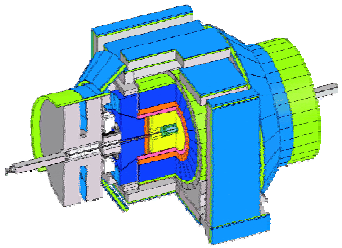
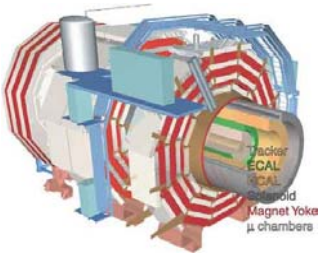
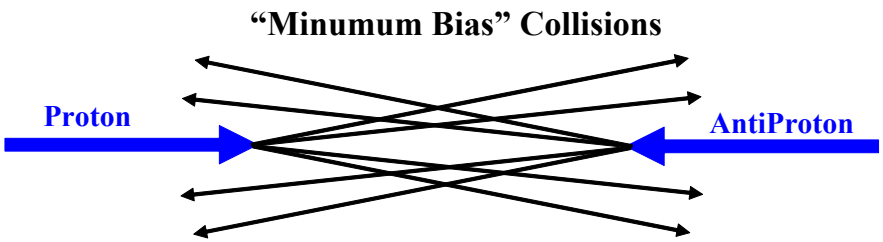
"Minimum Bias" at CDF and CMS



CDF Run 2



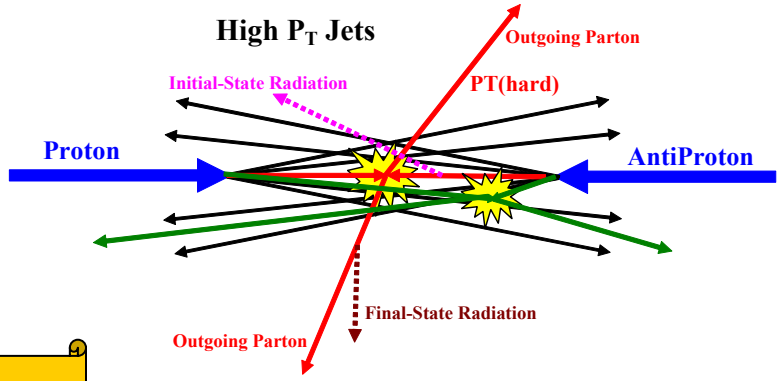
CMS



Outline of Talk

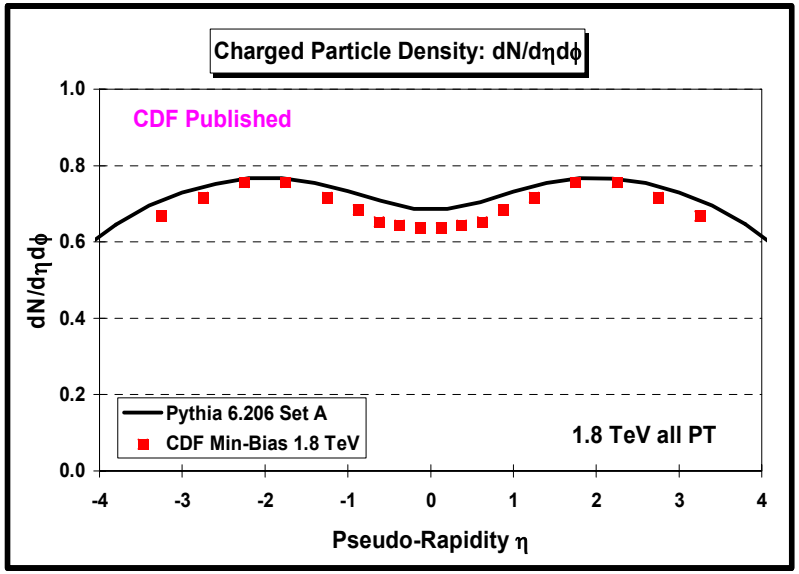
- Review the CDF Run 2 "minimum bias" tune (*i.e.* PYTHIA Tune A).
- Show the "minimum bias" predictions for PYTHIA Tune A, Tune DW, Tune DWT, and the ATLAS tune at the LHC.
- These tunes are discussed in our CMS note on the "underlying event".

