Azimuthal correlations at HERA and indications of multiparton interactions

1st part:

- Goals of the analysis
- Reminder of the basics of the analysis
- Comparisons to H1
- Results & conclusions

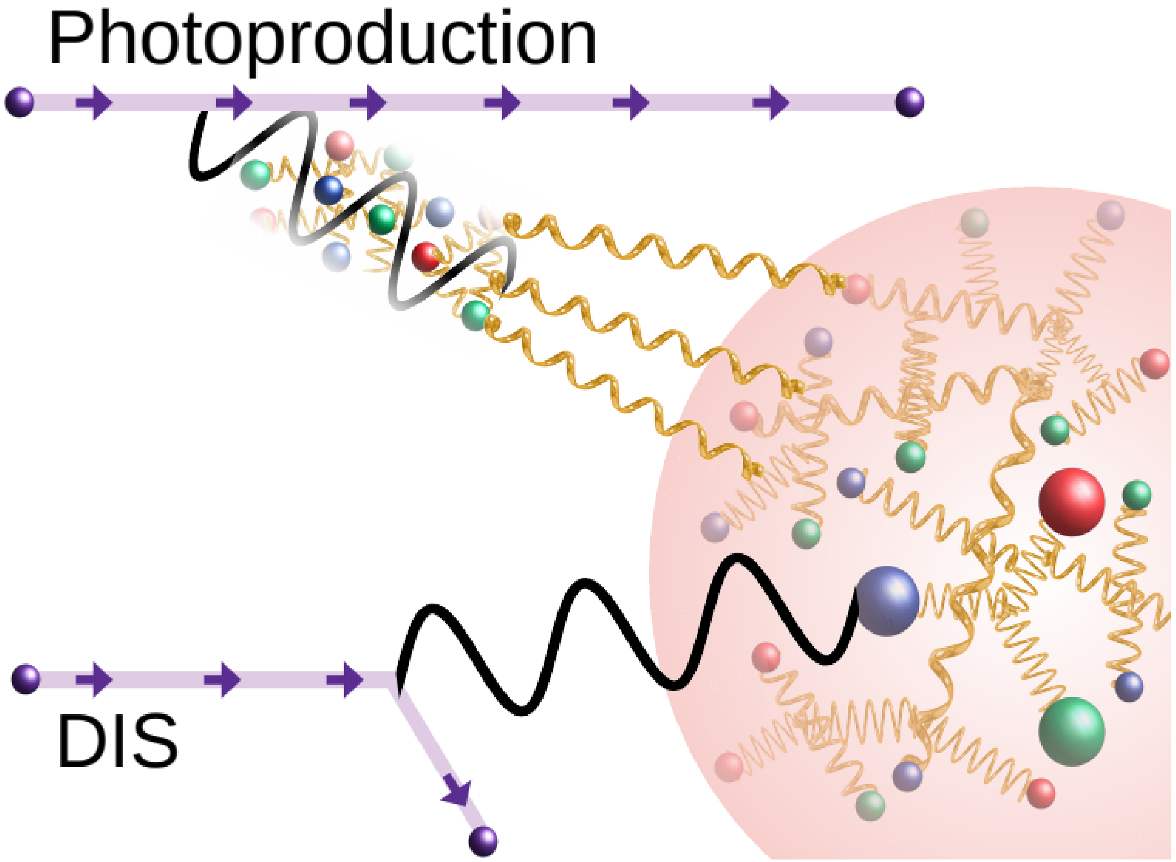
2nd part:

- Discussion of comments raised by Achim since November

Pre-EB meeting
22-01-2021
Dhevan Gangadharan

Topic of the publication

- In 2010, the LHC revealed evidence for "collective behavior" among the produced particles in *pp* collisions that resembles those found in heavy-ion collisions. This implies that a quark-gluon plasma might also form in "small" systems.
- **Goal:** search for collective behavior in DIS and PhP as well as multiparton interactions (MPIs) PhP.



- Figure 1 for the paper (work in progress)
- Illustrates the initial scattering in two separate scenarios at HERA.
- Hadronic component of photon shown for resolved PhP, as well as MPIs.

Azimuthal correlations to probe collective behavior and MPI

The correlation functions used in this analysis are defined as:

<u>2-particle azimuthal correlations</u>

$$c_n\{2\} = \langle \cos\left(n(\varphi_1 - \varphi_2)\right)\rangle$$

harmonic

Azimuthal angle particle 1

Azimuthal angle particle 2

Borghini, Dinh, Ollitrault
PRC 64 054901

<u>4-particle azimuthal cumulants</u>

$$c_n\{4\} = \langle \cos\left(n(\varphi_1 + \varphi_2 - \varphi_3 - \varphi_4)\right)\rangle - 2\,\underbrace{\langle \cos\left(n(\varphi_1 - \varphi_3)\right)\rangle \langle \cos\left(n(\varphi_2 - \varphi_4)\right)\rangle}$$

Explicit removal of 2-body “non-collecitve” bkg correlations

- What’s left, after the subtraction, is a measure of “genuine” 4-particle correlations and suppresses few body contributions.
- More robust probe of collectivity.

Data samples

ZEUS data

Dataset	Version	All events	T	T+V+O PHP (DIS)	T+V+O+N_{ch} > 20 PHP (DIS)
03p	v08b	3.7 M	0.99 M	0.27 M (0.2)	0.031 M (0.001)
04p	v08b	47.5	12.6	3.7 (4.7)	0.455 (0.019)
05e	v08b	130.0	43.9	14.8 (16.4)	1.972 (0.082)
06e	v08b	44.2	13.4	4.5 (7.0)	0.726 (0.034)
06p	v08b	86.6	26.3	9.3 (11.8)	1.402 (0.053)
07p	v08b	41.2	11.1	3.7 (5.4)	0.524 (0.022)
Total	-	353.2 M	108.3 M	36.3 M (45.5)	5.110 M (0.211)

Table 1: *Real data samples and event tallies for the PHP (DIS) analysis. The analyzed real data samples and number of events. T = trigger selection, V = Vertex cut, O = Offline cuts.*

PhP MC: Pythia light-flavor jet

DIS MC: Ariadne and Lepto

We do not have inclusive PhP MC. The closest one we have is this one below.

used for efficiency and trigger-bias corrections

Dataset and code names	All events	T	T+V+O	T+V+O+N_{ch} > 20
light-flavor jet 0304p cny324, cnx324, cnw324, cn3z24	128.2 M	14.2 M	8.9 M	1.0 M
light-flavor jet 05e dsmr25	121.4	14.0	8.9	0.9
light-flavor jet 06e etrr26	149.5	17.3	11.1	1.3
light-flavor jet 0607p fiw627	195.5	22.7	14.4	1.5
Total	594.6 M	68.2 M	43.3 M	4.7 M

Table 2: *The analyzed Pythia light-flavor jet PHP MC samples and number of events. MC $Q^2 < 2$. Both direct and resolved components were summed together. T = Trigger selections, V = Vertex cuts, O = Offline cuts. v08b orange nTuples used.*

Event selection

Trigger selection

	TLTs
PHP	HFL 1 || 5 || 21 || 28
DIS	DIS 1, 2, 3, 4, 5, 6, 11 SPP 1, 2, 3, 9 HFL 17, 31

N_{ch} >= 20
for all plots
except for a few N_{ch} or N_{rec} distributions

Primary vertex selection (same as in past DIS analysis)

	Vz	Vxy	$N_{vtx\ tracks}$	$N_{vtx\ tracks}$ / N_{tracks}	Event vertex Chi^2 / $N_{vtx\ tracks}$
PHP & DIS	-30 < V_z< 30 cm	< 0.5 cm	>= 1	**> 0.15** ***Was 0.1 before***	< 50

Offline selection

	Electron probability	Q2	Electron theta	Electron energy	E - P_z	Sinistra CAL entrance locations
PHP	< 0.9	No cut	No cut	< 15 GeV	< 55 GeV	No cut
DIS Q2 scan *same cuts as past DIS analysis*	> 0.9	> 5 GeV^2	> 1 rad	> 10 GeV	47 to 69	Listed in DIS AN and paper

Track selection & multiplicity definitions

Reconstructed track selection criteria:

- ZTT track type
- At least 1 MVD hit
- $DCA_{xy, z} < 2$ cm
- $0.1 < p_T < 5.0$ GeV
- $-1.5 < \eta < 2$
- $\Delta R > 0.4$ (DIS only)

MC generator particle selection criteria:

- Long-lived primary charged hadrons with mean proper lifetime $\tau > 1$cm, which were produced directly or from the decay of a particle with $\tau < 1$cm.
- $0.1 < p_T < 5.0$ GeV
- $-1.5 < \eta < 2$

Multiplicity definitions:

- N_{rec} = # of reconstructed tracks satisfying selection criteria.
- N_{gen} = # of generated particles satisfying selection criteria.
- N_{ch} = # of charged particles in data determined either by weights (as done in past DIS analysis) or by an unfolding procedure for the N_{ch} distribution itself.

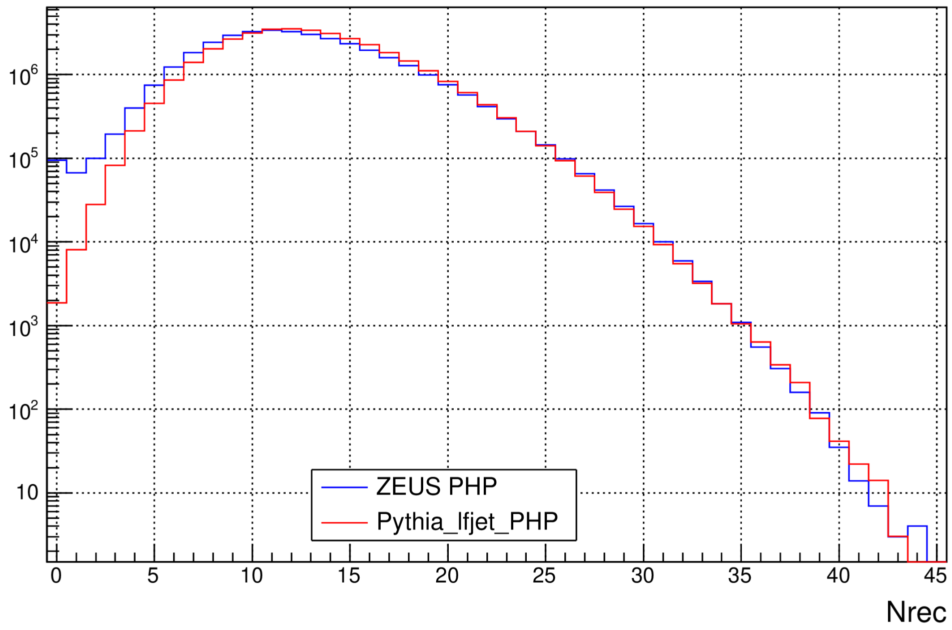
Correlation are measured as a function of:

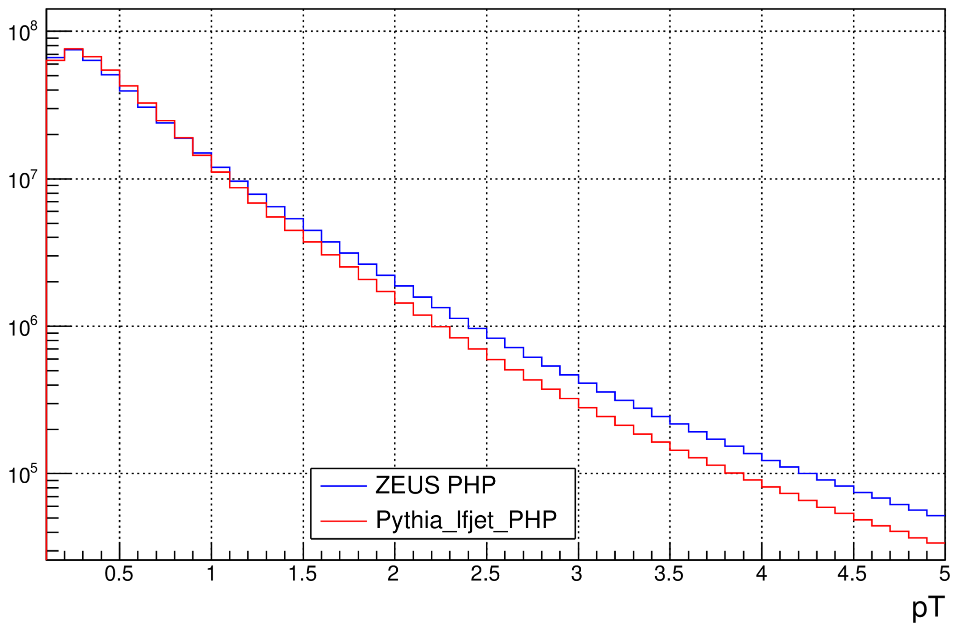
- 2-particle correlations: $\Delta\eta = | \eta_1 - \eta_2 |$ & $\langle p_T \rangle = (p_{T,1} + p_{T,2}) / 2$
- 4-particle cumulants: p_T particle of interest (poi), which is the p_T of particle 1.

Example Control Plots

Comparison of reconstructed quantities in ZEUS and MC (no corrections applied).

PhP offline cuts and HFL cocktail triggers applied to both.





- Agreement between data and MC is reasonable.
- Eta and phi distributions show similar agreement.

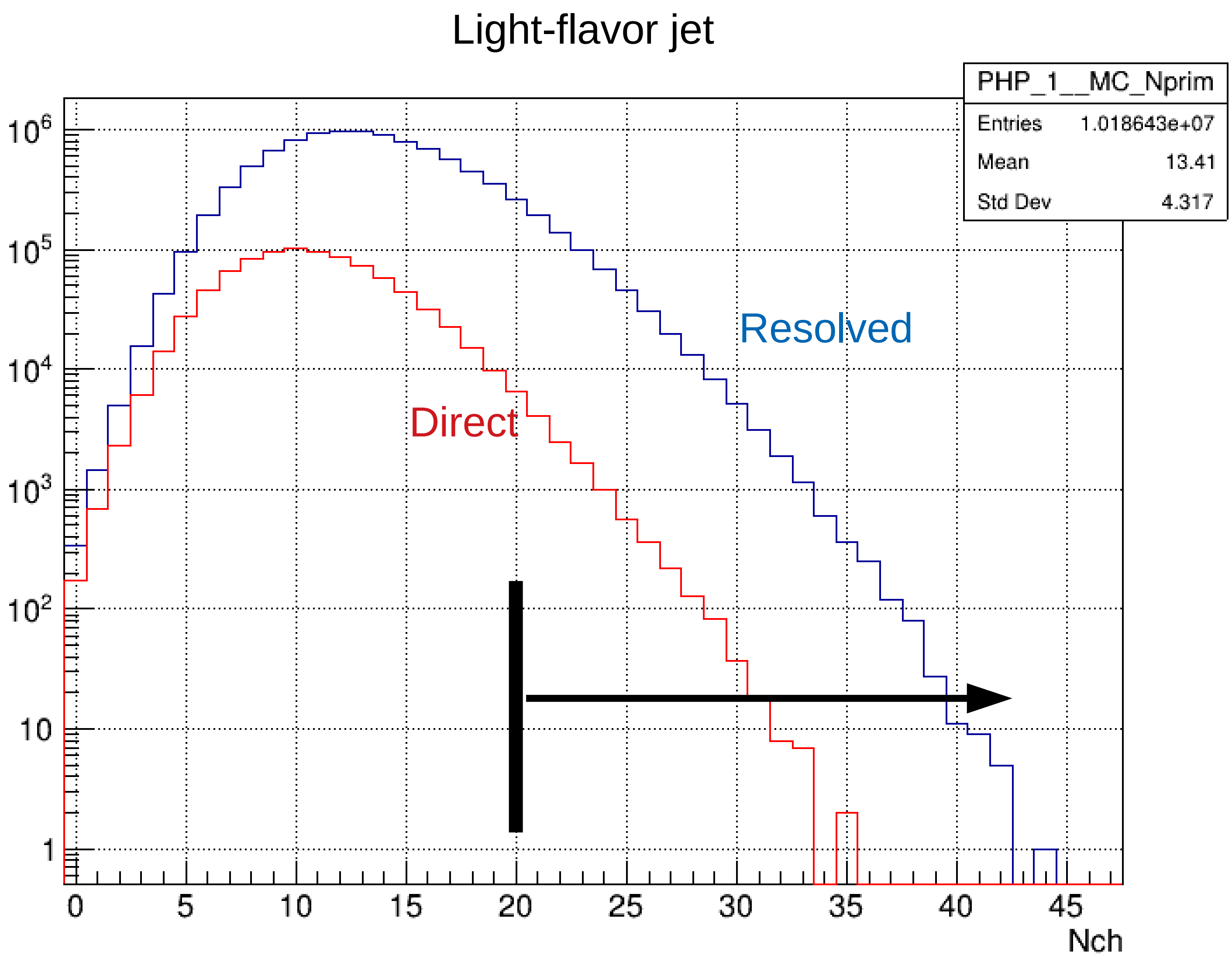
Table of systematic variations

Source of systematics	Reference (default)	Variation
MC nonclosure	Generator level distributions and correlations	Efficiency corrected reconstructed distributions and correlations
Track DCA variation *	$DCA_{xy, z}$ < 2 cm	$DCA_{xy, z}$ < 1 cm
Efficiency correction	PHP: Direct + Resolved DIS: Ariadne	PHP: Resolved only DIS: Lepto
Primary Vertex positions **	-30 < Vz < 30 cm	Vz < 0, Vz > 0
Low-pT tracking efficiency	With corrections from Libov & Bachynska	without
Data-taking conditions * **	All HERA II data: 2003 - 2007	Individual periods weighted by their relative contribution
PHP MC light-flavor jet bias	Ratio of inclusive to jet-biased PHP Pythia	without
PHP triggers *	- Trigger cocktail: HFL 1 || 5 || 21 || 28 - **DIS triggers**	- HFL 5, 28. - **DIS && HFL cocktail**
PHP Offline cuts	P_e < 0.9 && E-Pz < 55 GeV && E_e < 15 GeV	P_e < 0.98 && E-Pz < 65 GeV && E_e < 30 GeV

Total Systematic Uncertainty: ~10-50% for 2-particle correlations

* = symmetrised uncertainty.
** = each variation weighted by their relative contribution.

Direct & resolved PhP mix from Monte Carlo



- At high multiplicity (N_{ch} > 20), **the resolved component clearly dominates.**
- The direct component is just a few % of the total.

