Measurement of *charged particle event multiplicity* in DIS at HERA using the H1 detector

Kong Tu, Stefan Schmitt, Thomas Ullrich

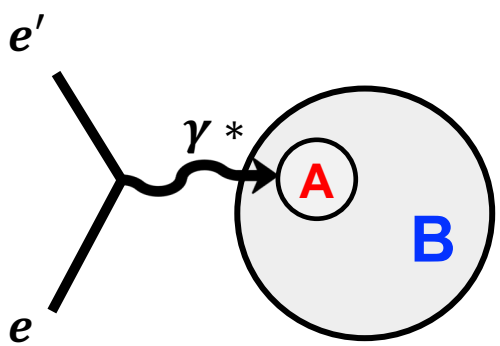
H1 meeting

12.13.2018

Motivation

- The parton model has been extremely successful, but has treated parton "quasi-free" in high energy limit.

- *Naively, partons are expected to be strongly entangled inside of proton*



High energy DIS only
probes a localized region **A**

Parton distribution function (PDF)

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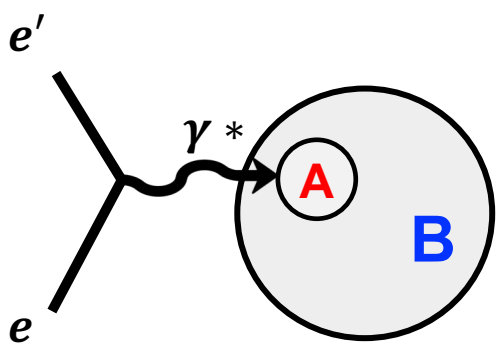

High energy DIS only
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Parton distribution function (PDF)

Major questions:

- "Quasi-free" and incoh. partons picture holds to what extend?
- Is there an entanglement entropy in DIS in terms of PDF?
- How does it relate to final-state observables?

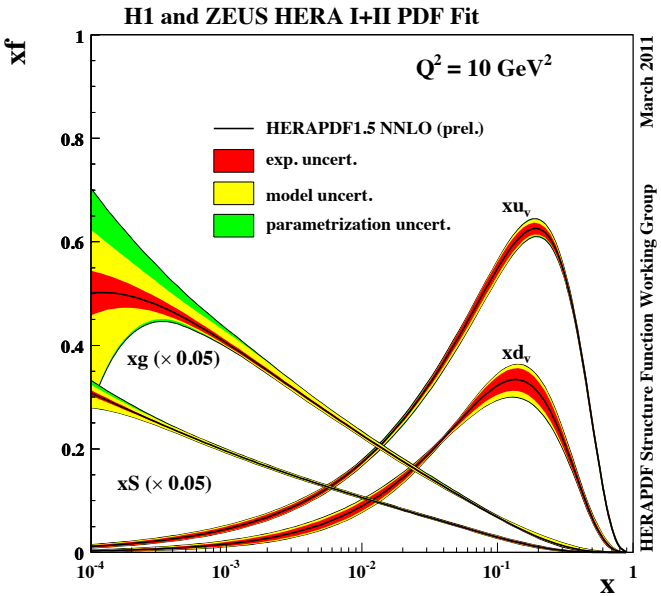
Entanglement in DIS

*(Phys. Rev. D **95**, 114008)*

- It has been proposed that in ***low x and large rapidity*** DIS events, the von Neumann entropy of localized region A,

