QCD Physics at CDF
Overview

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)

In person!
Thanks Bob!

The CDF-QCD Group

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

New!

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, Sergo 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"

The QCD Group
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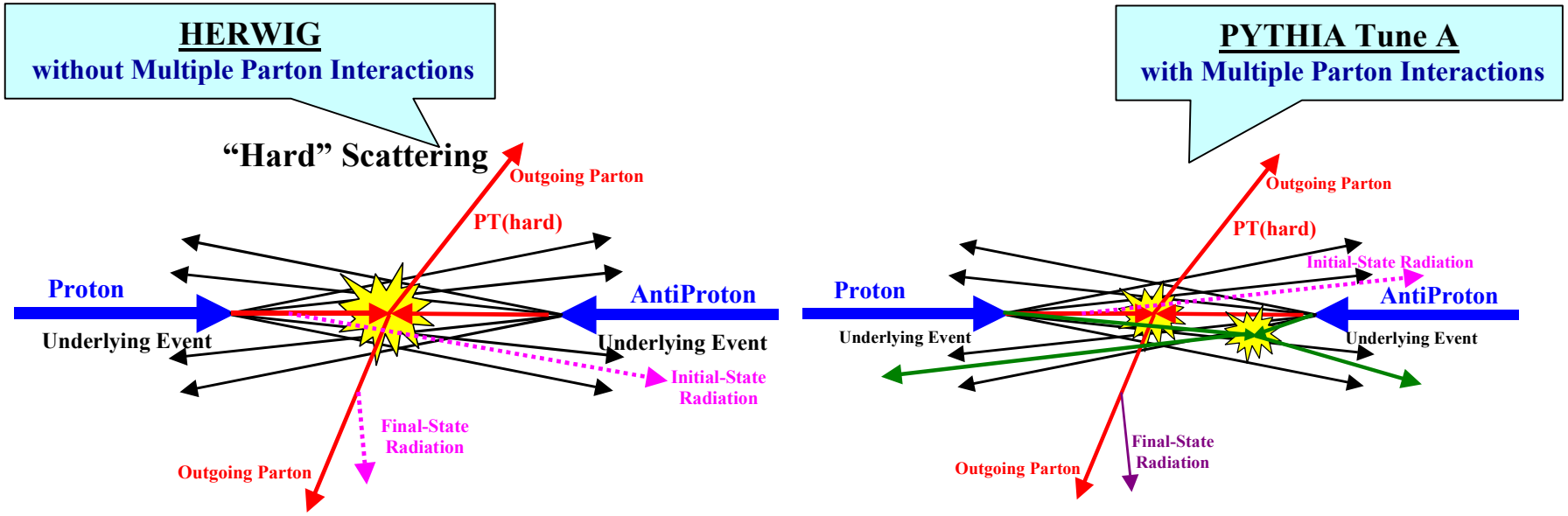
Godparent Committees!

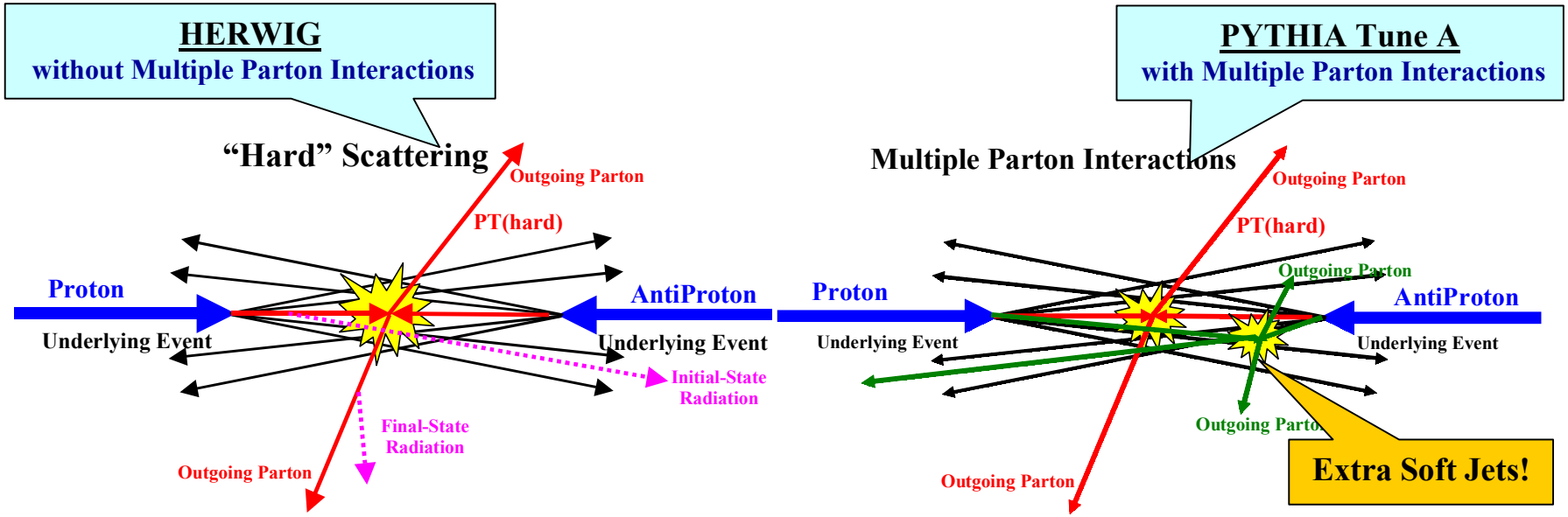
The Underlying Event



- **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)**.

