The Galileo Galilei Institute for Theoretical Physics
Arcetri, Florence

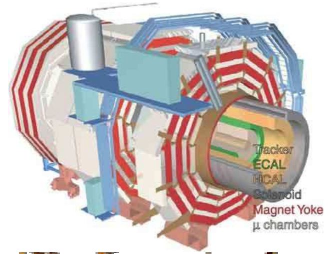
High Energy QCD after the start of the LHC

Physics of the Underlying Event

Rick Field
University of Florida

Quantum Chromo-Dynamics

CMS



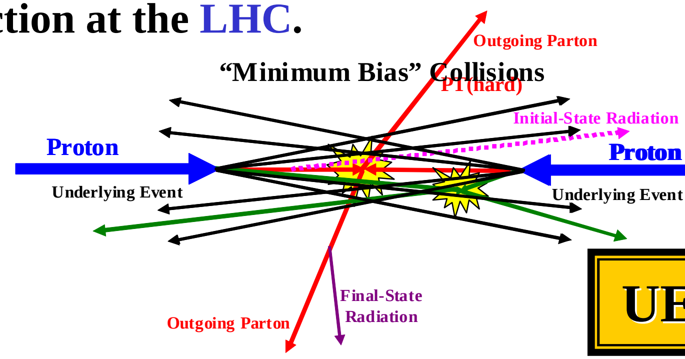
Outline

- How well did we do at predicting the behavior of the "underlying event" at the LHC (900 GeV and 7 TeV)?
- How universal are the QCD Monte-Carlo model tunes?
- Examine the connection between the "underlying event" in a hard scattering process (UE) and "min-bias" collisions (MB).
- How well can we predict "min-bias" collisions at the LHC?
- Strange particle and baryon production at the LHC.

ATLAS

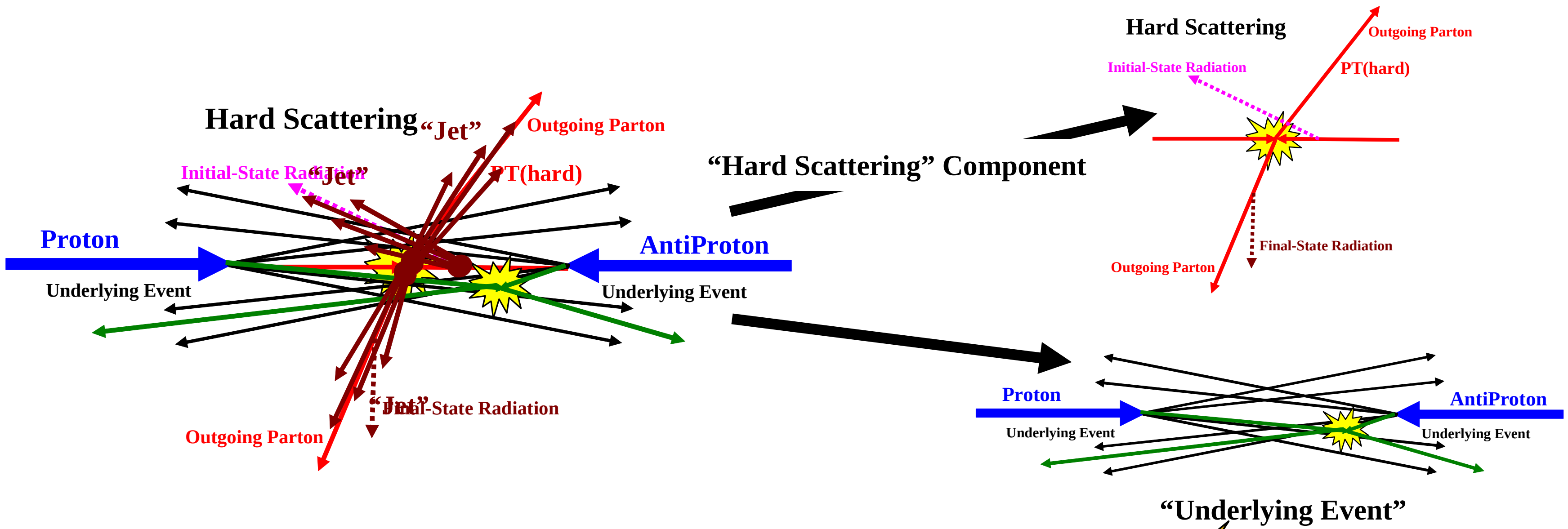
ALICE LHCb

K^+: u $\bar{s}$ | K_{short}: d $\bar{s}$ + $\bar{d}$ s | p: uud | K^-: $\bar{u}$ s | Λ: uds | Ξ^-: dss



UE&MB@CMS

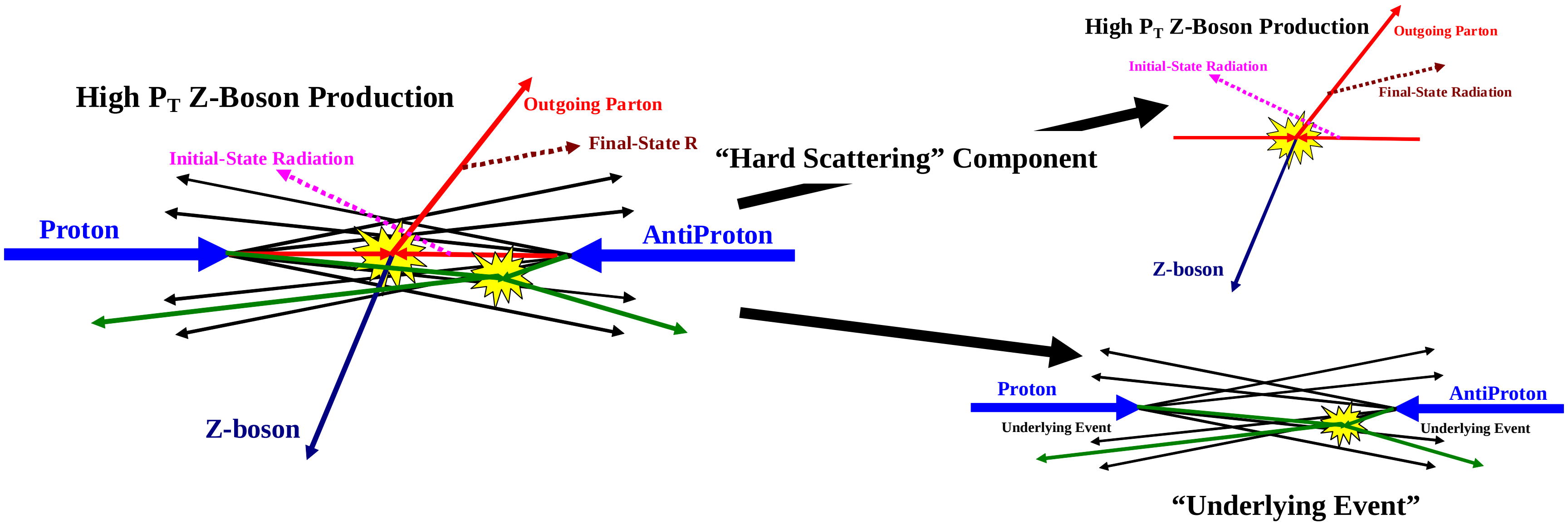
QCD Monte-Carlo Models: High Transverse Momentum Jets



- 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 g approximation).
- The "underlying event" consists of the "beam-beam remnants" and articles arising from soft or semi-soft multiple parton interactions (MPI).
- Of course the outgoing colored parton bly "underlying event" observables receive contributions fron

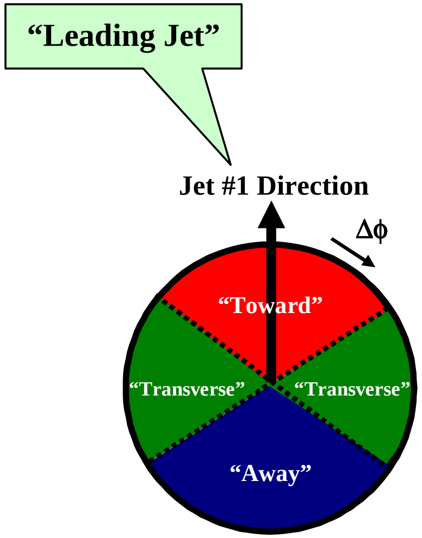
The "underlying event" is an unavoidable background to most collider observables and having good understand of it leads to more precise collider measurements!

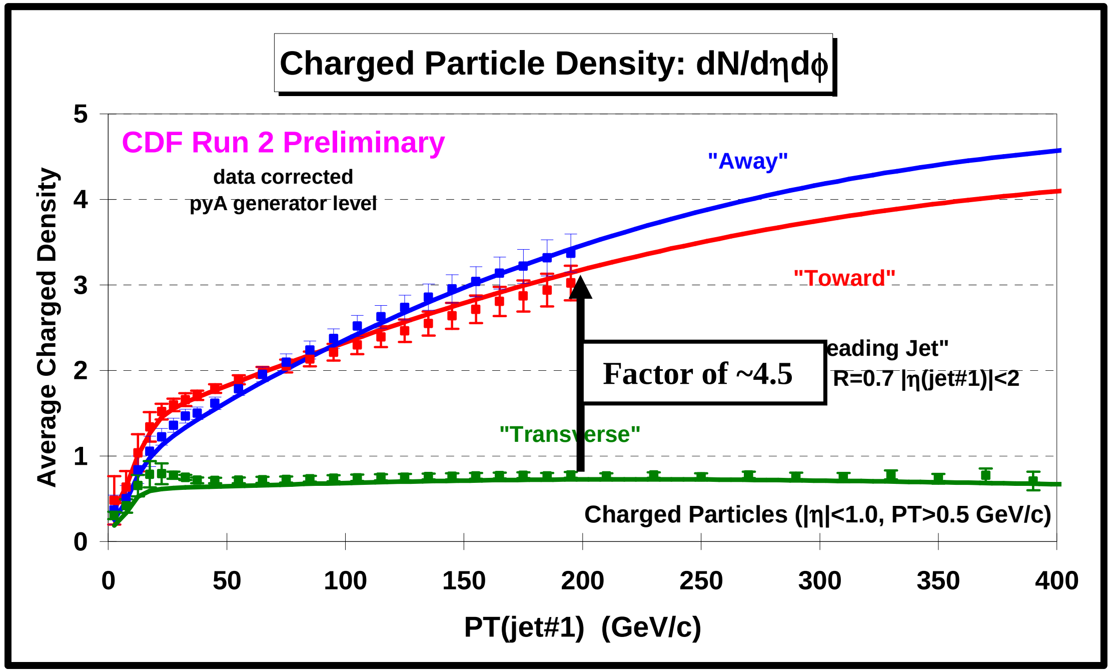
QCD Monte-Carlo Models: Lepton-Pair Production



- 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.

“Towards”, “Away”, “Transverse”





- **CDF data at 1.96 TeV on the density of charged particles, dN/dηdϕ, with $p_T > 0.5$ GeV/c and $|\eta| < 1$ for “leading jet” events as a function of the leading jet p_T for the “toward”, “away”, and “transverse” regions. The data are corrected to the particle level (*with errors that include both the statistical error and the systematic uncertainty*) and are compared with PYTHIA Tune A at the particle level (*i.e.* generator level).**

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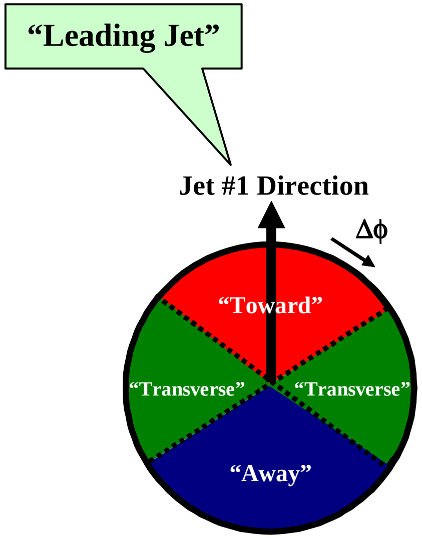

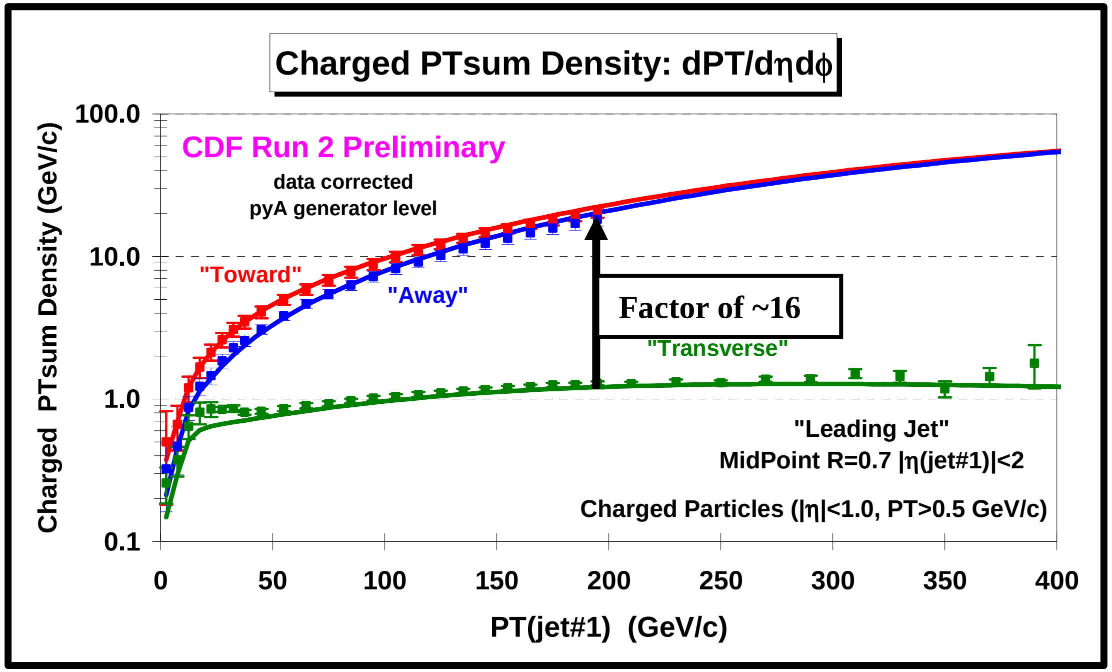

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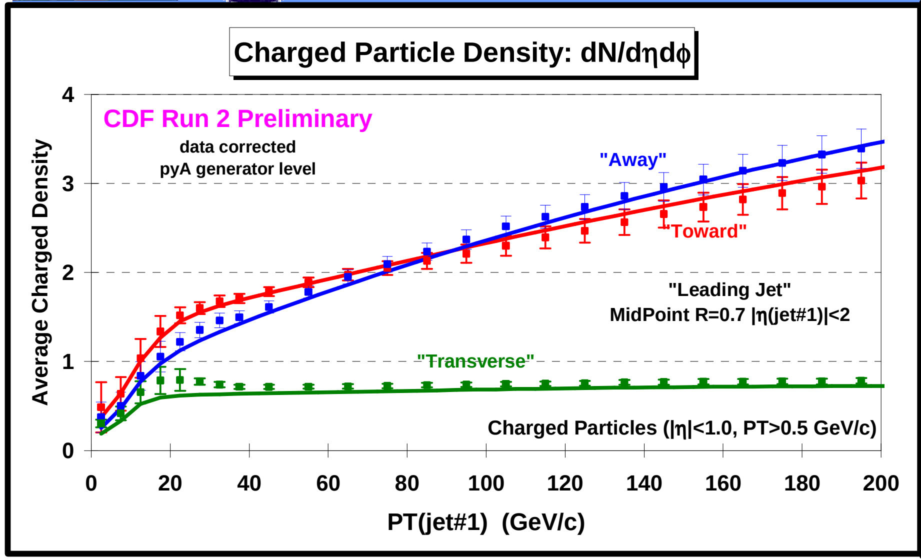
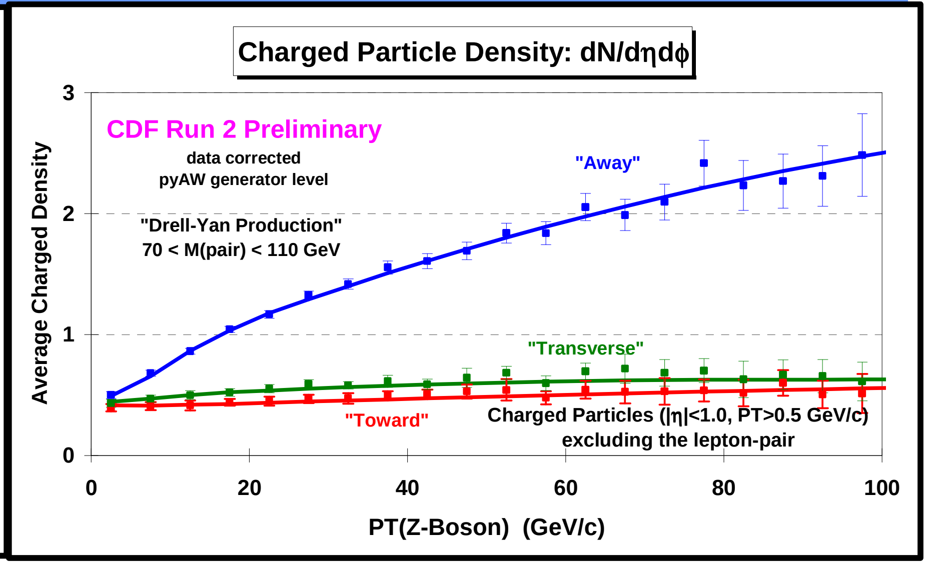
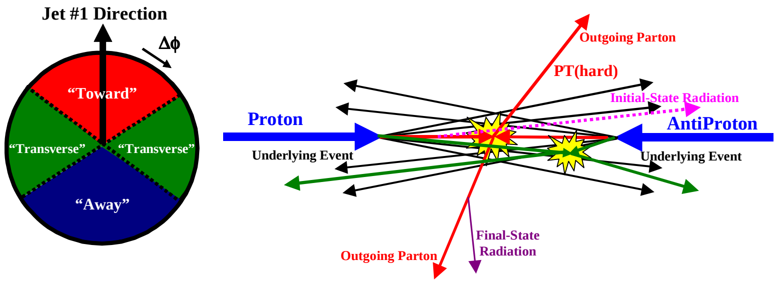
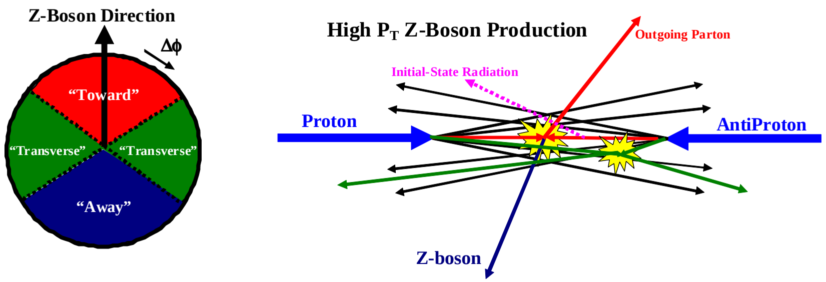
Charged Particle Density









- **CDF 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" and "Leading Jet" events as a function of the leading jet p_T or $P_T(Z)$ for the "toward", "away", and "transverse" regions. The data are corrected to the particle level and are compared with PYTHIA Tune AW and Tune A, respectively, at the particle level (*i.e.* generator level).**

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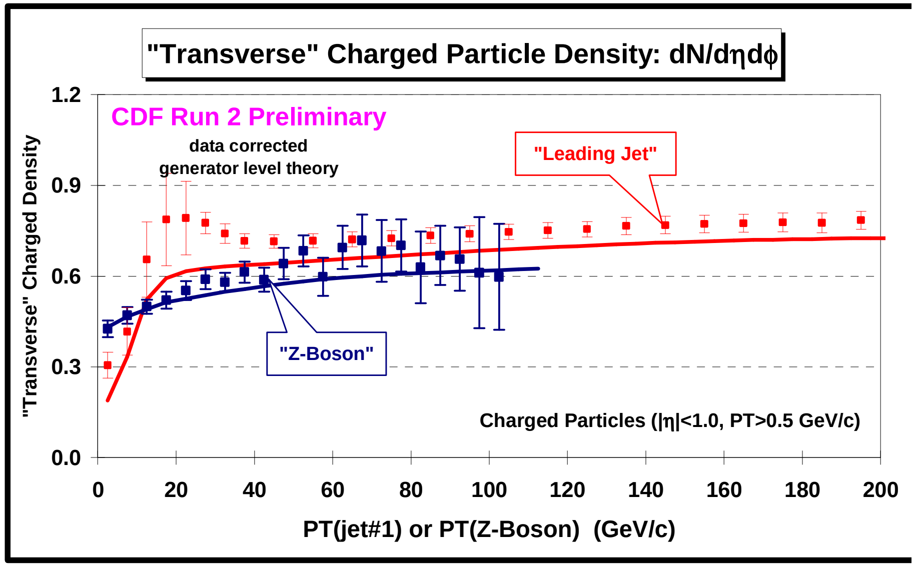

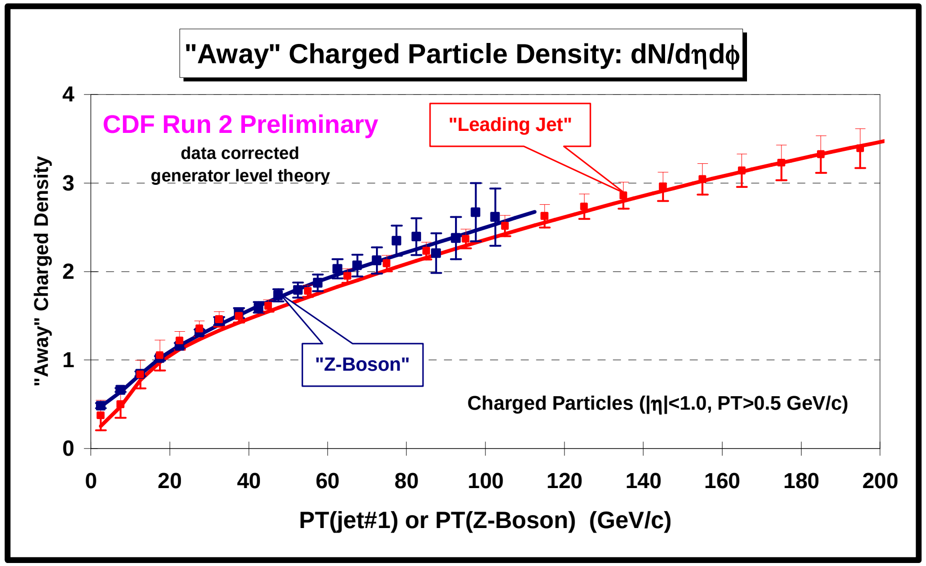

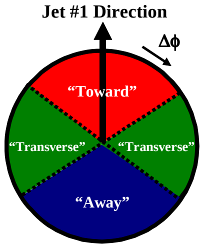

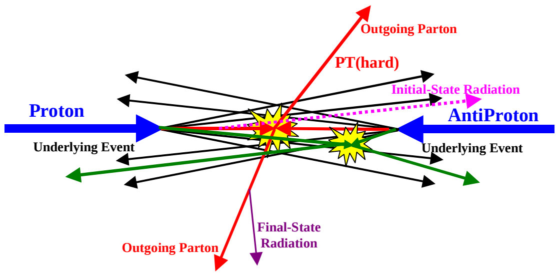

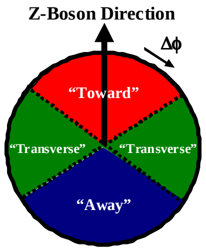

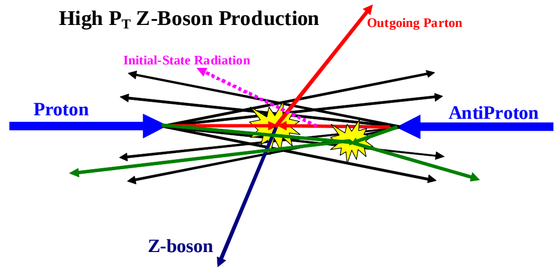

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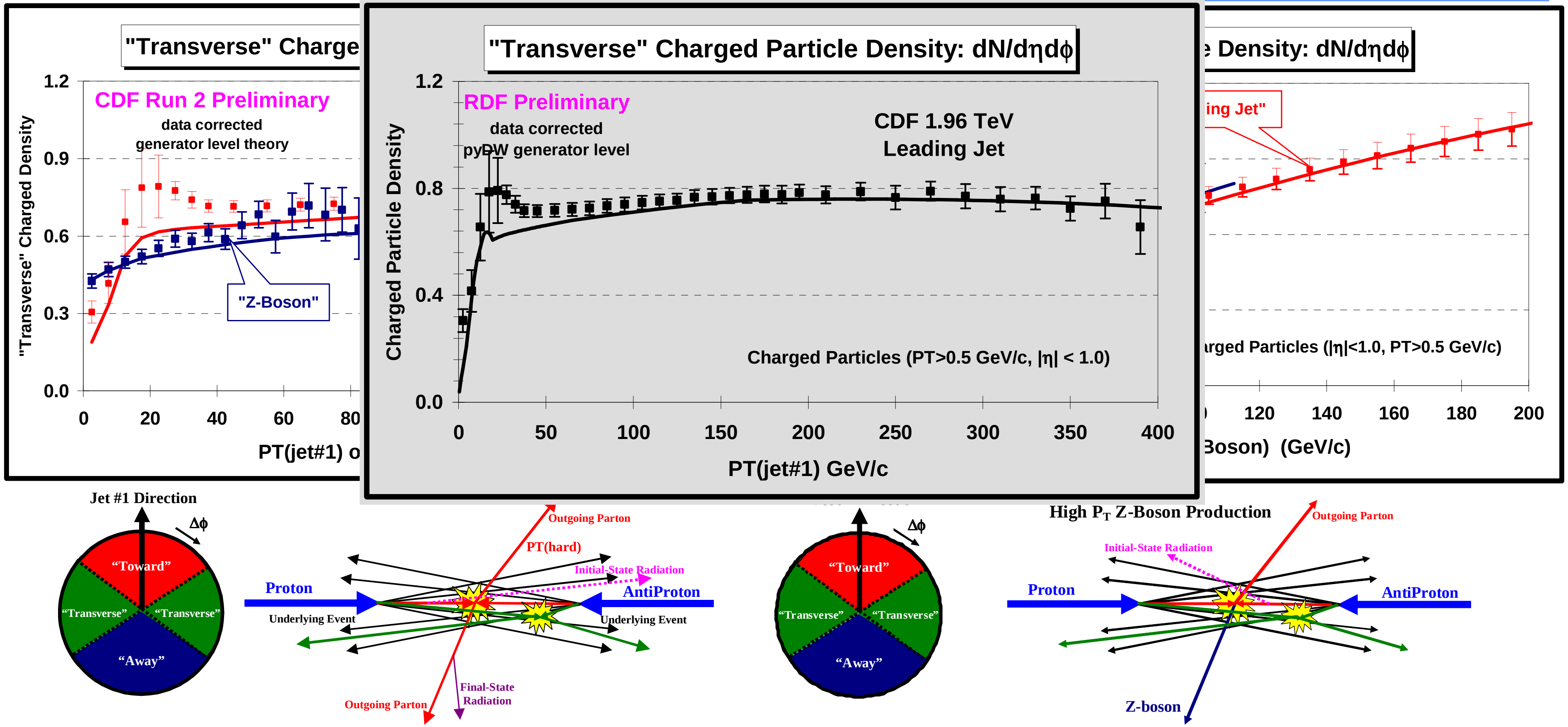

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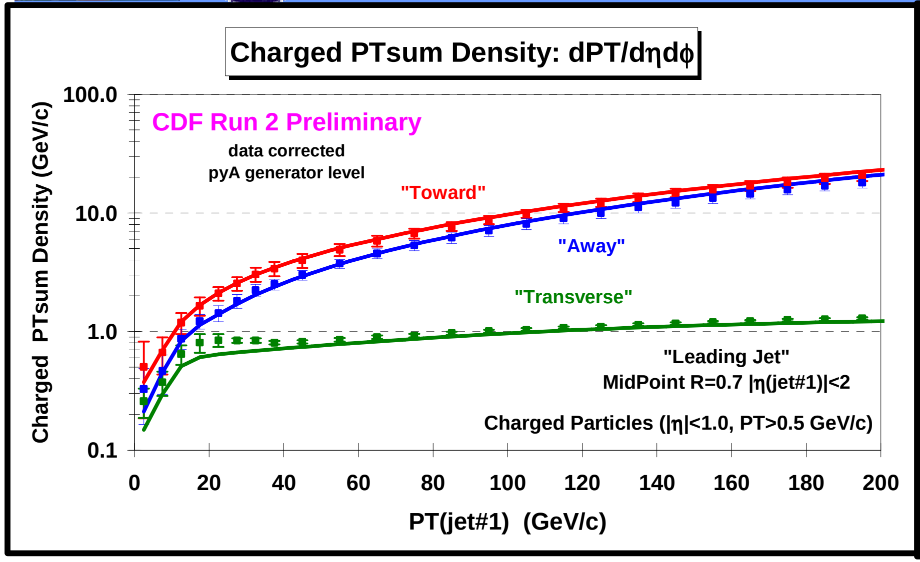
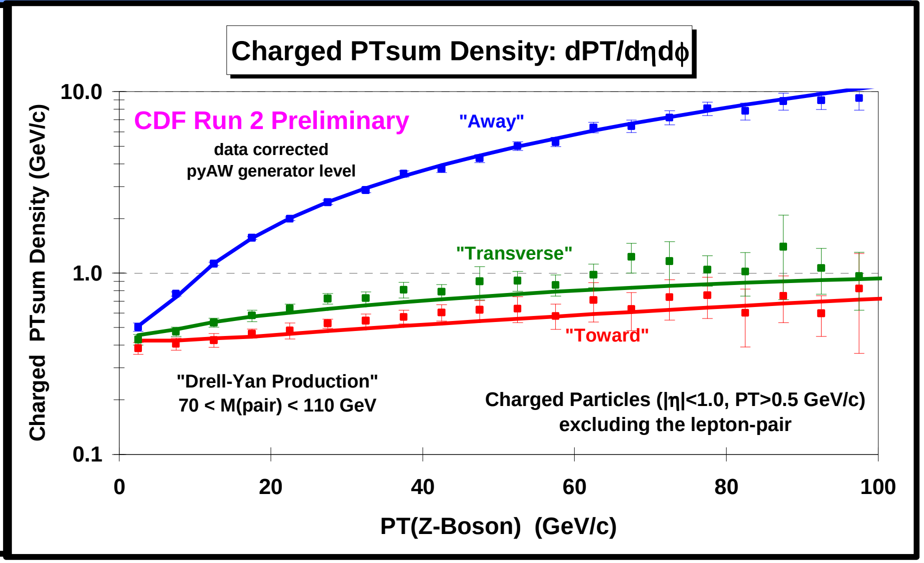
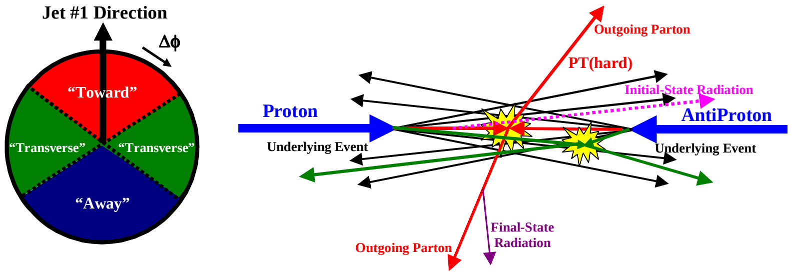
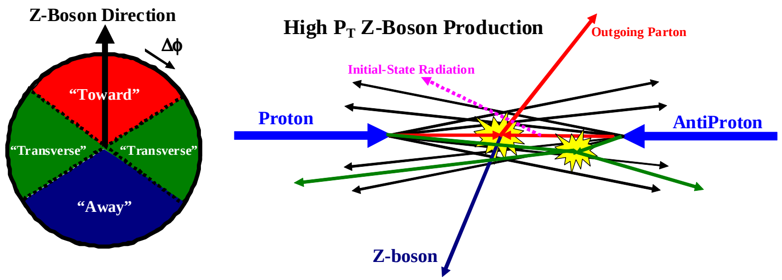
Charged PTsum Density









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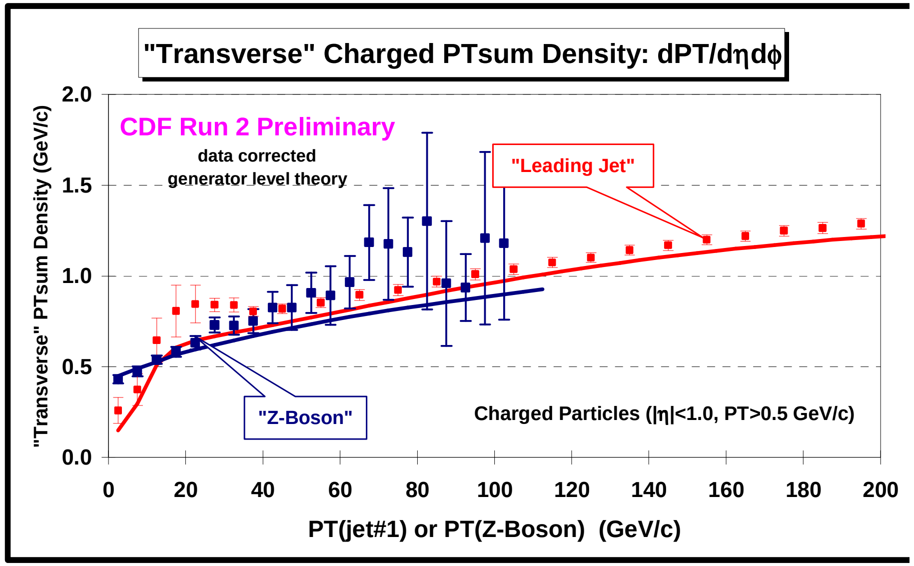

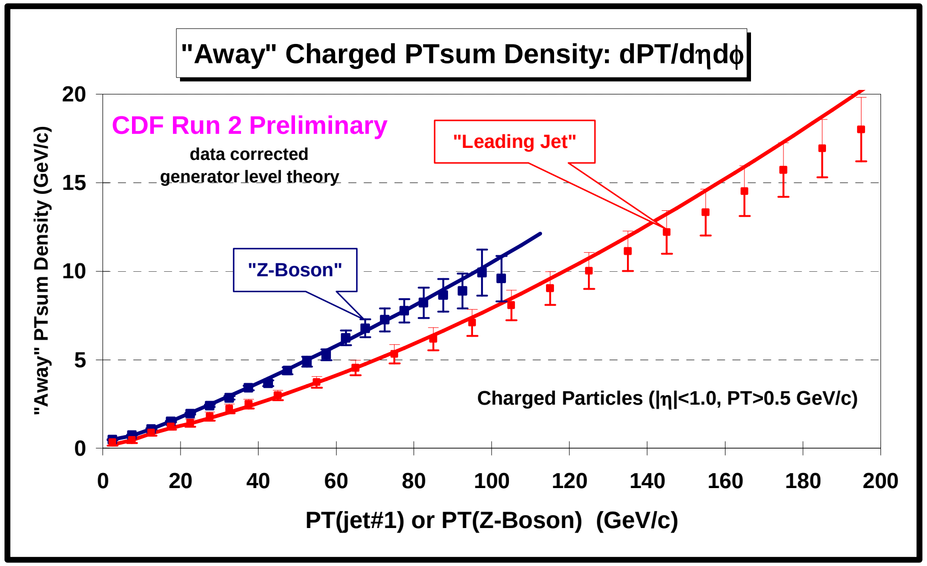

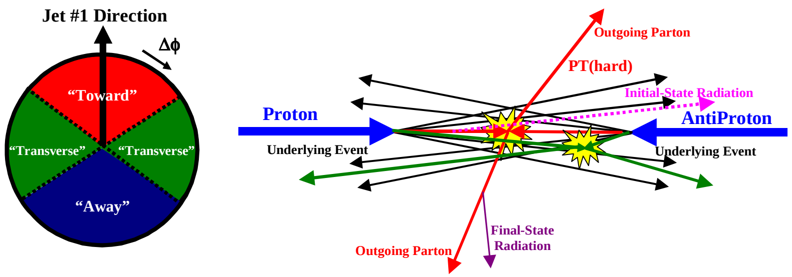

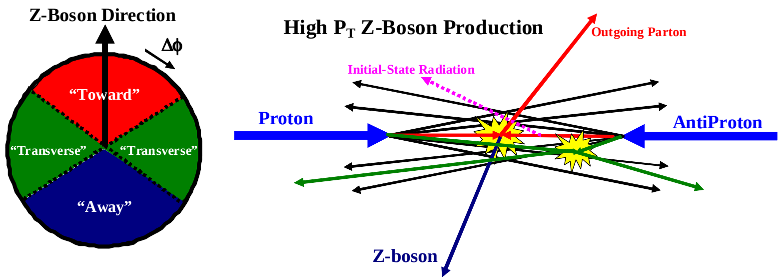

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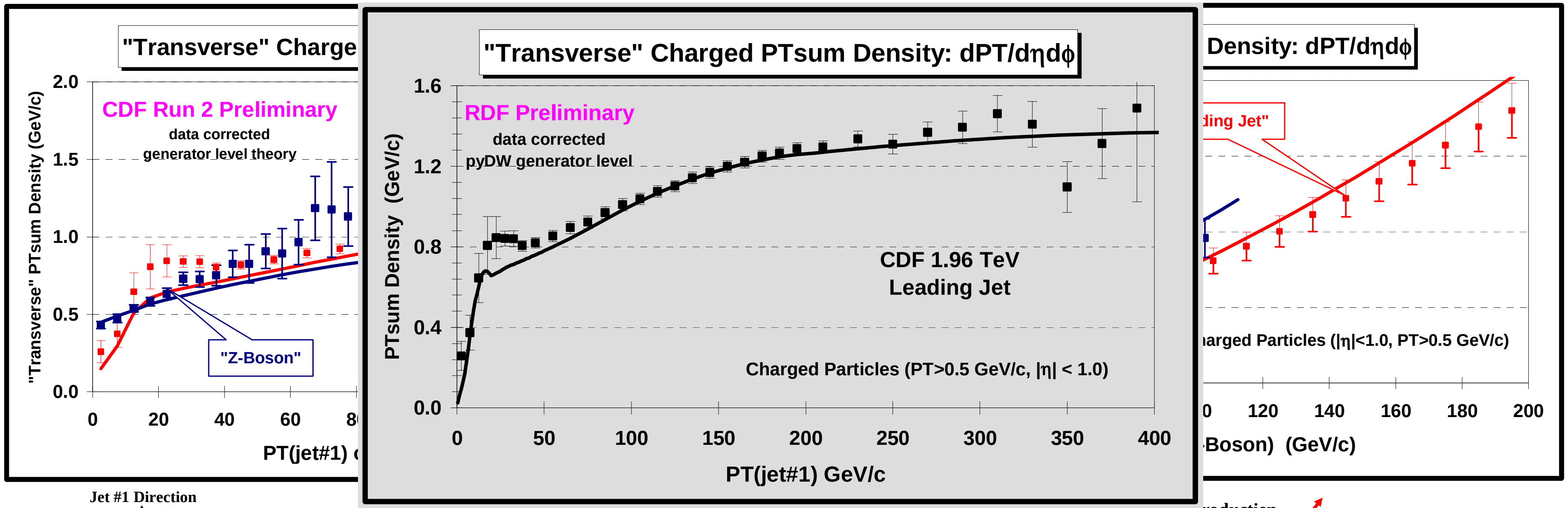

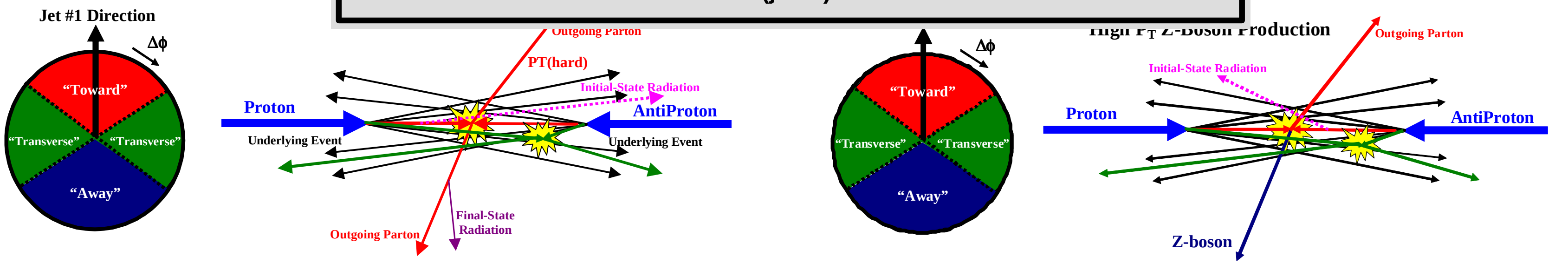

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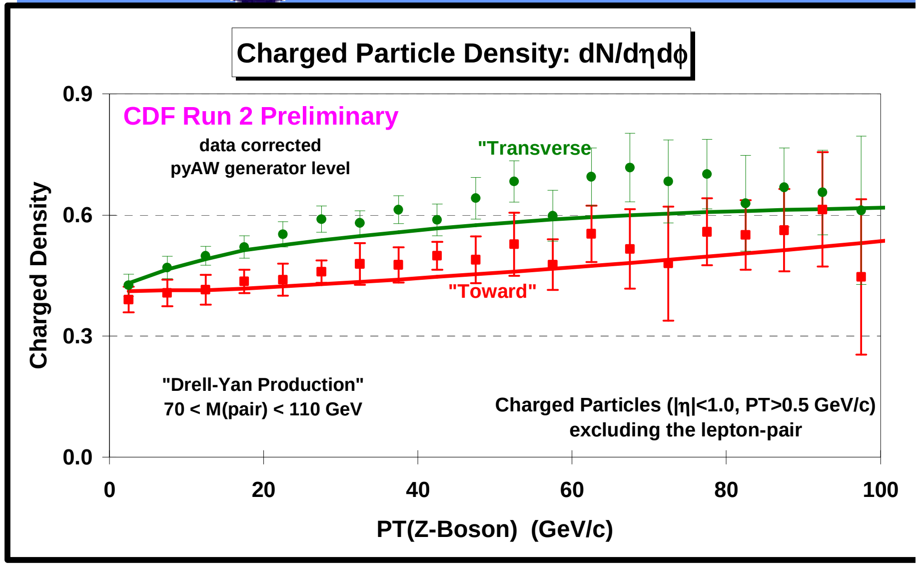
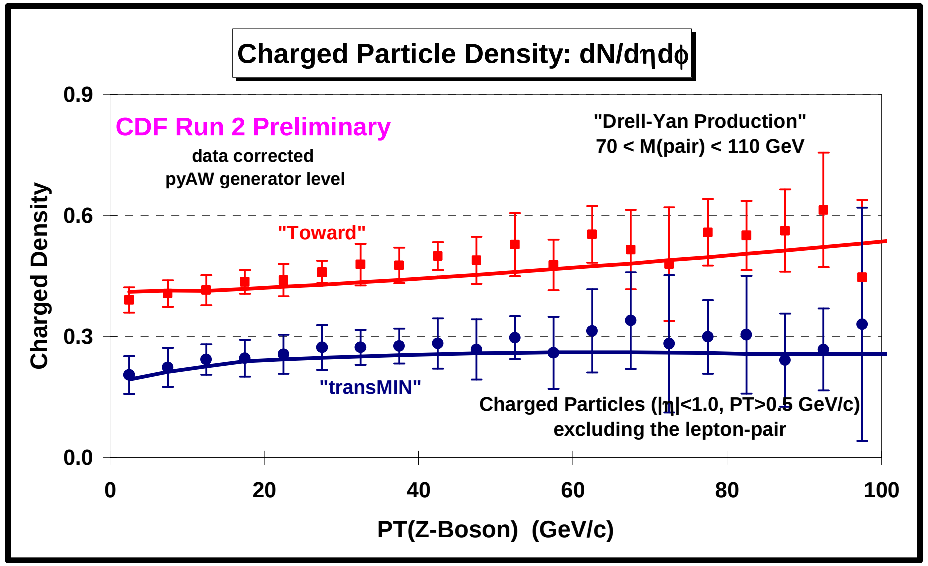
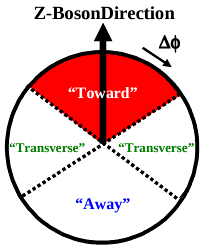
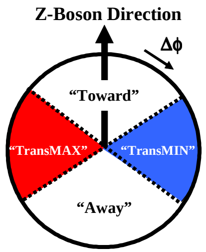
Z-Boson: “Towards”, Transverse”, & “TransMIN” Charge Density









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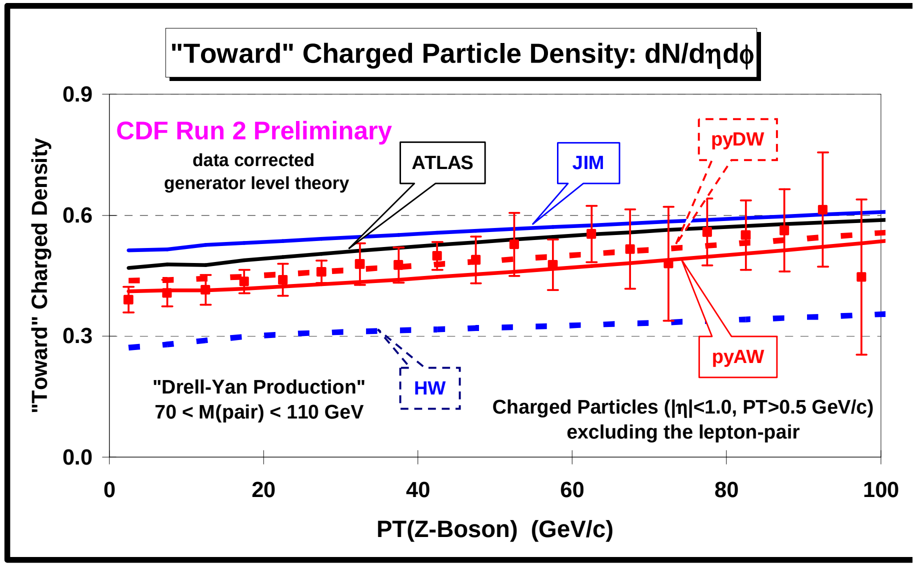

