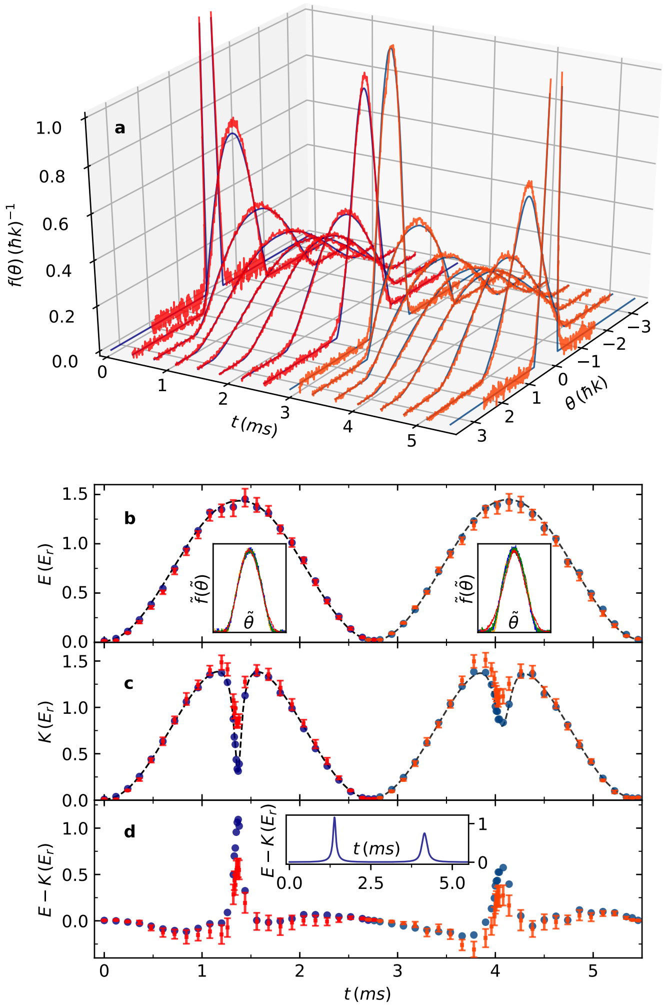

FIG. 3. **Strong coupling (100-times) trap quench.** **a**, Time evolution of the rapidity distribution after the trap is suddenly made 100 times deeper for 1D gases with $\bar{\gamma}_0$=9.3. The red and orange curves show the experimental rapidity distributions over the course of the first two collapse cycles. The dark blue and light blue curves are the associated GHD theory, accounting for the measured atom number at each point (see Extended Data Fig. 1c and d). The color change denotes a 1% change in the trap depth due to the slow experimental drift (see Methods). **b**, Time evolution of the rapidity energy, E, after the quench. The red and orange squares are extracted from experimental distributions like those in **a** (see Methods). The dark and light blue circles are for the associated GHD theory. The dashed line is the GHD theory using the average atom number. The two insets show the rescaled experimental rapidity distributions for points throughout the first and second cycle respectively (points near 0, $\pi/4$, $\pi/2$, $3\pi/4$, and π phases are shown in black, orange, blue, green, and red, respectively). By the second cycle the distributions are no longer self-similar. **c**, Time evolution of the kinetic energy, K, after the quench. The labeling is the same as for **b**, but the trap depths are slightly ($< 4\%$) different (see Extended Data Fig. 1e and f for the associated atom numbers). **d**, Time evolution of the interaction energy after the quench. The experimental and GHD theory points are obtained from **b** and **c** by subtracting K from E at each time. The inset shows GHD theory for a constant atom number and trap depth.

Figure 2a shows the evolution of the rapidity distribution starting from our intermediate coupling condition after a quench to a ten times deeper trap. Our quenches are small enough to ensure that two atoms never have enough energy to get transversely excited in a collision [26]. Over the first two cycles, the shapes of all the distributions are self-similar (see Fig. 2b insets). Figure 2b shows the evolution of the integrated energy associated with the rapidities, which is the total energy less the trap potential energy. The squares are for the experiment, the dashed line shows the theory for an average number of atoms, and the circles show the theory using the measured number of atoms at each point (see Methods). After the quench, the calculated average cloud size drops from 14 μm to 3 μm, and $\bar{\gamma}$ drops from 1.4 to 0.3 (see Extended Data Fig. 2a–j). Figure 2 clearly shows that GHD accurately describes these experiments, where the weighted average (maximum) number of atoms per 1D gas is 60 (140) and the nature of the quasiparticles changes gradually during the collapse. The onset of multiple Fermi seas for this setup occurs in the 3rd cycle. By the 11th cycle, we experimentally observe a loss of self-similarity that is consistent with our theoretical calculations. However, by that time a $\sim$20% atom loss complicates the theory beyond the scope of this work [27] (see Extended Data Fig. 3).

Our initial strong coupling condition allows us to measure dozens of cycles without appreciable loss, and it also allows us to do a much larger trap quench, to a 100 times deeper trap. Figure 3a shows the rapidity evolution over the first two cycles. The shapes are no longer self-similar by the end of the first cycle (see the insets of Fig. 3b). The GHD theory agrees well with the experiment throughout. A second Fermi sea (see Fig. 1c) emerges during the first collapse; GHD is essential past that point. Extended Data Fig. 2k shows theoretical calculations of the evolution of cloud sizes; averaged over all tubes, the full width at half the central density decreases by a factor of 35, from 17.5 μm to 0.5 μm.

The squares, the dashed line, and the circles in Fig. 3b show the integrated rapidity energy as a function of time respectively for the experiment, the theory with the average atom number, and the theory with the measured atom numbers. The squares in Fig. 3c show the inte-