"Underlying Events" Analysis Corrected to the Particle Level

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CDF Note
CDF/ANAL/CDF/CDFR/7703

Outline of the Talk

- **The goal of this note is to produce data on the "underlying event" that is corrected to the particle level so that it can be used to tune the QCD Monte-Carlo models without requiring CDF detector simulation (*i.e.* CDFSIM). Unlike the previous Run 2 "underlying event" analysis which used JetClu to define "jets" and compared uncorrected data with PYTHIA Tune A and HERWIG after detector simulation (CDFSIM), this analyses uses the MidPoint algorithm and corrects the observables to the particle level.**

- **Look at charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) and energy (calorimeter towers $E_T > 0.1$ GeV, $|\eta| < 1$) in the "transverse" region for both "leading jet" and "back-to-back" events.**

- **For completeness I will show both the uncorrected data compared with compared with PYTHIA Tune A + CDFSIM with HERWIG + CDFSIM and the corrected observables are compared with PYTHIA Tune A, HERWIG, and tuned JIMMY at the particle level (*i.e.* generator level).**

New!

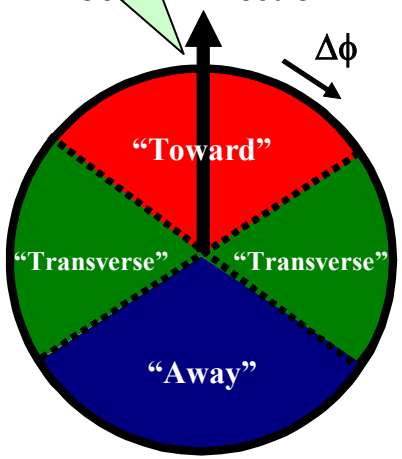
For "Blessing"!

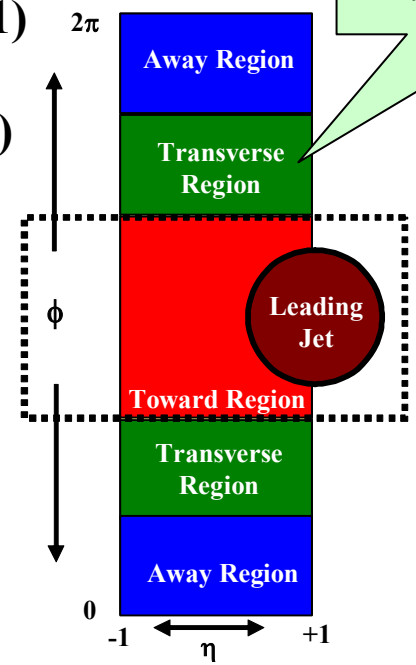
The "Transverse" Region

Use the leading jet to define the "transverse" region.

Look at the density of charged particles and calorimeter towers in the "transverse" region.

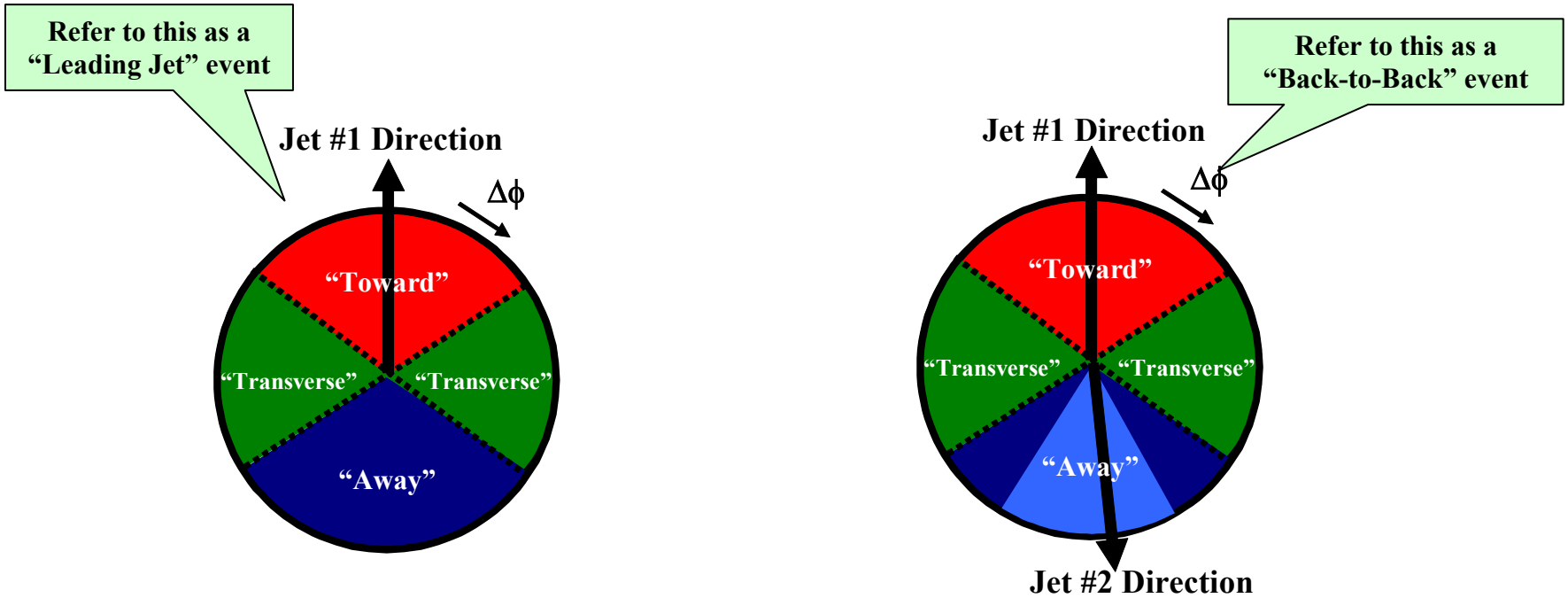
Charged Particles
(p_T > 0.5 GeV/c, |η| < 1)
Calorimeter Towers
(E_T > 0.1 GeV, |η| < 1)





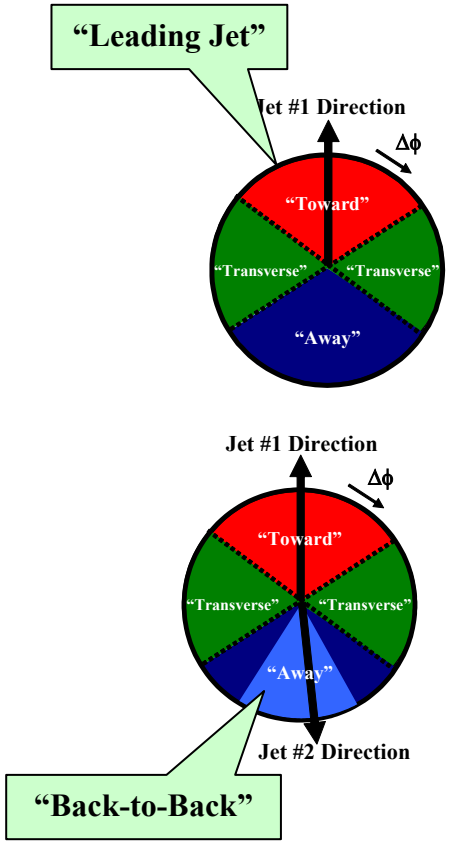
- Look at the "transverse" region as defined by the leading calorimeter jet (MidPoint, R = 0.7, f_{merge} = 0.75, |η| < 2).
- Study the charged particles (p_T > 0.5 GeV/c, |η| < 1) and form the charged particle density, dNchg/dηdϕ, and the charged scalar p_T sum density, dPTsum/dηdϕ.
- Study the calorimeter towers (E_T > 0.1 GeV, |η| < 1) and form the scalar E_T sum density, dE_T/dηdϕ.

"Transverse" Region: "Leading Jet" vs "Back-to-Back"



- **Look at the "transverse" regions as defined by the leading jet (MidPoint R = 0.7, $|\eta| < 2$) or by the leading two jets (MidPoint 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 (P_T(jet#2)/P_T(jet#1) > 0.8) and P_T(jet#3) < 15 GeV/c.**

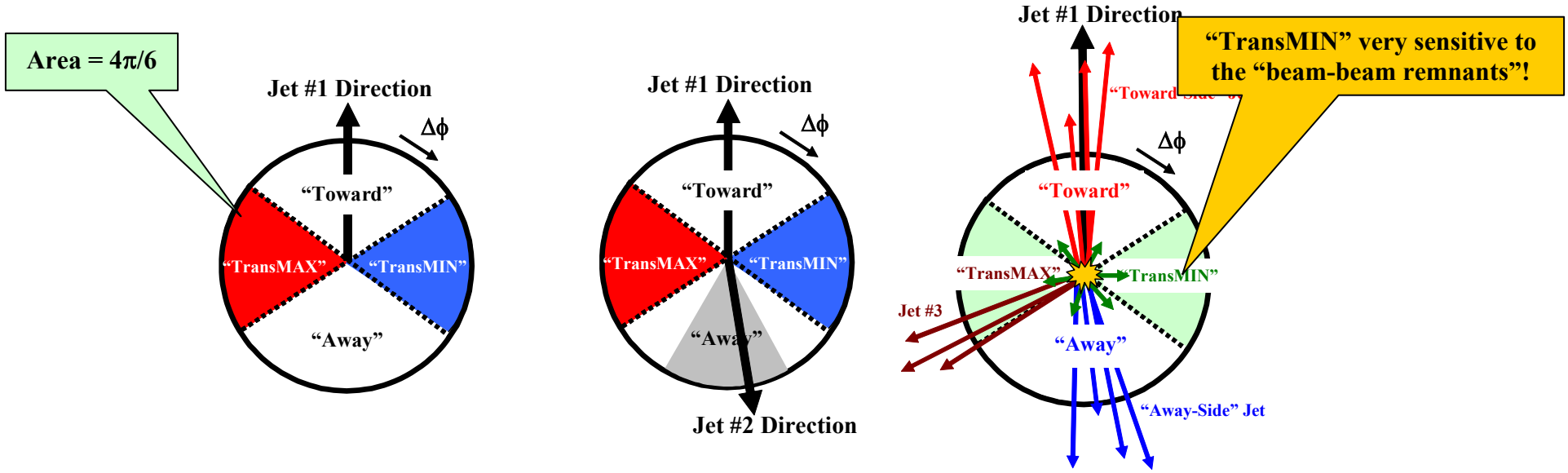
"Transverse" Observables: Particle and Detector Level



Observable	Particle Level	Detector Level
$dN_{chg}/d\eta d\phi$	Number of charged particles per unit η-ϕ ($p_T > 0.5$ GeV/c, $\lvert\eta\rvert < 1$)	Number of "good" charged tracks per unit η-ϕ ($p_T > 0.5$ GeV/c, $\lvert\eta\rvert < 1$)
$dPTsum/d\eta d\phi$	Scalar p_T sum of charged particles per unit η-ϕ ($p_T > 0.5$ GeV/c, $\lvert\eta\rvert < 1$)	Scalar p_T sum of "good" charged tracks per unit η-ϕ ($p_T > 0.5$ GeV/c, $\lvert\eta\rvert < 1$)
$\langle p_T \rangle$	Average p_T of charged particles ($p_T > 0.5$ GeV/c, $\lvert\eta\rvert < 1$)	Average p_T of "good" charged tracks ($p_T > 0.5$ GeV/c, $\lvert\eta\rvert < 1$)
PTmax	Maximum p_T charged particle ($p_T > 0.5$ GeV/c, $\lvert\eta\rvert < 1$) PTmax = 0 for no charged particle	Maximum p_T "good" charged tracks ($p_T > 0.5$ GeV/c, $\lvert\eta\rvert < 1$) PTmax = 0 for no "good" charged track
$dE_T/d\eta d\phi$	Scalar E_T sum of all particles per unit η-ϕ (all p_T, $\lvert\eta\rvert < 1$)	Scalar E_T sum of all calorimeter towers per unit η-ϕ ($E_T > 0.1$ GeV, $\lvert\eta\rvert < 1$)
PTsum/ETsum	Scalar p_T sum of charged particles ($p_T > 0.5$ GeV/c, $\lvert\eta\rvert < 1$) divided by the scalar E_T sum of all particles (all p_T, $\lvert\eta\rvert < 1$)	Scalar p_T sum of "good" charged tracks ($p_T > 0.5$ GeV/c, $\lvert\eta\rvert < 1$) divided by the scalar E_T sum of calorimeter towers ($E_T > 0.1$ GeV, $\lvert\eta\rvert < 1$)

- **Observables examined in the "transverse" region as they are defined at the particle level and the detector level. The mean charged particle $\langle p_T \rangle$ and the charged fraction PTsum/ETsum are constructed on and event-by-event basis and then averaged over the events. There is one PTmax per event with PTmax = 0 if there are no charged particles.**

"transMAX" and "transMIN" Densities



- **Define the MAX and MIN "transverse" regions on an event-by-event basis with MAX (MIN) having the largest (smallest) density. Each of the two "transverse" regions have an area in η-ϕ space of 4π/6.**
- **The "transMIN" region is very sensitive to the "beam-beam remnant" and multiple parton interaction components of the "underlying event".**
- **The difference, "transDIF" ("transMAX" minus "transMIN"), is very sensitive to the "hard scattering" component of the "underlying event" (*i.e.* hard initial and final-state radiation).**

Monte-Carlo Generation

QCD 5.3.3nt Stntuples

PYTHIA Tune A		HERWIG	
P_T(hard) minimum	Events	P_T(hard) minimum	Events
0 GeV/c	3,093,106	3 GeV/c	1,014,070
10 GeV/c	1,039,093	10 GeV/c	1,018,974
18 GeV/c	4,285,687	18 GeV/c	5,001,261
40 GeV/c	4,228,873	40 GeV/c	5,071,205
60 GeV/c	992,087	60 GeV/c	1,044,202
90 GeV/c	1,497,108	90 GeV/c	2,057,661
120 GeV/c	2,068,377	120 GeV/c	2,035,473
150 GeV/c	1,488,786	150 GeV/c	1,922,568
200 GeV/c	1,042,280	200 GeV/c	968,906
300 GeV/c	1,045,314	300 GeV/c	885,867
400 GeV/c	1,043,634	400 GeV/c	858,936
Total	21,824,345	Total	21,879,123

- **PYTHIA Tune A (5.3.3nt) and HERWIG (5.3.3nt) was generated with the minimum PT(hard) values shown. Stntuples (5.3.3nt dev242) were created for the QCD group by Anwar Bhatti, Ken Hatakeyama, and Craig Group.**

Data Selection: "Leading Jet" and "Back-to-Back"

Event Selection	Min-Bias	JET20	JET50	JET70	JET100
Total Events	20,586,733	30,470,383	9,908,366	4,641,247	5,366,515
"Good" Events (version 7)	18,180,015	19,835,681	6,868,114	3,432,992	4,031,324
MetSig < 5 $GeV^{1/2}$, sumET < 1.5 TeV	18,179,280	19,818,879	6,785,357	3,316,514	3,602,989
1 Q12 ZVtx, |z| < 60 cm	15,416,180	10,851,963	3,745,616	1,794,739	1,939,382
"Leading Jet" |η(jet#1) < 2|	3,712,407	7,679,594	3,200,065	1,648,764	1,884,353
"Back-to-Back" P_T(jet#3) < 15 GeV/c	2,474	1,462,547	878,014	491,930	602,256
"Back-to-Back"/"Leading Jet"	0.07%	19.04%	27.44%	29.84%	31.96%

"Back-to-Back" events are a subset of the "Leading Jet" events

QCD 5.3.3nt Stntuples

- The data used in this analysis arise from the set of Stntuples created for the QCD group by Anwar Bhatti, Ken Hatakeyama, and Craig Group ($L \sim 380$ pb^{-1}). Events are required to be on the "goodrun" list (version 7). They are also required to have a missing E_T significance less than 5 $GeV^{1/2}$ and to have a sumE_T < 1.5 TeV. Except for the Min-Bias data we require events to have one and only one quality 12 vertex with |z| < 60 cm. For the Min-Bias data we allow zero or one quality 12 vertices. This only affects the observables for leading jet P_T below 10 GeV/c. Above P_T(jet#1) = 10 GeV/c the fraction of events with no quality 12 vertex is negligible.

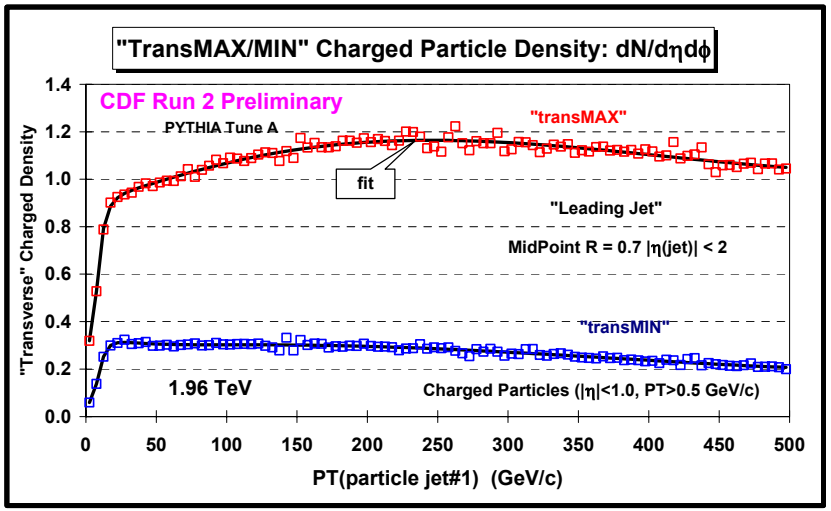
Method 1: Correcting to the Particle Level

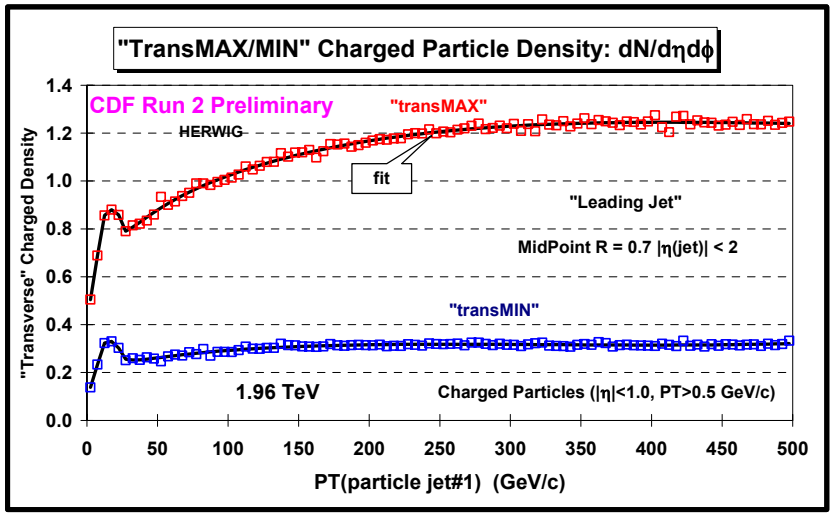
Method 1 (one step method):

Particle Level Observable	Detector Level Observable	"Response" Factor	"Correction" Factor
GEN = Particle Jet#1 P_T Bin	CDFSIM = Calorimeter Jet#1 P_T Bin (uncorrected)	CDFSIM/GEN	GEN/CDFSIM

Differences between pyA and HW used to estimate systametic uncertainties!

- **PYTHIA Tune A (or HERWIG) are used to calculate the observables at the particle level in bins of particle jet#1 P_T (GEN) and at the detector level in bins of calorimeter jet#1 P_T (uncorrected). The detector level data in bins of calorimeter jet#1 PT (uncorrected) are corrected by multiplying by QCD Monte-Carlo factor, GEN/CDFSIM.**
- **Smooth curves have been drawn through the QCD Monte-Carlo predictions to aid in comparing the theory with the data.**





Fits to the QCD Monte-Carlo results the density of charged particles in the "transMAX" and "transMIN" regions for "leading jet" events as a function of the leading particle jet P_T for PYTHIA Tune A (left) and HERWIG (right).

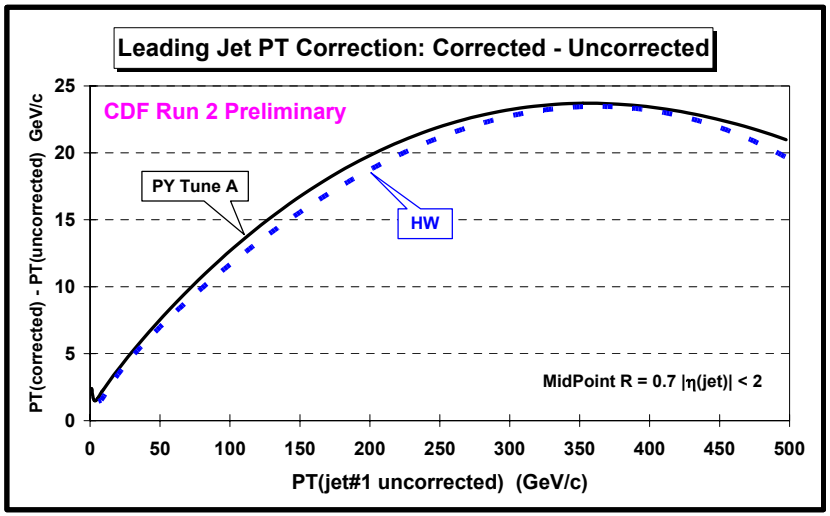
Method 2: Correcting to the Particle Level

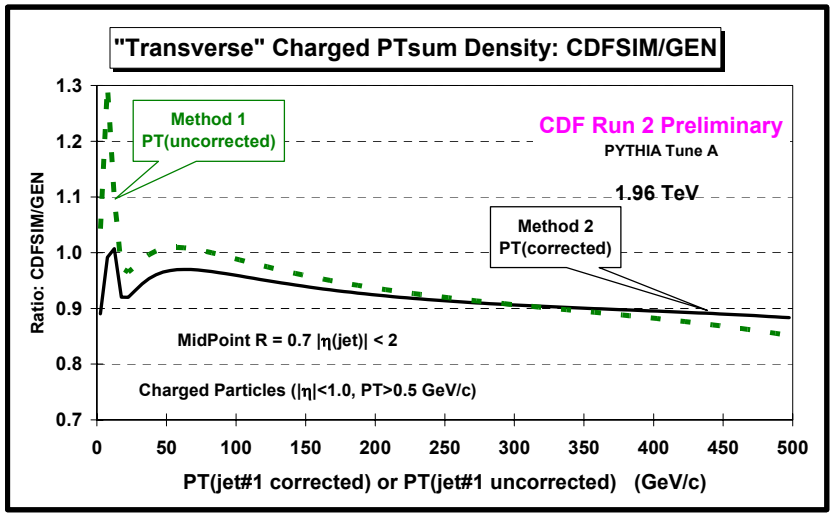
Method 2 (two step method):

Particle Level Observable	Detector Level Observable	"Response" Factor	"Correction" Factor
GEN = Particle Jet#1 P_T Bin	CDFSIM = Calorimeter Jet#1 P_T Bin (corrected)	CDFSIM/GEN	GEN/CDFSIM

Differences between method 1 and 2 used to estimate systametic uncertainties!

- **Correct the leading calorimeter jet P_T by comparing the matching leading particle jet with the leading calorimeter jet.**
- **PYTHIA Tune A is used to calculate the observables at the particle level in bins of particle jet#1 P_T (GEN) and at the detector level in bins of calorimeter jet#1 P_T (corrected). The detector level data in bins of calorimeter jet#1 PT (corrected) are corrected by multiplying by QCD Monte-Carlo factor, GEN/CDFSIM.**

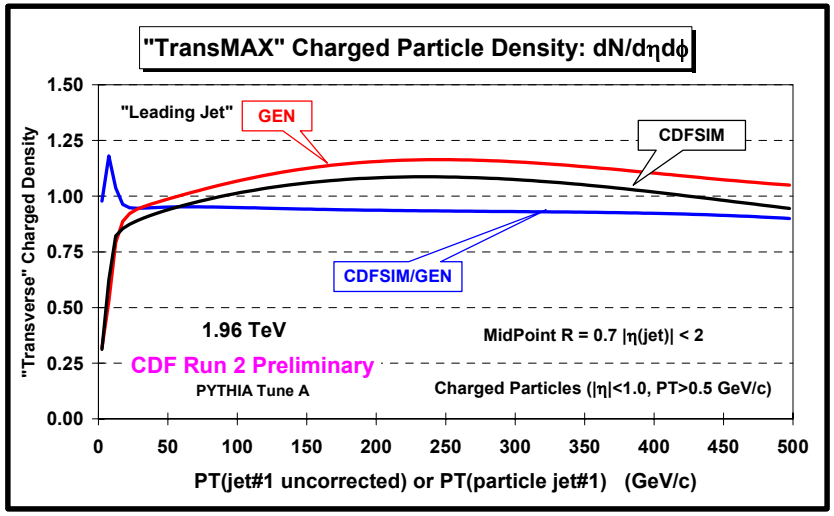




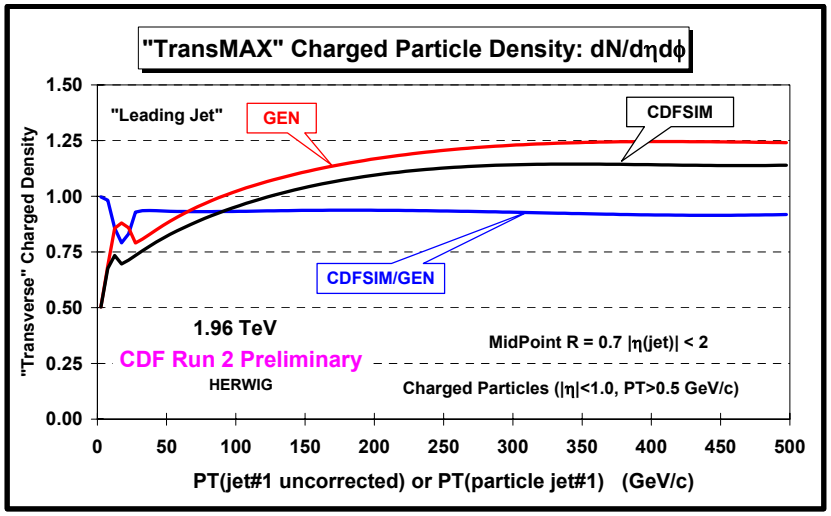
Shows the correction to the leading calorimeter jet PT from PYTHIA Tune A and HERWIG (*left*) and the "response" factor from PYTHIA Tune A for method 1 and method 2 (*right*).

