JETS AND MULTIPARTON INTERACTIONS IN PHOTON AND PROTON COLLISIONS

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MOTIVATION AND TALK STRUCTURE

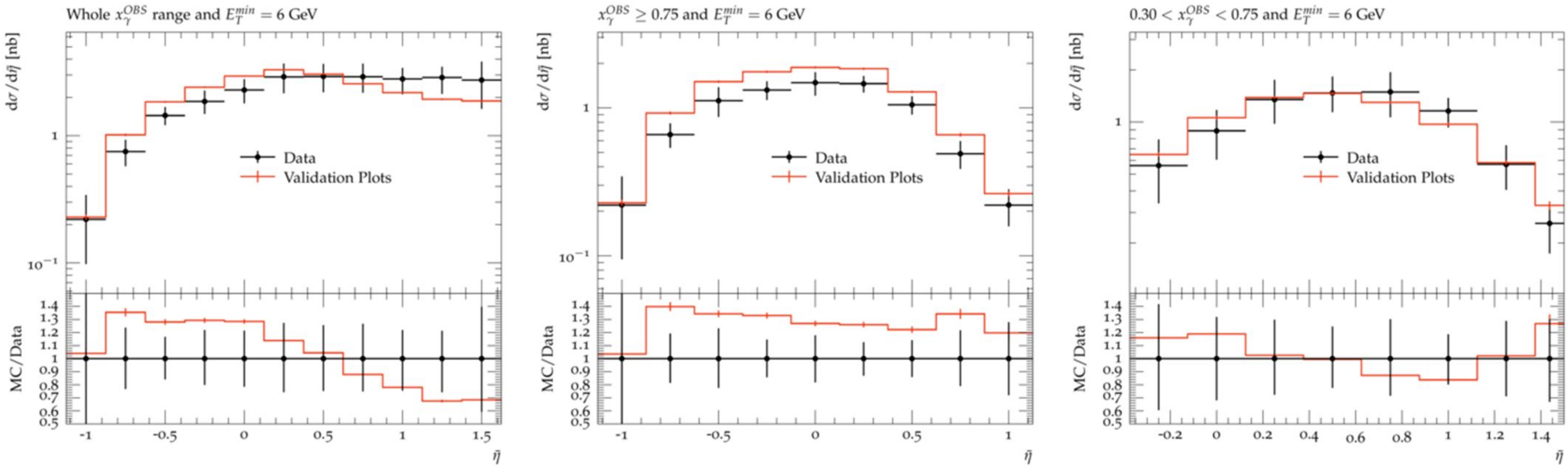
- Motivation:
  - Current model for MPI in photoproduction is not tuned to ep data.
  - Groundwork for such a tune laid out by Ilkka Helenius [1] and Shahzad Sanjrani (UCL) [2].
  - Shahzad Sanjrani showed LEP reference values described HERA photoproduction data.
  - Include the low-E_T dijet photoproduction data from [3] to the study. Requires a new Rivet [4] routine.
  - The work by S. Sanjrani provided evidence of two operating regimes: LEP/HERA and LHC.
  - We hope this work will contribute for the study of ϒϒ collisions at the LHC and for studies related to the upcoming EIC.
- Talk structure:
  - Discuss new routine and its validation.
  - Simultaneous description of HERA and LEP regimes.
  - Attempting to create a general tune.
  - Comparing pp, ϒp And ϒϒ data. Testing if the regimes arise only due to he vastly different collision energies.
- Note: Pythia version 8.308 [5] was used.

RIVET ROUTINE FOR LOW E_T PHOTOPRODUCTION DATA

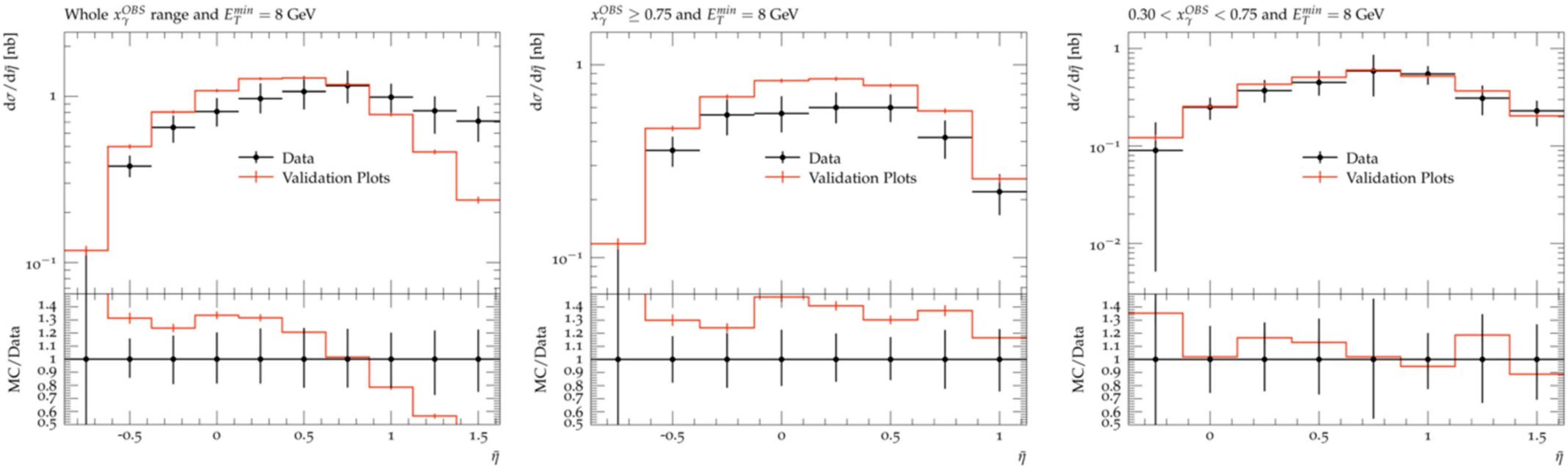
Variable	Relevant kinematic range
Jet energy	$E_T^{jet} \geq 6\,\text{GeV}$
Jet pseudorapidity	$-1.375 < \eta^{jet} < 1.875$
Pseudorapidity difference	$\lvert\Delta\eta\rvert < 0.5$
Photon four-momentum squared	$Q^2 \lesssim 4\,\text{GeV}^2$
Inelasticity	$0.2 < y < 0.8$

Kinematic cuts that were implemented in the Rivet routine, these cuts are those from [3]. K_T algorithm used for jet reconstruction. For clarification, $|\Delta\eta|$ is the absolute value of the difference between the pseudorapidities of the two jets. Rivet routine based on that for an analysis of higher-E_T dijet photoproduction data [6].

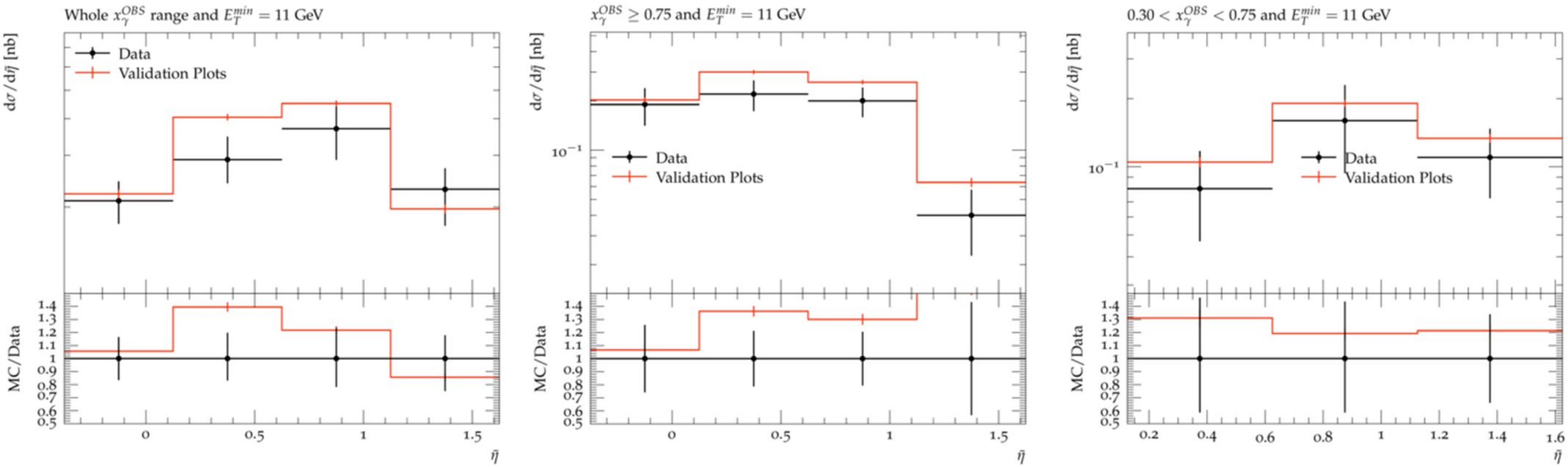
ROUTINE VALIDATION (ZEUS DATA)



