QCD@LHC 2011

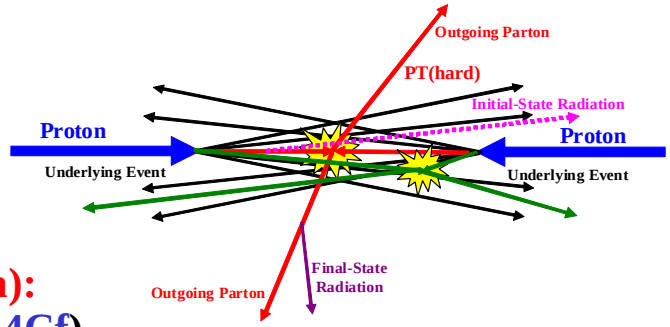
CMS QCD MC Model Tuning Efforts?

Rick Field

University of Florida

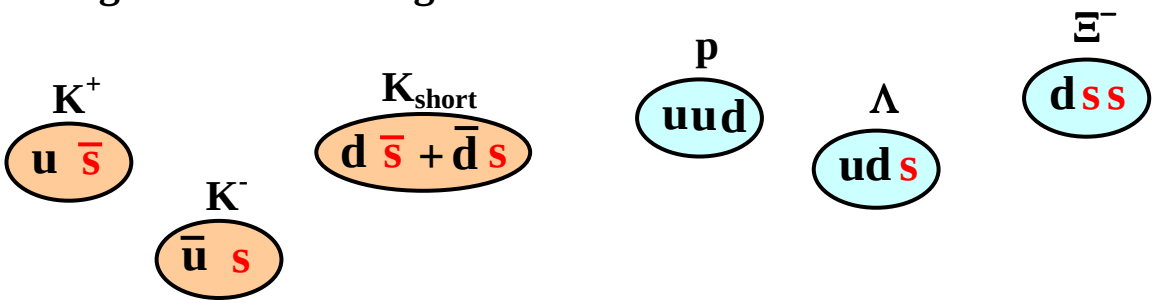
Outline

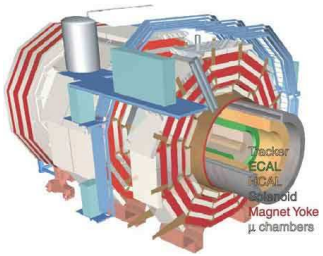
- **A few of the LHC PYTHIA Tunes:** Rick's CMS PYTHIA 6.4 tunes (Z1, Z2), Peter's PYTHIA 6.4 Perugia 2011 tunes (S350, S356), and PYTHIA 8 Tune 4C (Corke & Sjöstrand).



- **CMS Related PYTHIA Tunes (A. Knutsson, M. Zakaria):** Pythia 6.4 (Tune Z2* and Tune Z2f), Pythia 8 (4C* and 4Cf).

- **Baryon and Strange Particle Production at the LHC:** Fragmentation tuning.





CMS

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CMS QCD MC Model Tuning Efforts?

Rick Field

University of Florida

Quantum Chromo-Dynamics

Tune Z1 and Z2 are officially approved by CMS!

These tunes have not been officially approved by CMS!

Outline

- **A few of the LHC PYTHIA Tunes:** Rick's PYTHIA 6.4 tunes (Z1, Z2), Peter's PYTHIA Perugia 2011 tunes (S350, S356), and PYTHIA Tune 4C (Corke & Sjöstrand).
- **CMS Related PYTHIA Tunes (A. Knutsson, M. Zakaria):** Pythia 6.4 (Tune Z2* and Tune Z2f), Pythia 8 (4C* and 4Cf).
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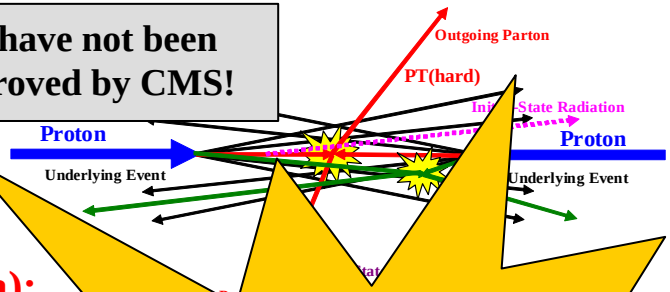
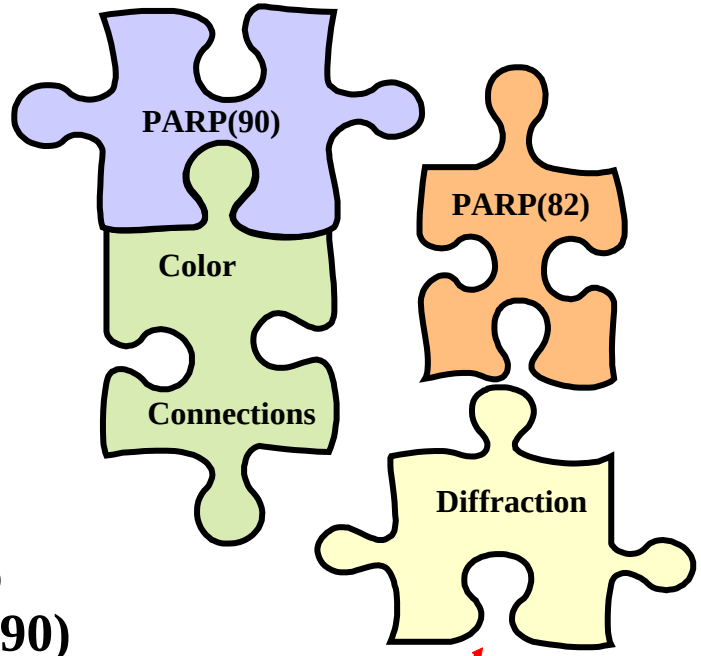


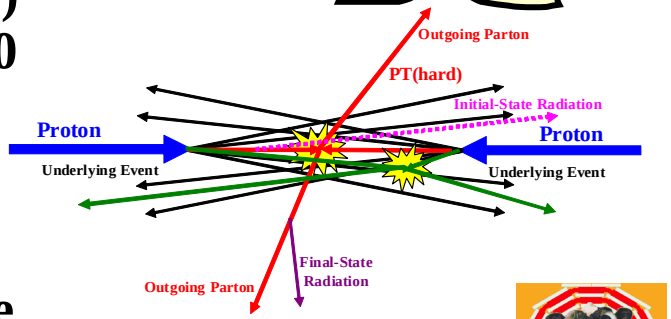
I am not going to discuss all the nice tunes coming from the ATLAS tuning effort which is very impressive!

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

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

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 gaussion 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

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

My guess!

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

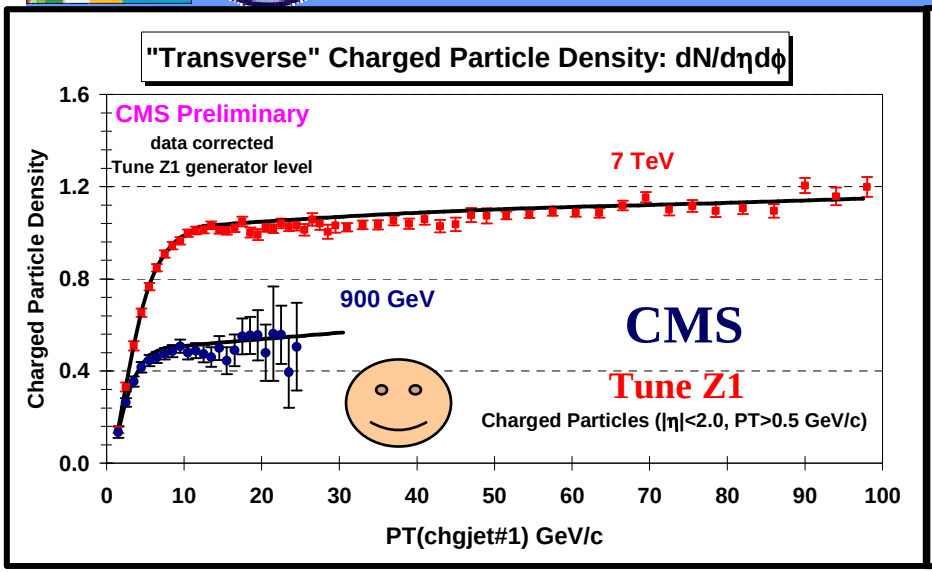
PT0 = PARP(82)

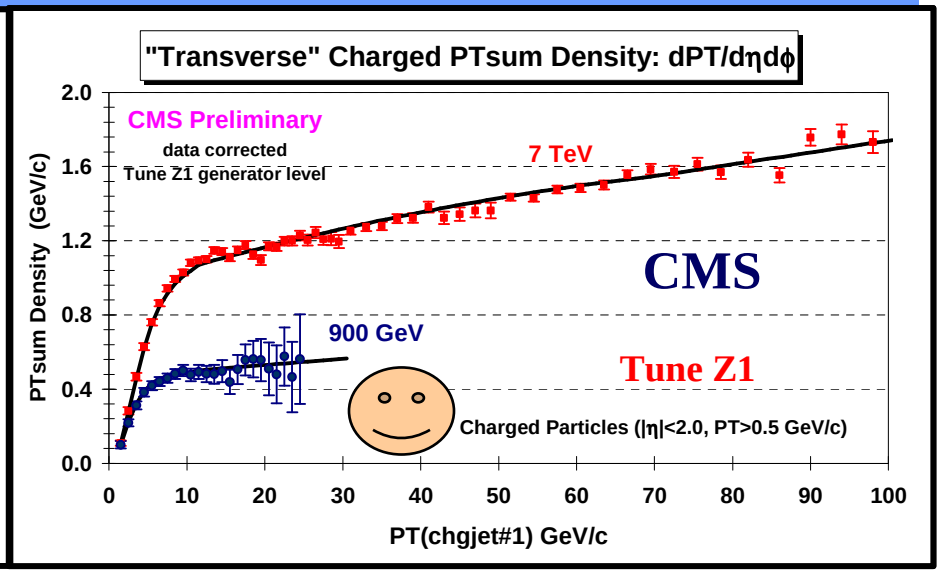
ε = PARP(90)

Parameter	Tune 2C (CTEQ6L)	Tune 2M (MRST LO**)	Tune 4C (CTEQ6L)
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
	Tevatron		LHC

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

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 $|\eta| < 2.0$. The data are corrected and compared with PYTHIA Tune Z1 at the generator level.**

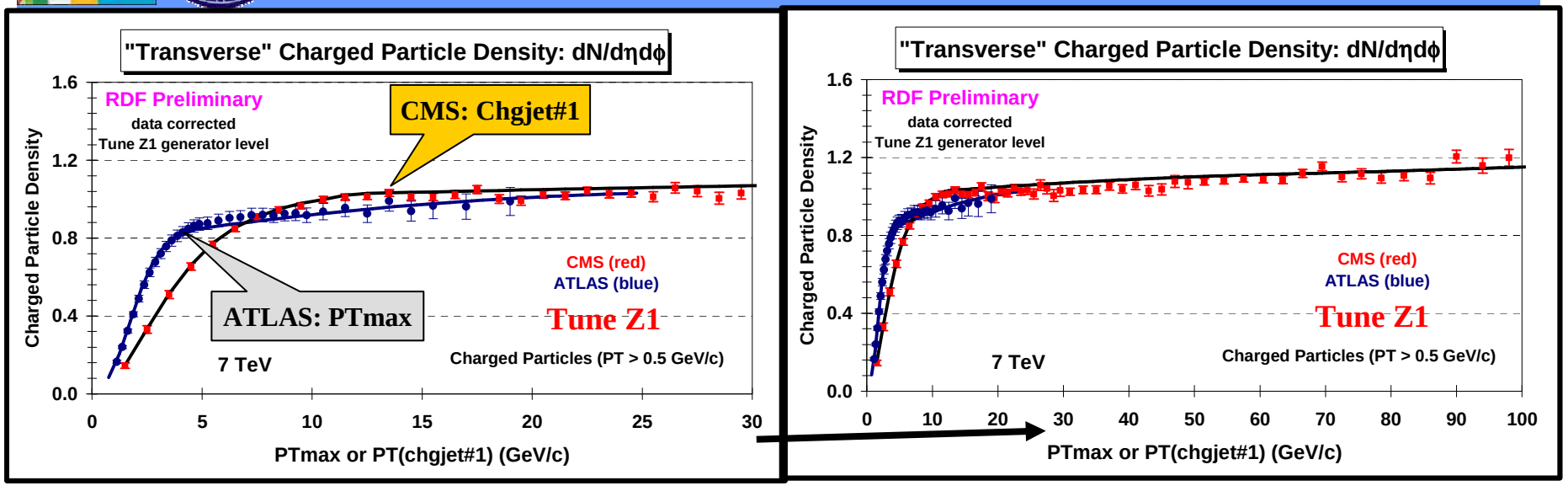
- **CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged PTsum density, dPT/dηdϕ, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$. The data are corrected and compared with PYTHIA Tune Z1 at the generator level.**

CMS corrected data!

Very nice agreement!

CMS corrected data!

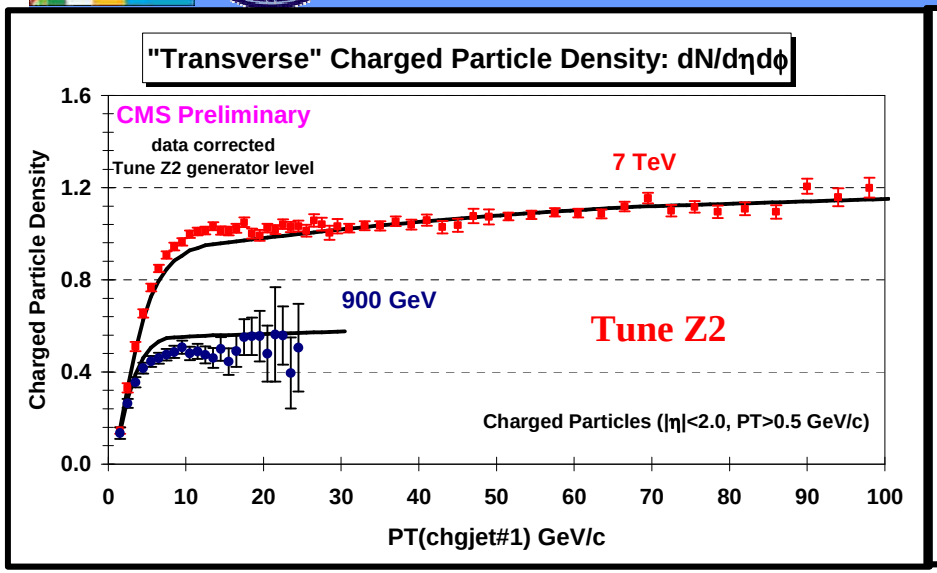
CMS-ATLAS UE Data

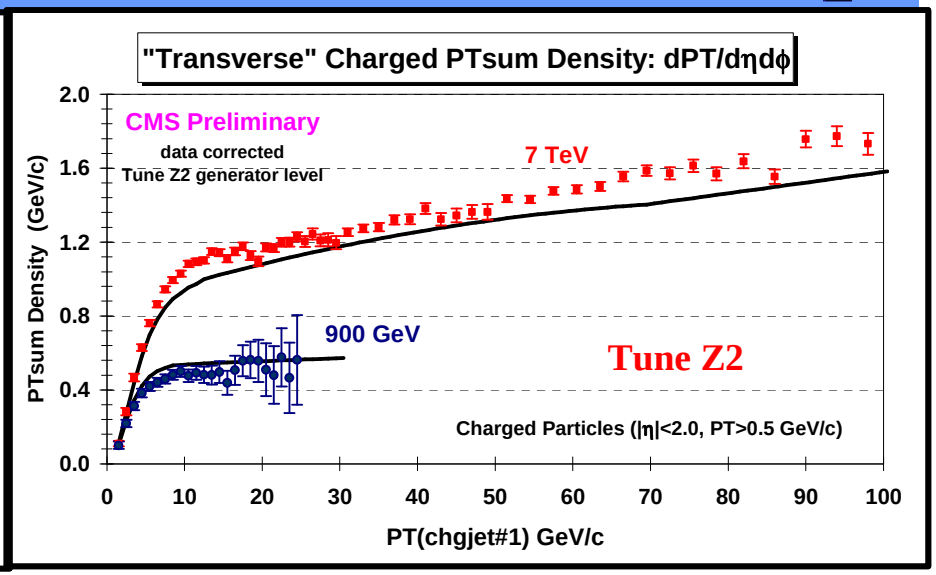


➡ **CMS preliminary data at 7 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$ together with the ATLAS published data at 7 TeV on the "transverse" charged particle density,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

Amazing agreement!

PYTHIA 6.4 Tune Z2





- **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 $|\eta| < 2.0$. The data are corrected and compared with PYTHIA Tune Z2 at the generator level.**

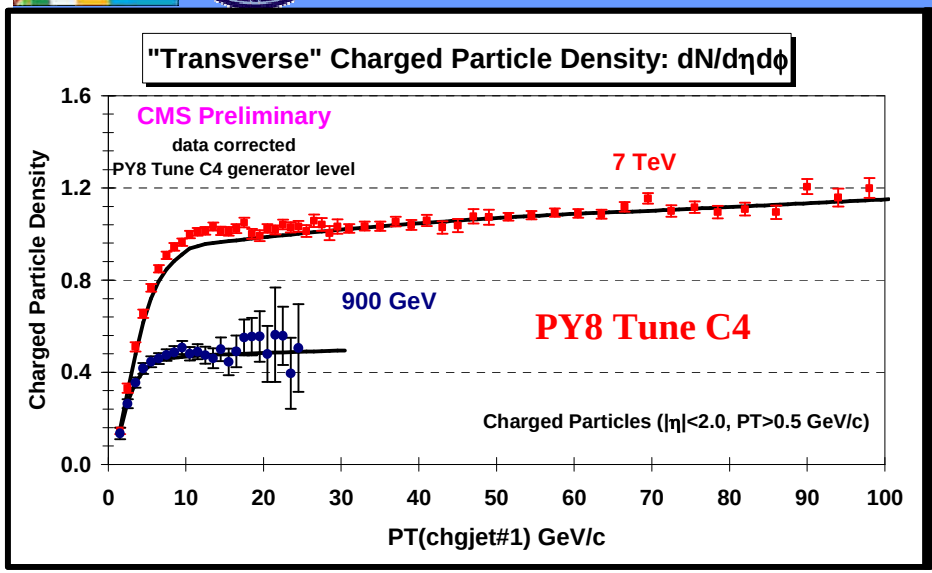
- **CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged PTsum density, dPT/dηdϕ, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$. The data are corrected and compared with PYTHIA Tune Z2 at the generator level.**

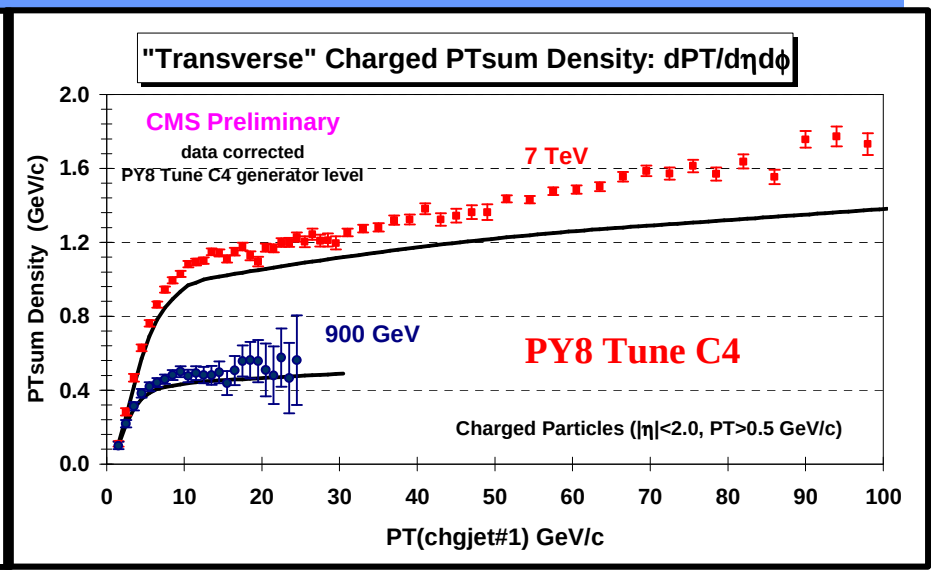
CMS corrected data!

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/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 8 Tune C4 at the generator level.**

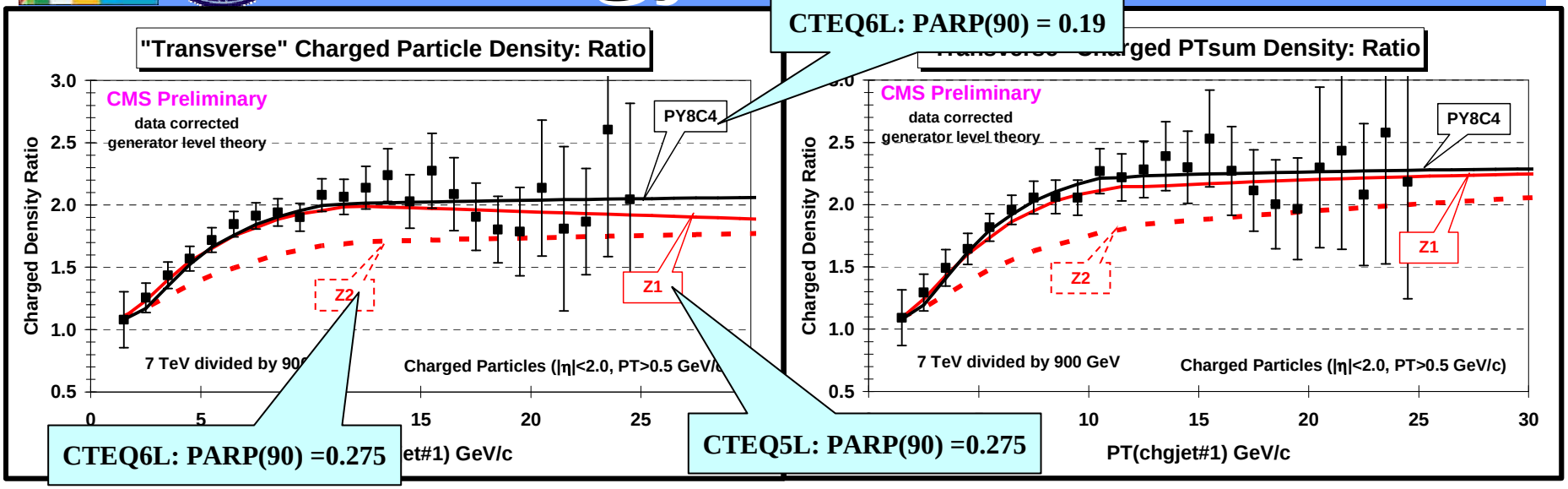
- **CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged PTsum density, dPT/dηdϕ, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$. The data are corrected and compared with PYTHIA 8 Tune C4 at the generator level.**

CMS corrected data!

