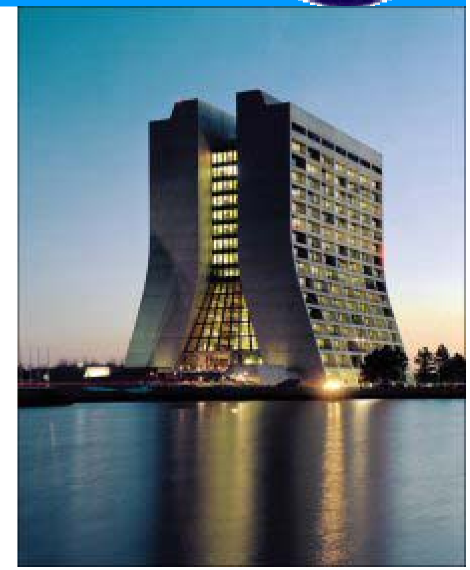
TeV4LHC Workshop

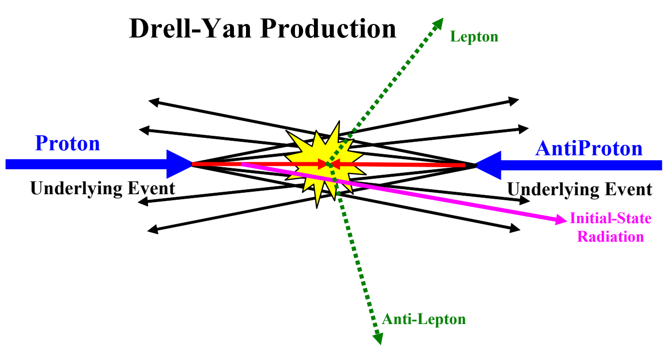
Quantum
Chromo-
Dynamics

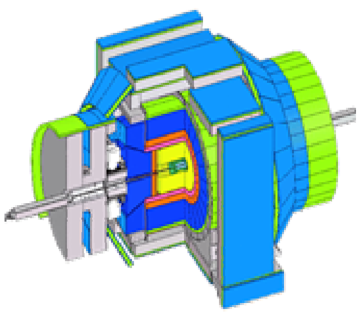
Talk #1

Rick Field
University of Florida

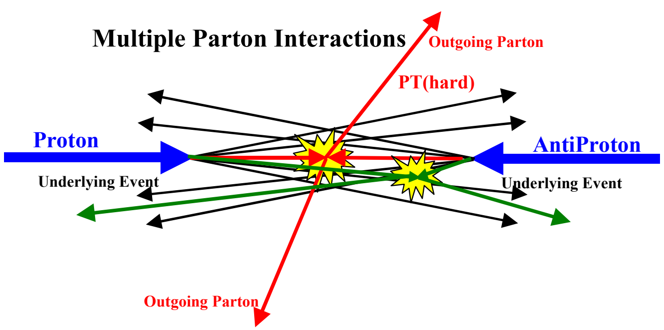
TeV4LHC



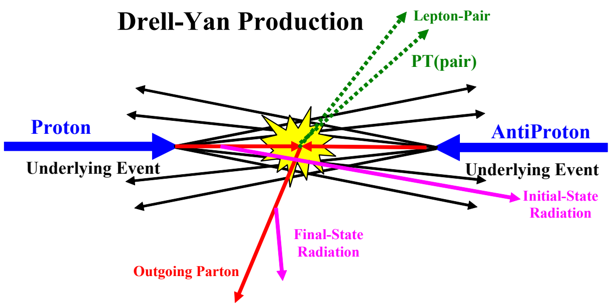


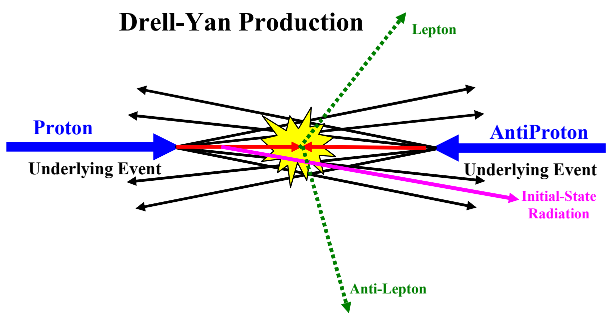


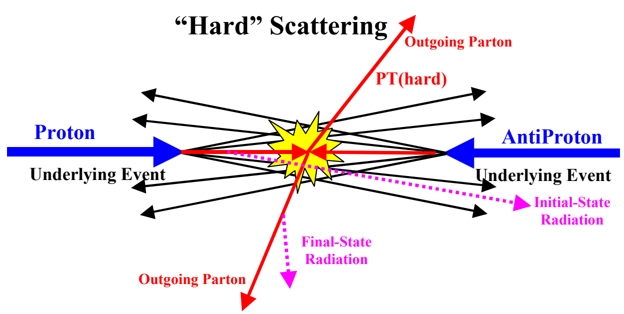
CDF Run 2



CDF Run 2
Monte Carlo Tunes







Outline of Talk

- **P_T(Z-boson): Tuning to fit the P_T(Z) distribution.**
- **Drell-Yan: Tuning to fit the "underlying event" in Drell-Yan production.**
- **Jet Production: Tuning to fit the "underlying event" is high P_T jet production.**
- **Energy: Tuning to fit the energy in the "underlying event".**

CDF Run 2 Tunes
PYTHIA Tune A
PYTHIA Tune A25
PYTHIA Tune A50
PYTHIA Tune AW
PYTHIA Tune Q
PYTHIA Tune QW
JIMMY Default
JIMMY 325