Method 1 "Response" Factors: "Leading Jet" Events

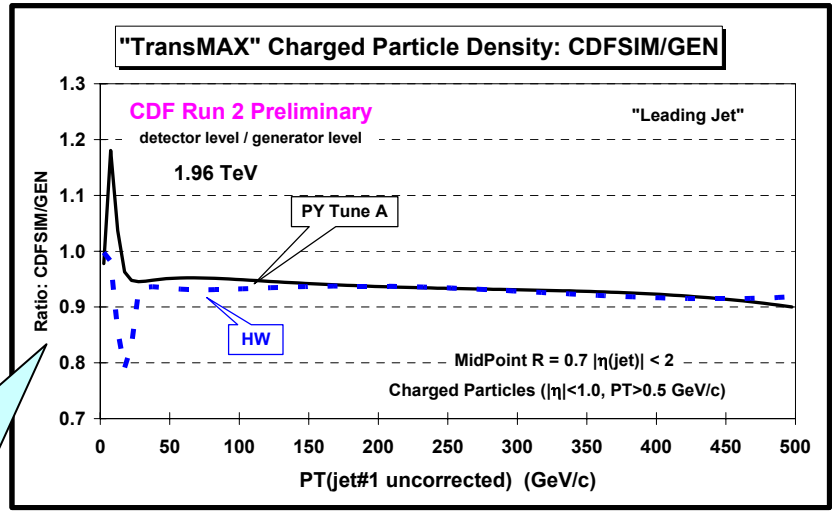
PYTHIA Tune A



HERWIG



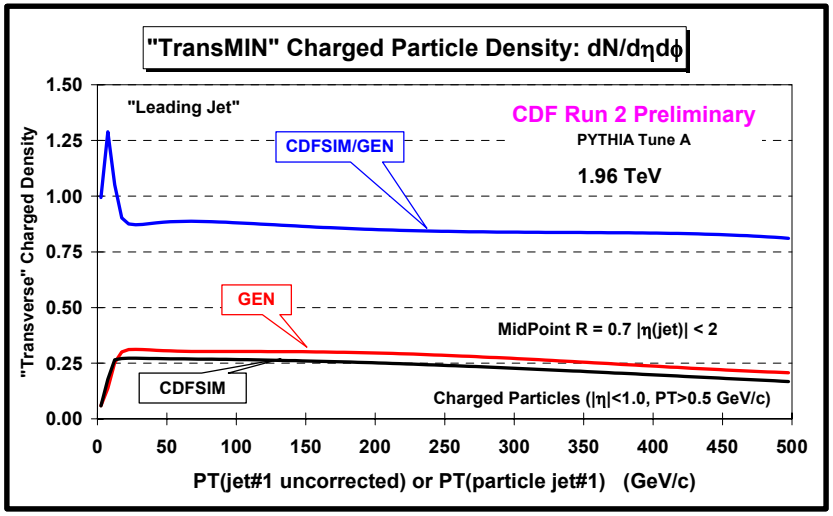
Method 1 "response" factors for the density of charged particles, $dN_{chg}/d\eta d\phi$, with $p_T > 0.5$ GeV/c and $|\eta| < 1$ in the "transMAX" region for "leading jet" events as a function of the leading jet P_T. Shows the particle level prediction (GEN) versus the leading particle jet P_T and the detector level result (CDFSIM) versus the leading calorimeter jet P_T (uncorrected) with $|\eta(\text{jet}\#1)| < 2$ for PYTHIA Tune A and HERWIG. Also shows the ratio of the detector level to the particle level, CDFSIM/GEN, versus the leading jet P_T (*i.e.* response factor).



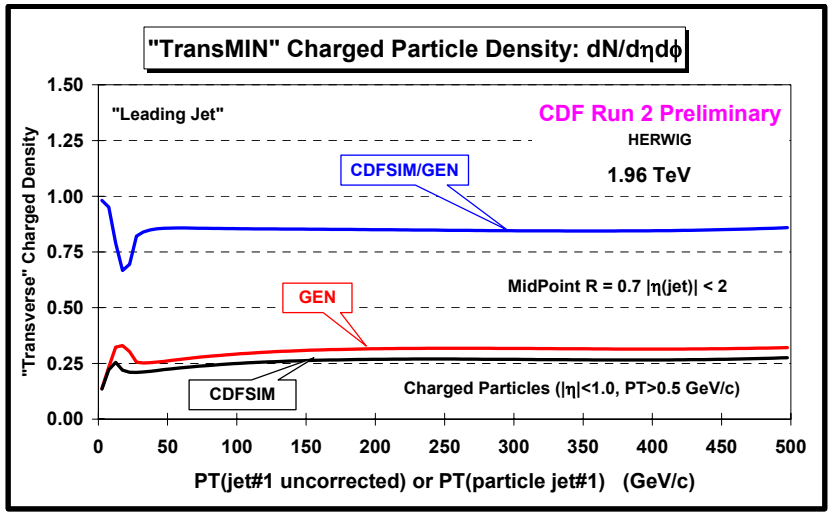
"Response" factor for PYTHIA Tune A and HERWIG!

Method 1 "Response" Factors: "Leading Jet" Events

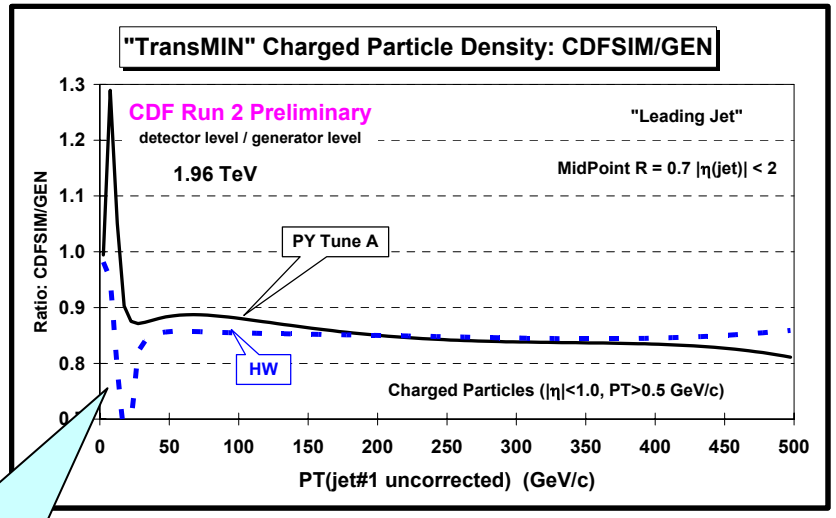
PYTHIA Tune A



HERWIG



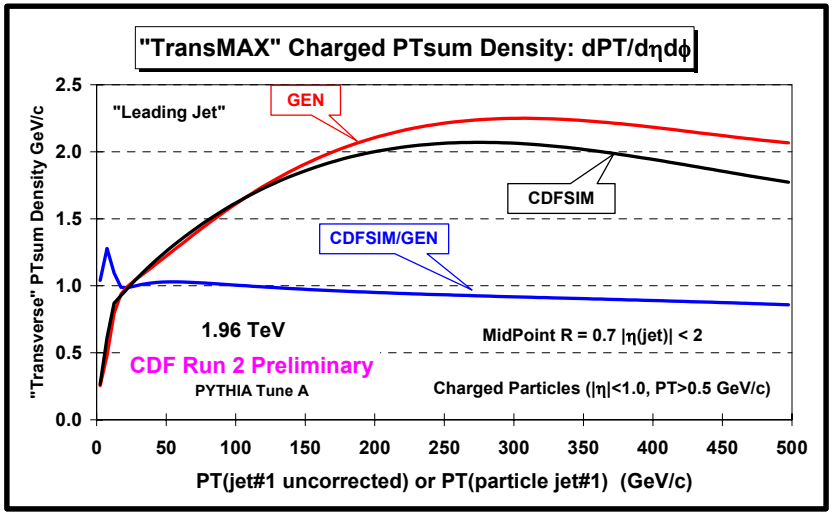
Method 1 "response" factors for the density of charged particles, $dN_{chg}/d\eta d\phi$, with $p_T > 0.5$ GeV/c and $|\eta| < 1$ in the "transMIN" region for "leading jet" events as a function of the leading jet P_T. Shows the particle level prediction (GEN) versus the leading particle jet P_T and the detector level result (CDFSIM) versus the leading calorimeter jet P_T (uncorrected) with $|\eta(\text{jet}\#1)| < 2$ for PYTHIA Tune A and HERWIG. Also shows the ratio of the detector level to the particle level, CDFSIM/GEN, versus the leading jet P_T (*i.e.* response factor).



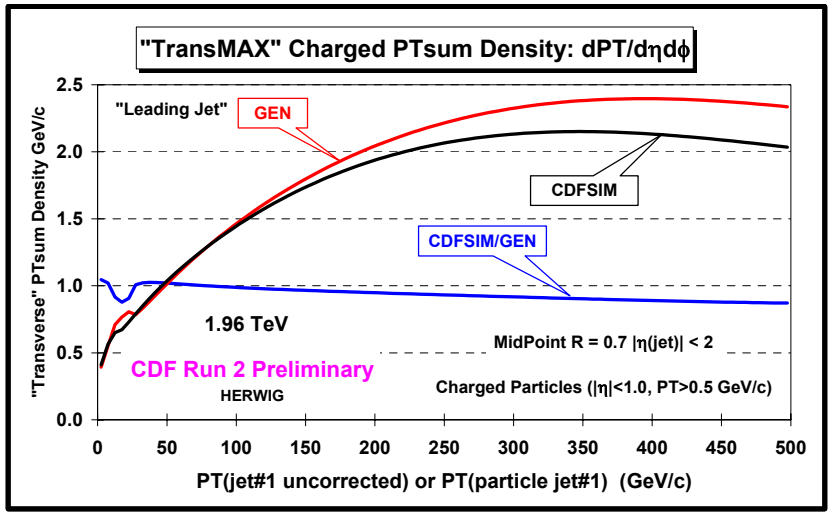
"Response" factor for PYTHIA Tune A and HERWIG!

Method 1 "Response" Factors: "Leading Jet" Events

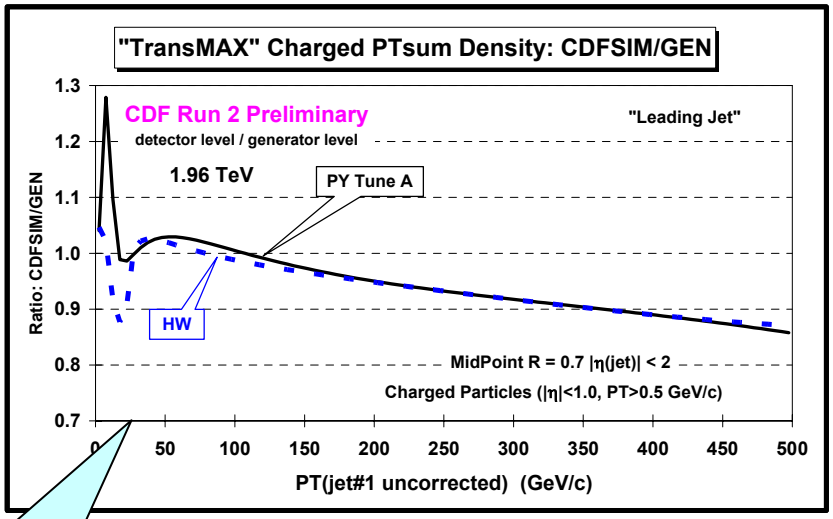
PYTHIA Tune A



HERWIG



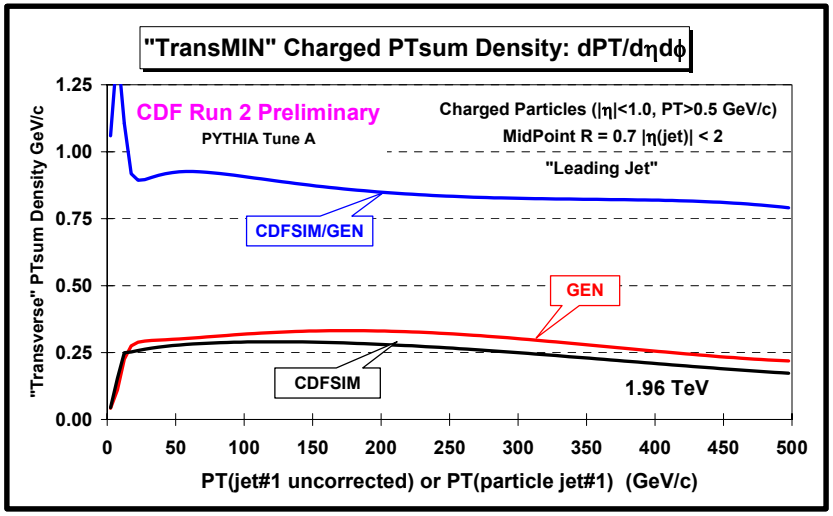
Method 1 "response" factors for the PTsum density of charged particles, dPTsum/dηdϕ, with $p_T > 0.5$ GeV/c and $|\eta| < 1$ in the "transMAX" region for "leading jet" events as a function of the leading jet P_T. Shows the particle level prediction (GEN) versus the leading particle jet P_T and the detector level result (CDFSIM) versus the leading calorimeter jet P_T (uncorrected) with $|\eta(\text{jet}\#1)| < 2$ for PYTHIA Tune A and HERWIG. Also shows the ratio of the detector level to the particle level, CDFSIM/GEN, versus the leading jet P_T (*i.e.* response factor).



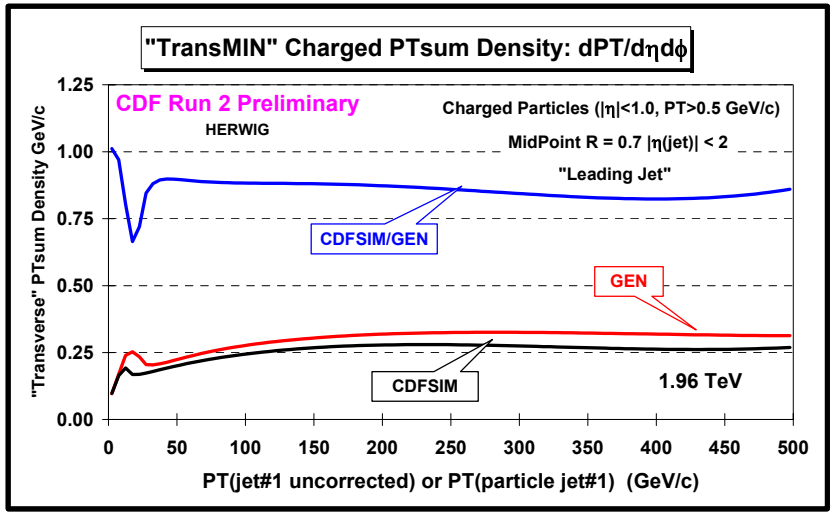
"Response" factor for PYTHIA Tune A and HERWIG!

Method 1 "Response" Factors: "Leading Jet" Events

PYTHIA Tune A



HERWIG



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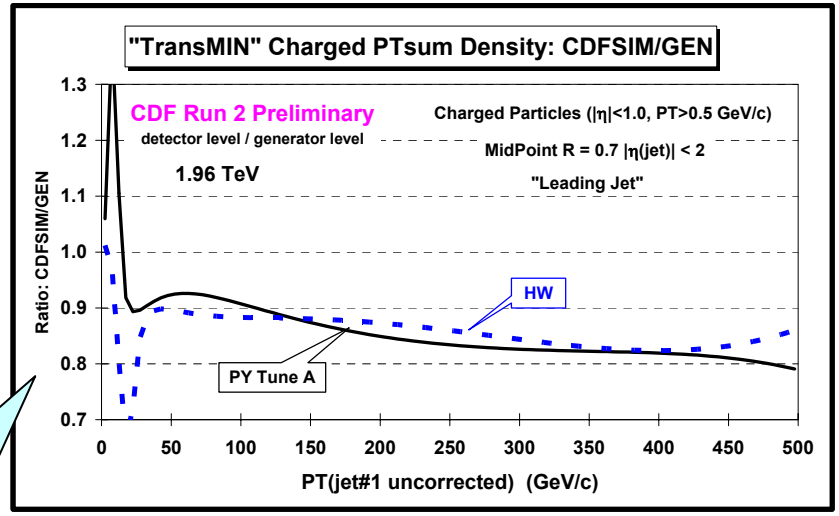
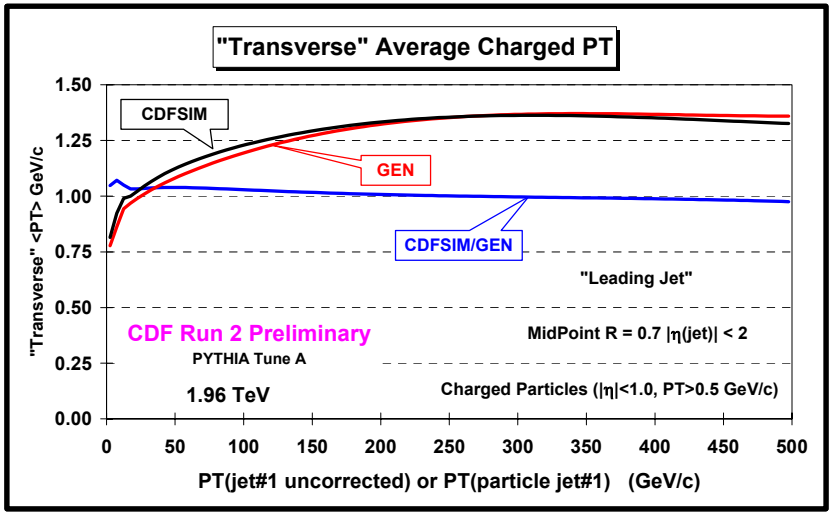


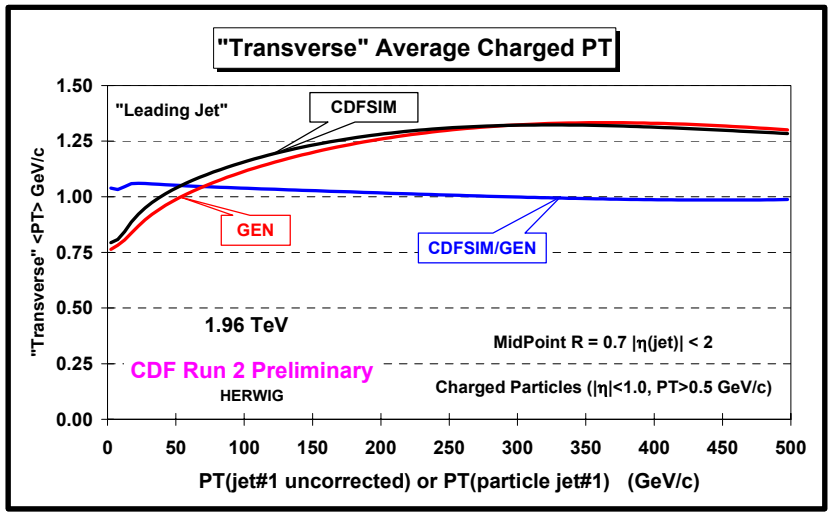
"Response" factor for PYTHIA Tune A and HERWIG!

Method 1 "Response" Factors: "Leading Jet" Events

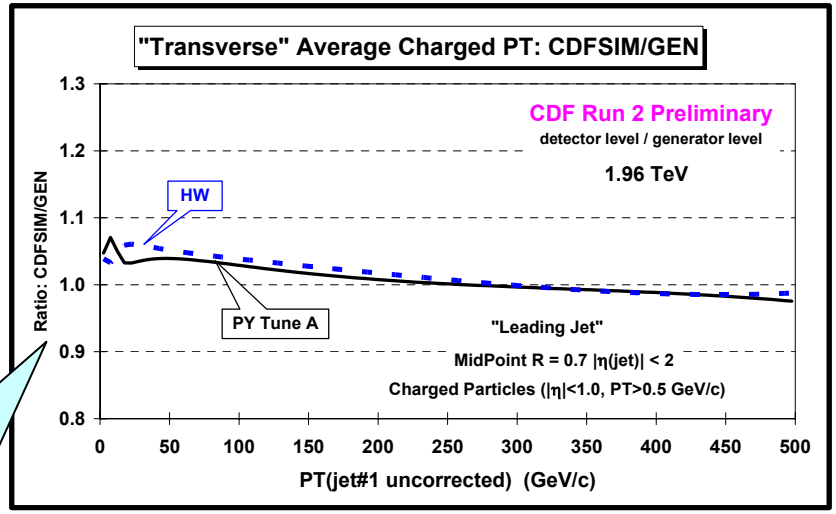
PYTHIA Tune A



HERWIG



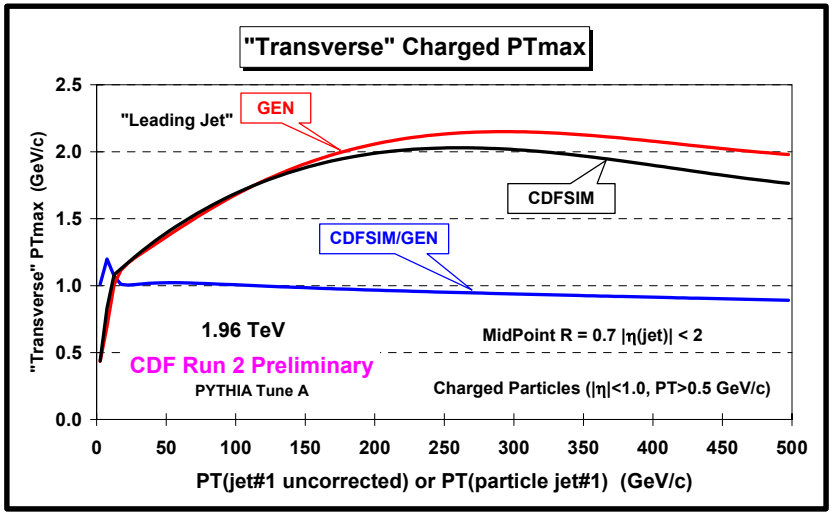
Method 1 "response" factors for the mean charged particle, $<p_T>$, for $p_T > 0.5$ GeV/c and $|\eta| < 1$ in the "transMIN" region for "leading jet" events as a function of the leading jet P_T. Shows the particle level prediction (GEN) versus the leading particle jet P_T and the detector level result (CDFSIM) versus the leading calorimeter jet P_T (uncorrected) with $|\eta(\text{jet}\#1)| < 2$ for PYTHIA Tune A and HERWIG. Also shows the ratio of the detector level to the particle level, CDFSIM/GEN, versus the leading jet P_T (*i.e.* response factor).



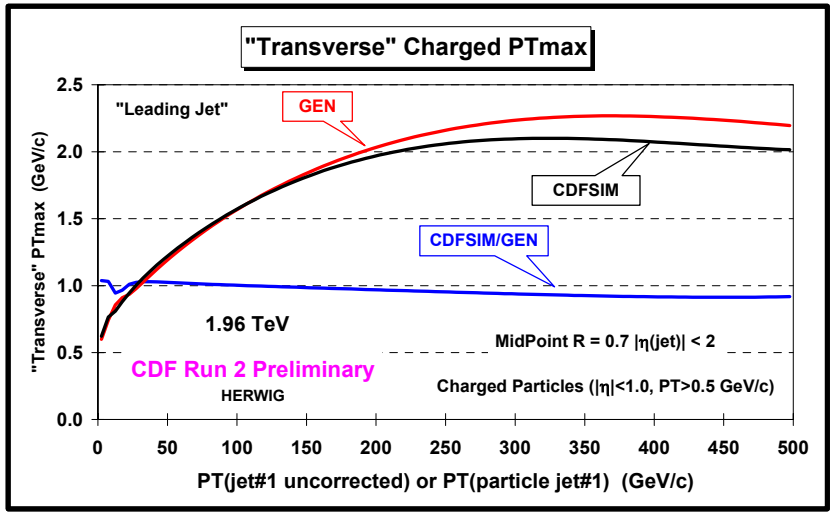
"Response" factor for PYTHIA Tune A and HERWIG!

Method 1 "Response" Factors: "Leading Jet" Events

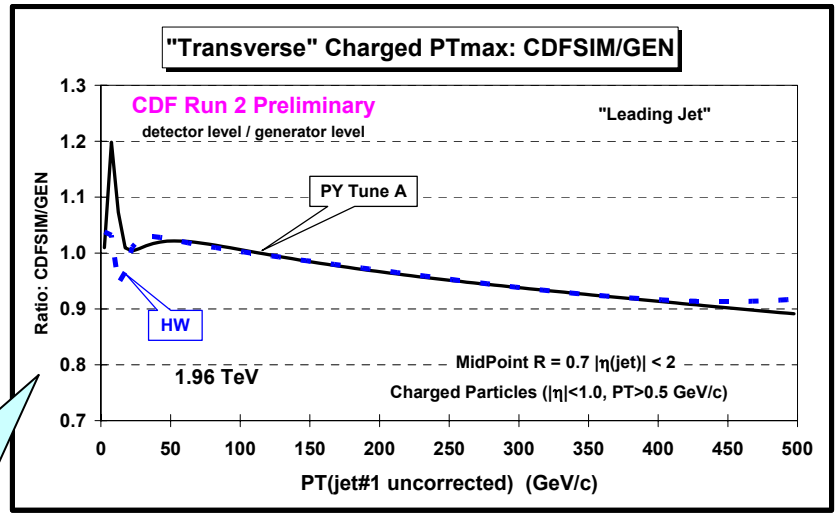
PYTHIA Tune A



HERWIG



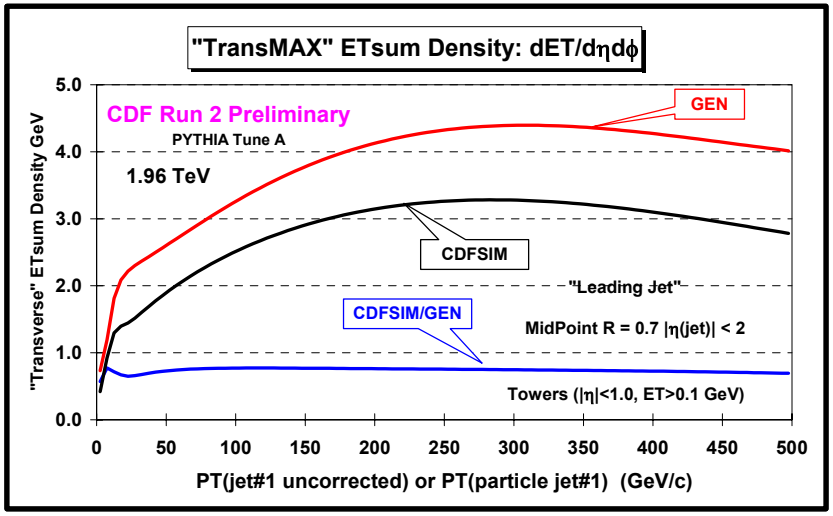
Method 1 "response" factors for the maximum p_T charged particles, PTmax, with $p_T > 0.5$ GeV/c and $|\eta| < 1$ in the "transverse" region for "leading jet" events as a function of the leading jet P_T. Shows the particle level prediction (GEN) versus the leading particle jet P_T and the detector level result (CDFSIM) versus the leading calorimeter jet P_T (uncorrected) with $|\eta(\text{jet}\#1)| < 2$ for PYTHIA Tune A and HERWIG. Also shows the ratio of the detector level to the particle level, CDFSIM/GEN, versus the leading jet P_T (*i.e.* response factor).



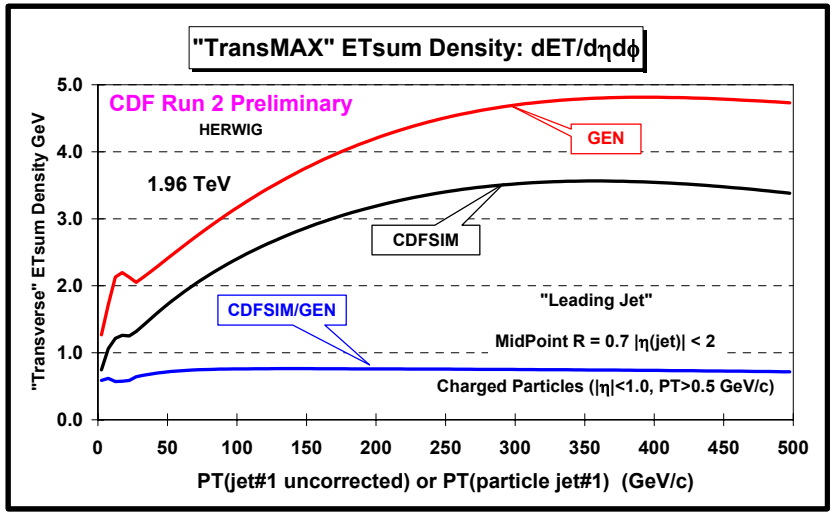
"Response" factor for PYTHIA Tune A and HERWIG!

