



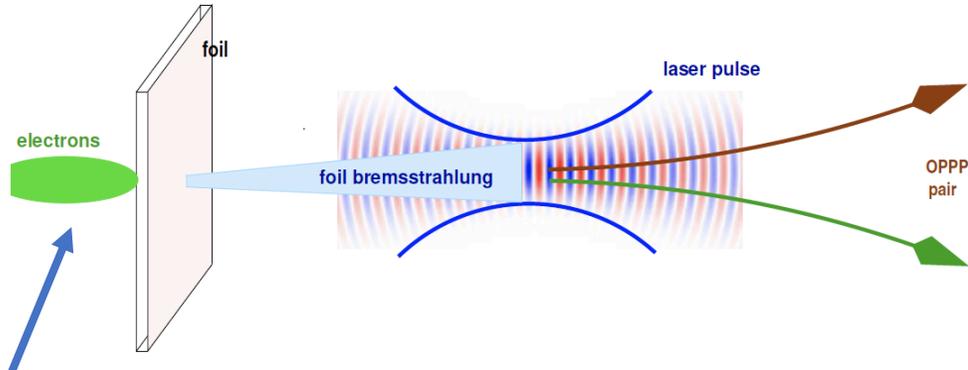
LUXE

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

Beate Heinemann (DESY and University of Freiburg)

Snowmass Meeting, October 7th 2020





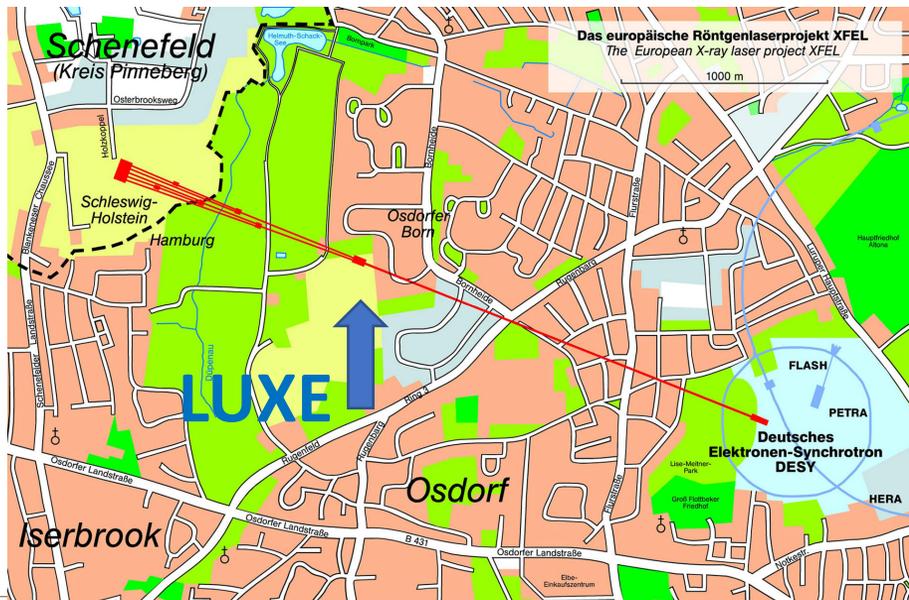
Letter of Intent for the LUXE Experiment

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Released on Sept. 2nd 2019
arXiv:1909.00860

36 scientists
12 institutes
4 countries
(+several new institutes since LOI)