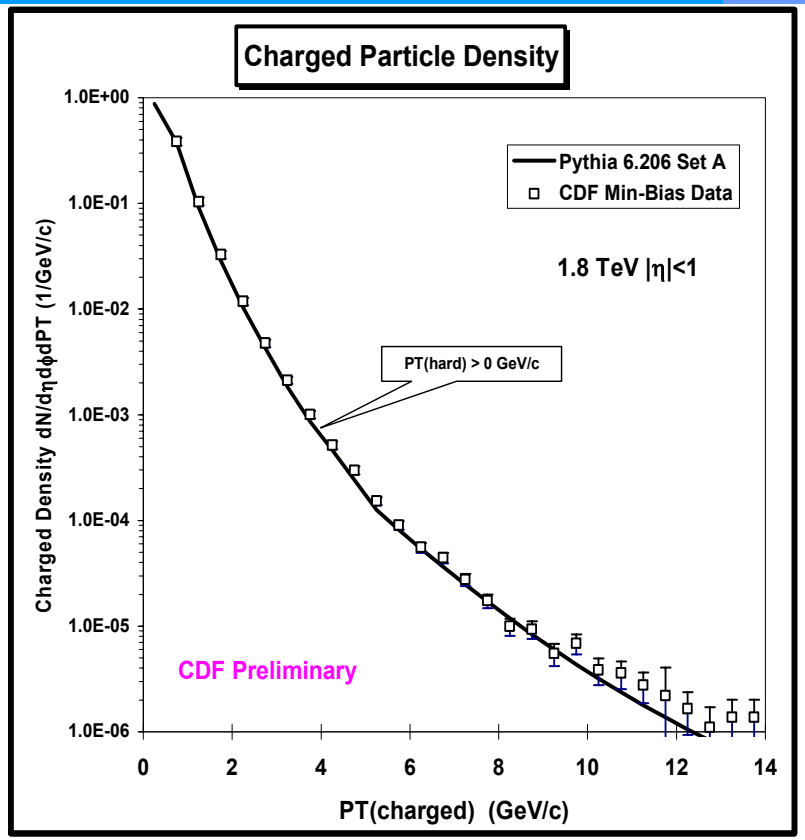
UE&MB@CMS



CMS NOTE-2006/067

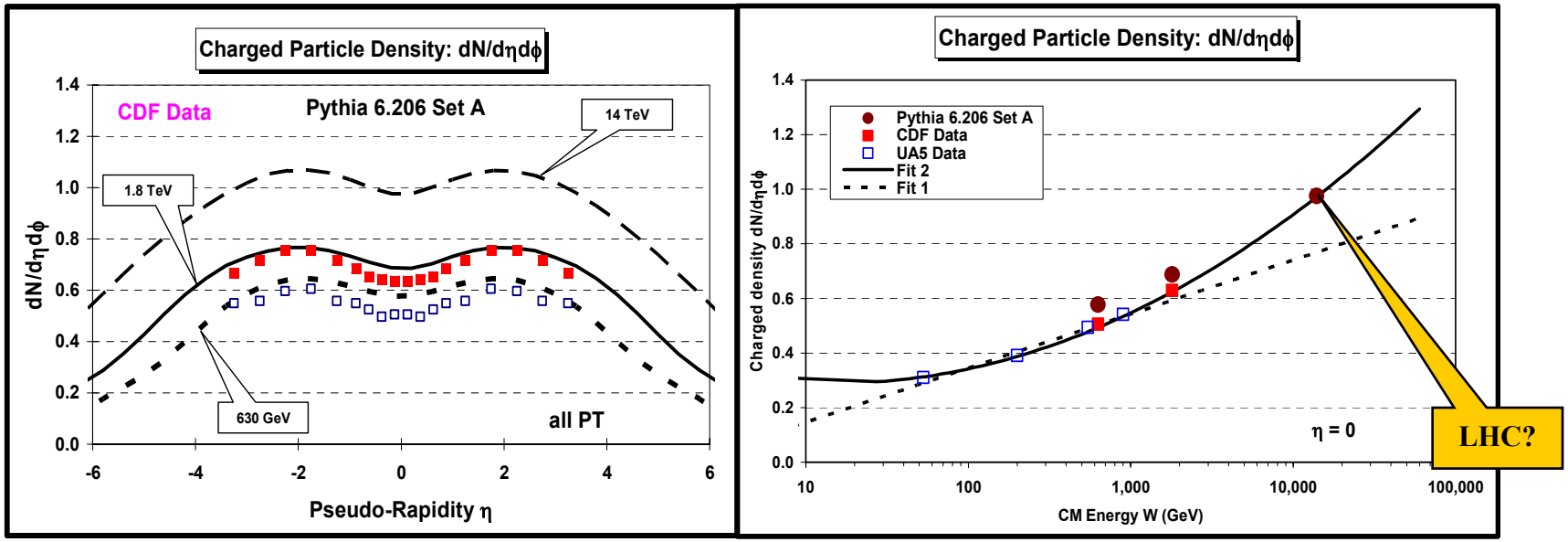
PYTHIA Tune A Min-Bias





- **PYTHIA regulates the perturbative 2-to-2 parton-parton cross sections with cut-off parameters which allows one to run with P_T(hard) > 0. One can simulate both "hard" and "soft" collisions in one program.**
- **The relative amount of "hard" 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, $dN_{chg}/d\eta d\phi$, for "Min-Bias" collisions compared with PYTHIA Tune A with $P_T(hard) > 0$.
- PYTHIA was tuned to fit the "underlying event" in hard-scattering processes at 1.8 TeV and 630 GeV.
- PYTHIA Tune A predicts a 42% rise in $dN_{chg}/d\eta d\phi$ at $\eta = 0$ in going from the Tevatron (1.8 TeV) to the LHC (14 TeV). Similar to HERWIG "soft" min-bias, 4 charged particles per unit η becomes 6.