$$S(x) = -tr[\rho_A \ln\{\rho_A\}] \sim \ln\{xG(x)\}$$

where $xG(x)$ is the gluon PDF, e.g., average number of gluons at a given x



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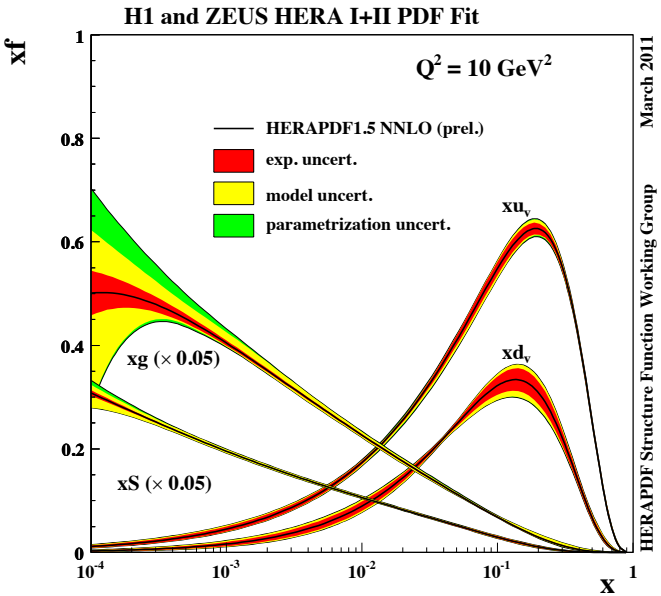


If region A and B are **strongly (maximally) entangled**,

$$\ln\{xG(x)\} \sim \sum_n \rho_n \ln\{\rho_n\}$$

ρ_n is the probability of finding n parton

Measurement of final-state hadron P_n can provide the entangle entropy

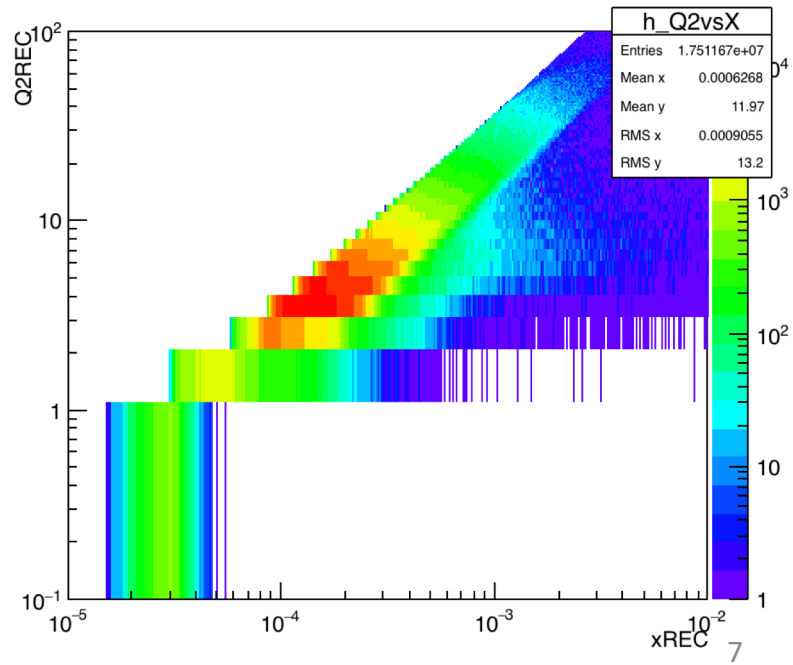
("local parton-hadron duality")

