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Particle Acceleration by Magnetic Reconnection: Single X-line vs Multiple X-lines

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Energetic particles (both ions and electrons) are produced during explosive phenomena in the solar corona as well as in the Earth's magnetotail. While many theoretical models consider magnetic reconnection as a possible way of generating energetic particles, the impact of having multiple X-lines in a system has remained unclear. Here we use 2.5D particle-in-cell simulations to show that a system with multiple reconnection sites or 'X-lines' along a thin current sheet leads to a larger number of energetic particles (both ions and electrons) when compared to a single (or isolated) X-line case. This is because, in a multiple X-lines case, magnetic islands bounded by two X-lines at both ends are attracted toward each other and coalesce. As for the mechanism of particle energization, the contracting motion of a merged island is found to be a dominant process particularly for ions. The ions have large gyro-radii so that they can gain significant amount of energy by a single interaction with an island edge. Electrons are also found to be energized by the contracting island mechanism but the highest energy electrons are produced at the secondary reconnection site formed by the merging islands. As for the energy budget, 30% of the released magnetic energy goes to electrons in the multiple X-lines case, compared to 20% in the single X-line case. However, a single X-line has a higher total energy release rate than multiple X-lines.