# FACET-II: Accelerator Research with Beams of Extreme Intensities

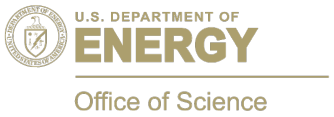
Facility for Advanced Accelerator Experimental Tests

Vitaly Yakimenko, SLAC

May 10, 2010

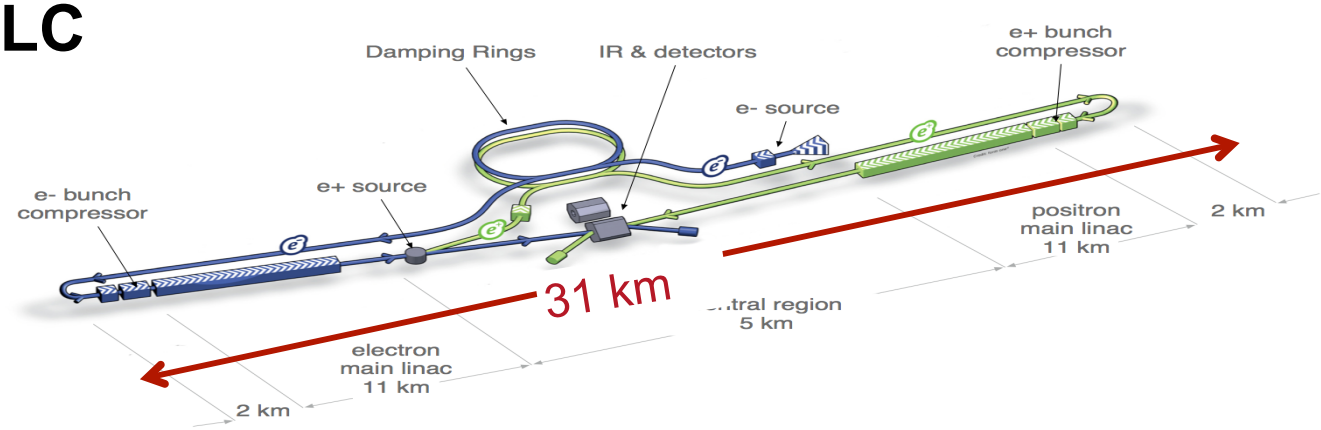
TUOBB02

7th International
Particle Accelerator Conference

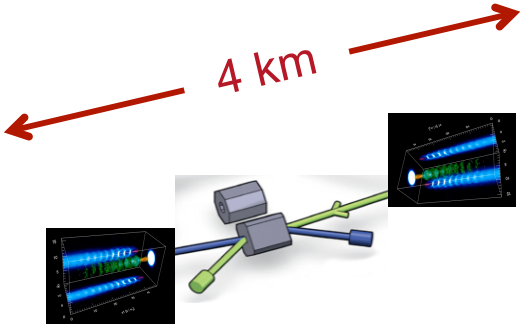



# The Scale for a TeV Linear Collider

**Today's technology LC**
**– a 31km tunnel:**




**Plasma Wakefield Technology LC:**




**The Luminosity Challenge:**

$$\mathcal{L} = \frac{P_b}{E_b}\left(\frac{N}{4\pi\sigma_x\sigma_y}\right)$$

# From Conception …

VOLUME 43, NUMBER 4 PHYSICAL REVIEW LETTERS 23 JU

**Laser Electron Accelerator**

T. Tajima and J. M. Dawson
*Department of Physics, University of California, Los Angeles, California 90024*
(Received 9 March 1979)

An intense electromagnetic pulse can create a weak of plasma oscillations through the action of the nonlinear ponderomotive force. Electrons trapped in the wake can be accelerated to high energy. Existing glass lasers of power density $10^{18}$W/cm$^2$ shone on plasmas of densities $10^{18}$ cm$^{-3}$ can yield gigaelectronvolts of electron energy per centimeter of acceleration distance. This acceleration mechanism is demonstrated through computer simulation. Applications to accelerators and pulsers are examined.

VOLUME 54, NUMBER 7 PHYSICAL REVIEW LETTERS 18 FEBRUARY 1985

**Acceleration of Electrons by the Interaction of a Bunched Electron Beam with a Plasma**

Pisin Chen[a]
*Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305*

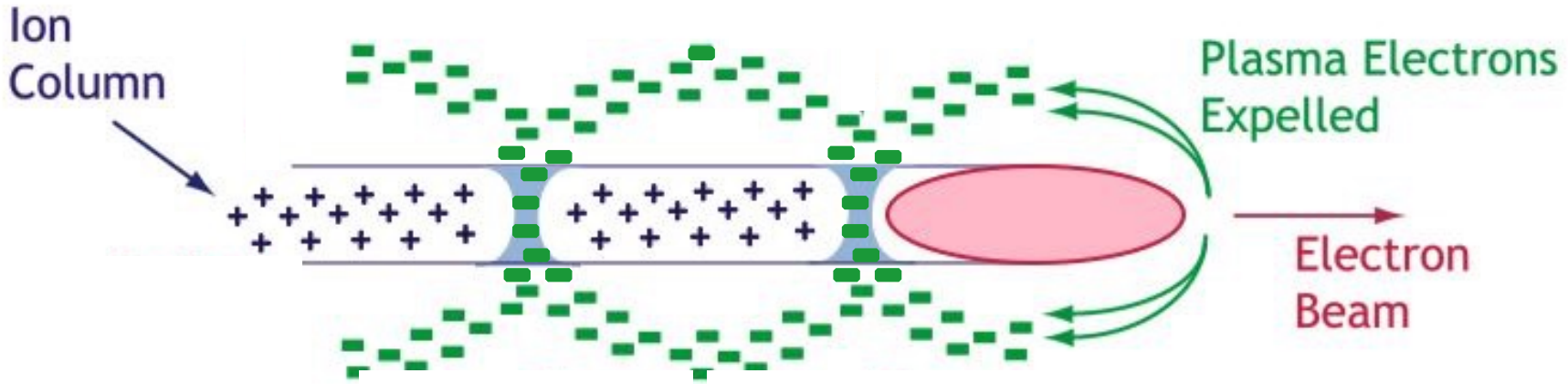
and

J. M. Dawson, Robert W. Huff, and T. Katsouleas
*Department of Physics, University of California, Los Angeles, California 90024*
(Received 20 December 1984)

A new scheme for accelerating electrons, employing a bunched relativistic electron beam in a cold plasma, is analyzed. We show that energy gradients can exceed 1 GeV/m and that the driven electrons can be accelerated from $\gamma_0 mc^2$ to $3\gamma_0 mc^2$ before the driving beam slows down enough to degrade the plasma wave. If the driving electrons are removed before they cause the collapse of the plasma wave, energies up to $4\gamma_0^2 mc^2$ are possible. A noncollinear injection scheme is suggested in order that the driving electrons can be removed.

PACS numbers: 52.75.Di, 29.15.−n

$$E_0 \sim 10\sqrt{\frac{n_0}{1\times 10^{16}[\mathrm{cm}^{-3}]}}[\mathrm{GeV/m}]$$



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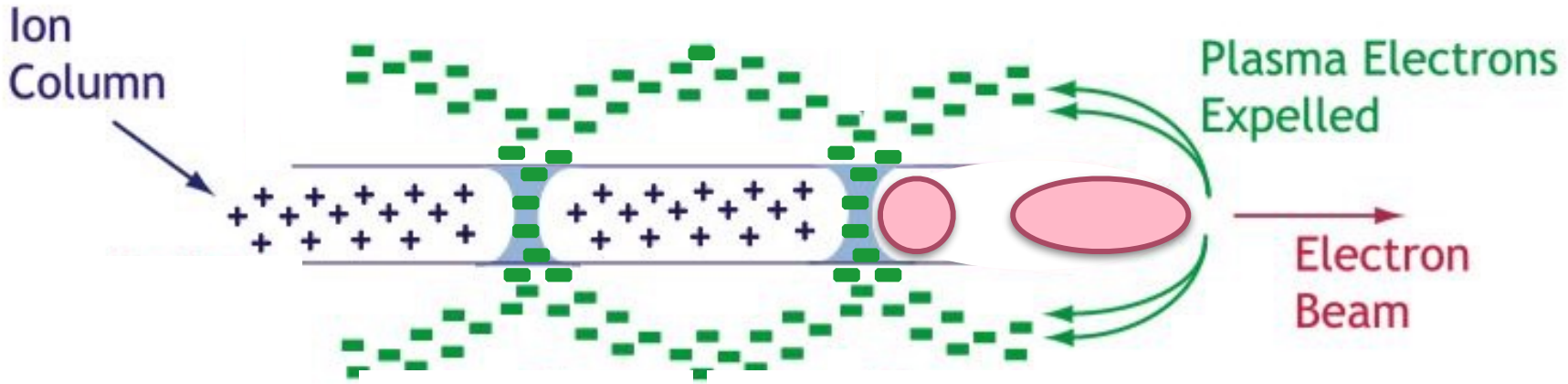


