Integrated Design Study on Beam-Driven Plasma Linear Collider

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SLAC NATIONAL ACCELERATOR LABORATORY

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Path towards a Beam-Driven Plasma Linear Collider

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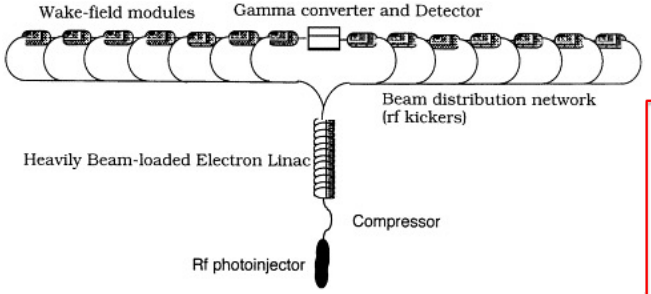
In parallel with ongoing experimental work, an integrated design study is required to inform PLC parameter choices and to compare the performance of a PLC to existing linear collider projects. Improving the maturity of the PLC concept will further guide experiments and keep the field on track with timelines proposed by the DOE [11] and ICFA [12].

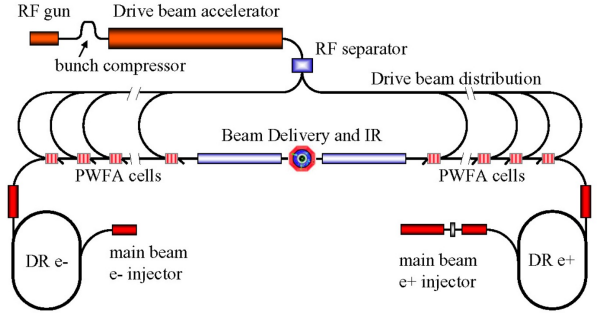
https://www.snowmass21.org/docs/files/summaries/AF/SNOWMASS21-AF6_AF4-168.pdf

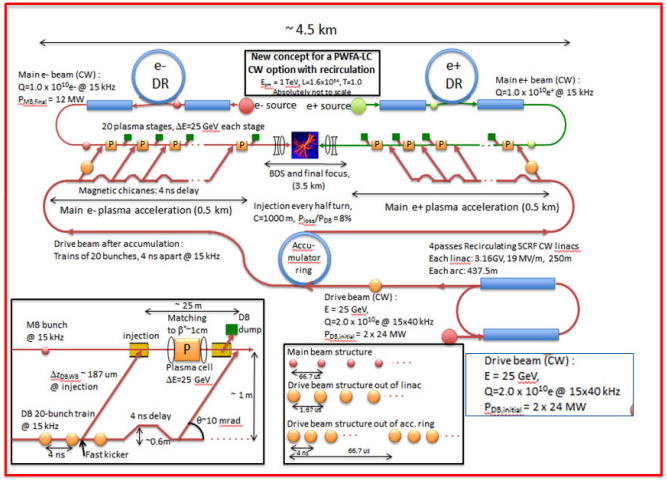
Past and Ongoing Design Efforts

J. Rosenzweig *et. al.*, NIM A 410 (1998)



A. Seryi *et. al.*, PAC WE6PFP081 (2009)





E. Adli *et. al.*, arXiv:1308.1145 [physics.acc-ph]

Table 1: Main Parameters for a 3 TeV PWFA Linear e^+e^- Collider

Parameter	Symbol [unit]	Value
Plasma density	n_0 [10^{16} cm^{-3}]	2.0
Particle number	N [10^9]	5
rms beam length	σ_z [μm]	5
Horizontal beta function at IP	β_x [mm]	5
Vertical beta function at IP	β_y [μm]	5
Normalised horizontal emittance	$\gamma\varepsilon_x$ [mm mrad]	0.887
Normalised vertical emittance	$\gamma\varepsilon_y$ [mm mrad]	0.02
Relative rms energy spread	$\sigma_\mathscr{E}/\langle\mathscr{E}\rangle$ [%]	1.1
Normalised amplification factor	Λ/Λ_0	6
Drive beam to main beam efficiency	η [%]	37.5
Beam power/beam	$P_b/(f_r n_b)$ [kWs]	1.2
Beamstrahlung photons/e^-	n_γ	2.3
Total luminosity/beam crossing	$\mathcal{L}$ [10^{35} m^{-2} bx^{-1}]	4.3
Peak 1% luminosity/beam crossing	$\mathcal{L}_{0.01}$ [10^{35} m^{-2} bx^{-1}]	1.4

