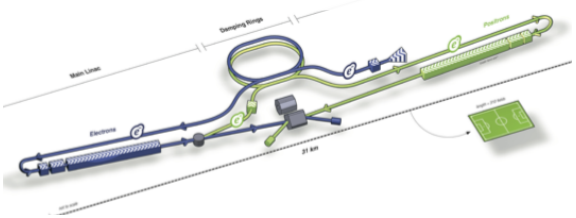
Developing new technologies for next-generation research facilities

SLAC

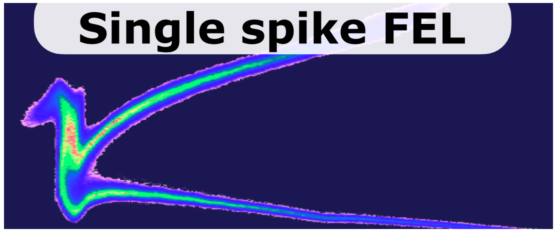
Future HEP collider



Alternative beamstrahlung mitigation strategy based on short, round beams: 100x reduction in beam power and thus costs $\sigma_z \sim 1\ \mu m @ 1\ TeV$

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

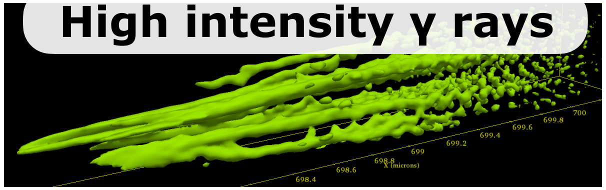
Single spike FEL



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 strong EM fields.
- Convert joule-level electron-beam energy into gamma-rays via plasma instabilities

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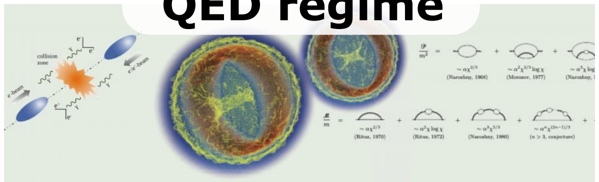
A. Benedetti et al. Nature Photon. 12, 319 (2018)

Fully non-perturbative QED regime



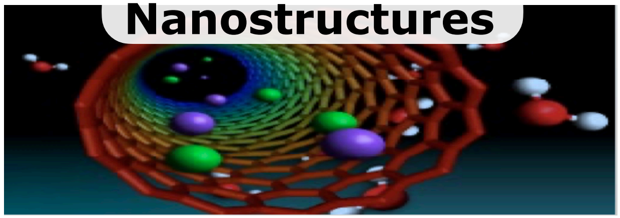
- Beam-beam collisions of short bunches can create the largest EM fields in the universe
- Access the regime where dynamical mass generation becomes dominant over the Higgs mechanism $\sigma_z \sim 0.1\ \mu m @ 100\ GeV$

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

Beam Physics Advancement

- Disruptive progress in accelerator technology is required in order to advance high energy physics
- Ultra-short, high-intensity beams promise to facilitate seminal research opportunities far beyond HEP
- The benefit of these opportunities outweigh the greater uncertainties associated with handling beams with such extreme parameters

TV/m in Crystals and Nanostructures



Acceleration in plasmas created from crystals and nanostructures facilitate extreme gradients, continuous focusing – the properties needed for producing high-quality, high-energy beams

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

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

Ultra-Short Bunches to Enable Qualitatively New Physics

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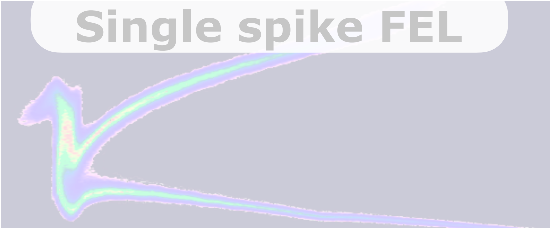

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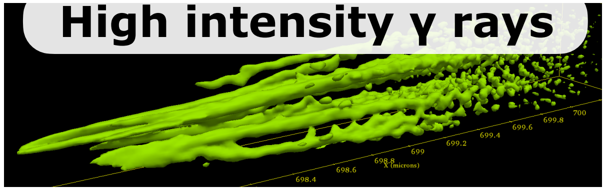

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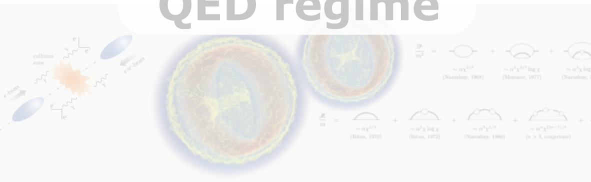

