Science Opportunities with Positrons at FACET-II

Spencer Gessner, SLAC

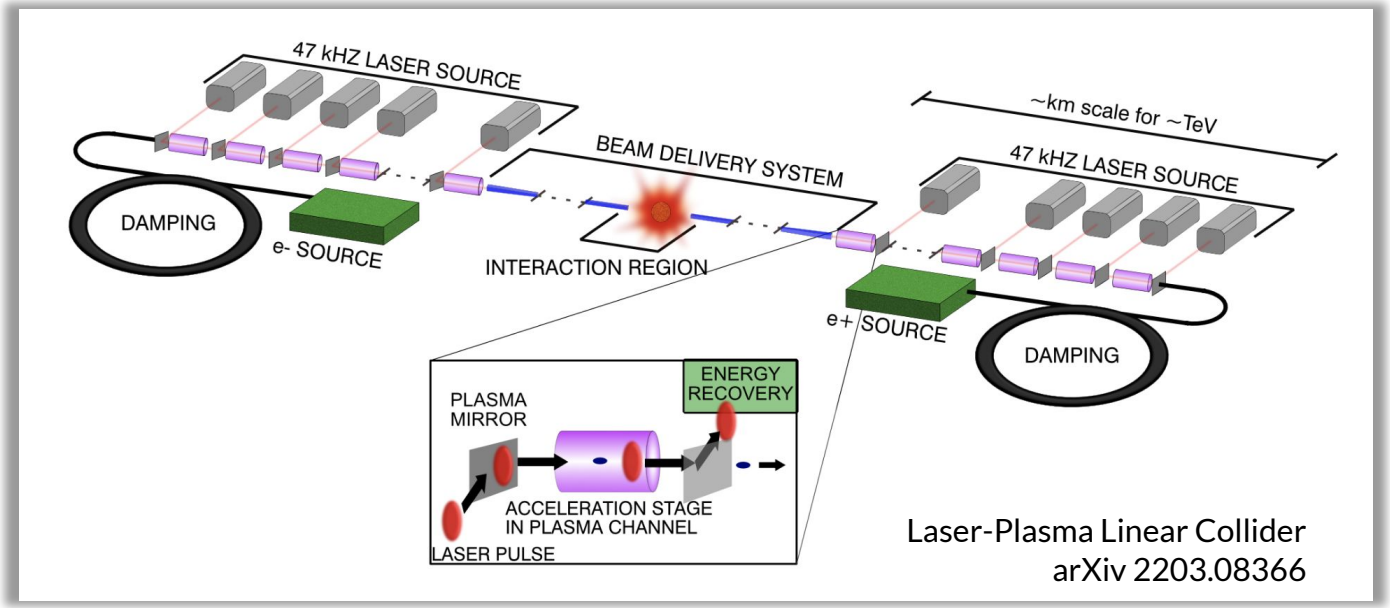
FACET Science Workshop

October 19, 2023

SLAC NATIONAL ACCELERATOR LABORATORY

Stanford University | U.S. DEPARTMENT OF ENERGY

Plasma Linear Colliders



Laser-Plasma Linear Collider
arXiv 2203.08366

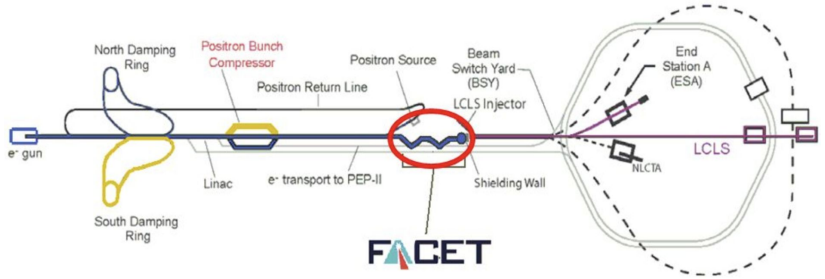
Challenge for our field: *How do we accelerate positron bunches in plasma?*

