Investigation of triggers to use for collectivity analysis in photoproduction events

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April 28th 2020

Search for hints of hydrodynamic “collective” effects in photoproduction

- Studies in heavy-ion collisions (A+A) have revealed evidence for a collective behavior that can be described within the framework of hydrodynamics applied to QCD matter. Hydrodynamics is an effective theory to describe **non-perturbative** QCD processes.

- Similar evidence has been revealed in p+A as well as p+p collisions.

- No evidence for it was found in our recent paper of two-particle azimuthal correlations in deep inelastic scattering e+p collisions.

- DIS is characterized by a highly virtual exchange boson ($Q^2 >> 1$ GeV). The initial scattering is therefore perturbative in nature.

- PHP lies at low Q^2 and can therefore be **non-perturbative** in nature. This makes PHP interesting to look for hydrodynamic collectivity.

Azimuthal correlations to probe collective behavior

For the PHP analysis, like the DIS analysis, **high multiplicity** remains the most interesting region to look for collective behavior.

Azimuthal correlations will continue to be our probe of such collective effects.

2-particle azimuthal correlations

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

harmonic

Azimuthal angle particle 1

Azimuthal angle particle 2

4-particle azimuthal correlations (more robust probe of collectivity)

Borghini, Dinh, Ollitrault PRC 64 054901

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

Explicit removal of 2-body "non-collecitve" bkg correlations

- Studied only briefly in the DIS analysis.
- Requires more statistics at high multiplicity, which PHP should provide.

Definitions for reconstructed primary tracks and generated particles (same as in DIS analysis)

N_{rec} is the number of reconstructed tracks passing the below criteria:

- ZTT track type
- >= 1 MVD hit
- DCAxy < 2 cm, DCAz < 2 cm
- 0.1 < pT < 5.0 GeV
- -1.5 < eta < 2

N_{ch} is defined as:
the number of long-lived primary charged hadrons with mean proper lifetime tau > 1cm, which were produced directly or from the decay of a particle with tau < 1cm.

Investigation of third-level triggers (TLTs)

- There is no inclusive PHP trigger available.
- We need to determine which subset of available third level triggers will be suitable in obtaining a minimally biased PHP sample for this study.
- We will investigate the available TLTs at high multiplicity from the HPP, HFL, and EXO trigger classes. The MUO class did not contain many high multiplicity events.
- To judge the biases induced from each TLT, we form a reference event sample which satisfy:
  1) Primary vertex QA cuts (same as in DIS analysis).
  2) Sinistra candidate energy < 5 GeV (basic PHP selection).

Ranking of TLTs according to # events at high multiplicity

$N_{rec} > 20$

TLT	:: # events
HFL 1	:: 6613759
HFL 21	:: 5830070
HFL 5	:: 4066308
HPP 4	:: 2567982
HPP 1	:: 2281568
HFL 27	:: 1865013
HFL 19	:: 1827380
HFL 28	:: 1734148
HFL 24	:: 1582638
EXO 15	:: 1579617
EXO 4	:: 1183435
HFL 9	:: 1120284
HFL 2	:: 908181
HPP 3	:: 868207
HPP 28	:: 865885
HFL 6	:: 836168
HPP 2	:: 741468
HFL 18	:: 674742
HPP 12	:: 645157
HFL 25	:: 605287
HFL 11	:: 558036
HFL 23	:: 554917
HPP 9	:: 532315
HPP 15	:: 504376
HPP 18	:: 446312
HFL 10	:: 436954
EXO 17	:: 419884

Top 20

Look into events which pass our primary vertex QA and where the TLTs from HPP, HFL or EXO fired.

Define high multiplicity as $N_{rec} > 20$.

Compute the # events with $N_{rec} > 20$ from the HERA II **real data set** for each TLT.

Rank them according to this number.

Investigate MC distributions and correlations from the top 20 TLTs individually.

HPP TLT definitions for those listed in the “top 20”

HPP TLT web page

TLT	Short description	Long description
HPP 1	Very high ET	HPP SLT: 1,2,3,4,5,8 E - pz > 8 GeV ET_cone > 25 GeV pz/E < 0.95 or E - pz > 12 GeV
HPP 2	Inclusive Jet, cone finder	HPP SLT: 1,2,3,4,5,8 >=1 eucell jet with ET > 10 Gev, eta < 2.5
HPP 3	Very high ET	HPP SLT: 1,2,3,4,5,8 ET_cone > 30 GeV
HPP 4	High ET NC DIS	HPP SLT: 1,2,3,4,5,8 E - pz > 30 GeV ET_cone > 20 GeV
HPP 12	Trijet Photoproduction, cone finder	HPP SLT: 1,2,3,4,8 >=3 eucell jets with ET > 5 Gev, eta < 2.5
HPP 28	Double K-short	SLT: HPP1,HFL1 E - pz > 7 GeV At least 4 tracks with pT > 0.25 GeV At least 2 combinations of tracks with invariant mass between 0.447 and 0.547 GeV

HFL TLT definitions for those listed in the “top 20”

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.

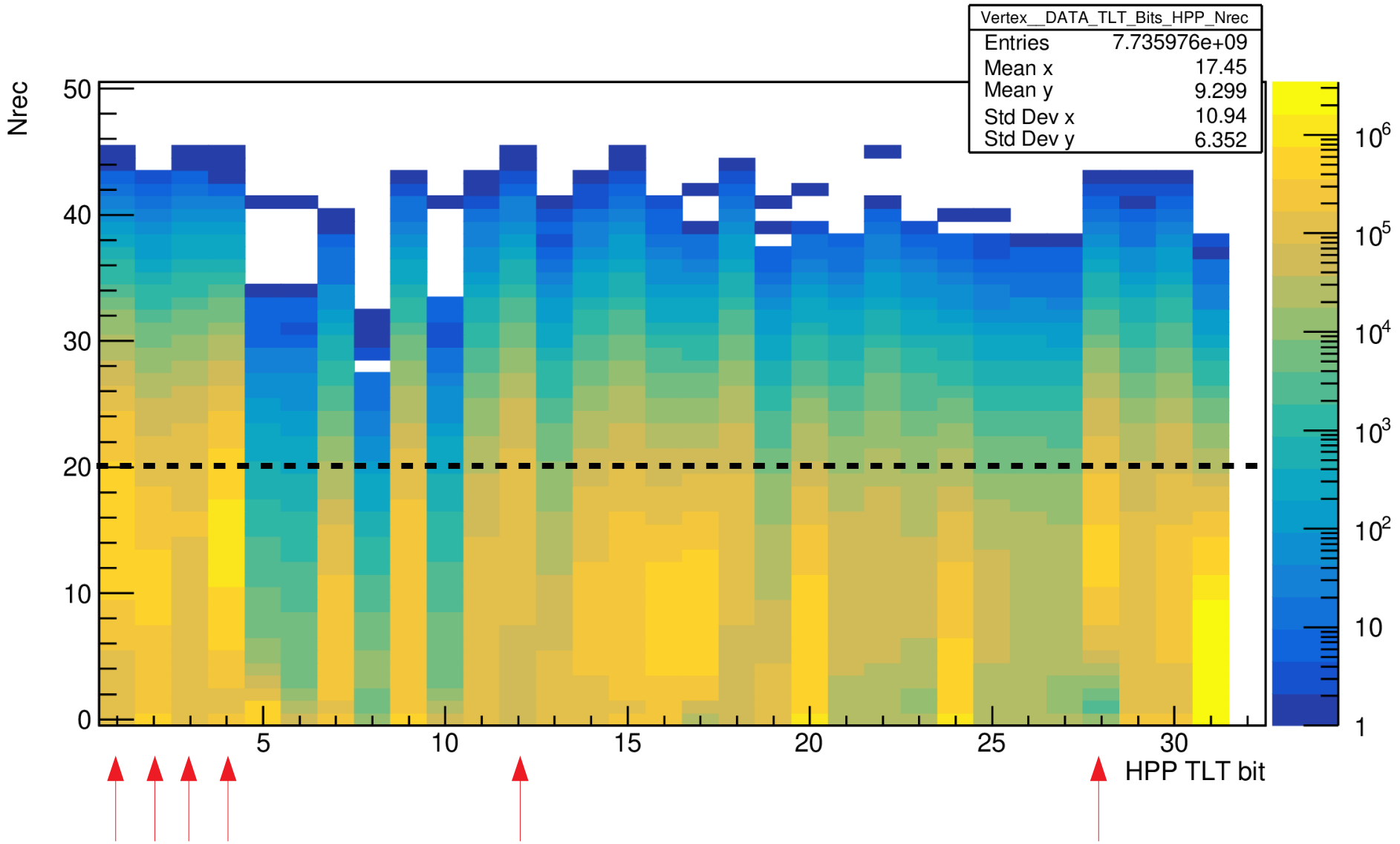
EXO TLT definitions for those listed in the “top 20”

EXO TLT web page

TLT	Short description	Long description
EXO 4	High ET NC	See web pages for more information
EXO 15	Island ET	See web pages for more information

