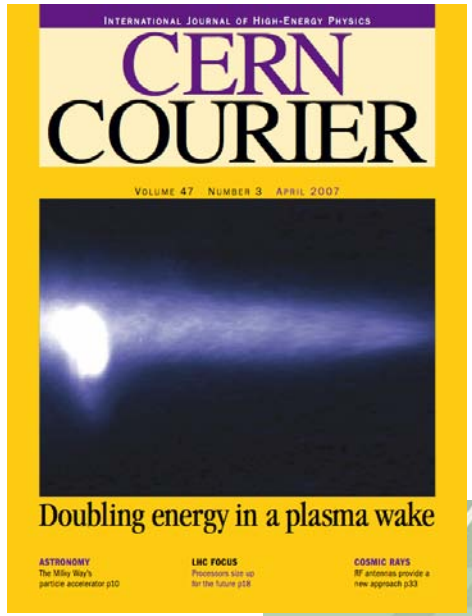
Plasma Accelerators : Progress and Future

C.Joshi
University of California Los Angeles



"Putting Beam Physics at the Forefront of Science"

Work supported by DOE


14 TeV *CM pp*
LHC at CERN
-27 km
-$6 Billion+?
Can Plasmas Play
A Role in Future
High-Energy Particle
Accelerators?
-Smaller?
-Cheaper?
Thinking big
Accelerators like the future LHC require long tunnels and powerful bending magnets.

Goals of Plasma Accelerators Community

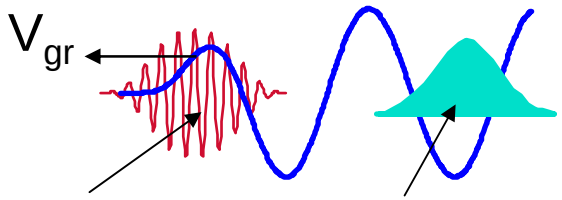
To develop a new paradigm for building accelerators at the energy frontier and on "table-top"

Our goals are strongly endorsed by the Marx subpanel

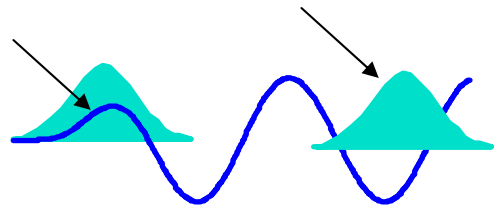
"The challenge is to undertake and sustain the difficult and complex R&D needed to enable a feasible,cost and energy effective technology on the several decade horizon. Achieving these goals will require creativity and the development and maturation of new accelerator approaches and technologies."

Why Plasma Based Accelerators

- **Laser Wake Field Accelerator**
  A single short-pulse of photons



- **Drive beam**
- **Trailing beam**



- **Plasma Wake Field Accelerator**
  A high energy electron bunch
- **Wake: phase velocity = driver velocity**

Large wake for a laser amplitude $a_o = eE_o/m\omega_o c \sim 1$ ***or a beam density*** $n_b \sim n_o$

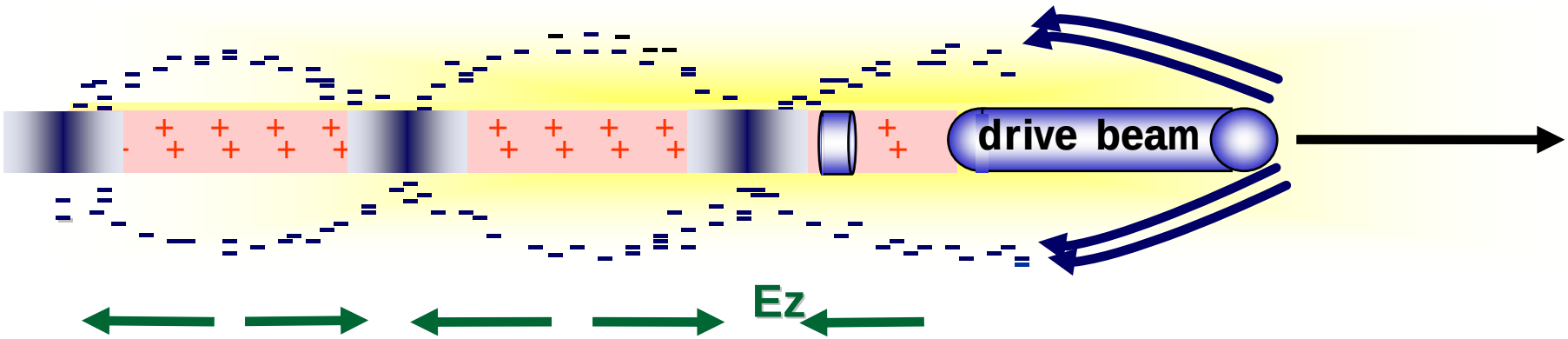
Accelerating Field $= 30\,GeV/m\,(10^{17}/n_o)^{1/2}$

T.Tajima and J.M.Dawson PRL(1979)
P.Chen et.al.PRL(1983)

Plasma Wakefield Accelerators

(Blowout Regime)

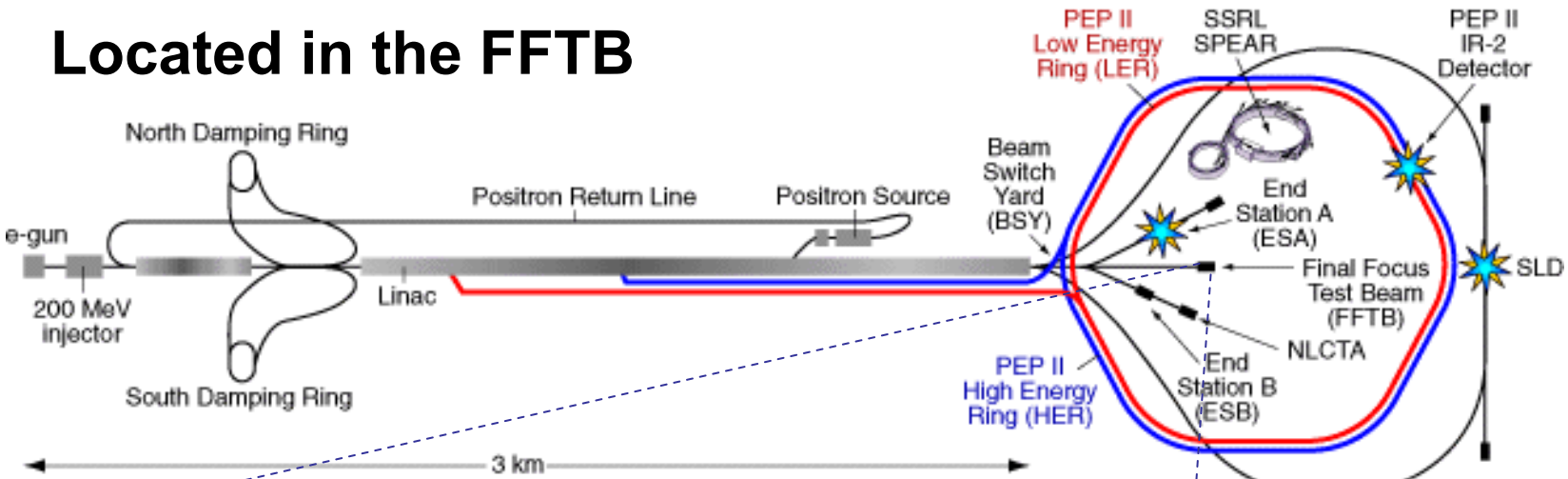
Rosenzweig et. 1990 *Pukhov and Meyer-te-vehn 2002 (Bubble)*