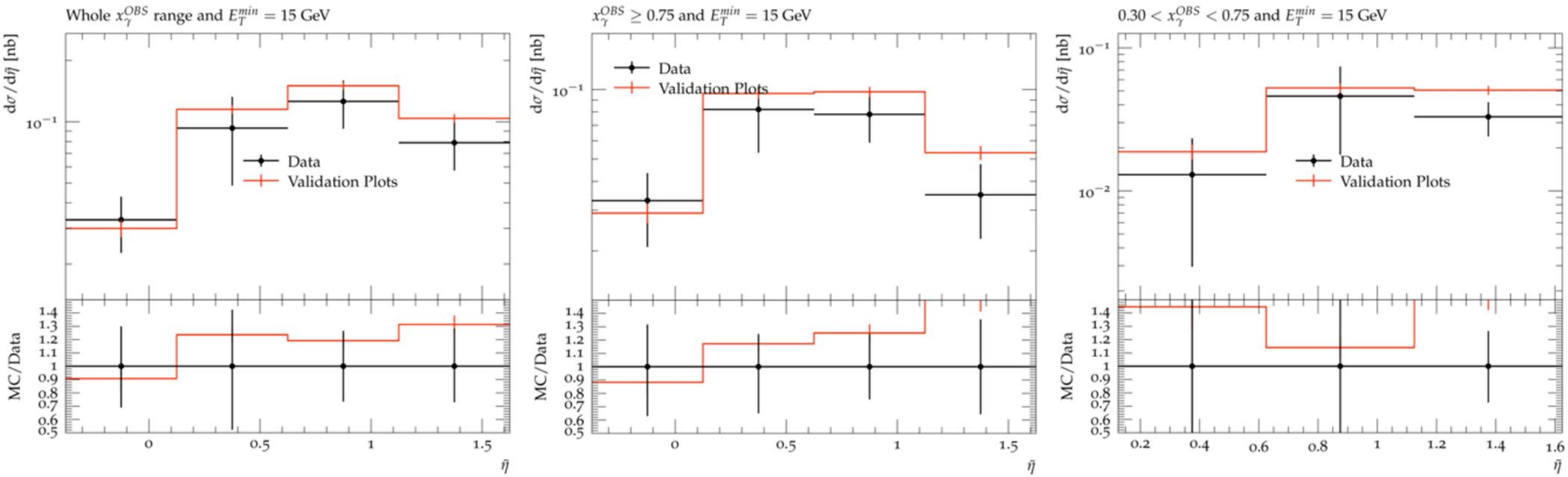
ROUTINE VALIDATION (ZEUS DATA)



ROUTINE VALIDATION (ZEUS DATA)



ROUTINE VALIDATION (ZEUS DATA)

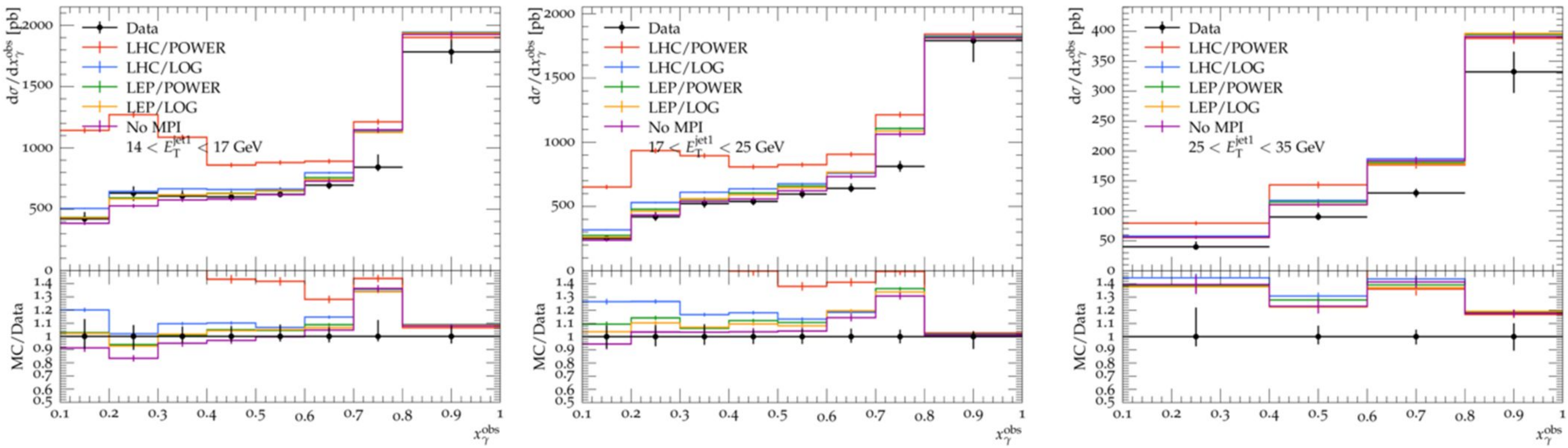


- Rivet analyses:
  - ZEUS 1997 I450085: New Rivet routine. 27.5 GeV positrons and 820 GeV protons [3].
  - ZEUS 2001 S4815815: ZEUS Dijet photoproduction, $E_T^{jet1} > 14$ GeV (for the leading jet), $E_T^{jet2} > 11$ GeV and $-1 < \eta^{jet} < 2.4$. Less sensitive to MPI. 27.5 GeV positrons and 820 GeV protons [6].
  - OPAL 2003 I611415: Dijet production at LEP $\gamma\gamma$ collisions. e+e- COM energy is 198 GeV [7].
  - CDF 2015 I1388868: Tevatron underlying event studies at 300, 900, 1960 GeV [8].
  - ATLAS 2010 S8918562: ATLAS MB at 0.9, 2.36 and 7 TeV [9].
  - ATLAS 2016 I1419652: ATLAS MB at 13 TeV [10].

- MPI tunes:
  - LHC/POWER or Monash: default Pythia pp (and ep) tune [11].
  - LEP/LOG: default photon-photon tune.
  - LHC/LOG: LHC/POWER but the p_{T0} scaling law switched to logarithmic.
  - LEP/POWER: LEP/LOG but the p_{T0} scaling law switched to power (validation plots).
  - Detroit: tune built do describe RHIC data, pp collisions at 200 GeV [12].
  - 2C: tune built to describe CDF data [13].

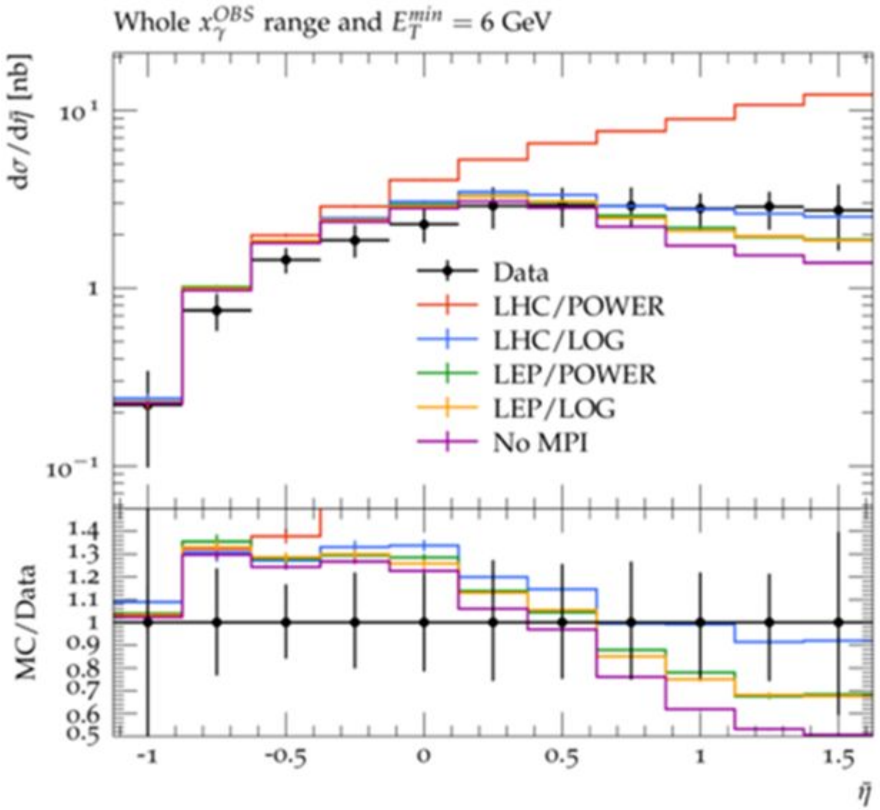
Parameter	LHC	LEP
p_{T0}^{ref}	2.28 GeV	1.54 GeV
$\sqrt{s}^{ref}$	7000 GeV	100 GeV
α	0.215	0.413
Scaling	Power	Logarithmic

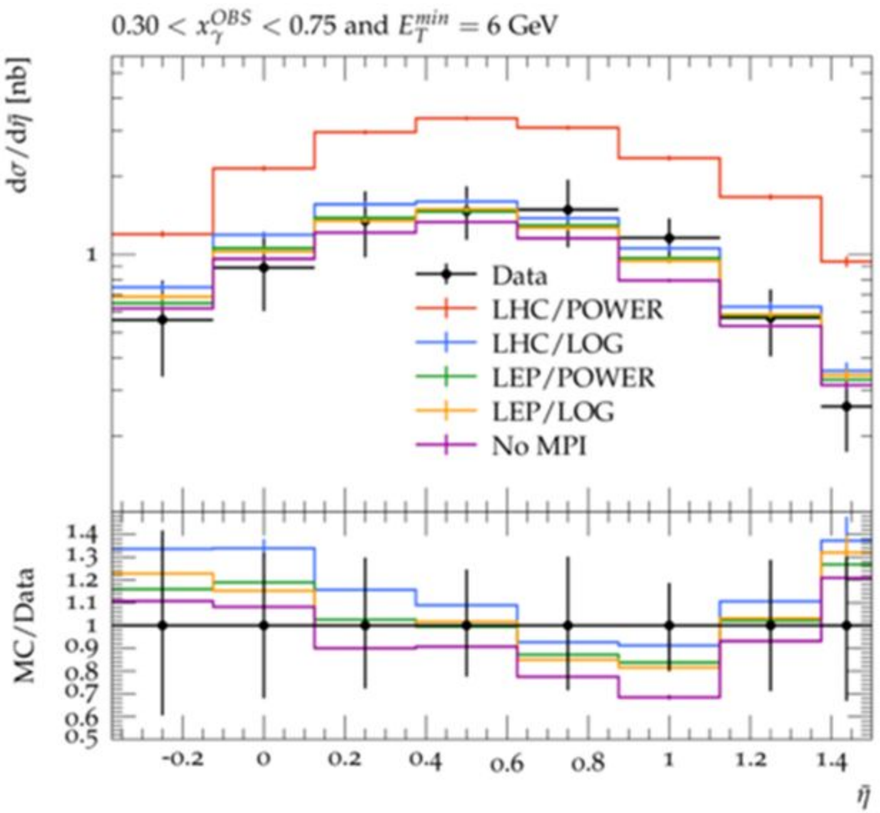
SIMULTANEOUS HERA DESCRIPTION.