Data and MC

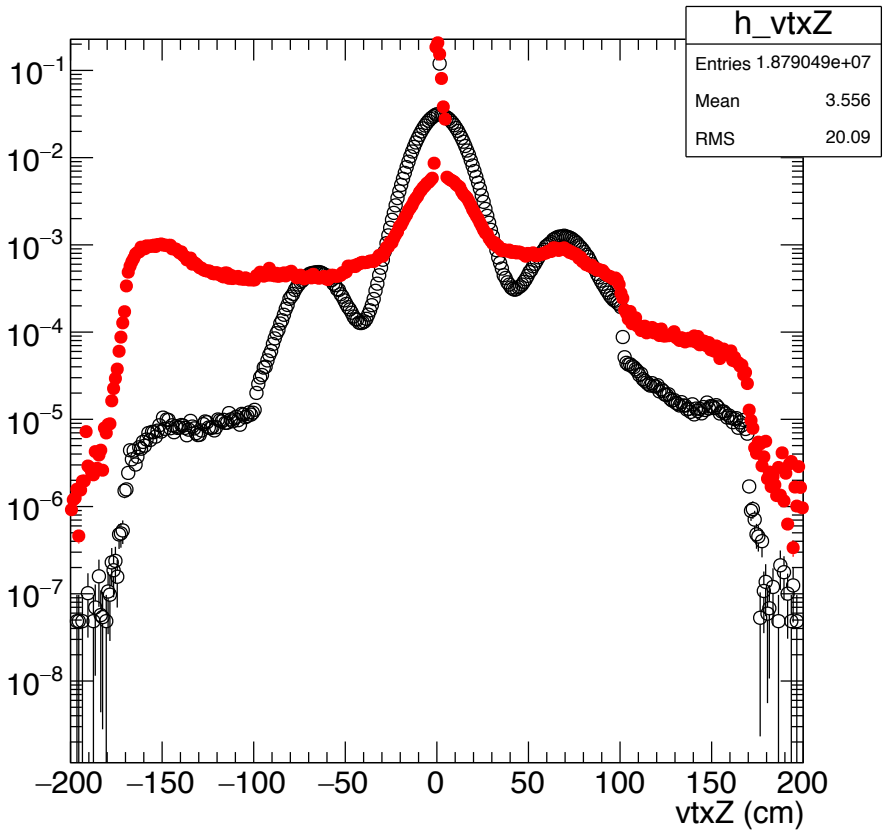
- Data sample:
  - **Low energy run: 27.5 GeV electron on 460 GeV proton**
  - Year: 2007, run# = 500927-507824
  - Statistics: total ~10 pb^{-1}, 150M events
- MC sample:
  - DJANGO14_2007_LOWE, low energy runs
  - ~16M events
- Triggers:
  - Subtrigger 1:
    - electron with E>10 GeV anywhere in SpaCal (huge prescale)
  - Subtrigger 0:
    - electron with E>7 GeV and R>20 cm in SpaCal (large prescale)
  - Subtrigger 2:
    - electron with E>10 GeV and R>20 cm in SpaCal (small prescale)
  - Subtrigger 3:
    - electron with E>10 GeV and R>30 cm in SpaCal (no prescale)
  - Subtrigger 61:
    - electron with E>10 GeV anywhere in SpaCal, and central track with pt>400 MeV (no prescale)