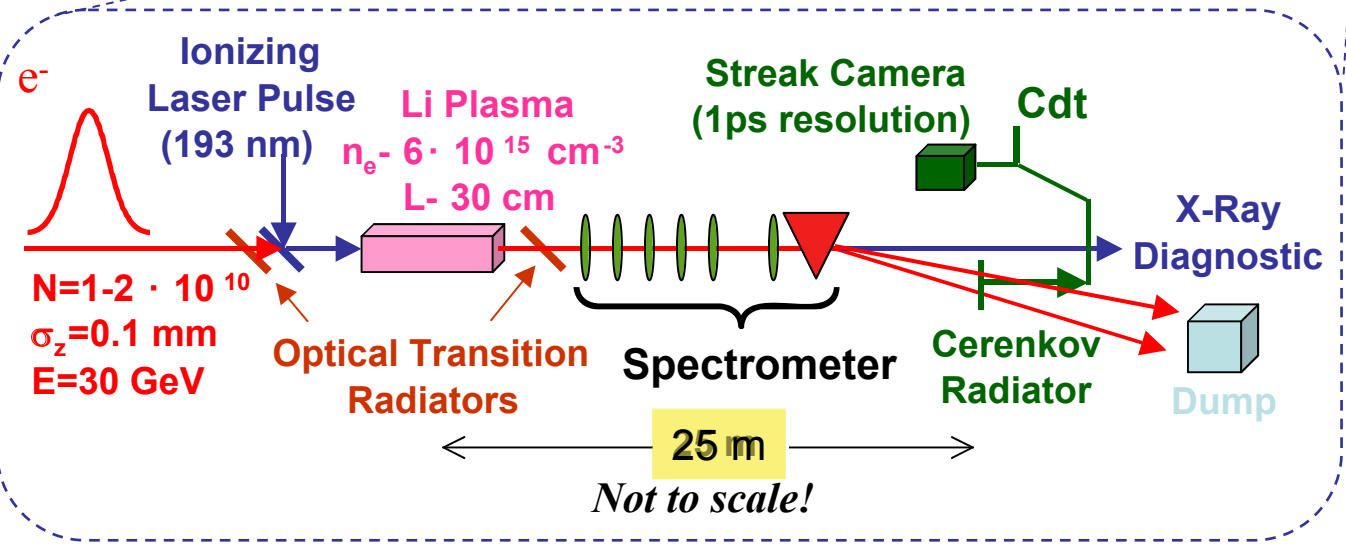


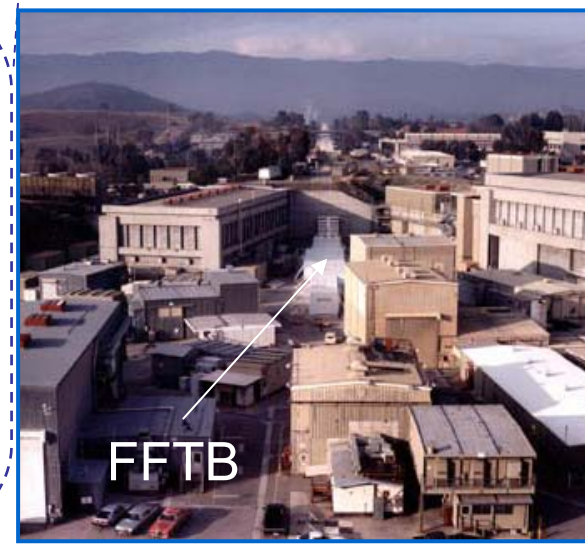
- Space charge/ponderomotive force of thee beam/laser pulse displaces plasma electrons
- Plasma ion channel exerts restoring force => space charge oscillations
  - Linear focusing force on beams ($F/r=2\pi ne^2/m$)