17 GeV electrons from LINAC of European XFEL



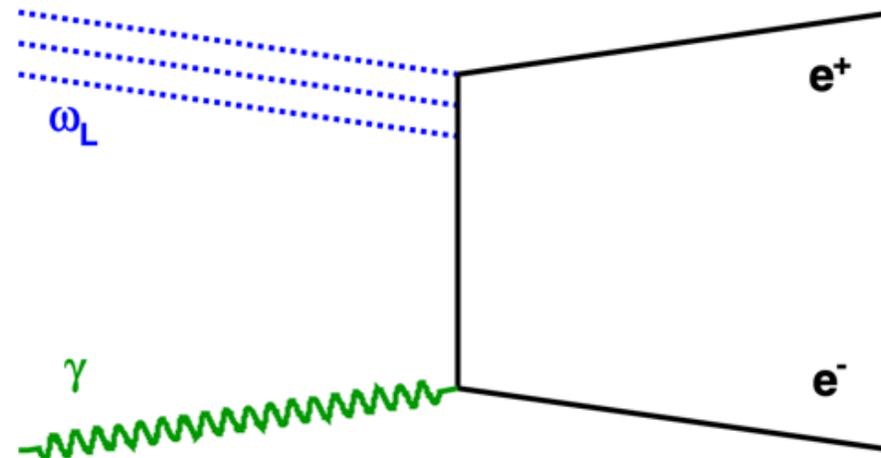
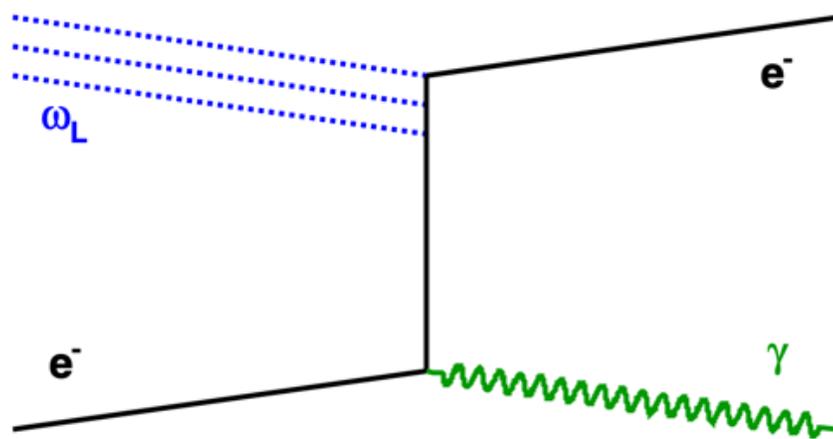
- Goal: Probe quantum physics in novel regime
- Observe transition from perturbative to non-perturbative regime
 - Compare with calculations

