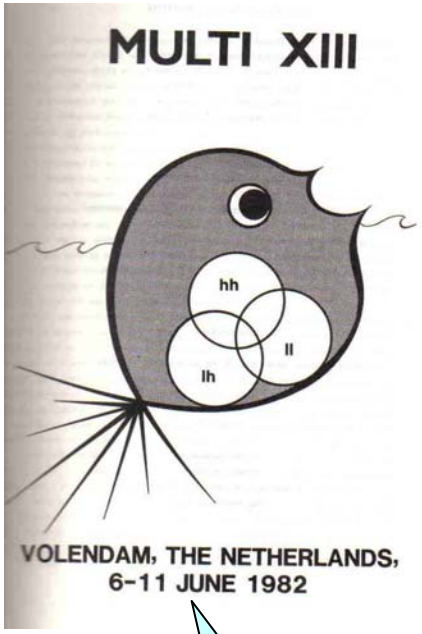
International Symposium on Multiparticle Dynamics

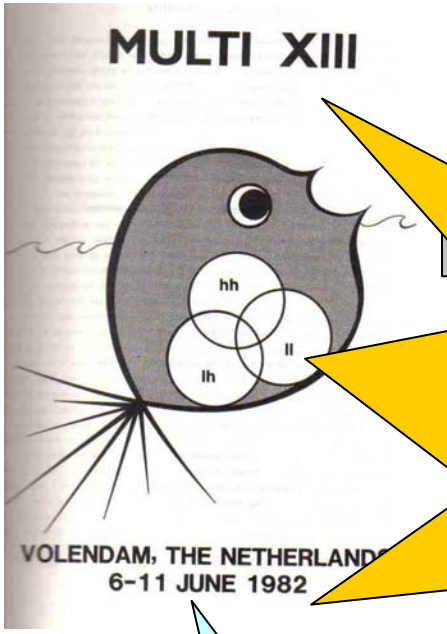


22 Years!

Rick Field (theorist?)
"Jet Formation in QCD"

Rick Field (experimenter?)
"Min Bias and the Underlying Events in Run 2 at CDF"

International Symposium on Multiparticle Dynamics



Many of you were at Volendam!

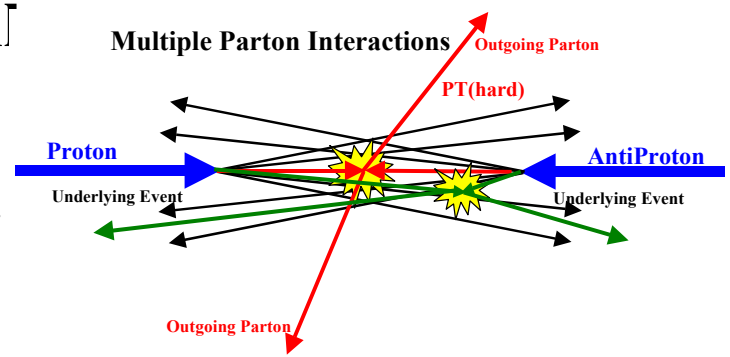
Rick Field (theorist?)
"Jet Formation in QCD"

Rick Field (experimenter?)
"Min Bias and the Underlying Events in Run 2 at CDF"

"Min-Bias" and the "Underlying Event" in Run 2 at CDF

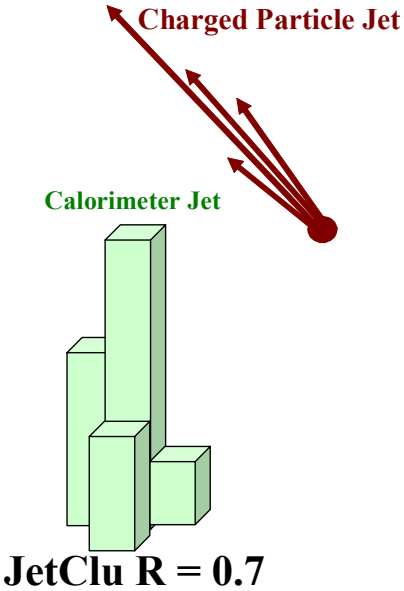
Outline of Tal

- Discuss briefly the components of the "underlying event" of a hard scattering as described by the QCD parton-shower Monte-Carlo Models.



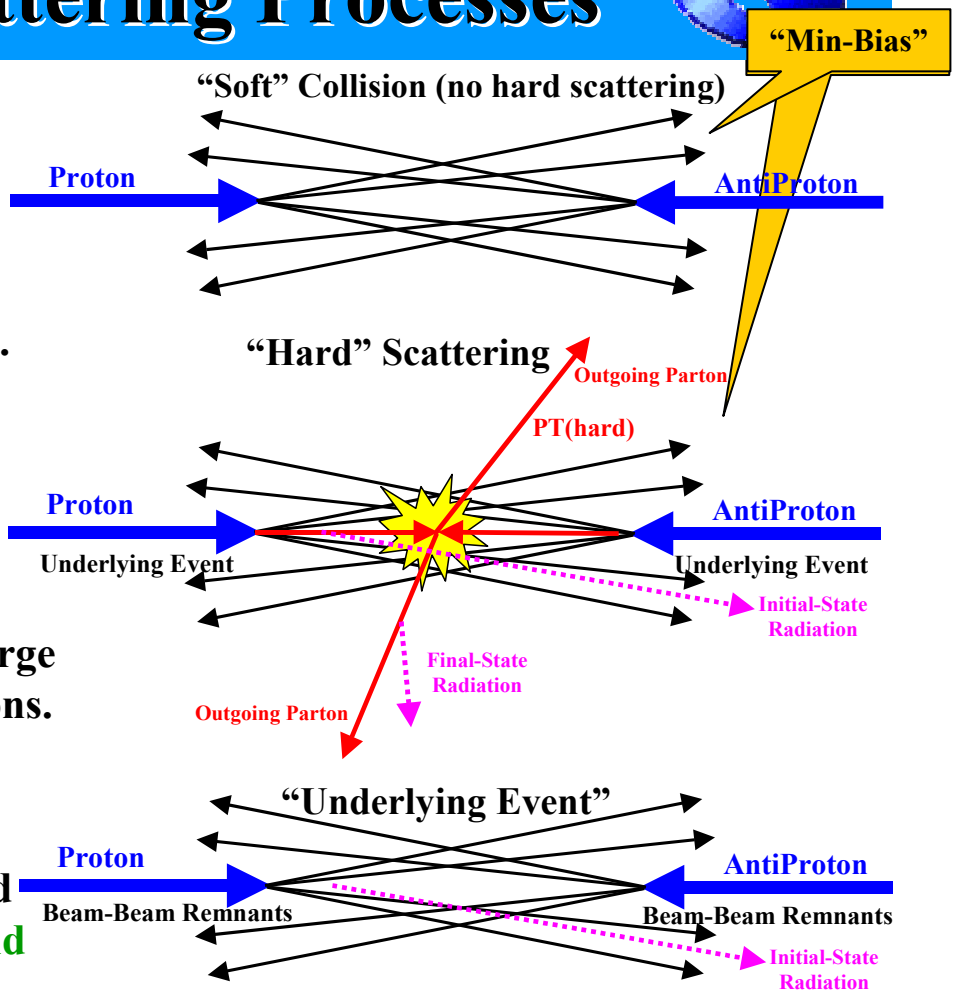
- Review the CDF Run 1 analysis which was used to tune the multiple parton interaction parameters in PYTHIA (*i.e.* Tune A and Tune B).

- Study the "underlying event" in CDF Run 2 as defined by the leading calorimeter jet and compare with PYTHIA Tune A (*with MPI*) and HERWIG (*without MPI*).



The "Underlying Event" in Hard Scattering Processes

- What happens when a high energy proton and an antiproton collide?
- Most of the time the proton and antiproton ooze through each other and fall apart (*i.e.* no hard scattering). The outgoing particles continue in roughly the same direction as initial proton and antiproton. A "Min-Bias" collision.
- Occasionally there will be a "hard" parton-parton collision resulting in large transverse momentum outgoing partons. Also a "Min-Bias" collision.
- The "underlying event" is everything except the two outgoing hard scattered "jets". It is an unavoidable background to many collider observables.



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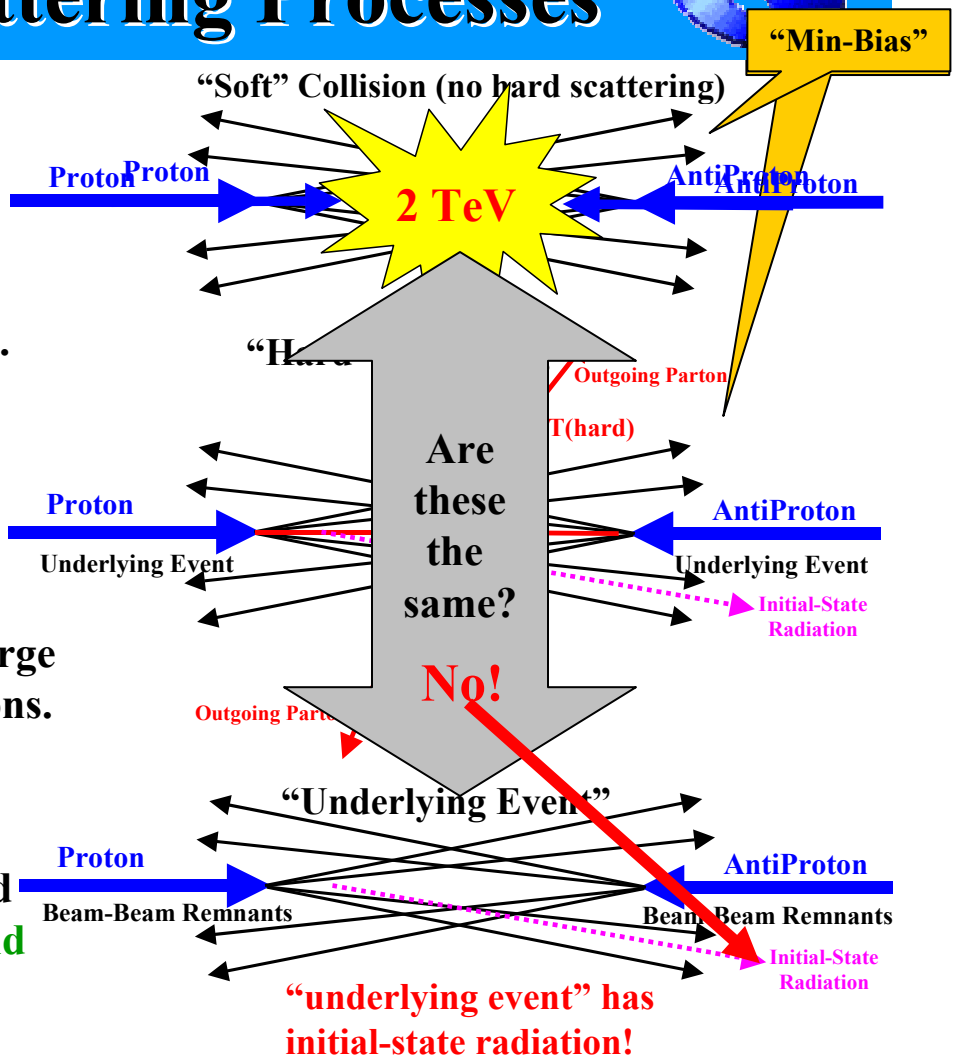
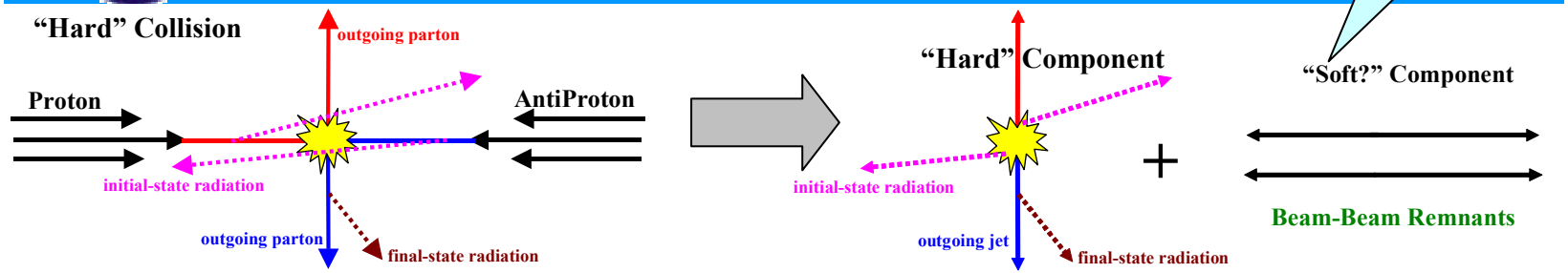
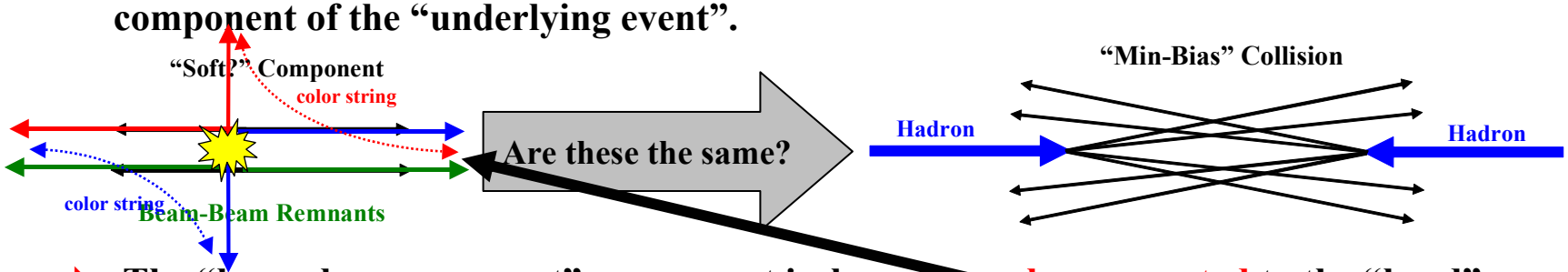


Beam-Beam Remnants

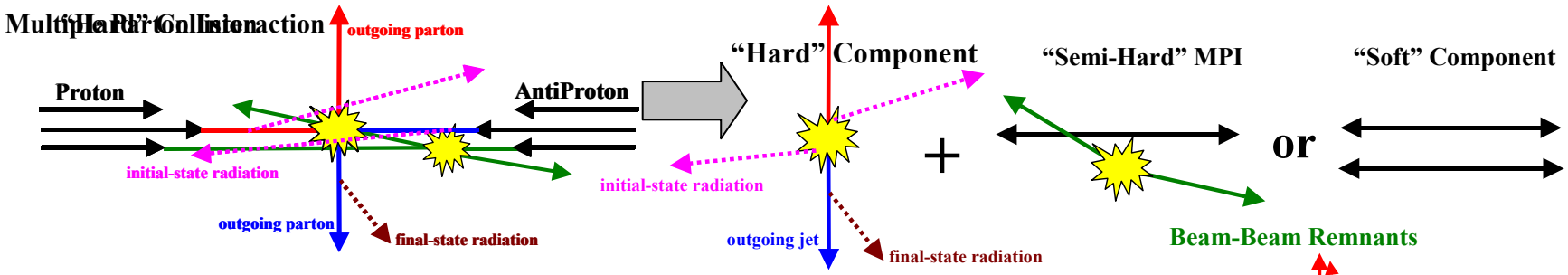


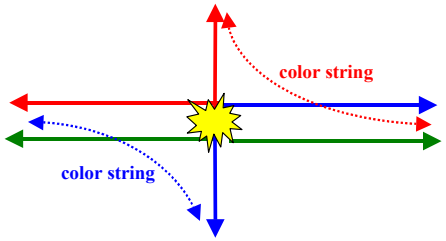
- The underlying event in a hard scattering process has a "hard" component (particles that arise from initial & final-state radiation and from the outgoing hard scattered partons) and a "soft?" component ("beam-beam remnants").
- Clearly? the "underlying event" in a hard scattering process should not look like a "Min-Bias" event because of the "hard" component (*i.e.* initial & final-state radiation).
- However, perhaps "Min-Bias" collisions are a good model for the "beam-beam remnant" component of the "underlying event".



- The "beam-beam remnant" component is, however, color connected to the "hard" component so this comparison is (at best) an approximation.

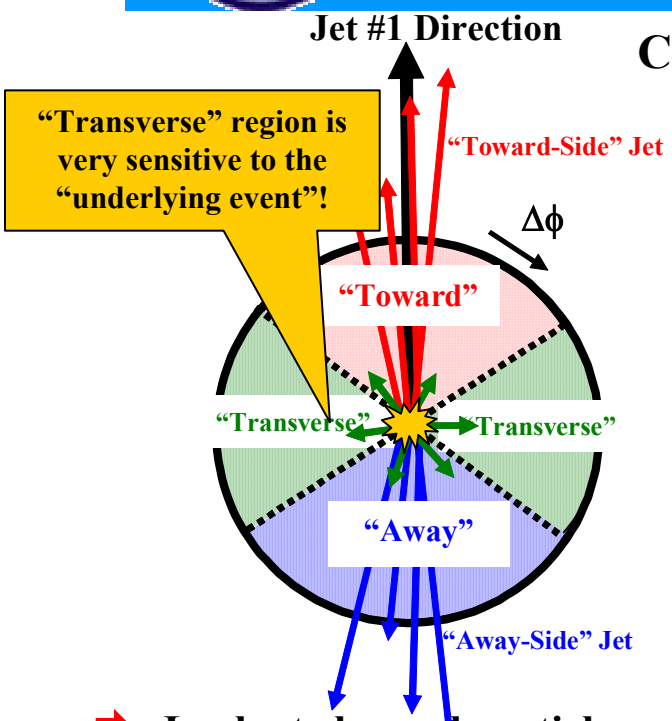
MPI: Multiple Parton Interactions





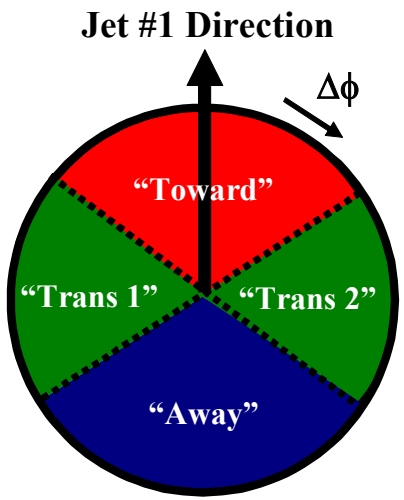
- PYTHIA models the "soft" component of the underlying event with color string fragmentation, but in addition includes a contribution arising from multiple parton interactions (MPI) in which one interaction is hard and the other is "semi-hard".
- The probability that a hard scattering events also contains a semi-hard multiple parton interaction can be varied but adjusting the cut-off for the MPI.
- One can also adjust whether the probability of a MPI depends on the P_T of the hard scattering, P_T(hard) (constant cross section or varying with impact parameter).
- One can adjust the color connections and flavor of the MPI (singlet or nearest neighbor, q-qbar or glue-glue).
- Also, one can adjust how the probability of a MPI depends on P_T(hard) (single or double Gaussian matter distribution).