CDF Run 1 $P_T(Z)$

PYTHIA 6.2 CTEQ5L

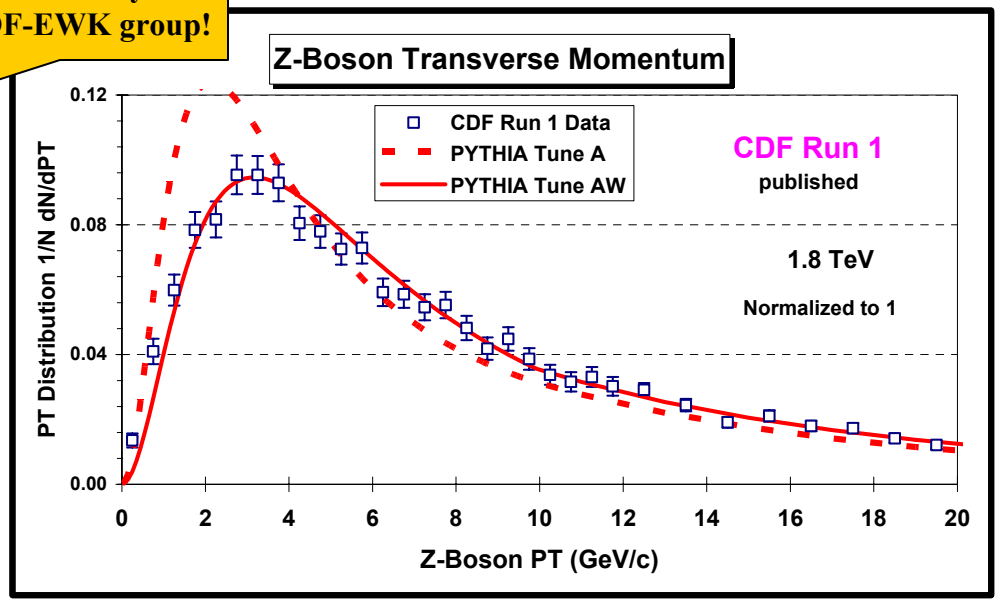
Parameter	Tune A	Tune AW
MSTP(81)	1	1
MSTP(82)	4	4
PARP(82)	2.0 GeV	2.0 GeV
PARP(83)	0.5	0.5
PARP(84)	0.4	0.4
PARP(85)	0.9	0.9
PARP(86)	0.95	0.95
PARP(89)	1.8 TeV	1.8 TeV
PARP(90)	0.25	0.25
PARP(62)	1.0	1.25
PARP(64)	1.0	0.2
PARP(67)	4.0	4.0
MSTP(91)	1	1
PARP(91)	1.0	2.1
PARP(93)	5.0	15.0

UE Parameters

ISR Parameters

Intrensic KT

Tune used by the CDF-EWK group!



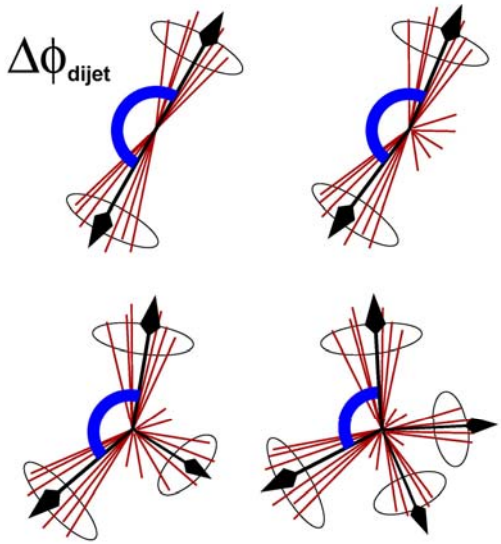
- **Shows the Run 1 Z-boson p_T distribution ($\langle p_T(Z)\rangle \approx 11.5$ GeV/c) compared with PYTHIA Tune A ($\langle p_T(Z)\rangle = 9.7$ GeV/c), and PYTHIA Tune AW ($\langle p_T(Z)\rangle = 11.7$ GeV/c).**

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

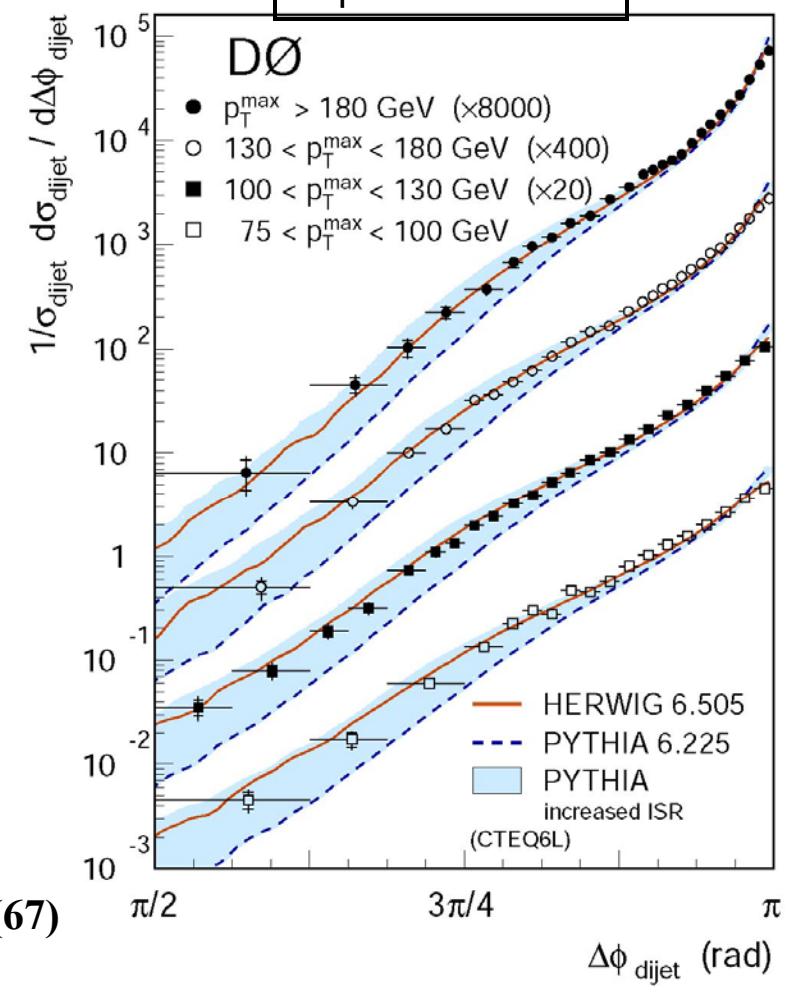
The $Q^2 = k_T^2$ in α_s for space-like showers is scaled by PARP(64)!