Application of correction factors

For the multiplicity distribution, we unfold using the response matrix from MC

$$N_{ch} = \frac{N_{gen,PhP}}{N_{gen,PhP}^{\geq 1jet}} \frac{N_{gen,lfjet}}{N_{gen,lfjet}^{\text{Trigger}}} \left[N_{rec}\right]_{\text{unfolding}}$$

For the other results, we use weights = 1 / efficiency
Of single tracks, pairs, or quadruplets from MC

$$D_{corrected} = \frac{D_{PhP}}{D_{PhP}^{\geq 1jet}} \frac{D_{lfjet}}{D_{lfjet}^{\text{Trigger}}} w^{(n)} D_{rec} \qquad D \in \{\frac{dN}{dp_T}, \frac{dN}{d\eta}, c_n\{2\}, c_n\{4\}\}$$

Typically a ~10% correction
I compute this from the Pythia that I generate

Typically a ~30% correction
Extracted from light-flavor jet MC

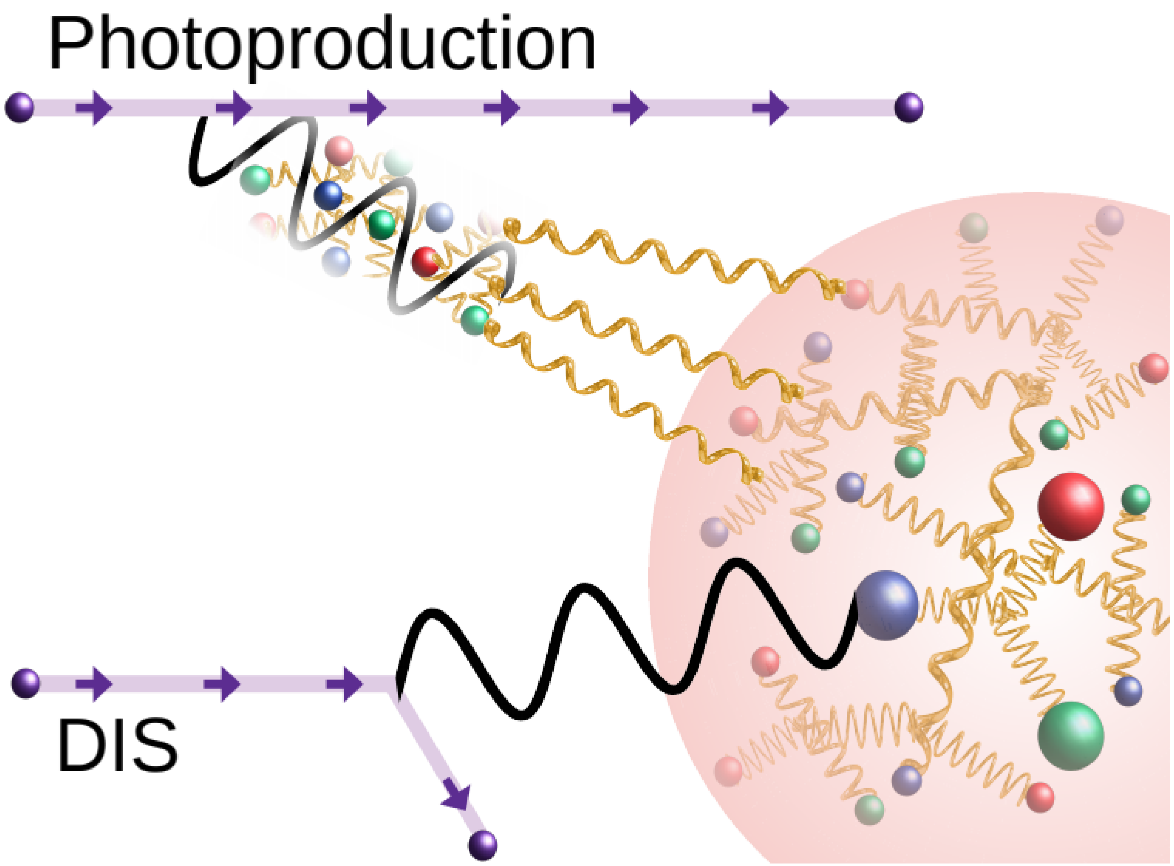
Typically a ~10% correction
Extracted from light-flavor jet MC

The corrections to the correlation functions can be larger where they cross zero

Results for publication

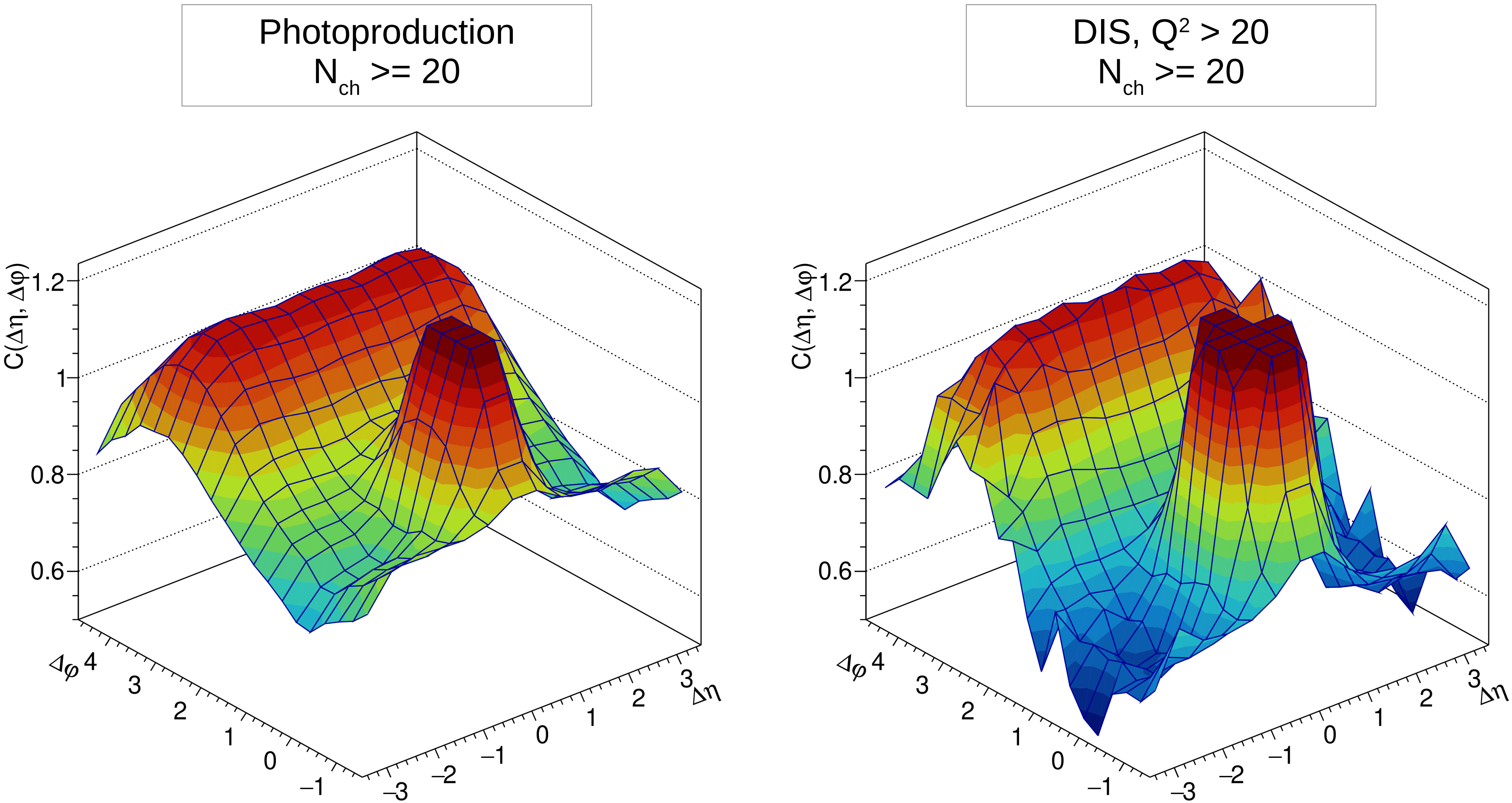
Format of figures and choice of pythia curves are not quite finalized.

Figure 1 for the paper



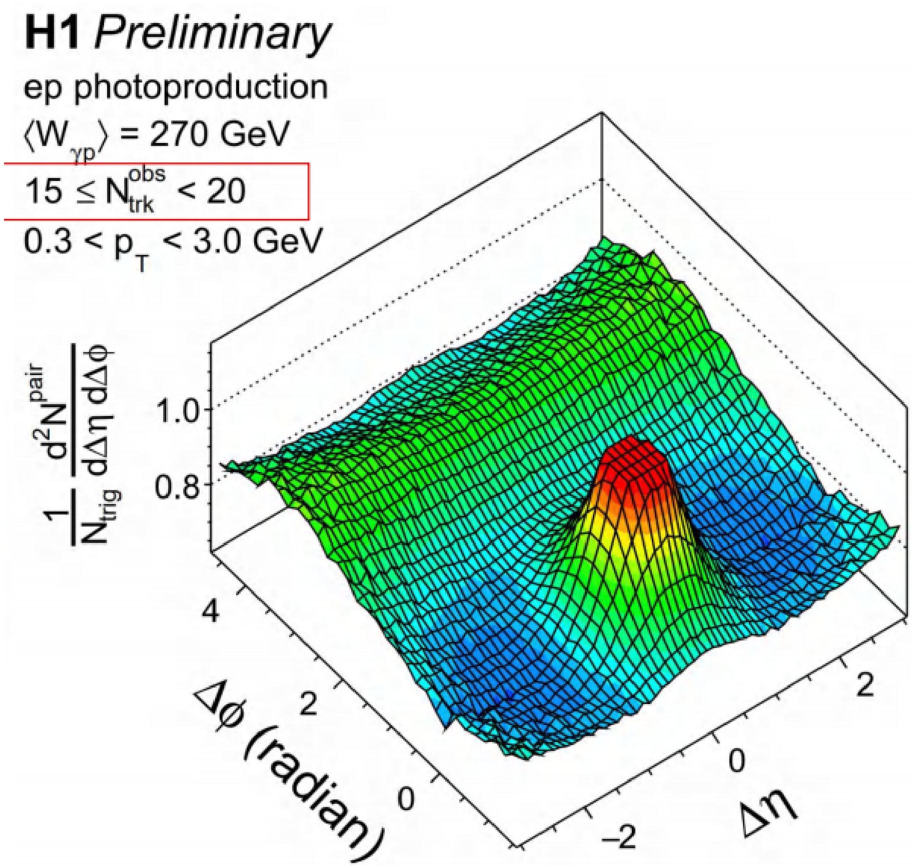
- work in progress (suggestions welcome)
- Illustrates the initial scattering in two separate scenarios at HERA.
- Hadronic component of photon shown for resolved PhP, as well as MPIs.

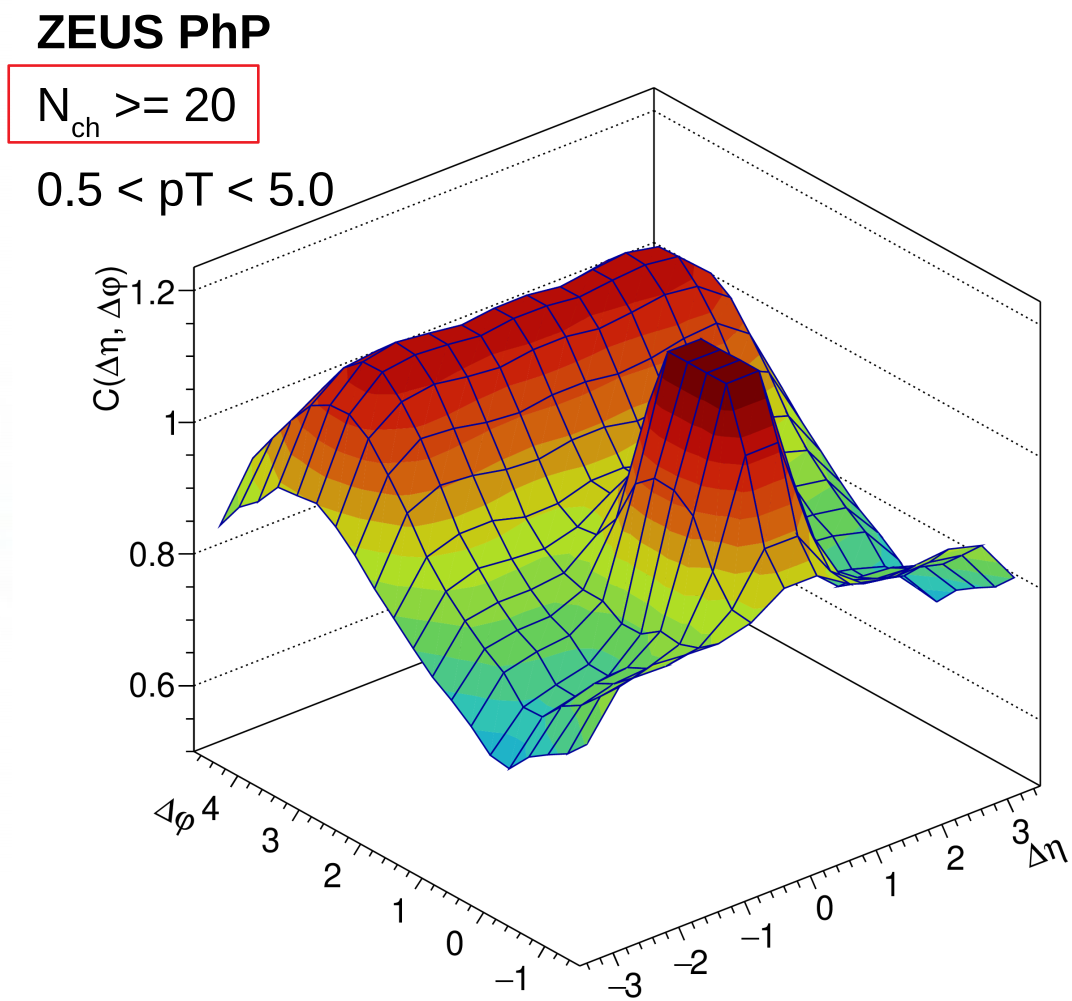
Figure 2 for the paper



- This plot illustrates that there is **no visible double-ridge** in high multiplicity PhP nor DIS at high Q2.
- As there are no systematics on these kinds of plots, they are purely qualitative.

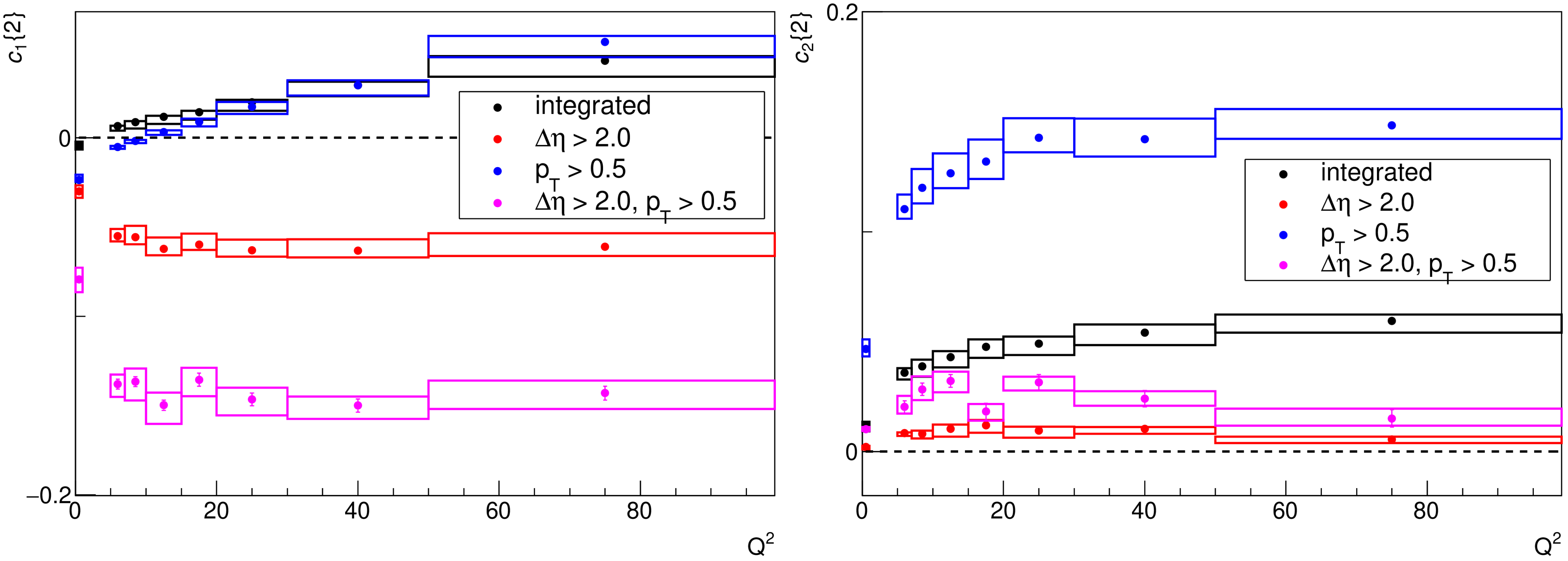
H1 preliminary compared to ZEUS in photoproduction





- There are differences in analysis details but either way, there is no clear double ridge.
- Austin Baty is one of the analyser’s for H1 **AND** for the ALEPH analysis as well.

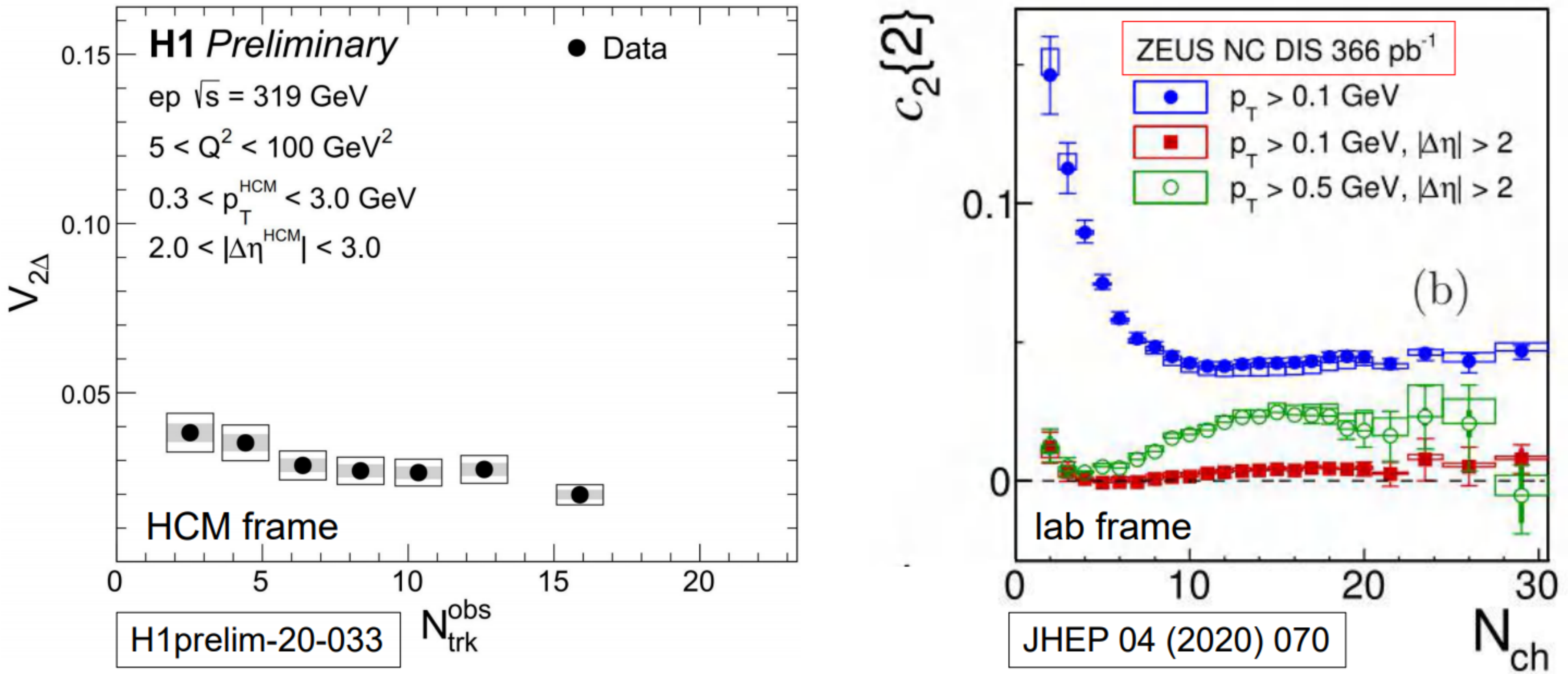
Figure 3 for the paper



- Conveys the message that correlations in PhP are markedly diminished wrt DIS.

- At high $Q^2 > 20$, weak or no Q^2 dependence of $c_n\{2\}$. $c_1\{2\}$ is much more negative than $c_2\{2\}$ is positive, which indicates the dominance of single-parton scattering kinematics in DIS.
- At lower Q^2, $c_n\{2\}$ magnitudes decrease with Q^2, which may indicate a change in the DIS kinematics and/or an emerging non point-like nature of photon.

