Colliding BECs – simulation of classical binary collisions

Scope of simulation

A classical simulation of BEC FWM experiment at ANU He* BEC lab is carried out to better understand the physics and progress for ghost imaging. The classical model is an elastic binary collision of point-like particles from colliding condensate sources which undergo s-wave scattering. The sources have identical momentum distribution (other than the mean collision momentum) calculated from the Thomas-Fermi approximation of trapped BEC. For simplicity, the analytical TF momentum distribution is approximated by a 3D Gaussian by matching the HWHM ($1.99/R_i$ from analytical solution). The model further assumes that momenta of the collision pairs are independent, except for the condition that they may not be both from the same source. Collision velocity in the centre of mass frame has been set to $hbar*k/m_{He}$, which resembles our experiment (1083nm laser for Bragg/Raman transitions).
The input simulation parameters relevant to the experiment are the condensate population, trap frequencies, detector quantum efficiency, and the number of scattered atoms detected.
Comparisons of the *width of the scattering halo* ($w^{(H)}$) is made to the g^2 *correlation length of back-to-back momentum pairs* ($g^{(2)}_{BB}$) and *source momentum width* ($w^{(S)}$).

Methods

From the Thomas-Fermi approximation, the momentum widths of the sources are determined. Collision pairs in momentum space are repeatedly generated from random selection and each particle is randomly selected for detection at the quantum efficiency, until the set number of scattered atoms are met (30 atoms per halo). When the simulation has been repeated for a sufficient number of times (5000 halos), the collated set of scattered atoms in momentum space show the familiar s-wave scattering halo from many experiments. Projected $g^{(2)}_{BB,i}$ correlations are fitted well by 1D Gaussians and compared with the momentum widths of the halo and the source condensate.

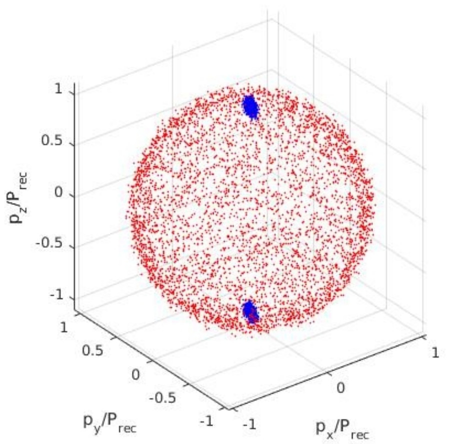
Results

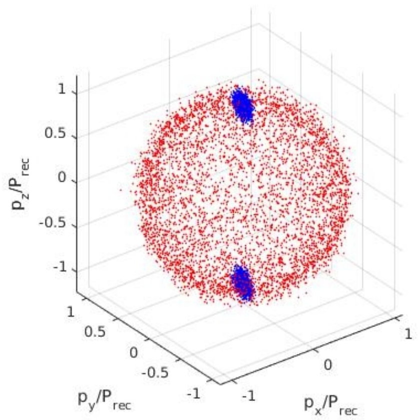
Summary for a weak {48,180,180}Hz, and strong trap {50,500,500}Hz†

*** Table of results‡**

Trap	Weak	Strong
$w_i^{(S)}$	0.0086, 0.0324, 0.0324	0.0059, 0.0593, 0.0593
$w^{(H)}$	0.0348	0.0629
$w(g^{(2)}_{BB,i})$	0.0151, 0.0574, 0.0572	0.0109, 0.1471, 0.1483

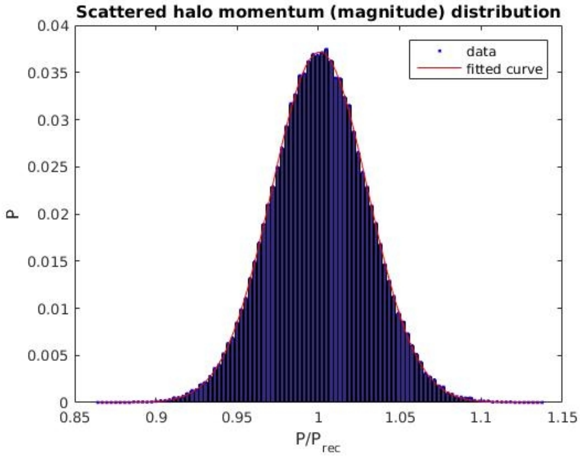
*** Scattering halo**

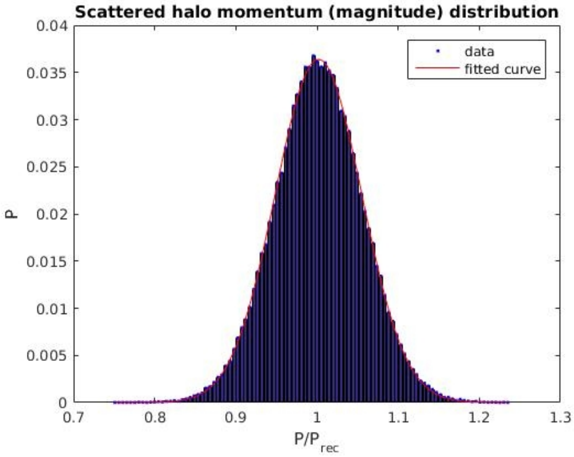




†Simulation parameters: $N_{sim}=5000$, $QE=0.1$, $N_{halo}=30$, $N_0=10^4$
‡All momentum widths are HWHM and normalised to the collision momentum

*** Halo momentum distribution**





*** $g^{(2)}_{BB}$**