# Bremsstrahlung Photon Production for BPPP Study

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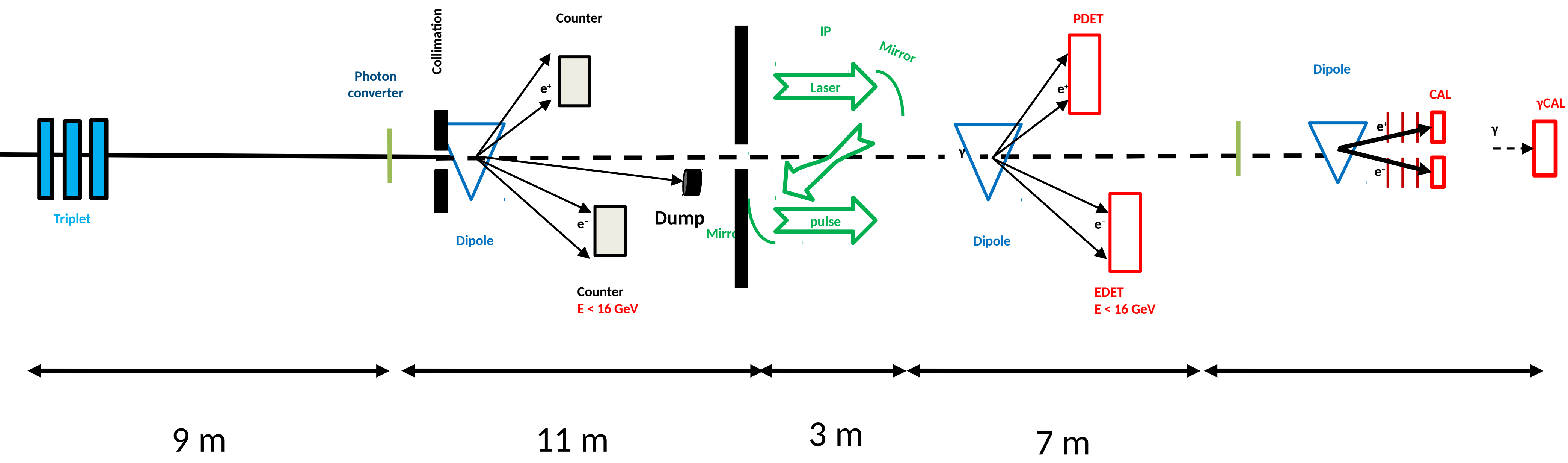
# Photon-Photon collisions at LUXE

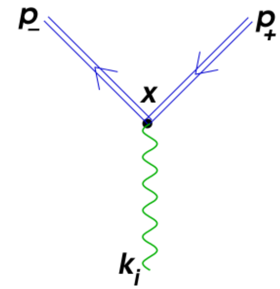



**Preliminary estimates!**

# Laser-assisted pair production[1]

The rate of laser-assisted one photon pair production (OPPP) rate:

$$\Gamma_{\mathrm{OPPP}} = \frac{\alpha m_e^2}{4\,\omega_{\mathrm{i}}} F_\gamma(\xi, \chi_\gamma)$$

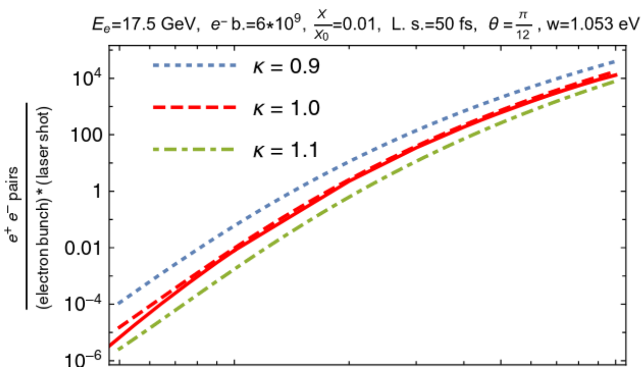



Bremsstrahlung photon pair production (BPPP):

$$\Gamma_{\mathrm{BPPP}} = \frac{\alpha\, m_e^2}{4} \int_0^{E_e} \frac{\mathrm{d}\omega_i}{\omega_{\mathrm{i}}} \frac{\mathrm{d}N_\gamma}{\mathrm{d}\omega_i} F_\gamma(\xi, \chi_\gamma(\omega_i))$$

