Positron Plasma Wakefield Acceleration Research at FACET-II

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EU Strategy Townhall #2

21 May, 2021

U.S. DEPARTMENT OF ENERGY | Stanford University

SLAC NATIONAL ACCELERATOR LABORATORY

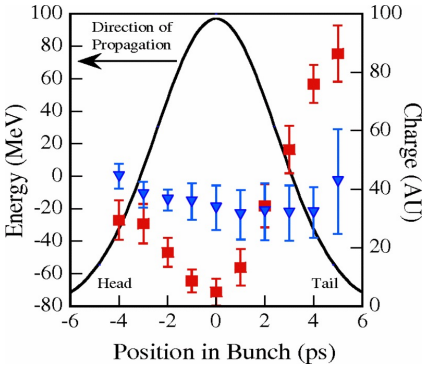
Positron PWFA Research at SLAC

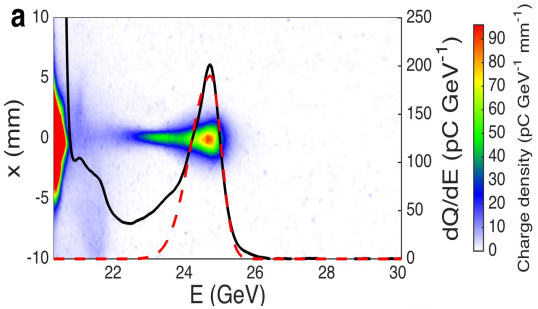
FFTB

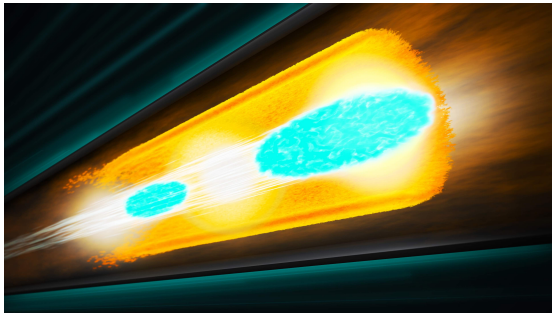
- First acceleration of positron beams in plasma
  - B. Blue et. al. *Phys. Rev. Lett.* 90 214801 (2003).
- Positron beam transport in plasma
  - M. J. Hogan et. al. *Phys. Rev. Lett*. 90 205002 (2003).
- Halo formation due to non-linear fields
  - P. Muggli et. al. *Phys. Rev. Lett*. 101 055001 (2008).

FACET

- Positron PWFA in non-linear regime
  - S. Corde et. al. *Nature* 524 442 (2015).
- Two bunch positron PWFA
  - A. Doche et. al. *Nat. Sci. Rep*. 7, 14180 (2017).
- Hollow channel positron PWFA
  - S. Gessner et. al. *Nat. Comm*. 7, 11785 (2016).
  - C. Lindstrom et. al. *Phys. Rev. Lett.* 120 124 (2018).

