Min-Bias and the Underlying Event at the LHC

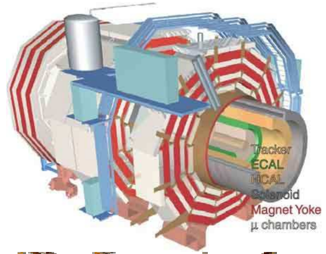
Rick Field
University of Florida

Quantum Chromo-Dynamics

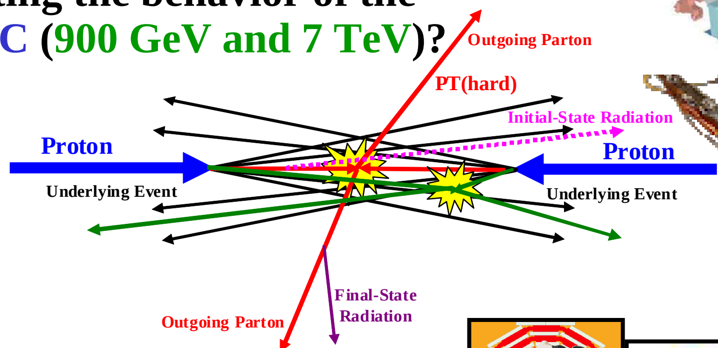
Zakopane, Poland, June 11-19, 2011

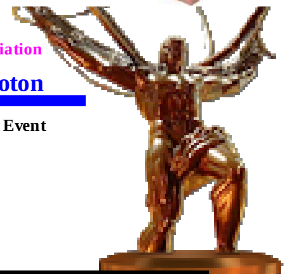
Lecture 1: Outline

- **Review:** The CDF Tevatron "underlying event" tunes (Tune A, B, D, AW, DW, D6, DWT, D6T).
- **Predicting the behavior of the "underlying event" at the LHC. What we expected to see.**
- **How well did we do at predicting the behavior of the "underlying event" at the LHC (900 GeV and 7 TeV)?**
- **LHC PYTHIA Tunes:** **PYTHIA 6.4 tunes (AMBT1, Z1, Z2) and PYTHIA 8 Tune C4.**



CMS





ATLAS

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Lecture 2: Tomorrow

- How are "min-bias" collisions related to the "underlying event".
- How well did we do at predicting the behavior of "min-bias" collisions at the LHC (900 GeV and 7 TeV)?
- **Baryon and Strange Particle Production at the LHC:** Fragmentation tuning.

K^+: $u\ \bar{s}$

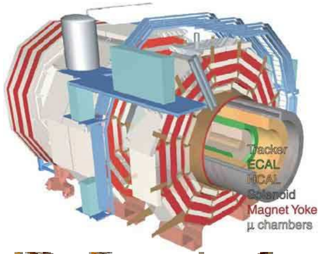
K_{short}: $d\ \bar{s} + \bar{d}\ s$

K^-: $\bar{u}\ s$

p: uud

Λ: uds

Ξ^-: dss



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From Feynman-Field to the LHC

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Chromo-
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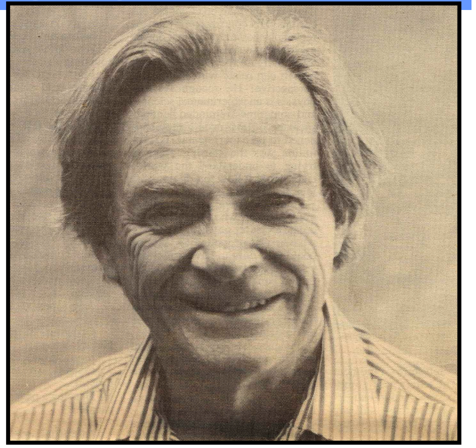
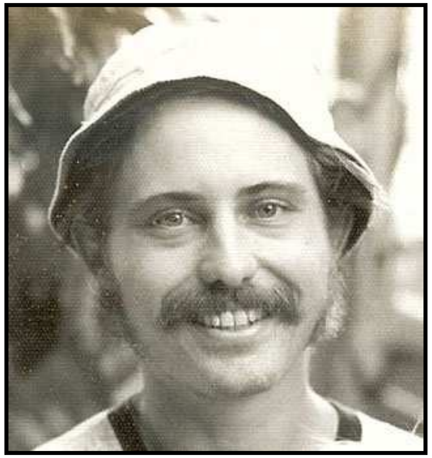
Lecture 3: Tuesday Evening

- **Before Feynman-Field Phenomenology: The Berkeley years.**
- **The early days of Feynman-Field Phenomenology.**
- **From 7 GeV/c π^0's to 1 TeV Jets!**

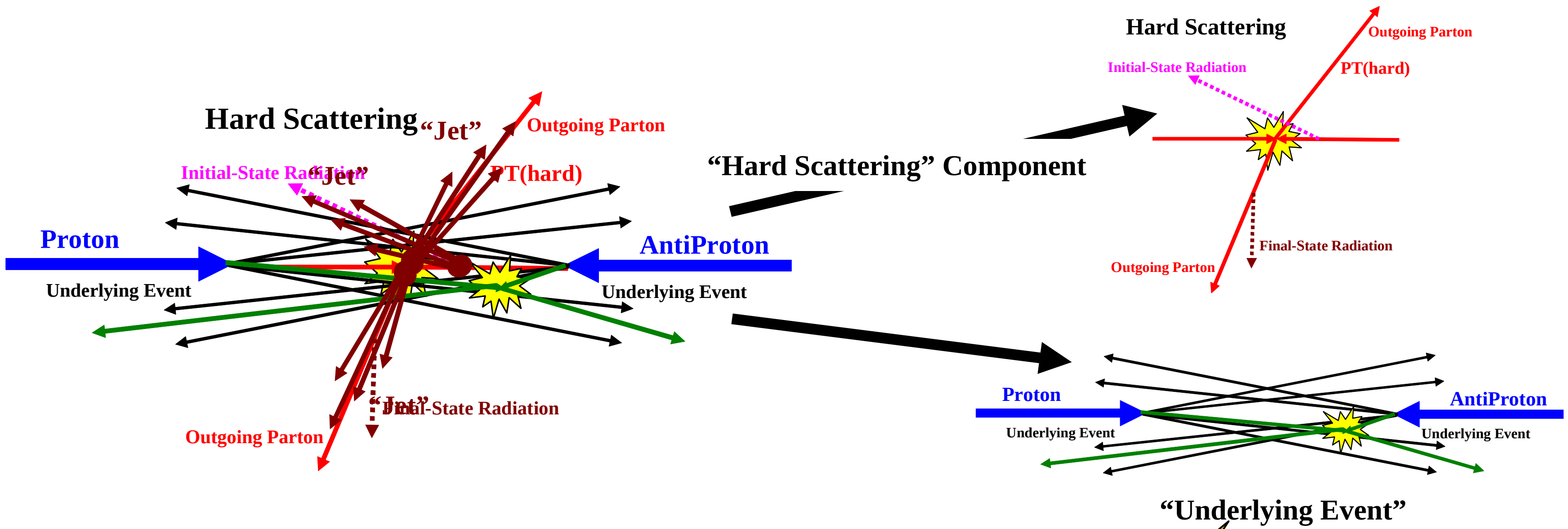


Feynman



Field

QCD Monte-Carlo Models: High Transverse Momentum Jets

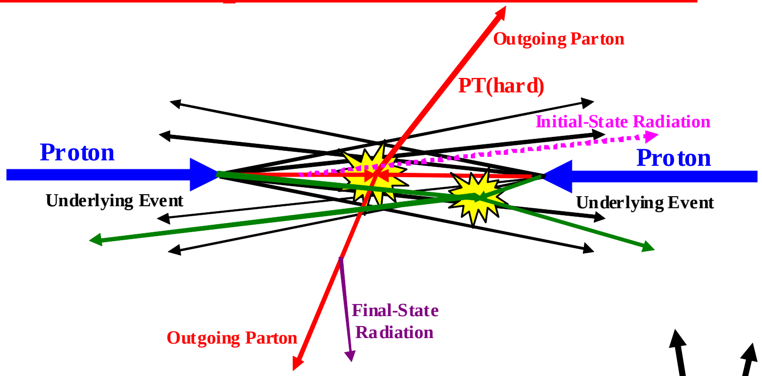


- **Start with the perturbative 2-to-2 (or sometimes 2-to-3) parton-parton scatter g and add initial and final-state gluon radiation (in the leading log approximation or modified leadin g approximation).**
- **The "underlying event" consists of the "beam-beam remnants" and articles arising from soft or semi-soft multiple parton interactions (MPI).**
- **Of course the outgoing colored parton bly "underlying event" observables receive contributions fron**

The "underlying event" is an unavoidable background to most collider observables and having good understand of it leads to more precise collider measurements!

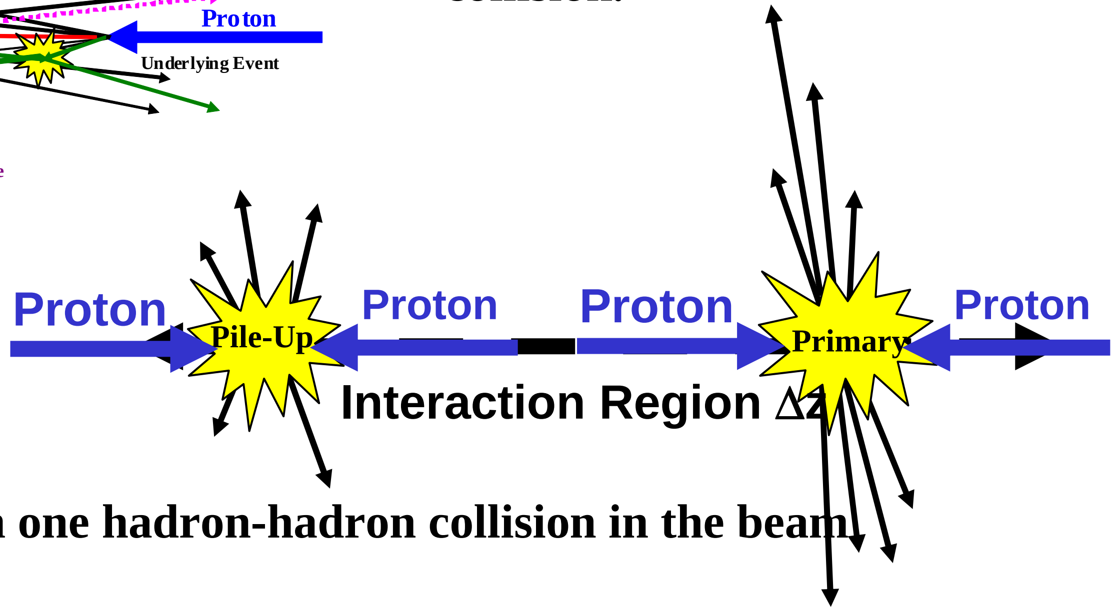
MPI, Pile-Up, and Overlap

MPI: Multiple Parton Interactions



- **MPI: Additional 2-to-2 parton-parton scatterings within a single hadron-hadron collision.**

Pile-Up

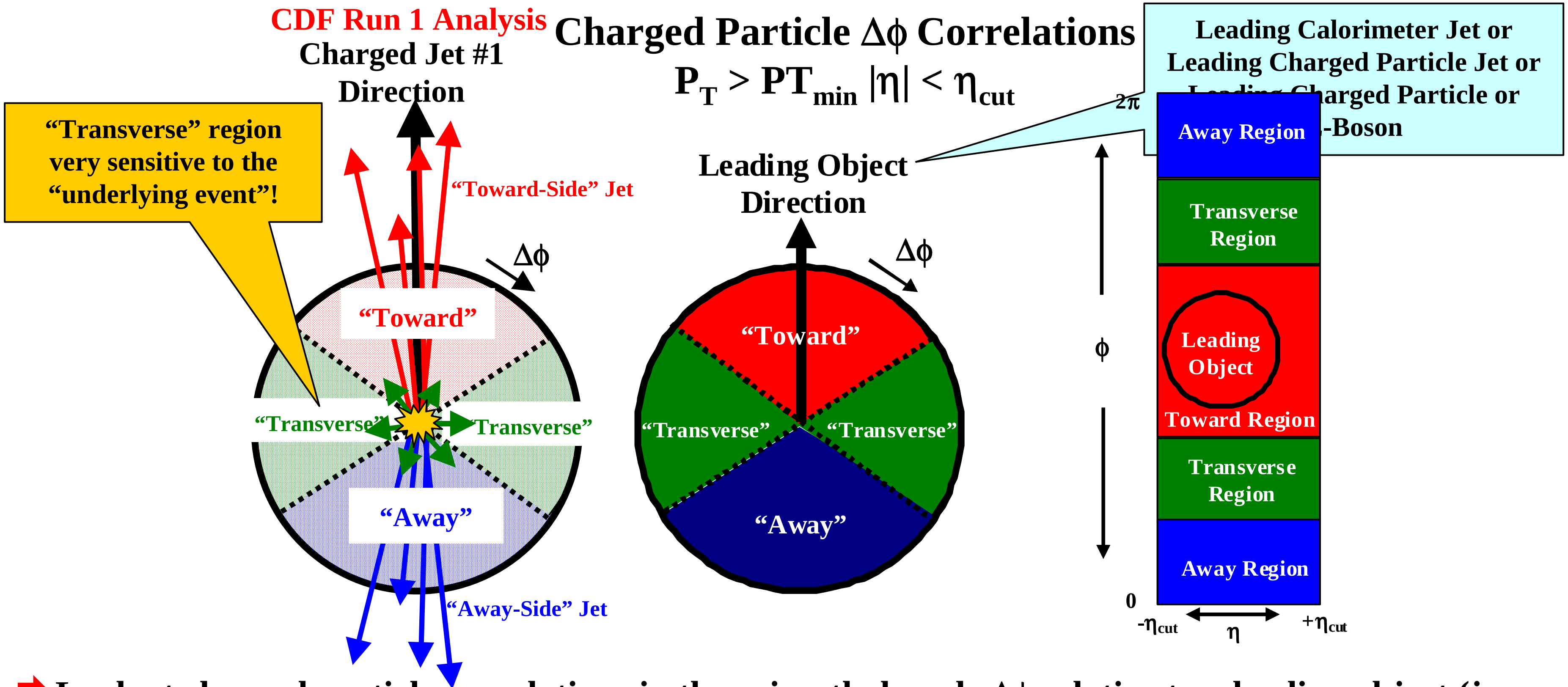


- **Pile-Up: More than one hadron-hadron collision in the beam crossing.**

Overlap

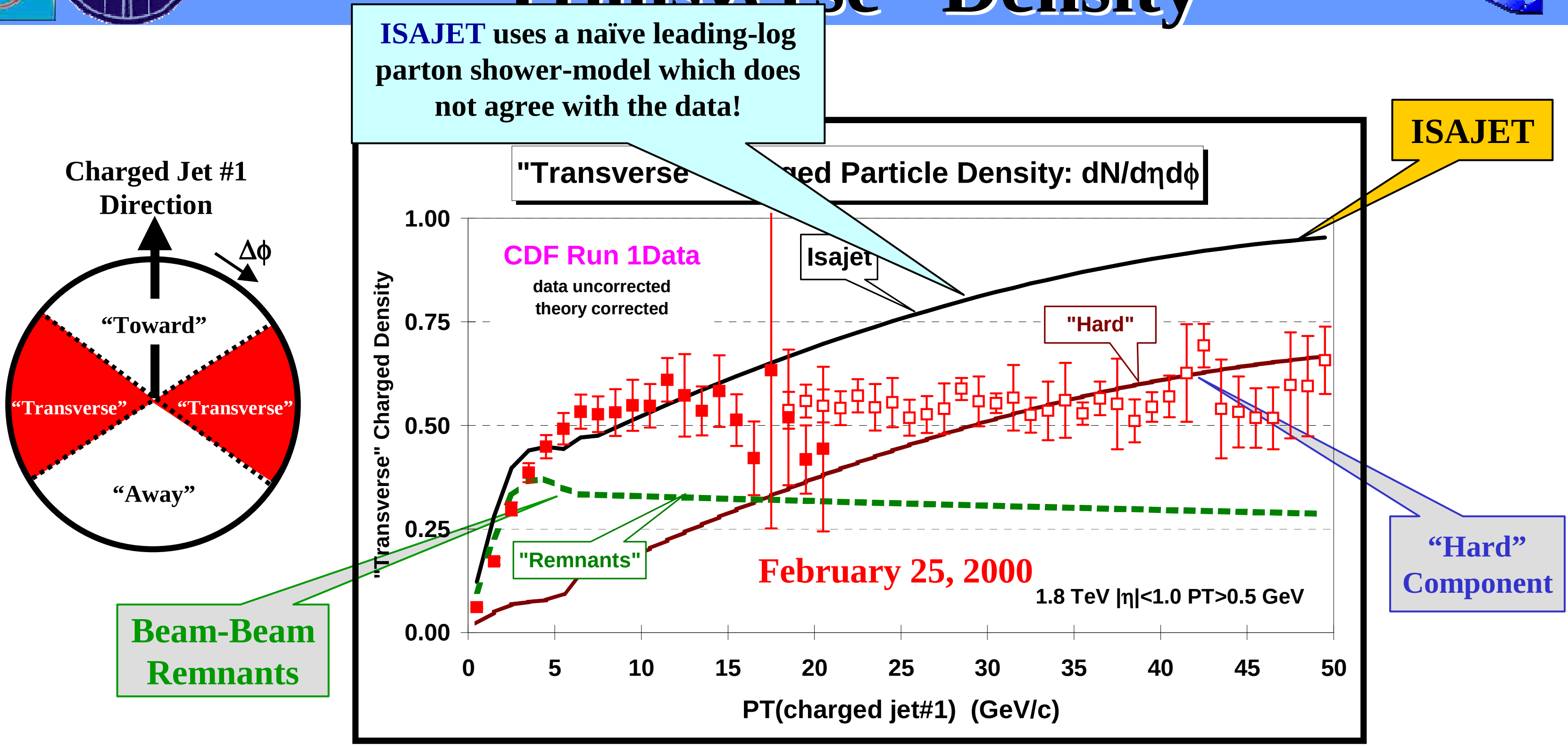
- **Overlap: An experimental timing issue where a hadron-hadron collision from the next beam crossing gets included in the hadron-hadron collision from the current beam crossing because the next crossing happened before the event could be read out.**

Traditional Approach



- Look at charged particle correlations in the azimuthal angle Δφ relative to a leading object (*i.e.* CaloJet#1, ChgJet#1, PTmax, Z-boson). For CDF PTmin = 0.5 GeV/c $\eta_{cut} = 1$.
- Define $|\Delta\phi| < 60^o$ as "Toward", $60^o < |\Delta\phi| < 120^o$ as "Transverse", and $|\Delta\phi| > 120^o$ as "Away".
- All three regions have the same area in η-φ space, $\Delta\eta\times\Delta\phi = 2\eta_{cut}\times120^o = 2\eta_{cut}\times2\pi/3$. Construct densities by dividing by the area in η-φ space.

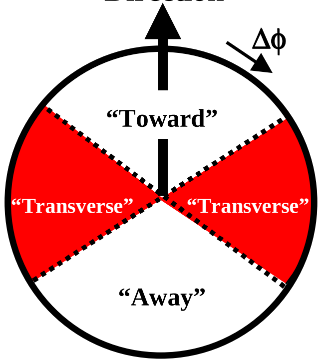
ISAJET 7.32 (without MPI) "Transverse" Density

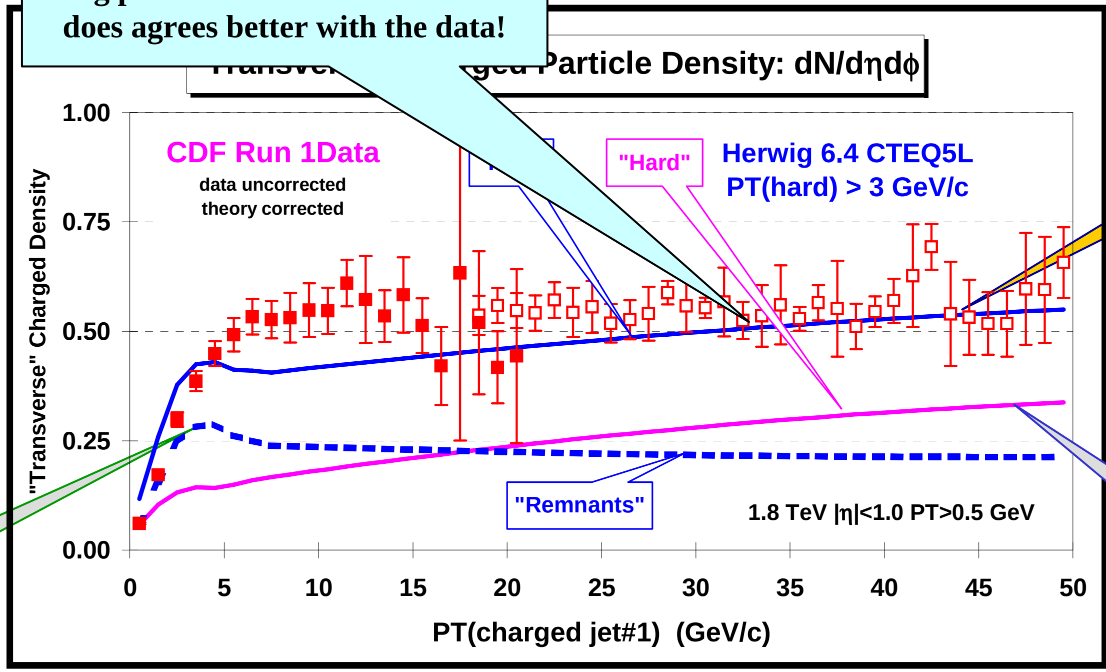


- Plot shows average "transverse" charge particle density ($|\eta|<1$, $p_T>0.5$ GeV) versus P_T(charged jet#1) compared to the QCD hard scattering predictions of ISAJET 7.32 (default parameters with P_T(hard)>3 GeV/c) .
- The predictions of ISAJET are divided into two categories: charged particles that arise from the break-up of the beam and target (beam-beam remnants); and charged particles that arise from the outgoing jet plus initial and final-state radiation (hard scattering component).

HERWIG 6.4 (without MPI) "Transverse" Density

HERWIG uses a modified leading-log parton shower-model which does agrees better with the data!





HERWIG

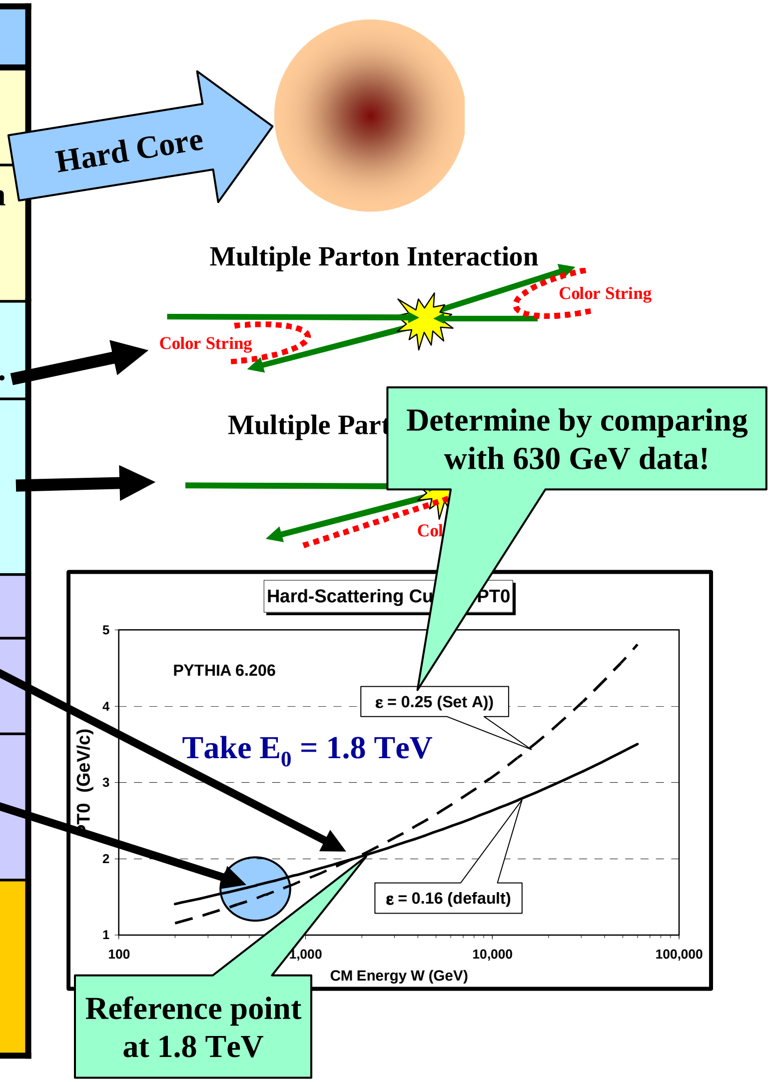
Beam-Beam Remnants

"Hard" Component

- Plot shows average "transverse" charge particle density ($|\eta|<1$, $p_T>0.5$ GeV) versus P_T(charged jet#1) compared to the QCD hard scattering predictions of **HERWIG 5.9** (default parameters with P_T(hard)>3 GeV/c without MPI).
- The predictions of HERWIG are divided into two categories: charged particles that arise from the break-up of the beam and target (**beam-beam remnants**); and charged particles that arise from the outgoing jet plus initial and final-state radiation (**hard scattering component**).

Tuning PYTHIA 6.2:
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 gluon loop. The remaining fraction consists of quark-antiquark pairs.
PARP(89)	1 TeV	Determines the reference energy E_0.
PARP(82)	1.9 GeV/c	The cut-off P_{T0} that regulates the 2-to-2 scattering divergence $1/PT^4 \rightarrow 1/(PT^2+P_{T0}^2)^2$
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.

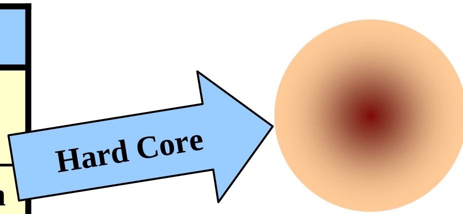


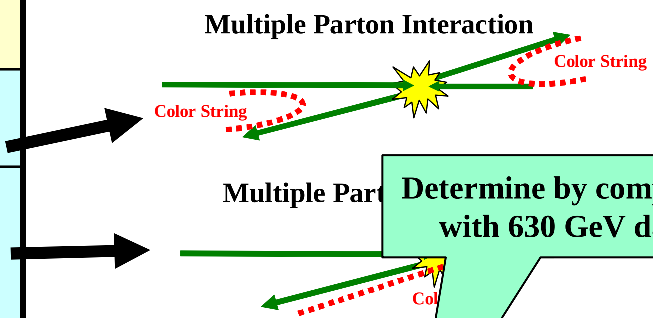
Tuning PYTHIA 6.2:
Multiple Parton Interaction Parameters

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	Pr... uces two gluons w... nearest neighbors.
PARP(86)	0.66	Prob... y t... luons eit... s des... closed ...l loop. ... ists of ...ark-antiqua... rs.
PARP(89)	1 Te...	Determin... reference energy E_0.
PARP(82)	...9 GeV/c	The c...ff P_{T0} that regulates the 2-to-2 sc...ring divergence $1/PT^4 \rightarrow 1/(PT^2+P_{T0}^2)^2$
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.

