Unpolarized Fragmentation Functions in Lepton-Nucleon Scattering

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Semi-inclusive deep-inelastic scattering and the concept of flavour-tagging has become an important tool in the determination of different parton distributions. However, to apply this technique, the fragmentation process has to be understood. In this talk the measurements of the fragmentation functions in unpolarised deep-inelastic lepton nucleon scattering are reviewed.

Besides some early neutrino experiments, unpolarised fragmentation functions have been measured by the two muon experiments EMC (CERN) and E665 (Fermilab) and recently by the HERMES experiment at DESY. Comparing the measured multiplicities for charged and neutral pions, isospin invariance has been demonstrated for z values below 0.7. For higher values of z, the multiplicity of the charged pion sample is found to be significantly higher than that of the neutral pions. Most likely this difference is caused by exclusive π^+ production, a process not present for negative or neutral pions.

A clear Q^2 dependence of the pion fragmentation functions is seen in the comparison of different experiments with different average values of Q^2. Using perturbative QCD to evolve the data to the same average Q^2, all existing data are found to be in excellent agreement.

Important information about the fragmentation process can be extracted from the p_T-dependence of the measured multiplicities. At the relatively low center-of-mass energy of the HERMES experiment, the observed p_T-dependence is well described over the entire p_T-range by contributions from intrinsic p_T and from the fragmentation process. At the much higher energies of the EMC experiment, additional contributions from gluon radiation seem to be needed for p_T^2-values above 1 GeV^2. A more detailed study of the HERMES data revealed an interesting observation: while the average p_T for positive and negative hadrons agrees for z-values below $z \sim 0.6$, the average p_T for positive hadrons is found to be significantly larger than that of the negative hadrons for z values above 0.6. This effect could be caused by contributions of pions from ρ decays (the relative importance of such pions compared to the pions from the direct fragmentation process is larger for π^- than for π^+), or, more interestingly, by different intrinsic p_T of u- and d-quarks. An indication of a similar difference is also seen in the high energy data of the EMC experiment.

By embedding the fragmentation process within a nucleus, the time scales of hadron formation can be investigated. Earlier data suggested that two time scales are relevant: a first time for the string formation and the time for the hadron formation. The new very precise HERMES data on the nuclear attenuation in nitrogen and krypton allow a more detailed study: for the first time both the dependence on ν and on the hadron energy have been measured. Those data at high values of z are well descibed by the gluon bremsstrahlung model which results into a large attenuation at high values of z. Additionally, these HERMES data show a clear difference in the attenuation of positive and negative hadrons. As the attenuation of positive and negative pions is found to be the same, this indicates a much larger formation time of the protons compared to the pions. Additional HERMES data with full pion/kaon/proton identification will allow the determination of the formation times for all these different hadrons in the near future.