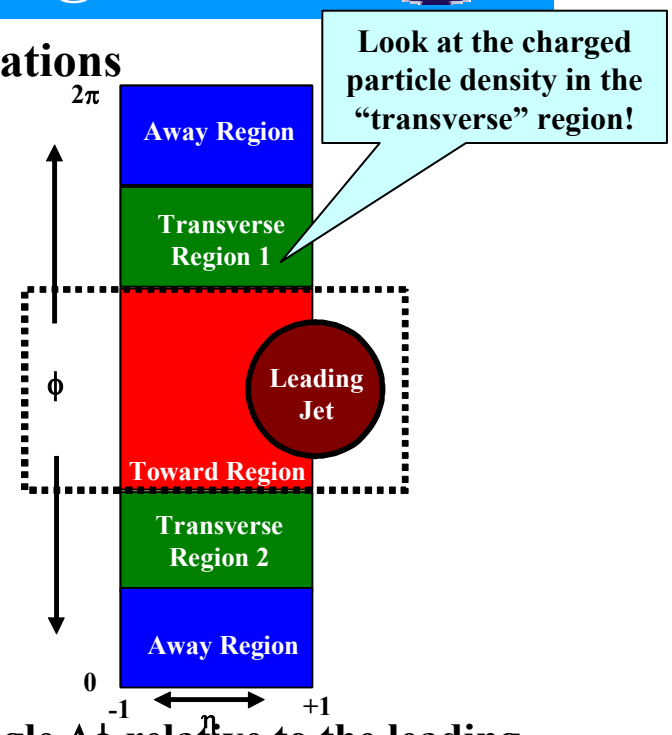
The "Transverse" Regions
as defined by the Leading Jet



Charged Particle Δϕ Correlations

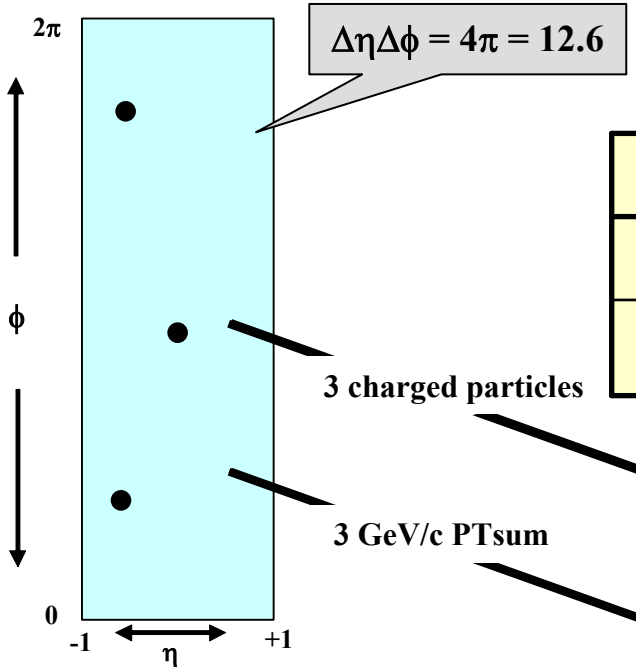
$p_T > 0.5$ GeV/c $|\eta| < 1$





- Look at charged particle correlations in the azimuthal angle Δϕ relative to the leading calorimeter jet (JetClu R = 0.7, $|\eta| < 2$).
- Define $|\Delta\phi| < 60^o$ as "Toward", $60^o < -\Delta\phi < 120^o$ and $60^o < \Delta\phi < 120^o$ as "Transverse 1" and "Transverse 2", and $|\Delta\phi| > 120^o$ as "Away". Each of the two "transverse" regions have area $\Delta\eta\Delta\phi = 2x60^o = 4\pi/6$. The overall "transverse" region is the sum of the two transverse regions ($\Delta\eta\Delta\phi = 2x120^o = 4\pi/3$).

Particle Densities



Charged Particles
$p_T > 0.5$ GeV/c $|\eta| < 1$

CDF Run 2 "Min-Bias"

	CDF Run 2 "Min-Bias" Observable	Average	Average Density per unit η-φ
Nchg	Number of Charged Particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$)	3.17 +/- 0.31	0.252 +/- 0.025
PTsum (GeV/c)	Scalar p_T sum of Charged Particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$)	2.97 +/- 0.23	0.236 +/- 0.018

Divide by 4π

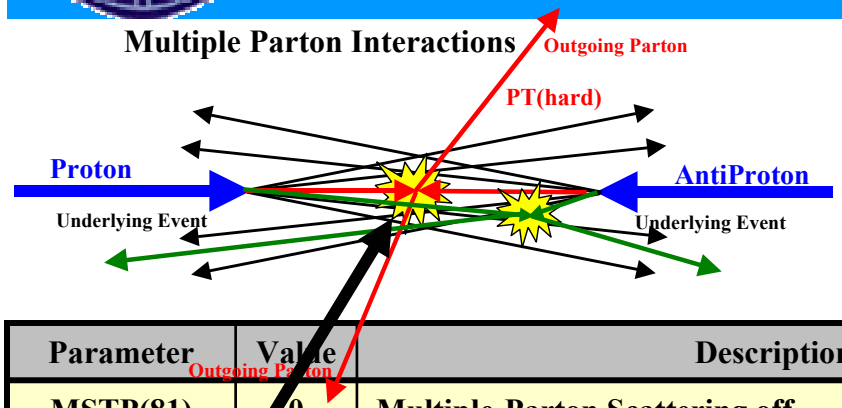
$dN_{chg}/d\eta d\phi = 3/4\pi = 0.24$

$dPT_{sum}/d\eta d\phi = 3/4\pi$ GeV/c = 0.24 GeV/c

- **Study the charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) and form the charged particle density, $dN_{chg}/d\eta d\phi$, and the charged scalar p_T sum density, $dPT_{sum}/d\eta d\phi$.**

PYTHIA: Multiple Parton Interaction Parameters

Multiple Parton Interactions



Pythia uses multiple parton interactions to enhance the underlying event.

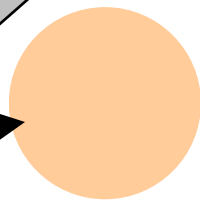
and now HERWIG!

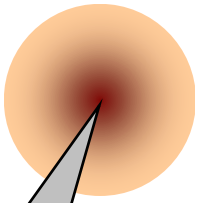
Jimmy: MPI
J. M. Butterworth
J. R. Forshaw
M. H. Seymour

Parameter	Value	Description
MSTP(81)	0	Multiple-Parton Scattering off
	1	Multiple-Parton Scattering on
MSTP(82)	1	Multiple interactions assuming the same probability, with an abrupt cut-off $P_T$min=PARP(81)
	3	Multiple interactions assuming a varying impact parameter and a hadronic matter overlap consistent with a single Gaussian matter distribution, with a smooth turn-off P_{T0}=PARP(82)
	4	Multiple interactions assuming a varying impact parameter and a hadronic matter overlap consistent with a double Gaussian matter distribution (governed by PARP(83) and PARP(84)), with a smooth turn-off P_{T0}=PARP(82)

Same parameter that cuts-off the hard 2-to-2 parton cross sections!

Multiple parton interaction more likely in a hard (central) collision!



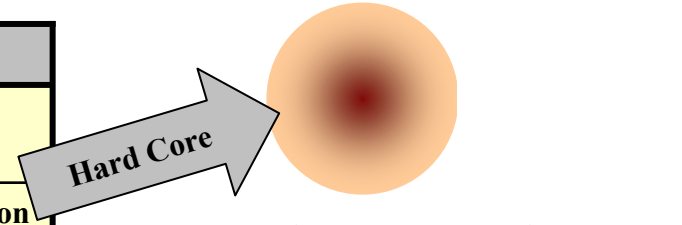


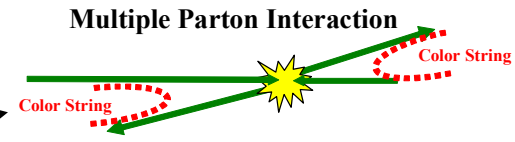
Hard Core

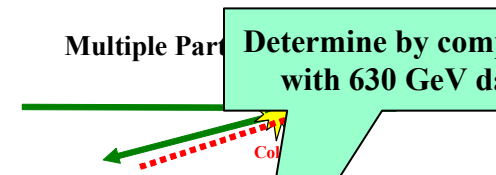
Tuning PYTHIA:
Multiple Parton Interaction Parameters

Parameter	Default	Description
PARP(83)	0.5	Double-Gaussian: Fraction of total hadronic matter within PARP(84)
PARP(84)	0.2	Double-Gaussian: Fraction of the overall hadron radius containing the fraction PARP(83) of the total hadronic matter.
PARP(85)	0.33	Probability that the MPI produces two gluons with color connections to the "nearest neighbors.
PARP(86)	0.66	Probability that the MPI produces two gluons either as described by PARP(85) or as a closed g fraction consists of
PARP(89)	1 TeV	D mes the reference energy E_0.
PARP(90)	0.16	Determines the energy dependence of the cut-off P_{T0} as follows $P_{T0}(E_{cm}) = P_{T0}(E_{cm}/E_0)^{\varepsilon}$ with ε = PARP(90)
PARP(67)	1.0	A scale factor that determines the maximum parton virtuality for space-like showers. The larger the value of PARP(67) the more initial-state radiation.

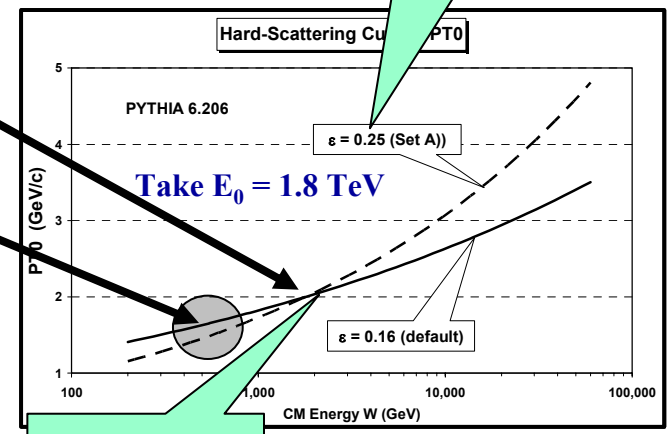
Affects the amount of initial-state radiation!







Determine by comparing with 630 GeV data!



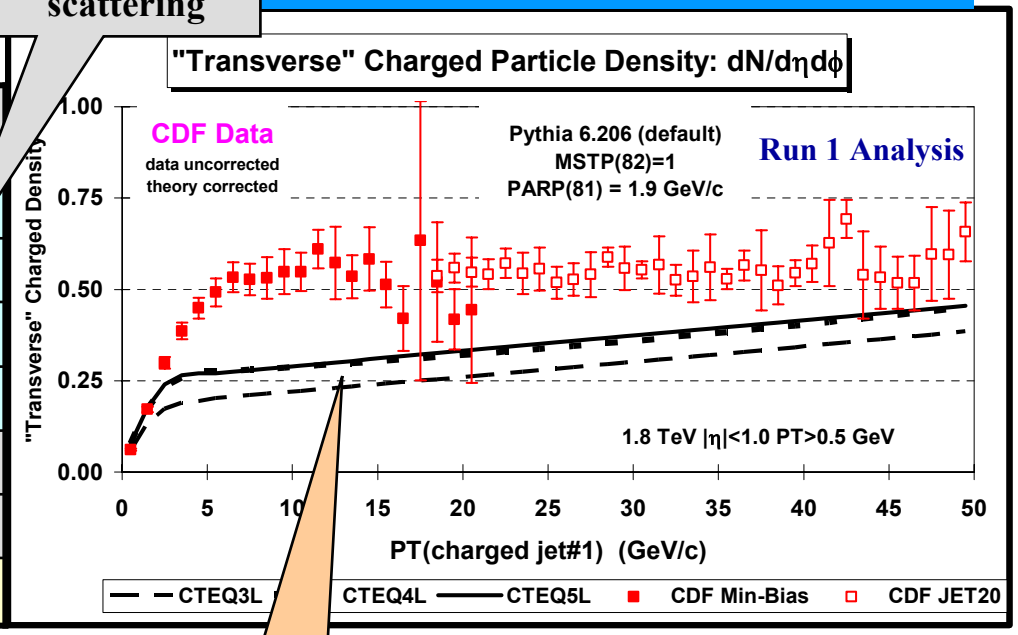
Reference point at 1.8 TeV

PYTHIA 6.206 Defaults

MPI constant probability scattering

PYTHIA default parameters

Parameter	6.115	6.125	6.158	6.206
MSTP(81)	1	1	1	1
MSTP(82)	1	1	1	1
PARP(81)	1.4	1.9	1.9	1.9
PARP(82)	1.55	2.1	2.1	1.9
PARP(89)		1,000	1,000	1,000
PARP(90)		0.16	0.16	0.16
PARP(67)	4.0	4.0	1.0	1.0



➡ Plot shows the "Transverse" charged particle density versus P_T(chgjet#1) compared to the QCD hard scattering predictions of PYTHIA 6.206 (P_T(hard) > 0) using the default parameters for multiple parton interactions and CTEQ3L, CTEQ4L, and CTEQ5L.

Note Change
PARP(67) = 4.0 (< 6.138)
PARP(67) = 1.0 (> 6.138)

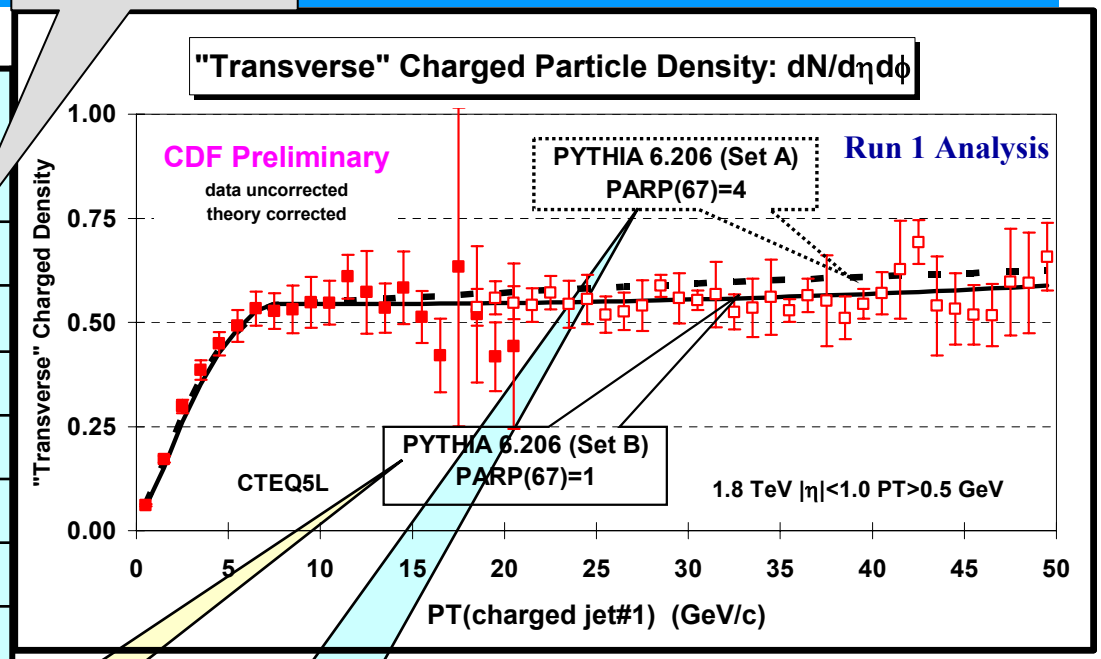
Default parameters give very poor description of the "underlying event"!

Tuned PYTHIA 6.206

PYTHIA 6.206 CTEQ5L

Parameter	Tune B	Tune A
MSTP(81)	1	1
MSTP(82)	4	4
PARP(82)	1.9 GeV	2.0 GeV
PARP(83)	0.5	0.5
PARP(84)	0.4	0.4
PARP(85)	1.0	0.9
PARP(86)	1.0	0.95
PARP(89)	1.8 TeV	1.8 TeV
PARP(90)	0.25	0.25
PARP(67)	1.0	4.0

Double Gaussian

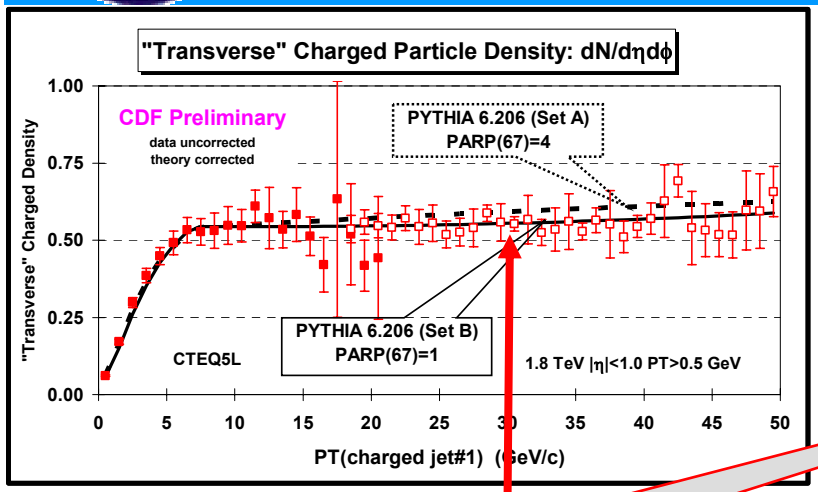


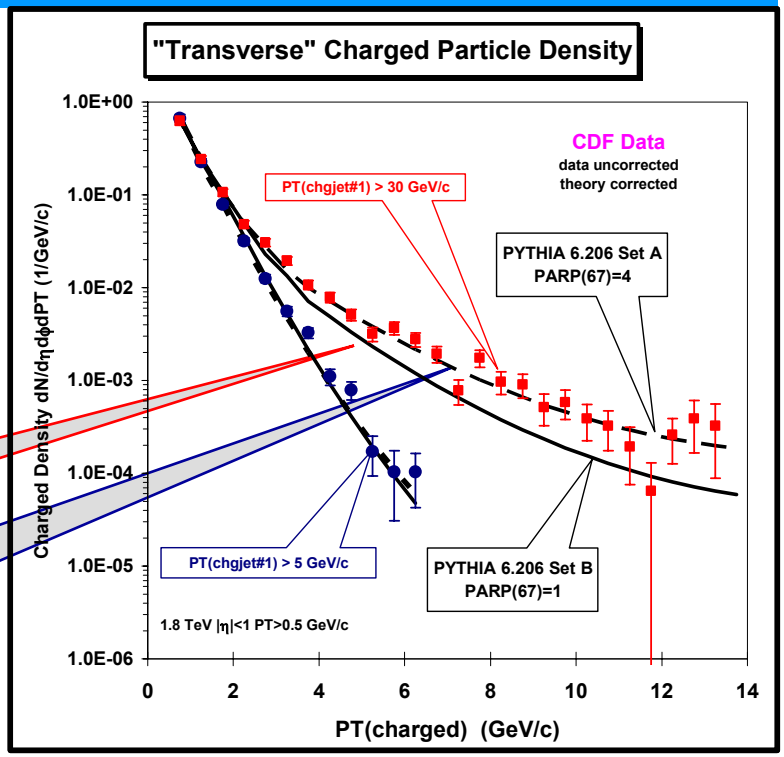
Plot shows the "Transverse" charged particle density versus P_T(chgjet#1) compared to the QCD hard scattering predictions of two tuned versions of PYTHIA 6.206 (CTEQ5L, Set B (PARP(67)=1) and Set A (PARP(67)=4)).

