Addressing the remaining comments from the post EB2 discussion

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Oct 23rd 2019

In-person discussions between Achim, Dhevan, and Ilya were arranged to discuss the details of the analysis procedure.
In particular, the event selection procedure was discussed.

<u>The following four issues were raised and investigated.</u>

1) DIS triggers: In addition to the desired inclusive DIS triggers, four extra triggers had always been included in the analysis (including preliminaries).

- HPP20 (forward jet in DIS)
- TLT HFL2 (inclusive mesons in DIS)
- TLT HFL6 (dijets in DIS)
- TLT HFL10 (e in DIS)

2) Sinistra charge misidentification: cross-check of PHP contamination.

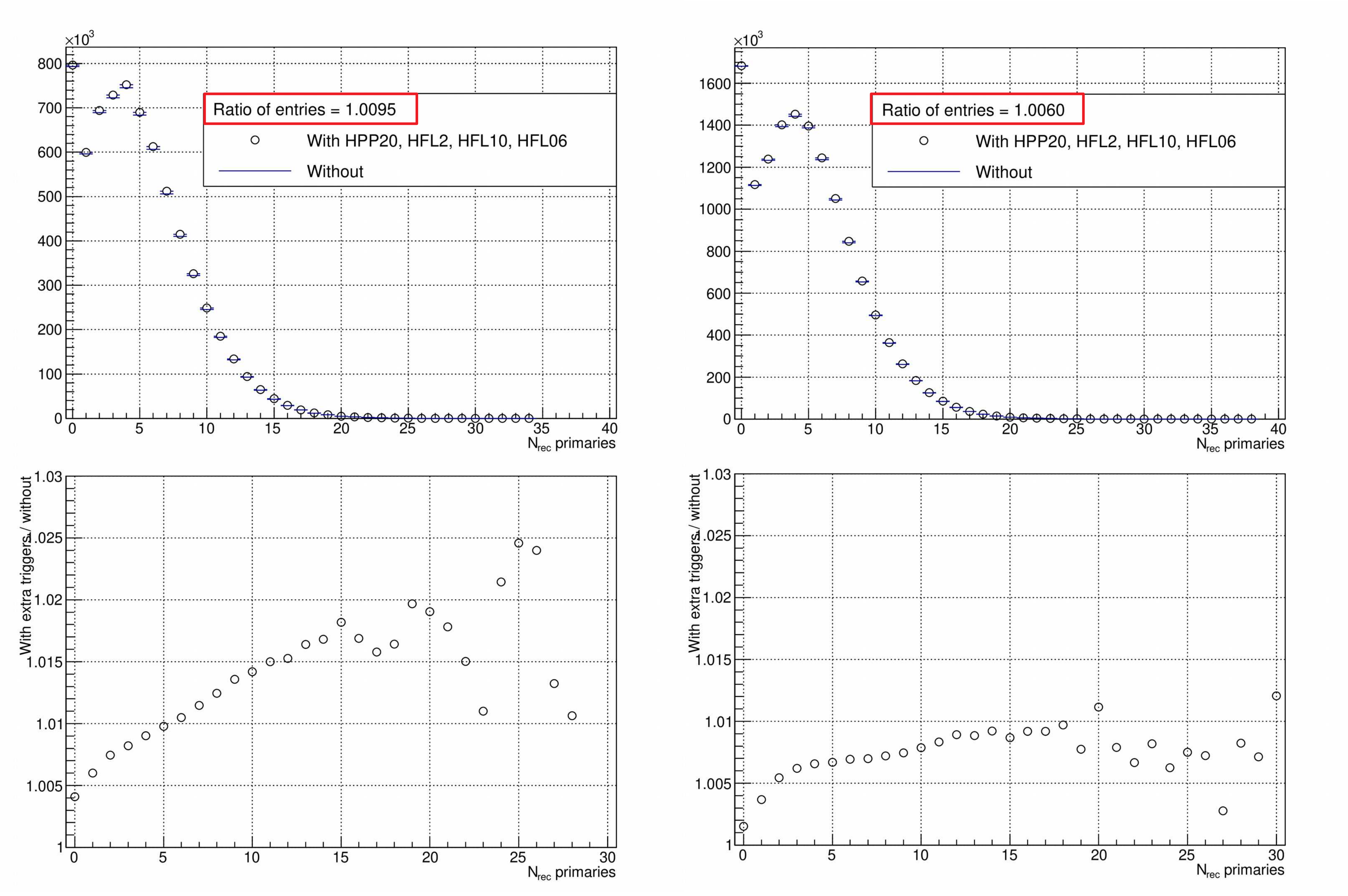
3) MC truth E - Pz cut for the selection of events used to calculate MC generator distributions/correlations: Investigate the physics selection vs. experimental bias resulting from this cut.

4) Event weights to correct the underestimation of secondaries in MC: not applied in the analysis. The effect on N_{rec} has been studied (N_{rec} presented in Fig 1 of paper).

Extra triggers:
HPP20, HFL02, HFL06, HFL10

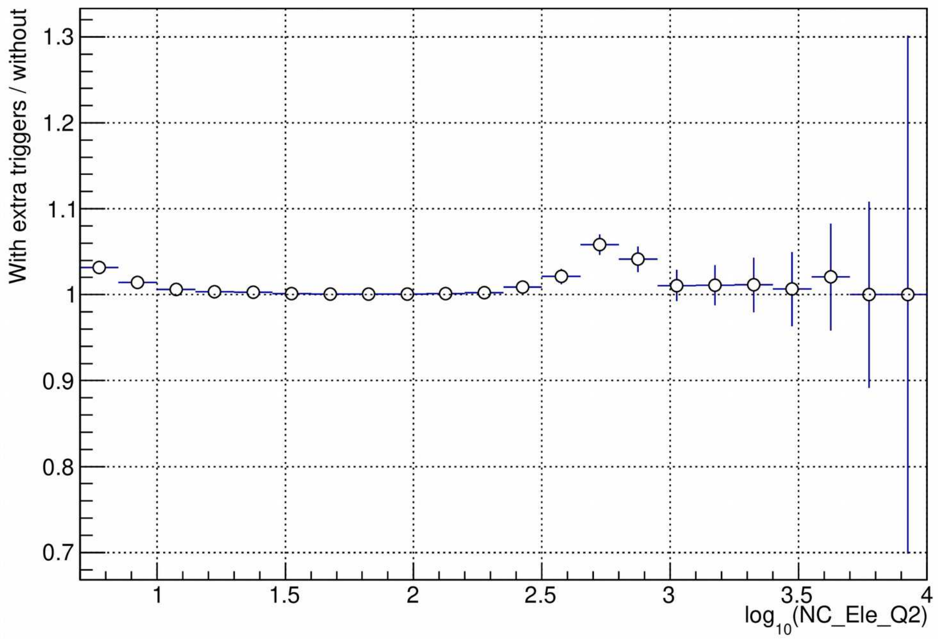
DATA MC

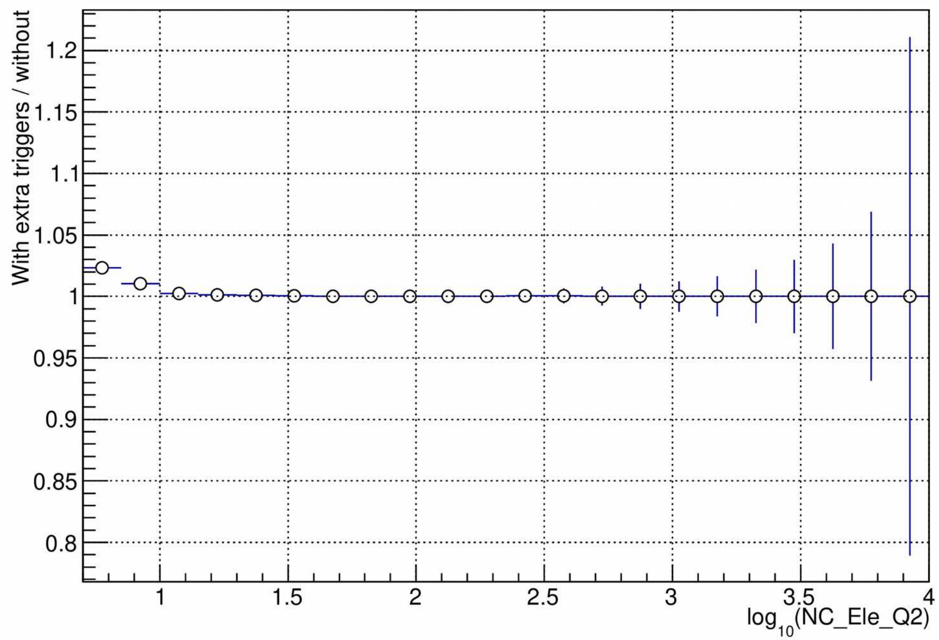
The four extra triggers add about 1% more events to our sample.



