QCD@LHC 2016

MB & UE Monte Carlo Model Tunes

QCD@LHC
22ND–26TH AUGUST 2016
INTERNATIONAL CONFERENCE ZURICH

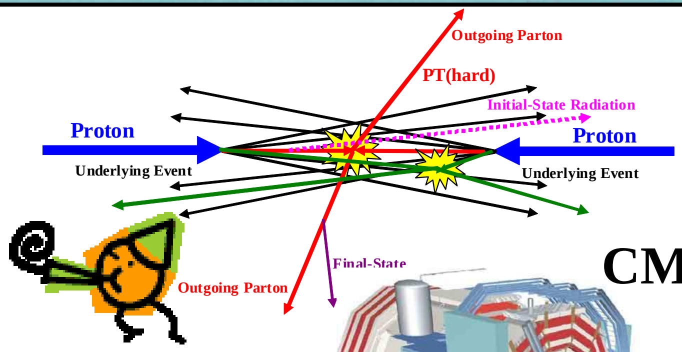
Rick Field

University of Florida

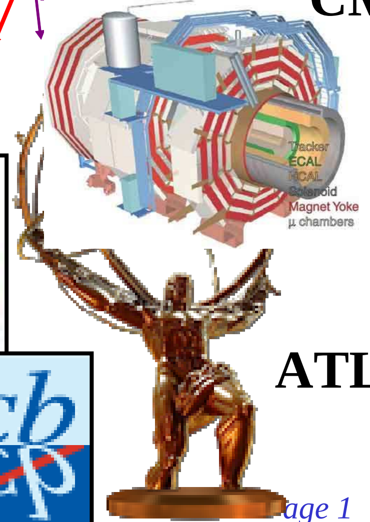
Quantum **C**hromo- **D**ynamics

Outline of Talk

- **MB-UE-DPS:** Relationships between Min-Bias (MB), the underlying event (UE), and double parton scattering (DPS).
- **ATLAS Tune A3:** New ATLAS PYTHIA 8 MB tune.
- **ATLAS Z-UE:** The UE in Z-Boson production at 7 TeV.
- **CMS UE Tunes:** Two PYTHIA 6 tunes, three PYTHIA 8 tunes, and one HERWIG++ tune from the CMS “Physics Comparisons & Generator Tunes” subgroup.
- **HERWIG 7 Tunes:** Tune CUETHS1-CTEQ6L (the same as the CMS HW++ tune CUETHS1-CTEQ6L except using HW7. HW7 Default Tune using the MMHT2014 PDF.
- **MB&UE@13TeV:** Some UE and MB measurements from the LHC and MC comparisons.
- **Simultaneous UE-MB-DPS Tunes:** Can we fit UE data, MB data, and DPS sensitive data with one universal tune?

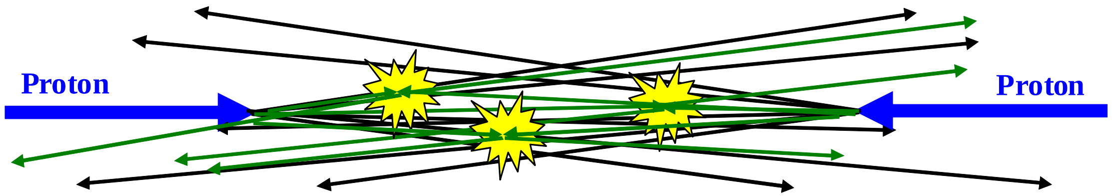


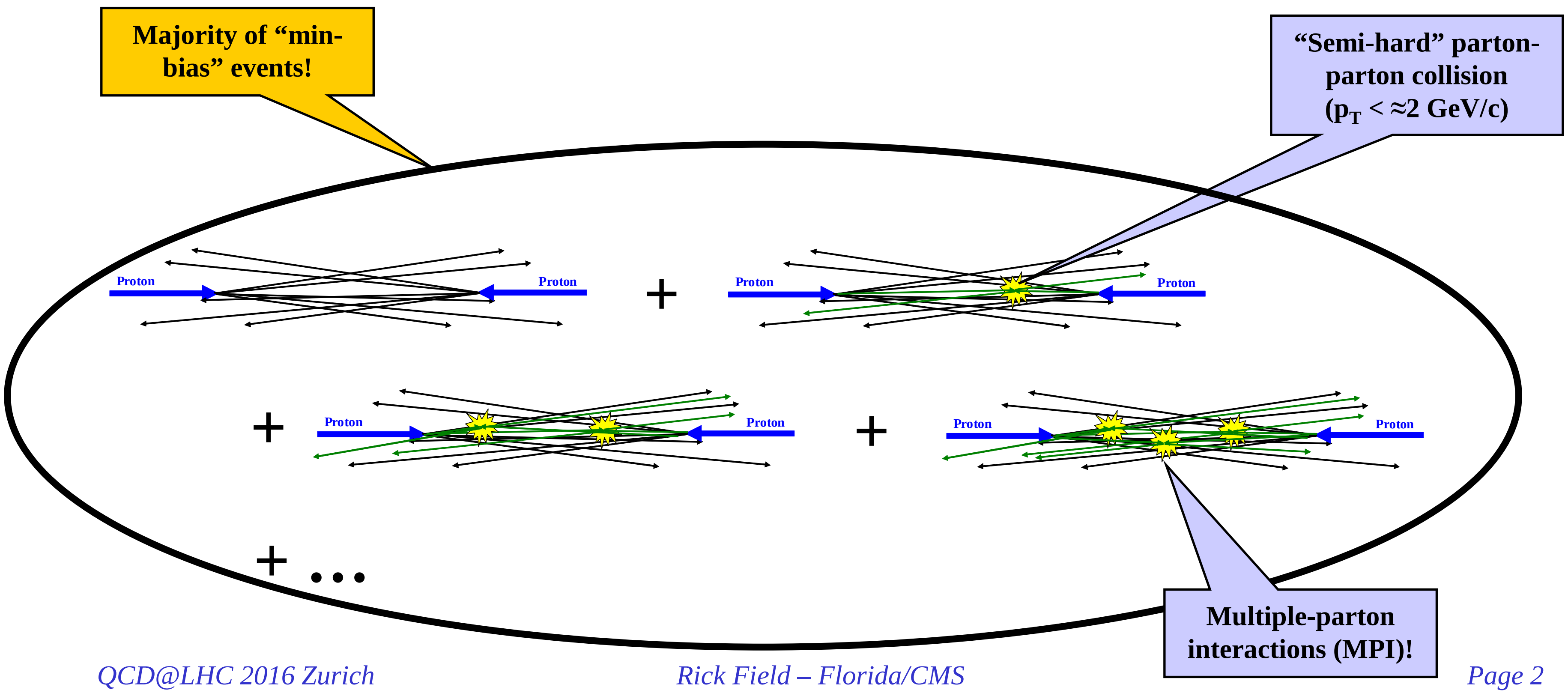
CMS



ATLAS

The Inelastic Non-Diffractive Cross-Section





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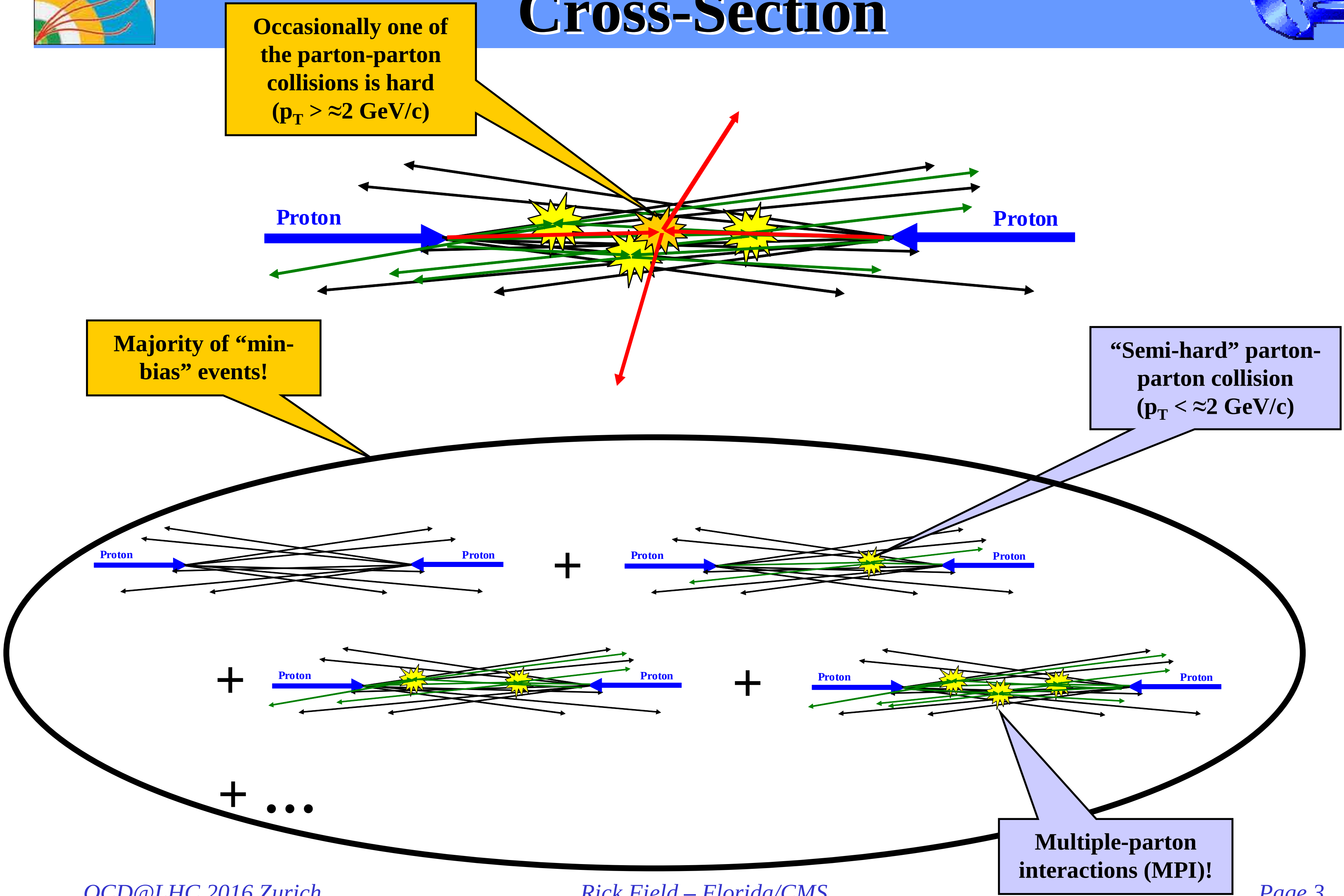
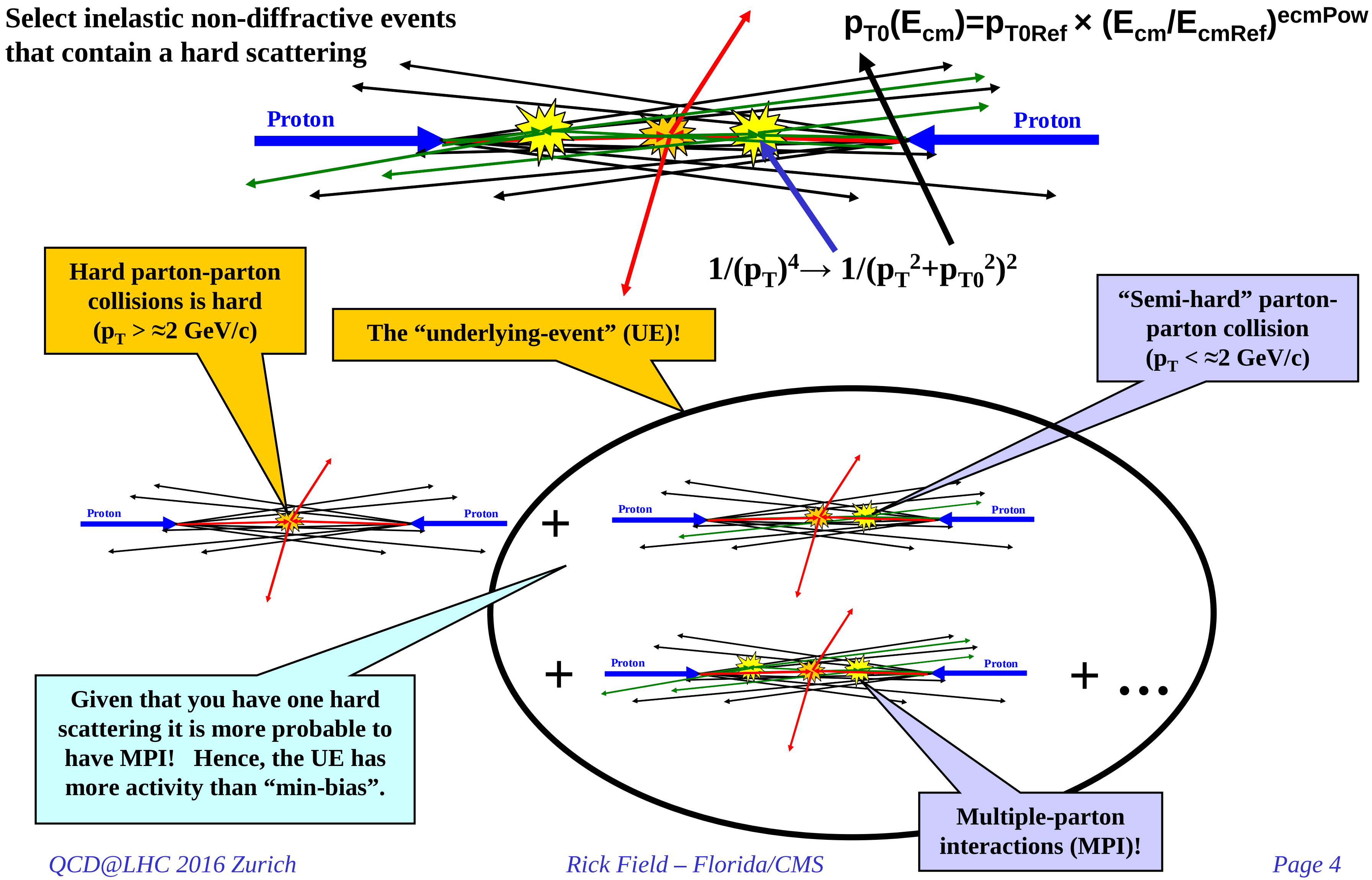


The "Underlying Event"

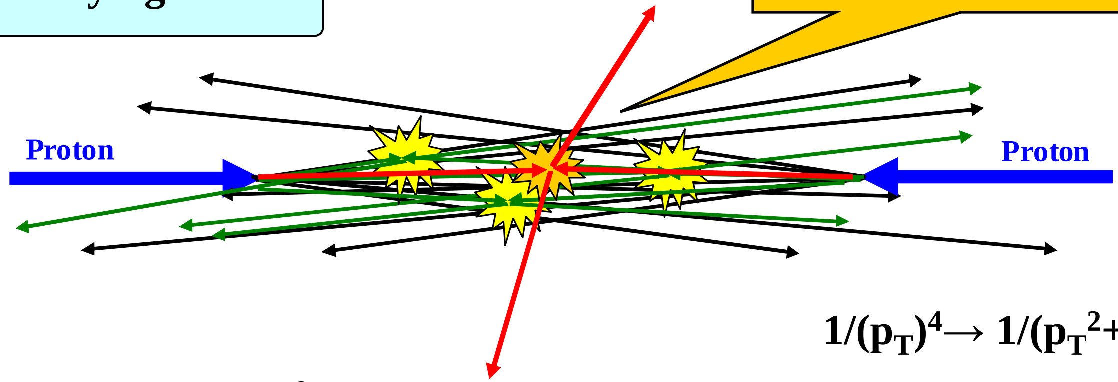


UE Tunes and MB

"Underlying Event"

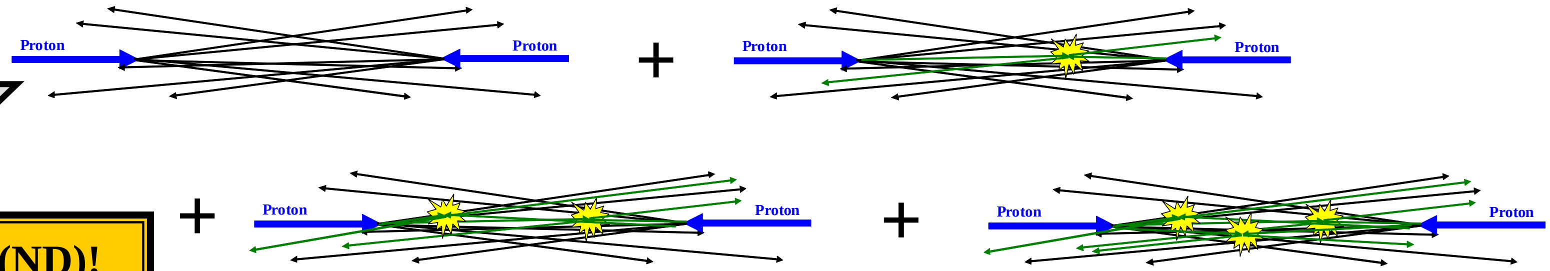
Allow primary hard-scattering to go to $p_T = 0$ with same cut-off!

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



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

"Min-Bias" (ND)



Predict MB (ND)!

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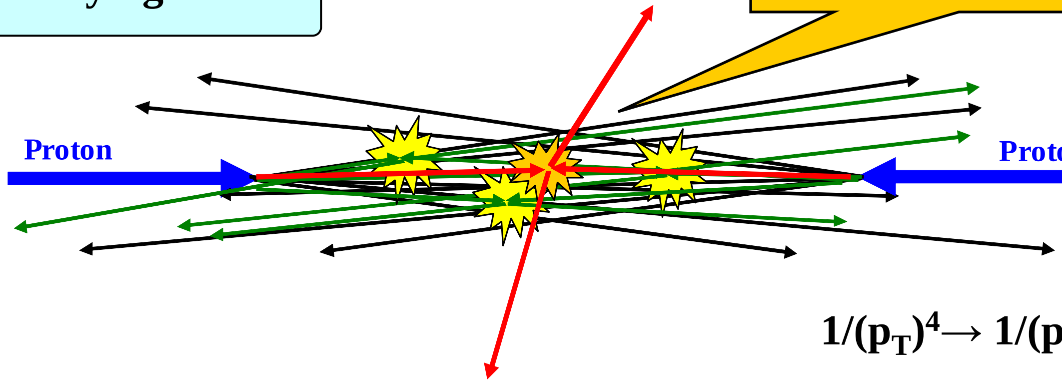
UE Tunes and MB

"Underlying Event"

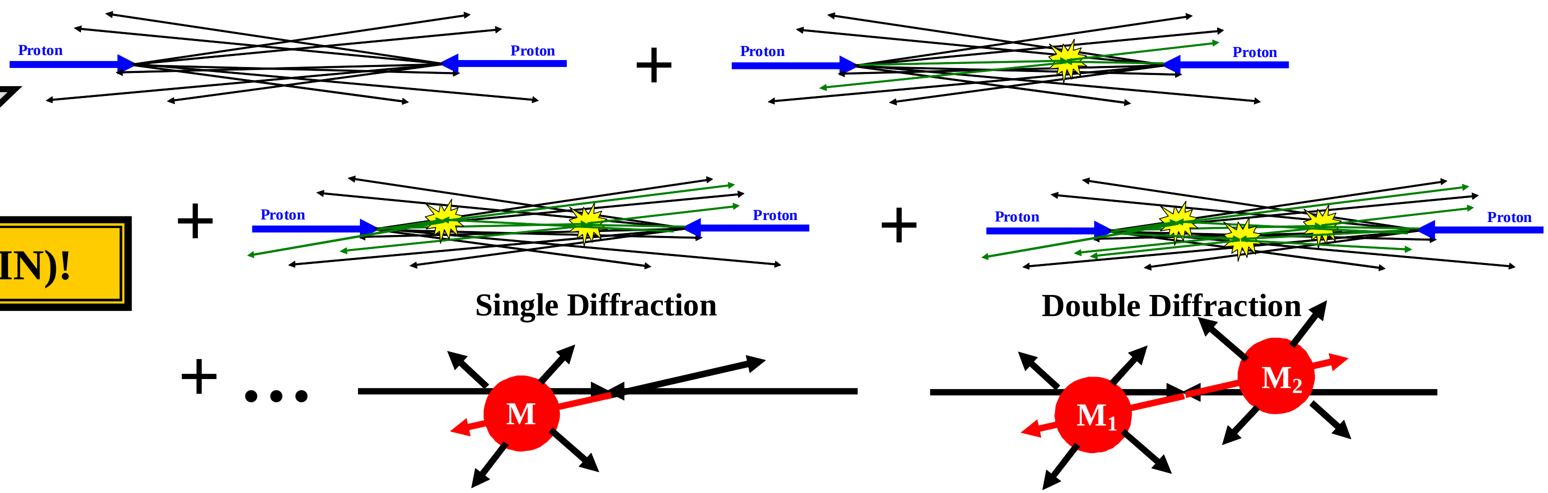
Fit the "underlying event" in a hard scattering process.

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



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

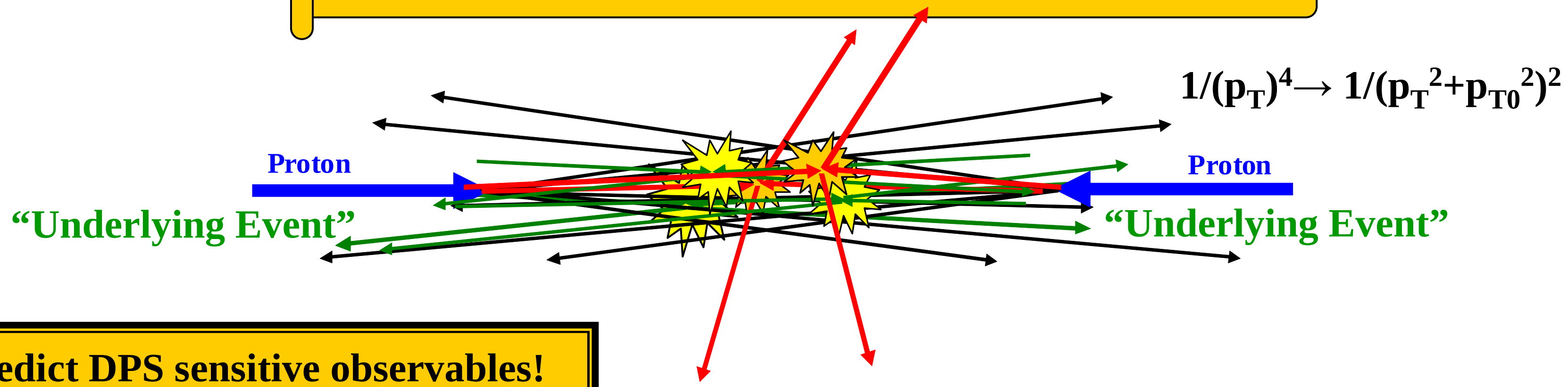
"Min-Bias" (add single & double diffraction)



Predict MB (IN)!

UE Tunes and DPS

DPS: Double Parton Scattering

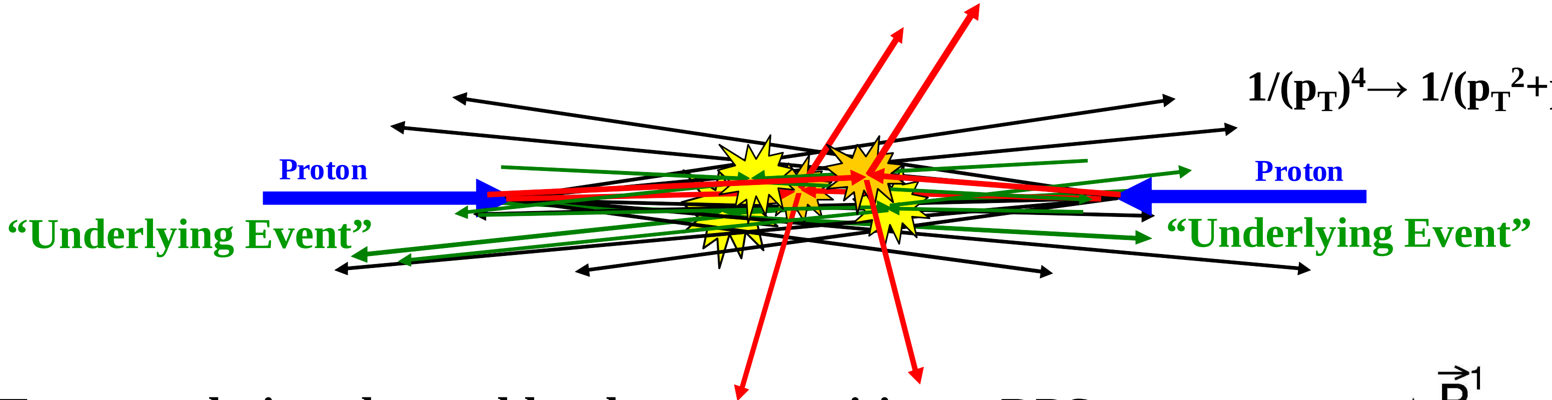


Predict DPS sensitive observables!

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

Most of the time MPI are much "softer" than the primary "hard" scattering, however, occasionally two "hard" 2-to-2 parton scatterings can occur within the same hadron-hadron. This is referred to as double parton scattering (DPS).

DPS Observables

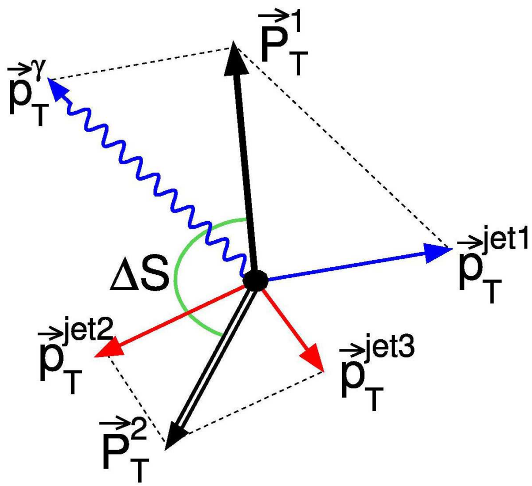


$1/(p_T)^4 \rightarrow 1/(p_T^2+p_{T0}^2)^2$

- Two correlation observables that are sensitive to DPS are ΔS and $\Delta^{rel}pT$ defined as follows:

$$\Delta S = \arccos\left(\frac{\vec{p}_T(object\#1)\cdot\vec{p}_T(object\#2)}{|\vec{p}_T(object\#1)|\times|\vec{p}_T(object\#2)|}\right)$$

$$\Delta^{rel}p_T = \frac{\left|\vec{p}_T^{\,jet\#1}+\vec{p}_T^{\,jet\#2}\right|}{\left|\vec{p}_T^{\,jet\#1}\right|+\left|\vec{p}_T^{\,jet\#2}\right|)}$$



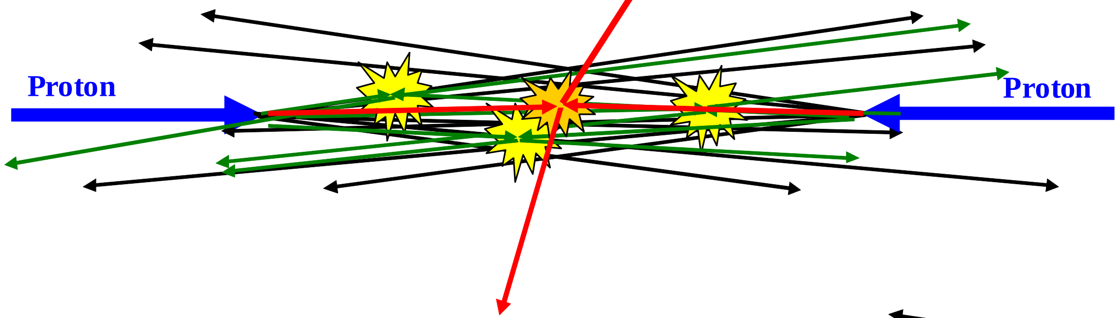
For γ+3jets object#1 is the photon and the leading jet (jet1) and object#2 is jet2 and jet3. For W+dijet production object#1 is the W-boson and object#2 dijet. For 4-jet production object#1 is hard-jet pair and object#2 is the soft-jet pair. For $\Delta^{rel}p_T$ in W+dijet production jet#1 and jet#2 are the two dijets, while in 4-jet production jet#1 and jet#2 are the softer two jets.

Universal UE-MB-DPS Tune

My dream!

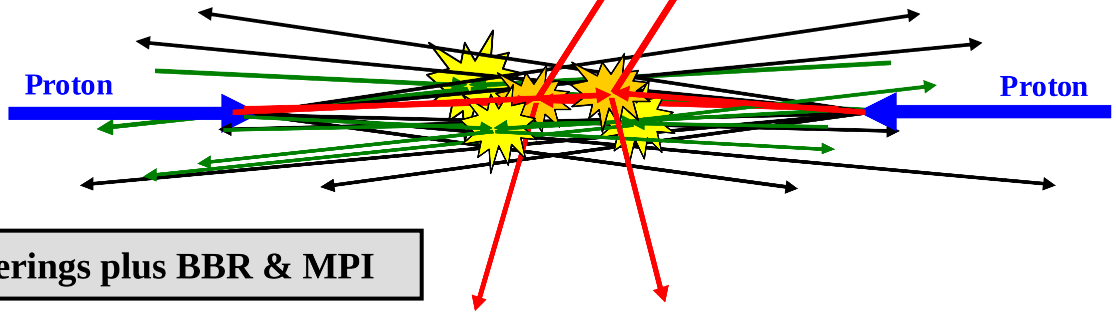
"Underlying Event"

One hard scattering plus BBR & MPI



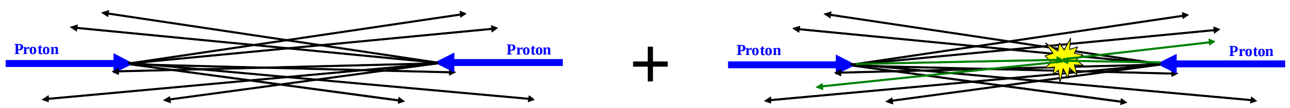
DPS

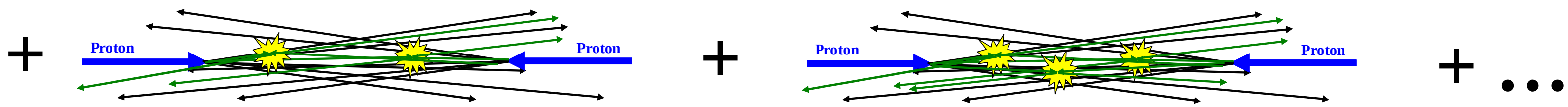
Two hard scatterings plus BBR & MPI



"Min-Bias" (ND)

No hard scatterings plus BBR & MPI





Universal UE-MB-DPS Tune

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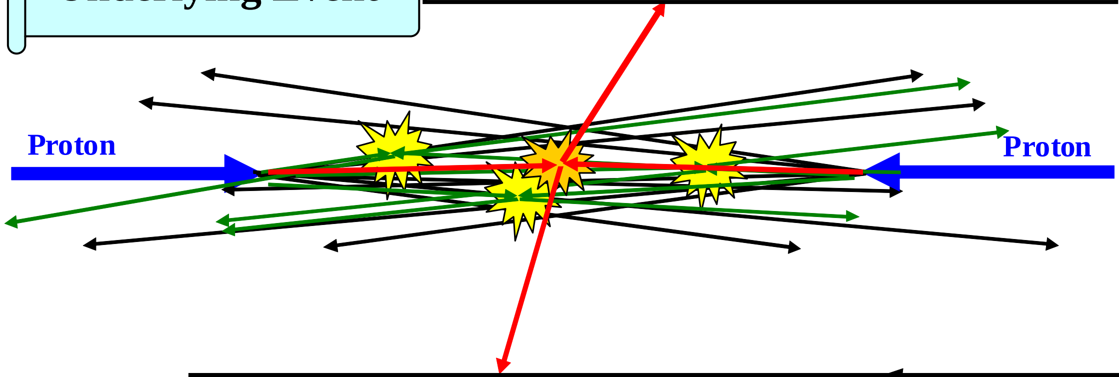


DPS

Two hard scatterings plus BBR & MPI

Proton

"Min-

Proton

Alternatively one can produce separate MB tunes (like ATLAS Tune A2 & A3), and separate UE tunes (like ATLAS Tune A14), and separate DPS tunes (like CMS Tune CDPSTP8S2-4j).

The experimental side of me thinks this is fine.

The theoretical side of me dreams of a universal tune.

