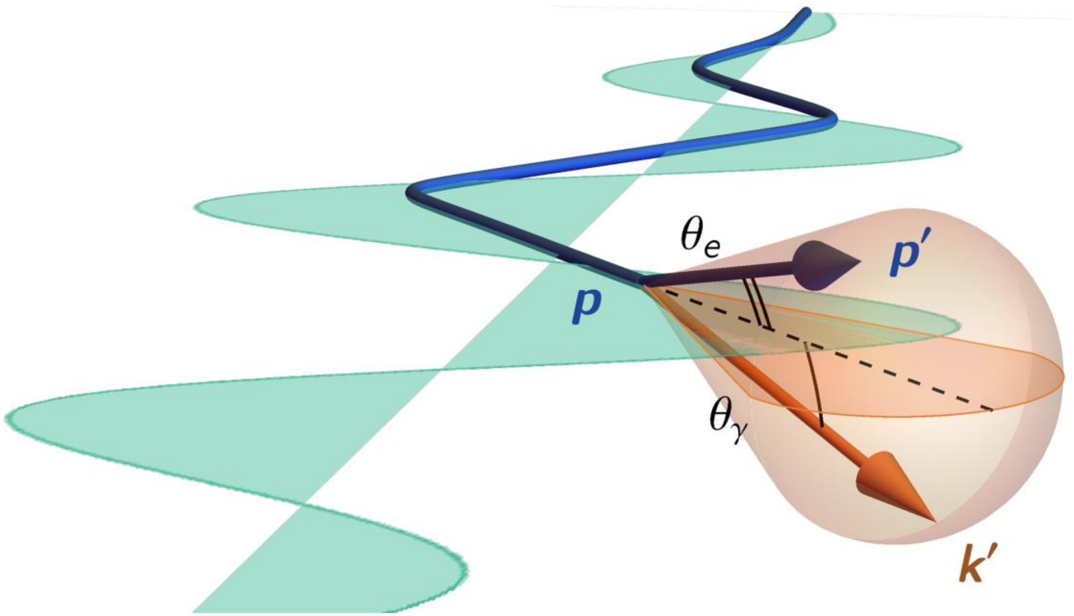
UNIVERSITY OF GOTHENBURG

Linearly polarised lasers: Simulations

Tom Blackburn
Department of Physics, University of Gothenburg

31 August 2021
LUXE Simulation and Analysis Task Force

How does Ptarmigan simulate photon emission?



- Two possible approximations:
- LCFA: requires that the photon formation time be much smaller than the laser period. If these scales are comparable, interference effects are important and the LCFA fails.
- LMA: move the electron's fast oscillation into the QED rates and use rates for a monochromatic plane EM wave background.

LCFA and LMA compared

- Rate calculated for a constant, crossed background.
- Quantity that enters the rate is the instantaneous (kinetic) momentum π^μ and the quantum parameter χ.
- Equation of motion is the Lorentz force $\dot{\pi}^\mu = -\mathrm{e}\, F^{\mu\nu}\pi_\nu/m$.

  fast quiver motion here

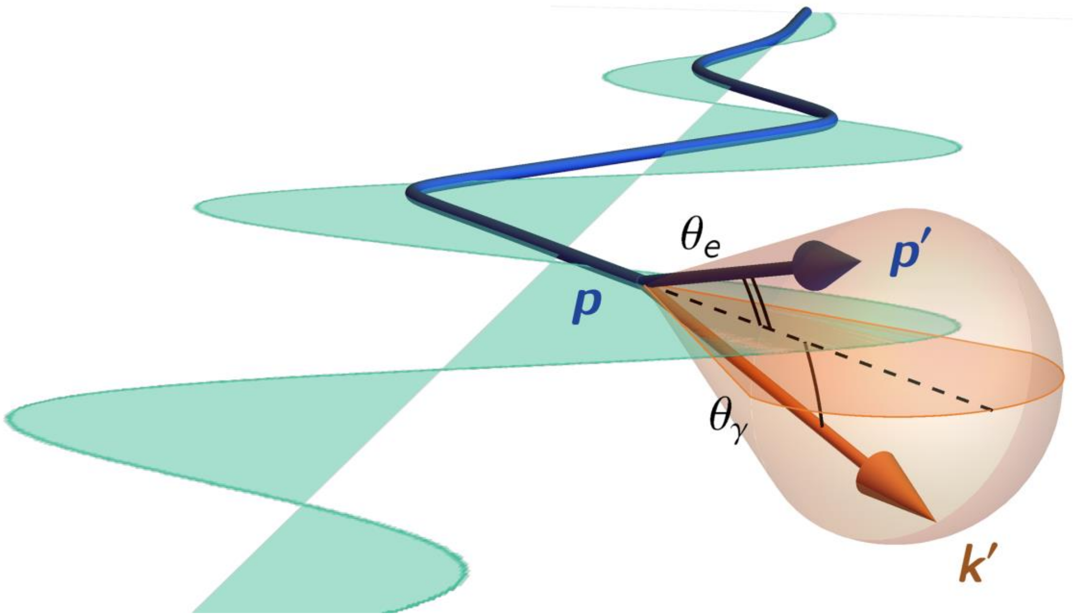
- Rate calculated for a plane EM wave with a slowly varying envelope.