HPP N_{rec} distribution vs TLT bit

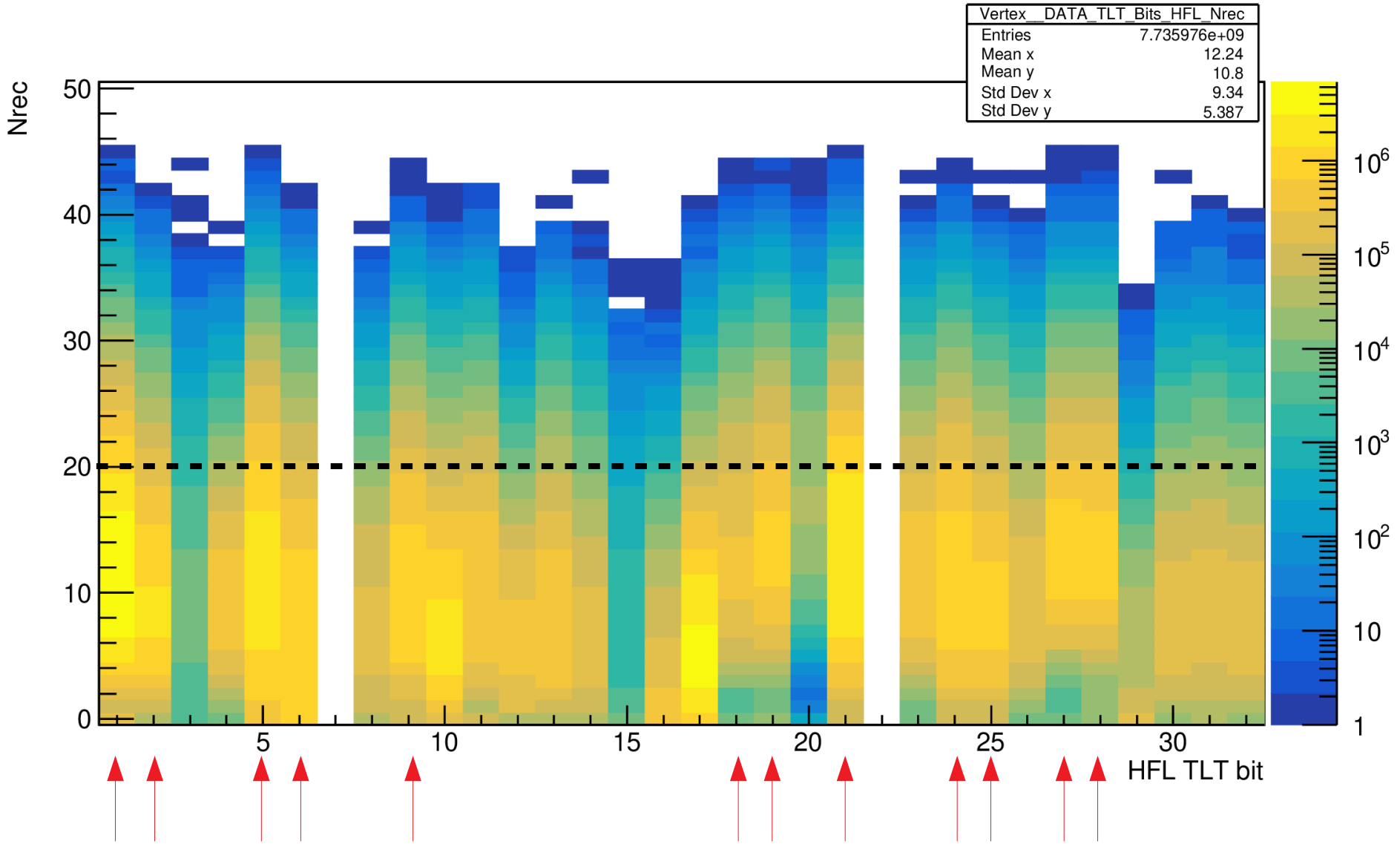
data



- Arrows indicate those TLTs which are part of the “top 20”

HFL N_{rec} distribution vs TLT bit

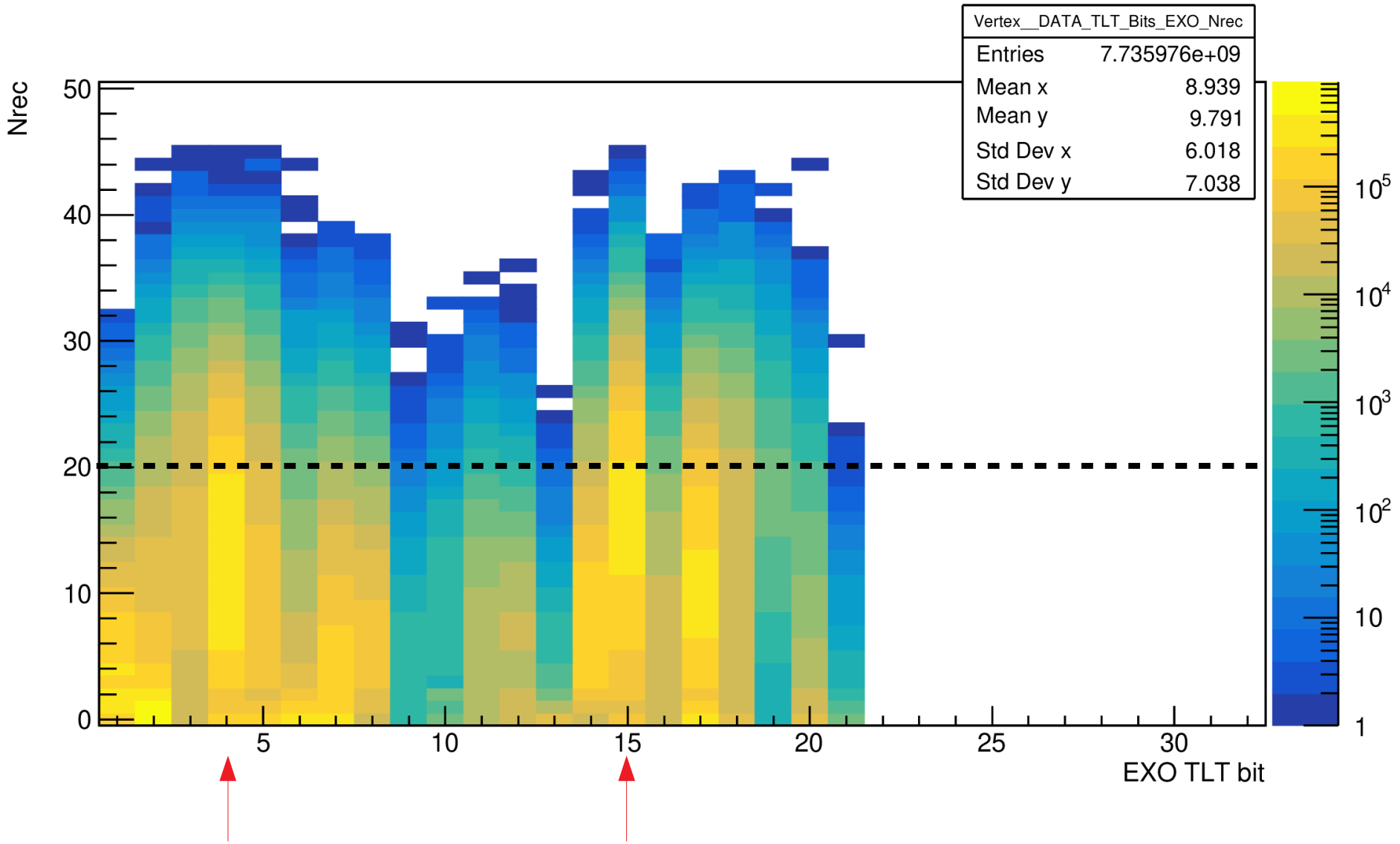
data



- Arrows indicate those TLTs which are part of the “top 20”

EXO N_{rec} distribution vs TLT bit

data



- Arrows indicate those TLTs which are part of the “top 20”

Distributions and correlations using
generator level MC information

Pythia PHP light flavor jet 0607p (direct + resolved)

Removing events with poor vertices

MC

Vertex constraint (from DIS analysis):

