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E-144: Rate Estimate for Beamstrahlung Positron Production

We report on an estimate of the rate of positron production at IP1 from the two-step process $e+$ laser $\to e'+\gamma$, $\gamma+$ laser $\to e^+e^-$ for intense laser field such that $\Upsilon = E^\star/E_{\rm crit} \approx 1$.

We reviewed the Fortran program KTHOMBW and made two improvement/corrections:

1. We now avoid looping when the Bessel functions are smaller than 10^{-38}, the smallest number representable in floating-point notation.
2. A error in the plotting of positron energies has been fixed.

The program still calculates only nonlinear Compton scattering, or pair creation, and does not yet perform a true convolution of the two processes as will occur in nature. We have made an estimate of the rate for the combined process as follows:

1. First calculate the rate of Compton scattering *vs.* photon energy, as shown in Figs. 1 and 3. For this the electron beam has 47 GeV, 3-ps FWHM, and 1-mm-σ radius. The laser beam is focused with a lens of $f/D = 5$, has pulse width of 1-ps FWHM, and we assume the infrared pulse ($\lambda = 1.06$ μm) has 3 Joule energy, but the green pulse ($\lambda = 0.53$ μm) has only 2 Joule energy due to losses in the doubling process. The calculation then integrates over the overlapping Gaussion profiles of the two beams in both space and time to yield a total rate estimate of 5×10^{-5} backscattered photons per electron with the infrared laser, and 7×10^{-6} photons per electron for the green laser.

2. A backscattered photon propagates from its production point across the rest of the laser pulse at a very small angle. Pair creation can then occur by the Breit-Wheeler process. We calculated the rate of pair creation for several fixed energies of the backscattered photon, assuming the transverse dimension of the backscattered photon beam is only slightly larger than the waist of the laser beam. The total pair creation cross section *vs.* photon energy is plotted in Figs. 1 and 3 (although the normalization of the curves does not correspond to the labelling of the vertical axis).

3. We suppose that the backscattered photons are produced at the middle of the laser pulse on average, so multiple the photon rate by 1/2 the pair rate according to step 2 at each photon energy to produce the estimate of the pair-creation rate. The latter is shown at the bottom of Figs. 1 and 3, normalized according to the labelling of the vertical axis. The total pair rate is 2×10^{-10} per electron with the infrared laser, and 3×10^{-9} with the green laser. That is, a pulse of 10^{10} electrons in collision with the infrared laser should yield two electron-positron pairs.

4. The spectrum of positron energies has not been calculated including the effect of the spectrum of backscatter photon energies. However, Figs. 2 and 4 show the positron-energy spectra per backscattered photon at several fixed photon energies. For the infrared laser, the curve for 25-GeV photons is perhaps most representative, which shows that the positron spectrum extends from 6 to 19 GeV at 10% peak height. For the green laser, the 30-GeV curve is more representative, and in this case the positron spectrum extends from 5 to 25 GeV at 10% peak height.

These calculations indicate that if the infrared laser performs as assumed, the positron rate will be a few per pulse, and the beamstrahlung pair creation experiment should have plenty of rate. Of course, if the electron beam were focused to, say, 100 μm at IP1, the rates would increase by a factor of 100. This provides a safety factor in case the laser intensity is lower. For example, if the infrared laser pulse energy is only 1 Joule, the pair rate drops by two orders of magnitude! Also, it reminds us that for a green-laser pulse of design intensity and a focused electron beam there will be in excess of 1000 positrons per pulse.

$\lambda = 1.06\,\mu m$ $\eta = 2.2$ $\tau_{LASER} = 1\,ps$ $\sigma_{Y,LASER} = 2.4\,\mu m$ $\Upsilon = 1.0$ AT $E = 50\,GeV$

