Lifting the Electron Veil

Differences in Electron and Gamma Induced Air Showers

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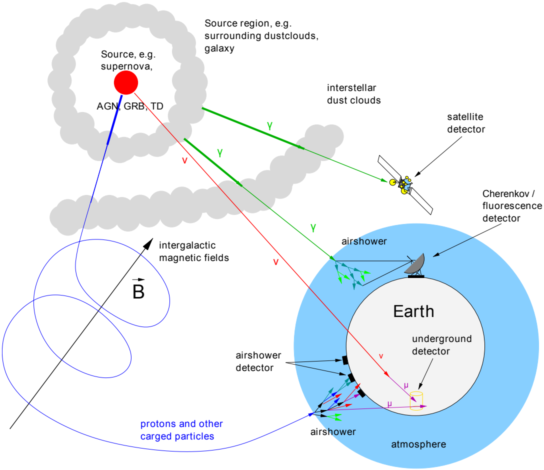
Background in gamma ray astronomy

- Cherenkov telescopes deal with cosmic ray background
- Hadronic showers discriminable by sub cascades
- Electron background only rejectable by arrival direction



[W. Wagner 2004]

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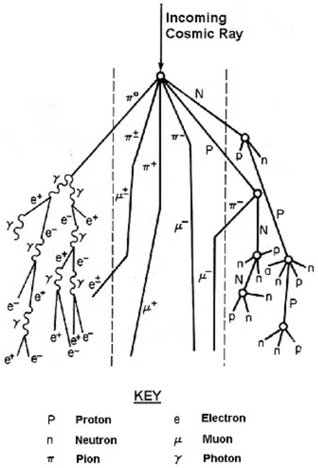
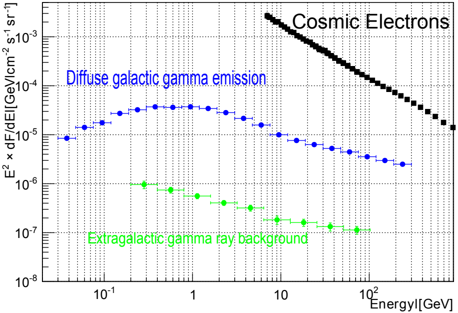


[http://neutronm.bartol.udel.edu/]

What can be studied if we had another discrimination tool than arrival direction

- Galactic and extragalactic diffuse gamma rays (data points from Fermi-LAT)
- Extended sources, e.g. galactic gamma ray halo from Dark Matter annihilation or galaxy cluster



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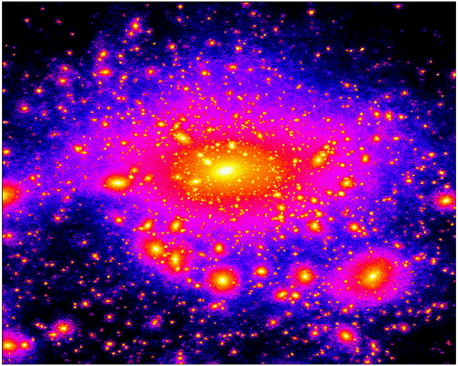

[Mayer,Kazantzidis 2007]

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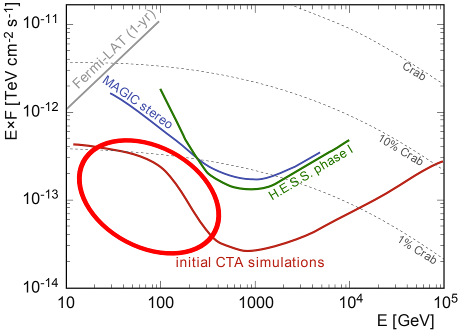
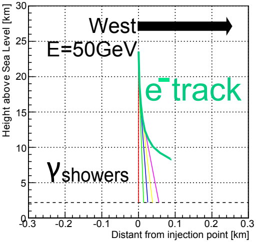
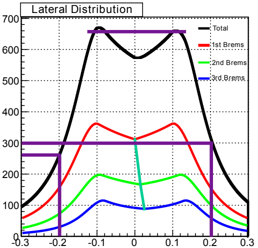


[Lorenz,Wagner 2012]

Methods to discriminate γ / e^-

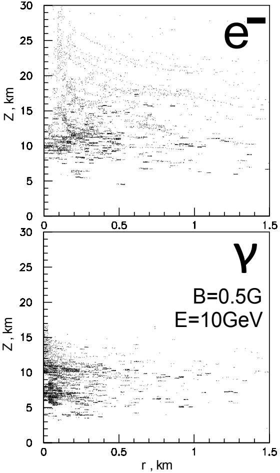
1. Geomagnetic effect





Very small effect

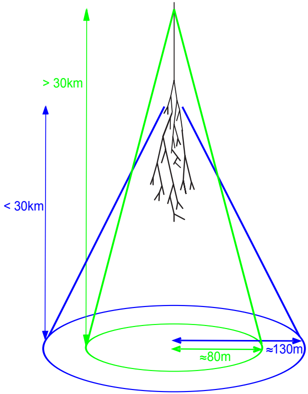
2. Height of the shower maximum



[Sahakian 2006]