Not good! PTsum too small!

CMS corrected data!

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.

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CMS corrected data!

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

CMS corrected data!

PYTHIA Tune Z2

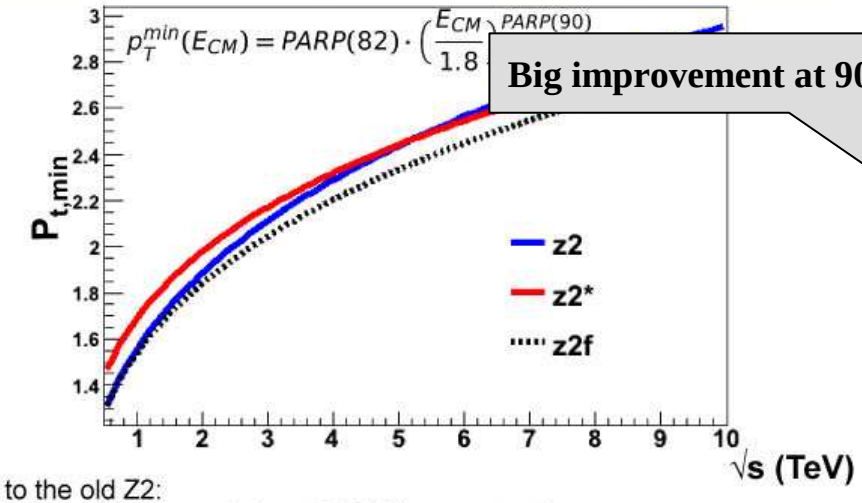
Parameter	Tune Z2 (R. Field CMS)	PY8 Tune C4 (Corke-Sjöstrand)
Parton Distribution Function	CTEQ6L	CTEQ6L
PARP(82) – MPI Cut-off	1.832	2.085
PARP(89) – Reference energy, E0	1800.0	1800.0
PARP(90) – MPI Energy Extrapolation	0.275	0.19
PARP(77) – CR Suppression	1.016	
PARP(78) – CR Strength	0.538	
PARP(80) – 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 gaussion matter distribution	4	
MSTP(91) – Gaussian primordial kT	1	
MSTP(95) – strategy for color reconnection	6	

PARP(90) much different!

PYTHIA Tune Z2*

CMS Tune Z2*
(Professor tune, A. Knutsson & M. Zakaria)

	Tuning Range	Z2	Z2* (UE)	Z2f (Forward)
PARP(82)	1.0 - 3.0	1.83	1.93	1.79
PARP(90)	0.0 - 0.4	0.28	0.23	0.26

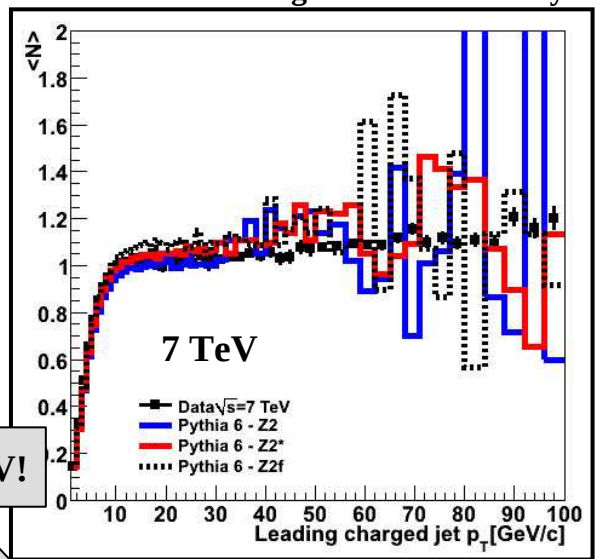


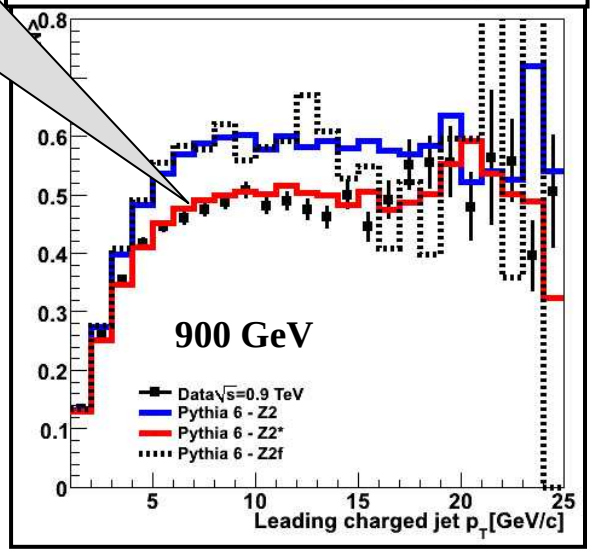
Compared to the old Z2:

- Z2* will increase the activity at 7 TeV (lower pt-cut)
  Z2* will decrease the activity at 0.9 TeV (higher pt-cut)
- Z2f will not do much at 0.9 TeV, but will increase the activity at 7 TeV.

Big improvement at 900 GeV!

"Transverse" Charged Particle Density



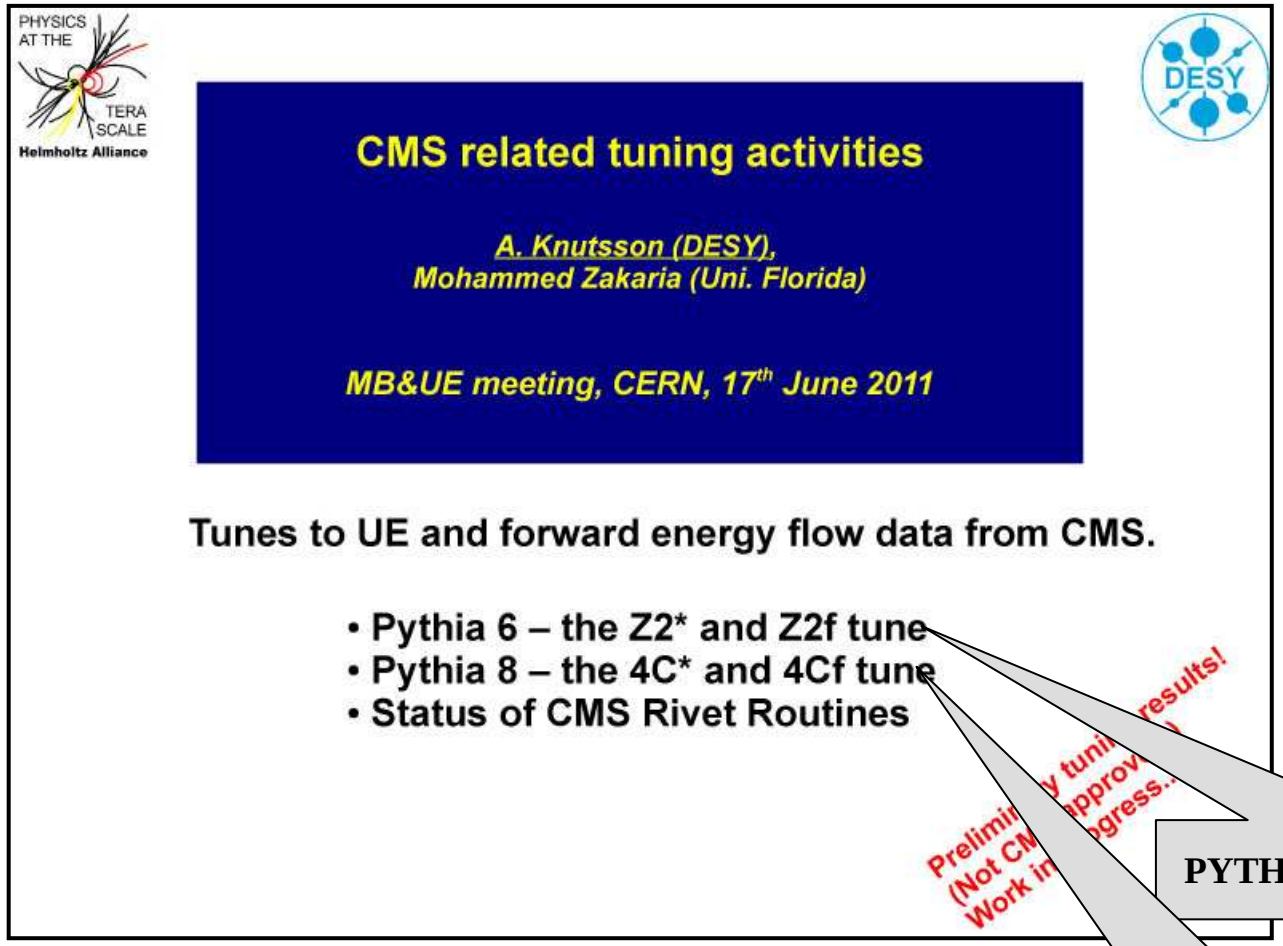


PYTHIA Tune Z2*

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 gaussion 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).

Other CMS Tunes



PYTHIA 6.4 "Forward Tune"!

Two PYTHIA tunes!

PYTHIA 6.4.25

4th generation: tunes incorporating 7-TeV data **PYTUNE**

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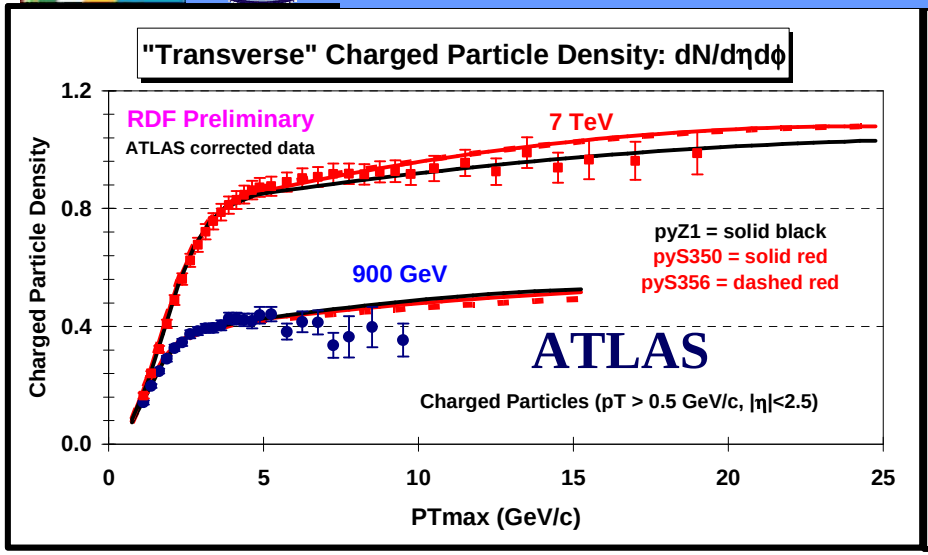
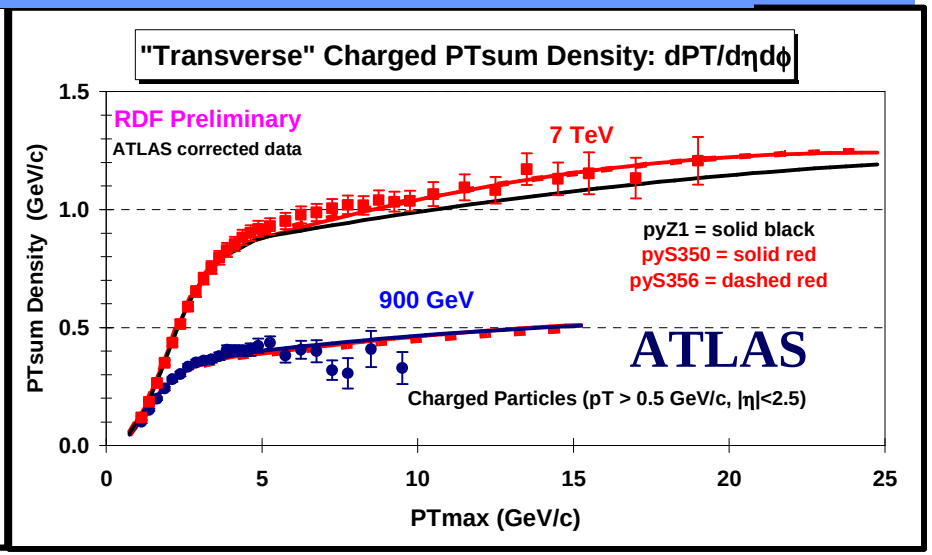
340 AMBT1 : 1st ATLAS tune incl 7 TeV, w. LO* PDFs (2010)
341 Z1 : Retune of AMBT1 by Field w CTEQ5L PDFs (2010)
342 Z1-LEP : Retune of Z1 by Skands w CTEQ5L PDFs (2010)
343 Z2 : Retune of Z1 by Field w CTEQ6L1 PDFs (2010)
344 Z2-LEP : Retune of Z1 by Skands w CTEQ6L1 PDFs (2010)
350 Perugia 2011 : Retune 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

The Perugia tunes have "improved" LEP fragmentation tuning!

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 partic[illegible]/c and |η| < 2.5. The d[illegible] compared with PYTHIA Tune Z1, T[illegible] S350, and Tune S356 at the generator le[illegible].**

Very similar to Tune Z1!

- **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 [illegible] 0.5 GeV/c and |η| < 2.5. [illegible] data are corrected and compared with PYTHIA Tune Z1, Tune S350, and Tune S356 at the generrator level.**

Very similar to Tune Z2*!

Tune S350 & S356 (Perugia 2011) fit the UE data at 900 GeV & 7 TeV very well!

PY6.4 CTEQ5L Tunes

Parameter	Tune Z1 (R. Field CMS)	Tune S350 (P. Skands)
Parton Distribution Function	CTEQ5L	CTEQ5L
PARP(82) – MPI Cut-off	1.932	2.93
PARP(89) – Reference energy, E0	1800.0	7000.0
PARP(90) – MPI Energy Extrapolation	0.275	0.265
PT0(at 900 GeV)	1.597	1.701
PT0(at 1.96 TeV)	1.978	2.091
PT0(at 7 TeV)	2.807	2.930

Tune S350 and Tune Z1 are very similar!

PY6.4 CTEQ6L Tunes

Parameter	Tune Z2 (CMS)	Tune Z2* (CMS)	Tune S356 (P. Skands)
Parton Distribution Function	CTEQ6L	CTEQ6L	CTEQ6L
PARP(82) – MPI Cut-off	1.832	1.927	2.65
PARP(89) – Reference energy, E0	1800.0	1800.0	7000.0
PARP(90) – MPI Energy Extrapolation	0.275	0.225	0.220
PT0(at 900 GeV)	1.514	1.649	1.688
PT0(at 1.96 TeV)	1.875	1.964	2.003
PT0(at 7 TeV)	2.662	2.616	2.650

Tune S356 and Tune Z2* are very similar!

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*.

ALICE INEL

ALICE INEL

CMS NSD

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

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

K^+	K^-	K_{short}	p	Λ	Ξ^-
$u\,\bar{s}$	$\bar{u}\,s$	$d\,\bar{s} + \bar{d}\,s$	uud	ud s	d s s

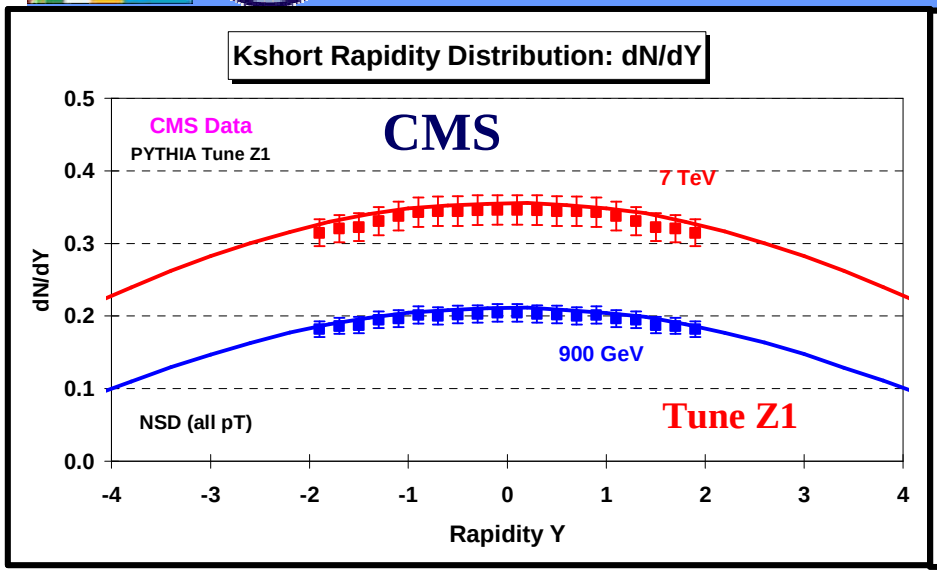
Step 2: Look at the ratios of the overall particle yields (all p_T).

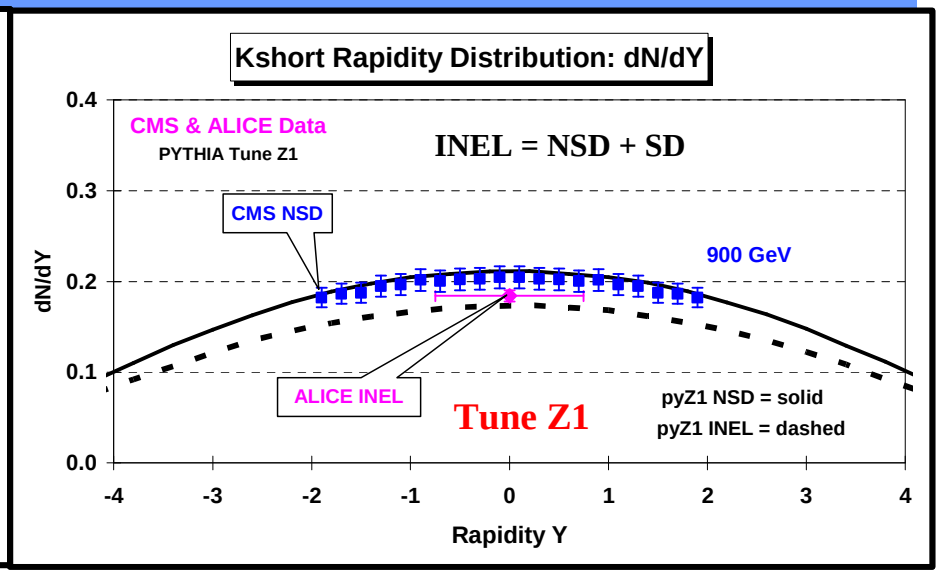
$$\frac{(K^+ + K^-)}{(\pi^+ + \pi^-)} = \frac{\text{Strange Meson}}{\text{Non-strange Meson}} \qquad \frac{K_{short}}{(\pi^+ + \pi^-)} = \frac{\text{Strange Meson}}{\text{Non-strange Meson}}$$

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

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

Kaon Production





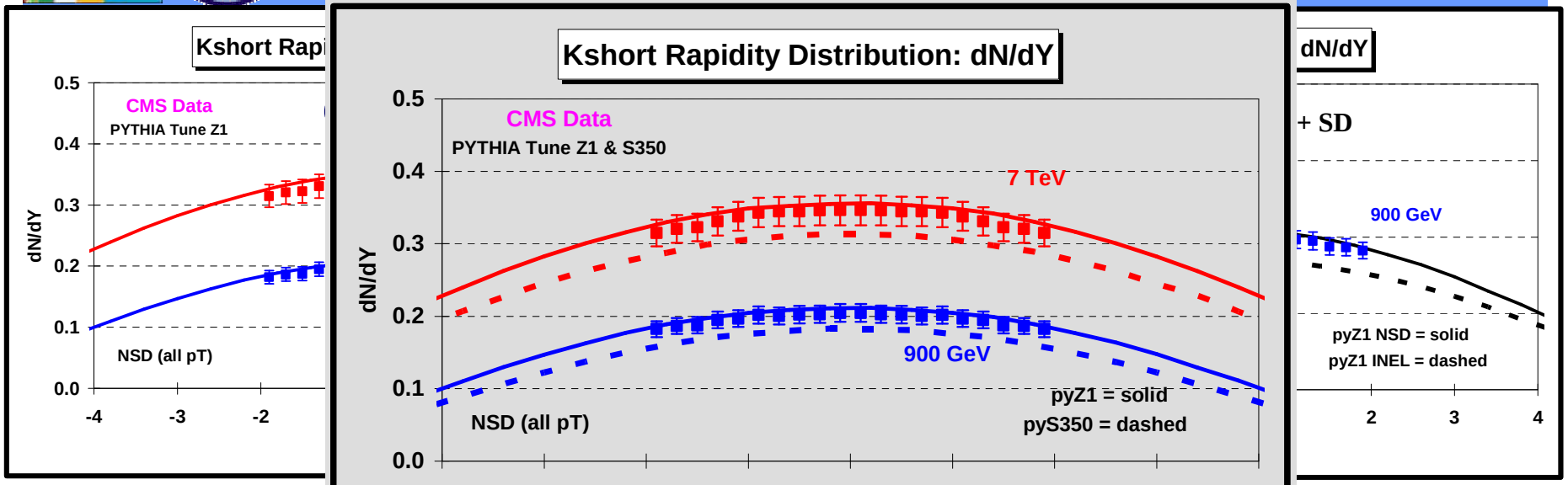
- **CMS NSD data on the K_{short} rapidity distribution at 7 TeV and 900 GeV compared with PYTHIA Tune Z1. The plot shows the average number of K_{short} per NSD collision per unit Y, ($1/N_{NSD}$) dN/dY.**

- **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

No overall shortage of Kaons in PYTHIA Tune Z1!