CDF Run 1 $P_T(Z)$

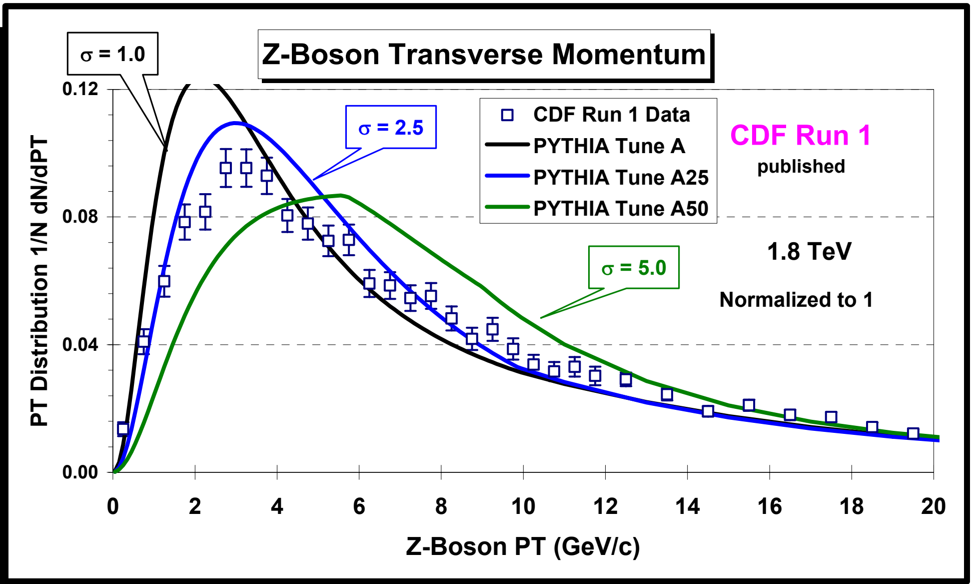
PYTHIA 6.2 CTEQ5L

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

UE Parameters

ISR Parameter

Intrensic KT



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

CDF Run 1 $P_T(Z)$

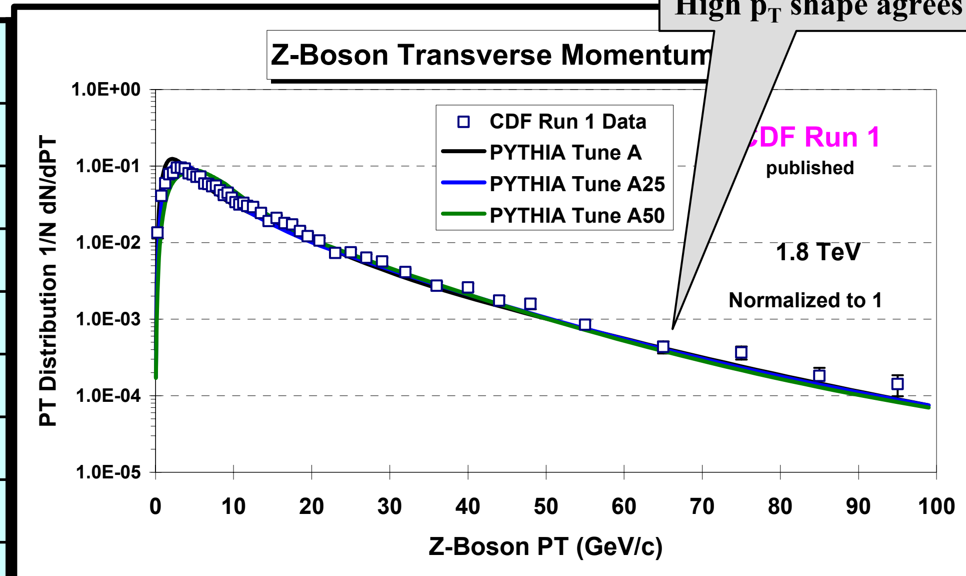
PYTHIA 6.2 CTEQ5L

UE Parameters

ISR Parameter

Intrensic KT

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



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

CDF Run 1 $P_T(Z)$

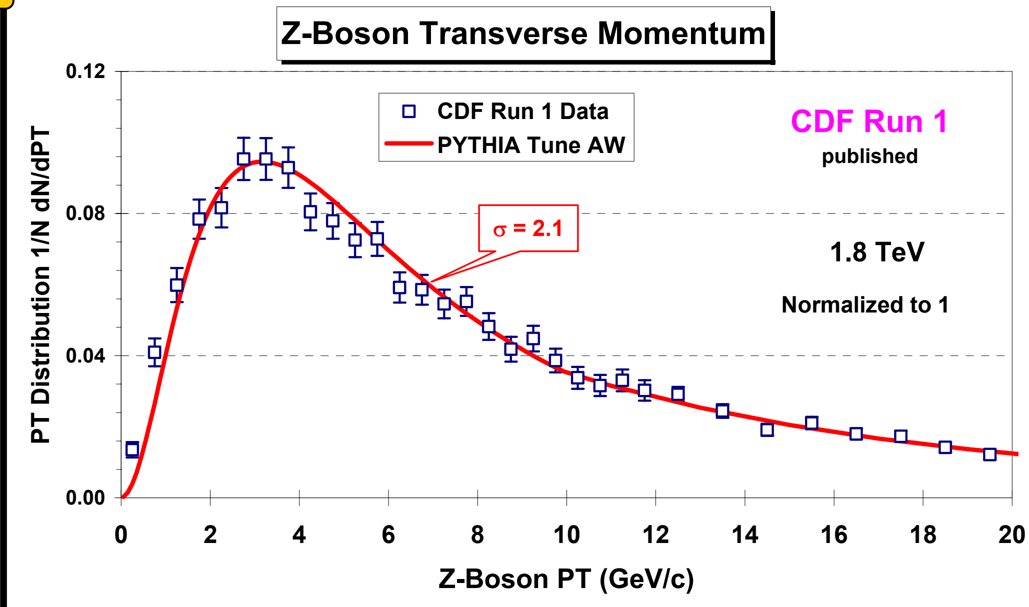
PYTHIA 6.2 CTEQ5L

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



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

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

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

CDF Run 1 $P_T(Z)$

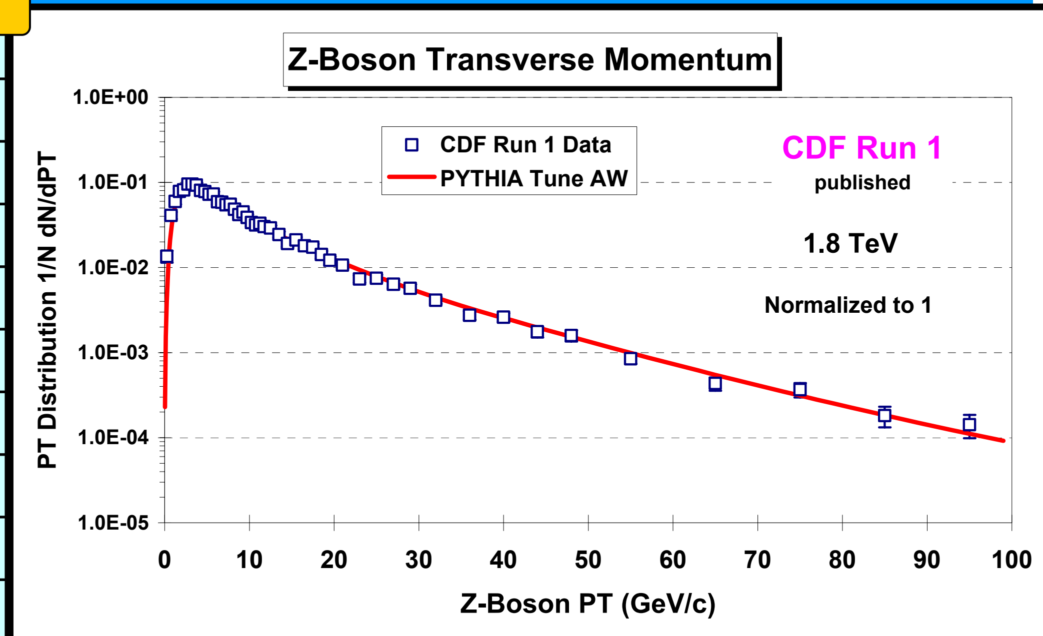
PYTHIA 6.2 CTEQ5L

UE Parameters

ISR Parameters

Intrensic KT

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



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

CDF Run 1 $P_T(Z)$

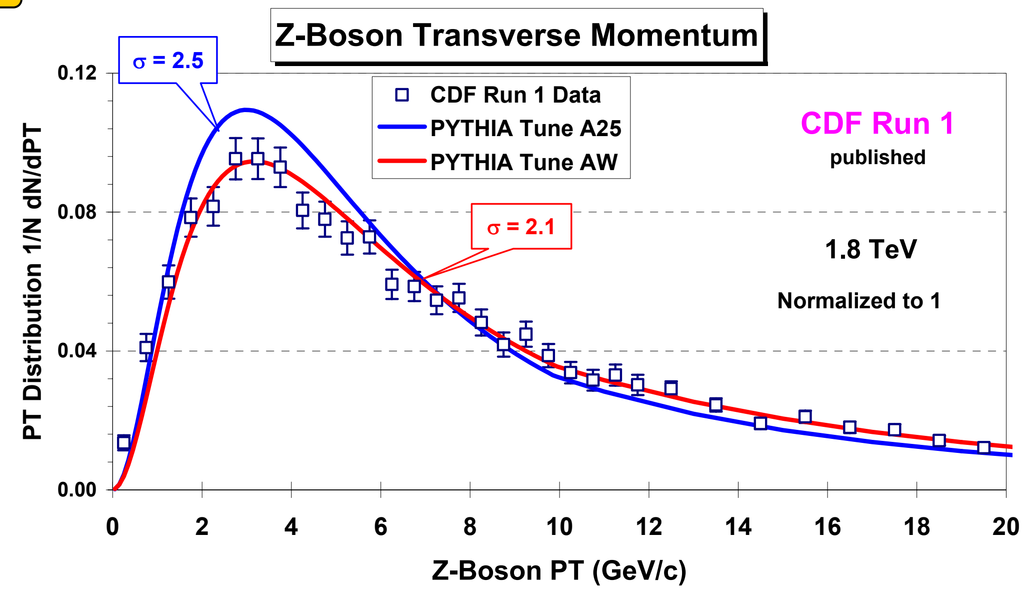
PYTHIA 6.2 CTEQ5L

UE Parameters

ISR Parameters

Intrensic KT

Parameter	Tune A25	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)	2.5	2.1
PARP(93)	5.0	15.0



- Shows the Run 1 Z-boson p_T distribution ($<p_T(Z)> \approx 11.5$ GeV/c) compared with PYTHIA Tune AW ($<p_T(Z)> = 11.7$ GeV/c) and PYTHIA Tune A25 ($<p_T(Z)> = 10.1$ GeV/c).

