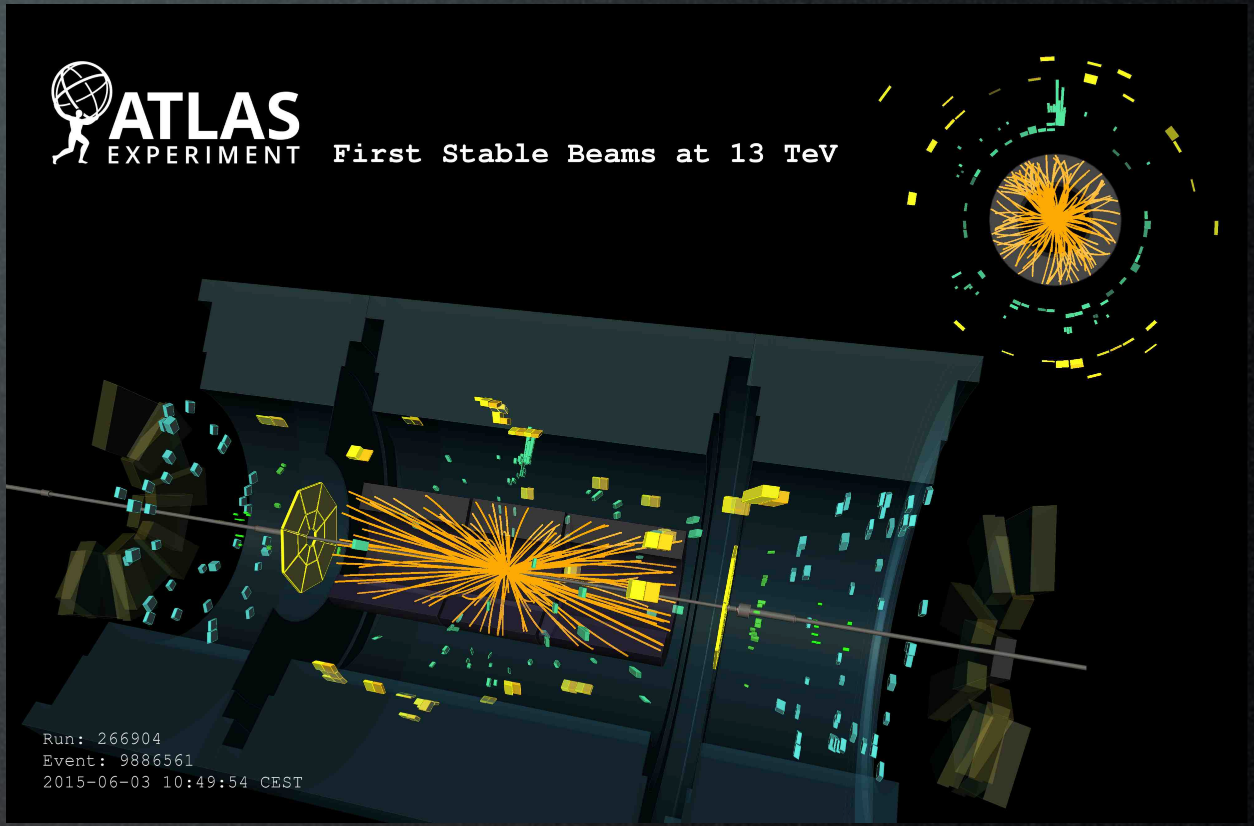
Event generators for simulating radiation background

Deepak Kar

Radiation Effects in the LC experiments, and impact on operation and performance, 11-12 February, 2019

Minimum Bias?

- Events selected with a minimally biased trigger selection
- Measurements performed with both with tracks and clusters
- Complementary information



Not to be confused with Underlying Event or Pileup

Monte Carlo Models

Pythia8 4C	(Author) MB+UE tune with CTEQ6L1
Pythia8 Monash	(Author) MB+UE tune with NNPDF2.3LO
Pythia8 CUETP8S1	(CMS) UE tune based on 4C
Pythia8 CUETP8M1	(CMS) UE tune based on Monash
Pythia8 A2	(ATLAS) Minbias/Central ET flow tune based on 4C
Pythia A3	(ATLAS) Minbias/inelastic cross-section
Herwig++ UE-EE-5C	(Author) UE tune with energy scaling using CTEQ6L1
Epos LHC	Based on Gribov's Pomeron exchange/collective flow approach, use LHC and fixed target experiment data to describe hadron and nuclear collisions.
QGSJET-II	
Sibyll	

Parton Shower

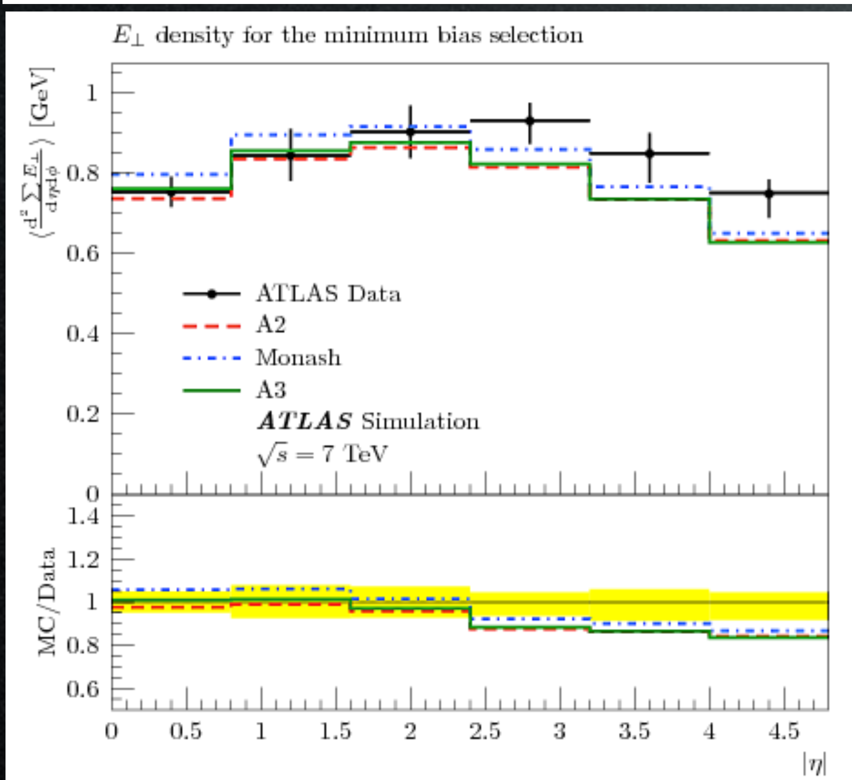
Cosmic Ray/Air Shower

Pythia8 A3 Tune

	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

Much improved visible inelastic cross section prediction



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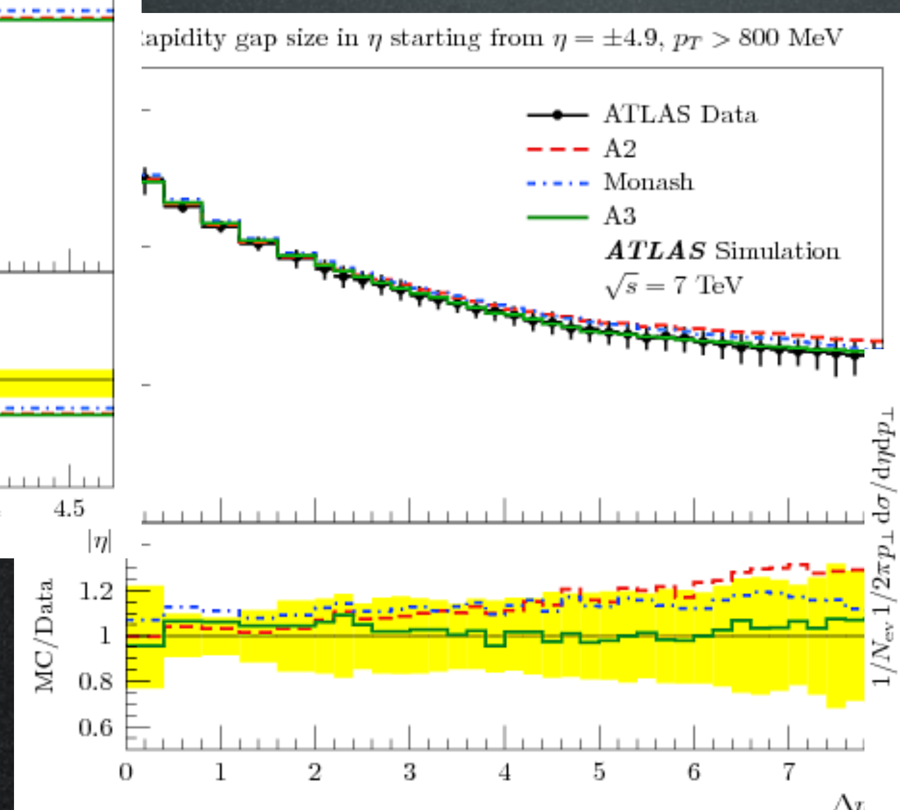

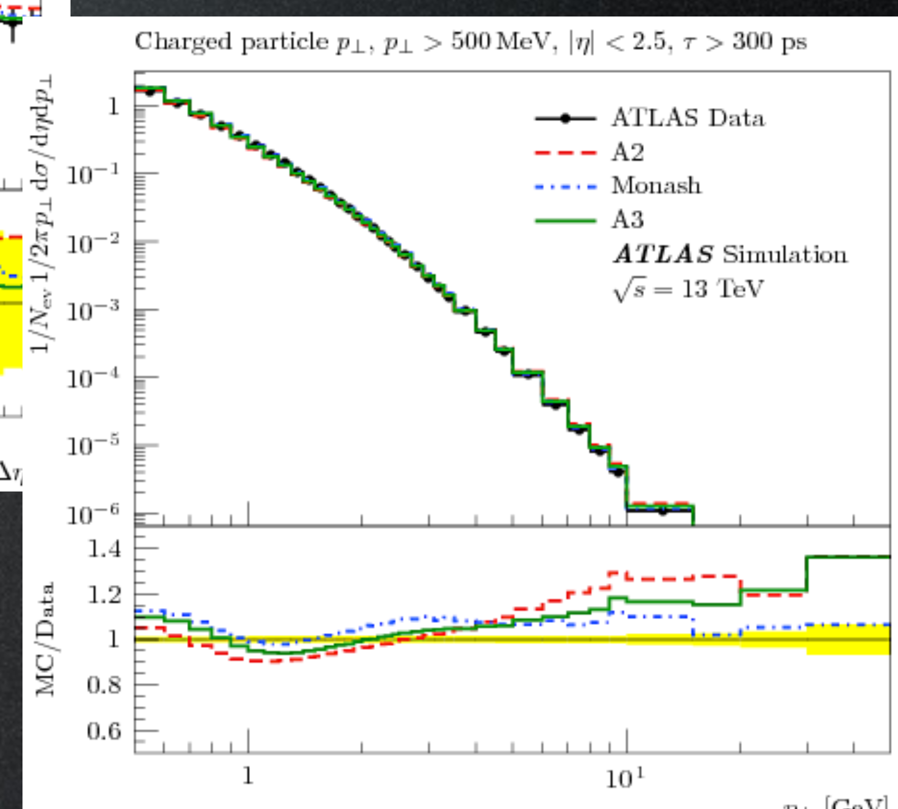

Mostly similar level of agreement with Minbias observables

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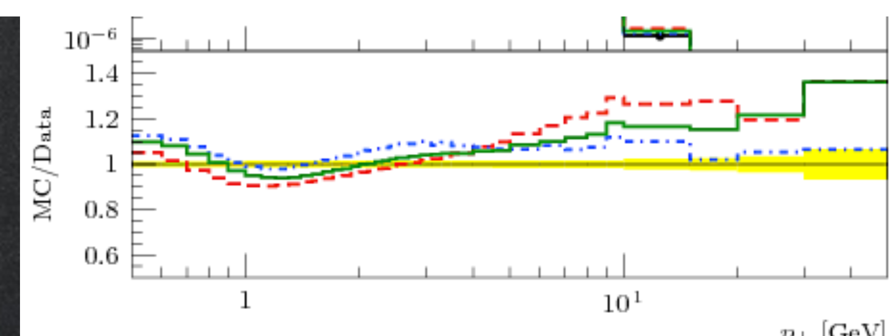
Parameter	A3 value	A2 value	Monash value
`MultipartonInteractions:pT0Ref`	2.45	1.90	2.28
`MultipartonInteractions:ecmPow`	0.21	0.30	0.215
`MultipartonInteractions:coreRadius`	0.55	-	-
`MultipartonInteractions:coreFraction`	0.90	-	-
`MultipartonInteractions:a1`	-	0.03	-
`MultipartonInteractions:expPow`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