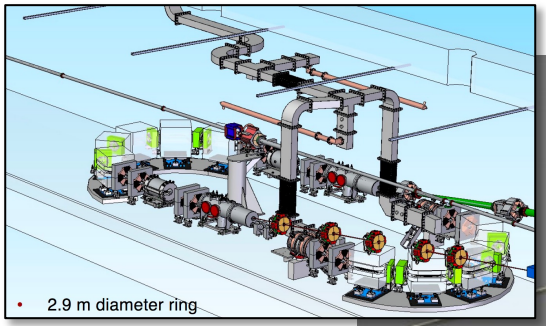




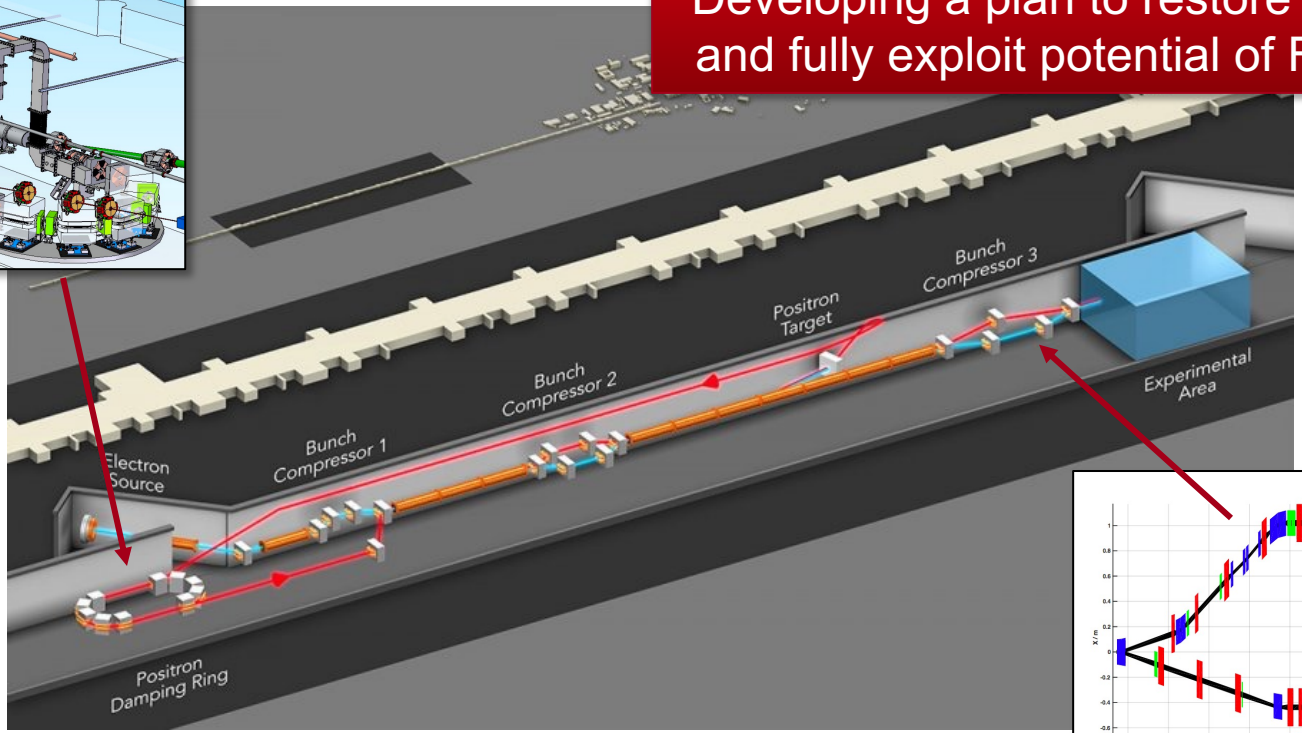


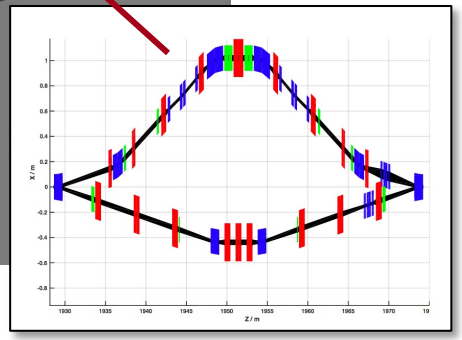
Positron Facilities at FACET-II

SLAC



Developing a plan to restore positrons and fully exploit potential of FACET-II.





Positron Generation and Trapping

We can use an electron beam to generate positrons in a tungsten foil.

Some positrons will get trapped and accelerated in the electron-driven wake.

E305 experiment: P.I. K. Marsh, UCLA.

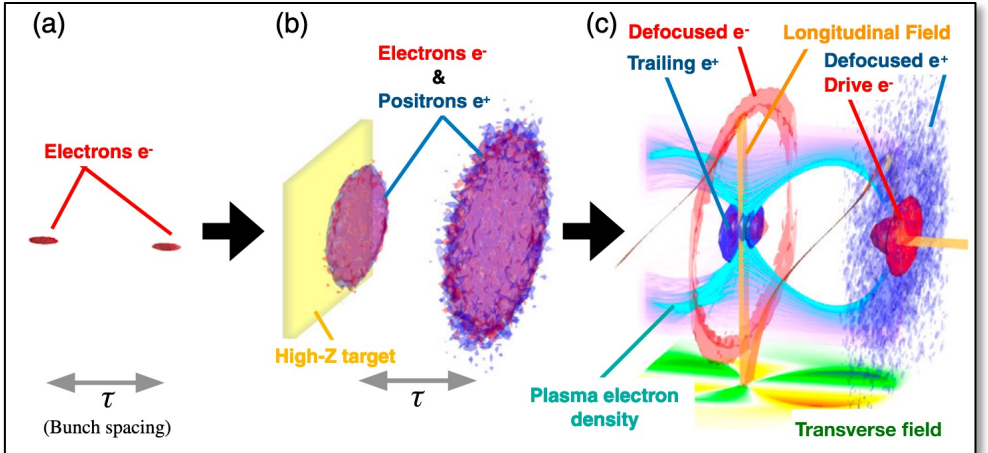


FIG. 1. Schematic diagram of the positron acceleration.