# FACET project history


**Primary Goal:**

- Demonstrate a single-stage high-energy plasma accelerator for electrons

**Timeline:**

- CD-0 2008
- CD-4 2012, Commissioning (2011)
- Experimental program (2012-2016)

**A National User Facility:**

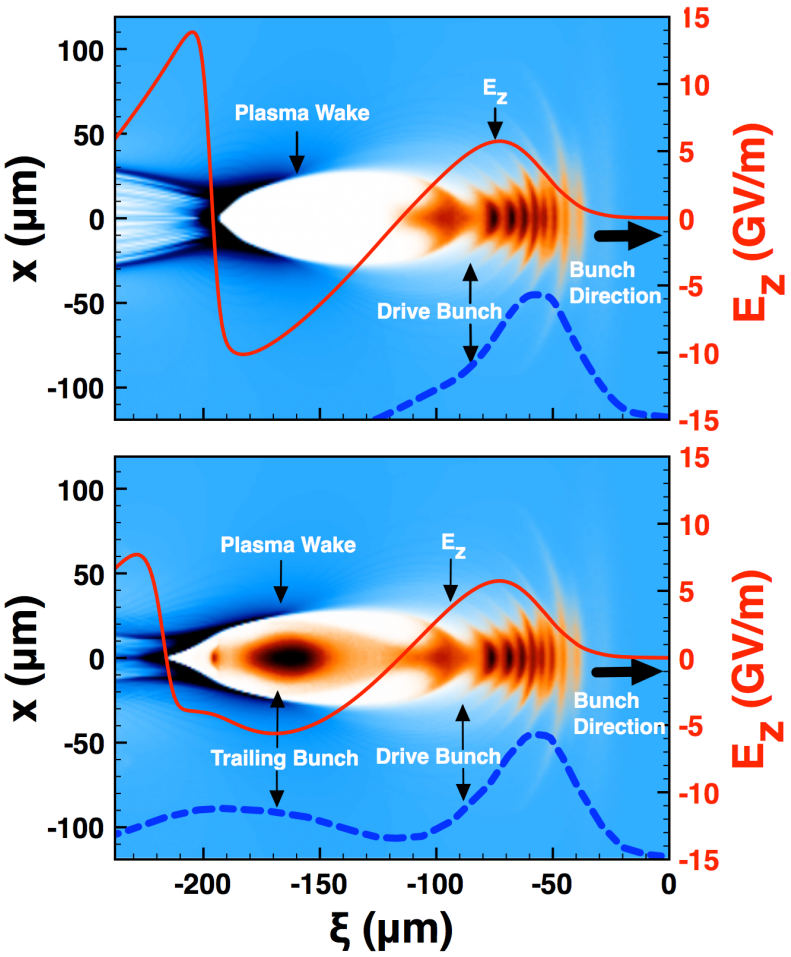
- Externally reviewed experimental program
- 150 Users, 25 experiments, 8 months/year operation

**Key PWFA Milestones:**

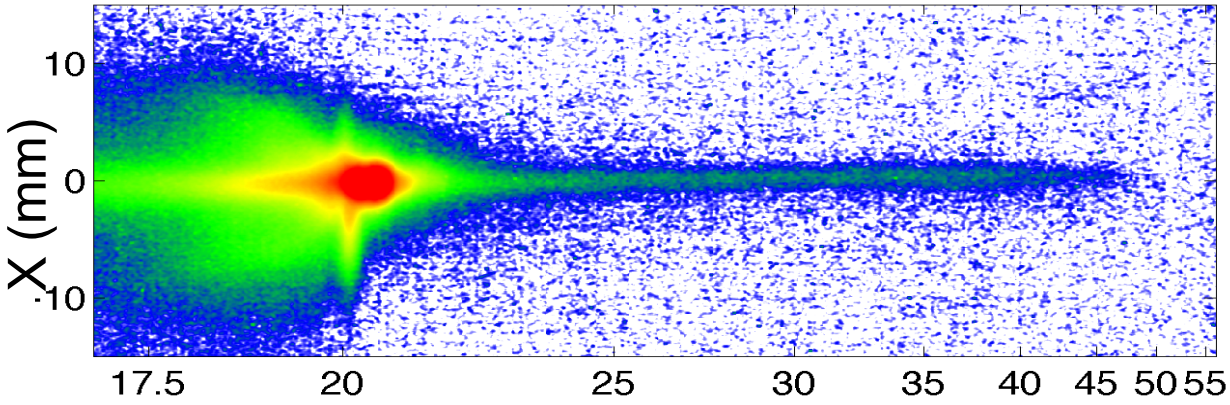
- ✓ Mono-energetic e- acceleration
- ✓ High efficiency $e^-$ acceleration
- ✓ First high-gradient $e^+$ PWFA
- Demonstrate required emittance, energy spread (FY16)

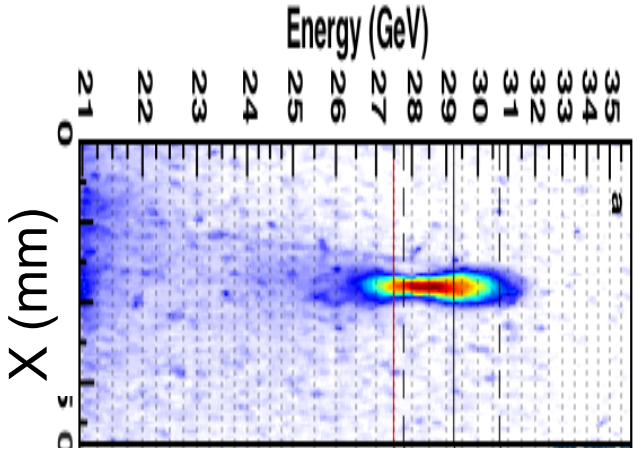
The premier R&D facility for PWFA: Only facility capable of e+ acceleration
Highest energy beams uniquely enable gradient > 1 GV/m

# FACET: acceleration of beams




27 GeV energy gain in just 25 cm of plasma!




9GeV energy gain in ~1 m of plasma, ~30% efficient, <3% energy spread acceleration of beams

# FACET PWFA Milestones

*(V. Yakimenko, Dec. 7, 2012)*

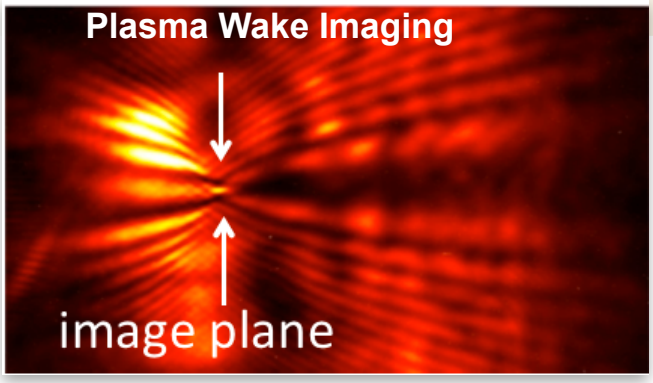
SLAC

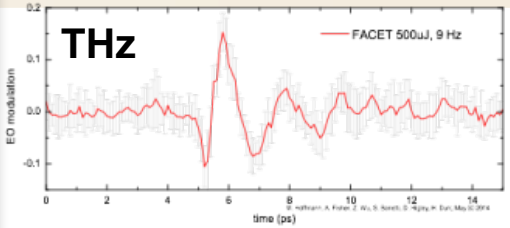
| FY | Facet Run | PWFA goal |
|---|---|---|
| 2013 | 2/1 - 6/30 | 2 beam generation, laser commissioning, **2 beams with laser**-> mono energetic acceleration **(all successful and more…)** |
| 2014 | 10/15-12/20<br>2/1 - 6/30 | 2 beams with laser-> **mono energetic acceleration**, positron commissioning, positron PWFA, high brightness PWFA injector **(all successful & positrons!)** |
| 2015 | 10/15-12/20<br>2/1 - 6/30 | **positron PWFA**, one stage, efficiency, high brightness PWFA injector **(successful - unexpected positrons result!)** |
| 2016 | 4/4<br>10/1-~~5/31~~ | Finalizing the program, **emittance preservation** (Single stage: energy spread, emittance, efficiency) |

