Summary

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Since their beginning the studies of cosmic ray and elementary particle physics have always be closely related and it has been demonstrated that the very high energy cosmic ray puzzle can not be solved without the results of the HERA or LHC experiments.

Using a simple cascade model, it is possible to find the main parameters of hadronic interactions that influence air shower predictions. These parameters, namely the inelastic cross sections, the secondary particle multiplicity, the inelasticity, and the ratio of charged to neutral hadrons, depend of the hadronic interaction model. As a consequence, realistic simulations of hadron induced air-showers are model-dependent, leading to theoretical uncertainties in the analysis of experimental data. For a ground based detector, the model-related systematic error on energy estimation can be as large as about 20% at 10^{19} eV if the mass of the primary particle is unknown. The theoretical uncertainties of the energy reconstruction are much smaller for fluorescence light detectors (less than 5% even for unknown primary particle mass). The model dependence of the primary mass estimation is crucial and currently the mass composition can only be derived for a given hadronic model. As a consequence, the models have to be carefully tested at the highest energy reached in experiments and especially in the forward region where HERA and LHC can provide crucial informations.

The data on the total photoproduction cross section and jet final states with emphasis on the phase space near the forward (proton) direction from HERA have been summarized, discussing the extraction of the parton distribution functions from a combined data set of the two collider experiments H1 and ZEUS. These data shed light on the parton evolution models and also enable a unique measurement of the running strong coupling, providing new insight into QCD dynamics at very low values of the Bjorken variable x.

In addition, the HERA experiments provide a wealth of measurements of leading baryon production. These measurements give an important input for an improved theoretical understanding of the proton fragmentation mechanism. As shown, the HERA data on forward particle production can help to reduce the uncertainty in the model predictions for very high energy cosmic ray air showers.

In the near future, the integration of the data from not only the LHC experiment dedicated for the cosmic ray science (LHCf) but also the others, especially the forward experiments introduced in [1] will be important to constrain the interaction models used in the cosmic-ray studies.

The charged current neutrino cross-section at NLO have been calculated in the Standard Model using the best available DIS data along with a careful estimate of the associated uncertainties. If cross-sections much outside the uncertainty bands presented here are observed at UHE cosmic neutrino detectors, it would be a clear signal of the need for extensions to conventional QCD DGLAP formalism.

Finally the extrapolation of photoproduction and neutrino cross-section towards very high energy is needed if we want to estimate flux of ultrahigh energy photons and neutrinos of ex-

tragalactic sources like Active Galactic Nuclei. Such estimation might be useful for the Pierre Auger Observatory to set a proper limit on the photon flux and Ice Cube experiment which can detect neutrinos of energy 10^{12} GeV and higher. Here again, the best constrains are given by both HERA and LHC experiments.

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References

[1] A. Bunyatyan et al, *Experimental results*. These proceedings.