Jet-Jet Correlations (DØ)

Jet#1-Jet#2 Δϕ Distribution



Δϕ Jet#1-Jet#2



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

PYTHIA Tune DW

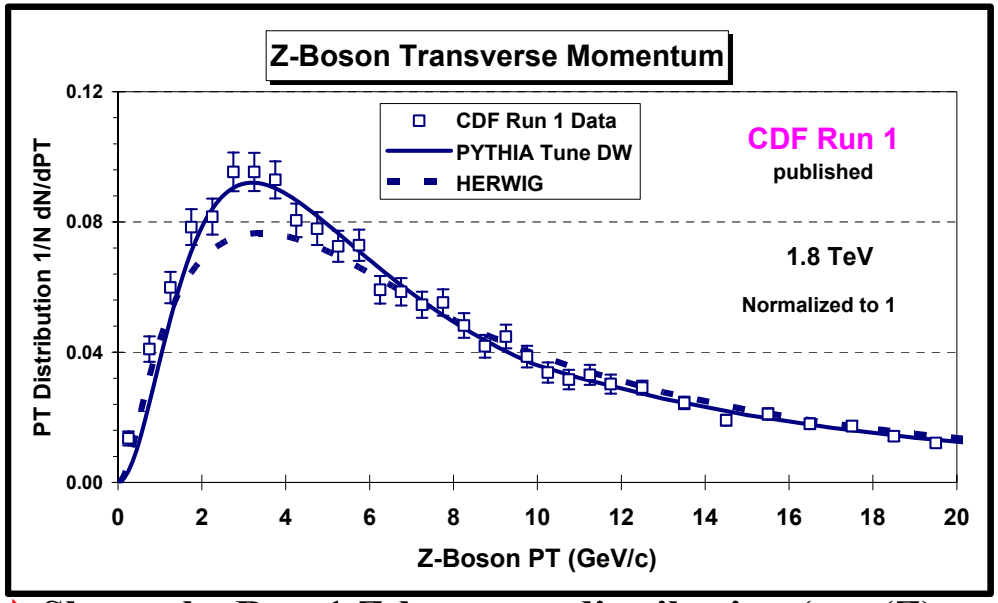
PYTHIA 6.2 CTEQ5L

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

UE Parameters

ISR Parameters

Intrensic KT



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

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

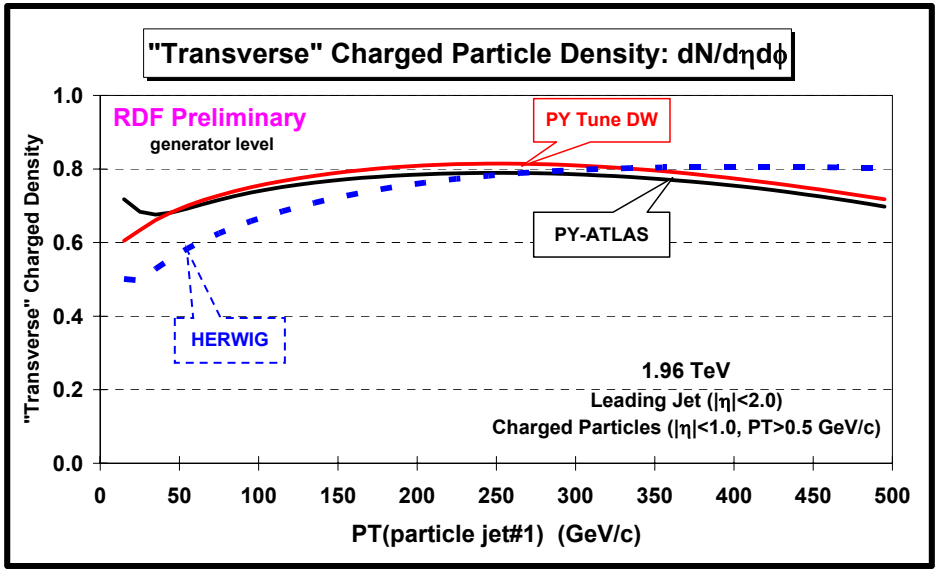
Tune DW has a lower value of PARP(67) and slightly more MPI!

PYTHIA 6.2 Tunes

PYTHIA 6.2 CTEQ5L

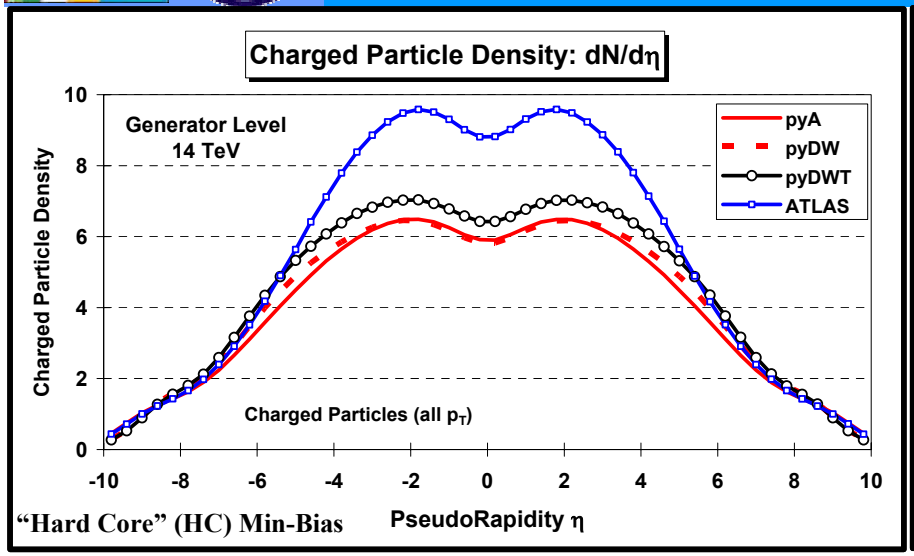
Parameter	Tune A	Tune DW	Tune DWT	ATLAS
MSTP(81)	1	1	1	1
MSTP(82)	4	4	4	4
PARP(82)	2.0 GeV	1.9 GeV	1.9409 GeV	1.8 GeV
PARP(83)	0.5	0.5	0.5	0.5
PARP(84)	0.4	0.4	0.4	0.5
PARP(85)	0.9	1.0	1.0	0.33
PARP(86)	0.95	1.0	1.0	0.66
PARP(89)	1.8 TeV	1.8 TeV	1.96 TeV	1.0 TeV
PARP(90)	0.25	0.25	0.16	0.16
PARP(62)	1.0	1.25	1.25	1.0
PARP(64)	1.0	0.2	0.2	1.0
PARP(67)	4.0	2.5	2.5	1.0
MSTP(91)	1	1	1	1
PARP(91)	1.0	2.1	2.1	1.0
PARP(93)	5.0	15.0	15.0	5.0