Mostly similar level of agreement with Minbias observables

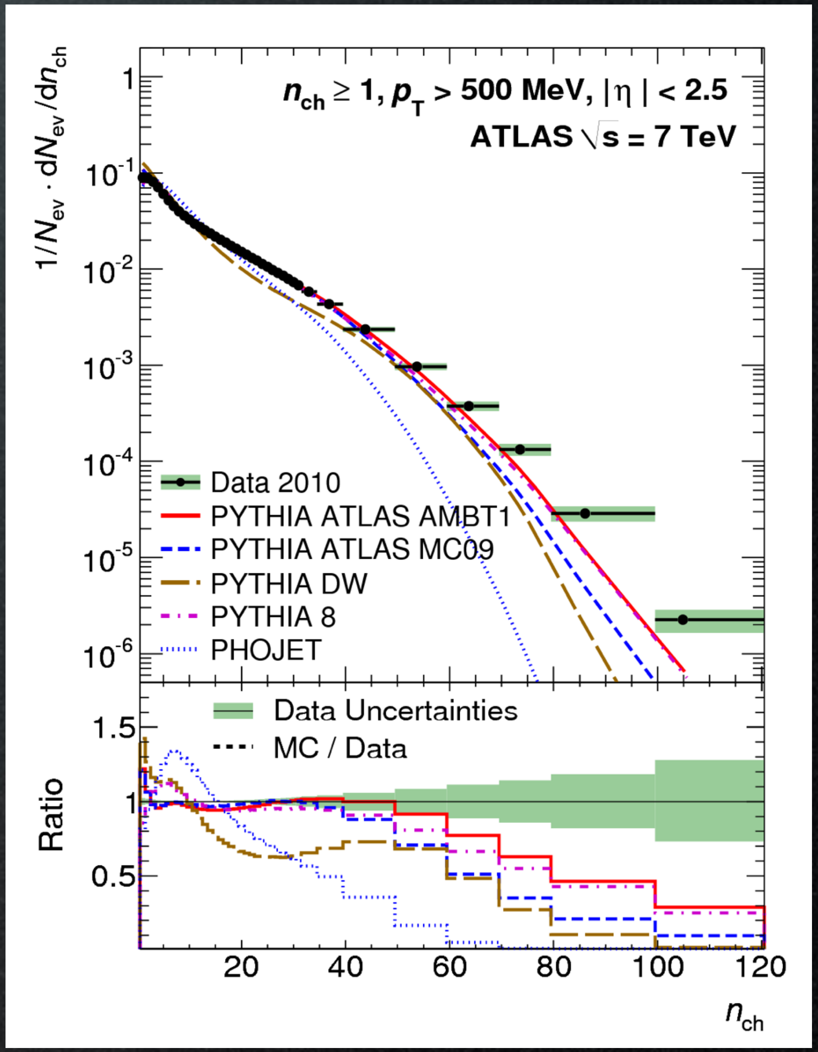


Looking back ...

- Measurements at the beginning of Run 1 showed bad description of data by then-existing (mostly from Tevatron) Monte Carlo models and tunes

- Significant effort went in both theory and experimental communities to improve the modelling, using LHC Run 1 data

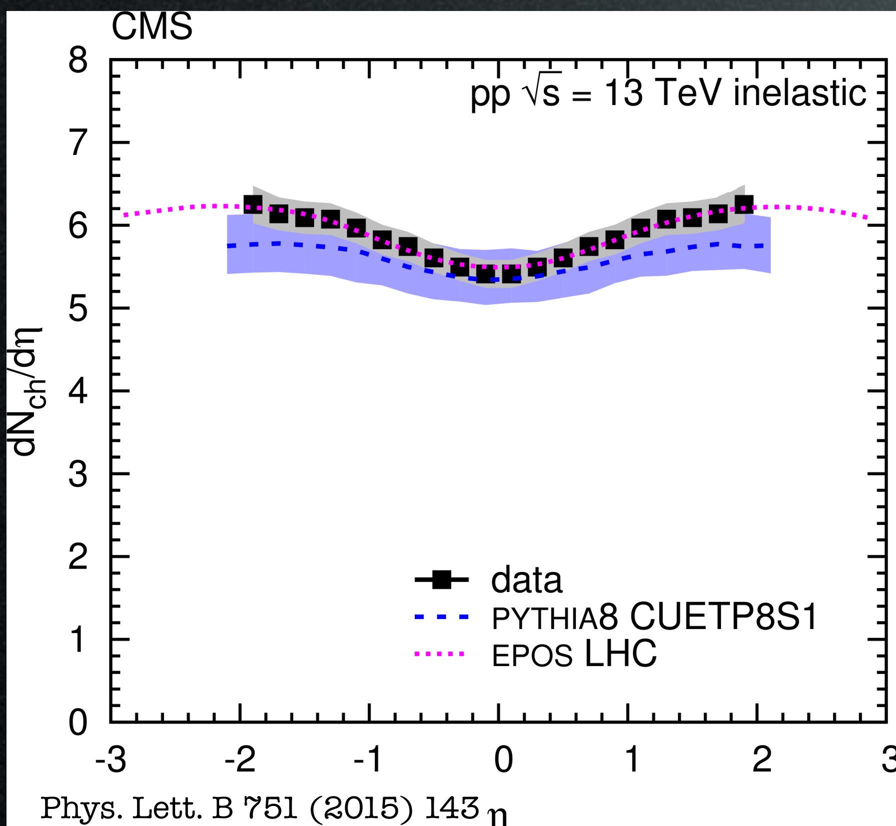
- Big question we had at the beginning of Run 2: can these models describe the 13 TeV data?

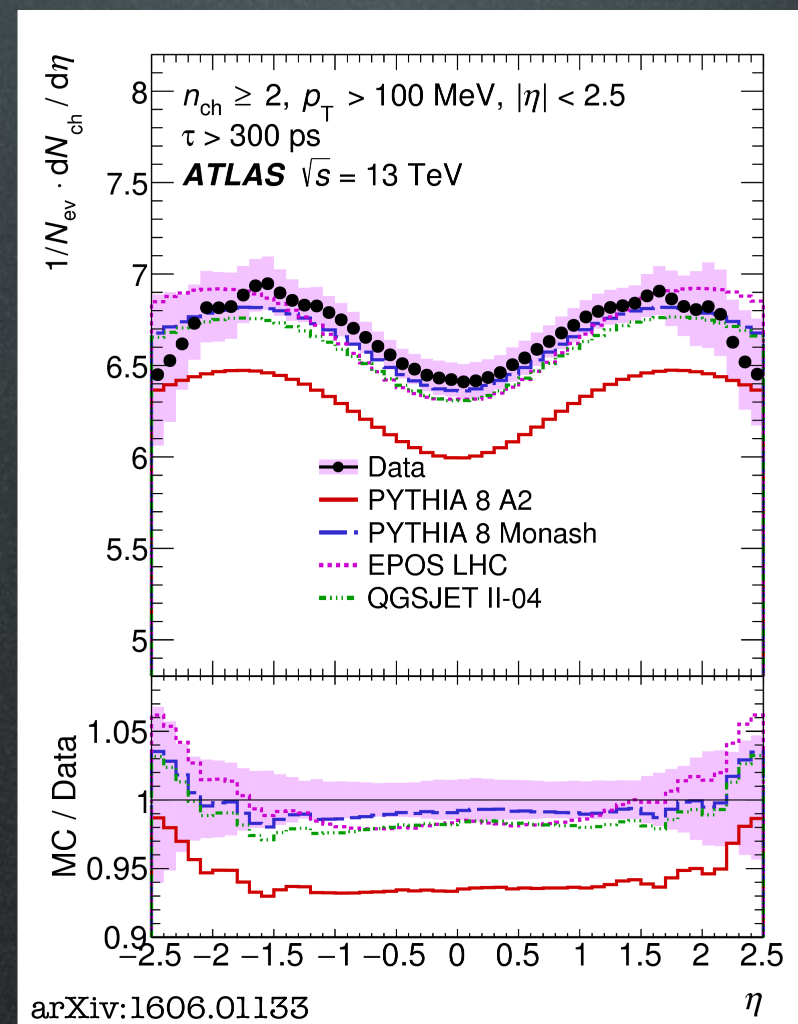


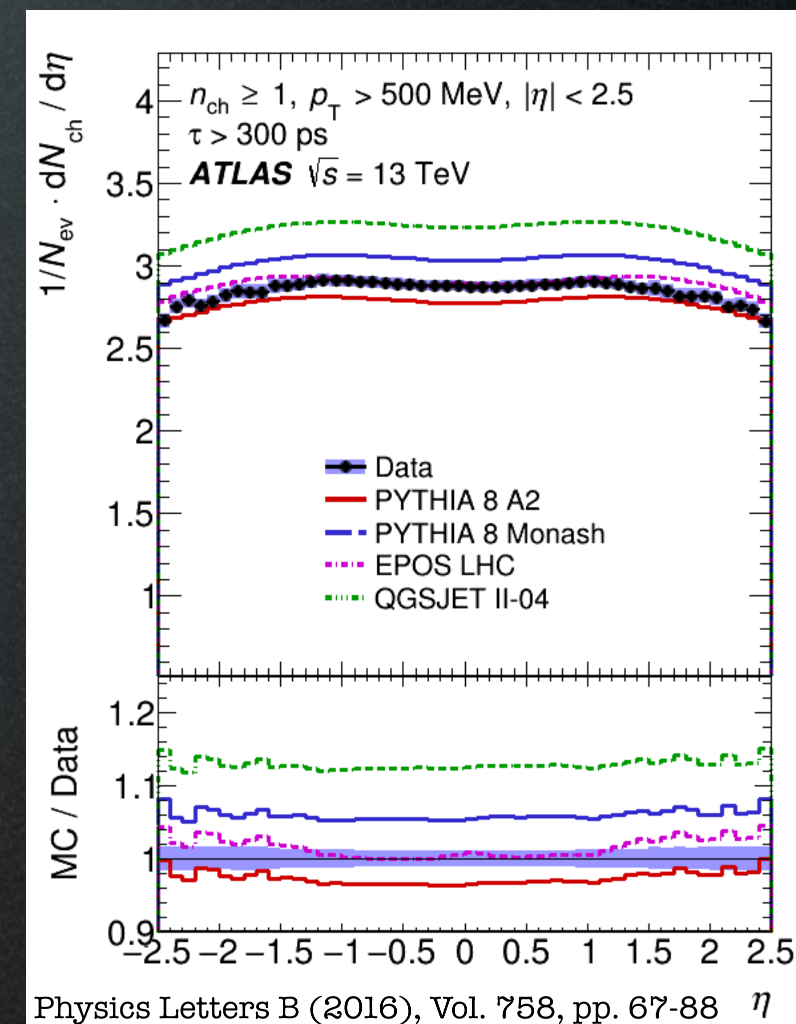
New J. Phys. 13 (2011) 053033

Charged Particle Pseudorapidity

Higher transverse momentum threshold







Overall Epos is the best, stark difference in A2 predictions going from 100 to 500 MeV