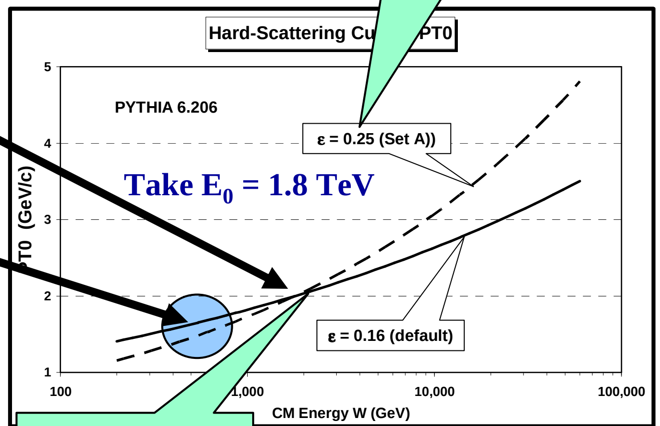
Determines the energy dependence of the MPI!

Affects the amount of initial-state radiation!





Determine by comparing with 630 GeV data!



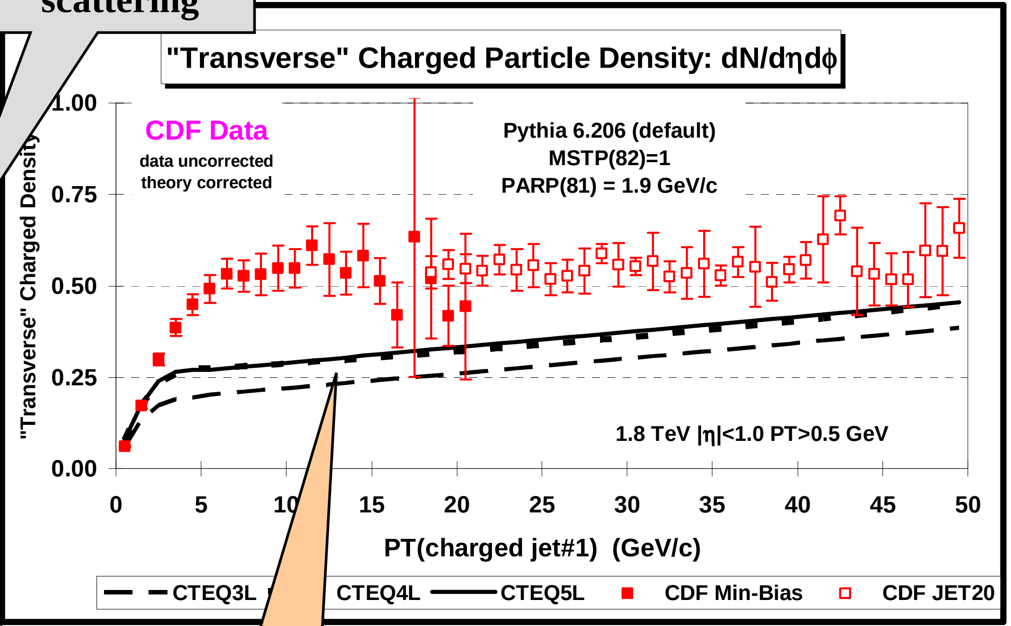
Reference point at 1.8 TeV

PYTHIA 6.206 Defaults

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

MPI constant probability scattering



- 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)

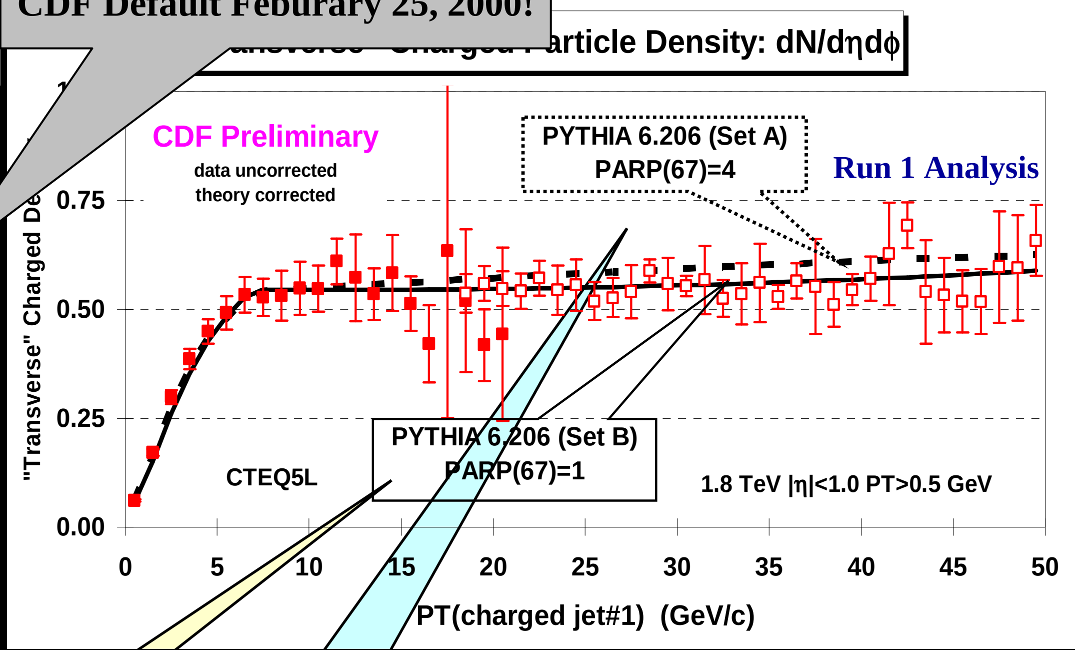
Default parameters give very poor description of the "underlying event"!

Run 1 PYTHIA Tune A

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

CDF Default Feburary 25, 2000!

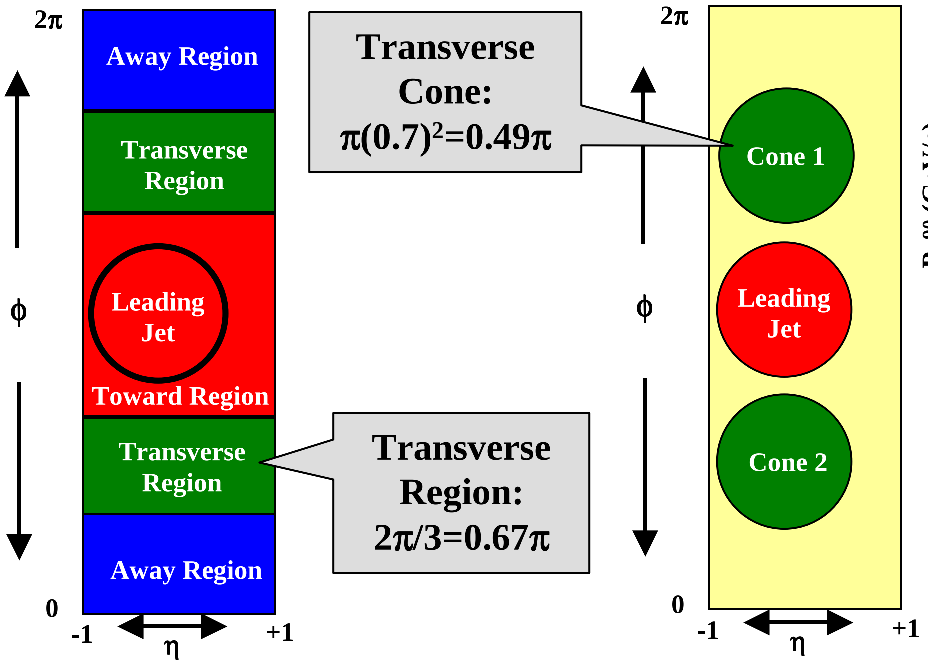


- **Plot shows the "transverse" charged particle density versus P_T(chgjet#1) compared to the QCD hard scattering predictions of two tuned versions of PYTHIA 6.206 (CTEQ5L, Set B (PARP(67)=1) and Set A (PARP(67)=4)).**

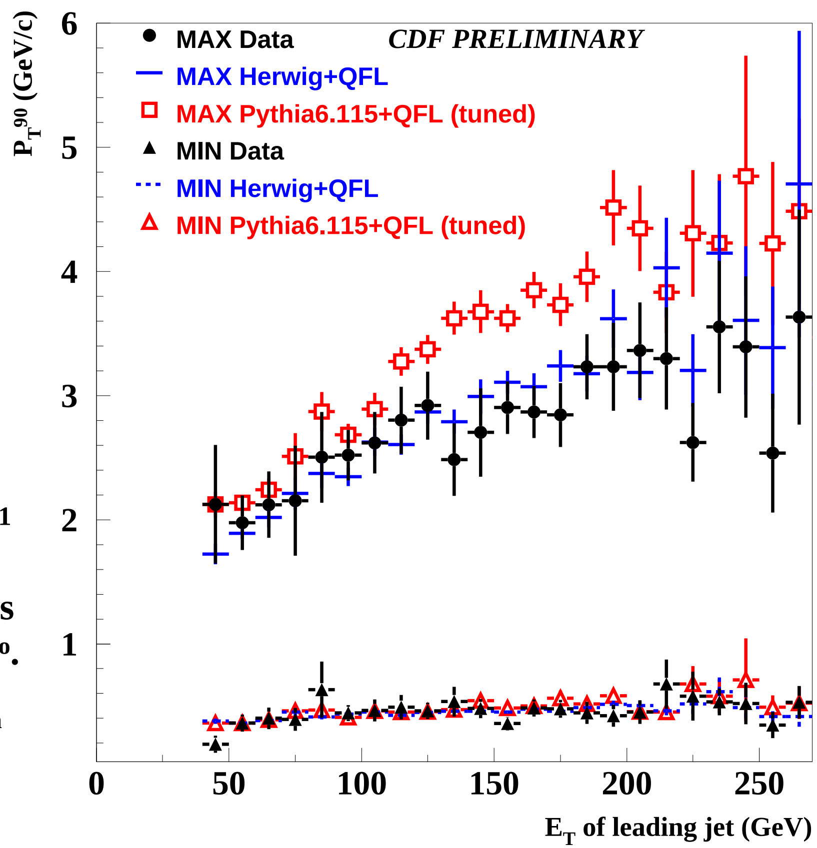
New PYTHIA default (less initial-state radiation)

Old PYTHIA default (more initial-state radiation)

"Transverse" Cones vs "Transverse" Regions

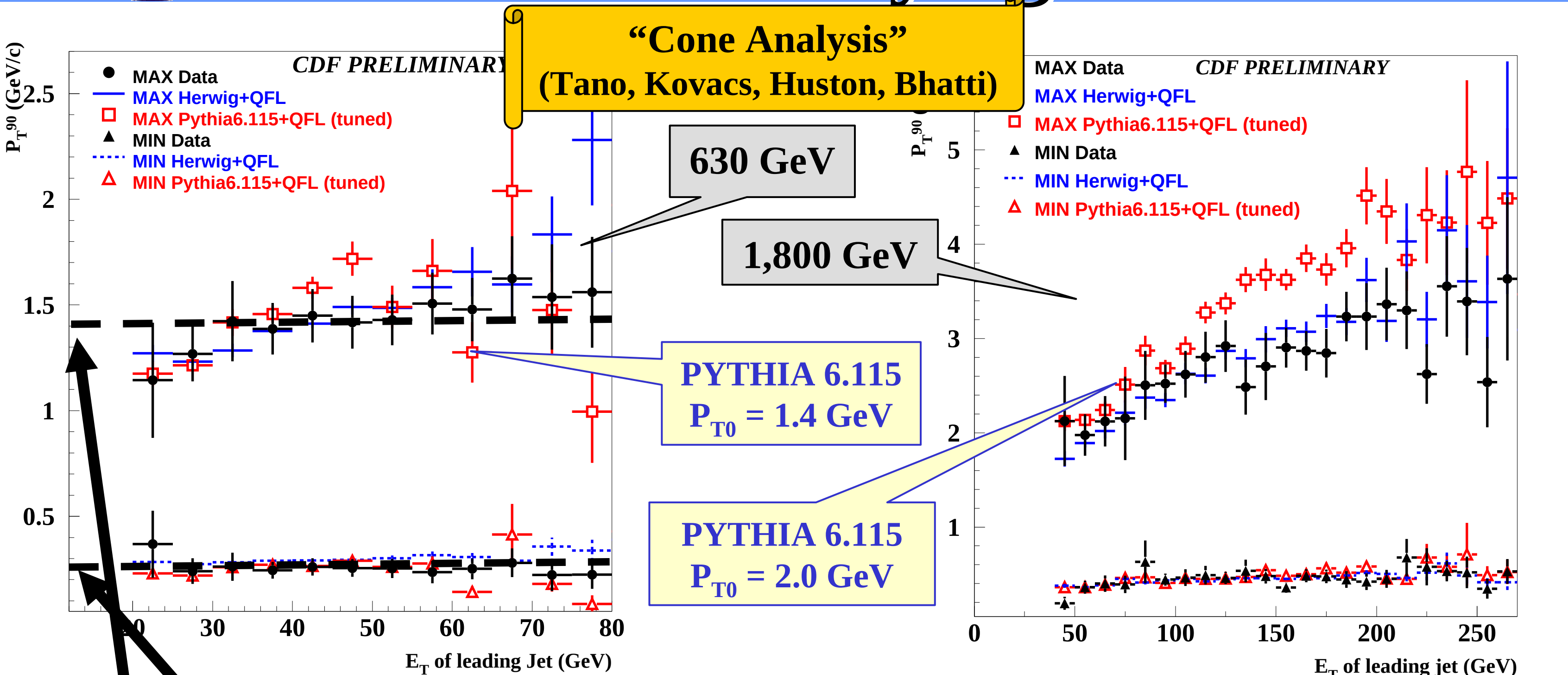


"Cone Analysis"
(Tano, Kovacs, Huston, Bhatti)



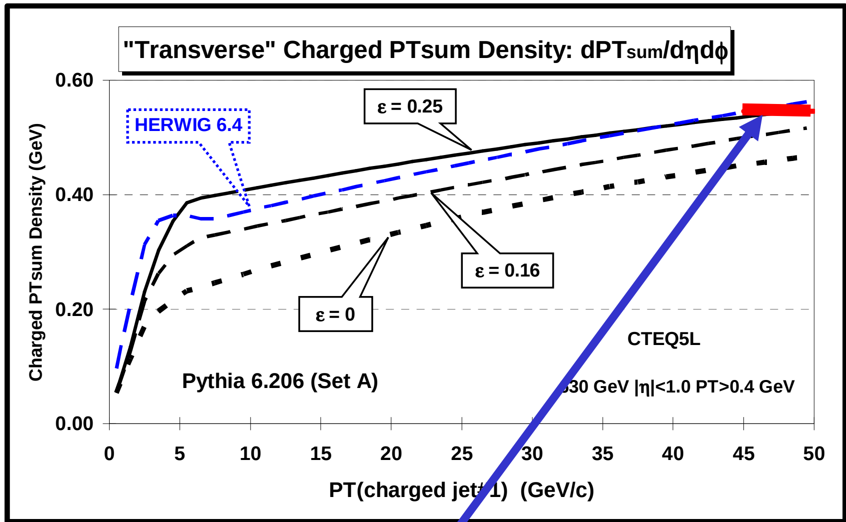
- Sum the P_T of charged particles in two cones of radius 0.7 at the same η as the leading jet but with $|\Delta\Phi| = 90^o$.
- Plot the cone with the maximum and minimum PT_{sum} versus the E_T of the leading (calorimeter) jet.

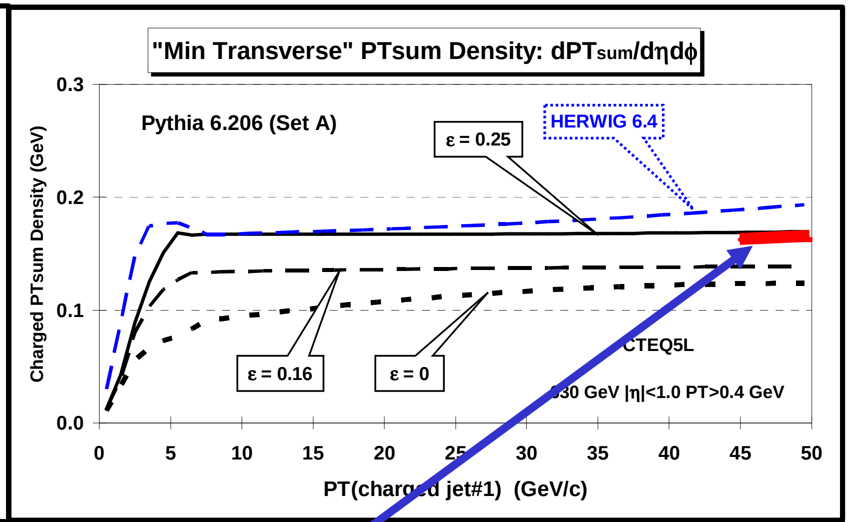
Energy Dependence of the "Underlying Event"



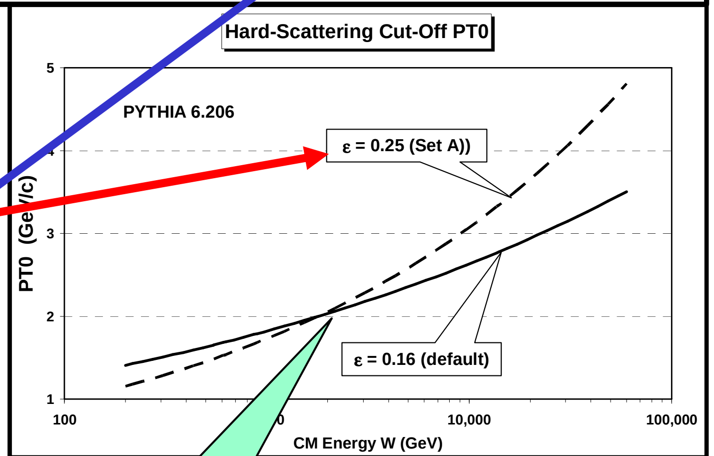
- Sum the P_T of charged particles (p_T > 0.4 GeV/c) in two cones of radius 0.7 at the same η as the leading jet but with |ΔΦ| = 90º. Plot the cone with the maximum and minimum PT_{sum} versus the E_T of the leading (calorimeter) jet.
- Note that PYTHIA 6.115 is tuned at 630 GeV with P_{T0} = 1.4 GeV and at 1,800 GeV with P_{T0} = 2.0 GeV. This implies that ε = PARP(90) should be around 0.30 instead of the 0.16 (default).
- For the MIN cone 0.25 GeV/c in radius R = 0.7 implies a PT_{sum} density of $dPT_{sum}/d\eta d\phi$ = 0.16 GeV/c and 1.4 GeV/c in the MAX cone implies $dPT_{sum}/d\eta d\phi$ = 0.91 GeV/c (average PT_{sum} density of 0.54 GeV/c per unit η-ϕ).

"Transverse" Charged Densities Energy Dependence



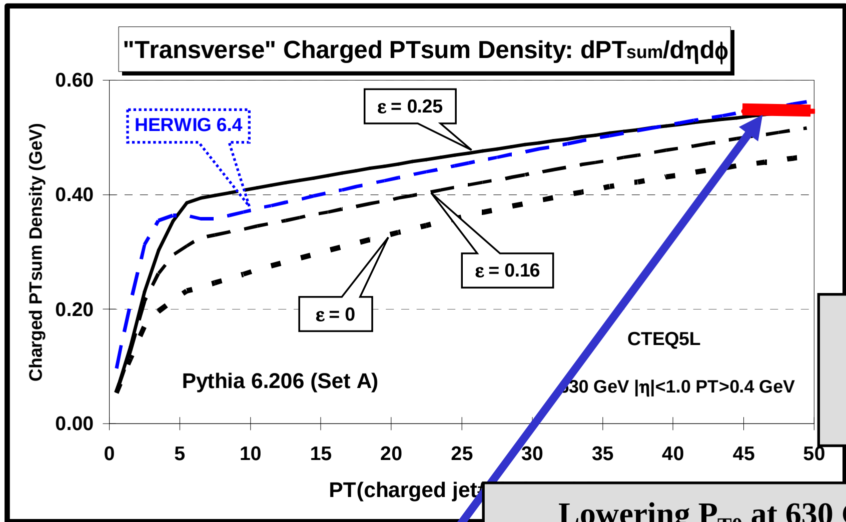


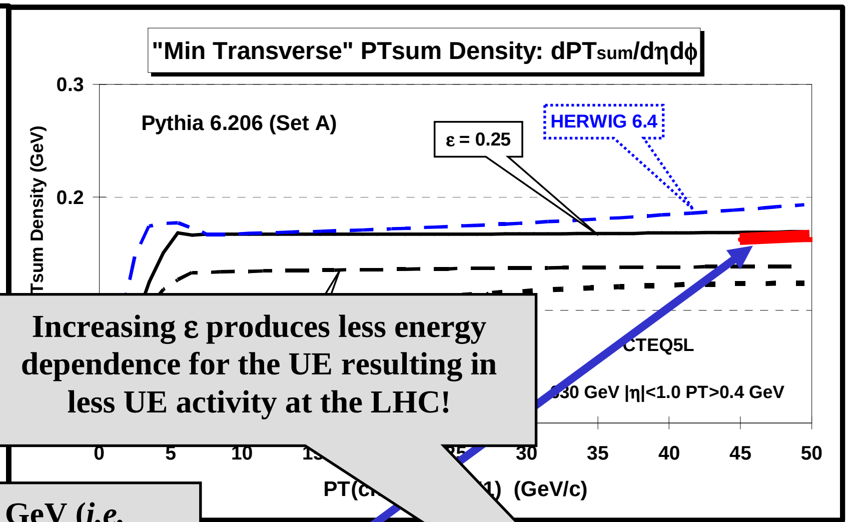
- Shows the "transverse" charged PT_{sum} density (|η|<1, P_T>0.4 GeV) versus P_T(charged jet#1) at 630 GeV predicted by HERWIG 6.4 (P_T(hard) > 3 GeV/c, CTEQ5L) and a tuned version of PYTHIA 6.206 (P_T(hard) > 0, CTEQ5L, Set A, ε = 0, ε = 0.16 (default) and ε = 0.25 (preferred)).
- Also shown are the PT_{sum} densities (0.16 GeV/c and 0.54 GeV/c) determined from the Tano, Kovacs, Huston, and Bhatti "transverse" cone analysis at 630 GeV.

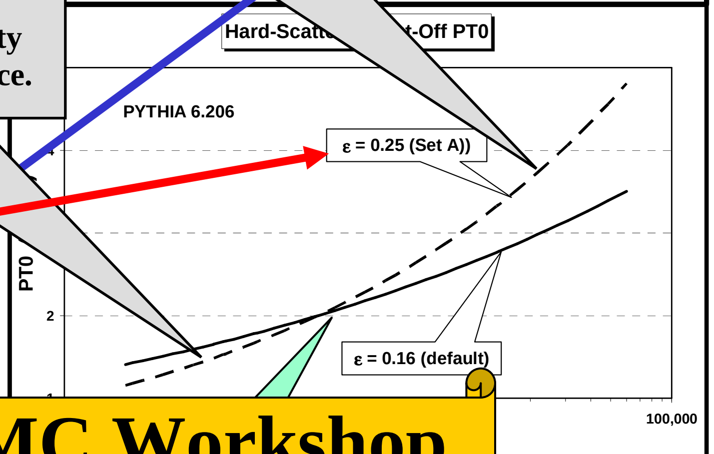


Reference point E_0 = 1.8 TeV

“Transverse” Charged Densities Energy Dependence







Increasing ε produces less energy dependence for the UE resulting in less UE activity at the LHC!

Lowering P_{T0} at 630 GeV (*i.e.* increasing ε) increases UE activity resulting in less energy dependence.

- **Shows the “transverse” ch ($|\eta|<1$, $P_T>0.4$ GeV) versus GeV predicted by HERWIG 6.4 (P_T(hard) > 3 GeV/c, CTEQ5L) and a tuned version of PYTHIA 6.206 (P_T(hard) > 0, CTEQ5L, Set A, ε = 0, ε = 0.16 (default) and ε = 0.25 (preferred)).**
- **Also shown are the PT_{sum} densities (0.16 GeV/c and 0.54 GeV/c) Huston, and 630 GeV.**

Rick Field Fermilab MC Workshop October 4, 2002!

CDF Run 1 $P_T(Z)$

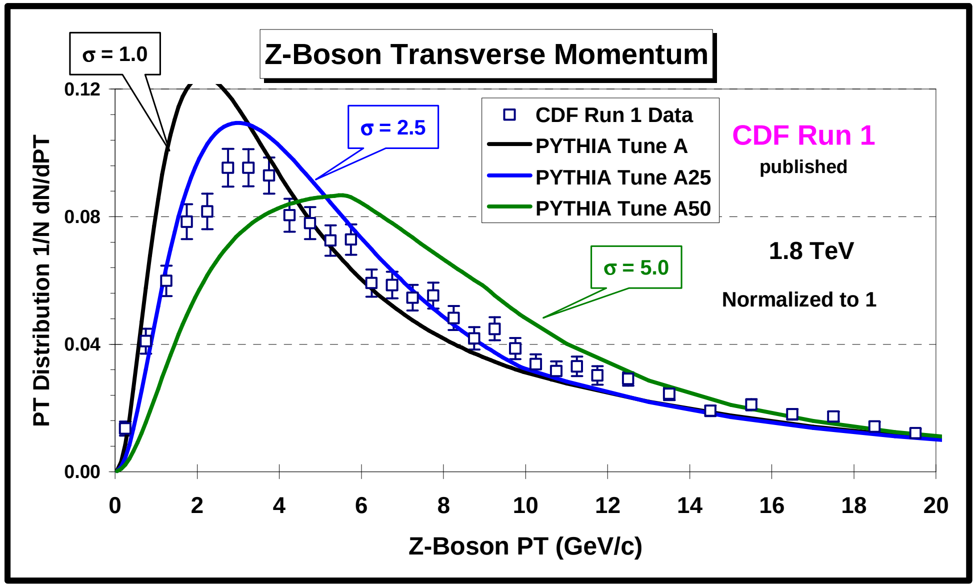
PYTHIA 6.2 CTEQ5L

UE Parameters

ISR Parameter

Intrensic KT

Parameter	Tune A	Tune A25	Tune A50
MSTP(81)	1	1	1
MSTP(82)	4	4	4
PARP(82)	2.0 GeV	2.0 GeV	2.0 GeV
PARP(83)	0.5	0.5	0.5
PARP(84)	0.4	0.4	0.4
PARP(85)	0.9	0.9	0.9
PARP(86)	0.95	0.95	0.95
PARP(89)	1.8 TeV	1.8 TeV	1.8 TeV
PARP(90)	0.25	0.25	0.25
PARP(67)	4.0	4.0	4.0
MSTP(91)	1	1	1
PARP(91)	1.0	2.5	5.0
PARP(93)	5.0	15.0	25.0



- Shows the Run 1 Z-boson p_T distribution ($<p_T(Z)> \approx 11.5$ GeV/c) compared with **PYTHIA Tune A** ($<p_T(Z)> = 9.7$ GeV/c), **Tune A25** ($<p_T(Z)> = 10.1$ GeV/c), and **Tune A50** ($<p_T(Z)> = 11.2$ GeV/c).

Vary the intrensic KT!