Fourier coefficient $V_{n\Delta}$ in ep DIS



Similar trend as ZEUS result

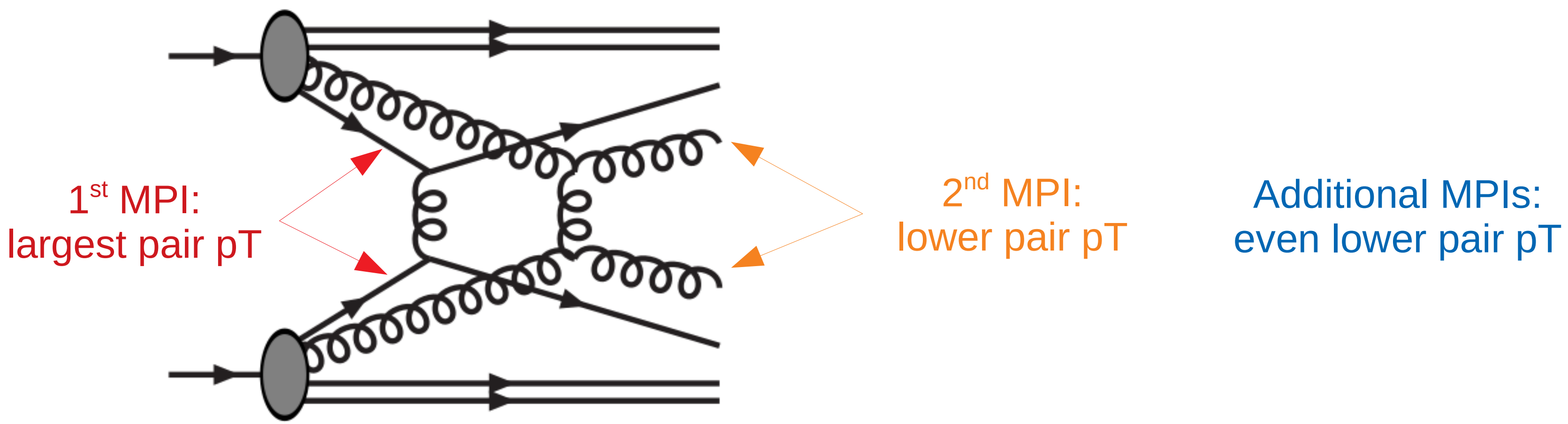
DIS HCM

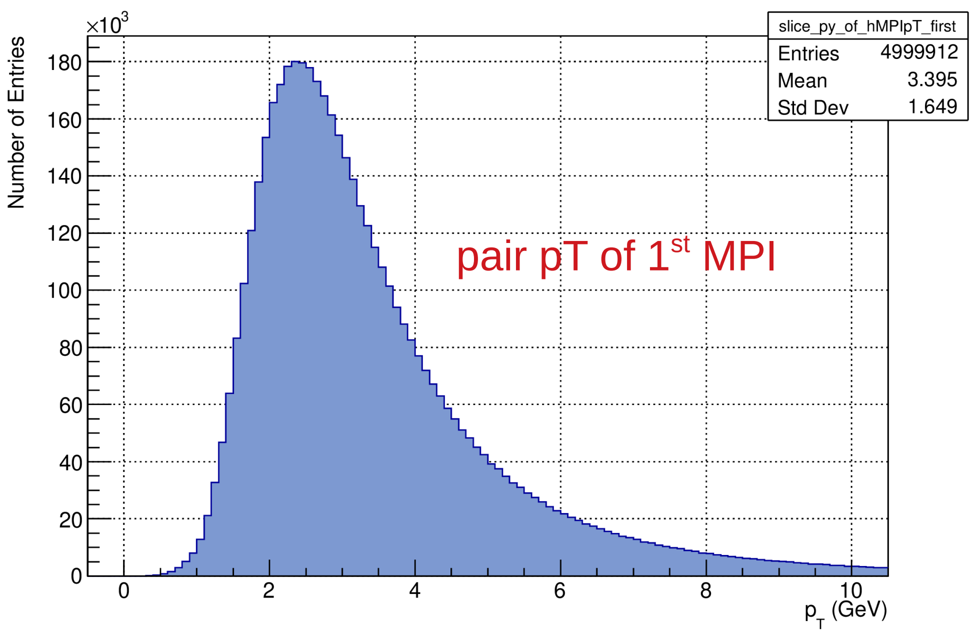
$$\frac{1}{N_{trig}}\frac{dN^{pair}}{d\Delta\phi} = \frac{N_{assoc}}{2\pi}\left(1 + \sum_n 2V_{n\Delta}\cos(n\Delta\phi)\right)$$

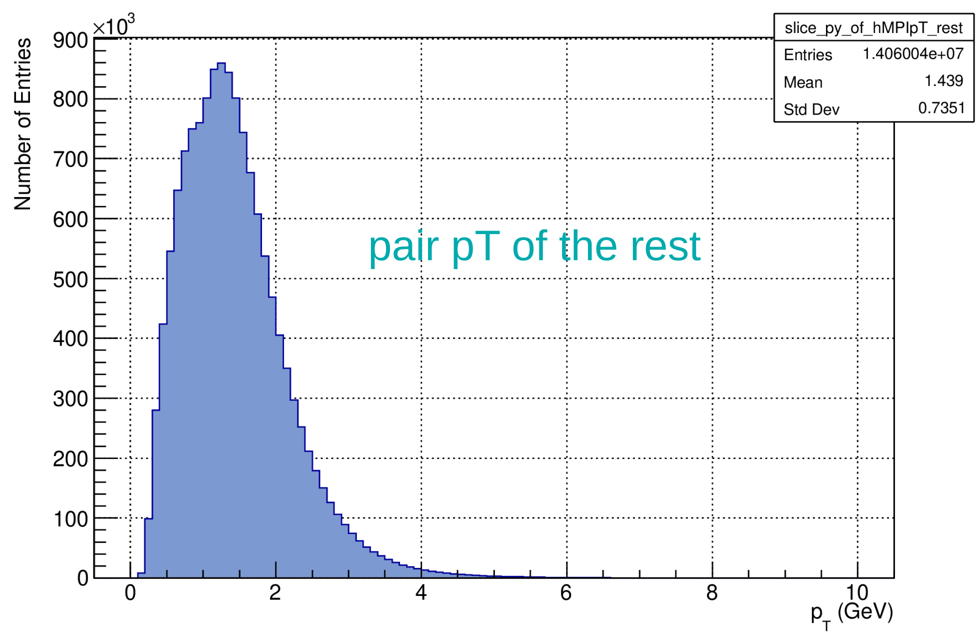
- Although their analysis is in the Hadronic Center of Mass frame, ZEUS and H1 look compatible.

Investigation of Multiparton Interactions in photoproduction

MPI scales in Pythia



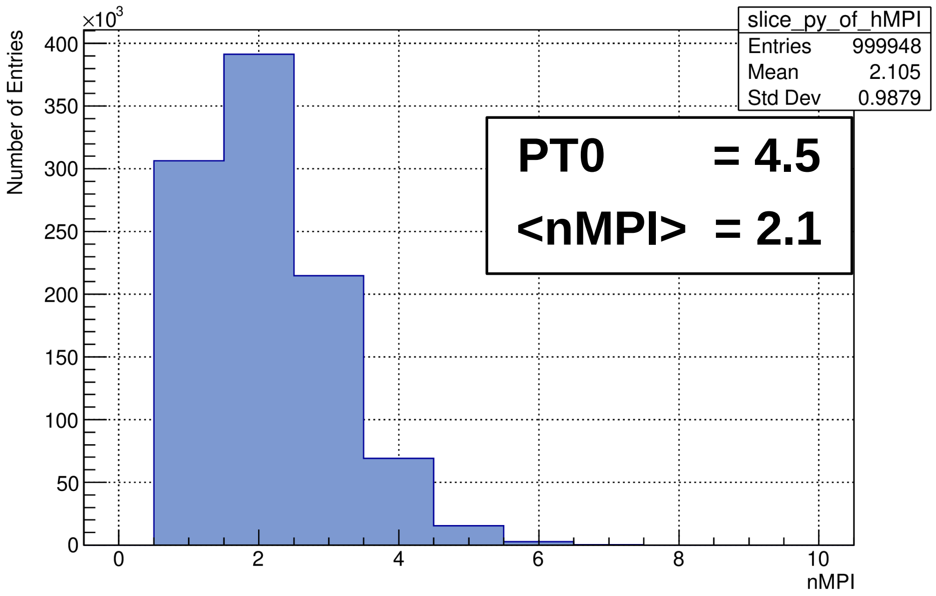


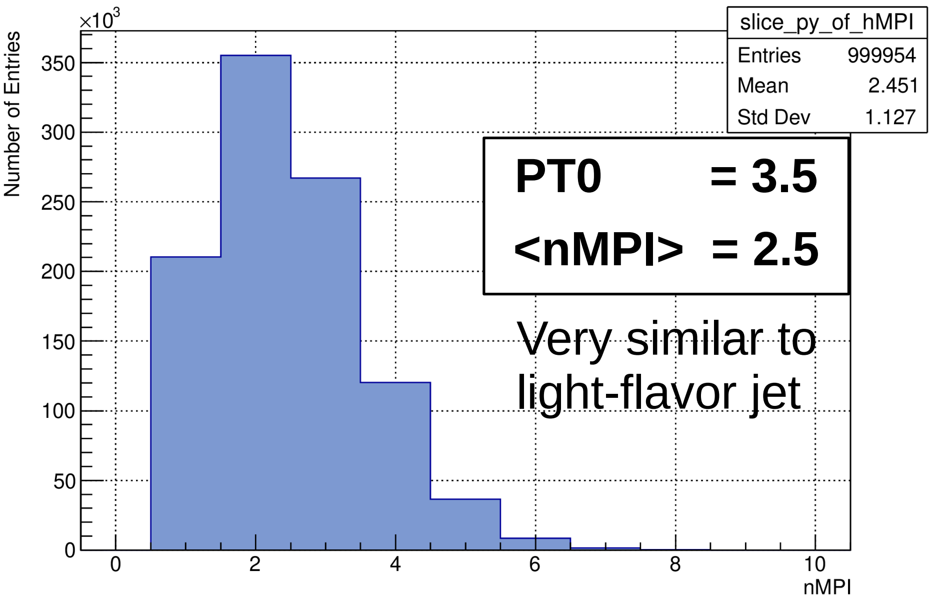


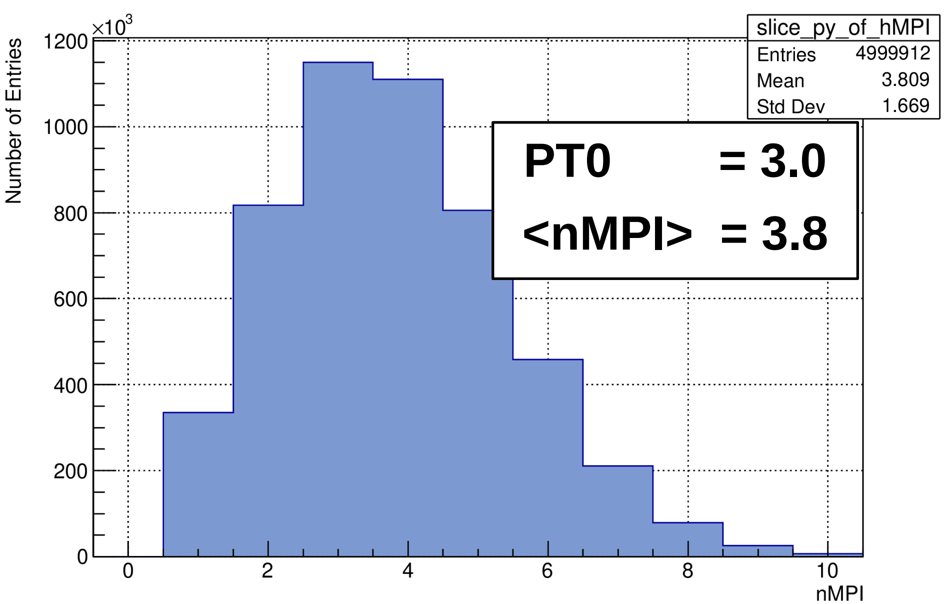
- Pair pT scale of $2 \rightarrow 2$ parton interactions decreases with each new MPI.
- Scales of a few subsequent MPIs are in the 1 GeV range and may still be reliably calculated from the **pQCD** elements within PYTHIA.

nMPI in pythia PHP

- In DIS as well as direct PHP, the **number of MPI** is one (nMPI = 1) by definition.
- In resolved PHP it can be greater than 1.
- The main parameter in Pythia controlling MPI is PT0: <nMPI> ~ 1 / PT0







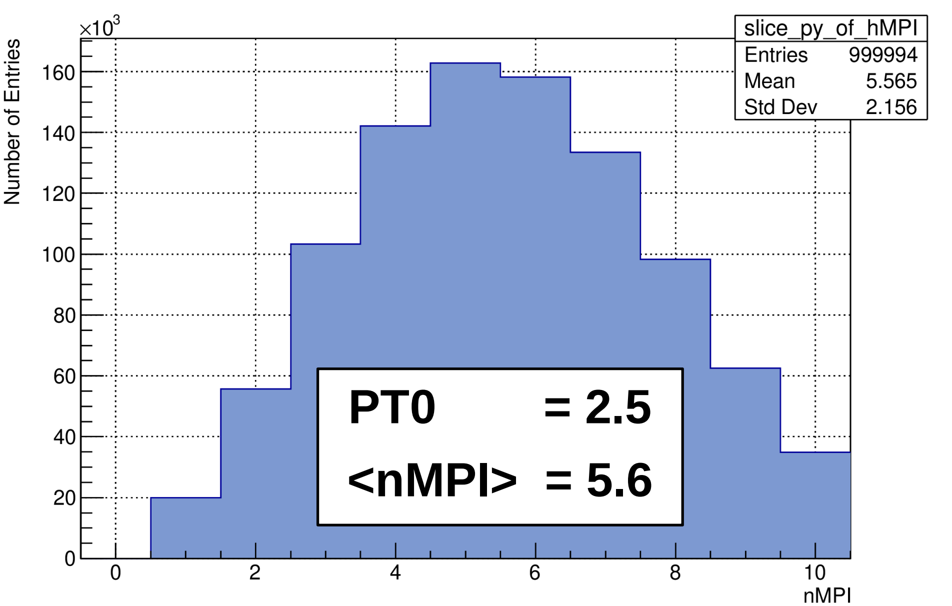
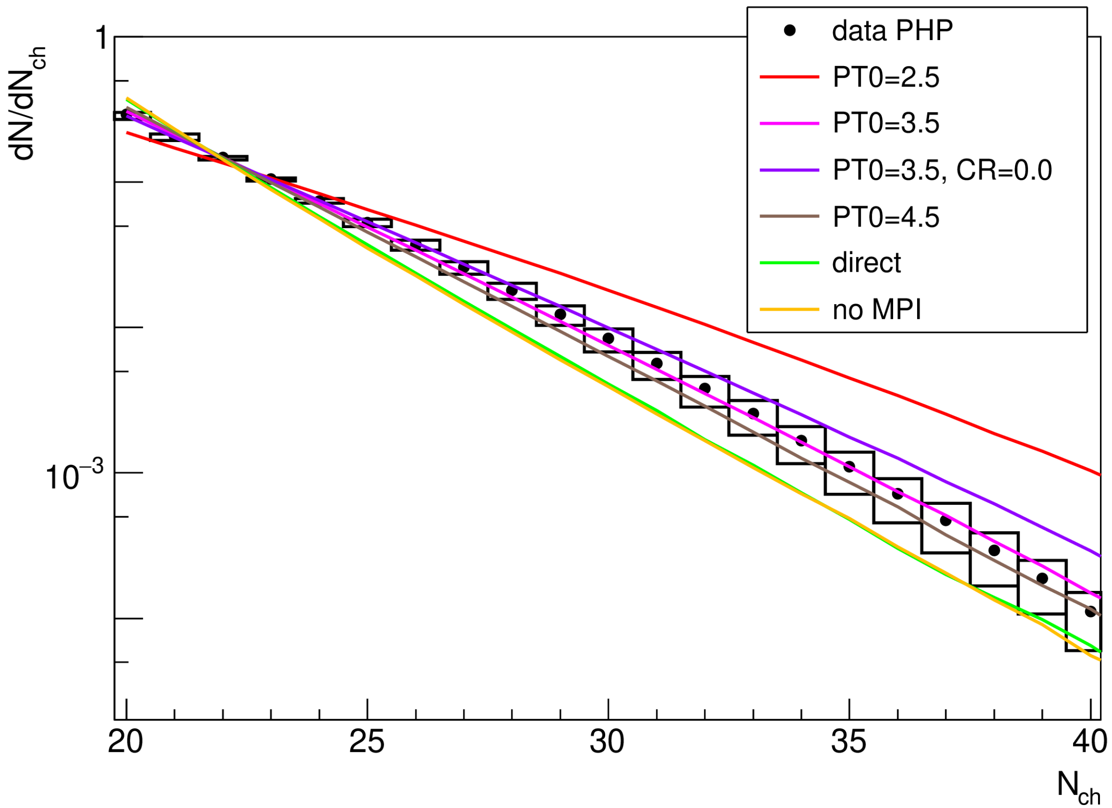


Figure 4 for the paper



- ZEUS multiplicity distribution compared to latest PYTHIA (8.303).
- Each curve has different degrees of MPI.
- Smaller PT0 → more MPI.
- Our data can help constrain this parameter and give us an estimate of the number MPI (nMPI) in PhP.

- The no MPI scenario & direct only component are clearly disfavored.
- Moderate MPI is favored (PT0=3.5) → <nMPI> ~ 2.5

Figure 5 for the paper

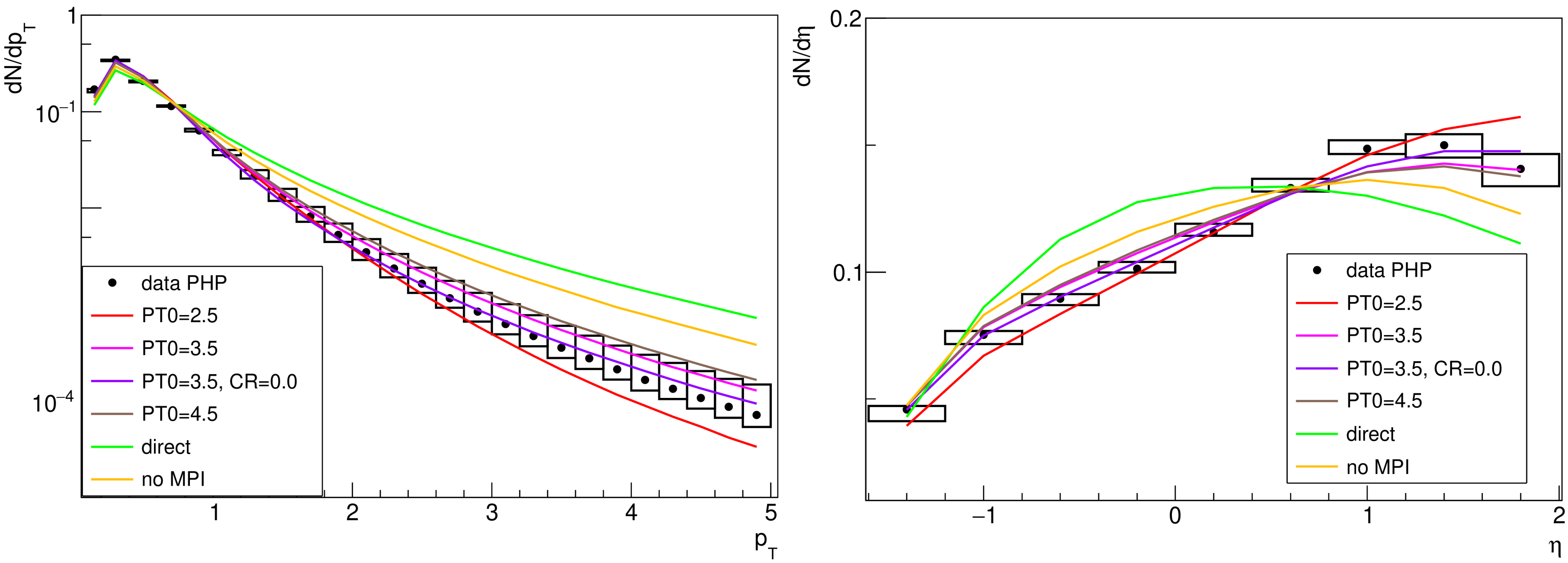


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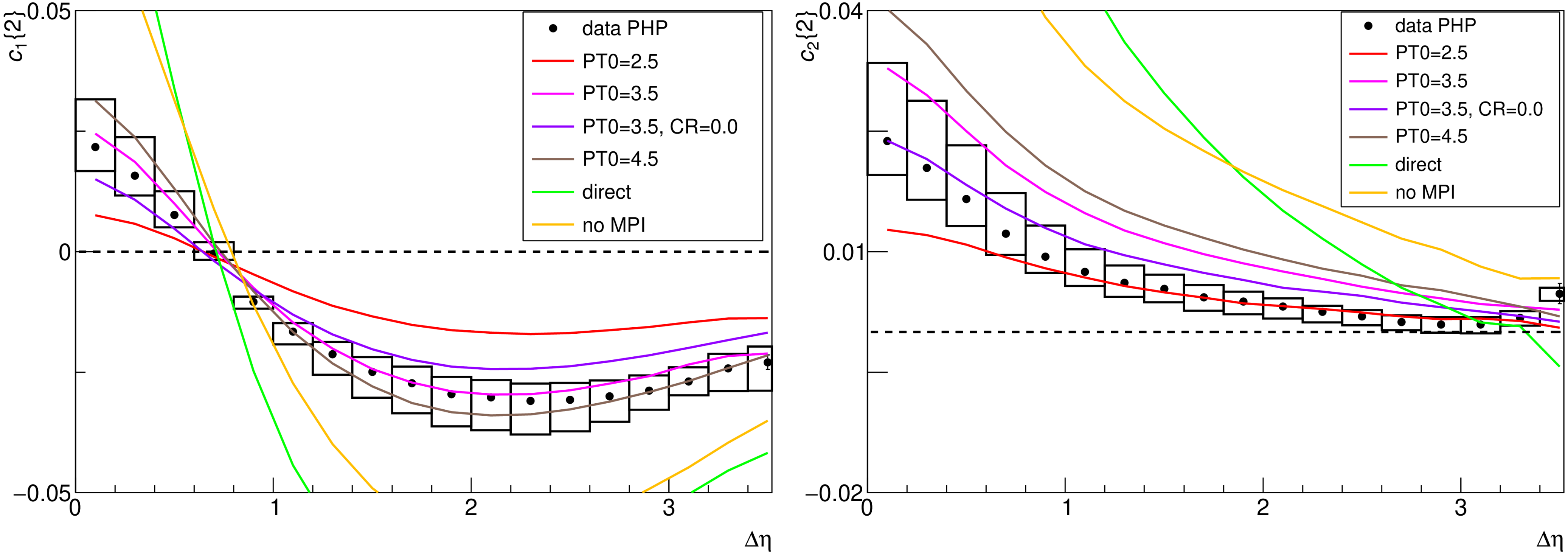
Figure 6 for the paper