CDF Run 1 $P_T(Z)$

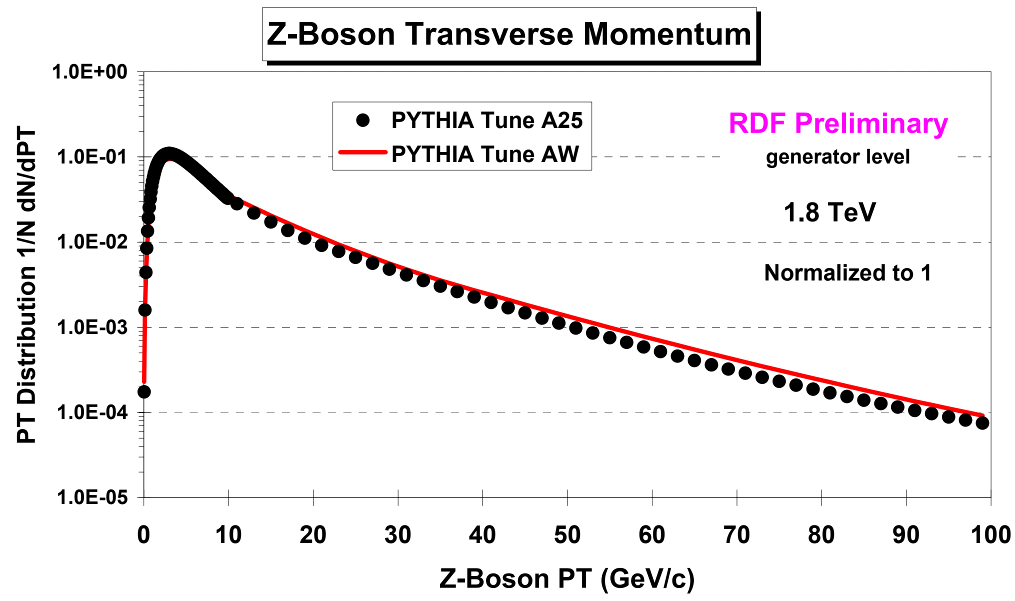
PYTHIA 6.2 CTEQ5L

Parameter	Tune A25	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)	2.5	2.1
PARP(93)	5.0	15.0

UE Parameters

ISR Parameters

Intrensic KT



➡ Compares PYTHIA Tune AW with PYTHIA Tune A25 (both normalized to one).

CDF Run 1 $P_T(Z)$

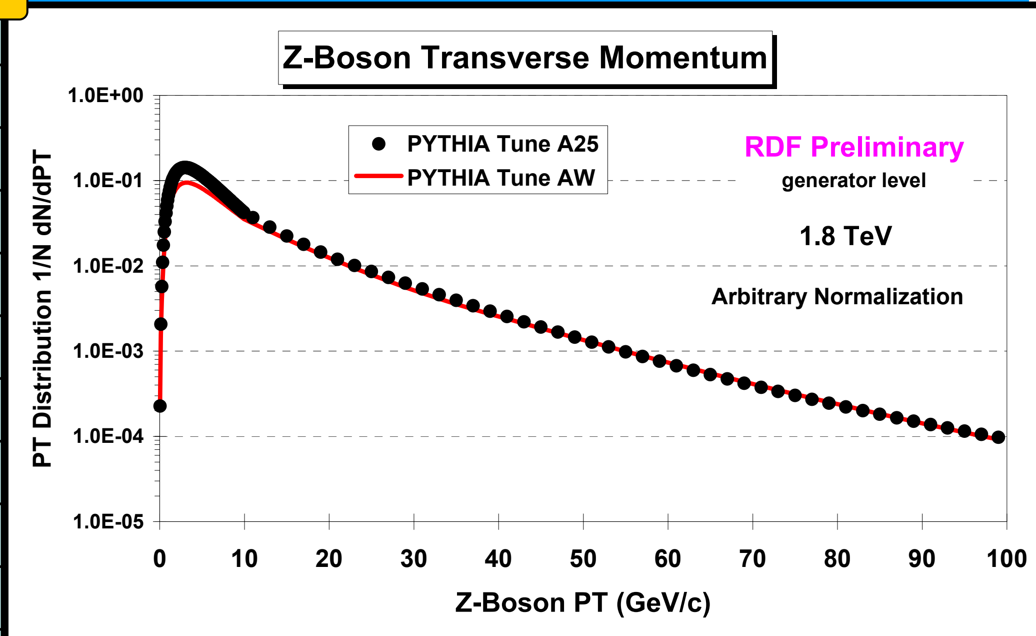
PYTHIA 6.2 CTEQ5L

UE Parameters

ISR Parameters

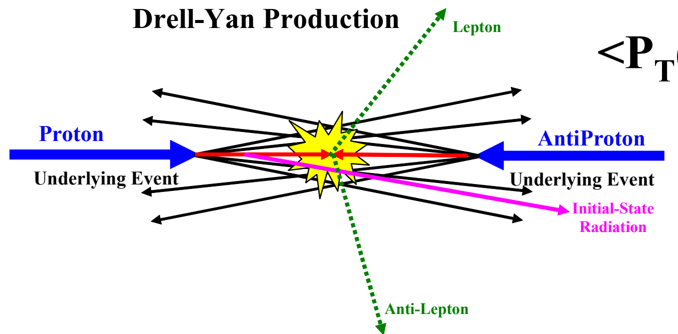
Intrensic KT

Parameter	Tune A25	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)	2.5	2.1
PARP(93)	5.0	15.0

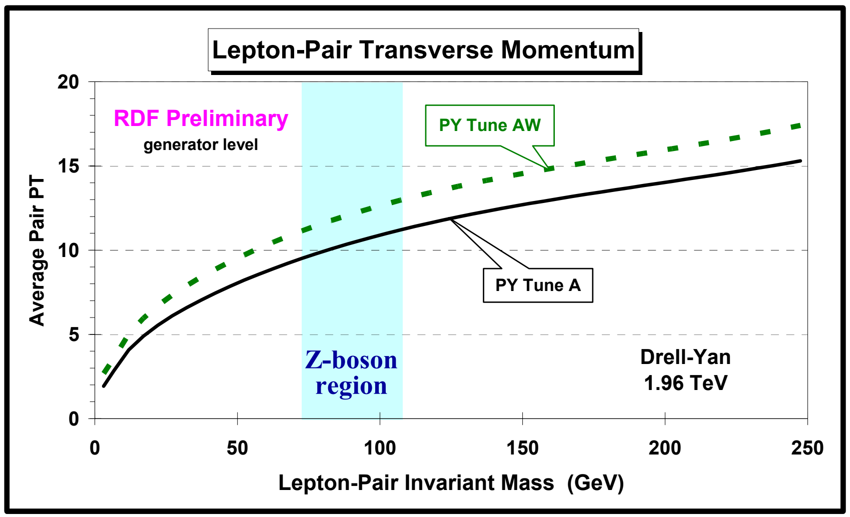


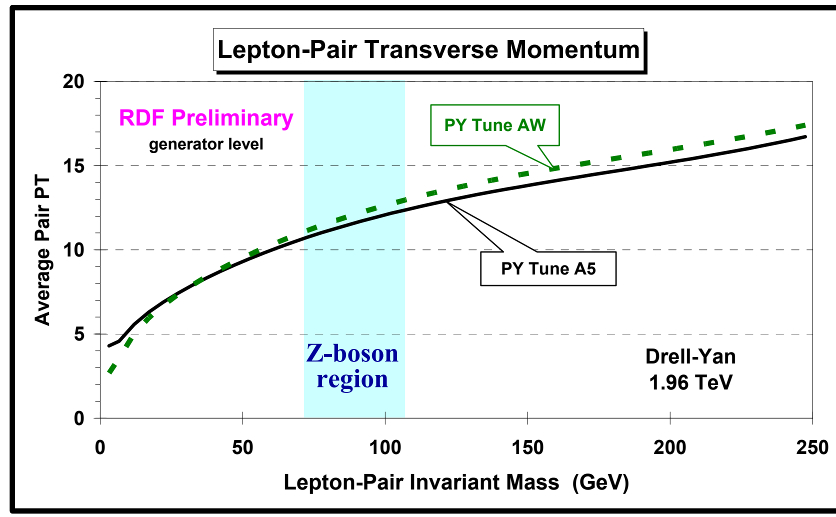
- Compares **PYTHIA Tune AW** with **PYTHIA Tune A25** (normalized to agree at high $P_T(Z)$).

