Predicting "Min-Bias" and the "Underlying Event" at the LHC

Extrapolations from the Tevatron to RHIC and the LHC

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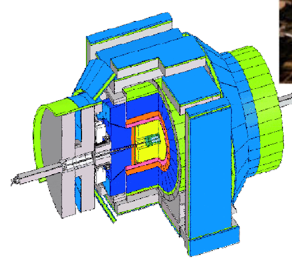
Quantum Chromo-Dynamics

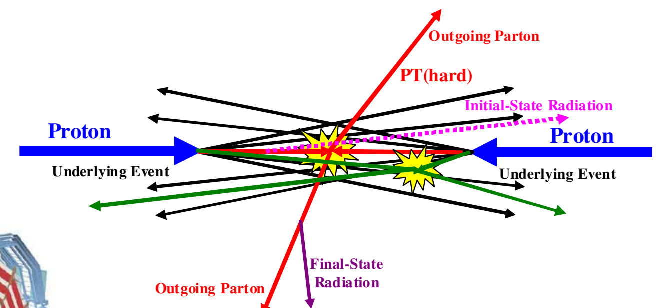
CERN August 13, 2009

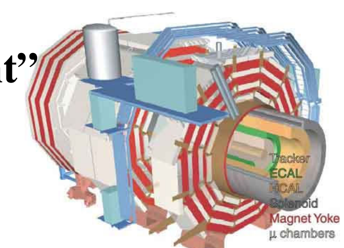
Outline of Talk

- Studying the formation of the "underlying event".
- 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).
- LHC predictions for "Min-bias".
- Summary & Conclusions.



CDF Run 2

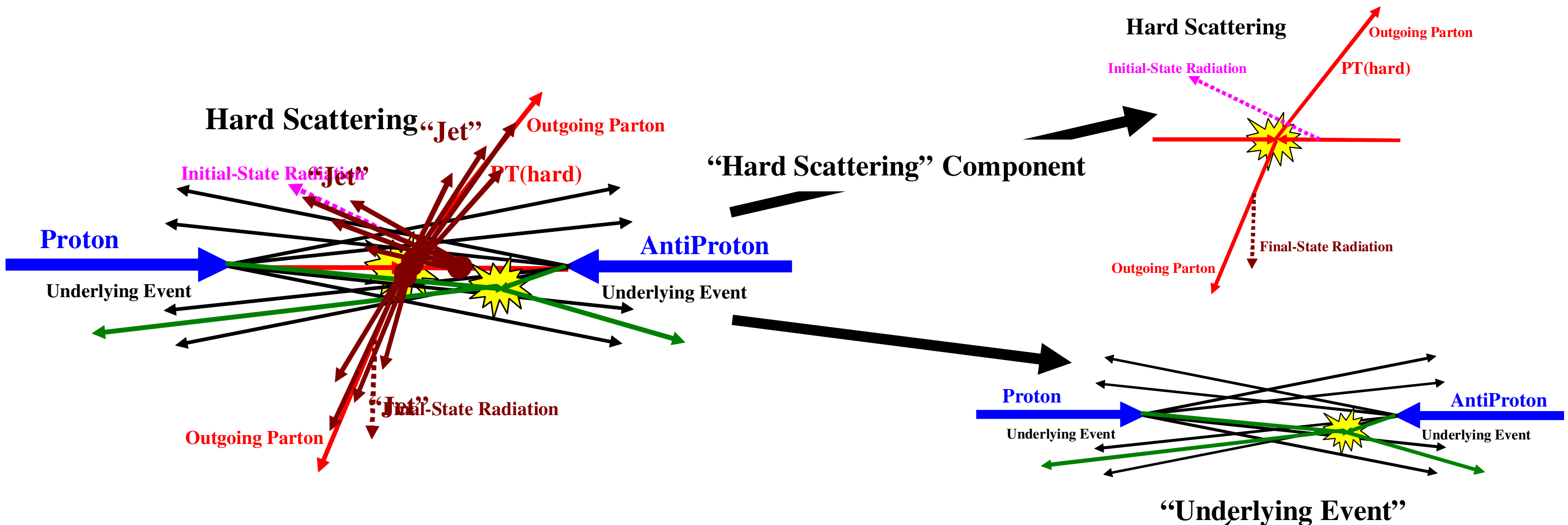




CMS at the LHC

UE&MB@CMS

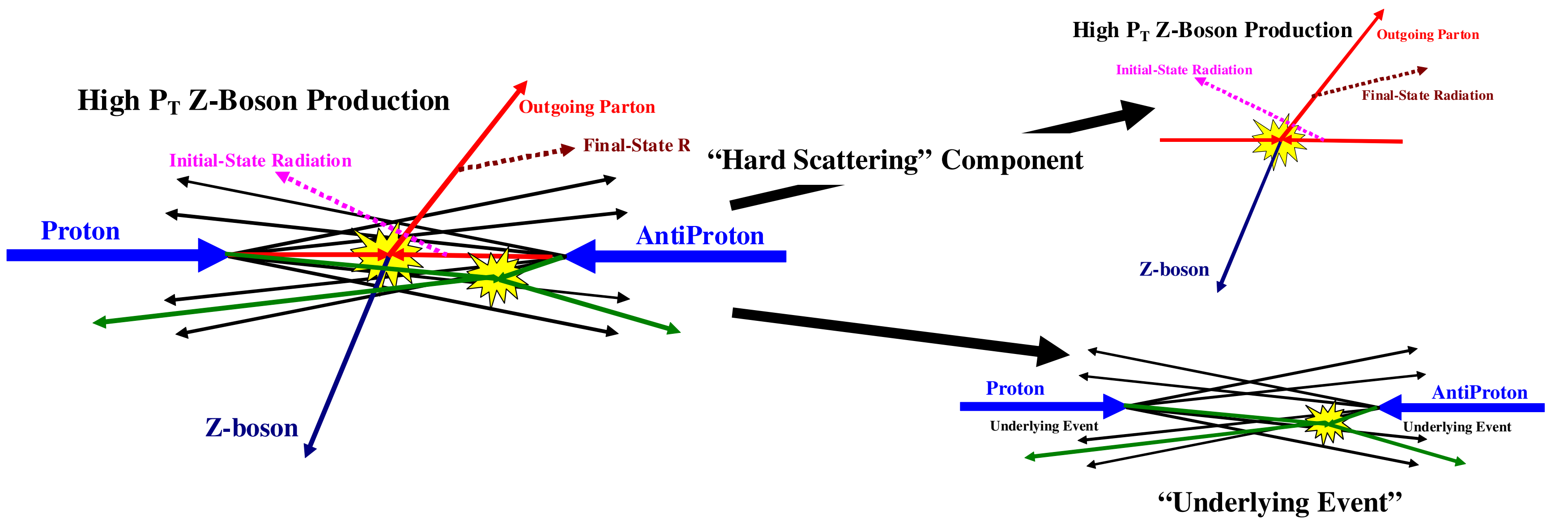
QCD Monte-Carlo Models: High Transverse Momentum Jets



- Start with the perturbative 2-to-2 (or sometimes 2-to-3) parton-parton scatteri… 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!

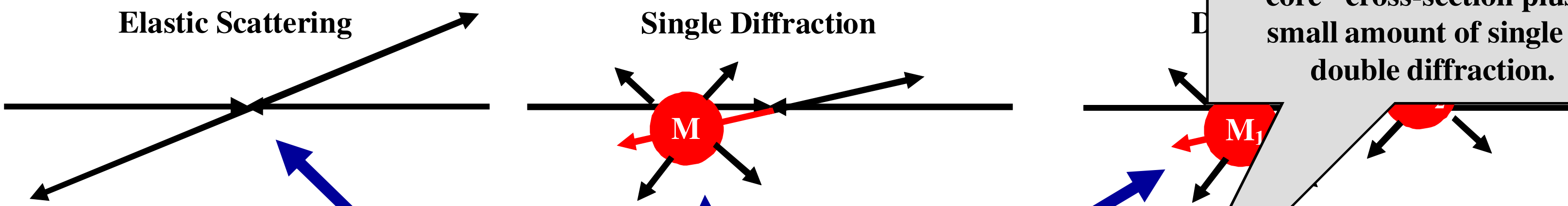
QCD Monte-Carlo Models: Lepton-Pair Production



- 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.

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.



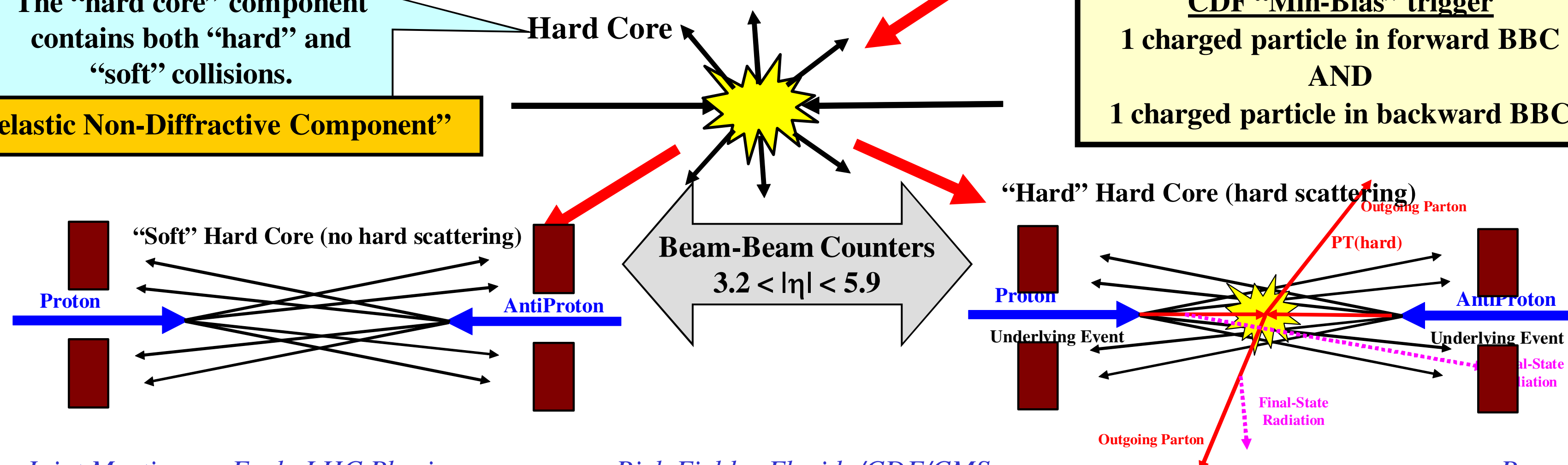
$$\sigma_{tot} = \sigma_{EL} + \sigma_{SD} + \sigma_{DD} + \sigma_{HC}$$

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

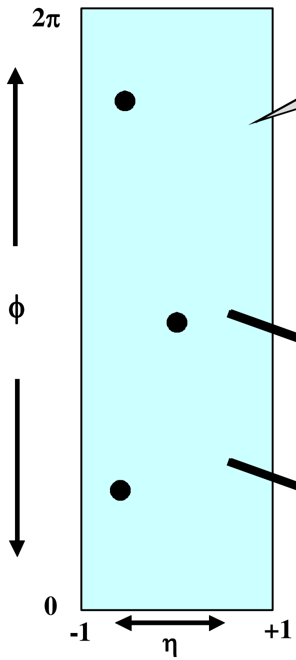
The "hard core" component contains both "hard" and "soft" collisions.

