SUPPLEMENTAL MATERIAL

Magnus expansion. Solving the time-dependent Schrödinger equation for a time-independent system described by the Hamiltonian H yields the well-known time-evolution operator $U(0,t) = e^{-iHt}$. If the system is time-dependent, the time-evolution operator can be expressed as

$$U(0,t) = e^{\Omega(t)} = \exp\left\{\sum_{k}^{\infty} \Omega_k(t)\right\}, \tag{8}$$

where $t \mapsto \Omega(t)$ is a series known as the Magnus expansion. The first three terms in the Magnus expansion are given by

$$\begin{aligned}\Omega_1(t) &= \int_0^t \mathrm{d}t_1\, A(t_1),\\ \Omega_2(t) &= \frac{1}{2}\int_0^t \mathrm{d}t_1 \int_0^{t_1} \mathrm{d}t_2\, [A(t_1), A(t_2)],\\ \Omega_3(t) &= \frac{1}{6}\int_0^t \mathrm{d}t_1 \int_0^{t_1} \mathrm{d}t_2 \int_0^{t_2} \mathrm{d}t_3\\ &\quad [A(t_1),[A(t_2),A(t_3)]] + [A(t_3),[A(t_2),A(t_1)]],\end{aligned} \tag{9}$$

with $A(t) = -iH(t)$. If the Hamiltonian is time-independent, all Magnus terms but the first vanish.

The time-periodic Hamiltonian of Eqs. (1) and (2) is now plugged into this expansion, and one focuses on times t which are an integer multiple of the driving period $T = 2\pi/\omega$. The first-order term involving H_1 vanishes (since the time-average is zero), and the one involving H_2 yields the second and third term of Eq. (3). The second-order contribution associated with $[H_1(t_1), H_1(t_2)]$ yields the first term of Eq. (3). The second-order contribution involving $[H_1(t_1), H_2(t_2)]$ as well as all higher-order terms scale away with $1/\sqrt{\omega}$ or faster. A benchmark of how well the time-evolution computed using the effective Hamiltonian H^{eff} agrees with the one governed by the full $t \mapsto H(t)$ is shown in Fig. 3, Fig. 6, and Fig. 7.

Single preparations. An important question relates to the behavior of individual systems in contrast to disorder averaged ones such as those directly feasible in experiments. In Fig. 8 we show typical individual calculations that enter the disorder average focused upon in the main text. We show that those qualitatively behave like the averaged results.

Numerical details. In order to tackle the time-evolution governed by $t \mapsto H(t)$, we first compute the time-evolution operator $U(0,t)$ for $t = T = 2\pi/\omega$ numerically using a discrete time step of $\Delta t = T/100$. The periodicity of the Hamiltonian implies that $U(t_1,t_2) = U(t_1+T, t_2+T)$ and thus $U(0,2T) = U(0,T)^2$, $U(0,4T) = U(0,2T)^2$, which allows one to efficiently propagate the system to large times $t/T \sim 10^7$.

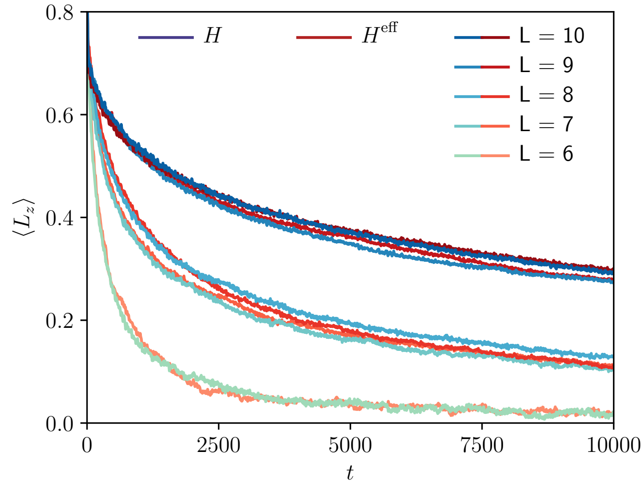

FIG. 6. Same as Fig. 3 of the main text but for more values of the system size L. The driving frequency is $\omega = 1000$.

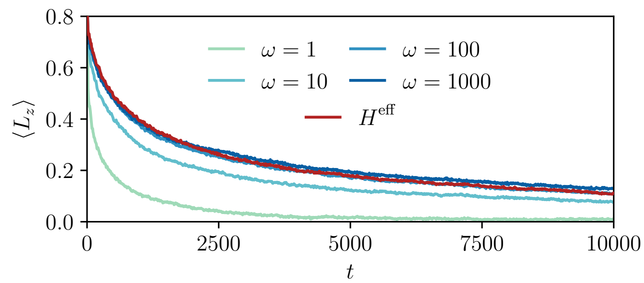

FIG. 7. Same as Fig. 3 of the main text but for various driving frequencies ω at a fixed system size $L = 8$.

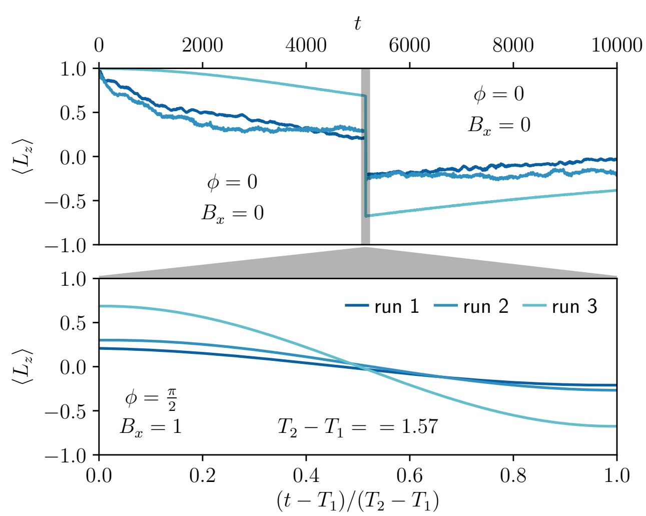

FIG. 8. Same as Fig. 5 of the main text but for three individual disorder configurations for a fixed value of $T_2 - T_1 = 1.57$.