HADRONIC PARTICLE PRODUCTION AND HIGH ENERGY SHOWERS

1 HADRONIC INTERACTIONS

The overall characteristics of hadronic particle production is introduced with the aim of later applying it to different phenomena in cosmic ray physics. Three different energy ranges will be discussed. Resonance region: At low energy particle production is most efficiently described by the formation and subsequent decay of resonances. Scaling region: In a limited energy range starting above the resonance region, Feynman scaling can be used to parametrize many distributions with sufficient accuracy. Minijet region: At high energy, a new phenomenon gets increasingly important. The interaction of sea quarks and gluons begins to dominate the characteristics of multiparticle production.

2 INCLUSIVE PHOTON AND NEUTRINO FLUXES

Hadronic interactions of high-energy particles with, for example, the gas of molecular clouds, the interstellar medium, and nuclei of the atmosphere of the Earth give rise to secondary particle fluxes of electrons, photons, and neutrinos. Many important features of these fluxes can be estimated without simulating hadronic interactions in detail. The overall energy distribution of the secondary fluxes and some examples of benchmark calculations, including the Waxmann-Bahcall flux, will be calculated and implications discussed.

3 EXTENSIVE AIR SHOWERS

The tools introduced in the previous lectures will be used to discuss the general characteristics of air showers. After illustrating the fundamental processes that lead to shower formation within the Heitler-Matthews model the expectations on experimentally accessible observables are presented. Universality features of high-energy showers are reviewed and differences between electromagnetic and hadronic showers are highlighted. Finally the importance of the characteristics of hadronic interactions for some of the key observables of extensive air showers is illustrated by deriving the elongation rate theorem and comparing predictions calculated with different hadronic interaction models.