

Plasma Wakefield Acceleration with Positron Beams

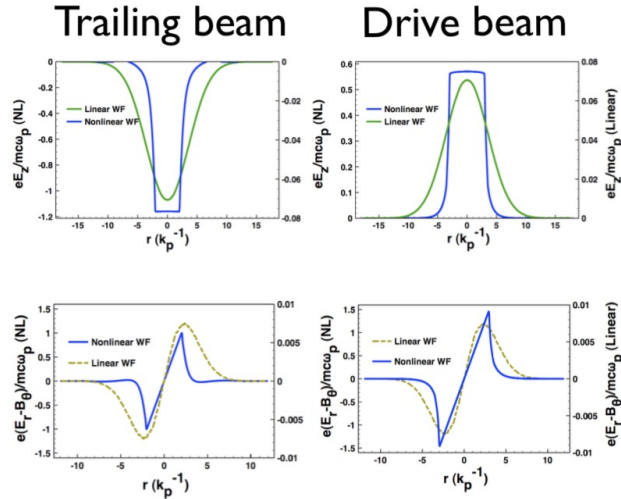
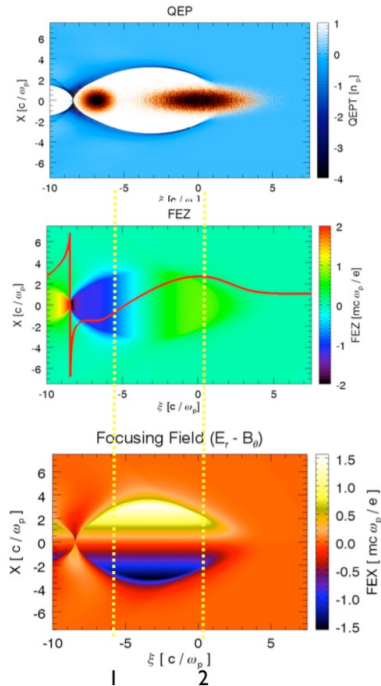


Spencer Gessner, SLAC

Positron Mini-Meeting, March 30 2022

The Case for Electron Acceleration

Nonlinear wakefield is IDEAL for accelerating/focusing electrons
 Trailing beam does not modify focusing fields of wake



