Measurement of azimuthal decorrelation between leading jets and DIS lepton at HERA

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We present measurements of the azimuthal decorrelation between the most energetic jet of an event and the deep inelastic scattered lepton, obtained by the ZEUS experiment during the HERA II data taking. The analysis consist of 189 pb^{-1} for $e^{-}p$ and 143 pb^{-1} for $e^{+}p$, of integrated luminosity. Results for each collision sample period are presented. The results are also compared to predictions from perturbative QCD calculations.

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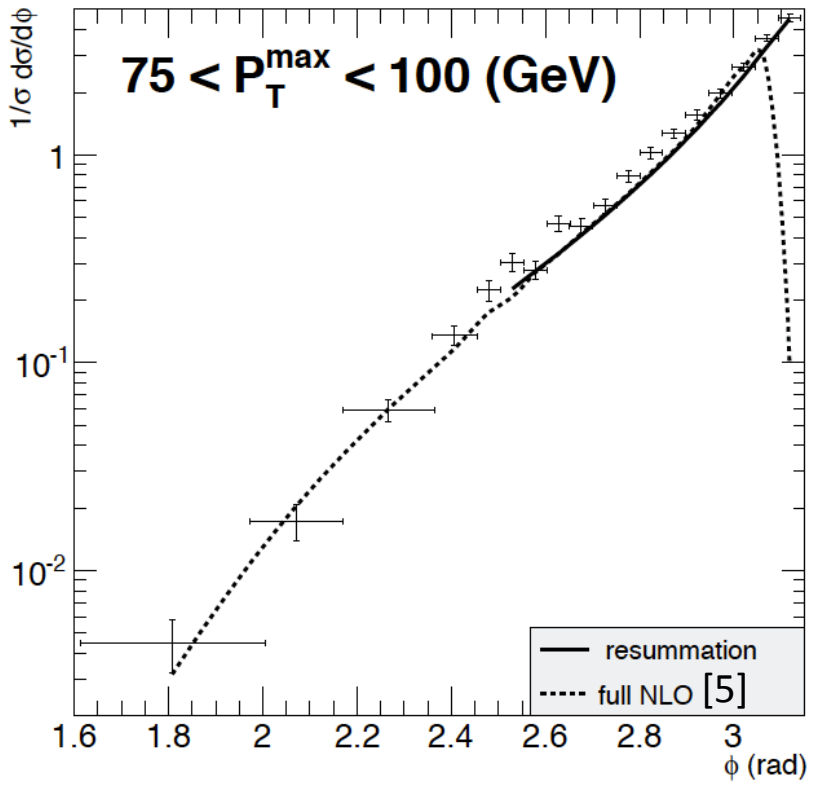
Introduction

- Azimuthal angular decorrelation of two jets, have been studies in hadron collisions [1-3].
- The leading order (Born diagram) naïve parton picture calculations, there is a divergence when $\phi = \pi$.
- Gluon radiation produce this singularity which persist at higher orders.
- Resummation needs to be include to avoid these divergences (Feng Yuan studies [4]) .
- Good matching of resummation method[4] with Tevatron[1], CMS[2] and Atlas[3] results.

Figure from [4]



Motivation*

- Build the case for **EIC** i.e. what is the pt range, what is the systematics, etc.
- Understand **small-x TMDs**. The kinematic region at HERA has not been covered before.
- Study the **Q^2 dependence** on TMD evolution. Previous measurements for proton collisions were done at very high p_T (~100GeV). **Low p_T** will probe the non-perturbative TMDs.

* From Feng Yuan

Zeus data analysis

Data:
040506e ~189 pb^{-1}
0607p ~143 pb^{-1}

MC:
ari_incl_nc_DIS_lowQ2_05e
ari_incl_nc_DIS_lowQ2_06e
ari_incl_nc_DIS_lowQ2_0607p

Phase Space:
$10 < Q^2 < 350\ GeV^2$

Cleaning cuts:
-40 < Zvtx/cm < 40
35 GeV < $E - p_z$ < 65 GeV

Electron cuts:
Siecorr > 10 GeV
140^o < Theta < 180^o
Electron position sqrt($x^2 + y^2$) > 20.0
Siprob[0], the lepton with highest prob.

Triggers:
SPP02 (Tltw[2] & (1 << 1)) for 0405e
SPP09 (Tltw[2] & (1 << 8)) for 06e and 0607p

Jet selection:
E_T > 2.5 GeV (energy corrected)*
|eta| < 1.0
Using "Kt_etjet_b[0]", the leading jet only

* Already applied in the orange
Cuts similar to slide 5 of: (in red the differences)
[0] https://www-zeus.desy.de/ZEUS_ONLY/meetings/zems/group30/meet276/sess2812/pres12368/01_pr_photons_jets_04_05_2.pdf

Control plots

Total number of jets:

040506e: 6 180 493

0607p: 4 334 200

MC sample is not weighted by luminosity but normalized to the number of entries of the data.

electron

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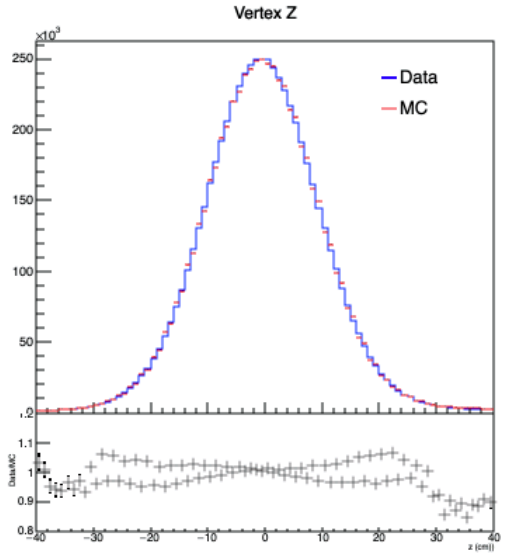

