Impact of tunes in high p_T jet and boson measurements

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A brief CMS Tunes chronology

In CMS we developed a set of tunes based on UE in Pythia8.

The (six) tunes differ by PDF order, α_S evolution and are extracted by fitting simultaneously charged-particle multiplicity and trans- verse momentum densities at various hadron collision energies

The idea was to obtain a tune for the official MC production that was tested over a variety of different final states, from soft to hard physics

One of the six tunes was selected as the main “official” one for CMS Run2 MC production

A huge paper containing the validation of the tune, methodology and cross checks was prepared (arxiv:903.12179 under EPJC review)

A brief CMS Tunes chronology

people involved ~20 time needed to get the paper submitted ~ 3 yr

Available on CMS information server

CMS AN -2017/001

The Compact Muon Solenoid Experiment

Analysis Note

The content of this note is intended for CMS internal use and distribution only

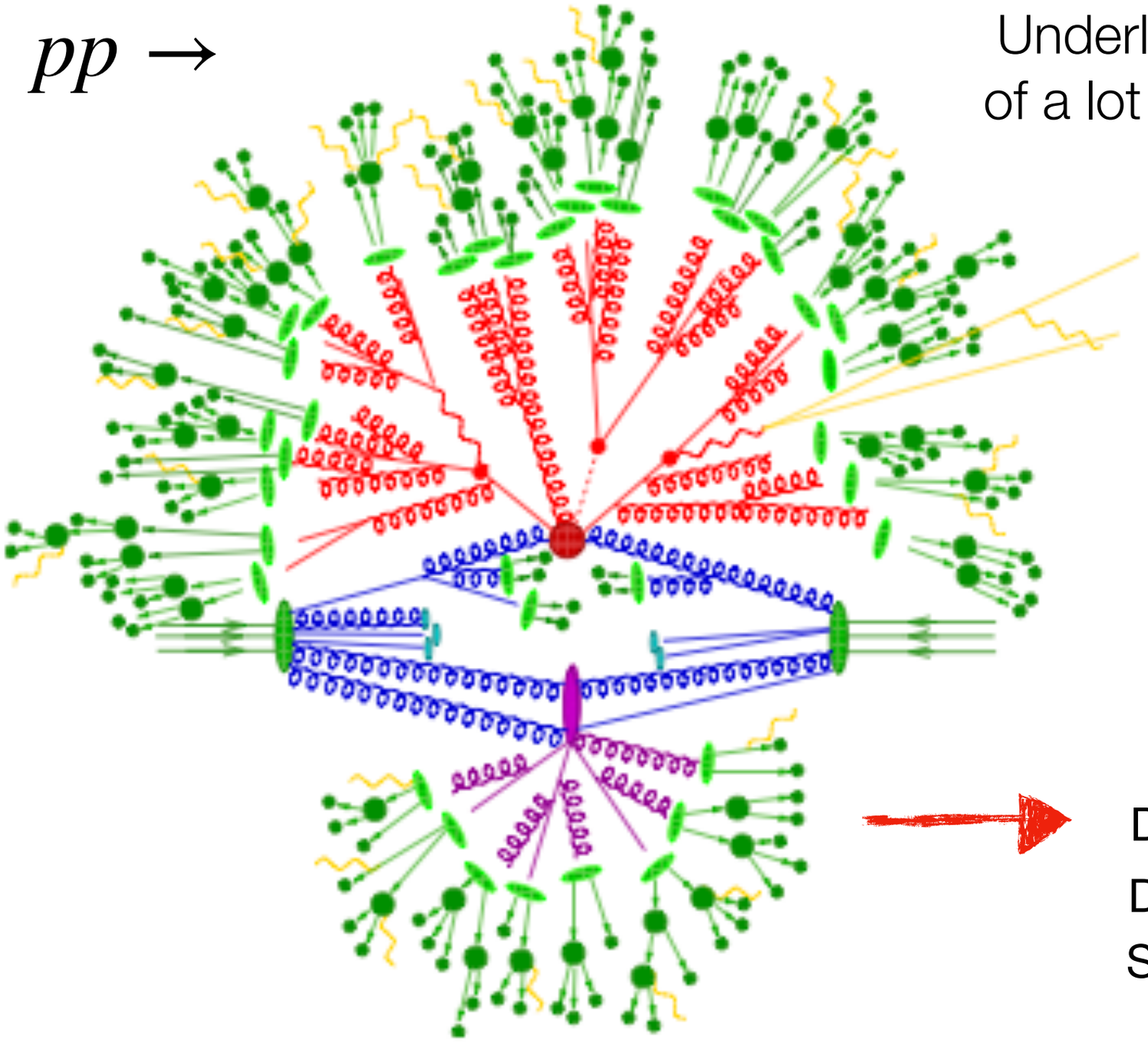
(first complete version)

06 January 2017

Tuning and validation for RunII Monte Carlo production

The usual good old UE sketch

$pp \rightarrow$



Underlying Event at the LHC consists of a lot of processes at different scales

hadronization modelling

initial/final state radiation (PS)

multiple parton interactions (UE)

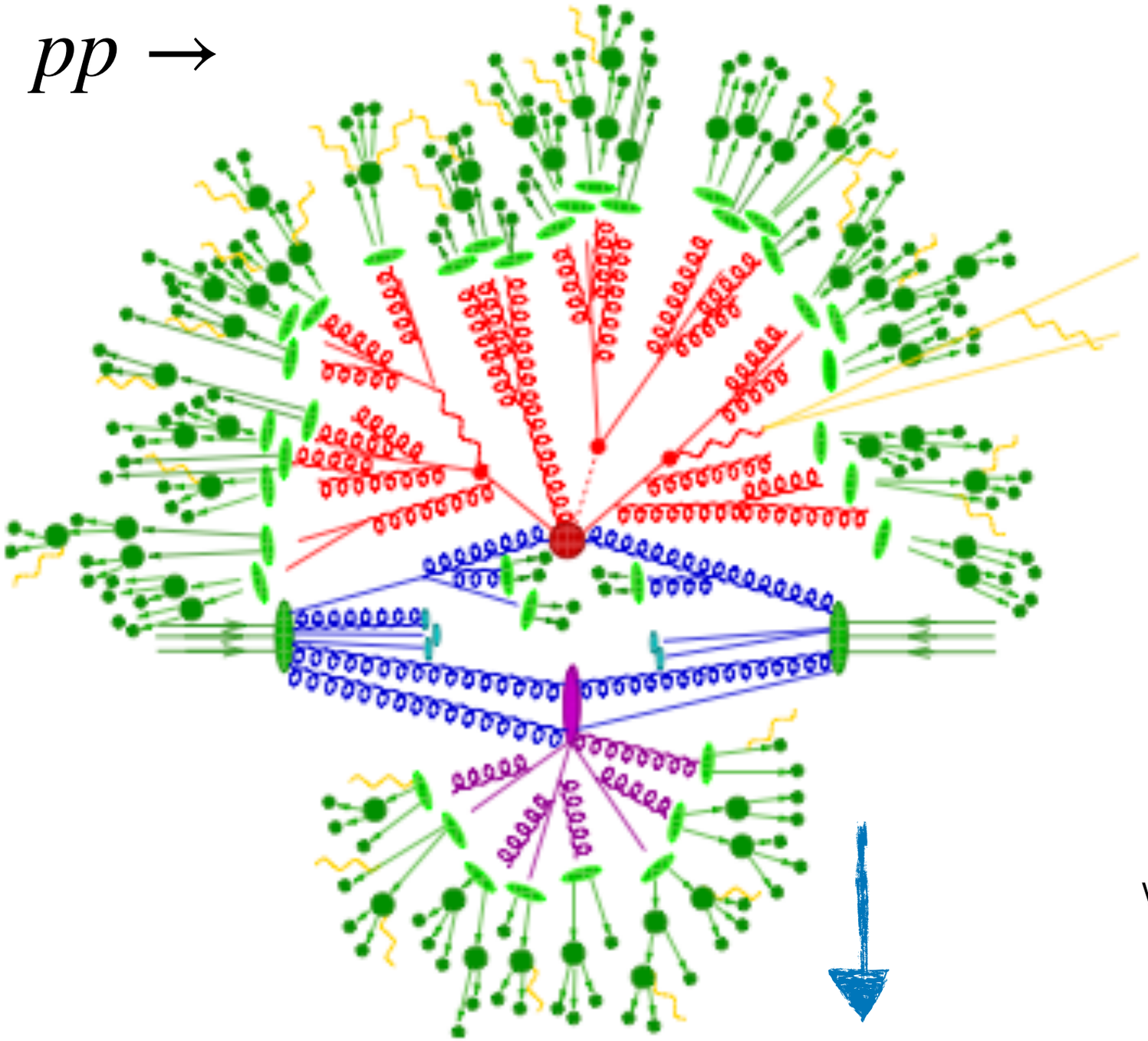
beam remnants (primordial kT)

Double Parton Scattering
Diffraction
Semi-hard MPI processes

a rich physics relying on phenomenological parameters. We need data to understand QCD

Many possible sensitive parameters

$pp \rightarrow$



MPI

$$p_T^0 = p_T^{ref} \cdot (E/E_{ref})^{\epsilon}$$

initial/final state radiation (PS)

strong coupling, regularization upper scale…

hadronization modelling

length of fragmentation string, strange baryon suppresion…

beam remnants (primordial kT)

width of the gaussian of the primordial kT in the proton…

we use Professor as main tool to choose parameters ranges, interpolation and minmization