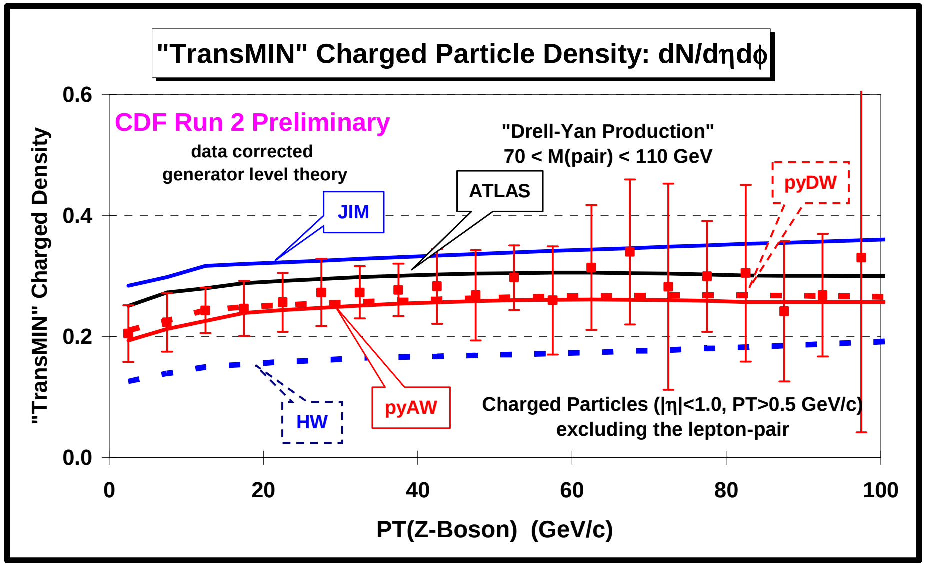

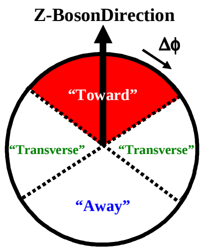

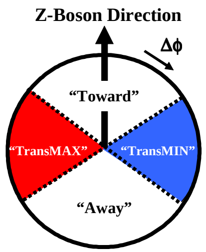

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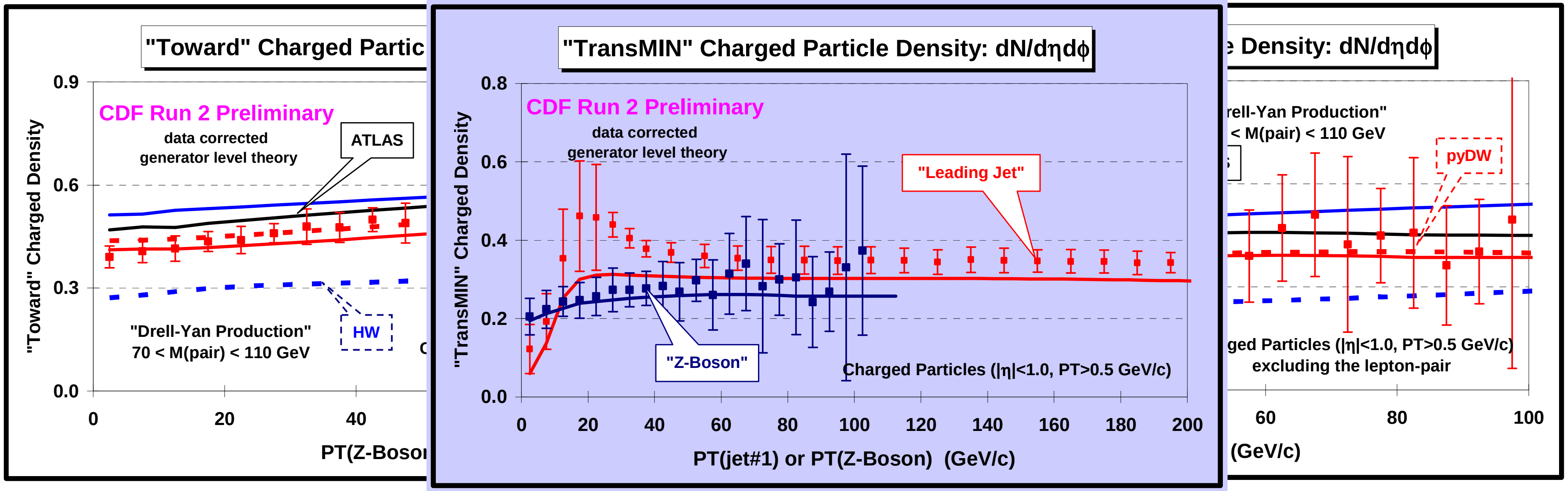

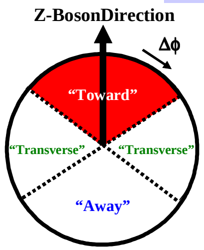

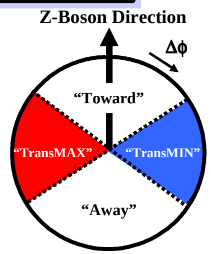

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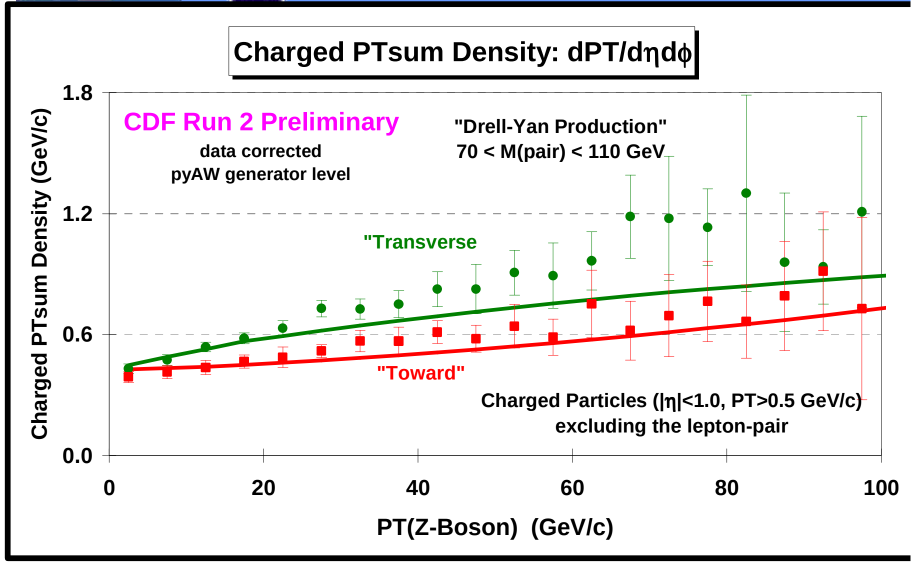

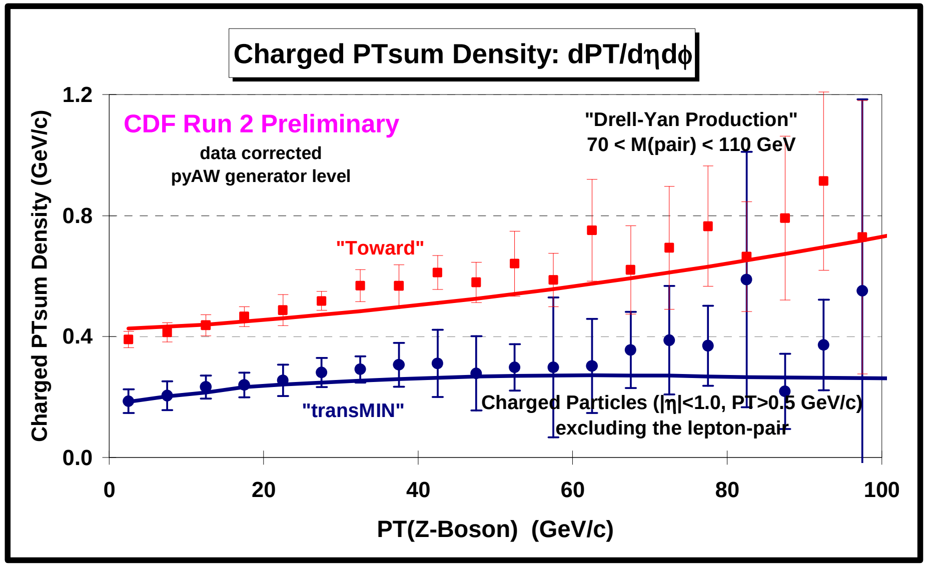

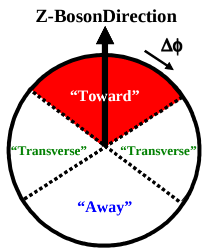

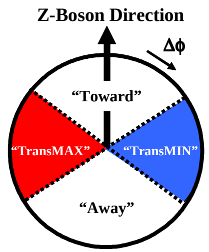

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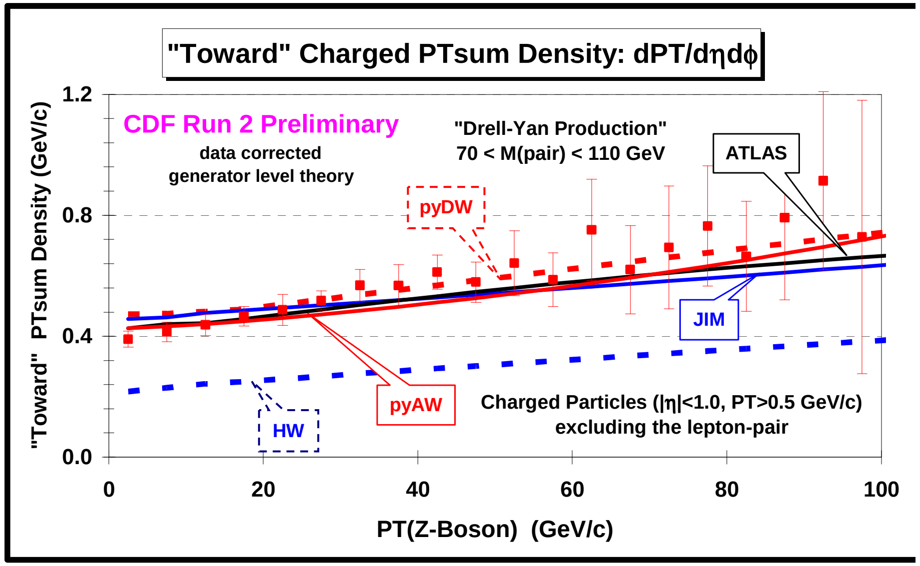

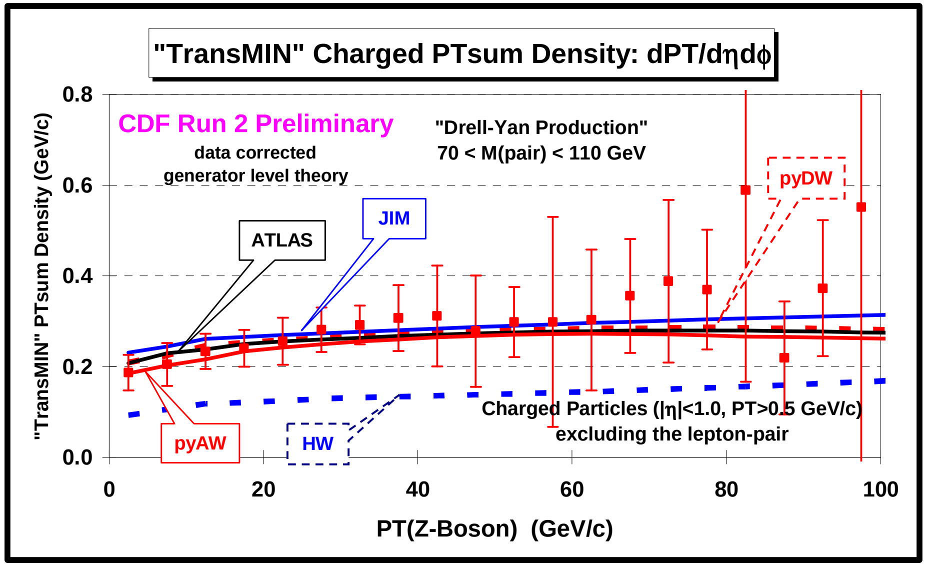

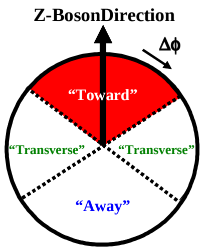

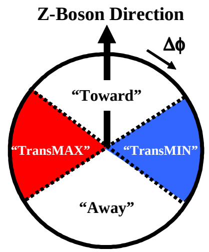

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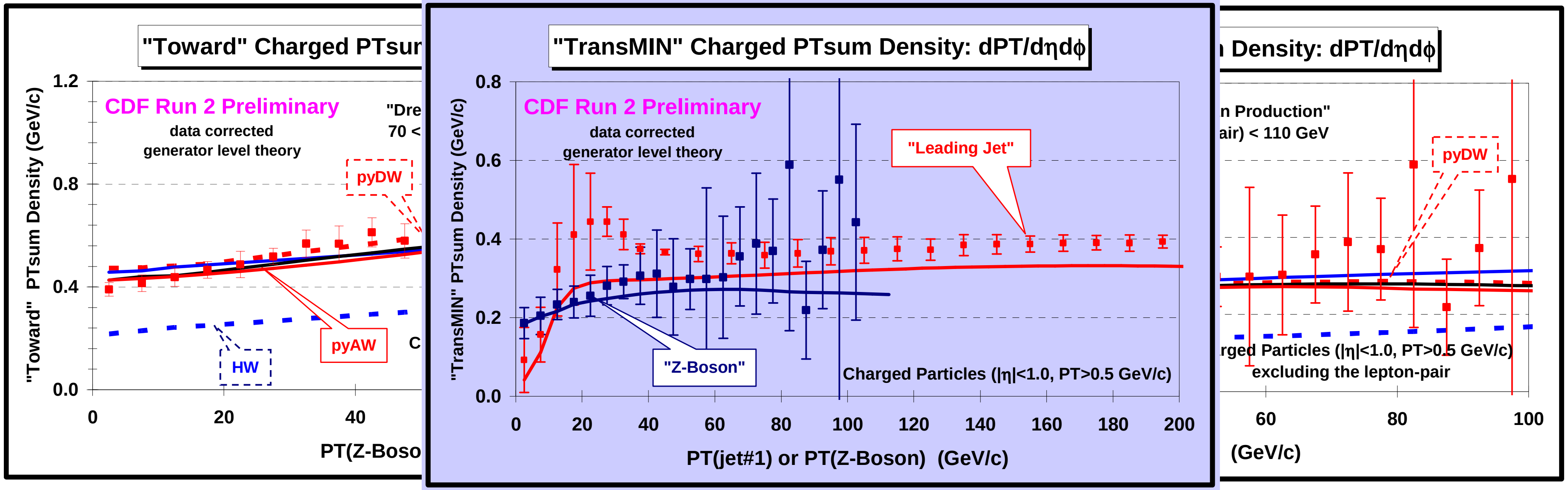

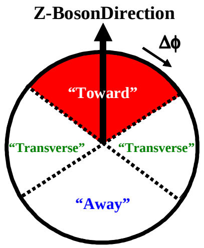

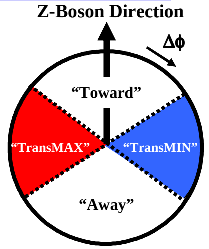

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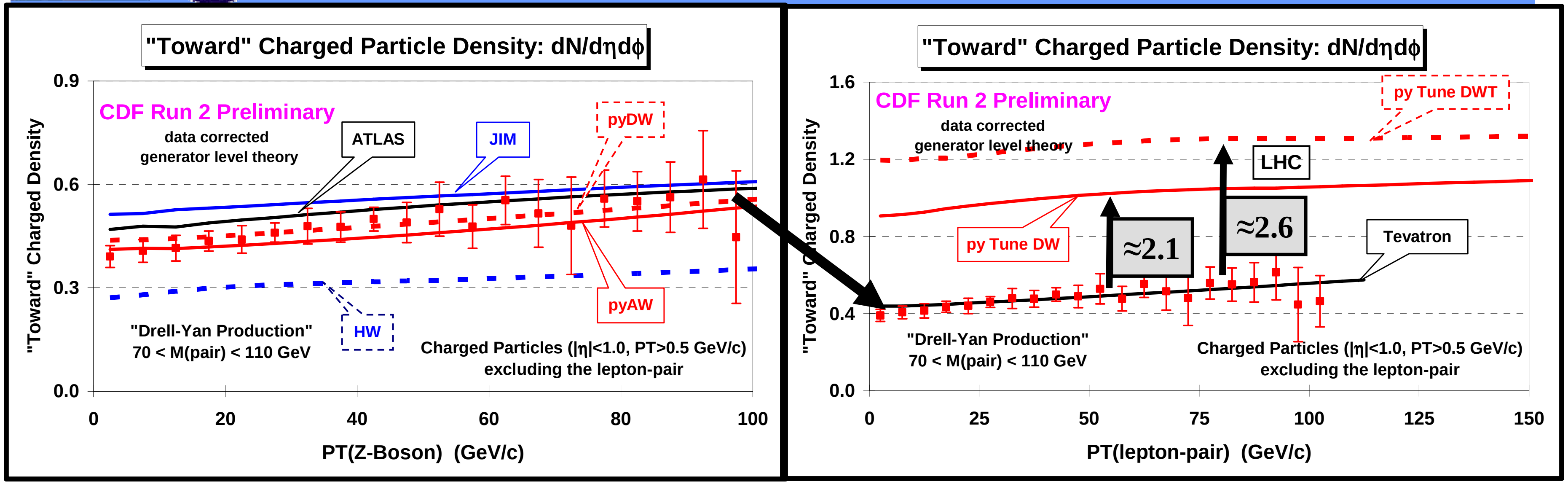
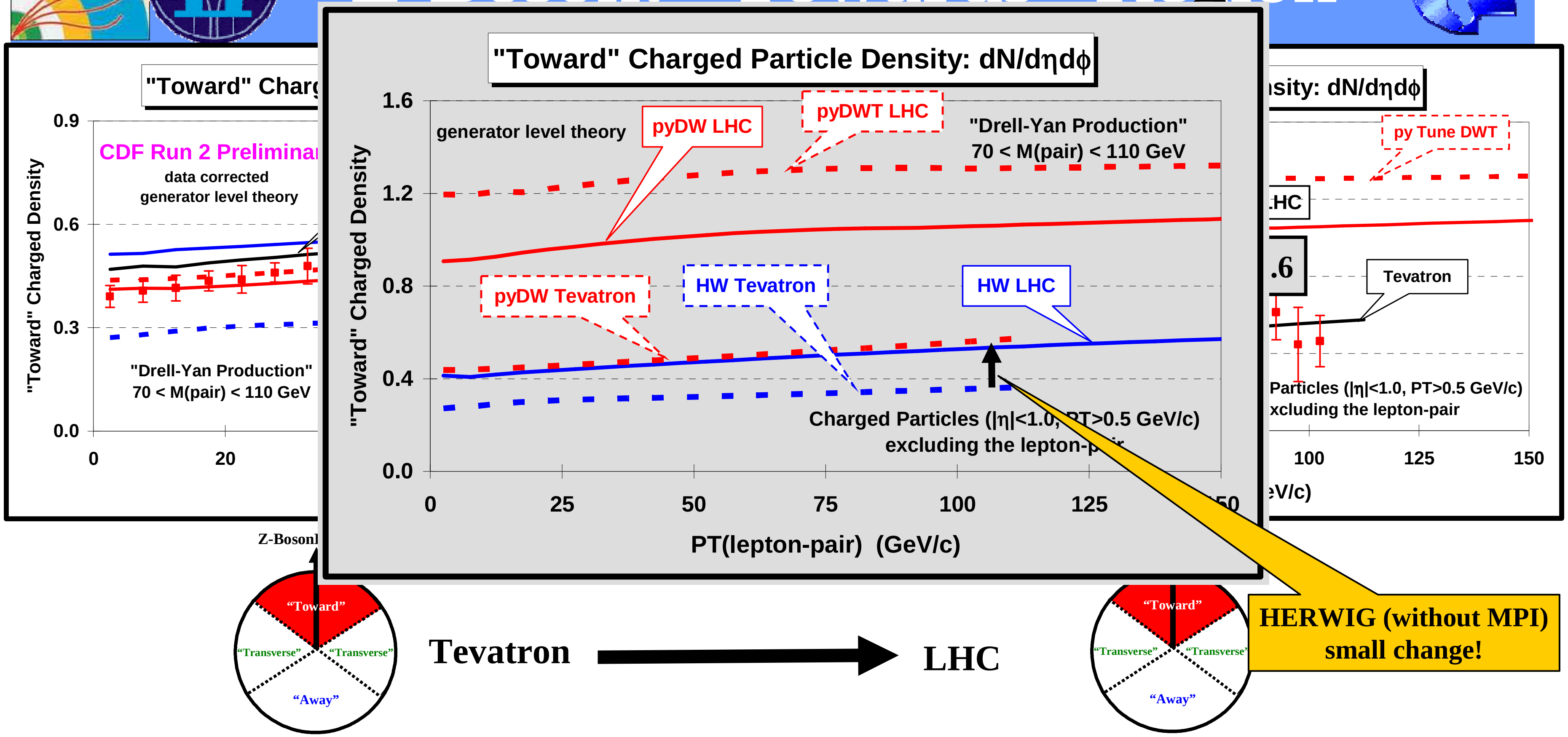
Z-Boson: "Towards" Region



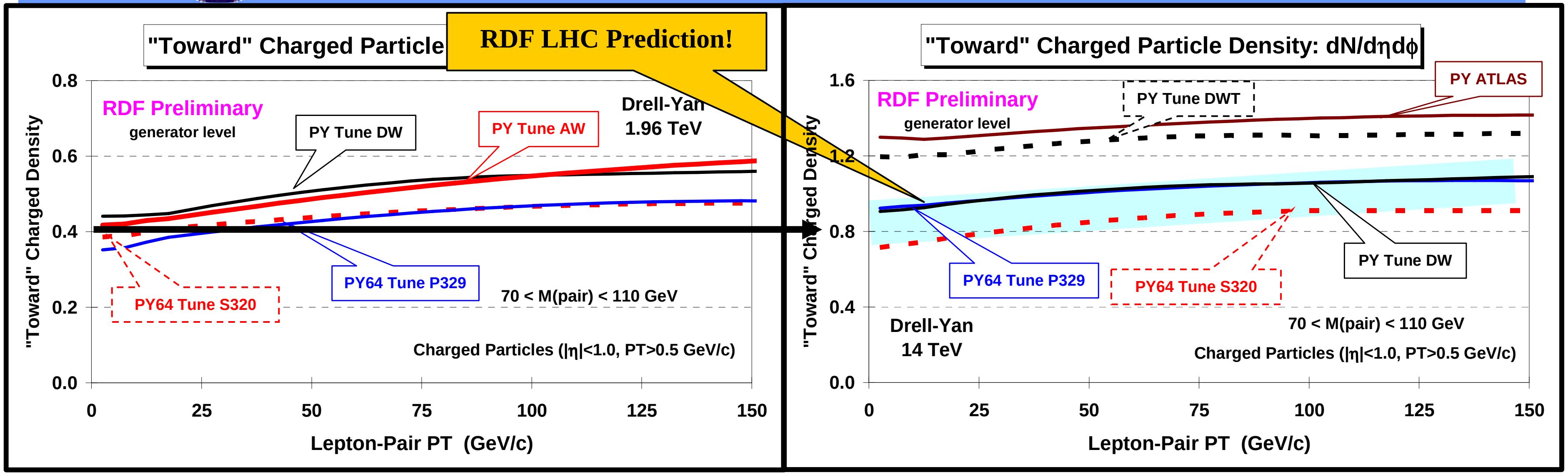
- **Data at 1.96 TeV on the density of charged particles, dN/dηdϕ, with p_T > 0.5 GeV/c and |η| < 1 for "Z-Boson" events as a function of P_T(Z) for the "toward" region. The data are corrected to the particle level (*with errors that include both the statistical error and the systematic uncertainty*) and are compared with PYTHIA Tune AW, Tune DW, PYTHIA ATLAS Tune, HERWIG (without MPI), and HERWIG (with JIMMY MPI) at the particle level (*i.e.* generator level).**

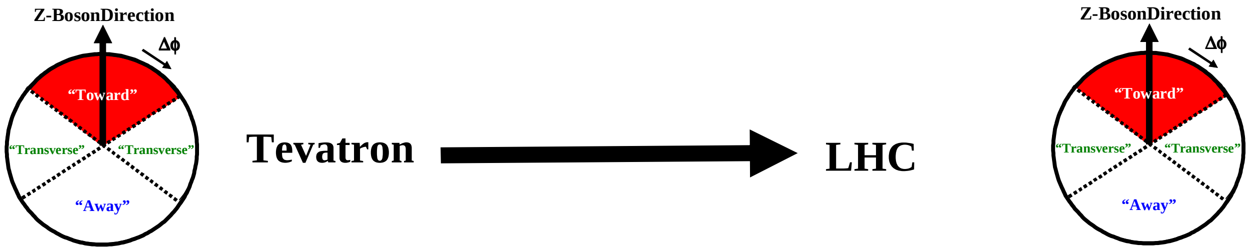
Z-Boson: “Towards” Region



- 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. The data are corrected to the particle level (*with errors that include both the statistical error and the systematic uncertainty*) and are compared with PYTHIA Tune AW, Tune DW, PYTHIA ATLAS Tune, HERWIG (without MPI), and HERWIG (with JIMMY MPI) at the particle level (*i.e.* generator level).

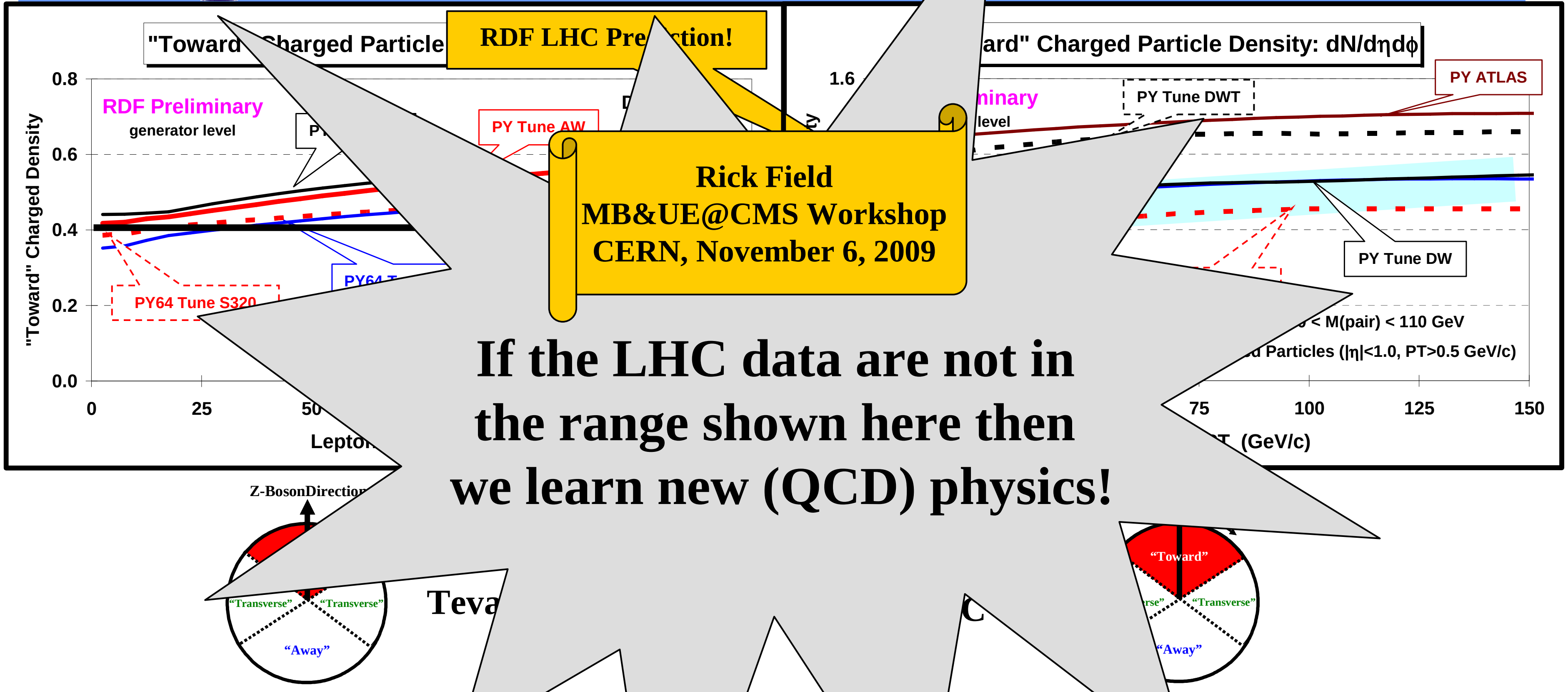
Z-Boson: "Towards" Region





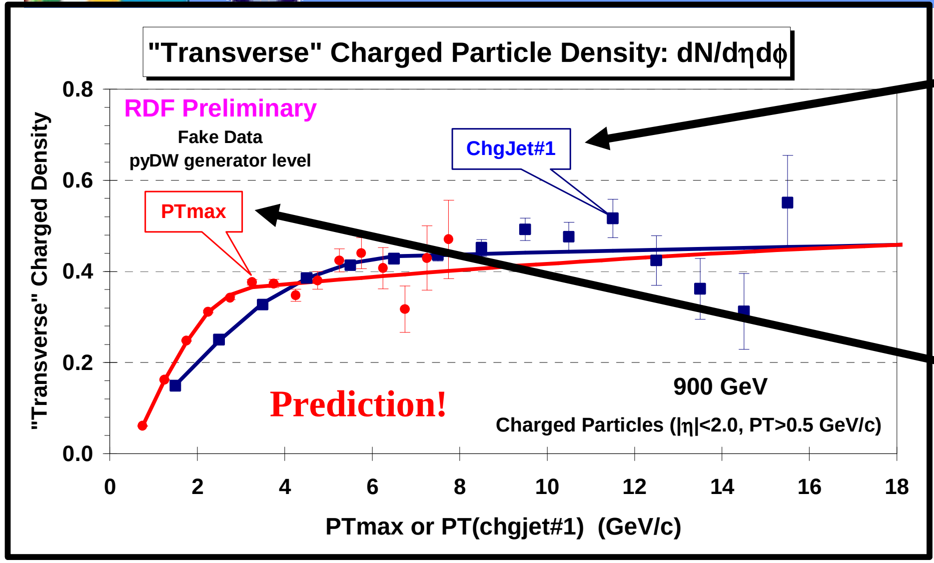
- Data at 1.96 TeV on the density of charged particles, dN/dηdϕ, with p_T > 0.5 GeV/c and |η| < 1 for "Z-Boson" events as a function of $P_T(Z)$ for the "toward" region from PYTHIA Tune AW, Tune DW, Tune S320, and Tune P329 at the particle level (*i.e.* generator level).
- Extrapolations of PYTHIA Tune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

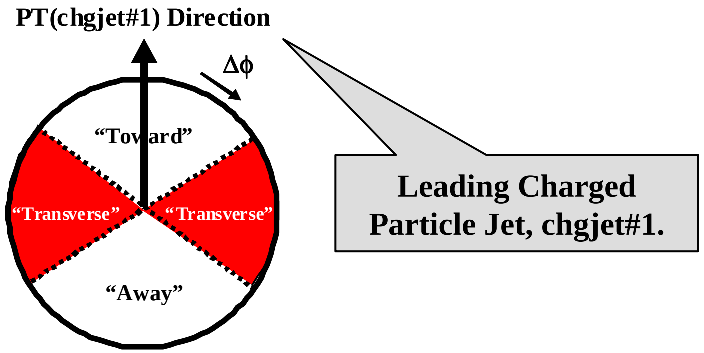
Z-Boson: "Towards" Region

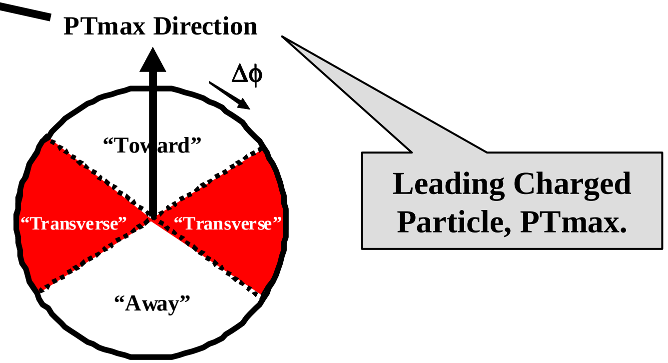


- Data at 1.96 TeV on the density of charged particles, dN/dηdφ, with p_T > 0.5 GeV/c and |η| < 1 for "Z-Boson" events as a function of $P_T(Z)$ for the "Toward" region from PYTHIA Tune AW, Tune DW, Tune S320, and Tune P329 at the particle level (i.e. generator level).
- Extrapolations of PYTHIA Tune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

"Transverse" Charged Particle Density







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

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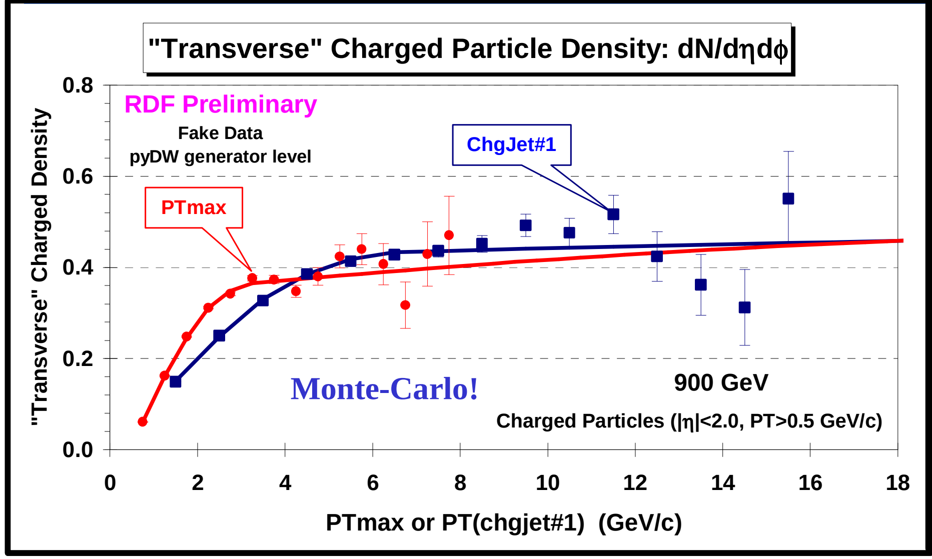
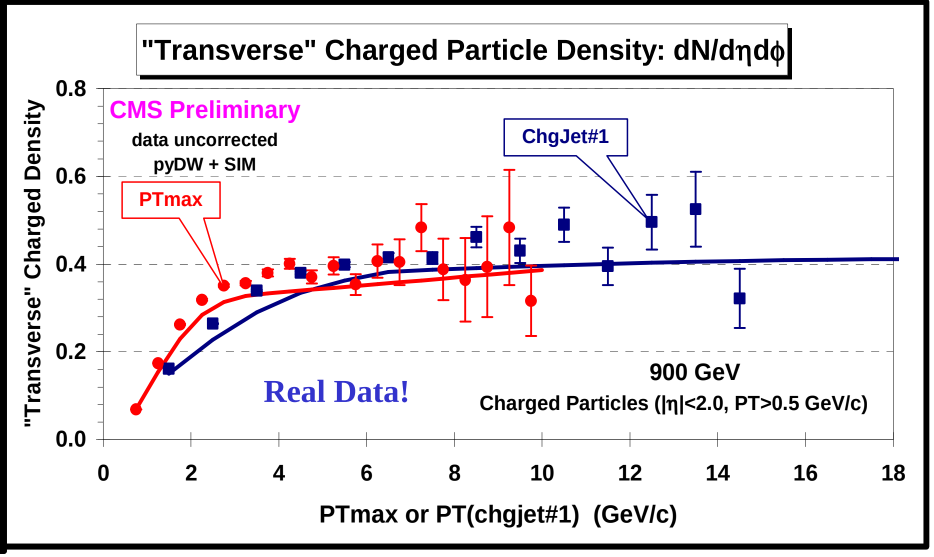
MB&UE@CMS Workshop
CERN, November 6, 2009

“Transverse” Charged Particle Density

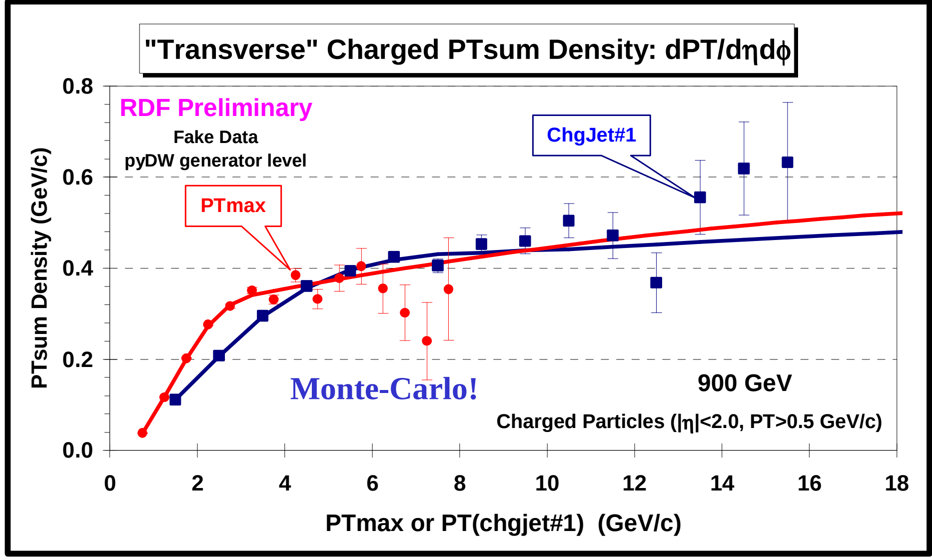


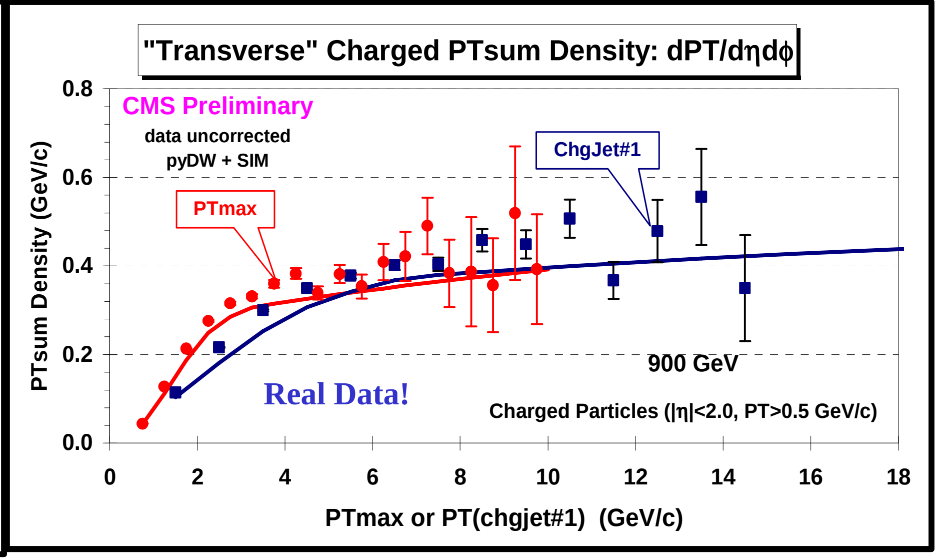


- **Fake data (from MC) at 900 GeV on the “transverse” charged particle density, dN/dηdφ, as defined by the leading charged particle (PTmax) and the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2. The fake data (from PYTHIA Tune DW) are generated at the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

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

“Transverse” Charged PTsum Density

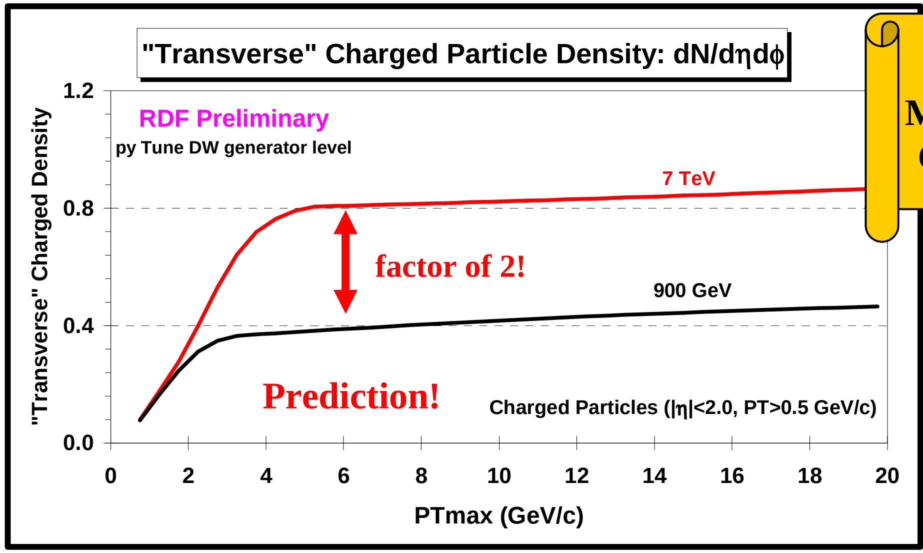




- **Fake data (from MC) at 900 GeV on the “transverse” charged PTsum density, dPT/dηdϕ, as defined by the leading charged particle (PTmax) and the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2. The fake data (from PYTHIA Tune DW) are generated at the particle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

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

“Transverse” Charge Density



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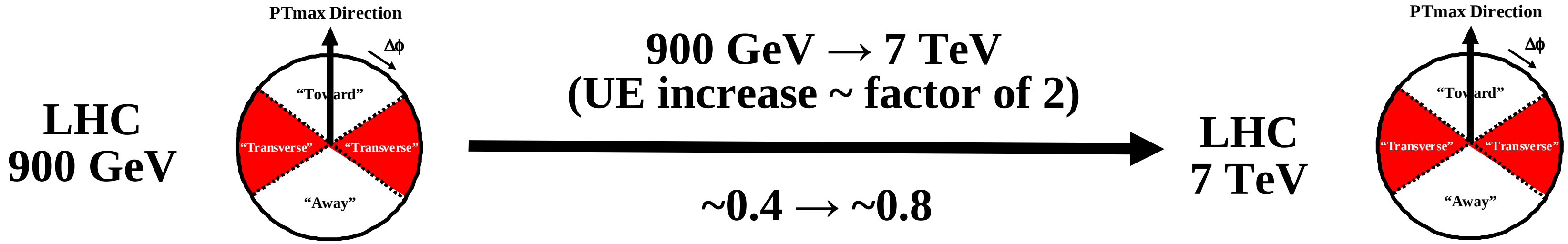
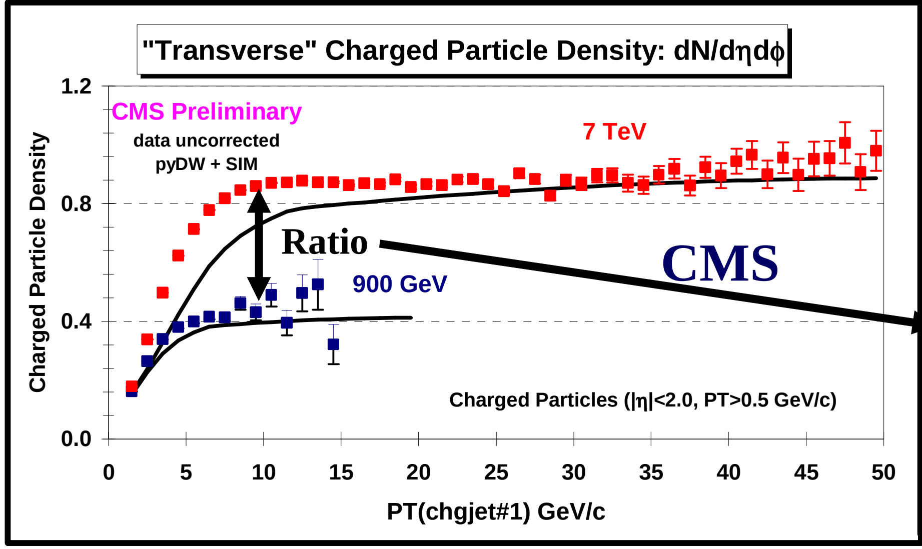
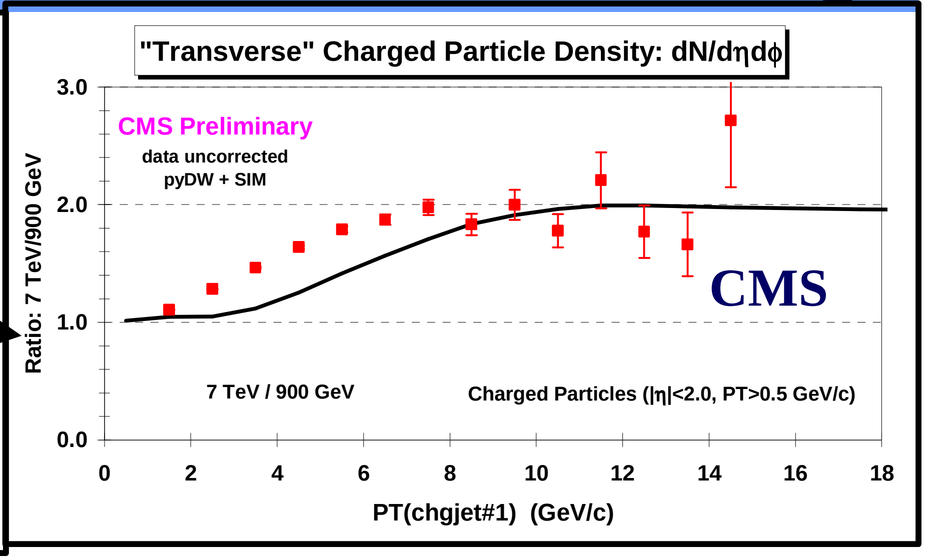


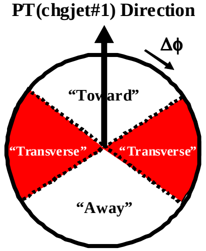
- **Shows the charged particle density in the “transverse” region for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 2$) at 900 GeV and 7 TeV as defined by PTmax from PYTHIA Tune DW and at the particle level (*i.e.* generator level).**