"Inelastic Non-Diffractive Component"

<u>CDF "Min-Bias" trigger</u>
1 charged particle in forward BBC
AND
1 charged particle in backward BBC



Particle Densities



ΔηΔφ = 4π = 12.6

3 charged particles

3 GeV/c PTsum

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

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

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

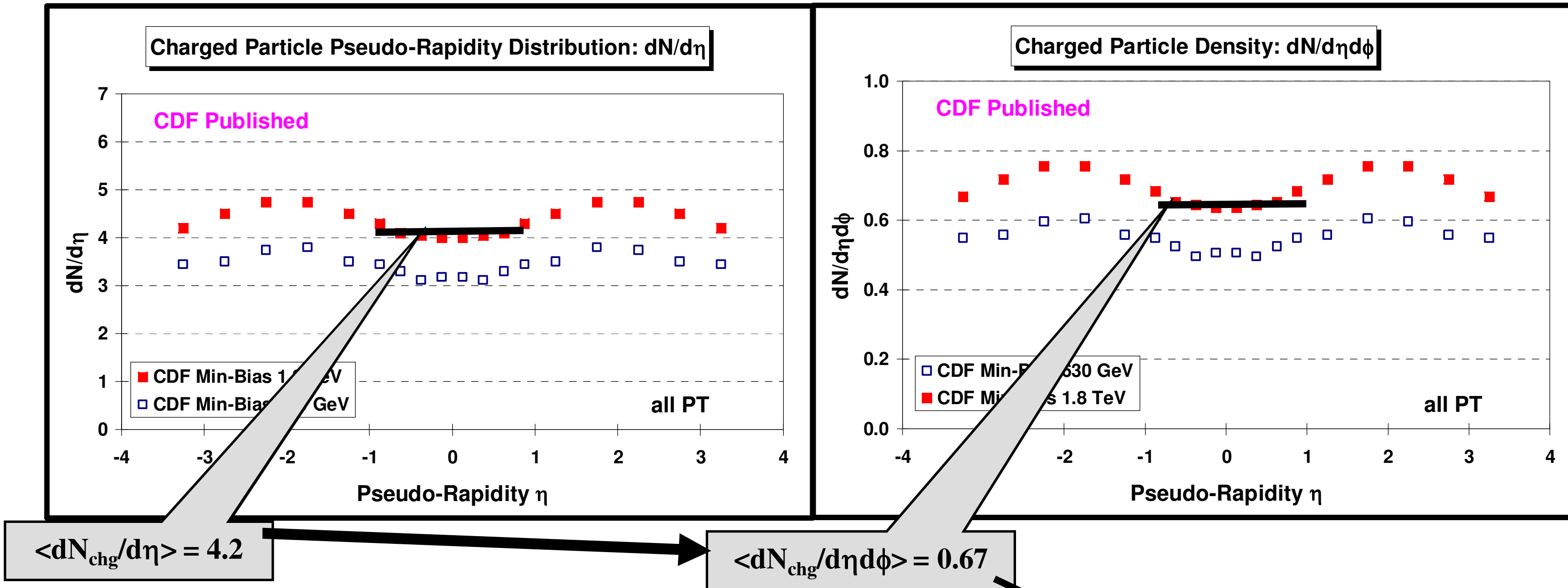
CDF Run 2 "Min-Bias"

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

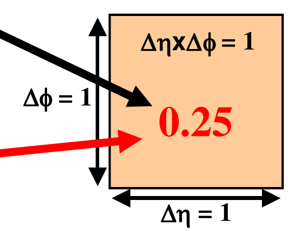
Divide by 4π

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

CDF Run 1 “Min-Bias” Data
Charged Particle Density

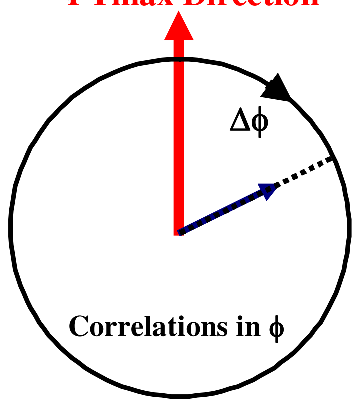


- Shows CDF “Min-Bias” data on the number of charged particles per unit pseudo-rapidity at 630 and 1,800 GeV. There are about **4.2 charged particles per unit η in “Min-Bias” collisions at 1.8 TeV** ($|\eta| < 1$, all p_T).
- Convert to charged particle density, $dN_{chg}/d\eta d\phi$, by dividing by 2π. There are about **0.67 charged particles per unit η-φ in “Min-Bias” collisions at 1.8 TeV ($|\eta| < 1$, all p_T).**
- There are about **0.25 charged particles per unit η-φ in “Min-Bias” collisions at 1.96 TeV ($|\eta| < 1$, $p_T > 0.5$ GeV/c).** **$<dN_{chg}/d\eta> = 1.6$!**

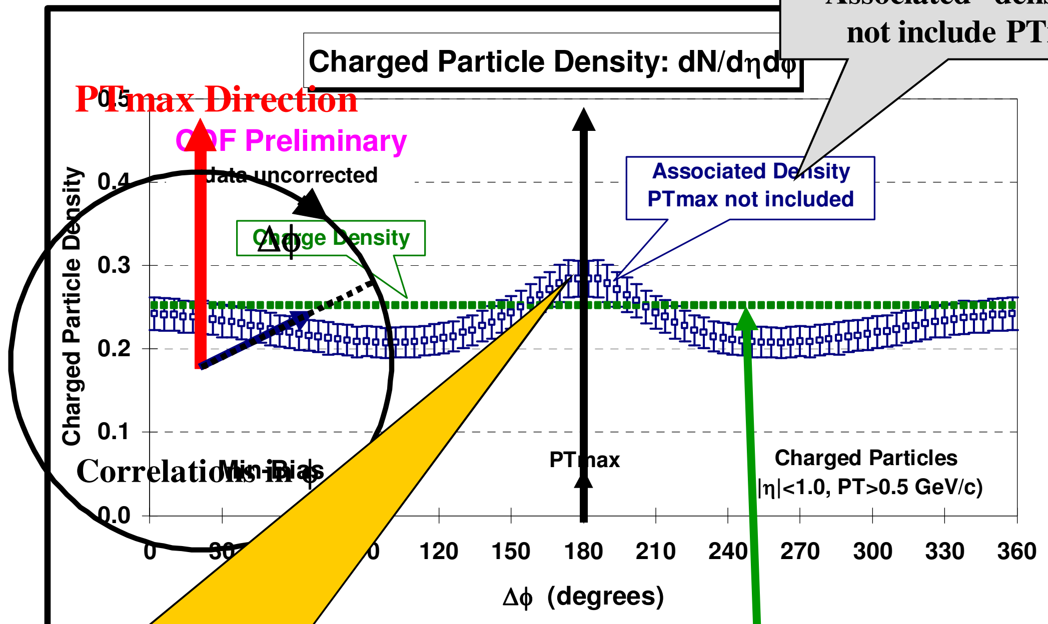


CDF Run 1 Min-Bias "Associated" Charged Particle Density

Highest p_T charged particle!



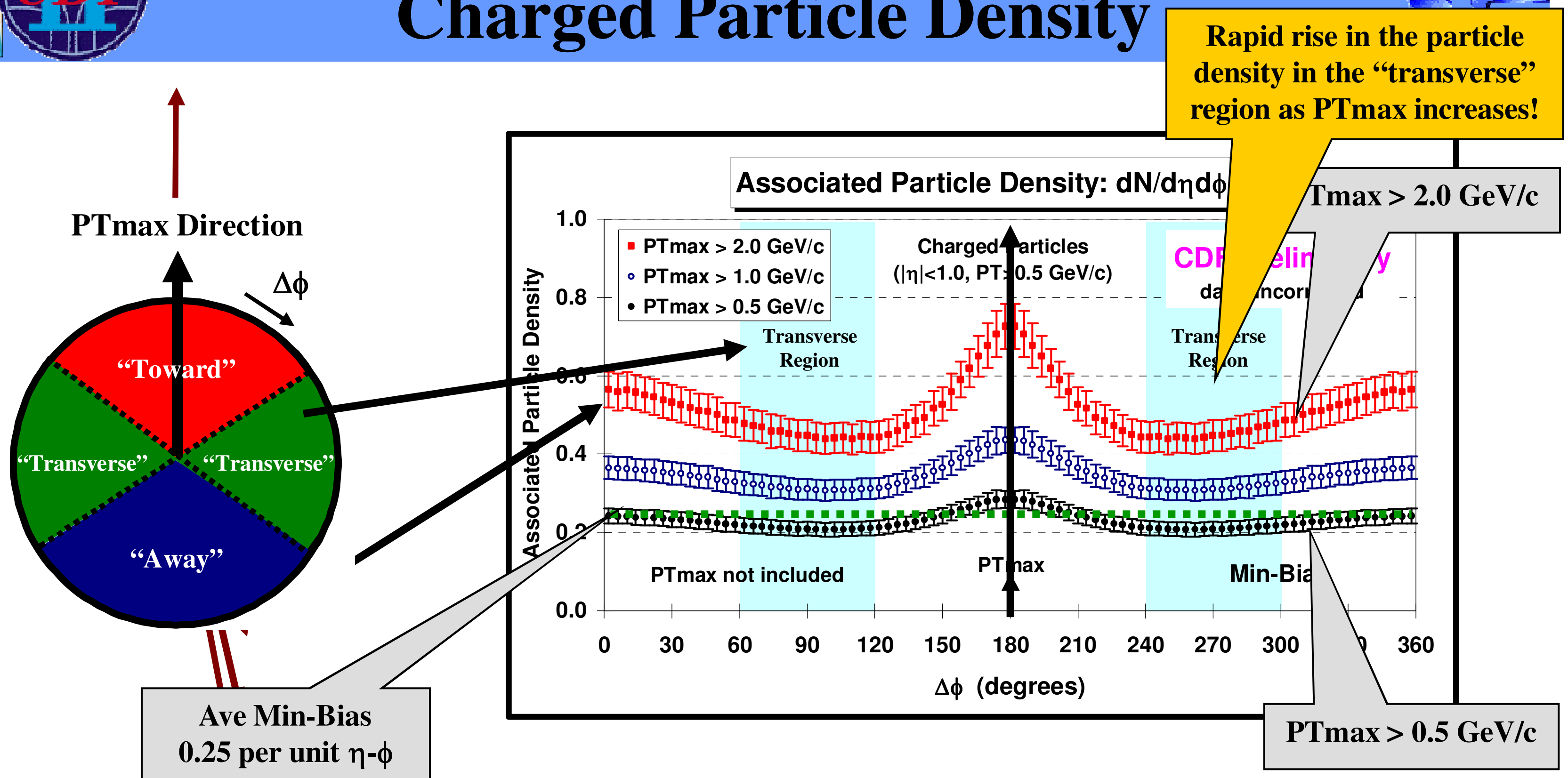
"Associated" densities do not include PTmax!



It is more probable to find a particle accompanying PTmax than it is to find a particle in the central region!

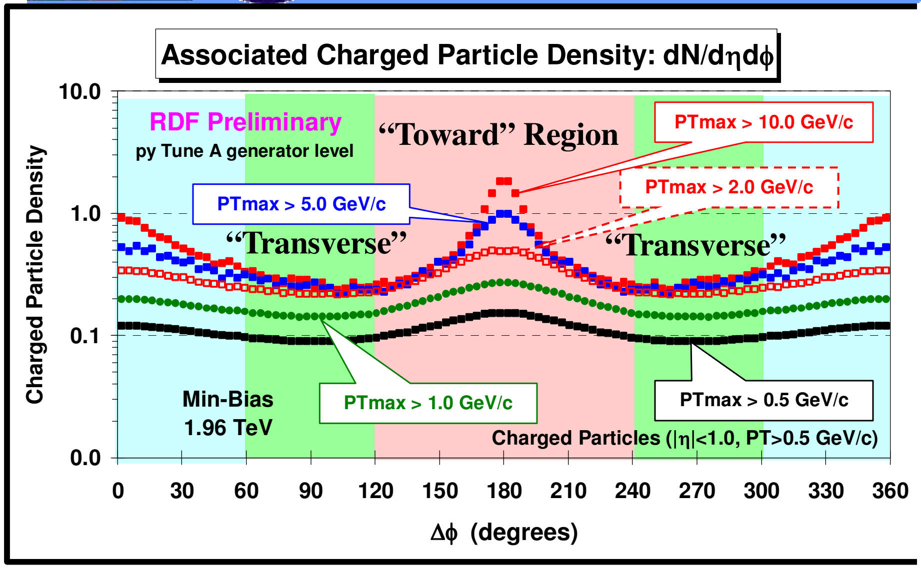
- Use the m… , **PTmax**, to define a direction and look at the the "… n-bias" collisions (p_T > 0.5 GeV/c, |η| < 1).
- Shows the … iated" charged particle density, dNchg/dηdφ, for charged particles (p_T > 0.5 GeV/c, |η| < 1, *not including PTmax*) relative to PTmax (rotated to 180°) for "min-bias" events. Also shown is the average charged particle density, dNchg/dηdφ, for "min-bias" events.

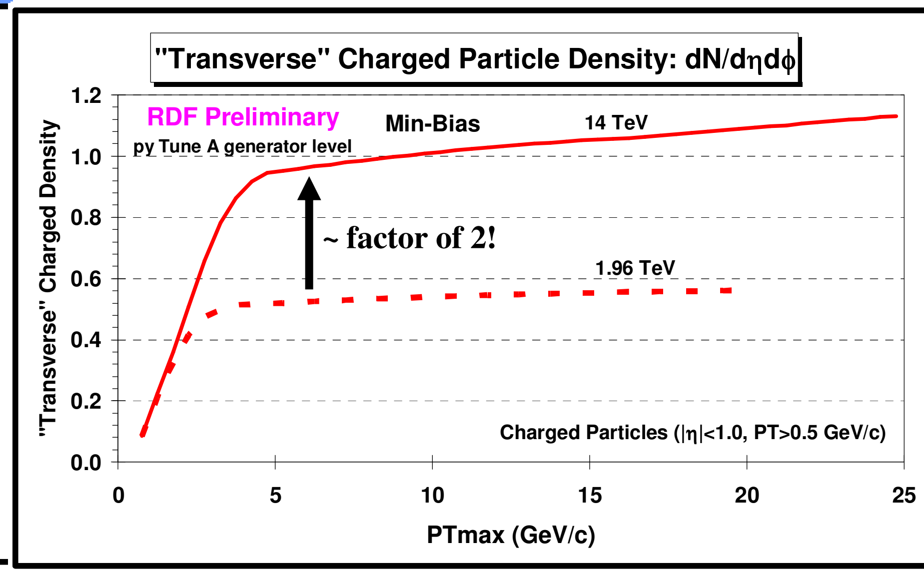
CDF Run 1 Min-Bias "Associated" Charged Particle Density



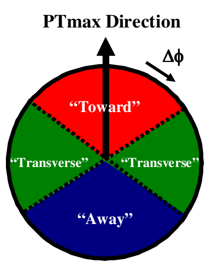
- Shows the data on the Δφ dependence of the "associated" charged particle density, $dN_{chg}/d\eta d\phi$, for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$, *not including PTmax*) relative to PTmax (rotated to 180°) for "min-bias" events with PTmax > 0.5, 1.0, and 2.0 GeV/c.
- Shows "jet structure" in "min-bias" collisions (*i.e.* the "birth" of the leading two jets!).