CMS Tunes: The CP*X* Family

PYTHIA8 parameter	CP1	CP2
PDF Set	NNPDF3.1 LO	NNPDF3.1 LO
$\alpha_S(m_Z)$	0.130	0.130
`SpaceShower:rapidityOrder`	off	off
`MultipartonInteractions:EcmRef` [GeV]	7000	7000
$\alpha_S^{\mathrm{ISR}}(m_Z)$ value/order	0.1365/LO	0.130/LO
$\alpha_S^{\mathrm{FSR}}(m_Z)$ value/order	0.1365/LO	0.130/LO
$\alpha_S^{\mathrm{MPI}}(m_Z)$ value/order	0.130/LO	0.130/LO
$\alpha_S^{\mathrm{ME}}(m_Z)$ value/order	0.130/LO	0.130/LO
`MultipartonInteractions:pT0Ref` [GeV]	2.4	2.3
`MultipartonInteractions:ecmPow`	0.15	0.14
`MultipartonInteractions:coreRadius`	0.54	0.38
`MultipartonInteractions:coreFraction`	0.68	0.33
`ColorReconnection:range`	2.63	2.32
χ^2/dof	0.89	0.54

Fixed Inputs

Fitted parameters

The Leading Order Tunes CP1 and CP2

CP Tunes = CMS Pythia Tunes

CMS Tunes: The CP*X* Family

PYTHIA8 parameter	CP3	CP4	CP5
PDF Set	NNPDF3.1 NLO	NNPDF3.1 NNLO	NNPDF3.1 NNLO
$\alpha_S(m_Z)$	0.118	0.118	0.118
`SpaceShower:rapidityOrder`	off	off	on
`MultipartonInteractions:EcmRef` [GeV]	7000	7000	7000
$\alpha_S^{\mathrm{ISR}}(m_Z)$ value/order	0.118/NLO	0.118/NLO	0.118/NLO
$\alpha_S^{\mathrm{FSR}}(m_Z)$ value/order	0.118/NLO	0.118/NLO	0.118/NLO
$\alpha_S^{\mathrm{MPI}}(m_Z)$ value/order	0.118/NLO	0.118/NLO	0.118/NLO
$\alpha_S^{\mathrm{ME}}(m_Z)$ value/order	0.118/NLO	0.118/NLO	0.118/NLO
`MultipartonInteractions:pT0Ref` [GeV]	1.52	1.48	1.41
`MultipartonInteractions:ecmPow`	0.02	0.02	0.03
`MultipartonInteractions:coreRadius`	0.54	0.60	0.76
`MultipartonInteractions:coreFraction`	0.39	0.30	0.63
`ColorReconnection:range`	4.73	5.61	5.18
χ^2/dof	0.76	0.80	1.04

Fixed Inputs

Fitted parameters

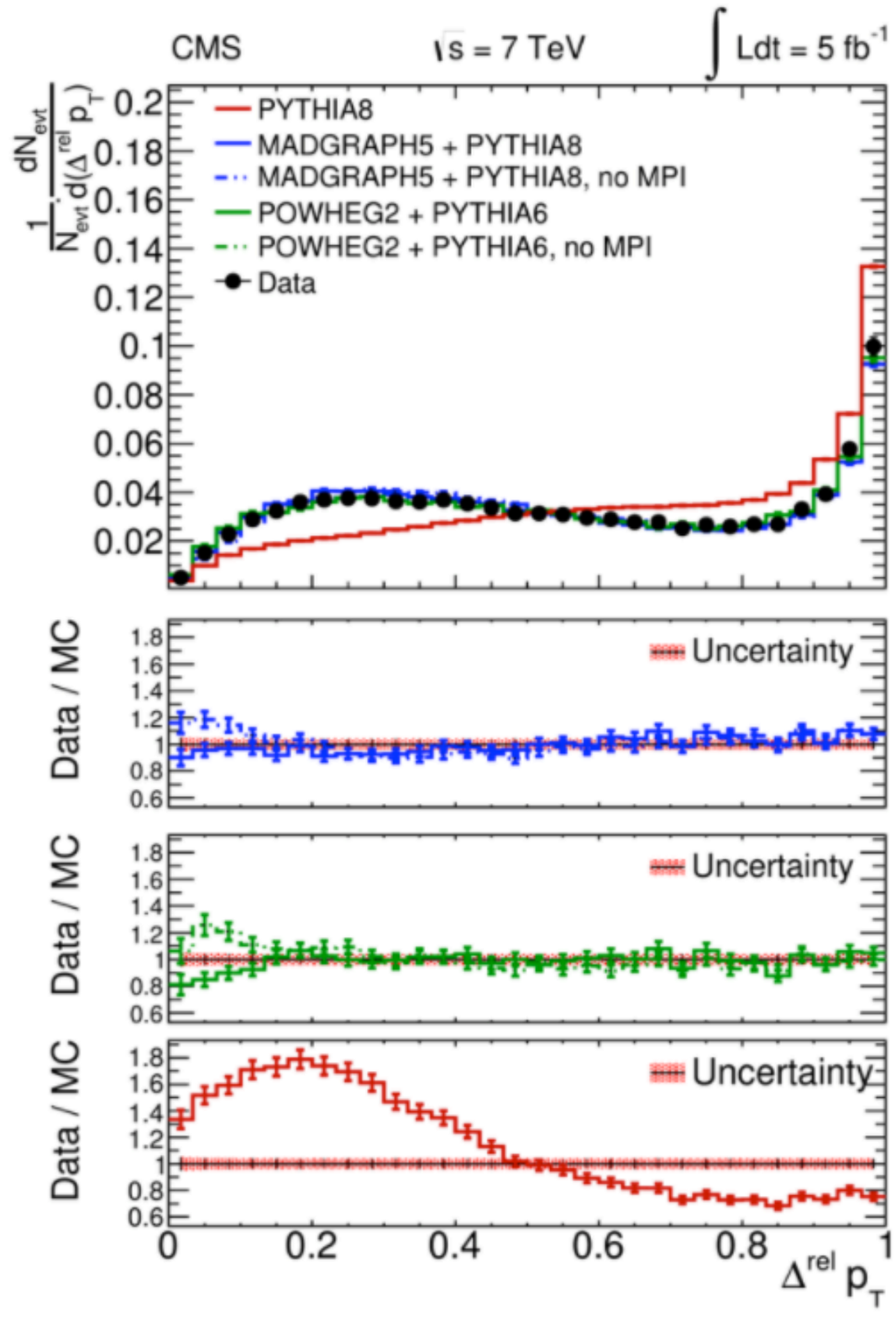
The Next-to-Leading Order Tunes CP3, CP4, CP5