New PYTHIA default
(less initial-state radiation)

Old PYTHIA default
(more initial-state radiation)

Tuned PYTHIA 6.206 "Transverse" P_T Distribution



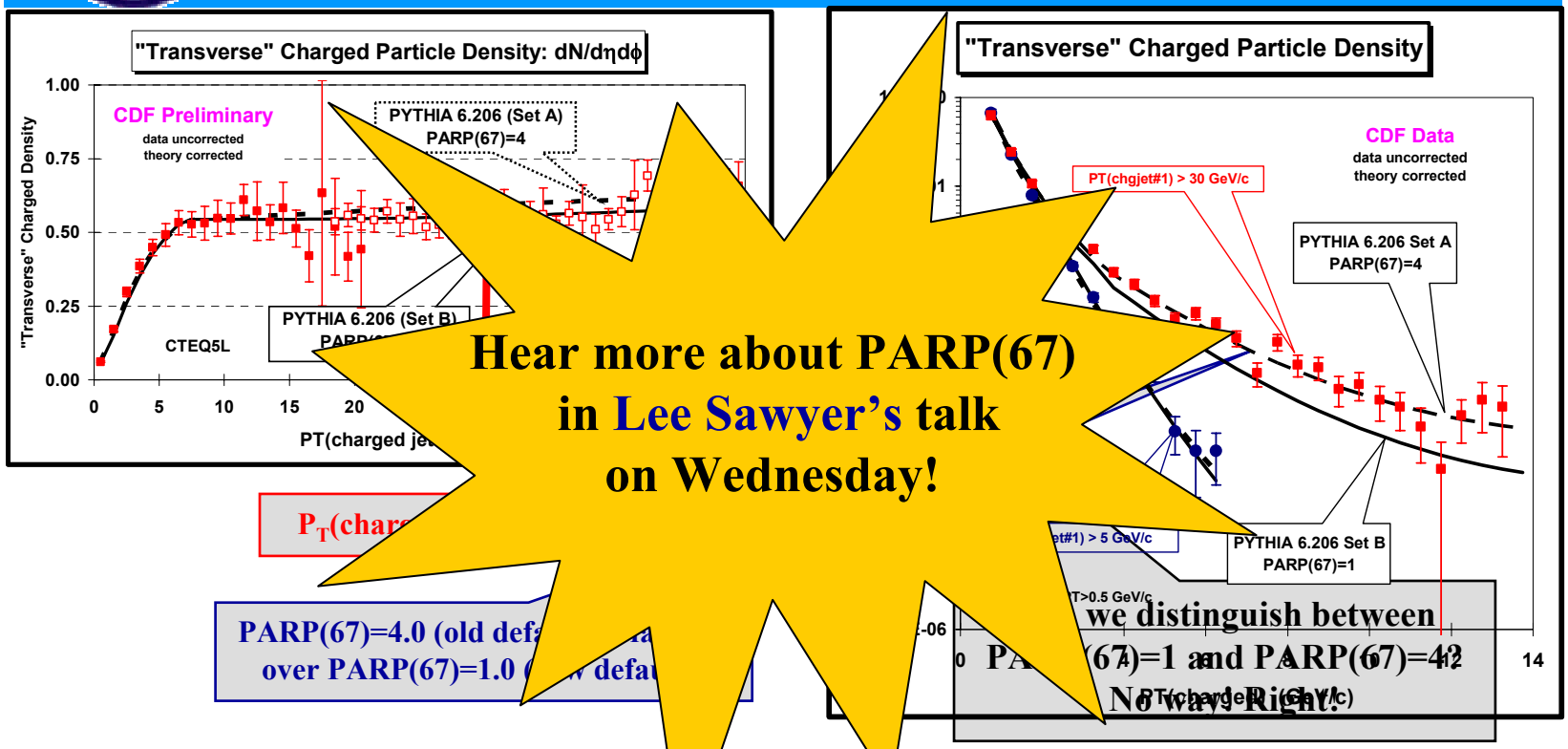


P_T(charged jet#1) > 30 GeV/c

PARP(67)=4.0 (old default) is favored over PARP(67)=1.0 (new default)!

- **Compares the average "transverse" charge particle density ($|\eta|<1$, $P_T>0.5$ GeV) versus P_T(charged jet#1) and the P_T distribution of the "transverse" density, $dN_{chg}/d\eta d\phi dP_T$ with the QCD Monte-Carlo predictions of two tuned versions of PYTHIA 6.206 (P_T(hard) > 0, CTEQ5L, Set B (PARP(67)=1) and Set A (PARP(67)=4)).**

Tuned PYTHIA 6.206 "Transverse" P_T Distribution

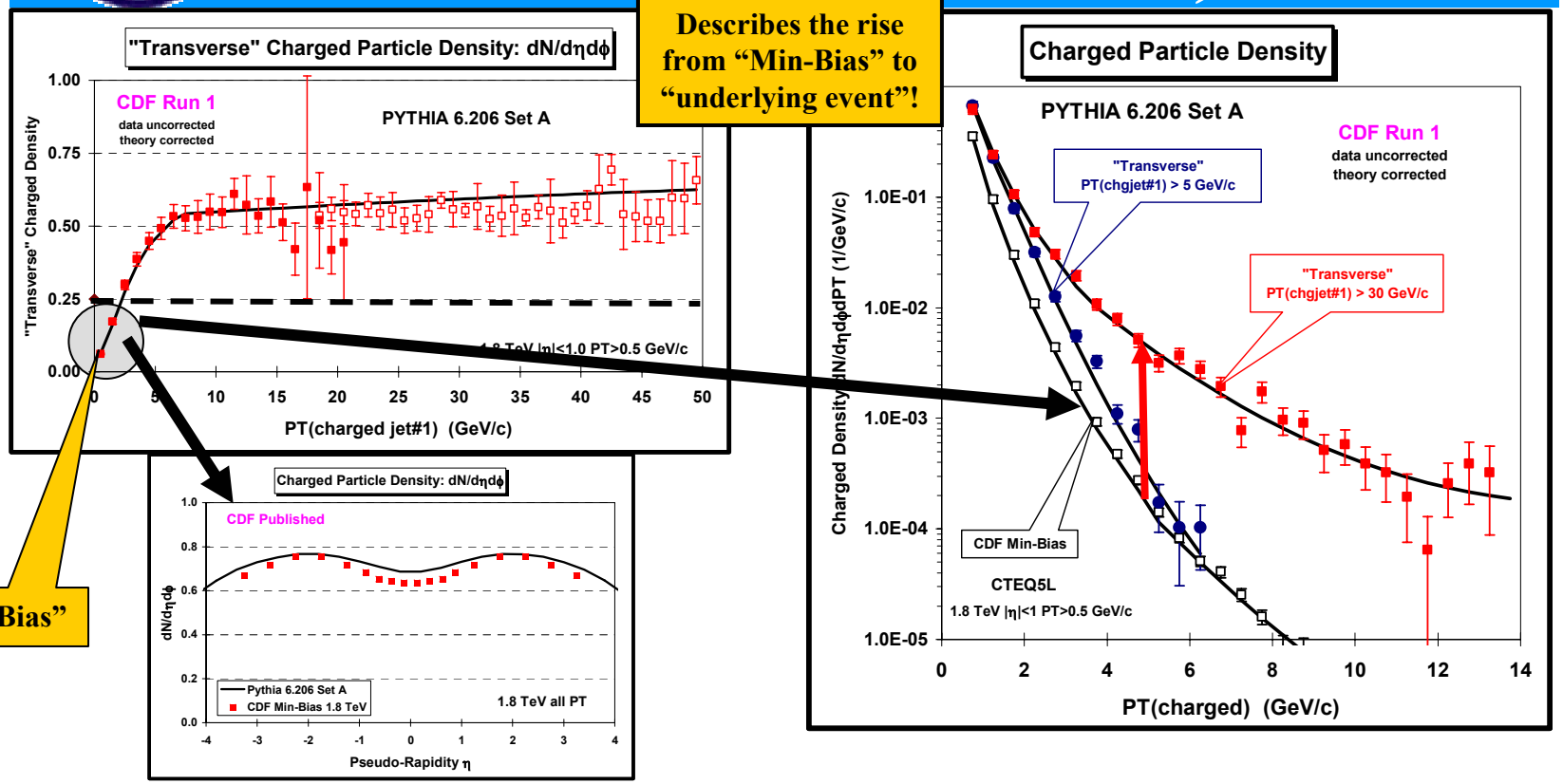


Hear more about PARP(67) in Lee Sawyer's talk on Wednesday!

we distinguish between PARP(67)=1 and PARP(67)=4? No way! Right!

- **Compares the average "transverse" charge particle density ($|\eta|<1$, $P_T>0.5$ GeV) versus P_T(charged jet#1) and the P_T distribution of the "transverse" density, $dN_{chg}/d\eta d\phi dP_T$ with the QCD Monte-Carlo predictions of two tuned versions of PYTHIA 6.206 (P_T(hard) > 0, CTEQ5L, Set B (PARP(67)=1) and Set A (PARP(67)=4)).**

PYTHIA 6.206
Tune A (CDF Default)

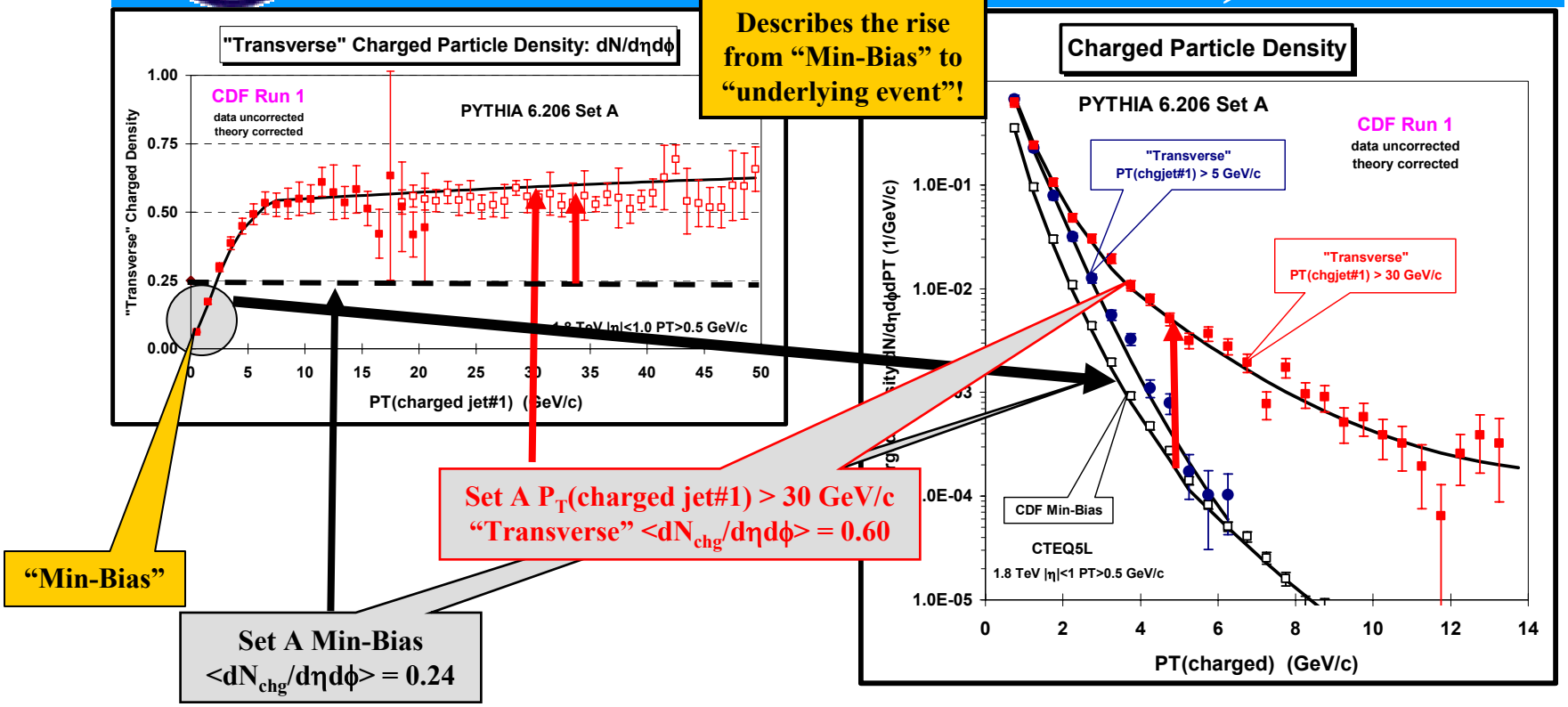


Describes the rise from "Min-Bias" to "underlying event"!

"Min-Bias"

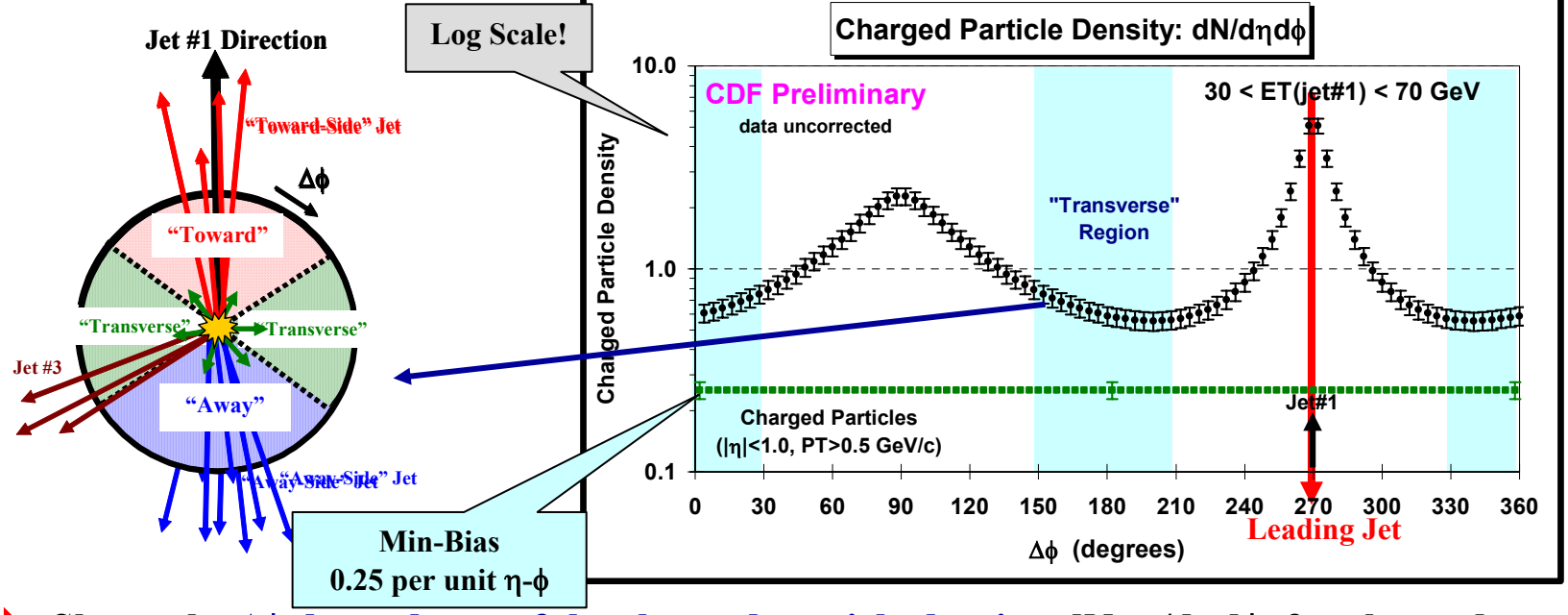
- **Compares the average "transverse" charge particle density ($|\eta|<1$, $P_T>0.5$ GeV) versus P_T(charged jet#1) and the P_T distribution of the "transverse" and "Min-Bias" densities with the QCD Monte-Carlo predictions of a tuned version of PYTHIA 6.206 (P_T(hard) > 0, CTEQ5L, Set A). Describes "Min-Bias" collisions! Describes the "underlying event"!**

PYTHIA 6.206
Tune A (CDF Default)



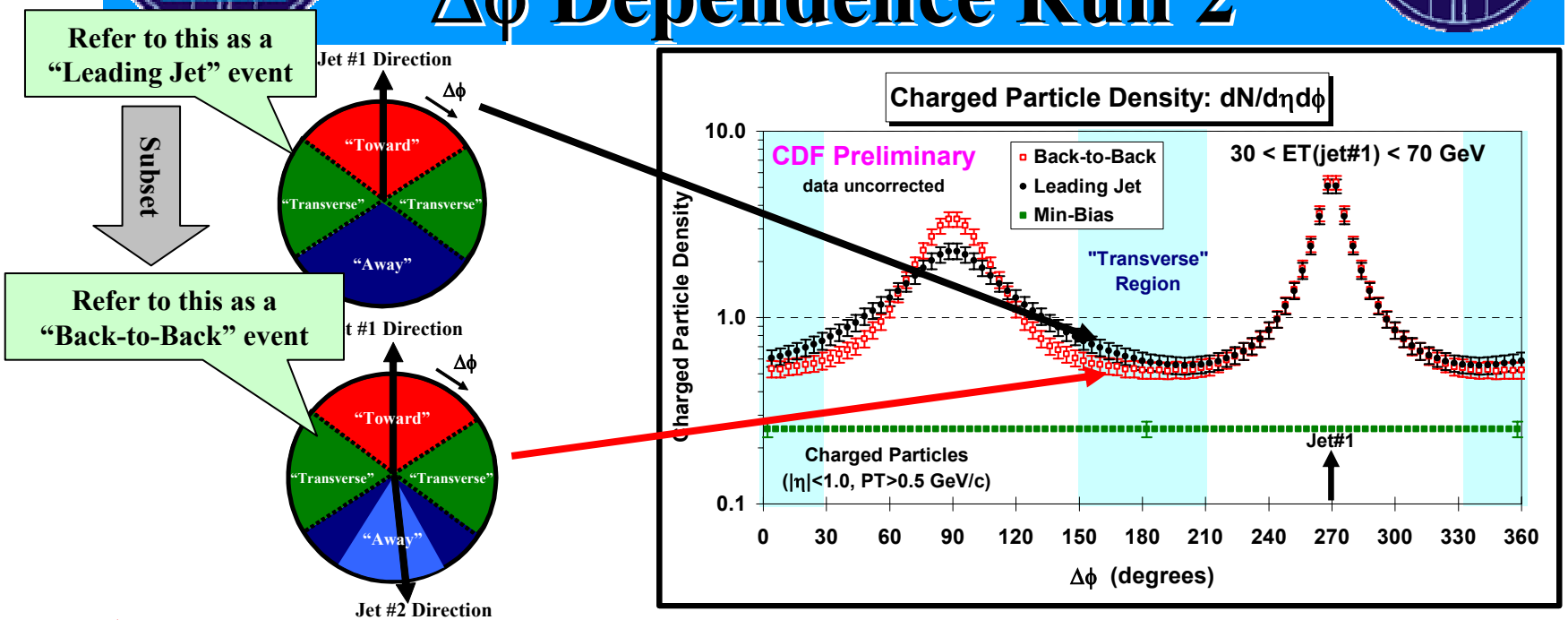
- **Compares the average "transverse" charge particle density ($|\eta|<1$, $P_T>0.5$ GeV) versus P_T(charged jet#1) and the P_T distribution of the "transverse" and "Min-Bias" densities with the QCD Monte-Carlo predictions of a tuned version of PYTHIA 6.206 (P_T(hard) > 0, CTEQ5L, Set A). Describes "Min-Bias" collisions! Describes the "underlying event"!**