Min-Bias "Associated" Charged Particle Density



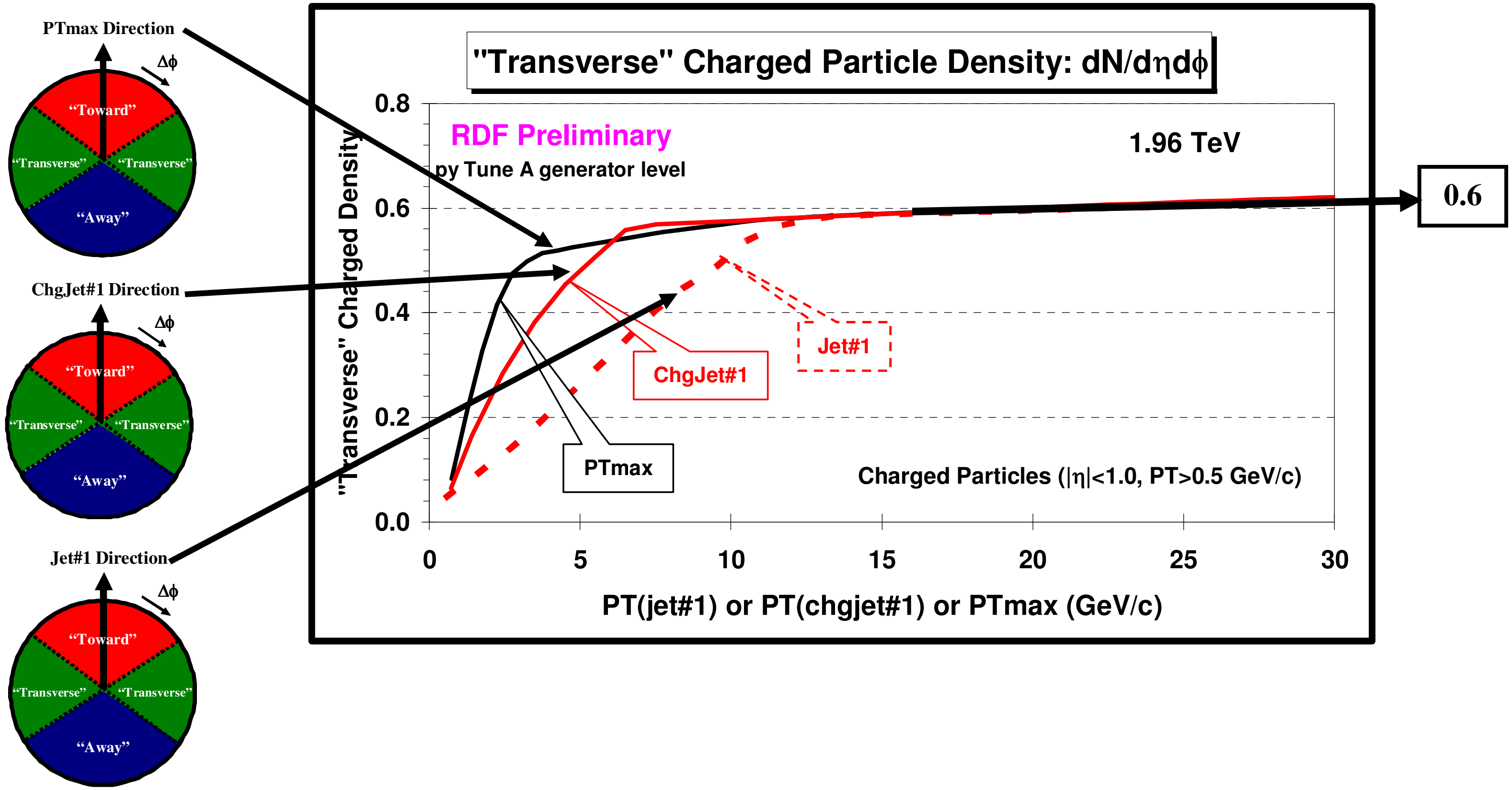


- Shows the $\Delta\phi$ dependence of the "associated" charged particle density, $dN_{chg}/d\eta d\phi$, for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$, *not including PTmax*) relative to PTmax (rotated to 180°) for "min-bias" events at 1.96 TeV with PTmax > 0.5, 1.0, 2.0, 5.0, and 10.0 GeV/c from PYTHIA Tune A (generator level).



- 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 from PYTHIA Tune A (generator level).

"Transverse" Charged Density



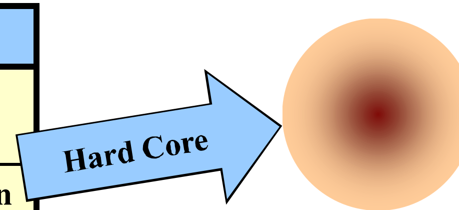
➡ Shows the charged particle density in the "transverse" region for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) at 1.96 TeV as defined by PTmax, PT(chgjet#1), and PT(jet#1) from PYTHIA Tune A at the particle level (*i.e.* generator level).

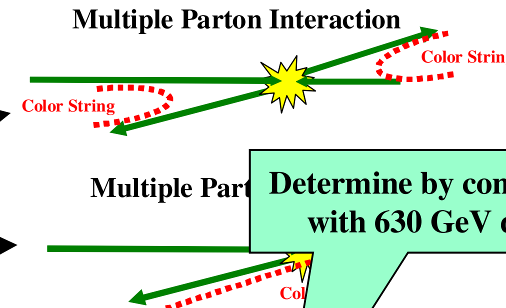
Tuning PYTHIA:
Multiple Parton Interaction Parameters

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	Pr… uces two gluons w… nearest neighbors.
PARP(86)	0.66	Prob… eit… s des… losed … loop. … ists of … ark-antiqua… s.
PARP(89)	1 Te…	Determin… reference energy E_0.
PARP(82)	…9 GeV/c	The c… off 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.

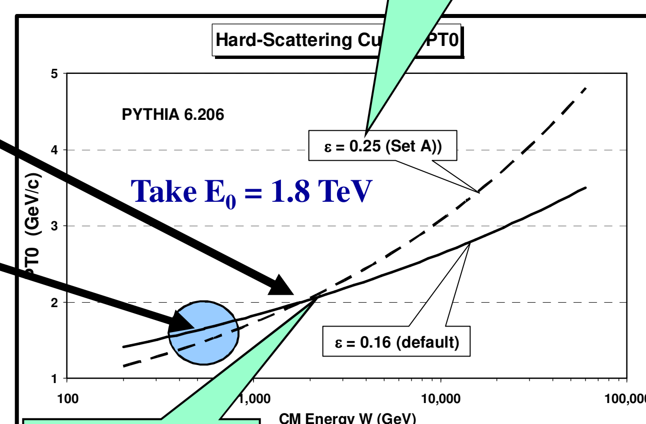
Determines the energy dependence of the MPI!

Affects the amount of initial-state radiation!



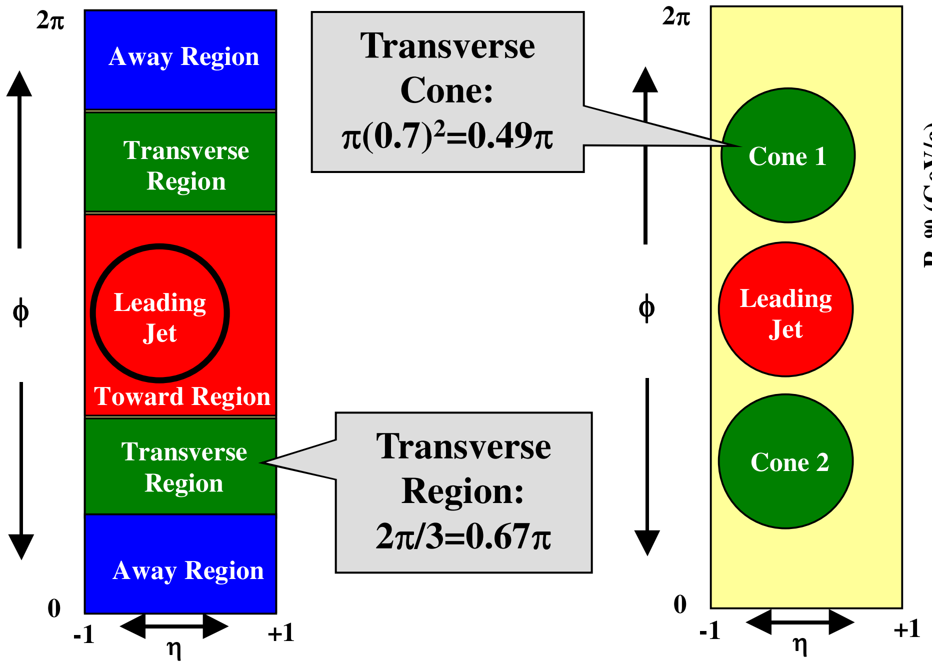


Determine by comparing with 630 GeV data!

