Advanced Accelerator Concepts: Plasma accelerators

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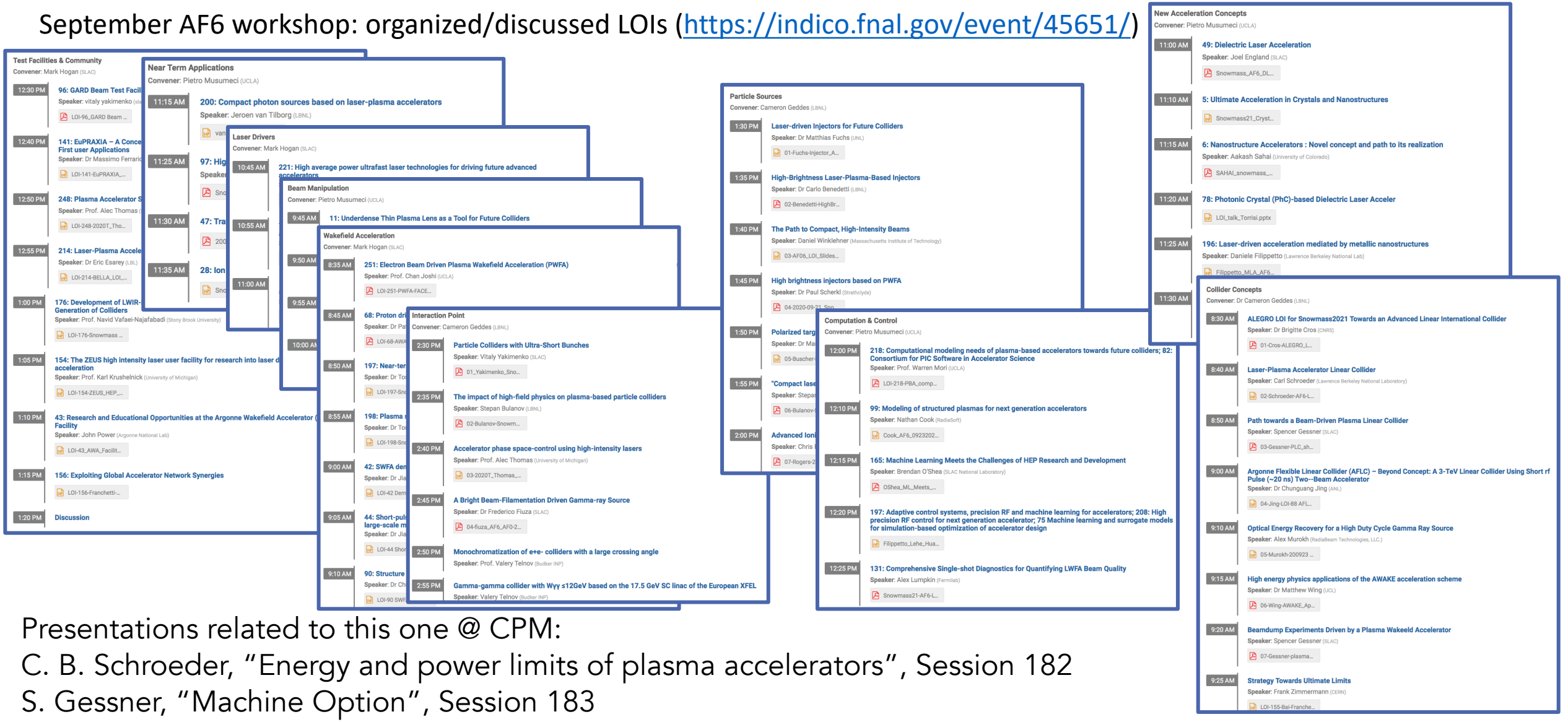
AF6: Advanced Accelerator Concepts (AAC) community is addressing the path to future plasma-based collider

September AF6 workshop: organized/discussed LOIs (https://indico.fnal.gov/event/45651/)



Presentations related to this one @ CPM:

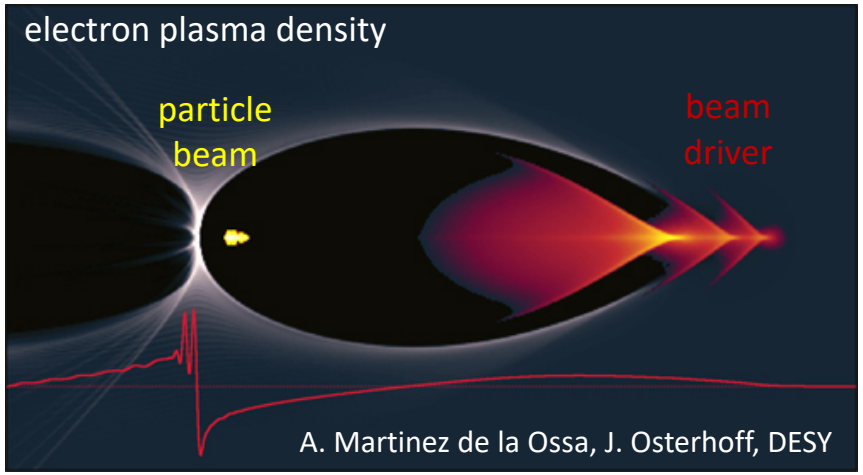
C. B. Schroeder, "Energy and power limits of plasma accelerators", Session 182