Method 1 "Response" Factors: "Leading Jet" Events

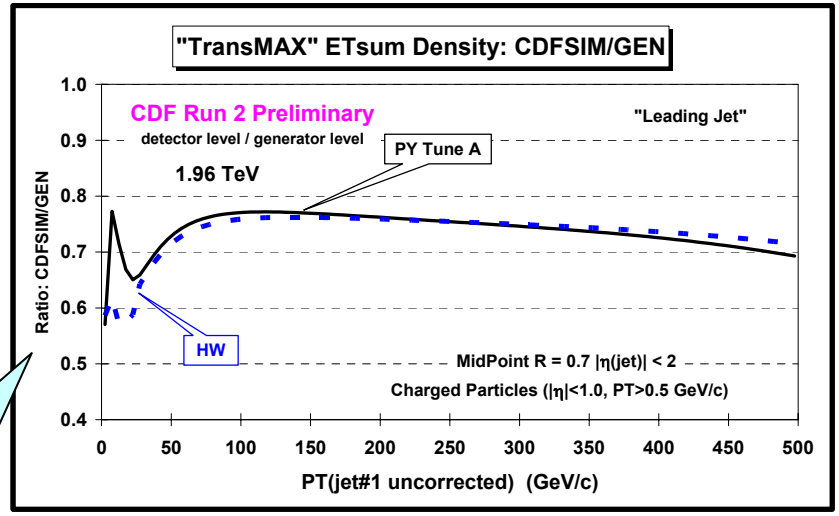
PYTHIA Tune A



HERWIG



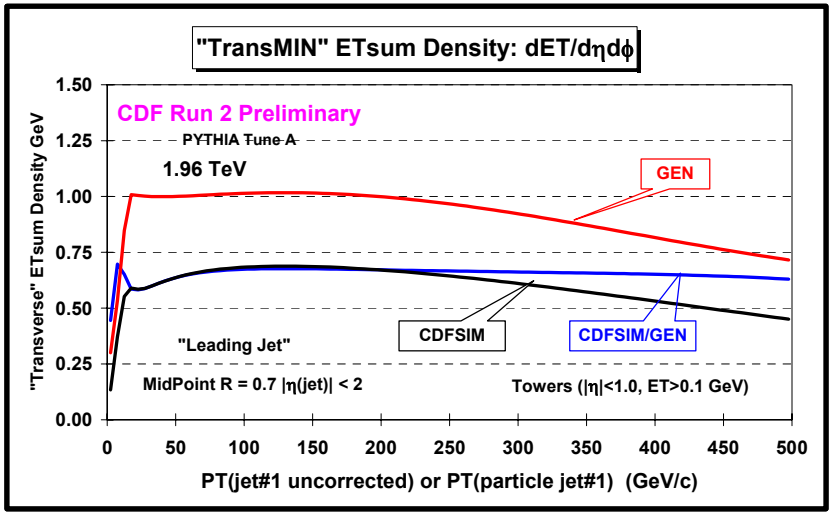
Method 1 "response" factors for the ETsum density of all particles, dET/dηdϕ, with |η| < 1 in the "transMAX" region for "leading jet" events as a function of the leading jet P_T. Shows the particle level prediction (GEN) versus the leading particle jet P_T and the detector level result (CDFSIM) versus the leading calorimeter jet P_T (uncorrected) with |η(jet#1)| < 2 for PYTHIA Tune A and HERWIG. Also shows the ratio of the detector level to the particle level, CDFSIM/GEN, versus the leading jet P_T (*i.e.* response factor).



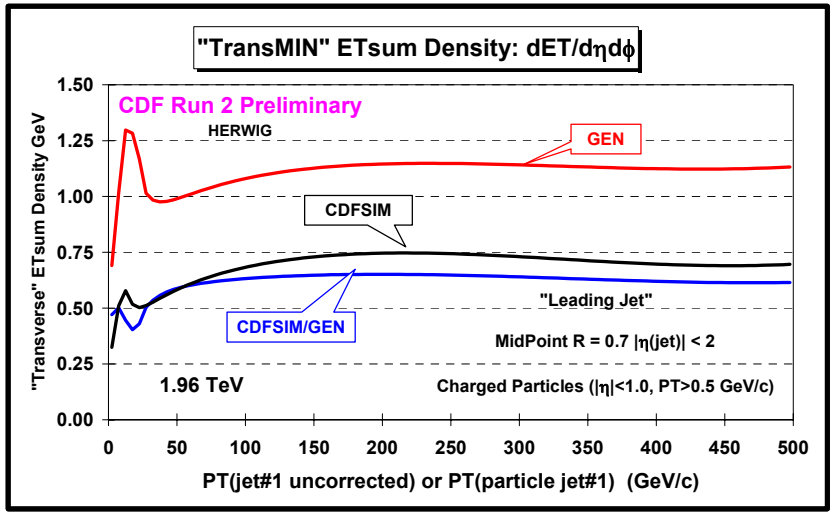
"Response" factor for PYTHIA Tune A and HERWIG!

Method 1 "Response" Factors: "Leading Jet" Events

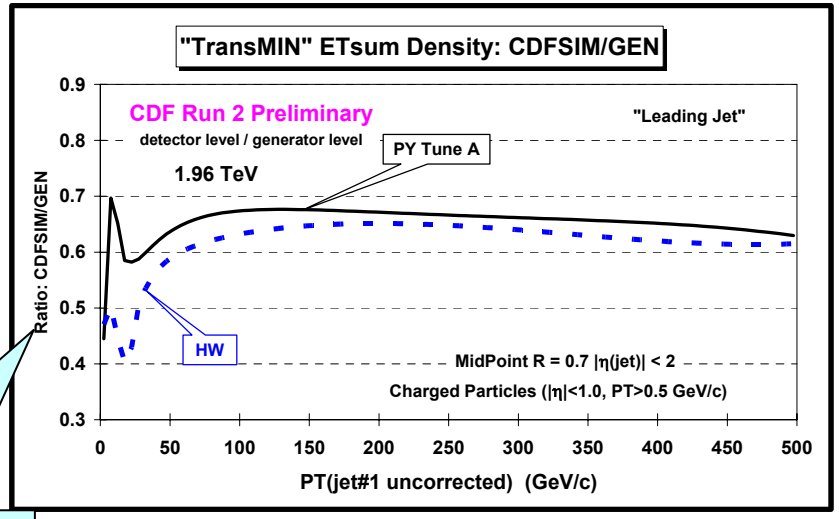
PYTHIA Tune A



HERWIG



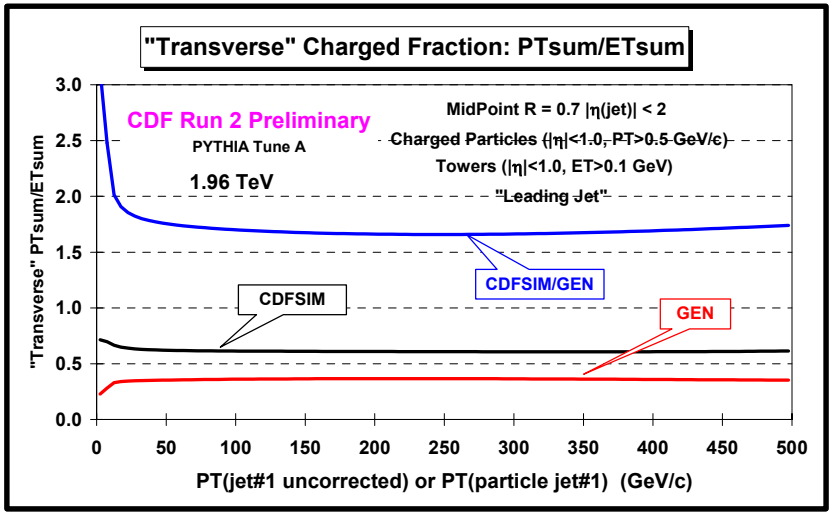
Method 1 "response" factors for the ETsum density of all particles, dET/dηdϕ, with |η| < 1 in the "transMIN" region for "leading jet" events as a function of the leading jet P_T. Shows the particle level prediction (GEN) versus the leading particle jet P_T and the detector level result (CDFSIM) versus the leading calorimeter jet P_T (uncorrected) with |η(jet#1)| < 2 for PYTHIA Tune A and HERWIG. Also shows the ratio of the detector level to the particle level, CDFSIM/GEN, versus the leading jet P_T (*i.e.* response factor).



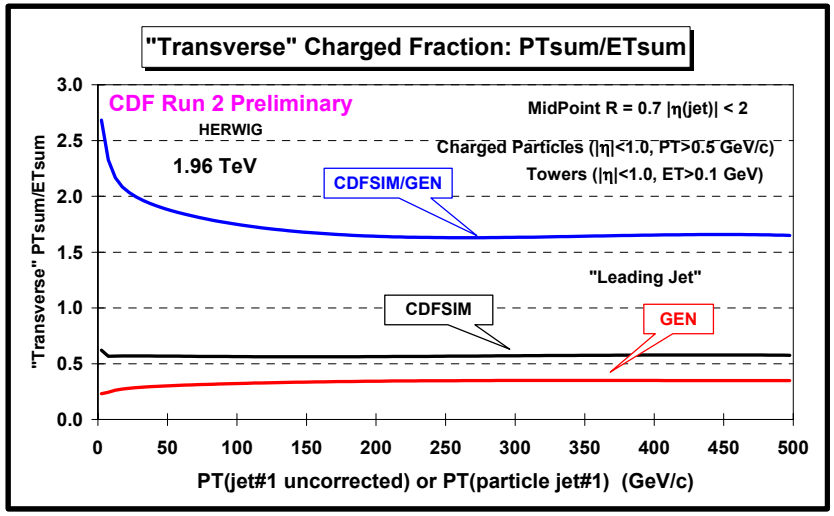
"Response" factor for PYTHIA Tune A and HERWIG!

Method 1 "Response" Factors: "Leading Jet" Events

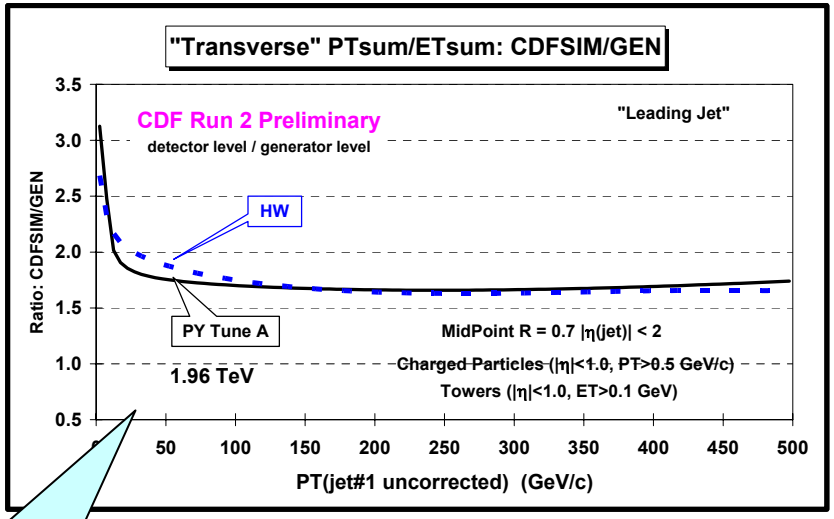
PYTHIA Tune A



HERWIG



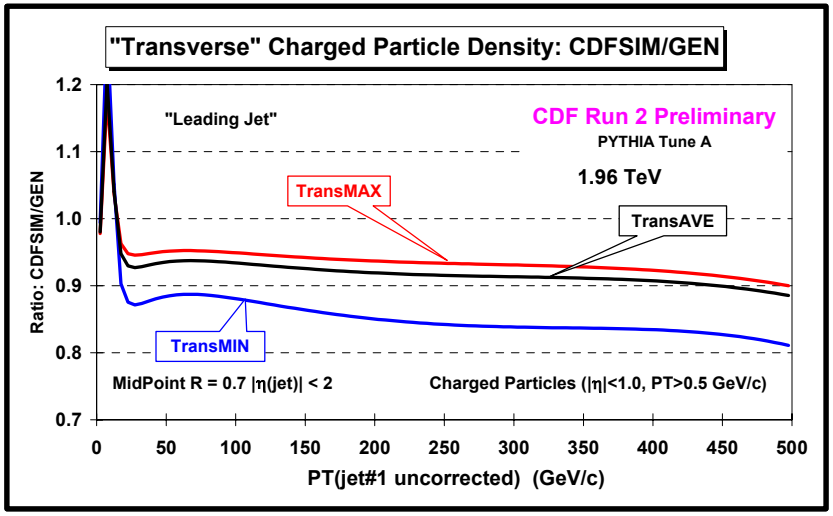
Method 1 "response" factors for the charged fraction, PTsum/ETsum, in the "transverse" region for "leading jet" events as a function of the leading jet P_T, where PTsum includes charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 1$ and the ETsum includes all particles with $|\eta| < 1$. Shows the particle level prediction (GEN) versus the leading particle jet P_T and the detector level result (CDFSIM) versus the leading calorimeter jet P_T (uncorrected) with $|\eta(\text{jet}\#1)| < 2$ for PYTHIA Tune A and HERWIG. Also shows the ratio of the detector level to the particle level, CDFSIM/GEN, versus the leading jet P_T (*i.e.* response factor).



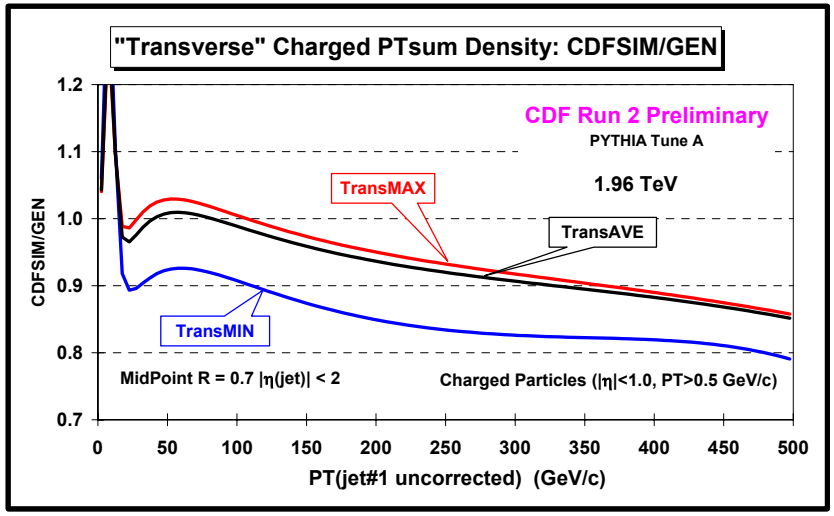
"Response" factor for PYTHIA Tune A and HERWIG!

Method 1 "Response" Factors: "Leading Jet" Events

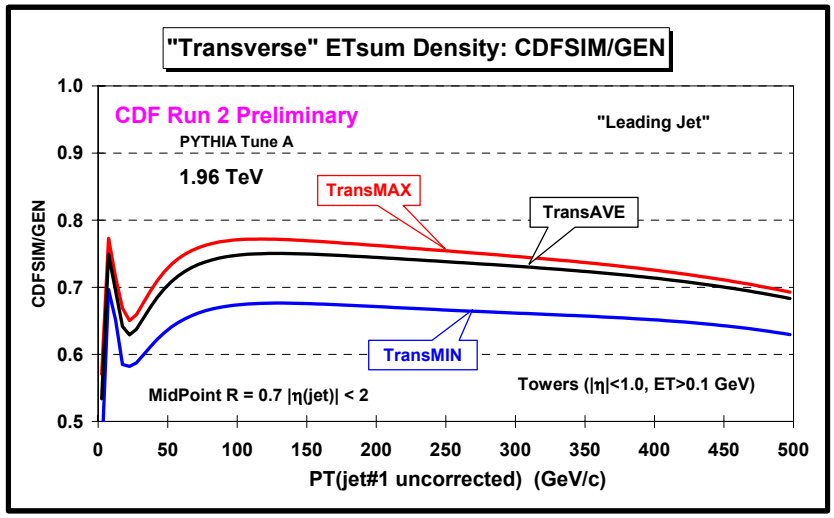
PYTHIA Tune A



HERWIG

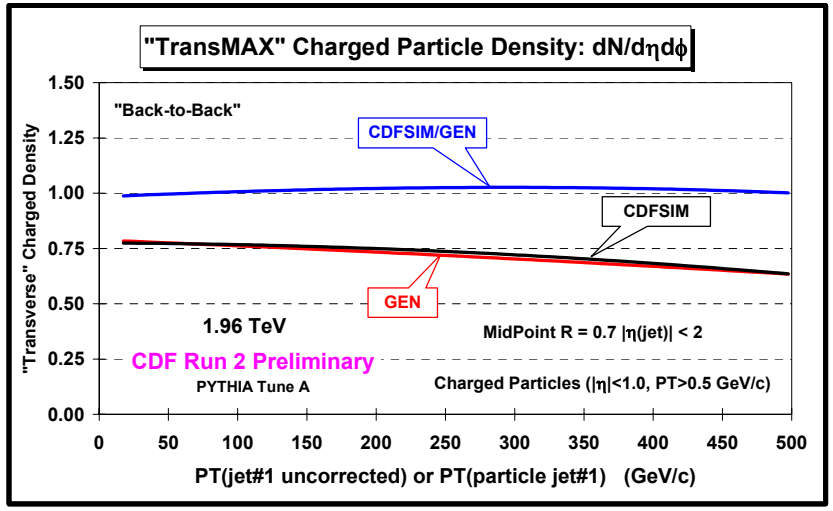


Method 1 "response" factors for the "transMAX", transMIN" and the "transverse" region (average of "transMAX" and "transMIN") for "leading jet" events as a function of the leading jet P_T for PYTHIA Tune A. Shows the ratio of the detector level to the particle level, CDFSIM/GEN, versus the leading jet P_T (*i.e.* response factor) for the charged particle density, the charged PTsum density and the energy density.

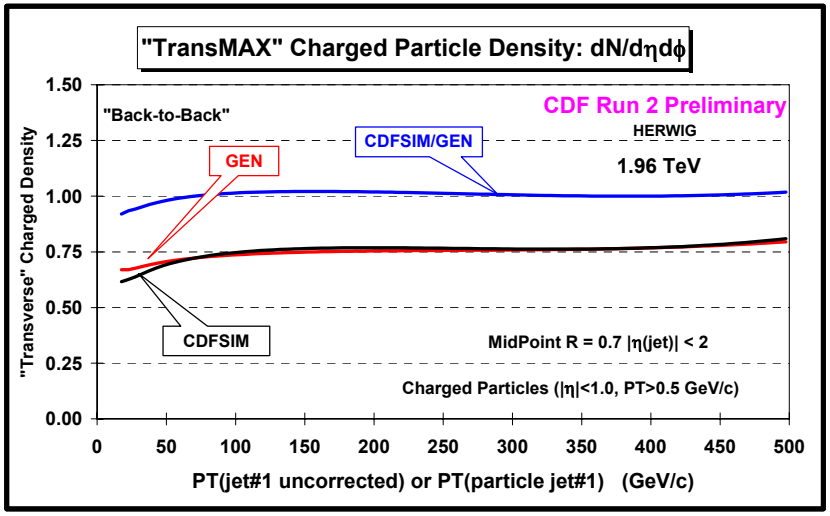


Method 1 "Response" Factors: "Back-to-Back" Events

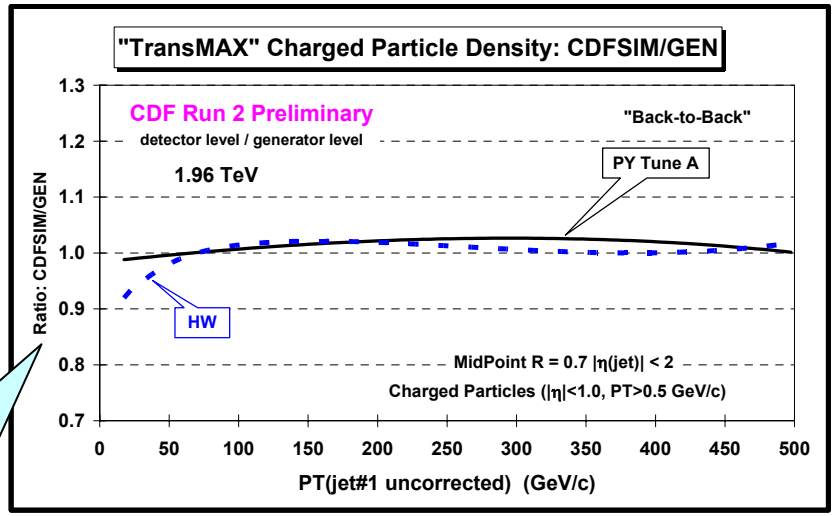
PYTHIA Tune A



HERWIG



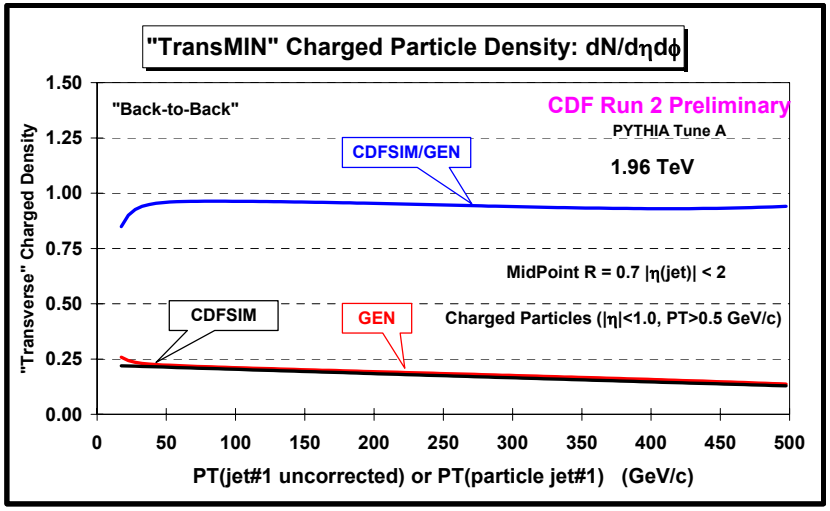
Method 1 "response" factors for the density of charged particles, $dN_{chg}/d\eta d\phi$, with $p_T > 0.5$ GeV/c and $|\eta| < 1$ in the "transMAX" region for "back-to-back" events as a function of the leading jet P_T. Shows the particle level prediction (GEN) versus the leading particle jet P_T and the detector level result (CDFSIM) versus the leading calorimeter jet P_T (uncorrected) with $|\eta(\text{jet}\#1)| < 2$ for PYTHIA Tune A and HERWIG. Also shows the ratio of the detector level to the particle level, CDFSIM/GEN, versus the leading jet P_T (*i.e.* response factor).



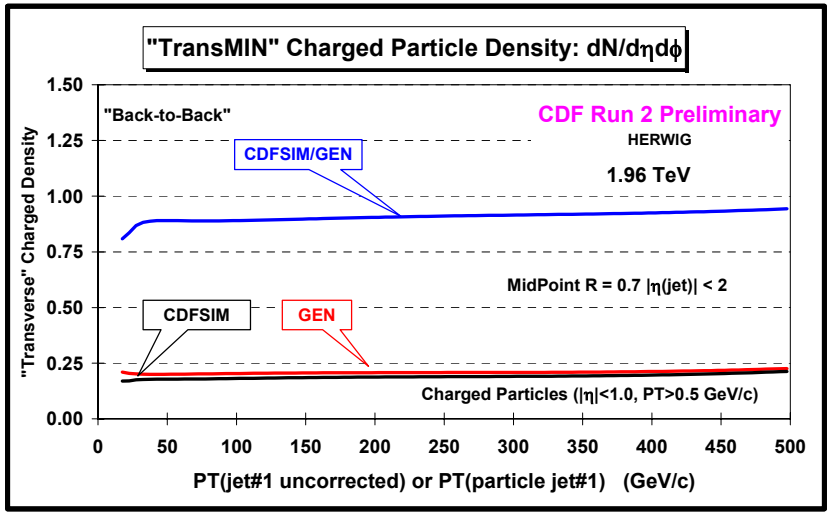
"Response" factor for PYTHIA Tune A and HERWIG!

Method 1 "Response" Factors: "Back-to-Back" Events

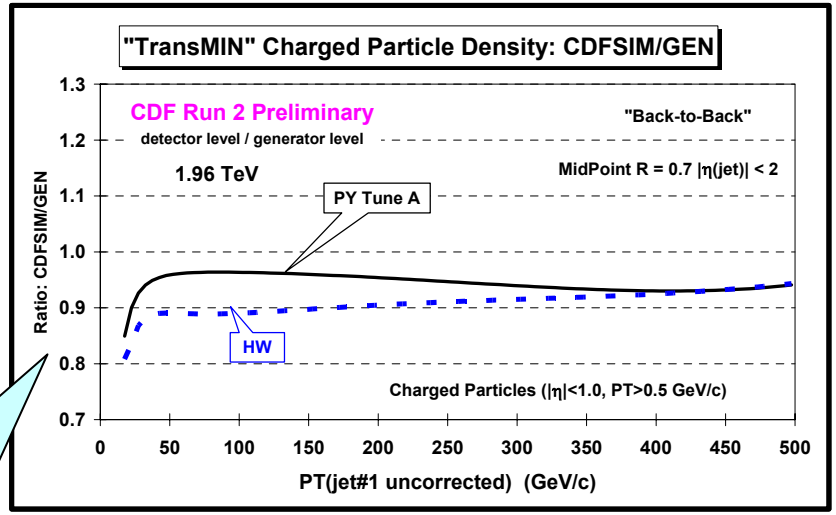
PYTHIA Tune A



HERWIG



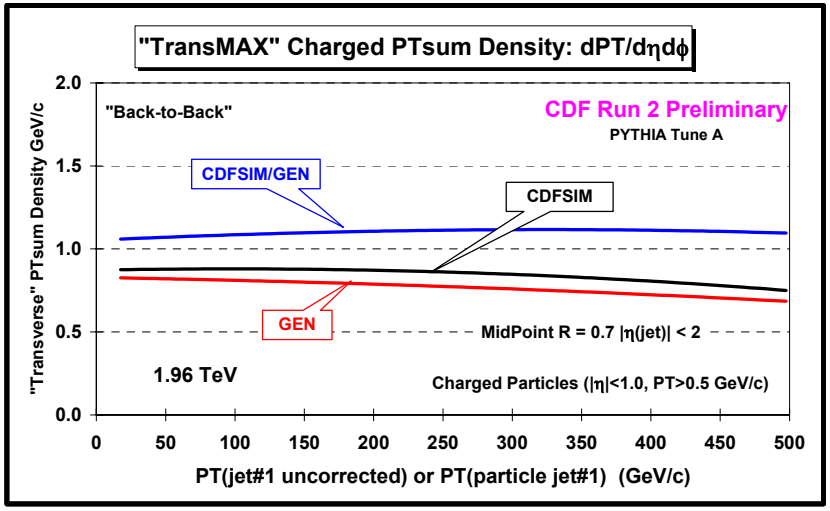
Method 1 "response" factors for the density of charged particles, $dN_{chg}/d\eta d\phi$, with $p_T > 0.5$ GeV/c and $|\eta| < 1$ in the "transMIN" region for "back-to-back" events as a function of the leading jet P_T. Shows the particle level prediction (GEN) versus the leading particle jet P_T and the detector level result (CDFSIM) versus the leading calorimeter jet P_T (uncorrected) with $|\eta(\text{jet}\#1)| < 2$ for PYTHIA Tune A and HERWIG. Also shows the ratio of the detector level to the particle level, CDFSIM/GEN, versus the leading jet P_T (*i.e.* response factor).