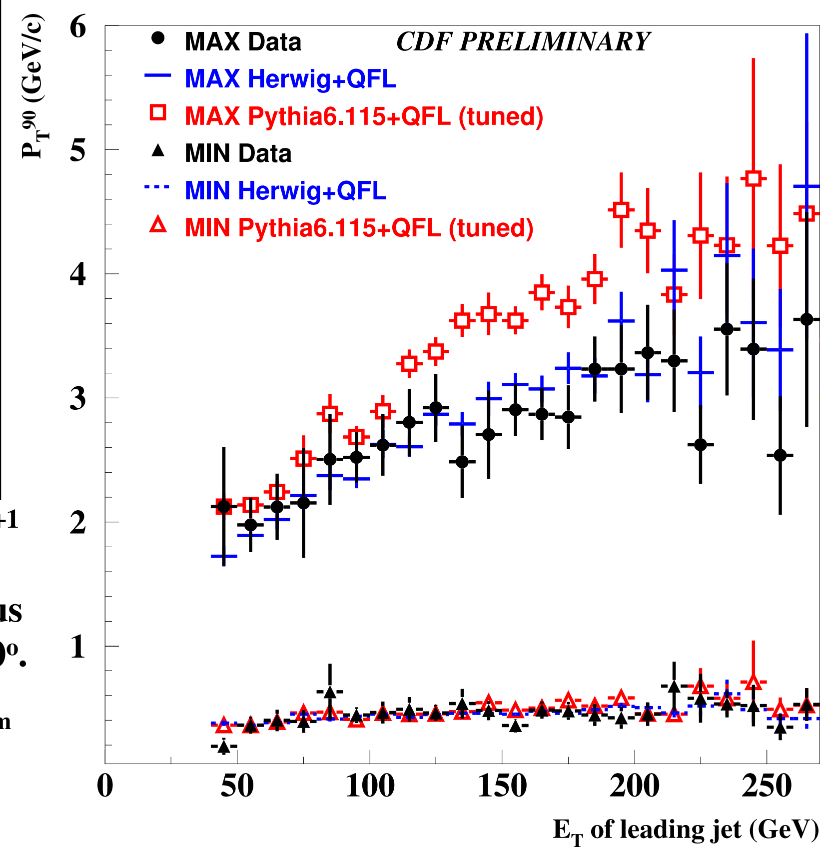


Reference point at 1.8 TeV

"Transverse" Cones vs "Transverse" Regions

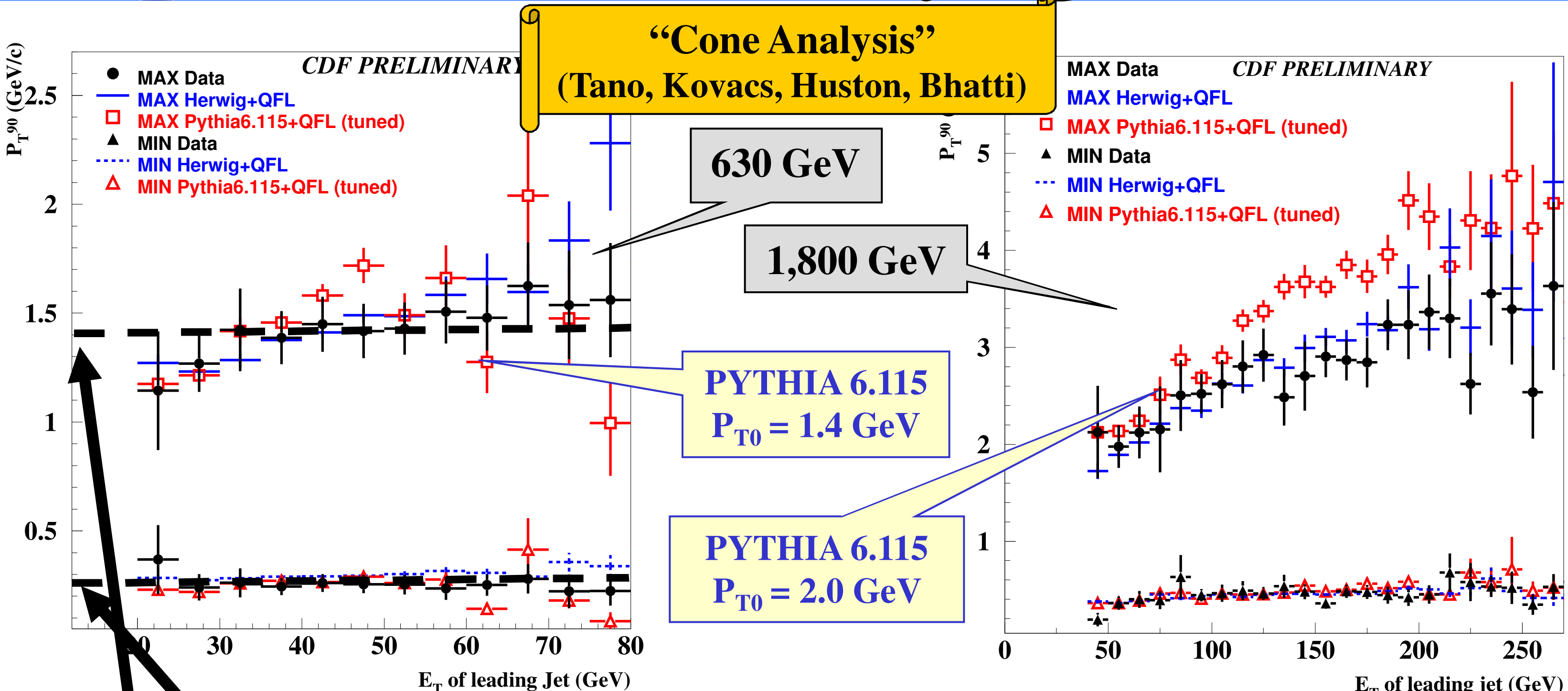


"Cone Analysis"
(Tano, Kovacs, Huston, Bhatti)



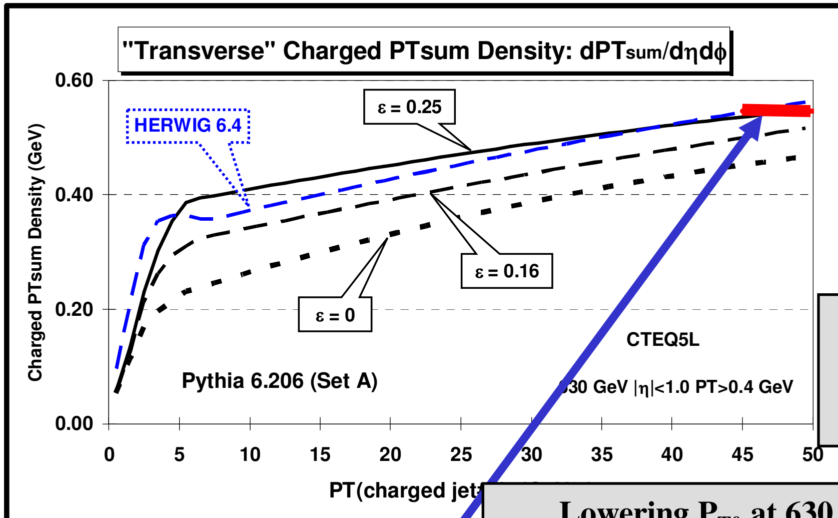
- Sum the P_T of charged particles in two cones of radius 0.7 at the same η as the leading jet but with |ΔΦ| = 90°.
- Plot the cone with the maximum and minimum PT_{sum} versus the E_T of the leading (calorimeter) jet.

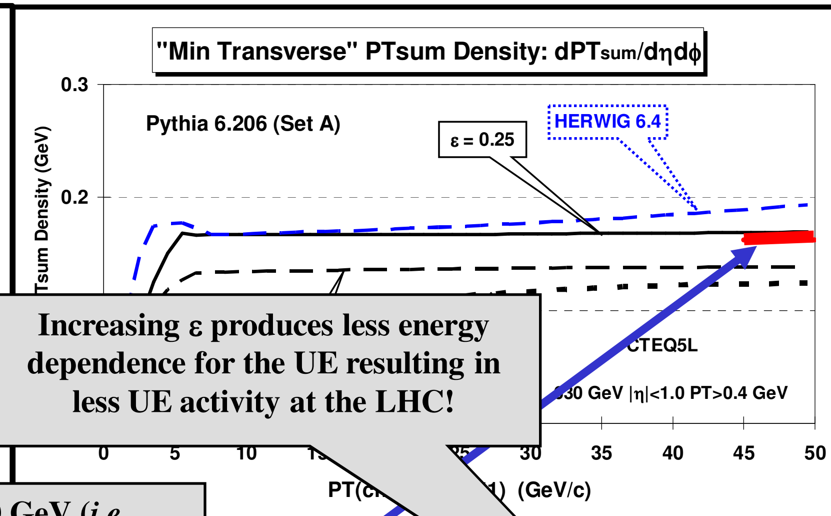
Energy Dependence of the "Underlying Event"

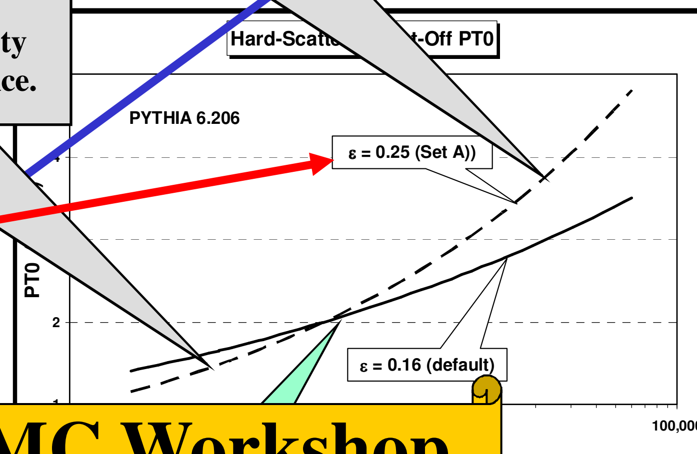


- Sum the P_T of charged particles ($p_T > 0.4$ GeV/c) in two cones of radius 0.7 at the same η as the leading jet but with |ΔΦ| = 90º. Plot the cone with the maximum and minimum PT_{sum} versus the E_T of the leading (calorimeter) jet.
- Note that PYTHIA 6.115 is tuned at 630 GeV with P_{T0} = 1.4 GeV 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







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 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! (not the default)

PYTHIA 6.2 Tunes

All use LO α_s with Λ = 192 MeV!

UE Parameters

Parameter	Tune DWT	Tune D6T	
PDF	CT	CTEQ6L	L
MSTP(81)		1	
STP(82)		4	

S energy dependence!

Tune A

Tune BW

Tune D

Tune 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 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 c
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

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

[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
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atron, 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]
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balance and different collider

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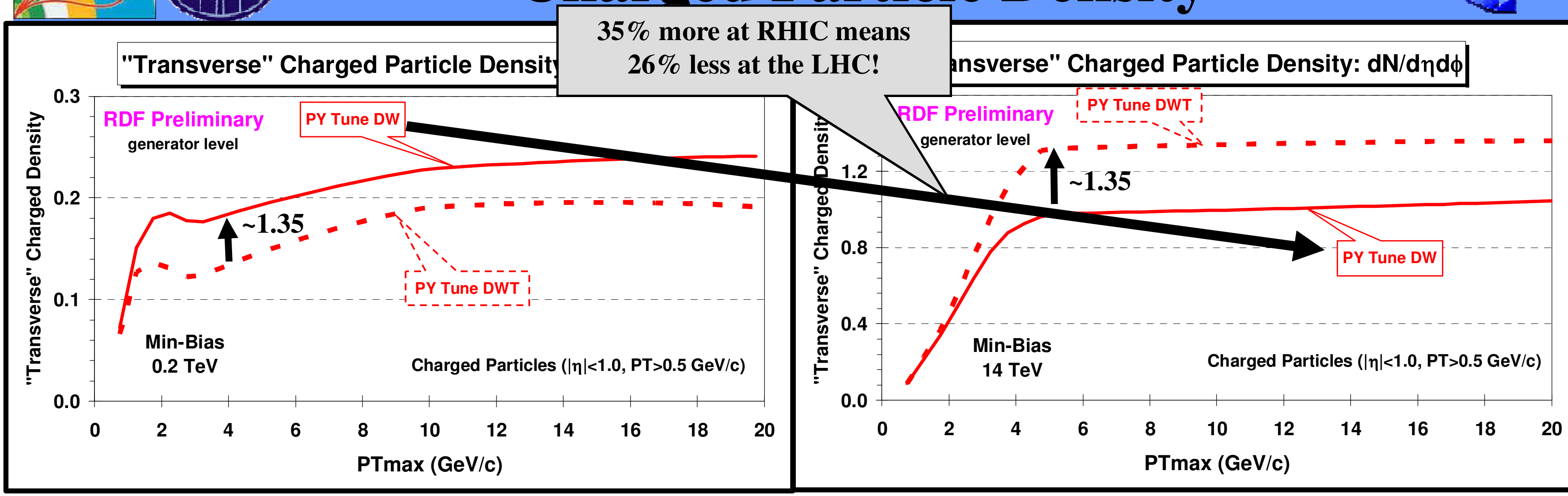
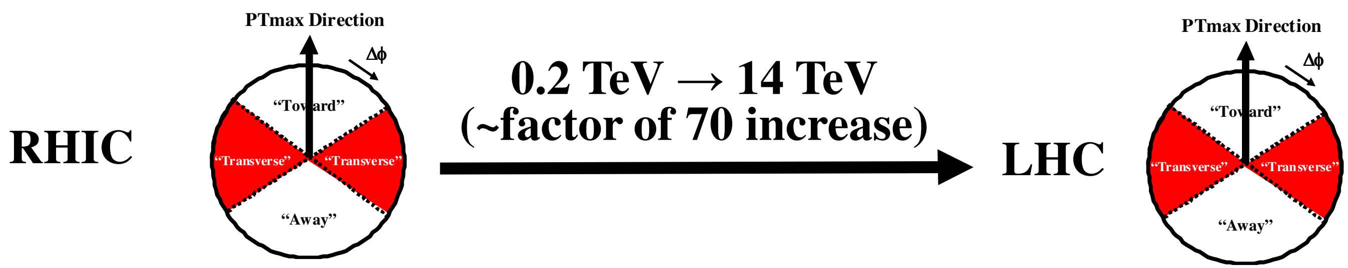
E framework made with

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

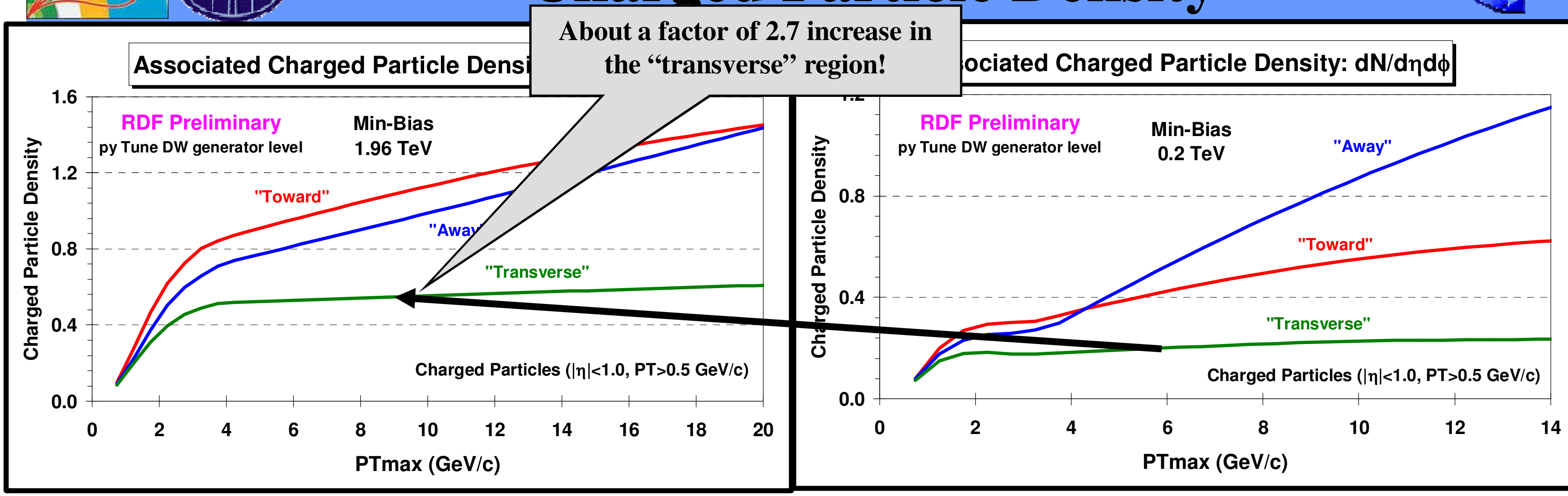
Min-Bias "Associated" Charged Particle Density