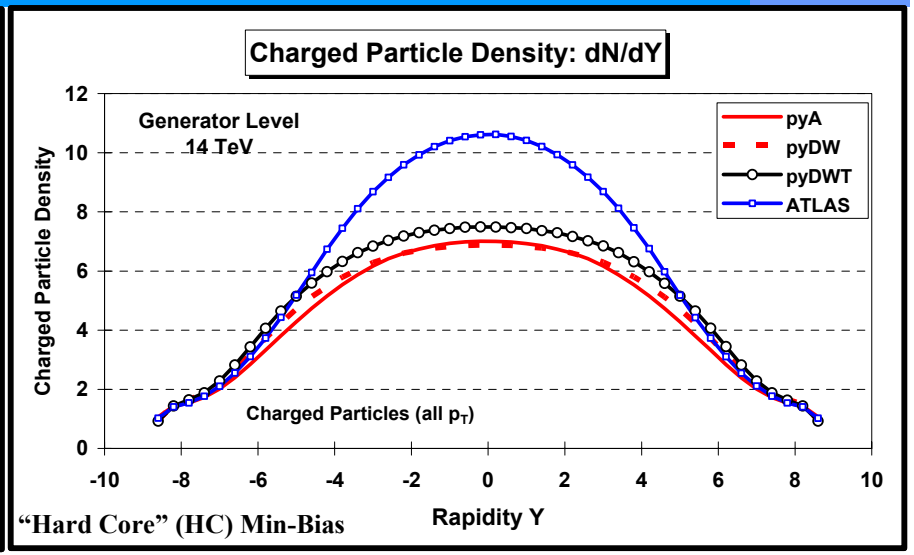
	σ(MPI) at 1.96 TeV	σ(MPI) at 14 TeV
Tune A	309.7 mb	484.0 mb
Tune DW	351.7 mb	549.2 mb
Tune DWT	351.7 mb	829.1 mb
ATLAS	324.5 mb	768.0 mb



➡ **Shows the "transverse" charged particle density, dN/dηdϕ, versus P_T(jet#1) for "leading jet" events at 1.96 TeV for Tune DW, ATLAS, and HERWIG (without MPI).**

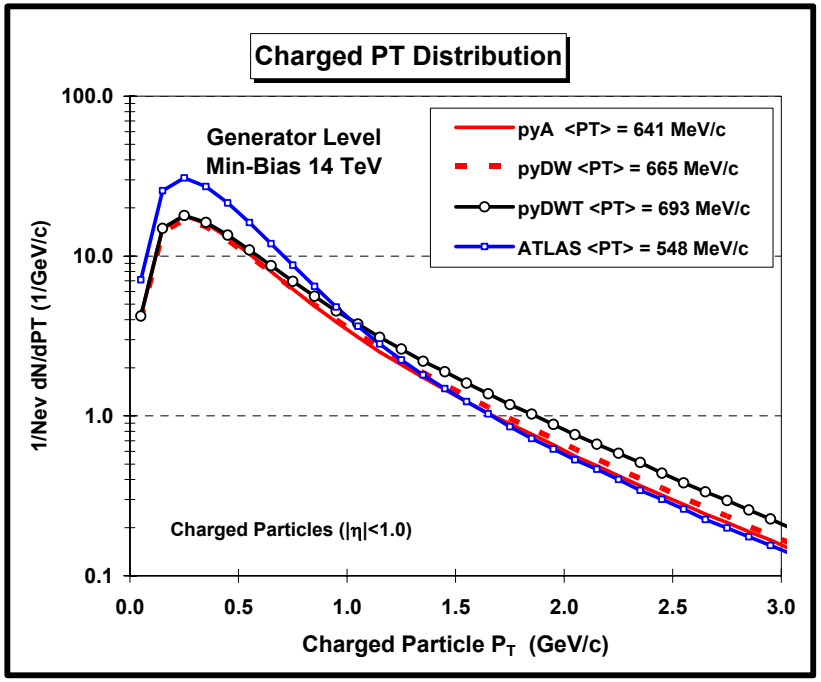
PYTHIA 6.2 Tunes
LHC HC Min-Bias Predictions