Run 2 Drell-Yan



<P_T(pair)> versus M(pair)

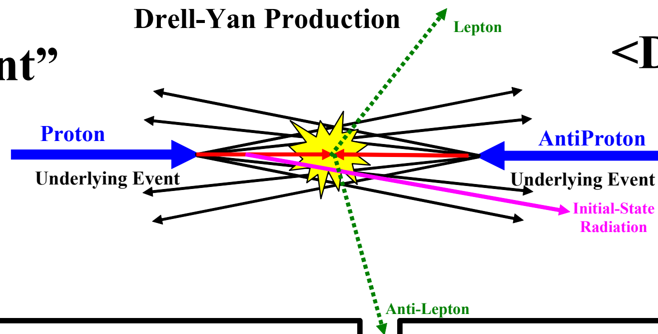




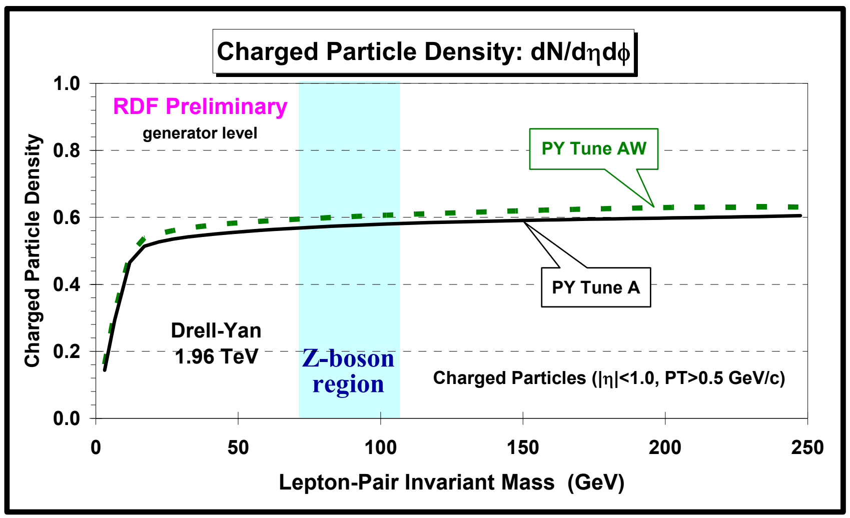
- **Shows the lepton-pair average P_T versus the lepton-pair invariant mass at 1.96 TeV for PYTHIA Tune AW and PYTHIA Tune A.**
- **Shows the lepton-pair average P_T versus the lepton-pair invariant mass at 1.96 TeV for PYTHIA Tune AW and PYTHIA Tune A5.**

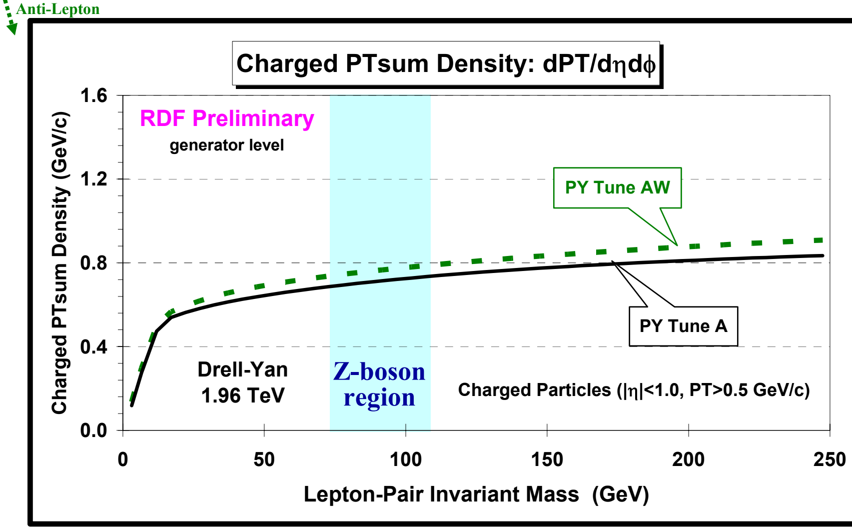
Run 2 Drell-Yan

The "Underlying Event"



<Densities> versus M(pair)



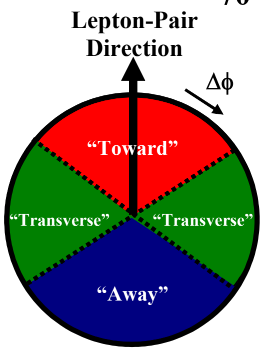


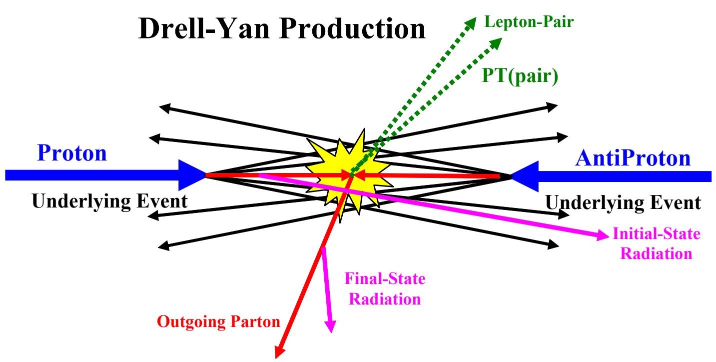
- Shows the charged particle density versus the lepton-pair invariant mass at 1.96 TeV for PYTHIA Tune AW and PYTHIA Tune A.
- Shows the charged PTsum density versus the lepton-pair invariant mass at 1.96 TeV for PYTHIA Tune AW and PYTHIA Tune A.

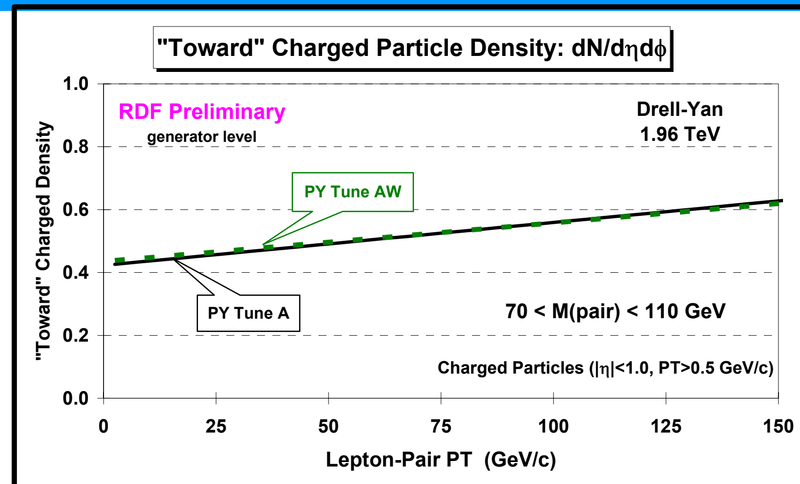
High P_T Drell-Yan

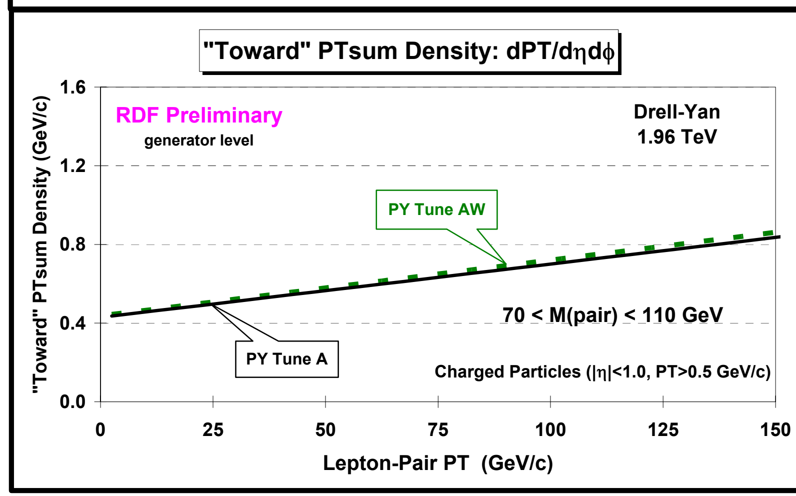
The "Underlying Event" in High P_T Lepton-Pair Production

70 < M(lepton-pair) < 110 GeV







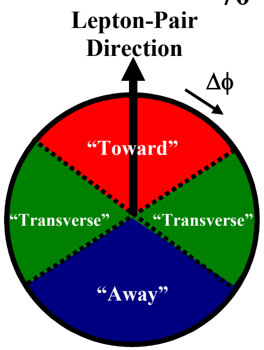


"Toward" <Densities> vs P_T(pair)

