small x. By tuning the currents in the four wires, we effectively control the coefficients of the x, x^2, x^3 and x^4 terms in that expansion: we can thus produce harmonic potentials, but also double-well potentials.

Using radio-frequency evaporative cooling we produce cold atomic clouds in the 1d regime, with a typical energy per atom smaller than the transverse energy gap: the temperature and chemical potential fulfill $k_{\rm B}T, \mu < \hbar\omega_\perp$. The gas is then well described by the 1d model (1), with the effective 1d repulsion strength $g = 2\hbar a\omega_\perp$ [47] where the 3d scattering length of ^{87}Rb is $a = 5.3\,$nm, and the mass is $m = 1.43\times 10^{-25}$kg. Moreover the lengthscale on which $n(x)$ varies is much larger than microscopic lengths —the phase correlation length at thermal equilibrium, which is the largest microscopic length in the quasicondensate regime, is of order $n\hbar^2/(mk_{\rm B}T)$ [48, 49], typically $0.1\,\mu$m for our clouds— so the hydrodynamic description applies. At equilibrium, the latter is equivalent to the Local Density Approximation (LDA), and the local properties of the gas are parametrized by the dimensionless repulsion strength $\gamma = mg/(\hbar^2 n)$ and the dimensionless temperature $\theta = 2\hbar^2 k_{\rm B}T/(mg^2)$ [50]. The range (γ, θ) explored by our data sets is displayed in Fig. 2.(b). In this Letter we analyze the density profiles $n(x)$, which we measure using absorption images [46], averaging over typically ten images, with a pixel size of 1.74 μm in the atomic plane.

The Yang-Yang initial profile. We start by trapping a cloud of $N = 4600 \pm 100$ atoms, with $\omega_\perp = 2\pi\times(7.75\pm0.02)\,$kHz, in a harmonic potential $V(x) = m\omega_\parallel^2 x^2/2$ with $\omega_\parallel = 2\pi\times(8.8\pm0.04)\,$Hz, and measure its density profile (Fig. 1.(ii)). To evaluate the temperature of the cloud, we fit the experimental profile with the one predicted by the Yang-Yang equation of state [9–11, 40], relying on LDA and on the assumption that the cloud is at thermal equilibrium; we find $T = (0.43\pm0.013)\,\mu$K. This gives $\theta = (3.5\pm0.1)\times10^2$, while the interaction parameter is $\gamma = (2.8\pm0.1)\times10^{-2}$ at the center.

As the density varies from the center of the cloud to the wings, the gas locally explores several regimes [50], from quasicondensate to highly degenerate Ideal Bose Gas (IBG) to non-degenerate IBG, see Fig. 2(b). The Yang-Yang equation of state [40] is exact in the entire phase diagram of the Lieb-Liniger model, and thus faithfully describes the density profile within LDA. We stress that this is the most natural and powerful method to describe the initial state of the gas [9–11], and that no simpler approximate theory [51] can account for the whole initial density profile, see Fig. 1(ii). The Gross-Pitaevskii (GP) theory works in the central part—because it is close to the quasicondensate regime—, but not in the wings. The opposite is true for the IBG model: it correctly describes the wings, but not the center of the cloud—the chemical potential is positive in the center, so the density diverges in the IBG—. The classical field theory captures the quasicondensation transition for gases deep in the weakly interacting regime but it fails to reproduce faithfully the wings of our cloud since the latter are not highly degenerate.

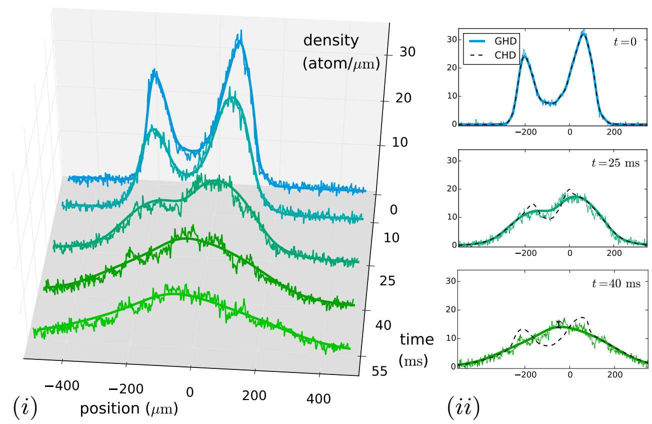

FIG. 3. (i) Longitudinal expansion of a cloud of $N = 6300 \pm 200$ atoms initially trapped in a double-well potential, compared with GHD. (ii) Even though the initial state is the same for GHD and CHD, both theories clearly differ at later times. CHD wrongly predicts the formation of two large density waves. The error bar shown at the center at $t = 40$ms corresponds to a 68% confidence interval, and is representative for all data sets.

Expansion from harmonic trap: agreement with both GHD and CHD. At $t = 0$, we suddenly switch off the longitudinal harmonic potential $V(x)$, and let the cloud expand freely in 1d. We measure the in situ profiles at times $t = 10, 20, 30$ and 40 ms, see Fig. 1(i).

Two theories are able to give predictions for the expansion starting from the locally thermal initial state. One is GHD, presented above, where the full distribution of quasi-particles $\rho(x, v)$ is evolved in time [52]. The other is the *conventional* hydrodynamics (CHD) of the gas which, contrary to GHD, assumes that all local fluid cells are at thermal equilibrium, and keeps track only of three quantities that entirely describe the local state of the gas: the density $n(x)$, the fluid velocity $u(x)$, and the internal energy $e(x)$ [51]. We calculate the evolution of the density profile with both theories, and find that both of them are in excellent agreement with the experimental data, see Fig. 1(iii) for the result at $t = 30$ ms.

GHD and CHD thus appear to be indistinguishable in that situation, at least for the expansion times that we probe here. We attribute this coincidence to the initial *harmonic* potential, which is very special. In this case it is simple to see that the GHD and CHD predictions coincide in the ideal Bose gas regime, and they can be shown to stay relatively near even beyond that regime [53].

Discussion: GHD vs. CHD. We wish to identify a setup where the theoretical predictions of both theories clearly differ, in order to experimentally discriminate between them. This will be the case if GHD predicts, for some time t and at some position x, that the distribution of rapidities $\rho(x, v)$ will differ strongly from a thermal equilibrium one.

Such a situation occurs during the expansion of a