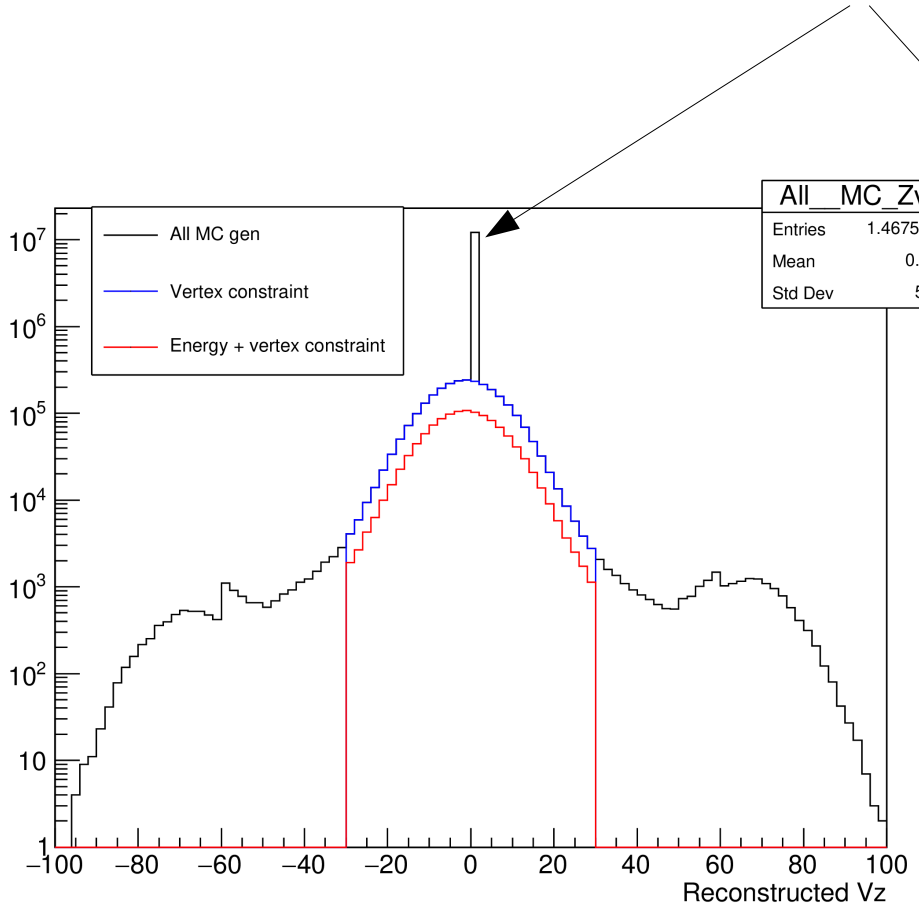
-30 < V_z < 30 cm

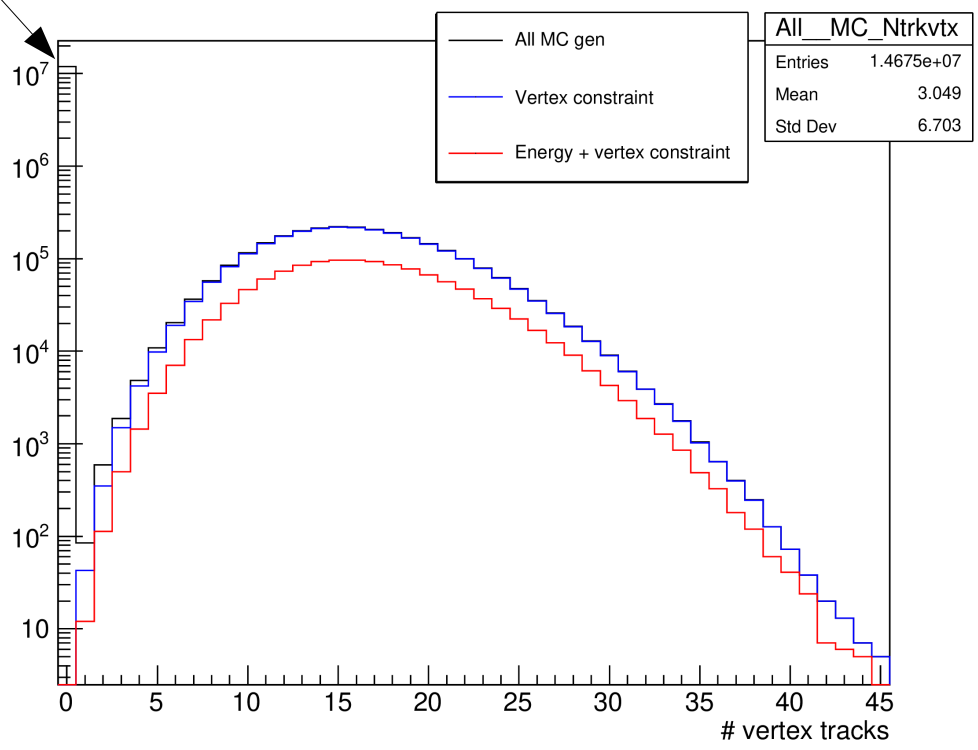
vertex tracks >= 1

(# vertex tracks) / (# total tracks) > 0.1 this may need to be tightened for PHP

| V_r | < 0.5 cm

poor-vertex events



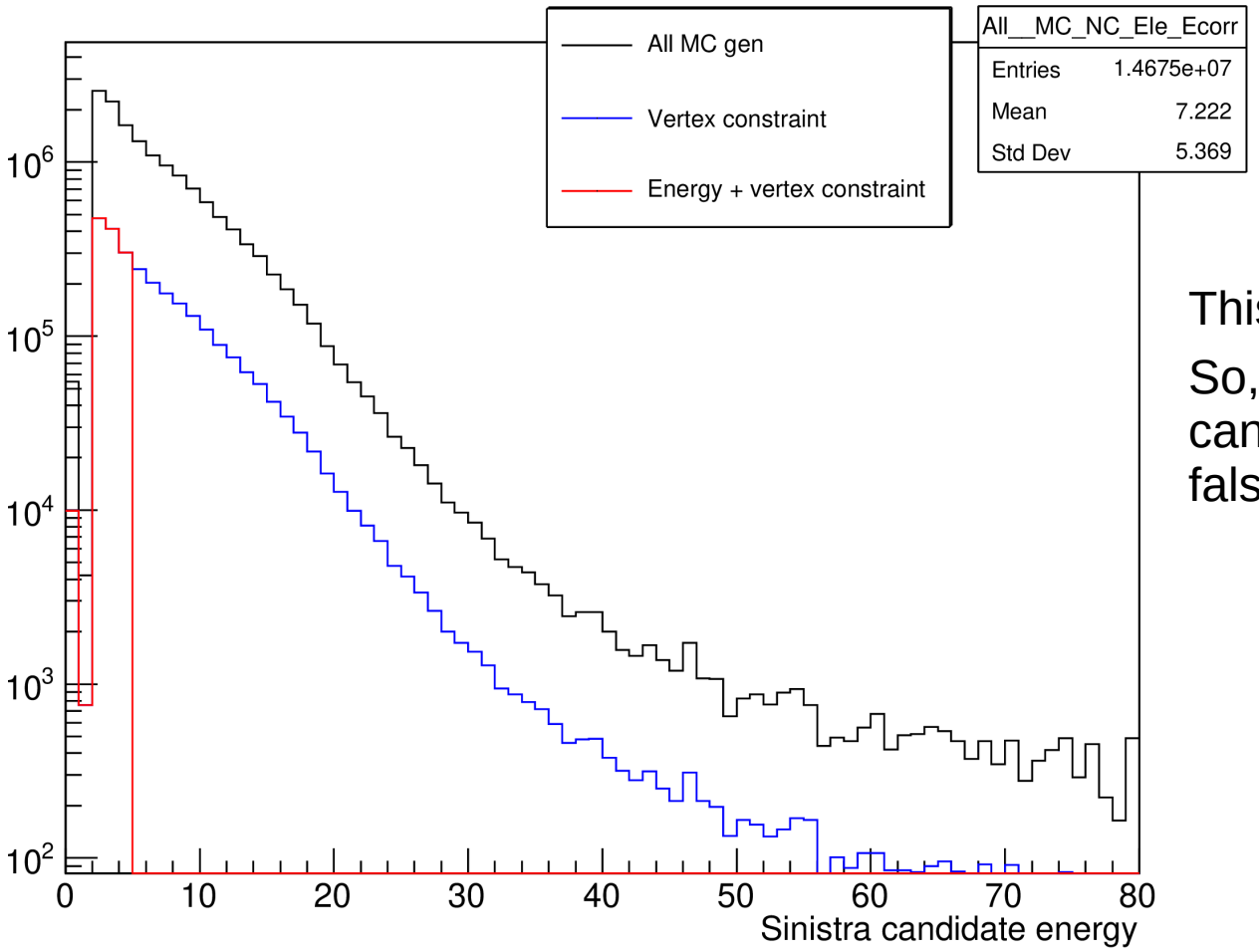


Removing non-PHP events based on sinistra energy

MC

Energy constraint:

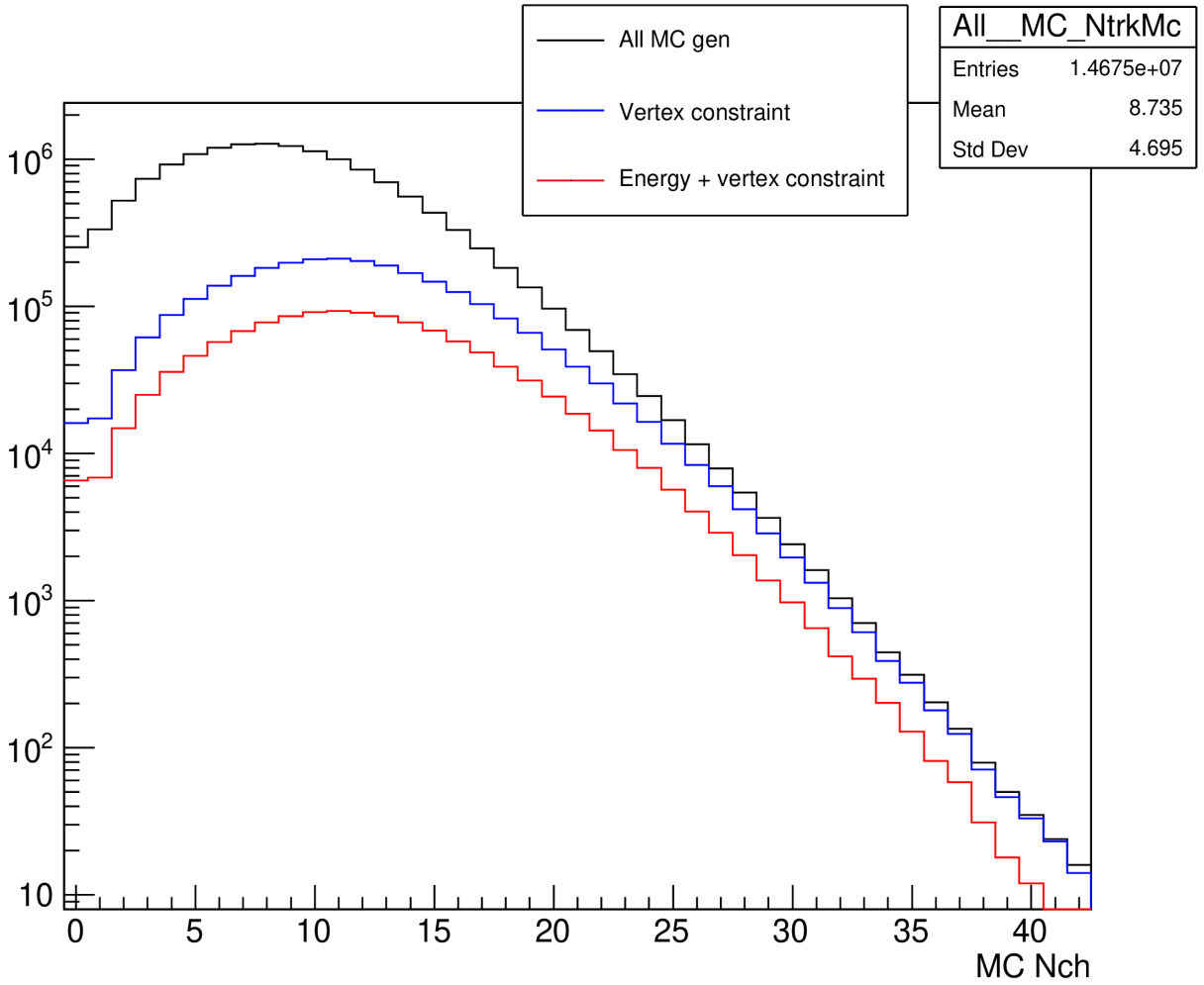
Sinistra candidate energy < 5 GeV



This is a PHP MC dataset.

So, nearly all of the sinistra candidates with large energy are false positives.