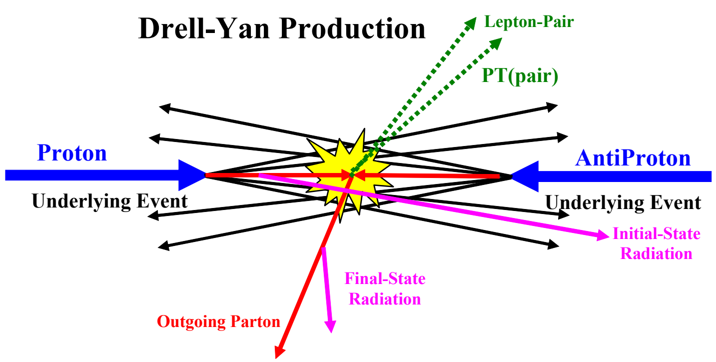
High P_T Drell-Yan

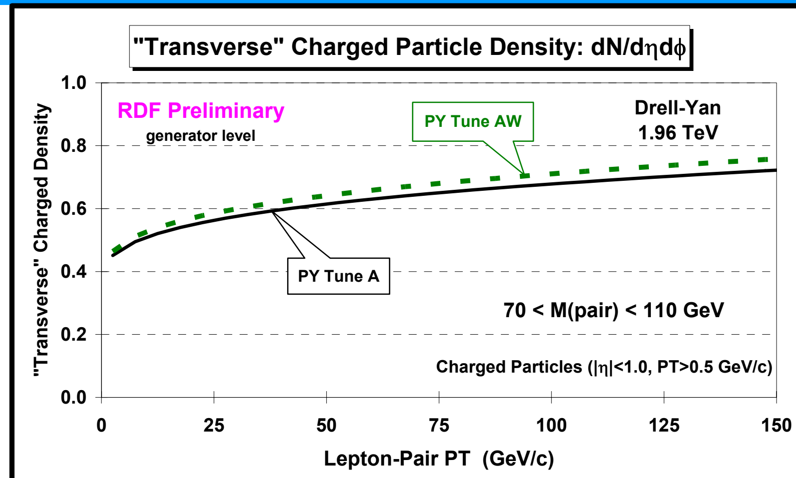
The "Underlying Event" in High P_T Lepton-Pair Production

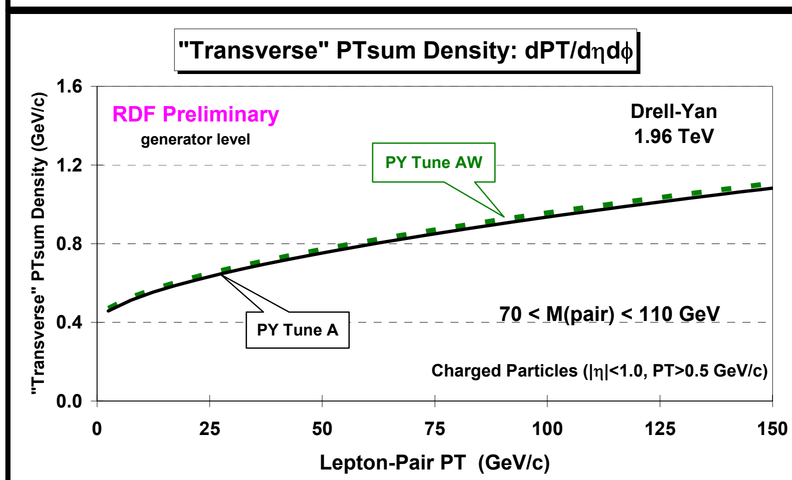
70 < M(lepton-pair) < 110 GeV



Drell-Yan Production



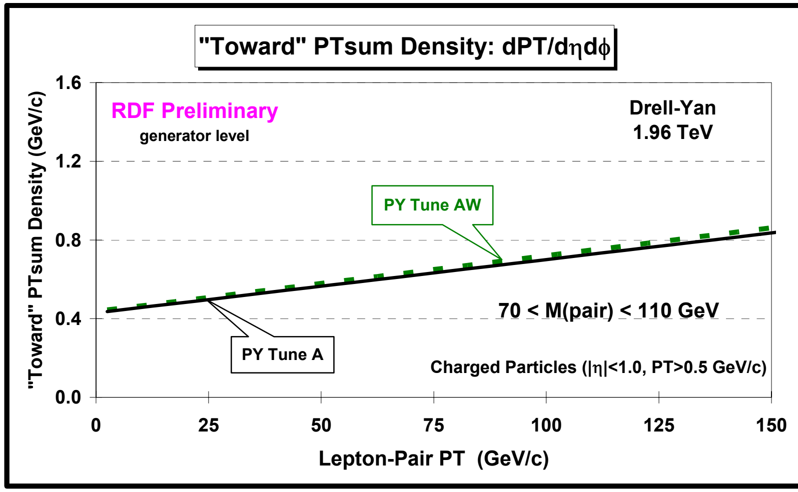


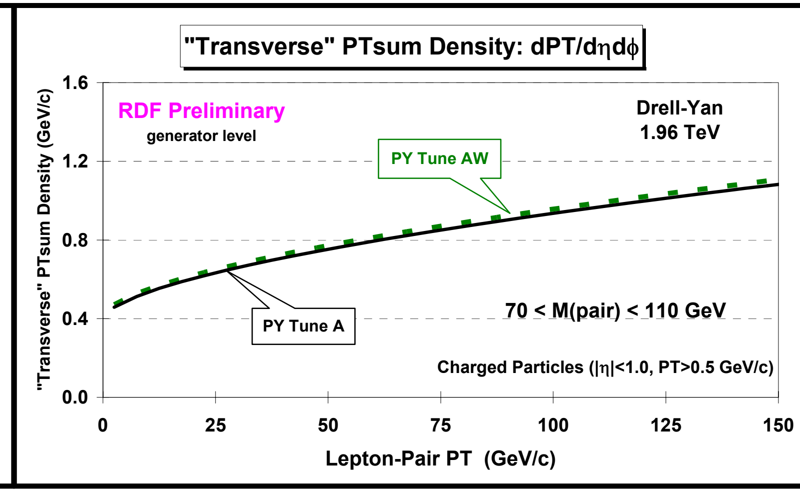


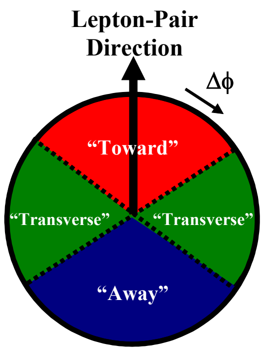
"Transverse" <Densities> vs P_T(pair)

High P_T Drell-Yan

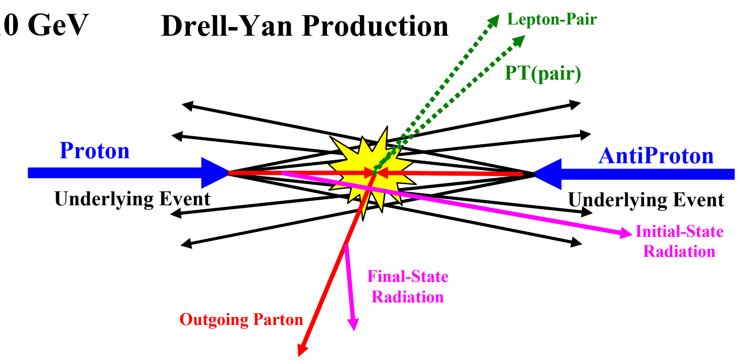
The "Underlying Event" in High P_T Lepton-Pair Production