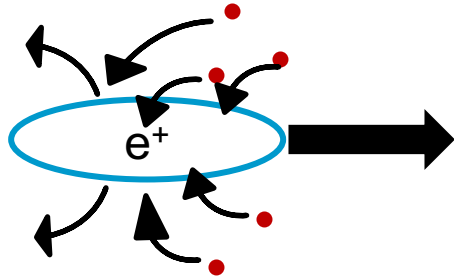
$$\partial_\xi F_z = 0$$

$$\partial_\xi F_\perp = 0$$

$$\nabla_\perp F_\perp = C_{constant}$$

$$\nabla_\perp F_z = 0$$

“Ideal” Positron PWFA

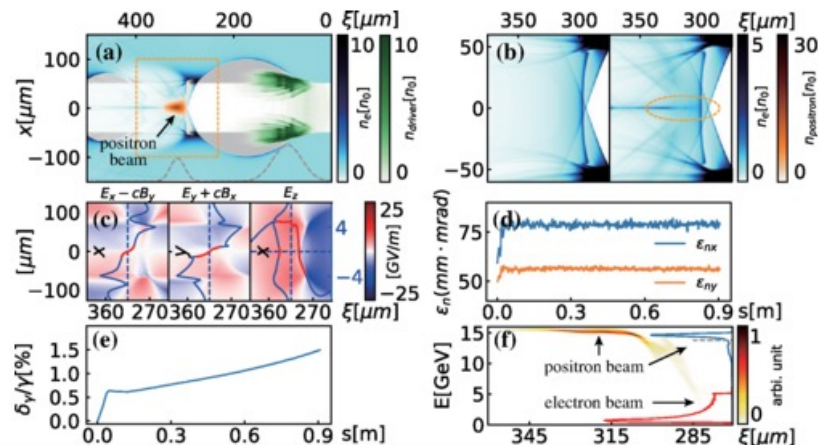
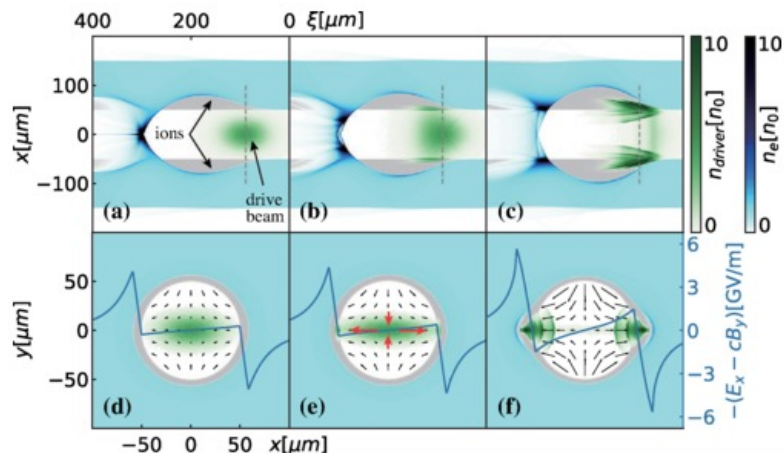


$$\begin{aligned}\partial_{\xi} F_z &\approx 0 & \partial_{\xi} F_{\perp} &\approx 0 \\ \nabla_{\perp} F_{\perp} &\approx C_{\text{constant}} & \nabla_{\perp} F_z &\approx 0\end{aligned}$$

Can we create conditions where the plasma electron density in the vicinity of the positron beam roughly recreates the “ideal” equations?

- How do we create an “ideal” situation for positron acceleration?
 - Hollow Channel: Eliminate transverse focusing.
 - Filament Plasma: Tailor transverse focusing.
 - Ion motion: Create focusing with positively-charged ions.
 - Moderately Non-Linear: Accept variation in wake strength across the witness bunch.

Hollow Channel with Asymmetric Modes



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Editors' Suggestion

Access by Stanford University

High Efficiency Uniform Wakefield Acceleration of a Positron Beam Using Stable Asymmetric Mode in a Hollow Channel Plasma

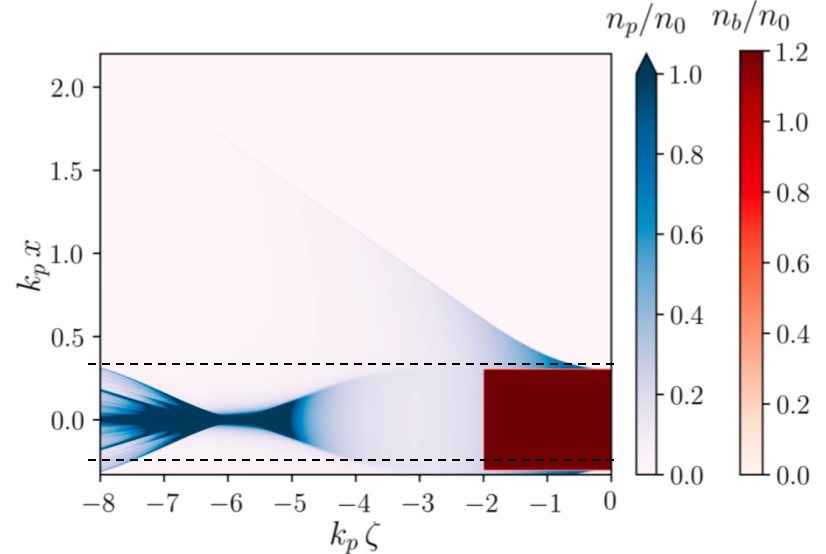
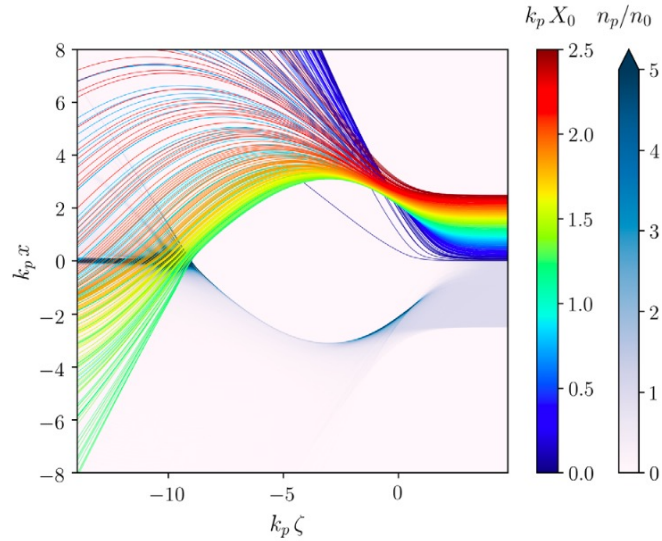
Shiyu Zhou, Jianfei Hua, Weiming An, Warren B. Mori, Chan Joshi, Jie Gao, and Wei Lu
Phys. Rev. Lett. **127**, 174801 – Published 22 October 2021