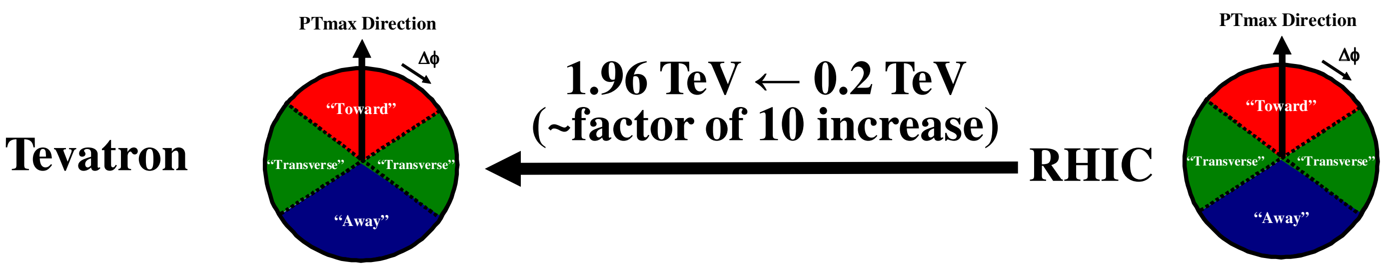




- Shows the "associated" charged particle density in the "transverse" regions as a function of PTmax for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$, *not including PTmax*) for "min-bias" events at 0.2 TeV and 14 TeV from PYTHIA Tune DW and Tune DWT at the particle level (*i.e.* generator level).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

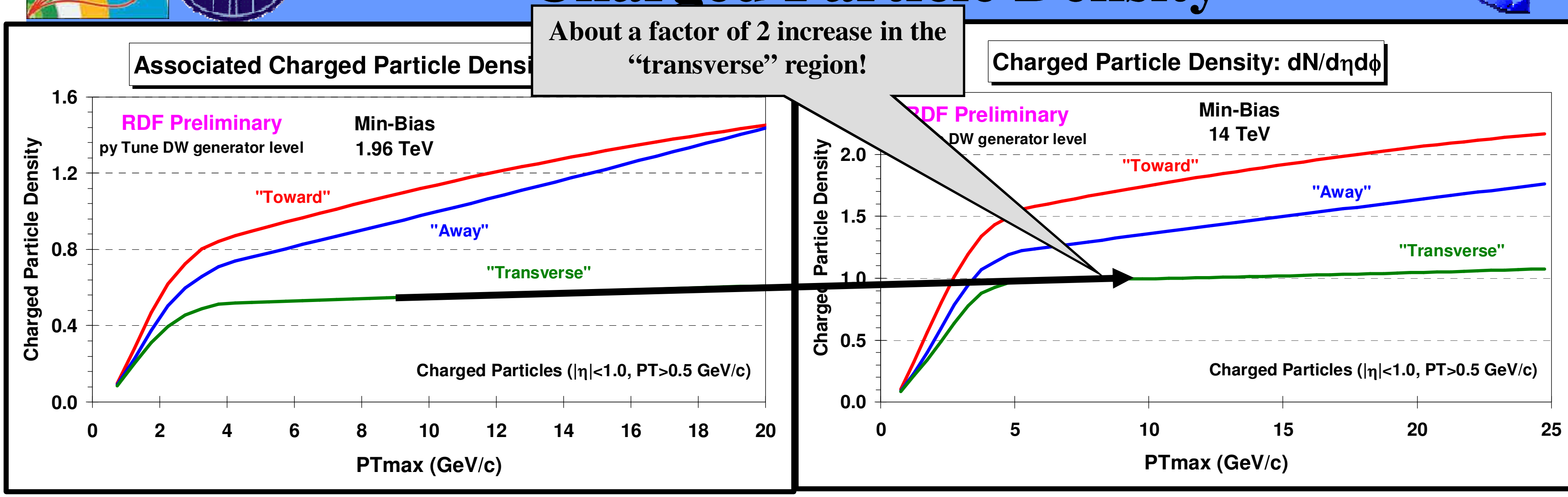
Min-Bias "Associated" Charged Particle Density



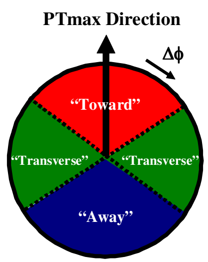


- Shows the "associated" charged particle density in the "toward", "away" and "transverse" regions as a function of PTmax for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$, *not including PTmax*) for "min-bias" events at 1.96 TeV and at 0.2 TeV from PYTHIA Tune DW at the particle level (*i.e.* generator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

Min-Bias "Associated" Charged Particle Density

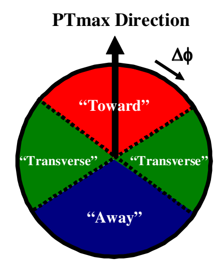


Tevatron



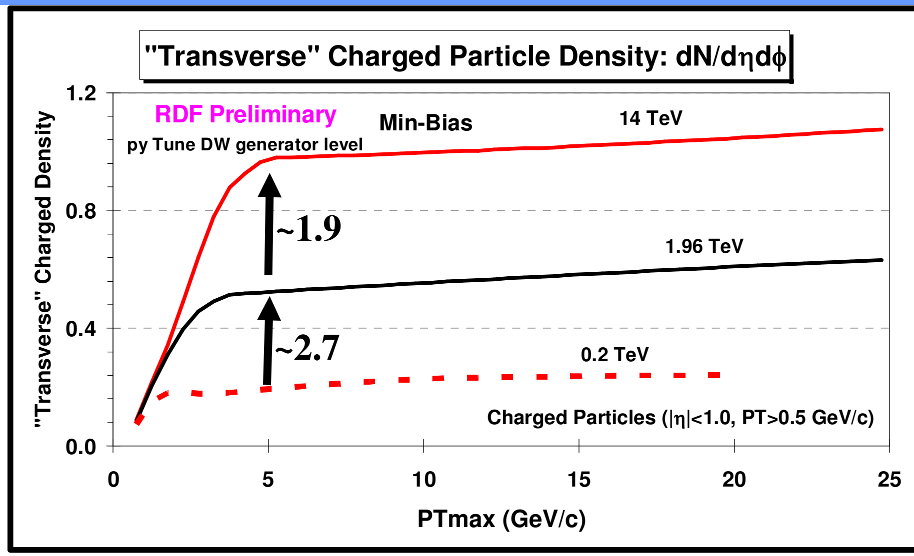
1.96 TeV → 14 TeV (~factor of 7 increase)

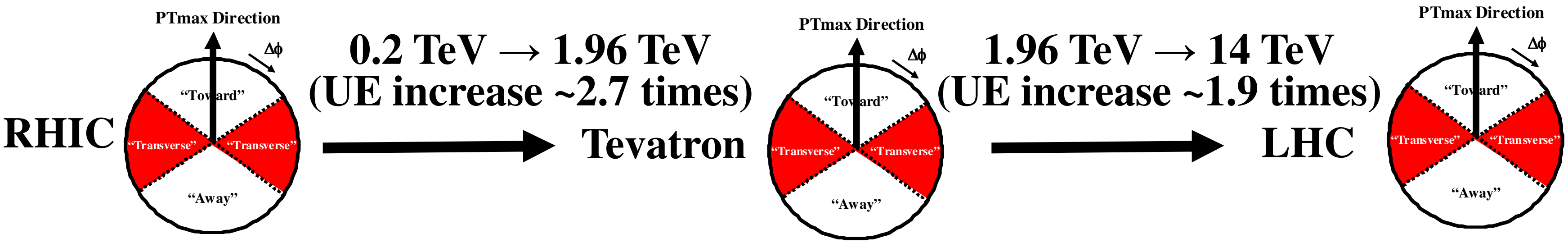
LHC



- **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

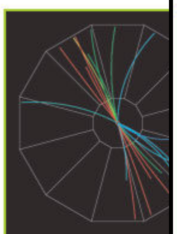




- Shows the "associated" charged particle density in the "transverse" region as a function of PTmax for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$, *not including PTmax*) for "min-bias" events at 0.2 TeV, 1.96 TeV and 14 TeV predicted by PYTHIA Tune DW at the particle level (*i.e.* generator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

The "Underlying Event" at STAR

RHIC



UK

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.

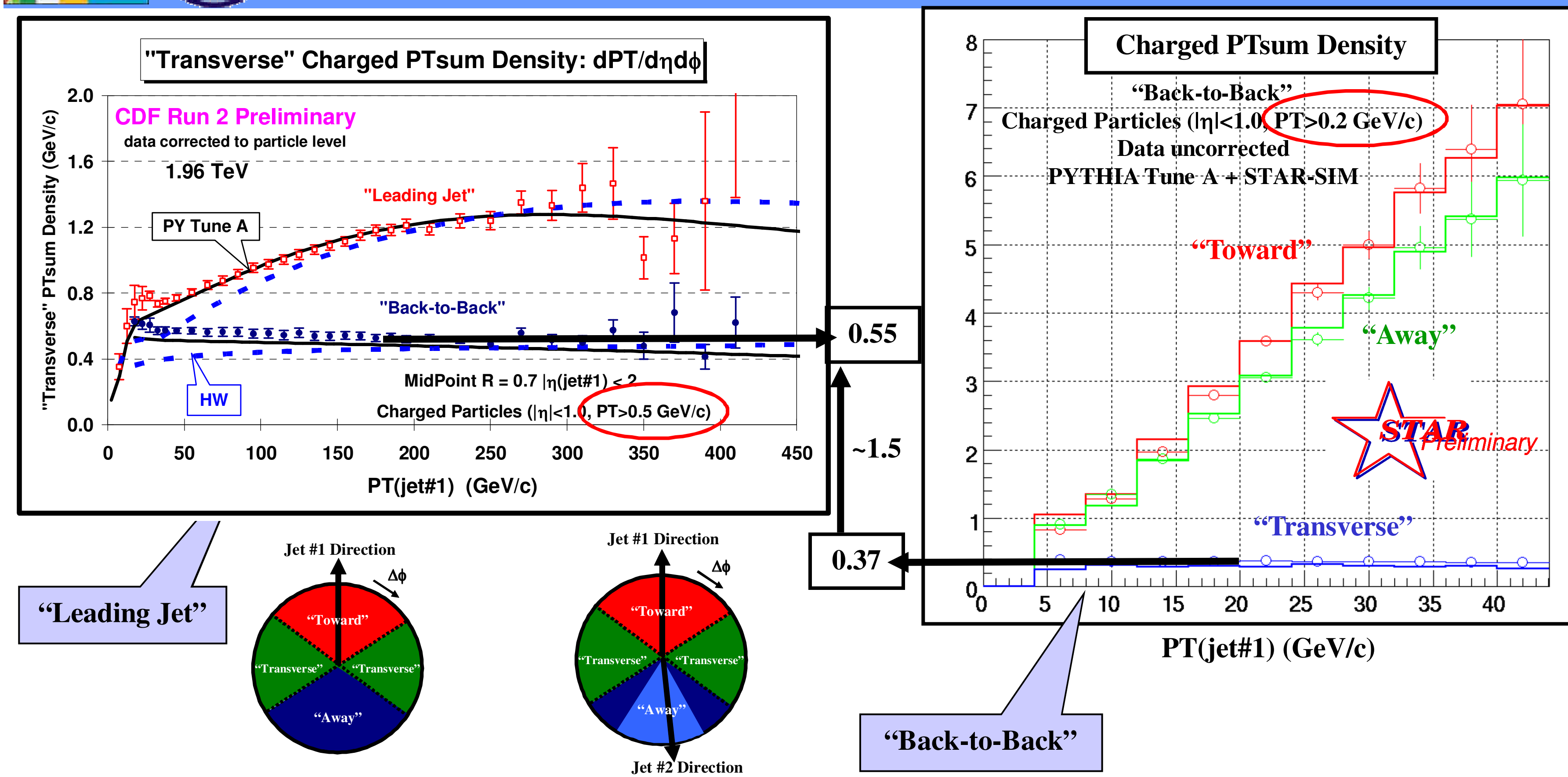
VII. For a cone jet with R=0.7 UE contributes 0.5-0.9 GeV.

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

ergies are
egion.