ZEUS photoproduction, high E_T^{jet} data.

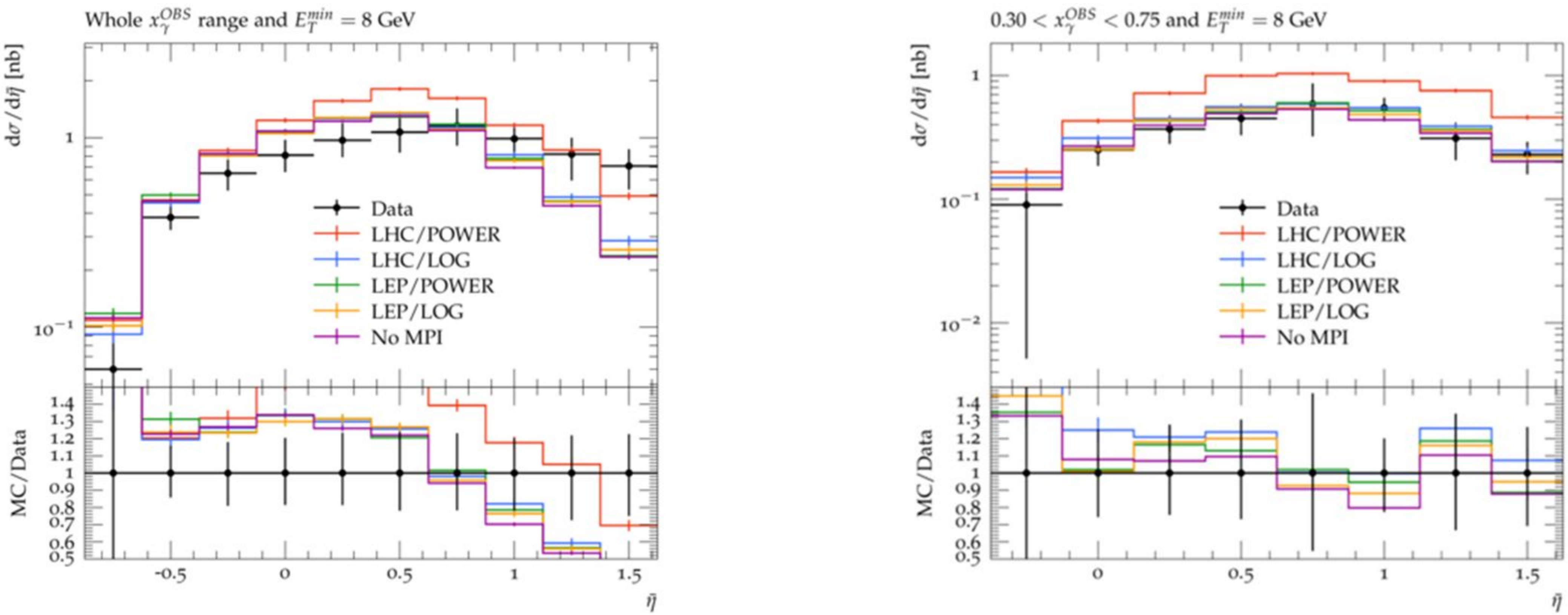
- Qualitative analysis (supplemented by X^2).
- LEP/LOG, LEP/POWER best agreement.
- LHC/POWER very poor description.





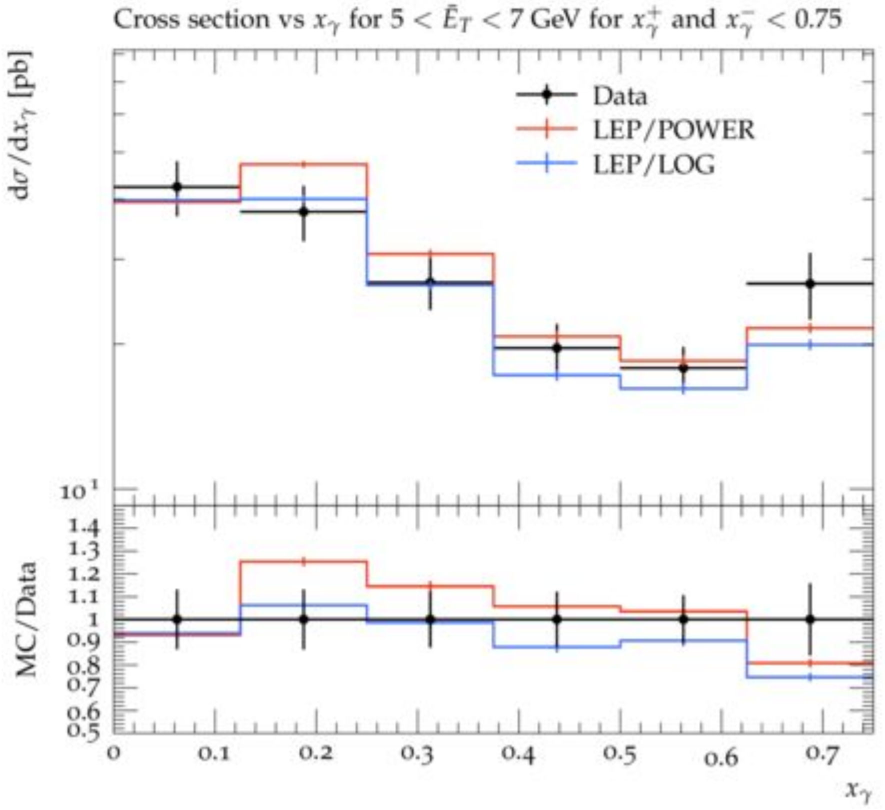
ZEUS photoproduction, low E_T^{jet} data.

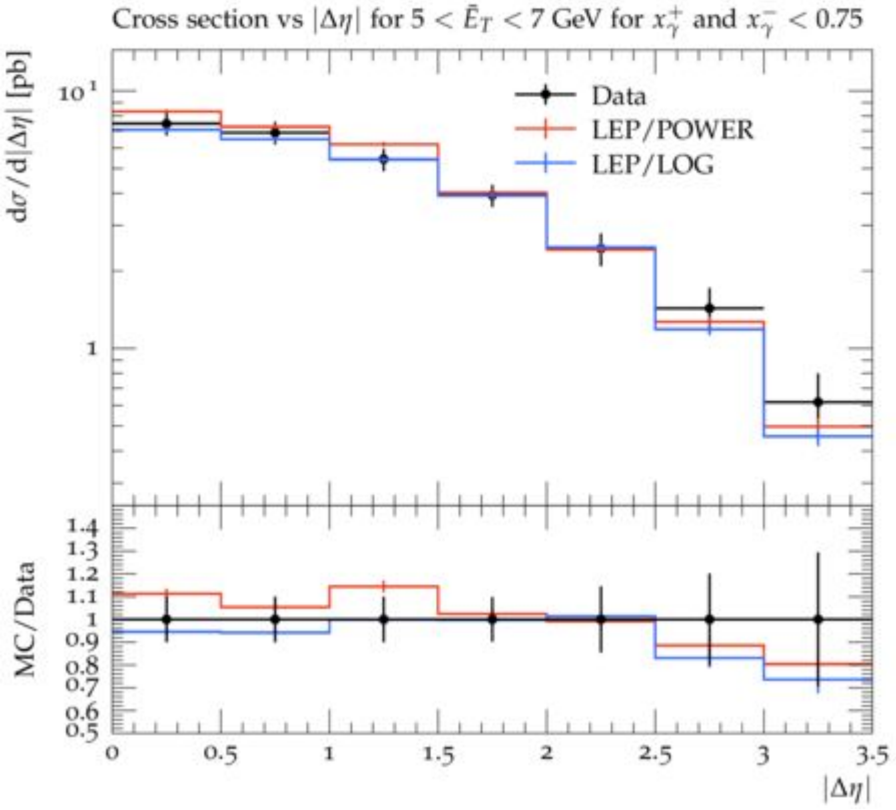
- LEP/LOG, LEP/POWER and LHC/LOG best description.
- LHC/POWER poor agreement.
- MPI off provides worse agreement accounting for uncertainty correlations.



