Outline

- The QCD Group: Organization, Activities, Run 2 Analyses
- QCD Analyses: “Isolating the Multiple Parton Scattering Component of the Underlying Event in Run 2”
- Other QCD Group Presentations:
  - “Jet Production using a Cone Algorithm” - Frank Chlebana (15 min)
  - “Jet Production using the KT Algorithm” - Regis Lefevre (15 min)
  - “Jet Shapes” - Mario Martinez (15 min)
  - “Diphoton Production” – Yanwen Liu (15 min)
  - “Diffraction @ CDF” - Koji Terashi (15 min)
Conveners:

- Mario Martinez-Perez (2nd year)
- Rick Field (1st year)

Meetings:

- On Weeks 9:00-11:30am CDF Theater
- Off Weeks 11:30-1:00pm Trailer 159

QCD Internal WEBsite:

- Meeting Agenda & Archived Talks (with author index)
- Blessed Plots and Analyses
- Information of Monte-Carlo Datasets
- QCD Secondary Datasets
- QCD Graduate Students
The QCD Group
Run 2 Analyses

- **Inclusive Jet Cross Section (JetClu & MidPoint)**: Frank Chlebana, Anwar Bhatti, Ken Hatakeyama, Giuseppe Latino, Joey Huston, Gene Flanagan
- **Inclusive Jet Cross Section (KT Algorithm)**: Regis Lefevre, Olga Norniella
- **DiJet Mass/Angular Distribution**: Robert Harris, Lee Pondrom
- **DiPhoton Production**: Yanwen Liu
- **b-Jet & b-bbar Jet Cross Sections**: Monica D'Onofrio, Anant Gajjar
- **Jet Shapes (light and heavy quarks)**: Mario Martinez, Olga Norniella, Alison Lister
- **Quark and Gluon Fragmentation**: Andrey Korytov, Sasha Pronko, Lester Pinera, Sergio Jindariani
- **W+Jets**: Andrea Messina, Ben Cooper
- **Z+jets (event structure & underlying event)**: Rick Field, Craig Group
- **Min-Bias and the Underlying Event**: Rick Field, Alberto Cruz
- **Diffractive Physics**: The “Diffractive Group”
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The “Underlying Event” in a Hard Scattering: Consists of hard initial & final state radiation (unavoidable) plus the “beam-beam remnants”. Plus possible multiple parton interactions (more active underlying event!).

The “Underlying Event” in Run II at CDF: The Run 2 analysis gives a more detailed look at the “underlying event” in hard scattering processes and compares the data with PYTHIA Tune A (with multiple parton interactions) and HERWIG (without multiple parton interactions).
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Charged Particle Density $\Delta\phi$ Dependence

- Look at the “transverse” region as defined by the leading jet ($\text{JetClu R} = 0.7$, $|\eta| < 2$) or by the leading two jets ($\text{JetClu R} = 0.7$, $|\eta| < 2$). “Back-to-Back” events are selected to have two jets and only two jets with $E_T > 15$ GeV with Jet#1 and Jet#2 nearly “back-to-back” ($\Delta\phi_{12} > 150^\circ$) with almost equal transverse energies ($E_T(\text{jet#2})/E_T(\text{jet#1}) > 0.8$).

- Shows the $\Delta\phi$ dependence of the charged particle density, $dN_{\text{chg}}/d\eta d\phi$, for charged particles in the range $p_T > 0.5$ GeV/c and $|\eta| < 1$ relative to jet#1 (rotated to 270$^\circ$) for $30 < E_T(\text{jet#1}) < 70$ GeV for “Leading Jet” and “Back-to-Back” events.
Shows the average charged particle density, $dN_{\text{chg}}/d\eta d\phi$, in the "transverse" region ($p_T > 0.5$ GeV/c, $|\eta| < 1$) versus $E_T(jet#1)$ for "Leading Jet" and "Back-to-Back" events.

Comparing the (uncorrected) data with PYTHIA Tune A and HERWIG after CDFSIM.
"Transverse" Charge Density versus $E_T$(jet#1)

- Shows the average charged particle density, $dN_{\text{chg}}/d\eta d\phi$, in the "transverse" region ($p_T > 0.5$ GeV/c, $|\eta| < 1$) versus $E_T$(jet#1) for "Leading Jet" and "Back-to-Back" events.

