Towards an experimental violation of a motional-state Bell's inequality using ultracold helium

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We present our experimental progress towards demonstrating quantum non-locality in a matter wave system via a Rarity-Tapster interferometer. The entangled state for the system is generated using two *s*-wave scattering halos created by colliding helium Bose-Einstein condensates. The theoretical basis for this method is discussed, and its suitability is experimentally quantified. Thus far we have achieved an interferometric visibility of $V = 0.42(9)$, corresponding to a maximum CSHS-Bell parameter of $S = 1.1(1)$, for the Clauser-Horne-Shimony-Holt (CHSH) version of the Bell inequality, between atoms separated by ~ 4 correlation lengths. This constitutes a significant step towards a demonstration of a Bell inequality violation for motional degrees of freedom of massive particles and possible measurements of quantum effects in a gravitationally sensitive system.