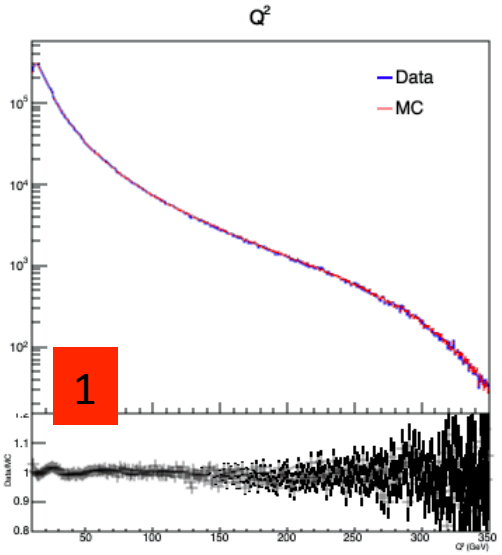

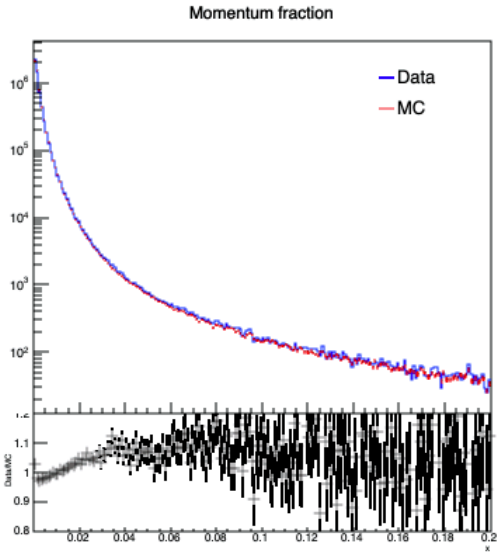

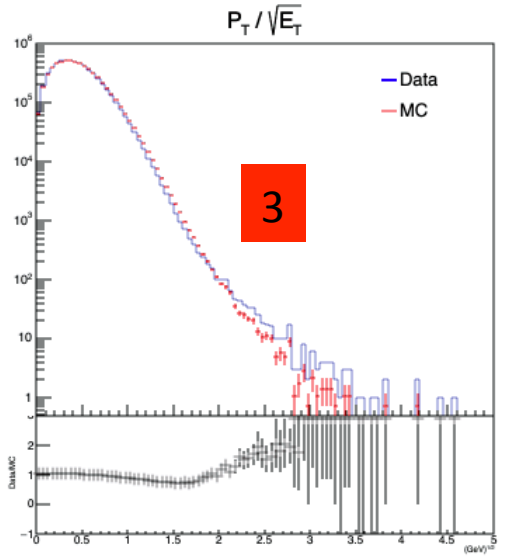

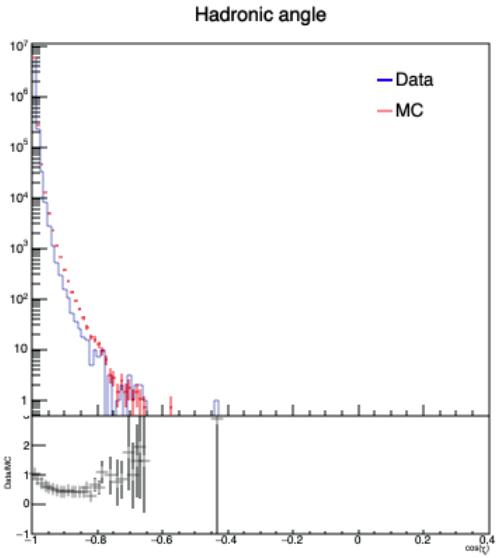

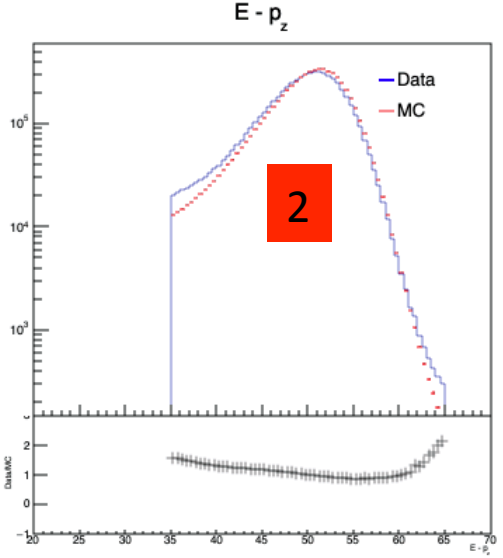

positron

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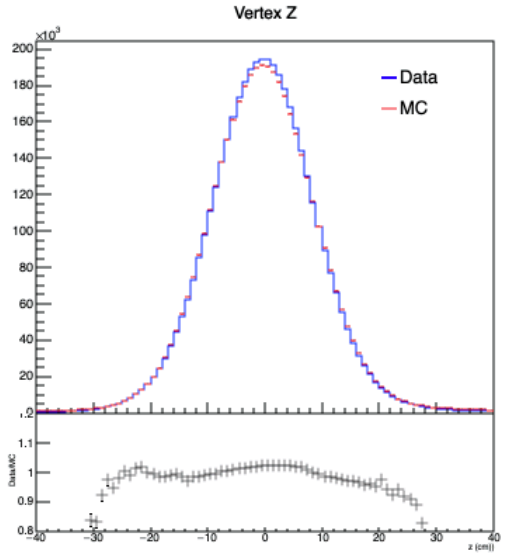

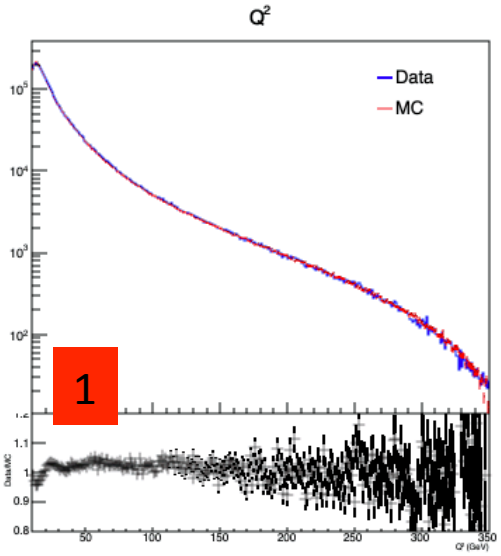

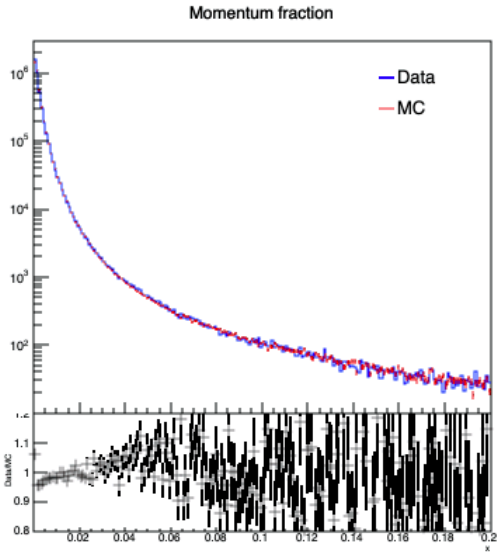

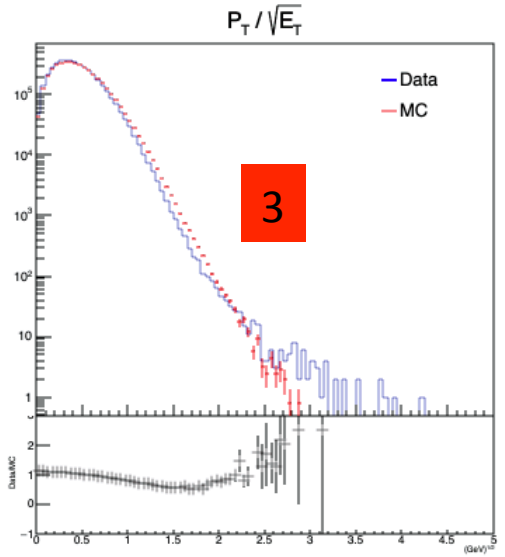

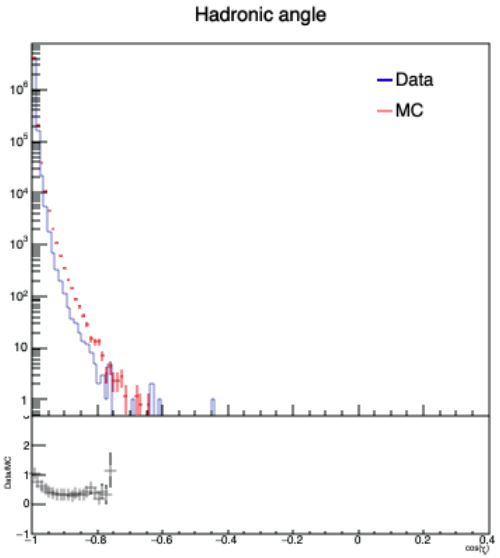

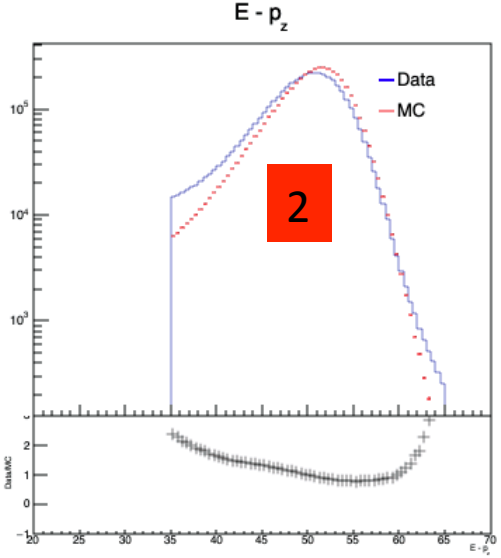

Data − MC comparison

1. Moderate matching at $\mathbf{Q^2 < 30}$, in particular for positron (Siq2el[0]).
2. Very bad matching for $\mathbf{E - p_z}$ (Cal_empz). MC seems to be shifted to the right.
3. No cut applied in $P_T/\sqrt{E_T}$. Also seems shifted.

→Apply $P_T/\sqrt{E_T} < 2.0$ like inclusive jets in NC DIS (they used 2.5). Not working!

- Using Cal_pt / sqrt(Cal_et) < 2.0
- Plotting cos(Cc_gamma) in the middle lower plot but no appliying any cut. In previous jet analyses it was used $|\cos(\gamma)| < 0.65$ but not possible to apply here.

electron

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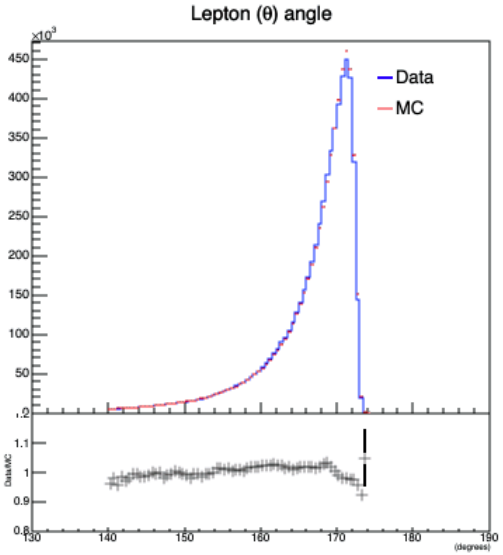