DATA

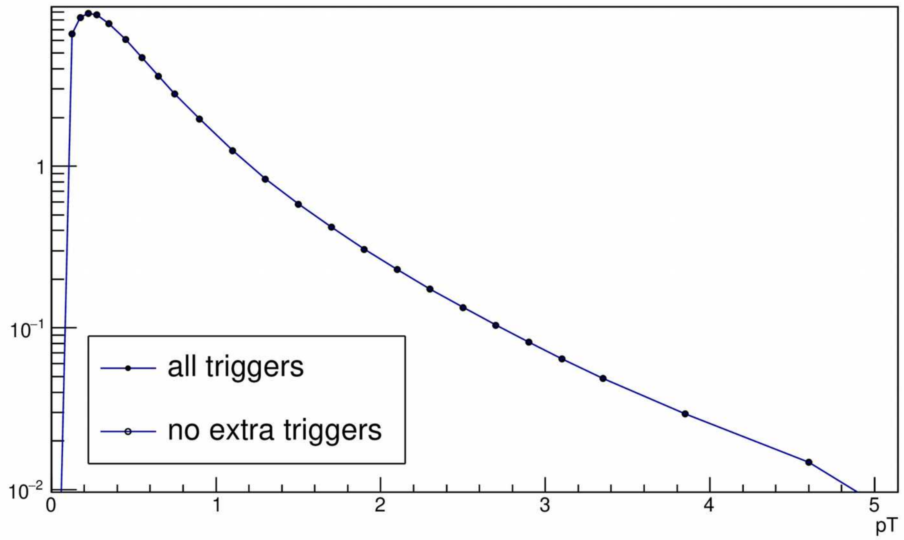
MC

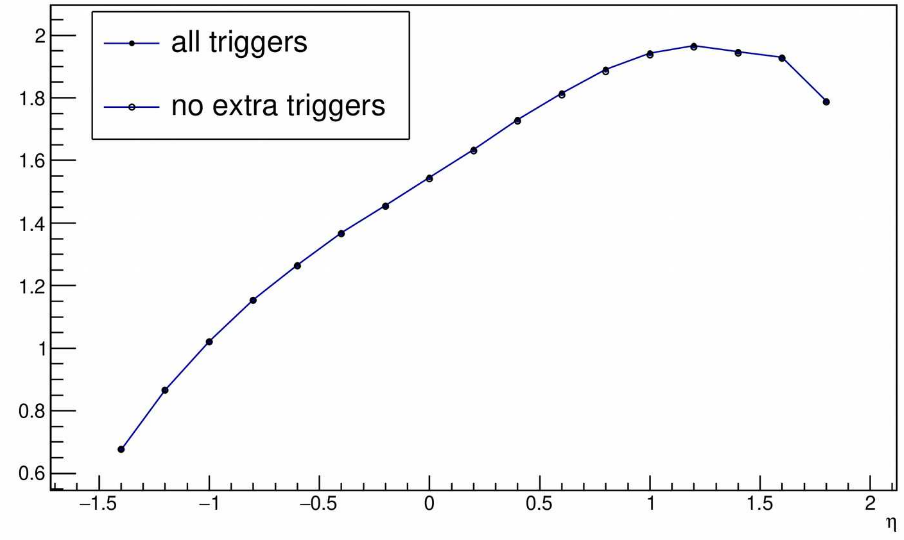




The extra triggers increase the event population at low Q2 by a few percent.
MC reproduces this feature reasonably well.
An additional hump at Q^2~500 GeV^2 appears in data but not in MC.

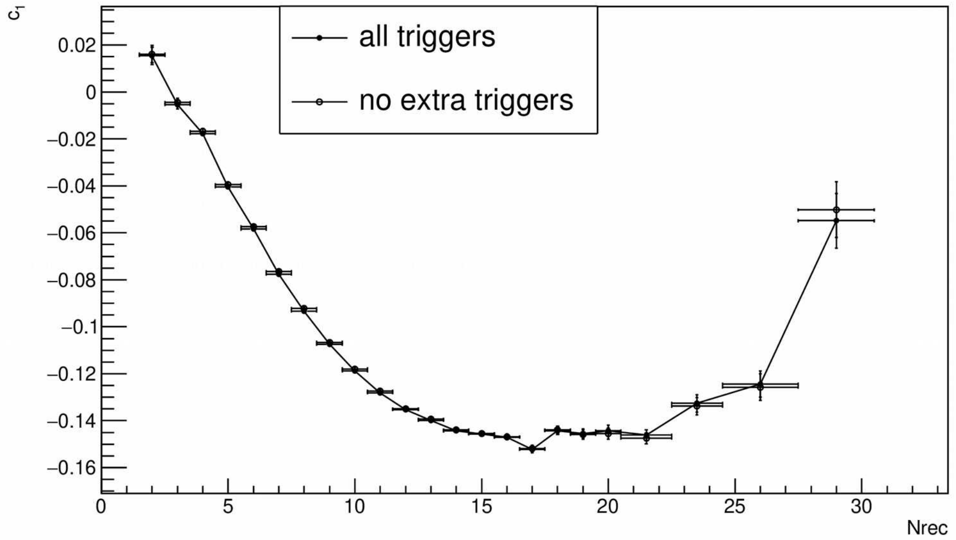
Comparison of p_T and eta distributions

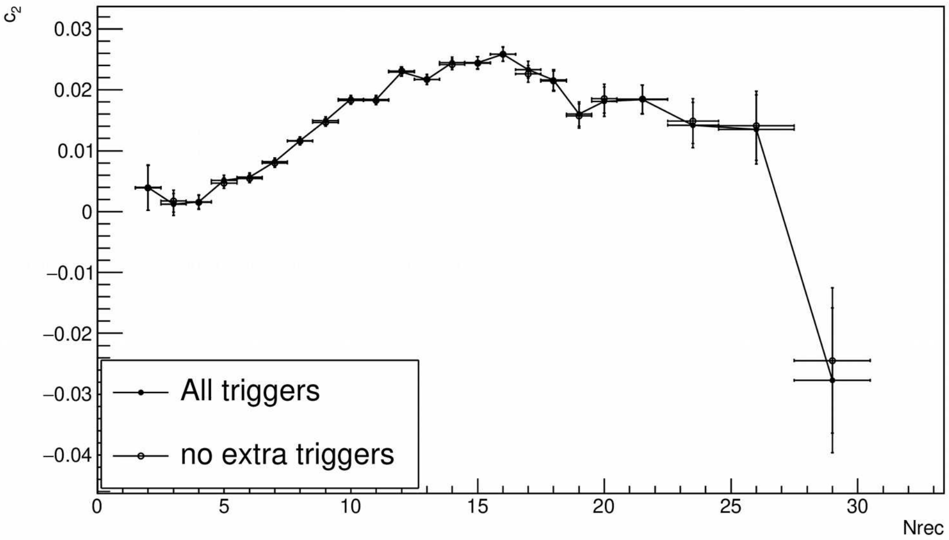




Efficiency corrections not applied.
Difference is negligible.

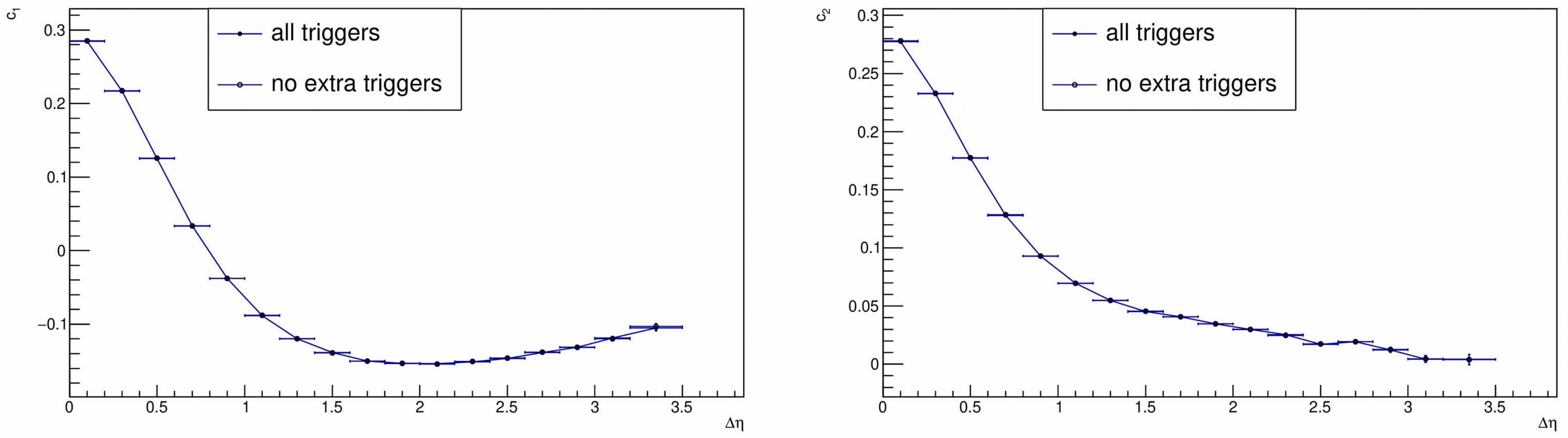
Comparison of c_1 and c_2 vs N_{rec}
$\Delta\eta > 2$, $p_T > 0.5$





Efficiency corrections not applied.
Difference is negligible.

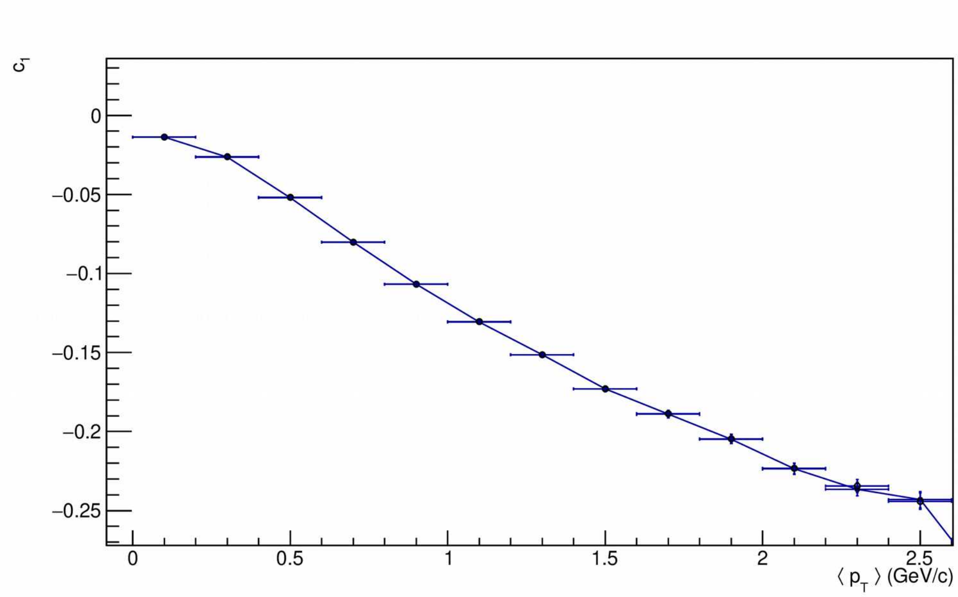
Comparison of c_1 and c_2 vs $\Delta\eta$
$p_T > 0.5$, $15 < N_{rec} < 30$