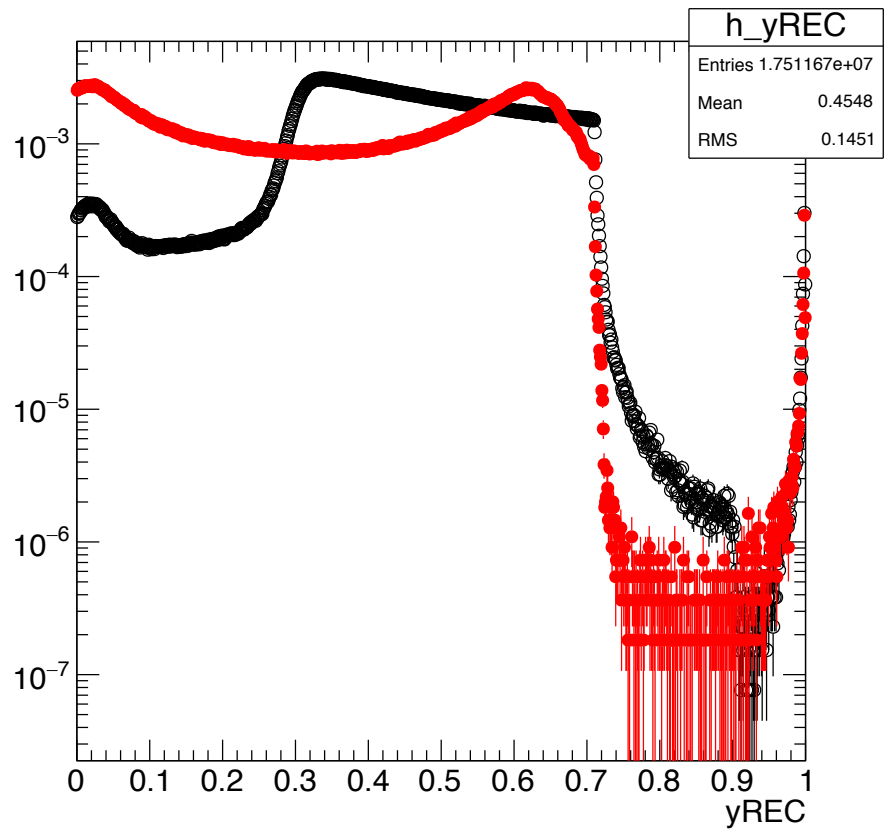
Event selections and weights

- Triggers (s0,s1,s2,s3,s61)
  - Proper weights account for different prescales are calculated
  - ~ (1-1./prescale)
  - ~12M events left after trigger selections
- Vertex Z position
  - Nominal vertex |vz| < 30
  - Shifted vertex |vz+70| < 30 (gain acceptance for FST tracks)
- Kinematics:
  - 0.05 < y < 0.6
  - 2 < Q2 < 100, with 4 bins (2,5,10,15,100). Detail investigation of very low Q2 events, maybe not feasible below 5.
  - For whatever available x range up to 10E-3 – 10E-2. (~ 5 bins)