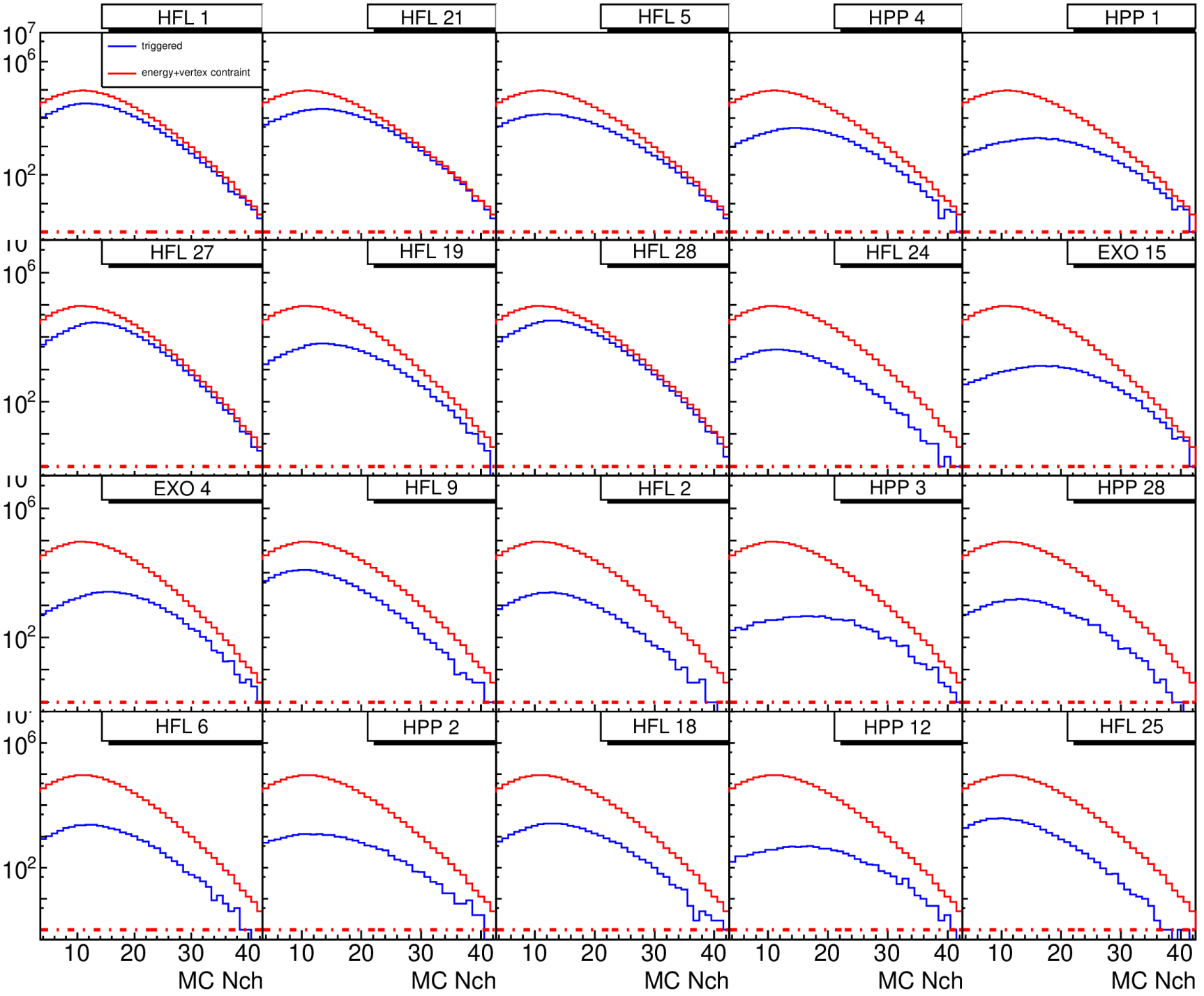
MC gen Nch distributiions



For the correlation functions, $c_n\{2\}$ & $c_n\{4\}$,
the “Energy + vertex constraint” will form our reference to compare with each TLT.
The additional bias from the TLT can be judged this way.

