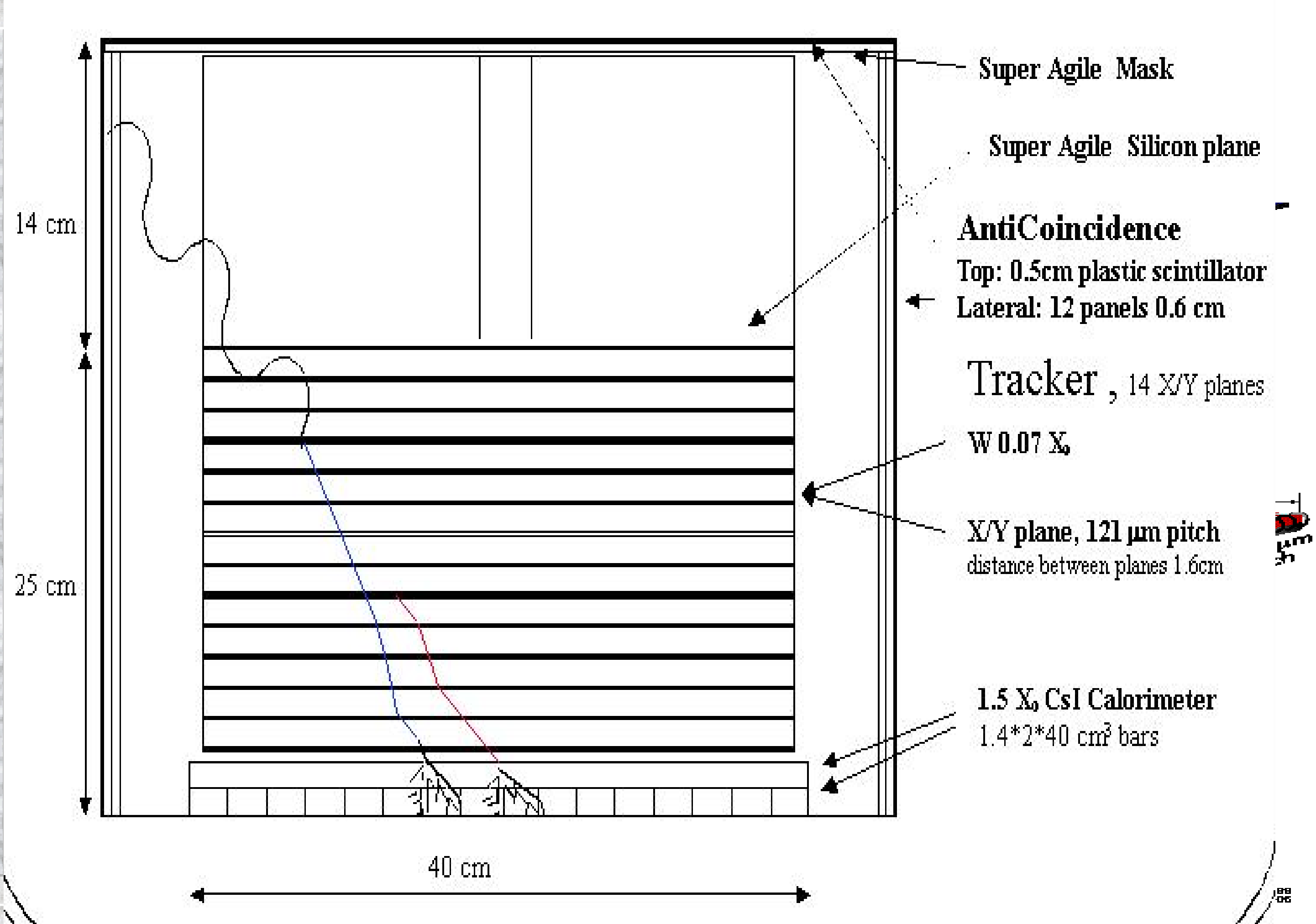
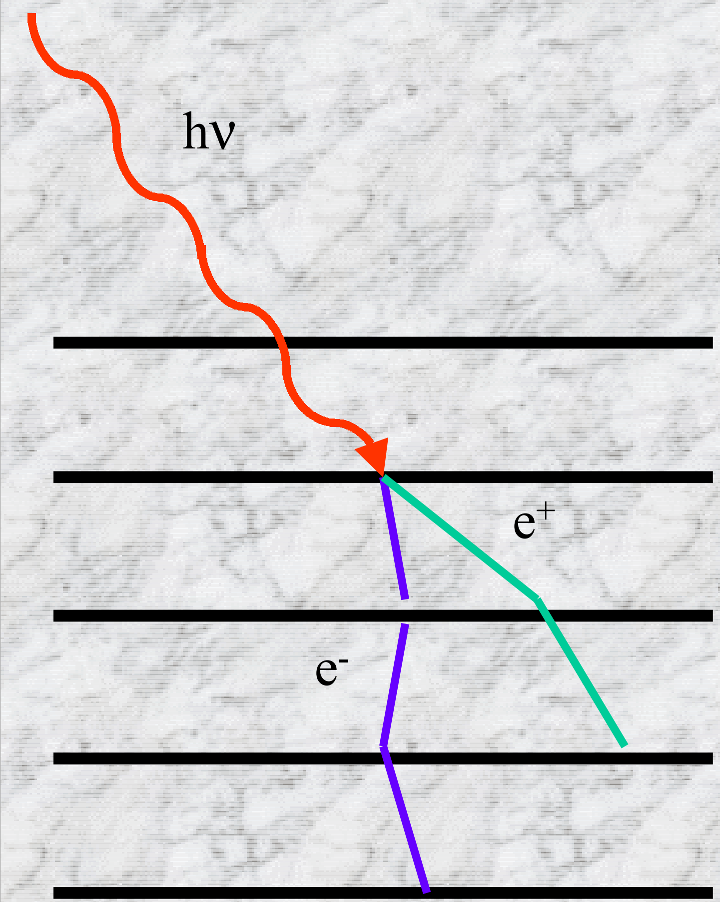
Experiment