Kaon Production



- **CMS NSD data** … **rapidity distribution at** … **the ALICE point at Y = 0 (INEL) 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.** **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.**

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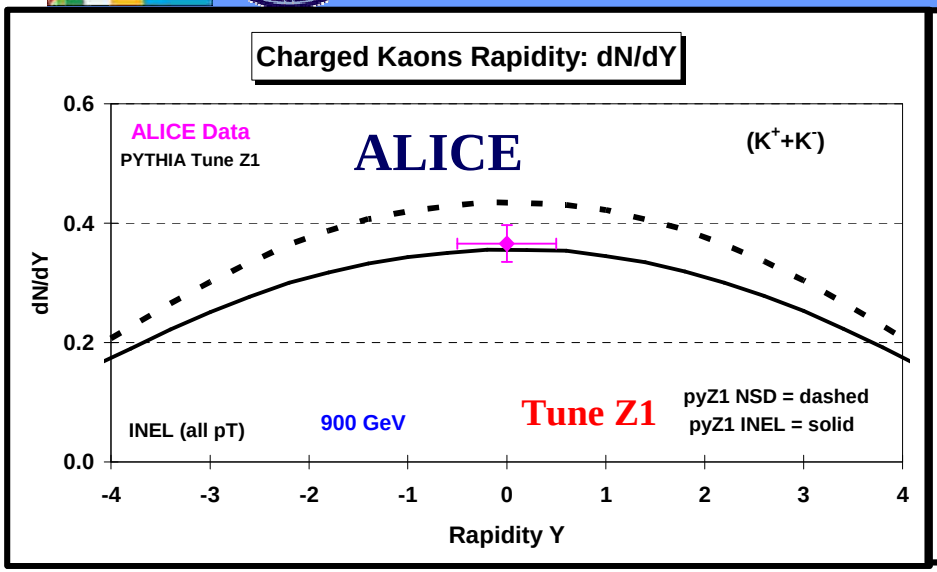

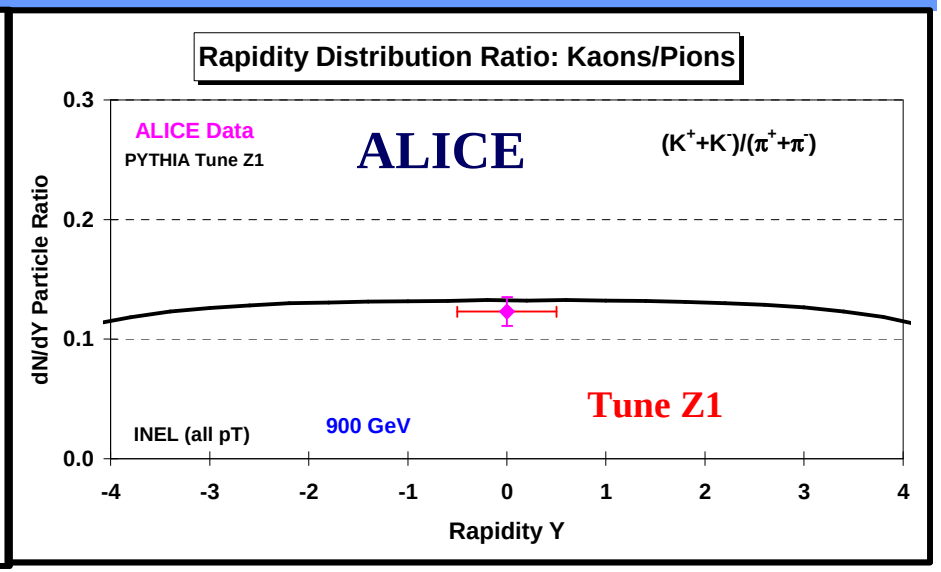

- **ALICE INEL data on the charged kaon rapidity distribution at 900 GeV compared with PYTHIA Tune Z1. The plot shows the average number of charged kaons per INEL collision per unit Y at Y = 0, $(1/N_{INEL})\ dN/dY$.**

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

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

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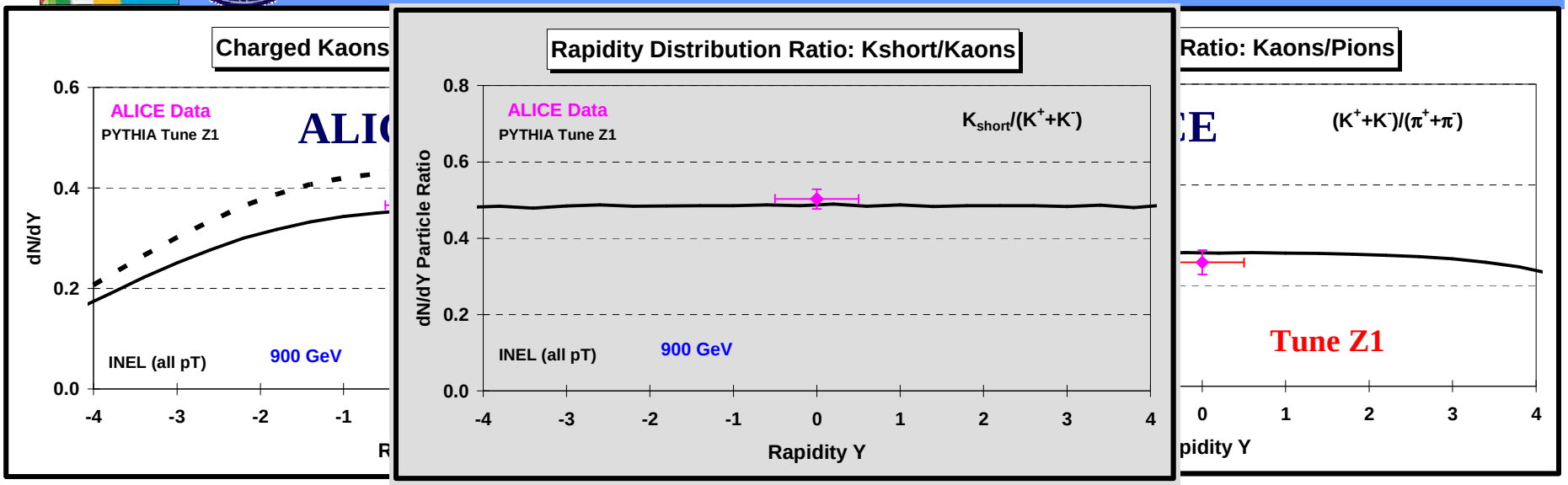

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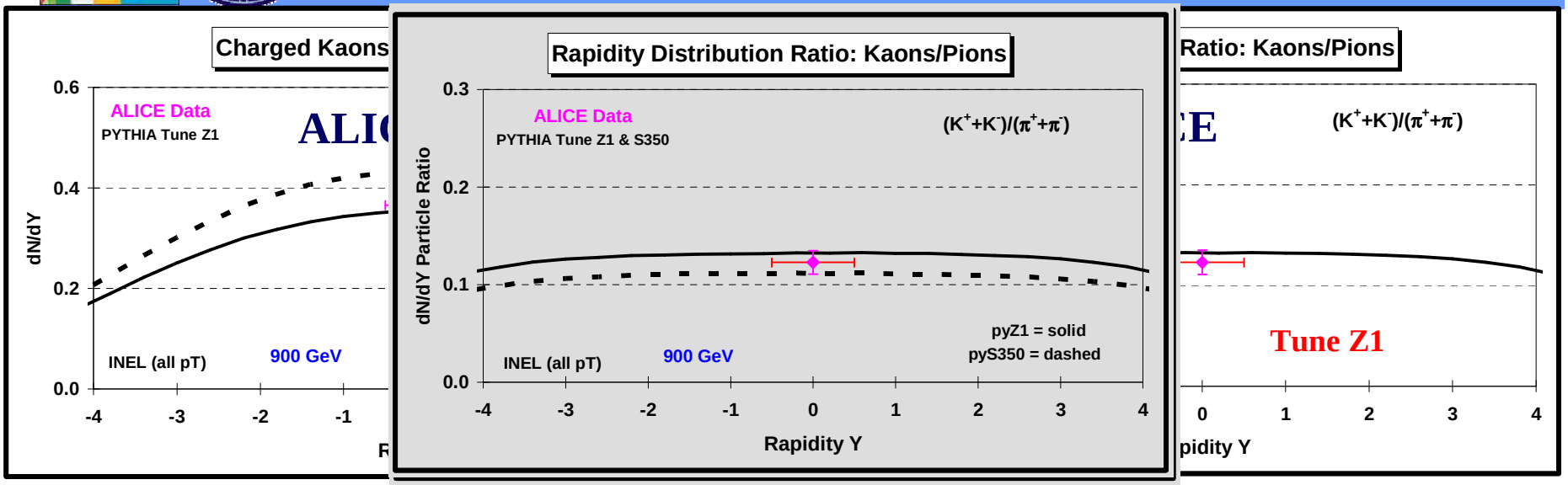

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"Minimum Bias" Collisions

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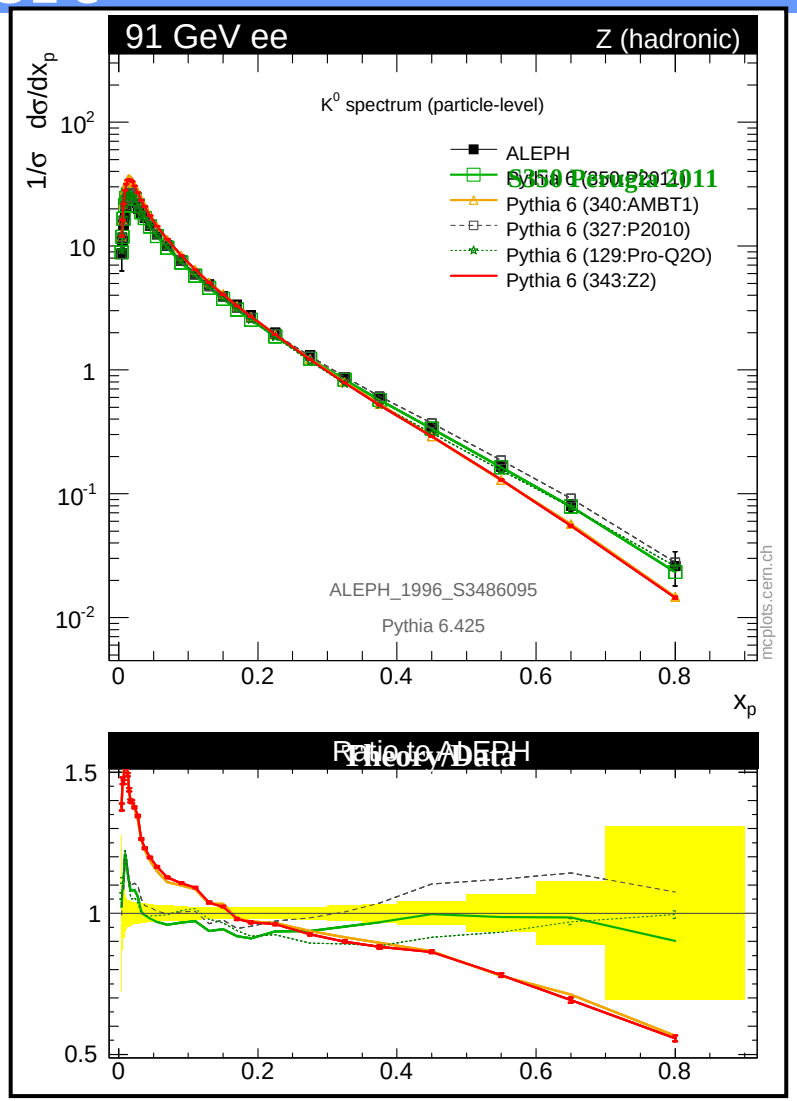
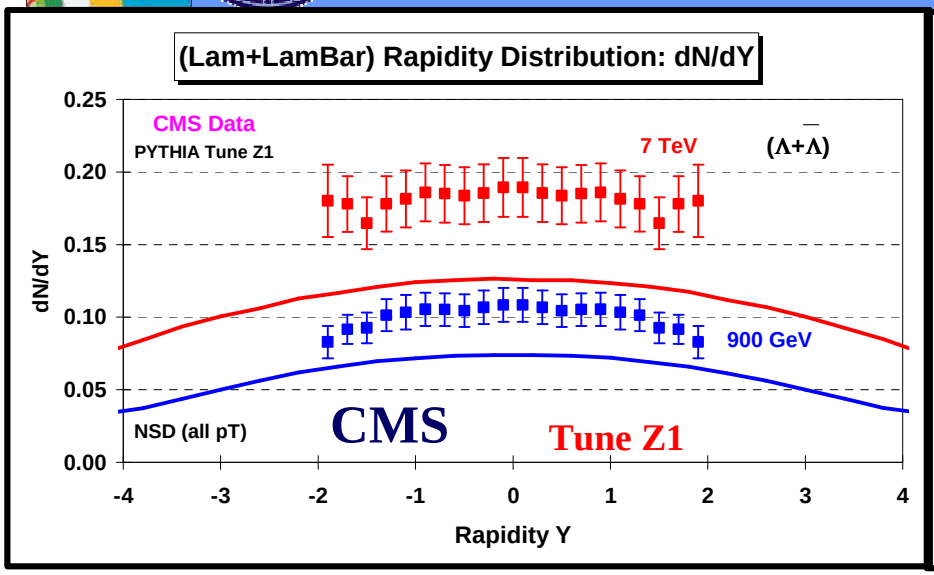
LEP: K_{short} Spectrum

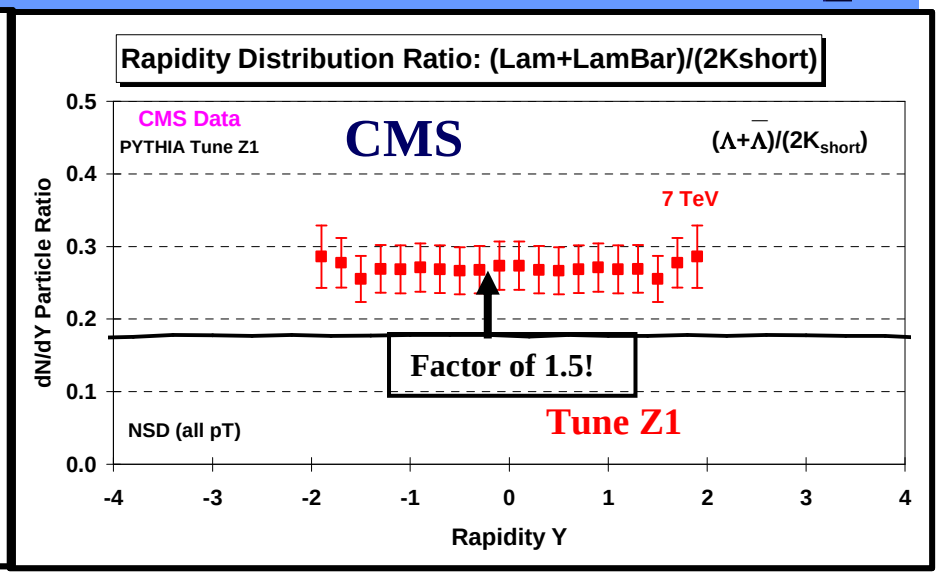
mcplots.cern.ch

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



Lambda Production





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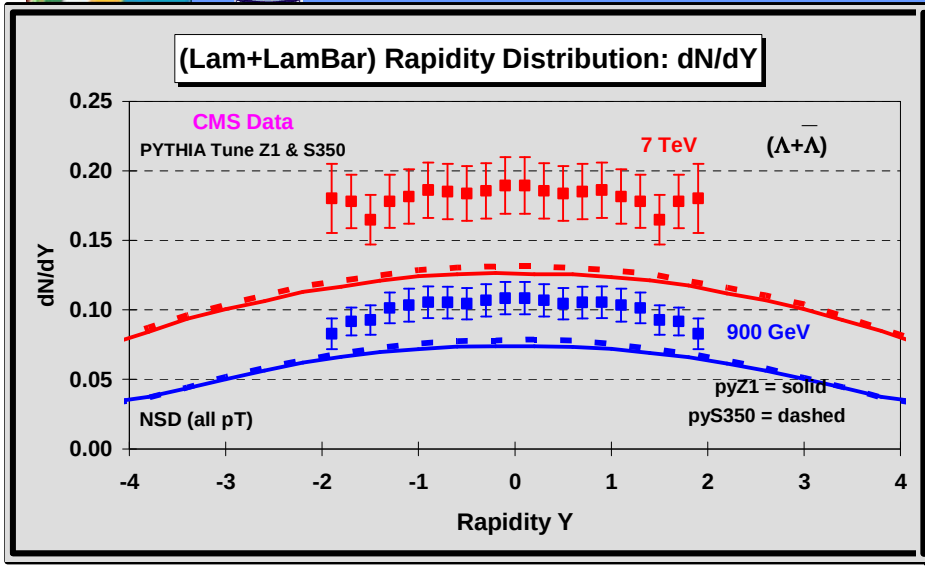
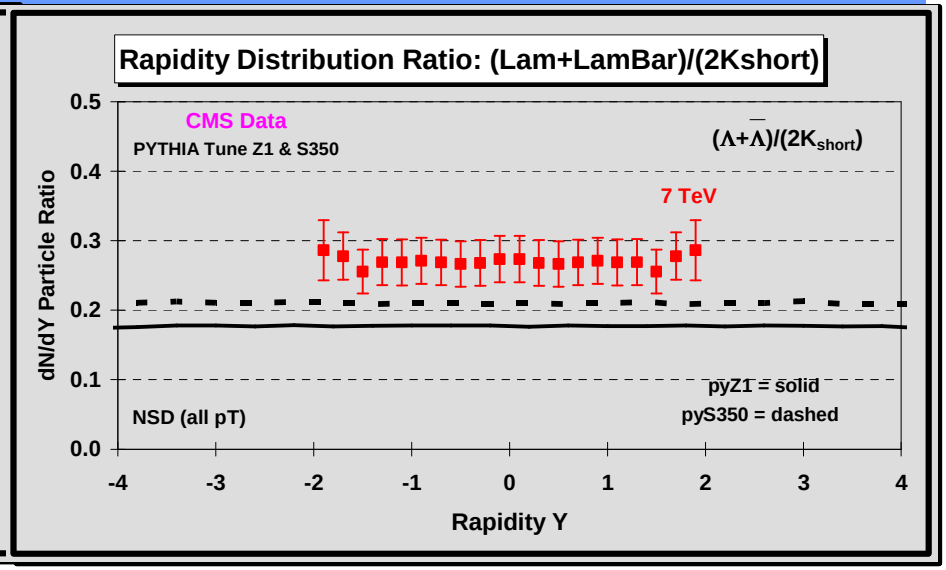
"Minimum Bias" Collisions

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

Lambda Production





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LEP: Λ Spectrum

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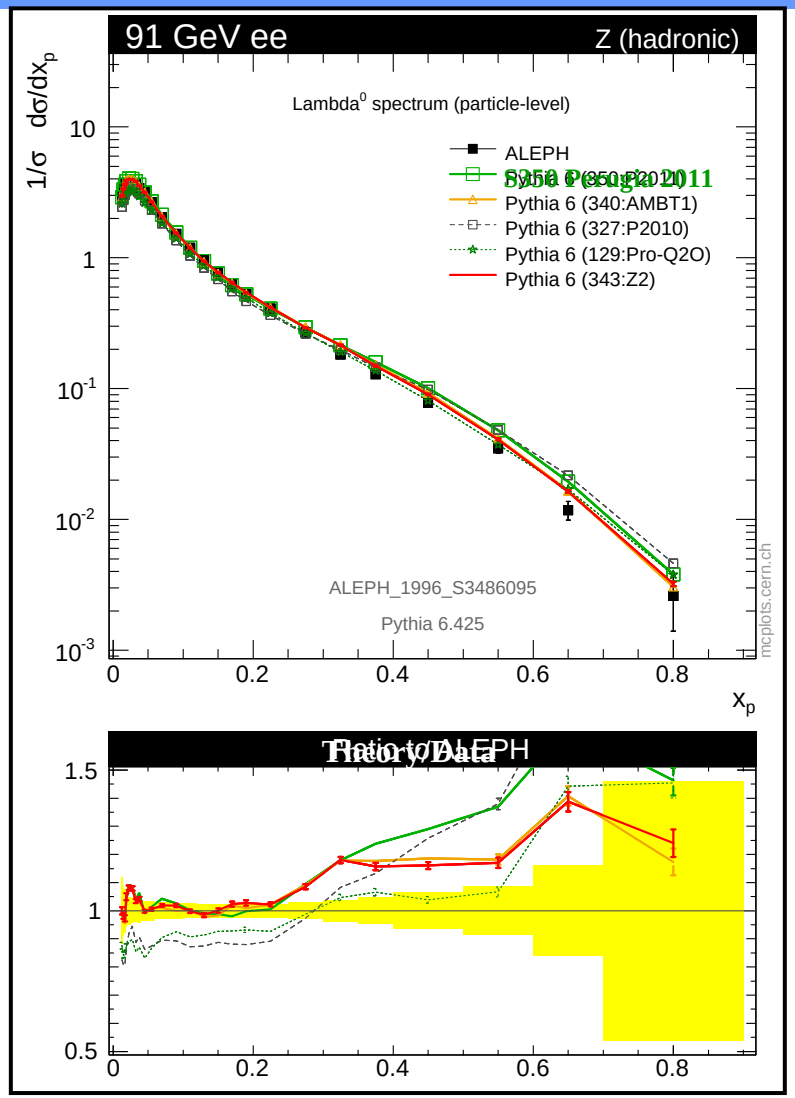
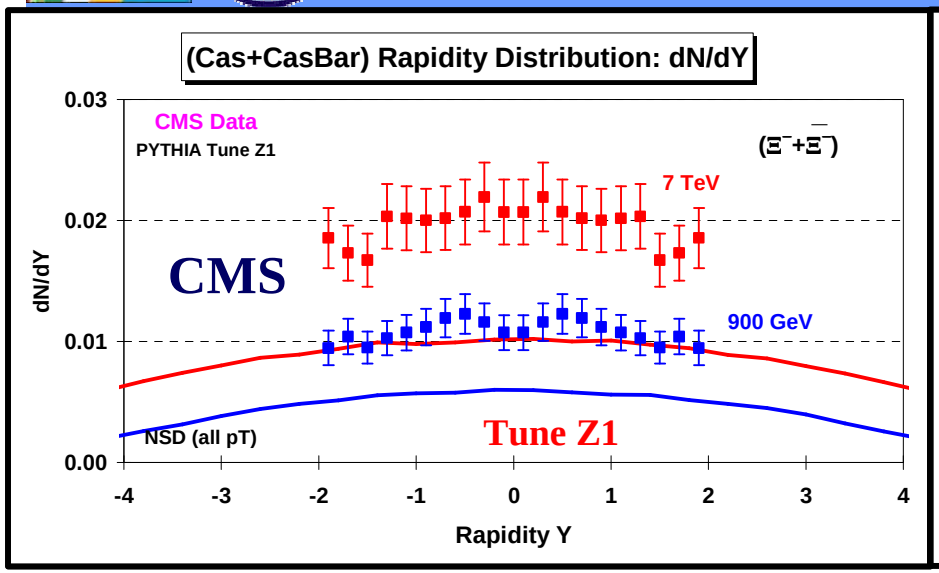
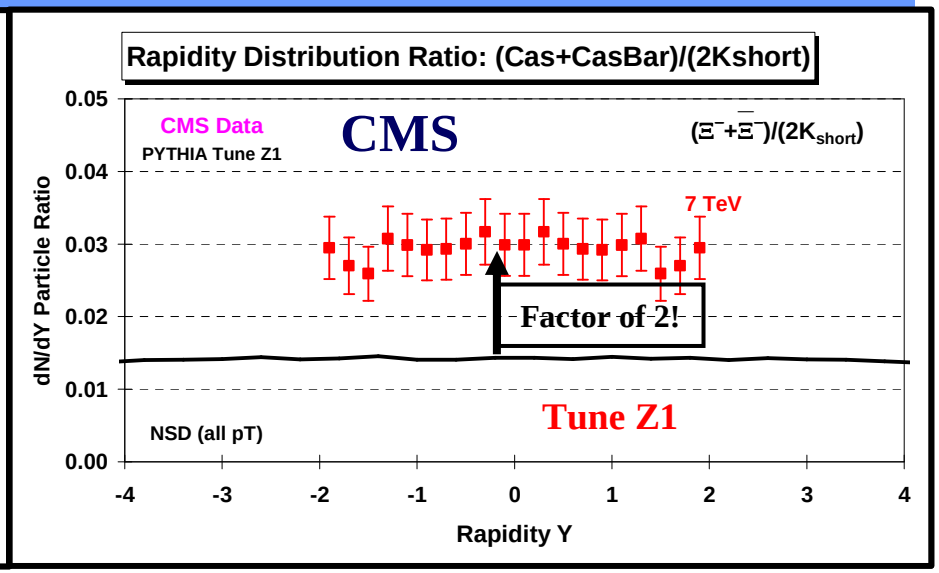