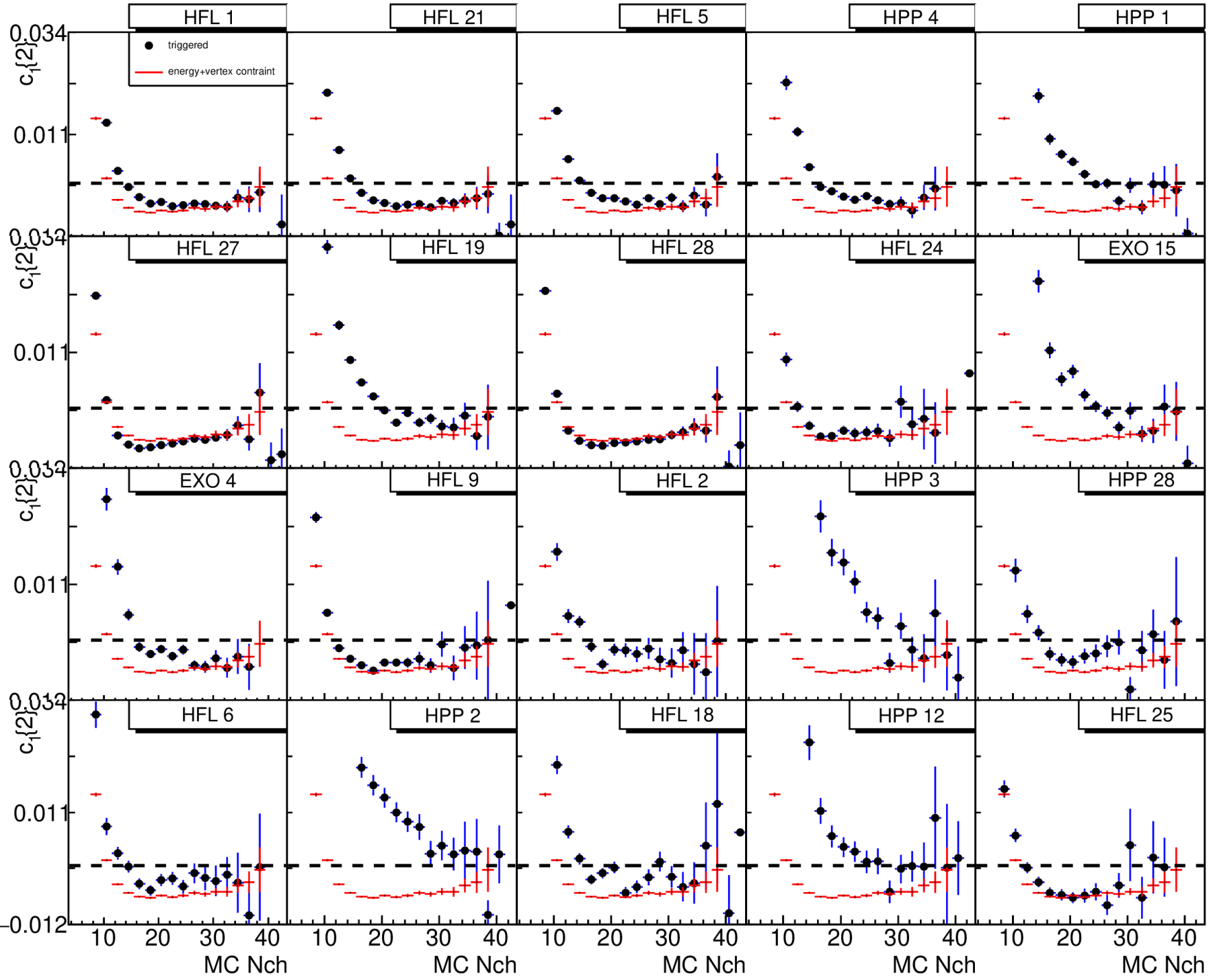
MC gen Nch distributiions

MC



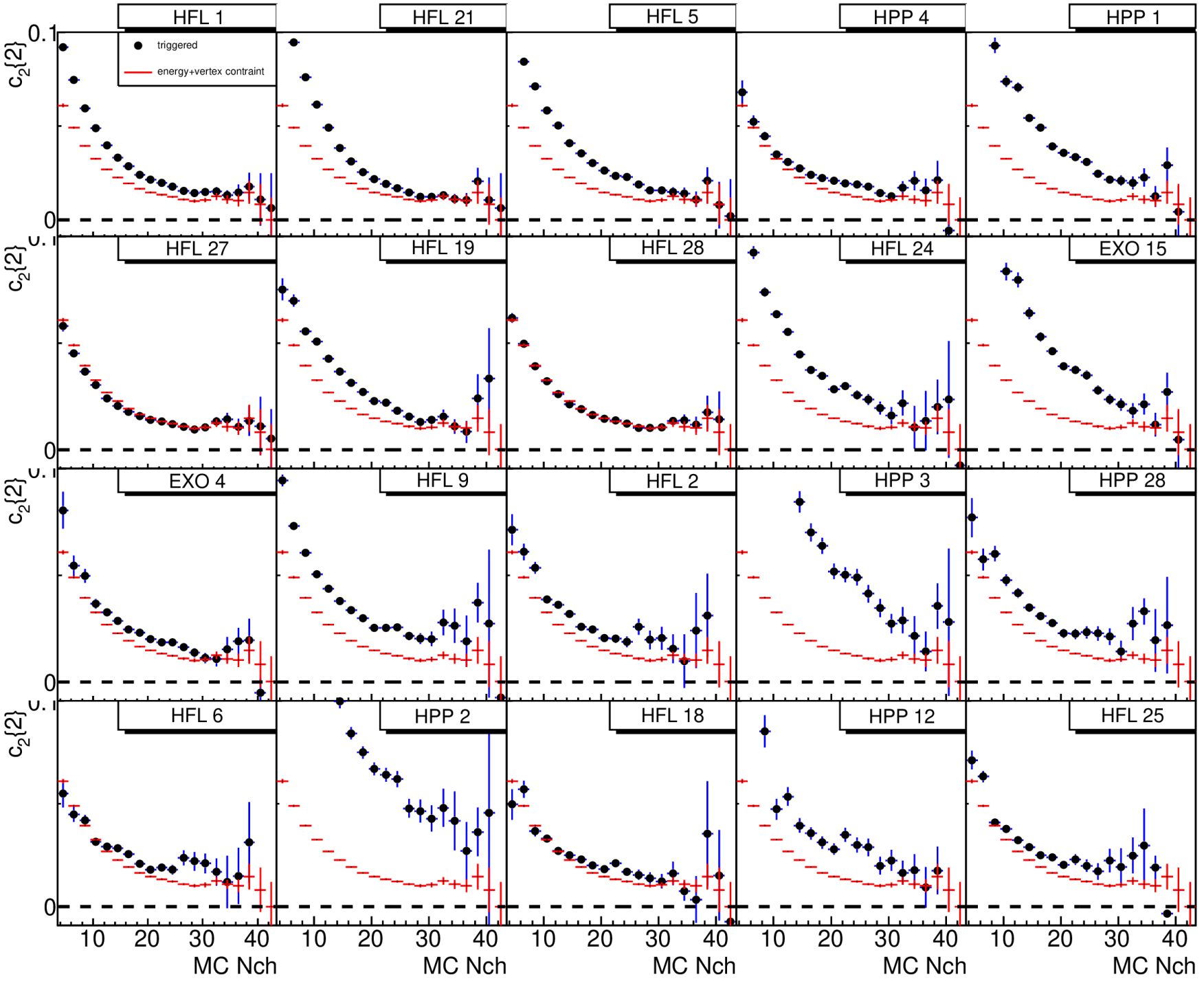
Generated $c_1\{2\}$ vs Nch

MC



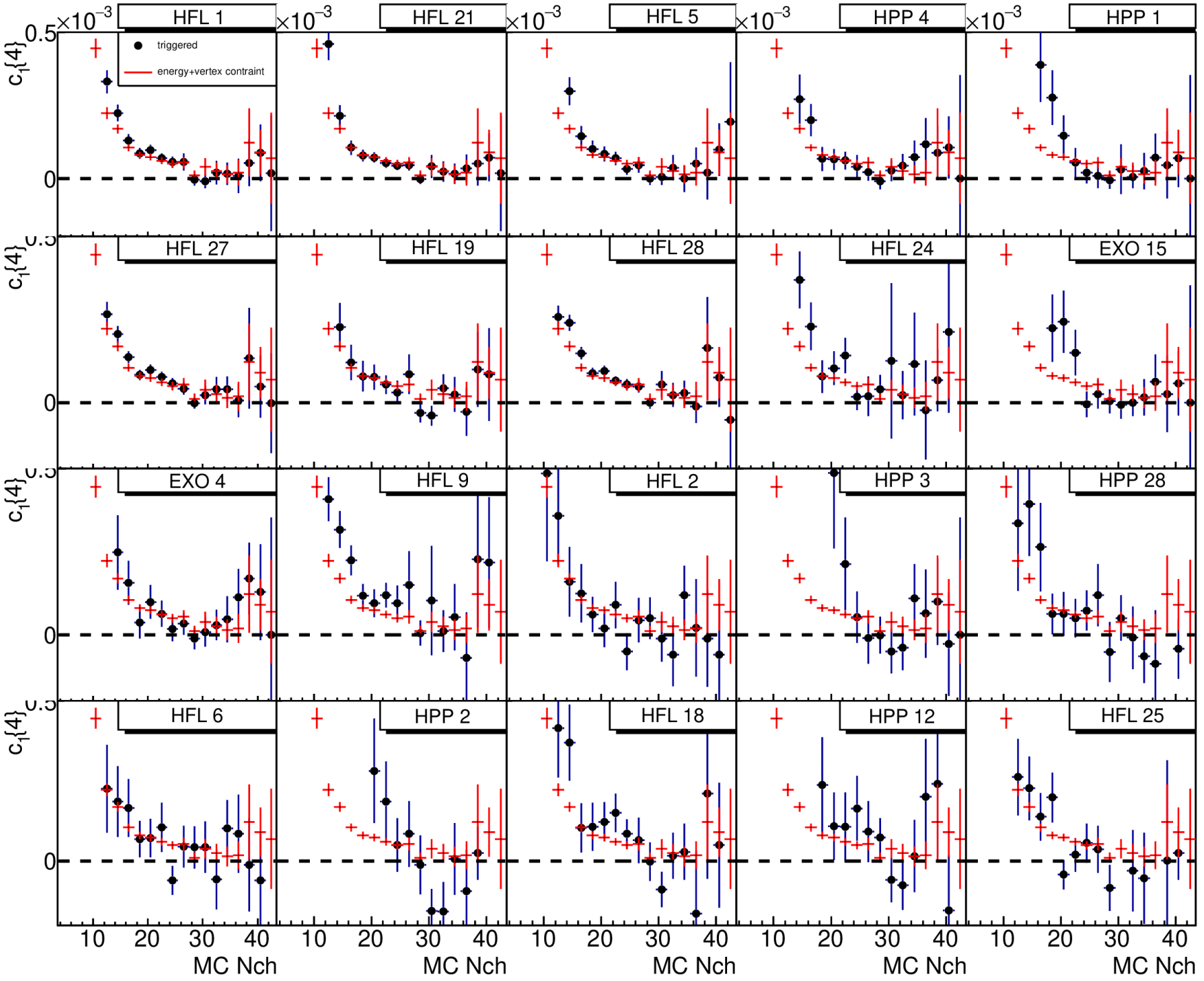
Generated $c_2\{2\}$ vs Nch

MC



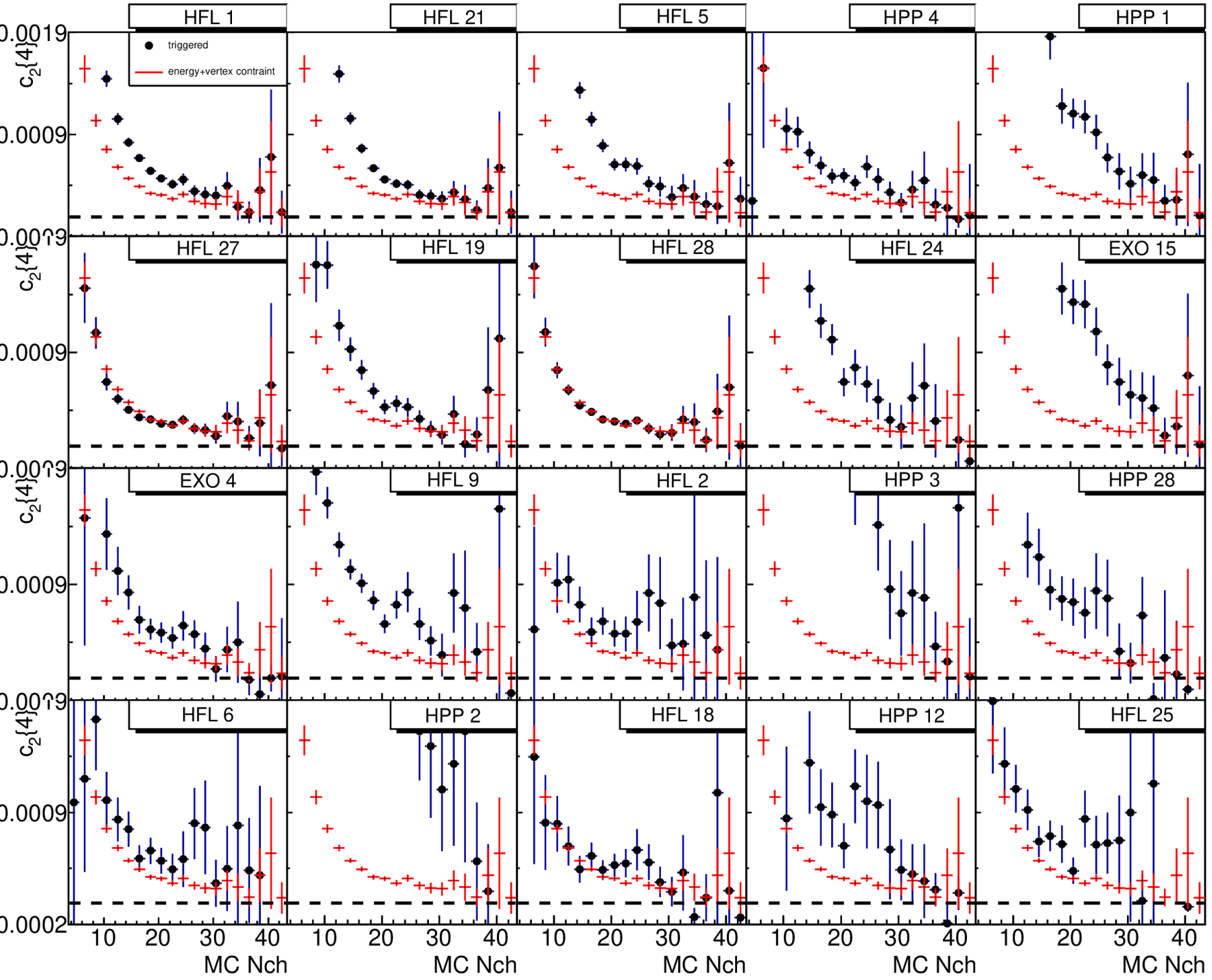
Generated $c_1\{4\}$ vs Nch

MC



Generated $c_2\{4\}$ vs Nch

MC



Cocktail triggers

We also form sets of TLTs and evaluate the bias on the correlation function wrt the reference (Energy + vertex constraint).

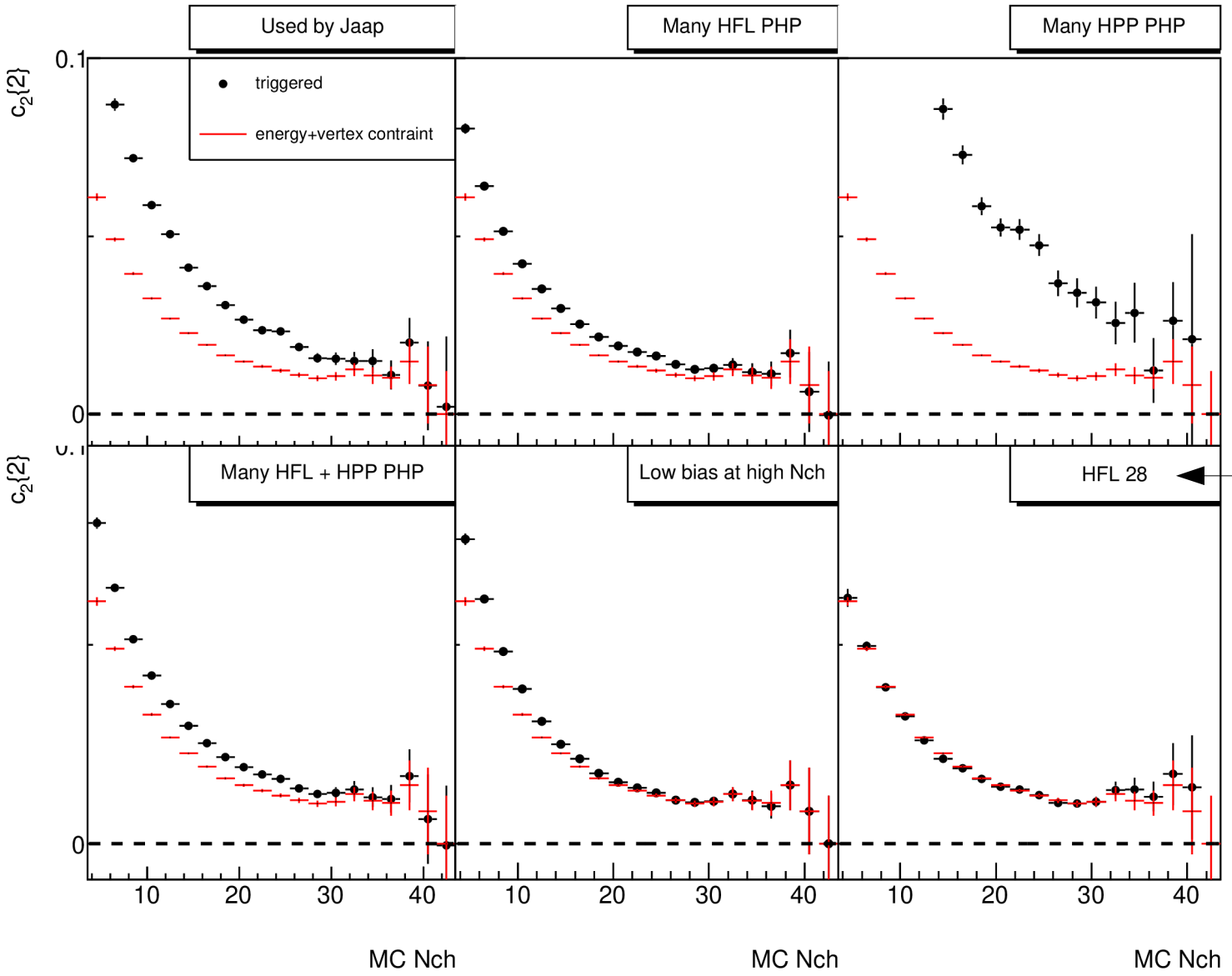
The motivation behind this is that an “or” of many TLTs can be more inclusive and therefore reduce the overall bias.