The Underlying Event



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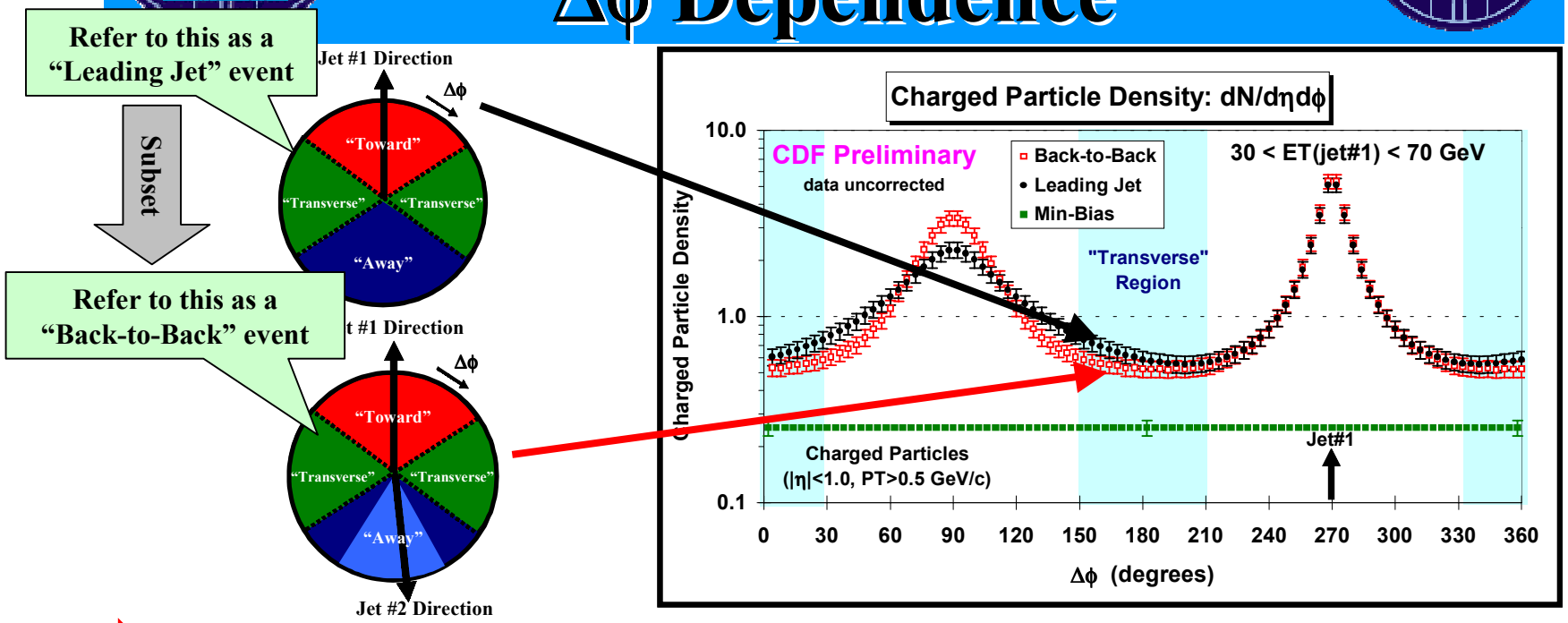
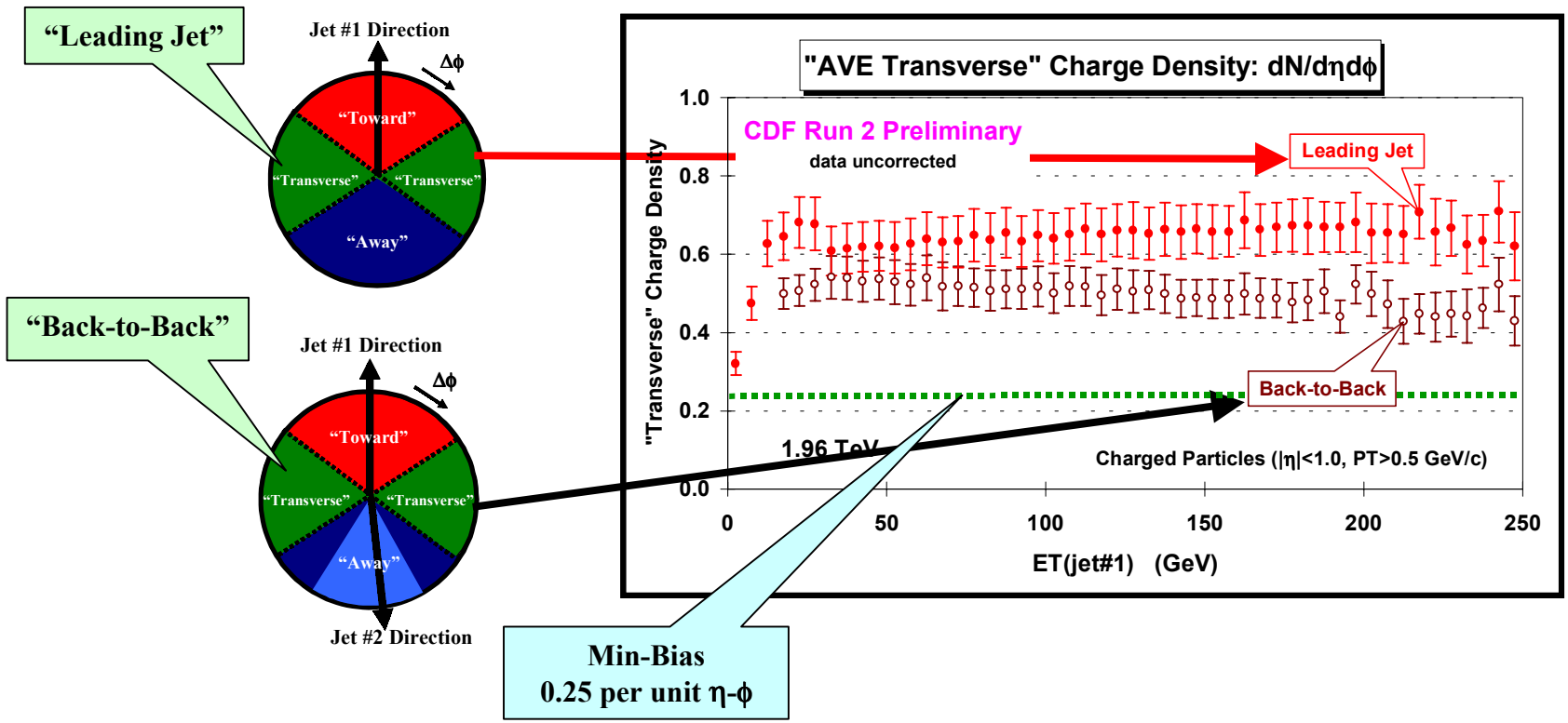
Charged Particle Density
Δϕ Dependence



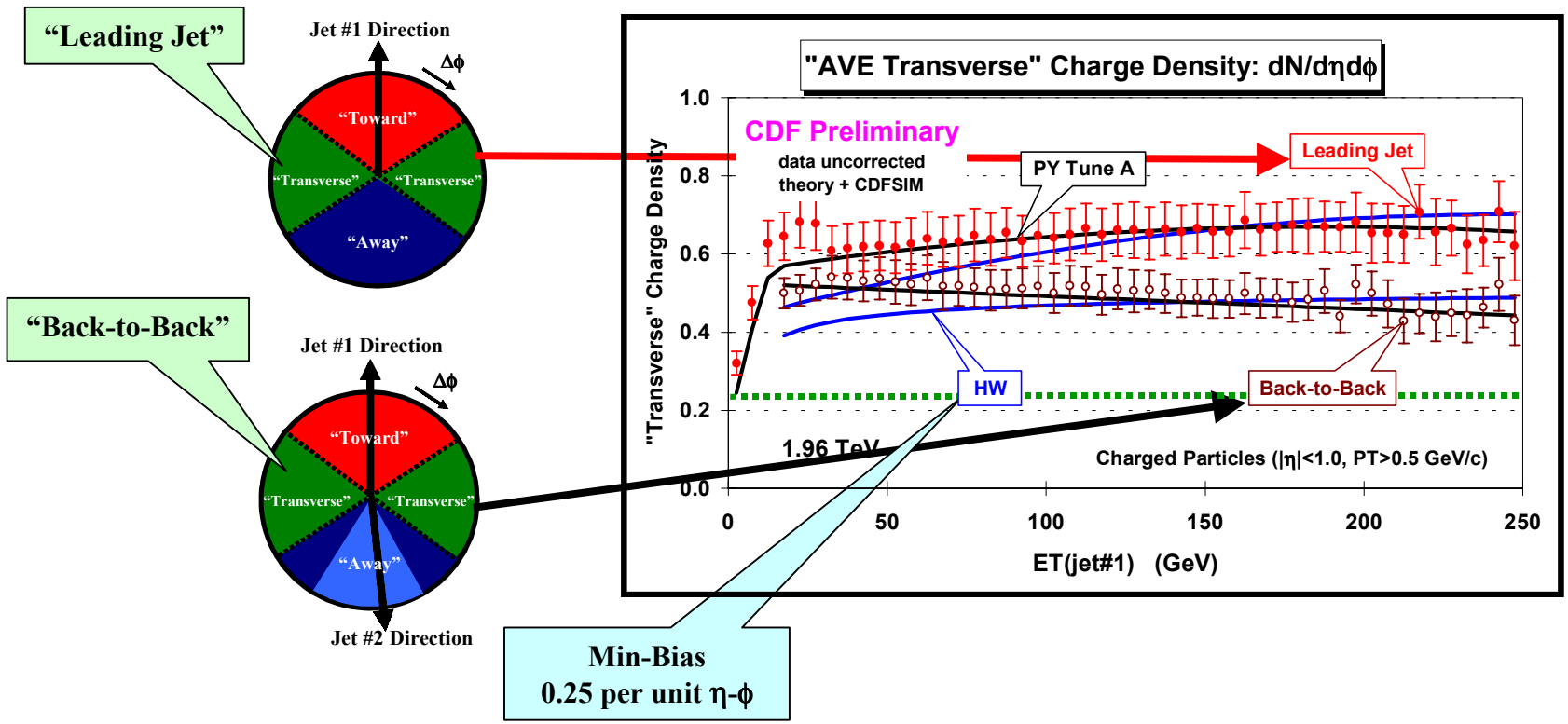
- Look at the "transverse" region as defined by the leading jet (JetClu R = 0.7, $|\eta| < 2$) or by the leading two jets (JetClu R = 0.7, $|\eta| < 2$). "Back-to-Back" events are selected to have two jets and only two jets with $E_T > 15$ GeV with Jet#1 and Jet#2 nearly "back-to-back" ($\Delta\phi_{12} > 150^o$) with almost equal transverse energies (E_T(jet#2)/E_T(jet#1) > 0.8).
- Shows the Δϕ dependence of the charged particle density, $dN_{chg}/d\eta d\phi$, for charged particles in the range $p_T > 0.5$ GeV/c and $|\eta| < 1$ relative to jet#1 (rotated to 270º) for 30 < E_T(jet#1) < 70 GeV for "Leading Jet" and "Back-to-Back" events.

"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 "Leading Jet" and "Back-to-Back" events.
- Compares the (*uncorrected*) data with PYTHIA Tune A and HERWIG after CDFSIM.