J.B.B. Chen, D. Schulte, E. Adli arXiv:2009.13672

Research Roadmaps

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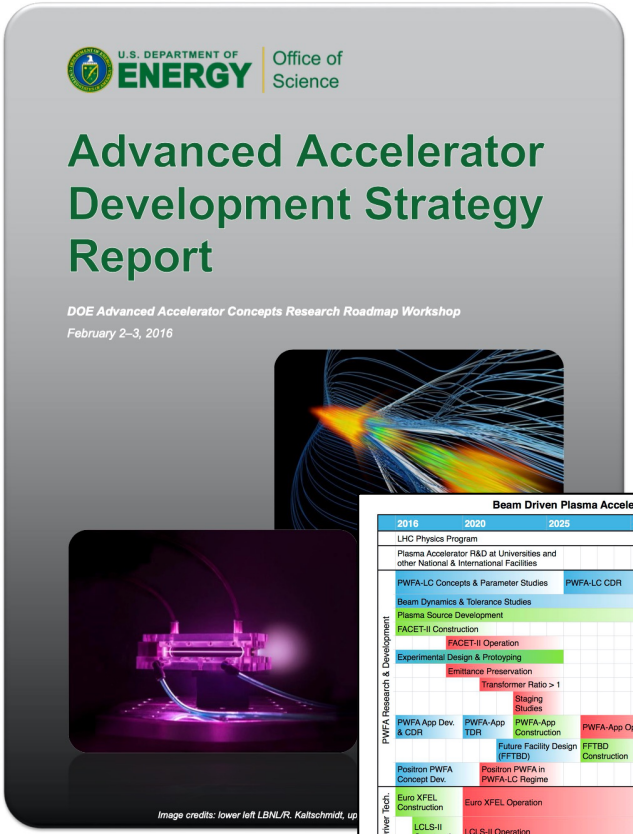
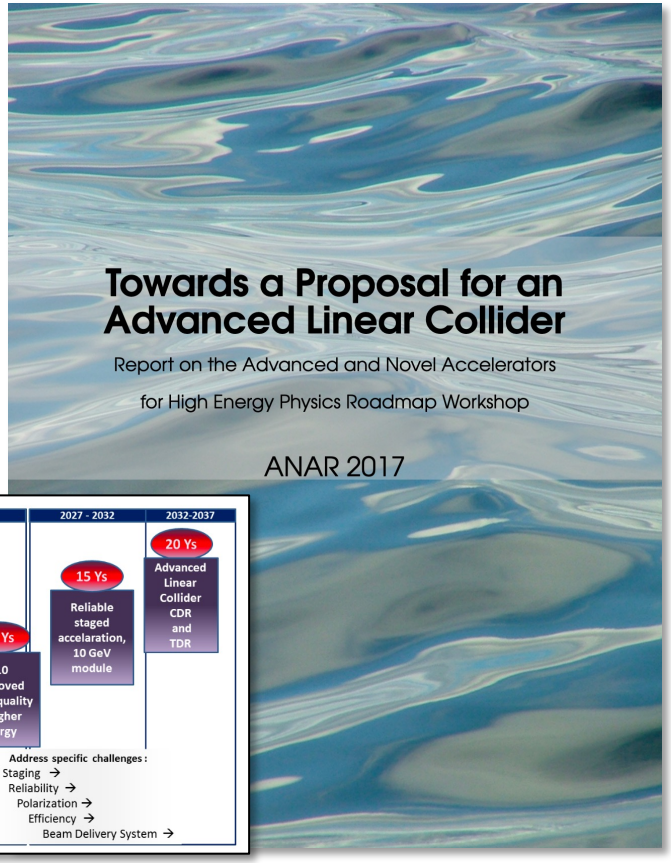
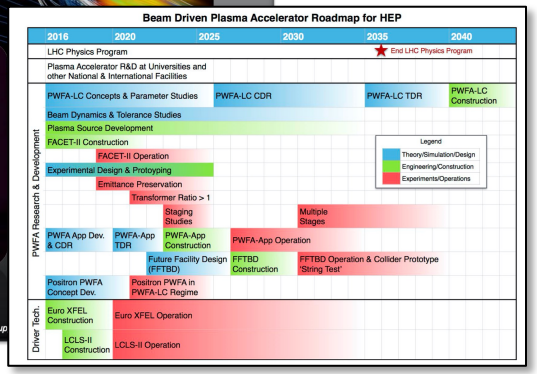
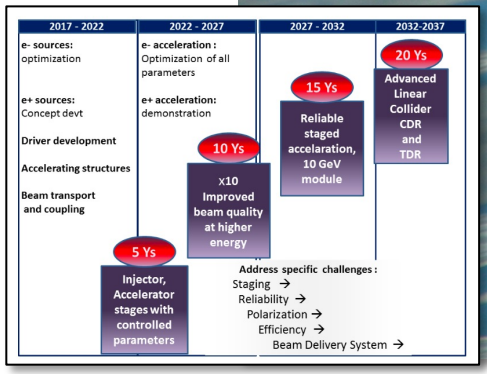


What is needed now?







Integrated Design Study

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An integrated design study is a *funded* effort to design a plasma linear collider.

Similar in scope to the Eupraxia design effort.

Considers both machine infrastructure (*facility footprint, power consumption*) and accelerator physics (*beam quality, staging, positron PWFA, beam delivery system*).

Two Perspectives on the IDS

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Bottom-Up:

- What have we demonstrated in PWFA experiments and simulation?
- What are the physics challenges? (beam quality, positrons, staging, BDS, high rep-rate)
- How can we piece these results together to form a PLC?

Top-Down:

- What is the required physics reach (energy and luminosity)?
- What are the other constraints (size, power, $$$$)?
- Is it a greenfield accelerator or a facility improvement (e.g. ILC)?

Ongoing Efforts and Next Steps

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1. As part of Snowmass, we are presenting the case for a *funded* IDS.
2. We are providing input to the Implementation Task Force.
   - The ITF has a “top-down” approach.
   - Input is in the form of LC parameter tables.
3. We formed interest groups to develop concepts for Snowmass White Papers:
   - Improved and novel Beam Delivery Systems is a vital concept for multi-TeV LCs, irrespective of accelerator technology. https://snowmass21.org/accelerator/advanced/start#white_paper_coordination
   - Can PWFA extend the reach of the ILC? https://agenda.linearcollider.org/event/9135/overview

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?
   - **Improved BDS design helps all LC concepts, independent of acc.**
4. What is the role of your work here?
   - **Define “top-down” constraints on the PLC.**
   - **Close credibility gap with conv. acc. community.**
   - **Present case for funding design study.**

Questions 2

1. What are the important milestones for the next 10 years?
   - **Positrons (next 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.**