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Jet Production in Deep-Inelastic Muon Scattering at 490 GeV

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Abstract

Measurements of jet rates in deep-inelastic muon scattering are presented. The JADE algorithm is used to define jets in the kinematic region $9 < W < 33$ GeV. Data taken on a proton target are analyzed within the QCD framework, with the goal of extracting α_s. Results on the Q^2 dependence of the average transverse momentum of jets are used to demonstrate the running of the strong coupling constant α_s. In addition, first measurements of the production of jets from heavy nuclei in the region $x_{Bj} > 0.001$ are discussed. Initial results indicate a suppression in the rate of two forward jets in carbon, calcium and lead as compared to deuterium. All results presented are preliminary.

Introduction

Fermilab experiment E665 uses a general purpose, open geometry detector to study the hadronic final state produced in inelastic muon scattering. Data were taken during 1987-88 and 1990-91 on hydrogen, deuterium, carbon, calcium, xenon and lead targets using a muon beam with average energy of ~490 GeV (r.m.s of ~60 GeV). The experiment was made up of proportional and drift chambers to detect the incoming muon, outgoing muon, and final state charged hadrons. In addition, an electromagnetic calorimeter was used to detect photons and electrons.

Jets in μp scattering

At lowest order, deep-inelastic μp interactions involve the elastic scattering of muons with constituent quarks within the proton through the exchange of virtual photons resulting in two final state "jets" (1+1 topology). First order QCD corrections predict three jet events, from either gluon bremsstrahlung or photon-gluon fusion (2+1 topology), whose rates are directly proportional to the strong coupling constant α_s. Because of collinear and soft singularities, the calculated 2+1 cross sections are infinite, thus requiring the introduction of a new cut-off scale $y_{cut} \equiv m_{ij}^2/W^2$, where m_{ij} is the invariant mass of each pair of partons and W is the hadronic center-of-mass energy. In order to compare more directly with such calculations, we have chosen to use the JADE algorithm to define jets within E665. In the interest of space, I refer the reader to Ref. 1) for a description of E665's first measurements of jet rates. For this analysis, the following cuts were applied: $Q^2 \geq 4$ GeV^2, $\nu \geq 40$ GeV, $x_{Bj} \geq 0.003$, $0.05 \leq y_{Bj} \leq 0.95$.

Figure 1a shows the measured 2+1 hadronic jet rates vs. y_{cut} for $28 \leq W \leq 33$ GeV. Note that E665 is unable to detect the target remnant jet and so the "+1" is assumed. Superimposed in Figure 1 are results from the Lepto 5.2 Monte Carlo. The solid curves come from the leading-log parton shower option, and the dashed curves are the $O(\alpha_s)$ matrix element option. The data tend to prefer the parton shower Monte Carlo, with the matrix element model underestimating the 2+1 rates. Using the parton shower model, the data have been corrected to the partonic level in Figure 1b. Here, a much bigger difference is observed between matrix elements and parton shower. It is clear that large differences exist in the hadronization parameters within these two models.

We have found that another property of jets, namely the average transverse momentum squared, is less sensitive to the different fragmentation models. In particular, we define $< P_T^2 >_{jet} \equiv \sum_{2+1}[(P_T^a + P_T^b)/2]^2/N_{ev}$, where P_T^a and P_T^b are the tranverse momenta of the 2 forward-most jets in the 2+1 events and N_{ev} is the total number of events. The average over P_T^a and P_T^b reduces the sensitivity to fragmentation and