Transversely Tailored Plasmas

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

S. Dietrichs. M.S.c. Thesis, DESY



By driving a wakefield in a plasma filament, you can create a region of uniform focusing and acceleration for positrons at the back of the wake.

Transverse plasma electron motion appears to be an important factor.

Transversely Tailored Plasmas

Positron Acceleration in an Elongated Bubble Regime

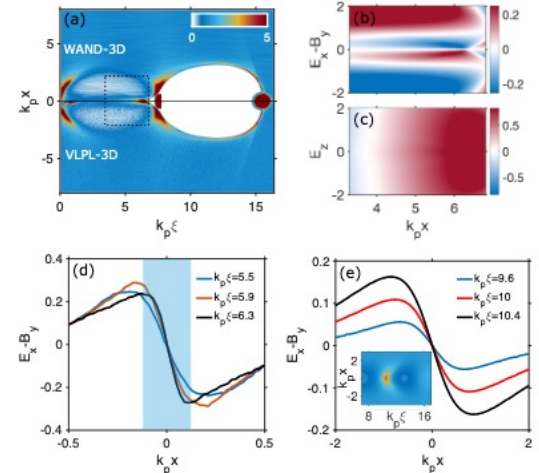
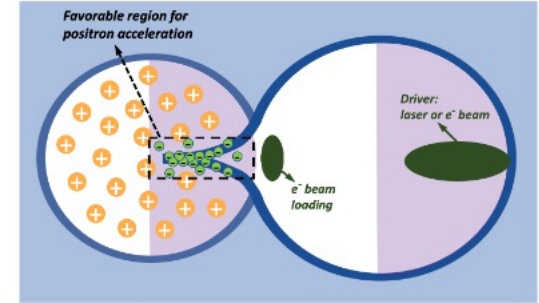
Tianhong Wang¹, Vladimir Khudik², and Gennady Shvets¹

¹School of Applied and Engineering Physics, Cornell University, Ithaca, New York 14850, USA.