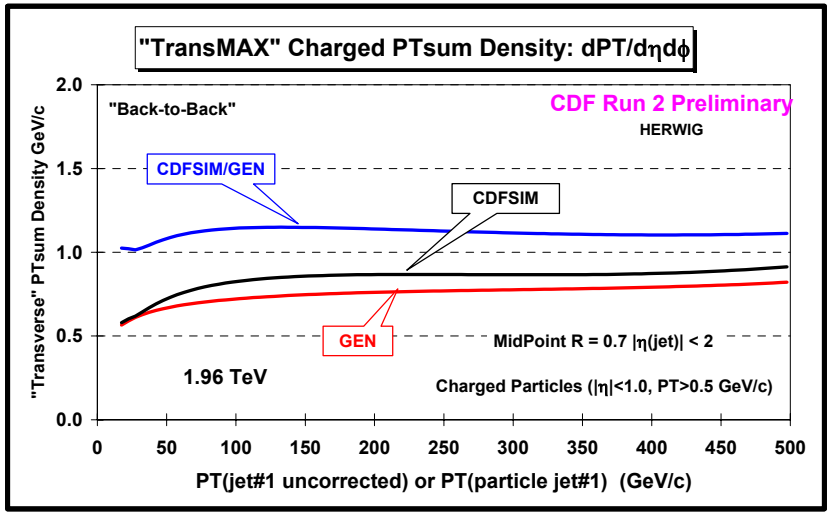
"Response" factor for PYTHIA Tune A and HERWIG!

Method 1 "Response" Factors: "Back-to-Back" Events

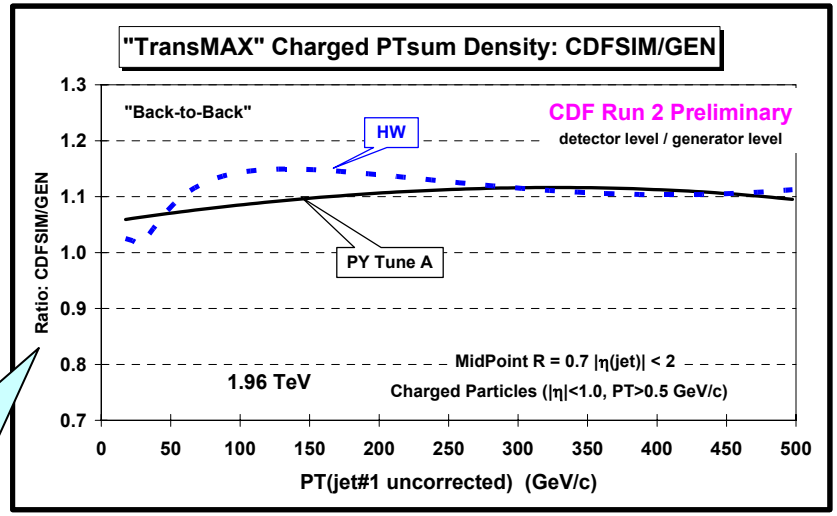
PYTHIA Tune A



HERWIG



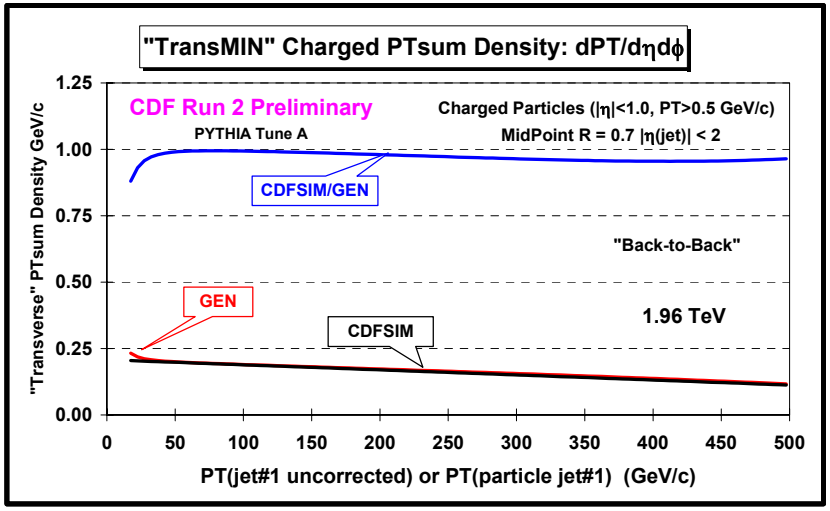
Method 1 "response" factors for the PTsum density of charged particles, dPTsum/dηdφ, with $p_T > 0.5$ GeV/c and $|\eta| < 1$ in the "transMAX" region for "back-to-back" events as a function of the leading jet P_T. Shows the particle level prediction (GEN) versus the leading particle jet P_T and the detector level result (CDFSIM) versus the leading calorimeter jet P_T (uncorrected) with $|\eta(\text{jet}\#1)| < 2$ for PYTHIA Tune A and HERWIG. Also shows the ratio of the detector level to the particle level, CDFSIM/GEN, versus the leading jet P_T (*i.e.* response factor).



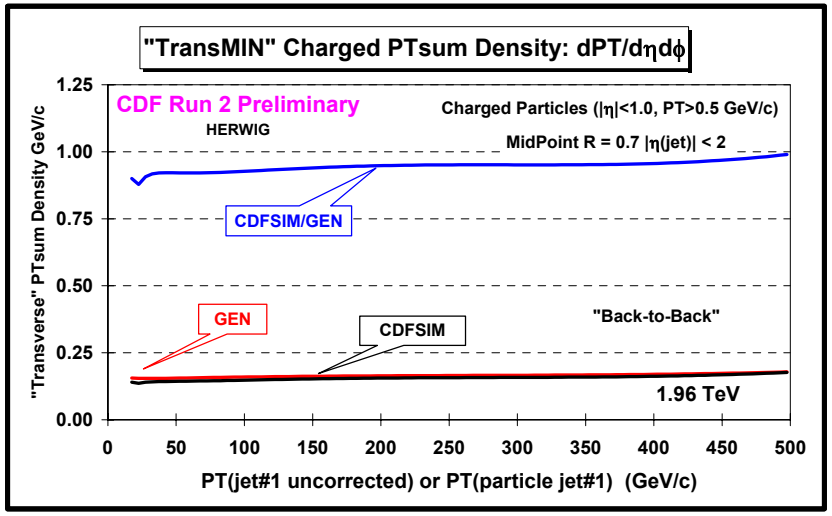
"Response" factor for PYTHIA Tune A and HERWIG!

Method 1 "Response" Factors: "Back-to-Back" Events

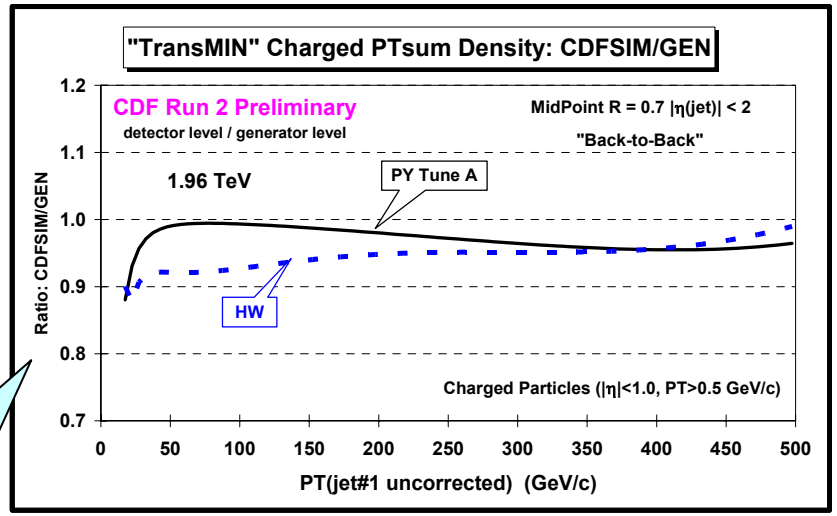
PYTHIA Tune A



HERWIG



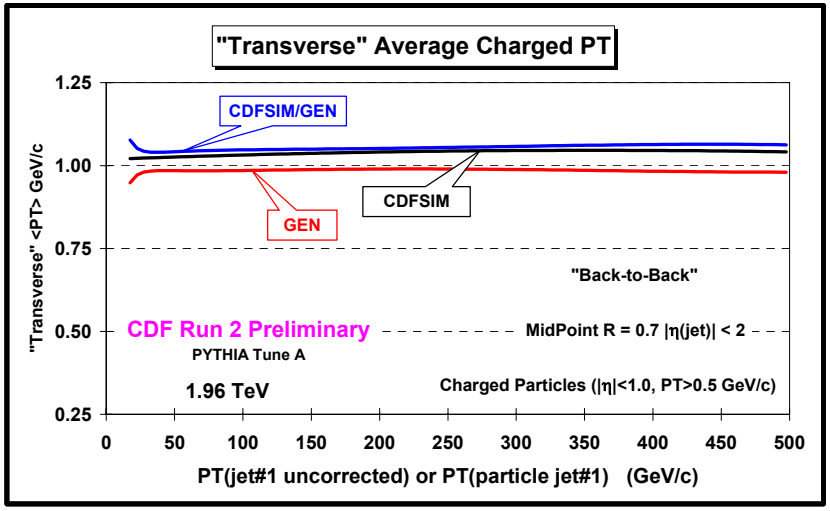
Method 1 "response" factors for the PTsum density of charged particles, dPTsum/dηdϕ, with $p_T > 0.5$ GeV/c and $|\eta| < 1$ in the "transMIN" region for "back-to-back" events as a function of the leading jet P_T. Shows the particle level prediction (GEN) versus the leading particle jet P_T and the detector level result (CDFSIM) versus the leading calorimeter jet P_T (uncorrected) with $|\eta(\text{jet}\#1)| < 2$ for PYTHIA Tune A and HERWIG. Also shows the ratio of the detector level to the particle level, CDFSIM/GEN, versus the leading jet P_T (*i.e.* response factor).



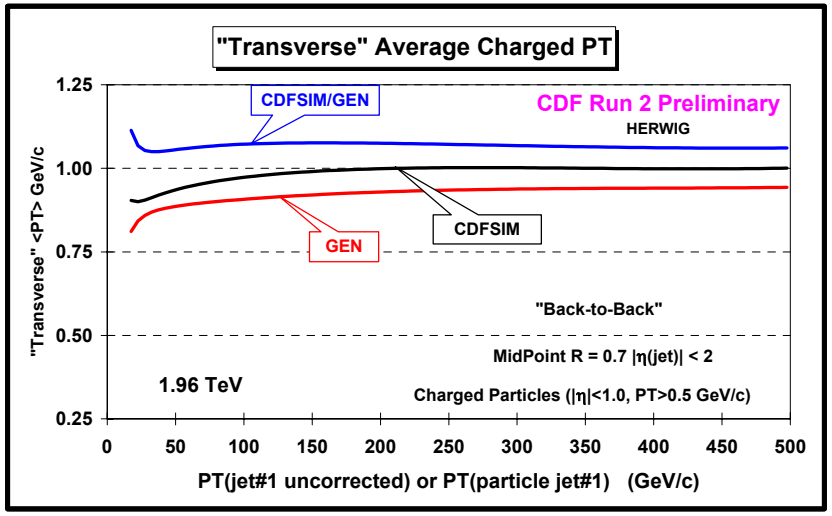
"Response" factor for PYTHIA Tune A and HERWIG!

Method 1 "Response" Factors: "Back-to-Back" Events

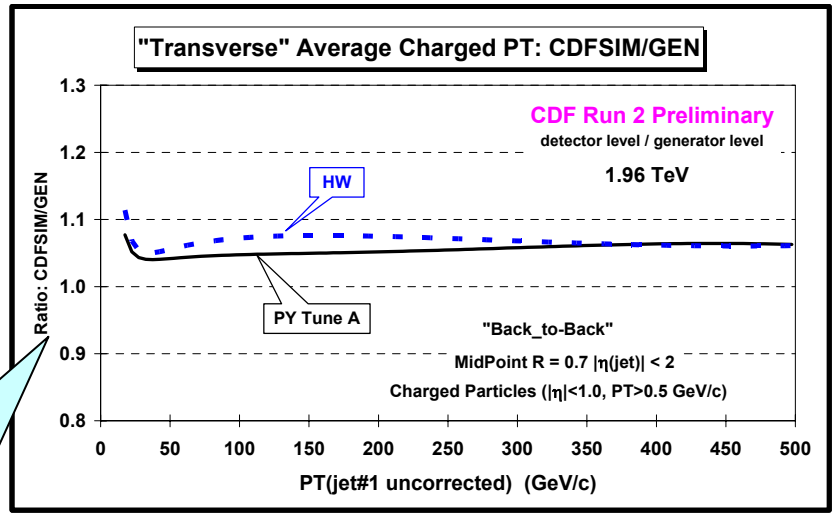
PYTHIA Tune A



HERWIG



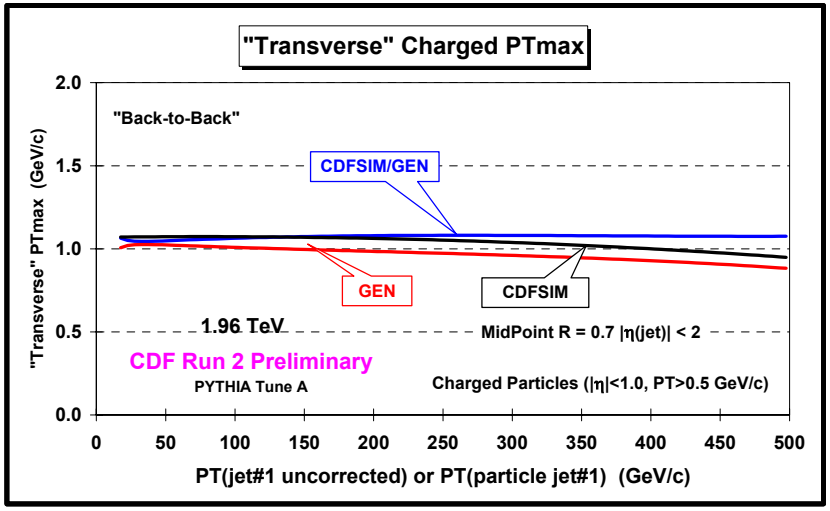
Method 1 "response" factors for the mean charged particle, $<p_T>$, for $p_T > 0.5$ GeV/c and $|\eta| < 1$ in the "transverse" region for "back-to-back" events as a function of the leading jet P_T. Shows the particle level prediction (GEN) versus the leading particle jet P_T and the detector level result (CDFSIM) versus the leading calorimeter jet P_T (uncorrected) with $|\eta(\text{jet}\#1)| < 2$ for PYTHIA Tune A and HERWIG. Also shows the ratio of the detector level to the particle level, CDFSIM/GEN, versus the leading jet P_T (*i.e.* response factor).



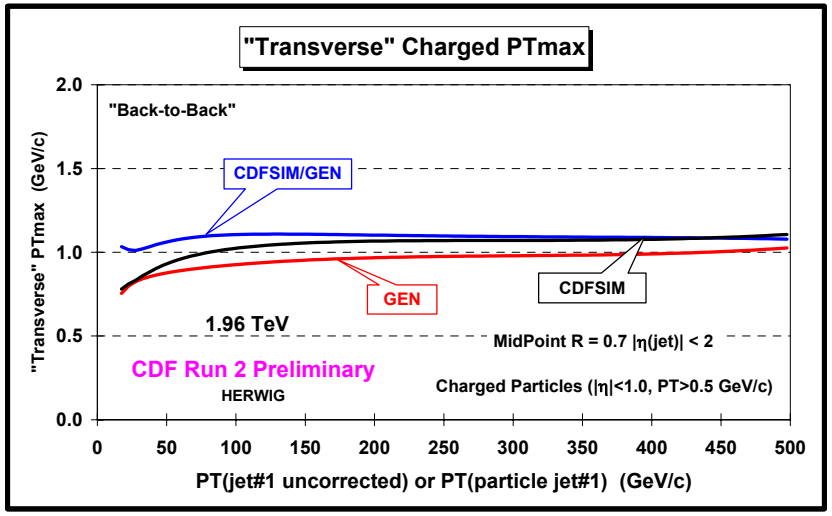
"Response" factor for PYTHIA Tune A and HERWIG!

Method 1 "Response" Factors: "Back-to-Back" Events

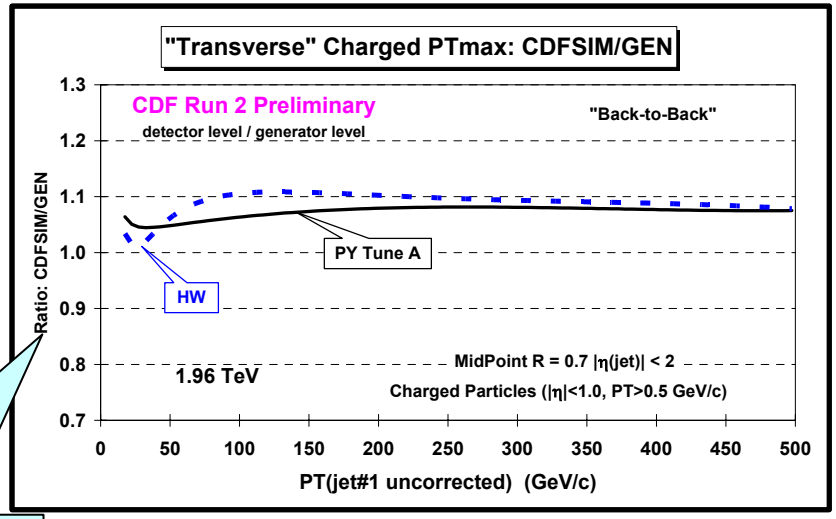
PYTHIA Tune A



HERWIG



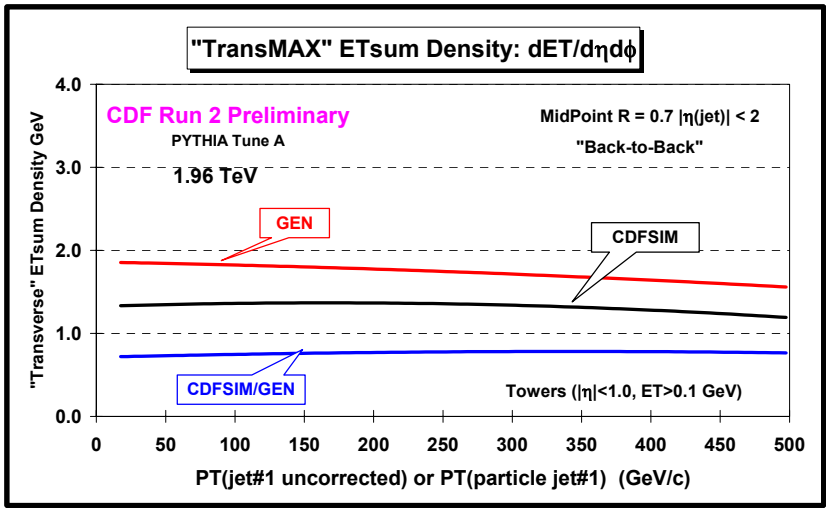
Method 1 "response" factors for the maximum p_T charged particle, PTmax, with $p_T > 0.5$ GeV/c and $|\eta| < 1$ in the "transverse" region for "back-to-back" events as a function of the leading jet P_T. Shows the particle level prediction (GEN) versus the leading particle jet P_T and the detector level result (CDFSIM) versus the leading calorimeter jet P_T (uncorrected) with $|\eta(\text{jet}\#1)| < 2$ for PYTHIA Tune A and HERWIG. Also shows the ratio of the detector level to the particle level, CDFSIM/GEN, versus the leading jet P_T (*i.e.* response factor).

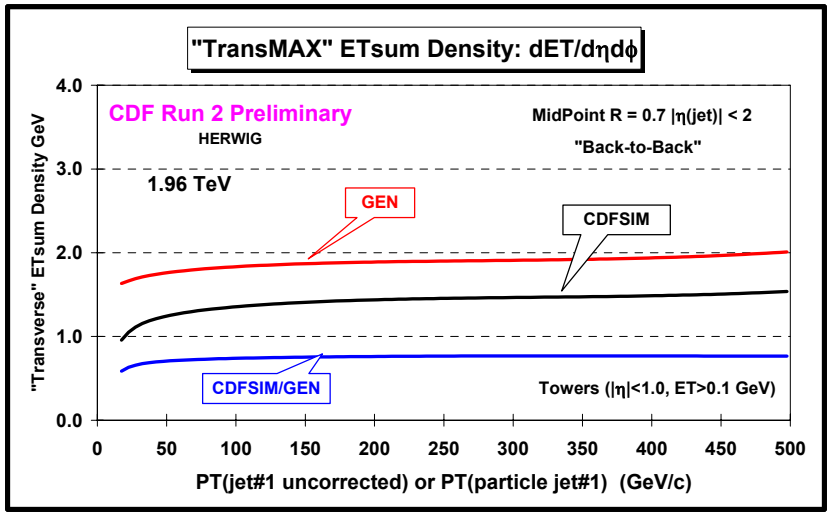


"Response" factor for PYTHIA Tune A and HERWIG!

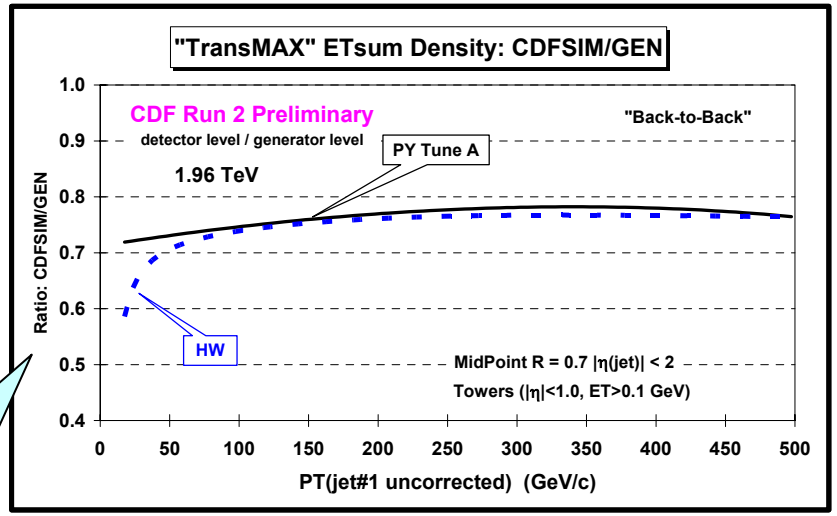
Method 1 "Response" Factors: "Back-to-Back" Events

PYTHIA Tune A HERWIG





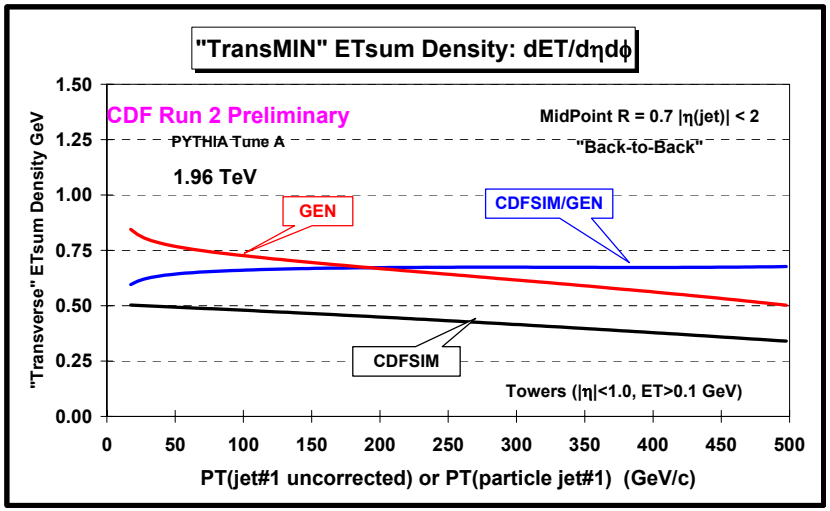
Method 1 "response" factors for the ETsum density of all particles, dET/dηdϕ, with |η| < 1 in the "transMAX" region for "back-to-back" events as a function of the leading jet P_T. Shows the particle level prediction (GEN) versus the leading particle jet P_T and the detector level result (CDFSIM) versus the leading calorimeter jet P_T (uncorrected) with |η(jet#1)| < 2 for PYTHIA Tune A and HERWIG. Also shows the ratio of the detector level to the particle level, CDFSIM/GEN versus the leading jet P_T (*i.e.* response factor).



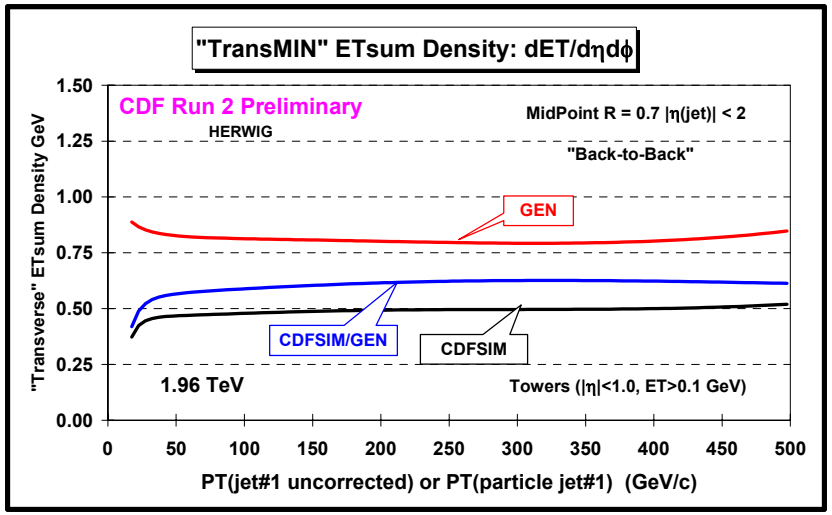
"Response" factor for PYTHIA Tune A and HERWIG!

