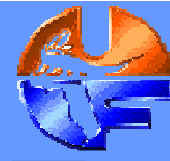




Boost 2011



May 22-26, 2011

PRINCETON CENTER FOR THEORETICAL SCIENCE

The Underlying Event & Fragmentation Tuning

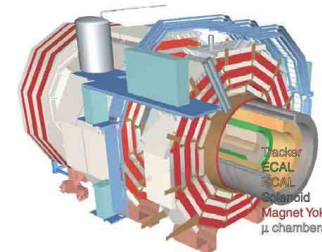
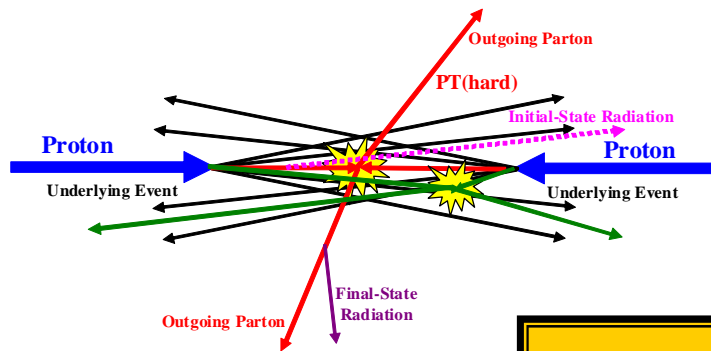


Rick Field
University of Florida

Quantum
Chromo-
Dynamics

Outline

- ➔ **LHC PYTHIA Tunes:** PYTHIA 6.4 tunes (AMBT1, Z1, Z2) and PYTHIA 8 Tune C4.
- ➔ **CMS-ATLAS-ALICE (corrected) UE data** at (900 GeV and 7 TeV) and comparisons with the LHC tunes.



CMS



ATLAS

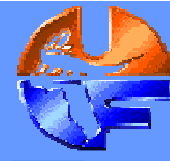


UE&MB@CMS





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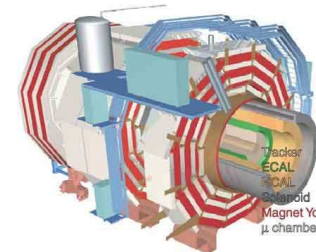


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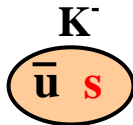
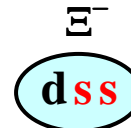
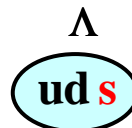
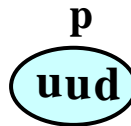
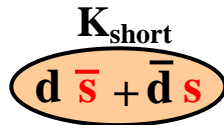
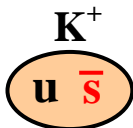
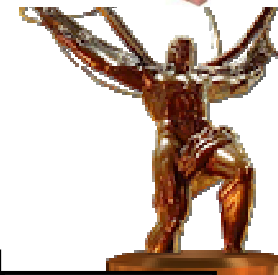
- ➔ **LHC PYTHIA Tunes:** PYTHIA 6.4 tunes (AMBT1, Z1, Z2) and PYTHIA 8 Tune C4.
- ➔ **CMS-ATLAS-ALICE (corrected) UE data** at (900 GeV and 7 TeV) and comparisons with the LHC tunes.
- ➔ **Baryon and Strange Particle Production at the LHC:** Fragmentation tuning.



CMS



ATLAS

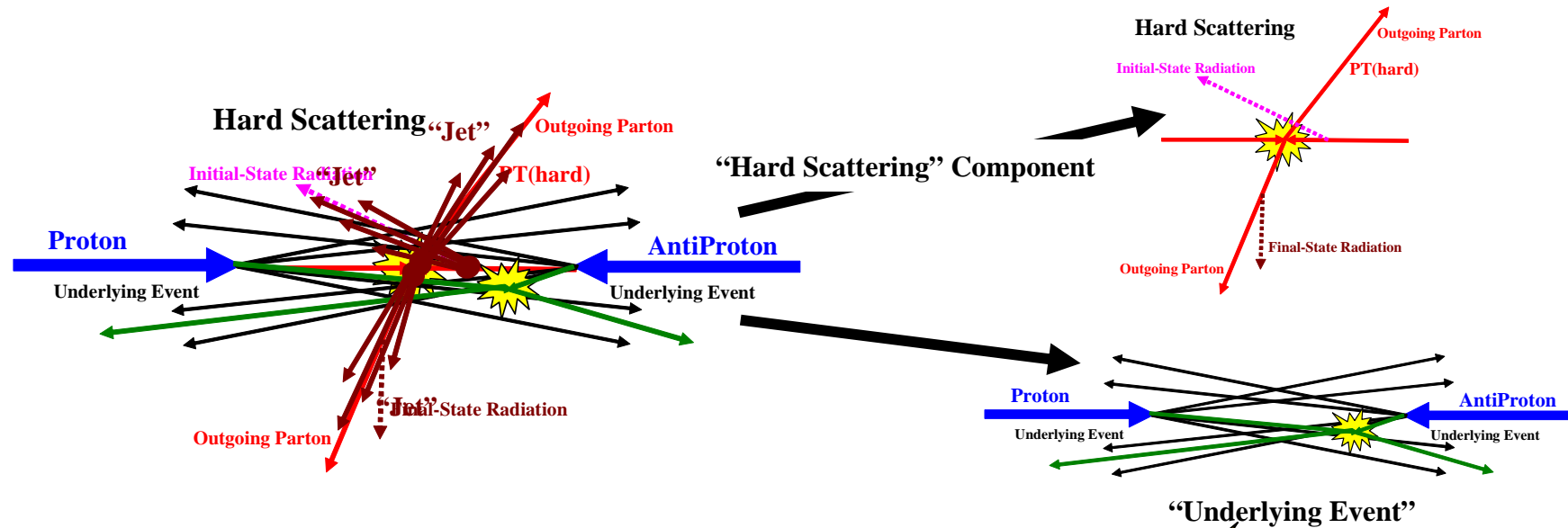
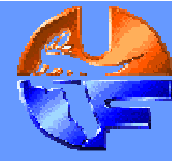


UE&MB@CMS





QCD Monte-Carlo Models: High Transverse Momentum Jets

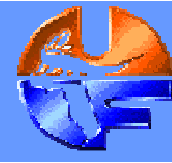


- ➔ Start with the perturbative 2-to-2 (or sometimes 2-to-3) parton-parton scattering and add initial and final-state gluon radiation (in the leading log approximation or modified leading log approximation).
- ➔ The “underlying event” consists of the “beam-beam remnants” and particles arising from soft or semi-soft multiple parton interactions (MPI).
- ➔ Of course the outgoing colored parton observables receive contributions from the underlying event.

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



Traditional Approach

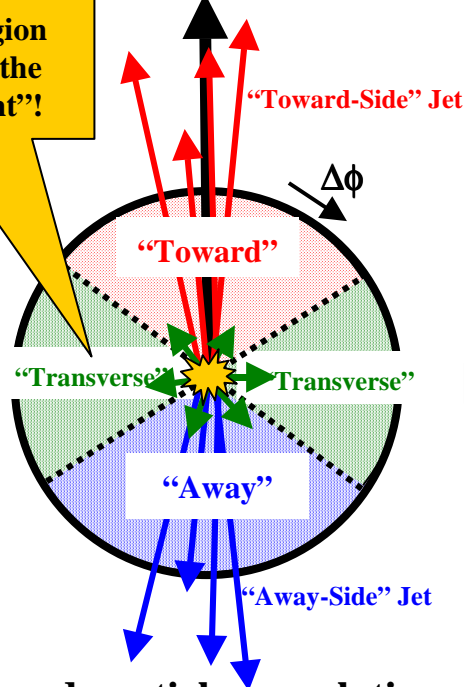


CDF Run 1 Analysis Charged Particle $\Delta\phi$ Correlations

Charged Jet #1

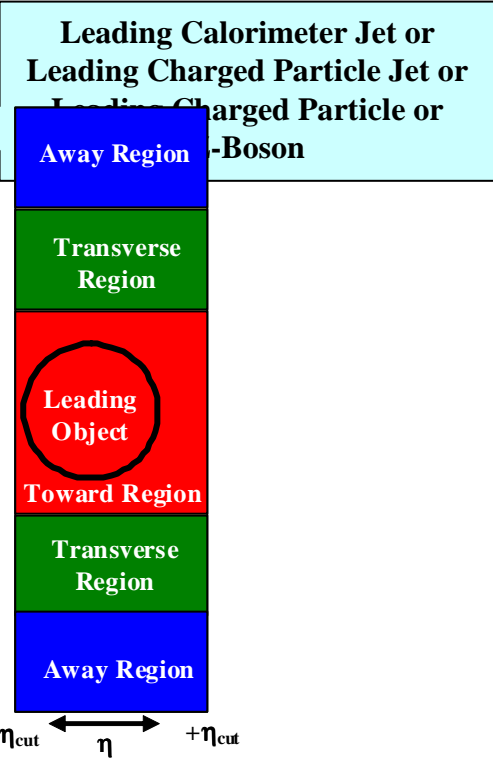
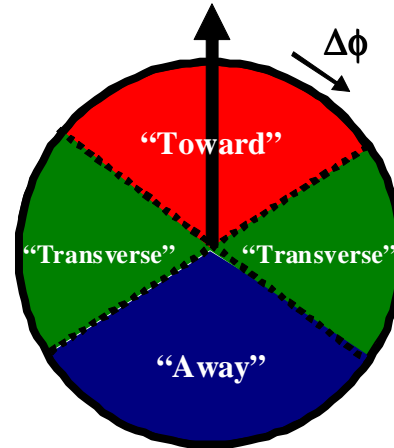
Direction

“Transverse” region very sensitive to the “underlying event”!

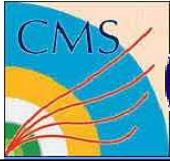


$$P_T > P_{T\min} \quad |\eta| < \eta_{\text{cut}}$$

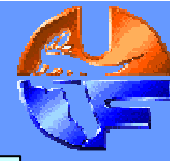
Leading Object
Direction



- ➔ Look at charged particle correlations in the azimuthal angle $\Delta\phi$ relative to a leading object (*i.e.* CaloJet#1, ChgJet#1, $P_{T\max}$, Z-boson). For CDF $P_{T\min} = 0.5 \text{ GeV}/c$ $\eta_{\text{cut}} = 1$.
- ➔ Define $|\Delta\phi| < 60^\circ$ as “Toward”, $60^\circ < |\Delta\phi| < 120^\circ$ as “Transverse”, and $|\Delta\phi| > 120^\circ$ as “Away”.
- ➔ All three regions have the same area in η - ϕ space, $\Delta\eta \times \Delta\phi = 2\eta_{\text{cut}} \times 120^\circ = 2\eta_{\text{cut}} \times 2\pi/3$. Construct densities by dividing by the area in η - ϕ space.



ATLAS Tune AMBT1



Charged particle multiplicities in p p interactions at $\sqrt{s} = 0.9$ and 7 TeV in a diffractive limited phase-space and a new Pythia tune.

Judith Katzy (DESY)
On behalf of the ATLAS Collaboration

Judith Katzy LPCC
MB&UE working group
meeting, *May 31, 2010.*



Minimum bias and Underlying Event studies with Monte Carlo tune for pp events with the ATLAS detector



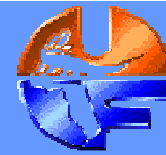
Emily Nurse
(for the ATLAS collaboration)
ICHEP, Paris
24th July 2010

Emily Nurse ICHEP,
July 24, 2010.

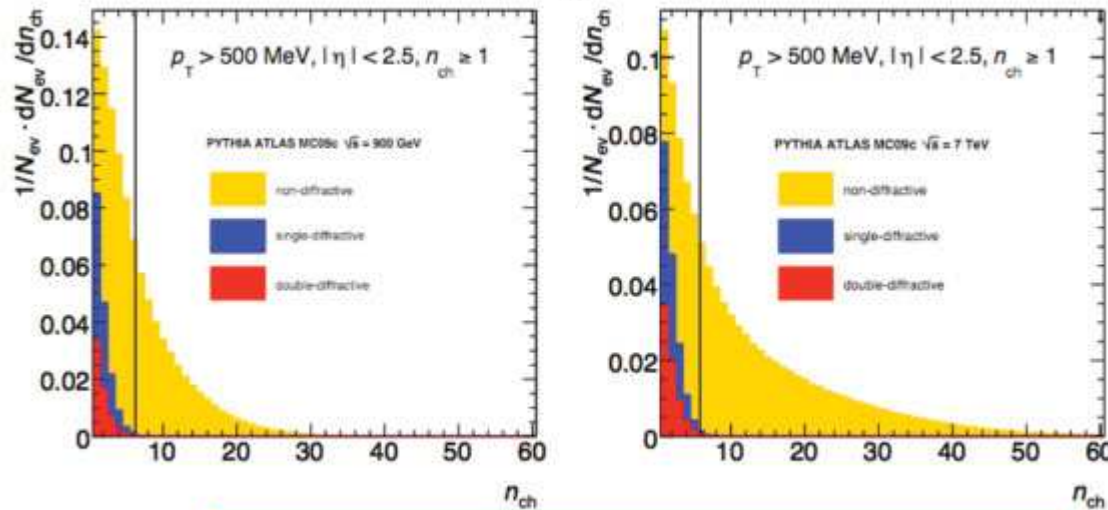
ATLAS-CONF-2010-031



ATLAS Tune AMBT1



Example: pythia6 predictions



Build diffractive suppressed sample with $n_{ch} \geq 6$

Resulting number of events:	
$n_{ch} \geq 1$	$n_{ch} \geq 6$
7TeV: 369673	231665
900 GeV: 326201	157896

Subset of the “min-bias” data!

Parameters used for tuning

Parameter	related model	MC09c value	scanning range	AMBT1 value
PARP(62)	ISR cut-off	1.0	fixed	1.025
PARP(93)	primordial kt	5.0	fixed	10.0
PARP(77)	CR suppression	0.0	0.25 --- 1.15	1.016
PARP(78)	CR strength	0.224	0.2 --- 0.6	0.538
PARP(83)	MPI (matter fraction in core)	0.8	fixed	0.356
PARP(84)	MPI (core of matter overlap)	0.7	0.0 --- 1.0	0.651
PARP(82)	MPI (p_T^{min})	2.31	2.1 --- 2.5	2.292
PARP(90)	MPI (energy extrapolation)	0.2487	0.18 --- 0.28	0.250

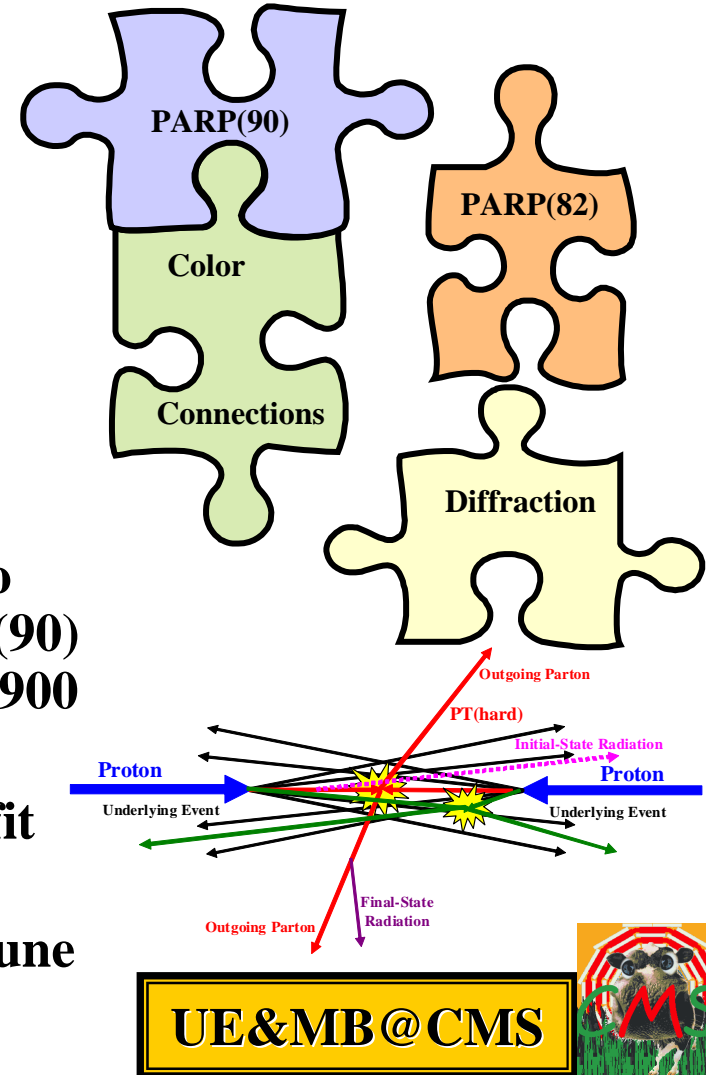
➔ Attempt to fit a subset of the “min-bias” data ($N_{chg} \geq 6$) where the contamination due to diffraction is expected to be small!



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 $N_{chg} \geq 6$ and to fit the PT_{max} UE data with $PT_{max} > 10$ GeV/c. Tune AMBT1 is primarily a min-bias tune, while Tune Z1 is a UE tune!



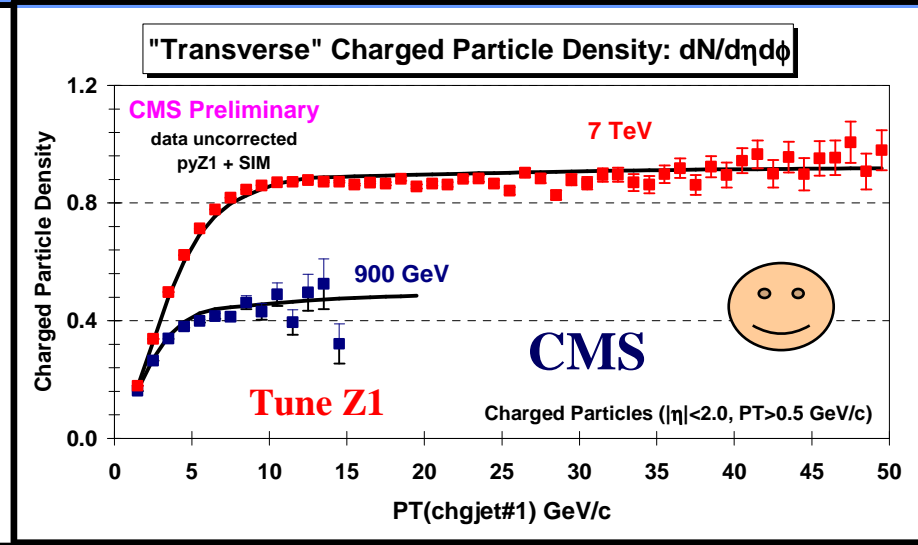
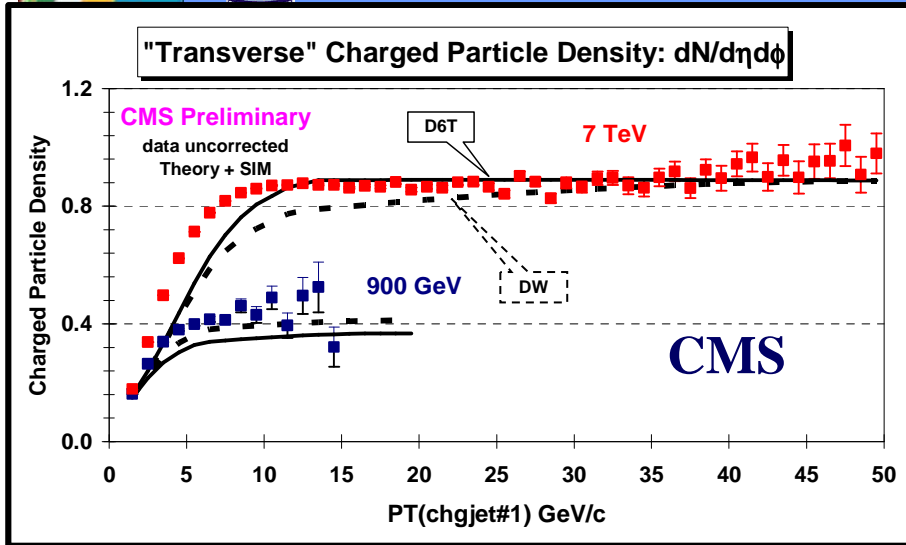


PYTHIA Tune Z1



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 gaussian matter distribution	4	4
MSTP(91) – Gaussian primordial kT	1	1
MSTP(95) – strategy for color reconnection	6	6



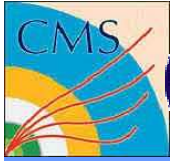
➔ CMS preliminary data at 900 GeV and 7 TeV on the “transverse” charged particle density, $dN/d\eta d\phi$, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$. The data are uncorrected and compared with **PYTHIA Tune DW** and **D6T** after detector simulation (SIM).