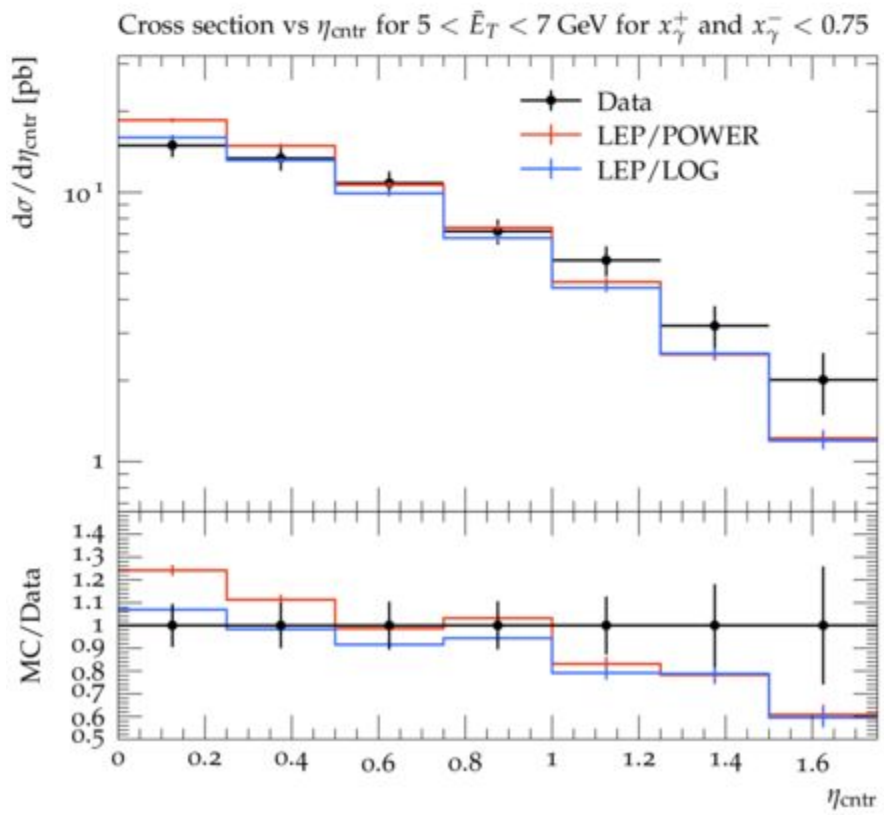
ZEUS photoproduction, low E_T^{jet} data.

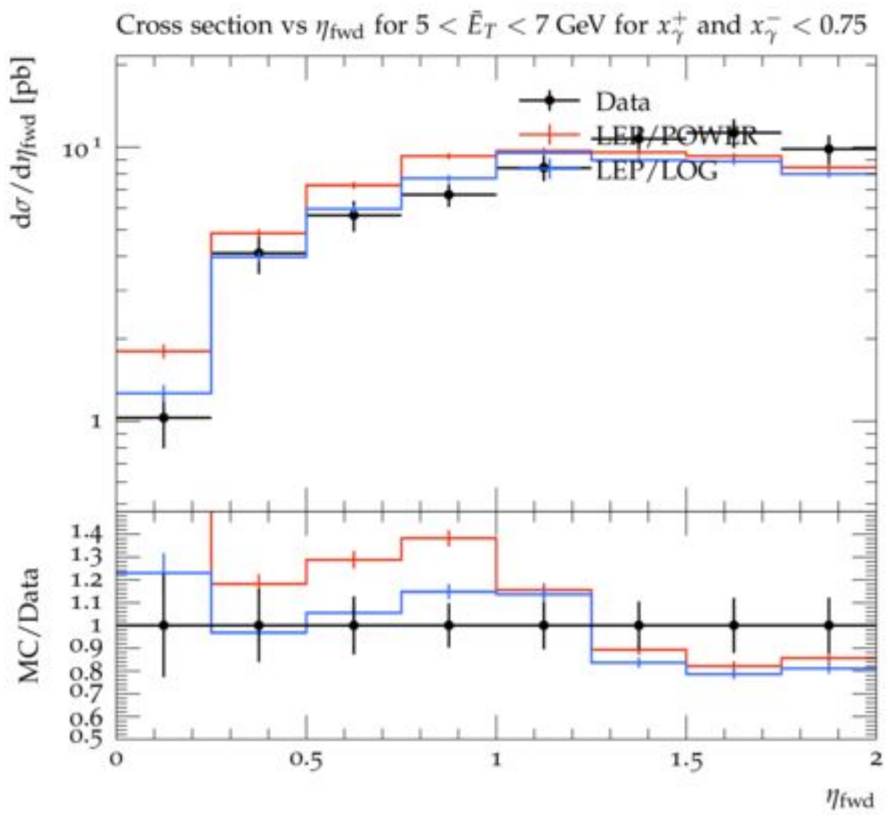
EXTENSION TO LEP





OPAL resolved-resolved $\gamma\gamma$ data.



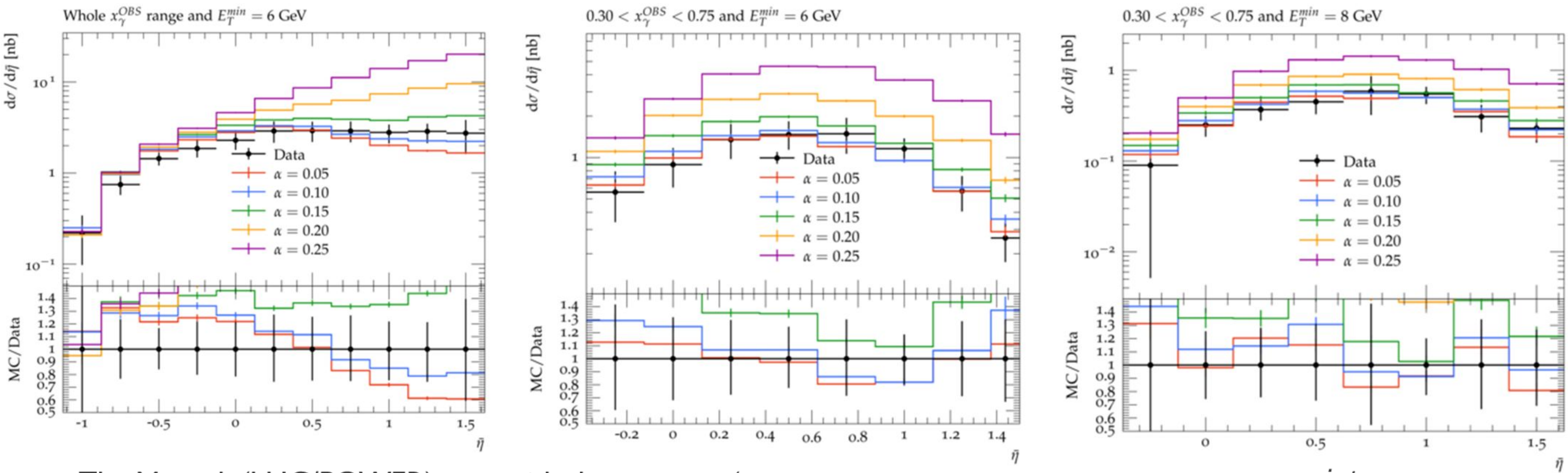


OPAL resolved-resolved $\gamma\gamma$ data.

- LEP/LOG better agreement than LEP/POWER.

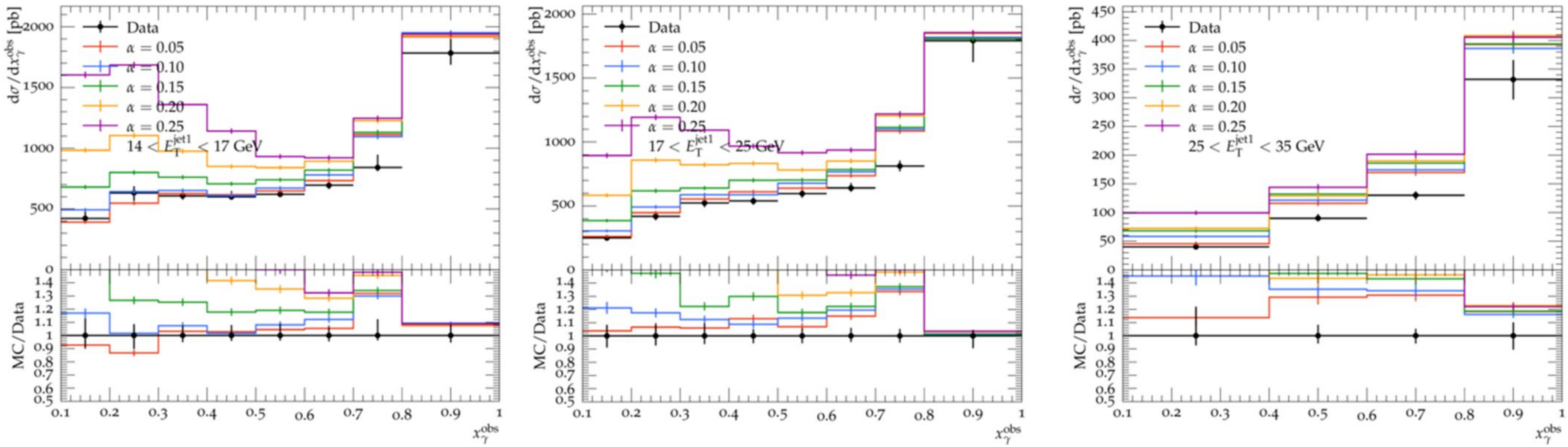
ATTEMPTING A GENERAL TUNE

DESIGNING "LHCVAR"



- The Monash (LHC/POWER) tune with the ecmpow (or α) changed.
- Similar work conducted by Ilkka Helenius but with a change in P_{T0}^{ref} [1].