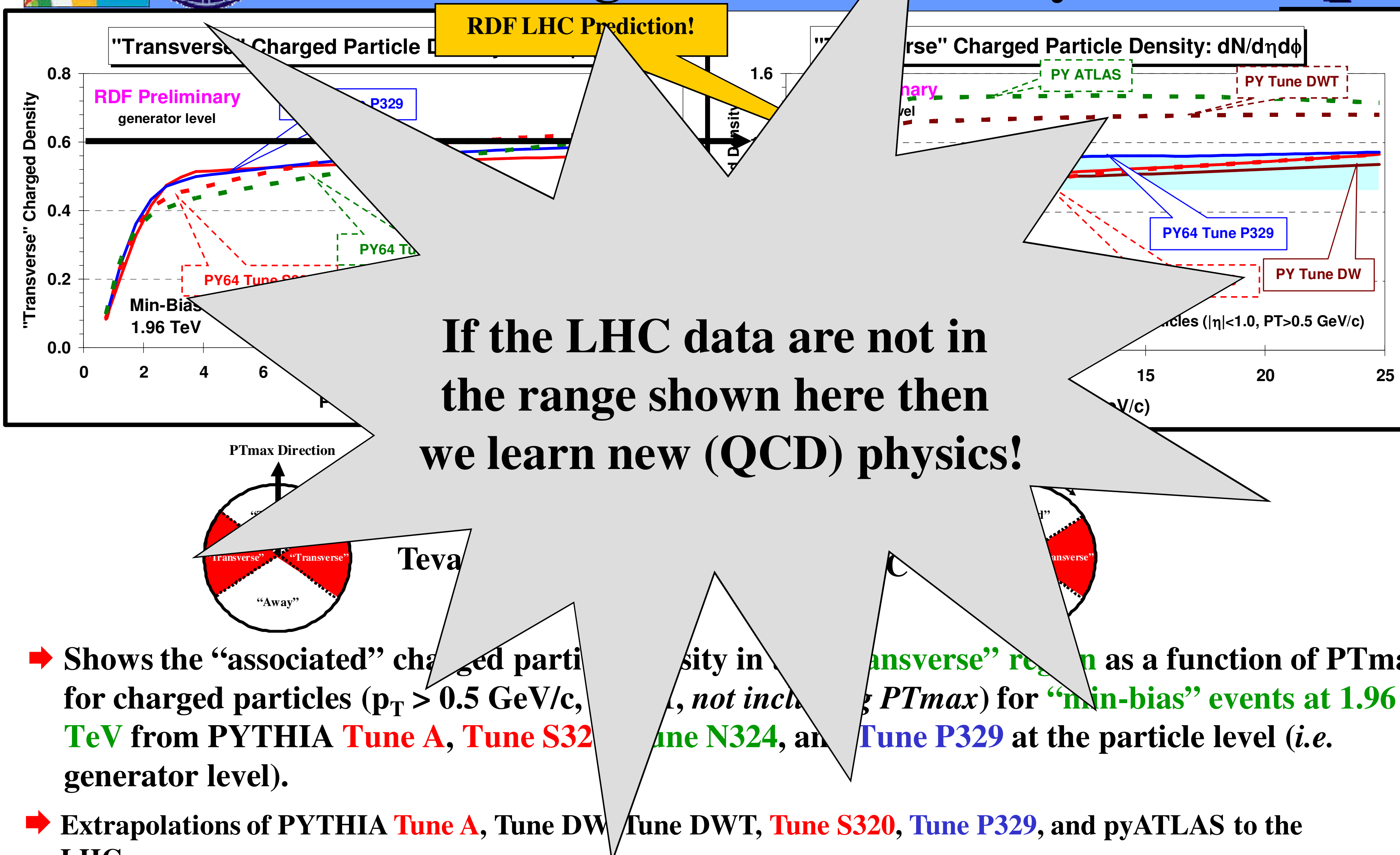
➡ **At STAR** ... **2 GeV)**
and com...

The "Underlying Event" at STAR



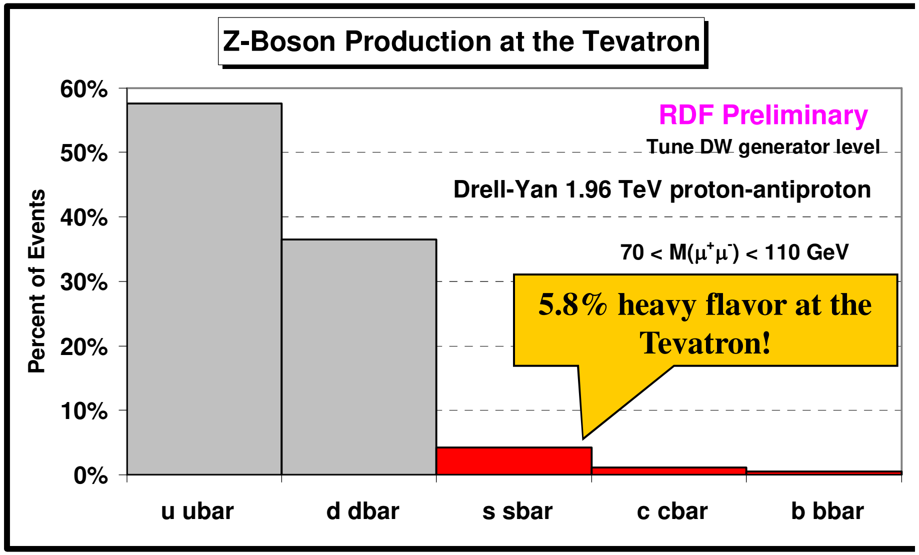
- Data on the charged particle *scalar* p_T sum density, $dPT/d\eta d\phi$, as a function of the leading jet p_T for the "toward", "away", and "transverse" regions compared with PYTHIA Tune A.

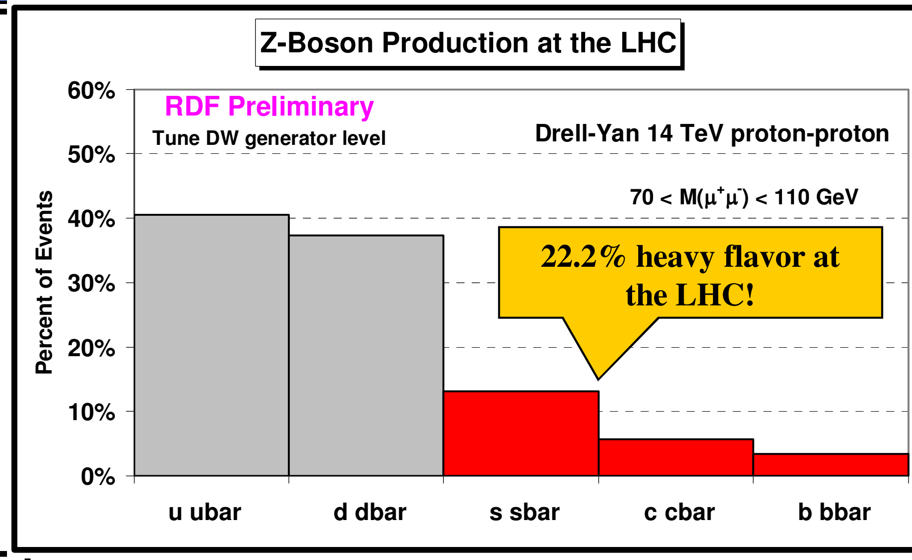
Min-Bias "Associated" Charged Particle Density

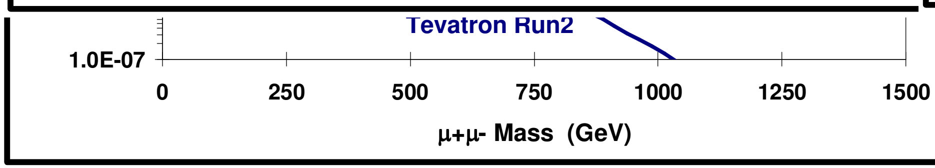


- Shows the "associated" cha ged parti sity in ansverse" re n as a function of PTmax for charged particles (p_T > 0.5 GeV/c, , *not incl g PTmax*) for "min-bias" events at 1.96 TeV from PYTHIA Tune A, Tune S32 une N324, an Tune P329 at the particle level (*i.e.* generator level).
- Extrapolations of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

The Drell-Yan Cross Section





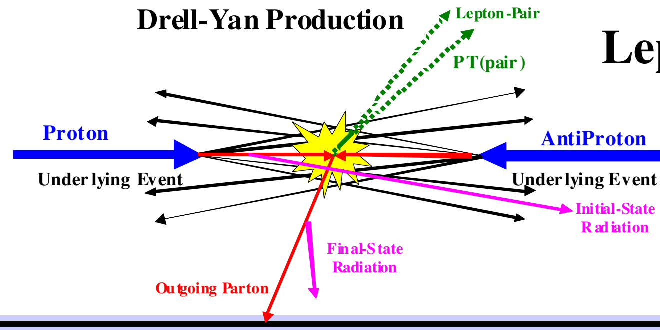


Yan Lepton-Pair ($\mu^+\mu^-$) cross section, $d\sigma/dM$, versus the lepton-pair invariant mass from PYTHIA Tune AW.

- **Shows the Drell-Yan Lepton-Pair ($\mu^+\mu^-$) cross section, $d\sigma/dM$, at the 1.96 TeV (Tevatron Run 2) and at 14 TeV (LHC) versus the lepton-pair invariant mass from PYTHIA Tune AW.**

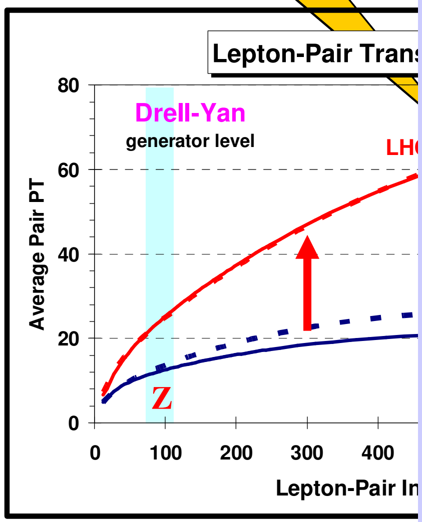
Drell-Yan Production Tevatron vs LHC

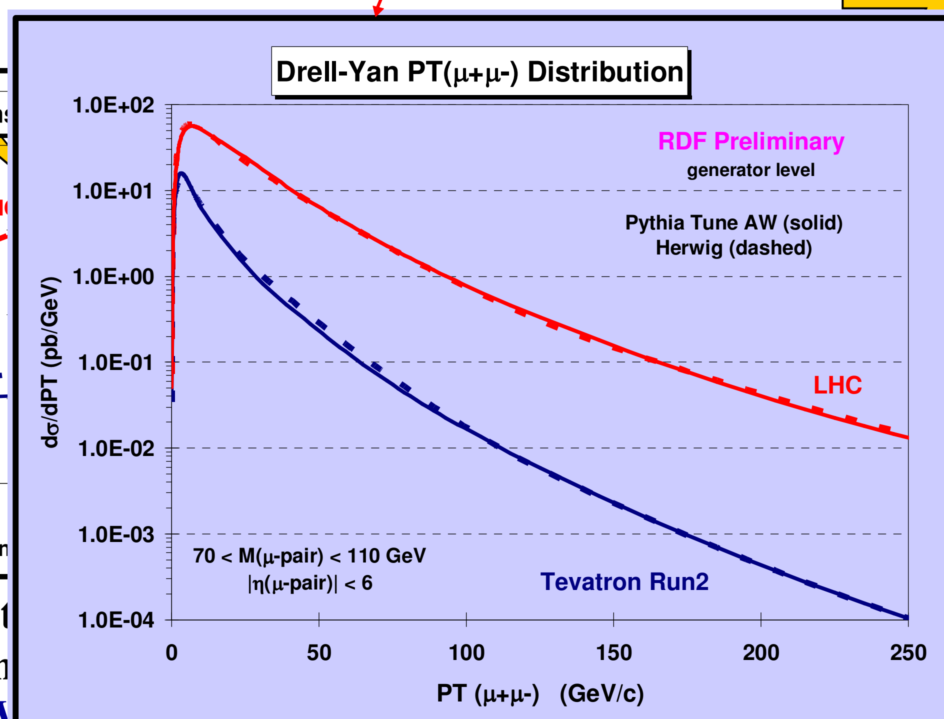
Lepton-Pair Transverse Momentum

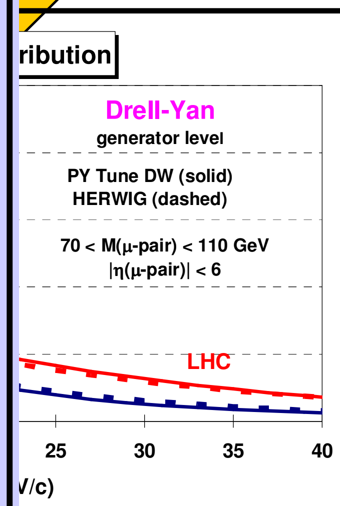


$<p_T(\mu^+\mu^-)>$ is much larger at the LHC!

Shapes of the $p_T(\mu^+\mu^-)$ distribution at the Z-boson mass.