Approximation for bremsstrahlung photon spectrum :

$$\omega_i \frac{\mathrm{d}N_\gamma}{\mathrm{d}\omega_i} \approx \left[\frac{4}{3} - \frac{4}{3}\left(\frac{\omega_i}{E_e}\right) + \left(\frac{\omega_i}{E_e}\right)^2\right] \frac{X}{X_0}$$




At high laser intensities $\quad \xi \gtrsim 1/\sqrt{\chi_e} \gg 1$

laser-assisted BPPP rate: $\quad \Gamma_{\mathrm{BPPP}} \to \frac{\alpha\, m_e^2}{E_e} \frac{9}{128} \sqrt{\frac{3}{2}}\, \chi_e^2\, e^{-\frac{8}{3\chi_e}\left(1 - \frac{1}{15\xi^2}\right)} \frac{X}{X_0}$

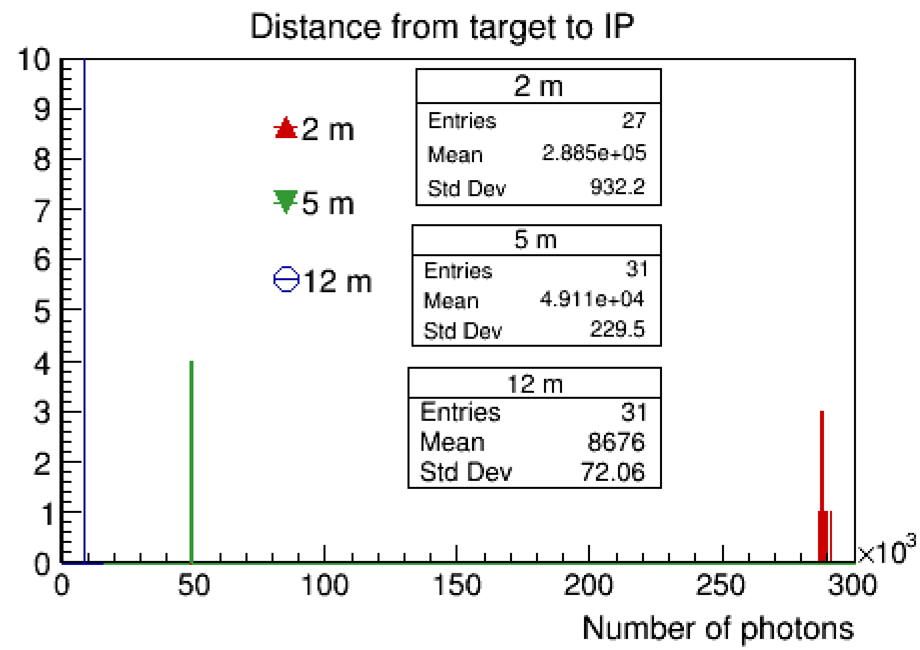
For comparison between paper results and MC:

- Test bremsstrahlung MC production and PDG formula;
- Take into account space distribution of the laser intensity;

[1] A. Hartin, A. Ringwald, and N. Tapia Measuring the Boiling Point of the Vacuum of Quantum Electrodynamics [arXiv:1807.10670] Presented at LUXE meeting August 9, 2018.