"Transverse" Charge Density versus E_T(jet#1)



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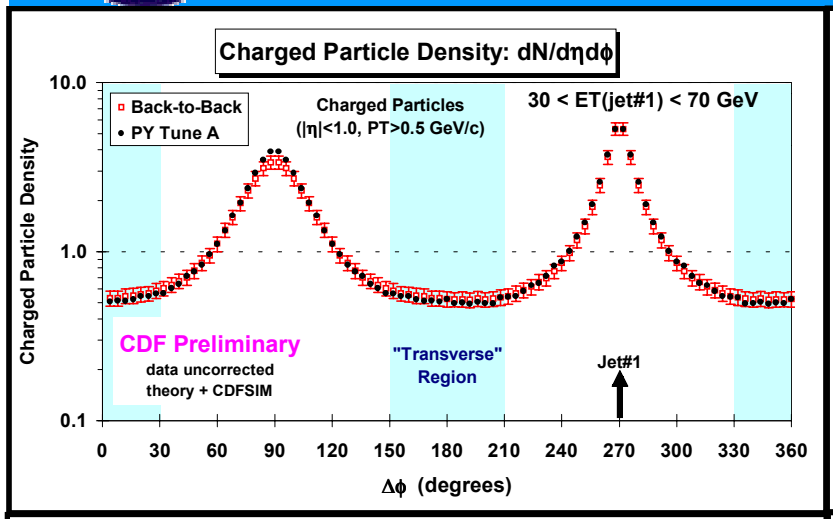
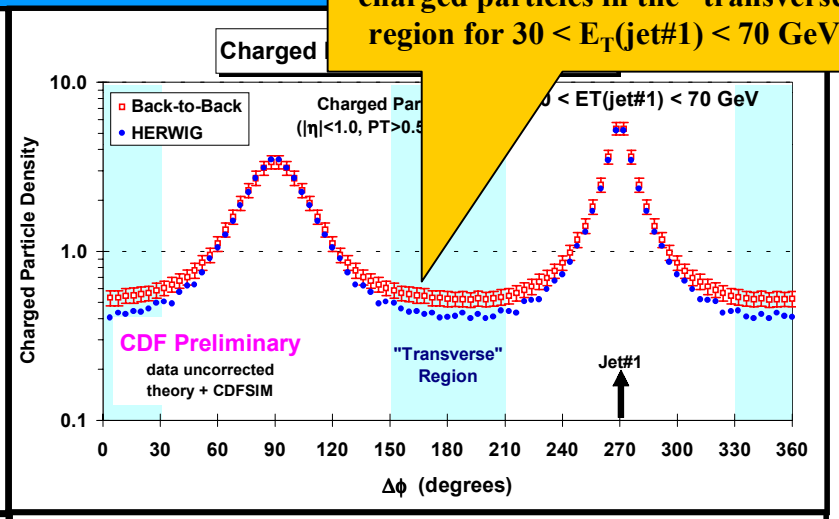
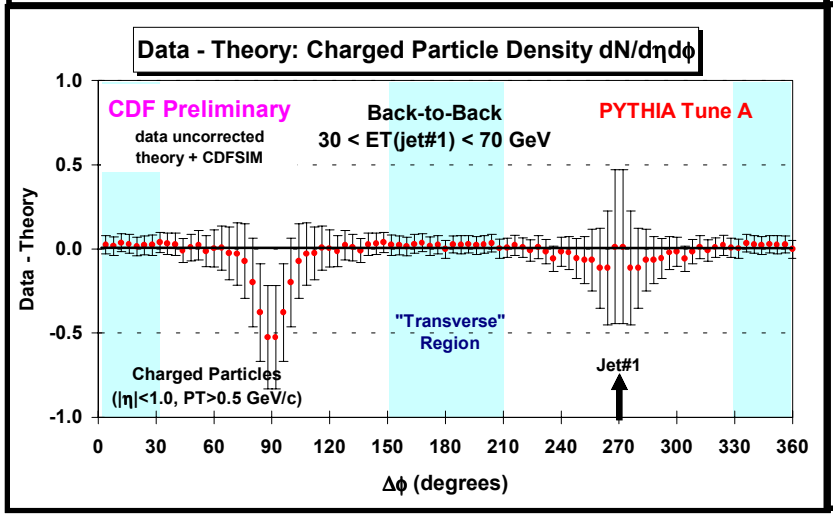
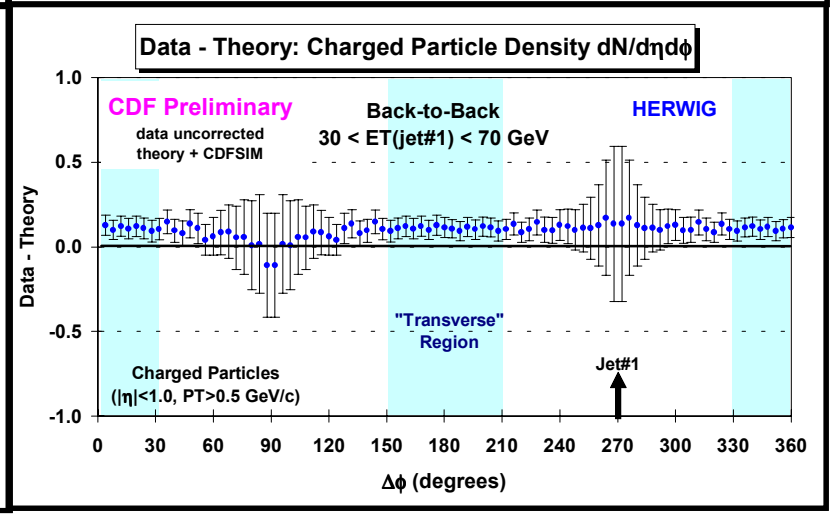
Charged Particle Density
PYTHIA Tune A vs HE

HERWIG (*without multiple parton interactions*) produces too few charged particles in the "transverse" region for 30 < E_T(jet#1) < 70 GeV!