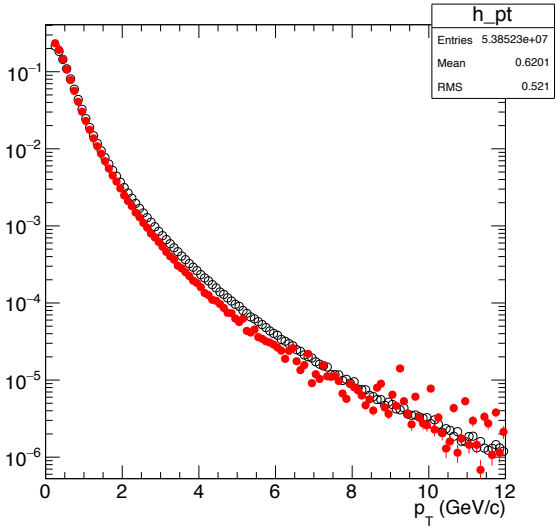
Data and MC comparison

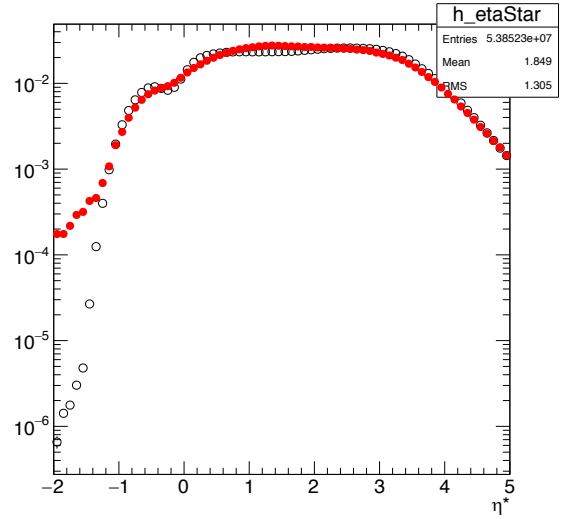


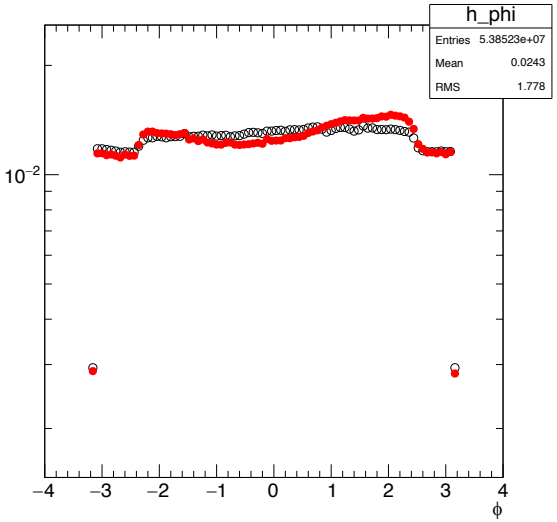


Discrepancy due to triggers? Vertex reweight for the MC?