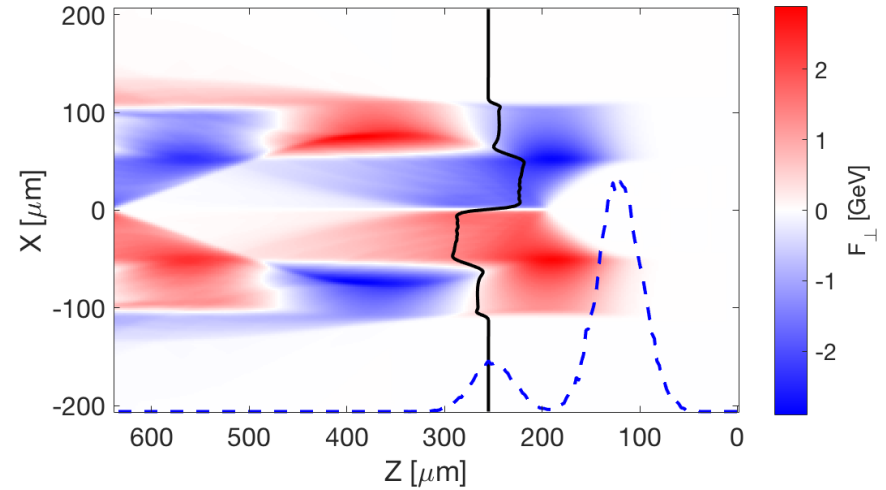
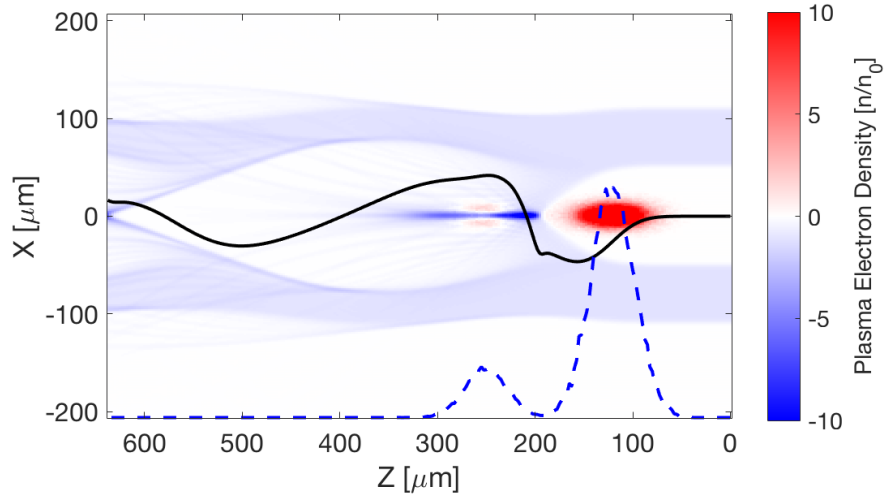
²Department of Physics and Institute for Fusion Studies,
The University of Texas at Austin, Austin, Texas 78712, USA.

(Dated: October 22, 2021)

A new concept is proposed for accelerating positrons in a nonlinear plasma wakefield accelerator. By loading the wakefield (back of the plasma bubble) with a short electron bunch, an extended area of excessive plasma electron accumulation is created after the first bubble, resulting in a favorable region with simultaneous focusing and accelerating fields for positrons. Scaling laws for optimized loading parameters are obtained through extensive parameters scans. Owing to the good quality of the focusing field, positron acceleration with emittance preservation can be achieved in this new regime and it has been demonstrated in the three-dimensional particle-in-cell simulations.

