# The LHC Physics Environment

## Talk 2: Extrapolations from the Tevatron to RHIC and the LHC

University of Wisconsin, Madison

June 24$^{th}$ – July 2$^{nd}$, 2009

C T E Q

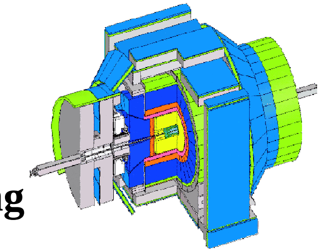

**Rick Field**

**University of Florida**

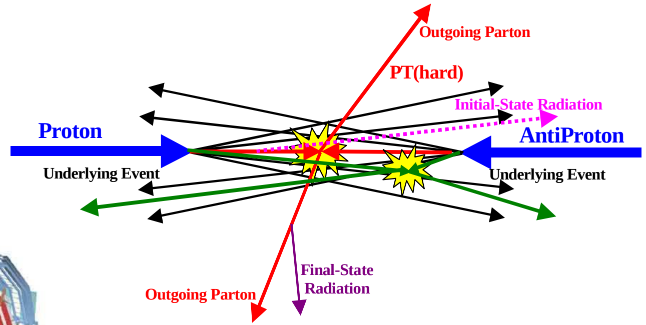

Quantum Chromo-Dynamics

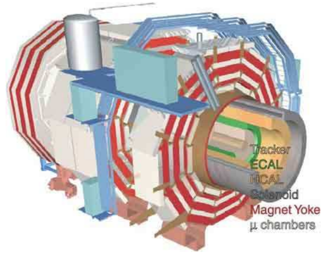
**Outline of Talk**

- The PYTHIA MPI energy scaling parameter PARP(90).
- The “underlying event” at STAR. Extrapolations to RHIC.
- LHC predictions for the “underlying event” (hard scattering QCD & Drell-Yan).
- “Min-bias” and “pile-up” at the LHC.
- Correlations: charged particle <$p_T$> versus the charged multiplicity in “min-bias” and Drell-Yan.
- Summary & Conclusions.
- Early LHC Thesis Projects.



CDF Run 2

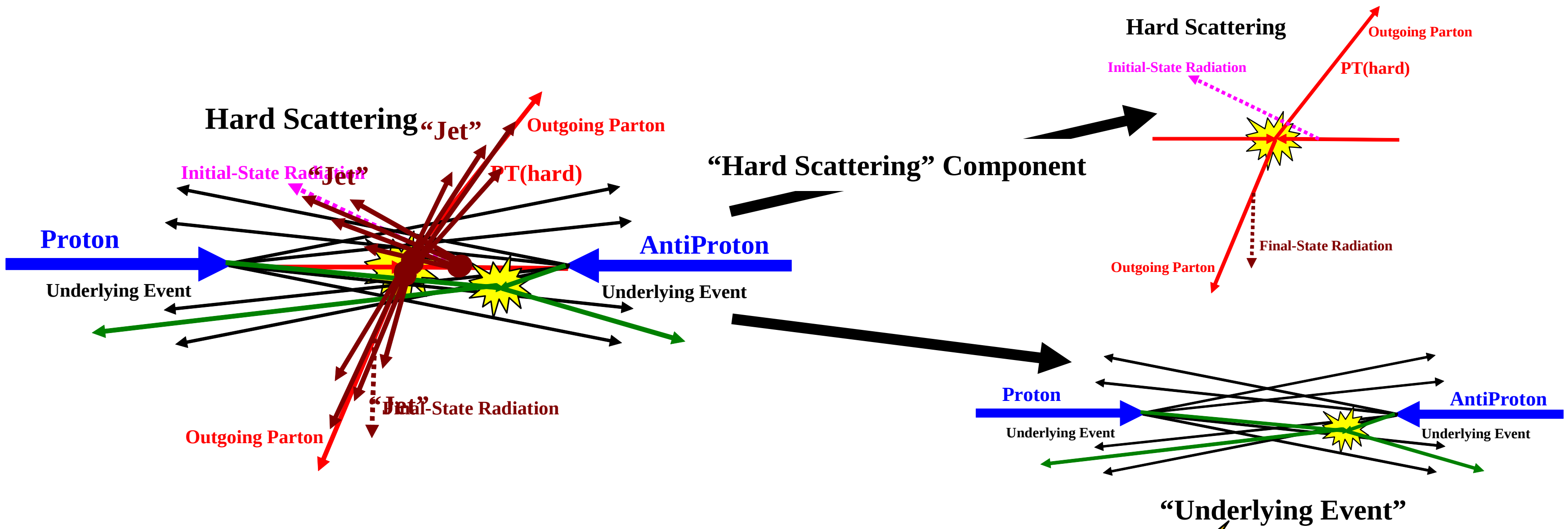



CMS at the LHC

UE&MB@CMS

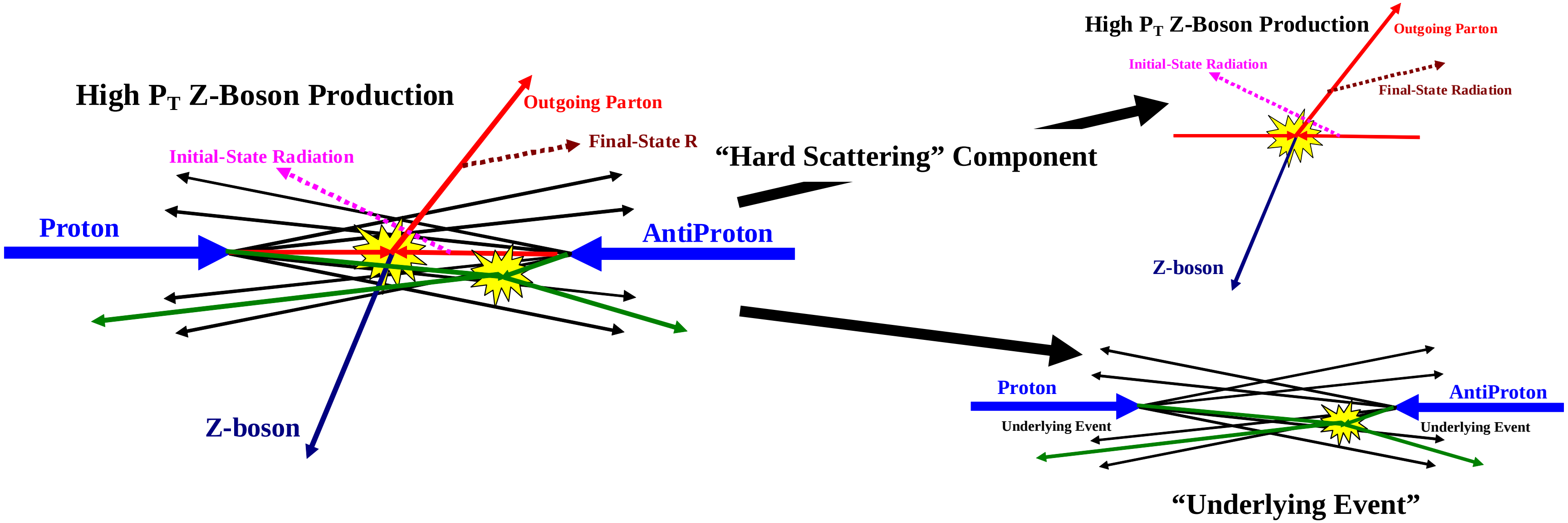
# QCD Monte-Carlo Models: High Transverse Momentum Jets




- 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 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

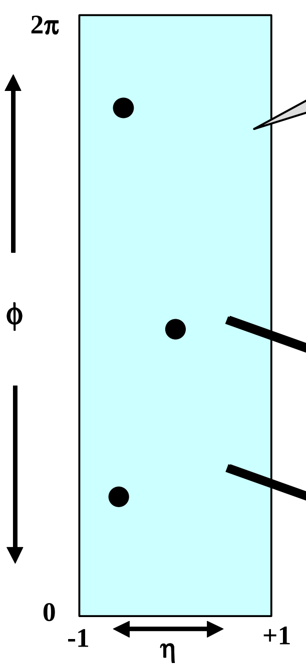
**The "underlying event" is an unavoidable background to most collider observables and having good understand of it leads to more precise collider measurements!**

# QCD Monte-Carlo Models: Lepton-Pair Production




- Start with the perturbative Drell-Yan muon pair production and add initial-state gluon radiation (in the leading log approximation or modified leading log approximation).
- The "underlying event" consists of the "beam-beam remnants" and from particles arising from soft or semi-soft multiple parton interactions (MPI).
- Of course the outgoing colored partons fragment into hadron "jet" and inevitably "underlying event" observables receive contributions from initial-state radiation.

# Particle Densities




ΔηΔφ = 4π = 12.6

3 charged particles

3 GeV/c PTsum

## Charged Particles
## $p_T$ > 0.5 GeV/c |η| < 1

CDF Run 2 "Min-Bias"

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

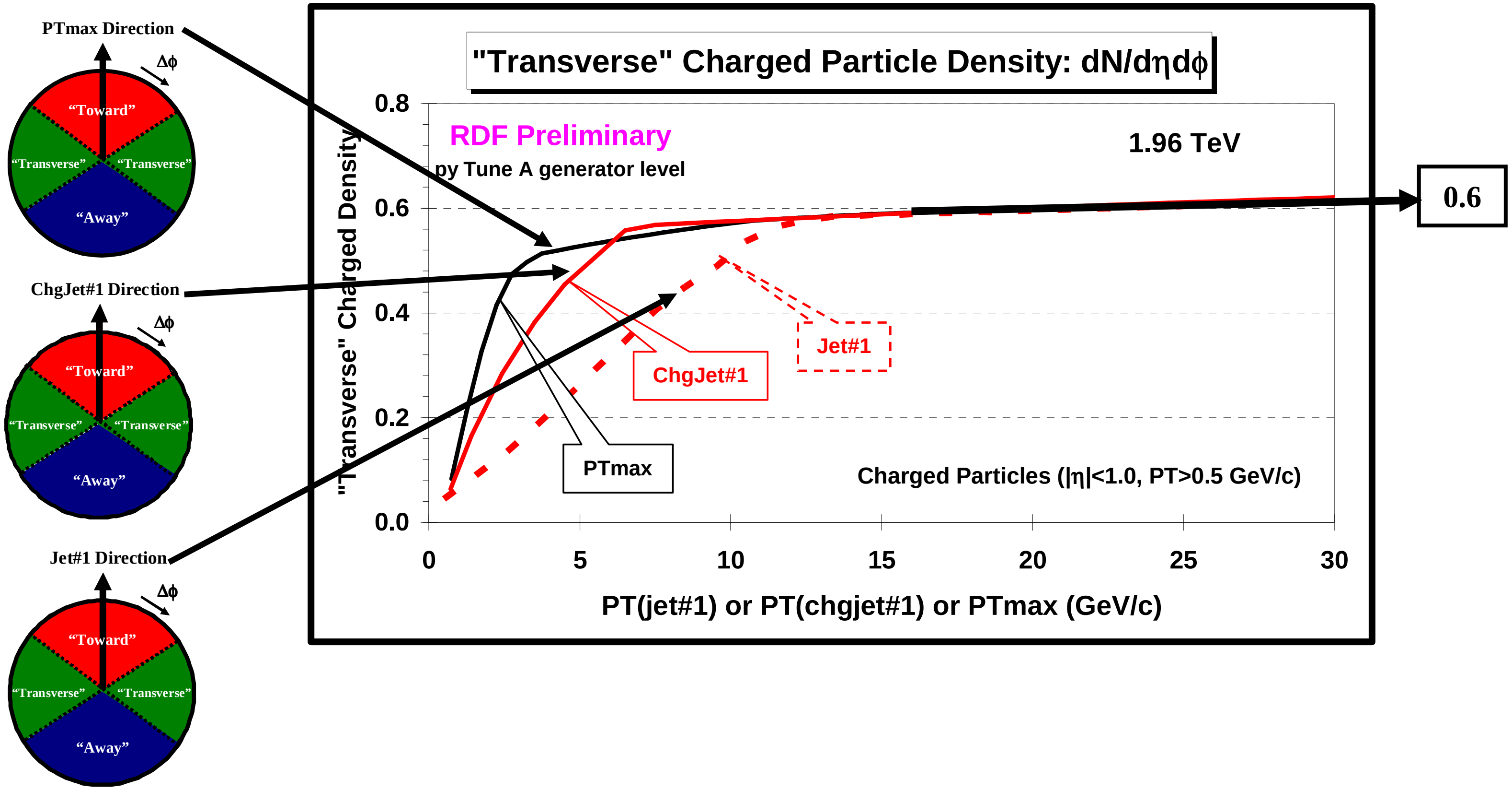
Divide by 4π

dNchg/dηdφ = 3/4π = 0.24

dPTsum/dηdφ = 3/4π GeV/c = 0.24 GeV/c

- **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.**

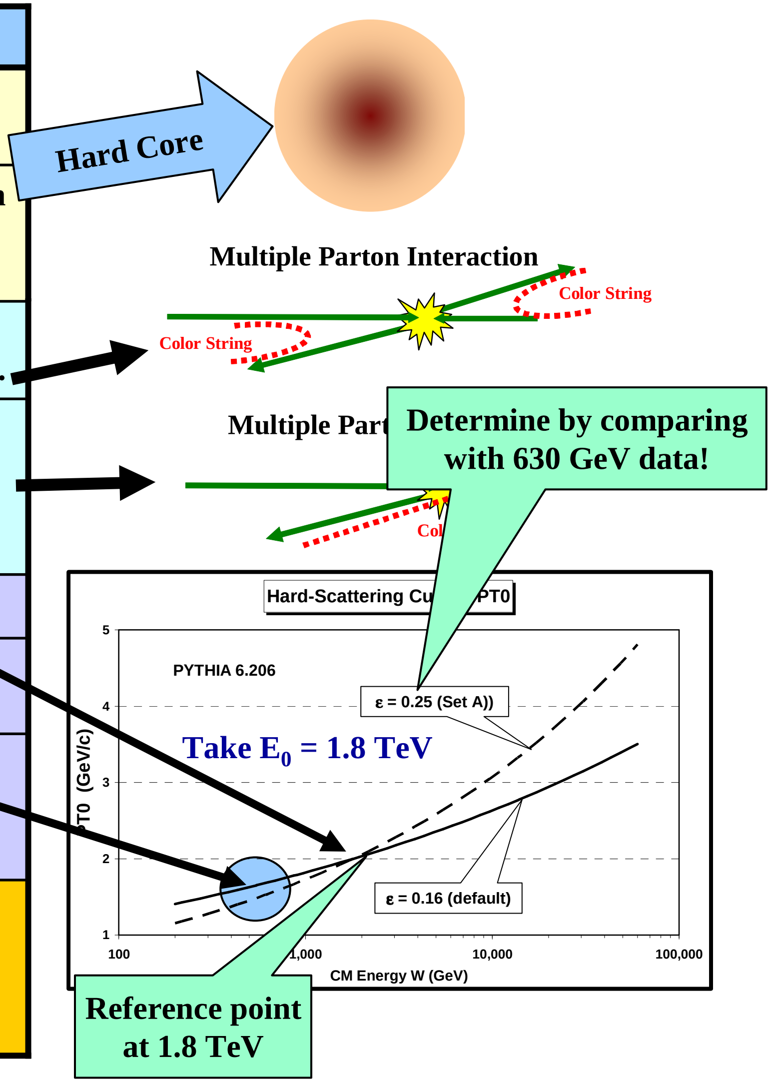
# "Transverse" Charged Density




- **Shows the charged particle density in the "transverse" region for charged particles ($p_T$ > 0.5 GeV/c, |η| < 1) at 1.96 TeV as defined by PTmax, PT(chgjet#1), and PT(jet#1) from PYTHIA Tune A at the particle level (*i.e.* generator level).**

# Tuning PYTHIA:
## Multiple Parton Interaction Parameters

| Parameter | Default | Description |
|---|---|---|
| PARP(83) | 0.5 | Double-Gaussian: Fraction of total hadronic matter within PARP(84) |
| PARP(84) | 0.2 | Double-Gaussian: Fraction of the overall hadron radius containing the fraction PARP(83) of the total hadronic matter. |
| PARP(85) | 0.33 | Probability that the MPI produces two gluons with color connections to the "nearest neighbors. |
| PARP(86) | 0.66 | Probability that the MPI produces two gluons either as described by PARP(85) or as a closed 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 $\varepsilon$ = 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:
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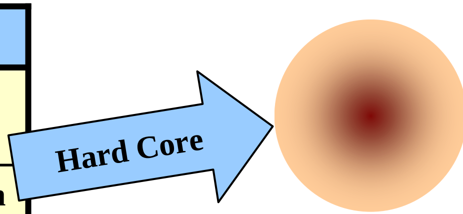
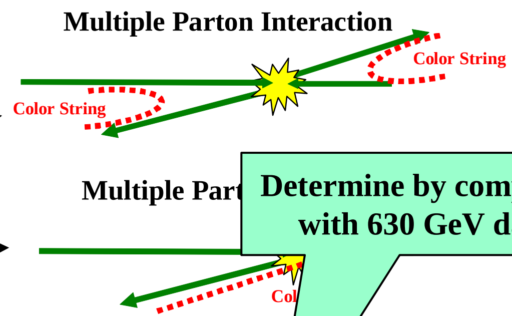
| PARP(85) | 0.33 | Pr[illegible]uces two gluons w[illegible] nearest neighbors. |
| PARP(86) | 0.66 | Prob[illegible]luons eit[illegible]s des[illegible]closed [illegible] loop. [illegible]ists of [illegible]ark-antiqua[illegible]s. |
| PARP(89) | 1 Te[illegible] | Determin[illegible] reference energy $E_0$. |
| PARP(82) | [illegible].9 GeV/c | The c[illegible]off $P_{T0}$ that regulates the 2-to-2 sc[illegible]ring divergence $1/PT^4 \to 1/(PT^2+P_{T0}^2)^2$ |
| 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 $\varepsilon$ = 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. |

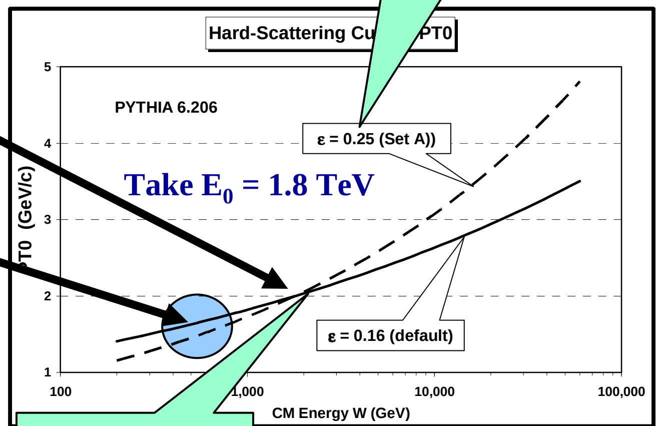
Determines the energy dependence of the MPI!

Affects the amount of initial-state radiation!



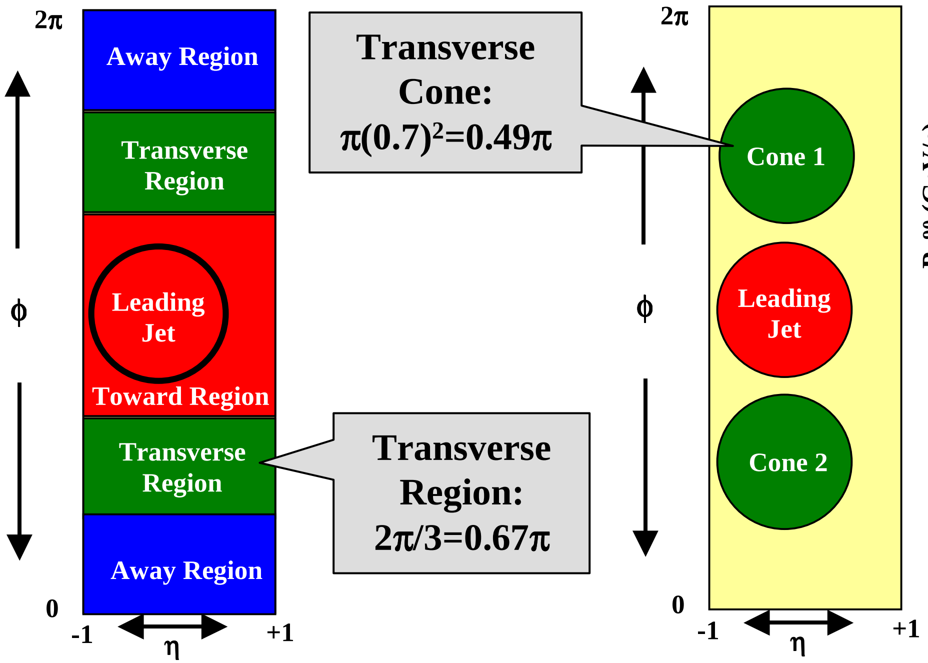




Determine by comparing with 630 GeV data!

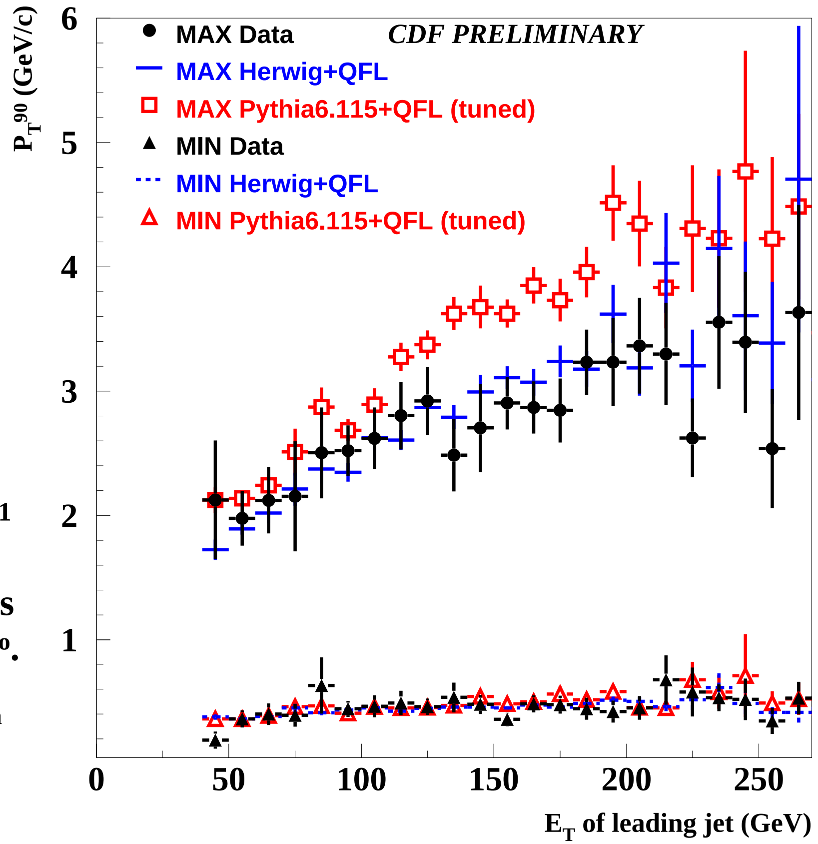



Reference point at 1.8 TeV

# "Transverse" Cones vs "Transverse" Regions

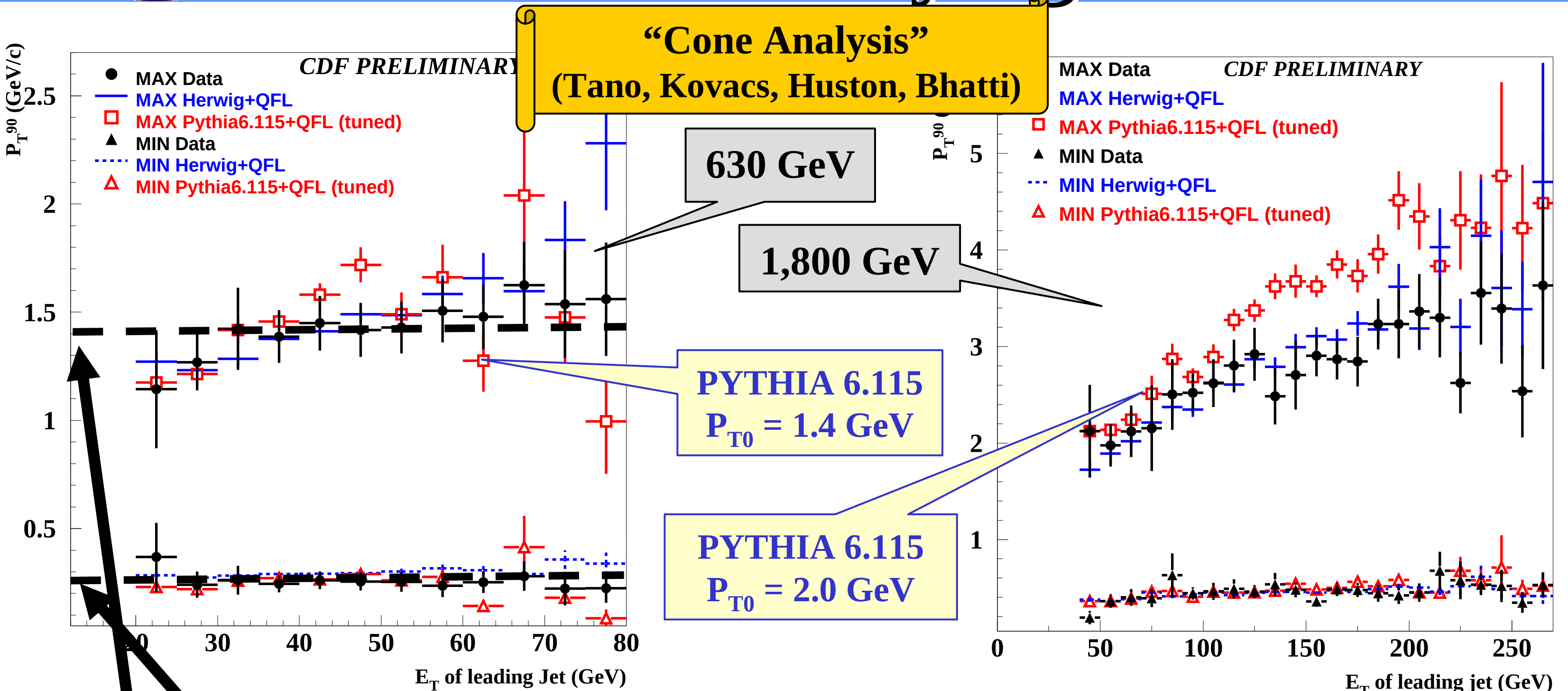



"Cone Analysis"
(Tano, Kovacs, Huston, Bhatti)



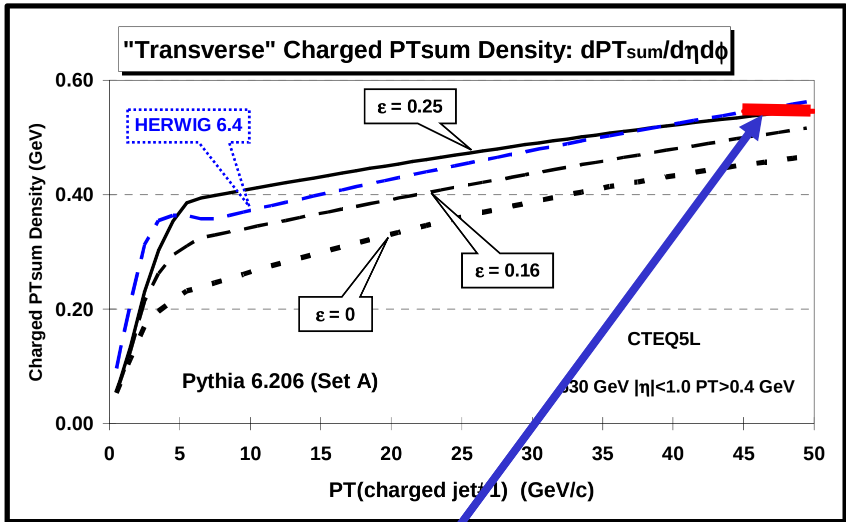

- Sum the $P_T$ of charged particles in two cones of radius 0.7 at the same η as the leading jet but with |ΔΦ| = 90°.
- Plot the cone with the maximum and minimum $PT_{sum}$ versus the $E_T$ of the leading (calorimeter) jet.