CDF Run 1 $P_T(Z)$

PYTHIA 6.2 CTEQ5L

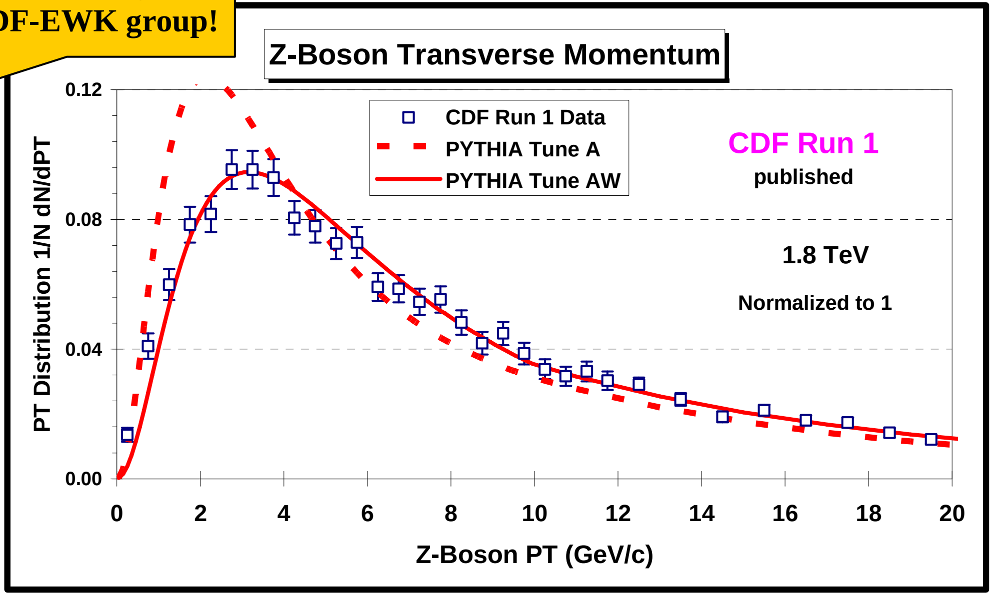
Tune used by the CDF-EWK group!

Parameter	Tune A	Tune AW
MSTP(81)	1	1
MSTP(82)	4	4
PARP(82)	2.0 GeV	2.0 GeV
PARP(83)	0.5	0.5
PARP(84)	0.4	0.4
PARP(85)	0.9	0.9
PARP(86)	0.95	0.95
PARP(89)	1.8 TeV	1.8 TeV
PARP(90)	0.25	0.25
PARP(62)	1.0	1.25
PARP(64)	1.0	0.2
PARP(67)	4.0	4.0
MSTP(91)	1	1
PARP(91)	1.0	2.1
PARP(93)	5.0	15.0

UE Parameters

ISR Parameters

Intrensic KT



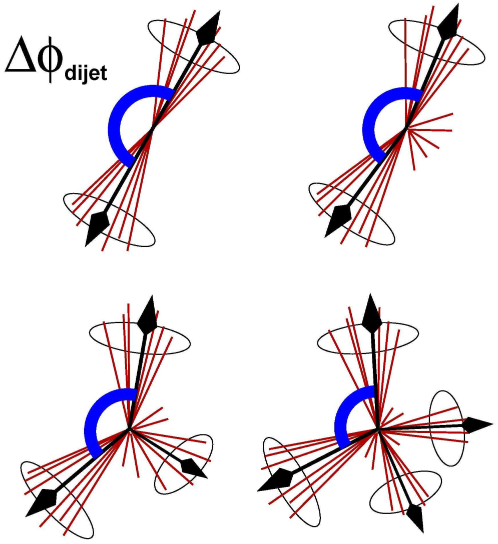
- Shows the Run 1 Z-boson p_T distribution ($<p_T(Z)> \approx$ 11.5 GeV/c) compared with PYTHIA Tune A ($<p_T(Z)>$ = 9.7 GeV/c), and PYTHIA Tune AW ($<p_T(Z)>$ = 11.7 GeV/c).

Effective Q cut-off, below which space-like showers are not evolved.

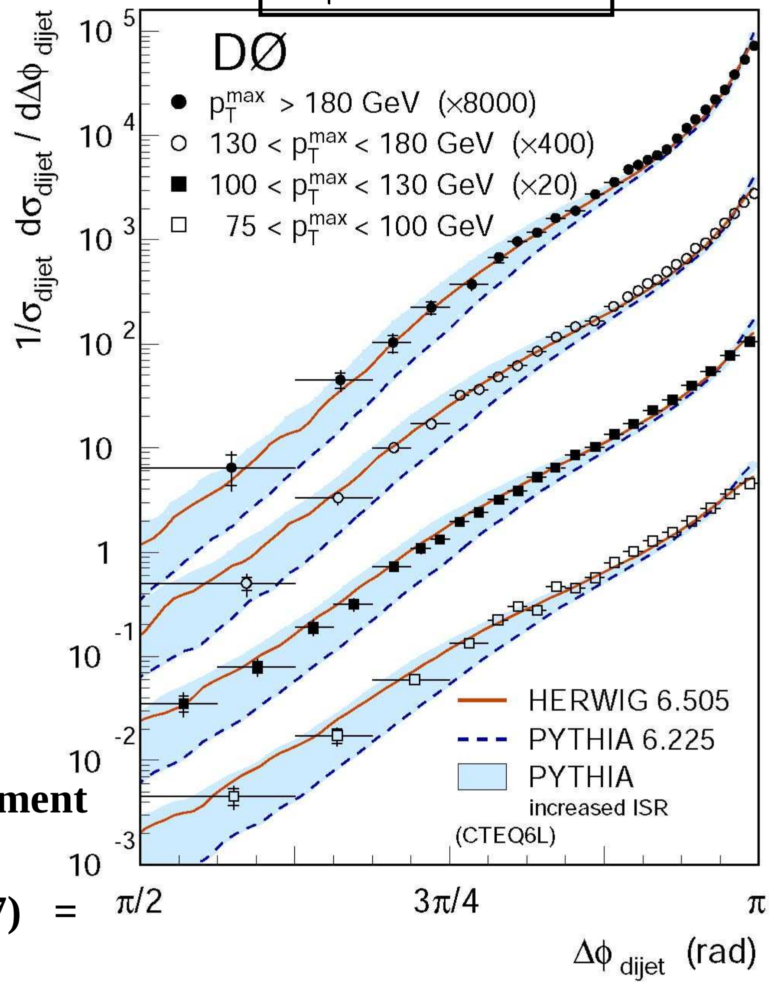
The $Q^2 = k_T^2$ in α_s for space-like showers is scaled by PARP(64)!

Jet-Jet Correlations (DØ)

Jet#1-Jet#2 Δφ Distribution



Δφ Jet#1-Jet#2



- **MidPoint Cone Algorithm (R = 0.7, f_{merge} = 0.5)**
- **$\mathcal{L}$= 150 pb^{-1} (Phys. Rev. Lett. 94 221801 (2005))**
- **Data/NLO agreement good. Data/HERWIG agreement good.**
- **Data/PYTHIA agreement good provided PARP(67) = 1.0→4.0 (i.e. like Tune A, best fit 2.5).**

CDF Run 1 $P_T(Z)$

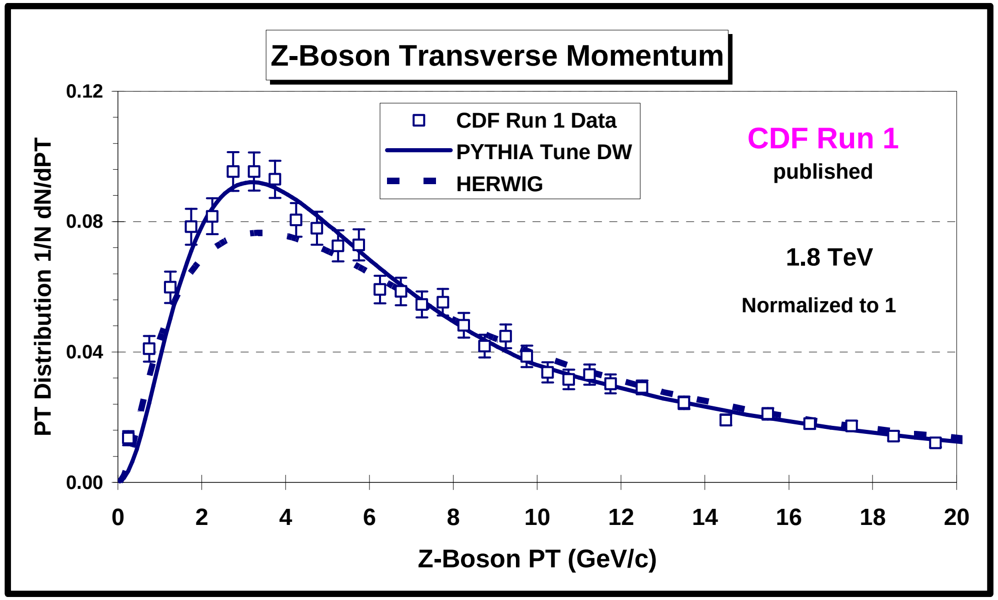
PYTHIA 6.2 CTEQ5L

Parameter	Tune DW	Tune AW
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(62)	1.25	1.25
PARP(64)	0.2	0.2
PARP(67)	2.5	4.0
MSTP(91)	1	1
PARP(91)	2.1	2.1
PARP(93)	15.0	[illegible]

UE Parameters

ISR Parameters

Intrensic KT



- Shows the Run 1 Z-boson p_T distribution ($<p_T(Z)> \approx 11.5$ GeV/c) compared with PYTHIA Tune DW, and HERWIG.

Tune DW uses D0's perfered value of PARP(67)!

Tune DW has a lower value of PARP(67) and slightly more MPI!

PYTHIA 6.2 Tunes

All use LO α_s with Λ = 192 MeV!

Parameter	Tune AW	Tune DW	Tune D6
PDF	CTEQ5L	CTEQ5L	CTEQ6L
MSTP(81)	1	1	1
MSTP(82)	4	4	4
PARP(82)	2.0 GeV	1.9 GeV	1.8 GeV
PARP(83)	0.5	0.5	0.5
PARP(84)	0.4	0.4	0.4
PARP(85)	0.9	1.0	1.0
PARP(86)	0.95	1.0	1.0
PARP(89)	1.8 TeV	1.8 TeV	1.8 TeV
PARP(90)	0.25	0.25	0.25
PARP(62)	1.25	1.25	1.25
PARP(64)	0.2	0.2	0.2
PARP(67)	4.0	2.5	2.5
MSTP(91)	1	1	1
PARP(91)	2.1	2.1	2.1
PARP(93)	15.0	15.0	15.0

UE Parameters

ISR Parameter

Intrinsic KT

Uses CTEQ6L

Tune A energy dependence!

PYTHIA 6.2 Tunes

All use LO α_s with Λ = 192 MeV!

UE Parameters

ISR Parameter

Intrinsic KT

ATLAS energy dependence!

Parameter	Tune DWT	Tune D6T	ATLAS
PDF	CTEQ5L	CTEQ6L	CTEQ5L
MSTP(81)	1	1	1
MSTP(82)	4	4	4
PARP(82)	1.9409 GeV	1.8387 GeV	1.8 GeV
PARP(83)	0.5	0.5	0.5
PARP(84)	0.4	0.4	0.5
PARP(85)	1.0	1.0	0.33
PARP(86)	1.0	1.0	0.66
PARP(89)	1.96 TeV	1.96 TeV	1.0 TeV
PARP(90)	0.16	0.16	0.16
PARP(62)	1.25	1.25	1.0
PARP(64)	0.2	0.2	1.0
PARP(67)	2.5	2.5	1.0
MSTP(91)	1	1	1
PARP(91)	2.1	2.1	1.0
PARP(93)	15.0	15.0	5.0

PYTHIA 6.2 Tunes

All use LO α_s with Λ = 192 MeV!

UE Parameters

rameter

AT ce!

Parameter	Tune DWT	Tune D6T	ATLAS
PDF	CTEQ5L	CTEQ6L	CTEQ5L
MSTP(81)	1	1	1
MSTP(82)	4	4	4
ARP( )	1.9409 GeV	1.8387 eV	1.8 GeV
[illegible]	0.5	[illegible]	0.5
[illegible]	0.4	[illegible]	.5
[illegible]	1.0	[illegible]	.33
)	1.0	1.	66
ARP(9)	1.96 TeV	1.96 TeV	1.0 TeV
PARP(90)	0.16	0.16	0.16
PARP(62)	1.25	1.25	1.0
PARP(64)	0.	0.2	1.0
PARP(6	[illegible]	2.5	1.0
MSTP(91)	[illegible]	1	[illegible]
PARP(9	[illegible]	2.1	[illegible]
PARP	[illegible]	15.0	[illegible]

Tune A

Tune AW

Tune B

Tune BW

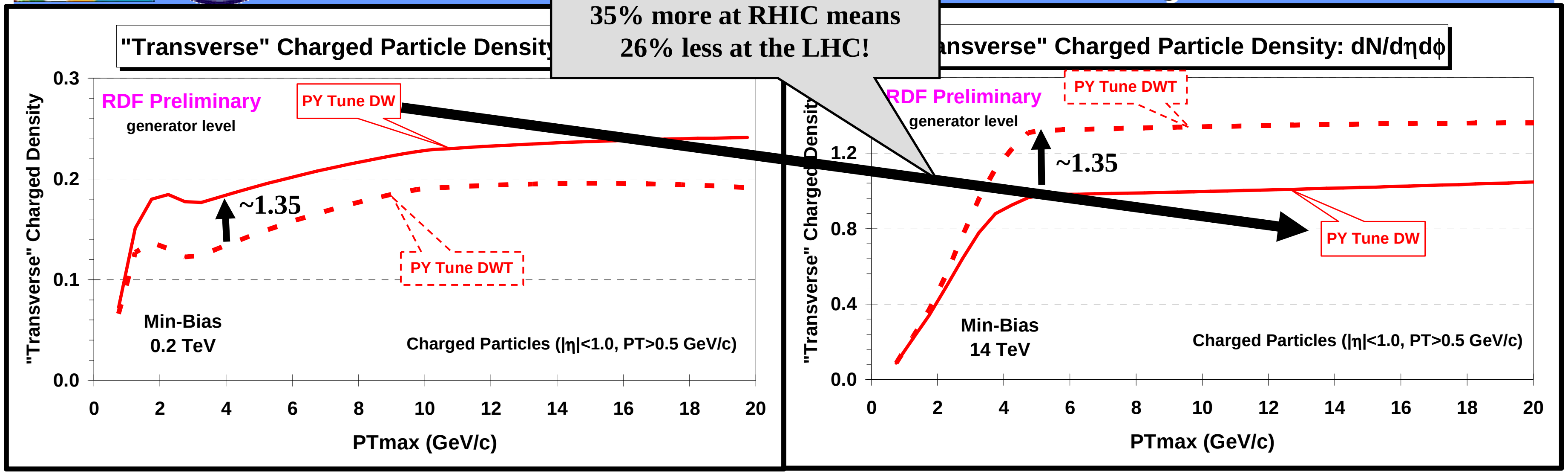
Tune D

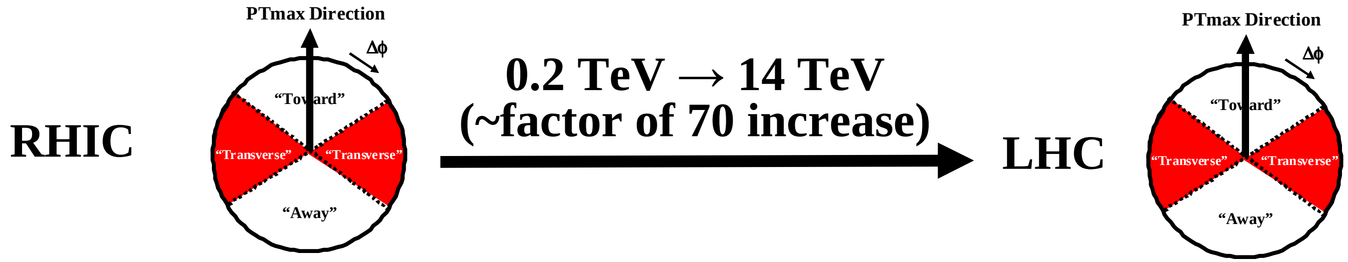
Tune DW

Tune D6

Tune D6T

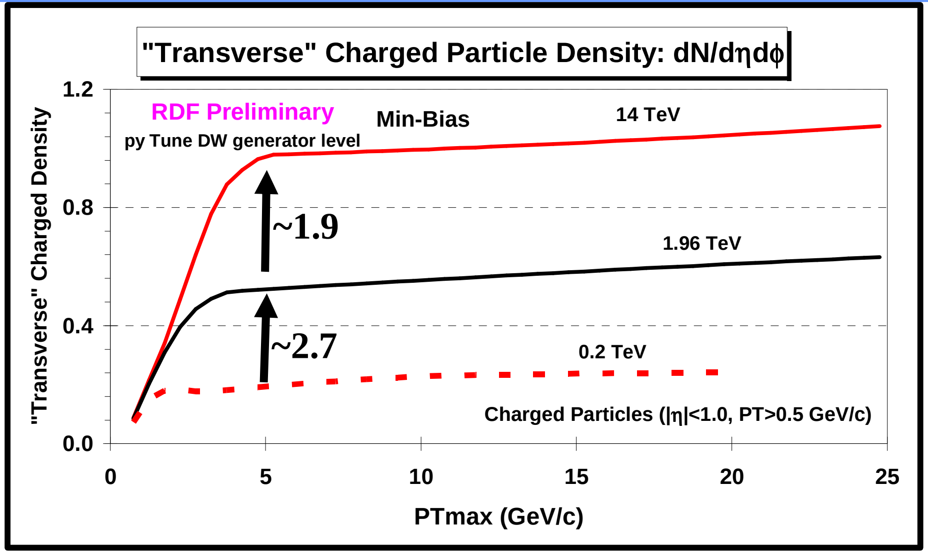
Min-Bias "Associated" Charged Particle Density

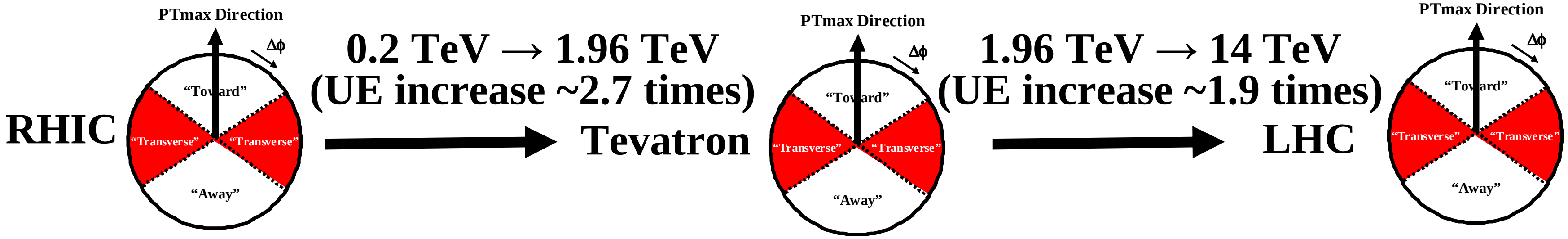




- Shows the "associated" charged particle density in the **"transverse"** regions as a function of PTmax for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$, *not including PTmax*) for "min-bias" events at 0.2 TeV and 14 TeV from PYTHIA **Tune DW and Tune DWT** at the particle level (*i.e.* generator level). **The STAR data from RHIC favors Tune DW!**

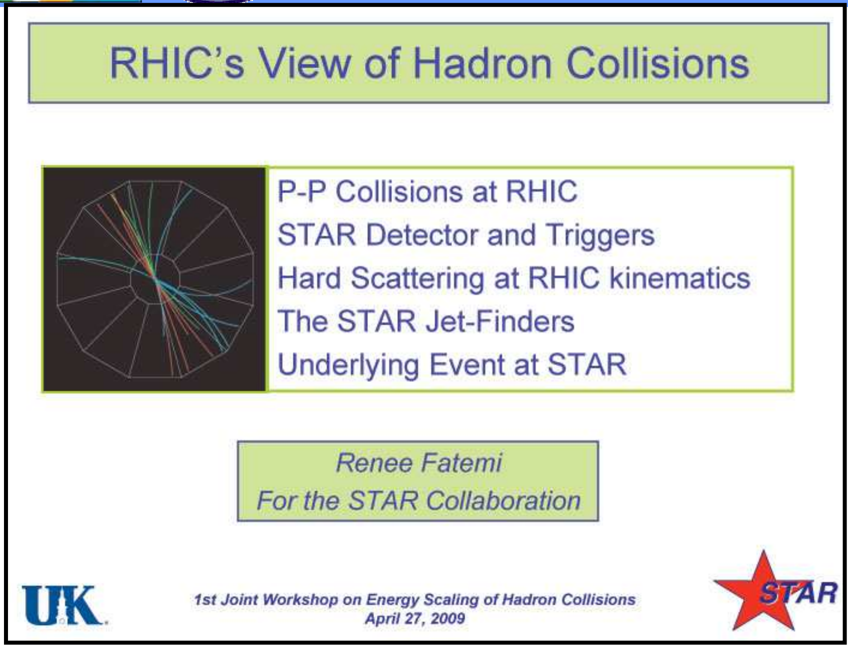
Min-Bias "Associated" Charged Particle Density

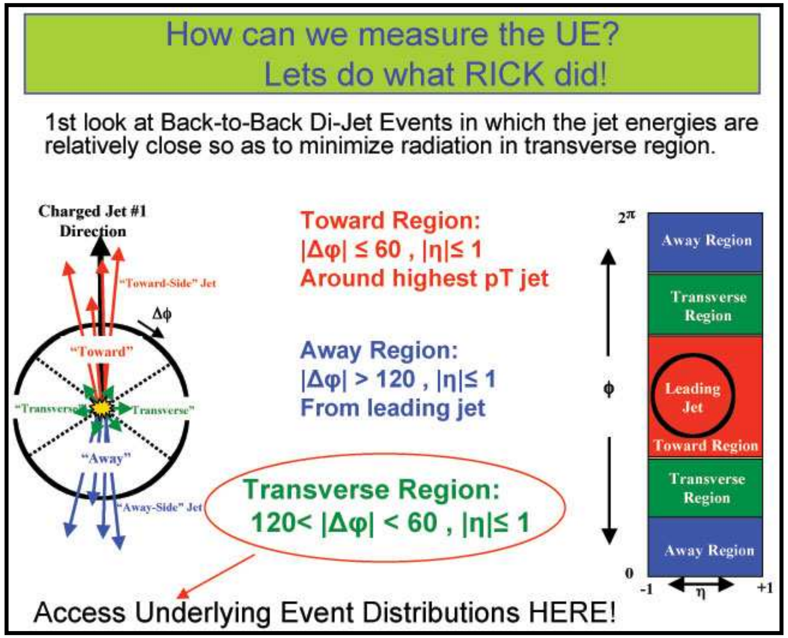




- Shows the "associated" charged particle density in the "transverse" region as a function of PTmax for charged particles (p_T > 0.5 GeV/c, |η| < 1, *not including PTmax*) for "min-bias" events at 0.2 TeV, 1.96 TeV and 14 TeV predicted by PYTHIA Tune DW at the particle level (*i.e.* generator level).

The "Underlying Event" at STAR

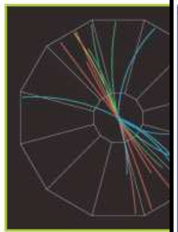




➡ **At STAR they have measured the "underlying event at W = 200 GeV (|η| < 1, p_T > 0.2 GeV) and compared their uncorrected data with PYTHIA Tune A + STAR-SIM.**

The "Underlying Event" at STAR

RHIC



ergies are
egion.

Conclusions

I. Hadron Collisions at RHIC take place at an order of magnitude smaller $\sqrt{s}$ than the Tevatron. Nevertheless, jets are observed and reconstructed down to pT=5 GeV and are well described by pQCD

II. Comparisons between several jetfinders reveal consistent results

III. Interest in the Underlying Event at RHIC Kinematics is driven by the need for jet energy scale corrections as well as pure physics interests (see talks by M. Lisa and H. Caines)

IV. UE at RHIC appears to be independent of jet pT and decoupled from hard interaction

V. CDF Tune A provides an excellent description of the UE at $\sqrt{s}$ =200 GeV (thanks Rick!)

VI. Underlying Event distributions in general smaller than those at CDF. Tower & Track Multiplicities are the exception, but this may be due to the 0.2 (STAR) versus 0.5 GeV (CDF) pT/Et cut-off.

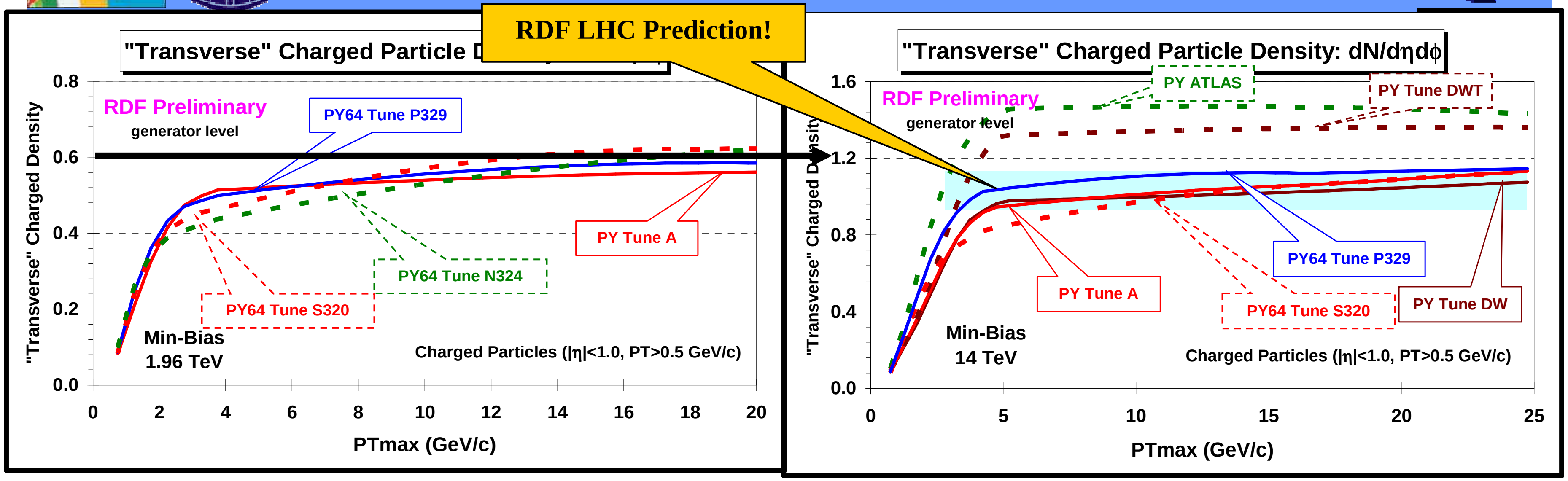
VII. For a cone jet with R=0.7 UE contributes 0.5-0.9 GeV.

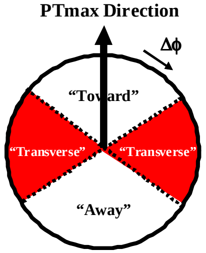
VIII. Comparison of Leading Jet and Back-to-Back distributions indicate that large angle radiation contributions are small at RHIC energies.