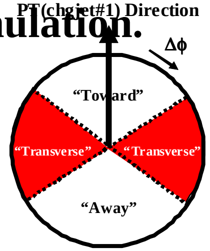
PYTHIA Tune DW



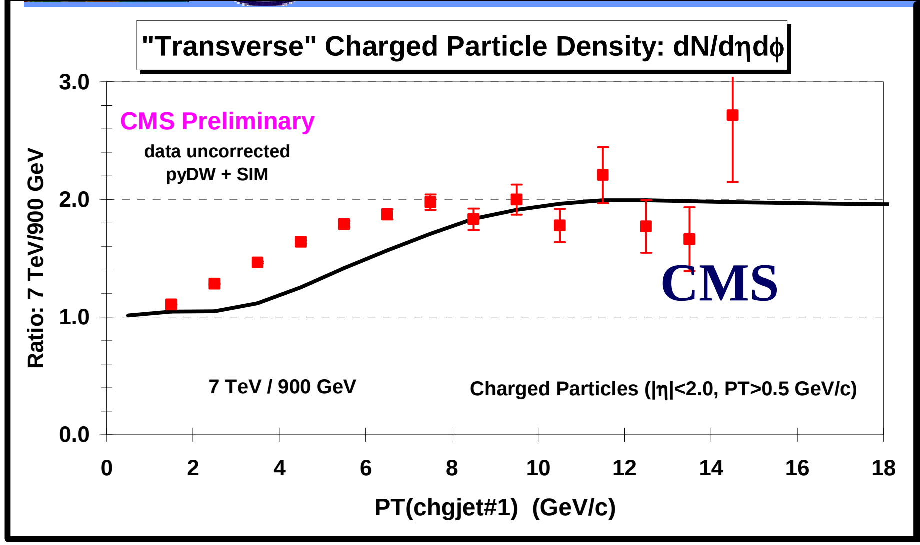


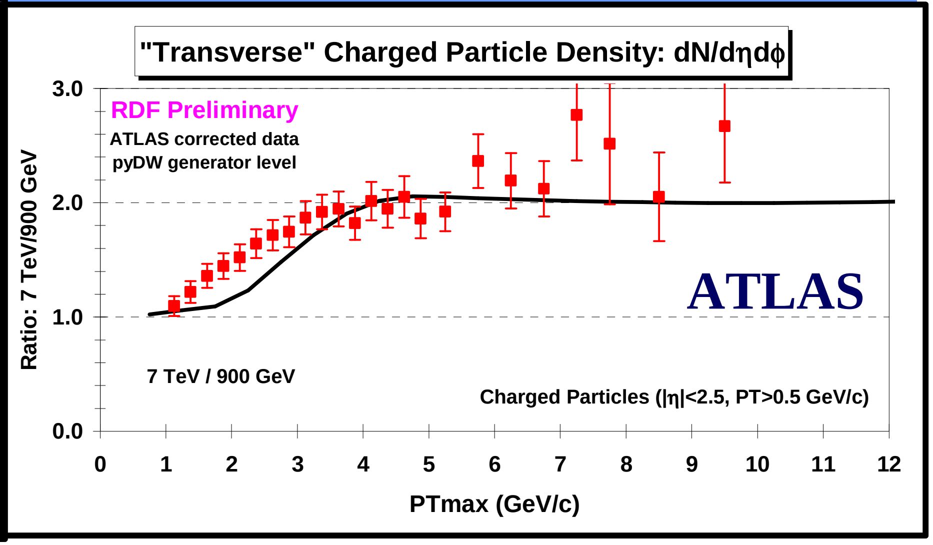
- **CMS preliminary data at 900 GeV and 7 TeV** on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2$. The data are uncorrected and compared with PYTHIA **Tune DW** after detector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



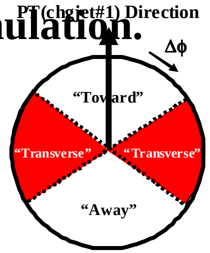


PYTHIA Tune DW

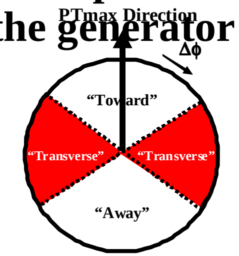




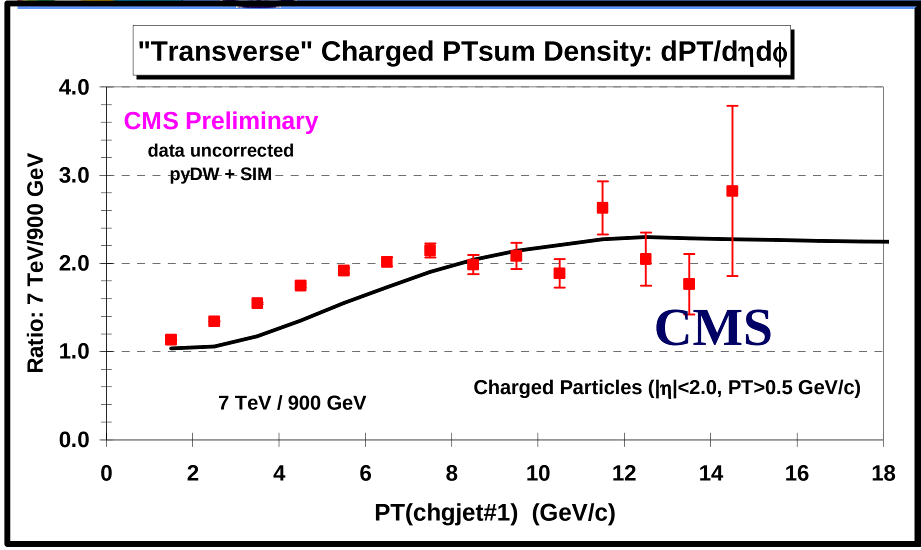
- **Ratio of CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2. The data are uncorrected and compared with PYTHIA Tune DW after detector simulation.**

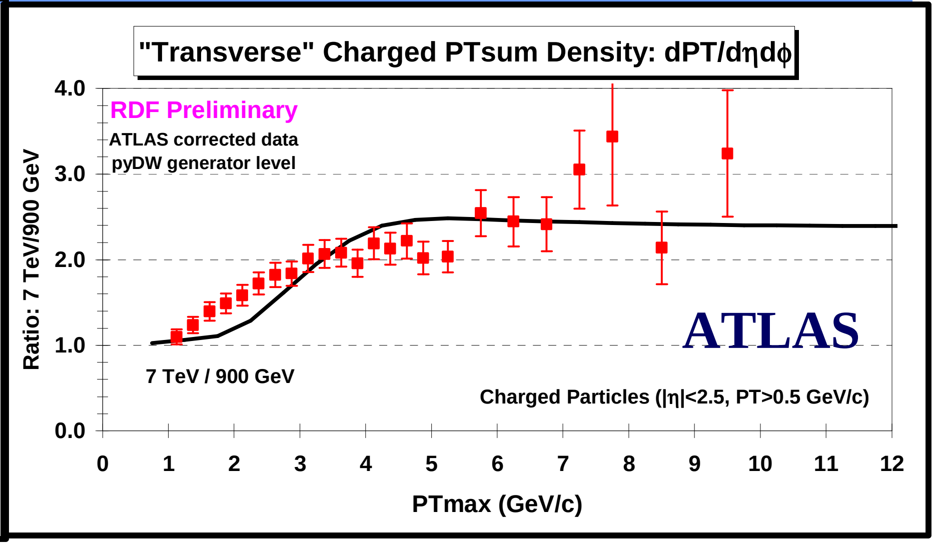


- **Ratio of the ATLAS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 2.5. The data are corrected and compared with PYTHIA Tune DW at the generator level.**

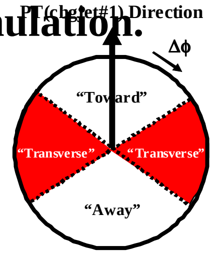


PYTHIA Tune DW

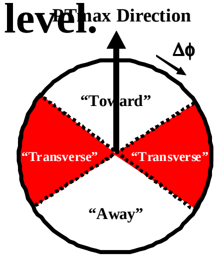




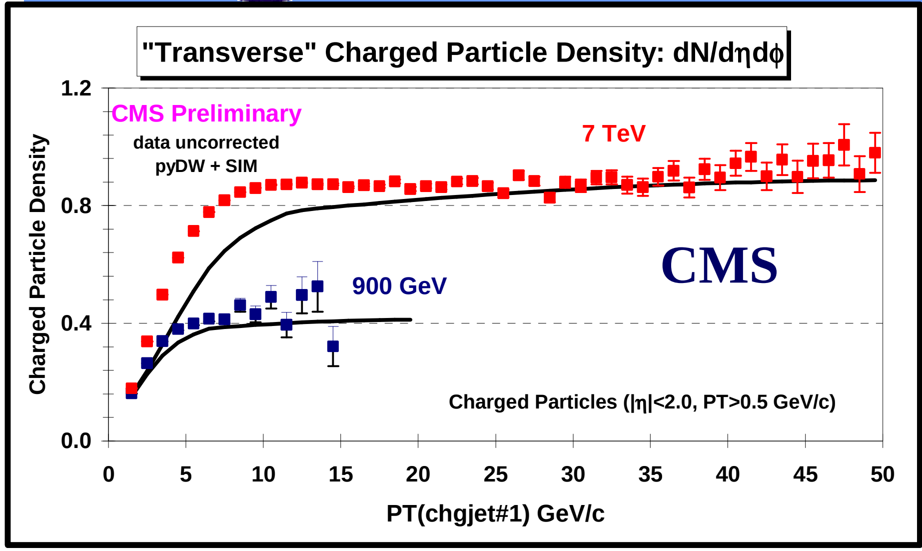
- **Ratio of the CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged PTsum density, dPT/dηdφ, as defined by the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2. The data are uncorrected and compared with PYTHIA Tune DW after detector simulation.**

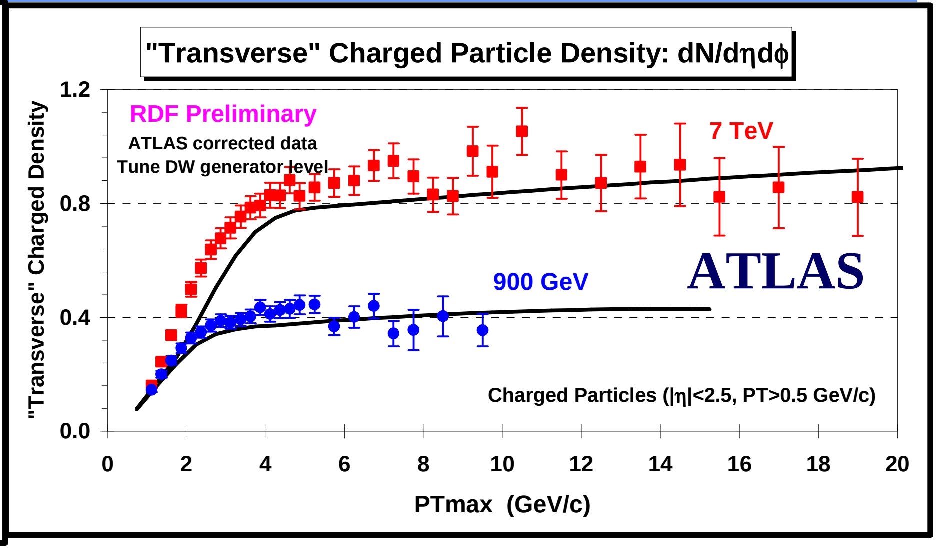


- **Ratio of the ATLAS preliminary data at 900 GeV and 7 TeV on the "transverse" charged PTsum density, dPT/dηdφ, as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 2.5. The data are corrected and compared with PYTHIA Tune DW at the generator level.**



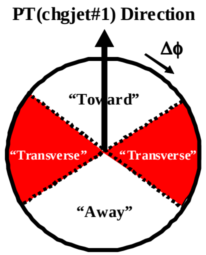
PYTHIA Tune DW

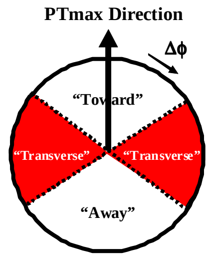




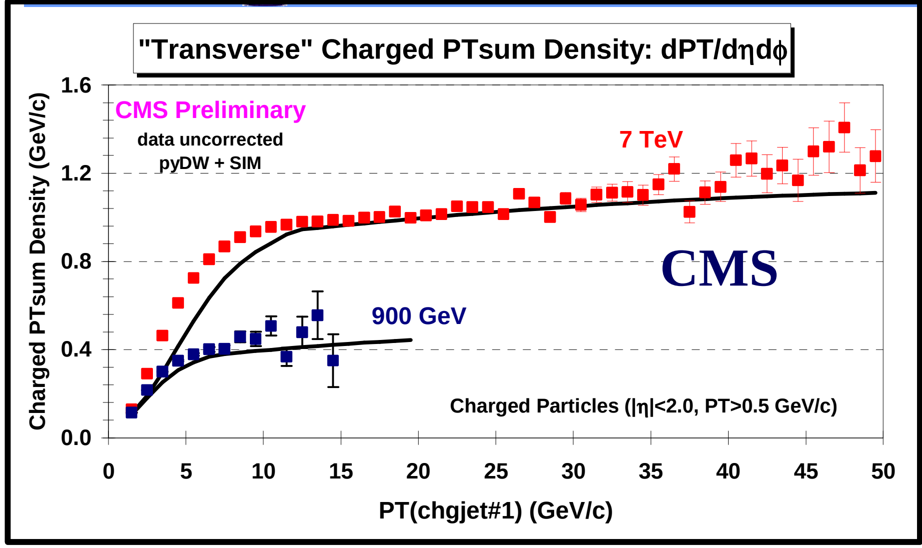
- **CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2. The data are uncorrected and compared with PYTHIA Tune DW after detector simulation.**

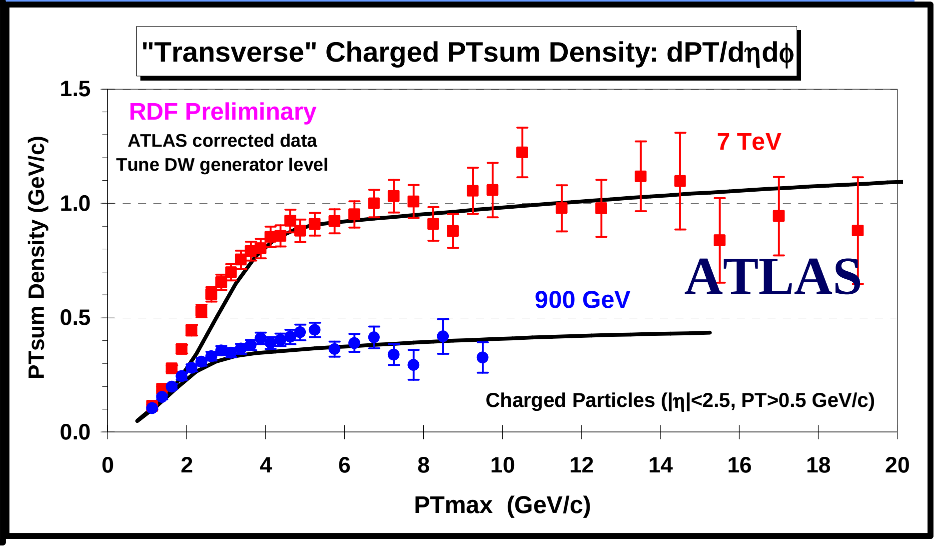
- **ATLAS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 2.5. The data are corrected and compared with PYTHIA Tune DW at the generator level.**



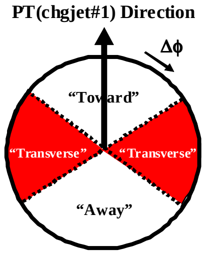


PYTHIA Tune DW

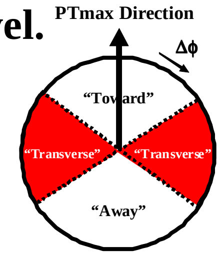




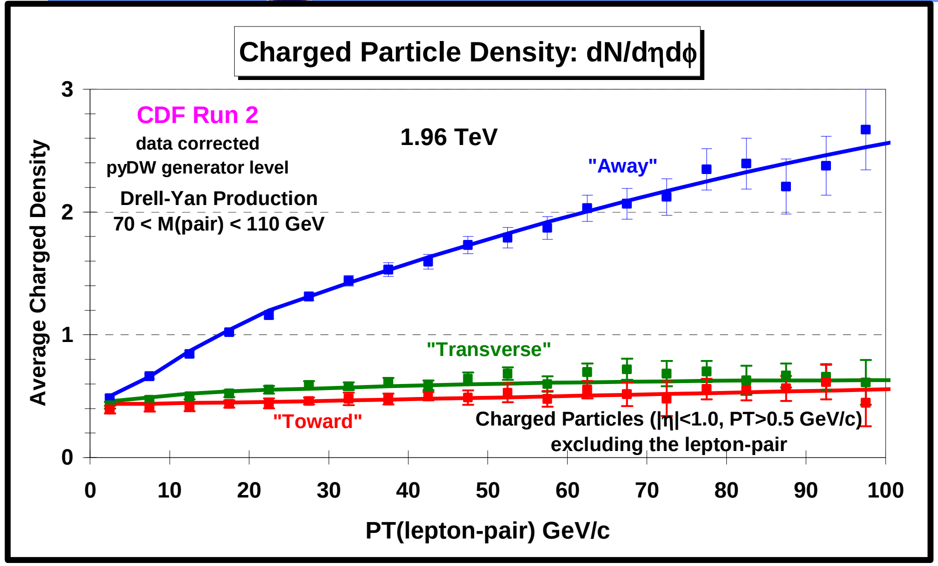
- **CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged PTsum density, dPT/dηdφ, as defined by the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2. The data are uncorrected and compared with PYTHIA Tune DW after detector simulation.**

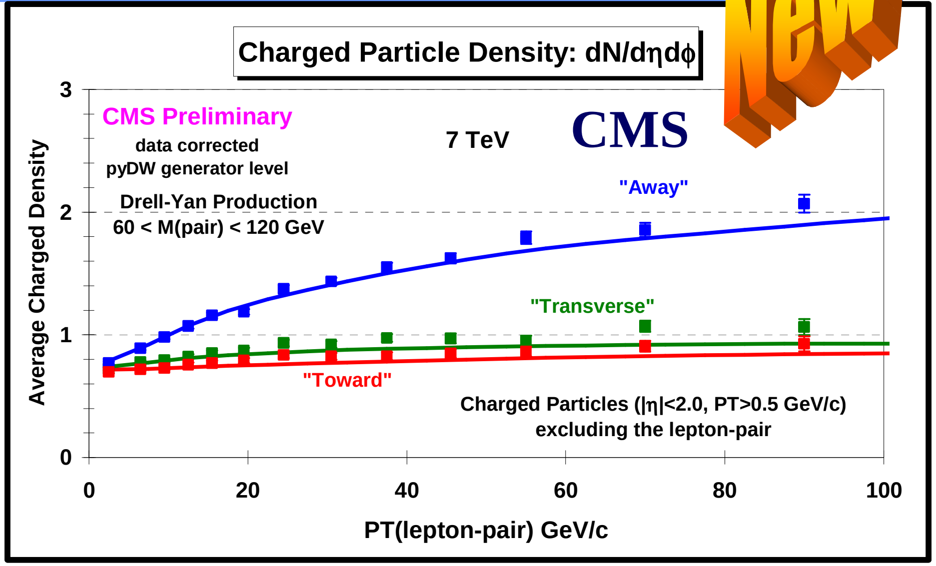


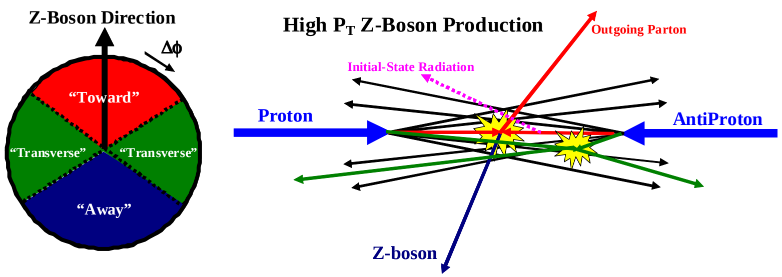
- **ATLAS preliminary data at 900 GeV and 7 TeV on the "transverse" charged PTsum density, dPT/dηdφ, as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 2.5. The data are corrected and compared with PYTHIA Tune DW at the generator level.**

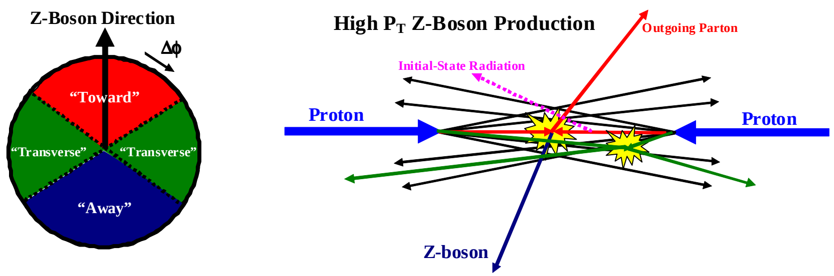


Charged Particle Density



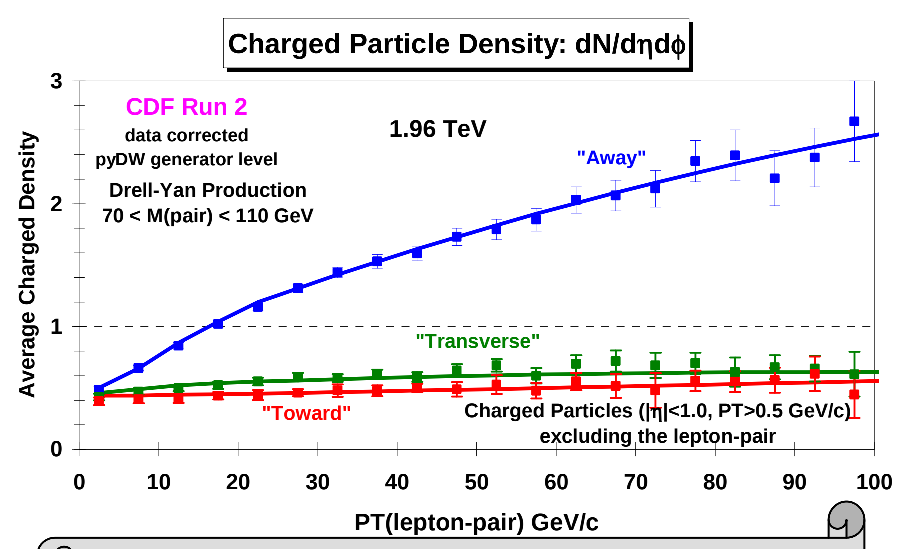


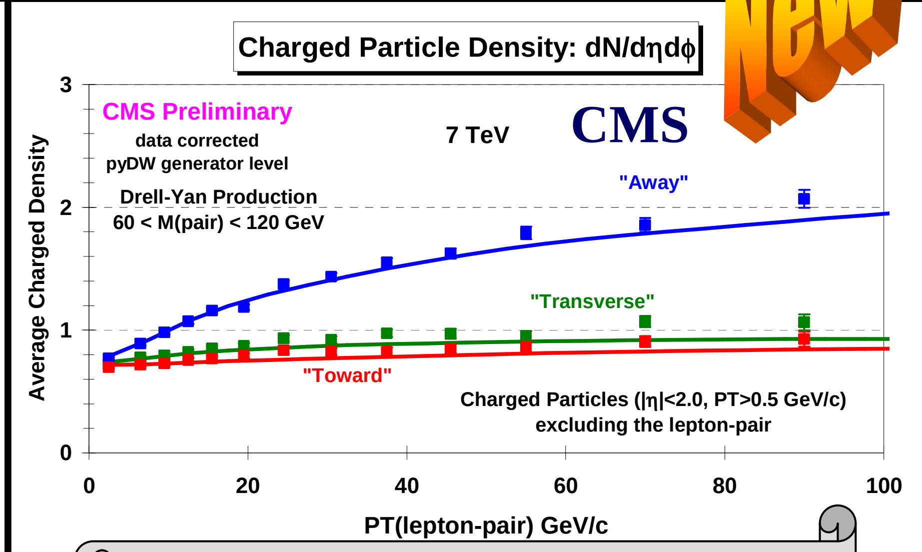


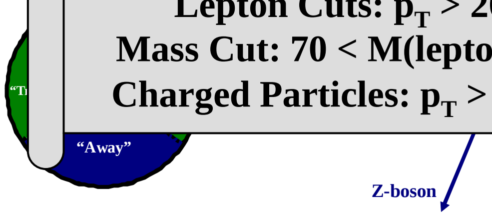


- **CDF data at 1.96 TeV** on the density of charged particles, dN/dηdϕ, with $p_T > 0.5$ GeV/c and $|\eta| < 1$ for Drell-Yan production as a function of $P_T(Z)$ for the "toward", "away", and "transverse" regions compared with **PYTHIA Tune DW**.
- **CMS data at 7 TeV** on the density of charged particles, dN/dηdϕ, with $p_T > 0.5$ GeV/c and $|\eta| < 2$ for Drell-Yan production as a function of $P_T(Z)$ for the "toward", "away", and "transverse" regions compared with **PYTHIA Tune DW**.

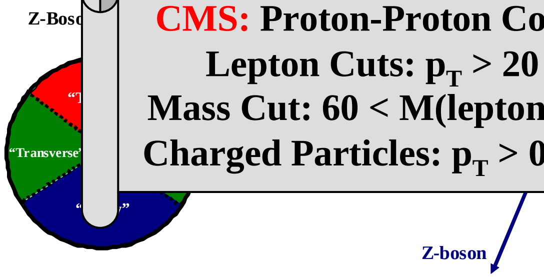
Charged Particle Density







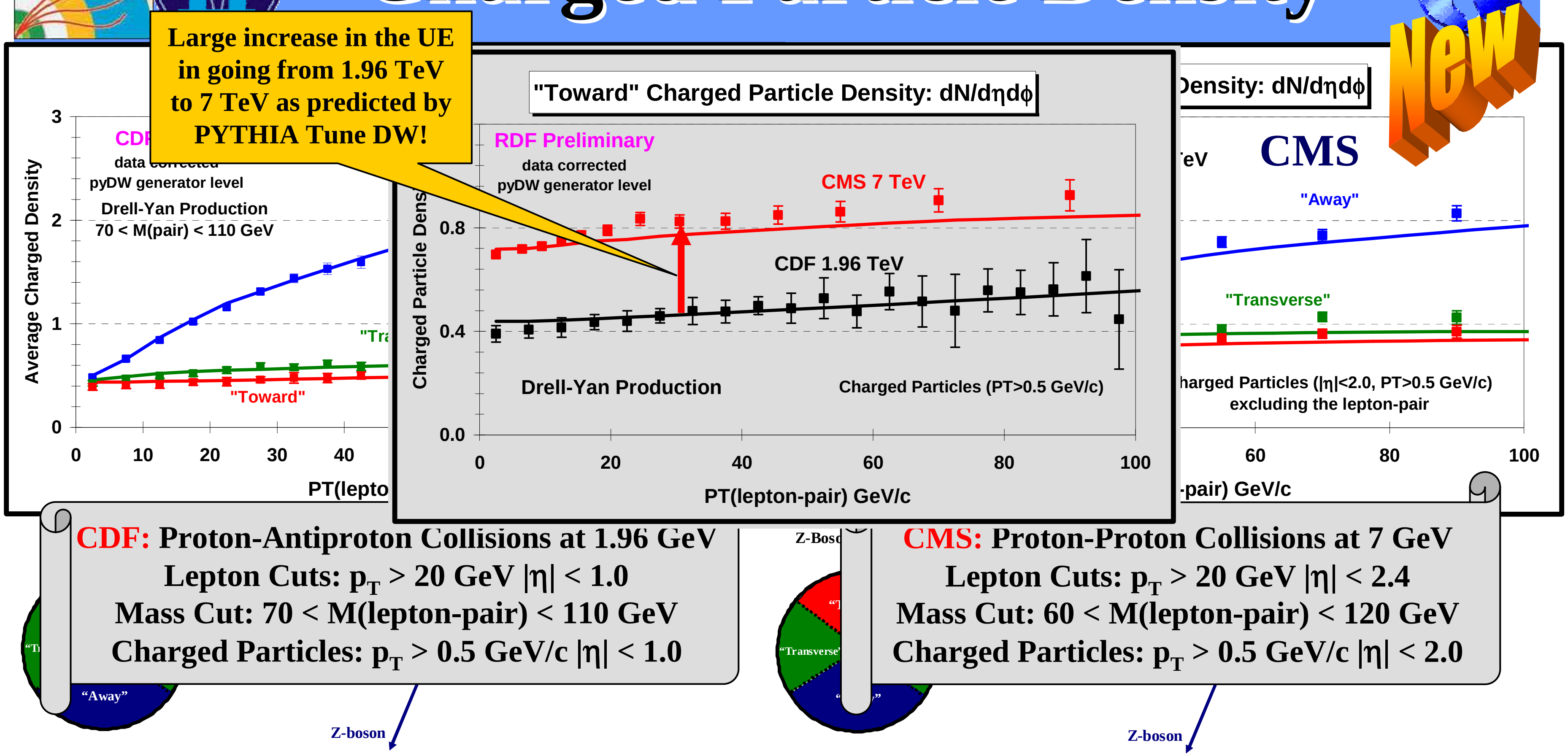
CDF: Proton-Antiproton Collisions at 1.96 GeV
Lepton Cuts: p_T > 20 GeV |η| < 1.0
Mass Cut: 70 < M(lepton-pair) < 110 GeV
Charged Particles: p_T > 0.5 GeV/c |η| < 1.0



CMS: Proton-Proton Collisions at 7 GeV
Lepton Cuts: p_T > 20 GeV |η| < 2.4
Mass Cut: 60 < M(lepton-pair) < 120 GeV
Charged Particles: p_T > 0.5 GeV/c |η| < 2.0

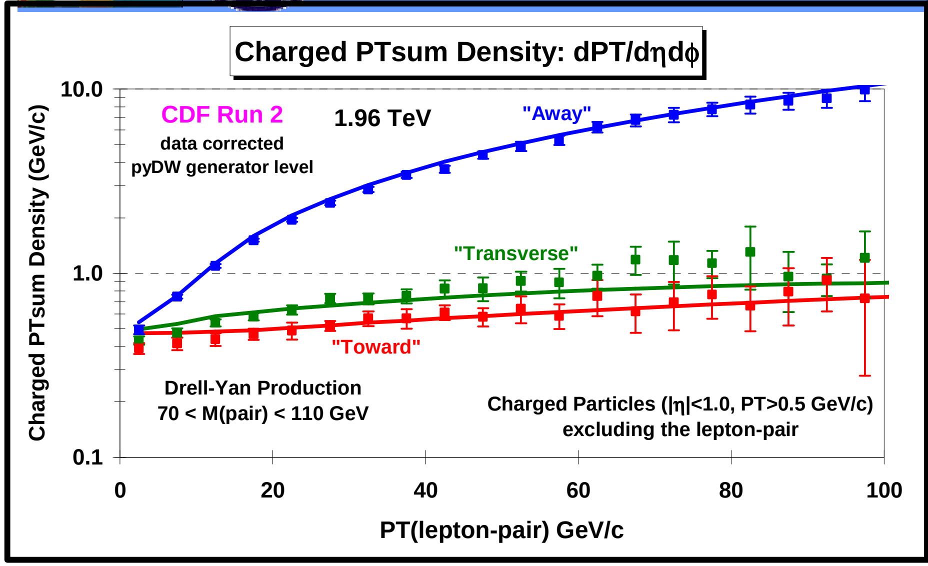
- **CDF data at 1.96 TeV** on the density of charged particles, dN/dηdϕ, with p_T > 0.5 GeV/c and |η| < 1 for Drell-Yan production as a function of P_T(Z) for the "toward", "away", and "transverse" regions compared with **PYTHIA Tune DW**.
- **CMS data at 7 TeV** on the density of charged particles, dN/dηdϕ, with p_T > 0.5 GeV/c and |η| < 2 for Drell-Yan production as a function of P_T(Z) for the "toward", "away", and "transverse" regions compared with **PYTHIA Tune DW**.

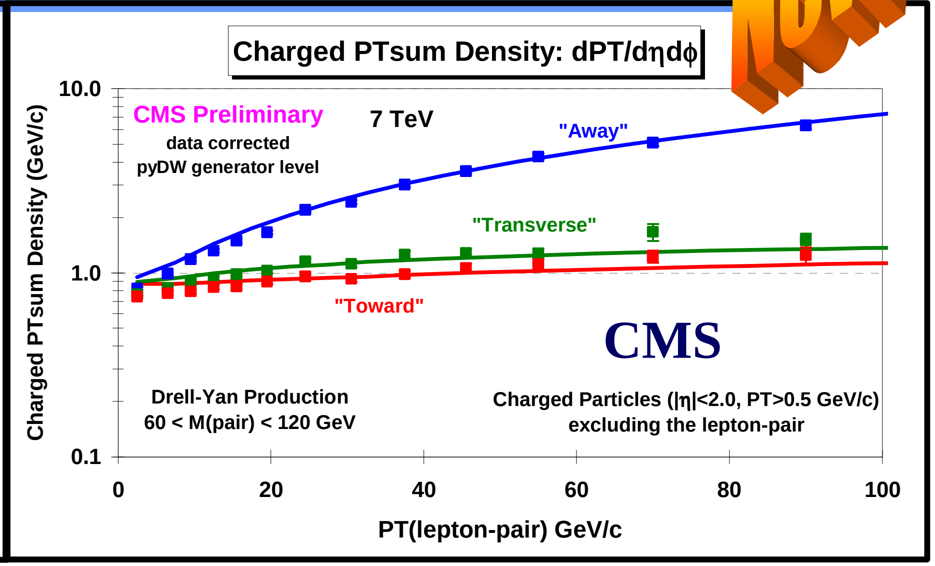
Charged Particle Density

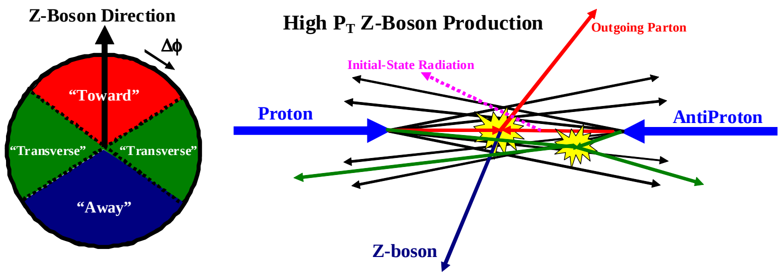


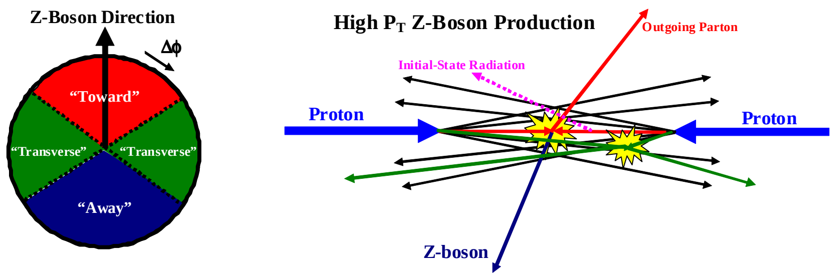
- **CDF data at 1.96 TeV** on the density of charged particles, $dN/d\eta d\phi$, with $p_T > 0.5$ GeV/c and $|\eta| < 1$ for Drell-Yan production as a function of $P_T(Z)$ for the "toward", "away", and "transverse" regions compared with **PYTHIA Tune DW**.
- **CMS data at 7 TeV** on the density of charged particles, $dN/d\eta d\phi$, with $p_T > 0.5$ GeV/c and $|\eta| < 2$ for Drell-Yan production as a function of $P_T(Z)$ for the "toward", "away", and "transverse" regions compared with **PYTHIA Tune DW**.

Charged PTsum Density



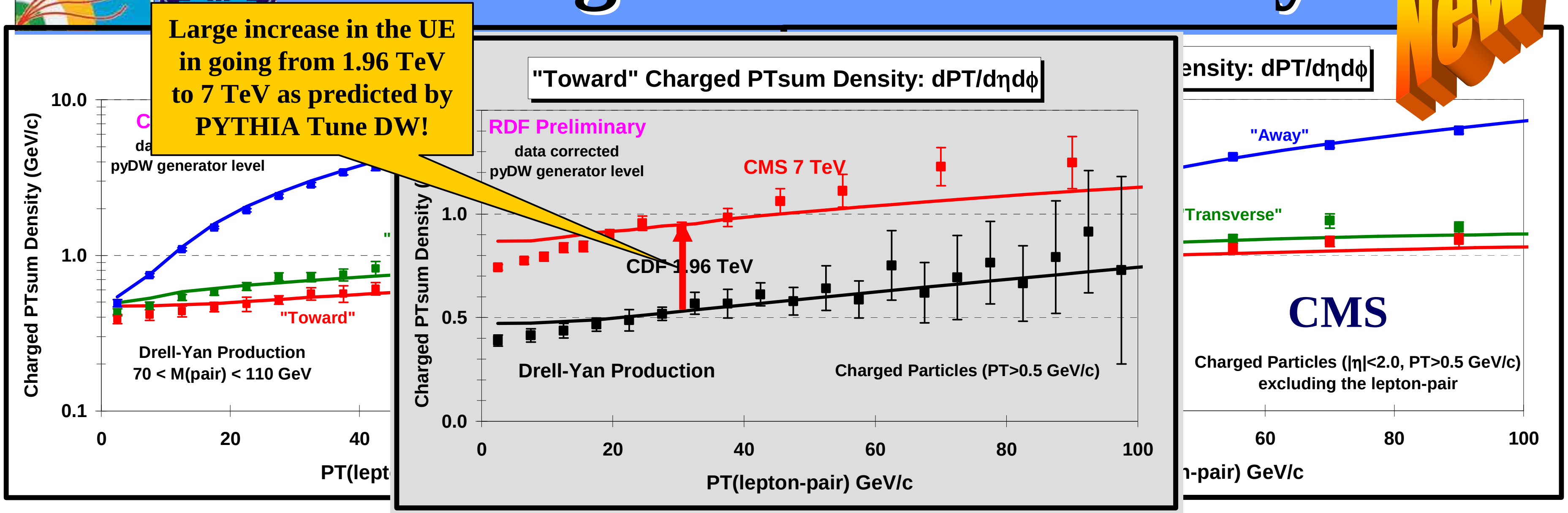


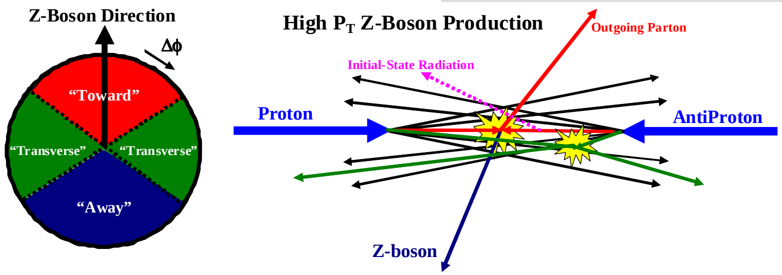


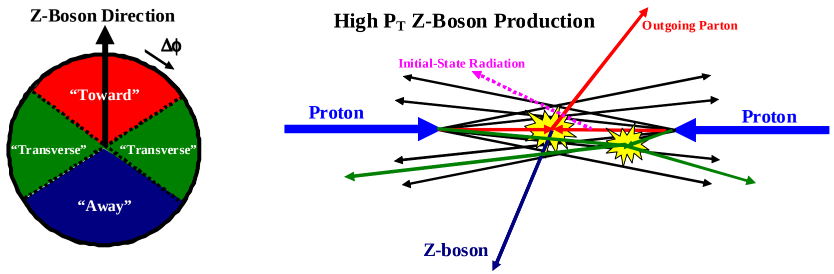


- **CDF data at 1.96 TeV** on the charged PTsum density, dPT/dηdϕ, with p_T > 0.5 GeV/c and |η| < 1 for Drell-Yan production as a function of PT(Z) for the **"toward"**, **"away"**, and **"transverse"** regions compared with PYTHIA Tune DW.
- **CMS data at 7 TeV** on the charged PTsum density, dPT/dηdϕ, with p_T > 0.5 GeV/c and |η| < 1 for Drell-Yan production as a function of PT(Z) for the **"toward"**, **"away"**, and **"transverse"** regions compared with PYTHIA Tune DW.

Charged PTsum Density

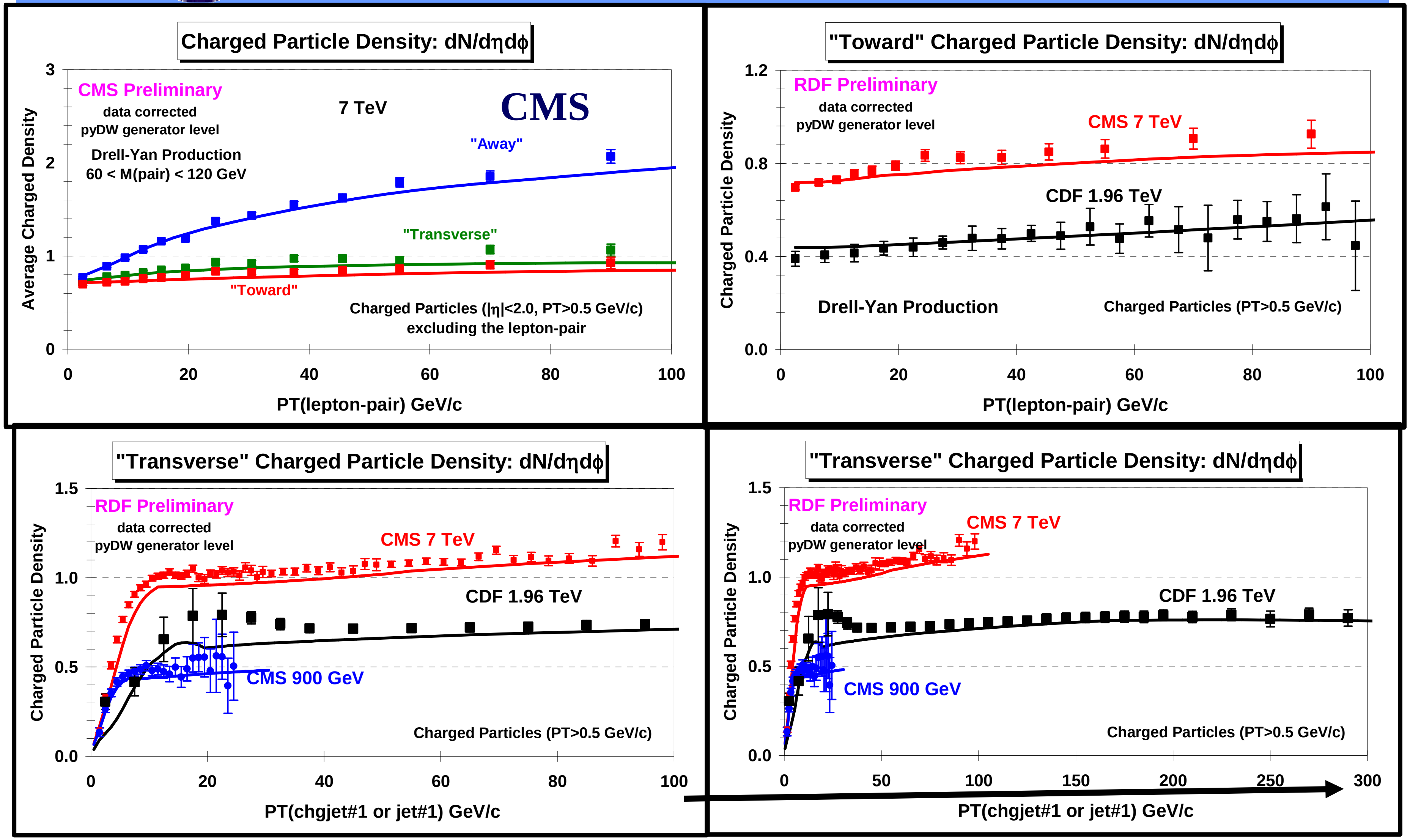




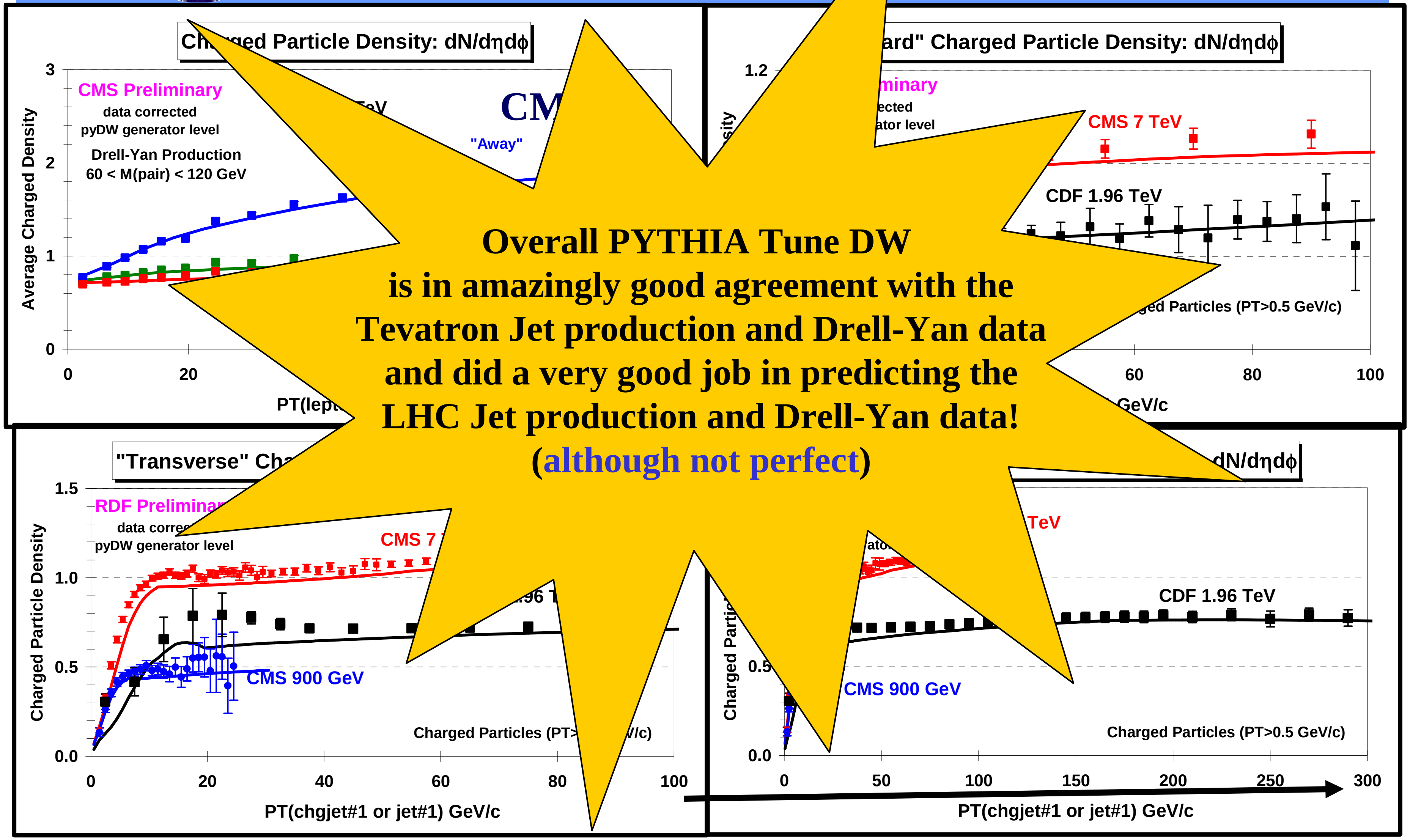


- **CDF data at 1.96 TeV** on the charged PTsum density, dPT/dηdϕ, with p_T > 0.5 GeV/c and |η| < 1 for Drell-Yan production as a function of PT(Z) for the "toward", "away", and "transverse" regions compared with PYTHIA Tune DW.
- **CMS data at 7 TeV** on the charged PTsum density, dPT/dηdϕ, with p_T > 0.5 GeV/c and |η| < 1 for Drell-Yan production as a function of PT(Z) for the "toward", "away", and "transverse" regions compared with PYTHIA Tune DW.