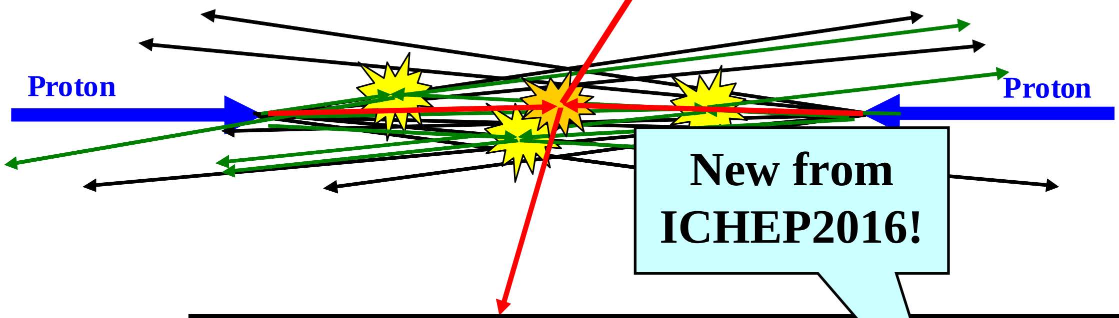
\+ …

Universal UE-MB-DPS Tune

"Underlying Event"

One hard scattering plus BBR & MPI

My dream!



New from ICHEP2016!

DPS

Two hard scatterings plus BBR & MPI

Proton

"Min-

Proton

+

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ATLAS A3 Tune

Deepak Kar ICHEP2016

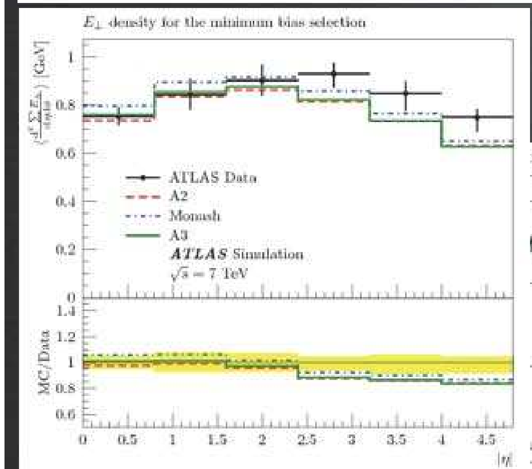
Pythia8 A3 Tune

New

Tom Sykora's Talk

	ATLAS data (mb)	SS (mb)	A3 (mb)
At $\sqrt{s}$ = 13 TeV	68.1 ± 1.4	74.4	69.9
At $\sqrt{s}$ = 7 TeV	60.3 ± 2.1	66.1	62.3

Using Donnachie-Landshoff diffractive model and NNPDF2.3LO



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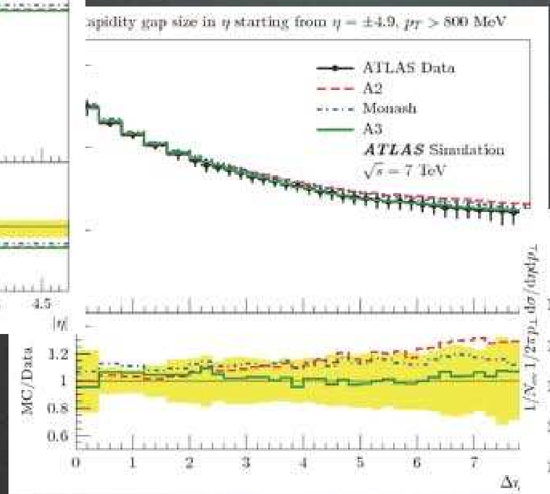
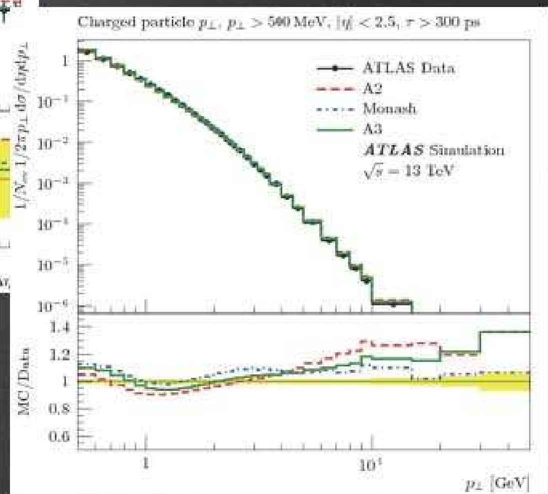


Much improved total inelastic cross section prediction



Mostly similar level of agreement with Minbias observables 16

ATLAS A3 Tune

Deepak Kar ICHEP2016

Pythia8 A3 Tune

New

Tom Syko

At $\sqrt{s}$ = 13 T
At $\sqrt{s}$ = 7 Te

Parameter	A3 value	A2 value	Monash value
`MultipartonInteractions:pT0Ref`	2.45	1.90	2.28
`MultipartonInteractions:ecmPow`	0.21	0.30	0.215
`MultipartonInteractions:coreRadius`	0.55	-	-
`MultipartonInteractions:coreFraction`	0.90	-	-
`MultipartonInteractions:a1`	-	0.03	-
`MultipartonInteractions:expPow`	-	-	1.85
`BeamRemnants:reconnectRange`	1.8	2.28	1.8
`Diffraction:PomFluxEpsilon`	0.07 (0.085)	-	-
`Diffraction:PomFluxAlphaPrime`	0.25 (0.25)	-	-

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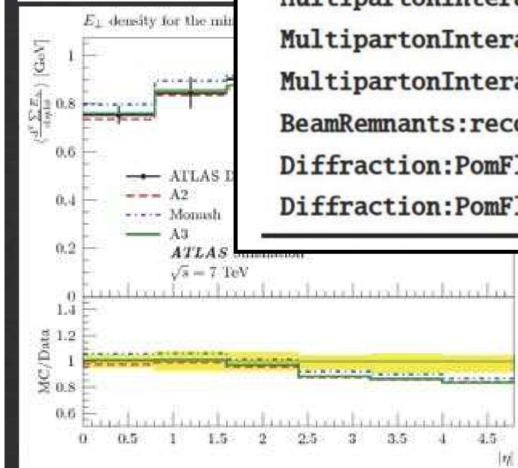
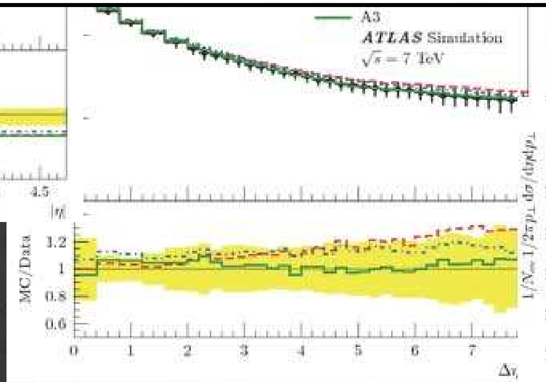
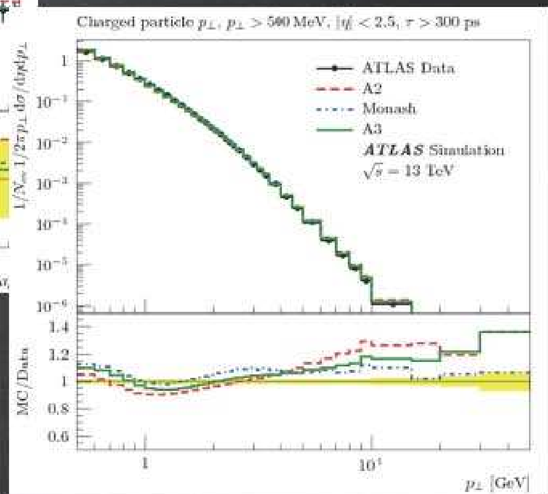




prediction



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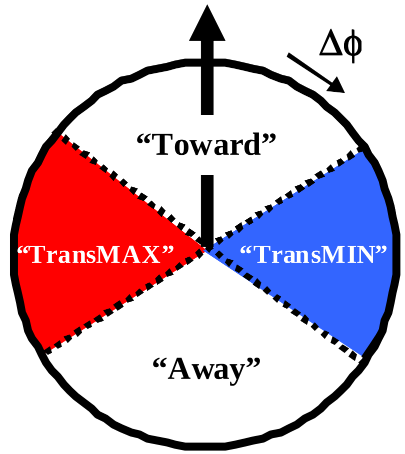
Mostly similar level of agreement with Minbias observables

UE Observables

- **"transMAX" and "transMIN" Charged Particle Density:** Number of charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 0.8$) in the the maximum (minimum) of the two "transverse" regions as defined by the leading charged particle, PTmax, divided by the area in η-ϕ space, $2\eta_{cut} \times 2\pi/6$, averaged over all events with at least one particle with $p_T > 0.5$ GeV/c, $|\eta| < \eta_{cut}$.



- **"transMAX" and "transMIN" Charged PTsum Density:** Scalar p_T sum of charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 0.8$) in the the maximum (minimum) of the two "transverse" regions as defined by the leading charged particle, PTmax, divided by the area in η-ϕ space, $2\eta_{cut} \times 2\pi/6$, averaged over all events with at least one particle with $p_T > 0.5$ GeV/c, $|\eta| < \eta_{cut}$.

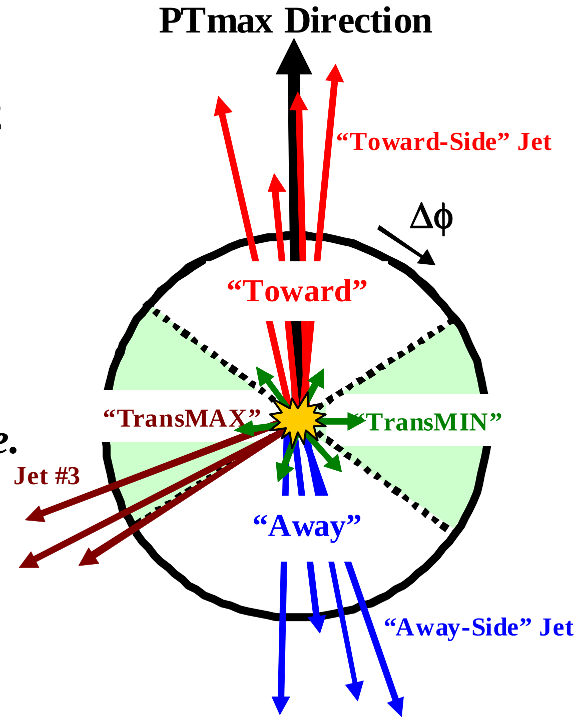
Note: The overall "transverse" density is equal to the average of the "transMAX" and "TransMIN" densities. The "TransDIF" Density is the "transMAX" Density minus the "transMIN" Density

"Transverse" Density = "transAVE" Density = ("transMAX" Density + "transMIN" Density)/2

"TransDIF" Density = "transMAX" Density - "transMIN" Density

"transMIN" & "transDIF"

- **The "toward" region contains the leading "jet", while the "away" region, on the average, contains the "away-side" "jet". The "transverse" region is perpendicular to the plane of the hard 2-to-2 scattering and is very sensitive to the "underlying event". For events with large initial or final-state radiation the "transMAX" region defined contains the third jet while both the "transMAX" and "transMIN" regions receive contributions from the MPI and beam-beam remnants. Thus, the "transMIN" region is very sensitive to the multiple parton interactions (MPI) and beam-beam remnants (BBR), while the "transMAX" minus the "transMIN" (*i.e.* "transDIF") is very sensitive to initial-state radiation (ISR) and final-state radiation (FSR).**



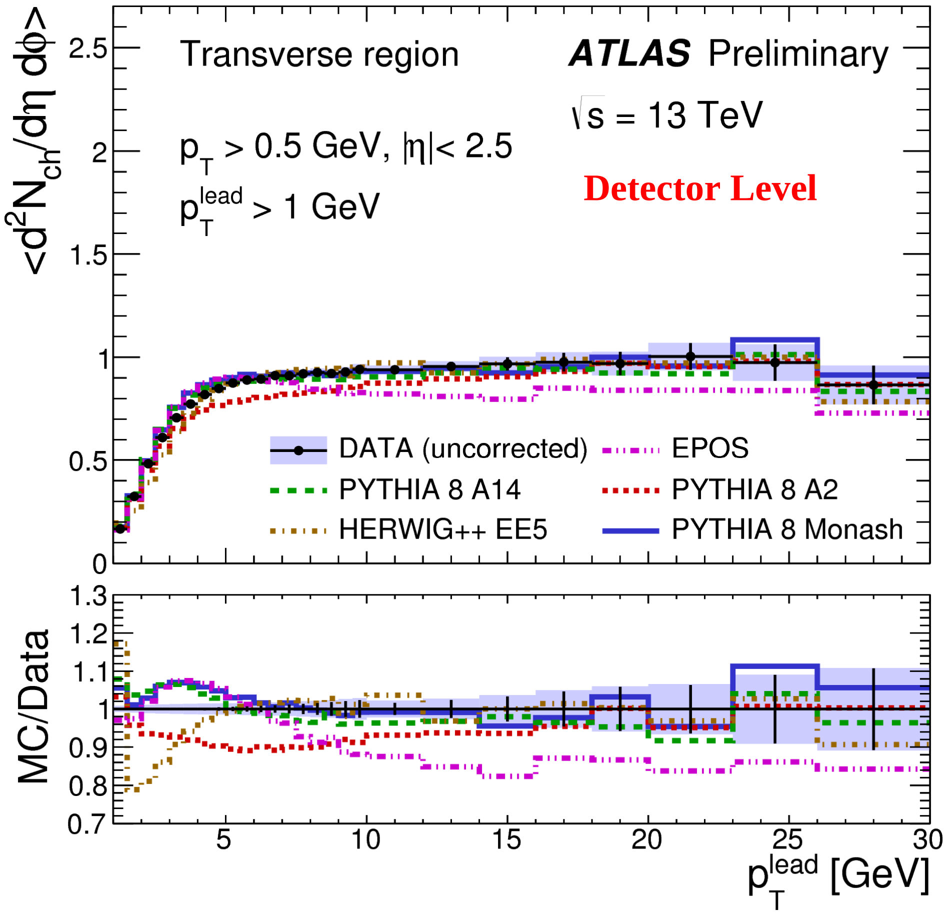
"TransMIN" density more sensitive to MPI & BBR.

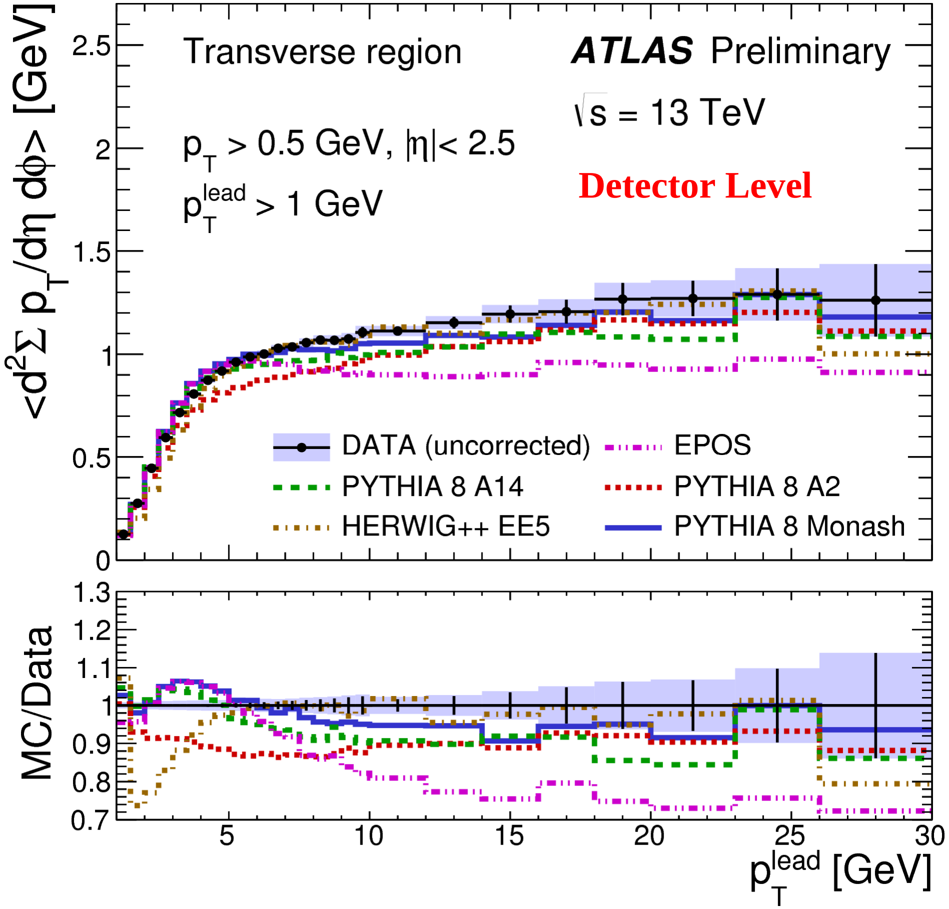
"TransDIF" density more sensitive to ISR & FSR.

0 ≤ "TransDIF" ≤ 2×"TransAVE"

"TransDIF" = "TransAVE" if "TransMIX" = 3×"TransMIN"

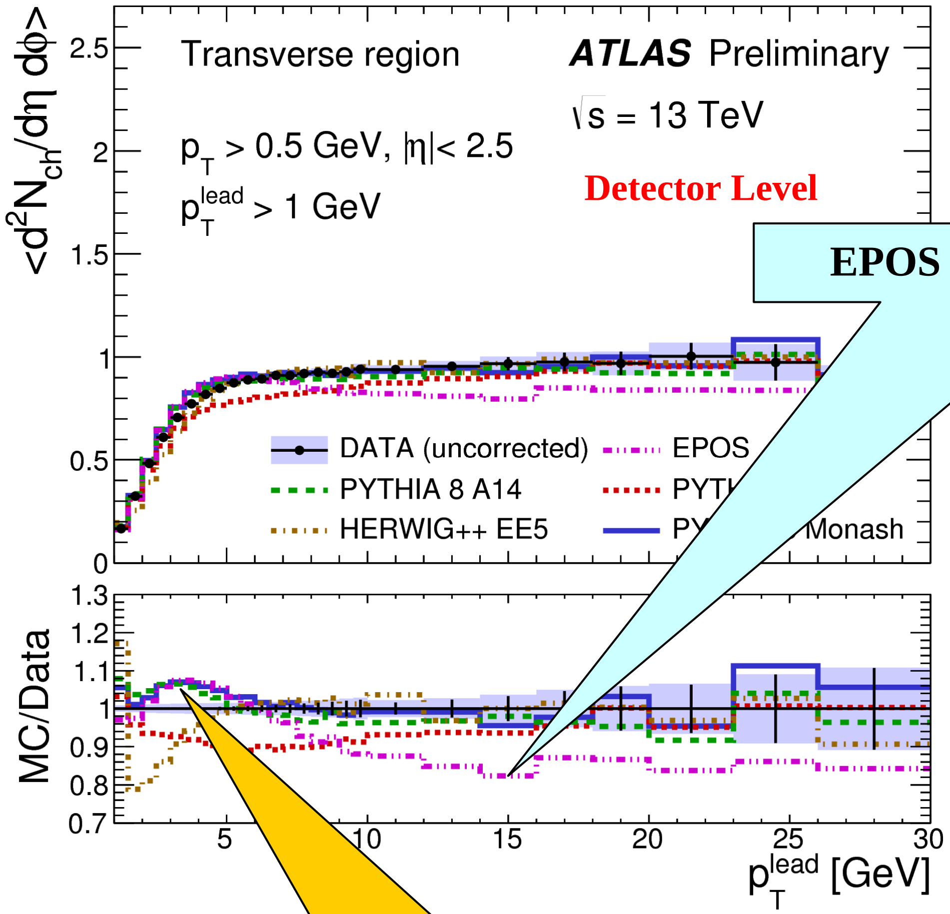
ATLAS 13 TeV UE Data

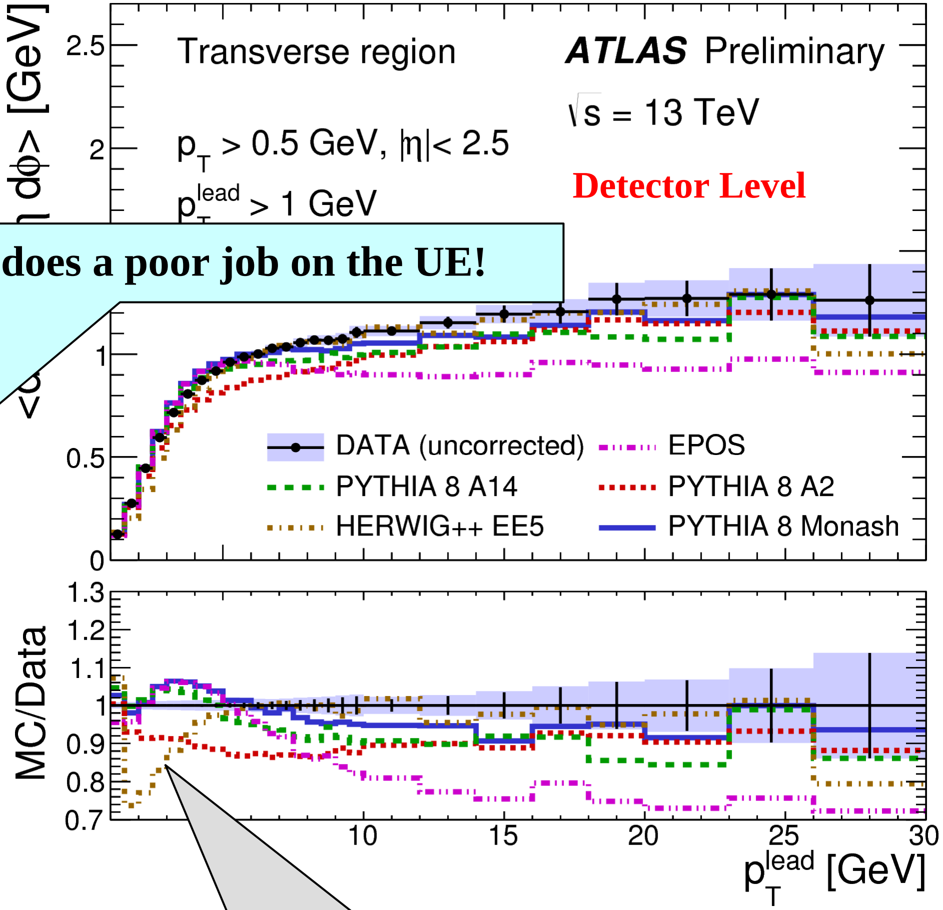




- **ATLAS data at 13 TeV on the charged particle density (*left*) and charged PTsum density (*right*) in the "transAVE" region as defined by the leading charged particle for charged particles with p_T > 0.5 GeV/c and |η| < 2.5. The data are uncorrected and compared with the MC models after detector simulation.**

ATLAS 13 TeV UE Data





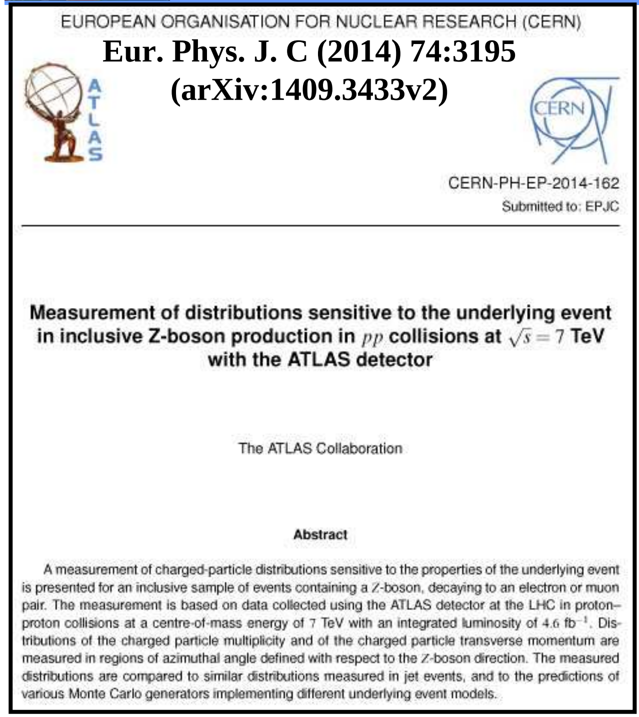
EPOS does a poor job on the UE!

Monash doing well except the turn on region!

Very strange behavior by HERWIG++ in the turn on region!

- **ATLAS data ... eV on the charged particle density (keft) ... rged PTsum density in the "transA ... ading charged p ... GeV/c a ... rected and com ... simulation.**

The UE in Z-Boson Production


EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH (CERN)

Eur. Phys. J. C (2014) 74:3195
(arXiv:1409.3433v2)

CERN-PH-EP-2014-162
Submitted to: EPJC

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Abstract

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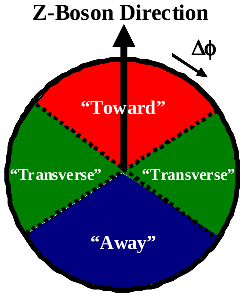
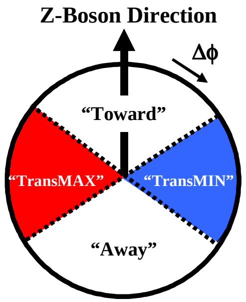
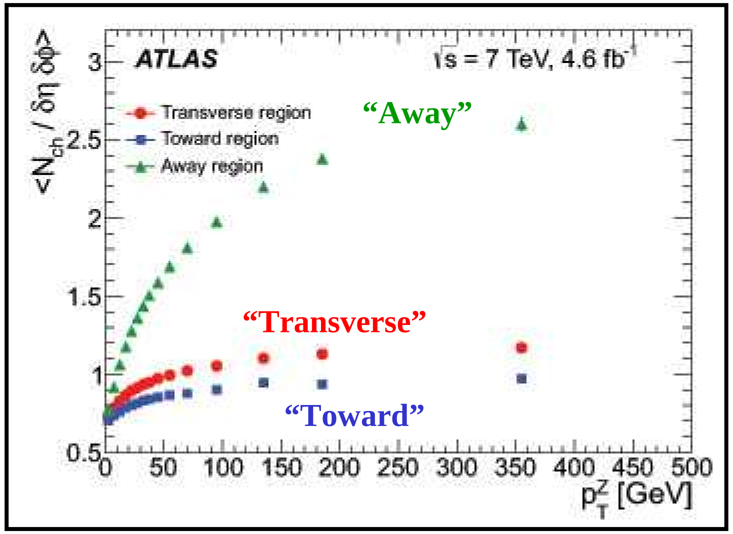
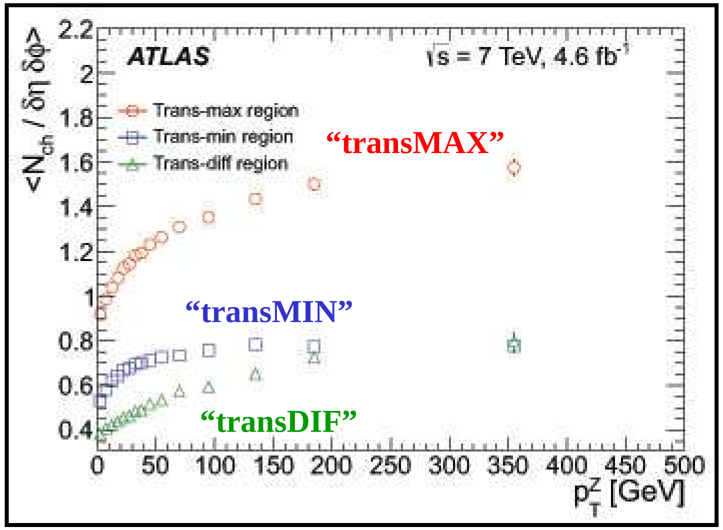
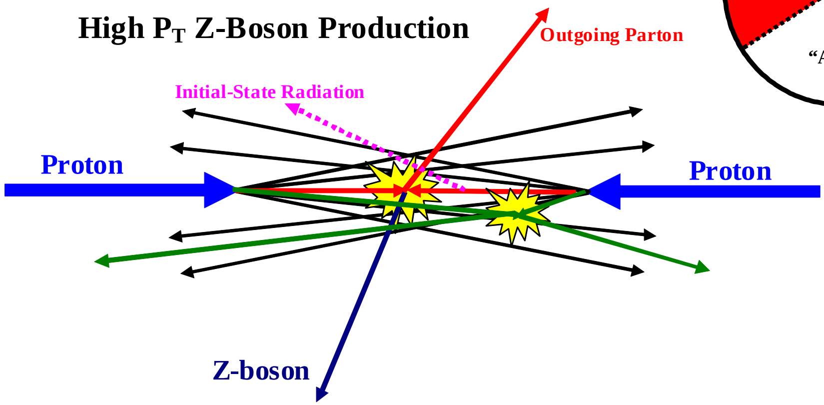








High P_T Z-Boson Production



The UE in Z-Boson Production

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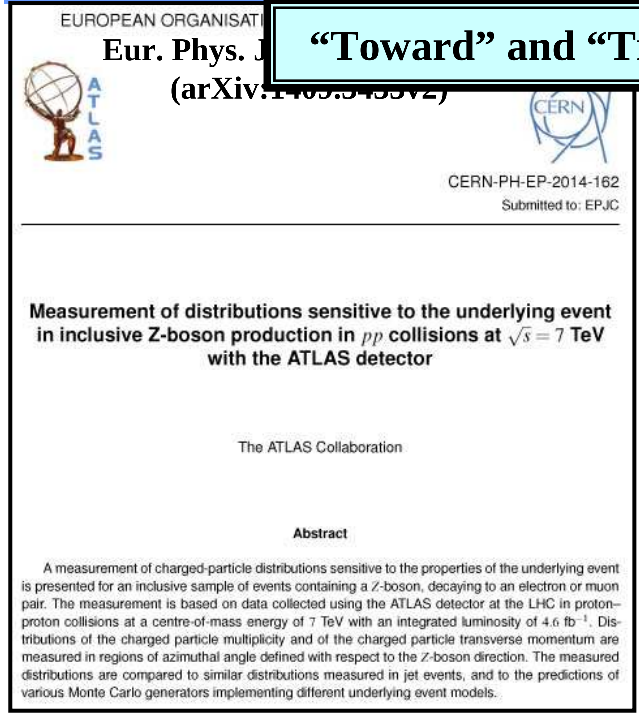

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Eur. Phys. J...