- The no MPI scenario & direct only component are clearly disfavored.
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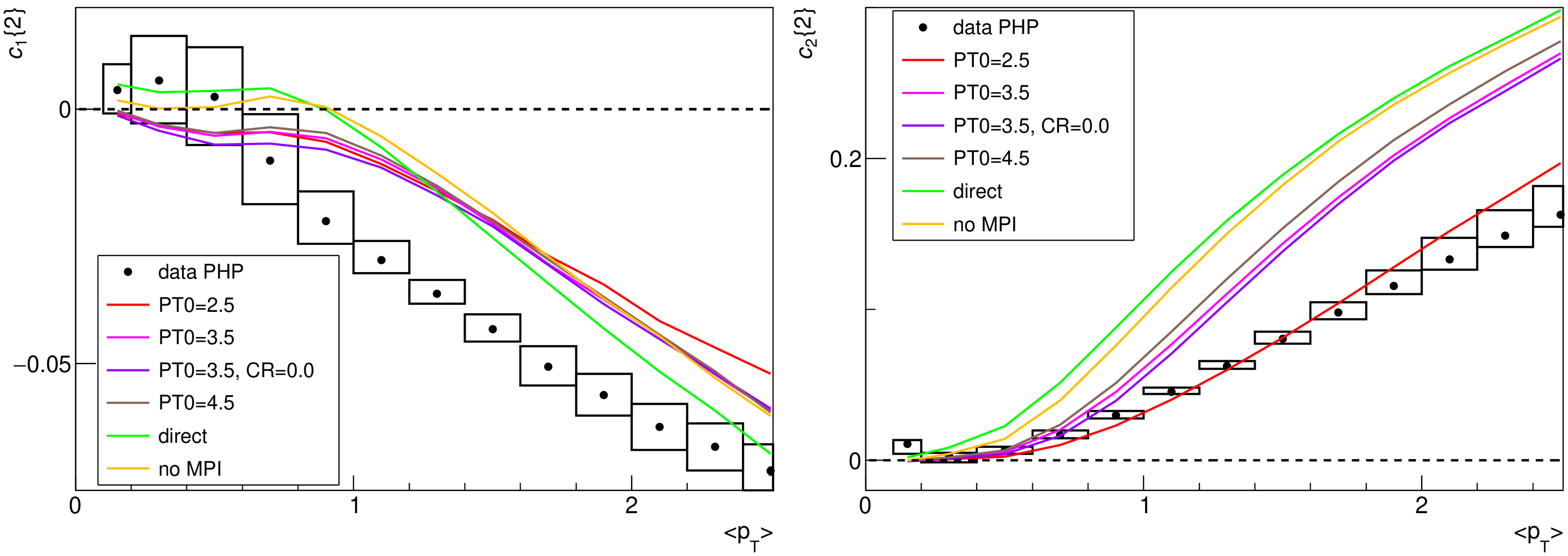
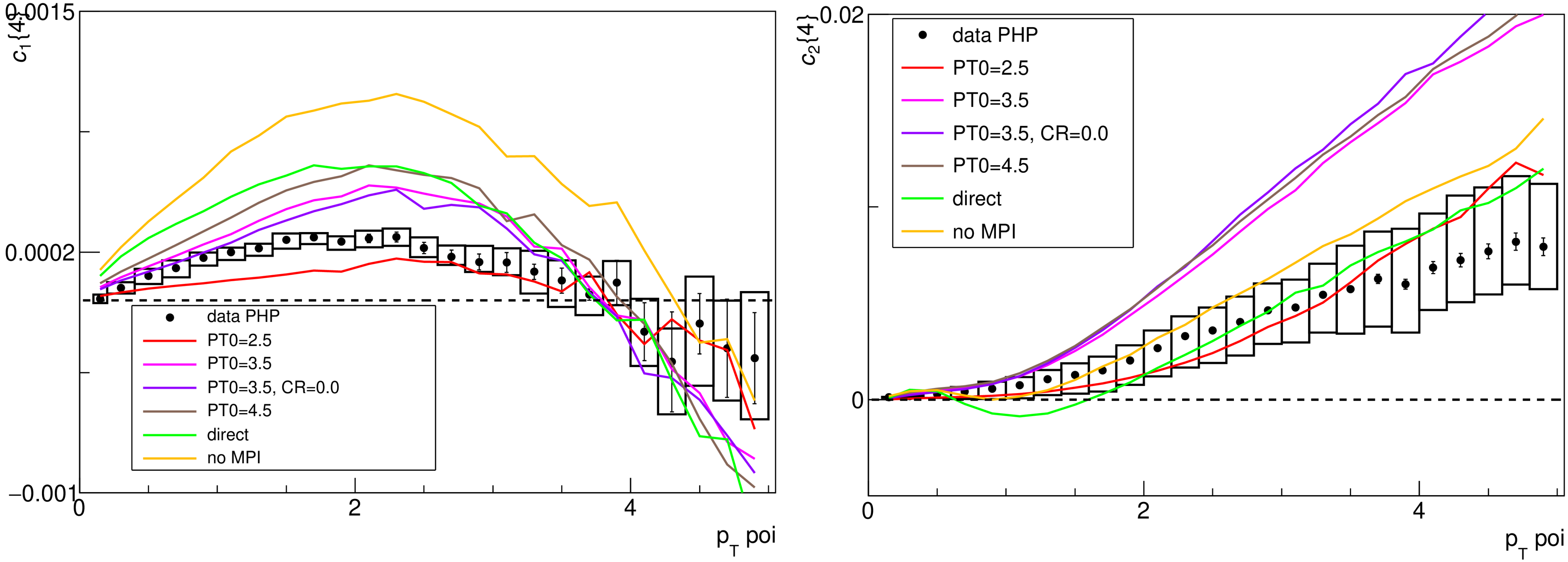
Figure 7 for the paper



- $c_1\{2\}$ is not described by any of our pythia variations.
- $c_2\{2\}$ is best described by PT0=2.5 → <nMPI>~5.6

Figure 8 for the paper



- $c_1\{4\}$ is better described by 2.5 < PT0 < 3.5 → <nMPI>~3.8
- $c_2\{4\}$ doesn't clearly distinguish between no MPI and large MPI scenario.
- $c_2\{4\}$ is positive. This is usually negative in heavy-ion collisions where collective behavior has been observed.

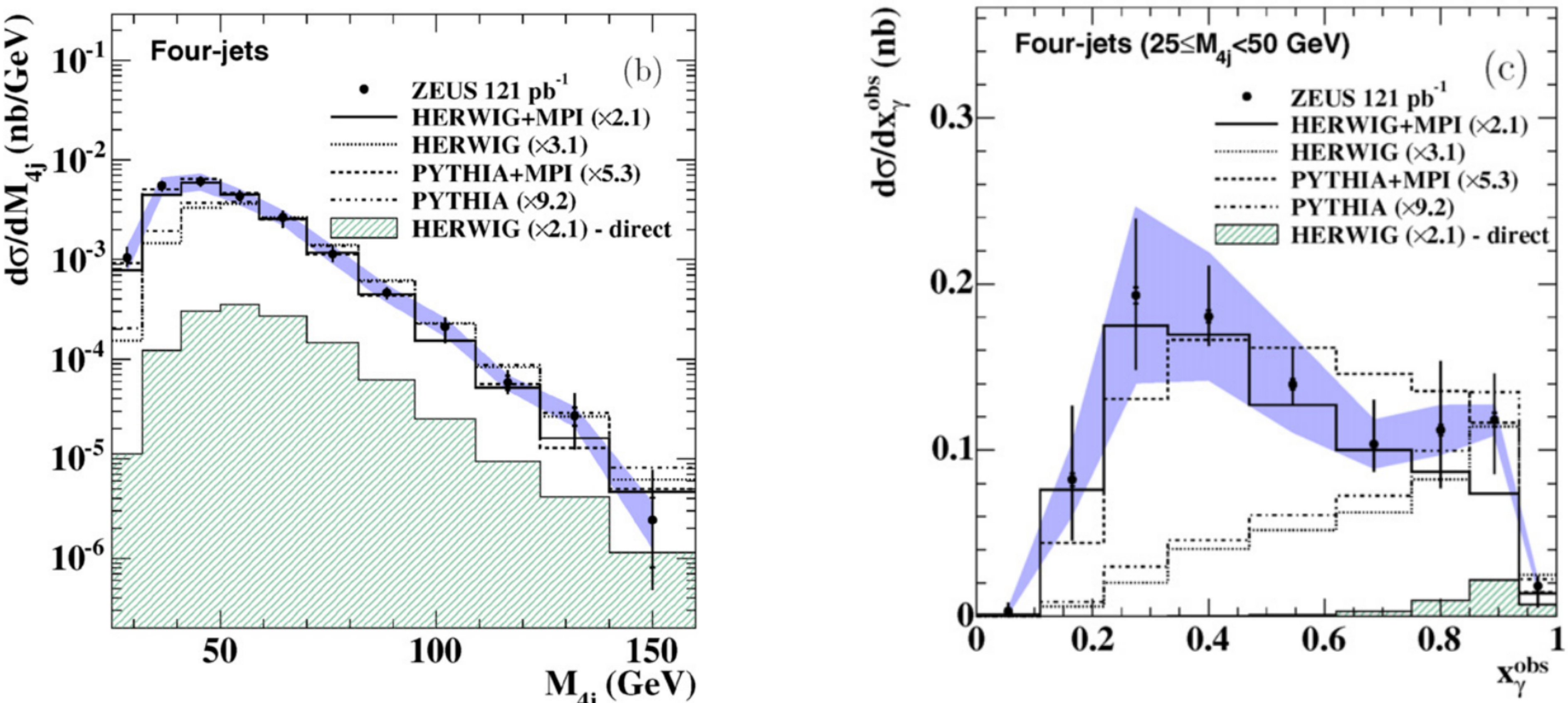
Summary of physics conclusions

Physics conclusions part 1

- No double-ridge visible.
- At high $Q^2 > 20$, weak or no Q^2 dependence of $c_n\{2\}$. $c_1\{2\}$ is much more negative than $c_2\{2\}$ is positive, which indicates the dominance of single-parton scattering kinematics in DIS.
- At lower Q^2, $c_n\{2\}$ magnitudes decrease with Q^2, which may indicate a change in the DIS kinematics and/or an emerging non point-like nature of photon.
- **We do not observe significant heavy-ion like collective behavior in PhP nor in Q^2 dependent DIS.**

Physics conclusions part 2

- **Comparisons of our data to PYTHIA provide a (strong?) indication for Multiparton interactions in PhP at HERA.**
- <nMPI> roughly between 2 and 4.
- Our data provides many additional constraints for models to incorporate.
- This was similarly concluded by a ZEUS study of multijet production in PhP.
  "Three- and four-jet final states in photoproduction at HERA"
  Nucl. Phys. B 792 (2008) 1-47



Discussions of comments raised by Achim since November

Challenges of an inclusive PhP analysis

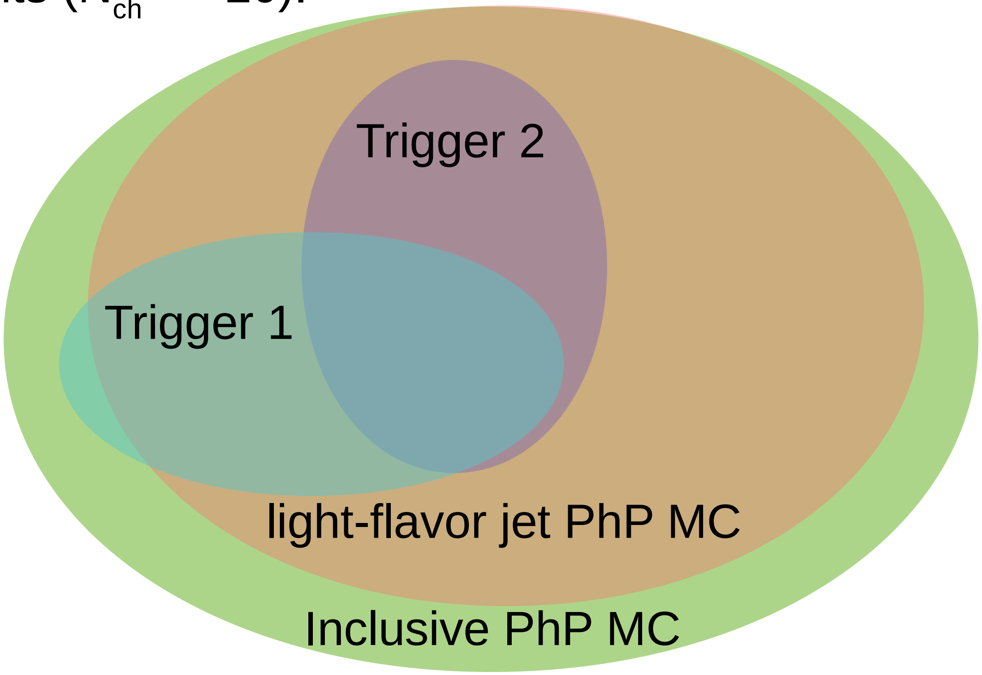
1) **PhP Monte Carlo investigations:** we don't have an inclusive PhP MC dataset.

- Employed MC---"light-flavor jet"---has a jet pre-selection at generator level. An additional correction is applied based on newly generated PYTHIA with and without the known jet bias.
- This implies that the extracted tracking efficiency and trigger-bias corrections are not quite correct.

2) Trigger investigations: we don't have an inclusive set of triggers in PhP.

- Use a cocktail of certain triggers and correct for biases with Monte Carlo simulations.

However, these problems can be largely avoided simply by analyzing only high-multiplicity events (N_{ch} >= 20).



PhP Monte Carlo investigations

- The bias intrinsic to the light-flavor jet MC is mild at high multiplicity.
- The comparison of reconstructed quantities in data and light-flavor jet MC demonstrate reasonable agreement.

ZEUS light-flavor jet MC sample

The least biased PHP MC sample generated by ZEUS is the “light-flavor jet” sample. The dominant bias here is the **jet requirement.**

Resolved PHP for 06e
generated by Sebastian Mergelmeyer <mergelm@desy.de>
with PYTHIA 6.220, AMADEUS v2_03

gamma/e p mode with mi
Ep = 920
Ee = 27.52
mb = 4.75
mc = 1.35

Resolved PHP Processes:
f + f' -> f + f' (QCD) (11)
f + fbar -> f' + fbar' (12)
f + fbar -> g + g (13)
f + g -> f + g (28)
g + g -> f + fbar (53)
g + g -> g + g (68)

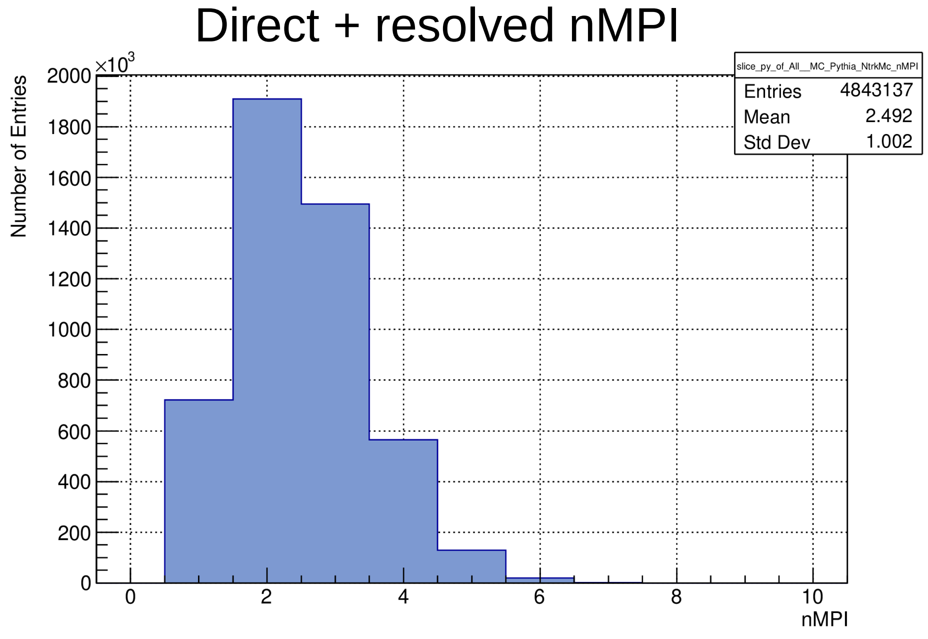
Direct PHP Processes:
gamma g -> q qbar (54)
gamma q -> q g (33)

Q^2 < 2
Ptmin = 1.9
Fragmentation: Peterson
epsilon = 0.0041

cuts:
1 jet requirement, with E_t > 3 and -3 < eta < 3

PDF Proton = CTEQ4L
PDF Photon = GRV G LO

Sigma = 9156801.88 pb
Red.Factor = 3.1485



Correcting the light-flavor jet MC bias

- We estimate and correct for the jet bias intrinsic to light-flavor jet by generating new inclusive PHP pythia as well as a “jet-biased” sample.
- Jet reconstruction is chosen to match that used in the light-flavor jet MC.