Cascade Production





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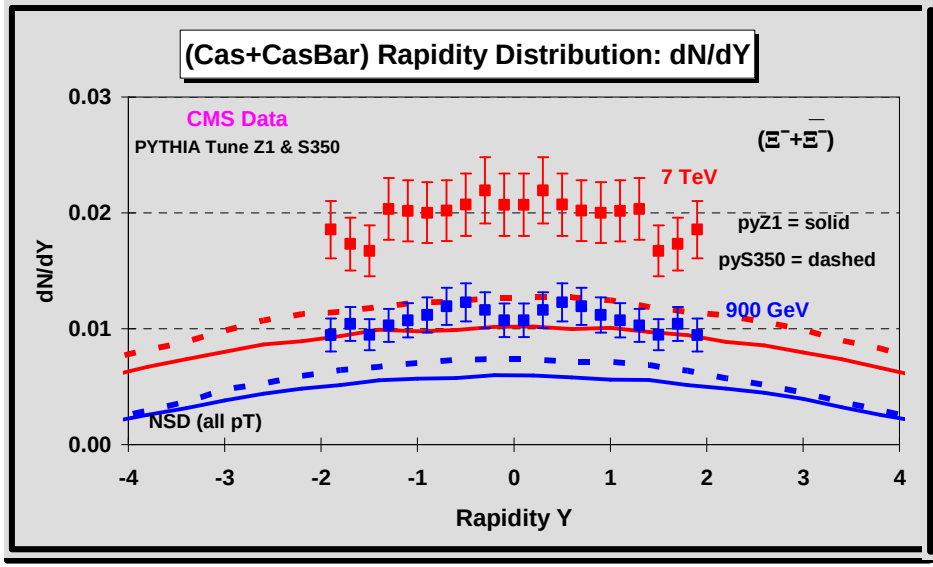
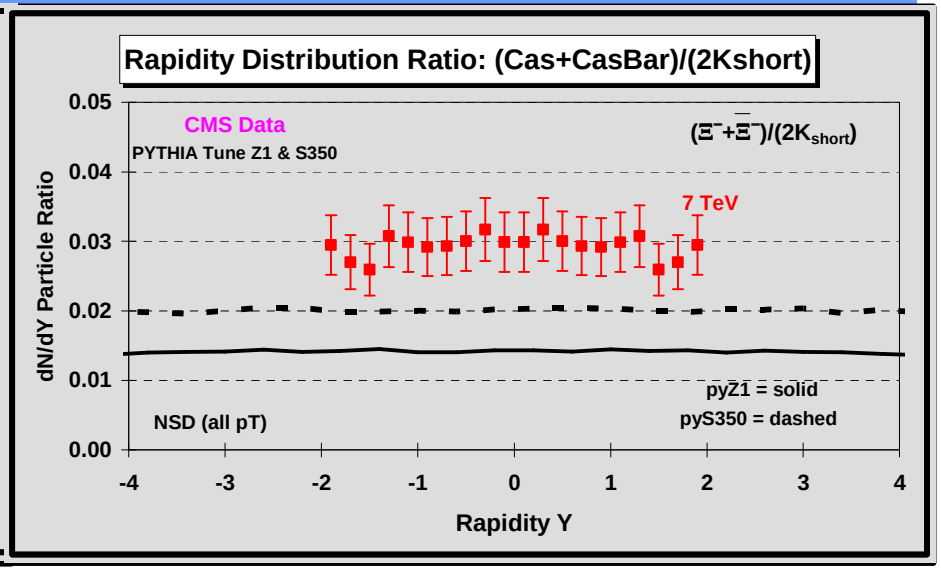
$$\frac{(\Xi + \bar{\Xi})}{2K_{short}} = \frac{\text{Double-strange Baryon}}{\text{Strange Meson}}$$

"Minimum Bias" Collisions

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

Cascade Production





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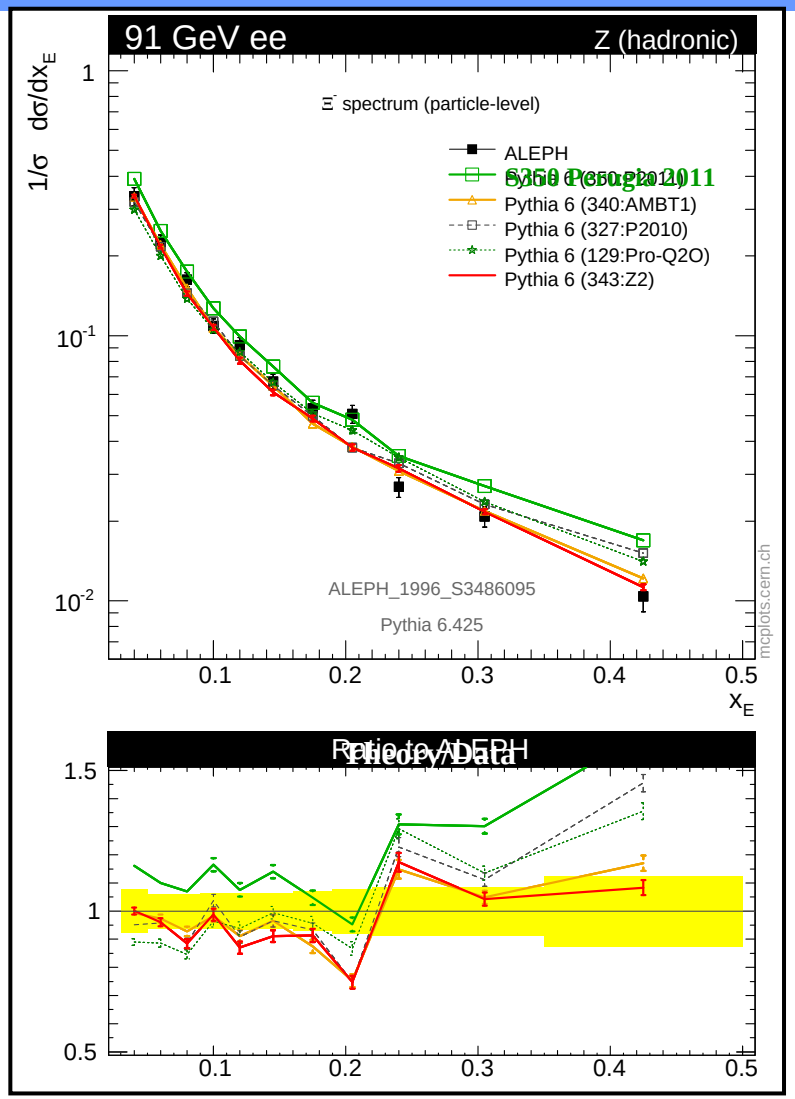


PYTHIA Fragmentation Parameters

Can we increase the overall rate of strange baryons by varying a few fragmentation parameters? For now ignore e^+e^-!

- **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 .

This work is in progress!

PYTHIA Fragmentation Parameters

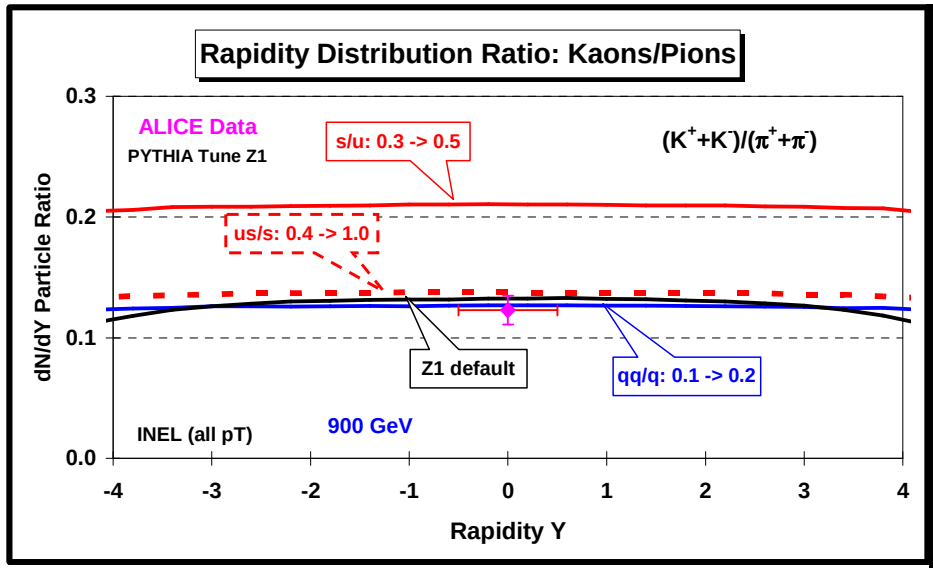
Can we increase the overall rate of strange bary by varying a few fragm tation parameters? F now ignore e

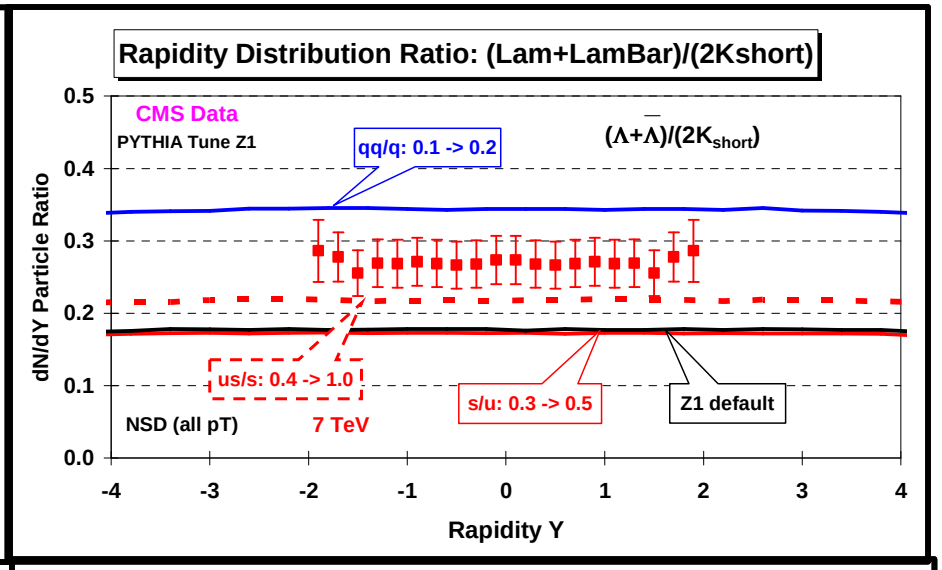
Warning! This may cause problems fitting the LEP data. If so we must understand why! We do not want one tune for e^+e^- and another one for hadron-hadron collisions!

- **PARJ(1) oduction in the colou (1) = qq/q**
- **PARJ(2) : (D = 0 he field compared wi**
- **PARJ(3) : (D = 0.4) is (P(upp strange diquark production compared wi nor ress nge qua**
  Notation: PARJ(3) = u d .

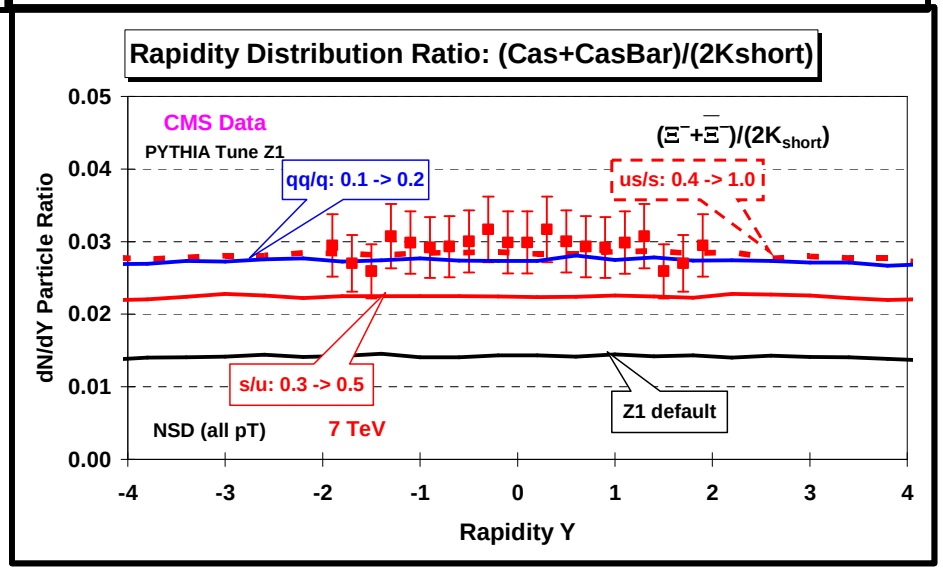
This w k is in progress!

PYTHIA Fragmentation Parameters

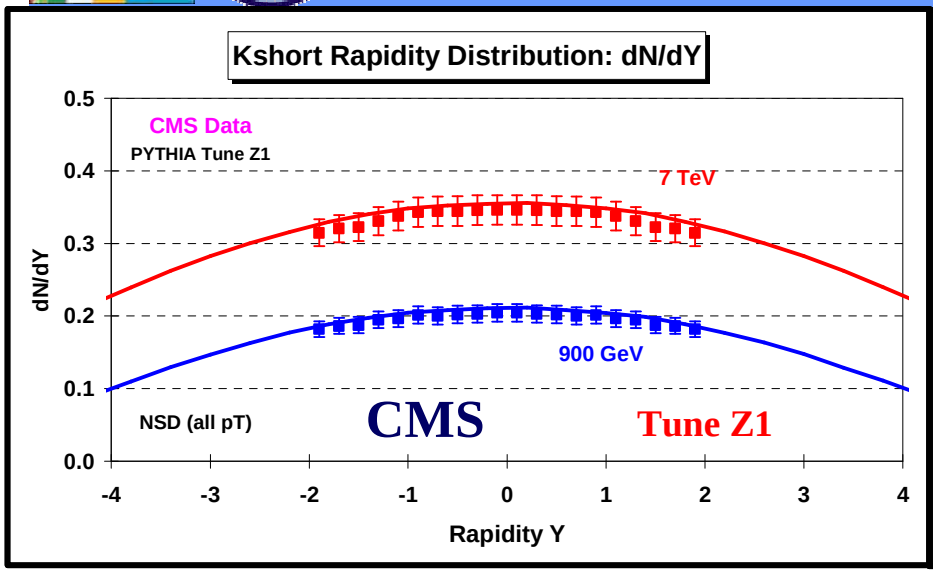


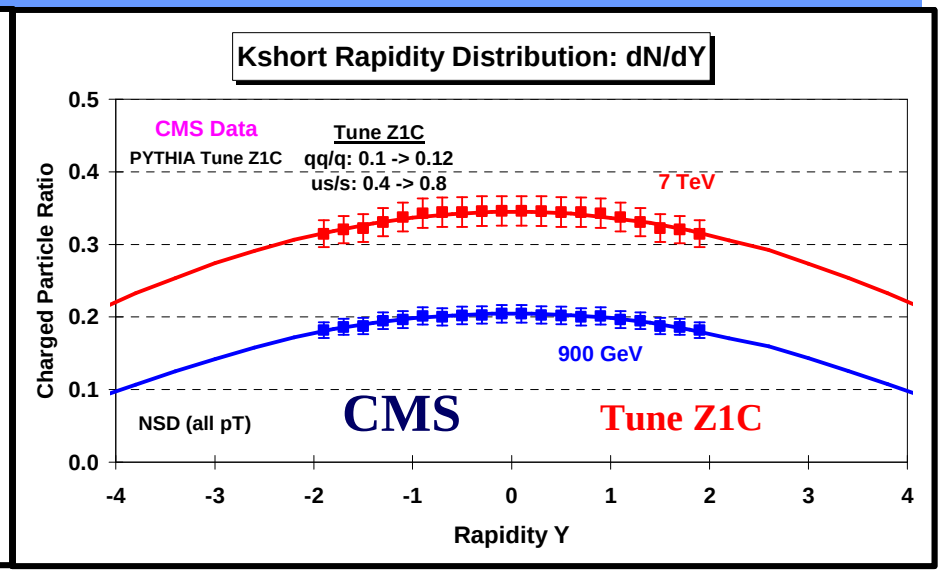


➡ **PYTHIA Tune Z1C: Same as Tune Z1 except qq/q is increased 0.1 → 0.12 and us/s is increased from 0.4 → 0.8.**



Kaon Production



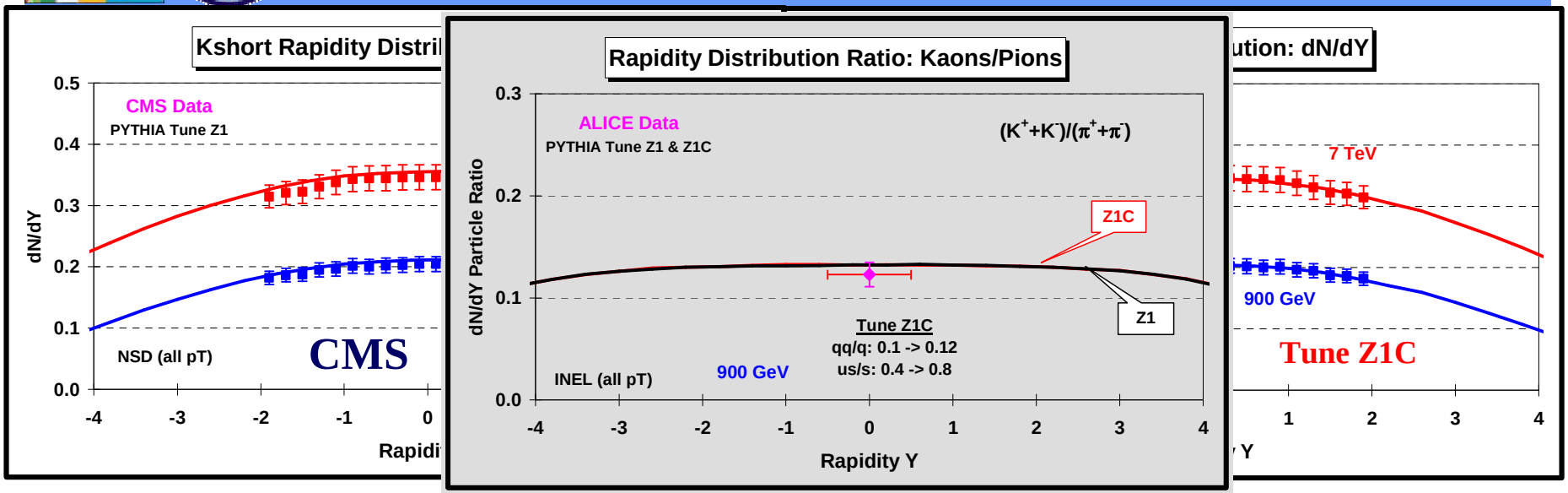


- **CMS NSD data on the K_{short} rapidity distribution at 7 TeV and 900 GeV compared with PYTHIA Tune Z1. The plot shows the average number of K_{short} per NSD collision per unit Y, $(1/N_{NSD})$ dN/dY.**
- **CMS dNSD ata on the K_{short} rapidity distribution at 7 TeV and 900 GeV compared with PYTHIA Tune Z1C. The plot shows the average number of K_{short} per NSD collision per unit Y, $(1/N_{NSD})$ dN/dY.**

"Minimum Bias" Collisions

For Kaon production Tune Z1 and Z1C are almost identical!

