LINAC2004 Invited

SURVEY OF ADVANCED ACCELERATOR CONCEPTS

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University of California Los Angeles,U.S.A.

ADVANCED ACCELERATION WORKSHOP
Stony Brook , June 2004

Electromagnetic Wave Schemes : IFEL

Laser Plasma Schemes : LWFA

Beam Driven Schemes : PWFA

Exotic Schemes : Ion Acceleration

Laser Guiding in Plasmas

Sources

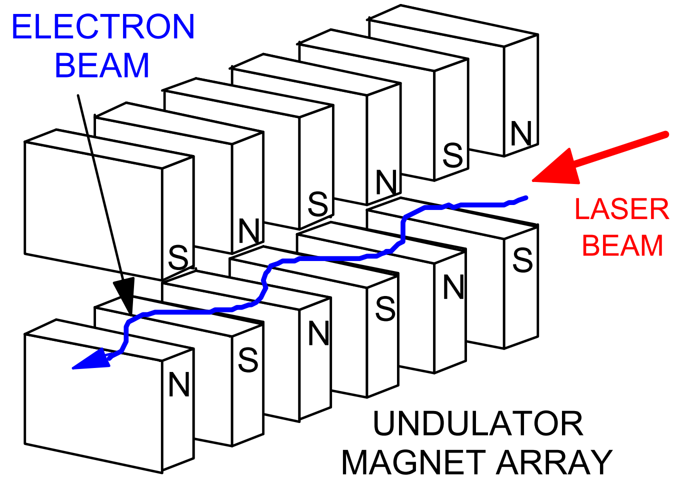
Inverse Free Electron Laser (IFEL)

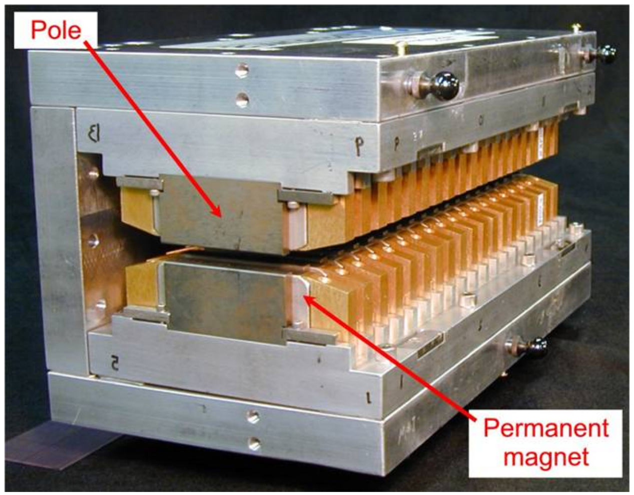
- Use periodic magnet array (wiggler/undulator) to cause electron trajectory to oscillate while traveling through array
- Net energy exchange between electrons and laser beam possible if resonance condition is satisfied

$$\gamma^2 = \frac{\lambda_w}{2\lambda_L}\left(1 + \frac{K^2}{2}\right)$$

where λ_L = laser wavelength
λ_w = wiggler wavelength
γ = Lorentz factor
$K = eB_o\lambda_w/2\pi mc$
B_o = peak magnetic field

- Higher energy exchange possible using tapered wiggler/undulator

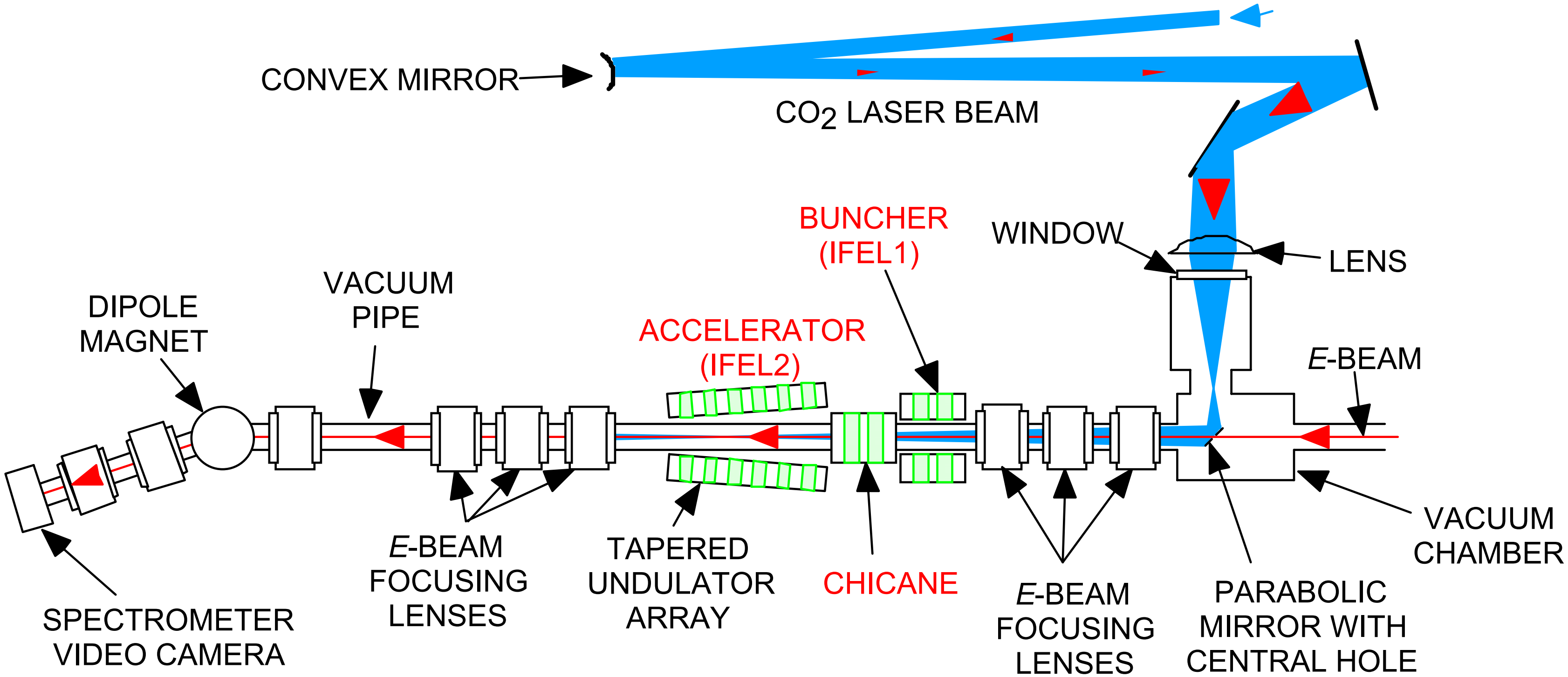




STELLA
Staged Electron Laser Acceleration

STI OPTRONICS

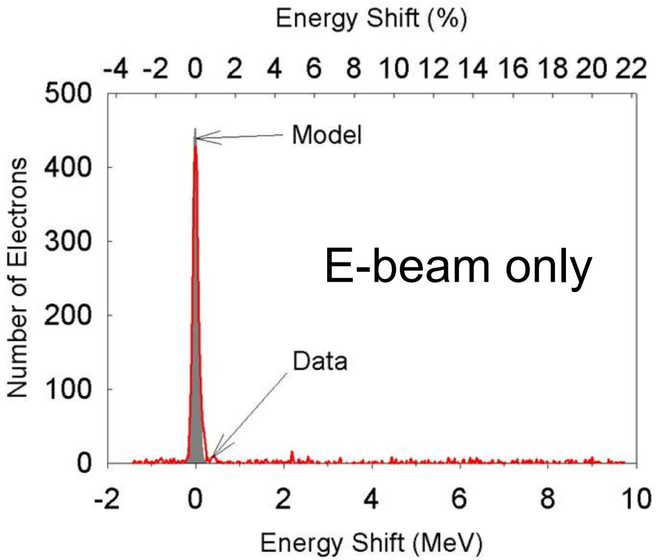
Schematic Layout of STELLA Experiment

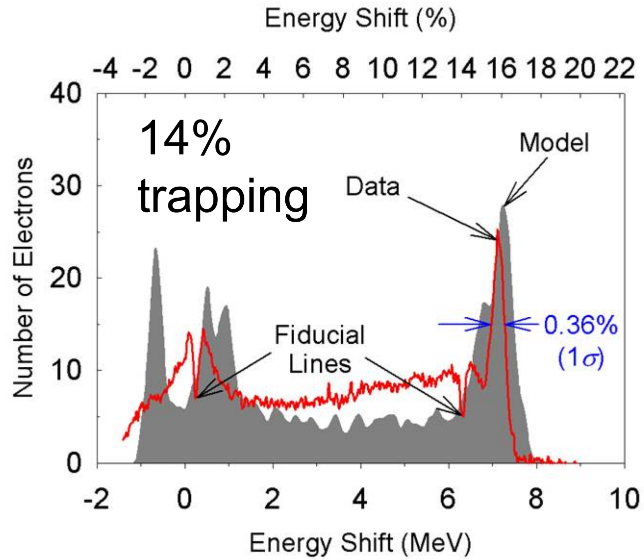


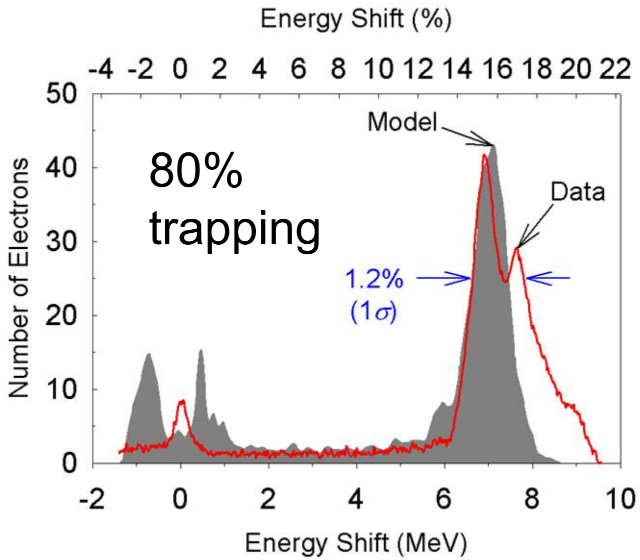
STELLA
Staged Electron Laser Acceleration

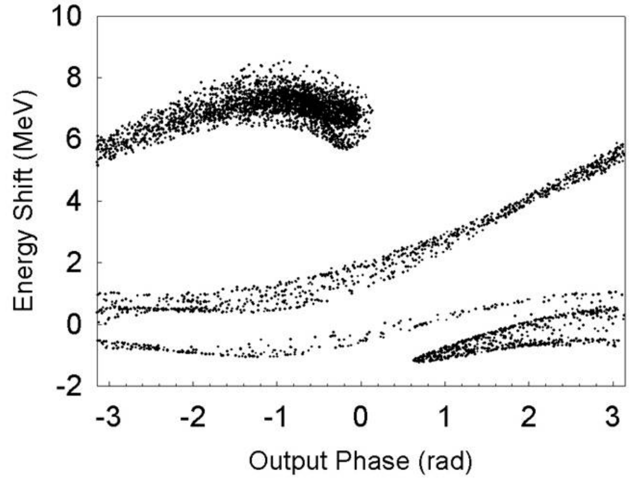
STI OPTRONICS

Examples of Experimental Results





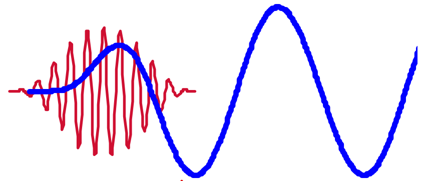




Laser Wakefield Acceleration

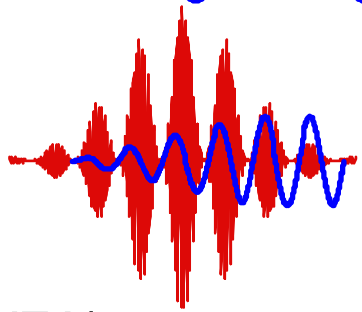
- Laser Wake Field Accelerator(LWFA)

  A single short-pulse of photons



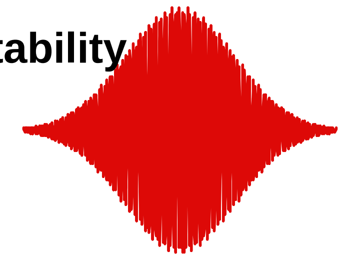
- Plasma Beat Wave Accelerator(PBWA)

  Two-frequencies, i.e., a train of pulses

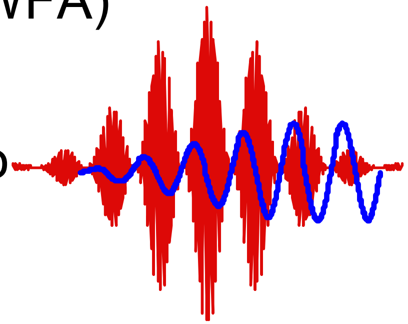


- Self Modulated Laser Wake Field Accelerator(SMLWFA)

  Raman forward scattering instability



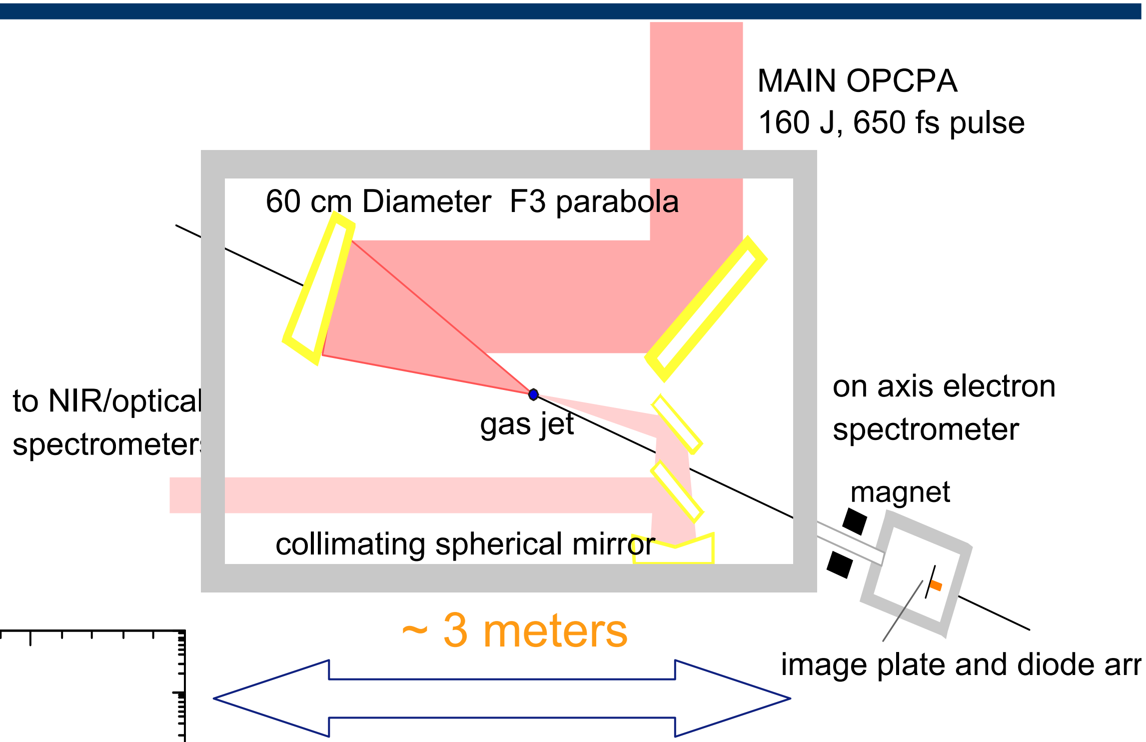
evolves to

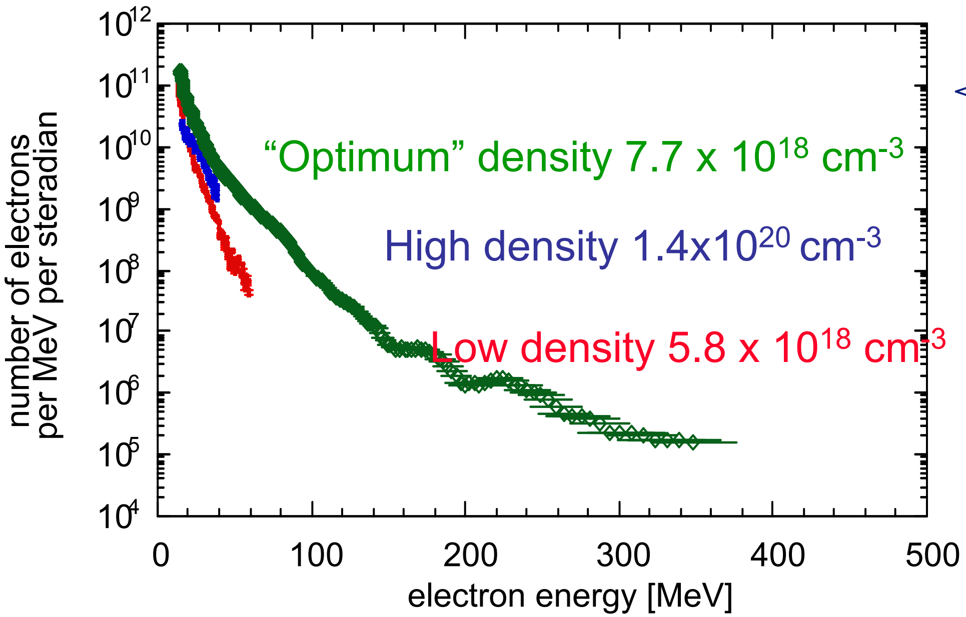


Laser acceleration experiments using the VULCAN PetaWatt

Courtesy of K. Krushelnick et al.

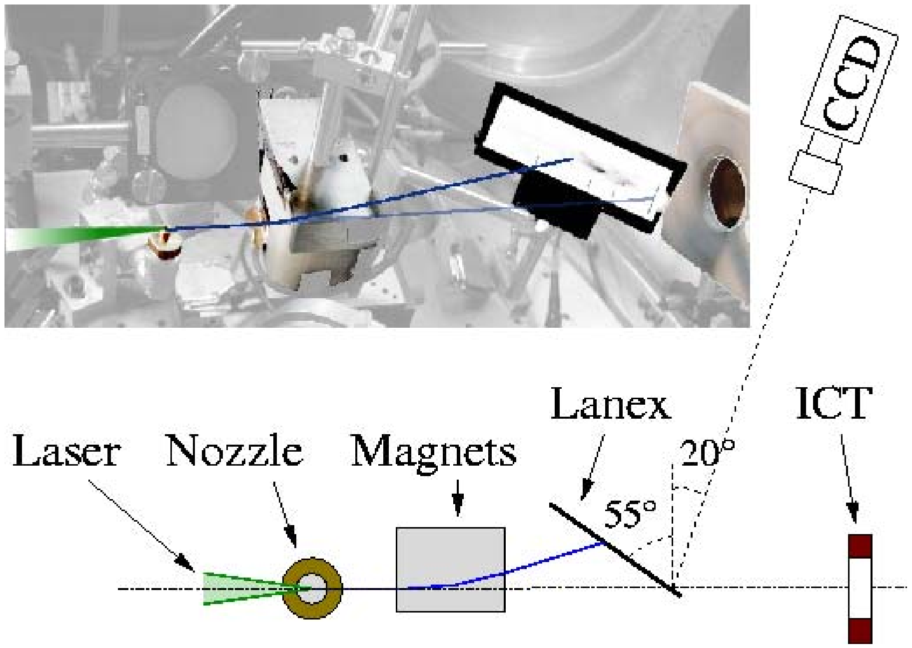
- Vulcan@RAL: 160 J in 650 fs
- Single shot laser



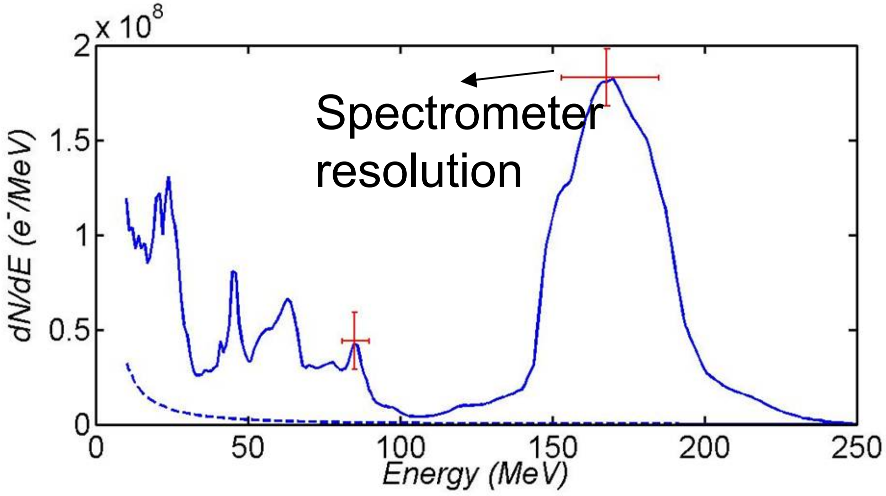


- 350 MeV electrons observed
- Energy spread large

Recent Breakthrough -- Mono-energetic Beams! 3 Labs!