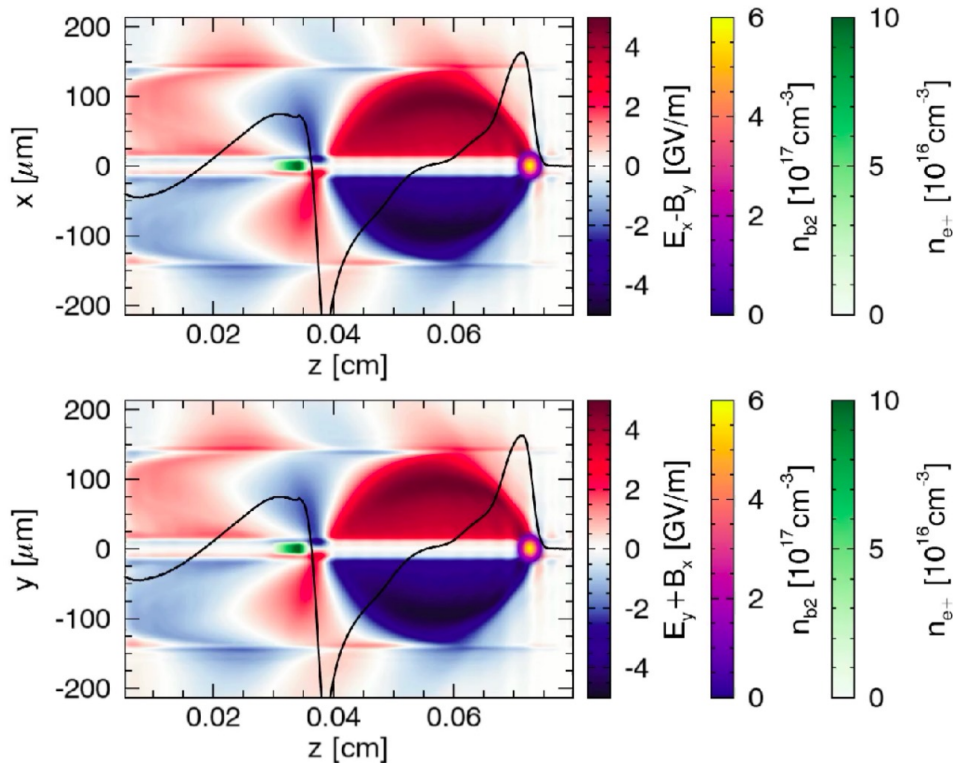
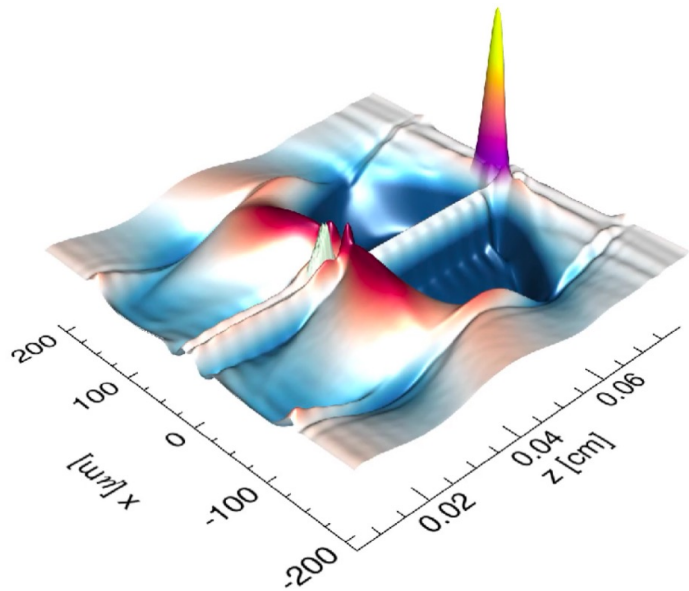


Transverse Tailoring has a HUGE Parameter Space

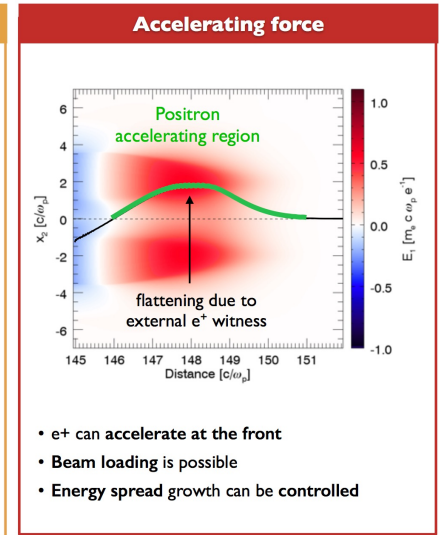
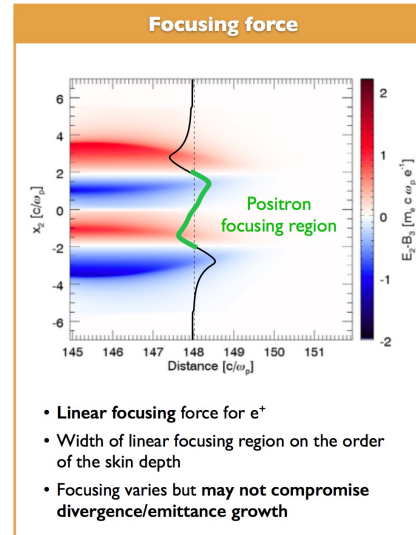
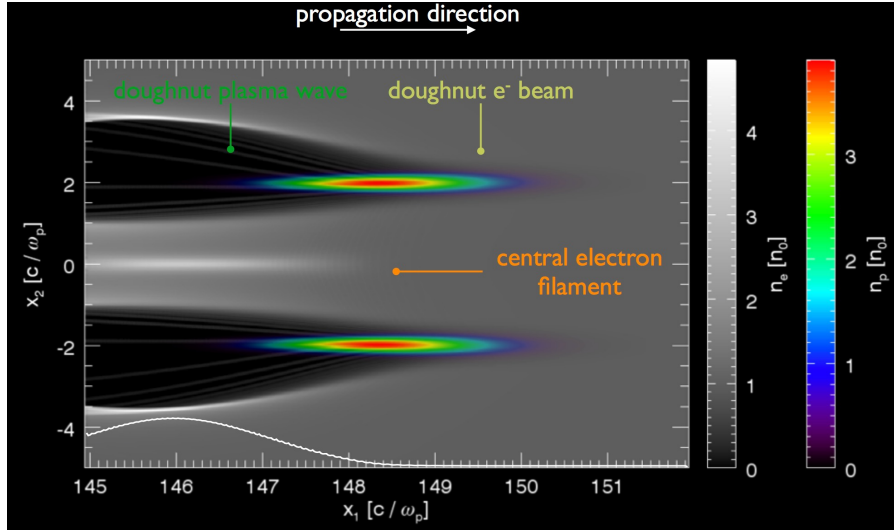