➔ CMS preliminary data at 900 GeV and 7 TeV on the “transverse” charged particle density, $dN/d\eta d\phi$, 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 uncorrected and compared with **PYTHIA Tune Z1** after detector simulation (SIM).

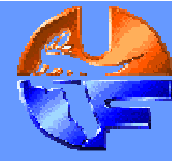
Color reconnection suppression.
Color reconnection strength.

Tune Z1 (CTEQ5L)
 PARP(82) = 1.932
 PARP(90) = 0.275
 PARP(77) = 1.016
 PARP(78) = 0.538

Tune Z1 is a PYTHIA 6.4 using p_T -ordered parton showers and the new MPI model!



PYTHIA 6.2 Tunes



Parameter	Tune AW	Tune DW	Tune D6
PDF	CTEQ5L	CTEQ5L	CTEQ6L
MSTP(81)	1	1	1
MSTP(82)	4	4	4
PARP(82)	2.0 GeV	1.9 GeV	1.8 GeV
PARP(83)	0.5	0.5	0.5
PARP(84)	0.4	0.4	0.4
PARP(85)	0.9	1.0	1.0
PARP(86)	0.95	1.0	1.0
PARP(89)	1.8 TeV	1.8 TeV	1.8 TeV
PARP(90)	0.25	0.25	0.25
PARP(62)	1.25	1.25	1.25
PARP(64)	0.2	0.2	0.2
PARP(67)	4.0	2.5	2.5
MSTP(91)	1	1	1
PARP(91)	2.1	2.1	2.1
PARP(93)	15.0	15.0	15.0

UE Parameters

ISR Parameter

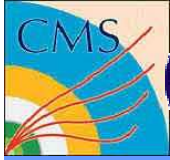
Intrinsic KT

Uses CTEQ6L

Reduce PARP(82) by factor of $1.8/1.9 = 0.95$
Everything else the same!

Tune A energy dependence!
(not the default)

CMS: We wanted a CTEQ6L version of Tune Z1 in a hurry!



PYTHIA Tune Z2



My guess!

Parameter	Tune Z1 (R. Field CMS)	Tune Z2 (R. Field CMS)
Parton Distribution Function	CTEQ5L	CTEQ6L
PARP(82) – MPI Cut-off	1.932	1.832
PARP(89) – Reference energy, E0	1800.0	1800.0
PARP(90) – MPI Energy Extrapolation	0.275	0.275
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 gaussian matter distribution	4	4
MSTP(91) – Gaussian primordial kT	1	1
MSTP(95) – strategy for color reconnection	6	6

Reduce PARP(82) by factor of $1.83/1.93 = 0.95$
Everything else the same!



PYTHIA Tune Z2



My guess!

Parameter	Tune Z1 (R. Field CMS)	Tune Z2 (R. Field CMS)
Parton Distribution Function	CTEQ5L	CTEQ6L
PARP(82) – MPI Cut-off	1.932	1.832
PARP(89) – Reference energy, E0	1800.0	1800.0
PARP(90) – MPI Energy Extrapolation	0.275	0.275
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 gaussian matter distribution	4	4
MSTP(91) – Gaussian primordial kT	1	1
MSTP(95) – strategy for color reconnection	6	6

Reduce PARP(82) by factor of $1.83/1.93 = 0.95$
Everything else the same!

PARP(90) same
For Z1 and Z2!



PYTHIA 8 Tunes



R. Corke and T. Sjöstrand

CTEQ6L

MRST LO**

CTEQ6L

Parameter	Tune 2C	Tune 2M	Tune 4C
SigmaProcess:alphaSvalue	0.135	0.1265	0.135
SpaceShower:rapidityOrder	on	on	on
SpaceShower:alphaSvalue	0.137	0.130	0.137
SpaceShower:pT0Ref	2.0	2.0	2.0
MultipleInteractions:alphaSvalue	0.135	0.127	0.135
MultipleInteractions:pT0Ref	2.320	2.455	2.085
MultipleInteractions:ecmPow	0.21	0.26	0.19
MultipleInteractions:bProfile	3	3	3
MultipleInteractions:expPow	1.60	1.15	2.00
BeamRemnants:reconnectRange	3.0	3.0	1.5
SigmaDiffractive:dampen	off	off	on
SigmaDiffractive:maxXB	N/A	N/A	65
SigmaDiffractive:maxAX	N/A	N/A	65
SigmaDiffractive:maxXX	N/A	N/A	65

PT0 = PARP(82)

$\epsilon = \text{PARP}(90)$

Tevatron

LHC

$$p_{T0}(W) = p_{T0}(W/W_0)^\epsilon \quad \epsilon = \text{PARP}(90) \quad p_{T0} = \text{PARP}(82) \quad W = E_{\text{cm}}$$



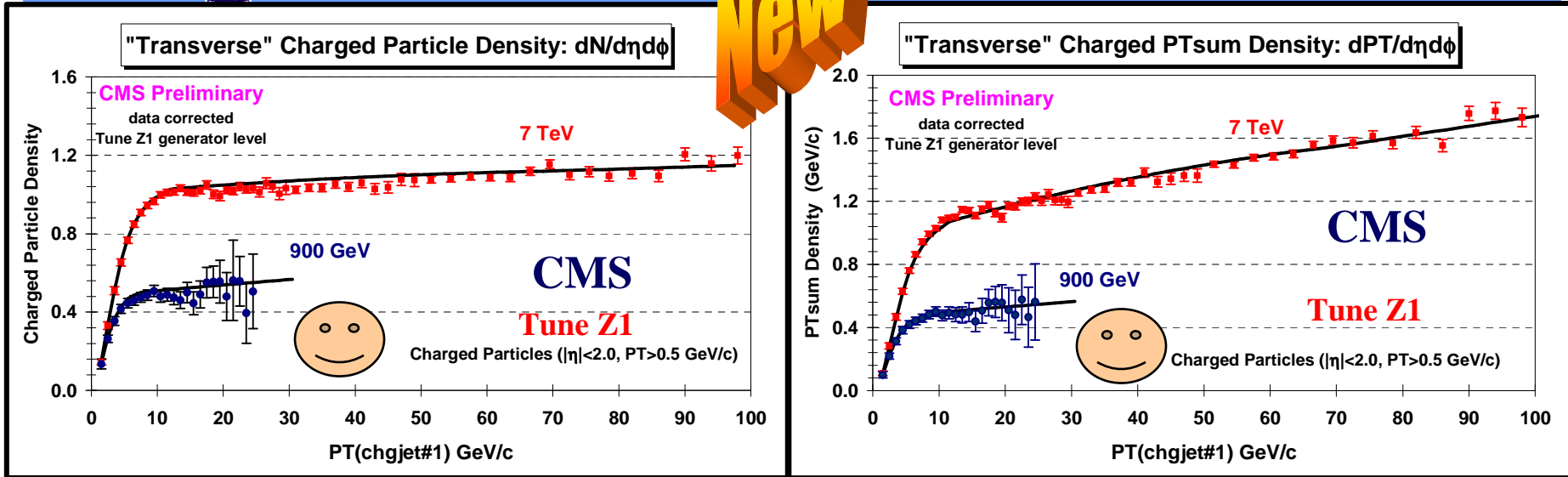
PYTHIA Tune Z2



Parameter	Tune Z2 (R. Field CMS)	PY8 Tune C4 (Corke-Sjöstrand)
Parton Distribution Function	CTEQ6L	CTEQ6L
PARP(82) – MPI Cut-off	1.832	2.085
PARP(89) – Reference energy, E0	1800.0	1800.0
PARP(90) – MPI Energy Extrapolation	0.275	0.19
PARP(77) – CR Suppression	1.016	
PARP(78) – CR Strength	0.538	
PARP(80) – Probability colored parton from BBR	0.1	
PARP(83) – Matter fraction in core	0.356	
PARP(84) – Core of matter overlap	0.651	
PARP(62) – ISR Cut-off	1.025	
PARP(93) – primordial kT-max	10.0	
MSTP(81) – MPI, ISR, FSR, BBR model	21	
MSTP(82) – Double gaussian matter distribution	4	
MSTP(91) – Gaussian primordial kT	1	
MSTP(95) – strategy for color reconnection	6	

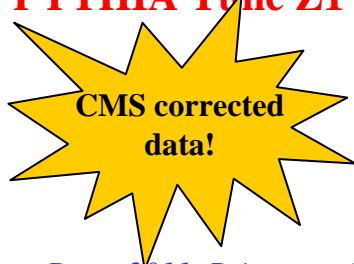
PARP(90) much different!

New

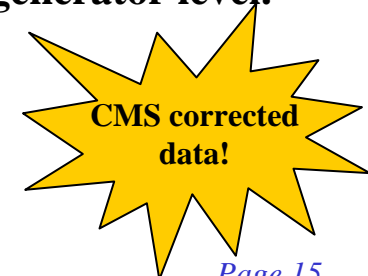


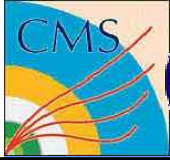
→ CMS preliminary data at 900 GeV and 7 TeV on the “transverse” charged particle density, $dN/d\eta d\phi$, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$. The data are corrected and compared with **PYTHIA Tune Z1** at the generator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

→ CMS preliminary data at 900 GeV and 7 TeV on the “transverse” charged PTsum density, $dPT/d\eta d\phi$, 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.

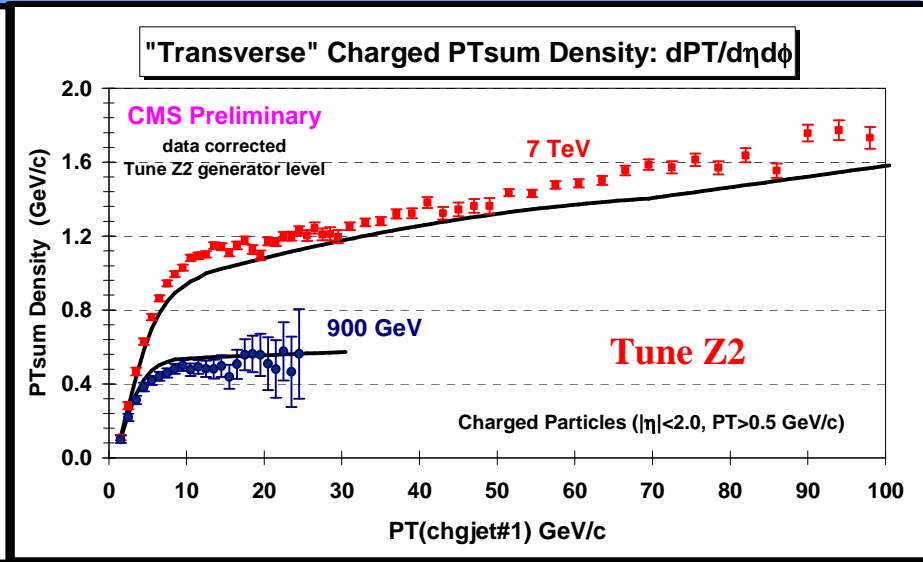
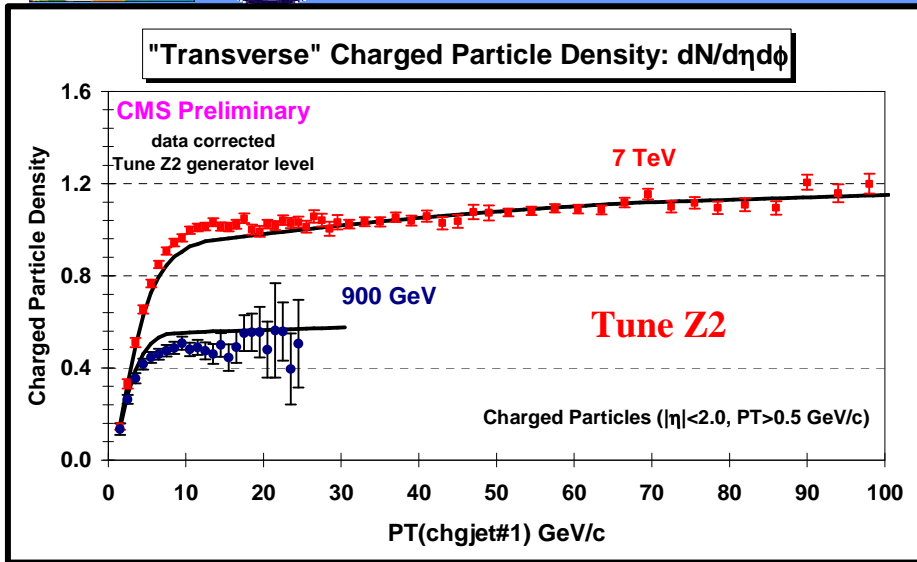
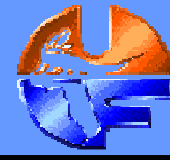


Very nice agreement!



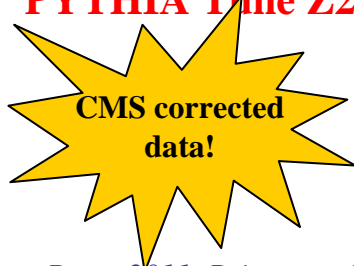


PYTHIA 6.4 Tune Z2



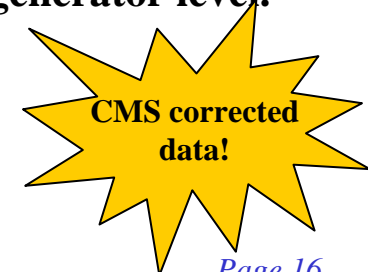
➔ CMS preliminary data at 900 GeV and 7 TeV on the “transverse” charged particle density, $dN/d\eta d\phi$, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$. The data are corrected and compared with **PYTHIA Tune Z2** at the generator level.

➔ CMS preliminary data at 900 GeV and 7 TeV on the “transverse” charged PTsum density, $dPT/d\eta d\phi$, 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 Z2** at the generator level.



CMS corrected data!

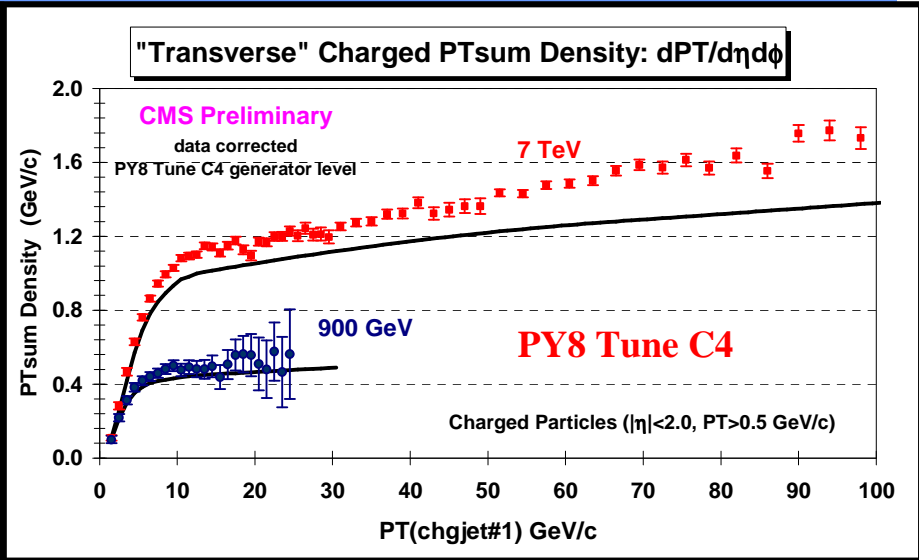
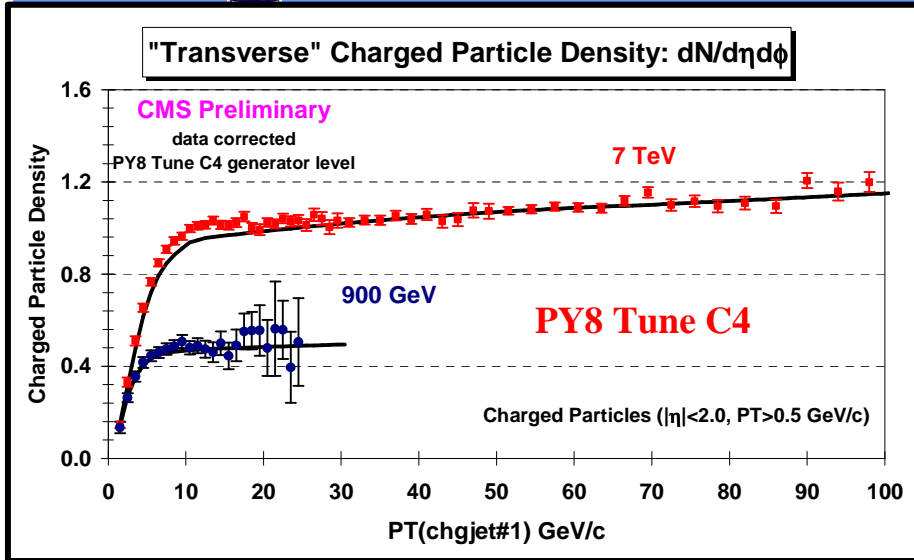
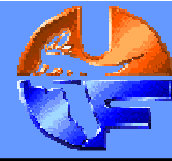
Not good! Bad energy dependence!



CMS corrected data!

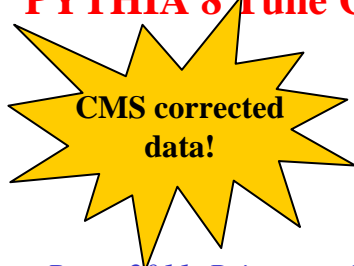


PYTHIA 8 Tune C4

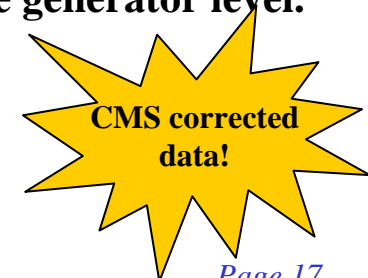


→ CMS preliminary data at 900 GeV and 7 TeV on the “transverse” charged particle density, $dN/d\eta d\phi$, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$. The data are corrected and compared with **PYTHIA 8 Tune C4** at the generator level.

→ CMS preliminary data at 900 GeV and 7 TeV on the “transverse” charged PTsum density, $dPT/d\eta d\phi$, 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 8 Tune C4** at the generator level.

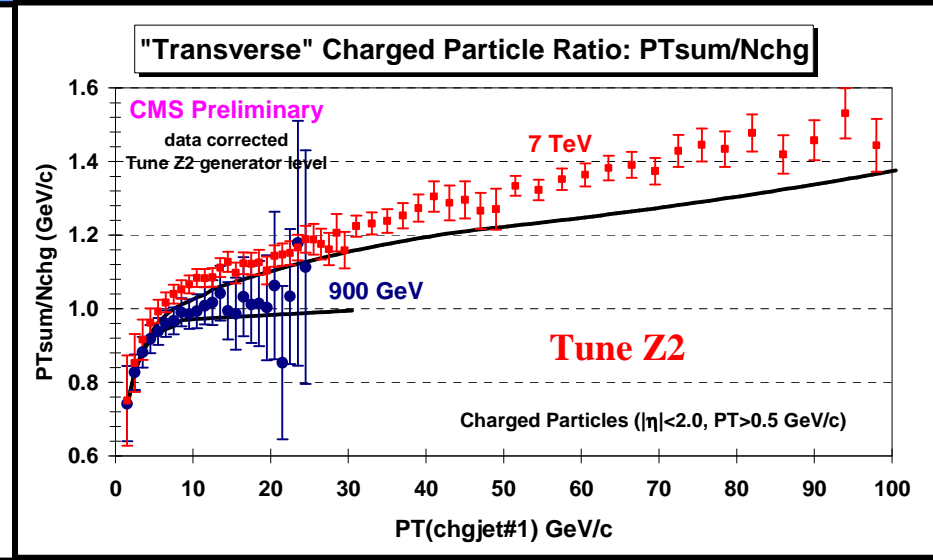
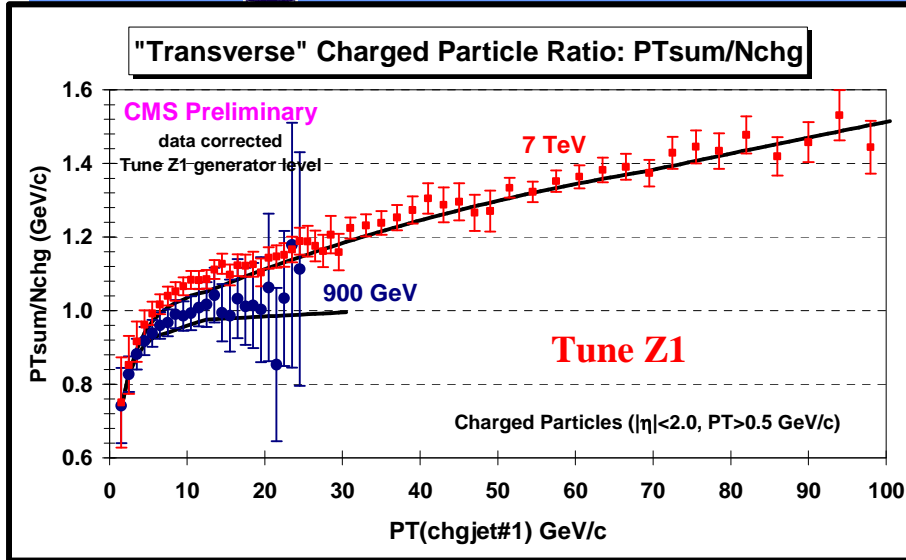


Not good! PTsum too small!