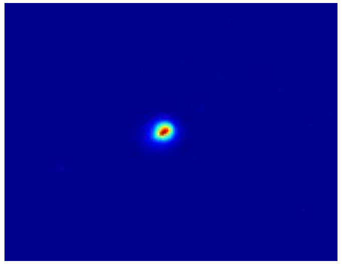


Quasi-monoenergetic spectrum
Hundreds of pC at 170 MeV +/- 20 MeV



Parameters: n_e=6x10^{18} cm^{-3},
a_0=1.3, τ=30 fs P=30 TW
Results obtained with 1 m off-axis parabola:
w_0=18 µm, z_R=1.25 mm

Electron beam profile on LANEX

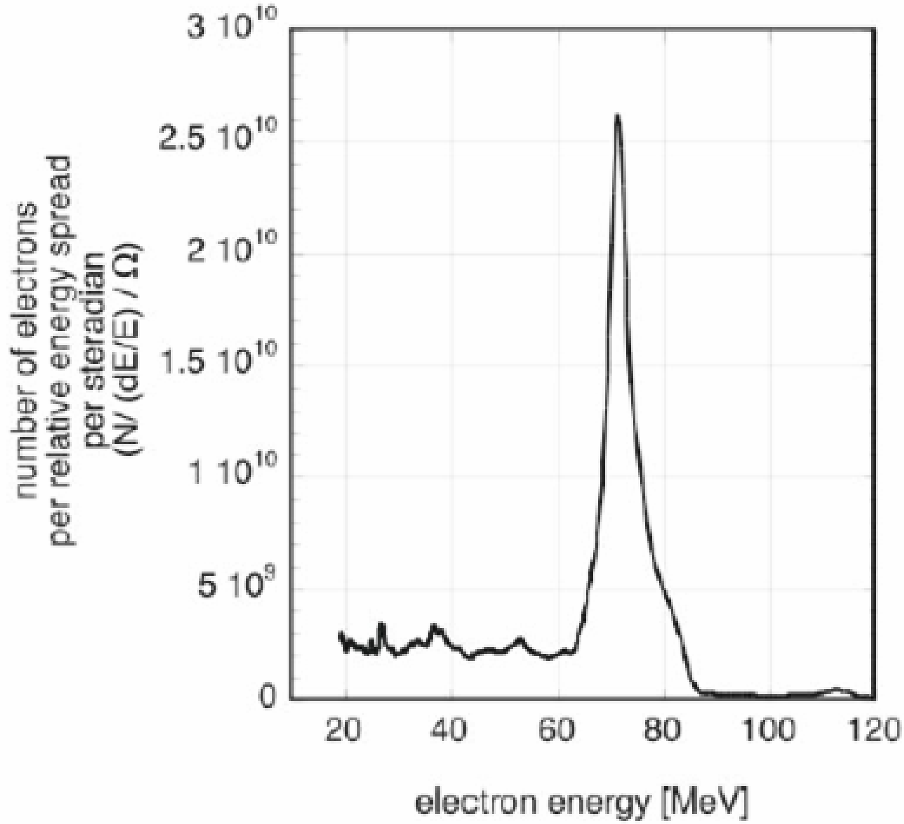


Divergence FWHM = 6 mrad

Courtesy J. Faure, LOA

Imperial College London

Mono-energetic spectra can be observed at higher power ($\Delta E/E = 6\ \%$)



E ~ 500 mJ,

pulse duration ~ 40 fsec

Focal spot ~ 25 µm

Density ~ 2×10^{19} cm^{-3}

Significant shot-to-shot fluctuations in

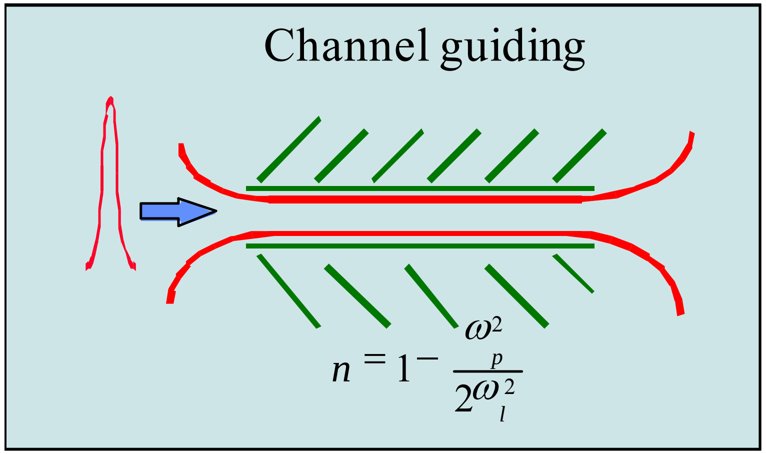
a) energy spread

b) peak energy

Careful control of laser and plasma conditions is necessary

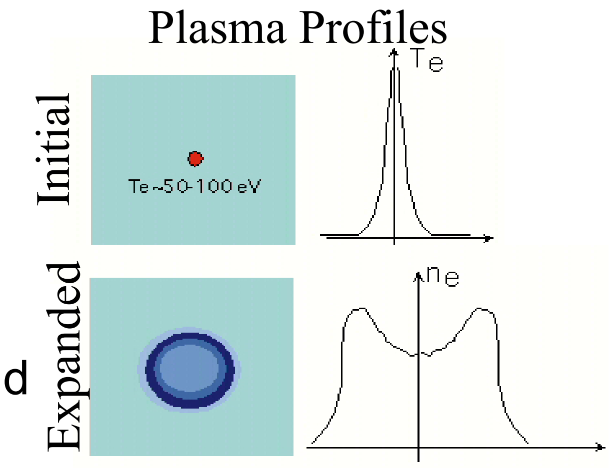
Courtesy: K. Krushelnick, RAL

Plasma channel: structure for guiding and acceleration



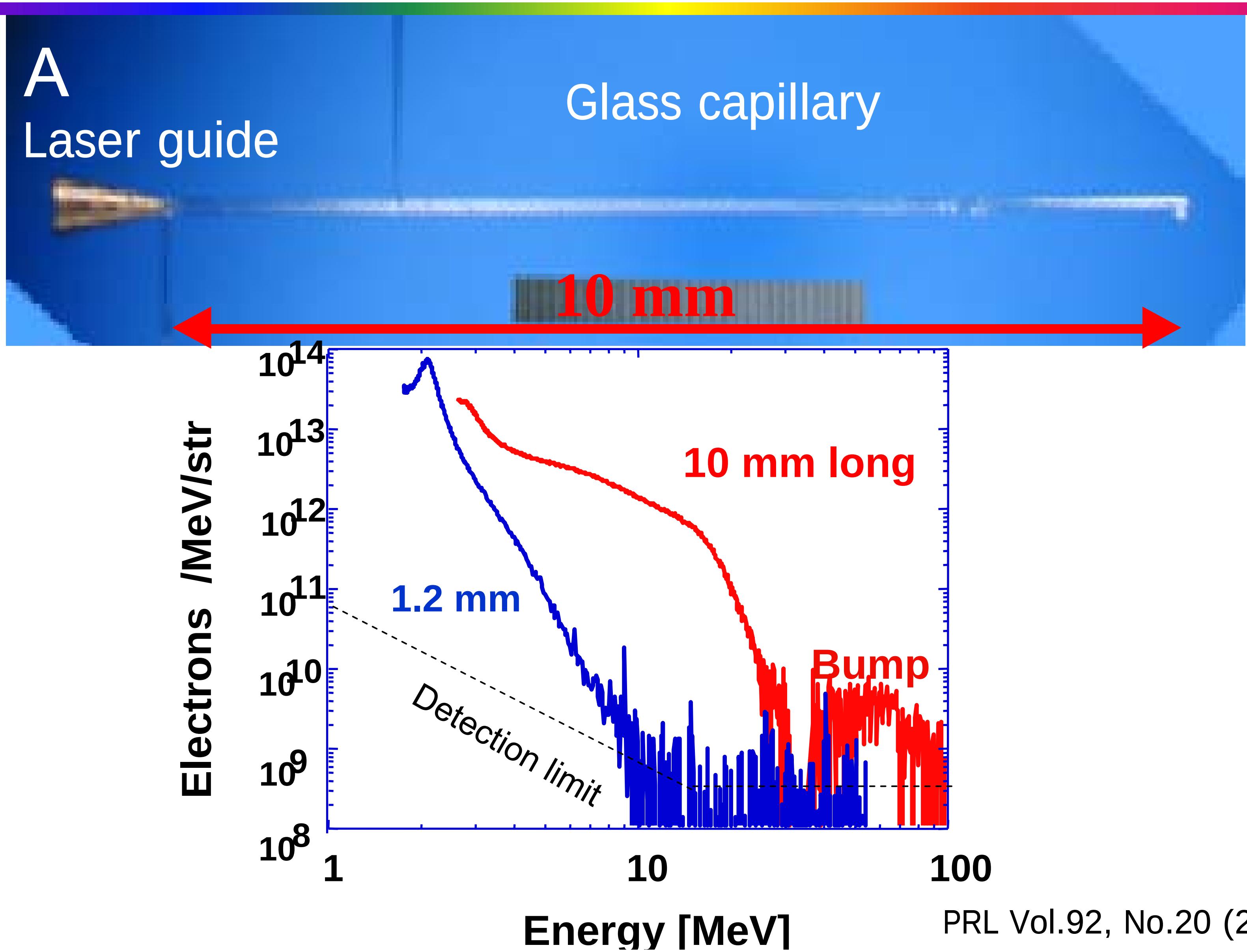
Step 1: Heat

Step 2: expand



- Hydro-dynamically formed plasma channel
  - On-axis axicon (C.G. Durfee and H. Milchberg, PRL 71 (1993))
  - Ignitor-Heater (P. Volfbeyn et al., Phys. Plasmas 6 (1999))
  - Discharge assisted (E. Gaul et al., Appl. Phys. Lett. 77 (2000))
  - Cluster jets (Kim et al., PRL 90 (2003))
- Discharge ablated capillary discharges (Y. Ehrlich et al., PRL 77 (1996))
- Z-pinch discharge (T. Hosokai et al., Opt. Lett. 25 (2000))
- Hydrogen filled capillary discharge (D. Spence and S. M. Hooker, JOSA B (2000))
- Glass capillaries (B. Cross et al., IEEE Trans. PS 28(2000), Y. Kitagawa PRL (2004))

Ultra-Intense Laser is illuminated into a glass capillary, which accelerates plasma electrons to 100 MeV-- Y.Kitagawa-Osaka

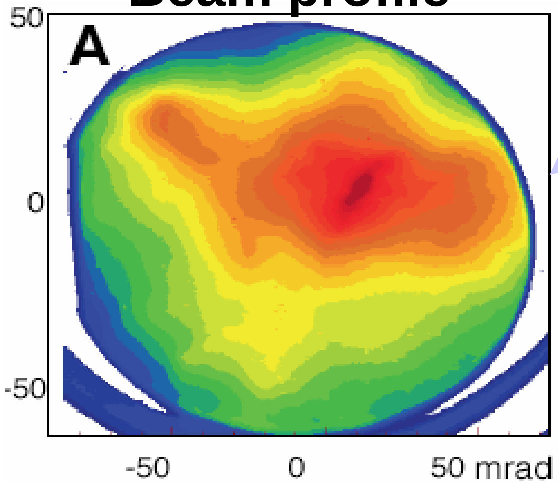


PRL Vol.92, No.20 (2004)

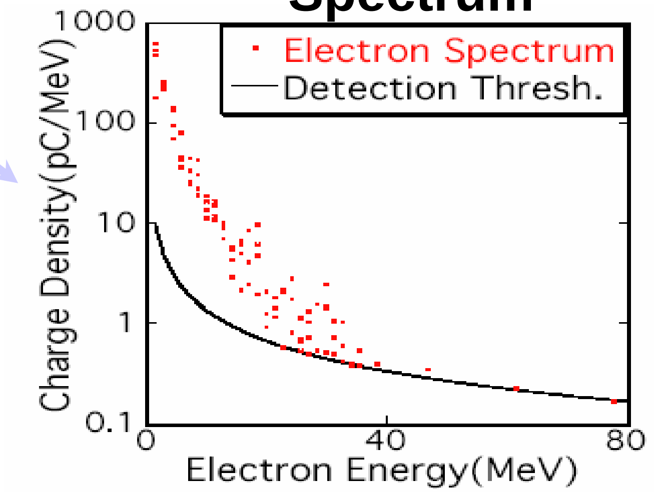
85 MeV e-beam with %-level energy spread observed from ... accelerator

Beam profile

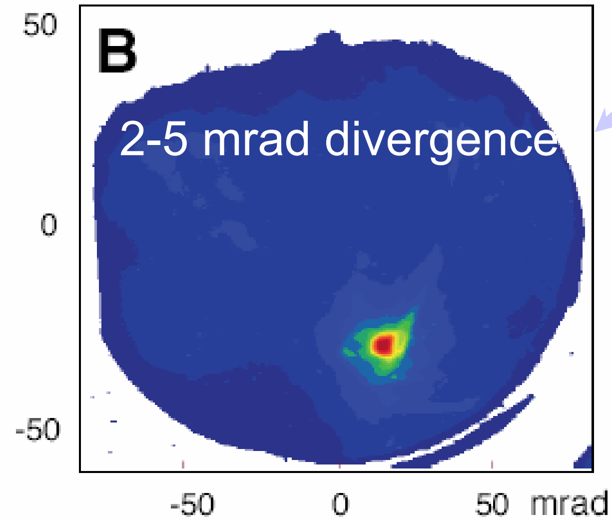
Unguided



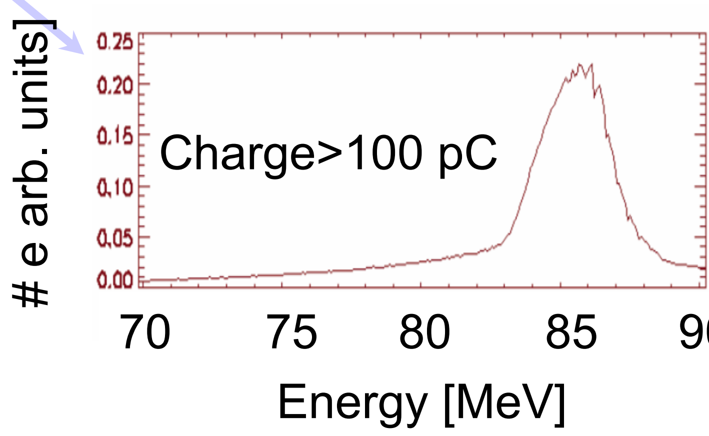
Spectrum



Guided

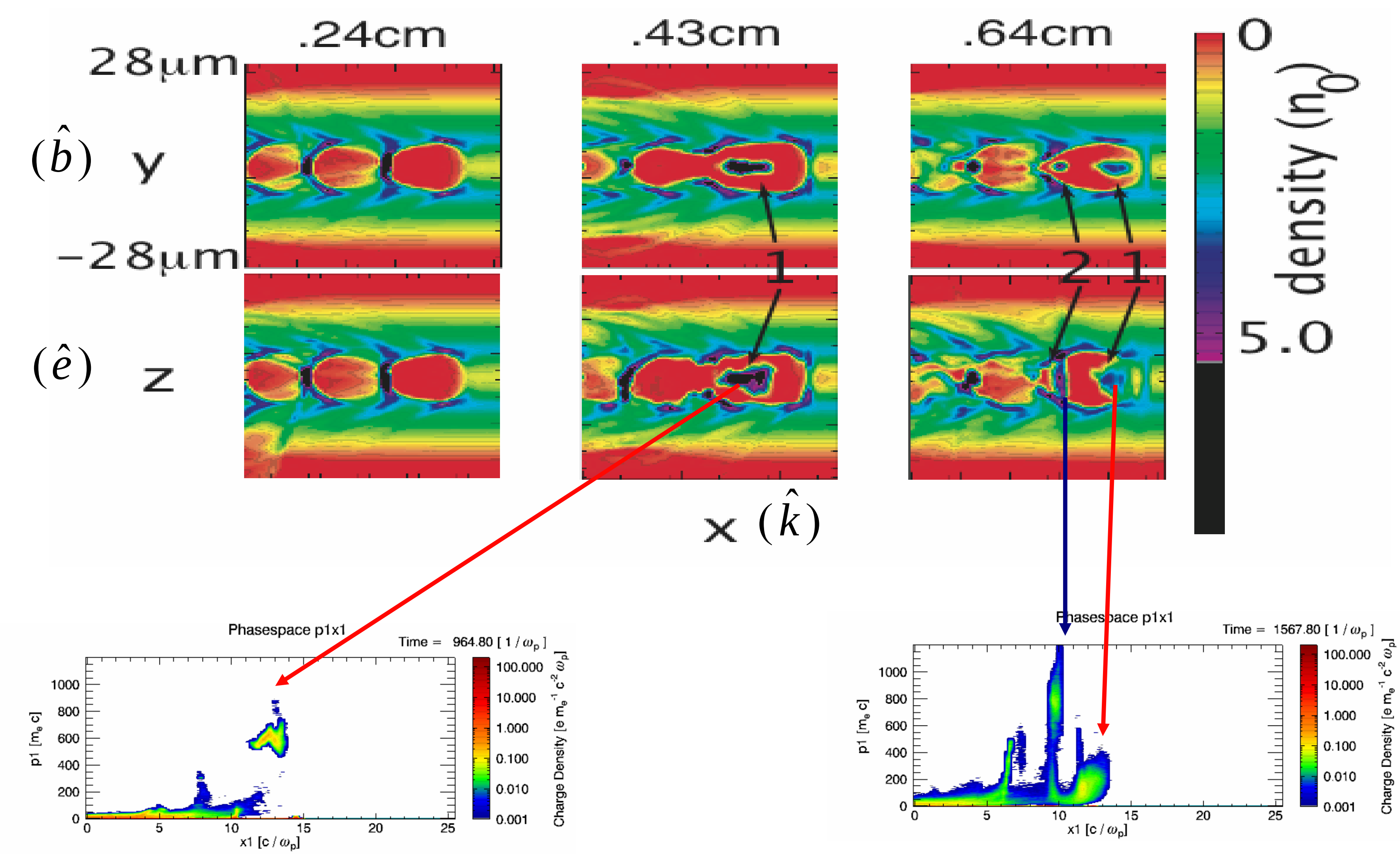


C.Geddes et al., submitted

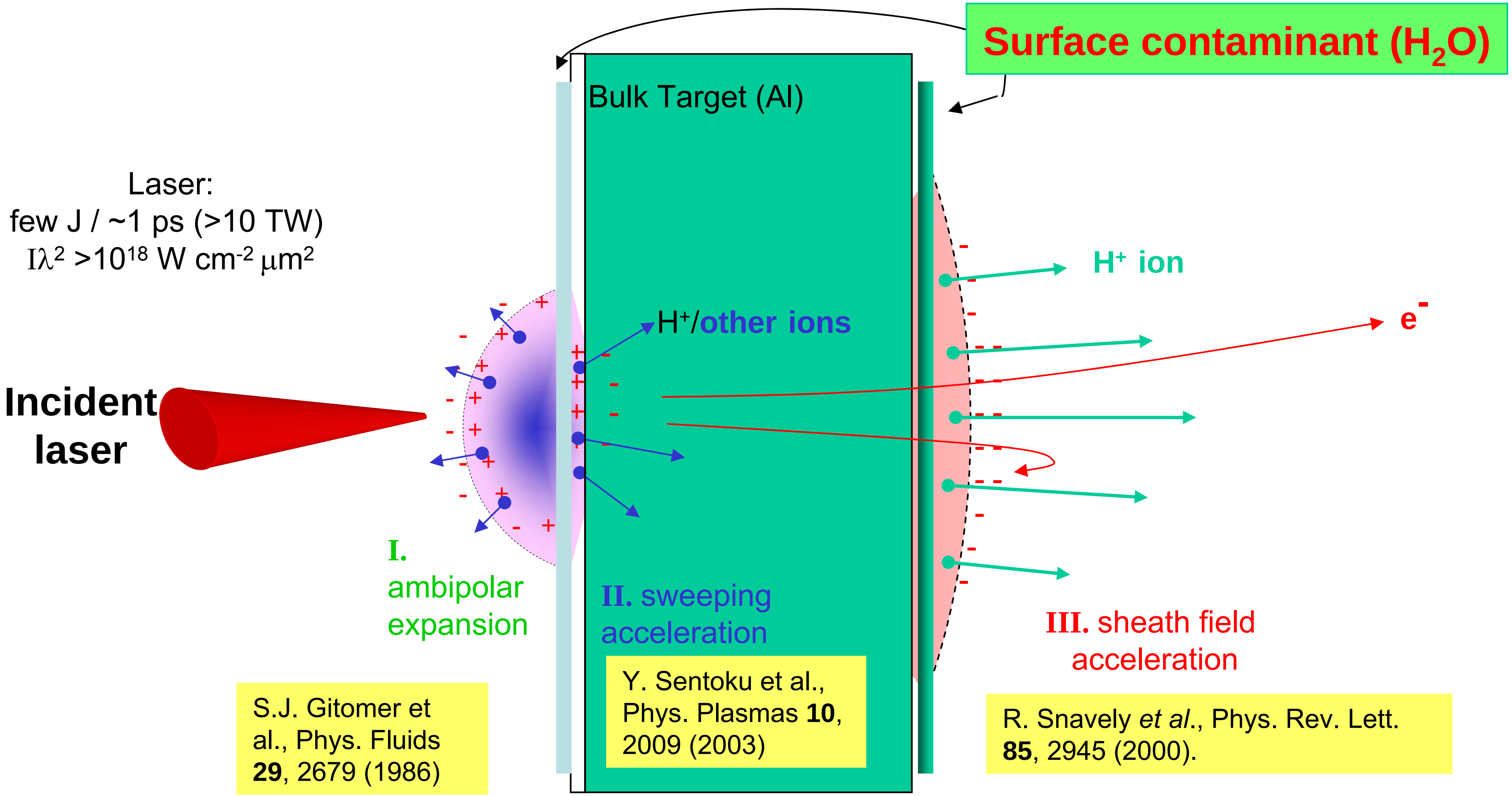


Electrons > 150 MeV observed

Slowing of the laser pulse leads to dephasing of the trapped particles to give a narrower energy spread in 3D PIC simulations



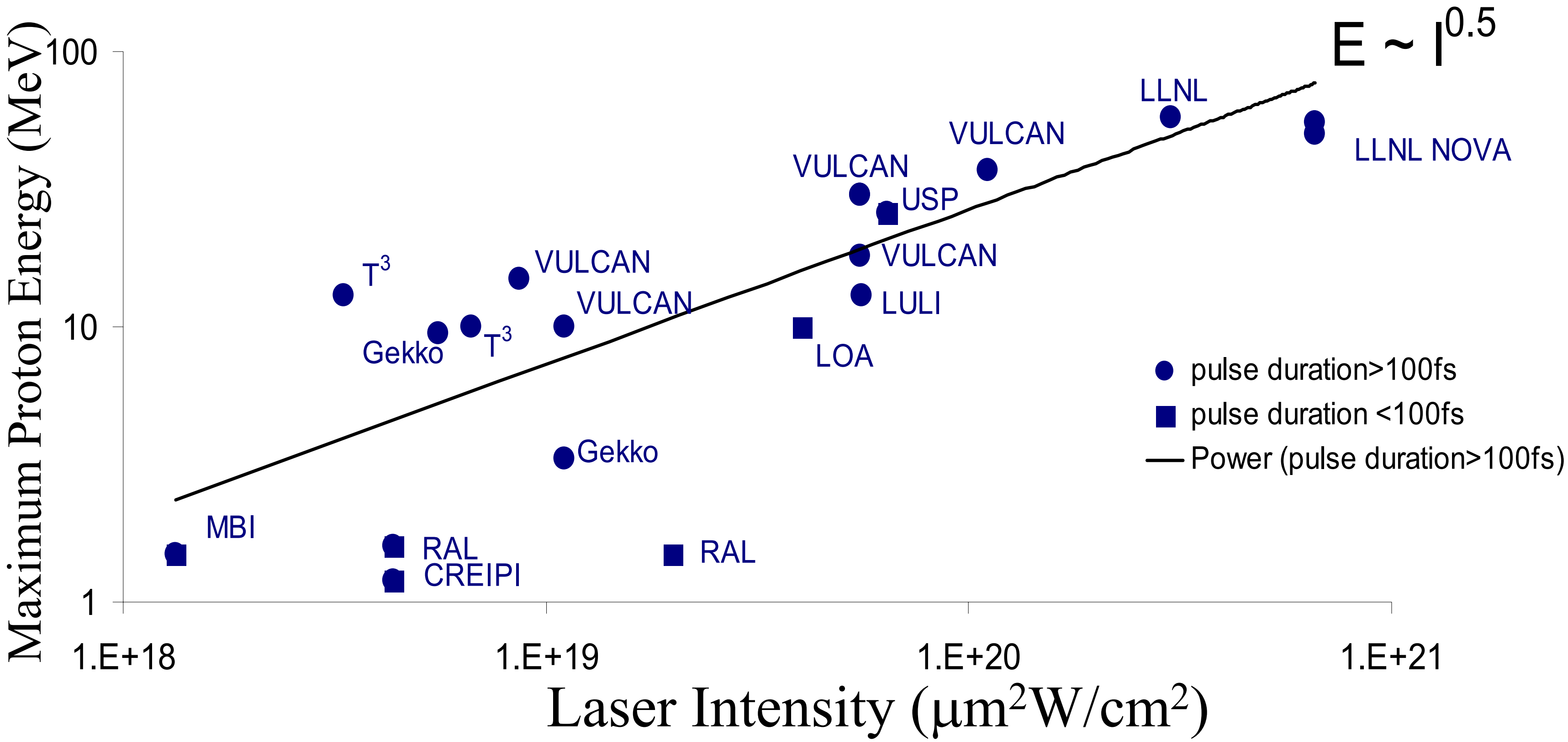
Laser-acceleration of *ions* from solid targets



if target is heated ➔ efficient acceleration of heavy ions

[M. Hegelich et al., Phys. Rev. Lett. **89**, 085002 (2002).]