Method 1 "Response" Factors: "Back-to-Back" Events

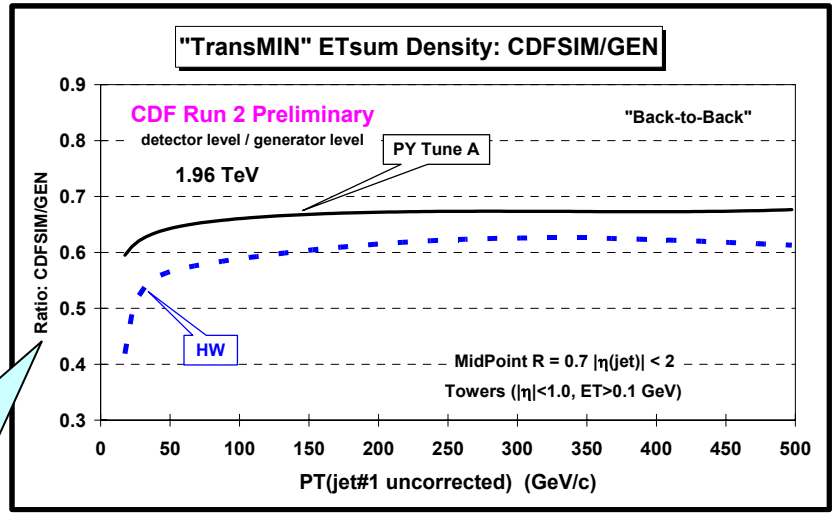
PYTHIA Tune A



HERWIG



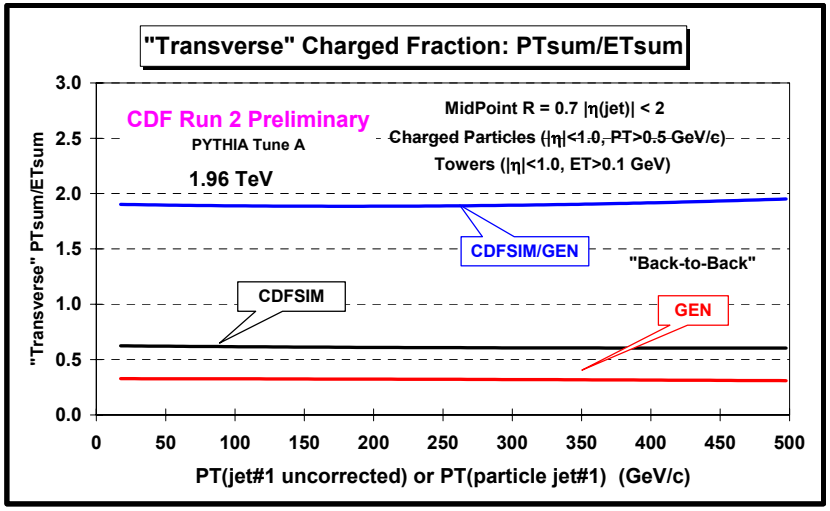
Method 1 "response" factors for the ETsum density of all particles, dET/dηdϕ, with |η| < 1 in the "transMIN" region for "back-to-back" events as a function of the leading jet P_T. Shows the particle level prediction (GEN) versus the leading particle jet P_T and the detector level result (CDFSIM) versus the leading calorimeter jet P_T (uncorrected) with |η(jet#1)| < 2 for PYTHIA Tune A and HERWIG. Also shows the ratio of the detector level to the particle level, CDFSIM/GEN versus the leading jet P_T (*i.e.* response factor).



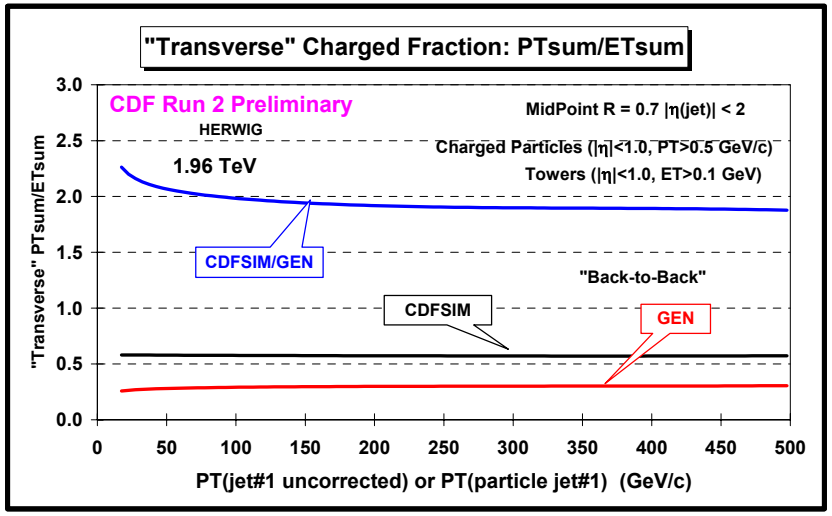
"Response" factor for PYTHIA Tune A and HERWIG!

Method 1 "Response" Factors: "Back-to-Back" Events

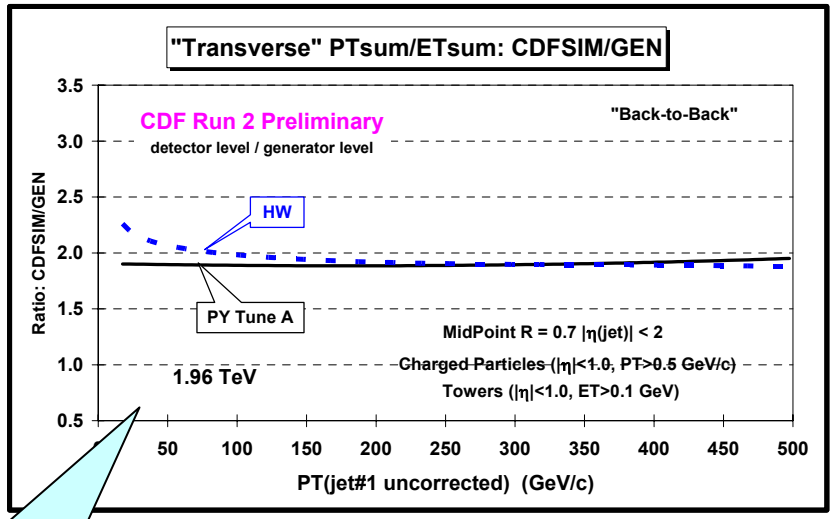
PYTHIA Tune A



HERWIG



Method 1 "response" factors for the charged fraction, PTsum/ETsum, in the "transverse" region for "back-to-back" events as a function of the leading jet P_T, where PTsum includes charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 1$ and the ETsum includes all particles with $|\eta| < 1$. Shows the particle level prediction (GEN) versus the leading particle jet P_T and the detector level result (CDFSIM) versus the leading calorimeter jet P_T (uncorrected) with $|\eta(\text{jet}\#1)| < 2$ for PYTHIA Tune A and HERWIG. Also shows the ratio of the detector level to the particle level, CDFSIM/GEN, versus the leading jet P_T (*i.e.* response factor).



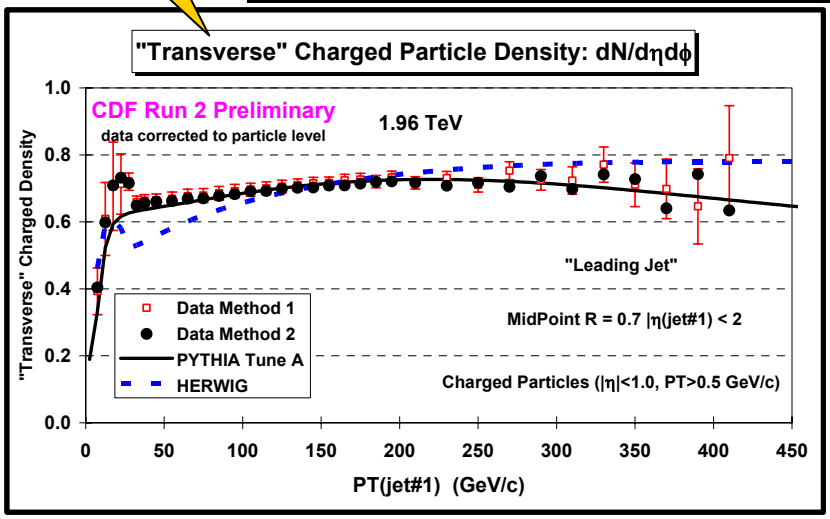
"Response" factor for PYTHIA Tune A and HERWIG!

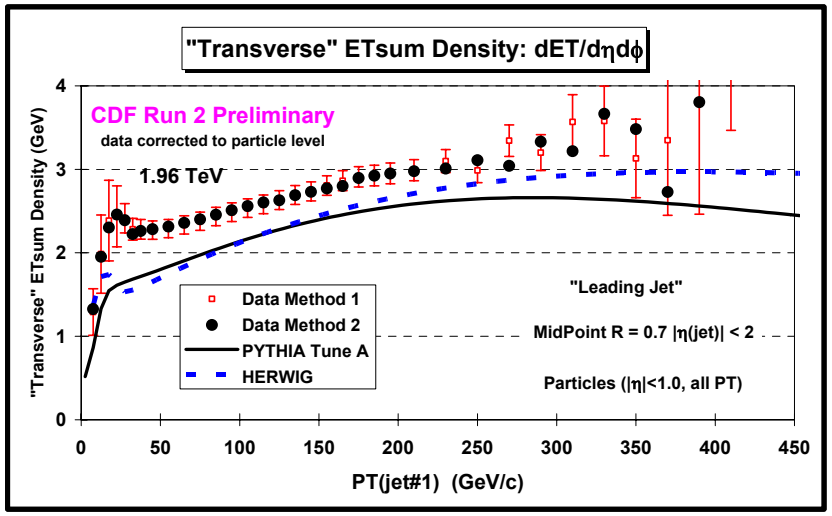
Systematic Uncertainties

- The systematic uncertainty in correcting to the particle level is estimated by combining the two factors shown below. The first factor, σ_1, comes from correcting the observables to the particle level using method 1 and examining the bin-by-bin difference between PYTHIA Tune A and HERWIG for each observable. The second factor, σ_2, is set large enough to include the differences between method 1 and method 2 and pile-up (only affects the transverse energy).
- The systematic uncertainty is added in quadrature with the statistical error.

Compared with pyA and HW at the particle level!

Uncertainty	Origin
σ_1	Bin by bin difference between the data corrected by PYTHIA Tune A and HERWIG using method 1.
σ_2	Difference between method 1 and method 2 and pile-up and miscellaneous (3% for charged particle, 5% for energy)

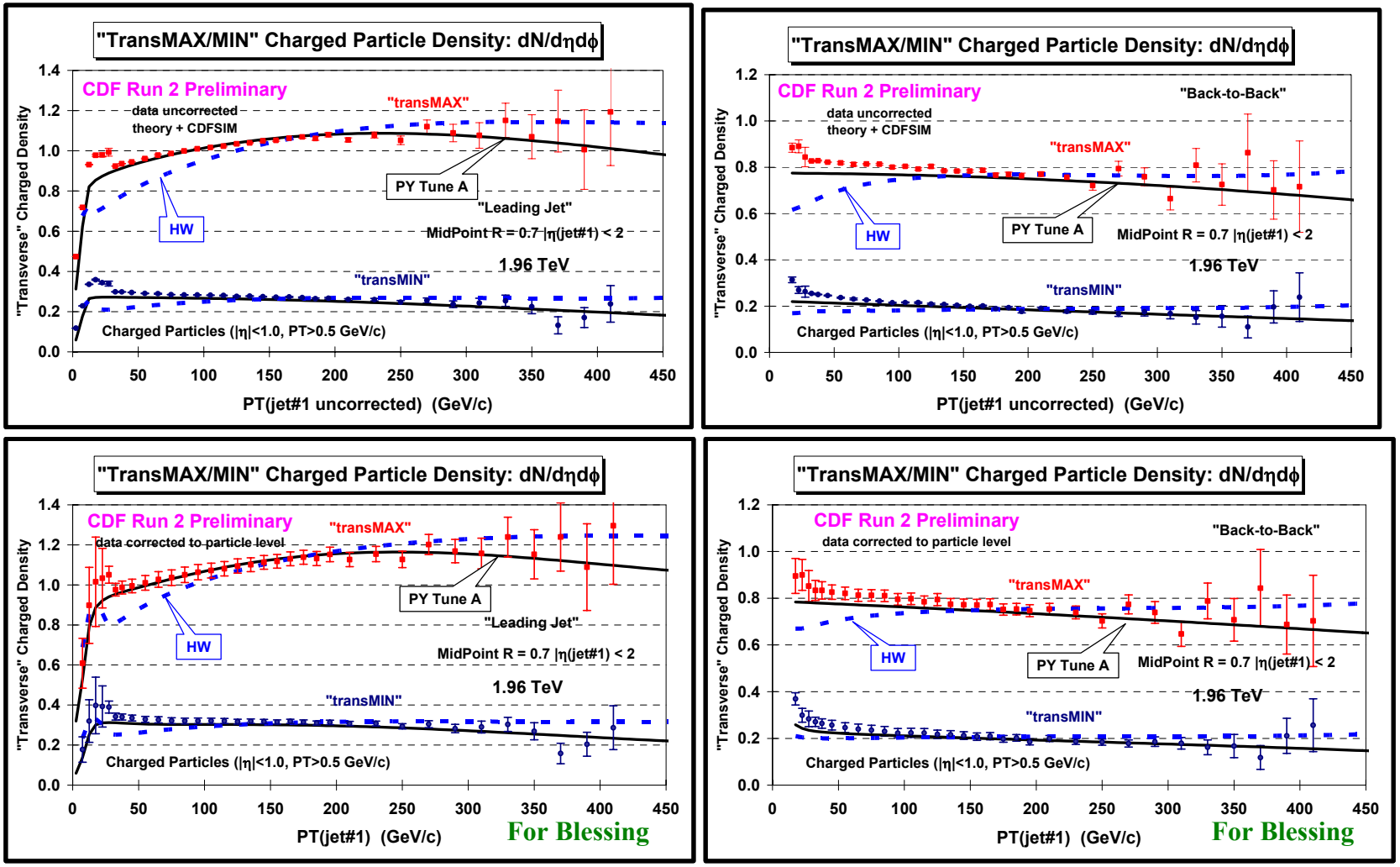




Data at 1.96 TeV corrected to the particle level using method 1 and method 2 using PYTHIA Tune A. The open red squares are the data corrected to the particle level using method 1 with errors that include both the statistical error and the systematic uncertainty. The black dots are the data corrected to the particle level using method 2 (with no errors).

Charged Particle Density: Detector Level vs Particle Level

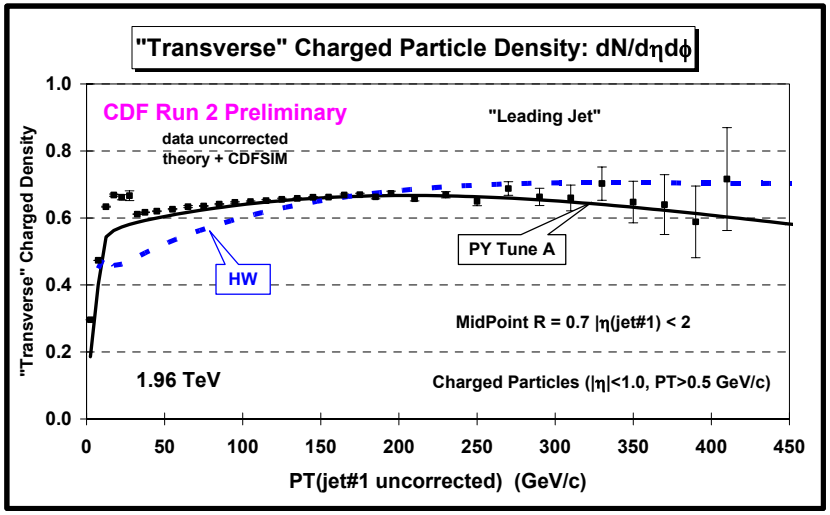
"Leading Jet" "Back-to-Back

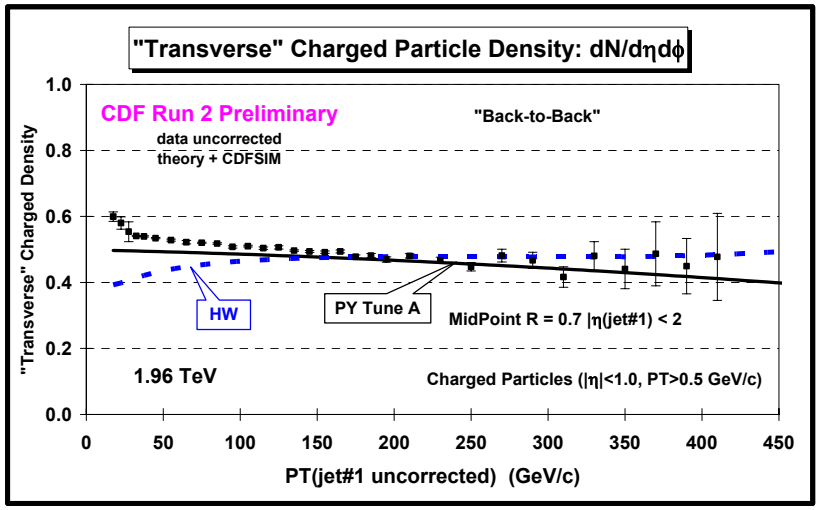


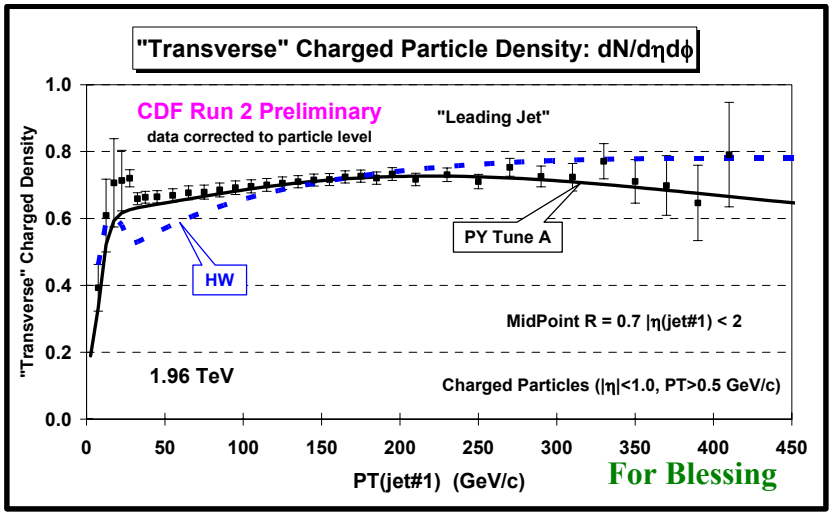
(*top*) Uncorrected data compared with theory + CDFSIM (*bottom*) Corrected data compared with theory at the particle level.

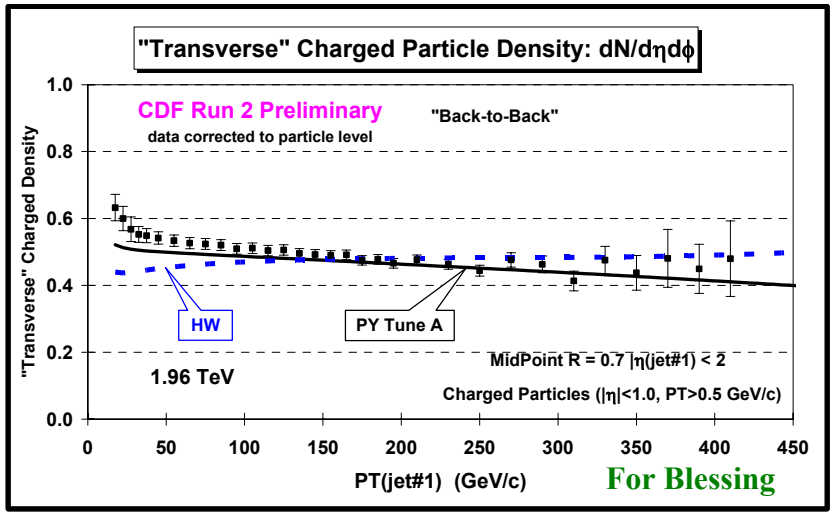
Charged Particle Density: Detector Level vs Particle Level

"Leading Jet" **"Back-to-Back"**





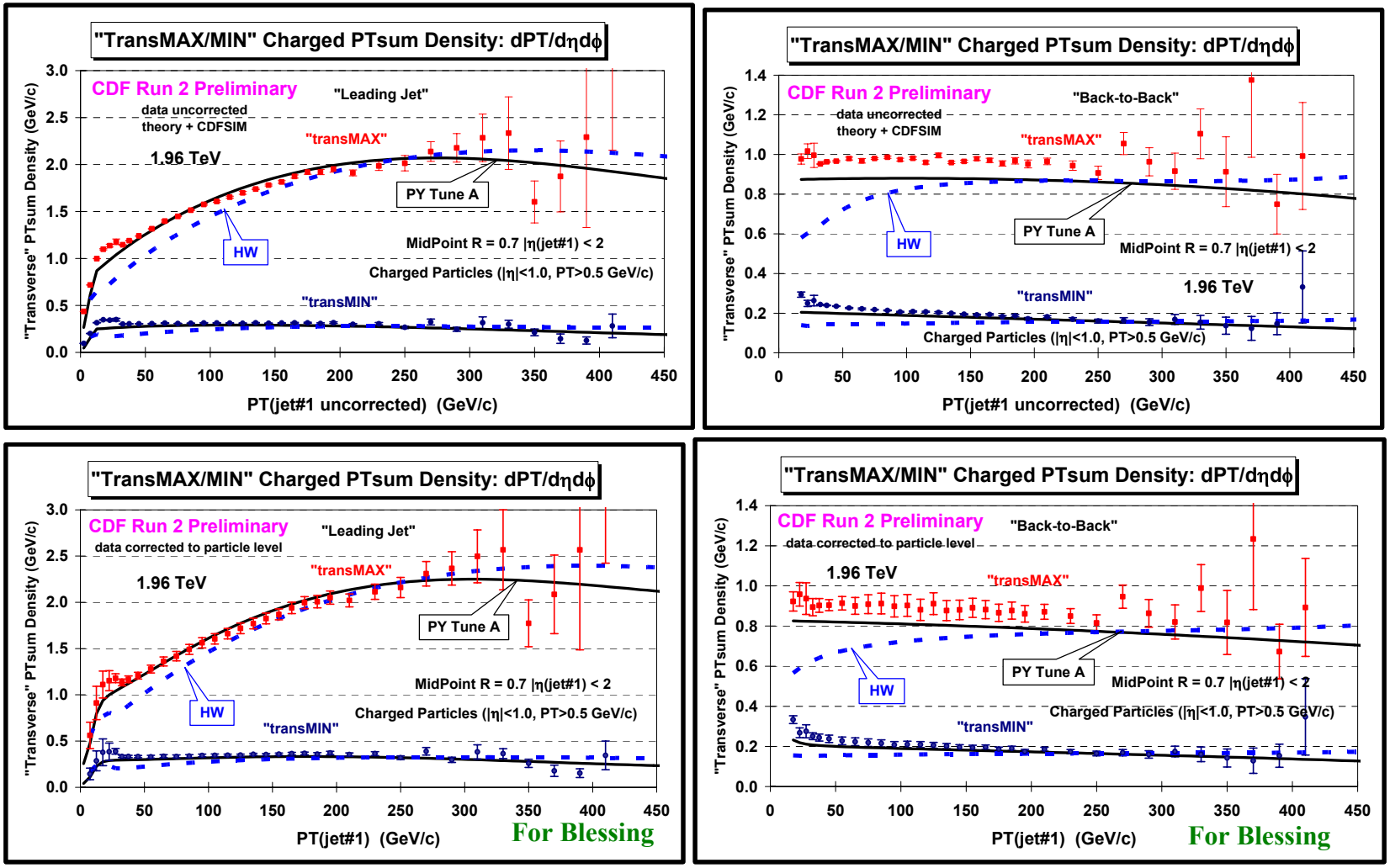




(*top*) Uncorrected data compared with theory + CDFSIM (*bottom*) Corrected data compared with theory at the particle level.

Charged PTsum Density: Detector Level vs Particle Level

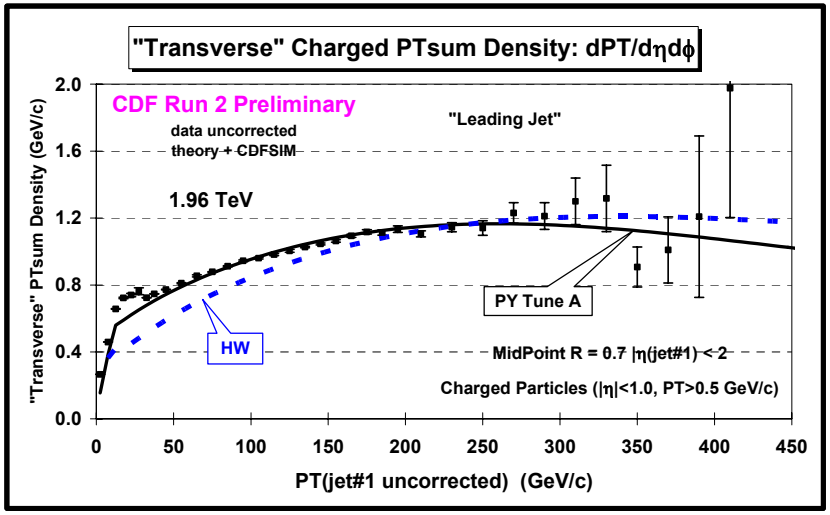
"Leading Jet" "Back-to-Back

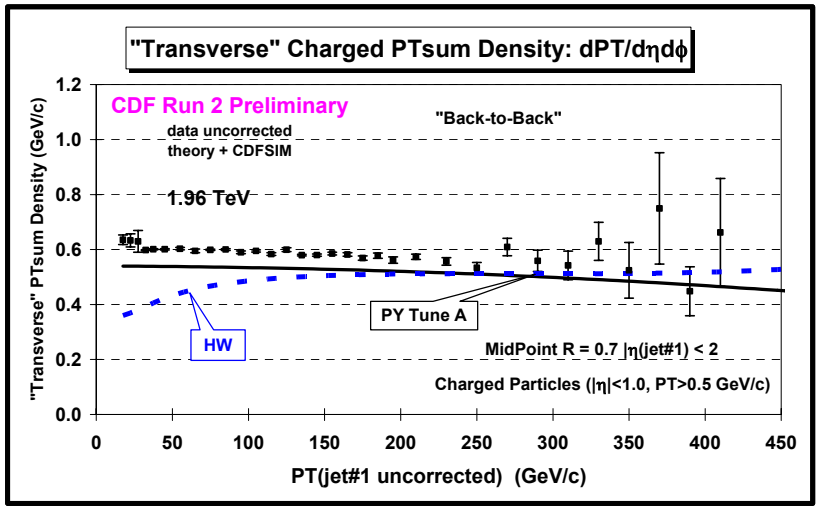


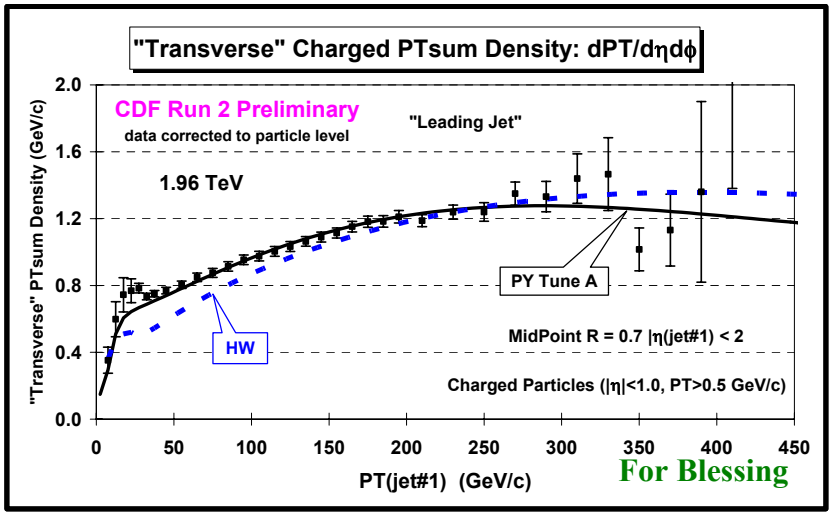
(*top*) Uncorrected data compared with theory + CDFSIM (*bottom*) Corrected data compared with theory at the particle level.