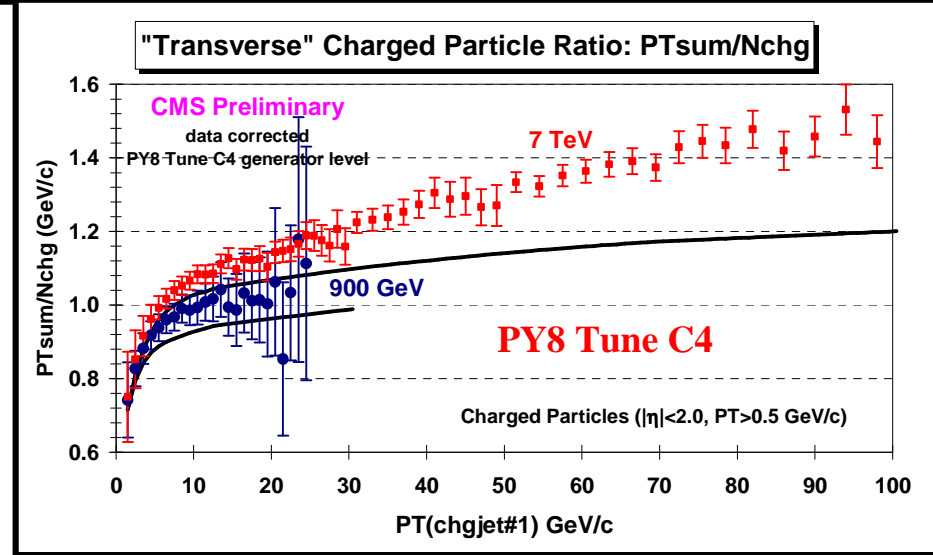


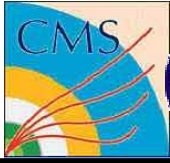
Transverse Ratio: PT_{sum}/N_{chg}



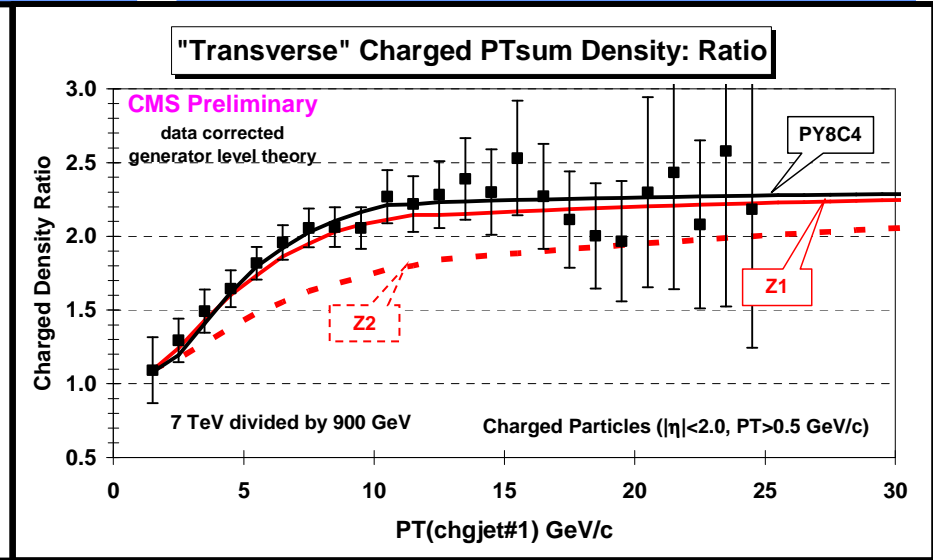
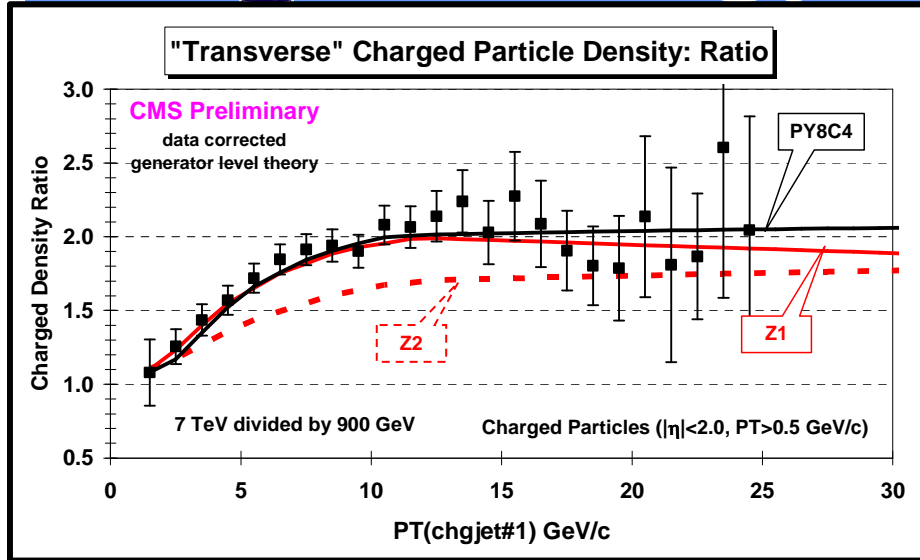
➔ CMS preliminary data at 900 GeV and 7 TeV on the “transverse” ratio PT_{sum}/N_{chg} as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$ compared with **PYTHIA Tune Z1, Z2, and PY8C4** at the generator level.

Z1 good! PY8C4 and Z2 Bad!



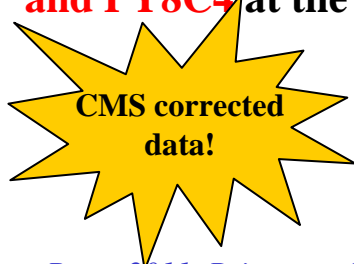


Energy Dependence

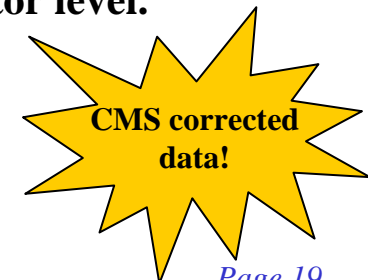


➔ CMS data on the energy dependence (7 TeV divided by 900 GeV) of the “transverse” charged particle density as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$ compared with **PYTHIA Tune Z1, Z2, and PY8C4** at the generator level.

➔ CMS data on the energy dependence (7 TeV divided by 900 GeV) of the “transverse” charged PTsum density as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$ compared with **PYTHIA Tune Z1, Z2, and PY8C4** at the generator level.

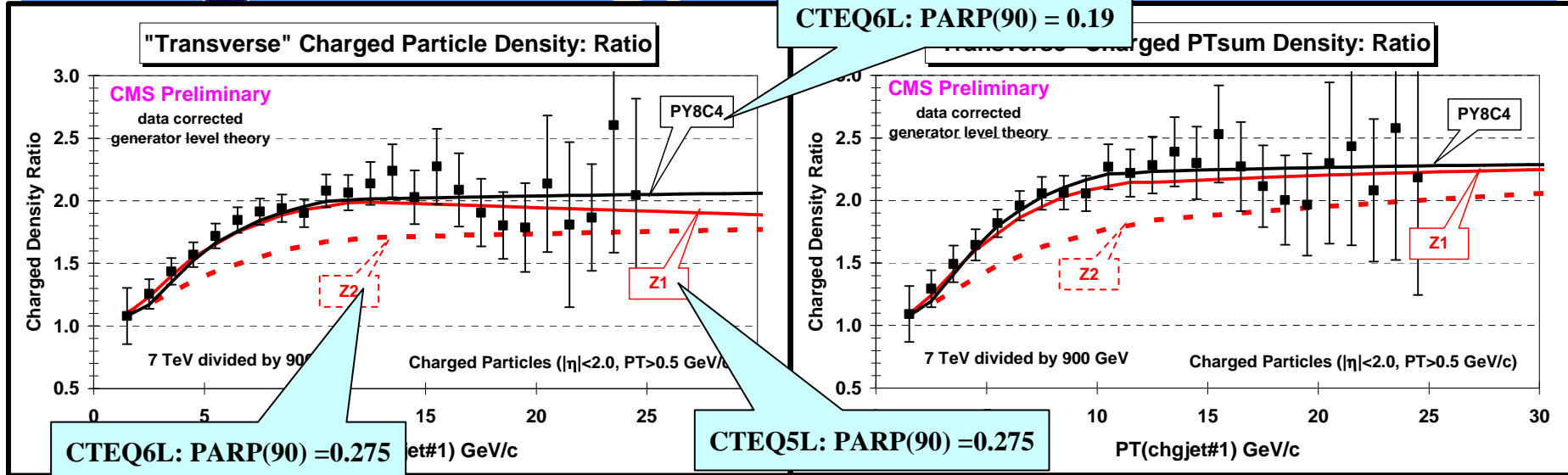
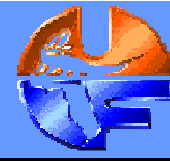


Z1 and PY8C4 good! Z2 Bad!



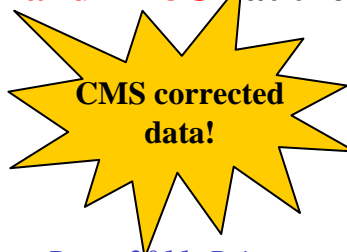


Energy Dependence

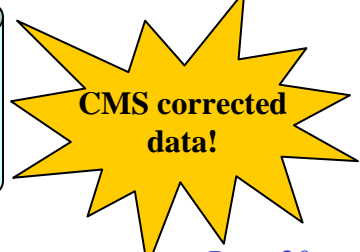


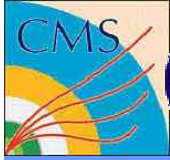
➔ CMS data on the energy dependence (7 TeV divided by 900 GeV) of the “transverse” charged particle density as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$ compared with **PYTHIA Tune Z1, Z2, and PY8C4** at the generator level.

➔ CMS data on the energy dependence (7 TeV divided by 900 GeV) of the “transverse” charged PTsum density as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$ compared with **PYTHIA Tune Z1, Z2, and PY8C4** at the generator level.

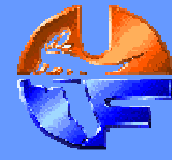


Duh! The energy dependence depends on both PARP(90) and the structure function!





PYTHIA Tune Z2*

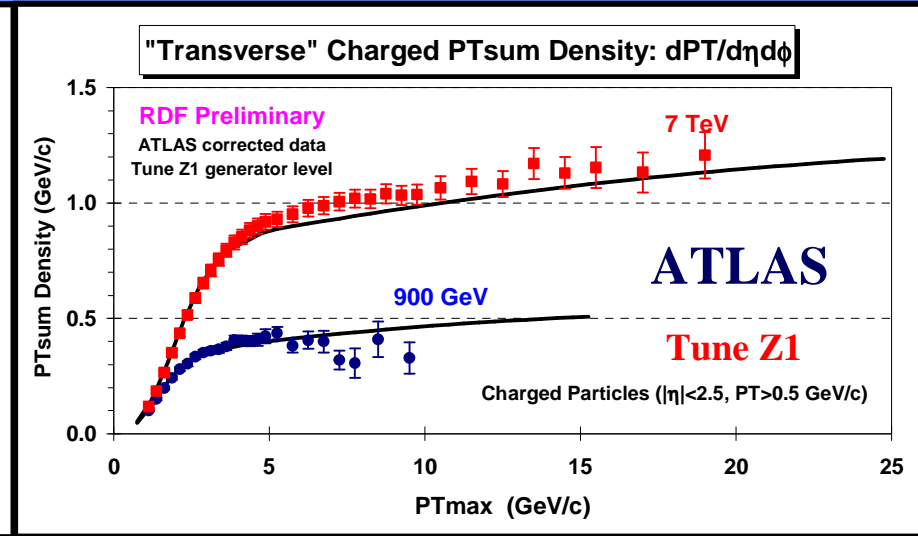
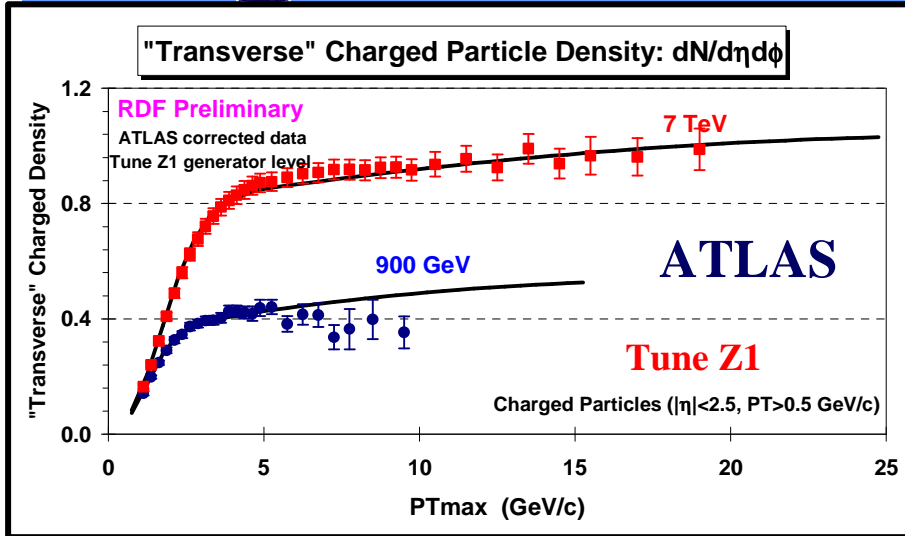


Parameter	Tune Z2 (R. Field CMS)	Tune Z2* (CMS)	PY8 Tune C4 (Corke-Sjöstrand)
Parton Distribution Function	CTEQ6L	CTEQ6L	CTEQ6L
PARP(82) – MPI Cut-off	1.832	1.927	2.085
PARP(89) – Reference energy, E0	1800.0	1800.0	1800.0
PARP(90) – MPI Energy Extrapolation	0.275	0.225	0.19
PARP(77) – CR Suppression	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 gaussian matter distribution	4	4	
MSTP(91) – Gaussian primordial kT	1	1	
MSTP(95) – strategy for color reconnection	6	6	

CMS GEN Group: Working on an improved Z2 tune (Tune Z2*) using the Professor (A. Knutsson & M. Zakaria).



ATLAS UE Data



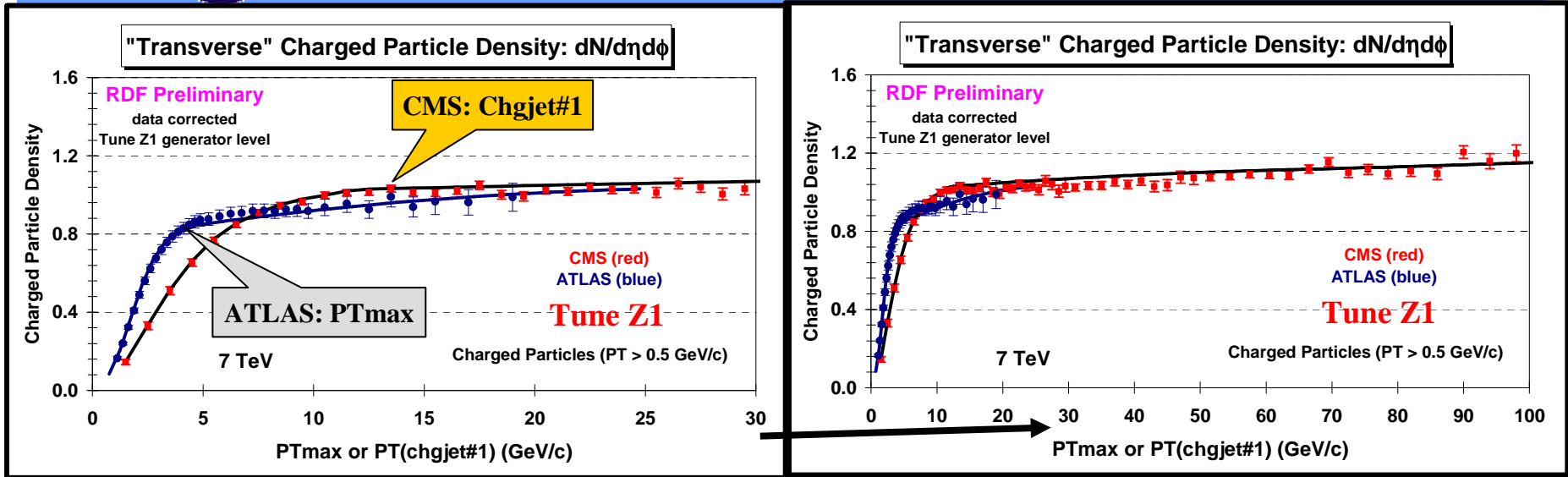
➔ ATLAS published data at 900 GeV and 7 TeV on the “transverse” charged particle density, $dN/d\eta d\phi$, as defined by the leading charged particle (PT_{max}) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.5$. The data are corrected and compared with **PYTHIA Tune Z1** at the generator level.

➔ ATLAS published data at 900 GeV and 7 TeV on the “transverse” charged PTsum density, $dPT/d\eta d\phi$, as defined by the leading charged particle (PT_{max}) 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.

ATLAS publication – arXiv:1012.0791
December 3, 2010



CMS-ATLAS UE Data

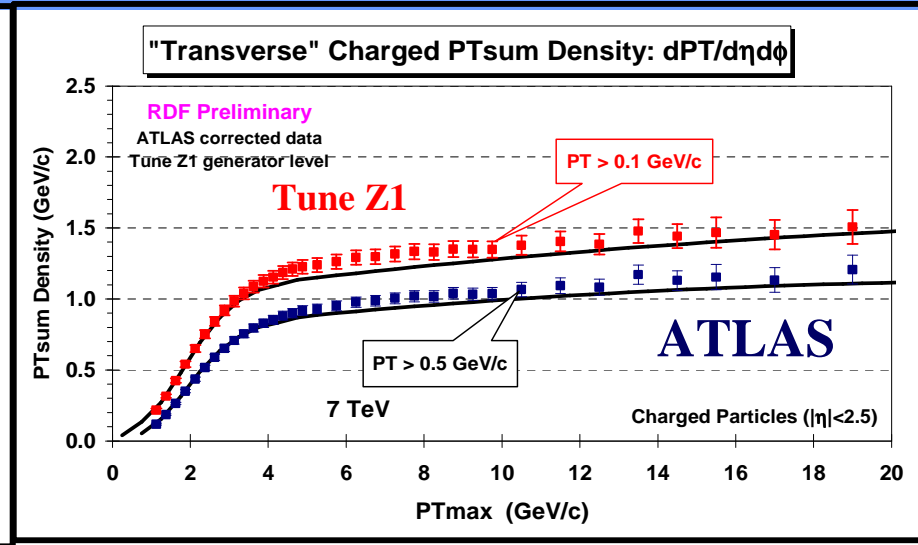
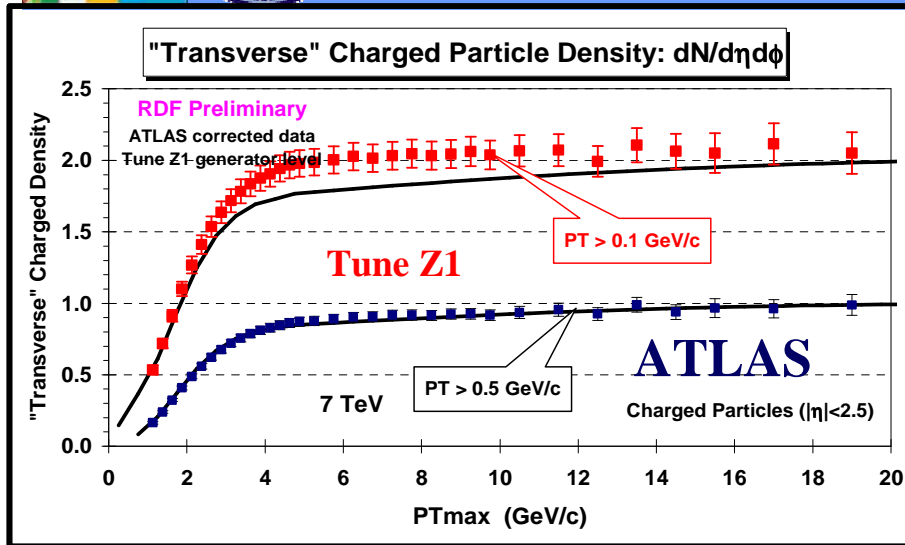


➔ **CMS preliminary data at 7 TeV** on the “transverse” charged particle density, $dN/d\eta d\phi$, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$ together with the **ATLAS published data at 7 TeV** on the “transverse” charged particle density, $dN/d\eta d\phi$, as defined by the leading charged particle (PT_{max}) 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.

