Outline of Talk

- Alberto and I are working on the publication level “underlying event” analysis.

- We have corrected the leading jet $P_T$ and corrected all the observables to the hadron level (I will show you this soon!).

- I am also checking to see if we need to make any corrections for “pile-up” (even thought we require only one Q12 vertex).

- Today I will show you the effect of “pile-up” on the “underlying event”.

"Underlying Event" in Run 2 at CDF
Publication Level
Look at charged particle correlations in the azimuthal angle $\Delta \phi$ relative to the leading calorimeter jet (JetClu R = 0.7, $|\eta| < 2$).

Define $|\Delta \phi| < 60^\circ$ as “Toward”, $60^\circ < -\Delta \phi < 120^\circ$ and $60^\circ < \Delta \phi < 120^\circ$ as “Transverse 1” and “Transverse 2”, and $|\Delta \phi| > 120^\circ$ as “Away”. Each of the two “transverse” regions have area $\Delta \eta \Delta \phi = 2 \times 60^\circ = 4\pi/6$. The overall “transverse” region is the sum of the two transverse regions ($\Delta \eta \Delta \phi = 2 \times 120^\circ = 4\pi/3$).
"Transverse" Charge Density versus $E_T(jet#1)$

- Shows the average charged particle density, $dN_{chg}/d\eta d\phi$, in the "transverse" region ($p_T > 0.5$ GeV/c, $|\eta| < 1$) versus $E_T(jet#1)$ for JetClu, $R = 0.7$, $|\eta(jet#1)|<2$ (zero or 1 vertex). Includes systematic errors.

- Compares the (uncorrected) data with PYTHIA Tune A and HERWIG after CDFSIM.
"Transverse" Charge Density

Shows the average charged particle density, \( \frac{dN_{\text{chg}}}{d\eta d\phi} \), in the "transverse" region \((p_T > 0.5 \text{ GeV/c}, |\eta| < 1)\) versus \(E_T(\text{jet#1})\) for JetClu, \(R = 0.7, |\eta(\text{jet#1})|<2\) (zero or 1 vertex).

Shows the average charged particle density, \( \frac{dN_{\text{chg}}}{d\eta d\phi} \), in the "transverse" region \((p_T > 0.5 \text{ GeV/c}, |\eta| < 1)\) versus \(P_T(\text{jet#1})\) for MidPoint, \(R = 0.7, f = 0.75, |\eta(\text{jet#1})|<2\) (zero or 1 quality 12 vertex).

Compares the (uncorrected) data with PYTHIA Tune A and HERWIG after CDFSIM.
**“Transverse” PTsum Density**

- Shows the **average charged PTsum density**, \( d\text{PTsum}/d\eta d\phi \), in the “transverse” region (\( p_T > 0.5 \text{ GeV/c}, |\eta| < 1 \)) versus \( E_T(jet#1) \) for JetClu, \( R = 0.7 \), \( |\eta(jet#1)| < 2 \) (zero or 1 vertex).

- Shows the **average charged PTsum density**, \( d\text{PTsum}/d\eta d\phi \), in the “transverse” region (\( p_T > 0.5 \text{ GeV/c}, |\eta| < 1 \)) versus \( P_T(jet#1) \) for MidPoint, \( R = 0.7 \), \( f = 0.75 \), \( |\eta(jet#1)| < 2 \) (zero or 1 quality 12 vertex).

- Compares the (uncorrected) data with **PYTHIA Tune A** and **HERWIG** after CDFSIM.
**Shows the “generator level” average ETsum density, dET\text{sum}/d\eta d\phi, in the “transverse” region (p_T > 0 GeV/c, |\eta| < 1) versus P_T(particle jet#1) for MidPoint, R = 0.7, f = 0.75, |\eta(jet#1)|<2.**

**Shows the average tower ETsum density, dET\text{sum}/d\eta d\phi, in the “transverse” region (E_T > 0.1 GeV, |\eta| < 1) versus P_T(jet#1) for MidPoint, R = 0.7, f = 0.75, |\eta(jet#1)|<2 (zero or 1 quality 12 vertex).**

**Compares the (uncorrected) data with PYTHIA Tune A and HERWIG after CDFSIM.**


**“Transverse” Density vs Number of Q12 Verticies**

- Shows the **charged PTsum density**, $dP_T/d\eta d\phi$, in the “transverse” region ($p_T > 0.5$ GeV/c, $|\eta| < 1$) versus $P_T(jet#1$ uncorrected) for MidPoint, $R = 0.7$, $f = 0.75$, $|\eta(jet#1)| < 2$ for the number of Q12 vertices $N_{Q12} = 1, 2, 3, 4$.