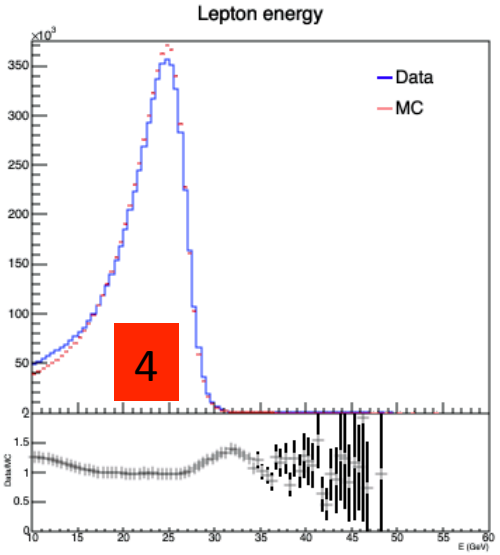

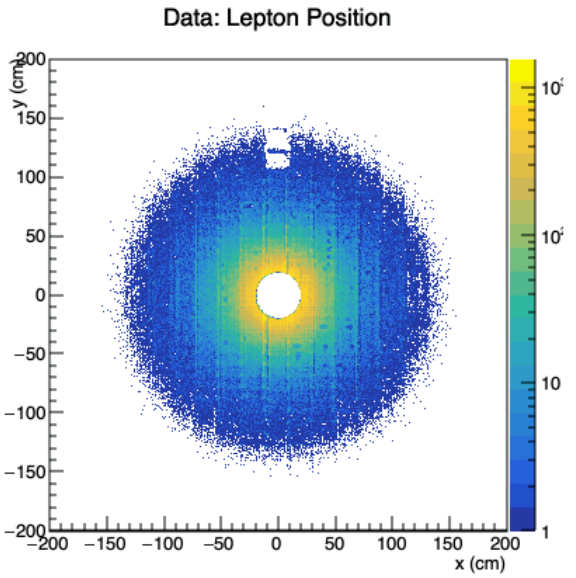

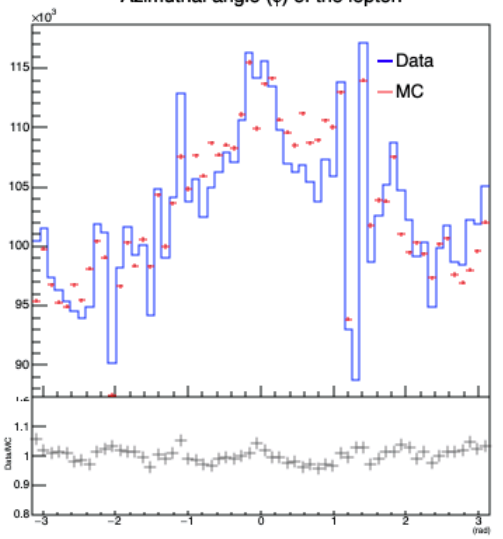

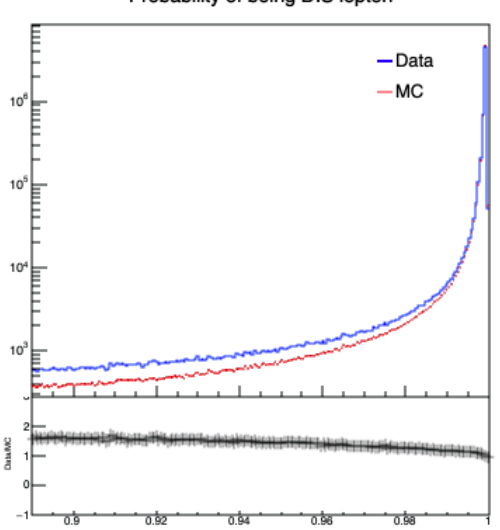

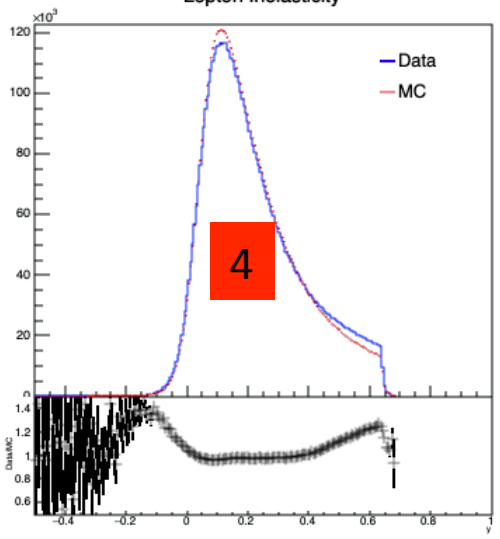

positron

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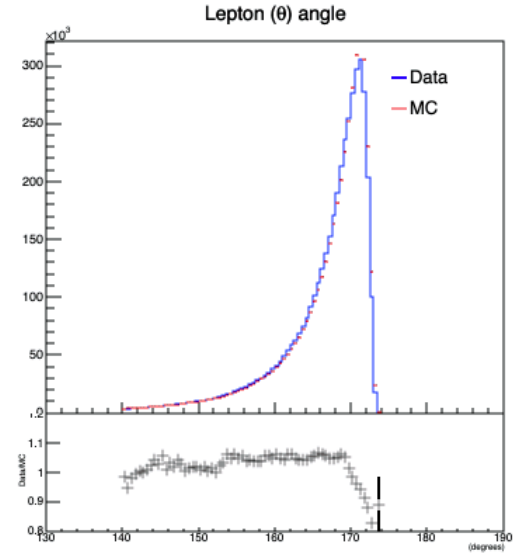
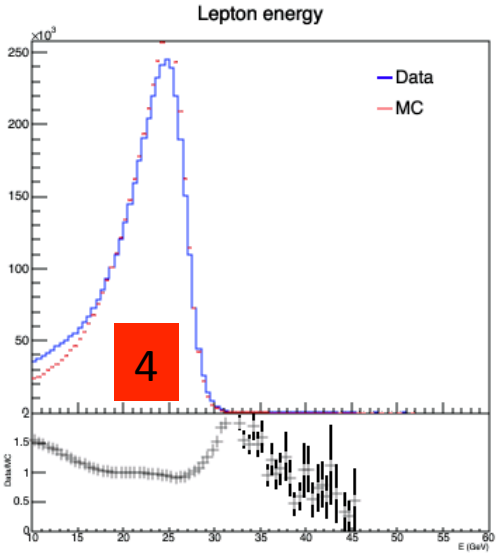
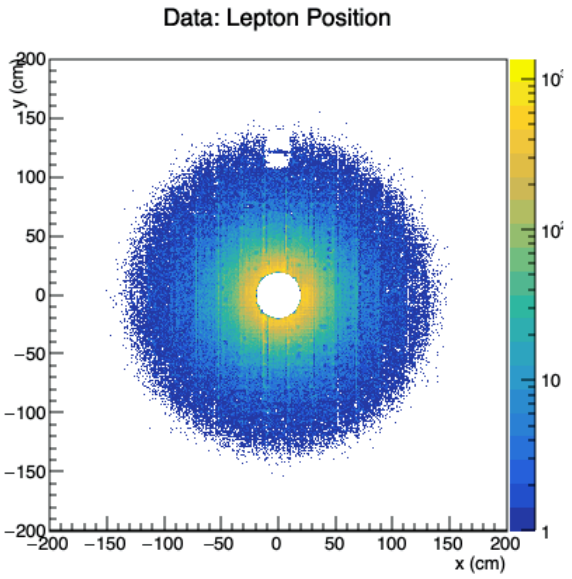
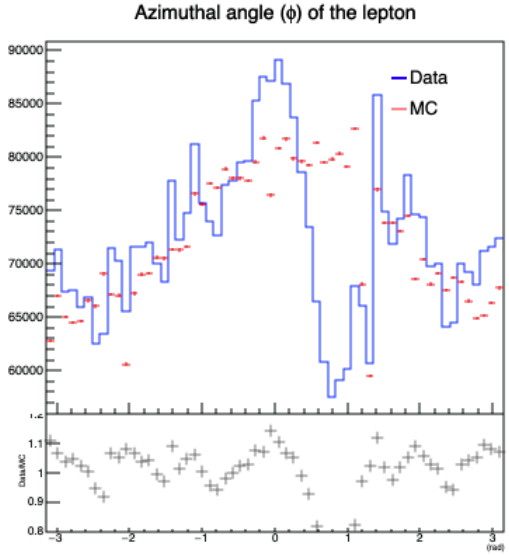
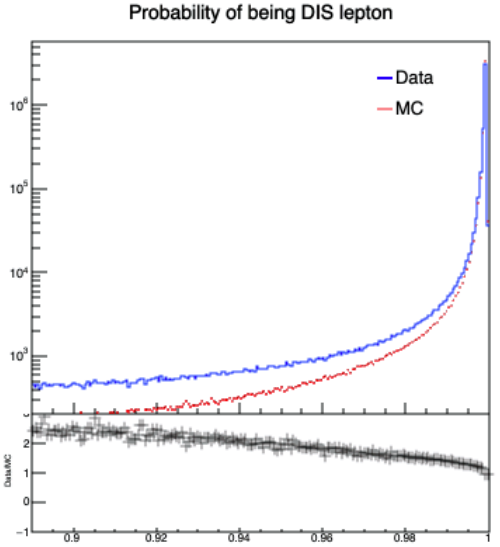
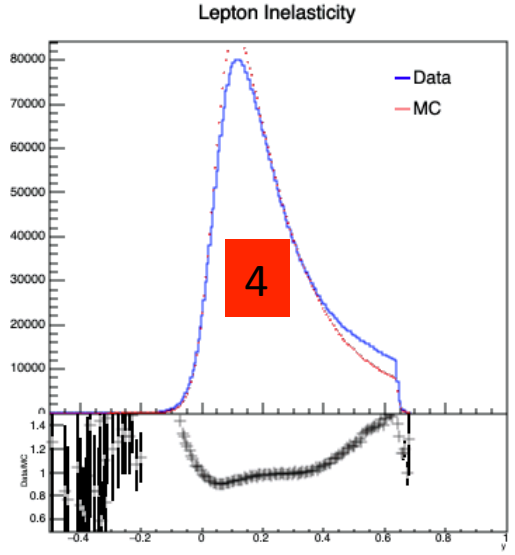












Data – MC comparison

4 Poor matching for low and high lepton **energy** which reflects also in the **inelasticity** (due PHP?). Also might be related to $P_T/\sqrt{E_T}$.