$U < 3$ Joules $f/D = 5$ $\tau_e = 3\,ps$ $\sigma_{Y,e} = 1000\,\mu m$

MODEL   DATE

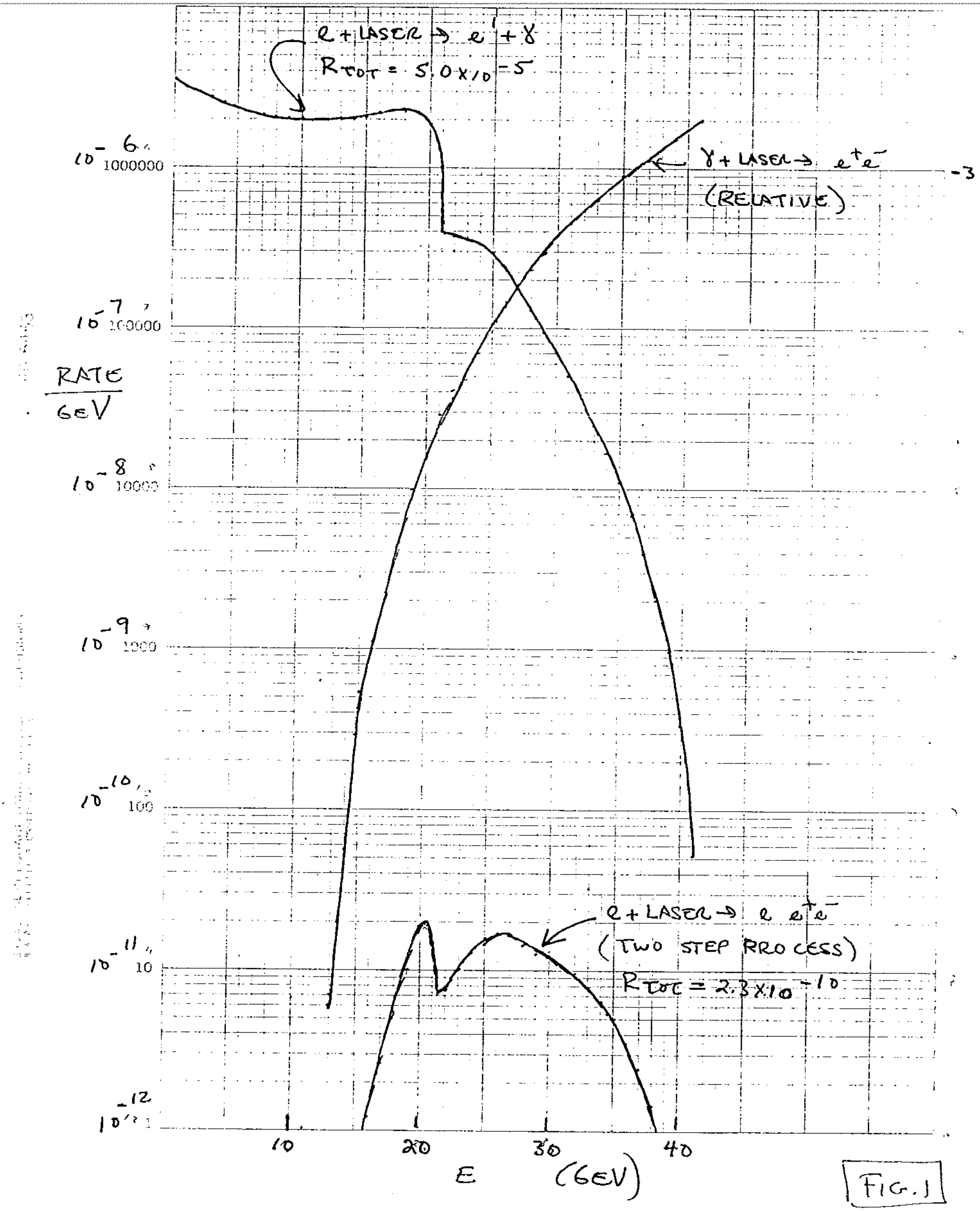

FIG. 1

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$\lambda = 1.06\,\mu m$ $\eta = 2.2$ $\tau_{LASER} = 1\,ps$ $\sigma_{Y,LASER} = 2.4\,\mu m$ $\Upsilon = 0.5$ AT $E_\gamma = 25$ GeV