MAIN PROCESSES OF INTEREST

$$e^- + n\omega_L \rightarrow e^- + \gamma$$

$$\gamma + n\omega_L \rightarrow e^+ e^-$$

Low-energy photons
from laser

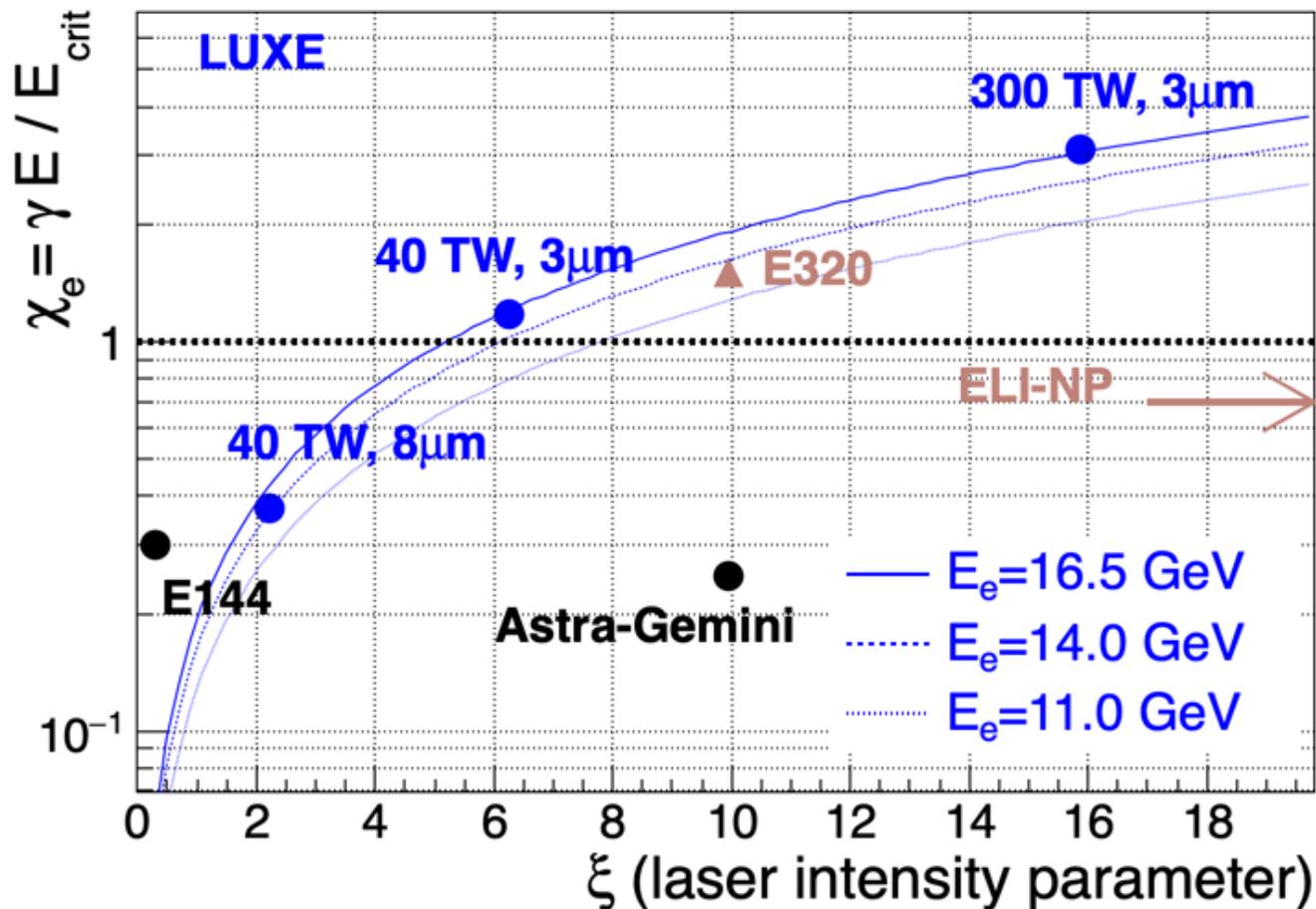


High energy electron or photon interacts with laser

- Also higher order process $e^- + n\omega_L \rightarrow e^- e^+ e^-$
- Observed by E144 experiment in perturbative regime



PARAMETER SPACE



Intensity parameter:

$$\xi = \sqrt{4\pi\alpha} \left(\frac{\varepsilon_L}{\omega_L m_e} \right) = \frac{m_e \varepsilon_L}{\omega_L \varepsilon_{cr}}$$

Quantum parameters:

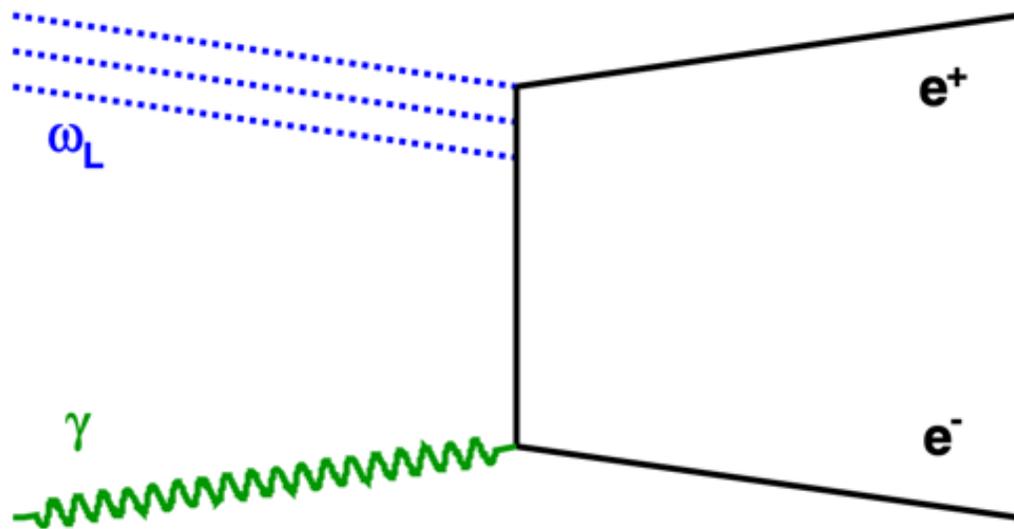
$$\chi_e = (1 + \cos \theta) \frac{E_e}{m_e} \frac{\varepsilon_L}{\varepsilon_{cr}}$$

