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Plasma Wakefield Accelerators in Application: the Road to Discovery Science

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Plasma wakefield techniques permit controlled acceleration of high quality charged particle beams with unprecedented high gradients, extending beyond 100's of Ge/m. As such, the essential, ultimate goal of plasma wakefield accelerator (PWFA) is to enable TeV energies in (e+e-, gamma, muon) colliders for discovery science in particle physics. To arrive at this ambitious goal will take a generation of dedicated research, a long road in which many theoretical, computational, and experimental physics issues must be attacked and resolve. In this talk, we discuss recent experimental progress in the PWFA field, and identify the important milestones, including resolution critical remaining problems, which will be encountered on the march down this road. One interim application stands out: the development of a compact PWFA's for a new generation of X-ray free-electron lasers. This area concentrates PWFA research on obtaining frontier performance of accelerators at an intermediate energy, accessible now in in the near future. It also provides for the tantalizing option of an ultra-compact X-ray free-electron laser. Such an option is currently being actively explored in the context of both PWFA and laser-driven plasma accelerators. We discuss the current state and future prospects of such initiatives.