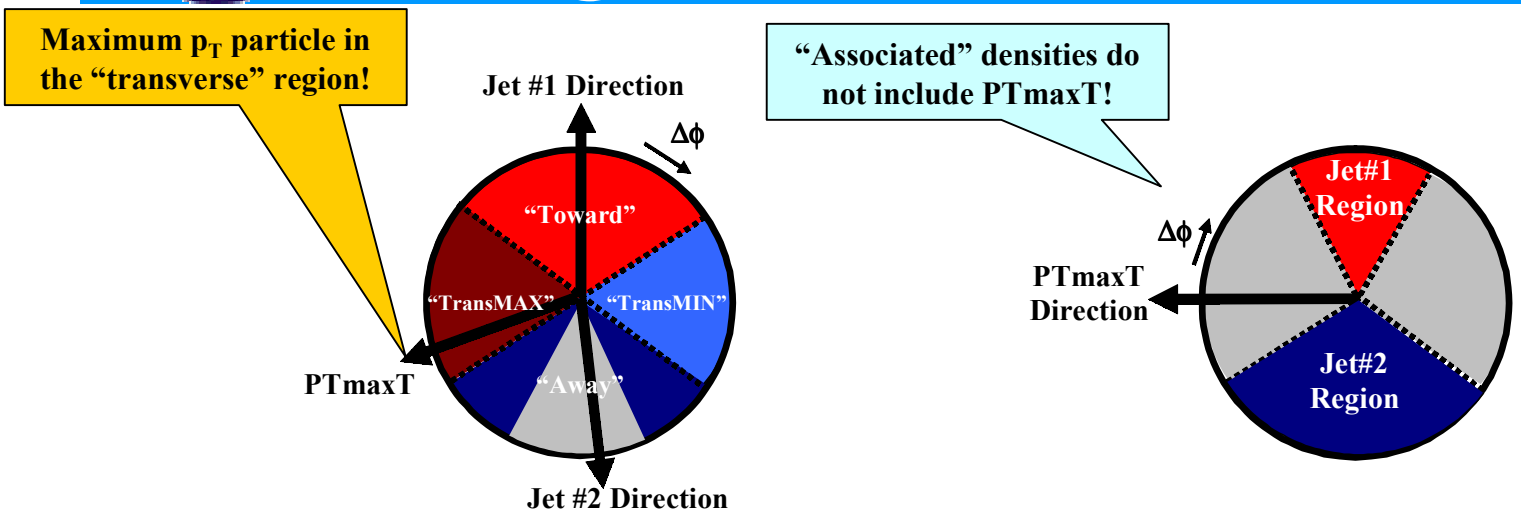






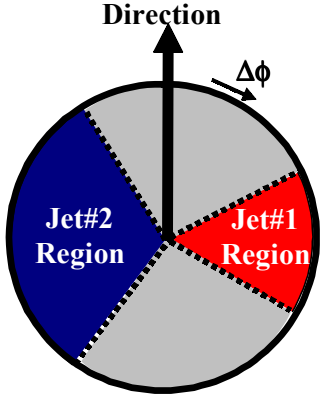


Back-to-Back "Associated" Charged Particle Densities

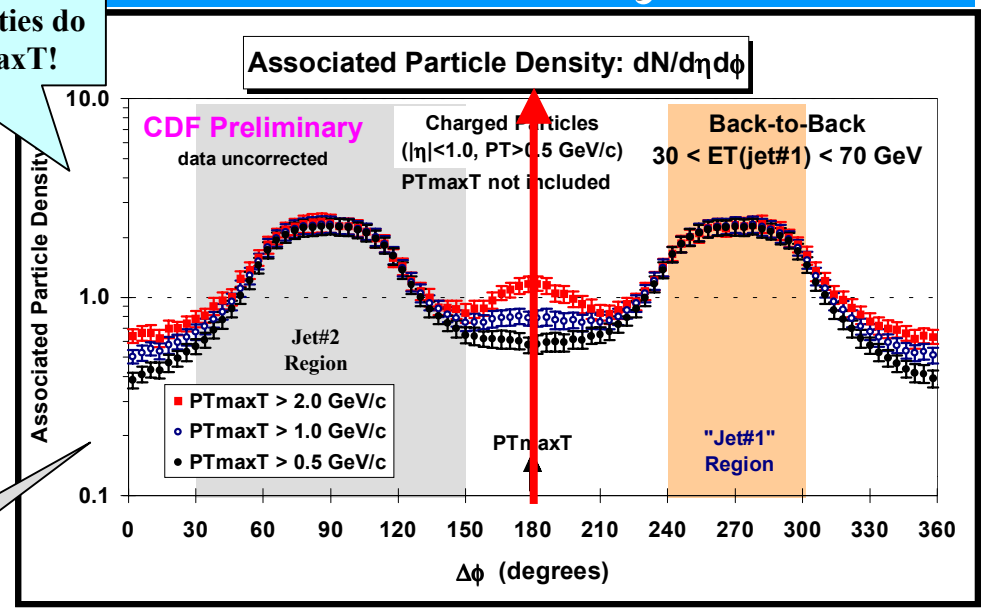


- Use the leading jet in "back-to-back" events to define the "transverse" region and look at the maximum p_T charged particle in the "transverse" region, PTmaxT.
- Look at the Δϕ dependence of the "associated" charged particle and PTsum densities, $dN_{chg}/d\eta d\phi$ and $dPT_{sum}/d\eta d\phi$ for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$, *not including PTmaxT*) relative to PTmaxT.
- Rotate so that PTmaxT is at the center of the plot (*i.e.* 180°).

Back-to-Back "Associated" Charged Particle Density



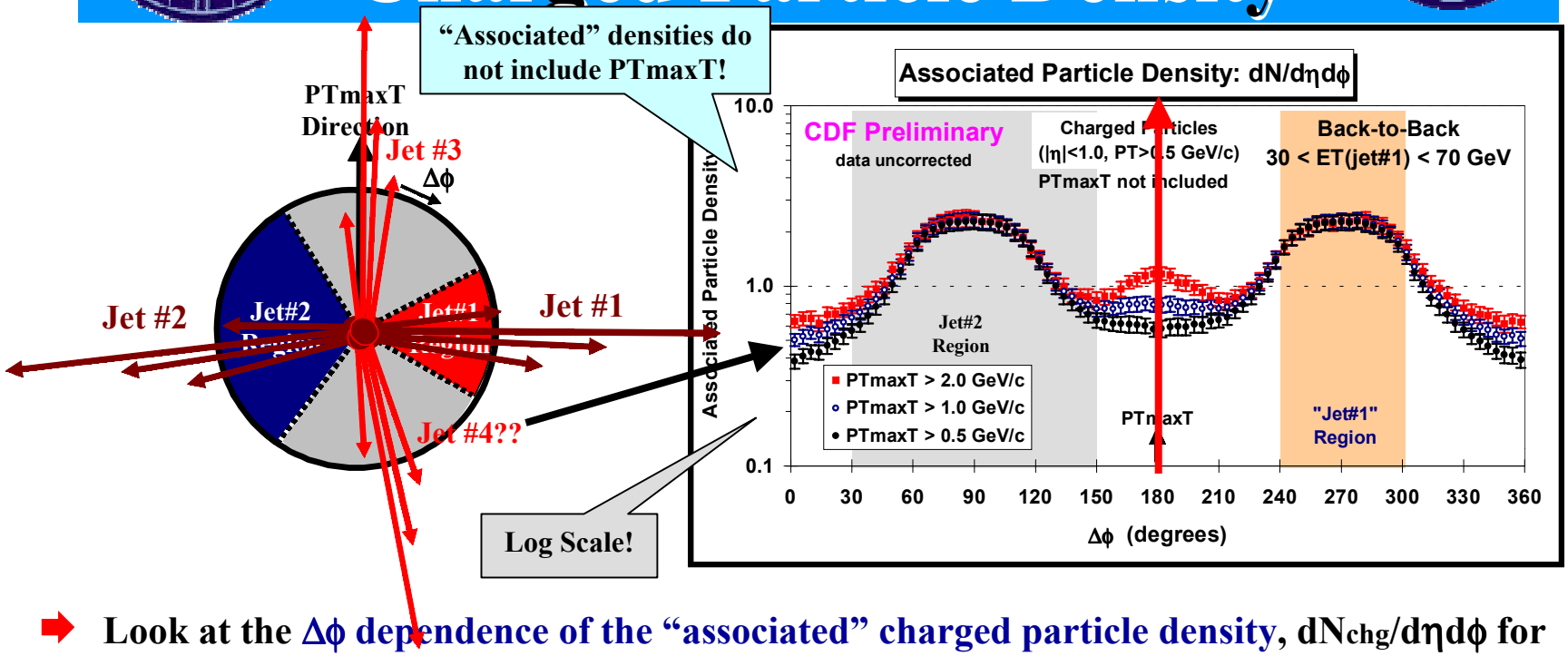
"Associated" densities do not include PTmaxT!



Log Scale!

- Look at the **Δϕ 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 PTmaxT*) relative to PTmaxT (rotated to 180°) for PTmaxT > 0.5 GeV/c, PTmaxT > 1.0 GeV/c and PTmaxT > 2.0 GeV/c, for **"back-to-back" events with $30 < E_T$(jet#1) < 70 GeV** .

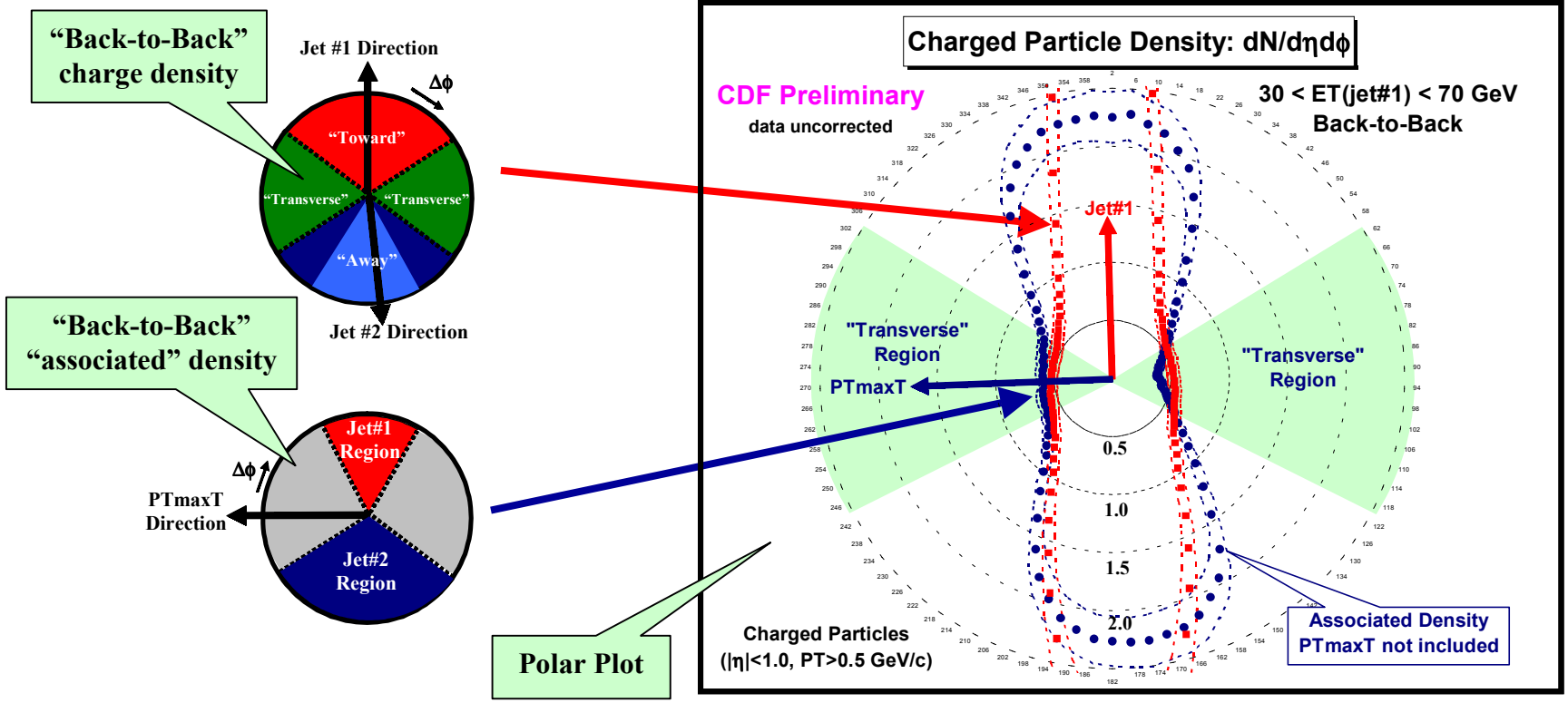
Back-to-Back "Associated" Charged Particle Density



- Look at the Δφ 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 PTmaxT*) relative to PTmaxT (rotated to 180°) for PTmaxT > 0.5 GeV/c, PTmaxT > 1.0 GeV/c and PTmaxT > 2.0 GeV/c, for "back-to-back" events with $30 < E_T$(jet#1) < 70 GeV .

