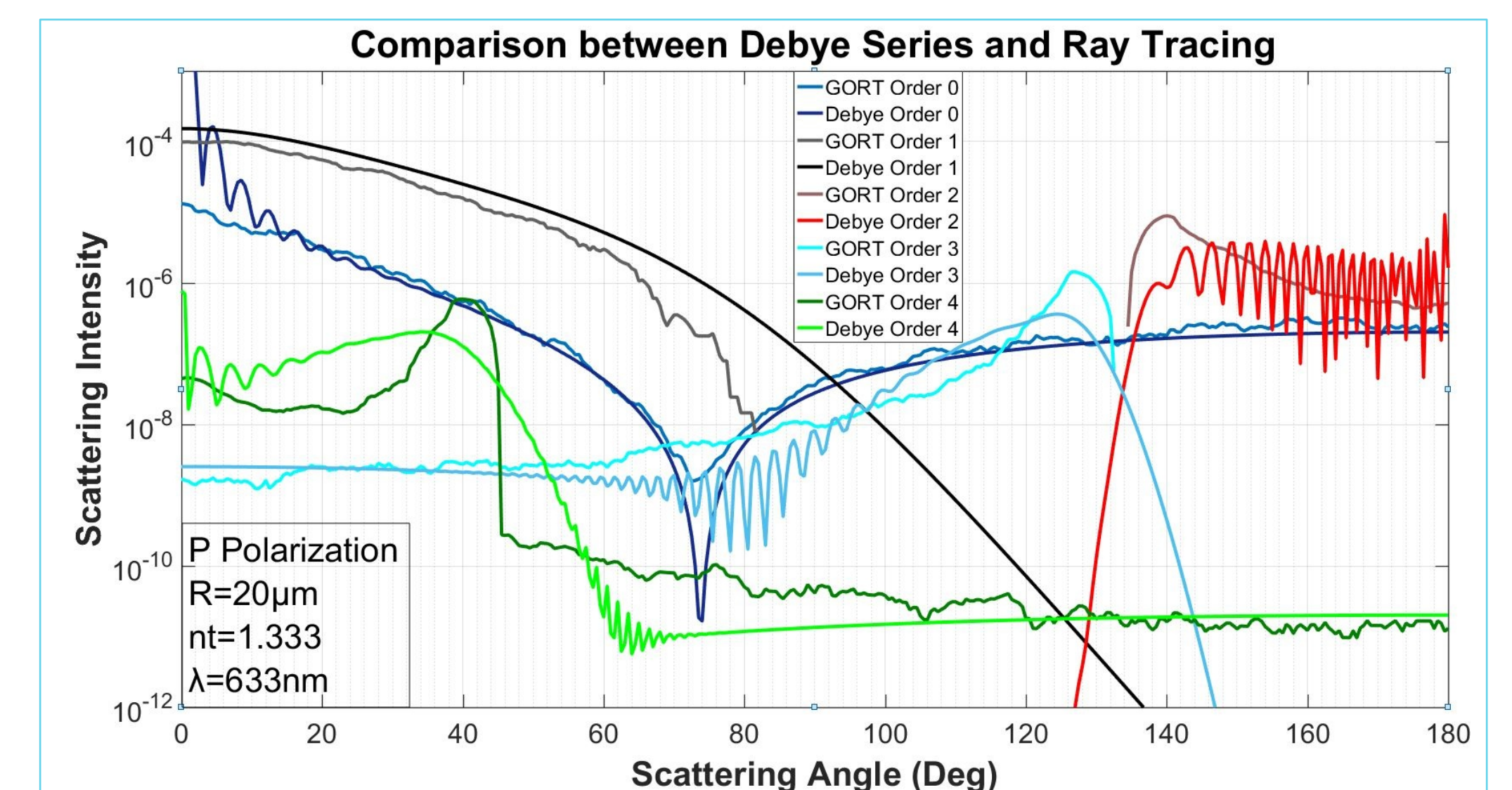


Fig. 3 Ray tracing (GORT) versus Debye series [1, 3]; P polarization, $R = 20 \mu\text{m}$, $nt = 1.333$, $\lambda = 633 \text{ nm}$.