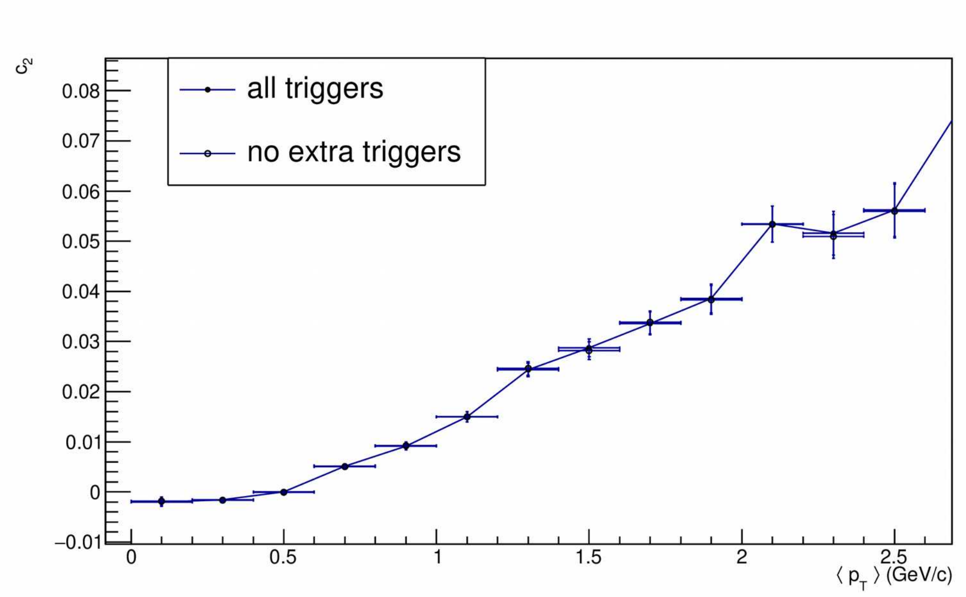


Efficiency corrections not applied.
Difference is negligible.

Comparison of c_1 and c_2 vs mean p_T

$\Delta\eta > 2$, $15 < N_{rec} < 30$

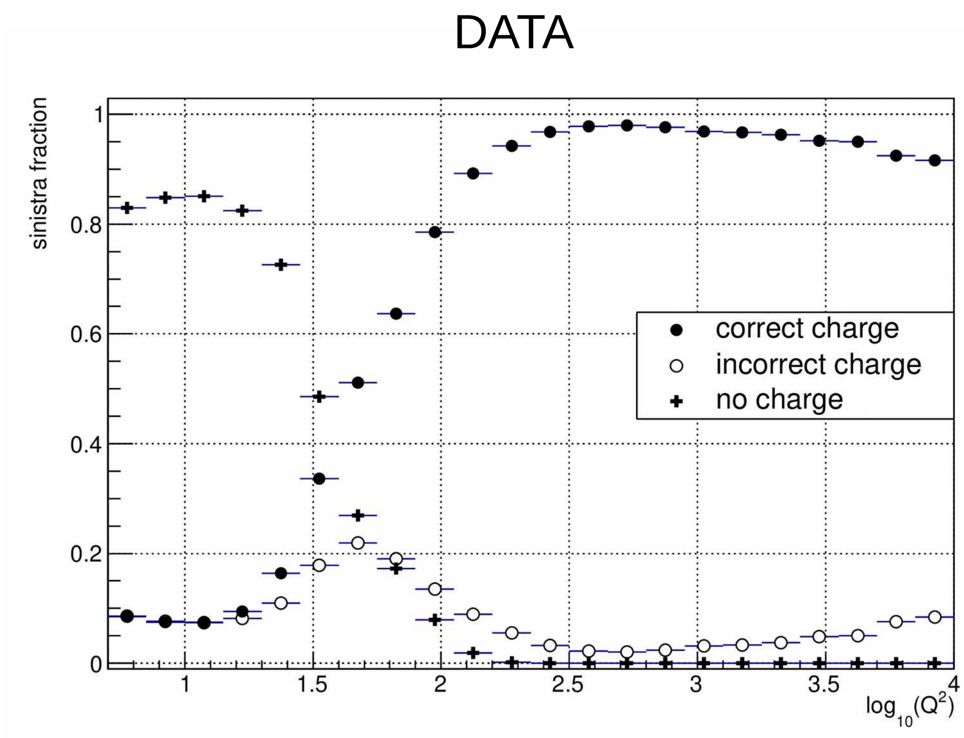


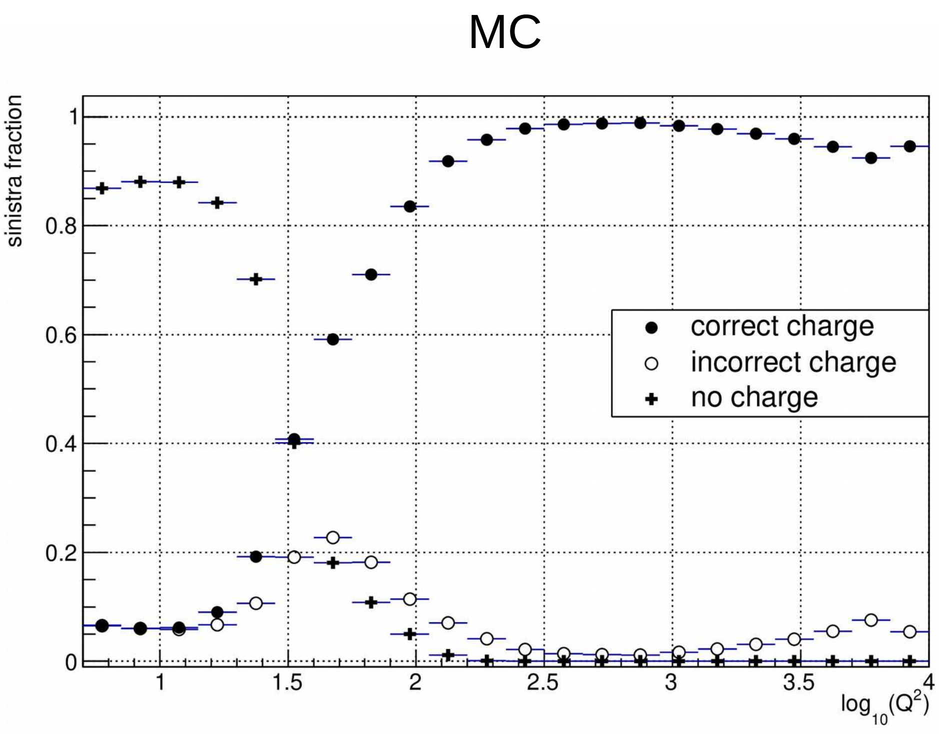


Efficiency corrections not applied.
Difference is negligible.

Sinistra charge misidentification

Compare the sinistra candidate electron charge with the known electron beam charge

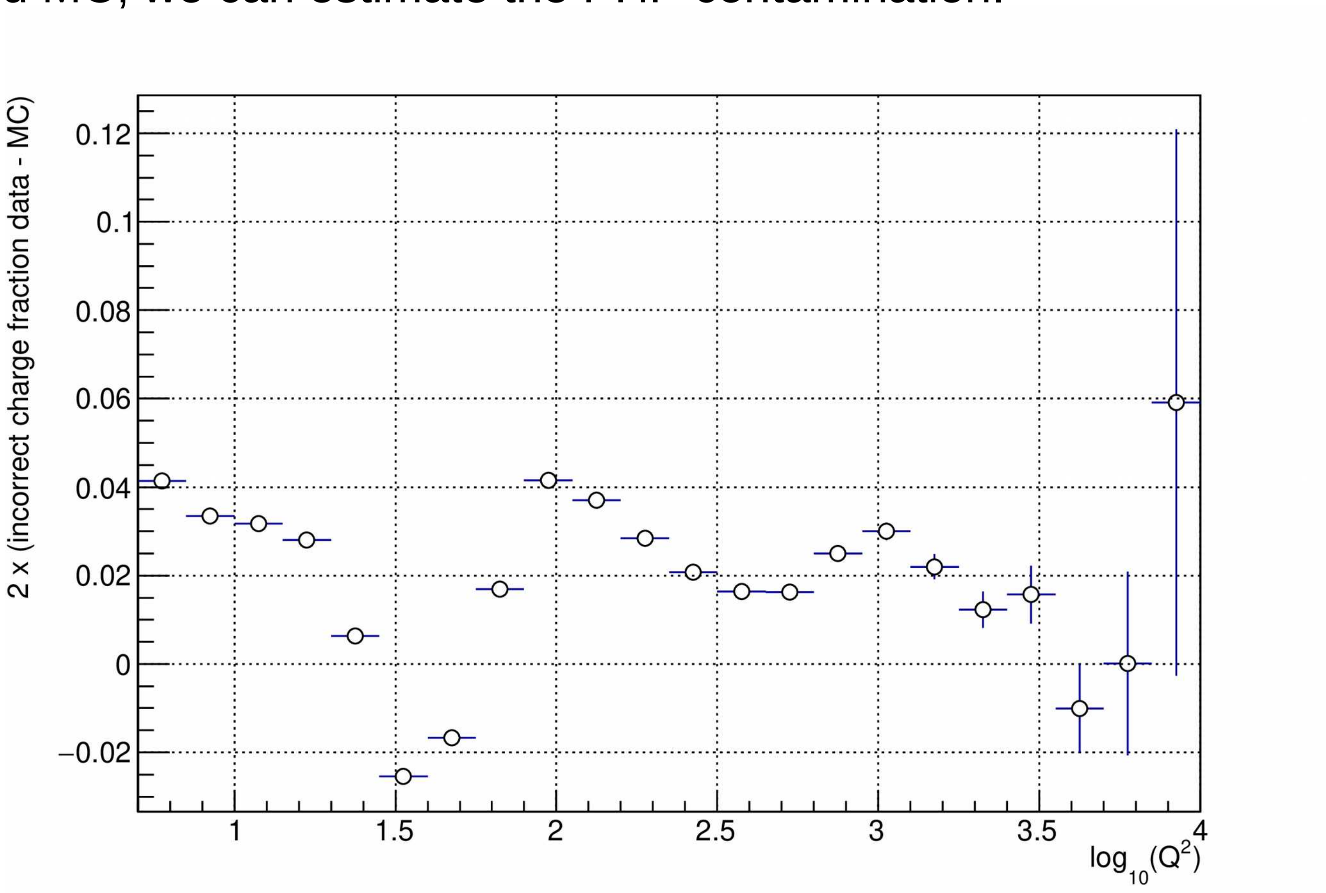




At low Q^2, there are no reliable tracks that can be associated with the cluster in the CAL. Therefore the correct charge fraction is very small there.
At high Q^2, the scattered electron enters a substantial portion of the tracking fiducial and is therefore more likely to be assigned the correct charge.