	HPP													HFL											EXO
	2	4	9	11	12	14	15	18	19	21	28	29	30	1	5	9	11	13	18	19	21	23	24	25	28	4
Cocktail 1 (used by Jaap)	X		X	X		X	X	X				X	X		X											
Cocktail 2 (many PHP tagged HFL triggers)														X	X	X	X	X				X	X	X		
Cocktail 3 (many PHP tagged HPP triggers)				X	X	X	X	X				X	X													
Cocktail 4 (many PHP tagged HPP & HFL triggers)				X	X	X	X	X				X	X	X	X	X	X	X				X	X	X		
Cocktail 5 (least biased at high Nch)		X												X	X				X	X	X				X	X

Note:
Some triggers from the top 20 were not used in the cocktails because they are actually intended for CC or NC DIS.
Also, HFL 27 is largely equivalent to HFL 28.

Generated $c_2\{2\}$ vs Nch

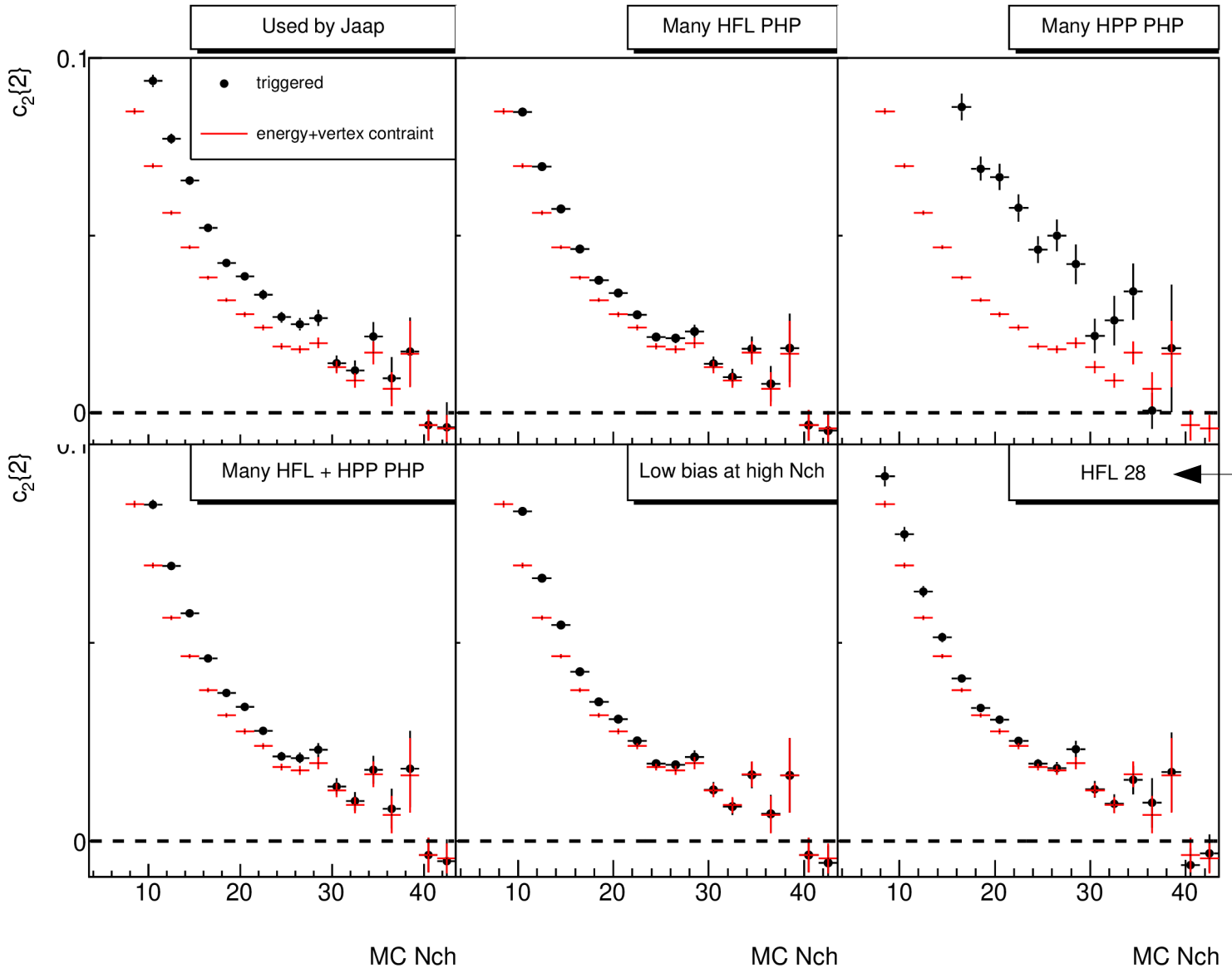
Pythia PHP **light flavor jet** 0607p (direct + resolved)



Least biased

Generated $c_2\{2\}$ vs Nch

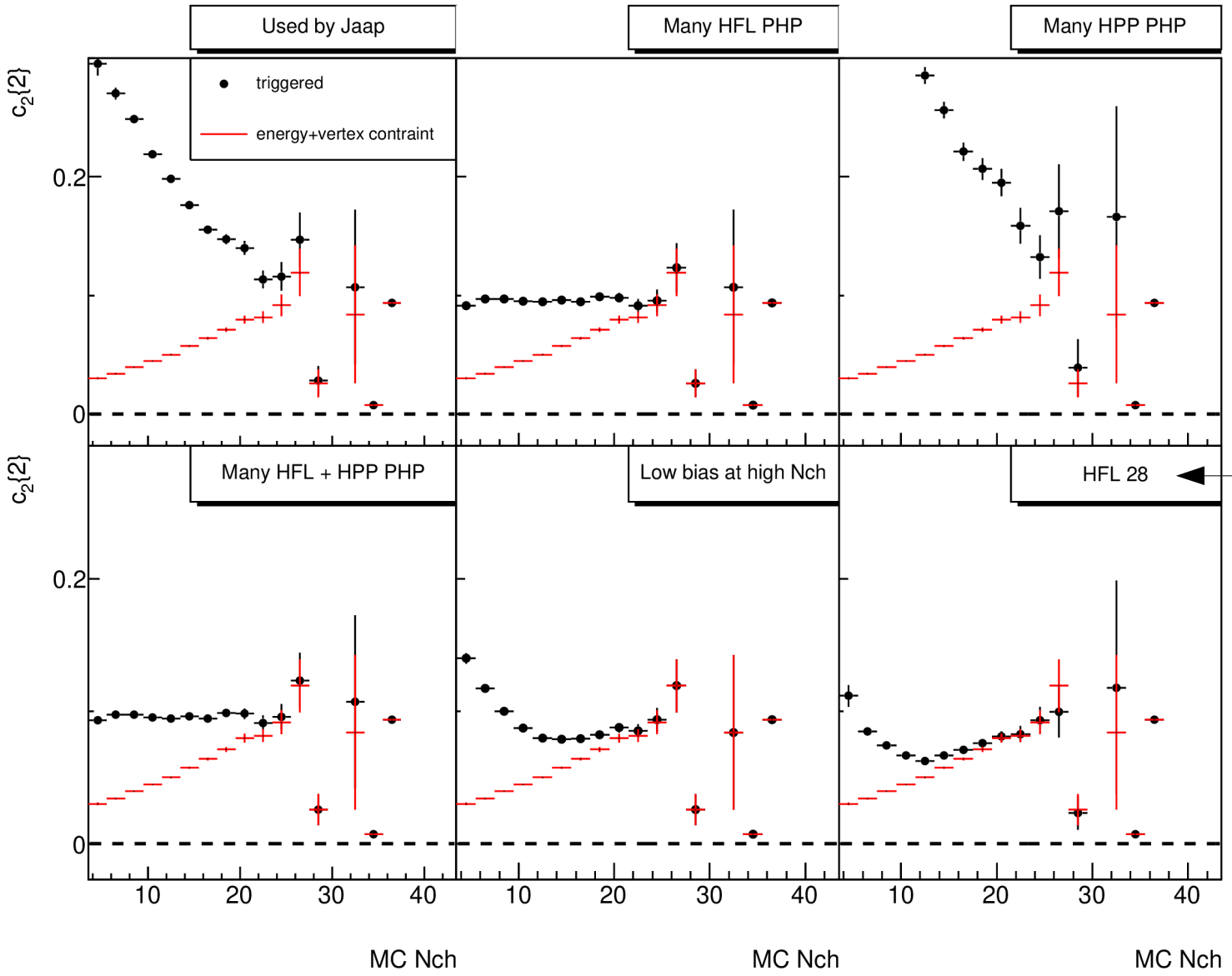
Pythia PHP **light flavor dijet** 0607p (direct + resolved)