2 Light Scattering Diagram for a Drop with an Embedded Particle

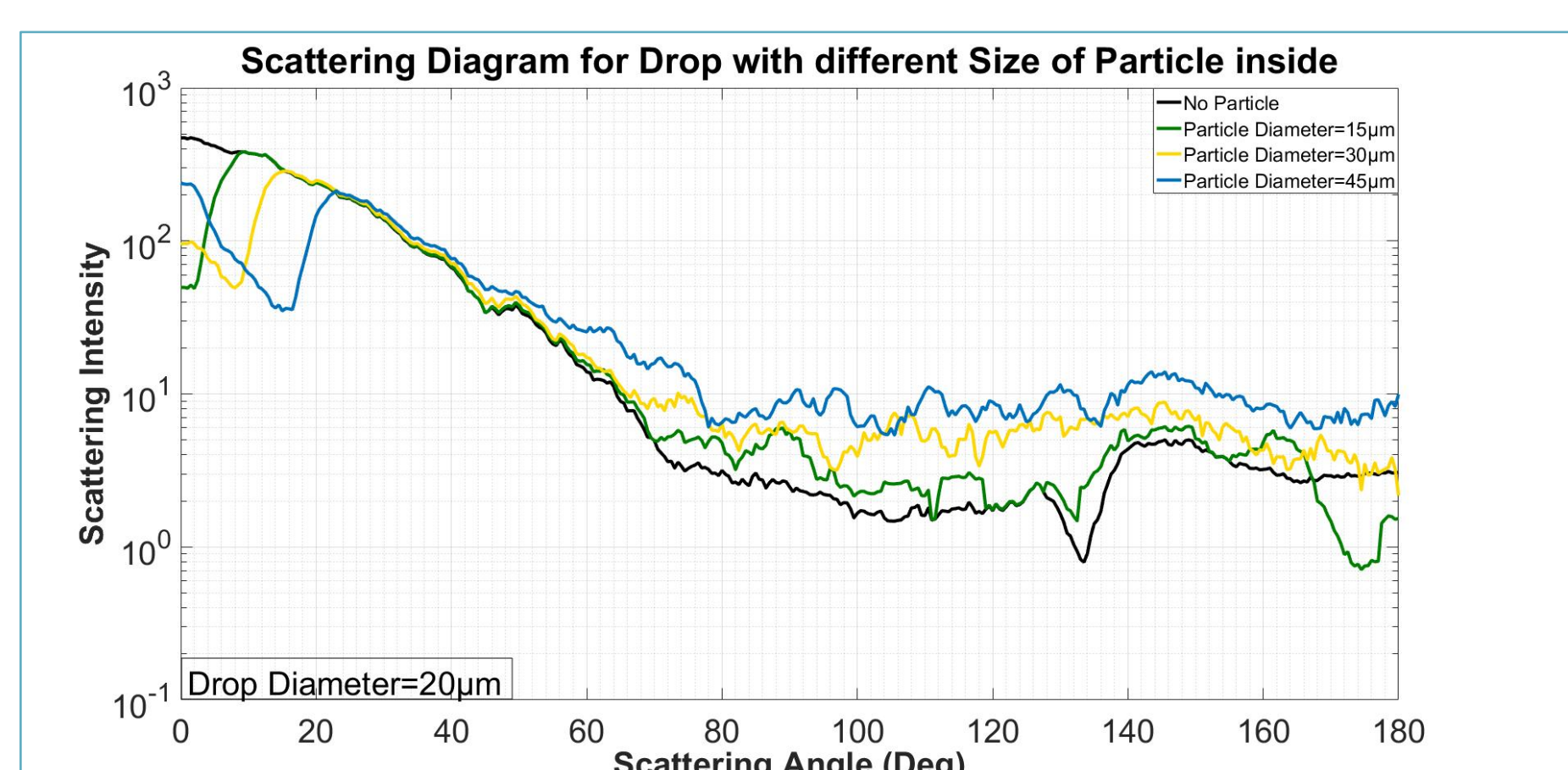


Fig. 4 Varying particle size (drop diameter $20 \mu\text{m}$).