UK

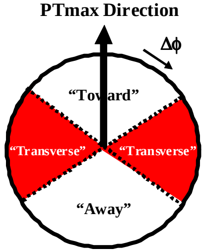
➡ **At STAR** ... **2 GeV)**
and com

Transverse Charged Particle Density



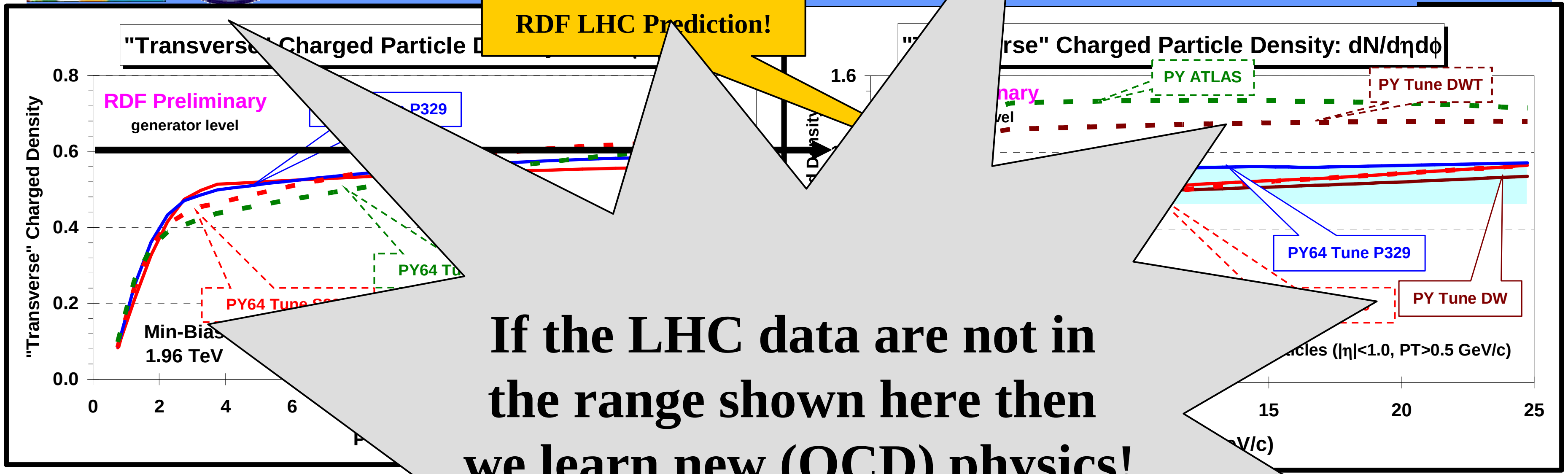


Tevatron → LHC



- Shows the "associated" charged particle density in the "transverse" region as a function of PTmax for charged particles (p_T > 0.5 GeV/c, |η| < 1, *not including PTmax*) for "min-bias" events at 1.96 TeV from PYTHIA Tune A, Tune S320, Tune N324, and Tune P329 at the particle level (*i.e.* generator level).
- Extrapolations of PYTHIA Tune A, Tune DW, Tune DWT, Tune S320, Tune P329, and pyATLAS to the LHC.

Transverse Charged Particle Density

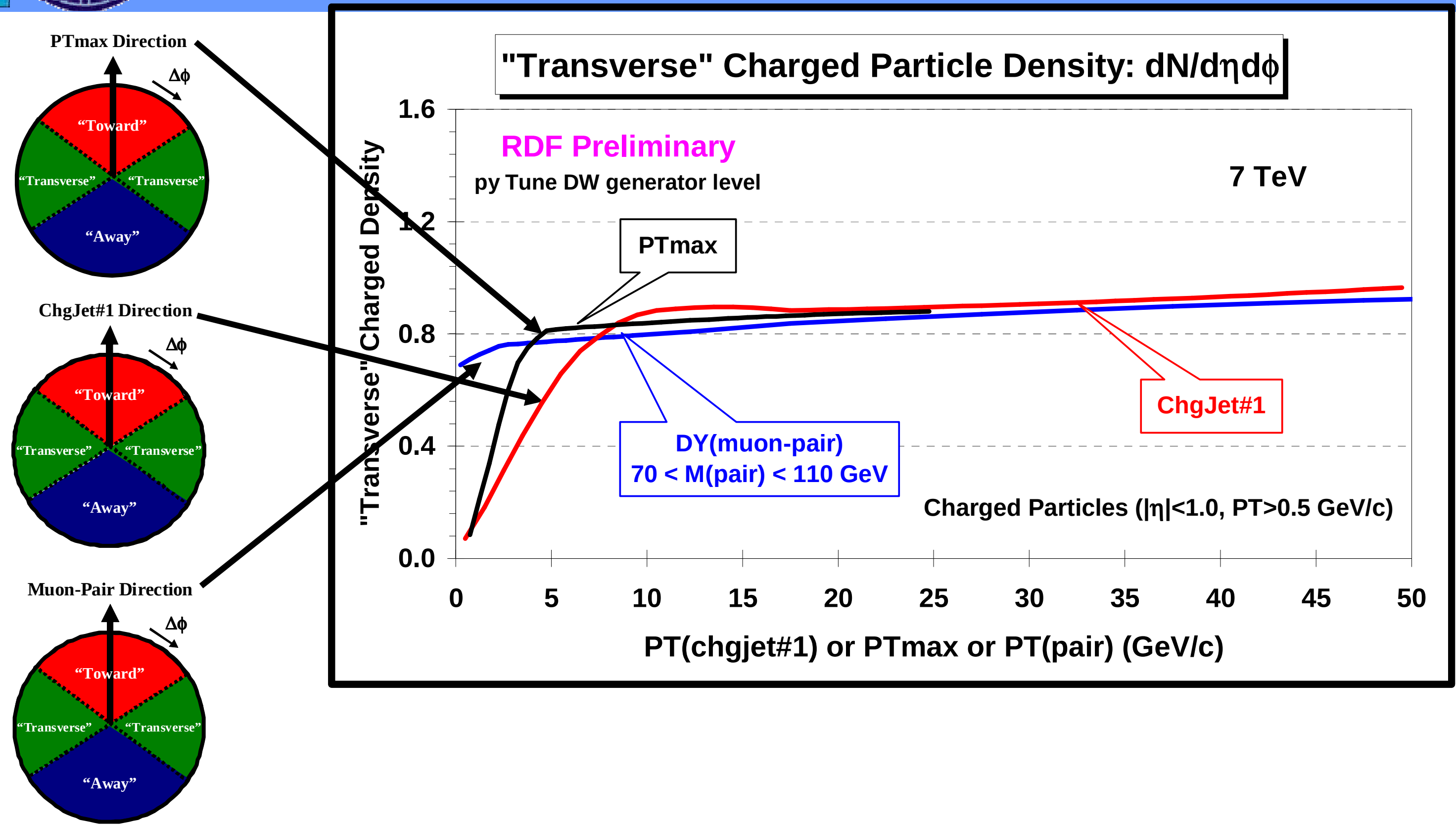


If the LHC data are not in the range shown here then we learn new (QCD) physics!

Rick Field October 13, 2009

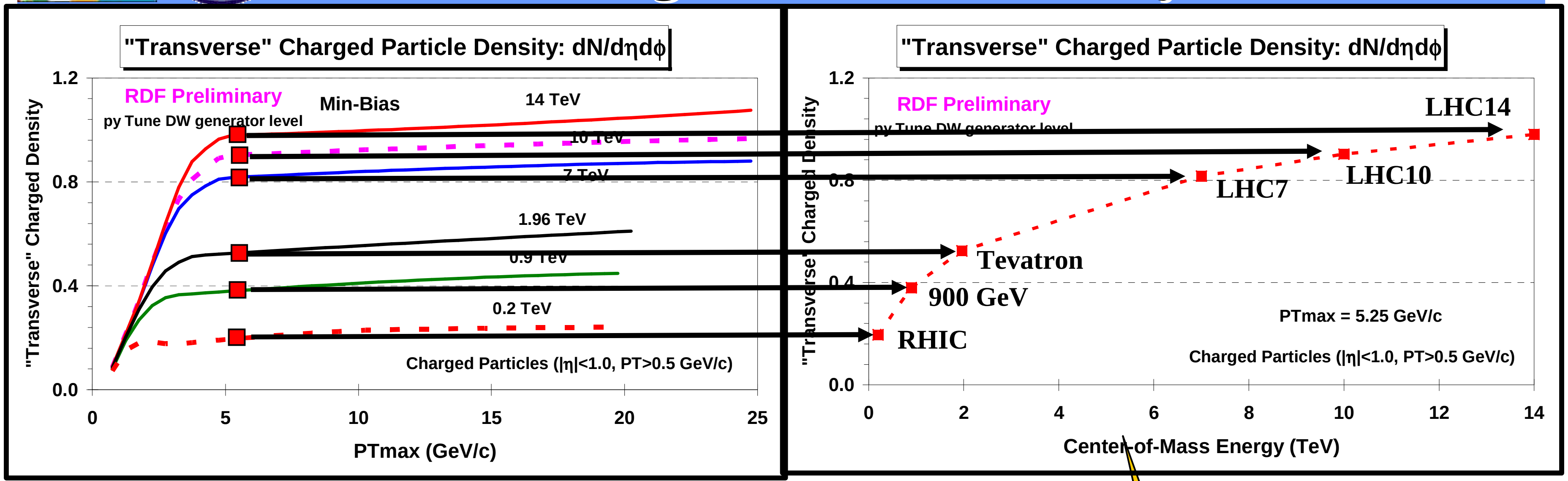
- Shows the "associated" cha ged parti sity in ansverse" re n as a function of PTmax for charged particles (p_T > 0.5 GeV/c, , *not incl g PTmax*) for "m n-bias" events at 1.96 TeV from PYTHIA Tune A, Tune S32 une N324, a Tune P329 at the particle level (*i.e.* generator level).
- Extrapolations of PYTHIA Tune A, Tune DW, Tune DWT, Tune S320, Tune P329, and pyATLAS to the LHC.

"Transverse" Charged Density

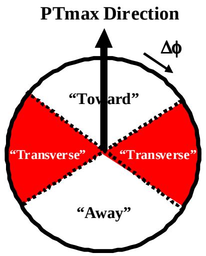


➡ **Shows the charged particle density in the "transverse" region for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) at 7 TeV as defined by PTmax, PT(chgjet#1), and PT(muon-pair) from PYTHIA Tune DW at the particle level (*i.e.* generator level). Charged particle jets are constructed using the Anti-KT algorithm with d = 0.5.**

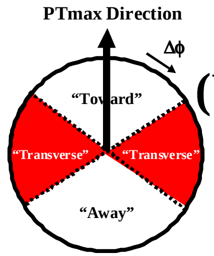
Min-Bias "Associated" Charged Particle Density



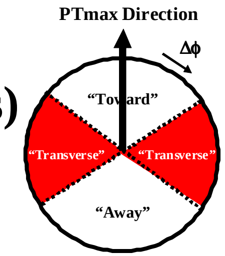
RHIC



0.2 TeV → 1.96 TeV (UE increase ~2.7 times) Tevatron



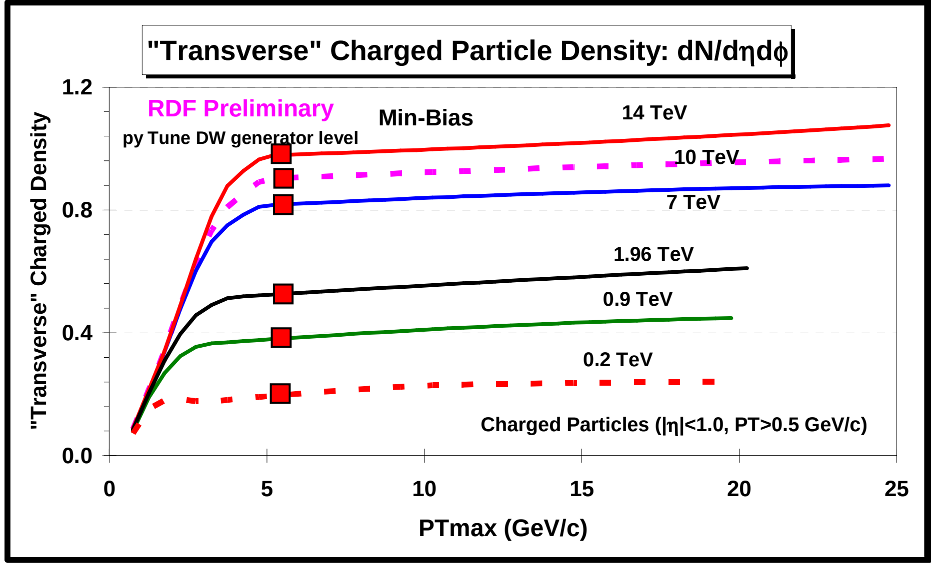
1.96 TeV → 14 TeV (UE increase ~1.9 times) LHC

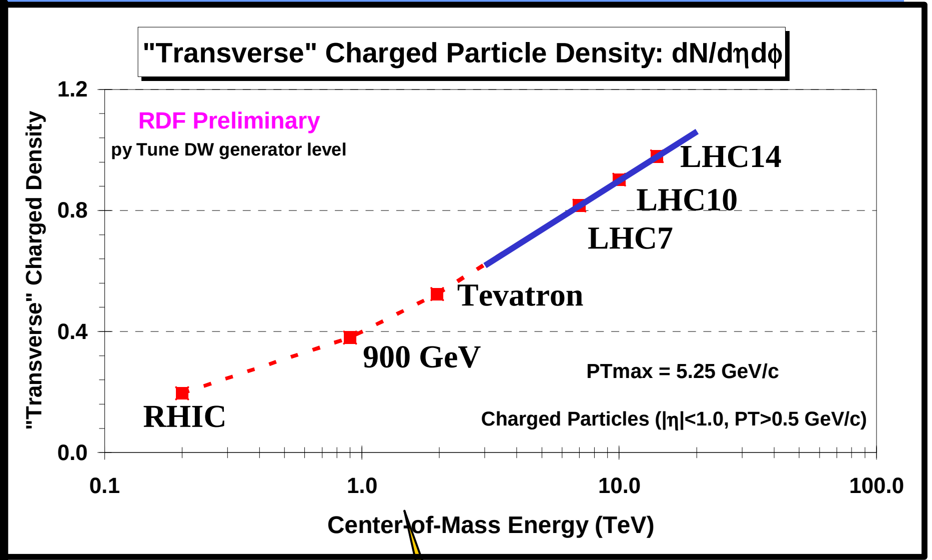


- Shows the "associated" charged particle density in the "transverse" region as a function of PTmax for charged particles (p_T > 0.5 GeV/c, |η| < 1, *not including PTmax*) for "min-bias" events at 0.2 TeV, 0.9 TeV, 1.96 TeV, 7 TeV, 10 TeV, 14 TeV predicted by PYTHIA Tune DW at the particle level (*i.e.* generator level).

Linear scale!

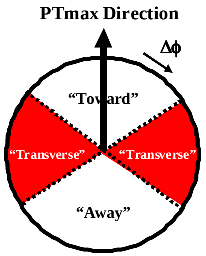
Min-Bias "Associated" Charged Particle Density





Log scale!

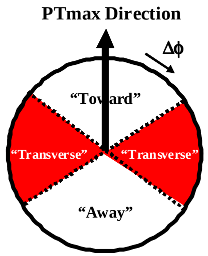
LHC7



7 TeV → 14 TeV
(UE increase ~20%)

Linear on a log plot!

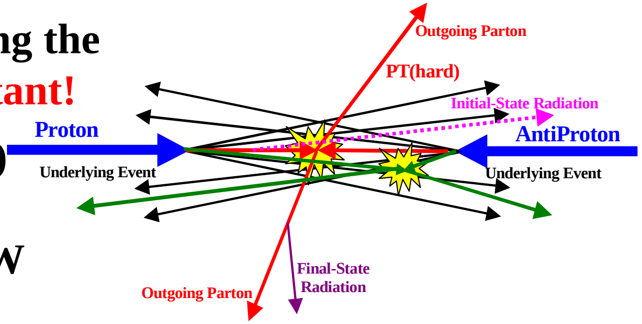
LHC14



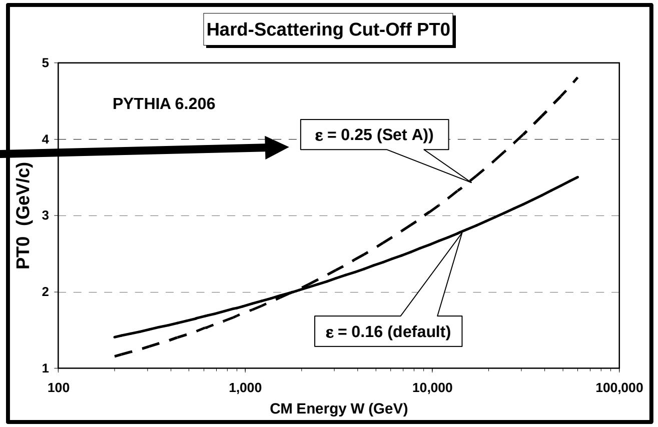
- Shows the "associated" charged particle density in the "transverse" region as a function of PTmax for charged particles (p_T > 0.5 GeV/c, |η| < 1, *not including PTmax*) for "min-bias" events at 0.2 TeV, 0.9 TeV, 1.96 TeV, 7 TeV, 10 TeV, 14 TeV predicted by PYTHIA Tune DW at the particle level (*i.e.* generator level).

Conclusions November 2009

- We are making good progress in understanding and modeling the "underlying event". RHIC data at 200 GeV are very important!



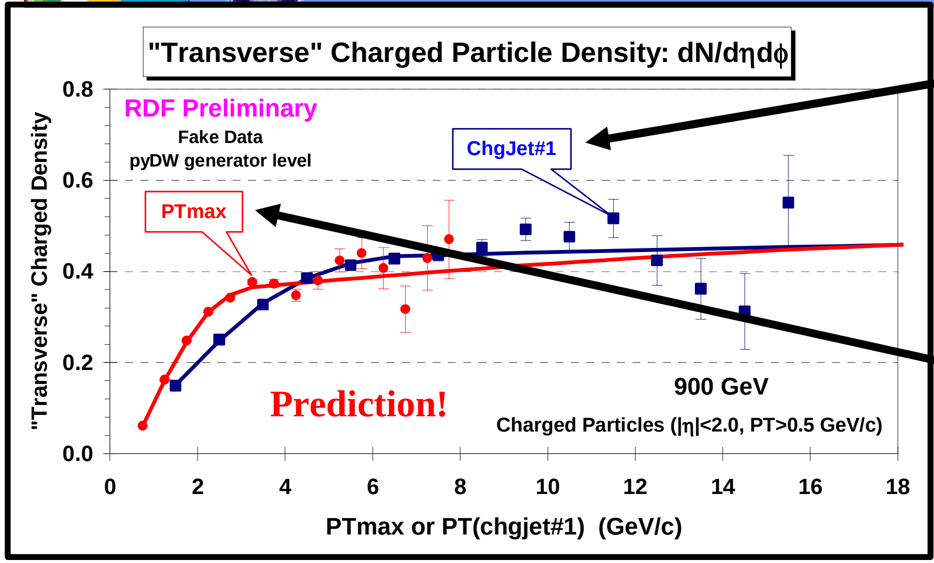
- The new Pythia p_T ordered tunes (py64 S320 and py64 P329) are very similar to Tune A, Tune AW, and Tune DW. At present the new tunes do not fit the data better than Tune AW and Tune DW. However, the new tune are theoretically preferred!
- It is clear now that the default value PARP(90) = 0.16 is not correct and the value should be closer to the Tune A value of 0.25.

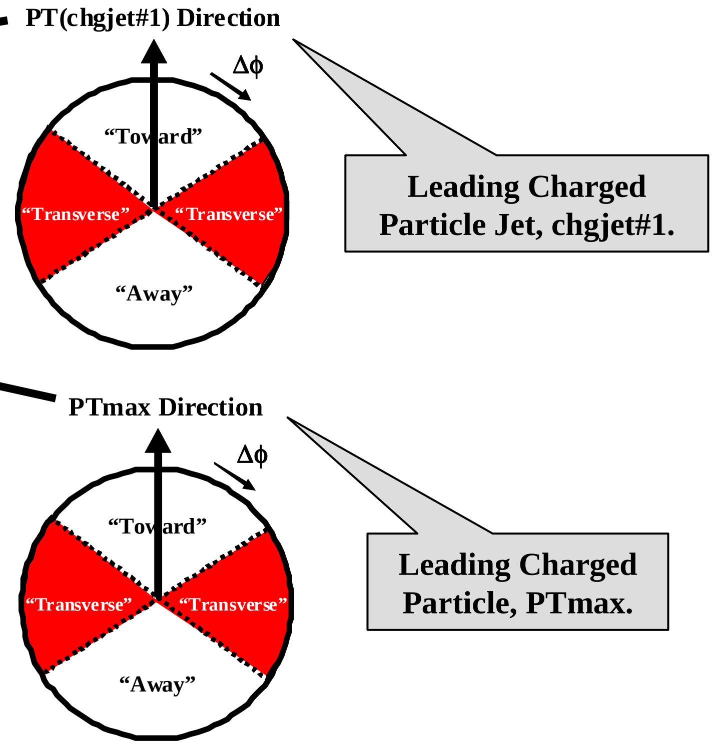


- The new and old PYTHIA tunes are beginning to converge and I believe we are finally in a position to make some legitimate predictions at the LHC!
- All tunes with the default value PARP(90) = 0.16 are wrong and are overestimating the activity of min-bias and the underlying event at the LHC! This includes all my "T" tunes and the (old) ATLAS tunes!
- Need to measure "Min-Bias" and the "underlying event" at the LHC as soon as possible to see if there is new QCD physics to be learned!

UE&MB@CMS

“Transverse” Charged Particle Density

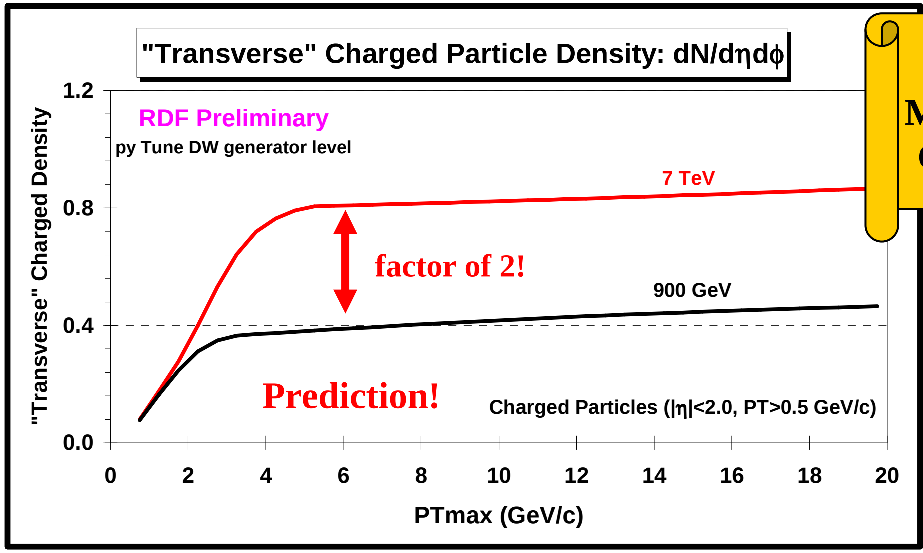




- **Fake data (from MC) at 900 GeV on the “transverse” charged particle density, dN/dηdϕ, as defined by the leading charged particle (PTmax) and the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2. The fake data (from PYTHIA Tune DW) are generated at the particle level (*i.e.* generator level) assuming 0.5 M min-bias events at 900 GeV (361,595 events in the plot).**

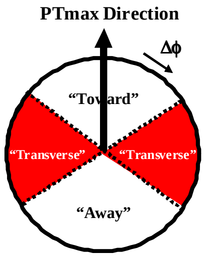
Rick Field
MB&UE@CMS Workshop
CERN, November 6, 2009

“Transverse” Charge Density



Rick Field
MB&UE@CMS Workshop
CERN, November 6, 2009

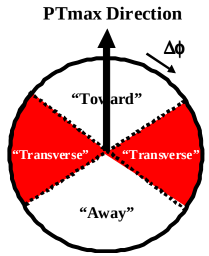
LHC 900 GeV



900 GeV → 7 TeV
(UE increase ~ factor of 2)

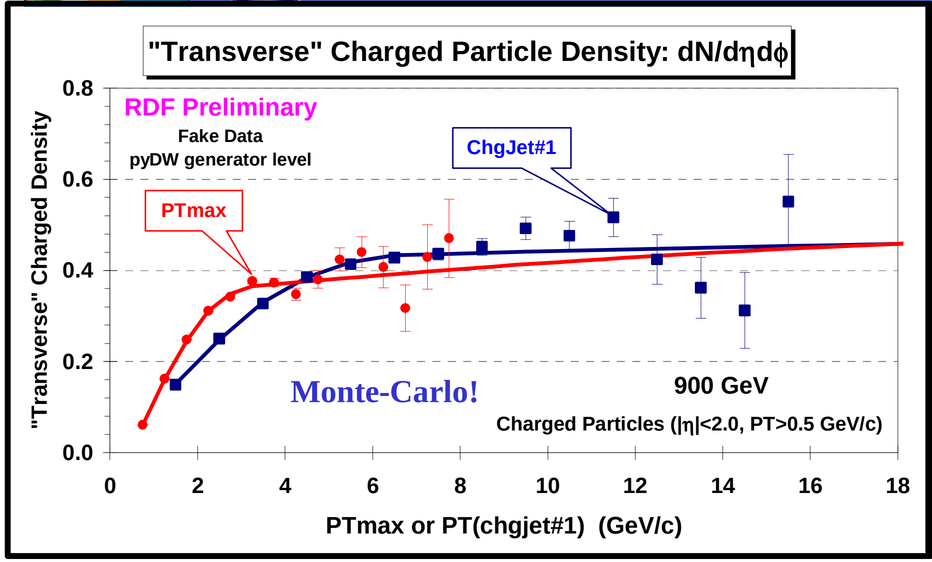
~0.4 → ~0.8

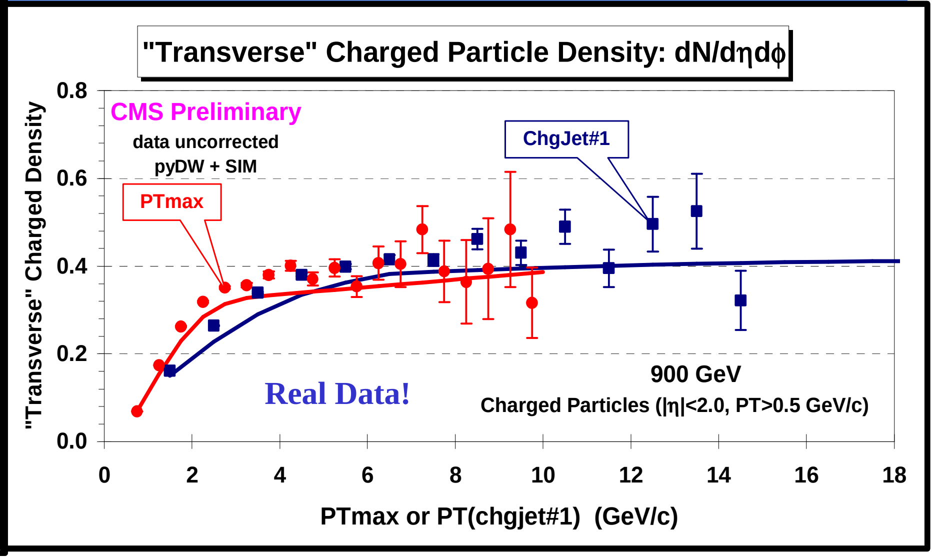
LHC 7 TeV



- **Shows the charged particle density in the “transverse” region for charged particles (p_T > 0.5 GeV/c, |η| < 2) at 900 GeV and 7 TeV as defined by PTmax from PYTHIA Tune DW and at the particle level (*i.e.* generator level).**

