Simulations support GeV/cm lepton acceleration in the lab

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Accelerating gradients in plasma can be orders of magnitude higher than those in evacuated metal structures, holding promise for future high-energy lepton colliders with dramatically smaller footprint cost. Laser-plasma experiments have demonstrated GeV electron beams with percent level energy spread in cm-scale plasmas. Beam-driven plasma experiments have demonstrated energy gain of nearly 50 GeV in m-scale plasmas. Algorithms and software developed and continually improved by the SciDAC project ComPASS and run on massively parallel computers made important contributions to these advances. The subtle 3D dynamics of particle trapping and acceleration that forms high quality bunches has been carefully explored through simulations in a manner not accessible to experiment. Characterization of highly-nonlinear plasma bubbles and shaping of the plasma density resulted in better understanding and subsequent optimization of the worldwide experimental efforts. The simulation tools used to design and interpret experiments using control of driver shape and particle injection methods to improve beams for applications (left) and optimize efficiency (right), in preparation for the BELLA and FACET facilities, which will each target 10 GeV level high quality beams from laser and beam drivers respectively.

Reference(s): I. Bloomenfeld et al. “Energy doubling of 42 GeV electrons in a metre-scale plasma wakefield accelerator” Nature 445, 741-744 (2007); C. Geddes *et al.*, “Laser Plasma Particle Accelerators: Large Fields for Smaller Facility Sources,” SciDAC Review **13** (Summer, 2009); Leemans *et al.,* Nature Physics 2006 (exp.); N. Hafz *et al.*, “Stable generation of GeV-class electron beams…,” Nature Photonics **2**, 571 (2008). C. Huang et al., “Recent results and future challenges for large-sale particle-in-cell simulations of plasma-based accelerator concepts, “ Journal of Physics: Conference series 180, 012005 (2009).

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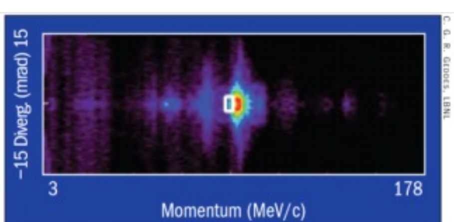
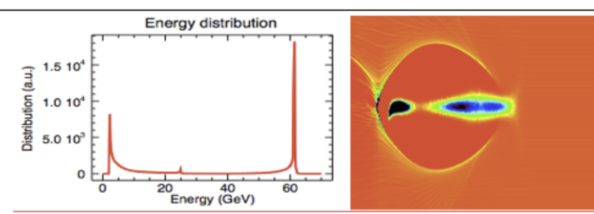


VORPAL simulated electrons show narrow divergence, similar to white overlain circle showing the experimental beam envelope.



QuickPIC simulation of a plasma wakefield accelerator stage showing high efficiency while maintaining a small energy spread.