Proton Energy Scaling



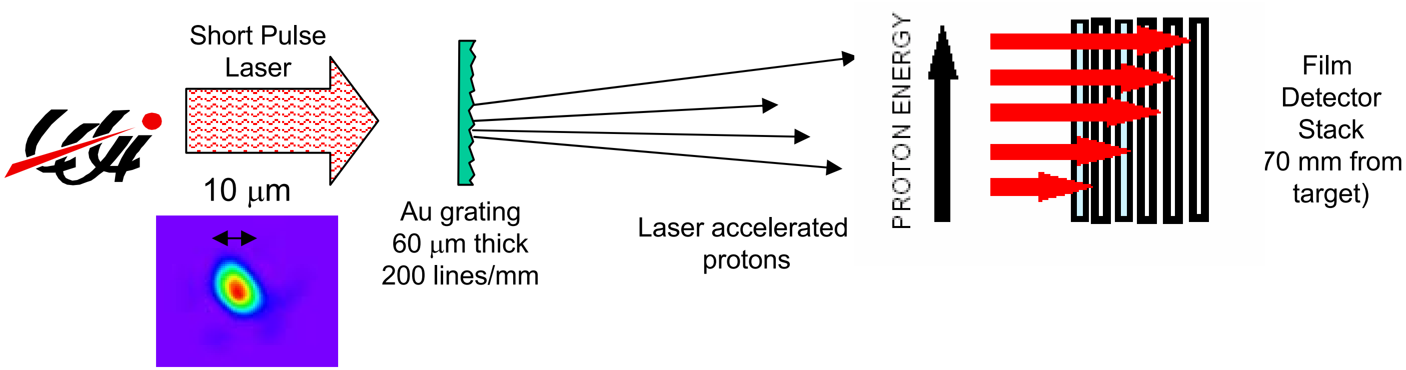
- **Hi charge: 10^{10}-10^{13} ions**
- **Short pulses**
- **100's MA/cm^2**

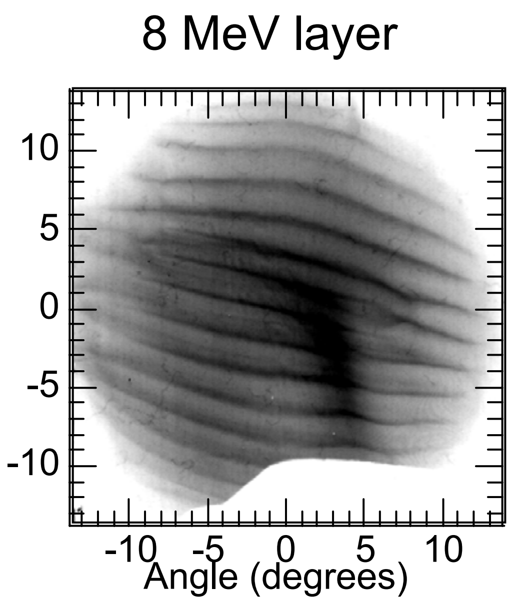
(Courtesy T. Lin)

Recent Highlight: Record beam quality ε_n < .004 mm-mrad!

10x lower ε than conventional ion injectors

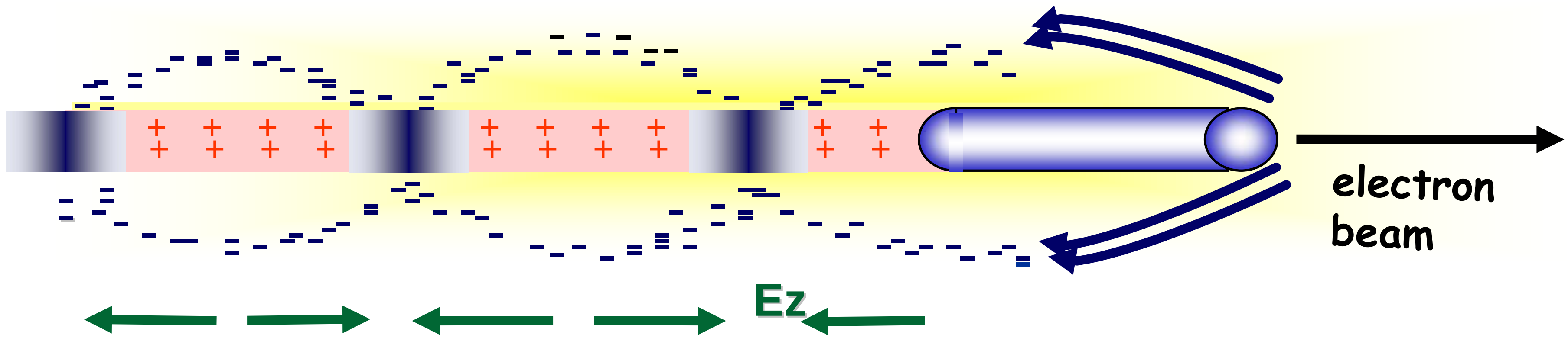
T. Cowan, J. Fuchs. H. Ruhl *et al*., Phys. Rev. Lett. **92**, 204801 (2004).





Beam-driven Wakefield Accelerators

- Space charge of beam displaces plasma electrons



- Plasma ions exert restoring force =>
  - •Net Focusing force on beam ($F/r=2\pi ne^2/m$)
  - •Space charge oscillations (short beam)

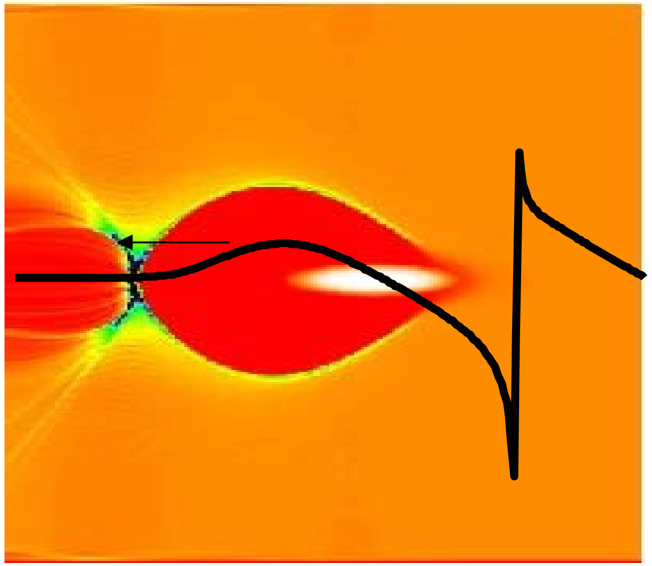
No diffraction

- Wake Phase Velocity = Beam Velocity (like wake

No dephasing

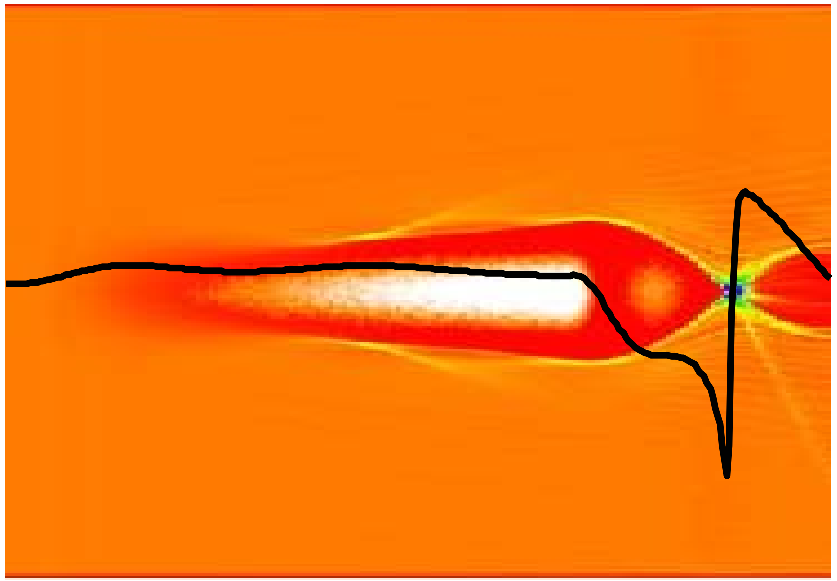
- Wake amplitude $\propto N_b / \sigma_z^2$

PIC Simulations of Beam and Plasma Wakes



Bi-Gaussian shape

$\sigma_z = 1.2\ c/\omega_p$, $n_b/n_p = 26$



Wedge shape w/ beam load

beam length = 6 $c/\omega_{p,}$ $n_b/n_p = 8.4$,

$N_{drive} = 3x10^{10}$, $N_{trailing} = 0.5x10^{10}$

E-162/E-164/E-164X PWA Experiments

Collaboration:

C. Barnes, F.-J. Decker, P. Emma, M. J. Hogan, R. Iverson, P. Krejcik, C. O'Connell, P. Raimondi, R.H. Siemann, D. Walz

Stanford Linear Accelerator Center

B. Blue, C. E. Clayton, C. Huang, C. Joshi, D. Johnson, K. A. Marsh, W. B. Mori, W. Lu

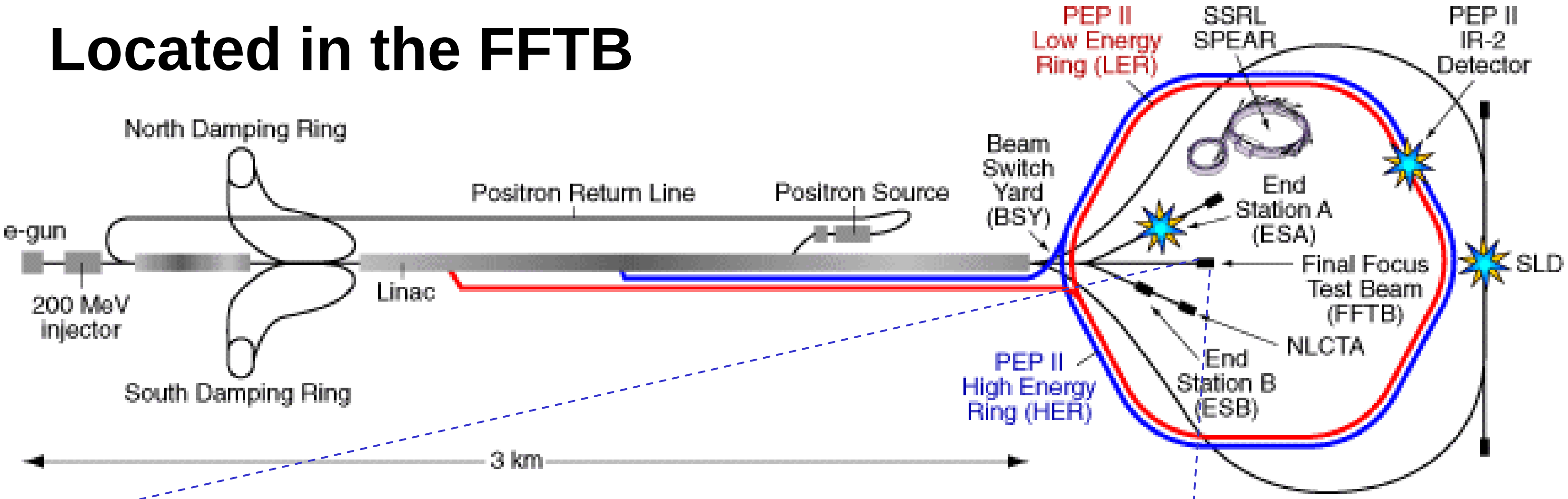
University of California, Los Angeles

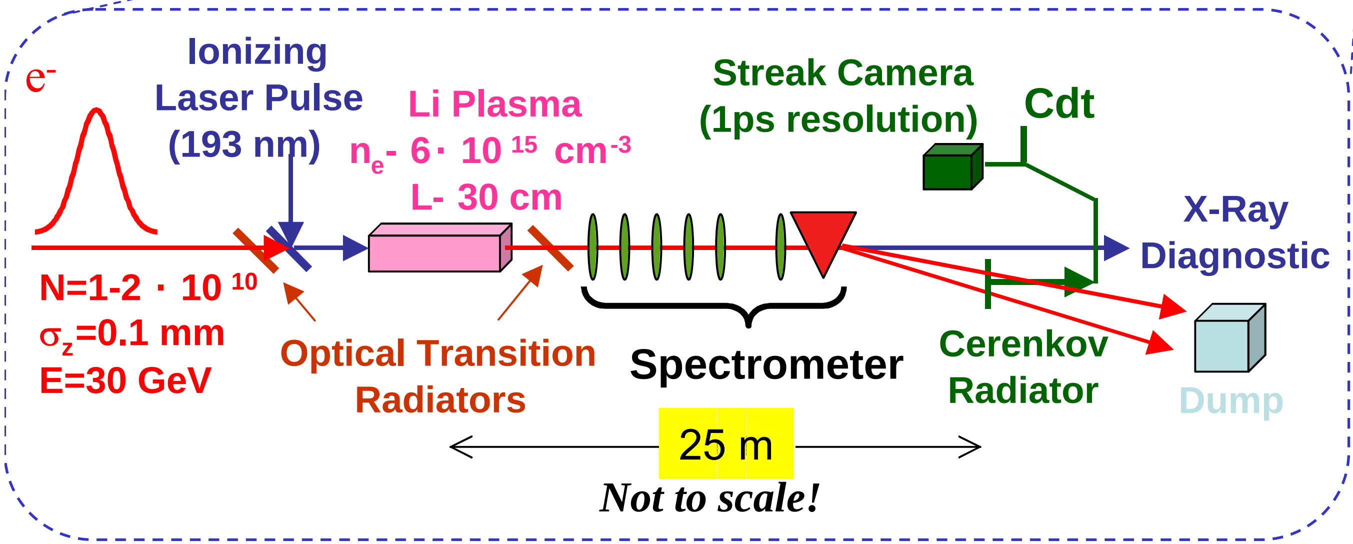
T. Katsouleas, S. Lee, P. Muggli, E. Oz

University of Southern California

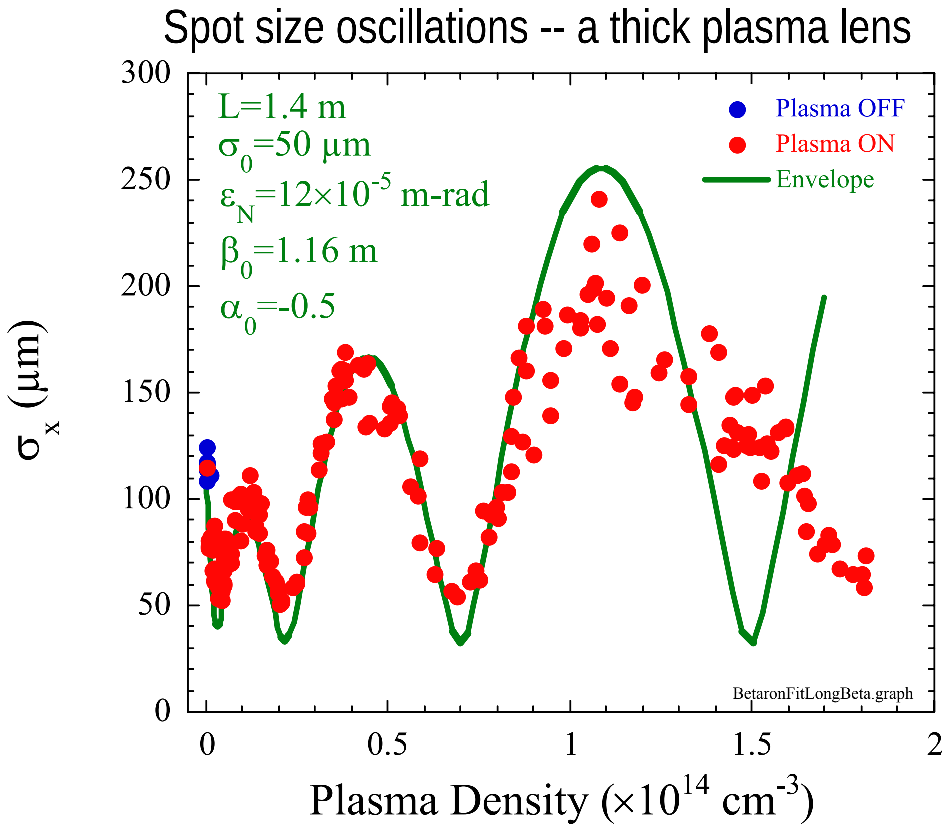
PWFA Experiments @ SLAC
Share Common Apparatus

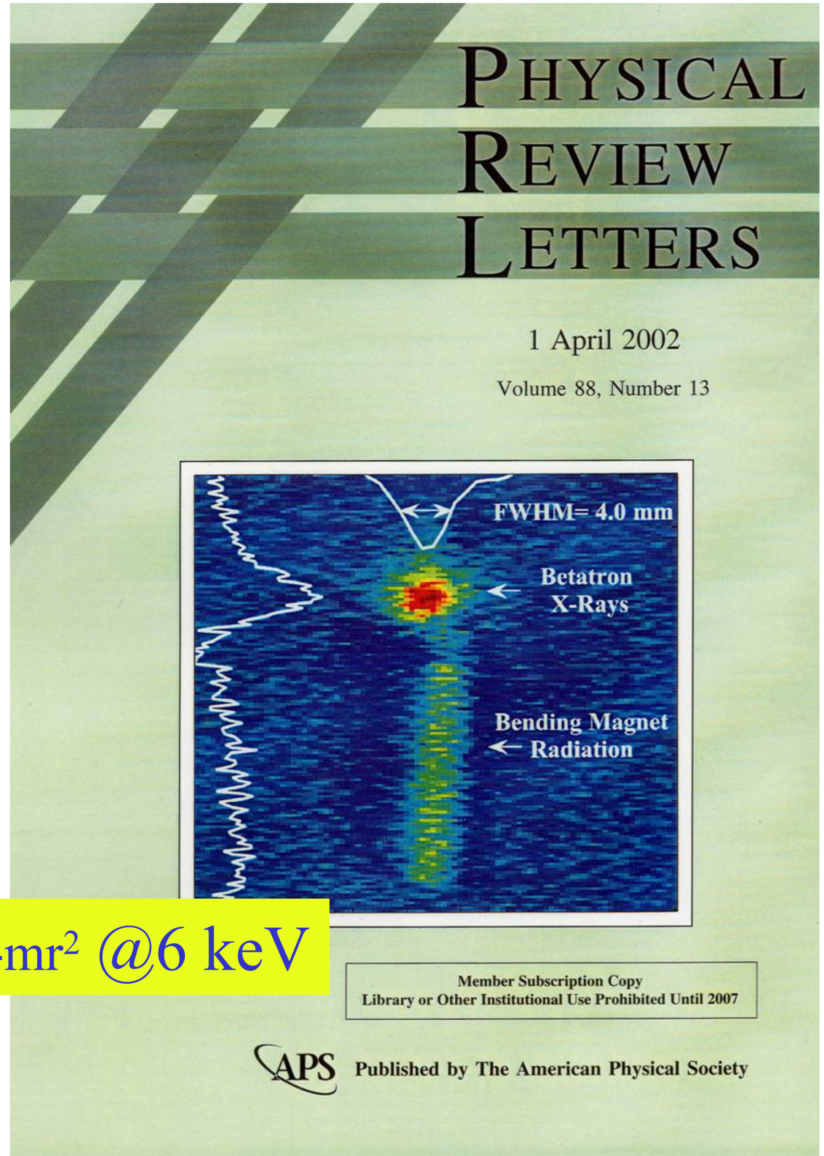
Located in the FFTB





X-Ray Emission from Betatron Motion in a Plasma Wiggler



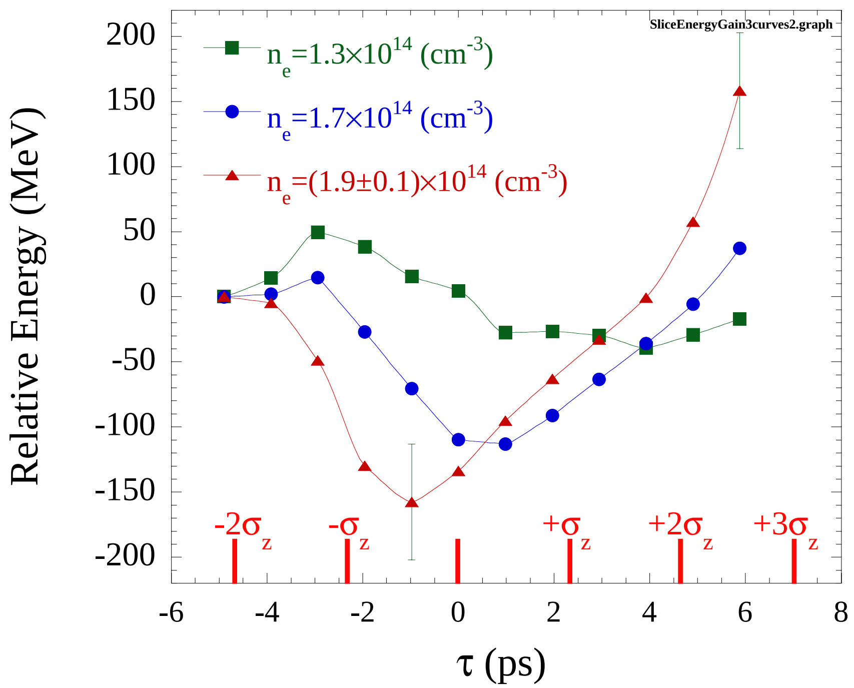


$I \sim 10^{19}$ photons/s-.1%bw-mm²-mr² @6 keV

S. Wang et al. Phys. Rev. Lett. Vol. 88 Num. 13

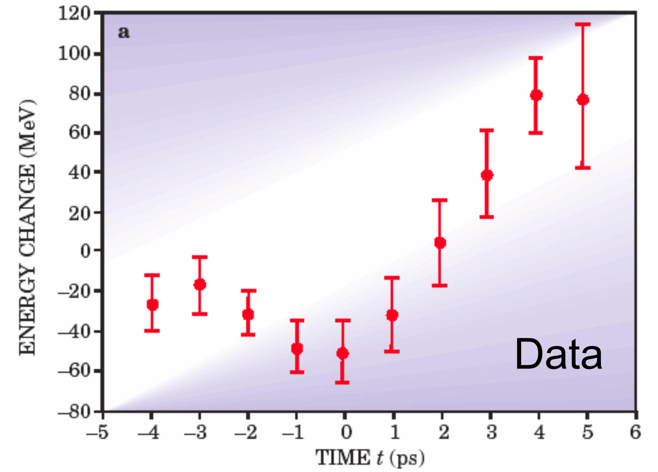
Acceleration Of Electrons & Positrons: E-162

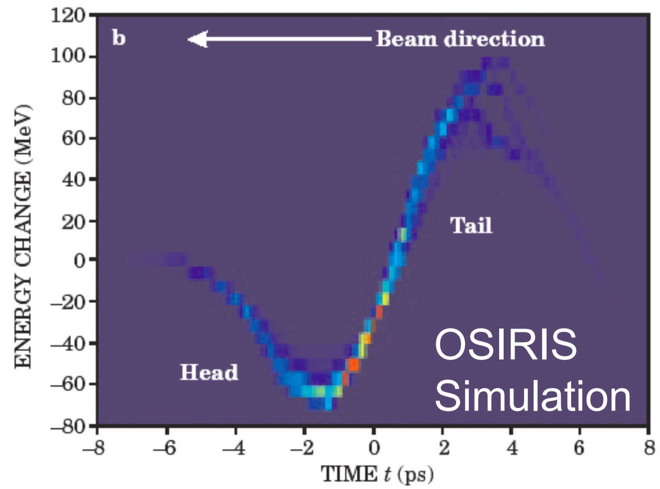
Electrons



- *Some electrons gained* *280 MeV (200 MeV/m)*
- *Now going for 2 GeV at a rate of 10,000 MeV/m this month at SLAC*