<u>Fast-jet reconstruction in Pythia</u>

- kT algorithm
- ΔR = 1
- p_T min = 3.0 GeV
- $-3 < \eta < 3$
- Jet clustering uses all observable massive final-state particles

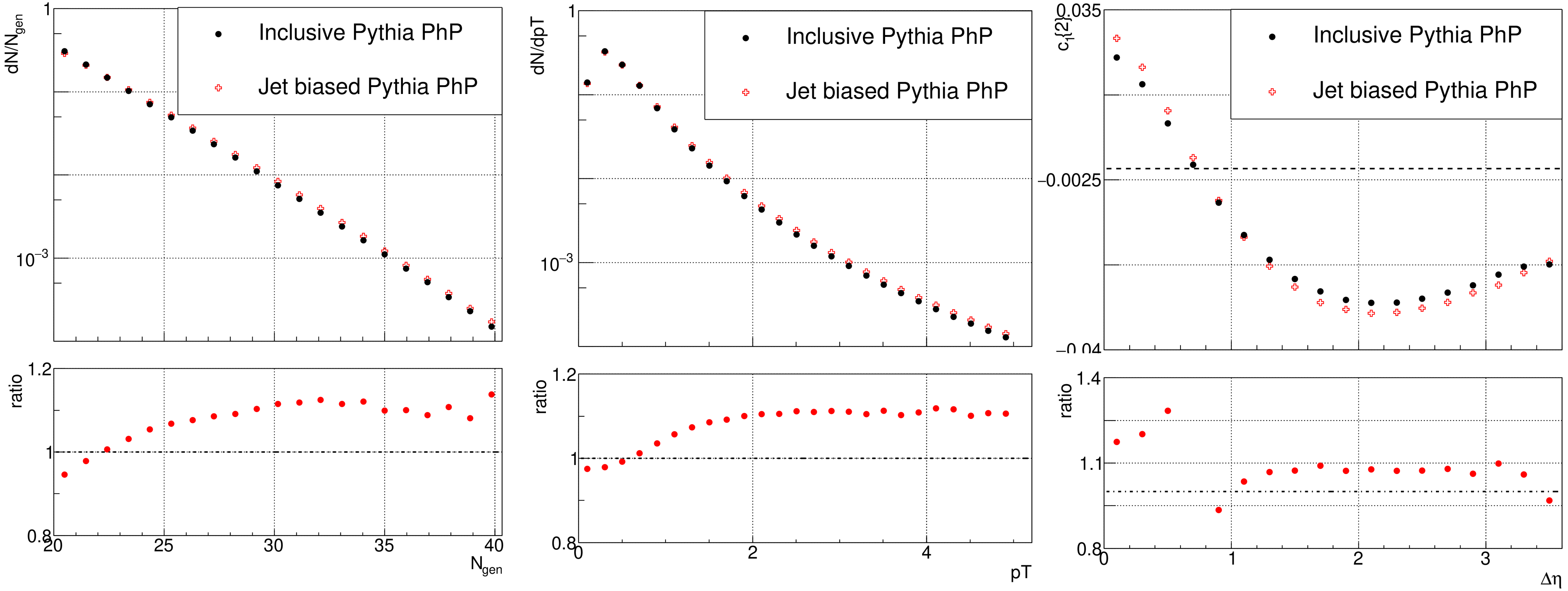
- The ratio of inclusive to jet-biased Pythia will form a correction factor to the previously mentioned trigger bias factor.
- This jet-bias correction factor will also be assigned as a systematic uncertainty.

$$\text{jet correction} = \frac{D_{PHP}}{D_{PHP}^{\geq 1\,jet}} \qquad D \in \{N_{ch}, \frac{dN}{dp_T}, \frac{dN}{d\eta}, c_n\{2\}, c_n\{4\}\}$$

Light-flavor jet bias

The jet bias within “light-flavor jet” estimated with new Pythia MC

Pythia 8.303
PHP MC
PT0=3.5

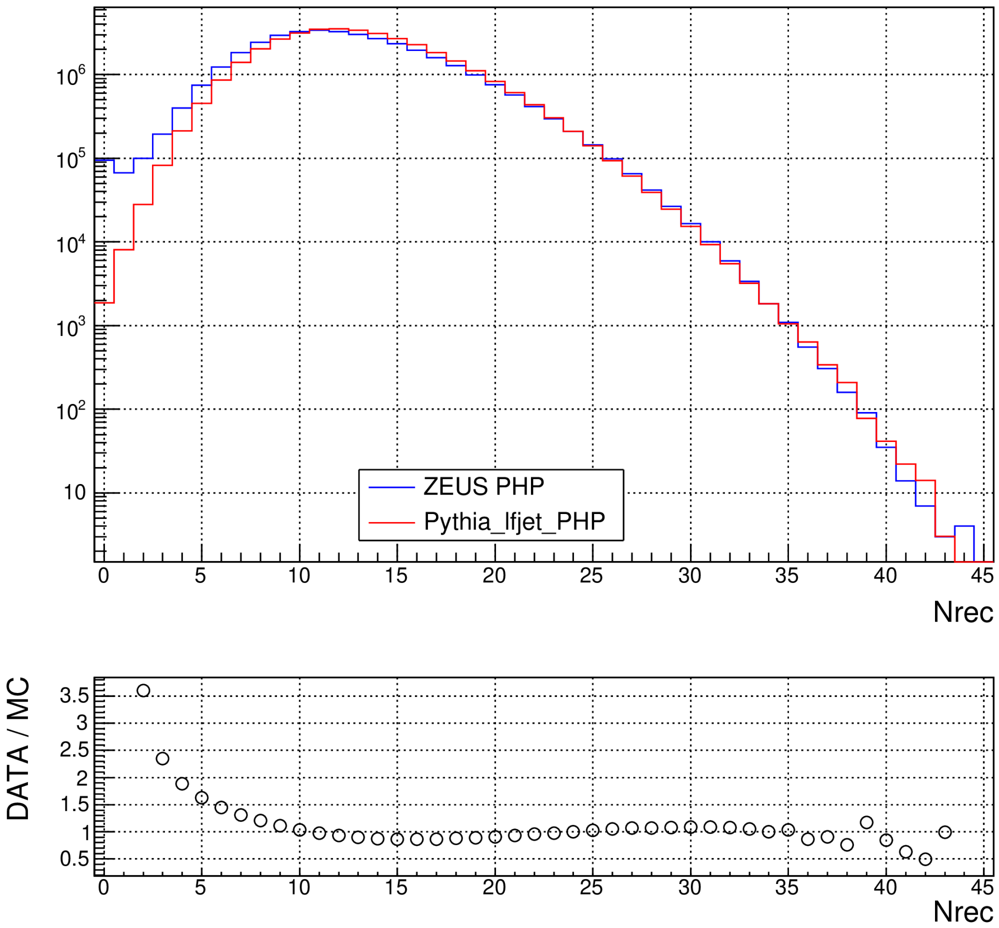


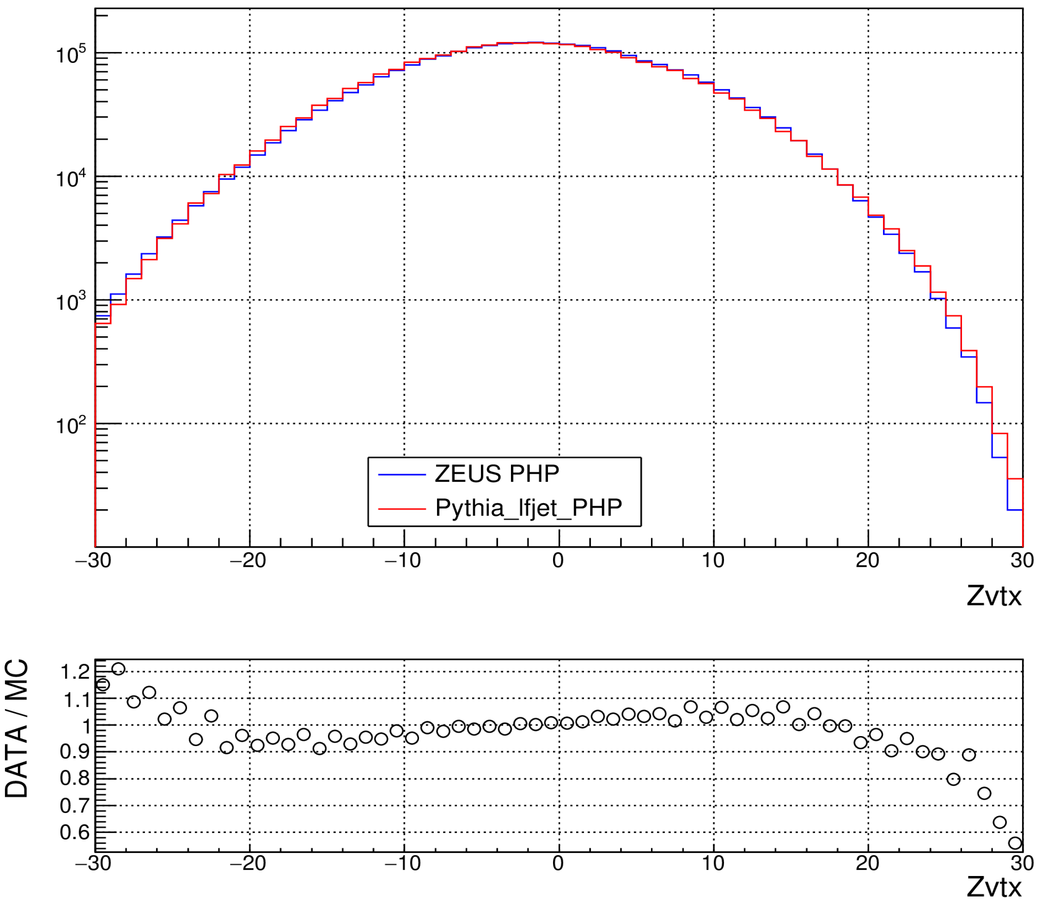
- **Bias is generally quite small** compared to the size of our systematic uncertainties.
- Also checked correlations vs <p_T>: no substantial bias there.

Control Plots

Comparison of reconstruced quantities in ZEUS and MC (no corrections applied).

PhP offline cuts and HFL cocktail triggers applied to both.



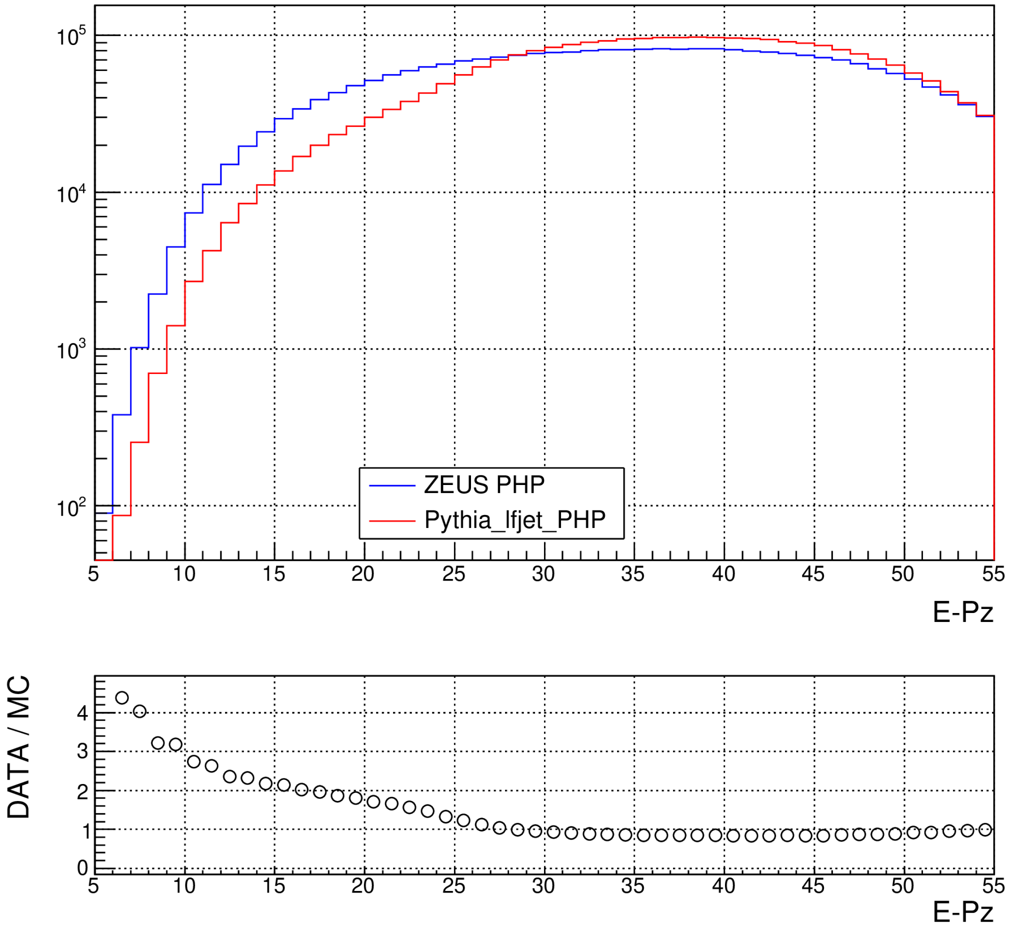


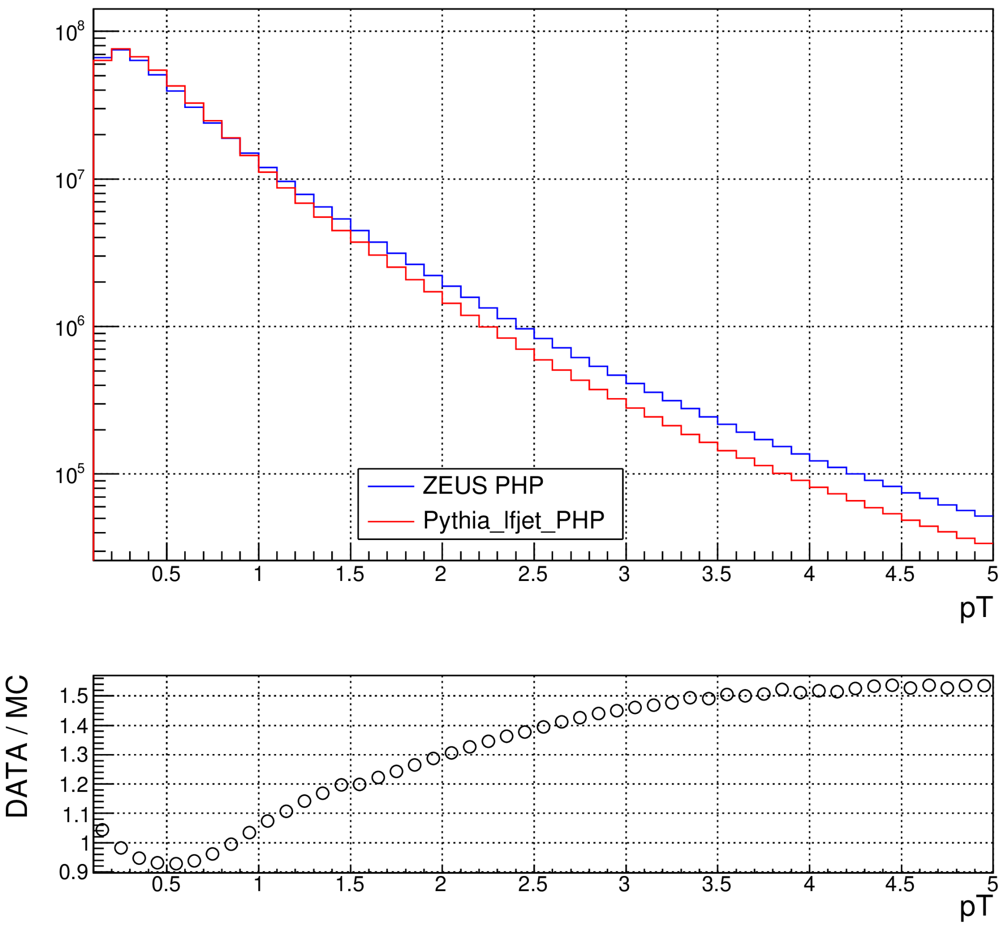
- Agreement is quite good except at low multiplicity where we don’t perform the analysis.

Control Plots

Comparison of reconstructed quantities in ZEUS and MC (no corrections applied).

PhP offline cuts and HFL cocktail triggers applied to both.

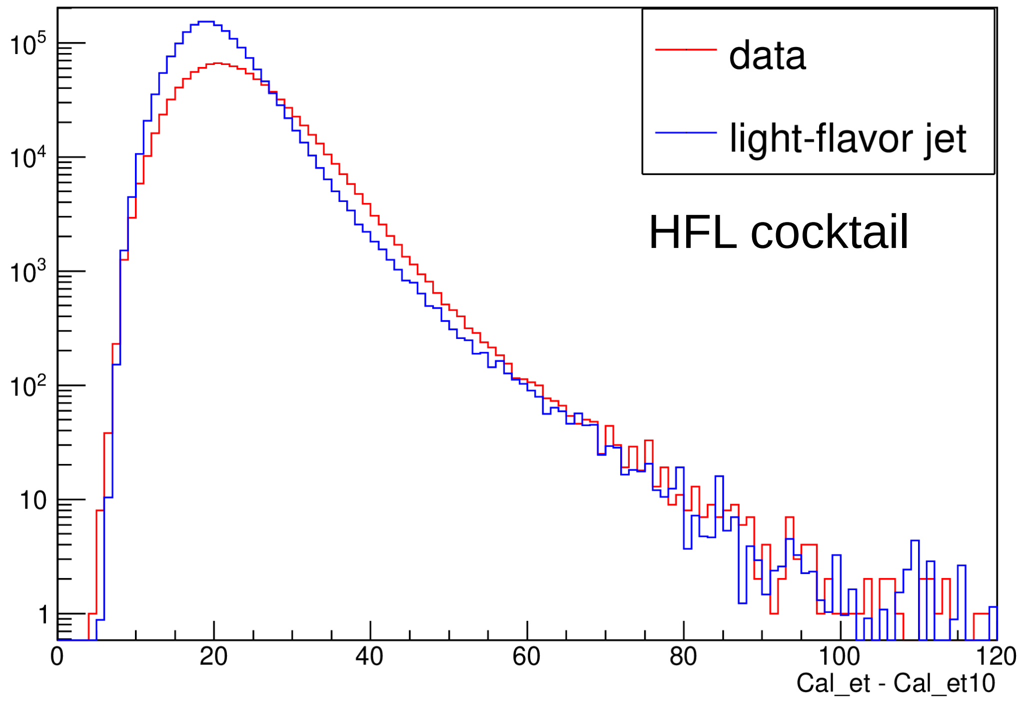


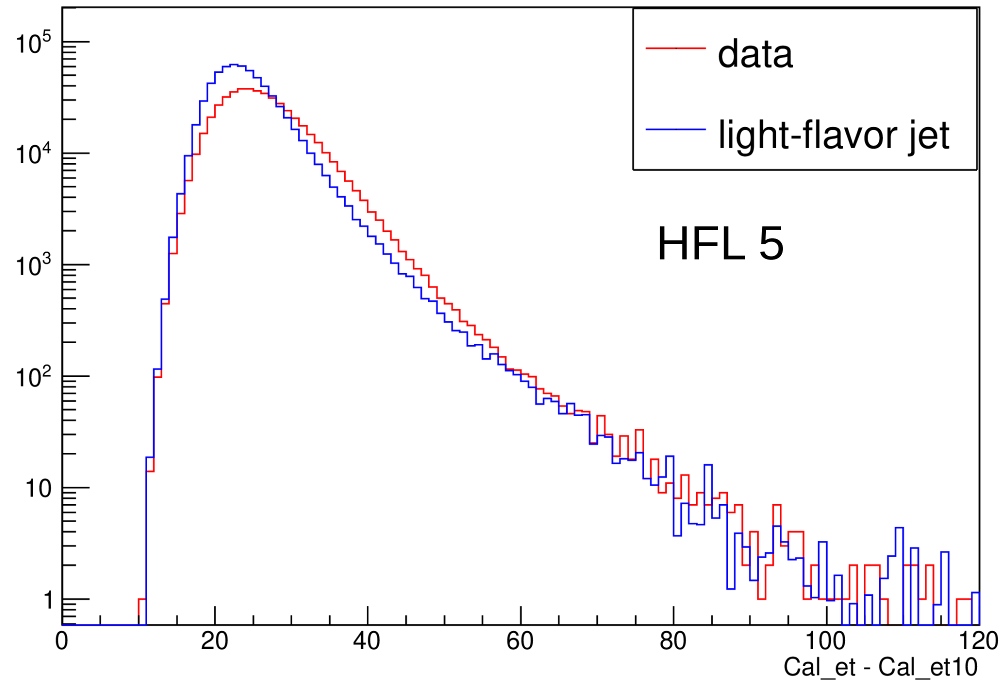


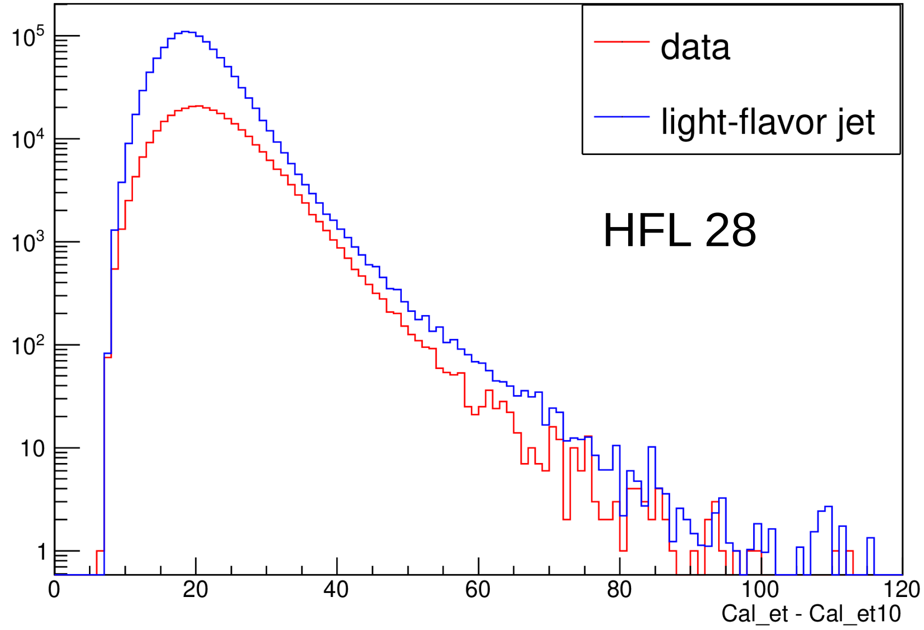
- Agreement is decent.