PYTHIA Tune DW



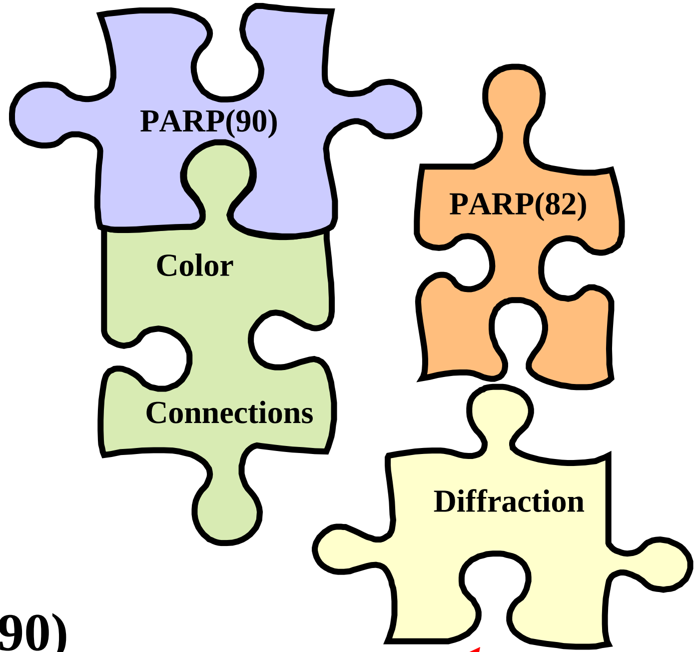
PYTHIA Tune DW

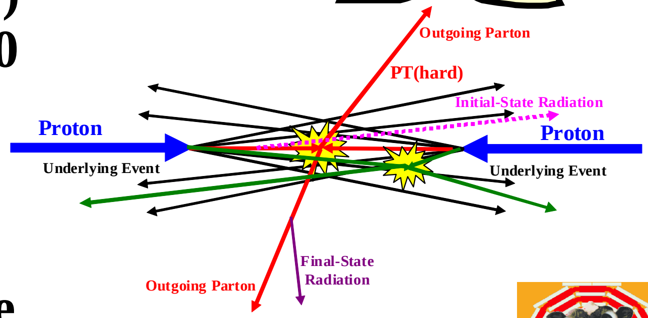


Overall PYTHIA Tune DW is in amazingly good agreement with the Tevatron Jet production and Drell-Yan data and did a very good job in predicting the LHC Jet production and Drell-Yan data! (although not perfect)

PYTHIA Tune Z1

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





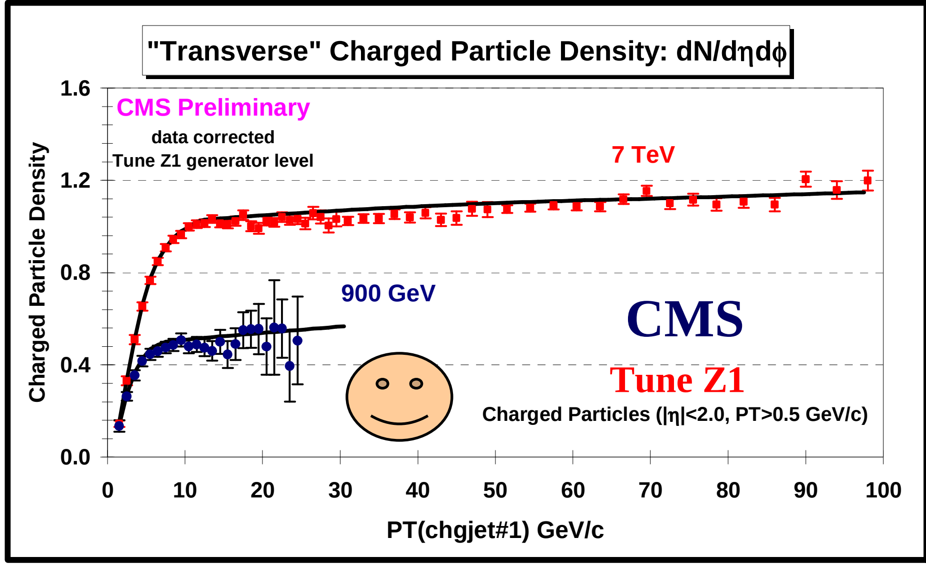
UE&MB@CMS

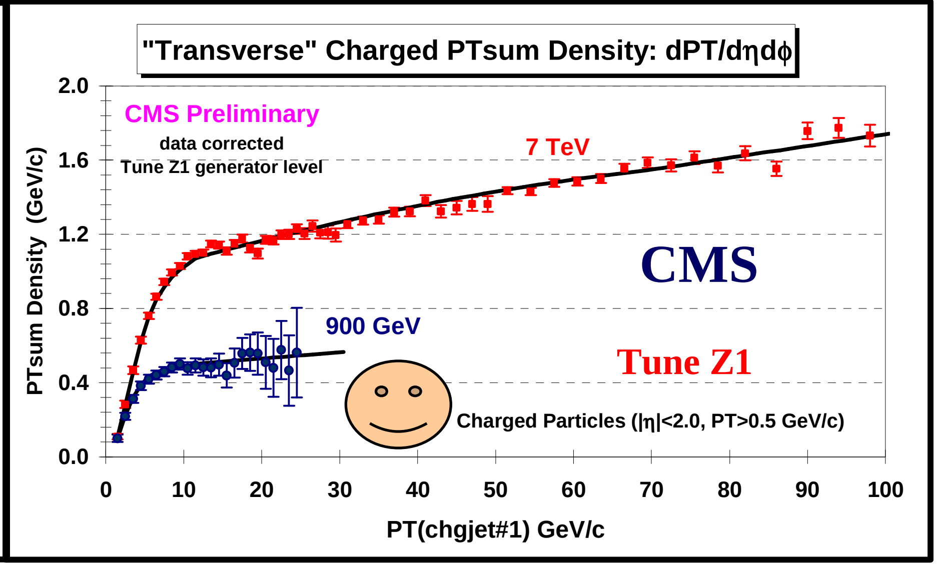
PYTHIA Tune Z1

Parameters not shown are the PYTHIA 6.4 defaults!

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

CMS UE Data





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

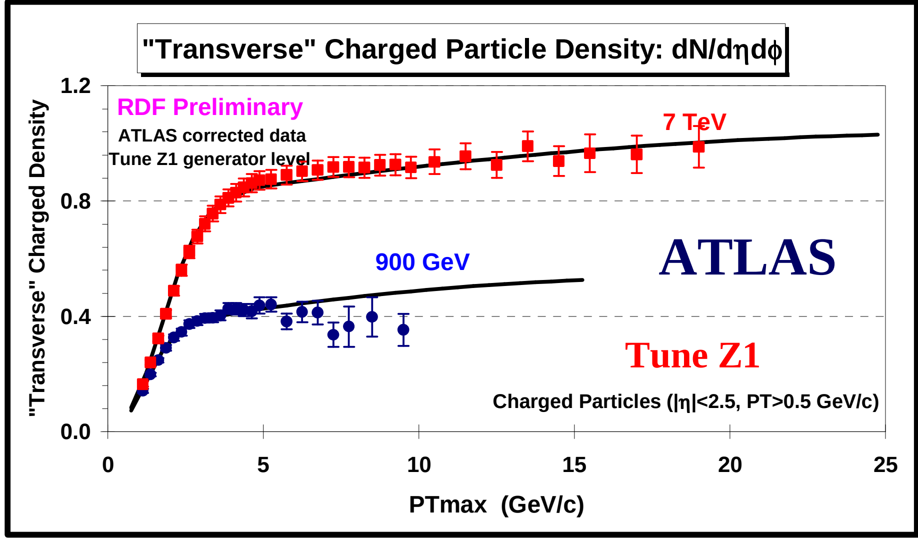
- **CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged PTsum density, dPT/dηdφ, as defined by the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2.0. The data are corrected and compared with PYTHIA Tune Z1 at the generator level.**

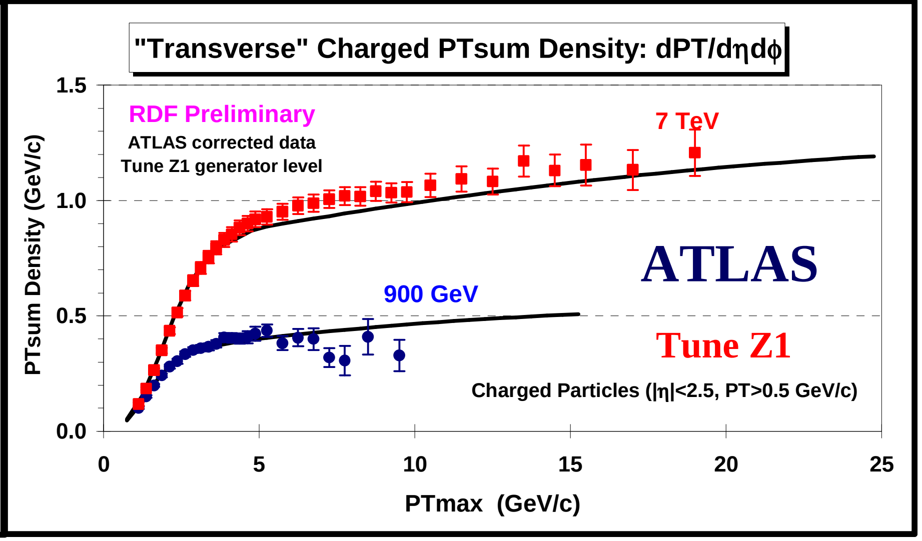
CMS corrected data!

Very nice agreement!

CMS corrected data!

ATLAS UE Data

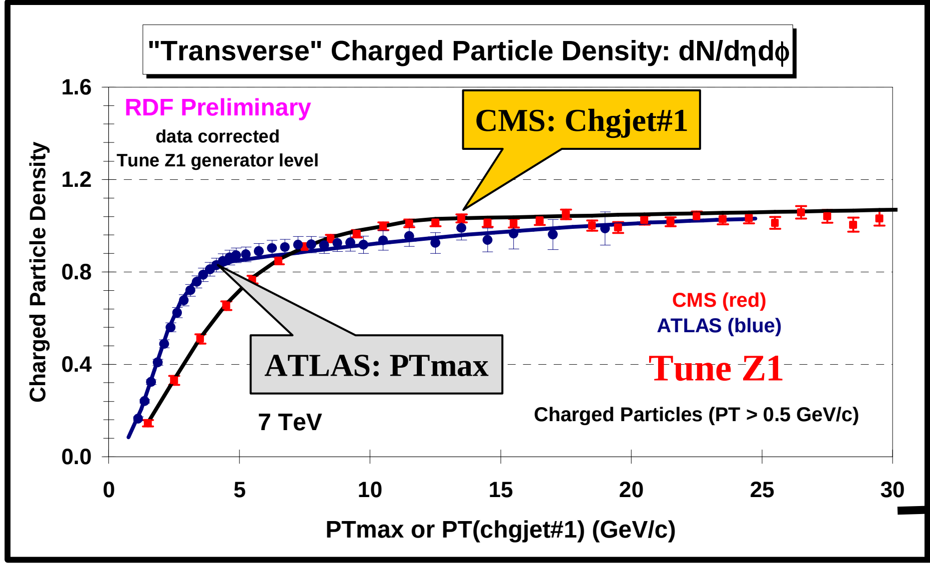


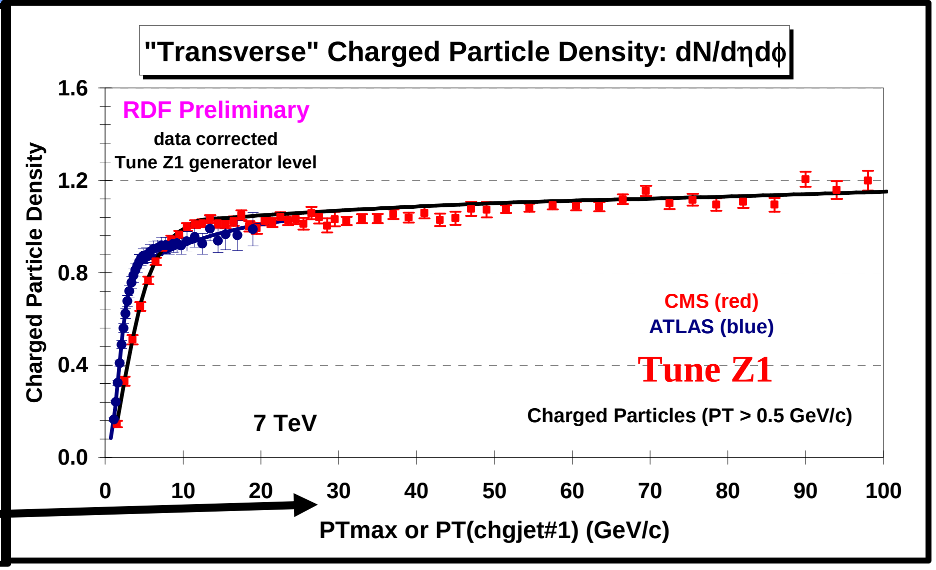


- **ATLAS published data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 2.5. The data are corrected and compared with PYTHIA Tune Z1 at the generator level.**
- **ATLAS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

ATLAS publication – arXiv:1012.0791
December 3, 2010

CMS-ATLAS UE Data

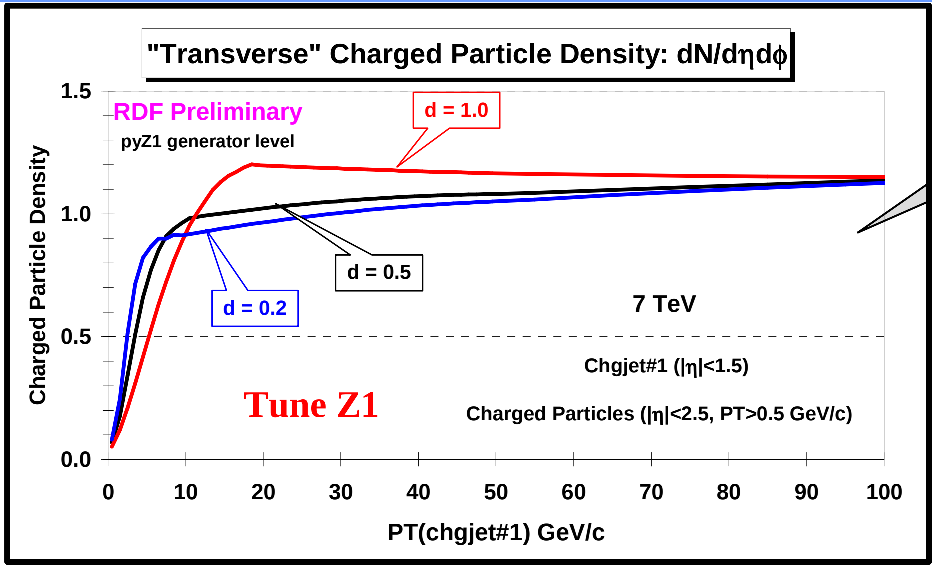




- **CMS preliminary data at 7 TeV on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2.0 together with the ATLAS published data at 7 TeV on the "transverse" charged particle density, dN/dηdφ,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

Amazing agreement!

Jet Radius Dependence

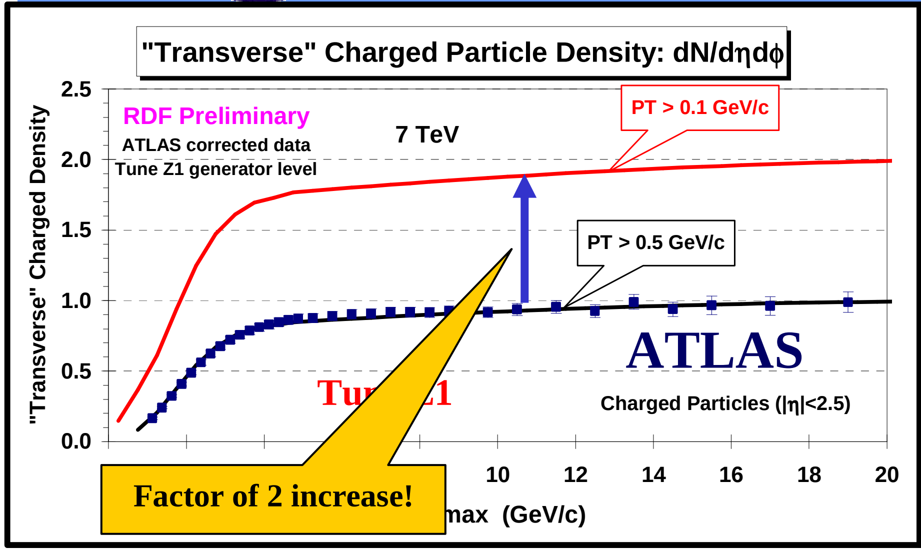


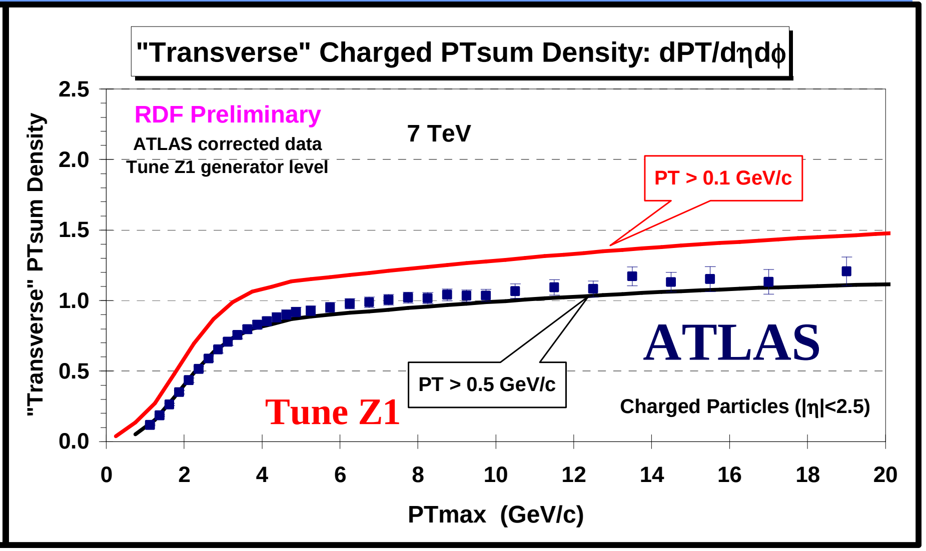
The UE activity is higher for large jet radius!

- **The charged particle density in the "transverse" region as defined by the leading charged particle jet from PYTHIA Tune Z1. The charged particles are in the region $p_T > 0.5$ GeV/c and $|\eta| < 2.5$. Charged particle jets are constructed using the Anti-KT algorithm with d = 0.2, 0.5, and 1.0 from charged particles in the region $p_T > 0.5$ GeV/c and $|\eta| < 2.5$, however, the leading charged particle jet is required to have $|\eta(\text{chgjet\#1})| < 1.5$.**

It appears that large jet radius "biases" the UE to be more active!

PYTHIA Tune Z1

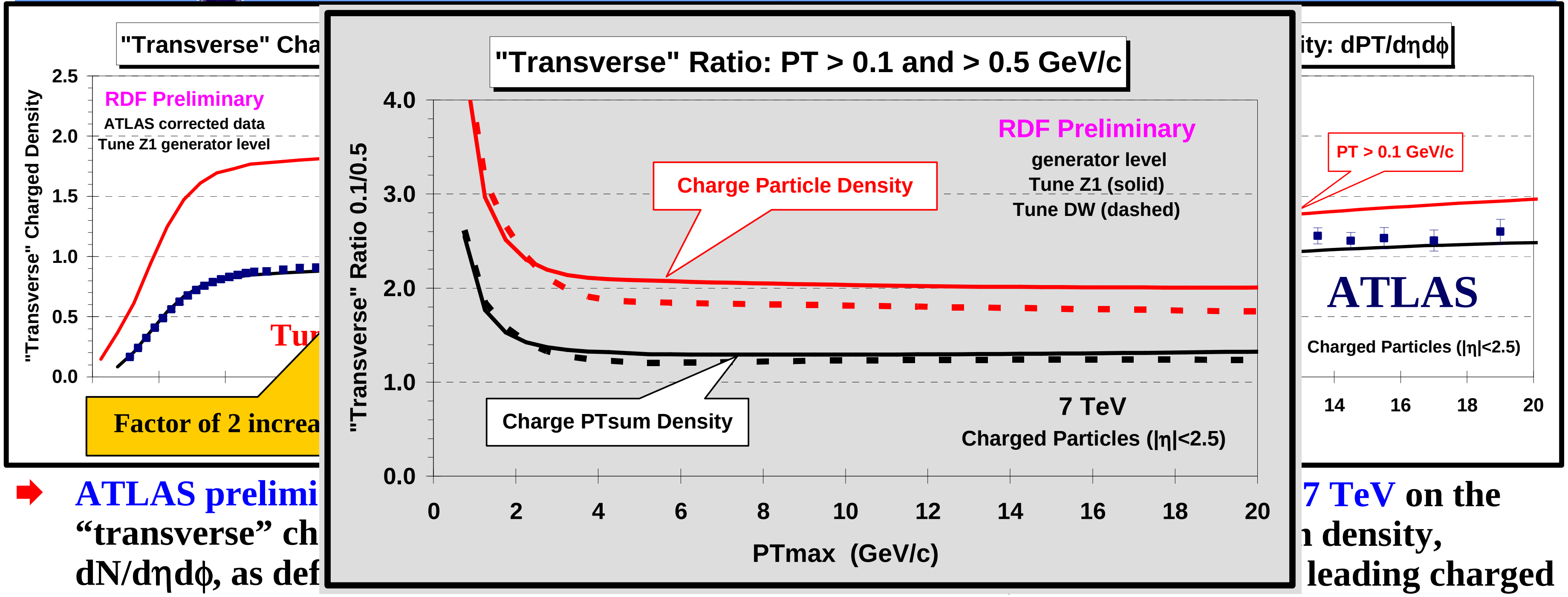




- **ATLAS preliminary data at 7 TeV on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 2.5. The data are corrected and compared with PYTHIA Tune Z1 at the generator level. Also shows the prediction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

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

PYTHIA Tune Z1

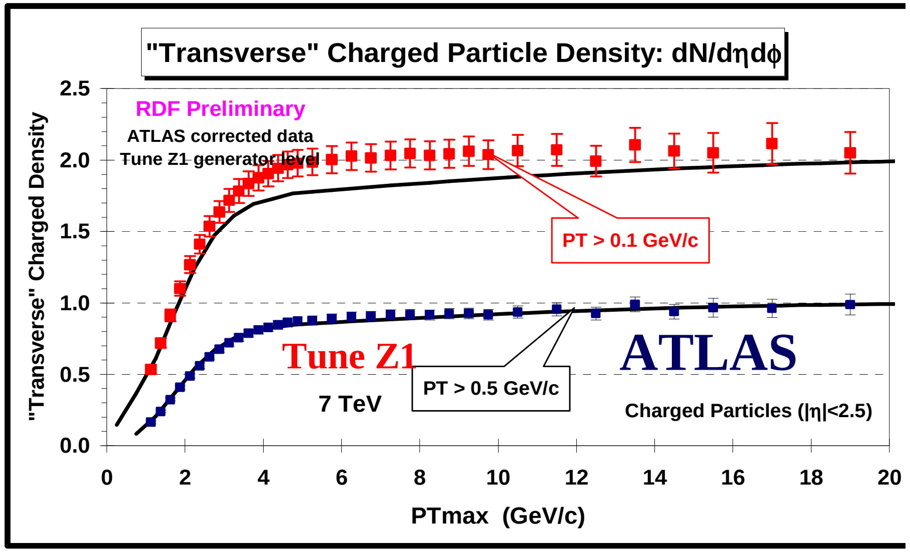


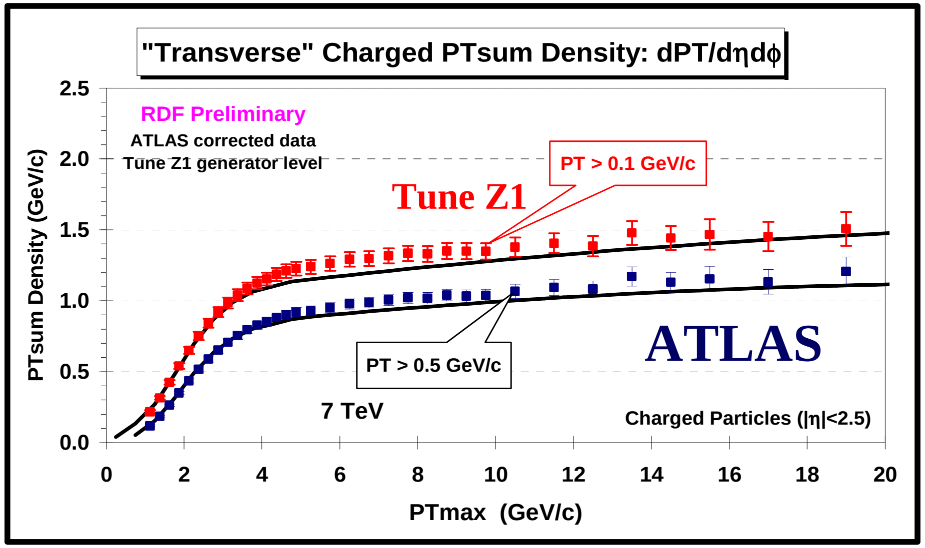
- ATLAS prelimi … “transverse” ch … dN/dηdϕ, as def … particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.5$. The data are corrected and compared with PYTHIA Tune Z1 at the generator level. Also shows the prediction of Tune Z1 for the “transverse” cha … $p_T > 0.1$ GeV/c a …

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

Rick Field
MPI@LHC 2010 Glasgow, Scotland
December 2, 2010

PYTHIA Tune Z1

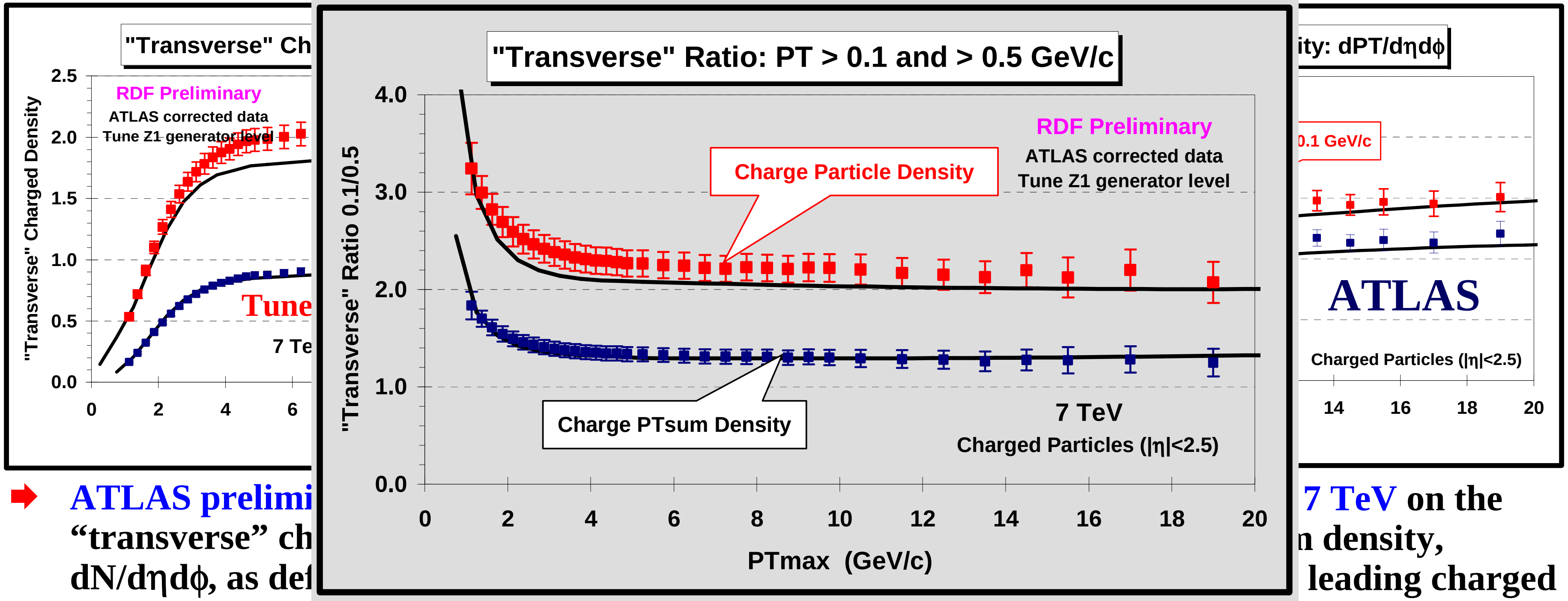




- **ATLAS preliminary data at 7 TeV on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $p_T > 0.1$ GeV/c ($|\eta| < 2.5$). The data are corrected and compared with PYTHIA Tune Z1 at the generator level.**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

ATLAS publication – arXiv:1012.0791
December 3, 2010

PYTHIA Tune Z1

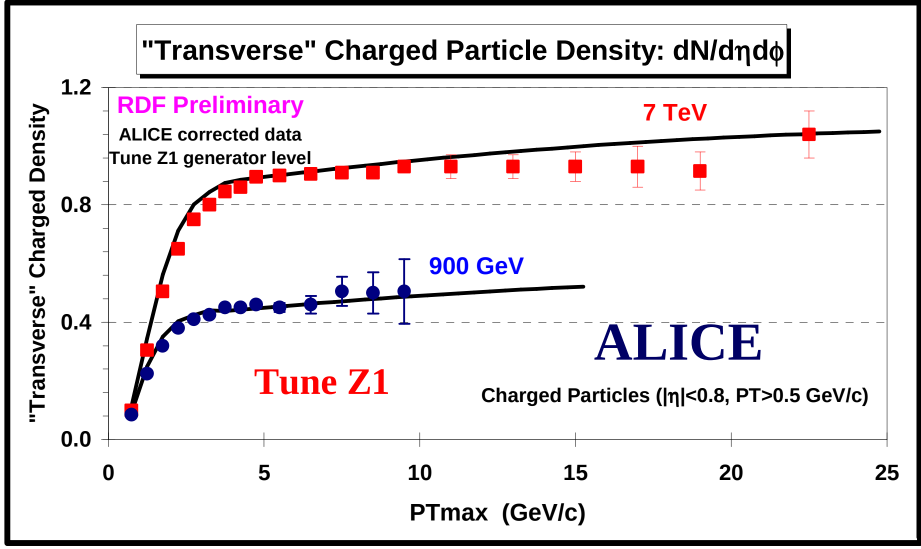


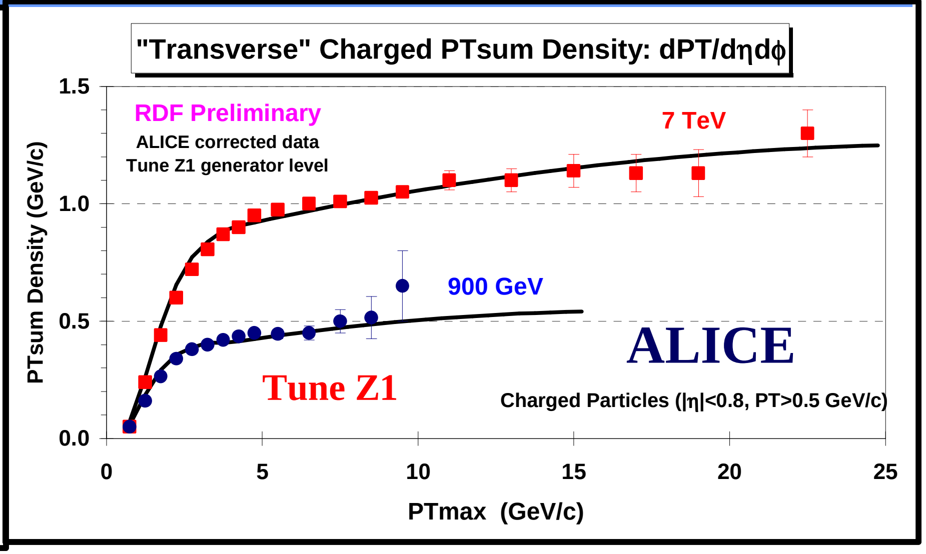
- ATLAS prelimi… “transverse” ch… dN/dηdϕ, as de… particle (PTmax) for charged particles with p_T > 0.5 GeV/c and p_T > 0.1 GeV/c (|η| < 2.5). The data are corrected and compared with PYTHIA Tune Z1 at the generator level.

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

ATLAS publication – arXiv:1012.0791
December 3, 2010

ALICE UE Data





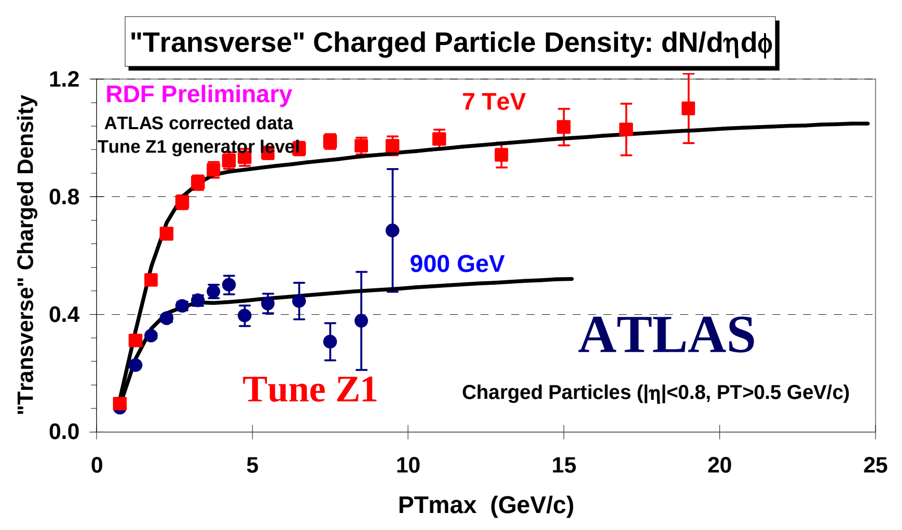
- **ALICE preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$. The data are corrected and compared with PYTHIA Tune Z1 at the generator level.**

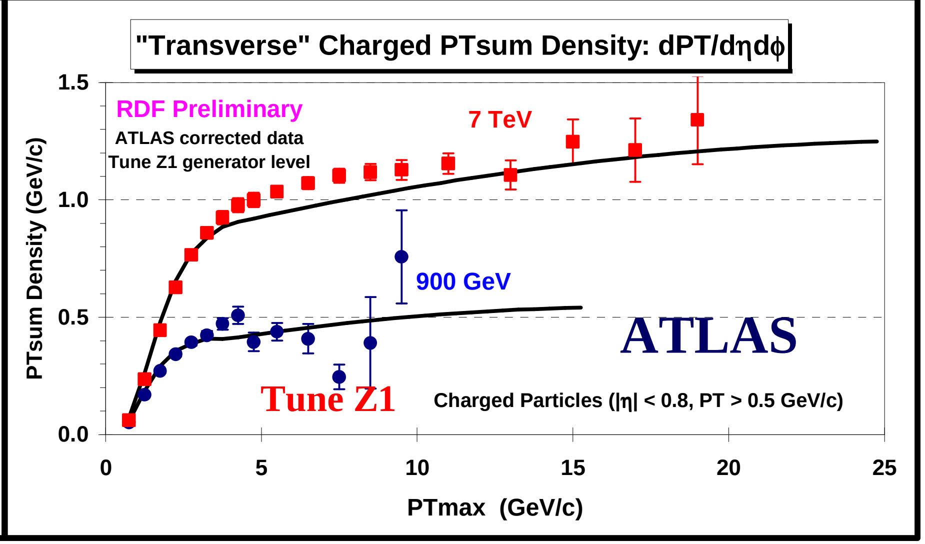
- **ALICE preliminary data at 900 GeV and 7 TeV on the "transverse" charged PTsum density, dPT/dηdφ, as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$. The data are corrected and compared with PYTHIA Tune Z1 at the generrator level.**

I read the points off with a ruler!

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

ATLAS UE Data





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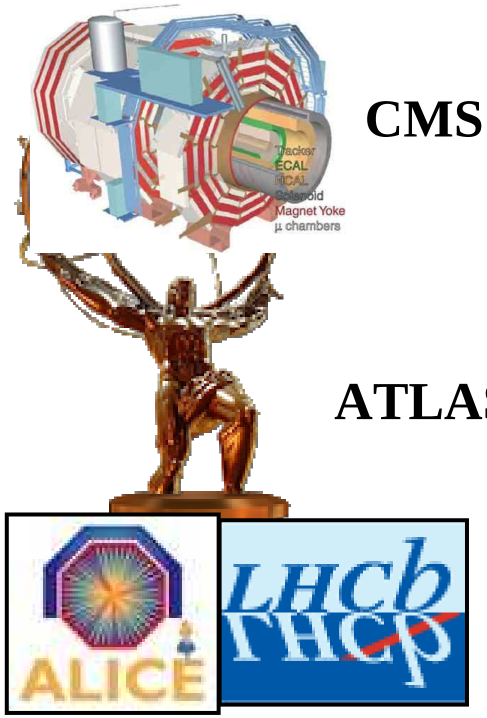
- ATLAS preliminary data at 900 GeV and 7 TeV on the "transverse" charged PTsum density, dPT/dηdφ, as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$. The data are corrected and compared with PYTHIA Tune Z1 at the generrator level.

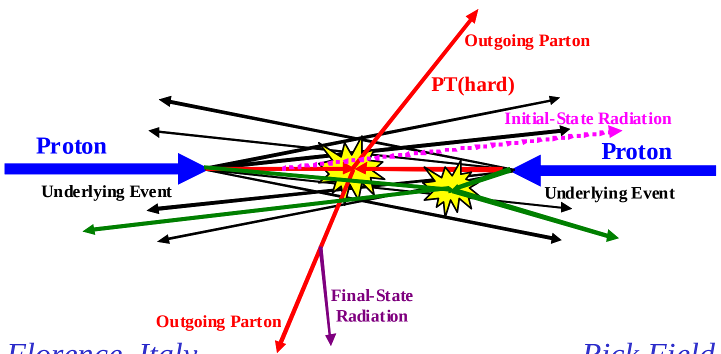
ATLAS-CONF-2011-009
February 21, 2011

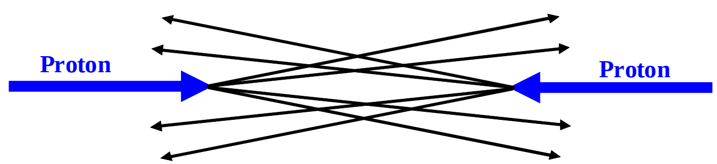
MB & UE Common Plots

Quantum
Chromo-
Dynamics

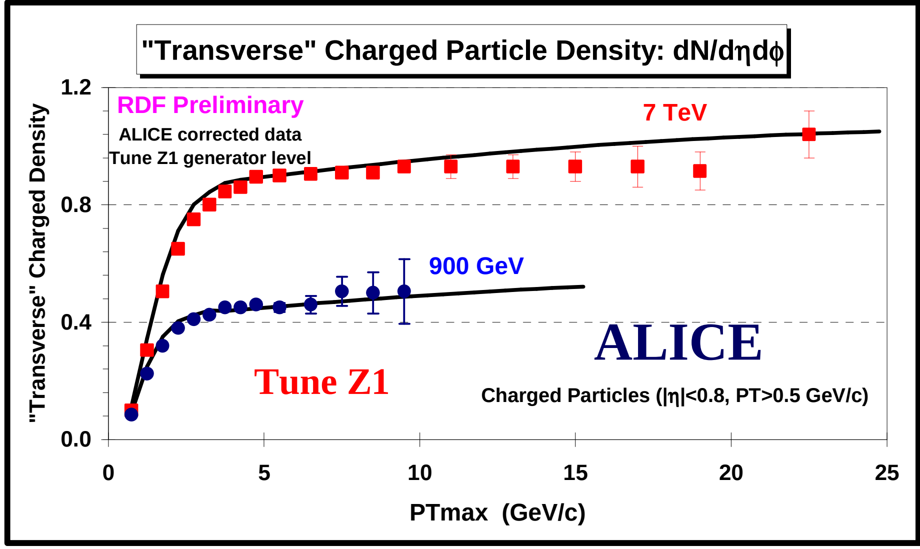


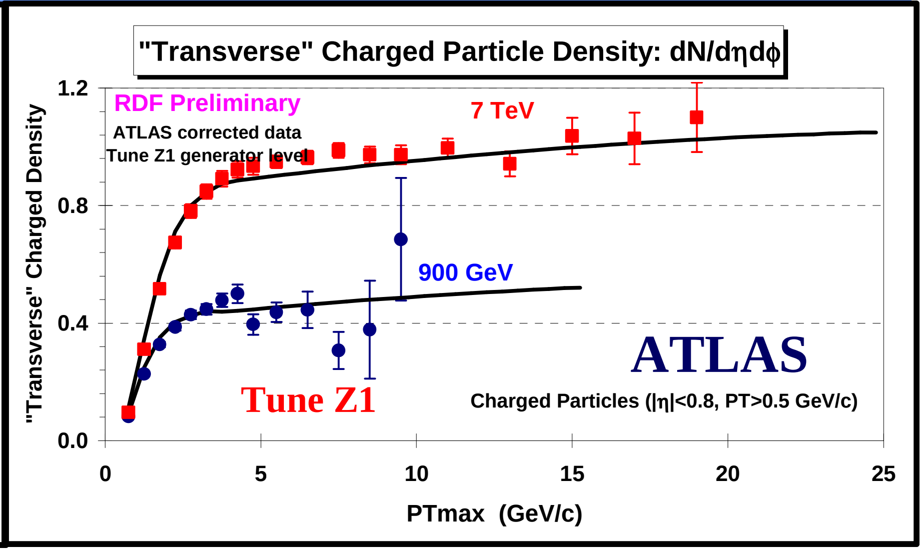
- **The LPCC MB&UE Working Group has suggested several MB&UE "Common Plots" the all the LHC groups can produce and compare with each other.**





ALICE-ATLAS UE

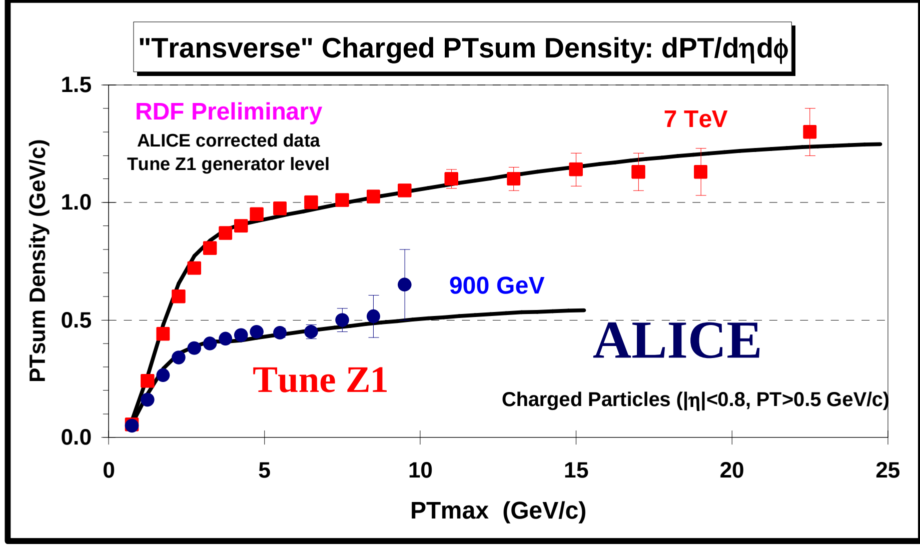


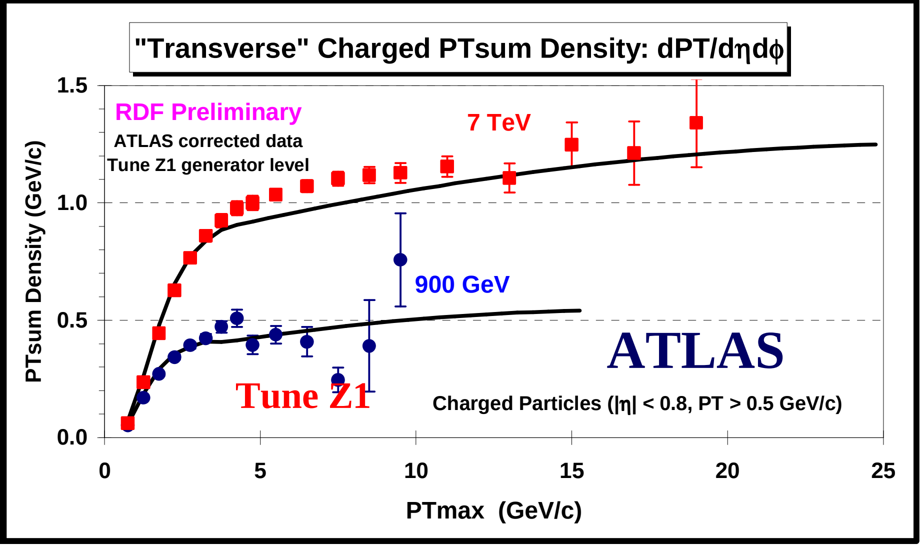


- **ALICE preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 0.8. The data are corrected and compared with PYTHIA Tune Z1 at the generator level.**

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

ALICE-ATLAS UE





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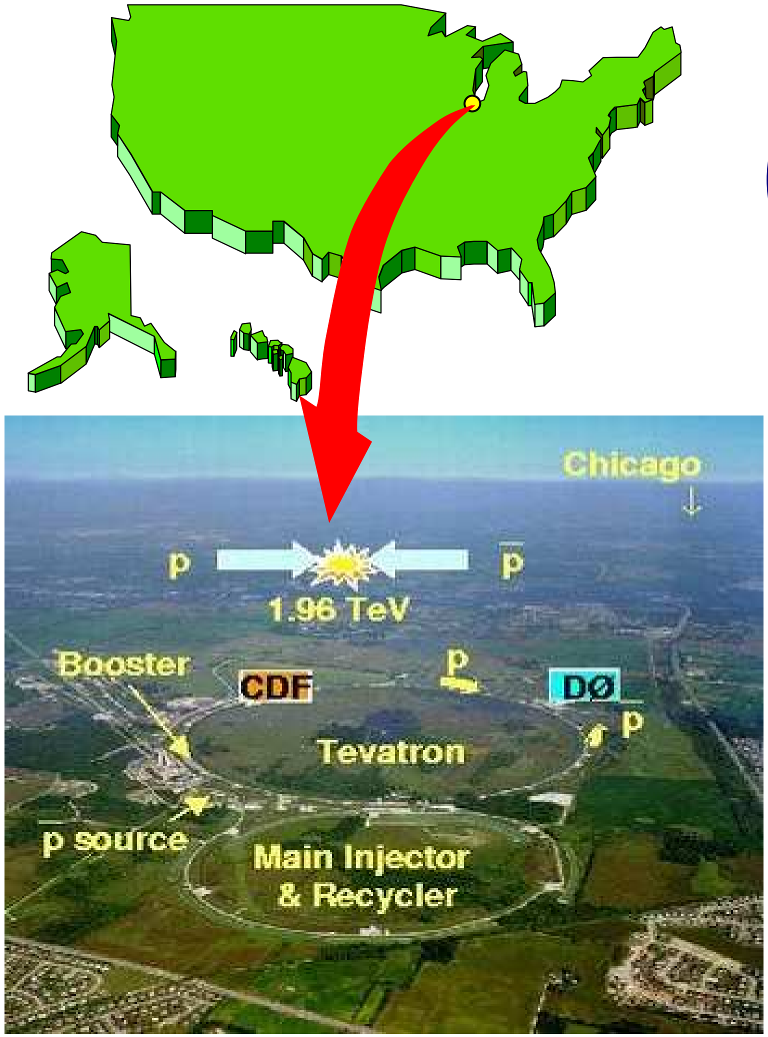
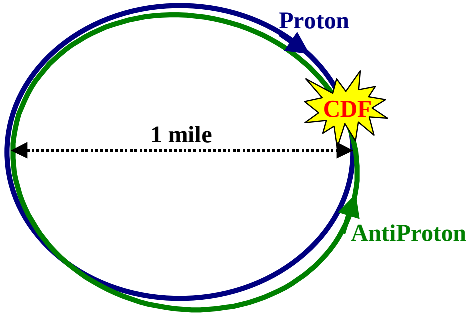
- **ATLAS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 0.8. The data are corrected and compared with PYTHIA Tune Z1 at the generrator level.**

