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Preliminary Plots of the x_3x_4 Analysis of Three Jet Events at CDF

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QCD explains three jet events in hadron-hadron collisions by a single hard bremsstrahlung in a $2 \rightarrow 2$ process, the bremsstrahlung taking place in either the initial or final 2-parton states. There are specific predictions for the distributions of the fraction of the total subprocess energy each of these final partons carries away. The goal of this analysis is to produce distributions of these fractions from the 1988 CDF data run and compare them to a QCD calculation. Similar studies have been conducted at lower energy by UA1 [1]. These results have marginal statistical power for distinguishing QCD predictions from phase space.

The TOTAL_ET_120 triggers were used for this analysis. So far half the 1988 data has been analyzed (about 2 pb^{-1}). All events were required to have at least three jets with an uncorrected $E_t > 10$ GeV and a detector $\eta < 3.5$. In addition the z-vertex of the event was required to be within 60 cm of the center of the detector. There were 89046 events which survived these cuts out of 132035 triggers.

For each event, the corrected four-momenta of the three highest E_t jets were boosted to their center-of-momentum (COM) frame. The boosted four-momenta are assumed to be those of the final state partons. Following the convention of refs. [1] and [2], the initial state partons are labelled 1 and 2 and the final state partons are labelled 3 through 5 in order of decreasing energy. For this analysis, the direction of parton-1 is defined to be the direction of the proton or antiproton, whichever has the higher momentum in the COM frame. The final state parton energy fractions are called x_3, x_4, and x_5 where

$$x_i = \frac{2E_i}{M_{3j}}. \qquad (1)$$

Here M_{3j} is the invariant mass of the three partons, which equals to the subprocess energy if there are no more than three jets. The final three parton state can be completely described by six variables: M_{3j}, x_3, x_4, $\cos\theta^*$, ψ^* and ϕ^*. θ^* is the angle between parton-3 and parton-1. ψ^* is the angle between the plane described by the three final state partons and the plane described by parton-1 and parton-3. ϕ^* is the azimuthal angle of parton-3. It has no dynamic importance. These energies and angles were all measured in the COM frame of the three final state partons.

After boosting, another set of cuts was made on the data:

$$M_{3j} > 200 \text{ GeV}, \qquad (2)$$

$$x_3 < 0.9, \tag{3}$$

$$30^\circ < \psi^* < 150^\circ, \tag{4}$$

$$|\cos\theta^*| < 0.72. \tag{5}$$

Given arbitrary values for the angles θ^* and ψ^*, the TOTAL_ET_120 trigger probably biases the x_3 and x_4 distributions toward a shape consistent with the three final state partons being of equal COM energy. The M_{3j} cut should eliminate most of this bias, but this effect is still being studied. Above $x_3 = .9$ the jet E_t cut starts eliminating events because parton-5 is soft. The x_3 cut takes care of this, as well as events eliminated by the fact that jets must be seperated in η-ϕ space by .85 in order to be resolved. The angle cuts, in conjunction with the other cuts, insure that all three jets have a detector η of less than 3.5. There were 4973 events which survived these last set of cuts.

Figure 1 shows the scatter plot of x_3 vs. x_4. Phase space should produce an equally populated triangle in x_3-x_4, but there is a visible enhancement in the upper right hand corner. This corner of the plot corresponds to a configuration where parton-3 and parton-4 are very hard and nearly equal in energy and parton-5 is very soft. The deviation of QCD from phase space is strongest here and this is where the signal will come from. At the lower right-hand corner parton-4 and parton-5 are equal in energy and parton-3 is hard. At the left corner all final partons have equal energy.

The x_3 and x_4 distributions from the data were compared to QCD and phase space predictions corrected for the detector energy resolution. The phase space monte carlo was a simple three-body phase space generator with massless final particles. The initial partons' momenta were generated using EHLQ1 structure functions from ISAJET. There were no cuts on the final partons, so any parton could have a momentum as low as zero or as high as $\sqrt{\hat{s}}$. They could end up any where in the detector or even down the beam pipe.

The final partons were "converted" to real jets using QDJTMC, an Analysis_control module which degrades and smears partons. QDJTMC does the exact inverse of QDJSCO, the jet correction module. Given a jet E_t, QDJSCO provides a parton E_t using a second order polynomial whose coefficients depend on the pseudo-rapidity of the jet. QDJTMC uses the quadratic formula to reverse the procedure. It then smears the jet E_t using a guassian whose σ is the resolution of the jet. Gaussian smearing of the jet direction (η and ϕ) is also done. The gaussian σ for the η smearing ranged from .256 for the lowest energy partons to .035 for the highest; for the ϕ smearing it similarly ranged from .182 to .008. For this study, the z-vertex was not smeared, nor was there any k_t kick.