Control Plots **(new)**

Transverse energy distribution in calorimeters (no corrections applied).



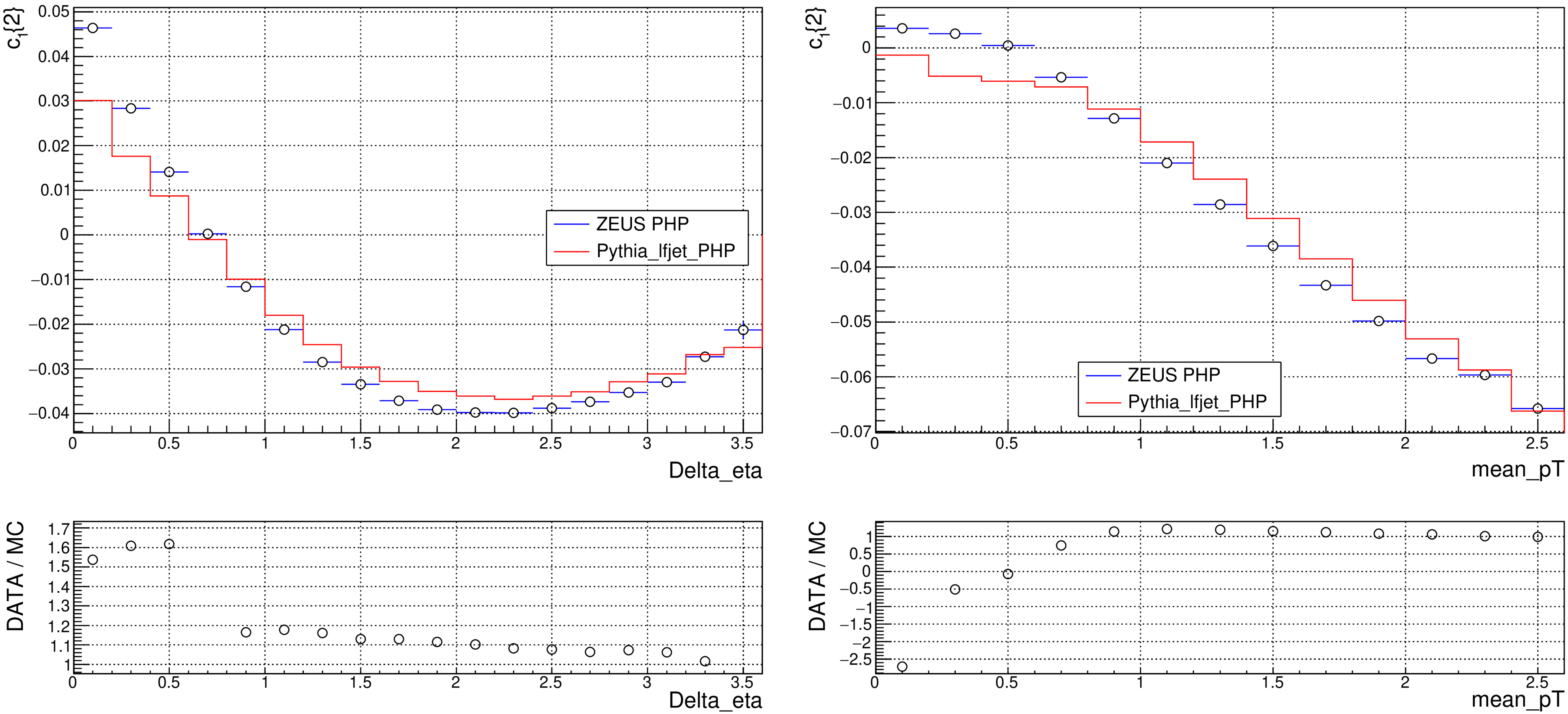




Control Plots **(new)**

Comparison of reconstructed quantities in ZEUS and MC (no corrections applied).

PhP offline cuts and HFL cocktail triggers applied to both.



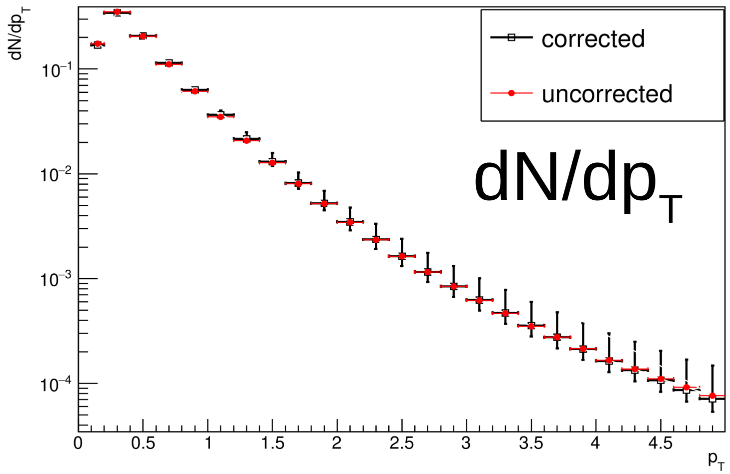
- Agreement is decent.
- Systematic uncertainties for the final results are large where above deviations are large.

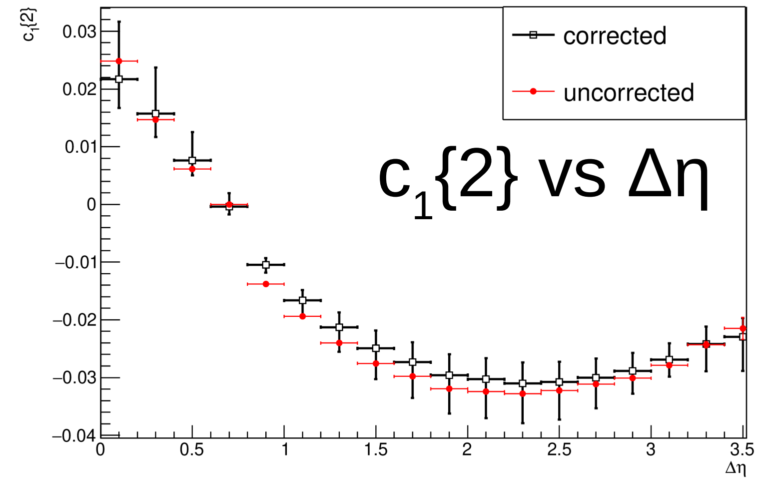
Effect of tracking efficiency corrections **(new)**

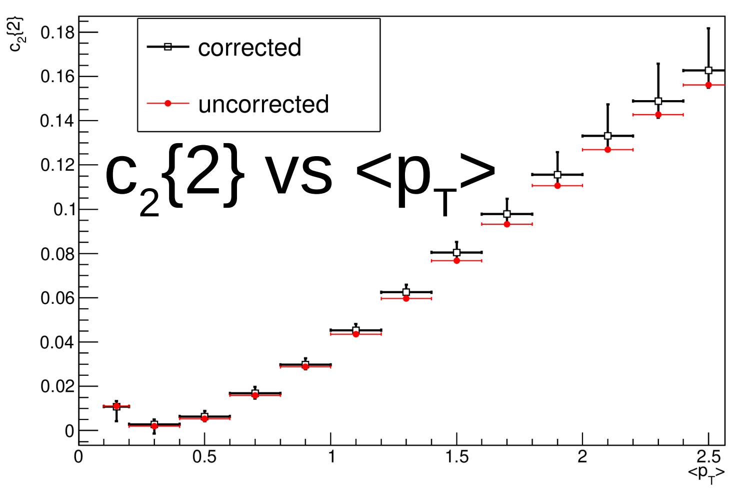
- We also depend on the light-flavor jet MC for tracking efficiency corrections.
- Here we can see the magnitude of the correction compared to the total systematic uncertainties.

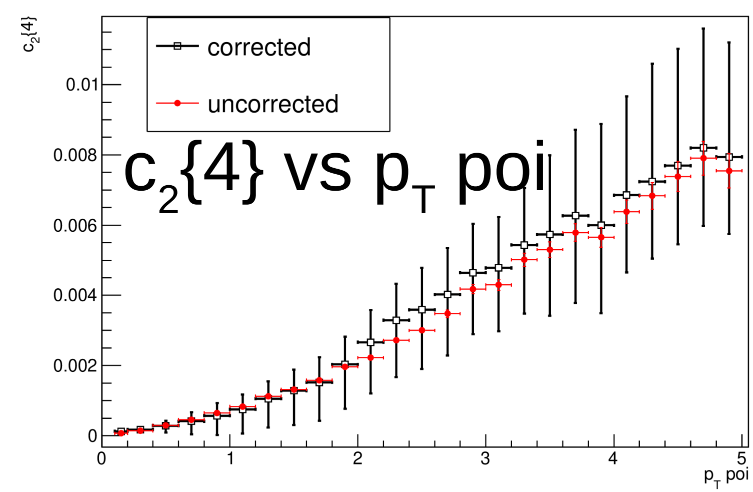
Red points have only statistical errors.

Black points are fully corrected with systematic errors







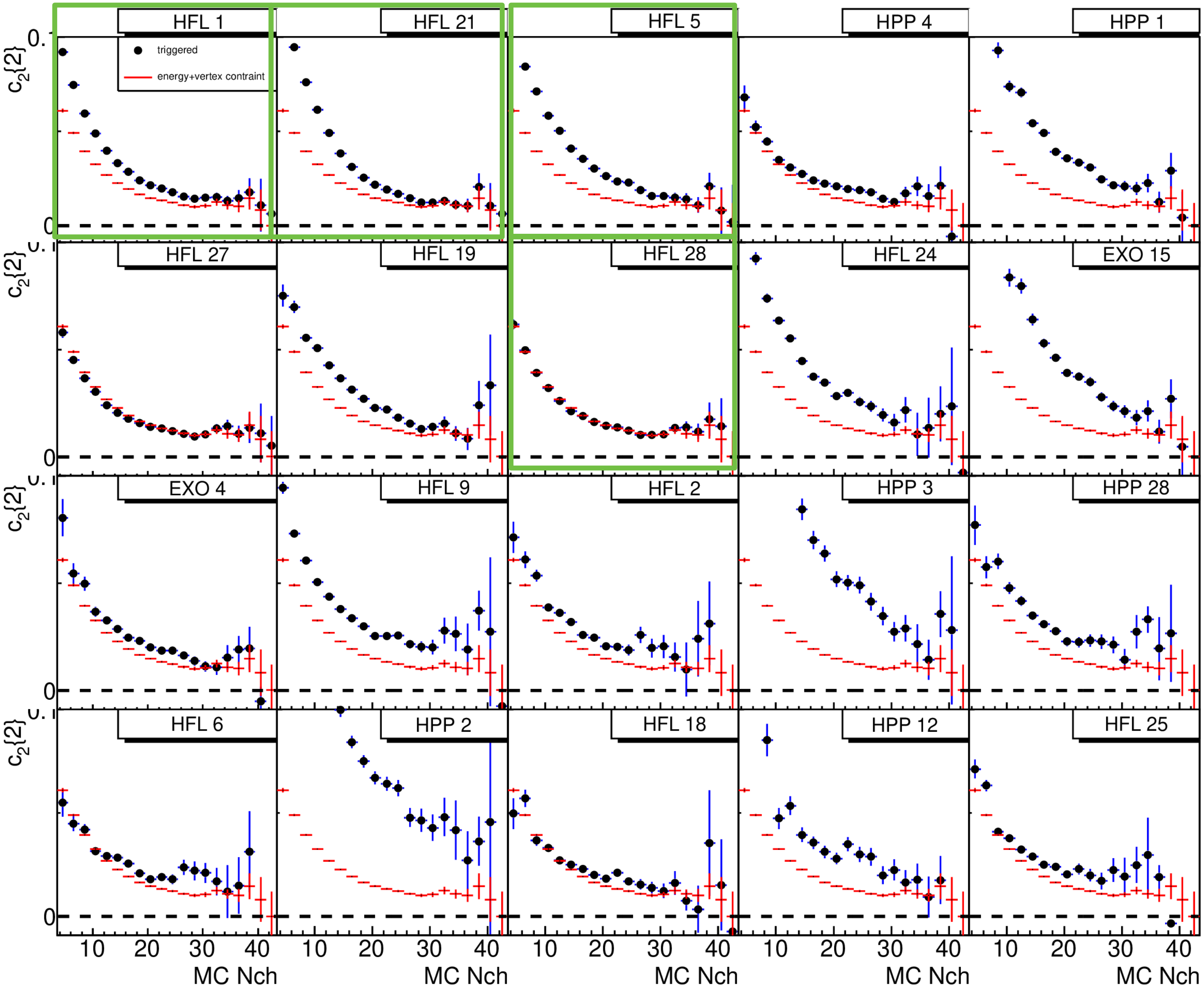


Trigger investigations

- The trigger bias to our measurements is corrected for.
- The analysis is repeated for 3 different trigger choices and the resulting differences to our measurements are assigned as a systematic uncertainty.

Top 20 triggers rich in high-multiplicity events

1) Early studies of HPP, HFL, & EXO triggers showed that HFL 1, 5, 21, and 28 were among the least-biasing triggers of the generator-level 2-particle correlations.

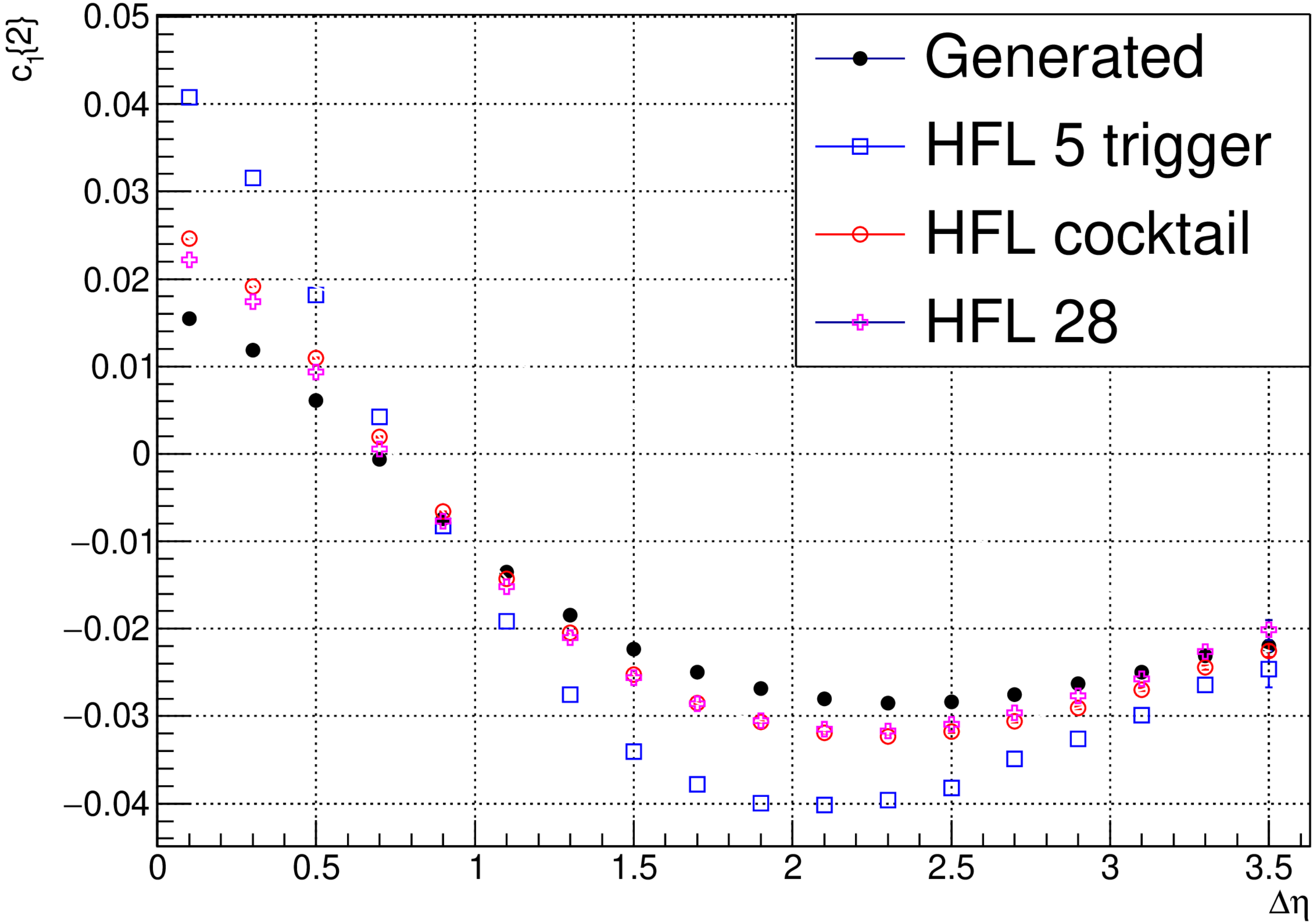


Red lines: reference correlations

Black points: specifically triggered correlations

View of the trigger bias

Light-flavor jet
PhP MC



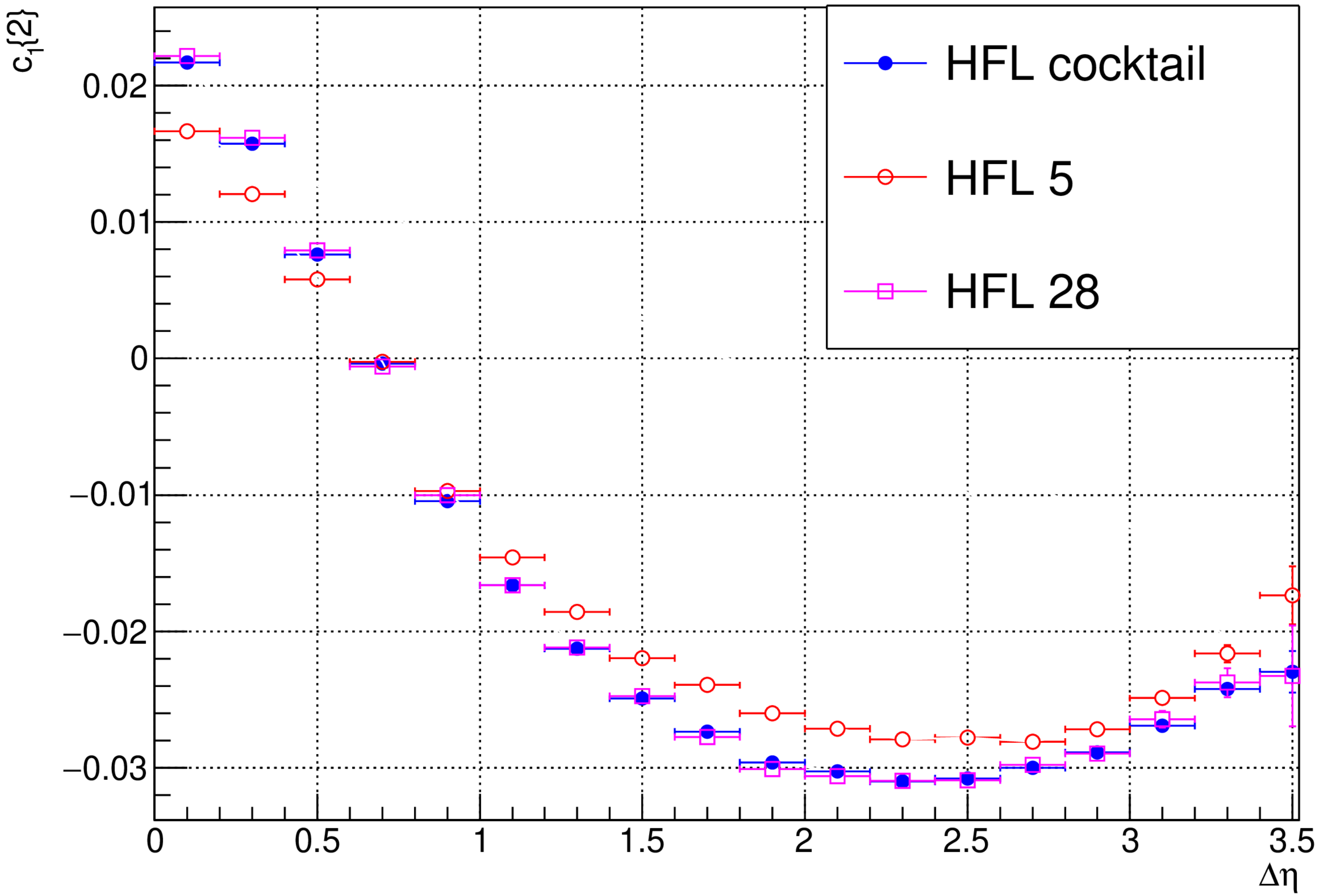
Extracted correction factor

$$\frac{D_{lfjet}}{D_{lfjet}^{\mathrm{Trigger}}}$$

- This correlation projection was among the most biased.
- We use the simulated response of the triggers in Monte Carlo to correct for the trigger bias in data.
- The ratio of gen over triggered forms our correction factor.
- **HFL cocktail is our default choice and HFL 5, 28 alone are used for systematics.**