Tevatron Energy Scan



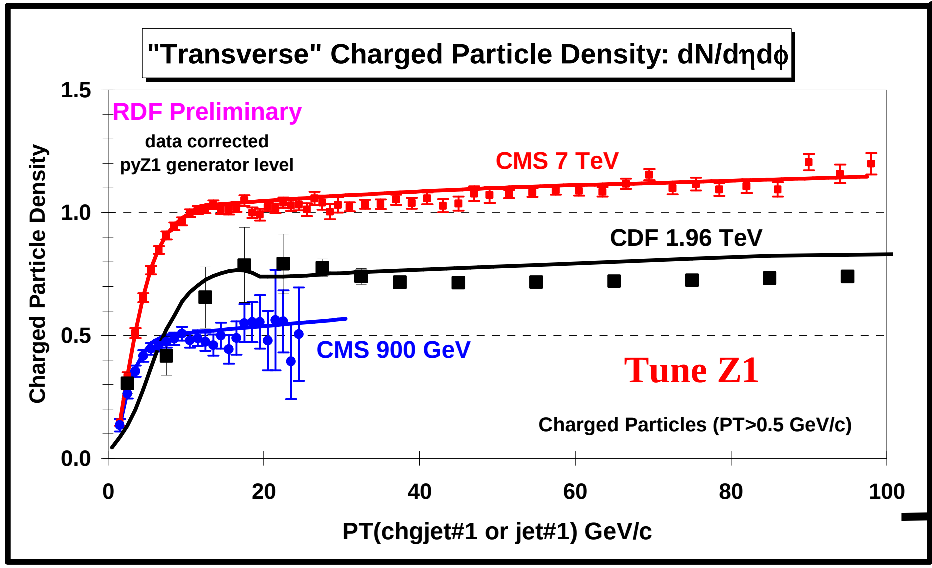


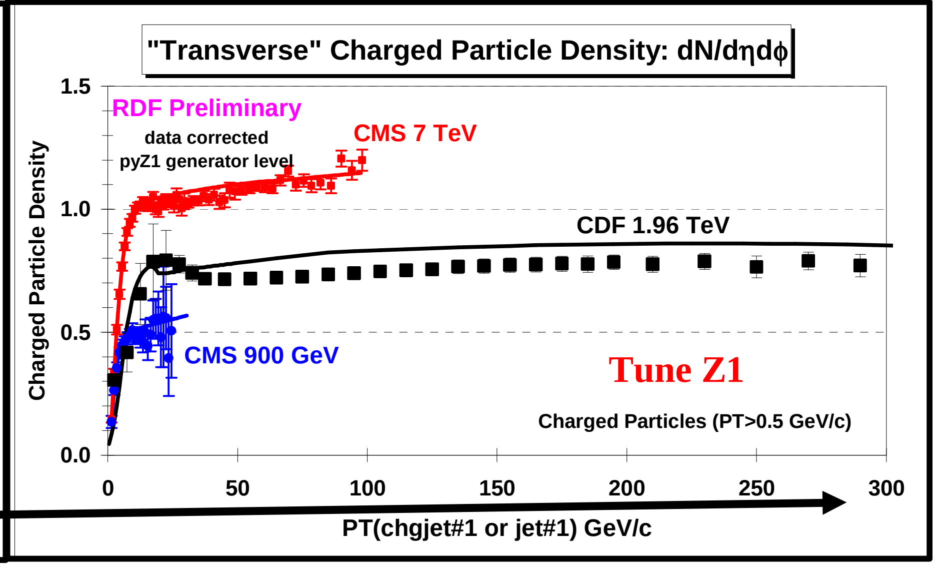
- **Over the past few days CDF has collected more than 10M "min-bias" events at several center-of-mass energies!**

300 GeV 12M MB Events

900 GeV 17M MB Events

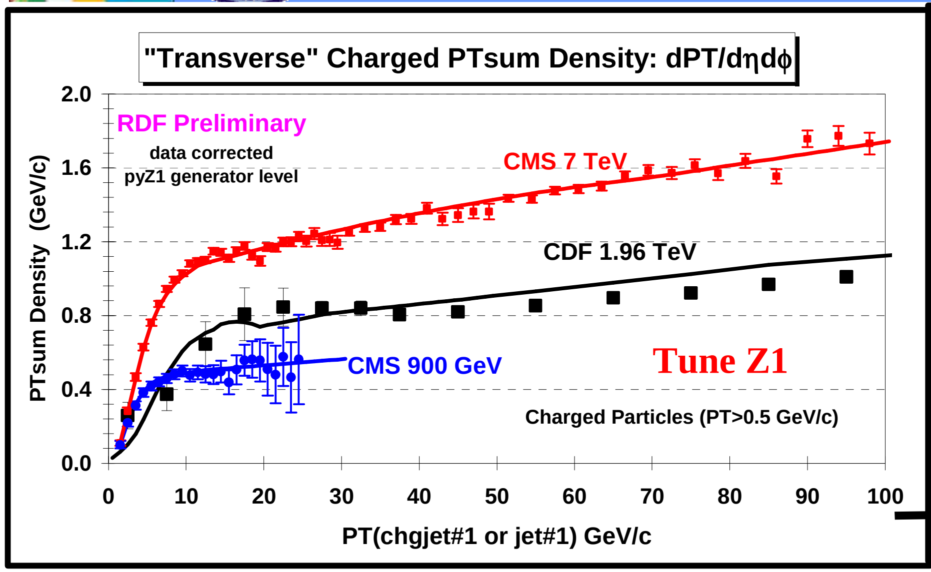
PYTHIA Tune Z1

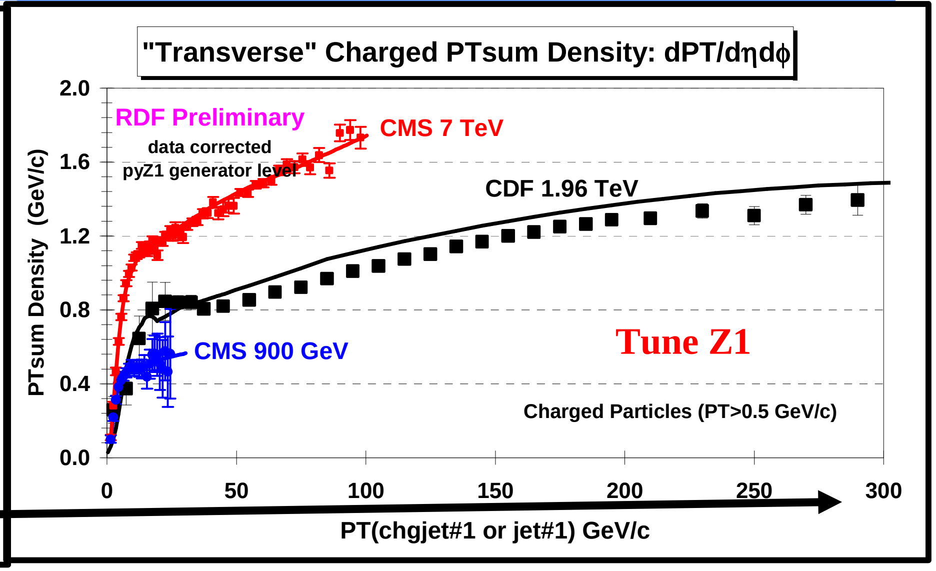




- **CMS data at 900 GeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2.0. The data are corrected and compared with PYTHIA Tune Z1 at the generator level.**
- **CDF data at 1.96 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading calorimeter jet (jet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 1.0. The data are corrected and compared with PYTHIA Tune Z1 at the generator level.**

PYTHIA Tune Z1





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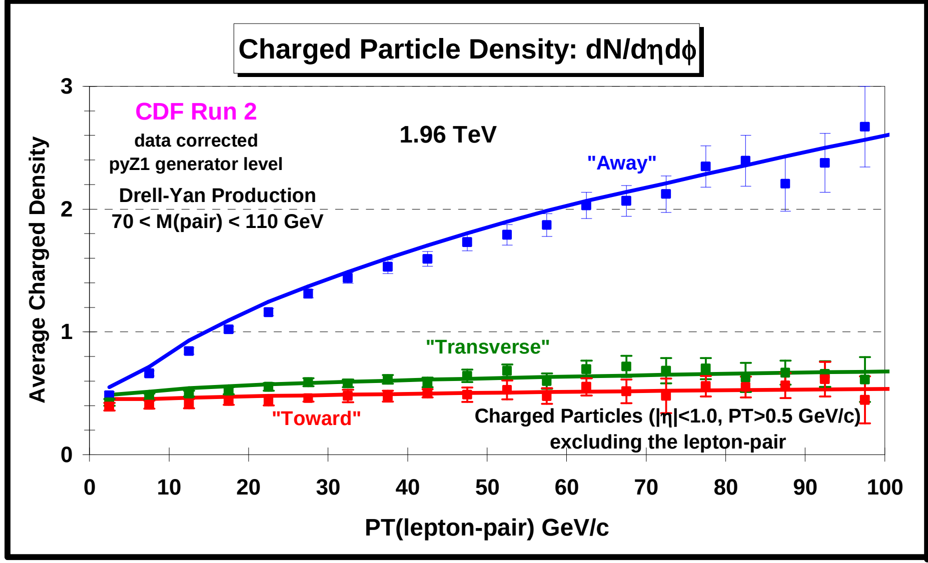
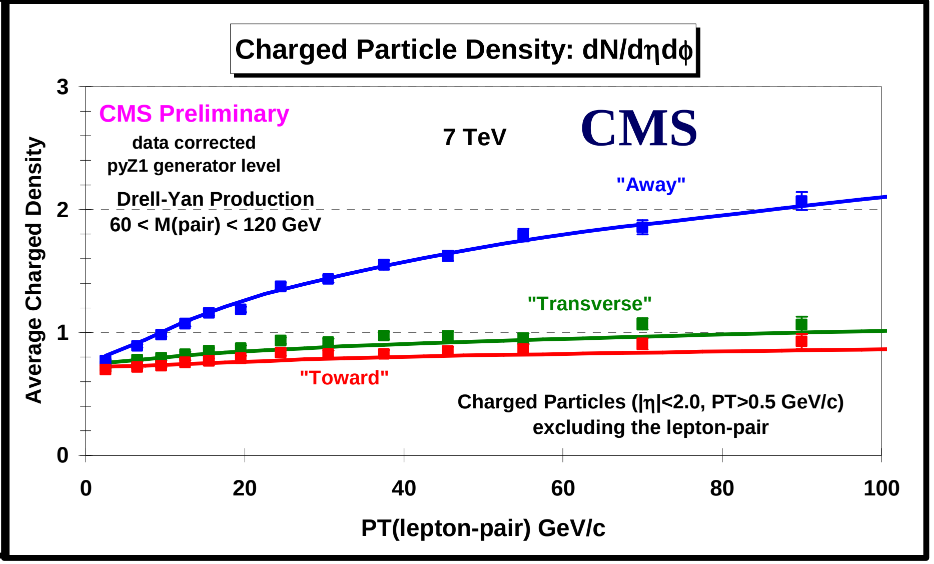
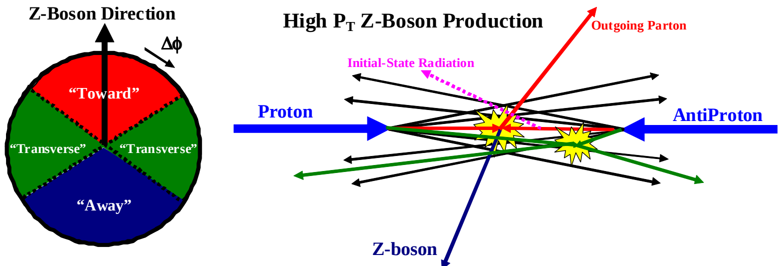
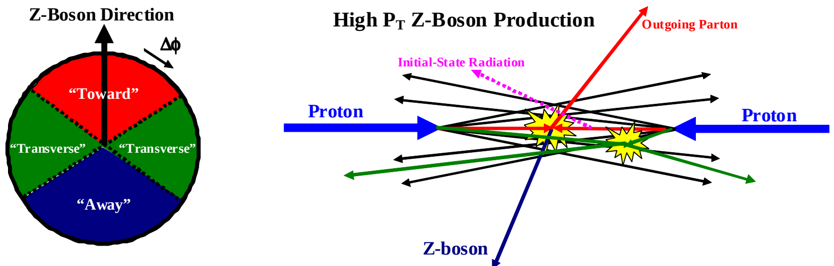
PYTHIA Tune Z1



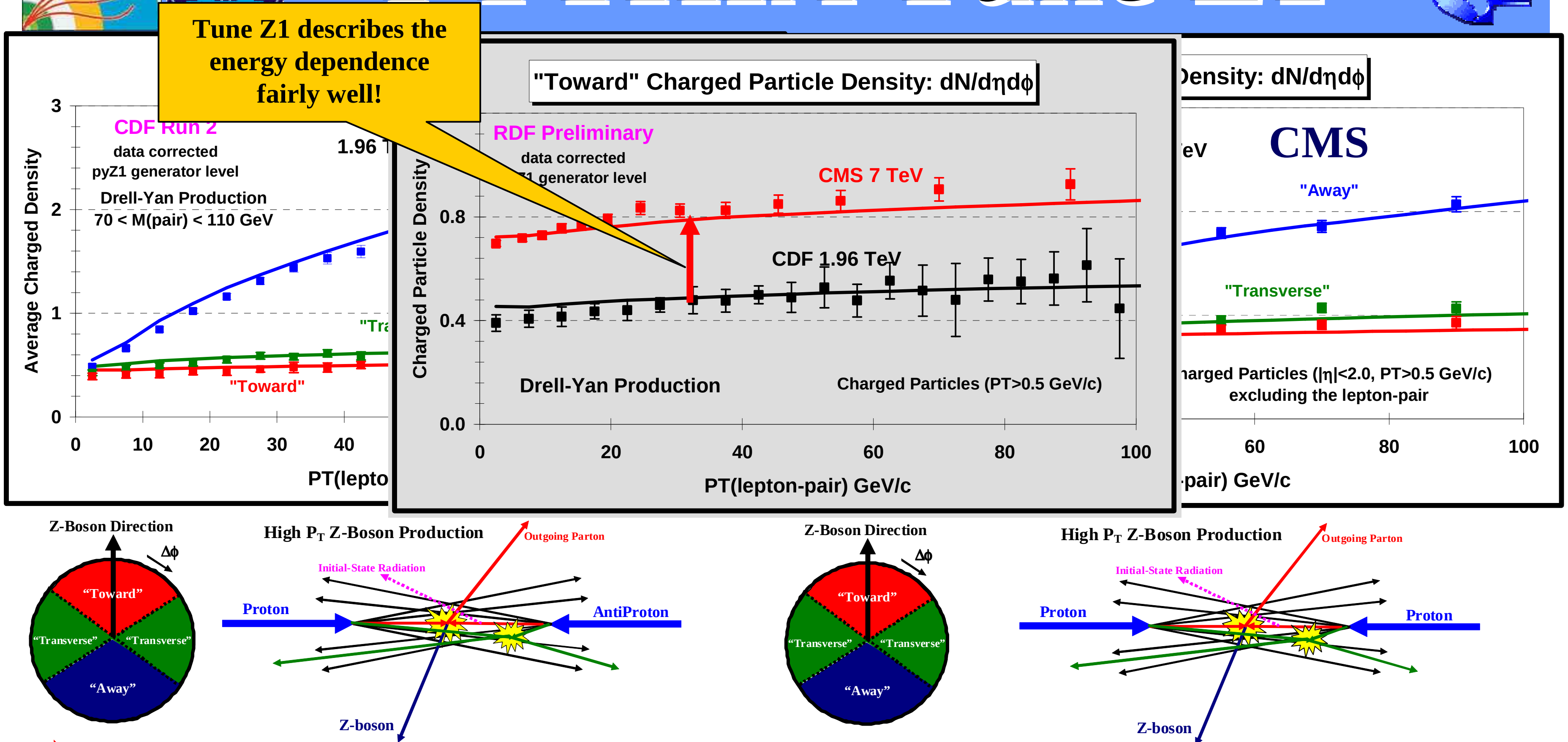






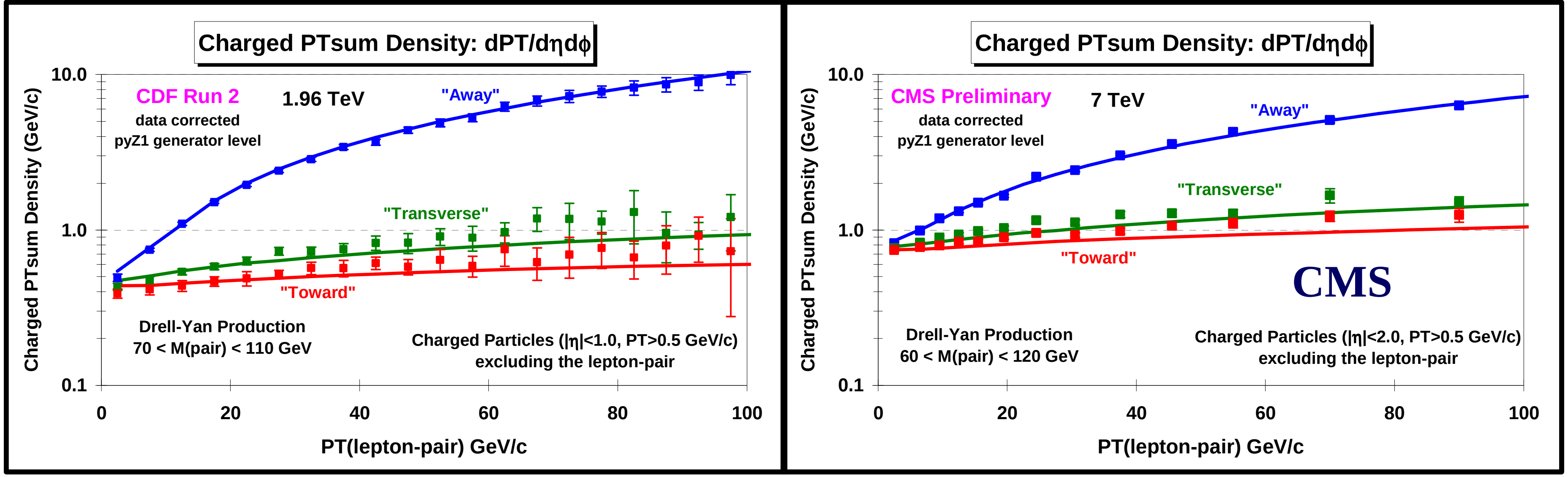
- **CDF data at 1.96 TeV** on the density of charged particles, dN/dηdφ, with $p_T > 0.5$ GeV/c and $|\eta| < 1$ for Drell-Yan production as a function of $P_T(Z)$ for the "toward", "away", and "transverse" regions compared with PYTHIA Tune Z1.
- **CMS data at 7 TeV** on the density of charged particles, dN/dηdφ, with $p_T > 0.5$ GeV/c and $|\eta| < 2$ for Drell-Yan production as a function of $P_T(Z)$ for the "toward", "away", and "transverse" regions compared with PYTHIA Tune Z1.

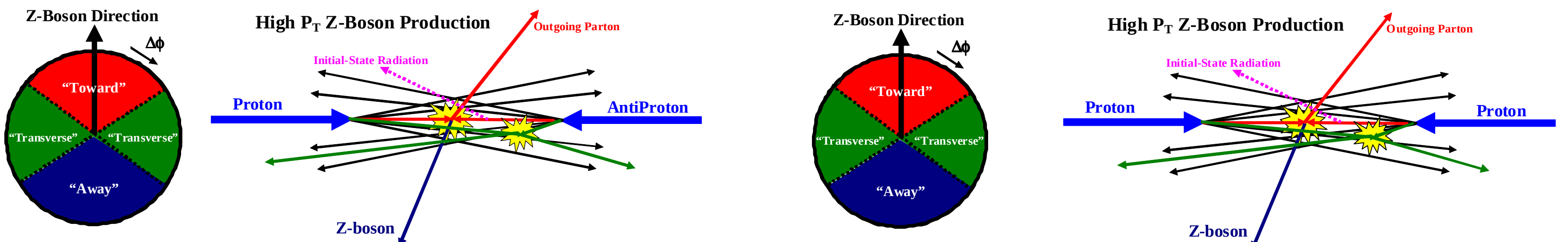
PYTHIA Tune Z1



- **CDF data at 1.96 TeV** on the density of charged particles, dN/dηdφ, with p_T > 0.5 GeV/c and |η| < 1 for Drell-Yan production as a function of $P_T(Z)$ for the "toward", "away", and "transverse" regions compared with PYTHIA Tune Z1.
- **CMS data at 7 TeV** on the density of charged particles, dN/dηdφ, with p_T > 0.5 GeV/c and |η| < 2 for Drell-Yan production as a function of $P_T(Z)$ for the "toward", "away", and "transverse" regions compared with PYTHIA Tune Z1.

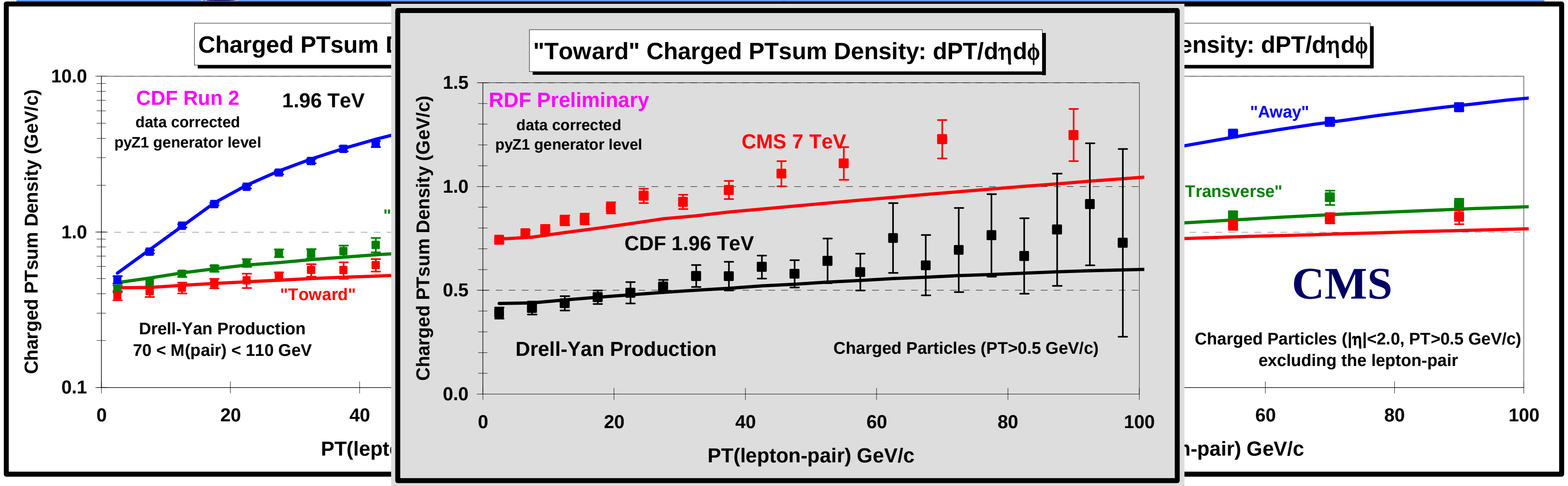
PYTHIA Tune Z1

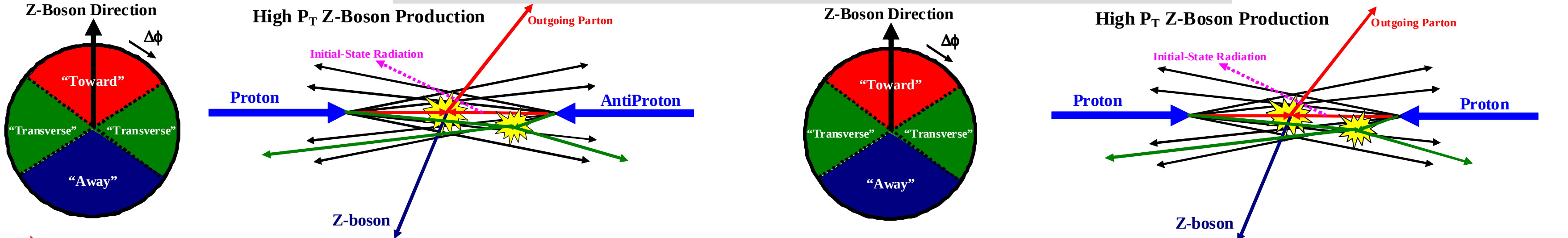




- **CDF data at 1.96 TeV** on the charged PTsum density, dPT/dηdφ, with p_T > 0.5 GeV/c and |η| < 1 for Drell-Yan production as a function of $P_T(Z)$ for the **"toward"**, **"away"**, and **"transverse"** regions compared with **PYTHIA Tune Z1**.
- **CMS data at 7 TeV** on the charged PTsum density, dPT/dηdφ, with p_T > 0.5 GeV/c and |η| < 2 for Drell-Yan production as a function of $P_T(Z)$ for the **"toward"**, **"away"**, and **"transverse"** regions compared with **PYTHIA Tune Z1**.

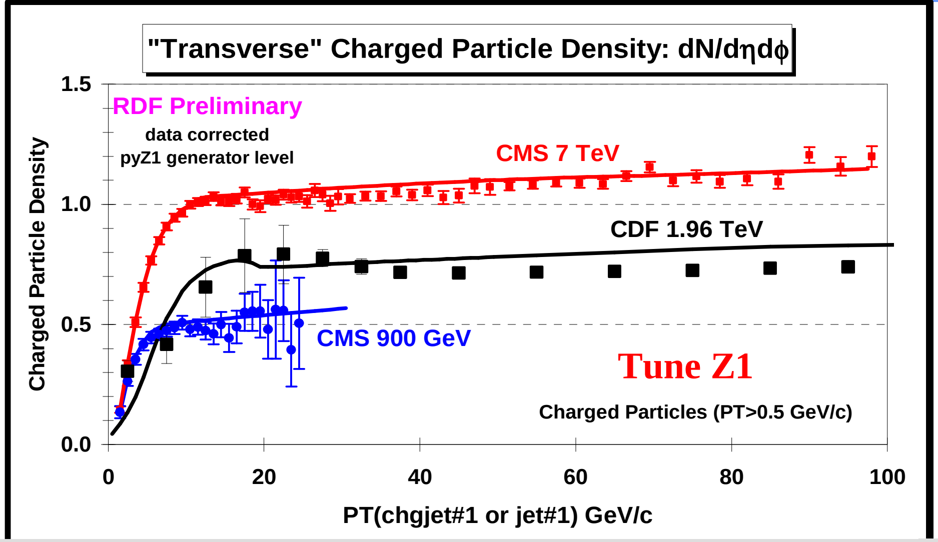
PYTHIA Tune Z1

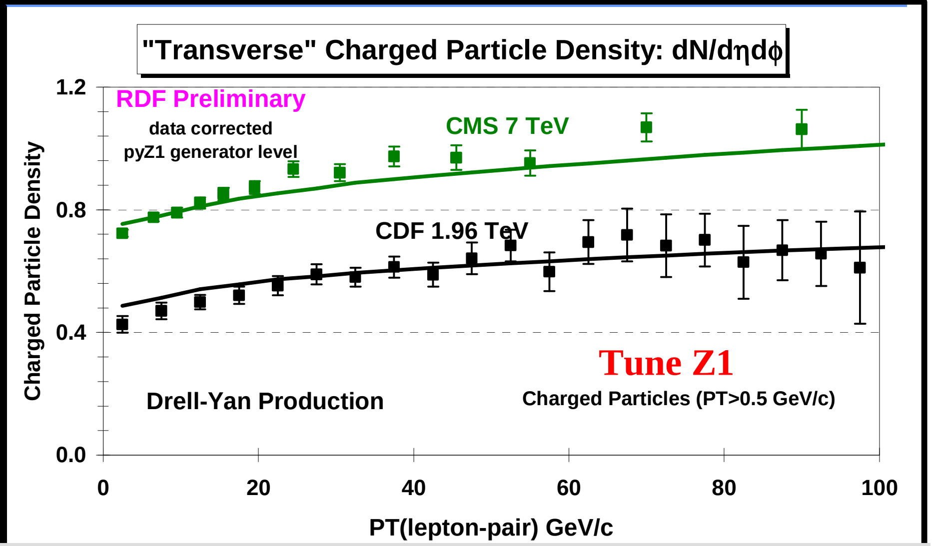


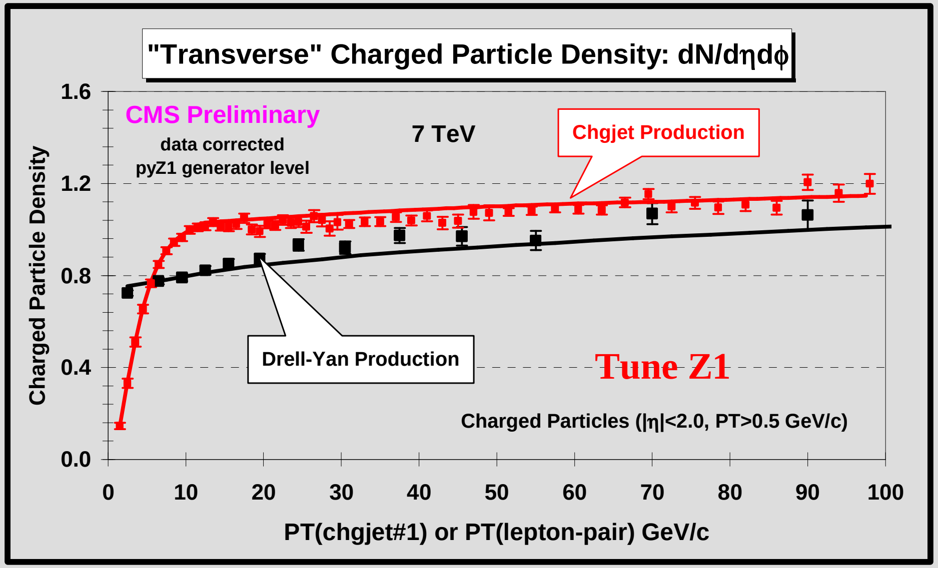


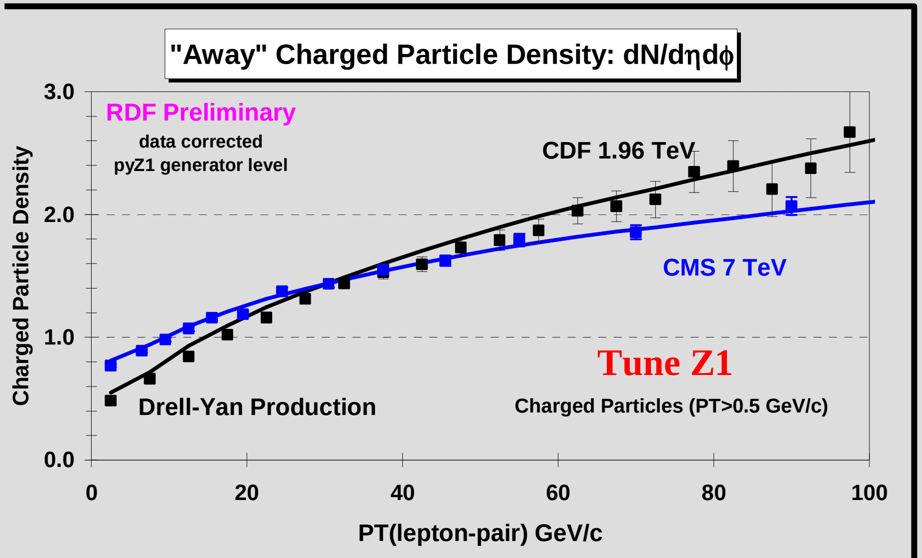
- **CDF data at 1.96 TeV** on the charged PTsum density, dPT/dηdφ, with $p_T > 0.5$ GeV/c and $|\eta| < 1$ for Drell-Yan production as a function of $P_T(Z)$ for the **"toward"**, **"away"**, and **"transverse"** regions compared with **PYTHIA Tune Z1**.
- **CMS data at 7 TeV** on the charged PTsum density, dPT/dηdφ, with $p_T > 0.5$ GeV/c and $|\eta| < 2$ for Drell-Yan production as a function of $P_T(Z)$ for the **"toward"**, **"away"**, and **"transverse"** regions compared with **PYTHIA Tune Z1**.

PYTHIA Tune Z1

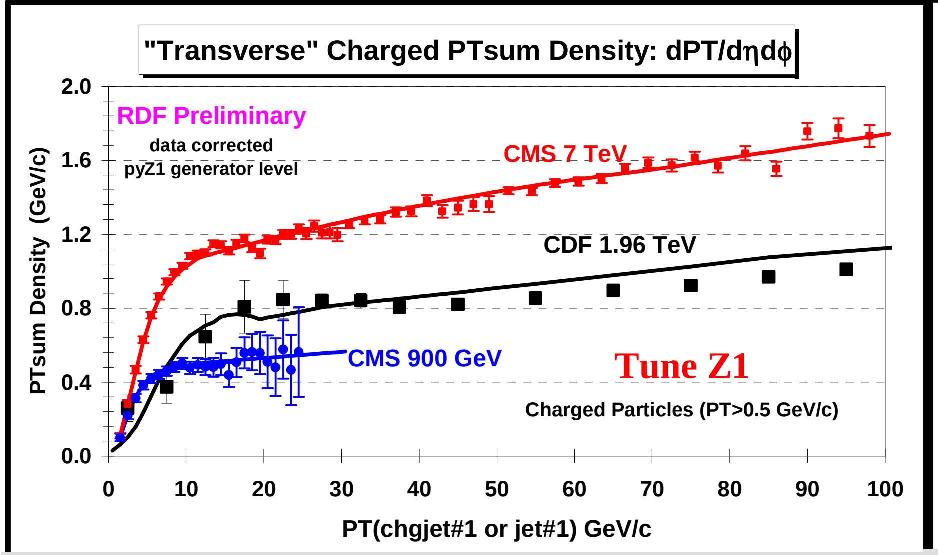


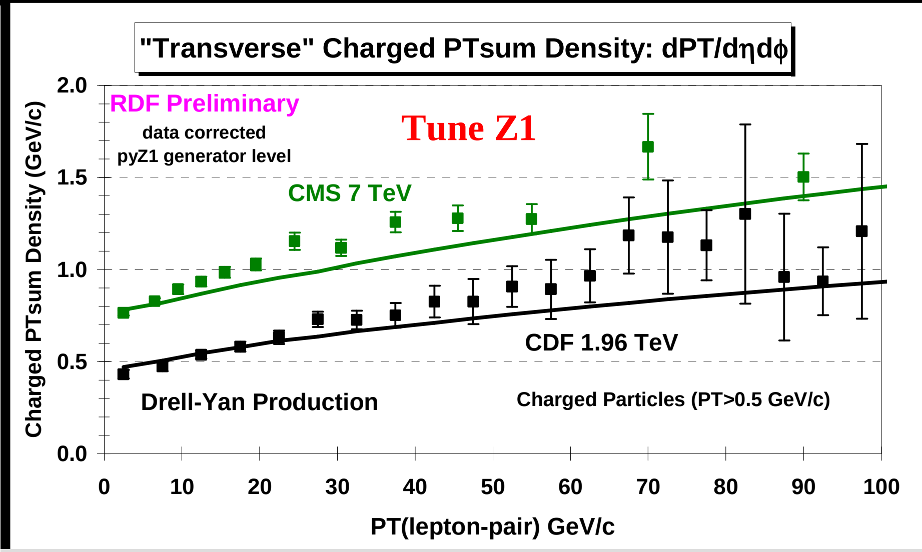


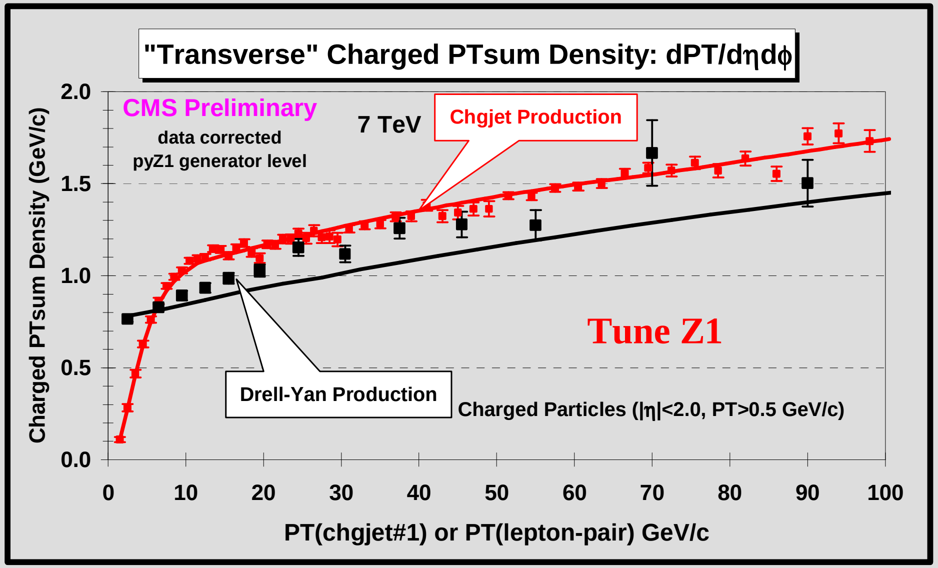


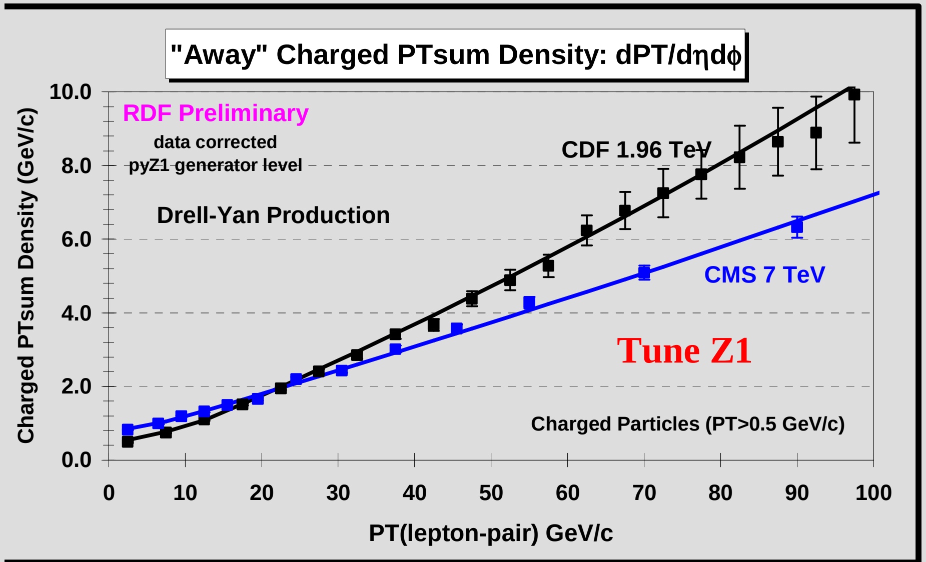


PYTHIA Tune Z1

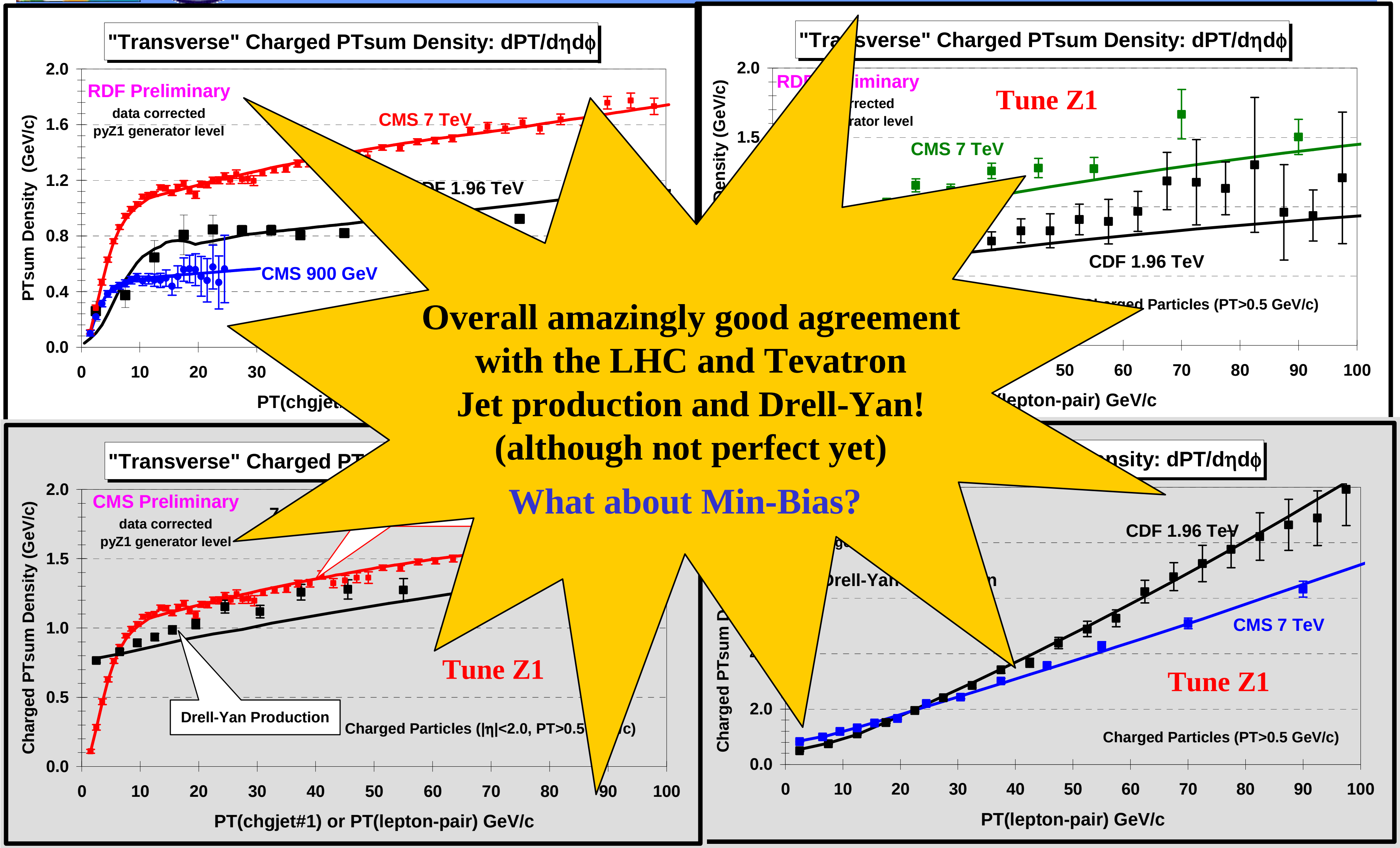








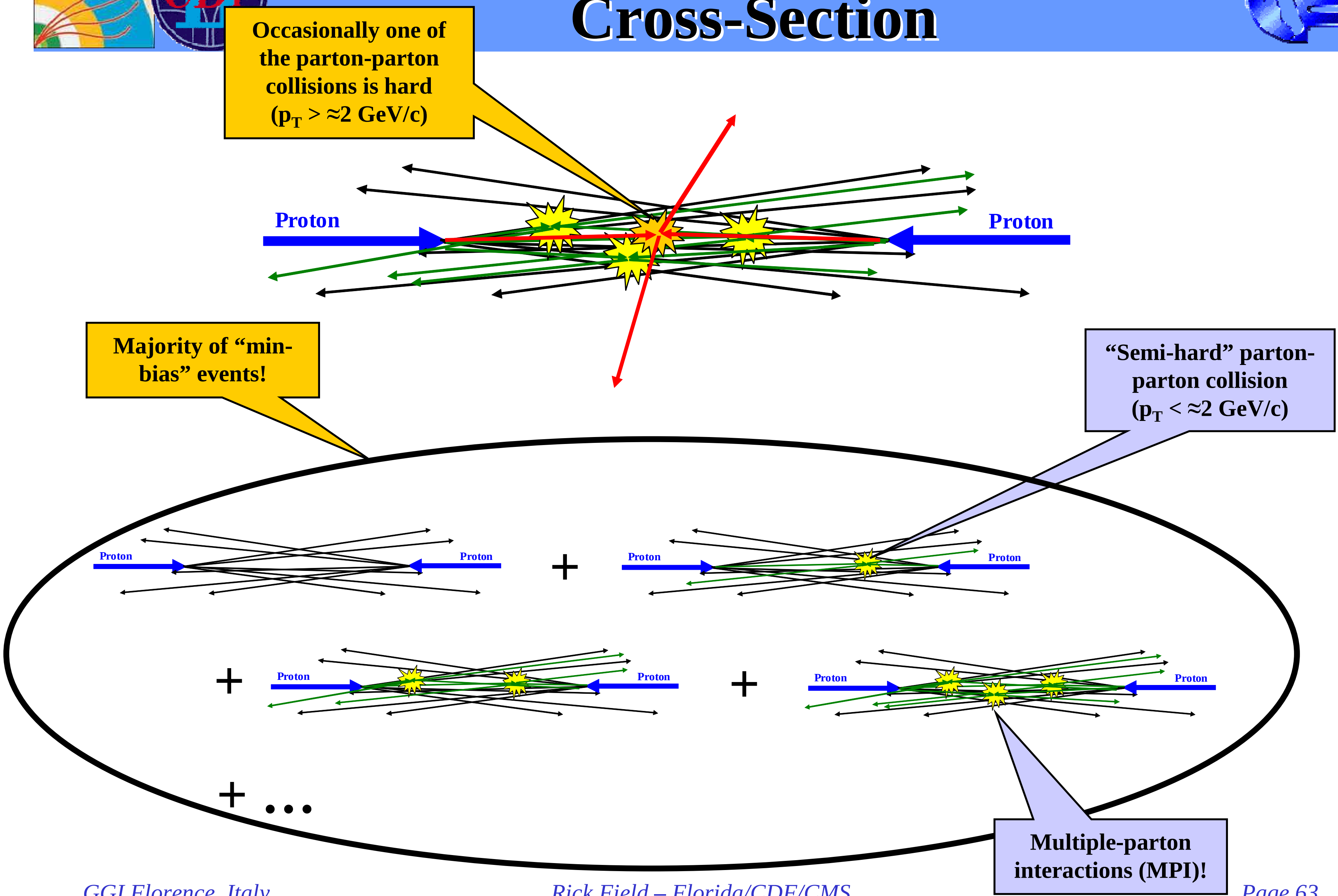
PYTHIA Tune Z1



Overall amazingly good agreement with the LHC and Tevatron Jet production and Drell-Yan! (although not perfect yet)

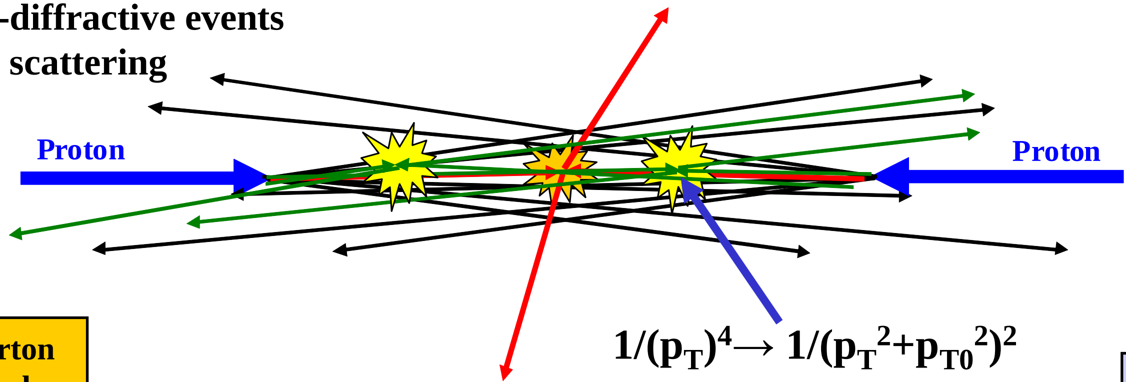
What about Min-Bias?