Least biased

Generated $c_2\{2\}$ vs Nch

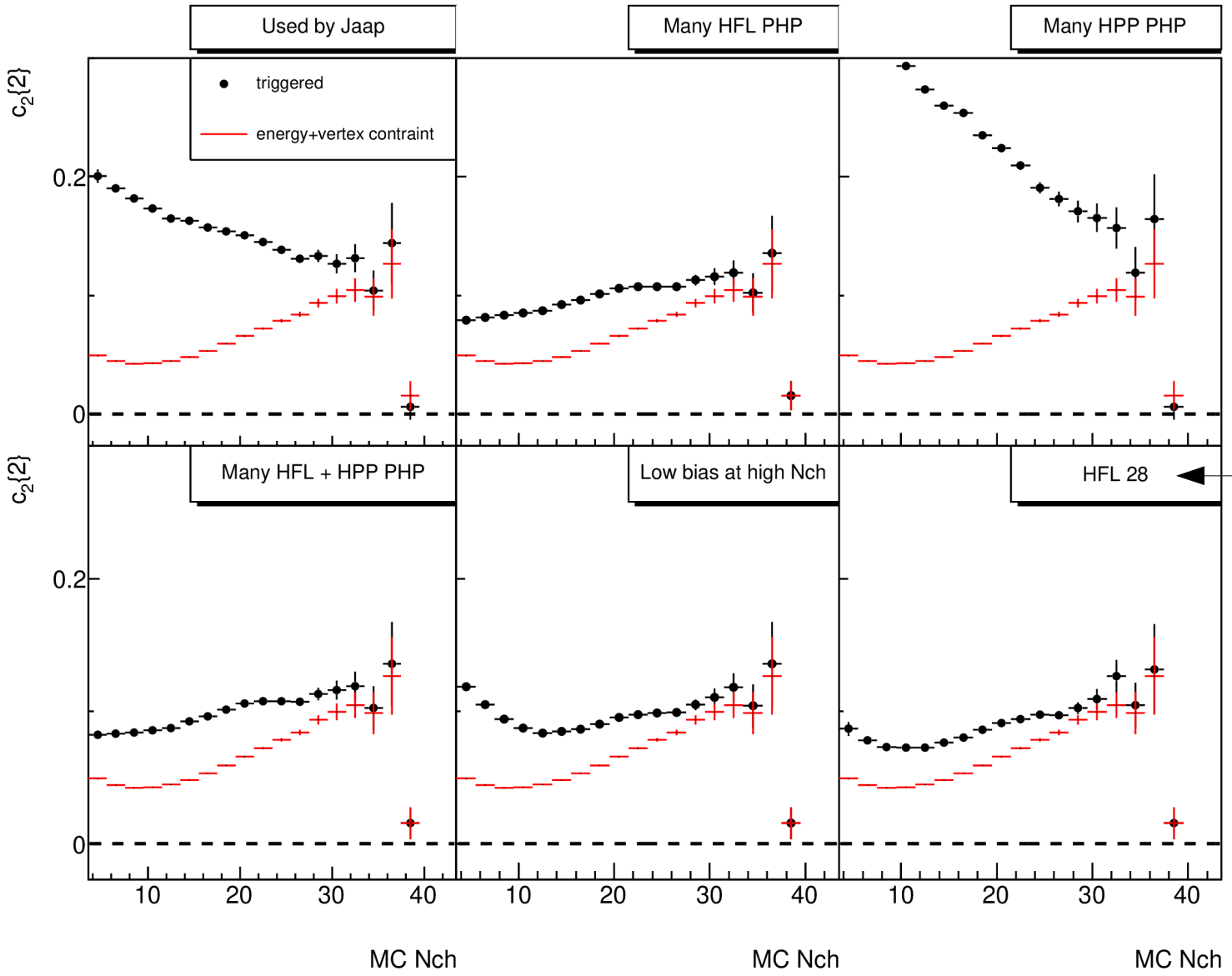
Pythia PHP **charm inclusive** 0607p (direct + resolved)



Least biased

Generated $c_2\{2\}$ vs Nch

Pythia PHP **bottom inclusive** 0607p (direct + resolved)



Least biased

Remarks

- Some combination of the “top 20” triggers presented should be the most promising to search for collective effects at high Nch in PHP.

- Trigger biases, while not completely removable, can be at least minimized.

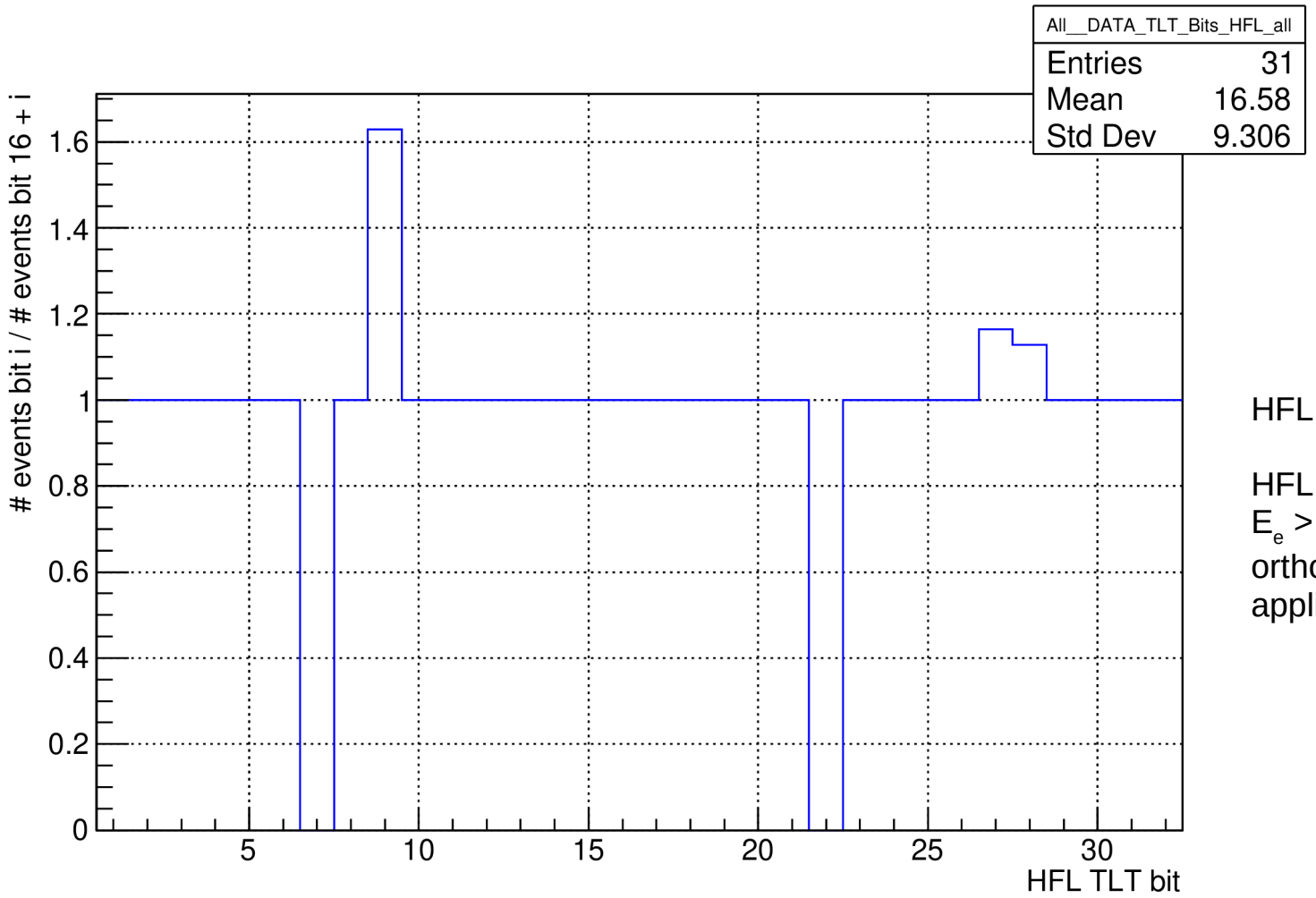
- It can be estimated by comparing generator level correlations from each trigger to events with only a primary vertex + sinistra energy constraint.

- In particular, HFL 28 shows the least bias in all analyzed MC PHP datasets: single-jet, dijet, charm inclusive, and beauty inclusive pythia.

- However, HFL 28 is only available since May 30 2006. That corresponds to about 40% of the HERA II integrated luminosity. Accounting for the trigger efficiency will lower this still further. It still might be worth pursuing, as it would correspond to a trade-off between systematics from trigger biases (if we choose to call it that) and statistical precision...

