AbstractID: 7666 Title: A Primer on Plasma wakefields: a new method of particle acceleration

Objective:
We present in this paper a pedestrian, pedagogical introduction to the basic concepts, physical mechanisms and recent breakthroughs in the use of plasma wakefields as a completely new method of particle acceleration. This new method is attractive because it offers the possibility of really compact accelerators as electron, proton and ion beam sources; although here we focus on electrons. We describe the original ideas, basic equations and recent experimental results. Since the medical physics community is more familiar with RF microwave technology and concepts than those of plasma physics, we believe this primer would be useful and instructive.

Summary:
Finding new ways to accelerate particles has been a Holy Grail eversince it was realized 25 years ago that RF technology could only get to a theoretical limit of 100MeV/m field gradient. Past that, waveguide electrical breakdown and beam instability are insurmountable(1). The seminal work of Tajima-Dawson (2-3) showed however that plasma, being fully ionized media can support much higher gradients, and when excited by short, high-intensity laser pulse or similar electromagnetic pulse, can generate wakefields that can trap and accelerate the plasma electrons to fields as high as 10GeV/cm. With such high accelerating fields, particles can gain huge energy over very short distance. The 2-mile SLAC accelerator can thus be shrunk into a few meters, a medical linac "waveguide" into about a millimeter.

We describe the basic equations characterizing a plasma, its parametric instabilities, and dispersion relations as response to any incoming disturbance. We derive the ponderomotive force(fig.1-3)(exerted by the incident laser/electromagnetic pulse on the plasma), which generates the wakefields (much like a moving boat would generate wakes along its trail) and show analytically how these wakefields trap and accelerate the plasma electrons. Finally, we describe several important breakthroughs(4-6,fig.4) as proofs-of-principle and advances towards a real, practical accelerator device.