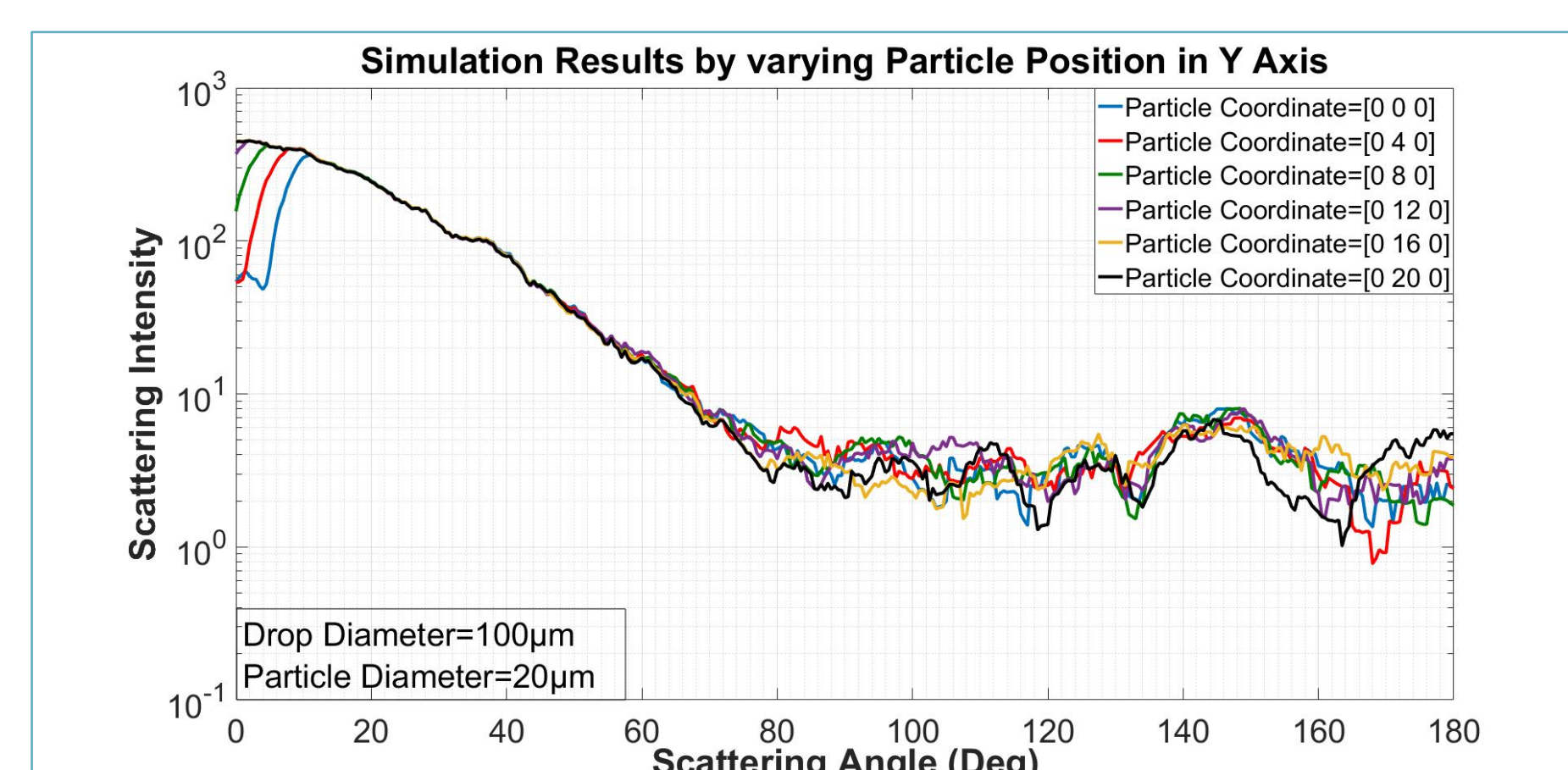


Fig. 5 Varying particle position in y (drop $100 \mu\text{m}$, particle $20 \mu\text{m}$).