PHP contamination estimation

Data contains DIS + PHP contamination.
Analyzed MC sample contains only DIS.
By comparing the fraction of incorrectly charged sinistras (wrt electron beam charge) in data and MC, we can estimate the PHP contamination.



Part of this difference can be due to the modeling of DIS in MC. Therefore, an upper limit to the PHP contamination is estimated to be 2-4% from this perspective.
This is consistent with the estimation from the previous study using Pythia PHP MC.

E – Pz MC truth cut

Selection of true DIS events in MC using truth information

For the generator level calculations of the single particle distributions in Figs 1 and 2 in the paper as well as those for c_n in Figs 7 and 8, DIS events are selected in a similar way as in data but using truth information:

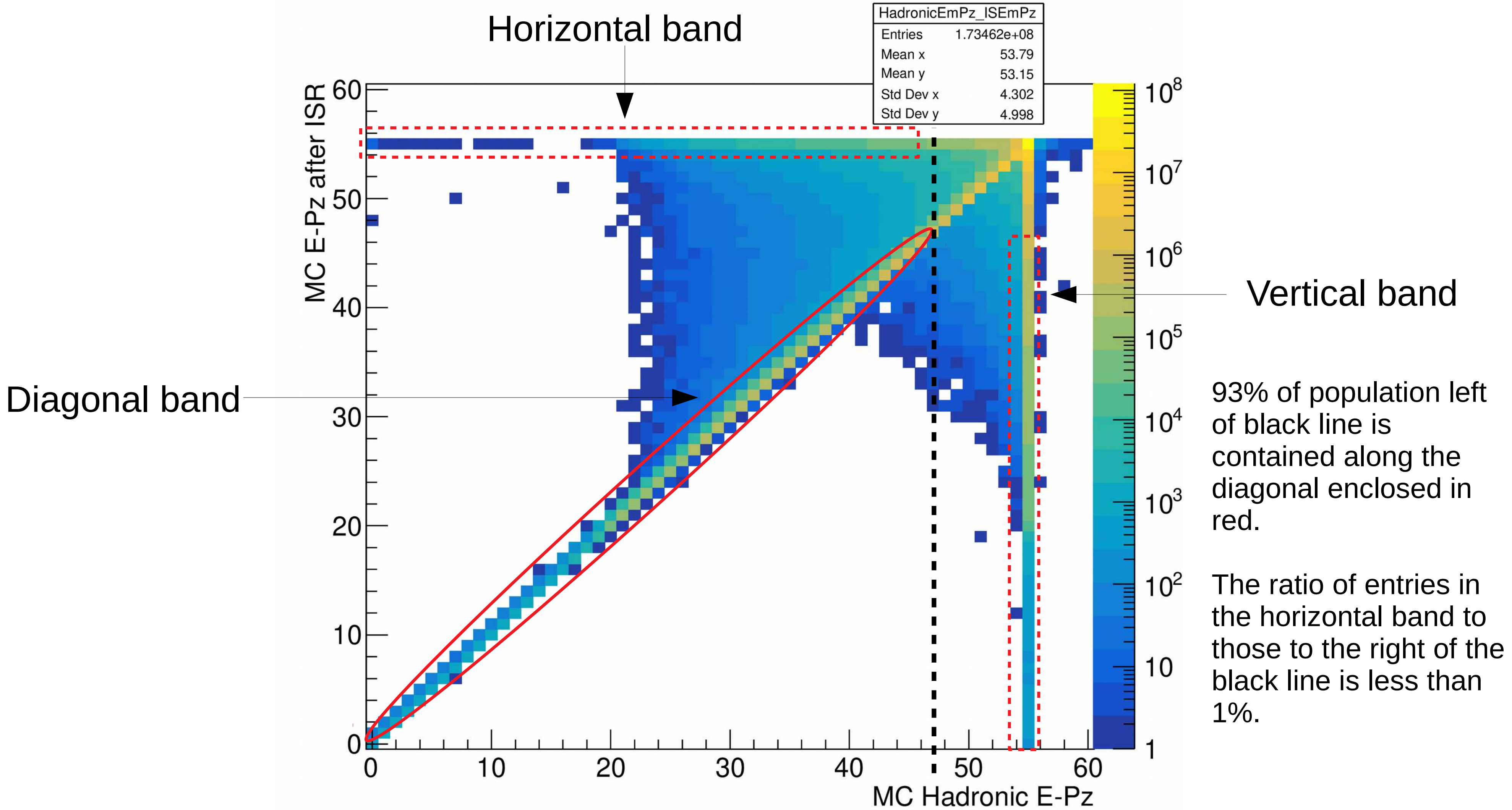
$Q^2_{true} > 5$ GeV^2 (calculated from initial and final state electron)
$\theta_{true} > 57°$
$E_{true} > 10$ GeV
$47 < E - P_z < 69$ GeV

The issued raised was whether the E-Pz cut induces an experimental bias which a theoretical calculation cannot easily emulate. The quantity was calculated based on the particles in ZEUS MC which "should reach CAL" and includes a cut on final state hadrons.

The E-Pz cut also suppresses events with strong Initial State Radiation (ISR) which can be easily simulated in a model.

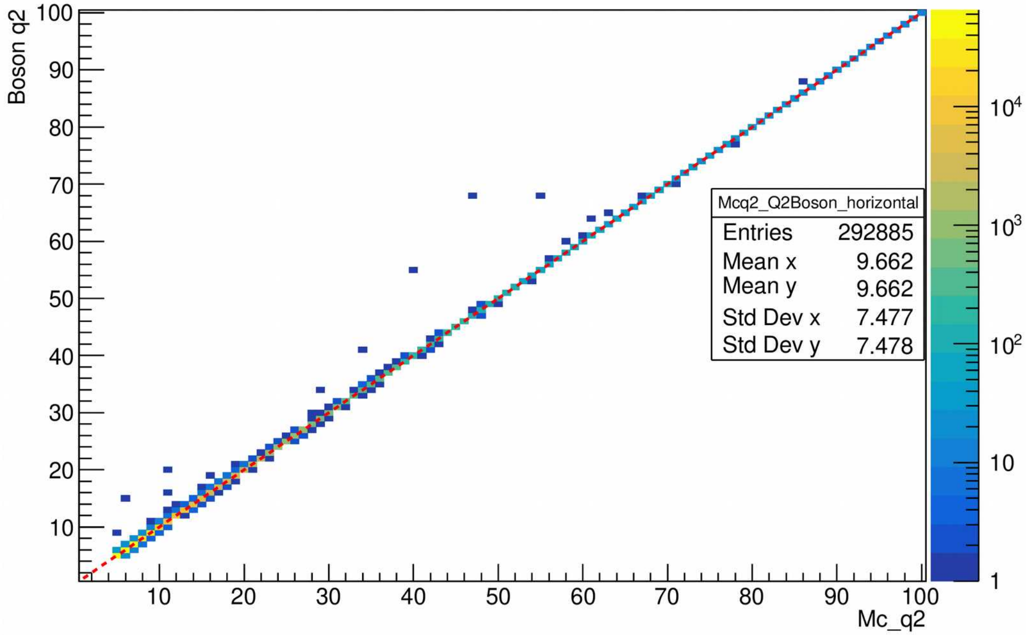
On the next slide E-Pz is calculated two ways and compared:

- Hadronic E-Pz: calculated from particles which "should reach CAL"
- E-Pz after ISR: calculated directly from the exchanged photon and final state electron. For strong Initial State Radiation, this will differ from $2 {*} E_e = 55$ GeV

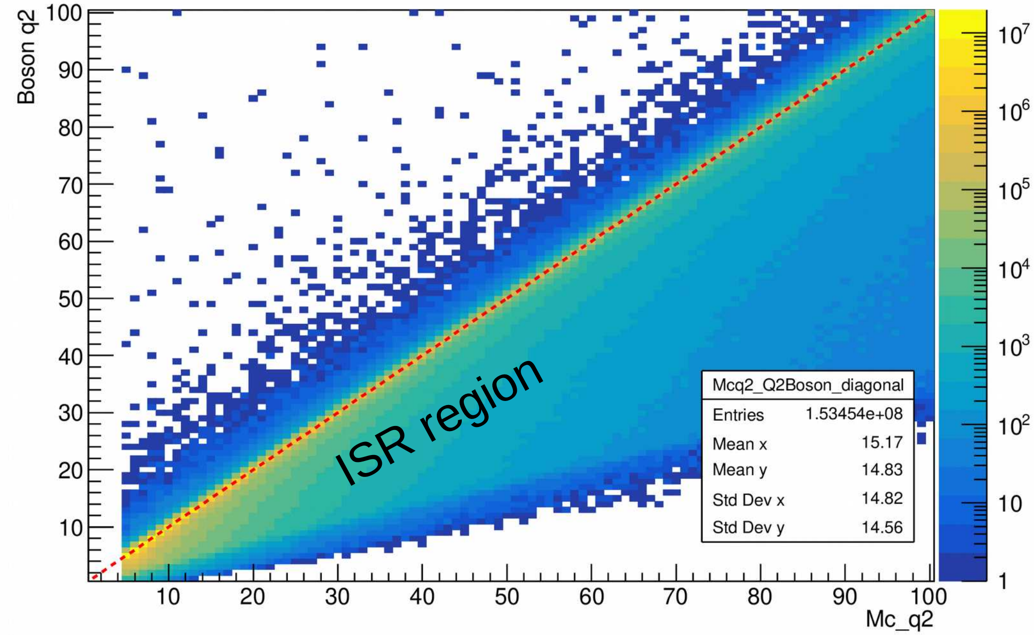


MC generator curves calculated in events with: 47 < MC Hadronic E-Pz < 69.
There are three dominant structures above.
The diagonal band is expected from initial state radiation.
The horizontal band is expected from a loss of hadrons in the ZEUS acceptance.
The vertical band is probably from *final* state electron radiation (see next slide).