- Shows the **tower ETsum density**, $dET/d\eta d\phi$, in the “transverse” region ($p_T > 0.5$ GeV/c, $|\eta| < 1$) versus $P_T(jet#1$ uncorrected) for MidPoint, $R = 0.7$, $f = 0.75$, $|\eta(jet#1)| < 2$ for the number of Q12 vertices $N_{Q12} = 1, 2, 3, 4$.

- There is a big increase in the “transverse” ETsum density as the number of Q12 vertices increases (about 1.3 GeV/vertex)!
“Transverse” Density vs Number of Q12 Verticies

Shows the tower ET sum density, dET_{sum}/d\eta d\phi, in the “transverse” region (p_T > 0.5 GeV/c, |\eta| < 1) versus P_T(jet#1 uncorrected) for MidPoint, R = 0.7, f = 0.75, |\eta(jet#1)|<2 for the number of Q12 vertices NQ12 = 1, 2, 3, 4.

Shows the tower ET sum density, dET_{sum}/d\eta d\phi, in the “transverse” region (E_T > 0.1 GeV, |\eta| < 1) for 50 < P_T(jet#1 uncorrected) < 60 GeV/c for MidPoint, R = 0.7, f = 0.75, |\eta(jet#1)|<2 versus the number of Q12 vertices.

Shows the tower ET sum density, dET_{sum}/d\eta d\phi, in the “transverse” region (E_T > 0.1 GeV, |\eta| < 1) for 150 < P_T(jet#1 uncorrected) < 160 GeV/c for MidPoint, R = 0.7, f = 0.75, |\eta(jet#1)|<2 versus the number of Q12 vertices.
“Transverse” Density vs Number of Q12 Verticies

- Shows the tower ETsum density, $d\text{ET}_{\text{sum}}/d\eta d\phi$, in the “transverse” region ($p_T > 0.5$ GeV/c, $|\eta| < 1$) versus $P_T(\text{jet#1 uncorrected})$ for MidPoint, $R = 0.7$, $f = 0.75$, $|\eta(\text{jet#1})|<2$ for the number of Q12 vertices $NQ12 = 1, 2, 3, 4$.

- Shows the tower ETsum density, $d\text{ET}_{\text{sum}}/d\eta d\phi$, in the “transverse” region ($E_T > 0.1$ GeV, $|\eta| < 1$) for $50 < P_T(\text{jet#1 uncorrected}) < 60$ GeV/c for MidPoint, $R = 0.7$, $f = 0.75$, $|\eta(\text{jet#1})|<2$ versus the number of Q12 vertices.

- Shows the tower ETsum density, $d\text{ET}_{\text{sum}}/d\eta d\phi$, in the “transverse” region ($E_T > 0.1$ GeV, $|\eta| < 1$) for $150 < P_T(\text{jet#1 uncorrected}) < 160$ GeV/c for MidPoint, $R = 0.7$, $f = 0.75$, $|\eta(\text{jet#1})|<2$ versus the number of Q12 vertices.
“Transverse” ETsum Density vs Min-Bias Density Pile-Up

- Shows the tower ETsum density, $dE_T/d\eta d\phi$, in the “transverse” region ($E_T > 0.1$ GeV, $|\eta| < 1$) for $150 < P_T{(\text{jet#1 uncorrected})} < 160$ GeV/c for MidPoint, $R = 0.7$, $f = 0.75$, $|\eta{(\text{jet#1})}| < 2$ versus the number of Q12 vertices.

- Shows the tower ETsum density, $dE_T/d\eta d\phi$, in the central region ($E_T > 0.1$ GeV, $|\eta| < 1$) for min-bias collisions versus the number of Q12 vertices.