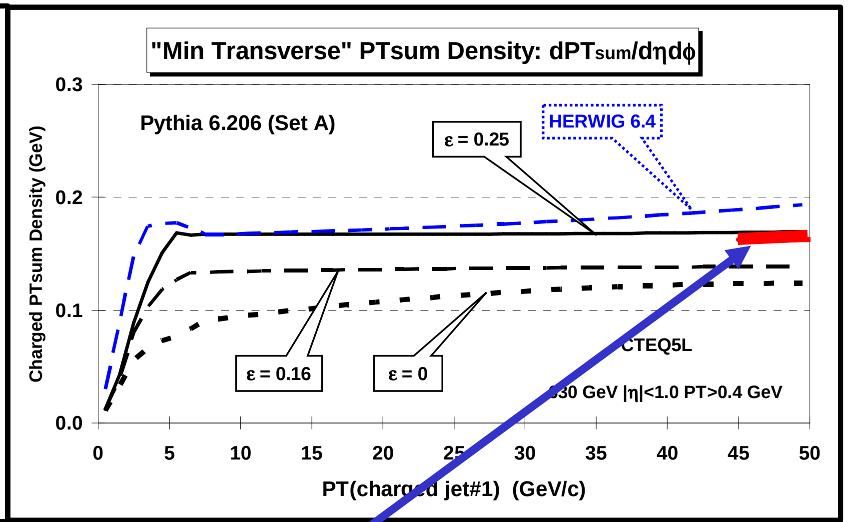
# Energy Dependence of the "Underlying Event"



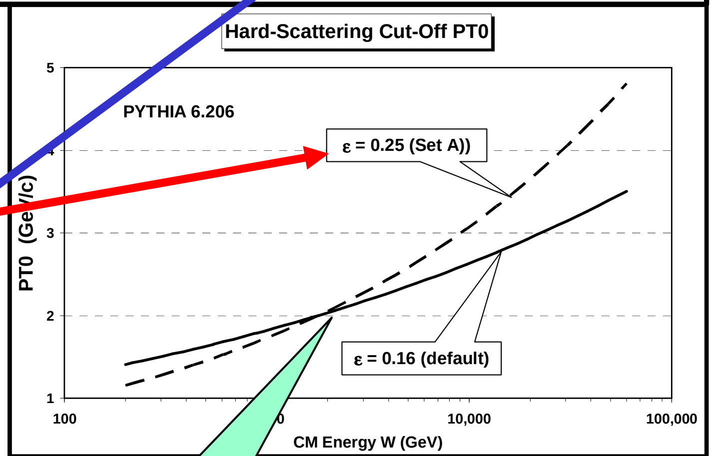

- Sum the $P_T$ of charged particles ($p_T > 0.4$ GeV/c) in two cones of radius 0.7 at the same $\eta$ as the leading jet but with $|\Delta\Phi| = 90^o$. Plot the cone with the maximum and minimum $PT_{sum}$ versus the $E_T$ of the leading (calorimeter) jet.
- Note that PYTHIA 6.115 is tuned at 630 GeV with $P_{T0}$ = 1.4 GeV and at 1,800 GeV with $P_{T0}$ = 2.0 GeV. This implies that $\varepsilon$ = 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 $\eta$-$\phi$).

# "Transverse" Charged Densities Energy Dependence



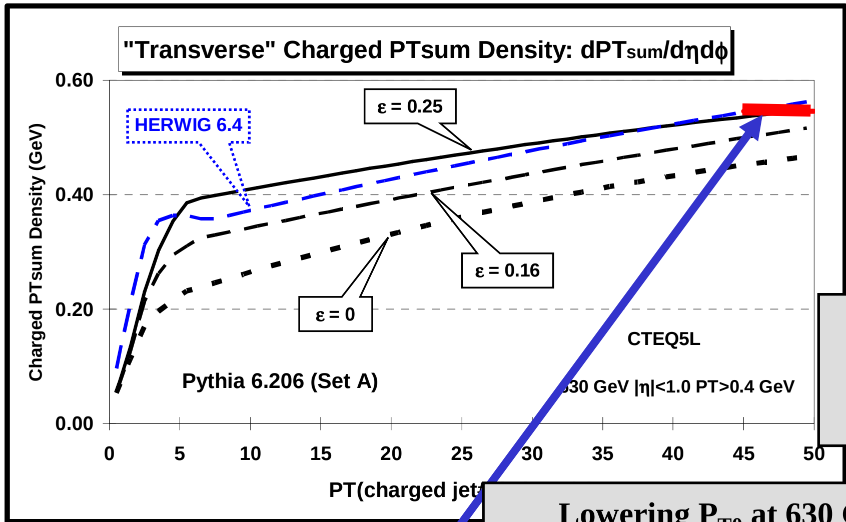



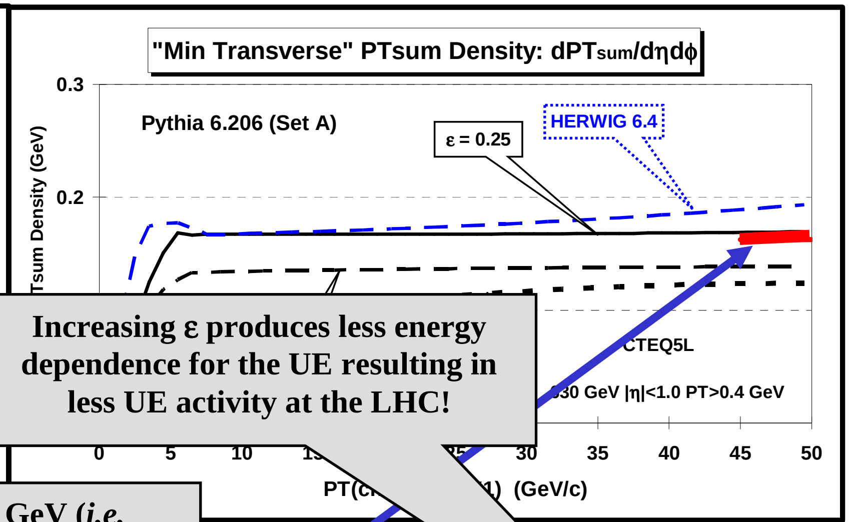

- Shows the "transverse" charged $PT_{sum}$ density ($|\eta|<1$, $P_T>0.4$ GeV) versus $P_T$(charged jet#1) at 630 GeV predicted by **HERWIG 6.4** ($P_T$(hard) > 3 GeV/c, CTEQ5L) and a **tuned** version of **PYTHIA 6.206** ($P_T$(hard) > 0, CTEQ5L, Set A, **ε = 0, ε = 0.16 (default) and ε = 0.25 (preferred)**).
- 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

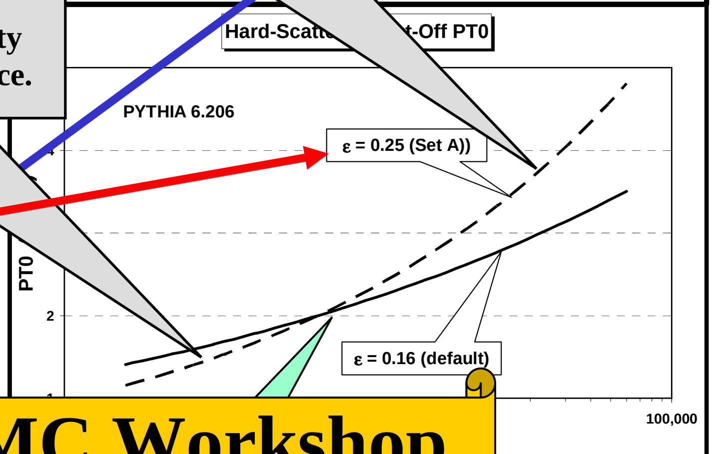
# "Transverse" Charged Densities Energy Dependence




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 (|η|<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!**

# PYTHIA 6.2 Tunes

All use LO $\alpha_s$ with $\Lambda$ = 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! (not the default)

# PYTHIA 6.2 Tunes

All use LO $\alpha_s$ with $\Lambda$ = 192 MeV!

UE Parameters

ISR Parameter

Intrinsic KT

ATLAS energy dependence! (PYTHIA default)

| 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 $\alpha_s$ with $\Lambda$ = 192 MeV!

UE Parameters

[illegible]arameter

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

ATLAS energy dep[illegible]ndence! [illegible](PYTHI[illegible] def[illegible]lt)

Tune A

Tune AW

Tune B

Tune BW

Tune D

Tune DW

Tune D6

Tune D6T

# PYTHIA 6.2 Tunes

All use LO $\alpha_s$ with $\Lambda$ = 192 MeV!

UE Parameters

| Parameter | Tune DWT | Tune D6T | |
|---|---|---|---|
| PDF | CT | CTEQ6L | L |
| MSTP(81) | | 1 | |
| TP(82) | | 4 | |

S energy dependence!

Tune A

Tune BW

Tune D

e D6

Tune D6T

These are “old” PYTHIA 6.2 tunes!

There are new 6.420 tunes by

Peter Skands (Tune S320, update of S0)

Peter Skands (Tune N324, N0CR)

Hendrik Hoeth (Tune P329, “Professor”)

# Peter's Pythia Tunes WEBsite

## Peter's Pythia Plots

February 2009 © P. Z. Skands

**Navigate these pages** by using the menu to the left. More plots will be added, as new tunes become available, and as the available data increases. The default for each topic is a comparison of a small number of tunes to available data (or just to each other if no data exists), but look for links at the top of each page for comparisons with more models.

Apr 2009: Full descriptions and parameters of the "Perugia" tunes (submitted to the Perugia MPI workshop proceedings)
Dec 2007: Some interesting min-bias distributions for early LHC runs (submitted to the 2007 Les Houches workshop proceedings)

The tunes currently available on the plots are (numbered as in PYTUNE):

### Tunes using Q2-ordered model

- 100: **A**: Rick Field's Tune A to Tevatron Underlying-Event Data. Uses the "old" UE and shower models, with a double-gaussian matter profile, 1 GeV of primordial kT, and near-maximal color correlations. [Oct 2002]
- 103: **DW**: Rick Field's Tune DW to Tevatron Underlying-Event and Drell-Yan Data. Similar to Tune A, but has 2 GeV of primordial kT and uses a very small renormalization scale for initial-state radiation (i.e., more ISR radiation). It also has completely maximal color correlations. [Apr 2006]
- 104: **DWT**: Variant of DW using the Pythia 6.2 default collider energy scaling (has worse agreement with Tevatron energy scaling quantities than DW). [Apr 2006]
- 106: **ATLAS-DC2** ("Rome"): first ATLAS tune of the Q2-ordered showers and old UE framework. Does not give very good agreement with Tevatron min-bias quantities.
- 107: **A-CR**: variant of Tune A using the Pythia 6.2 default color connections but with the new "color annealing" color reconnection model applied as an afterburner. Is intended as an example of strong color reconnections. [Mar 2007]
- 108: **D6**: Rick Field's Tune D6 to Tevatron data, using CTEQ6L1 PDFs.
- 110: **A-Pro**: Tune A with LEP tune from Professor. [Oct 2008]
- 113: **DW-Pro**: Tune DW with LEP tune from Professor. [Oct 2008]
- 114: **DWT-Pro**: Tune DWT with LEP tune from Professor. [Oct 2008]
- 116: **ATLAS-DC2-Pro**: ATLAS-DC2 with LEP tune from Professor. [Oct 2008]
- 117: **A-CR-Pro**: Tune A-CR with LEP tune from Professor. [Oct 2008]
- 118: **D6-Pro**: Tune D6 with LEP tune from Professor. [Oct 2008]
- 129: **Pro-Q20**: Tune of the Q2-ordered showers and old UE framework made with Professor, an automated tuning tool. [Feb 2009]

### Tunes intermediate between Q2- and pT-ordered models

- 201: **A-PT**: Retune of Tune A with pT-ordered final-state showers. [Mar 2007]
- 211: **A-PT-Pro**: Tune A-PT with LEP tune from Professor. [Oct 2008]
- 221: **Perugia A-PT**: "Perugia" update of A-PT-Pro. [Feb 2009]
- 226: **Perugia A6-PT**: "Perugia" update of A-PT-Pro, using CTEQ6L1 PDFs. [Feb 2009]

### Tunes using pT-ordered model

- 300: **S0**: First Sandhoff-Skands Tune of the "new" UE and shower framework, with a smoother matter profile than Tune A, 2 GeV of primordial kT, and "colour annealing" color reconnections. Uses the default Pythia energy scaling rather than that of Tune A. [Apr 2006]
- 303: **S0A**: A variant of S0 which is identical to S0 at the Tevatron, but which uses the Tune A energy scaling of the UE activity. [Apr 2006]
- 304: **NOCR**: Sandhoff-Skands "best try" without color reconnections. Gives less good agreement with Tevatron data. [Apr 2006]
- 306: **ATLAS-CSC**: first ATLAS tune of the pT-ordered showers and new UE framework. Does not give very good agreement with Tevatron min-bias quantities.
- 313: **S0A-Pro**: A variant of S0A revamped with a comprehensive retune of the fragmentation parameters to LEP data (by the "Professor" tool, hence the name). [Oct 2008]
- 314: **NOCR-Pro**: NOCR with LEP tune from Professor. [Oct 2008]
- 320: **Perugia 0**: "Perugia" update of S0-Pro. [Feb 2009]
- 321: **Perugia HARD**: Systematically "hard" variant of Perugia 0. [Feb 2009]
- 322: **Perugia SOFT**: Systematically "soft" variant of Perugia 0. [Feb 2009]
- 323: **Perugia 3**: Variant of Perugia 0 with different ISR/MPI balance and different collider energy scaling. [Feb 2009]
- 324: **Perugia NOCR**: "Perugia" update of NOCR-Pro. [Feb 2009]
- 325: **Perugia X**: Variant of Perugia 0 using MRST LO* PDFs. [Feb 2009]
- 326: **Perugia 6**: Variant of Perugia 0 using CTEQ6L1 PDFs. [Feb 2009]
- 329: **Pro-pT0**: Tune of the pT-ordered showers and new UE framework made with Professor, an automated tuning tool. [Feb 2009]

➡ **http://home.fnal.gov/~skands/leshouches-plots/**

# Peter's Pythia Tunes WEBsite

Peter's Pyth…

February 2009 © P…

**Navigate these pages** by using the menu to the lef… become available, and as the available data increas… comparison of a small number of tunes to available… but look for links at the top of each page for compar…

Apr 2009: Full descriptions and parameters of the "P… MPI workshop proceedings)
Dec 2007: Some interesting min-bias distributions fo… Houches workshop proceedings)

The tunes currently available on the plots are (numb…

## Tunes using Q2-ordered model…

- 100: **A**: Rick Field's Tune A to Tevatron Underl… shower models, with a double-gaussian matte… near-maximal color correlations. [Oct 2002]
- 103: **DW**: Rick Field's Tune DW to Tevatron U… to Tune A, but has 2 GeV of primordial kT and… initial-state radiation (i.e., more ISR radiation)… correlations. [Apr 2006]
- 104: **DWT**: Variant of DW using the Pythia 6.2… agreement with Tevatron energy scaling quant…
- 106: **ATLAS-DC2** ("Rome"): first ATLAS tune o… framework. Does not give very good agreemen…
- 107: **A-CR**: variant of Tune A using the Pythia… new "color annealing" color reconnection mod… an example of strong color reconnections. [Ma…
- 108: **D6**: Rick Field's Tune D6 to Tevatron data…
- 110: **A-Pro**: Tune A with LEP tune from Profes…
- 113: **DW-Pro**: Tune DW with LEP tune from P…
- 114: **DWT-Pro**: Tune DWT with LEP tune from…
- 116: **ATLAS-DC2-Pro**: ATLAS-DC2 with LEP t…

[Oct 2008]
…2008]
…framework made with

## …pT-ordered models

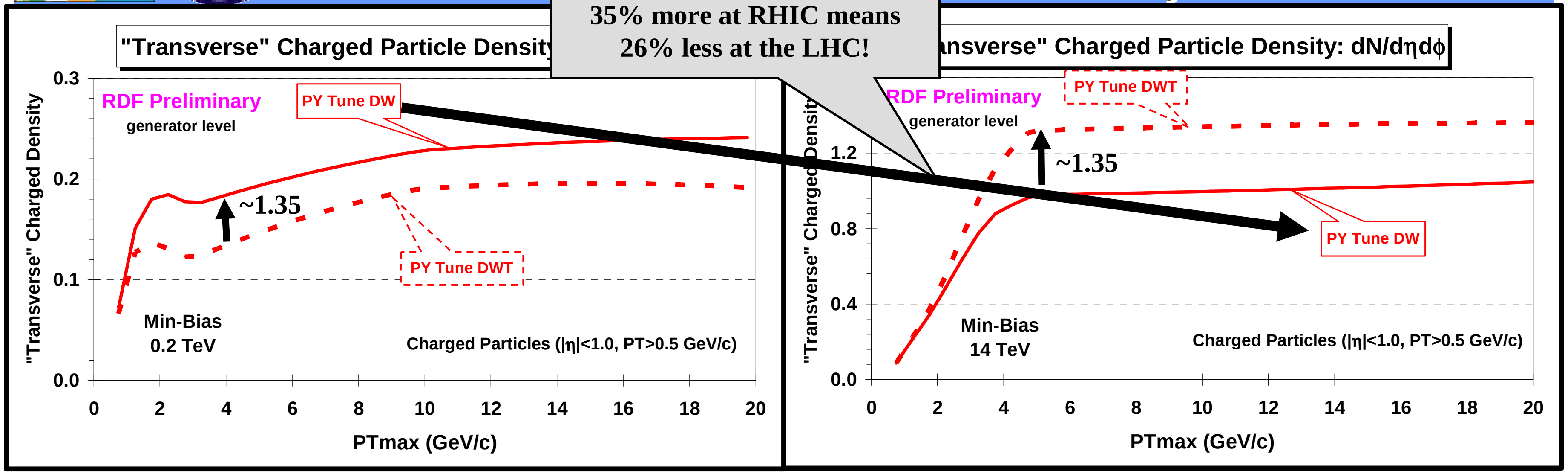
…owers. [Mar 2007]
…Oct 2008]
…09]
…CTEQ6L1 PDFs. [Feb 2009]
…shower framework, with a …T, and "colour annealing" color …er than that of Tune A. [Apr
…vatron, but which uses the Tune
…nnections. Gives less good
…ers and new UE framework. …quantities.
…nsive retune of the …ool, hence the name). [Oct
…2008]
…ia 0. [Feb 2009]
…a 0. [Feb 2009]
…balance and different collider
…2009]
…s. [Feb 2009]
…. [Feb 2009]
…E framework made with

| Parameter | Type | S0A-Pro | P-0 | P-HARD | P-SOFT | P-3 | P-NOCR | P-X | P-6 |
|---|---|---|---|---|---|---|---|---|---|
| MSTP(51) | PDF | 7 | 7 | 7 | 7 | 7 | 7 | 20650 | 10042 |
| MSTP(52) | PDF | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| MSTP(64) | ISR | 2 | 3 | 3 | 2 | 3 | 3 | 3 | 3 |
| PARP(64) | ISR | 1.0 | 1.0 | 0.25 | 2.0 | 1.0 | 1.0 | 2.0 | 1.0 |
| MSTP(67) | ISR | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| PARP(67) | ISR | 4.0 | 1.0 | 4.0 | 0.5 | 1.0 | 1.0 | 1.0 | 1.0 |
| MSTP(70) | ISR | 2 | 2 | 0 | 1 | 0 | 2 | 2 | 2 |
| PARP(62) | ISR | - | - | 1.25 | - | 1.25 | - | - | - |
| PARP(81) | ISR | - | - | - | 1.5 | - | - | - | - |
| MSTP(72) | ISR | 0 | 1 | 1 | 0 | 2 | 1 | 1 | 1 |
| PARP(71) | FSR | 4.0 | 2.0 | 4.0 | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| PARJ(81) | FSR | 0.257 | 0.257 | 0.3 | 0.2 | 0.257 | 0.257 | 0.257 | 0.257 |
| PARJ(82) | FSR | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| MSTP(81) | UE | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 |
| PARP(82) | UE | 1.85 | 2.0 | 2.3 | 1.9 | 2.2 | 1.95 | 2.2 | 1.95 |
| PARP(89) | UE | 1800 | 1800 | 1800 | 1800 | 1800 | 1800 | 1800 | 1800 |
| PARP(90) | UE | 0.25 | 0.26 | 0.30 | 0.24 | 0.32 | 0.24 | 0.23 | 0.22 |
| MSTP(82) | UE | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| PARP(83) | UE | 1.6 | 1.7 | 1.7 | 1.5 | 1.7 | 1.8 | 1.7 | 1.7 |
| MSTP(88) | BR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PARP(79) | BR | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| PARP(80) | BR | 0.01 | 0.05 | 0.01 | 0.05 | 0.03 | 0.01 | 0.05 | 0.05 |
| MSTP(91) | BR | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| PARP(91) | BR | 2.0 | 2.0 | 1.0 | 2.0 | 1.5 | 2.0 | 2.0 | 2.0 |
| PARP(93) | BR | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| MSTP(95) | CR | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| PARP(78) | CR | 0.2 | 0.33 | 0.37 | 0.15 | 0.35 | 0.0 | 0.33 | 0.33 |
| PARP(77) | CR | 0.0 | 0.9 | 0.4 | 0.5 | 0.6 | 0.0 | 0.9 | 0.9 |
| MSTJ(11) | HAD | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| PARJ(21) | HAD | 0.313 | 0.313 | 0.34 | 0.28 | 0.313 | 0.313 | 0.313 | 0.313 |
| PARJ(41) | HAD | 0.49 | 0.49 | 0.49 | 0.49 | 0.49 | 0.49 | 0.49 | 0.49 |
| PARJ(4[illegible]) | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1.2 | 1.2 |
| PARJ(46) | HAD | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| PARJ(47) | HAD | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |

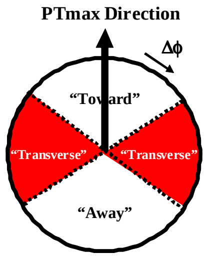
PS, Proceedings of the Perugia MPI Workshop 2008

➡ **http://home.fnal.gov/~skands/leshouches-plots/**

# Min-Bias "Associated" Charged Particle Density

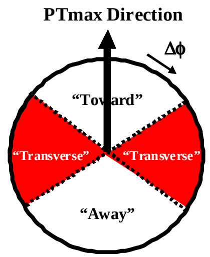



**RHIC**



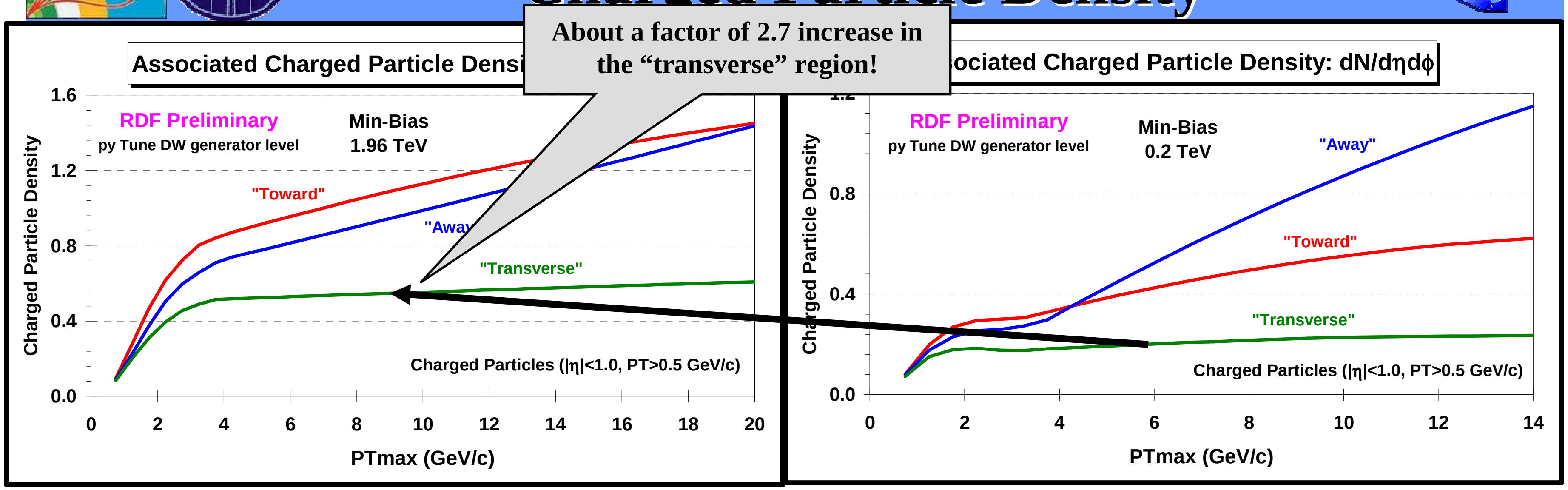

**0.2 TeV → 14 TeV**
**(~factor of 70 increase)**

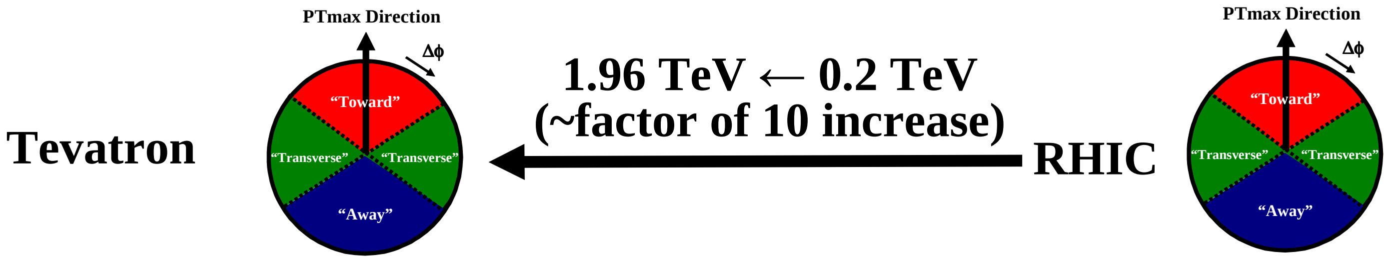
**LHC**




- **Shows the "associated" charged particle density in the "transverse" regions 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 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!**