$U = 3$ Joules $f/D = 5$ $\tau_\gamma = 3\,ps$ $\sigma_{Y,\gamma} = 3.0\,\mu m$

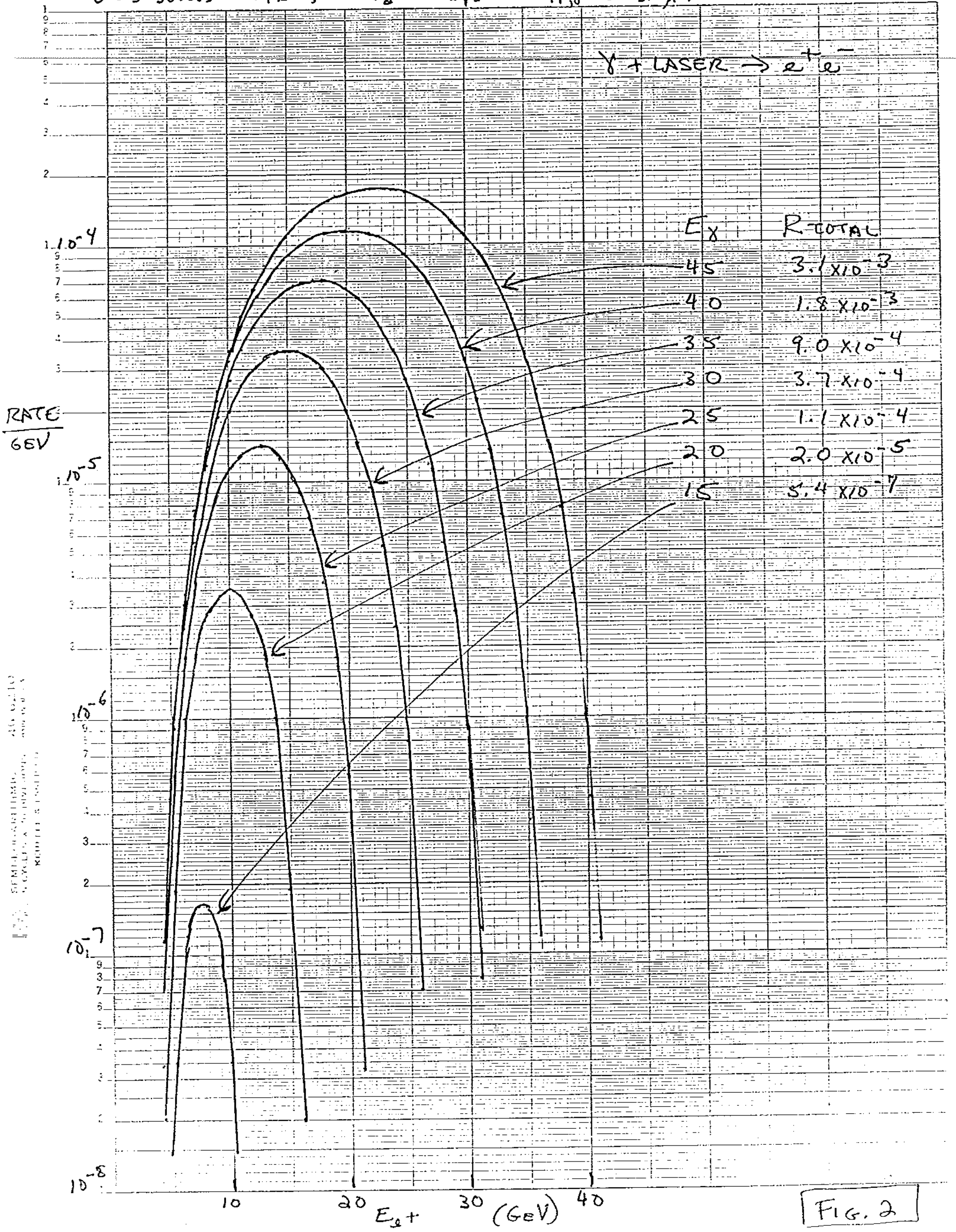

FIG. 2

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$\lambda = 0.53\,\mu m$ $\eta = 1.8$ $\tau_{LASER} = 1\,ps$ $\sigma_{y,LASER} = 1.2\,\mu m$

