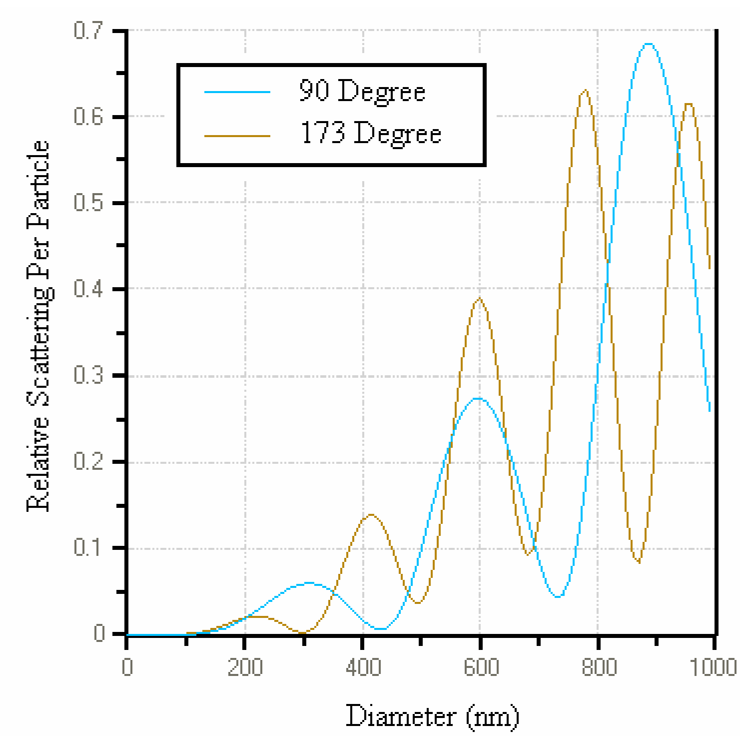
# Will Backscatter And 90 Degree Results Be Consistent?

This is a common question posed by customers switching from classical 90 degree scattering instruments to the latest generation of backscatter light scattering systems. The answer to the question is that sometimes the results will be consistent and other times they will not. Differences in the results are a direct consequence of the angle dependence of the light scattered from larger particles, as predicted by Mie theory.

According to light scattering theory, small particles (< ~100 nm diameter) are isotropic scattering centers, meaning that the intensity of light scattered is the same in all directions within the detection plane. Isotropic scattering is also referred to as Rayleigh scattering. As the particle size increases however, so does the probability of multiple scattering centers arising within the same particle, which will lead to constructive and destructive interference at the detector, and an observable angular dependence in the scattering intensity. This dependence is predicted by Mie theory, as exemplified in the figure below, which shows the theory predicted relative scattering per particle as a function of particle size for a classical 90 degree scattering angle and a backscatter angle of 173 degrees.




The Mie data shown in the above figure can be more easily understood by means of a hypothetical example. At a 90 degree scattering angle, theory predicts a local Mie maxima and minima at 300 and 415 nm respectively. If one particle of each size was present, the magnitude of the scattering intensity from the smaller 300 nm particle would be ~11 times greater than that of the larger 415 nm particle. If the same two particles are measured at 173 degrees however, theory predicts that the scattering from the larger 415 nm particle would be more than 200 fold greater than the smaller 300 nm particle. Now while the magnitude of the per particle scattering intensity has little effect on the per particle measured size, the scattering magnitudes will certainly have an influence on any type of intensity weighted average, such as the Z average derived from the Cumulants analysis.

As working examples, consider the figures below. Figures 1a & b show the intensity particle size distribution results for monodisperse latexes at 30 and 220 nm diameter measured at 90 and 173 degree scattering angles. As noted in both figures, there is no discernable angular dependence, with both systems generating nearly identical results. Since these samples are monodisperse, i.e. a single particle size, the absence any angular effect is expected, in that there is no "averaging" of intensity weighted sizes. Figure 2 on the other hand, indicates a distinct angular dependence in the intensity particle size distribution results generated for a mixture of 2 monodisperse latexes (60 & 200 nm). Note however, that while the relative intensities are angle dependent, the reported sizes for the two latex particles measured at 90 and 173 degrees are consistent. With regard to an "average" size value, the intensity weighted Z average also shows the expected angular dependence predicted by Mie theory.