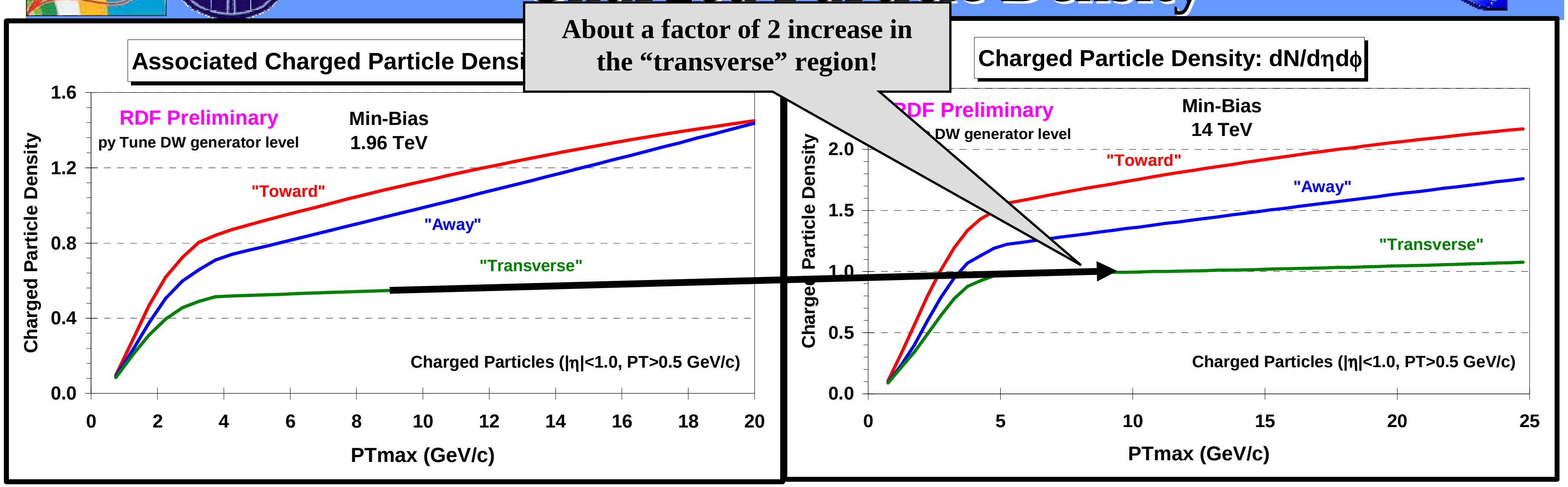
# Min-Bias "Associated" Charged Particle Density

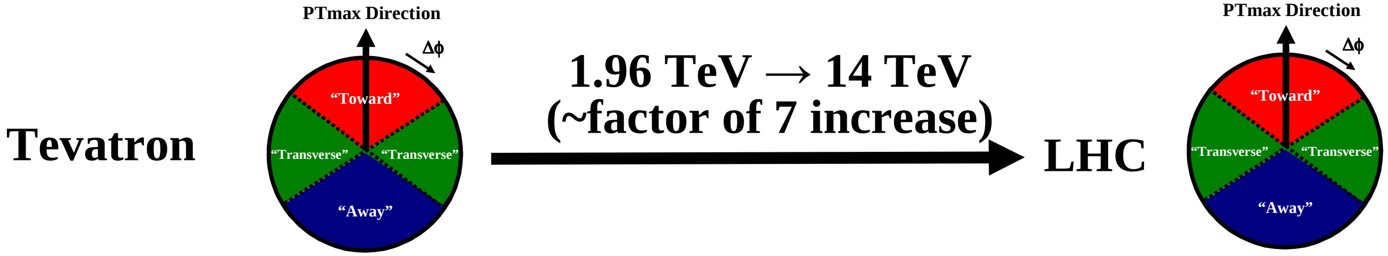



- **Shows the "associated" charged particle density in the "toward", "away" and "transverse" regions as a function of PTmax for charged particles ($p_T$ > 0.5 GeV/c, |η| < 1, *not including PTmax*) for "min-bias" events at 1.96 TeV and at 0.2 TeV from PYTHIA Tune DW at the particle level (*i.e.* generator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

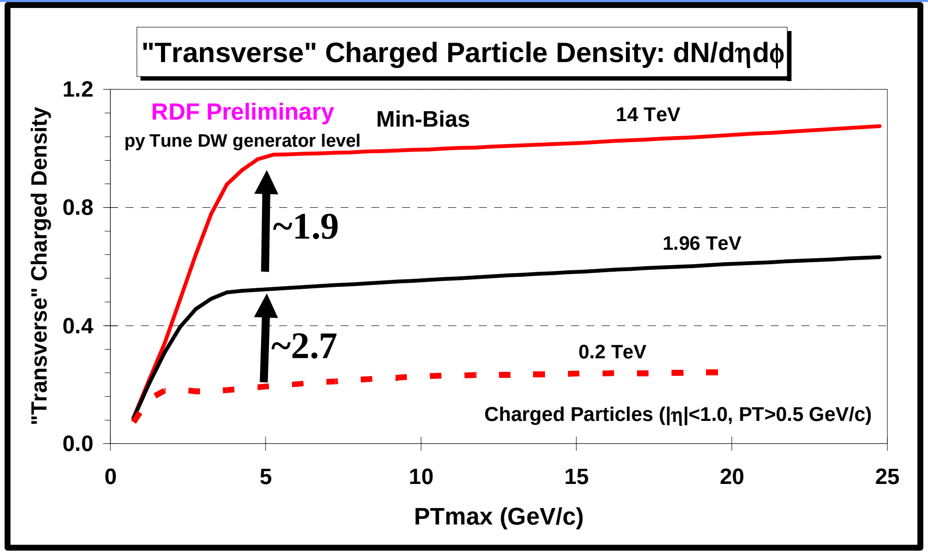
# Min-Bias "Associated" Charged Particle Density



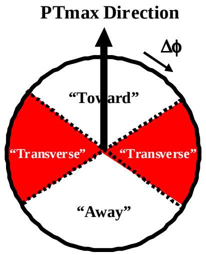




- Shows the "associated" charged particle density in the "toward", "away" and "transverse" regions as a function of PTmax for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$, *not including PTmax*) for "min-bias" events at 1.96 TeV and at 14 TeV from PYTHIA Tune DW at the particle level (*i.e.* generator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

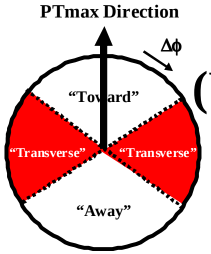
# Min-Bias "Associated" Charged Particle Density



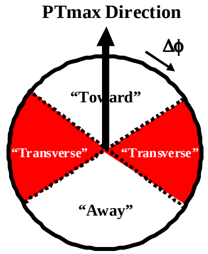

RHIC




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

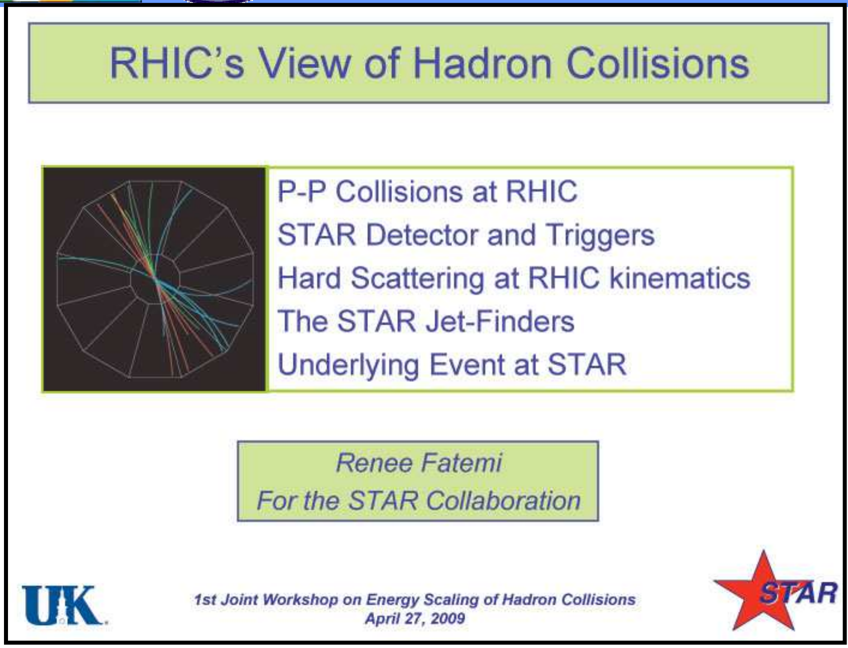


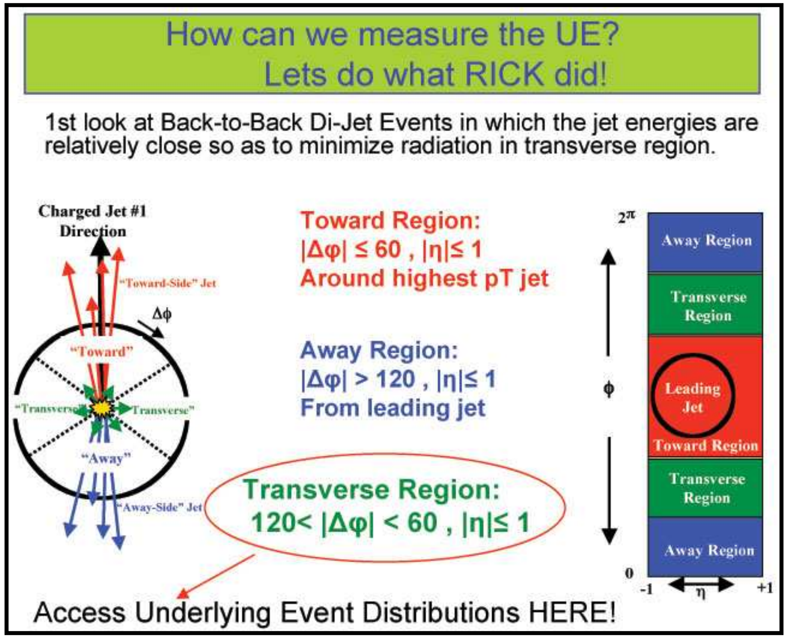

**1.96 TeV → 14 TeV (UE increase ~1.9 times)** → **LHC**




- **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, 1.96 TeV and 14 TeV predicted by PYTHIA Tune DW at the particle level (*i.e.* generator level).**

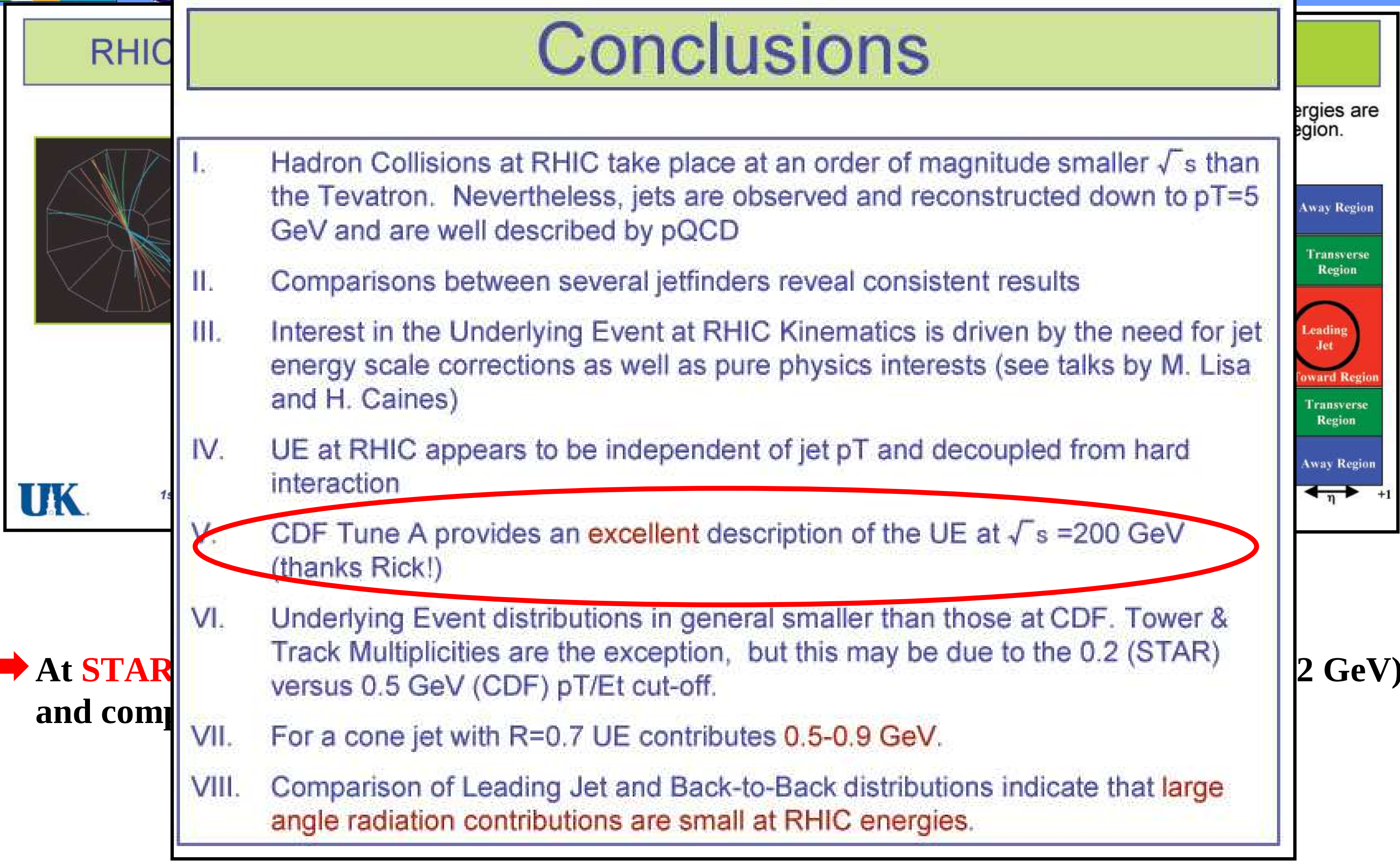
# The "Underlying Event" at STAR




➡ **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




## 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!)

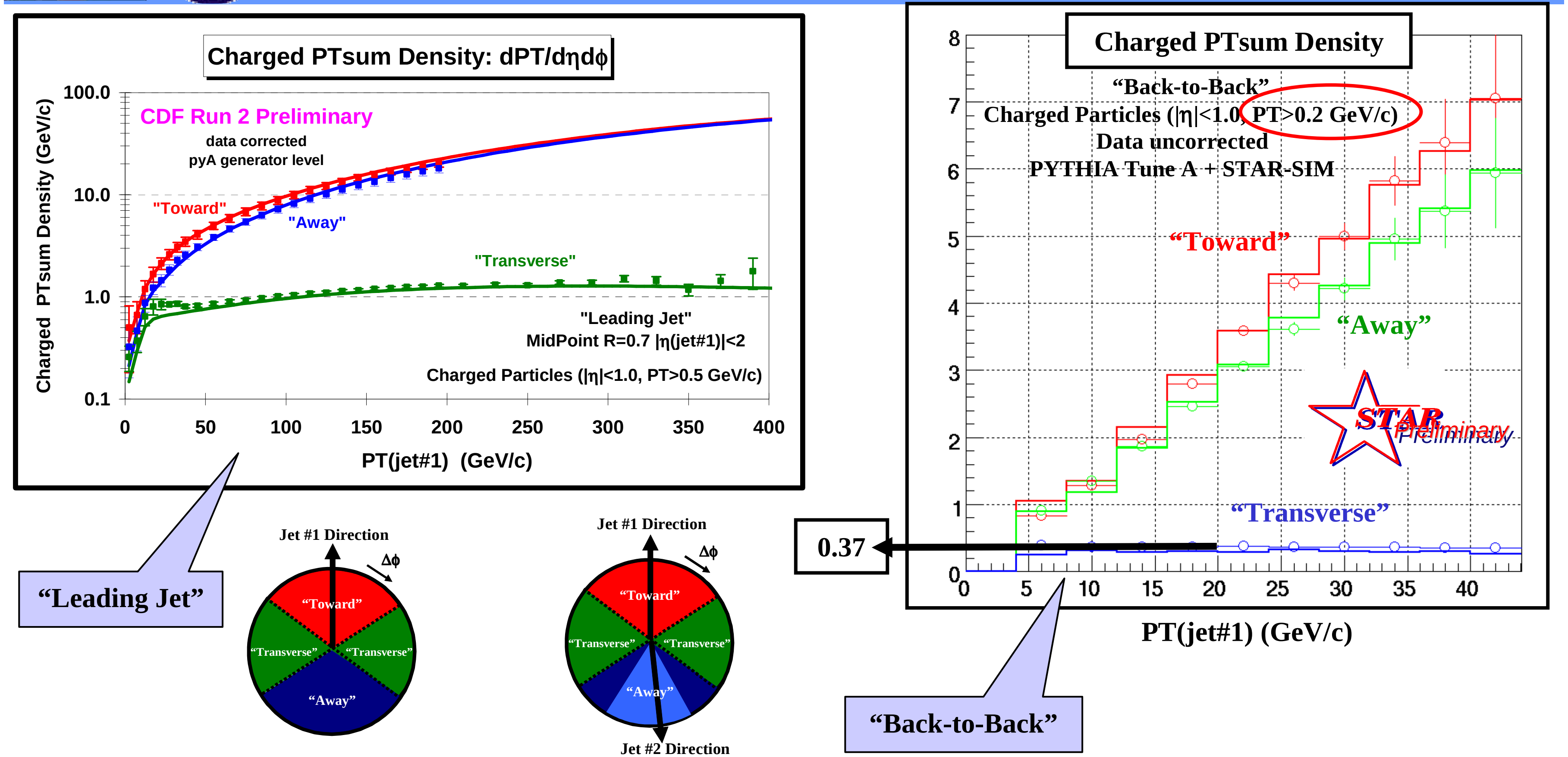
VI. Underlying Event distributions in general smaller than those at CDF. Tower & Track Multiplicities are the exception, but this may be due to the 0.2 (STAR) versus 0.5 GeV (CDF) pT/Et cut-off.

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.

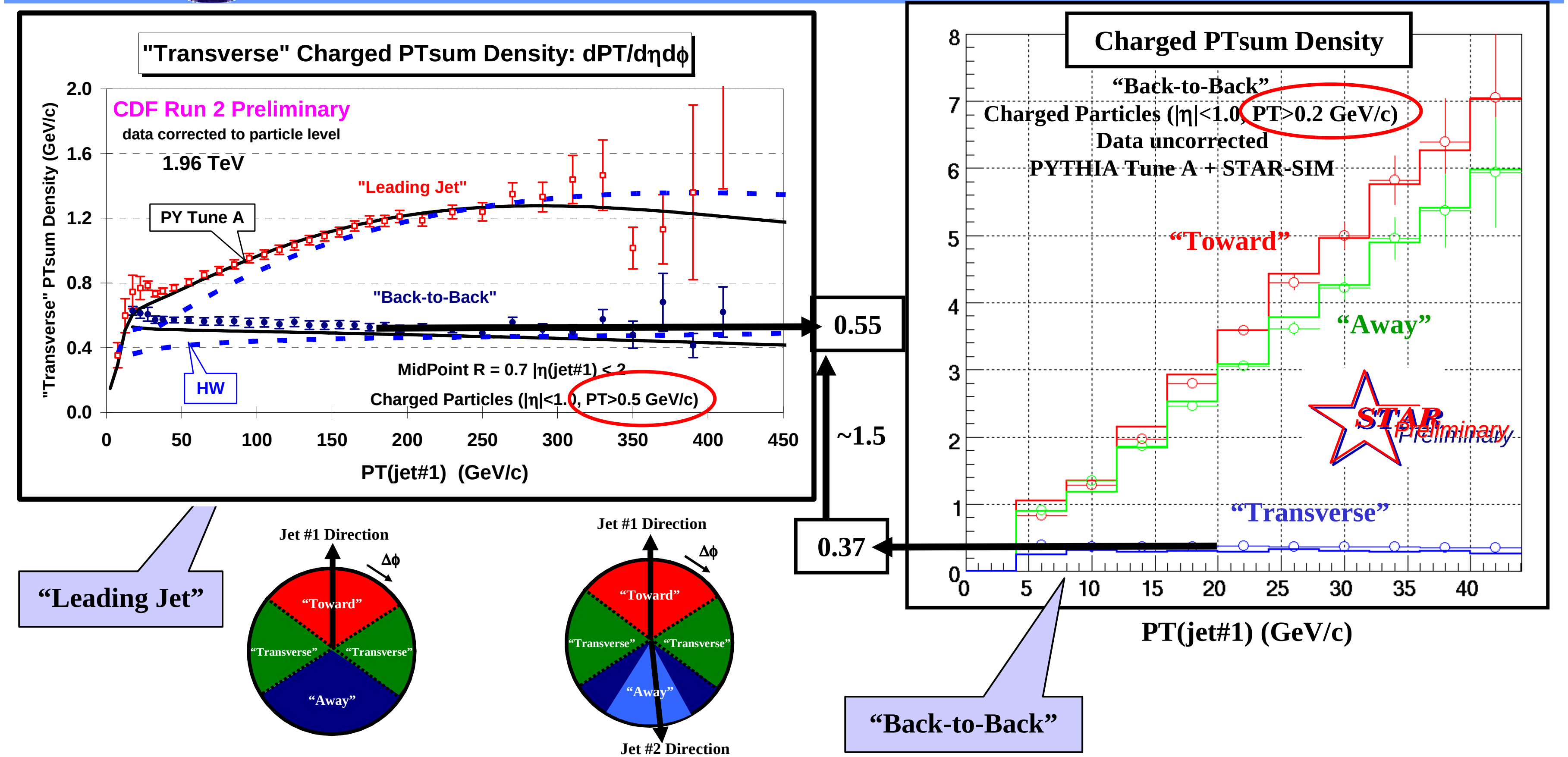
➡ **At STAR** ... **2 GeV)**
**and com**...

# The "Underlying Event" at STAR



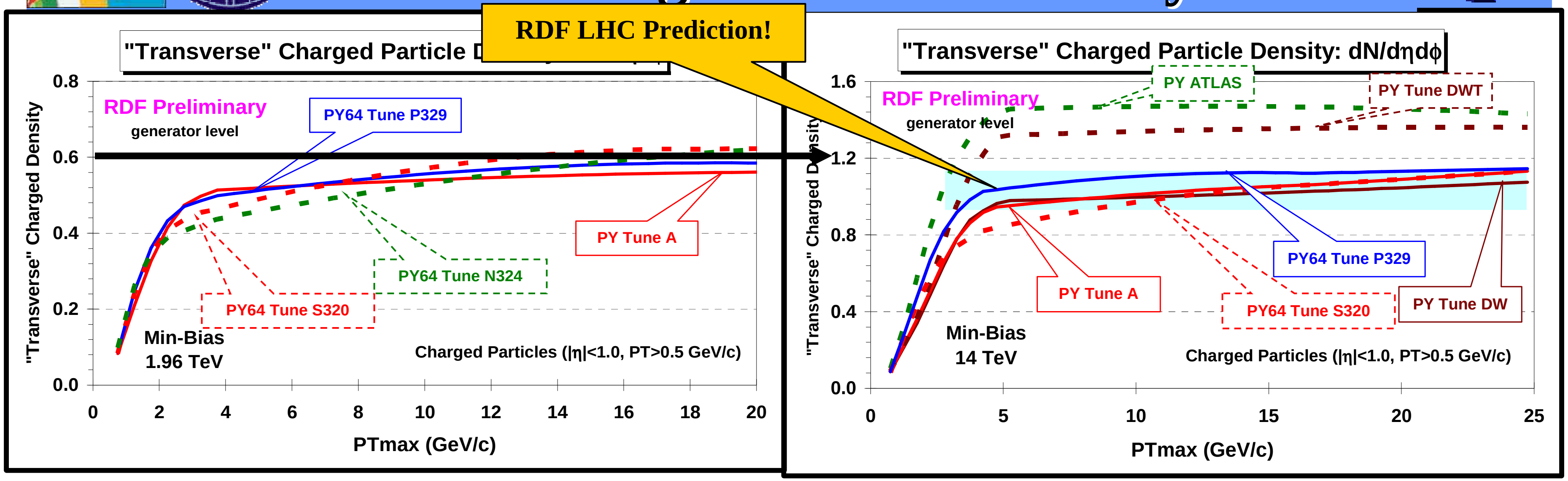

➡ **Data on the charged particle *scalar* $p_T$ sum density, dPT/dηdφ, as a function of the leading jet $p_T$ for the "toward", "away", and "transverse" regions compared with PYTHIA Tune A.**

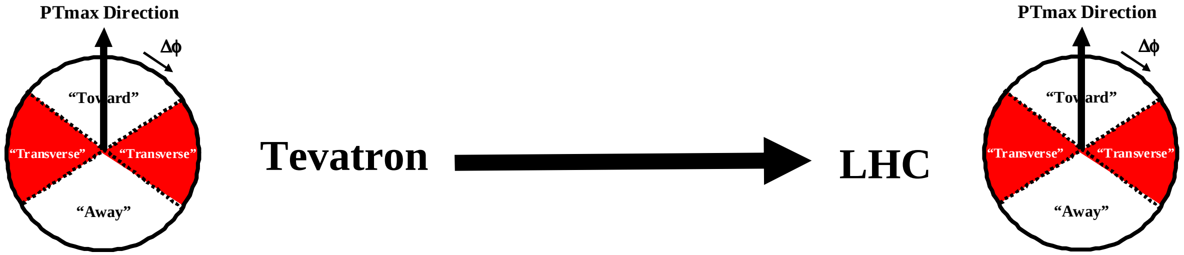
# The "Underlying Event" at STAR




- Data on the charged particle *scalar* $p_T$ sum density, dPT/dηdϕ, as a function of the leading jet $p_T$ for the "toward", "away", and "transverse" regions compared with PYTHIA Tune A.