Charged Particle Density
Δϕ Dependence Run 2



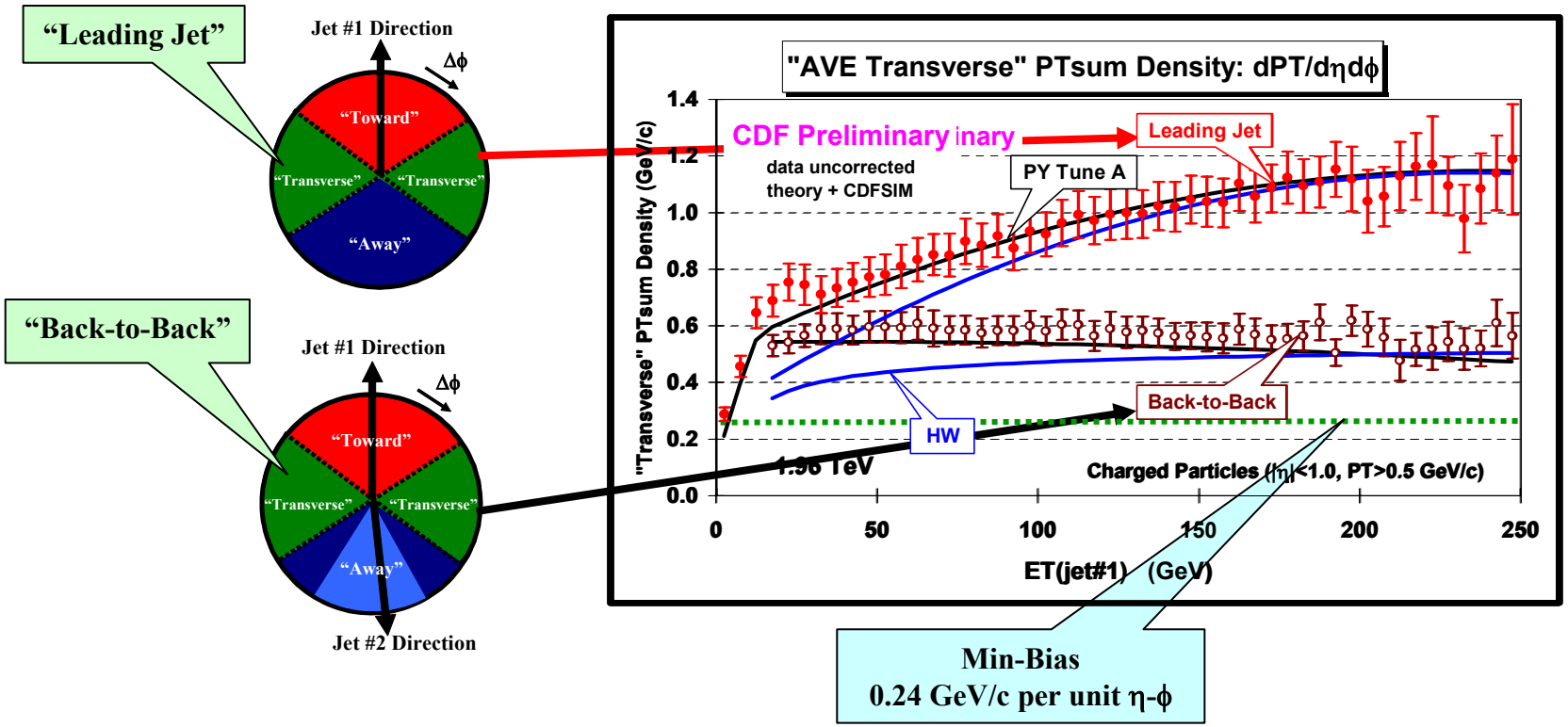
- Shows the Δϕ dependence of the charged particle density, $dN_{chg}/d\eta d\phi$, for charged particles in the range $p_T > 0.5$ GeV/c and $|\eta| < 1$ relative to jet#1 (rotated to 270°) for "leading jet" events $30 < E_T(\text{jet\#1}) < 70$ GeV.
- Also shows charged particle density, $dN_{chg}/d\eta d\phi$, for charged particles in the range $p_T > 0.5$ GeV/c and $|\eta| < 1$ for "min-bias" collisions.

Charged Particle Density $\Delta\phi$ Dependence Run 2



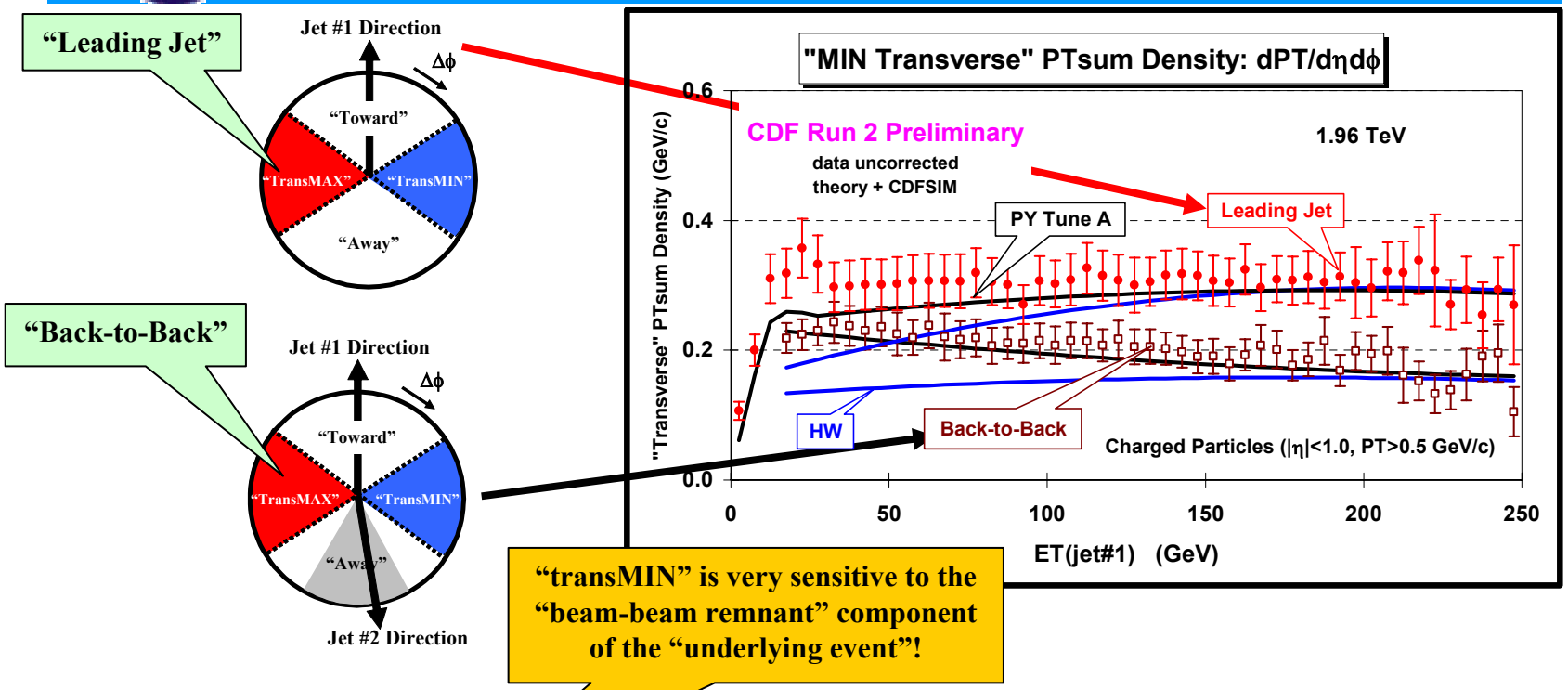
- Look at the "transverse" region as defined by the leading jet (JetClu R = 0.7, $|\eta| < 2$) or by the leading two jets (JetClu R = 0.7, $|\eta| < 2$). "Back-to-Back" events are selected to have at least two jets with Jet#1 and Jet#2 nearly "back-to-back" ($\Delta\phi_{12} > 150^o$) with almost equal transverse energies (E_T(jet#2)/E_T(jet#1) > 0.8).
- Shows the $\Delta\phi$ 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 270°) for 30 < E_T(jet#1) < 70 GeV for "Leading Jet" and "Back-to-Back" events.

"Transverse" PTsum Density versus E_T(jet#1) Run 2



- Shows the average charged PTsum density, $dPT_{sum}/d\eta d\phi$, 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.

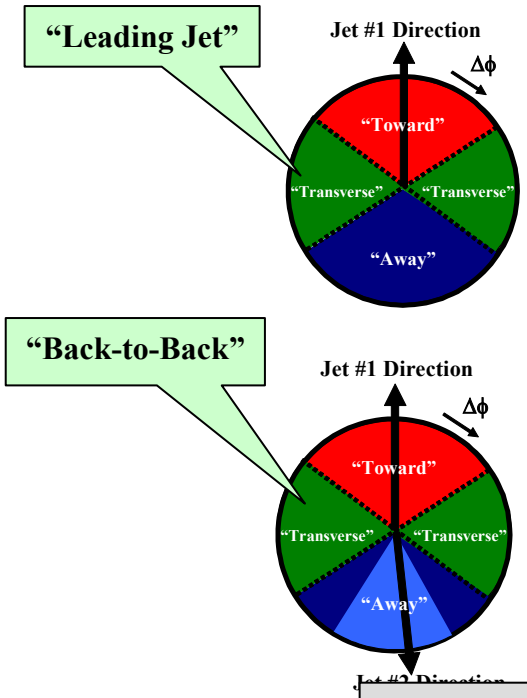
"TransMIN" PTsum Density versus E_T(jet#1)

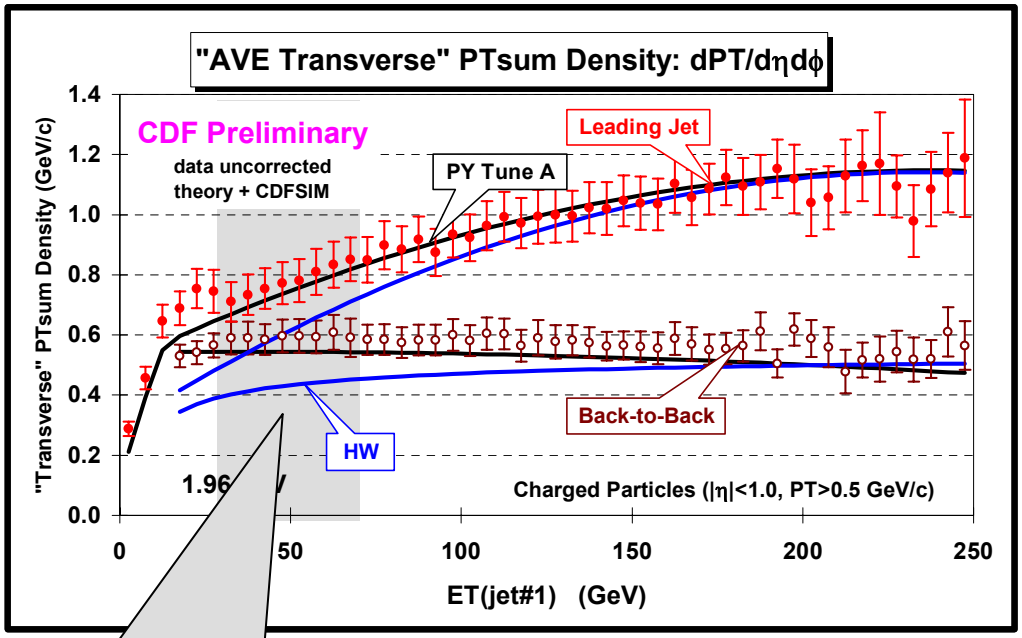


"transMIN" is very sensitive to the "beam-beam remnant" component of the "underlying event"!

- Use the leading jet to define MAX and MIN "transverse" regions on an event-by-event basis with MAX (MIN) having the largest (smallest) charged particle density.
- Shows the "transMIN" charge particle density, $dN_{chg}/d\eta d\phi$, for $p_T > 0.5$ GeV/c, $|\eta| < 1$ versus E_T(jet#1) for "Leading Jet" and "Back-to-Back" events.

"Transverse" PTsum Density
PYTHIA Tune A vs HERWIG



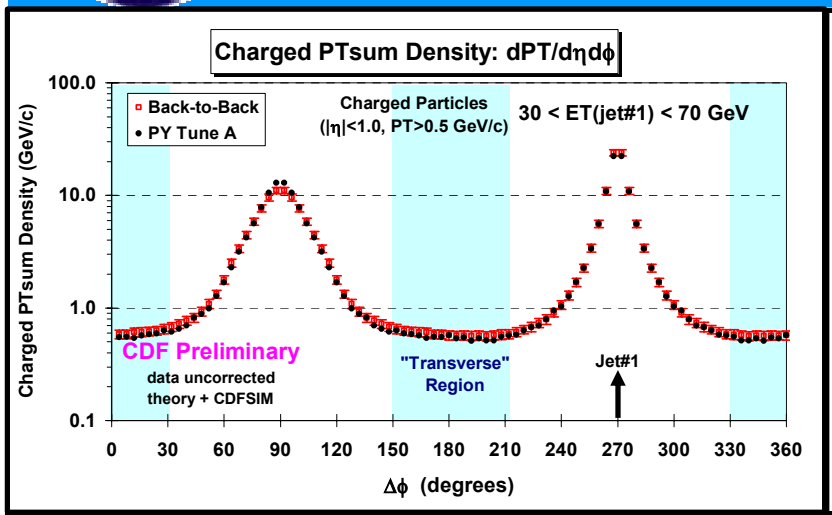


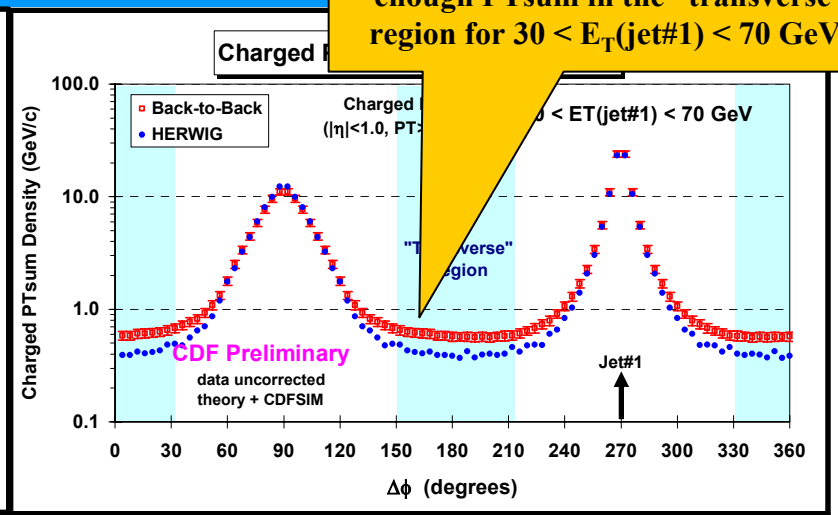
Now look in detail at "back-to-back" events in the region $30 < E_T(\text{jet\#1}) < 70$ GeV!

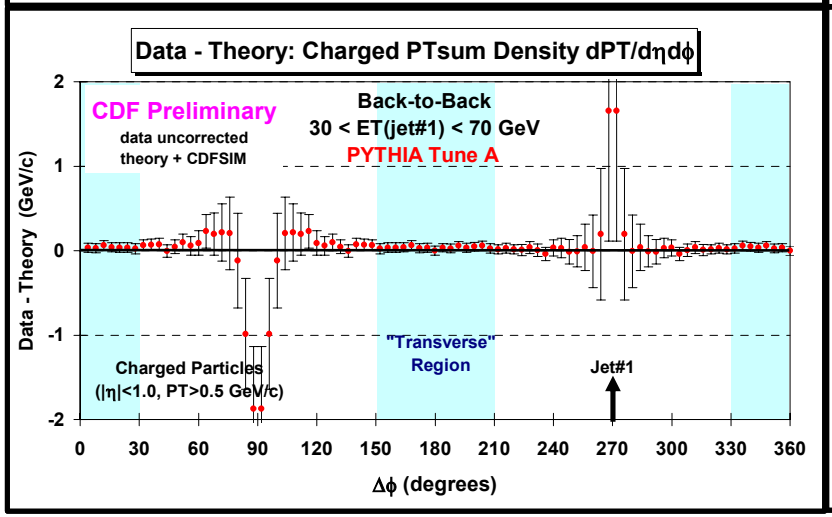
- Shows the average charged PTsum density, $dPT_{sum}/d\eta d\phi$, in the "transverse" region ($p_T > 0.5$ GeV/c, $|\eta| < 1$) versus E_T(jet#1) for "Leading Jet" and "Back-to-Back" events.
- Compares the (*uncorrected*) data with PYTHIA Tune A and HERWIG after CDFSIM.

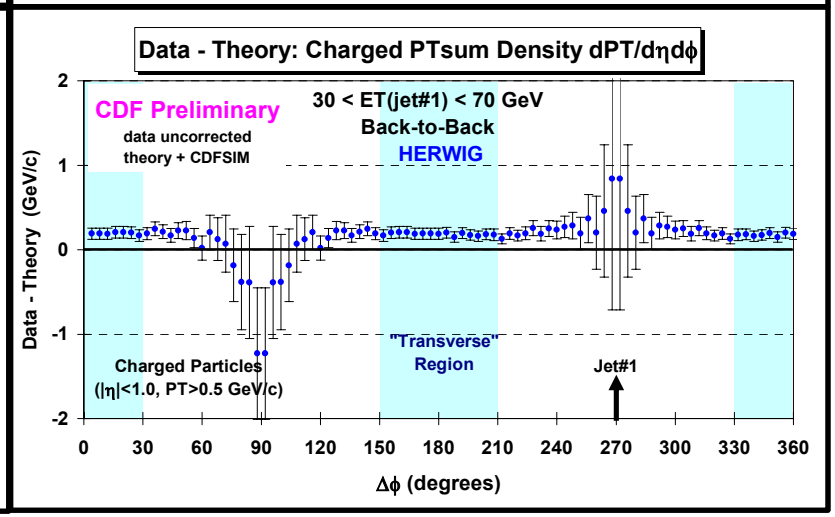
Charged PTsum Density
PYTHIA Tune A vs HE

HERWIG (*without multiple parton interactions*) does not produces enough PTsum in the "transverse" region for 30 < E_T(jet#1) < 70 GeV!