- Shows the affect of adding “min-bias pile-up” the the “transverse” region.
“Transverse” ETsum Density: \( \frac{dE_T}{d\eta d\phi} \)

- Shows the tower ETsum density, \( dE_T^{\text{sum}}/d\eta d\phi \), in the “transverse” region (\( E_T > 0.1 \text{ GeV}, |\eta| < 1 \)) for \( 150 < P_T(\text{jet#1 uncorrected}) < 160 \text{ GeV/c} \) for MidPoint, \( R = 0.7, f = 0.75, |\eta(\text{jet#1})| < 2 \) versus the number of Q12 vertices.

- Shows the tower ETsum density, \( dE_T^{\text{sum}}/d\eta d\phi \), in the central region (\( E_T > 0.1 \text{ GeV}, |\eta| < 1 \)) for min-bias collisions versus the number of Q12 vertices.

- Shows the affect of adding “min-bias pile-up” the the “transverse” region.
Why is the “pile-up” in the “transverse” region of a hard scattering greater than the “pile-up” in min-bias collisions?  

- Shows the tower ETsum density, \( \frac{dE_T}{d\eta d\phi} \), in the “transverse” region (\( E_T > 0.1 \) GeV, \(|\eta| < 1\)) for 150 < \( P_T(jet#1\text{ uncorrected}) < 160 \) GeV/c for MidPoint, \( R = 0.7, f = 0.75, |\eta(jet#1)|<2 \) versus the number of Q12 vertices.

- Shows the tower ETsum density, \( \frac{dE_T}{d\eta d\phi} \), in the central region (\( E_T > 0.1 \) GeV, \(|\eta| < 1\)) for min-bias collisions versus the number of Q12 vertices.

- Shows the affect of adding “min-bias pile-up” the the “transverse” region.
Shows the tower ETsum density, $dE_T/d\eta d\phi$, in the “transverse” region ($E_T > 0.1$ GeV, $|\eta| < 1$) for $150 < P_T(jet#1 \text{ uncorrected}) < 160$ GeV/c for MidPoint, $R = 0.7$, $f = 0.75$, $|\eta(jet#1)| < 2$ versus the number of Q12 vertices.

Shows the tower ETsum density, $dE_T/d\eta d\phi$, in the “transverse” region ($E_T > 0.1$ GeV, $|\eta| < 1$) for $150 < P_T(jet#1 \text{ uncorrected}) < 250$ GeV/c for MidPoint, $R = 0.7$, $f = 0.75$, $|\eta(jet#1)| < 2$ versus the instantaneous luminosity.
Shows the tower ETsum density, $dE_T/d\eta d\phi$, in the “transverse” region ($E_T > 0.1$ GeV, $|\eta| < 1$) for $150 < P_T(\text{jet#1 uncorrected}) < 250$ GeV/c for MidPoint, $R = 0.7$, $f = 0.75$, $|\eta(\text{jet#1})|<2$ versus the instantaneous luminosity.

Shows the tower ETsum density, $dE_T/d\eta d\phi$, in the central region ($E_T > 0.1$ GeV, $|\eta| < 1$) for min-bias collisions versus the instantaneous luminosity.

Why is the “pile-up” in the “transverse” region of a hard scattering greater than the ‘pile-up” in min-bias collisions?
“Transverse” Density vs Instantaneous Luminosity

Shows the charged PTsum density, \( dP_{T\text{sum}}/d\eta d\phi \), in the “transverse” region (\( p_T > 0.5 \) GeV/c, \( |\eta| < 1 \)) for \( 150 < P_T(\text{jet}\#1 \text{ uncorrected}) < 250 \) GeV/c for MidPoint, \( R = 0.7 \), \( f = 0.75 \), \( |\eta(\text{jet}\#1)| < 2 \) versus the instantaneous luminosity with \( NQ12 = 1 \) and no vertex cut.

Shows the tower ETsum density, \( dE_{\text{Tsum}}/d\eta d\phi \), in the “transverse” region (\( E_T > 0.1 \) GeV, \( |\eta| < 1 \)) for \( 150 < P_T(\text{jet}\#1 \text{ uncorrected}) < 250 \) GeV/c for MidPoint, \( R = 0.7 \), \( f = 0.75 \), \( |\eta(\text{jet}\#1)| < 2 \) versus the instantaneous luminosity with \( NQ12 = 1 \) and no vertex cut.

No correction needed for tracks! Slight correction needed for ETsum!