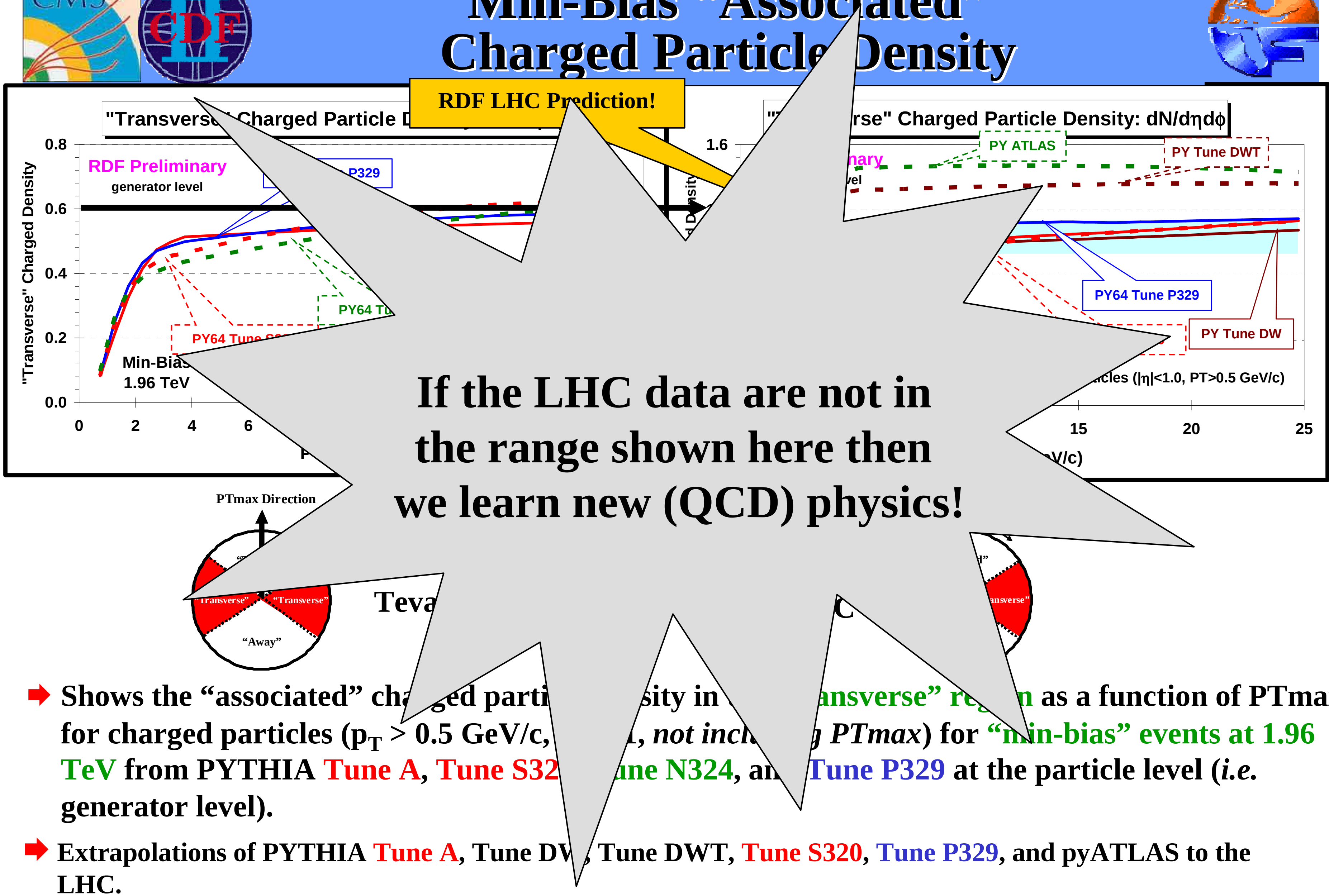
# Min-Bias "Associated" Charged Particle Density



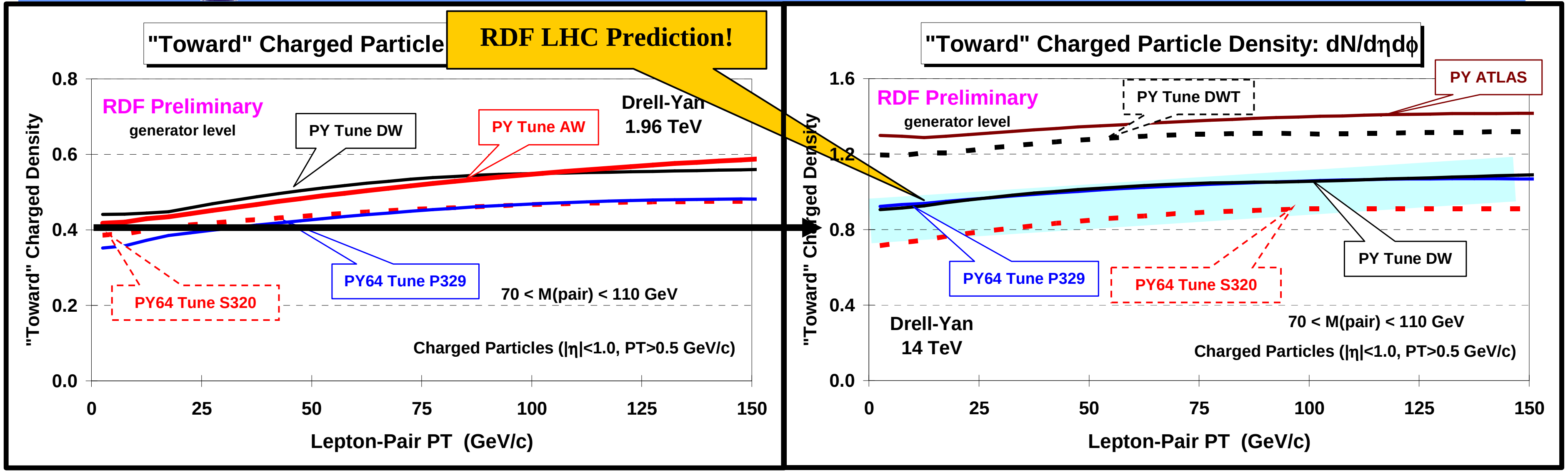

- Shows the "associated" charged particle density in the "transverse" region as a function of PTmax for charged particles ($p_T$ > 0.5 GeV/c, |η| < 1, *not including PTmax*) for "min-bias" events at 1.96 TeV from PYTHIA Tune A, Tune S320, Tune N324, and Tune P329 at the particle level (*i.e.* generator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

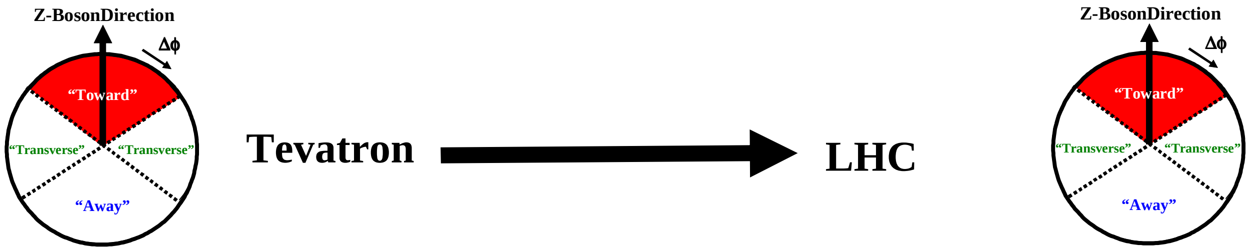
# Min-Bias "Associated" Charged Particle Density




- 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 DV, Tune DWT, Tune S320, Tune P329, and pyATLAS to the LHC.

# Z-Boson: “Towards” Region

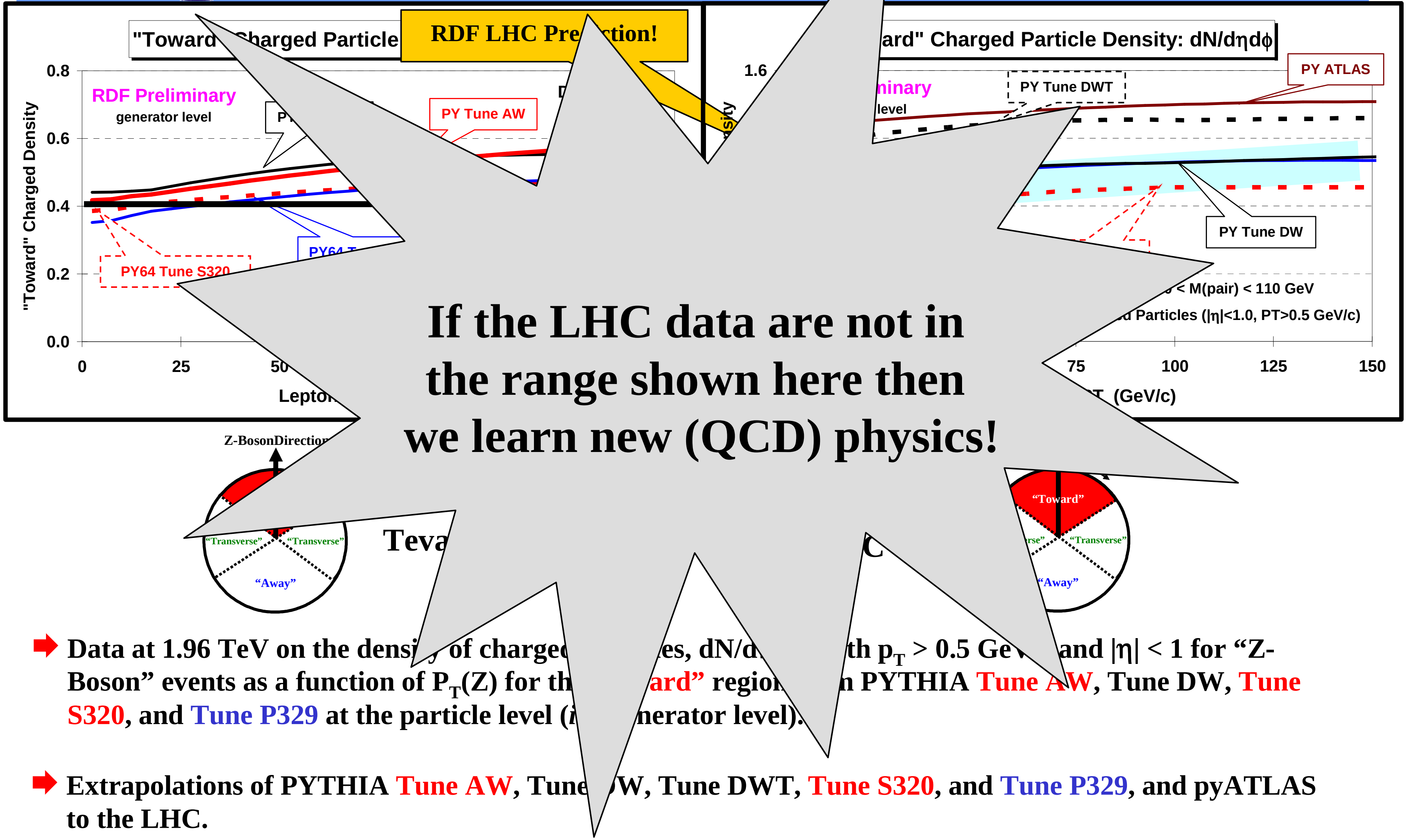



- **Data at 1.96 TeV on the density of charged particles, dN/dηdϕ, with $p_T$ > 0.5 GeV/c and |η| < 1 for “Z-Boson” events as a function of $P_T$(Z) for the “toward” region from PYTHIA Tune AW, Tune DW, Tune S320, and Tune P329 at the particle level (*i.e.* generator level).**

- **Extrapolations of PYTHIA Tune AW, Tune DW, Tune DWT, Tune S320, and Tune P329, and pyATLAS to the LHC.**

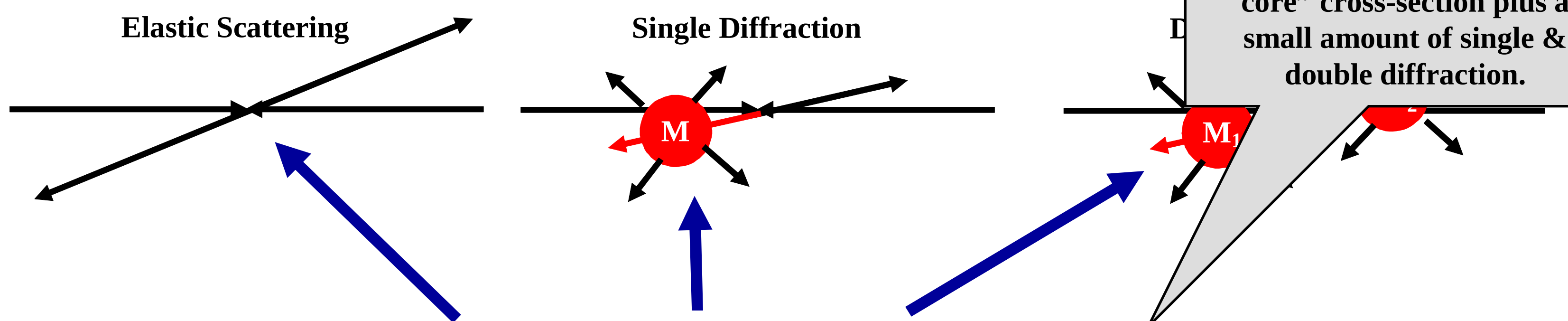
# Z-Boson: "Towards" Region




- Data at 1.96 TeV on the densi… of charged …es, dN/d… …th $p_T$ > 0.5 Ge… and |η| < 1 for "Z-Boson" events as a function of $P_T$(Z) for th… …ard" regio… …n PYTHIA Tune AW, Tune DW, Tune S320, and Tune P329 at the particle level (i… …nerator level).

- Extrapolations of PYTHIA Tune AW, Tune …W, Tune DWT, Tune S320, and Tune P329, and pyATLAS to the LHC.

# Proton-AntiProton Collisions at the Tevatron




The CDF "Min-Bias" trigger picks up most of the "hard core" cross-section plus a small amount of single & double diffraction.

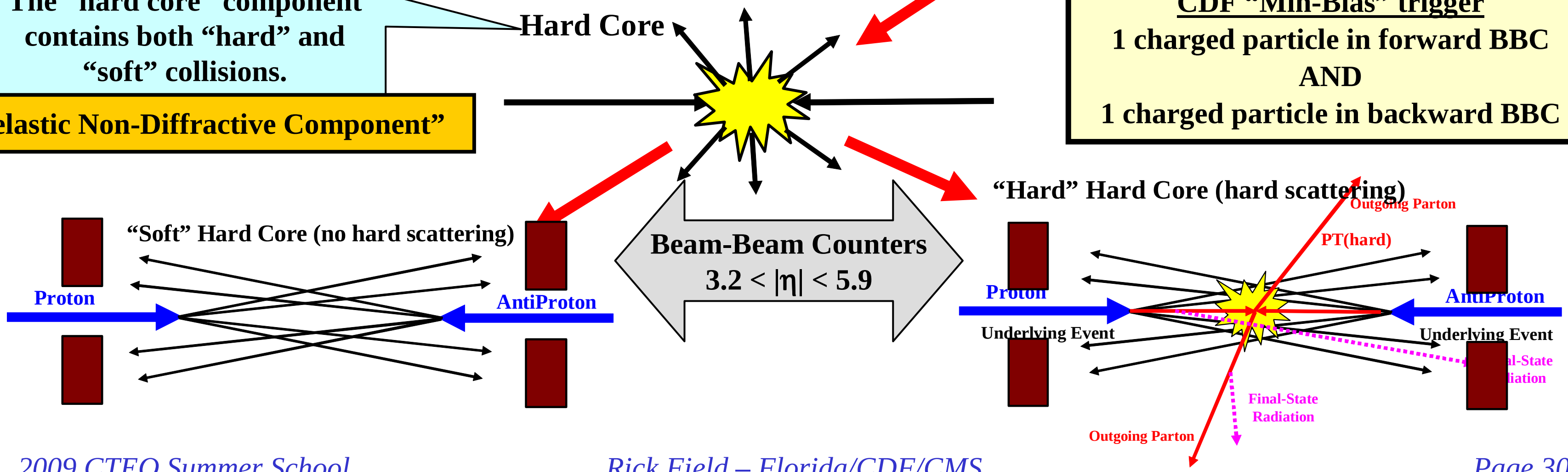
$$\sigma_{tot} = \sigma_{EL} + \sigma_{SD} + \sigma_{DD} + \sigma_{HC}$$

1.8 TeV: 78mb = 18mb + 9mb + (4-7)mb + (47-44)mb

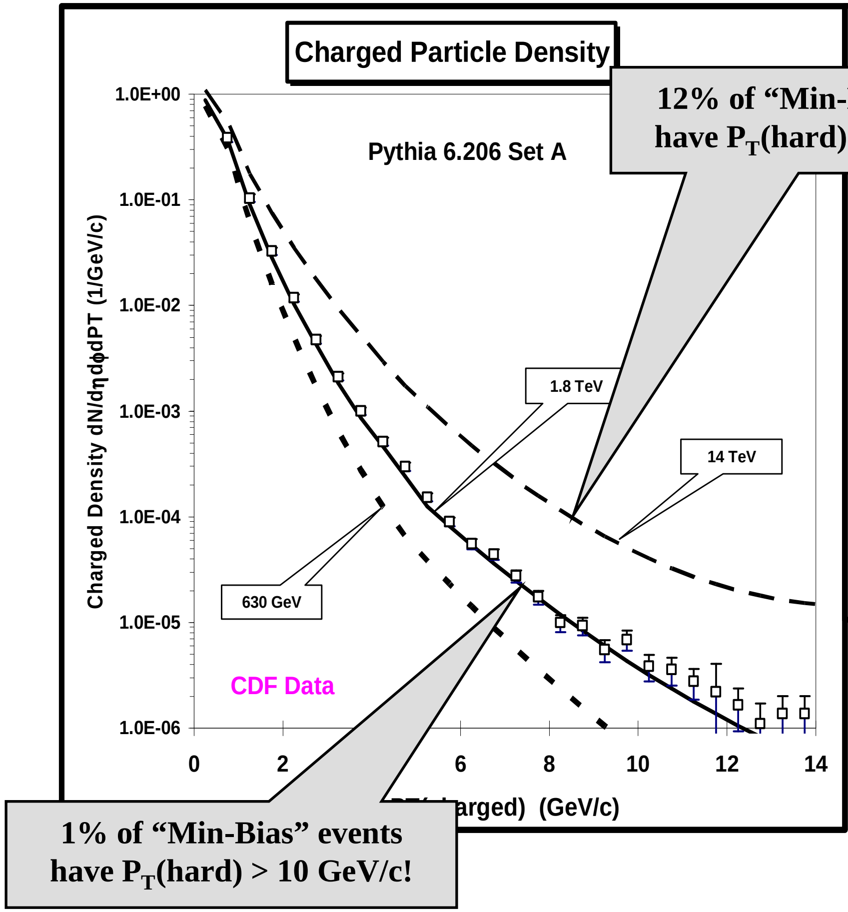
The "hard core" component contains both "hard" and "soft" collisions.

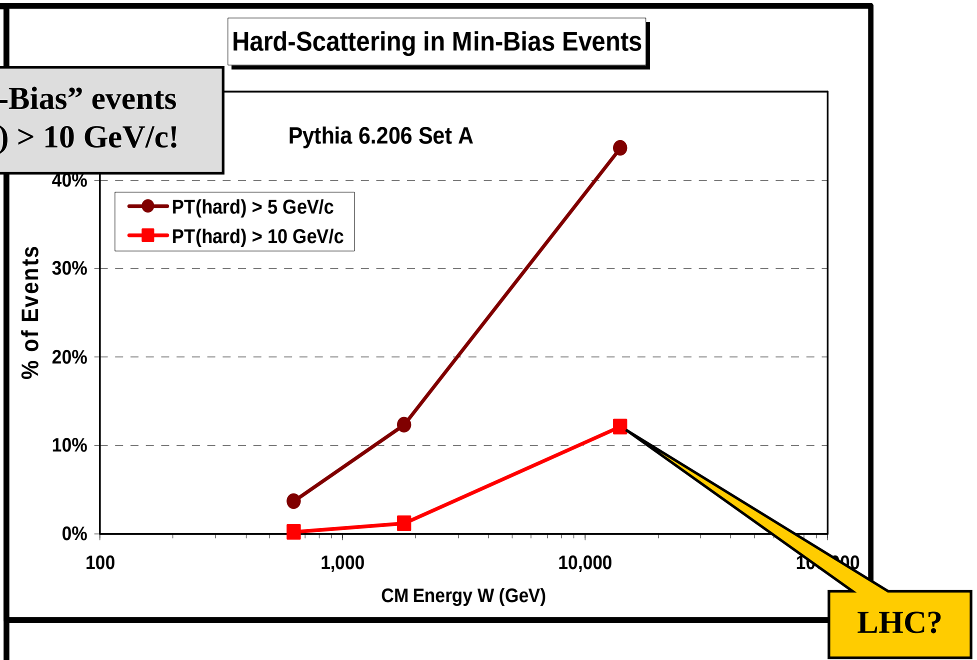
"Inelastic Non-Diffractive Component"

**CDF "Min-Bias" trigger**
1 charged particle in forward BBC
AND
1 charged particle in backward BBC



# PYTHIA Tune A
# LHC Min-Bias Predictions

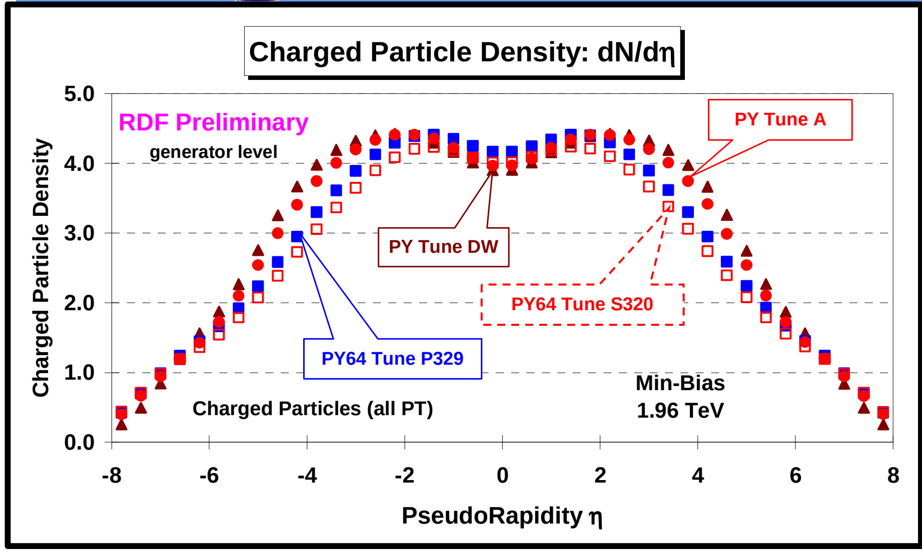


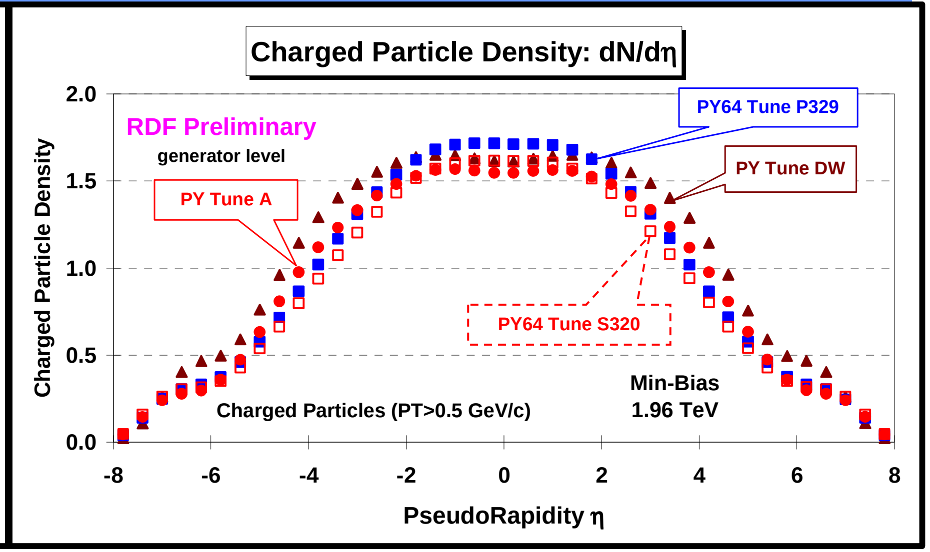




- Shows the center-of-mass energy dependence of the charged particle density, $dN_{chg}/d\eta d\phi dP_T$, for "Min-Bias" collisions compared with **PYTHIA Tune A** with $P_T$(hard) > 0.

- **PYTHIA Tune A** predicts that 1% of all "Min-Bias" events at 1.8 TeV are a result of a hard 2-to-2 parton-parton scattering with $P_T$(hard) > 10 GeV/c which increases to **12% at 14 TeV**!