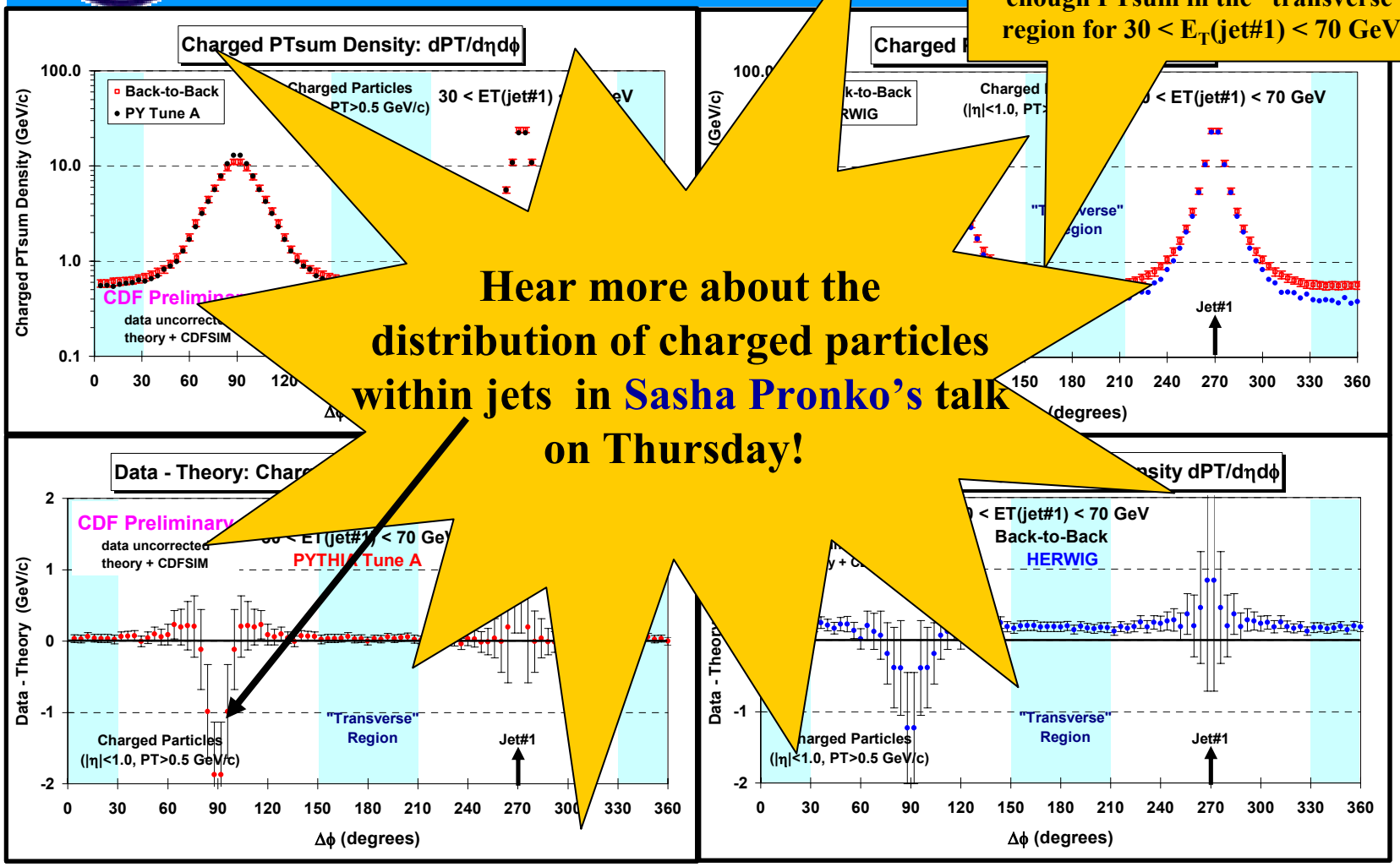






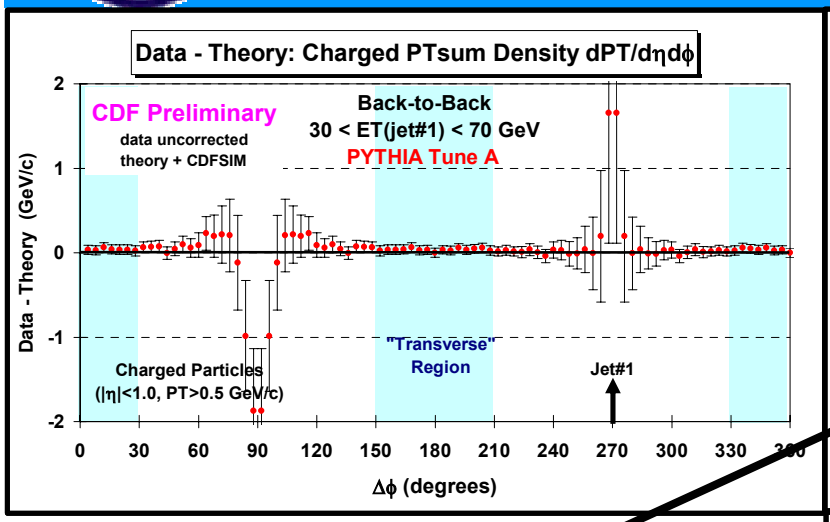
Charged PTsum Density
PYTHIA Tune A vs HE

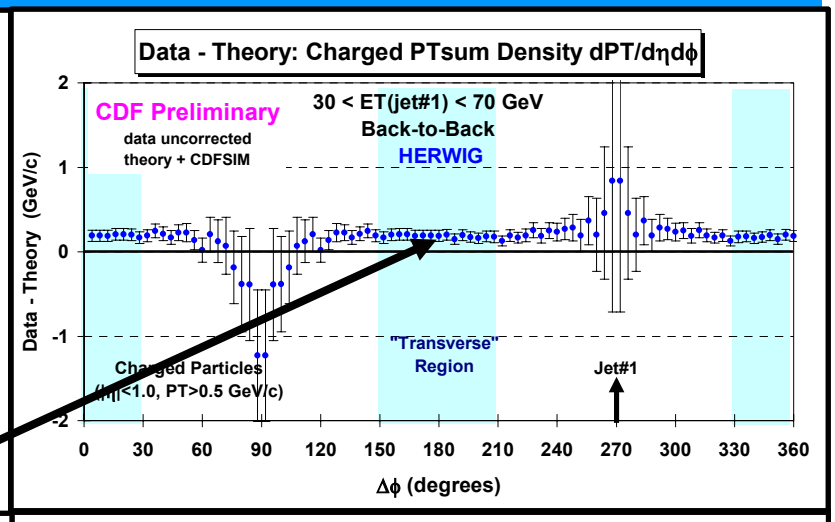
HERWIG (*without multiple parton interactions*) does not produces enough PTsum in the "transverse" region for 30 < E_T(jet#1) < 70 GeV!



Hear more about the distribution of charged particles within jets in Sasha Pronko's talk on Thursday!

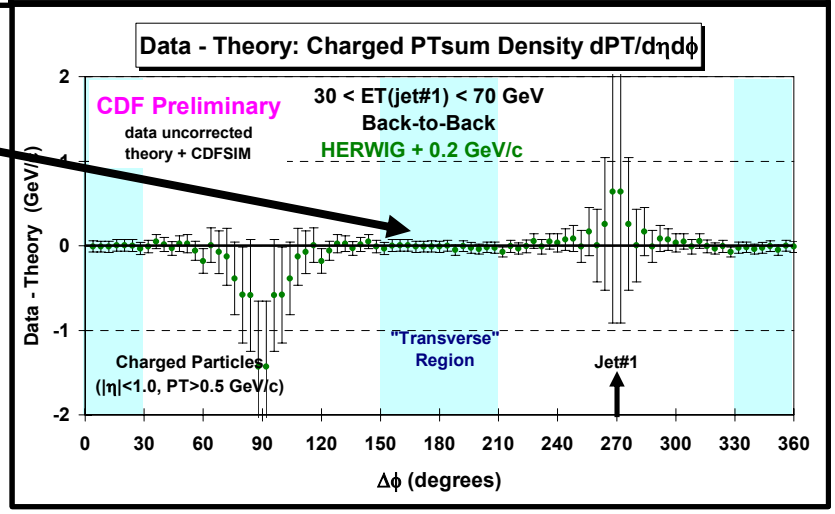
Charged PTsum Density
PYTHIA Tune A vs HERWIG





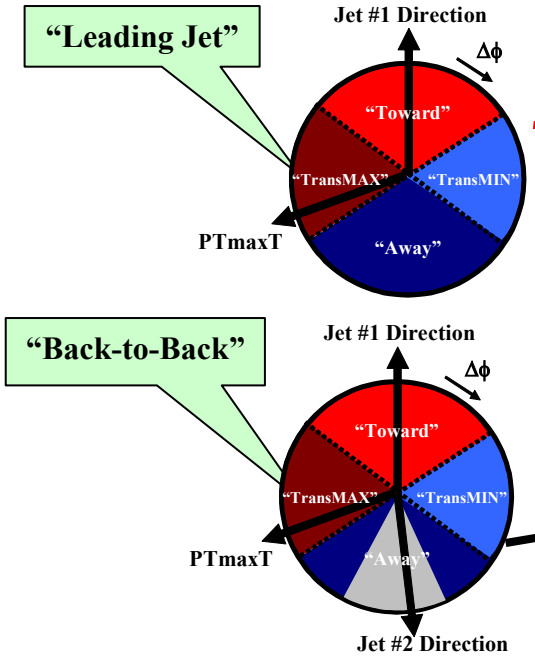
308 MeV in R = 0.7 cone!

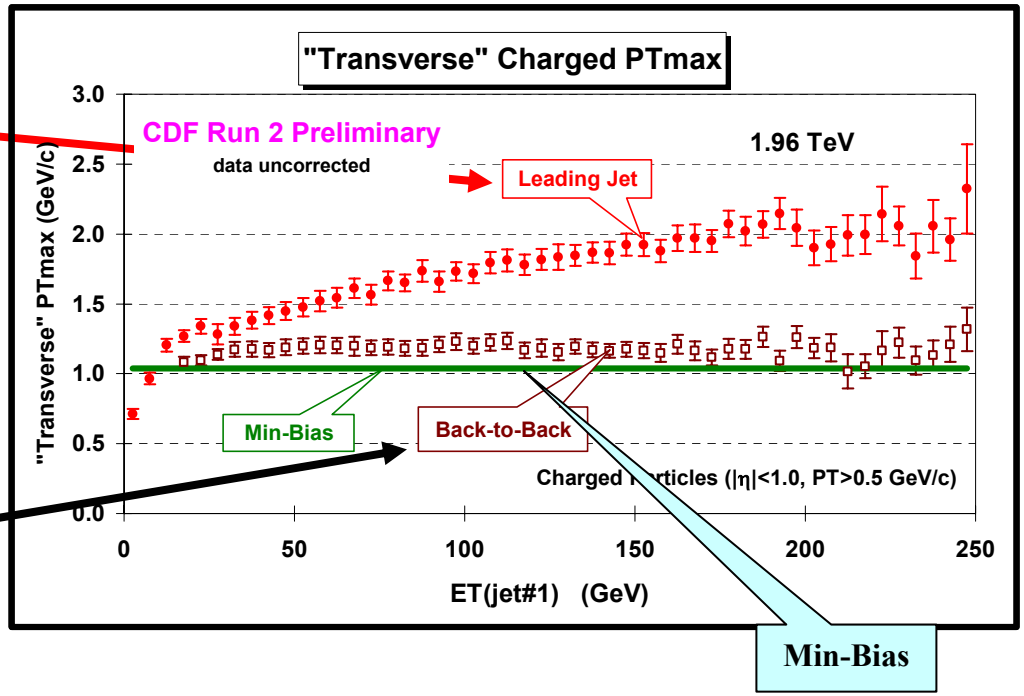
dPT/dηdϕ + 0.2 GeV/c



- **Add 0.2 GeV/c per unit η-ϕ to HERWIG scalar PTsum density, $dPT_{sum}/d\eta d\phi$.**
- **This corresponds to 0.2 x 4π = 2.5 GeV/c in the entire range p_T > 0.5 GeV/c, |η| < 1.**

"Transverse" PTmax versus E_T(jet#1)

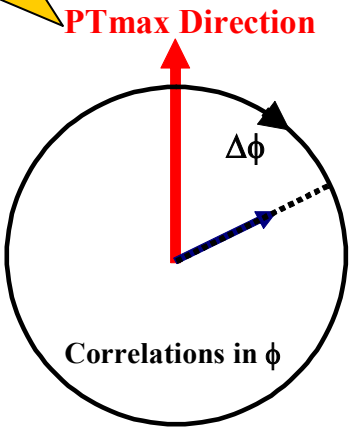




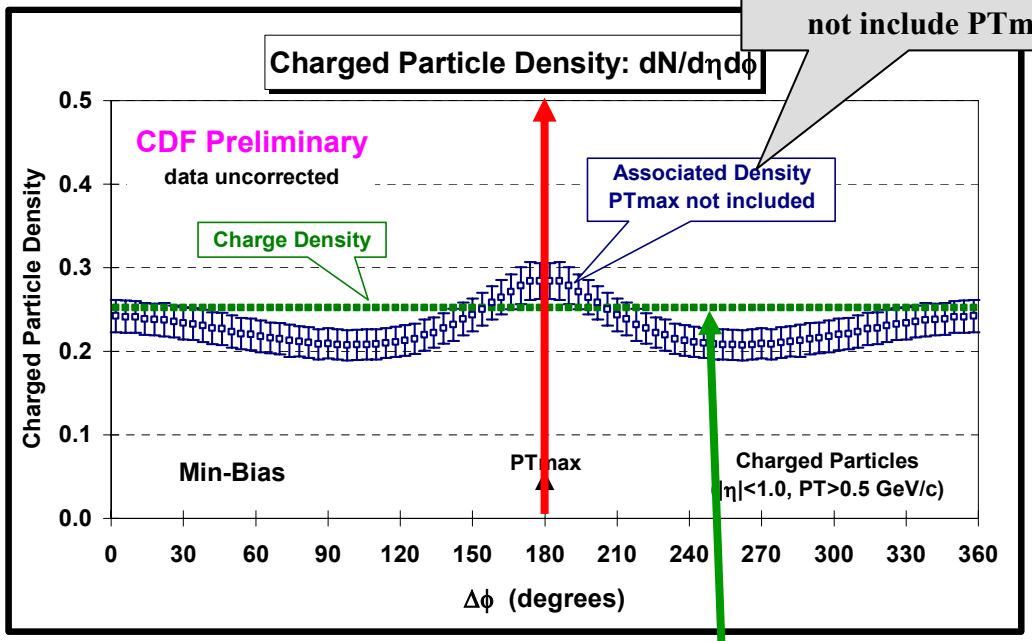
- Use the leading jet to define the "transverse" region and look at the maximum p_T charged particle in the "transverse" region, PTmaxT.
- Shows the average PTmaxT, in the "transverse" region ($p_T > 0.5$ GeV/c, $|\eta| < 1$) versus E_T(jet#1) for "Leading Jet" and "Back-to-Back" events compared with the average maximum p_T particle, PTmax, in "min-bias" collisions ($p_T > 0.5$ GeV/c, $|\eta| < 1$).

Min-Bias "Associated" Charged Particle Density

Highest p_T charged particle!

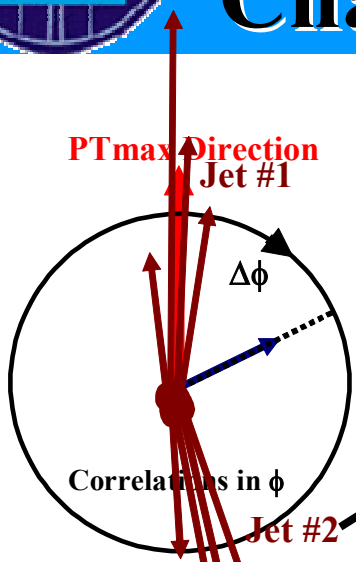


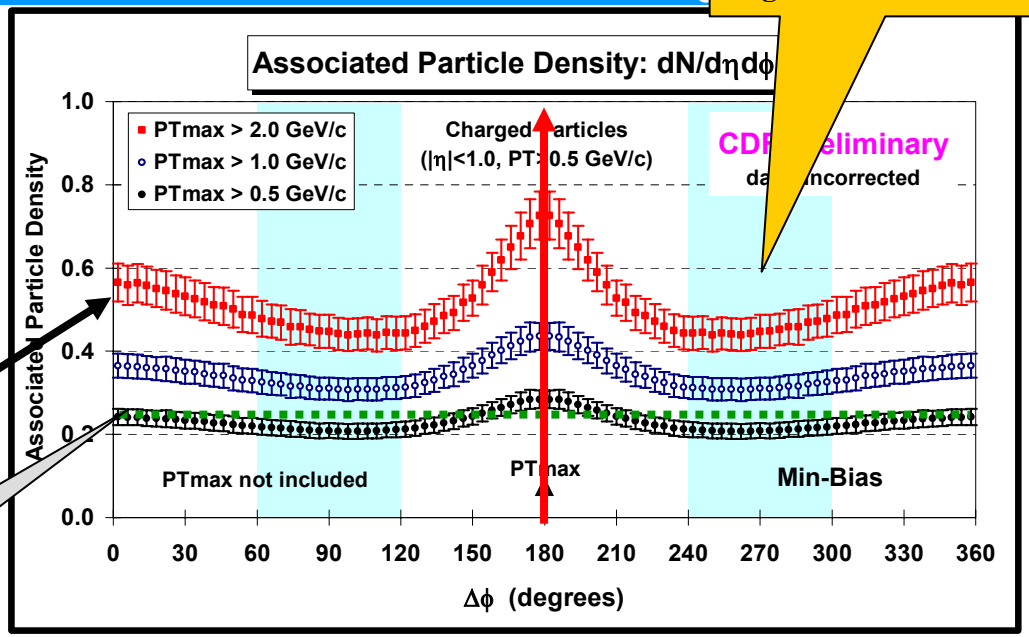
"Associated" densities do not include PTmax!



- Use the maximum p_T charged particle in the event, PTmax, to define a direction and look at the the "associated" density, $dN_{chg}/d\eta d\phi$.
- Shows the data on 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 PTmax*) relative to PTmax (rotated to 180°) for "min-bias" events. Also shown is the average charged particle density, $dN_{chg}/d\eta d\phi$, for "min-bias" events.

Min-Bias "Associated" Charged Particle Density





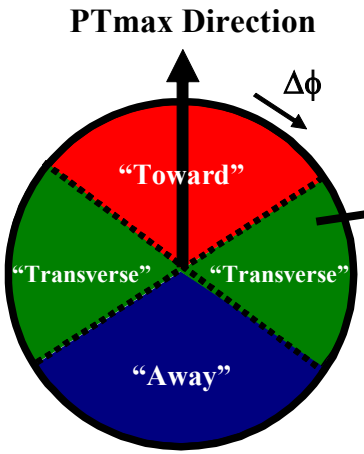
Rapid rise in the particle density in the "transverse" region as PTmax increases!

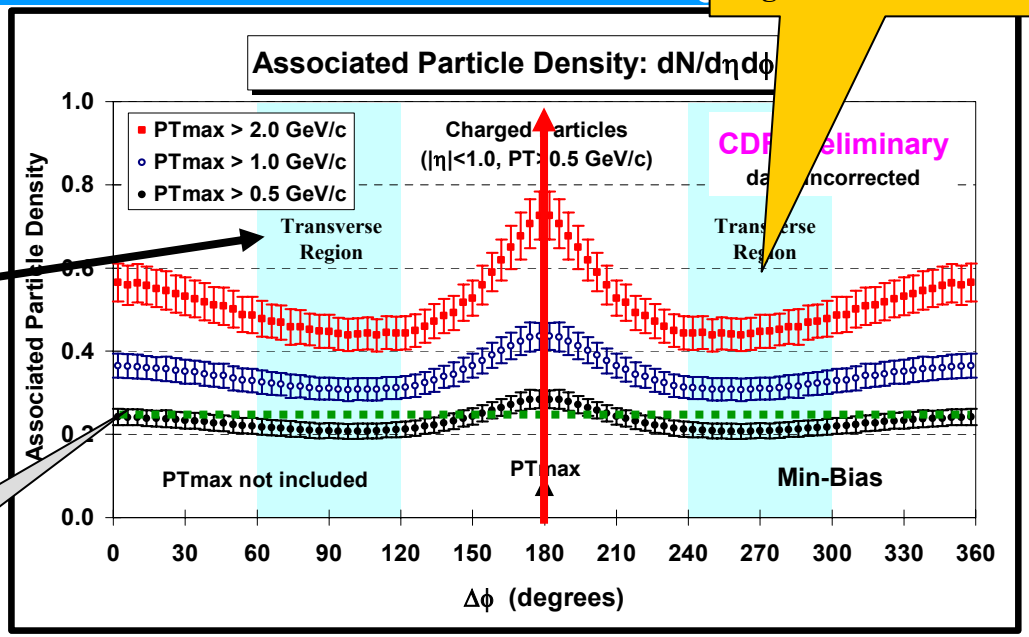
Ave Min-Bias
0.25 per unit η-ϕ

- Shows the data on 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 PTmax*) relative to PTmax (rotated to 180°) for "min-bias" events with PTmax > 0.5, 1.0, and 2.0 GeV/c.
- Shows "jet structure" in "min-bias" collisions (*i.e.* the "birth" of the leading two jets!).