There are gamma ray telescope projects that are or will be simulated with GEAN4



AGILE

The direction of the gamma ray is obtained from a careful analysis of the e^- e^+ direction => the gamma ray direction is, on a first approximation, the bisector of these two directions:



In the G4LowEnergyGammaConversion class: positronDirection(-dirX,-dirY,dirZ)

(dirX, dirY, dirZ) is the e^- direction, that is $\theta^- = \theta^+$ and coplanar event ($\phi=\pi$) => the bisector method must return the exact gamma ray direction, so the angular resolution obtained is due only to the multiple scattering suffer by the particles when they cross the planes.

Proposal for the polar angles sampling:

Sauter-Gluckstern-Hull formula: $$\frac{dP}{d\theta_\pm} = \frac{\sin\theta_\pm}{2p_\pm\left(E_\pm - p_\pm\cos\theta_\pm\right)^2}$$

From this distribution the calculate angles are:

$$\sin\theta_\pm = \frac{2\sqrt{\mathrm{rnd}(1-\mathrm{rnd})}}{p_\pm(2\mathrm{rnd}-1)+E_\pm} \quad ; \quad \cos\theta_\pm = \frac{E_\pm(2\mathrm{rnd}-1)+p_\pm}{p_\pm(2\mathrm{rnd}-1)+E_\pm}$$

This formula produce the same distribution -> G4GammaConvertion class:

$$f(u) = C\left(ue^{-au} + due^{-2au}\right); u = E_\pm\theta_\pm$$

The advantage of the first formula is -> sample directly the sin θ and cos θ of the polar angle

A more accurate cross section, to take into account the screening potential, for sampling the polar angles is to use the Schiff distribution:

$$\frac{d\sigma^2}{dE_\pm d\theta_\pm} = \frac{2\alpha Z^2 r_0^2}{\pi}\frac{E_\pm^2}{k^3}\left\{-\frac{(E_+ - E_-)^2}{(u^2+1)^2} - \frac{16u^2E_+E_-}{(u^2+1)^4} + \left[\frac{(E_+^2 - E_-^2)}{(u^2+1)^2} + \frac{4u^2E_+E_-}{(u^2+1)^4}\right]\ln M(y)\right\}$$

Where: $$\frac{1}{M(y)} = \left(\frac{k}{2E_+E_-}\right)^2 + \left(\frac{Z^{1/3}}{111(u^2+1)^4}\right)^2$$