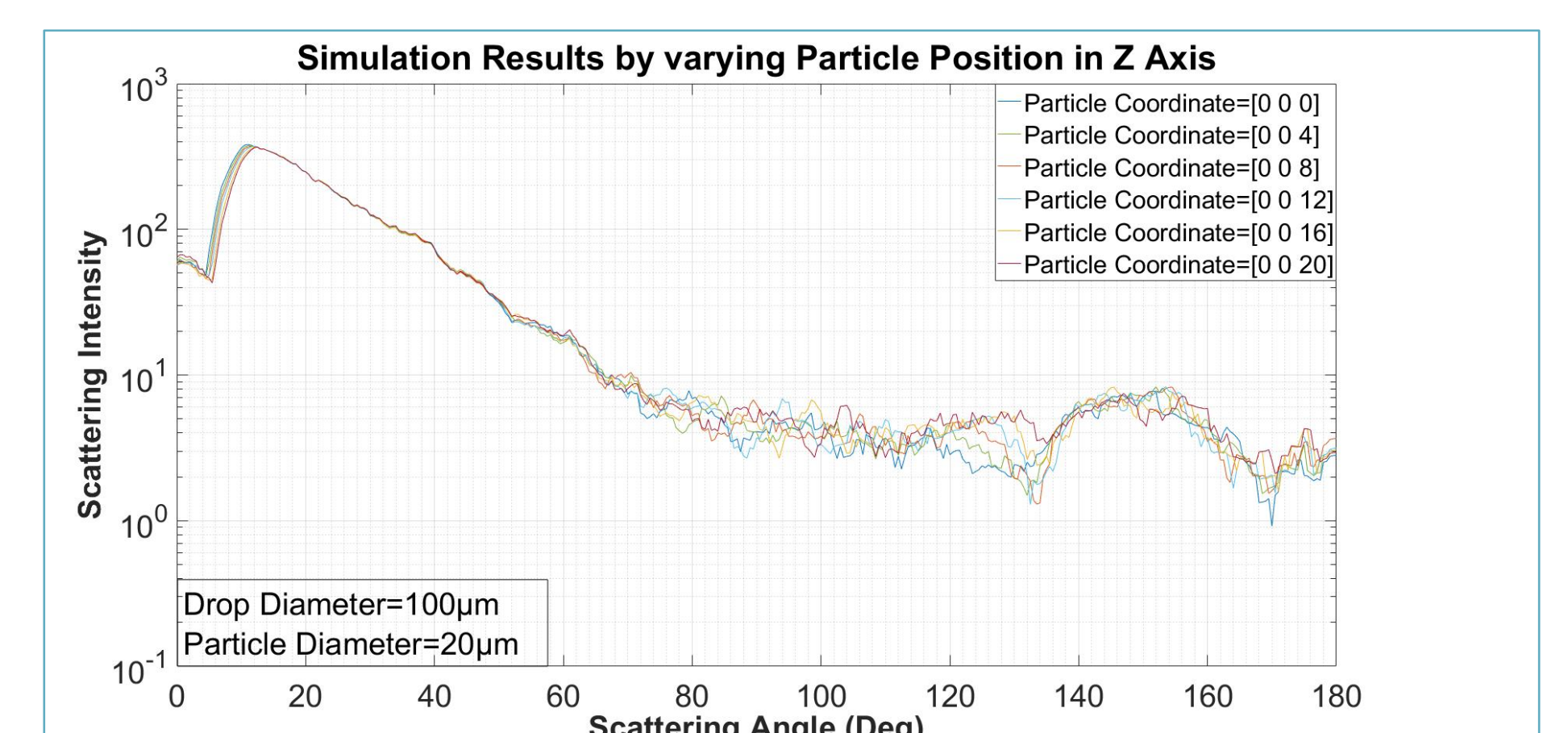


Fig. 6 Varying particle position in z (drop $100 \mu\text{m}$, particle $20 \mu\text{m}$).

- Forward scattering is **less sensitive** to a change of the particle position in z direction.
- The **size of the embedded particle** has a significant influence on the forward scattering intensity.