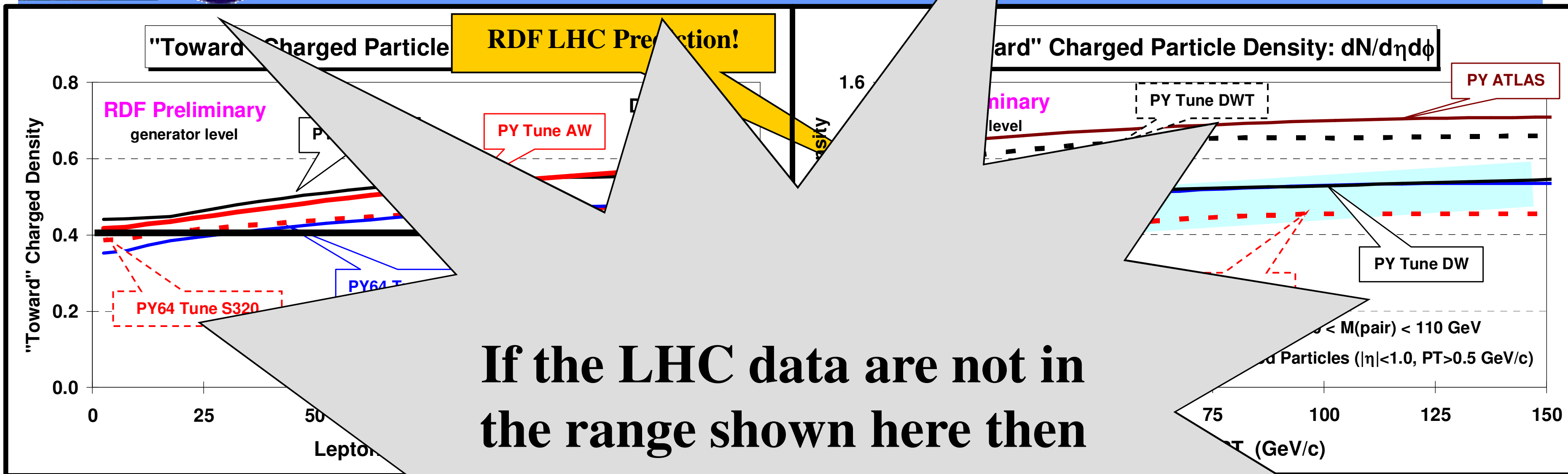




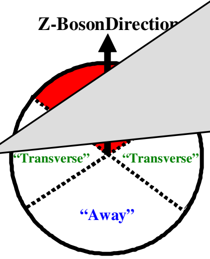


- **Average Lepton-Pair t** … **p_T distribution at the at the Tevatron and th** … **tron and the LHC for Tune DW and HERW** … **HERWIG (*without MPI*).**

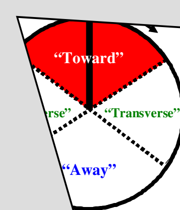
Z-Boson: “Towards” Region



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

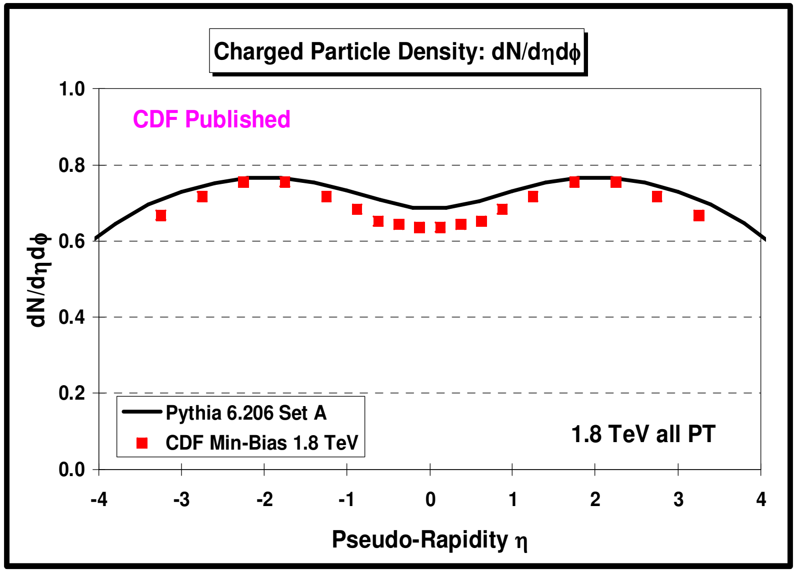


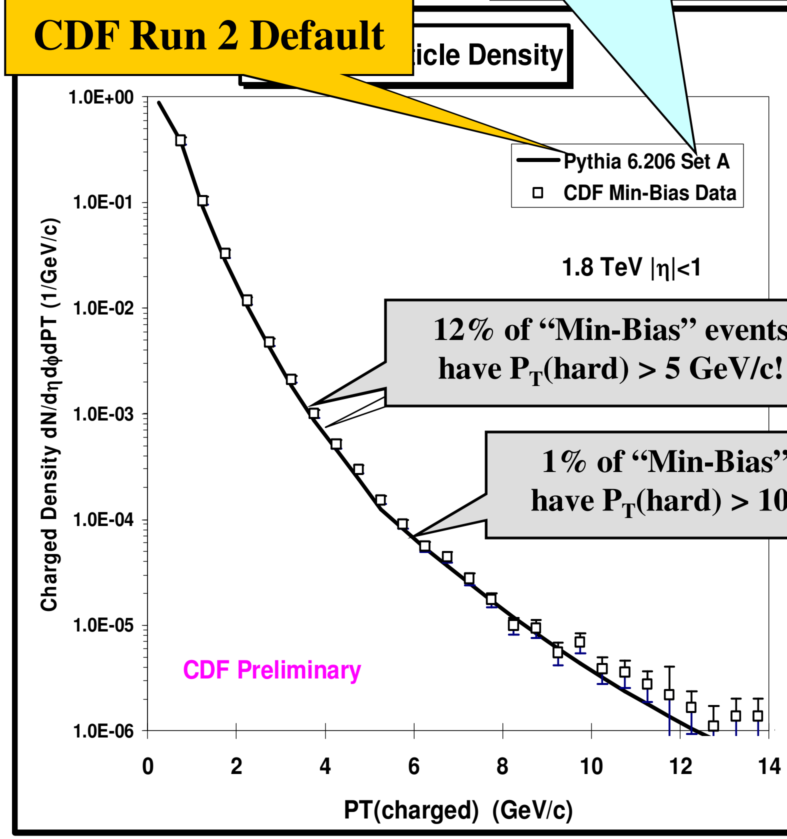
Teva



- Data at 1.96 TeV on the densi of charge 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” region 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.

PYTHIA Tune A Min-Bias “Soft” + ”Hard”





PYTHIA Tune A CDF Run 2 Default

Tuned to fit the CDF Run 1 “underlying event”!

12% of “Min-Bias” events have P_T(hard) > 5 GeV/c!

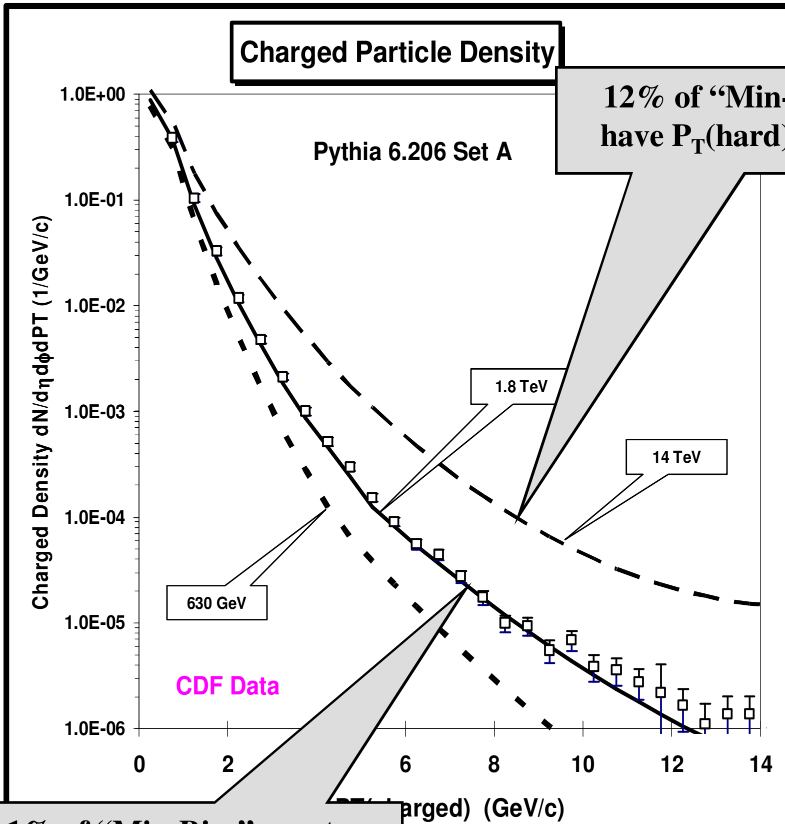
1% of “Min-Bias” events have P_T(hard) > 10 GeV/c!

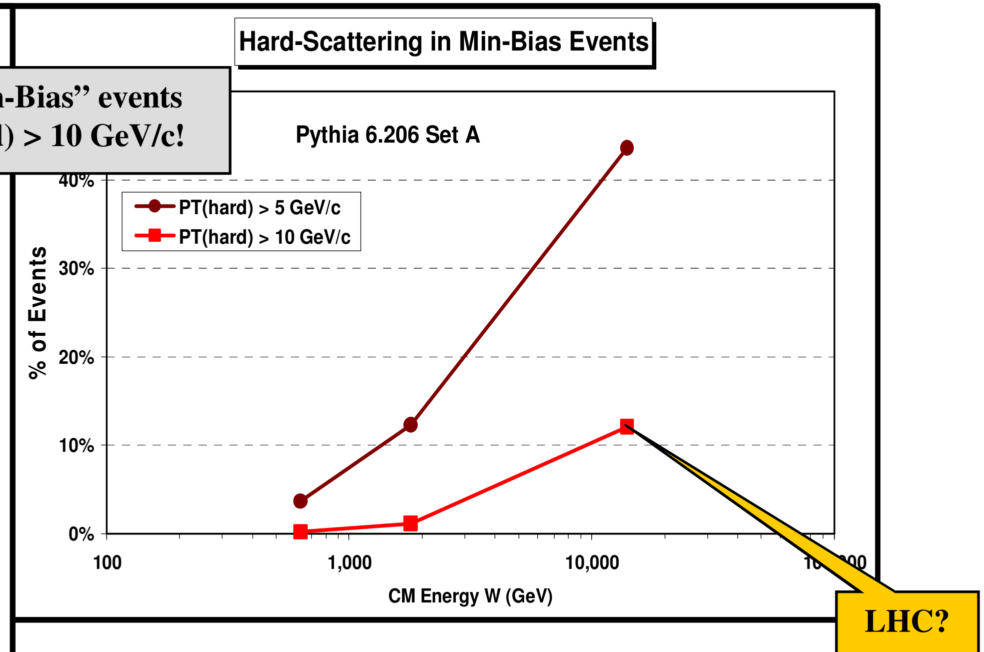
- **PYTHIA regulates the perturbative 2-to-2 parton-parton cross sections with cut-off ... one to run with ... ulate both “hard” and “soft” collisio... one program.**

Lots of “hard” scattering in “Min-Bias” at the Tevatron!

- **The relative amount of ...rd” versus “soft” depends on the cut-off and can be tuned.**
- **This PYTHIA fit predicts that 12% of all “Min-Bias” events are a result of a hard 2-to-2 parton-parton scattering with P_T(hard) > 5 GeV/c (1% with P_T(hard) > 10 GeV/c)!**

PYTHIA Tune A LHC Min-Bias Predictions

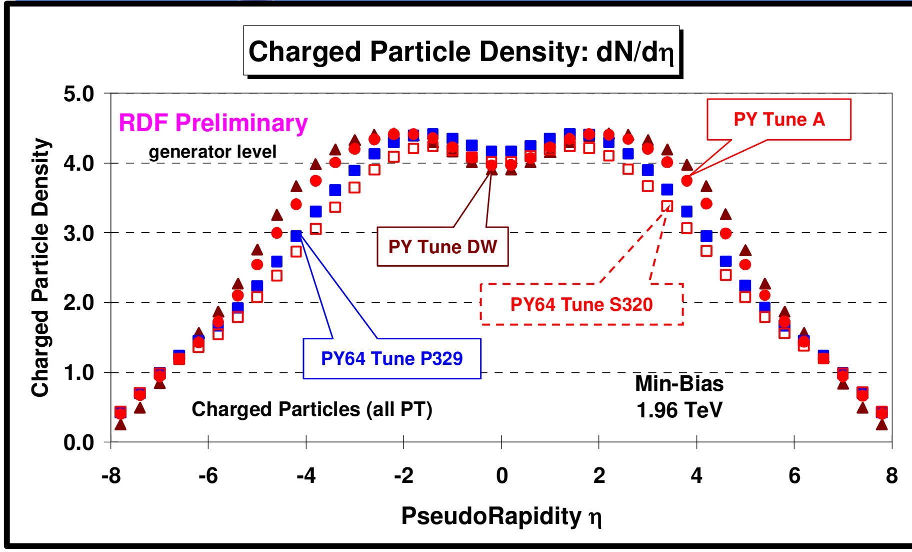


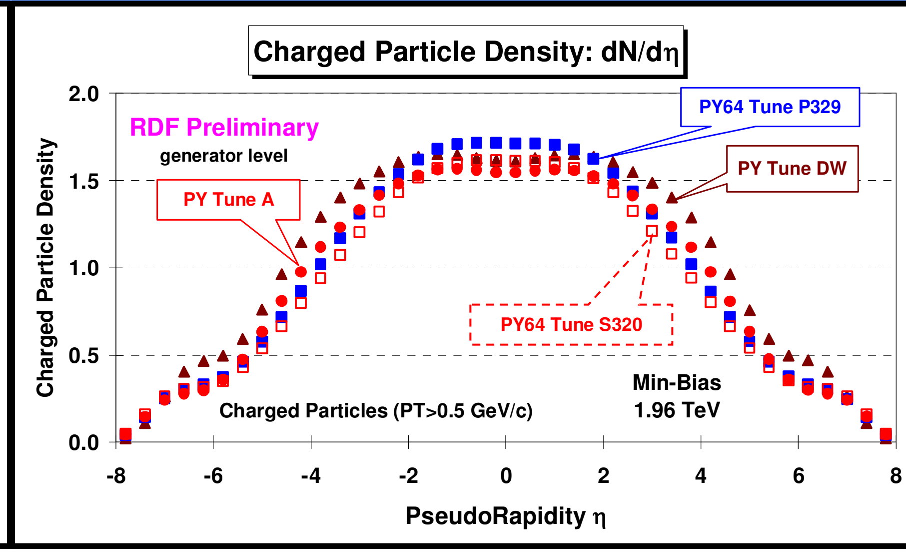


- Shows the center-of-mass energy dependence of the charged particle density, $dN_{chg}/d\eta d\phi dP_T$, for "Min-Bias" collisions compared with PYTHIA Tune A with P_T(hard) > 0.