Amazing agreement!



ATLAS UE Data



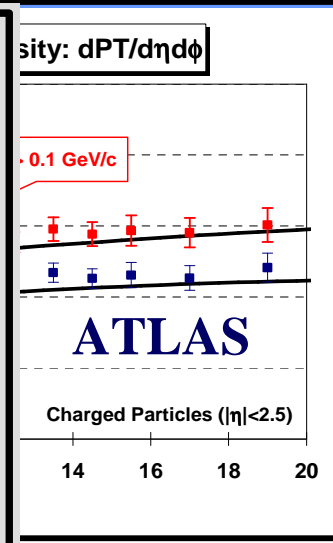
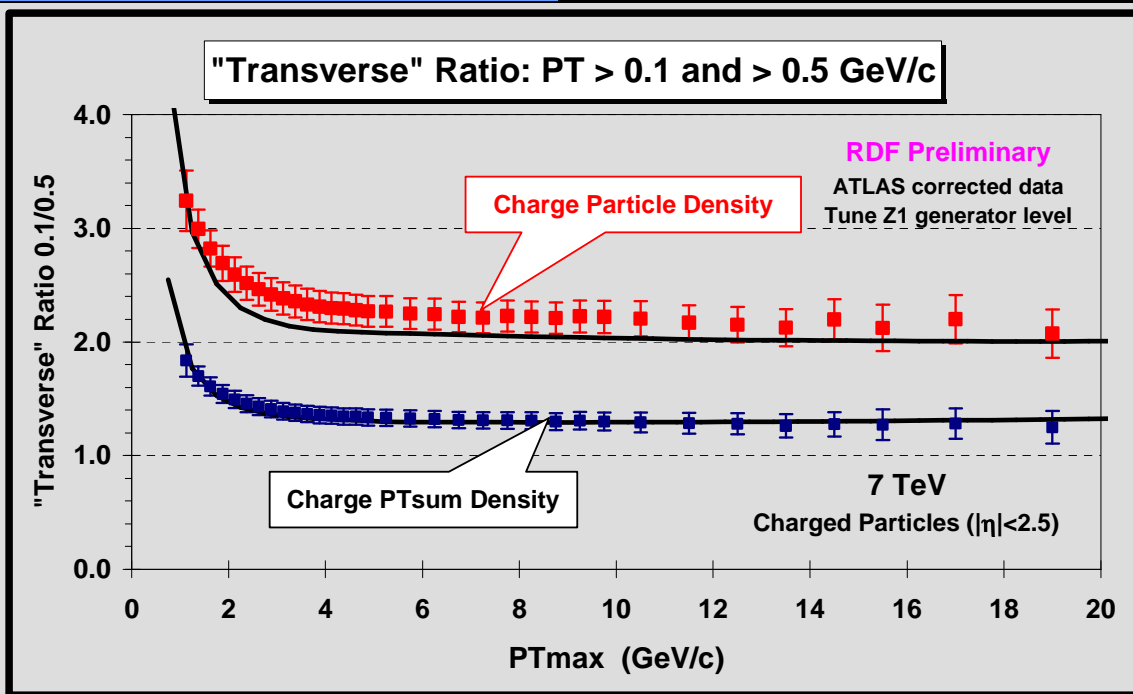
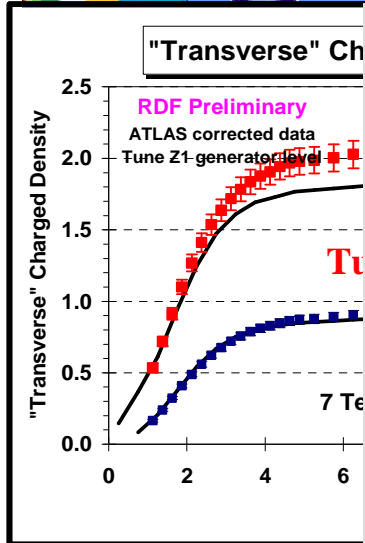
➔ **ATLAS published data at 7 TeV** on the “transverse” charged particle density, $dN/d\eta d\phi$, as defined by the leading charged particle (PT_{max}) for charged particles with $p_T > 0.5$ GeV/c and $p_T > 0.1$ GeV/c ($|\eta| < 2.5$). The data are corrected and compared with **PYTHIA Tune Z1** at the generator level.

➔ **ATLAS published data at 7 TeV** on the “transverse” charged PTsum density, $dPT/d\eta d\phi$, as defined by the leading charged particle (PT_{max}) 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



ATLAS UE Data



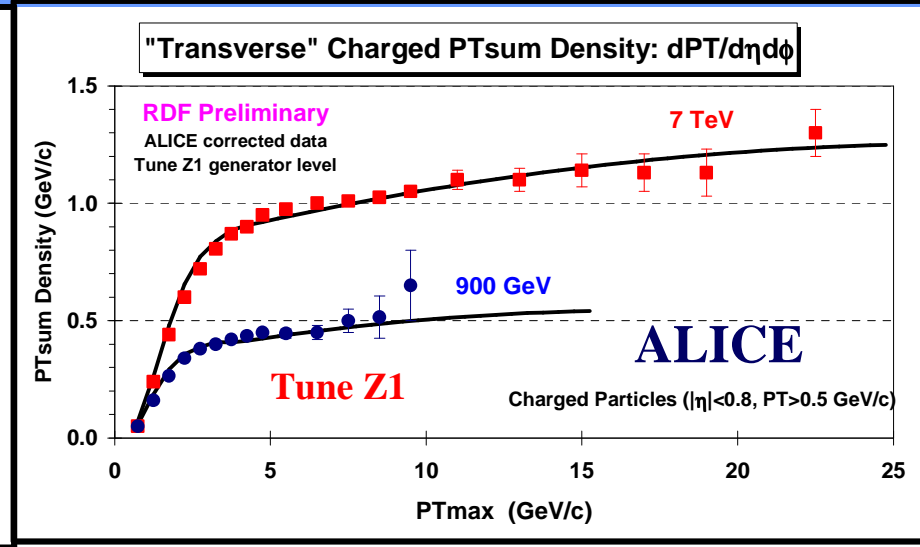
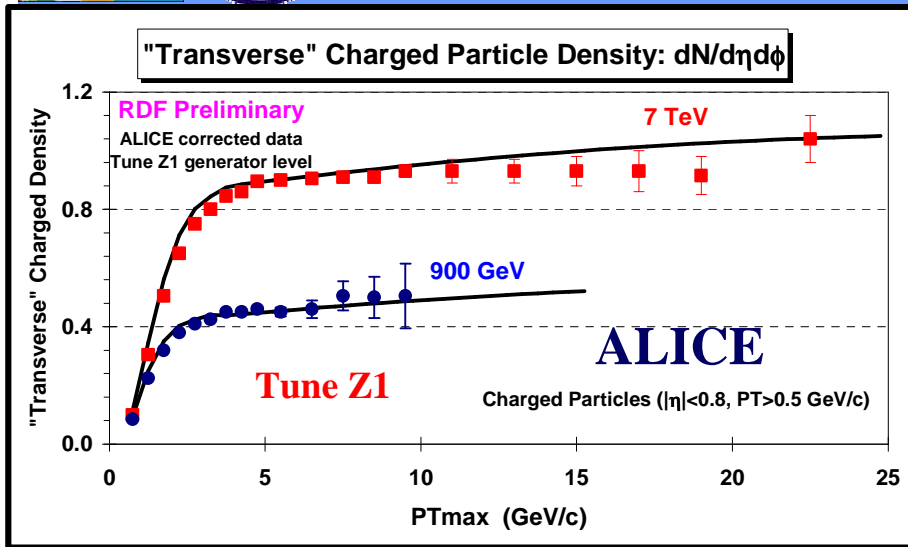
→ **ATLAS publishes** the “transverse” charged particle density, $dN/d\eta d\phi$, as defined by the number of particles per unit pseudorapidity and azimuthal angle per particle (PT_{max}) for charged particles with $p_T > 0.5$ GeV/c and $p_T > 0.1$ GeV/c ($|\eta| < 2.5$). The data are corrected and compared with **PYTHIA Tune Z1** at the generator level.

ATLAS publishes the “transverse” ratio of the charged particle density, $dN/d\eta d\phi$, on the ratio of the charged particle density, $dN/d\eta d\phi$, leading charged particles per particle (PT_{max}) 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



ALICE UE Data

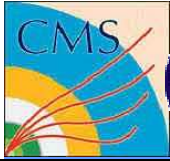


➔ ALICE preliminary data at 900 GeV and 7 TeV on the “transverse” charged particle density, $dN/d\eta d\phi$, as defined by the leading charged particle (PT_{max}) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$. The data are corrected and compared with **PYTHIA Tune Z1** at the generator level.

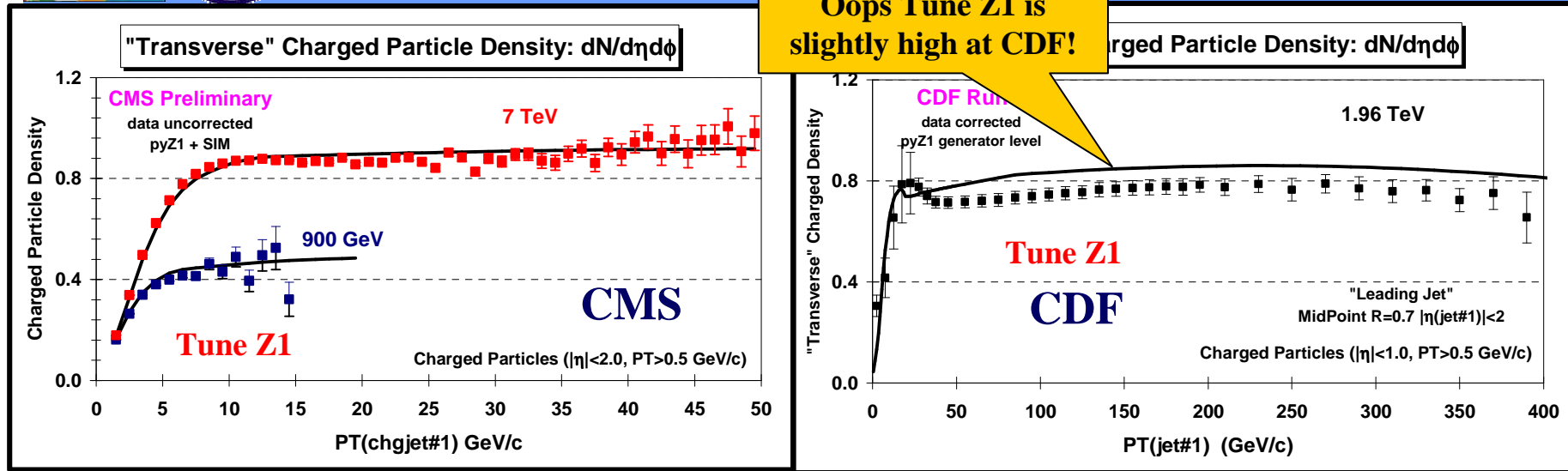
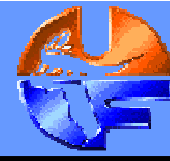
➔ ALICE preliminary data at 900 GeV and 7 TeV on the “transverse” charged PTsum density, $dPT/d\eta d\phi$, as defined by the leading charged particle (PT_{max}) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$. The data are corrected and compared with **PYTHIA Tune Z1** at the generator level.

I read the points off with a ruler!

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



PYTHIA Tune Z1

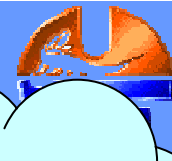


➔ CMS preliminary data at 900 GeV and 7 TeV on the “transverse” charged particle density, $dN/d\eta d\phi$, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5 \text{ GeV}/c$ and $|\eta| < 2$. The data are uncorrected and compared with PYTHIA **Tune Z1** after detector simulation.

➔ CDF published data at 1.96 TeV on the “transverse” charged particle density, $dN/d\eta d\phi$, as defined by the leading calorimeter jet (jet#1) for charged particles with $p_T > 0.5 \text{ GeV}/c$ and $|\eta| < 1.0$. The data are corrected and compared with PYTHIA **Tune Z1** at the generator level.



UE Summary & Conclusions



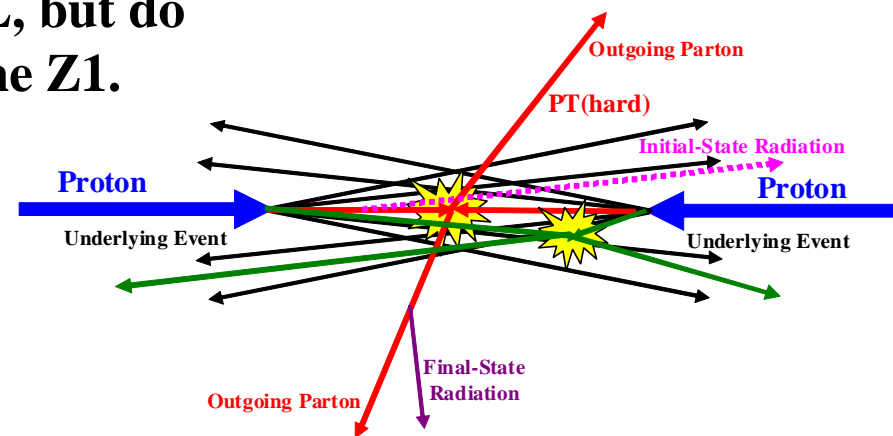
➔ We now have lots of corrected UE data from the LHC! Tune Z1 (CTEQ5L) does nice job of fitting the CMS, ATLAS, and ALICE UE data at 900 GeV and 7 TeV! **But Tune Z1 is a little high at CDF (1.96 TeV)!**

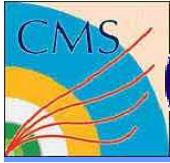
I still dream of a “universal” tune that fits the UE at all energies! **Need to simultaneously tune LHC plus CDF (“professor” tune)!**

➔ **CTEQ6L Tune:** PYTHIA 6.4 Tune Z2 and PYTHIA 8 Tune C4 both use CTEQ6L, but do not fit the LHC UE data as well as Tune Z1.

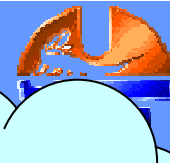
➔ **Next Step:** More PYTHIA 6.4 and PYTHIA 8 tunes. Time to look more closely at Sherpa and HERWIG++!

➔ **ATLAS Tuning Effort (A. Buckley, J. Katzy et al.):** AMBT1, AUET1 (Herwig+Jimmy). Coming soon AUET2 (Herwig + Jimmy), AMBT2! Four stage approach: Flavor, FS fragmentation, ISR, MPI.





UE Summary & Conclusions



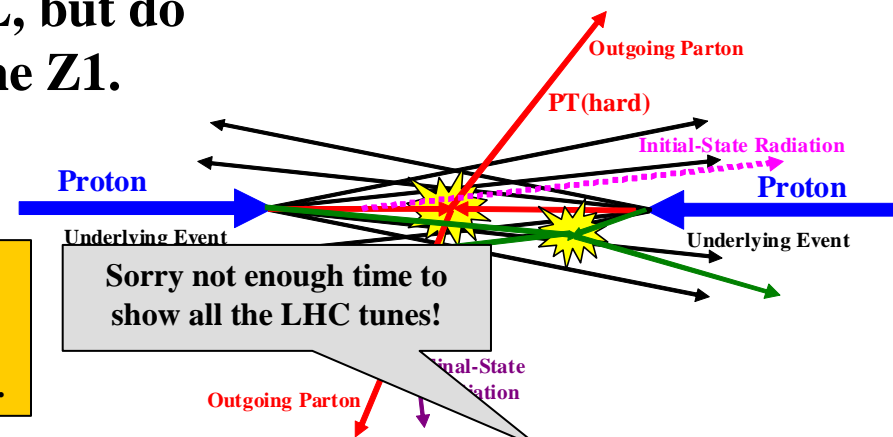
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➔ **CTEQ6L Tune:** PYTHIA 6.4 Tune Z2 and PYTHIA 8 Tune C4 both use CTEQ6L, but do not fit the LHC UE data as well as Tune Z1.

➔ **Next Step:** Modify PYTHIA 6.4 and PYTHIA 8 to fit the LHC UE data more closely at SLAC.

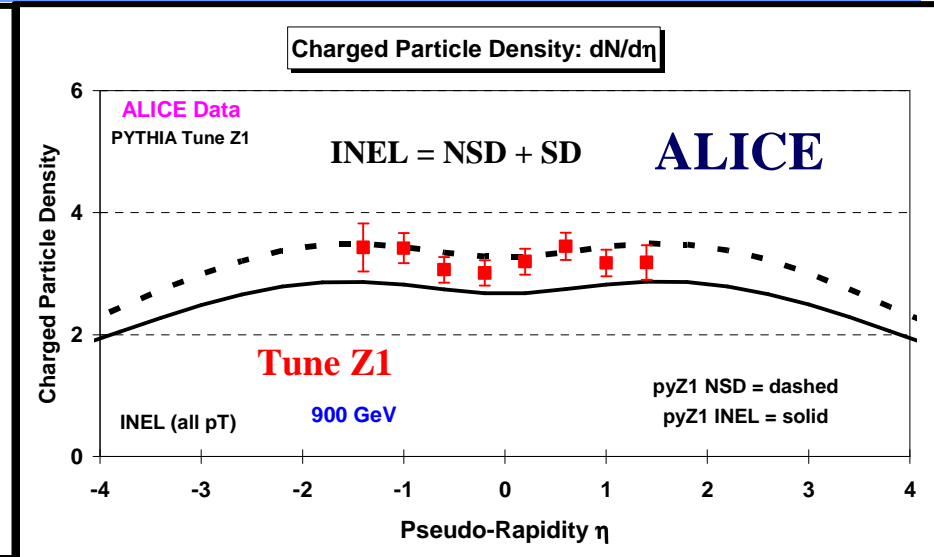
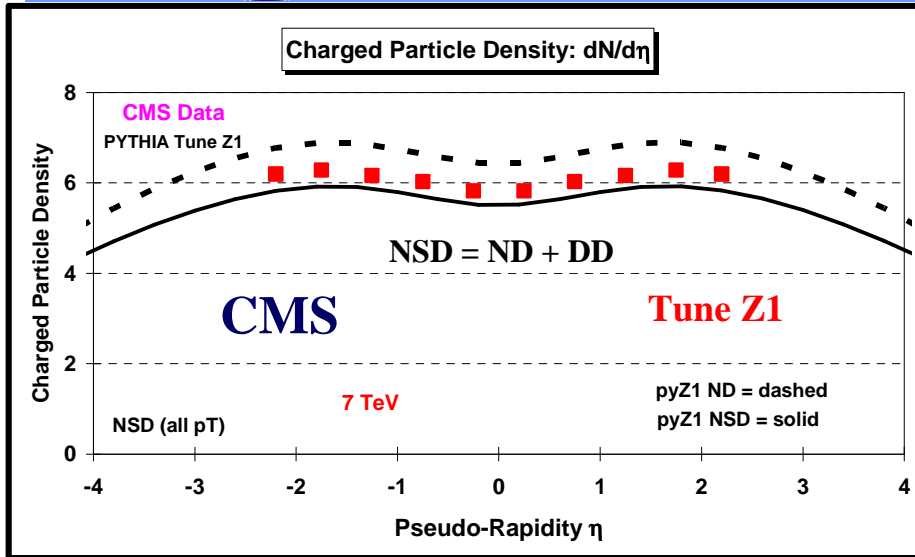
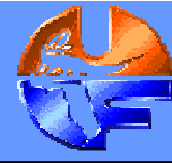
CMS GEN Group: Working on an improved Z2 tune (Tune Z2*) and an improved PY8C4 tune (Tune C4*) using the Professor (A. Knutsson & M. Zakaria).



➔ **ATLAS Tuning Effort (A. Buckley, J. Katzy et al.):** AMBT1, AUET1 (Herwig+Jimmy). Coming soon AUET2 (Herwig + Jimmy), AMBT2! Four stage approach: Flavor, FS fragmentation, ISR, MPI.



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 , $(1/N_{NSD}) dN/d\eta$.

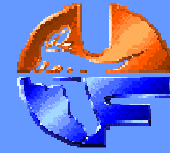
➔ **ALICE NSD data** on the charged particle rapidity distribution at 900 GeV compared with **PYTHIA Tune Z1**. The plot shows the average number of particles per INEL collision per unit η , $(1/N_{INEL}) dN/d\eta$.

“Minimum Bias” Collisions

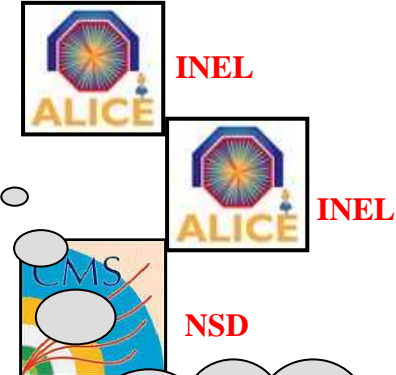
Okay not perfect, but remember we know that SD and DD are not modeled well!