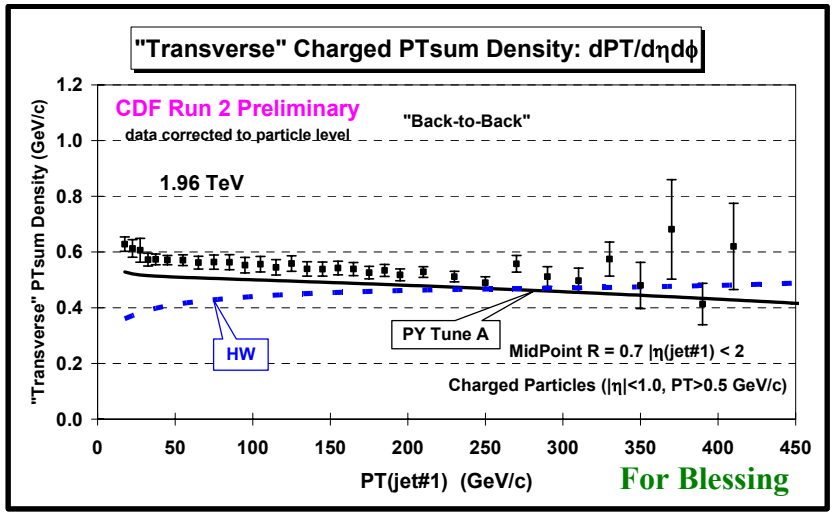
Charged PTsum Density: Detector Level vs Particle Level

"Leading Jet" "Back-to-Back





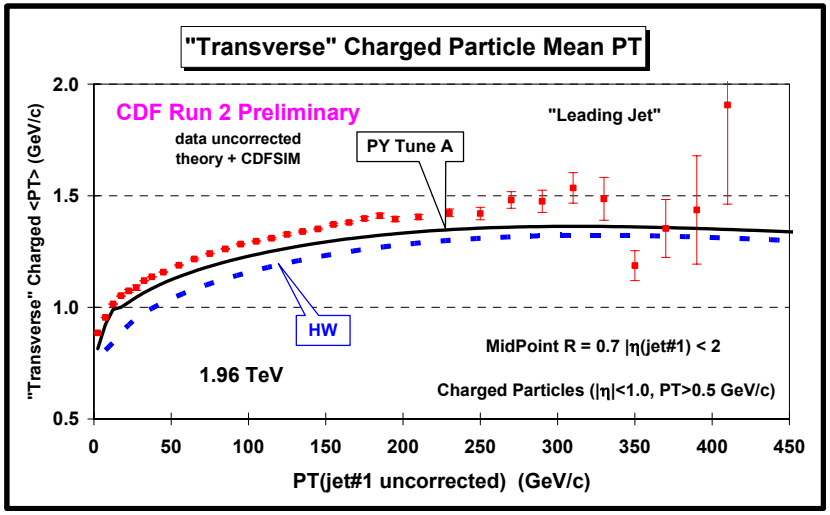


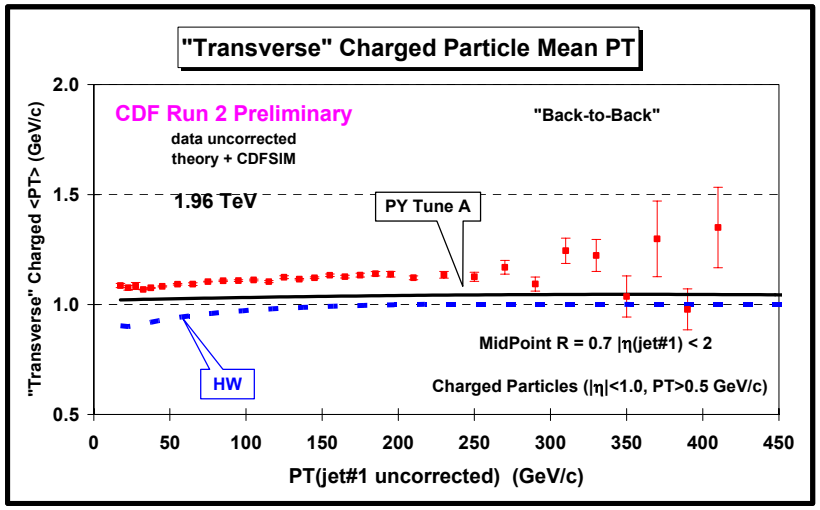


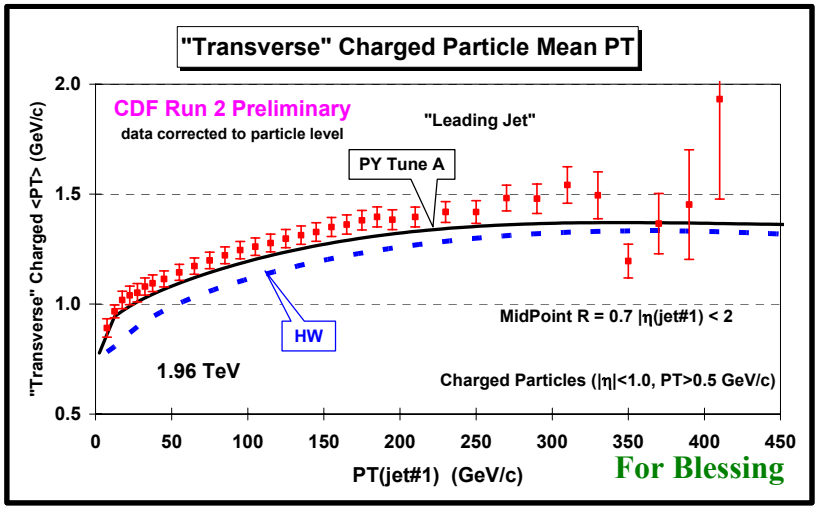
(*top*) Uncorrected data compared with theory + CDFSIM (*bottom*) Corrected data compared with theory at the particle level.

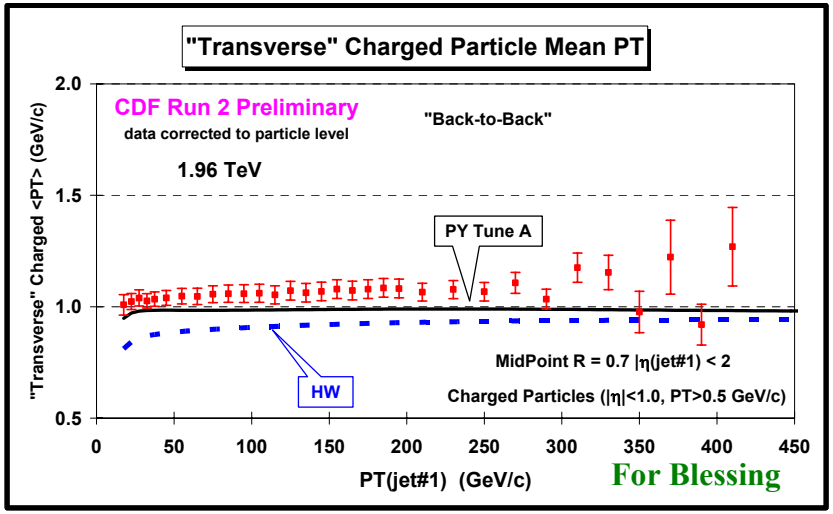
Charged Average <PT>: Detector Level vs Particle Level

"Leading Jet" "Back-to-Back





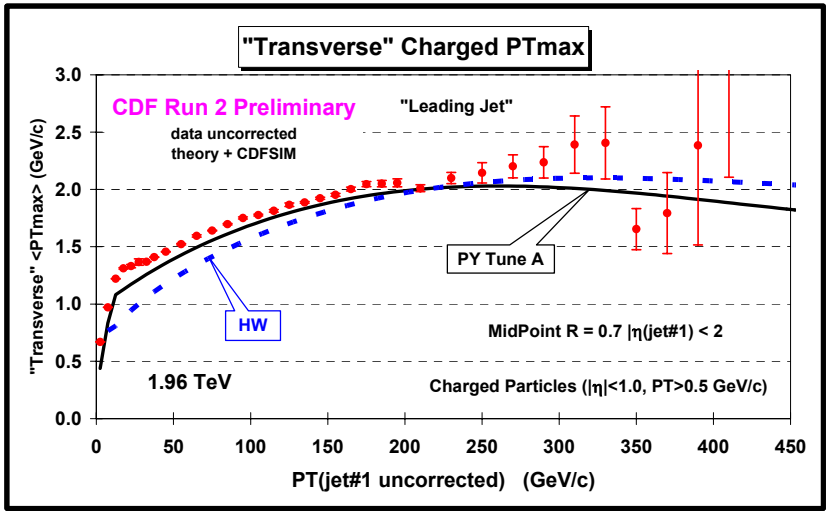


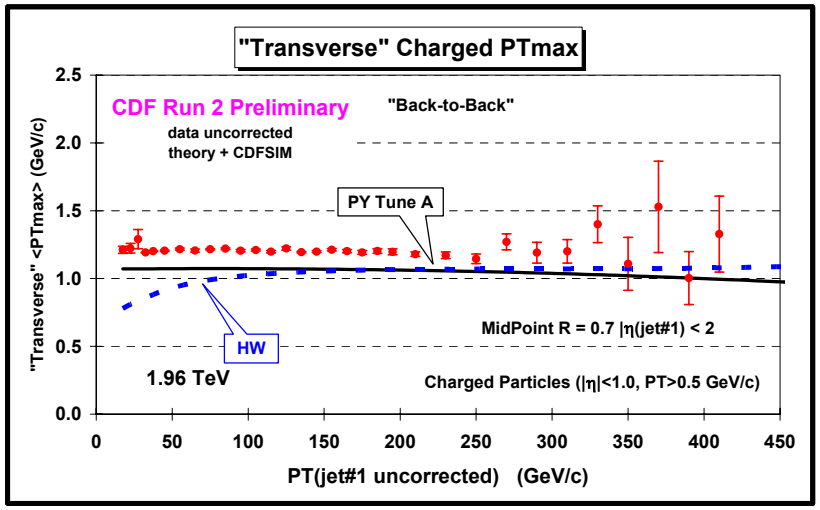


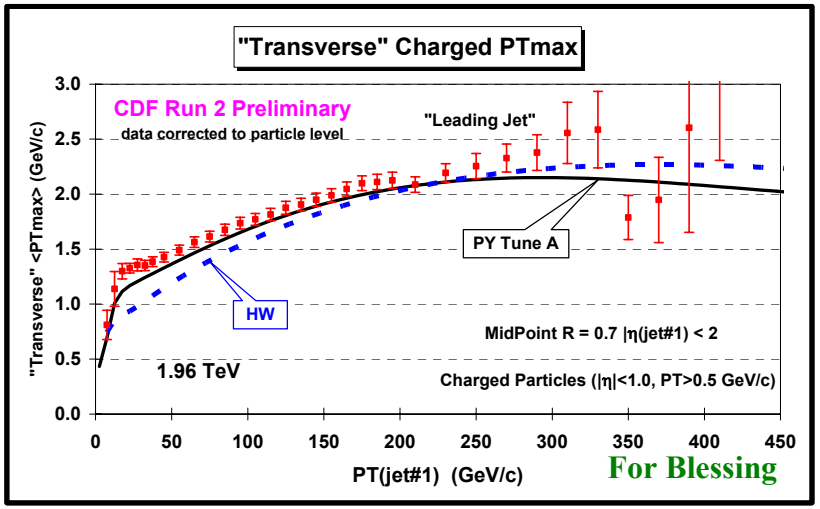
(*top*) Uncorrected data compared with theory + CDFSIM (*bottom*) Corrected data compared with theory at the particle level.

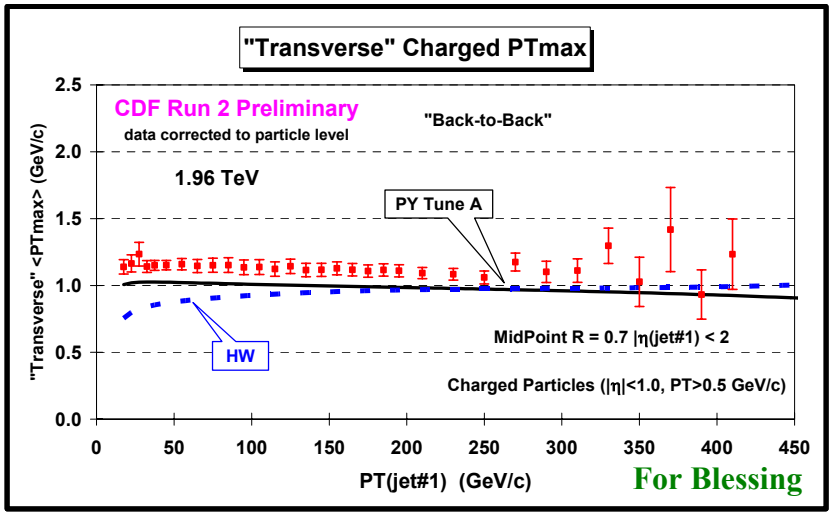
Charged PTmax: Detector Level vs Particle Level

"Leading Jet" "Back-to-Back





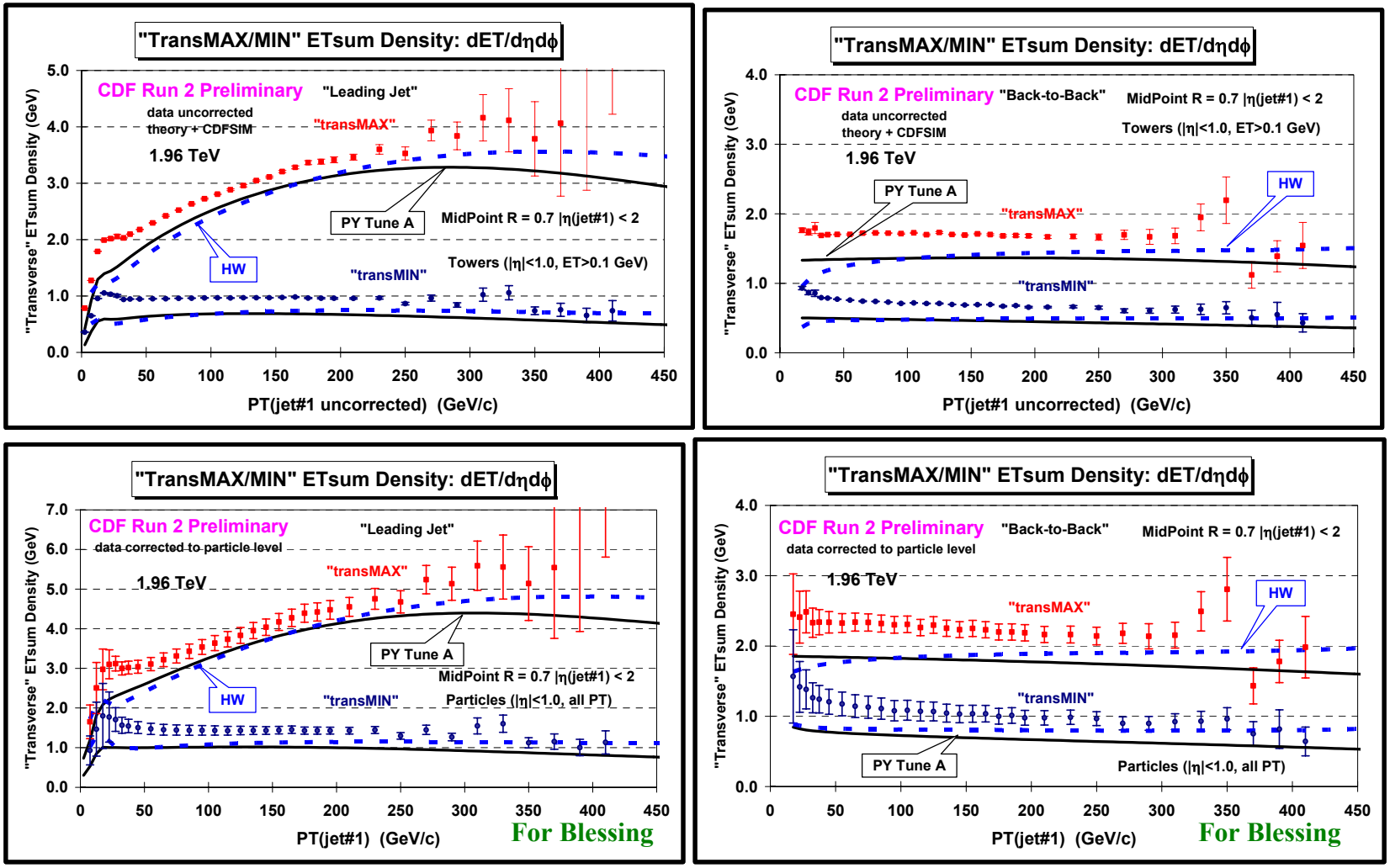




(*top*) Uncorrected data compared with theory + CDFSIM (*bottom*) Corrected data compared with theory at the particle level.

ETsum Density: Detector Level vs Particle Level

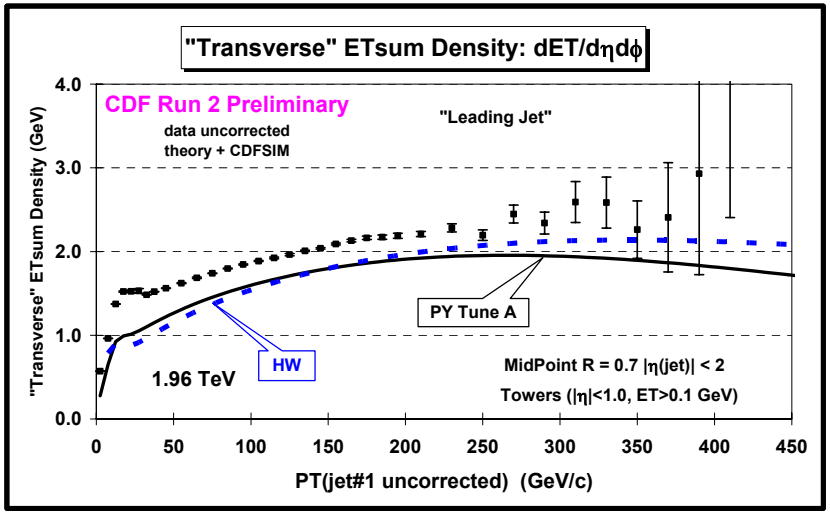
"Leading Jet" "Back-to-Back

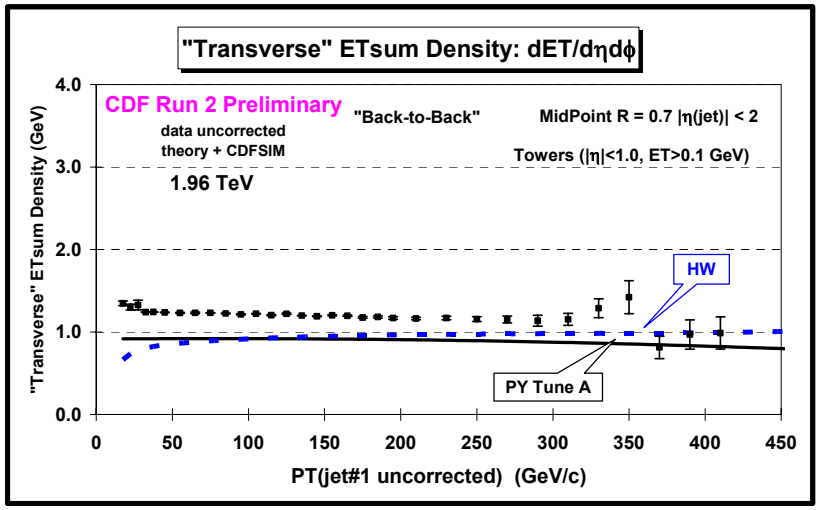


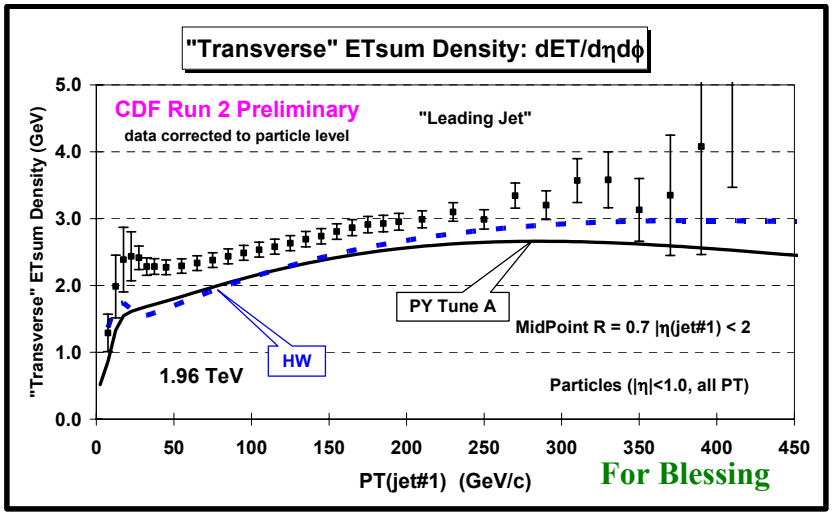
(*top*) Uncorrected data compared with theory + CDFSIM (*bottom*) Corrected data compared with theory at the particle level.

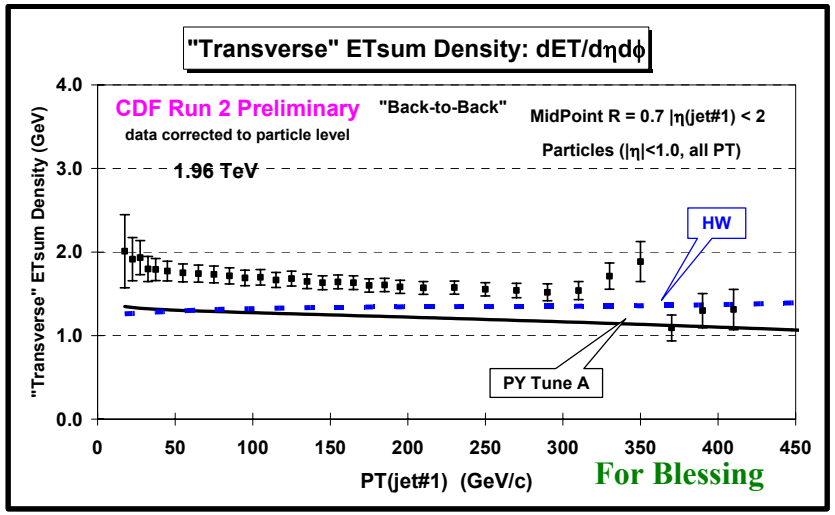
ETsum Density: Detector Level vs Particle Level

"Leading Jet" "Back-to-Back





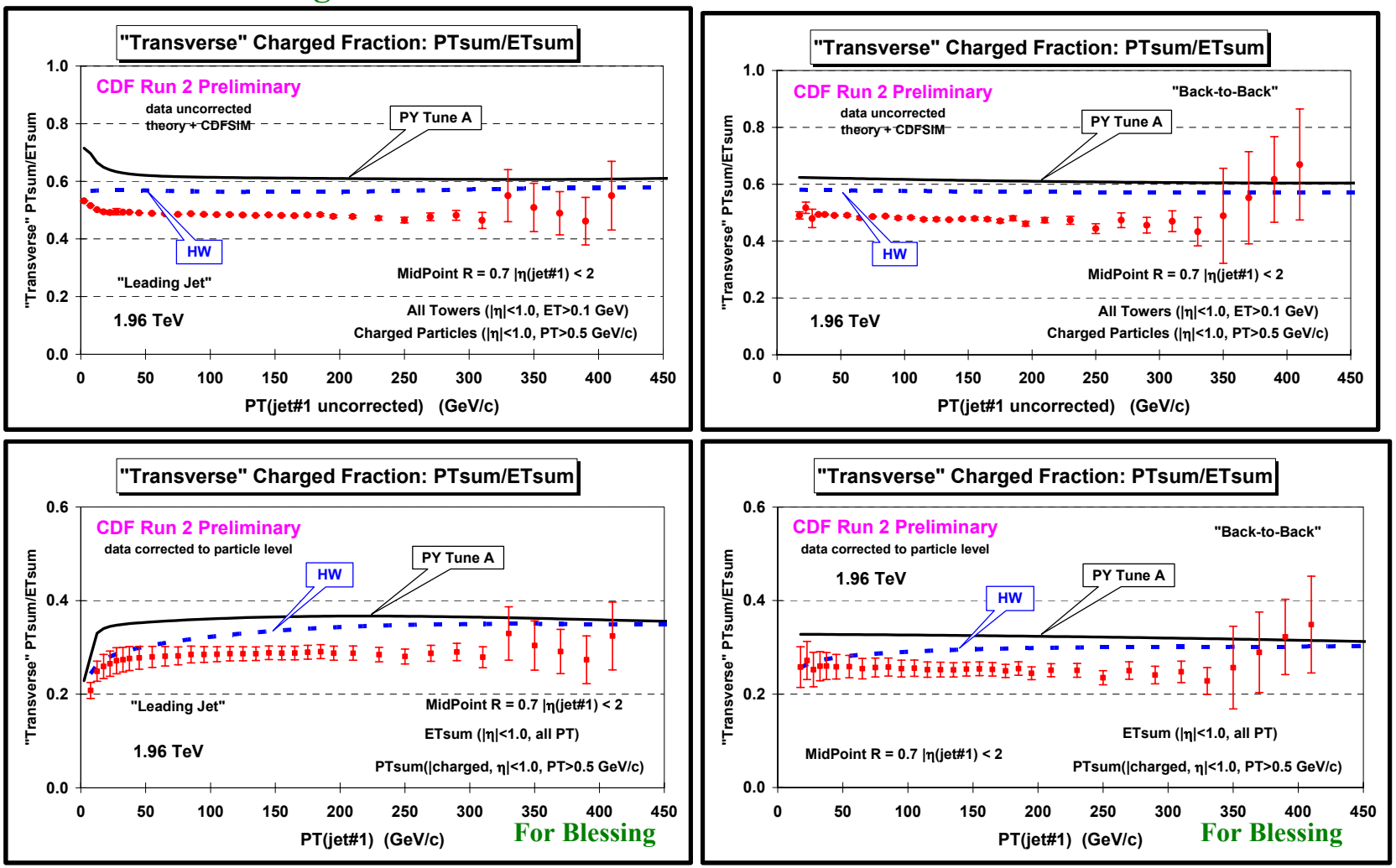




(*top*) Uncorrected data compared with theory + CDFSIM (*bottom*) Corrected data compared with theory at the particle level.