3 Light Scattering Simulation for the Time-Shift Technique

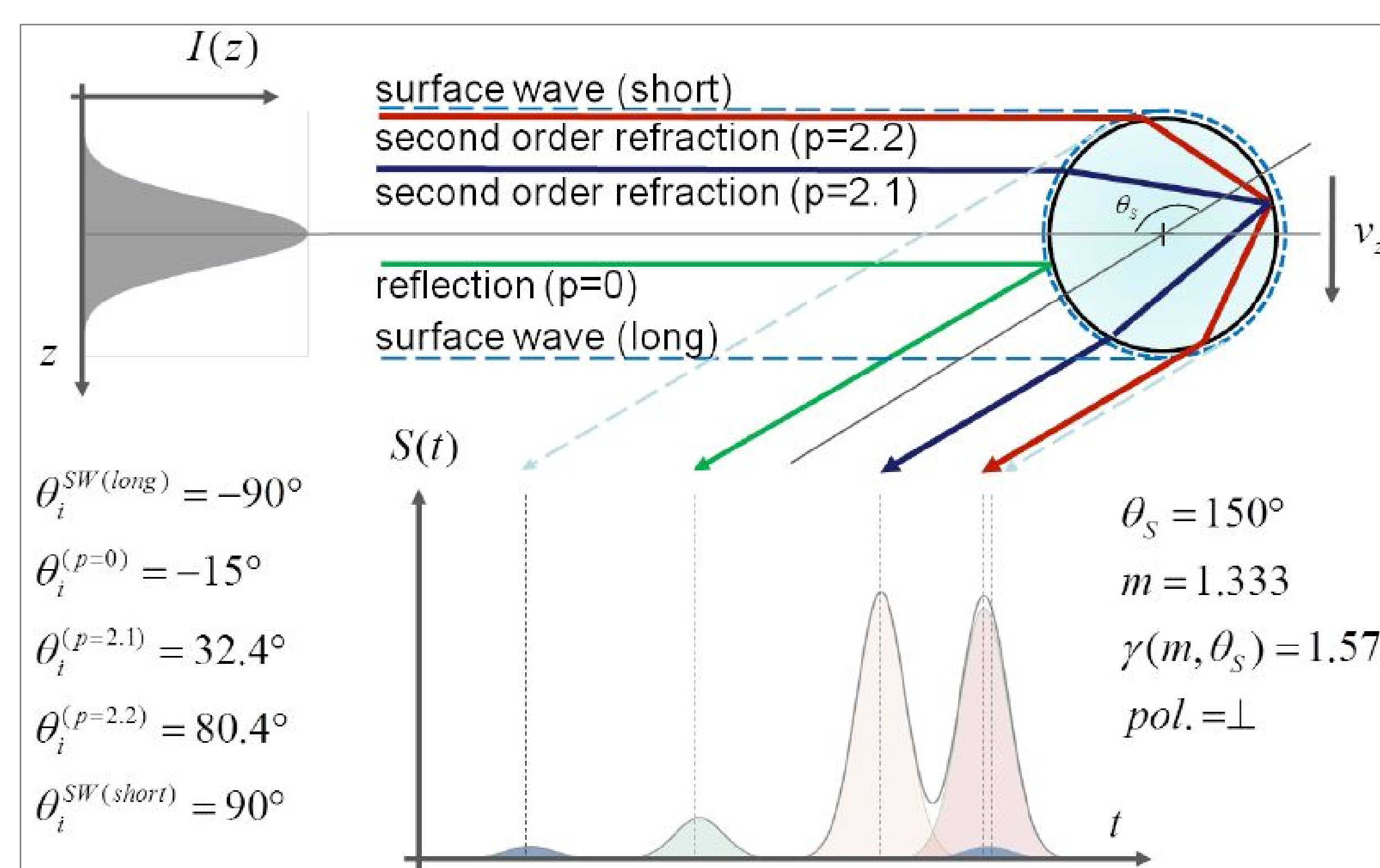


Fig. 7 Principle of the time-shift technique: scattering orders and signal peaks ($\theta_s = 150^\circ$, $m = 1.333$, $\perp$ polarization).

