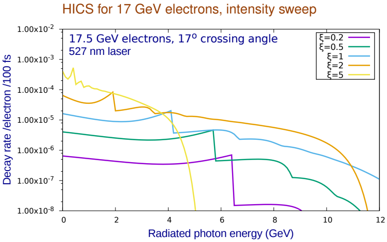
HICS - High Intensity (strong field) Compton scattering

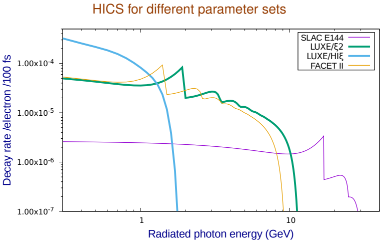
- Created parameter sets - a "LUXE/ξ2" (FACET II "special" laser), and a "LUXE/HIξ" (ANGUS type)
- Increasing ξ increases the HICS rate, but suppresses the photon energy (the mass shift). LUXE/HIξ, only smooth multiphoton edge visible
- Optimise ξ - need energetic enough photons for pair production, trade off between photon rate and photon energy
- Compare experiments.. LUXE/ξ2 nigher beam energy than FACET II. ELI-NP not competitive for HICS
- **TODO: linear polarisation, beyond IPW - finite pulse length**

Experiment	$\lambda(nm)$	E_{laser}	focus	pulse	E_{e^-}(GeV)	ξ	χ
SLAC E144	527/**1053**	1 J	50 μm^2	1.88 ps	46.6	0.66	0.28
LUXE/ξ2	**527**/1053	2 J	100 μm^2	0.05 ps	17.5	2	0.63
LUXE/HIξ	800	5 J	100 μm^2	0.02 ps	17.5	7.7	1.6
FACET II	**527**/800/1053	1 J	64 μm^2	0.04 ps	15	2	0.54
ELI-NP	1053	2.2 J	50 μm^2	0.022 ps	0.750	9.25	0.06

ξ is laser intensity parameter, χ is electron recoil parameter

$$\xi \equiv \eta \equiv a_0 = \frac{e|E|}{\omega\, m}, \quad \chi_{\text{i}} = \frac{\xi\, k\cdot p_{\text{i}}}{m^2}$$

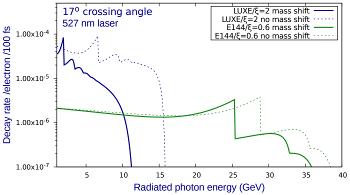




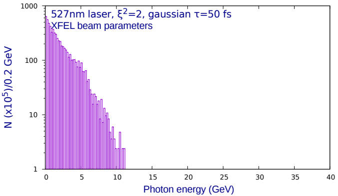
HICS - Mass shift

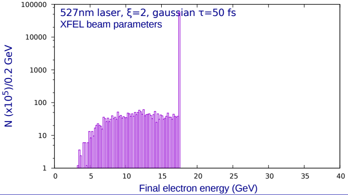
- Decay rate proportional to
  $$\sum_{n} \delta^{(4)}\left[p_i + k\frac{\xi^3}{2\chi_i} + nk - p_f - k\frac{\xi^3}{2\chi_f} - k_f\right]$$
- Momentum conservation is a sum over external field photon contributions, nk
- Even for $n = 0$ there is an irreducible contribution
  $$p_i + k\frac{\xi^3}{2\chi_i} \to p_i^2 = m^2(1+\xi^2)$$
- Manifests in Compton edge shift
  $$\frac{\omega_f}{\epsilon_i - \omega_f} \leq \frac{2nk\cdot p_i}{m^2(1+\xi^2)} \text{ c.f. } \frac{2nk\cdot p_i}{m^2}$$
- Significant part of electron energy taken up by electron motion in the field/dispersive vacuum. Less energy available for radiated photon
- $\xi^2 \sim 1$ large compared to $\frac{k\cdot p_i}{m^2} \approx 0.1$.
  Big shift! ...in principle
- Real bunch collision smears the edge - recover with cuts?

HICS with mass shift for LUXE and E144



IPstrong monte-carlo, HICS for LUXE/ξ2





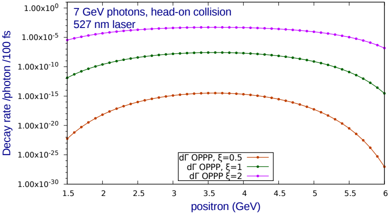
OPPP - strong field pair production

- In a world where we are in control of initial state photon energy...
- The produced positron spectra is smooth, maximum at about half the photon energy
- Total OPPP rate is much better with higher laser intensity (and higher photon energy)
  - Pair must be created with the mass shift

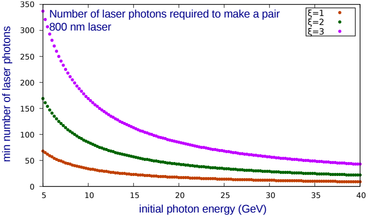
$$n \geq \frac{m^2(1+\xi^2)}{k \cdot k_{\rm i}}$$

...so another way to detect mass shift?

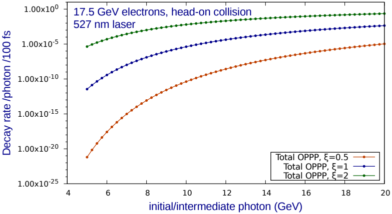
Positron spectra for OPPP, alone



Minimum laser photons needed for OPPP



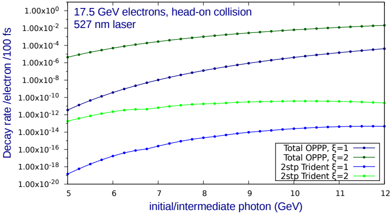
Total OPPP rate for LUXE with different ξ



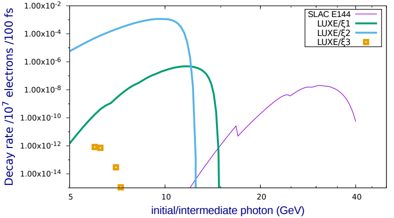
2 step trident - HICS + OPPP

- This is the effective way pairs are produced **(to 1st order!)**
- $\frac{d\Gamma_{\text{trident}}}{d\omega_f} = \frac{d\Gamma_{\text{HICS}}}{d\omega_f} \times \Gamma_{\text{OPPP}}(\omega_f)$
- Trident rate several orders lower than OPPP. Fortunately, we have a lot of electrons... match the beam to laser spot, given ξ constraints
- Estimate 10^7 interactions per bunch crossing (E144)... total rate VERY ξ dependent
- Total positron rate dependence on ξ will start to decrease somewhere between ξ=1 and ξ=3
- Will produce plot of positron rate versus intensity (with ξ beyond that in the literature)

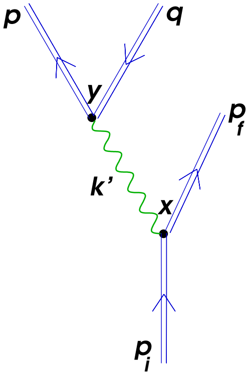
HICS with mass shift for LUXE and E144



Positron rate for different parameter sets



HICS, OPPP, 2 step trident



The trident process.