Positron PWFA Experimental Research

FFTB

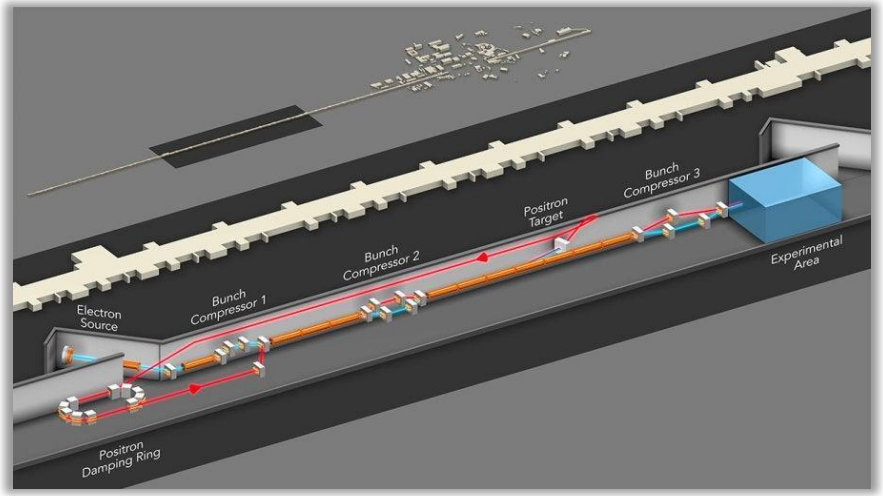
M. J. Hogan et. al. *Phys. Rev. Lett.* 90 205002 (2003).
B. Blue et. al. *Phys. Rev. Lett.* 90 214801 (2003).
P. Muggli et. al. *Phys. Rev. Lett.* 101 055001 (2008).

FACET



S. Corde et. al. *Nature.* 524 442445 (2015).
S. Gessner et. al. *Nat. Comm.* 7 11785 (2016).
A. Doche et. al. *Nat. Sci. Rep.* 7 14180 (2017).
C. A. Lindstrøm et. al. *Phys. Rev. Lett.* 120 124802 (2018).
S. Gessner et. al. *arXiv:*2304.01700 (2023).

FACET-II*



*E333 experiment planned for filament regime positron PWFA.

Plus many new ideas!

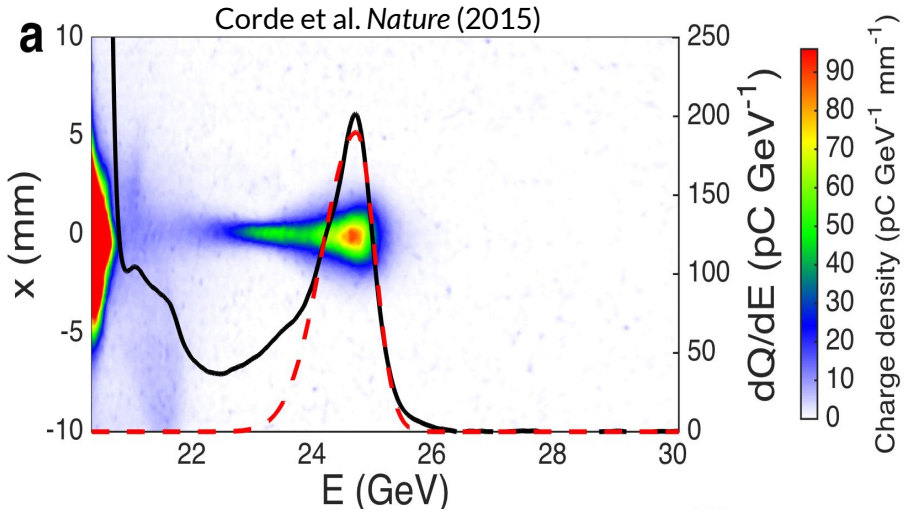
Positron PWFA experiments have only taken place at SLAC, enabled by pre-existing SLC infrastructure.