It is possible to reproduce some features of the wake seen in the narrow plasma filament case by driving a non-linear wake in the hollow channel.

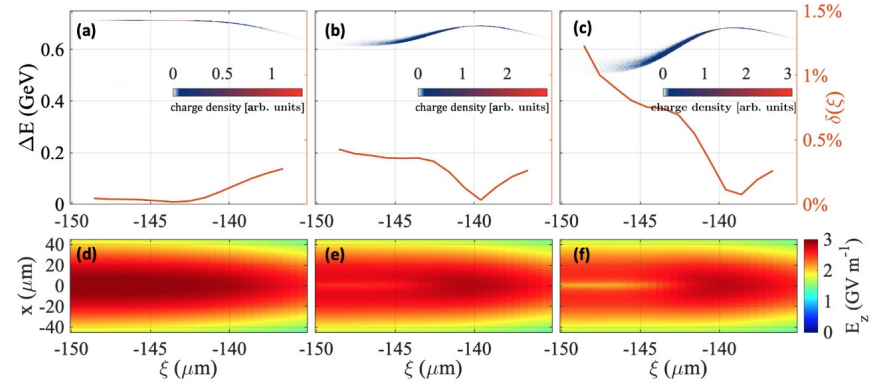
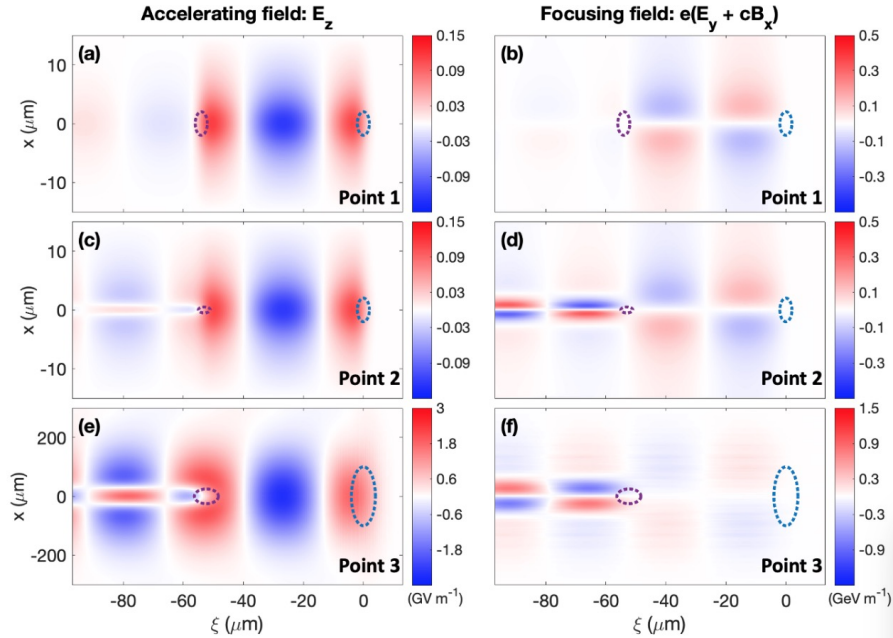
Positron Acceleration in Ion Channels



