FACET-II | Facility for Advanced Accelerator Experimental Tests

Electron Beam Driven Plasma Wakefield Acceleration (PWFA) – LOI #251

24-SEP-2020

U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

Perspective on the Status of Plasma Wakefield Acceleration Experiments

- High gradient acceleration sustained over one meter
  - 43GeV acceleration of tail particles at FFTB in 2007[1]
- Beam acceleration with high efficiency & narrow energy spread
  - 9GeV 28pC with 30% efficiency and 4% dE/E at FACET in 2014[2]
- Positron PWFA: Investigation of various techniques at FACET (2014-16)
  - Non-linear self-loaded (4GeV 200pC 2% dE/E)[3]
  - Hollow channel[4]
  - Quasi-nonlinear (2GeV 150pC)[5]
- Bright Beam generation
  - Initial studies of Density Downramp, Ionization[6], Trojan Horse[7]
- Global thermodynamics of multi-GeV plasma accelerators[8]
  - Studies of timescales for plasma response <10μsec

[1] *Nature* **445**, 741–744 (2007)
[2] *Nature* **515**, 92–95 (2014), PPCF **58** 034017 (2016)
[3] *Nature* **524**, 442–445 (2015)
[4] *Nature Communications* **7**, 11785 (2016)
[5] *Scientific Reports* **7**, 14180 (2017)
[6] *Phys. Rev. Lett.* **112**, 025001 (2014)
[7] *Nature Physics* **15**, 1156–1160 (2019)
[8] *Nature Communications* **11**, 4753 (2020)

PWFA Experimental Program at FACET-II is Motivated by Roadmap for Future Colliders Based on Advanced Accelerators

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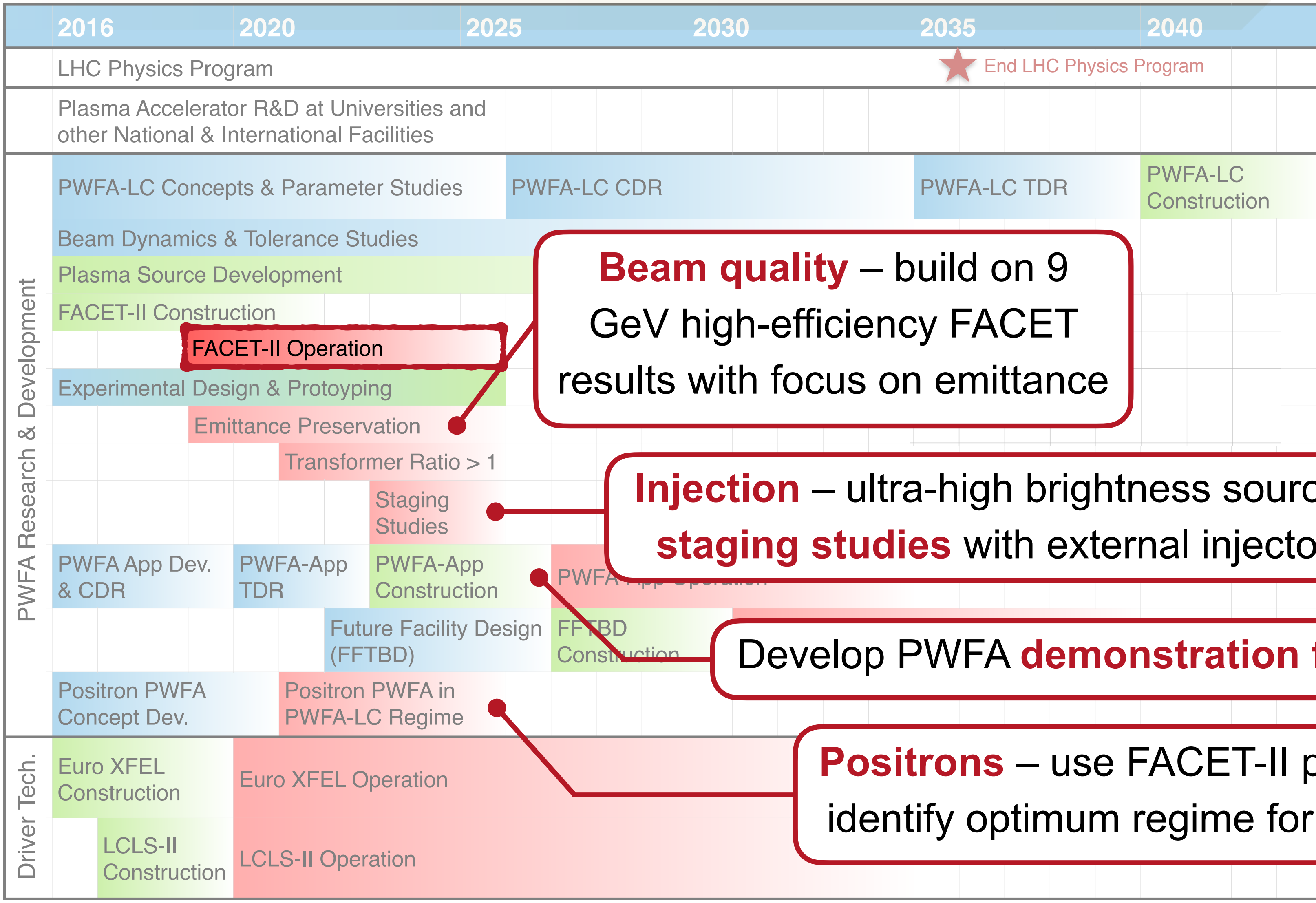
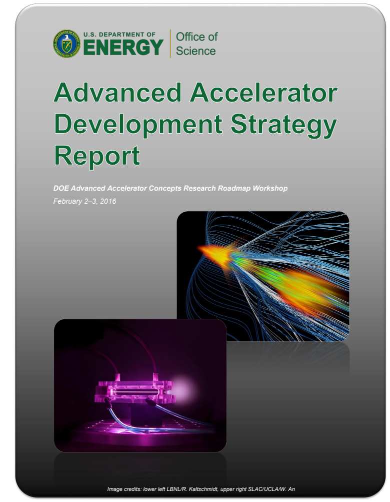


