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On the pronounced increase of the co-extracted electron current during long pulses in H-/D- negative ion sources for fusion

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The negative ion sources for ITER's NBI must provide 47 A of negative ion current in hydrogen (H^-) and 40 A in deuterium (D^-). Particles must be accelerated to 870 keV for 1000 s in H and to 1 MeV for 3600 s in D. Inherently, the extracted negative ions are accompanied by co-extracted electrons, which must be removed from the beam. Magnets are embedded in the extraction system to deflect electrons onto one of the grids. The resulting heat load on the grid is a critical limitation : under full-performance conditions, ITER's grid design requires the co-extracted electron current I_e to stay below the extracted negative ion current I_{ext}. The ELISE test facility hosts a negative ion source at half the scale of ITER's and supports its development. Since 2021, ELISE has been capable of performing long pulses (> 100 s) with continuous extraction. The present work provides an overview of these campaigns. The main outcome is that I_e remains difficult to keep low, stable, and vertically symmetric –particularly in deuterium. Notably, I_e rises significantly during long pulses, although this rise is not monotonic. A range of diagnostic data has been analyzed to investigate the origin and time dependence of this behavior. The evolution of I_e is found to correlate with several parameters, including caesium concentration, negative ion and electron densities, plasma potential and sheath potential drop. Based on these observations, a mechanism is proposed to explain the temporal evolution of the co-extracted electron current, outlining a sequence of contributing effects. Particular attention is given to the differences between hydrogen and deuterium.

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