# Number of photons

- Geant4 simulation;
- Tungsten target 1%X0 (35um) at different distance to IP;
- Gaussian beam focused on IP;
- 6.25e7 electrons;



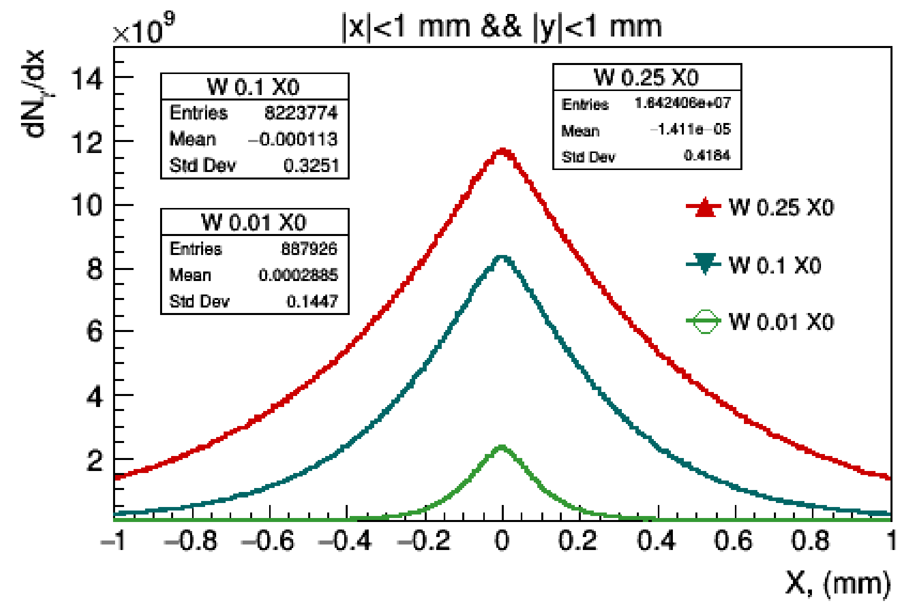

Number of photons inside |x|<25um and |y|<25um around IP.

Within 10% scales as $N \sim \frac{1}{l^2}$

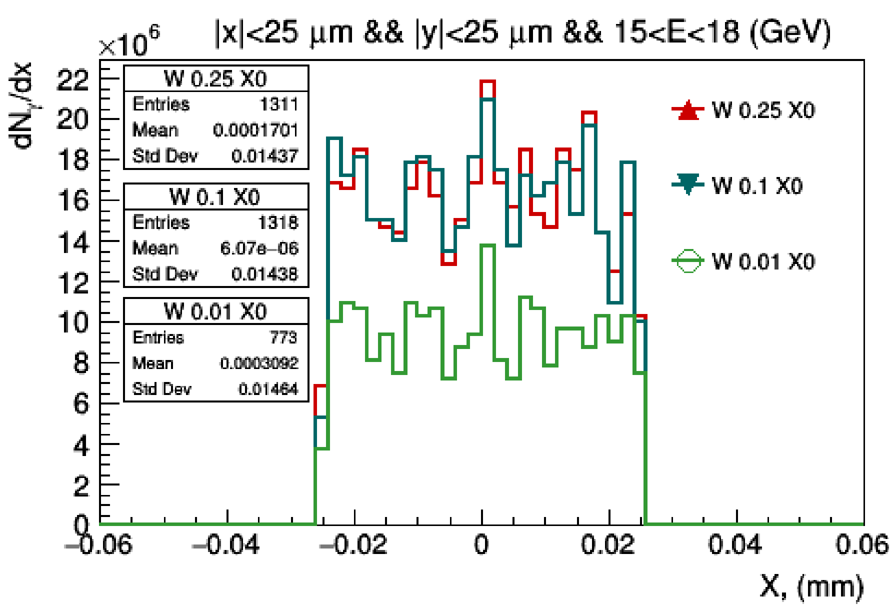
| Z, (m) | Z^2 | N_Gamma | Z1^2 / Z2^2 | N2 / N1 | | Z1^2 / Z2^2 | N2 / N1 | |
|---|---|---|---|---|---|---|---|---|
| 2 | 4 | 2.89E+05 | 6.25 | 5.87 | 0.94 | 36 | 33.2565 | 0.924 |
| 5 | 25 | 4.91E+04 | 5.76 | 5.66 | 0.98 | | | |
| 12 | 144 | 8675 | | | | | | |

