Measuring polarization at gamma-rays with Fermi

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SCINEGHE 2010 Trieste

Why?

One of the science goals of LAT since the beginning, as Polarization contains information about magnetic field and gamma-ray production.

Brightest Fermi sources have potentially polarized emission:

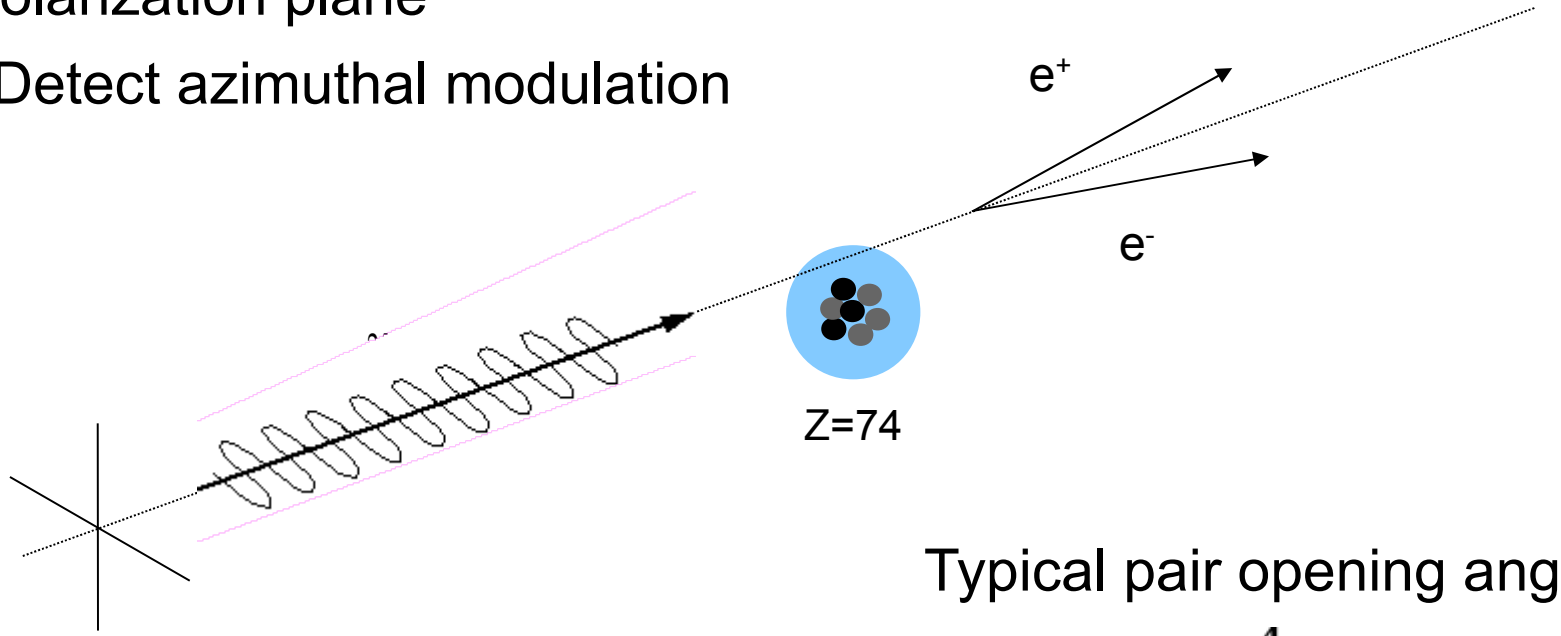
- *Pulsar* : curvature radiation, phase and location dependent (Vela)
- *Pulsar Wind Nebula* : synchrotron radiation (Crab)
- *Active Galactic Nuclei :* proton synchrotron radiation or Inverse Compton radiations (3C 454, 3C 279)

→ Models not very specific yet (to my knowledge), this is the time!

How?