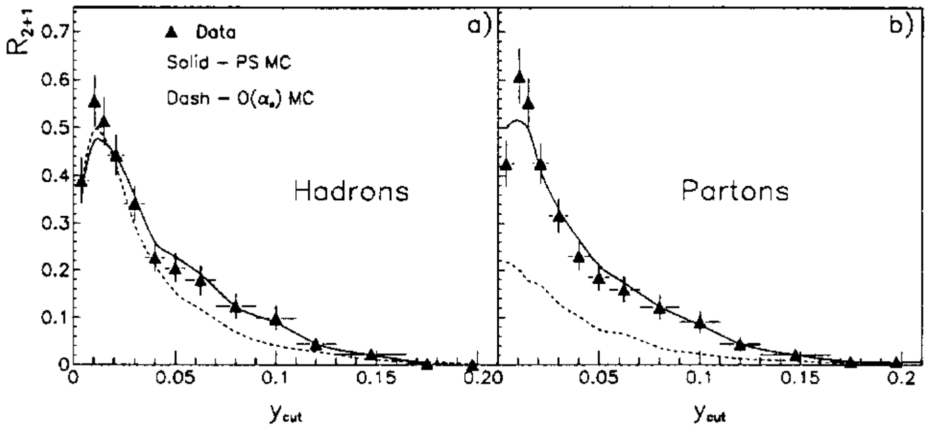

Figure 1: The 2+1 jet rate vs. y_{cut} for $28 \leq W \leq 33$ GeV, for a) hadrons and b) partons.

intrinsic transverse momentum. Leading order perturbative QCD predicts that this quantity is proportional to $\alpha_s(Q^2)$. Figure 2a shows the measured values of $< P_T^2 >_{jet}$ vs. Q^2. Superimposed are two leading order QCD predictions, one with α_s "running" with Q^2 (solid curve), and the other with α_s fixed at $Q^2 = 12$ GeV^2 (dashed curve). The data clearly prefer a running strong coupling constant. Figure 2b shows α_s extracted at leading order from $< P_T^2 >$ vs. Q^2, with comparisons to other (next-to-leading order) α_s determinations[2)]. This data smoothly bridges the gap between low Q^2 and high Q^2 measurements; however next-to-leading order calculations (soon to be available) will have to be employed before detailed comparisons can be made.

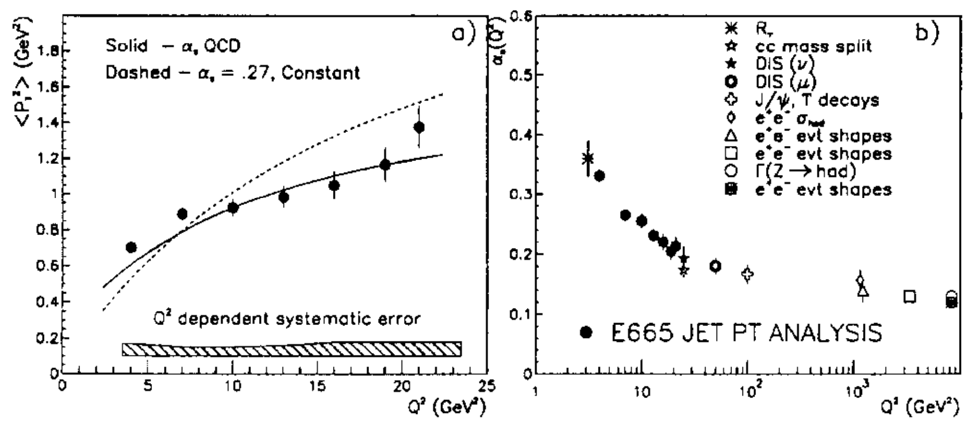

Figure 2: a) $< P_T^2 >_{jet}$ vs. Q^2. The solid curve is a leading order PQCD calculation with α_s allowed to vary with Q^2. The dashed curve is the same calculation with α_s fixed at Q^2=12 GeV^2. b) α_s extracted from $< P_T^2 >_{jet}$ vs. Q^2.