Steady, methodical progress according to plan

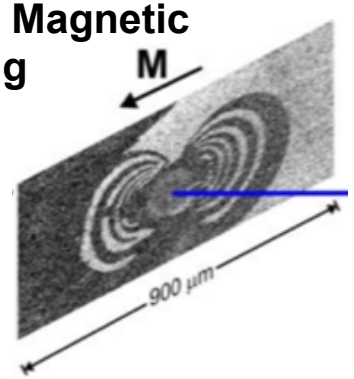
# FACET: A National User Facility Based on High-energy Beams and Their Interaction with Plasmas and Lasers

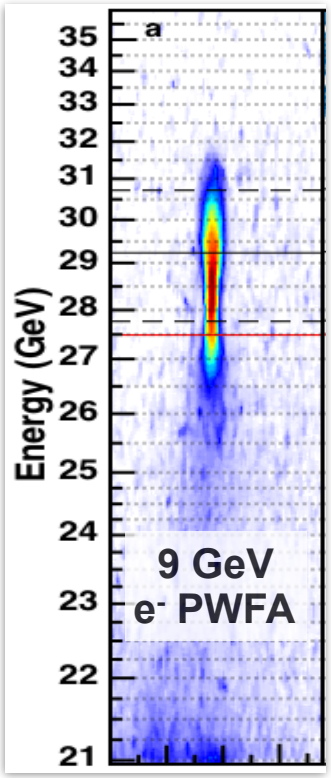
SLAC

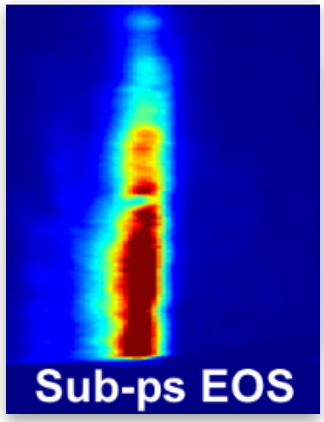


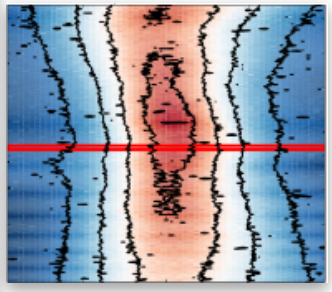

Ultrafast Magnetic Switching



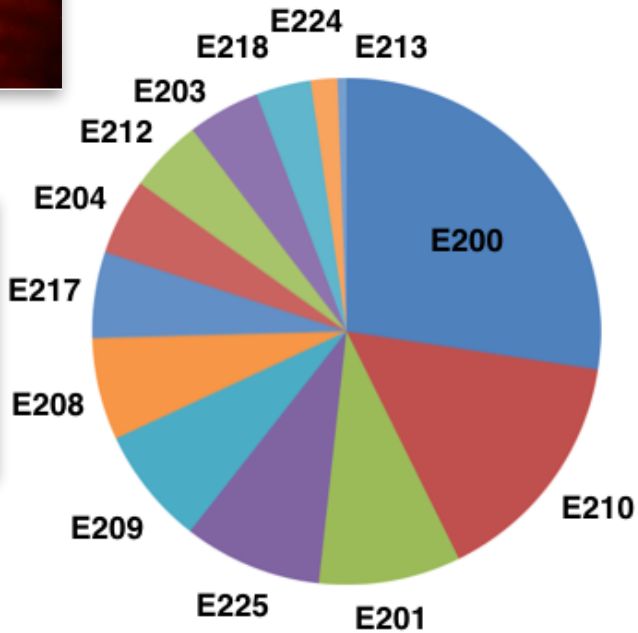



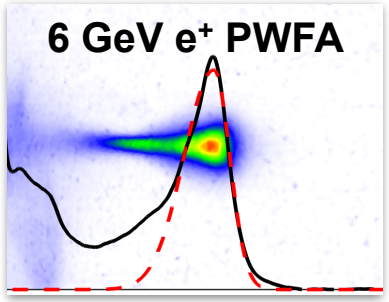



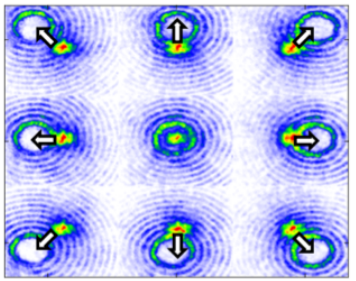

Ionization

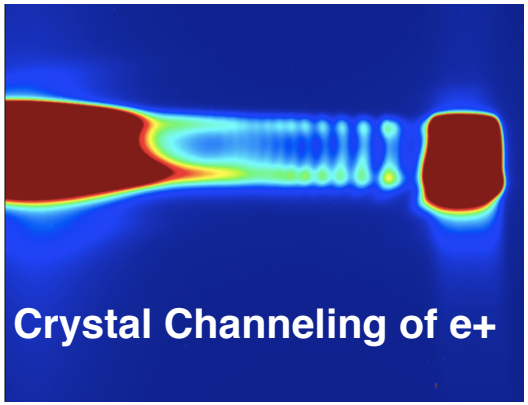


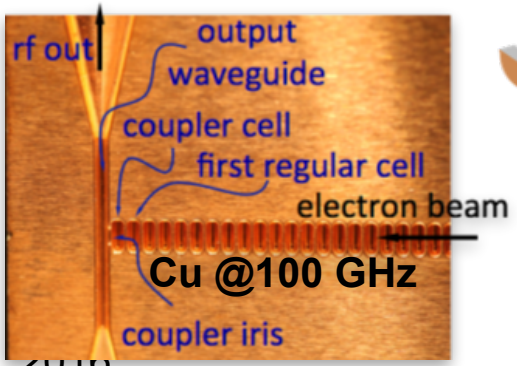
Injection

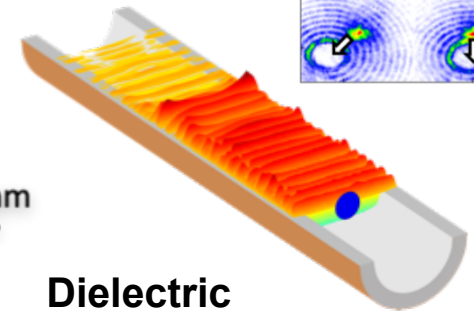


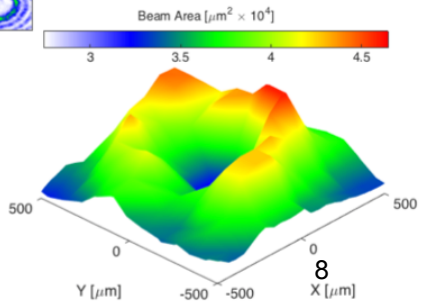