Beam-Driven PWFA@ SLAC

Located in the FFTB

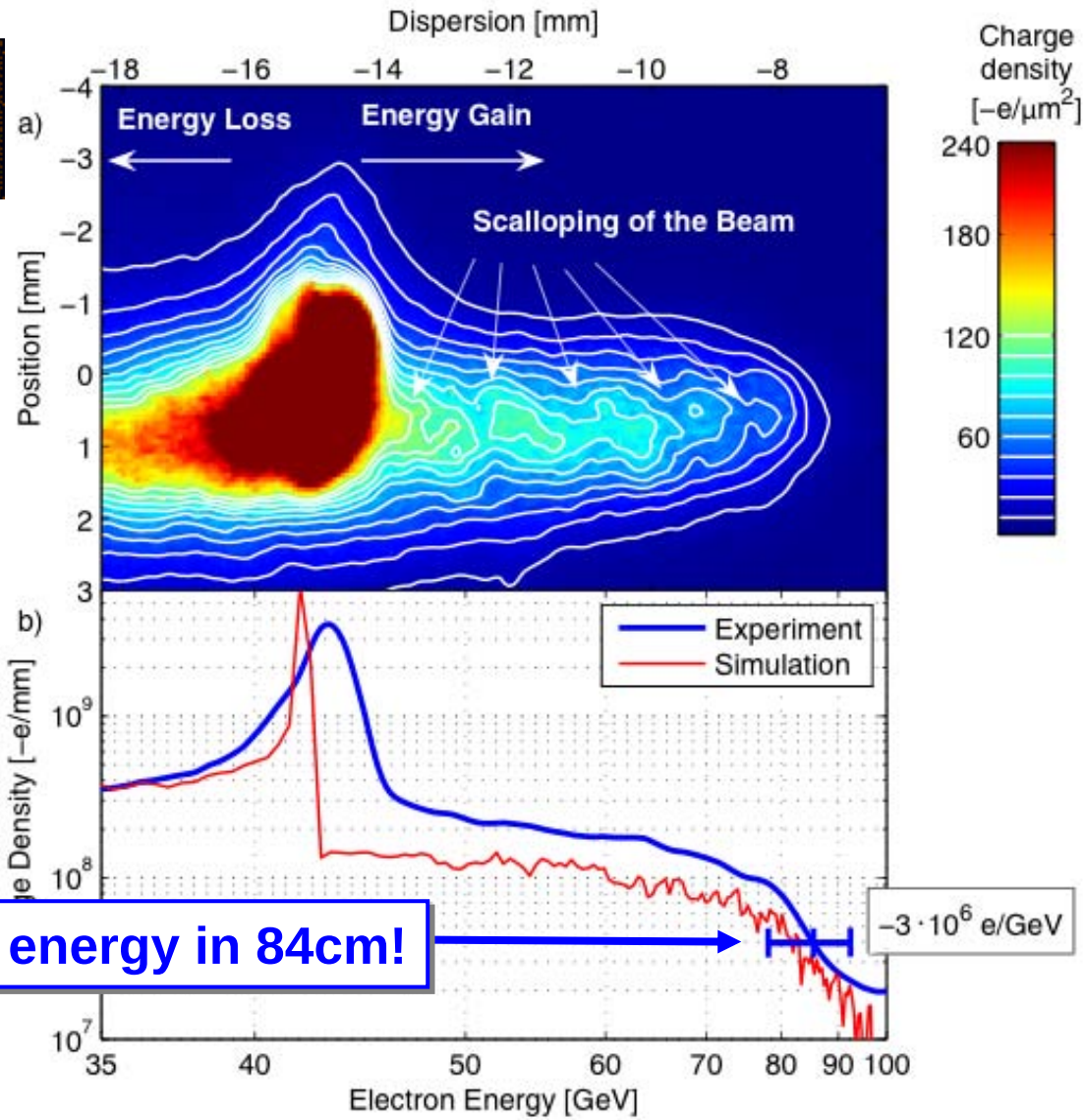






E-167: Energy Doubling with a Plasma Wakefield Accelerator in the FFTB

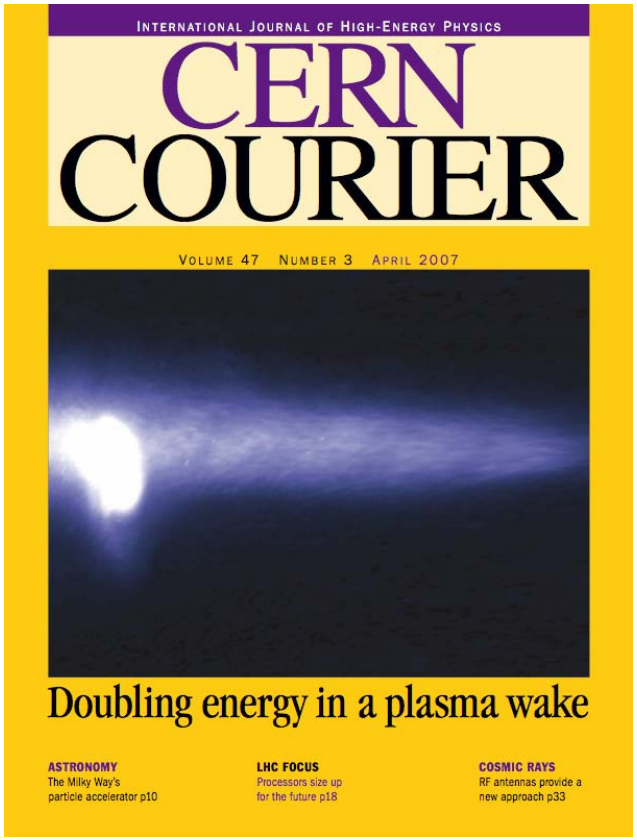
Linac running all out to deliver compressed 42GeV Electron Bunches to the plasma
Record Energy Gain
Highest Energy Electrons Ever Produced @ SLAC
Significant Advance in Demonstrating Potential of Plasma Accelerators



Some electrons double their energy in 84cm!

Nature vol 445,p741 (2007)