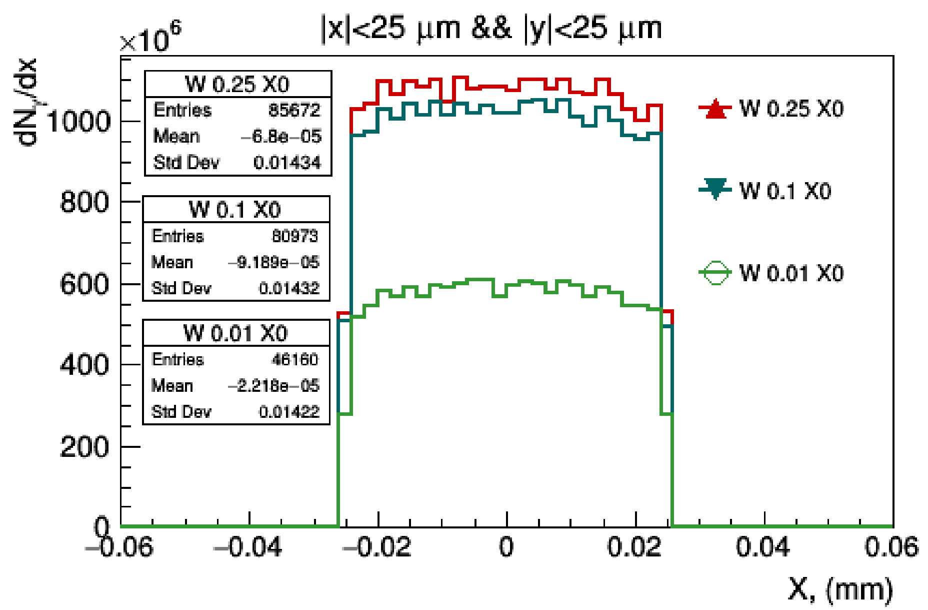
# Bremsstrahlung Production

- Gaussian beam;
- Different tungsten thickness, 2m from IP;
- 10M electrons;
- Bin content multiplied by 625/bin_width.