# Charged Particle Density: dN/dη

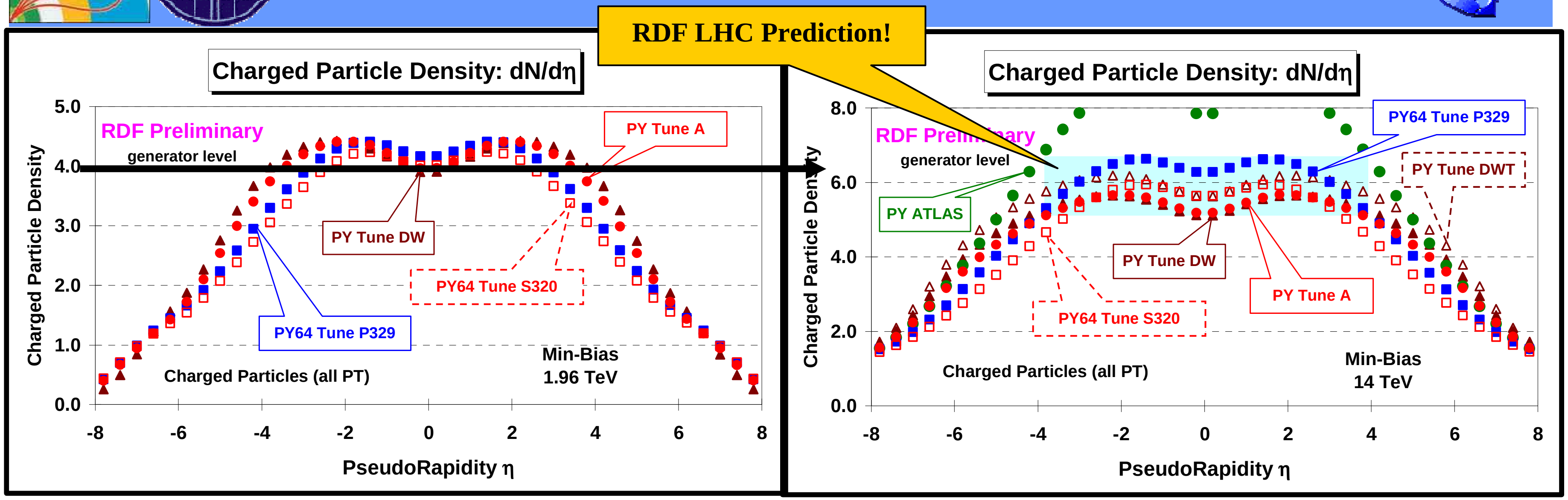



- **Charged particle (all $p_T$) pseudo-rapidity distribution, $dN_{chg}/d\eta d\phi$, at 1.96 TeV for inelastic non-diffractive collisions from PYTHIA Tune A, Tune DW, Tune S320, and Tune P324.**

- **Charged particle ($p_T$>0.5 GeV/c) pseudo-rapidity distribution, $dN_{chg}/d\eta d\phi$, at 1.96 TeV for inelastic non-diffractive collisions from PYTHIA Tune A, Tune DW, Tune S320, and Tune P324.**

# Charged Particle Density: dN/dη





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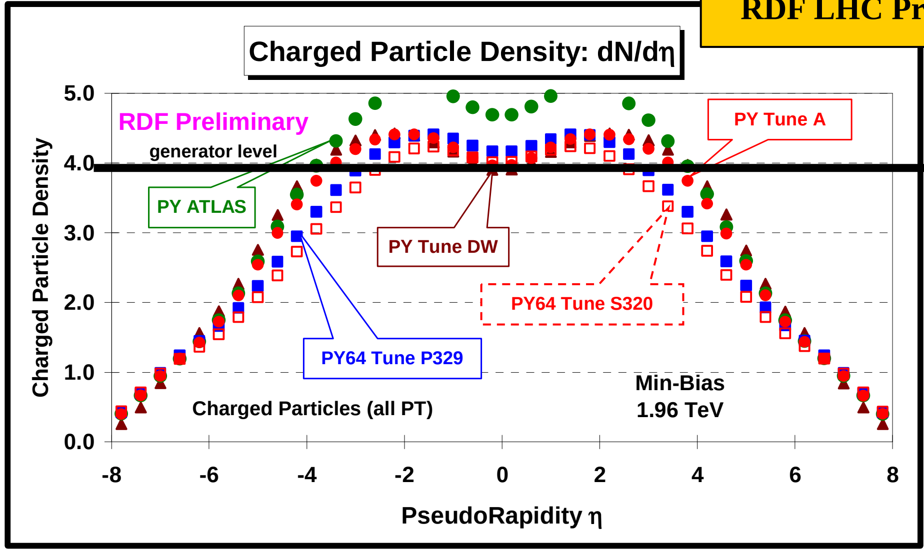
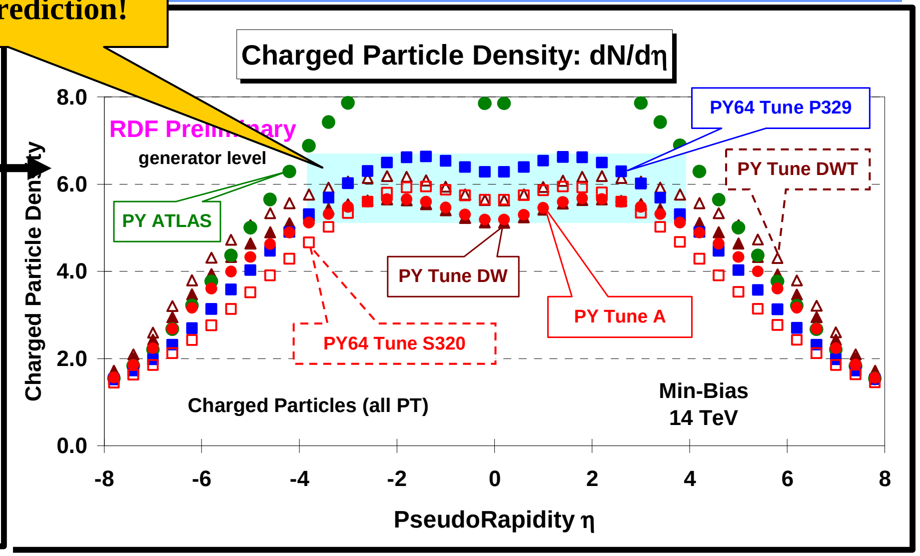
- Extrapolations (all pT) of PYTHIA Tune A, Tune DW, Tune S320, Tune P324. and ATLAS to the LHC.

# Charged Particle Density: dN/dη

RDF LHC Prediction!





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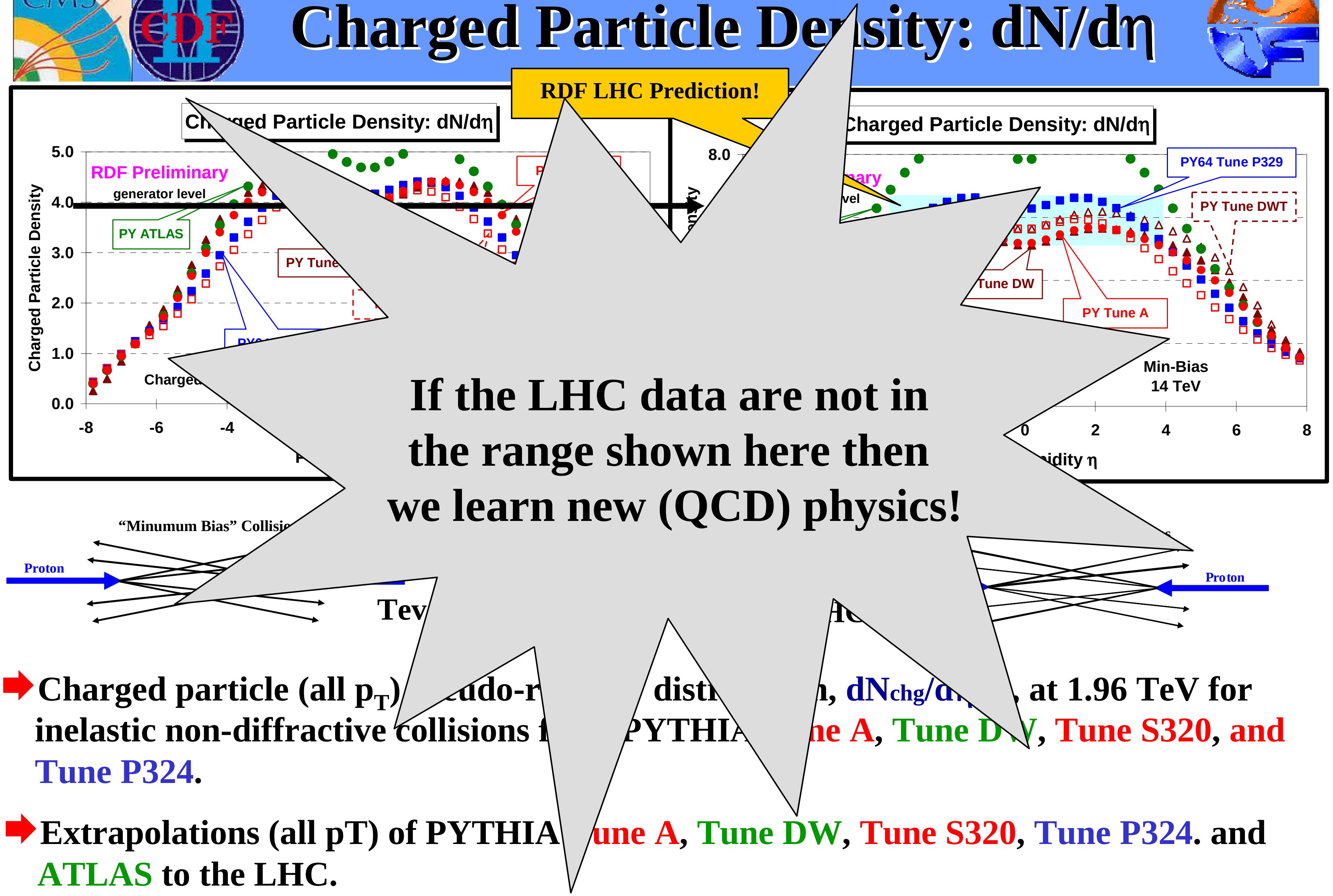


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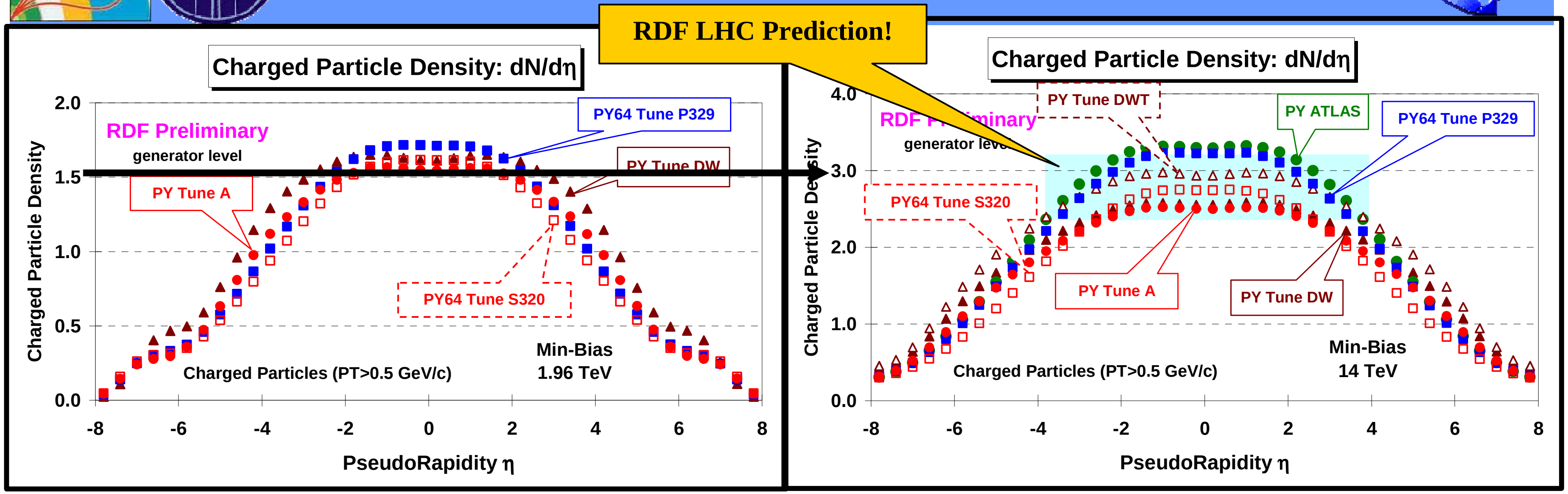



- Charged particle ($p_T$ > 0.5 GeV/c) pseudo-rapidity distribution, $dN_{chg}/d\eta d\phi$, at 1.96 TeV for inelastic non-diffractive collisions from PYTHIA Tune A, Tune DW, Tune S320, and Tune P324.
- Extrapolations ($p_T$ > 0.5 GeV/c) of PYTHIA Tune A, Tune DW, Tune S320, Tune P324. and ATLAS to the LHC.

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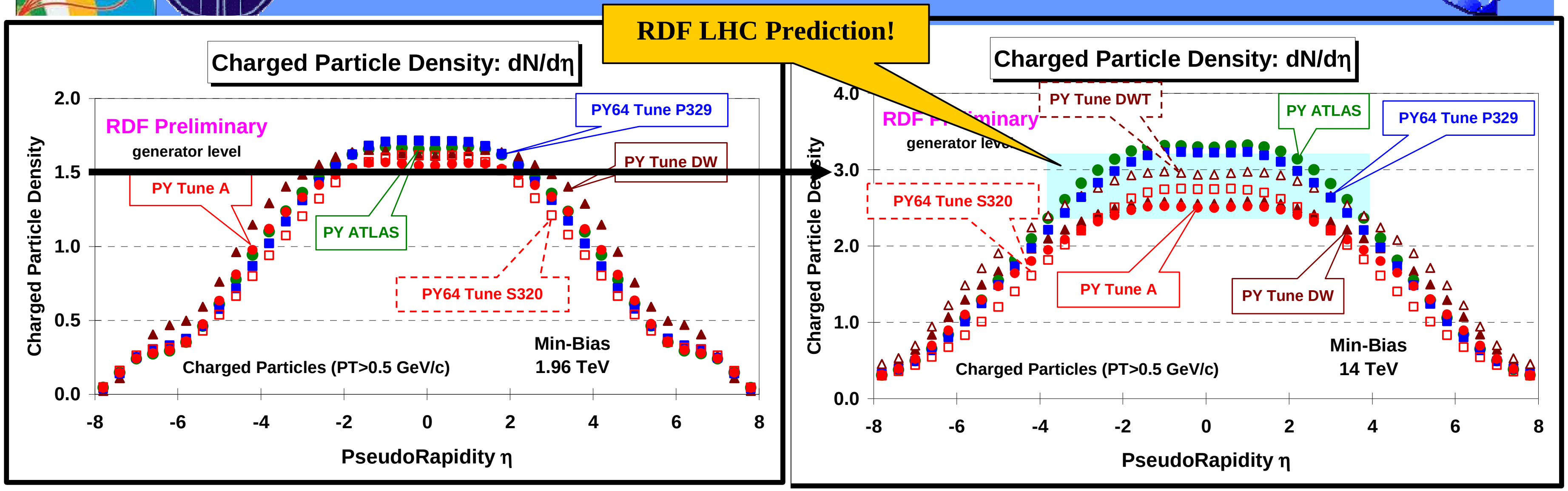



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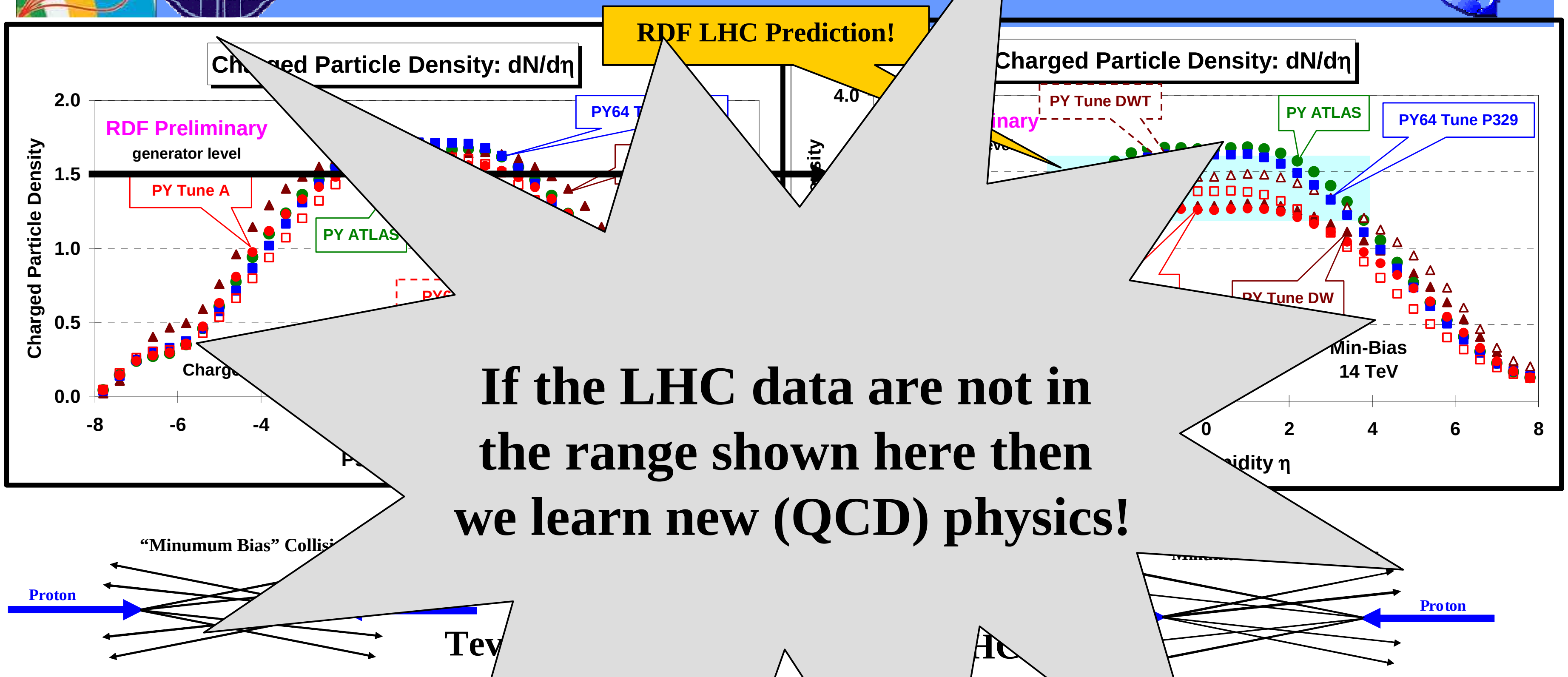
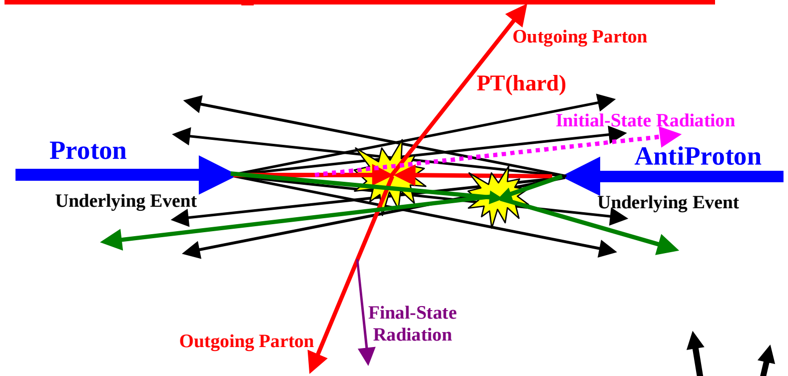
# Charged Particle Density: dN/dη




- Charged particle ($p_T$ > 0.5 GeV/c) pseudo-rapidity distribution, $dN_{chg}/d\eta d\phi$, at 1.96 TeV for inelastic non-diffractive collisions from PYTHIA Tune A, Tune DW, Tune S320, and Tune P324.
- Extrapolations ($p_T$ > 0.5 GeV/c) of PYTHIA Tune A, Tune DW, Tune S320, Tune P324. and ATLAS to the LHC.

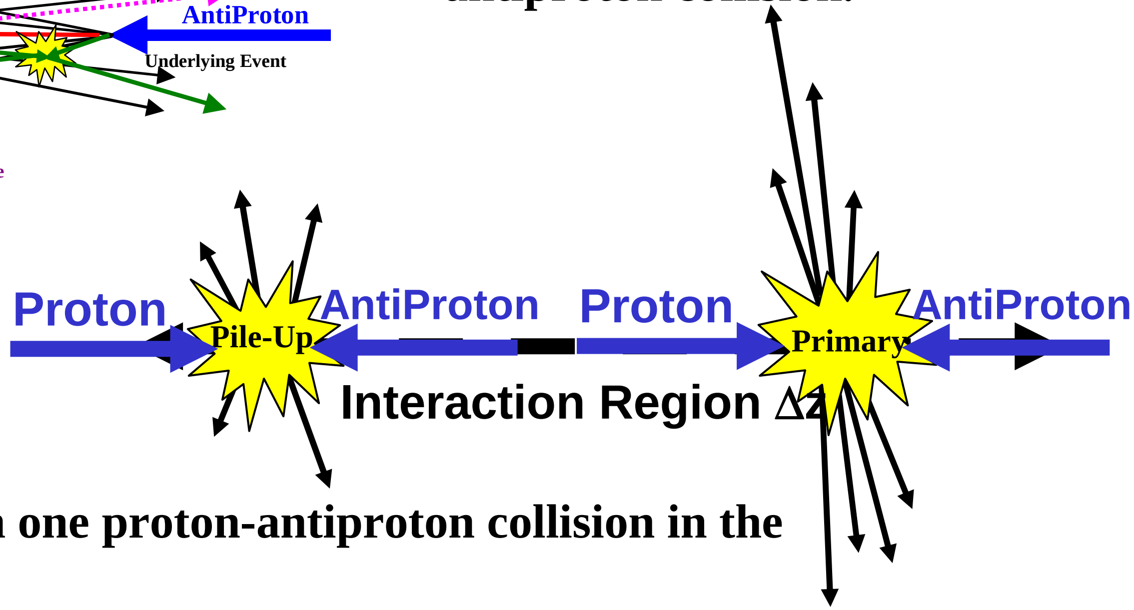
# MPI, Pile-Up, and Overlap

**MPI: Multiple Parton Interactions**




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

## Pile-Up

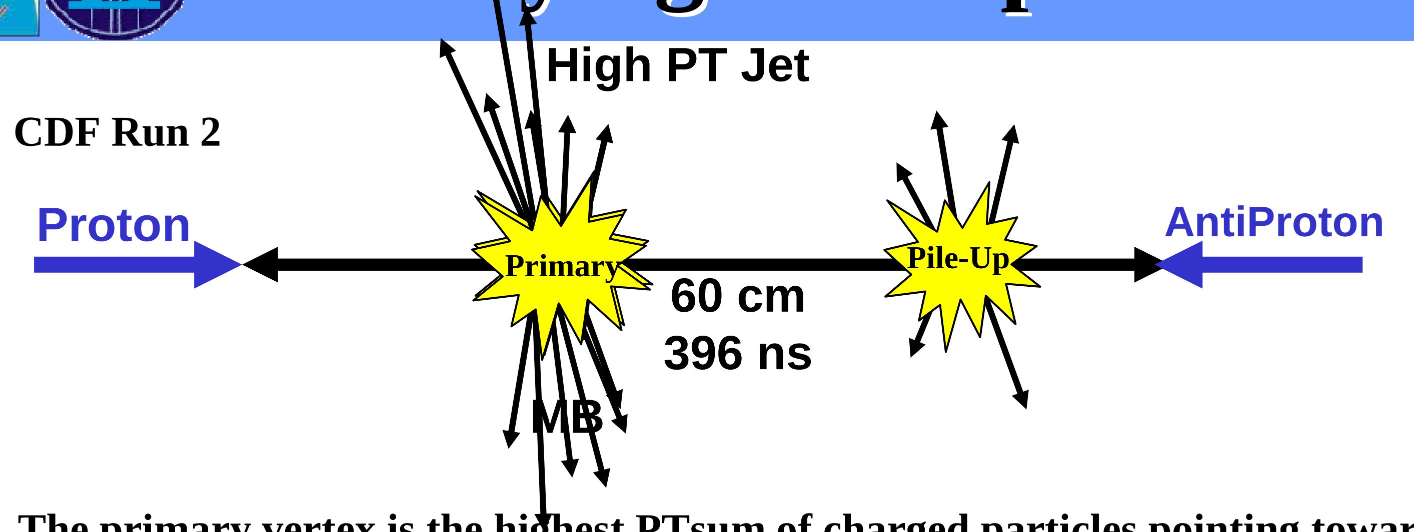



- **Pile-Up: More than one proton-antiproton collision in the beam crossing.**

## Overlap

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

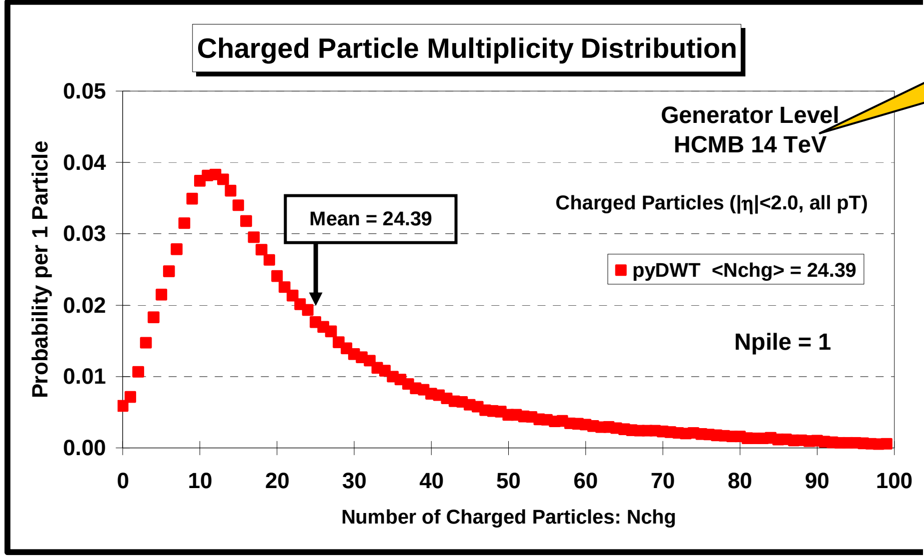
# Studying Pile-Up at CDF

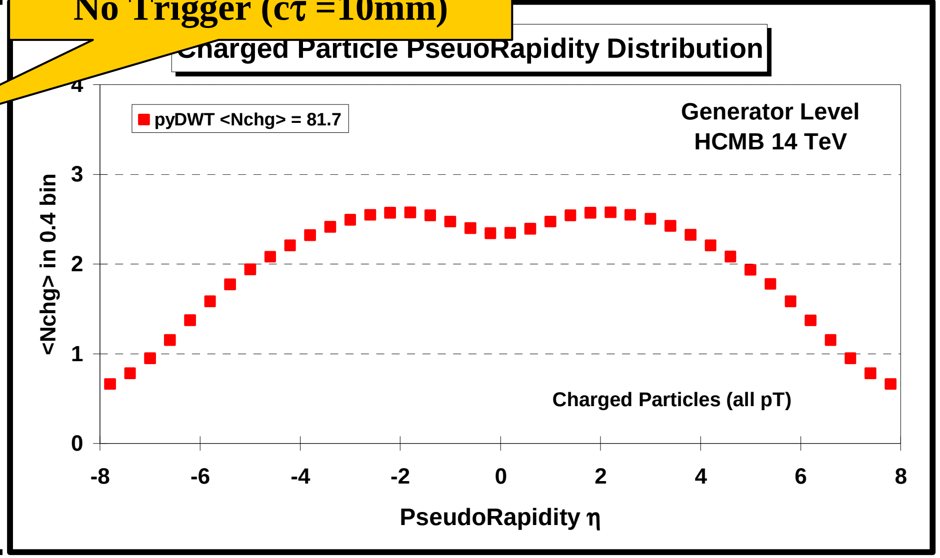



- The primary vertex is the highest PTsum of charged particles pointing towards it.
- Normally one only includes those charged particles which point back to the primary vertex.
- The primary vertex is presumably the collision that satisfied the trigger. Maybe not for "min-bias" events?