Kaon Production



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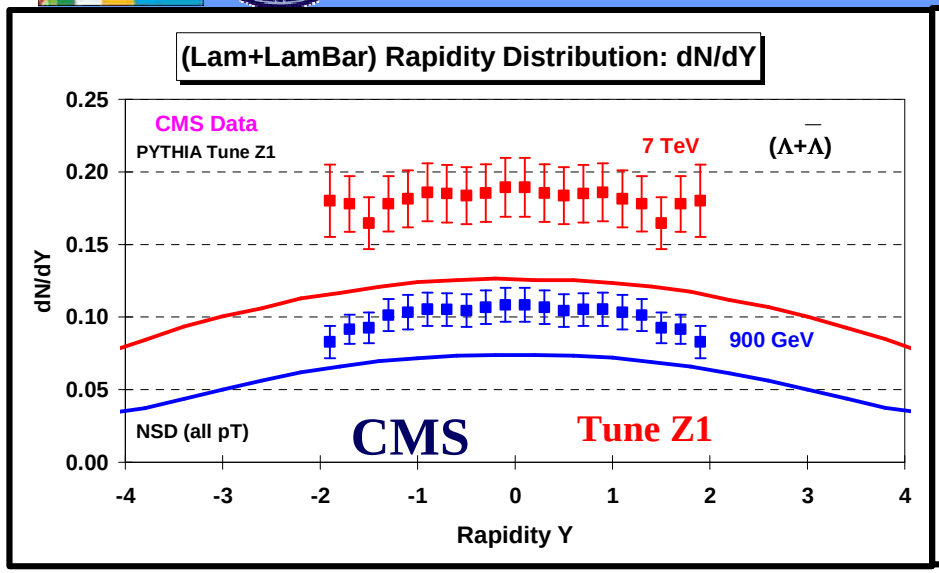

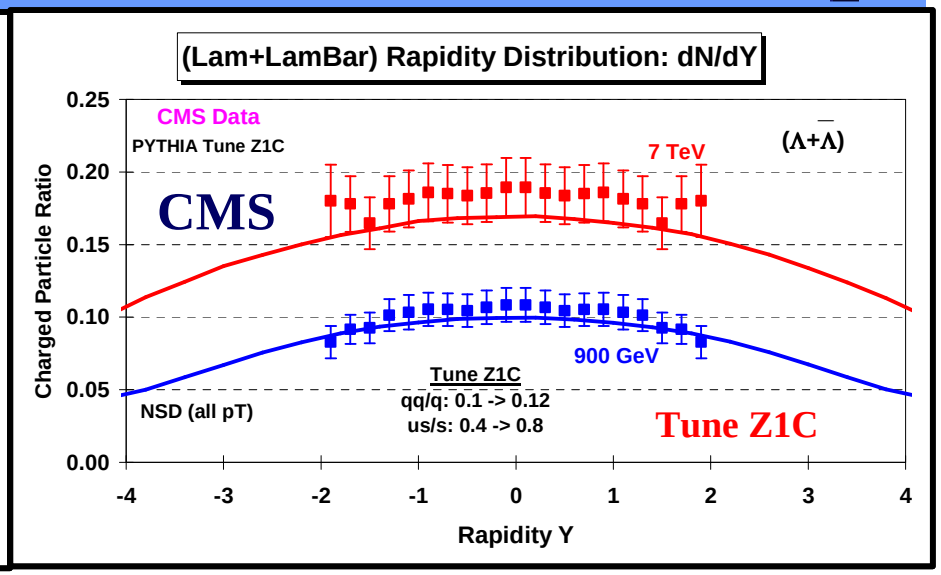

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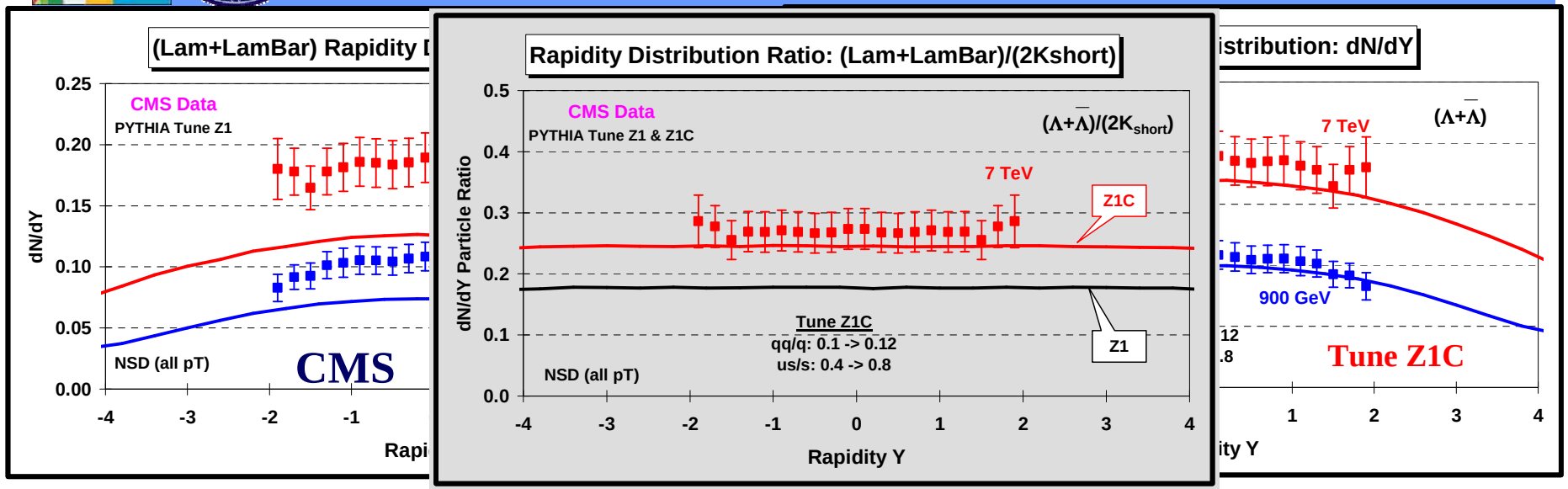
"Minimum Bias" Collisions

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

Lambda Production



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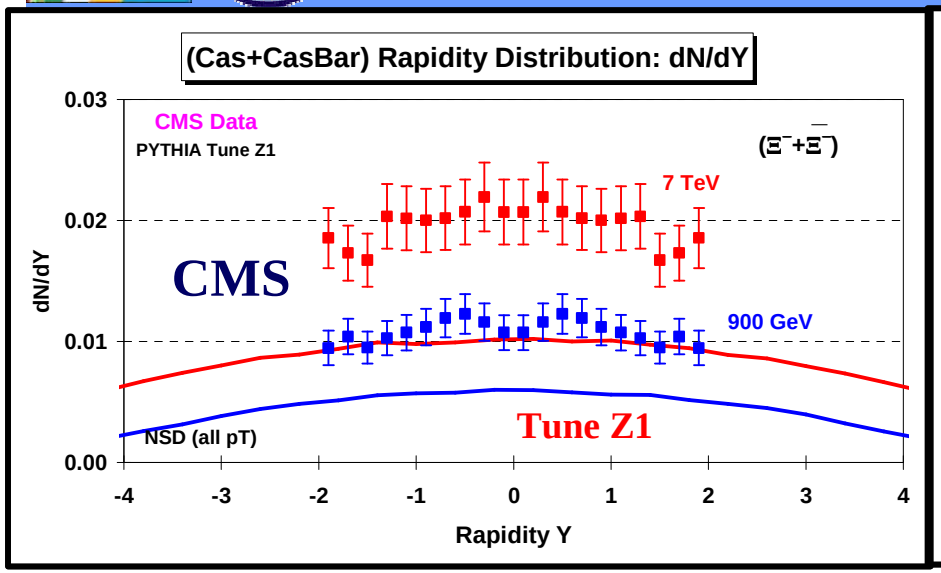

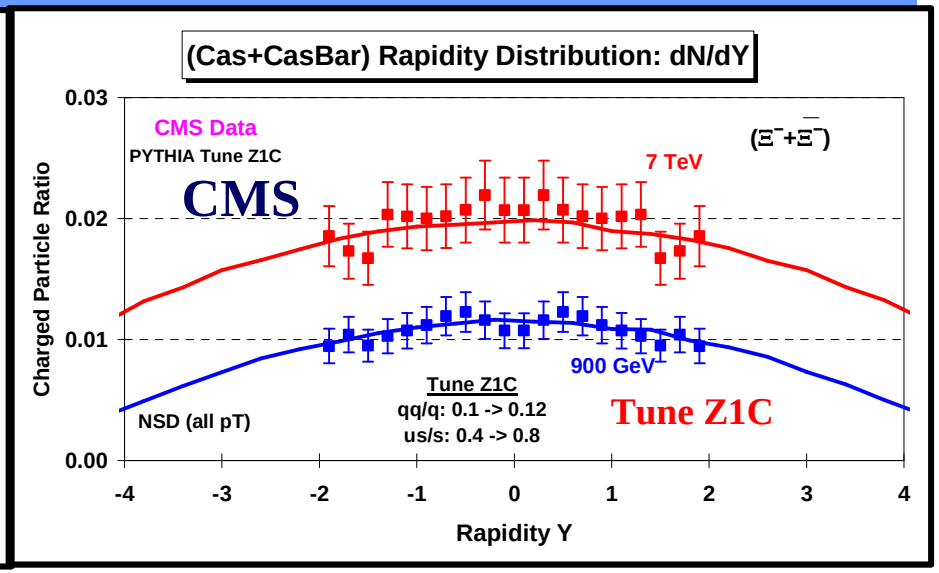

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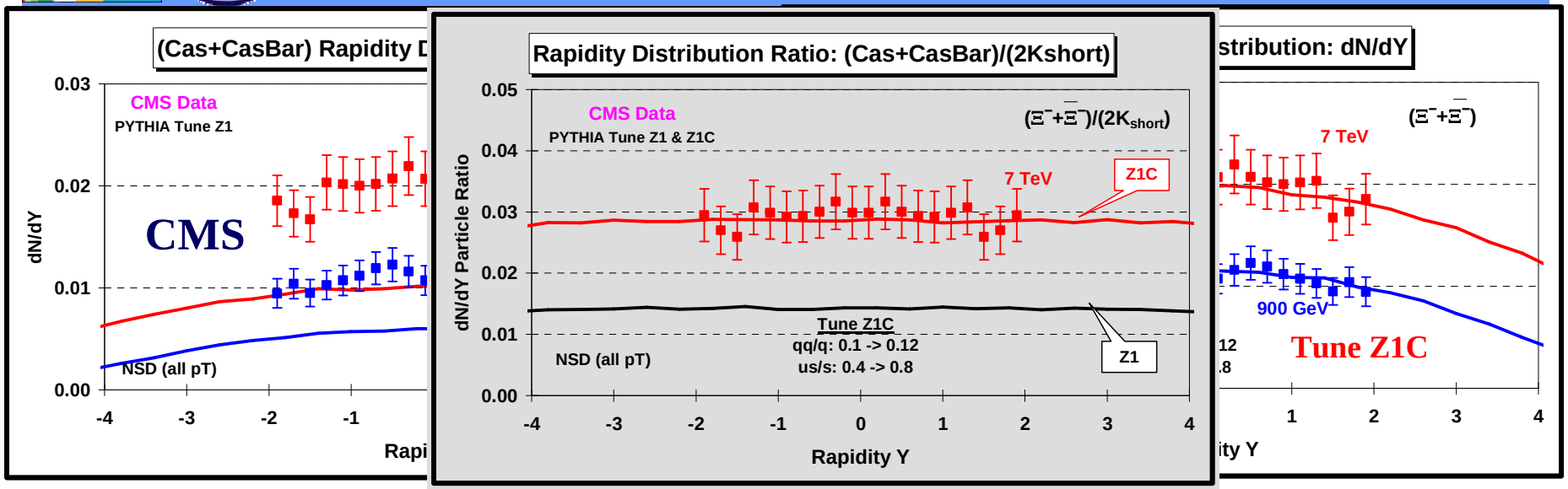
"Minimum Bias" Collisions

Wow! PYTHIA Tune Z1C looks very nice here!

Cascade Production



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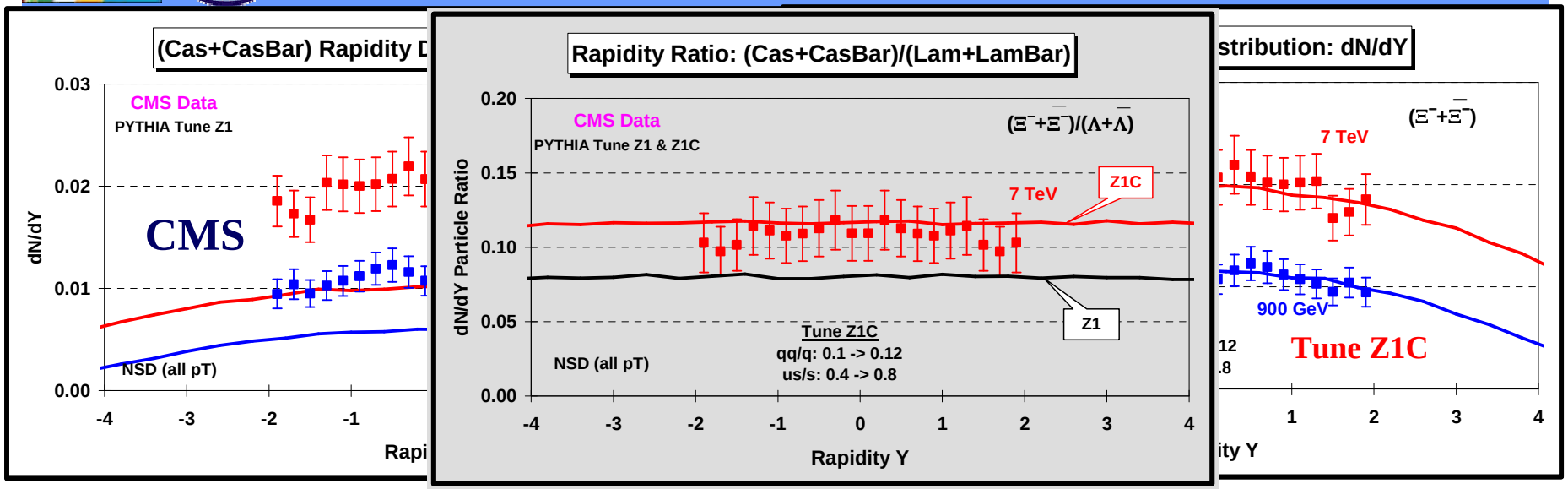

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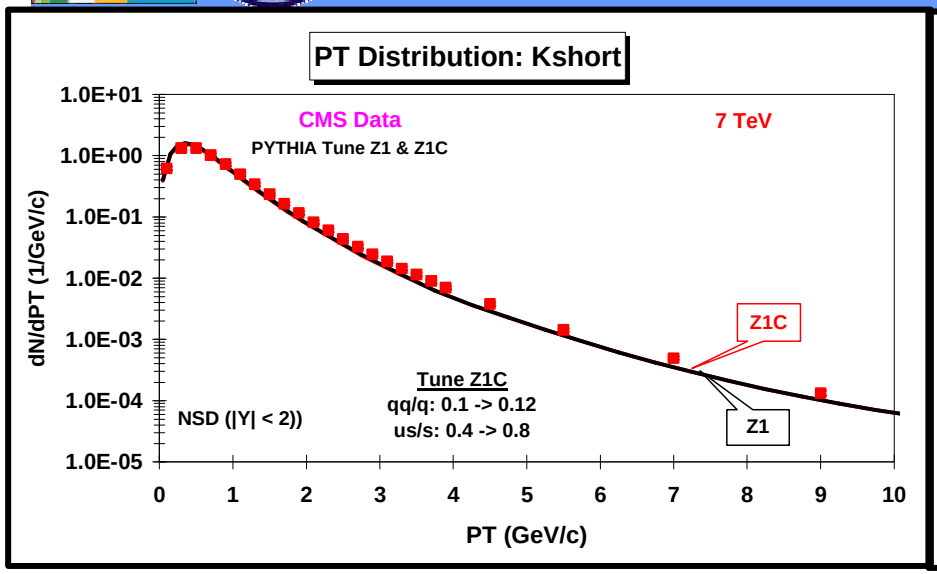
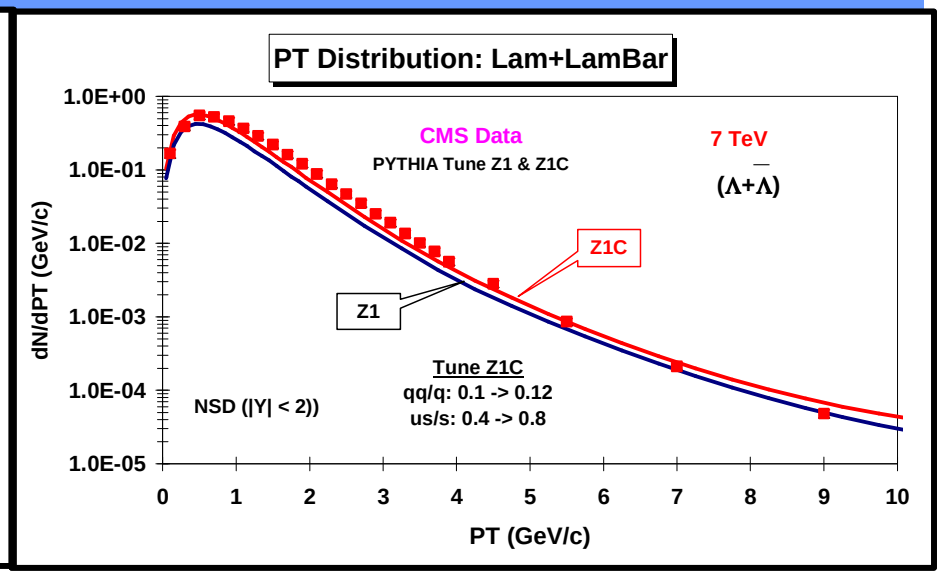
Wow! PYTHIA Tune Z1C looks very nice here!

Transverse Momentum Distributions





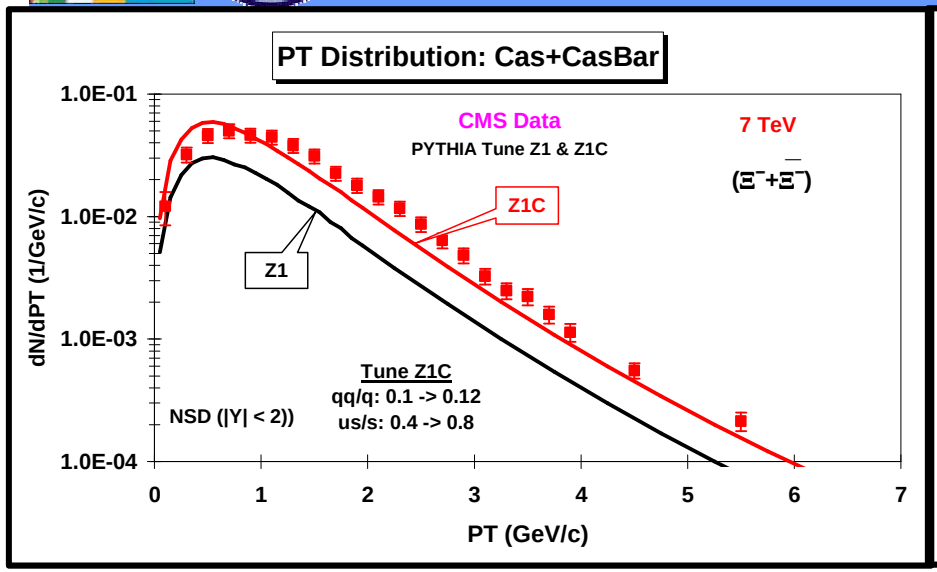
- **CMS NSD data on the K_{short} transverse momentum distribution at 7 TeV compared with PYTHIA Tune Z1 & Z1C. The plot shows the average number of particles per NSD collision per unit p_T, $(1/N_{NSD})\ dN/dp_T$ for $|Y| < 2$.**

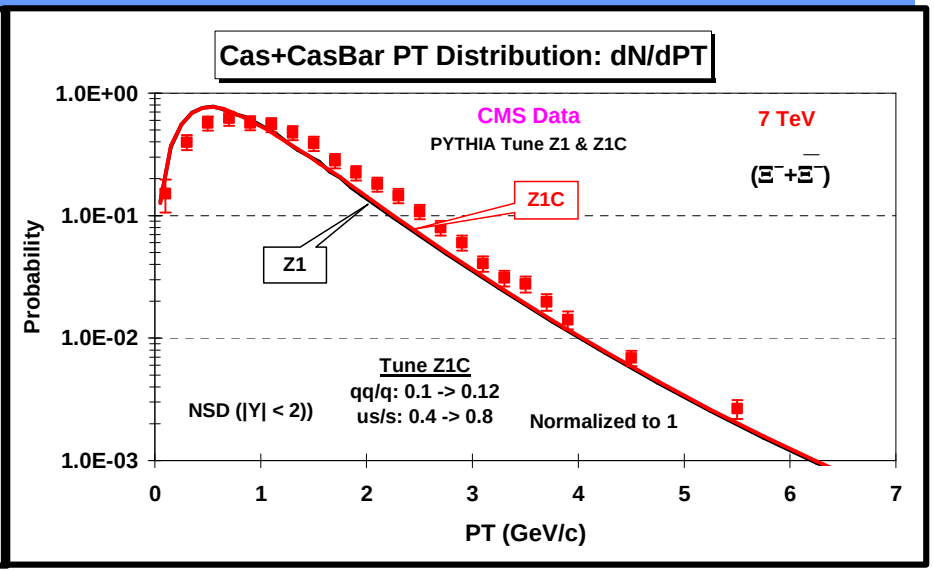
- **CMS NSD data on the Lambda+AntiLambda transverse momentum distribution at 7 TeV compared with PYTHIA Tune Z1 & Z1C. The plot shows the average number of particles per NSD collision per unit p_T, $(1/N_{NSD})\ dN/dp_T$ for $|Y| < 2$.**

"Minimum Bias" Collisions

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

Transverse Momentum Distributions





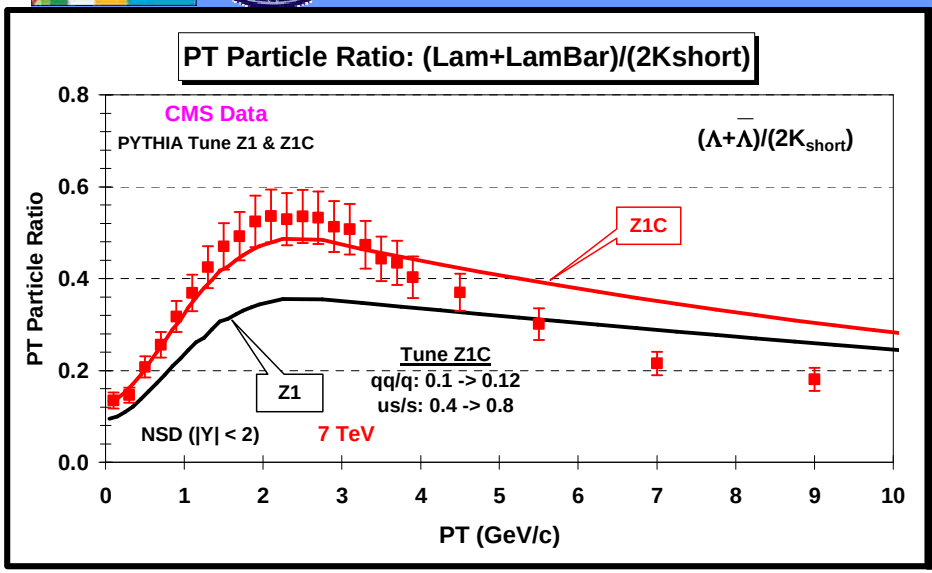
- **CMS NSD data on the Cascade⁻ +AntiCascade⁻ transverse momentum distribution at 7 TeV compared with PYTHIA Tune Z1 & Z1C. The plot shows the average number of particles per NSD collision per unit p_T, $(1/N_{NSD})\ dN/dp_T$ for $|Y| < 2$.**

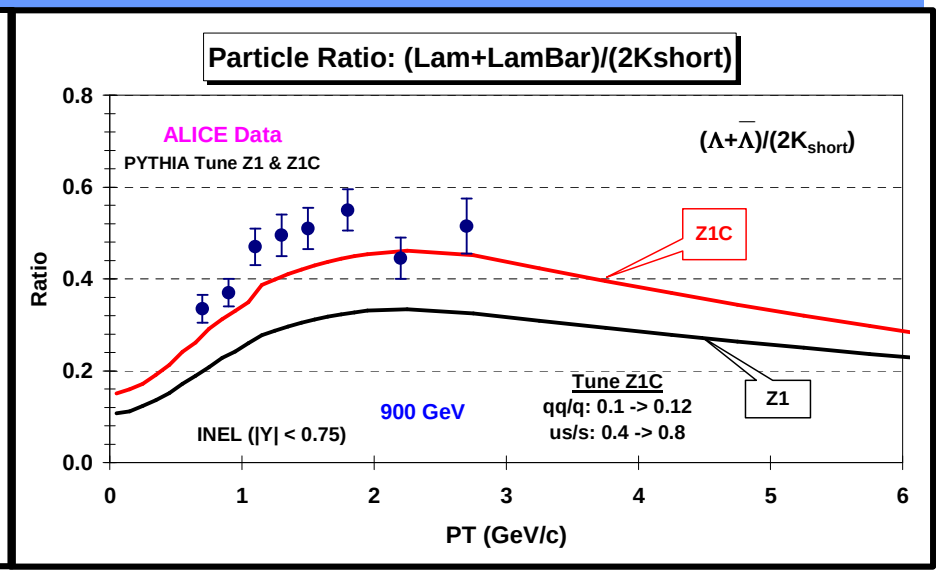
- **CMS NSD data on the Cascade⁻ +AntiCascade⁻ transverse momentum distribution at 7 TeV (normalized to 1) compared with PYTHIA Tune Z1 & Z1C.**