Small separation power

3. Cherenkov light at high altitude



Most promising effect

Effect of geomagnetic field

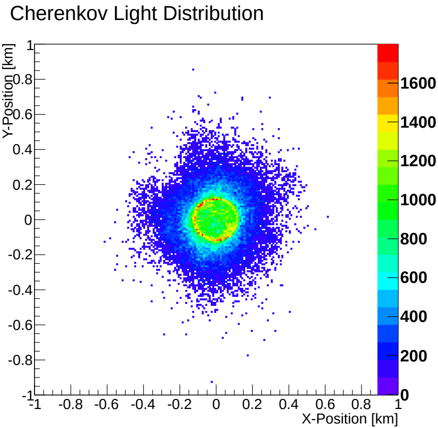


Figure: Single 50 GeV γ event

Air shower simulation studies with CORSIKA

- Observing the Cherenkov photon distribution (x,y-coordinate)
- Obsl. of MAGIC Telescope (2200 m) and magnetic field over La Palma
- 10m x 10m pixel
- Primaries injected from zenith

Lateral distribution of Cherenkov photons

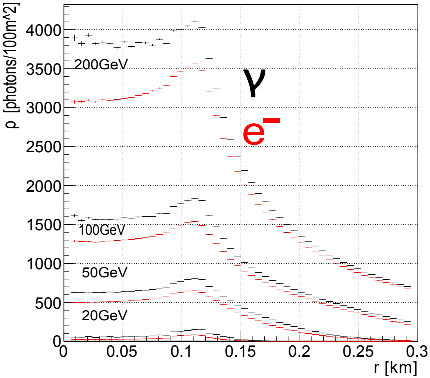
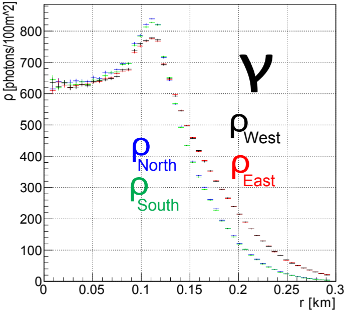
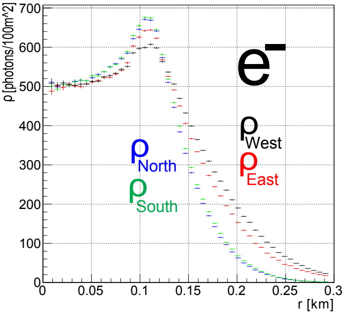


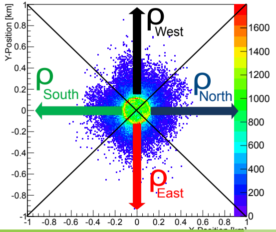
Figure: Averaged lateral distribution of 1000 events for several energies.

- Intensity for gamma shower is higher than that for electron shower with the same energy
- Feature not usable as shower energy is unknown
- Shape of the lateral distribution is similar for both shower types

Lateral distribution of $\rho_{\text{East, South, West, North}}$ for 50 GeV showers





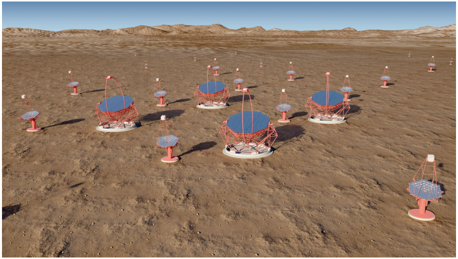


- Electron showers show asymmetry in East-West direction: Higher hump in east, more intensive slope in west.
- Effect very small, even at low energies

Height of the shower maximum

Simulation for CTA

- 200 000 events for each shower type simulated with CORSIKA and sim_telarray
- 2000m observation level
- magnetic field mixture of La Palma and Namibia
- Configuration E



[G. Perez 2012]

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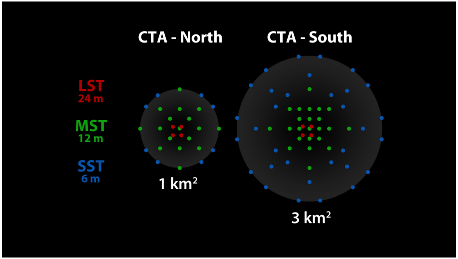