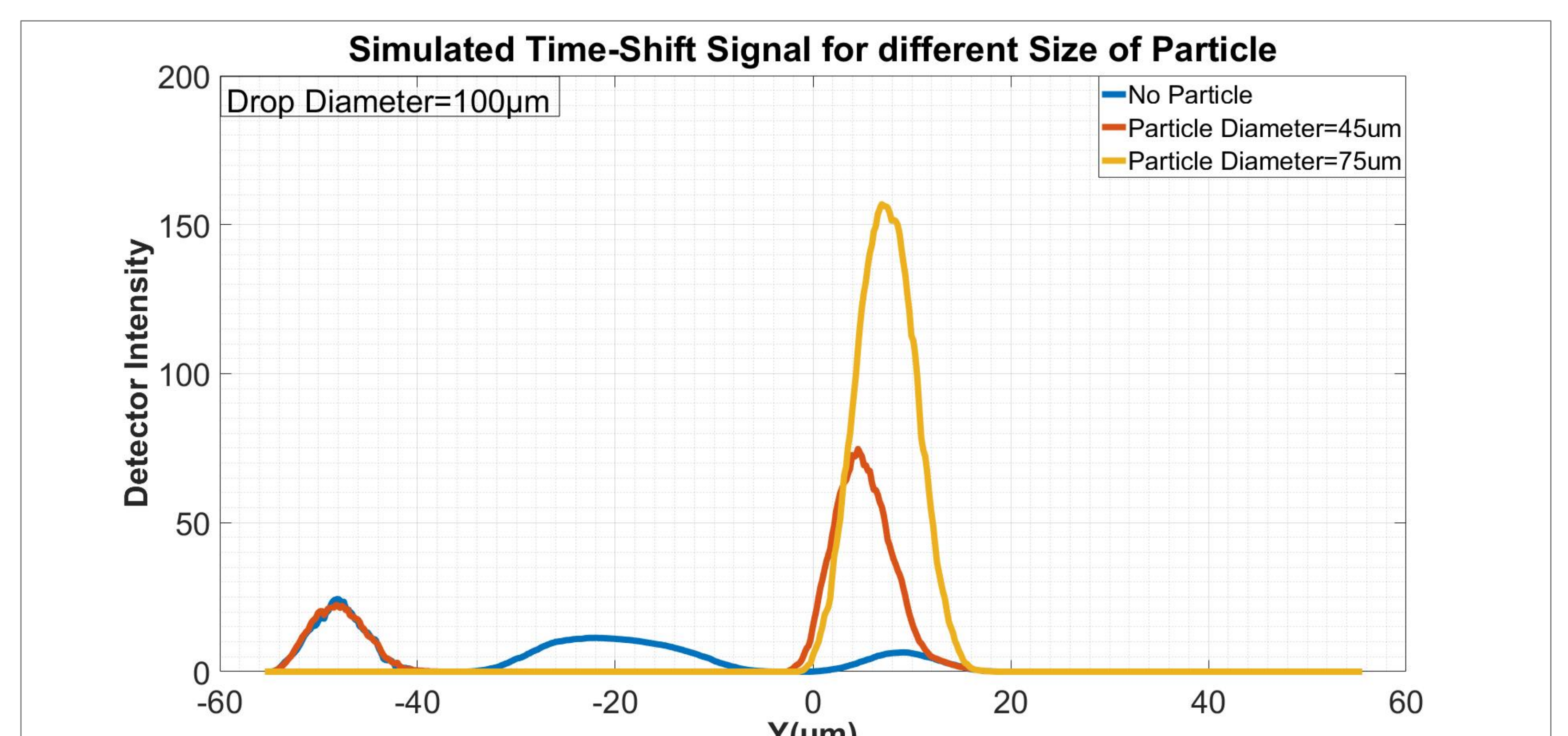


Fig. 8 Simulated TSTOF signal for different particle sizes (drop diameter $100 \mu\text{m}$).

- With a particle diameter of **45 μm** , the signal of the scattering order **$p = 2.1$** vanishes.
- With a particle diameter **above 75 μm** , both second-order refractions **$p = 2.1$** and **$p = 2.2$** vanish, because the particle blocks the internal reflection of the light.