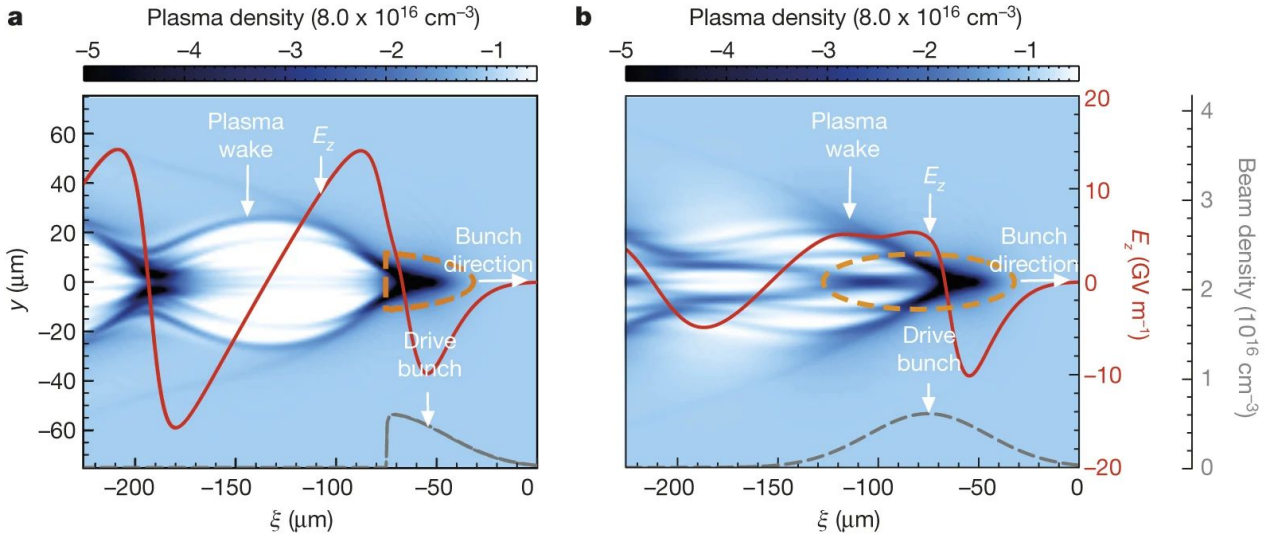
FACET: Positron PWFA with ultra-short bunches

At FACET, we made an exciting and unexpected observation:

Monoenergetic acceleration of self-loaded positron bunches

The FACET results inspired the development of novel concepts for accelerating positrons in plasma.



