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A photon-photon collider in a vacuum hohlraum: Supplementary information

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Photon distribution. The energy distribution of the gamma-ray photons leaving the back surface of the gold target is presented in Fig. 1, in the case of 10^9 incident electrons of energy $E = 1$GeV. This is similar to the standard bremsstrahlung cross-section, equation (1), with modifications due to the slowing of the electrons in the target and the attenuation of the photon beam due to Bethe-Heitler pair production (see Methods). We note that the bremsstrahlung emission of the electrons and positrons formed in the Bethe-Heitler process is not included; the spectrum is therefore a lower-bound estimate. The shape of the distribution is unchanged for initial electron energies of $E = 500$MeV and $E = 2$GeV (though stretched in energy accordingly). As the absorption probability due to Breit-Wheeler pair production is at most $\sim 10^{-4}$, these spectra will also accurately describe the gamma-ray photons exiting the back of the hohlraum.

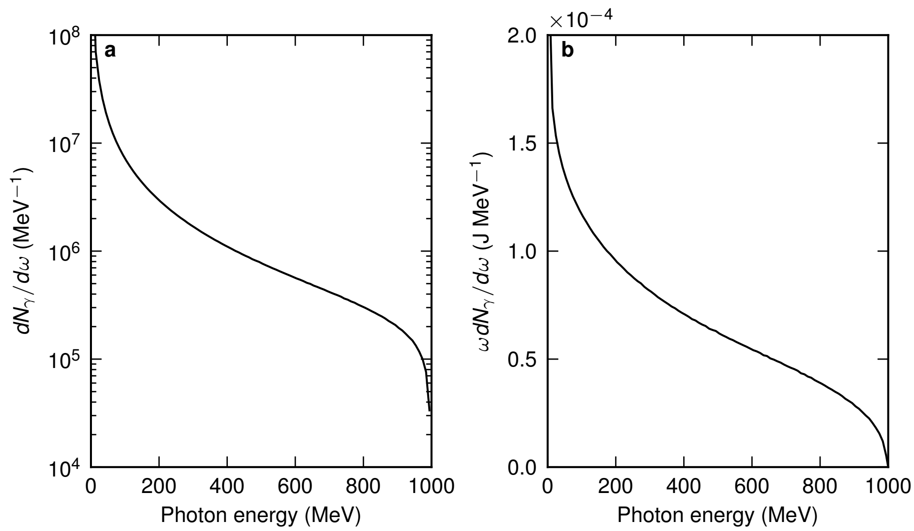

Figure 1 | Gamma-ray photon distribution. a The energy distribution $dN_\gamma/d\omega$ and **b** normalised energy distribution $\omega dN_\gamma/d\omega$ of the bremsstrahlung photons emerging from the back surface of a gold target of optimal width, for an electron beam of initial energy $E = 1$GeV.

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Although the distribution is broad, a significant number of very high energy photons escape the target: 1.9×10^8 with energies $\hbar\omega > E/2$ (Fig. 1a), which is consistent with our previous estimate. Approximately 30% of the energy in the distribution is contained within these photons (Fig. 1b).

Positron distribution. The Breit-Wheeler positrons are produced with energies $\sim$ 100MeV, although their exact energy distribution varies with the electron beam energy and hohlraum temperature, as shown in Fig. 2. Despite the broad gamma-ray distribution, these spectra are reasonably narrow, as it is typically the higher energy photons in the distribution that are above threshold for Breit-Wheeler pair production. In fact, for the lowest beam energy considered (500MeV), the positron energy spectrum is at its narrowest, as this effect is maximised. Some broadening of the energy spectra is seen at higher electron energies (1GeV and 2GeV), though this is offset by the considerably higher positron yields. Increasing the hohlraum temperature (Fig. 2b and 2c) results in both higher yields and a shift towards lower positron energies, as the significant numbers of lower energy photons in the distribution (Fig. 1a) reach the threshold for pair creation.

The energy distribution of the Breit-Wheeler electrons is identical to that shown for the positrons.

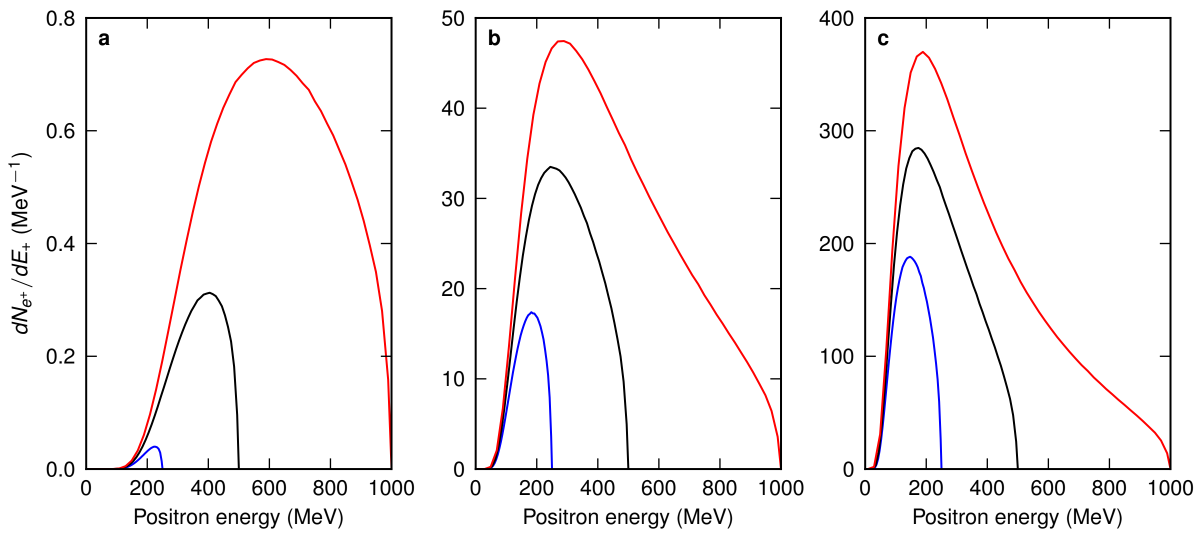

Figure 2 | Breit-Wheeler positron distribution. The energy distribution dN_{e^+}/dE_+ of positrons formed through the Breit-Wheeler process for hohlraums of temperature **a** 100eV, **b** 250eV and **c** 400eV, length $l = 1$cm and electron beams containing 10^9 particles at energies of 500MeV (blue), 1GeV (black) and 2GeV (red). (The shape of the distributions are independent of hohlraum length.) The electron distribution is identical.