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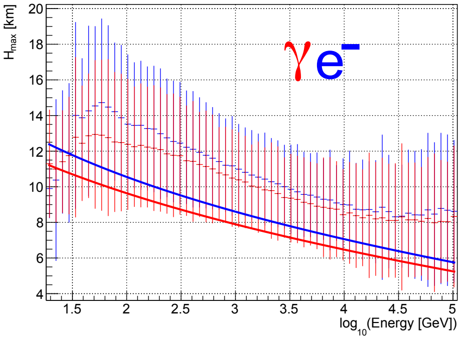
Height of the shower maximum

Results

- ⇒ Difference decreases logarithmically with energy
- ⇒ Separation power low even at optimal range
- ⇒ Q-factor $= N_{signal} / \sqrt{N_{bg}}$ maximal 1.04



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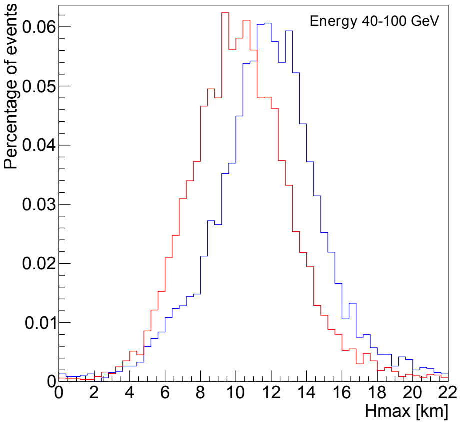
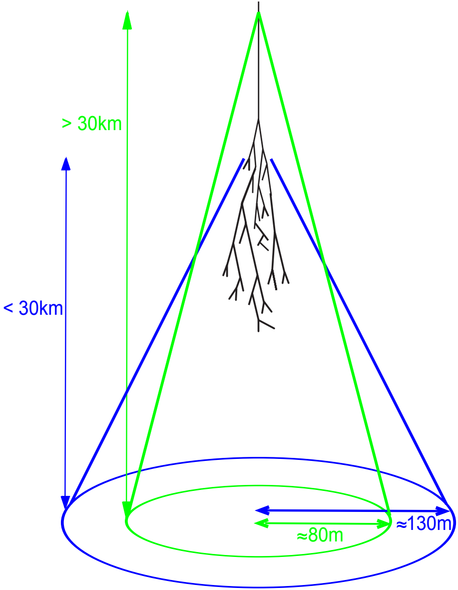


Direct Cherenkov Light - DCL

Simulation with Corsika

- In contrast to hadronic and gamma ray events e^{-} have not clear first interaction point
- Optimal height may be around 30 km
- DCL arrives in very small time slot and under small angle
- Backtracking of photons to height



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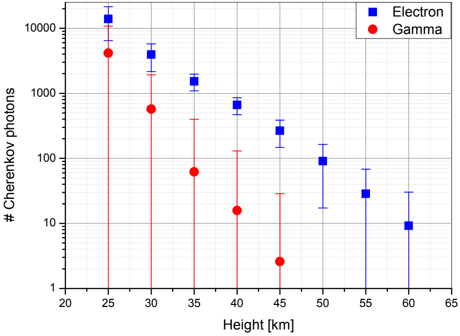

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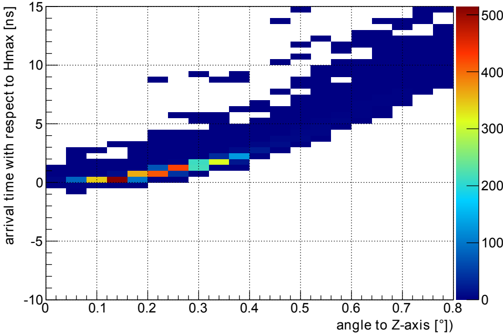


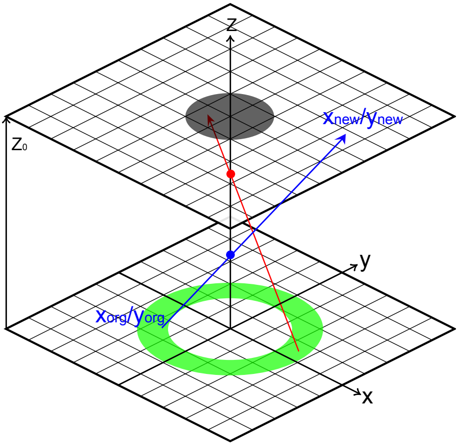
Direct Cherenkov Light

Method to catch DCL

- Only take photons arriving within 3 ns within radius of 90 m around core
- Backtracking of photons to height $z_0 = 30$ km, angular precision 0.01°
- Integrating photon within radius of 30 m around mean value

⇒ Q-factor of 9.06 by cutting after first bin, keeping 20% gamma events

⇒ 50% gamma can be kept with Q-factor of 4.14



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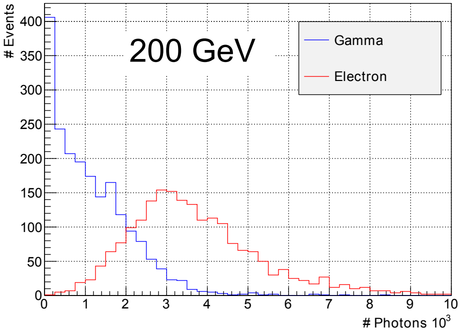


Summary

- Separation of γ/e^- by Hmax is low, maybe FIP advancement, will still be affected by fluctuations
- Asymmetry due to magnetic field too small, even with perfect detector and at small energies
- Direct Cherenkov Light is a promising tool for gamma/e^- separation

Thank you for your kind attention and interest!