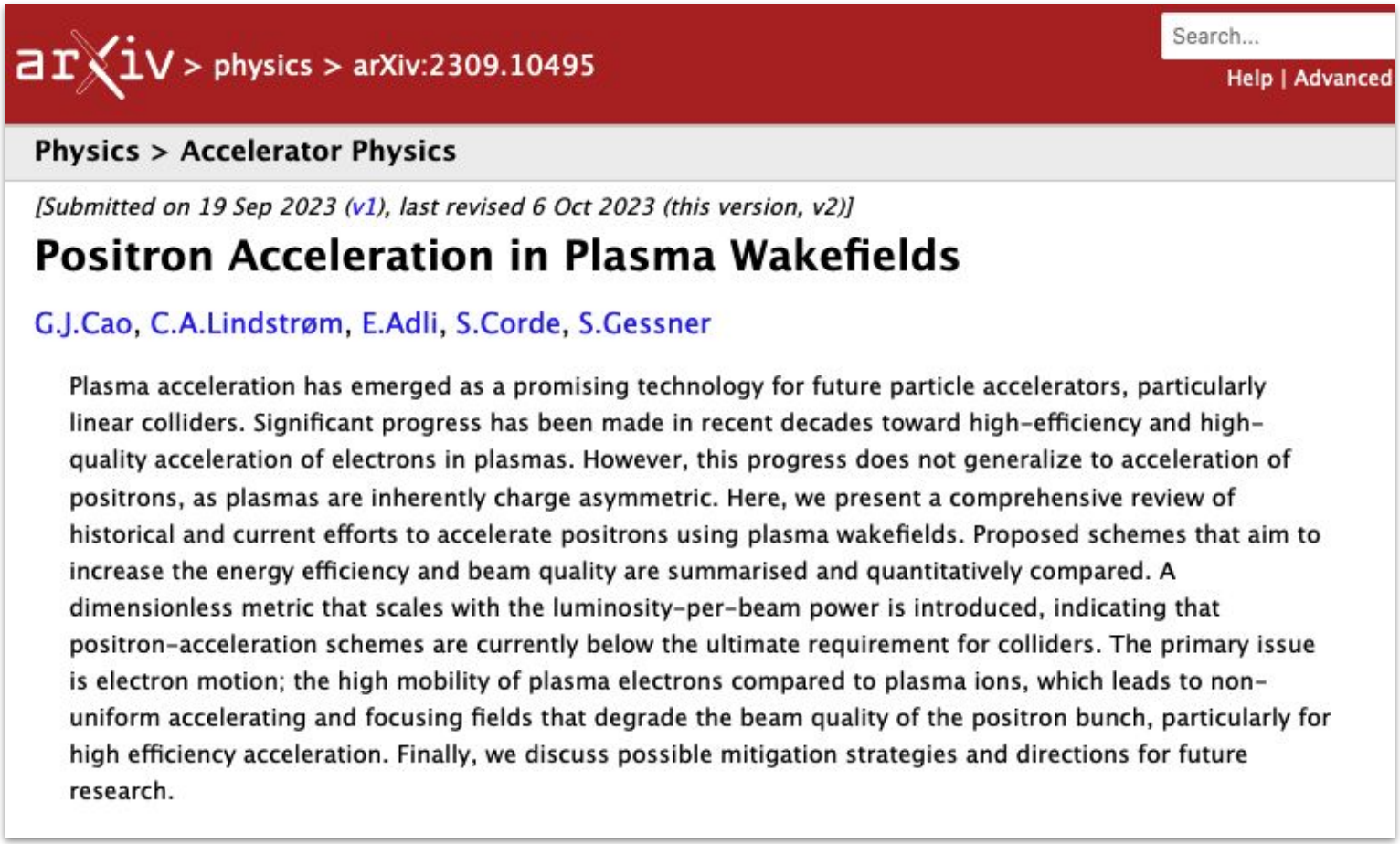


FACET Sparked New Ideas in Positron PWFA Research

Novel concepts on electron beam-driven acceleration of positrons in plasma:

- S. Diederichs et al. "Positron transport and acceleration in beam-driven plasma wakefield accelerators using plasma columns," Phys. Rev. Accel. Beams 22, 081301 (2019).
- S. Diederichs et al. "High-quality positron acceleration in beam-driven plasma accelerators," Phys. Rev. Accel. Beams 23, 121301 (2020).
- T. Wang et al. "Positron Acceleration in an Elongated Bubble Regime," arXiv:2110.10290 (2021).
- S. Zhou et al. "High Efficiency Uniform Wakefield Acceleration of a Positron Beam Using Stable Asymmetric Mode in a Hollow Channel Plasma," Phys. Rev. Lett. 127, 174801 (2021).
- T. Silva et al. "Stable Positron Acceleration in Thin, Warm, Hollow Plasma Channels," Phys. Rev. Lett. 127, 104801 (2021).
- C. S. Hue et al. "Efficiency and beam quality for positron acceleration in loaded plasma wakefields," Phys. Rev. Research 3, 043063 (2021).
- S. Zhou et al. "Positron beam loading and acceleration in the blowout regime of plasma wakefield accelerator," arXiv:2211.07962 (2022).
- S. Zhou et al. "High efficiency uniform positron beam loading in a hollow channel plasma wakefield accelerator," Phys. Rev. Accel. Beams 25, 091303 (2022).
- S. Diederichs et al. "Stable electron beam propagation in a plasma column," Phys. Plasmas 29, 043101 (2022).
- S. Diederichs et al. "Self-stabilizing positron acceleration in a plasma column," Phys. Rev. Accel. Beams 25, 091304 (2022).
- T. Silva et al. "Positron acceleration in plasma waves driven by non-neutral fireball beams," Phys. Rev. Accel. Beams 26, 091301 (2023).
- S. Diederichs et al. "Temperature effects in plasma-based positron acceleration schemes using electron filaments," Phys. Plasmas 30, 073104 (2023).

Review of Positron Acceleration in Plasma



arXiv > physics > arXiv:2309.10495

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Physics > Accelerator Physics

[Submitted on 19 Sep 2023 (v1), last revised 6 Oct 2023 (this version, v2)]

Positron Acceleration in Plasma Wakefields

G.J.Cao, C.A.Lindstrøm, E.Adli, S.Corde, S.Gessner

Plasma acceleration has emerged as a promising technology for future particle accelerators, particularly linear colliders. Significant progress has been made in recent decades toward high-efficiency and high-quality acceleration of electrons in plasmas. However, this progress does not generalize to acceleration of positrons, as plasmas are inherently charge asymmetric. Here, we present a comprehensive review of historical and current efforts to accelerate positrons using plasma wakefields. Proposed schemes that aim to increase the energy efficiency and beam quality are summarised and quantitatively compared. A dimensionless metric that scales with the luminosity-per-beam power is introduced, indicating that positron-acceleration schemes are currently below the ultimate requirement for colliders. The primary issue is electron motion; the high mobility of plasma electrons compared to plasma ions, which leads to non-uniform accelerating and focusing fields that degrade the beam quality of the positron bunch, particularly for high efficiency acceleration. Finally, we discuss possible mitigation strategies and directions for future research.

Gevy Cao will cover all of those topics and more!