Azimuthal distribution and Polarization

Bethe-Heitler Cross Section:Unscreened point nucleus

$$d\sigma = \frac{-2\alpha Z^2}{(2\pi)^2}\frac{r_0 m^2}{\omega^3} dE\,d\Omega_+ d\Omega_- \frac{E(\omega-E)}{|\bar{q}|^4}\left\{4\left[E\frac{\sin\theta_-\cos\psi}{1-\cos\theta_-}+(\omega-E)\frac{\sin\theta_+\cos(\psi+\phi)}{1-\cos\theta_+}\right]^2 - \right.$$

$$-|\bar{q}|^2\left[\frac{\sin\theta_-\cos\psi}{1-\cos\theta_-}-\frac{\sin\theta_+\cos(\psi+\phi)}{1-\cos\theta_+}\right]^2-\omega^2\frac{\sin\theta_-}{1-\cos\theta_-}\frac{\sin\theta_+}{1-\cos\theta_+}\times$$

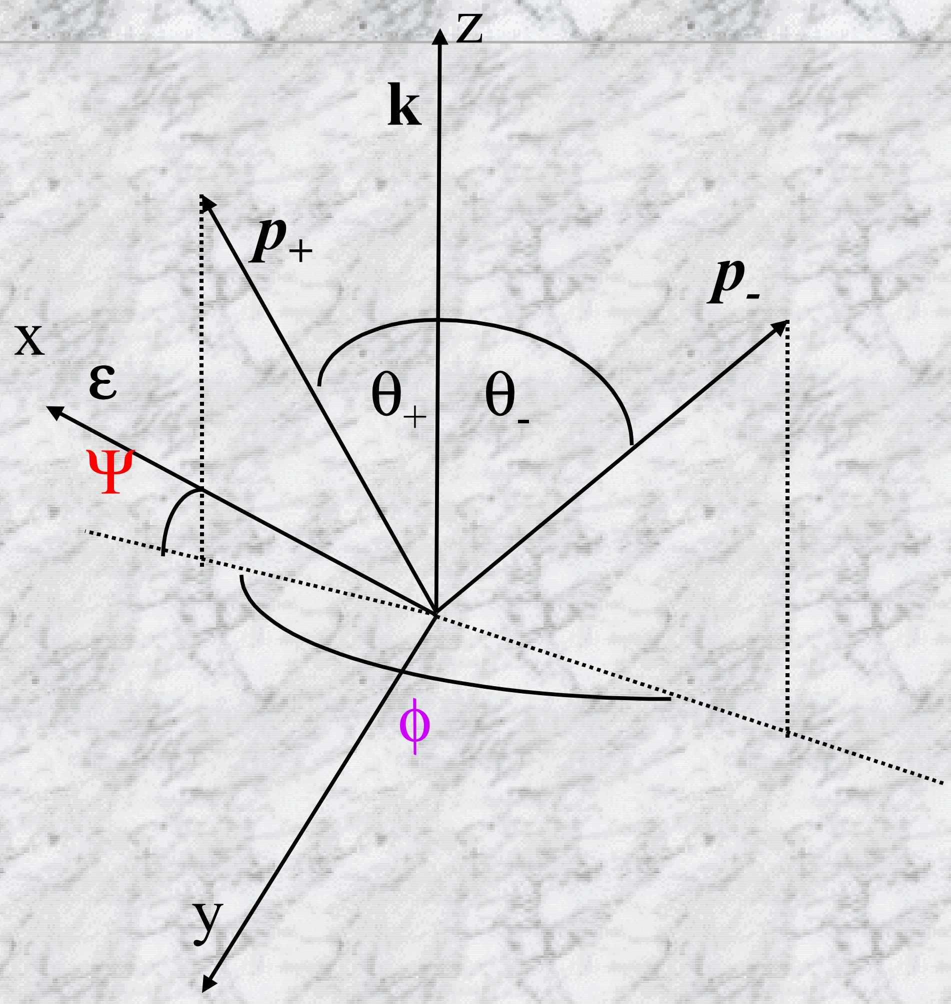
$$\left.\times\left[\frac{E}{(\omega-E)}\frac{\sin\theta_+}{\sin\theta_-}+\frac{(\omega-E)}{E}\frac{\sin\theta_-}{\sin\theta_+}+2\cos\phi\right]\right\}$$