Beam quality – build on 9 GeV high-efficiency FACET results with focus on emittance

Injection – ultra-high brightness sources, **staging studies** with external injectors

Develop PWFA **demonstration facility**

Positrons – use FACET-II positron beam to identify optimum regime for positron PWFA



Experimental program over next decade will enable well informed decisions on viability of the technology

Electron Beam Plasma Wakefield Acceleration – Next 5 Years

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Beam quality

- Preserve emittance of witness bunch at few μm level
  - with high-gradient high-efficiency and depletion of drive beam energy

Injection: plasma based high brightness beam source e.g. (#179)

- Demonstrate beams beyond state of the art (photoinjector)

Develop Demonstration Facility

- Experimental program at FACET-II is expected to support developing concepts for facilities with MA beams(#37), 5th generation light source(#97), gamma source(#252)…

Positrons

- Develop concept for positron PWFA compatible with HEP collider application (ion wakes, tailored plasmas…)

PWFA-LC concept will be updated based on HEP input at Snowmass 2021 targeting afterburner and/or discovery collider

Strawman concepts guide future R&D

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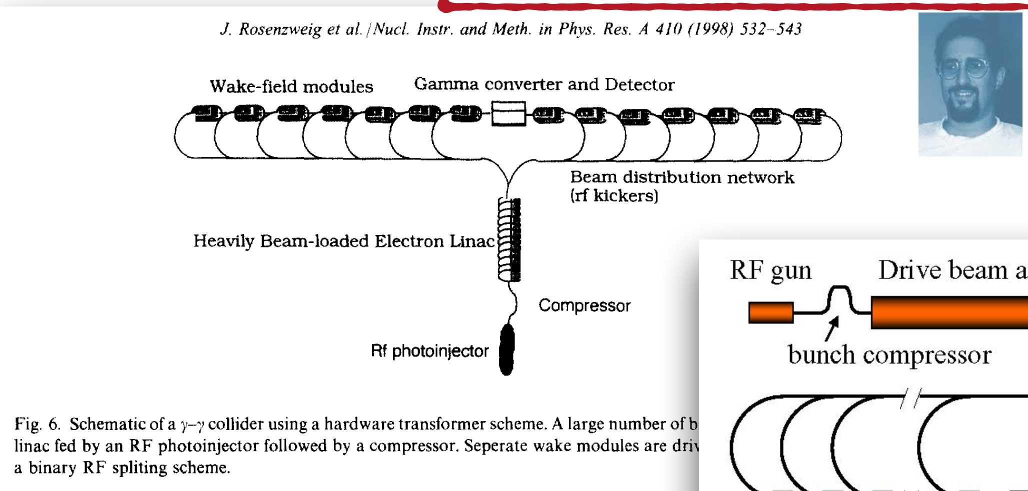
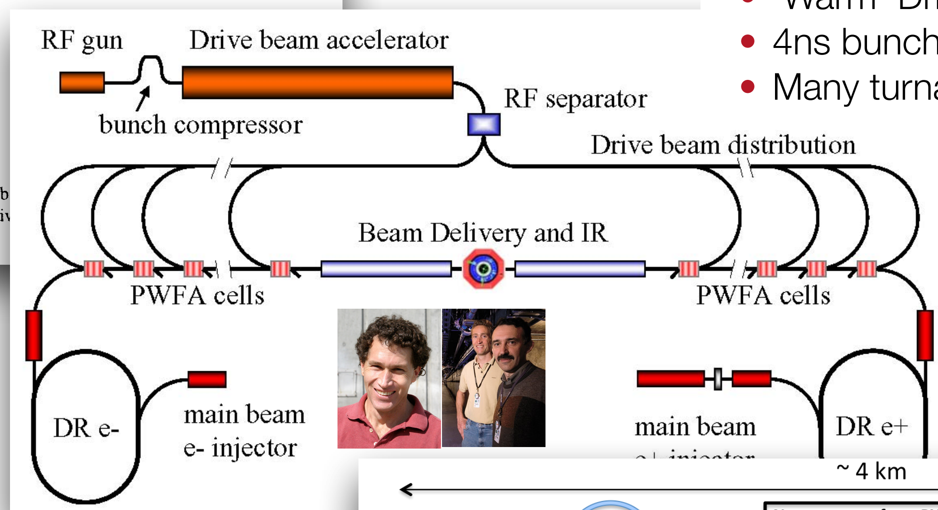