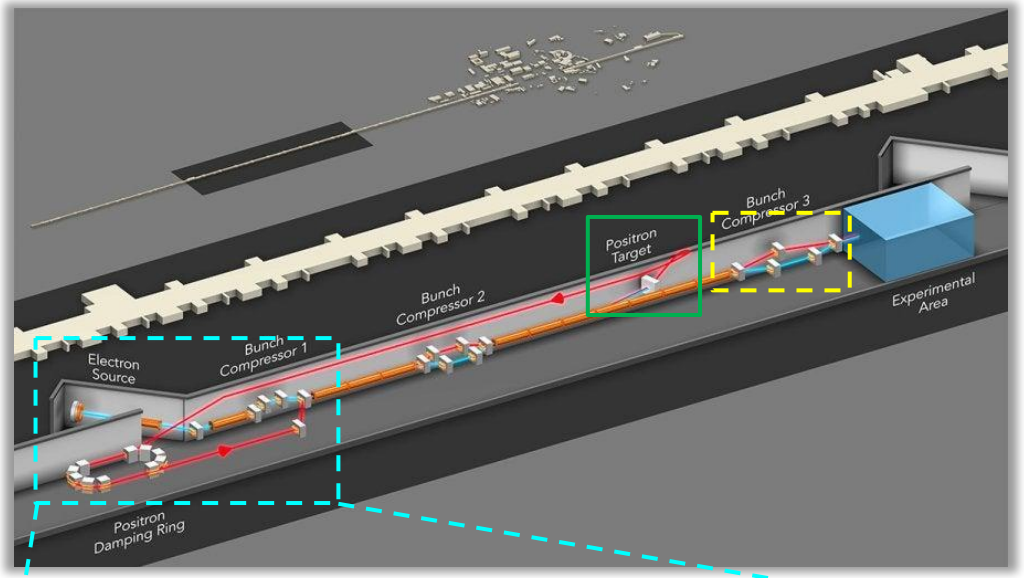
SLAC

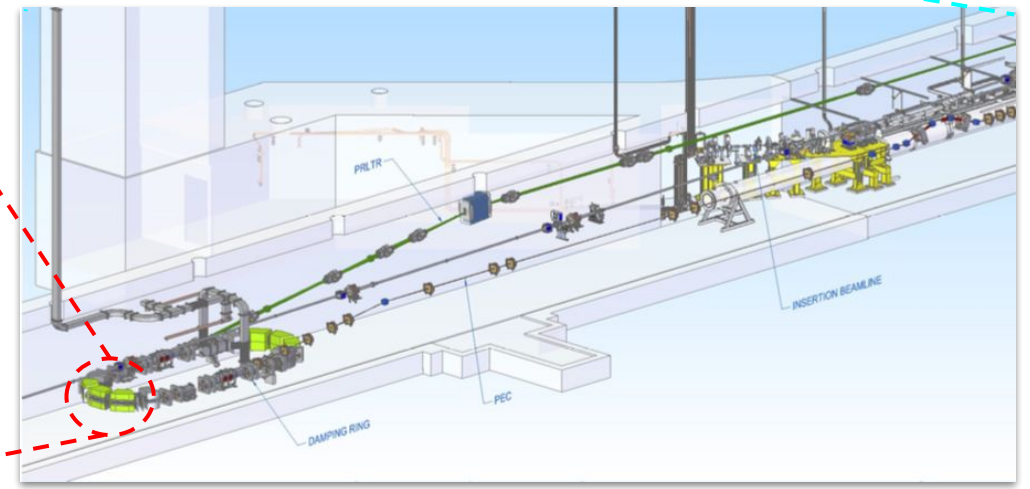
Positrons at FACET-II

Repairs on the positron source vacuum system are underway (see talk by C. Hast).

The next step is to install a compact positron damping ring in S10. We have a prototype for one of the magnets.

Lastly, we will reconfigure the S20 to chicane to allow for simultaneous delivery of electron and positron beams.





Agenda

Start Time (PST)	Duration	Title	Name	Affiliation
9:00 AM	45m	Positron beam loading in uniform regime	Shiyu Zhou	Tsinghua
9:45 AM	45m	Plasma Temperature Effects in Positron PWFA	Severin Diederichs	DESY
10:30 AM	**30m**	**Coffee Break**		
11:00 AM	30m	Energy recover in positron PWFA wake	Max Varverakis	Cal Poly
11:30 AM	60m	Positron PWFA review and scaling laws	Gevy Cao and Carl Lindstrom	
12:30 PM	**30m**	**Lunch**		
1:00 PM	30m	Beam-based laboratory astrophysics	Gianluca Gregori	Oxford
1:30 PM	20m	Electron trapping in positron driven wakefields	James Allen	SLAC/Stanford
1:50 PM	10m	Discussion	Mark Hogan	SLAC
2:00 PM		**Adjourn**		