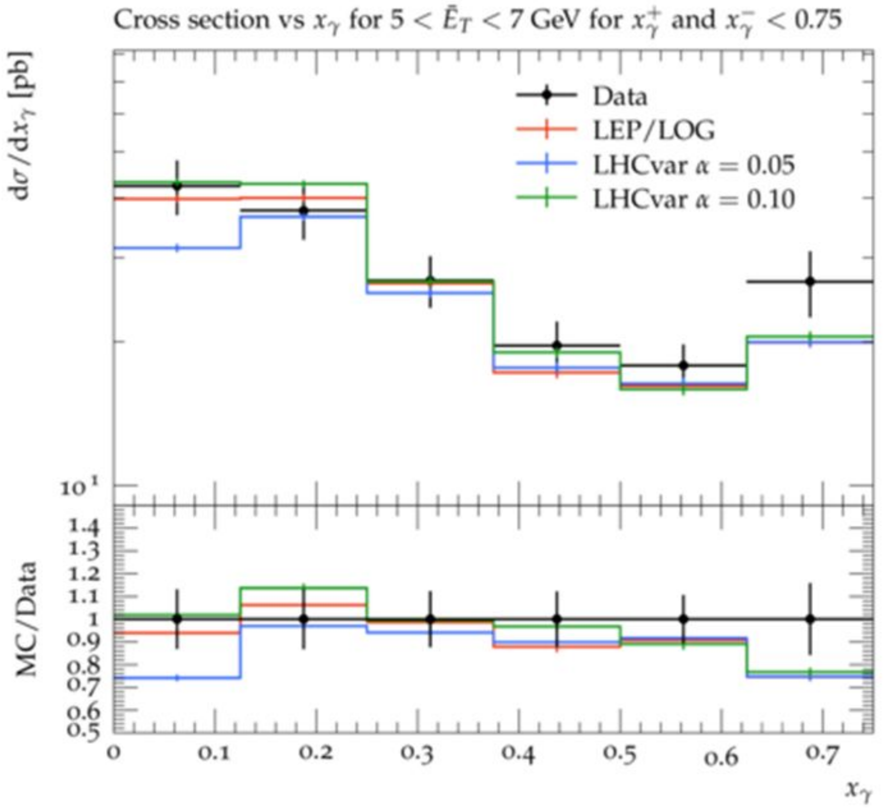
ZEUS photoproduction, low E_T^{jet} data.

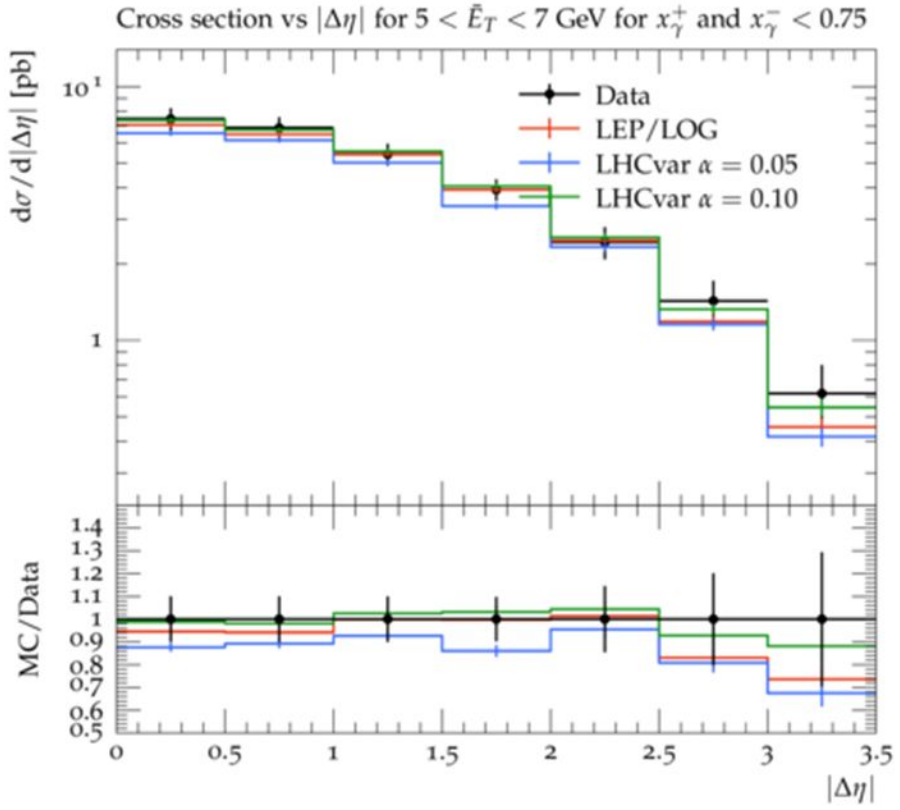


ZEUS photoproduction, high E_T^{jet} data.

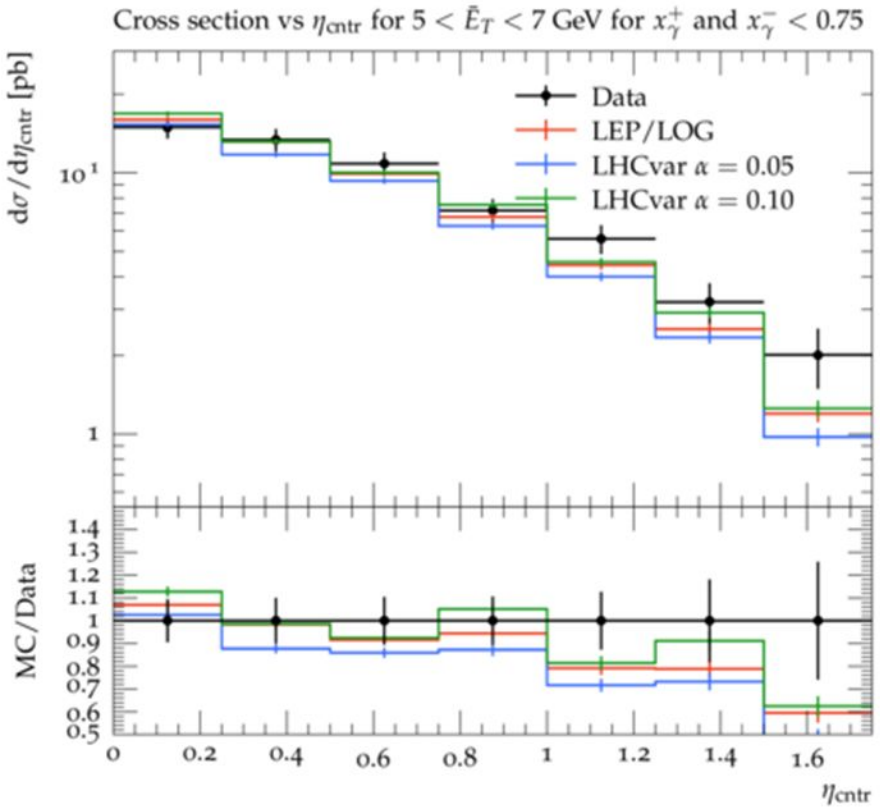
- $\alpha = 0.05$ best agreement.

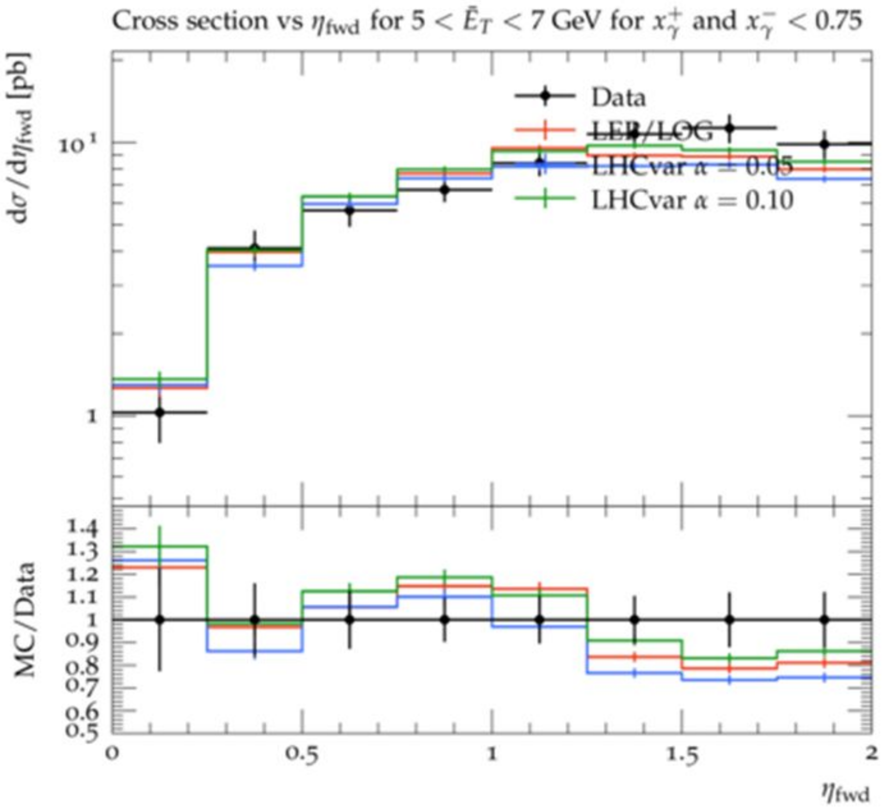
TESTING ON LEP





OPAL resolved-resolved $\gamma\gamma$ data.