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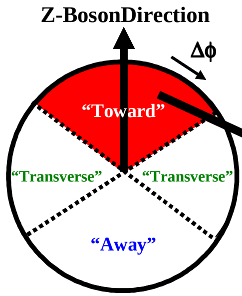

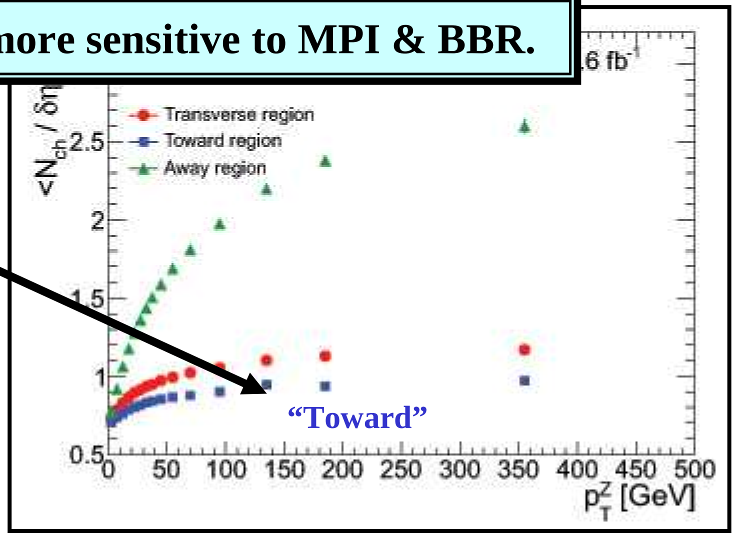

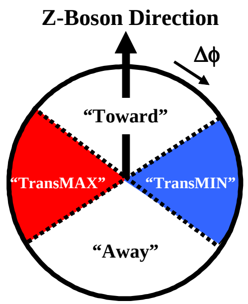

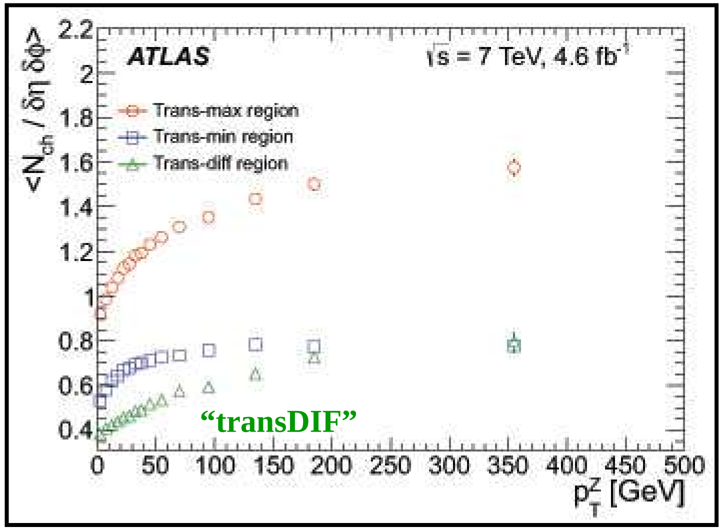

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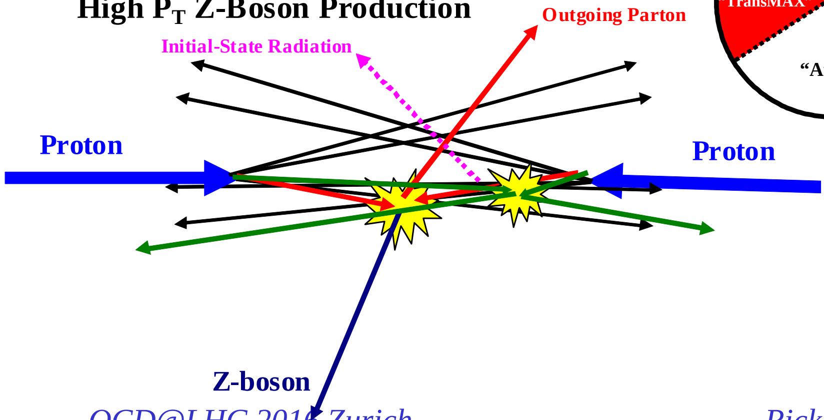

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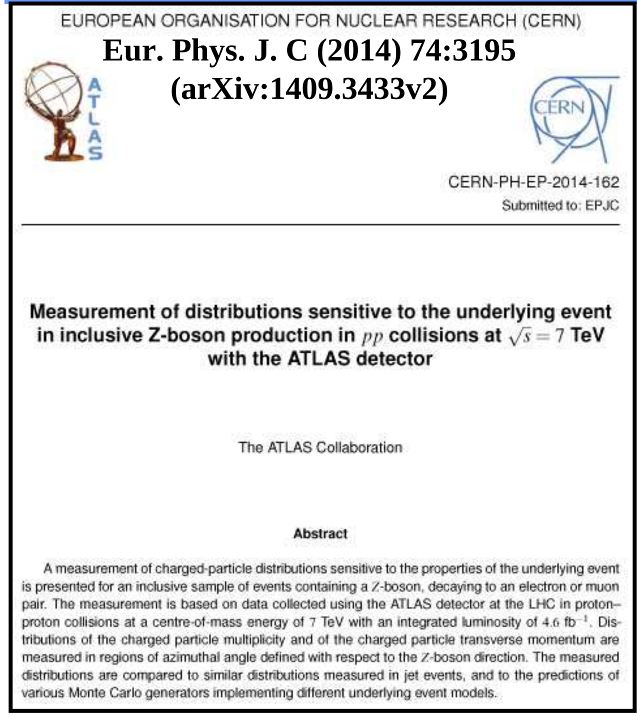

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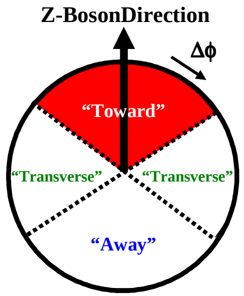
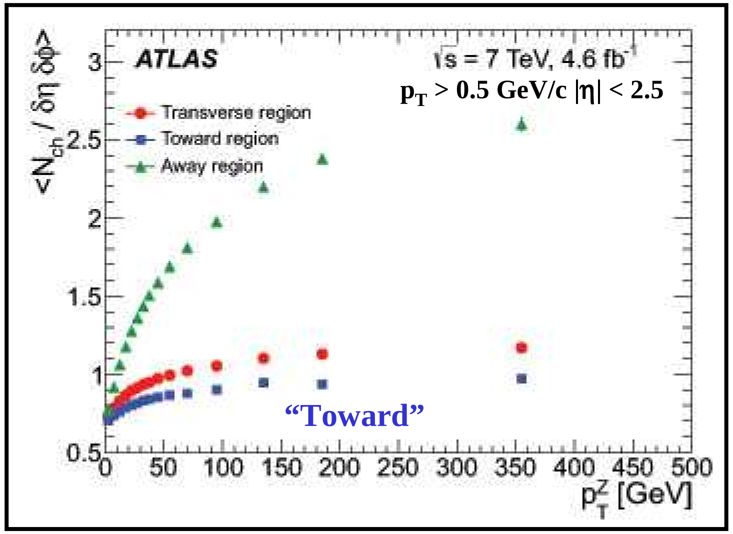
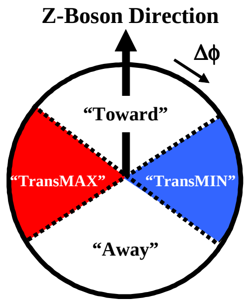
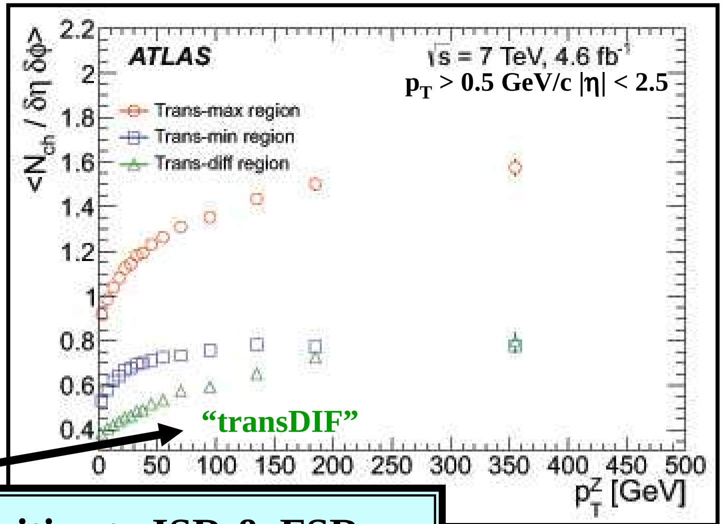
Abstract

A measurement of charged-particle distributions sensitive to the properties of the underlying event is presented for an inclusive sample of events containing a Z-boson, decaying to an electron or muon pair. The measurement is based on data collected using the ATLAS detector at the LHC in proton–proton collisions at a centre-of-mass energy of 7 TeV with an integrated luminosity of 4.6 fb^{-1}. Distributions of the charged particle multiplicity and of the charged particle transverse momentum are measured in regions of azimuthal angle defined with respect to the Z-boson direction. The measured distributions are compared to similar distributions measured in jet events, and to the predictions of various Monte Carlo generators implementing different underlying event models.

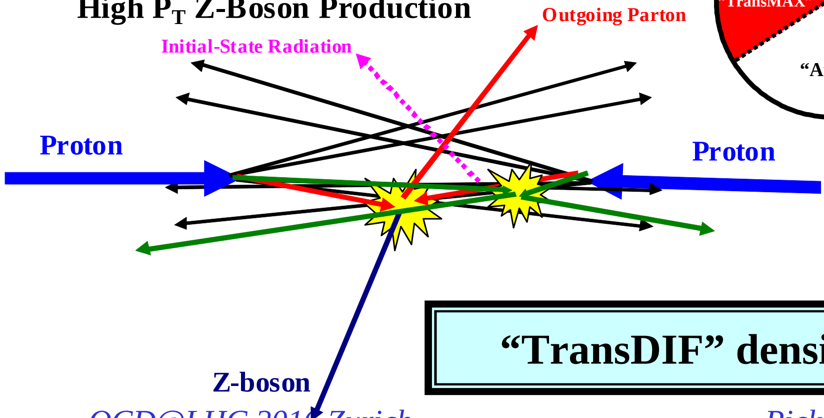






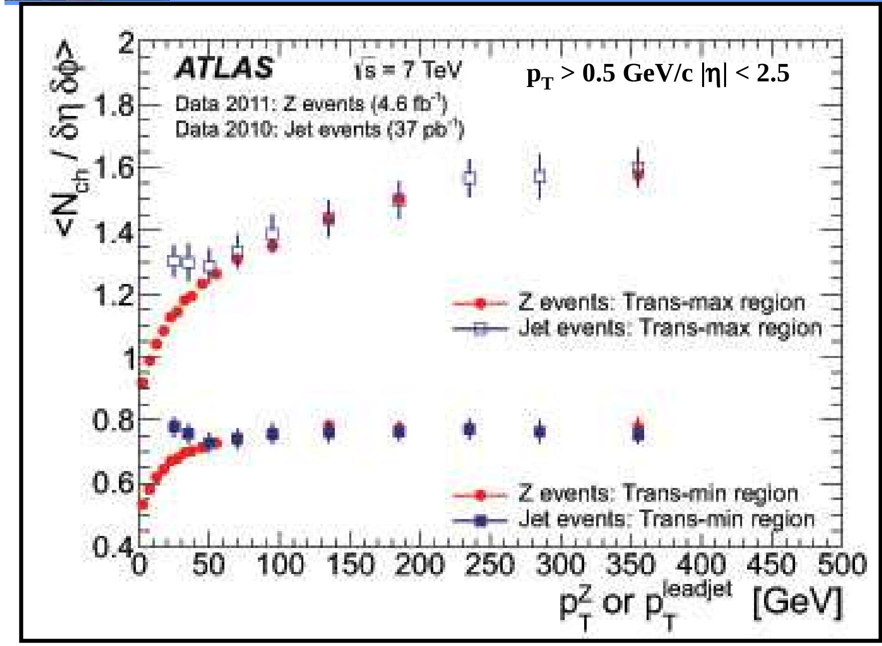


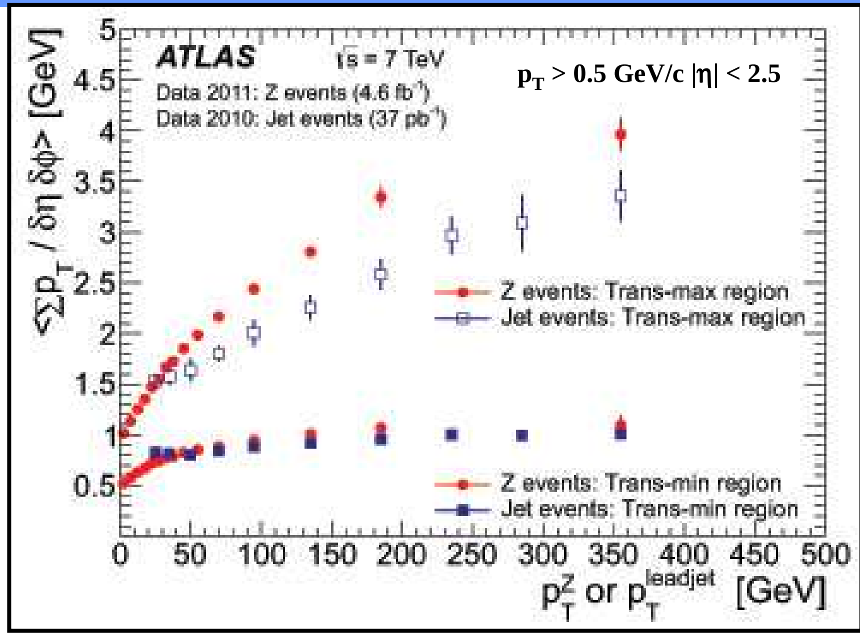
High P_T Z-Boson Production



"TransDIF" density more sensitive to ISR & FSR.

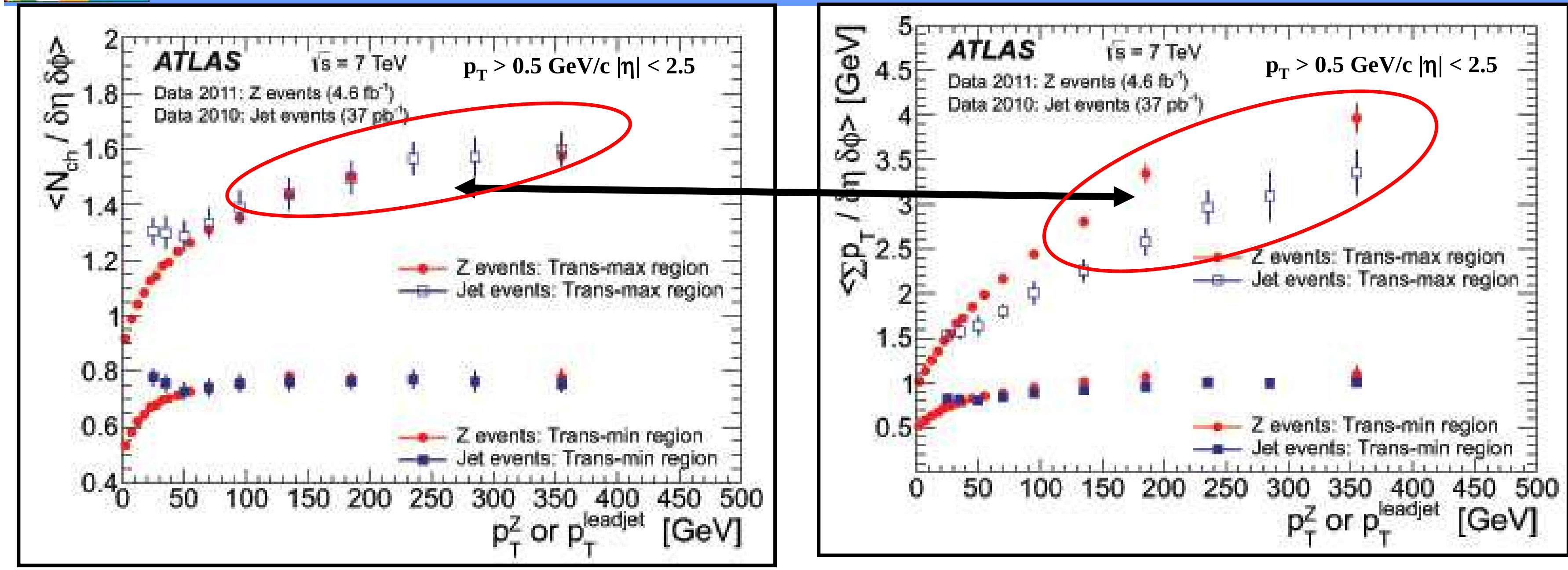
Z-Boson versus "Leading Jet"





- **ATLAS data at 7 TeV on the charged particle density and charged PTsum density for the "transMAX" and "transMIN" regions for "Z-Boson" events and for "Leading Jet" events as a function of the leading jet p_T or $P_T(Z)$.**

Z-Boson versus "Leading Jet"

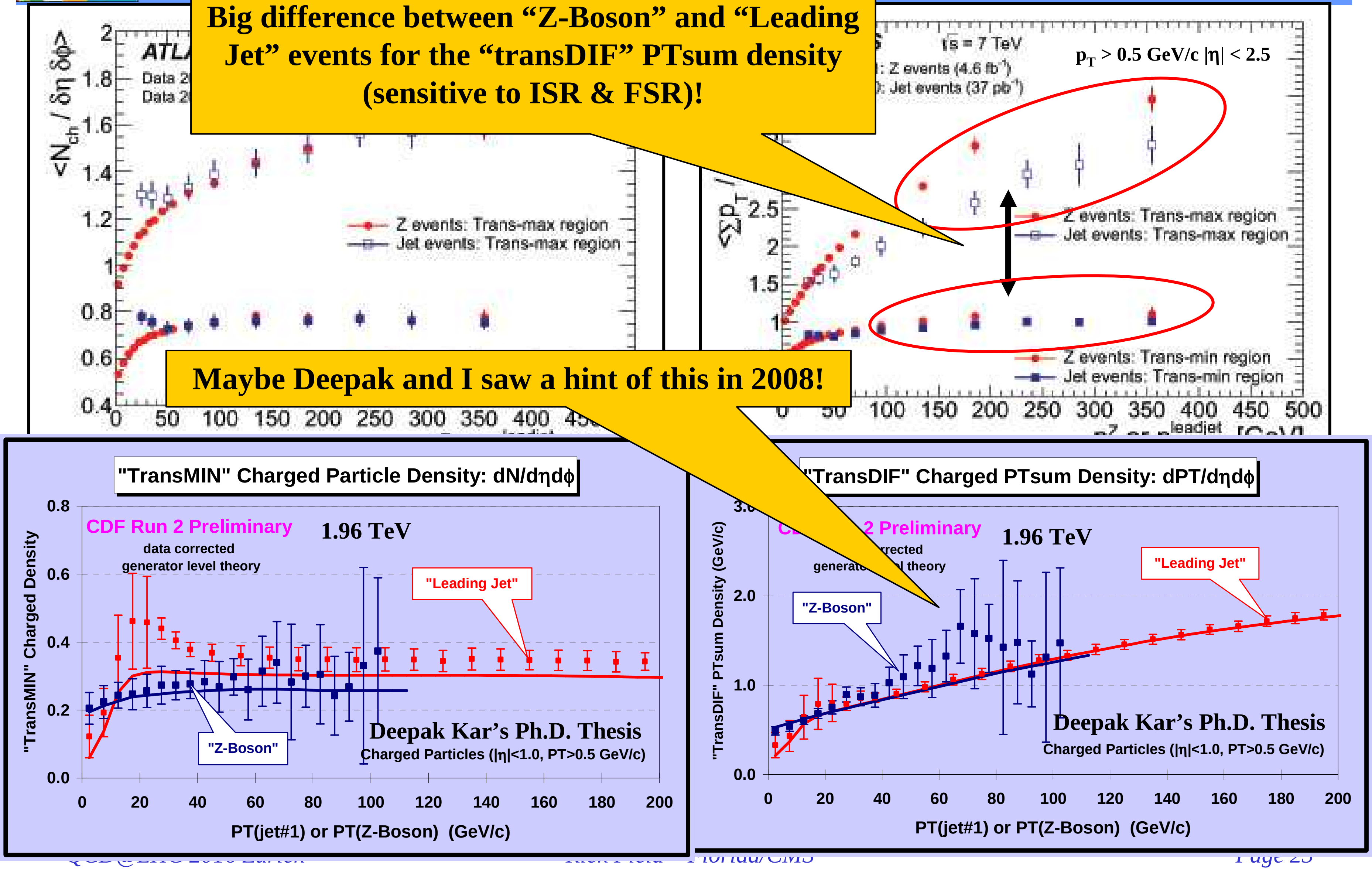


➡ **ATLAS data at 7 TeV on the charged particle density and charged PTsum density for the "transMAX" and "transMIN" regions for "Z-Boson" events and for "Leading Jet" events as a function of the leading jet p_T or $P_T(Z)$.**

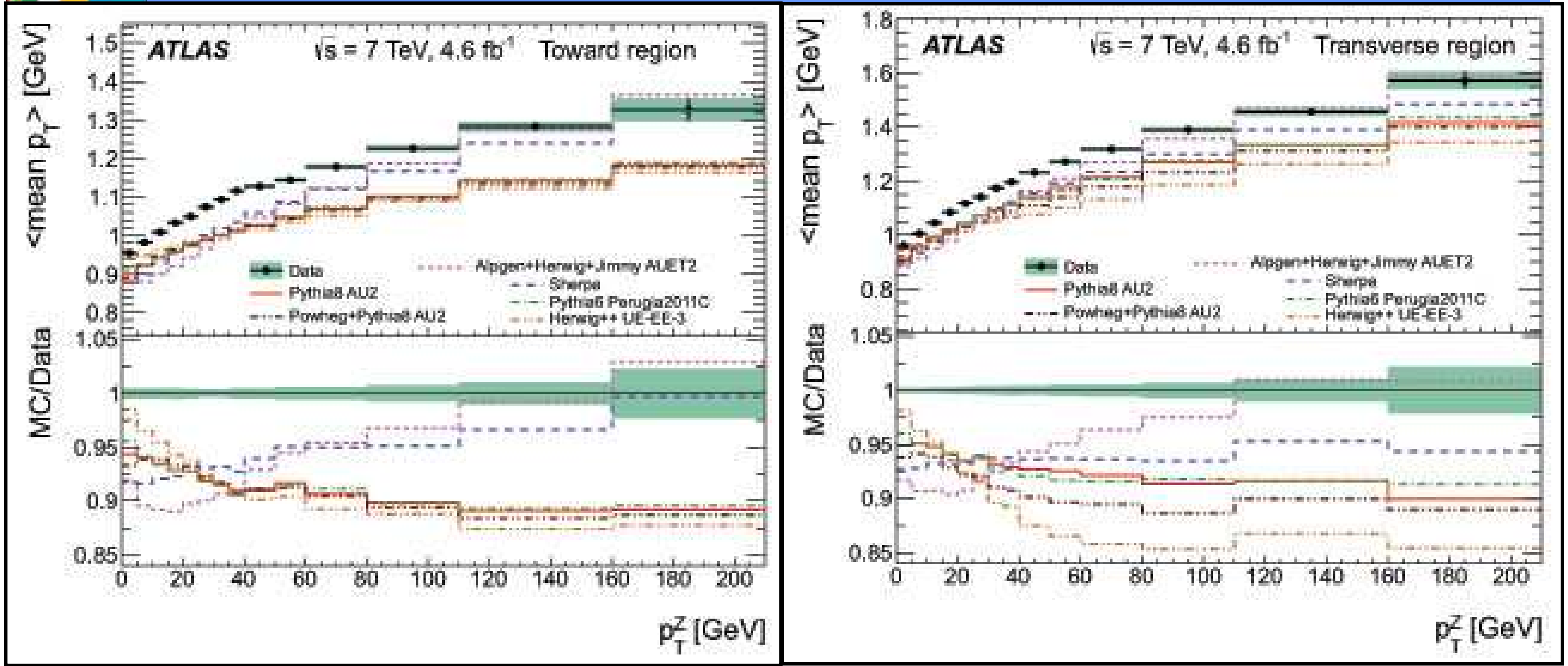
Z-Boson versus "Leading Jet"

Big difference between "Z-Boson" and "Leading Jet" events for the "transDIF" PTsum density (sensitive to ISR & FSR)!

Maybe Deepak and I saw a hint of this in 2008!

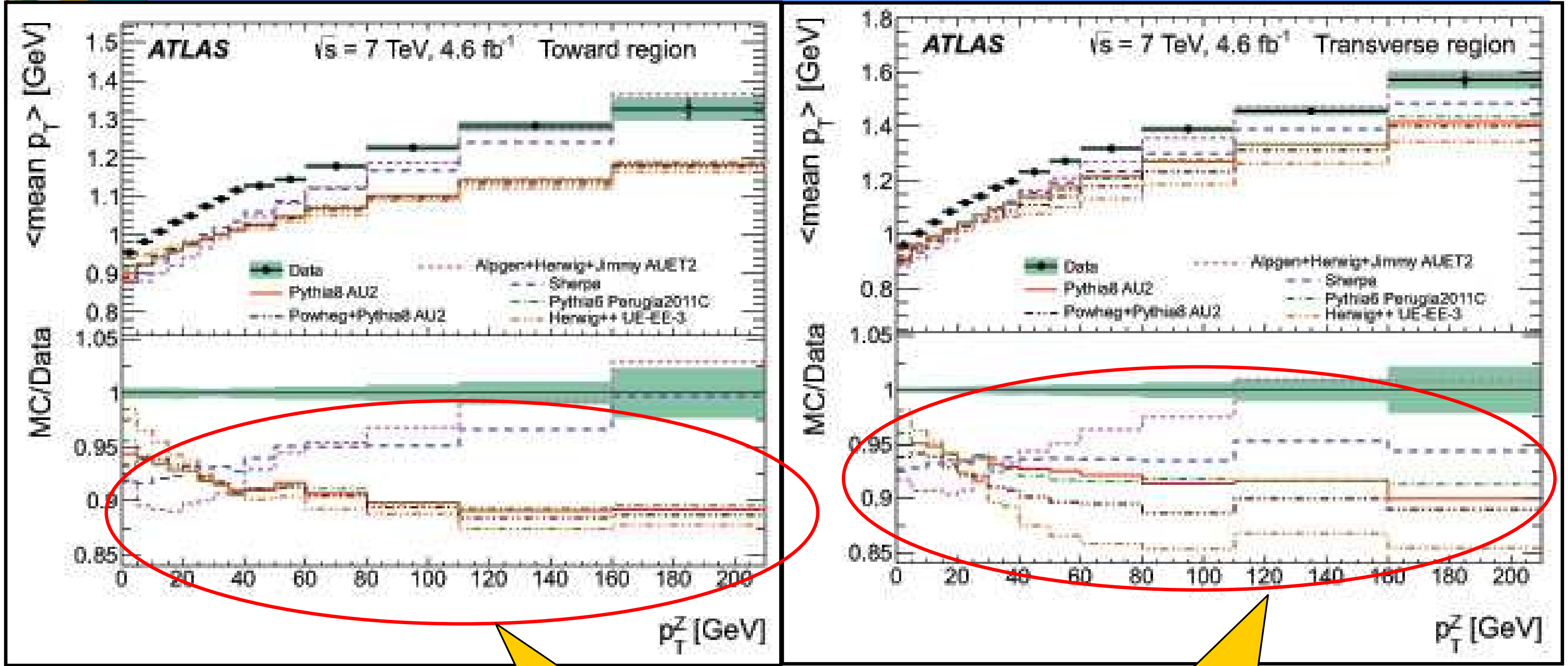


The UE in Z-Boson Production



➡ **ATLAS data at 7 TeV on the average charged particle p_T for the "Toward" and "Transverse" regions for "Z-Boson" events as a function of $P_T(Z)$.**

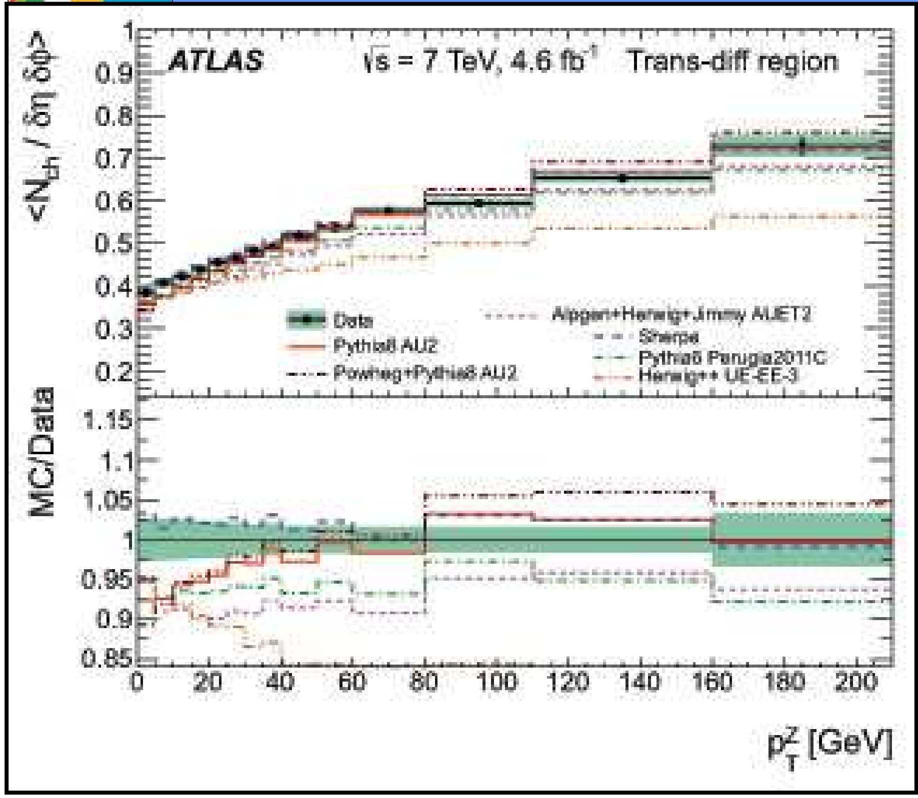
The UE in Z-Boson Production

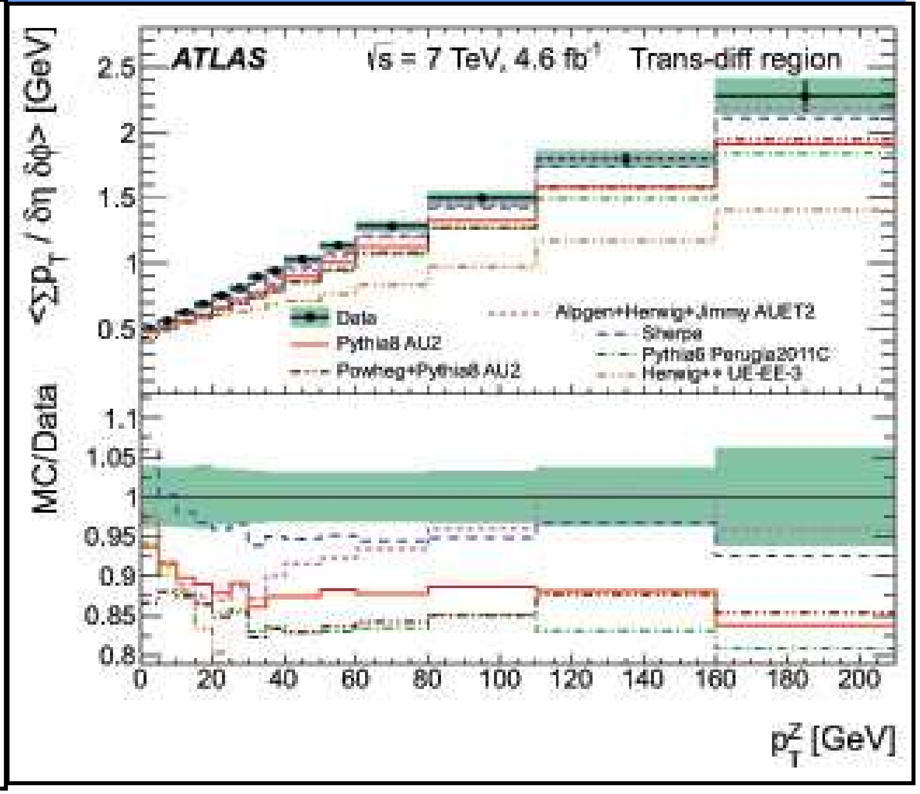


- ATLAS data at 7 TeV on th verage charged particle p_T for th oward" and "Transverse" regions for "Z n" events as a function of P

The QCD Monte-Carlo models are doing poorly on this!

The UE in Z-Boson Production

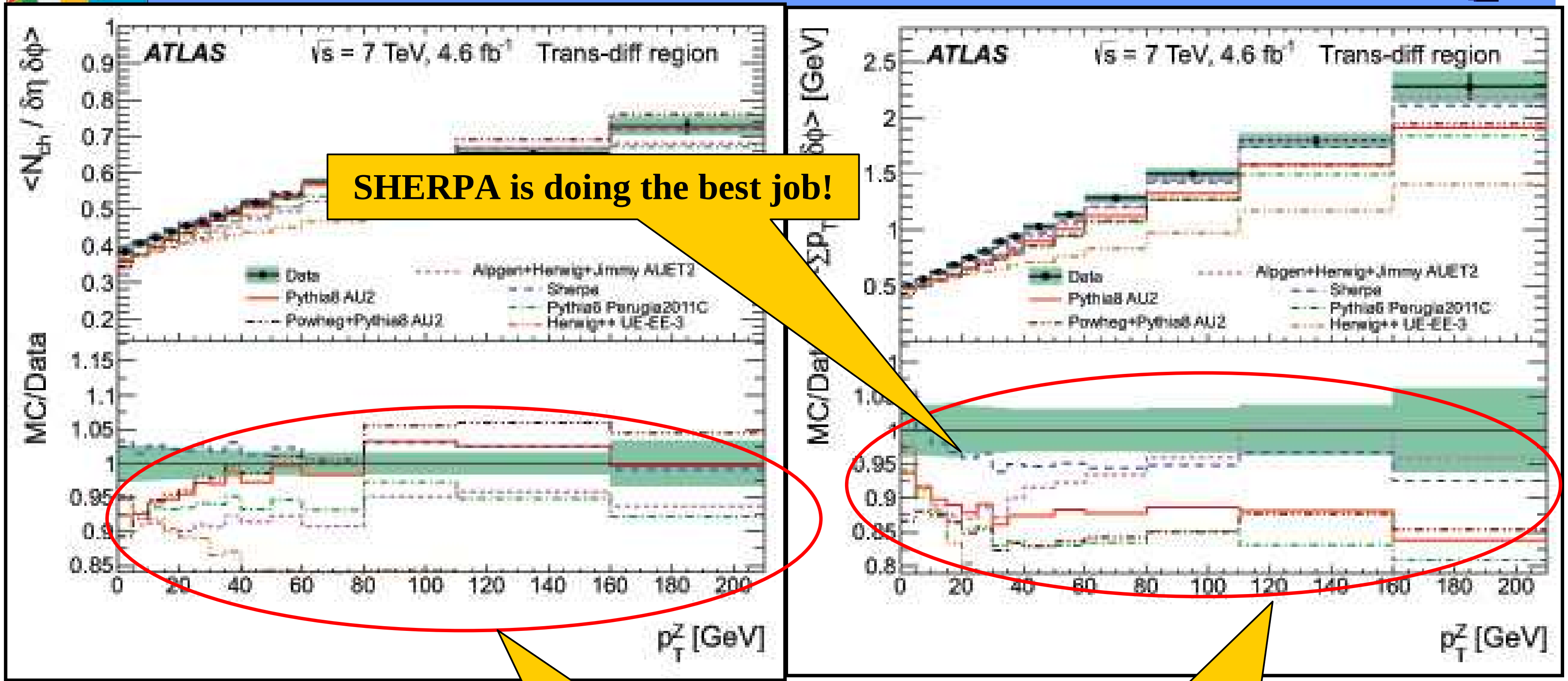




- **ATLAS data at 7 TeV on the charged particle and PTsum densities for “tranDIF” for “Z-Boson” events as a function of P_T(Z).**

“TransDIF” density more sensitive to ISR & FSR.