$$|\bar{q}|^2 = -2[E(\omega-E)(1-\sin\theta_+\sin\theta_-\cos\phi-\cos\theta_+\cos\theta_-)+\omega E(\cos\theta_+-1)+$$

$$+\omega(\omega-E)(\cos\theta_- -1)+m^2]$$

Validity: First Born approximation, no screening, negligible nuclear recoil

Angles occurring in the pair production

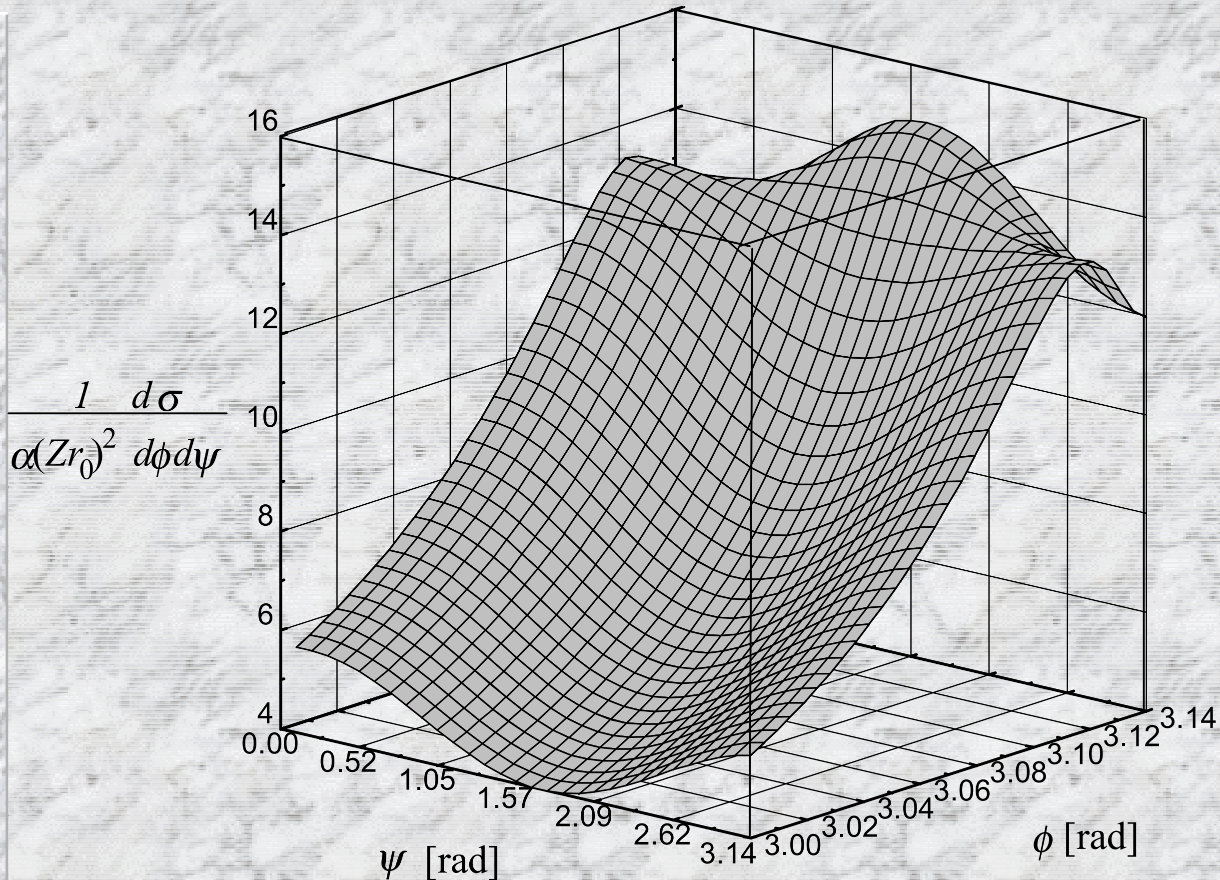


The polarization dependence is represented trough the angle Ψ.

The angle ϕ is the angle between the projection of the particle moments in the x-y plane.

For unpolarized beam => Ψ is isotropic, not ϕ which is related to the azimuthal distribution of the pair.

Integration over the energy an polar angles => azimuthal distribution of a pair created by 100 MeV photon.



This surface can be parameterized and its parameters can be put in function on the photon energy.

Integrating over Ψ one obtain the ϕ distribution .