Charged Particle Pseudorapidity

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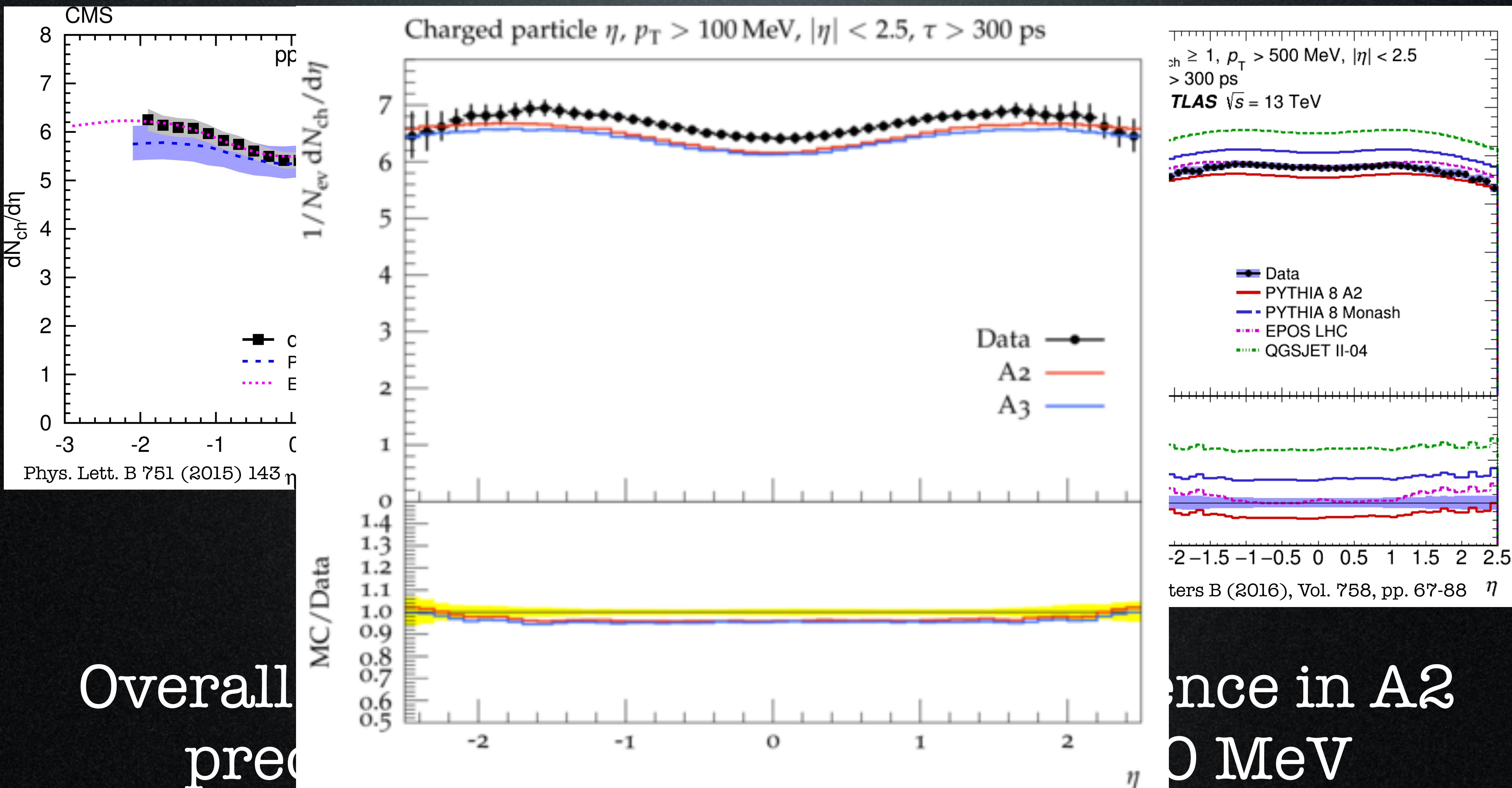
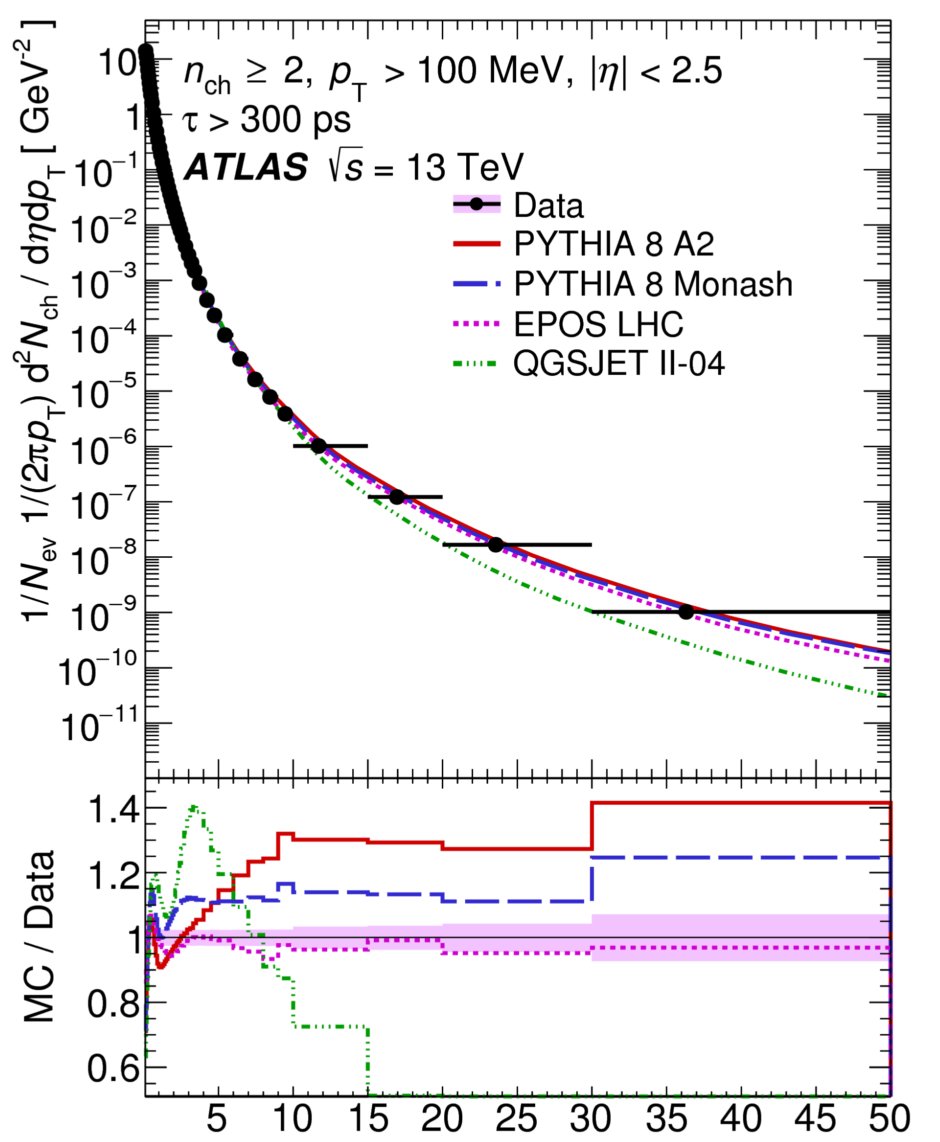


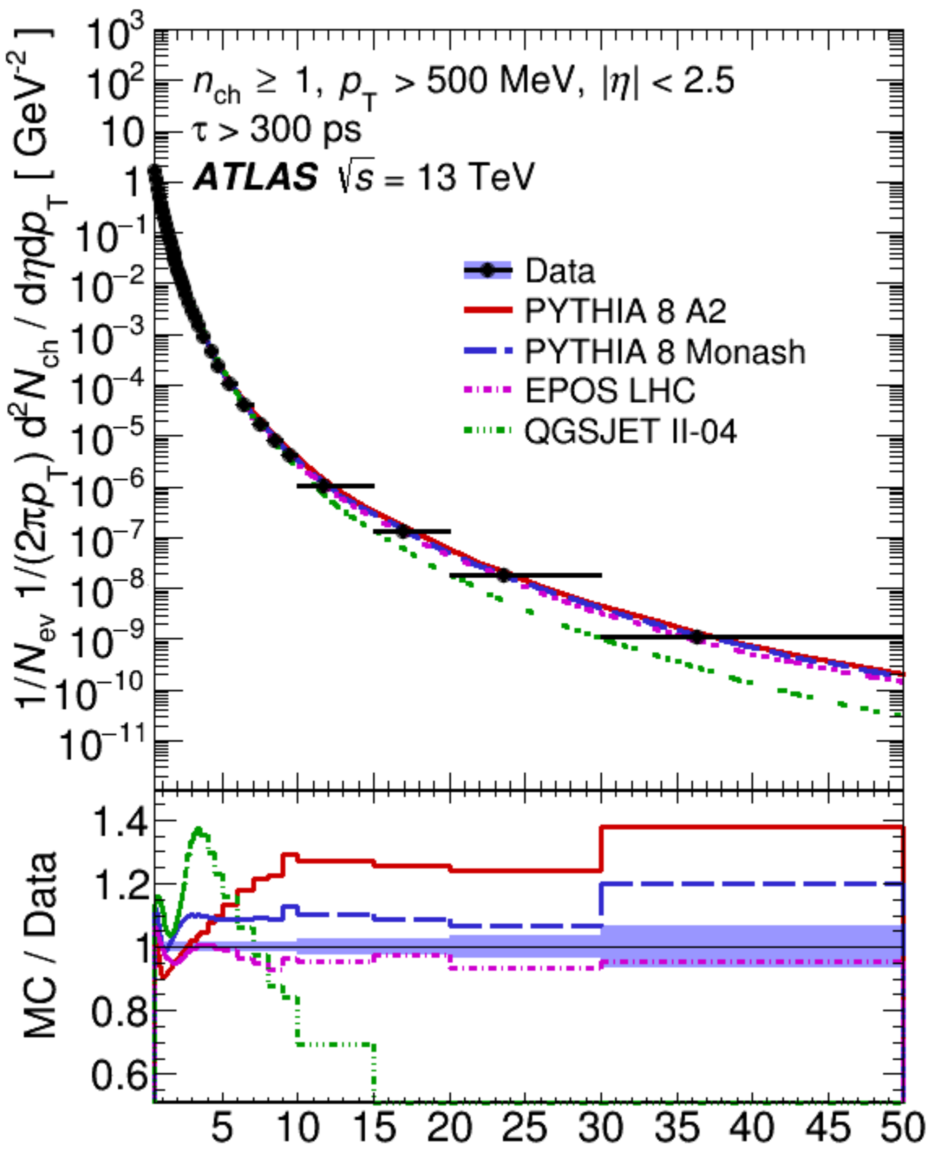
Overall … ence in A2
prec … 0 MeV

Charged Particle Transverse Momentum

Higher transverse momentum threshold



arXiv:1606.01133



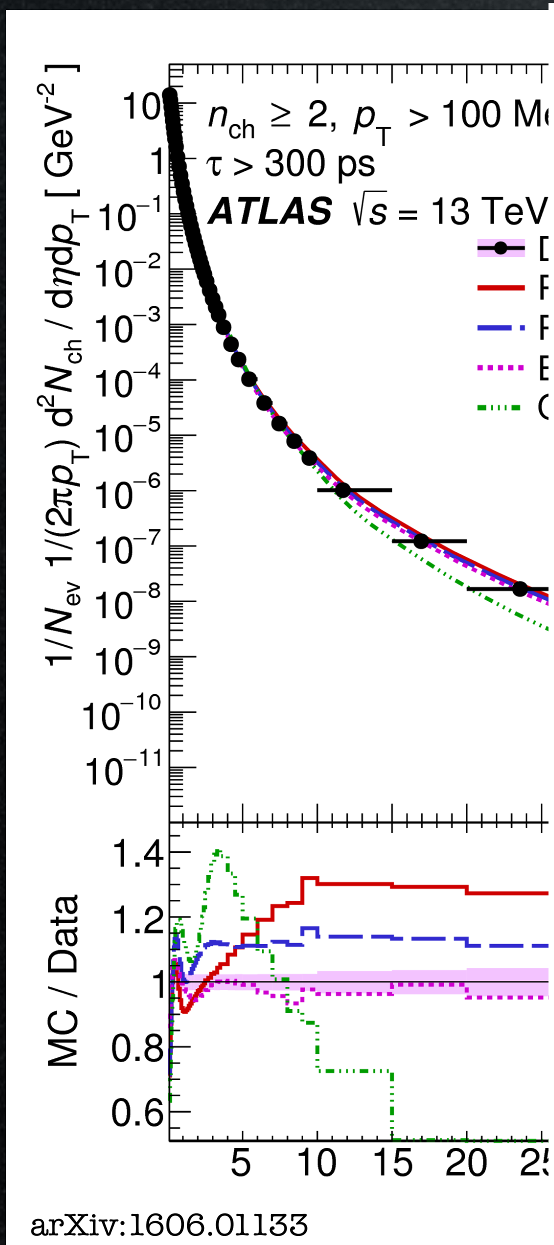
Physics Letters B (2016), Vol. 758, pp. 67-88