CP Tunes = CMS Pythia Tunes

Sensitivity on higher orders in V+jets topologies

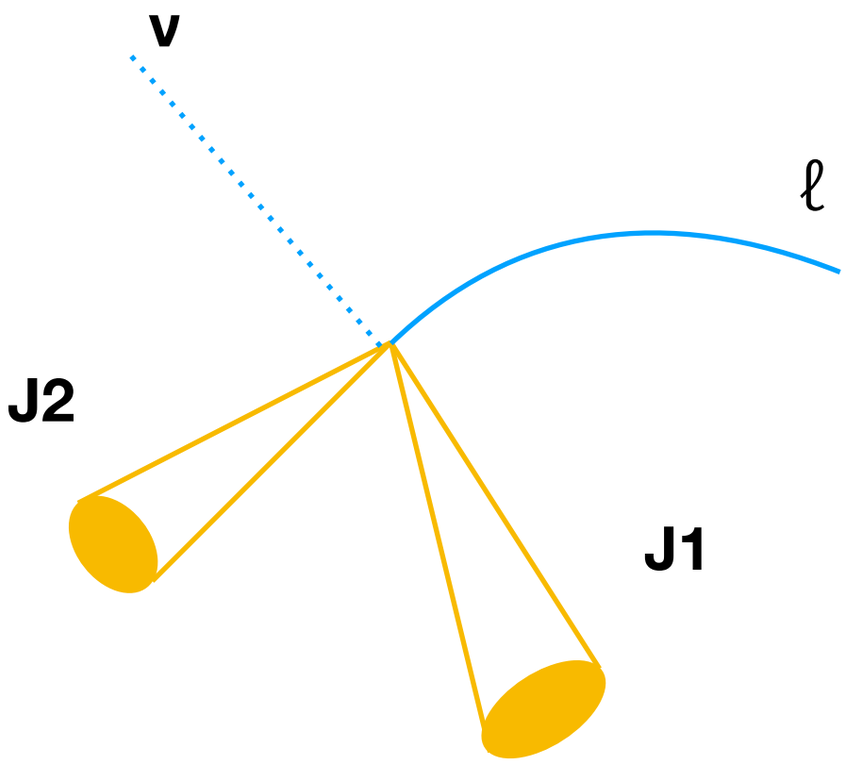
ME+P8

P8 standalone



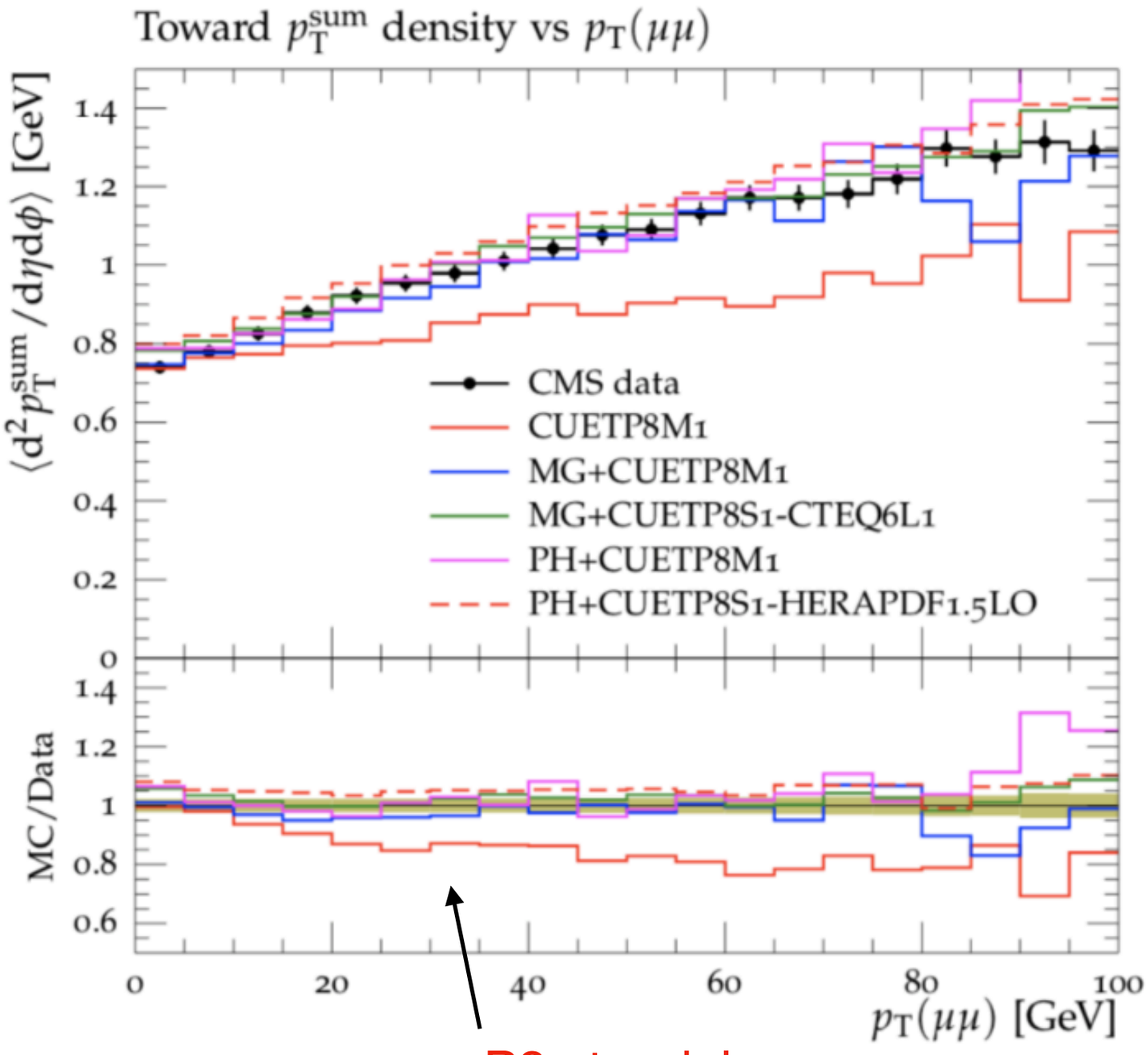
jet pt>30GeV
jet eta<2.5

W+jets



$$\Delta^{rel}p_T = |p_T(W) - \sum p_T(jes)|$$

Sensitivity on higher orders in V+jets topologies

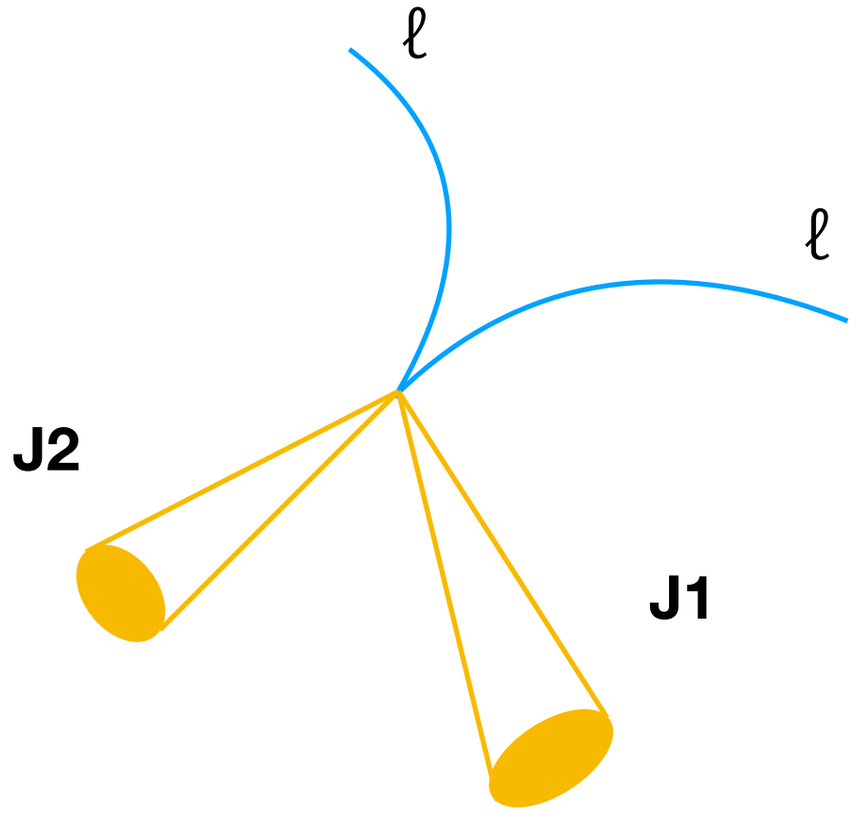


P8 standalone
("Monash" Tune, NNPDF23 LO PDF)

jet pt>30GeV
jet eta<2.5

Z+jets

toward region ($|\Delta\phi| \leq 60$)