Extra

HFL prescales from 2003 to 2007 data



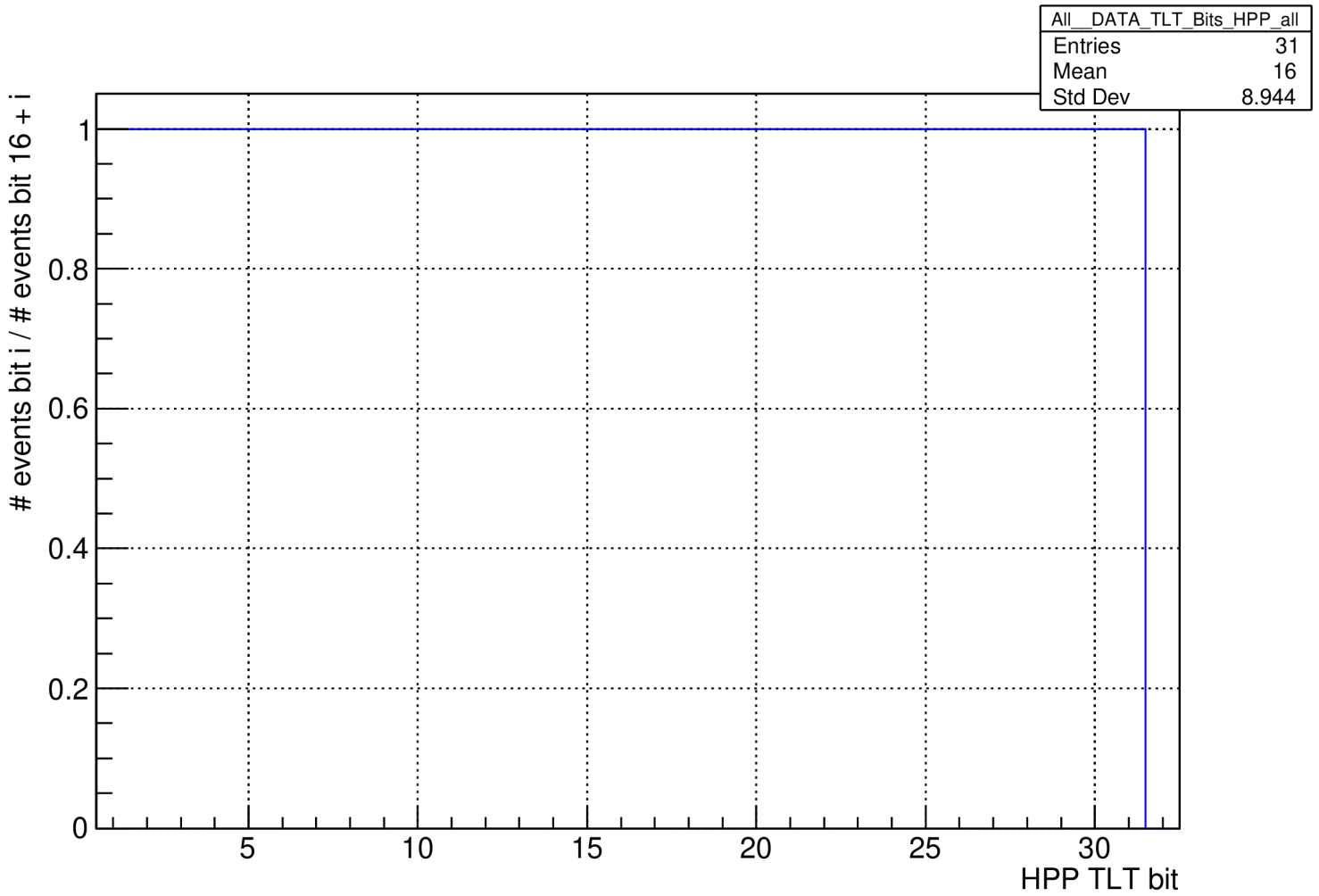
HFL 7 is disabled.

HFL 22 requires $E_e > 6$, which is orthogonal to the applied constraint.

Calculate the number of events with bit fired <u>before</u> prescale.
Calculate the same using the bits which fired <u>after</u> prescale.
The ratio of the two is plotted.

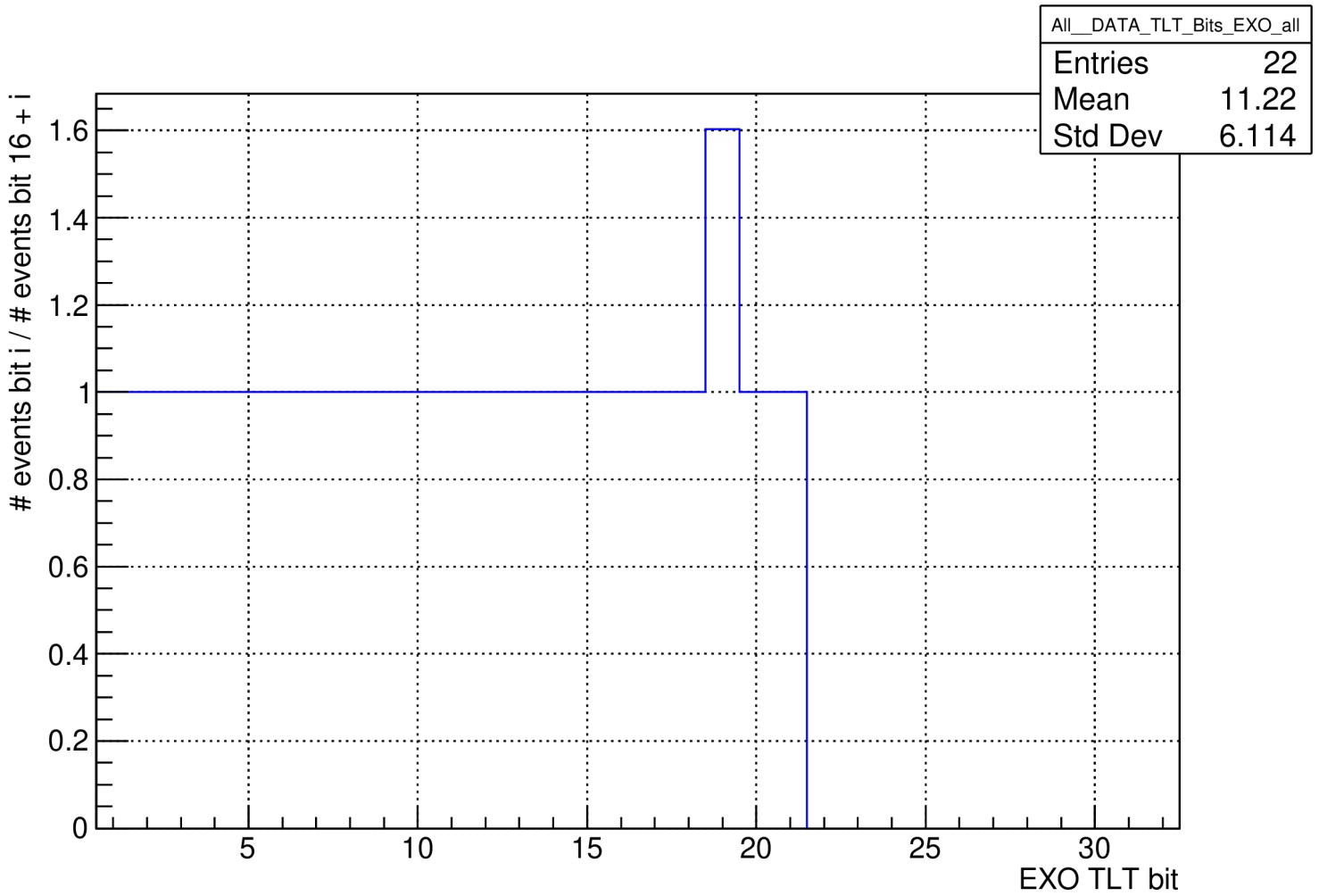
For example, HFL 1 prescale is:
events [ibits(Tltw[9], 0, 1)] / # events [ibits(Tltw[9], 16, 1)]

HPP prescales from 2003 to 2007 data



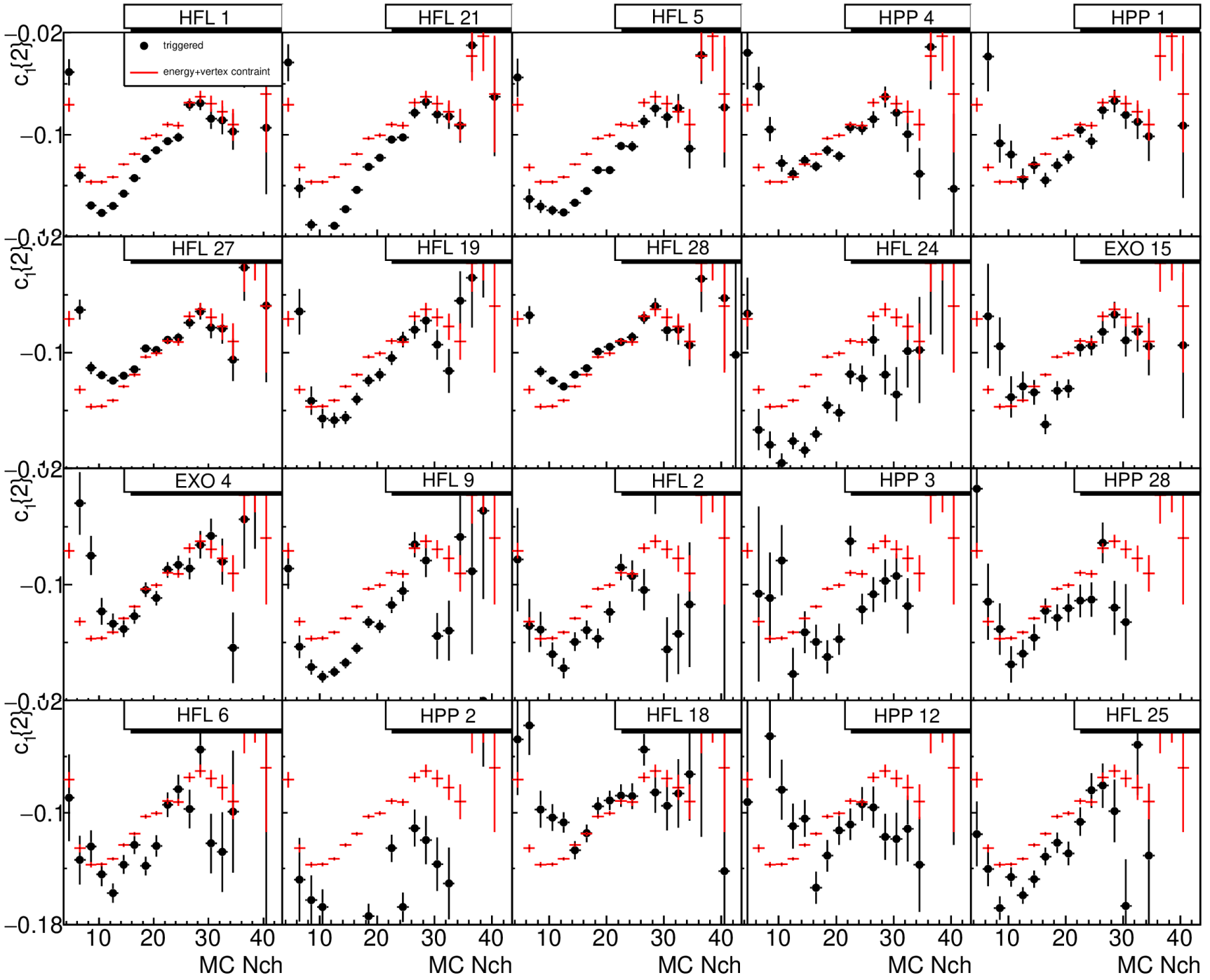
No prescales

EXO prescales from 2003 to 2007 data



Only EXO 19 prescaled

$c_1\{2\}$ vs Nch (pT>0.5, Δη>2)



$c_2\{2\}$ vs Nch (pT>0.5, Δη>2)