Compton Polarimeter

G. Peterson reporting for Yong Wu and Ross Hicks

Circularly polarized photons

Circular photon polarization P_γ of bremsstrahlung in a crystal in terms of electron polarization P_e

$$P_\gamma = P_e \frac{1-(1-y)^2-\frac{2}{3}y(1-y)}{1+(1-y)^2-\frac{2}{3}(1-y)} \doteq P_e \frac{y(4-y)}{4-4y+3y^2},$$

where y = k/E , k (E) is the photon (electron) energy.

Rates and sensitivity to photon polarization,

$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2}{2m_e^2}\left(\frac{k}{k_0}\right)^2\left[\frac{k}{k_0}+\frac{k_0}{k}-\sin^2\theta - P_\gamma P_e(1-\cos\theta)\cos\theta\frac{(k+k_0)}{m_e}\right],$$

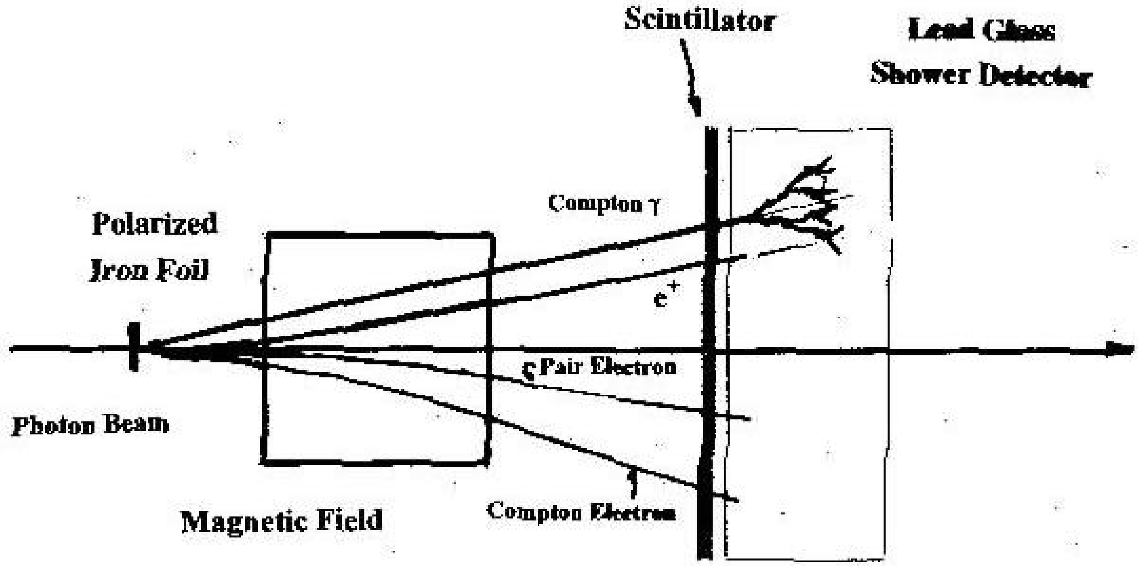
where

θ is the photon laboratory scattering angle,

k_0 (k) is the energies of the incident (scattered) photon,

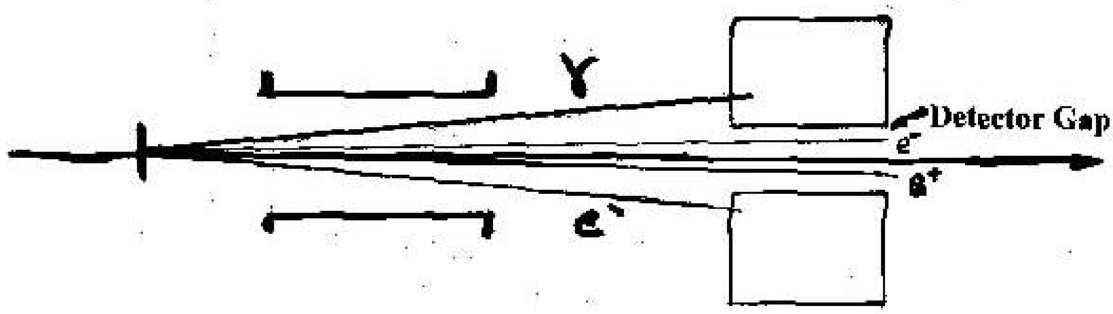
and P_γ (P_e) is the polarization of the photon (electron).