$$p_T^{\mu\mu} = p_T^Z$$

Sensitivity on CP tunes in high p_T jets & EW bosons final states

Underlying Events

CP tunes in high p_T jets & EW bosons final states

Benchmark matrix elements used in V+jets in CMS

for each CPn tune

PDF: NNPDF3.1 @NNLO

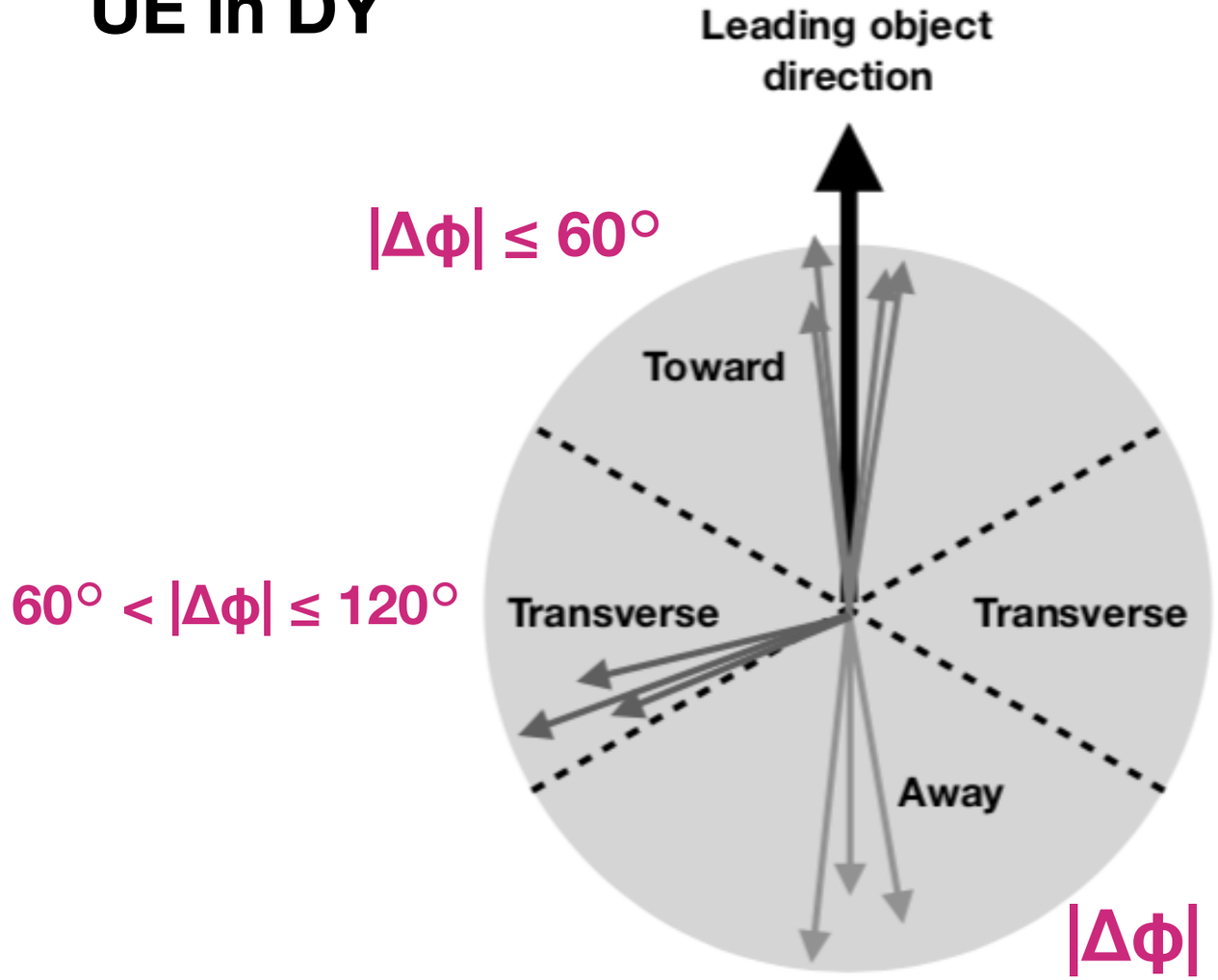
$\alpha_S = 0.118$

MadGraph5_aMC@NLO + Pythia8

LO-Mode kT–MLM merging scheme
0,1,2,3 partons

NLO-Mode FxFx merging scheme
up to 2 partons NLO

UE in DY



observables

charged particle density

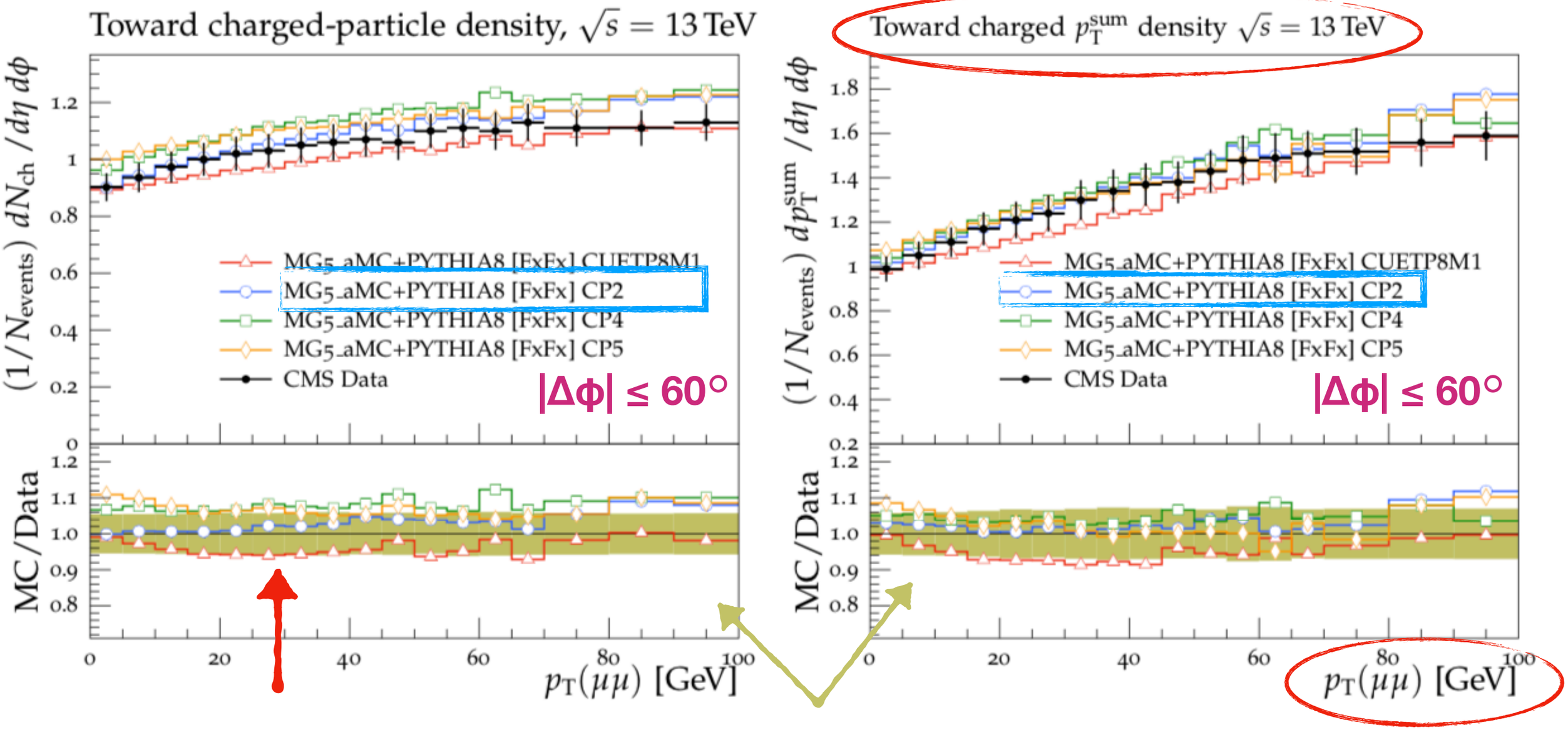
charged pT sum

as a function of

Z boson properties

CP tunes in high p_T jets & EW bosons final states

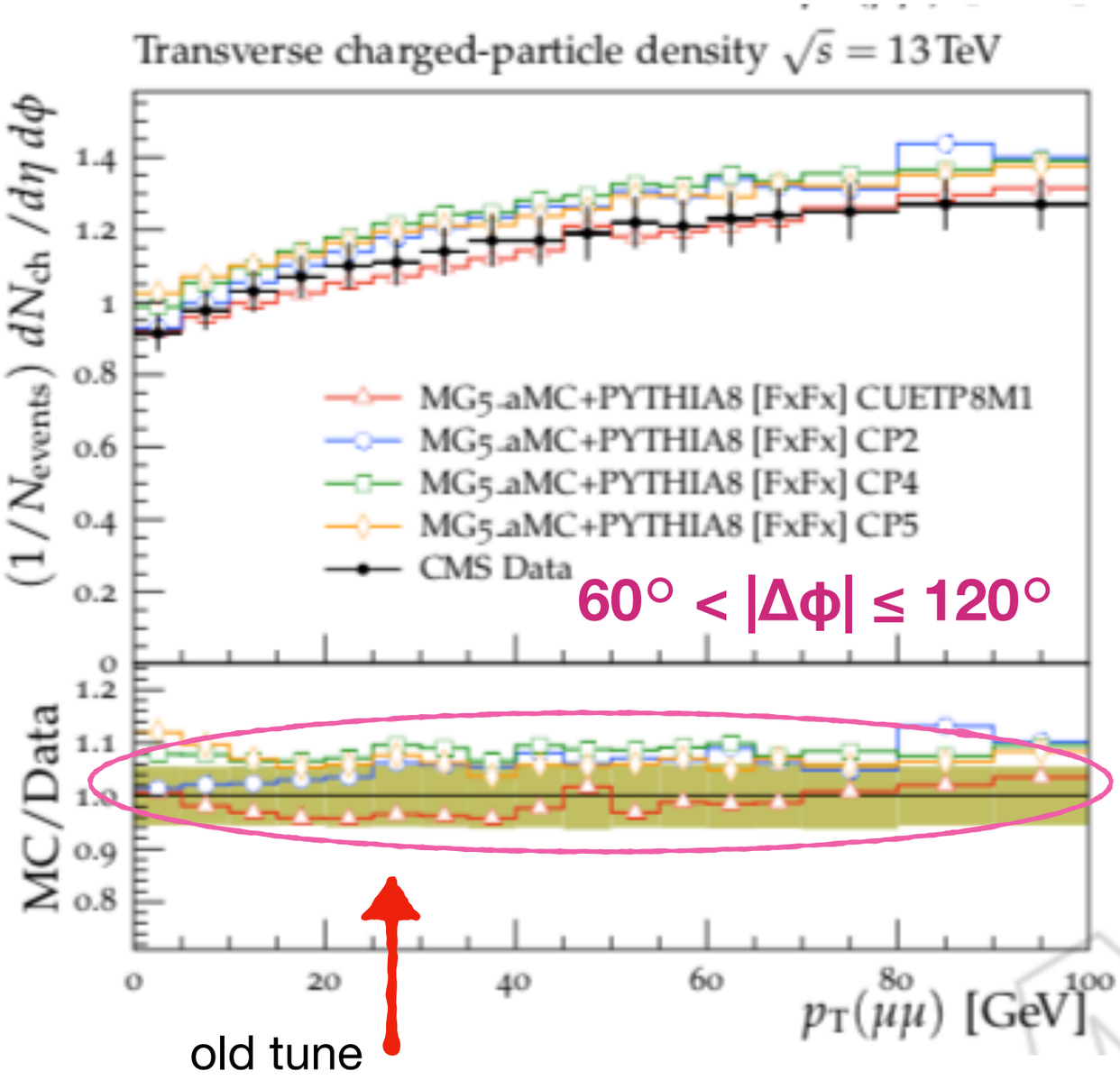
Towards region

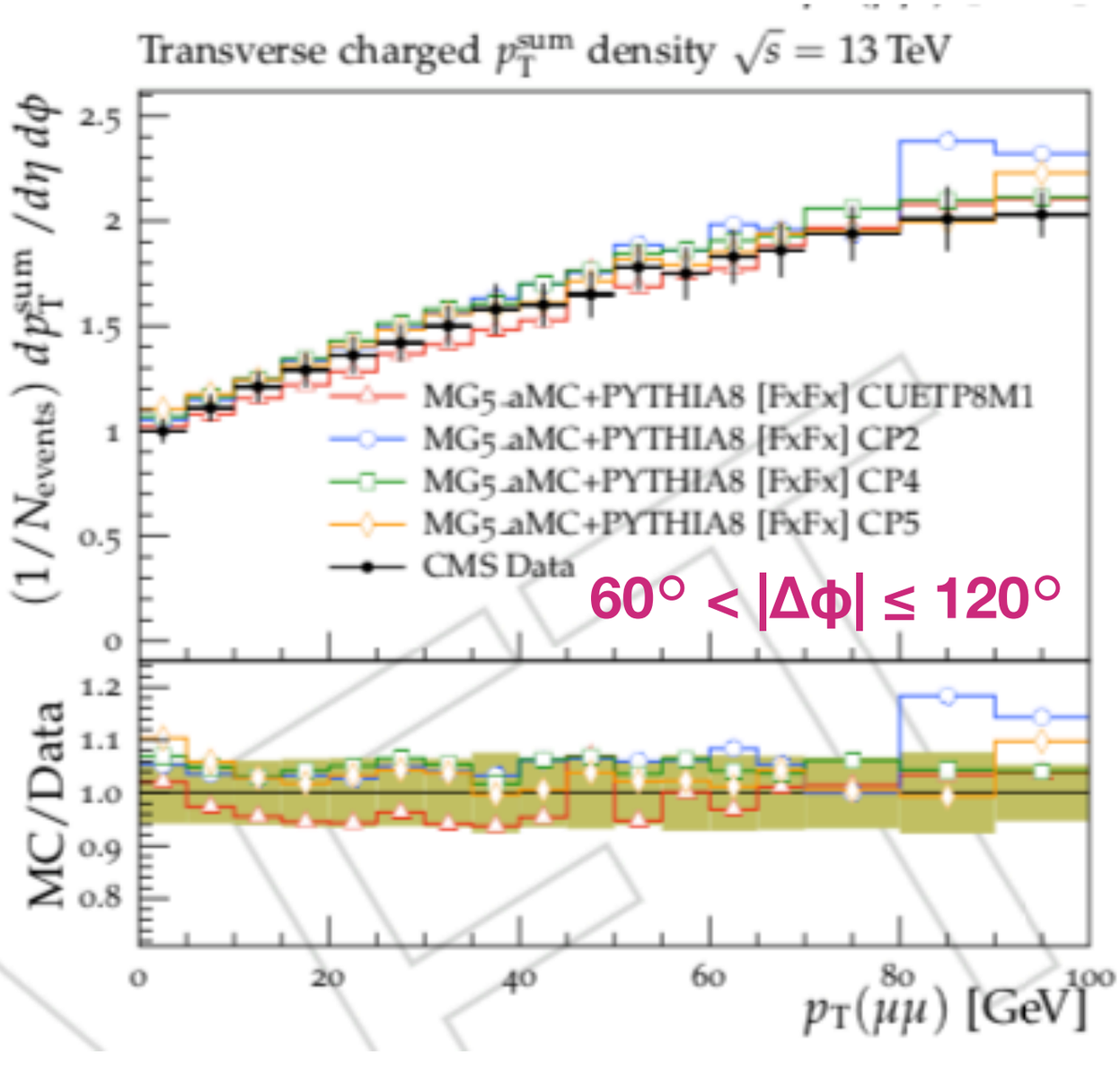