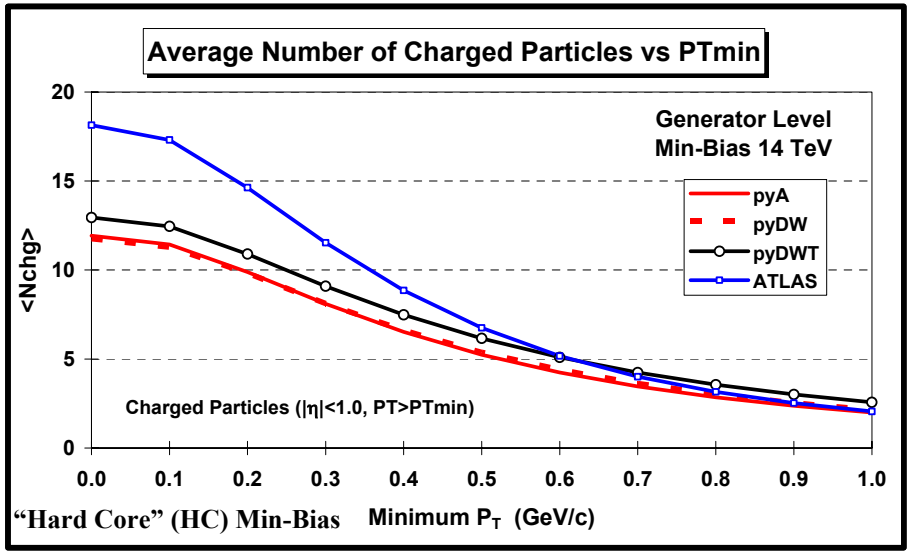




- **Shows the predictions of PYTHIA Tune A, Tune DW, Tune DWT, and the ATLAS tune for the charged particle density dN/dη and dN/dY for "hard core" (HC) Min-Bias at 14 TeV (all p_T).**
- **PYTHIA Tune A and Tune DW predict about 6 charged particles per unit η at η = 0, while the ATLAS tune predicts around 9.**
- **PYTHIA Tune DWT is identical to Tune DW at 1.96 TeV, but extrapolates to the LHC using the ATLAS energy dependence.**

PYTHIA 6.2 Tunes
LHC HC Min-Bias Predictions

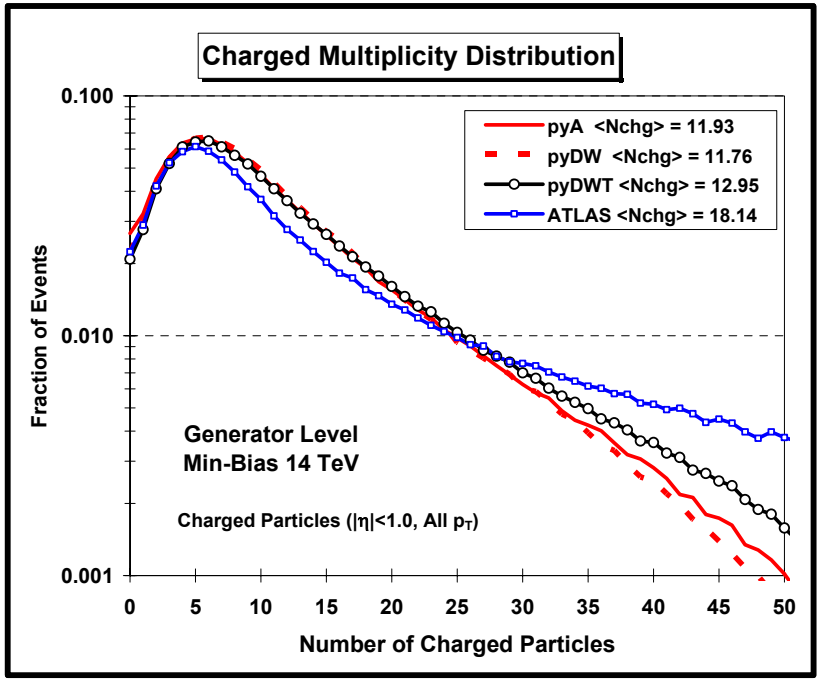


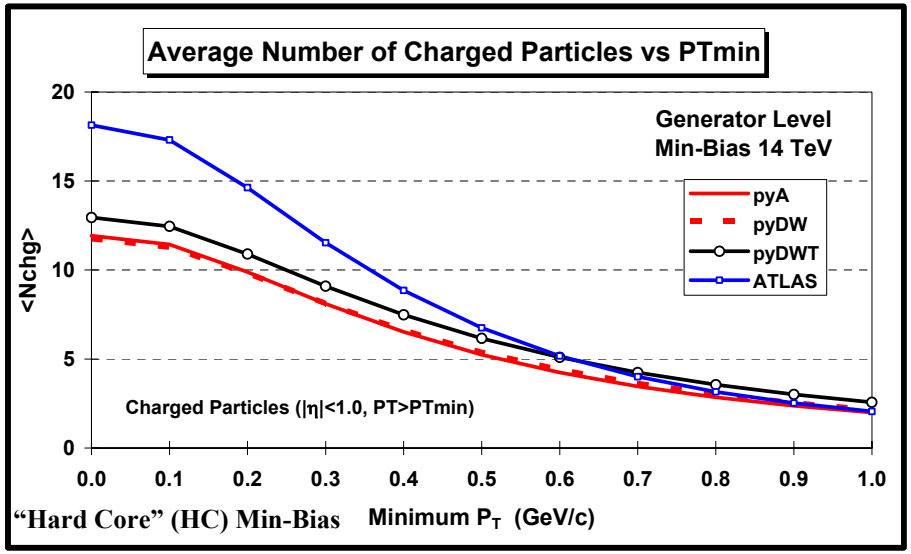


- **Shows the predictions of PYTHIA Tune A, Tune DW, Tune DWT, and the ATLAS tune for the charged particle p_T distribution for "hard core" (HC) Min-Bias at 14 TeV ($|\eta| < 1$) and the average number of charged particles with $p_T > p_T^{min}$ ($|\eta| < 1$).**