The UE in Z-Boson Production



SHERPA is doing the best job!

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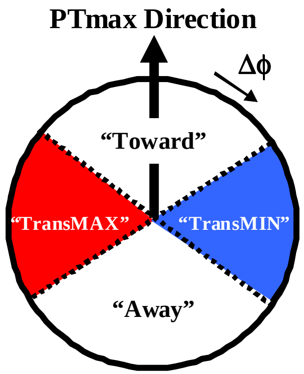
CMS UE Tunes



- **PYTHIA 6.4 Tune CUETP6S1-CTEQ6L:** Start with Tune Z2*-lep and tune to the CDF PTmax "transMAX" and "transMIN" UE data at 300 GeV, 900 GeV, and 1.96 TeV and the CMS PTmax "transMAX" and "transMIN" UE data at 7 TeV.
- **PYTHIA 6.4 Tune CUETP6S1-HERAPDF1.5LO:** Start with Tune Z2*-lep and tune to the CDF PTmax "transMAX" and "transMIN" UE data at 300 GeV, 900 GeV, and 1.96 TeV and the CMS PTmax "transMAX" and "transMIN" UE data at 7 TeV.
- **PYTHIA 8 Tune CUETP8S1-CTEQ6L:** Start with Corke & Sjöstrand Tune 4C and tune to the CDF PTmax "transMAX" and "transMIN" UE data at 900 GeV, and 1.96 TeV and the CMS PTmax "transMAX" and "transMIN" UE data at 7 TeV. Exclude 300 GeV data.
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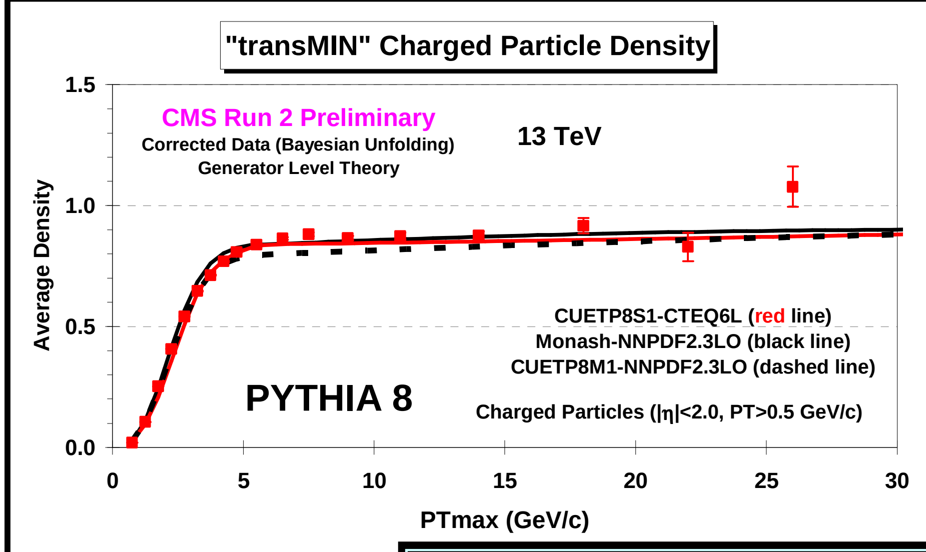
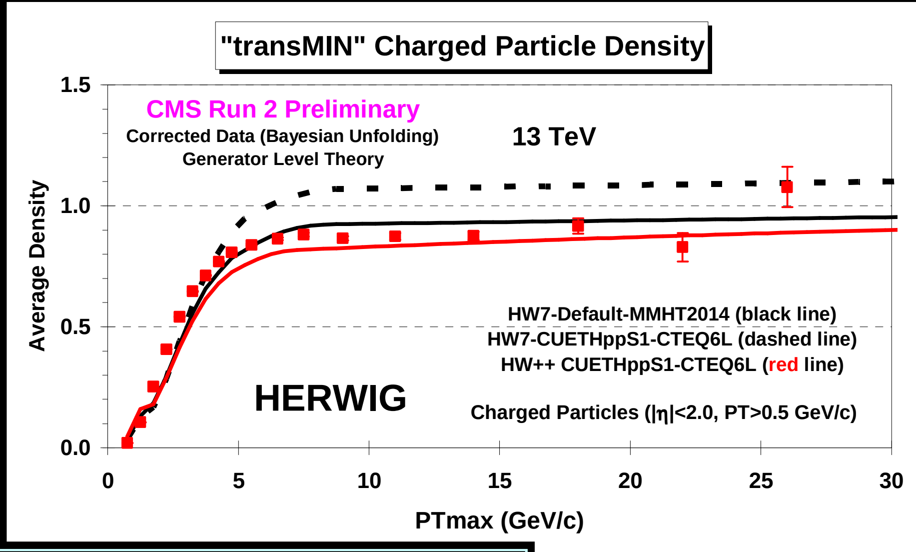
- **PYTHIA 8 Tune CUETP8M1-NNPDF2.3LO:** Start with the Skands Monash-NNPDF2.3LO tune and tune to the CDF PTmax "transMAX" and "transMIN" UE data at 900 GeV, and 1.96 TeV and the CMS PTmax "transMAX" and "transMIN" UE data at 7 TeV. Exclude 300 GeV data.
- **HERWIG++ Tune CUETHS1-CTEQ6L:** Start with the Seymour & Siódmok UE-EE-5C tune and tune to the CDF PTmax "transMAX" and "transMIN" UE data at 900 GeV, and 1.96 TeV and the CMS PTmax "transMAX" and "transMIN" UE data at 7 TeV. Bug in HW++!

"transMIN" NchgDen





"TransMIN" density more sensitive to MPI & BBR.

- **CMS corrected data at 13 TeV on the "transMIN" charged particle density with p_T > 0.5 GeV/c and |η| < 2.0 as defined by the leading charged particle, as a function of the transverse momentum of the leading charged particle, PTmax. The data are compared with the PYTHIA 8 tune CUETP8S1-CTEQ6L, tune CUETP8M1-NNPDF2.3LO, and tune Monash at the generator level.**

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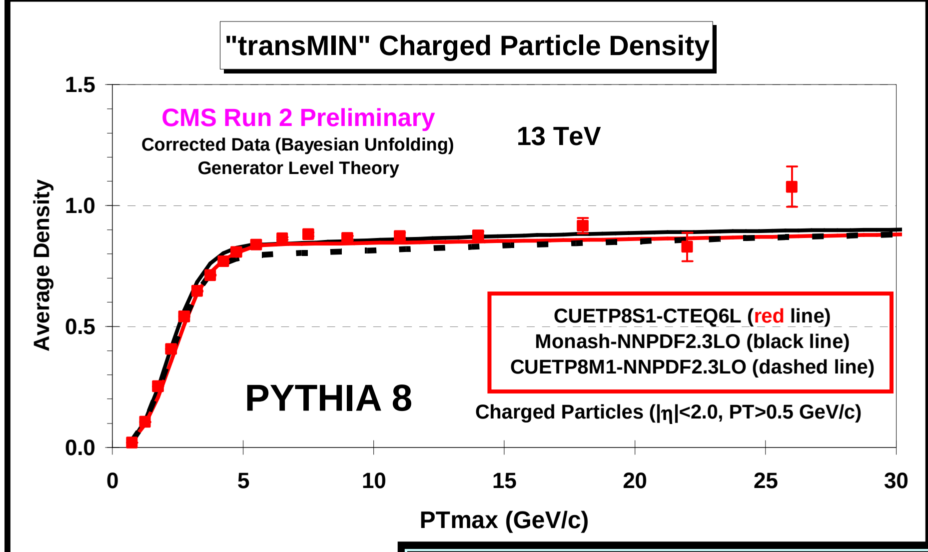

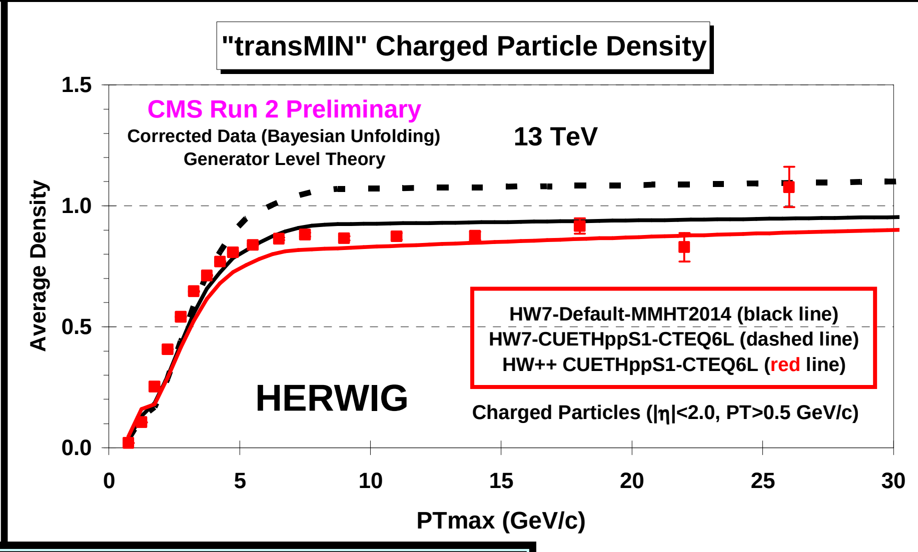

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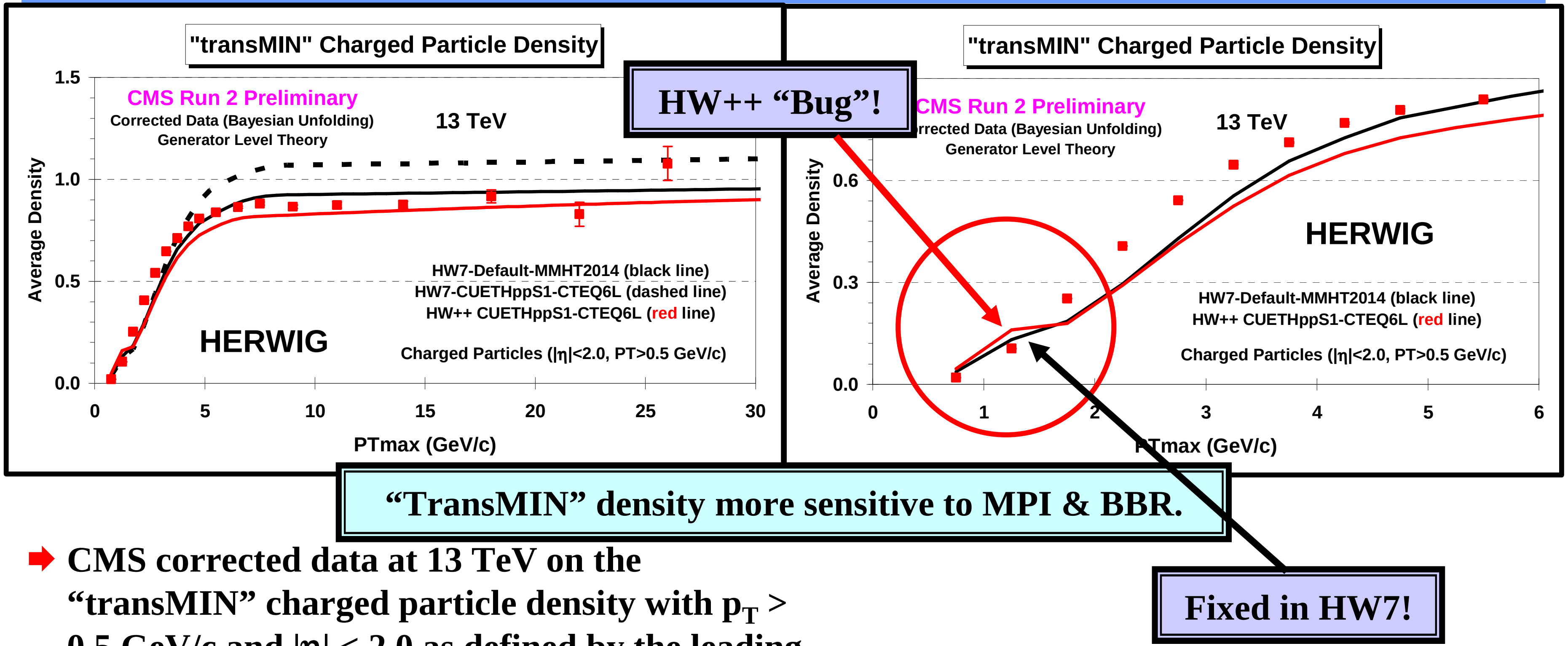

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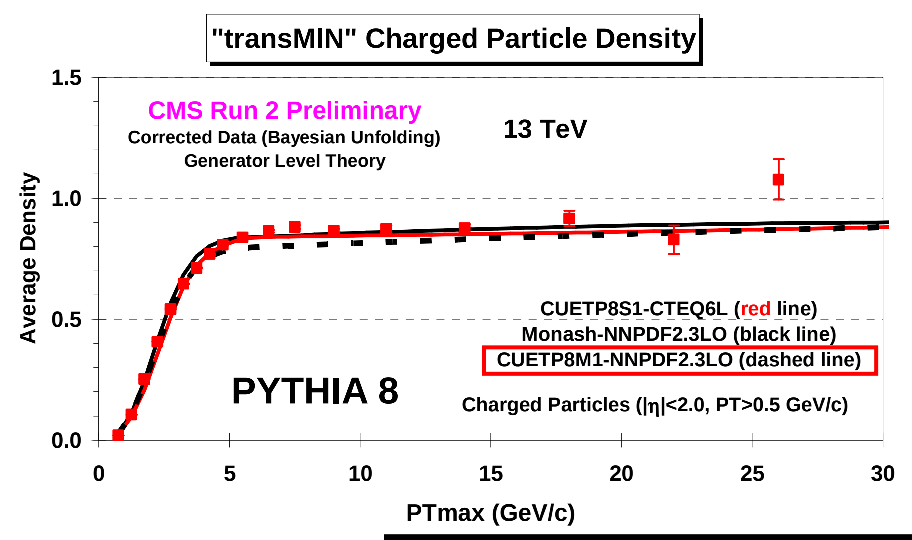

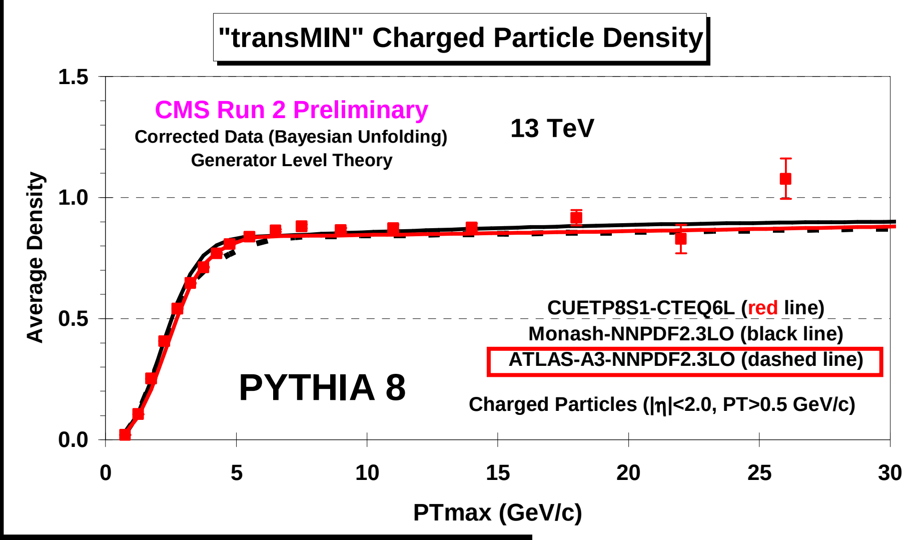

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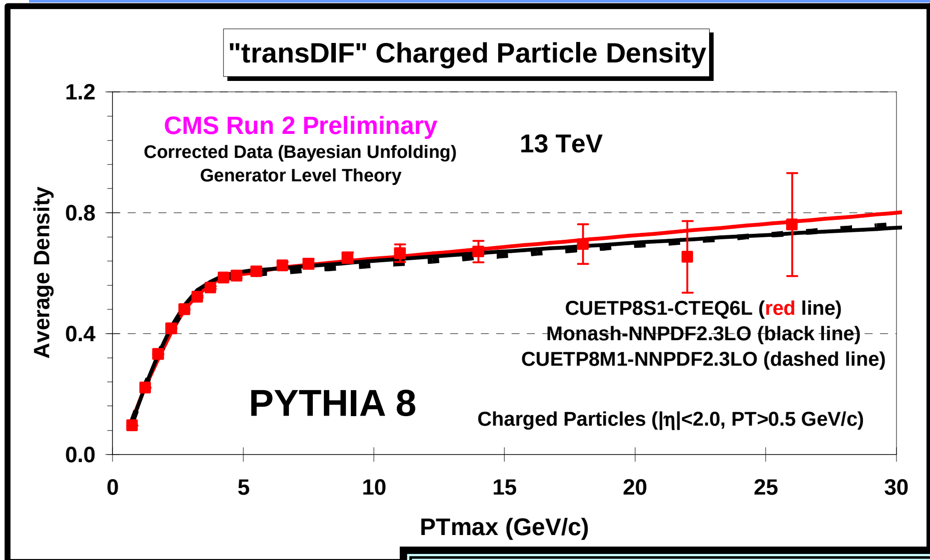

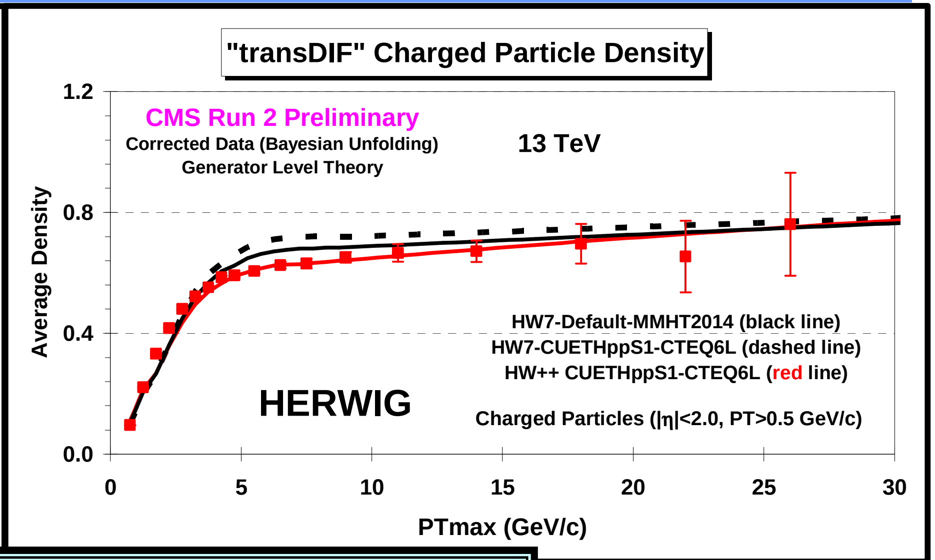

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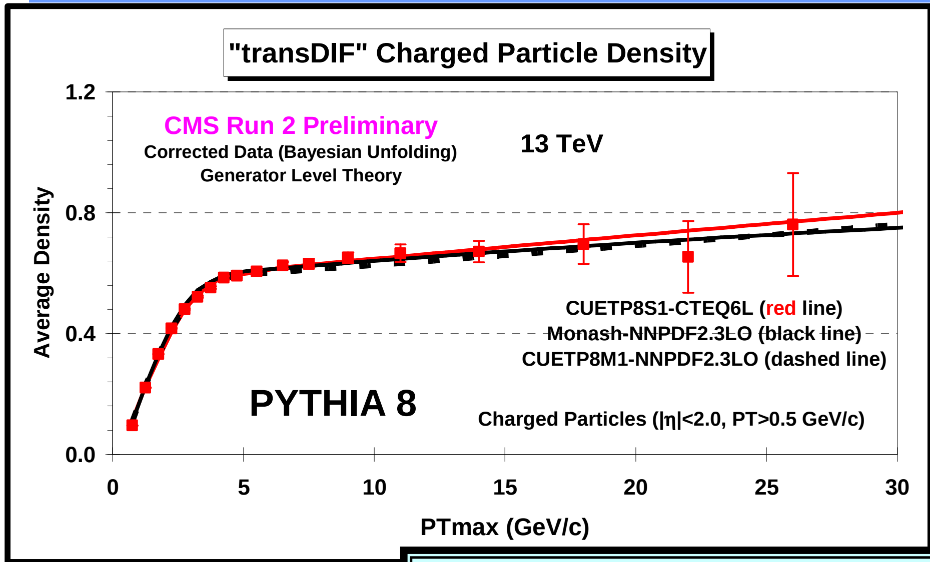

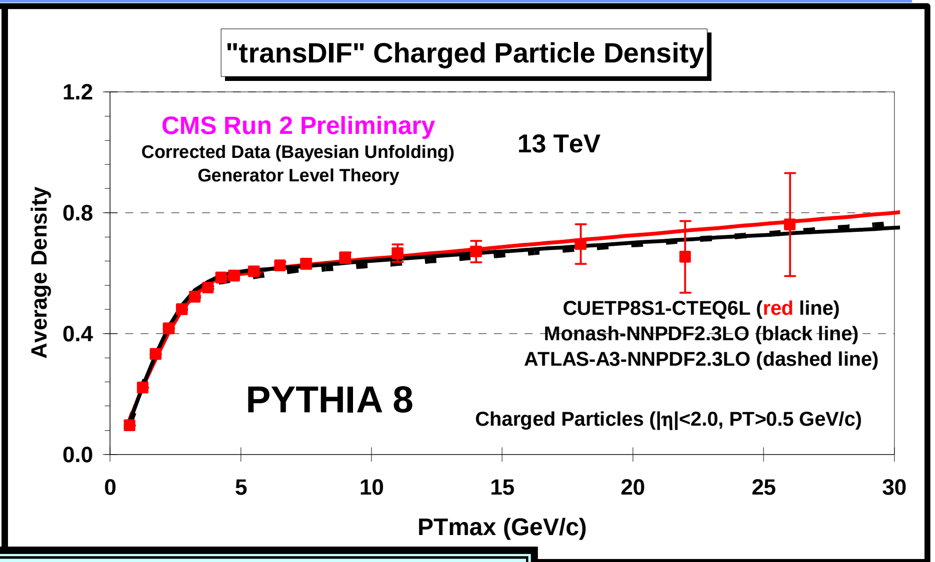

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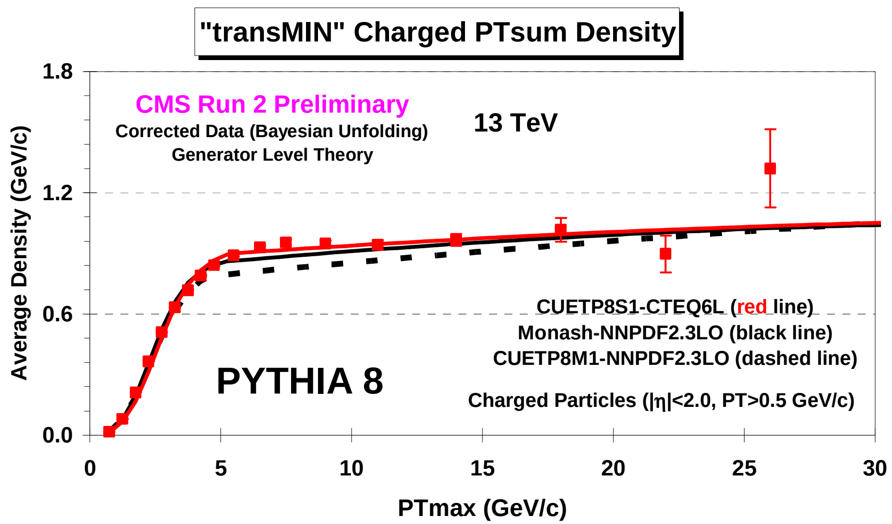
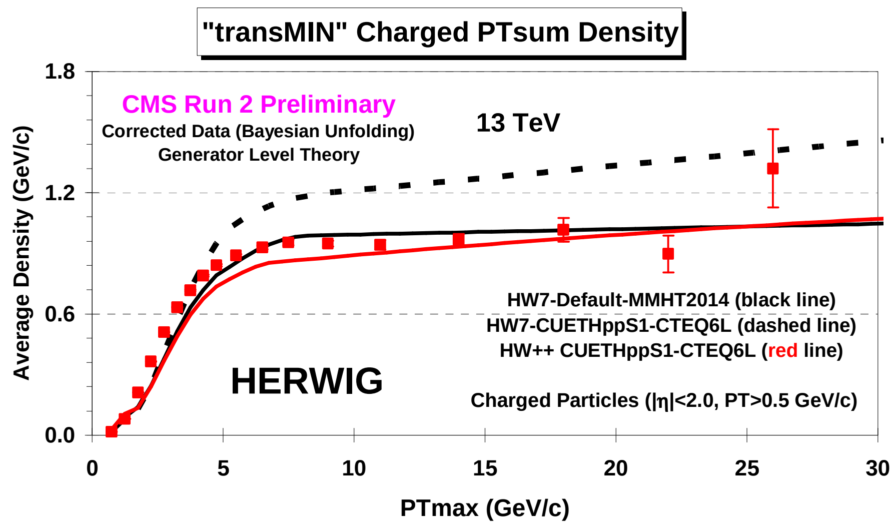
"transMIN" PTsumDen





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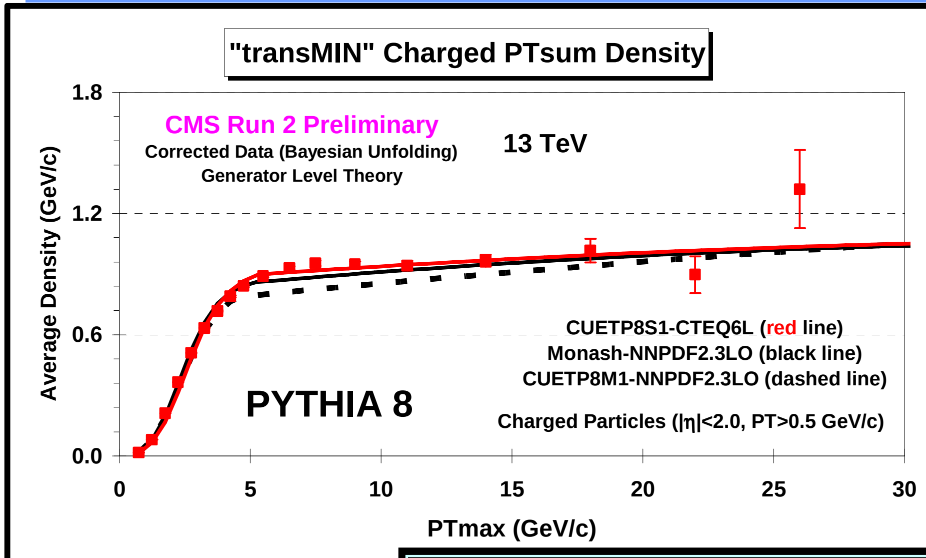

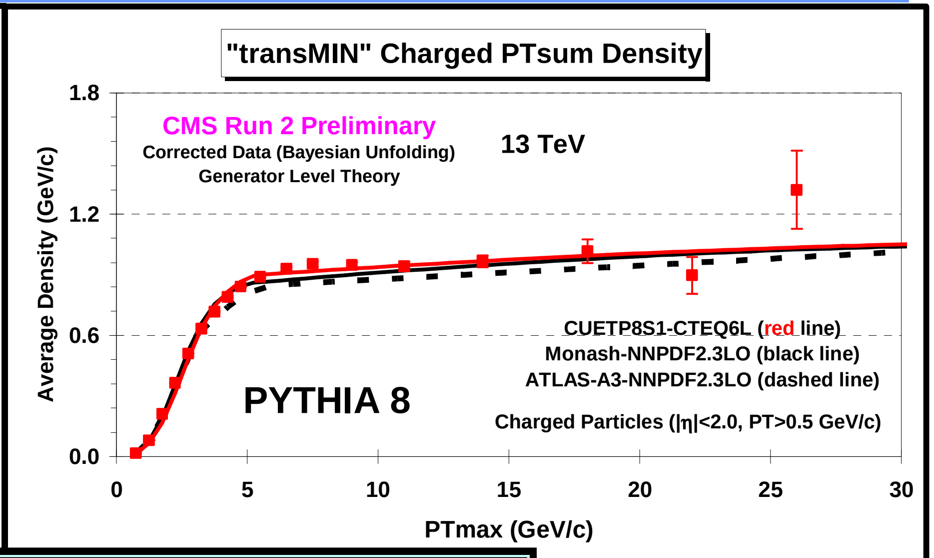

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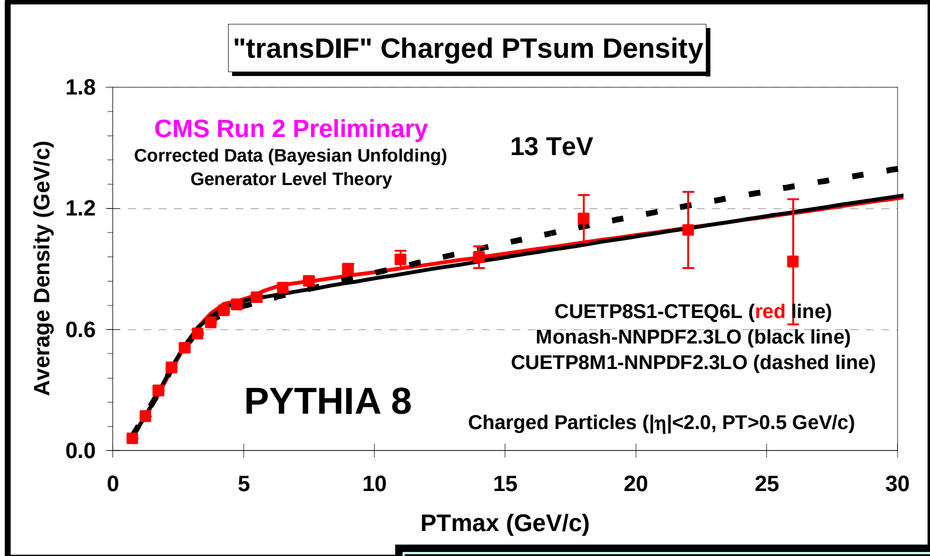

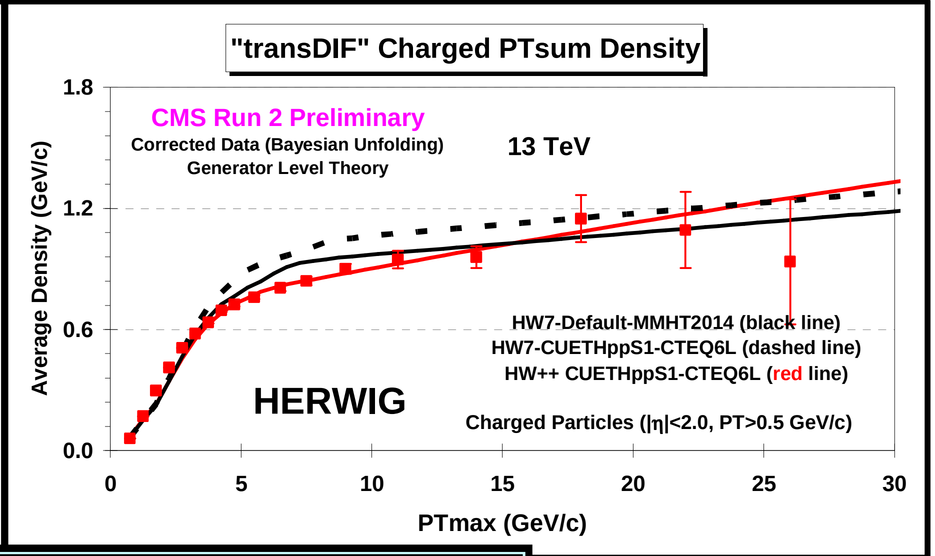

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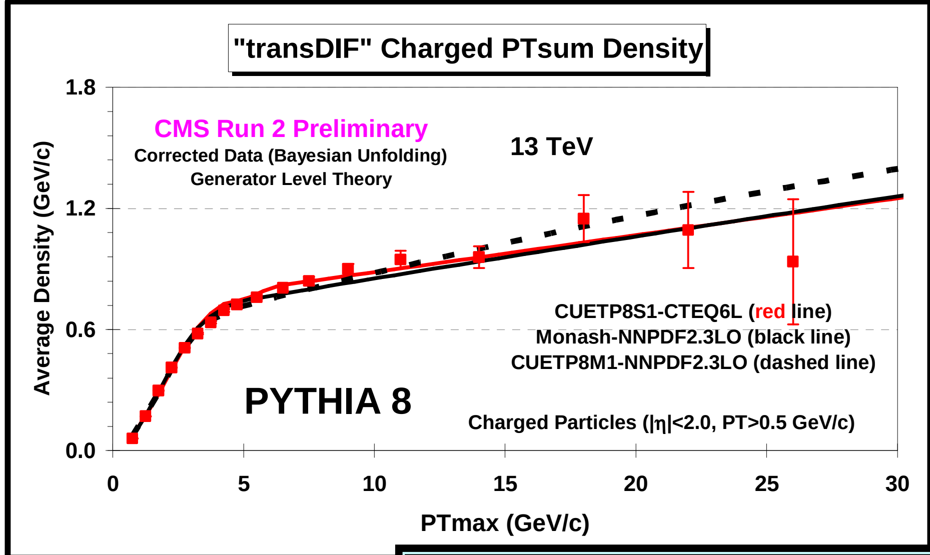

