Proposal of Gamma Rays Measuring Instrument with Position Resolution of 0.1 mm

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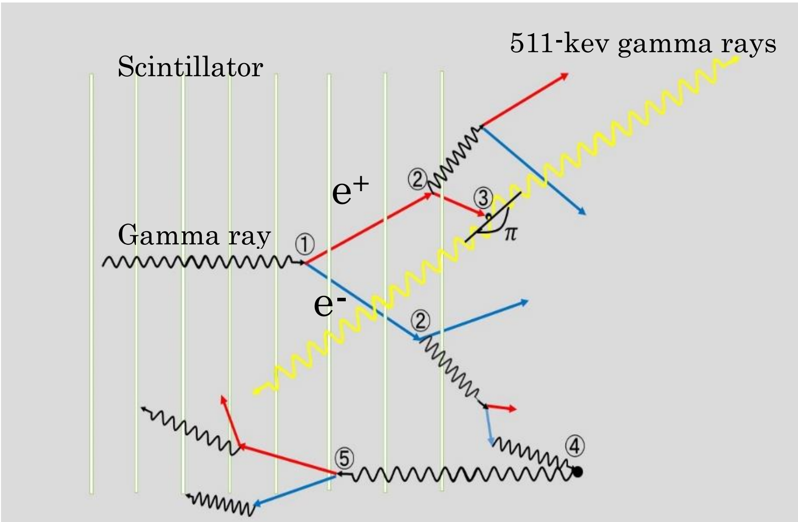
Introduction： In particle physics experiment, since high energy gamma rays are often emitted, it is indispensable for development of particle physics experiment to measure the position and energy of high energy gamma rays. Conventionally, since high energy gamma rays create electromagnetic shower in the scintillator, the energy and incident position of gamma rays are estimated from the sum of the centers of gravity multiplied by energy sum and energy of each light emitting point of the scintillator. Since it spreads over about 10 cm in the vertical and lateral directions with respect to a plane perpendicular to the incidence direction, its position resolution is approximately 10 mm at most.

Method： We anticipated that we can achieve high position resolution by arranging the detectors in layers perpendicular to the incident gamma rays. A conceptual diagram that the gamma ray enters the detector proposed by us and have various interactions is indicated in Fig1. Electrons and positrons produced by gamma rays emit gamma rays by bremsstrahlung (shown at ① and ② of Fig1). Two 511-keV gamma rays are produced by electron-positron pair annihilation (shown at ③ of Fig1). When the energy of gamma rays is 1 GeV or more, almost all electron-positron pair production events are predominant, but Compton scattering (incoherent scattering in Fig3 which is described later) occurs with a probability of 1/100 compared with pair production. Among them, if angle of Compton scattering of gamma rays is 180 °, it can create electromagnetic shower in the opposite direction to the incident gamma ray (shown at ④and ⑤ of Fig1). As described above, there are three kinds of other gamma rays which are not gamma rays to be detected. The first described gamma rays can be separated from the original one by the difference of the position of scintillation light. The second described gamma rays can be separated from the original one by difference of the energy. The third described gamma rays can be separated from the original one by the difference in scintillation light spreading direction.

Our developing detector： The feature of the detectors we will use is in the scintillator part. Main components of the scintillator part are plate-like high growth-rate (HGR) La-GPS scintillators and wavelength shifting fibers (WLSF). Our detectors have high position resolution because WLSF with a diameter of 0.2 mm are spread over the upstream face and the downstream face of the scintillator plate without a gap in the scintillator part (fig.2). The types and probabilities of interaction between gamma ray and La-GPS with energy between 100 keV and 1 GeV are indicated in the Fig3. We are developing two types of scintillators with different price and energy resolution, each of their thicknesses are 1 mm and 3 mm. One is a plate-like scintillator having a thickness of approximately 1 mm arranged without a gap. When the WLSF is measured one by one, the resolution of the light emitting position is 0.1 mm as the standard deviation. The other adhere a large number of SiPM to the four sides of a 3.4 mm scintillator. Since it is proportional to the thickness of the scintillator, the position resolution is about 0.3 mm.

Insistence：Using the above described theory and detectors, we propose a high-resolution gamma-ray measuring instrument (0.1 mm as the standard deviation) installed on the upstream side of the existing high-energy gamma ray measuring instrument.



Fig,1: Gamma ray interaction diagram

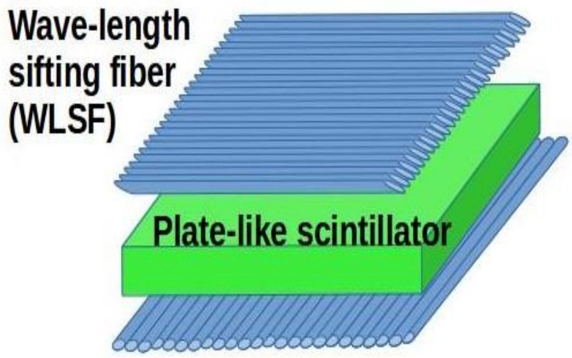


Fig.2 ; Structure of our developing detector

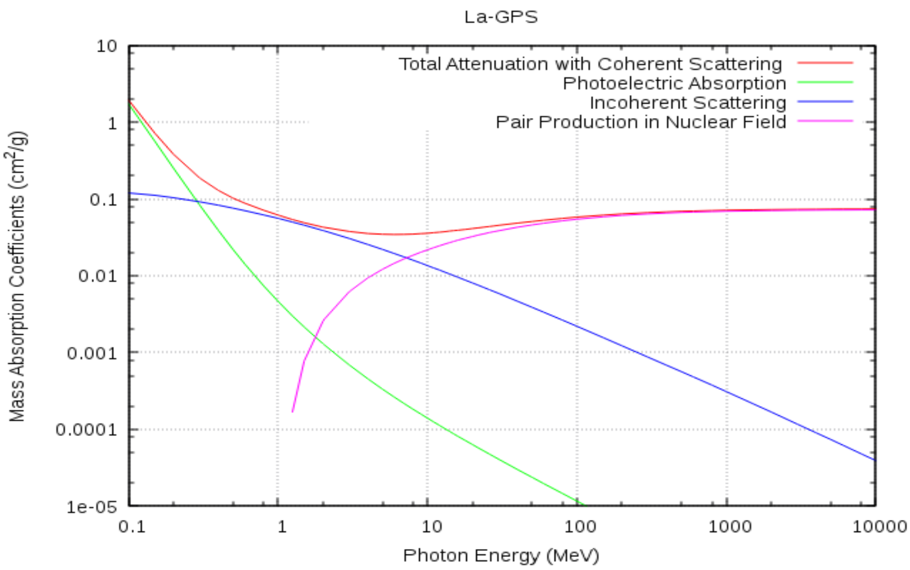


Fig.3: Percentage of interaction per energy