Fig. 6. Schematic of a γ–γ collider using a hardware transformer scheme. A large number of b… linac fed by an RF photoinjector followed by a compressor. Seperate wake modules are driv… a binary RF spliting scheme.

Rosenzweig *et al* (1998)

Seryi *et al* (2008) SLAC-PUB-13766

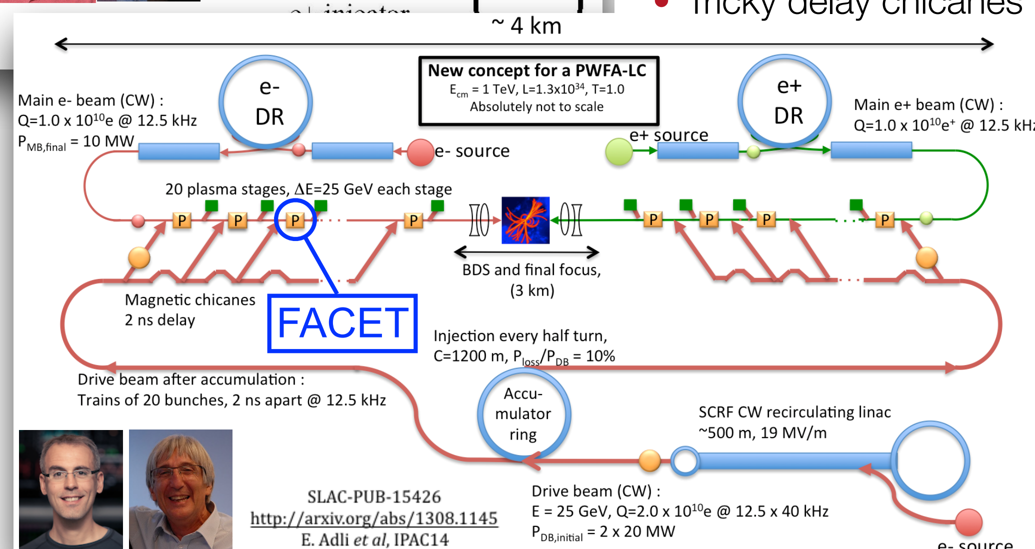
- 'Warm' Drive Linac
- 4ns bunch spacing
- Many turnarounds



Adli *et al* (2013)
SLAC-PUB-15426

- 'Cold' Drive Linac
- 100μs bunch spacing
- Tricky delay chicanes

- Assume SLC/NLC/ILC/CLIC made smart choices that we can start from for main beam and driver
- Focus on the accelerator module itself (the plasma)
- **The plasma is a transformer**
- For luminosity – Power efficiency and beam quality are critical!



Concluding Thoughts

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- Many accelerator beam physics challenges en route to a collider (and even to first applications) – see partial list 'AAC Colliders: PWFA, LWFA & SWFA' M. J. Hogan, HEP GARD ABP Workshop #2, April 2019
- US and International collaborations have proposed many exciting and challenging experiments to address key physics issues on US Roadmap – success will require theory, computation, diagnostic development and facilities to test
- Each 'Advanced Accelerator' technology has prioritized milestones but there are also many common issues:
  - Beam loading and beam shaping for narrow energy spread and high efficiency
  - Emittance preservation at μm and sub-μm levels
  - Knowledge of structure dynamics at long timescales
  - Investigations of paths to positron acceleration comparable to electrons
- Applying lessons learned to update collider designs will take community involvement and motivated/dedicated personnel with time to do so (#46, #216, #168, #88)