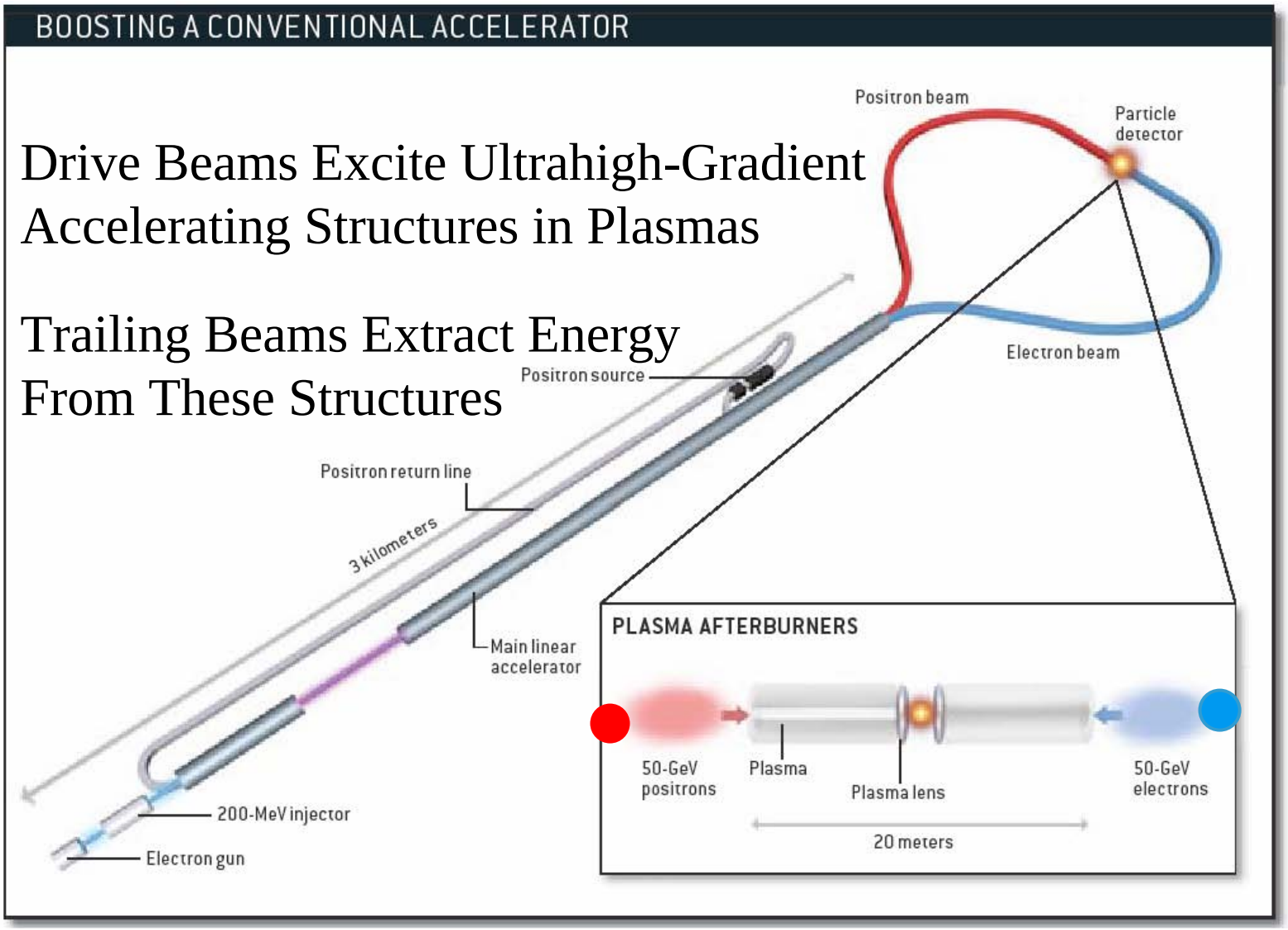
Goals and Relevance



To address critical issues for realizing a plasma-based accelerator at the energy frontier in the next decade.

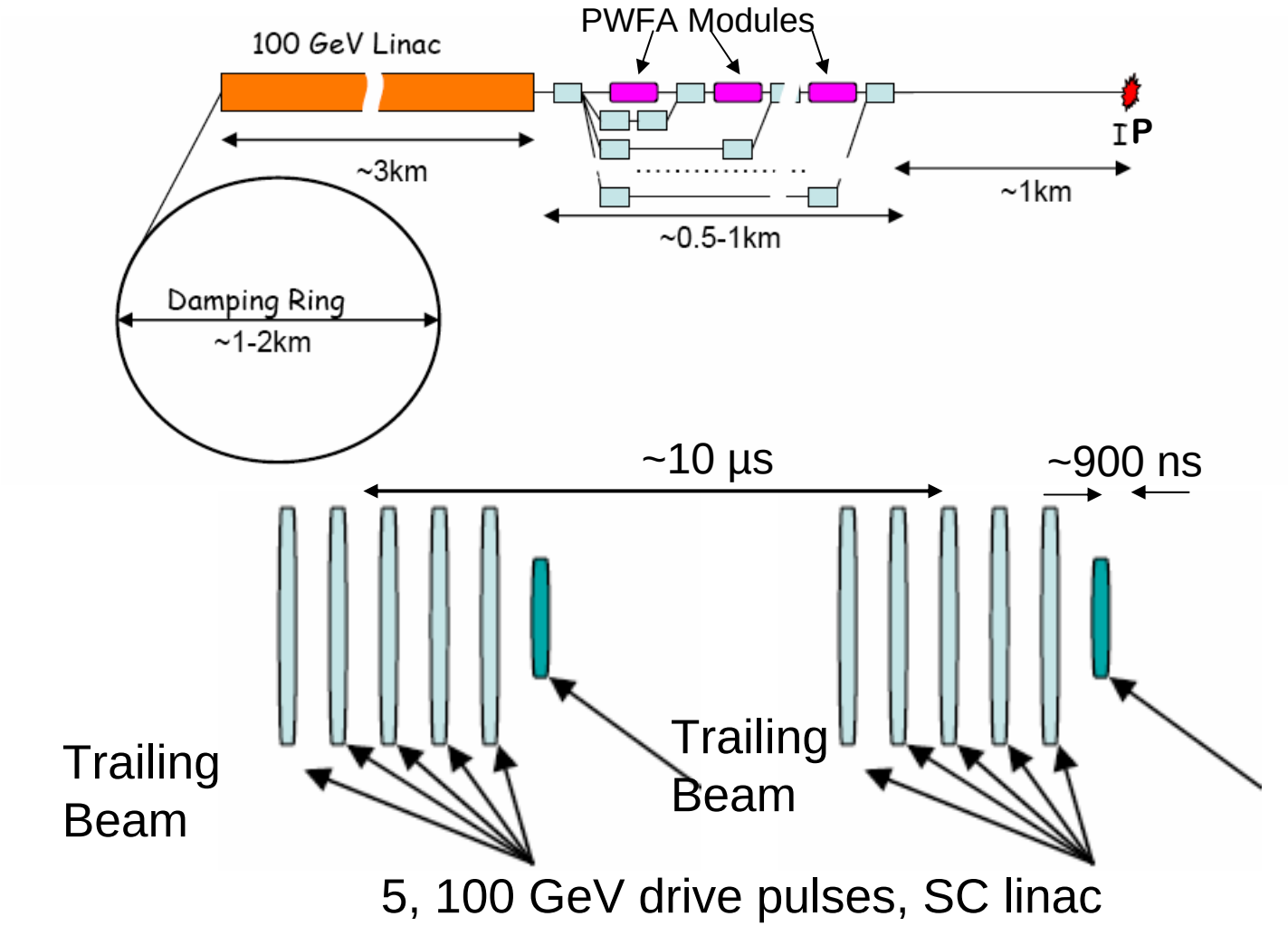
Plasma Afterburner for a conventional linear collider