Data and MC comparison single track



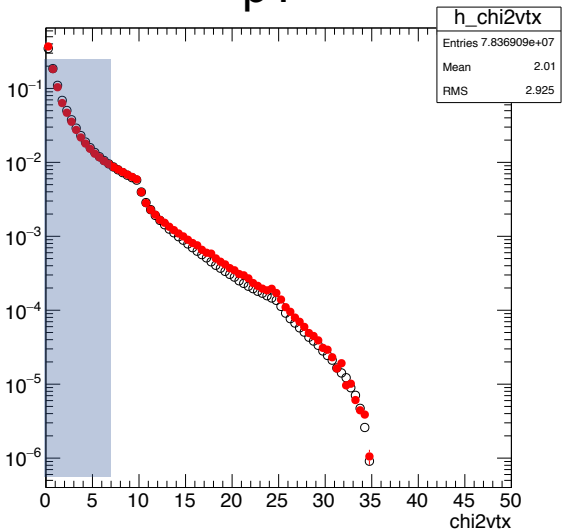


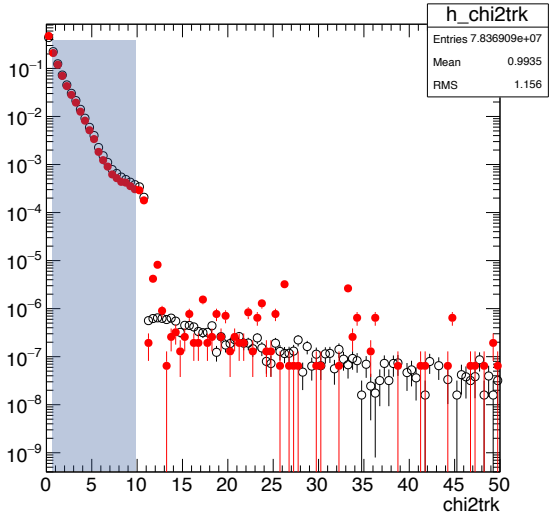


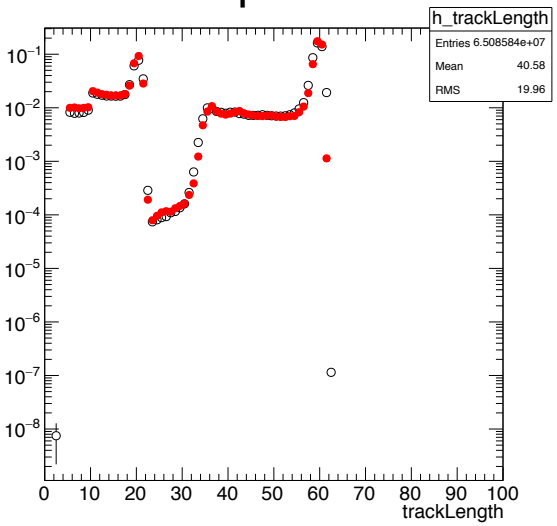
pT

eta*

phi





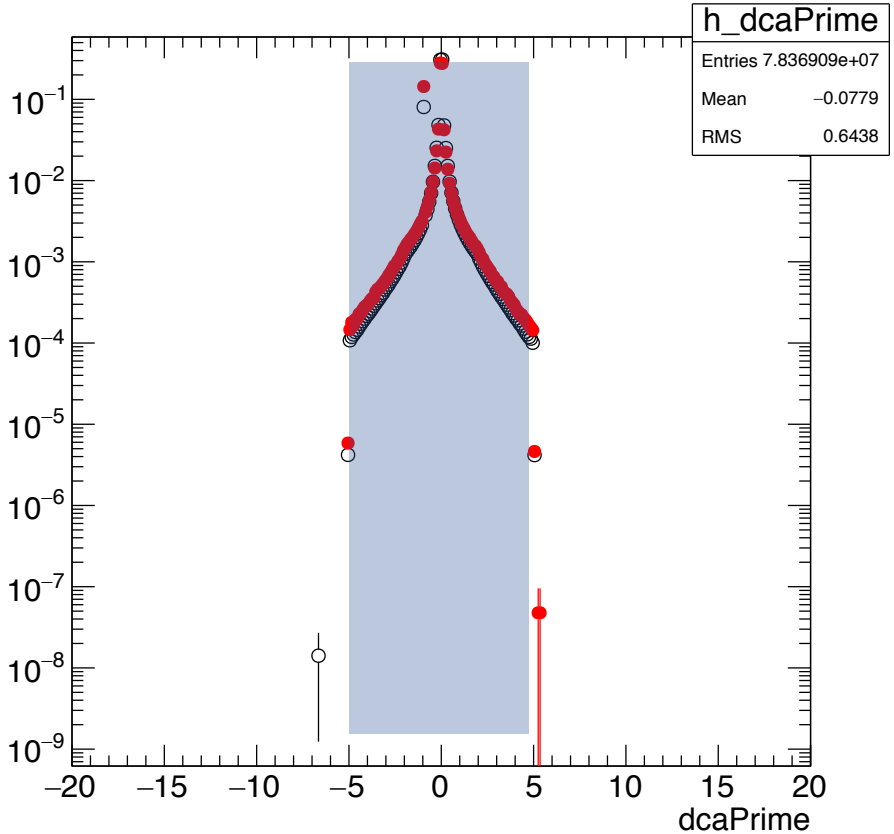


Chi2/NDF for vertex fitting < 7

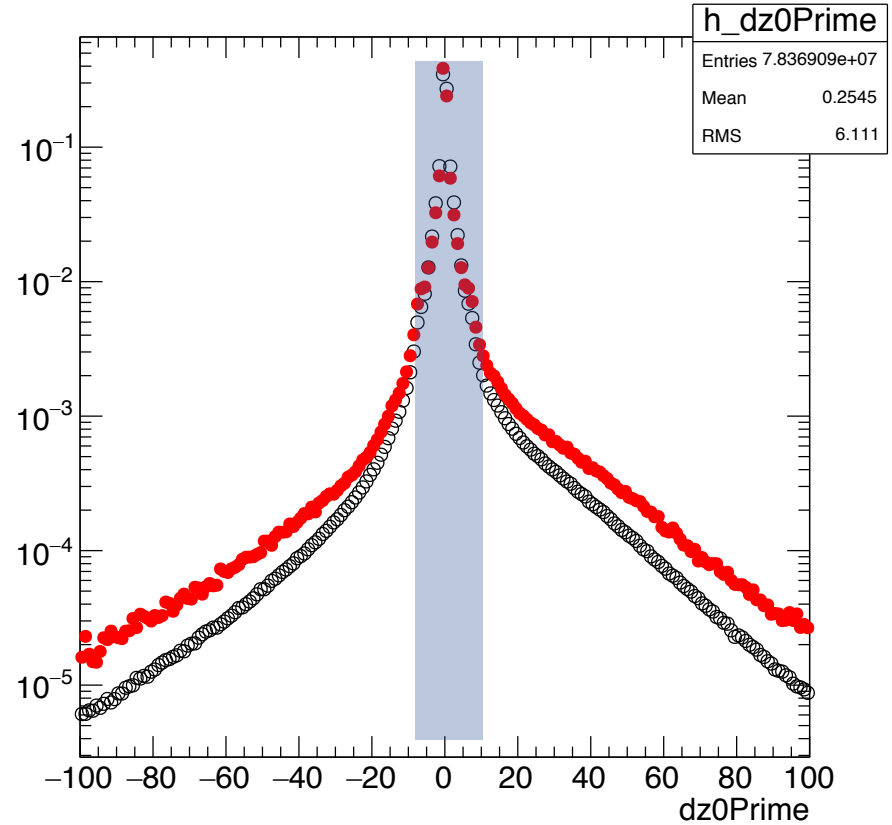
