The impact of high-field physics on plasma-based particle colliders

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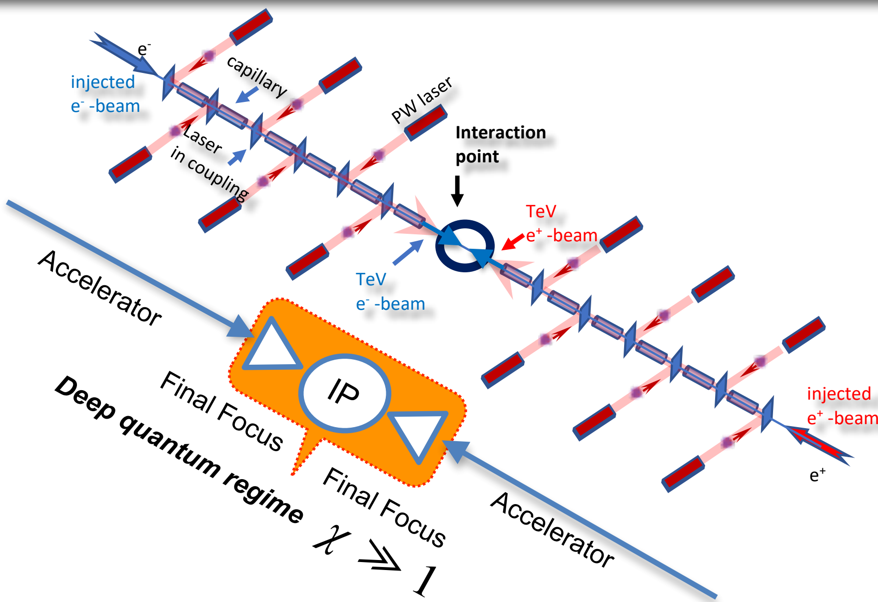
Final focusing and subsequent beam behavior at the interaction point of a plasma-based lepton collider received relatively little attention



The physics associated with high-field phenomena in this deep quantum regime is at present poorly understood and requires new theoretical developments. The theory addressing them, *Strong Field Quantum Electrodynamics* (SFQED), thus needs to be updated or generalized.

Current status of SFQED studies:

Theory and Simulations: Significant progress achieved in understanding high-field phenomena, mostly in the domain of laser plasma interactions.
Experiments (Laser - e-beam): E144 (SLAC, 1997), 2 at Astra Gemini (CLF, 2018), planned: LUXE (DESY), E320 (SLAC).

Theory developments in the non-perturbative regime.

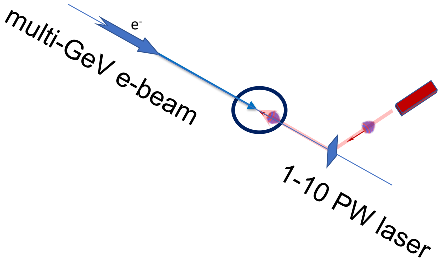
Studies will need to go beyond:
(i) simple approximations of the geometry of strong fields
(ii) limited 'locally constant field' approximations used in numerical simulations
(iii) the external field approximation itself

A new non-perturbative formulation (an exact theory of the interaction with the radiation field) may be required in order to understand and control non-perturbative effects, and, thus, properly analyze *beamstrahlung, cascades, and beam disruption* at the interaction point of future colliders.

Plasma based collider can easily be made multi-purpose with minimal adjustments to the collider configuration, allowing for more general studies at the same location

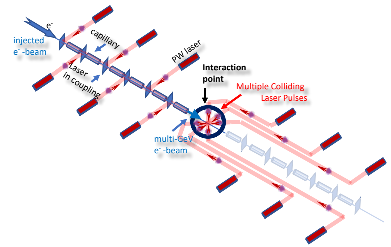
Near term goals:

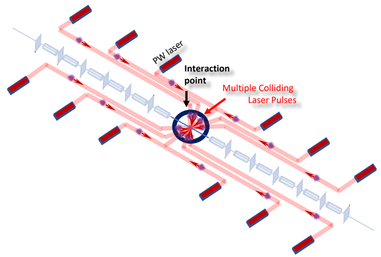
Theory and simulation development should be accompanied by ultra-high intensity laser experiments relevant to high energy physics studies in terms final focusing and interaction point design at existing and next generation laser facilities



SFQED at a plasma based lepton collider:

high-multiplicity cascades, spin-polarized high energy lepton beams, high energy photon sources, and prototype $\gamma\gamma$ colliders, and nonlinear vacuum polarization.





Conclusions:

- Extensive R&D is required for the design of its final focus and interaction point taking the effects of Strong Field QED into account.

- A dedicated research program including interdisciplinary and international collaboration is needed to
  1. develop new approaches for theoretical and numerical studies of high field phenomena
  2. design a new class of ultra-high intensity laser experiments analyzing the outlined development of the Strong Field QED theory in preparation of future collider studies
  3. explore compact set-ups for transporting electron and positron beams to the interaction point.