Sketch of a Compton Polarimeter



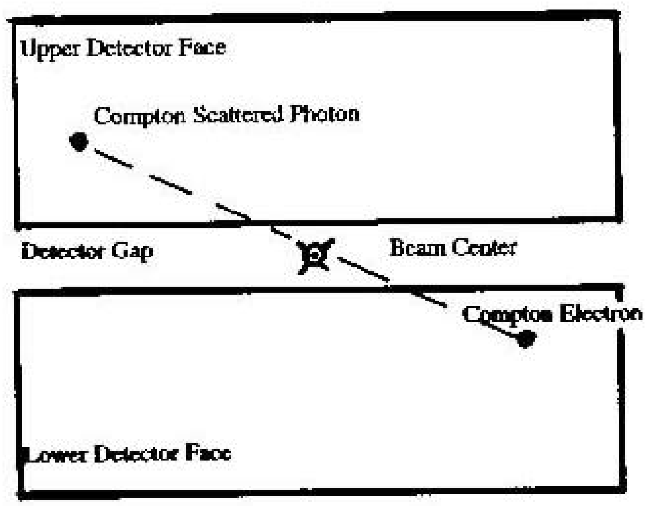
Mid-Plane View

Detect Compton $\gamma + e^-$ in Coincidence



Side View

Co-planarity Requirement
Looking Downstream in Beam Direction



Conditions Assumed for Calculation

9 meter flight path from iron target to detector

2 meters from target to edge of 18D36 dipole magnet
1 meter straight path through magnet
<u>6 meters from magnet to detector</u>
9 meters flight path

15 kG uniform field

Detector gap: 6 cm.

Detector width: +/- 15 cm.

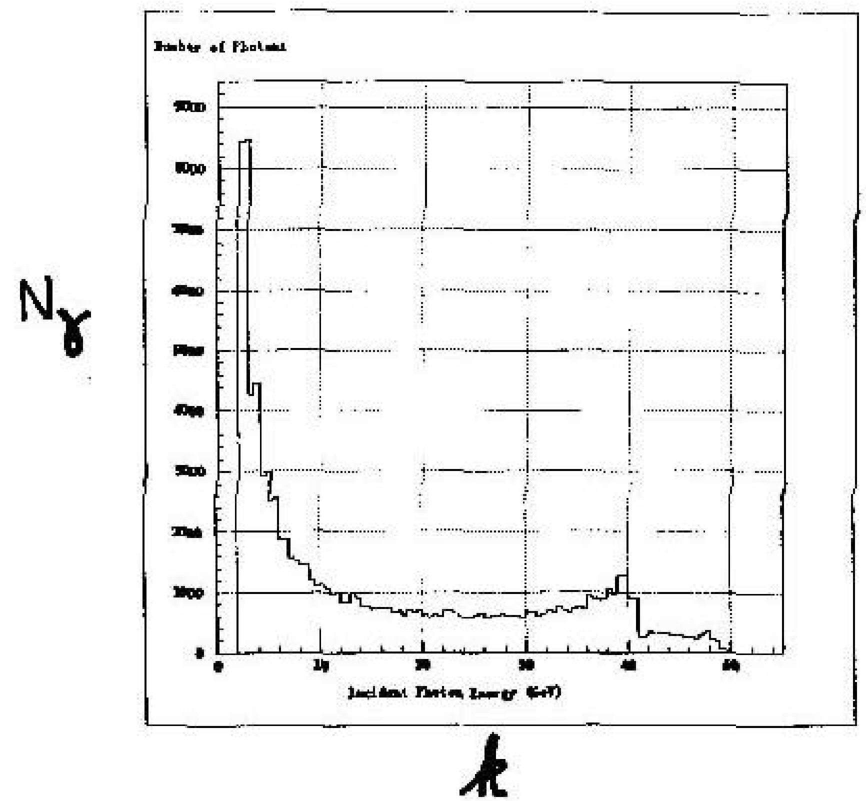
Incident electron energy: 50 GeV

Incident photon energy: 40 GeV

Rate for:
10^9 photons/second
40 GeV spectrum
0.25 gm/cm^2 iron target:

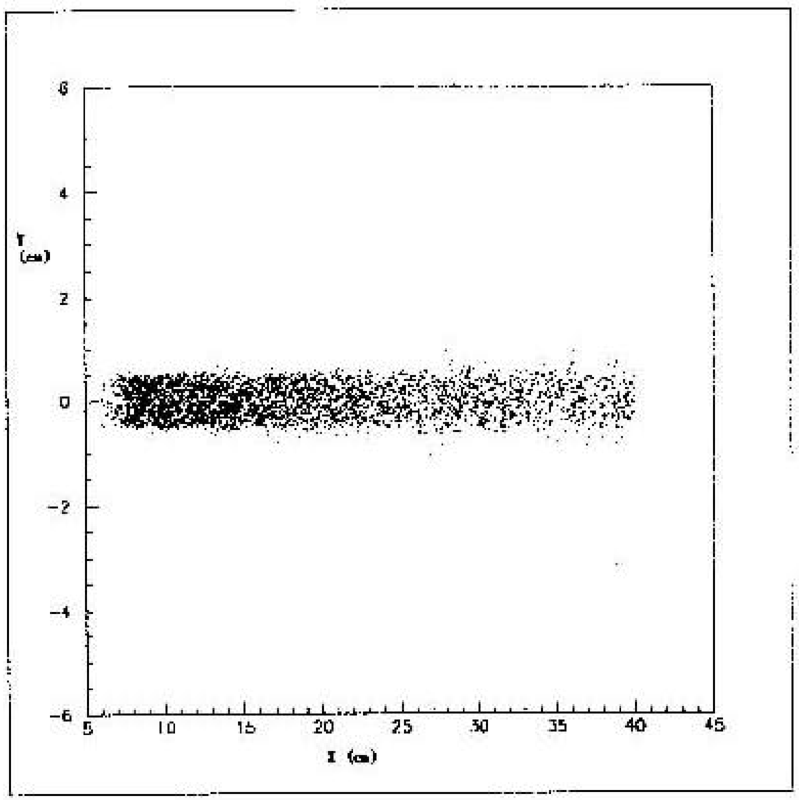
200 pair electrons/second
15 Comptons/second

Photon Spectrum

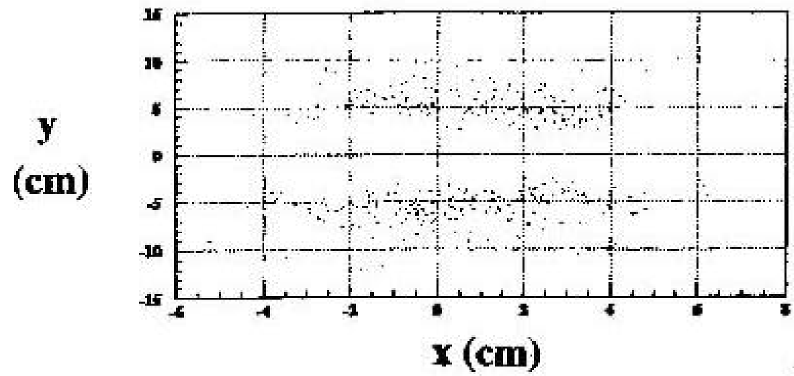


E = 50 GeV

Spatial distribution of pair created electrons of the detector face, most of them fall on the gap of the detector. (1e6 incident photons)