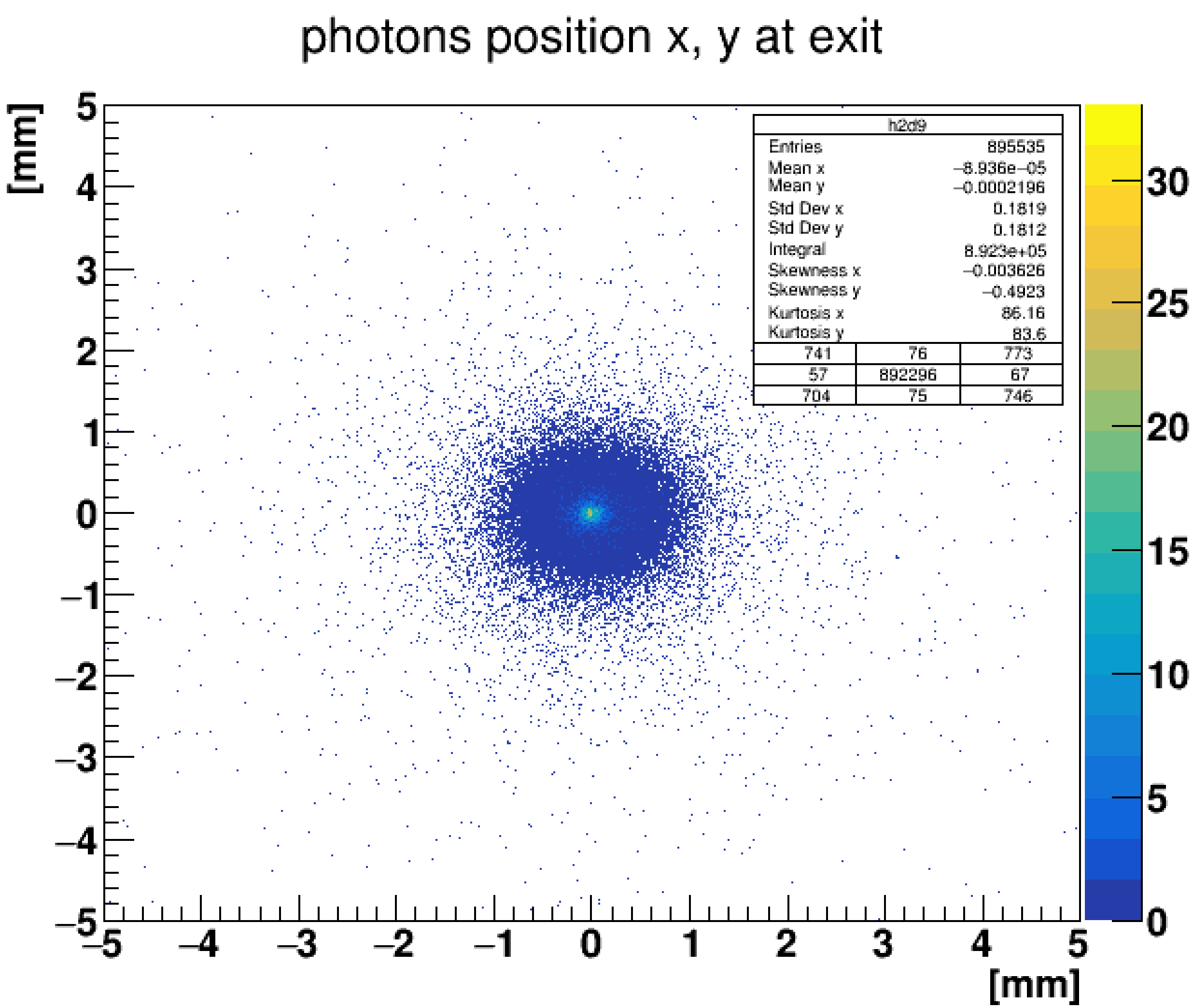

The fraction of photons inside
|x|<25um and
|y|<25um
can be estimated as 46160/887926 = 0.052.
More accurate estimation is on the next page.

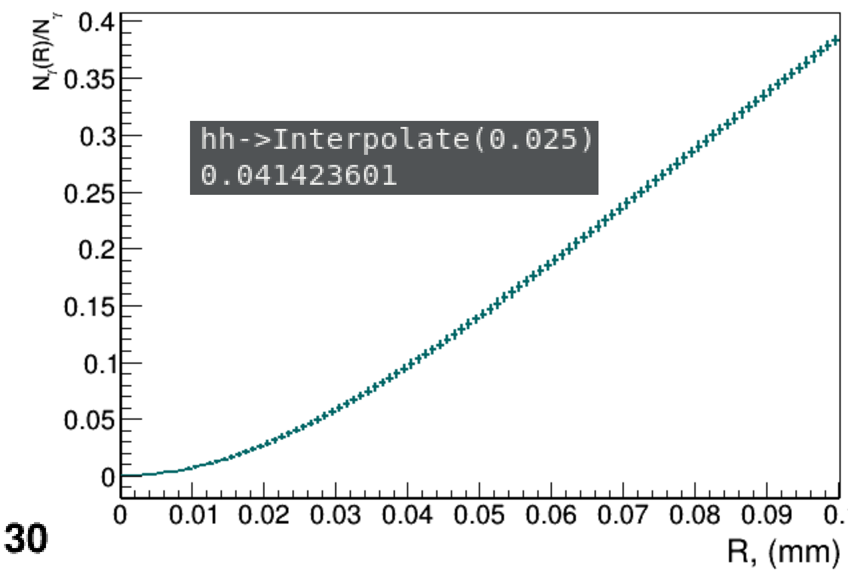


# Fraction of photons as a function of spot size (R)

Tungsten 1%X0.
Taking into account overflow
and underflow bins (~0.3%)
the fraction of photons inside R < 25um is 4.1%

