Physics Lab

ETH zürich

D PHYS

e^+e^- Annihilation

Abstract

The e^+e^- annihilation is a well known physical process, in which an electron (e^-) and its antiparticle, a positron (e^+), annihilate. Besides the physics of the annihilation process the experiment offers an introduction to fast electronics (triggering), detectors and methods used in particle physics.

Before annihilation the electron and positron form a short-lived bound state, the Positronium. Depending on whether the spins of the e^- and e^+ are parallel or anti-parallel, a spin triplet state (ortho-Positronium) or a spin singlet state (para-Positronium) is formed. To conserve the total spin the para-Positronium (p-Ps) decays into two photons and the ortho-Positronium (o-Ps) into three photons.

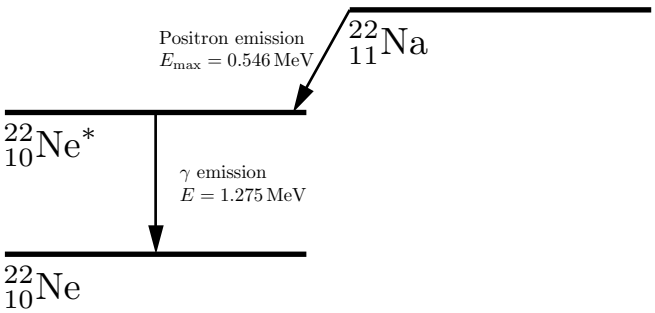
$$p\text{-Ps}(\uparrow\downarrow) \rightarrow \gamma\gamma$$

$$o\text{-Ps}(\uparrow\uparrow) \rightarrow \gamma\gamma\gamma$$

The most probable result of this process is the production of two photons. In this case the two photons are emitted with equal energy and opposite momenta.

Setup

In this setup a Na-22 source is used. The radioactive sodium nuclei β^+ decays into an excited state of the Ne-22 isotope by emitting a positron. Ne-22 decays to its ground state with the emission of a photon of energy 1.275 MeV.

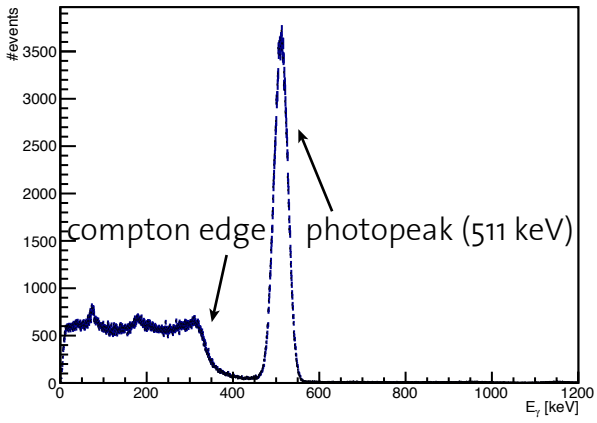


The positron loses energy via scattering processes before it annihilates with an electron at rest.
The photons are detected by NaI scintillators at 180°. The emitted scintillation light is measured by photomultipliers (PM).

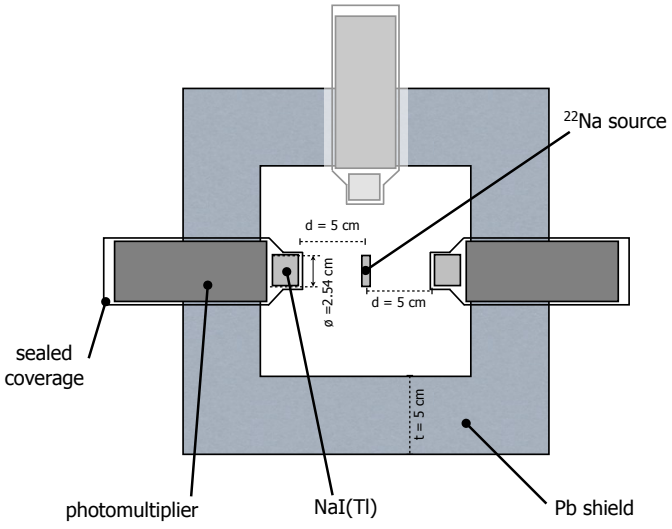
Measurement

Events are selected by a trigger. In this setup a coincidence circuit is used. It allows only events in which both PMs detected a signal at the same time. For every triggered event the signal of one PM gets read out. The signal is proportional to the photon energy.

In the histogram below the number of triggered events is plotted as a function of the measured photon energy.



Due to energy conservation both photons have an energy which is equal to the electron rest mass (E = 511 keV). The photopeak represents the photons which deposited their entire energy in the scintillator (NaI) through the photoelectric effect. Less energetic events are the result of compton scattering.



Author: Lukas Bäni

12.05.2012