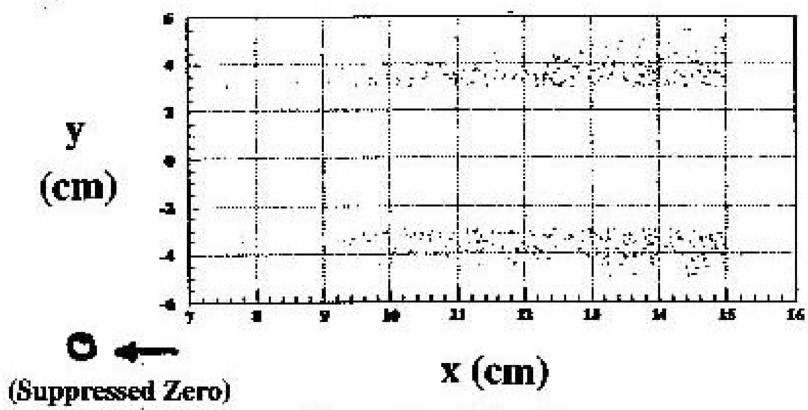


Spatial Distribution of Compton Events
On Detector Face



Compton Scattered Photons

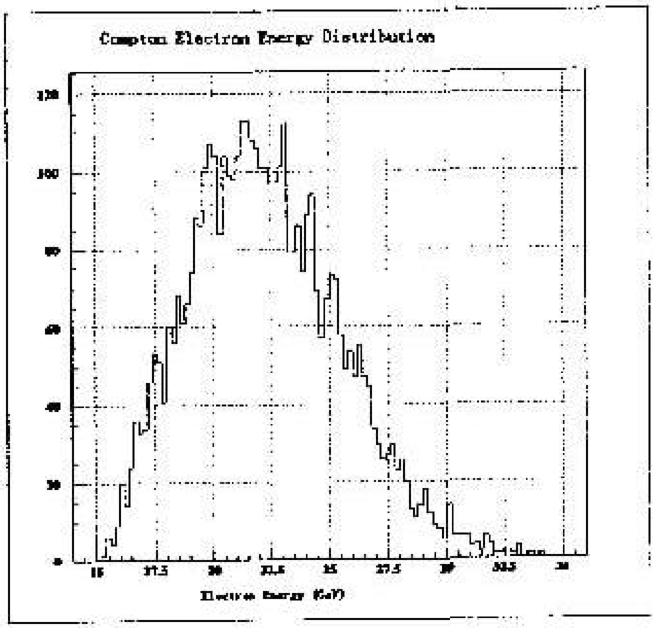
(Nothing in +/- 3 cm gap of detector)

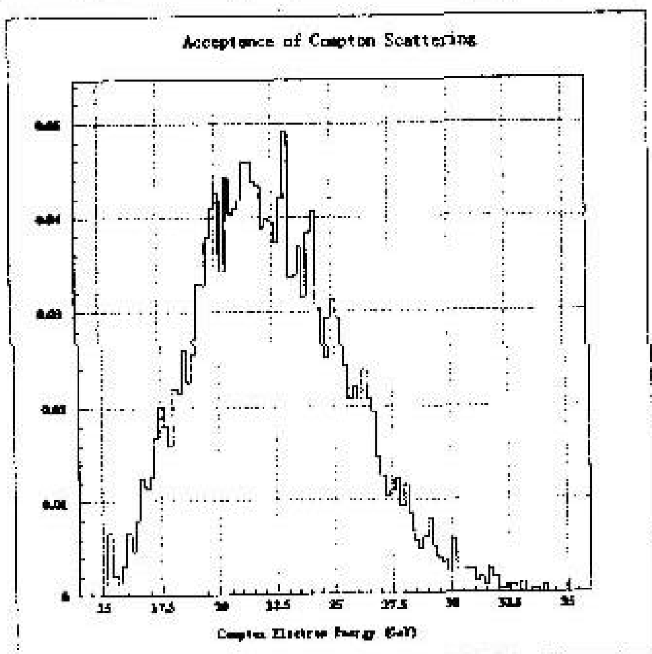


Compton Electrons

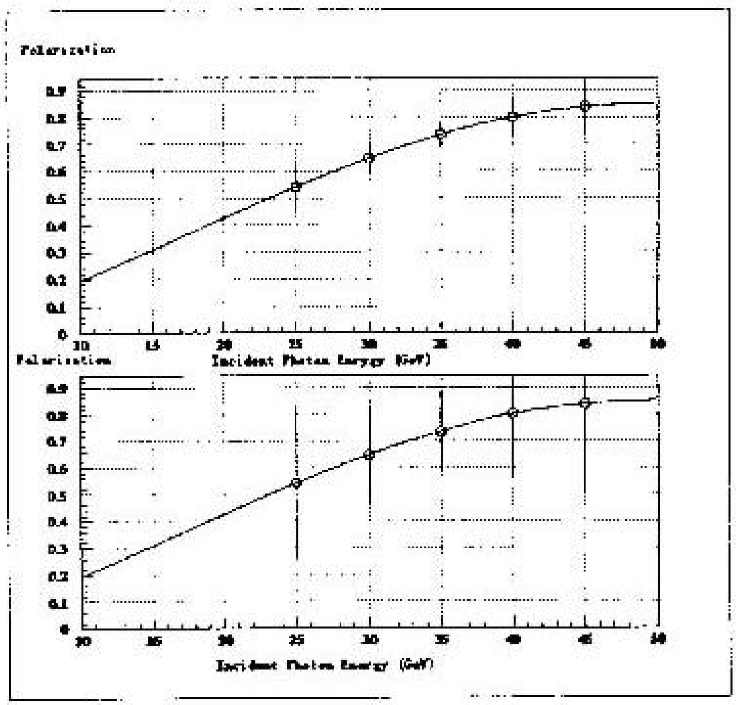
(Nothing in +/- 3 cm gap of detector)