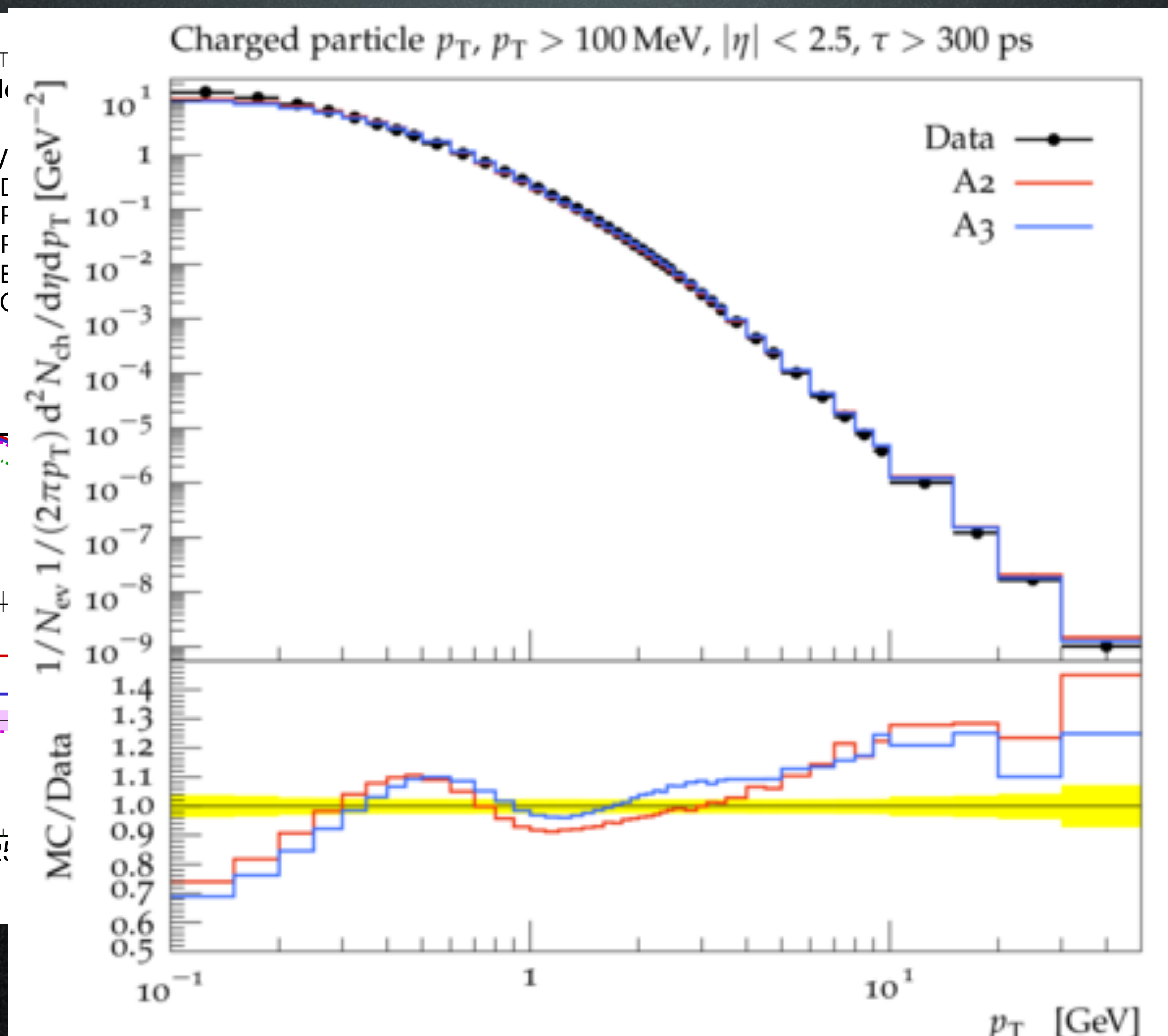
Epos is best for both

A2 and Monash are competitive but not over the full range

Charged Particle Transverse Momentum

Higher transverse momentum threshold





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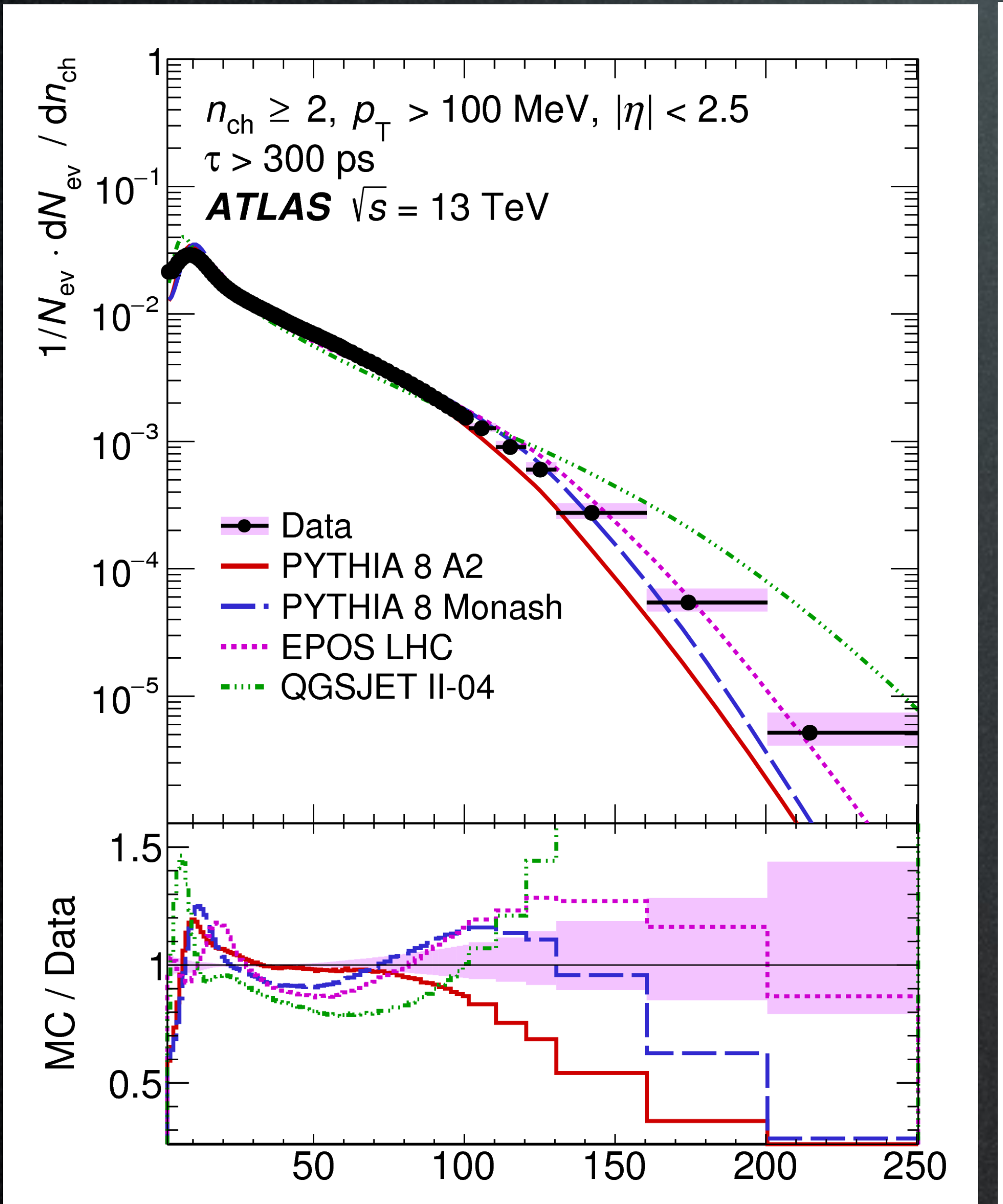
Charged Particle Multiplicity

Higher transverse momentum threshold



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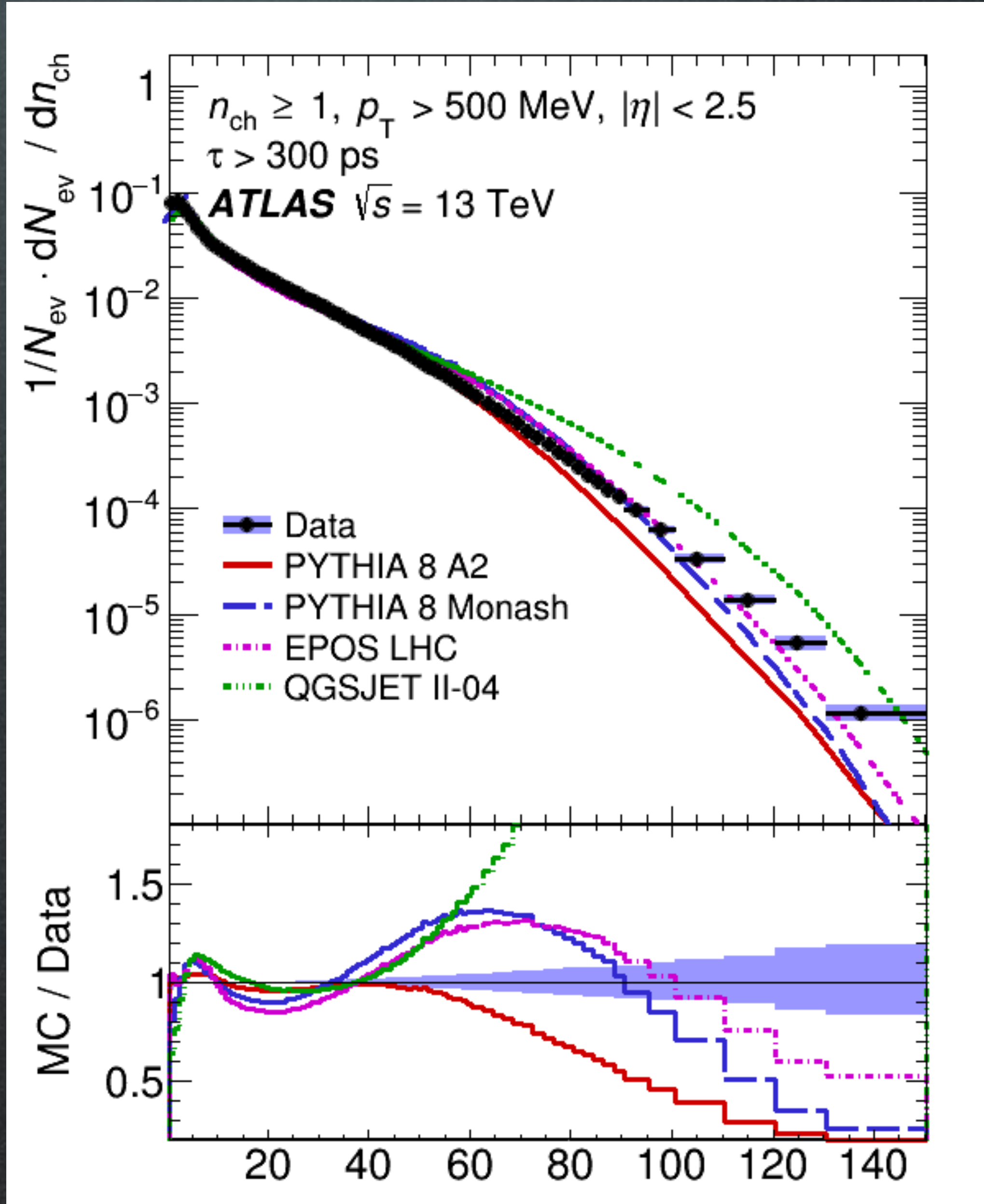