PHYSICAL REVIEW ACCELERATORS AND BEAMS **22,** 091301 (2019)

Positron beam extraction from an electron-beam-driven plasma wakefield accelerator

H. Fujii,[1] K. A. Marsh,[1] W. An,[1] S. Corde,[2] M. J. Hogan,[3] V. Yakimenko,[3] and C. Joshi[1]
[1]*University of California, Los Angeles, Los Angeles, California 90095, USA*
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[3]*SLAC National Accelerator Laboratory, Menlo Park, California 94025, USA*

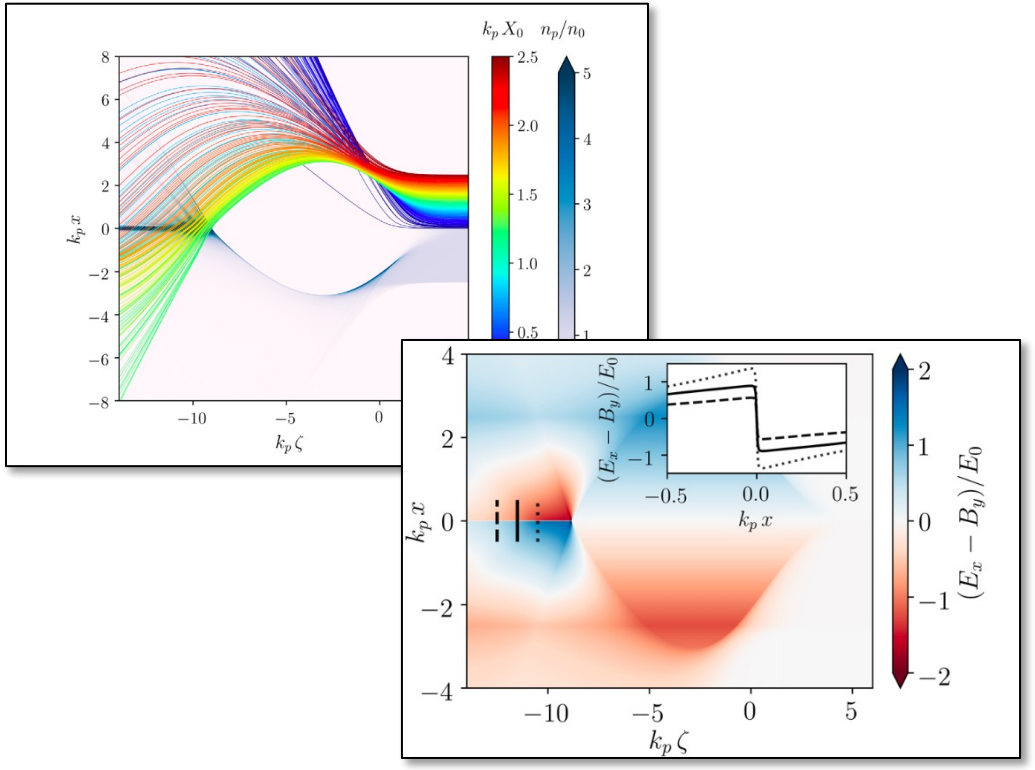
Positron PWFA in Plasma Filaments

Changing the shape of the ionized plasma region modifies the trajectories of plasma electrons in the wake.

This leads to an elongated region in the back of the wake where positron bunches are focused and accelerated.

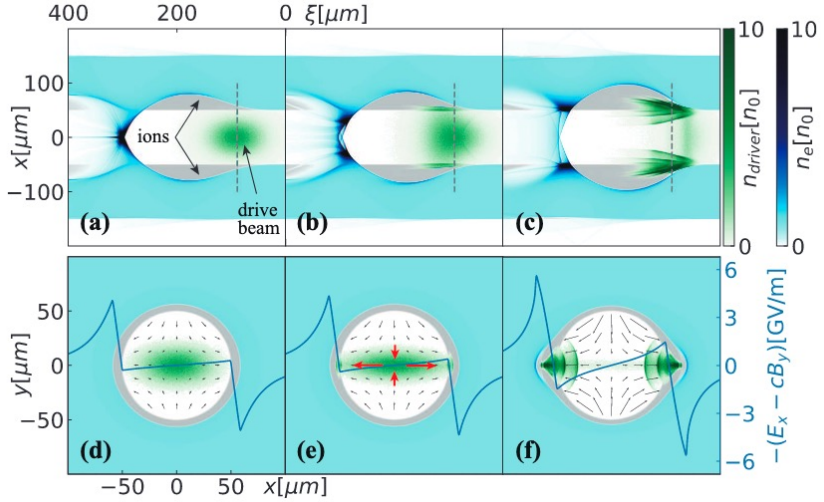
E333 experiment: P.I. SG, SLAC.