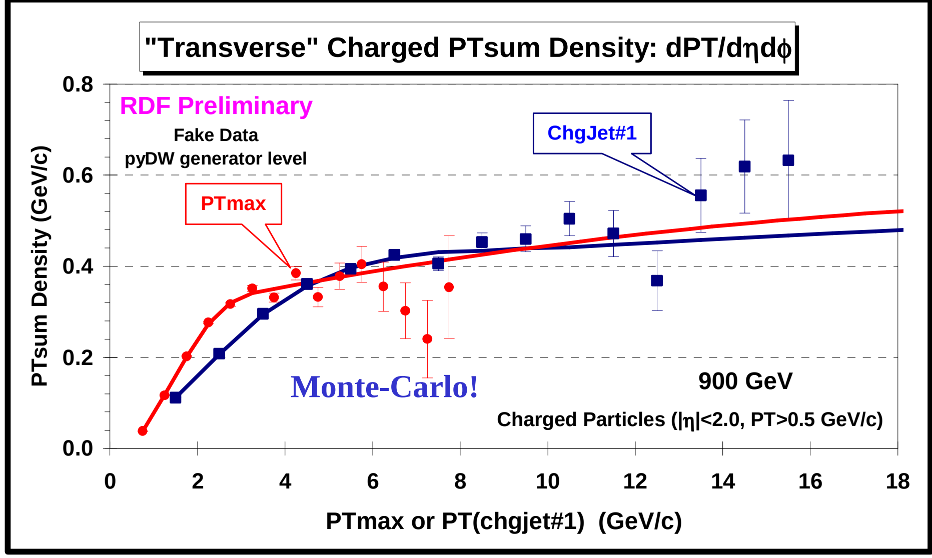
"Transverse" Charged Particle Density

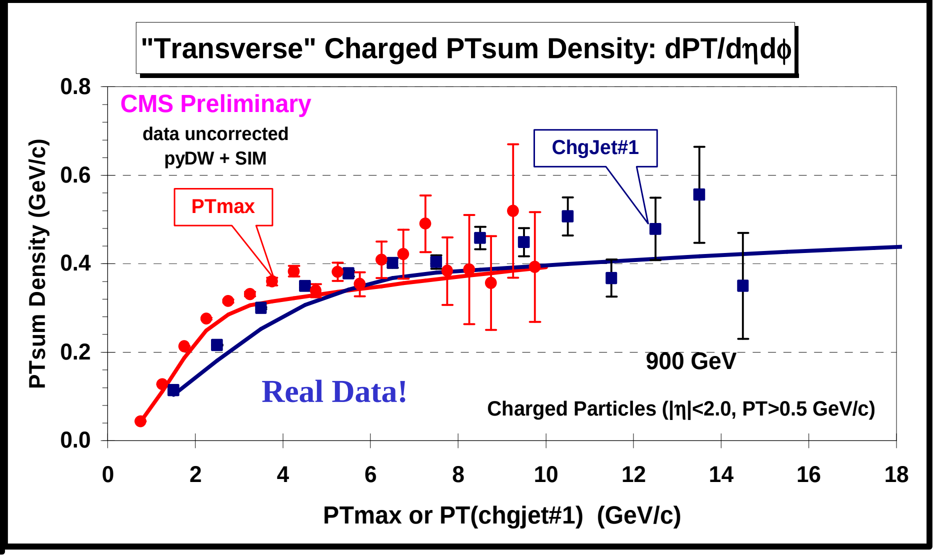




- **Fake data (from MC) at 900 GeV on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle (PTmax) and the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2$. The fake data (from PYTHIA Tune DW) are generated at the particle level (*i.e.* generator level) assuming 0.5 M min-bias events at 900 GeV (361,595 events in the plot).**

- **CMS preliminary data at 900 GeV on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle (PTmax) and the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2$. The data are uncorrected and compared with PYTHIA Tune DW after detector simulation (216,215 events in the plot).**

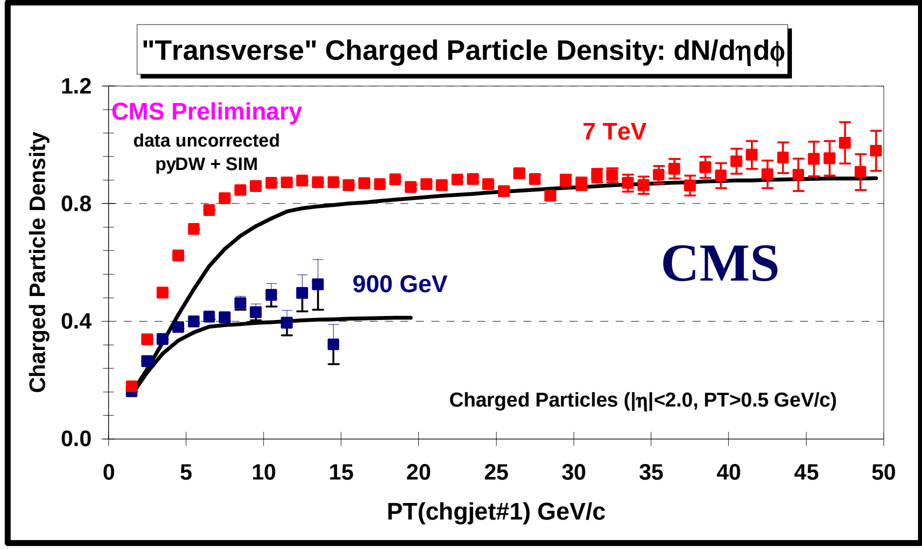


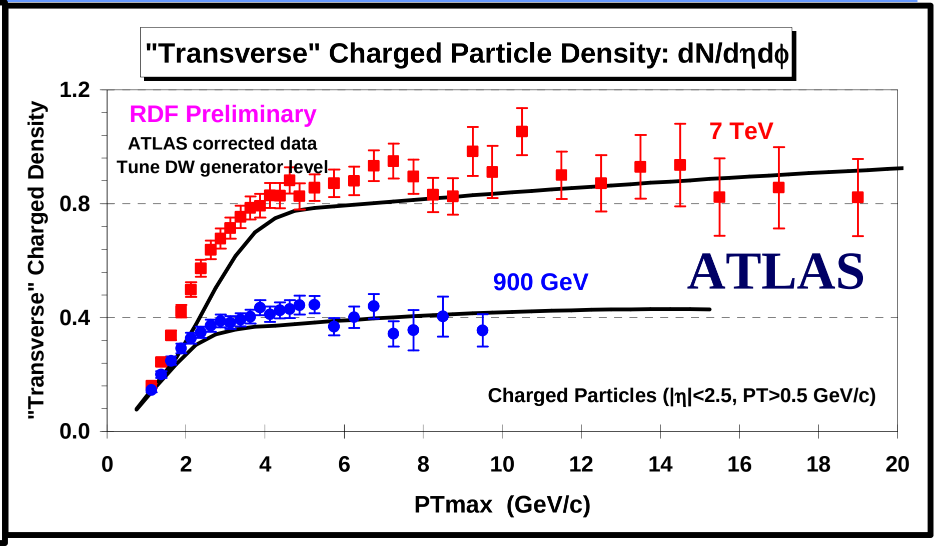


- **Fake data (from MC) at 900 GeV on the "transverse" charged PTsum density, dPT/dηdϕ, as defined by the leading charged particle (PTmax) and the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2. The fake data (from PYTHIA Tune DW) are generated at the particle level (*i.e.* generator level) assuming 0.5 M min-bias events at 900 GeV (361,595 events in the plot).**

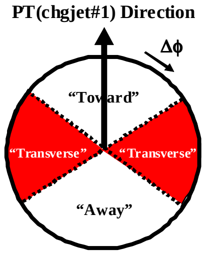
- **CMS preliminary data at 900 GeV on the "transverse" charged PTsum density, dPT/dηdϕ, as defined by the leading charged particle (PTmax) and the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2. The data are uncorrected and compared with PYTHIA Tune DW after detector simulation (216,215 events in the plot).**

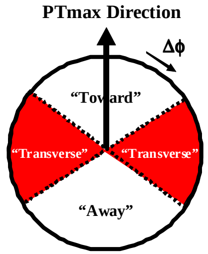
PYTHIA Tune DW



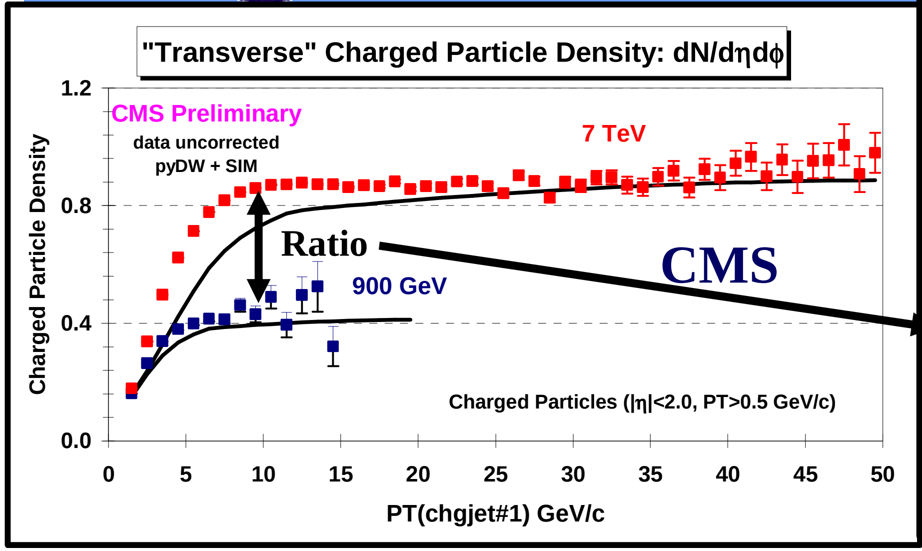


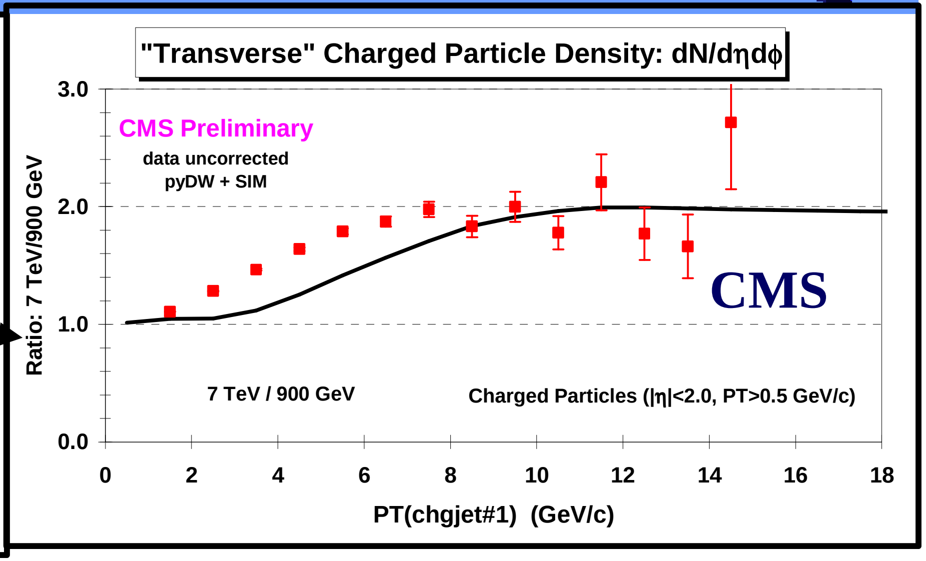
- **CMS preliminary data at 900 GeV and 7 TeV** on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2$. The data are uncorrected and compared with PYTHIA **Tune DW** after detector simulation.
- **ATLAS preliminary data at 900 GeV and 7 TeV** on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.5$. The data are corrected and compared with PYTHIA **Tune DW** at the generator level.



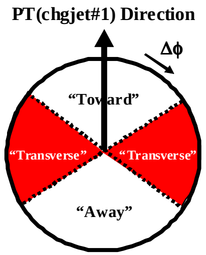


PYTHIA Tune DW

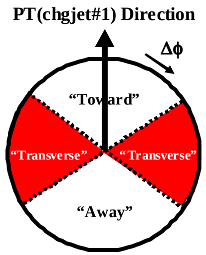




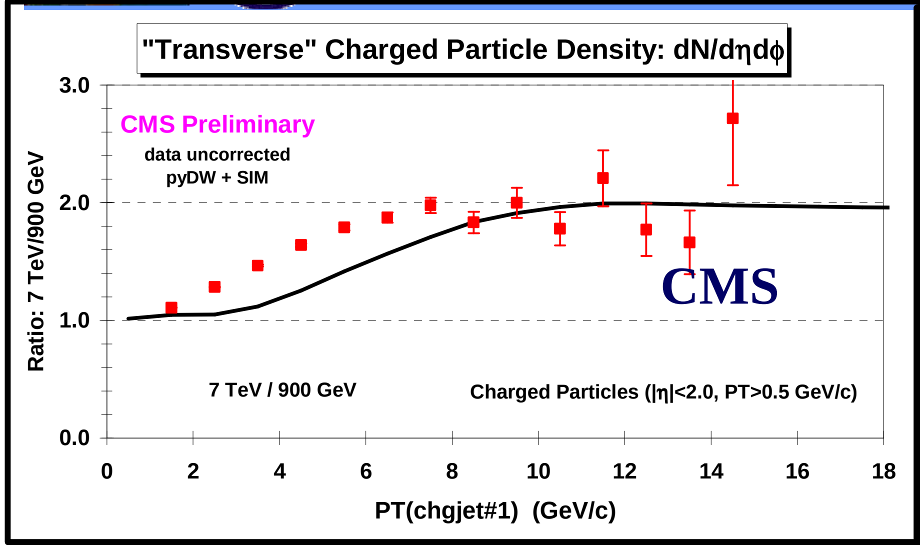
- **CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2$. The data are uncorrected and compared with PYTHIA Tune DW after detector simulation.**

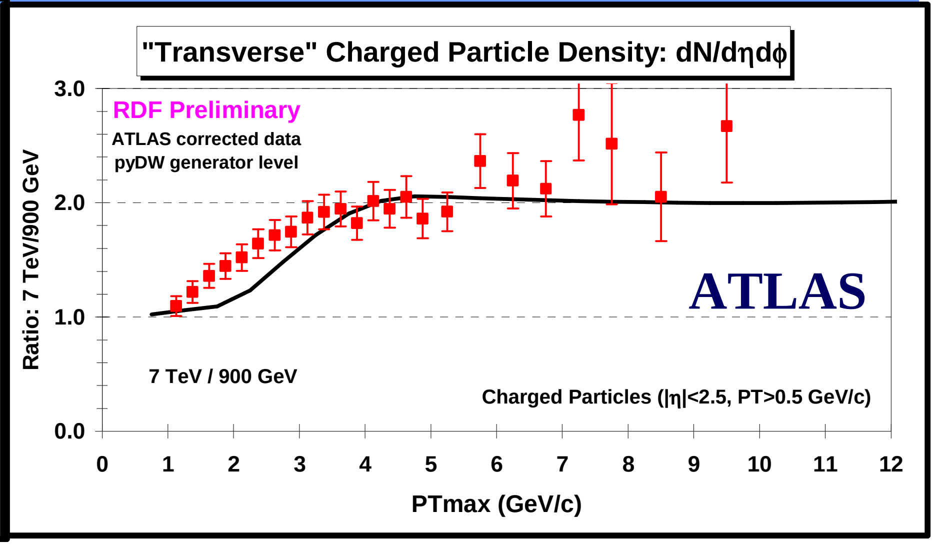


- **Ratio of CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2$. The data are uncorrected and compared with PYTHIA Tune DW after detector simulation.**

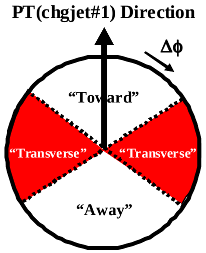


PYTHIA Tune DW

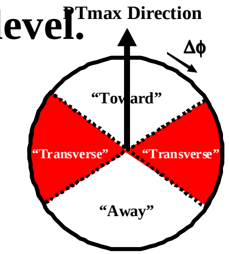




- **Ratio of CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2$. The data are uncorrected and compared with PYTHIA Tune DW after detector simulation.**

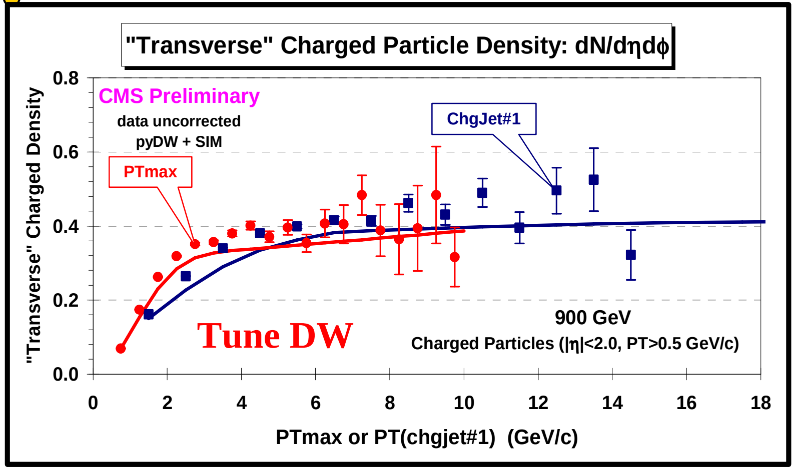


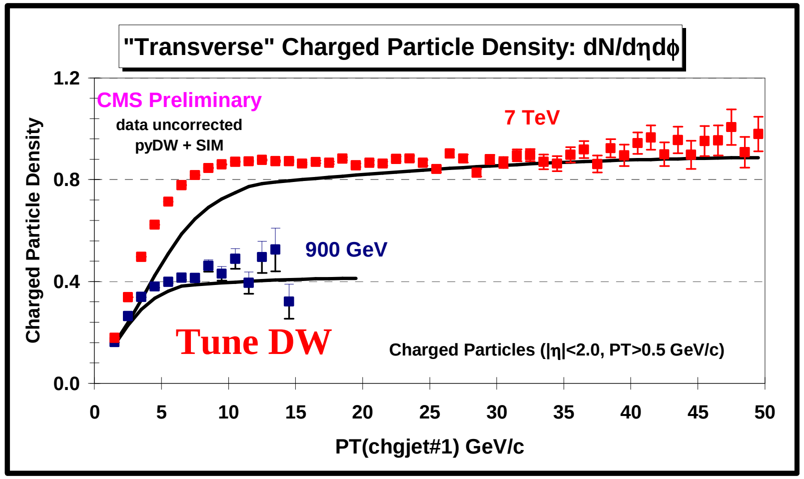
- **Ratio of the ATLAS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.5$. The data are corrected and compared with PYTHIA Tune DW at the generator level.**



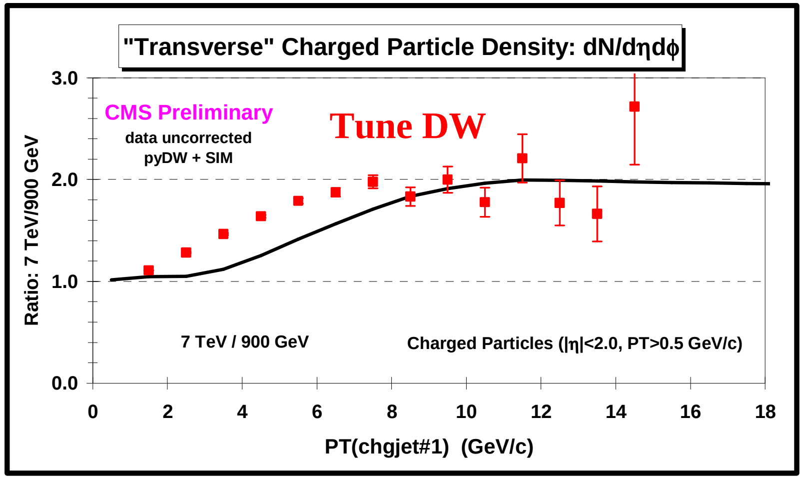
PYTHIA Tune DW

How well did we do at predicting the "underlying event" at 900 GeV and 7 TeV?



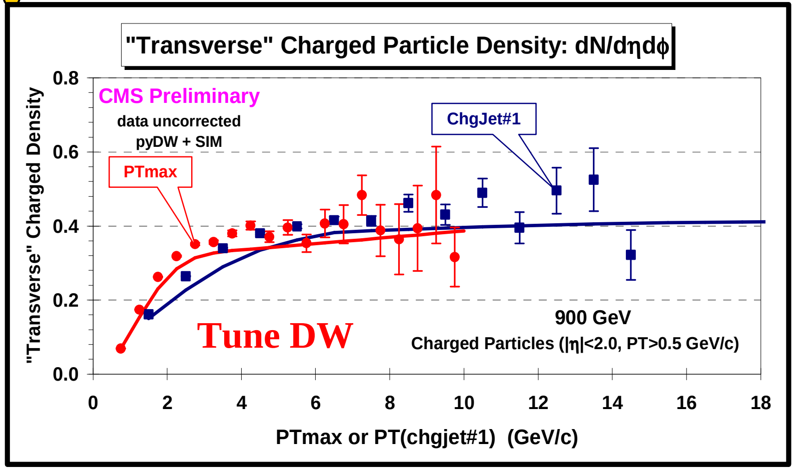


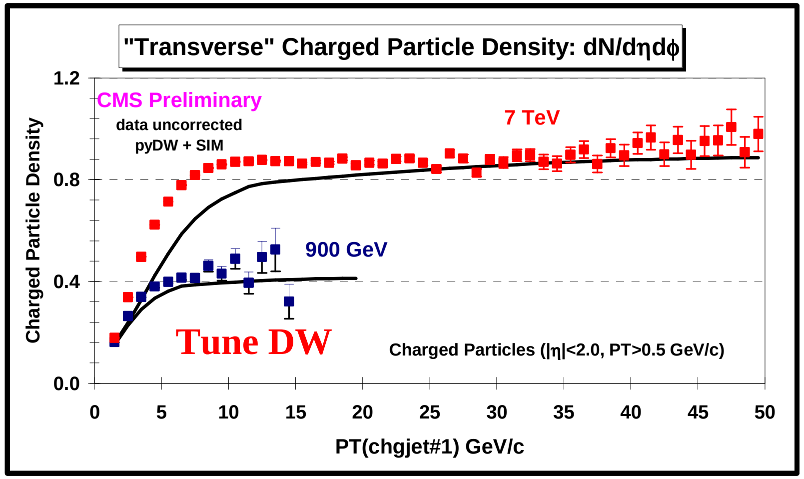
➡ **I am surprised that the Tunes did not do a better job of predicting the behavior of the "underlying event" at 900 GeV and 7 TeV!**



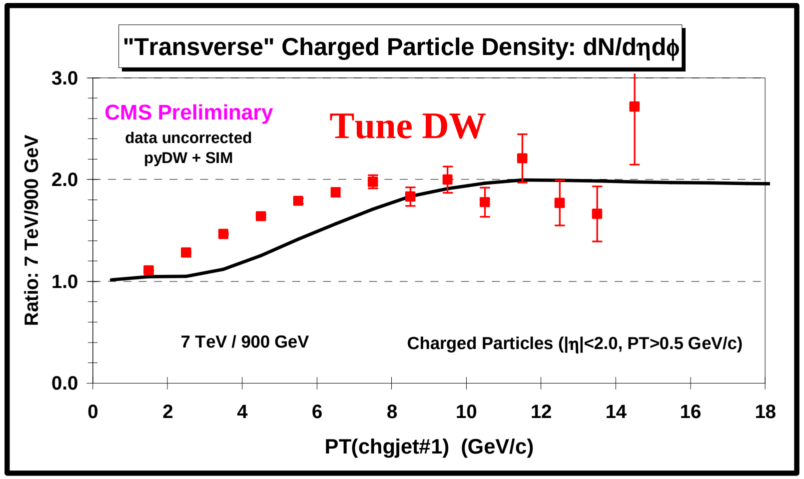
PYTHIA Tune DW

How well did we do at predicting the "underlying event" at 900 GeV and 7 TeV?



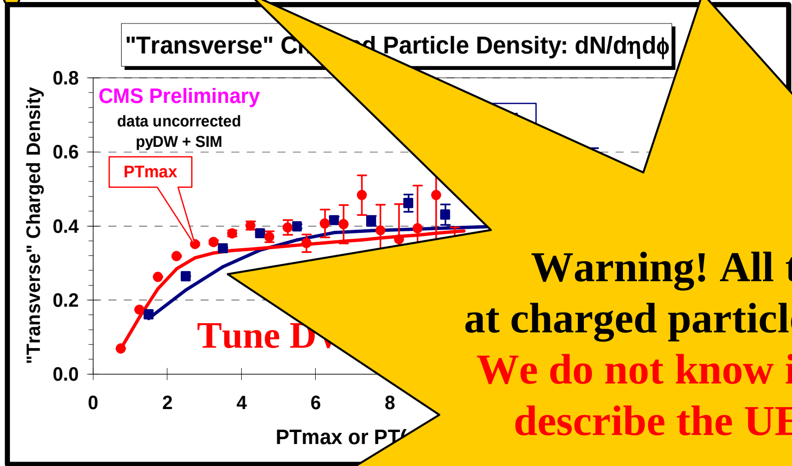


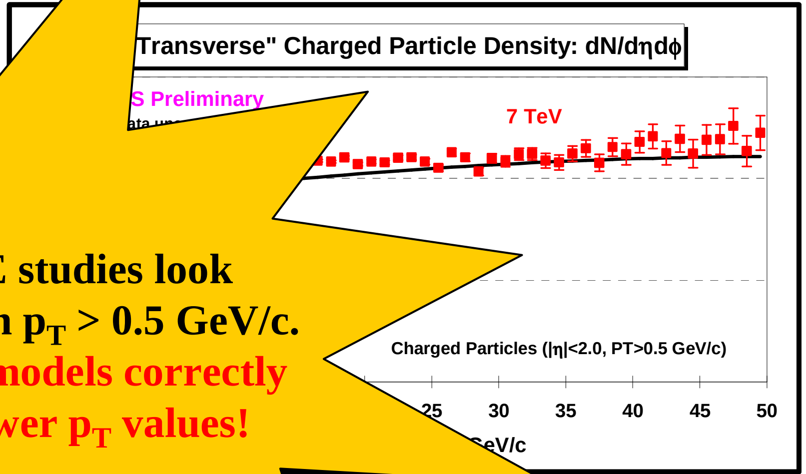
- I am surprised that the Tunes did as well as they did at predicting the behavior of the "underlying event" at 900 GeV and 7 TeV!



PYTHIA Tune DW

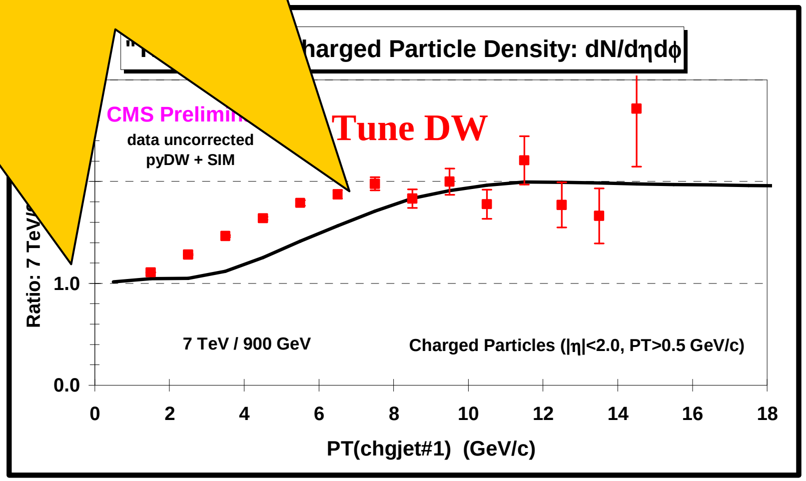
How well did we do at predicting the "underlying event" at 900 GeV and 7 TeV?