"Minimum Bias" Collisions

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

Particle Ratios versus PT





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

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

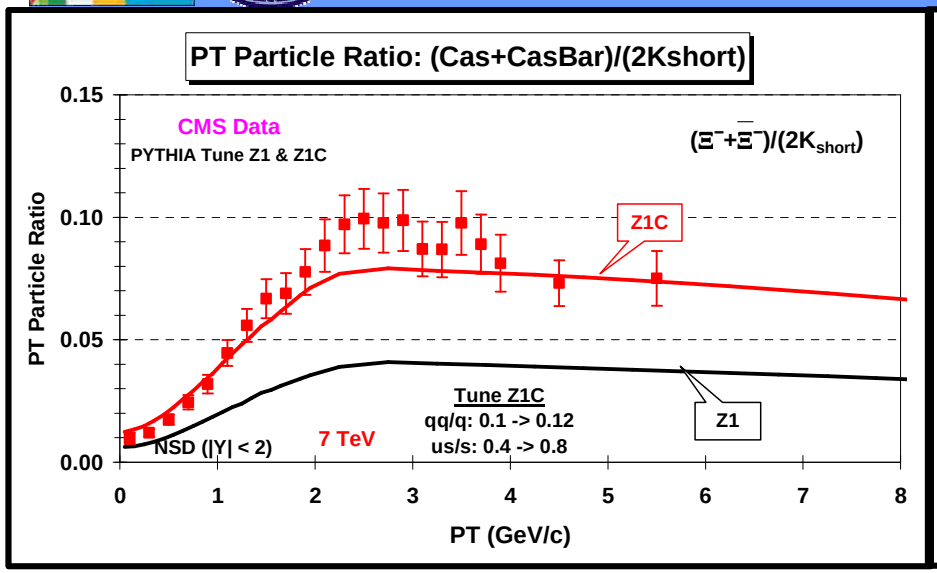
➡ **ALICE INEL data on the Lambda+AntiLambda to $2K_{short}$ ratio versus p_T at 900 GeV (|Y| < 0.75) compared with PYTHIA Tune Z1 & Z1C.**

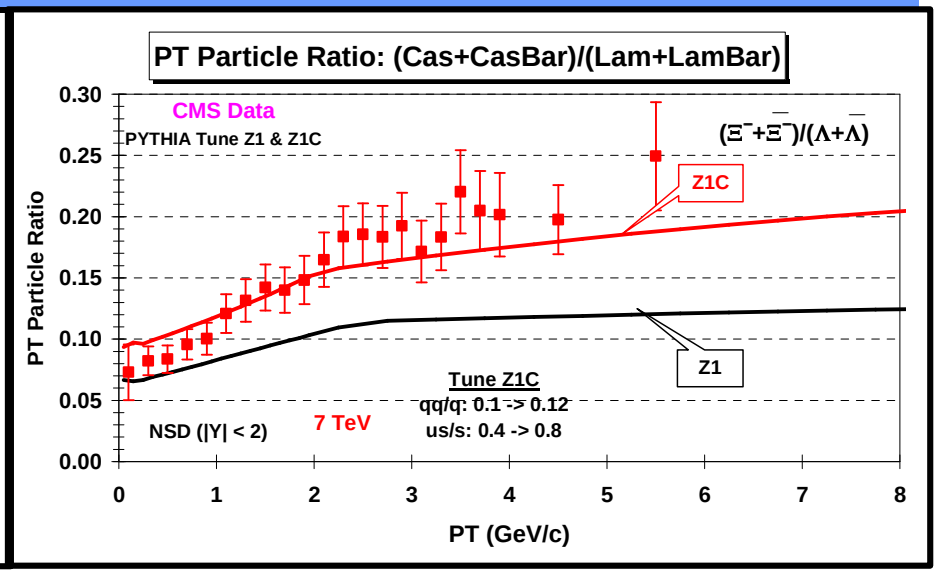
$$\frac{(\Lambda + \bar{\Lambda})}{2K_{short}} = \frac{\text{Single-strange Baryon}}{\text{Strange Meson}}$$

"Minimum Bias" Collisions

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

Particle Ratios versus PT





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

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

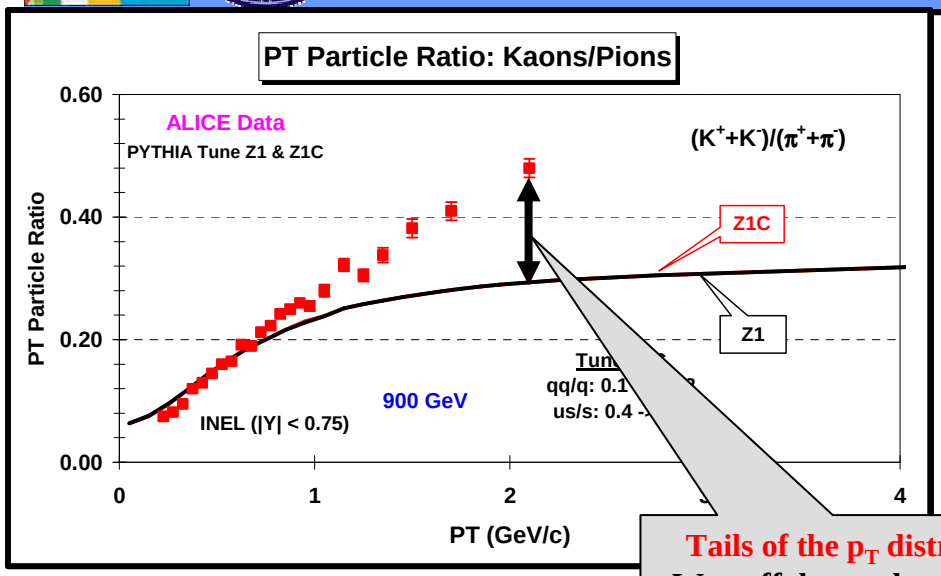
- **CMS NSD data on the Cascade$^-$+AntiCascade$^-$ to Lambda+AntiLambda ratio versus p_T at 7 TeV (|Y| < 2) compared with PYTHIA Tune Z1 & Z1C.**

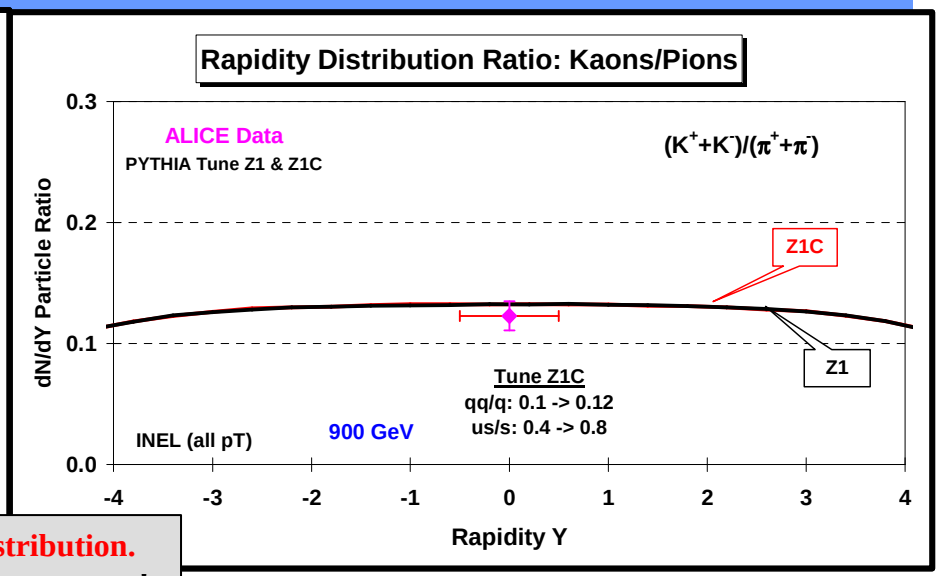
$$\frac{(\Xi + \bar{\Xi})}{(\Lambda + \bar{\Lambda})} = \frac{\text{Double-strange Baryon}}{\text{Single-strange Baryon}}$$

"Minimum Bias" Collisions

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

Particle Ratios versus 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.**

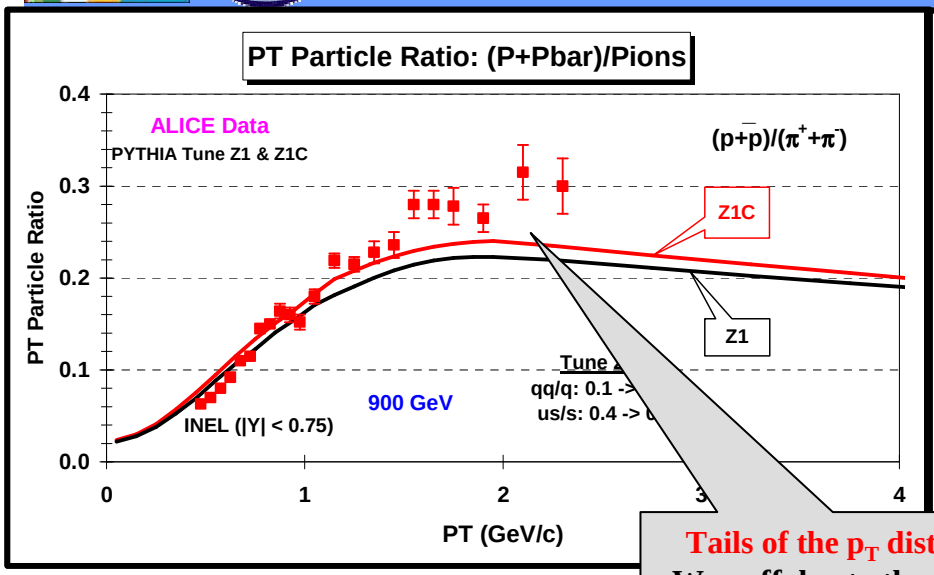
$$\frac{(K^+ + K^-)}{(\pi^+ + \pi^-)} = \frac{\text{Strange Meson}}{\text{Non-strange Meson}}$$

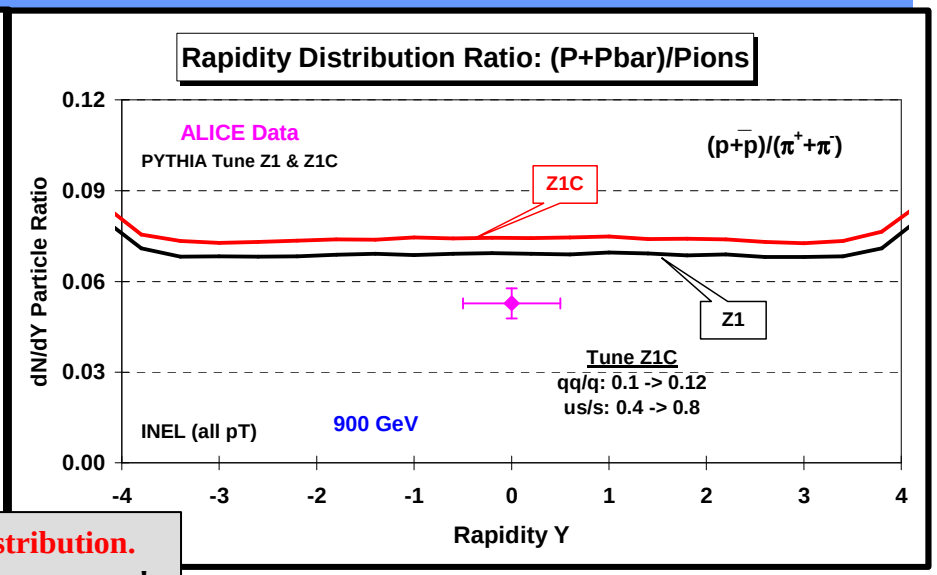
"Minimum Bias" Collisions

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

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

Particle Ratios versus PT





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.**

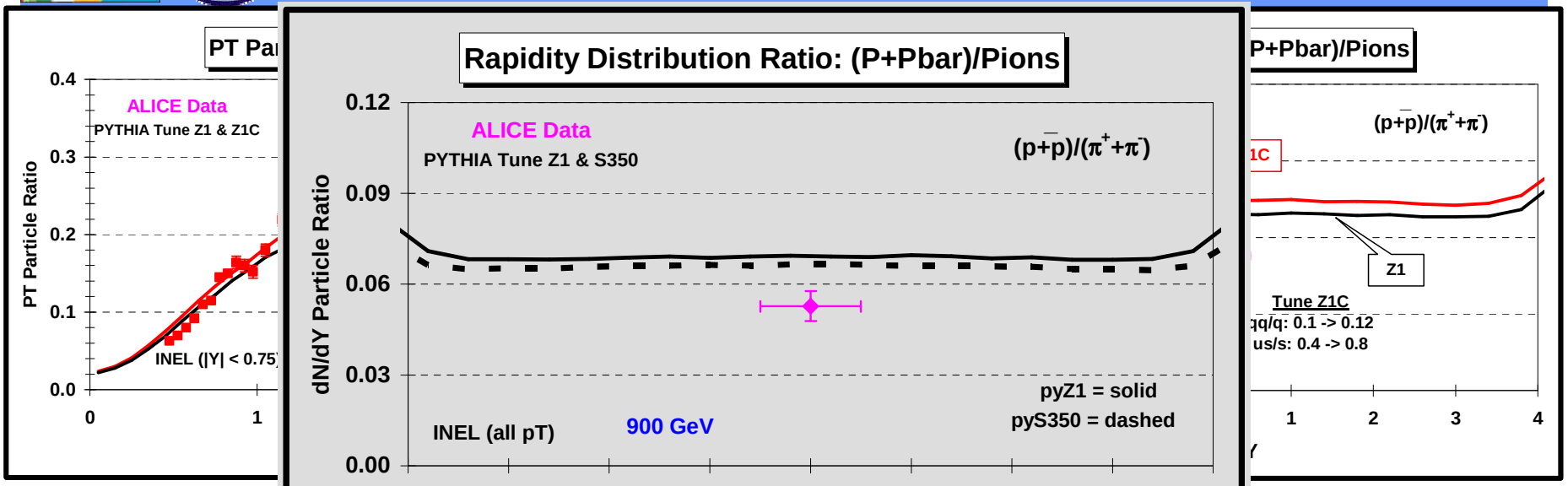
$$\frac{(p+\bar{p})}{(\pi^+ + \pi^-)} = \frac{\text{Non-strange Baryon}}{\text{Non-strange Meson}}$$

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

"Minimum Bias" Collisions

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

Particle Ratios versus PT



➡ **ALICE INEL** … **to charged pio** … **arged pion rapidity (|Y| < 0.75) compared with PYTHIA Tune Z1 & Z1C.** … **ratio at 900 GeV compared with PYTHIA Tune Z1 & Z1C.**

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

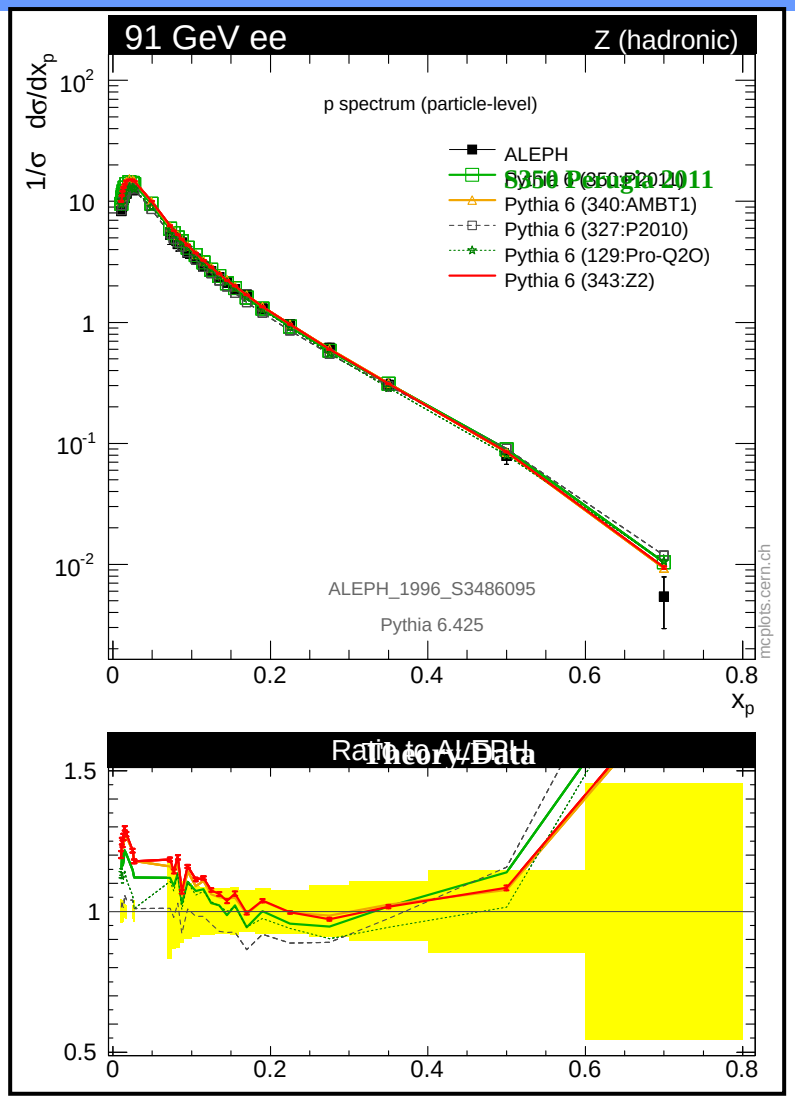
"Minimum Bias" Collisions

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

LEP: Proton Spectrum

mcplots.cern.ch

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



Sherpa versus PYTHIA

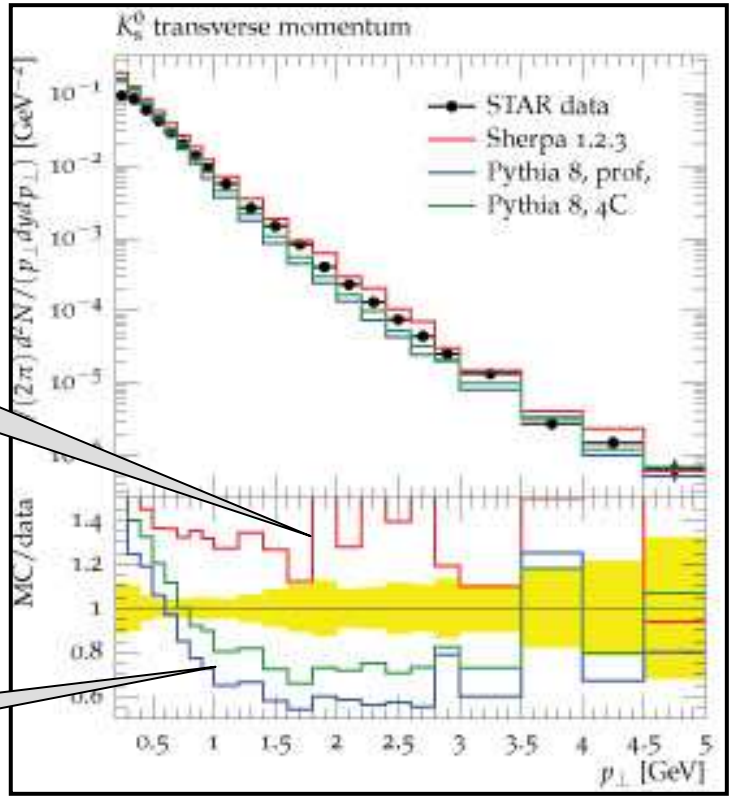
K_{short} Production at STAR

Strange particle production in pp at 200 GeV (STAR_2006_S6860818)

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

Too many K_{short} in Sherpa?

Sherpa and PYTHIA not the same!



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

Sherpa versus PYTHIA

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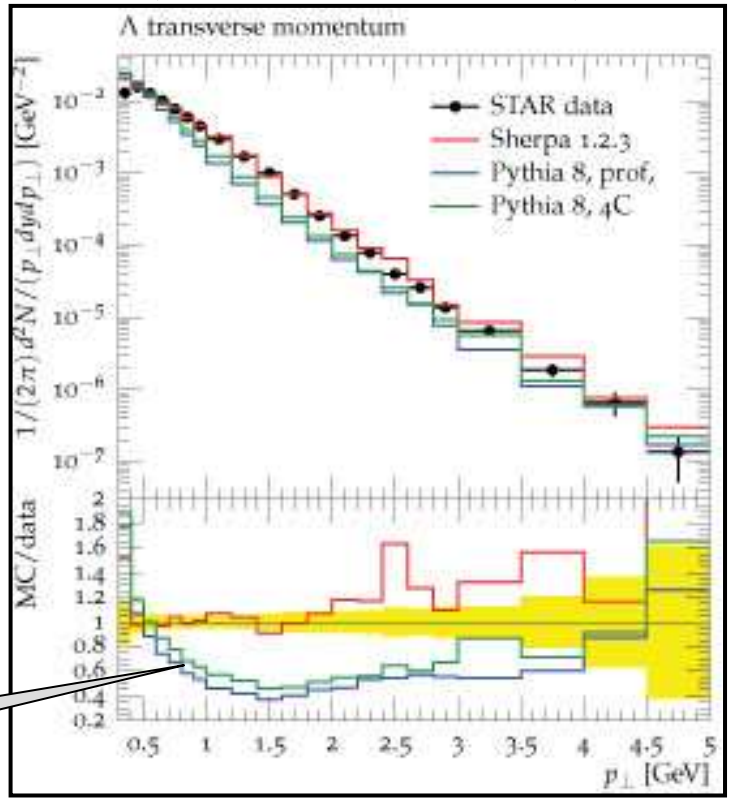


Sherpa does better than PYTHIA 8!