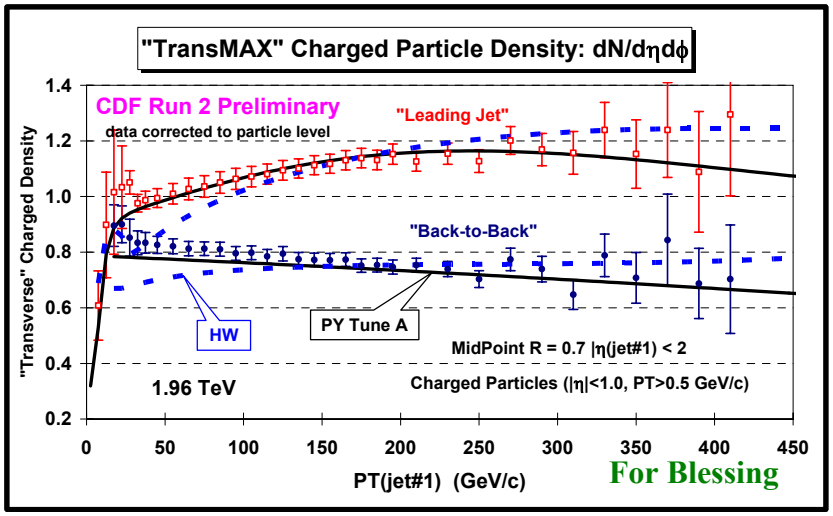
Charged Fraction PTsum/ETsum: Detector Level vs Particle Level

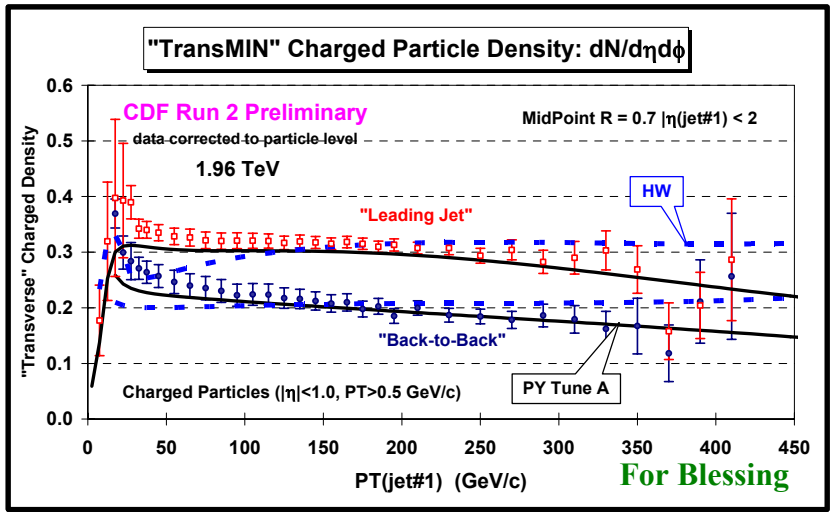
"Leading Jet" "Back-to-Back"

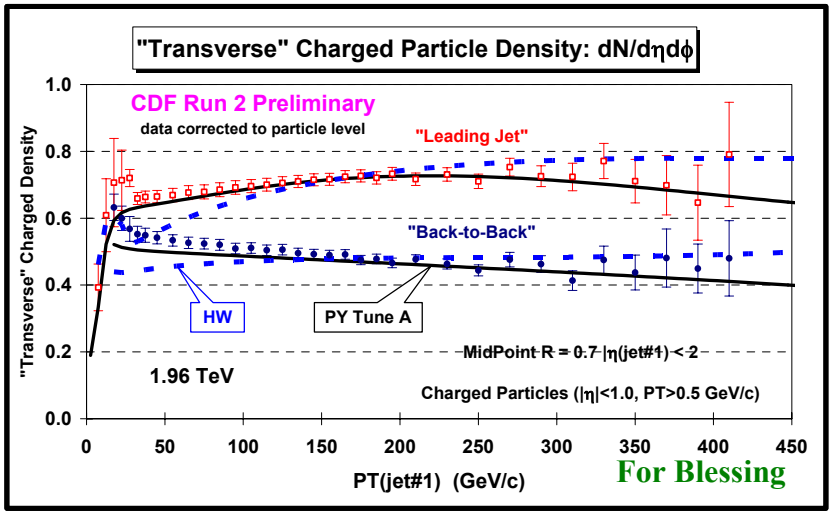


(*top*) Uncorrected data compared with theory + CDFSIM (*bottom*) Corrected data compared with theory at the particle level.

Charged Particle Density: "Leading Jet" vs "Back-to-Back"

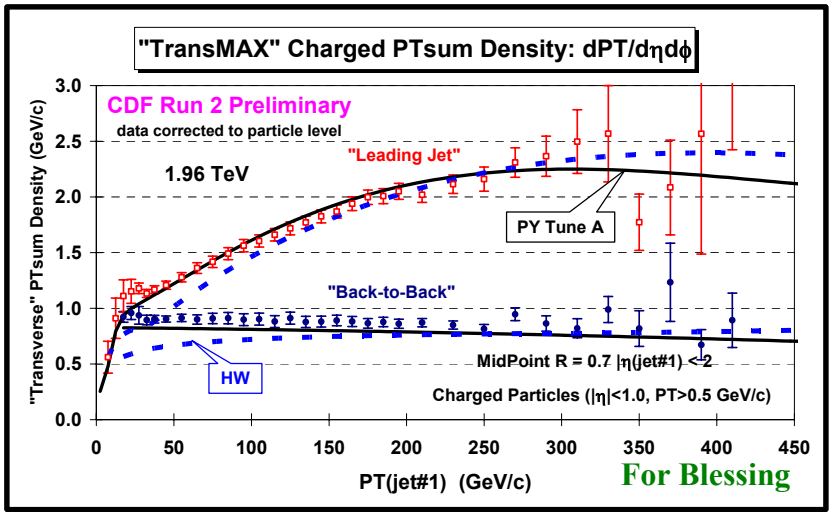


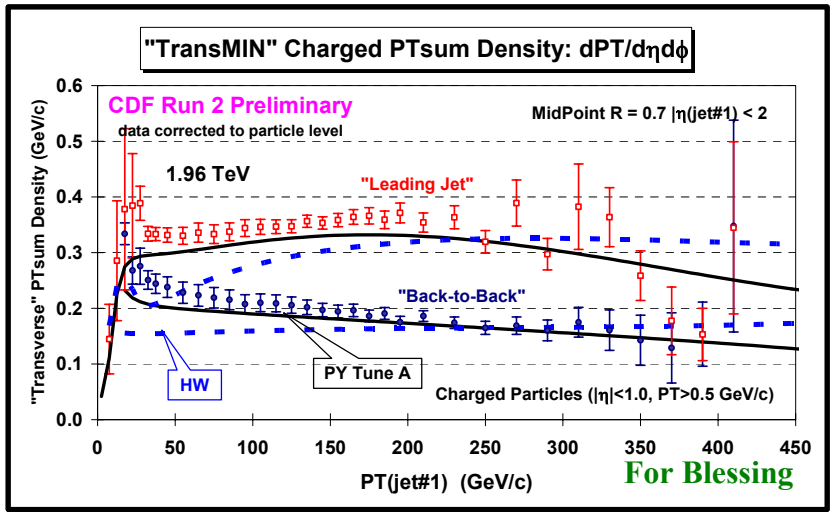


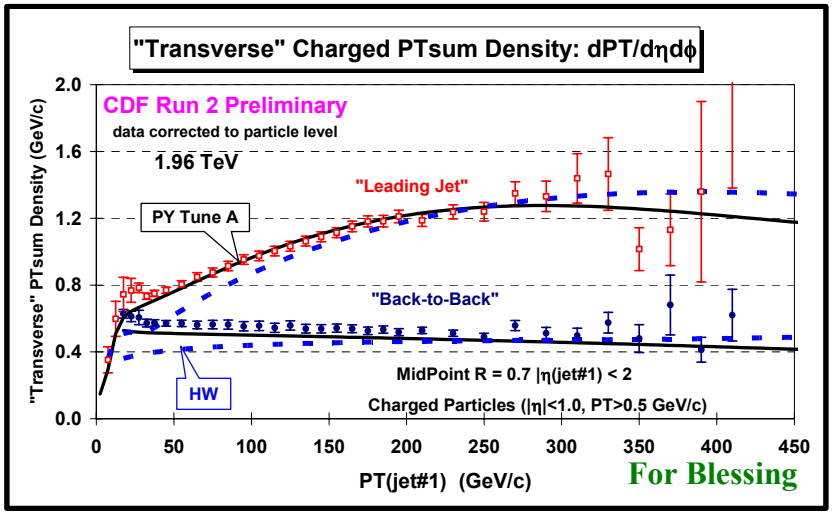


Data at 1.96 TeV on the charged particle density, $dN_{chg}/d\eta d\phi$ with $p_T > 0.5$ GeV/c and $|\eta| < 1$ in the "transMAX" region, "transMIN" region, and "transverse" region (average of "transMAX" and "transMIN") for "leading jet" and "back-to-back" events as a function of the leading jet P_T compared with PYTHIA Tune A and HERWIG. The data are corrected to the particle level (with errors that include both the statistical error and the systematic uncertainty) and compared with the theory at the particle level (*i.e.* generator level).

Charged PTsum Density: "Leading Jet" vs "Back-to-Back"

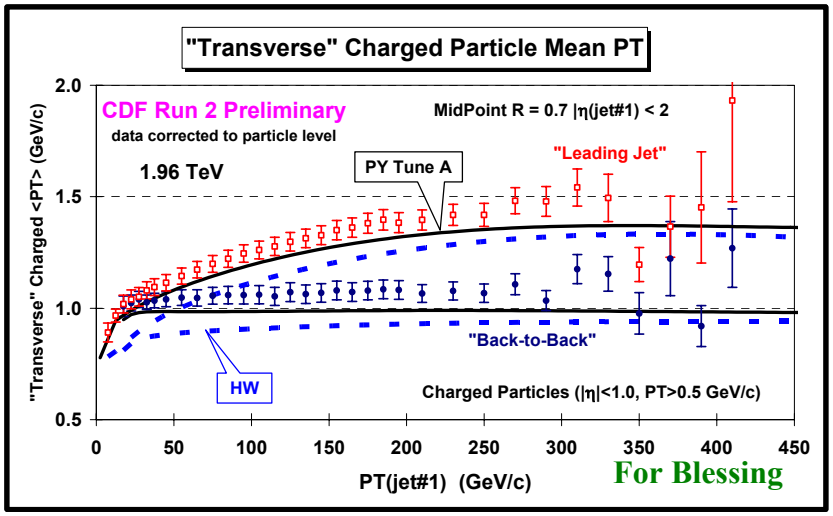


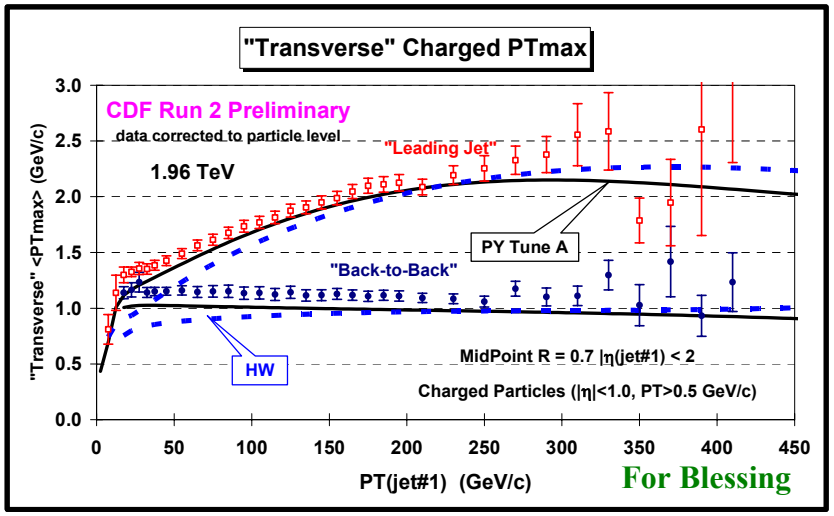




Data at 1.96 TeV on the charged PTsum density, $dPT_{sum}/d\eta d\phi$ with $p_T > 0.5$ GeV/c and $|\eta| < 1$ in the "transMAX" region, "transMIN" region, and "transverse" region (average of "transMAX" and "transMIN") for "leading jet" and "back-to-back" events as a function of the leading jet P_T compared with PYTHIA Tune A and HERWIG. The data are corrected to the particle level (with errors that include both the statistical error and the systematic uncertainty) and compared with the theory at the particle level (*i.e.* generator level).

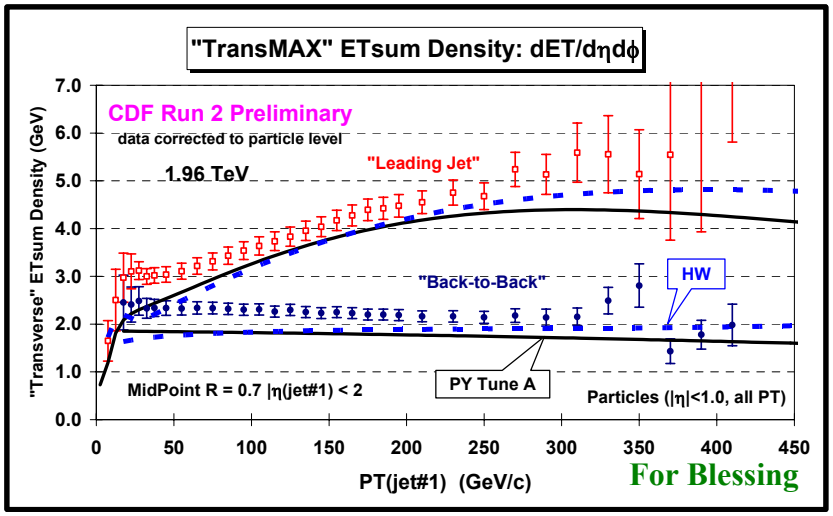
<p_T> and PTmax: "Leading Jet" vs "Back-to-Back"

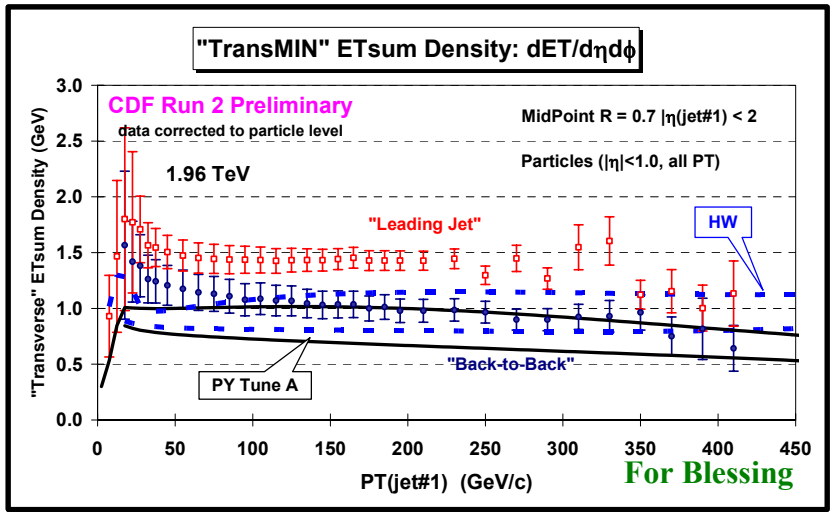


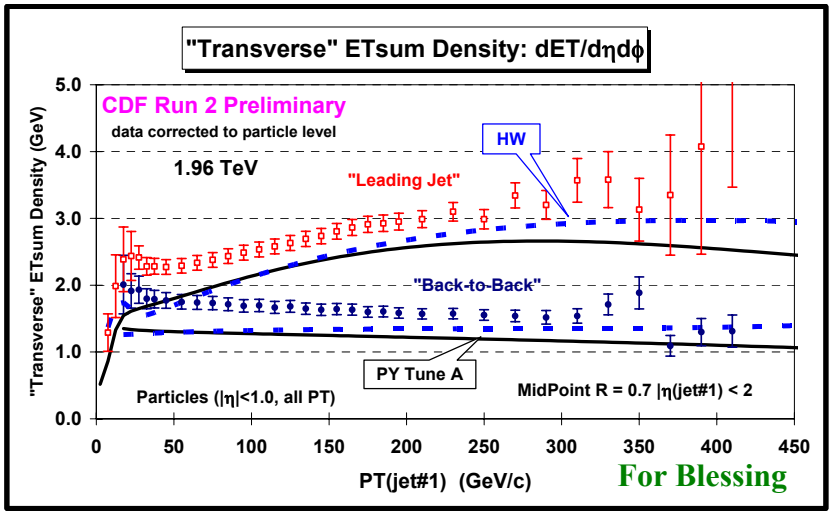


Data at 1.96 TeV on the average <p_T> and the maximum pT, PTmax, for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 1$ in the "transverse" region for "leading jet" and "back-to-back" events as a function of the leading jet P_T compared with PYTHIA Tune A and HERWIG. The data are corrected to the particle level (with errors that include both the statistical error and the systematic uncertainty) and compared with the theory at the particle level (*i.e.* generator level).

ETsum Density: "Leading Jet" vs "Back-to-Back"

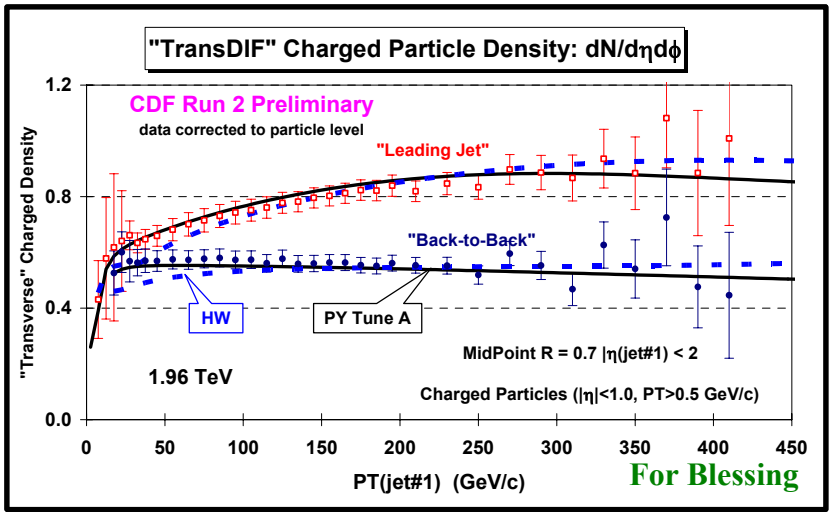


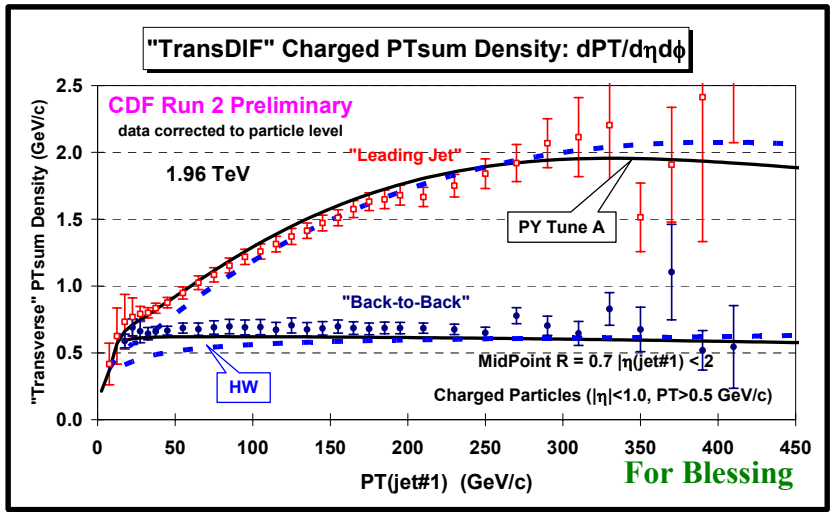


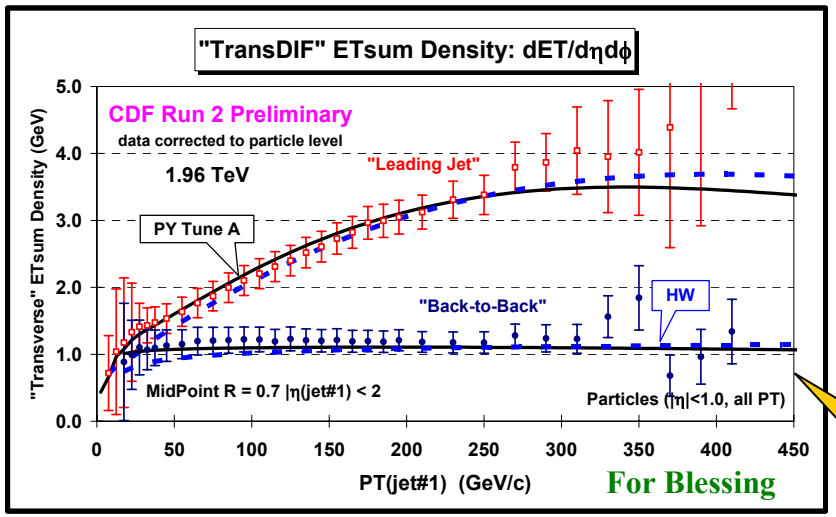


Data at 1.96 TeV on the ETsum density, $dE_T/d\eta d\phi$ for particles with $|\eta| < 1$ in the "transMAX" region, "transMIN" region, and "transverse" region (average of "transMAX" and "transMIN") for "leading jet" and "back-to-back" events as a function of the leading jet P_T compared with PYTHIA Tune A and HERWIG. The data are corrected to the particle level (with errors that include both the statistical error and the systematic uncertainty) and compared with the theory at the particle level (*i.e.* generator level).

"transDIF=MAX-MIN": "Leading Jet" vs "Back-to-Back"





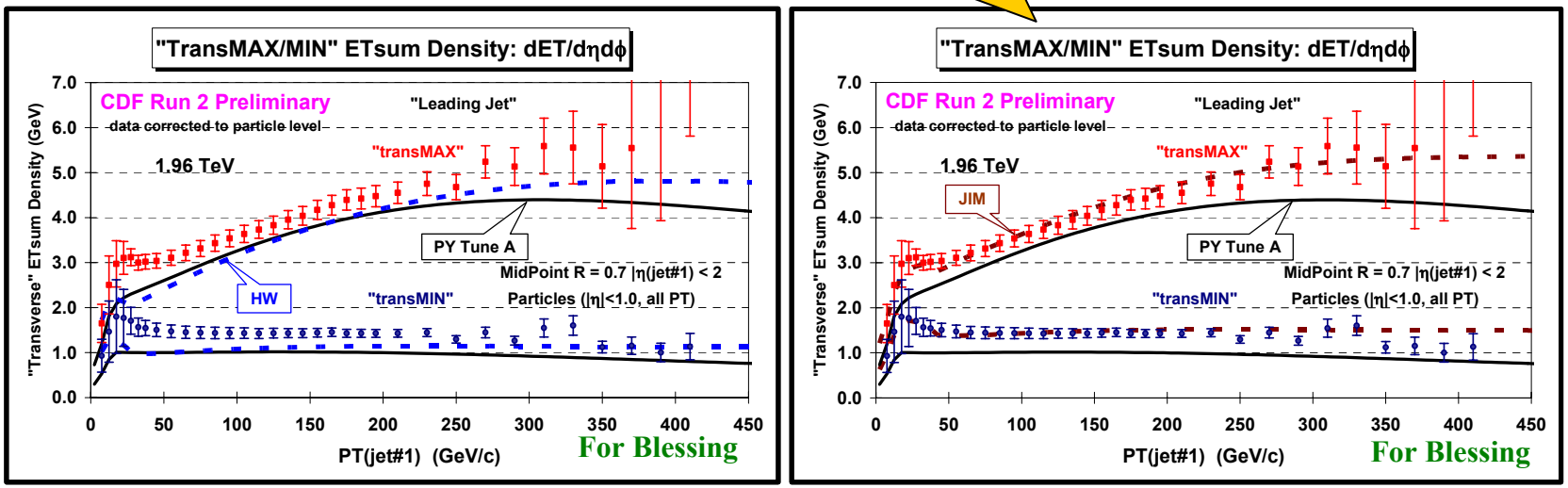


Data at 1.96 TeV on the difference of the "transMAX" and "transMIN" region ("transDIF" = "transMAX" minus "transMIN") for "leading jet" and "back-to-back" events as a function of the leading jet P_T compared with PYTHIA Tune A and HERWIG. The data are corrected to the particle level (with errors that include both the statistical error and the systematic uncertainty) and compared with the theory at the particle level (*i.e.* generator level).

PYTHIA Tun A and HERWIG agree with the "transDIF" energy density"!

"Leading Jet" Energy Density: HERWIG vs JIMMY

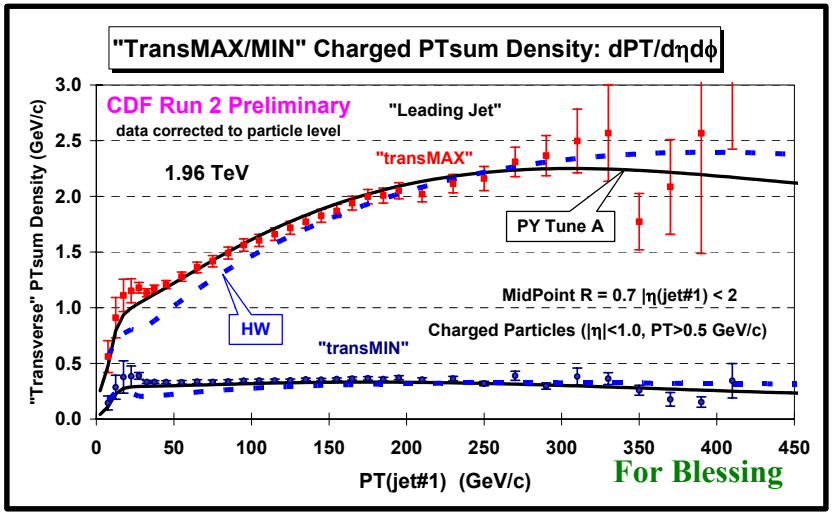
JIMMY tuned to fit the "transverse" energy density!

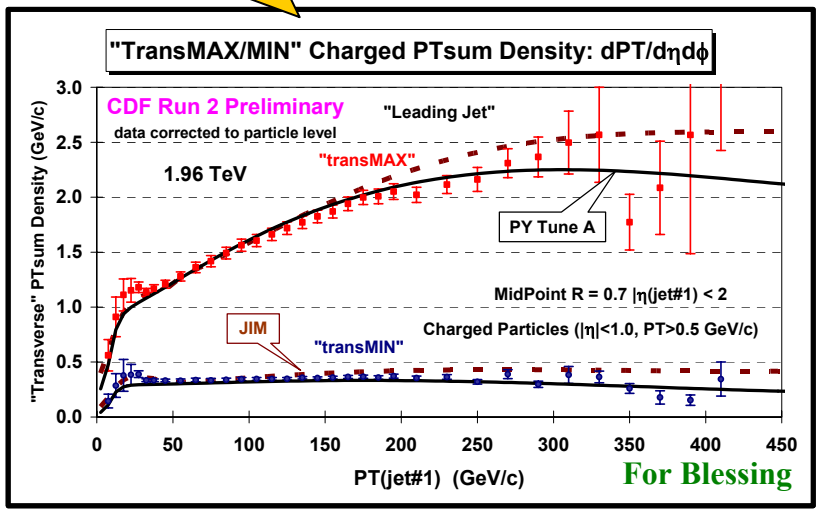


Data at 1.96 TeV on the ETsum density, $dE_T/d\eta d\phi$ for particles with $|\eta| < 1$ in the "transMAX" region and the "transMIN" region for "leading jet" events as a function of the leading jet P_T compared with PYTHIA Tune A and HERWIG (*left*) and compared with PYTHIA Tune A and tuned JIMMY (*right*). JIMMY was tuned to fit the "transverse" energy density (PTJIM = 3.25 GeV/c). The data are corrected to the particle level (with errors that include both the statistical error and the systematic uncertainty) and compared with the theory at the particle level (*i.e.* generator level).