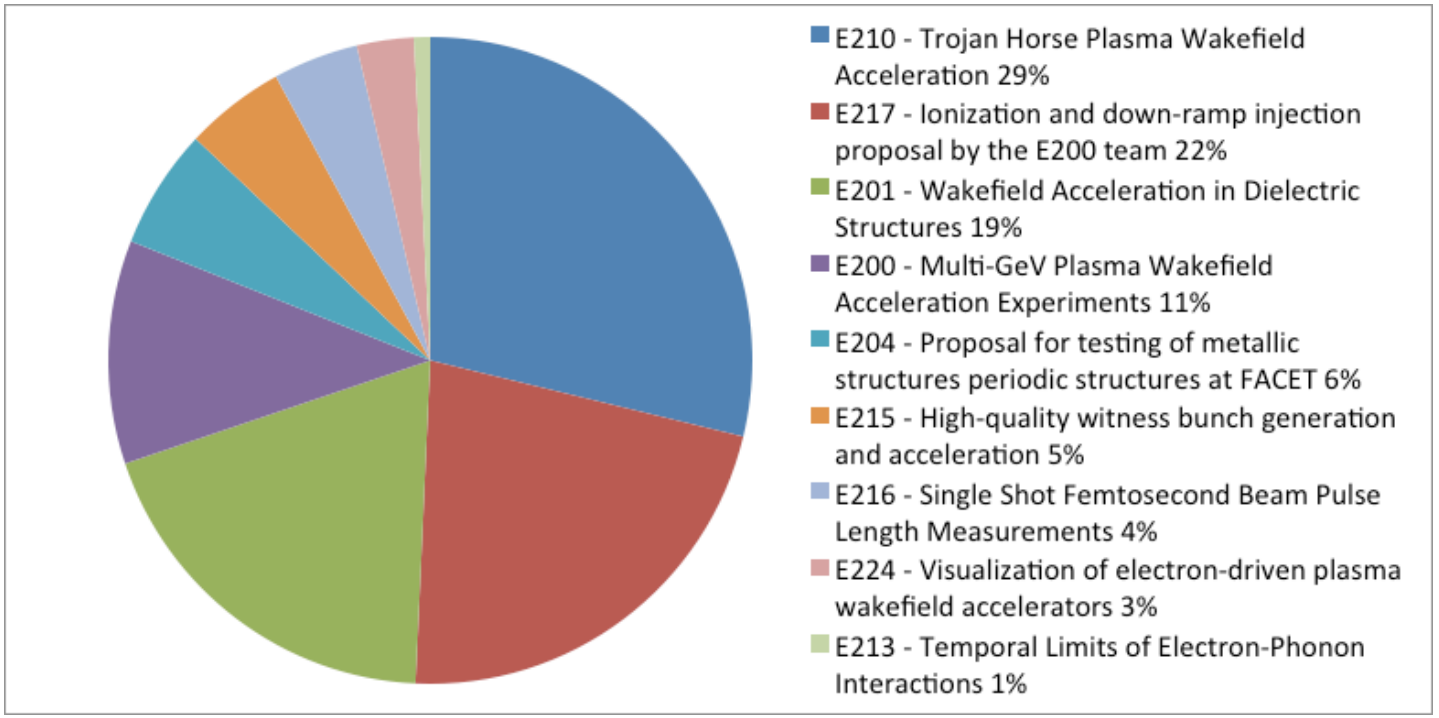



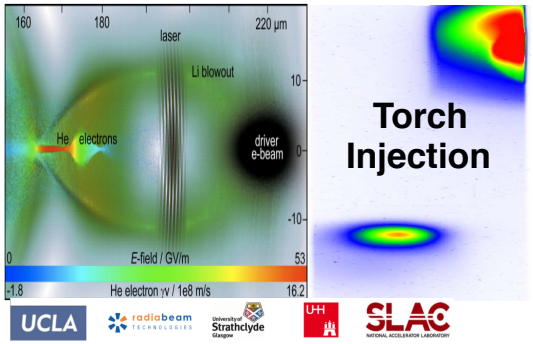
Dielectric Wakefield Accelerators

Hollow Channel Plasmas

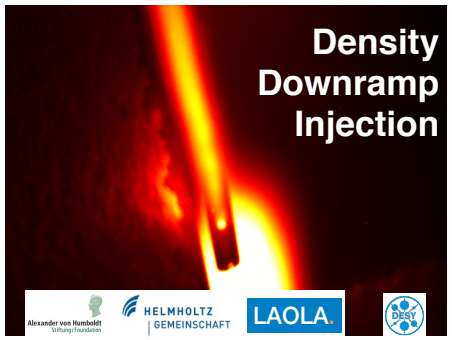


# FY16 Experimental Progress at FACET



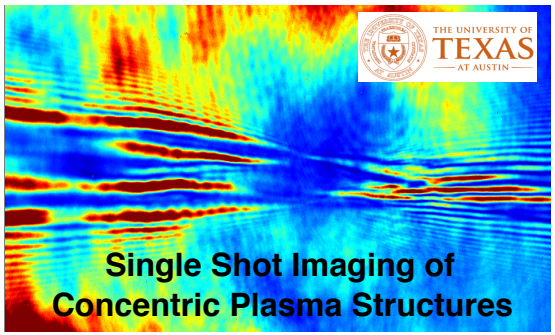




E210




E215


E217



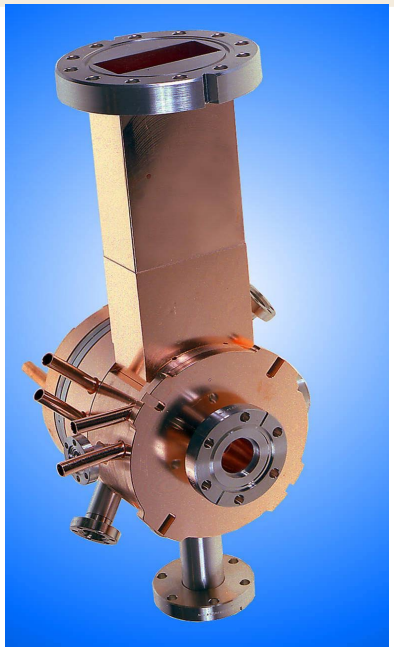

E224

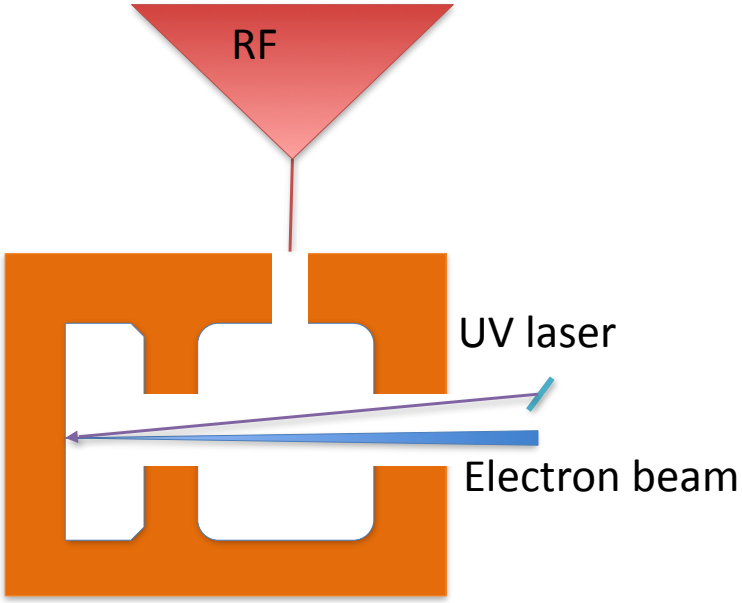
# Development of High-Brightness Electron Sources

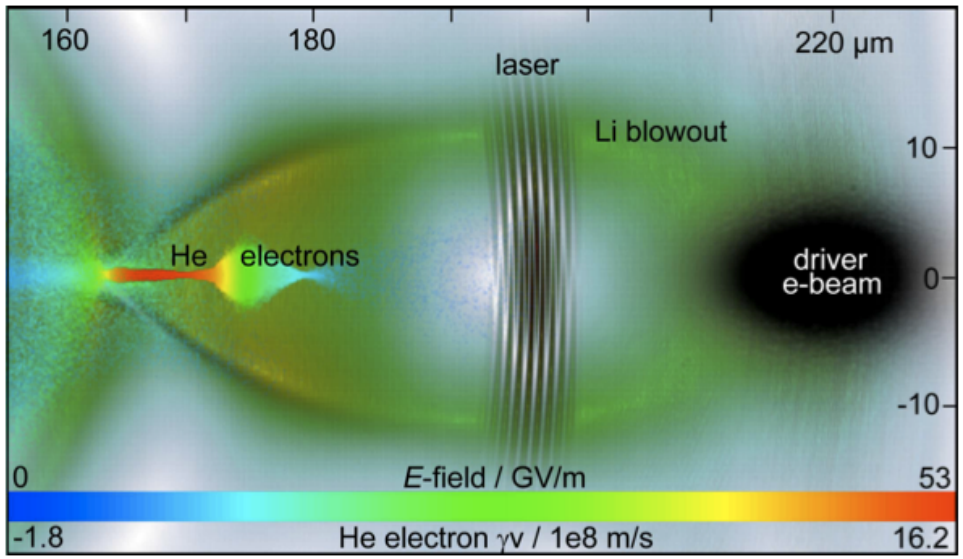
SLAC

**LCLS Style Photoinjector**

- 100MeV/m field on cathode
- Laser triggered release
- ps beams - multi-stage compressions & acceleration
  - Tricky to maintain beam quality (CSR, microbunching…)