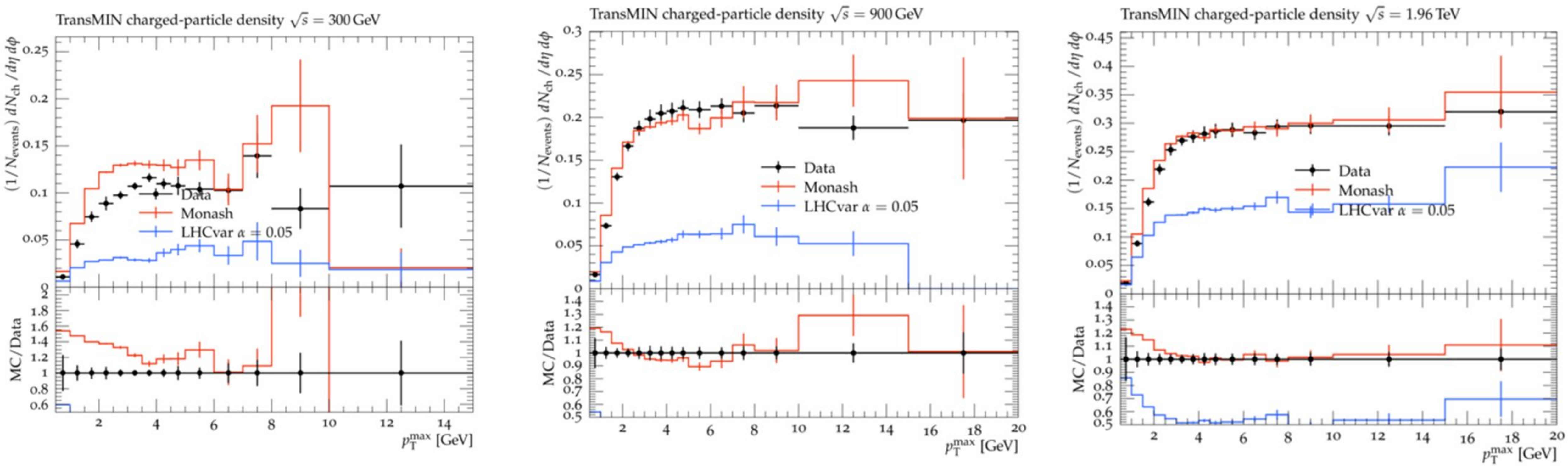




OPAL resolved-resolved $\gamma\gamma$ data.

- $\alpha = 0.10$ better agreement.
- $\alpha = 0.05$ also reasonable. Considered further.

TESTING ON PP

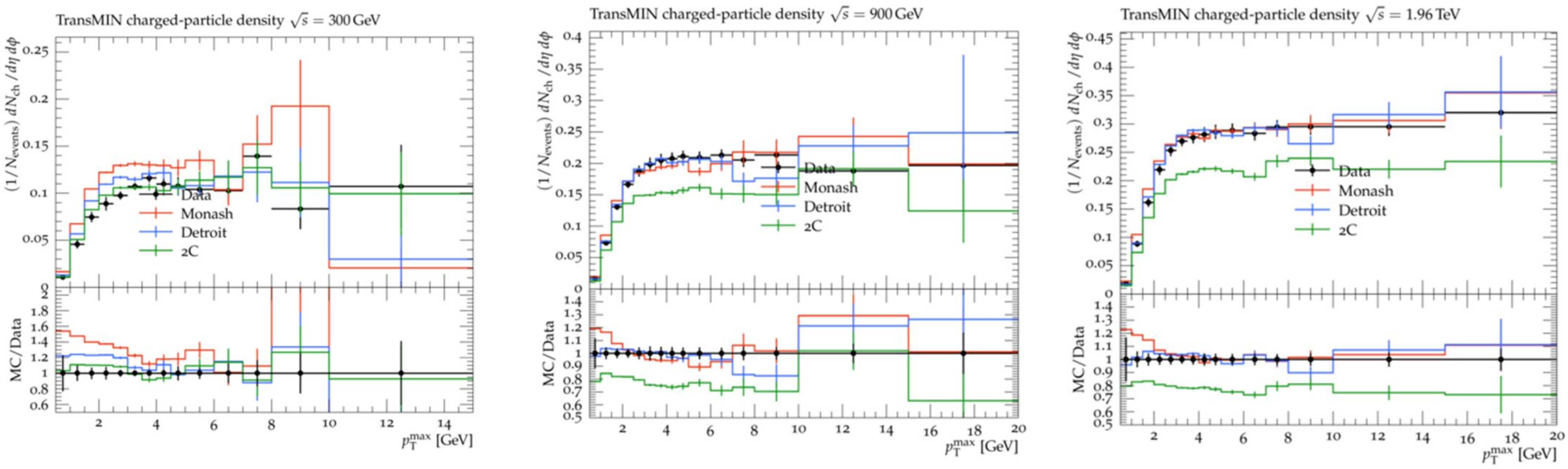


CDF UE data at 300, 900 and 1960 GeV.

- Very poor description.
- No evidence to support the existence of a unified tune produced.

COMPARING PP, YP AND YY

CDF DATA

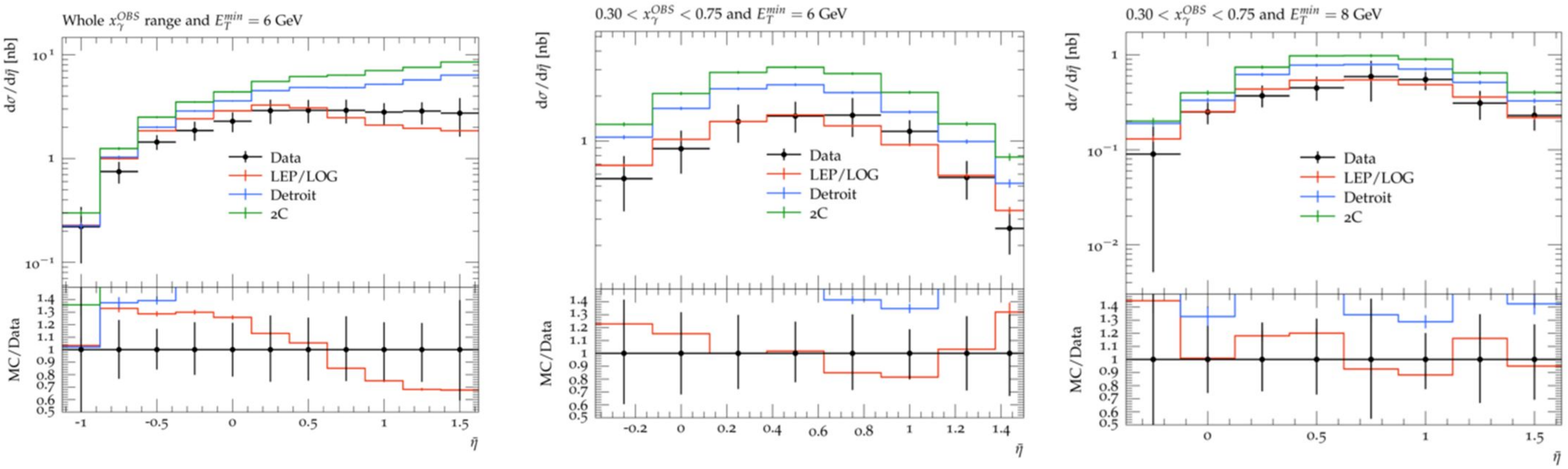


CDF UE data at 300, 900 and 1960 GeV.

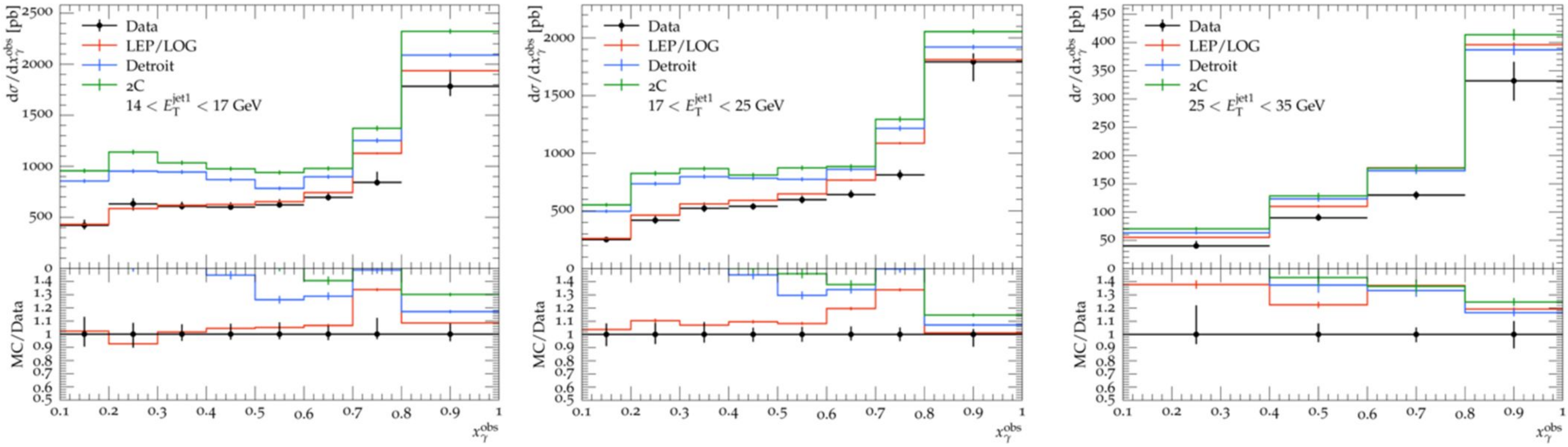
WHY DO WE CONSIDER THIS?