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Similar trends

None of the models do well over the whole range

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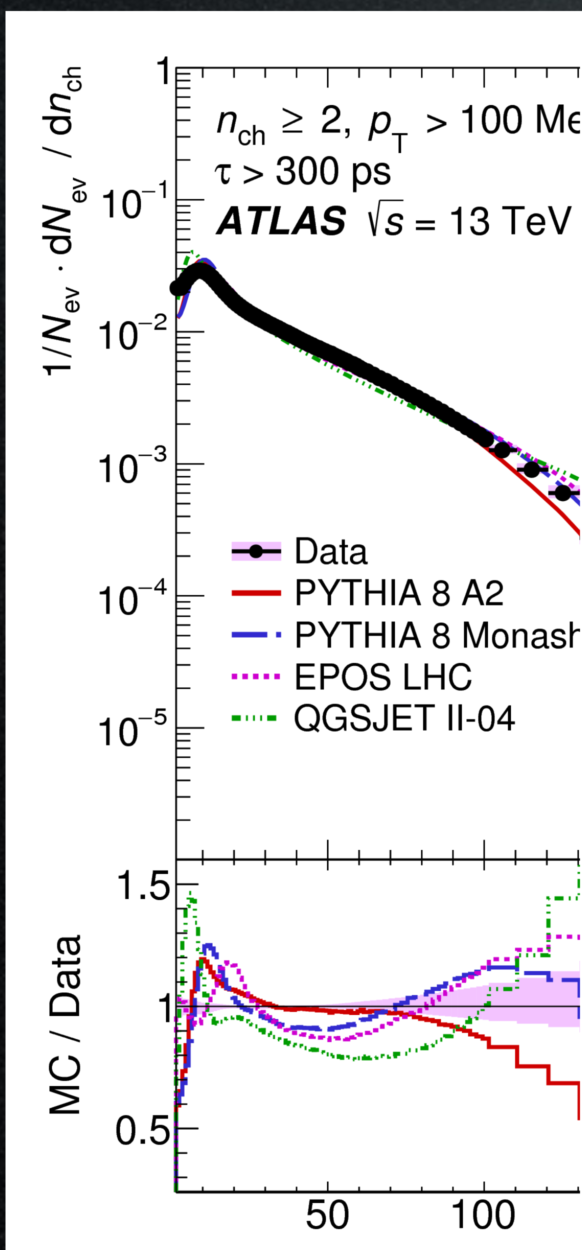

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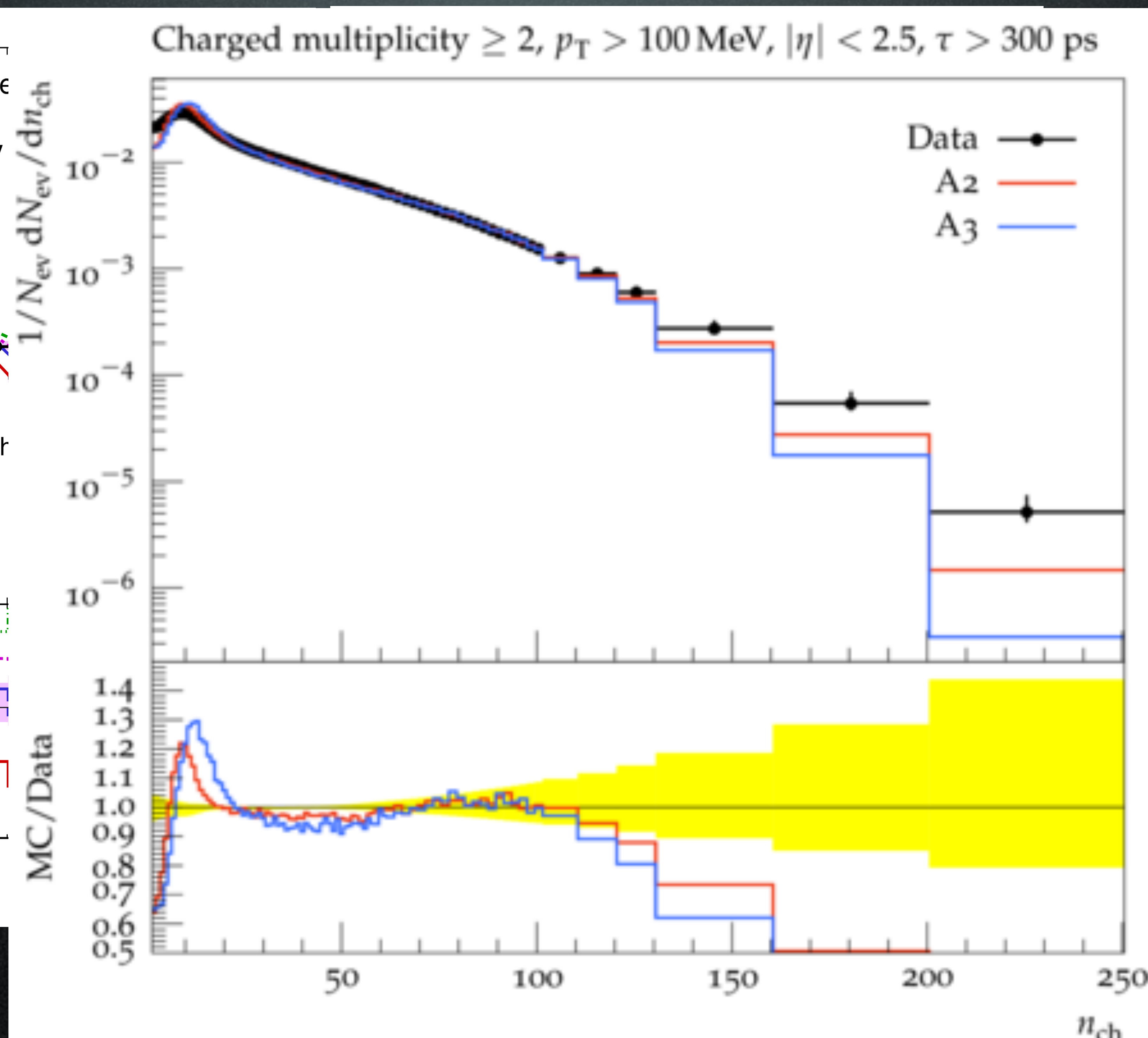
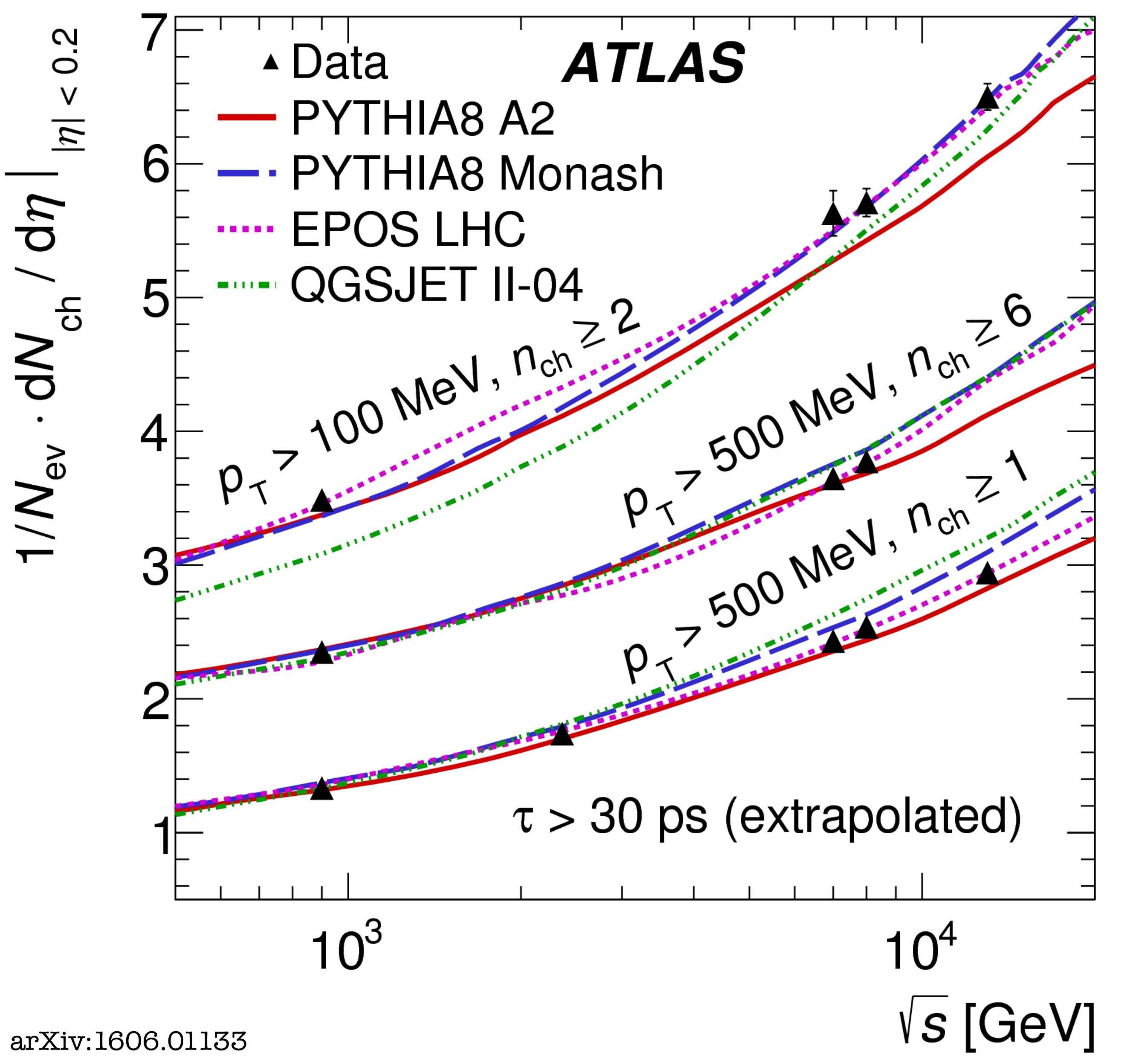