Positrons

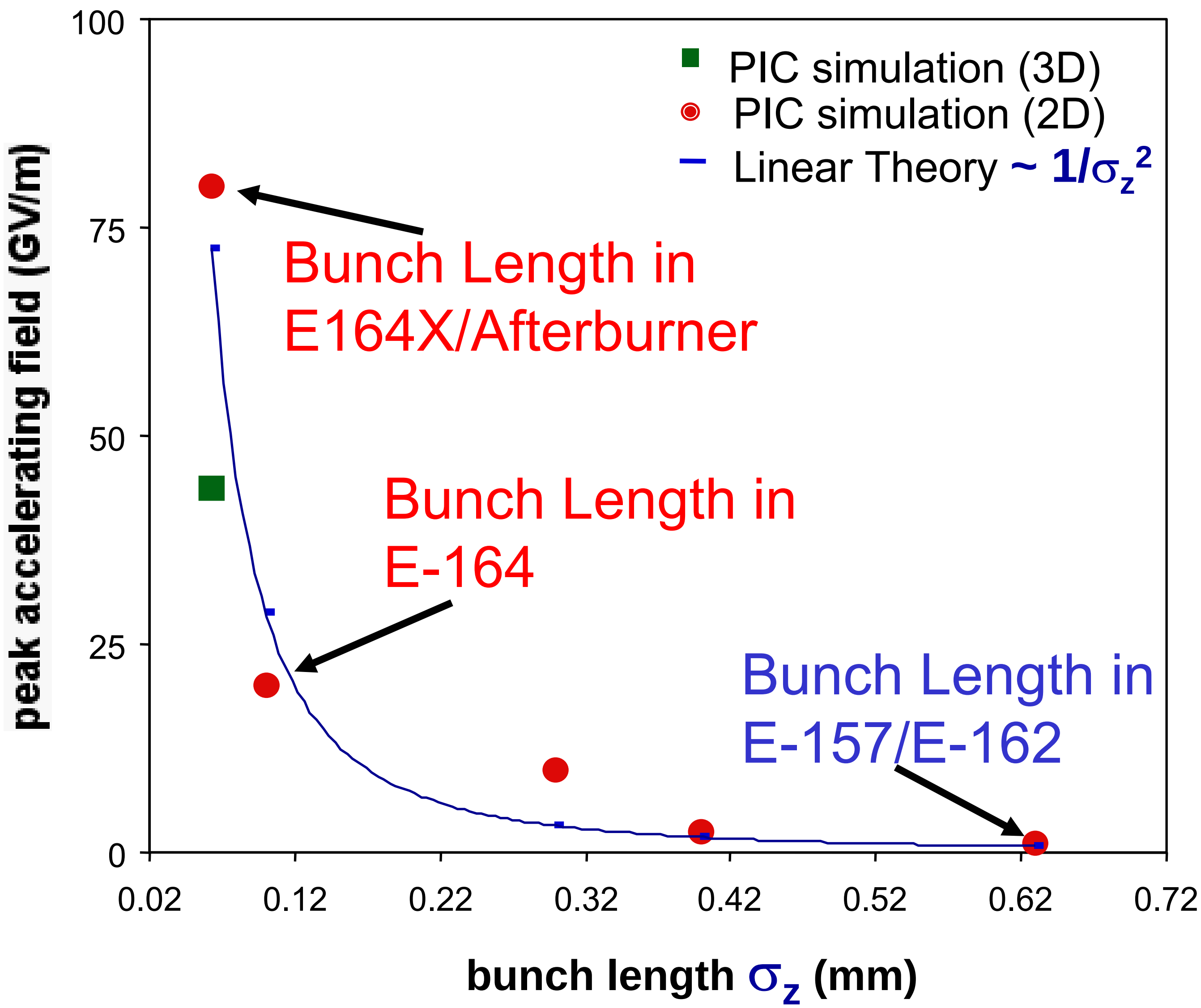




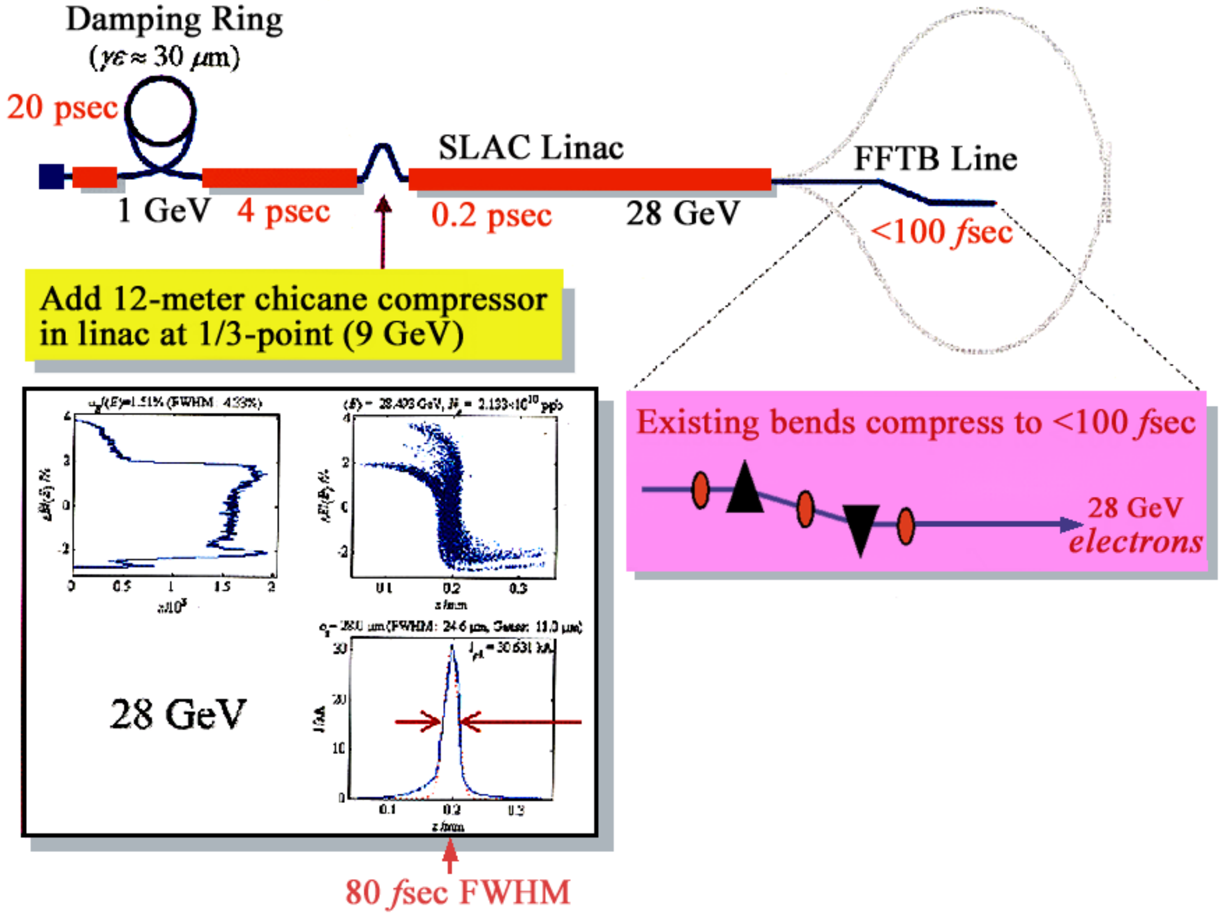
- Loss ≈ 50 MeV
- Gain ≈ 75 MeV

B. Blue *et al.*, Phys. Rev. Lett. 2003
R. Bingham, Nature, News and Views 2003

PWA Experiments at SLAC

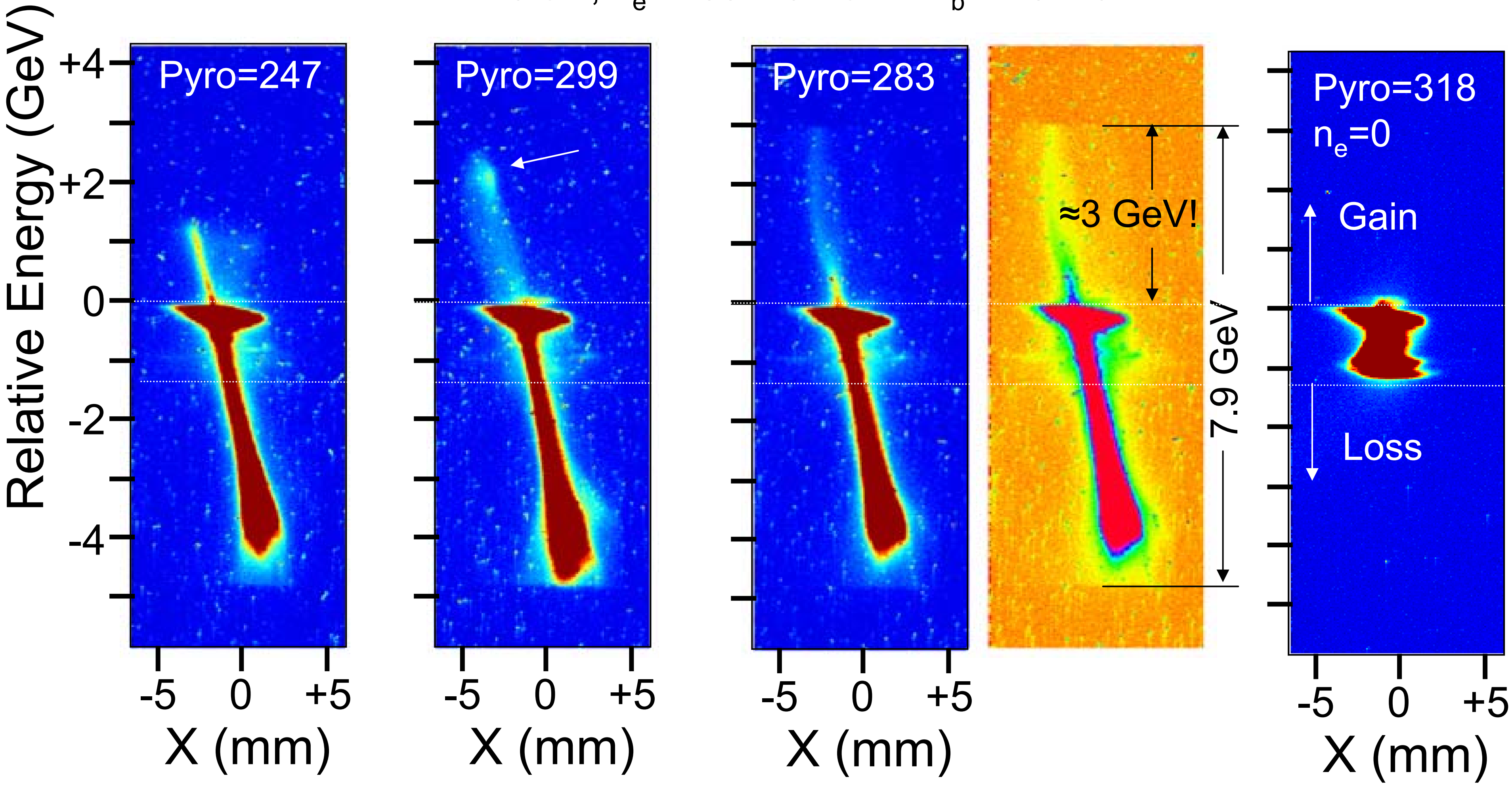


Sub-Picosecond Pulse Source



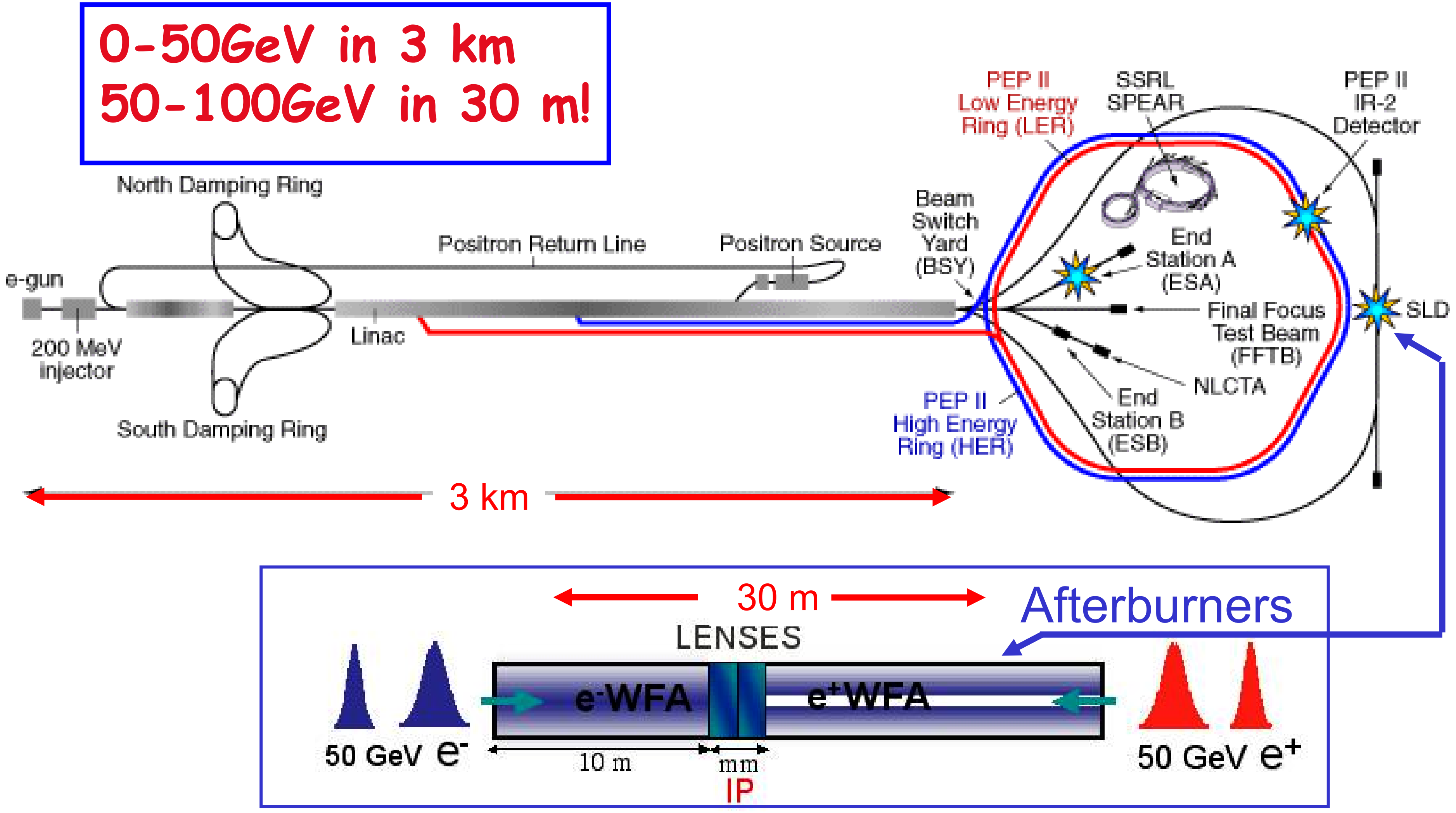
E164X Breaks GeV Barrier

L≈10 cm, $n_e \approx 2.55\times10^{17}$ cm^{-3} $N_b \approx 1.8\times10^{10}$



➡ Energy gain exceeds ≈ 4 GeV in 10 cm

A Plasma Afterburner (Energy Doubler) of Relevance to Future Colliders Could be Demonstrated at SLAC



S. Lee et al., Phys. Rev. STAB, 2001

USC UNIVERSITY OF SOUTHERN CALIFORNIA

Stanford Linear Accelerator Center

Afterburner simulation

Minimal hosing!

UCLA

QuickTime™ and a MPEG-4 Video decompressor are needed to see this picture.

QuickTime™ and a MPEG-4 Video decompressor are needed to see this picture.

QuickTime™ and a MPEG-4 Video decompressor are needed to see this picture.

1) Matched wedge shape drive beam with trailing bi-Gaussian beam.

2) Background plasma density.

New *FAST* 3-D Quasi-static PIC Model (QuickPIC)

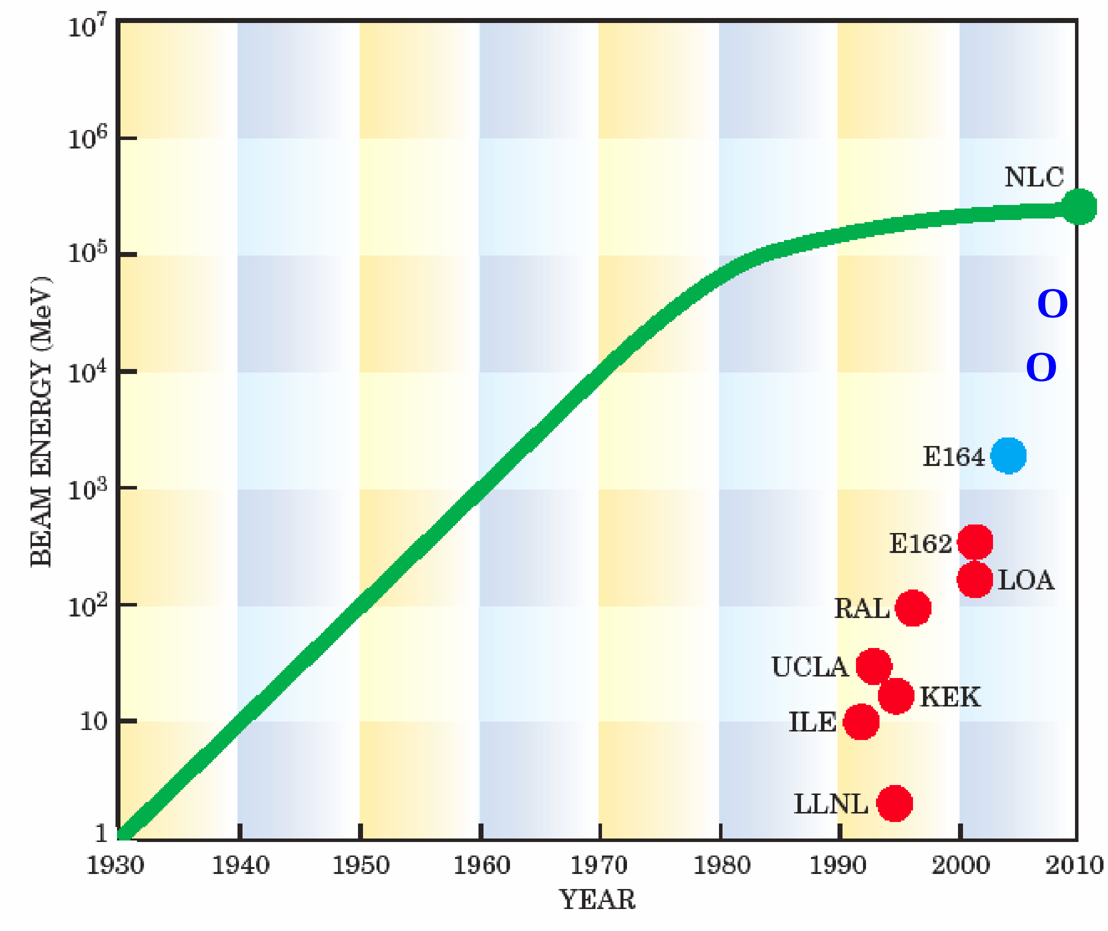
50 Gev energy gain in 3 meters !

QuickTime™ and a
MPEG-4 Video decompressor
are needed to see this picture.

QuickTime™ and a
MPEG-4 Video decompressor
are needed to see this picture.

Accelerating field
24GeV/m at the load

We are on the path to the energy frontier…



CONCLUSIONS

Significant Progress in the Past Two Years.

Quasi-mono energetic Beams of Electrons from Laser Plasma Accelerators @100 MeV , 200pC charge

GeV Energy Barrier Shattered at SLAC (E164X)

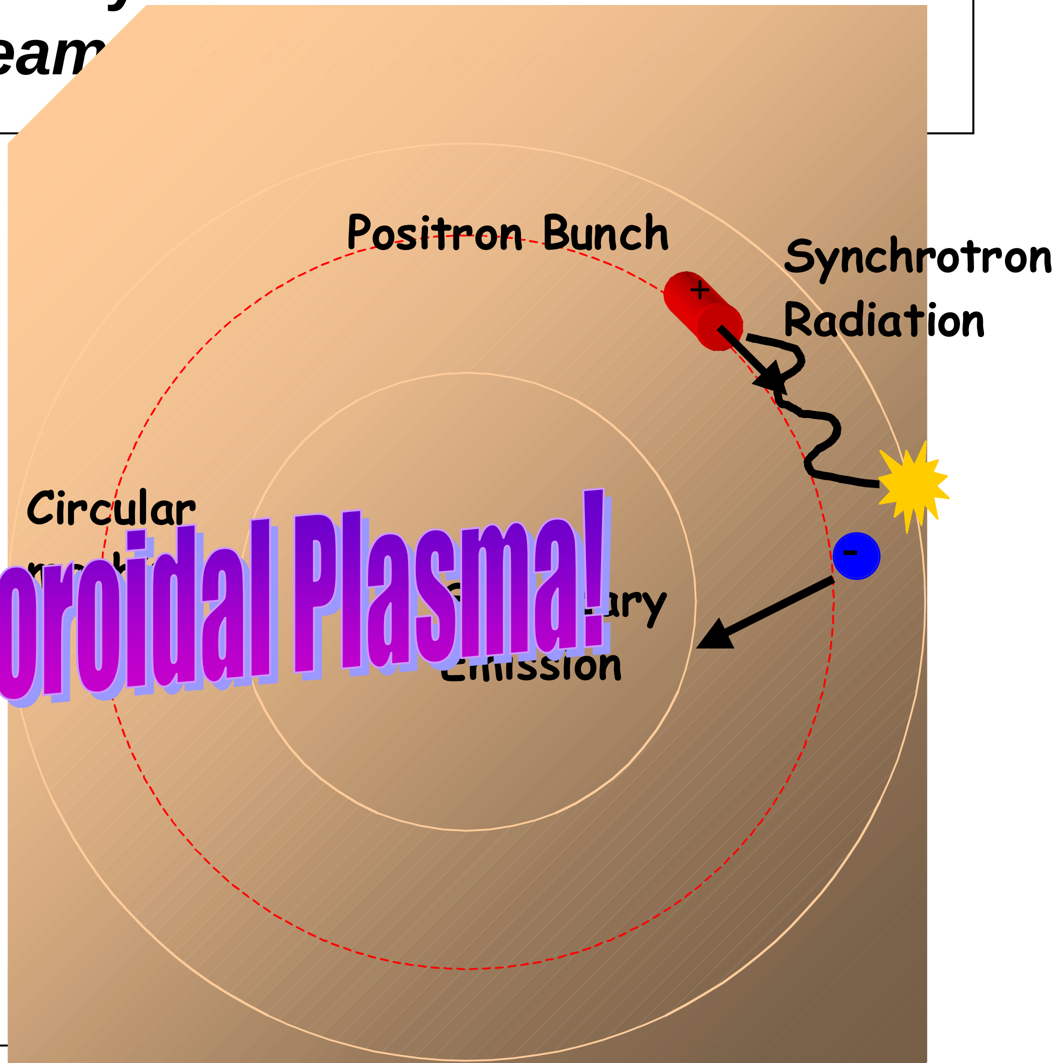
Extremely Low Emittance Proton Beams from Laser Plasmas

IFEL Achieves 50 MeV/m Gradients @ UCLA
Staged Acceleration with High Efficiency shown at ATF(BNL)

Possibility of 10 GeV Energy Gains in 1m Begins to Look Real

Electron-Cloud Instability in Circular Accelerators:
A 54000km beam

- E-cloud formation (Proton):
  halo scraping+secondary emission
- Low density (10^6 cm^{-3}) e-cloud builds
- Beam-cloud 2 stream instability results
- Major concern for LHC at CERN

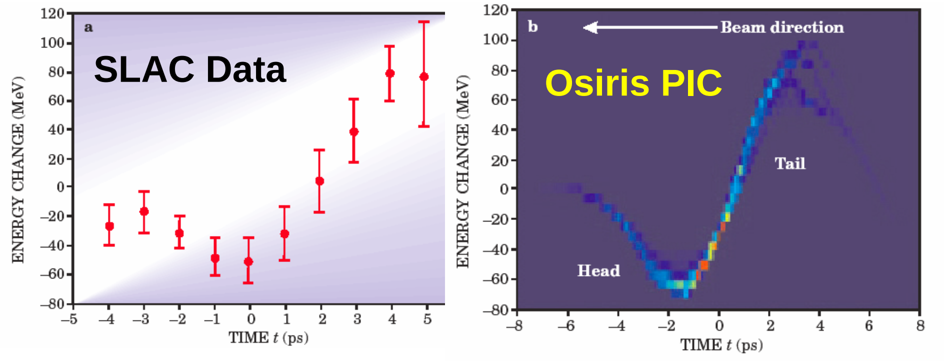


A Large Toroidal Plasma!