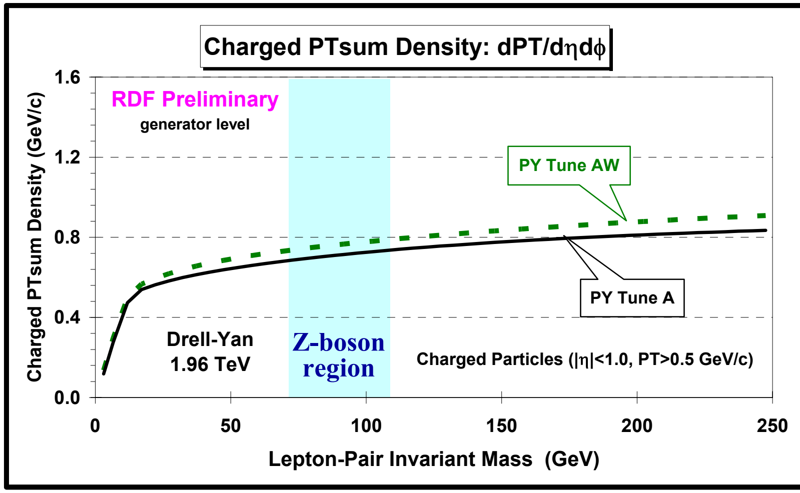
70 < M(lepton-pair) < 110 GeV



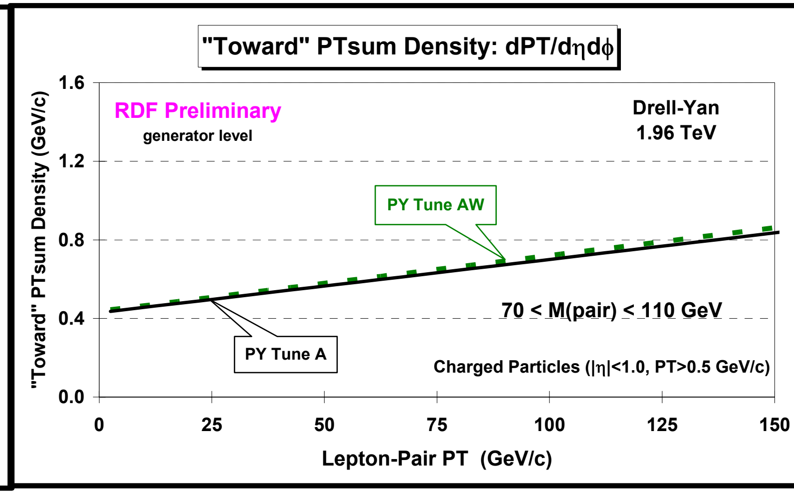
"Toward" <Densities> vs "Transverse" <Densities>

High P_T Drell-Yan

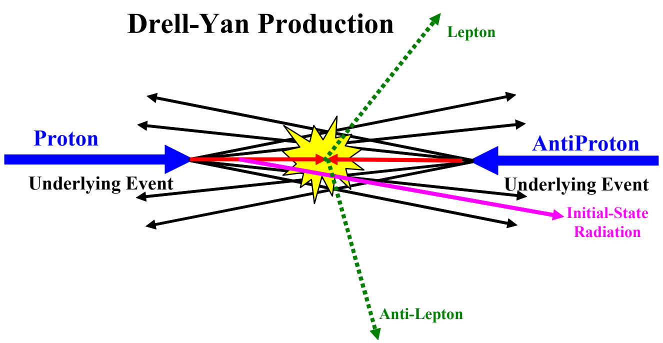
The “Underlying Event” in Lepton-Pair Production

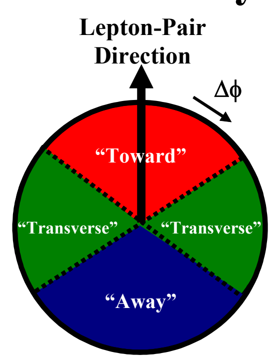


Overall PTsum Density vs M(pair)



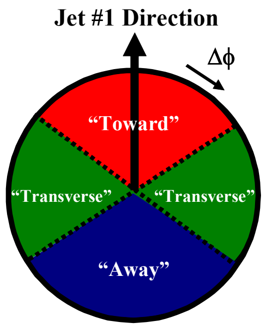
“Toward” PTsum Density vs P_T(pair)

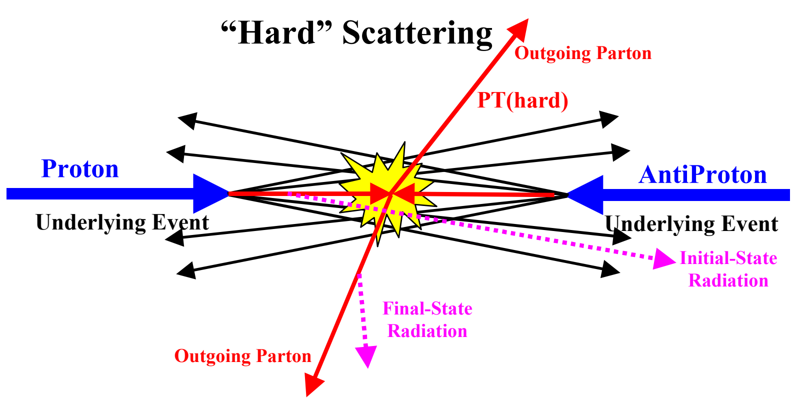




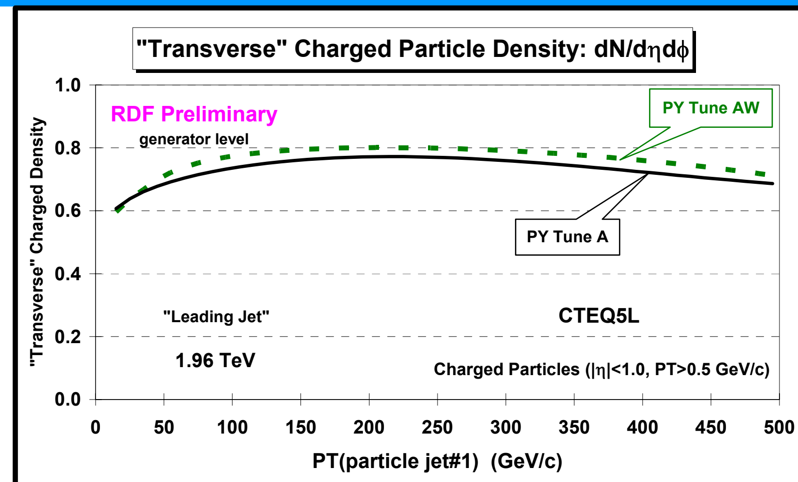
High P_T Jets

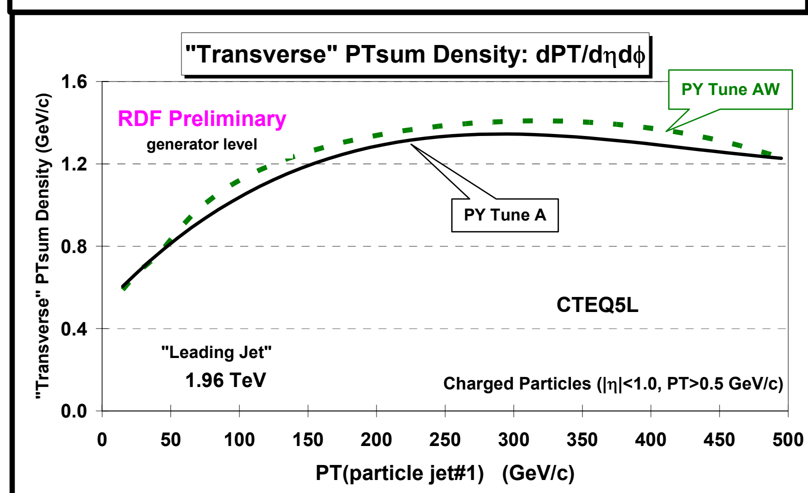
The "Underlying Event" in High P_T Jet Production





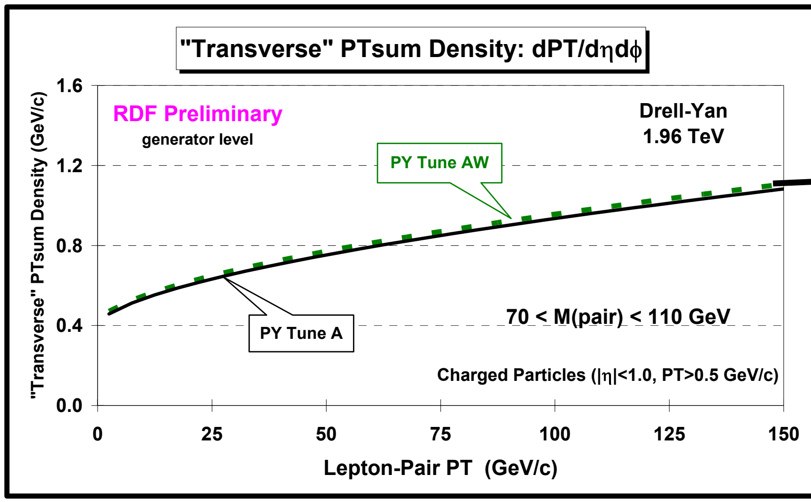
"Transverse" <Densities> vs P_T(jet#1)