old-Monash-LO tune

band: total experimental uncertainty of the data

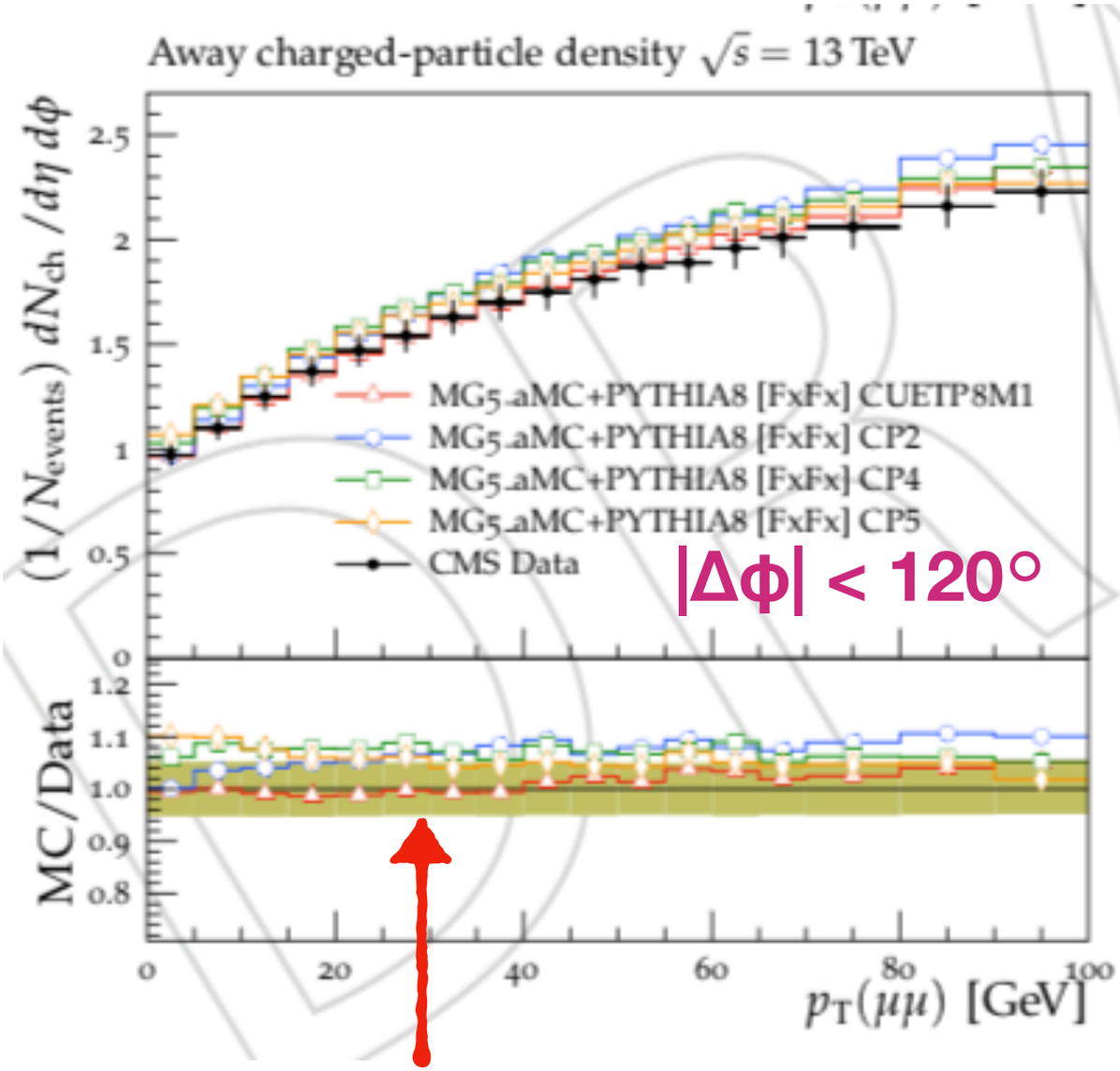
CP tunes in high p_T jets & EW bosons final states

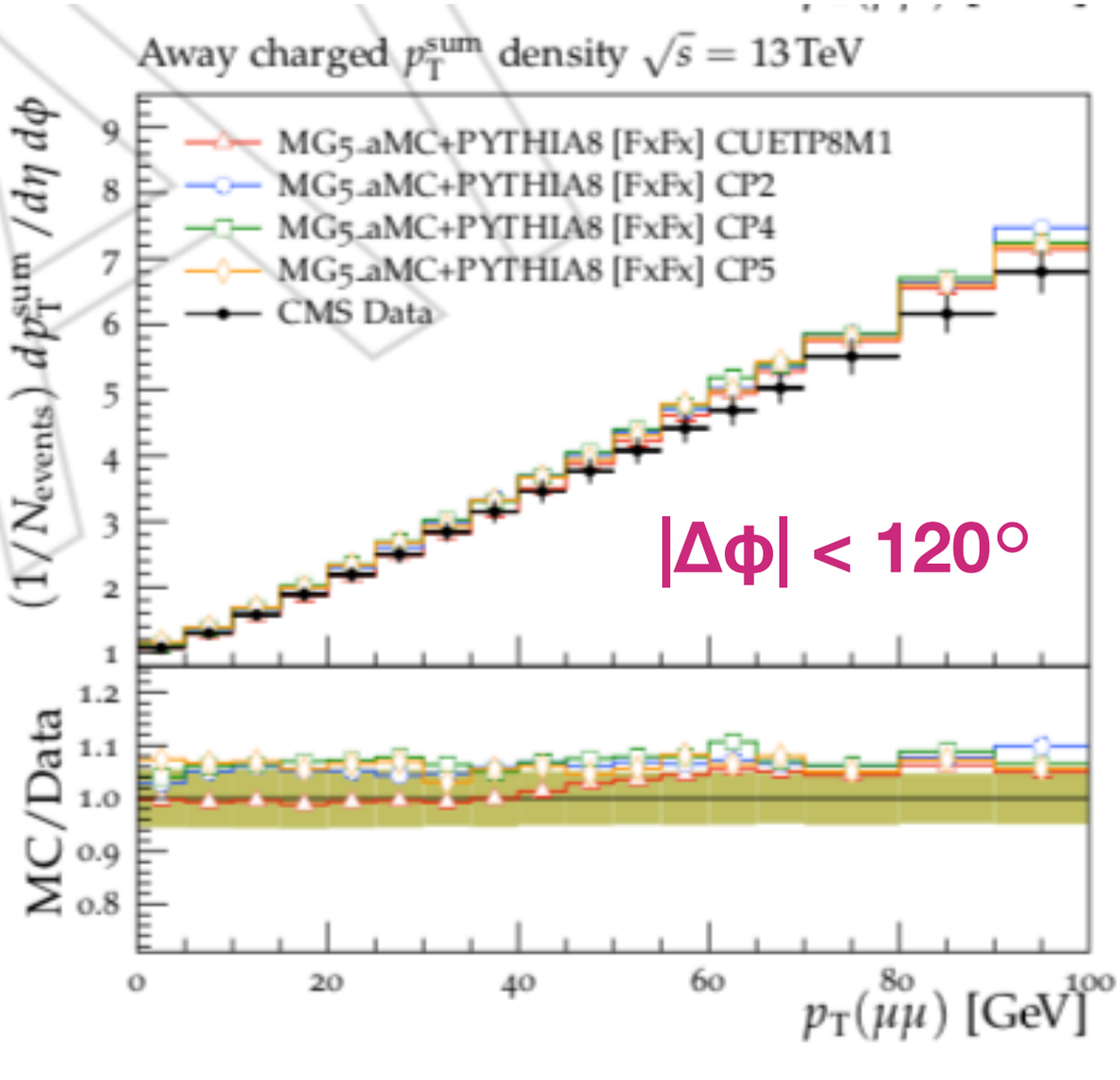




Transverse region: CPs are improving the description wrt CUETP8M (but still ~10% off in the central region)

CP tunes in high p_T jets & EW bosons final states





old tune better in the away region!

Away region: CUETP8M better, CP tunes up to ~10% off

Sensitivity on CP tunes in high p_T jets & EW bosons final states

W/Z+N jets

CP tunes in high p_T jets & EW bosons final states

phase space

Z-events: leptons $p_T > 20$ GeV and $|y| < 2.4$ and the dilepton mass lies in a ±20 GeV window around 91 GeV.