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fSumw[3]=0.000448602, x=0.0025, error=0.000352155
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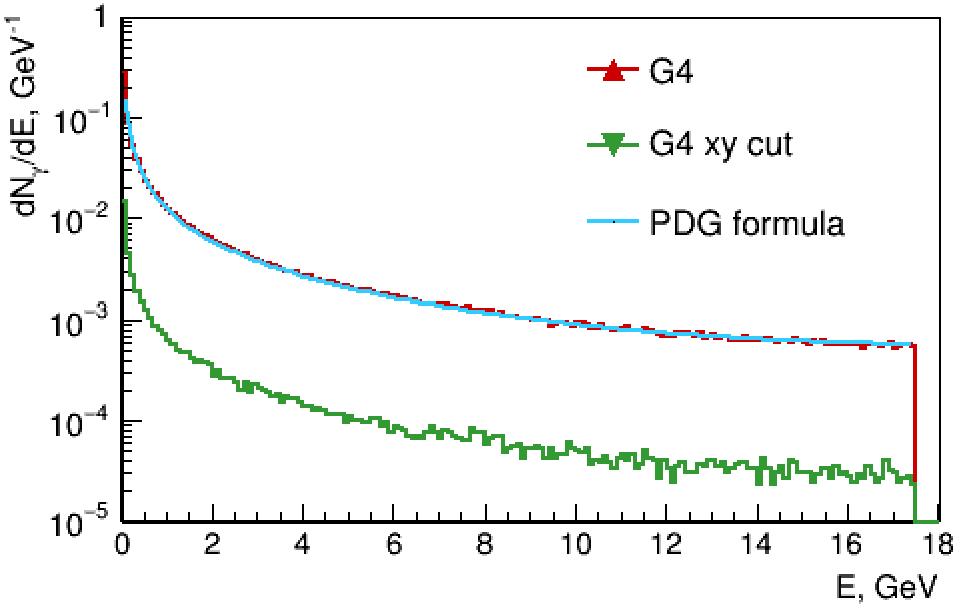
# Bremsstrahlung production Gent4 vs PDG formula

PDG formula for bremsstruhlung production:

$$\omega_i \frac{\mathrm{d}N_\gamma}{\mathrm{d}\omega_i} \approx \left[\frac{4}{3} - \frac{4}{3}\left(\frac{\omega_i}{E_e}\right) + \left(\frac{\omega_i}{E_e}\right)^2\right] \frac{X}{X_0}$$




- Gaussian beam;
- Tungsten target 1%X0 (35um), 2m from IP;
- 10M electrons
- Two histograms are compered:
  - |x| < 1mm  and |y| < 1mm;
  - |x| < 25um and |y| < 25um.

# Summary and plans

- Bremsstrahlung photons were generated in Geant4 simulation with 1%X0 tungsten target 2m, 5m and 12 m to IP and are used for BPPP simulation study.
- Number of Bremsstrahlung photons in IP area scales with the distance from the target as $1/L^2$ (within 10%).
- Number and spectrum of bremsstrahlung photons produced in Geant4 without geometrical constraints agree well with PDG recommended formula.
- Geometrical selection criteria reduce the number of bremsstrahlung photons in IP down to ~4%, but does not change the spectrum.
- Internal note on bremsstrahlung photons production for LUXE is in preparation.

# Electron and laser beam parameters

| E_pulse, μJ | Crossing angle, rad | Laser σxy, μm | Laser σz, ps | N Electrons | Electron σx, mm | Electron σy, mm | Electron σz, ps |
|---|---|---|---|---|---|---|---|
| 3.5*10^6 | 0.3 | 10 | 0.035 | 6.25E+09 | 0.005 | 0.005 | 0.08 |

- Laser wavelength = 800.00 nm (1.5498 eV);
- Circular polarized.