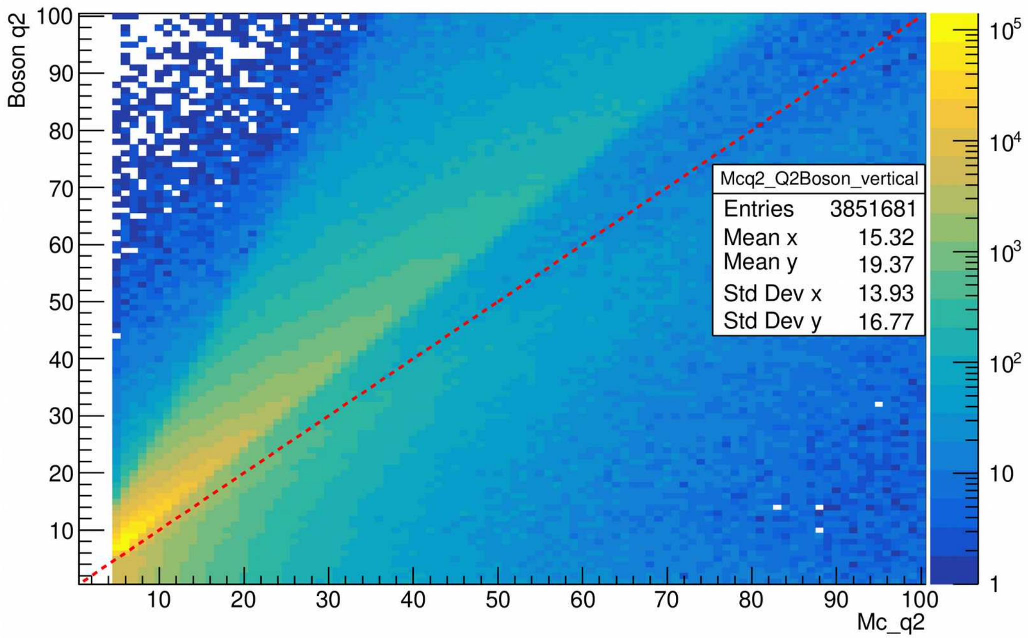
Horizontal Band



Full Diagonal Band:
| (Hadronic E-Pz) – (E-Pz after ISR) | < 1 GeV



Vertical Band



Red dotted line is to guide the eye.

True photon Q^2 = “Boson q2”

<u>Full diagonal band:</u>

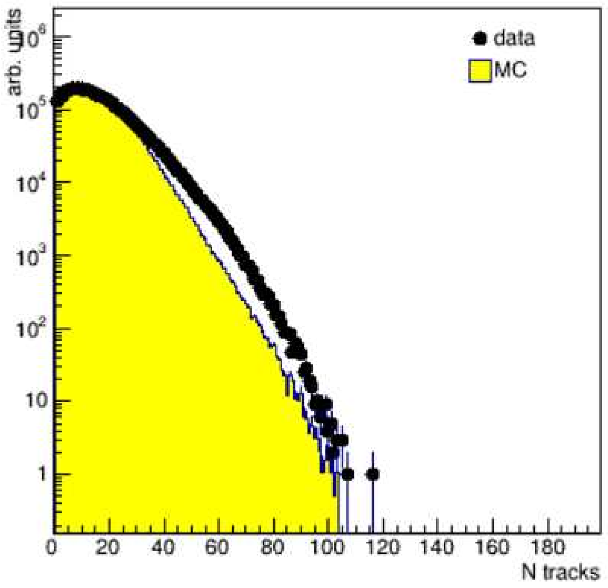
Includes events for which
(Hadronic E-Pz) ~ (E-Pz after ISR) ~ 55 GeV.
This produces the diagonal line above and is not a region of strong ISR. The region of strong ISR is below the red dotted line.

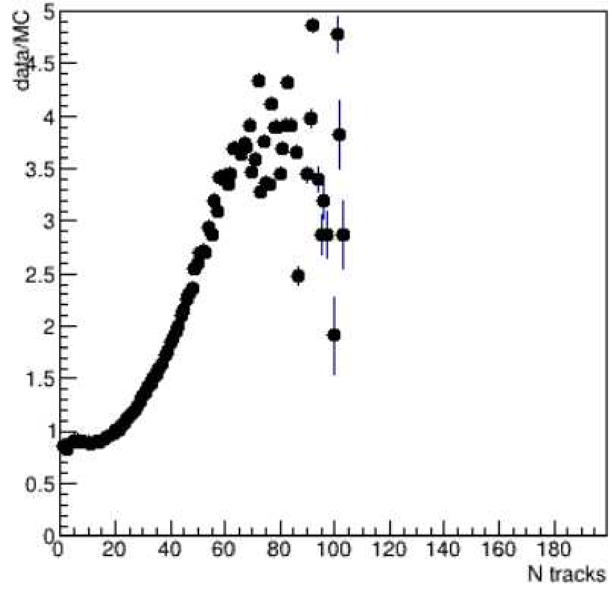
<u>Vertical Band:</u>

Boson Q^2 is often larger than that calculated from initial and final state lepton momenta.
Probably caused by final state electron radiation.

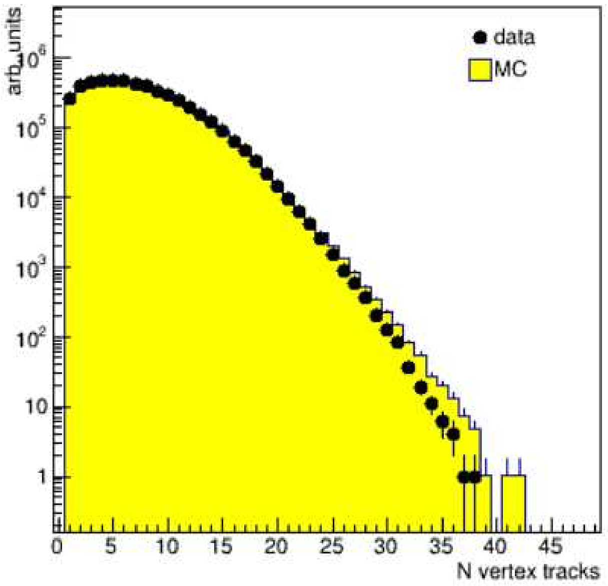
Event weights

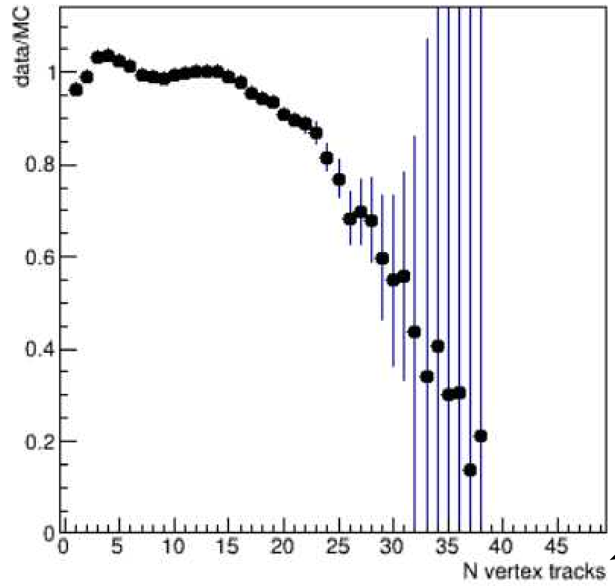
Observation:
vertex tracks are reasonably well simulated in ZEUS MC
but not secondary tracks