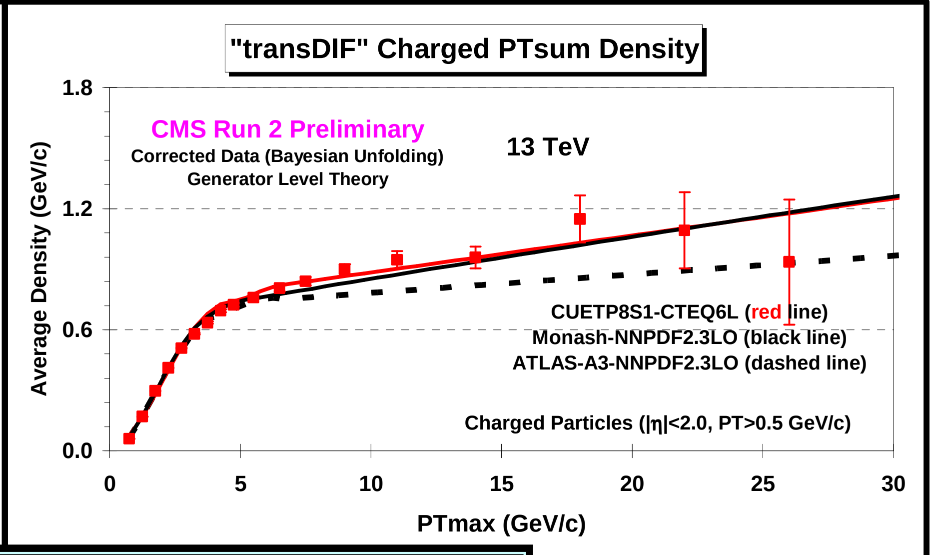

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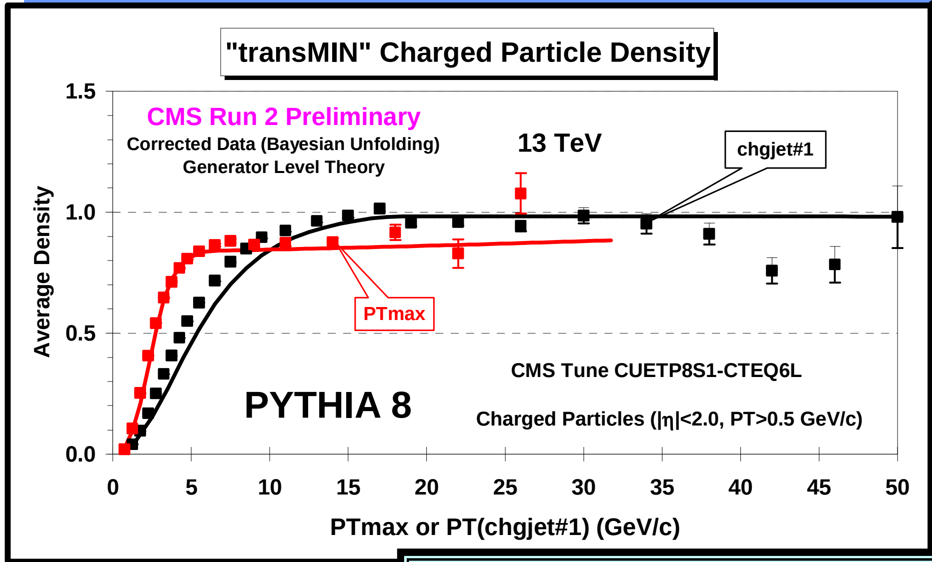
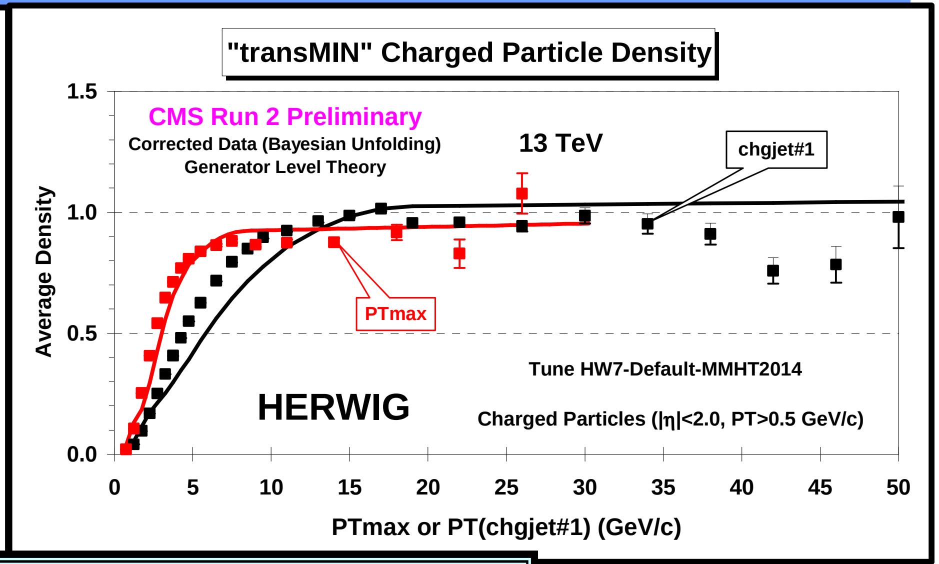
ChgJet#1 vs PTmax





"TransMIN" density more sensitive to MPI & BBR.

- **CMS corrected data at 13 TeV on the "transMIN" charged particle density with p_T > 0.5 GeV/c and |η| < 2.0 as defined by the leading charged particle, PTmax, and as defined by the leading charged particle jet, chgjet#1. The data are compared with the PYTHIA 8 tune CUETP8S1-CTEQ6L at the generator level.**
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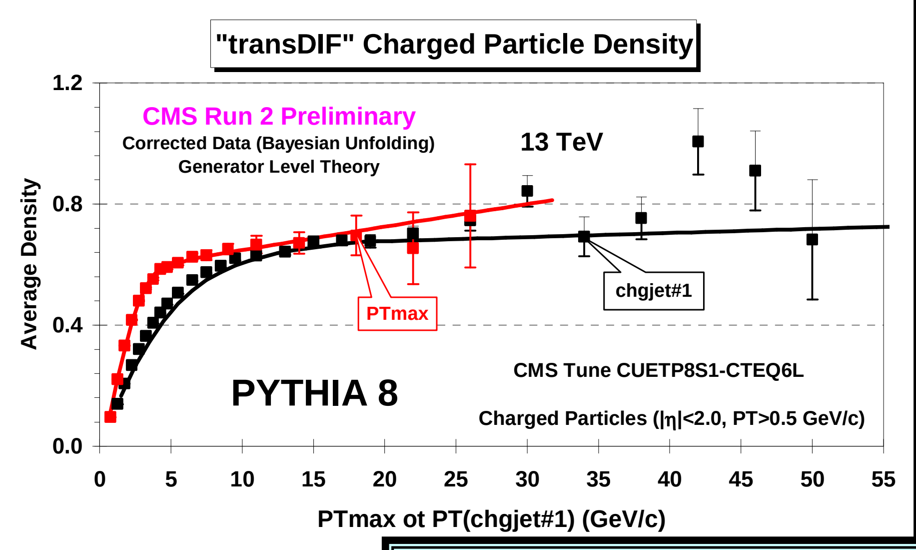

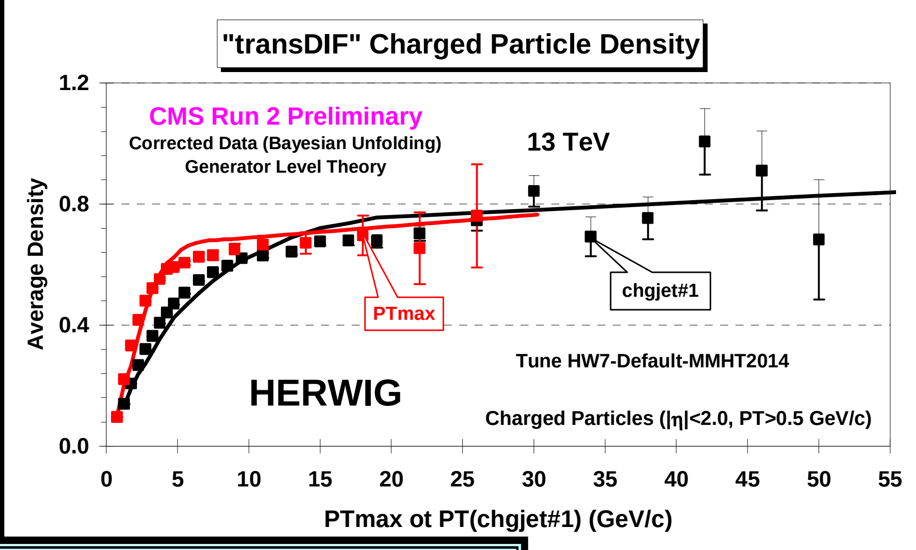

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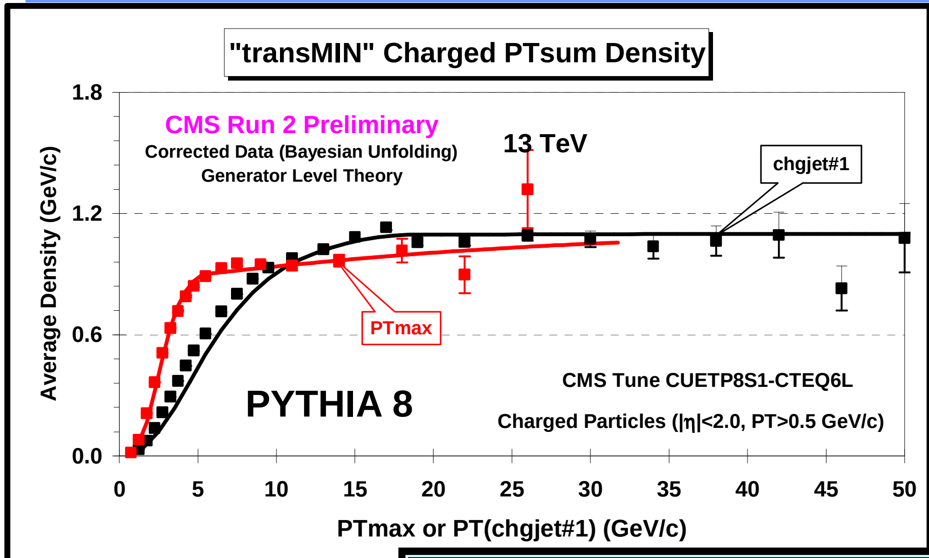
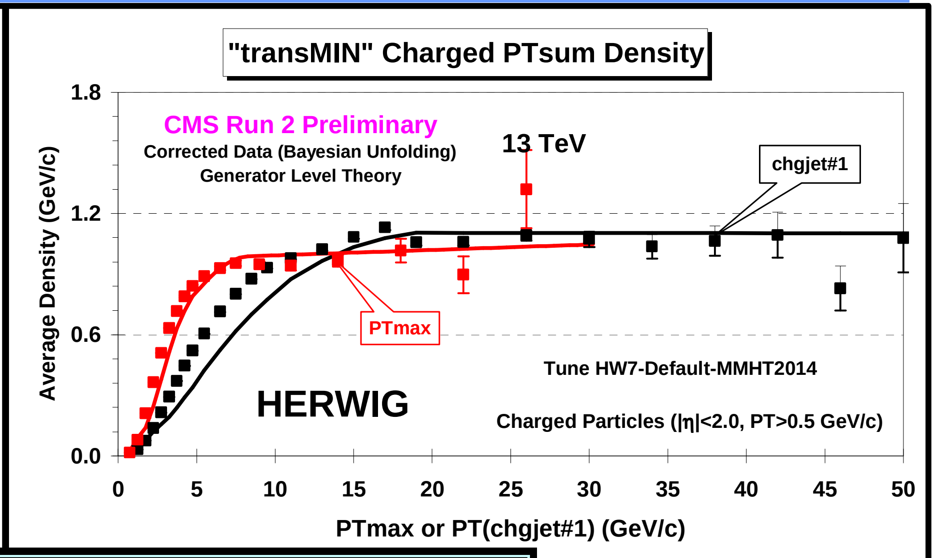
ChgJet#1 vs PTmax



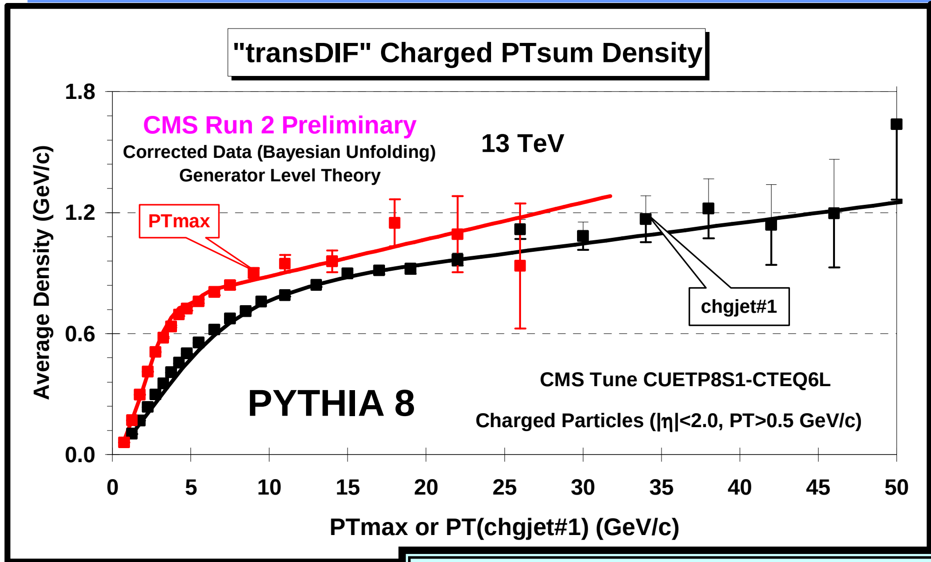


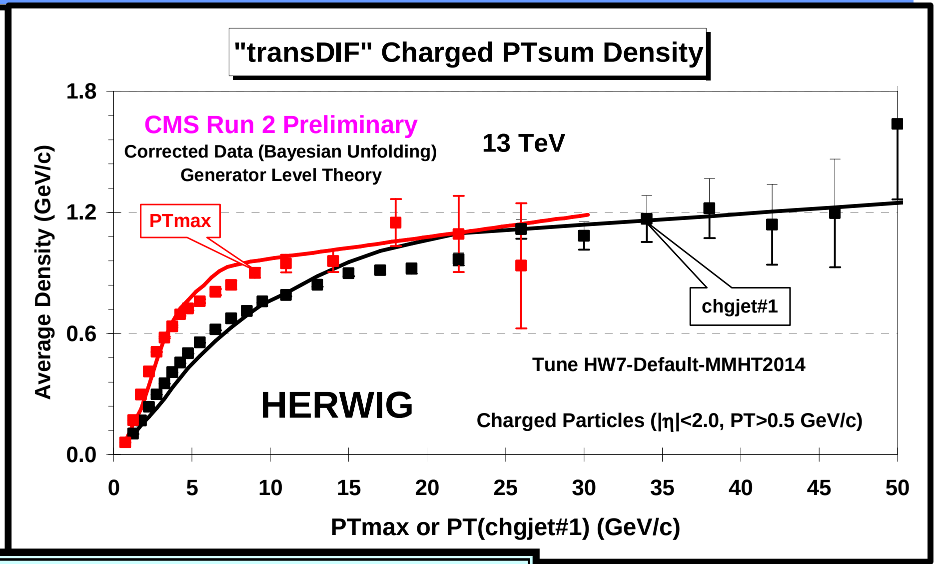
"TransMIN" density more sensitive to MPI & BBR.

- **CMS corrected data at 13 TeV on the "transMIN" charged PTsum density with p_T > 0.5 GeV/c and |η| < 2.0 as defined by the leading charged particle, PTmax, and as defined by the leading charged particle jet, chgjet#1. The data are compared with the PYTHIA 8 tune CUETP8S1-CTEQ6L at the generator level.**

- **CMS corrected data at 13 TeV on the "transMIN" charged PTsum density with p_T > 0.5 GeV/c and |η| < 2.0 as defined by the leading charged particle, PTmax, and as defined by the leading charged particle jet, chgjet#1. The data are compared with the HW7 default tune (MMHT2014) at the generator level.**

ChgJet#1 vs PTmax



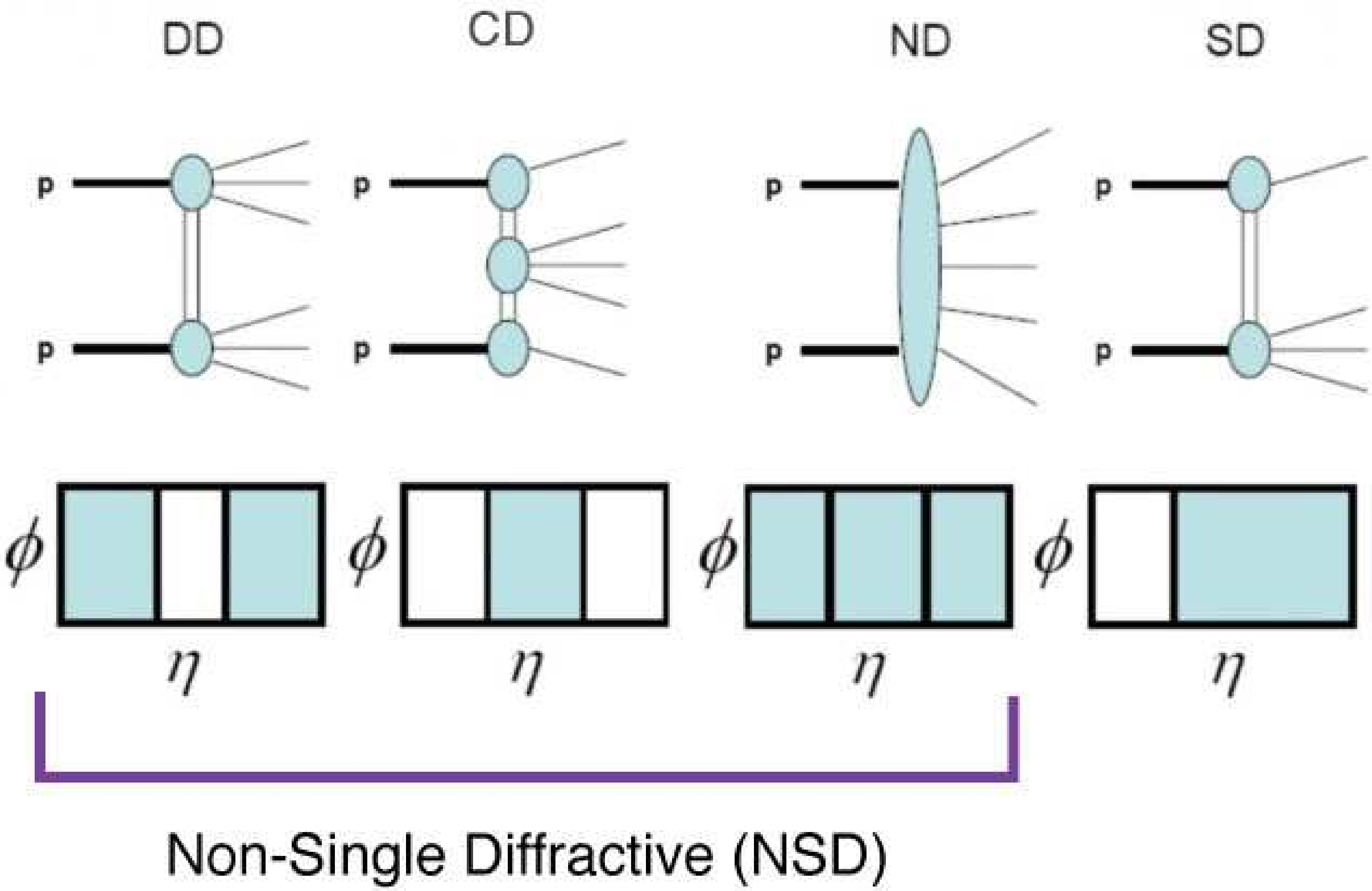


"TransDIF" density more sensitive to ISR & FSR.

- **CMS corrected data at 13 TeV on the "transDIF" charged PTsum density with p_T > 0.5 GeV/c and |η| < 2.0 as defined by the leading charged particle, PTmax, and as defined by the leading charged particle jet, chgjet#1. The data are compared with the PYTHIA 8 tune CUETP8S1-CTEQ6L at the generator level.**
- **CMS corrected data at 13 TeV on the "transDIF" charged PTsum density with p_T > 0.5 GeV/c and |η| < 2.0 as defined by the leading charged particle, PTmax, and as defined by the leading charged particle jet, chgjet#1. The data are compared with the HW7 default tune (MMHT2014) at the generator level.**

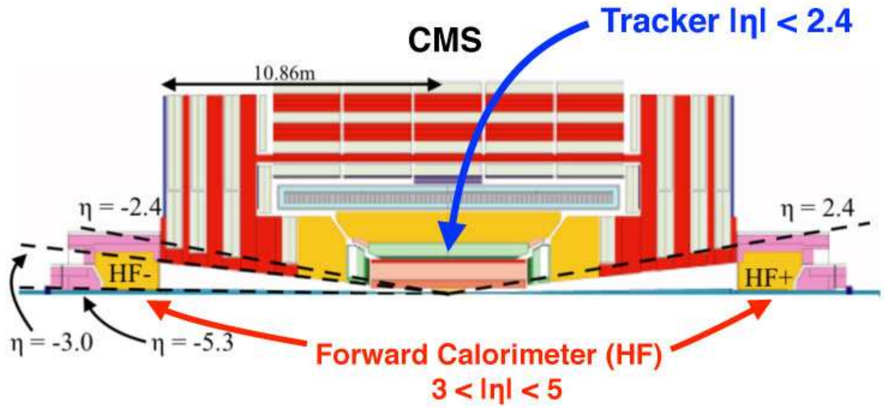
Inelastic Collisions

Today's terminology courtesy of Juan M. G. Luyando, Benoit Roland, and Paolo Gunnellini.



CMS MB Trigger Selections

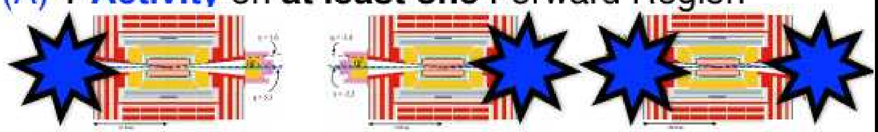
CMS PAS FSQ-15-008



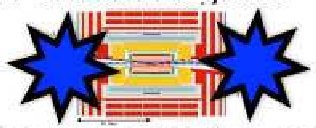
(A) At least 1 charged particle { $p_T > 0.5$ GeV, $|\eta| < 2.4$ }

- ✦ **Activity**: at least 1 particle with E > 5 GeV
- ✦ **Veto**: no particle with E > 5 GeV

- **Inclusive**: (A)
- **Inelastic enhanced**: (A) + **Activity** on **at least one** Forward Region



- **NSD enhanced**: (A) + **Activity** on **both** Forward Regions



- **SD enhanced**: (A) + **Activity** on one Forward Region **and Veto** on the other side

Available on the CERN CDS information server — **CMS PAS FSQ-15-008**

CMS Physics Analysis Summary

Contact: cms-pag-conveners-fsq@cern.ch — 2016/04/11

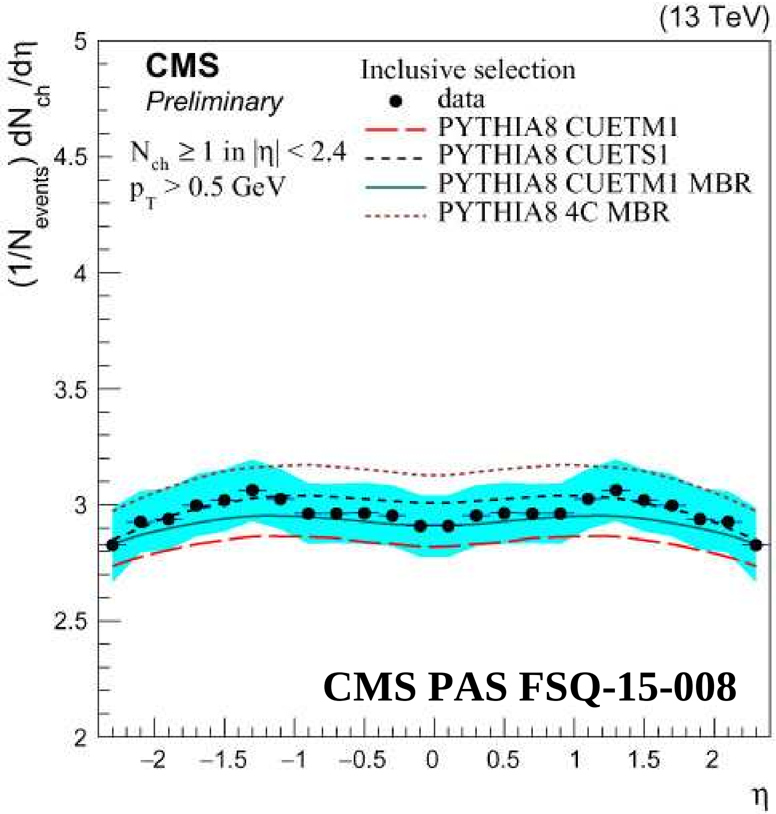
Measurement of pseudorapidity distributions of charged particles in proton-proton collisions at $\sqrt{s} = 13$ TeV by the CMS experiment.

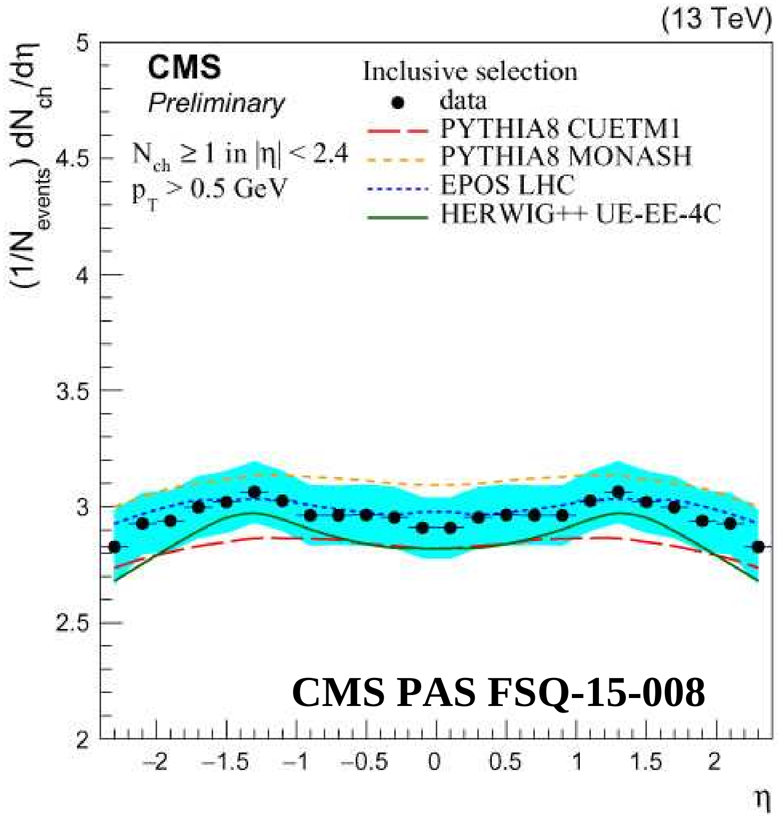
The CMS Collaboration

Abstract

Pseudorapidity distributions of charged particles, $dN_{ch}/d\eta$, produced in proton-proton collisions at a centre-of-mass energy $\sqrt{s} = 13$ TeV are measured in the pseudorapidity range $|\eta| < 2.4$ for charged particles with a transverse momentum $p_T > 0.5$ GeV. Measurements are presented for four event categories. The first two categories correspond to inclusive and inelastic-enhanced event samples. The other two categories are disjoint subsets of the inelastic-enhanced event sample that are either enhanced or depleted in single diffractive dissociation events. The measurements are compared to predictions from Monte Carlo event generators which were tuned to describe the underlying event properties at lower centre-of-mass energies.

13 TeV “Inclusive” dN/dη



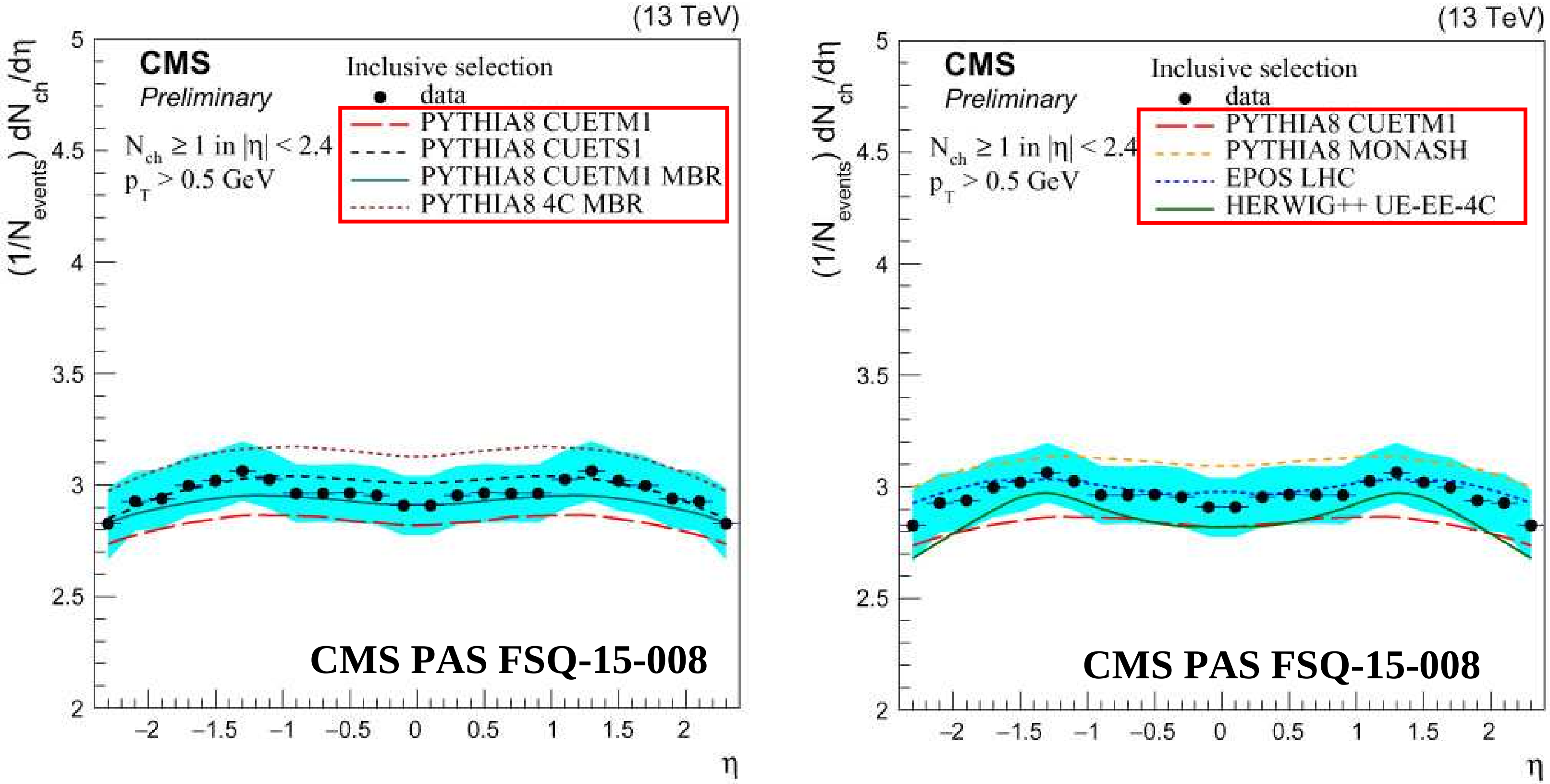


- **CMS “inclusive” data at 13 TeV on the charged particle density, dN/dη, with $p_T > 0.5$ GeV/c and $|\eta| < 2.4$ for events with at least one charged particle with $p_T > 0.5$ GeV/c and $|\eta| < 2.4$. The data are corrected to the particle level and compared with several MC models at generator level.**

- **Inclusive**: (A)

(A) At least 1 charged particle { $p_T > 0.5$ GeV, $|\eta| < 2.4$ }

13 TeV "Inclusive" dN/dη

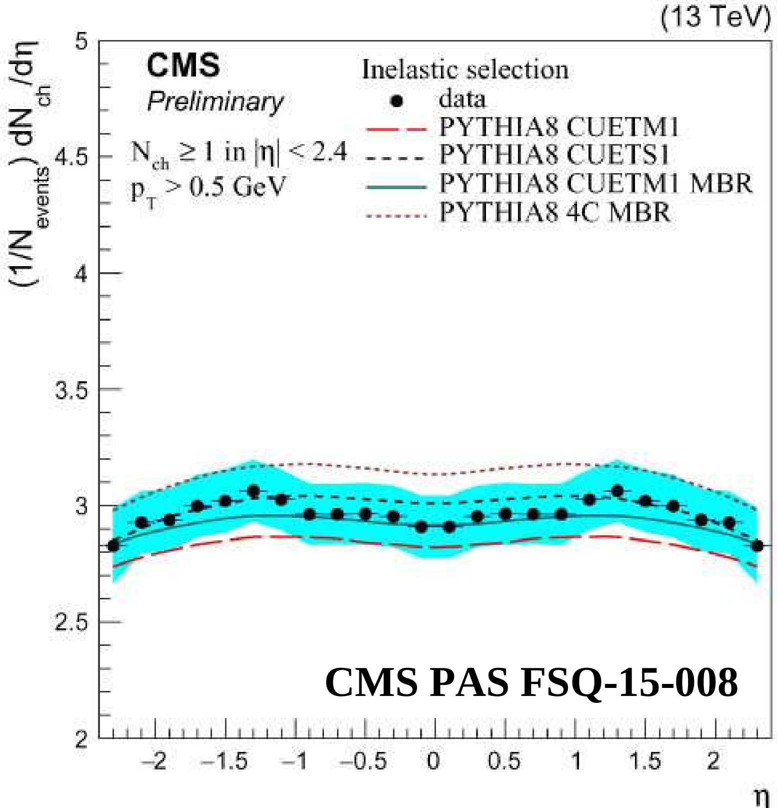


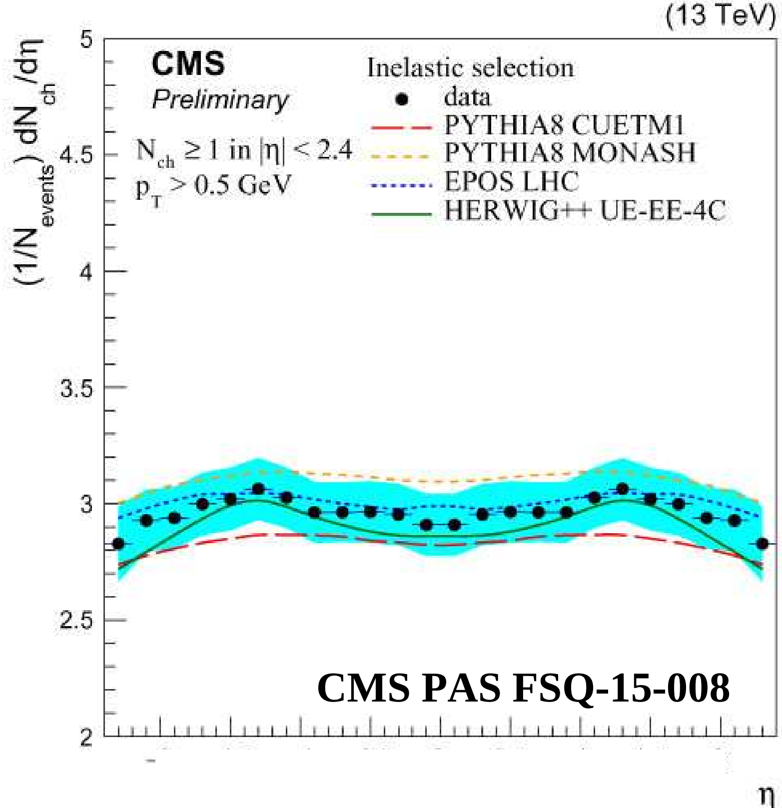
- **CMS "inclusive" data at 13 TeV** on the charged particle density, dN/dη, with $p_T > 0.5$ GeV/c and $|\eta| < 2.4$ for events with at least one charged particle with $p_T > 0.5$ GeV/c and $|\eta| < 2.4$. The data are corrected to the particle level and compared with several MC models at generator level.

