The recent detection of the Vela pulsar in the GeV band up to ∼100 GeV by both H.E.S.S. and the Fermi Large Area Telescope provides evidence for a curved spectral component in this band, distinct from the TeV pulsed emission seen by H.E.S.S. up to ∼7 TeV. We interpret these GeV pulsations to be the result of curvature radiation due to primary particles in the pulsar magnetosphere, primarily the current sheet. We predict energy-dependent light curves and phase-resolved spectra using an extended slot gap and current sheet model in a force-free magnetosphere, invoking a step function for the accelerating electric field as motivated by kinetic simulations. Our refined calculation of the curvature radius of particle trajectories in the lab frame impacts the particle transport and resulting light curves and spectra. As a result our model reproduce the decrease of flux of the first peak versus the second one (P1/P2 effect), evolution of the bridge emission, near constant phase positions of peaks, and narrowing of pulses with increasing energy. We can also isolate the distribution of Lorentz factors and curvature radii of trajectories associated with the first and second gamma-ray light curve peaks. The median values of these quantities are slightly larger for the second peak, leading to larger spectral cutoffs (i.e., a ‘harder’ second peak), and thus explaining the P1/P2 effect.