Cosmic Ray Measurements at PeV energies

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Cosmic Ray all particle energy spectrum



KASCADE & KASCADE-Grande



Located in Karlsruhe – Germany at atmospheric depth of 1022g/cm². Operated in 1993-2012 Measures electromagnetic, muonic and hadronic components of air showers KASCADE: dense array (13m grid 200x200 m2) 100 TeV– 80 PeV KASCADE-Grande: 100 TeV – 1 EeV (0.5 km2) (37 plastic scintillators ~ 130m grid)

KASCADE

All particle spectrum and 5 mass group composition



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model

results

KASCADE-Grande

All particle spectrum and light & heavy composition



KASCADE + KASCADE-Grande combined analysis (in progress)



Raw spectra: detector and reconstruction efficiencies not accounted yet

KASCADE + KASCADE-Grande combined analysis (in progress)



- structures confirmed
- all particle spectrum good agreement
- relative abundance of light and heavy quite different

Post-LHC models

- better agreement on light primaries,
- heavy primaries show differences

IceCube Neutrino Telescope & 3D Cosmic Ray Detector



Air shower detection @ 2835m altitude (692 g/cm²)

IceTop

EM component near shower max shower size & arrival times over 1km²

IceCube

Muonic component @ 1450m-2450m depth in ice muon bundle energy over 1km

Run 116545 Event 58761981 top hlc clusters/0 [Ons, 3919

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IceCube/IceTop Air Shower Reconstruction



On the surface: IceTop shower size S_{125} , Shower core: x,y,z, Shower direction: θ, ϕ





IceCube/IceTop Primary Mass Composition



- 5-7-4-2 Neural Network structure maps
 5 observables to Primary Energy and Mass
- Energy spectrum directly from NN output
- Composition from fitting data in each E_{reco} bin to template histograms (H,He,0,Fe) from NN mass output



Template example energy bin Log₁₀(E/GeV): 7.45

IceCube/IceTop CR Energy Spectrum



IceTop-alone spectrum with high statistics

IceCube/IceTop coincidence spectrum

- uses unfolding method

- results of neural net method

with 2 different methods

IceCube/IceTop Primary Mass Composition



Confirms KASCADE-Grande

- Light primary flux rapidly decrease until ~100 PeV then slightly upturn to explain Auger's proton flux
- Heavy primary flux increases, Iron is most abundant ~100 PeV

Cosmic Ray Mass Composition