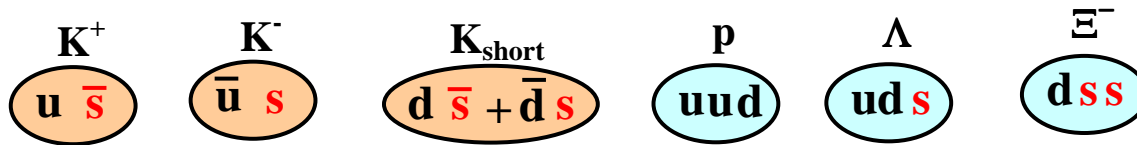
Baryon & Strange Particle Production at the LHC



- ➔ Strange Particle Production in Proton-Proton Collisions at 900 GeV with ALICE at the LHC, arXiv:1012.3257 [hep-ex] December 18, 2010.
- ➔ Production of Pions, Kaons and Protons in pp Collisions at 900 GeV with ALICE at the LHC, arXiv:1101.4110 [hep-ex] January 25, 2011.
- ➔ Strange Particle Production in pp Collisions at 900 GeV and 7 TeV, CMS Paper: arXiv:1102.4282 [hep-ex] Feb 21, 2011, *submitted to JHEP*.



Step 1: Look at the overall particle yields (all p_T).



I know there are more nice results from the LHC, but this is all I can show today. Sorry!

Step 2: Look at the ratios of the overall particle yields (all p_T).

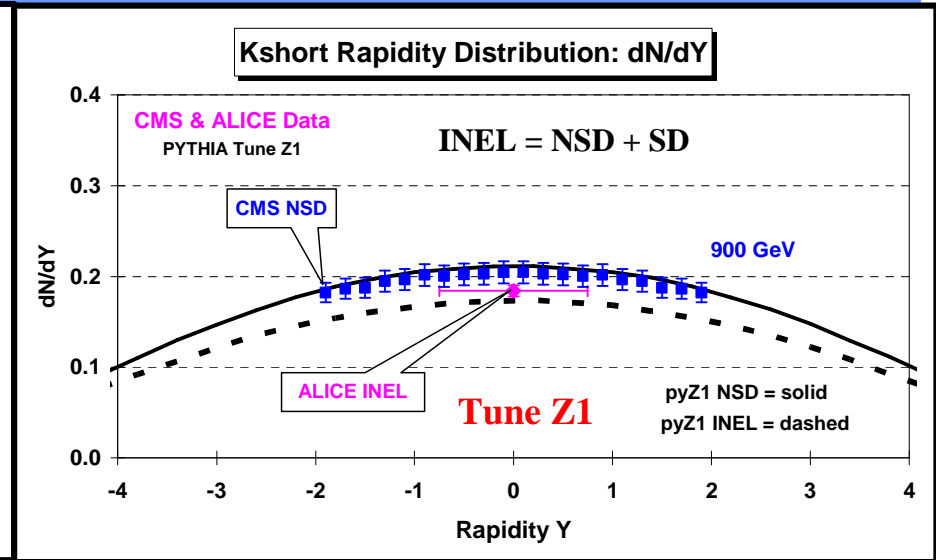
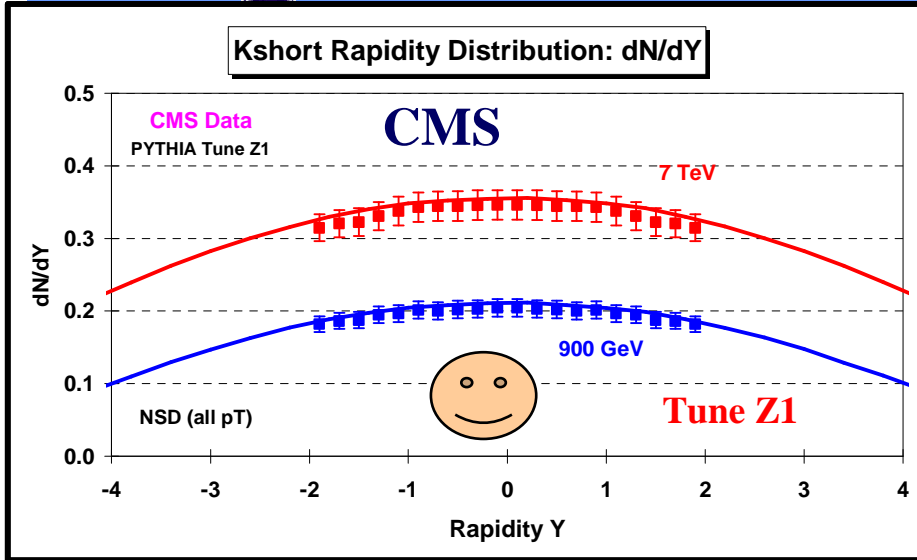
$$\frac{(K^+ + K^-)}{(\pi^+ + \pi^-)} = \frac{\text{Strange Meson}}{\text{Non-strange Meson}} \quad \frac{K_{short}}{(\pi^+ + \pi^-)} = \frac{\text{Strange Meson}}{\text{Non-strange Meson}}$$

$$\frac{(p + \bar{p})}{(\pi^+ + \pi^-)} = \frac{\text{Non-strange Baryon}}{\text{Non-strange Meson}} \quad \frac{(\Lambda + \bar{\Lambda})}{2K_{short}} = \frac{\text{Single-strange Baryon}}{\text{Strange Meson}} \quad \frac{(\Xi + \bar{\Xi})}{2K_{short}} = \frac{\text{Double-strange Baryon}}{\text{Strange Meson}}$$

Step 3: Look at the p_T dependence of the particle yields and ratios.



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 , $(1/N_{\text{NSD}}) dN/dY$.

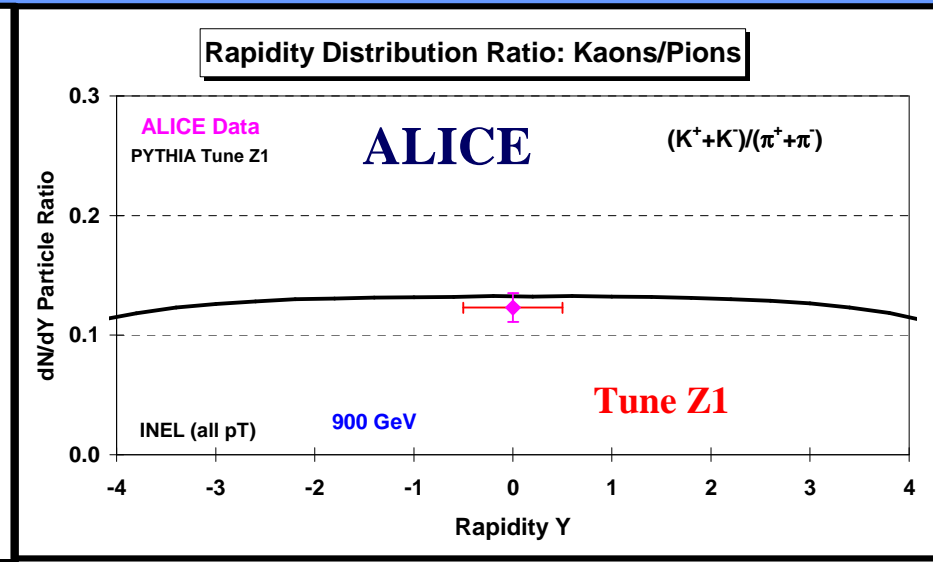
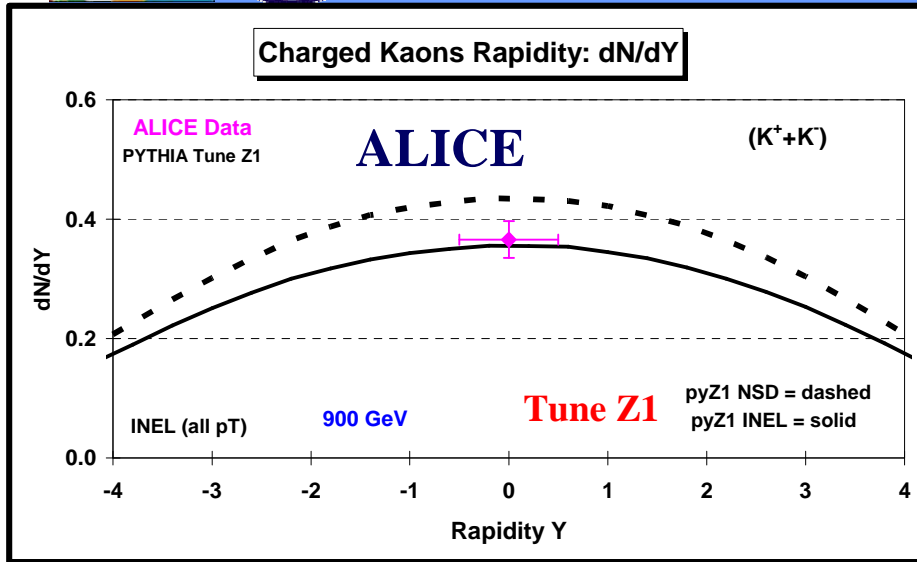
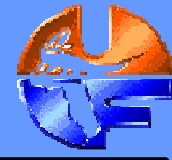
➔ **CMS NSD data** on the K_{short} rapidity distribution at 900 GeV and the **ALICE** point at $Y = 0$ (INEL) compared with **PYTHIA Tune Z1**. The ALICE point is the average number of K_{short} per INEL collision per unit Y at $Y = 0$, $(1/N_{\text{INEL}}) dN/dY$.

“Minimum Bias” Collisions

No overall shortage of Kaons in PYTHIA Tune Z1!



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, $(1/N_{\text{INEL}}) dN/dY$.

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

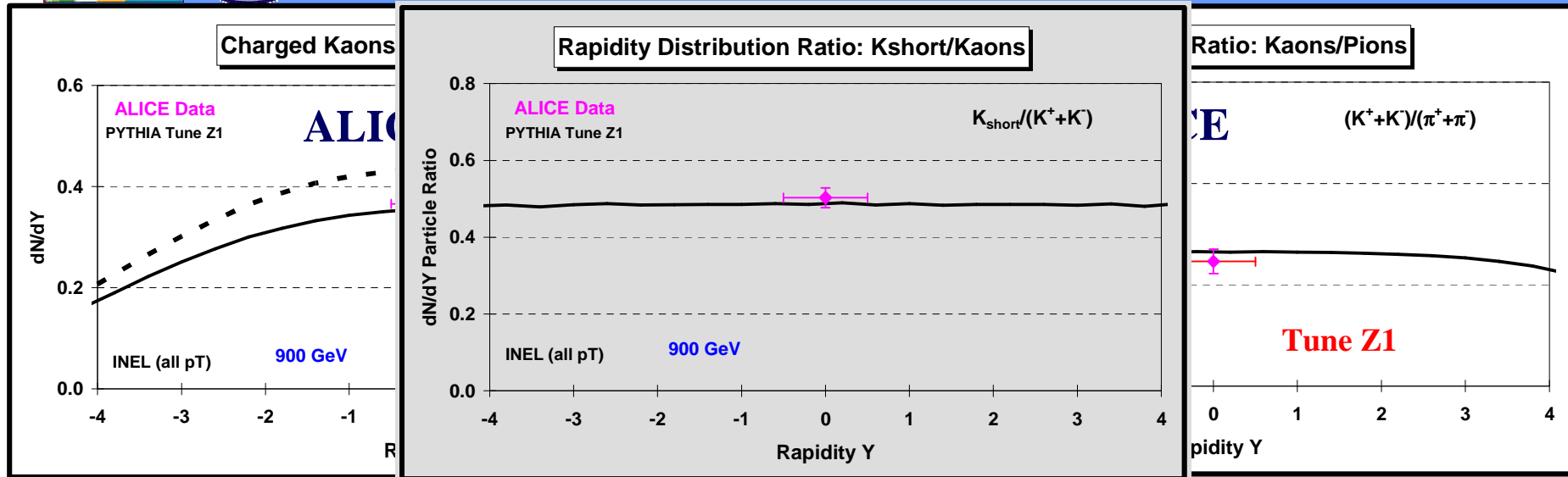
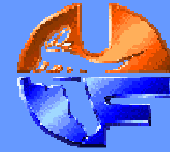
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Kaon Production



➔ **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, $(1/N_{\text{INEL}}) dN/dY$.

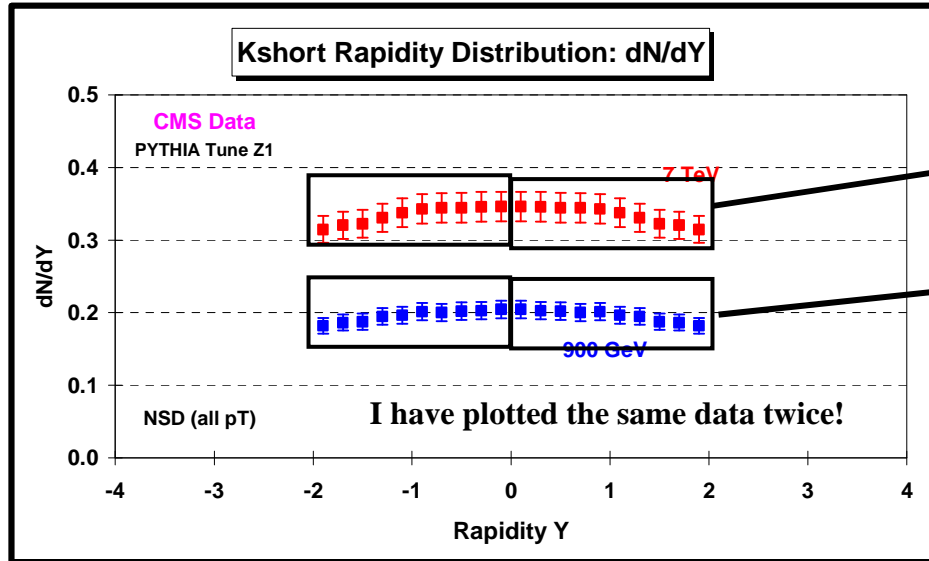
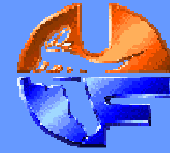
➔ **ALICE INEL data** on the charged kaon to charged pion rapidity ratio at 900 GeV compared with **PYTHIA Tune Z1**.

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

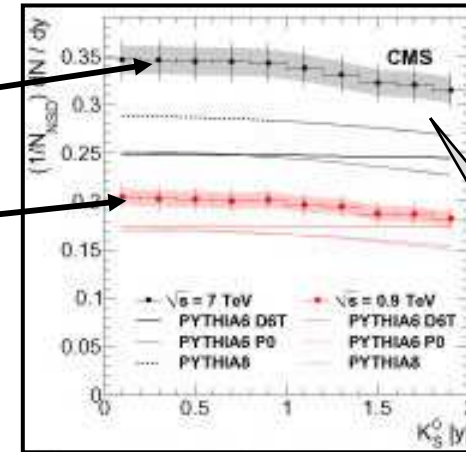
“Minimum Bias” Collisions

No overall shortage of Kaons in PYTHIA Tune Z1!

Kaon Production



CMS measures $(1/N_{NSD}) dN/dY$



versus $|Y|$ from $0 \rightarrow 2$

This is the correct way!

➔ Rick's plot of the CMS NSD data on the K_{short} rapidity distribution at 7 TeV and 900 GeV. The plot shows the average number of K_{short} per NSD collision per unit Y, $(1/N_{NSD}) dN/dY$, versus Y from $-2 \rightarrow 2$.

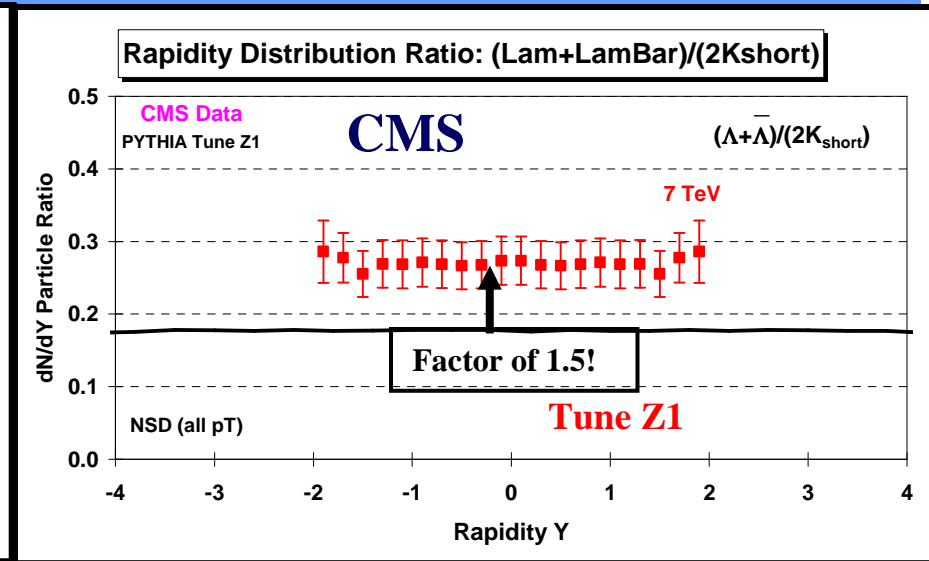
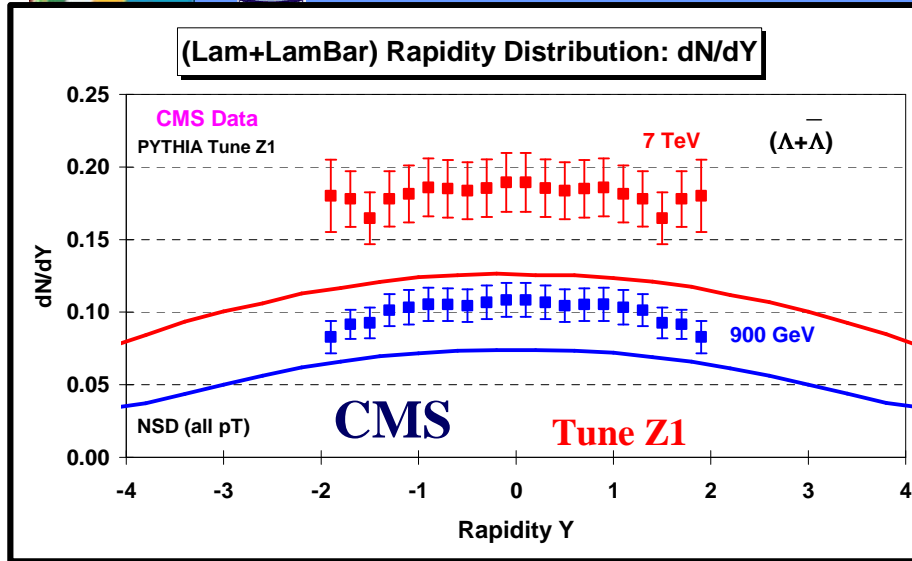
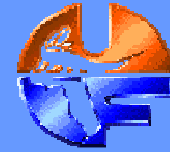
➔ Real CMS NSD data on the K_{short} rapidity distribution at 7 TeV and 900 GeV. The plot shows the average number of K_{short} per NSD collision per unit Y, $(1/N_{NSD}) dN/dY$, versus $|Y|$ from $0 \rightarrow 2$.

Warning: I am not plotting what CMS actually measures!

I am old and I like to see both sides so I assumed symmetry about $Y = 0$ and plotted the same data on both sides ($Y \rightarrow -Y$). **The way CMS does it is the correct way!** But my way helps me see better what is going on. **Please refer to the CMS publication for the official plots!**



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**.