- Described 300 GeV pp data well with 2C tune, Detroit tune also provides a reasonable description.
- HERA photoproduction (in high E_T analysis) has 134 < $W_{\gamma p}$ < 277 GeV.
- Very similar energies to that 300 GeV Tevatron data, RHIC data within this range.
- Can reasonably assume we are controlling for collision energy.
- If different MPI tune was required only because of different energy regime, expect these tunes to work on HERA data.
- LEP $W_{\gamma\gamma}$ is lower (< 120 GeV) so weaker assumption that we are controlling for energy.
- However, given simultaneous description of LEP and HERA achieved, can assume that this difference of energy will not have a great impact.

ZEUS DATA



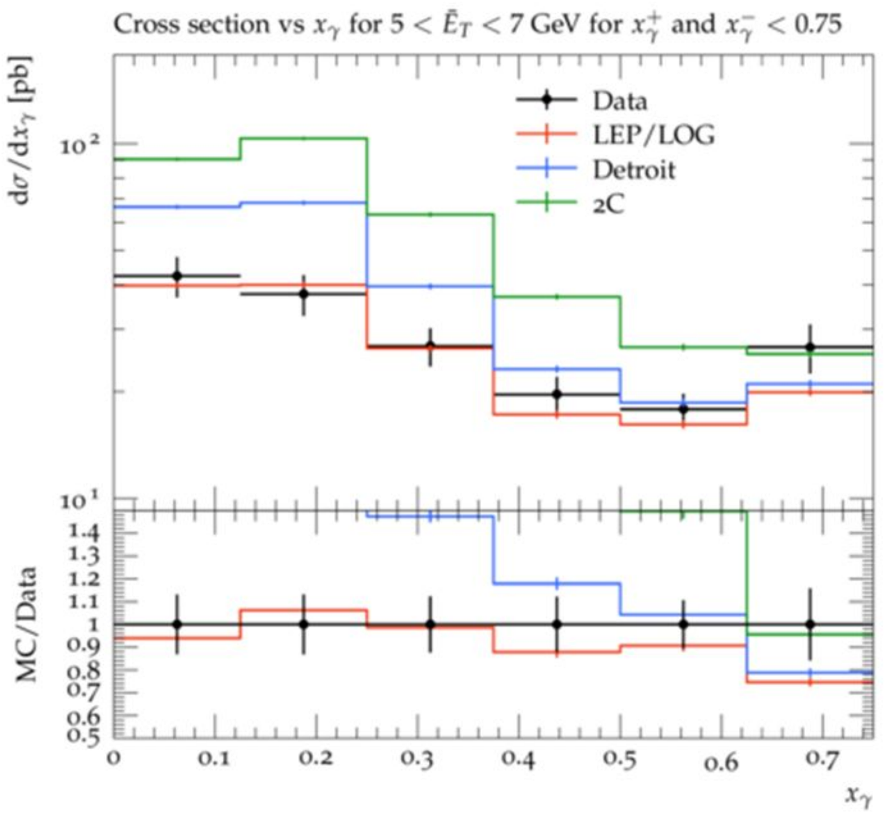
ZEUS photoproduction, low E_T^{jet} data.

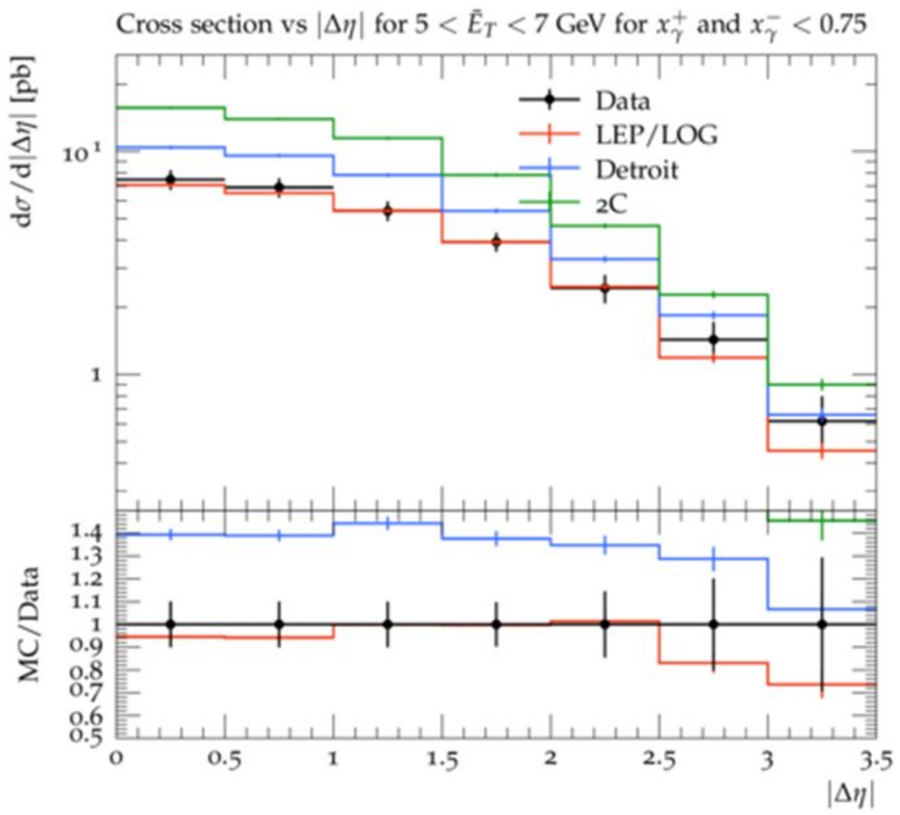


ZEUS photoproduction, low E_T^{jet} data.

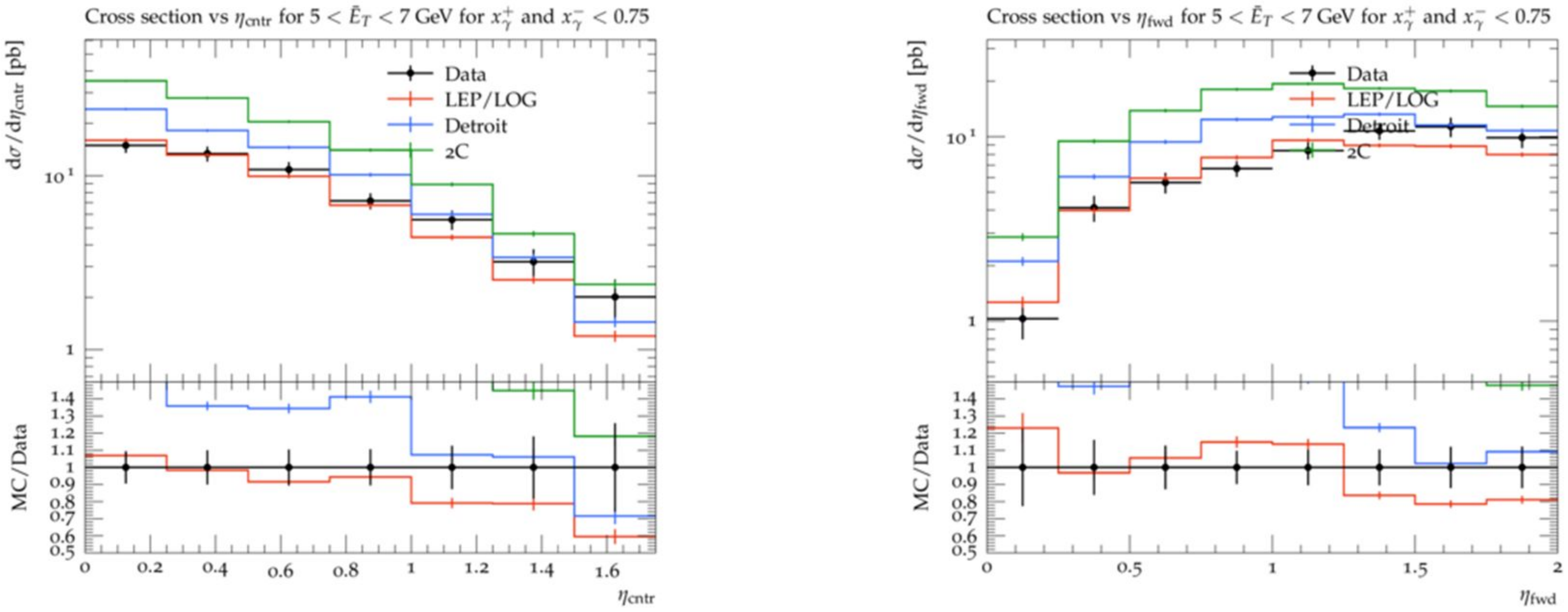
- Both Detroit and 2C tunes overestimate the cross section.
- γp and pp collisions require a different MPI model regardless of collision energy.