Warning! All the UE studies look at charged particles with $p_T > 0.5$ GeV/c.
We do not know if the models correctly describe the UE at lower p_T values!

➡ I am surprised th... Tunes did as well as th... at predicting the behav... of the "underlying event" at 900 GeV and 7 TeV!



ATLAS Tune AMBT1

Charged particle multiplicities in p p interactions at $\sqrt{s}$ = 0.9 and 7 TeV in a diffractive limited phase-space and a new Pythia tune.

Judith Katzy (DESY)
On behalf of the ATLAS Collaboration

Judith Katzy LPCC MB&UE working group meeting, *May 31, 2010*.

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UCL

Minimum bias and Underlying Event studies with Monte Carlo tune for pp events with the ATLAS detector

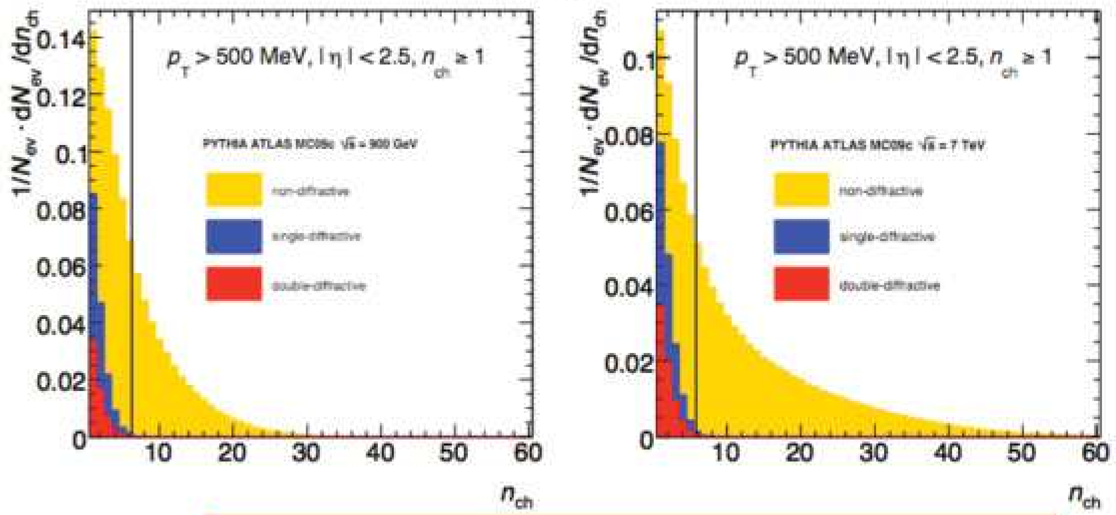
Emily Nurse
(for the ATLAS collaboration)
ICHEP, Paris
24th July 2010

Emily Nurse ICHEP, *July 24, 2010*.

ATLAS-CONF-2010-031

ATLAS Tune AMBT1

Example: pythia6 predictions



Build diffractive suppressed sample with $n_{ch} \geq 6$

Resulting number of events:

	$n_{ch} \geq 1$	$n_{ch} \geq 6$
7TeV:	369673	231665
900 GeV:	326201	157896

Subset of the "min-bias" data!

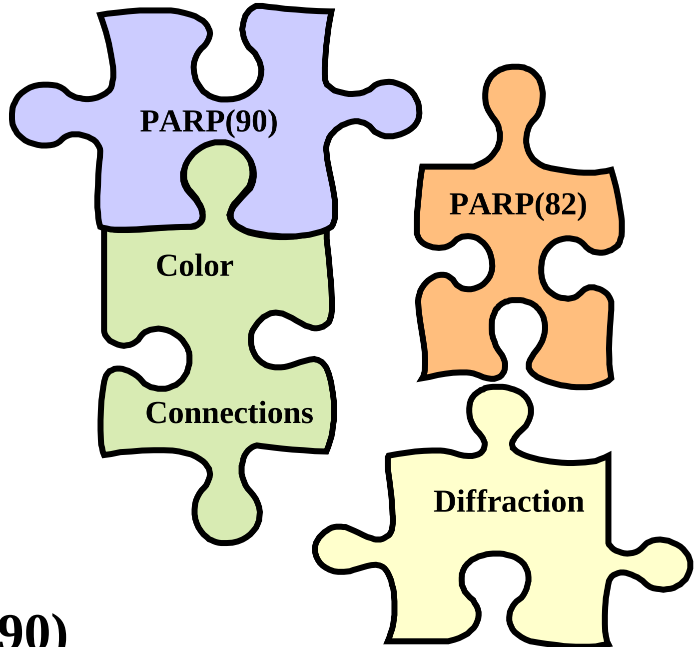
Parameters used for tuning

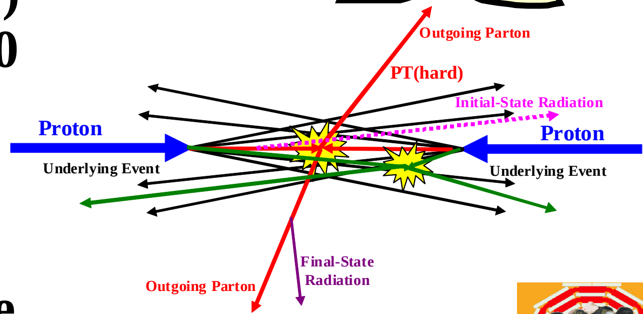
Parameter	related model	MC09c value	scanning range	AMBT1 value
PARP(62)	ISR cut-off	1.0	fixed	1.025
PARP(93)	primordial kt	5.0	fixed	10.0
PARP(77)	CR suppression	0.0	0.25 − − − 1.15	1.016
PARP(78)	CR strength	0.224	0.2 − − − 0.6	0.538
PARP(83)	MPI (matter fraction in core)	0.8	fixed	0.356
PARP(84)	MPI (core of matter overlap)	0.7	0.0 − − − 1.0	0.651
PARP(82)	MPI (p_T^{min})	2.31	2.1 − − − 2.5	2.292
PARP(90)	MPI (energy extrapolation)	0.2487	0.18 − − − 0.28	0.250

➡ **Attempt to fit a subset of the "min-bias" data (Nchg ≥ 6) where the contamination due to diffraction is expected to be small!**

PYTHIA Tune Z1

- **All my previous tunes (A, DW, DWT, D6, D6T, CW, X1, and X2) were PYTHIA 6.4 tunes using the old Q^2-ordered parton showers and the old MPI model (really 6.2 tunes)!**
- **I believe that it is time to move to PYTHIA 6.4 (p_T-ordered parton showers and new MPI model)!**
- **Tune Z1: I started with the parameters of ATLAS Tune AMBT1, but I changed LO* to CTEQ5L and I varied PARP(82) and PARP(90) to get a very good fit of the CMS UE data at 900 GeV and 7 TeV.**
- **The ATLAS Tune AMBT1 was designed to fit the inelastic data for Nchg ≥ 6 and to fit the PTmax UE data with PTmax > 10 GeV/c. Tune AMBT1 is primarily a min-bias tune, while Tune Z1 is a UE tune!**





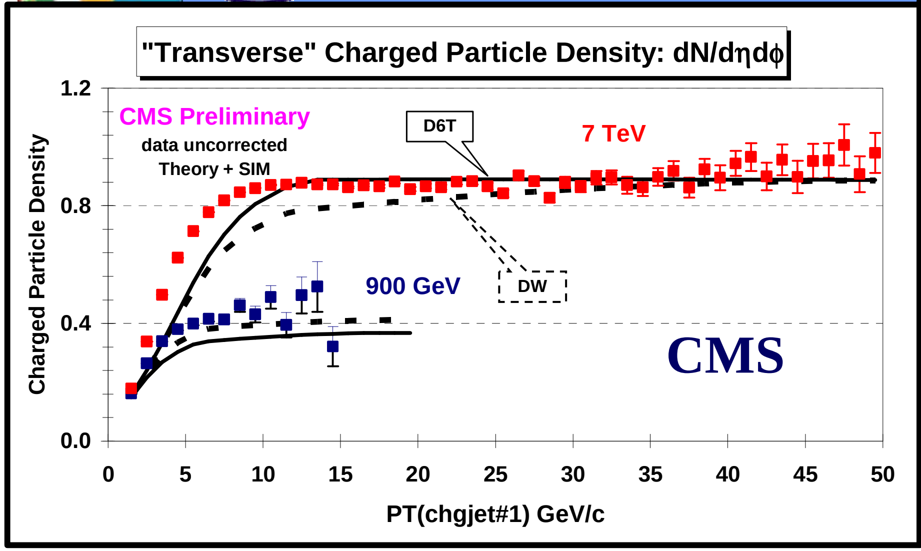
UE&MB@CMS

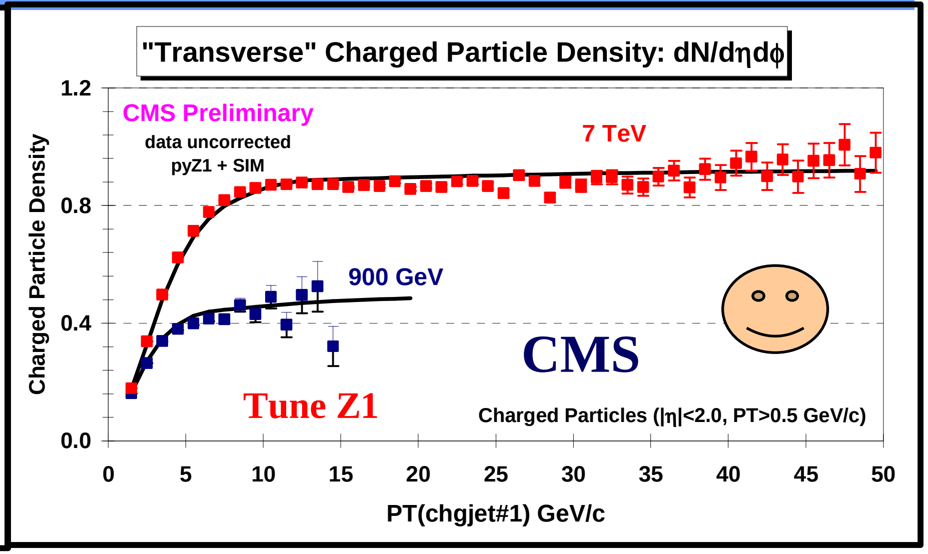
PYTHIA Tune Z1

Parameters not shown are the PYTHIA 6.4 defaults!

Parameter	Tune Z1 (R. Field CMS)	Tune AMBT1 (ATLAS)
Parton Distribution Function	CTEQ5L	LO*
PARP(82) – MPI Cut-off	1.932	2.292
PARP(89) – Reference energy, E0	1800.0	1800.0
PARP(90) – MPI Energy Extrapolation	0.275	0.25
PARP(77) – CR Suppression	1.016	1.016
PARP(78) – CR Strength	0.538	0.538
PARP(80) – Probability colored parton from BBR	0.1	0.1
PARP(83) – Matter fraction in core	0.356	0.356
PARP(84) – Core of matter overlap	0.651	0.651
PARP(62) – ISR Cut-off	1.025	1.025
PARP(93) – primordial kT-max	10.0	10.0
MSTP(81) – MPI, ISR, FSR, BBR model	21	21
MSTP(82) – Double gaussion matter distribution	4	4
MSTP(91) – Gaussian primordial kT	1	1
MSTP(95) – strategy for color reconnection	6	6

CMS UE Data





- **CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2.0. The data are uncorrected and compared with PYTHIA Tune DW and D6T after detector simulation (SIM).**

- **CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2.0. The data are uncorrected and compared with PYTHIA Tune Z1 after detector simulation (SIM).**

Color reconnection suppression.
Color reconnection strength.

<u>Tune Z1 (CTEQ5L)</u>
PARP(82) = 1.932
PARP(90) = 0.275
PARP(77) = 1.016
PARP(78) = 0.538

Tune Z1 is a PYTHIA 6.4 using p_T-ordered parton showers and the new MPI model!

PYTHIA 6.2 Tunes

Parameter	Tune AW	Tune DW	Tune D6
PDF	CTEQ5L	CTEQ5L	CTEQ6L
MSTP(81)	1	1	1
MSTP(82)	4	4	4
PARP(82)	2.0 GeV	1.9 GeV	1.8 GeV
PARP(83)	0.5	0.5	0.5
PARP(84)	0.4	0.4	0.4
PARP(85)	0.9	1.0	1.0
PARP(86)	0.95	1.0	1.0
PARP(89)	1.8 TeV	1.8 TeV	1.8 TeV
PARP(90)	0.25	0.25	0.25
PARP(62)	1.25	1.25	1.25
PARP(64)	0.2	0.2	0.2
PARP(67)	4.0	2.5	2.5
MSTP(91)	1	1	1
PARP(91)	2.1	2.1	2.1
PARP(93)	15.0	15.0	15.0

UE Parameters

ISR Parameter

Intrinsic KT

Uses CTEQ6L

Reduce PARP(82) by factor of 1.8/1.9 = 0.95 Everything else the same!

Tune A energy dependence! (not the default)

CMS: We wanted a CTEQ6L version of Tune Z1 in a hurry!

PYTHIA Tune Z2

Parameter	Tune Z1 (R. Field CMS)	Tune Z2 (R. Field CMS)
Parton Distribution Function	CTEQ5L	CTEQ6L
PARP(82) – MPI Cut-off	1.932	1.832
PARP(89) – Reference energy, E0	1800.0	1800.0
PARP(90) – MPI Energy Extrapolation	0.275	0.275
PARP(77) – CR Suppression	1.016	1.016
PARP(78) – CR Strength	0.538	0.538
PARP(80) – Probability colored parton from BBR	0.1	0.1
PARP(83) – Matter fraction in core	0.356	0.356
PARP(84) – Core of matter overlap	0.651	0.651
PARP(62) – ISR Cut-off	1.025	1.025
PARP(93) – primordial kT-max	10.0	10.0
MSTP(81) – MPI, ISR, FSR, BBR model	21	21
MSTP(82) – Double gaussion matter distribution	4	4
MSTP(91) – Gaussian primordial kT	1	1
MSTP(95) – strategy for color reconnection	6	6

My guess!

Reduce PARP(82) by factor of 1.83/1.93 = 0.95 Everything else the same!

PYTHIA Tune Z2

My guess!

Parameter	Tune Z1 (R. Field CMS)	Tune Z2 (R. Field CMS)
Parton Distribution Function	CTEQ5L	CTEQ6L
PARP(82) – MPI Cut-off	1.932	1.832
PARP(89) – Reference energy, E0	1800.0	1800.0
PARP(90) – MPI Energy Extrapolation	0.275	0.275
PARP(77) – CR Suppression	1.016	1.016
PARP(78) – CR Strength	0.538	0.538
PARP(80) – Probability colored parton from BBR	0.1	0.1
PARP(83) – Matter fraction in core	0.356	0.356
PARP(84) – Core of matter overlap	0.651	0.651
PARP(62) – ISR Cut-off	1.025	1.025
PARP(93) – primordial kT-max	10.0	10.0
MSTP(81) – MPI, ISR, FSR, BBR model	21	21
MSTP(82) – Double gaussion matter distribution	4	4
MSTP(91) – Gaussian primordial kT	1	1
MSTP(95) – strategy for color reconnection	6	6

Reduce PARP(82) by factor of 1.83/1.93 = 0.95 Everything else the same!

PARP(90) same For Z1 and Z2!

PYTHIA 8 Tunes

R. Corke and T. Sjöstrand

	CTEQ6L	MRST LO**	CTEQ6L
Parameter	Tune 2C	Tune 2M	Tune 4C
SigmaProcess:alphaSvalue	0.135	0.1265	0.135
SpaceShower:rapidityOrder	on	on	on
SpaceShower:alphaSvalue	0.137	0.130	0.137
SpaceShower:pT0Ref	2.0	2.0	2.0
MultipleInteractions:alphaSvalue	0.135	0.127	0.135
MultipleInteractions:pT0Ref	2.320	2.455	2.085
MultipleInteractions:ecmPow	0.21	0.26	0.19
MultipleInteractions:bProfile	3	3	3
MultipleInteractions:expPow	1.60	1.15	2.00
BeamRemnants:reconnectRange	3.0	3.0	1.5
SigmaDiffractive:dampen	off	off	on
SigmaDiffractive:maxXB	N/A	N/A	65
SigmaDiffractive:maxAX	N/A	N/A	65
SigmaDiffractive:maxXX	N/A	N/A	65

PT0 = PARP(82)

ε = PARP(90)

Tevatron LHC

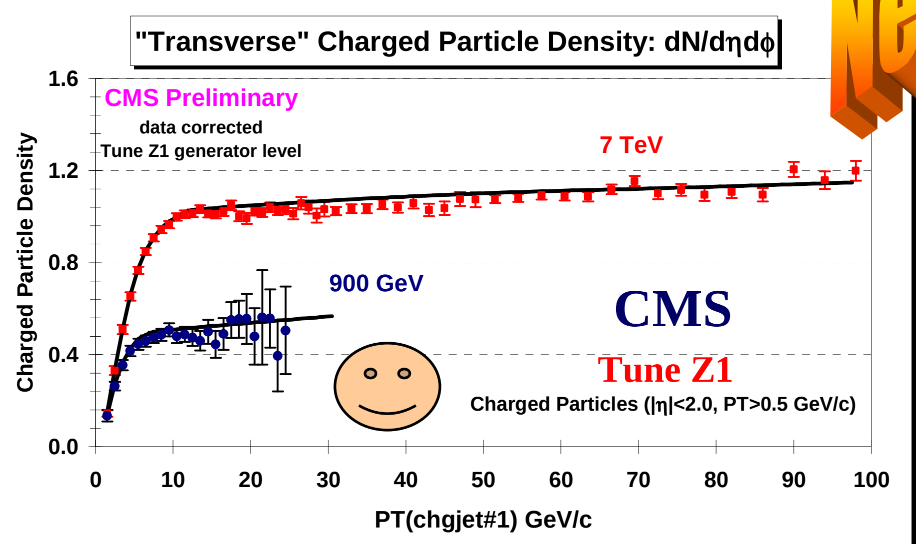
$p_{T0}(W)=p_{T0}(W/W_0)^{\varepsilon}$ ε = PARP(90) p_{T0} = PARP(82) $W = E_{cm}$

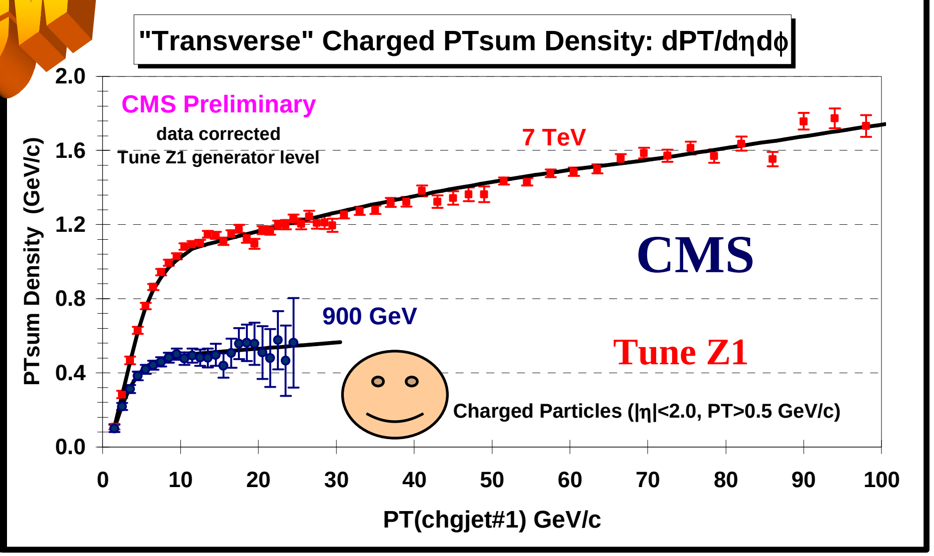
PYTHIA Tune Z2

Parameter	Tune Z2 (R. Field CMS)	PY8 Tune C4 (Corke-Sjöstrand)
Parton Distribution Function	CTEQ6L	CTEQ6L
PARP(82) – MPI Cut-off	1.832	2.085
PARP(89) – Reference energy, E0	1800.0	1800.0
PARP(90) – MPI Energy Extrapolation	0.275	0.19
PARP(77) – CR Suppression	1.016	
PARP(78) – CR Strength	0.538	
PARP(80) – Probability colored parton from BBR	0.1	
PARP(83) – Matter fraction in core	0.356	
PARP(84) – Core of matter overlap	0.651	
PARP(62) – ISR Cut-off	1.025	
PARP(93) – primordial kT-max	10.0	
MSTP(81) – MPI, ISR, FSR, BBR model	21	
MSTP(82) – Double gaussion matter distribution	4	
MSTP(91) – Gaussian primordial kT	1	
MSTP(95) – strategy for color reconnection	6	

PARP(90) much different!

CMS UE Data





- CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2.0. The data are corrected and compared with PYTHIA Tune Z1 at the generator level.

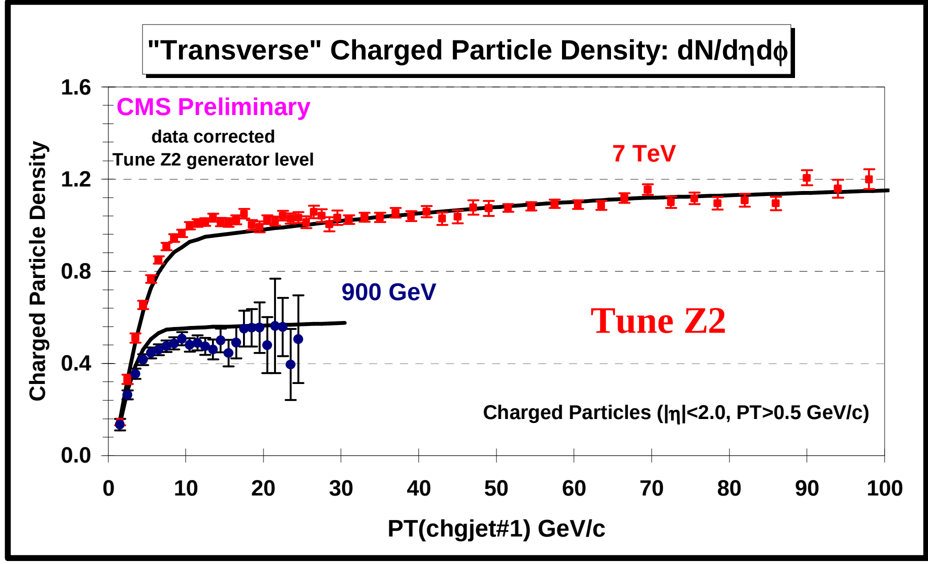
- CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged PTsum density, dPT/dηdφ, as defined by the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2.0. The data are corrected and compared with PYTHIA Tune Z1 at the generator level.

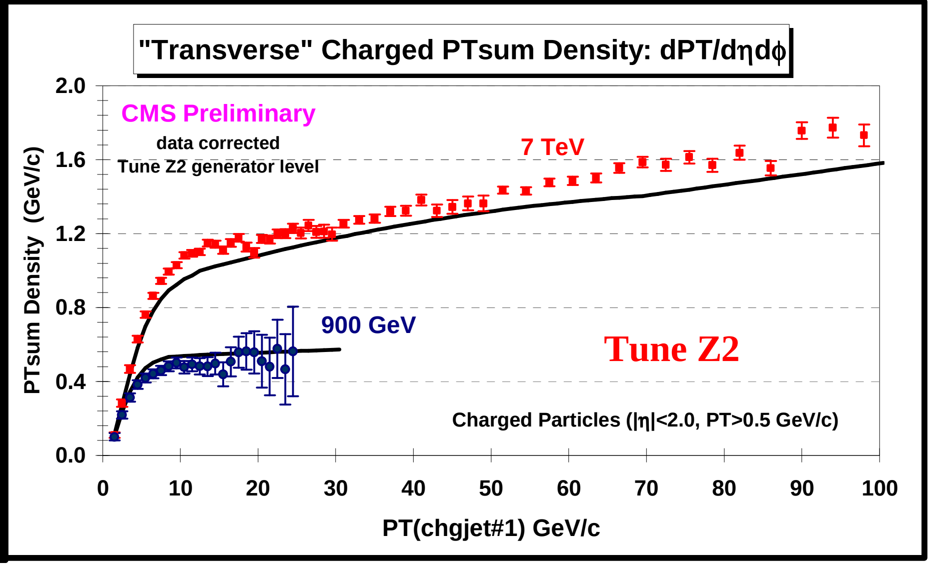
CMS corrected data!

Very nice agreement!

CMS corrected data!

PYTHIA 6.4 Tune Z2





- **CMS preliminary data at 900 GeV and 7 TeV** on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$. The data are corrected and compared with **PYTHIA Tune Z2** at the generator level.

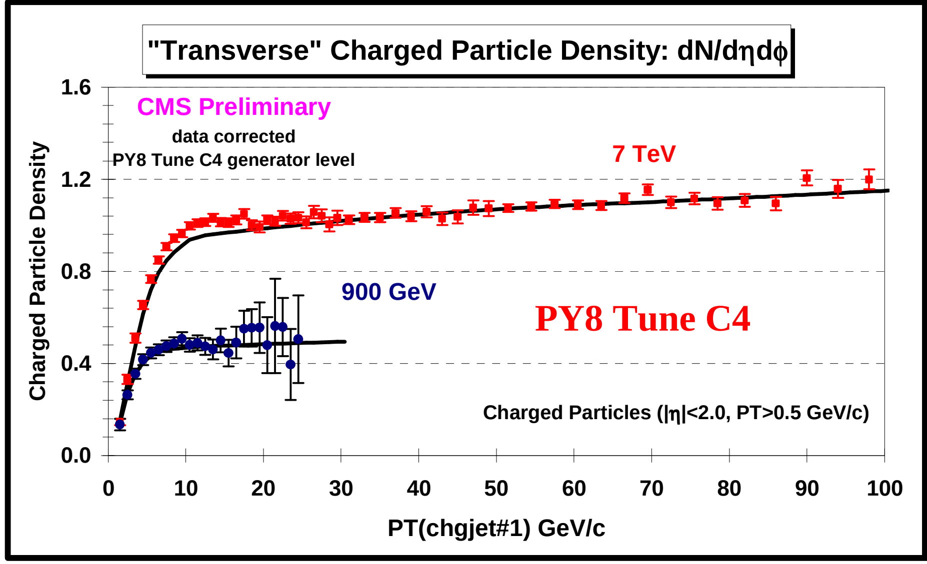
- **CMS preliminary data at 900 GeV and 7 TeV** on the "transverse" charged PTsum density, dPT/dηdφ, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$. The data are corrected and compared with **PYTHIA Tune Z2** at the generator level.