After the simulation, the monte carlo events were put through the same analysis as the data (the trigger threshold was not simulated). The two sets of distributions are compared in figure 2 with the monte carlo area normalized to the data. The solid line represents phase space in x_3-x_4 without any simulation. The data and the resolution corrected phase space distributions differ markedly.

The QCD calculation was performed using the generator PAPAGENO with EHLQ1 structure functions. PAPAGENO uses the exact leading order QCD calculations for a $2 \rightarrow 3$ process. Primary cuts are made on the final state partons to prevent divergences in the calculations. For this analysis the primary cuts were $p_t > 8.80$ GeV, $\eta < 4.0$ and $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2} > 0.45$. ($\Delta R$ is the distance in η-ϕ space between any two final state partons). These cuts were selected to be 3σ away from the initial data cuts in the variables

QDJTMC smears (see paragraph 2). A monte carlo run with a primary cut of $p_t < 5.56$ GeV was performed and the conclusions were the same, proving insensitivity to this cut. As before, the events were simulated using QDJTMC and the monte carlo distributions were area normalized to the data. The results are shown in figure 3. The data clearly follow QCD.

References

[1] Arnison, G. et al. (UA1 Collaboration), Phys. Lett. 158B (1985) 494.

[2] Berends, F. A. et al., Phys. Lett. 103B (1981) 124.