Plasma Afterburner for Linear Collider



C.Joshi and T.Katsouleas Physics Today June 2003 p47

1 TeV Plasma Wakefield Accelerator

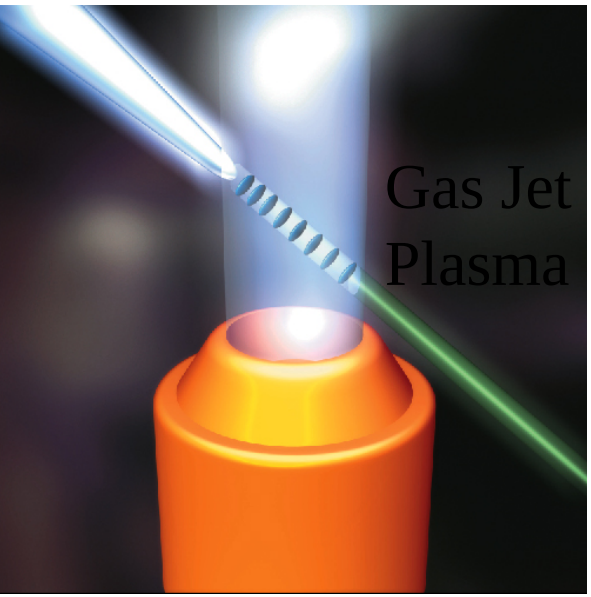


Ref.: AAC Conference Proceeding, No. 877, p. 158 (2007)

Jet Age of Laser-Plasma Accelerators

3-5 TW ,50 fs Laser focused in a 2e19 Plasma

Laser



Gas Jet

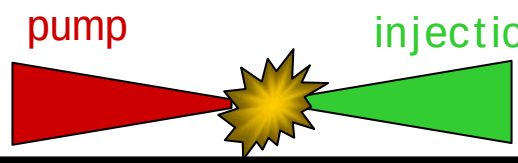
Self Trapped Electron Beams
100 MeV, Quasi-monoenergetic
> 100 GeV/m Accelerating Fields

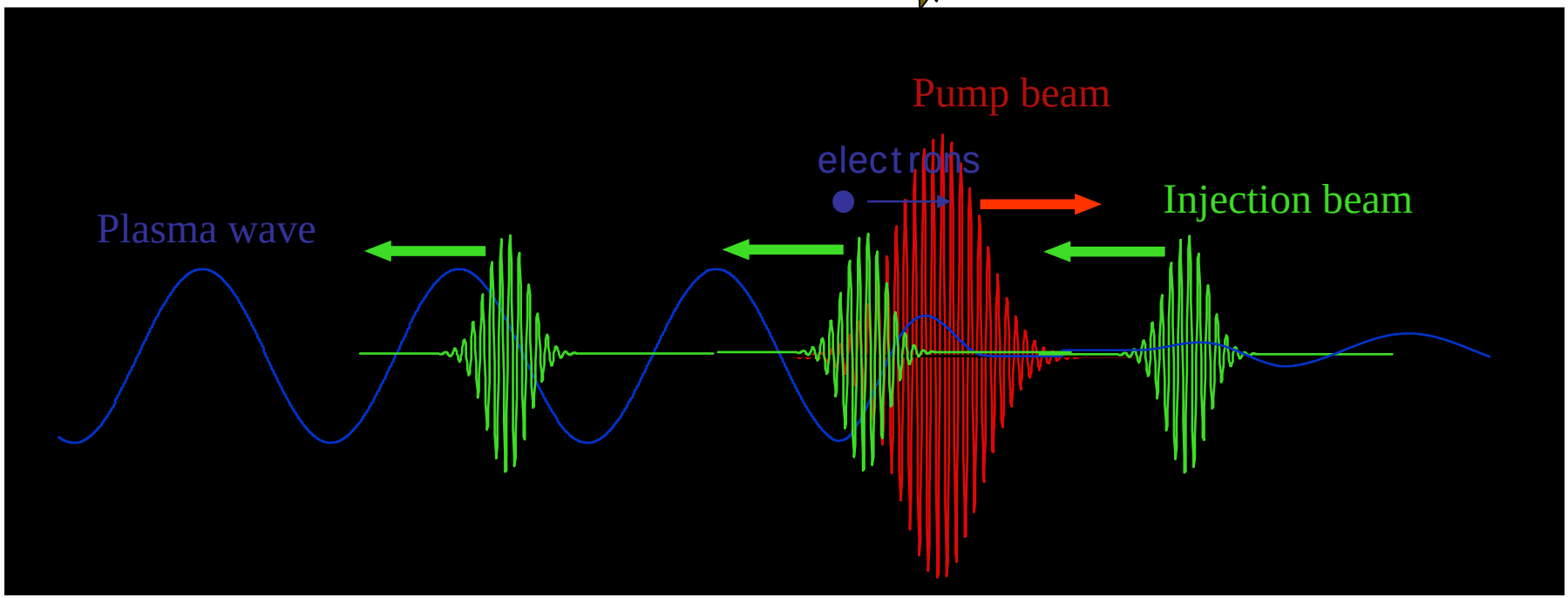
Electron beam

Many Players
UCLA,LLNL,IC/RAL,LOA,UMich,NRL,LBNL,KEK/JERRI & others

Controlling injection & Final Energy (LOA)

Counter-propagating geometry:





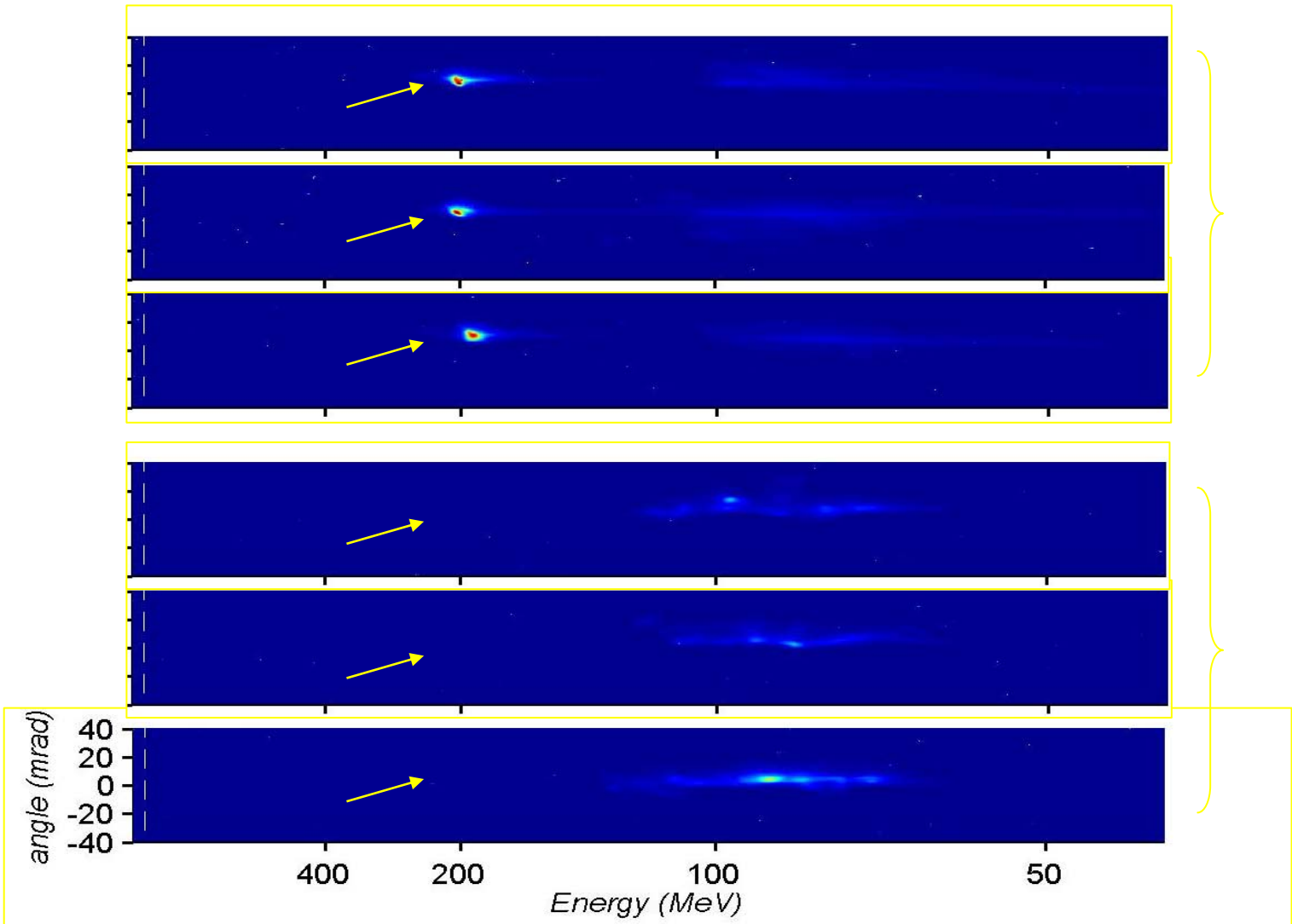
Ponderomotive force of beatwave: $F_p \sim 2a_0a_1/\lambda_0$ (a_0 et a_1 can be "weak")

Boost electrons locally and injects them:

INJECTION IS LOCAL IN FIRST BUCKET

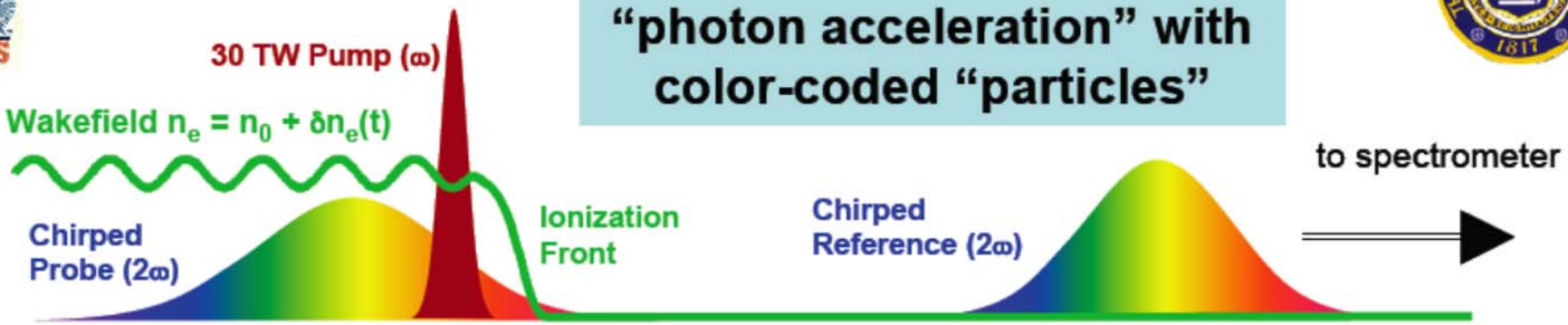
E. Esarey et al, PRL 79, 2682 (1997), G. Fubiani et al. (PRE 2004)

Monoenergetic bunch comes from colliding pulses: polarization test

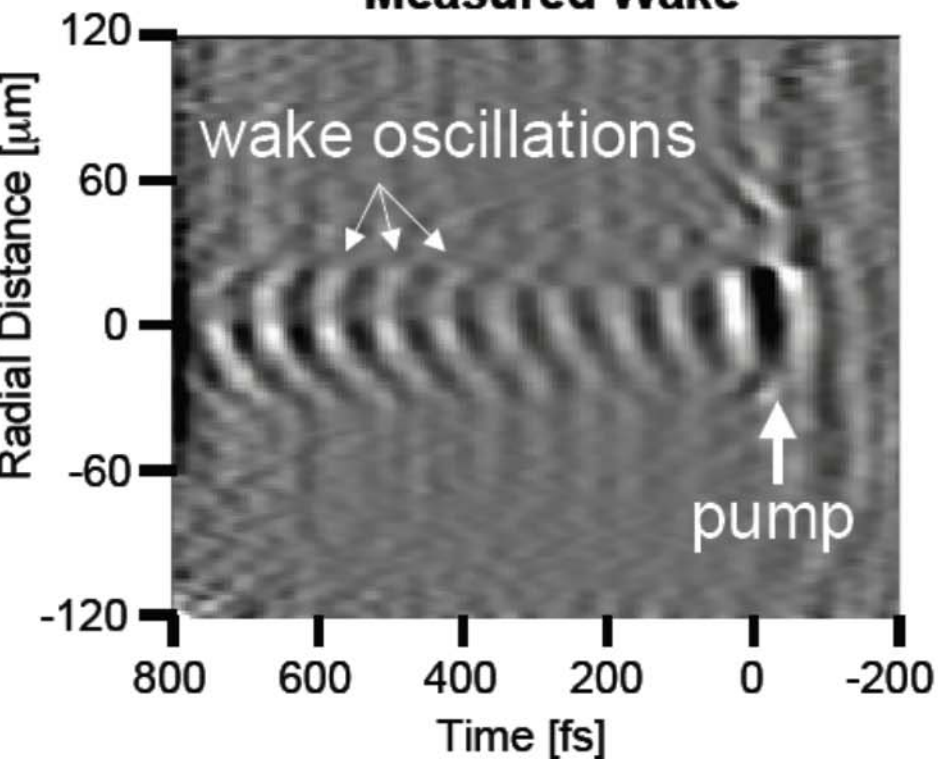


Wakefield Snapshots using Frequency Domain Holography enrich experiment-theory dialog:

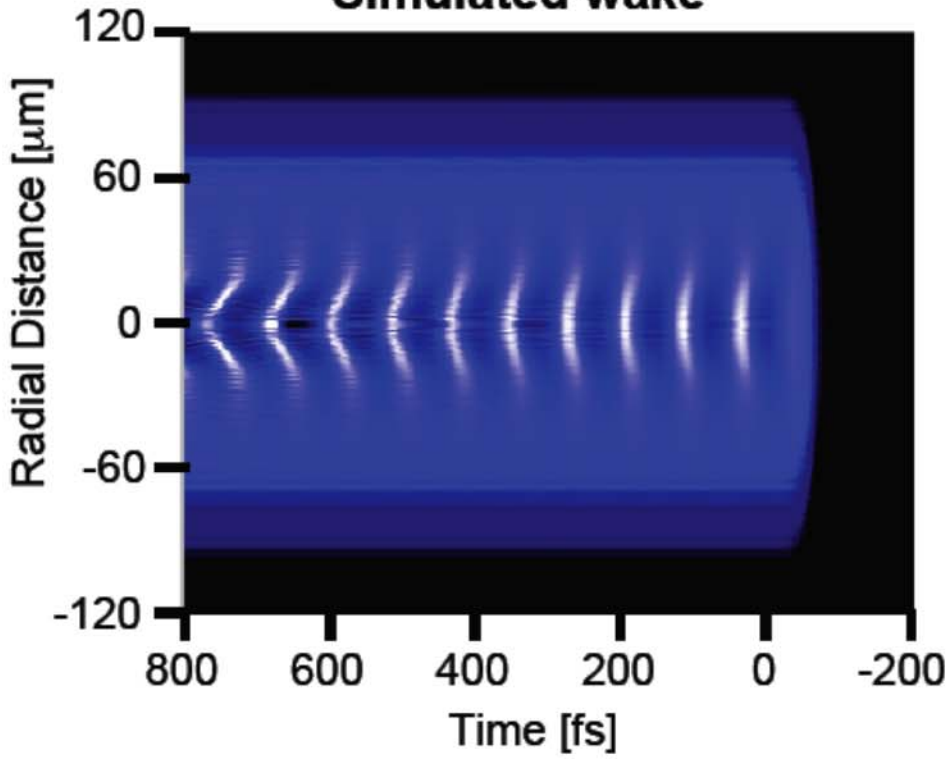
"photon acceleration" with color-coded "particles"



