Proposal for a new experiment using a Laser and XFEL to test quantum physics in the strong-field regime

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COLLIDING HIGH ENERGY PHOTONS/ELECTRONS WITH INTENSE LASER

17 GeV electrons from LINAC of European XFEL

Goal: Probe quantum physics in novel regime
• Observe transition from perturbative to non-perturbative regime
• Compare with calculations

Letter of Intent for the LUXE Experiment

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Released on Sept. 2nd 2019
arXiv:1909.00860

36 scientists
12 institutes
4 countries
(+several new institutes since LOI)
High energy electron or photon interacts with laser
- Also higher order process $e^- + n\omega_L \rightarrow e^- e^+ e^-$
- Observed by E144 experiment in perturbative regime
Quantum parameters:
\[\chi_e = (1 + \cos \theta) \frac{E_e \mathcal{E}_L}{m_e \mathcal{E}_{cr}}\]
\[\chi_\gamma = (1 + \cos \theta) \frac{E_\gamma \mathcal{E}_L}{m_e \mathcal{E}_{cr}}\]

Intensity parameter:
\[\xi = \sqrt{4\pi \alpha} \left( \frac{\mathcal{E}_L}{\omega L m_e} \right) = \frac{m_e \mathcal{E}_L}{\omega L \mathcal{E}_{cr}}\]

Planning laser for upgrade to 300 TW from start
• **Prediction for rate of positrons per laser shot**

\[ \xi \ll 1: \quad R_{e^+} \propto \xi^{2n} \propto I^n \]  

- Perturbative regime: strong rise, follows power-law

\[ \xi \gg 1: \quad R_{e^+} \propto \chi_\gamma \exp \left( -\frac{8}{3\chi_\gamma} \right) \]  

- Non-perturbative regime: departure from power-law
• Detection of electrons, positrons and photons
• System of silicon pixel tracking, silicon tungsten calorimeters and Cherenkov detectors
• Particle fluxes vary between $\sim 0.01$ and $10^9$ per laser shot!

TWO RUNNING MODES OF LUXE
Example for possible result of experiment

Low laser intensity
• Encounter power-law behaviour

High intensity
• Should observe deviation from power-law behaviour
• Aim to quantify by extracting coefficient
CONCLUSIONS

• LUXE will boil the vacuum using a minute fraction of European XFEL electron beam
  • Measure several phenomena predicted more than 60 years ago
  • Test quantum field theory in a new regime
• International collaboration of performed feasibility study
  • “Letter of Intent” released in September 2019
  • Currently preparing Conceptual Design Report
• Only possible in synergy between accelerator, laser and particle physicists

S. Weinberg: “My advice is to try crazy ideas and innovative experiments. Something will come up.”