The Inelastic Non-Diffractive Cross-Section



The “Underlying Event”

Select inelastic non-diffractive events that contain a hard scattering

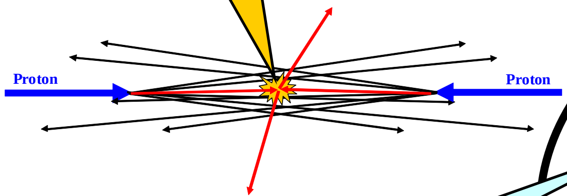


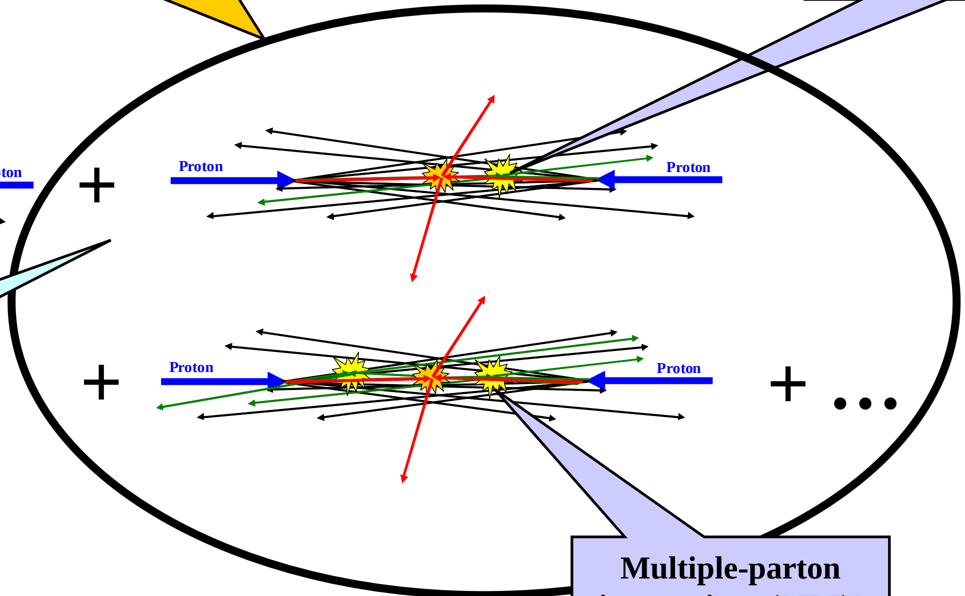
$1/(p_T)^4 \rightarrow 1/(p_T^2 + p_{T0}^2)^2$

Hard parton-parton collisions is hard ($p_T > \approx 2$ GeV/c)

The “underlying-event” (UE)!

“Semi-hard” parton-parton collision ($p_T < \approx 2$ GeV/c)



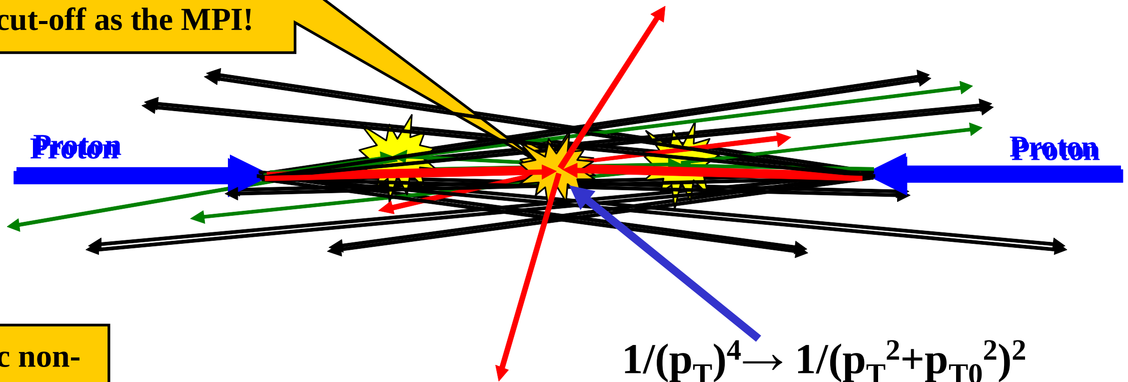


Given that you have one hard scattering it is more probable to have MPI! Hence, the UE has more activity than “min-bias”.

Multiple-parton interactions (MPI)!

Model of σ_{ND}

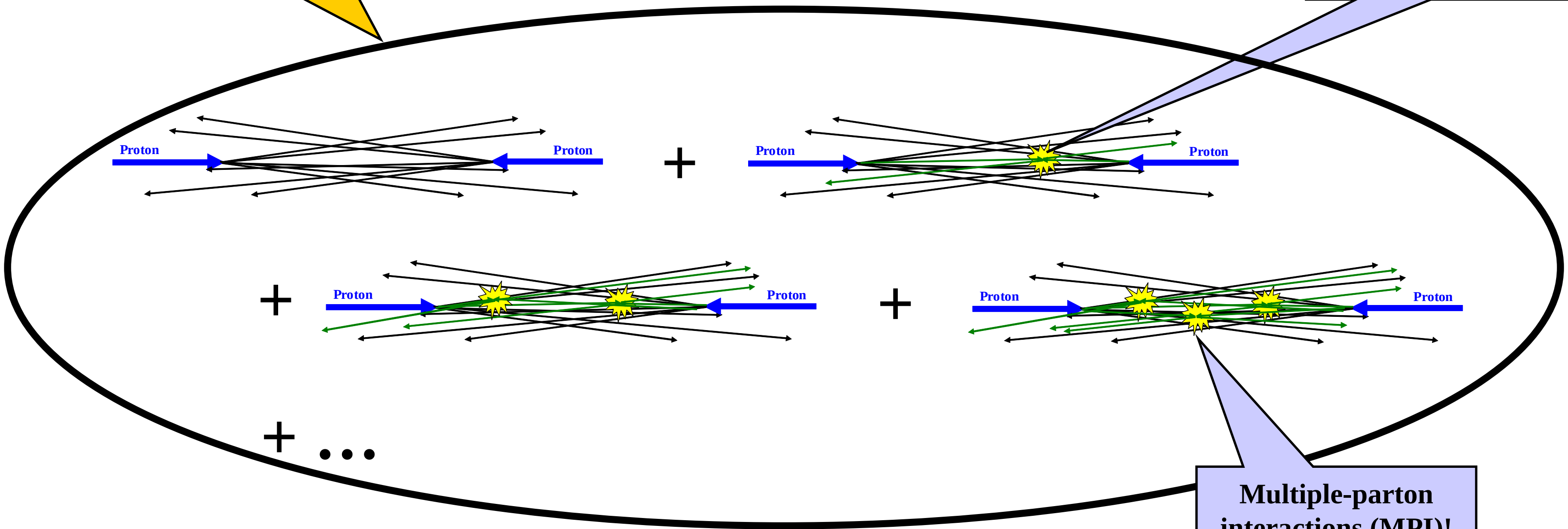
Allow leading hard scattering to go to zero p_T with same cut-off as the MPI!



$1/(p_T)^4 \rightarrow 1/(p_T^2+p_{T0}^2)^2$

Model of the inelastic non-diffractive cross section!

"Semi-hard" parton-parton collision (p_T < ≈2 GeV/c)

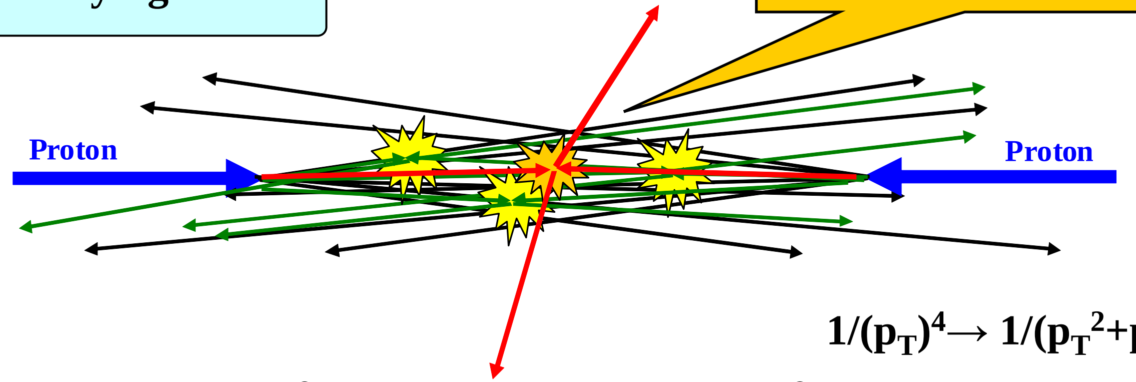


Multiple-parton interactions (MPI)!

UE Tunes

"Underlying Event"

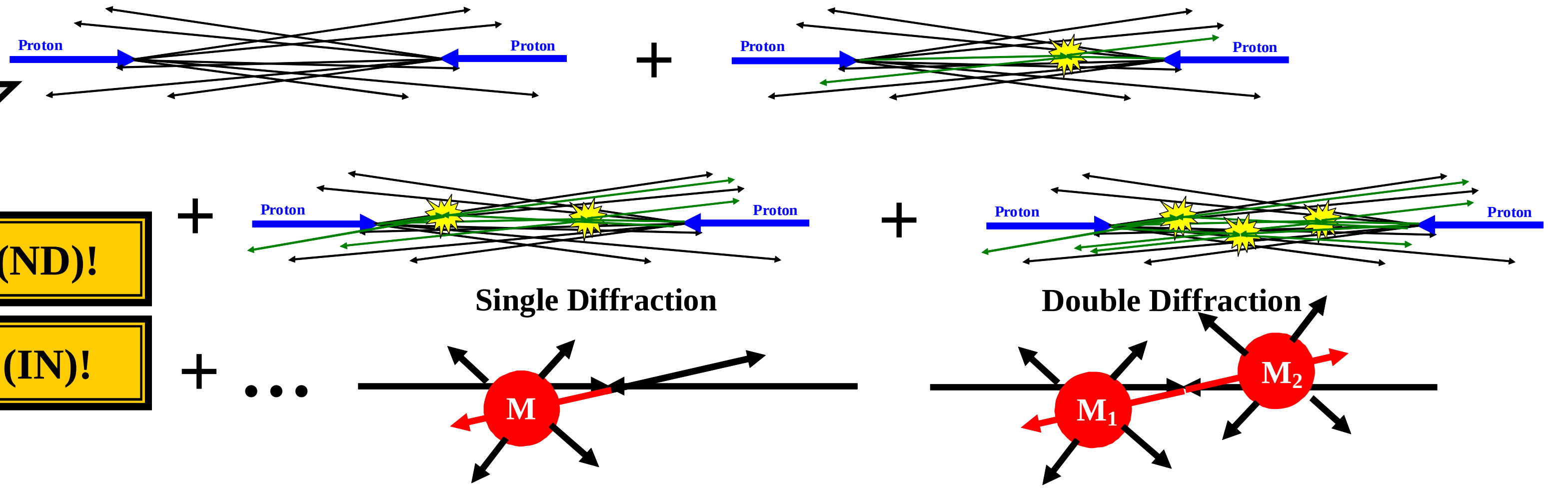
Allow primary hard-scattering to go to $p_T = 0$ with same cut-off!



$1/(p_T)^4 \rightarrow 1/(p_T^2+p_{T0}^2)^2$

Fit the "underlying event" in a hard scattering process.

"Min-Bias" (add single & double diffraction)

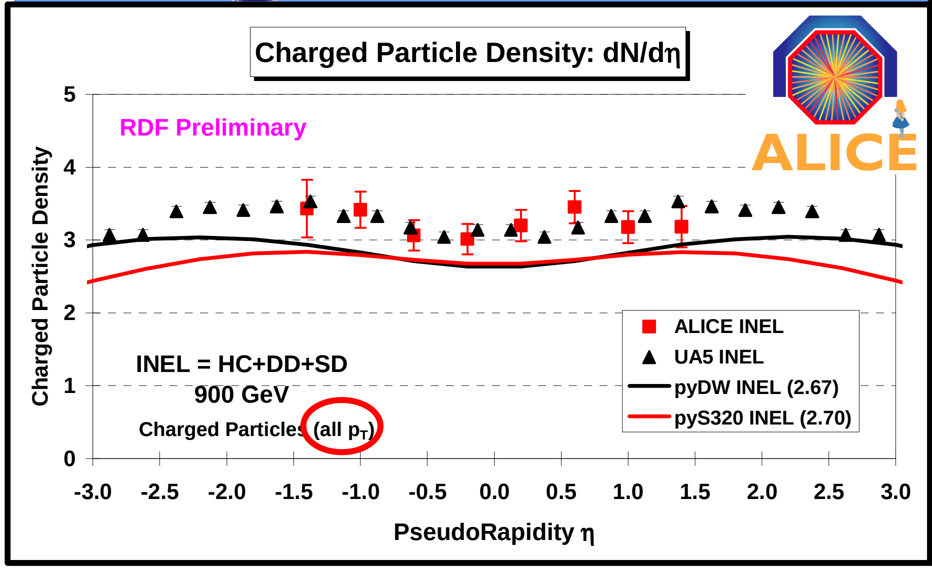


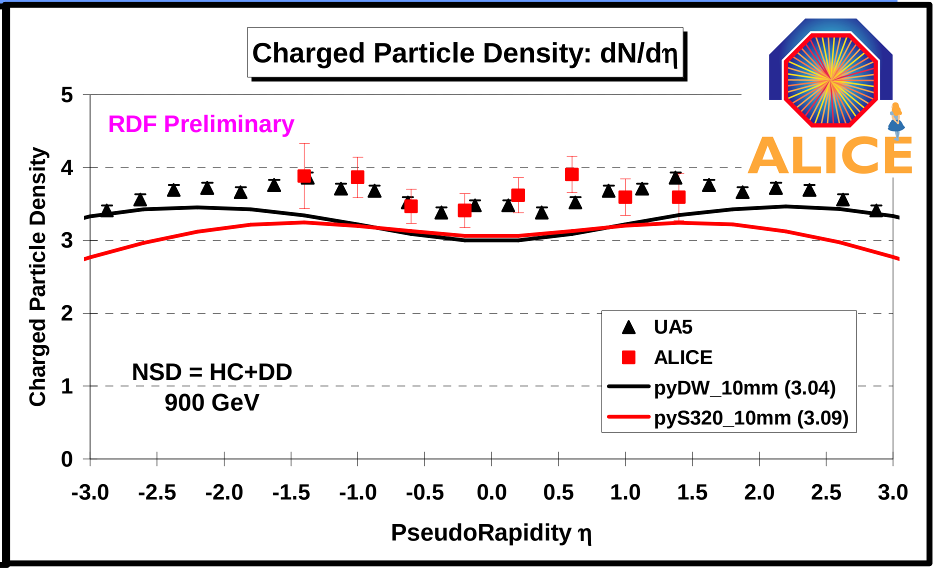
Predict MB (ND)!

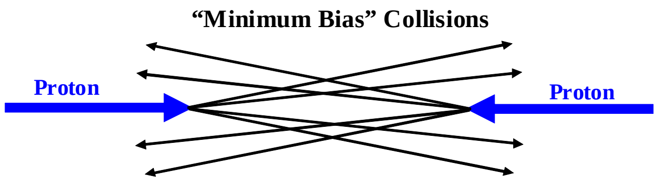
Predict MB (IN)!

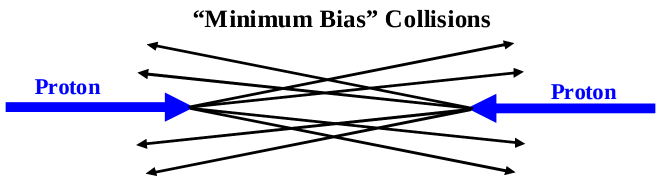
+ …

LHC MB Predictions: 900 GeV



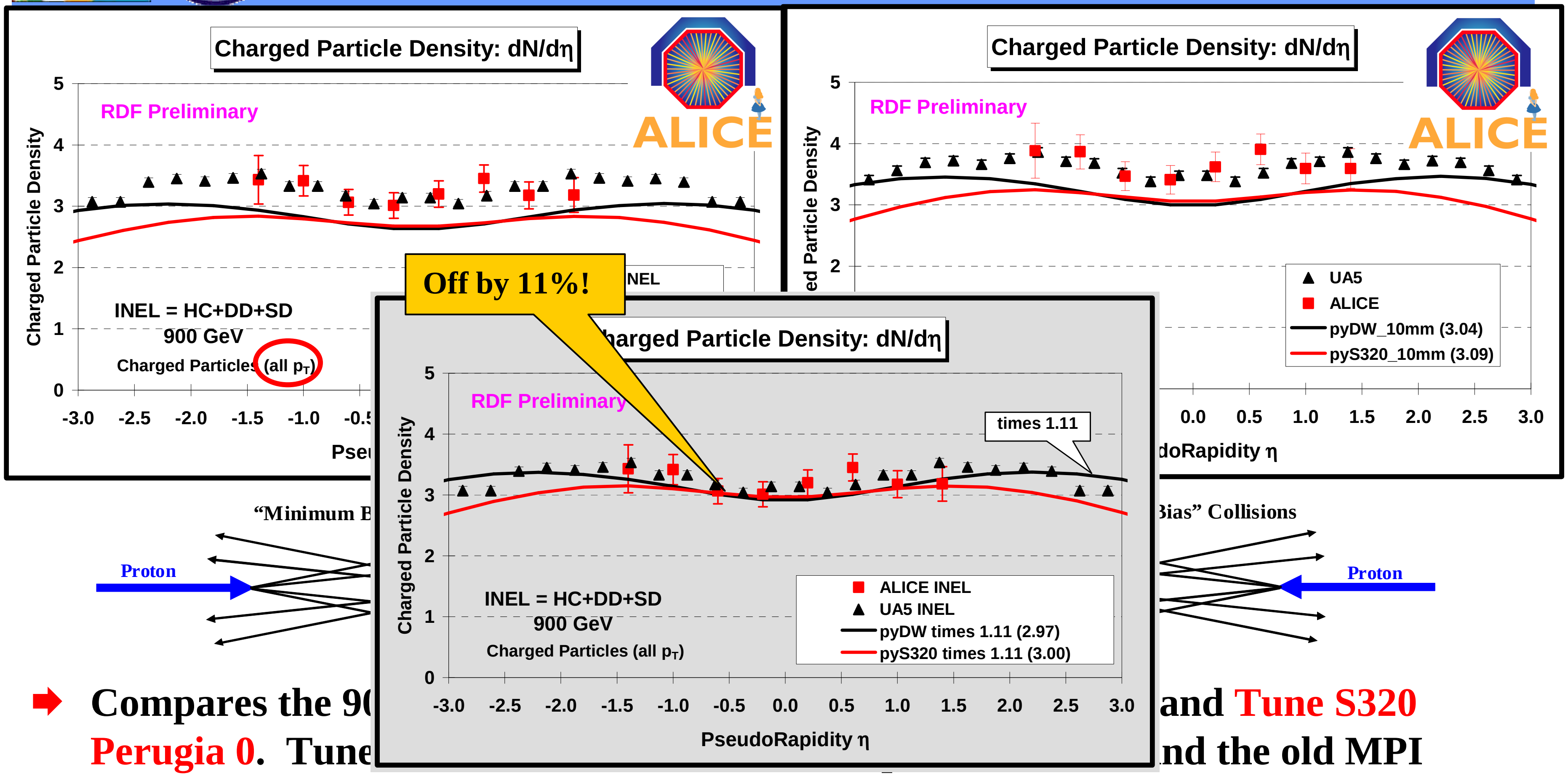






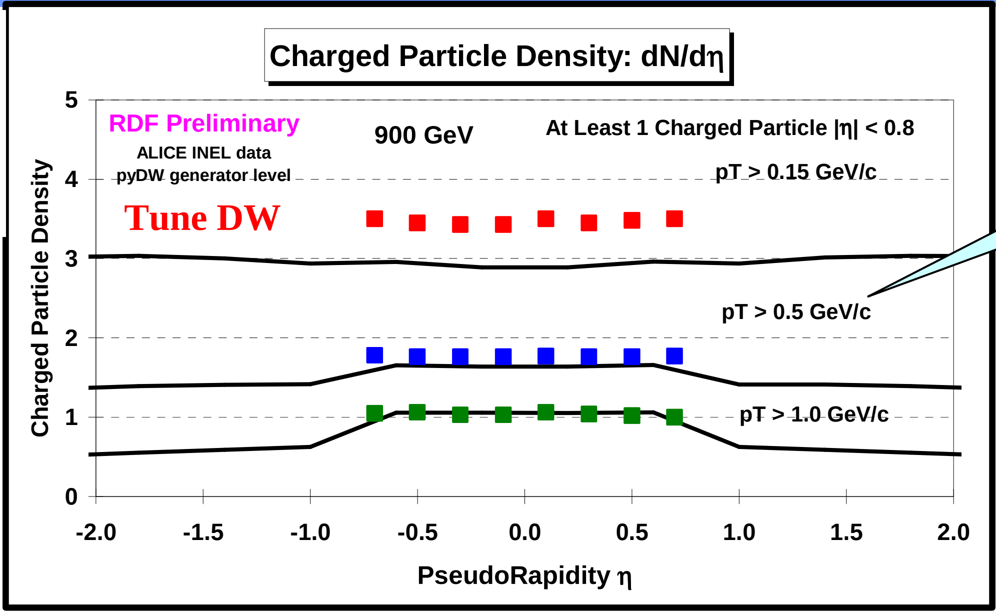
- **Compares the 900 GeV ALICE data with PYTHIA Tune DW and Tune S320 Perugia 0. Tune DW uses the old Q^2-ordered parton shower and the old MPI model. Tune S320 uses the new p_T-ordered parton shower and the new MPI model. The numbers in parentheses are the average value of dN/dη for the region |η| < 0.6.**

LHC MB Predictions: 900 GeV



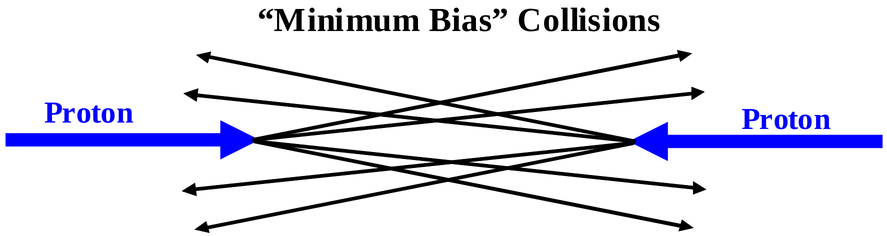
- Compares the 9… and Tune S320 Perugia 0. Tune … nd the old MPI model. Tune S320 uses the new p_T-ordered parton shower and the new MPI model. The numbers in parentheses are the average value of dN/dη for the region |η| < 0.6.

PYTHIA Tune DW

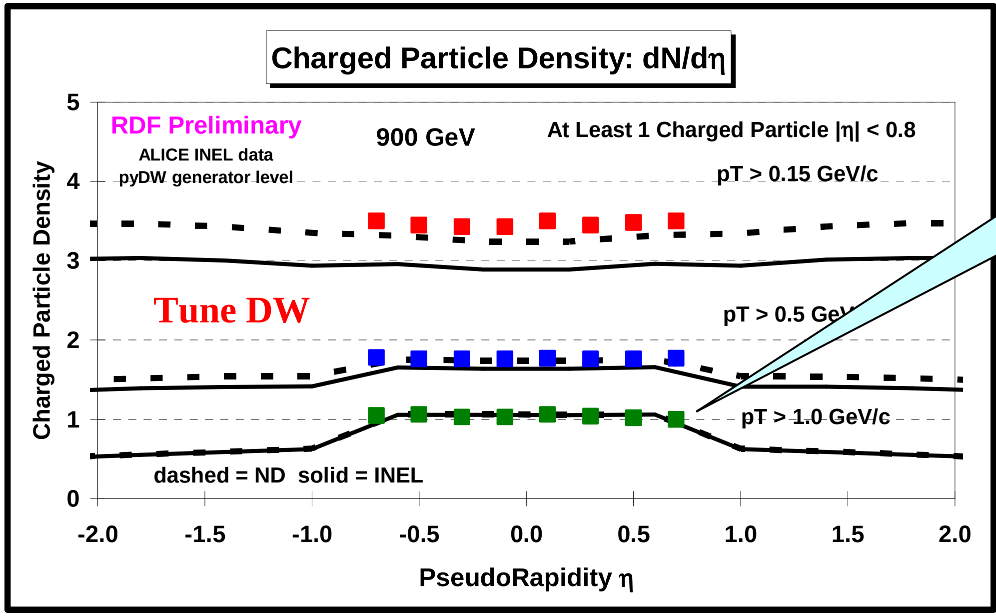


If one increases the p_T the agreement improves!

- **ALICE inelastic data at 900 GeV on the dN/dη distribution for charged particles (p_T > PTmin) for events with at least one charged particle with p_T > PTmin and |η| < 0.8 for PTmin = 0.15 GeV/c, 0.5 GeV/c, and 1.0 GeV/c compared with PYTHIA Tune DW at the generator level.**



PYTHIA Tune DW



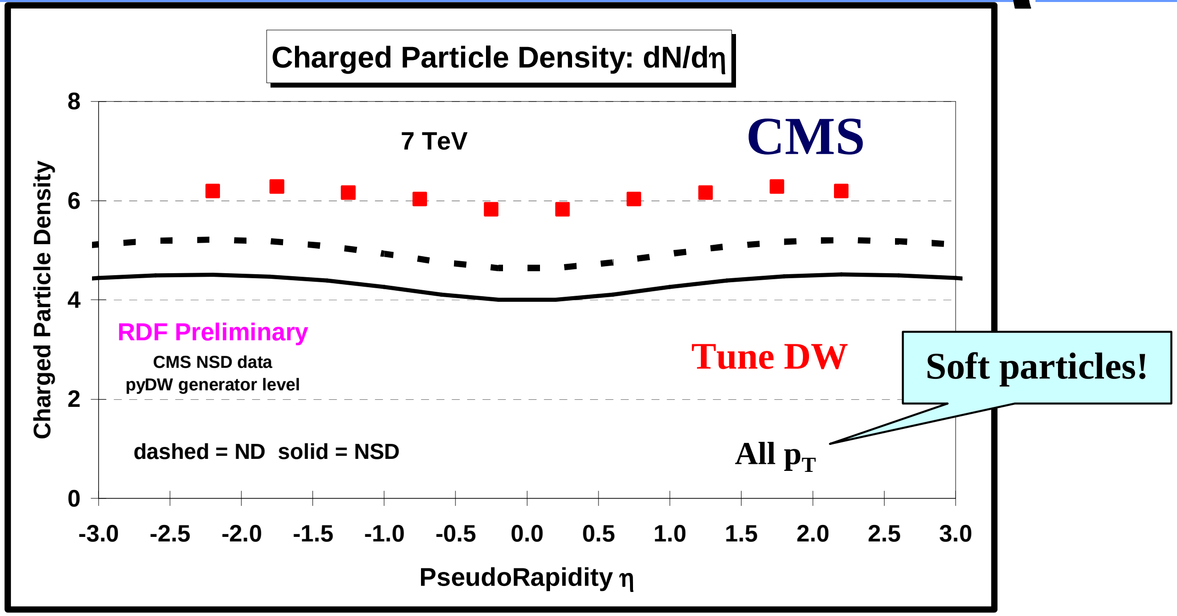
Diffraction contributes less at harder scales!

- **ALICE inelastic data at 900 GeV on the dN/dη distribution for charged particles (p_T > PTmin) for events with at least one charged particle with p_T > PTmin and |η| < 0.8 for PTmin = 0.15 GeV/c, 0.5 GeV/c, and 1.0 GeV/c compared with PYTHIA Tune Z1 at the generator level (dashed = ND, solid = INEL).**

"Minimum Bias" Collisions

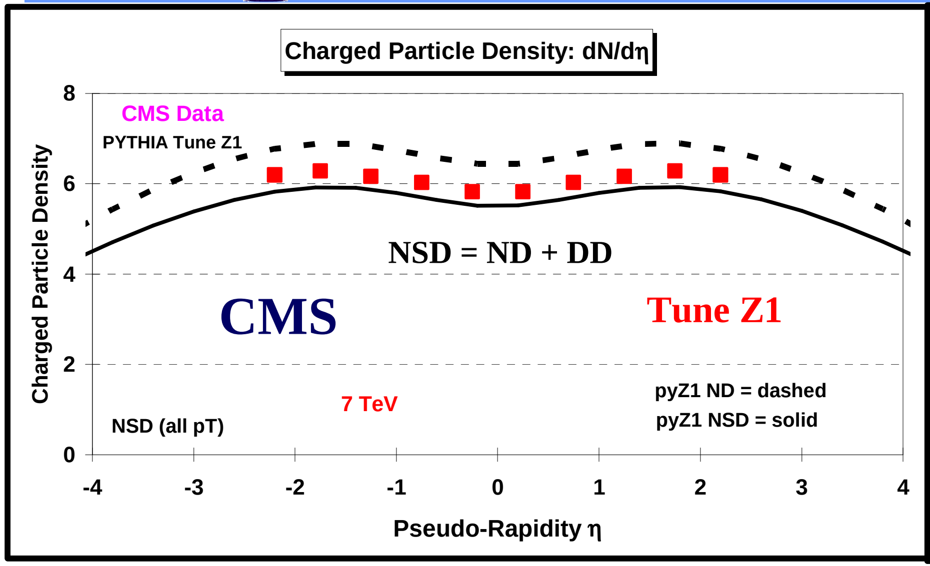
Cannot trust PYTHIA 6.2 modeling of diffraction!

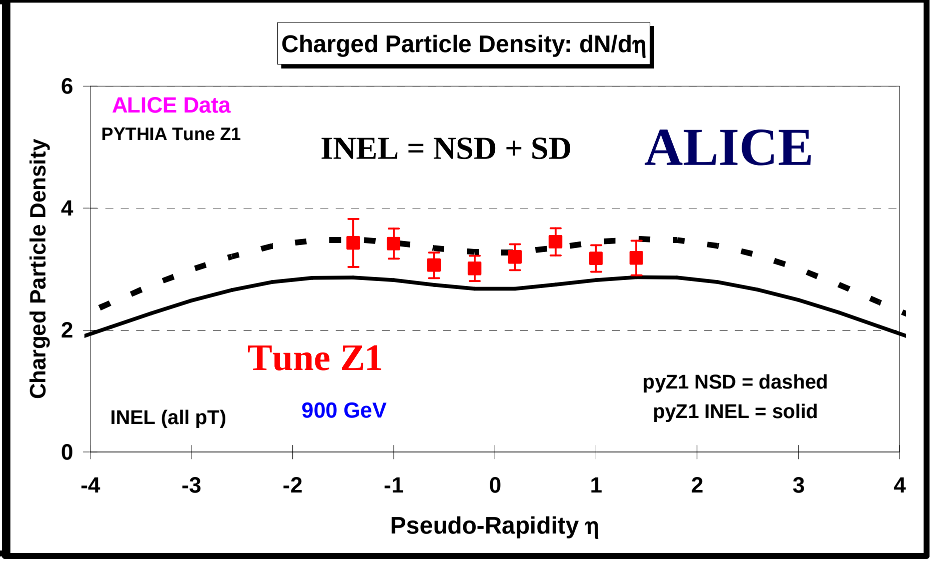
CMS dN/dη



➡ **Generator level dN/dη (all pT). Shows the NSD = HC + DD and the HC = ND contributions for Tune DW. Also shows the CMS NSD data.**

Min-Bias Collisions



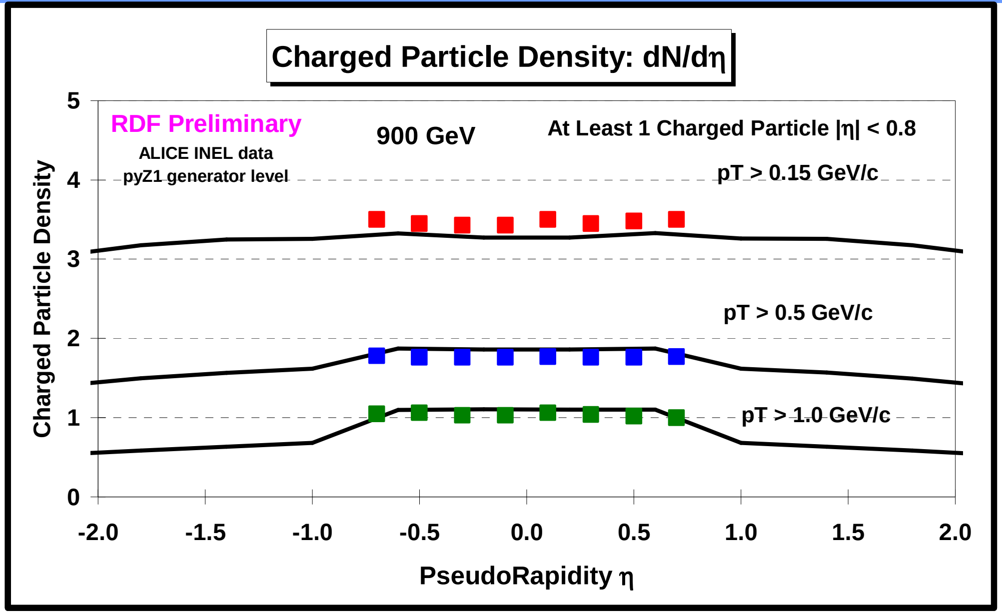


- **CMS NSD data** on the charged particle rapidity distribution at 7 TeV compared with **PYTHIA Tune Z1**. The plot shows the average number of particles per NSD collision per unit η, $(1/N_{NSD})\ dN/d\eta$.
- **ALICE NSD data** on the charged particle rapidity distribution at 900 GeV compared with **PYTHIA Tune Z1**. The plot shows the average number of particles per INEL collision per unit η, $(1/N_{INEL})\ dN/d\eta$.

"Minimum Bias" Collisions

Okay not perfect, but remember we know that SD and DD are not modeled well!

PYTHIA Tune Z1

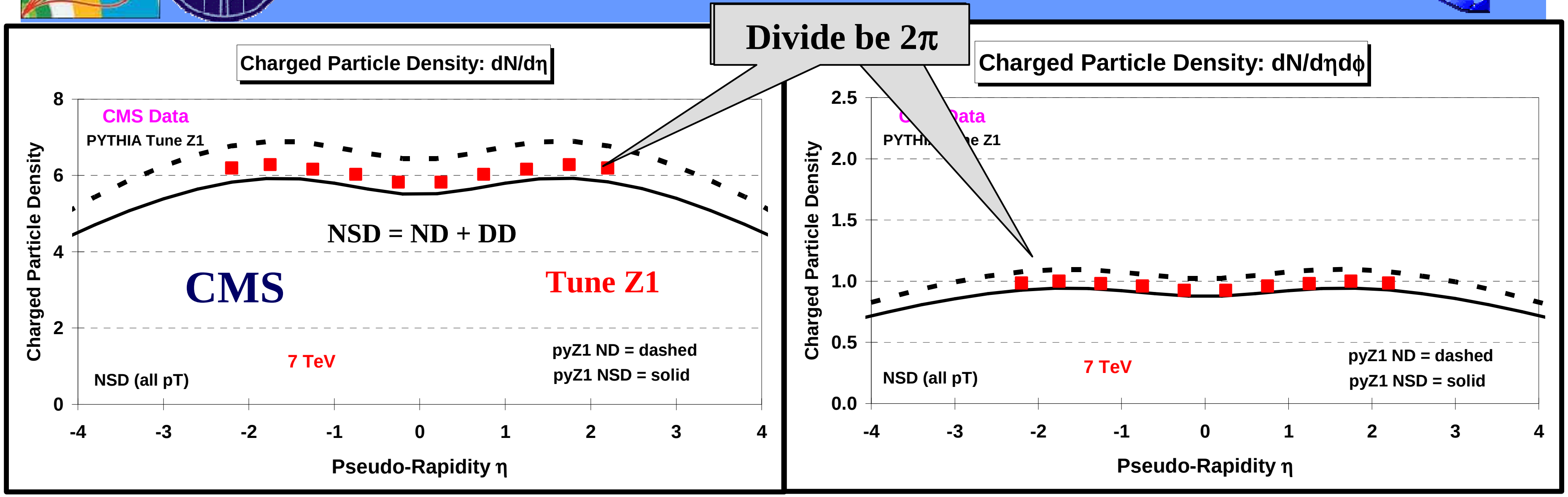


- ALICE inelastic data at 900 GeV on the dN/dη distribution for charged particles (p_T > PTmin) for events with at least one charged particle with p_T > PTmin and |η| < 0.8 for PTmin = 0.15 GeV/c, 0.5 GeV/c, and 1.0 GeV/c compared with PYTHIA Tune Z1 at the generator level.

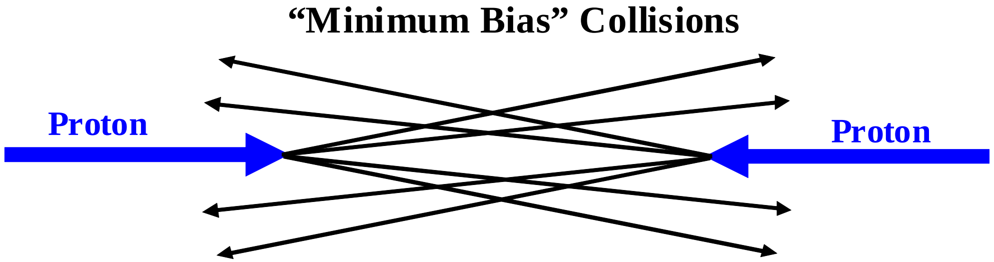
"Minumum Bias" Collisions

Okay not perfect, but remember we do not know if the SD & DD are correct!

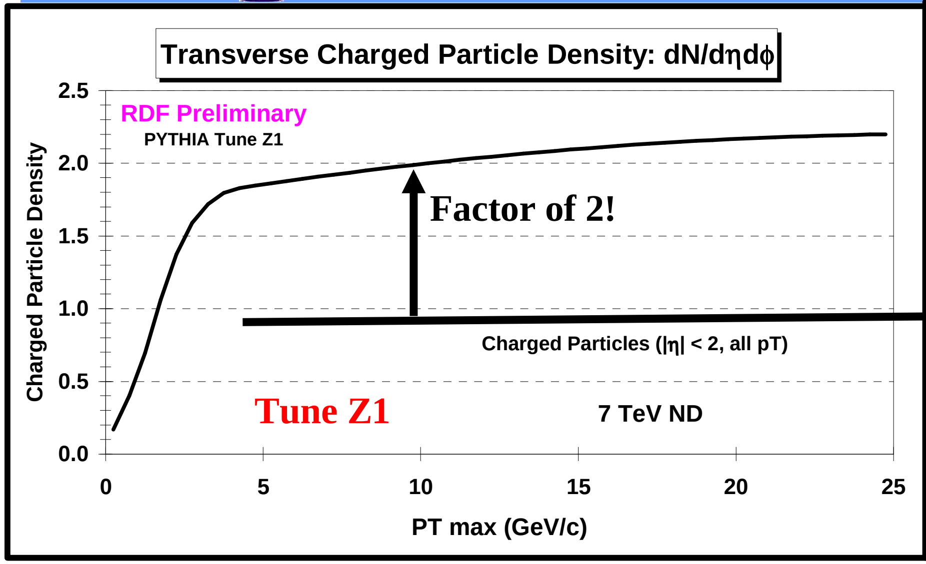
MB versus UE

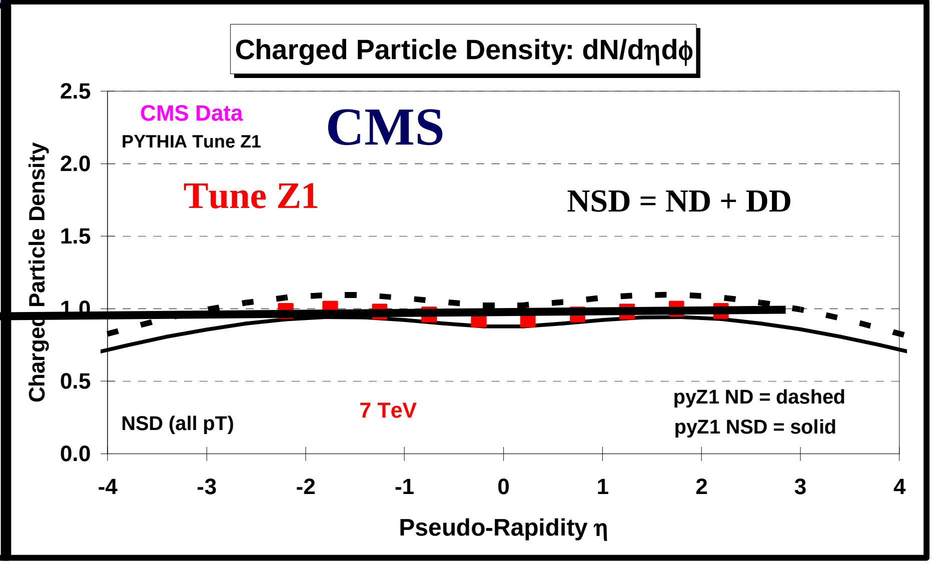


- **CMS NSD data** on the charged particle rapidity distribution at 7 TeV compared with **PYTHIA Tune Z1**. The plot shows the average number of charged particles per NSD collision per unit η, $(1/N_{NSD})$ dN/dη.
- **CMS NSD data** on the charged particle rapidity distribution at 7 TeV compared with **PYTHIA Tune Z1**. The plot shows the average number of charged particles per NSD collision per unit η−ϕ, $(1/N_{NSD})$ dN/dηdϕ.

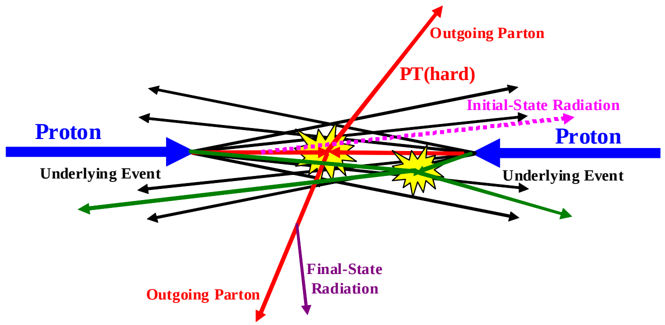


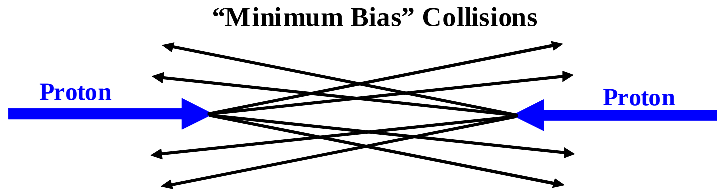
MB versus UE



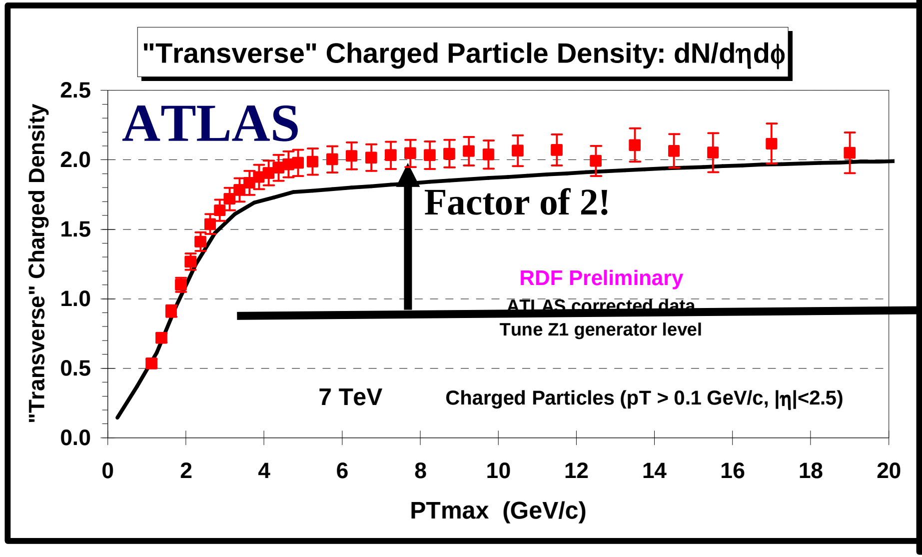


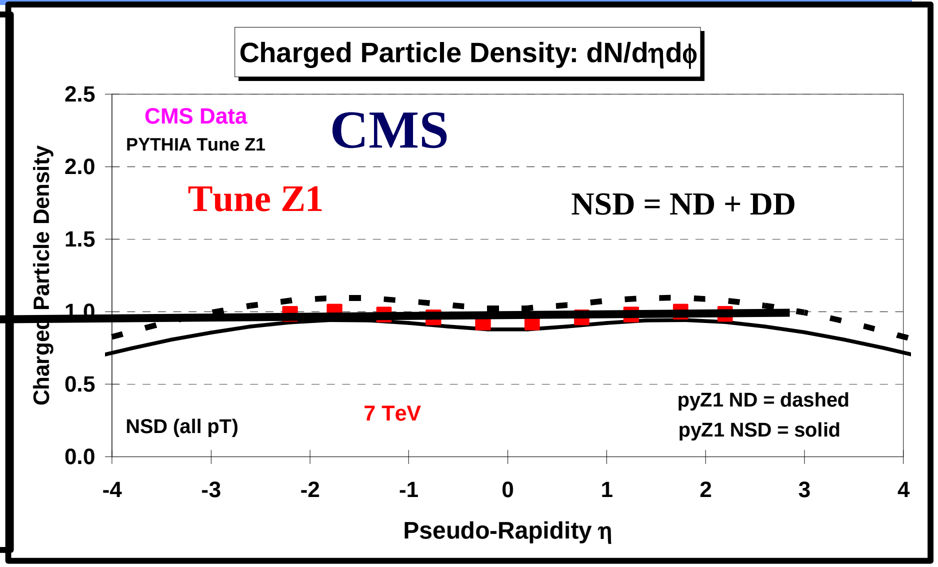
- Shows the density of charged particles in the **"transverse" region** as a function of PTmax for charged particles (All p_T, $|\eta| < 2$) at 7 TeV from PYTHIA **Tune Z1**.
- **CMS NSD data** on the charged particle rapidity distribution at 7 TeV compared with **PYTHIA Tune Z1**. The plot shows the average number of charged particles per NSD collision per unit $\eta-\phi$, $(1/N_{NSD})\ dN/d\eta d\phi$.