- Compares the (uncorrected) data with PYTHIA Tune A and HERWIG after CDFSIM.
Charged Particle Density

**PYTHIA Tune A vs HERWIG**

**HERWIG** (without multiple parton interactions) produces too few charged particles in the “transverse” region for $30 < E_T(\text{jet#1}) < 70$ GeV!
Use the leading jet in “back-to-back” events to define the “transverse” region and look at the maximum $p_T$ charged particle in the “transverse” region, $PT_{max}$.

Look at the $\Delta \phi$ dependence of the “associated” charged particle and $PT_{sum}$ densities, $dN_{chg}/d\eta d\phi$ and $dPT_{sum}/d\eta d\phi$ for charged particles ($p_T > 0.5 \text{ GeV/c, } |\eta| < 1$, not including $PT_{max}$) relative to $PT_{max}$.

Rotate so that $PT_{max}$ is at the center of the plot (i.e. $180^\circ$).
Look at the $\Delta \phi$ dependence of the “associated” charged particle density, $dN_{chg}/d\eta d\phi$ for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$, not including $PT_{maxT}$) relative to $PT_{maxT}$ (rotated to 180°) for $PT_{maxT} > 0.5$ GeV/c, $PT_{maxT} > 1.0$ GeV/c and $PT_{maxT} > 2.0$ GeV/c, for “back-to-back” events with $30 < E_T(jet#1) < 70$ GeV.
Look at the $\Delta \phi$ dependence of the “associated” charged particle density, $dN_{chg}/d\eta d\phi$ for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$, not including $PT_{maxT}$) relative to $PT_{maxT}$ (rotated to 180°) for $PT_{maxT} > 0.5$ GeV/c, $PT_{maxT} > 1.0$ GeV/c and $PT_{maxT} > 2.0$ GeV/c, for “back-to-back” events with $30 < E_T(jet#1) < 70$ GeV.

Shows “jet structure” in the “transverse” region (i.e. the “birth” of the 3rd & 4th jet).
Shows the $\Delta \phi$ dependence of the “associated” charged particle density, $dN_{\text{chg}}/d\eta d\phi$, $p_T > 0.5$ GeV/c, $|\eta| < 1$ (not including $P_T^{\text{max}}$) relative to $P_T^{\text{max}}$ (rotated to 180°) and the charged particle density, $dN_{\text{chg}}/d\eta d\phi$, $p_T > 0.5$ GeV/c, $|\eta| < 1$ relative to jet#1 (rotated to 270°) for “back-to-back events” with $30 < E_T^{\text{jet#1}} < 70$ GeV.
Shows the $\Delta \phi$ dependence of the “associated” charged particle density, $dN_{\text{chg}}/d\eta d\phi$, $p_T > 0.5$ GeV/c, $|\eta| < 1$, $\text{PTmaxT} > 2.0$ GeV/c (not including $\text{PTmaxT}$) relative to $\text{PTmaxT}$ (rotated to $180^\circ$) and the charged particle density, $dN_{\text{chg}}/d\eta d\phi$, $p_T > 0.5$ GeV/c, $|\eta| < 1$, relative to jet#1 (rotated to $270^\circ$) for “back-to-back events” with $30 < E_T(\text{jet#1}) < 70$ GeV.

<table>
<thead>
<tr>
<th>$\Delta \phi$</th>
<th>Charged Particle Density: $dN/d\eta d\phi$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.5$</td>
<td>$1.0$</td>
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<tr>
<td>$1.0$</td>
<td>$1.5$</td>
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<tr>
<td>$1.5$</td>
<td>$2.0$</td>
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<tr>
<td>$2.0$</td>
<td>$2.5$</td>
</tr>
</tbody>
</table>

CDF Preliminary data uncorrected
"Associated" Charge Density
PYTHIA Tune A vs HERWIG

- Charged Particles
  - \(|\eta|<1.0, PT>0.5\text{ GeV/c}\)
  - \(PT_{\text{max}}T\) not included

- Back-to-Back
  - \(30 < ET(\text{jet#1}) < 70\text{ GeV}\)

CDF Preliminary
data uncorrected theory + CDFSIM

HERWIG (without multiple parton interactions) too few "associated" particles in the direction of \(PT_{\text{max}}T\)!

And HERWIG (without multiple parton interactions) too few particles in the direction opposite of \(PT_{\text{max}}T\)!
For $\text{PTmaxT} > 2.0$ GeV both PYTHIA and HERWIG produce slightly too many “associated” particles in the direction of $\text{PTmaxT}$!