$$\chi_\gamma = (1 + \cos \theta) \frac{E_\gamma}{m_e} \frac{\varepsilon_L}{\varepsilon_{cr}}$$

Planning laser for upgrade to 300 TW from start

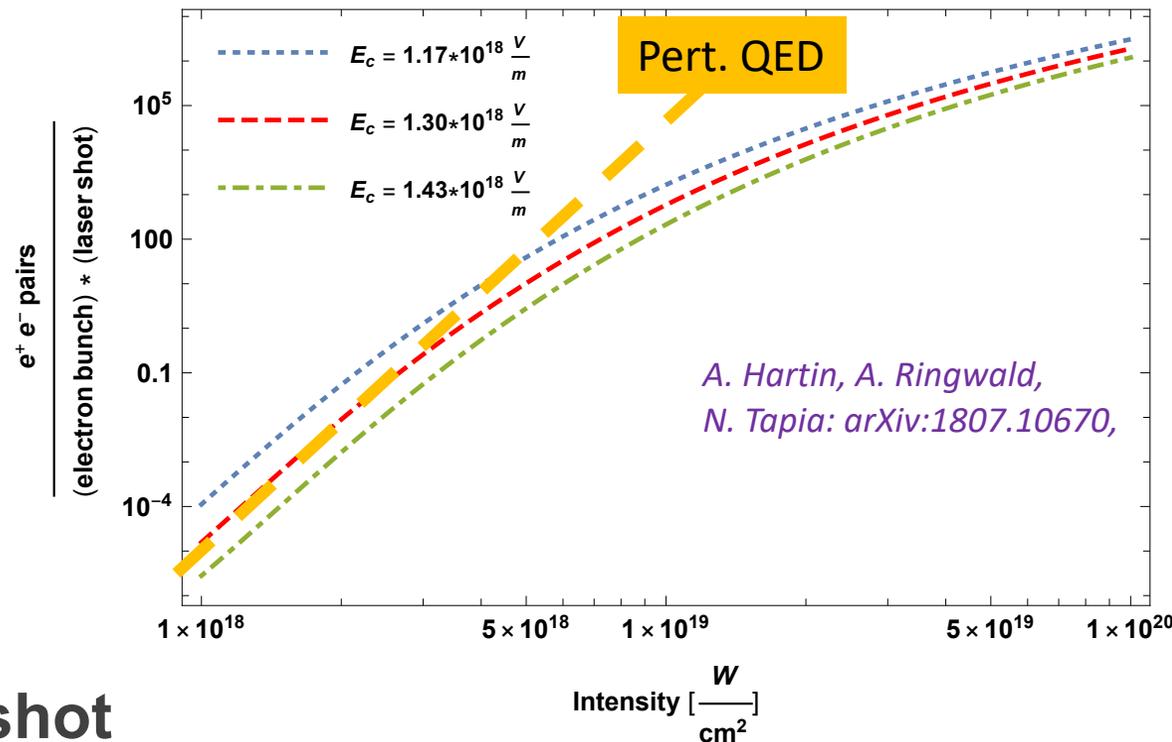
ABSORBING LIGHT WITH LIGHT

Low-energy photons from laser



High-energy (relativistic) photon

$$E_e = 17.5 \text{ GeV}, \quad e^- \text{ b.} = 6 \times 10^9, \quad \frac{X}{X_0} = 0.01, \quad L. \text{ s.} = 35 \text{ fs}, \quad \theta = \frac{\pi}{12}, \quad w = 1.053 \text{ eV}$$