Similar trends

None of ...e models do well ...over the whole range

Dependence on E.C.M



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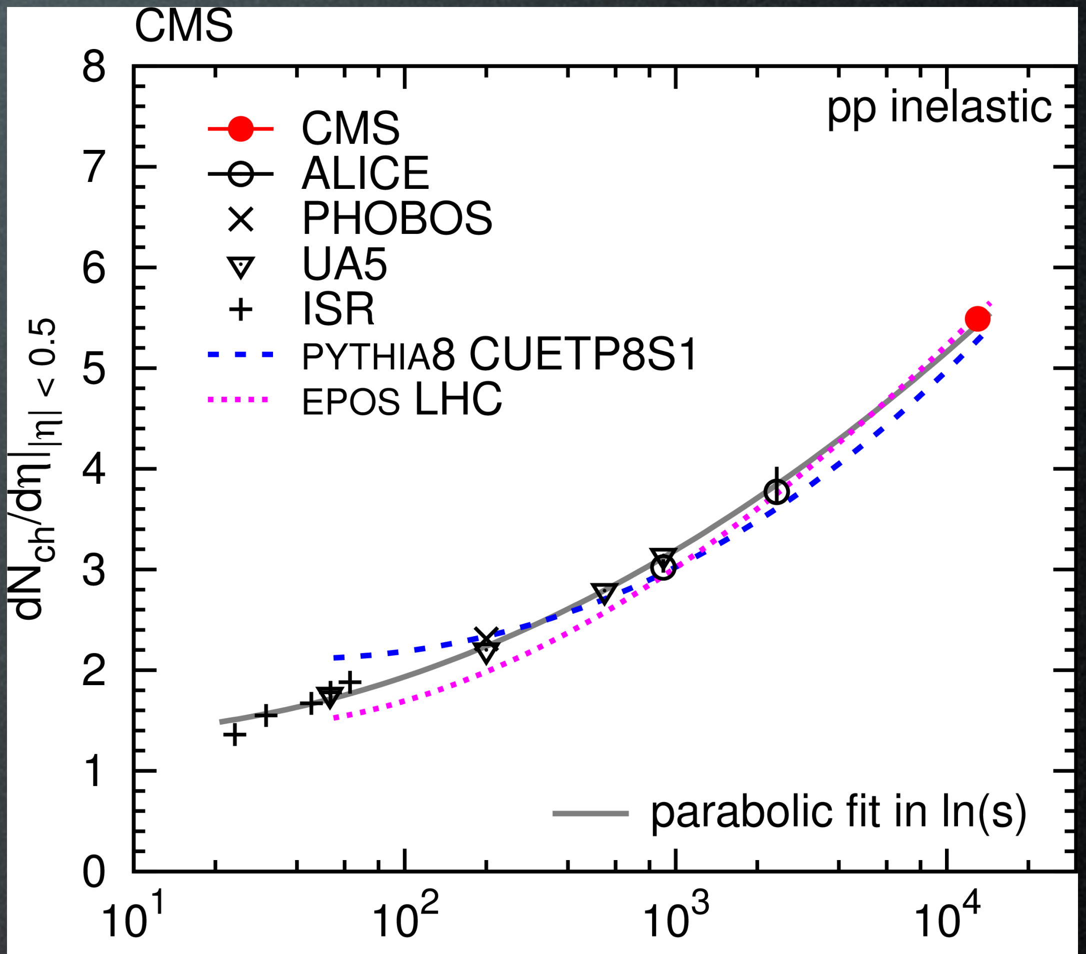