Pair is preferably (~20%) produced in polarization plane

→ Detect azimuthal modulation



Typical pair opening angle:

$$\theta_{op} \cong \frac{4m_e}{E_\gamma}$$

(≈1 deg at 100 MeV)

Pair production cross section

$$d\sigma = \frac{-2\alpha Z^2}{(2\pi)^2}\frac{r_0 m^2}{\omega^3}\,dE\,d\Omega_+\,d\Omega_-\,\frac{E(\omega-E)}{|\bar{q}|^4}$$

$$\times\left\{4\left[E\frac{\sin\theta_-\cos\psi}{1-\cos\theta_-}+(\omega-E)\frac{\sin\theta_+\cos(\psi+\phi)}{1-\cos\theta_+}\right]^2\right.$$

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

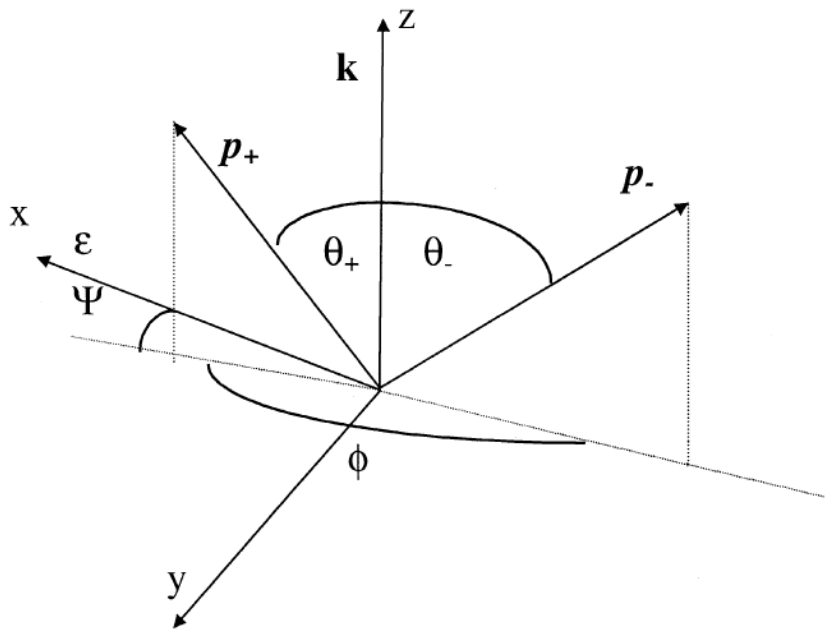
$$\left.-\omega^2\frac{\sin\theta_-}{1-\cos\theta_-}\frac{\sin\theta_+}{1-\cos\theta_+}\right.$$

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

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

$$-\cos\theta_+\cos\theta_-)+\omega E(\cos\theta_+-1)$$

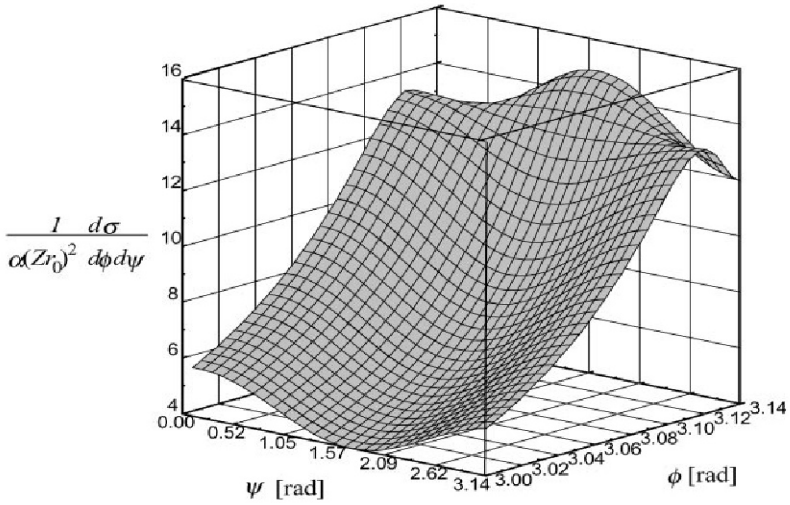
$$+\omega(\omega-E)(\cos\theta_--1)+m^2]$$