• Prediction for rate of positrons per laser shot

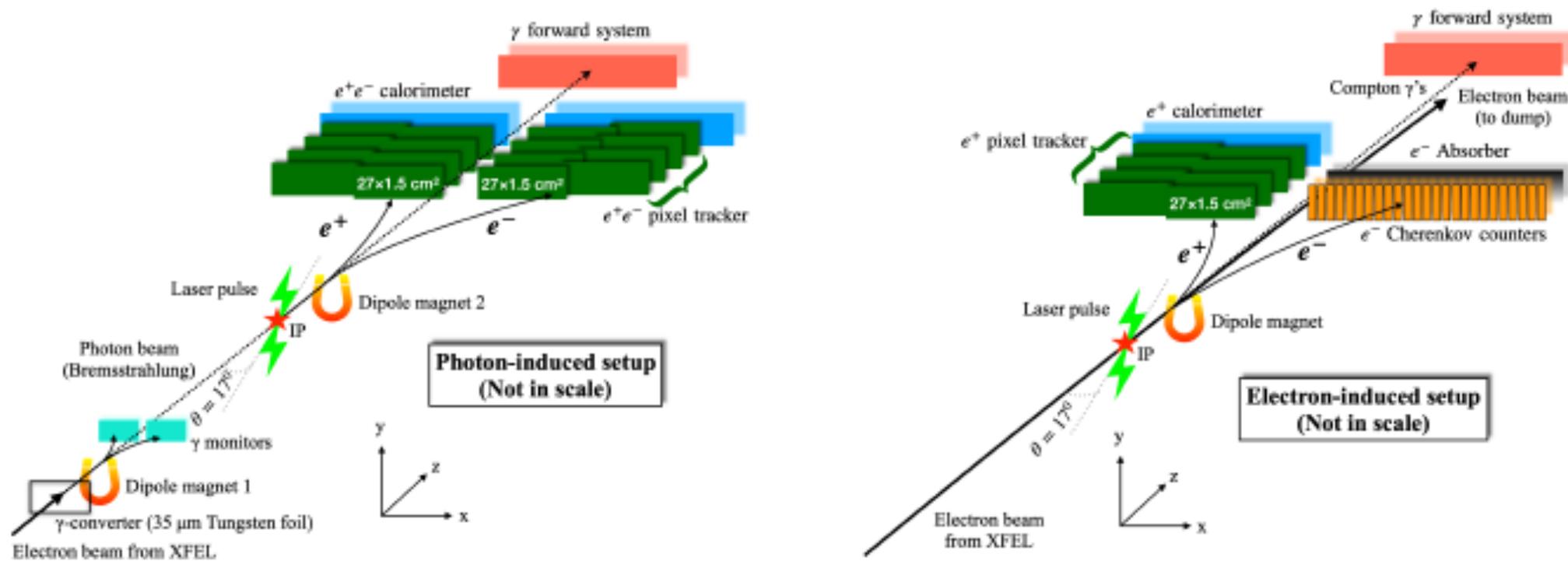
$$\xi \ll 1: R_{e^+} \propto \xi^{2n} \propto I^n$$

➡ Perturbative regime: strong rise, follows power-law

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

➡ Non-perturbative regime: departure from power-law

TWO RUNNING MODES OF LUXE



- Detection of electrons, positrons and photons
- System of silicon pixel tracking, silicon tungsten calorimeters and Cherenkov detectors
- Particle fluxes vary between ~ 0.01 and 10^9 per laser shot!