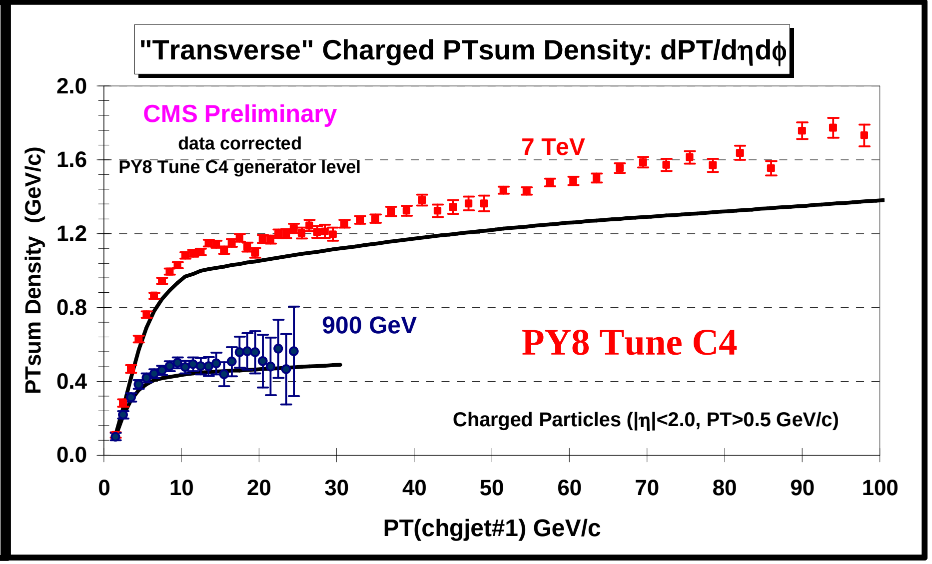
CMS corrected data!

Not good! Bad energy dependence!

CMS corrected data!

PYTHIA 8 Tune C4





- **CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2.0. The data are corrected and compared with PYTHIA 8 Tune C4 at the generator level.**

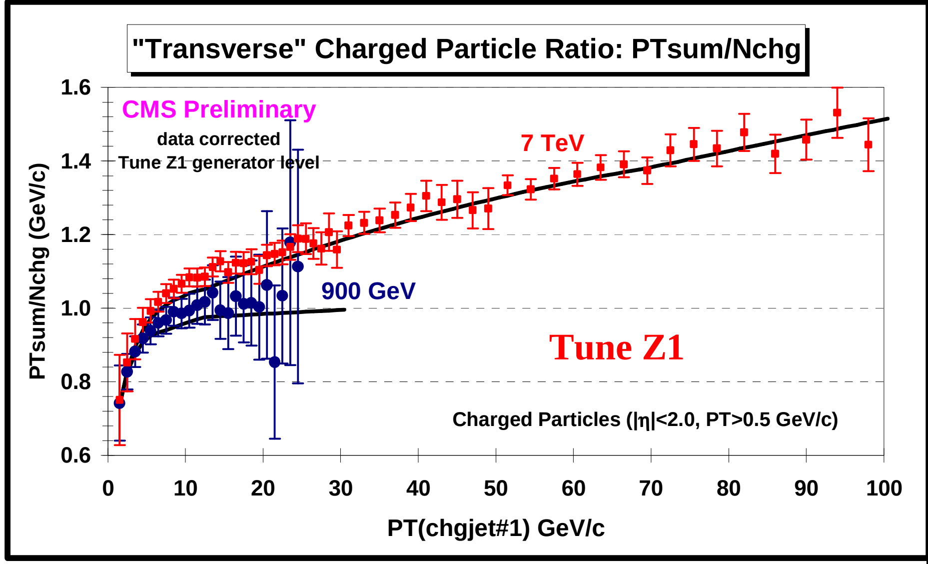
- **CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged PTsum density, dPT/dηdφ, as defined by the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2.0. The data are corrected and compared with PYTHIA 8 Tune C4 at the generator level.**

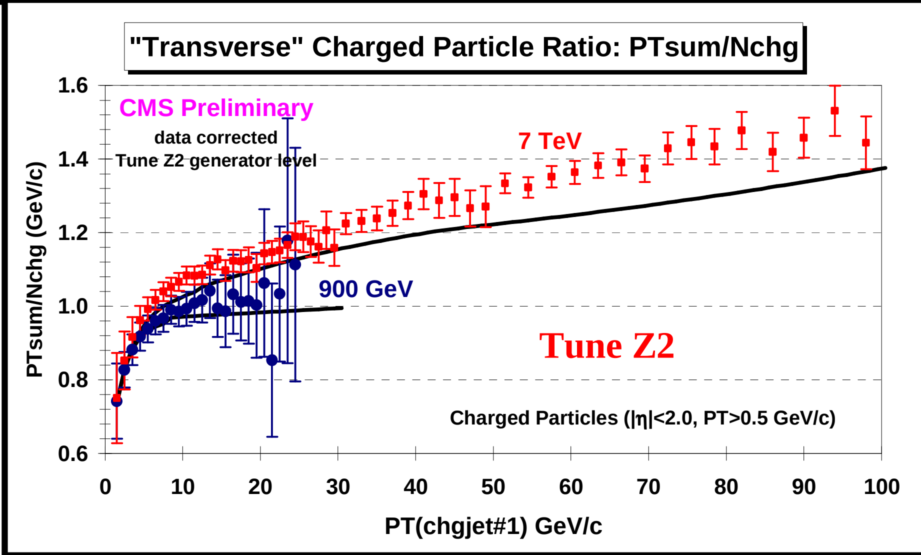
CMS corrected data!

Not good! PTsum too small!

CMS corrected data!

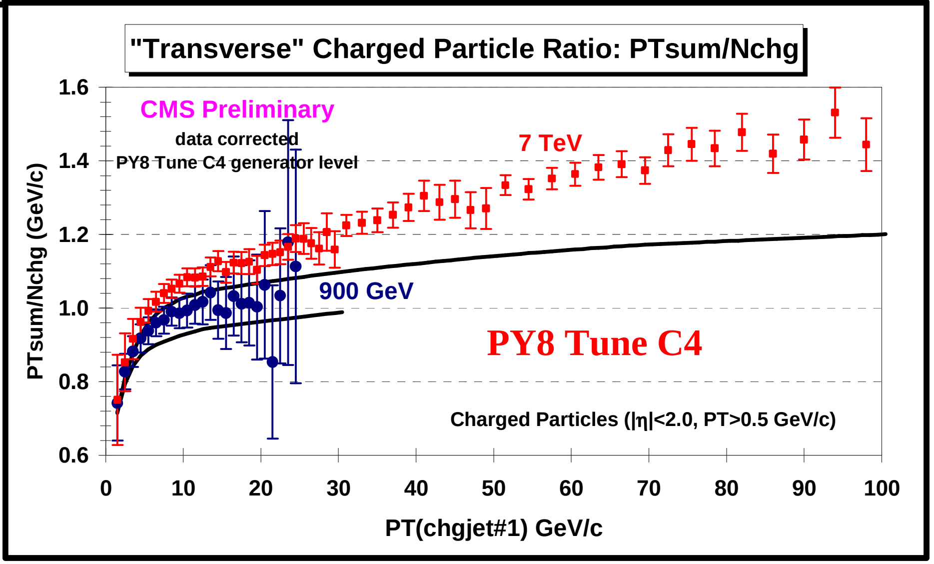
Transverse Ratio: PTsum/Nchg



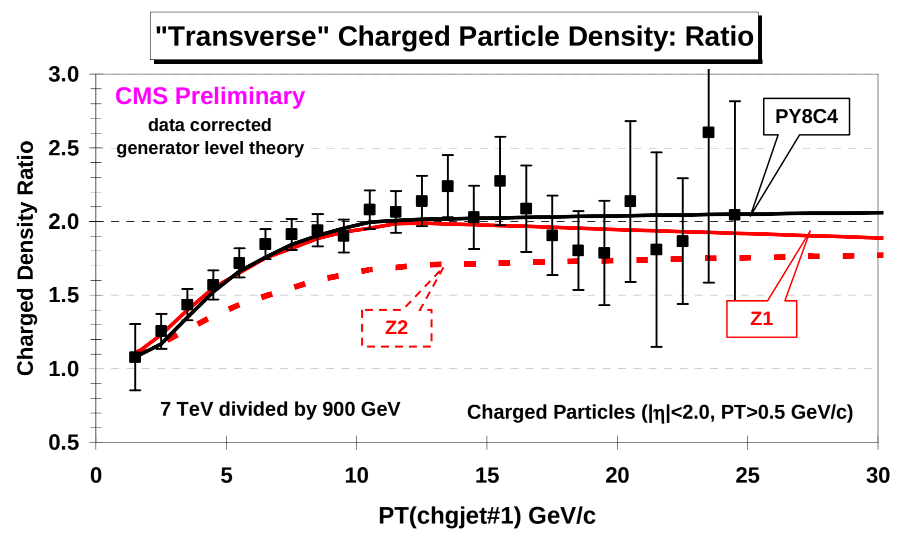


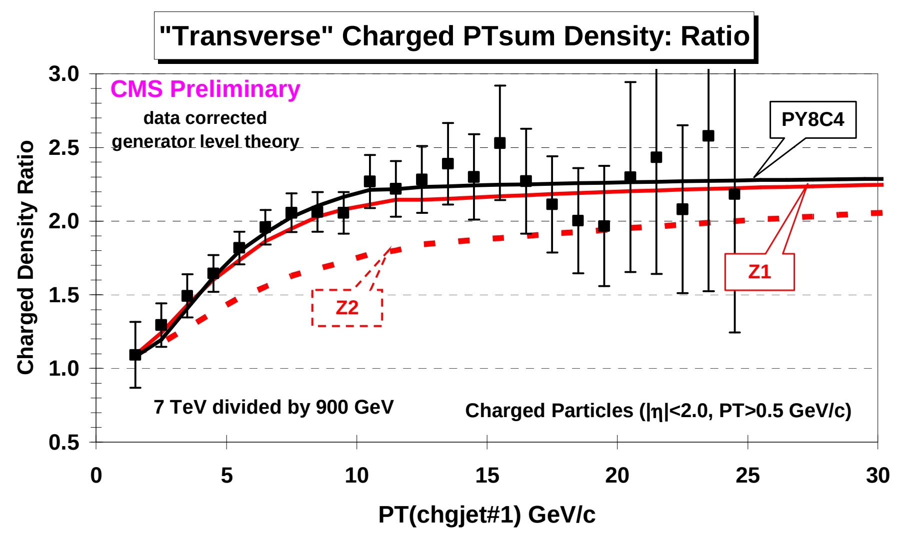
- CMS preliminary data at 900 GeV and 7 TeV on the “transverse” ratio PTsum/Nchg as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$ compared with PYTHIA Tune Z1, Z2, and PY8C4 at the generator level.

Z1 good! PY8C4 and Z2 Bad!



Energy Dependence





- **CMS data on the energy dependence (7 TeV divided by 900 GeV) of the "transverse" charged particle density as defined by the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2.0 compared with PYTHIA Tune Z1, Z2, and PY8C4 at the generator level.**

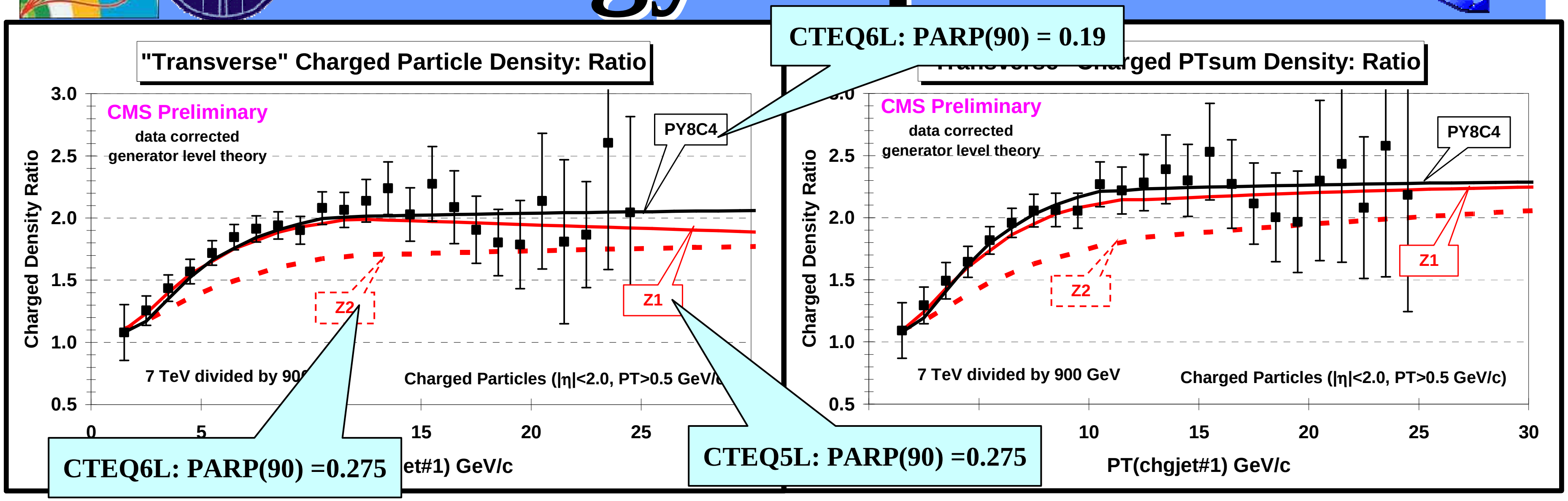
- **CMS data on the energy dependence (7 TeV divided by 900 GeV) of the "transverse" charged PTsum density as defined by the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2.0 compared with PYTHIA Tune Z1, Z2, and PY8C4 at the generator level.**

CMS corrected data!

Z1 and PY8C4 good! Z2 Bad!

CMS corrected data!

Energy Dependence



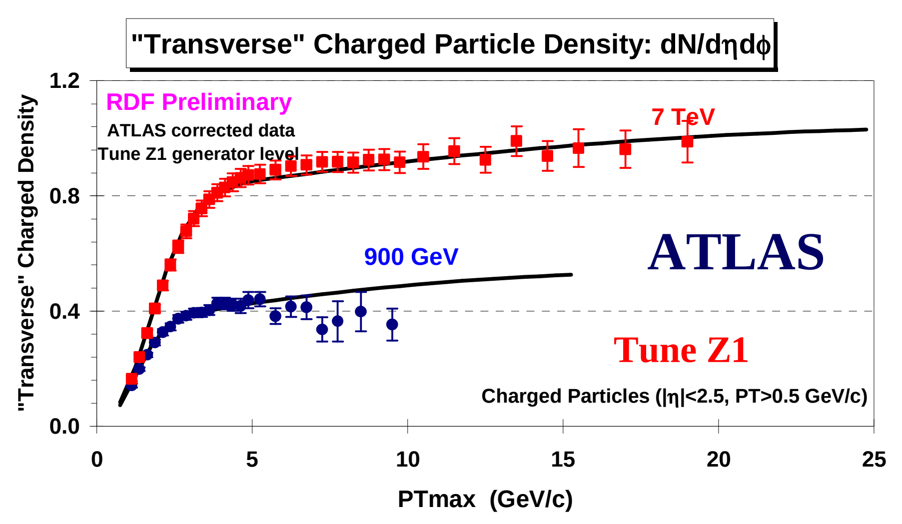
- **CMS data on the energy dependence (7 TeV divided by 900 GeV)** of the "transverse" charged particle density as defined by the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2.0 compared with **PYTHIA Tune Z1, Z2, and PY8C4** at the generator level.
- **CMS data on the energy dependence (7 TeV divided by 900 GeV)** of the "transverse" charged PTsum density as defined by the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2.0 compared with **PYTHIA Tune Z1, Z2, and PY8C4** at the generator level.

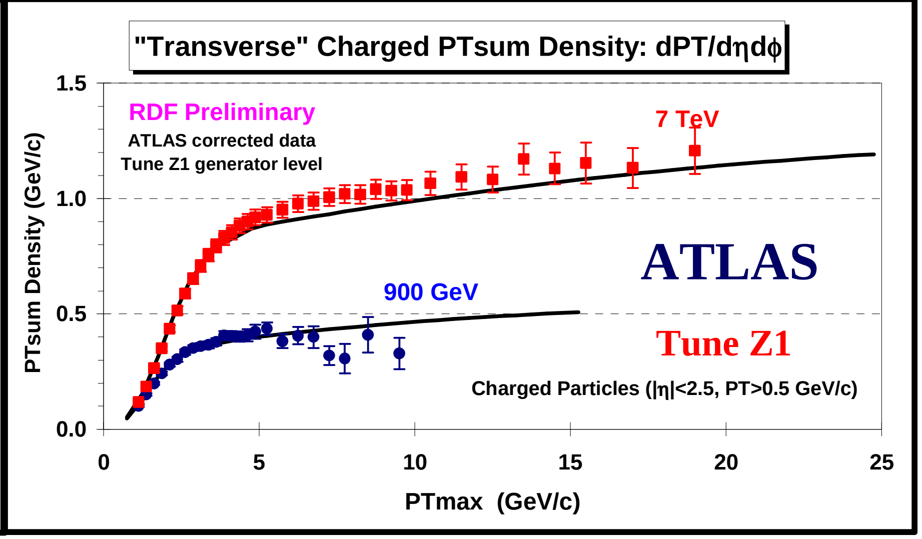
CMS corrected data!

Duh! The energy dependence depends on both PARP(90) and the structure function!

CMS corrected data!

ATLAS UE Data



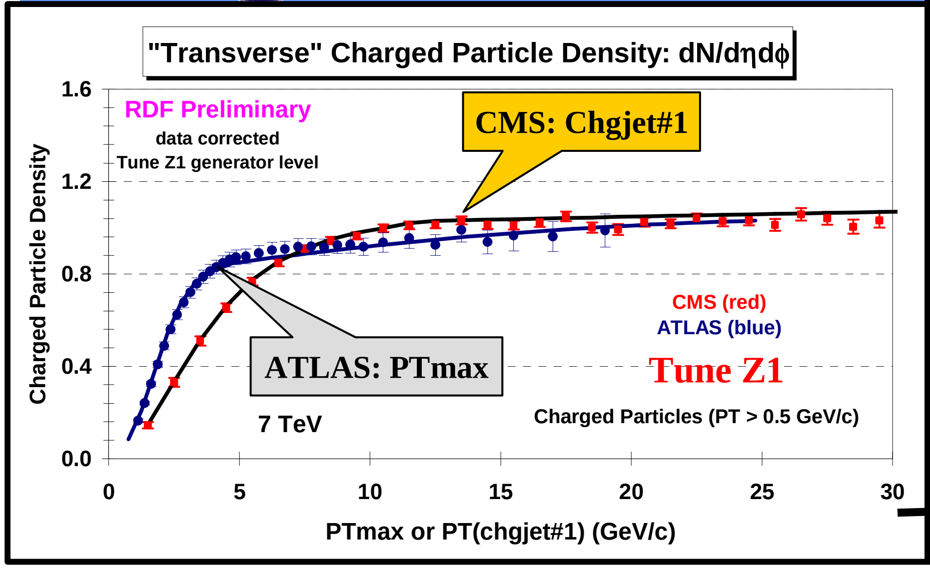


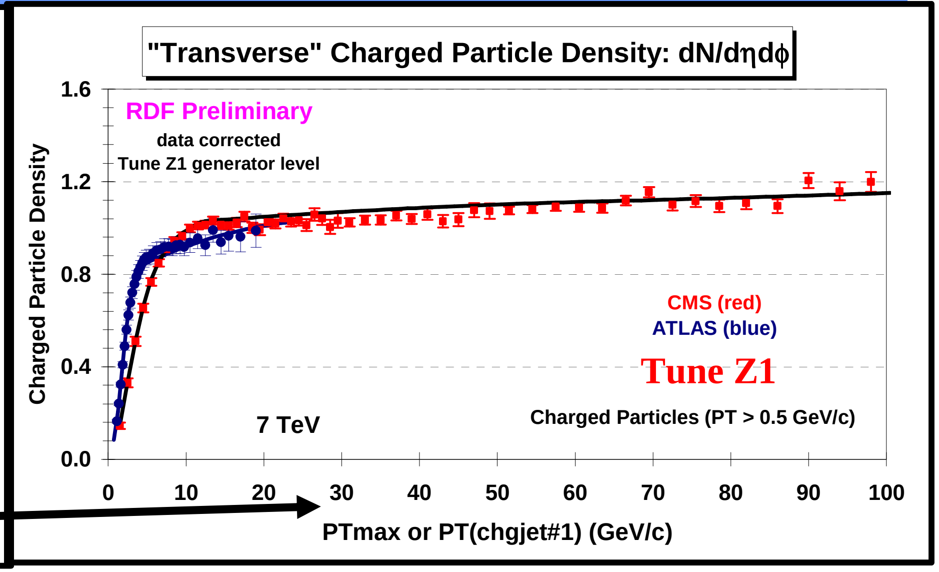
- **ATLAS published data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 2.5. The data are corrected and compared with PYTHIA Tune Z1 at the generator level.**

- **ATLAS published data at 900 GeV and 7 TeV on the "transverse" charged PTsum density, dPT/dηdφ, as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 2.5. The data are corrected and compared with PYTHIA Tune Z1 at the generrator level.**

ATLAS publication – arXiv:1012.0791
December 3, 2010

CMS-ATLAS UE Data

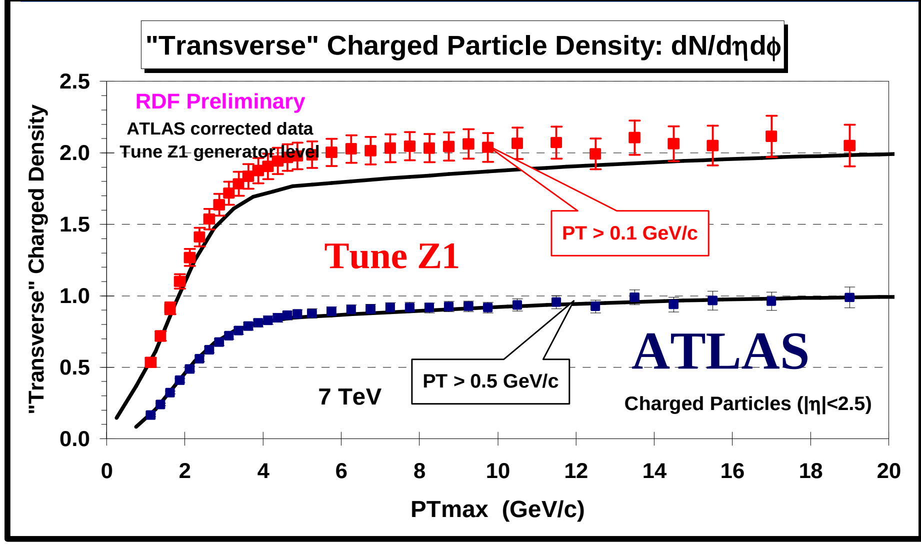


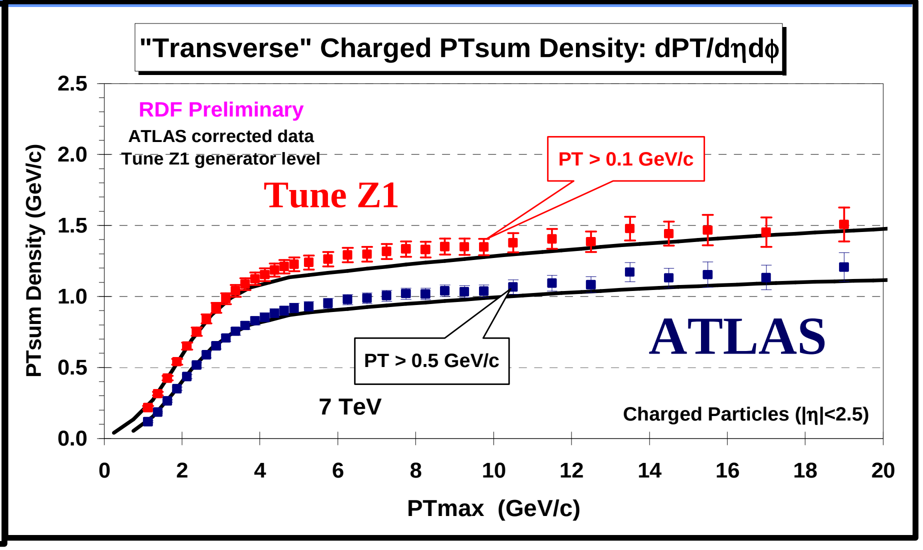


- **CMS preliminary data at 7 TeV on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$ together with the ATLAS published data at 7 TeV on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.5$ The data are corrected and compared with PYTHIA Tune Z1 at the generator level.**

Amazing agreement!

ATLAS UE Data





- **ATLAS published data at 7 TeV on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $p_T > 0.1$ GeV/c ($|\eta| < 2.5$). The data are corrected and compared with PYTHIA Tune Z1 at the generator level.**

- **ATLAS published data at 7 TeV on the "transverse" charged PTsum density, dPT/dηdφ, as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $p_T > 0.1$ GeV/c ($|\eta| < 2.5$). The data are corrected and compared with PYTHIA Tune Z1 at the generator level.**

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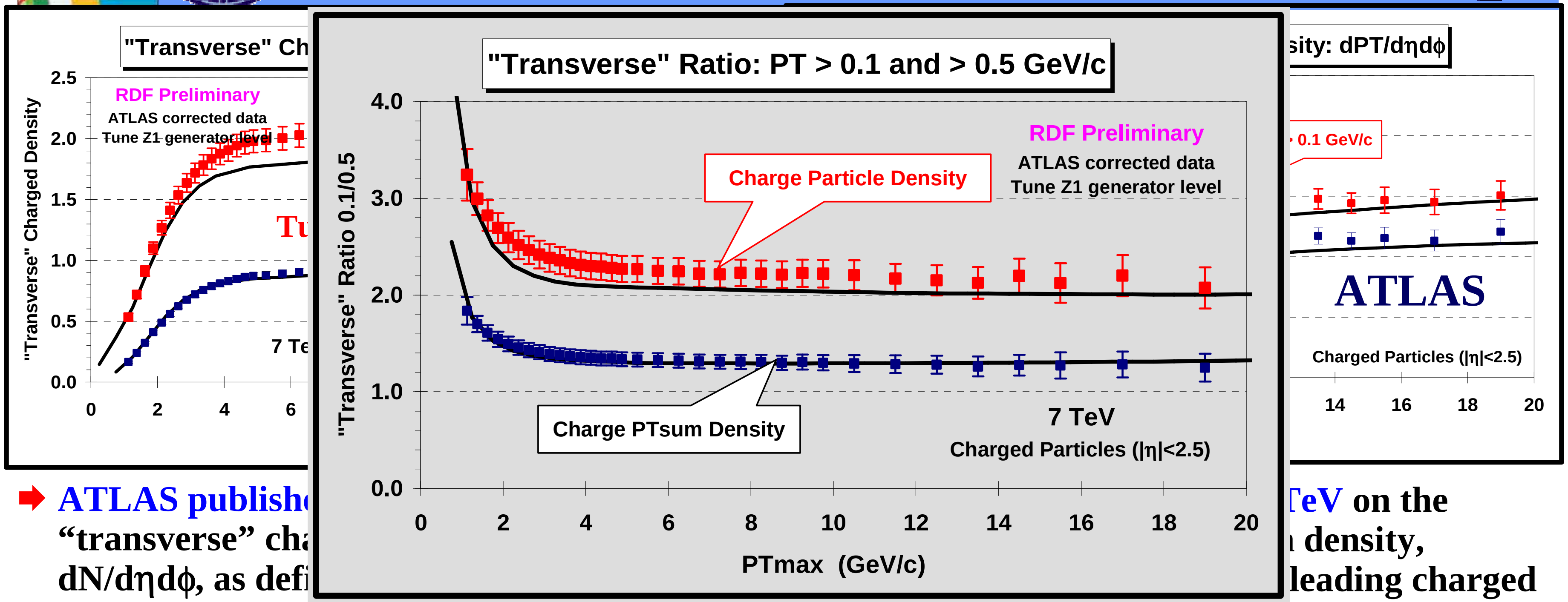
ATLAS UE Data



- ATLAS publish… "transverse" cha… $dN/d\eta d\phi$, as defi… particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $p_T > 0.1$ GeV/c ($|\eta| < 2.5$). The data are corrected and compared with PYTHIA Tune Z1 at the generator level.