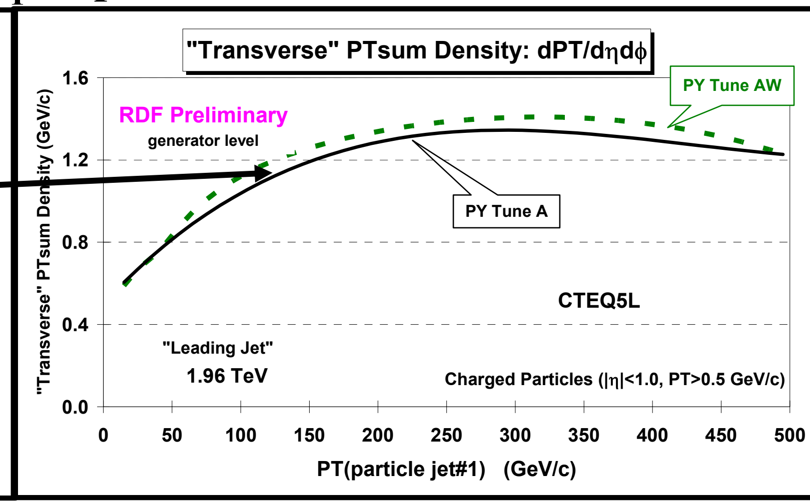




Drell-Yan vs Jets

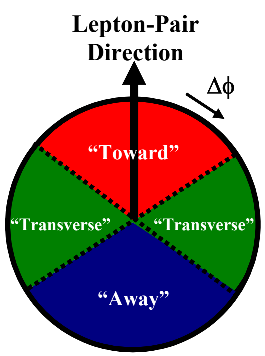
The "Underlying Event" in High P_T Lepton-Pair and Jet Production

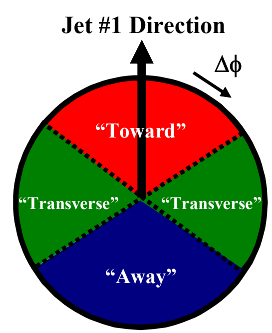




"Transverse" <Densities> vs P_T(pair)

"Transverse" <Densities> vs P_T(jet#1)





CTEQ6.1 Tune

I used LHAPDF! See the next talk by Craig Group!

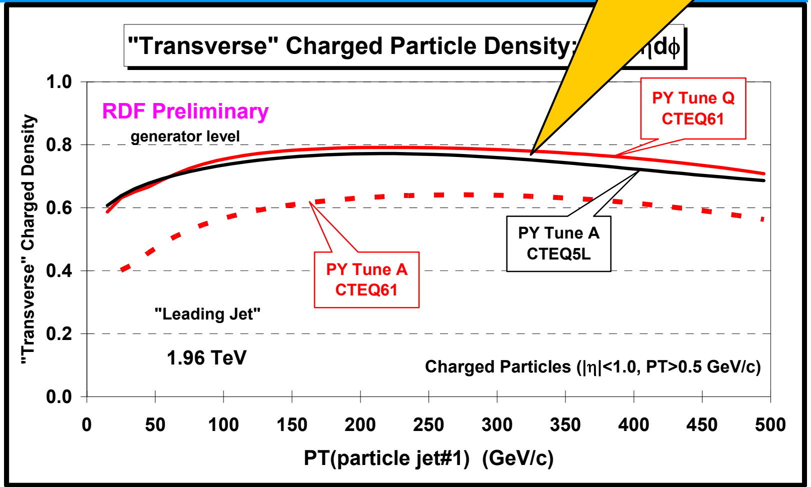
PYTHIA 6.2 CTEQ6.1

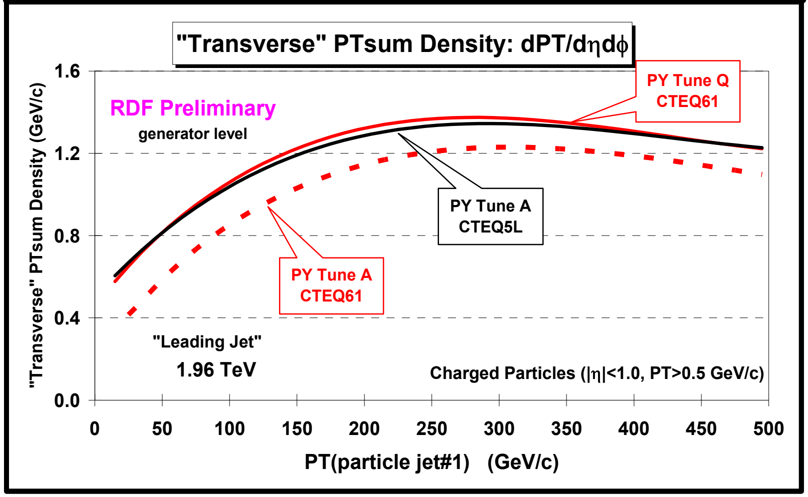
Parameter	Tune Q	Tune QW
MSTP(81)	1	1
MSTP(82)	4	4
PARP(82)	1.2 GeV	1.2 GeV
PARP(83)	0.5	0.5
PARP(84)	0.4	0.4
PARP(85)	0.9	0.9
PARP(86)	0.95	0.95
PARP(89)	1.8 TeV	1.8 TeV
PARP(90)	0.25	0.25
PARP(62)	1.0	1.25
PARP(64)	1.0	0.2
PARP(67)	4.0	4.0
MSTP(91)	1	1
PARP(91)	1.0	2.1
PARP(93)	5.0	15.0

UE Parameters

ISR Parameters

Intrensic KT





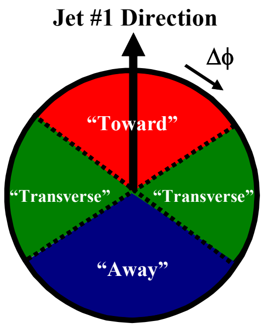
JIMMY at CDF

JIMMY
Runs with HERWIG and adds multiple parton interactions!

JIMMY was tuned to fit the energy density in the "transverse" region for "leading jet" events!

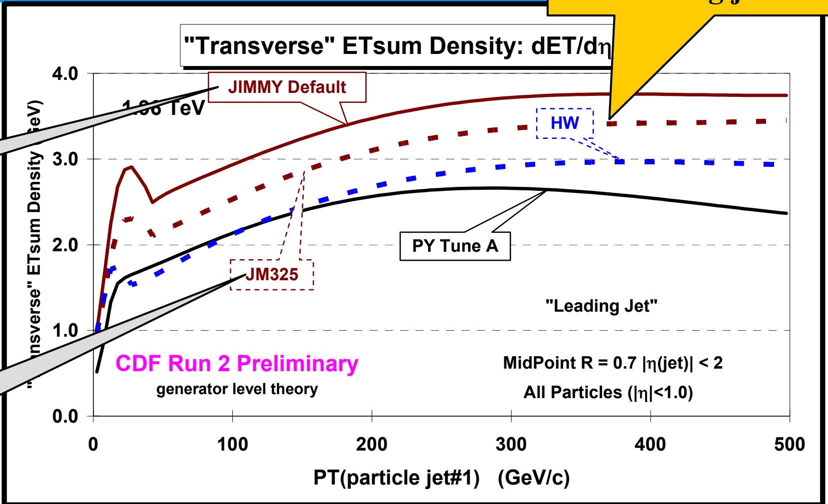
The Energy in the "Underlying Event" in High P_T Jet Production