Different routes to PhP using different triggers

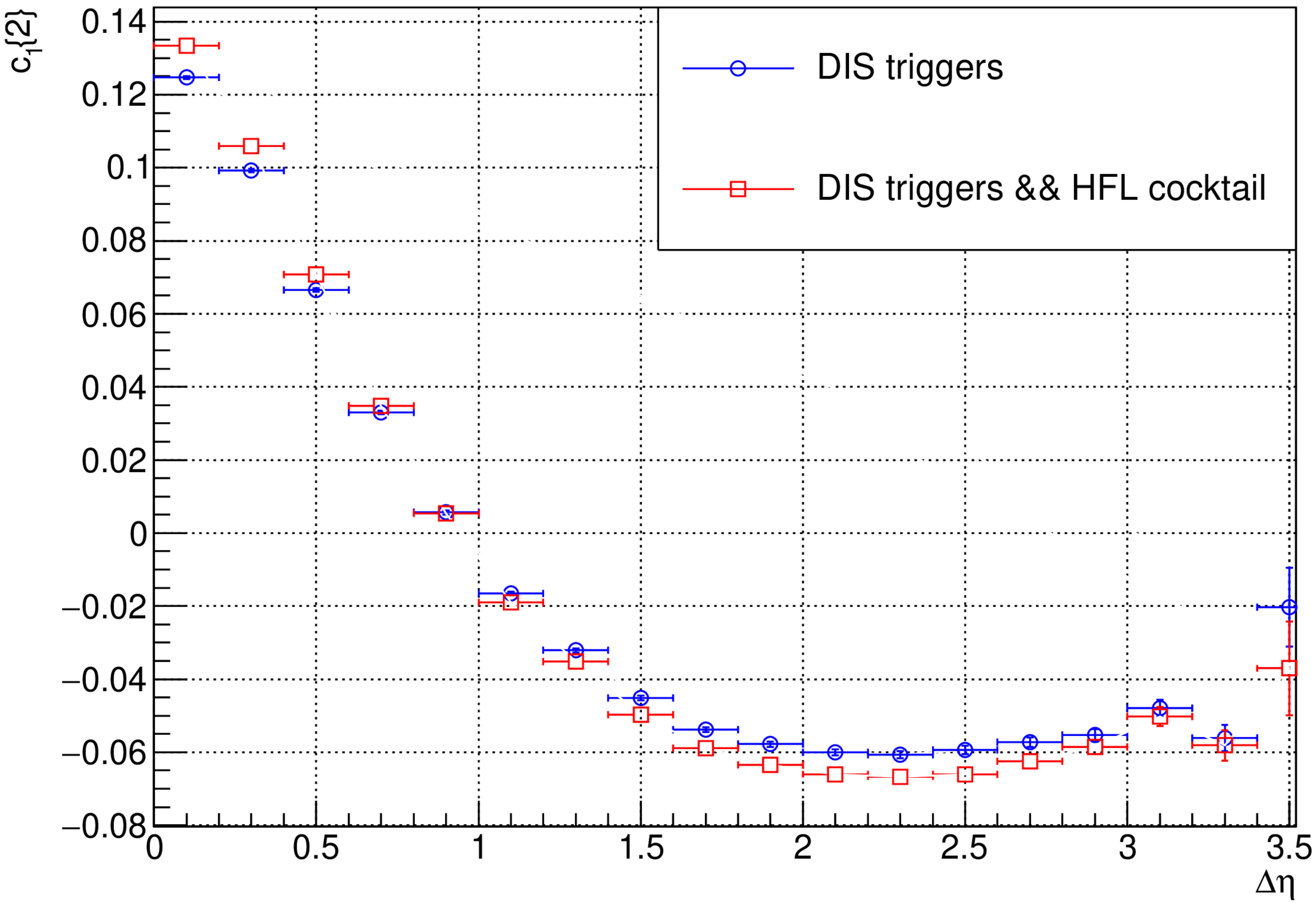
ZEUS



- After correcting for their biases (obtained from MC), we don't arrive at the same result in zeus data for each trigger.
- **Fractional difference between them is used as a systematic uncertainty.**

Another way to estimate the bias of the HFL cocktail triggers

ZEUS



- The DIS triggers are a proven route to capture inclusive DIS.
- Adding the HFL cocktail triggers on top provides another way of assessing the trigger bias to the PhP analysis.
- **Fractional difference between them is used as a systematic uncertainty.**

Towards publication

- We feel that the results are robust and ready to be published.
- We should now focus on swiftly writing the letter.
- It should be as concise as possible and then we can determine which journal is most appropriate.

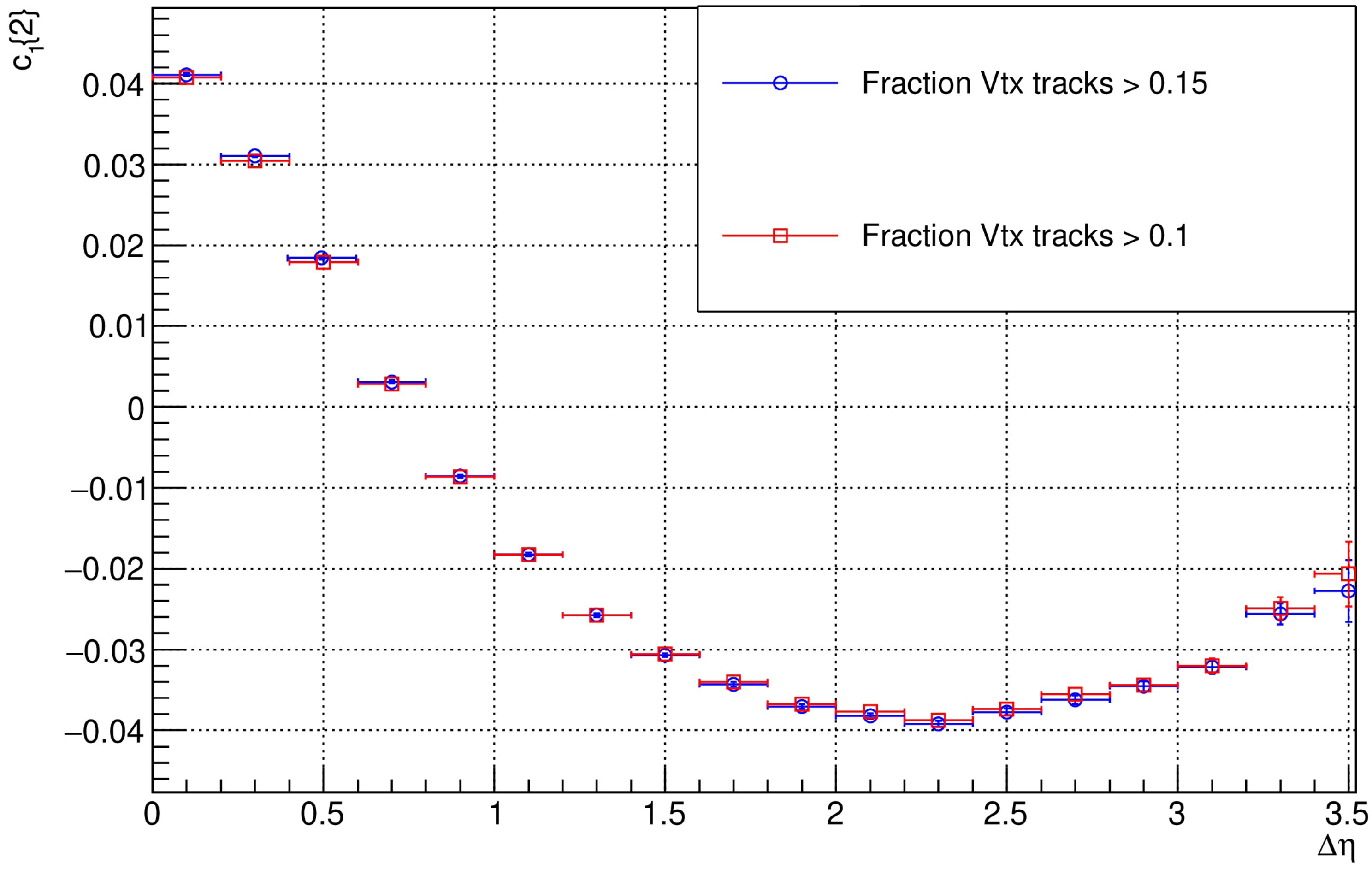
Backup

Reminder of HFL TLT descriptions

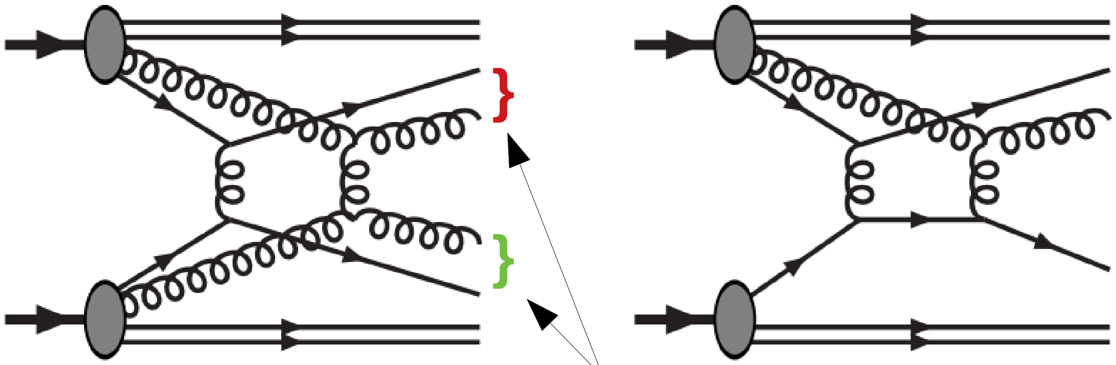
HFL TLT web page

TLT	Short description	Long description
HFL 1	Charmed hadrons in PHP	Or of all HFM triggers with hard cuts: pT thresholds and invariant mass thresholds of decay daughters.
HFL 2	Charmed hadrons in DIS	DIS electron Or of all HFM triggers with loose cuts:
HFL 5	inclusive dijets (similar to old HPP 14)	Two jets ET>4.5, eta<2.5 (EUCELL) Pz/E < 0.95 and E-Pz<100
HFL 6	jets in DIS	Two Jets ET>3.5, eta<2.5 (EUCELL) Pz/E < 1.0 and E-Pz<100
HFL 9	electron in PHP	Number of tracks > 2, Island Energy < 1000 Momentum track > 0 , pt of the track > 1.4 GeV , 0.6 < track theta < 2.55 , DCA < 30. EMC Island energy Fraction eEMCIsland/EIsland < 0.8
HFL 18	D* gold selection	See web pages for longer description.
HFL 19	D0/D0-bar mixing	See web pages for longer description.
HFL 21	MESON + jets	Two Jets ET>3.5, eta<2.5 (EUCELL) Pz/E < 1.0 and E-Pz<100 .or. of any of the 6 D meson low Pt cut channels
HFL 24	jet(s) + electron	See web pages for longer description
HFL 25	jet(s) + muon	See web pages for longer description
HFL 27	MVD inclusive trigger Only active since May 30th 2006 (~40% of HERA II integrated lumi)	All SLT PHP, DIS and MUON slots MVD vertex within -30 cm < z(vtx) < 30 cm at least 4 tracks fitted to the primary vertex Et > 8 GeV (excluding the 1st two inner rings around the beam pipe) At least three tracks with pt > 0.75, 0.6, 0.45 GeV Impact parameter significance cut for the 3rd highest significance track. The impact parameter significance is evaluated with respect to the primary event vertex.
HFL 28	MVD inclusive trigger using beam spot Only active since May 30th 2006	Same cuts as for HFL 27, but the impact parameter significance is evaluated with respect to the beam spot.

Effect of changing the cut for Fraction of Vtx tracks



Multi Parton Interactions (MPI) in Pythia



(a) (b)

R. Corke and T. Sjostrand
arXiv:0911.1909

Figure 1: (a) Two $2 \to 2$ scatterings, (b) a $2 \to 2$ scattering followed by a rescattering

- Due to infrared divergencies in perturbative QCD, the interaction cross sections are regularized with a p_{T0} parameter.
- p_{T0} can also be thought of as a color screening parameter.
- Smaller p_{T0} → more MPI.
- **In pythia, one can count the number of 2-to-2 initial parton scatterings: nMPI.**
- Color Reconnection (CR) occurs when 2 or more separate MPI systems merge into 1 "color-flow" object. It is controlled by a "range" parameter.

Pythia PHP event generation

Pythia version 8.303

Settings (based on a photoproduction macro provided by Ilkka Helenius):

Tunes:

e+e-: Choice of tune to e^+e^- data, mainly for the hadronization and timelike-showering aspects of PYTHIA.
Monash 2013 tune by Peter Skands (default in Pythia 8).

pp/$\bar{p}$p: Choice of tune to pp/ppbar data, mainly for the initial-state-radiation, multiparton-interactions and beam-remnants aspects of PYTHIA.
Monash 2013 tune by Peter Skands (default in Pythia 8).

Beams:frameType = 2	(beams are back-to-back with different energies)
Beams:idA = 2212	(proton beam)
Beams:idB = 11	(electron beam)
Beams:eA = 920	(proton beam energy)
Beams:eB = 27.52	(electron beam energy)

PDF:lepton2gamma = on	(Gives photon beams from leptons)
Photon:Q2max = 1.0	(max Q2)
Photon:Wmin = 10.0	(min sqrt(s) of photon-proton system)
Photon:ProcessType = 0	(automatic mix of resolved and direct)

Two options to treat scatterings:

<u>Use Soft QCD part of pythia:</u>

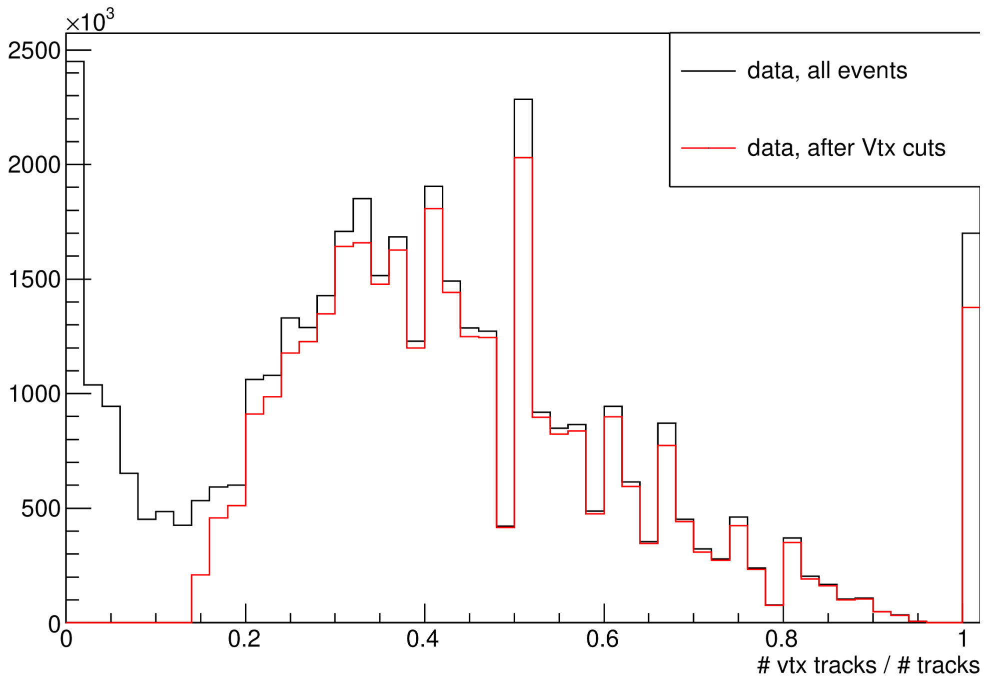
SoftQCD:nonDiffractive = on
MultipartonInteractions:pT0Ref = 3.5 (related to MPI probability, larger value means fewer MPI)

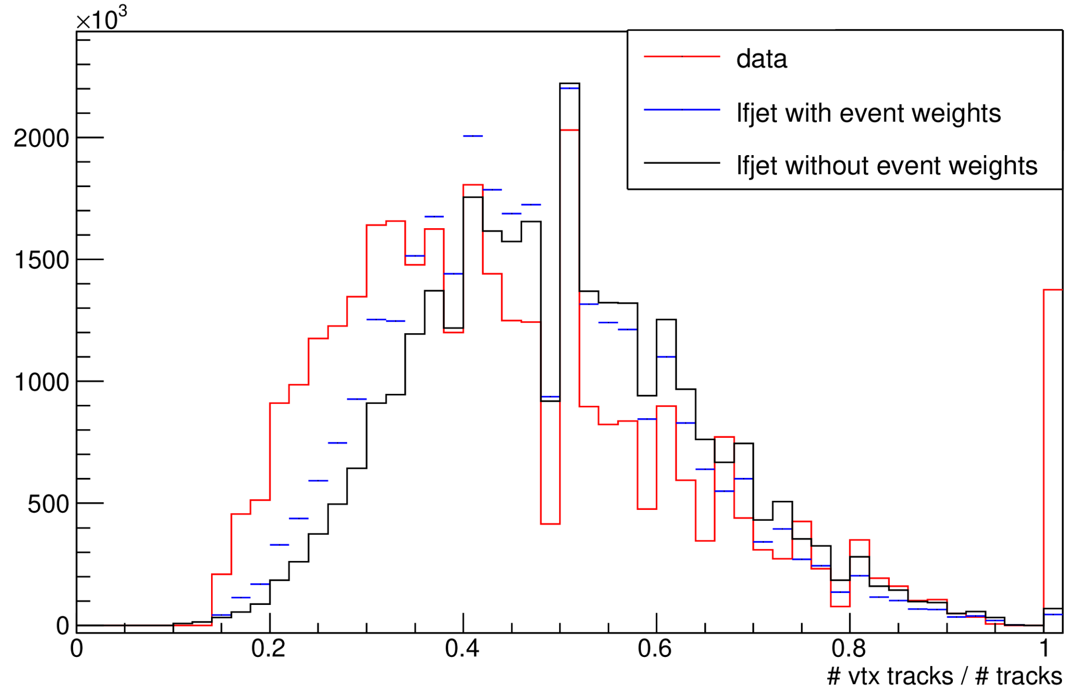
or

<u>Use Hard QCD part of pythia:</u>

PhaseSpace:pTHatMin = 1.8	(lower cutoff of invariant pT in 2 $\rightarrow$ 2 process)
HardQCD:all = on	(resolved component)
PhotonParton:all = on	(direct component)

