A STUDY OF EVENTS WITH LARGE TOTAL TRANSVERSE ENERGY PRODUCED IN PROTON-ANTIPROTON COLLISIONS AT $\sqrt{s} = 1.8\ TeV$

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ABSTRACT

Properties of events originating from proton–antiproton interactions in which the total transverse energy, $\Sigma|E_T|$, of the event exceeded 400 GeV are presented. These events were produced at the Fermilab Tevatron Collider operating at a center–of–mass energy of 1.8 TeV and recorded in the DØ detector. We describe our analysis method which minimizes the effect of multiple interactions in the data sample. Based on a data sample of $5.45 \pm 0.65\ pb^{-1}$, the topology of these hard scattering events as well as preliminary results for the cross–section, $d\sigma/d\Sigma|E_T|$, are presented and discussed.

The motivation for studying events with large $\Sigma|E_T|$ is threefold. First, the phenomenology of events with the highest $\Sigma|E_T|$ is of great interest as such events result from the hardest scatterings, the most central collisions. Second, these events allow us to test our understanding of QCD where predictions are extrapolated from lower energy data. Third, these events provide a window on physics beyond the Standard Model. One such scenario is quark compositeness, characterized by a contact interaction[1] with energy scale Λ^*, which could be seen as an enhancement in the cross–section, $d\sigma/d\Sigma|E_T|$, at large values of $\Sigma|E_T|$. In Fig. 1 we compare $d\sigma/d\Sigma|E_T|$ for QCD (no compositeness) with QCD (including compositeness with $\Lambda^* = 1.5\ TeV$). These curves were generated using PYTHIA V5.6 (including the quark compositeness model of Ref. 1) and the DØGEANT detector simulation. They show the sensitivity at leading order to the existence of composite quarks at a scale of $\Lambda^* = 1.5\ TeV$ for $\Sigma|E_T| > 500\ GeV$.

The data presented here were obtained using the DØ detector[2] at the Fermilab Tevatron Collider at $\sqrt{s} = 1.8\ TeV$. They were collected in Run 1a, from March – May, 1993 and correspond to an integrated luminosity of $5.45 \pm 0.65\ pb^{-1}$. The DØ detector has a hermetic, compensating sampling calorimeter with fine longitudinal and transverse segmentation in azimuth, ϕ, and pseudorapidity, $|\eta| \leq 4.2$. The calorimeter has good energy resolution which can be parametrized as $\sigma/E = A/(\sqrt{E})(E \text{ in } GeV)$, where $A = 0.15$ for electrons and 0.50 for single hadrons.

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*Representing the DØ Collaboration.

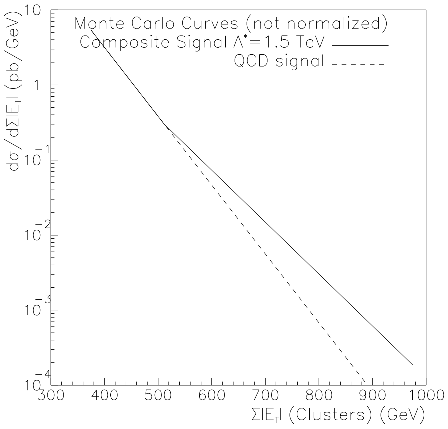

Fig. 1. PYTHIA generated $d\sigma/d\Sigma|E_T|$ for QCD (no compositeness – dotted line) and QCD (compositeness at $\Lambda^* = 1.5\ TeV$ – solid line) indicating the sensitivity at leading order of $\Sigma|E_T|$ to quark compositeness.

The hardware trigger used a scalar sum of E_T in calorimeter cells in the range, $|\eta| \leq 3.2$ with a threshold on the sum of 225 GeV. The software trigger increased this threshold to 300 GeV and imposed an upper limit on the total energy (E_{tot}) for the event of 1.8 TeV, both calculated over the range, $|\eta| \leq 4.0$. By requiring only a minimum E_T in the calorimeter we are naturally sensitive to multiple interaction events where a less central collision plus several minimum bias events will satisfy the trigger conditions. The cut on E_{tot} was necessary to limit the rising trigger rate due to multiple interactions as the luminosity increased.