POSITRON RATE VS LASER INTENSITY

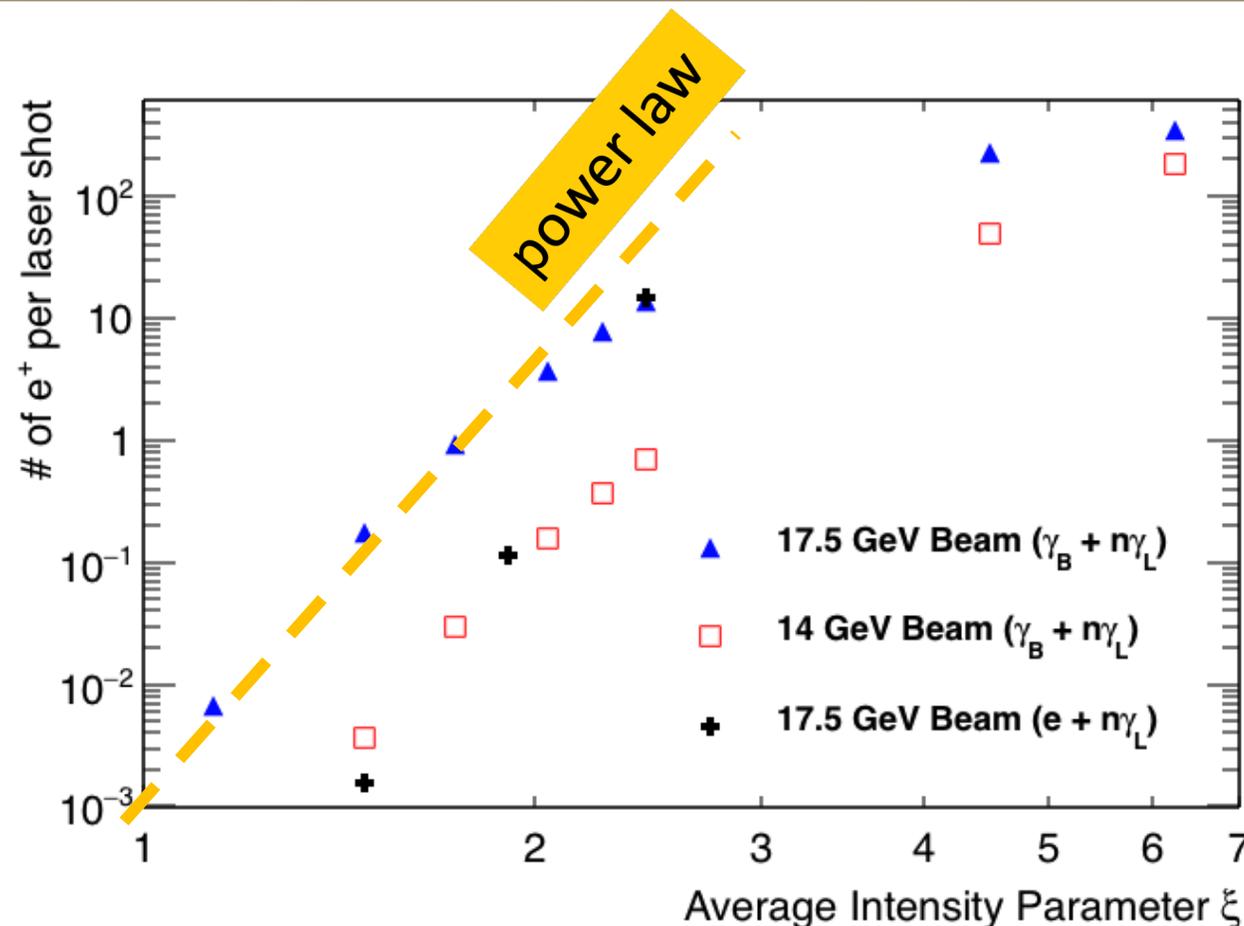
Example for possible result of experiment

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.”*