> - **Is the pile-up biased?**
> - **Is the pile-up the same for all triggers?**
> - **Does pile-up conspire to help satisfy your trigger?**
> - **How well do we model pile-up?**

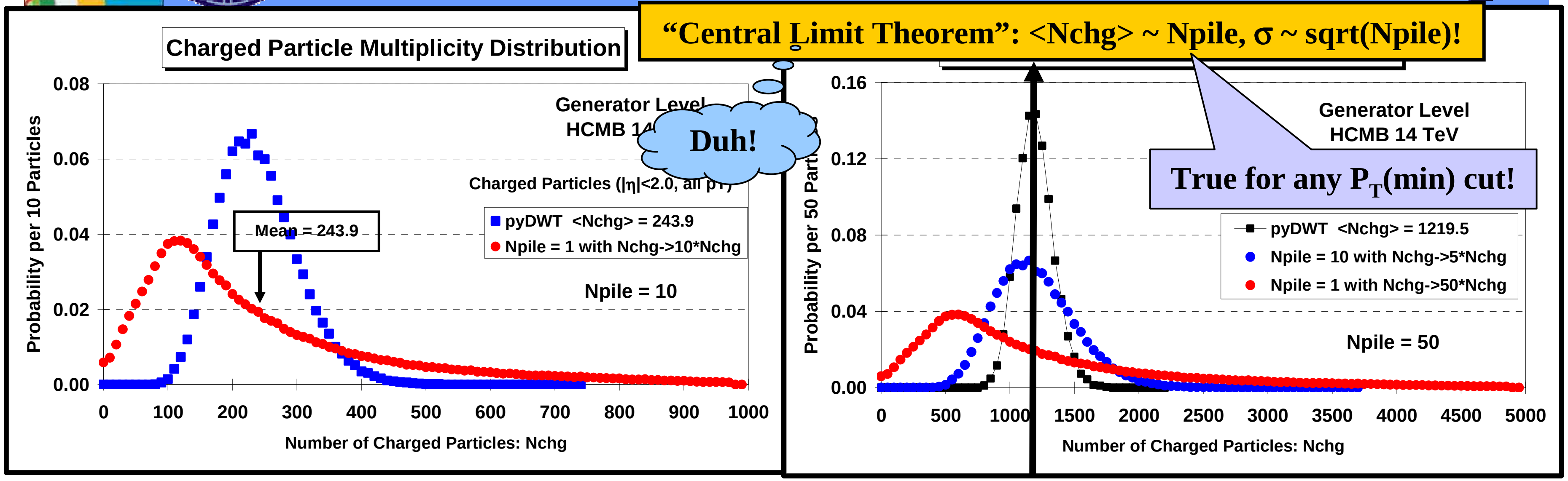
# Pile-Up at the LHC




- Shows the charged multiplicity distribution ($|\eta| < 2$, all $p_T$) for Npile = 1 (*i.e.* shows, on the average, what one event looks like). The plot shows the probability of finding 0, 1, 2, … etc. charged particles. The sum of the points is equal to one. The mean is 24.39 charged particles and $\sigma$ = 19.7.
- Shows the charged particle pseudo-rapidity distribution (all $p_T$) for Npile = 1 (*i.e.* shows, on the average, what one event looks like). The plot shows the <Nchg> in a 0.4 bin (*i.e.* not divided by bin size). The sum of the points with $|\eta| < 2$ is 24.39.

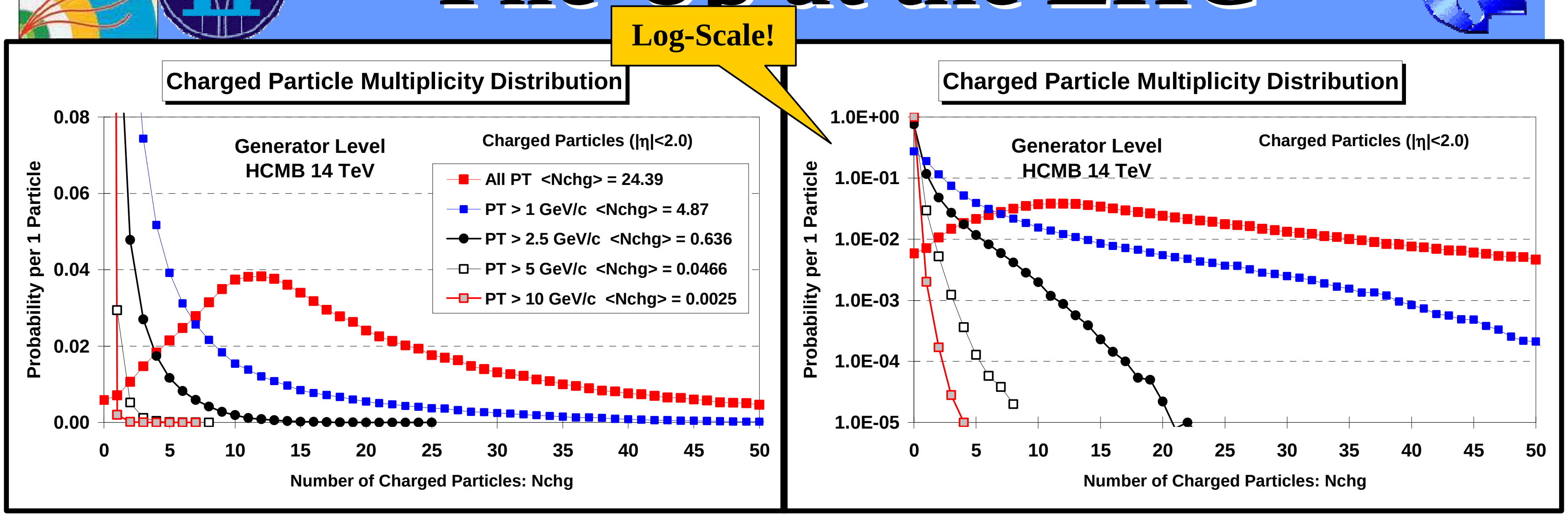
# Pile-Up at the LHC




- Shows the charged multiplicity distribution (|η| < 2, all $p_T$) for Npile = 10 (*i.e.* shows, on the average, what 10 events looks like). The plot shows the probability of finding 0, 10, 20, … etc. charged particles. The sum of the points is equal to one. The mean is 243.9 charged particles and σ = 62.3. Also shown is the Npile = 1 distribution scaled by a factor of 10 (*i.e.* Nchg → 10 × Nchg).

- Shows the charged multiplicity distribution (|η| < 2, all $p_T$) for Npile = 50 (*i.e.* shows, on the average, what 50 events looks like). The plot shows the probability of finding 0, 50, 100, … etc. charged particles. The sum of the points is equal to one. The mean is 1219.5 charged particles and σ = 138.9. Also shown is the Npile = 1 distribution scaled by a factor of 50 (*i.e.* Nchg → 50 × Nchg) and the Npile = 10 distribution scaled by a factor of 5 (*i.e.* Nchg → 5 × Nchg).

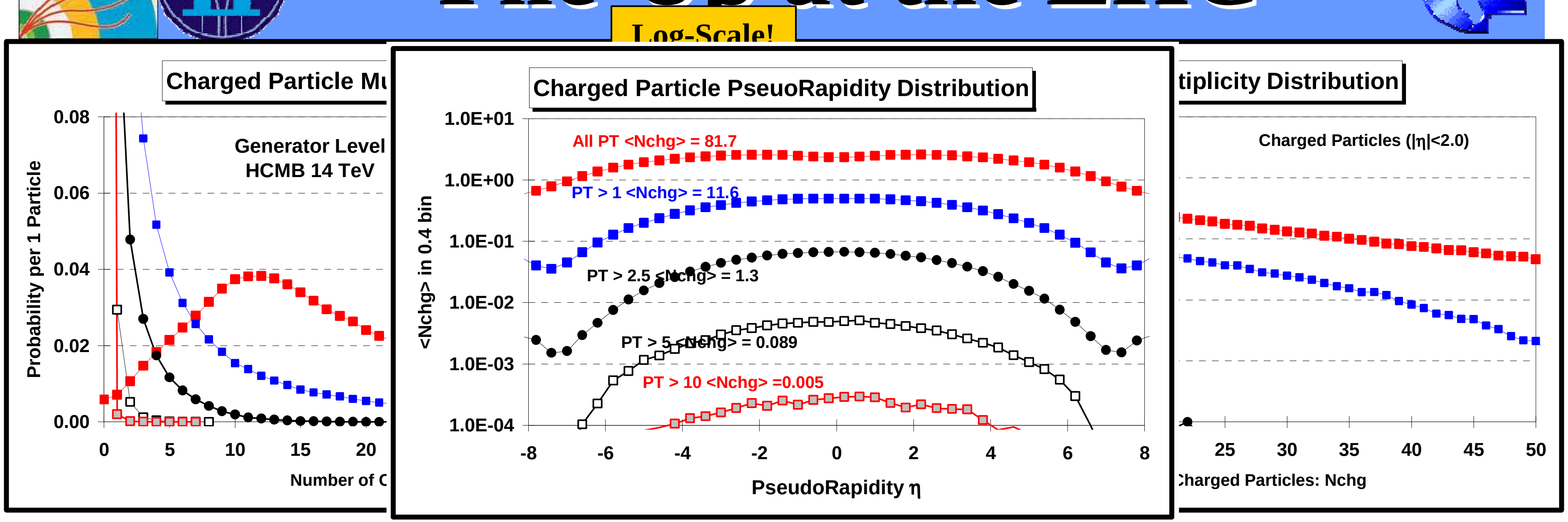
# Pile-Up at the LHC




- Charged multiplicity distribution (|η| < 2) for Npile = 1 (*i.e.* shows, on the average, what one event looks like). The plot shows the probability of finding 0, 1, 2, … etc. charged particles. The five curves correspond to $p_T$(min) = 0, 1.0 , 2.5, 5.0, and 10.0 GeV/c.

- Shows the charged particle pseudo-rapidity distribution for Npile = 1 (*i.e.* shows, on the average, what one event looks like). The plot shows the <Nchg> in a 0.4 bin (*i.e.* not divided by bin size). The five curves correspond to $p_T$(min) = 0, 1.0 , 2.5, 5.0, and 10.0 GeV/c.

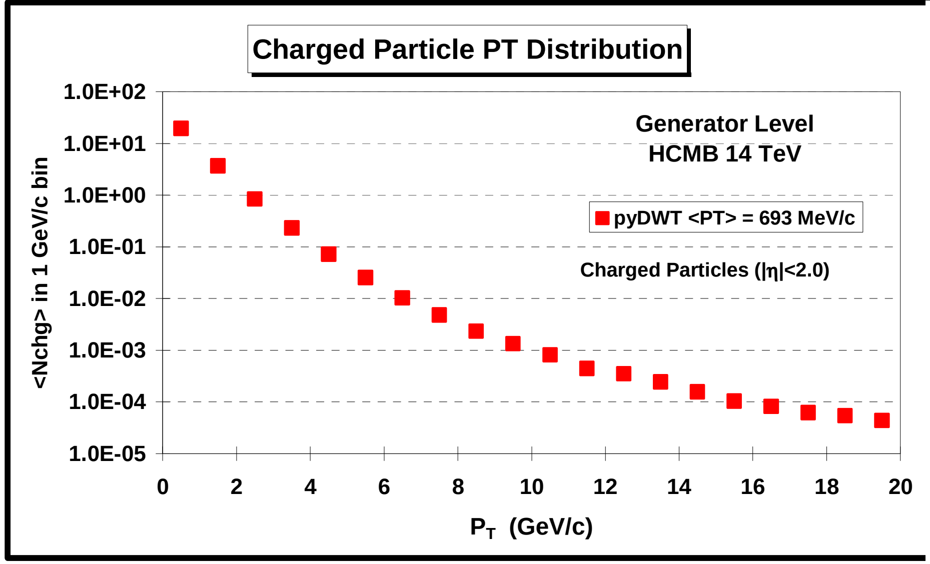
# Pile-Up at the LHC

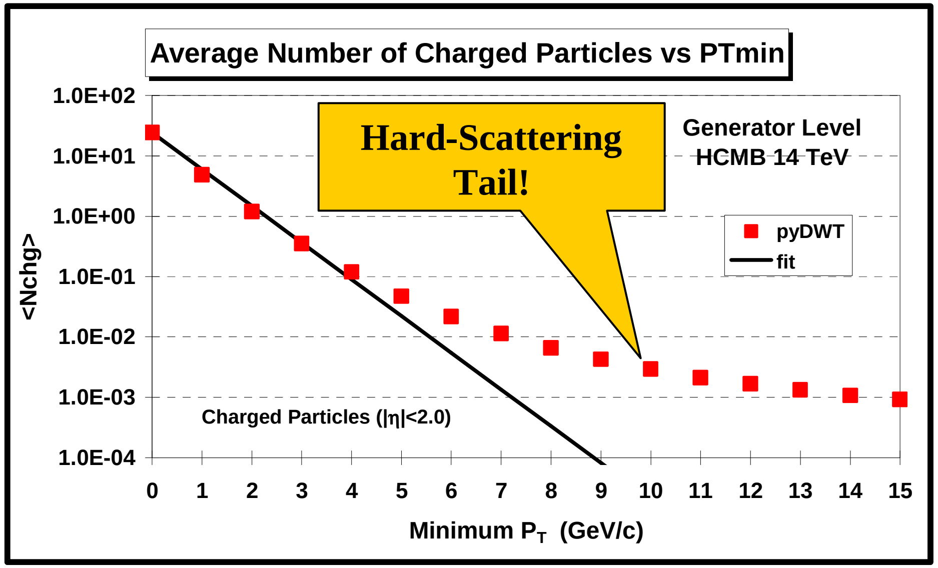



- Charged multiplicity distribution (|η| < 2) for Npile = 1 (*i.e.* shows, on the average, what one event looks like). The plot shows the probability of finding 0, 1, 2, … etc. charged particles. The five curves correspond to $p_T$(min) = 0, 1.0 , 2.5, 5.0, and 10.0 GeV/c.

- Shows the charged particle pseudo-rapidity distribution for Npile = 1 (*i.e.* shows, on the average, what one event looks like). The plot shows the <Nchg> in a 0.4 bin (*i.e.* not divided by bin size). The five curves correspond to $p_T$(min) = 0, 1.0 , 2.5, 5.0, and 10.0 GeV/c.

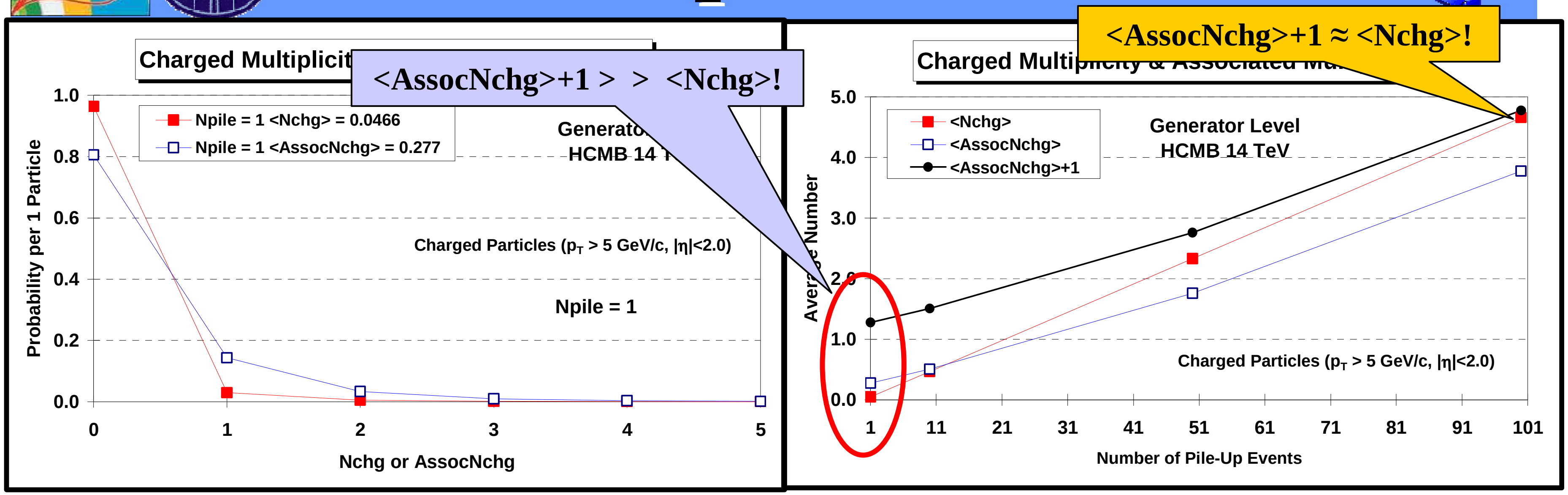
# Pile-Up at the LHC



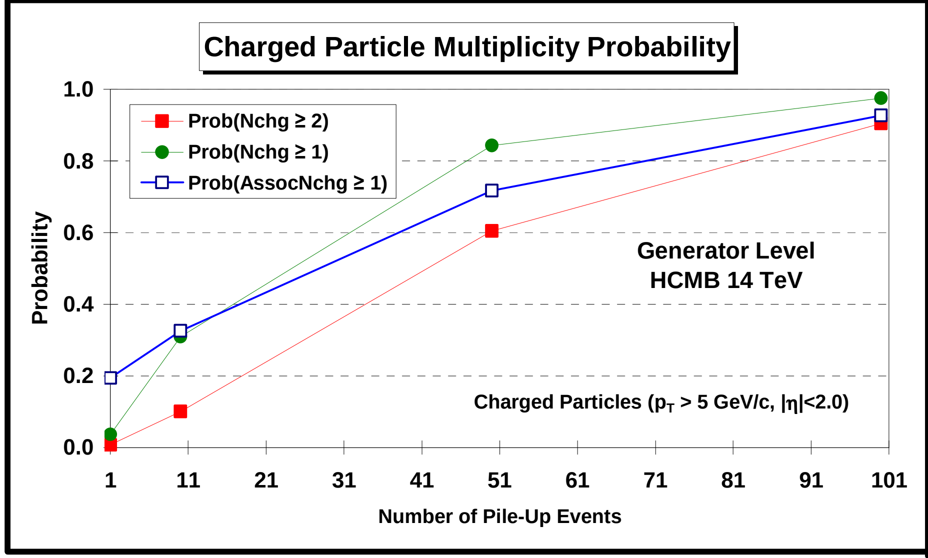

- **Shows the charged particle $p_T$ distribution ($|\eta| < 2$) for Npile = 1 (*i.e.* shows, on the average, what one event looks like). The plot shows the <Nchg> in a 1.0 GeV/c bin (*i.e.* not divided by bin size). The sum of the points gives 24.39.**
- **Shows the average number of charged particle the $P_T$-cut ($|\eta| < 2$) for Npile = 1 (*i.e.* shows, on the average, what one event looks like). The first point corresponds to <Nchg> = 24.39. The fit corresponds to $\langle Nchg \rangle = 24.39\exp(-1.4p_T(\text{min}))$.**

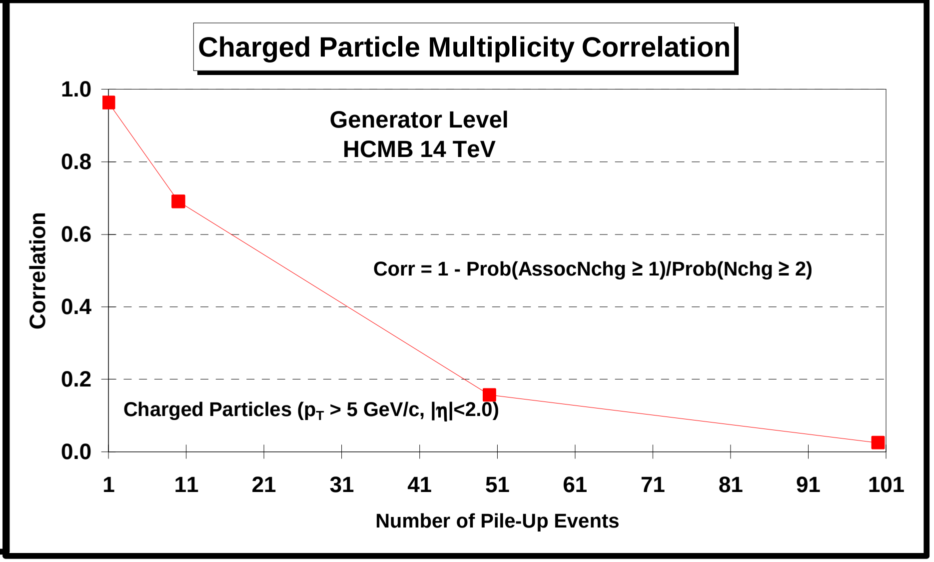
# Pile-Up at the LHC




- Shows the charged multiplicity distribution ($p_T$ > 5 GeV/c, |η| < 2) for Npile = 1 (*i.e.* shows, on the average, what one event looks like). The plot shows the probability of finding 0, 1, 2, … etc. charged particles. The plot also shows the "associated multiplicity" distribution (open squares), <AssocNchg> = <Nchg> -1, for events with at least one charged particle with $p_T$ > 5 GeV/c (*i.e.* the overall average multiplicity is <AssocNchg> +1 ) . Note that <AssocNchg> +1 = 1.277 and <Nchg> = 0.0466. There are many more particles in events with at least one charged particle with $p_T$ > 5 GeV/c, than in an average "min-bias" event. Also, note that the probability of getting an additional particle in an event with at least one charged particle with $p_T$ > 5 GeV/c (*i.e.* AssocNchg = 1 is greater than the probability of getting one particle in a typical "min-bias" event, Nchg = 1).

# Pile-Up at the LHC



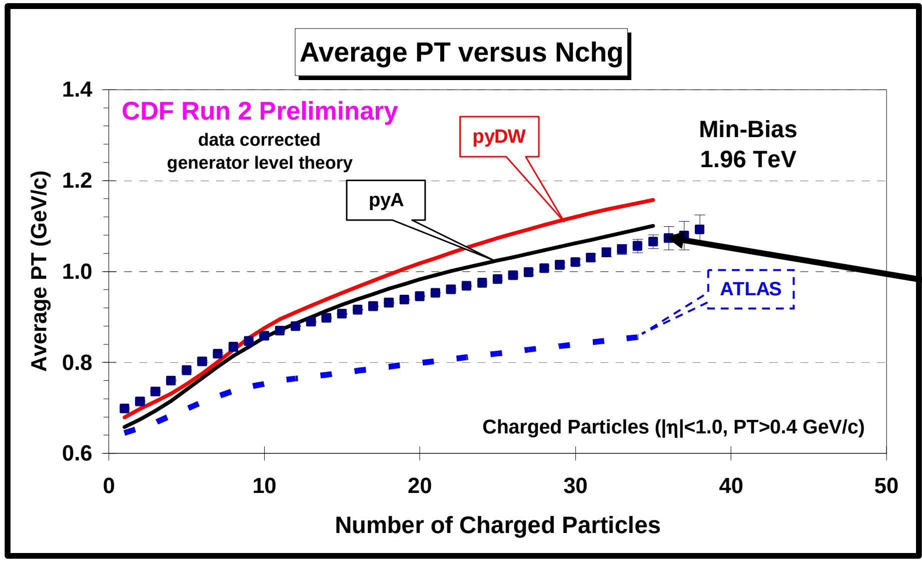



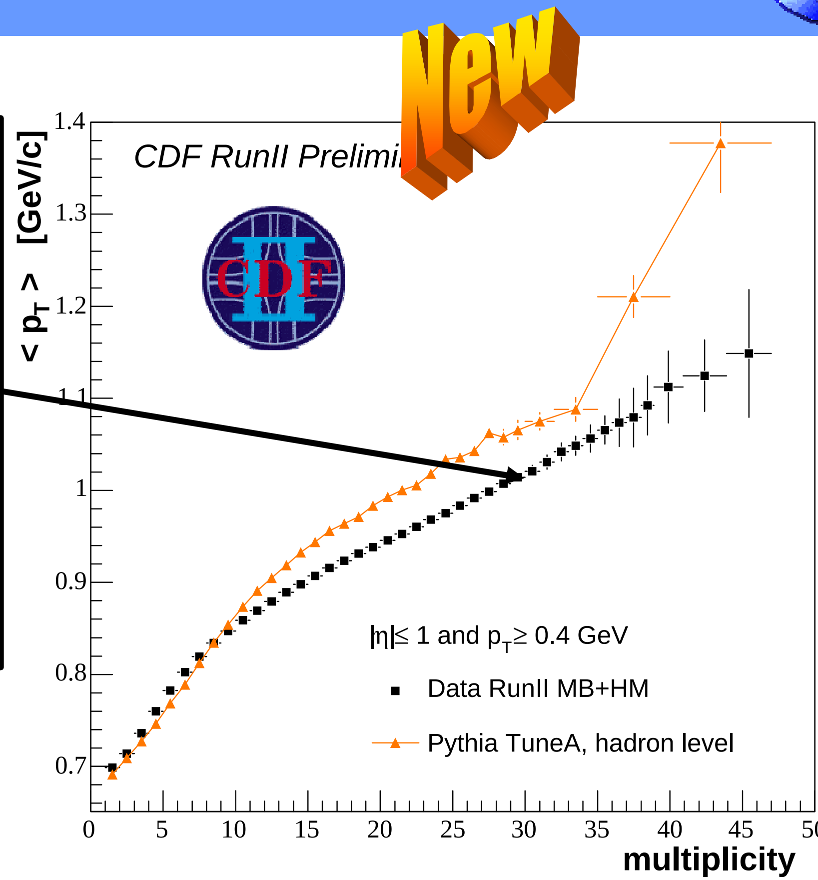

- **Shows the probability of finding Nchg ≥ 1 and Nchg ≥ 2 ($p_T$ > 5 GeV/c, |η| < 2) versus Npile, where Npile = 1 means one event, Npile = 10 means 10 events, etc.. . The plot also shows the probability of finding AssocNchg ≥ 1 (overall multiplicity ≥ 2) for events with at least one charged particle with $p_T$ > 5 GeV/c. For Npile = 1 (*i.e.* one event) there is a strong correlation since Prob(AssocNchg≥ 1) is much greater than Prob(Nchg≥ 2). However, this correlation diminishes as Npile becomes large!**