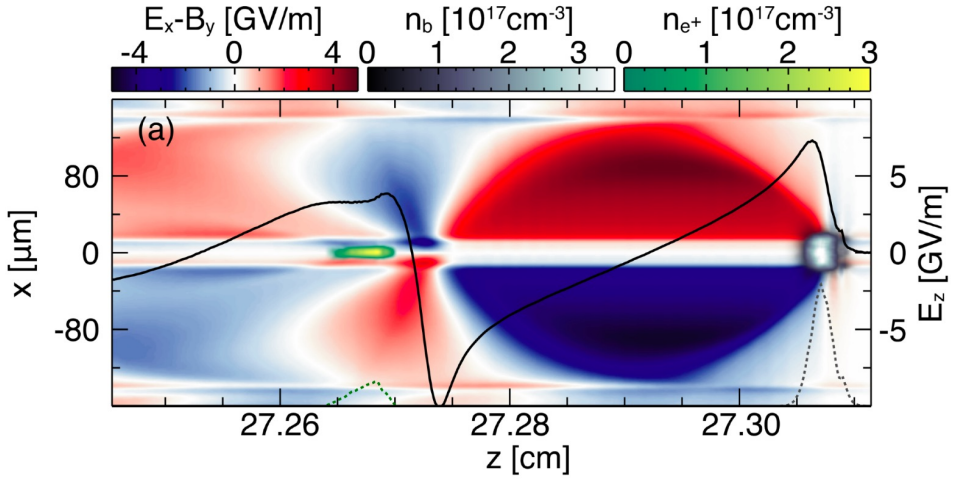
S. Diederichs et. al. *Phys. Rev. Accel. Beams* **22** 081301 (2019)



S. Diederichs et. al. *Phys. Rev. Accel. Beams* **23** 121301 (2020)

Proposals





"Stable Positron Acceleration Mode in Hollow Plasma Channel Driven by an Asymmetric Beam"
S. Zhou, W. Lu, Tsinghua, et. al.

https://arxiv.org/abs/2012.06095

"Electron and positron acceleration in self-generated, thin, warm hollow plasma channels."

T. Silva, J. Viera, IST, et. al.

Conclusions

FACET-II will be first facility capable of critical *electron-driven, positron witness* PWFA.

FACET-II can explore issues on beam loading and beam quality that was only touched upon at FACET, as well as donut-shaped drivers (t.b.p. C. S. Hue, G. Cao, S. Corde et. al.)

Program is slightly delayed due to COVID-19. Help maintain the momentum and submit new ideas at the FACET PAC meeting in the fall!

Questions 1

1. Where do you see HEP applications of Adv. Acc. in 30 years?
   - **Linear collider**
2. What intermediate applications/steps do you until a linear collider?
   - **Fixed target searches** SNOWMASS21-AF5_AF6-170
3. What is the synergy with related fields?
   - **Positron sources for LCs.**
4. What is the role of your work here?
   - **Demonstrate that positron PWFA can work!**

Questions 2

1. What are the important milestones for the next 10 years?
   - **Positrons (this talk)**
   - **BDS and plasma lenses (C. Doss @ 10:10)**
   - **Staging (C. Lindstrøm @ 16:45)**
2. What additional support is needed to achieve these?
   - **Facility for positron PWFA (FACET-II, next talk)**
   - **Facility for staging (FACET-III I hope!)**
3. What are proposed deliverables until 2026?
   - **Efficient, high-quality PWFA.**
   - **Plasma lens demonstration.**
   - **Electron-driven positron acceleration.**
4. Is the R&D work for those deliverables already funded?
   - **FACET-II positrons planned but not yet funded.**

Questions 3

1. What key R&D can be achieved in existing facilities?
   - **High-quality PWFA at FlashForward and FACET.**
   - **High-repetition rate at FlashForward (R. D'Arcy @ 16:00)**
2. What is the role of planned future facilities in Europe and world-wide?
   - **AWAKE -> Highest-energy particle beams from PWFA.**
   - **Eupraxia -> Reliable operation and delivery to users.**
3. What can be done with existing and planned funding base?
   - 🤷‍♂️
4. Is a completely new facility needed?
   - **Yes! Staging facility and BDS facility (can be the same facility).**
5. Are additional structures needed, e.g. a design study?
   - **Yes, a funded design study is needed.**