Fig. 1

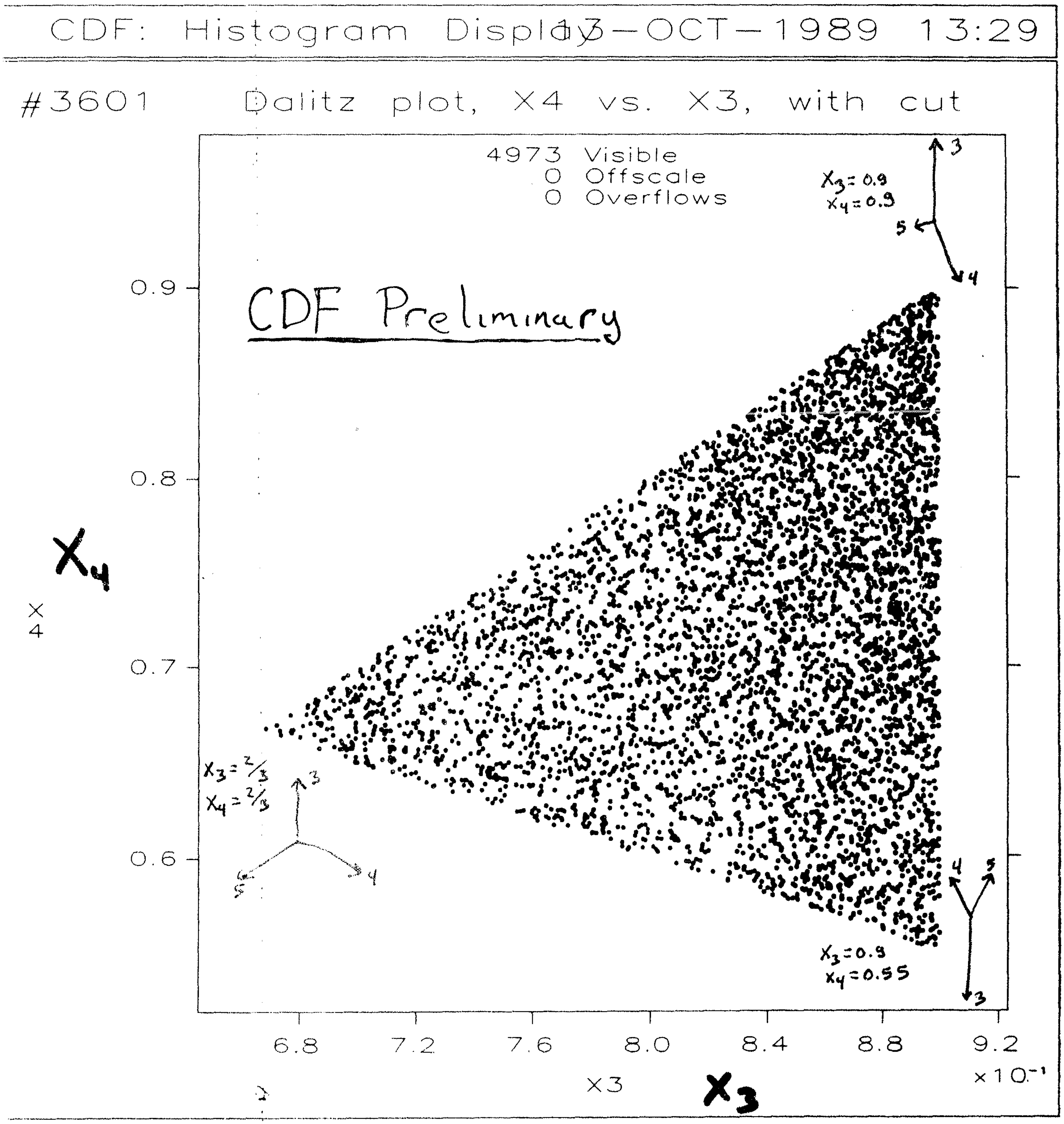

CDF: Histogram Display 13-OCT-1989 13:29
#3601 Dalitz plot, X4 vs. X3, with cut
4973 Visible
0 Offscale
0 Overflows
CDF Preliminary
X3 = 0.9
X4 = 0.9
X3 = 2/3
X4 = 2/3
X3 = 0.9
X4 = 0.55
0.9
0.8
0.7
0.6
6.8
7.2
7.6
8.0
8.4
8.8
9.2
×10⁻¹
X3
X4