Following event reconstruction the data sample was further reduced by increasing the $\Sigma|E_T|$ threshold to 370 GeV and applying the same E_{tot} cut of 1.8 TeV used in the Level 2 trigger. These cuts were applied to reconstructed quantities over the range, $|\eta| \leq 4.0$. In addition, we removed events with "bad" jets, which are defined as resulting from noisy calorimeter cells or accelerator Main Ring activity, and events with isolated high-E_T electron candidates. Events with multiple interactions occurring in the detector remain in the sample, and the mean $\Sigma|E_T|$ rises with the number of interactions present. To obtain a variable which does not show a large change with the addition of extra minimum bias events, we redefine $\Sigma|E_T|$ to be a sum over energy clusters only; that is, we sum over all NN jets found in the event. Jets were found using fixed cone algorithms as well as a nearest neighbor (NN) algorithm. The NN algorithm starts with a seed tower E_T of 0.5 GeV and searches for all towers within a radius, R $= \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} \leq 0.2$, above an E_T threshold of 0.5 GeV. It continues to sum all such towers that it finds; the resultant energy cluster is termed a jet if it has $E_T > 8\ GeV$. The NN jet algorithm, by requiring almost contiguous towers, is much less sensitive to both energy fluctuations in the calorimeter, which provide a seed tower for jet finding, and to extra minimum bias events. Using our PYTHIA–generated event sample we find that the ratio of $\Sigma|E_T|(clusters)$ to $\Sigma|E_T|(cells)$ is ~ 0.95. That is, $\sim 95\%$ of the $\Sigma|E_T|$ of the hard scattering event is contained in $\Sigma|E_T|(clusters)$. In addition, we find that $\Sigma|E_T|(clusters)$ increases only minimally as minimum bias events are added to each event. This very weak dependence of $\Sigma|E_T|(clusters)$ on additional minimum bias events overlaying the hard scattering event means that we can still extract useful information about the hard scattering event even in the multiple interaction environment. To select only the hardest scattering events we require $\Sigma|E_T|(clusters) \geq 400\ GeV$.

The efficiency for both the trigger and the offline data reduction was studied as a function of $\Sigma|E_T|(clusters)$. For $\Sigma|E_T|(clusters) \geq 400\ GeV$ we find this efficiency to be $> 99\%$. The efficiency of the E_{tot} cut is dependent on both the instantaneous luminosity as well as the $\Sigma|E_T|(clusters)$. We express this as a survival fraction which is flat for $\Sigma|E_T|(clusters) <\sim 600\ GeV$ and then linearly decreasing above $600\ GeV$. As the instantaneous luminosity increases, the survival fraction in the flat region decreases, and the linear decrease above that becomes steeper. This dependence is exactly what one would hypothesize for increasing luminosity as the number of multiple interactions also increases. For NN jets, the removal of "bad" jets as defined previously has an efficiency of $\sim 96\%$, nearly independent of E_T, and is applied on an event by event basis since it depends on the number of jets. Other corrections applied to the data concern the energy determination. The effect of multiple interactions on $\Sigma|E_T|(clusters)$ has been estimated to be $< 2\%$ for clusters formed using NN jets. Jet energies have been corrected using the DØ standard corrections for cone 0.5 jets. This correction is applied to the hadronic energy of the jet and has a magnitude of $\sim 20\%$; it underestimates the NN jet corrections by $\sim 2 - 4\%$ and is still under study. The overall energy scale systematic uncertainty is estimated to be $\sim 5\%$.

The data we present are based on an integrated luminosity of $5.45 \pm 0.65\ pb^{-1}$. We have studied the topology of these events using the following distributions: inclusive jet E_T, $\Sigma|E_T|(clusters)$, jet multiplicity, and inclusive jet η. As seen in Fig. 2, these events arise from very hard, central collisions as evidenced by the inclusive jet η distribution which is very strongly peaked at $\eta = 0$ and has very few entries for $|\eta| > 2$. The inclusive jet E_T distribution shows a peak at about $200\ GeV$. Combined with the jet multiplicity distribution showing that most of our events have 2, 3, or 4 jets, this is easily explained as a result of our threshold of $400\ GeV$ for $\Sigma|E_T|(clusters)$ where we have two very stiff jets and one or two small jets accompanying them. We observe about 14 events/pb^{-1} for $\Sigma|E_T|(clusters) \geq 500\ GeV$. Applying the corrections for inefficiencies and energy scale described above, we produce a preliminary cross–section, $d\sigma/d\Sigma|E_T|$, which is also shown in Fig. 2.