- **Inclusive**: (A)

(A) At least 1 charged particle { $p_T > 0.5$ GeV; $|\eta| < 2.4$ }

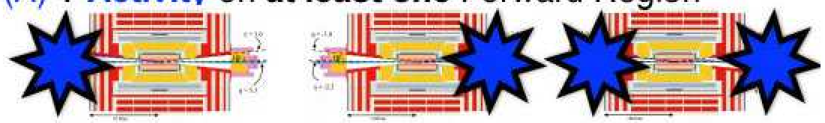
13 TeV "Inelastic" dN/dη



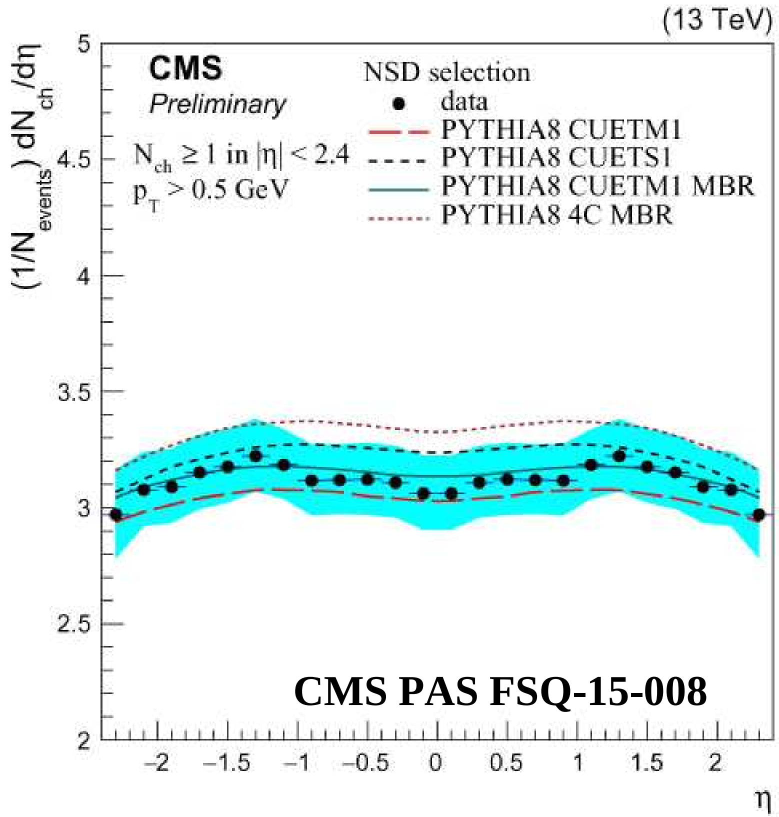


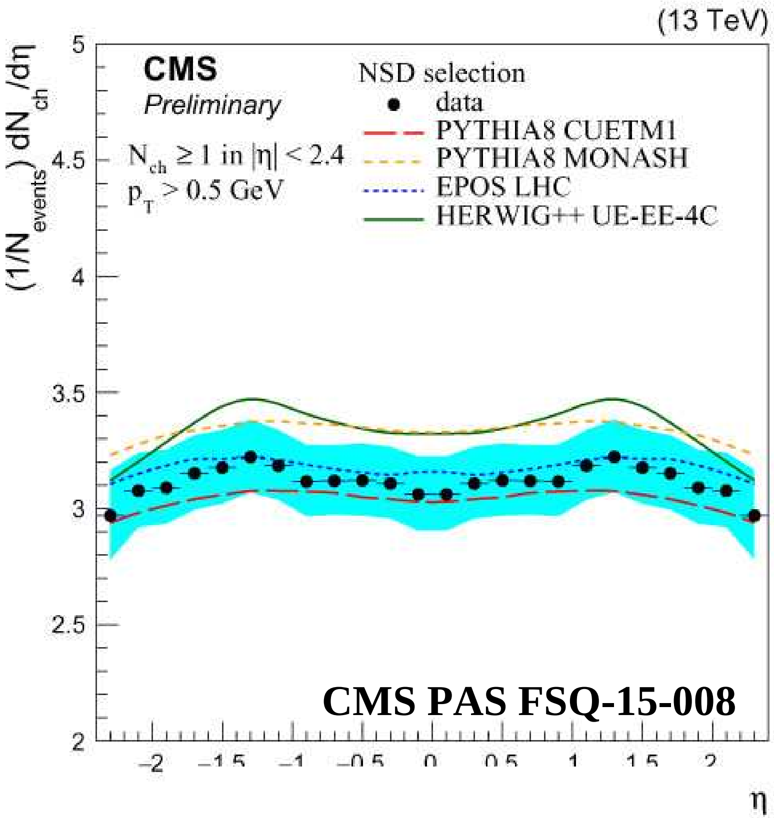
- **CMS "inelastic enhanced" data at 13 TeV on the charged particle density, dN/dη, with $p_T > 0.5$ GeV/c and $|\eta| < 2.4$ for events with at least one charged particle with $p_T > 0.5$ GeV/c and $|\eta| < 2.4$. The data are corrected to the particle level and compared with several MC models at generator level.**

- **Inelastic enhanced**: (A) + **Activity** on **at least one** Forward Region



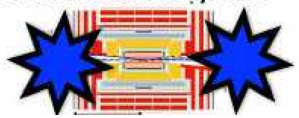
13 TeV “NSD Enhanced” dN/dη



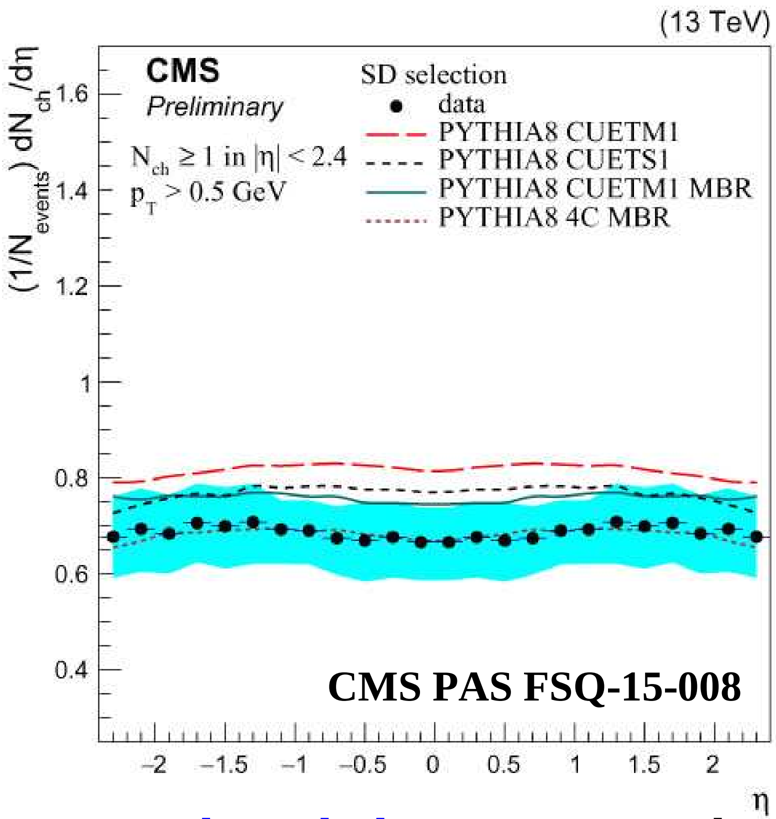


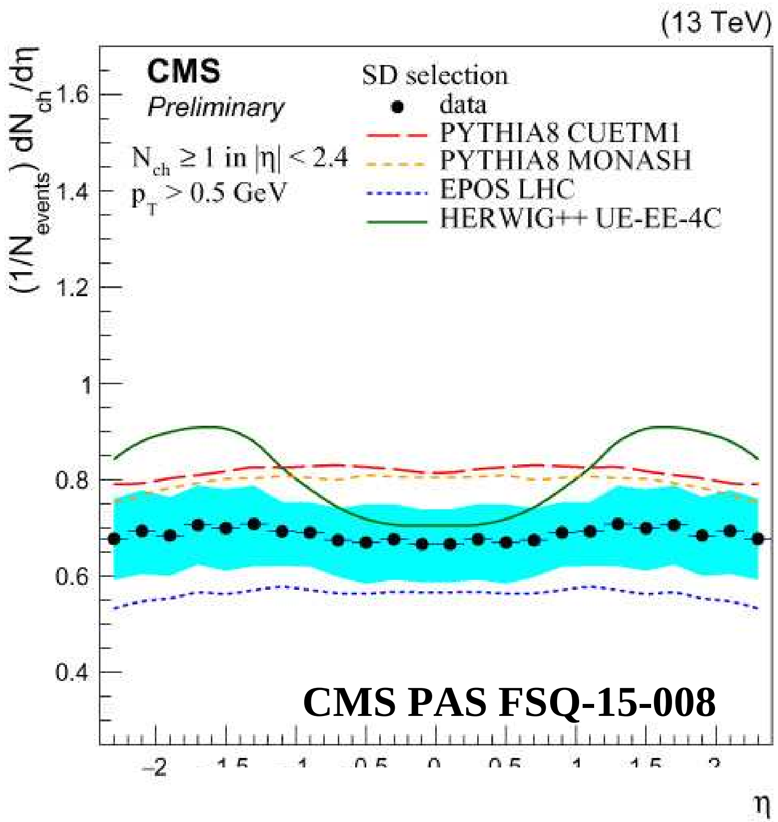
➡ **CMS “NSD enhanced” data at 13 TeV on the charged particle density, dN/dη, with $p_T > 0.5$ GeV/c and $|\eta| < 2.4$ for events with at least one charged particle with $p_T > 0.5$ GeV/c and $|\eta| < 2.4$. The data are corrected to the particle level and compared with several MC models at generator level.**

- **NSD enhanced**: (A) + **Activity** on **both** Forward Regions



13 TeV "SD Enhanced" dN/dη

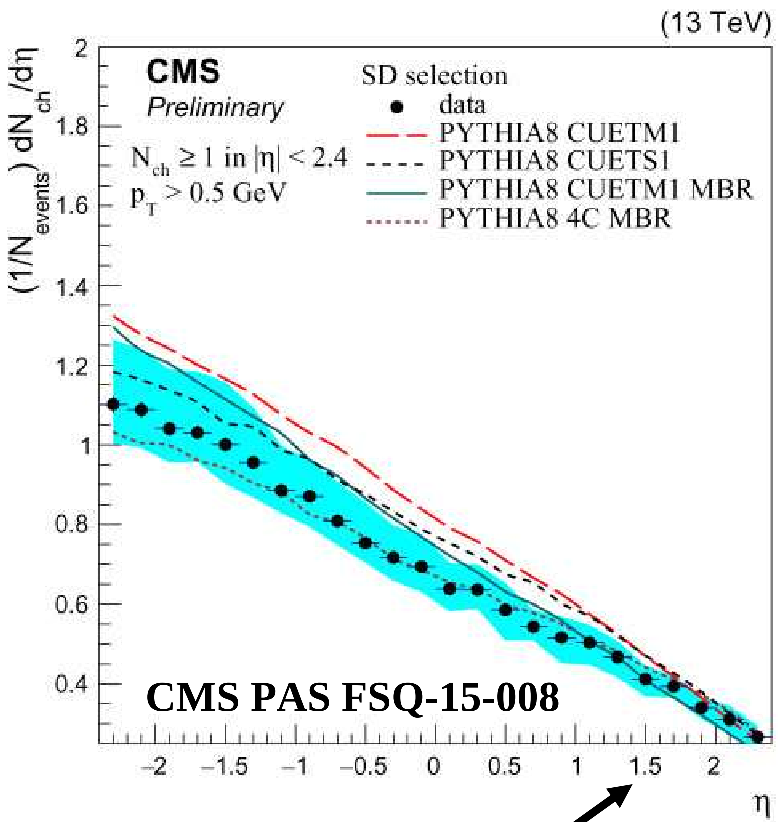


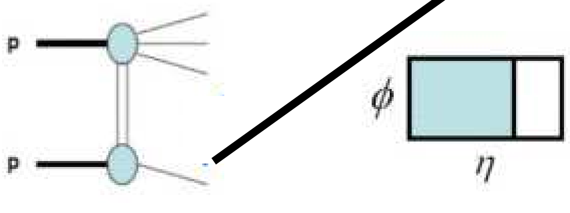


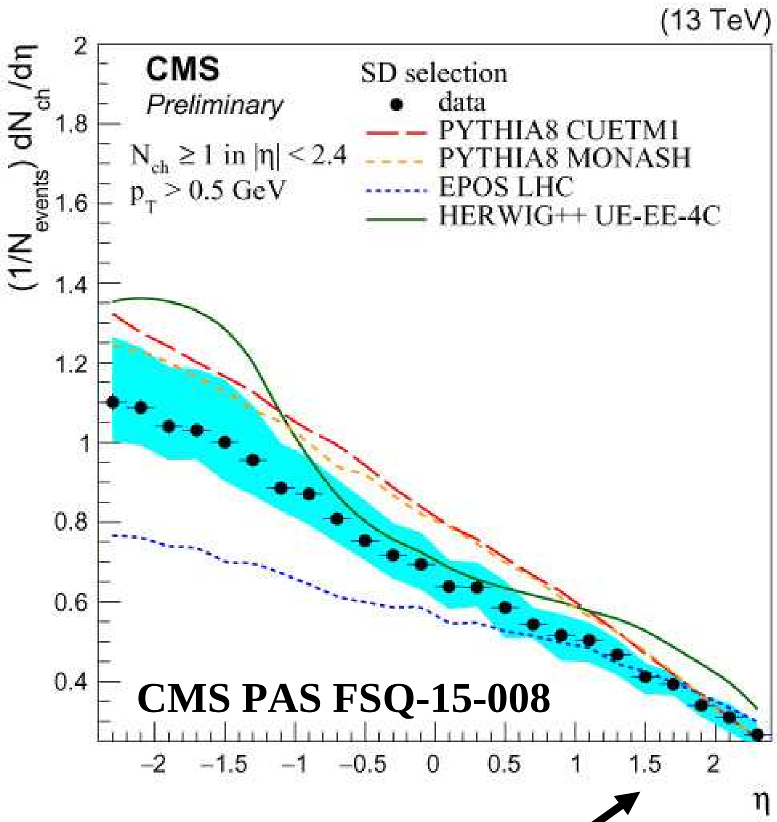
➡ **CMS "SD enhanced" data at 13 TeV on the charged particle density, dN/dη, with $p_T > 0.5$ GeV/c and $|\eta| < 2.4$ for events with at least one charged particle with $p_T > 0.5$ GeV/c and $|\eta| < 2.4$. The data are corrected to the particle level and compared with several MC models at generator level.**

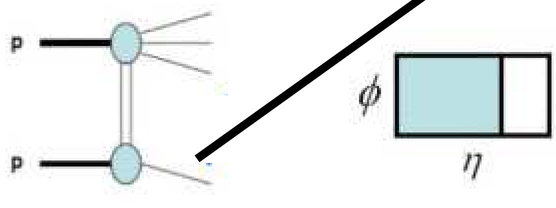
- **SD enhanced**: (A) + **Activity** on one Forward Region **and Veto** on the other side

13 TeV "SD Enhanced" dN/dη

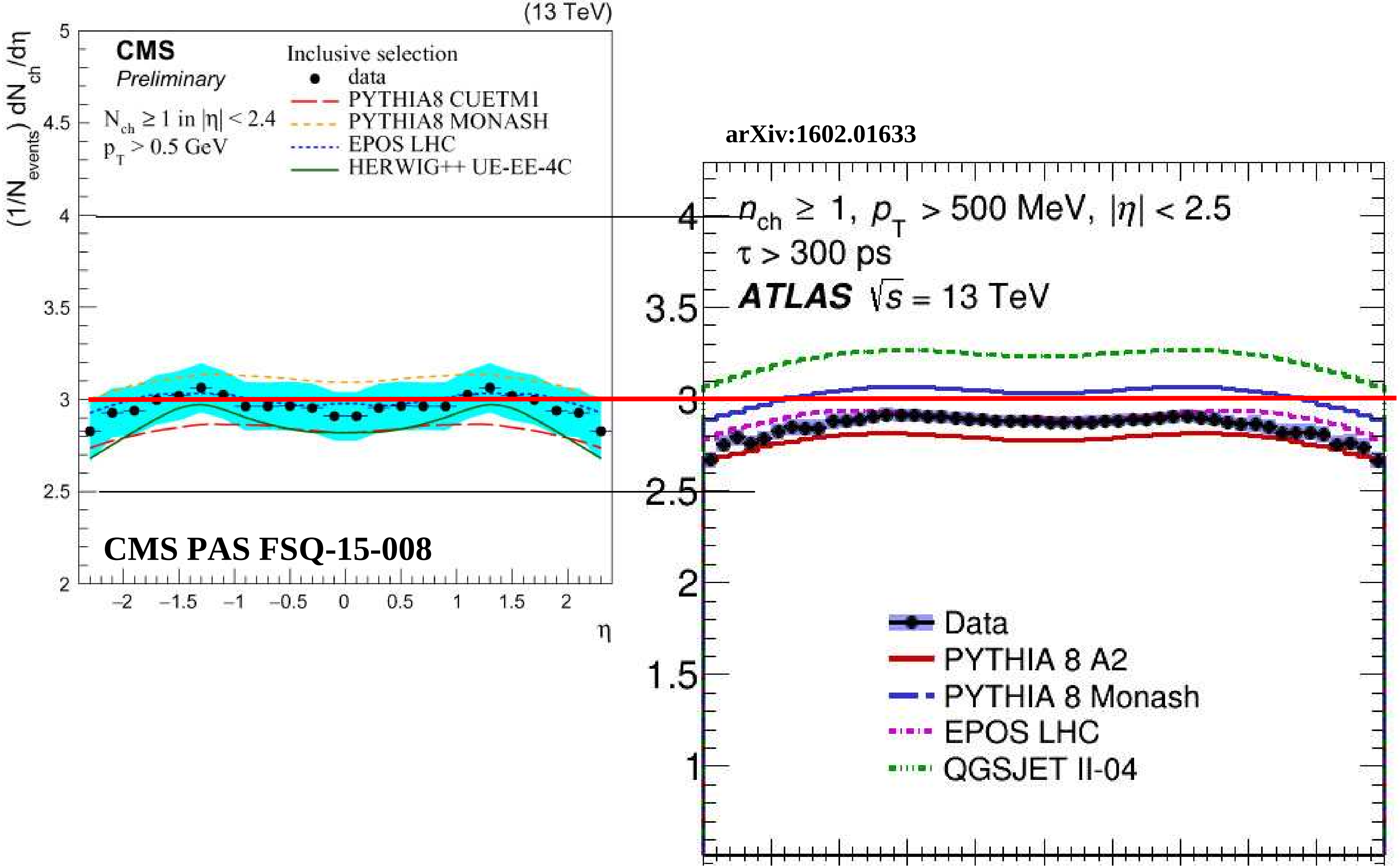




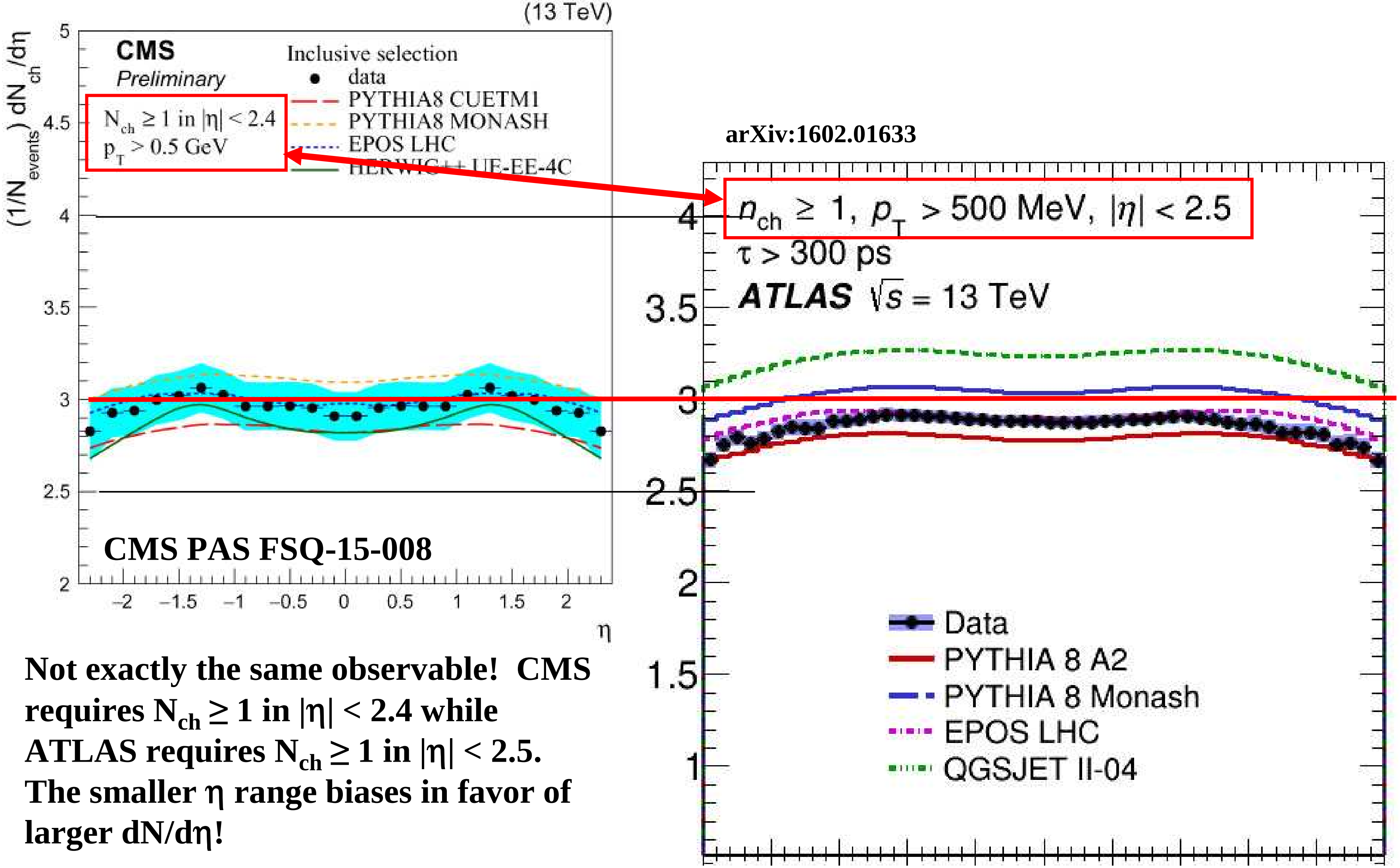




MB at 13 TeV: dN/dη



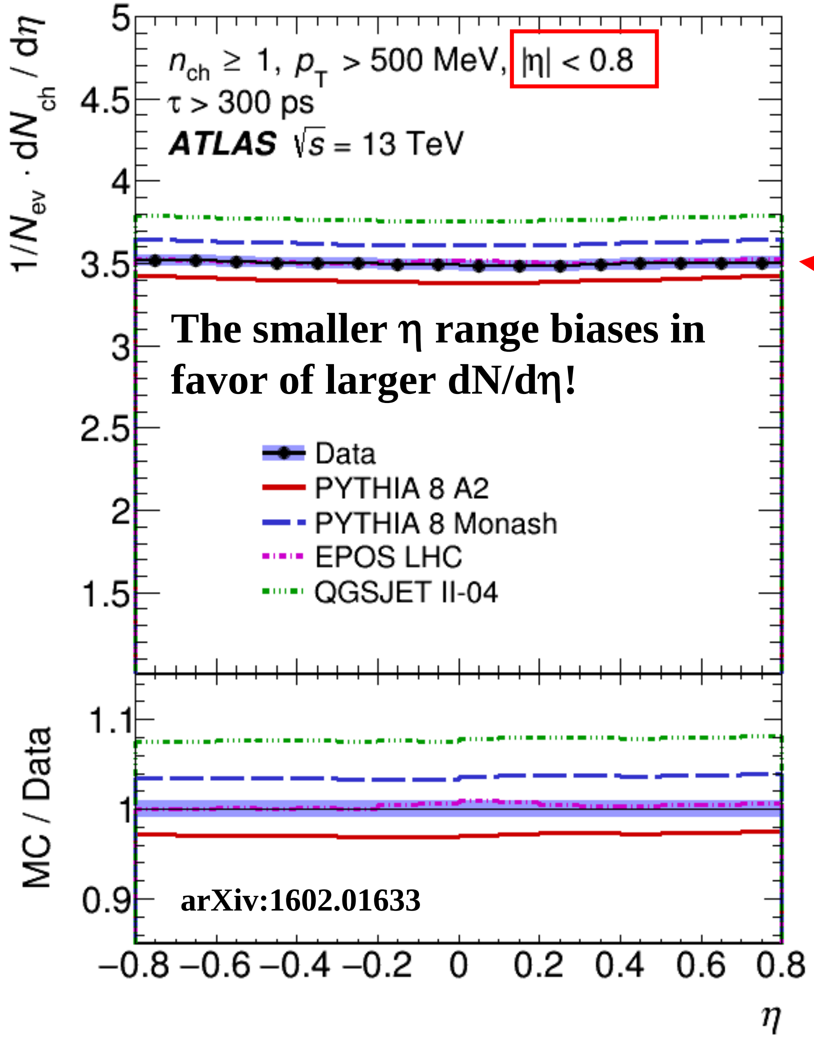
MB at 13 TeV: dN/dη



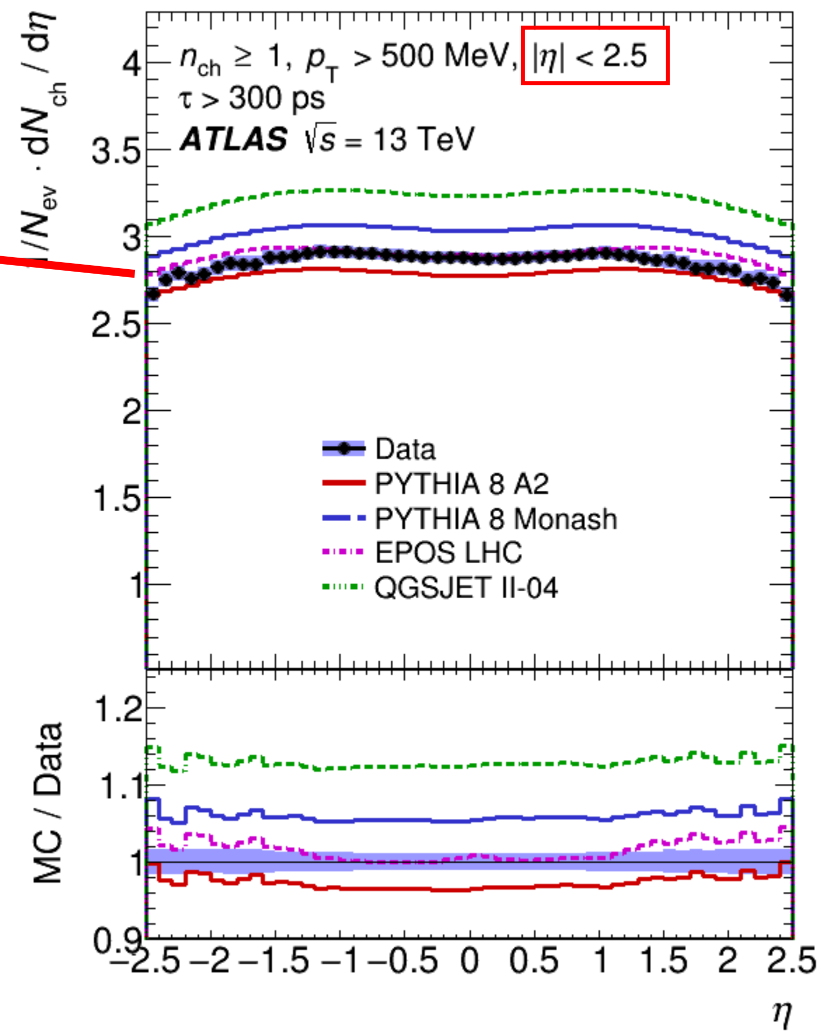
Not exactly the same observable! CMS requires $N_{ch} \geq 1$ in $|\eta| < 2.4$ while ATLAS requires $N_{ch} \geq 1$ in $|\eta| < 2.5$. The smaller η range biases in favor of larger dN/dη!