Fig. 2

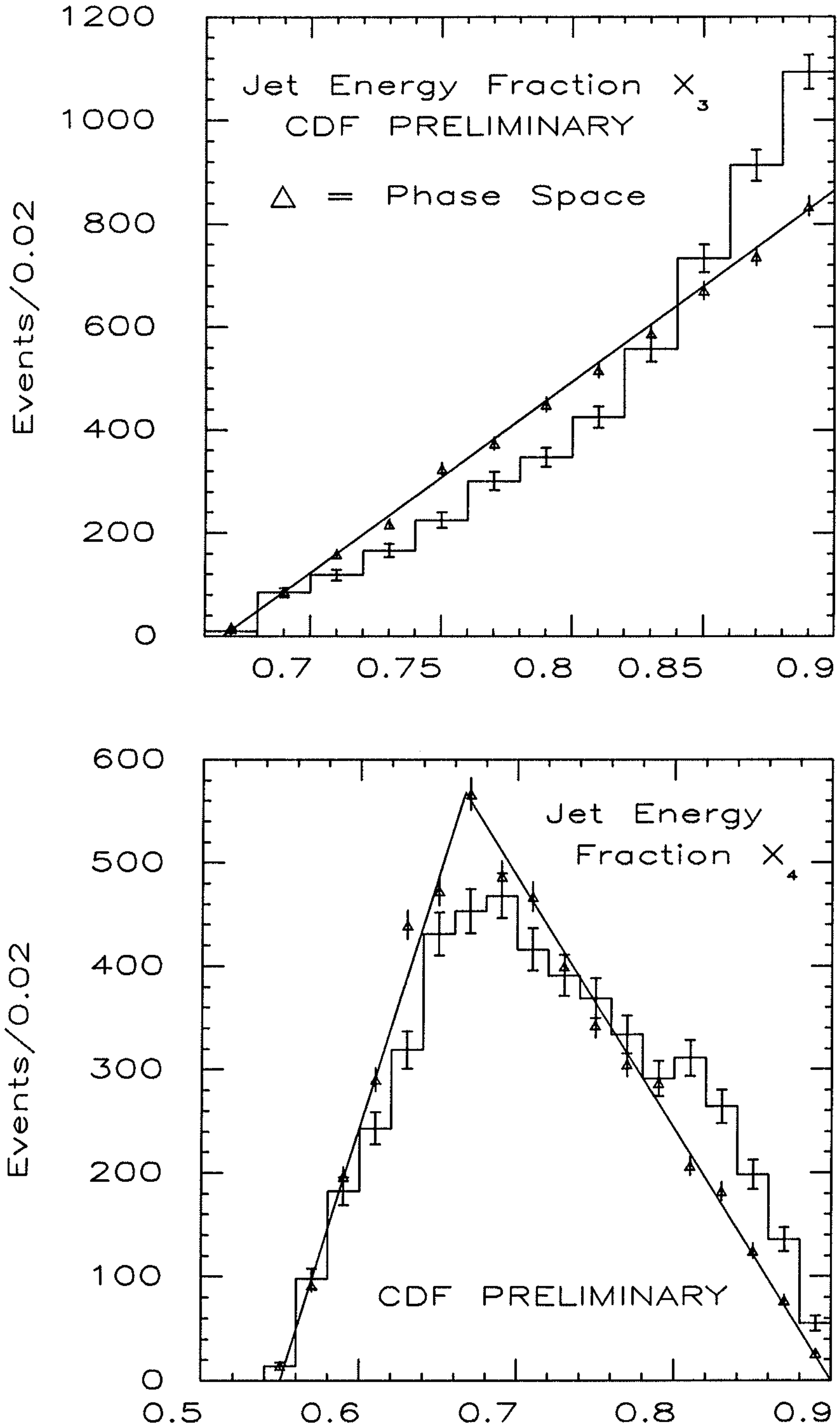
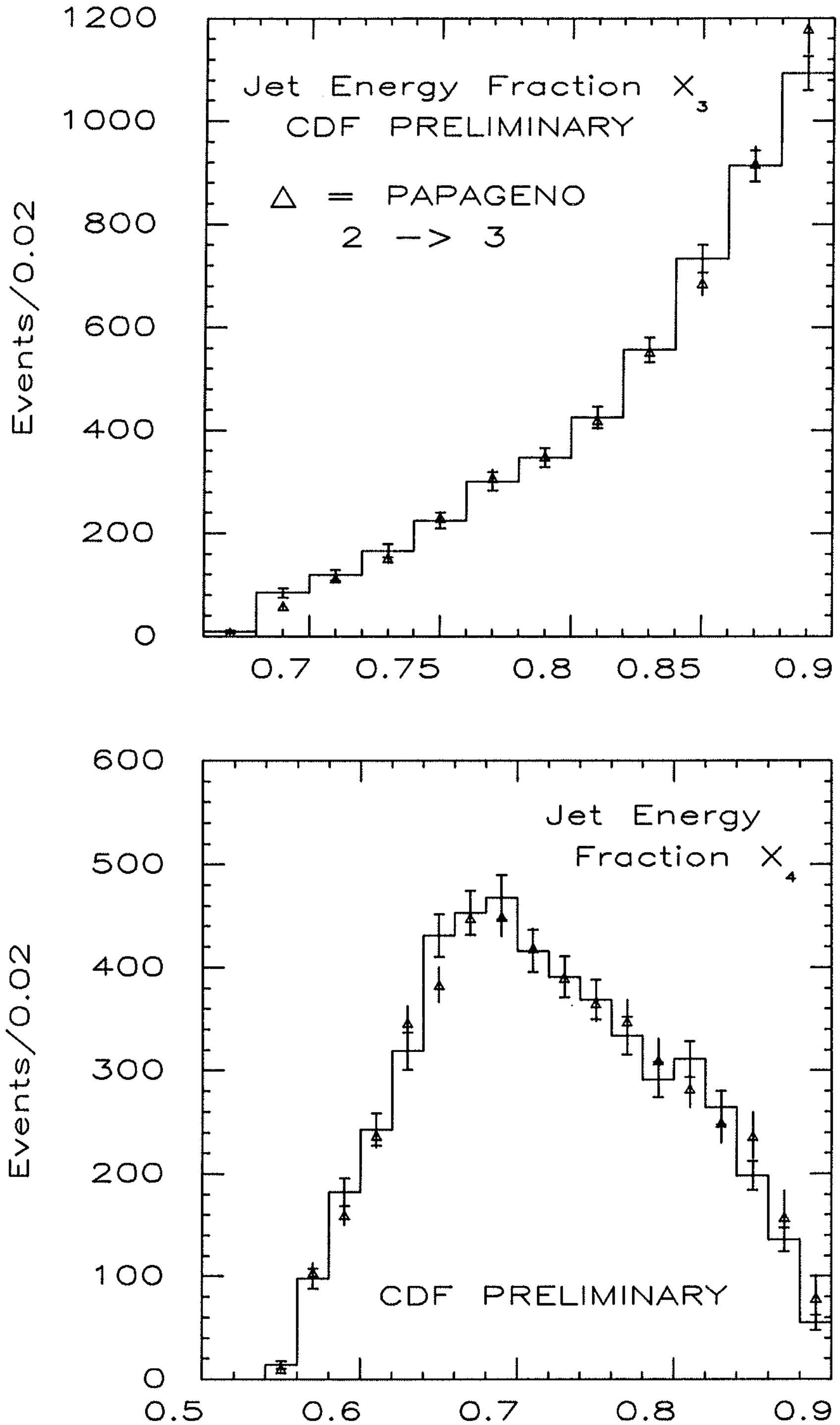

Jet Energy Fraction X_3
CDF PRELIMINARY
△ = Phase Space
Events/0.02
1200
1000
800
600
400
200
0
0.7
0.75
0.8
0.85
0.9
Jet Energy Fraction X_4
CDF PRELIMINARY
Events/0.02
600
500
400
300
200
100
0
0.5
0.6
0.7
0.8
0.9

Fig. 3



Jet Energy Fraction X3
CDF PRELIMINARY
△ = PAPAGENO
2 -> 3
Events/0.02
1200
1000
800
600
400
200
0
0.7
0.75
0.8
0.85
0.9
Jet Energy
Fraction X4
CDF PRELIMINARY
Events/0.02
600
500
400
300
200
100
0
0.5
0.6
0.7
0.8
0.9