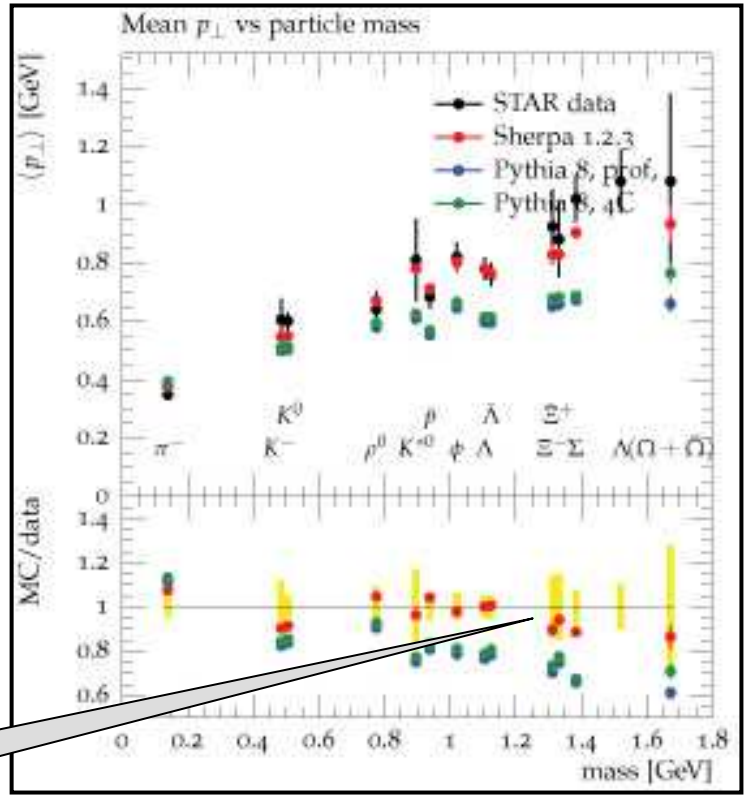
Hendrik Hoeth
http://users.hepforge.org/~hoeth/STAR_2006_S6860818/

Sherpa versus PYTHIA

$\langle p_T \rangle$ 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)



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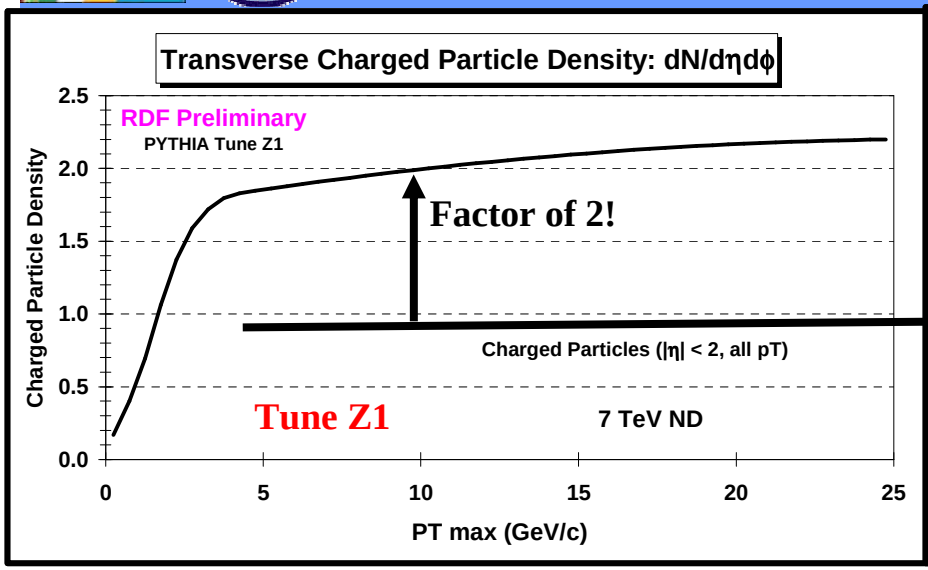
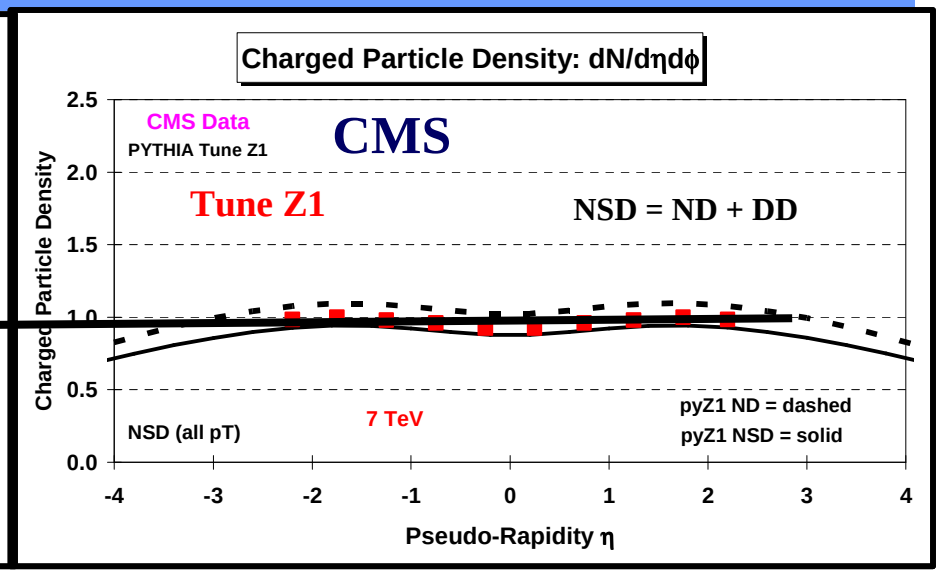
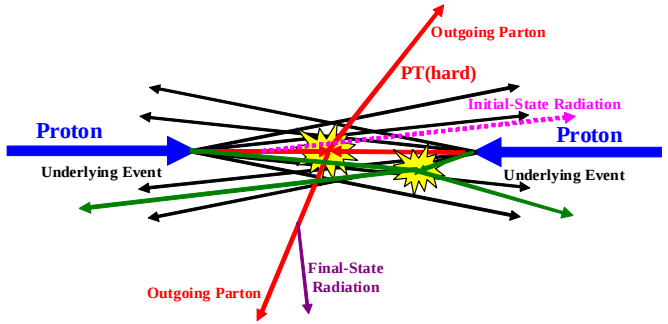
MB versus UE

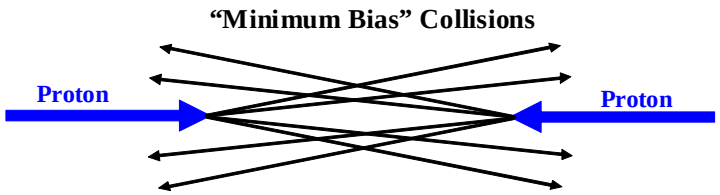




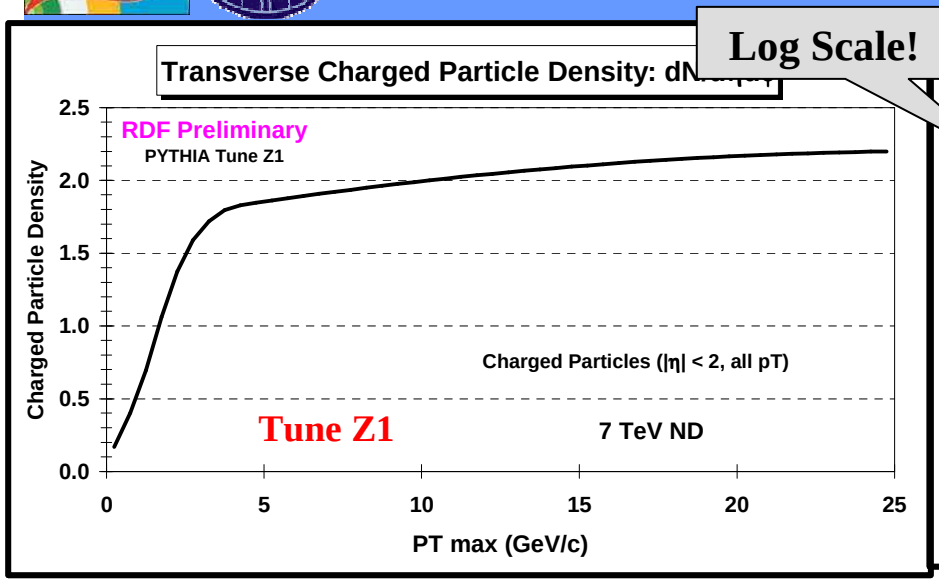
- **Shows the density of charged particles in the "transverse" region as a function of PTmax for charged particles (All p_T, $|\eta| < 2$) at 7 TeV from PYTHIA Tune Z1.**



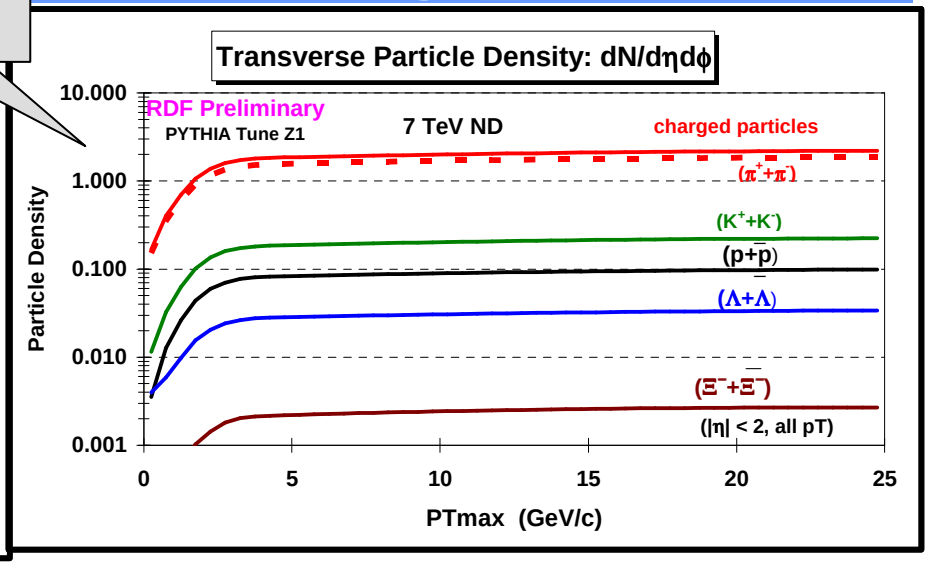
- **CMS NSD data on the charged particle rapidity distribution at 7 TeV compared with PYTHIA Tune Z1. The plot shows the average number of charged particles per NSD collision per unit $\eta-\phi$, $(1/N_{NSD})\, dN/d\eta d\phi$.**



UE Particle Type



Log Scale!



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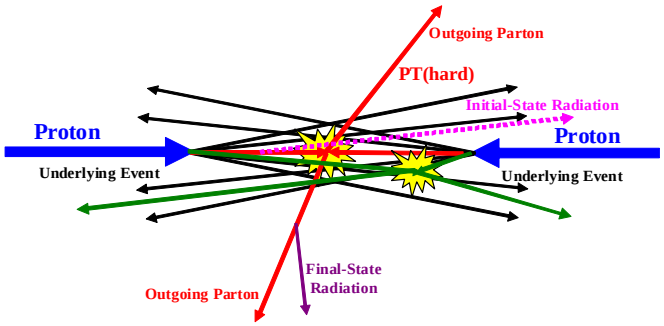

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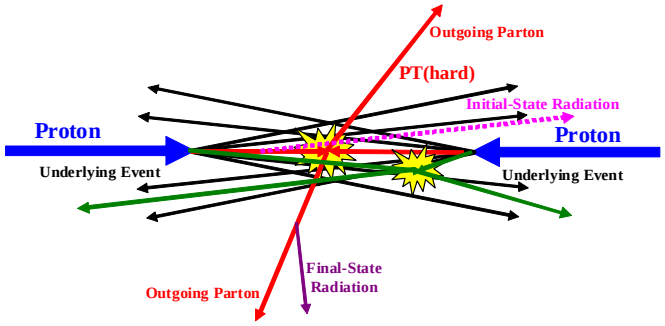
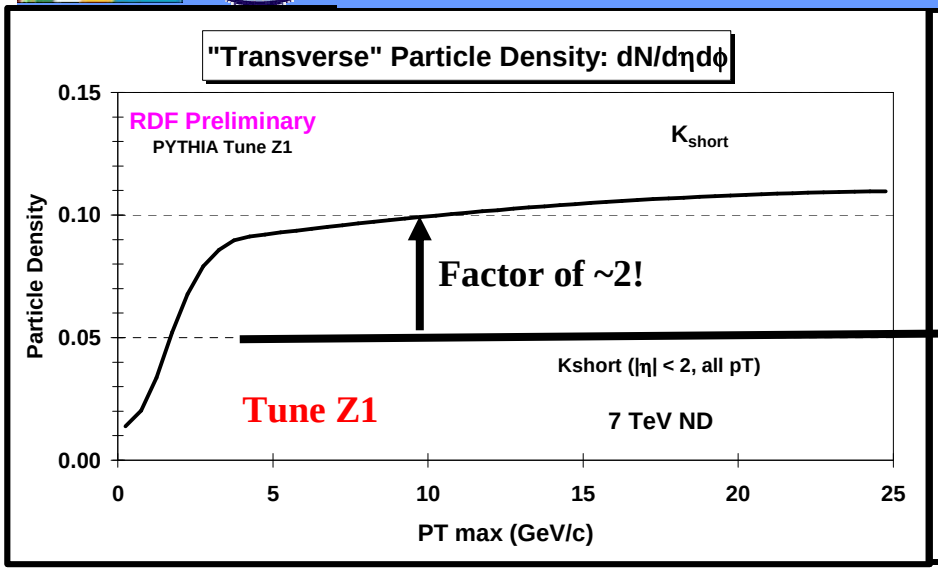
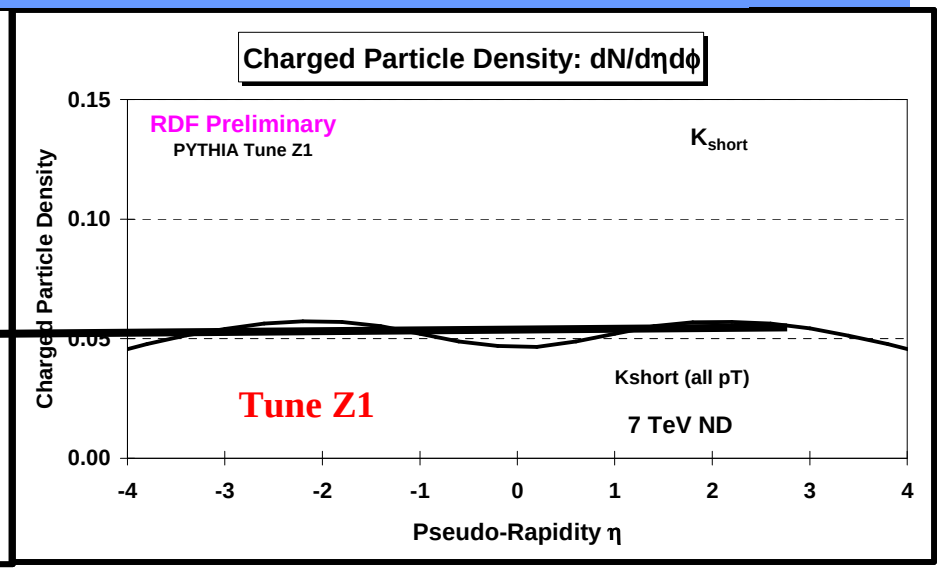
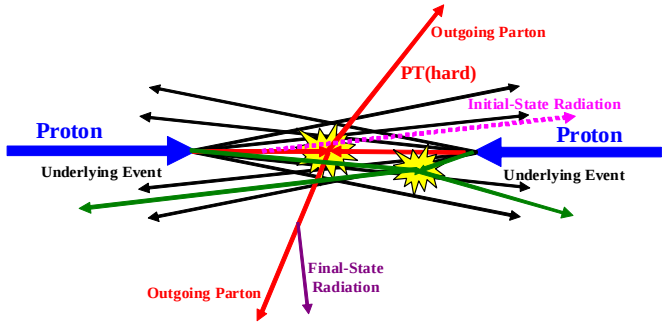


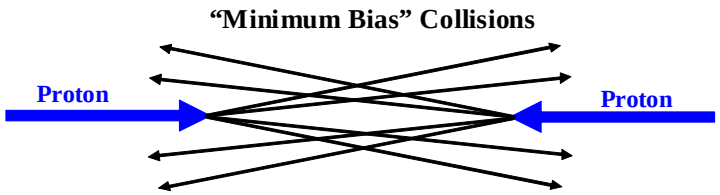
MB versus UE



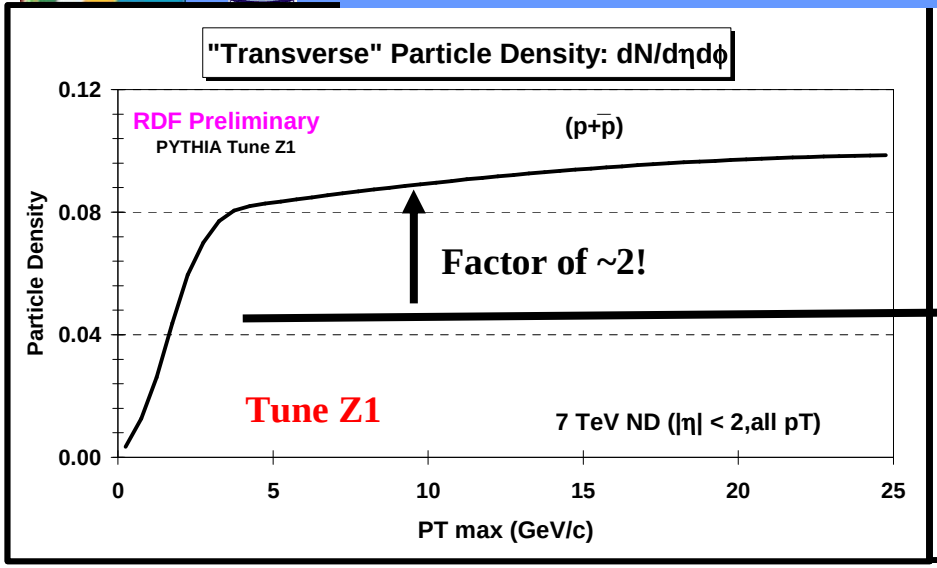


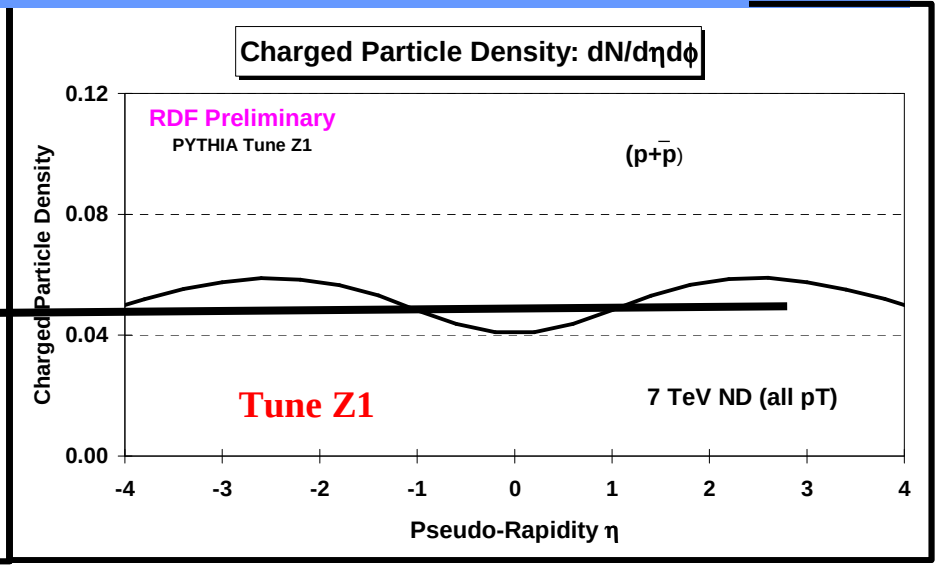
- Shows the density of K_{short} particles in the "transverse" region as a function of PTmax for charged particles (All p_T, $|\eta| < 2$) at 7 TeV from PYTHIA Tune Z1.
- Shows the K_{short} pseudo-rapidity distribution (all p_T) at 7 TeV from PYTHIA Tune Z1. The plot shows the average number of particles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



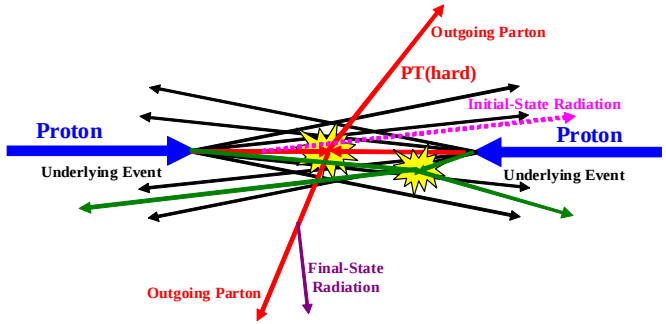


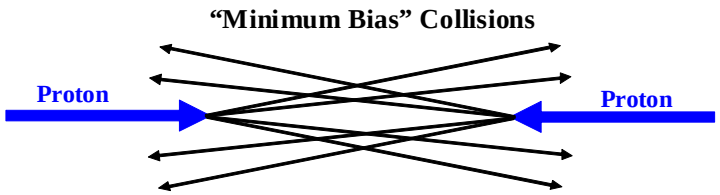
MB versus UE



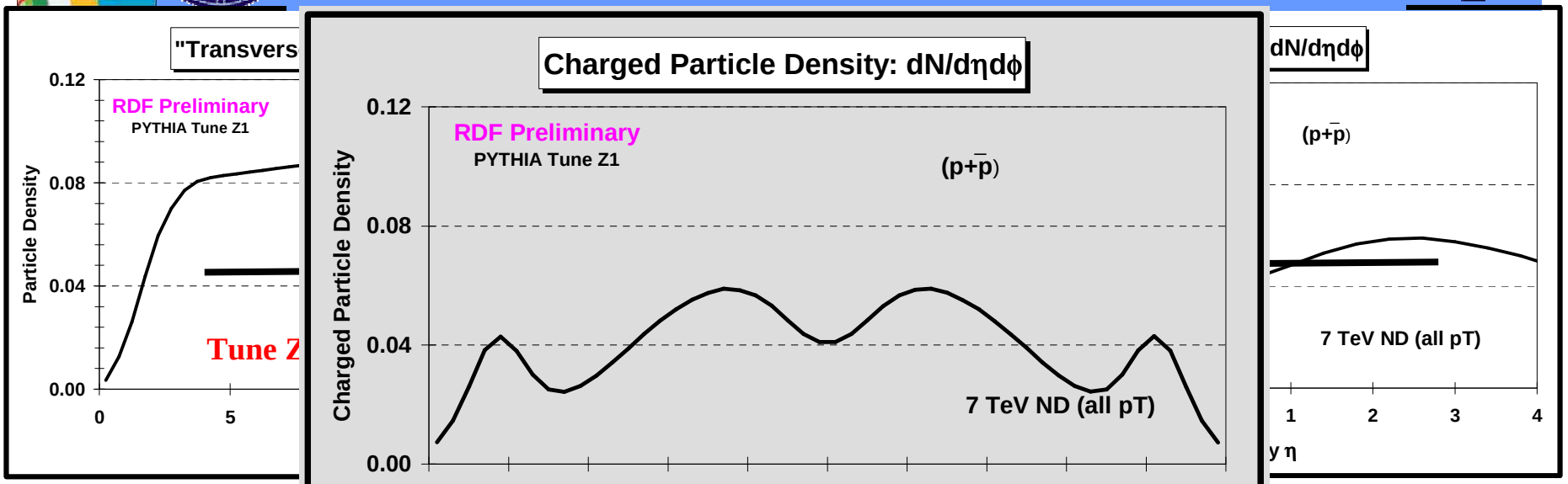


- Shows the density of P+antiP particles in the "transverse" region as a function of PTmax for charged particles (All p_T, $|\eta| < 2$) at 7 TeV from PYTHIA Tune Z1.
- Shows the P+antiP pseudo-rapidity distribution (all p_T) at 7 TeV from PYTHIA Tune Z1. The plot shows the average number of particles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

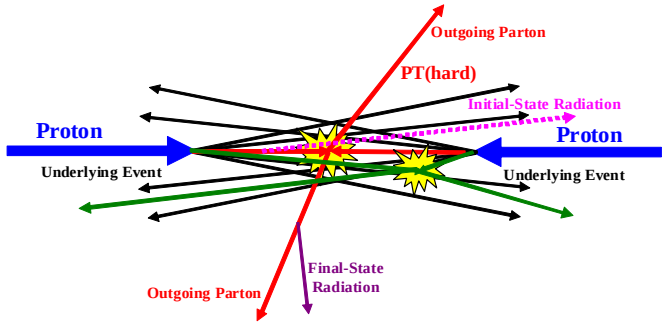


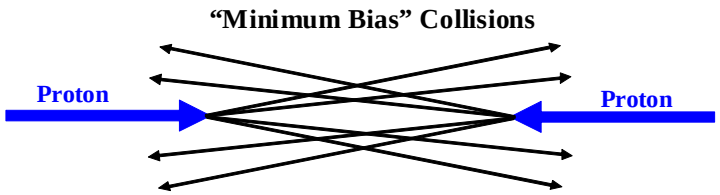


MB versus UE



- Shows the densi … pidity distribution the "transverse" … IA Tune Z1. The PTmax for charged particles (All p_T, $|\eta| < 2$) at 7 TeV from PYTHIA Tune Z1. plot shows the average number of particles per ND collision per unit $\eta-\phi$, $(1/N_{ND})\ dN/d\eta d\phi$.