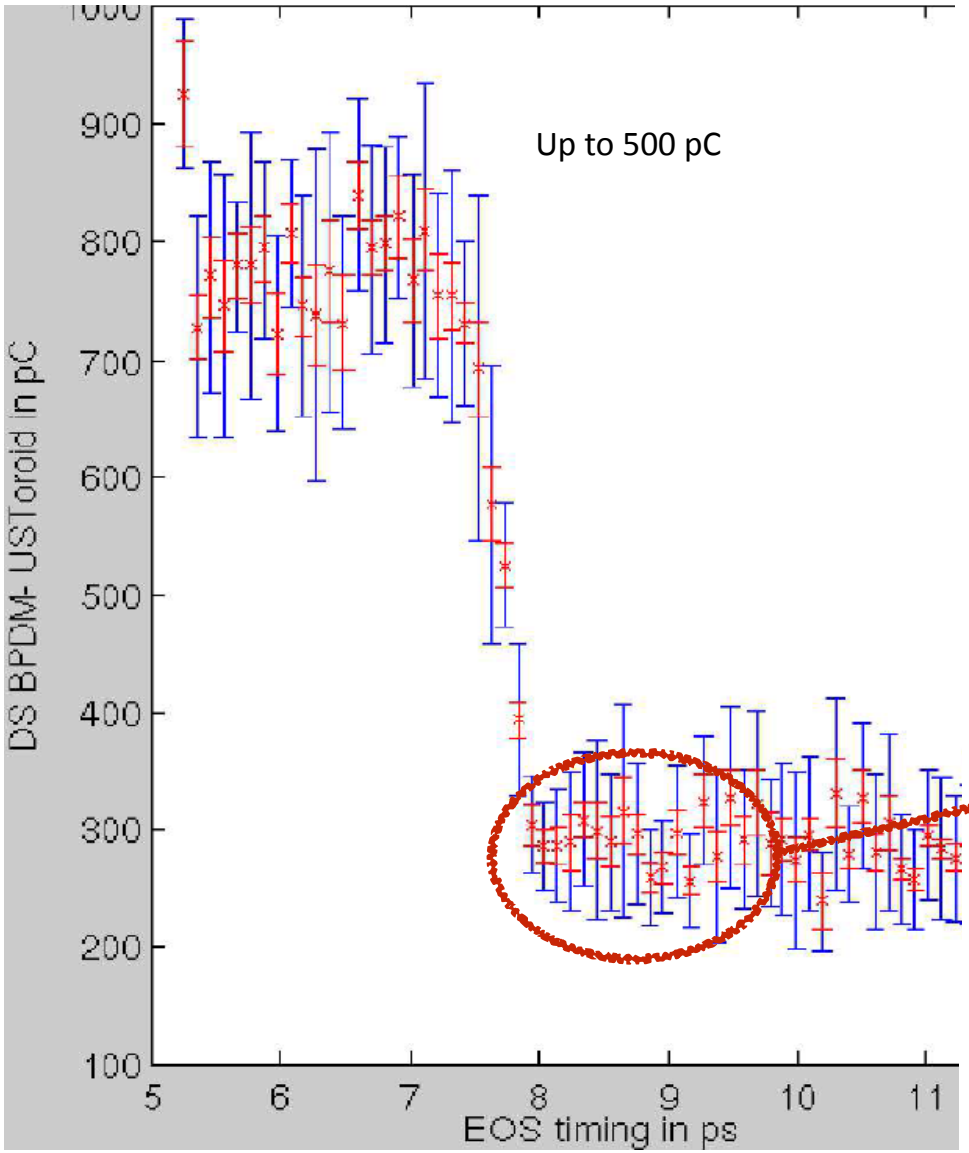


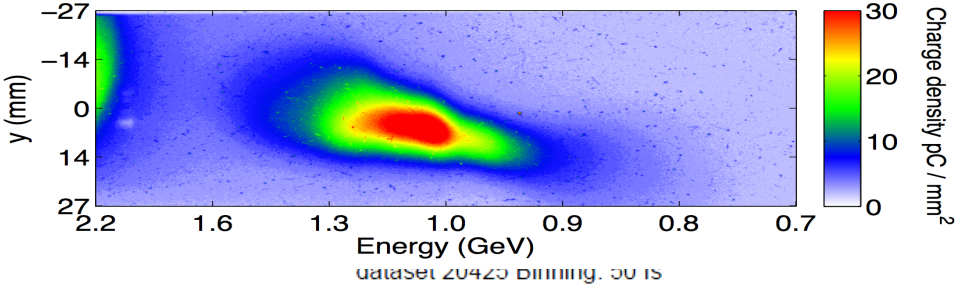



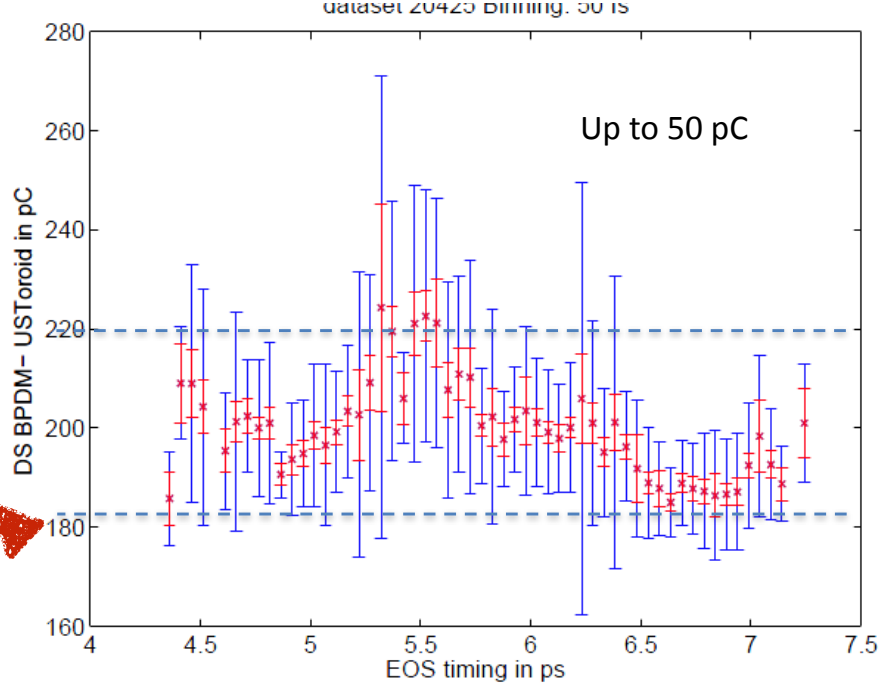

**Plasma Photoinjectors**

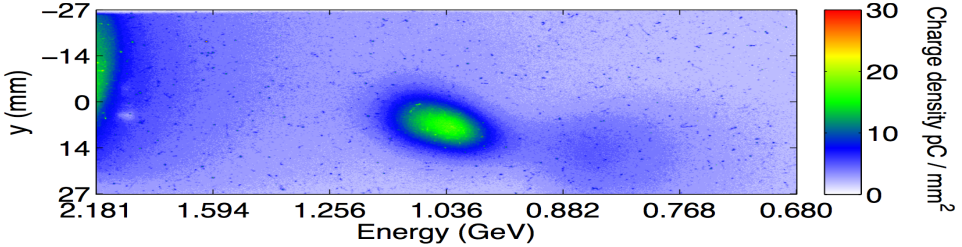
- 100 GeV/m
- fs beams, μm size
- Promise orders of magnitude improvement in emittance
- Injection from: TH, Ionization, DDR, CP…