- **The ATLAS tune has many more "soft" particles than does any of the CDF Tunes. The ATLAS tune has $\langle p_T \rangle = 548$ MeV/c while Tune A has $\langle p_T \rangle = 641$ MeV/c (100 MeV/c more per particle)!**

PYTHIA 6.2 Tunes
LHC HC Min-Bias Predictions

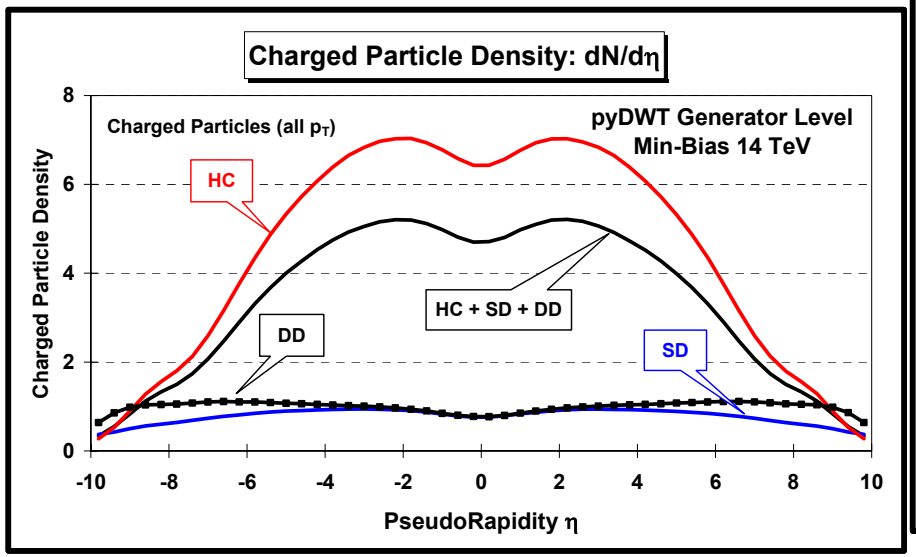


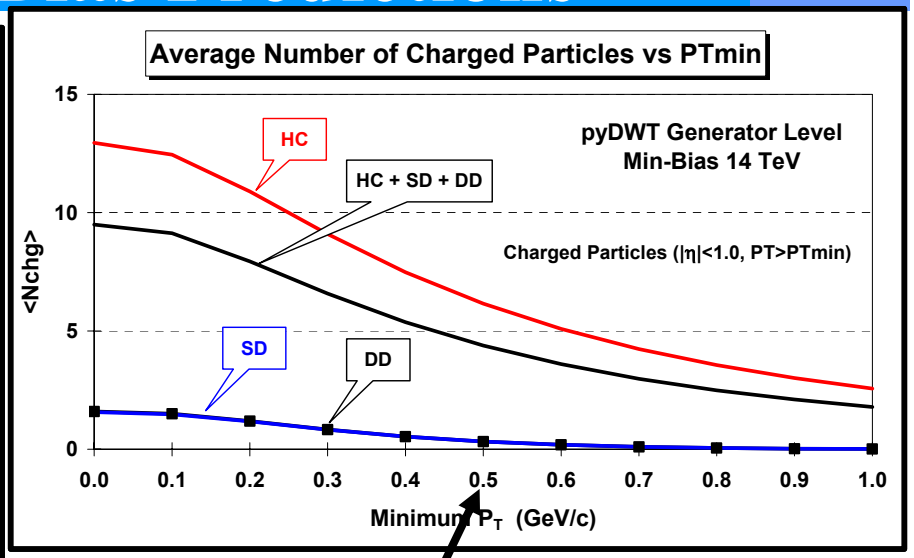


- **Shows the predictions of PYTHIA Tune A, Tune DW, Tune DWT, and the ATLAS tune for the charged particle multiplicity distribution for "hard core" (HC) Min-Bias at 14 TeV ($|\eta| < 1$) and the average number of charged particles with $p_T > p_T^{min}$ ($|\eta| < 1$).**

- **The ATLAS tune has many more "soft" particles than does any of the CDF Tunes. The ATLAS tune has $\langle N_{chg} \rangle = 18.14$ ($|\eta| < 1$) while Tune A has $\langle N_{chg} \rangle = 11.93$ ($|\eta| < 1$).**

PYTHIA Tune DWT
LHC Min-Bias Predictions





- **Shows the predictions of PYTHIA Tune DWT for the charged particle density dN/dη (all p_T) and the average number of charged particles with $p_T > p_T^{min}$ ($|\eta| < 1$) for Min-Bias at 14 TeV.**
- **Shows the contributions from the "hard core" (HC), Single-Diffraction (SD), and double-diffraction (DD) components of Min-Bias collisions. Also shows the sum (HC + SD + DD). Note the sum is actually (MB = 0.697HC + 0.181SD + 0.122DD)**
- **For $p_T > 0.5$ GeV/c and $|\eta| < 1$ one is simply adding in zero N_{chg} for SD and DD.**

PYTHIA Tune DWT LHC Min-Bias Predictions

Components	Cross-Section (14 TeV)	% Total
HC	55.22 mb	69.7%
SD	14.30 mb	18.1%
DD	9.69 mb	12.2%
Total	79.21 mb	100%

