Charged Particles versus the Calorimeter Towers

Outline of the Talk

• Look at the transverse energy in the “underlying event” \(i.e.\) the “transverse” region and compare with the PTsum of charged particles and with PYTHIA Tune A + CDFSIM.

• Look at the density of towers \(E_T > 100\text{ MeV}\) in the “underlying event” \(i.e.\) the “transverse” region and compare with the charged particle density \(P_T > 500\text{ MeV/c}\) and with PYTHIA Tune A + CDFSIM.

• Normalize PYTHIA Tune A + CDFSIM to the leading charged particle jet cross section and then compare to the calorimeter jet cross section.

• Compare the calorimeter tower \(E_T\) cross section with PYTHIA Tune A + CDFSIM \(\text{normalized to the charged particle jet cross section}\).
The “Transverse” Region

- Look at the “transverse” region as defined by the leading calorimeter jet (JetClu R = 0.7, |η| < 2).
- Study the charged particles (P_T > 0.5 GeV/c, |η| < 1) and the calorimeter towers (E_T > E_Tmin, |η| < 1) in the “transverse” region.
The “Transverse” PTsum and ETsum Densities

- Shows the “transverse” PTsum density \( dP_T/d\eta d\phi \) for charged particles \( (P_T > 0.5 \text{ GeV}/c, |\eta| < 1) \) versus \( E_T(jet#1) \) compared with PYTHIA Tune A (after CDFSIM).
- Shows the “transverse” ETsum density \( dE_T/d\eta d\phi \) for calorimeter towers \( (E_T > 100 \text{ MeV}, |\eta| < 1) \) versus \( E_T(jet#1) \) compared with PYTHIA Tune A (after CDFSIM).
The “Transverse” PTsum and ETsum Densities

- **PYTHIA Tune A + CDFSIM** predicts about 250 MeV per unit $\eta$-$\phi$ less energy than seen in the data. Adding 250 MeV per unit $\eta$-$\phi$ to PYTHIA Tune A + CDFSIM agrees with the data.

- **Question:** Is this disagreement “physics” (i.e. a problem with PYTHIA) or is there a problem with CDFSIM?
ETmin Dependence of the “Transverse” ETsum

- Shows the “transverse” ETsum density $dE_T/d\eta d\phi$ for calorimeter towers ($|\eta| < 1$) versus $E_T(jet#1)$ compared with PYTHIA Tune A (after CDFSIM) for minimum tower $E_T = 100$ MeV, 500 MeV, and 1 GeV.

PY Tune A +CDFSIM agrees with ETmin = 1 GeV!
"Transverse" Charged Fraction PTsum/ETsum

- Shows the "transverse" charged fraction PTsum/ETsum for charged particles (P_T > 0.5 GeV/c, |\eta| < 1) and calorimeter towers (|\eta| < 1) versus E_T(jet#1) compared with PYTHIA Tune A (after CDFSIM) for minimum tower E_T = 100 MeV, 500 MeV, and 1 GeV.

PY Tune A +CDFSIM agrees with ET_{min} = 1 GeV!
“Transverse” Tower ET\(_{\text{max}}\) and Charged PT\(_{\text{max}}\)

- Shows the average maximum “transverse” tower ET\(_T\) for calorimeter towers (|\(\eta\)| < 1) and the maximum charged particle PT\(_T\) (P\(_T\) > 0.5 GeV/c, |\(\eta\)| < 1) versus ET(jet#1) compared with PYTHIA Tune A (after CDFSIM).
The “Transverse” Tower and Particle Densities

- Shows the “transverse” density $dN/d\eta d\phi$ of charged particles ($P_T > 0.5$ GeV/c, $|\eta| < 1$) versus $E_T(jet#1)$ compared with PYTHIA Tune A (after CDFSIM).
- Shows the “transverse” density $dN/d\eta d\phi$ of calorimeter towers ($E_T > 100$ MeV, $|\eta| < 1$) versus $E_T(jet#1)$ compared with PYTHIA Tune A (after CDFSIM). Note that $\Delta\eta \times \Delta\phi = 0.1 \times 15^\circ$ corresponds to about 38 towers per unit $\eta$-$\phi$. 

More towers ($E_T > 100$ MeV) in the data than predicted by PY Tune A!