→ Apply Siyel[0] > 0.05 like the website

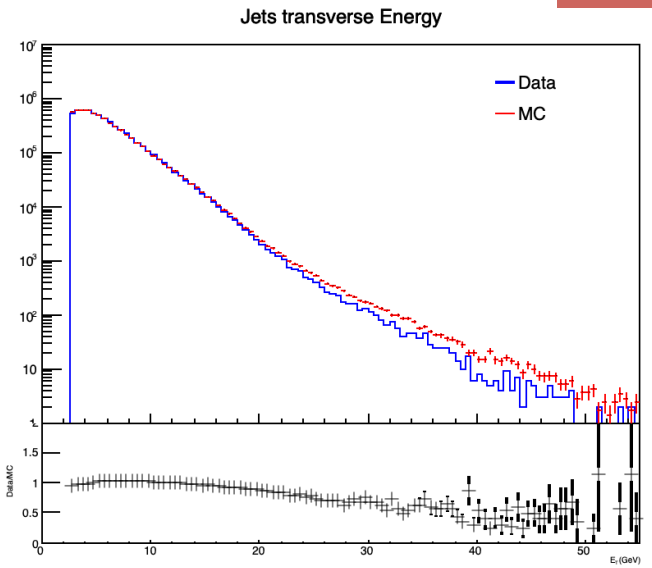
~ZEUS_ONLY/analysis/primer/DIS *

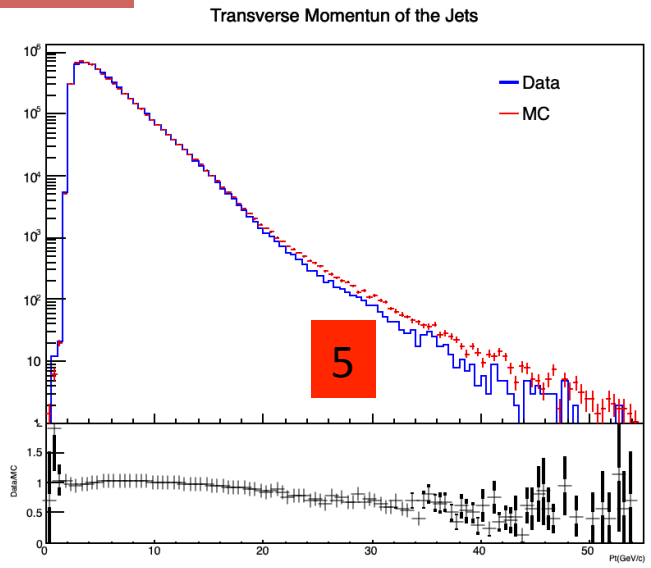
Not working!

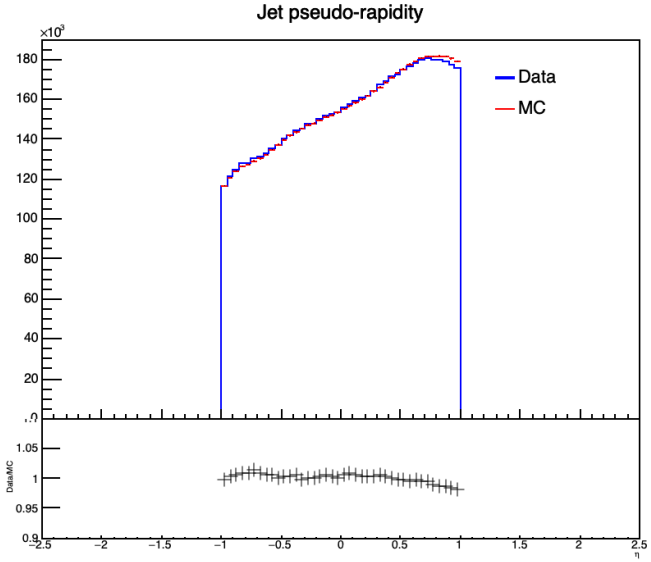
* In the web site the cut is Siyjb[0] > 0.04