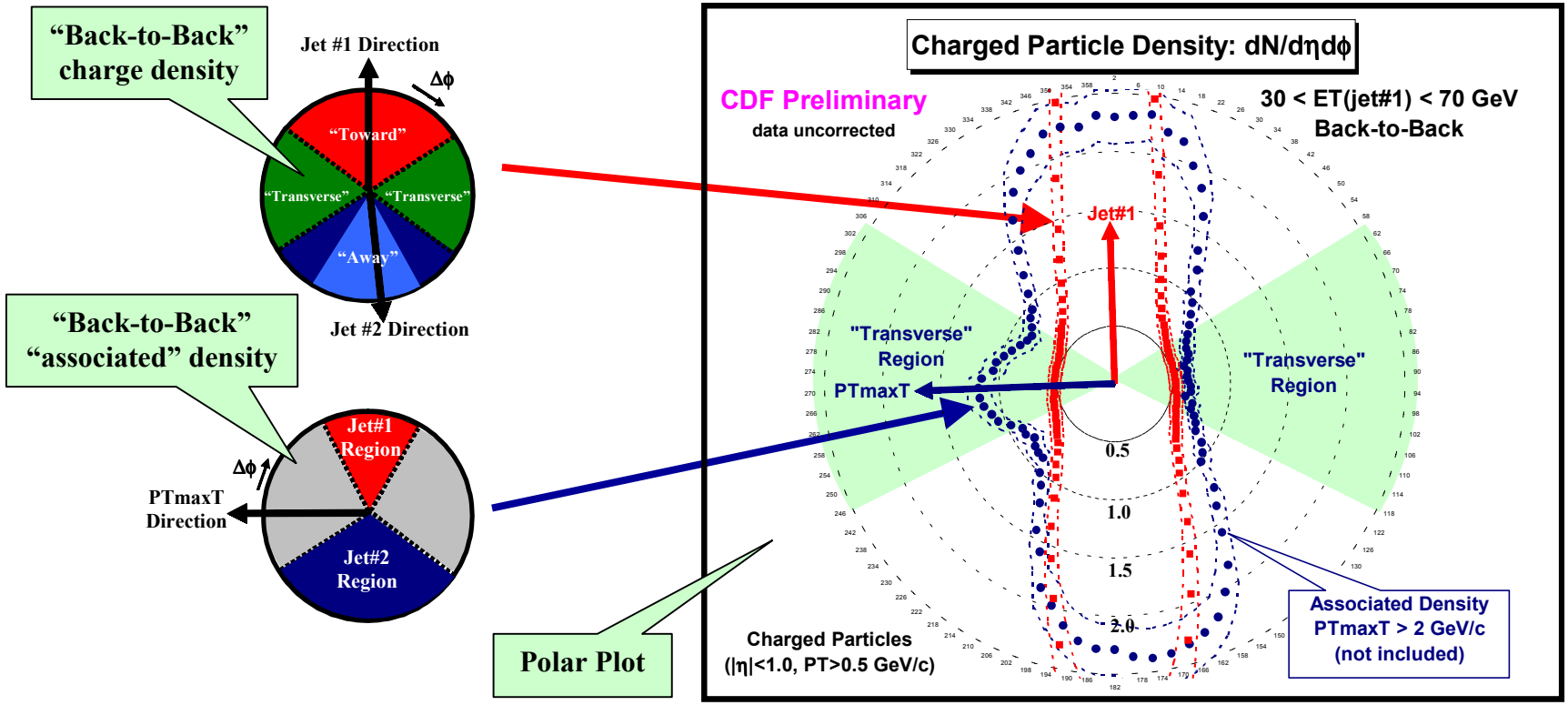
- Shows "jet structure" in the "transverse" region (*i.e.* the "birth" of the 3rd & 4th jet).

Back-to-Back "Associated" Charged Particle Densities



- **Shows the Δφ dependence of the "associated" charged particle density, $dN_{chg}/d\eta d\phi$, $p_T > 0.5$ GeV/c, $|\eta| < 1$ (*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 $30 < E_T(\text{jet\#1}) < 70$ GeV.**

Back-to-Back "Associated" Charged Particle Densities



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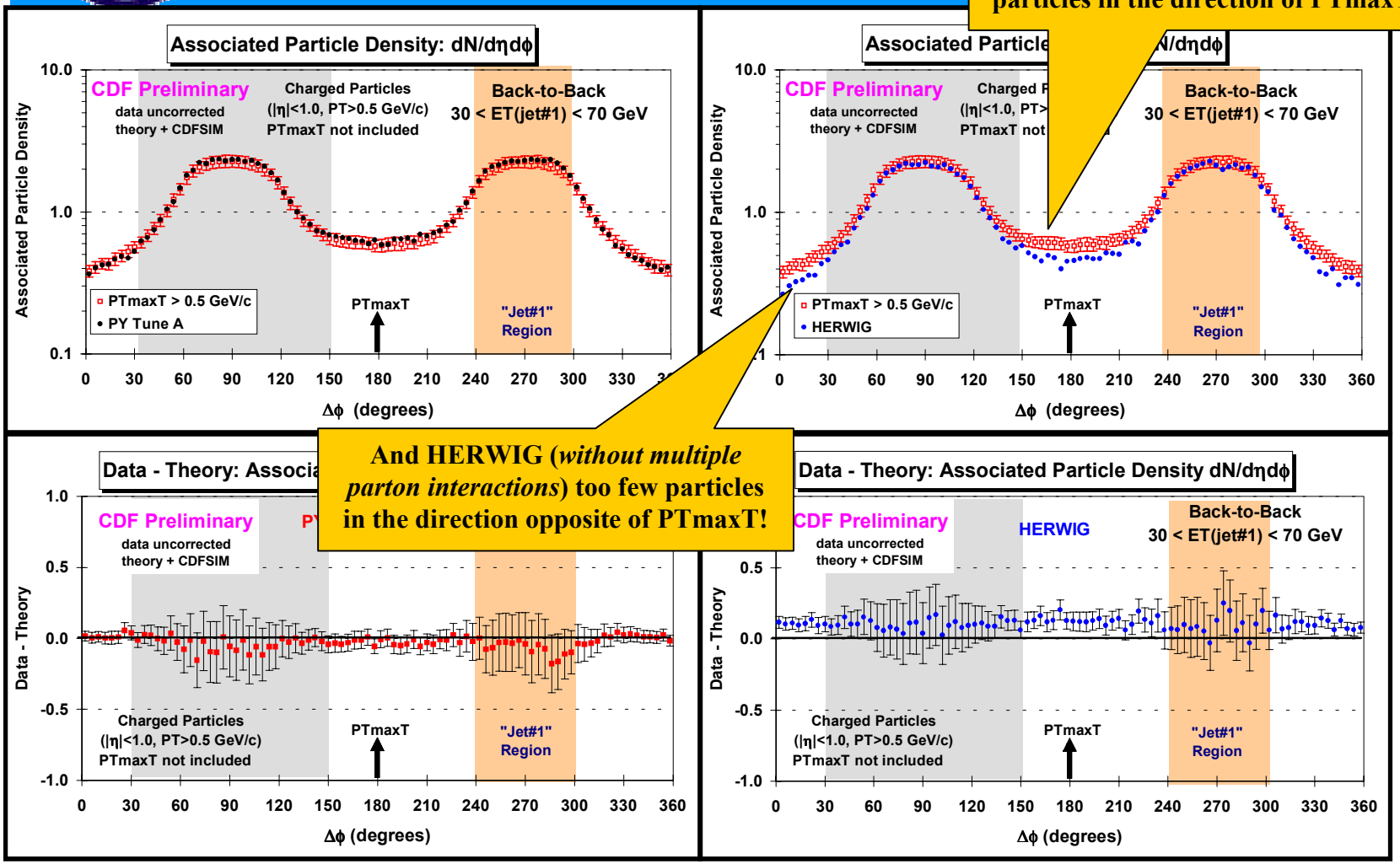
"Associated" Charge Density
PYTHIA Tune A vs HE