MB at 13 TeV: dN/dη

13 TeV MB "Common Plot"!

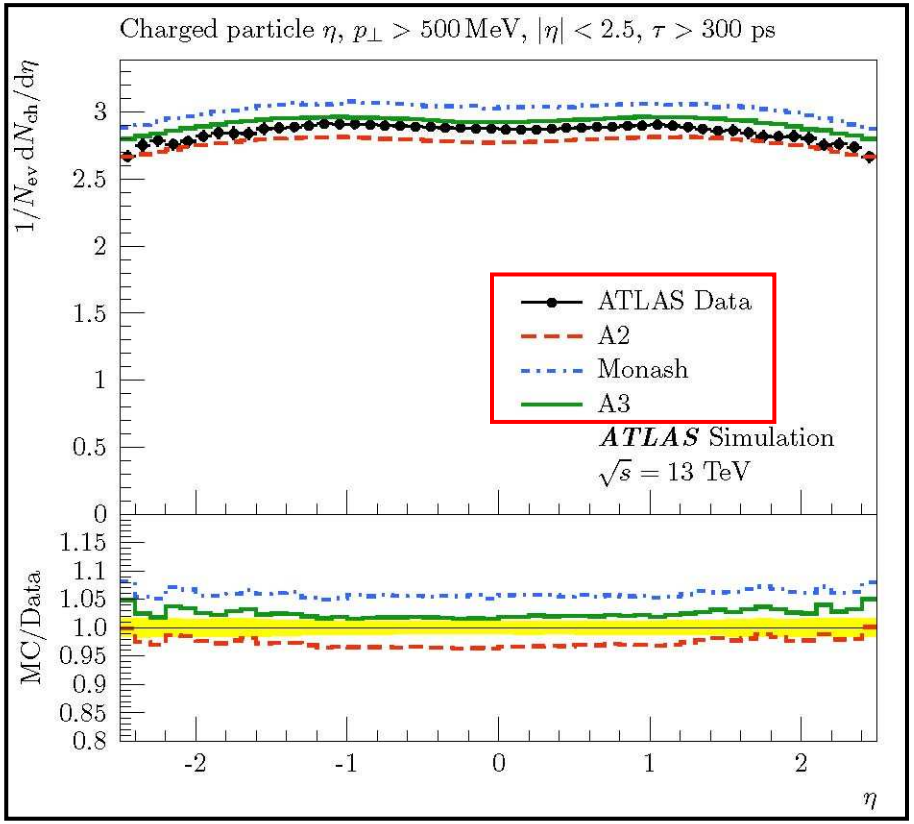


arXiv:1602.01633

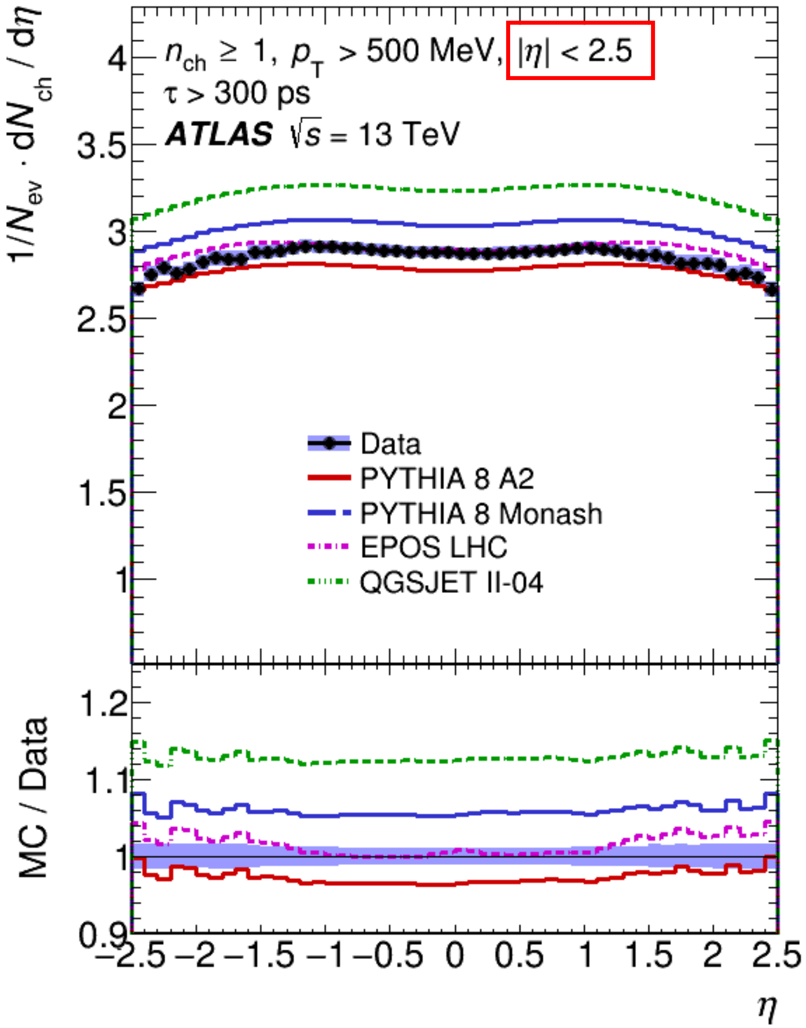


MB at 13 TeV: dN/dη

ATLAS-PHYS-PUB-2016-017



arXiv:1602.01633



ATLAS MB Measurements

EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH (CERN)

Submitted to: Phys. Lett. B.

CERN-EP-2016-014
5th February 2016

arXiv:1602.01633

Charged-particle distributions in $\sqrt{s}$ = 13 TeV *pp* interactions measured with the ATLAS detector at the LHC

The ATLAS Collaboration

Abstract

Charged-particle distributions are measured in proton–proton collisions at a centre-of-mass energy of 13 TeV, using a data sample of nearly 9 million events, corresponding to an integrated luminosity of 170 μb^{-1}, recorded by the ATLAS detector during a special Large Hadron Collider fill. The charged-particle multiplicity, its dependence on transverse momentum and pseudorapidity and the dependence of the mean transverse momentum on the charged-particle multiplicity are presented. The measurements are performed with charged particles with transverse momentum greater than 500 MeV and absolute pseudorapidity less than 2.5, in events with at least one charged particle satisfying these kinematic requirements. Additional measurements in a reduced phase space with absolute pseudorapidity less than 0.8 are also presented, in order to compare with other experiments. The results are corrected for detector effects, presented as particle-level distributions and are compared to the predictions of various Monte Carlo event generators.

EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH (CERN)

Submitted to: Eur. Phys. J. C

CERN-EP-2016-020
9th March 2016

arXiv:1603.02439

Charged-particle distributions in *pp* interactions at $\sqrt{s}$ = 8 TeV measured with the ATLAS detector at the LHC

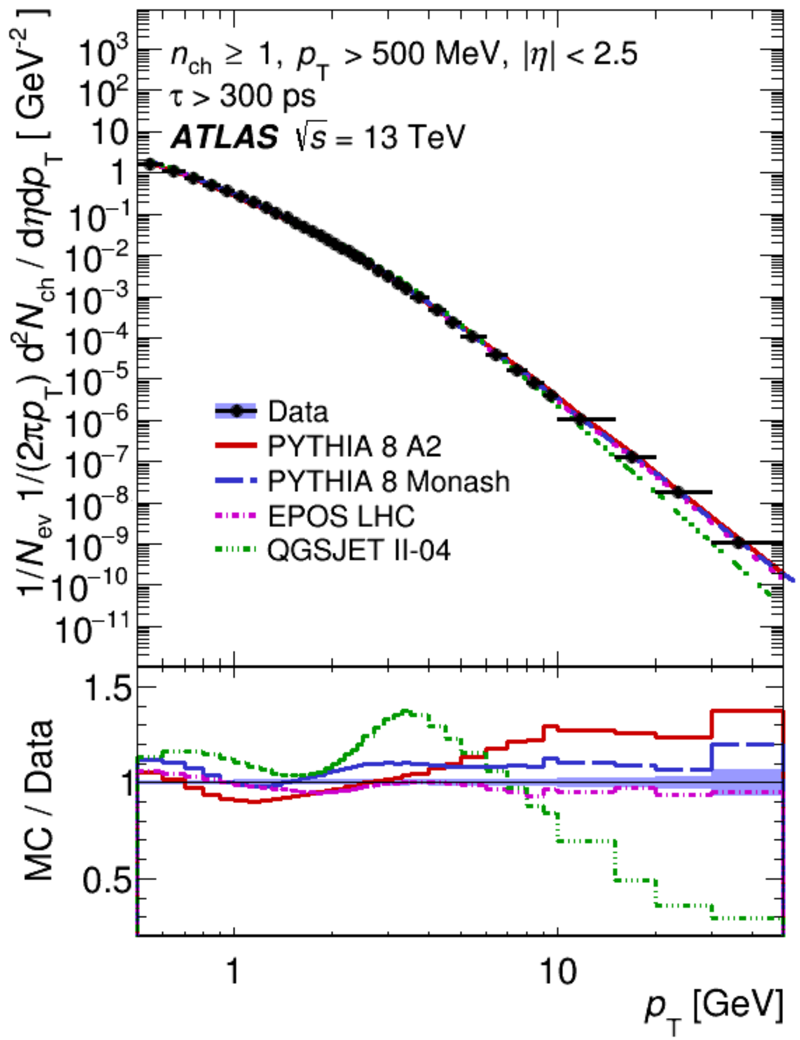
The ATLAS Collaboration

Abstract

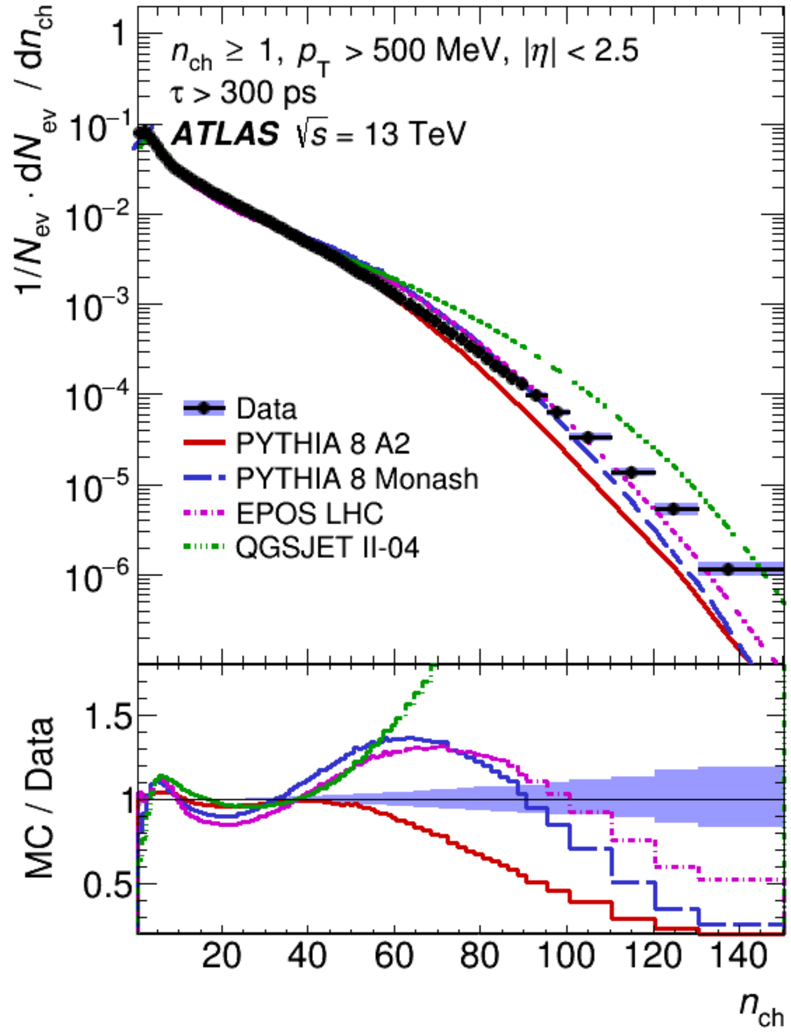
This paper presents measurements of charged-particle distributions which are produced in proton–proton collisions at a centre-of-mass energy of $\sqrt{s}$ = 8 TeV and recorded by the ATLAS detector at the LHC. A special dataset recorded in 2012 with a small number of interactions per beam crossing (below 0.004) and corresponding to an integrated luminosity of 160 μb^{-1} was used. A minimum-bias trigger was utilised to select a data sample of more than 9 million collision events. The multiplicity, pseudorapidity, and transverse momentum distributions of charged particles are shown in different regions of kinematics and charged-particle multiplicity, including measurements of final states at high multiplicity. The results are presented as particle-level distributions to which predictions of various Monte Carlo event generator models are compared.

MB Distributions at 13 TeV

arXiv:1602.01633

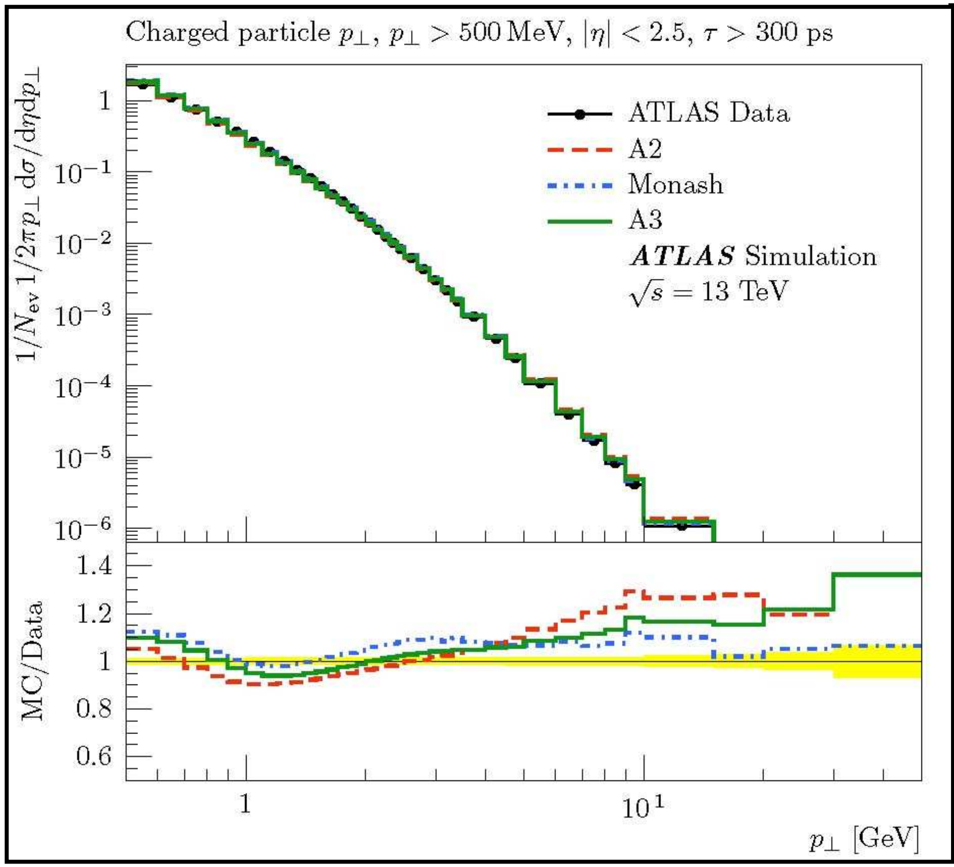


arXiv:1602.01633

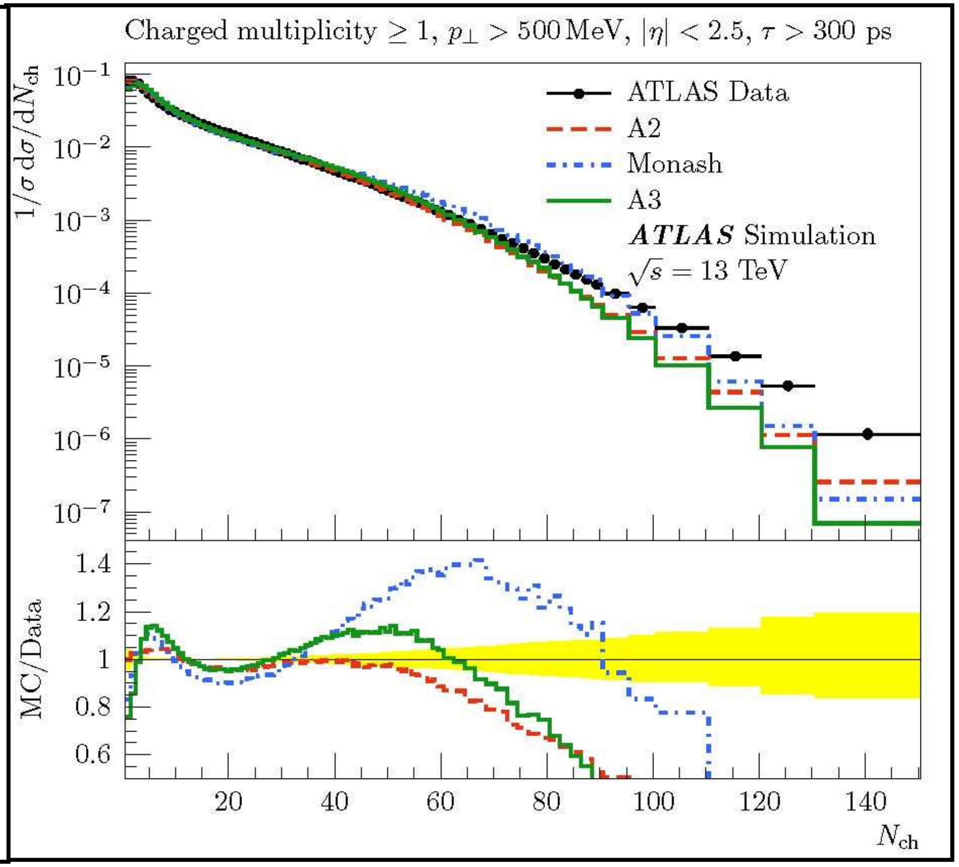


MB Distributions at 13 TeV

ATLAS-PHYS-PUB-2016-017

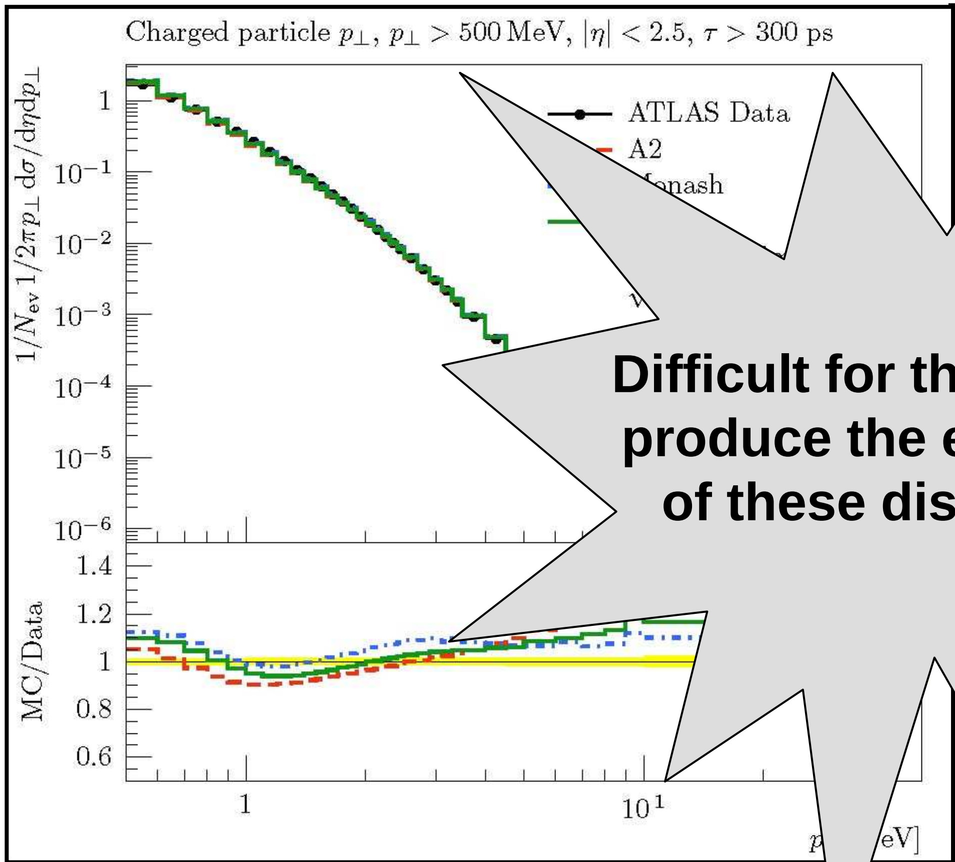


ATLAS-PHYS-PUB-2016-017

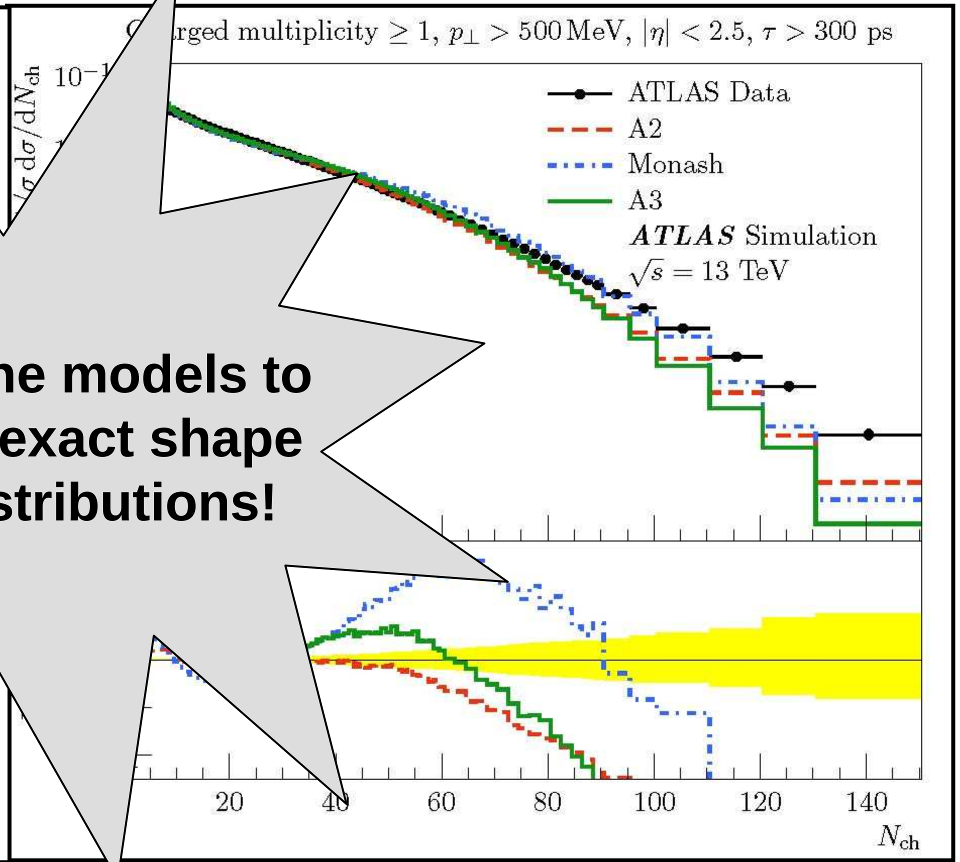


MB Distributions at 13 TeV

ATLAS-PHYS-PUB-2016-017

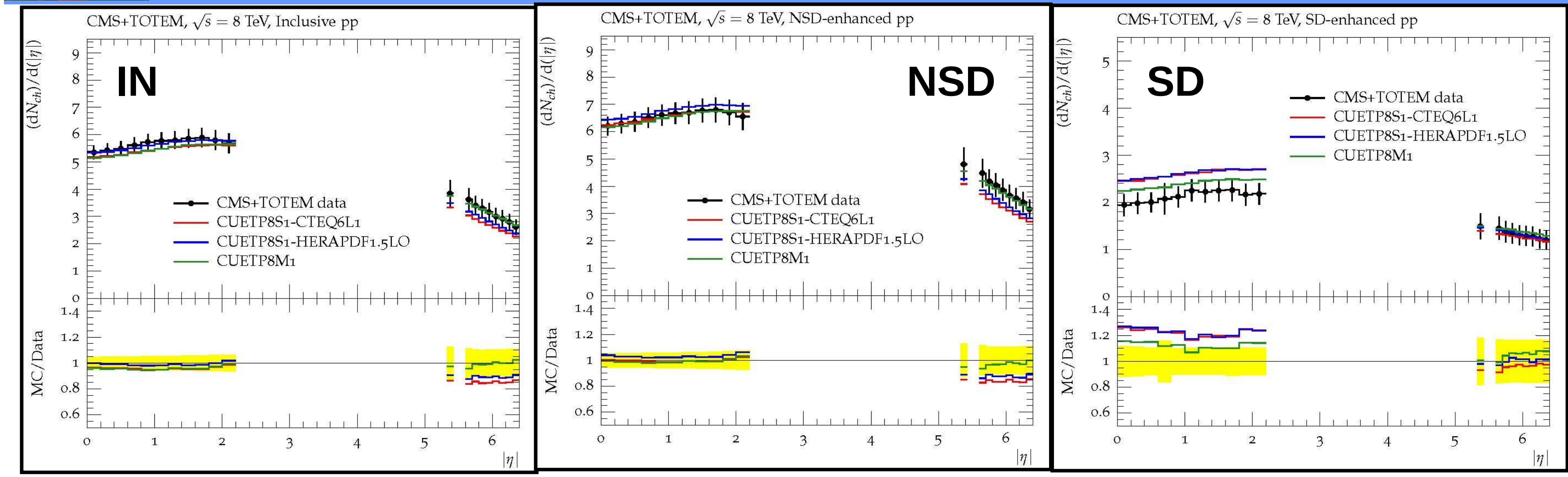


ATLAS-PHYS-PUB-2016-017



Difficult for the models to produce the exact shape of these distributions!

CMS+TOTEM dN/dη



- **Compares the CMS CUEP8M1-NNPDF2.3LO tune with the CMS+TOTEM dN/dη data at 8 TeV.**

The CMS UE tunes do a fairly good job (although not perfect) describing the MB data! No need for a separate MB tune.

The CMS UE tune CUEP8M1-NNPDF2.3LO (Mstar) does a better job in the forward region due to the PDF!

From CMS GEN-14-001

Energy Flow

Available on the CERN CDS information server — **CMS PAS FSQ-15-006**

CMS Physics Analysis Summary

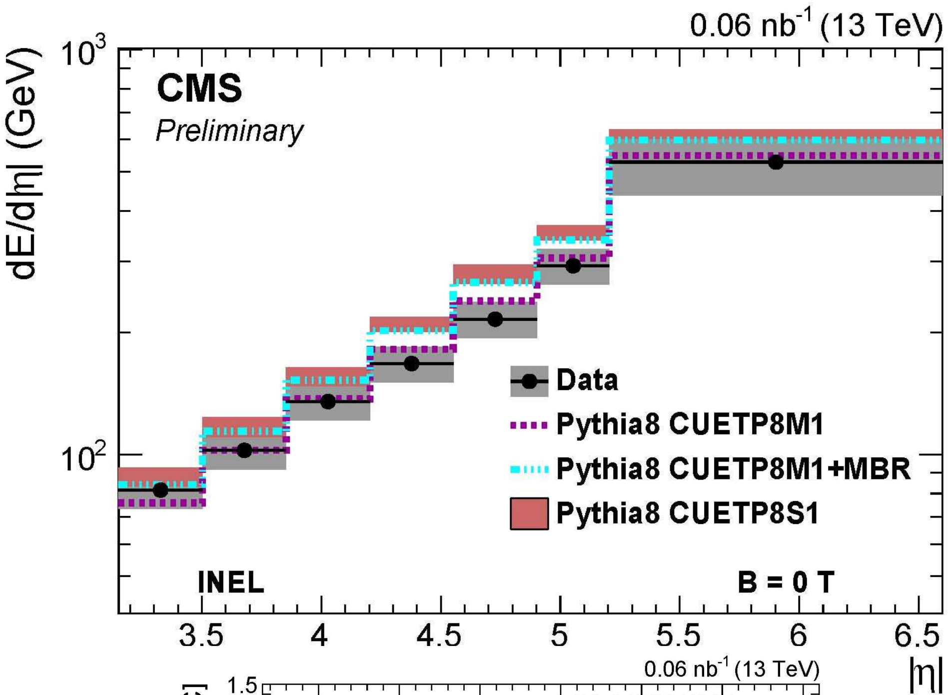
Contact: cms-pag-conveners-fsq@cern.ch — 2016/04/14

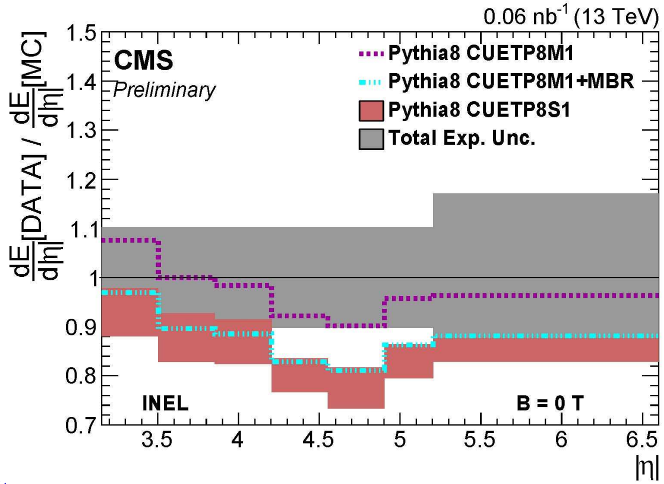
Measurement of the pseudorapidity dependence of the energy and transverse energy density in pp collisions at $\sqrt{s} = 13$ TeV with CMS

The CMS Collaboration

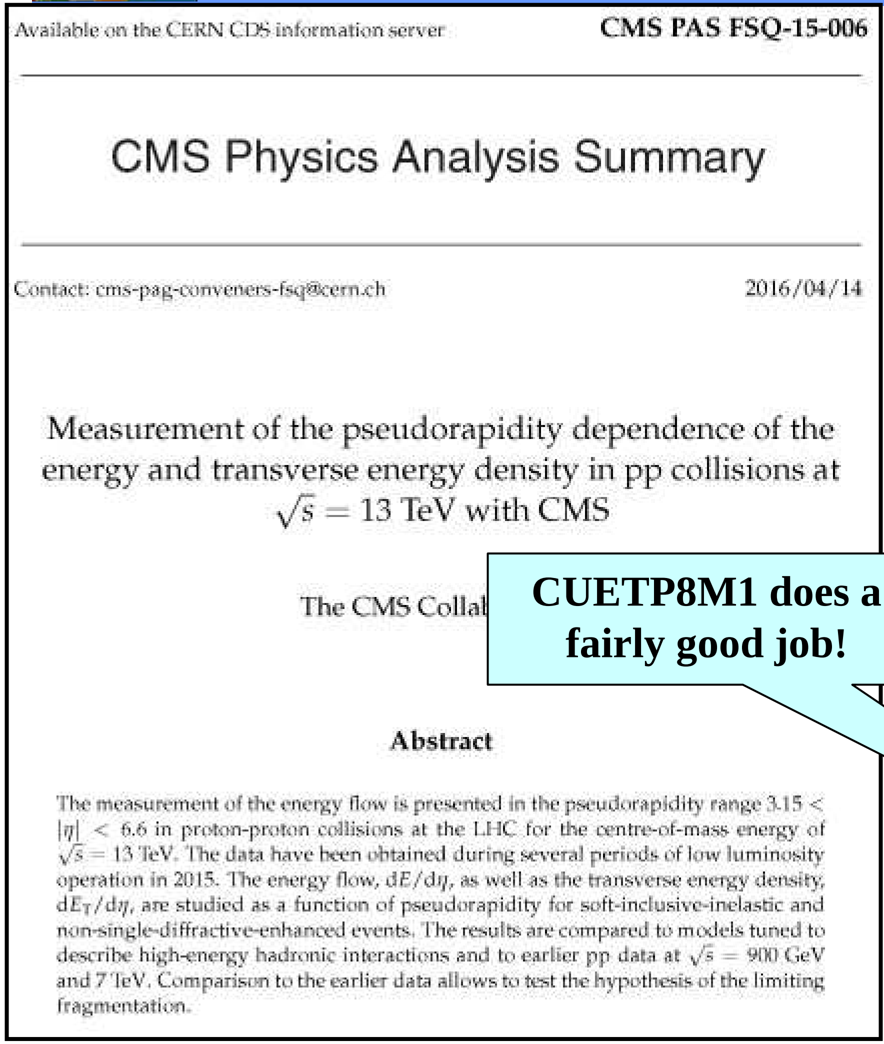
Abstract

The measurement of the energy flow is presented in the pseudorapidity range $3.15 < |\eta| < 6.6$ in proton-proton collisions at the LHC for the centre-of-mass energy of $\sqrt{s} = 13$ TeV. The data have been obtained during several periods of low luminosity operation in 2015. The energy flow, $dE/d\eta$, as well as the transverse energy density, $dE_T/d\eta$, are studied as a function of pseudorapidity for soft-inclusive-inelastic and non-single-diffractive-enhanced events. The results are compared to models tuned to describe high-energy hadronic interactions and to earlier pp data at $\sqrt{s} = 900$ GeV and 7 TeV. Comparison to the earlier data allows to test the hypothesis of the limiting fragmentation.