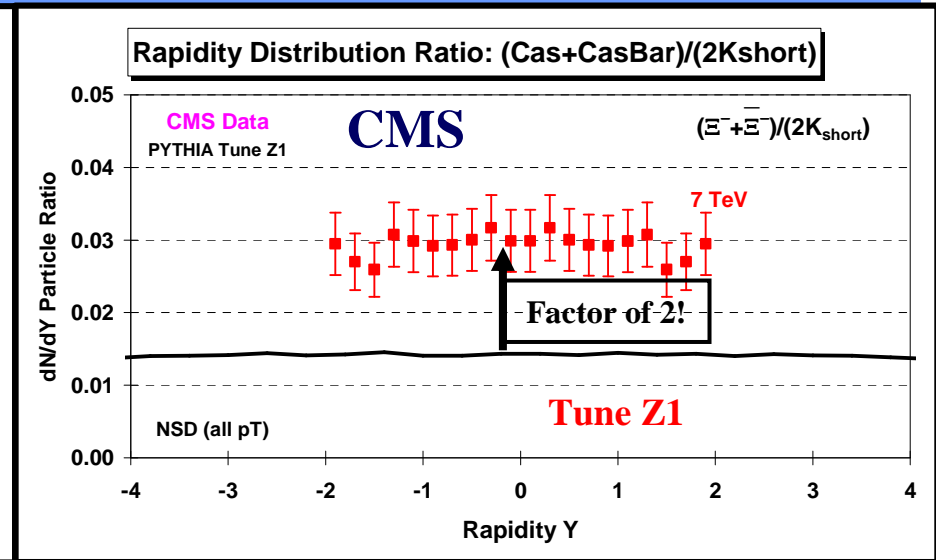
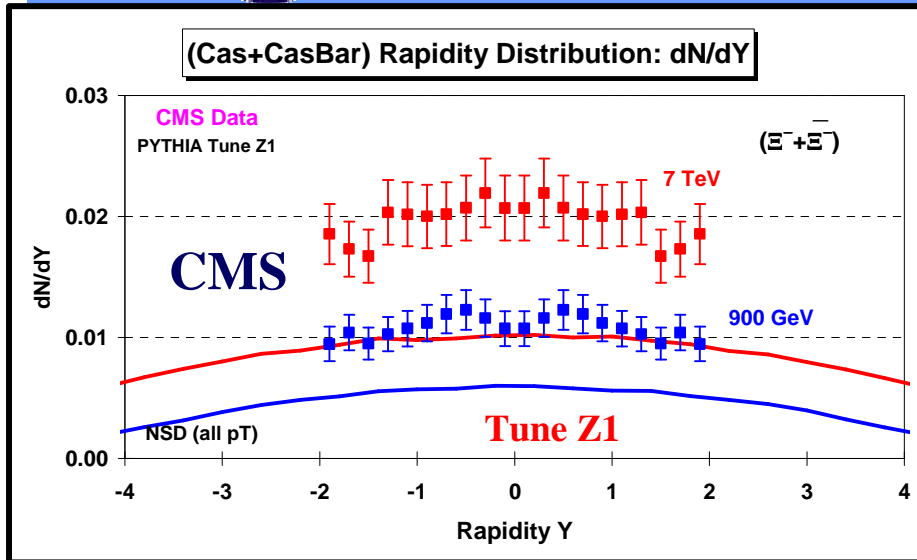
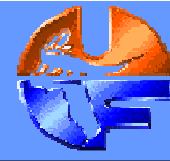
$$\frac{(\Lambda + \bar{\Lambda})}{2K_{short}} = \frac{\text{Single-strange Baryon}}{\text{Strange Meson}}$$

“Minimum Bias” Collisions

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



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**.

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

“Minimum Bias” Collisions

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



PYTHIA Fragmentation Parameters

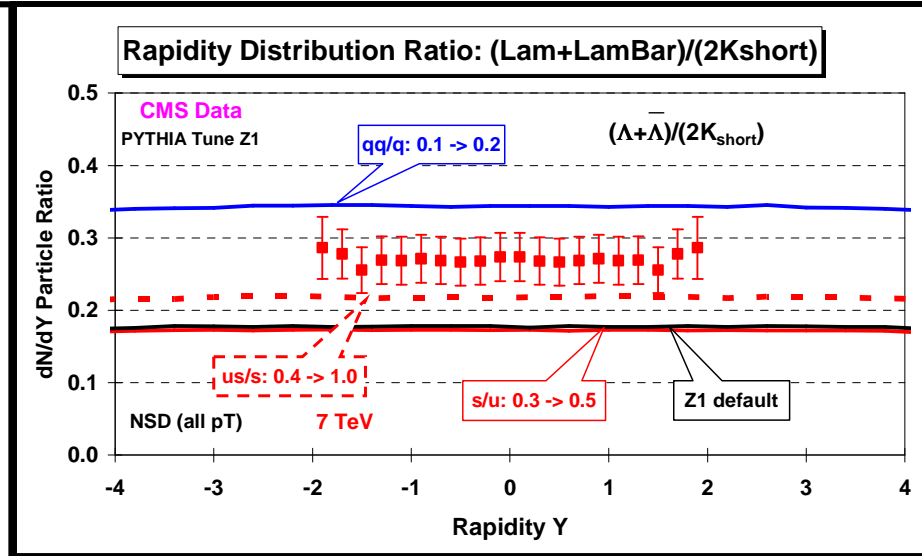
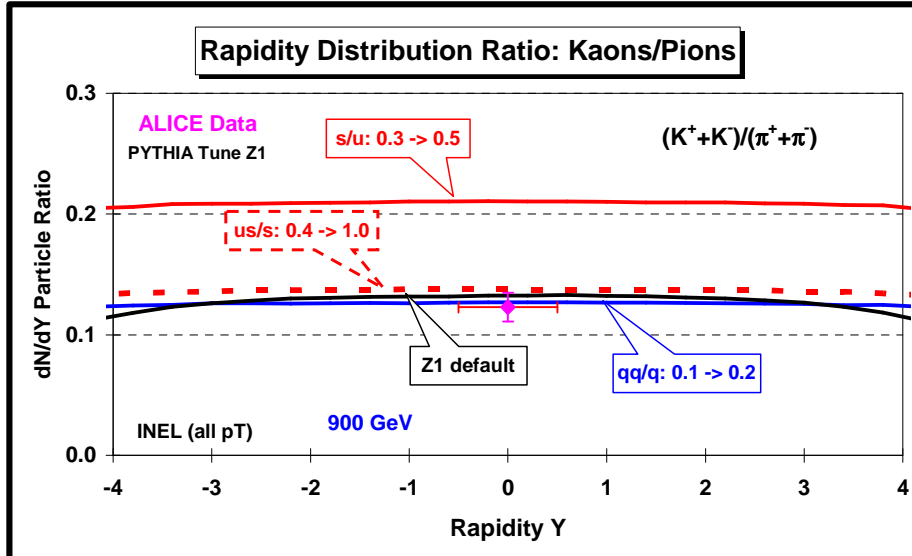


Can we increase the overall rate of strange baryons without messing up anything else?

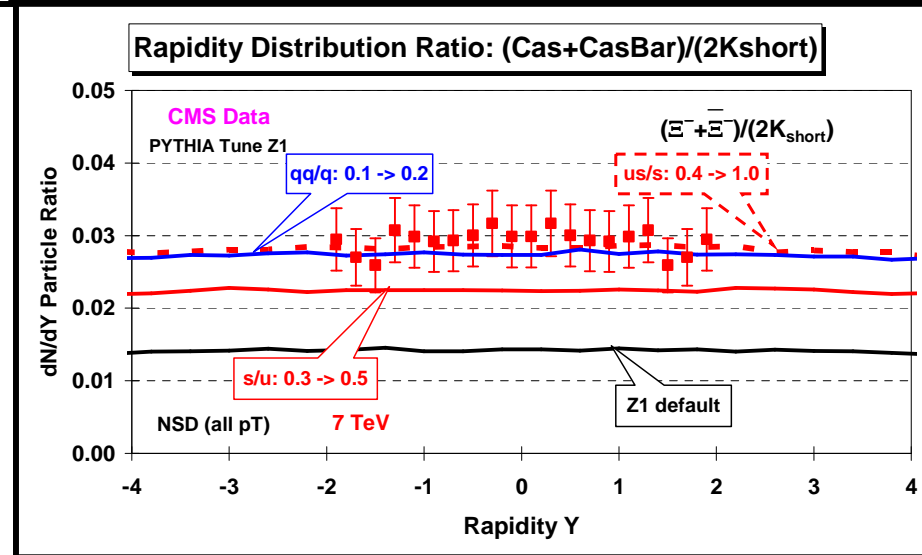
- ➔ **PARJ(1) : (D = 0.10)** is $P(qq)/P(q)$, the suppression of diquark-antidiquark pair production in the colour field, compared with quark-antiquark production. **Notation: $PARJ(1) = qq/q$**
- ➔ **PARJ(2) : (D = 0.30)** is $P(s)/P(u)$, the suppression of s quark pair production in the field compared with u or d pair production. **Notation: $PARJ(2) = s/u$.**
- ➔ **PARJ(3) : (D = 0.4)** is $(P(us)/P(ud))/(P(s)/P(u))$, the extra suppression of strange diquark production compared with the normal suppression of strange quarks. **Notation: $PARJ(3) = us/u$.**



PYTHIA Fragmentation Parameters

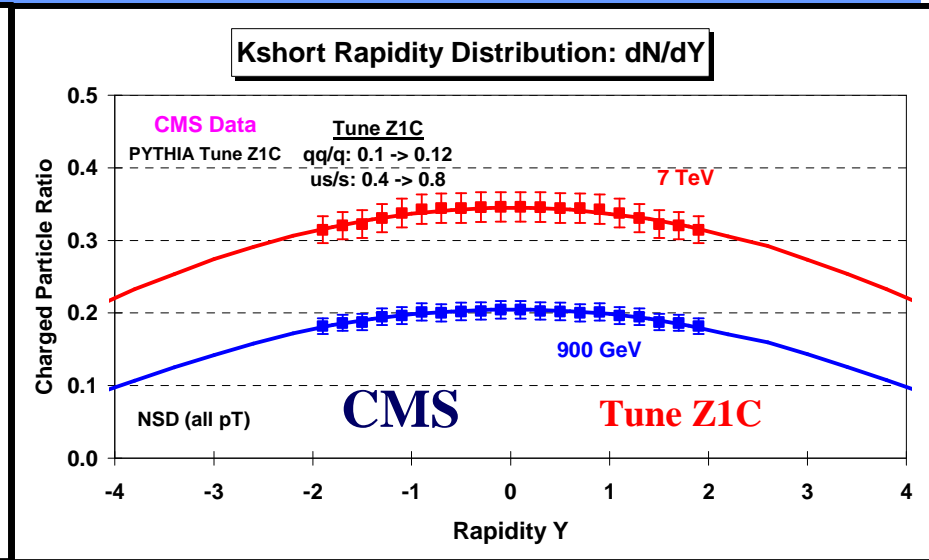
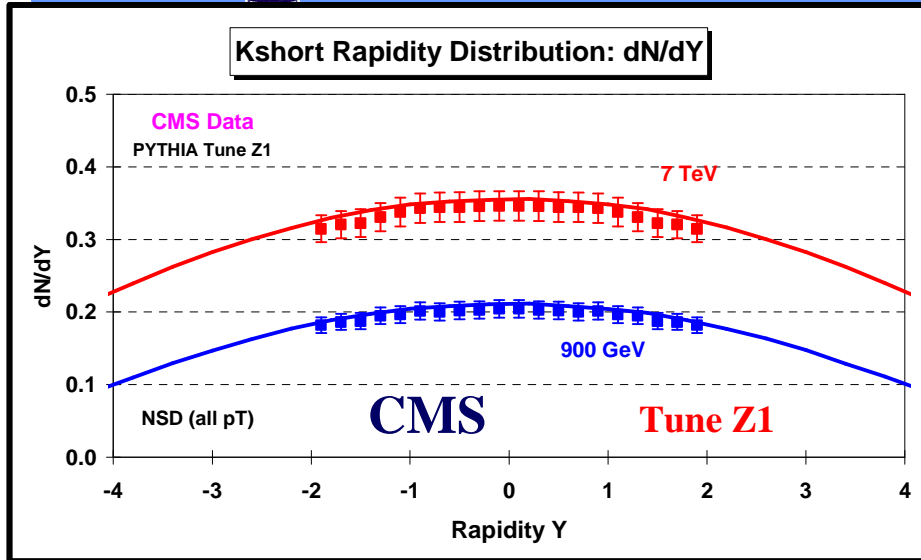
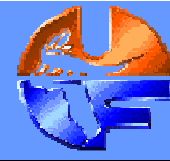


➔ **PYTHIA Tune Z1C:** Same as Tune Z1 except qq/q is increased 0.1 → 0.12 and us/s is increased from 0.4 → 0.8.





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, $(1/N_{\text{NSD}}) dN/dY$.

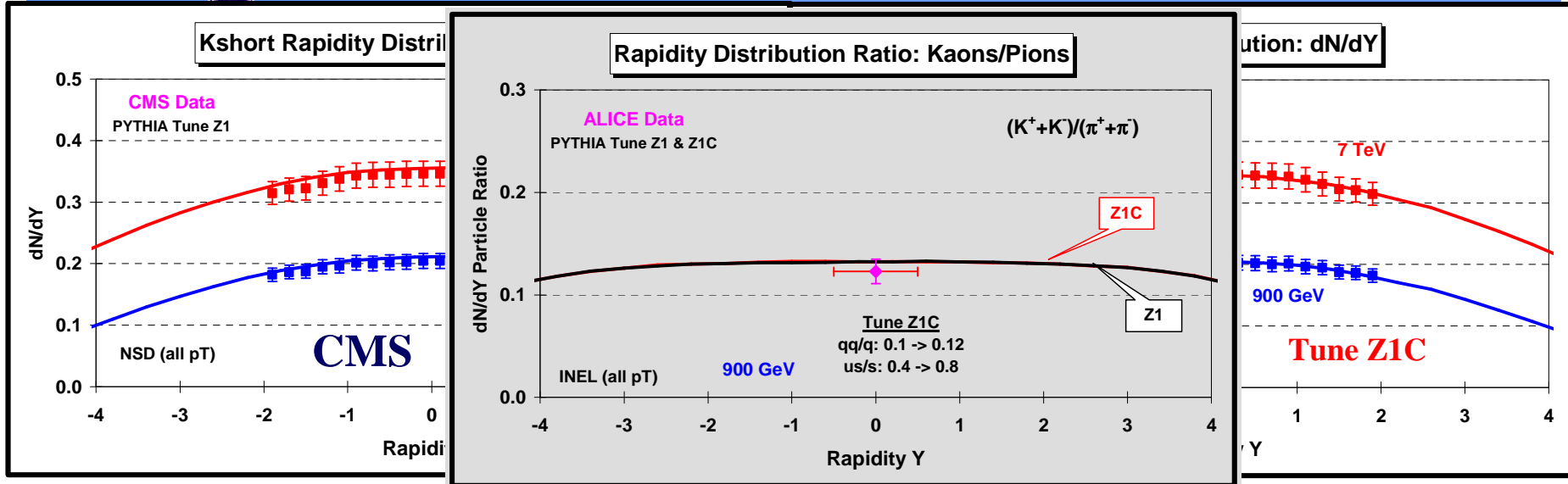
➔ **CMS dNSD data** on the K_{short} rapidity distribution at 7 TeV and 900 GeV compared with **PYTHIA Tune Z1C**. The plot shows the average number of K_{short} per NSD collision per unit Y, $(1/N_{\text{NSD}}) dN/dY$.

“Minimum Bias” Collisions

For Kaon production Tune Z1 and Z1C are almost identical!



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 , $(1/N_{\text{NSD}}) dN/dY$.

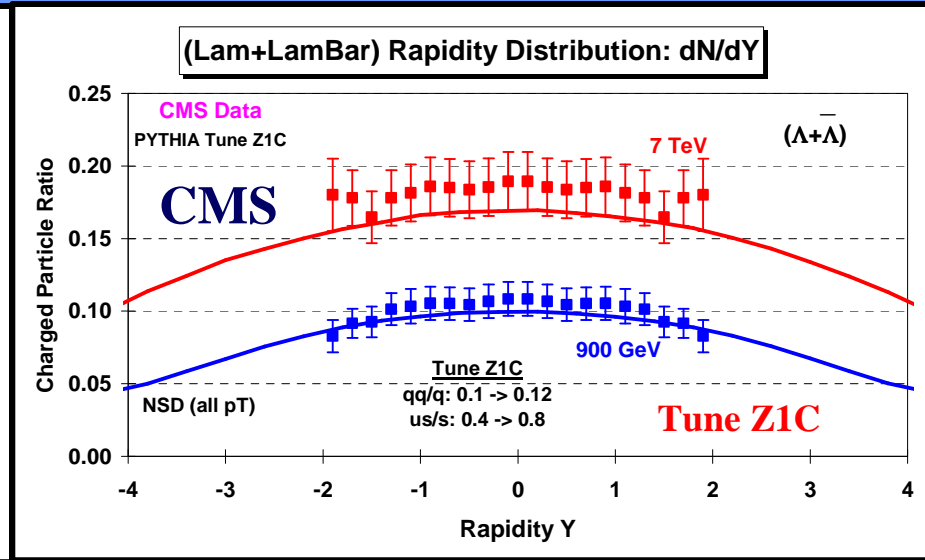
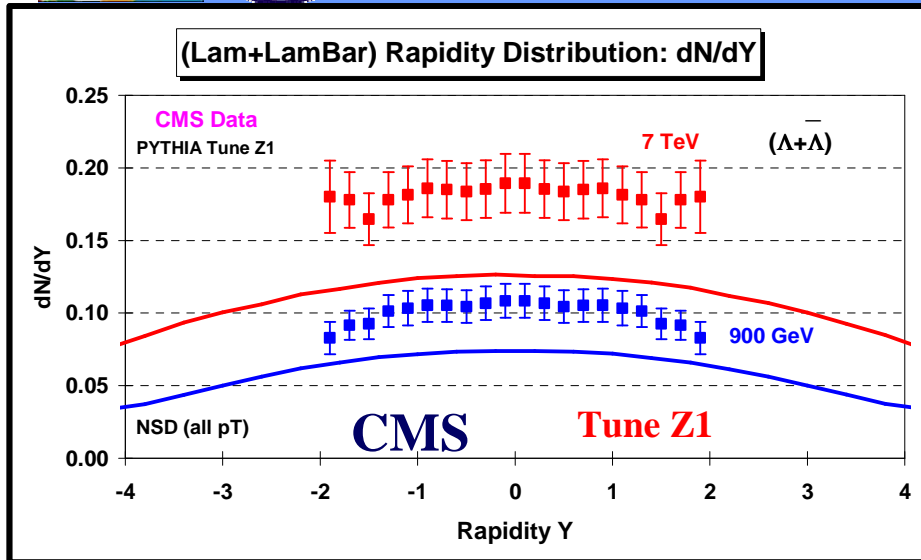
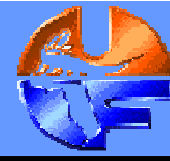
➔ **CMS dNSD data** on the K_{short} rapidity distribution at 7 TeV and 900 GeV compared with **PYTHIA Tune Z1C**. The plot shows the average number of K_{short} per NSD collision per unit Y , $(1/N_{\text{NSD}}) dN/dY$.

“Minimum Bias” Collisions

For Kaon production Tune Z1 and Z1C are almost identical!



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, $(1/N_{NSD}) dN/dY$.

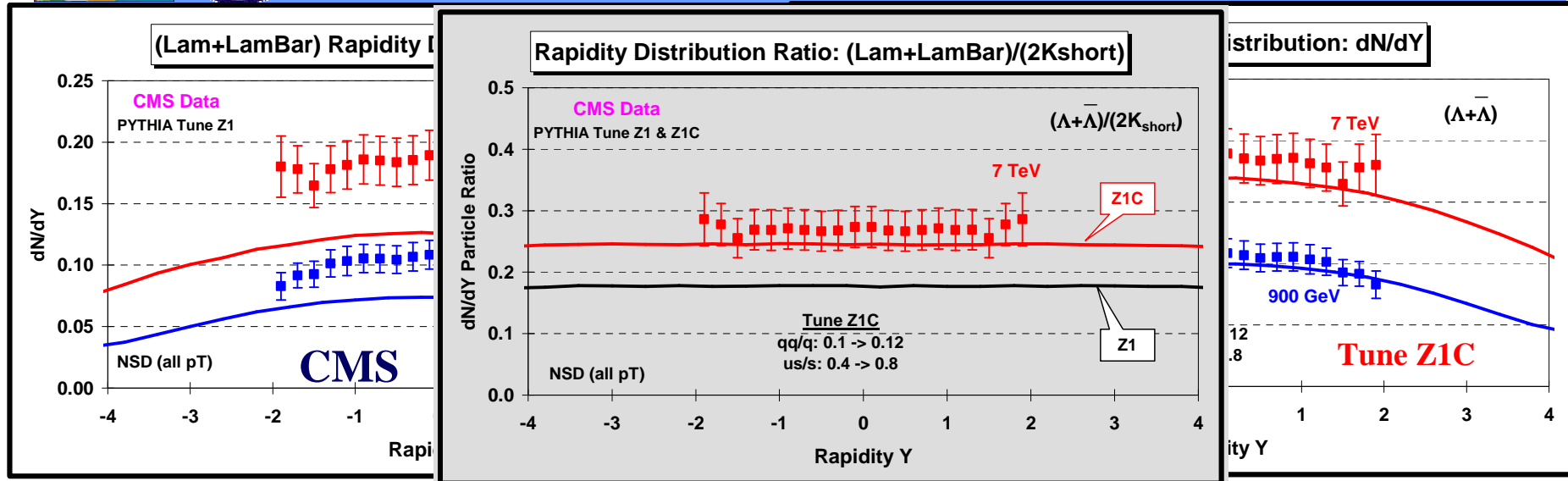
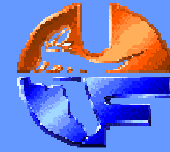
➔ **CMS NSD data** on the Lambda+AntiLambda rapidity distribution at 7 TeV and 900 GeV compared with **PYTHIA Tune Z1C**. The plot shows the average number of particles per NSD collision per unit Y, $(1/N_{NSD}) dN/dY$.