W-events: leptons $p_T > 20$ GeV and $|y| < 2.4$ and MT > 50 GeV

Jets anti-kT04 clustered with $pT > 30$ GeV and $|y| < 2.4$ $\Delta R(l, j) > 0.4$

observables data VS MG5aMC@NLO+P8CPn both MLM&FxFx

- ★ Jet Multiplicity (inclusive, >=Nj & exclusive =Nj)

  k_T–MLM predictions of the jet multiplicity have little sensitivity to the UE and PS tunes

- ★ pT balance Z-jet

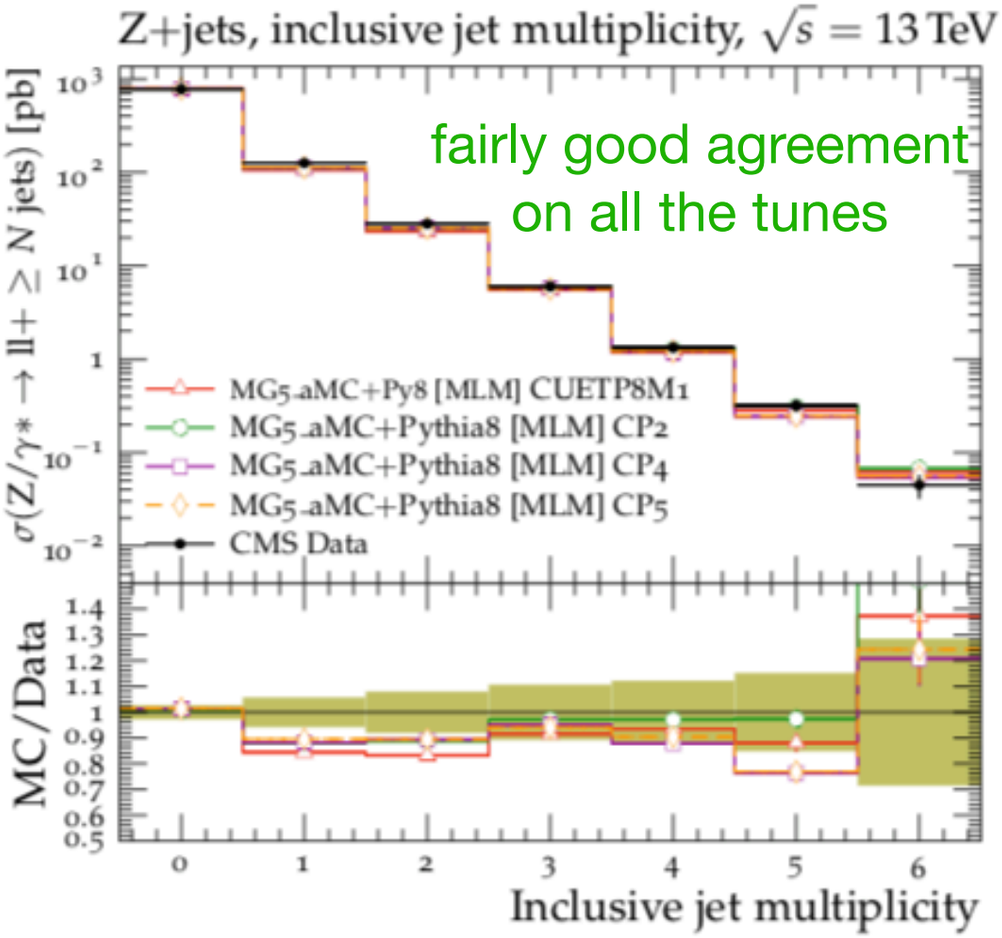
  sensitive to the UE and PS tunes

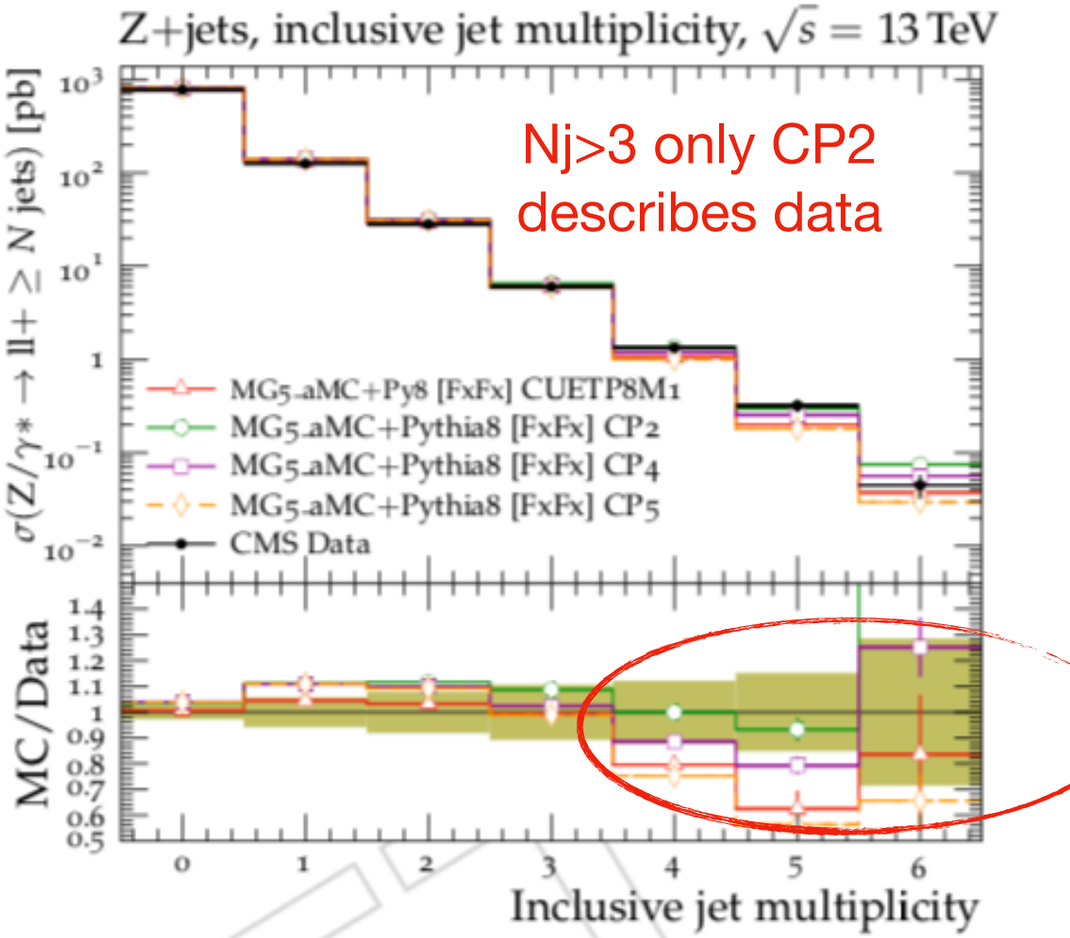
$$p_T^{bal} = |p_T(Z) + \sum_{jets} p_T^j|$$

- ★ Z boson momentum (for Z+>=1j)

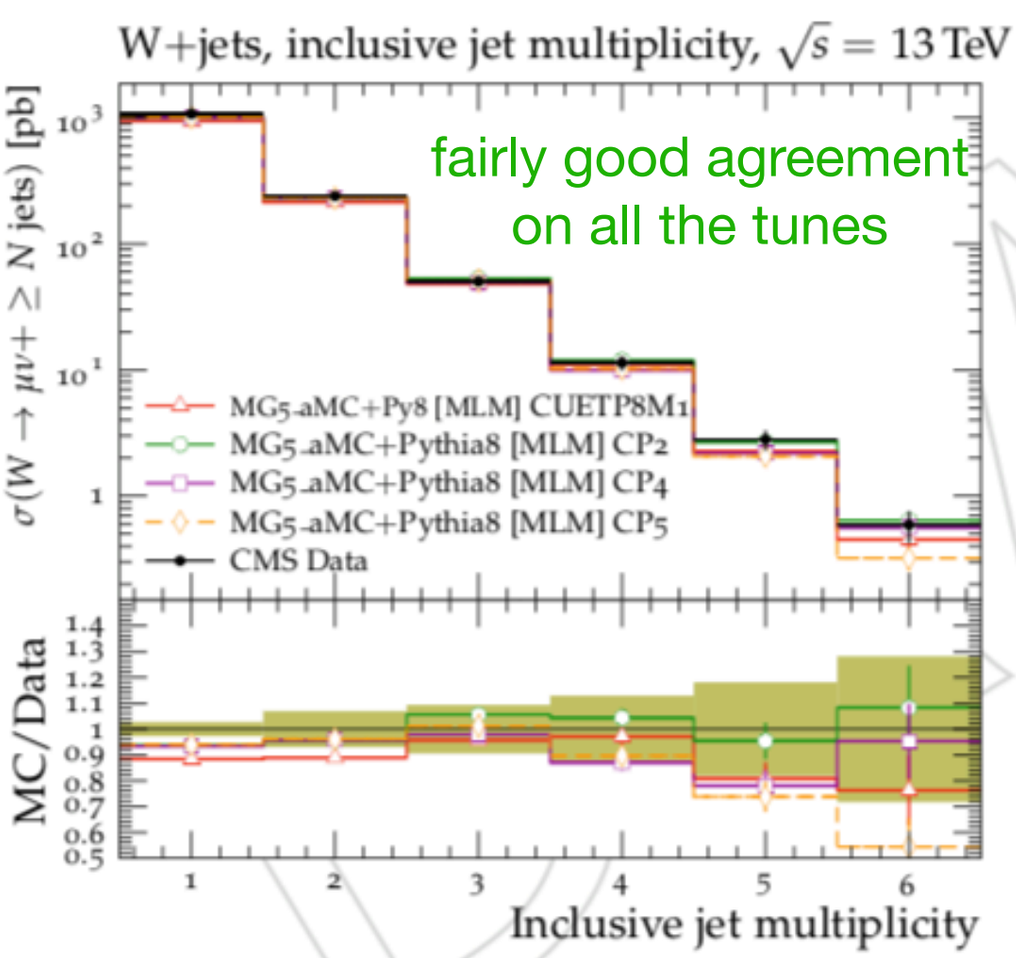
  interesting to see the effect of the tune especially at low momentum

