

## **Hierarchy of modes in an interacting system**

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Studying interacting fermions in 1D at high energy, we find a hierarchy in the spectral weights of the excitations theoretically and we observe evidence for second-level excitations experimentally. Diagonalising a model of fermions (without spin), we show that levels of the hierarchy are separated by powers of  $R^2/L^2$ , where  $R$  is a length-scale related to interactions and  $L$  is the system length. The first-level (strongest) excitations form a mode with parabolic dispersion, like that of a renormalised single particle. The second-level excitations produce a singular power-law line shape to the first-level mode and multiple power-laws at the spectral edge. We measure momentum-resolved tunnelling of electrons (fermions with spin) from/to a wire formed within a GaAs heterostructure, which shows parabolic dispersion of the first-level mode and well-resolved spin-charge separation at low energy with appreciable interaction strength. We find structure resembling the second-level excitations, which dies away quite rapidly at high momentum.