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The strongest acceleration of >40 keV electrons by ICME-driven Shocks at 1 AU

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We present two case studies of the in situ electron acceleration at the 11 February 2000 shock and the 22 July 2004 shock with the strongest electron flux enhancement at 40 keV across the shock, respectively, among all the quasi-perpendicular and quasi-parallel ICME-driven shocks observed by the *WIND* 3DP instrument from 1995 through 2014 at 1 AU. We find that for this quasi-perpendicular (quasi-parallel) shock on 11 February 2000 (22 July 2004), the shocked electron differential fluxes at ∼0.4–50 keV in the downstream generally fit well to a double-power-law spectrum, $J \sim E^{-\beta}$, with an index of $\beta \sim$ 3.15 (4.0) at energies below a break at ∼3 keV (∼1 keV) and of $\beta \sim$ 2.65 (2.6) at energies above. For both shock events, the downstream electron spectral indices appear to be similar for all pitch angles, significantly larger than the index prediction by diffusive shock acceleration. In addition, the downstream electron pitch-angle distributions show the anisotropic beams in the anti-sunward traveling direction, while the ratio of the downstream over ambient fluxes appears to peak near 90° pitch angles, at all energies of ∼0.4–50 keV. These results suggest that in both shocks, shock drift acceleration likely plays an important role in accelerating electrons in situ at 1 AU. Such ICME-driven shocks could contribute to the formation of solar wind halo electrons at energies $\lesssim$2 keV, as well as the production of solar wind superhalo electrons at energies $\gtrsim$2 keV, in interplanetary space.