“Minimum Bias” Collisions

Not bad! Many more Lambda's in PYTHIA Tune Z1C!



Lambda Production



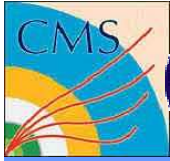
➔ CMS NSD data on the Lambda+AntiLambda rapidity distribution at 7 TeV and 900 GeV compared with **PYTHIA Tune Z1**. The plot shows the average number of particles per NSD collision per unit Y, $(1/N_{NSD}) dN/dY$.

➔ CMS NSD data on the Lambda+AntiLambda 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, $(1/N_{NSD}) dN/dY$.

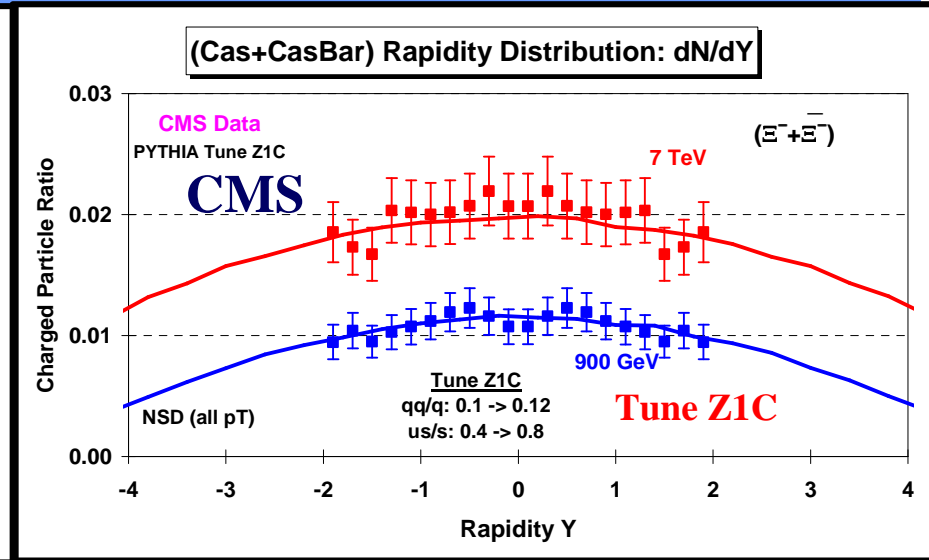
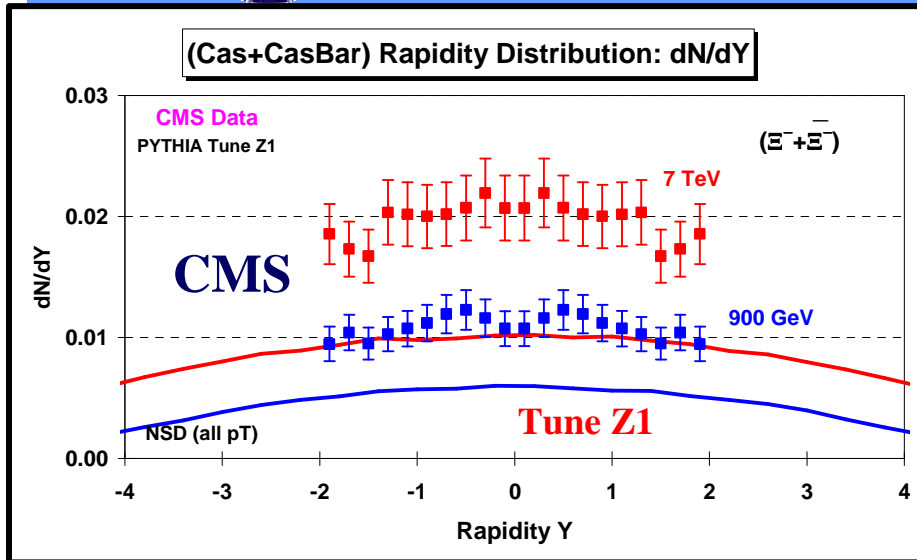
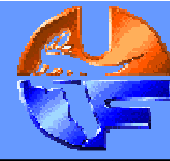
“Minimum Bias” Collisions

Not bad! Many more Lambda's in PYTHIA Tune Z1C!





Cascade Production

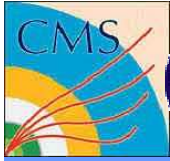


➔ **CMS NSD data** on the Cascade-+AntiCascade-rapidity distribution at 7 TeV and 900 GeV compared with **PYTHIA Tune Z1**. The plot shows the average number of particles per NSD collision per unit Y, $(1/N_{NSD}) dN/dY$.

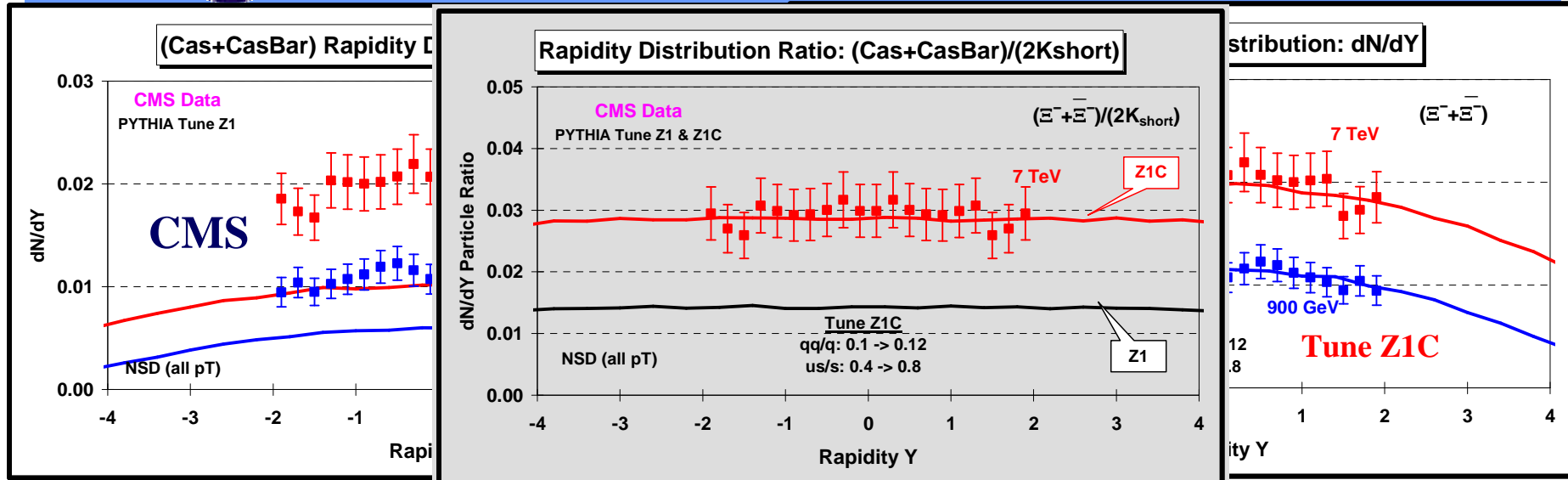
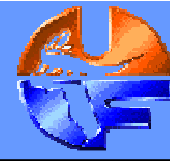
➔ **CMS NSD data** on the Cascade-+AntiCascade-rapidity distribution at 7 TeV and 900 GeV compared with **PYTHIA Tune Z1C**. The plot shows the average number of particles per NSD collision per unit Y, $(1/N_{NSD}) dN/dY$.

“Minimum Bias” Collisions

Wow! PYTHIA Tune Z1C looks very nice here!



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, $(1/N_{NSD}) dN/dY$.

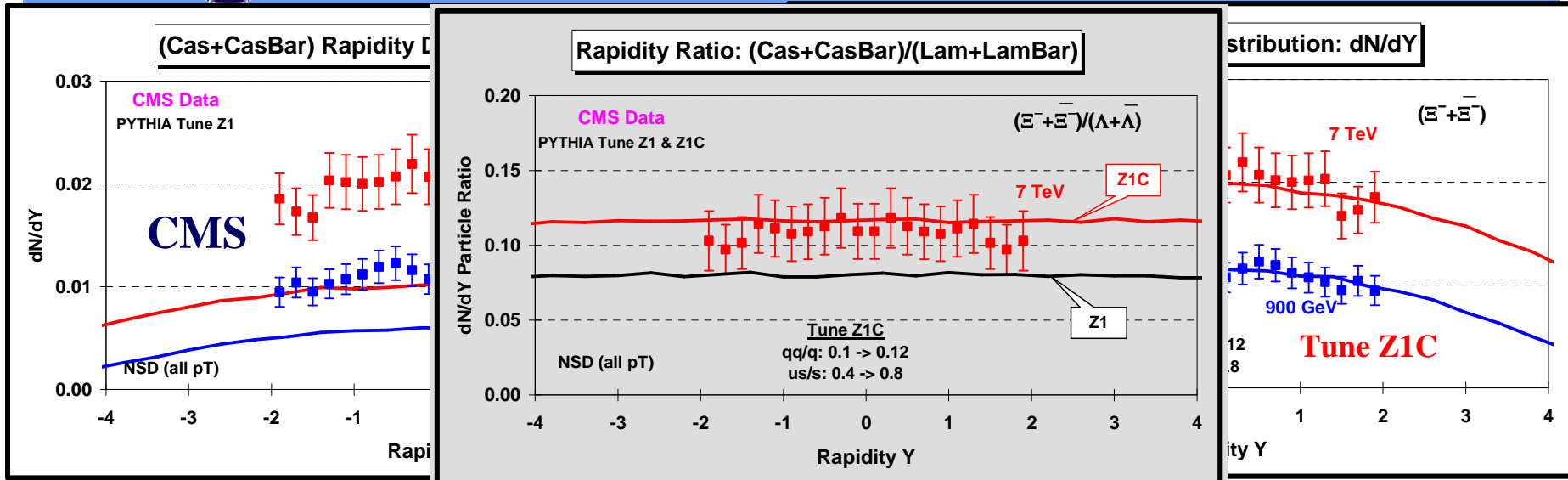
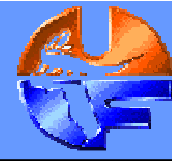
➔ **CMS NSD data** on the Cascade-+AntiCascade-rapidity distribution at 7 TeV and 900 GeV compared with **PYTHIA Tune Z1**. The plot shows the average number of particles per NSD collision per unit Y, $(1/N_{NSD}) dN/dY$.

“Minimum Bias” Collisions

Wow! PYTHIA Tune Z1C looks very nice here!



Cascade Production



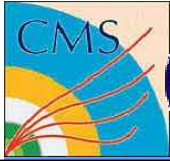
➔ CMS NSD data on the Cascade-+AntiCascade-rapidity distribution at 7 TeV and 900 GeV compared with **PYTHIA Tune Z1**. The plot shows the average number of particles per NSD collision per unit Y, $(1/N_{NSD}) dN/dY$.

➔ CMS 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, $(1/N_{NSD}) dN/dY$.

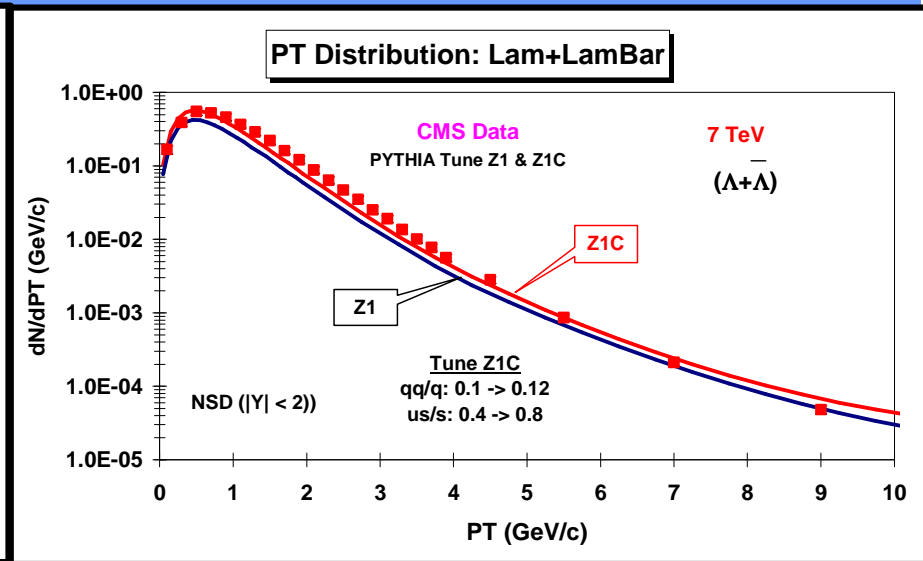
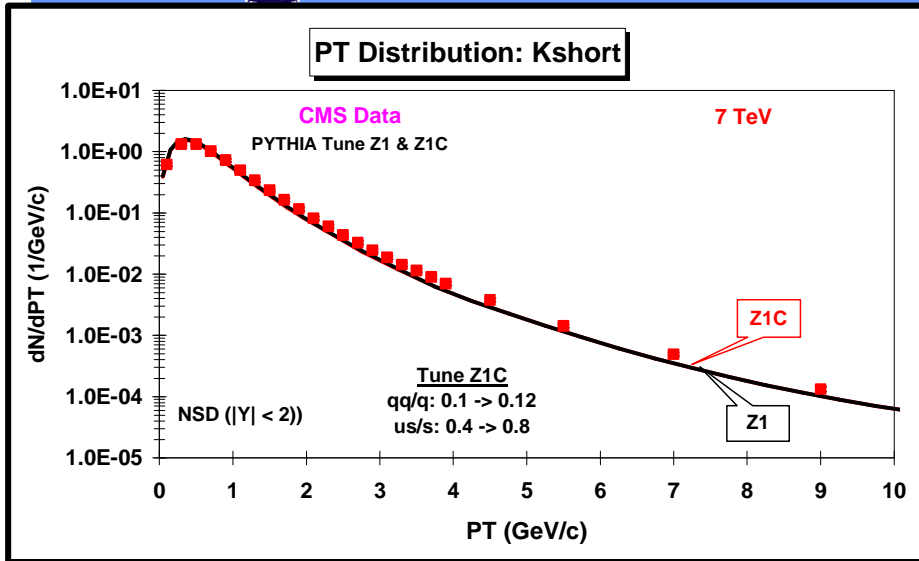
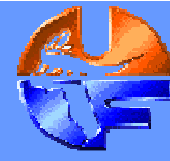
“Minimum Bias” Collisions

Wow! PYTHIA Tune Z1C looks very nice here!





Transverse Momentum Distributions



➔ **CMS NSD data on the K_{short} 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 , $(1/N_{\text{NSD}}) dN/dp_T$ for $|Y| < 2$.**

➔ **CMS NSD data on the Lambda+AntiLambda 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 , $(1/N_{\text{NSD}}) dN/dp_T$ for $|Y| < 2$.**

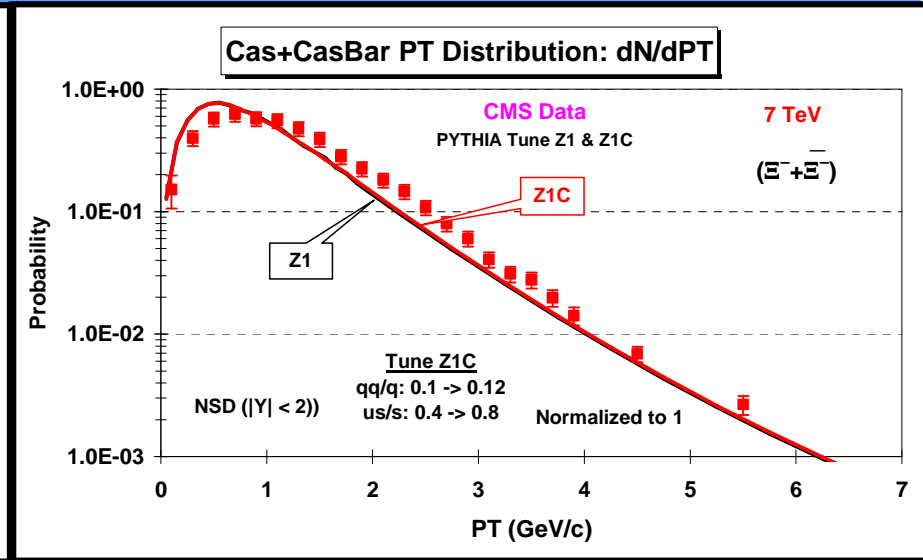
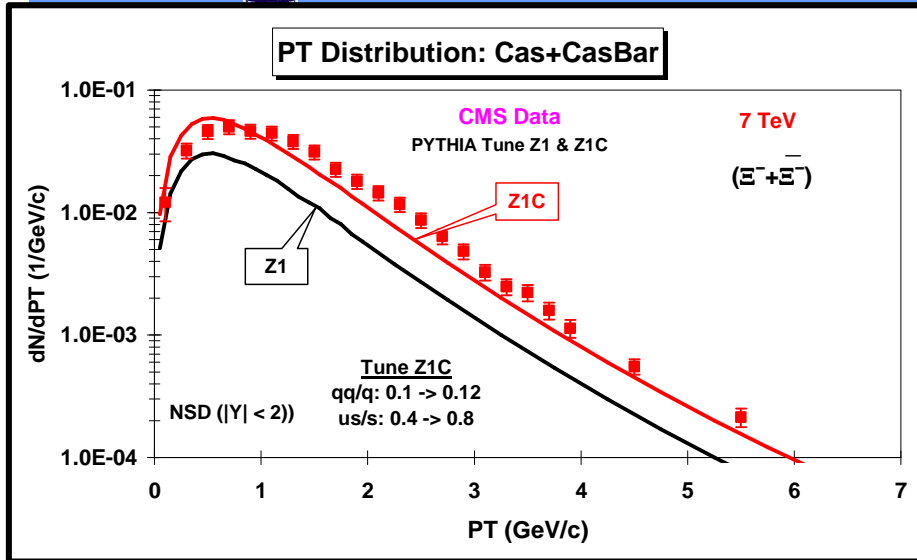
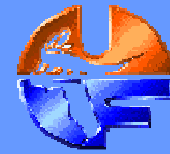
“Minimum Bias” Collisions

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





Transverse Momentum Distributions

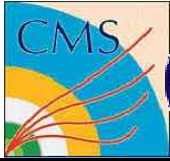


→ **CMS NSD data** on the Cascade⁻+AntiCascade⁻ transverse momentum distribution at 7 TeV compared with **PYTHIA Tune Z1 & Z1C**. The plot shows the average number of particles per NSD collision per unit p_T , $(1/N_{NSD}) dN/dp_T$ for $|Y| < 2$.

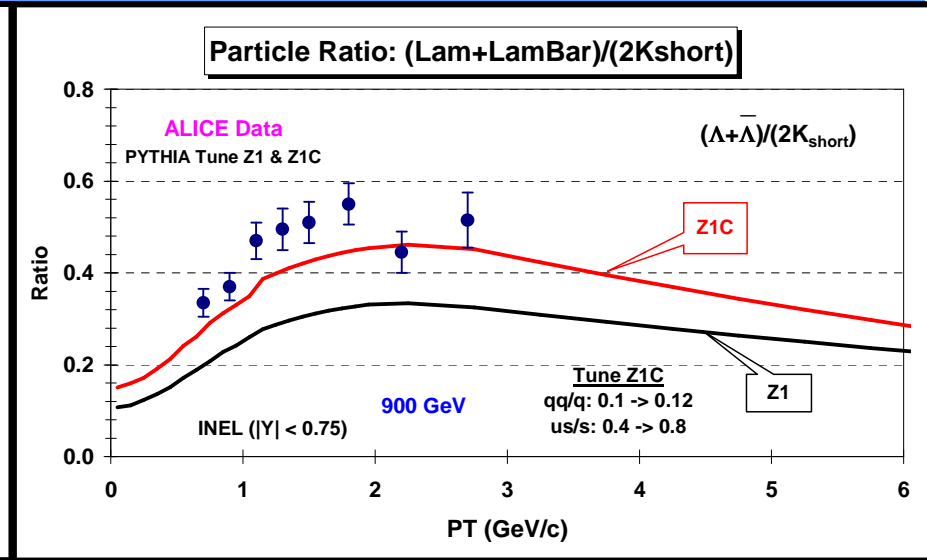
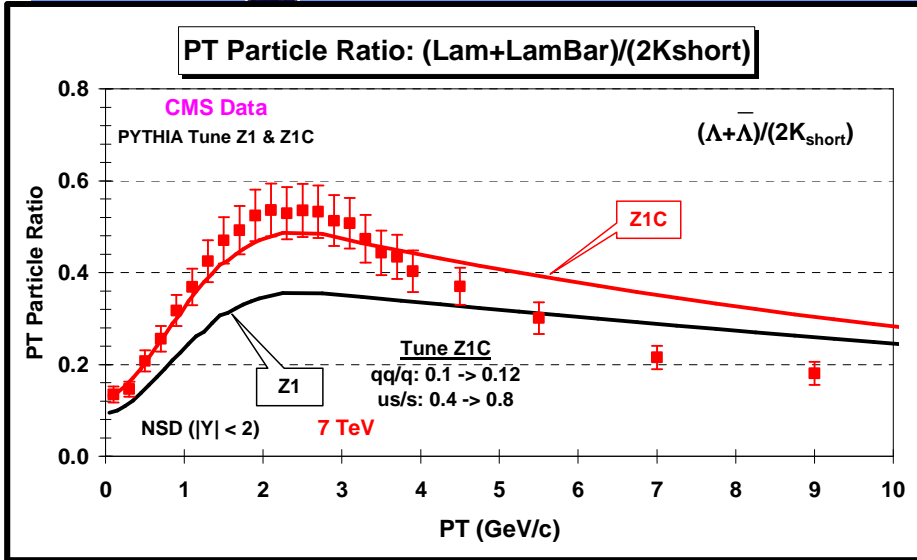
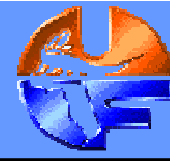
→ **CMS NSD data** on the Cascade⁻+AntiCascade⁻ transverse momentum distribution at 7 TeV (**normalized to 1**) compared with **PYTHIA Tune Z1 & Z1C**.