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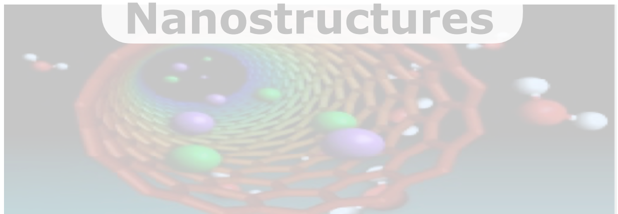

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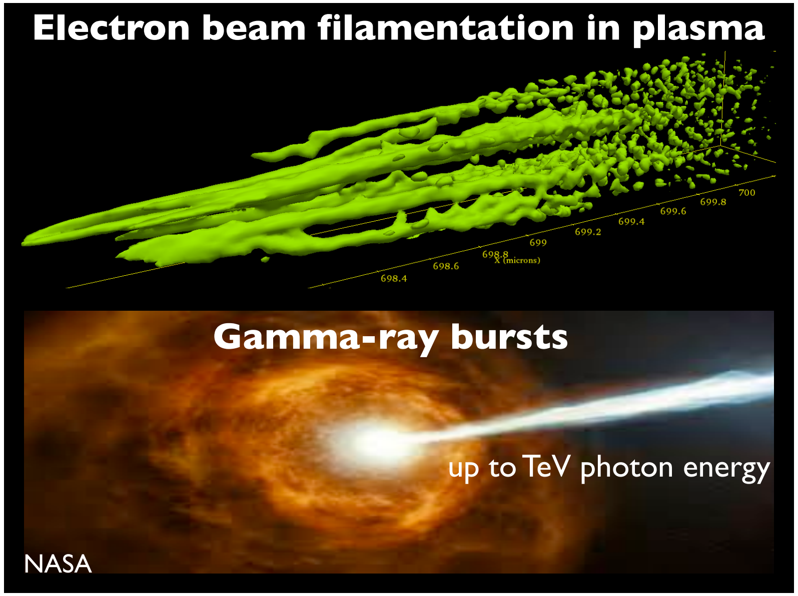
Ultra-Short Bunches to Enable Qualitatively New Physics

From γ-ray bursts to compact ultrabright light sources

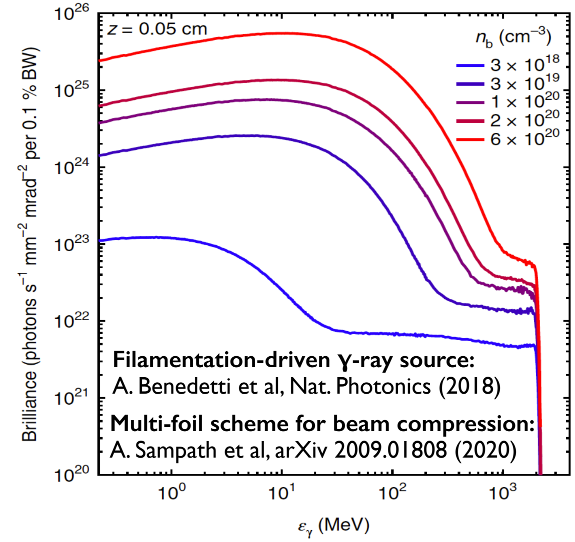
F. Fiuza, S. Gessner, M. Hogan, A. Marinelli, B. O'Shea, V. Yakimenko (SLAC), K. Marsh, W. Mori, C. Joshi (UCLA), S. Corde (LOA), M. Litos, J. Cary (CU Boulder), N. Vafaei-Najafabadi (SBU), L. Gremillet, X. Davoine (CEA), M. Tamburini, C. H. Keitel (MPI)

SLAC



- When e-beam propagates through a plasma, an e^- return current is established in the plasma
- The counter-streaming e-beam and return currents result in filamentation instability that exponentially amplifies EM fields
- Electrons wiggle in these fields producing strong synchrotron emission
- Same instabilities are thought to control the brightest radiation emission events in the Universe

A γ-ray source of unprecedented efficiency and brightness



- Synchrotrons and FELs revolutionized light sources but are limited to 100s keV
- Multi-GeV, nC, highly compressed ($n_b \sim 10^{21}$ cm^{-3}) e-beam can produce unprecedented γ-ray brilliance via filamentation over only a few mm of plasma
- Proof-of-concept experiment E-305 planned at FACET-II
- Potential to drive next generation light sources with strong impact from nuclear physics to high-energy physics

R&D of stable high-density e-beams can drive next-gen γ-ray light source