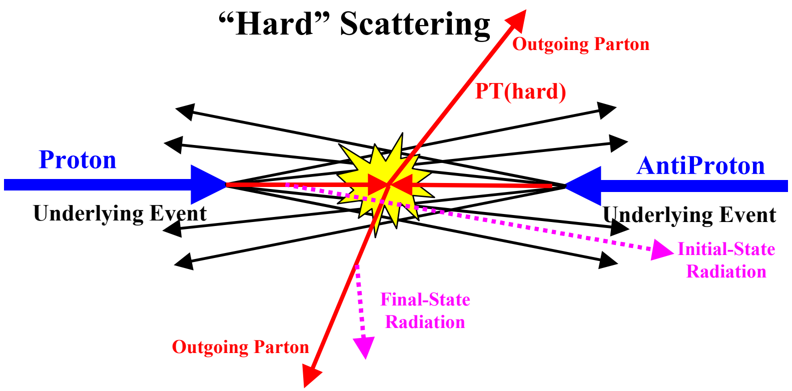
JIMMY: MPI
J. M. Butterworth
J. R. Forshaw
M. H. Seymour

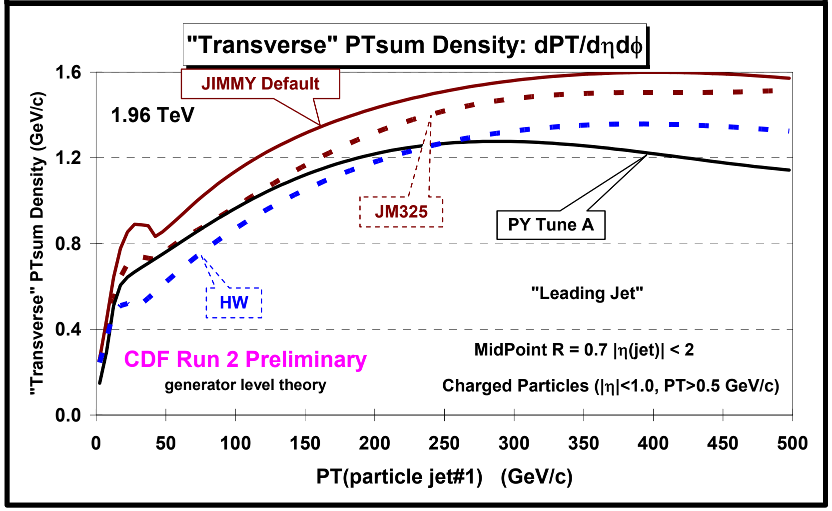


PT(JIM)= 2.5 GeV/c.

PT(JIM)= 3.25 GeV/c.



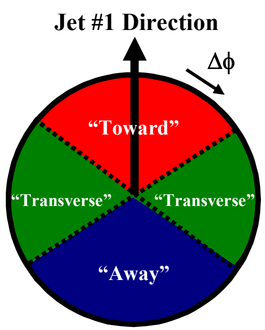


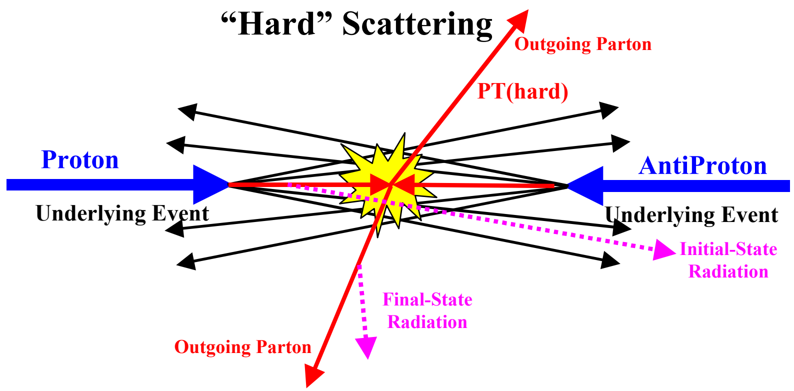


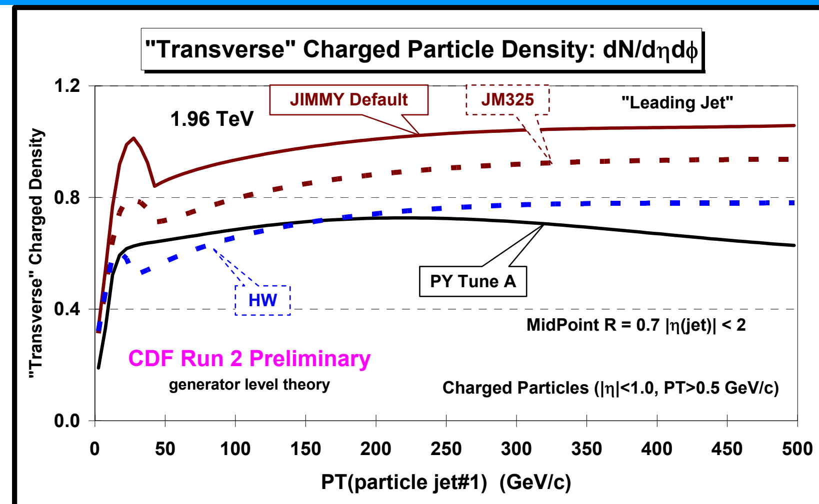
"Transverse" <Densities> vs P_T(jet#1)

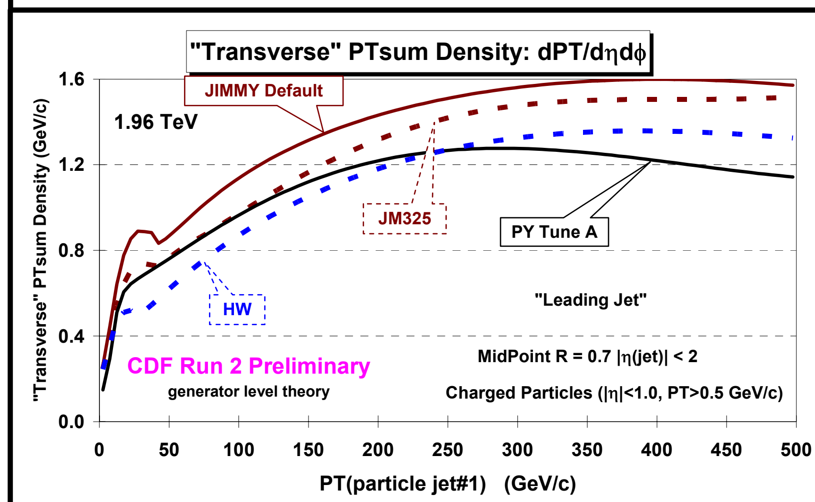
JIMMY at CDF

The "Underlying Event" in High P_T Jet Production







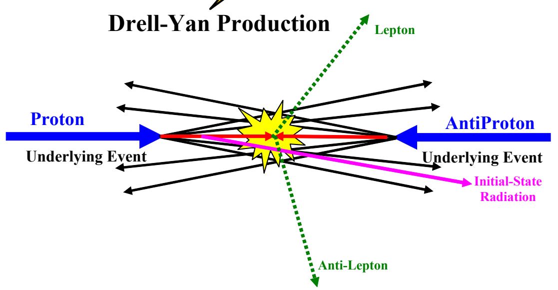


"Transverse" <Densities> vs P_T(jet#1)

Summary

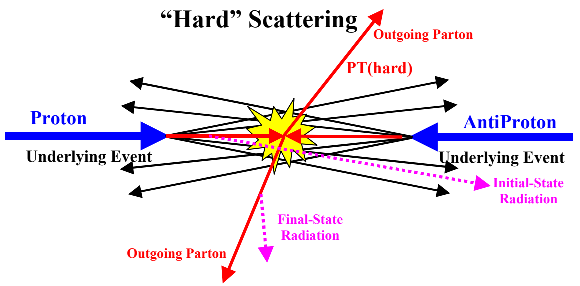
Good way to study the "underlying event"!

- **PYTHIA Tune AW** correctly describes the Z-boson P_T distribution and also fits the "underlying event" as well as Tune A does! I do not see anything wrong with it, except that it may only work at the Tevatron. You can not trust the energy dependence!



- **PYTHIA Tune Q** works as well as Tune A but uses CTEQ6.1! At the Tevatron use Tune QW!

- **Default JIMMY (PTJIM = 2.5 GeV/c)** does not fit the CDF "underlying event" data! Default JIMMY's "underlying event" is much too active!



- **JIMMY 325 (PTJIM = 3.25 GeV/c)** fits the energy in the "underlying event" but does so by producing too many particles (*i.e.* it is too soft). See my talk tomorrow!

- We are making good progress in understanding and modeling the "underlying event". However, we do not yet have a perfect fit to all the features of the "underlying event". PYTHIA Tune A does not produce enough energy in the "underlying event"! See my talk tomorrow!