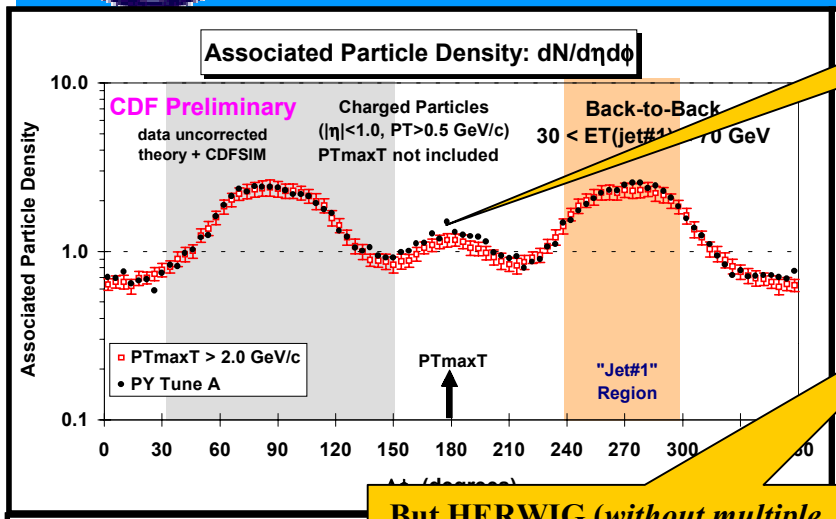


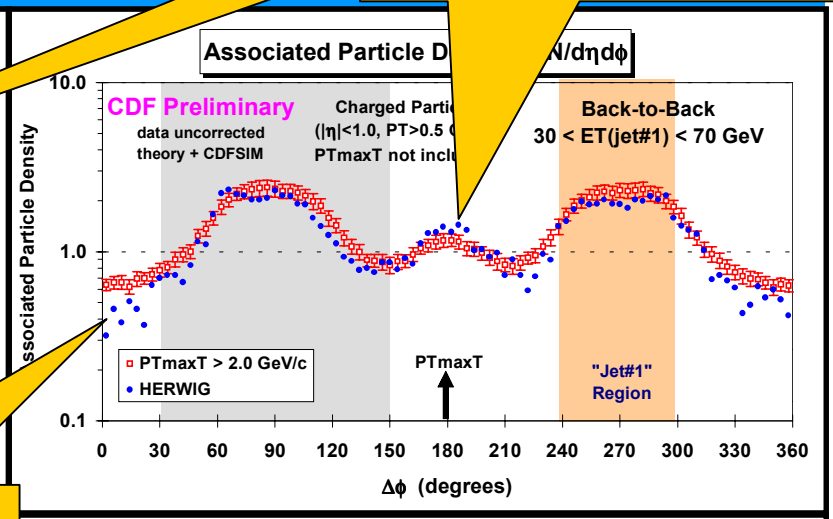
HERWIG (*without multiple parton interactions*) too few "associated" particles in the direction of PTmaxT!

And HERWIG (*without multiple parton interactions*) too few particles in the direction opposite of PTmaxT!

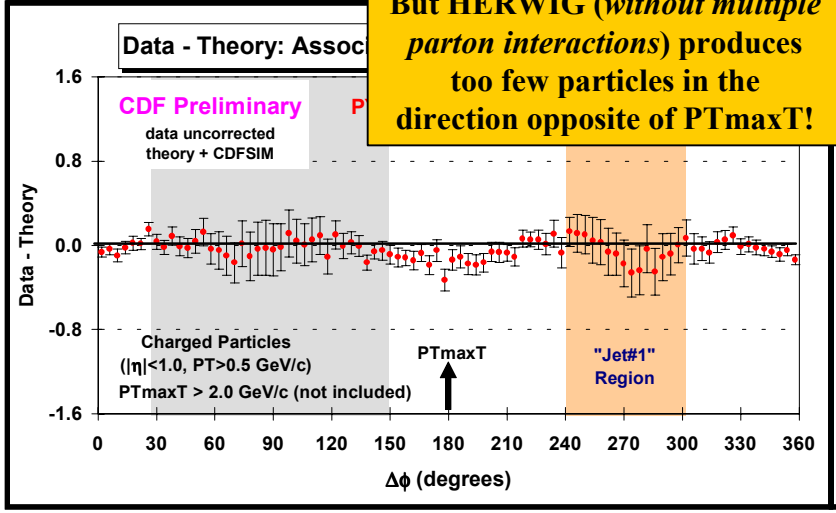
"Associated" Charge De
PYTHIA Tune A vs HE

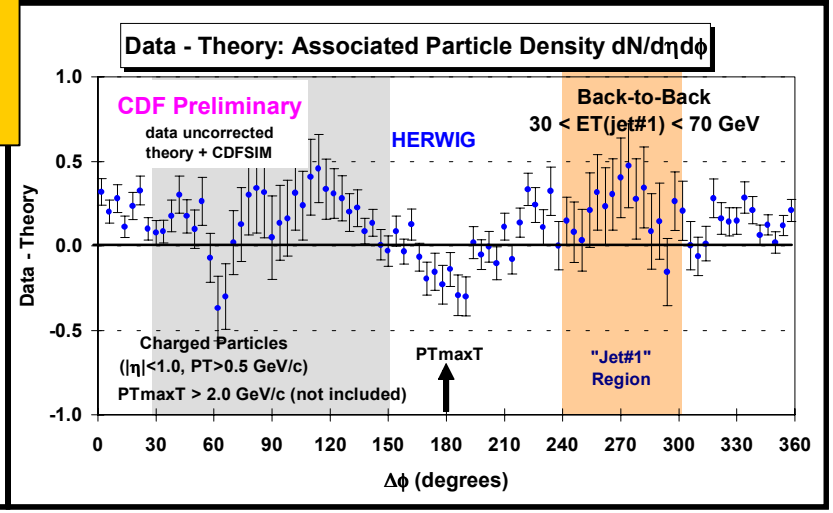
For PTmaxT > 2.0 GeV both PYTHIA and HERWIG produce slightly too many "associated" particles in the direction of PTmaxT!





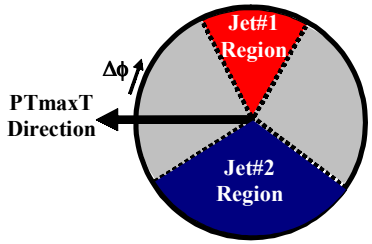
But HERWIG (*without multiple parton interactions*) produces too few particles in the direction opposite of PTmaxT!