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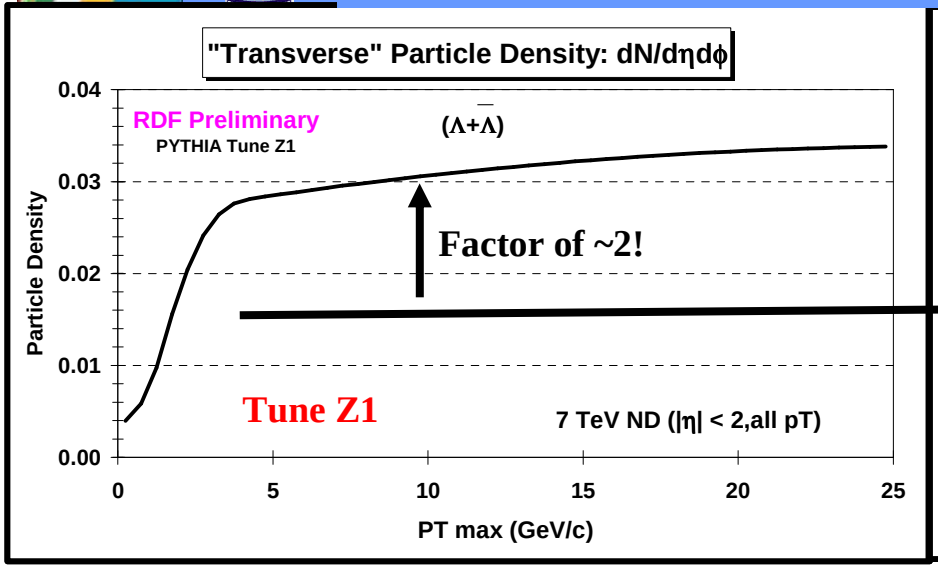
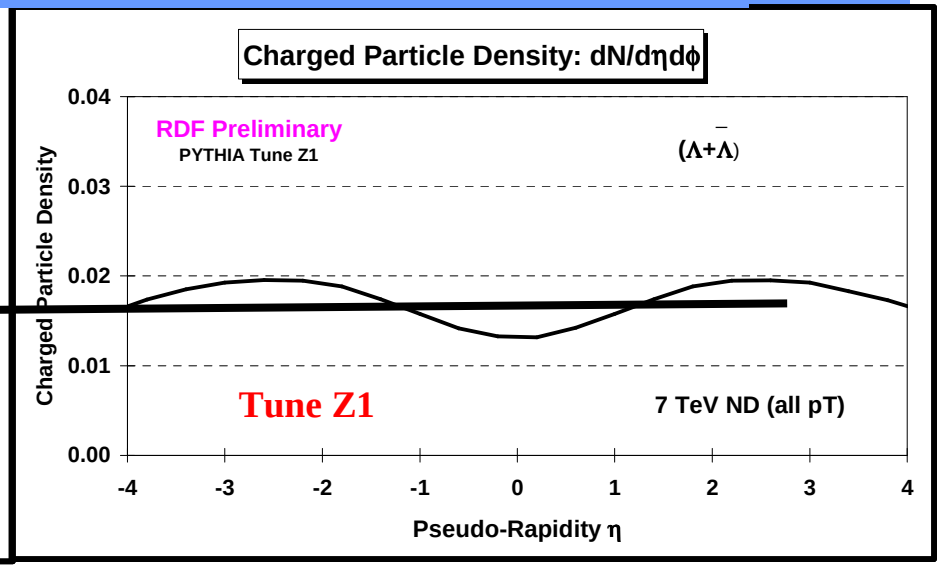
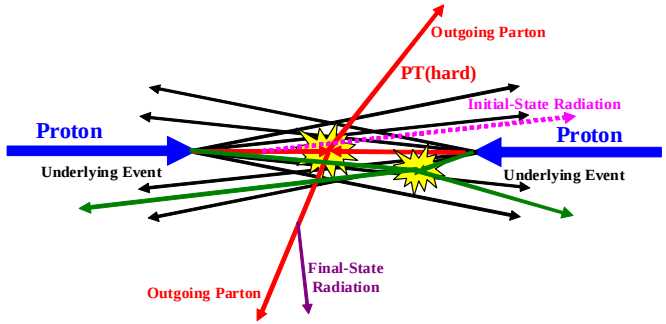
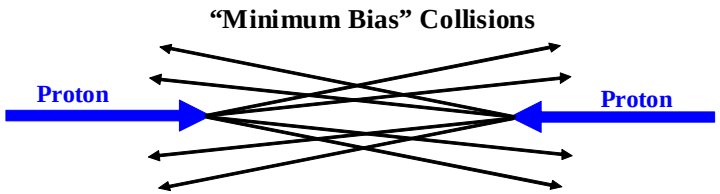


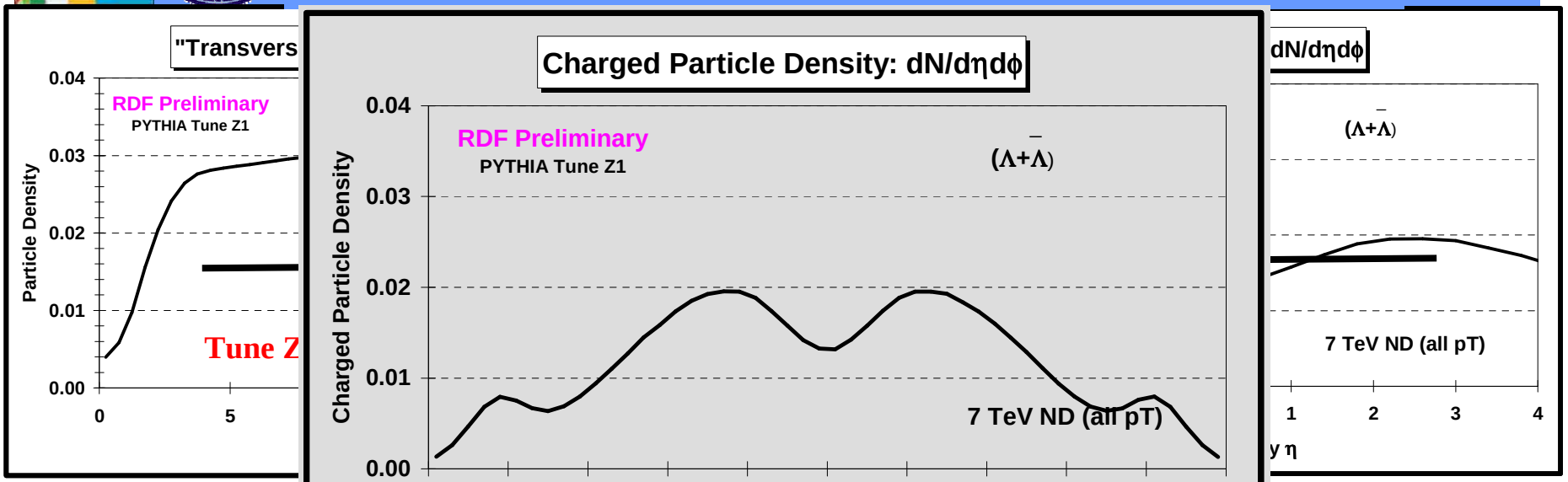


- Shows the density of Λ+antiΛ particles in the "transverse" region as a function of PTmax for charged particles (All p_T, $|\eta| < 2$) at 7 TeV from PYTHIA Tune Z1.
- Shows the Λ+antiΛ pseudo-rapidity distribution (all p_T) at 7 TeV from PYTHIA Tune Z1. The plot shows the average number of particles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





MB versus UE



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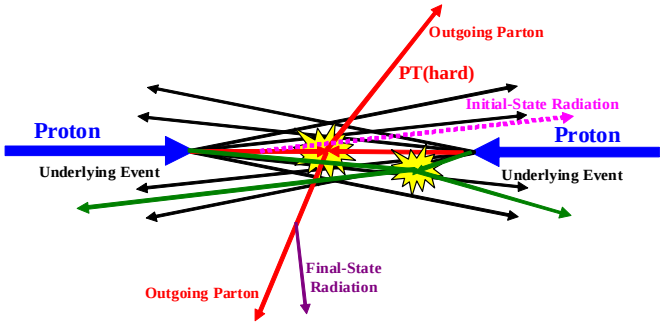
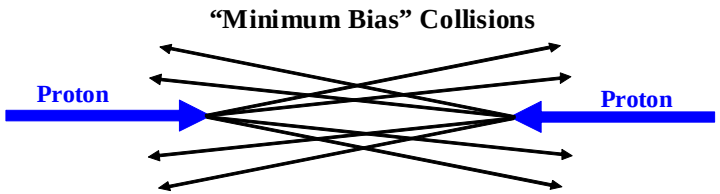
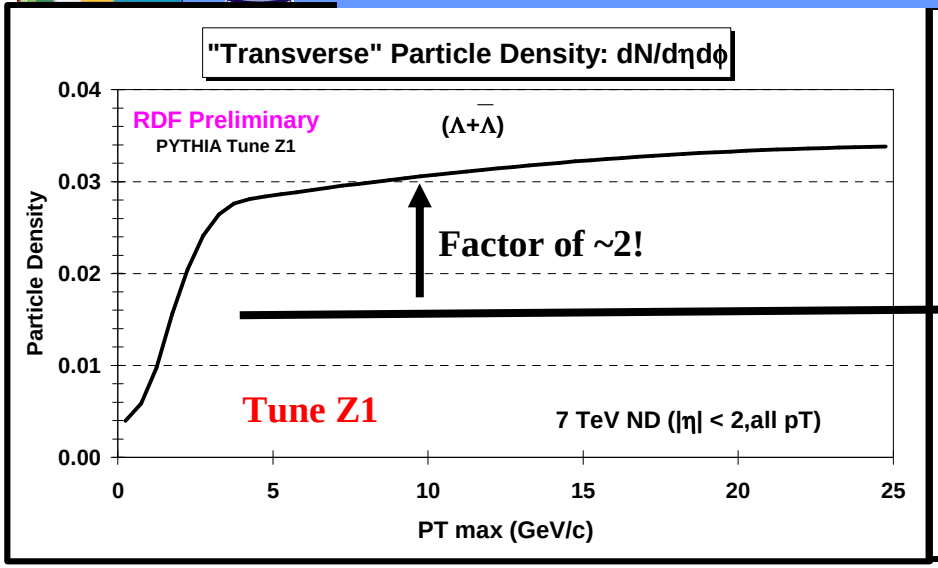
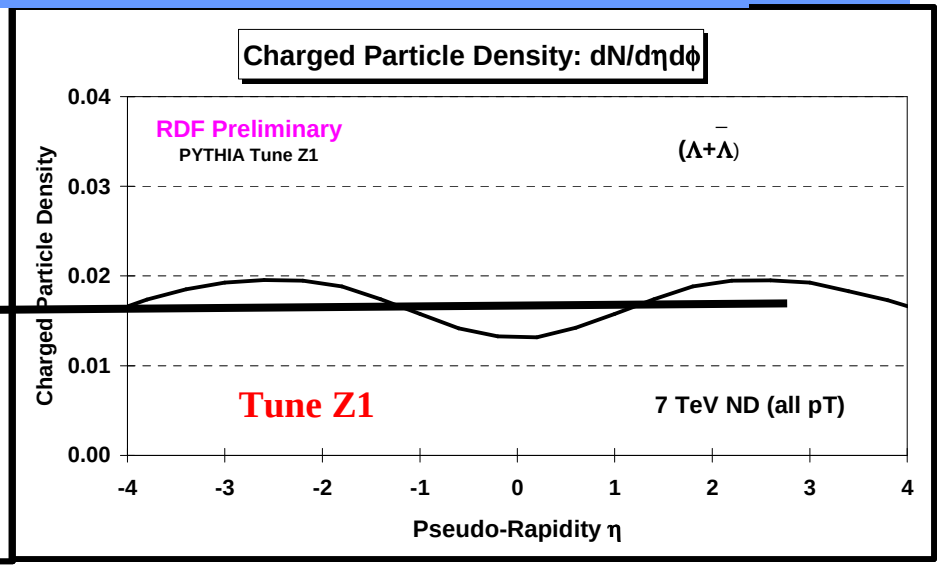


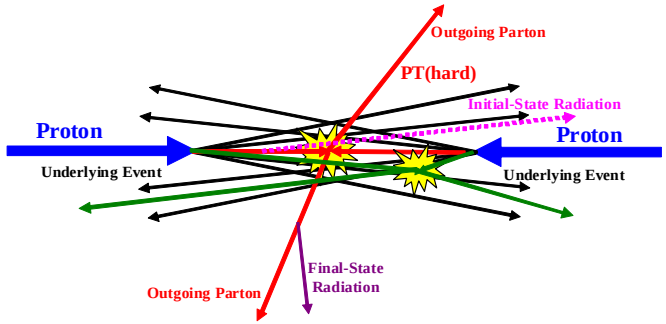


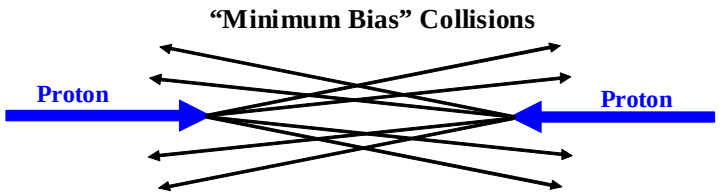
MB versus UE



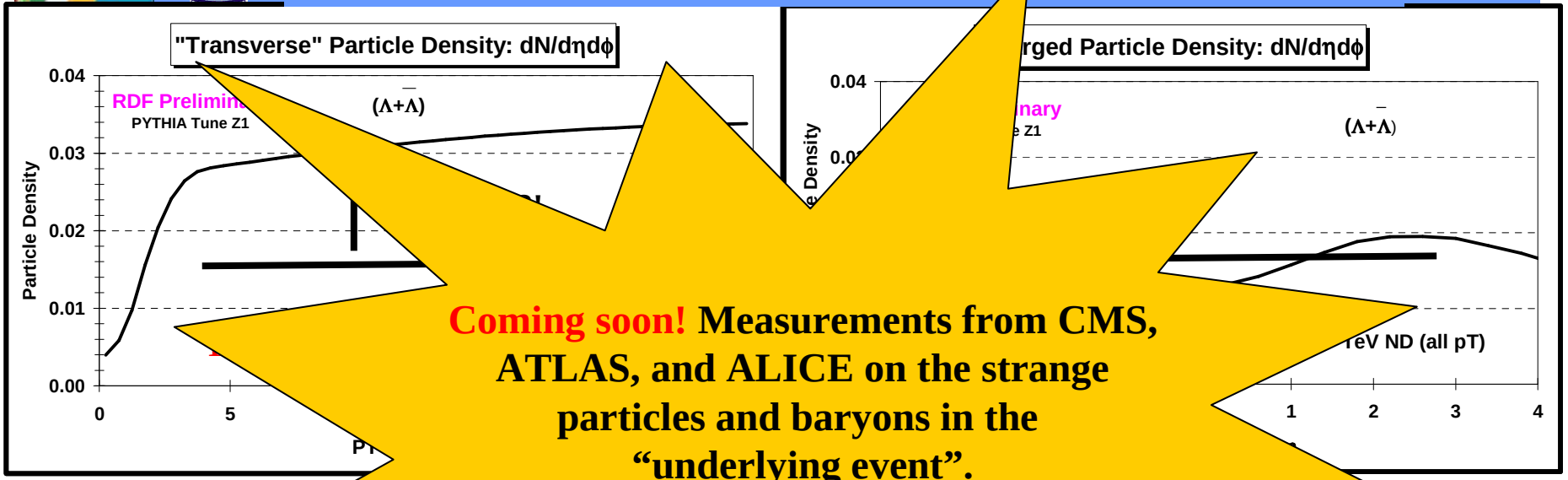


- Shows the density of Λ+antiΛ particles in the "transverse" region as a function of PTmax for charged particles (All p_T, $|\eta| < 2$) at 7 TeV from PYTHIA Tune Z1.
- Shows the Λ+antiΛ pseudo-rapidity distribution (all p_T) at 7 TeV from PYTHIA Tune Z1. The plot shows the average number of particles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



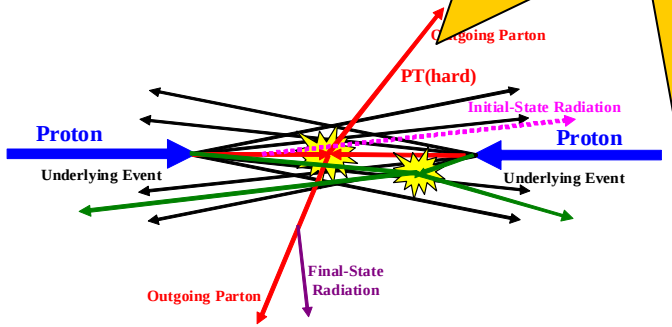


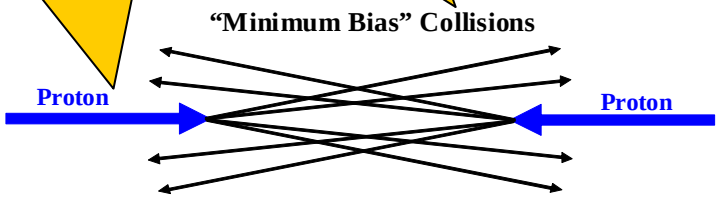
MB versus UE



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

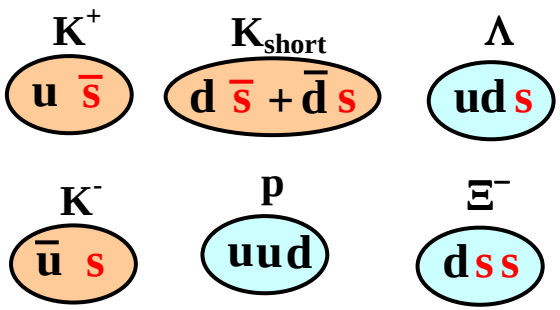
- **Shows the densit** … **istribution the "transve** … **PYTHIA Tune Z1. The PTmax for charged particles** … **the** … **umber of particles per 2) at 7 TeV from PYTHIA T** … **n per u** … **, (1/N_{ND}) dN/dηdϕ.**





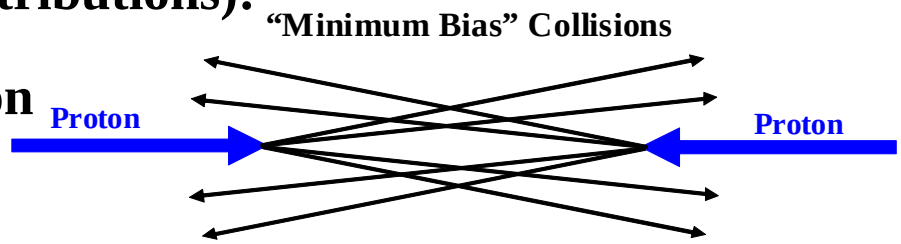
Fragmentation Summary

- **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)!**

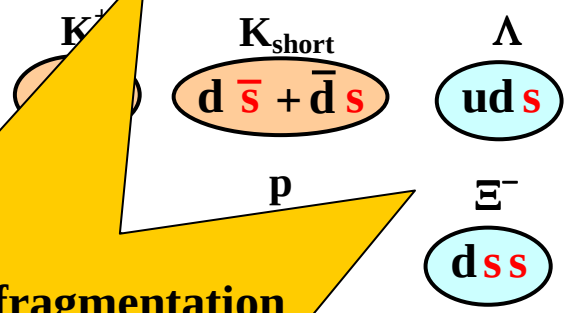
- **ATLAS Tuning Effort: Fragmentation flavor tuning at the one of the four stages.**



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

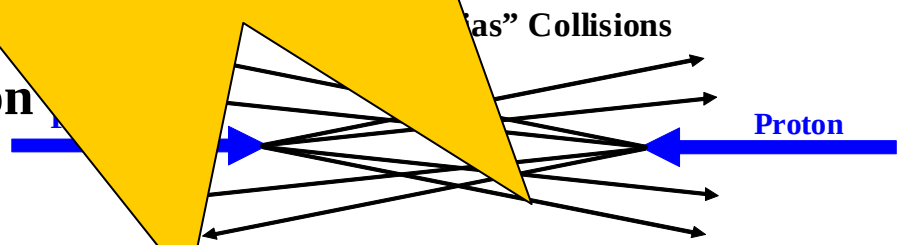
Fragmentation Summary

- Not too hard to get the overall yields of baryons and strange particles roughly right at 90[illegible]eV and 7 TeV. [illegible] Z1C does a fairly g[illegible] with th[illegible]ll particle yields at [illegible]



- PT Dist[illegible]utions of heavy pa[illegible]mentation parameters I ha[illegible]e, if one looks at partic[illegible]en data and M[illegible]

Warning! The Tune Z1C fragmentation parameters may cause problems fitting the LEP data. If so we must understand why! We do not want one tune for e^+e^- and another one for hadron-hadron collisions!



- ATLAS Tuning Effo[illegible]ag[illegible]on [illegible] flavor tuning at the [illegible]ne of the [illegible] stages.

- **Herwig++ & Sherpa:** Before m[illegible]king any conclusions about fragmentation one must check the predictions of Herwig++ and Sherpa carefully!