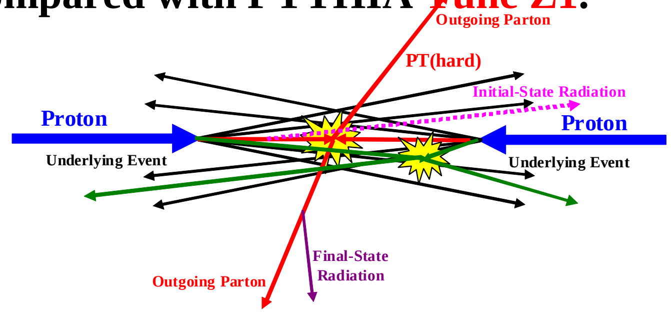


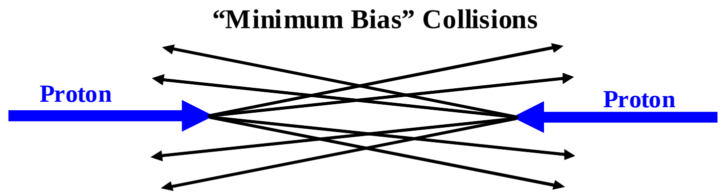
MB versus UE



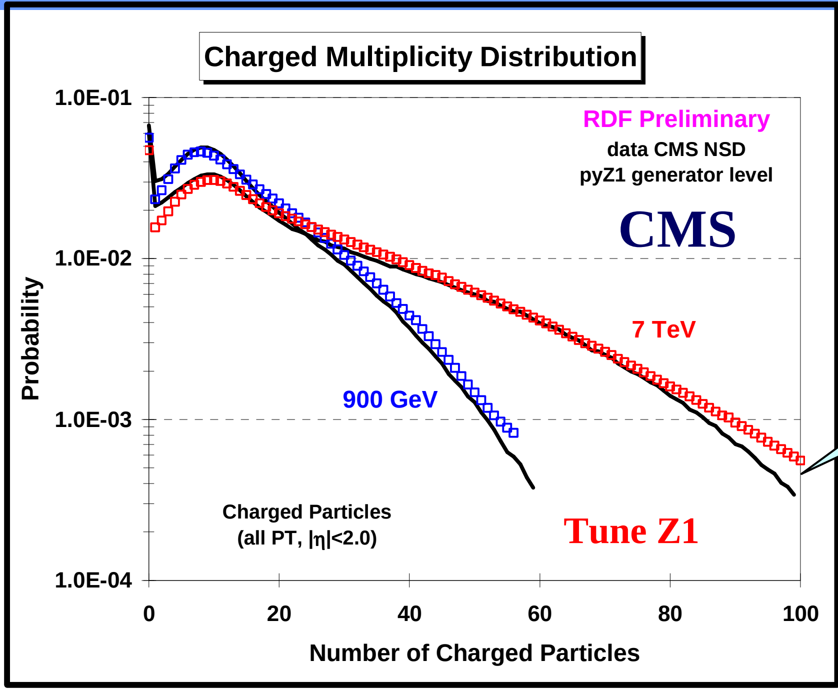


- **ATLAS data** on the density of charged particles in the **"transverse" region** as a function of PTmax for charged particles (p_T > 0.1 GeV/c, $|\eta|$ < 2.5) at 7 TeV compared with PYTHIA **Tune Z1**.
- **CMS NSD data** on the charged particle rapidity distribution at 7 TeV compared with **PYTHIA Tune Z1**. The plot shows the average number of charged particles per NSD collision per unit η−φ, $(1/N_{NSD})\ dN/d\eta d\phi$.





NSD Multiplicity Distribution



Difficult to produce enough events with large multiplicity!

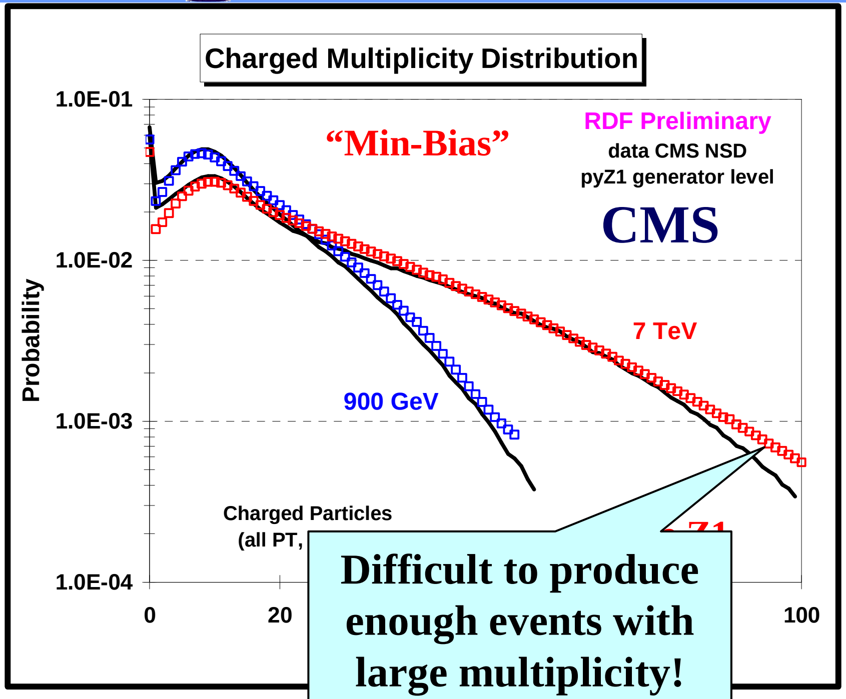
- **Generator level charged multiplicity distribution (all pT, |η| < 2) at 900 GeV and 7 TeV. Shows the NSD = HC + DD prediction for Tune Z1. Also shows the CMS NSD data.**

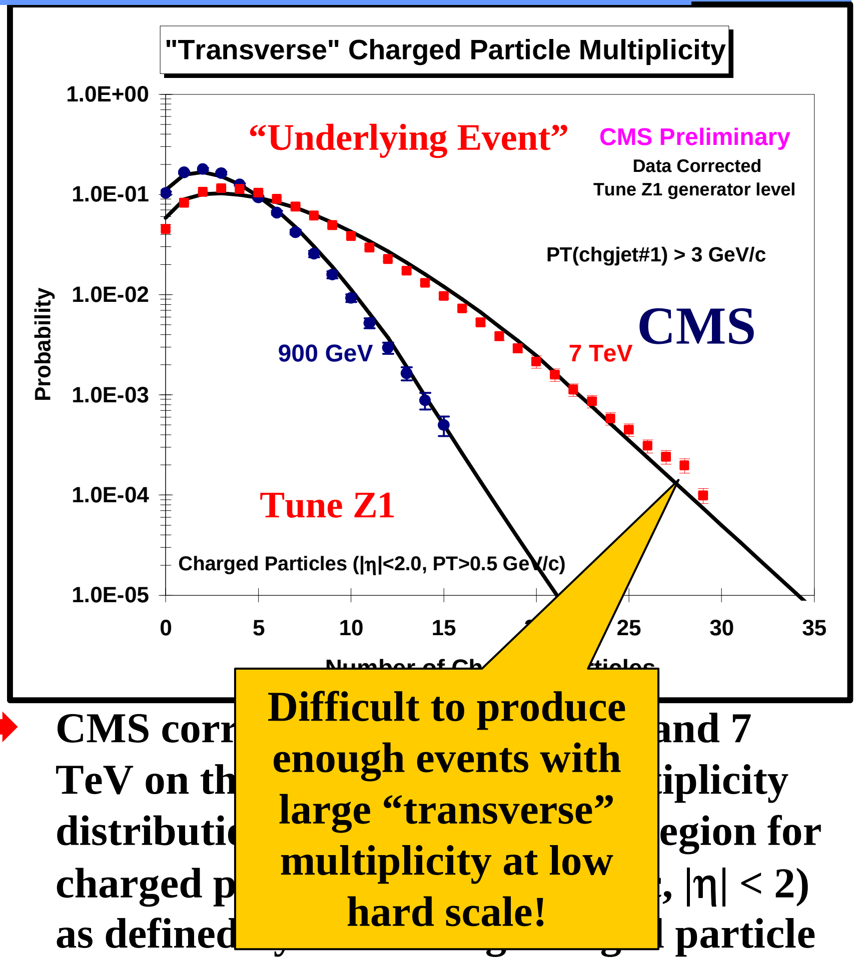
"Minumum Bias" Collisions

Proton ... **oton**

Okay not perfect!
But not that bad!

MB & UE





- **Generator level charged multiplicity distribution (all pT, |η| < 2) at 900 GeV and 7 TeV. Shows the NSD = HC + DD prediction for Tune Z1. Also shows the CMS NSD data.**

- **CMS corr… and 7 TeV on th… iplicity distributi… egion for charged p… , |η| < 2) as defined … particle jet with PT(chgjet#1) > 3 GeV/c compared with PYTHIA Tune Z1 at the generator level.**

How **Universal** are the Tunes?

- **Do we need a separate tune for each center-of-mass energy? 900 GeV, 1.96 TeV, 7 TeV, etc.**

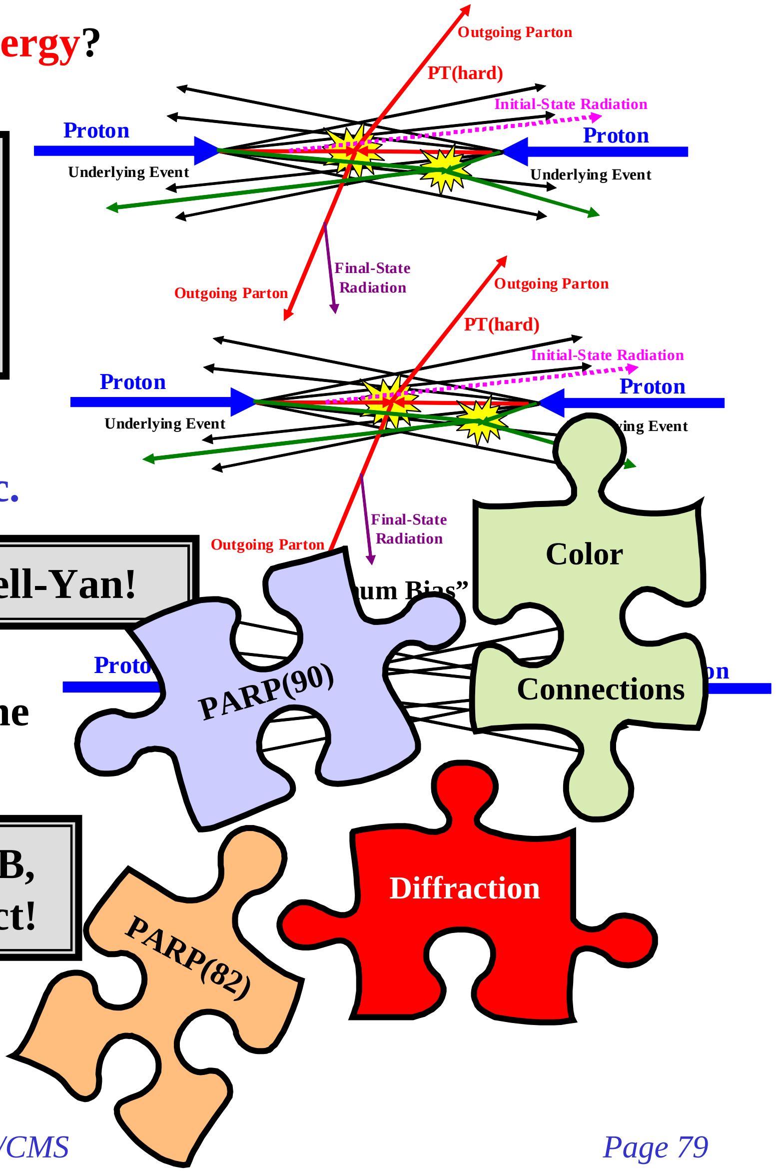
> **PYTHIA Tune DW did a nice (although not perfect) job predicting the LHC Jet Production and Drell-Yan UE data. I am still hoping for a single tune that will describe all energies!**

- **Do we need a separate tune for each hard QCD subprocess? Jet Production, Drell-Yan Production, etc.**

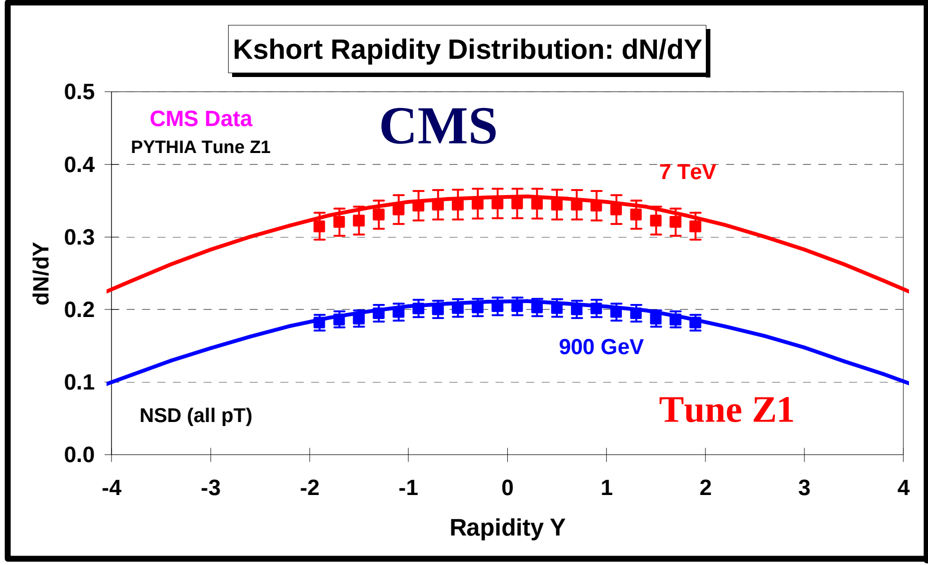
> **The same tune can describe both Jet Production and Drell-Yan!**

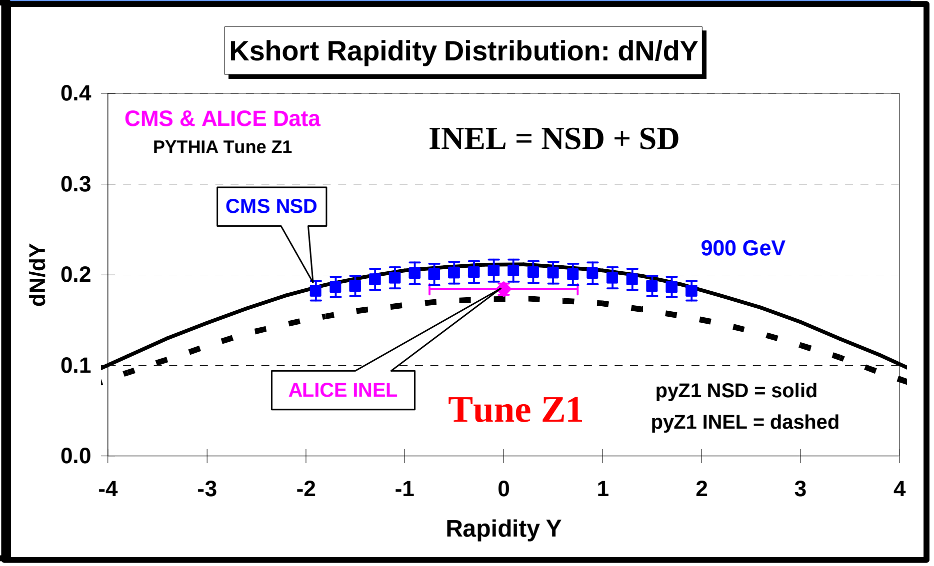
- **Do we need separate tunes for "Min-Bias" (MB) and the "underlying event" (UE) in a hard scattering process?**

> **PHTHIA Tune Z1 does fairly well at both the UE and MB, but you cannot expect such a naïve approach to be perfect!**



Kaon Production





- **CMS NSD data** on the K_{short} rapidity distribution at 7 TeV and 900 GeV compared with **PYTHIA Tune Z1**. The plot shows the average number of K_{short} per NSD collision per unit Y, $(1/N_{NSD})$ dN/dY.
- **CMS NSD data** on the K_{short} rapidity distribution at 900 GeV and the **ALICE** point at Y = 0 (INEL) compared with **PYTHIA Tune Z1**. The ALICE point is the average number of K_{short} per INEL collision per unit Y at Y = 0, $(1/N_{INEL})$ dN/dY.

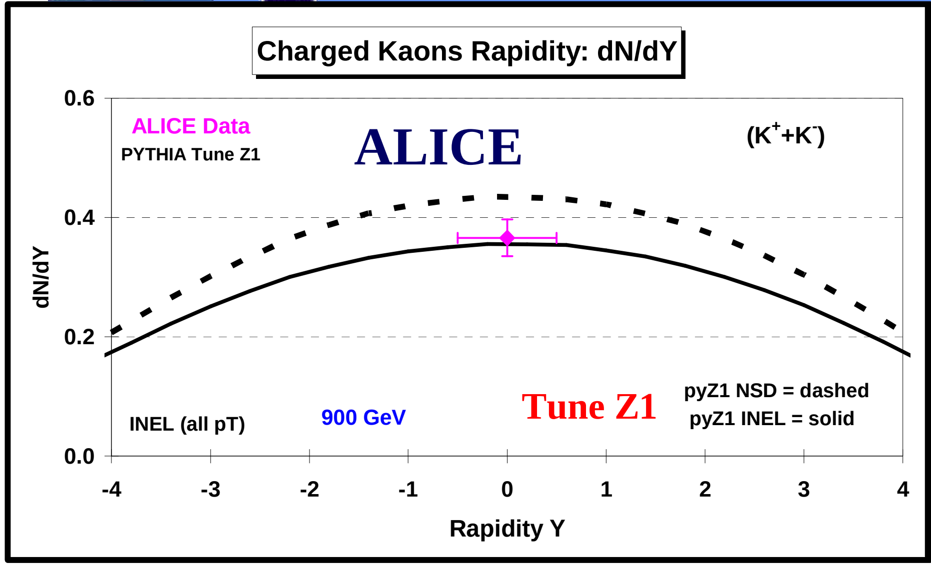
"Minimum Bias" Collisions

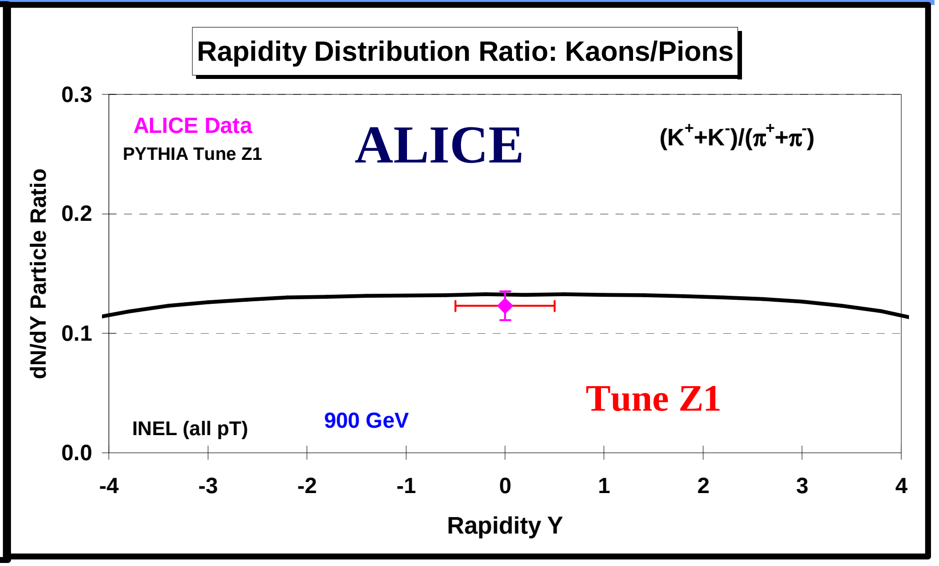
K_{short}: $d\bar{s} + \bar{d}s$

No overall shortage of Kaons in PYTHIA Tune Z1!

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

Kaon Production



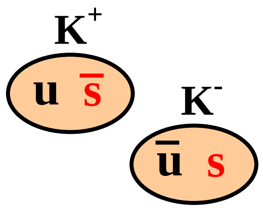


- **ALICE INEL data on the charged kaon rapidity distribution at 900 GeV compared with PYTHIA Tune Z1. The plot shows the average number of charged kaons per INEL collision per unit Y at Y = 0, $(1/N_{INEL})\, dN/dY$.**

- **ALICE INEL data on the charged kaon to charged pion rapidity ratio at 900 GeV compared with PYTHIA Tune Z1.**

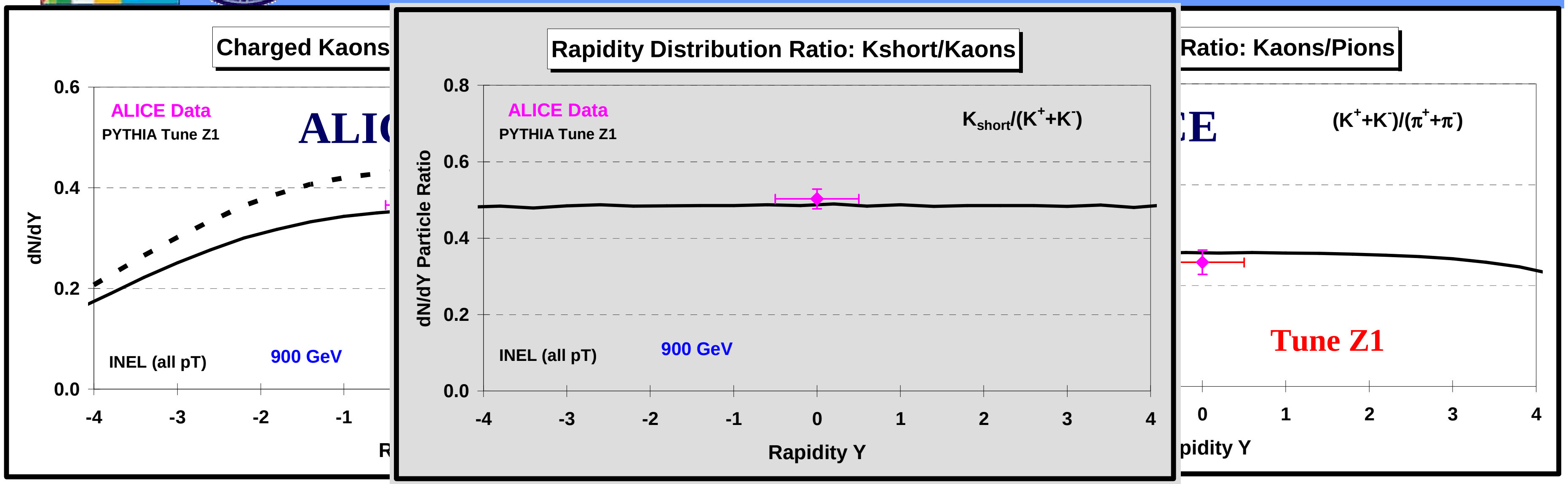
$$\frac{(K^+ + K^-)}{(\pi^+ + \pi^-)} = \frac{\text{Strange Meson}}{\text{Non-strange Meson}}$$

"Minimum Bias" Collisions



No overall shortage of Kaons in PYTHIA Tune Z1!

Kaon Production



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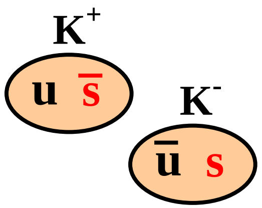
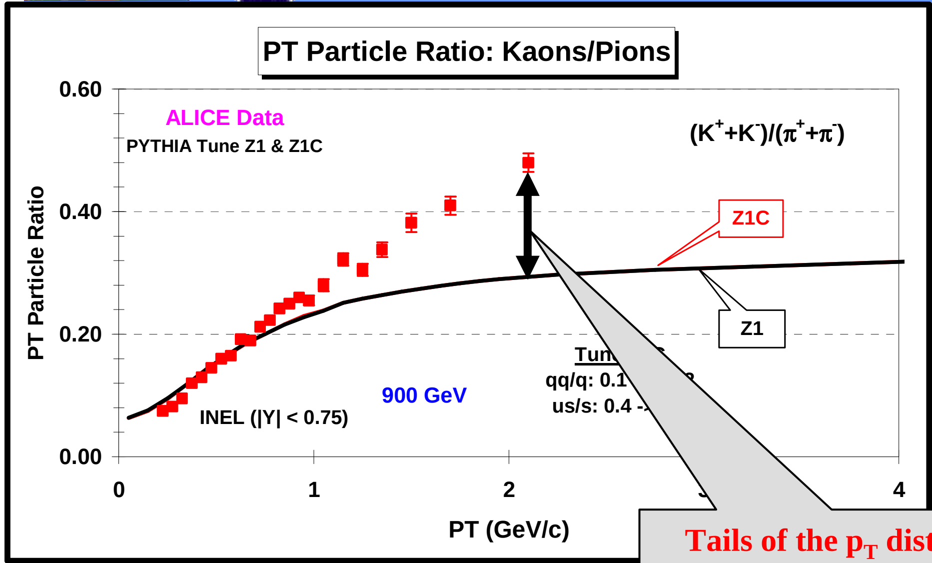
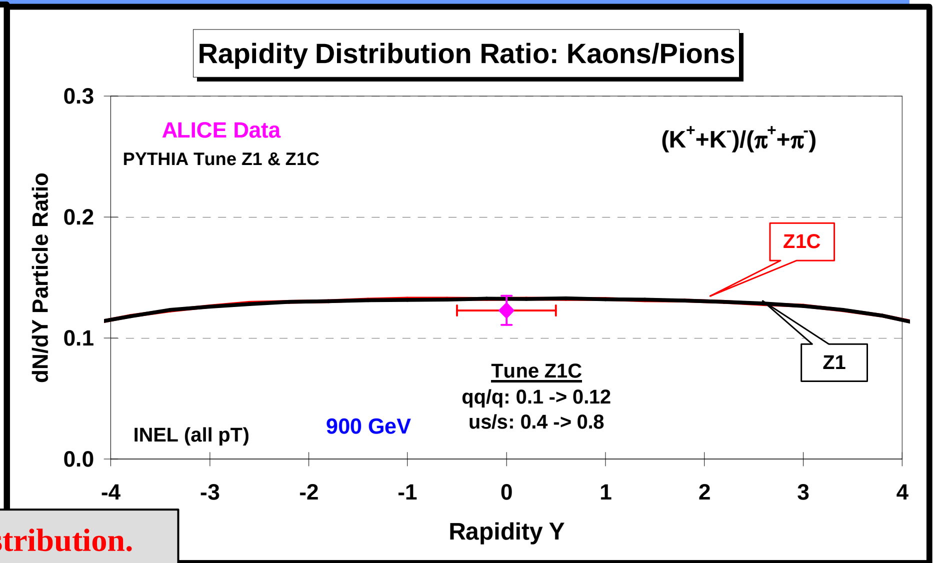
"Minimum Bias" Collisions



No overall shortage of Kaons in PYTHIA Tune Z1!

Particle Ratios versus PT

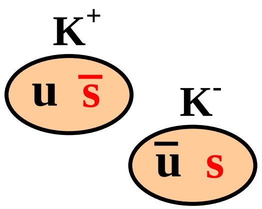




Tails of the p_T distribution. Way off due to the wrong p_T!

- **ALICE INEL data** on the charged kaons to charged pions ratio versus p_T at 900 GeV (|Y| < 0.75) compared with **PYTHIA Tune Z1 & Z1C**.
- **ALICE INEL data** on the charged kaon to charged pion rapidity ratio at 900 GeV compared with **PYTHIA Tune Z1**.

$$\frac{(K^+ + K^-)}{(\pi^+ + \pi^-)} = \frac{\text{Strange Meson}}{\text{Non-strange Meson}}$$



"Minimum Bias" Collisions

PYTHIA p_T dependence off on Kaons!

PYTHIA 6.4.25

PYTUNE

```
-------------------------------------------------------------------
 4th generation: tunes incorporating 7-TeV data
-------------------------------------------------------------------
 340 AMBT1       : 1st ATLAS tune incl 7 TeV, w. LO* PDFs      (2010)
 341 Z1          : Retune of AMBT1 by Field w CTEQ5L PDFs      (2010)
 342 Z1-LEP      : Retune of Z1 by Skands w CTEQ5L PDFs        (2010)
 343 Z2          : Retune of Z1 by Field w CTEQ6L1 PDFs        (2010)
 344 Z2-LEP      : Retune of Z1 by Skands w CTEQ6L1 PDFs       (2010)
 350 Perugia 2011 : Retune of Perugia 2010 incl 7-TeV data (Mar 2011)
 351 P2011 radHi : Variation with alphaS(pT/2)
 352 P2011 radLo : Variation with alphaS(2pT)
 353 P2011 mpiHi : Variation with more semi-hard MPI
 354 P2011 noCR  : Variation without color reconnections
 355 P2011 LO**  : Perugia 2011 using MSTW LO** PDFs       (Mar 2011)
 356 P2011 C6    : Perugia 2011 using CTEQ6L1 PDFs         (Mar 2011)
 357 P2011 T16   : Variation with PARP(90)=0.16 away from 7 TeV
 358 P2011 T32   : Variation with PARP(90)=0.32 awat from 7 TeV
 359 P2011 TeV   : Perugia 2011 optimized for Tevatron     (Mar 2011)
 360 S Global    : Schulz-Skands Global fit                (Mar 2011)
 361 S 7000      : Schulz-Skands at 7000 GeV               (Mar 2011)
 362 S 1960      : Schulz-Skands at 1960 GeV               (Mar 2011)
 363 S 1800      : Schulz-Skands at 1800 GeV               (Mar 2011)
 364 S 900       : Schulz-Skands at 900 GeV                (Mar 2011)
 365 S 630       : Schulz-Skands at 630 GeV                (Mar 2011)
=====================================================================
```

Tune Z1 — CTEQ5L

Tune Z2 — CTEQ6L

Tune S350 — CTEQ5L

Tune S356 — CTEQ6L

LEP: K_{short} Spectrum

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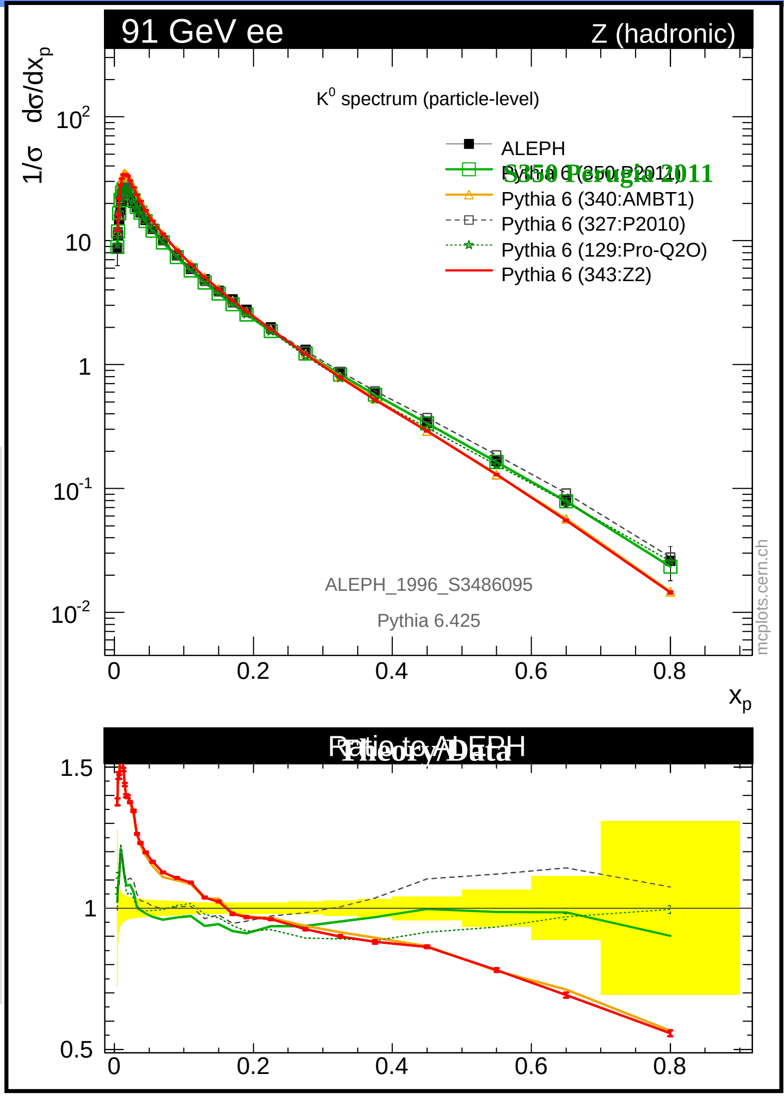
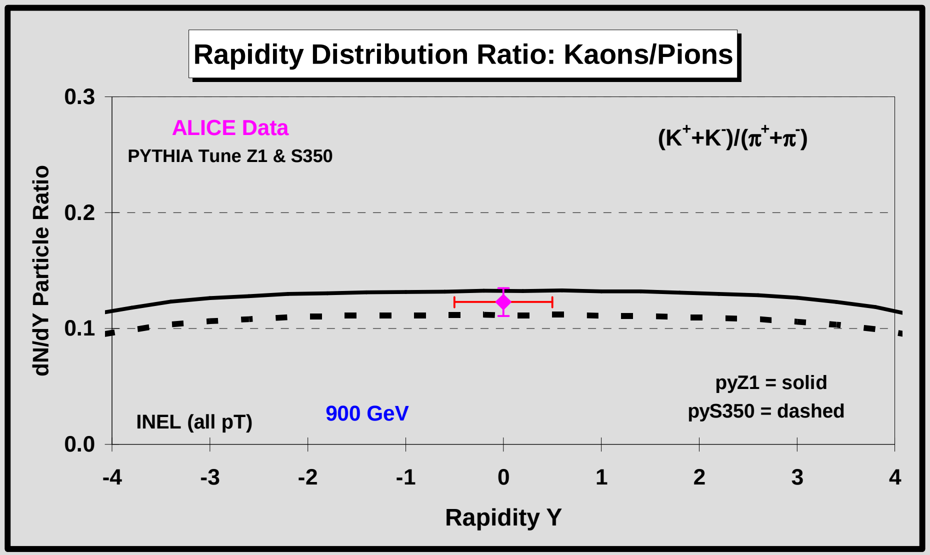
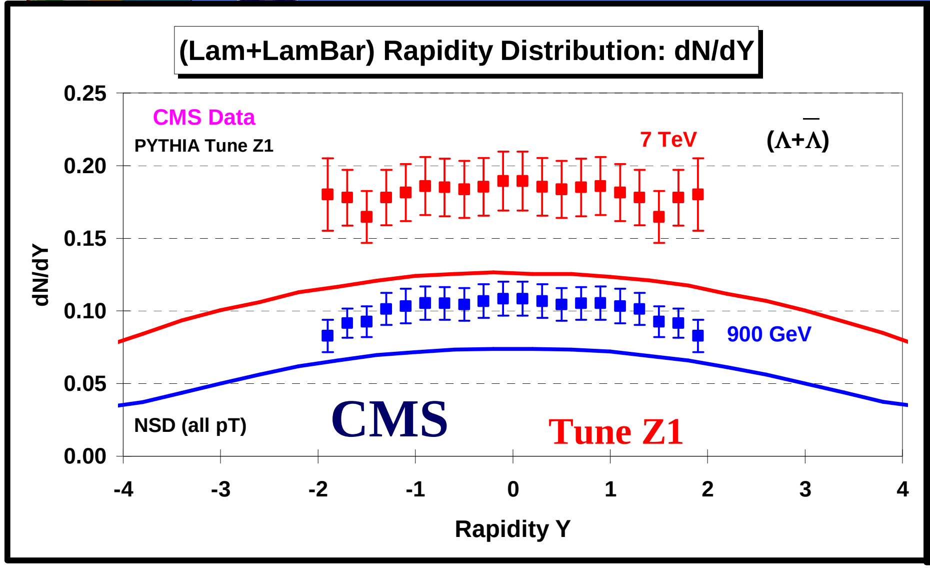
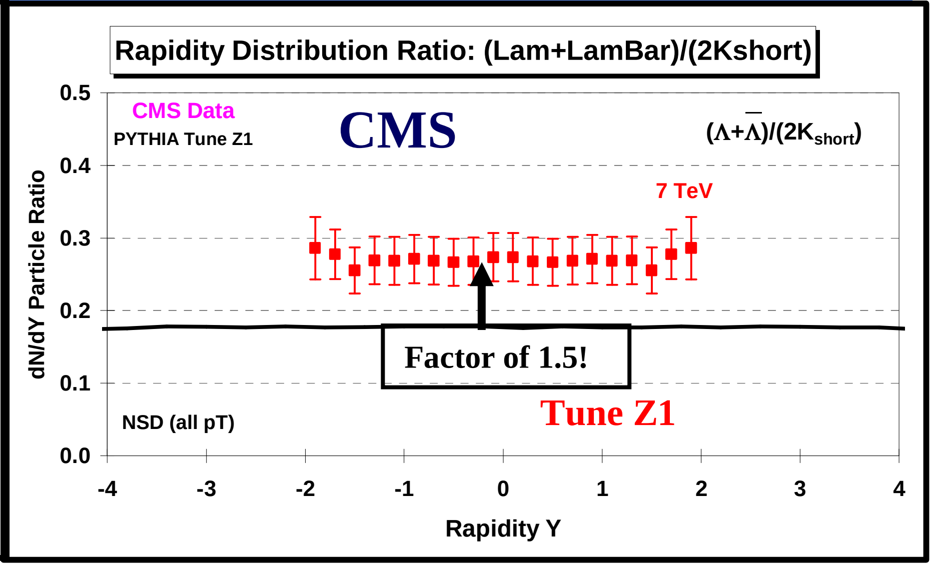




Lambda Production





- **CMS NSD data** on the Lambda+AntiLambda rapidity distribution at 7 TeV and 900 GeV compared with **PYTHIA Tune Z1**. The plot shows the average number of particles per NSD collision per unit Y, $(1/N_{NSD})$ dN/dY.
- **CMS NSD data** on the Lambda+AntiLambda to 2Kshort rapidity ratio at 7 TeV compared with **PYTHIA Tune Z1**.

$$\frac{(\Lambda + \bar{\Lambda})}{2K_{short}} = \frac{\text{Single-strange Baryon}}{\text{Strange Meson}}$$

"Minimum Bias" Collisions

Λ

ud s

Oops! Not enough Lambda's in PYTHIA Tune Z1!

LEP: Λ Spectrum

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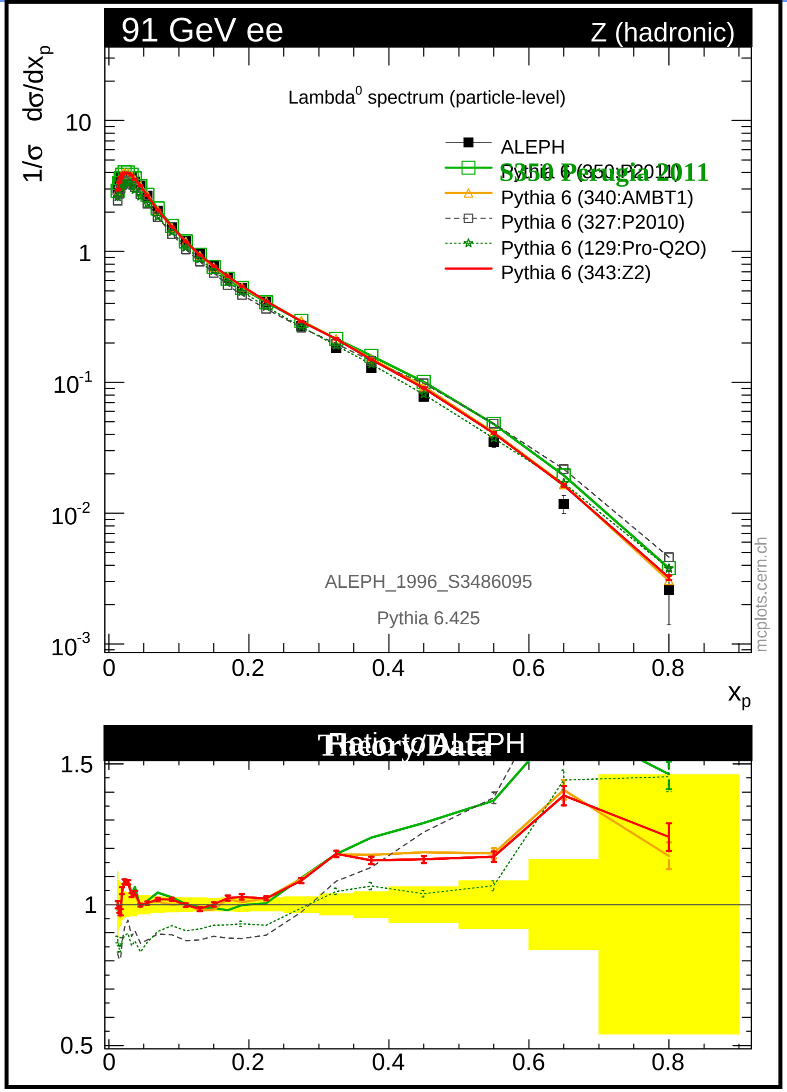
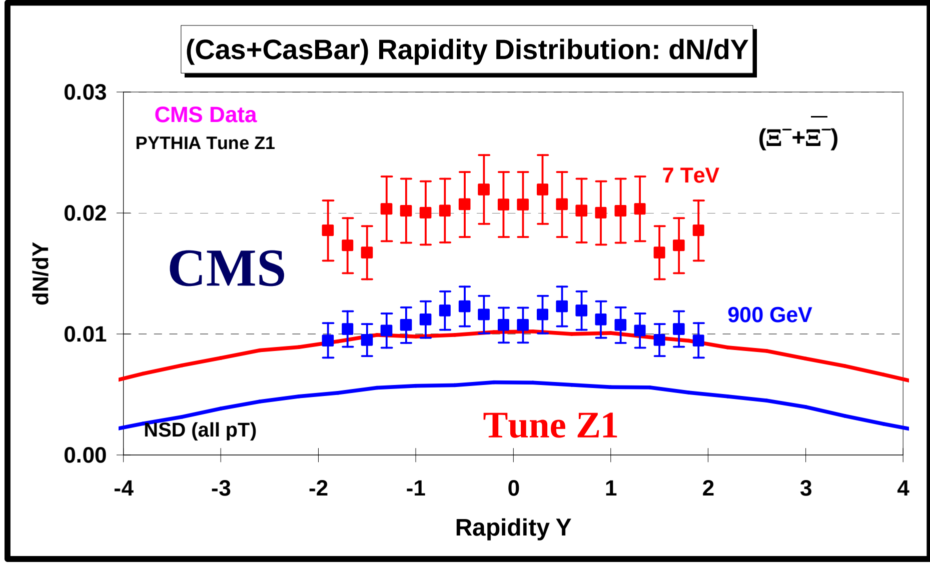
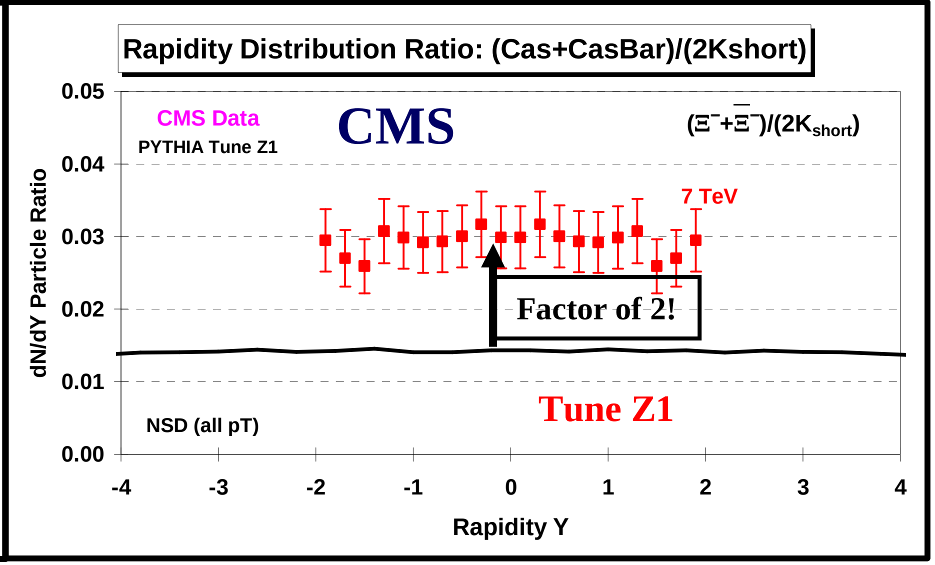
June 2011 - A. Karneyeu, D. Konstantinov, M. Mangano, L. Mijovic, W. Pokorski, S. Prestel, A. Pytel, P. Skands (BOINC users, see Test4Theory@Home page)



Cascade Production





- **CMS NSD data** on the Cascade$^-$ +AntiCascade$^-$ rapidity distribution at 7 TeV and 900 GeV compared with **PYTHIA Tune Z1**. The plot shows the average number of particles per NSD collision per unit Y, $(1/N_{NSD})\, dN/dY$.

- **CMS data** on the Cascade$^-$+AntiCascade$^-$ to 2Kshort rapidity ratio at 7 TeV compared with **PYTHIA Tune Z1**.

$$\frac{(\Xi + \bar{\Xi})}{2K_{short}} = \frac{\text{Double-strange Baryon}}{\text{Strange Meson}}$$

Ξ^- = d s s

"Minimum Bias" Collisions

Yikes! Way too few Cascade's in PYTHIA Tune Z1!