Min-Bias "Associated" Charged Particle Density

Rapid rise in the particle density in the "transverse" region as PTmax increases!



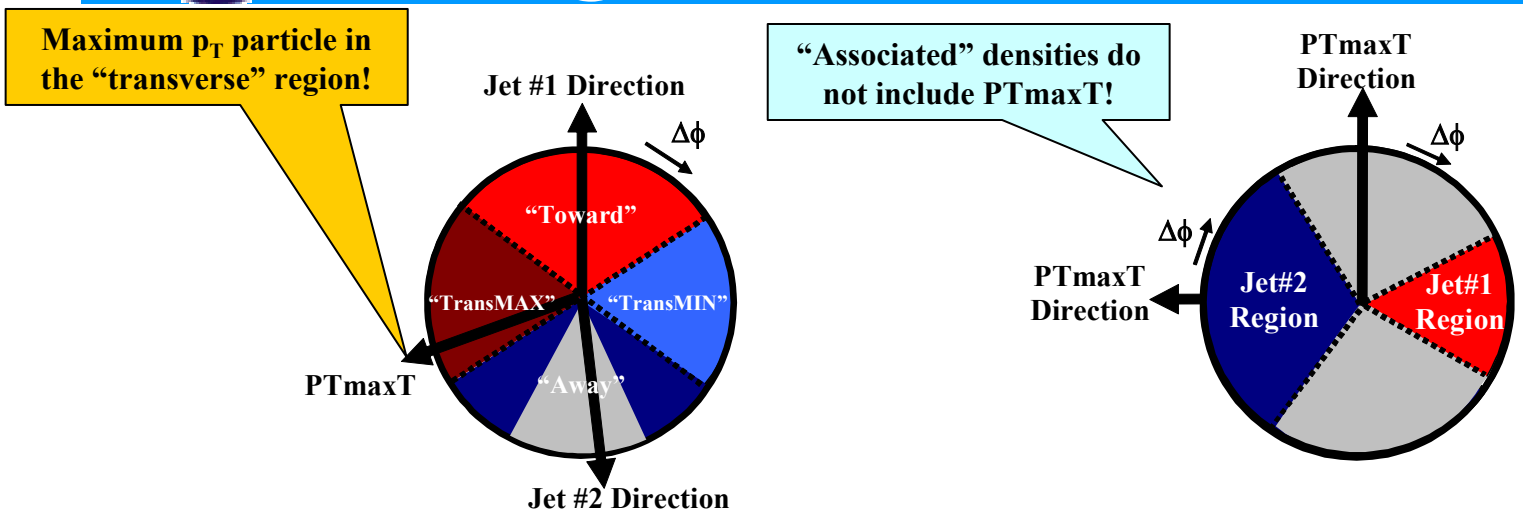


Ave Min-Bias
0.25 per unit η-ϕ

- Shows the data on 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 PTmax*) relative to PTmax (rotated to 180°) for "min-bias" events with PTmax > 0.5, 1.0, and 2.0 GeV/c.

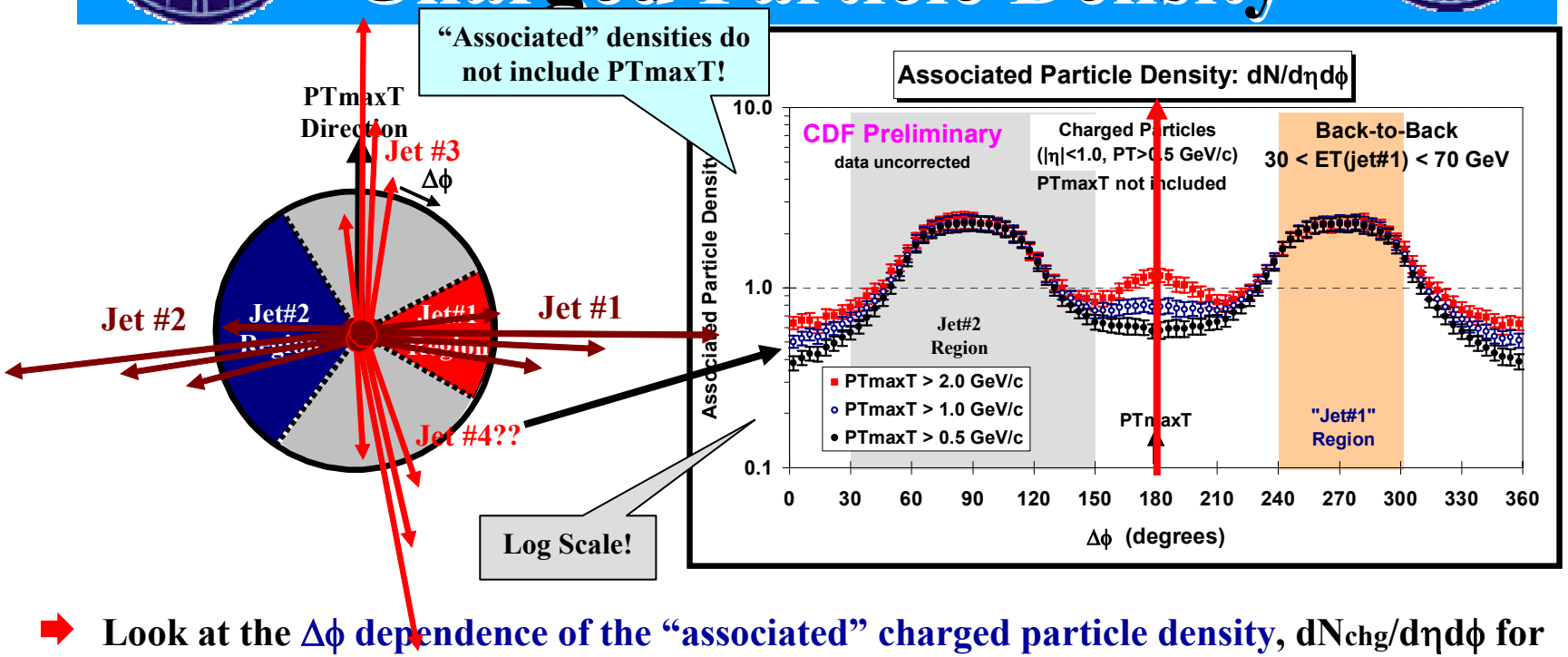
- Shows "jet structure" in "min-bias" collisions (*i.e.* the "birth" of the leading two jets!).

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°).

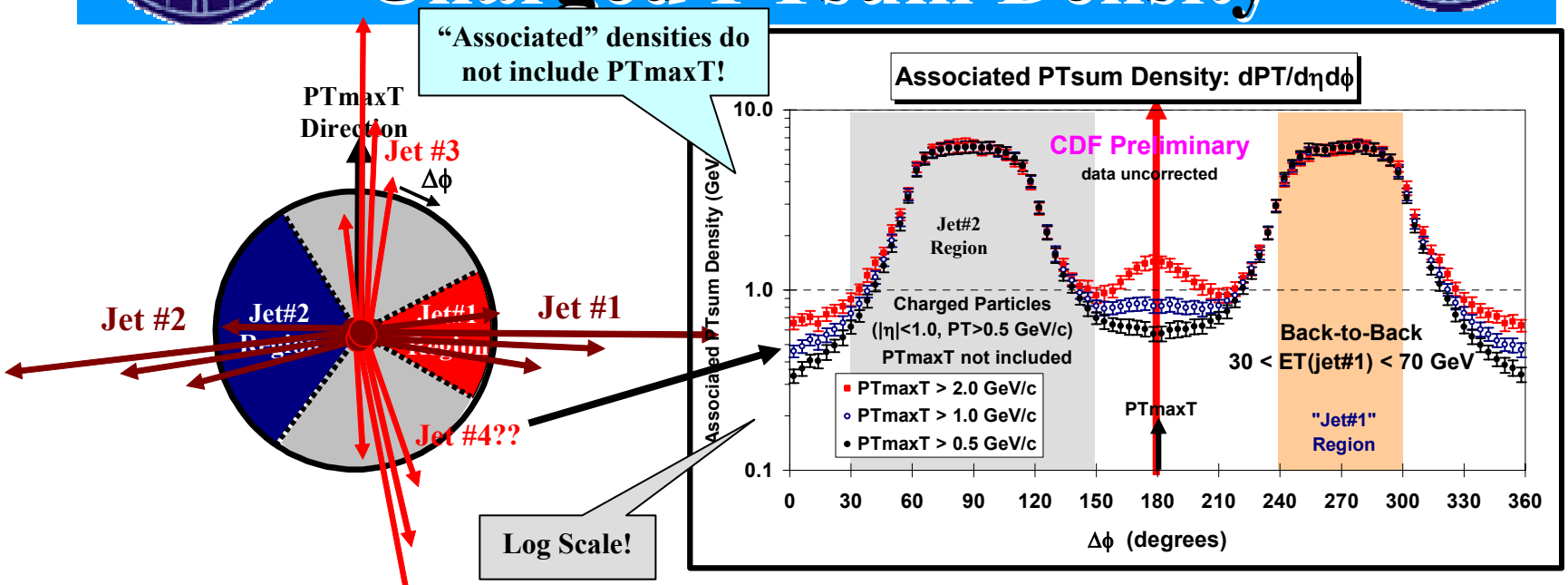
Back-to-Back "Associated" Charged Particle Density



- 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, |η| < 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 PTsum Density

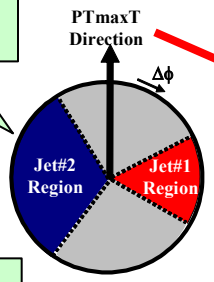


- Look at the Δϕ dependence of the "associated" charged particle density, $dPT_{sum}/d\eta d\phi$ for charged particles (p_T > 0.5 GeV/c, |η| < 1, *not including PTmaxT*) relative to PTmaxT (rotated to 180°) for PTmaxT > 0.5 GeV/c, PTmaxT > 1.0 GeV/c and PTmaxT > 2.0 GeV/c, for "back-to-back" events with 30 < E_T(jet#1) < 70 GeV .

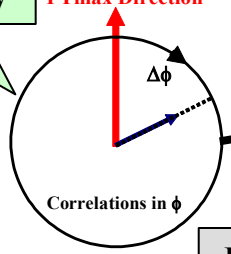
- Shows "jet structure" in the "transverse" region (*i.e.* the "birth" of the 3rd & 4th jet).

"Back-to-Back" vs "MinBias" "Associated" Charge Density

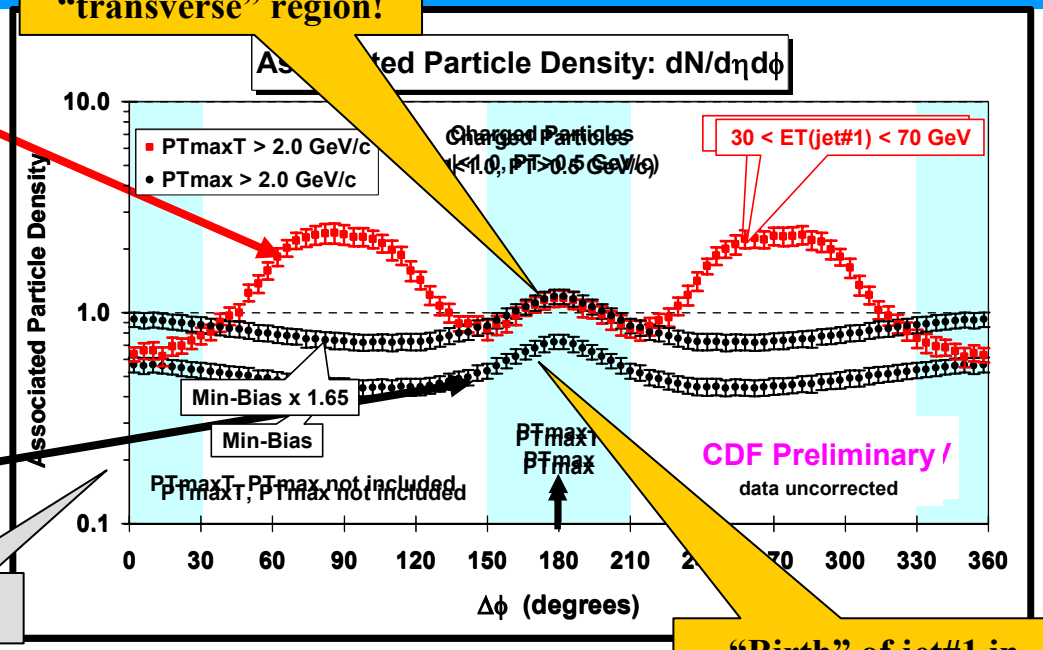
"Back-to-Back" "Associated" Density



"Min-Bias" "Associated" Density



"Birth" of jet#3 in the "transverse" region!

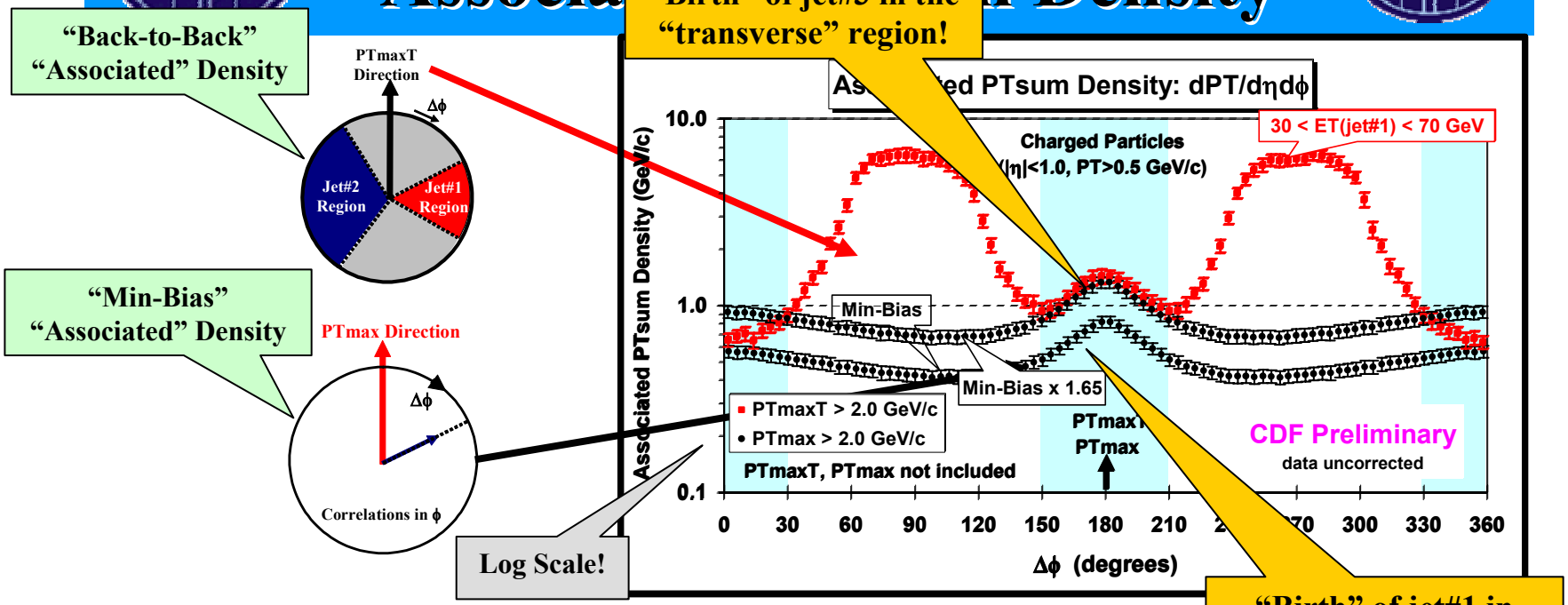


Log Scale!

"Birth" of jet#1 in "min-bias" collisions!

- Shows the Δϕ dependence of the "associated" charged particle densi[illegible] p_T > 0.5 GeV/c, |η| < 1 (*not including PTmaxT*) relative to PTmaxT ([illegible]) for PTmaxT > 2.0 GeV/c, for "back-to-back" events with 30 < E_T(jet#1) < 70 GeV.
- Shows the data on the Δϕ dependence of the "associated" charged particle density, $dN_{chg}/d\eta d\phi$, p_T > 0.5 GeV/c, |η| < 1 (*not including PTmax*) relative to PTmax (rotated to 180°) for "min-bias" events with PTmax > 2.0 GeV/c.

"Back-to-Back" vs "MinBias" "Associated" PTsum Density

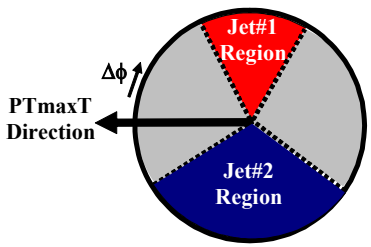


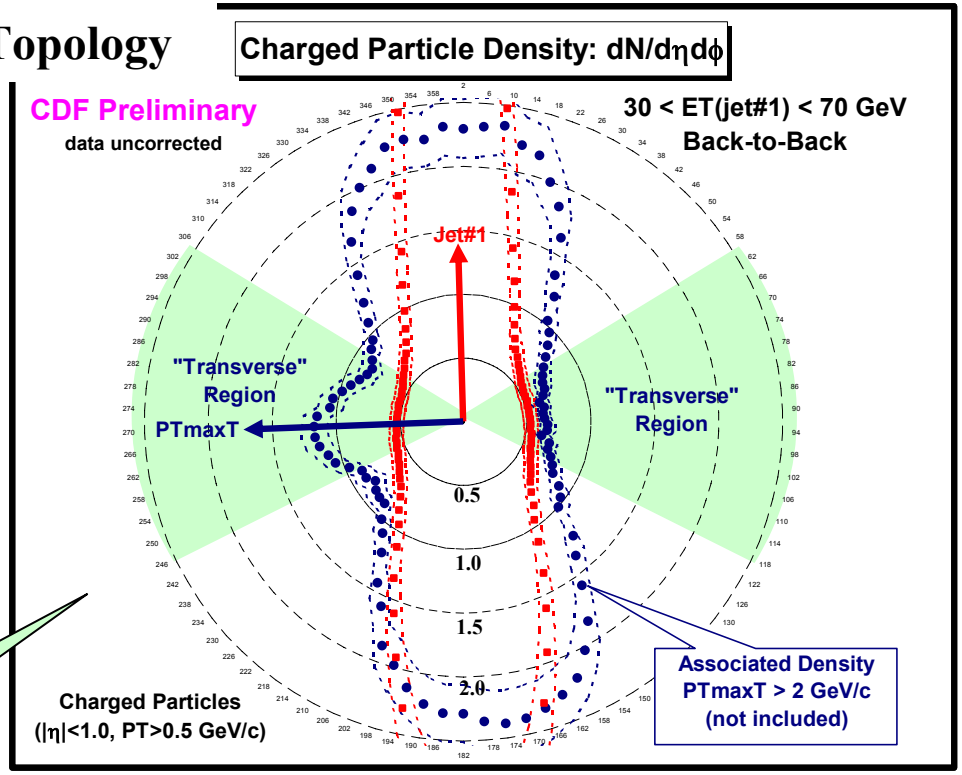
- Shows the Δϕ dependence of the "associated" charged particle densi $p_T > 0.5$ GeV/c, $|\eta| < 1$ (*not including PTmaxT*) relative to PTmaxT (rotated to 180°) for PTmaxT > 2.0 GeV/c, for "back-to-back" events with $30 < E_T(\text{jet\#1}) < 70$ GeV.