# E210: Trapped charge VS relative Time of Arrival

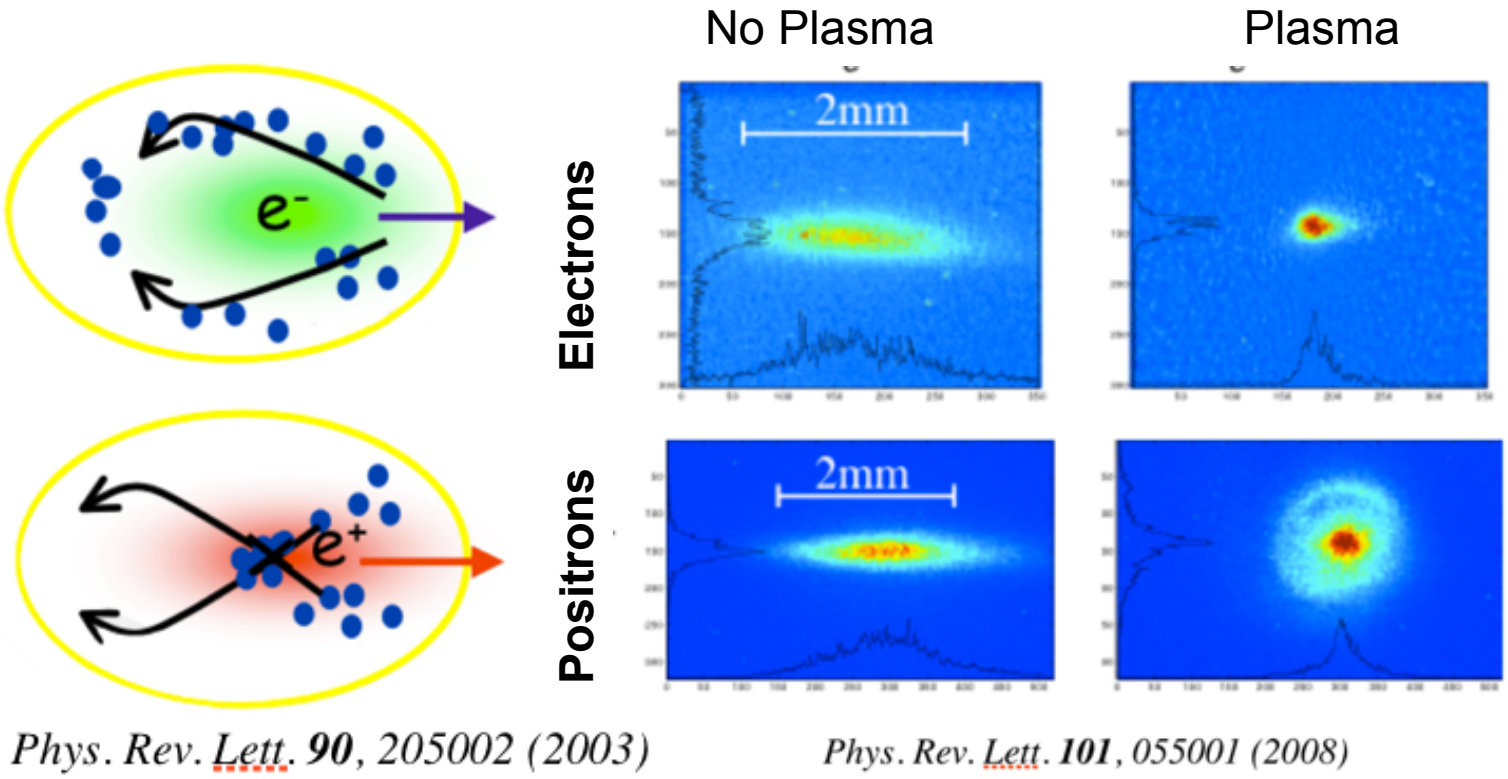


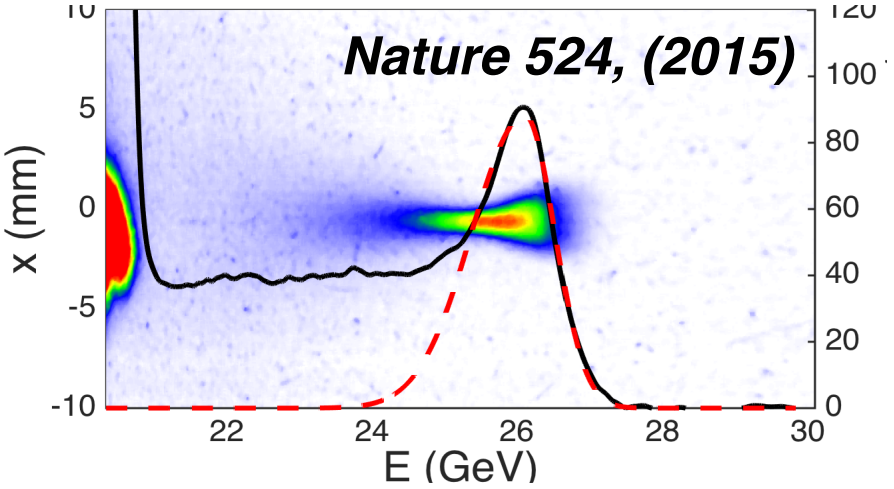



# What about positrons

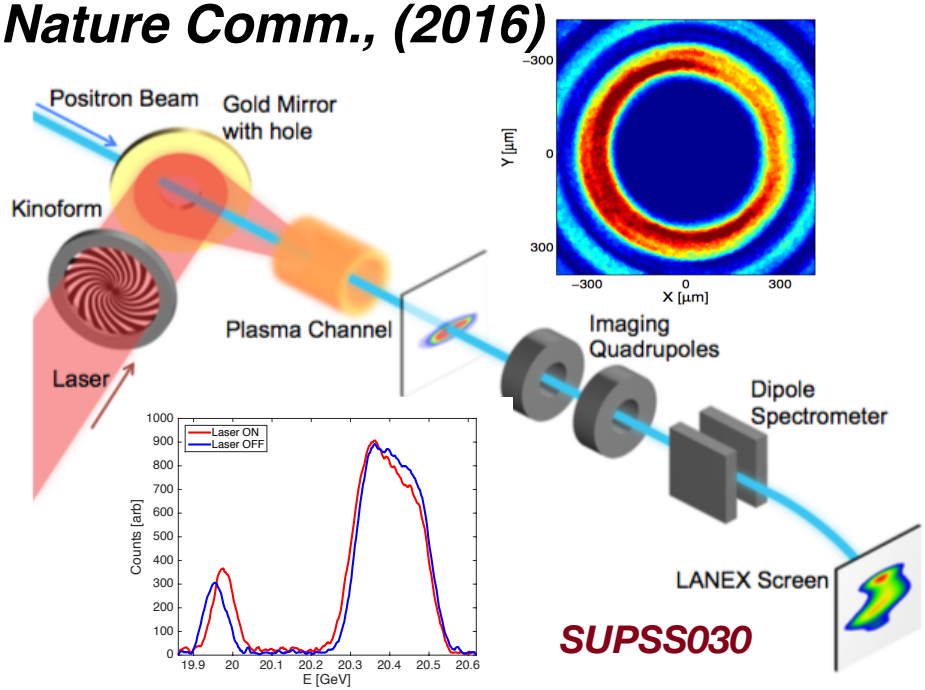



Experiments at SLAC FFTB in 2003 showed that the positron beam was distorted after passing through a low density plasma.

# Positron acceleration summary



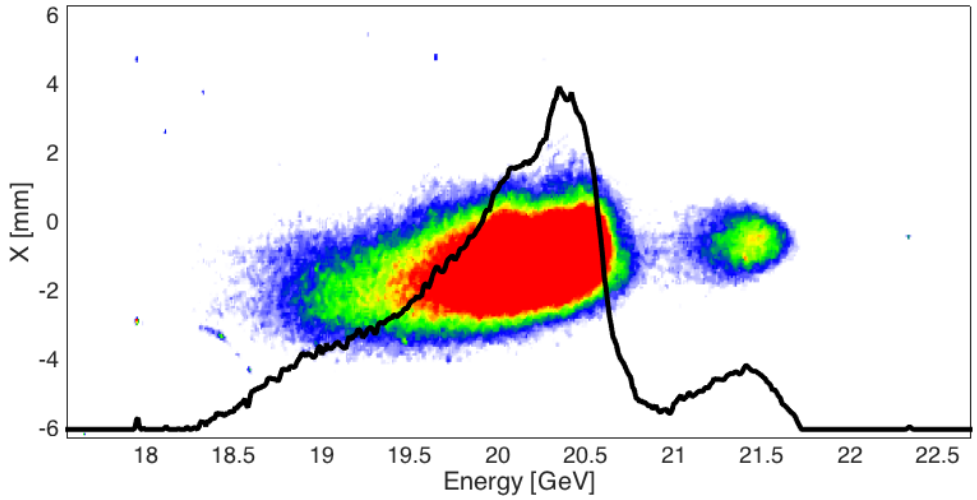

***Nature Comm., (2016)***




**SUPSS030**

In the past two years, we have demonstrated positron acceleration in plasma in a variety of scenarios:

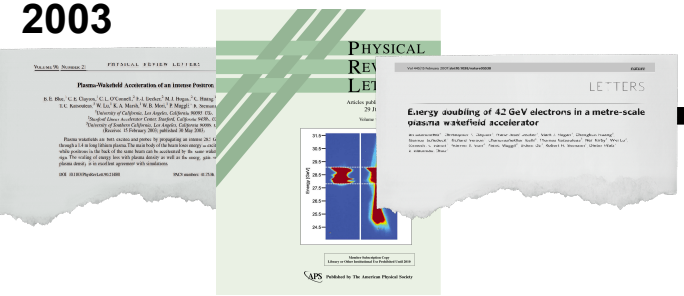
- **Nonlinear regime**
- **Hollow channel plasma**
- **Quasi-nonlinear regime**



# An exciting decade of fast experimental progress

SLAC

2003




2016

# FACET-II Plan


**Timeline:**

- ***Nov. 2013, FACET-II proposal, Comparative review***
- ***CD-0*** ***Aug. 2015***
- ***CD-1*** ***Oct. 2015, ESAAB Dec. 2015***
- CD-2/3A Sep. 2016
- CD-3B Mar. 2017
- CD-4 2022
- Experimental program (2019-2026)

**Key R&D Milestones:**

- Staging with witness injector
- High brightness beam generation, preservation, characterization
- $e^+$ acceleration in $e^-$ driven wakes
- Generation of high flux gamma radiation

**Three stages:**

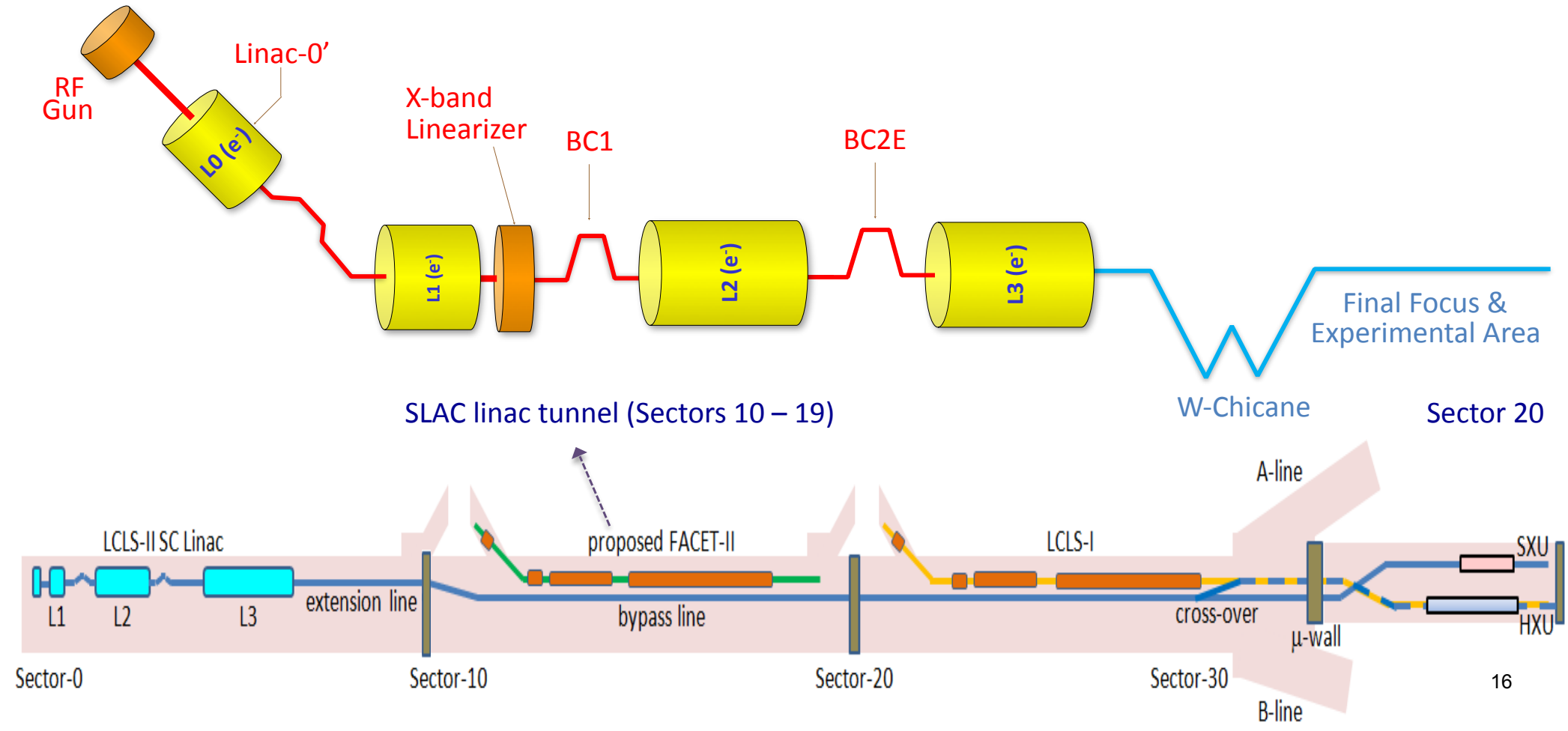
- Photoinjector (e- beam only) FY17-19
- e+ damping ring (e+ or e- beams) FY18-20
- "sailboat" chicane (e+ and e- beams)

FACET-II will enable research for a broad User Community

# FACET-II Stage I FY17-18

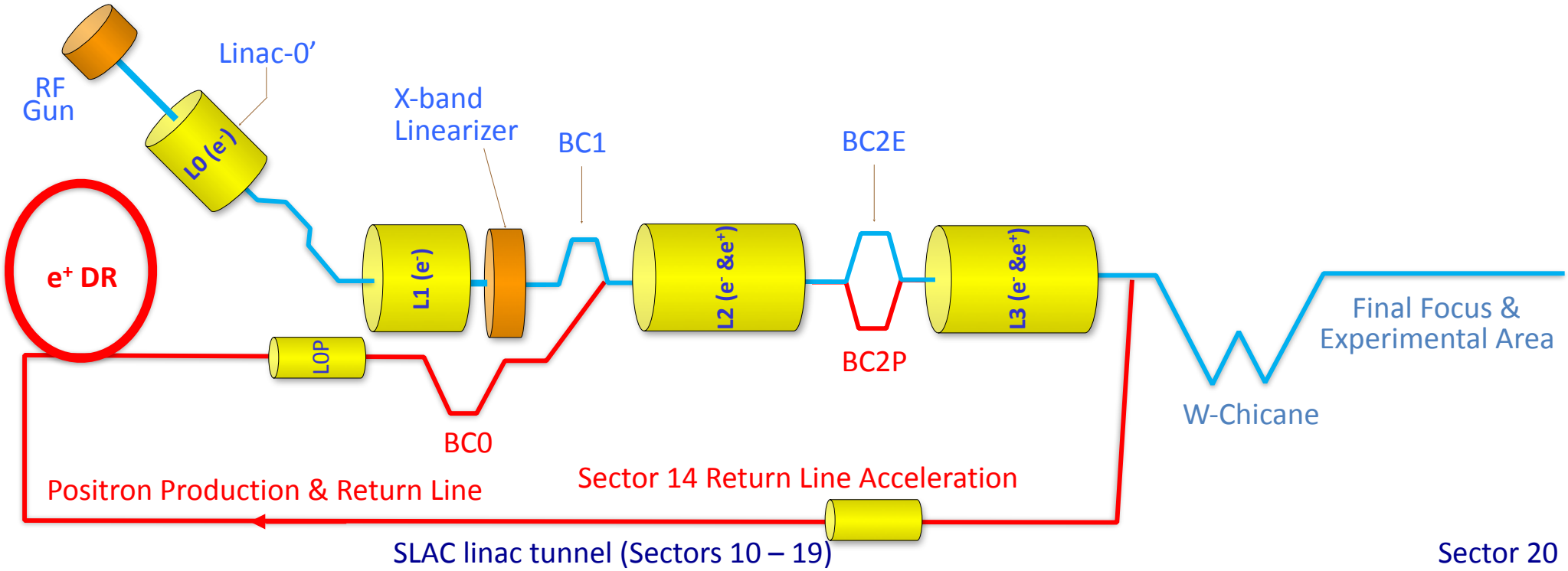


- **Goal:** deliver compressed electron beam to experiments in S20
- **Major upgrade:** Electron beam photoinjector in Sector 10
- **Scope:** Injector, Shield wall in S10, X-band linearizer, Bunch Compressors in S11 (BC1) and S14 (BC2), beam diagnostics, upgrade to experimental area