Total number of reconstructed tracks



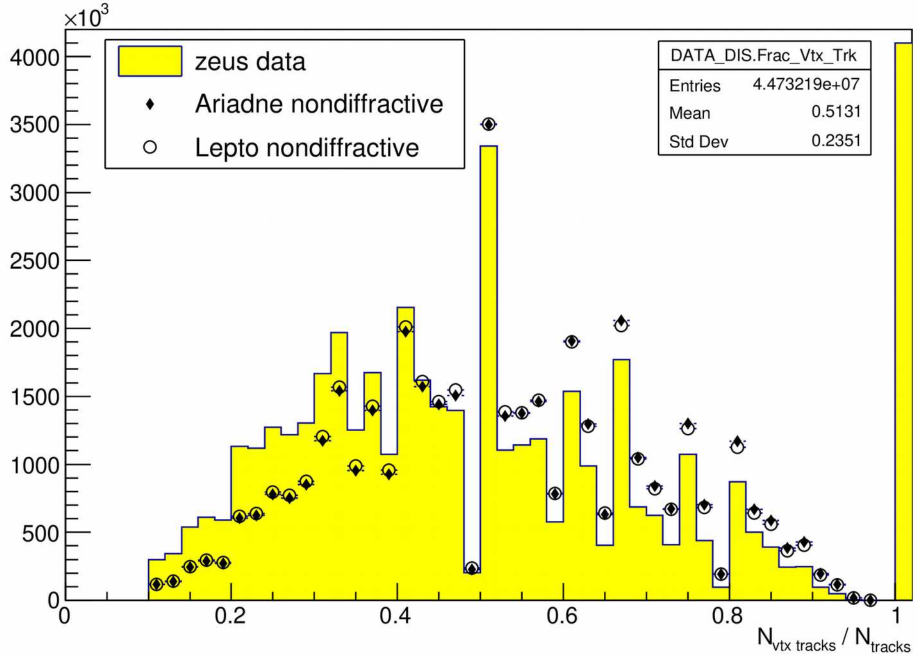


number of vertex tracks

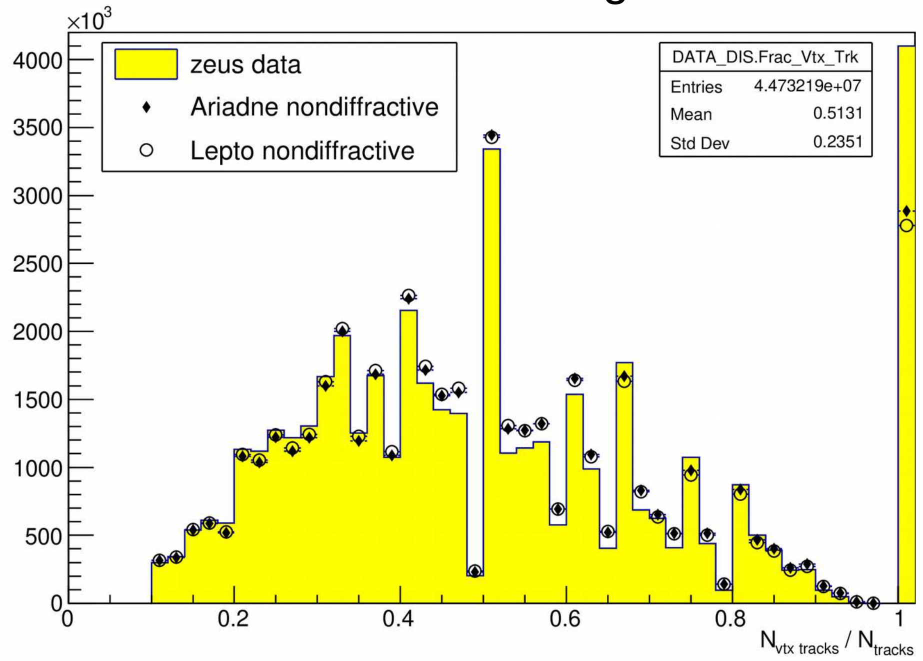
An event weight based on the fraction of vertex tracks
can be applied to the reconstructed MC to simulate this observation:

$$w = \left(\frac{0.5 \times N_{tracks}}{N_{vtx\_tracks}} \right)^{2/3}$$

Before event weights

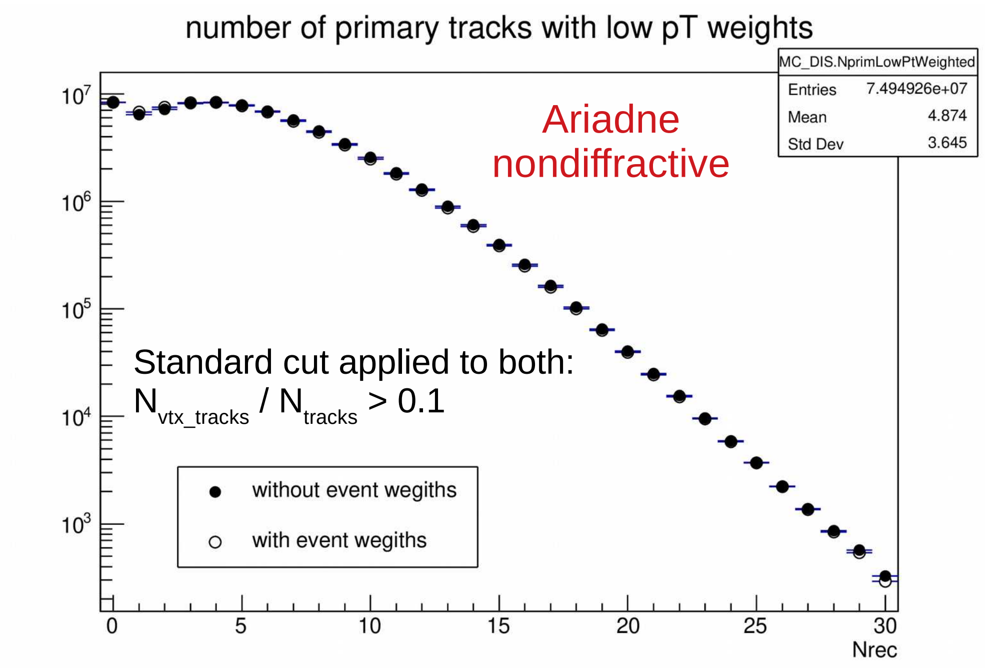


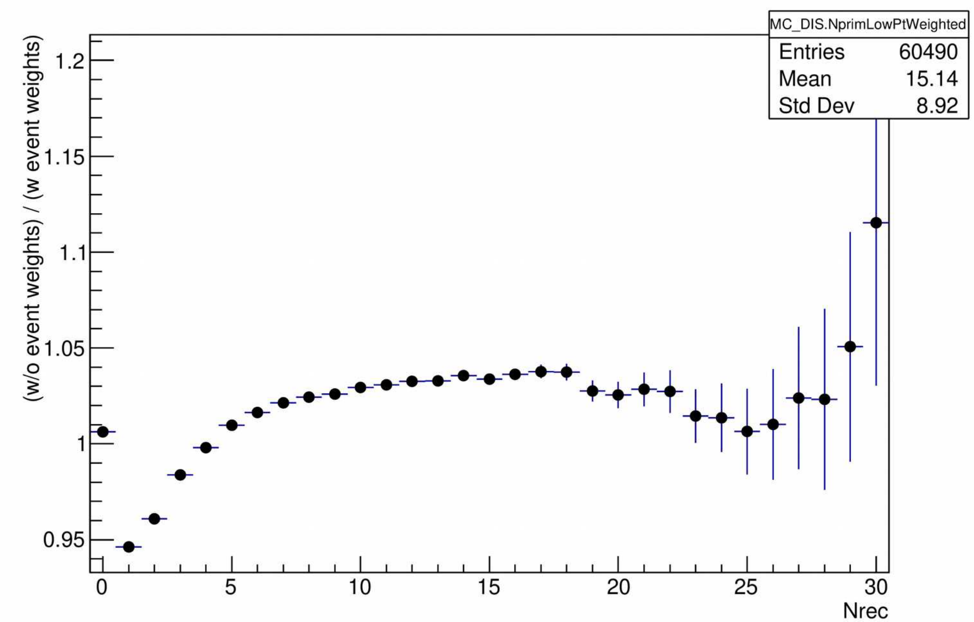
After event weights



Reconstructed tracks from both MC models reveal the same problem
(the observation is model independent).

The effect on the N_{rec} distribution in Ariadne nondiffractive.
The N_{rec} distribution is presented in Fig 1 of the paper.





The weight is not expected to work well at very low multiplicity.
Besides there, the weight causes a ~3% modification to the N_{rec} distribution.

ZEUS data differs from Ariadne predictions by as much as 50% at high N_{rec} as seen in Fig 1.

Summary

1) The extra triggers increase the event sample by about 1%. They have a negligible effect on the control plots and c_n.

2) The sinistra candidate charge in data and MC has been used to cross-check the PHP contamination. It is still “on the order of 1%.”

3) The E-Pz cut in MC using truth quantities mainly removes events with strong Initial State Radiation.

4) The event weights modify the N_{rec} distribution in Fig 1 of the paper by about 3%. This is small compared to the observed differences between ZEUS data and Ariadne.

5) All of the analysis comments from the post EB2 discussion have been taken into account. We are ready to switch back to the paper discussion.

Other Requests: What exactly is shown when we compare data and MC?
Verbatim from the paper draft “post EB2”

To compare our results to model predictions we select Monte Carlo events based on Q^2, E_e, θ_e, and δ, which are calculated using initial- and final-state electron momenta. These quantities were required to be in the same interval as that used with reconstructed data. Generated events are also passed through the GEANT3 [60] simulation of the particle transport in the ZEUS detector material to estimate the tracking efficiency. The selection of Monte Carlo events to compute reconstructed distributions and efficiency corrections follows the same criteria as for the reconstructed ZEUS data.

Generated and reconstructed primary particles are selected from the same kinematic p_{T} and η interval as for reconstructed tracks. Primary generated particles are defined as charged hadrons with a mean proper lifetime, $\tau > 1$ cm$/c$, which were produced directly or from the decay of a particle with $\tau < 1$ cm$/c$. This definition is similar to that used at the LHC [61].

Other Requests: What kind of corrections were applied to the data?

The main quantity we measure

$$c_n\{2\} = \sum_{e}^{N_{ev}} \left[\sum_{i,j>i}^{N_{rec}} w_{ij} \cos\left[n(\varphi_i - \varphi_j)\right] \right]_e \Bigg/ \sum_{e}^{N_{ev}} \left[\sum_{i,j>i}^{N_{rec}} w_{ij} \right]_e$$

The correction factor from MC

$$w_{ij} = w_{\mathbf{p}}^{(i)} w_{\mathbf{p}}^{(j)} w_{\Delta\varphi}$$

- $w_{\mathbf{p}}^{(i)}$ is the single particle correction factor for particle i. It is the ratio of the # of generated to reconstructed particles in MC.
- $w_{\Delta\varphi}$ is the two-particle correction factor. To obtain this, we first calculate $w_{\mathbf{p}}^{(i)}$ in the 1st pass over MC and then apply it in the 2nd pass, from which we construct the ratio of the # of generated to reconstructed pairs. This is $w_{\Delta\varphi}$.