LEP: Ξ Spectrum

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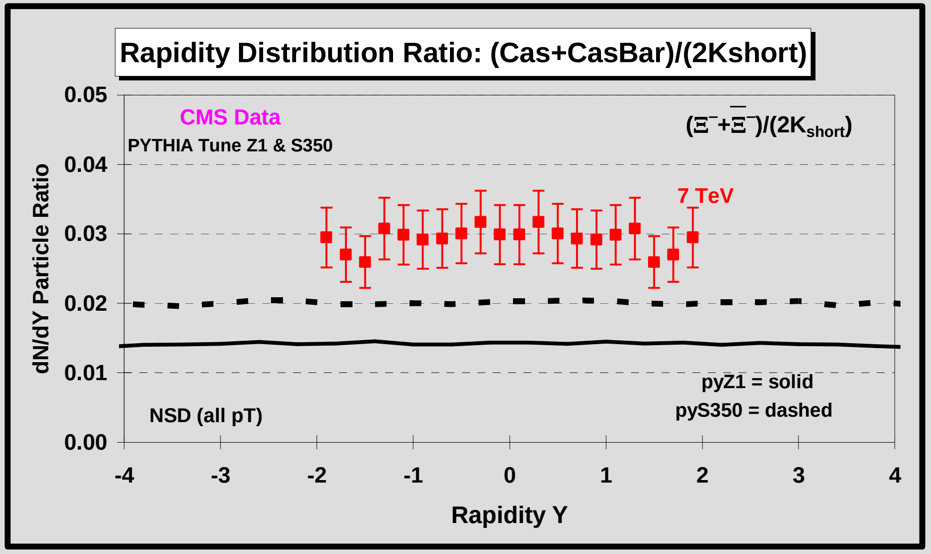
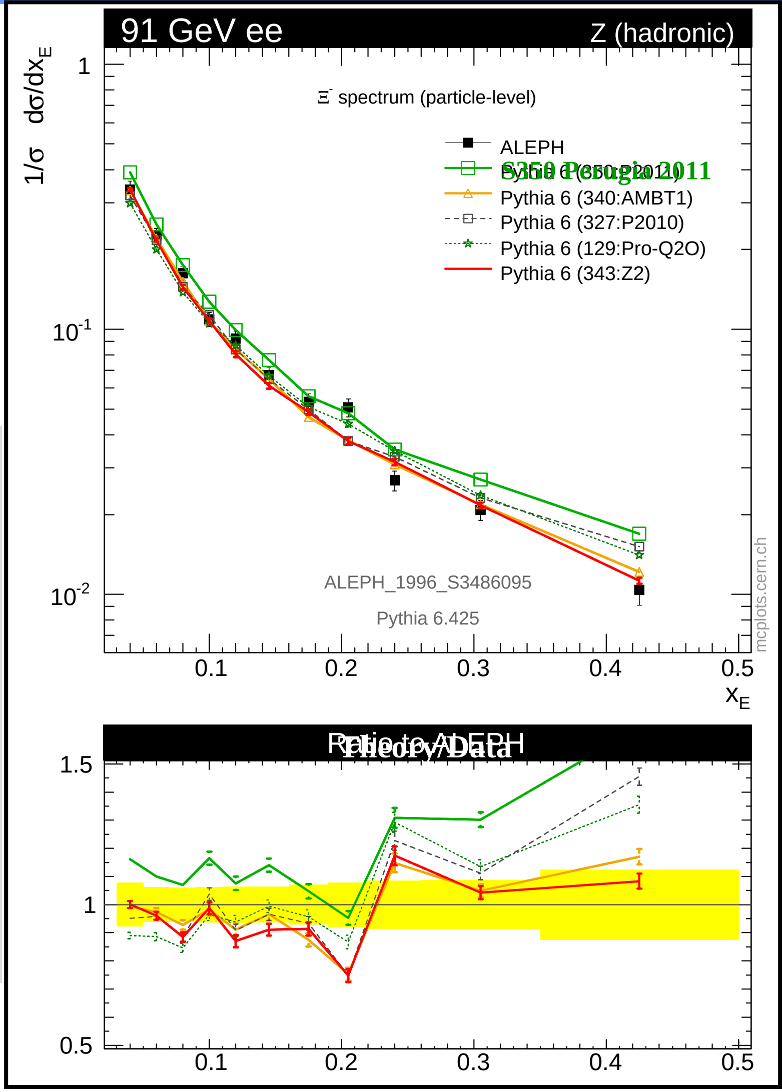
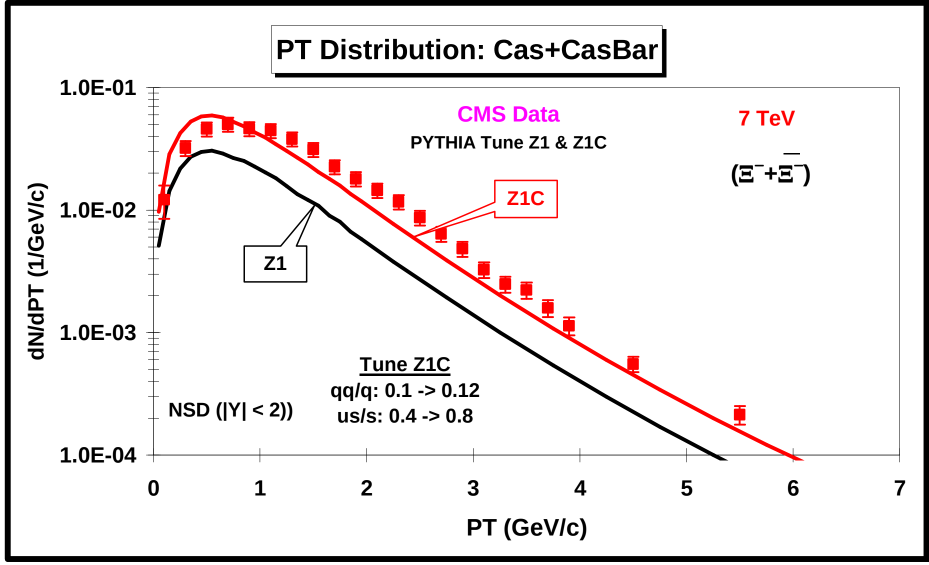
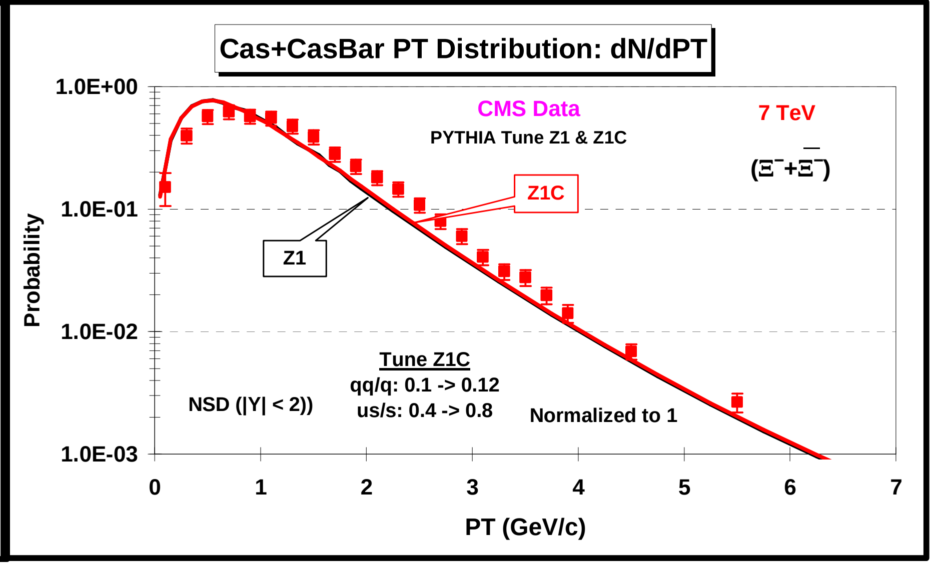




Transverse Momentum Distributions



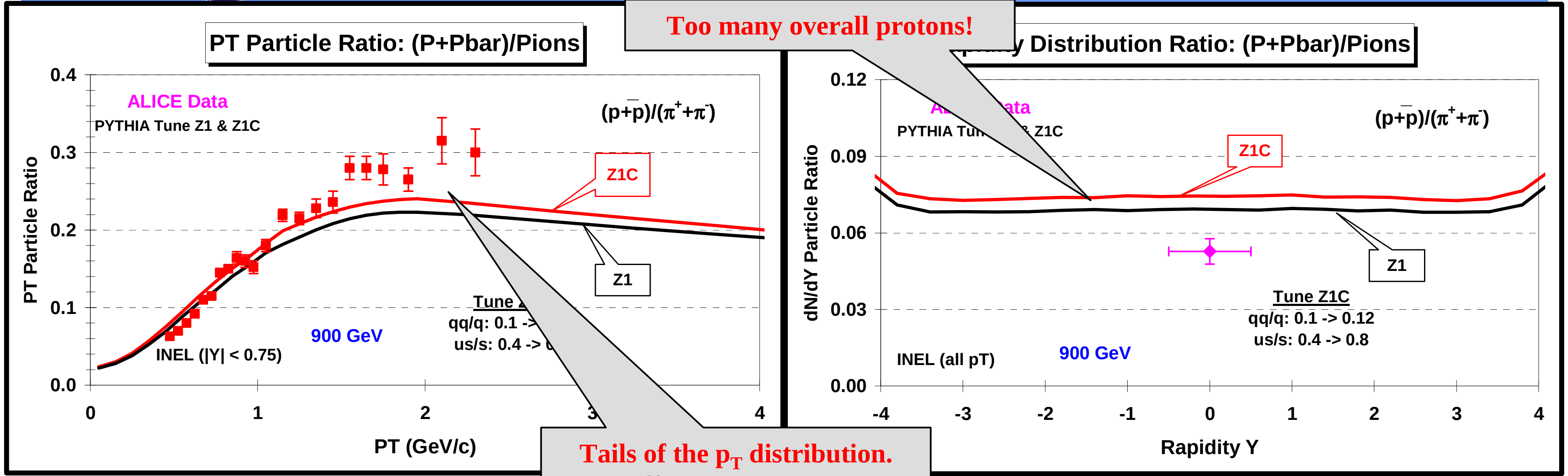


- **CMS NSD data** on the Cascade$^-$+AntiCascade$^-$ transverse momentum distribution at 7 TeV compared with **PYTHIA Tune Z1 & Z1C**. The plot shows the average number of particles per NSD collision per unit p_T, $(1/N_{NSD})\, dN/dp_T$ for $|Y| < 2$.
- **CMS NSD data** on the Cascade$^-$+AntiCascade$^-$ transverse momentum distribution at 7 TeV (**normalized to 1**) compared with **PYTHIA Tune Z1 & Z1C**.

"Minimum Bias" Collisions

PYTHIA Tune Z1 & Z1C are a bit off on the p_T dependence!

Particle Ratios versus PT



Too many overall protons!

Tails of the p_T distribution. Way off due to the wrong p_T!

- **ALICE INEL data** on the Proton+AntiProton to charged pions ratio versus p_T at 900 GeV (|Y| < 0.75) compared with **PYTHIA Tune Z1 & Z1C**.

$$\frac{(p+\bar{p})}{(\pi^+ + \pi^-)} = \frac{\text{Non-strange Baryon}}{\text{Non-strange Meson}}$$

- **ALICE INEL data** on the Proton+AntiProton to charged pion rapidity ratio at 900 GeV compared with **PYTHIA Tune Z1 & Z1C**.

"Minimum Bias" Collisions

p

uud

PYTHIA way off on the p_T dependence of Protons!

LEP: Proton Spectrum

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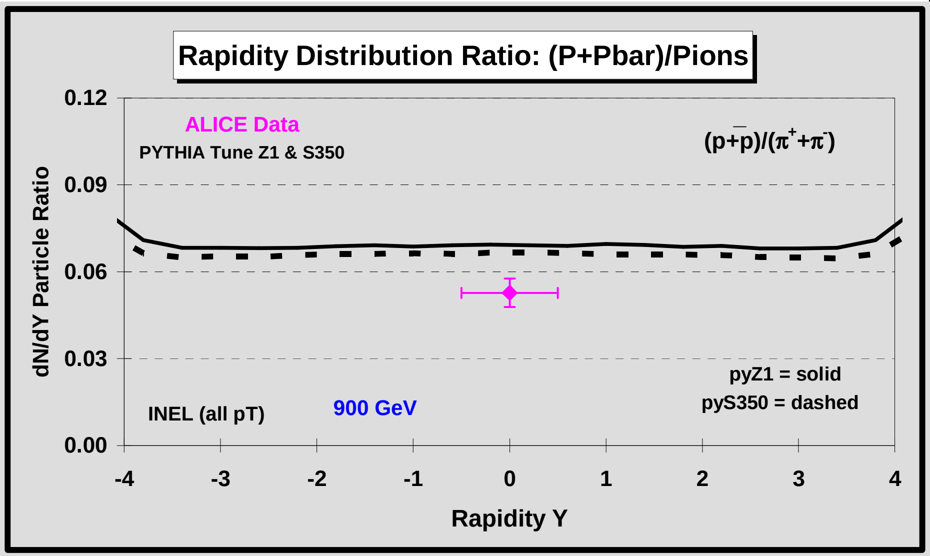
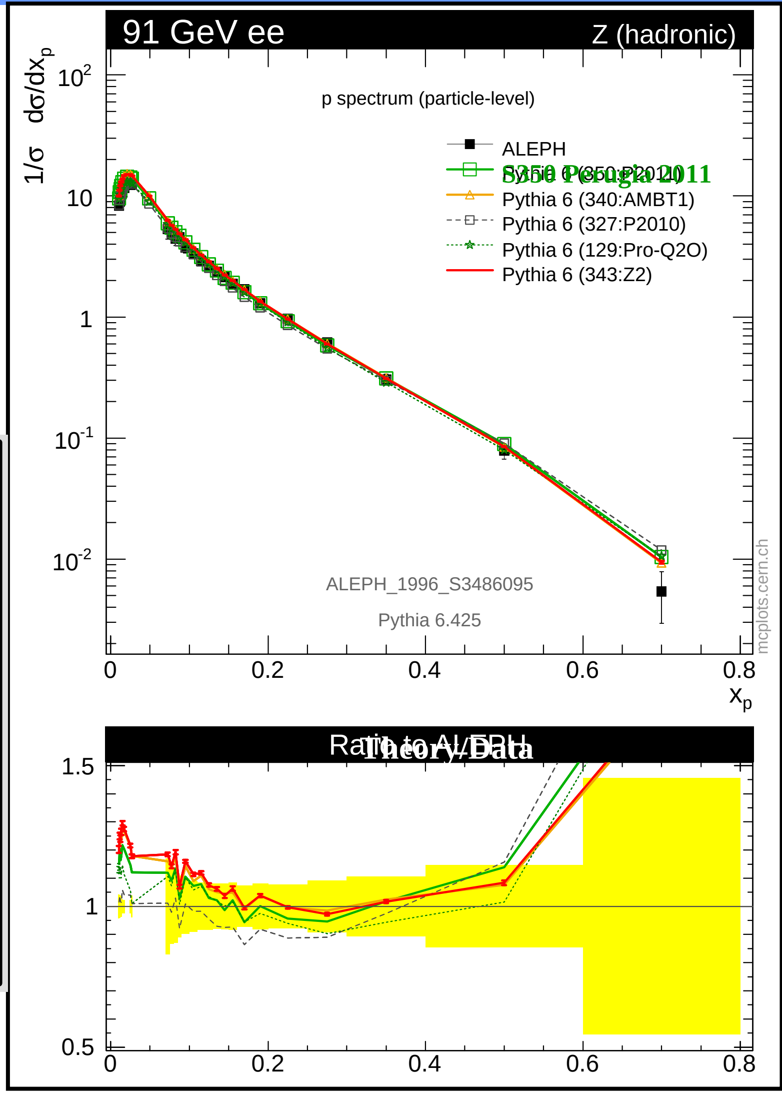
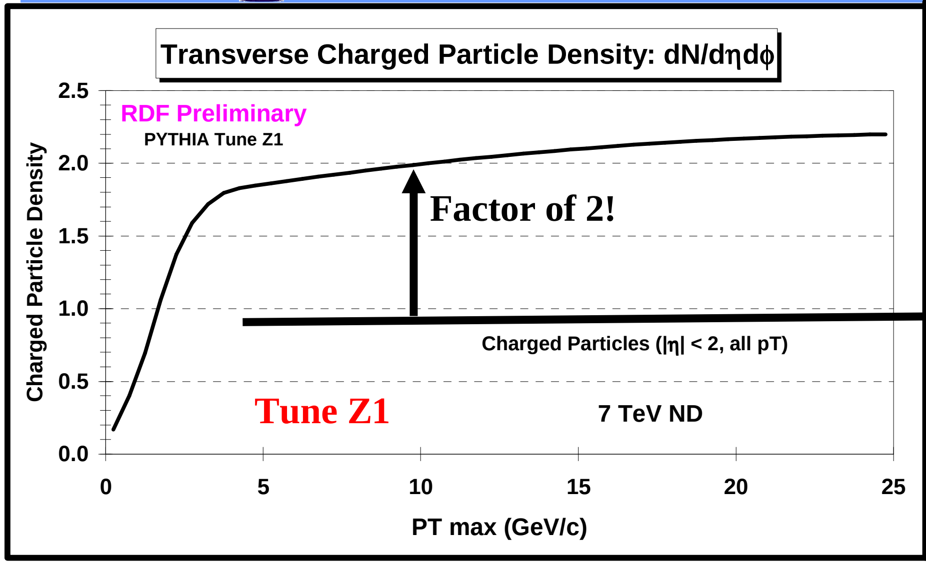
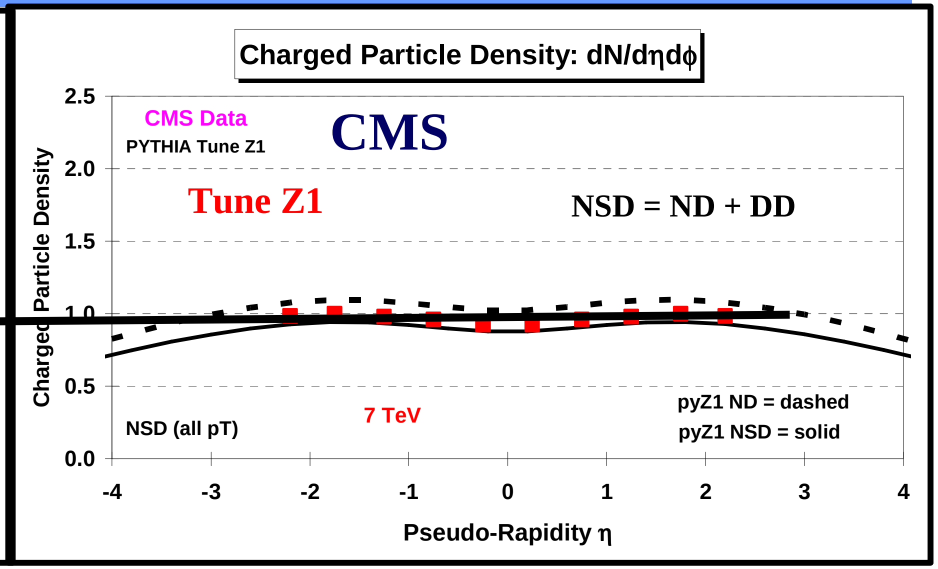


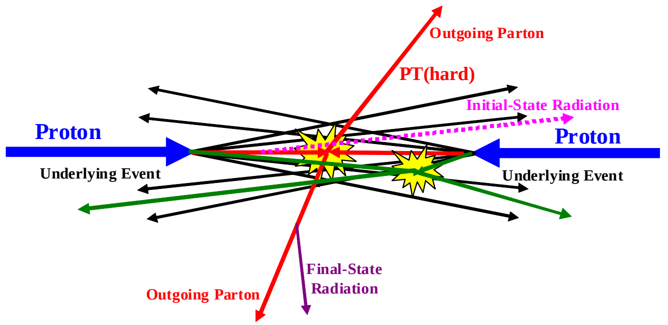


MB versus UE

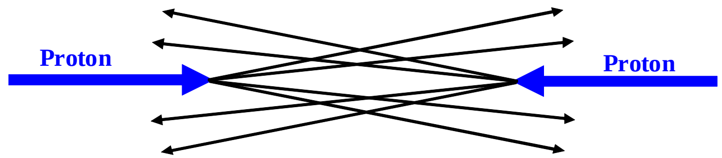




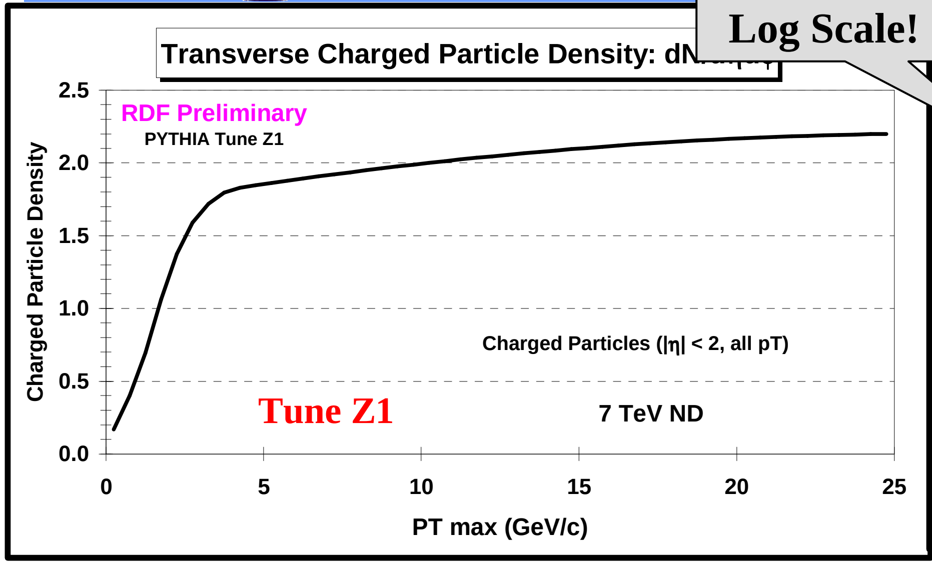
- Shows the density of charged particles in the "transverse" region as a function of PTmax for charged particles (All p_T, $|\eta| < 2$) at 7 TeV from PYTHIA Tune Z1.
- CMS NSD data on the charged particle rapidity distribution at 7 TeV compared with PYTHIA Tune Z1. The plot shows the average number of charged particles per NSD collision per unit $\eta-\phi$, $(1/N_{NSD})\, dN/d\eta d\phi$.



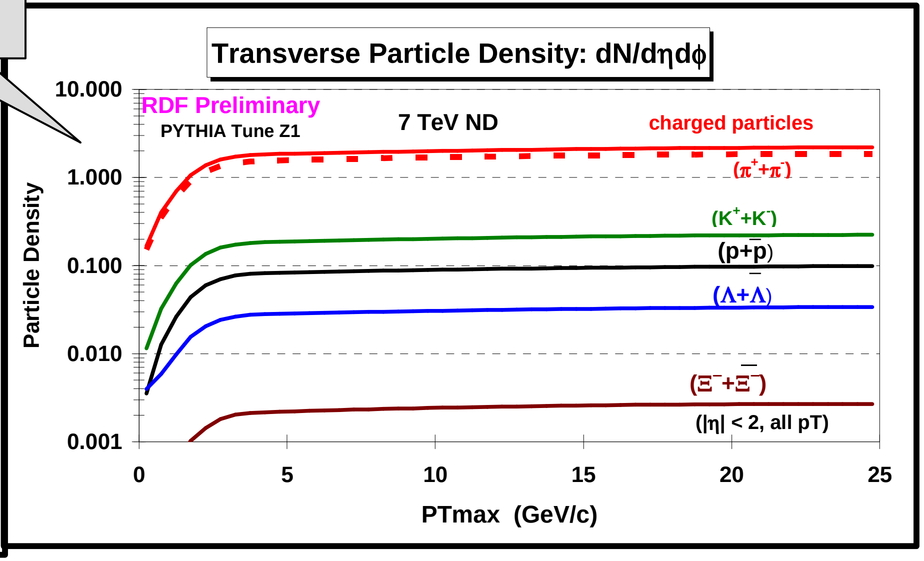
"Minimum Bias" Collisions



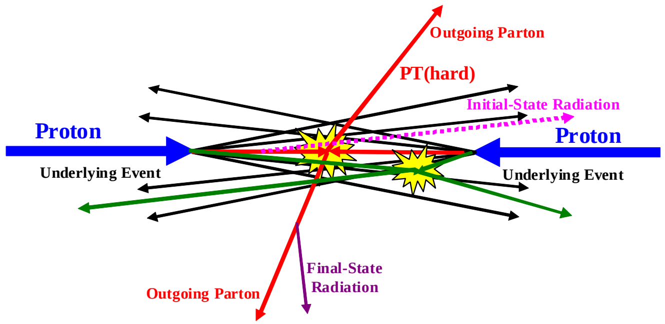
UE Particle Type



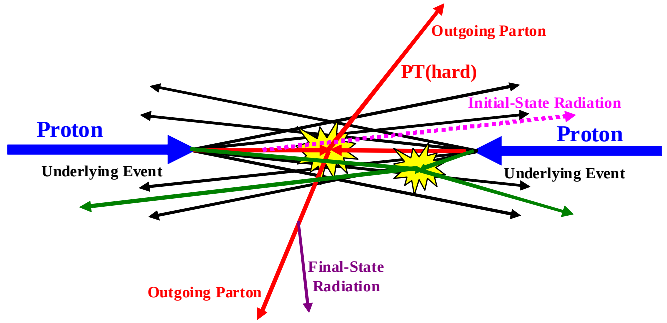
Log Scale!



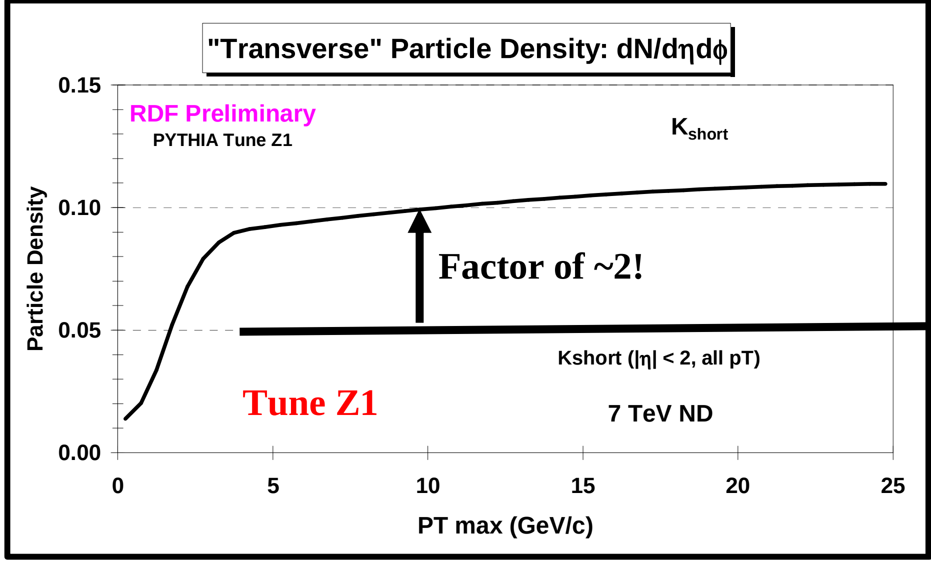
- Shows the density of charged particles in the "transverse" region as a function of PTmax for charged particles (All p_T, $|\eta| < 2$) at 7 TeV from PYTHIA Tune Z1.

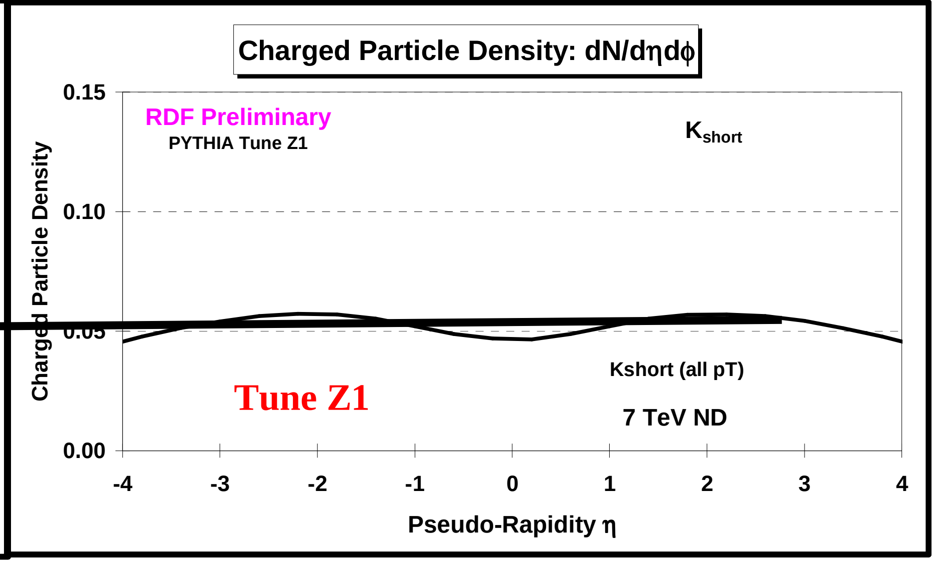


- Shows the density of particles in the "transverse" region as a function of PTmax for charged particles (All p_T, $|\eta| < 2$) at 7 TeV from PYTHIA Tune Z1.

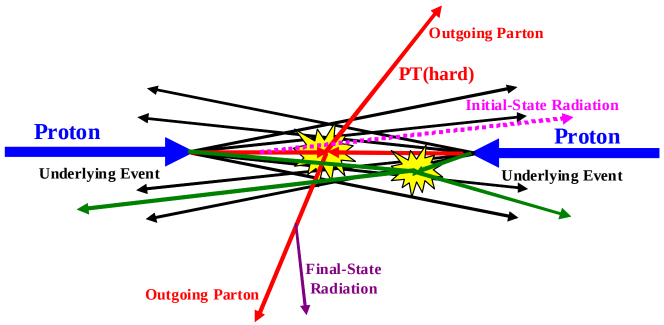


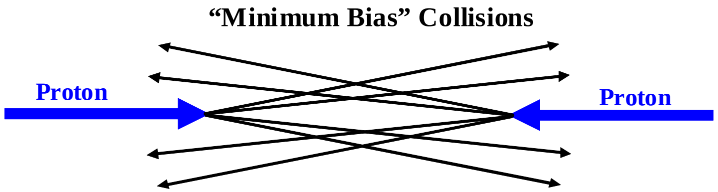
MB versus UE



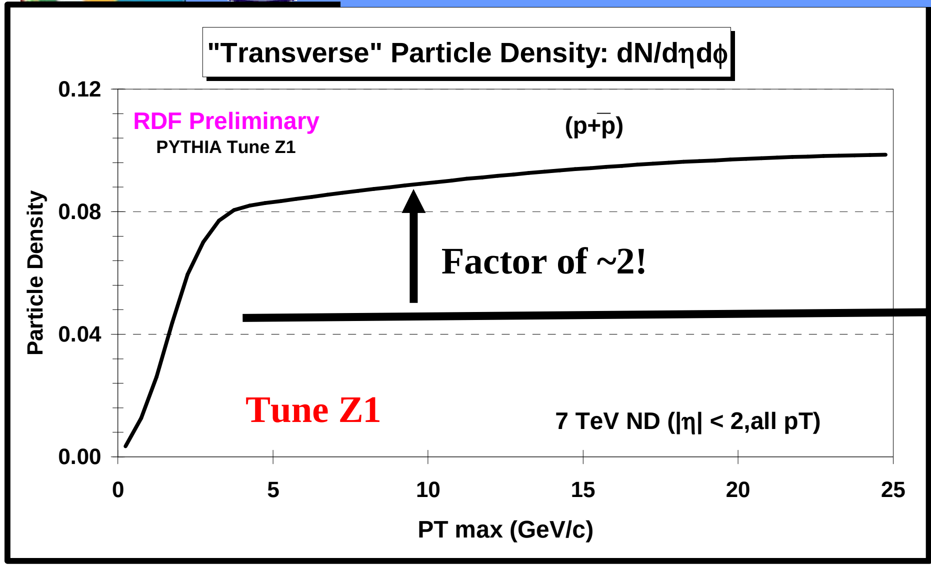


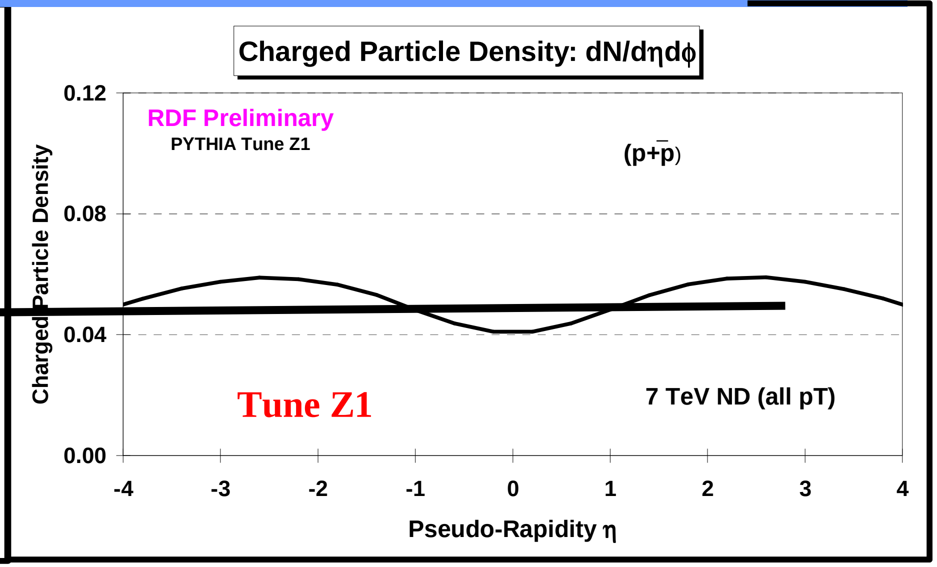
- **Shows the density of K_{short} particles in the "transverse" region as a function of PTmax for charged particles (All p_T, $|\eta| < 2$) at 7 TeV from PYTHIA Tune Z1.**
- **Shows the K_{short} pseudo-rapidity distribution (all p_T) at 7 TeV from PYTHIA Tune Z1. The plot shows the average number of particles per ND collision per unit η–φ, $(1/N_{ND})\ dN/d\eta d\phi$.**



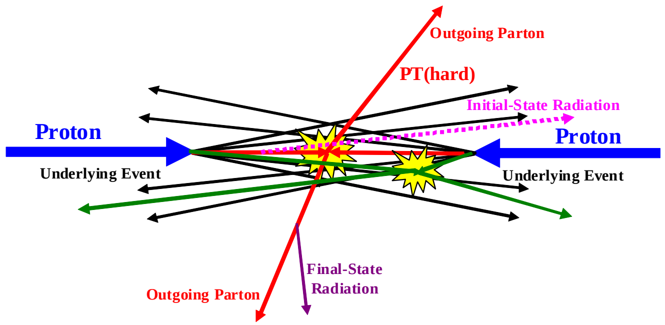


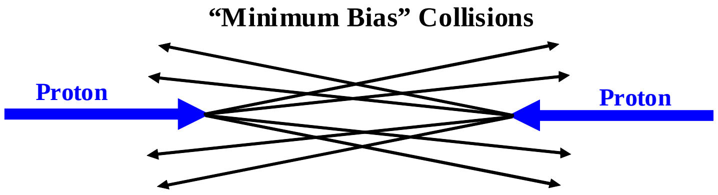
MB versus UE



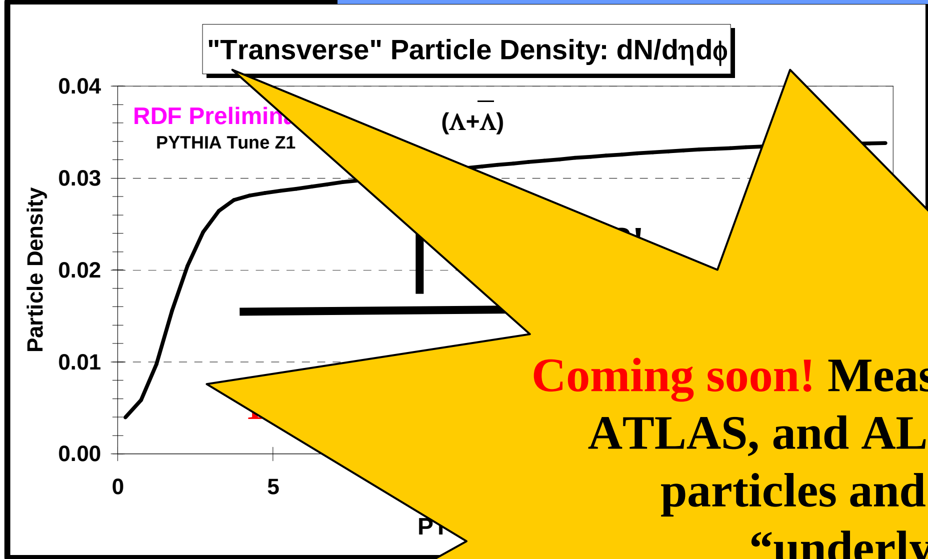


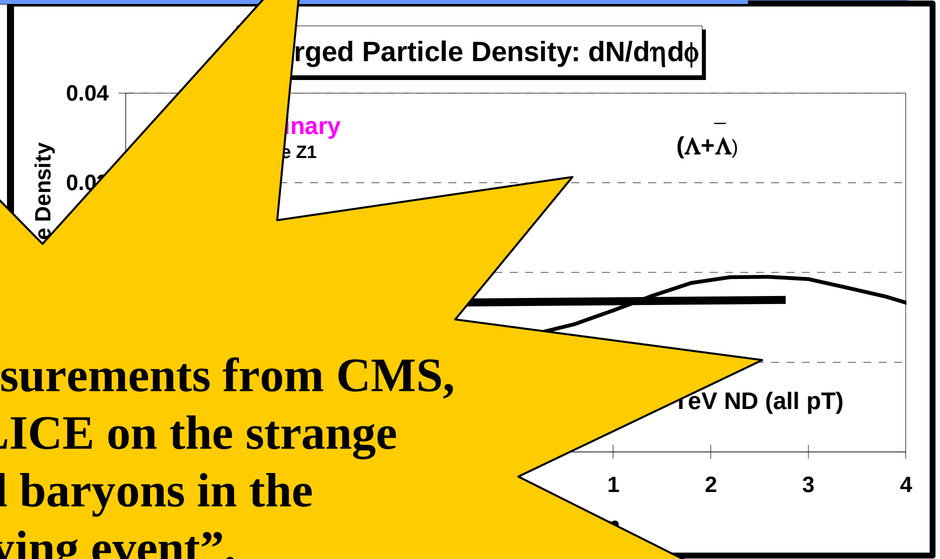
- Shows the density of P+antiP particles in the "transverse" region as a function of PTmax for charged particles (All p_T, $|\eta| < 2$) at 7 TeV from PYTHIA Tune Z1.
- Shows the P+antiP pseudo-rapidity distribution (all p_T) at 7 TeV from PYTHIA Tune Z1. The plot shows the average number of particles per ND collision per unit $\eta-\phi$, $(1/N_{ND})\, dN/d\eta d\phi$.





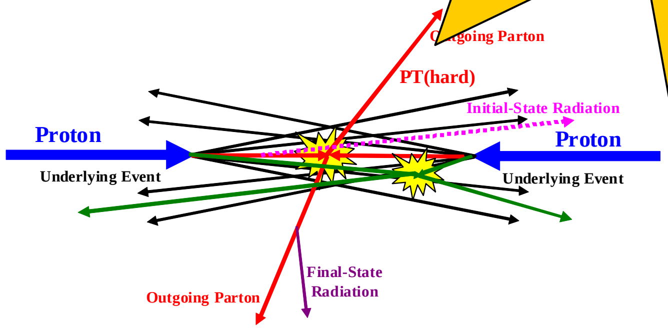
MB versus UE

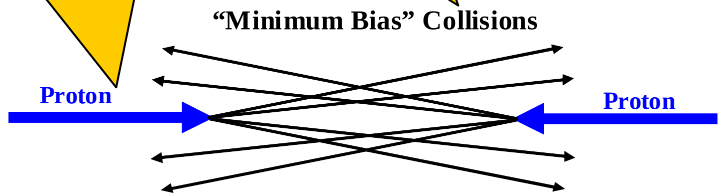




Coming soon! Measurements from CMS, ATLAS, and ALICE on the strange particles and baryons in the "underlying event".

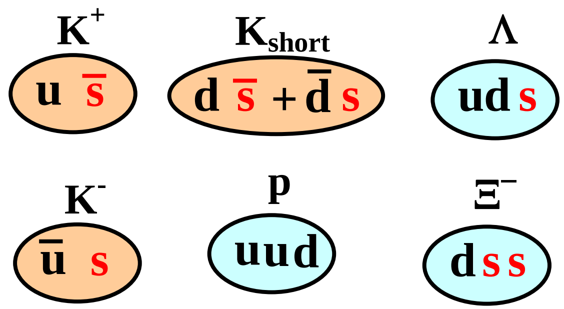
- Shows the densit… …istribution the "transve… …PYTHIA Tune Z1. The PTmax for charged particles… …the… …umber of particles per 2) at 7 TeV from PYTHIA T… . …n per u… , $(1/N_{ND})\ dN/d\eta d\phi$.





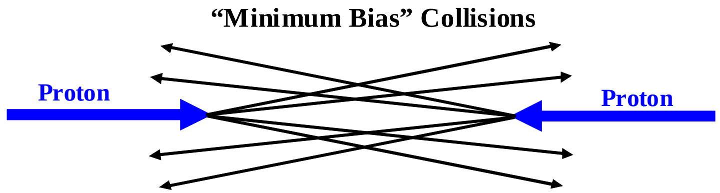
Fragmentation Summary

- **Strange Particle & Baryon Yields: PYTHIA is off on the overall yield of Lambda's and Cascades (MC below the data) and too high on the proton yield. Difficult to fix this without destroying agreement with LEP!**



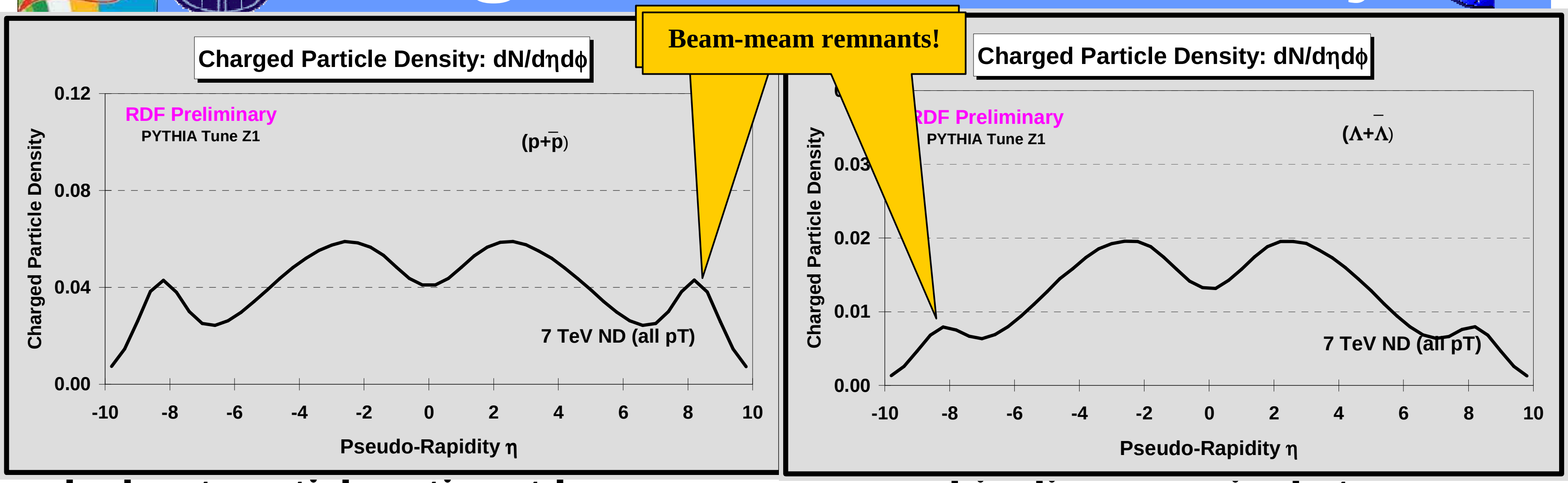
- **PT Distributions: PYTHIA does not describe correctly the p_T distributions of heavy particles (MC softer than the data). None of the fragmentation parameters I have looked at changes the p_T distributions. Hence, if one looks at particle ratios at large p_T you can see big discrepancies between data and MC (out in the tails of the distributions)!**

- **Factorization: Are we seeing a breakdown in factorization between e^+e^- annihilations and hadron-hadron collisions! Is something happening in hadron-hadron collisions that does not happen in e^+e^- annihilations?**



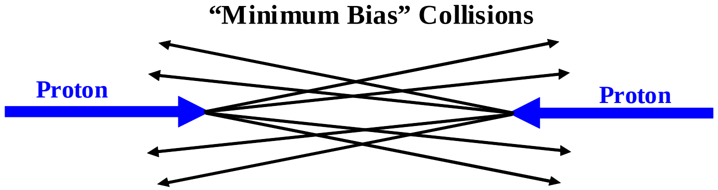
- **Herwig++ & Sherpa: Before making any conclusions about fragmentation one must check the predictions of Herwig++ and Sherpa carefully!**

Fragmentation Summary



looks at particle ratios at large p_T you can see big discrepancies between data and MC (out in the tails of the distributions)!

- **Factorization:** Are we seeing a breakdown in factorization between e^+e^- annihilations and hadron-hadron collisions! Is something happening in hadron-hadron collisions that does not happen in e^+e^- annihilations?



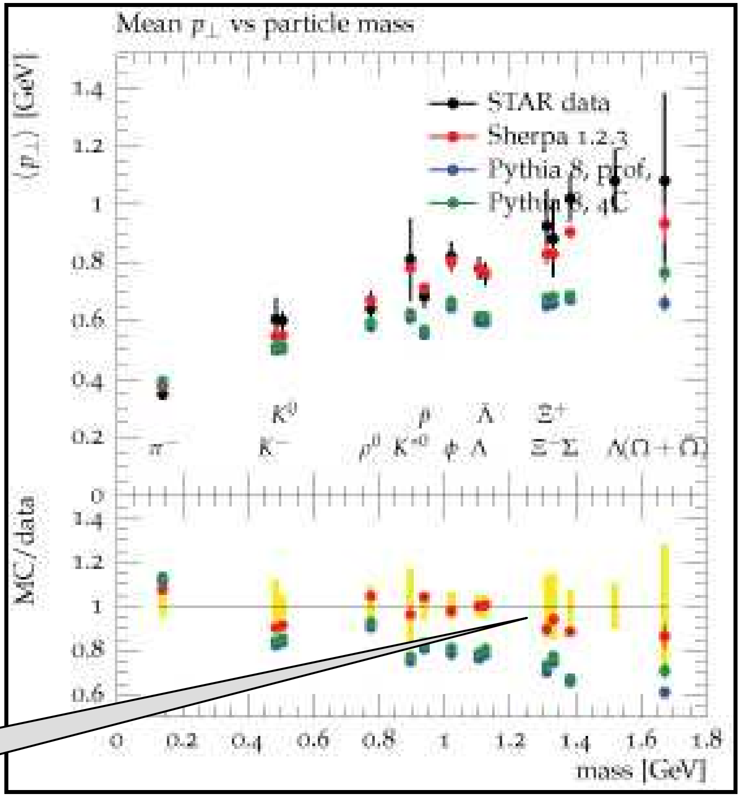
- **Herwig++ & Sherpa:** Before making any conclusions about fragmentation one must check the predictions of Herwig++ and Sherpa carefully!

Sherpa versus PYTHIA

$<p_T>$ versus Mass

- Before making any conclusion about e^+e^- versus pp collisions one must check the predictions of Herwig++ and Sherpa!

Strange particle production in pp at 200 GeV (STAR_2006_S6860818)



Sherpa does better than PYTHIA 8!

Hendrik Hoeth
http://users.hepforge.org/~hoeth/STAR_2006_S6860818/