# FACET-II Stage IIFY18-20

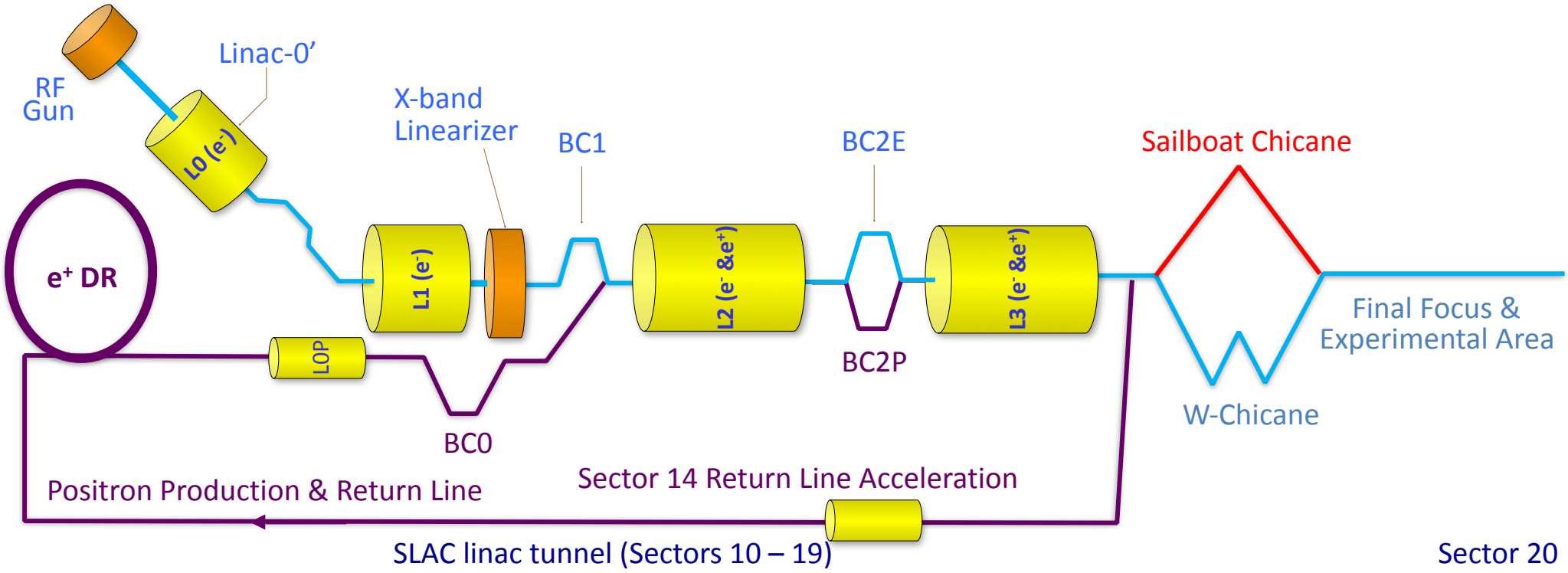
- **Goal:** deliver compressed positron beam to experiments in S20
- **Major upgrade:** positron damping ring
- **Scope:** damping ring, positron bunch compressor & return line




TUPMB021

# FACET-II Stage III

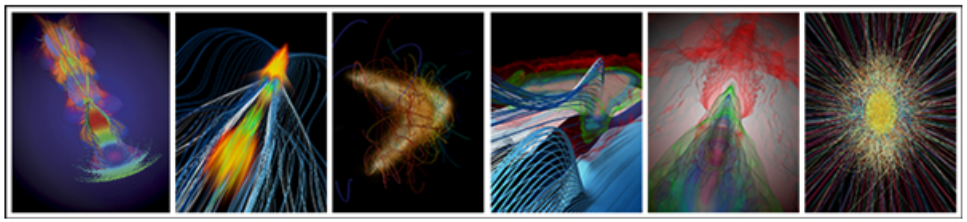
- **Goal:** deliver electron and positron beams to experiments in S20
- **Major upgrade:** Sailboat chicane
- **Scope:** Sailboat chicane



# FACET-II Science Opportunities Workshops:

SLAC NATIONAL ACCELERATOR LABORATORY

- Home
- Agenda
- FACET-II CDR
- Participants
- Register
- Accommodations
- Travel and Directions
- Meeting Rooms & Maps



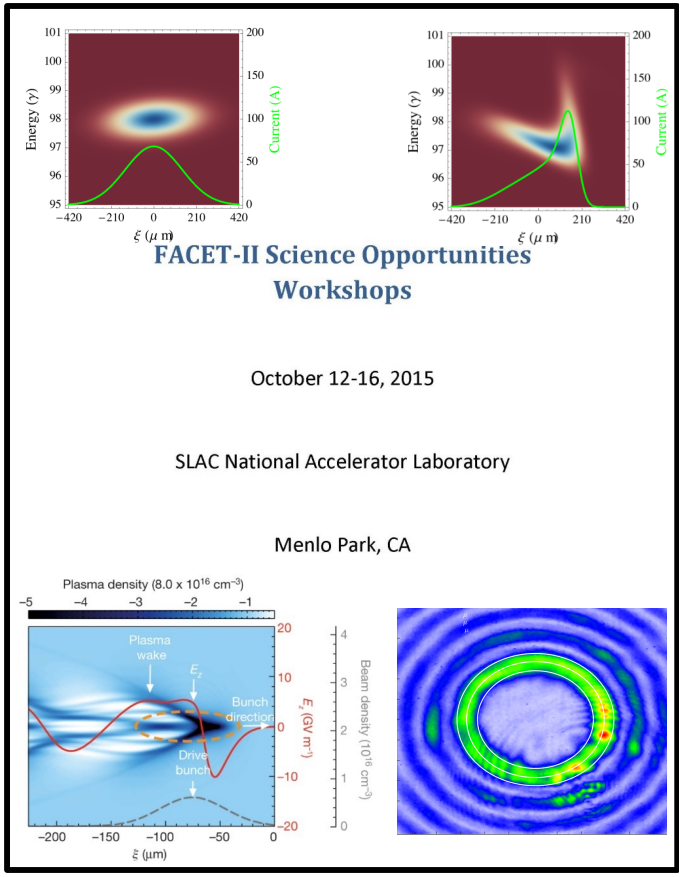
**FACET-II**
**Science Opportunities Workshops**

**12-16 October, 2015**
**SLAC National Accelerator Laboratory**
**Menlo Park, CA**

| October 12-16, 2015 | WG Leaders | Workshop |
|---|---|---|
| Monday | Pietro Musumeci (UCLA)<br>Zhirong Huang (SLAC) | Accelerator Physics of Extreme Beams |
| Tuesday | Ioan Tudosa (U. Penn.)<br>Jerome Hastings (SLAC) | Material Interactions with Extreme Fields |
| Wednesday | Andrei Seryi (JAI)<br>Jean-Pierre Delahaye (SLAC) | Plasma Acceleration Based Linear Colliders |
| Thursday | James Rosenzweig (UCLA)<br>Erik Hemsing (SLAC) | Plasma Acceleration Based XFELs |
| Friday | Vladimir Litvinenko (Stonybrook)<br>Carsten Hast (SLAC) | Application of Compton Based Gamma Rays |

**Representatives from:**

- DESY, FNAL,INFN, IST, JAI, LBNL, Oslo, MPP, SLAC, Strathclyde, UCLA




https://portal.slac.stanford.edu/sites/conf_public/facet_ii_wk_2015/Pages/Tabbed-Agenda.aspx