PY Tune A agrees with the charged particle density.
The "Transverse" Tower and Particle Densities

- Shows the "transverse" ratio $N_{\text{tower}}/N_{\text{charged}}$ for calorimeter towers ($E_T > 100$ MeV, $|\eta| < 1$) and charged particles ($P_T > 0.5$ GeV/c, $|\eta| < 1$) versus $E_T(\text{jet}#1)$ compared with PYTHIA Tune A (after CDFSIM).
The “Transverse” Tower and Particle Densities

**PYTHIA Tune A + CDFSIM** predicts about **0.75 less towers** ($E_T > 100$ MeV) per unit $\eta$-$\phi$ less than seen in the data. Adding 0.75 towers per unit $\eta$-$\phi$ to PYTHIA Tune A + CDFSIM agrees with the data.

**Question:** Is this disagreement “physics” *(i.e. a problem with PYTHIA)* or is there a problem with CDFSIM?
The **uncorrected** leading charged particle jet cross-section \((P_T > 0.5 \text{ GeV/c}, |\eta| < 1, R = 0.7)\) compared with PYTHIA Tune A + CDFSIM. The data and theory are normalized to agree at the one point \(P_T(chgjet#1) = 50 \text{ GeV/c}\).
The *uncorrected* inclusive jet cross-section (JetClu, R = 0.7, 0.1<|DET\eta|<0.7) compared with PYTHIA Tune A + CDFSIM (*normalized to the leading charged particle jet cross section*).
Jet#1, Jet#2, and Jet#3 Cross-Sections

The uncorrected cross-section for jet#1 (leading jet), jet#2 (2nd leading), and jet#3 (3rd leading) (JetClu, R = 0.7, 0.1<|DET\eta|<0.7) compared with PYTHIA Tune A + CDFSIM (normalized to the leading charged particle jet cross section).
Would like to understand why the “calorimeter jets” behave differently than the “charged particle jets”!

The **uncorrected** leading calorimeter jet cross-section (JetClu, $R = 0.7$, $0.1 < |\text{DET}\eta| < 0.7$) **uncorrected** and the **leading charged particle jet cross-section** ($P_T > 0.5$, $|\eta| < 1$, $R = 0.7$) compared with **PYTHIA Tune A + CDFSIM**. Note that the data/theory behave different for “charged particles jets” and “calorimeter jets”!
The uncorrected tower $E_T$ cross-section ($|\eta|<1$) compared with PYTHIA Tune A + CDFSIM (normalized to the leading charged particle jet cross section). Note that the data/theory = 1 down to tower $E_T = 5$ GeV!
Inclusive Tower $E_T$ Cross-Section: Data/Theory

The *uncorrected* tower $E_T$ cross-section ($|\eta|<1$) and the *uncorrected* leading charged particle jet cross-section ($P_T > 0.5$, $|\eta|<1$, $R = 0.7$) compared with PYTHIA Tune A + CDFSIM. It is the “soft” towers that are causing the difference between the data/theory for the “charged particle jets” and for the “calorimeter jets”!
** Conclusions **

- There are many more “soft” towers ($E_T > 100$ MeV) in the data than in PYTHIA Tune A + CDFSIM.

- For the “underlying event” (*i.e.* the transverse region) there is about 250 MeV more energy per unit $\eta$-$\phi$ in the data than in PYTHIA Tune A + CDFSIM.

- JetClu gobbles up the “soft” towers and it is the “soft” towers that are causing the difference between the data/theory for the “charged particle” and for the “calorimeter jets”!

- Question: Are these “soft” towers real “physics” (*i.e.* a problem with PYTHIA) or is there a problem with CDFSIM?

- We must make sure that our “physics” conclusions do not depend on the choice of the minimum tower $E_T$ (*i.e.* physics should be stable under a change in $E_{T\text{min}}$)!

I will know more after studying HERWIG!
** Plans **

- Redo everything using HERWIG! Soon!

- I will be at Fermilab all next week (August 10-17) for the Lepton-Photon Conference. I will go to a few talks, but I will mostly work on CDF.

- I would like to get some plots on the energy in the “underlying event” blessed, but I cannot proceed until I am convinced that what I am seeing is really “physics” and not problems with CDFSIM.

- In the mean time, I plan to get more plots blessed on the “charged particles” in the “underlying event” (MAX/MIN regions, multiplicity distributions, $<P_T>$, etc.). While at CERN I was amazed by how much people are using our “underlying event” data and I was given a big shopping list of more Run 2 plots people would like to see. I have the plots, I just need to write a CDF note and get them blessed!