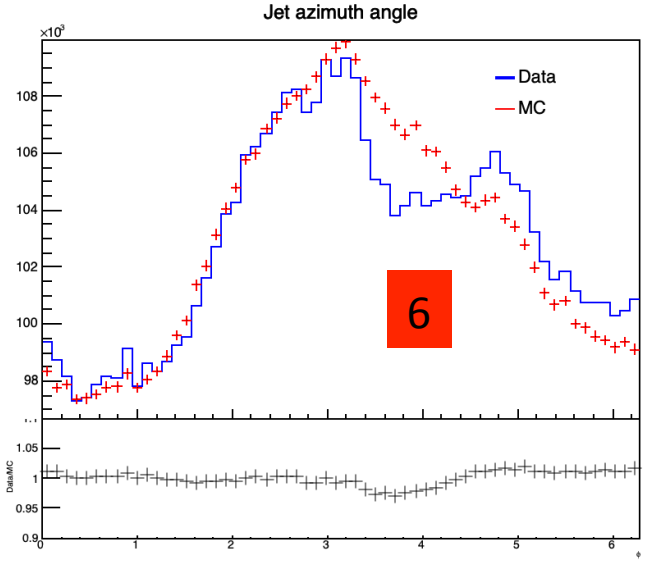
electron

File Edit View Options Tools Help



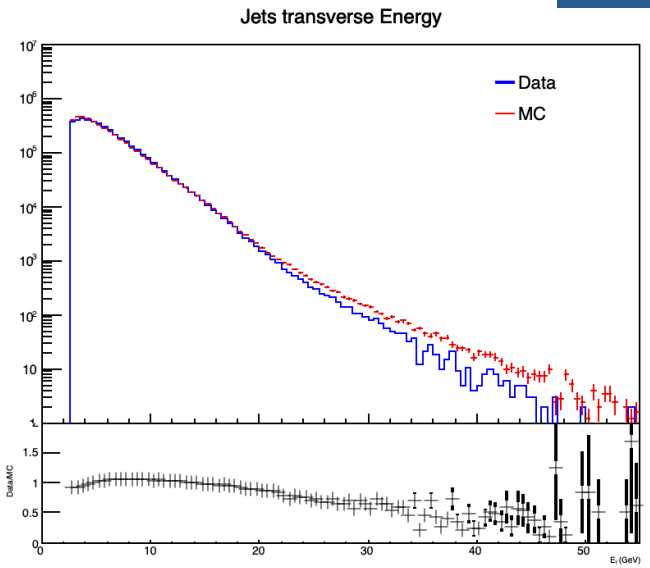


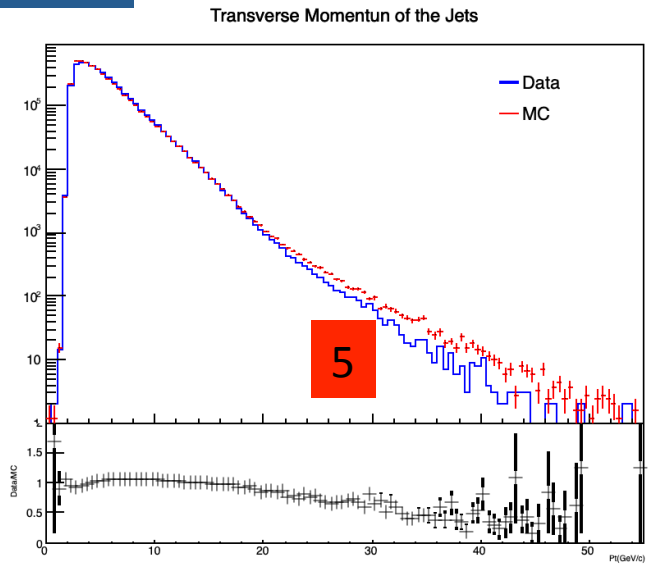


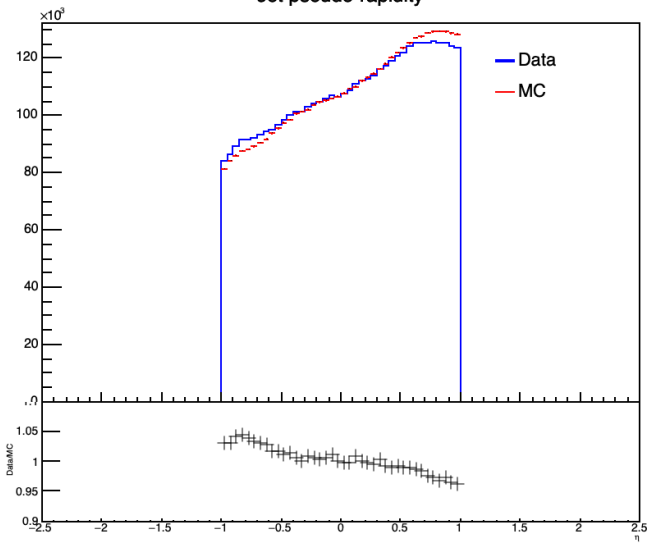


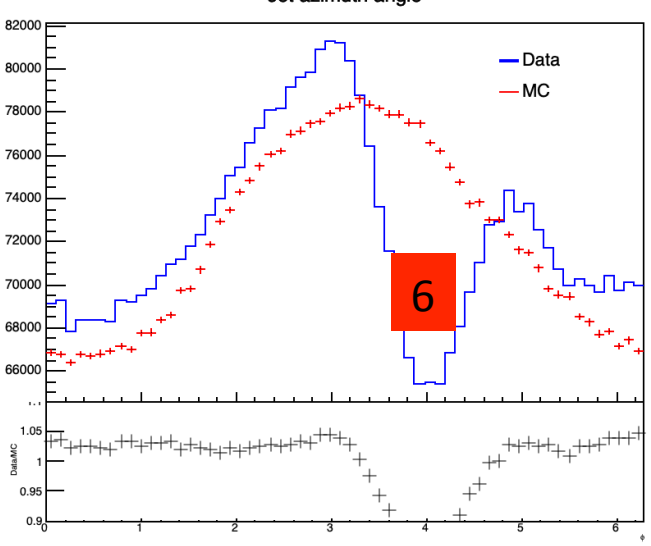
positron

File Edit View Options Tools Help









Data − MC comparison

5. Poor matching at jet $\mathbf{p_T > 20}$ ($p_T = \sqrt{(E^2_T - m^2)}$).

   → This seems to be related to the PHP background (see backup).

6. Small matching difference (5%) for jets at $\boldsymbol{\pi < \phi_e < 3\pi/4}$ (missing some detector status?).

electron

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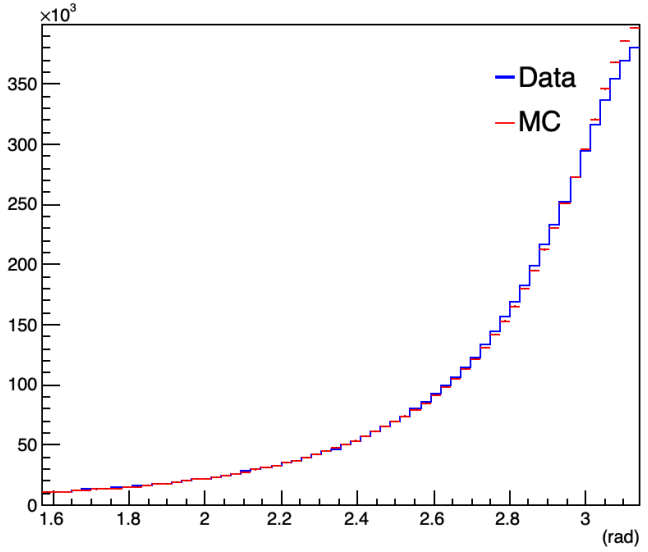
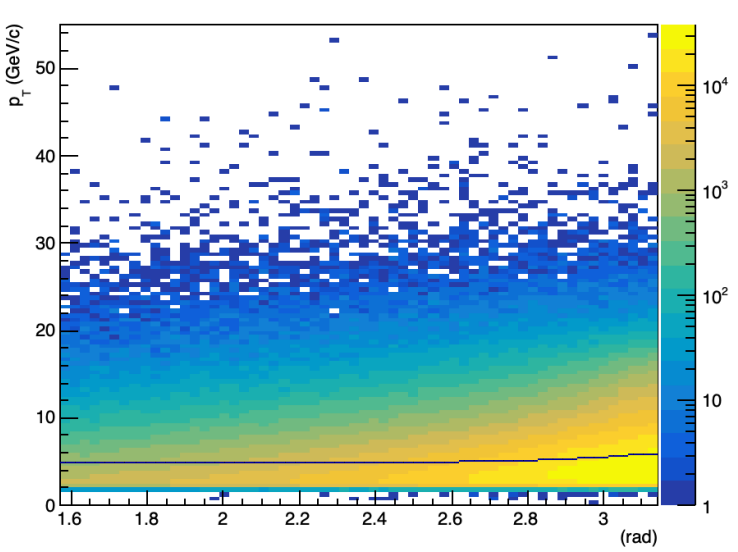
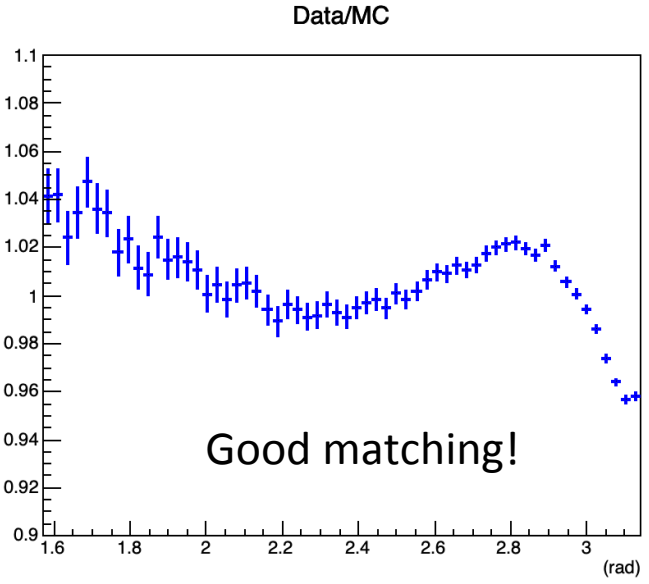






Jet: $0 < \phi_{jet} < 2\pi$

Lepton: $-\pi < \phi_{lep} < \pi$

➔ $\Phi_{lep} = \phi_{lep}$ if $\phi_{lep} > 0$

$= 2\pi + \phi_{lep}$ if $\phi_{lep} < 0$

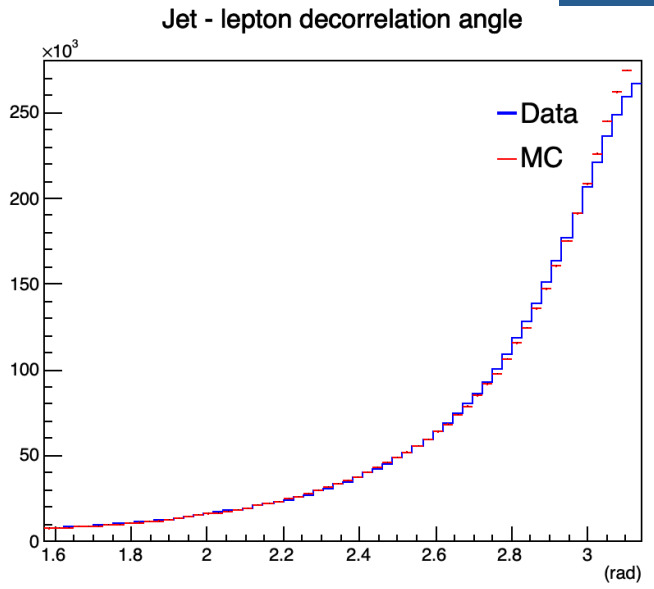
Decorrelation angle:

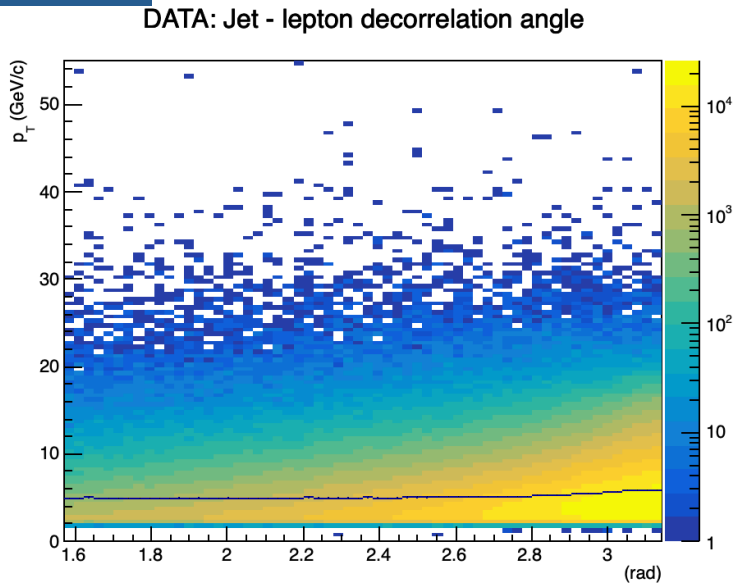
$\Phi = |\phi_{jet} - \phi_{lep}|$ if $< \pi$