  fast quiver motion here

- Quantity that enters the rate is the quasi-momentum $q^\mu = \langle \pi^\mu \rangle$, which is a cycle-averaged quantity, and the local parameters $\langle a^2 \rangle$ and $\eta = k.q/m^2$.
- Equation of motion is the relativistic ponderomotive force $\dot{\boldsymbol{q}} = -\frac{m^2}{2q^0}\boldsymbol{\nabla}\langle a^2 \rangle$

LP simulations

How does Ptarmigan simulate photon emission?



- Two possible approximations:
- LCFA is more versatile: any polarisation of background can be built from slices of constant, crossed field
- LMA: more accurate at moderate a_0 and reproduces harmonic structure, but rates are different for different polarisations.

LMA rates for a linearly polarised background

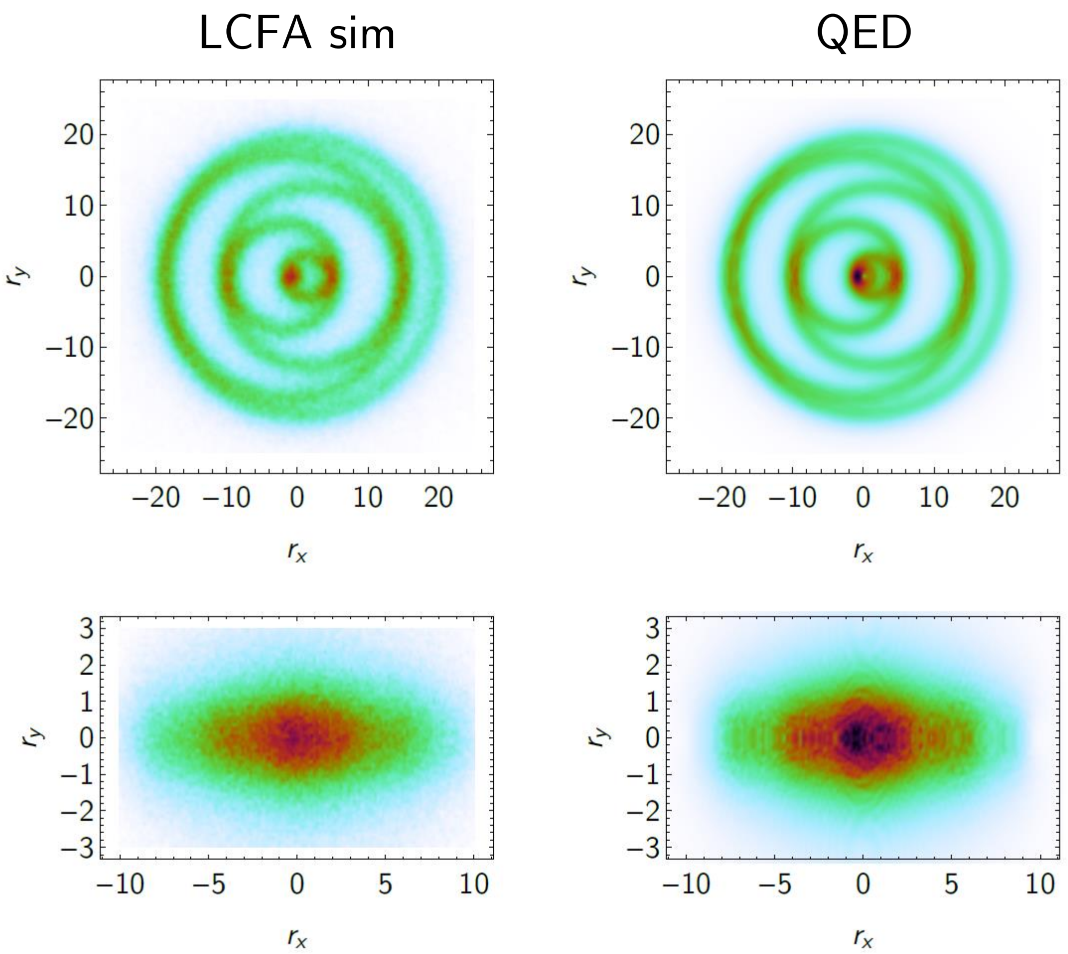
$$R^{\mathrm{CP}} = \sum_{n=1}^{\infty} \int_0^1 \mathrm{d}s \, [\cdots J_n(z) \cdots]$$