S. Gessner, "Machine Option", Session 183

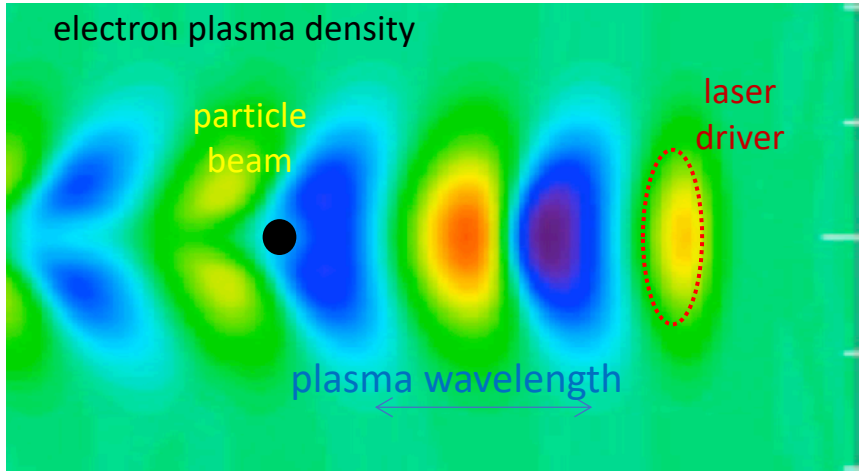
Plasma accelerators driven by intense particle beams or lasers achieve ultra-high accelerating gradients

- Plasma wave (wakefield) driven by space charge of particle beam or ponderomotive force of laser
- Focusing and acceleration provided by plasma wave
- Characteristic size of the electric field (depends on density): **10 – 100 GV/m** for 10^{16}–10^{19} cm^{-3}
- Short witness beam (a fraction of the plasma wave): $\lesssim$ 100 - $\lesssim$ 5 um for 10^{16}–10^{19} cm^{-3}

Beam-driven plasma accelerator
(in nonlinear bubble/blow-out regime)



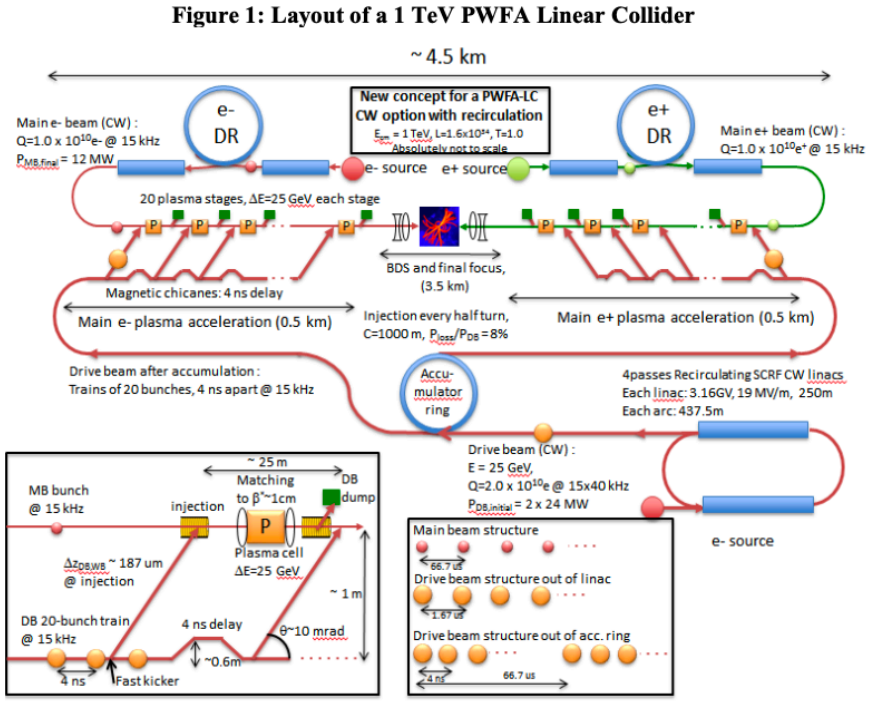
Laser-driven plasma accelerator
(in quasi-linear regime)



Plasma-based collider: staged plasma accelerators with >1 GV/m geometric gradients