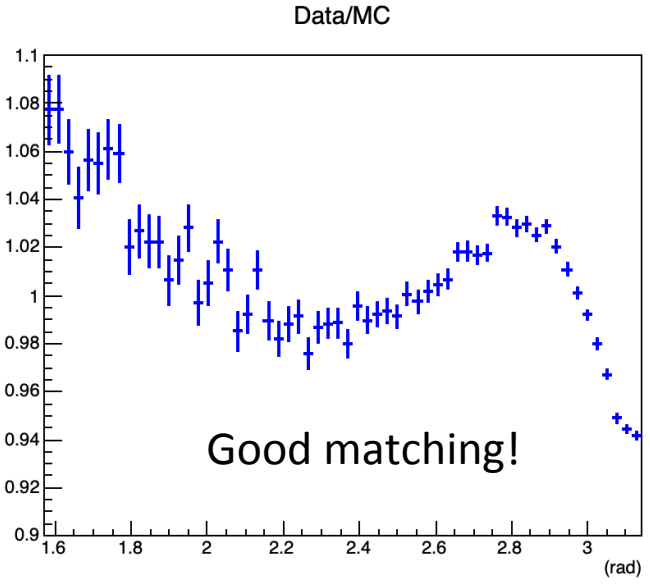
$2\pi - |\phi_{jet} - \phi_{lep}|$ if $> \pi$

positron

File Edit View Options Tools Help







Jet: $0 < \phi_{jet} < 2\pi$

Lepton: $-\pi < \phi_{lep} < \pi$

➔ $\Phi_{lep} = \phi_{lep}$ if $\phi_{lep} > 0$

$= 2\pi + \phi_{lep}$ if $\phi_{lep} < 0$

Decorrelation angle:

$\Phi = |\phi_{jet} - \phi_{lep}|$ if $< \pi$

$2\pi - |\phi_{jet} - \phi_{lep}|$ if $> \pi$

Summary

- Perform decorrelation measurements of DIS lepton with leading jet, similar to Tevatron, CMS and Atlas.
- Initial studies for futures EIC measurements.
- Providing measurements to test Feng Yuan resummation model with this data. Measurements needed at low x and broad Q^2 range.
- Mismatch at low Q^2. Also need to expand Q^2 range. How to do this? Triggers?
- Jet eta mismatch is a known issue?.
- Mismatch for leptons might be related to PHP contamination.
- Very tight inelasticity cut $0.05 < y < 0.4$ makes the matching works better (see backup).

To do

- Need to study a PHP simulation sample to improve the data MC matching.
- After good matching:
  - Might need to weight the MC sample DIS photon-jet study.
  - Need to calculate acceptance corrections.
- Separate the differential cross section in pt bins (maybe 2 or 3 bins).
- Systematics might be done as the DIS photon-jet study and/or NC DIS inclusive jets.
- Study decorrelation with jet multiplicity, like Atlas plot (see backup slide 27).

References

[1] Phys. Rev. Lett. **94**, 221801 (2005). D0

[2] Phys. Rev. Lett. **106**, 122003 (2011). CMS

[3] Phys. Rev. Lett. **106**, 172002 (2011). Atlas

[4] Phys. Rev. D **92**, 094007 (2015). Feng

Backup

Code

- Location: /afs/desy.de/user/q/quintera/public/ThirdTry
- Macro: MakeHist_v3_1.C
- Script to run: > sh runInc.sh # (# is a number)
- To submit: > condor_submit QA.job

Change the path of the script and submit script.

electron

$0.05 < y < 0.4$

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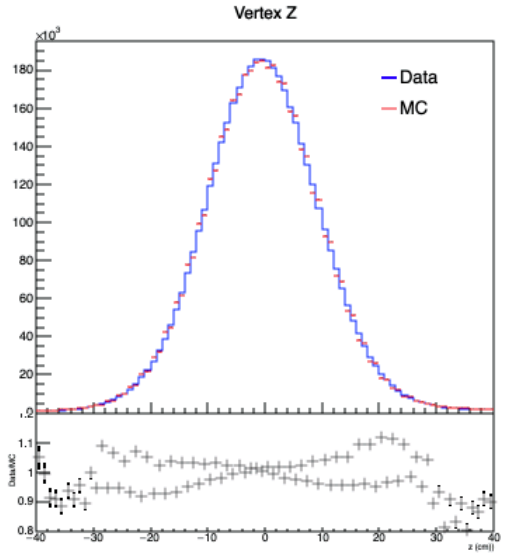
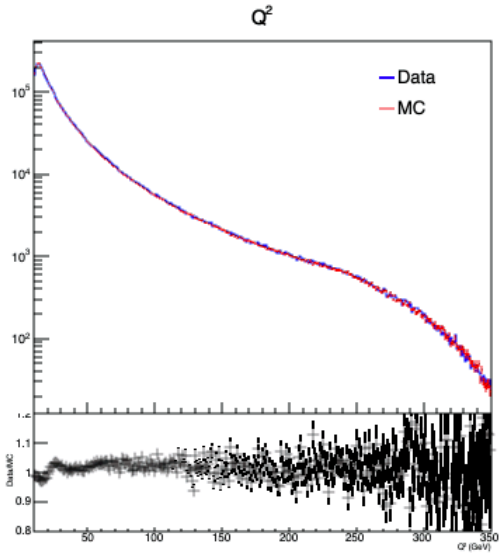
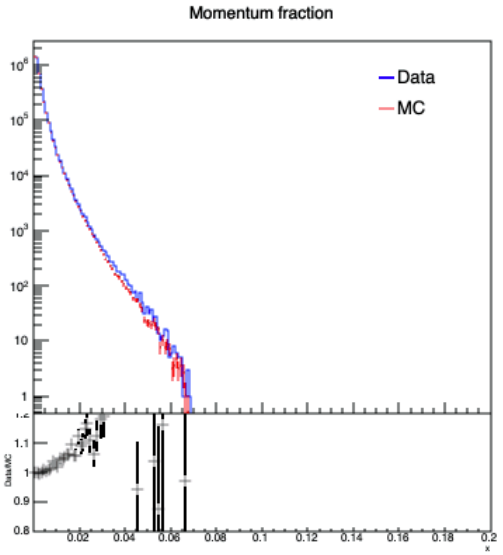
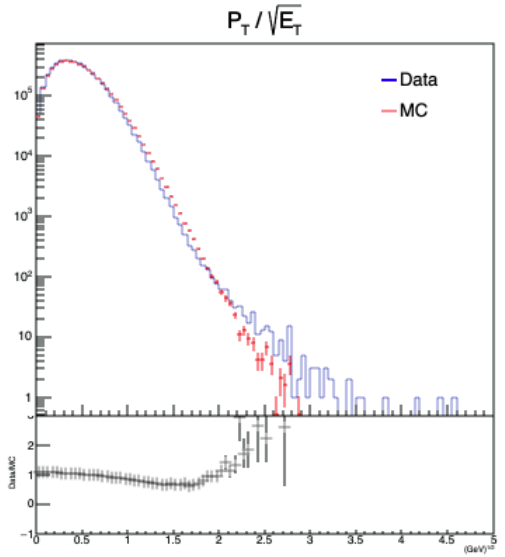
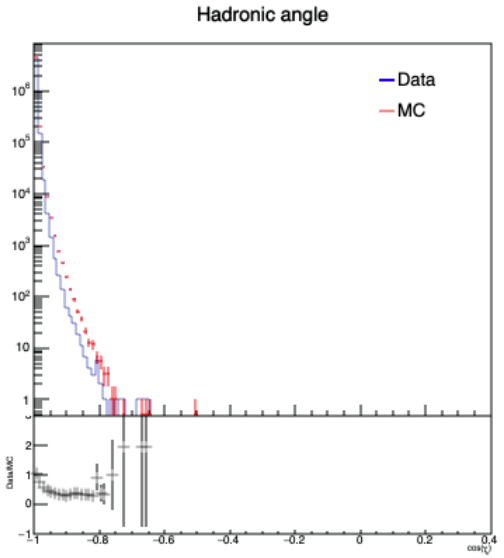
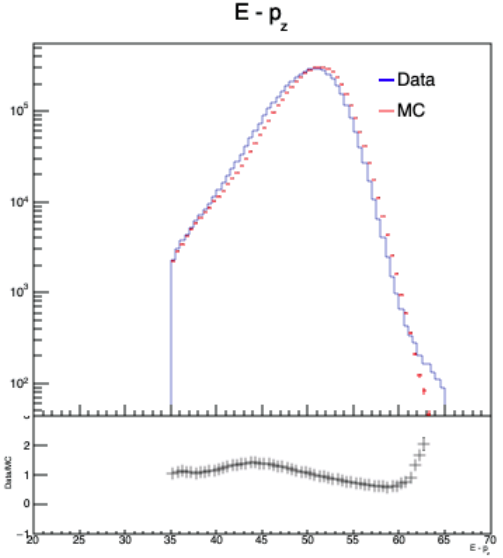