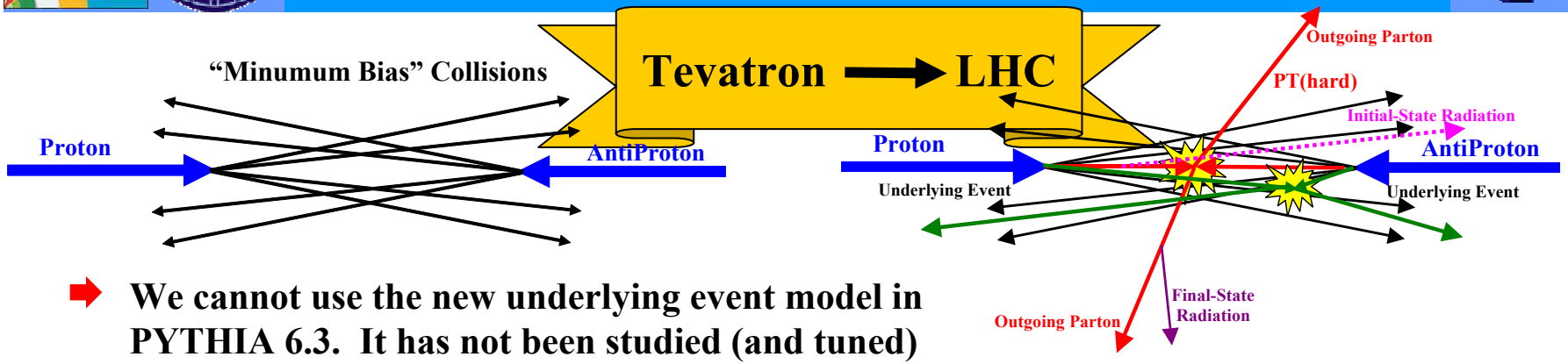
- Shows the cross-sections (in mb) the "hard core" (HC), Single-Diffraction (SD), and double-diffraction (DD) components of Min-Bias collisions from PYTHIA.

Average Number of charged particles with $p_T > p_T^{min}$ and $|\eta| < 1$

P_T^{min}	HC (pyDWT)	SD	DD	Total
0.0	12.95	1.57	1.60	9.50
0.1	12.45	1.48	1.50	9.13
0.2	10.90	1.17	1.19	7.94
0.3	9.09	0.82	0.83	6.58
0.4	7.48	0.54	0.54	5.37
0.5	6.16	0.33	0.33	4.38
0.6	5.09	0.19	0.19	3.60
0.7	4.24	0.10	0.10	2.98
0.8	3.56	0.05	0.05	2.49
0.9	3.01	0.03	0.03	2.10
1.0	2.57	0.01	0.01	1.79

- Shows the predictions of PYTHIA Tune DWT for the average umber of charged particles with $p_T > p_T^{min}$ ($|\eta| < 1$) for Min-Bias at 14 TeV.

Conclusions



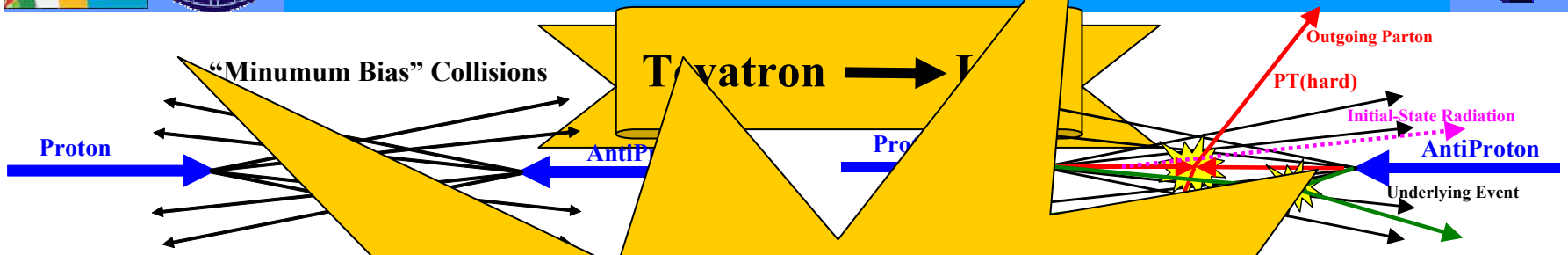
- We cannot use the new underlying event model in PYTHIA 6.3. It has not been studied (and tuned) well enough yet!

- The ATLAS tune is "goofy"! It produces too many "soft" particles. The charged particle <pT> is too low and does not agree with the CDF Run 2 data. The ATLAS tune agrees with <Nchg> but not with <PTsum> at the Tevatron.

- PYTHIA Tune DW is very similar to Tune A except that it fits the CDF $P_T(Z)$ distribution and it uses the DØ prefered value of PARP(67) = 2.5 (determined from the dijet $\Delta\phi$ distribution).

- PYTHIA Tune DWT is identical to Tune DW at 1.96 TeV but uses the ATLAS energy extrapolation to the LHC (*i.e.* PARP(90) = 0.16).

Conclusions



Tevatron → L

- **We cannot use the … PYTHIA 6.3. It h… well…**
- **The ATLA… charged particle <pT> … ATLAS tune agrees with <N…**
- **PYTH… F $P_T(Z)$ distribution and it uses … 7) … rmined from the dijet Δϕ distribution).**
- **PYTHIA Tune DWT … identical … DW at … V but uses the … TLAS energy extrapolation to the LHC (*i.e.* PA… = 0.16).**

I think more work needs to be done in comparing the various tunes. The ATLAS tune cannot be right because it does not fit the Tevatron data. Right now I like Tune DW. Probably no tune will fit the CMS data. That is why we want to measure MB&UE at CMS and retune the Monte-Carlo models!