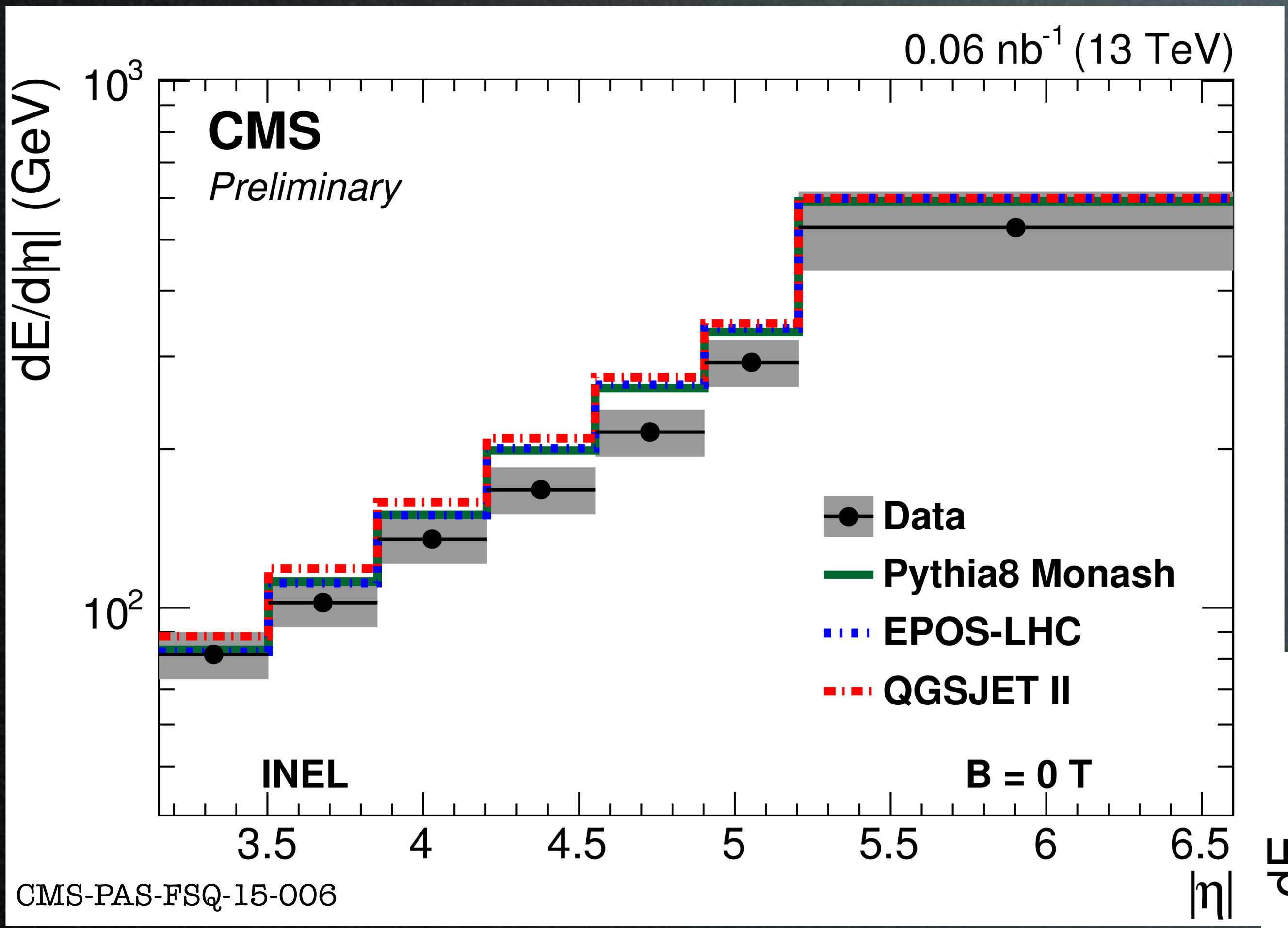
Phys. Lett. B 751 (2015) 143

About 20% increase from going from 7 to 13 TeV

Most models get the energy extrapolation trend right

Forward Energy Flow

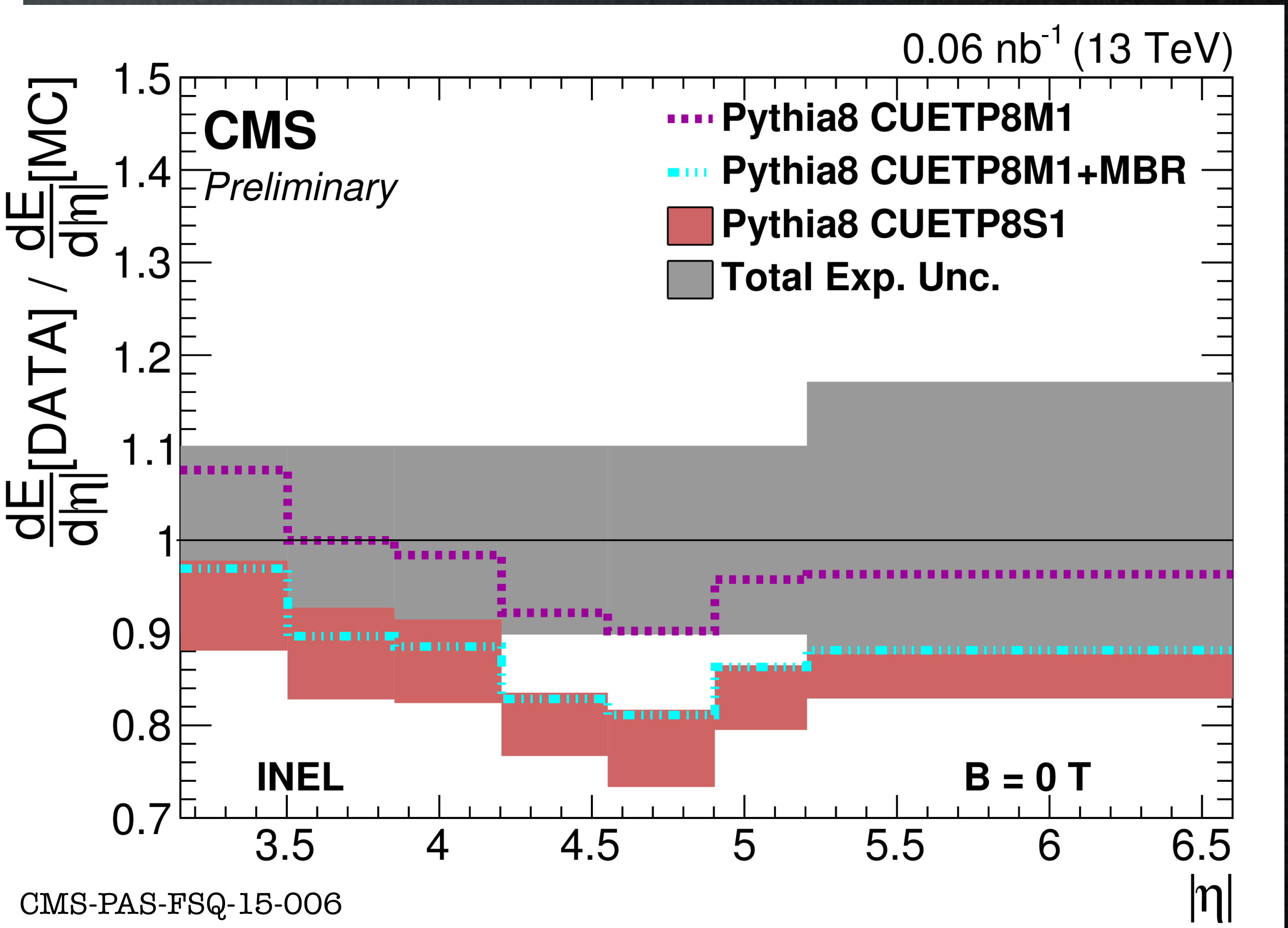
Measured in 3.15 < |η| < 6.6



Models in general perform worse in more forward region

Large spread in predictions

Also measured in non-single diffractive events, where models tend to do better



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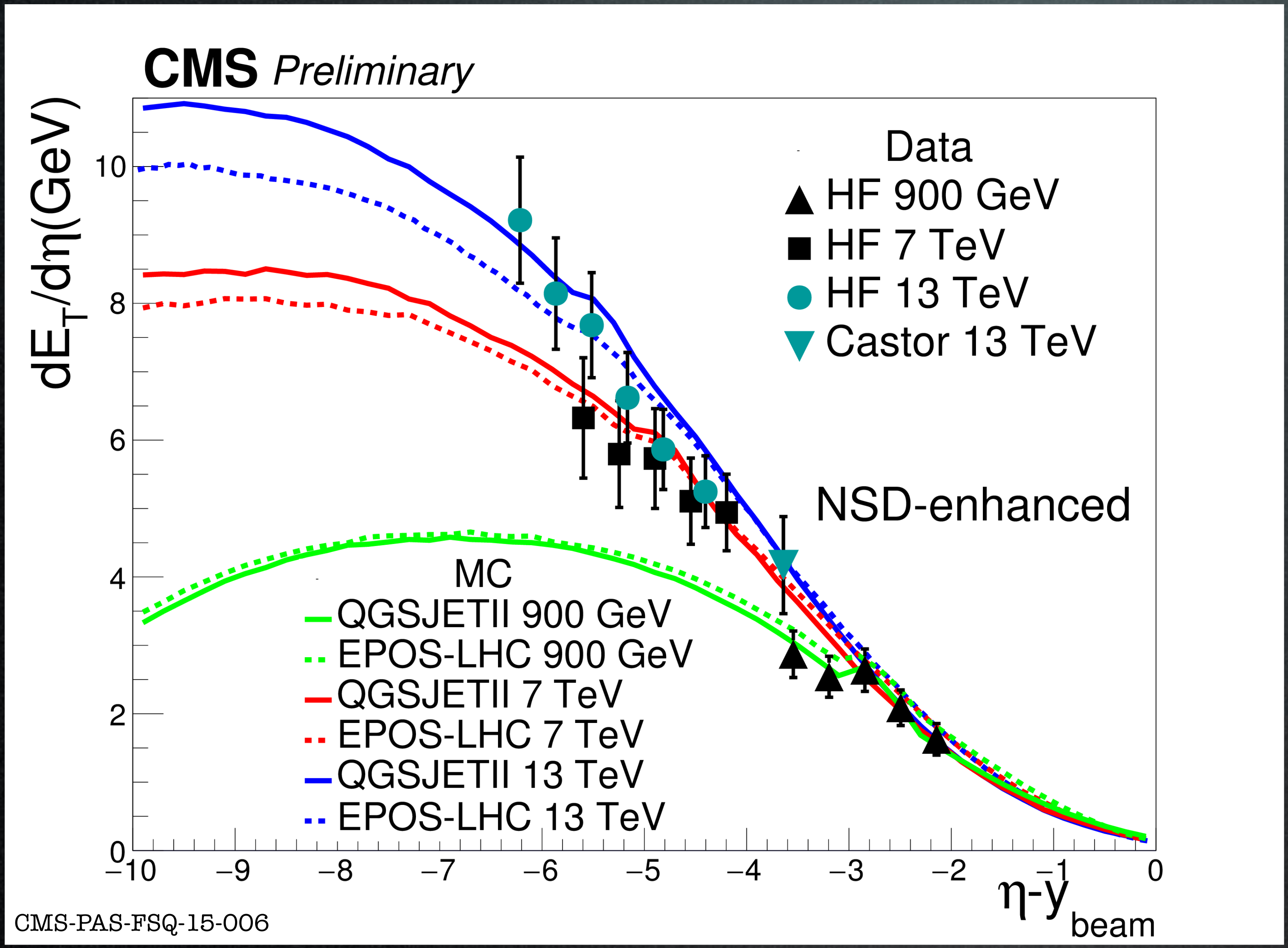
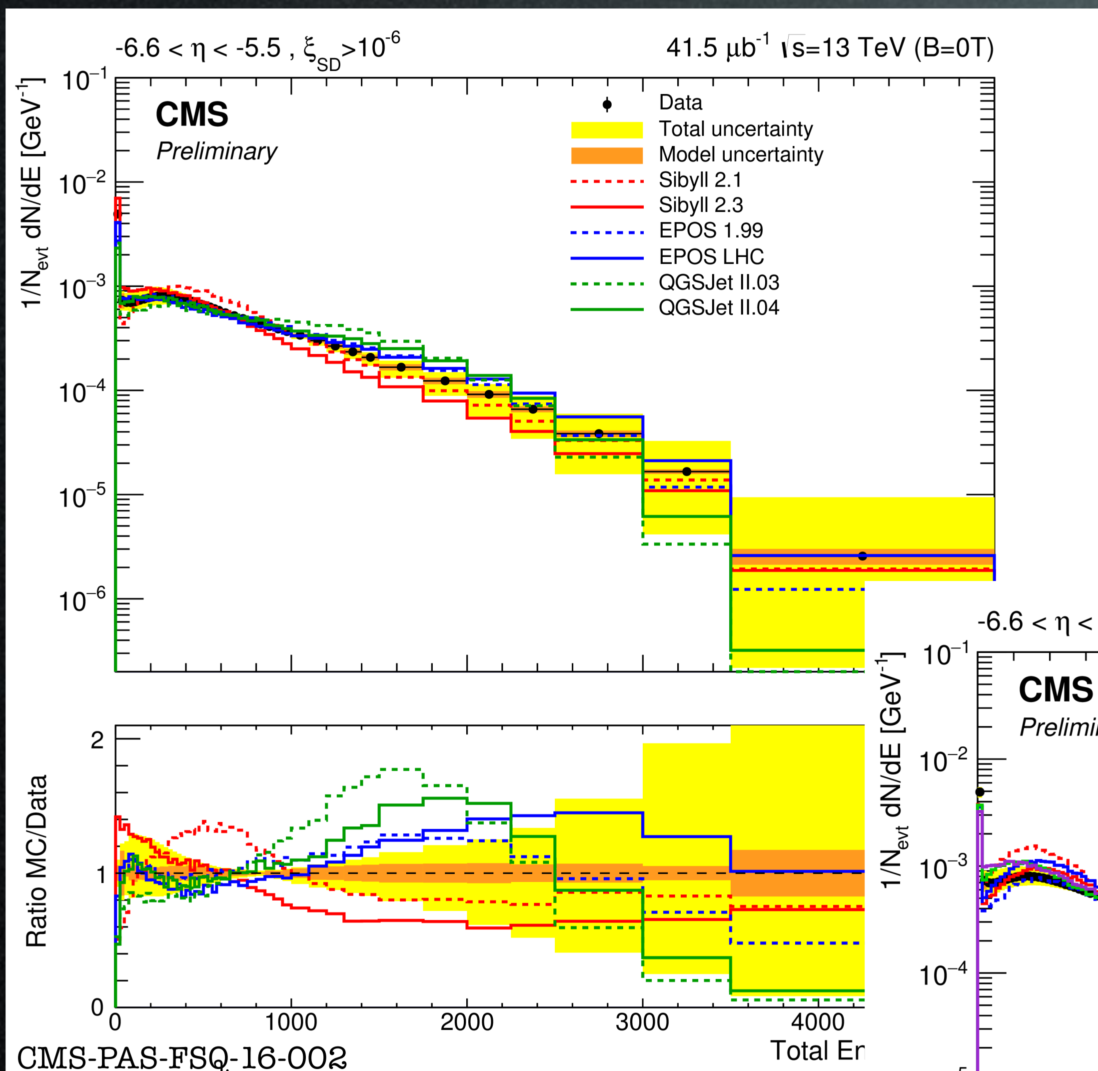


At least two charged particles in the range 3.9 <|η|< 4.4
At least one on each side with respect to the interaction point

Transverse energy flow as a function of shifted pseudorapidity (longitudinal scaling behaviour)

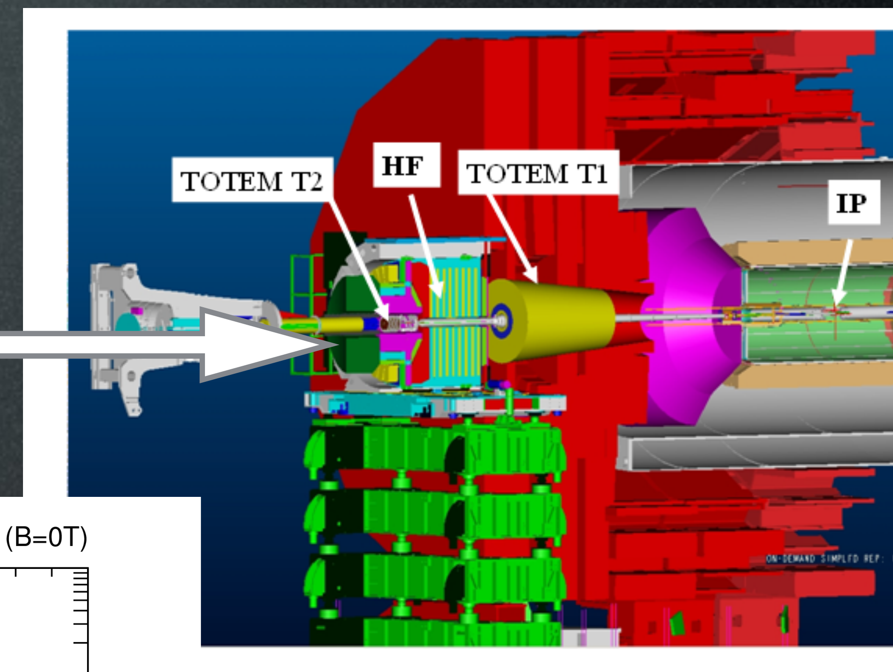
Consistent across wide range of collision energies, and becomes independent of sqrt(s) at beam fragmentation region