Ali Z. Ghalam, T. Katsouleas, A. Z. Ghalam, S. Lee (USC),
W. B. Mori, C. Huang, V. Decyk, C. Ren(UCLA)
Giovanni Rumolo, Frank Zimmermann, Francesco Rugierro (CERN)

Plasma Accelerators

1. Positron acceleration/ 3-D Modeling

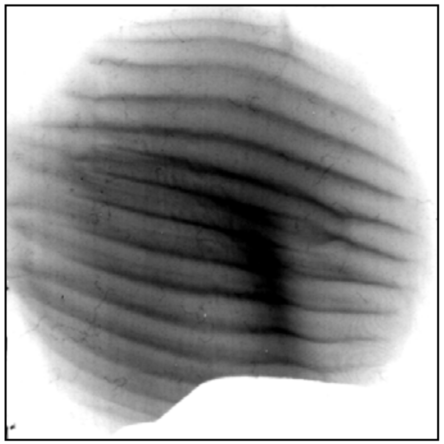


2. Monoenergetic electron beams

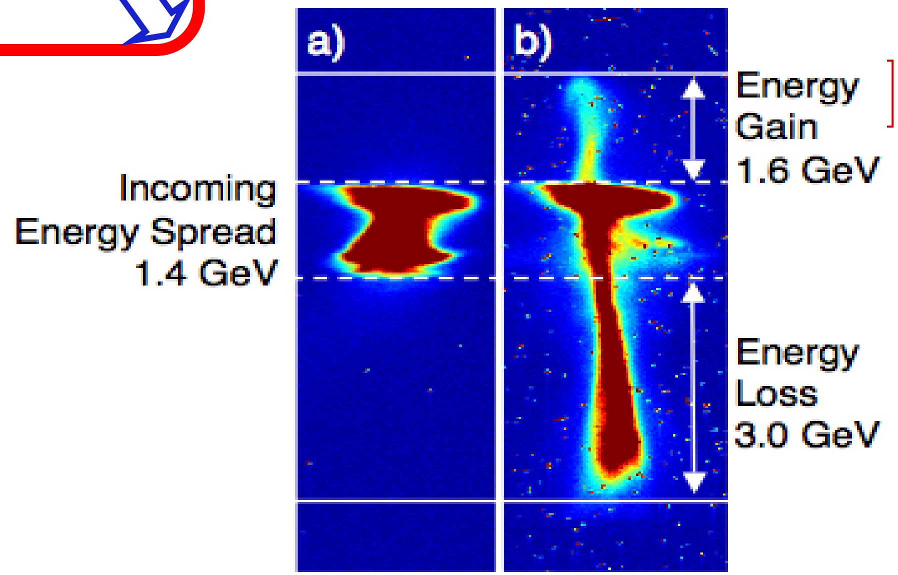
QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Four
Highlights!

3. Multi-MeV proton beams



4. GeV Milestone



Special thanks to Chan Joshi, Patric Muggli, Mark Hogan, Wim Leemans, Warren Mori, Ricardo Fonseca, Luis de Silva, Frank Tsung, Eric Esarey, Julien Fuchs, Jerome Faure, Viktor Malka, Karl Krushelnick, Chengkun Huang, Suzhi Deng, Bob Bingham for materials generously provided

…And to all my E-164 collaborators

Extra and backup slides

Simulations of Electon Cloud Instability in the LHC ring

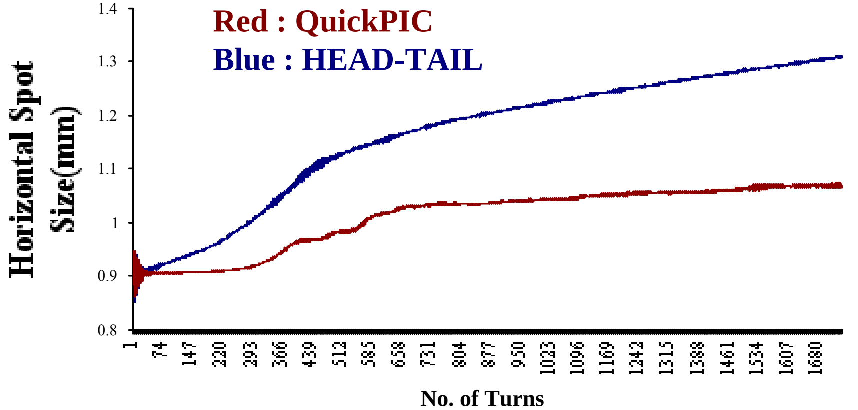
USC UNIVERSITY OF SOUTHERN CALIFORNIA

UCLA

QuickPIC simulations are performed On USC's Linux Cluster on 32 Processors for 28 days!

Horizontal Spot Size(mm) (rms)	0.884
Vertical Spot Size(mm)(rms)	0.884
Bunch Length(m)(rms)	0.115
Horizontal Box Size(mm)	18
Vertical Box Size(mm)	18
Bunch Population	1.1×10^{11}
Average Horizontal Beta Function(m)	66
Average Vertical Beta Function(m)	77.5
Momentum Spread	4.68×10^{4}
Beam Momentum(GeV/C)	479.6
Circumference(km)	26.659
Horizontal Betatron Tune	64.28
Vertical Betatron Tune	59.31
Synchrotron Tune	0.0059
Horizontal and Vertical Chromaticity	2,2
Electron Cloud Density(cm^{3})	6×10^{5}

Table 1. LHC parameters used in the simulations



Horizontal Spot Size of the beam predicted by the two codes

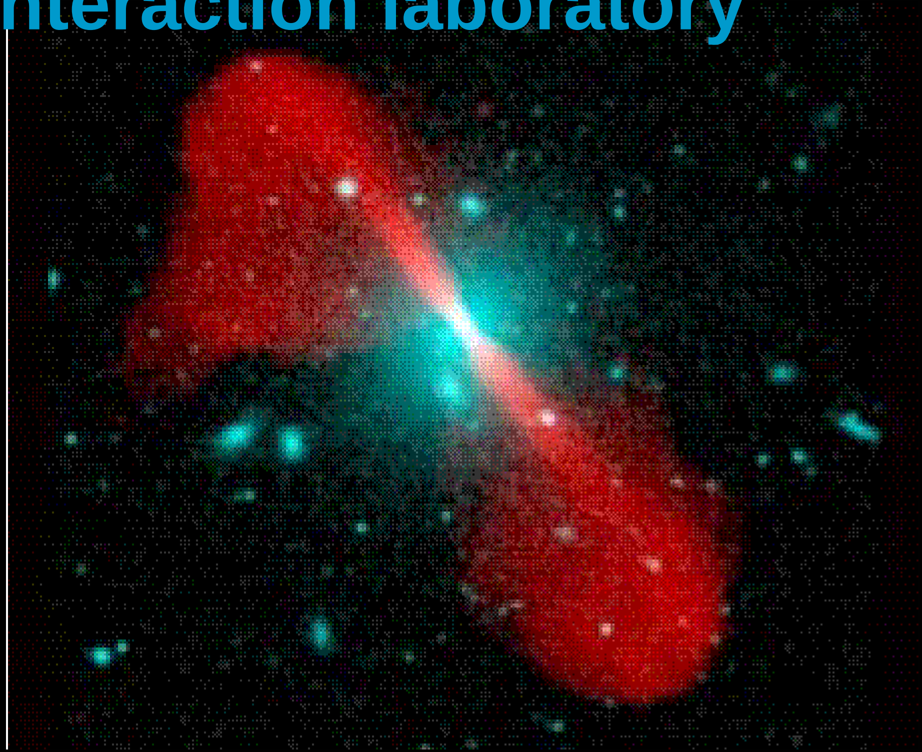
Beam Density in Horizontal Plane

Z

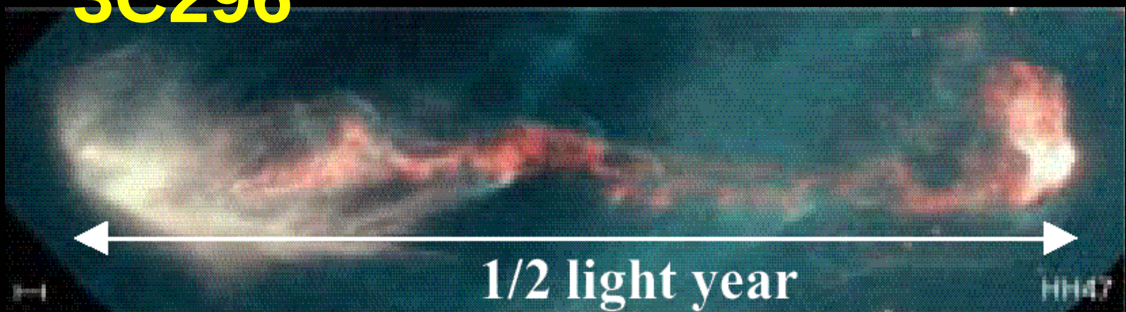
QuickTime™ and a
Video decompressor
are needed to see this picture.

Y

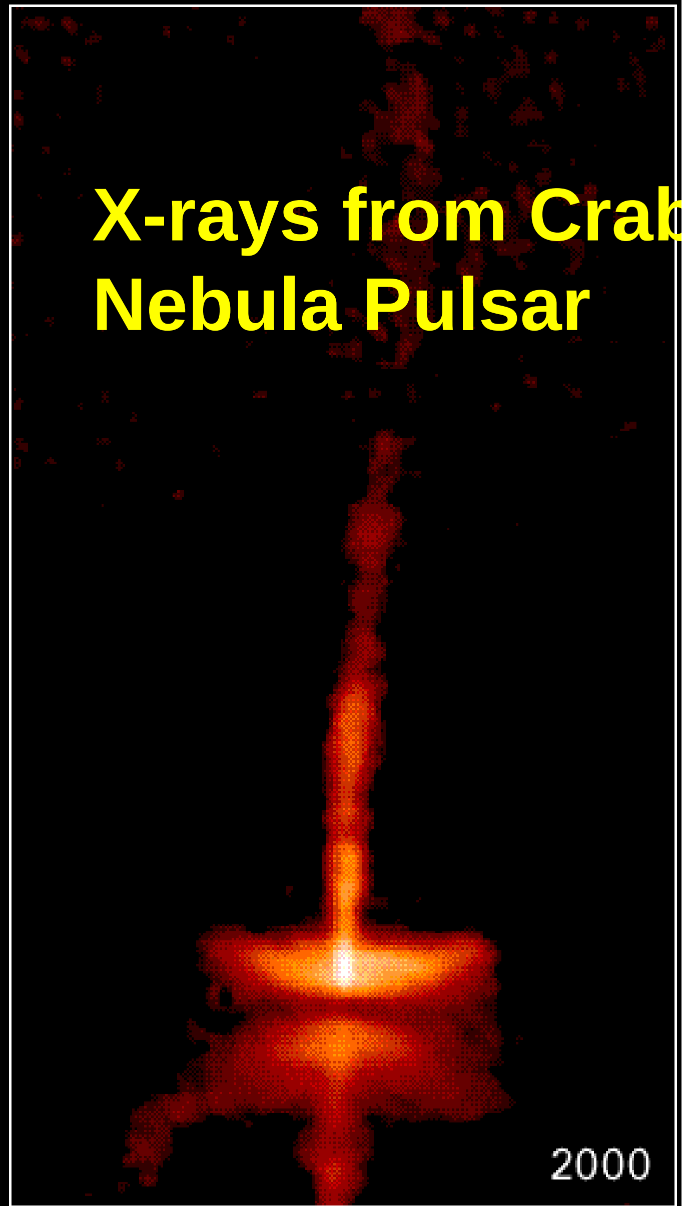
Astrophysical Jets -- the ultimate beam-plasma interaction laboratory



Radio Jets from Galaxy 3C296



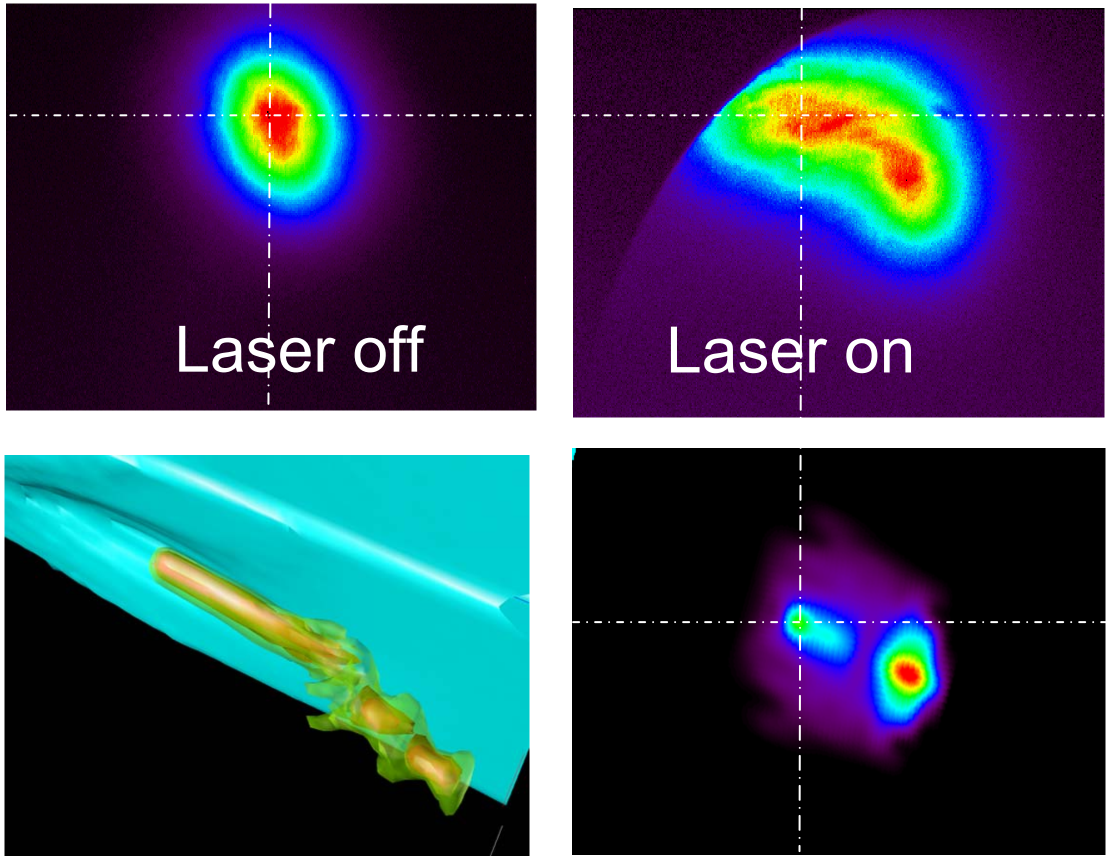
X-rays from Crab Nebula Pulsar



Refraction of an Electron Beam:
Interplay Between Simulation & Experiment

Experiment (Cherenkov images)

3-D OSIRIS PIC Simulation

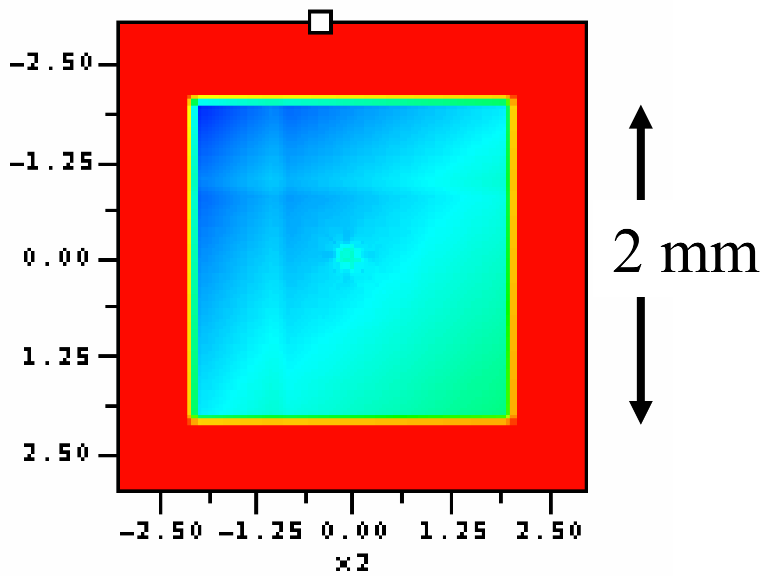


1 to 1 modeling of meter-scale experiment in 3-D!
(128 processors at NERSC, 5000 cpu hours)

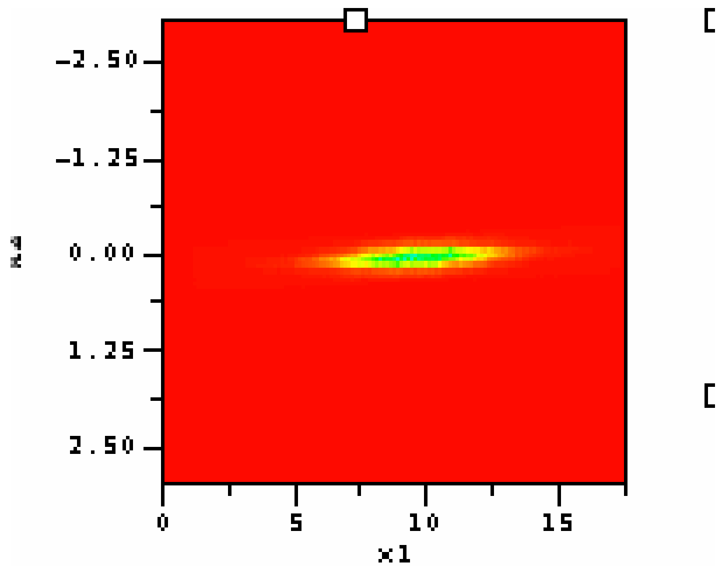
P. Muggli et al., Nature 411, 2001

E-162 Simulation Parameters

Beam Energy (Gev)	N	σ_z (μm)	σ_x (μm)	σ_y (μm)	Grids Size	ε_N (π μ-rad)	Simulation Size (c/ω_p=366μm)
28.5	$2*10^{10}$	650	25	25	384*120*120	58*5	6*2*2



Transverse density profile



Real space of tilted beam

- n_o =2.3e14 --> 1.9e14 cm^{-3}
- gradients in x, y

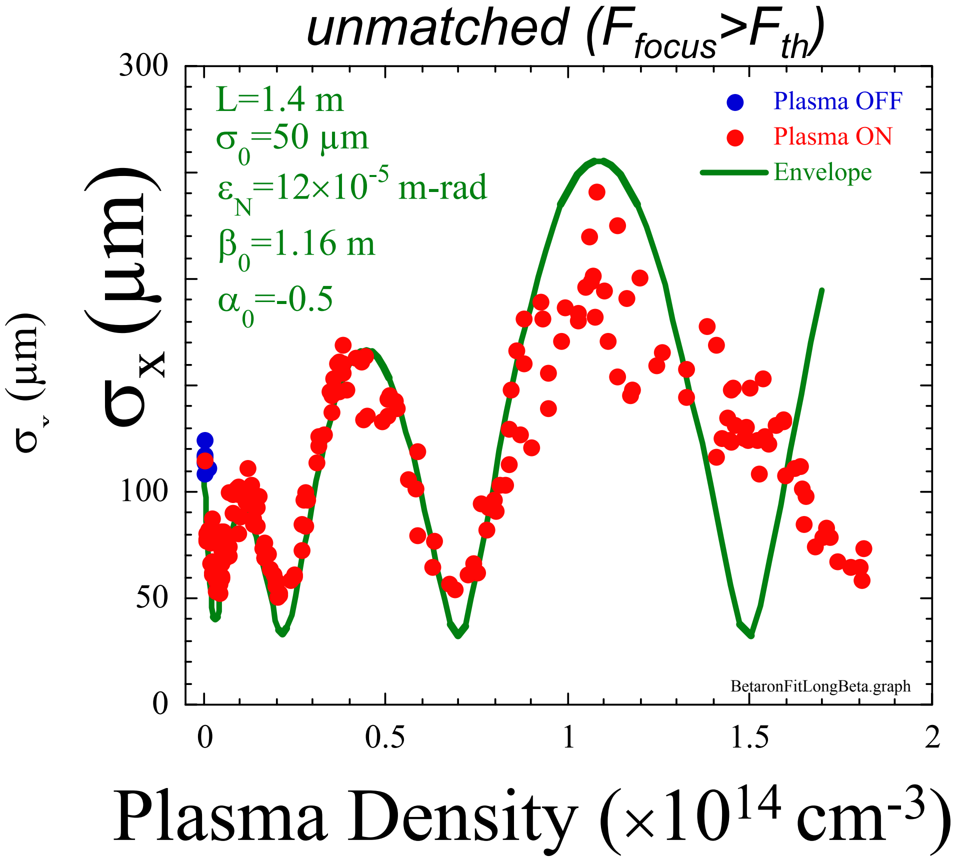
Tilt of beam = $0.4\sigma_x / 1\ \sigma_z$
= 10 μ/.65mm

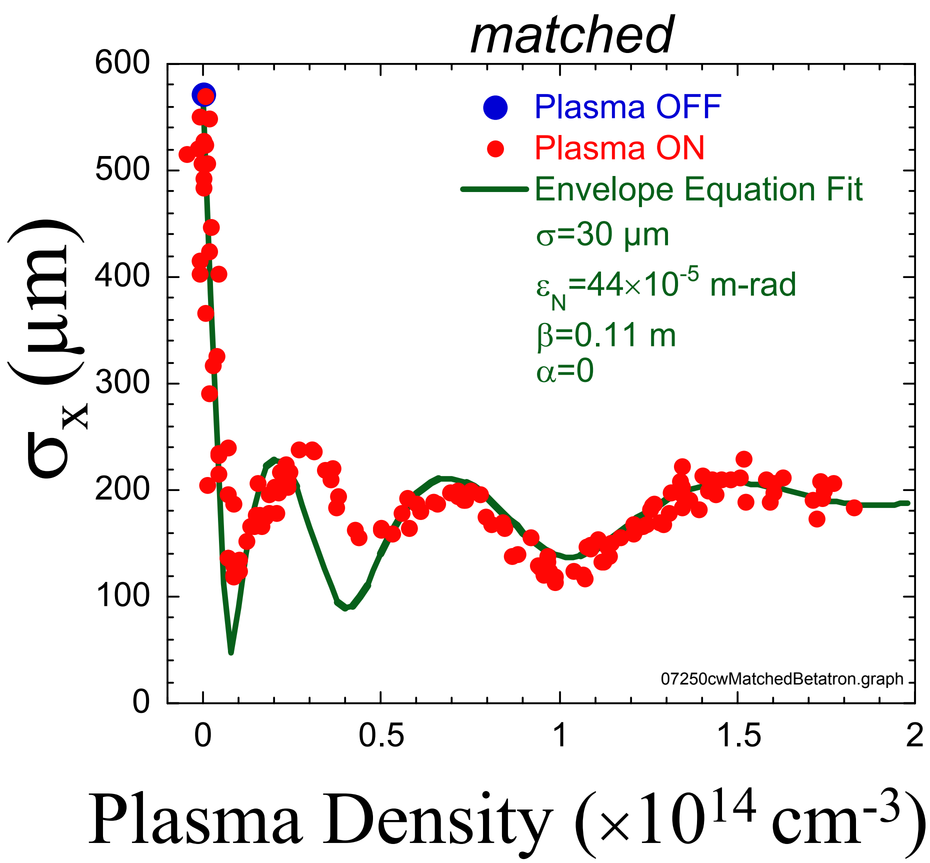
Beam propagation in a long plasma: r-z beam density contours

QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

Focusing & Propagation of e^-

OTR Images ≈1m downstream from plasma



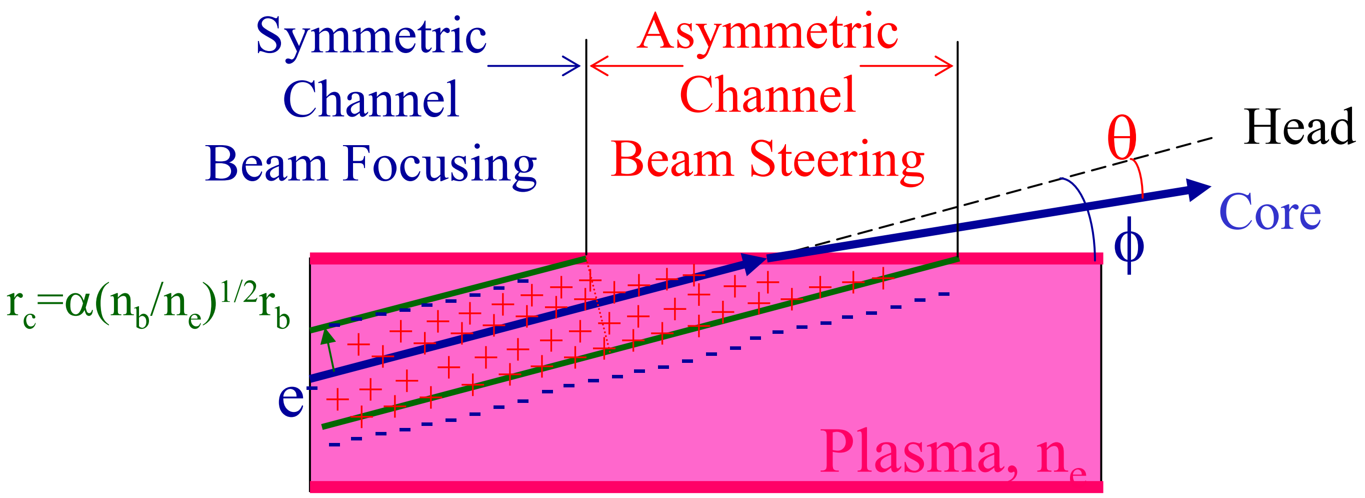


- Focusing of the beam well described by a simple model (n_b>n_e):
  Plasma = Ideal Thick Lens
- Emittance of 30 GeV beam preserved thru 1.4 m of plasma

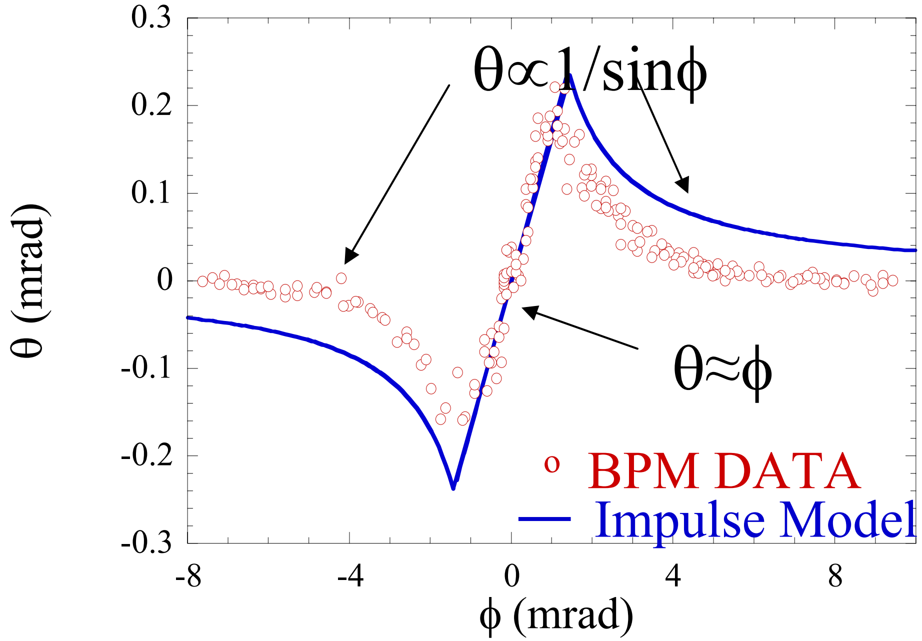
P. Muggli

C.E. Clayton *et al.*, PRL, 2001

Electron Beam Refraction At Plasma–Gas Boundary



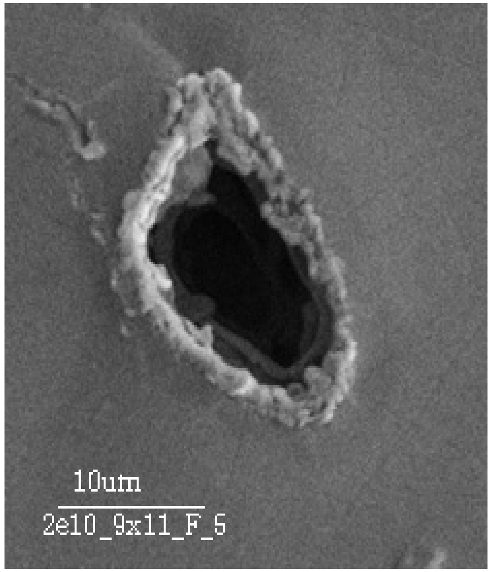
- Vary plasma – e^- beam angle ϕ using UV pellicle
- Beam centroid displacement @ BPM6130, 3.8 m from the plasma center



P. Muggli et al., Nature 411, 2001

High power beams tend to blow holes

- 30 GeV e-beam penetrates several mm's of copper…



Courtesy T. Raubenheimer, M. Ross

But we have seen…

- 30 GeV beam incident on 1mm of dilute gas
  (one million times less dense than air)

refracts and even...bounces off (total internal reflection)!

Short-pulse lasers and particle beams have similar peak power

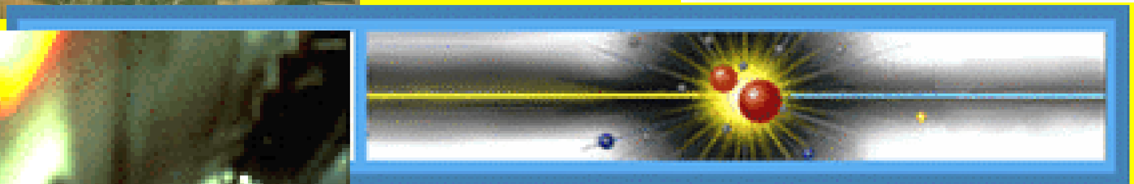
- **High-intensity lasers**
  - **100 Terawatt to Petawatt (1kJ/ps) --> 35J/35fs)**
  - **10^{21}-10^{22} W/cm^2**
- **High-intensity electron beams (SLC)**

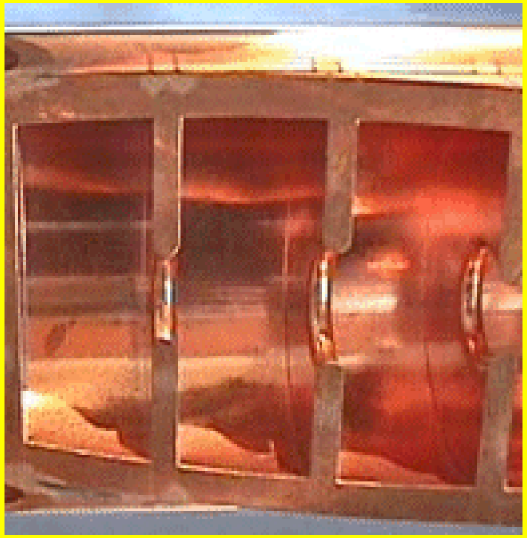
  4×10^{10} electrons at 50 GeV in 2ps - 200fs:
  - **100 Terawatt to 1 Petawatt**
  - **10^{21}-10^{22} W/cm^2**
- **Correspond to enormous forces and energy densities:**
  - **TeV/cm E-fields (quiver energies >10 GeV)**
  - **GigaGauss B-fields**
  - **TeraBar radiation pressure and energy densities (5 billion tons/in^2!)**

Critical Issues

- Beam Loading - create/phase 2nd bunch
- Transverse Beam Dynamics
  - hosing
  - lenses
  - pointing to sub-nm
- Positron Acceleration
- Plasma Source Development
- Modeling

Accelerators!

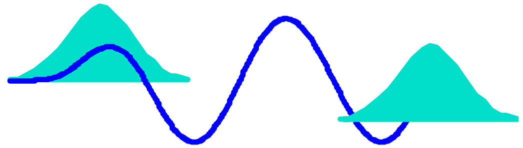




Concepts For Plasma Based Accelerators*

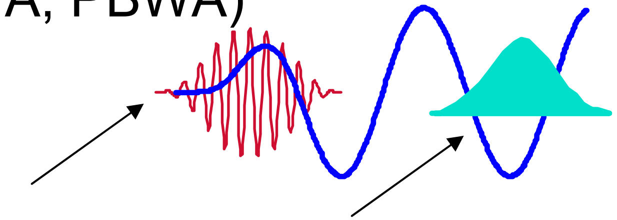
- Plasma Wake Field Accelerator(PWFA)

  A high energy electron bunch



- Laser Wake Field Accelerator(LWFA, SMLWFA, PBWA)

  A single short-pulse of photons



- Drive beam
- Trailing beam

Linear Plasma Wakefield Theory

$$(\partial_t^2 + \omega_p^2)\frac{n_1}{n_o} = -\omega_p^2\left(\frac{n_b}{n_o} + k_p^2\nabla^2\sqrt{1+a_o^2}\right)$$

Large wake for a beam density $\mathbf{n_b \sim n_o}$ or laser amplitude $\mathbf{a_o = eE_o/m\omega_o c \sim 1}$
for τ_{pulse} of order $\omega_p^{-1} \sim 100\text{fs}\,(10^{16}/n_o)^{1/2}$ and speed $\sim c=\omega_p/k_p$

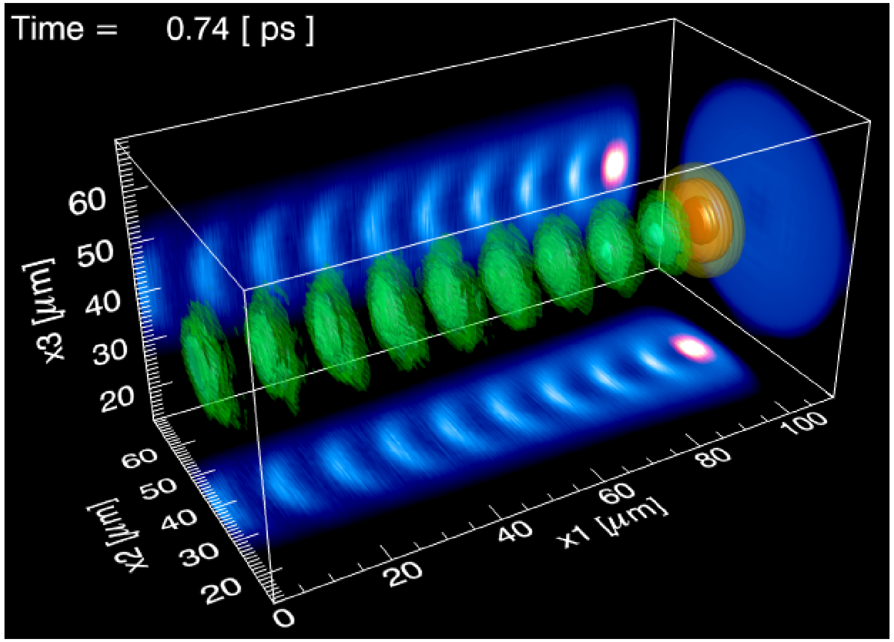
$$\nabla \bullet E = -4\pi e n_1 \Rightarrow \quad eE = \frac{n_1}{n_o}\sqrt{\frac{n_o}{10^{16}cm^{-3}}}10\,GeV/m\,\cos\omega_p(t - z/c)$$

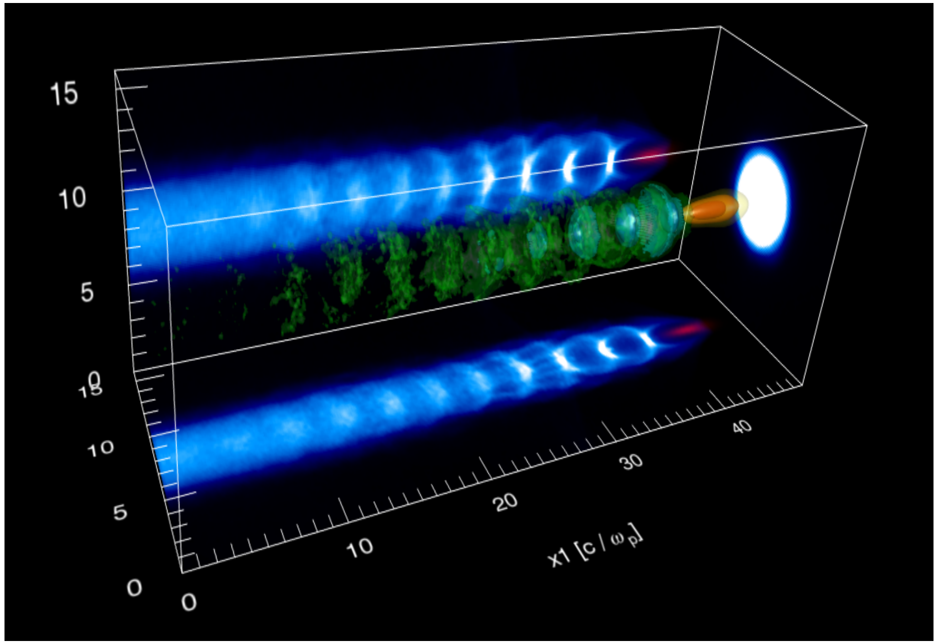
But interesting wakes are very nonlinear => PIC simulations

Nonlinear wakes are *similar* with laser or particle beam drivers:

3-D PIC OSIRIS Simulation

(self-ionized gas)

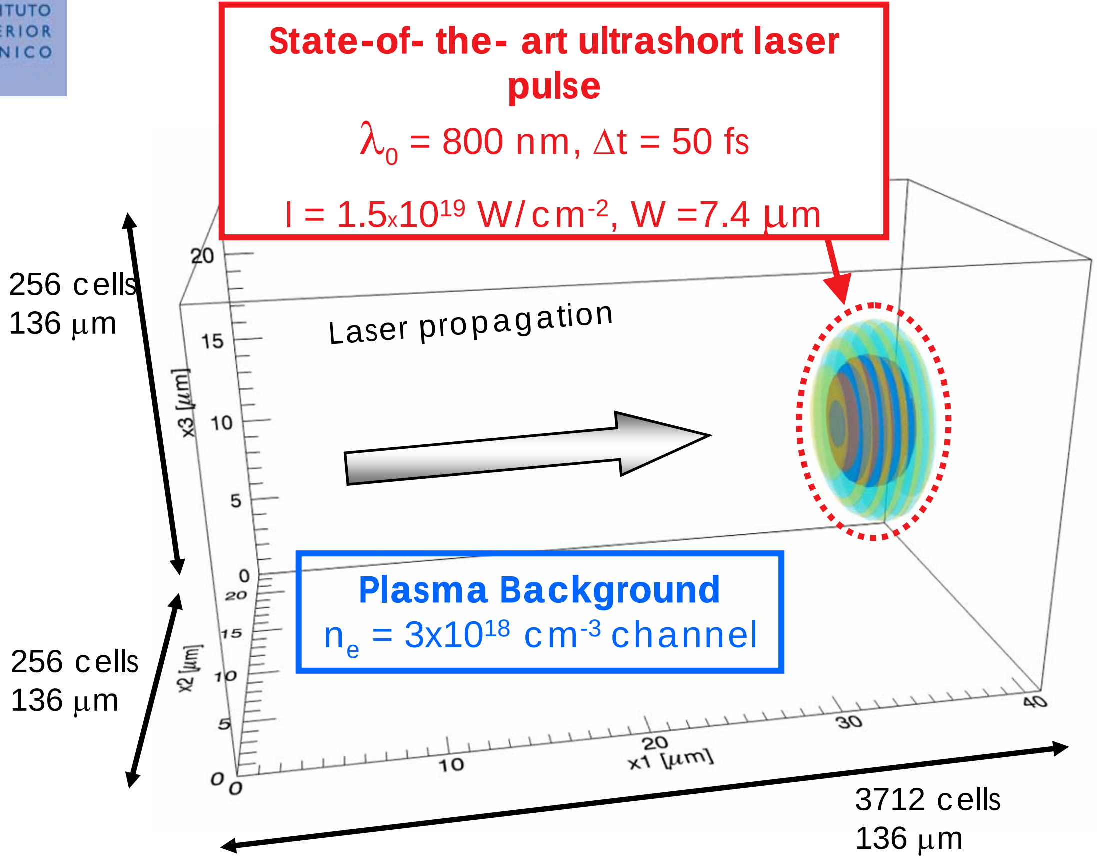




Laser Wake

Electron beam Wake

Full scale 3D LWFA simulation



Simulation ran for 200,000 hours
(~40 Rayleigh lengths)

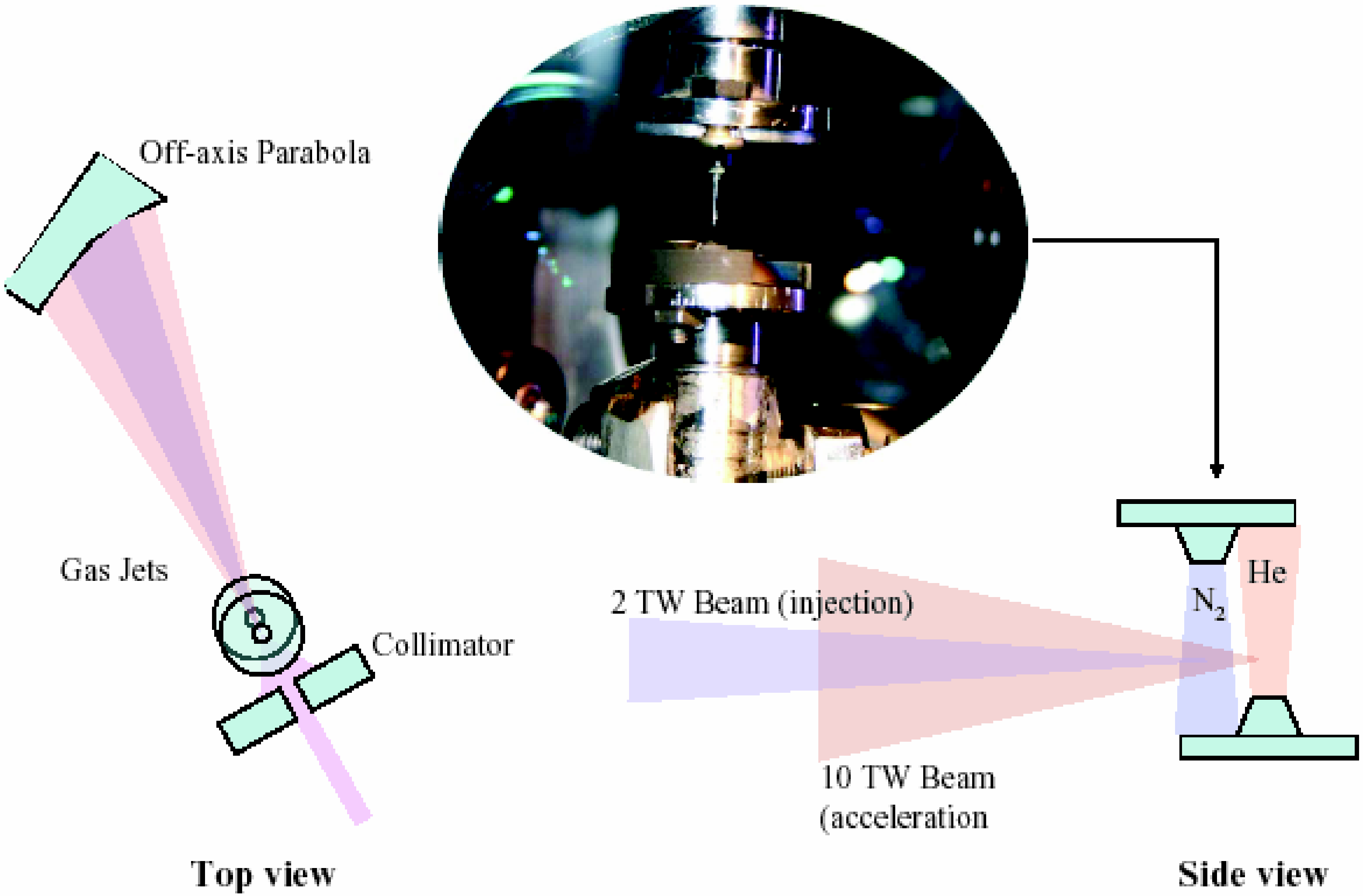
- Simulation Parameters
  - Laser:
    - $a_0 = 3$
    - W_0=9.25 λ=7.4 µm
    - $\omega_l/\omega_p = 22.5$
  - Particles
    - 1x2x2 particles/cell
    - 240 million total
  - Channel length
    - L=.828cm
    - 300,000 timesteps
- The parameters are similar to those at LOA and LBNL

F. Tsung, W. Mori, et al.

NRL Laser Injection Laser Wakefield Accelerator

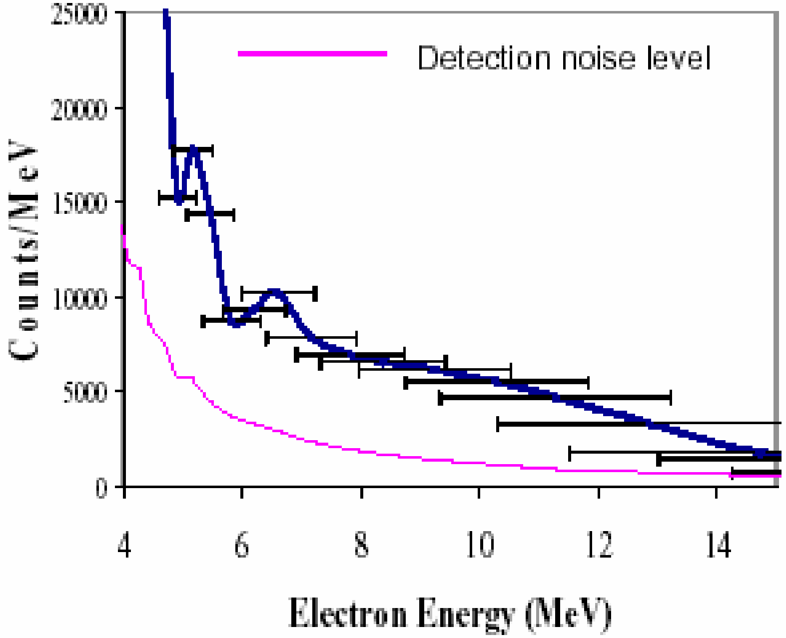
A. Ting, D. Kaganovich, D. Gordon, R. Hubbard and P. Sprangle