“Minimum Bias” Collisions

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



Particle Ratios versus p_T



→ CMS NSD data on the Lambda+AntiLambda to $2K_{\text{short}}$ ratio versus p_T at 7 TeV ($|Y| < 2$) compared with **PYTHIA Tune Z1 & Z1C**.

→ ALICE INEL data on the Lambda+AntiLambda to $2K_{\text{short}}$ ratio versus p_T at 900 GeV ($|Y| < 0.75$) compared with **PYTHIA Tune Z1 & Z1C**.

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

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

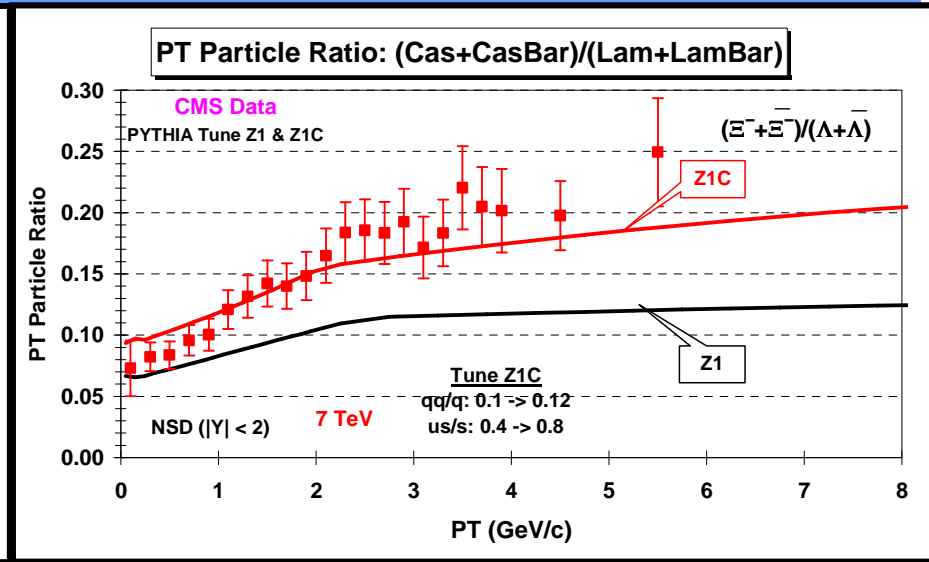
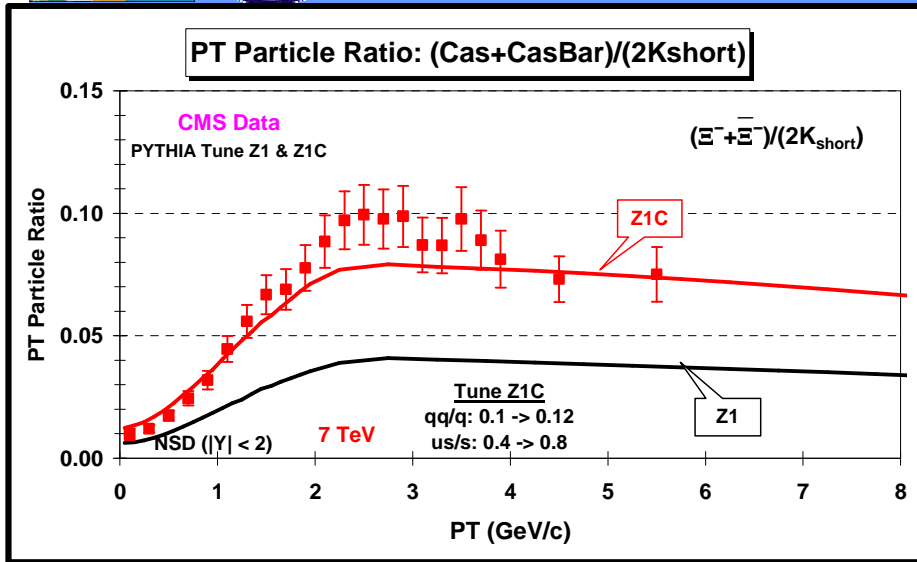
“Minimum Bias” Collisions

Tune Z1C is not too bad but a bit off on the p_T dependence!





Particle Ratios versus p_T



➔ **CMS NSD data** on the Cascade⁻+AntiCascade⁻ to $2K_{\text{short}}$ ratio versus p_T at 7 TeV ($|Y| < 2$) compared with **PYTHIA Tune Z1 & Z1C**.

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

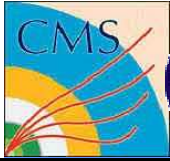
➔ **CMS NSD data** on the Cascade⁻+AntiCascade⁻ to Lambda+AntiLambda ratio versus p_T at 7 TeV ($|Y| < 2$) compared with **PYTHIA Tune Z1 & Z1C**.

$$\frac{(\Xi^- + \bar{\Xi}^-)}{(\Lambda + \bar{\Lambda})} = \frac{\text{Double-strange Baryon}}{\text{Single-strange Baryon}}$$

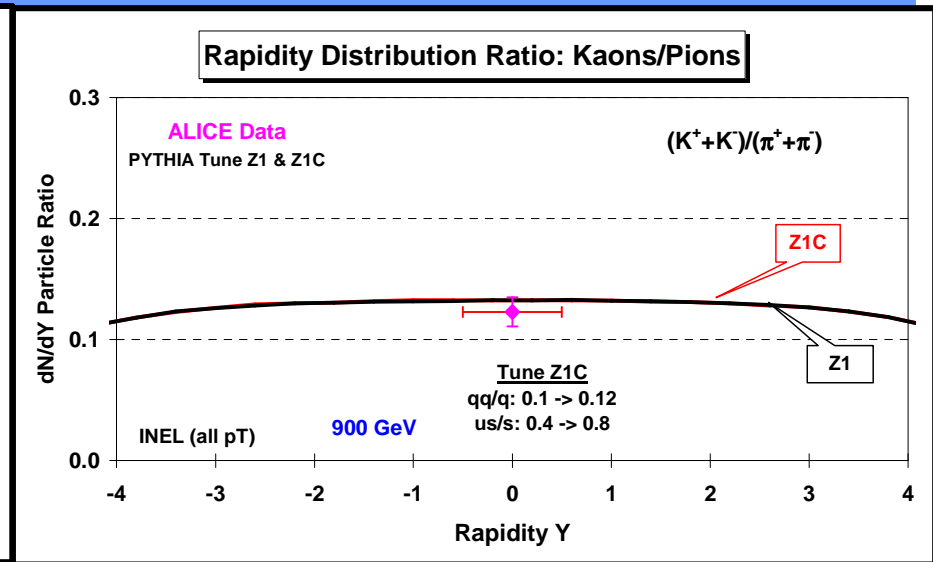
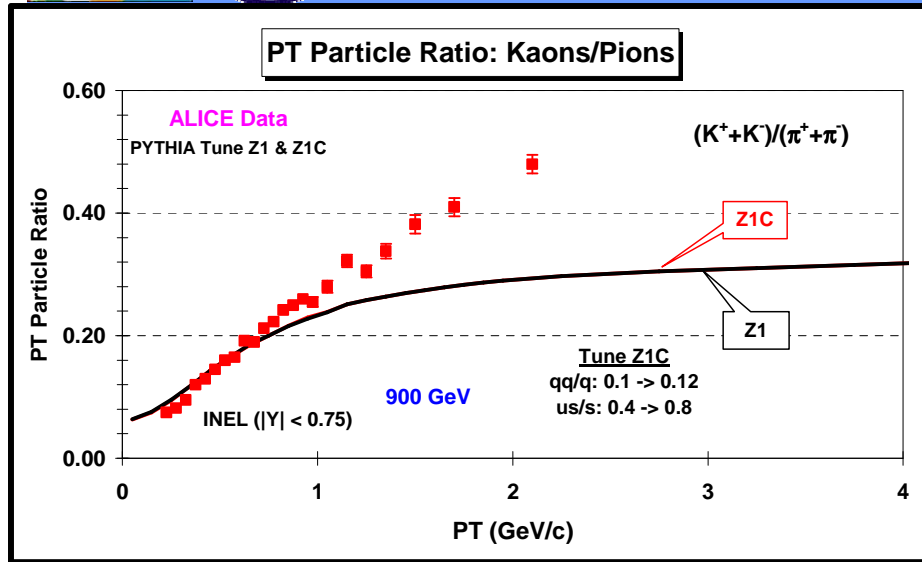
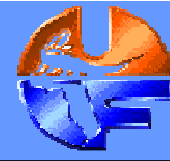
“Minimum Bias” Collisions

Tune Z1C is not too bad but a bit off on the p_T dependence!





Particle Ratios versus 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.

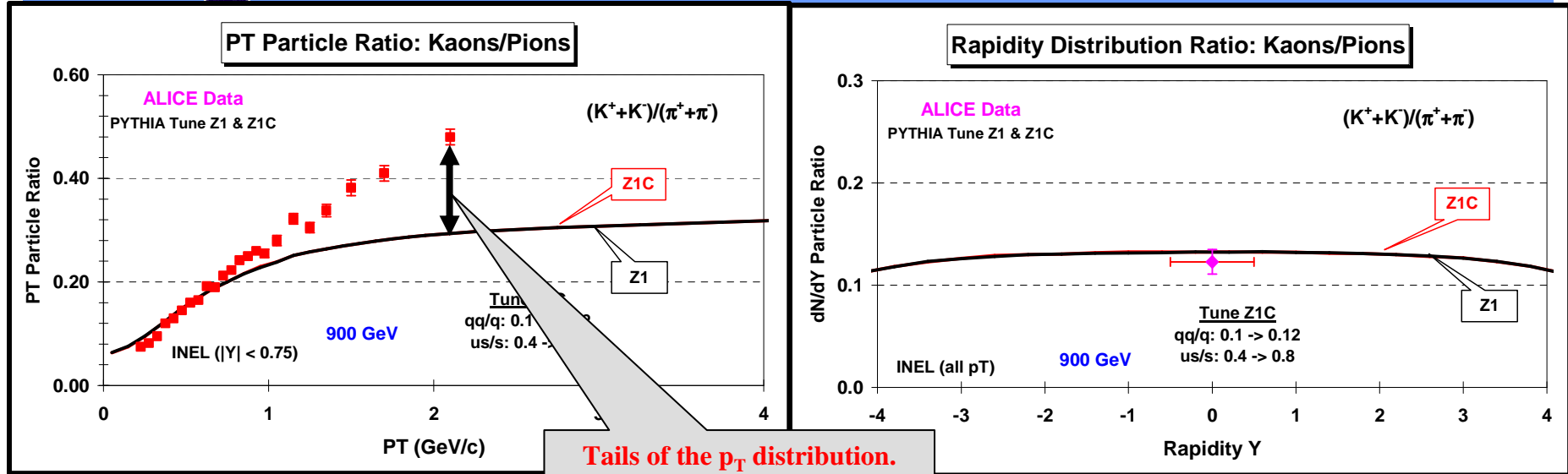
$$\frac{(K^+ + K^-)}{(\pi^+ + \pi^-)} = \frac{\text{Strange Meson}}{\text{Non-strange Meson}}$$

“Minimum Bias” Collisions

Tune Z1C is not too bad but a way off on the p_T dependence!



Particle Ratios versus 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**.

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

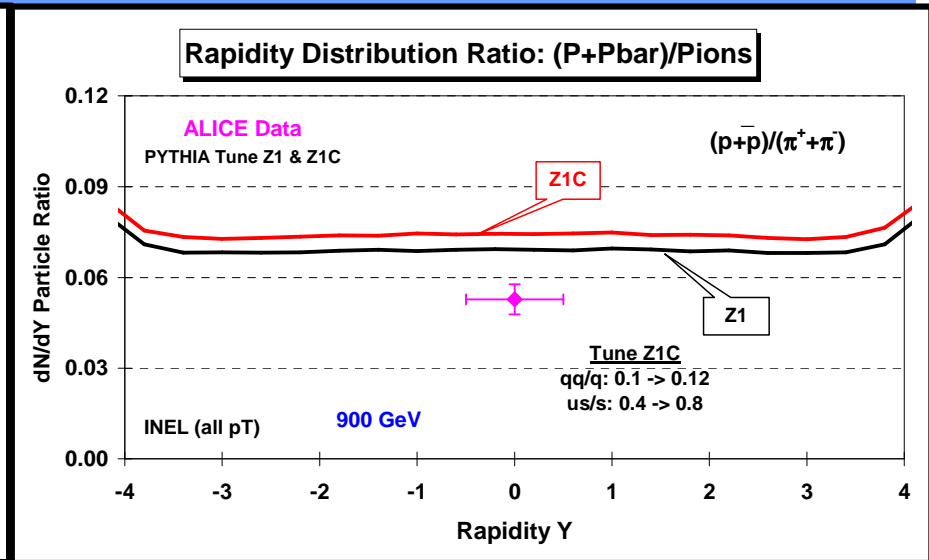
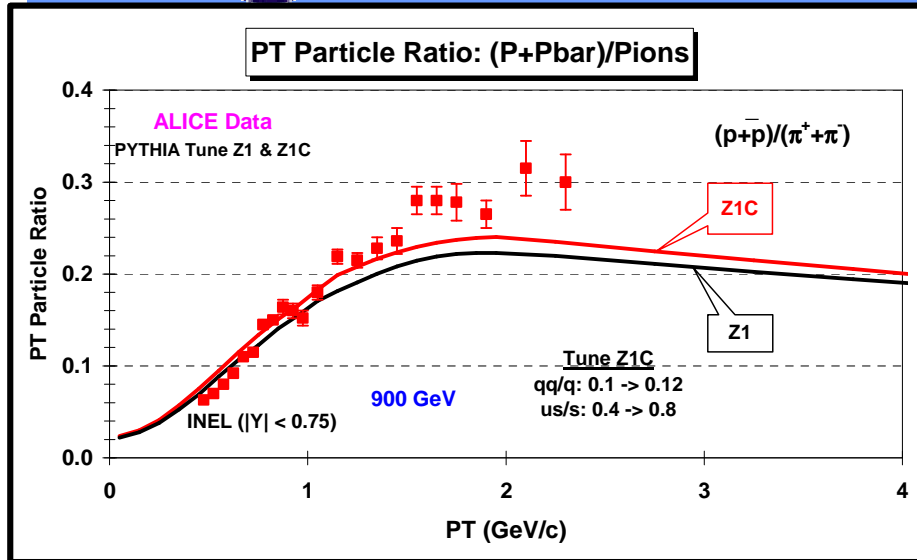
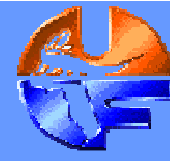
“Minimum Bias” Collisions

Tune Z1C is not too bad but a way off on the p_T dependence!





Particle Ratios versus p_T



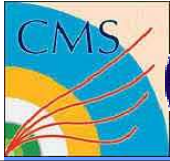
➔ ALICE INEL data on the Proton+AntiProton to charged pions ratio versus p_T at 900 GeV ($|Y| < 0.75$) compared with **PYTHIA Tune Z1 & Z1C**.

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

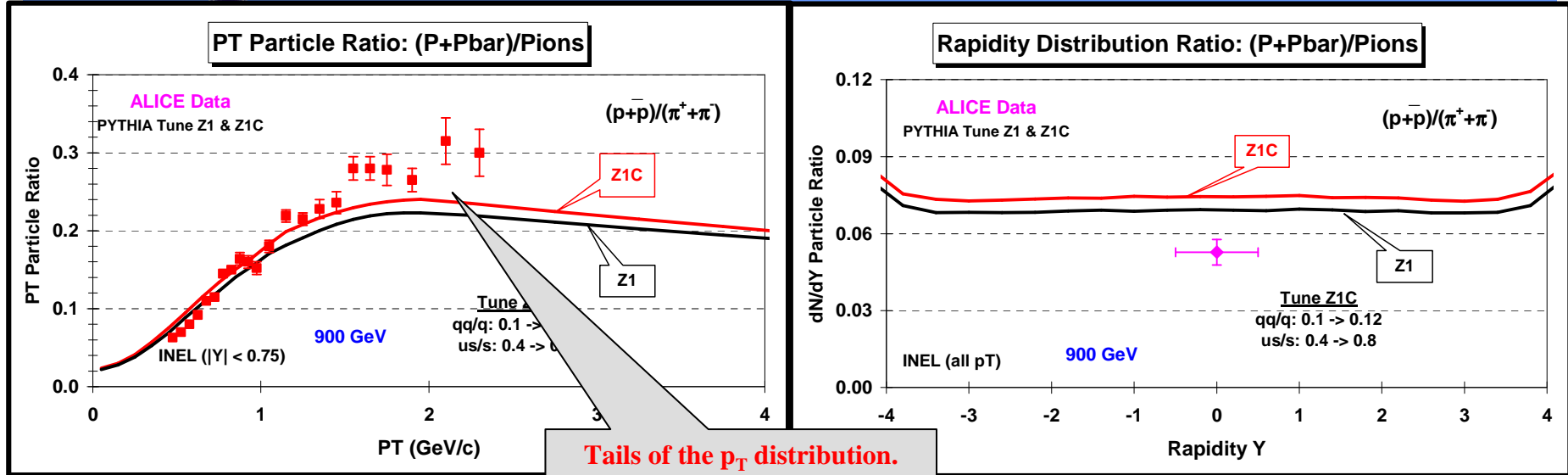
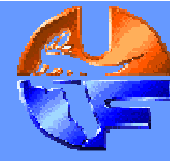
$$\frac{(p + \bar{p})}{(\pi^+ + \pi^-)} = \frac{\text{Non-strange Baryon}}{\text{Non-strange Meson}}$$

“Minimum Bias” Collisions

Tune Z1C is not too bad but way off on the p_T dependence!



Particle Ratios versus p_T



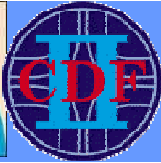
→ ALICE INEL data on the Proton+AntiProton to charged pions ratio versus p_T at 900 GeV ($|Y| < 0.75$) compared with **PYTHIA Tune Z1 & Z1C**.

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

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

“Minimum Bias” Collisions

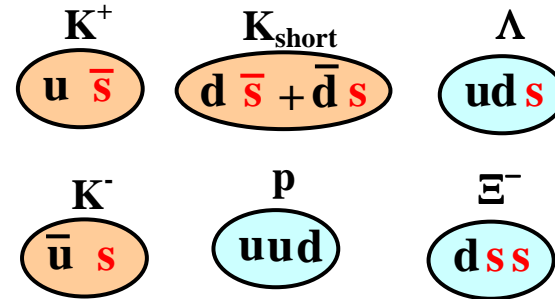
Tune Z1C is not too bad but way off on the p_T dependence!



Fragmentation Summary

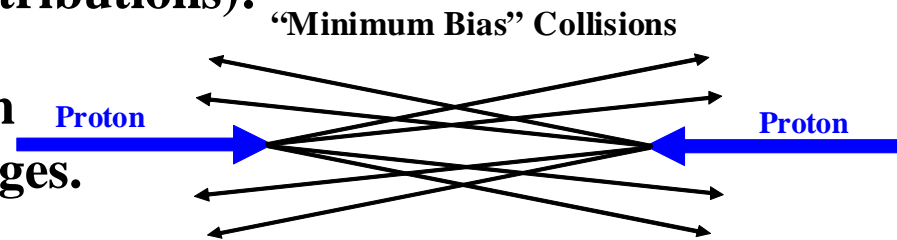


➔ Not too hard to get the overall yields of baryons and strange particles roughly right at 900 GeV and 7 TeV. **Tune Z1C does a fairly good job with the overall particle yields at 900 GeV and 7 TeV.**



➔ **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)!

➔ **ATLAS Tuning Effort:** Fragmentation flavor tuning at the one of the four stages.



➔ **Other Fragmentation Tuning:** There is additional tuning involving jet shapes, FSR, and ISR that I did not have time to include in this talk.