Jets in μA scattering

In addition to studying jets produced in μp scattering, E665 is able to look at jets produced in nuclear targets. The rates of 2+1 jet events from C, Ca and Pb are compared to the rates in D, in the kinematic region where shadowing is observed in the total cross section (see T. Carroll, these proceedings). In order to include the shadowing region, the following new set of kinematic cuts were applied: $Q^2 \geq 0.1$ GeV^2, $\nu \geq 40$ GeV, $x_{Bj} \geq 0.001$, $0.05 \leq y_{Bj} \leq 0.75$. The electromagnetic calorimeter was also used to remove the coherent $\mu\gamma$ backgrounds. The data were taken during the 1990 running period, and about one third of the available sample is presented.

Figure 3 shows the per nucleon cross section ratios (C/D, Ca/D and Pb/D) for events with 1+1 jets and 2+1 jets separately. Both samples clearly show the effect of shadowing, however the 2+1 events are suppressed more than the 1+1 events. The amount of suppression of the 2+1 events appears similar for C, Ca and Pb.

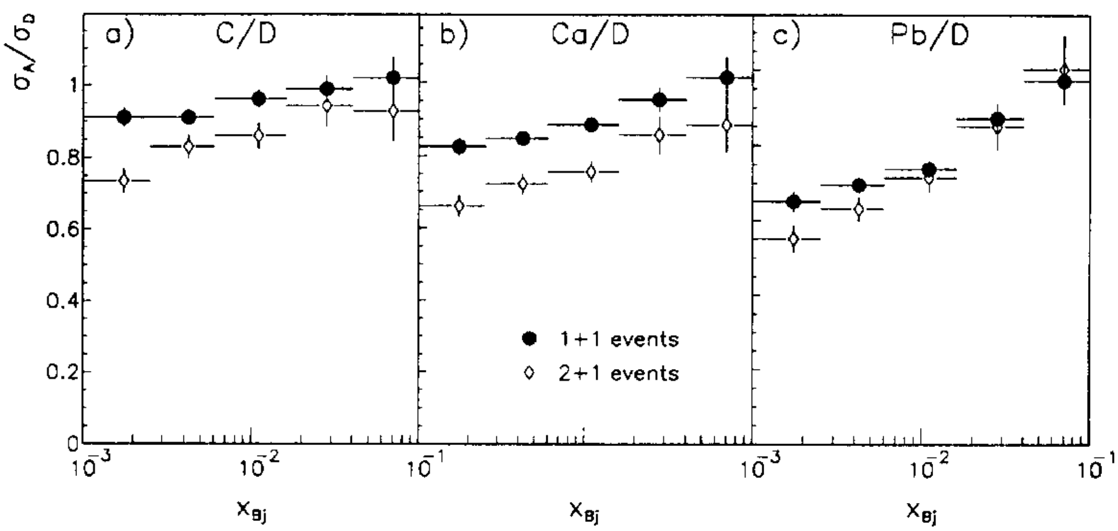

Figure 3: Per nucleon cross section ratios for events with 1+1 jets and 2+1 jets at $y_{cut} = 0.04$ vs x_{Bj} for C/D, Ca/D and Pb/D.

In order to reduce systematic errors, E665 rotated its targets every few minutes, and thus the overall acceptance and reconstruction efficiencies should cancel in the ratios. However, significant differences do exist between the radiation lengths and interaction lengths of C, Ca, Pb and D. We have performed various studies to determine the effect of these differences on the 2+1 jet rates, and conclude that the effects are small. However, more detailed studies with the full data sample will be required before final results may be presented.

Conclusion

The production of multi-jet events has been studied in μp and μA scattering by Fermilab experiment E665. Rates of 2+1 jet events have been measured, and compared to the Lepto 5.2 Monte Carlo. The data tend to prefer the parton shower option. The strong coupling constant α_s has been extracted at leading order from the average transverse momentum of jets as a function of Q^2 and the data indicate the need for a running coupling constant. First measurements of jets produced in nuclear targets in the shadowing region indicate a suppression of 2+1 jet events as compared to D. These data may help extend our knowledge of the gluon distributions within nuclei.

References

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2) S. Bethke, *et al.*, HD-PY92/73, 1992, reprinted in R.K. Ellis, Fermilab-Conf-93-011-T, 1993.