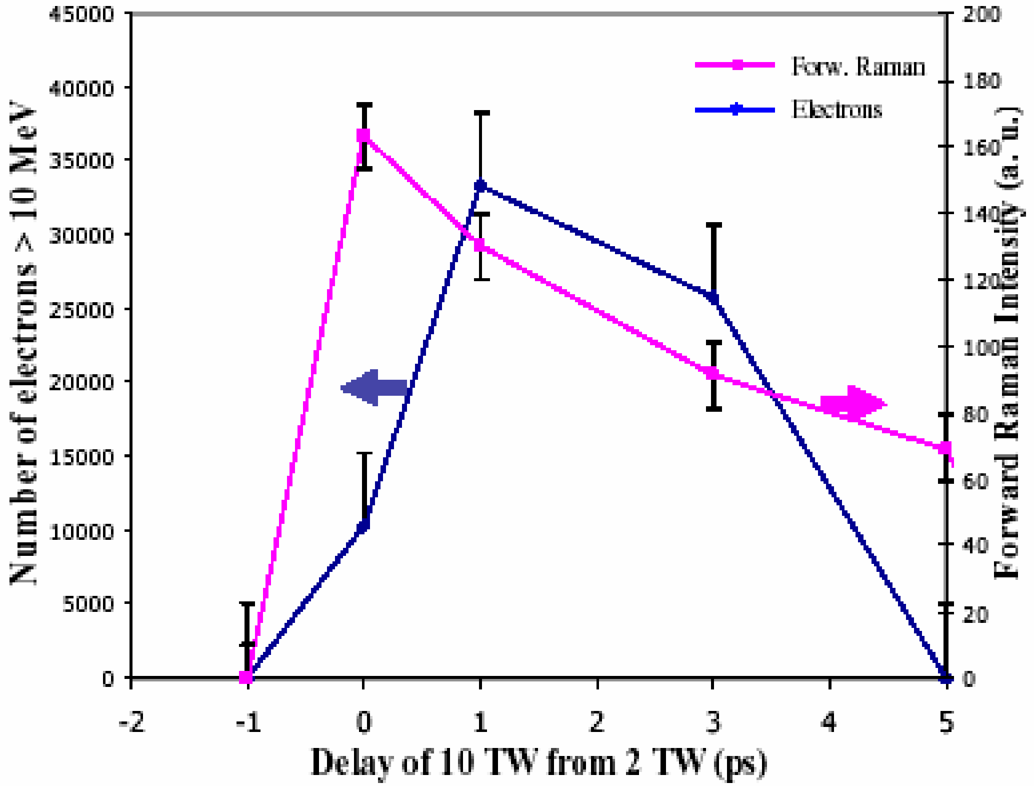
- **Synchronized, collinear, two jet, two-beam (2TW/10TW) laser configuration**



First demonstration of staged optical injection/acceleration LWFA experiment

- Injection electrons <0.5 MeV (high-density LIPA)
- Accelerated electrons >10 MeV
- Injection/Acceleration occurs only for time delays of <3 psec
- Delay of electrons from peak forward Raman signal shows:
  - Injection electrons not from background plasma
  - Slippage of injection electrons from laser pulse





Particle Accelerators
compact to country size
Rich Physics and Applications

Large

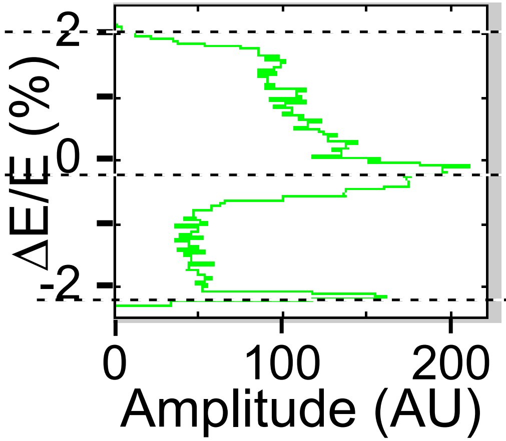
- Verified Standard Model of Elem particles
- W, Z bosons
- Quarks, gluons and quark-gluon plasmas
- Asymmetry of matter and anti-matter
- In pursuit of the Higgs Boson (cause of mass)

Compact

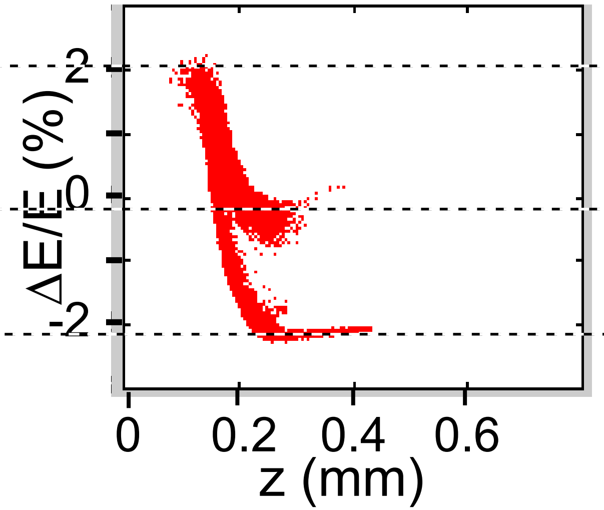
- Medicine
  - Cancer therapy, imaging
- Industry and Gov't
  - Killing anthrax
  - lithography
- Light Sources (synchrotrons)
  - Bio imaging
  - Condensed matter science

EXPERIMENTAL BEAM-IMAGE AGREES WELL WIT SIMULATION OF SUBPICOSECOND BEAM

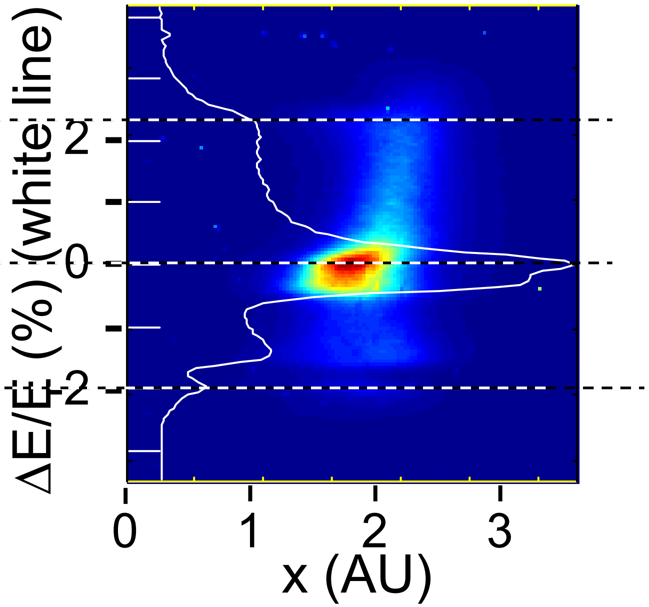
ENERGY SPECTRUM



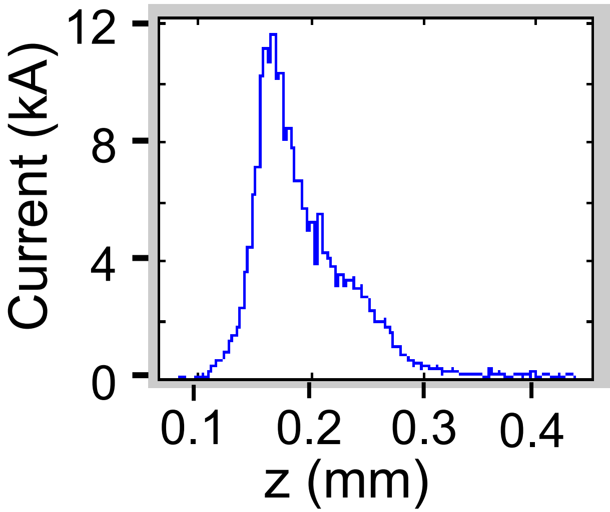
PHASE SPACE



SPECTROMETER IMAGE



PULSE SHAPE



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USC

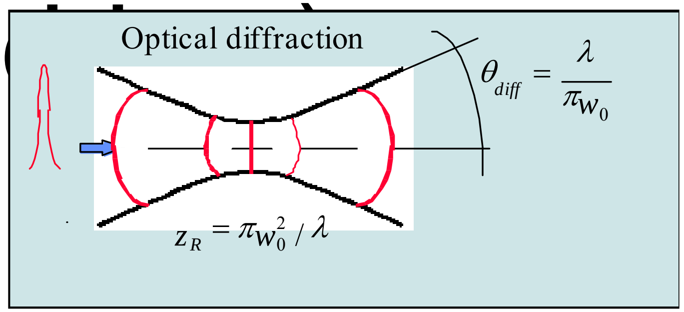
Particle Accelerators
Requirements for High Energy Physics

- High Energy
- High Luminosity (event rate)
  - $L = fN^2/4\pi\sigma_x\sigma_y$
- High Beam Quality
  - Energy spread $\delta\gamma/\gamma$ ~ .1 - 10%
  - Low emittance: $\varepsilon_n \sim \gamma\sigma_y\theta_y < 1$ mm-mrad
- Low Cost (one-tenth of $6B/TeV)
  - Gradients > 100 MeV/m
  - Efficiency > few %

3 Limits to Energy gain

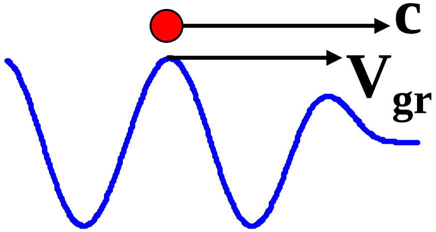
$\Delta W = eE_z L_{acc}$ (laser

- Diffraction: $L_{diff} = \pi Z_R = \pi^2 w_0^2 / \lambda$



order mm!
(but overcome w/ channels or relativistic self-focusing)

- Dephasing:



$$L_{dph} = \frac{\lambda_p / 2}{1 - V_{gr}/c}$$

order 10 cm x $10^{16}/n_o$

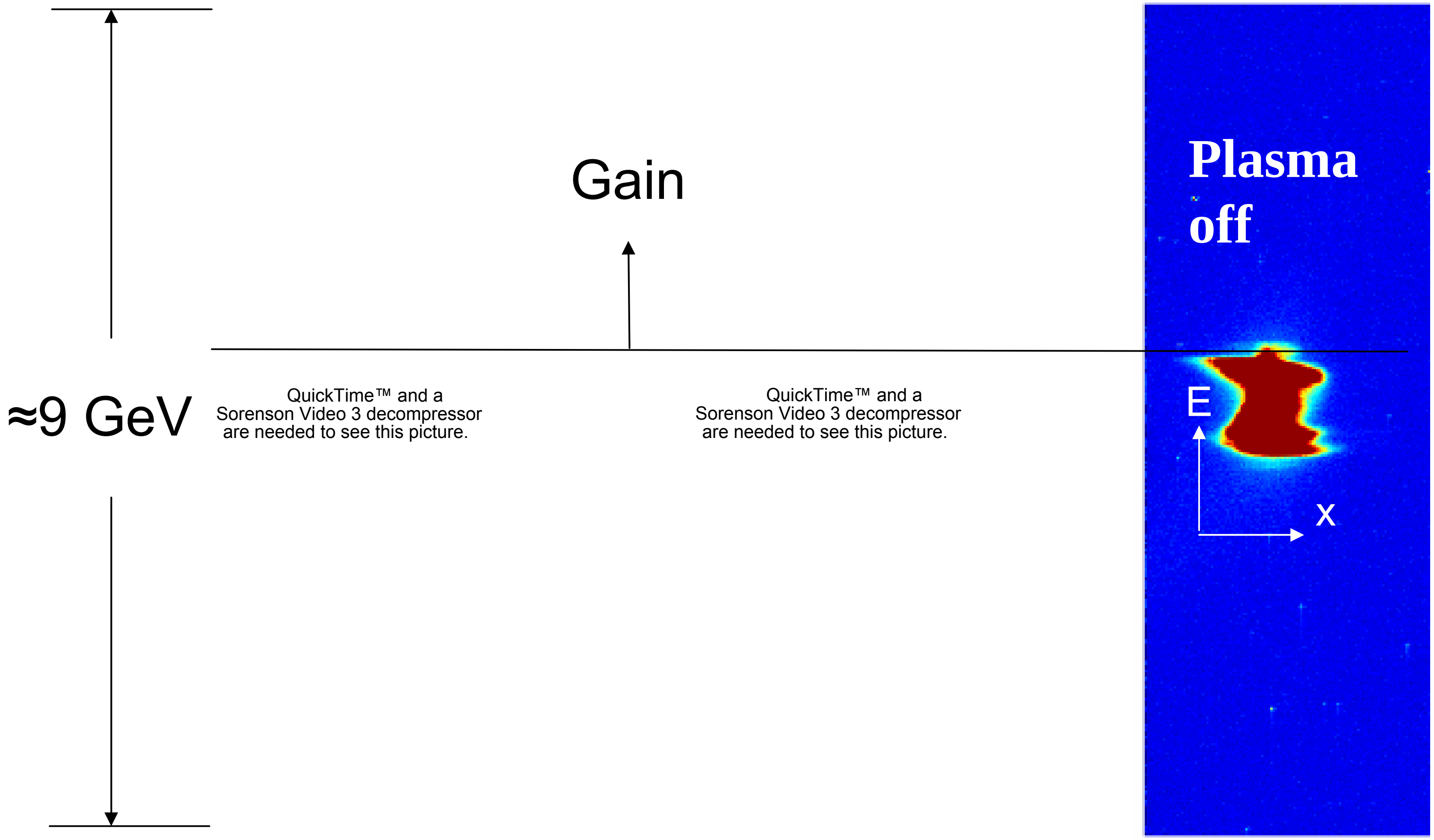
- Depletion:

For small a_0 >> L_{dph}
For a_0 >~ 1 L_{dph}~ L_{depl}

$$\Delta W_{ch}[MeV] \sim 60 \left(\lambda_p / w_0\right)^2 P[TW]$$

Raw Acceleration Data from 200 shots (3 minutes)

L≈10 cm, n=2x1017 cm^{-3}, N≈ 1.8×10^{10}



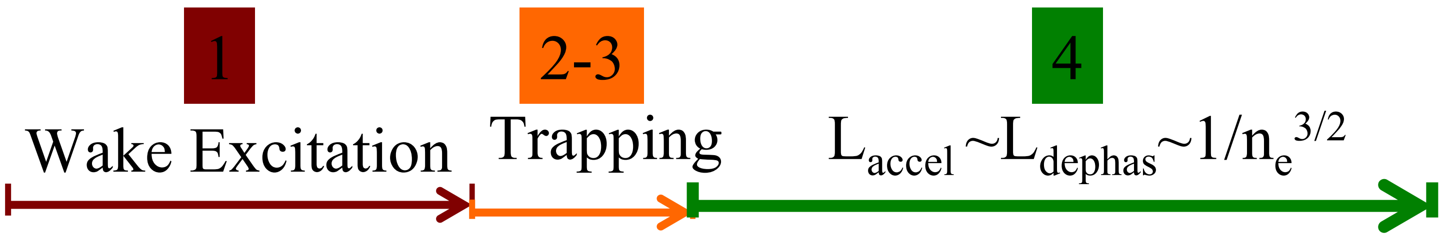
➡ Very consistent acceleration for similar incoming beam parameters

Production of a Monoenergetic Beam

1. Excitation of wake (e.g., self-modulation of laser)
2. Onset of self-trapping (e.g., wavebreaking)
3. Termination of trapping (e.g., beam loading)
4. Acceleration

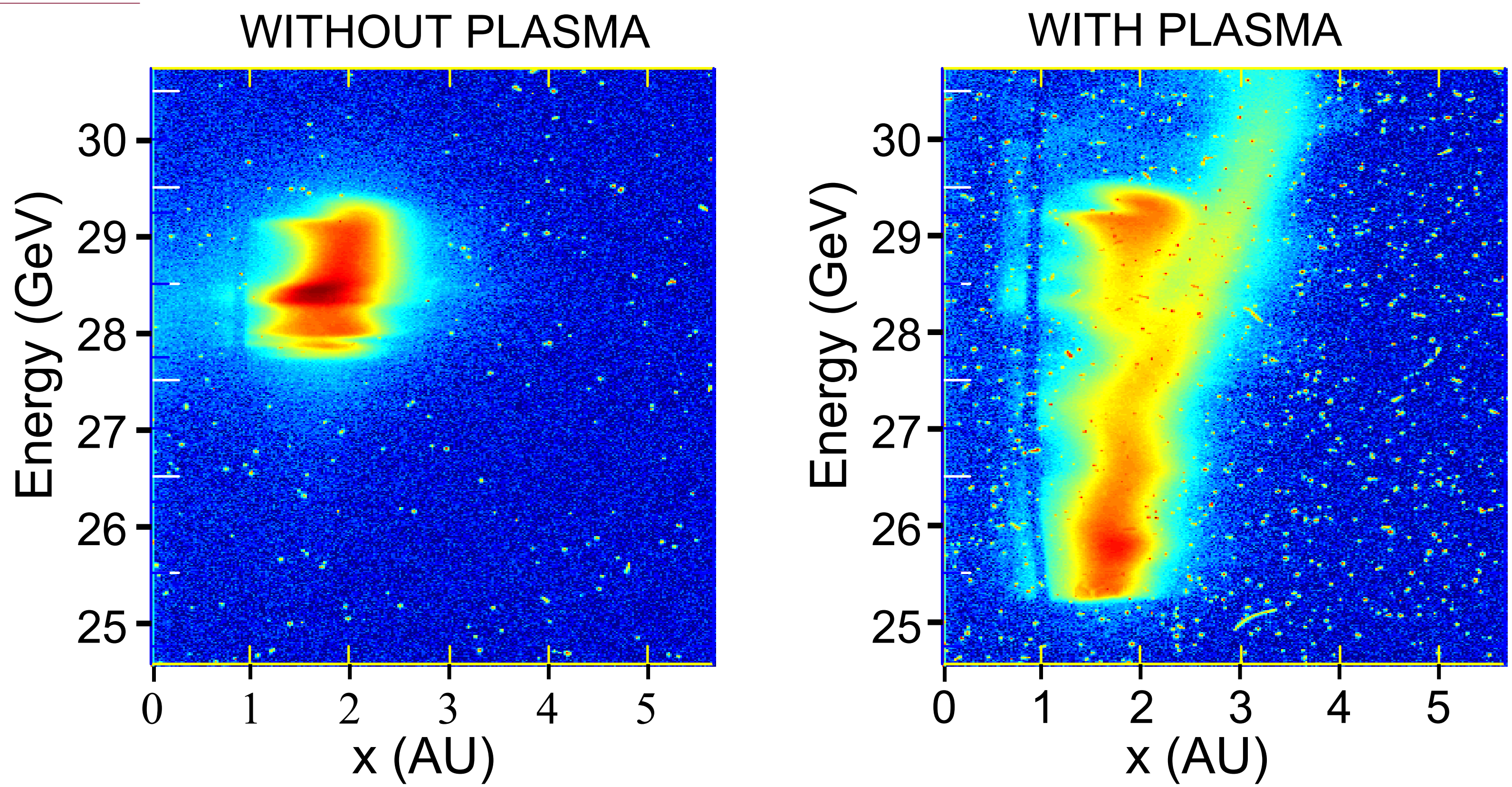
   If > or < dephasing length: large energy spread

   If ~ dephasing length: monoenergetic



Optimal choice of the plasma density: the smallest possible density
For conditions 1 -4 to be fulfilled.

Preliminary Results from E-164 (Run II)

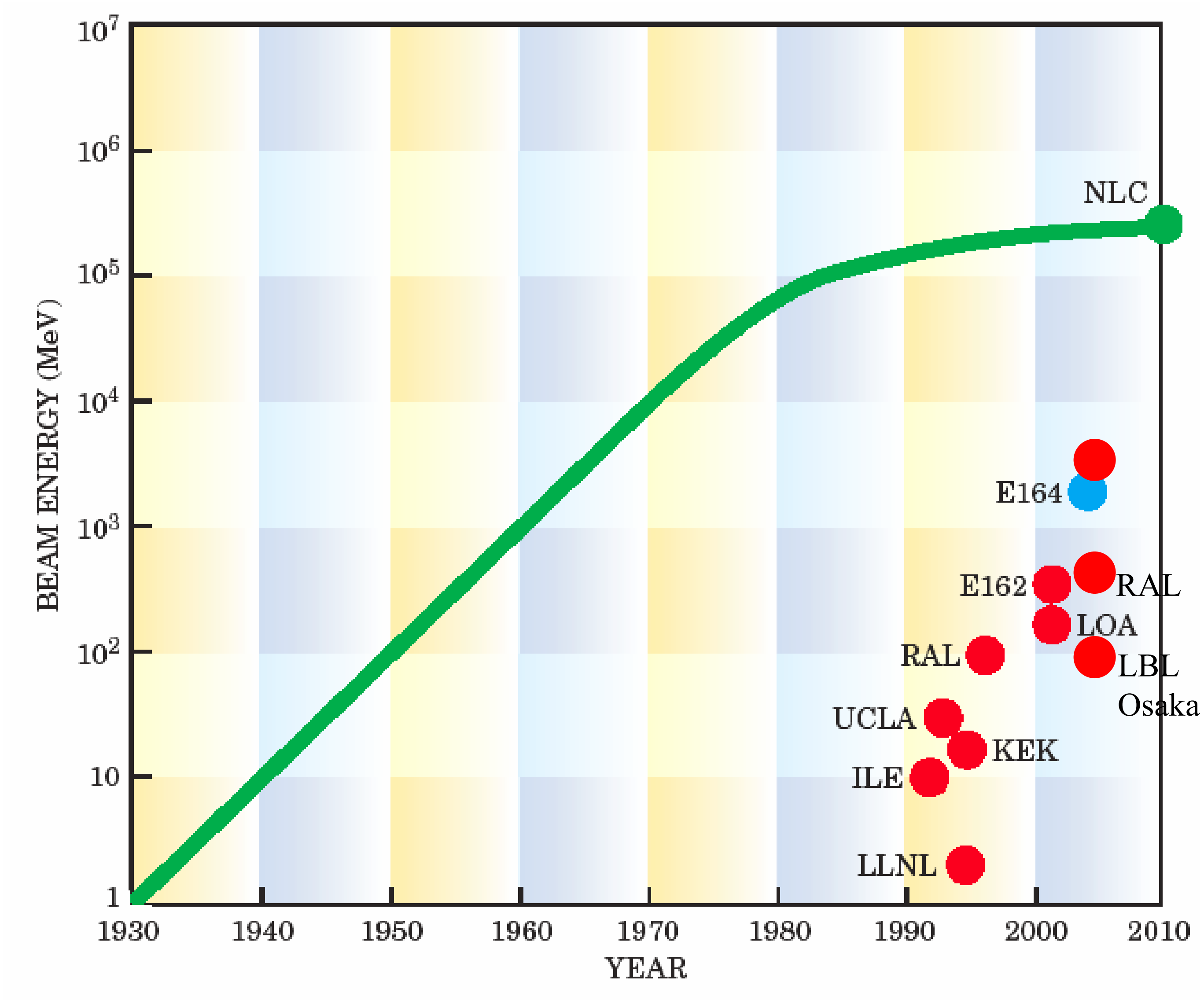


$n_e = 3 \times 10^{16}\ cm^{-3}$, L = 15 cm, N = 1.8×10^{10}

- Energy loss of ~ 2.5 GeV seen.
- Tail motion consistent with energy gain.

Further confirmation and scaling planned in Runs III-IV (May '04)

Plasma Accelerator Progress and the *"Accelerator Moore's Law"*



Particle Accelerators
Why Plasmas?

Conventional Accelerators

- Limited by peak power and breakdown
- 20-100 MeV/m
- Large Hadron Collider (LHC) -- 27km, 2010
- Plans for “Next” Linear Collider (NLC) - 50km ?