(Both Compton and pair electrons are swept to the right)

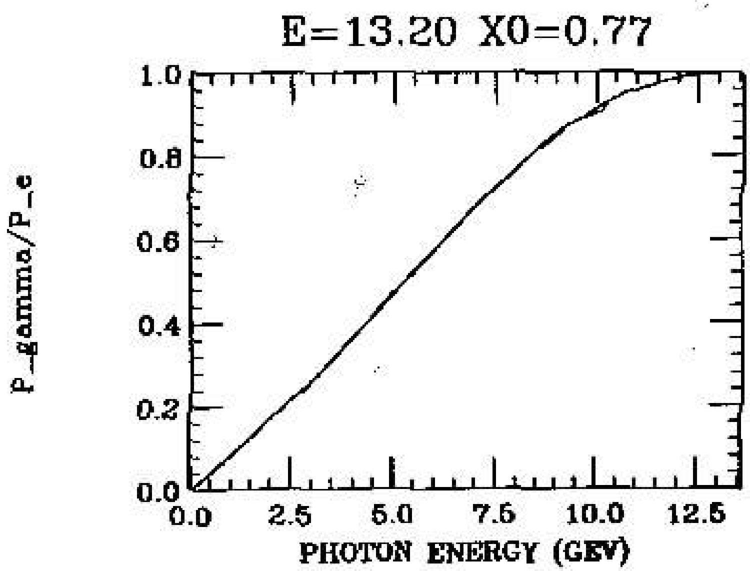

Compton Electron Energy Distribution
Electron Energy (GeV)


Acceptence of Compton Scattering
Compton Electron Energy (GeV)

Statistical error of polarization measurement (running time: 1 day)



For 40GeV photons, the relative error would be 30%. If one can increase the incident photon intensity by a factor of 10, the error decrease to 9%.



Photon circular polarization relative to electron polarization

(Dashed lines are for incoherent radiation, *solid* lines for coherent peaks)

(Figure 5, page 13 of the E159 Proposal)

→ Use incoherent radiation from a tungsten target to get better statistics.

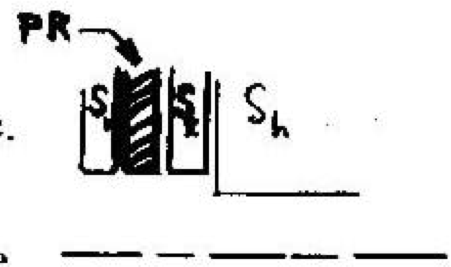
Edge Effects:

Many Compton electrons or photons are close to gap in shower detector. Large portion of shower lost.

Possible solution:

About a centimeter or so from the lead glass shower detector (S_h) edge, put pre-radiator PR between two scintillators S_1 and S_2.

- For Compton electron:
  S_1, S_2, and S_h coincidence.
- For Compton photon:
  S_1 and S_2 anti-coincidence
  S_2 and S_h coincidence.



(Acceptance for Compton coincidence reduced)
(Transverse development of shower needs study)

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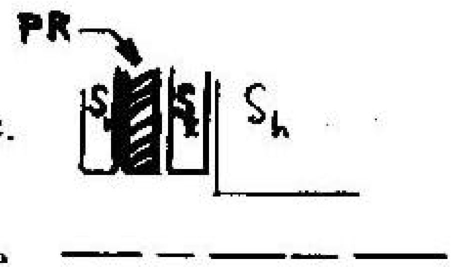

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Computations Needed

General:

(1) Large angle pair distributions

(A more efficient generator required. GEANT is only approximate).

(2) Transverse shower development

Specific:

(1) Vary positions of scintillators and pre-radiator with respect to detector median plane.

(2) More runs for better statistics to determine number of lead glass blocks needed.