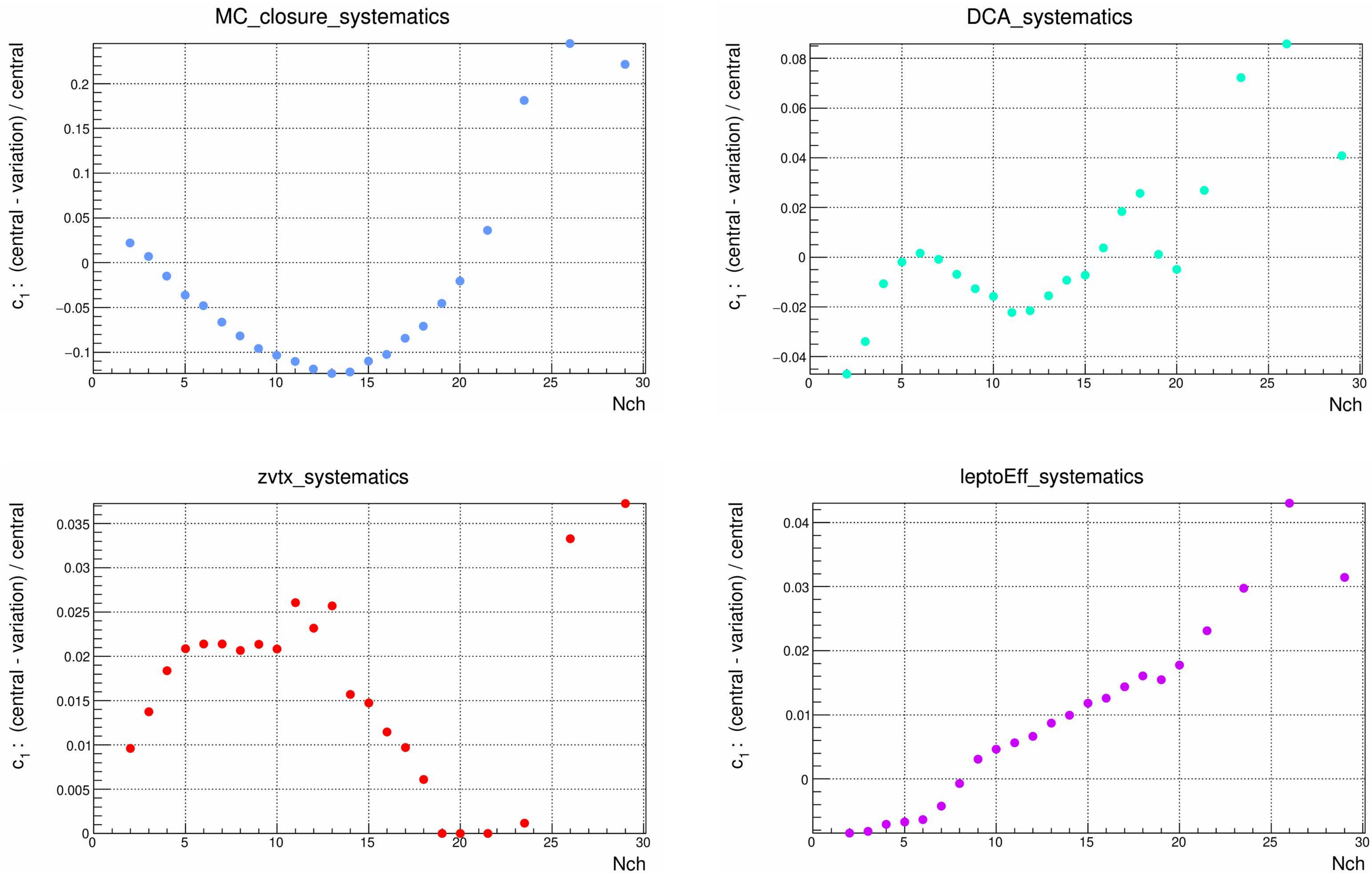
The comparison of generated $c_n\{2\}$ to reconstructed $c_n\{2\}$ in MC is the “closure test.”
The application of $w_{\Delta\varphi}$ is our method to correct for the closure test.
It is not perfect (probably because it was computed in limited dimensionality).
The remaining smaller closure test is applied as a systematic uncertainty.

Updated Systematic uncertainties

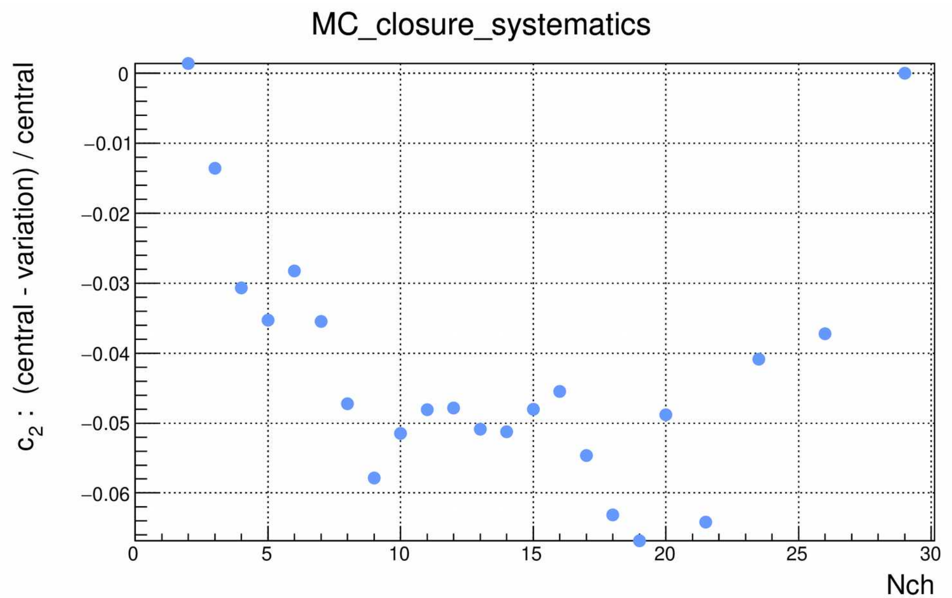
Type of Systematic	Reference	Variation(s)	
MC closure	generator correlations in MC true DIS events	reconstructed correlations with all correction factors in reco DIS events	Recalculated
Z-vertex interval*	$\|Vz\| < 30$ cm	Separate intervals: $[-30, 0]$, $[0, +30]$	Recalculated
Data taking conditions*	All	individual periods 04p to 07p	Recalculated
Efficiency corrections*	ARIADNE based	LEPTO based	New: requested from EB2 minutes
Tracking efficiency under-estimation at low p_{T} *	Using Libov and Bachynska's correction factors	1/2 correction factor	
DCA cuts*	DCA_xy,z < 2.0 cm	DCA_xy,z < 1.0 cm	Recalculated
DIS selection from hadronic component	$47 < E - P_z < 69$ GeV	$45, 49 < E - P_z < 71$	Recalculated
scattered electron probability and polar angle	$P_e > 0.9$, $\theta_e > 1$ rad	$P_e > 0.8$, $\theta_e > 0.5$	
scattered electron chimney cut (see Fig 48b)	Reject (-10 < x < 10 && y > 110 && z < -141)	Reject (-12 < x < 12 && y > 100 && z < -141)	
HES fiducial/CAL crack cut in RCAL (see Fig 48b)	Reject ($((5 < x < 11$ && $y > 0) \|\| (-15 < x < -9$ && $y < 0))$ && $z < -141$)	Reject ($((4 < x < 12$ && $y > 0) \|\| (-16 < x < -8$ && $y < 0))$ && $z < -141$)	

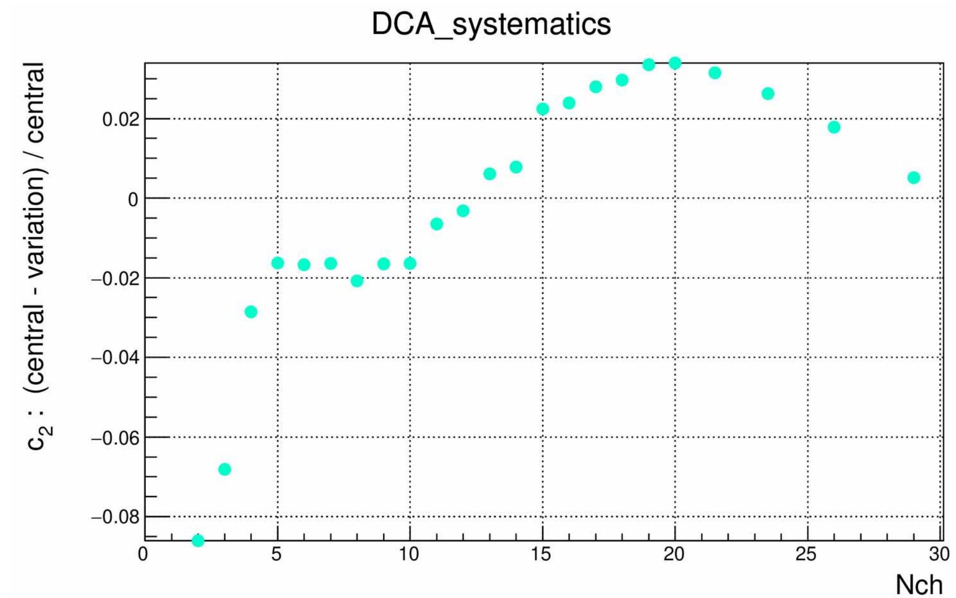
Table 9: *Systematic variations. * means that the efficiency corrections from MC were also recalculated.*

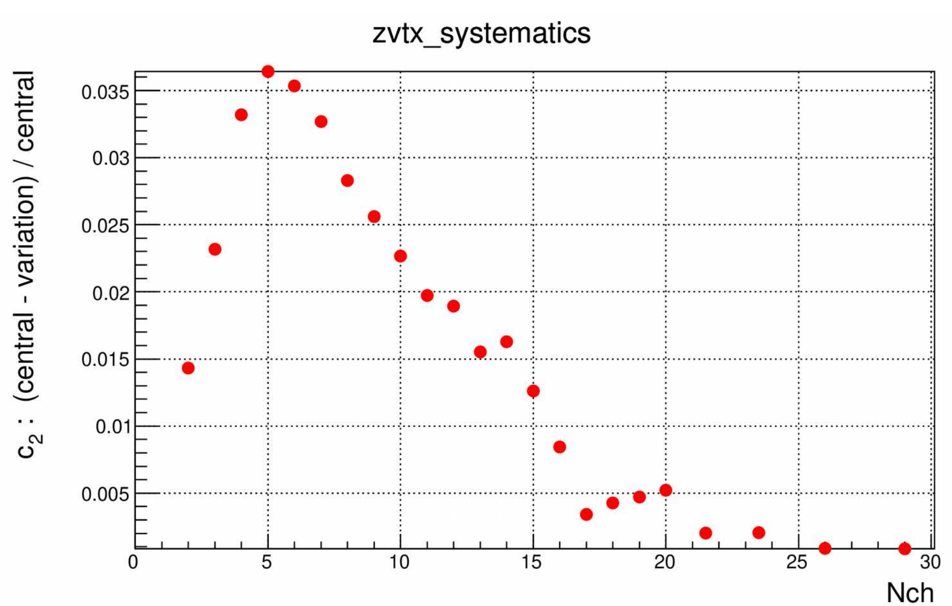
$c_1\{2\}$ vs N_{ch} dominant systematics
$\Delta\eta > 0$