$U = 2$ Joules $f/D = 5$ $\tau_e = 3\,ps$ $\sigma_{y,e} = 1000\,\mu m$

$\Upsilon = 1.6$ AT $E = 50$ GeV

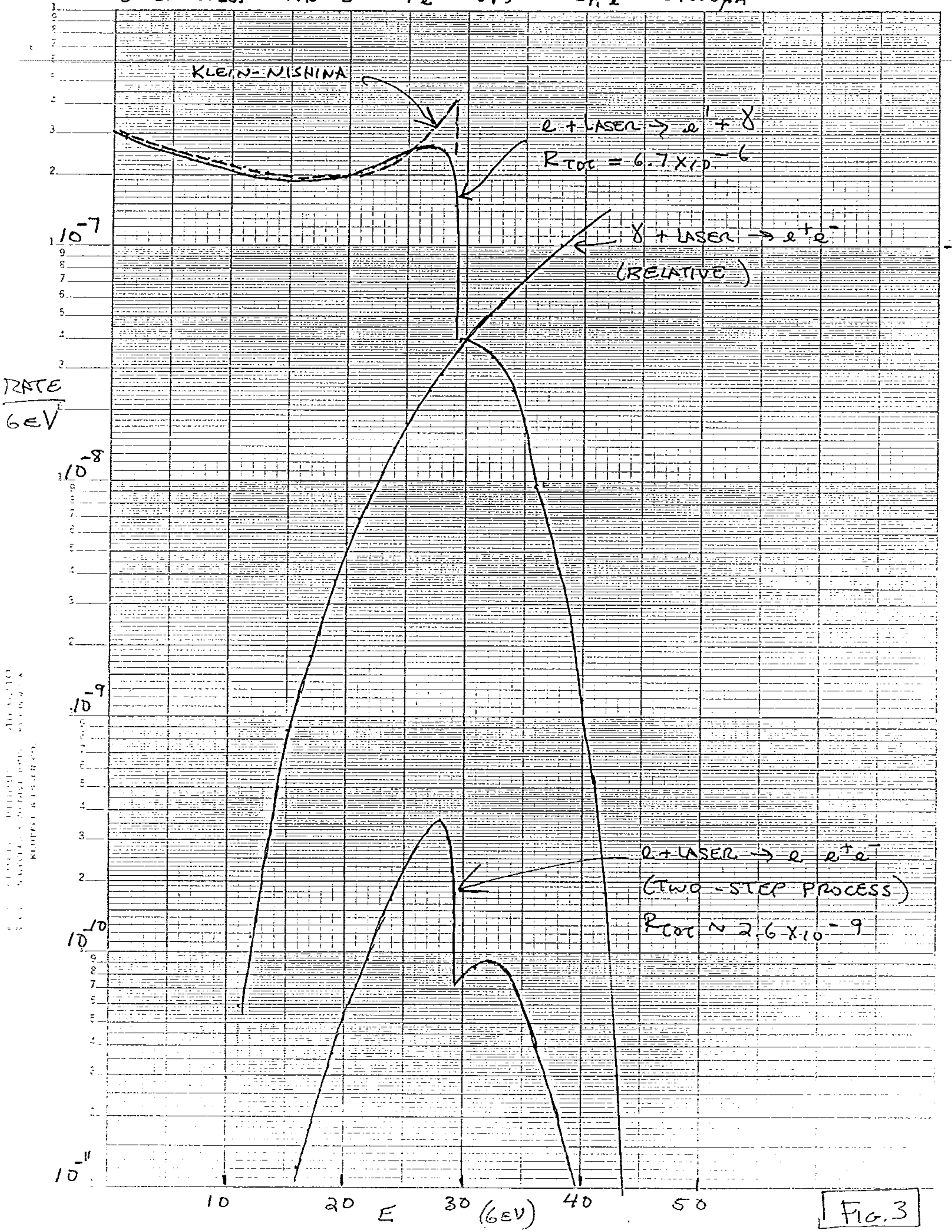

FIG. 3

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$\lambda = 0.53\ \mu m$ $\eta \approx 1.8$ $\tau_{LASER} = 1\ ps$ $\sigma_{y\ LASER} = 1.2\ \mu m$