Transversely Tailored Drivers



Quasi-Linear Regime



PHYSICAL REVIEW RESEARCH 3, 043063 (2021)

Efficiency and beam quality for positron acceleration in loaded plasma wakefields

C. S. Hue,^{1,*} G. J. Cao,^{1,2,*} I. A. Andriyash,¹ A. Knetsch,¹ M. J. Hogan,³ E. Adli,² S. Gessner,³ and S. Corde^{1,†}

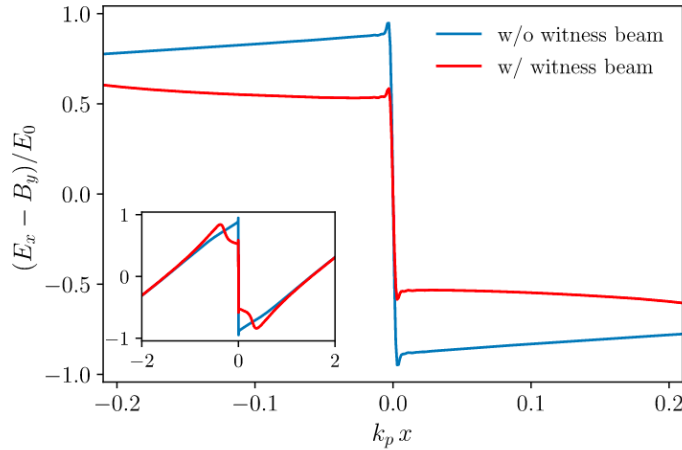
¹LOA, ENSTA Paris, CNRS, Ecole Polytechnique, Institut Polytechnique de Paris, 91762 Palaiseau, France

²Department of Physics, University of Oslo, NO-0316 Oslo, Norway

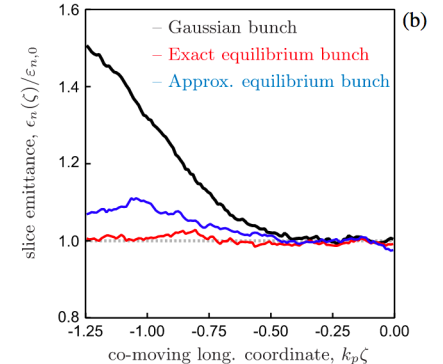
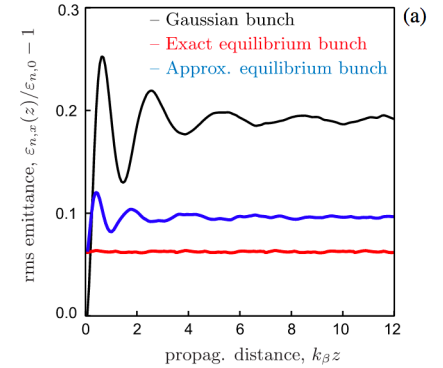
³SLAC National Accelerator Laboratory, Menlo Park, California 94025, USA

All scenarios have beam matching challenges

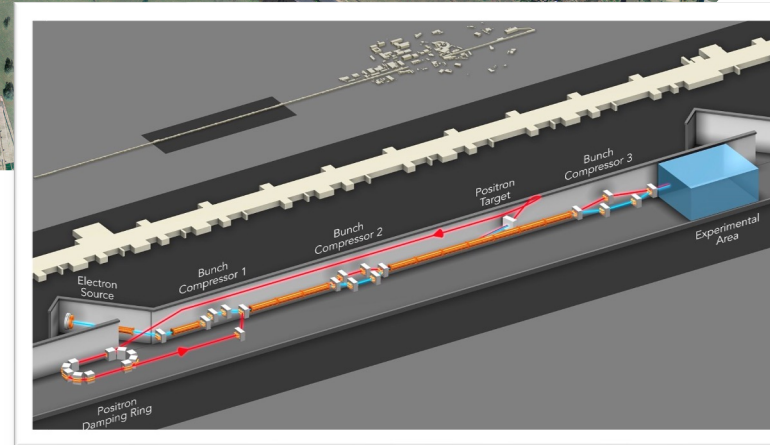
S. Diederichs et. al. *Phys. Rev. Accel. Beams* **22** 081301 (2019)