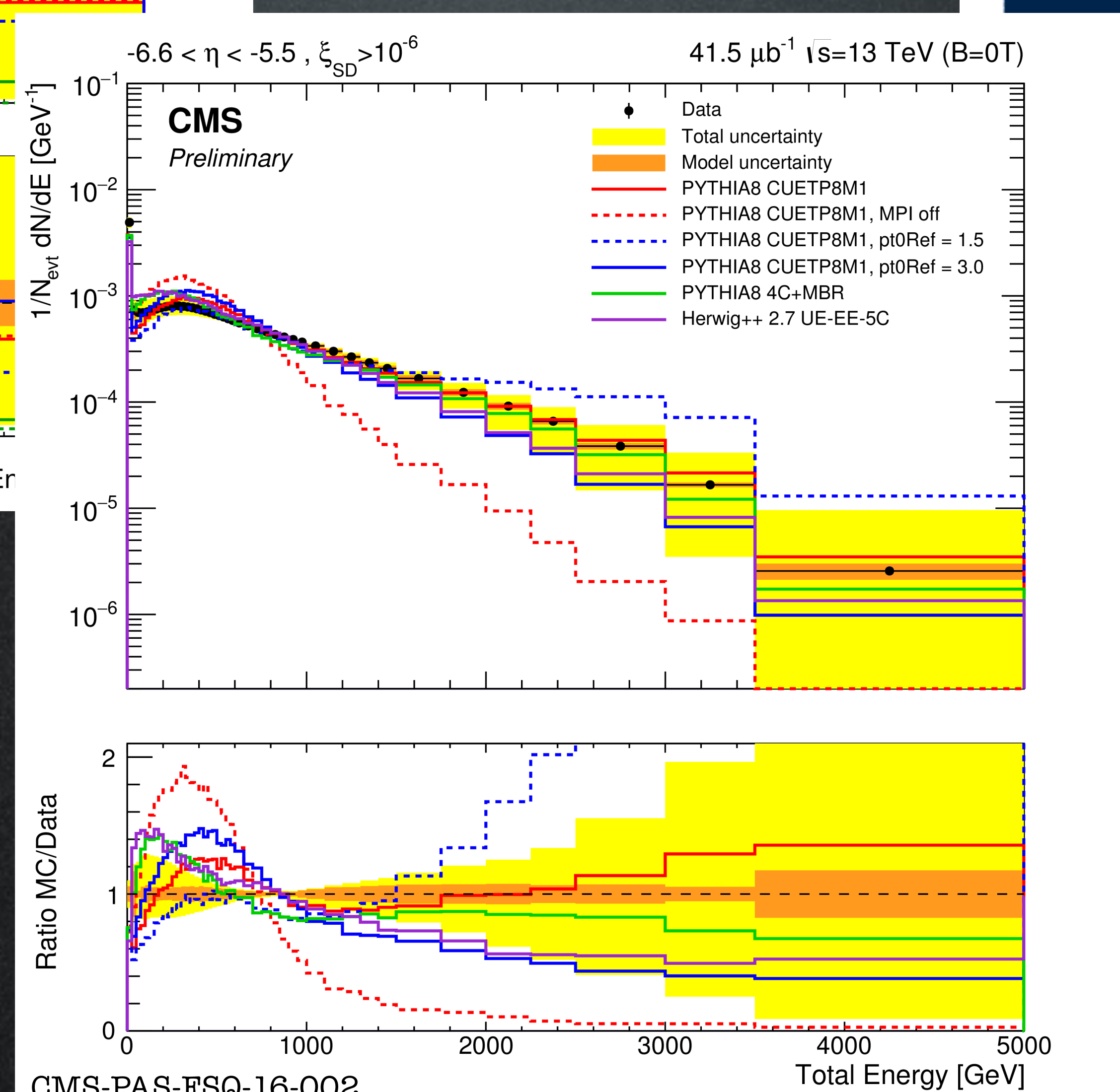
Very Forward Energy Flow



Castor

$-5.2 < \eta < -6.6$



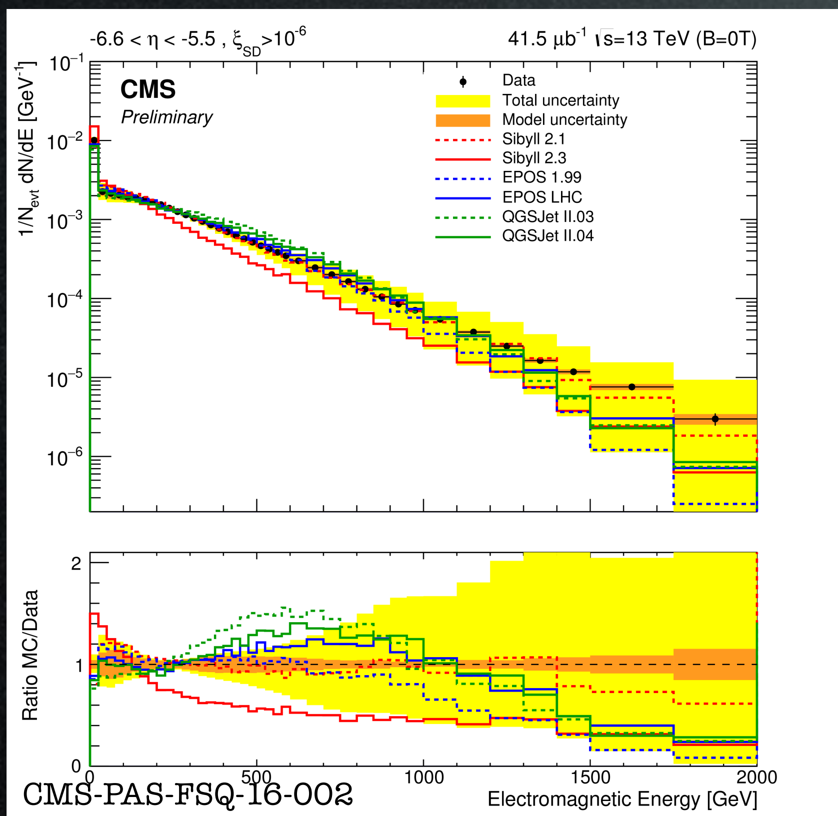


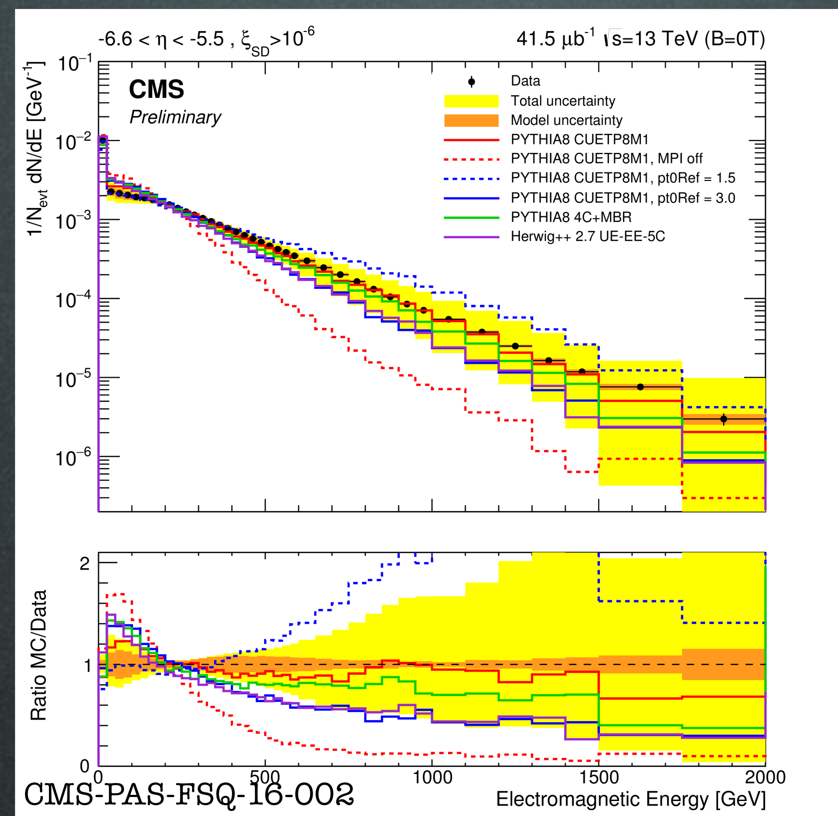
Bump at ~200 GeV, then steeply falling

Discriminating power between the models

Generally worse at the soft part of the spectrum

Very Forward Energy Flow





Electromagnetic

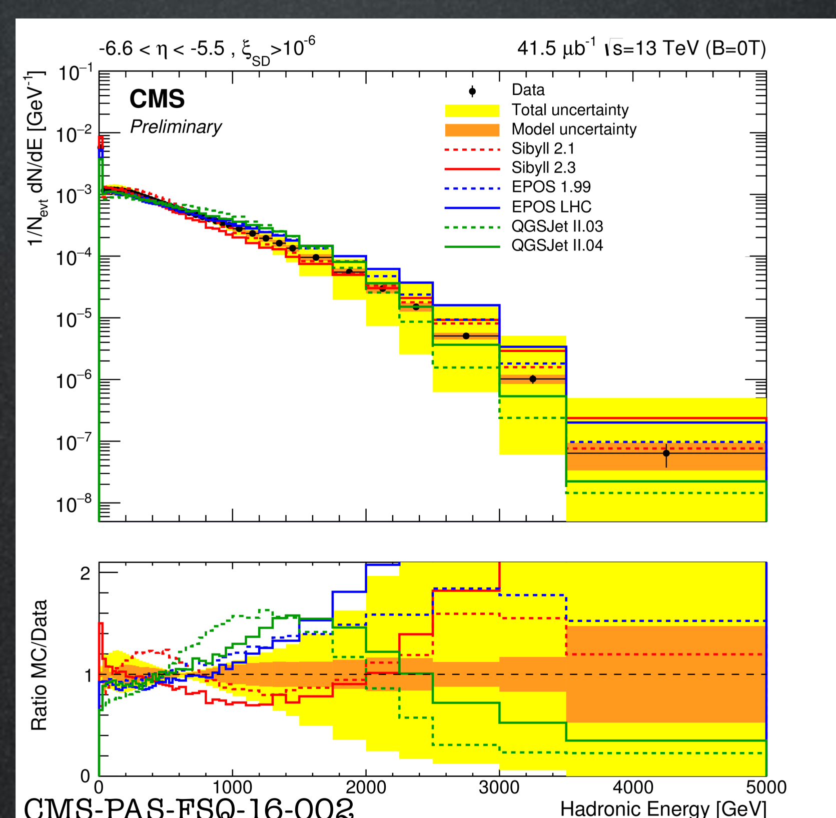
Models overall perform better

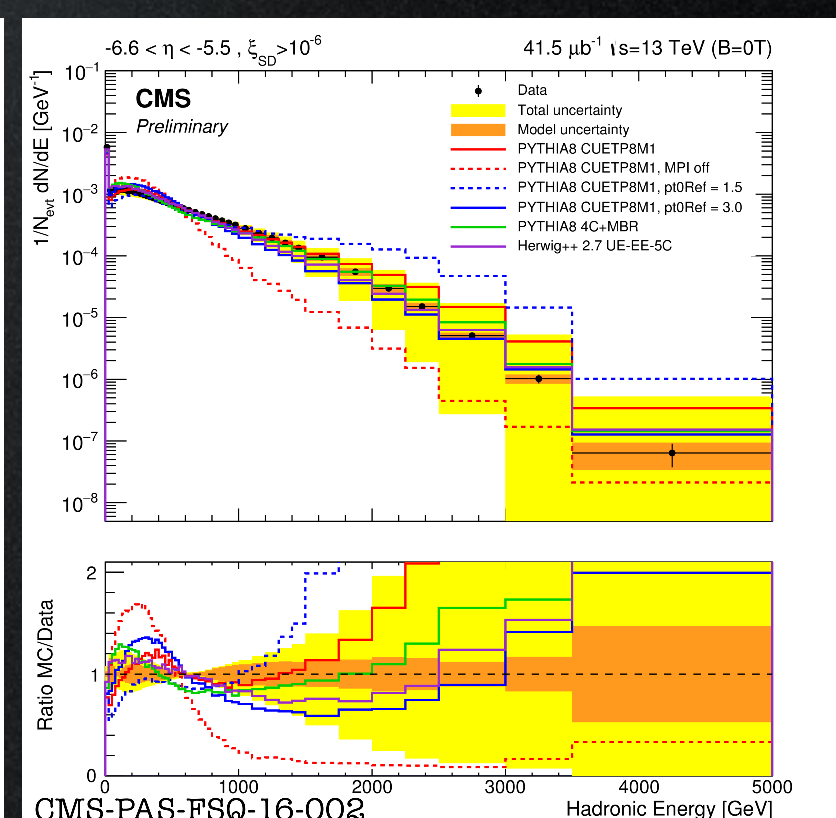
Sensitive to MPI

Hadronic

The bump comes from hadronic spectrum

Cosmic shower models better, but none predicts the entire shape well





Summary

- A wide range of minimum bias measurements, both with charged and neutral particles have been performed with LHC Run 2 data

- While none of the models considered is perfect for all observables and full ranges, many do a reasonable job

- Energy evolution of Multiple Parton Interactions is historically a poorly understood parametrisation, but most models seem to perform well at this new highest collision energy

- Important for pileup modelling, and constraining the Monte Carlo event generators

References

- CMS MB: Phys. Lett. B 751 (2015) 143
- ATLAS 13 TeV MB: Physics Letters B (2016), Vol. 758, pp. 67-88
- ATLAS 13 TeV low-pT MB: arXiv:1606.01133
- ATLAS 8 TeV MB: Eur. Phys. J. C (2016) 76: 403.
- ATLAS A3 Tune: ATL-PHYS-PUB-2016-017
- CMS forward energy flow: CMS-PAS-FSQ-15-006
- CMS/Totem very forward energy flow: CMS-PAS-FSQ-16-002

A Note on the Models

"The predictions of the model are reasonable enough physically that we expect it may be close enough to reality to be useful in designing future experiments and to serve as a reasonable approximation to compare to data. We do not think of the model as a sound physical theory . . . "

– Richard Feynman and Rick Field, 1978