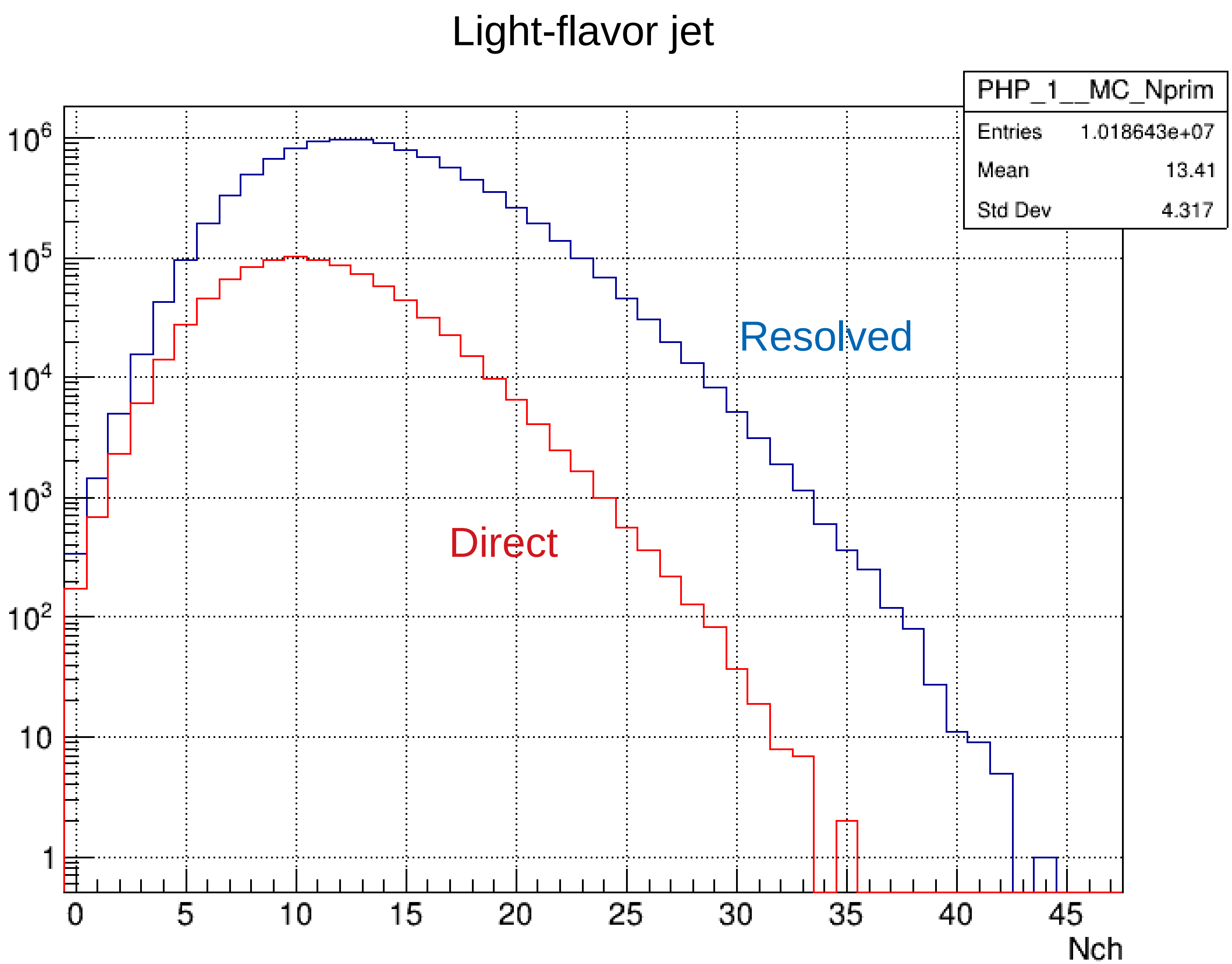
Fraction of primary vertex tracks





- Beam-gas background is clearly visible in data near zero.
- It is not simulated in the MC.
- Distributions in data and MC do not match so well --> Too few secondaries in MC.
- An event weight, which was invented to patch the problem in DIS, was applied to the PhP MC.

Variation of direct + resolved mix for PHP efficiency correction calculation



- At high multiplicity ($N_{ch} > 20$), the direct component in light-flavor jet is a few %.
- As a systematic variation of the efficiency corrections, we remove the direct component.

x-gamma

x-gamma refers to the fraction of the incoming photon energy given to the two leading jets.
It can be used to distinguish between direct and resolved photoproduction.

Reconstruct x-gamma using the two leading jets (index 0 and 1) from the orange ntuple jet class

kt_JETS_A: ”Zufos, without removal of electron candidate, are used as input for jet algorithm. Massive jets are reconstructed with E-scheme and in inclusive mode. Dead material corrections are applied. Information about 10 jets in laboratory frame is saved. Jets are required to have transverse energy greater than 2.5 GeV and pseudorapidity in range from -2.5 to 2.5”

$$x_\gamma^{meas} = \frac{E^{jet1} + E^{jet2} - p_Z^{jet1} - p_Z^{jet2}}{E^{all} - p_Z^{all}}$$

DESY-14-086

The denominator is the usual E - Pz calculated using ZUFOs.
The terms in the numerator need to be calculated from what’s provided in the kt_JETS_A block: E_T, m, η

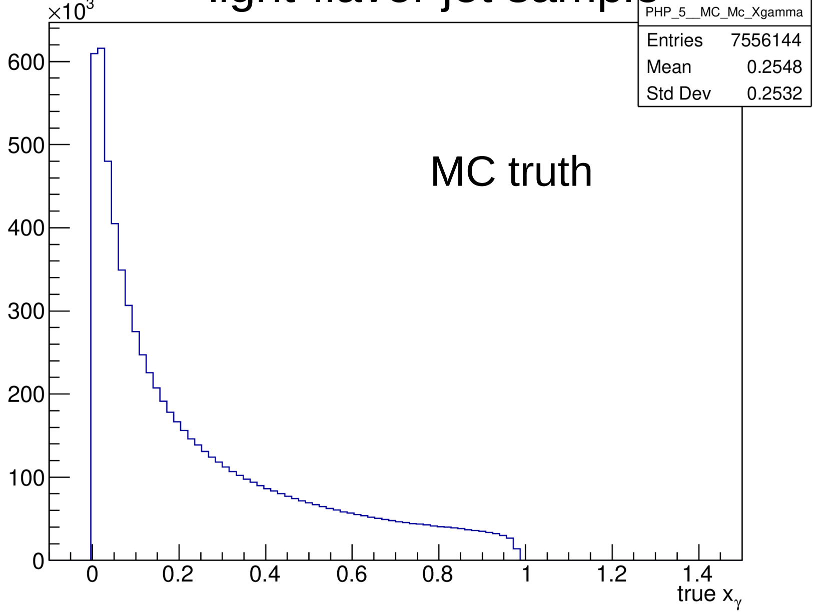
$$E^{jet} = E_T^{jet} \cosh \eta^{jet}$$

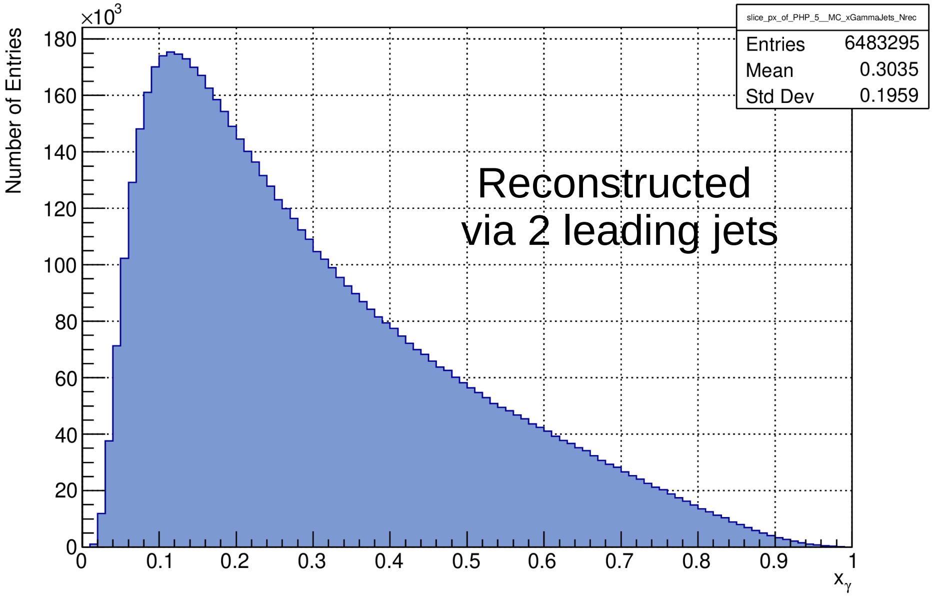
$$p^{jet} = \sqrt{(E^{jet})^2 - (m^{jet})^2}$$

$$p_Z^{jet} = p^{jet} \tanh \eta^{jet}$$

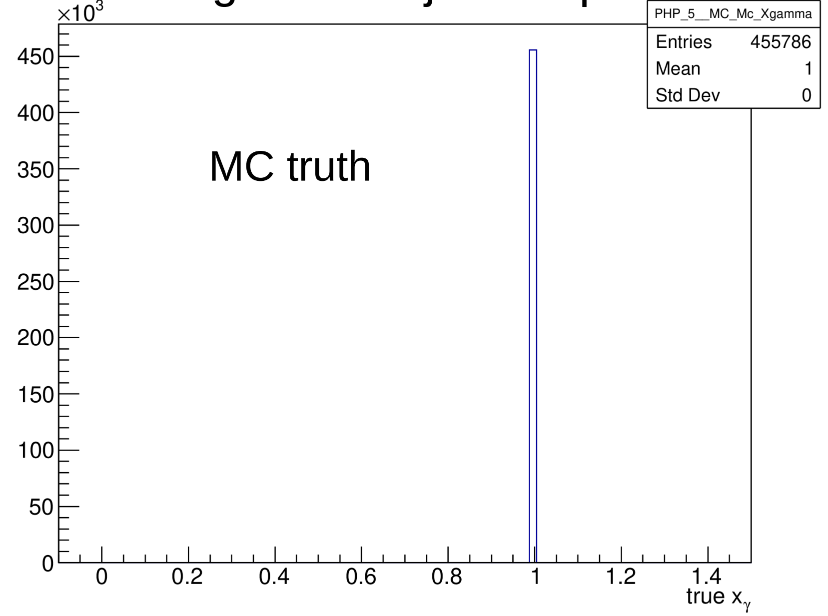
Smearing of MC true x-gamma distributions

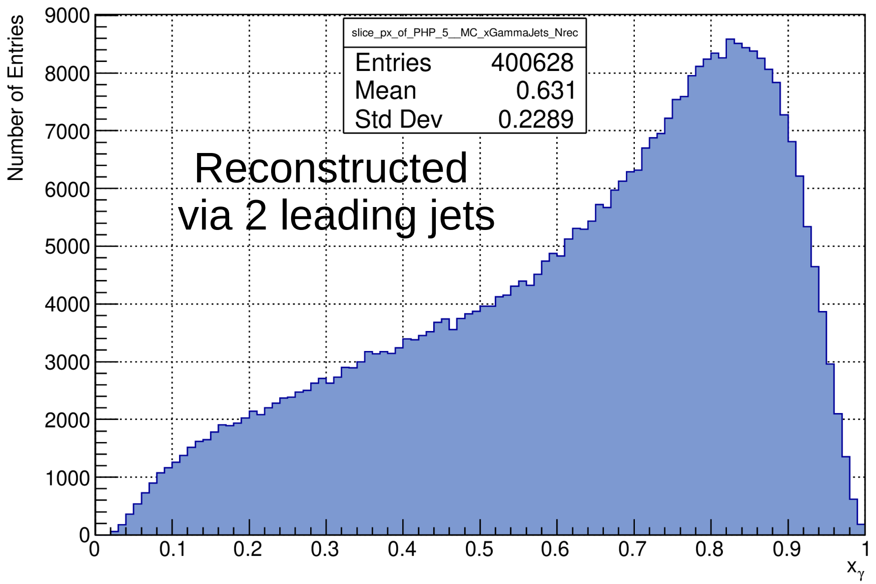
“resolved” component of Pythia light-flavor jet sample





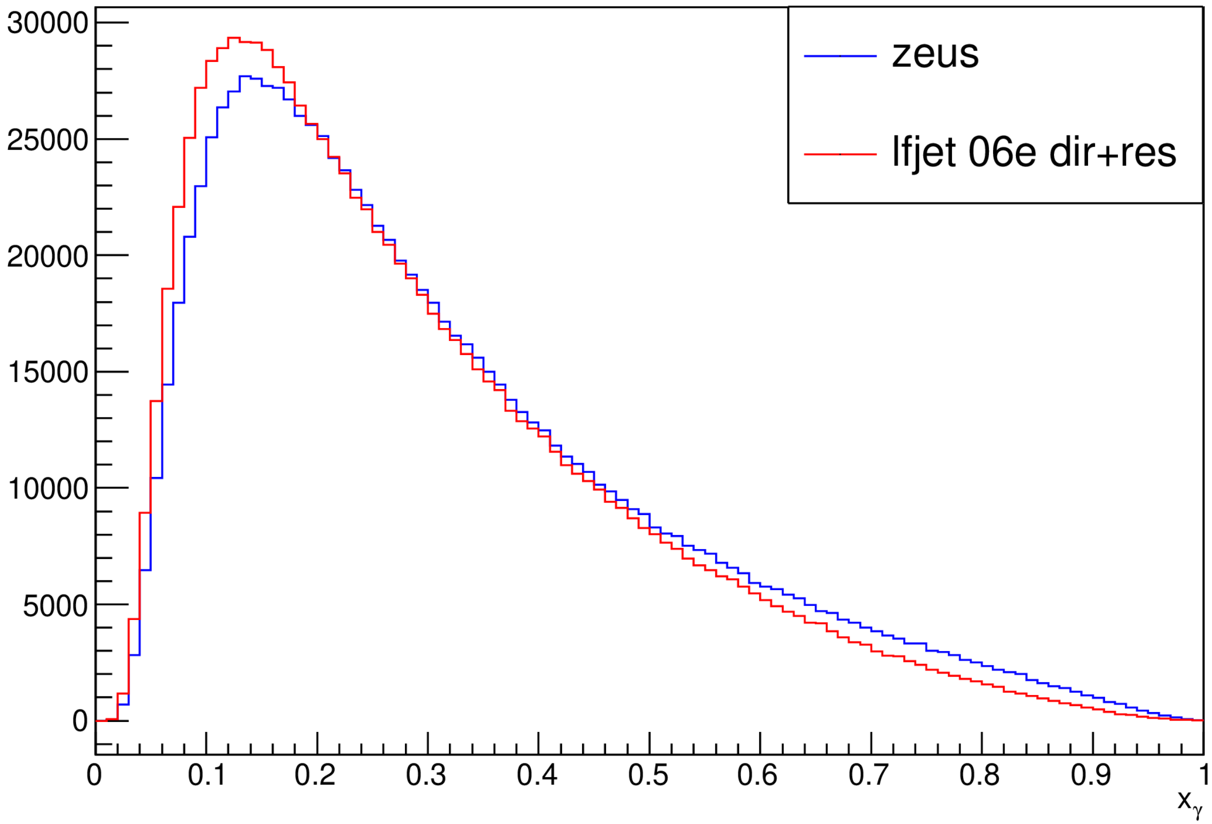
“direct” component of Pythia light-flavor jet sample





x-gamma distributions at mid and high N_{rec}

$N_{rec} > 20$



Red distributions are normalized to that of the blue distribution to allow for a better shape comparison.

Single-particle and pair efficiency correction

As in the DIS analysis, we will apply pair-reconstruction efficiency corrections to 2-particle correlations.

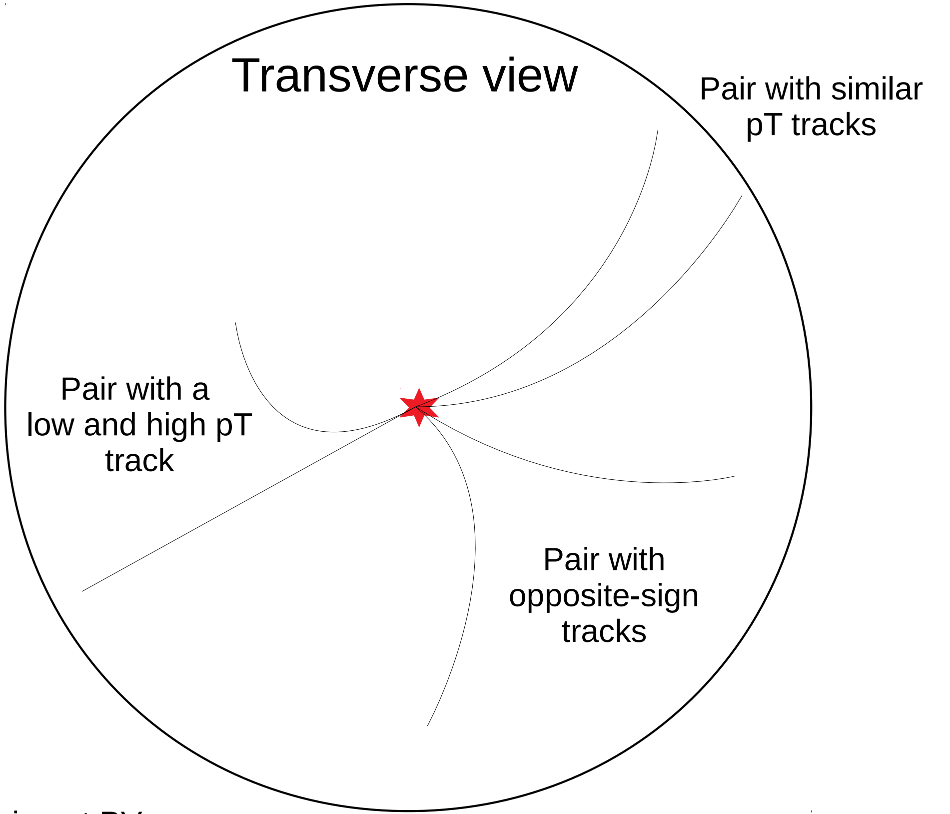
<u>Single-particle correction factor</u>

$$w_i = \frac{N_{gen}(p_T, \eta, \varphi, q)}{N_{rec}(p_T, \eta, \varphi, q)}$$

charge

<u>Pair correction factor</u>

$$w^{(2)} = \frac{N_{gen}^{pairs}(\vec{x})}{N_{rec}^{pairs}(\vec{x})}$$



$$x_1 = \Phi = \varphi_1 - \varphi_2$$ azimuthal angle dispersion at PV

$$x_2 = \langle \eta_i - \langle \eta \rangle \rangle$$ pseudorapidity dispersion in pair

$$x_3 = \langle p_{T,i} - \langle p_T \rangle \rangle$$ p_T dispersion in pair (depicted above)

$$x_4 = |q_1 + q_2|$$ charge combination: 0 or 1

$$x_5 = N_{ch}^{rec}$$ 6 bins: 0-8, 8-12, 12-16, 16-20, 20-25, 25-50