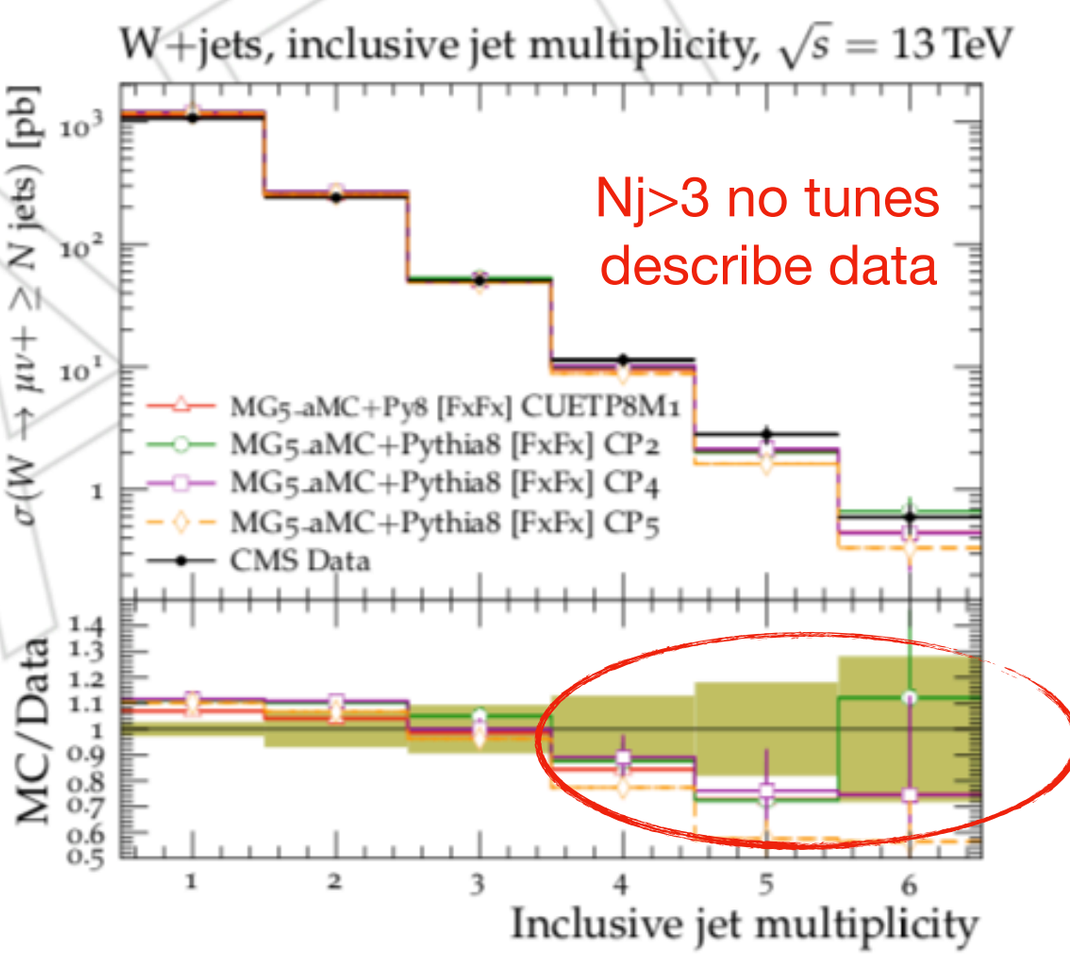
Jet-Z balance
in Z+jets



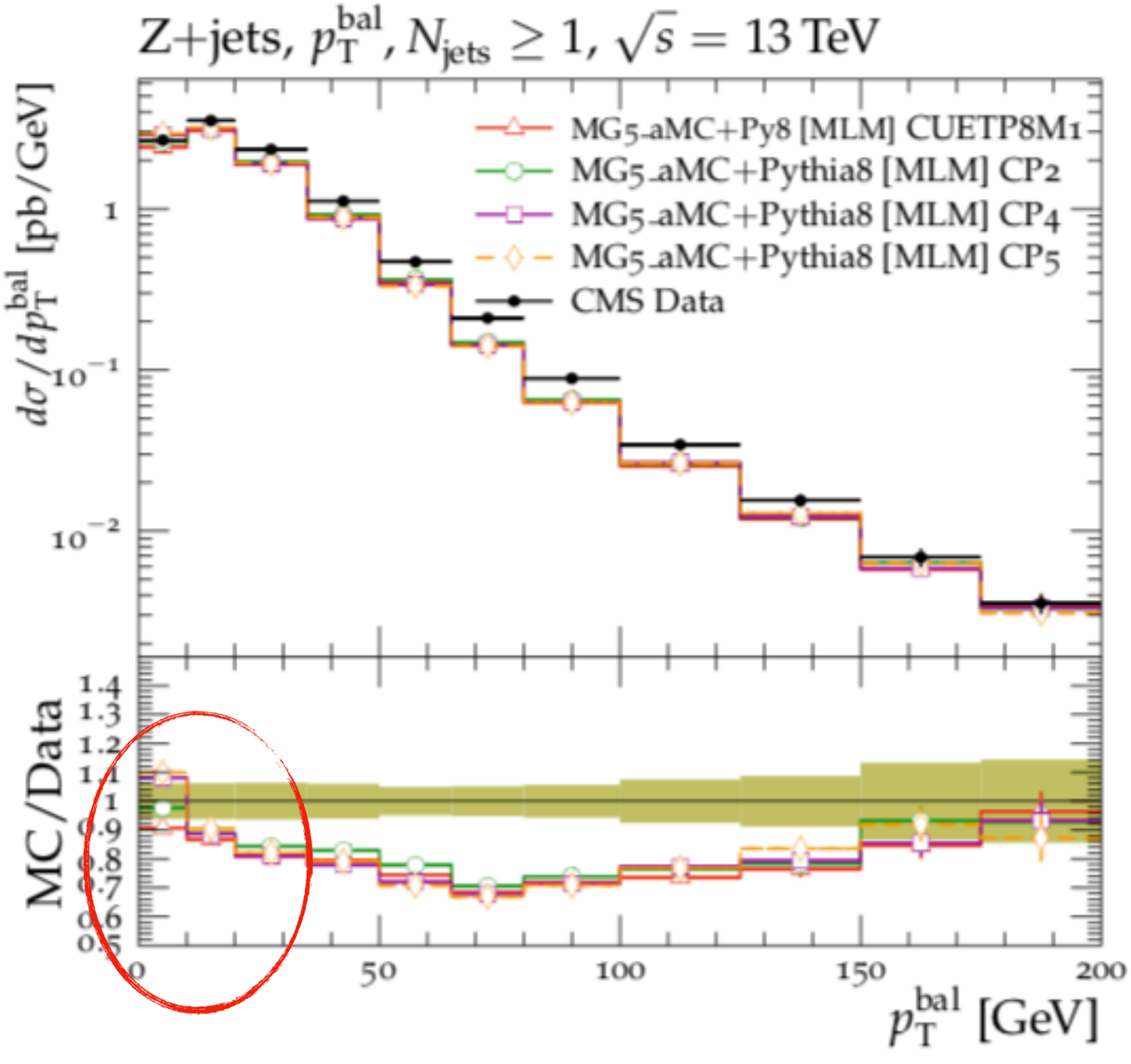


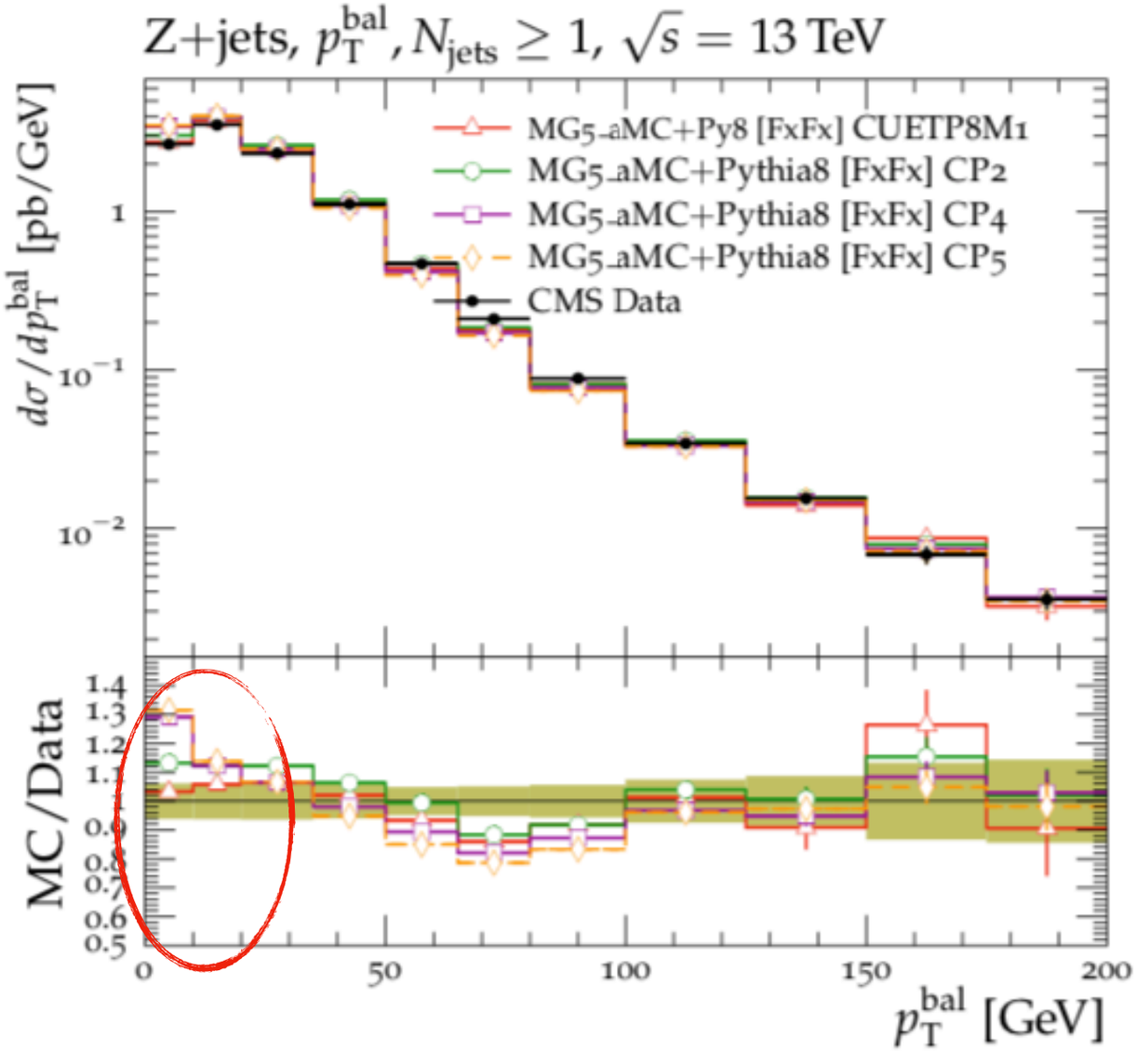
Jet-Z balance
in W+jets





CP tunes in high p_T jets & EW bosons final states





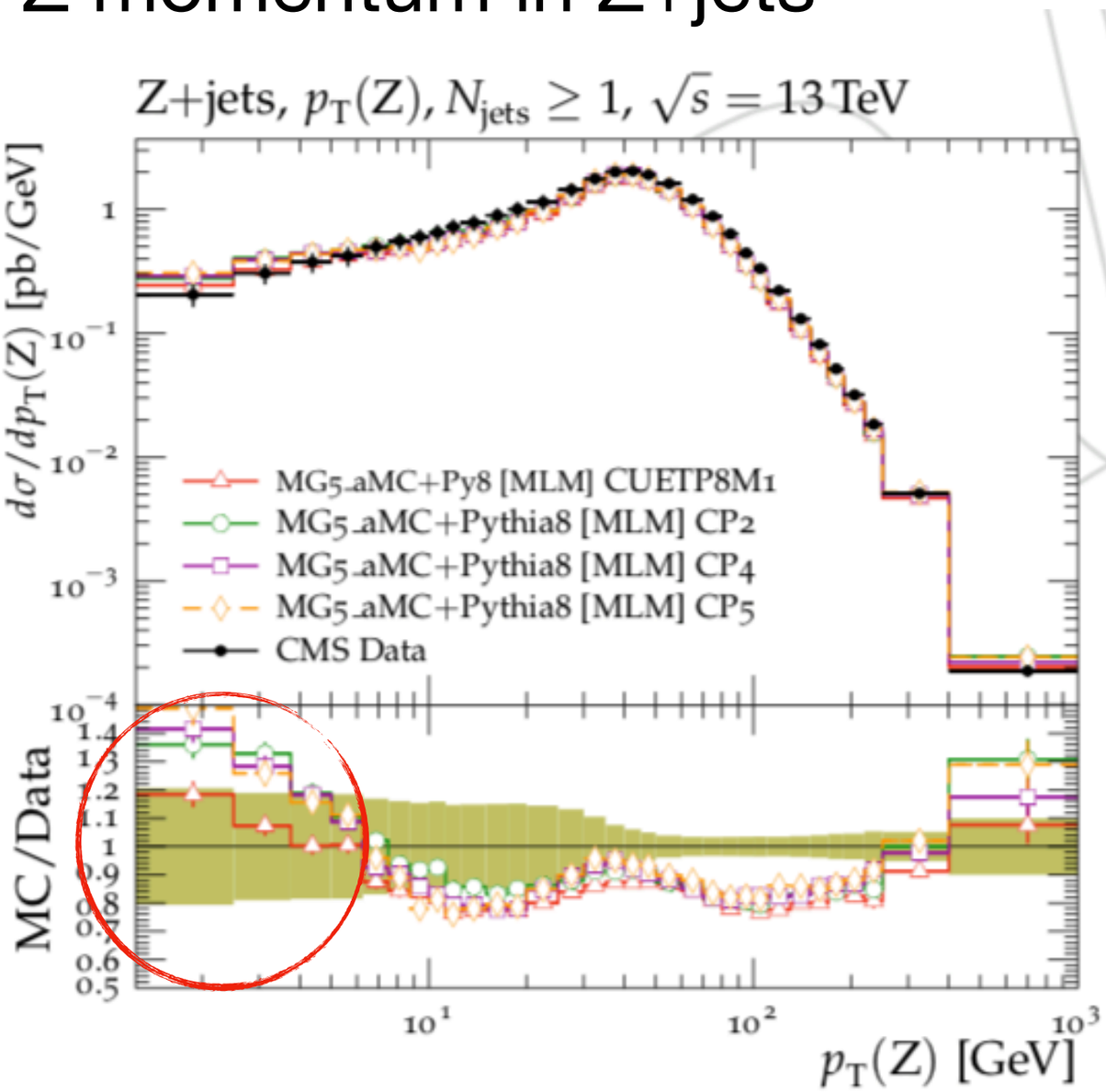
Jet-Z balance in Z+jets

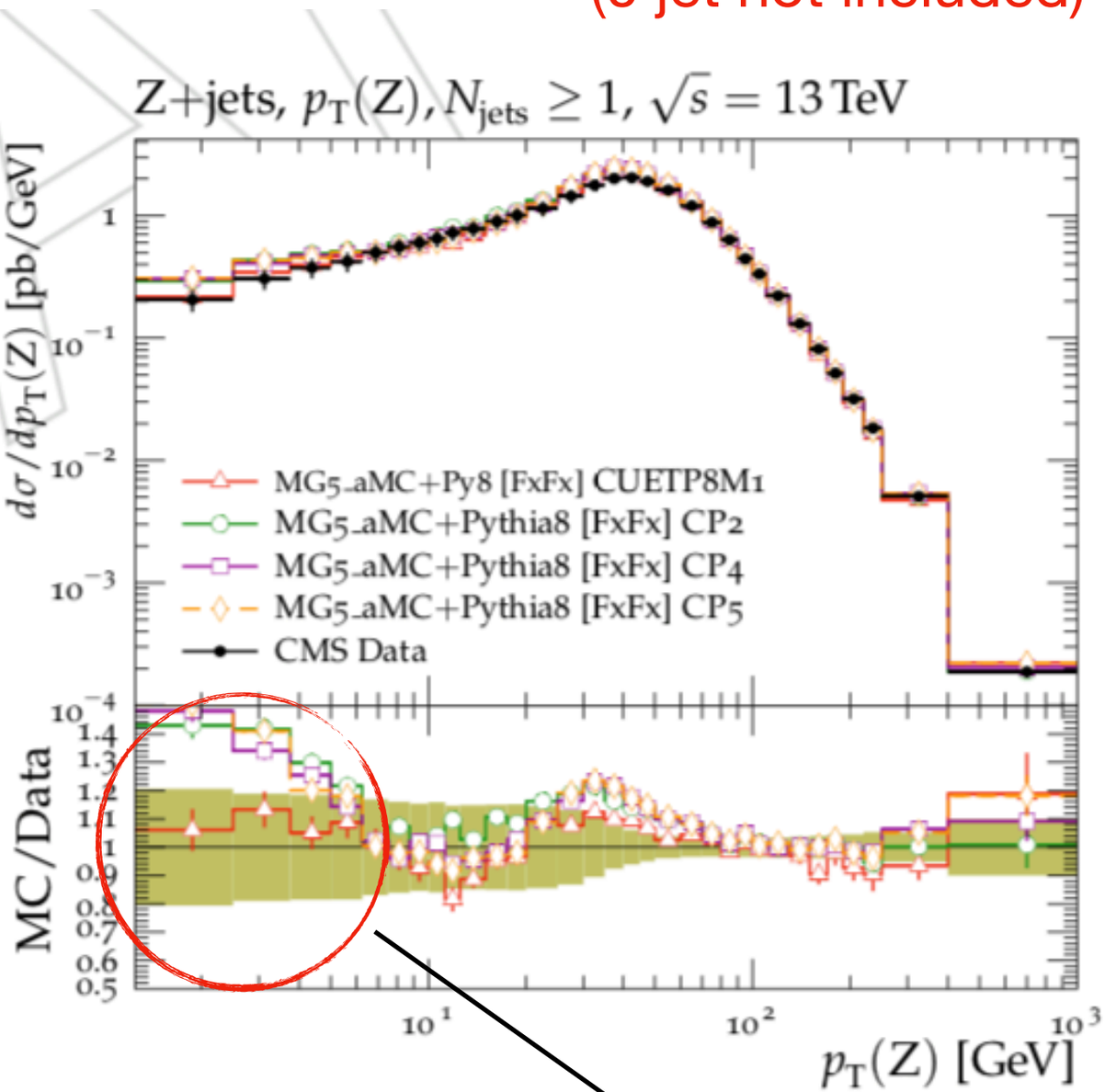
(!) Only below 20 GeV we see differences among tunes

CP tunes in high p_T jets & EW bosons final states

Z momentum in Z+jets

(0 jet not included)





FxFx always better than MLM independently of the tunes

below 10 GeV is the nightmare for CP tunes both in FxFx and MLM

CUETP8M1 does a better job!

Conclusions on tuning over V+Jets

- CP2, CP4, and CP5 tunes provide similar descriptions of the UE observables with a reasonable agreement with the data.

- In general, the CP2 tune performs better in describing variables such as p_T^{bal} and p_T (Z).

- For the jet multiplicity, the CP2 and CP4 tunes are equally good in describing the measurement, whereas CP5 tends to undershoot the PS dominated region with at least five jets.

Future improvements:

Jet multiplicity in W+Jets

Angular-differential cross sections

Explore comparisons&tuning with other generators: Geneva, Sherpa, Herwig…