OPAL DATA





OPAL resolved-resolved $\gamma\gamma$ data.



- Similarly, both Detroit and 2C tunes overestimate the cross section.
- $\gamma\gamma$ and pp collisions require a different MPI model regardless of collision energy.

OPAL resolved-resolved $\gamma\gamma$ data.

SUMMARY AND CONCLUSIONS

- Simultaneously described HERA data across the whole E_T range with LEP/LOG, LEP/POWER and LHCvar.
- MPI off seen to provide a worse agreement considering uncertainty correlations.
- LEP/LOG and LHCvar also appropriately described LEP data.
- No conclusive evidence to support the existence of a simultaneous tune.
- Difference in MPI in γp and pp collisions, regardless of collision energy. $\gamma\gamma$ and pp also require a different MPI model.
- Difference not present when comparing γp and $\gamma\gamma$.
- LEP and HERA have different energies but still were described by same tunes, small difference so not very conclusive.

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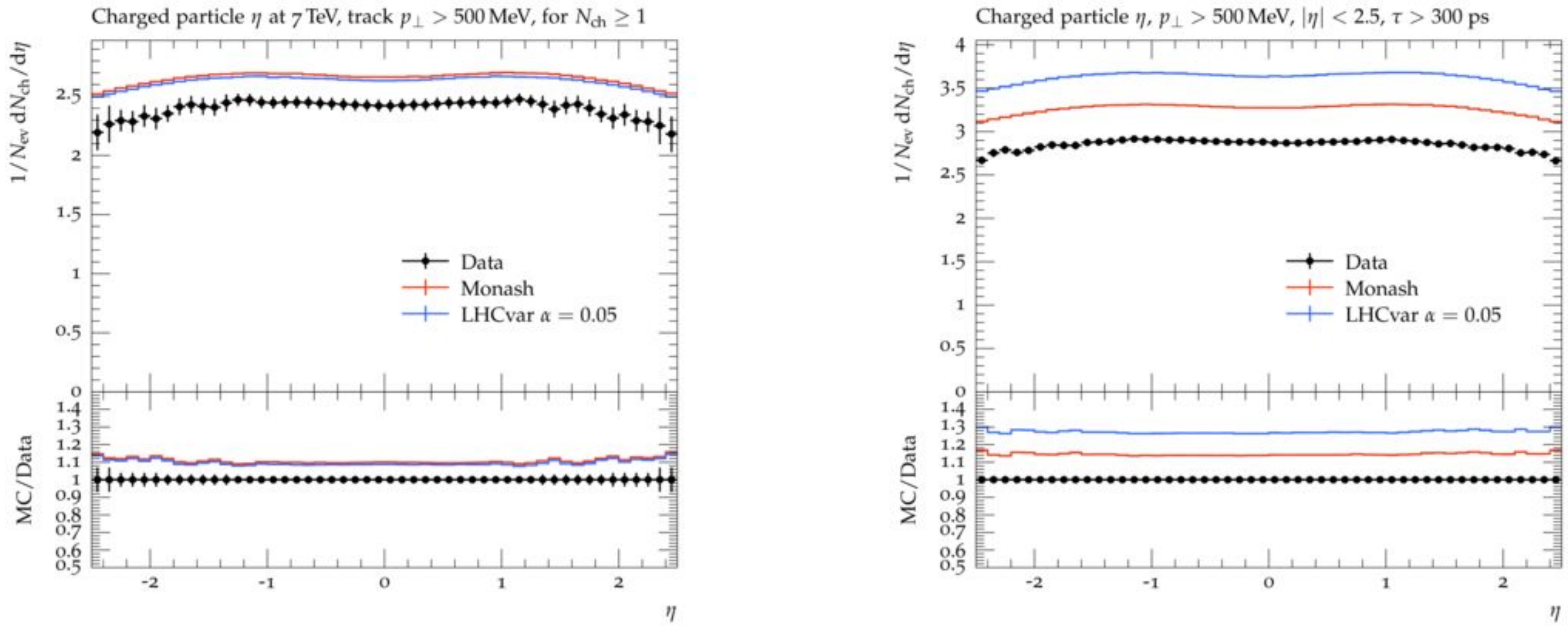
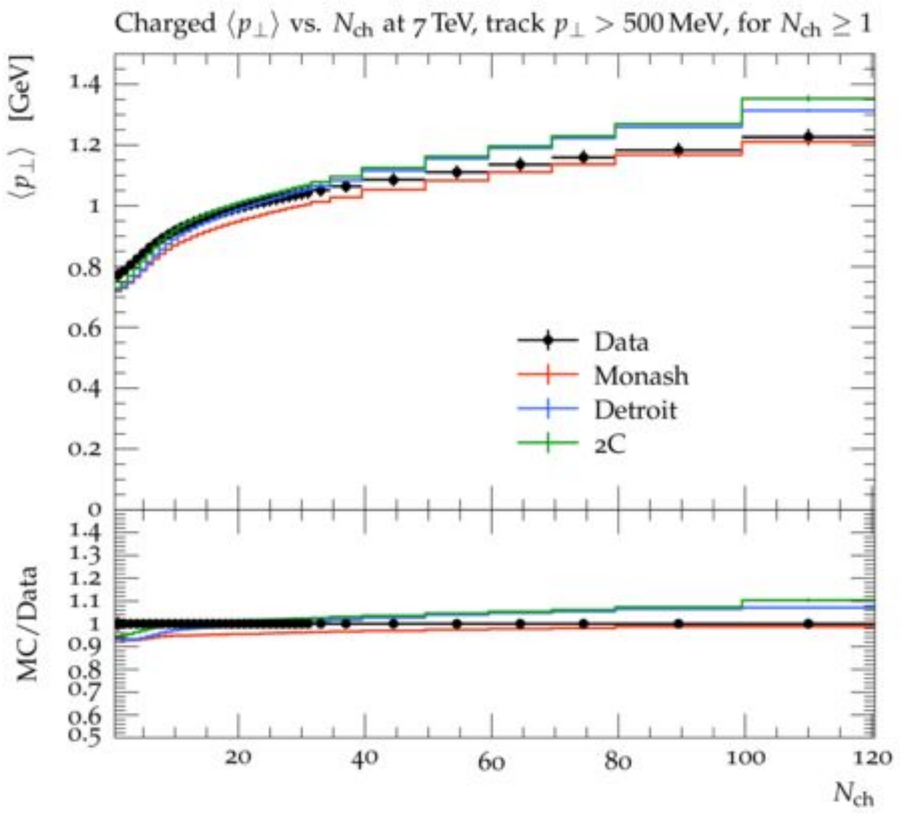
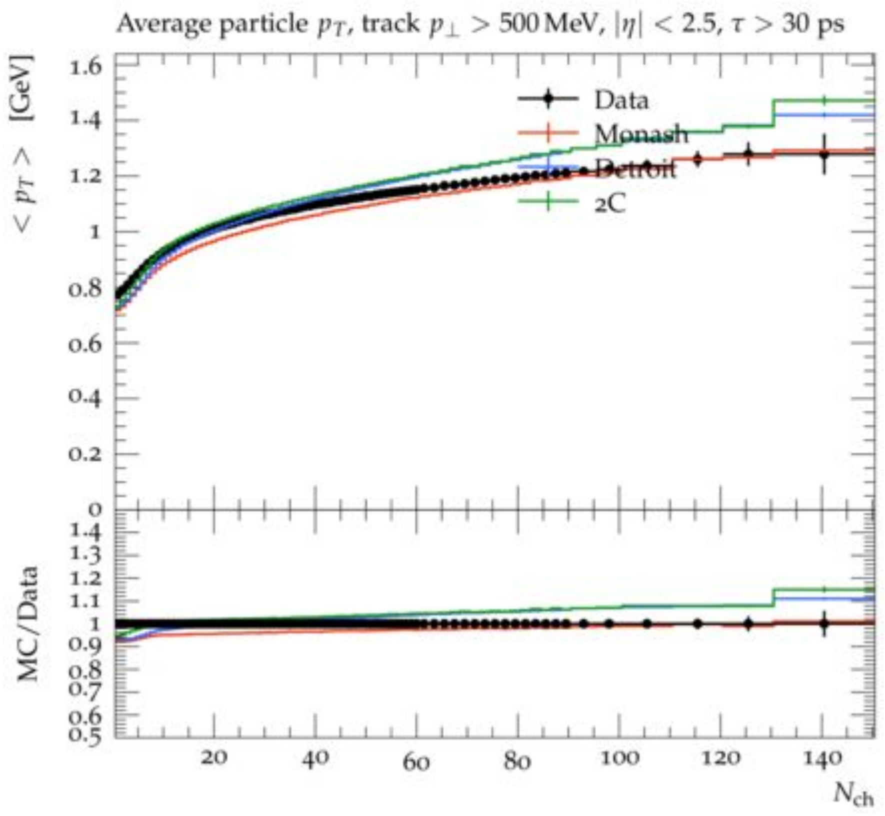
APPENDIX: LHC PLOTS



- Plots to test LHCvar on LHC MB data. 7 TeV data (left) and 13 TeV data (right).
- Tune performed well on 7 TeV data (by design) but not on 13 TeV data (compared to Monash)





- Plots to compare Detroit, 2C and Monash tunes on LHC MB data. 7 TeV data (left) and 13 TeV data (right).
- Monash tune provides best agreement.