Backup Slides

Height of the shower maximum

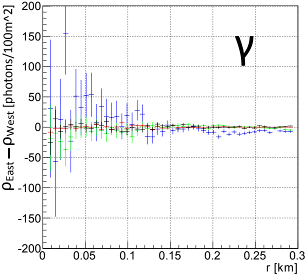
$$t_{max}(E) = 1.01 X_0 \left[\ln\left(\frac{E}{E_c}\right) - n\right], \text{ with } n = \begin{cases} -0.5, & \text{for } \gamma \\ 0.5, & \text{for } e^{\pm} \end{cases}$$

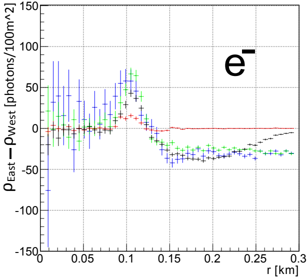
$$z_{max} = -h_s \ln\left(\frac{X_0\, t_{max}}{h_0\, \rho_0}\right)$$

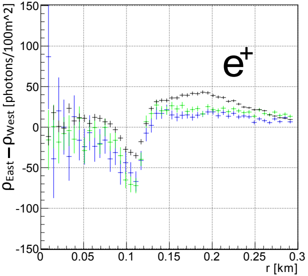
$$\Rightarrow \Delta(E) = h_s \ln\left[1 + \frac{1}{2\left(\ln\left(\frac{E}{E_c}\right) - 1\right)}\right] \approx \frac{h_s}{2\left(\ln\left(\frac{E}{E_c}\right) - 1\right)}$$

$\Rightarrow$ Difference descrease logaritmically with energy

Difference of $\rho_{East} - \rho_{West}$

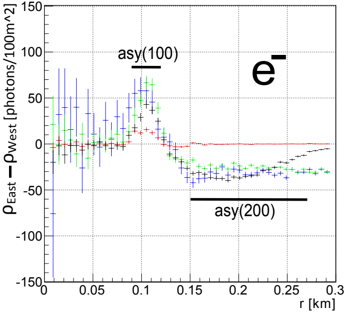


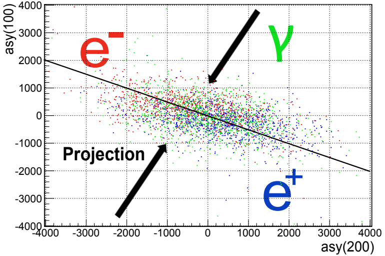


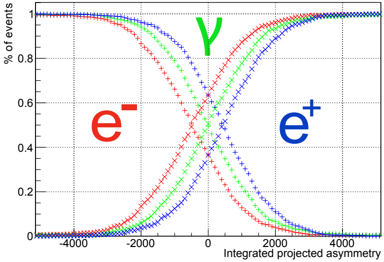


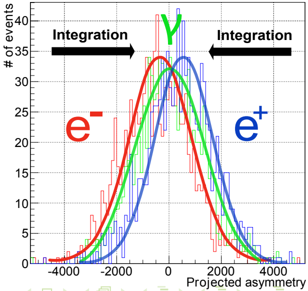
$\Rightarrow$ For all curves:
Averaged east-west lateral distribution of 1000 event:
20 GeV, 50 GeV, 100 GeV, 200 GeV.

Proof of separation power for 50 GeV showers









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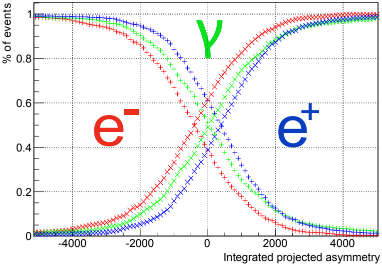

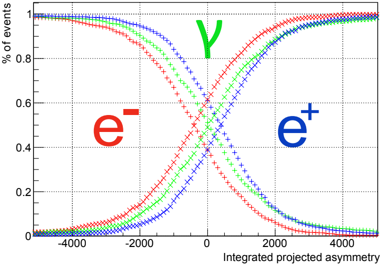

Integration over the histogram for 100 GeV (left) and 200 GeV (right) from right and left side.