$$R^{\mathrm{LP}} = \sum_{n=1}^{\infty} \int_0^1 \mathrm{d}s \int_0^{2\pi} \mathrm{d}\varphi \, [\cdots J_n(x, y) \cdots]$$

- Difficulty comes from the loss of azimuthal symmetry.
- Bessel functions J_n are replaced by generalised Bessel functions $J_n(x, y)$. Numerical recipes exist, but generally an extra recurrence relation needs to be evaluated.
- For each harmonic, integrate over both lightfront momentum and angle.

LP simulations

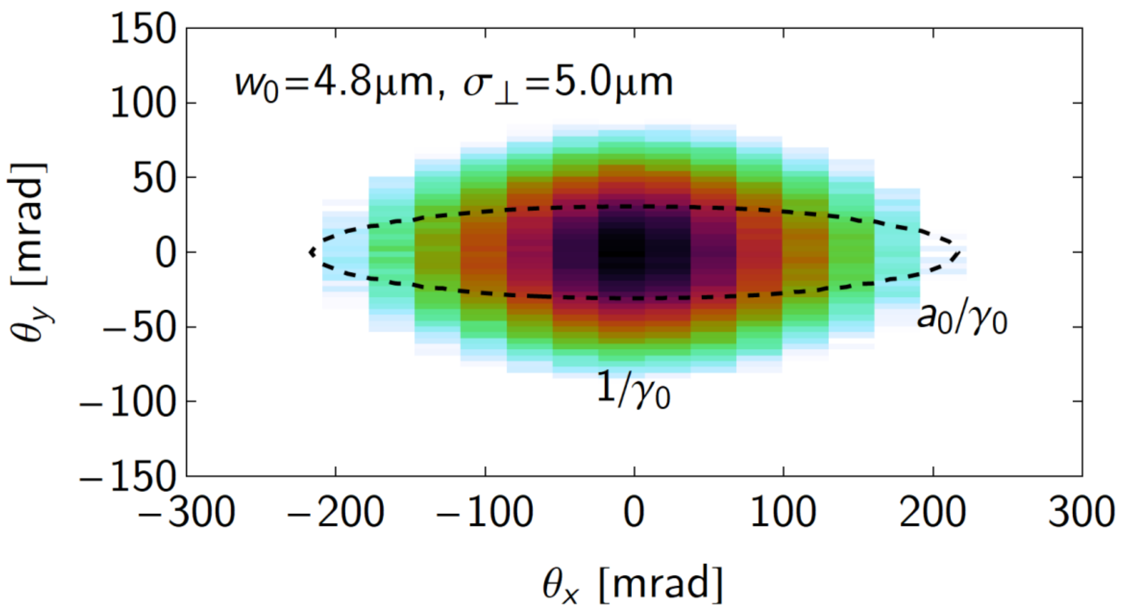
Proposal



- LCFA agrees well in the angular spectrum for large enough a_0 – particularly if we can ignore photons below a certain energy.
- What is the minimum a_0 that's relevant for the profiler?
- What is the sensitivity as a function of photon energy (if it is a function of photon energy)?

LP simulations

Example



- Phase 0 laser focused to peak $a_0 = 7.0$.
- Nominal electron beam parameters (16.5 GeV energy, 5 micron spot size, 1.4 mm mrad emittance)
- Range of effective a_0s encountered by the electron lead to less elliptical profile.