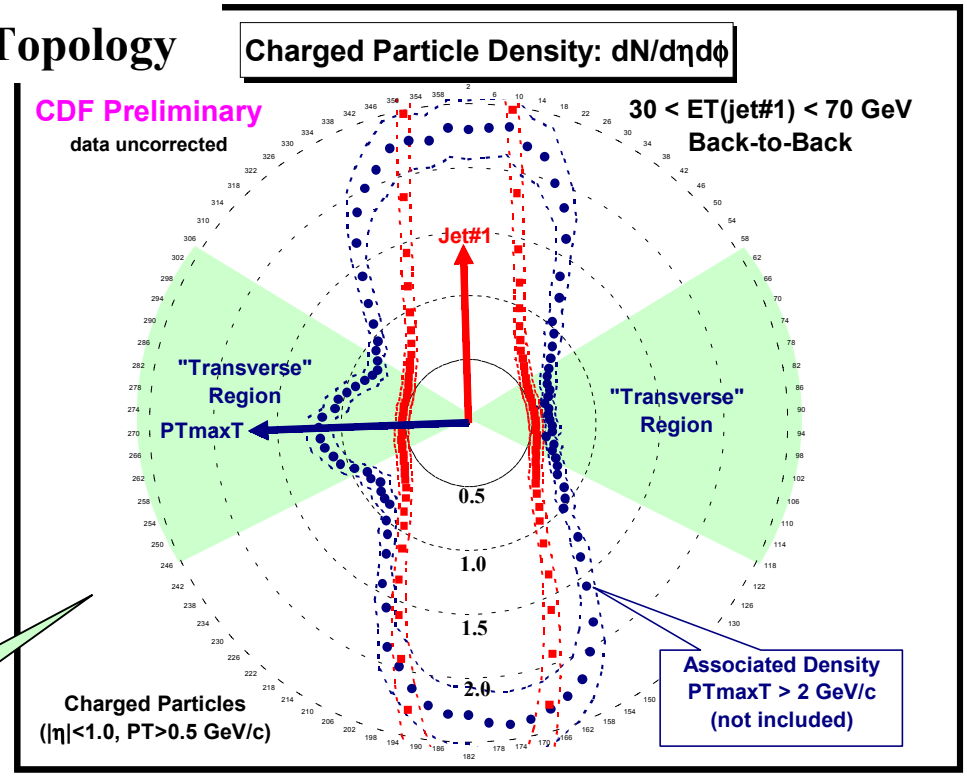




Jet Topologies

QCD Four Jet Topology

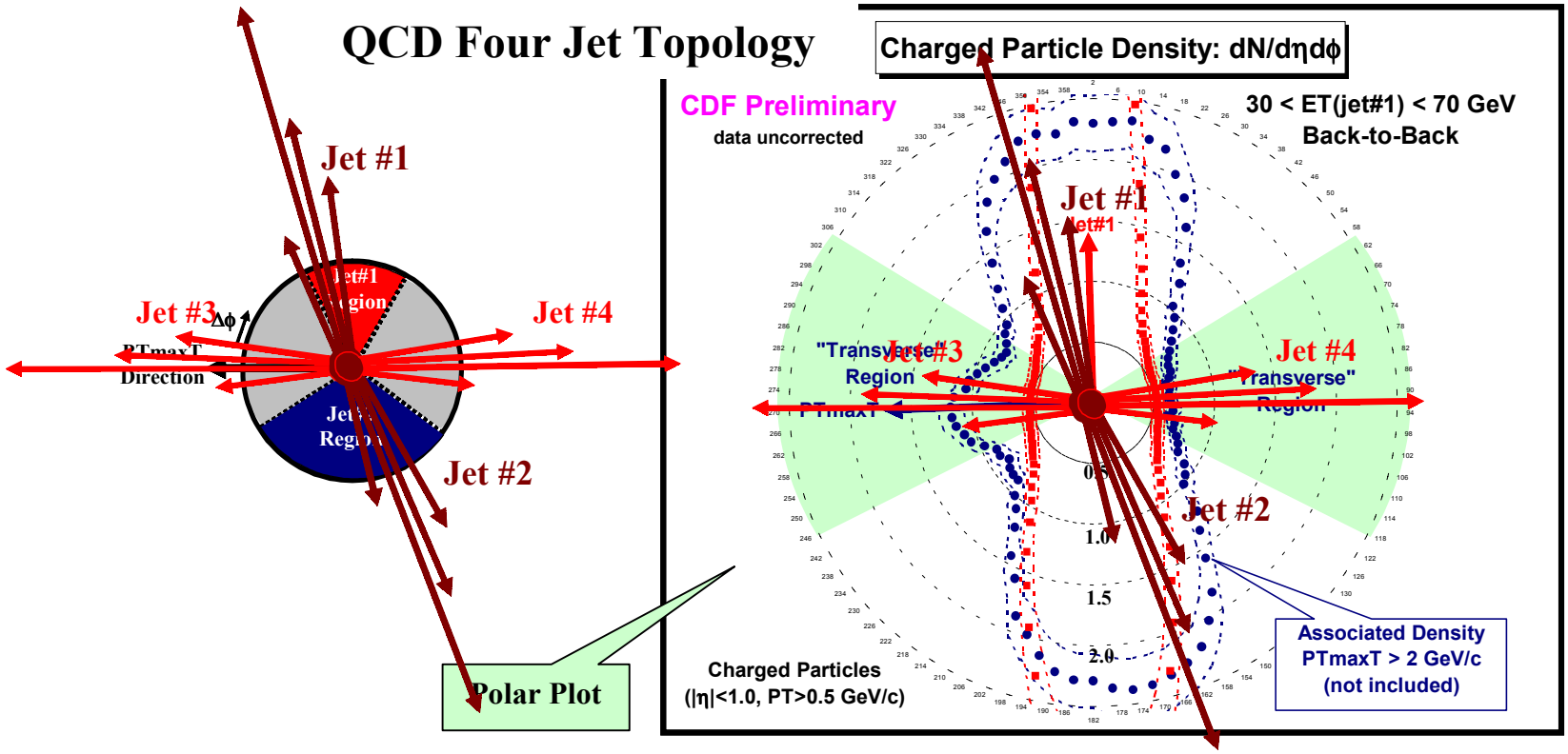




Polar Plot

- **Shows the Δφ 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 $30 < E_T(\text{jet\#1}) < 70$ GeV.**

Jet Topologies



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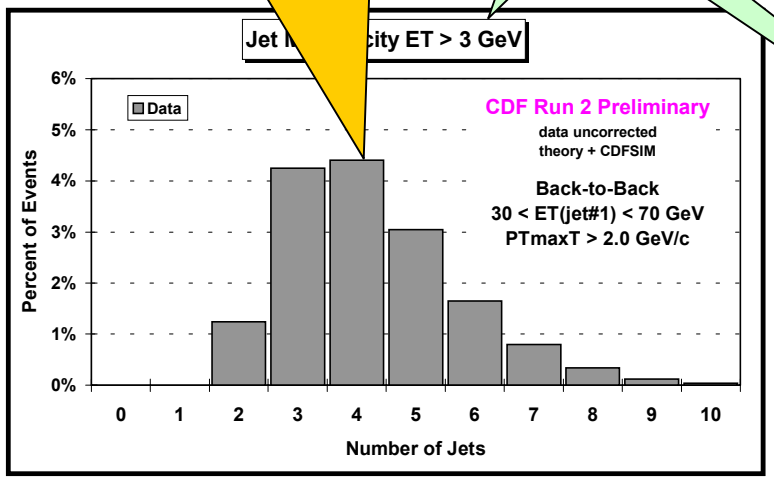
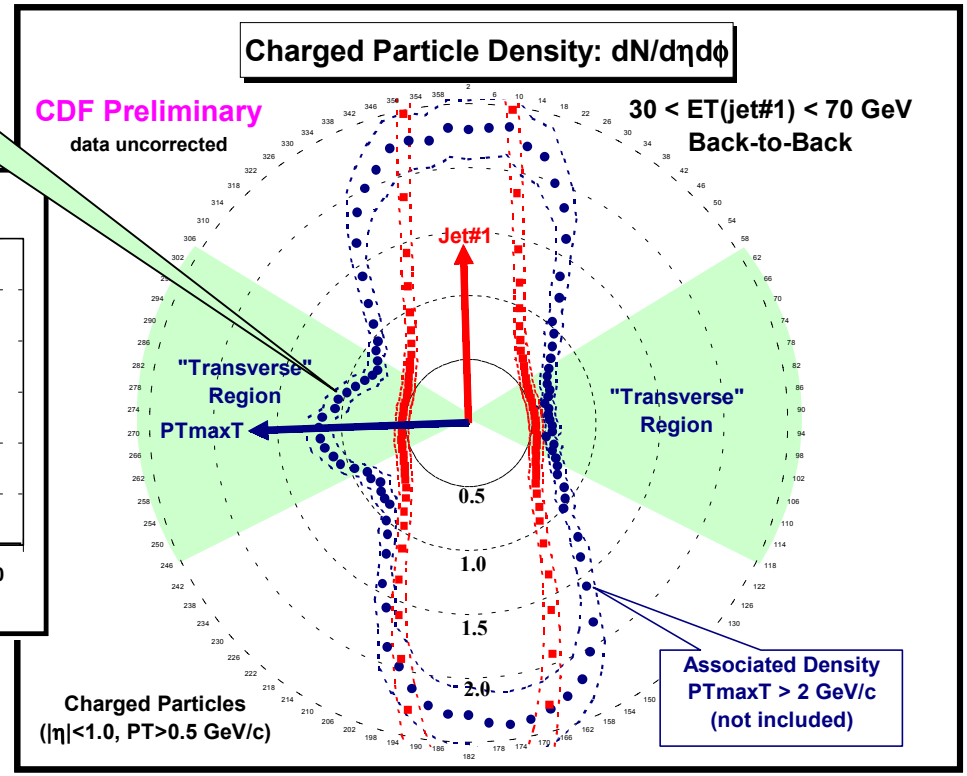
Jet Topologies

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

Same events!

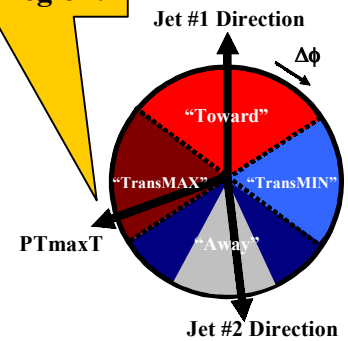


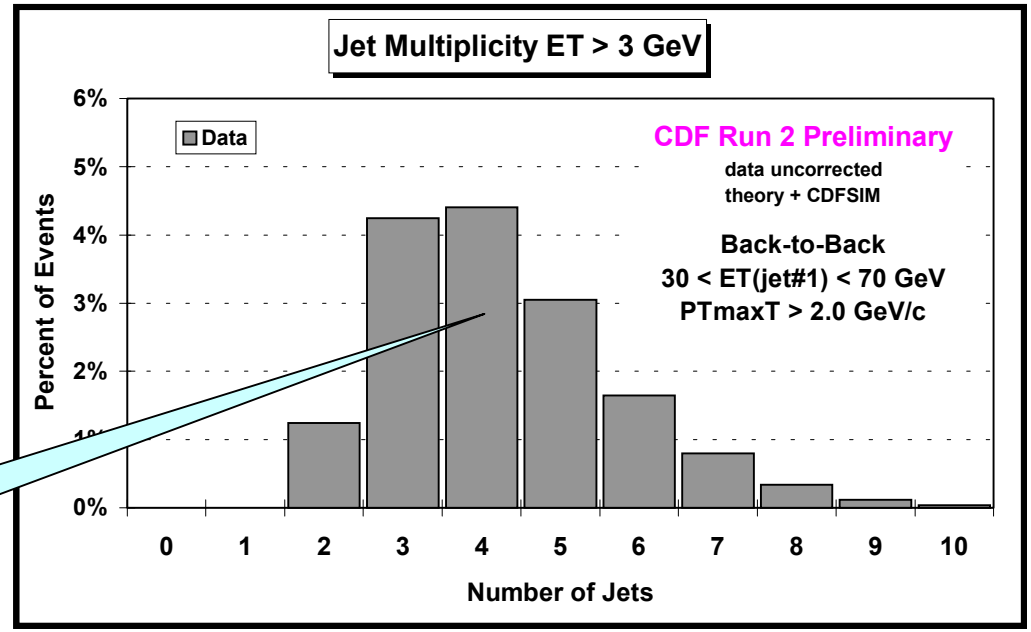


➡ **Shows the data on the number of jets (JetClu, R = 0.7, $|\eta| < 2$, E_T(jet) > 3 GeV) for "back-to-back" events with 30 < E_T(jet#1) < 70 GeV and PTmaxT > 2.0 GeV/c.**

Jet Multiplicity

Max p_T in the "transverse" region!