Measured Wake

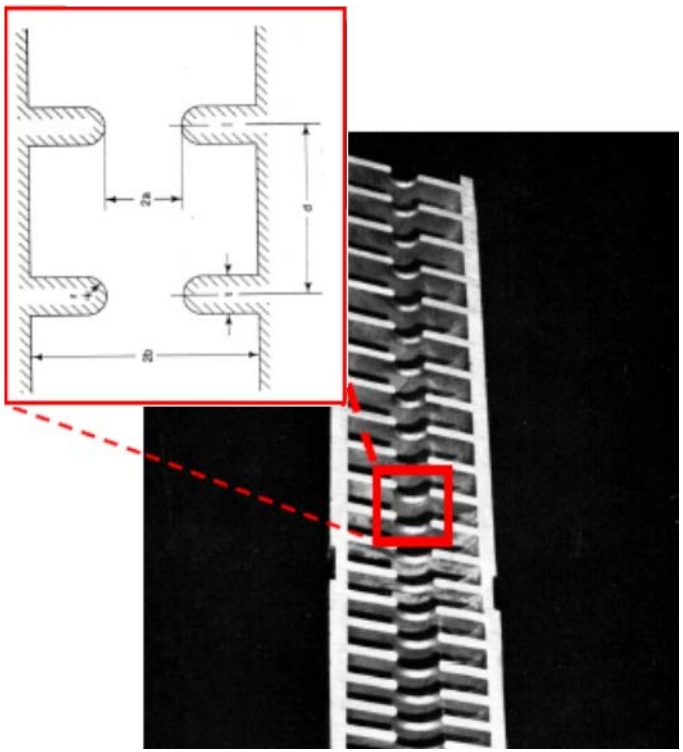


Simulated wake

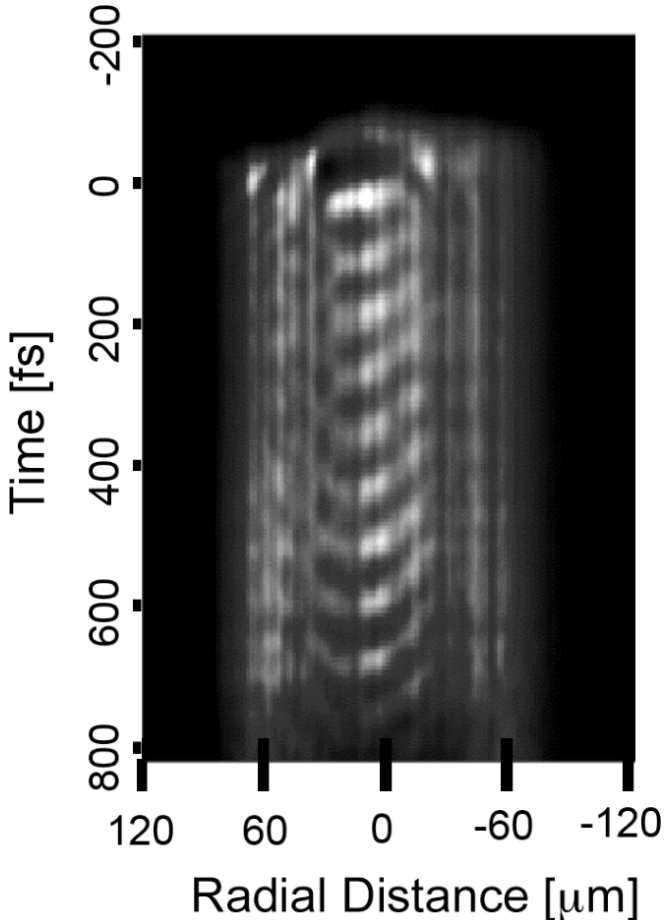


Plasma Accelerating Structure Visualized Using Frequency Domain Holography

Conventional Accelerator Cavity



Plasma Accelerator Cavity

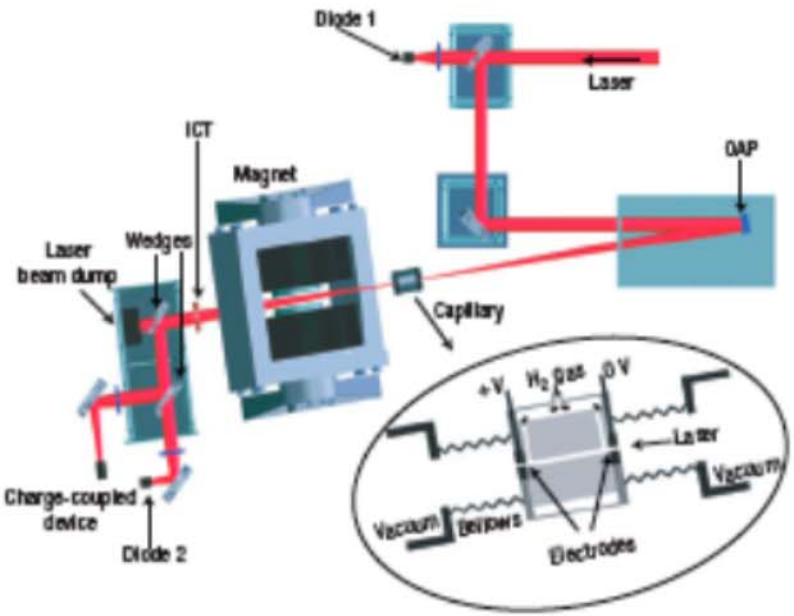


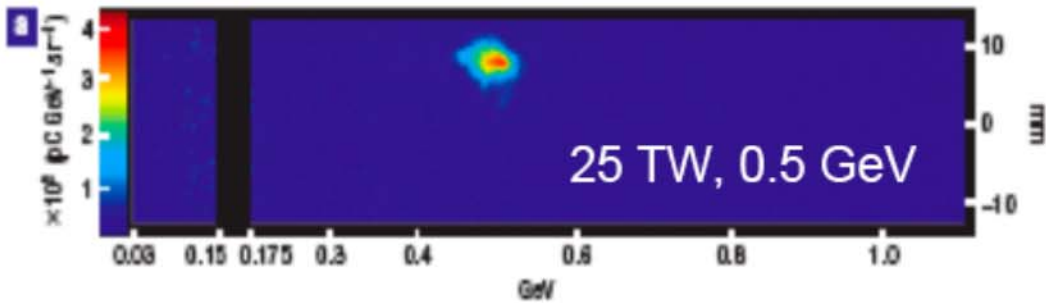
M.Downer:U.Texas Austin

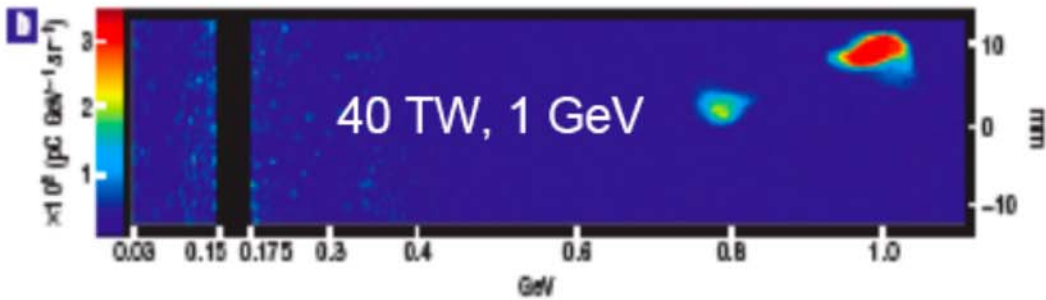
GeV electron beams from a cm-scale accelerator*

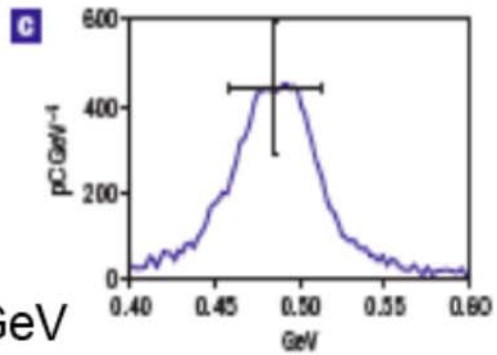
*W.P. Leemans et al., Nature Physics 2 (2006)

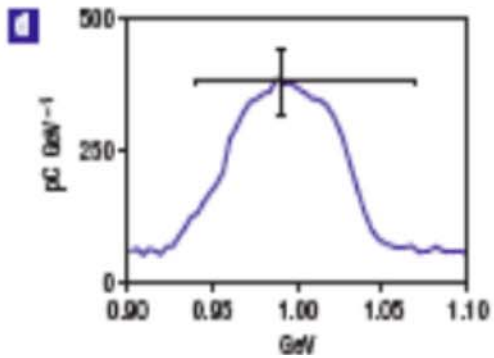
- First demonstration of a GeV beam from laser accelerator
  - Channel guided laser wakefield accelerator
  - 3.3 cm capillary from Oxford
  - TREX from LBNL: 2.5 J/37 fs @10 Hz











- Next step: BELLA -- 40 J/40 fs -> 10 GeV

Conclusion:

Best summarized by Marx Panel

"OHEP should accept proposals from the laboratories to pursue longer term accelerator R&D that has the potential for significant impact and to invest in appropriate research and funding infrastructure"

More specifically it recommends

"FFTB has been shut down in order to proceed with the construction of a new light source.A successor,called SABER, has been proposed, but not yet funded.We encourage an early review of this project in order not to hinder further progress in this critical area"