But HERWIG (without multiple parton interactions) produces too few particles in the direction opposite of $\text{PTmaxT}$!
Jet Toopologies

QCD Four Jet Topology

Charged Particle Density: $dN/d\eta d\phi$

CDF Preliminary data uncorrected

30 $< E_T(jet\#1) < 70$ GeV
Back-to-Back

Jet#1

“Transverse” Region

PTmaxT

Charged Particles
($|\eta|<1.0, PT>0.5$ GeV/c)

“Transverse” Region

Associated Density
PTmaxT $> 2$ GeV/c
(not included)

Shows the $\Delta\phi$ dependence of the “associated” charged particle density, $dN_{chg}/d\eta d\phi$, $p_T > 0.5$ GeV/c, $|\eta| < 1$, PTmaxT $> 2.0$ GeV/c (not including PTmaxT) relative to PTmaxT (rotated to 180°) and the charged particle density, $dN_{chg}/d\eta d\phi$, $p_T > 0.5$ GeV/c, $|\eta| < 1$, relative to jet#1 (rotated to 270°) for “back-to-back events” with 30 $< E_T(jet\#1) < 70$ GeV.
Jet Topologies

QCD Four Jet Topology

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<tbody>
<tr>
<td>Jet #3 Region</td>
<td></td>
</tr>
<tr>
<td>Jet #4 Region</td>
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</table>

Showed the $\Delta \phi$ dependence of the “associated” charged particle density, $dN_{\text{chg}}/d\eta d\phi$, $p_T > 0.5$ GeV/c, $|\eta| < 1$, $P_{T\text{max}} > 2.0$ GeV/c (not including $P_{T\text{max}}$) relative to $P_{T\text{max}}$ (rotated to 180°) and the charged particle density, $dN_{\text{chg}}/d\eta d\phi$, $p_T > 0.5$ GeV/c, $|\eta| < 1$, relative to jet#1 (rotated to 270°) for “back-to-back events” with $30 < E_T(\text{jet#1}) < 70$ GeV.
Jet Topologies

Data have about equal amounts of 3 and 4 jet topologies!

Same events!

Shows the data on the number of jets (JetClu, R = 0.7, |η| < 2, E_T(jet) > 3 GeV) for “back-to-back” events with 30 < E_T(jet#1) < 70 GeV and PTmaxT > 2.0 GeV/c.
Jet Multiplicity

Jet Multiplicity ET > 3 GeV

- Shows the data on the number of jets (JetClu, R = 0.7, |η| < 2, E_T(jet) > 3 GeV) for “back-to-back” events with 30 < E_T(jet#1) < 70 GeV and PTmaxT > 2.0 GeV/c.

- Compares the (uncorrected) data with HERWIG after CDFSIM.

Data have about equal amounts of 3 and 4 jet topologies!
Jet Multiplicity ET > 3 GeV

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Comparing the (uncorrected) data with PYTHIA Tune A after CDFSIM.
Jet Multiplicity ET > 3 GeV

Jet #1 Direction
- "Toward"
- "TransMAX"
- "TransMIN"
- "Away"

Jet #2 Direction
- "Toward"
- "TransMIN"
- "TransMAX"
- "Away"

Max $p_T$ in the “transverse” region!

HERWIG (without multiple parton interactions) does not have equal amounts of 3 and 4 jet topologies!

Data have about equal amounts of 3 and 4 jet topologies!

Showing the data on the number of jets (JetClu, $R = 0.7$, $|\eta| < 2$, $E_T(jet) > 3$ GeV) for “back-to-back” events with $30 < E_T(jet#1) < 70$ GeV and $PT_{maxT} > 2.0$ GeV/c.

Compared the (uncorrected) data with HERWIG after CDFSIM.
Jet Multiplicity

- Max \( p_T \) in the “transverse” region!

Jet #1 Direction
- "Toward"
- "TransMAX"

PTmaxT

Jet #2 Direction
- "Away"

Max \( p_T \) in the “transverse” region!

HERWIG (without multiple interactions) does not have equal amounts of 3 and 4 jet topologies!

Data have about equal amounts of 3 and 4 jet topologies!

- Shows the data on the number of jets (\( \text{JetCuts} = 0.7, |\eta| < 2, E_T(jet) > 3 \text{ GeV} \)) for “back-to-back” events with \( 30 < E_T(jet#1) < 70 \text{ GeV} \) and \( \text{PTmaxT} > 2.0 \text{ GeV/c} \).

- Compares the (uncorrected) data with HERWIG after CDFSIM.

Next Step
Look directly at multiple jet topologies (i.e. 4 jets) and show there is an excess due to multiple parton interactions!