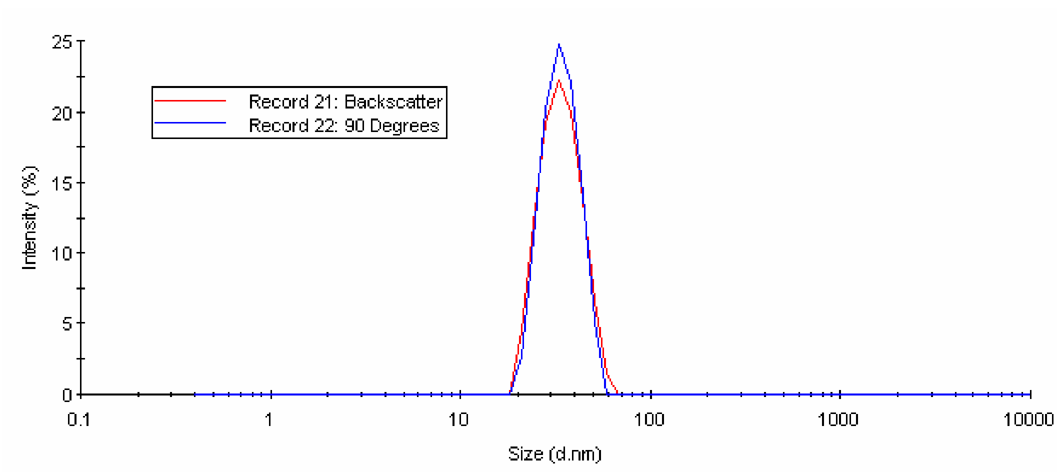



**Figure 1a:** Intensity particle size distributions measured at 90 and 173 degrees for a monodisperse 30 nm latex.

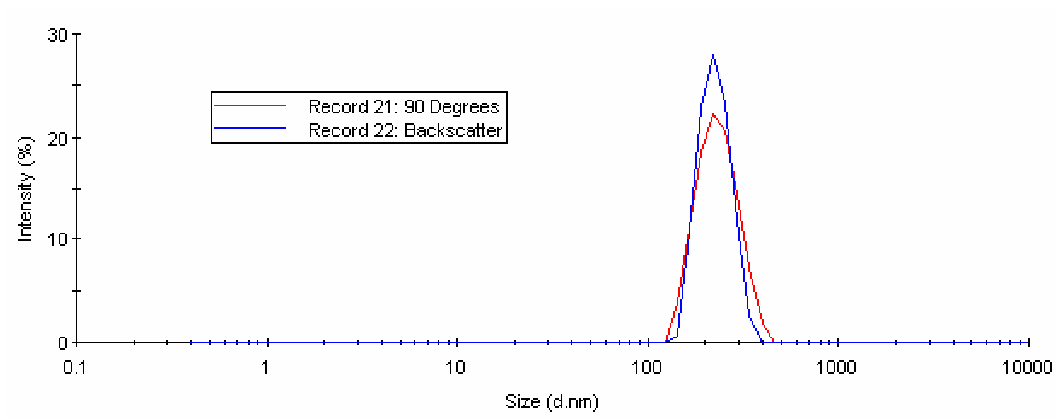



**Figure 1b:** Intensity particle size distributions measured at 90 and 173 degrees for a monodisperse 220 nm latex.

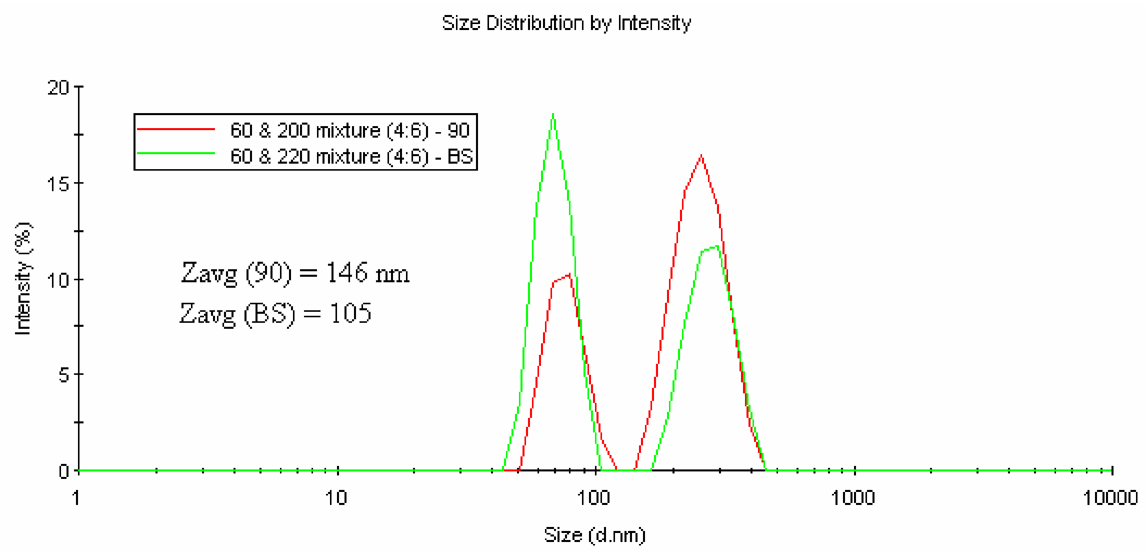



**Figure 2:** Intensity particle size distribution results for a mixture of monodisperse 60 and 200 nm latexes, at a 4:6 volume ratio, measured at 90 and 173 degree scattering angles.

Fortunately, the same theory that predicts an angular dependence of light scattered from large particles, can