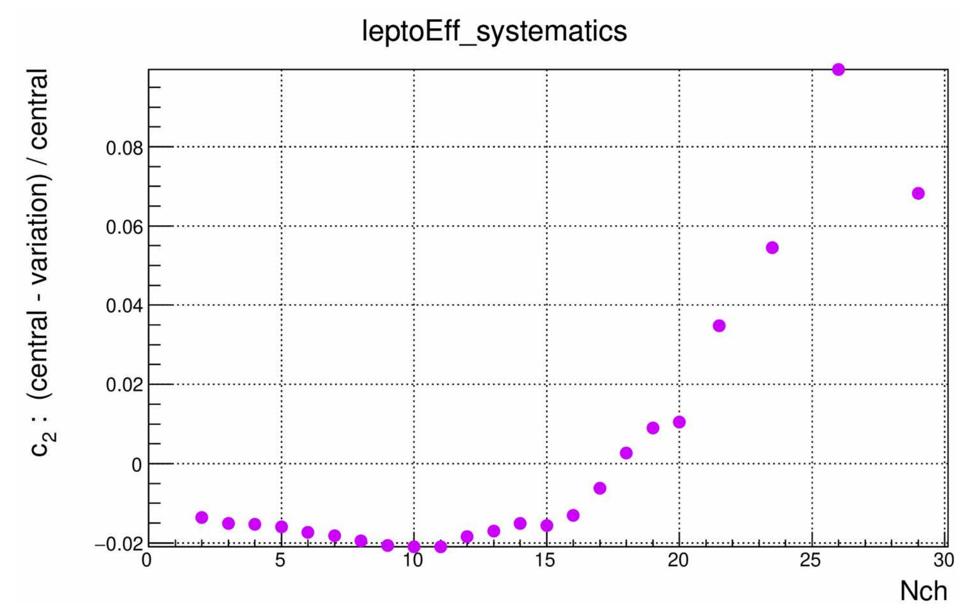


$c_2\{2\}$ vs N_{ch} dominant systematics
$\Delta\eta > 0$

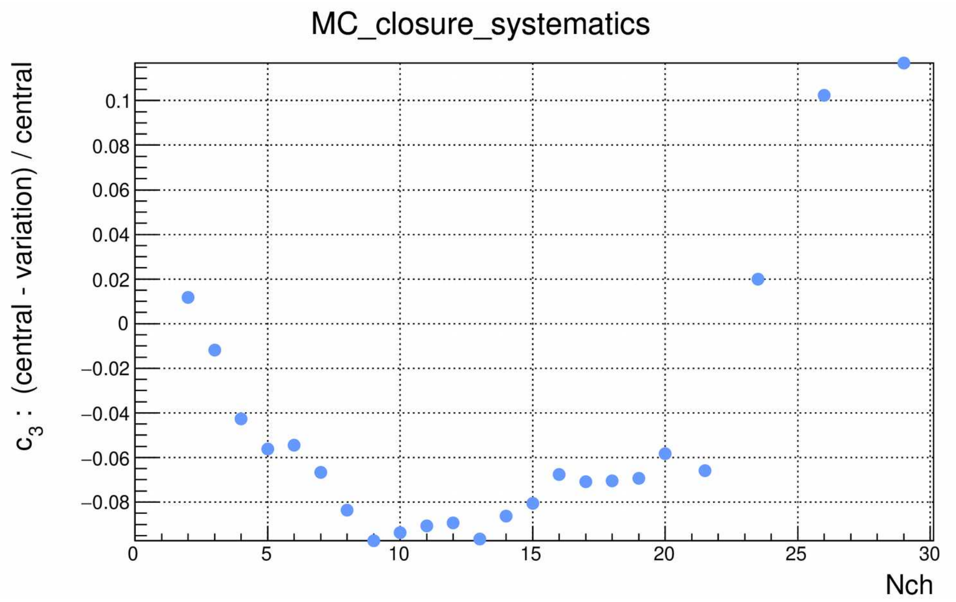


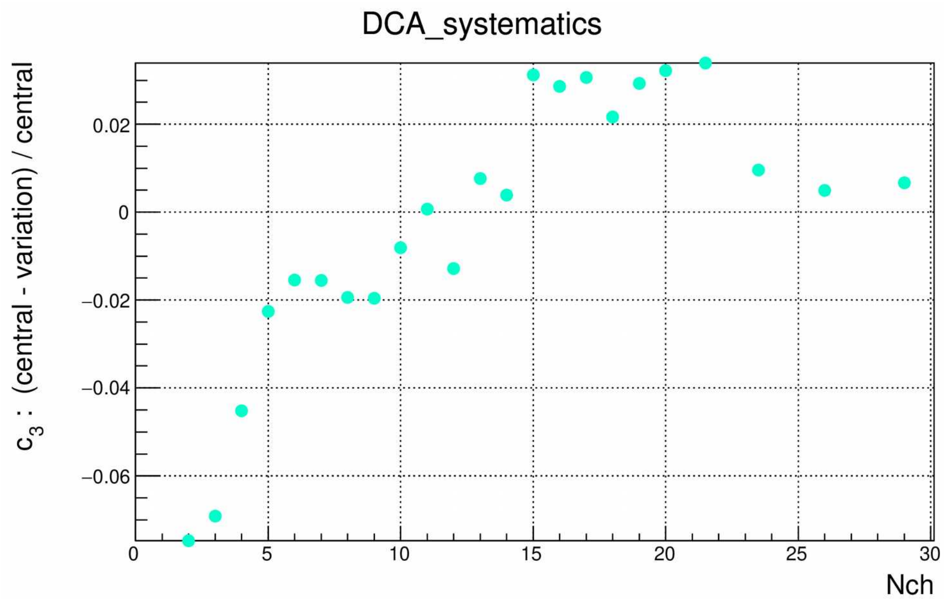


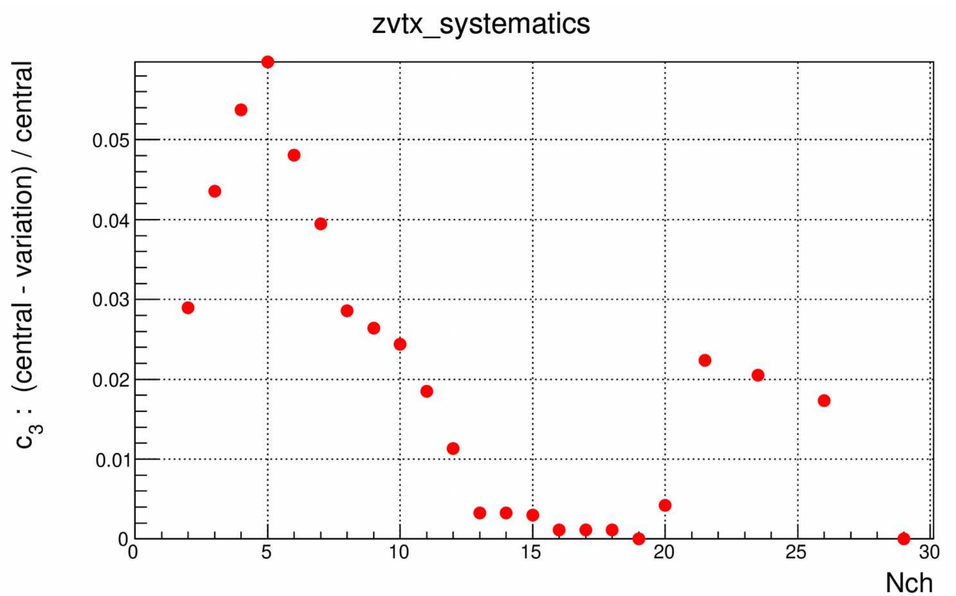


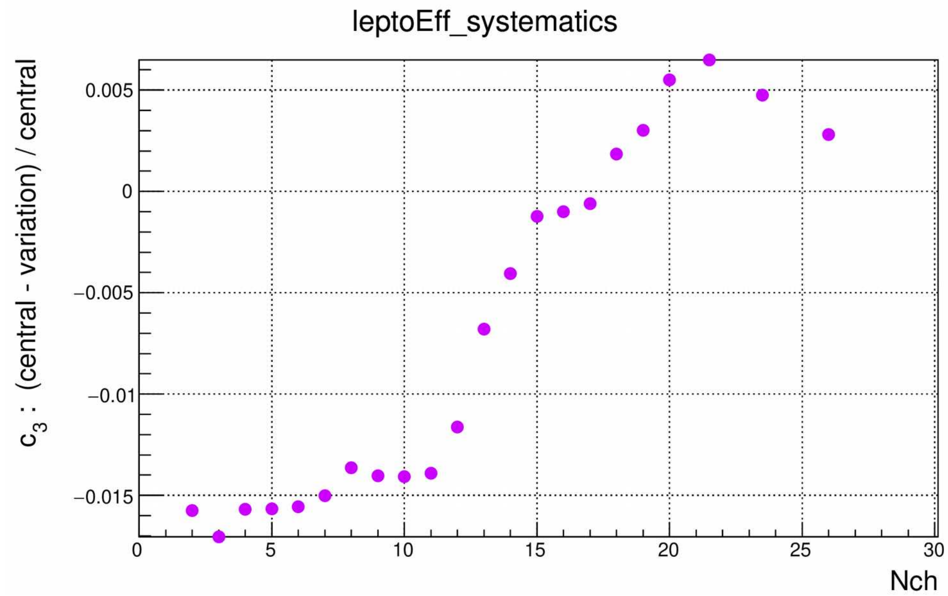


$c_3\{2\}$ vs N_{ch} dominant systematics
$\Delta\eta > 0$









$c_4\{2\}$ vs N_{ch} dominant systematics
$\Delta\eta > 0$