Chi2/NDF for track fitting < 10

Track length

Data and **MC** comparison single track



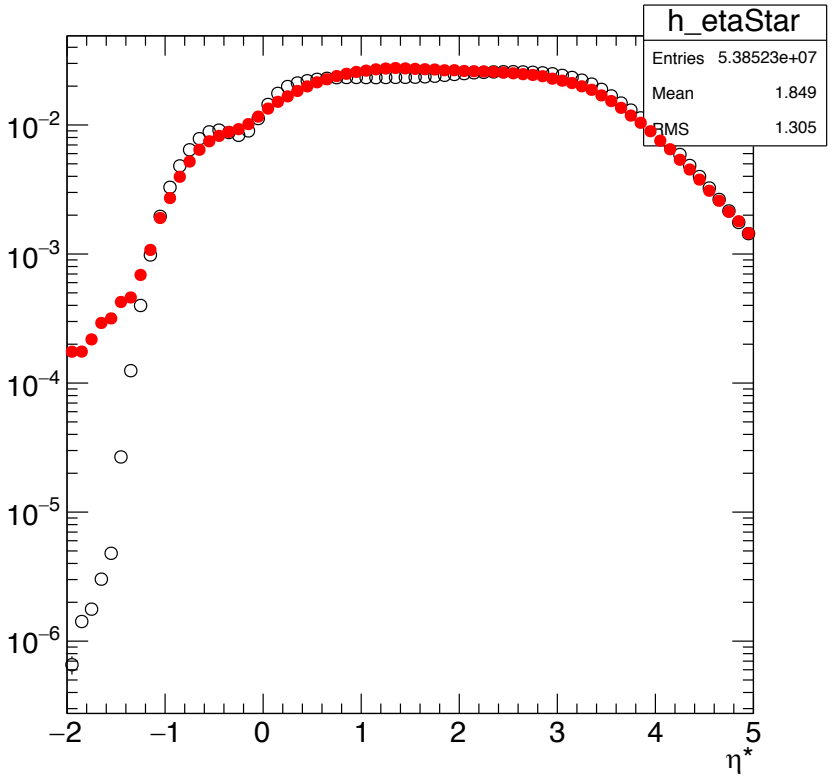
DCA xy



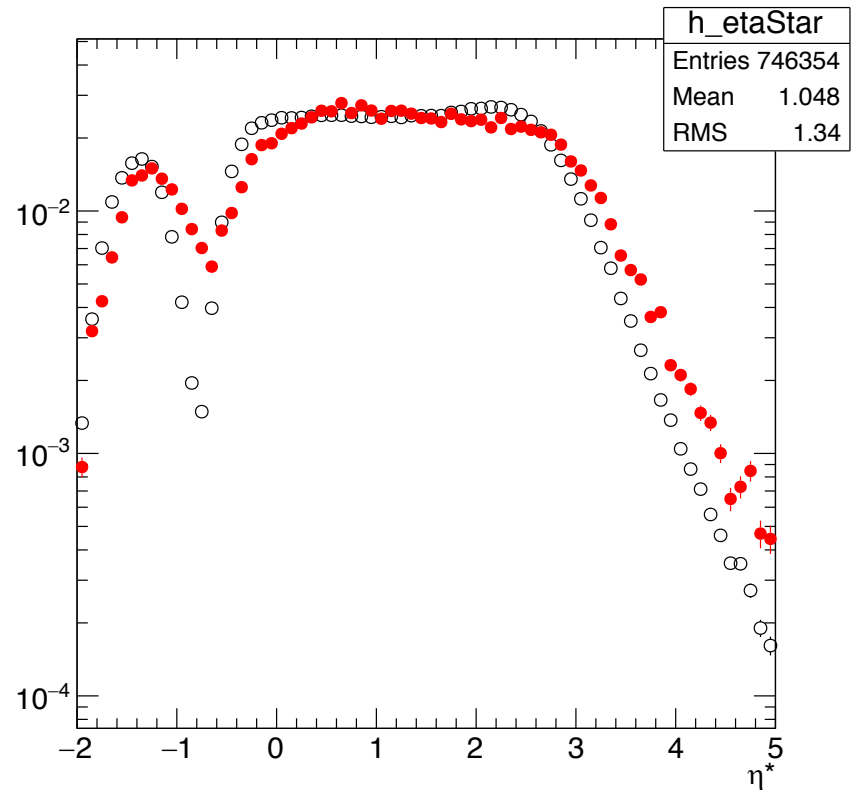
DCA z

Optimized track cuts DCA < 5 for both parameter

Data and MC comparison shifted vertex



Nominal vertex