- Shows the data on 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 PTmax*) relative to PTmax (rotated to 180°) for "min-bias" events with PTmax > 2.0 GeV/c.

Jet Topologies

QCD Four Jet Topology

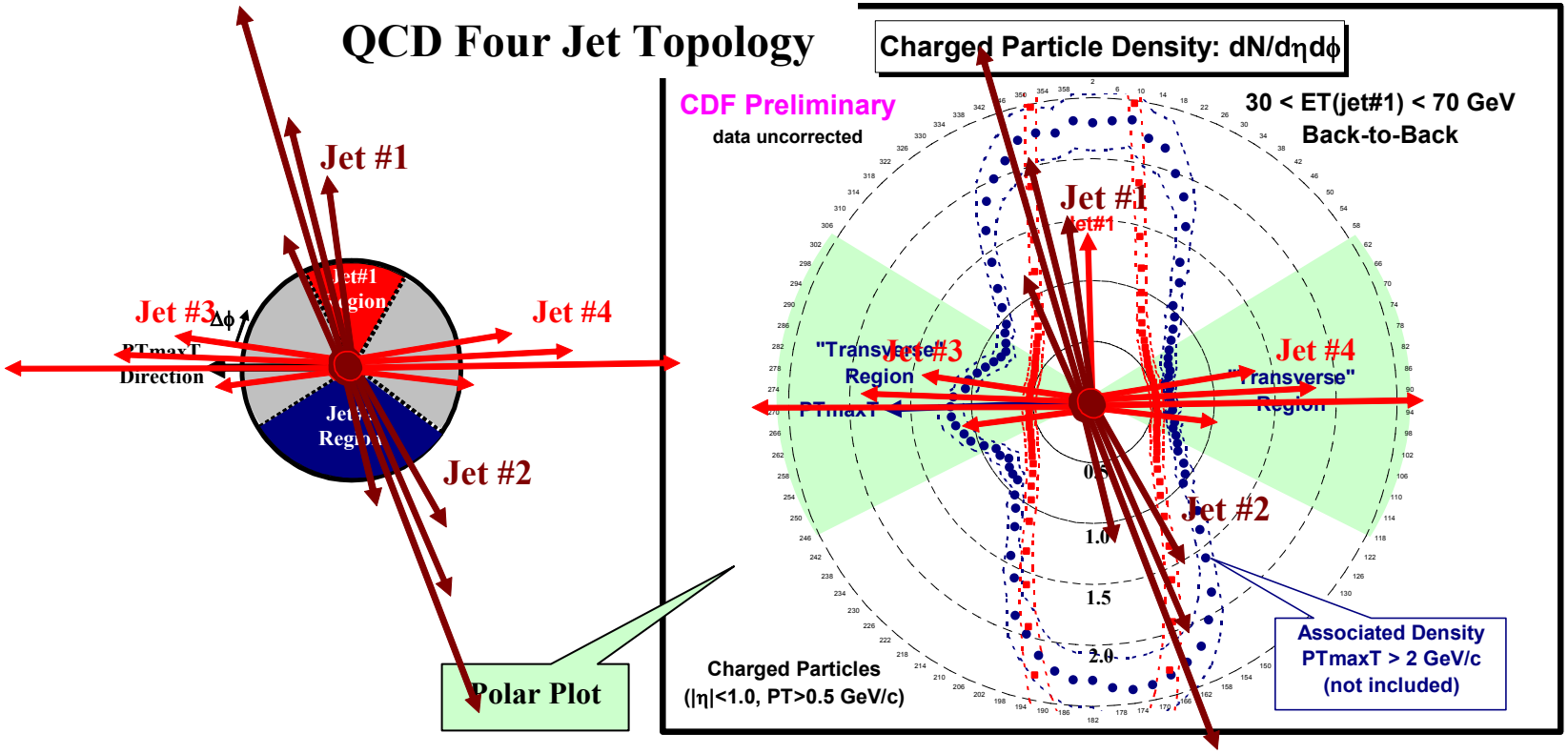




Polar Plot

- **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.**

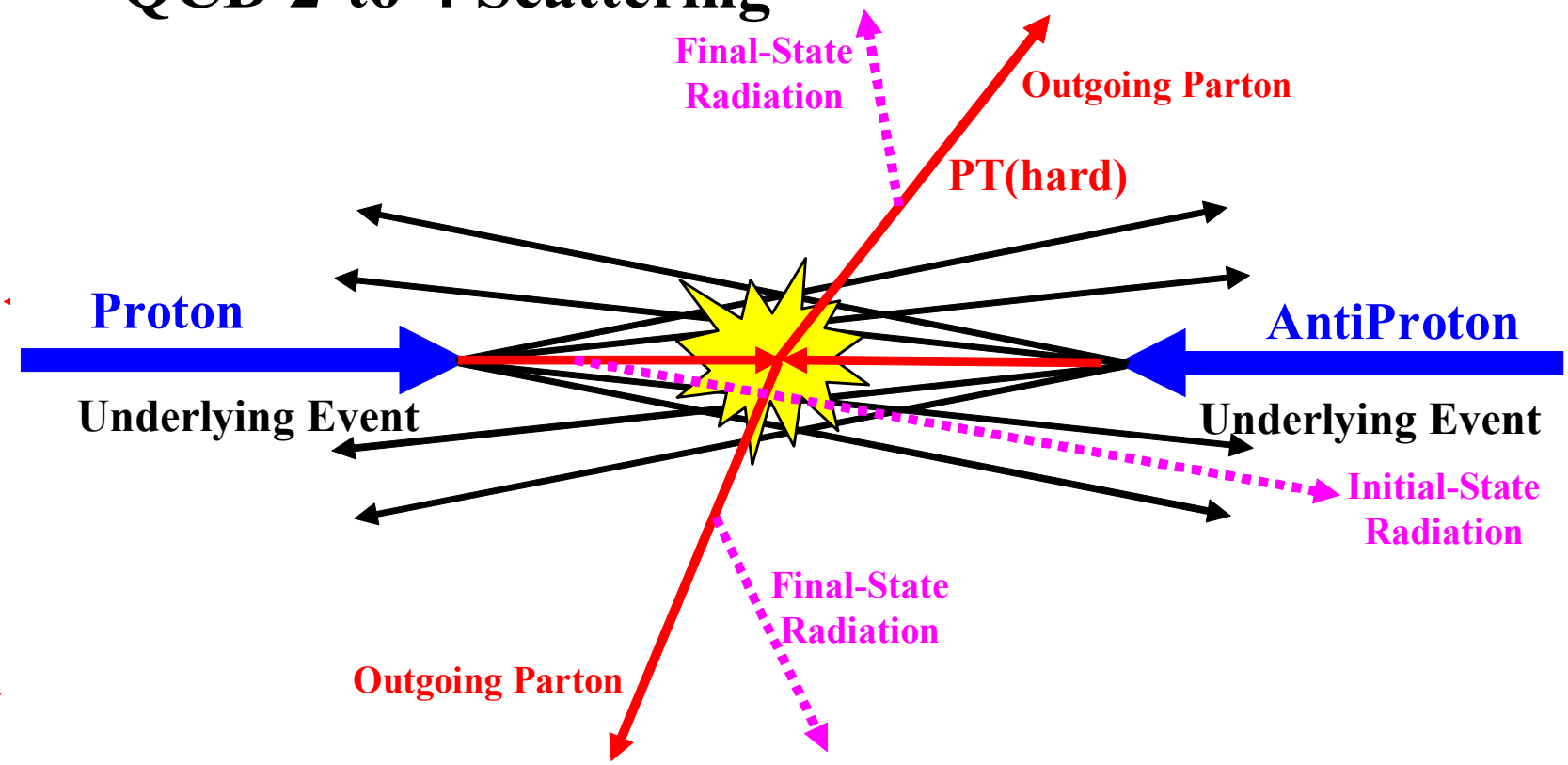
Jet Topologies



- **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

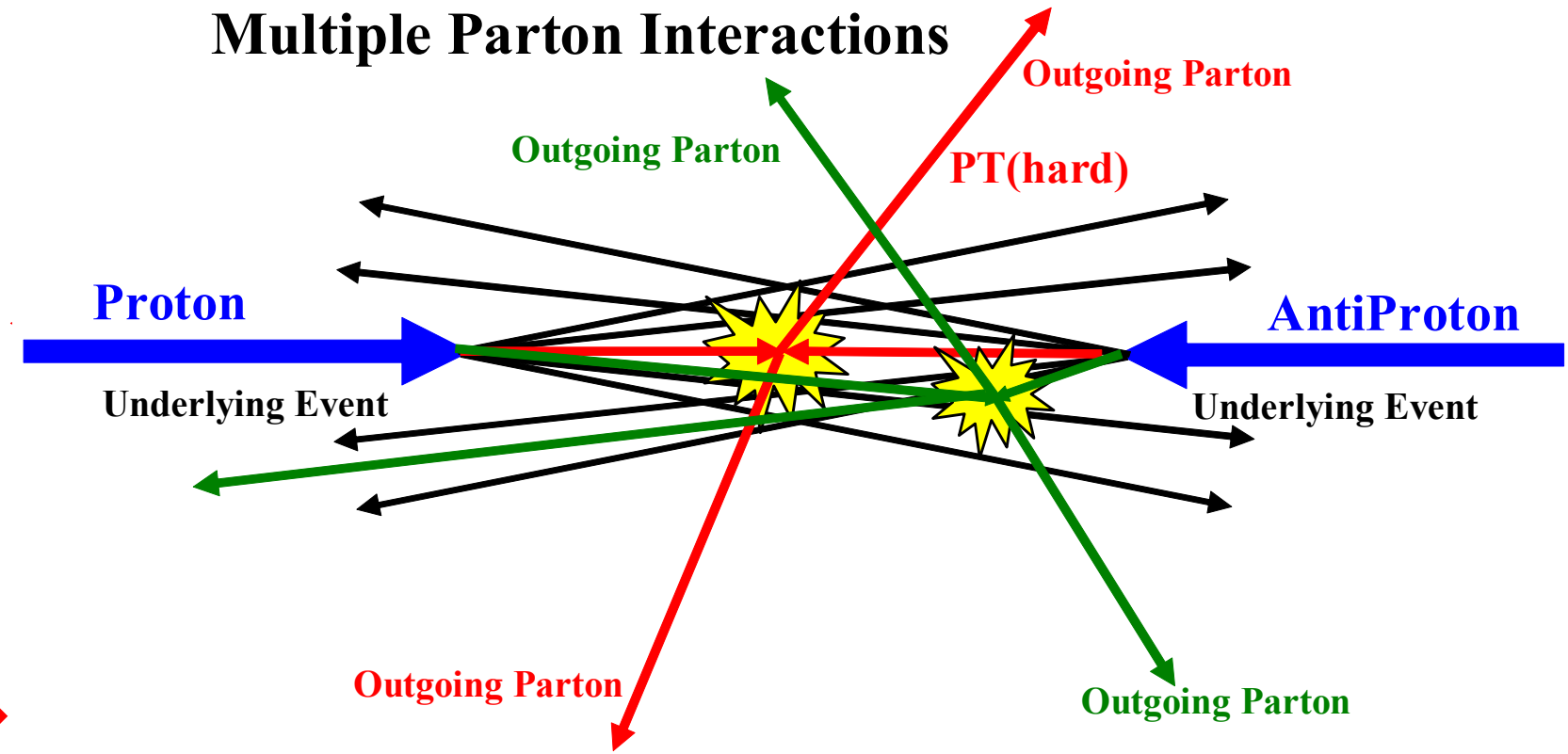
QCD 2-to-4 Scattering



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

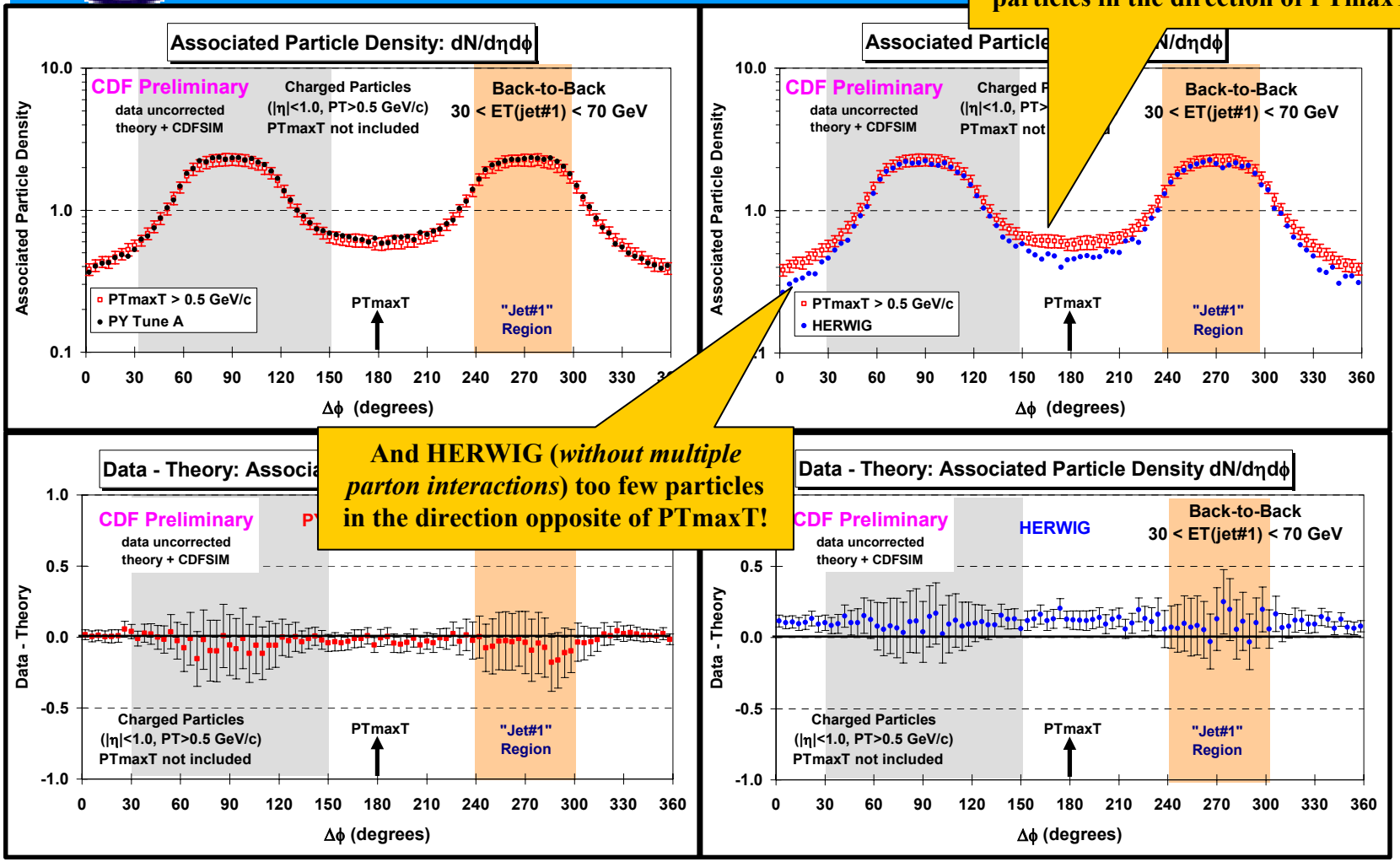
Multiple Parton Interactions



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.

"Associated" Charge Density
PYTHIA Tune A vs HE

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

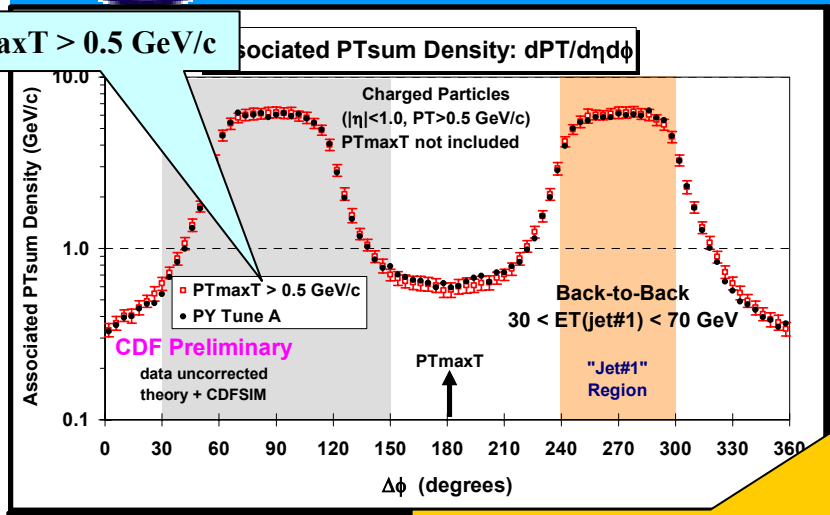


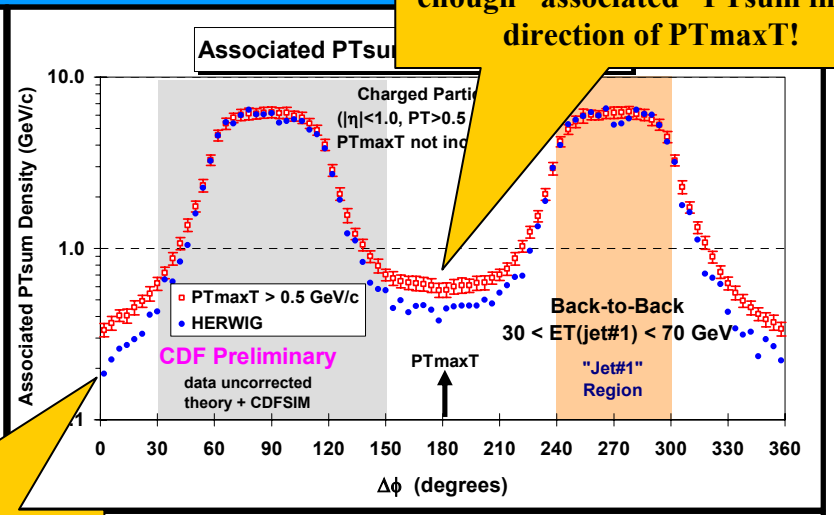
And HERWIG (*without multiple parton interactions*) too few particles in the direction opposite of PTmaxT!

