By colliding the FACET-II 10 GeV electron beam with 10 TW-class laser pulses the so-called critical (Schwinger) field will be explored at SLAC [1]. In this regime the QED vacuum becomes unstable with respect to electron-positron pair production and photon emission disrupts classical trajectories [2].

Laser-based strong-field QED experiments are characterized by two main parameters: the quantum parameter $\chi = E^*/E_{cr}$, which measures the magnitude of the electromagnetic field $E^*$ in the electron/positron rest-frame in units of the critical (Schwinger) field $E_{cr} = m^2 c^3/(\hbar e) \approx 1.3 \times 10^{18}$ V/m and the classical intensity parameter (reduced vector potential) $a_0 = eE/(m\omega c)$, which measures the classical energy transfer over a laser wavelength in units of the electron rest energy ($E$ and $\omega$ denote the peak field strength and central angular frequency of the laser, respectively).

Already with the baseline design ($\chi \sim 1$, $a_0 \sim 10$) FACET-II will be able to observe vacuum breakdown in locally constant fields, highly nonperturbative Compton scattering, the breakdown of the so-called local constant field approximation (LCFA) used in numerical codes, and clear signatures of quantum radiation reaction, e.g., stochasticity and a breakdown of the classical Landau-Lifshitz (LL) description [1].

By upgrading the laser to the 100 TW -1 PW scale and by employing plasma-wakefield-based energy doubling (25 GeV electron beam), CLIC parameters will become accessible ($\chi \sim 10$). In particular, one could measure quantum suppression of beamstrahlung, study vacuum birefringence/dichroism, induce a multi-stage QED cascade and thus produce an electron-positron pair plasma. A laser upgrade to the 10 -30 PW scale would facilitate $a_0 \gtrsim 200$ and thus muon pair production via electron-positron recollisions. Notably, $\chi \sim 100$ would be attainable with a 50 GeV electron beam. In this regime $\alpha \chi^{2/3} \sim 0.1$, which implies that radiative corrections have a significant influence (dynamically induced photon mass $m_\gamma \sim 0.1m$) [3].

Finally, a future 100 GeV-class high-luminosity lepton collider could enter the regime $\alpha \chi^{2/3} \gtrsim 1$, where according to the Ritus-Narozhny conjecture QED becomes a strongly coupled quantum field theory similar to QCD at low energies [4,5].

**Fig. 1:** Parameters achievable at SLAC with the following laser/electron beam combination: 100 TW + 10 GeV (black), 1 PW + 25 GeV (red), 10 PW + 25 GeV (orange), 20 PW + 50 GeV (yellow). Electron energies 20 – 30 GeV are achievable either by combining two thirds of the SLAC linac or by employing a PWFA afterburner at FACET-II.

### References