…TeV on the … density, … leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $p_T > 0.1$ GeV/c ($|\eta| < 2.5$). The data are corrected and compared with PYTHIA Tune Z1 at the generator level.

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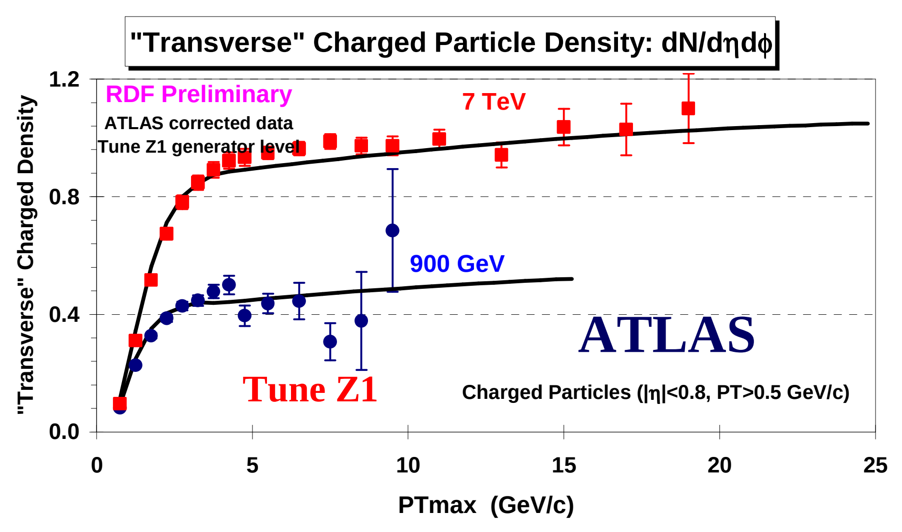

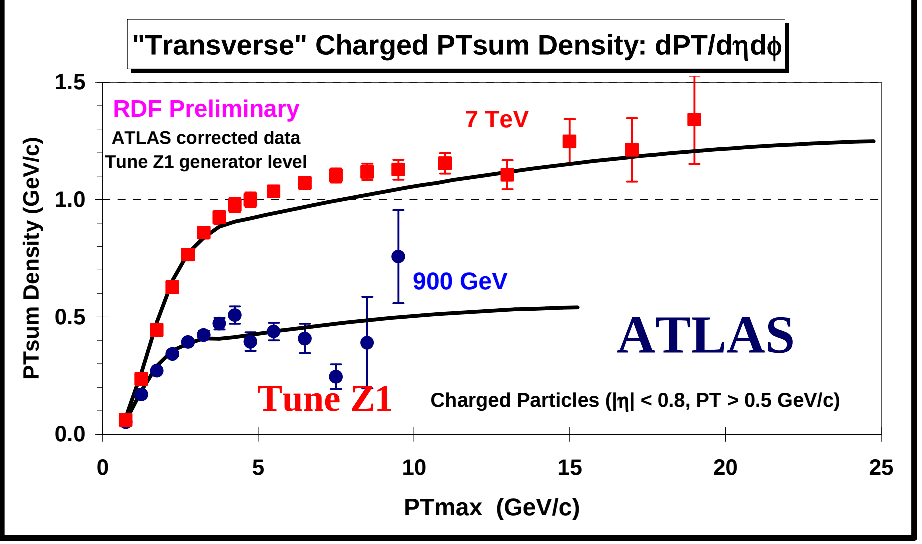

- **ATLAS preliminary data at 900 GeV and 7 TeV** on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 0.8. The data are corrected and compared with **PYTHIA Tune Z1** at the generator level.

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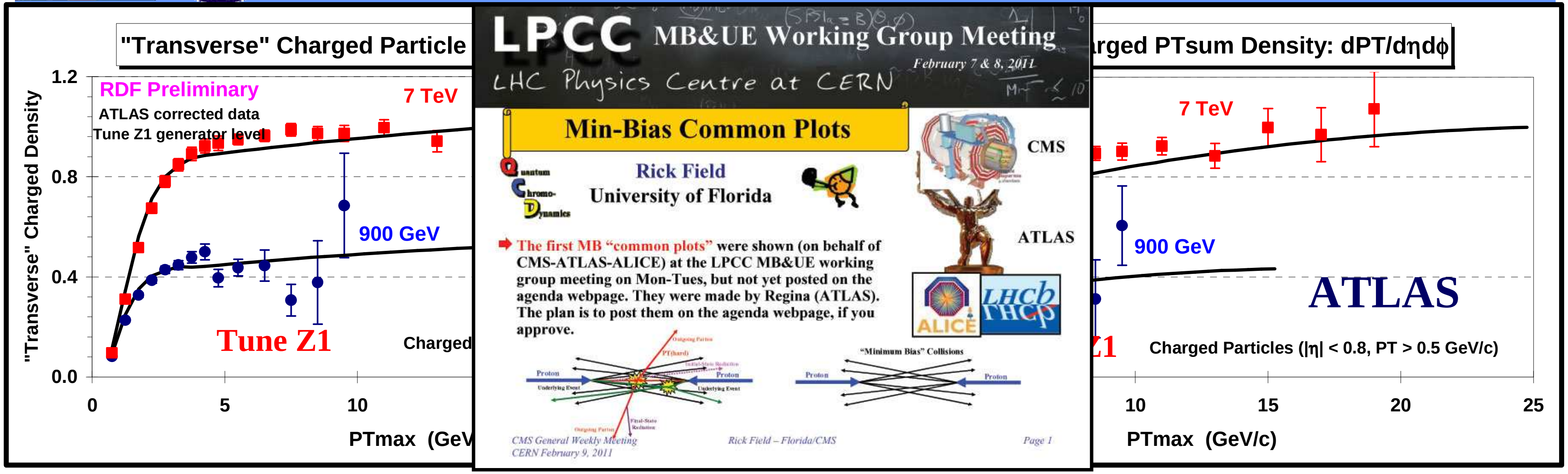
ATLAS-CONF-2011-009
February 21, 2011

ATLAS UE Data



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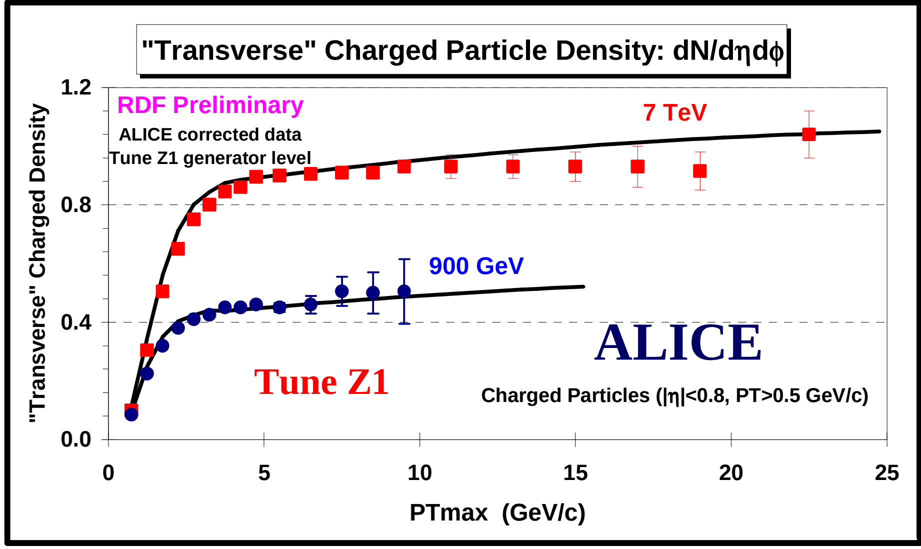
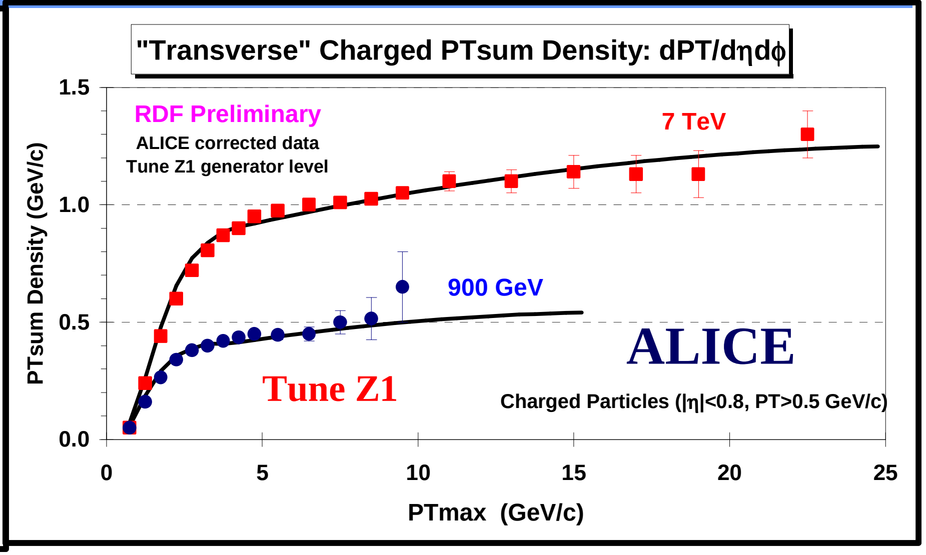
ATLAS-CONF-2011-009
February 21, 2011

ALICE UE Data





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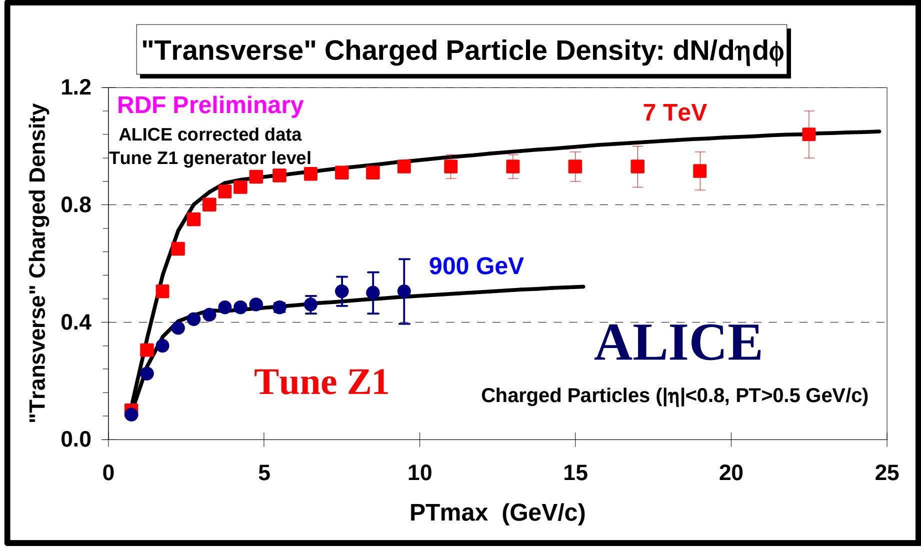
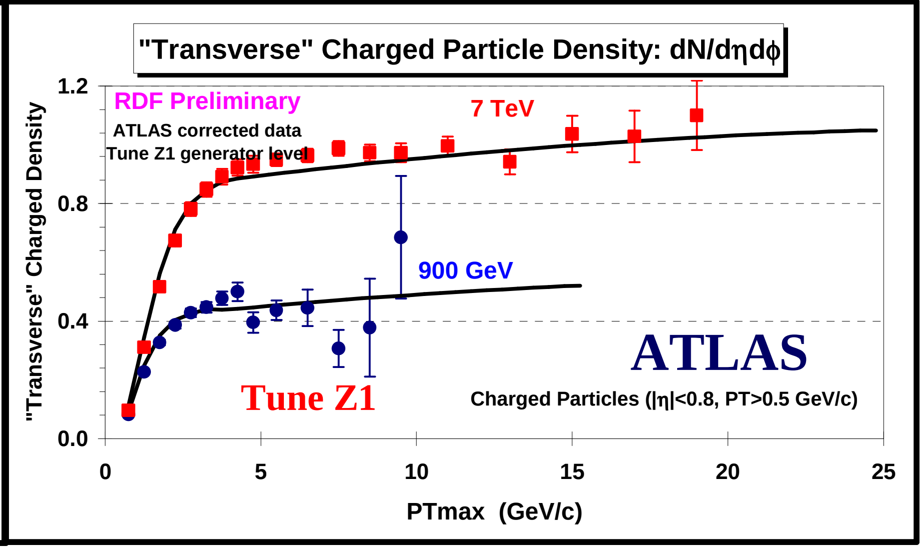
I read the points off with a ruler!

ALICE UE Data: Talk by S. Vallero
MPI@LHC 2010 Glasgow, Scotland
November 30, 2010

ALICE-ATLAS UE





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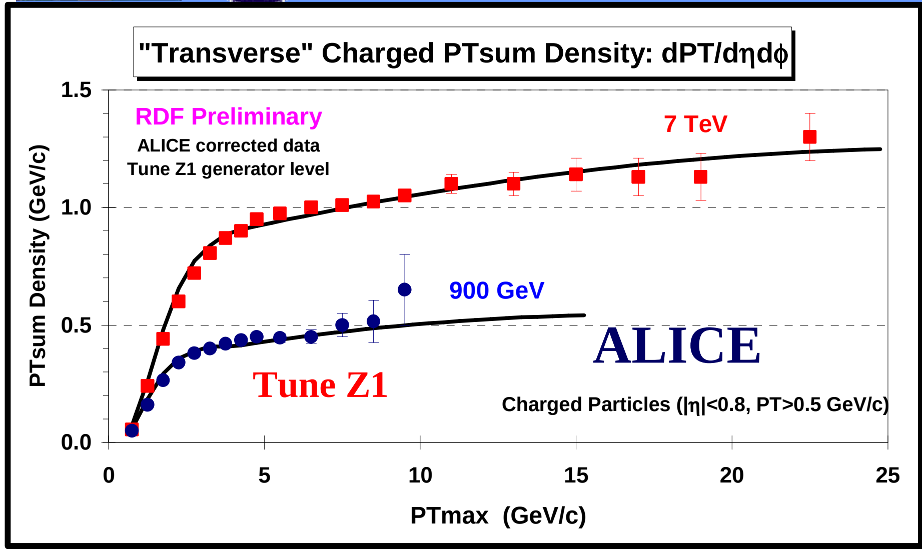
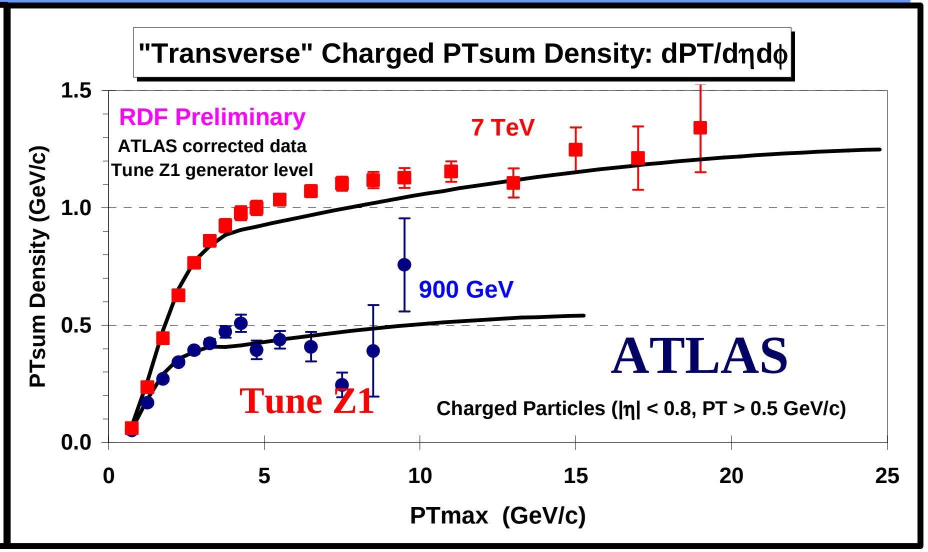
ALICE-ATLAS UE





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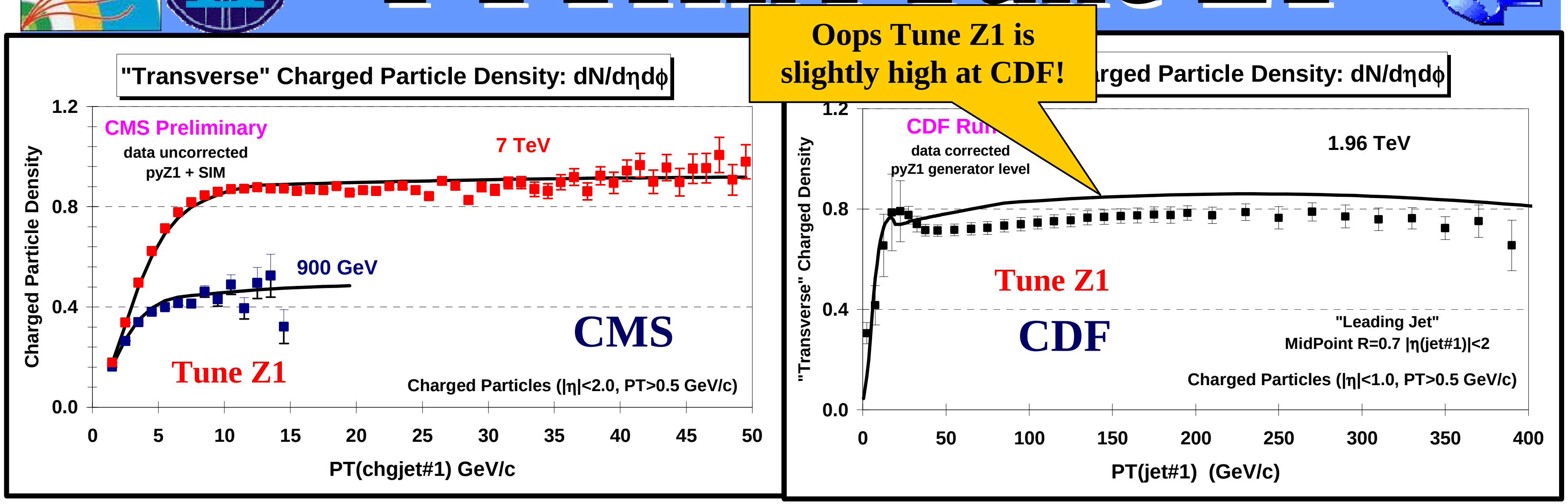
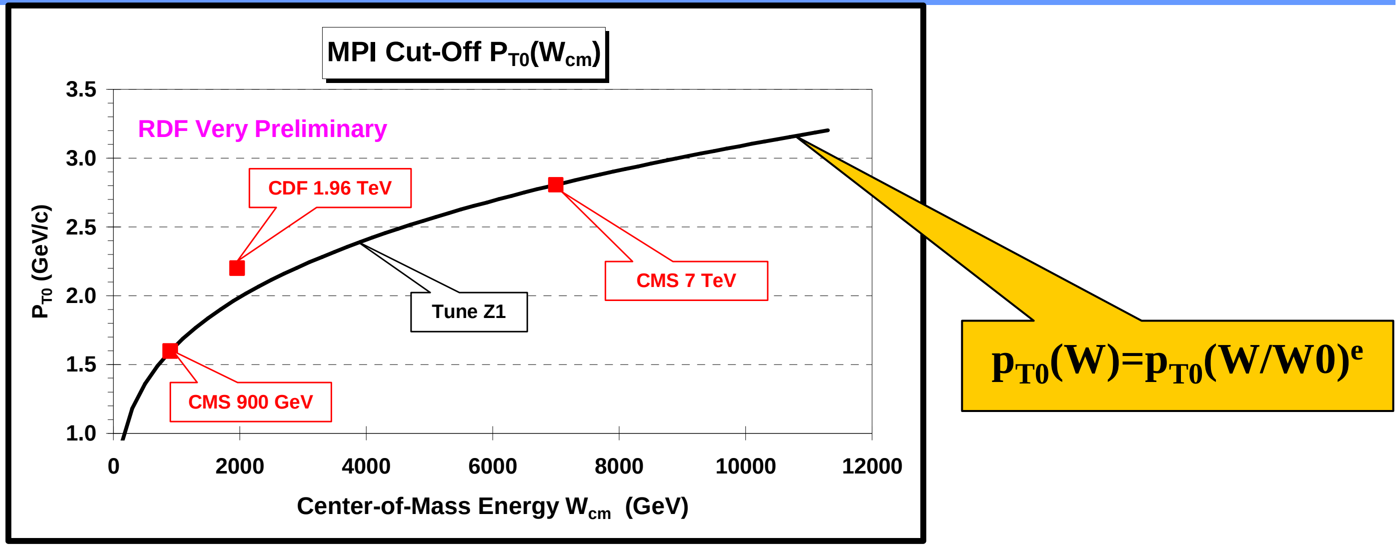
PYTHIA Tune Z1



- **CMS preliminary data at 900 GeV and 7 TeV** on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2. The data are uncorrected and compared with PYTHIA **Tune Z1** after detector simulation.
- **CDF published data at 1.96 TeV** on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading calorimeter jet (jet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 1.0. The data are corrected and compared with PYTHIA **Tune Z1** at the generator level.

PYTHIA Tune Z1



➡ **MPI Cut-Off versus the Center-of Mass Energy W_{cm}: PYTHIA Tune Z1 was determined by fitting p_{T0} independently at 900 GeV and 7 TeV and calculating ε = PARP(90). The best fit to p_{T0} at CDF is slightly higher than the Tune Z1 curve. This is very preliminary! Perhaps with a global fit to all three energies (*i.e.* "Professor" tune) one can get a simultaneous fit to all three??**

$$p_{T0}(W)=p_{T0}(W/W_0)^{\varepsilon} \quad \varepsilon = \text{PARP}(90) \quad p_{T0} = \text{PARP}(82) \quad W = E_{cm}$$

PYTHIA 8 Tunes

R. Corke and T. Sjöstrand

PT0 = PARP(82)

ε = PARP(90)

	CTEQ6L	MRST LO**	CTEQ6L
Parameter	Tune 2C	Tune 2M	Tune 4C
SigmaProcess:alphaSvalue	0.135	0.1265	0.135
SpaceShower:rapidityOrder	on	on	on
SpaceShower:alphaSvalue	0.137	0.130	0.137
SpaceShower:pT0Ref	2.0	2.0	2.0
MultipleInteractions:alphaSvalue	0.135	0.127	0.135
MultipleInteractions:pT0Ref	2.320	2.455	2.085
MultipleInteractions:ecmPow	0.21	0.26	0.19
MultipleInteractions:bProfile	3	3	3
MultipleInteractions:expPow	1.60	1.15	2.00
BeamRemnants:reconnectRange	3.0	3.0	1.5
SigmaDiffractive:dampen	off	off	on
SigmaDiffractive:maxXB	N/A	N/A	65
SigmaDiffractive:maxAX	N/A	N/A	65
SigmaDiffractive:maxXX	N/A	N/A	65

Tevatron **LHC**

$p_{T0}(W)=p_{T0}(W/W_0)^{\varepsilon}$ ε = PARP(90) p_{T0} = PARP(82) $W = E_{cm}$

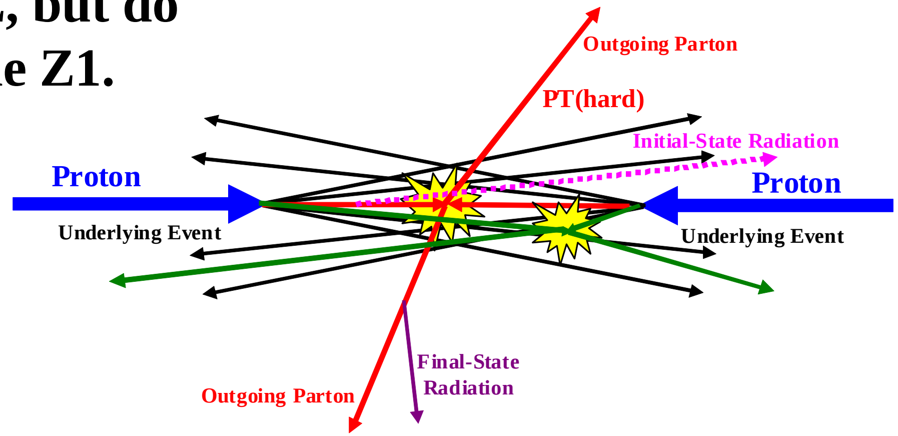
UE Summary & Conclusions

➡ We now have lots of corrected UE data from the LHC! Tune Z1 (CTEQ5L) does nice job of fitting the CMS, ATLAS, and ALICE UE data at 900 GeV and 7 TeV! But Tune Z1 is a little high at CDF (1.96 TeV)!

I still dream of a "universal" tune that fits the UE at all energies! Need to simultaneously tune LHC plus CDF ("professor" tune)!

➡ CTEQ6L Tune: PYTHIA 6.4 Tune Z2 and PYTHIA 8 Tune C4 both use CTEQ6L, but do not fit the LHC UE data as well as Tune Z1.

➡ Next Step: More PYTHIA 6.4 and PYTHIA 8 tunes. Time to look more closely at Sherpa and HERWIG++!



➡ ATLAS Tuning Effort (A. Buckley, J. Katzy et al.): AMBT1, AUET1 (Herwig+Jimmy). Coming soon AUET2 (Herwig + Jimmy), AMBT2! Four stage approach: Flavor, FS fragmentation, ISR, MPI.

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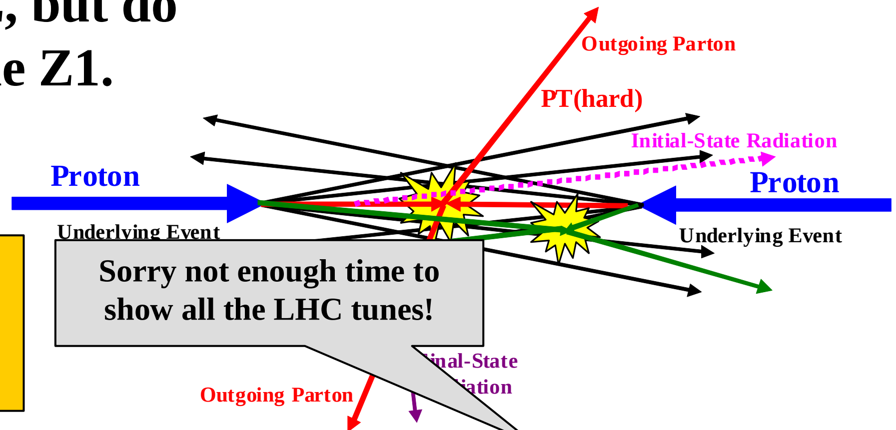
- **CTEQ6L Tune: PYTHIA 6.4 Tune Z2 and PYTHIA 8 Tune C4 both use CTEQ6L, but do not fit the L... UE data as well as Tune Z1.**

- **Next Step: Mo... ...THIA 6.4 and PYTHIA 8 t... closely at Sh...**

CMS GEN Group: Working on an improved Z2 tune (Tune Z2*) and an improved PY8C4 tune (Tune C4*) using the Professor (A. Knutsson & M. Zakaria).



Sorry not enough time to show all the LHC tunes!

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