- Preliminary designs (not integrated design studies) to outline a plasma collider and used to guide R&D

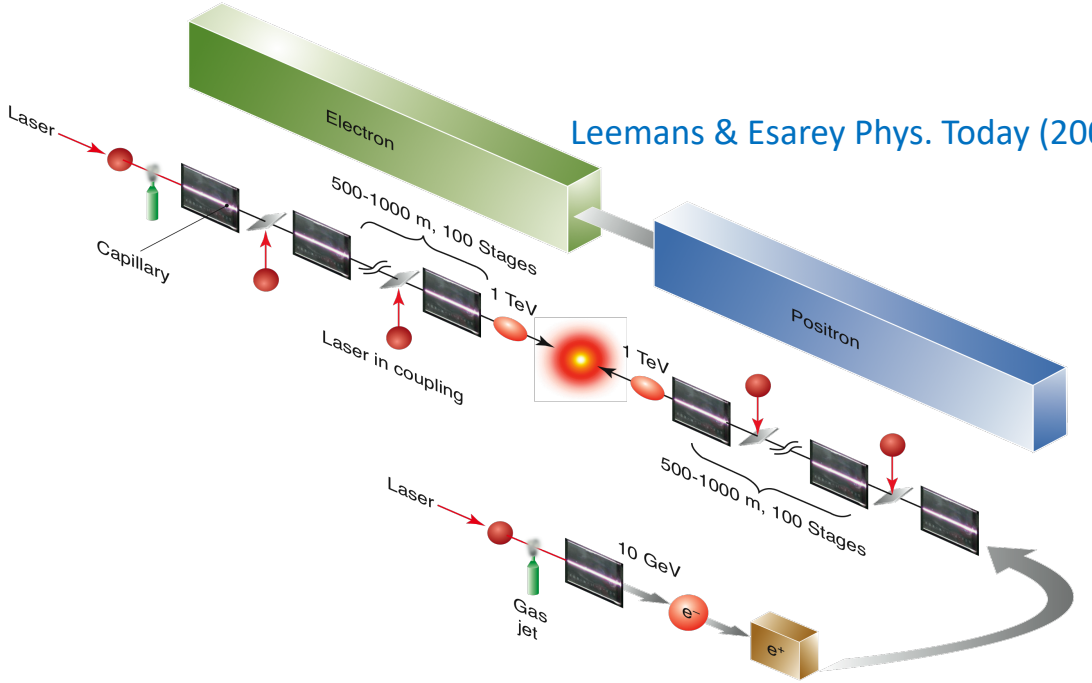
Beam-driven plasma accelerators (PWFA)



E. Adli et al., arXiv:1308.1145 (2013)

- Operating plasma density: 2×10^{16} cm^{-3}
- 25 GeV/stage
- Geometric gradient: 1 GV/m

Laser-driven plasma accelerators (LWFA)



Leemans & Esarey Phys. Today (2009)

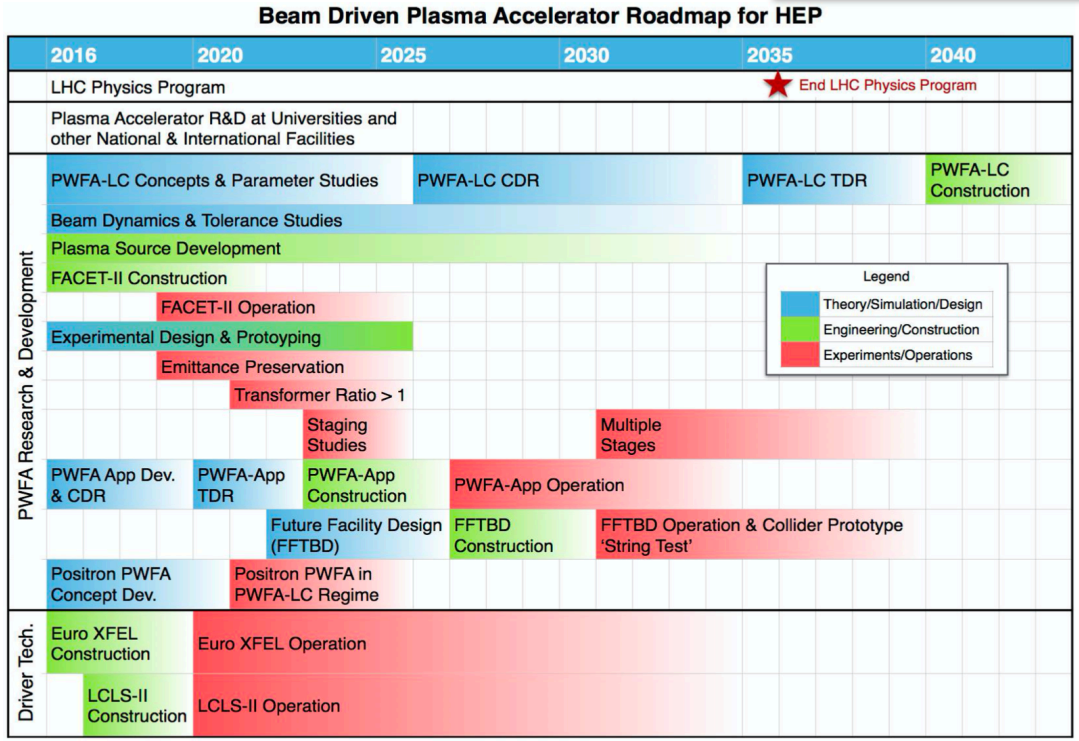
C. Schroeder et al., NIMA (2016)