Energy Flow


Available on the CERN CDS information server | CMS PAS FSQ-15-006

CMS Physics Analysis Summary

Contact: cms-pag-conveners-fsq@cern.ch | 2016/04/14

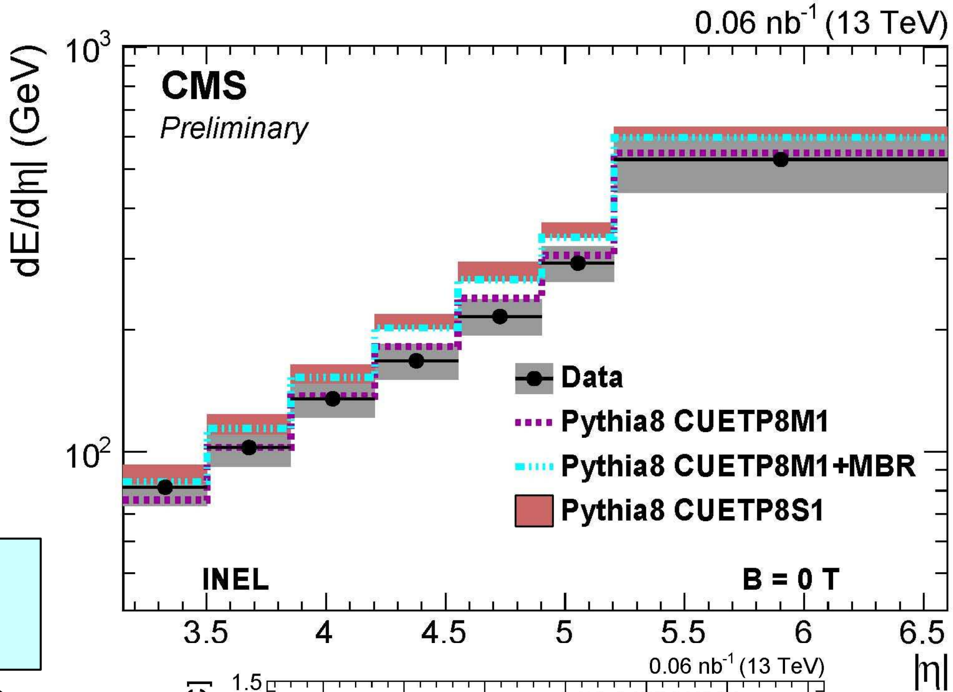
Measurement of the pseudorapidity dependence of the energy and transverse energy density in pp collisions at $\sqrt{s} = 13$ TeV with CMS

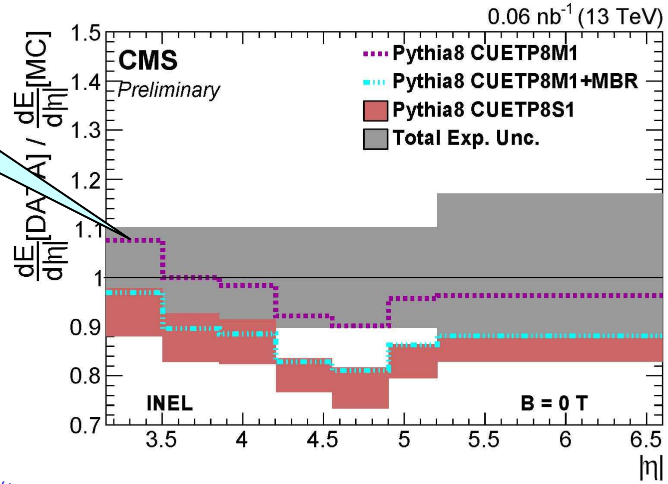
The CMS Collab

Abstract

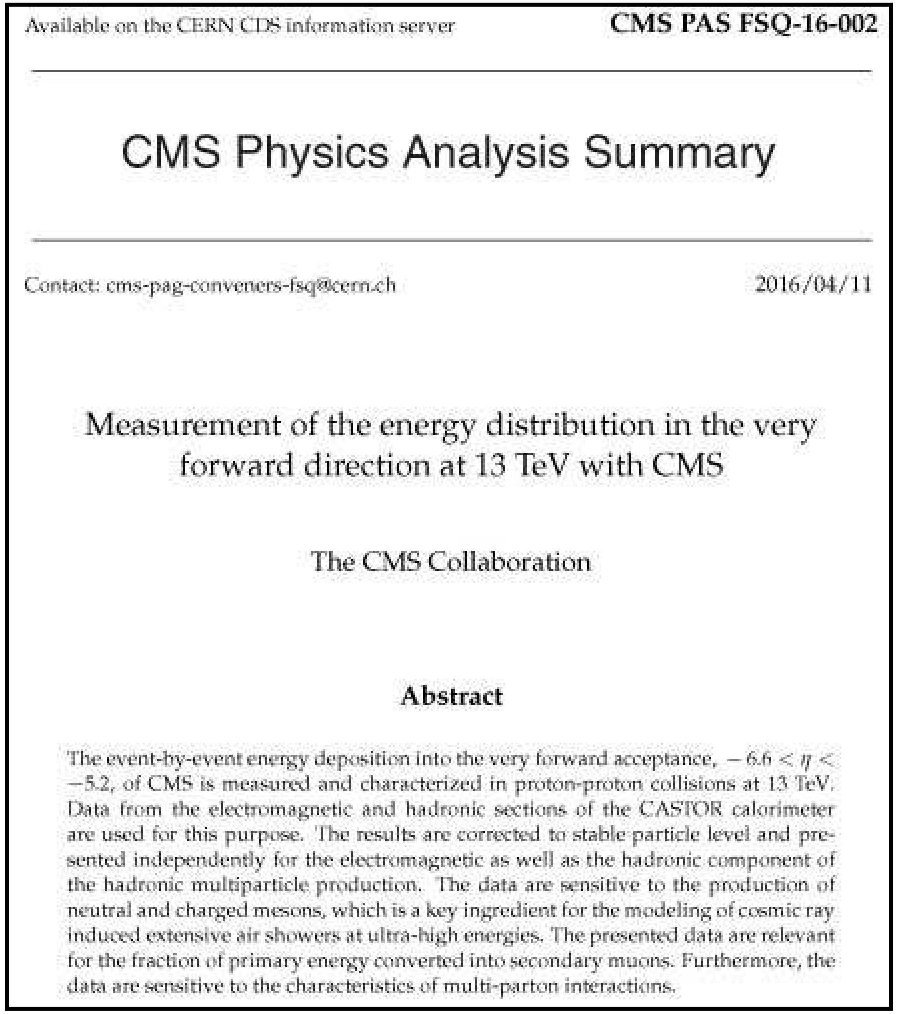
The measurement of the energy flow is presented in the pseudorapidity range $3.15 < |\eta| < 6.6$ in proton-proton collisions at the LHC for the centre-of-mass energy of $\sqrt{s} = 13$ TeV. The data have been obtained during several periods of low luminosity operation in 2015. The energy flow, $dE/d\eta$, as well as the transverse energy density, $dE_T/d\eta$, are studied as a function of pseudorapidity for soft-inclusive-inelastic and non-single-diffractive-enhanced events. The results are compared to models tuned to describe high-energy hadronic interactions and to earlier pp data at $\sqrt{s} = 900$ GeV and 7 TeV. Comparison to the earlier data allows to test the hypothesis of the limiting fragmentation.

CUETP8M1 does a fairly good job!





Forward Energy Distribution



Available on the CERN CDS information server

CMS PAS FSQ-16-002

CMS Physics Analysis Summary

Contact: cms-pag-conveners-fsq@cern.ch

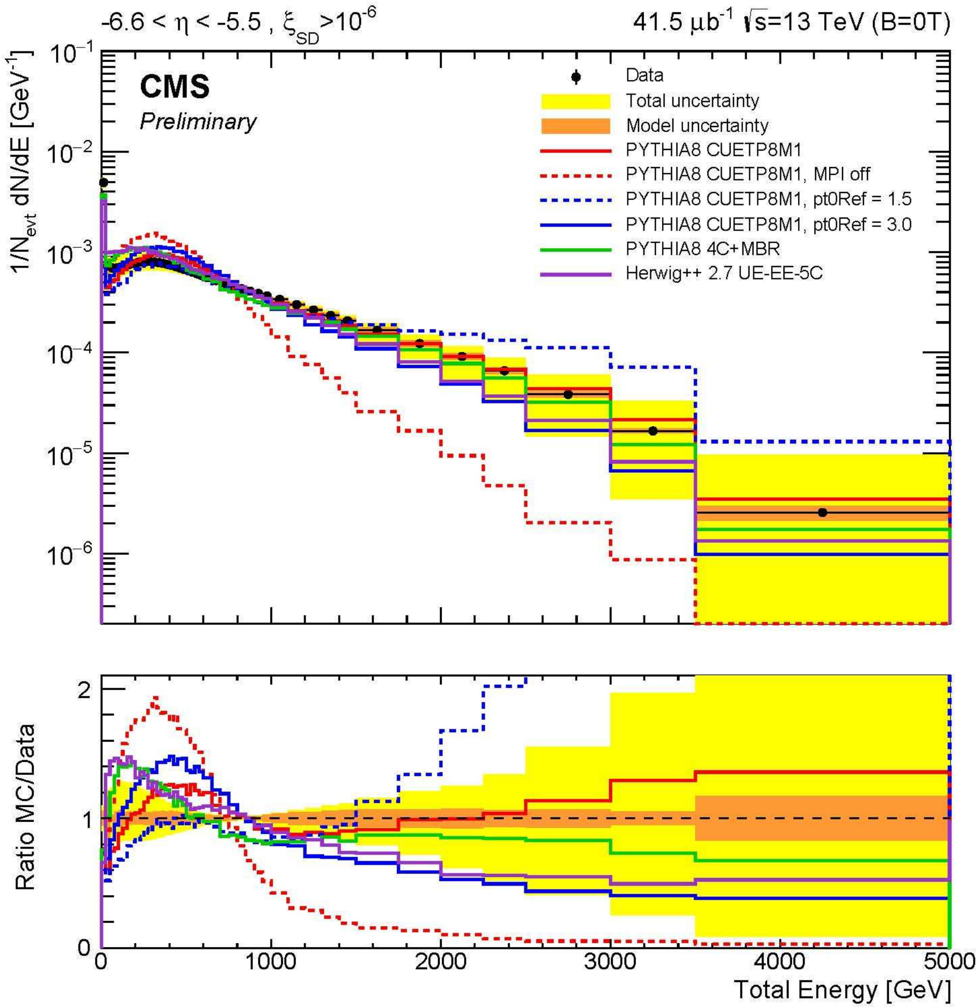
2016/04/11

Measurement of the energy distribution in the very forward direction at 13 TeV with CMS

The CMS Collaboration

Abstract

The event-by-event energy deposition into the very forward acceptance, $-6.6 < \eta < -5.2$, of CMS is measured and characterized in proton-proton collisions at 13 TeV. Data from the electromagnetic and hadronic sections of the CASTOR calorimeter are used for this purpose. The results are corrected to stable particle level and presented independently for the electromagnetic as well as the hadronic component of the hadronic multiparticle production. The data are sensitive to the production of neutral and charged mesons, which is a key ingredient for the modeling of cosmic ray induced extensive air showers at ultra-high energies. The presented data are relevant for the fraction of primary energy converted into secondary muons. Furthermore, the data are sensitive to the characteristics of multi-parton interactions.



Forward Energy Distribution

Available on the CERN CDS information server **CMS PAS FSQ-16-002**

CMS Physics Analysis Summary

Contact: cms-pag-conver... .../11

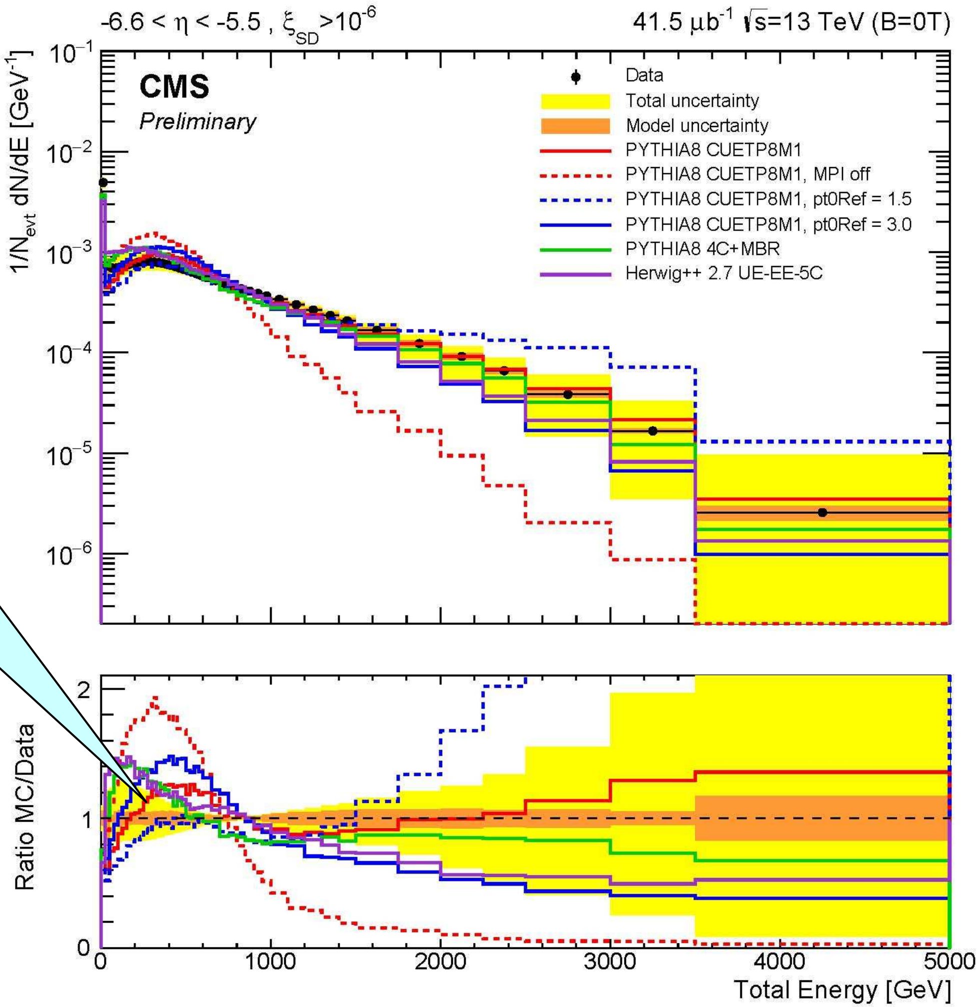
CUETP8M1 does a fairly good job, but overestimates the soft energy!

Measurement of the energy distributi... very forward direction at 13 TeV with C...

The CMS Collaboration

Abstract

The event-by-event energy deposition into the very forward acceptance, $-6.6 < \eta < -5.2$, of CMS is measured and characterized in proton-proton collisions at 13 TeV. Data from the electromagnetic and hadronic sections of the CASTOR calorimeter are used for this purpose. The results are corrected to stable particle level and presented independently for the electromagnetic as well as the hadronic component of the hadronic multiparticle production. The data are sensitive to the production of neutral and charged mesons, which is a key ingredient for the modeling of cosmic ray induced extensive air showers at ultra-high energies. The presented data are relevant for the fraction of primary energy converted into secondary muons. Furthermore, the data are sensitive to the characteristics of multi-parton interactions.



MB at 13 TeV: dN/dη

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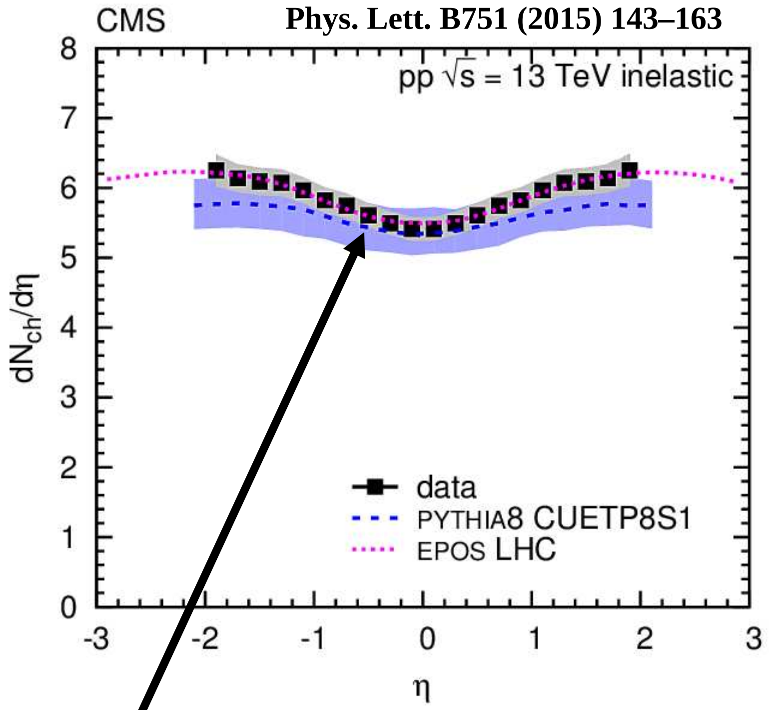
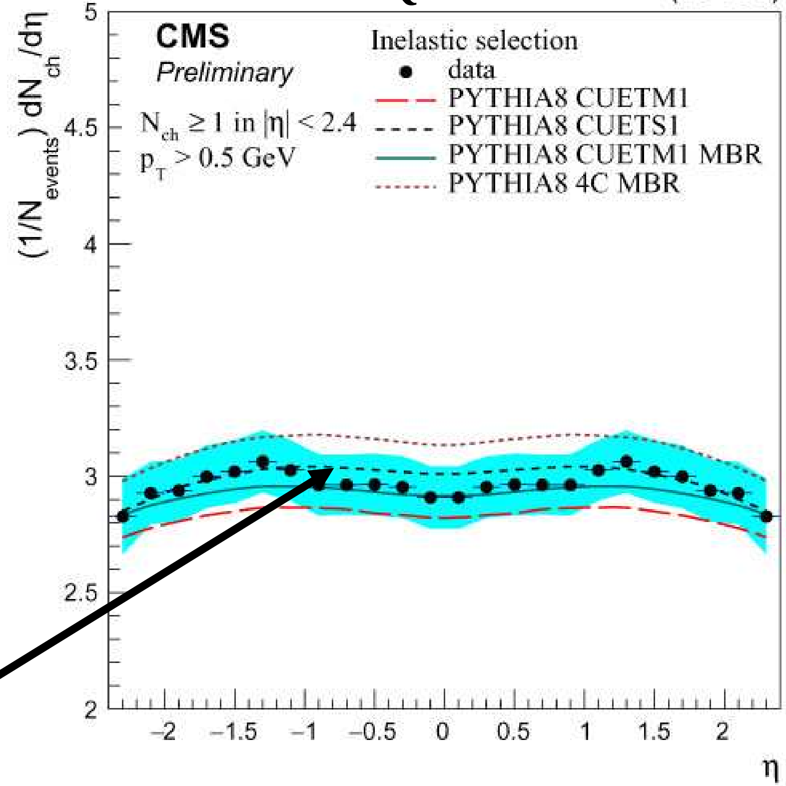


CMS PAS FSQ-15-008



CMS UE Tune CUETP8S1-HERAPDF1.5LO.

MB at 13 TeV: dN/dη

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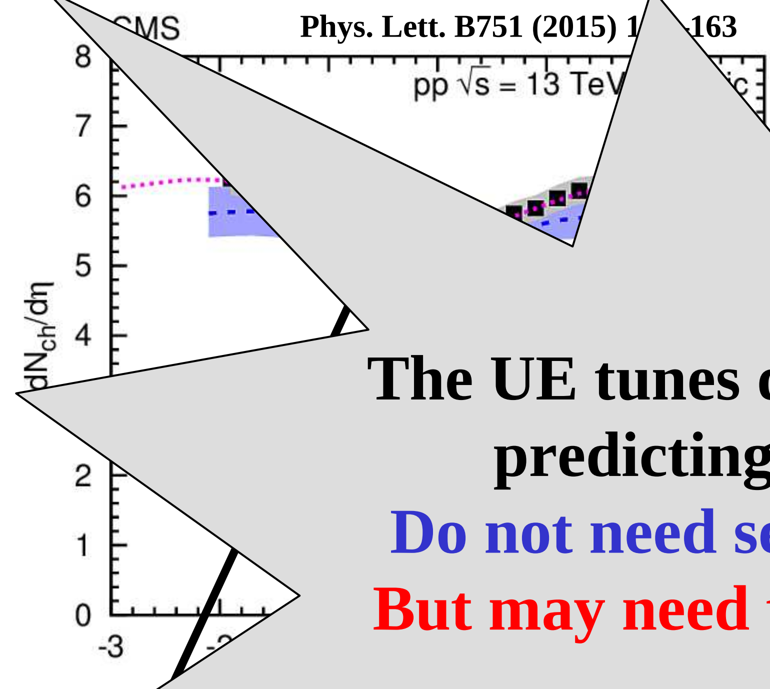

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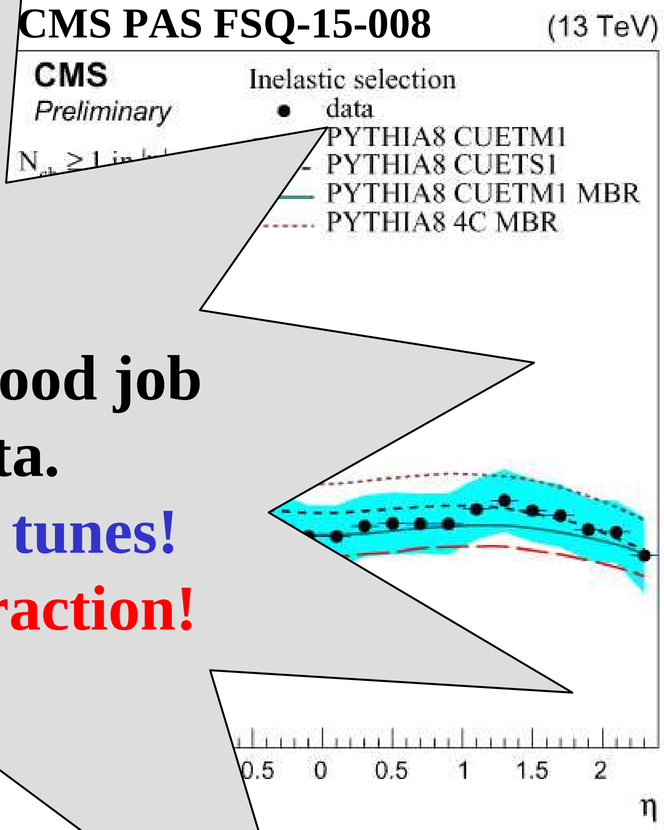


The UE tunes do a fairly good job predicting the MB data.

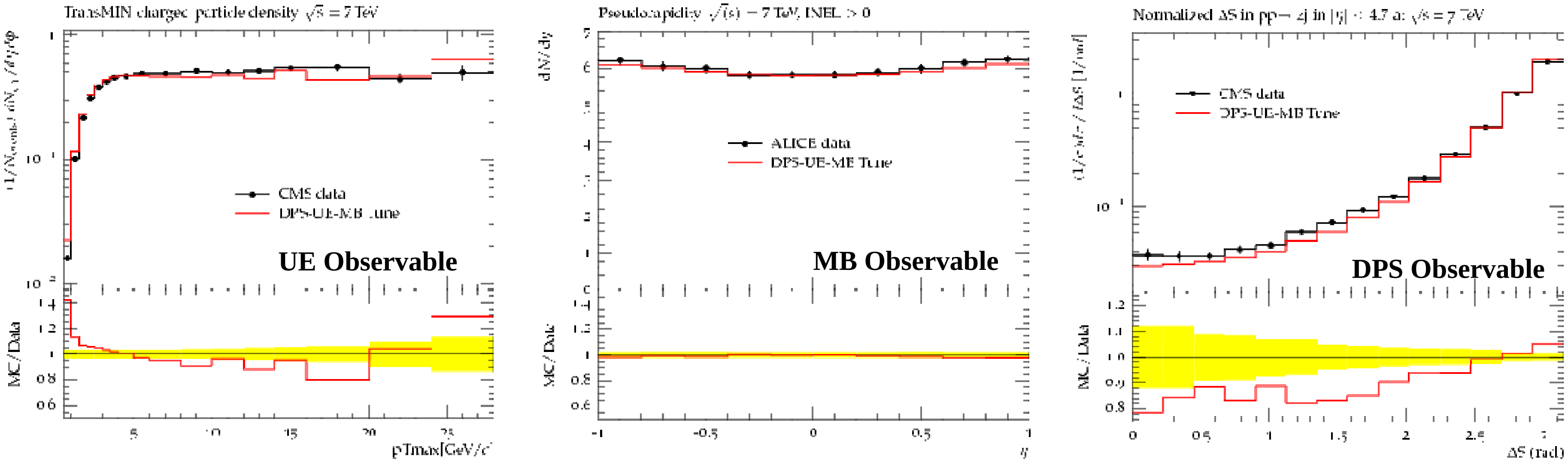
Do not need separate MB tunes!

But may need to tune diffraction!

CMS UE Tune CUET…

Simultaneous UE-MB-DPS Tune

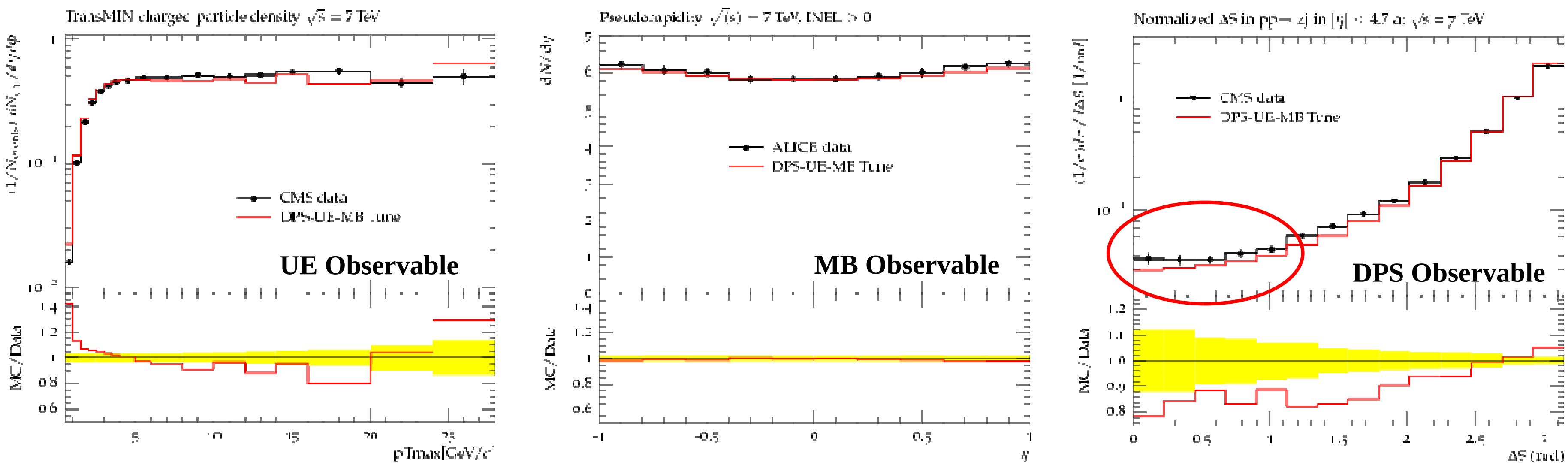
Paolo Gunnellini and the CMS PC&GT Team



- **Simultaneous UE-MB-DPS Tune at 7 TeV: Simultaneously fit the CMS PTmax UE data, the ALICE dN/dη data, and the CMS pp→4j DPS data starting with PYTHIA 8 tune CUETP8M1-NNPDF2.3LO and vary three parameters (MultipartonInteractions:pT0Ref, MultipartonInteractions:expPow, ColourReconnection:range). Weight all data equally.**

Simultaneous UE-MB-DPS Tune

Paolo Gunnellini and the CMS PC&GT Team



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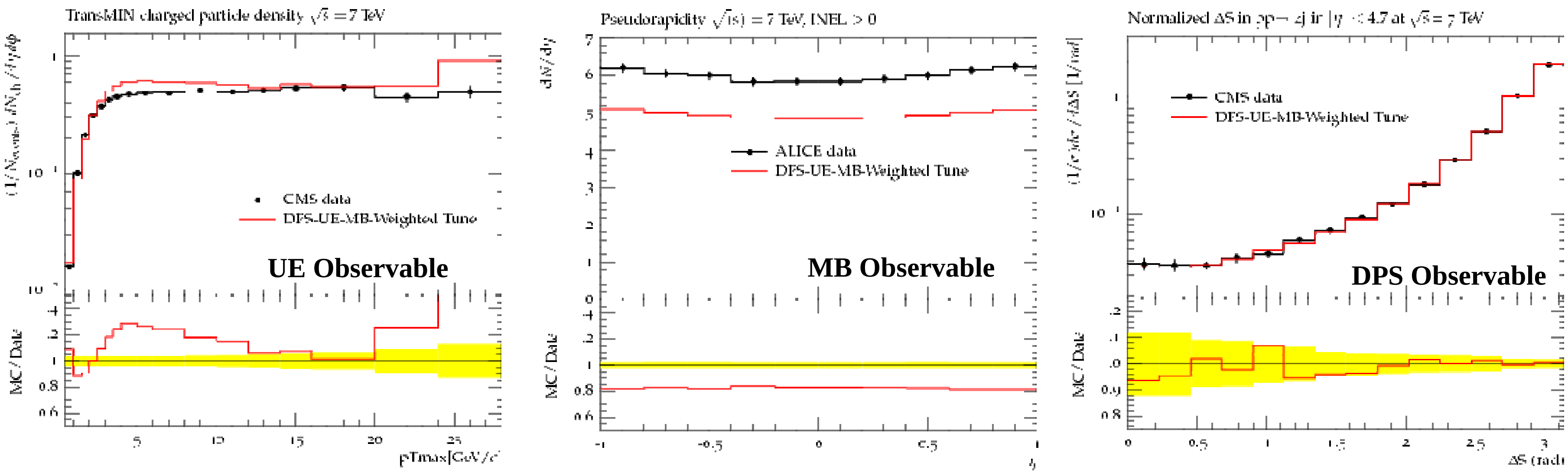
UE and MB are good, but DPS is bad!

Simultaneous UE-MB-DPS Tune

Paolo Gunnellini and the CMS PC&GT Team



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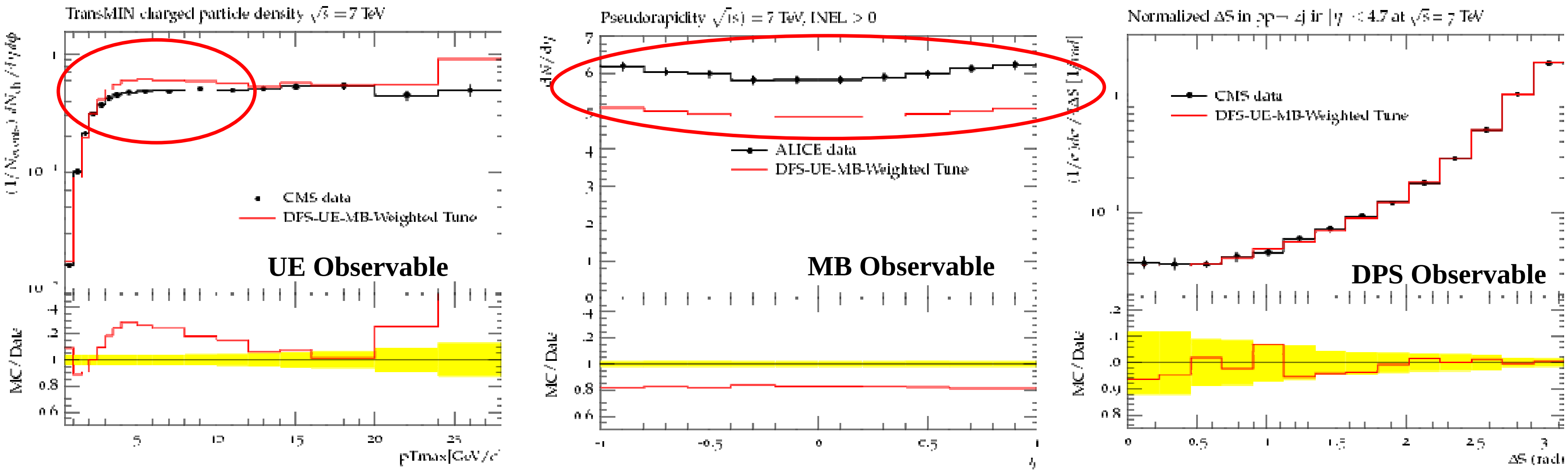
Simultaneous UE-MB-DPS Tune

Paolo Gunnellini and the CMS PC&GT Team



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DPS is good, but UE and MB are bad!

Summary & Conclusions

- No one QCD Monte-Carlo model describes everything perfectly.
- The PYTHIA 8 tunes such as CUETP8S1, CUETP8M1, and Monash, describe fairly well both the underlying event and the non-diffractive contribution to MB observables. We need to work on tuning the diffractive models! The ATLAS MB tune A3 does fairly well on the UE, but could do better!
- The CMS HW++ Tune CUETHS1-CTEQ6L fits the UE "plateau" region very well, but cannot use it because of the HW++ "bug". Big change in going from HW++ to HW7! Must re-tune. The HW7 Default Tune is not bad! But could do better!
- Tunes that use NPDF2.3LO PDF (*including the new ATLAS Tune A3*) do a better job in the forward region due to the low-x gluon distribution.
- Hard multi-jet production in Z-Boson events at large $P_T(Z)$ is not modeled very well by the QCD Monte-Carlo models (SHERPA is doing the best). Must tune the hard ISR!
- I do not understand why we cannot simultaneously fit both the UE and the DPS sensitive observables with the same tune. We will continue to work on this.
- The CMS PC&GT group is actively working of improved PYTHIA 8, HERWIG 7, and SHERPA tunes!