- 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!

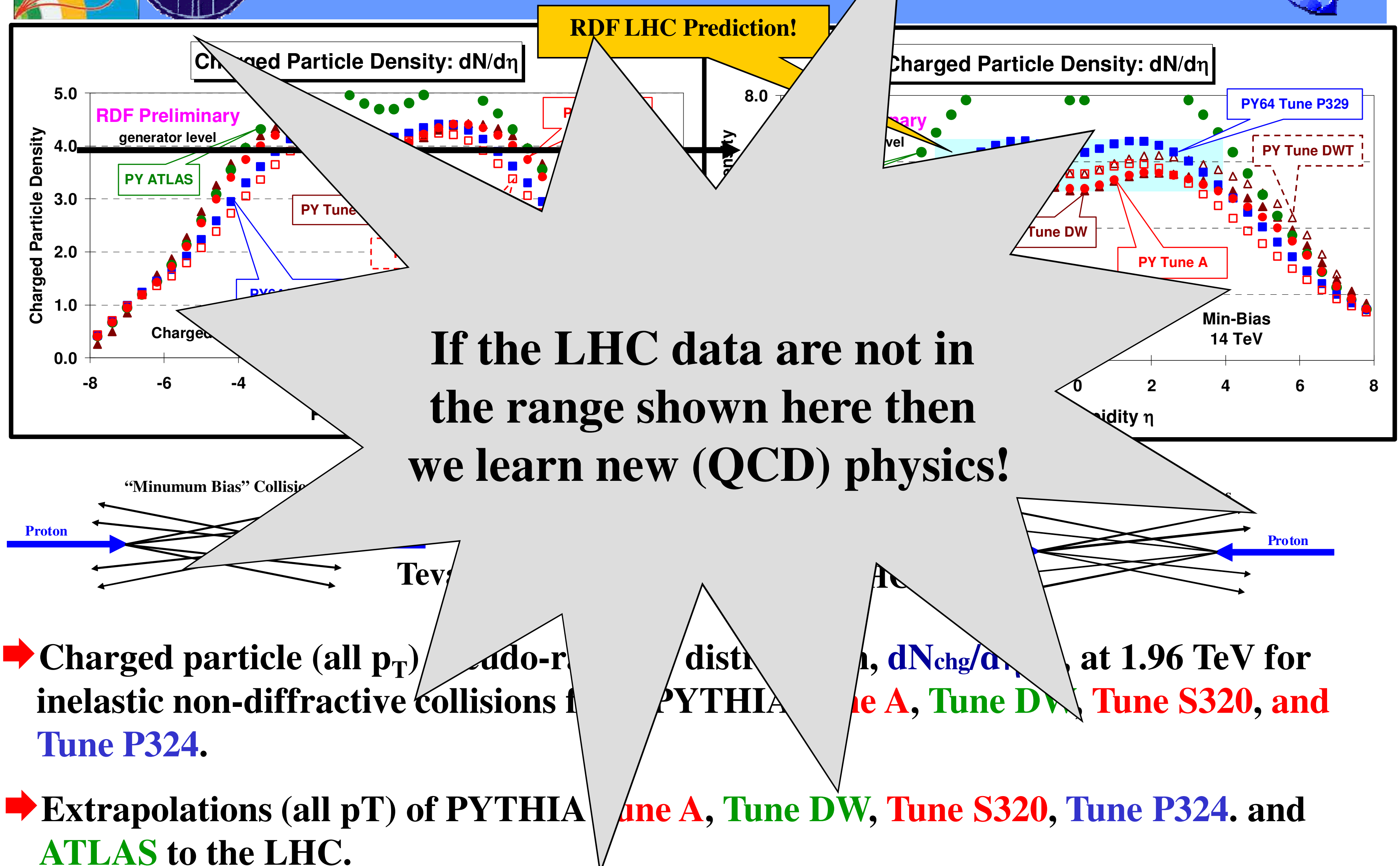
Charged Particle Density: dN/dη





- 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.

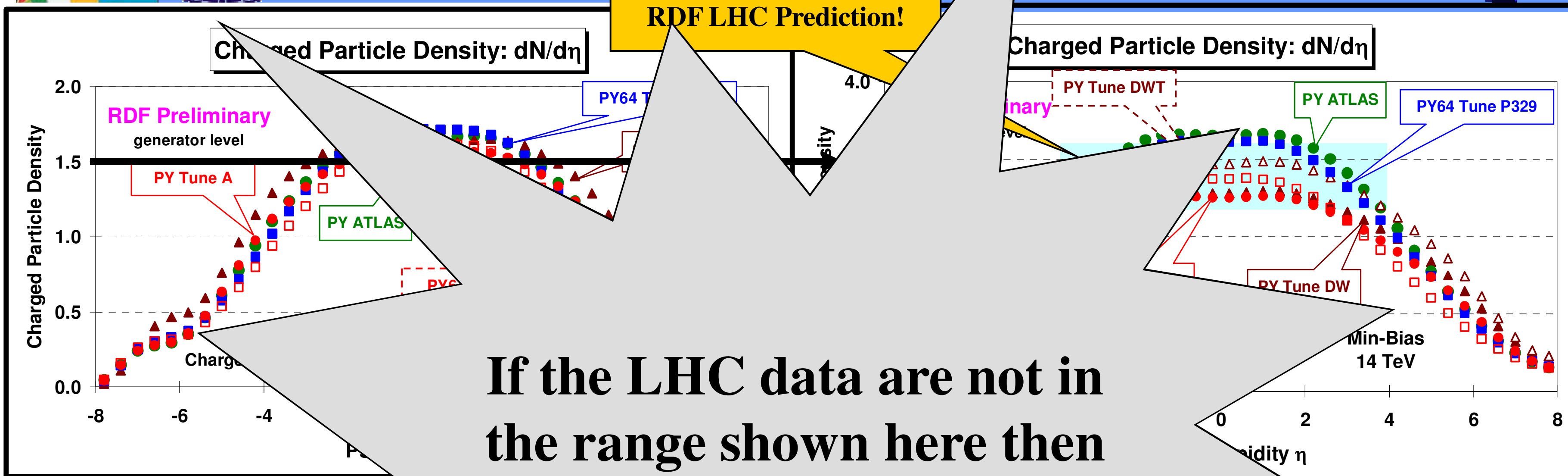
Charged Particle Density: dN/dη



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

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

Charged Particle Density: dN/dη

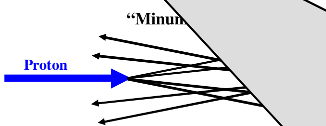


If the LHC data are not in the range shown here then we learn new (QCD) physics!

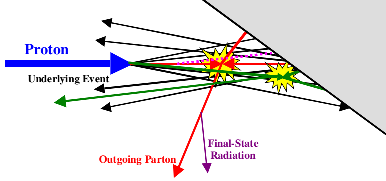
- Charged particle (p_T > 0. … eV/c) … -rap… stribution … $N_{chg}/d\eta d\phi$, at 1.96 TeV for inelastic non-diffractive collisio… om PYT… Tune A, Tune DW, Tune S320, and Tune P324.
- Extrapolations (p_T > 0.5 GeV/c) of P… THIA Tune A, Tune DW, Tune S320, Tune P324. and ATLAS to the LHC.

LHC Predictions

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

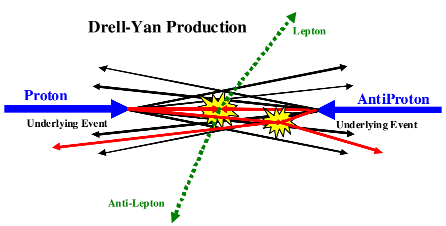


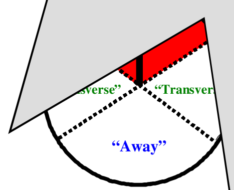
➡ The amount of activity in "mi...



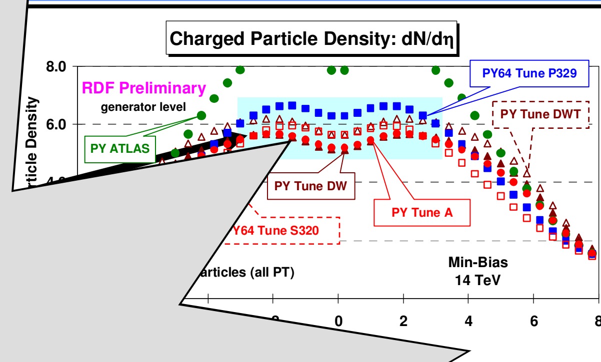
If the LHC data are not in the range shown here then we learn new (QCD) physics!

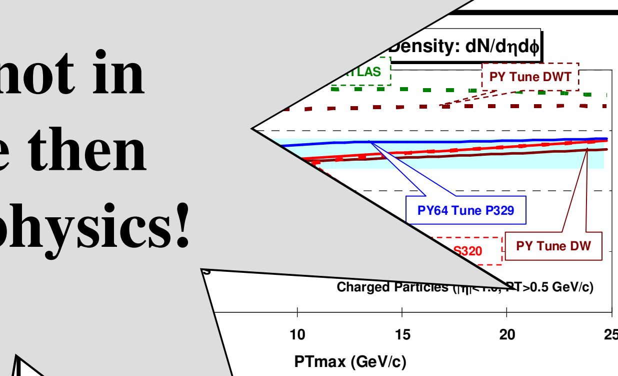
➡ The amount of acti... scattering eve...

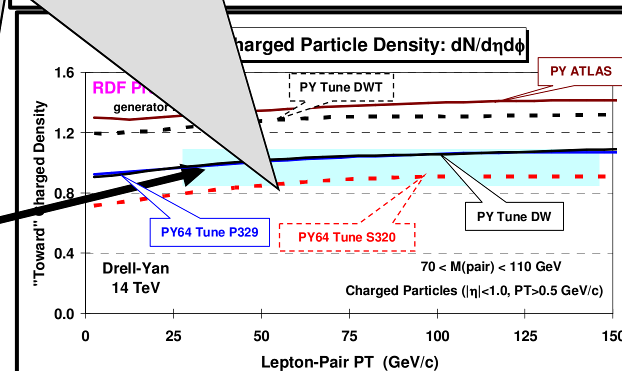




➡ The amount of activity in the "underlying ev..." in Drell-Yan events.

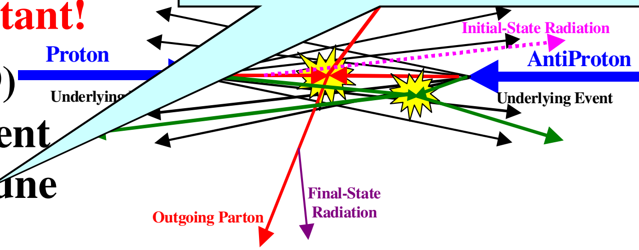




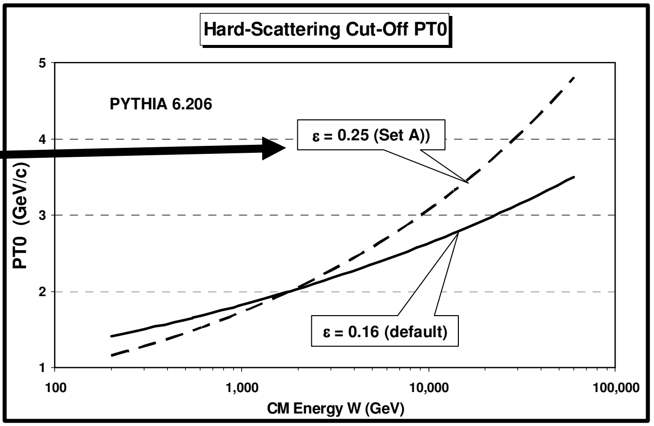


Summary & Conclus

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