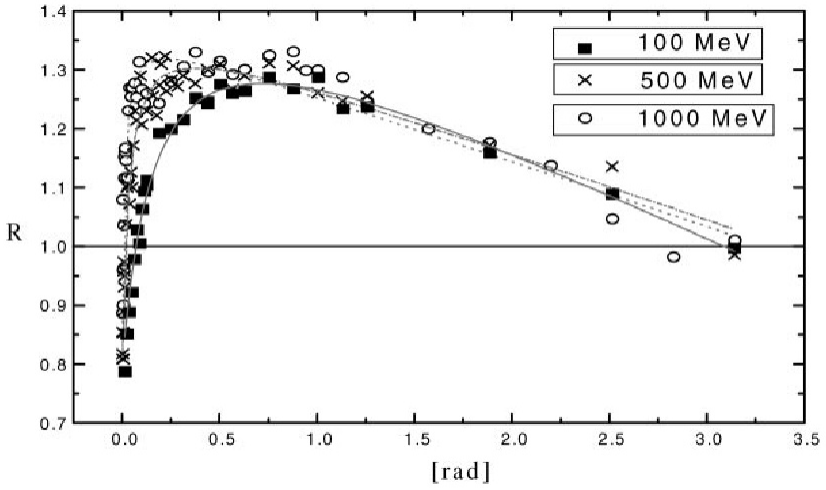


G. Depaola 1999, 2000

Azimuthal modulation

Cross-section complex. Past Studies typically made $\Phi = \pi$ Approximation (no recoil)





Simple diagnostic variable, *asymmetry ratio*:

$$R \equiv \frac{\text{Ne+e- (parallel in } \Delta\psi)}{\text{Ne+e- (orthogonal in } \Delta\psi)}$$

Can it be resolved?

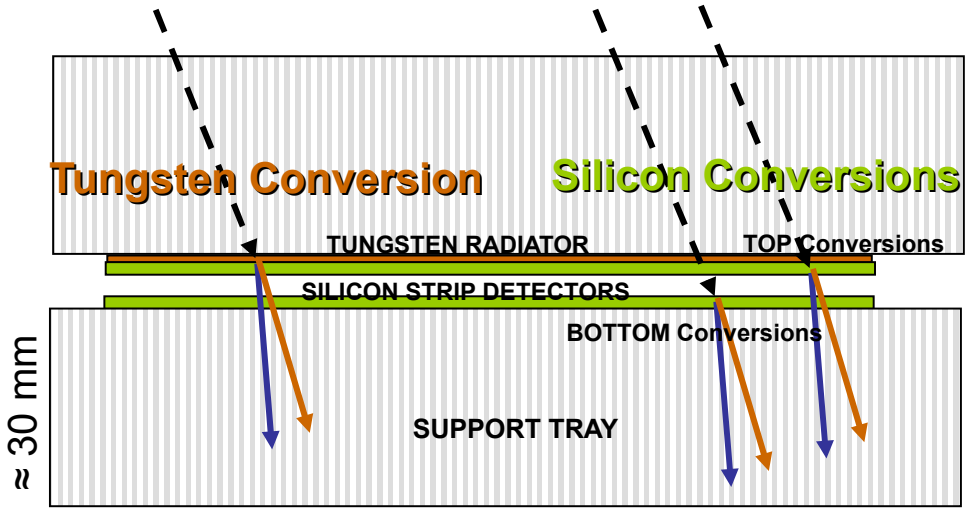
Multiple scattering

$$\theta_{MS} = \frac{13.6}{E_\gamma/2}\sqrt{X}\,(1+.038\ln(X))$$

θ_{MS} in mrad, E_γ in GeV, X in rad. Len.

