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**Plasmas and Trap Based Beams as Drivers for New Science with Antimatter**[1]

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The development of novel positron traps and beams has enabled new investigations with antimatter. This talk will discuss recent successes, the tools that enabled them, and prospects for further progress. Antiparticles are of interest for a range of applications, including fundamental tests of gravity and the symmetries predicted by field theories (e.g., CPT), astrophysical processes, and the characterization of materials. However, unlike electrons, positrons are scarce (e.g., currents of picoamps instead of amps) and must be used efficiently. This, and the need to keep positrons isolated from ordinary matter, has motivated the development of new methods to manipulate them in vacuum in the form of single-component plasmas. Three decades of development has enabled specially designed electromagnetic traps for long-term (e.g., weeks or more) antimatter confinement, cryogenically cooled and high-density plasmas, finely focused beams, methods to deliver large bursts and/or short temporal bursts of antiparticles, and guided positronium (Ps) atom beams.[2,3] Scientific progress includes the creation and study of antihydrogen; formation of the positronium molecule (the first many-electron, many-positron state, $e^+e^-e^+e^-$); and understanding Feshbach-resonances in positron annihilation and positron-molecule bound states.[4] Outstanding challenges will be discussed. One goal is study of many-body physics in the electron-positron system. Prospects and progress on this topic will be discussed in both the classical and quantum regimes: a positronium-atom Bose-Einstein condensed gas (BEC) and a classical "pair" (i.e., $e^+$- $e^-$) plasma.[4,5]

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[2]J. Fajans and C. M. Surko, *Phys. Plasmas* **27**, 030601 (2020).
[3]D. B. Cassidy, *Euro. Phys. J. D* **72**, 53 (2018).
[4]J. R. Danielson, et al., *Rev. Mod. Phys.* **87**, 247 (2015).
[5]T. S. Pedersen, et al., *New J. Phys.* **14**, 035010 (2012).