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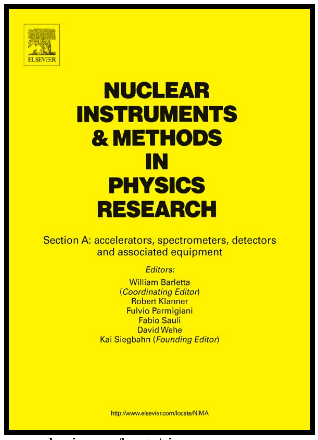

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Study of photon-photon scattering events

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We present the design of a photon-photon collider based on conventional Compton gamma sources for the observation of secondary $\gamma\gamma$ production. Two symmetric electron beams, generated by photocathodes and accelerated in linacs, produce two primary gamma rays through Compton back scattering with two high energy lasers. Tuning the system energy to the energy of the photon-photon cross section maximum, a flux of secondary gamma photons is generated. The process is analyzed by start-to-end simulations from the photocathodes to the propagation of the QED photons towards the detector. The new Monte Carlo code 'Rate Of Scattering Events' (ROSE) has been developed *ad hoc* for the counting of the QED events. Realistic numbers of the secondary gamma yield, referring to existing or approved set-ups and a discussion of the feasibility of the experiment are presented.

I. INTRODUCTION

The recent development of high-energy, large-brilliance photon and electron beams opens the way to the study of QED collisions or decays that are so far unobserved or detected only in an indirect way.

One of the most elusive processes foreseen by QED is the light to light scattering ($\gamma\gamma \to \gamma\gamma$) [1] that, implied by the Dirac's theory of the electrons and studied since the early thirties, has never been observed so far, except as radiative correction to other processes. In particular, all the experimental attempts performed with photons with energies from fraction of eV to few keV, that, due to the exceedingly low values of the interaction cross section at these energies, constituted really demanding experimental challenges, have not shown excess of events above background in this range of parameters [2–9]. The development of radiation sources in the range of hard X and gamma wavelengths gives the perspective to reach and explore the cross section peak at about 1-2 MeV [10–13]. A promising method for generating QED secondary γ beams is based on two symmetric electron beams, generated by photocathodes and accelerated in linacs, that produce two primary gamma rays through the Compton back-scattering with two high energy lasers [14]. The two primary gamma pulses encounter and scatter. Tuning the gamma energies to the energy of the maximum of the photon-photon cross section, an amount of secondary gamma photons can be generated.

In this paper, we first present the development of a new Monte Carlo numerical code, named ROSE (Rate Of Scattering Events), for the dimensioning of a $\gamma\gamma$ collider based on conventional Compton gamma sources. The design of the source and the evaluation of the rate of QED events are then presented.

II. ARCHITECTURE OF THE CODE ROSE

The kinematics of the $\gamma\gamma$ collision is usually analyzed in the center of mass reference frame (CM) where, assigning the invariant mass $\sqrt{s} = \sqrt{2(E_1E_2 - \underline{p}_1 \cdot \underline{p}_2)}$ (E_1, E_2 being the energies of two primary photons with momenta, in natural units, respectively $\underline{p}_1$ and $\underline{p}_2$ in the laboratory), the product particles acquire the energies:

$$E_{3,4}^{CM} = \frac{\sqrt{s}}{2} \quad (1)$$

whereas the momenta $\underline{p}_3^{CM} = -\underline{p}_4^{CM}$, equal in modulus, have angles $\theta_3^{CM} = \pi - \theta_4^{CM}$ and $\varphi_3^{CM} = \pi + \varphi_4^{CM}$.

Customary Monte Carlo strategies for solving the problem rely on the random sampling of the angles φ_4^{CM} and θ_4^{CM}, followed by the rejection test weighted by the differential cross section $d\sigma/d\Omega$.

The last step is the return to the laboratory system by inverse Lorentz transformation:

$$E_{3,4} = \gamma_{CM}(E_{3,4}^{CM} + \underline{\beta}_{CM} \cdot \underline{p}_{3,4}^{CM}) \quad (2)$$

$$\underline{p}_{3,4} = \underline{p}_{3,4}^{CM} + \frac{\gamma_{CM} - 1}{\beta_{CM}^2}(\underline{\beta}_{CM} \cdot \underline{p}_{3,4})\underline{\beta}_{CM} + \gamma_{CM} E_{3,4}^{CM} \underline{\beta}_{CM} \quad (3)$$

where $\gamma_{CM} = (E_1 + E_2)/\sqrt{s}$ and $\underline{\beta}_{CM} = (\underline{p}_1 + \underline{p}_2)/(E_1 + E_2)$. Our project is aimed at the analysis of the scattering involving two realistic relativistic beams of gamma photons.

The code ROSE (Rate Of Scattering Events) has been first constructed and implemented for studying the photon-photon scattering and then applied also to other particle collisions and decays, as Breit-Wheeler, Triplet Pair Production (TPP), Compton scattering. Its main peculiarity is that it treats the scattering between two