"Associated" PTsum Density
PYTHIA Tune A vs HERW

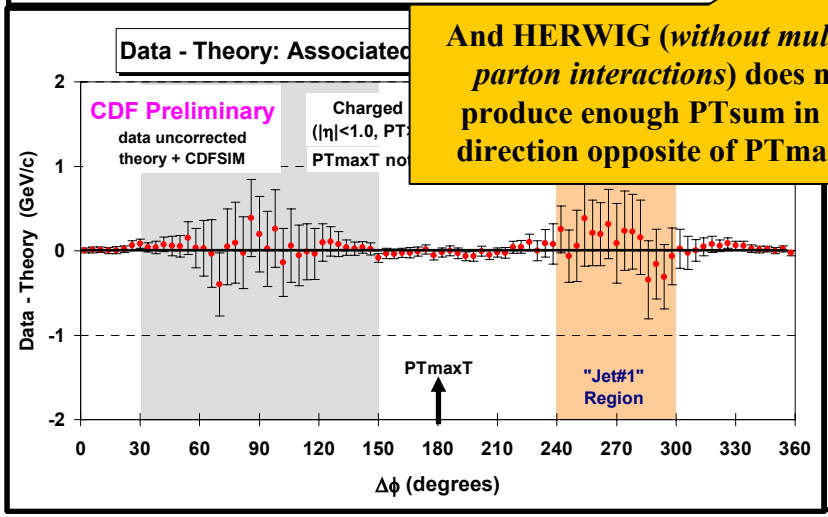
PTmaxT > 0.5 GeV/c

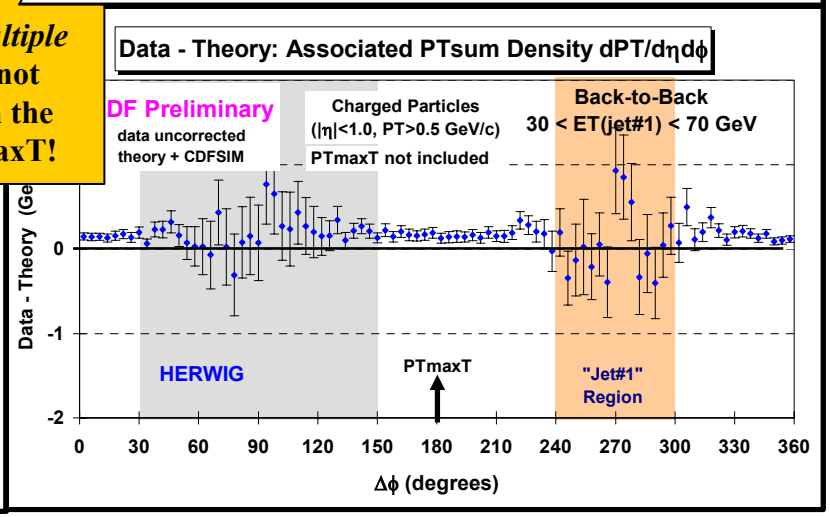
HERWIG (*without multiple parton interactions*) does not produce enough "associated" PTsum in the direction of PTmaxT!





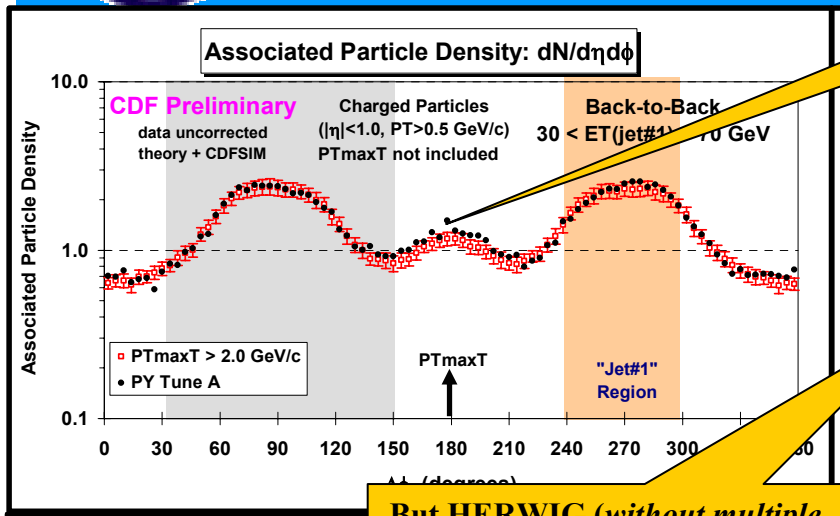
And HERWIG (*without multiple parton interactions*) does not produce enough PTsum in the direction opposite of PTmaxT!

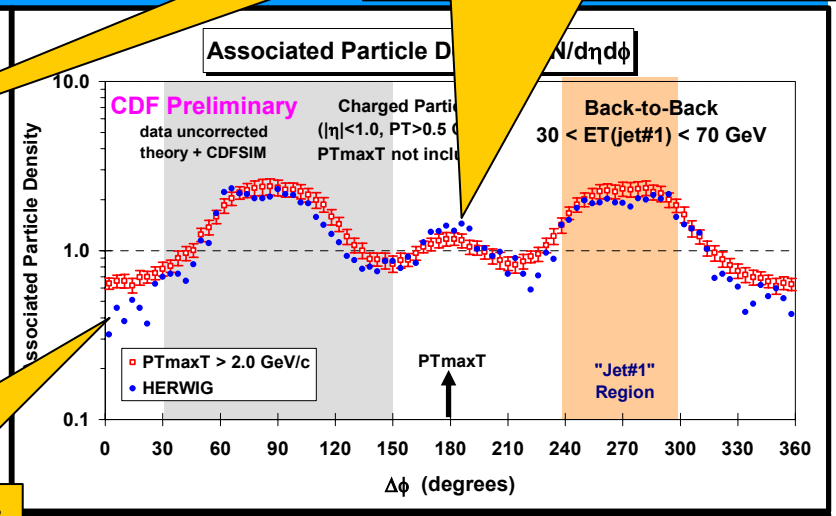




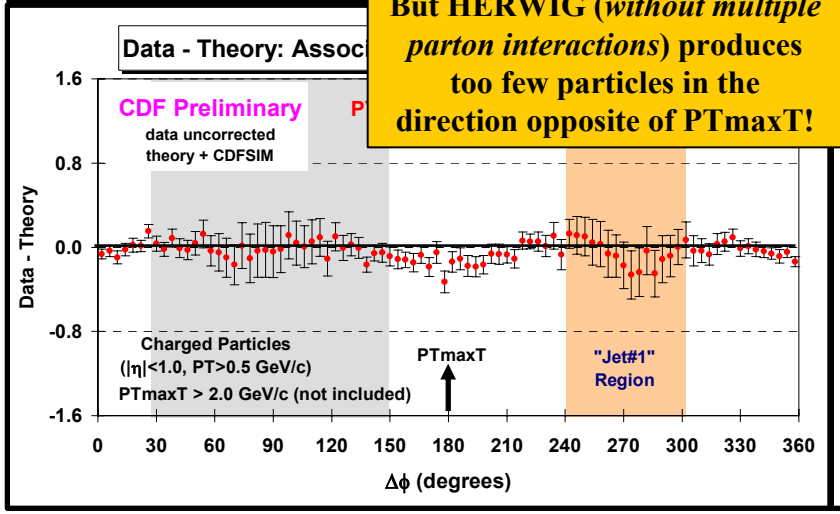
"Associated" Charge De
PYTHIA Tune A vs HE

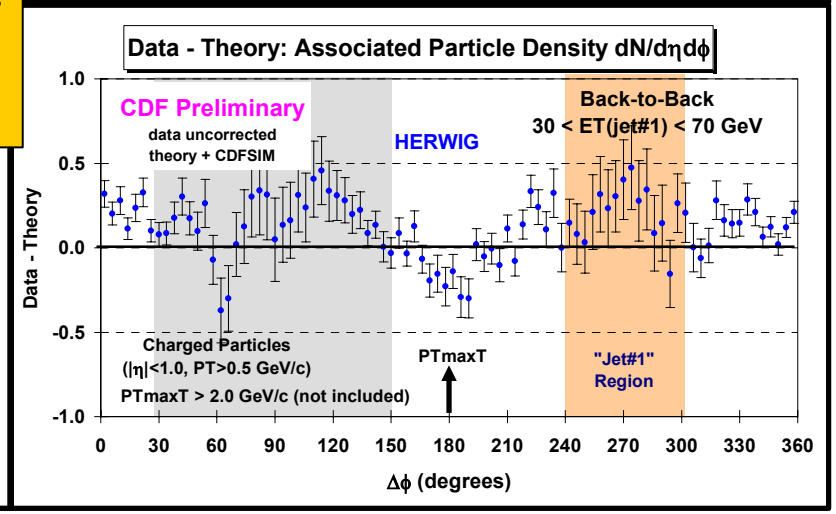
For PTmaxT > 2.0 GeV both PYTHIA and HERWIG produce slightly too many "associated" particles in the direction of PTmaxT!





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

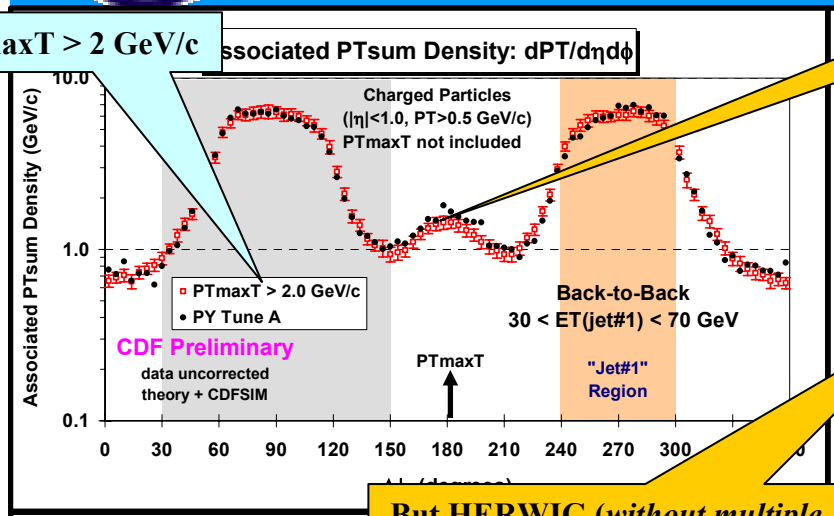


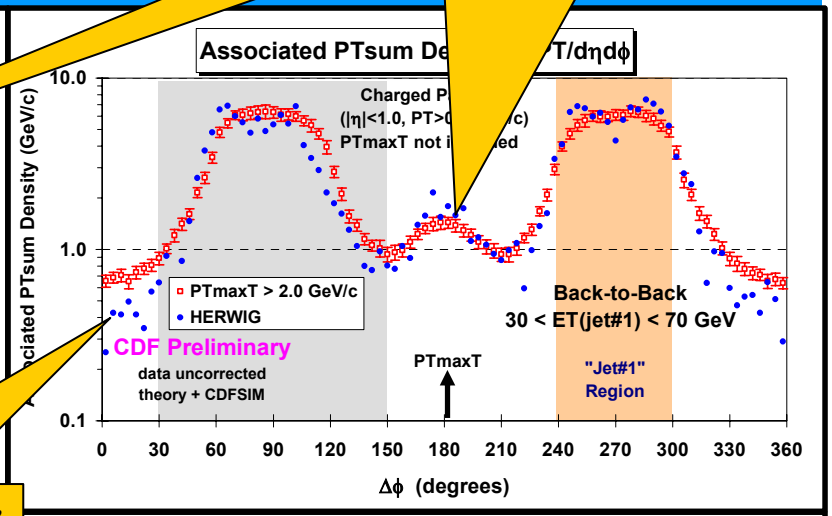


"Associated" PTsum De
PYTHIA Tune A vs HE

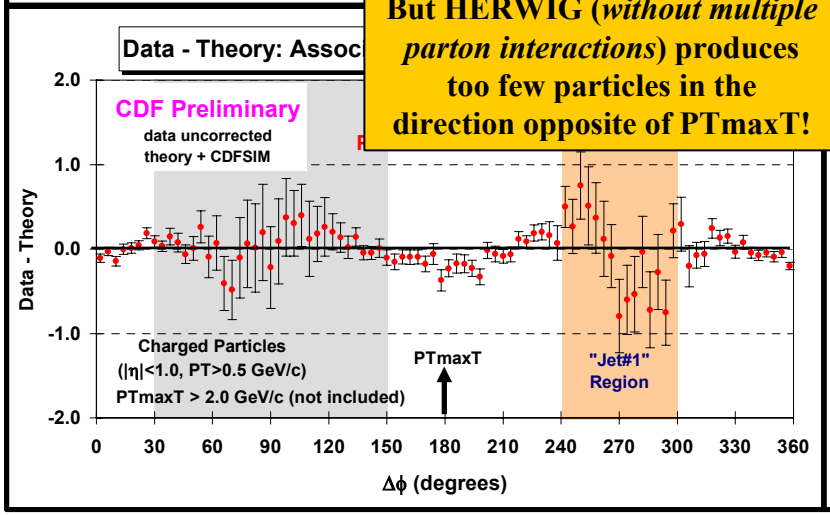
For PTmaxT > 2.0 GeV both PYTHIA and HERWIG produce slightly too much "associated" PTsum in the direction of PTmaxT!

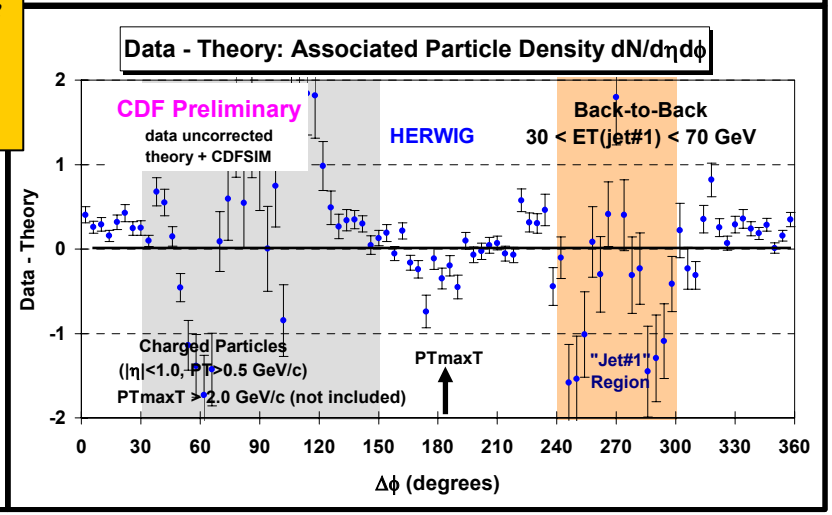
PTmaxT > 2 GeV/c



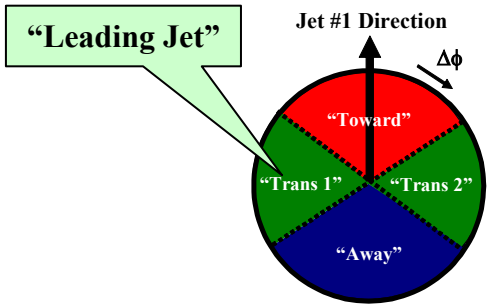


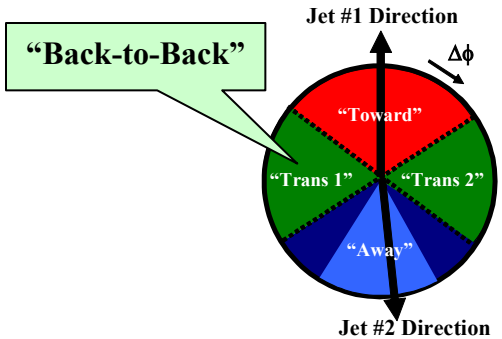
But HERWIG (*without multiple parton interactions*) produces too few particles in the direction opposite of PTmaxT!





Summary



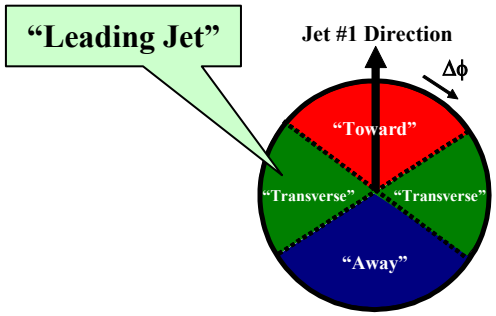


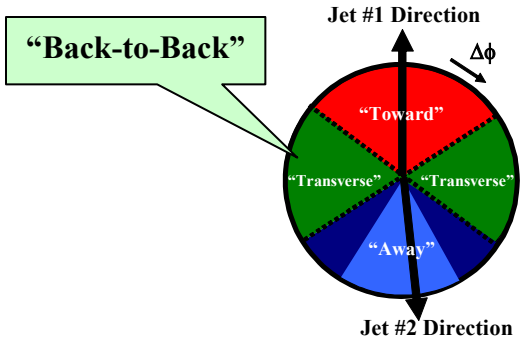
- There are some interesting correlations between the "transverse 1" and "transverse 2" regions both for "Leading-Jet" and "Back-to-Back" events!

- PYTHIA Tune A (*with multiple parton scattering*) does a much better job in describing these correlations than does HERWIG (*without multiple parton scattering*).

Question: Is this a probe of multiple parton interactions?

Summary

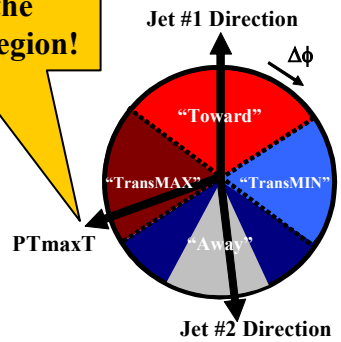




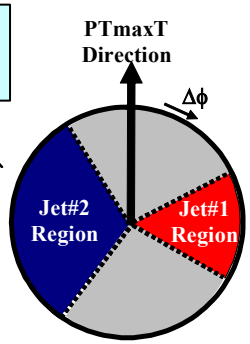
- **"Back-to-Back" events have less "hard scattering" (*initial and final state radiation*) component in the "transverse" region which allows for a closer look at the "beam-beam remnant" and multiple parton scattering component of the "underlying" event.**
- **PYTHIA Tune A (*with multiple parton scattering*) does a much better job in describing the "back-to-back" events than does HERWIG (*without multiple parton scattering*).**

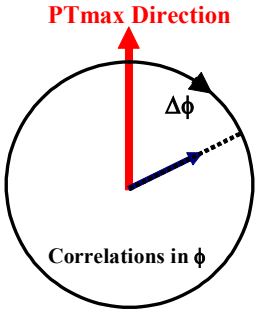
Summary

Max p_T in the "transverse" region!



"Associated" densities do not include PTmaxT!





- The "associated" densities show strong correlations (*i.e.* jet structure) in the "transverse" region both for "Leading Jet" and "Back-to-Back" events.

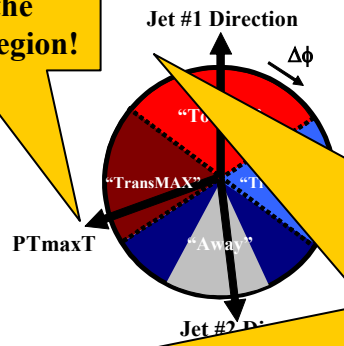
- The "birth" of the 1st jet in "min-bias" collisions looks very similar to the "birth" of the 3rd jet in the "transverse" region of hard scattering "Back-to-Back" events.

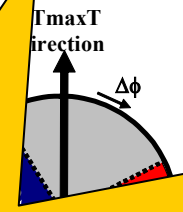
Question: Is the topology 3 jet or 4 jet?

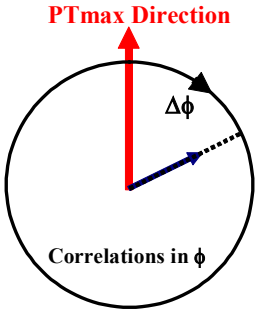
Summary

Max p_T in the "transverse" region!

"Associated" densities do not include PTmaxT!







Next Step

Look at the jet topologies (2 jet vs 3 jet vs 4 jet etc). See if there is an excess of 4 jet events due to multiple parton interactions!

- The "associated jet structure) in the "transverse" region -Back" events.
- The "birth" of the s very similar to the "birth" of the 3rd jet in the l scattering "Back-to-Back" events.

Question: Is the logy 3 jet or 4 je