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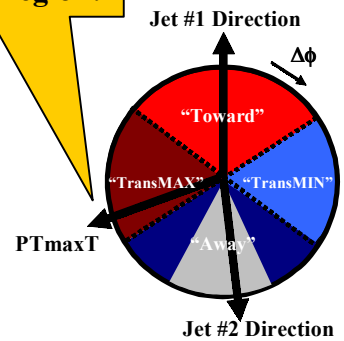

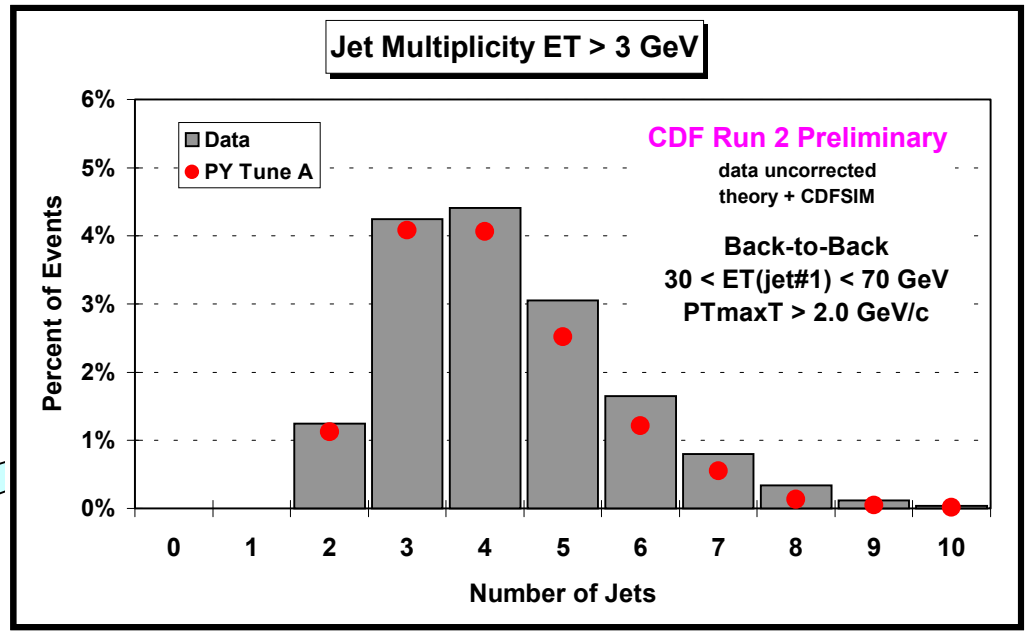

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Jet Multiplicity

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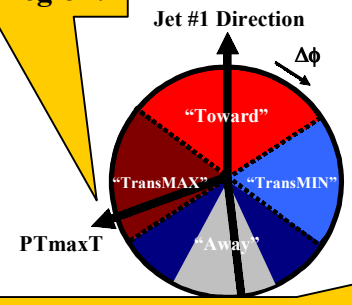
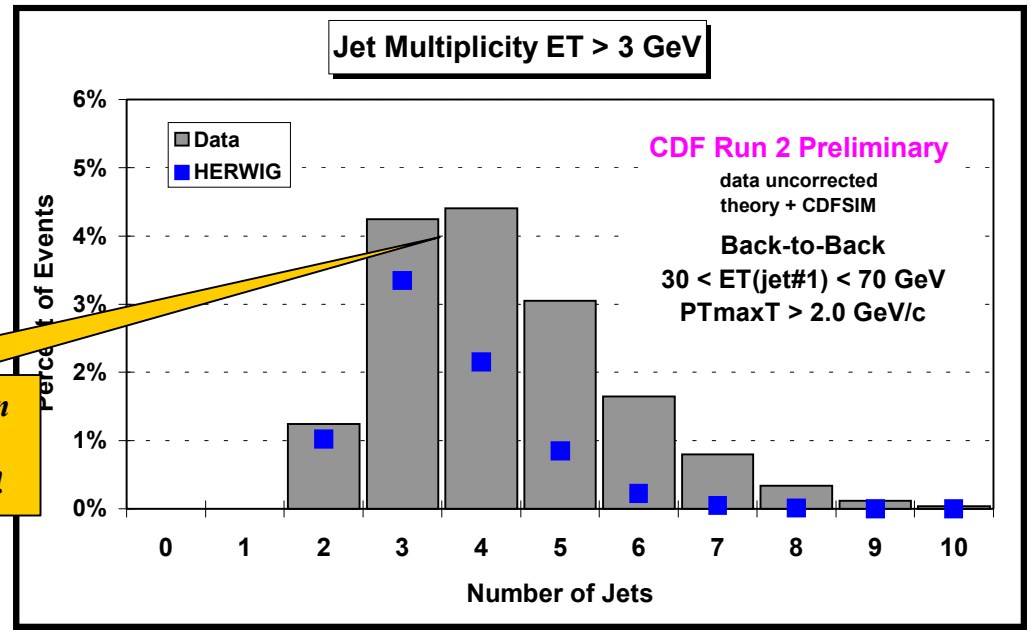


HERWIG (*without multiple parton interactions*) does not have equal amounts of 3 and 4 jet topologies!

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



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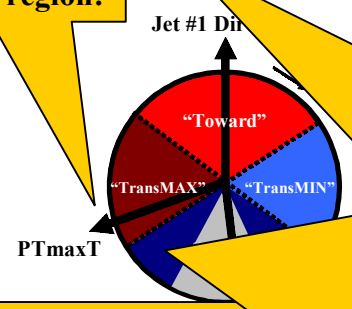
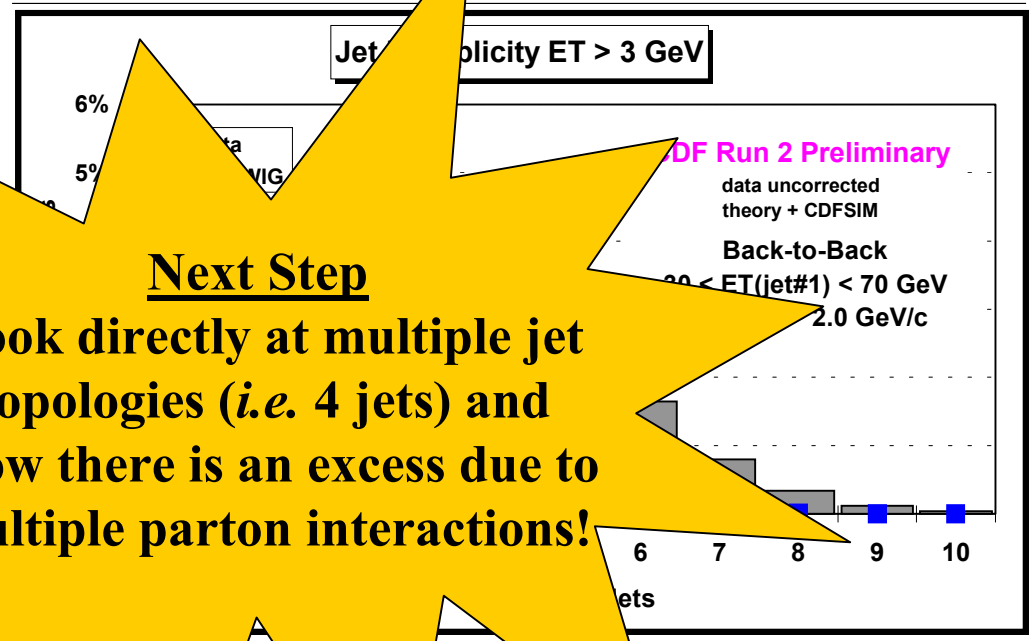
Jet Multiplicity

Max p_T in the "transverse" region!





HERWIG (*without* *interactions*) does not r amounts of 3 and 4 jet t

Data have about e of 3 and 4 jet topologies!

Next Step

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

- **Shows the data on the nu ber of JetC = 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.**