Focusing fields in general will not be perfectly linear, but approximate matching to minimize emittance growth is still possible. How do we limit number of electron on axis?

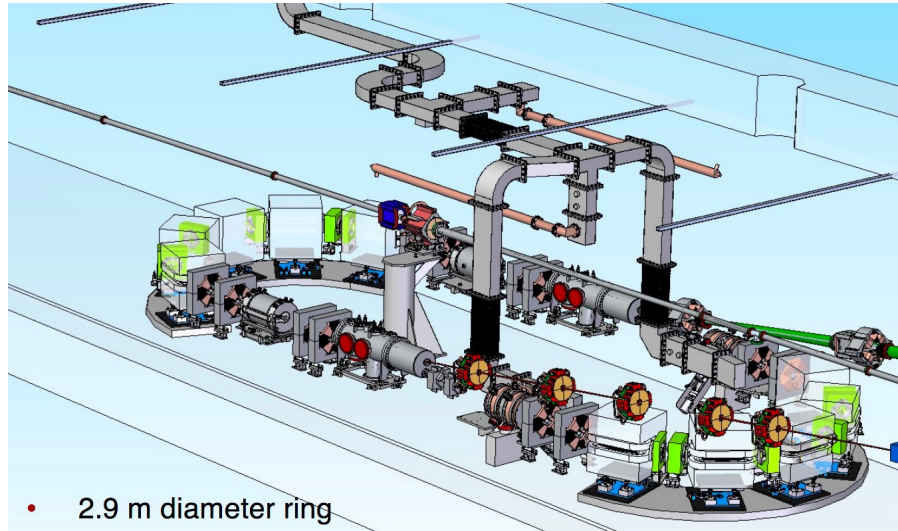


Positron Beams at FACET-II

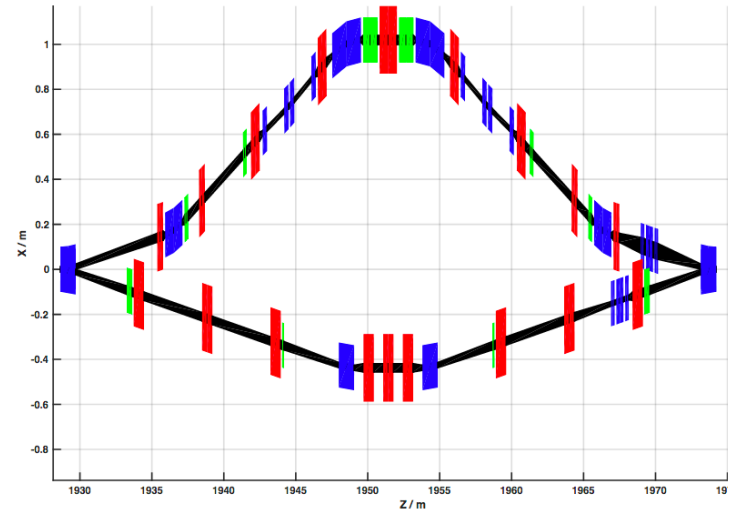


Positron Beams at FACET-II

New Positron Damping Ring



New UFO e^+/e^- Chicane



Next generation of experiments are planned for FACET-II.

- In most (all?) cases, there is no region of the wake with a uniform distribution of plasma electrons that can provide linear focusing for a positron witness bunch.
- Even if such a region existed, it would be modified by the presence of the positron witness bunch.
- Is there a strategy for tailoring the plasma and witness bunch parameters such that the net effect is uniform focusing for the witness bunch?
 - Would such a scenario be stable to perturbations?