$X_{tungsten} = 0.028$

$X_{silicon} = 0.004$

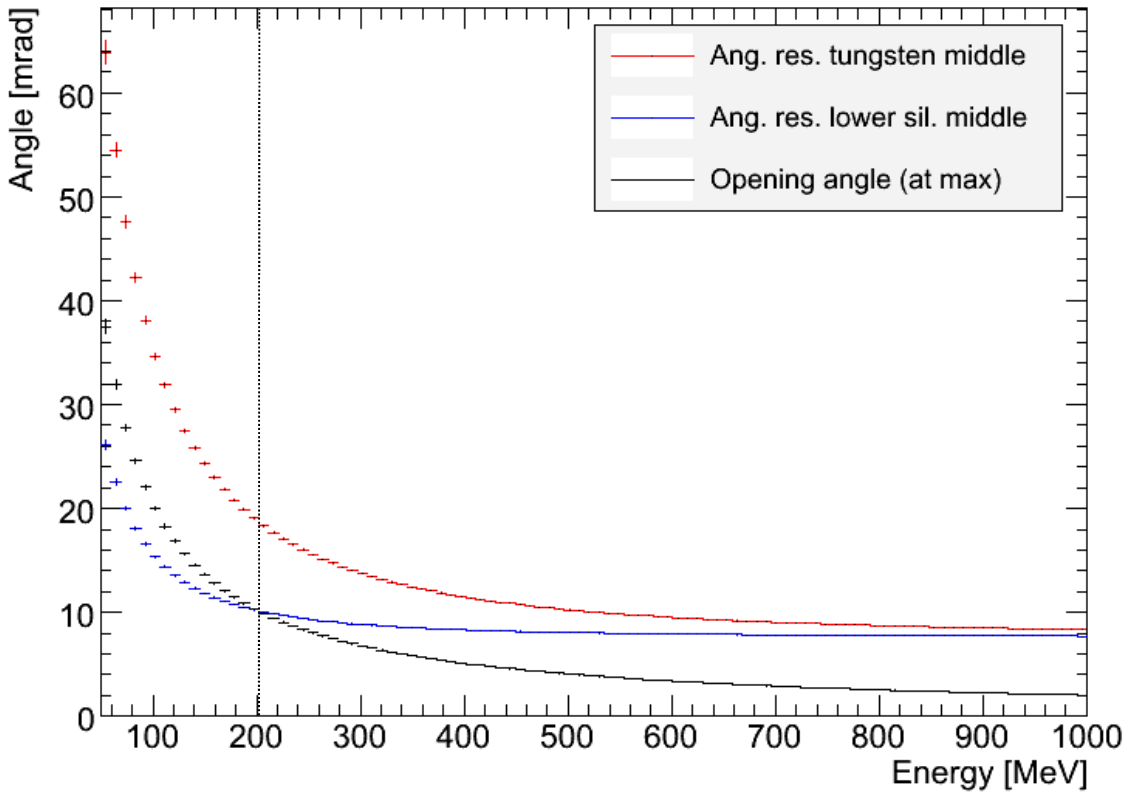


Tracker resolution

Minimum angle which can be resolved between two trackers (pitch=0.228 mm): $\theta_{Min} \approx 0.4$ deg

Can it be resolved?

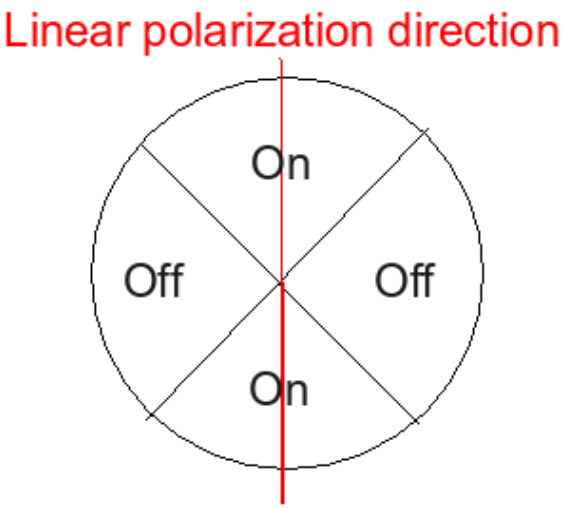
Requirement: e+ e- direction better measured than opening angle



No for typical tungsten conversion

Yes between ≈50-200 MeV for silicon conversions (Idea from Bill Atwood)

Sensitivity estimate



Purity in detecting silicon conversion ≈0.7 with standard reco

Efficiency in detecting silicon conversion ≈0.3 with standard reco

$$\rightarrow N_\gamma \approx \left(\frac{n_{sig}}{p_{open}\, p_{QED}\, p_{pol}\, p_{pur}} \right)^2 / (0.3\, p_{eff})$$

Events with resolvable opening angle ≈0.7

Degree of polarization

Cross section modulation ≈0.2

From Vela we get ≈200000 events/year between 50-200 MeV

→ 20% polarization detectable after 20 month at 3 sigma

(analysis far from optimal, but no background and trial factors considered)

Current status & Outlook

Polarization measurement possible with the LAT down to ~10% polarization level for bright sources.

Status:

- Francesco Longo modified Geant 4 in Fermi simulations, validation
- Improved detection of silicon conversion
- Unpolarized simulations show azimuthal asymmetries in the detector on 5% level. Major challenge.
- No look into data yet (keep analysis blind)

→ Measurement possible, expect results in near future.