Reconstruction of charge number of heavy cosmic rays using Cherenkov Light

Robert Stein, Attila Abramowski, Dieter Horns

Lateral Photon Distribution Method

- New reconstruction method, fitting received DC photons to known Lateral Distribution Function.
- Aim is to improve reconstruction of Charge.

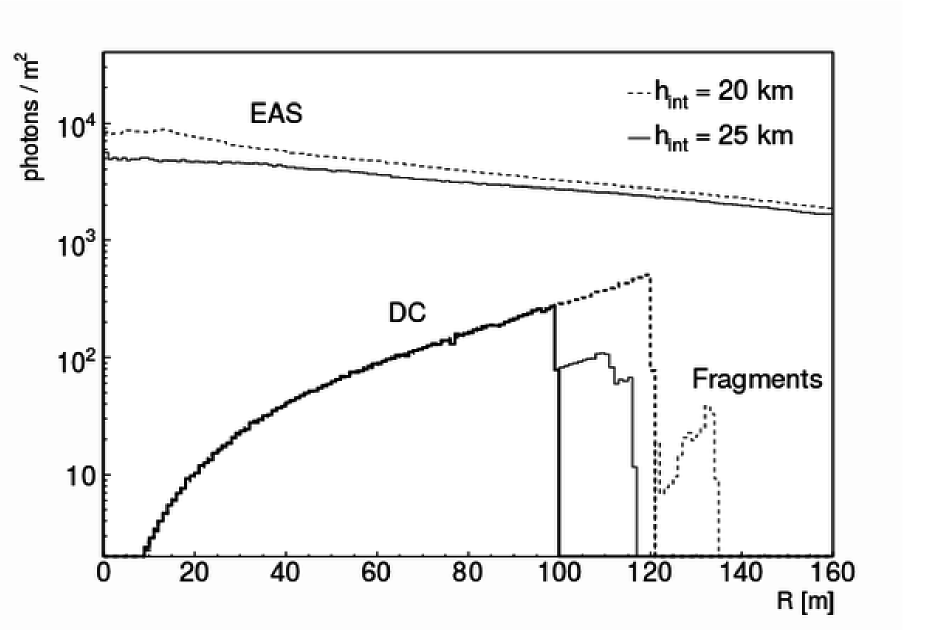

FIG. 2: Simulated intensity distribution on the ground for the EAS-light and DC-light of an individual 50 TeV iron nucleus, as a function of distance from the shower core, for two different first interaction heights (the shower core is defined as the intersection point of the shower axis on the ground). The zenith angle is 0°. The drop in DC-intensity at 100/120 m reflects the first interaction height. The low intensity tail at larger radii is caused by Cherenkov light from fragments of the primary nucleus.

Fitting and event reconstruction

- Five variables to reconstruct:
  - x/y Core Position,
  - First Interaction Height,
  - Energy per Nucleon
  - Charge.

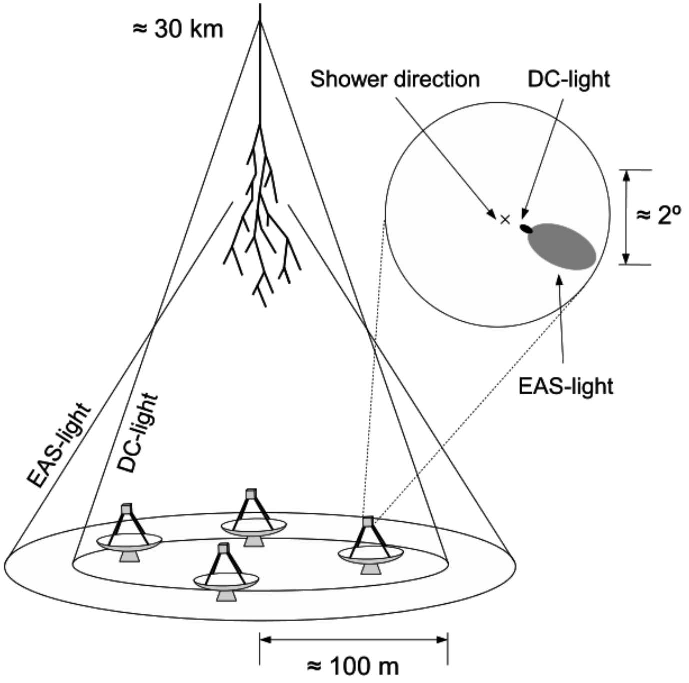

FIG. 1: Schematic representation of the Cherenkov emission from a cosmic-ray primary particle and the light distribution on the ground and in the camera plane of an IACT.

Likelihood

Poisson Distribution

$$P_i(N_{i,Received}|X, Y, Z, height, Epn) = \frac{e^{-\lambda_i} \times \lambda_i^{N_i}}{N_i!}$$

+

Stirling's Approximation

$$\ln(N!) \approx N\ln(N) - N + \frac{1}{2}\ln(2\Pi N)$$

=

$$-\ln(L) = -\sum_i \ln(P_i) = \sum_i \lambda_i - N_i \ln(\lambda_i) + N_i \ln(N_i) - N_i + \frac{1}{2}\ln(2\Pi N_i)$$

Iterative Minimisation

- Iterate over integer Z
- Select a ~100m² region
- Scan valid Height/Energy combinations

  – 13 Z values
  – 10 positions
  – 51 Epn/Height Combos
  – 13 x 10 x 51 = 6630

- **Candidate with smallest log likelihood of the 6630 runs is selected**

Optimised Telescope Array

- Grid of 3 x 3 telescopes (12m Diameter)
- Expected counts for 50 hours run time
- Minimise σ_z by balancing competing effects

Summary

- New Technique for Charge Reconstruction, valid for both current and future IACT systems.
- Simulation with HESS-type layout yields a much improved core reconstruction.
- Charge resolution of $\sigma_z < 0.3$ for five telescope events.
- Ideal future CT experiment would have 9 telescopes with a grid spacing of ~20-40m.
- Consequent event rate would be ~15 events per hour observed by 5 or more telescopes.