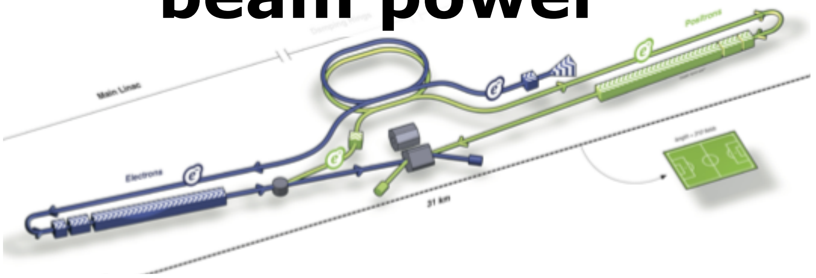
Short Bunches to Enable Qualitatively New Physics

SLAC

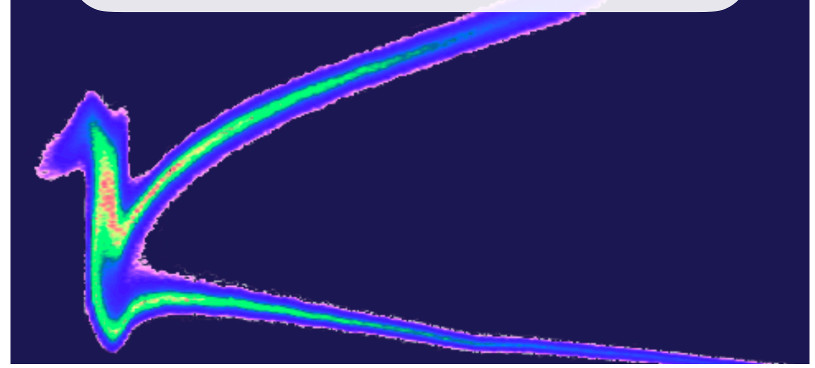
HEP collider with low beam power



Short bunches -> beamstrahlung suppressed -> round beams at IP -> ≳100x reduction in beam & wall power / backgrounds / activation / cost $\sigma_z \sim 1\ \mu m @ 1\ TeV$

R. Blankenbecler, S. Drell, PRD 36, 277 (1987)

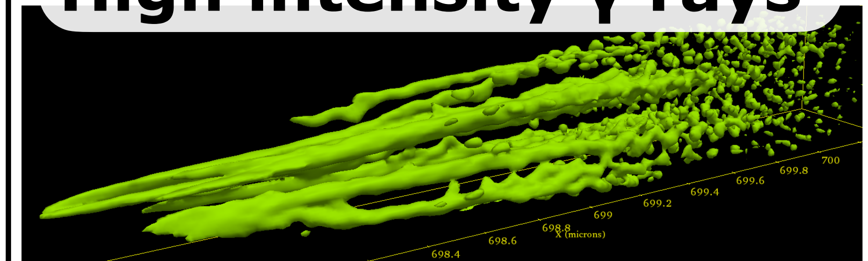
Single spike FEL



X-ray pulse has single spike when radiation emitted by the electrons in beam tail, travels to beam head in time shorter than few gain times $\sigma_z \sim 0.1\ \mu m @ 10\ GeV$

R. Bonifacio et al. PRL 73, 70 (1994)

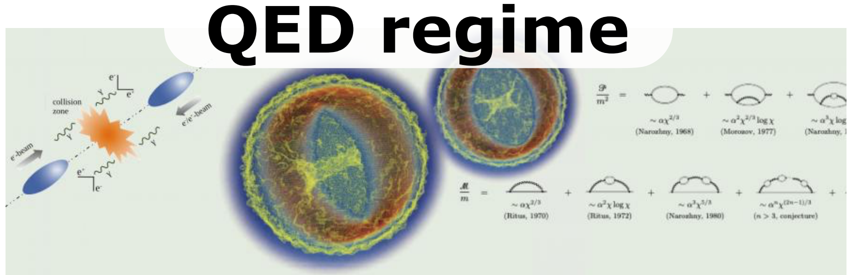
High intensity γ rays



- Counter-streaming beam and plasma electrons result in instability and form self-generated beam filaments and EM fields.
- Trajectories of the beam electrons are bent in these fields and synchrotron radiation is emitted $\sigma_z \sim 0.5\ \mu m @ 10\ GeV$

A. Benedetti et al. Nature Photon. 12, 319 (2018)

Fully non-perturbative QED regime



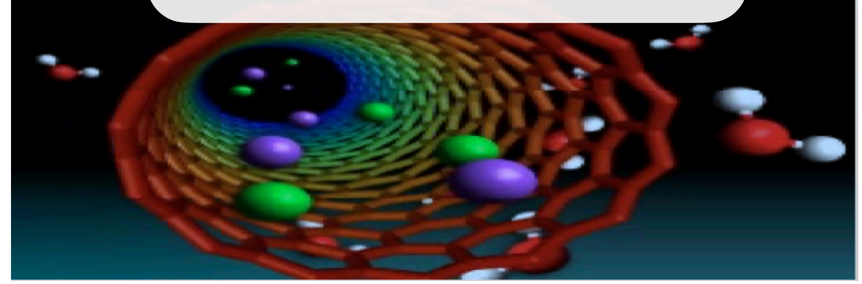
Key challenge: radiative energy loss in field transition (if $\chi \gtrsim 1$) prevents reaching $\chi \gg 1,\ \alpha\chi^{2/3} > 1$

Radiation probability: $W \sim \alpha\chi^{2/3}\frac{\sigma_z/\gamma}{\lambda\!\!\!^{-}_c} < 1$

$\sigma_z \sim 0.1\ \mu m @ 100\ GeV$

V. Yakimenko, et.al. PRL 122, 190404 (2019)

TV/m in Crystals and Nanostructures



Acceleration in solid-state plasma of crystals or nanostructures has promise of ultra-high accelerating gradients 1-10 TeV/m, continuous focusing and small emittances

$\sigma_z \sim 0.3\ \mu m @ 10\ GeV$

T. Tajima, et.al. PRL 59,1440 (1987)

Beam Physics Advancement

The research problems associated with generation and acceleration of extremely short and intense beams are fundamental and difficult, requiring sustained in-depth efforts and acceptance of greater uncertainty of the outcome.