- **Shows the "correlation" (Corr = 1 - Prob(AssocNchg≥ 1)/Prob(Nchg≥ 2)) versus Npile, where Npile = 1 means one event, Npile = 10 means 10 events, etc.. . This correlation is very large for one event (*i.e.* Npile = 1) and diminishes as Npile becomes large.**

**"Central Limit Theorem"strikes again??**

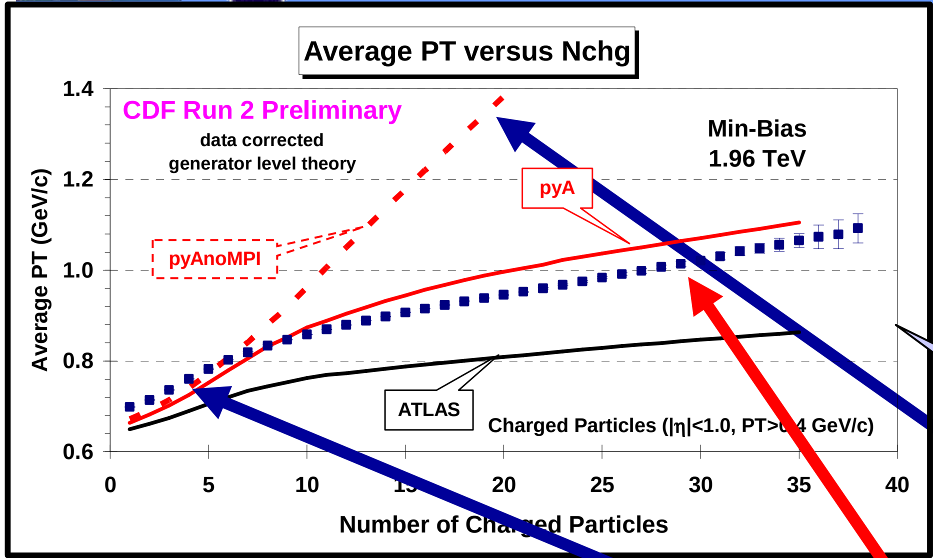
# Min-Bias Correlations



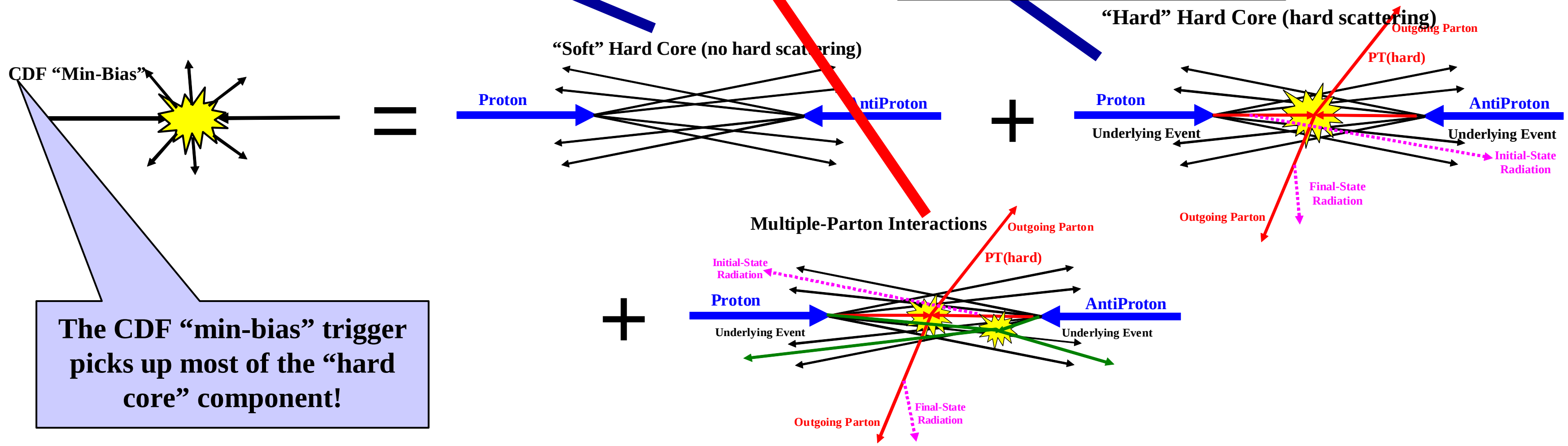

- **Data at 1.96 TeV on the average $p_T$ of charged particles versus the number of charged particles ($p_T$ > 0.4 GeV/c, |η| < 1) for "min-bias" collisions at CDF Run 2. The data are corrected to the particle level and are compared with PYTHIA Tune A at the particle level (*i.e.* generator level).**

# Min-Bias: Average PT versus Nchg



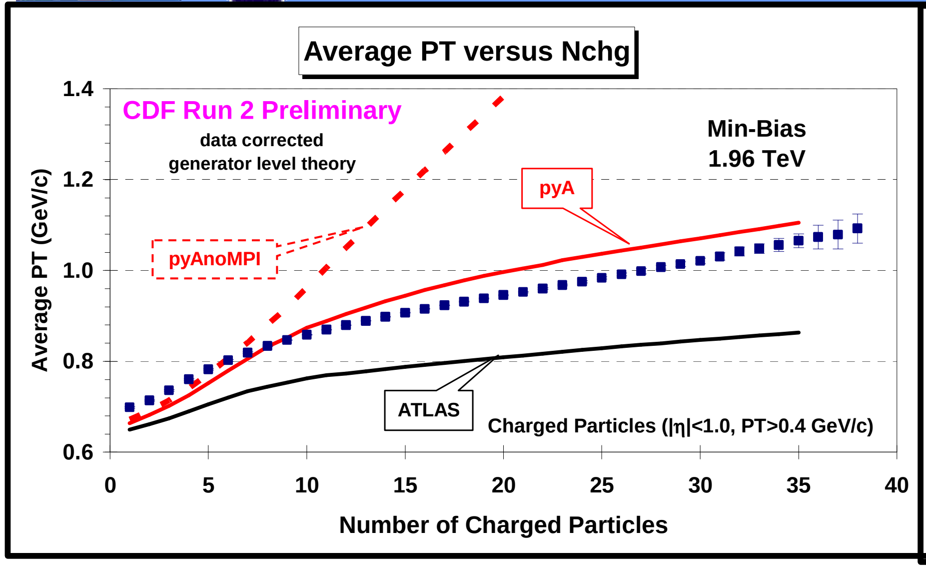

- Beam-beam remnants (*i.e.* soft hard core) produces low multiplicity and small $<p_T>$ with $<p_T>$ independent of the multiplicity.
- Hard scattering (with no MPI) produces large multiplicity and large $<p_T>$.
- Hard scattering (with MPI) produces large multiplicity and medium $<p_T>$.

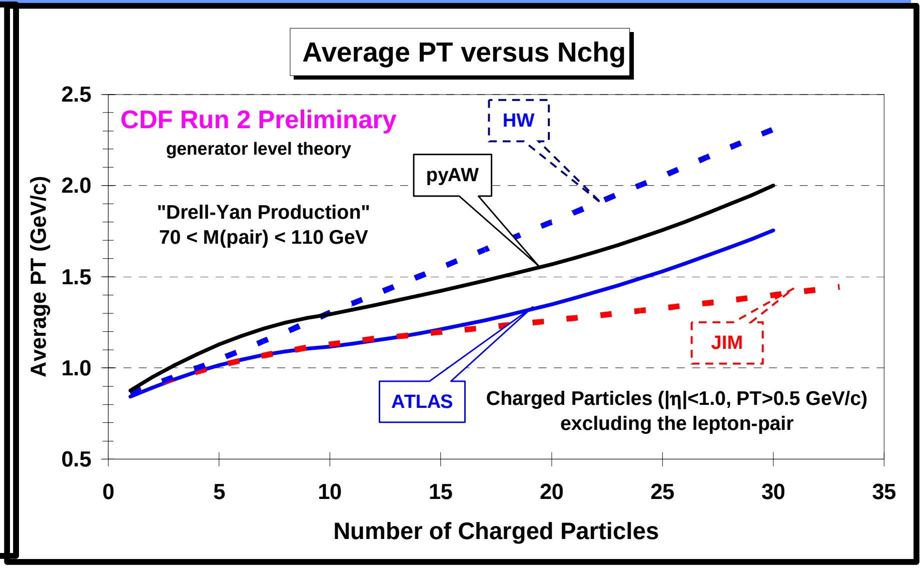
This observable is sensitive to the MPI tuning!

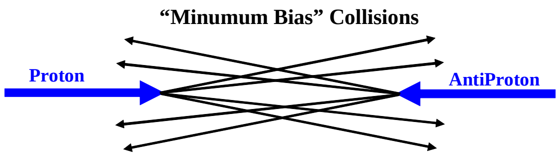


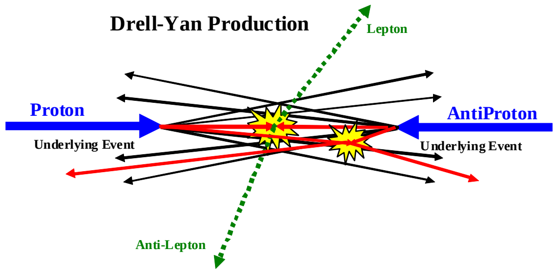

The CDF "min-bias" trigger picks up most of the "hard core" component!

# Average PT versus Nchg



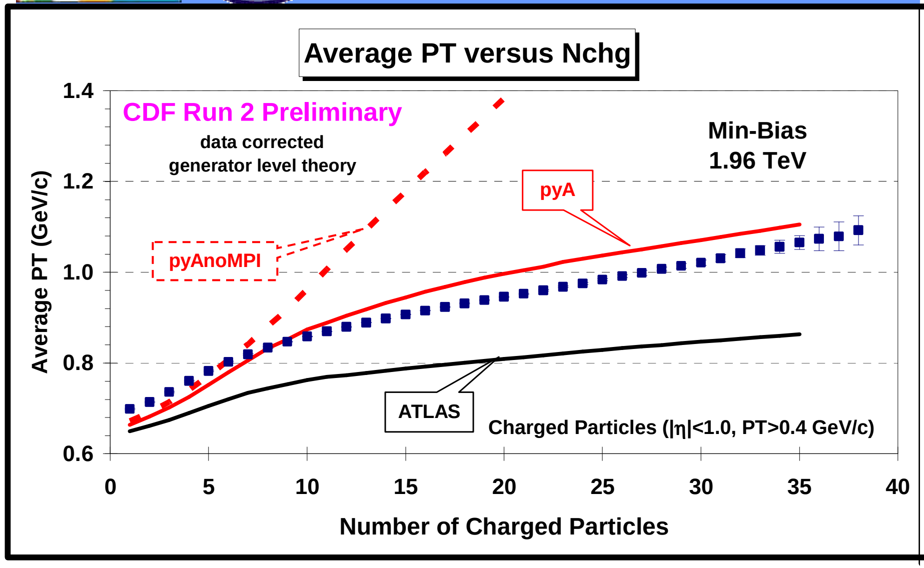



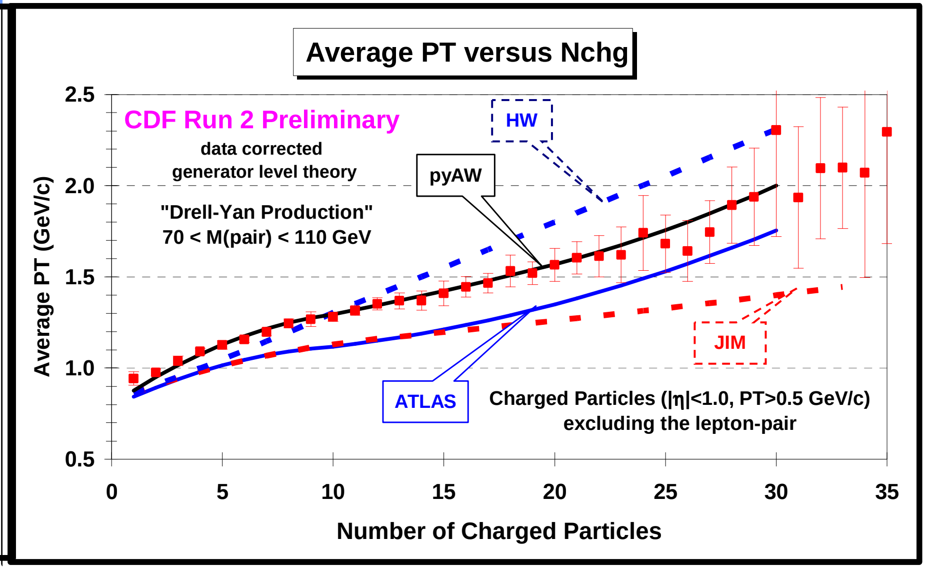



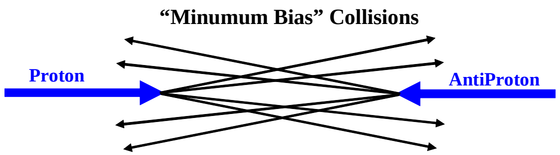

- **Data at 1.96 TeV on the average $p_T$ of charged particles versus the number of charged particles ($p_T$ > 0.4 GeV/c, |η| < 1) for "min-bias" collisions at CDF Run 2. The data are corrected to the particle leveland are compared with PYTHIA Tune A, Tune DW, and the ATLAS tune at the particle level (*i.e.* generator level).**

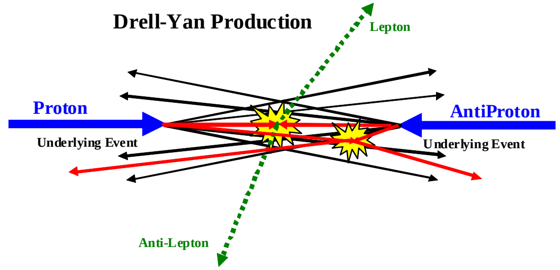
- **Particle level predictions for the average $p_T$ of charged particles versus the number of charged particles ($p_T$ > 0.5 GeV/c, |η| < 1, excluding the lepton-pair) for for Drell-Yan production (70 < M(pair) < 110 GeV) at CDF Run 2.**

# Average PT versus Nchg




- **Data at 1.96 TeV on the average $p_T$ of charged particles versus the number of charged particles ($p_T$ > 0.4 GeV/c, |η| < 1) for "min-bias" collisions at CDF Run 2. The data are corrected to the particle leveland are compared with PYTHIA Tune A, Tune DW, and the ATLAS tune at the particle level (*i.e.* generator level).**

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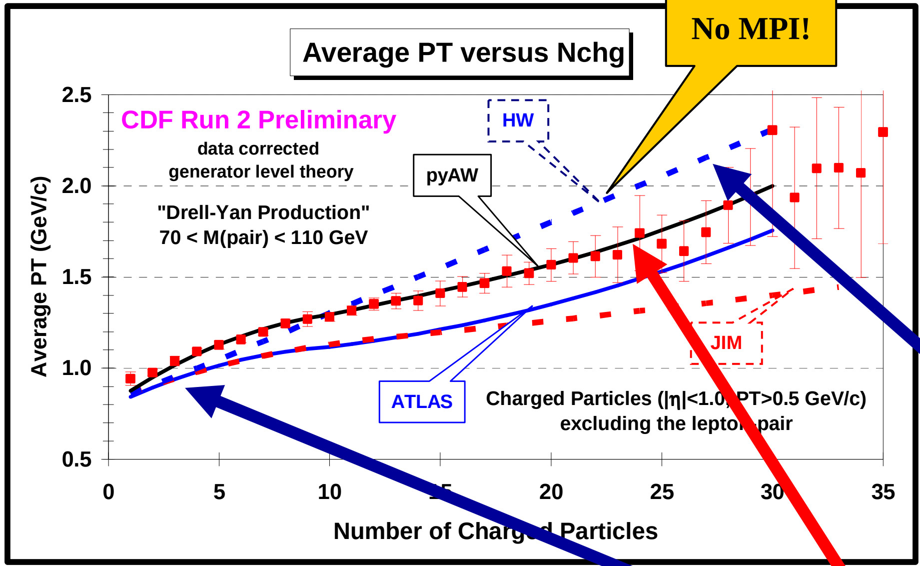
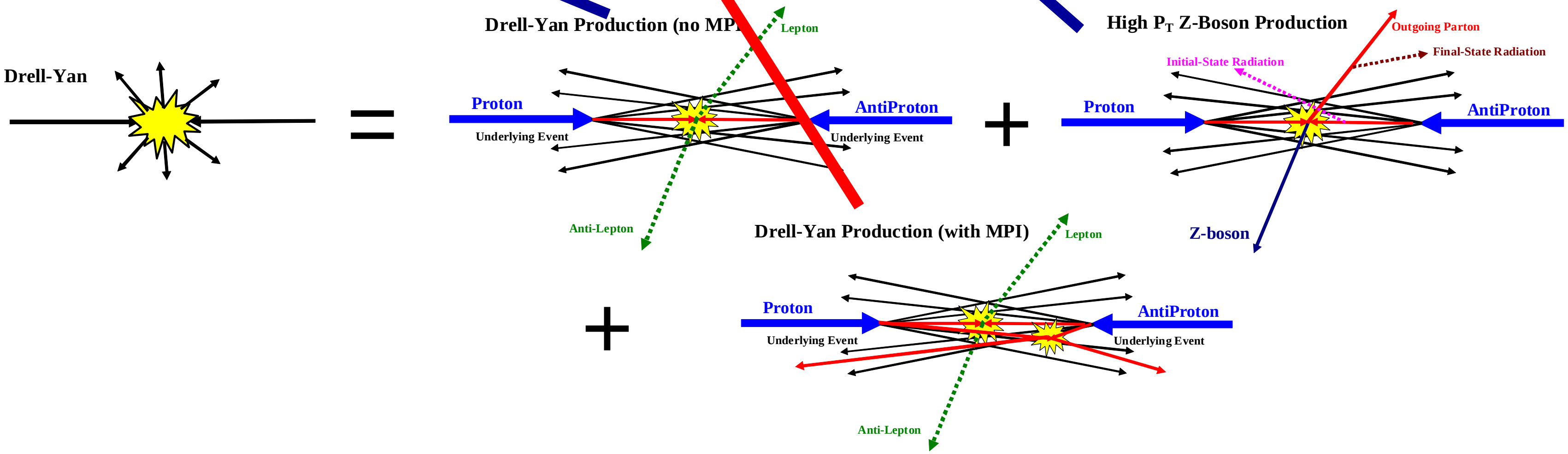
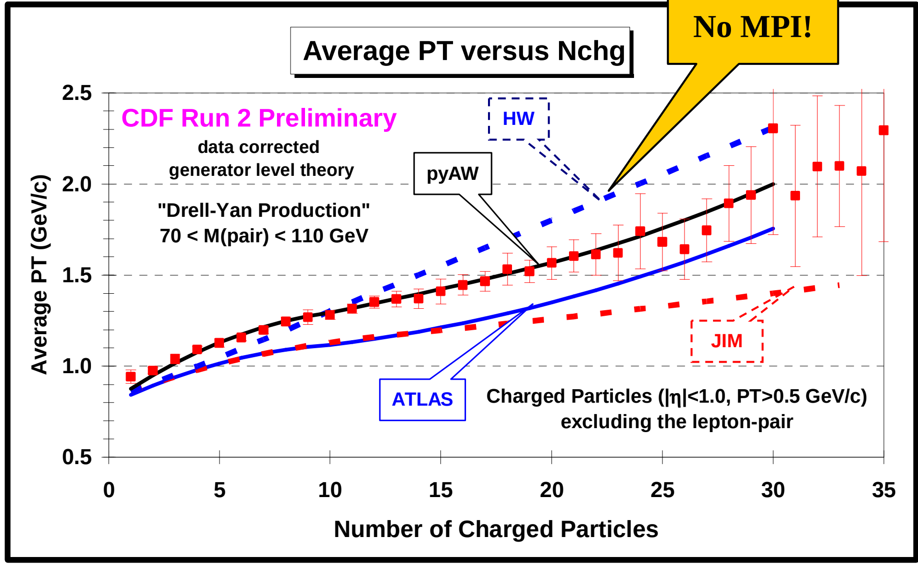
# Average PT versus Nchg

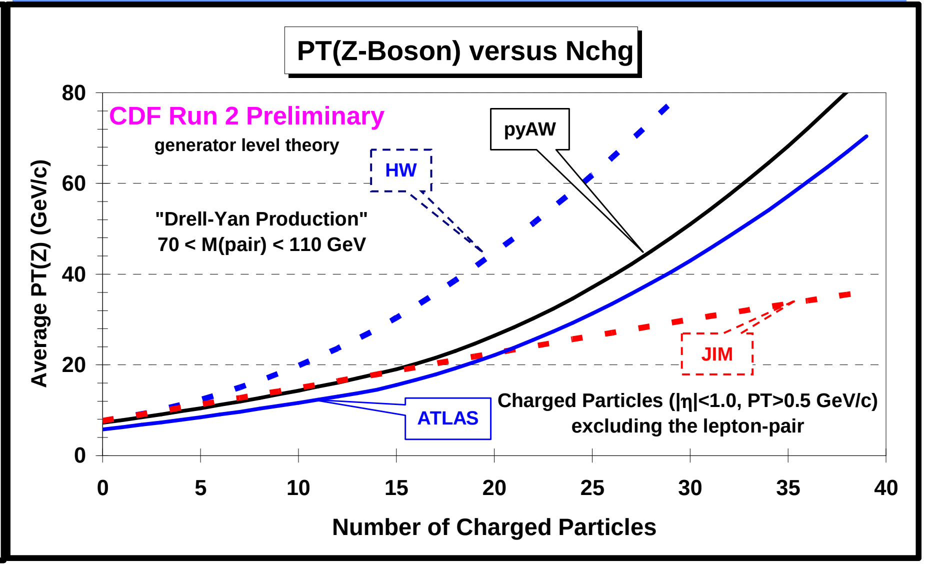


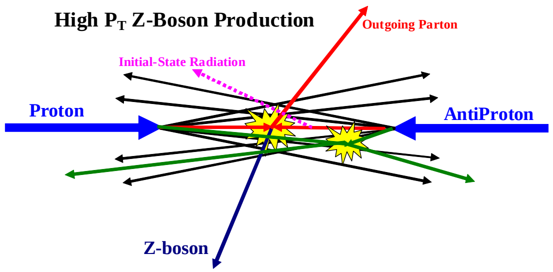

- Z-boson production (with low $p_T(Z)$ and no MPI) produces low multiplicity and small $\langle p_T \rangle$.
- High $p_T$ Z-boson production produces large multiplicity and high $\langle p_T \rangle$.
- Z-boson production (with MPI) produces large multiplicity and medium $\langle p_T \rangle$.