$U = 2$ JOULES $f/D = 5$ $\tau_{\gamma} = 3\ ps$ $\sigma_{r,\gamma} = 1.5\ \mu m$

$\Upsilon = 0.8$ AT $E_{\gamma} = 25$ GeV

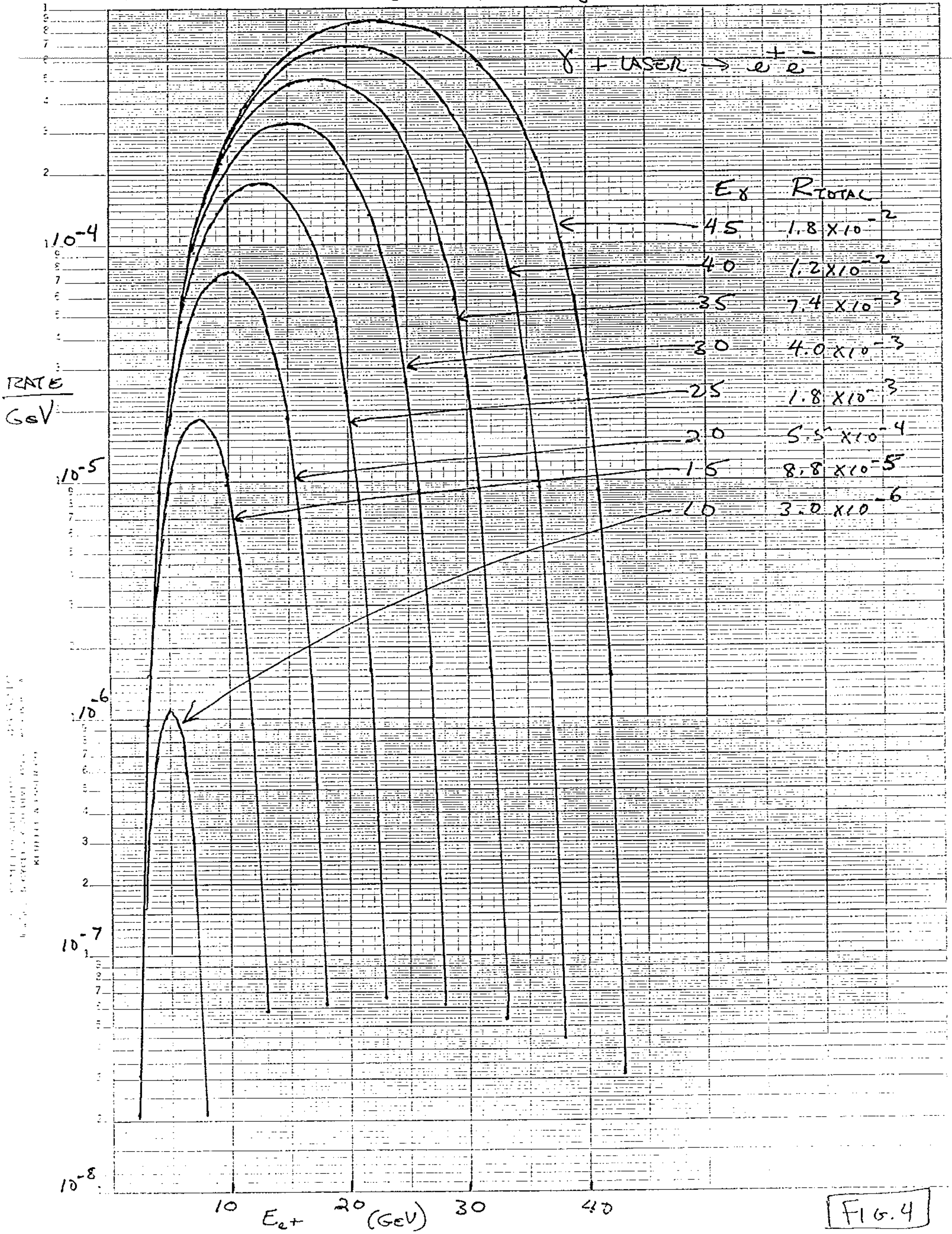

FIG. 4