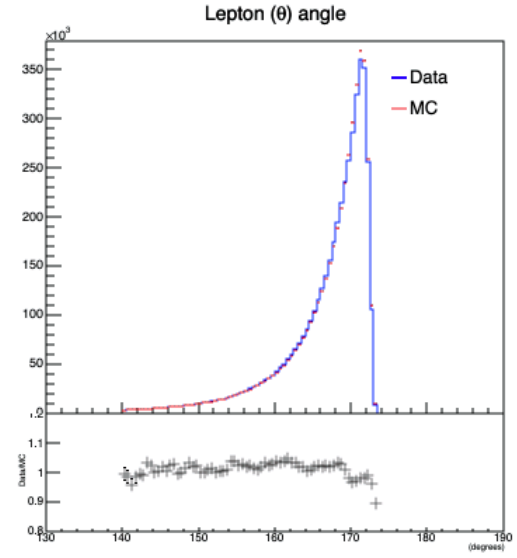


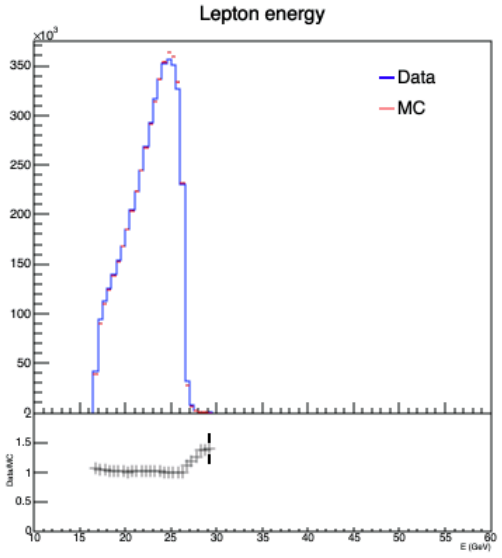


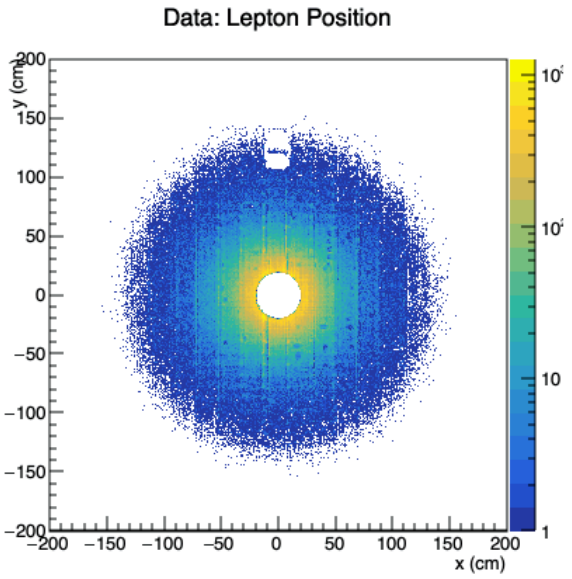
electron

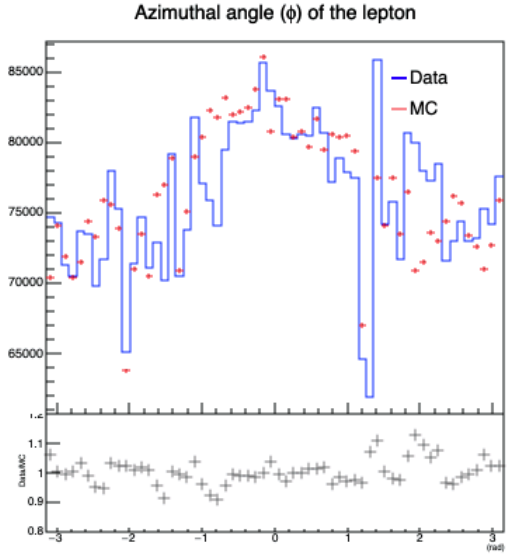
0.05 < y < 0.4

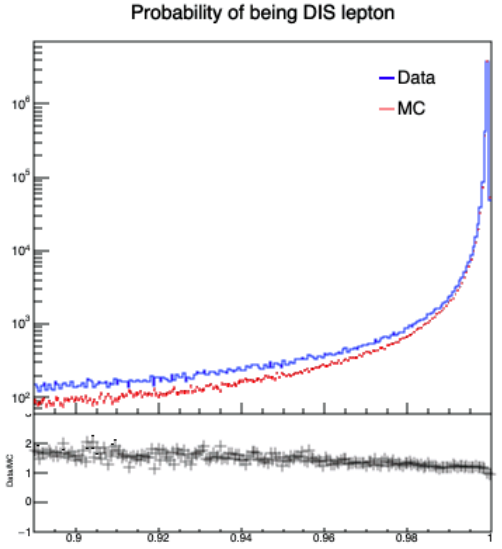
File Edit View Options Tools Help

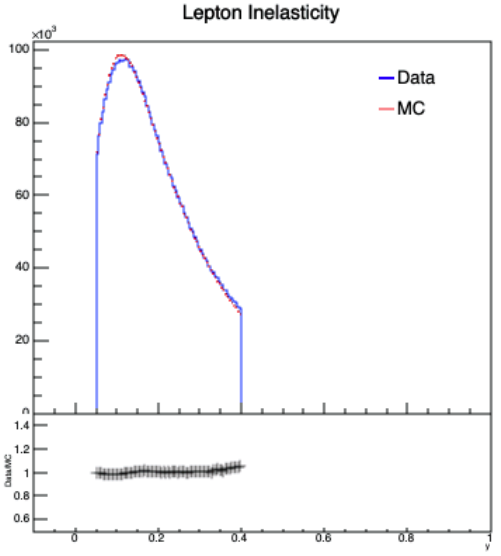








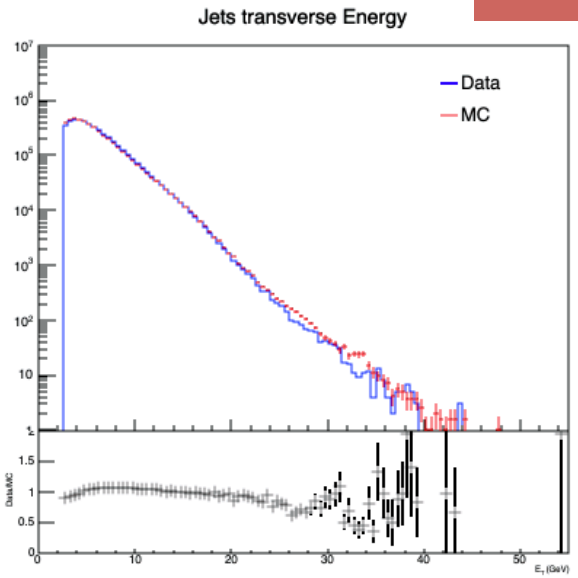


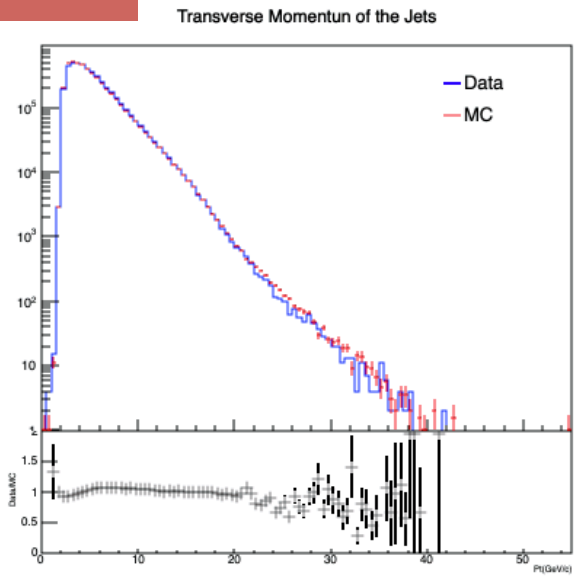


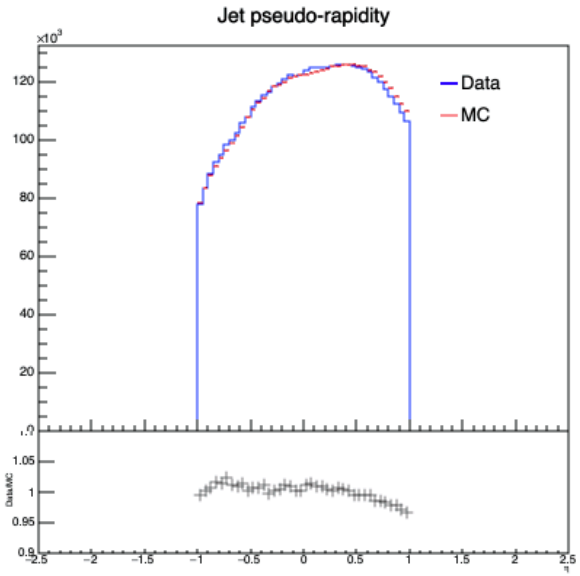
electron

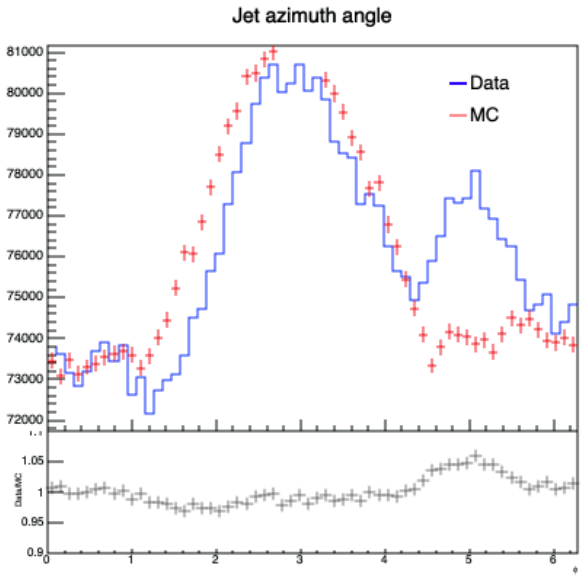
$0.05 < y < 0.4$

File Edit View Options Tools Help





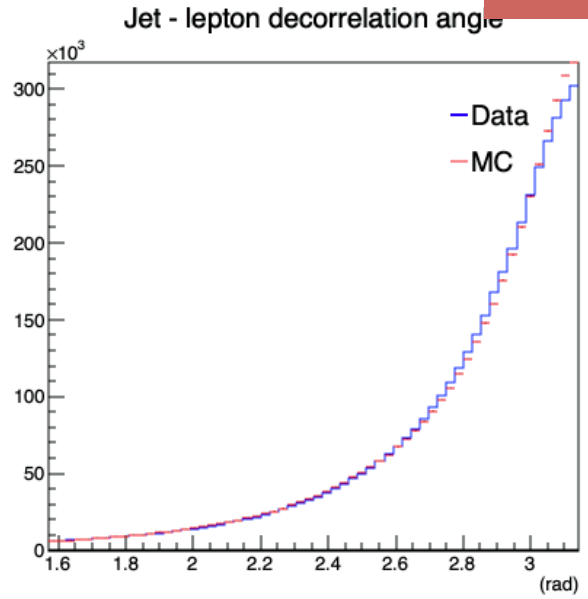


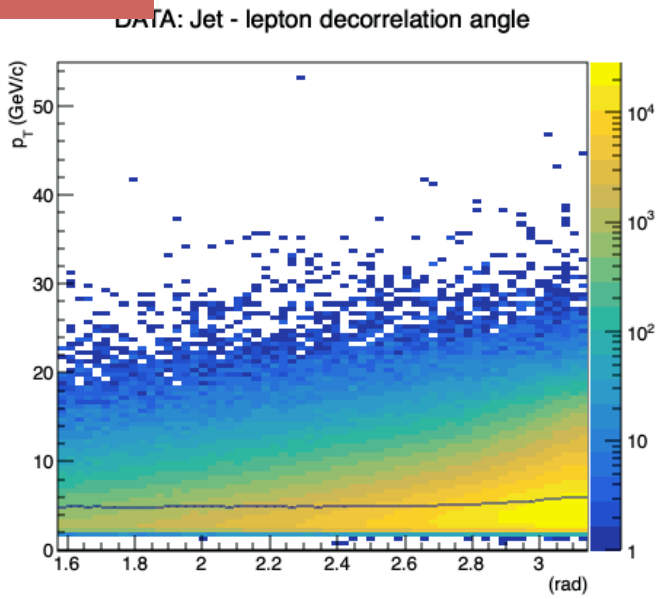