"Leading Jet" PTsum Density: HERWIG vs JIMMY

Tuned JIMMY also fits the "transverse" PTsum density!

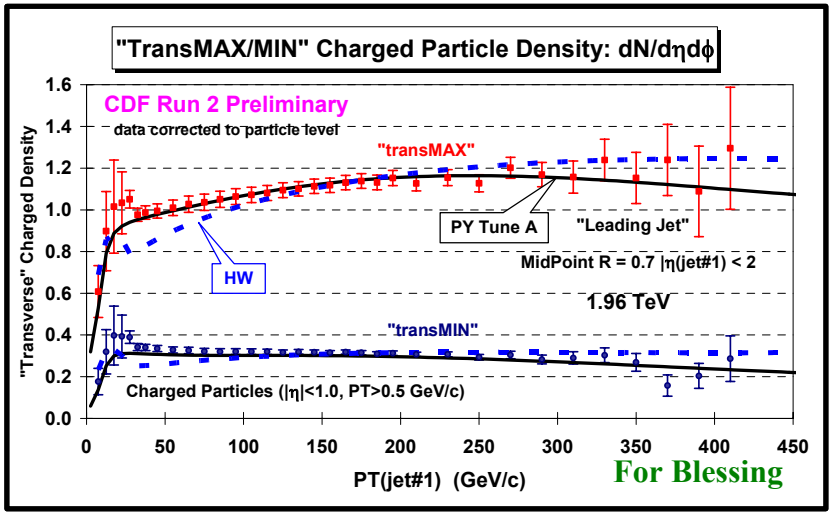


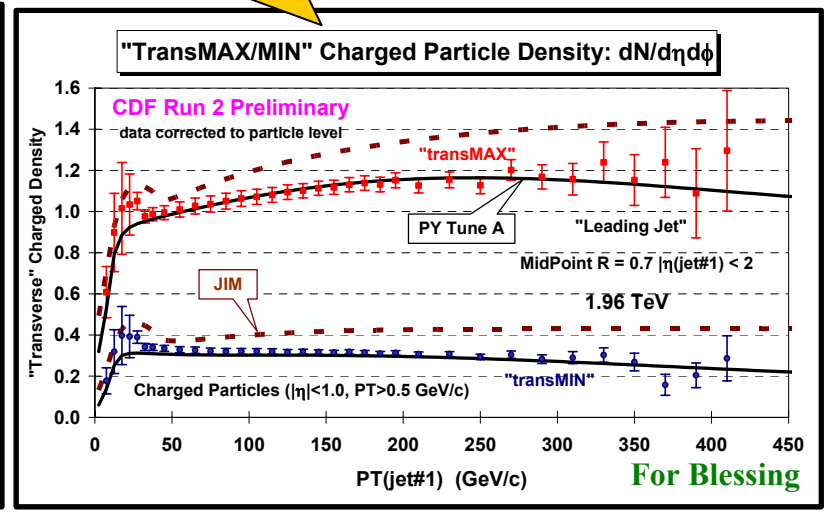


Data at 1.96 TeV on the charged PTsum density, $dPT_{sum}/d\eta d\phi$ with $p_T > 0.5$ GeV/c and $|\eta| < 1$ in the "transMAX" region and the "transMIN" region for "leading jet" events as a function of the leading jet P_T compared with PYTHIA Tune A and HERWIG (*left*) and compared with PYTHIA Tune A and tuned JIMMY (*right*). JIMMY was tuned to fit the "transverse" energy density (PTJIM = 3.25 GeV/c). The data are corrected to the particle level (with errors that include both the statistical error and the systematic uncertainty) and compared with the theory at the particle level (*i.e.* generator level).

"Leading Jet" Nchg Density: HERWIG vs JIMMY

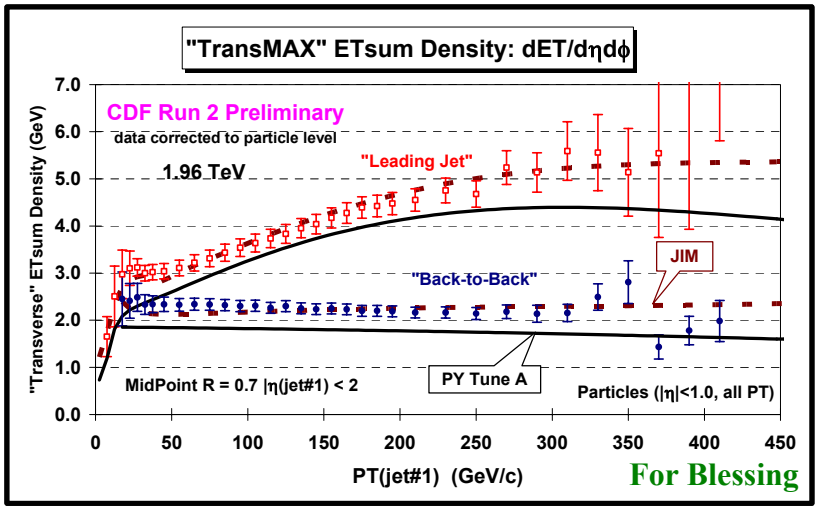
Tuned JIMMY produces too many charged particles!

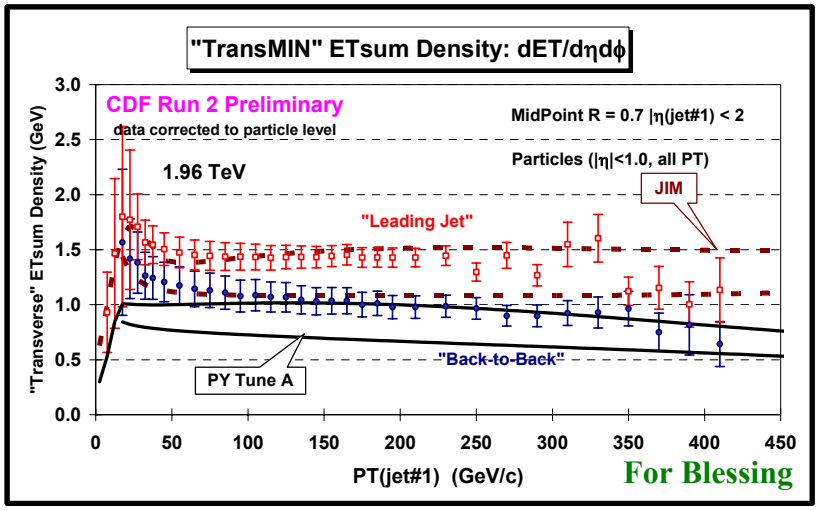


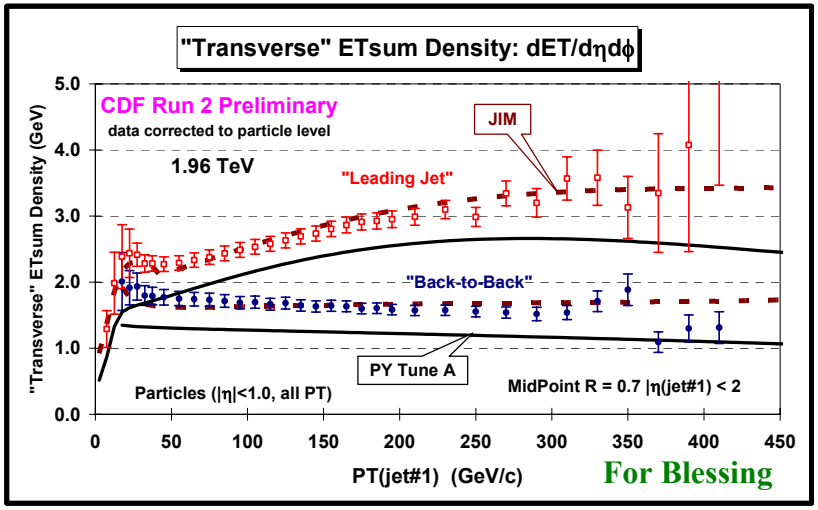


Data at 1.96 TeV on the charged particle density, $dN_{chg}/d\eta d\phi$ with $p_T > 0.5$ GeV/c and $|\eta| < 1$ in the "transMAX" region and the "transMIN" region for "leading jet" events as a function of the leading jet P_T compared with PYTHIA Tune A and HERWIG (*left*) and compared with PYTHIA Tune A and tuned JIMMY (*right*). JIMMY was tuned to fit the "transverse" energy density (PTJIM = 3.25 GeV/c). The data are corrected to the particle level (with errors that include both the statistical error and the systematic uncertainty) and compared with the theory at the particle level (*i.e.* generator level).

ETsum Density: "Leading Jet" vs "Back-to-Back"

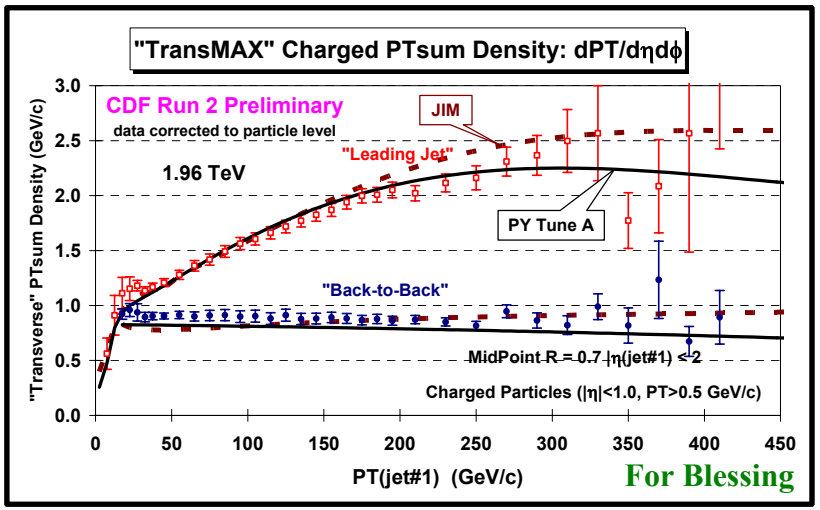


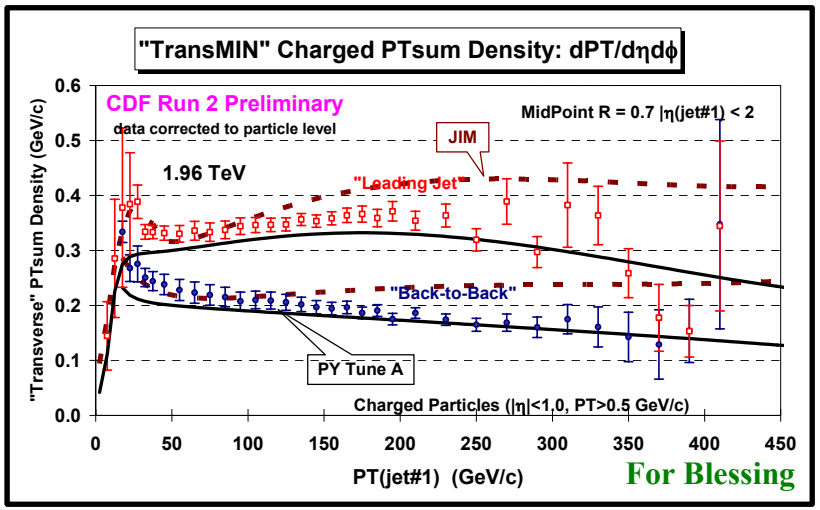


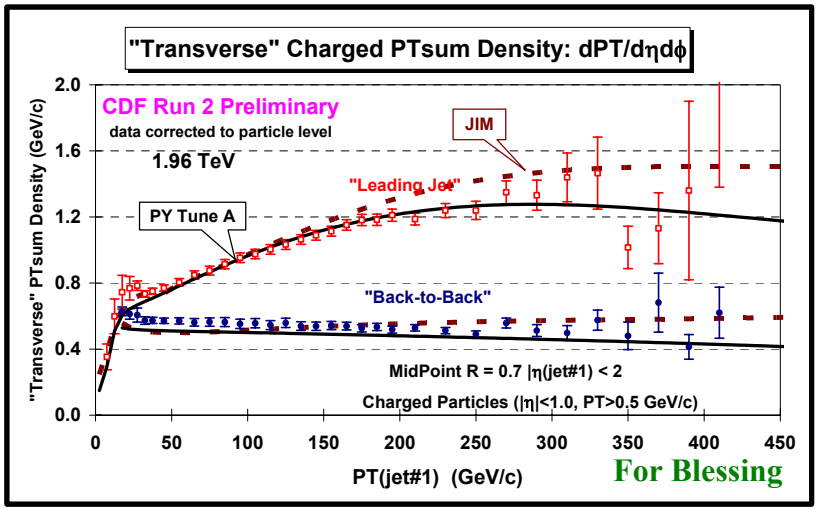


Data at 1.96 TeV on the ETsum density, $dE_T/d\eta d\phi$ for particles with $|\eta| < 1$ in the "transMAX" region, "transMIN" region, and "transverse" region (average of "transMAX" and "transMIN") for "leading jet" and "back-to-back" events as a function of the leading jet P_T compared with PYTHIA Tune A and tuned JIMMY (PTJIM = 3.25 GeV/c). The data are corrected to the particle level (with errors that include both the statistical error and the systematic uncertainty) and compared with the theory at the particle level (*i.e.* generator level).

Charged PTsum Density: "Leading Jet" vs "Back-to-Back"

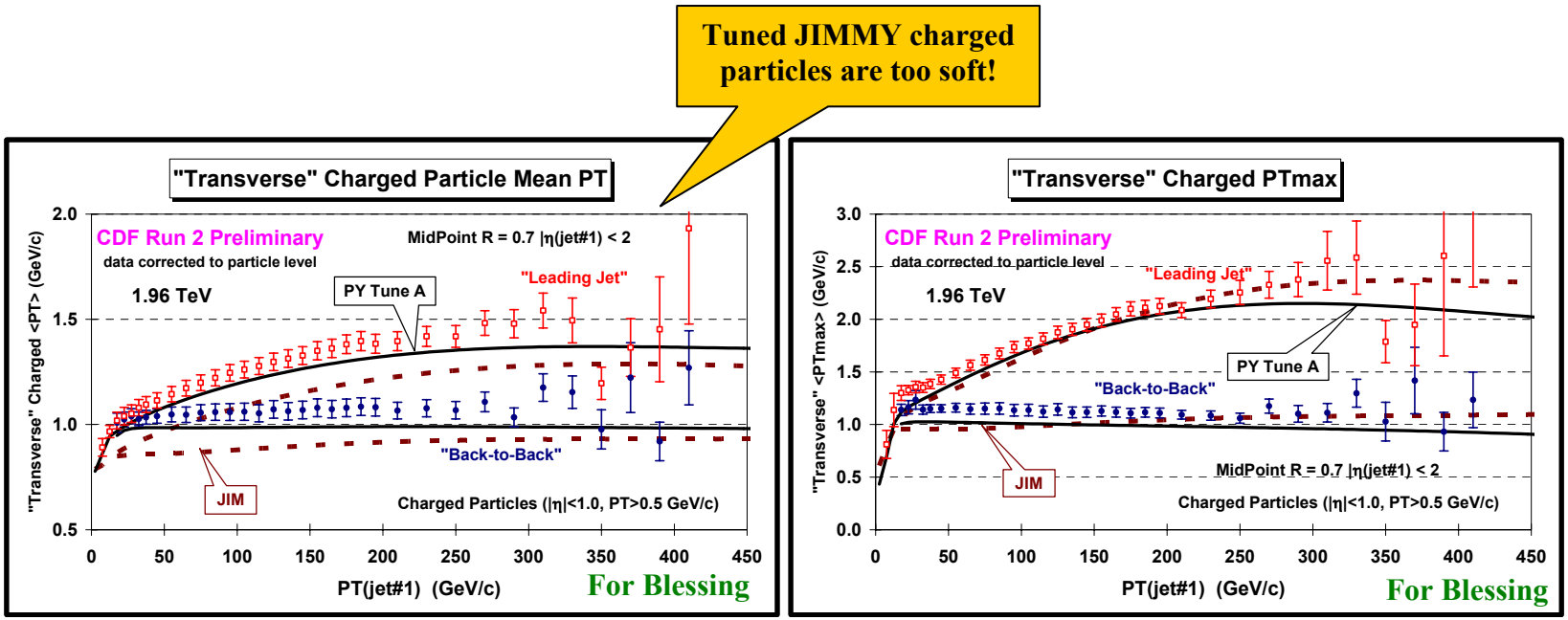






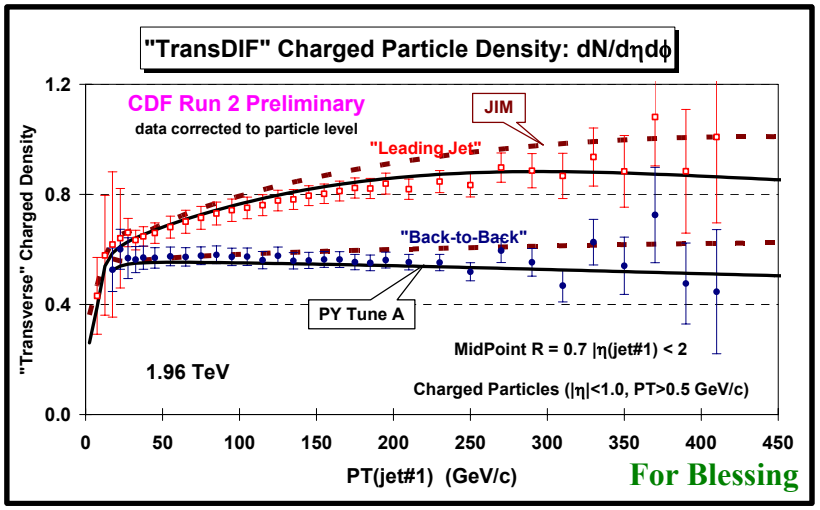
Data at 1.96 TeV on the charged PTsum density, $dPT_{sum}/d\eta d\phi$ with $p_T > 0.5$ GeV/c and $|\eta| < 1$ in the "transMAX" region, "transMIN" region, and "transverse" region (average of "transMAX" and "transMIN") for "leading jet" and "back-to-back" events as a function of the leading jet P_T compared with PYTHIA Tune A and tuned JIMMY (PTJIM = 3.25 GeV/c). The data are corrected to the particle level (with errors that include both the statistical error and the systematic uncertainty) and compared with the theory at the particle level (*i.e.* generator level).

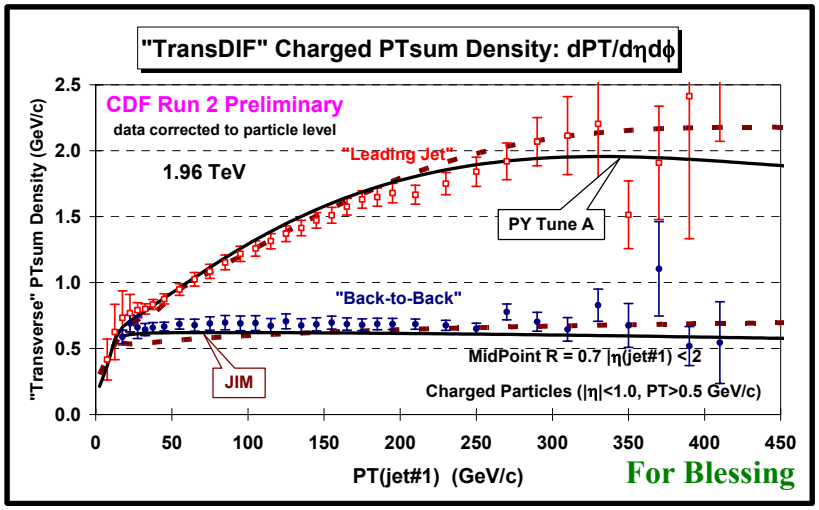
<p_T> and PTmax: "Leading Jet" vs "Back-to-Back"

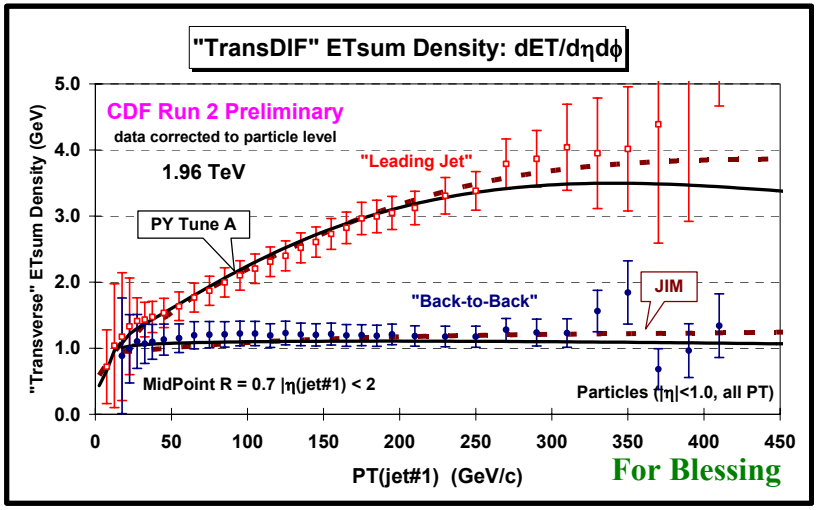


Data at 1.96 TeV on the average <p_T> and the maximum pT, PTmax, for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 1$ in the "transverse" region for "leading jet" and "back-to-back" events as a function of the leading jet P_T compared with PYTHIA Tune A and tuned JIMMY (PTJIM = 3.25 GeV/c). The data are corrected to the particle level (with errors that include both the statistical error and the systematic uncertainty) and compared with the theory at the particle level (*i.e.* generator level).

"transDIF=MAX-MIN": "Leading Jet" vs "Back-to-Back"

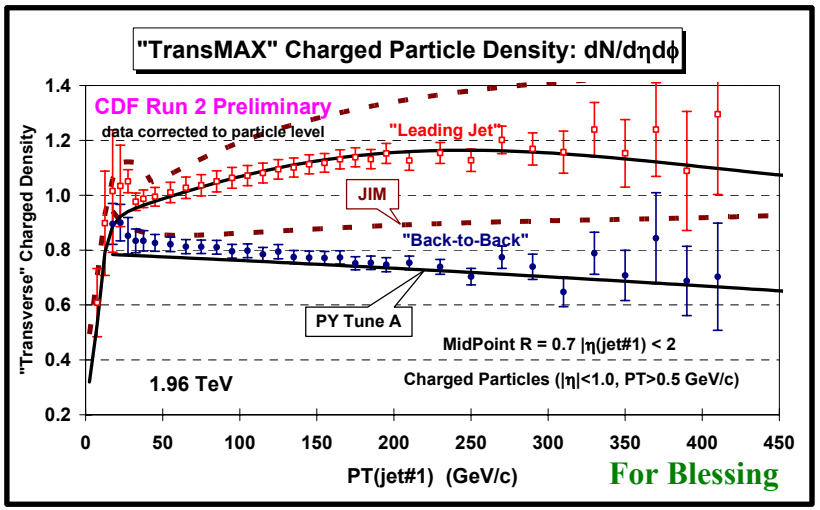


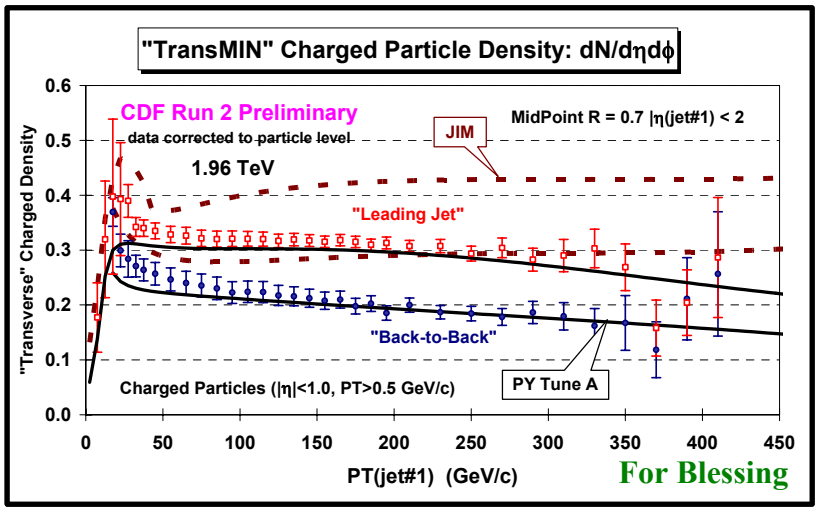


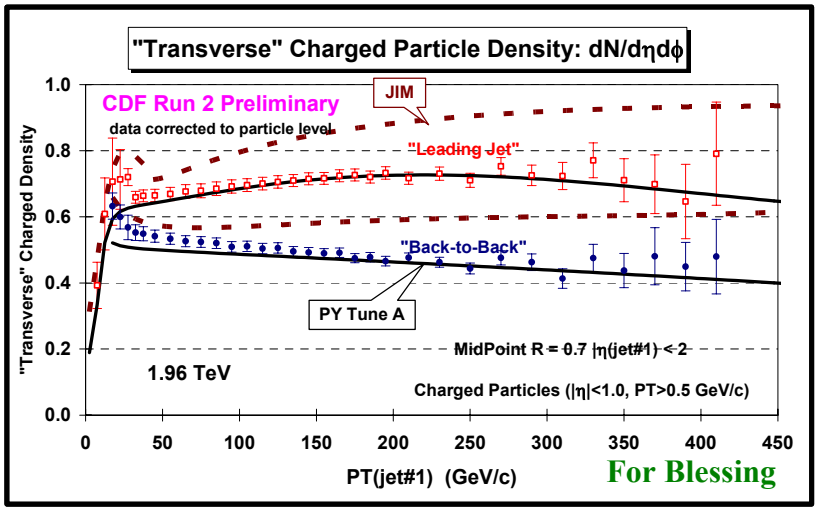


Data at 1.96 TeV on the difference of the "transMAX" and "transMIN" region ("transDIF" = "transMAX" minus "transMIN") for "leading jet" and "back-to-back" events as a function of the leading jet P_T compared with PYTHIA Tune A and tuned JIMMY (PTJIM = 3.25 GeV/c). The data are corrected to the particle level (with errors that include both the statistical error and the systematic uncertainty) and compared with the theory at the particle level (*i.e.* generator level).

Charged Particle Density: "Leading Jet" vs "Back-to-Back"







Data at 1.96 TeV on the charged particle density, $dN_{chg}/d\eta d\phi$ with $p_T > 0.5$ GeV/c and $|\eta| < 1$ in the "transMAX" region, "transMIN" region, and "transverse" region (average of "transMAX" and "transMIN") for "leading jet" and "back-to-back" events as a function of the leading jet P_T compared with PYTHIA Tune A and tuned JIMMY (PTJIM = 3.25 GeV/c). The data are corrected to the particle level (with errors that include both the statistical error and the systematic uncertainty) and compared with the theory at the particle level (*i.e.* generator level).