also be used to correct for intensity weighting effects. Figure 3 shows the volume distribution derived from a Mie theory transform of the measured intensity distribution for the latex mixture results shown above. As shown in this figure, the volume transform normalizes the intensity weighting effects, yielding distributions that are independent of the scattering angle.

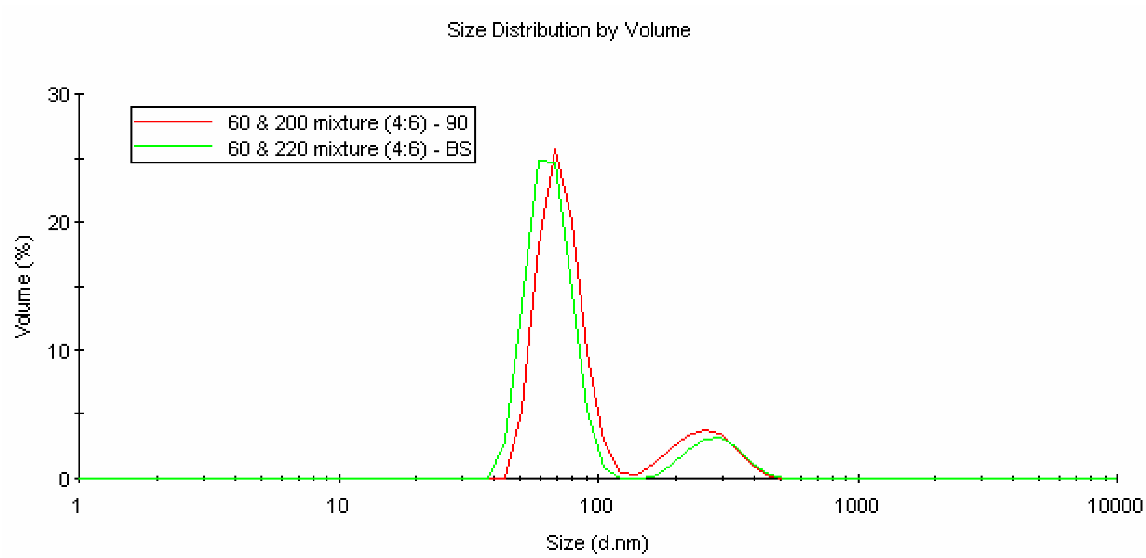



**Figure 3:** Volume weighted particle size distribution for a mixture of monodisperse 60 and 200 nm latexes, at a 4:6 volume ratio, measured at 90 and 173 degree scattering angles.

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