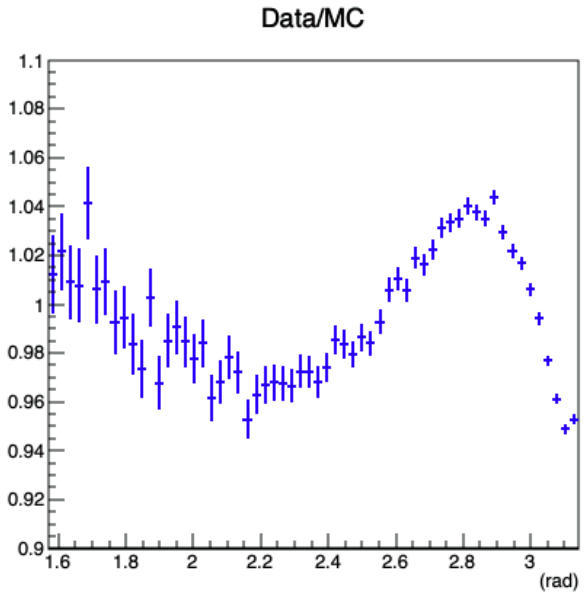
electron

0.05 < y < 0.4

File Edit View Options Tools Help

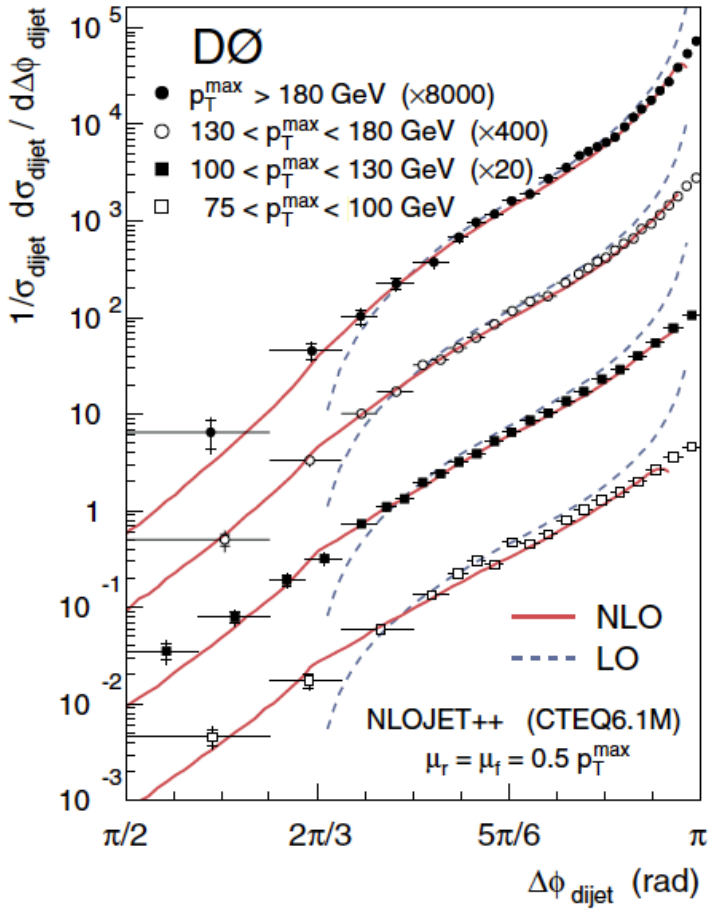






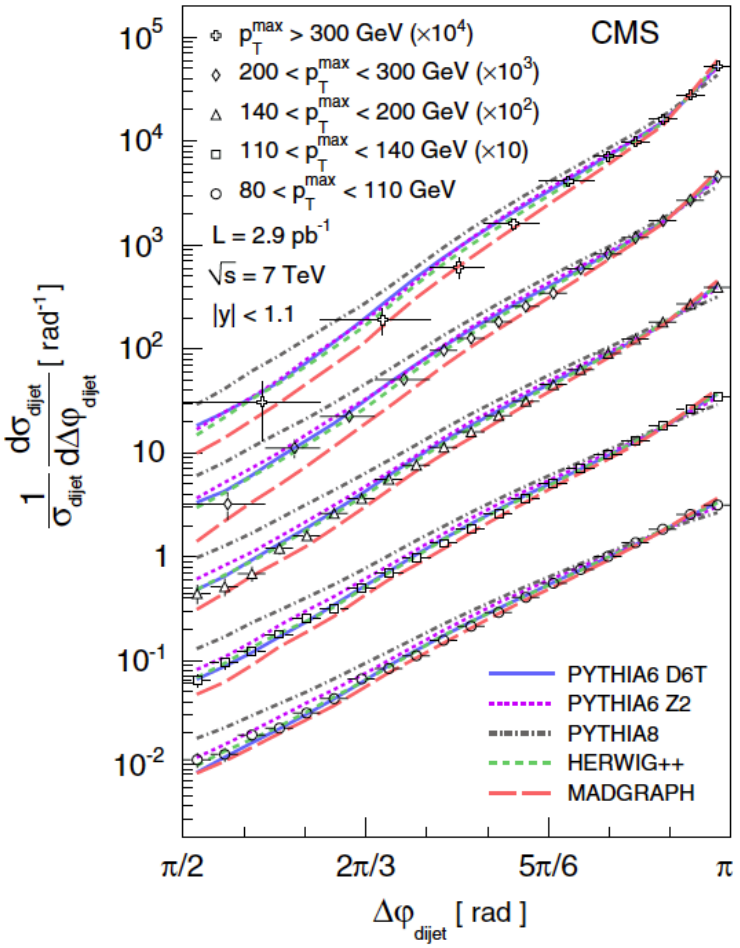
TEVATRON [2]

- Proton − antiproton
- √s = 1.96 TeV
- Di-jets, cone R=0.7
- Jet |y| < 0.5



CMS [3]

- Proton − proton
- √s = 7 TeV
- Di-jets, anti-kt R=0.5
- Jet |eta| < 2.5
- “The predictions near ϕ = π dijet have been excluded because of their sensitivity to higher-order corrections not included in the present calculations.”



ATLAS [4]

- Proton − proton
- √s = 7 TeV
- Di-jets, anti-kt R=0.6
- Jet |y| < 0.8
- Jet multiplicity figure also