Our highest $\Sigma|E_T|(clusters)$ event has $\Sigma|E_T|(clusters) = 830.6\ GeV$ and a calorimeter missing $E_T = 10.8\ GeV$. It is a 3 NN jet event with all of the jets at very central η. The event has $\Sigma|E_T|(cells) = 920.9\ GeV$ and $E_{tot} = 1445.9\ GeV$. Analyzing the data from the Level 0 trigger counters and the number of vertices found by the central tracker indicates that this is probably a multiple interaction event. Based on the very weak dependence of $\Sigma|E_T|(clusters)$ on multiple interactions, we expect the $\Sigma|E_T|$ of this hard scattering event to be $830.6\ GeV$.

We have presented results of an analysis of the hardest scattering events detected in the DØ detector. We have argued that $\Sigma|E_T|(clusters)$ is the correct variable for selection and study of these events since it is only minimally affected by multiple interactions. We have also shown that $\Sigma|E_T|(clusters)$, at least in leading order calculations, provides sensitivity to new physics, like quark compositeness. With an order of magnitude increase in the integrated luminosity, we hope to probe the scale, $\Lambda^* = 1.5\ TeV$, and may even be able to push it higher.

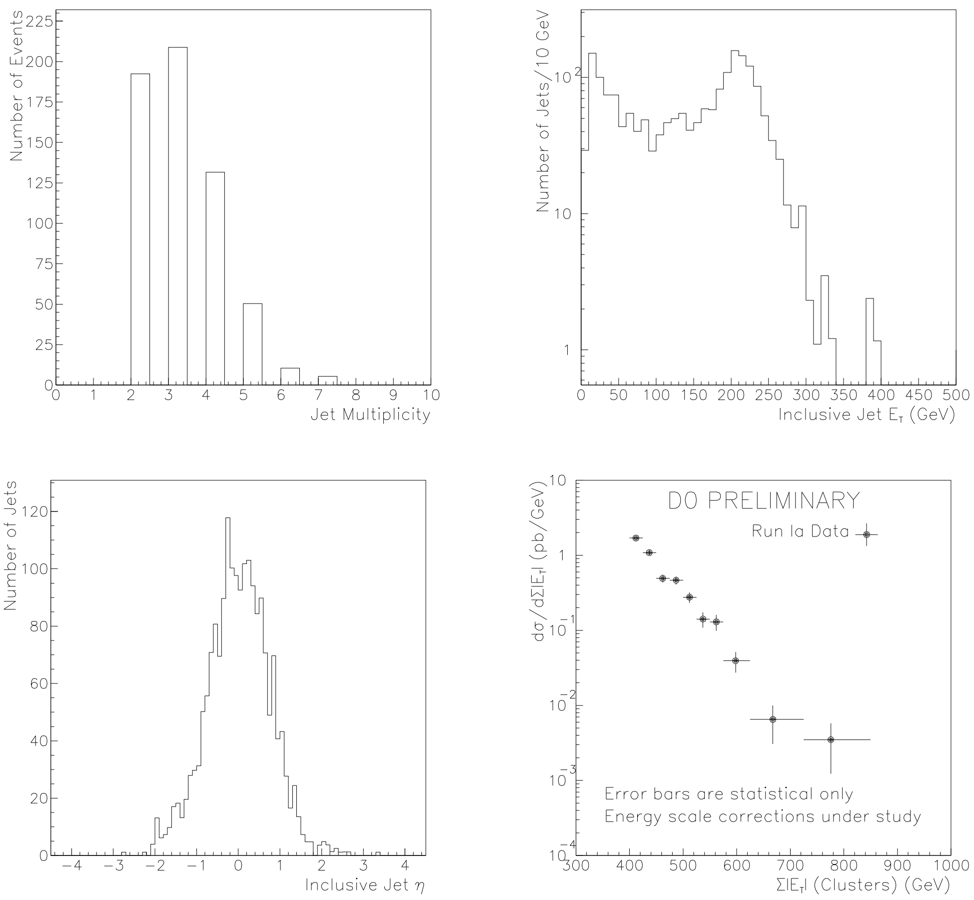

Fig. 2. Kinematic distributions of events with $\Sigma|E_T|(clusters) \geq 400\ GeV$ and preliminary cross–section, $d\sigma/d\Sigma|E_T|$, based on $5.45 \pm 0.65\ pb^{-1}$ of data.

References

1. E. Eichten *et al.*, Rev. Mod. Phys. **56**, 579 (1984).
2. S. Abachi *et al.*, Nucl. Instrum. Meth. **A338**, 185 (1994) and references therein.