# Average PT(Z) versus Nchg



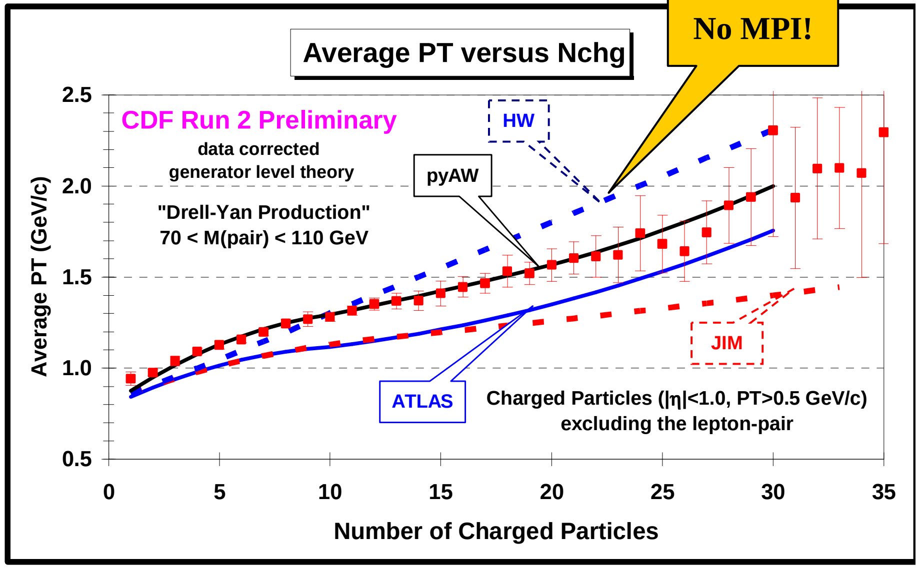



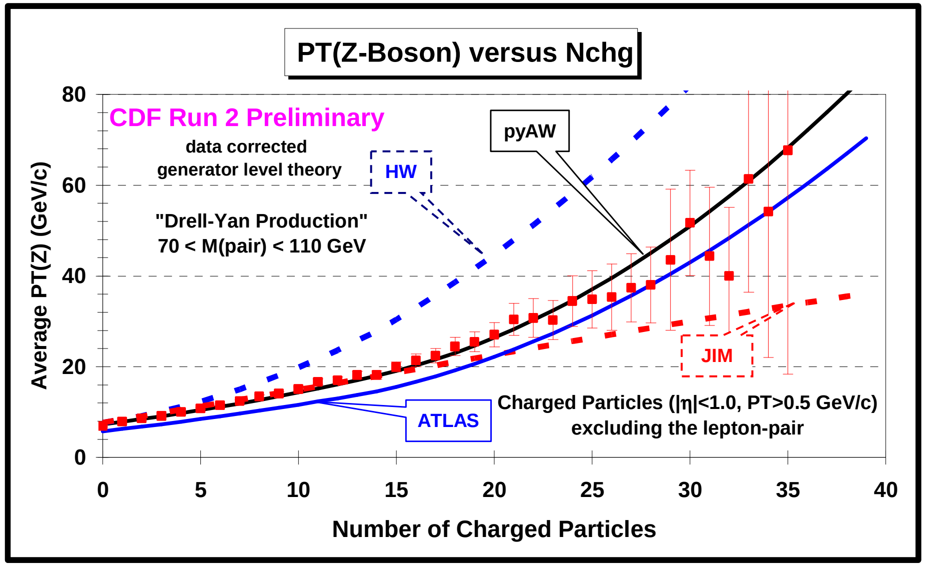



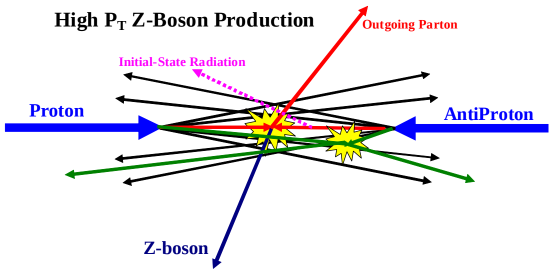

- **Predictions for the average $P_T$(Z-Boson) versus the number of charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$, excluding the lepton-pair) for for Drell-Yan production (70 < M(pair) < 110 GeV) at CDF Run 2.**

- **Data on the average $p_T$ of charged particles versus the number of charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$, excluding the lepton-pair) for for Drell-Yan production (70 < M(pair) < 110 GeV) at CDF Run 2. The data are corrected to the particle level and are compared with various Monte-Carlo tunes at the particle level (*i.e.* generator level).**

# Average PT(Z) versus Nchg




- **Predictions for the average $P_T$(Z-Boson) versus the number of charged particles ($p_T$ > 0.5 GeV/c, |η| < 1, excluding the lepton-pair) for for Drell-Yan production (70 < M(pair) < 110 GeV) at CDF Run 2.**

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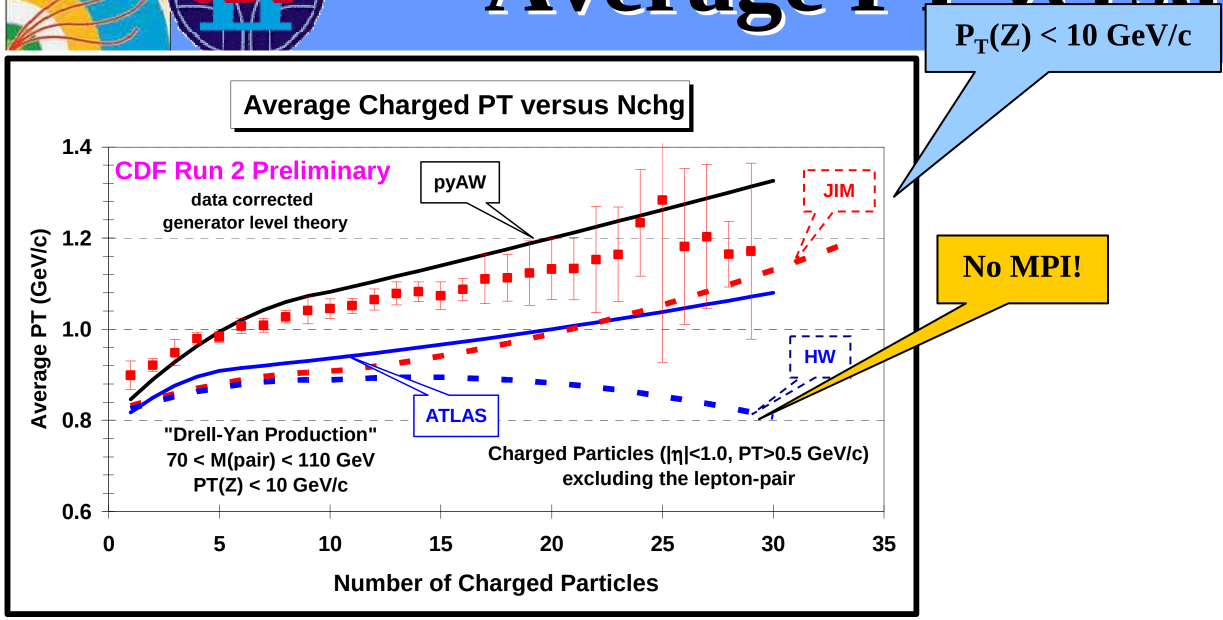
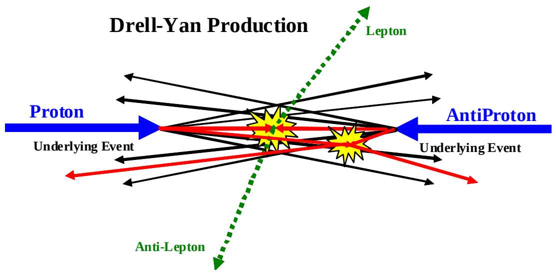
# Average PT versus Nchg

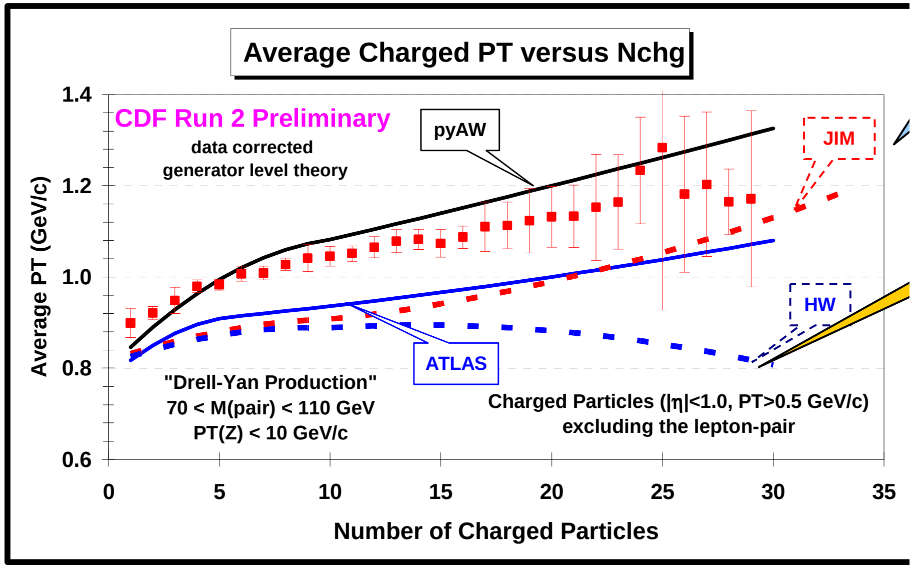


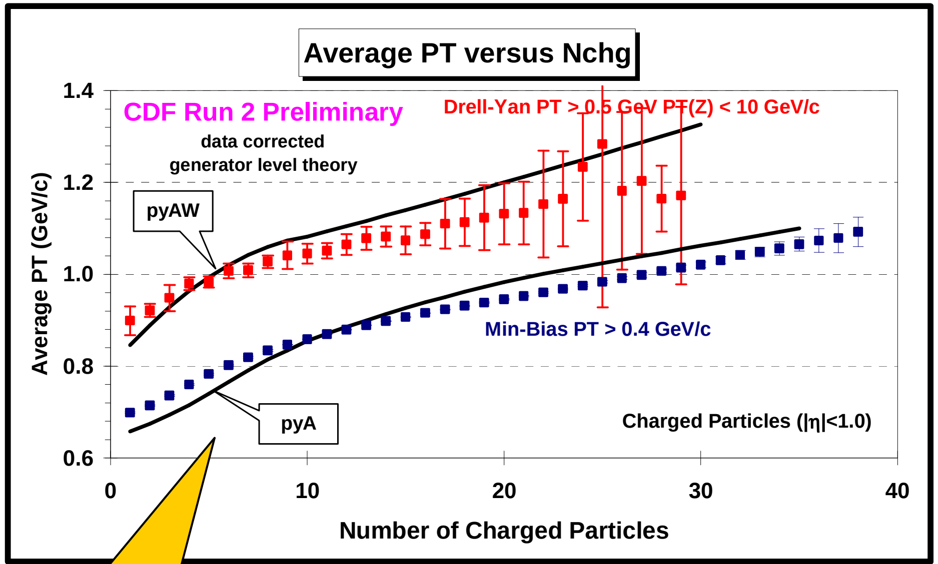



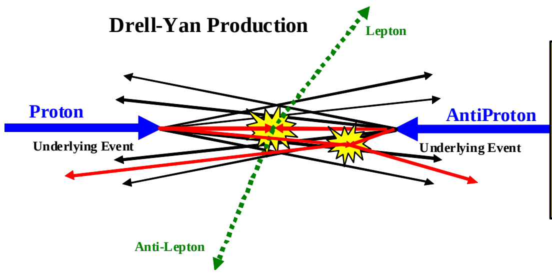

- Data the average $p_T$ of charged particles versus the number of charged particles ($p_T$ > 0.5 GeV/c, |η| < 1, excluding the lepton-pair) for for Drell-Yan production (70 < M(pair) < 110 GeV, $P_T$(pair) < 10 GeV/c) at CDF Run 2. The data are corrected to the particle level and are compared with various Monte-Carlo tunes at the particle level (*i.e.* generator level).

# Average PT versus Nchg

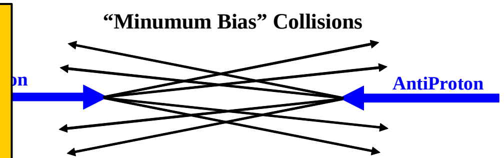
$P_T(Z) < 10$ GeV/c



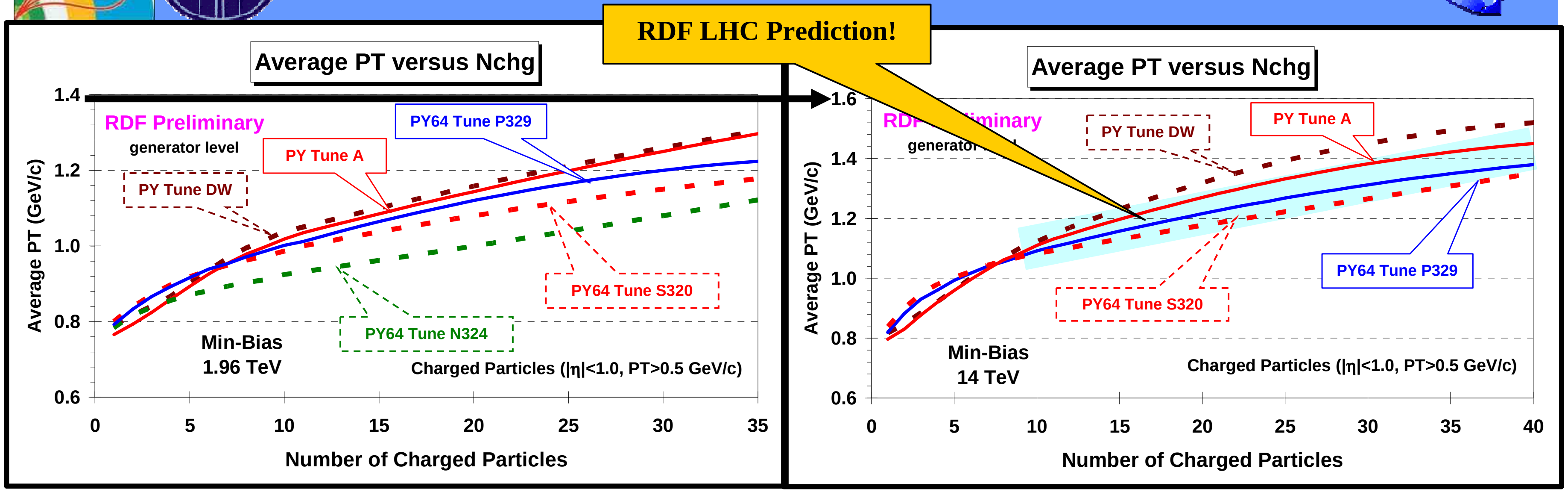




**Remarkably similar behavior! Perhaps indicating that MPI playing an important role in both processes.**




➡ **Data the average $p_T$ of charged particles versus the number of charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$, excluding the lepton-pair) for for Drell-Yan production (70 < M(pair) < 110 GeV, $P_T$(pair) < 10 GeV/c) at CDF Run 2. The data are corrected to the particle level and are compared with various Monte-Carlo tunes at the particle level (*i.e.* generator level).**

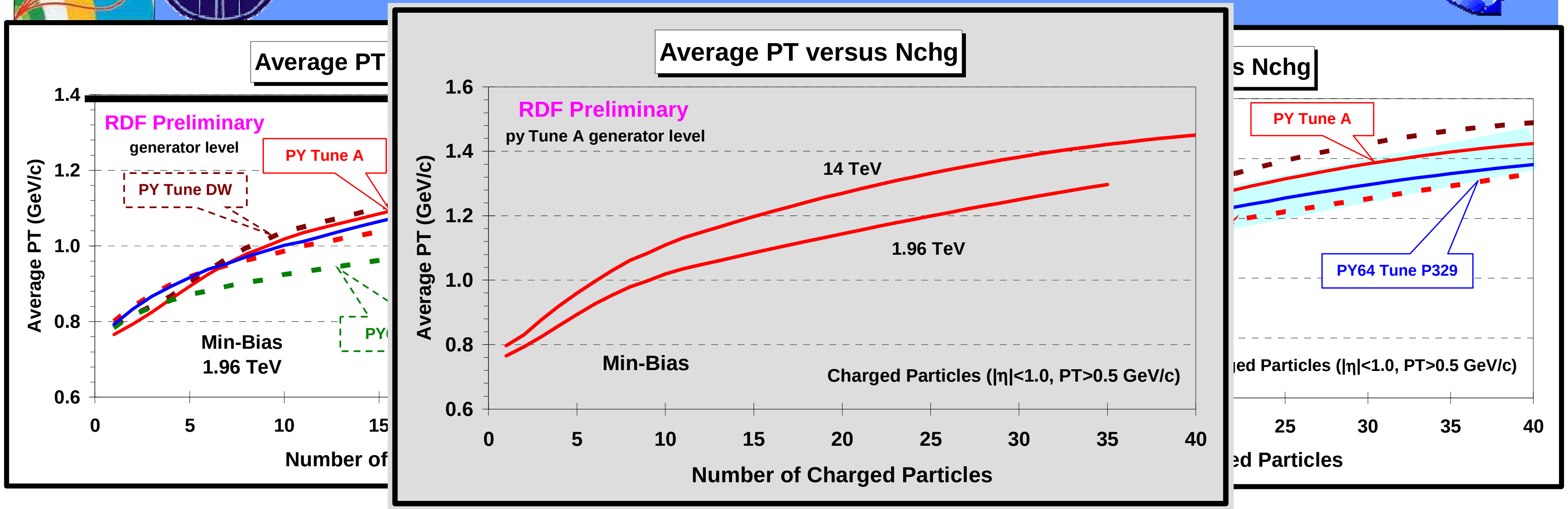
# Min-Bias: Average PT versus Nchg





- The average $p_T$ of charged particles versus the number of charged particles ($p_T$ > 0.5 GeV/c, |η| < 1) for "min-bias" collisions at 1.96 TeV from PYTHIA Tune A, Tune DW, Tune S320, Tune N324, and Tune P324.
- Extrapolations of PYTHIA Tune A, Tune DW, Tune S320, and Tune P324 to the LHC.

# Min-Bias: Average PT versus Nchg



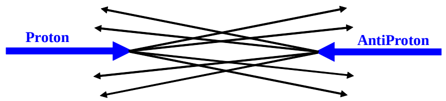


- The average $p_T$ of charged particles versus the number of charged particles ($p_T$ > 0.5 GeV/c, |η| < 1) for "min-bias" collisions at 1.96 TeV from PYTHIA Tune A, Tune DW, Tune S320, Tune N324, and Tune P324.
- Extrapolations of PYTHIA Tune A, Tune DW, Tune S320, and Tune P324 to the LHC.

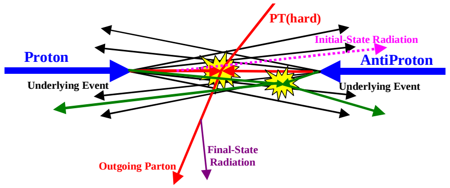
# LHC Predictions

**I believe because of the STAR analysis we are now in a position to make some predictions at the LHC!**

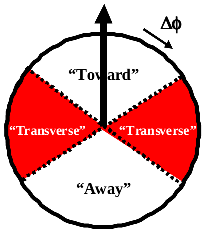
"Minumum Bias" Collisions




- **The amount of activity in "min-bias" collisions.**

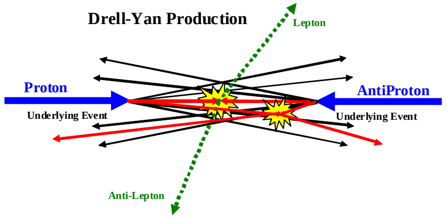



PTmax Direction

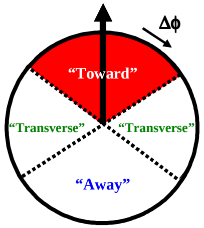



- **The amount of activity in the "underlying event" in hard scattering events.**

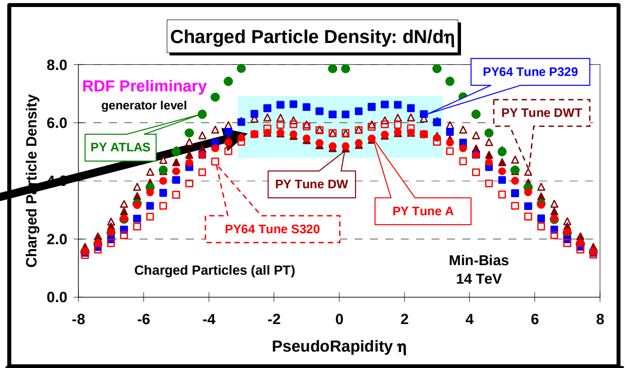
Drell-Yan Production

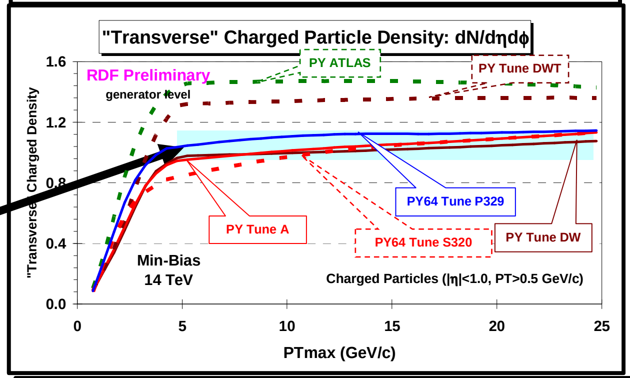


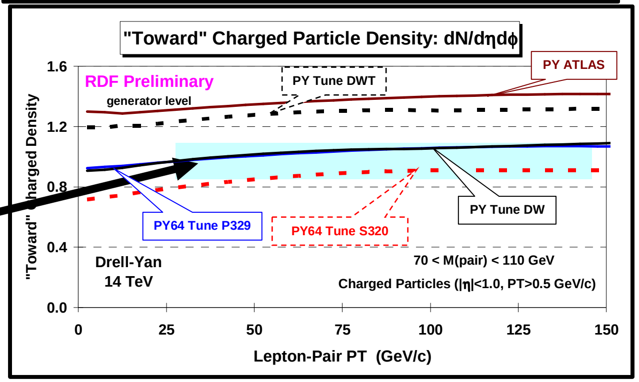

Z-Boson Direction




- **The amount of activity in the "underlying event" in Drell-Yan events.**

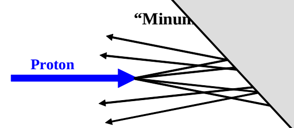


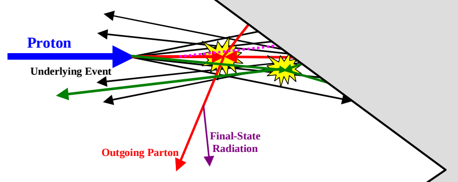



# LHC Predictions

I believe be… use of the STAR analysis …e are now in a position to …ke some predictions …he LHC!

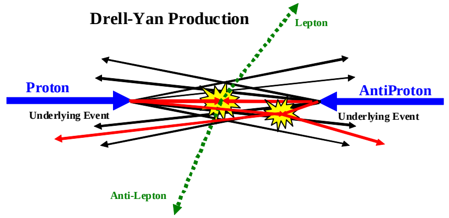


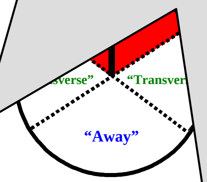

The amount of activity in “mi



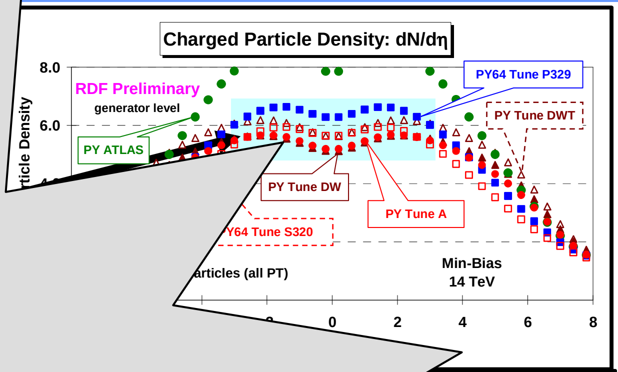

**If the LHC data are not in the range shown here then we learn new (QCD) physics!**

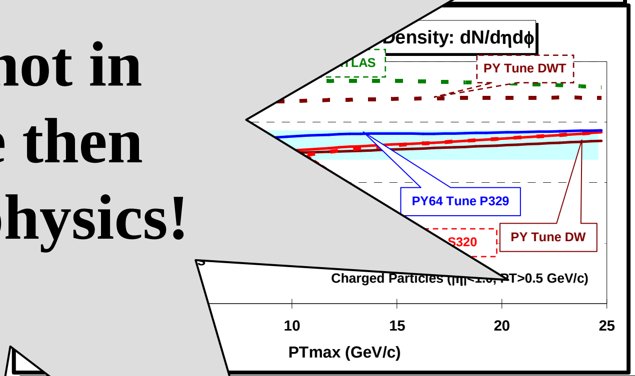
The amount of act… scattering eve…

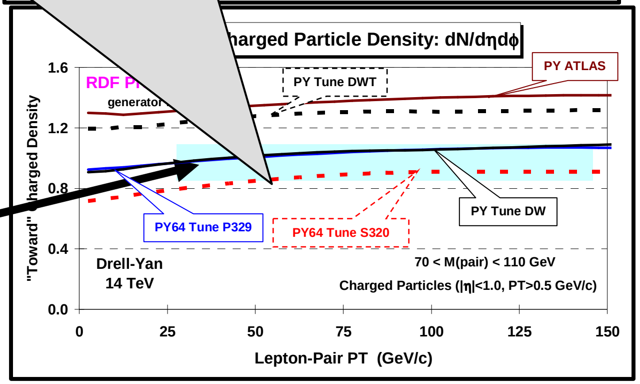



The amount of activity in the “underlying ev… ” in Drell-Yan events.



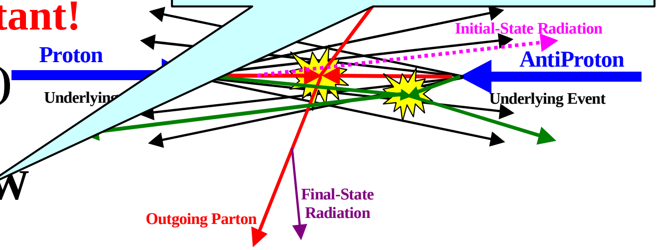



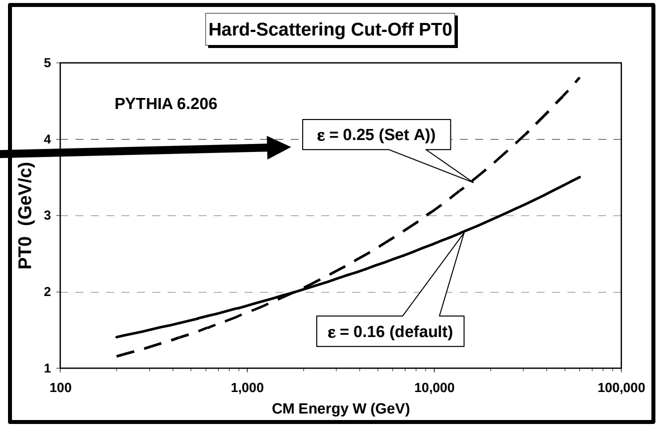



# Summary & Conclus

However, I believe that the better fits to the LEP fragmentation data at high z will lead to small improvements of Tune A at the Tevatron!

- 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 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!

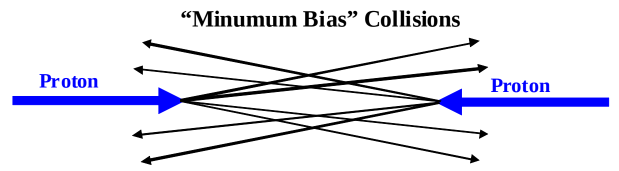


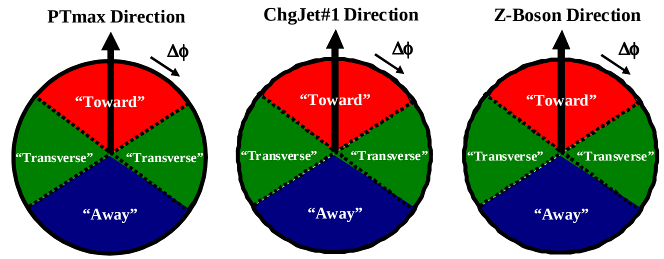

UE&MB@CMS

# Early LHC Thesis Projects

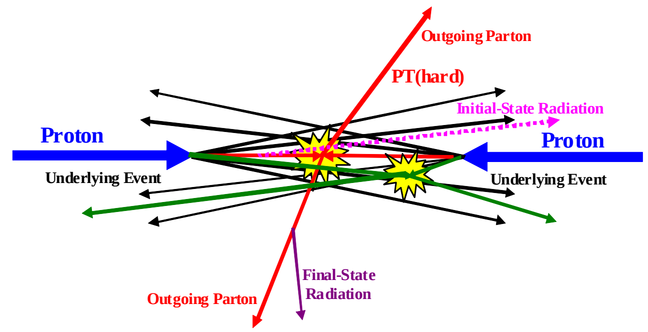
**Thesis 1: Measure dNchg/dη and <PT> versus Nchg in "min-bias" collisions.**



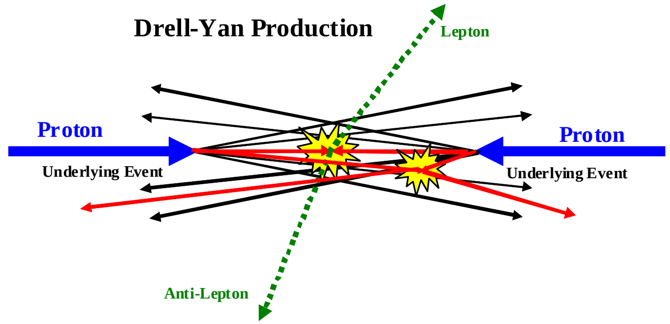

**Thesis 2: Measure the "toward", "away", and "transverse" region as a function of PTmax in "min-bias" collisions.**




**Thesis 3: Measure the "toward", "away", and "transverse" region as a function of PT(chgjet#1).**




**Thesis 4: Measure the "toward", "away", and "transverse" region as a function of PT(Z) for Z-boson production.**




**Thesis 5: Measure PT(Z) and <$p_T$> versus Nchg for Z-boson production (all PT(Z), PT(Z) < 10 GeV/c).**