Plasma

- No breakdown limit
- 10-100 GeV/m

Recent Laser Acceleration Results:

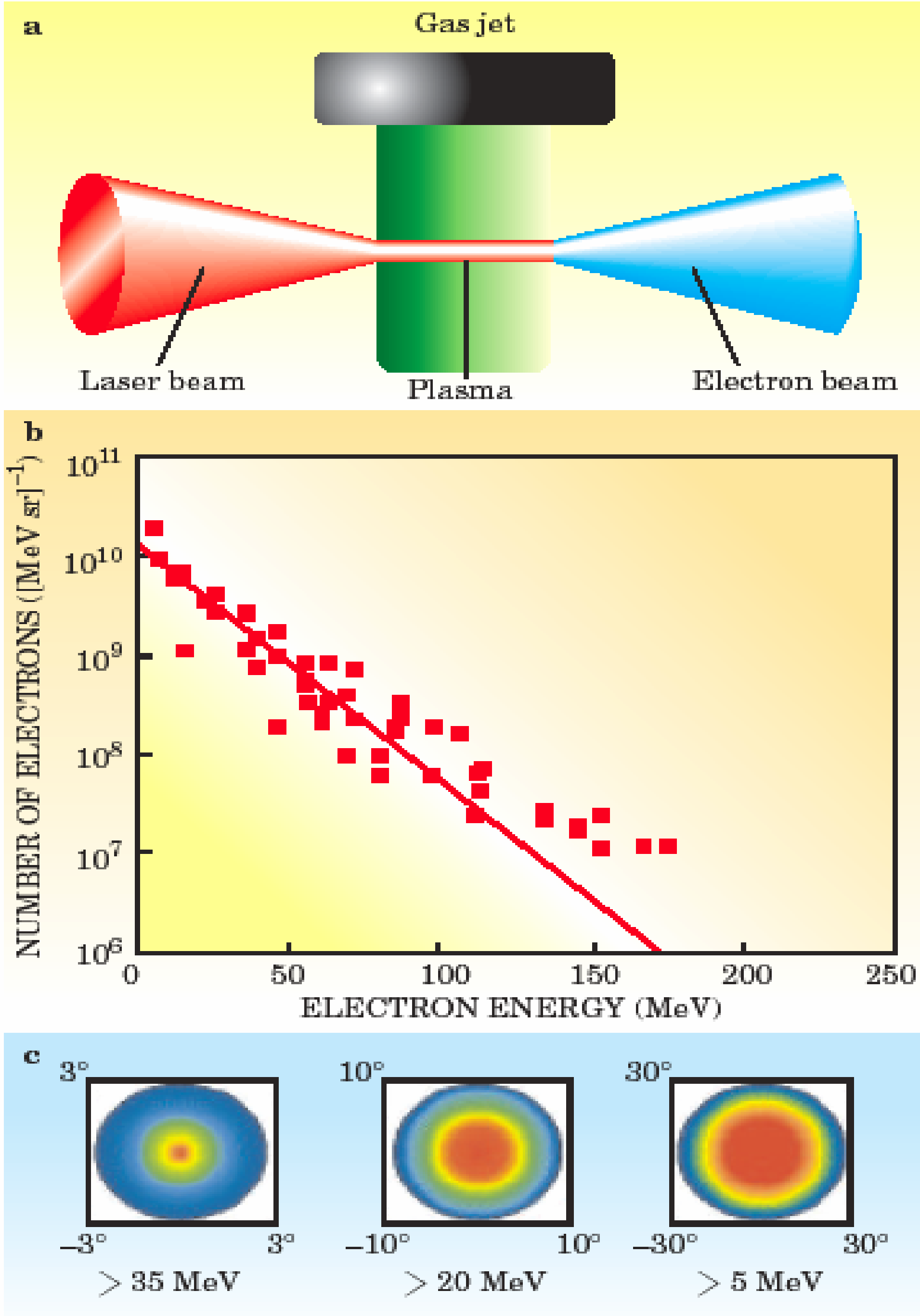
V. Malka et al., LOA France, Science 2002

•30TW, 35 fs laser

•200 MeV energy gain in a 1mm gas jet (> 200 GeV/m)

•Highly collimated beam:
$\varepsilon_n \sim 1$ mm-mrad

Fritzler et al., PRL92(2004)



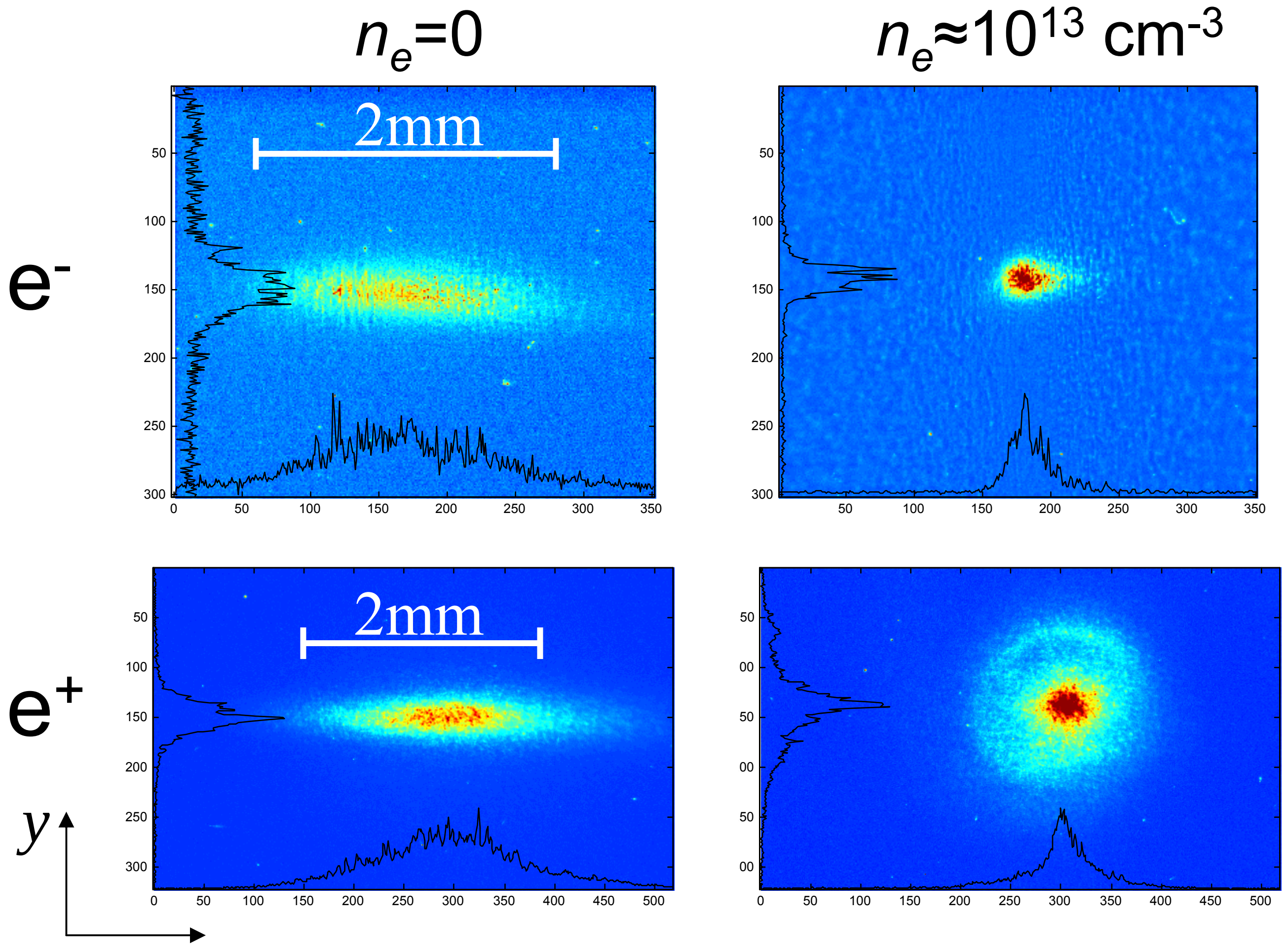
Intense Relativistic Beams in Plasmas:
PW/μ^2
New Plasma Physics

- Wake generation/ particle acceleration
- Focusing
- Hosing
- “Collective Refraction”
- Radiation generation
- Ionization effects

- Compact accelerators
- Plasma lens/astro jets
- E-cloud instability/LHC
- Fast kickers
- Tunable light sources
- Beam prop. physics/X-ray lasers

FOCUSING OF e^-/e^+

- OTR images ≈1m from plasma exit ($\varepsilon_x \neq \varepsilon_y$)



- Ideal Plasma Lens in Blow-Out Regime
- Plasma Lens with Aberrations
- e^+: halo formation from non uniform focusing

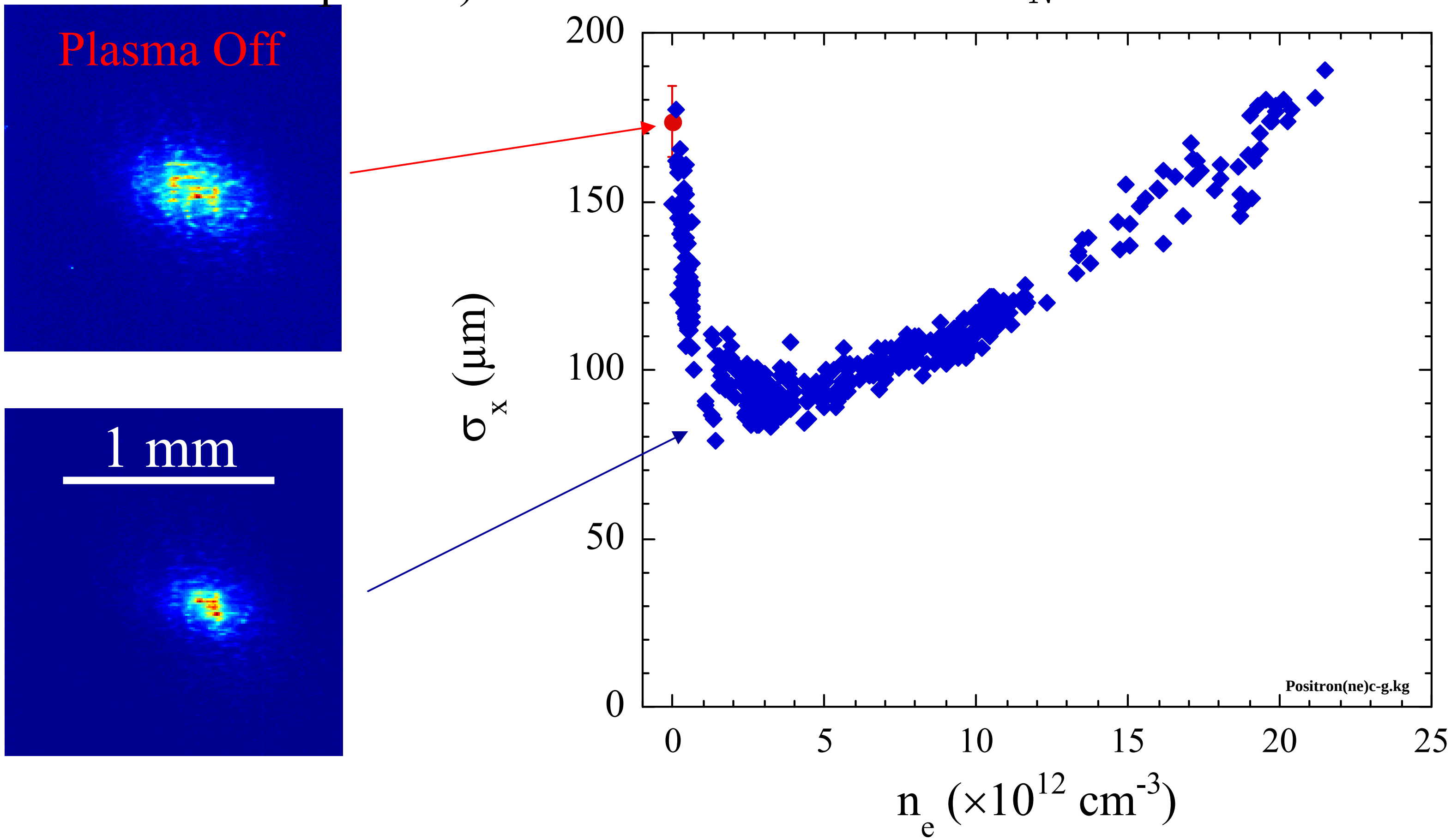
M.J. Hogan *et al.*, PRL, 2002; Also J. Ng et al., 2001 (**F/r~GG/cm**)

U C L A

FOCUSING OF e^+

OTR Images
(≈1m downstream from plasma)

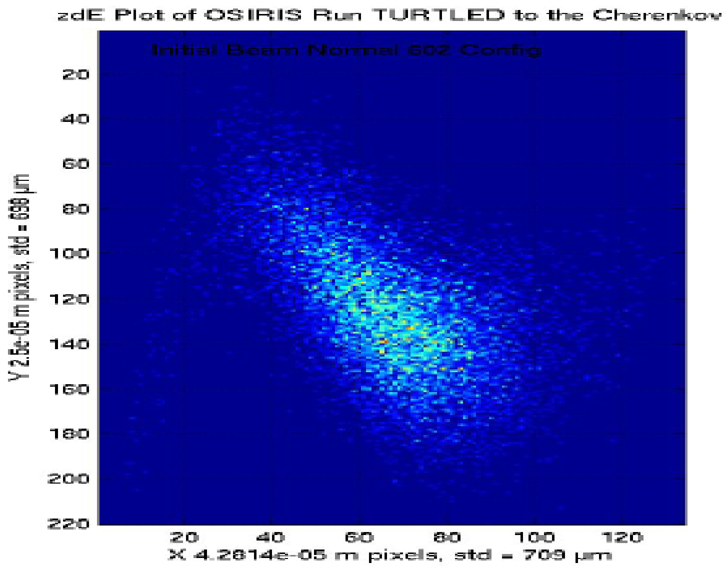
N=1.9×10^{10}, ε_N>5×10^{-5} m-rad

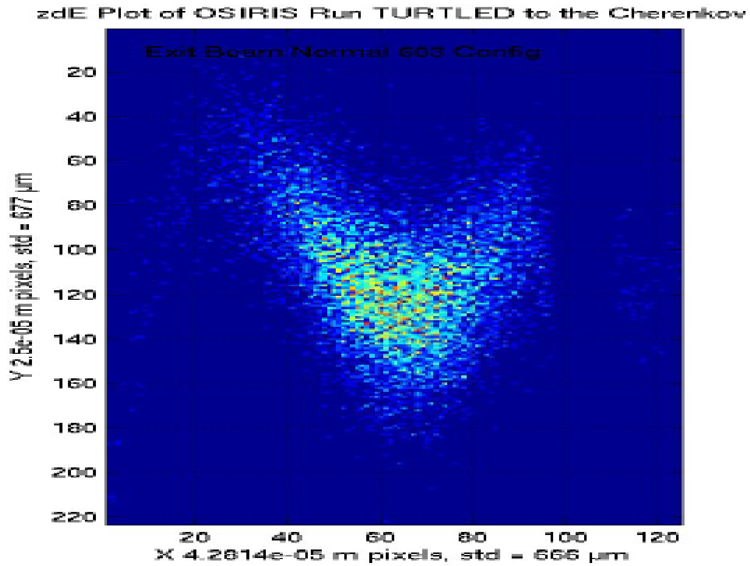


- Overall focusing at low plasma densities

M.J. Hogan *et al.*, PRL, 2002

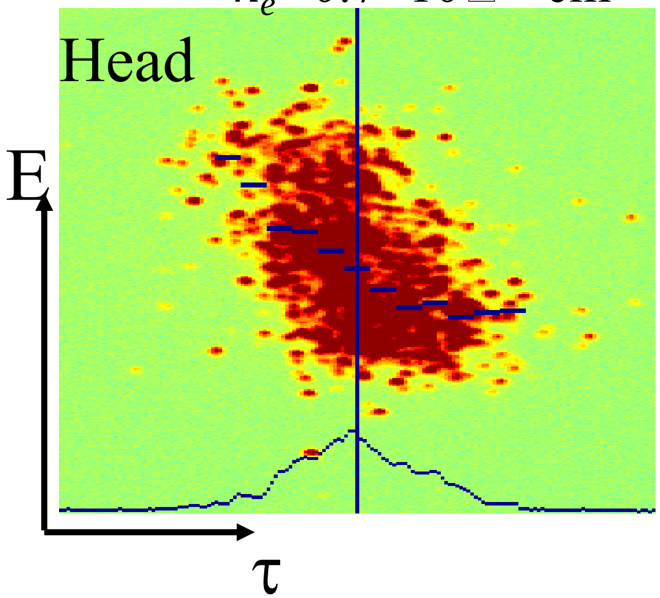
Simulation Data Vs. Experiment



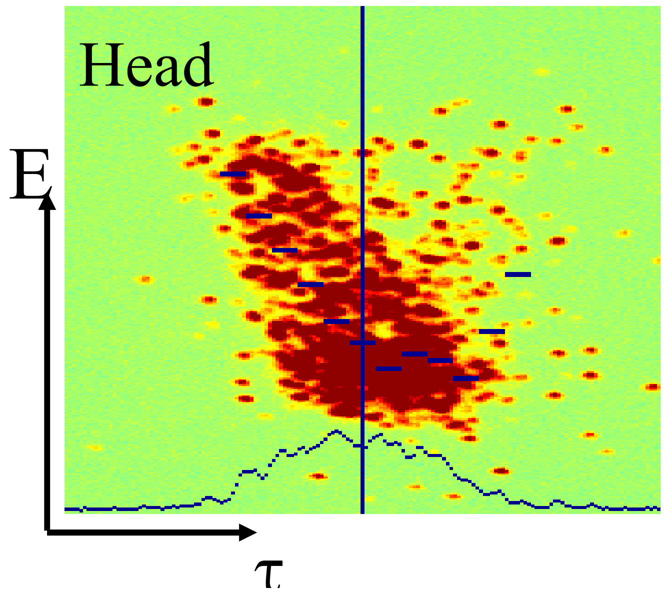


Results after propagating simulation data through experiment diagnostics

n_e=0.7×10□^{14} cm^{-3}



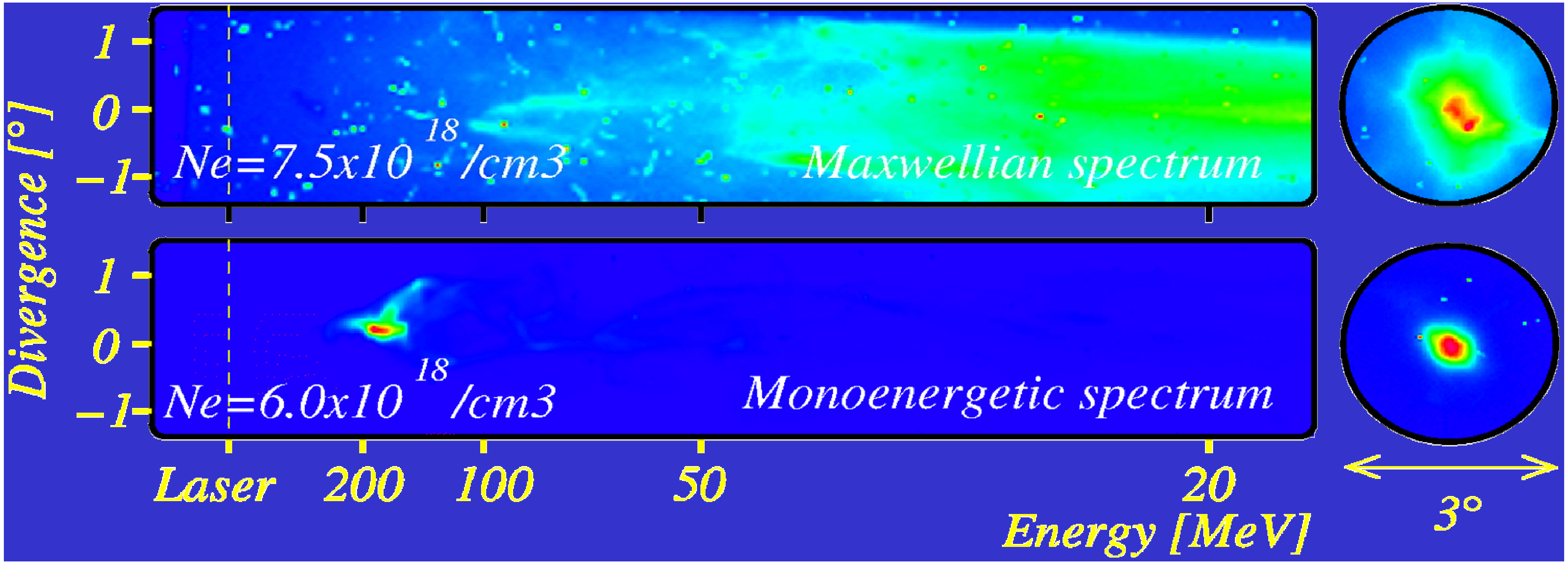
n_e=2.3×10□^{14} cm^{-3}



Experiment Results

*Use low n_e events as "plasma off"

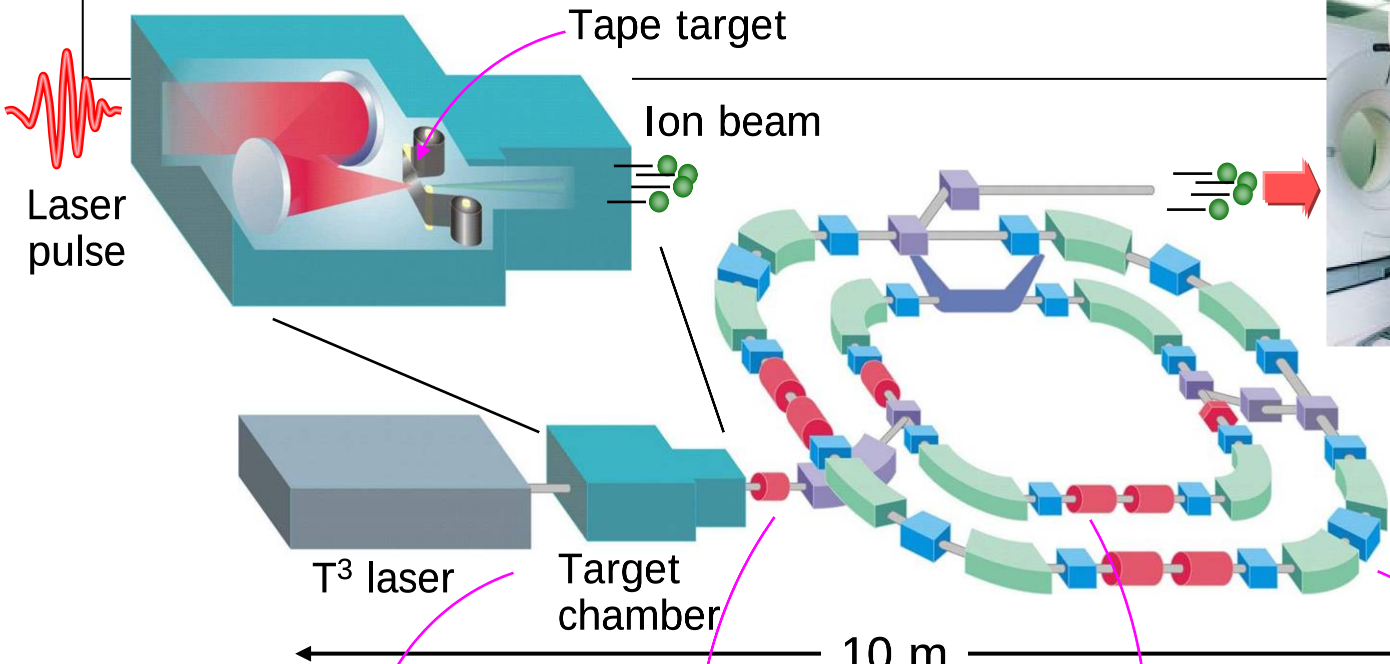
Recent results on e-beam : Energy distribution improvements



N.B. : color tables are different

J. Faure, LOA

National Institute of Radiological Sciences, JAPAN



Cancer therapy

Laser plasma ion source	RF cavity for phase rotation	Electron beam cooler ring	Compact heavy ion synchrotron
2 MeV/u p (10^{10}/sec.) C ion (10^{9}/sec.)	Energy spread ~±1%	Energy spread ~±0.1%	200 MeV/u
JAERI, Univ. of Tokyo, Hiroshima Univ.	Kyoto Univ., JAERI	Kyoto Univ.	KEK

Fukumi, Ogata, …