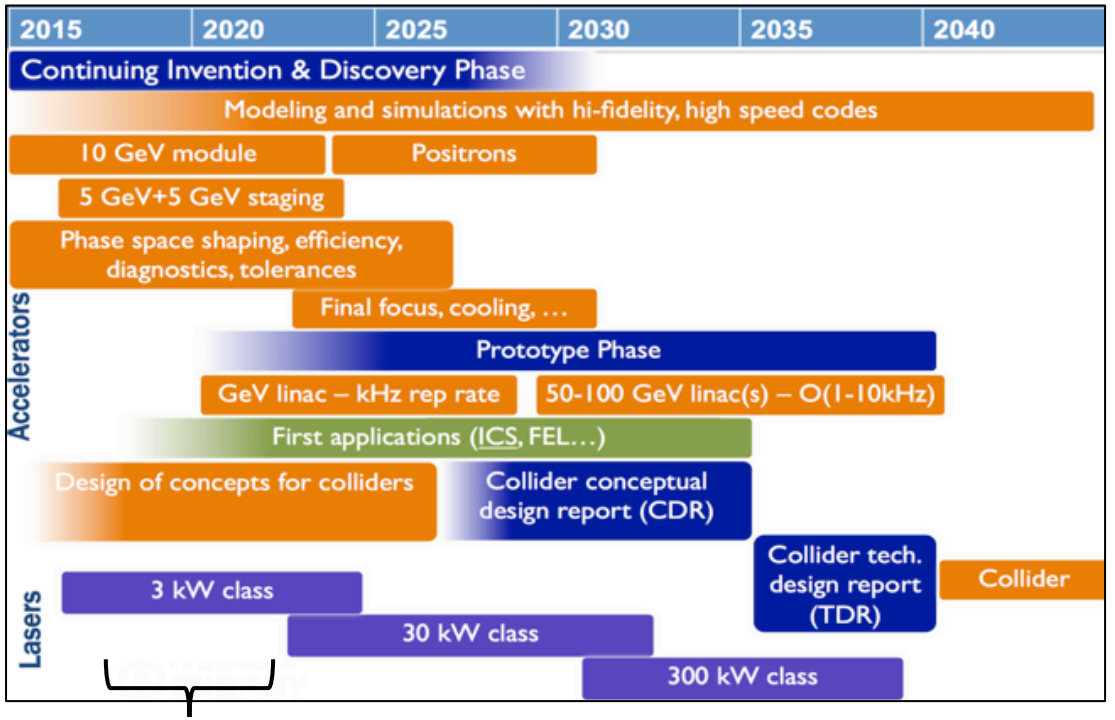
- Operating plasma density: 1×10^{17} cm^{-3}
- 5 GeV/stage
- Geometric gradient: 2.3 GV/m

DOE AAC Roadmap: R&D timeline towards a collider

- US AAC community outlined AAC R&D goals in 2016
- Significant and steady progress on all R&D goals since 2016

DOE HEP AAC Roadmap (2016)





Status and technical readiness

- Plasma accelerators
  - High geometric gradient accelerators: >1GV/m
  - e-/e+/gamma linear collider at multi-TeV, with much reduced footprint
  - Short beams in plasma accelerators yield reduced power costs: L/P ~$1/\sigma^{1/2}$

- High gradient accelerator technology has been demonstrated
  - key R&D challenges remain to be addressed for collider application: staging, beam quality-preservation, efficiency/stability, driver development, etc.

- Concepts require integrated collider design
  - Preliminary designs developed to guide accelerator R&D
  - Integrated design studies required
    - Integration of all collider sub-systems
    - Plasma-based upgrades to existing or future RF-based facilities (e.g., ILC)

- Advancing accelerator R&D in next decade toward collider requires sustained support and new/upgraded facilities:
    - kBELLA – high-rep rate (kHz) laser system; laser tech development for colliders
    - FACET-II upgrade -- positron capability

- Nearer-term applications (compact x-FEL, γ-ray sources, medical applications, etc.) are being pursued
  - Nearer-term applications are important demonstrations that will advance collider R&D