shifted vertex

With FST tracks, marginal gain?

Track selections and performance

Optimized selections [against eff*(1-fak)]

Central tracks:
Q2 > 5 && Q2 < 100 && y > 0.1 && y < 0.6 with nominal vertices

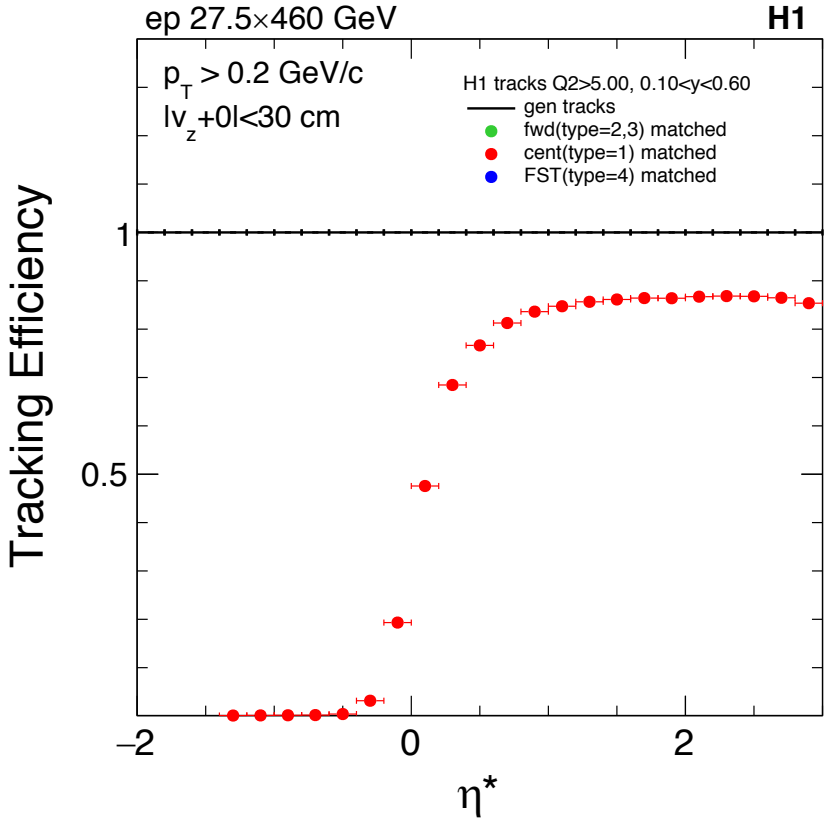
The best track selection now is the following:

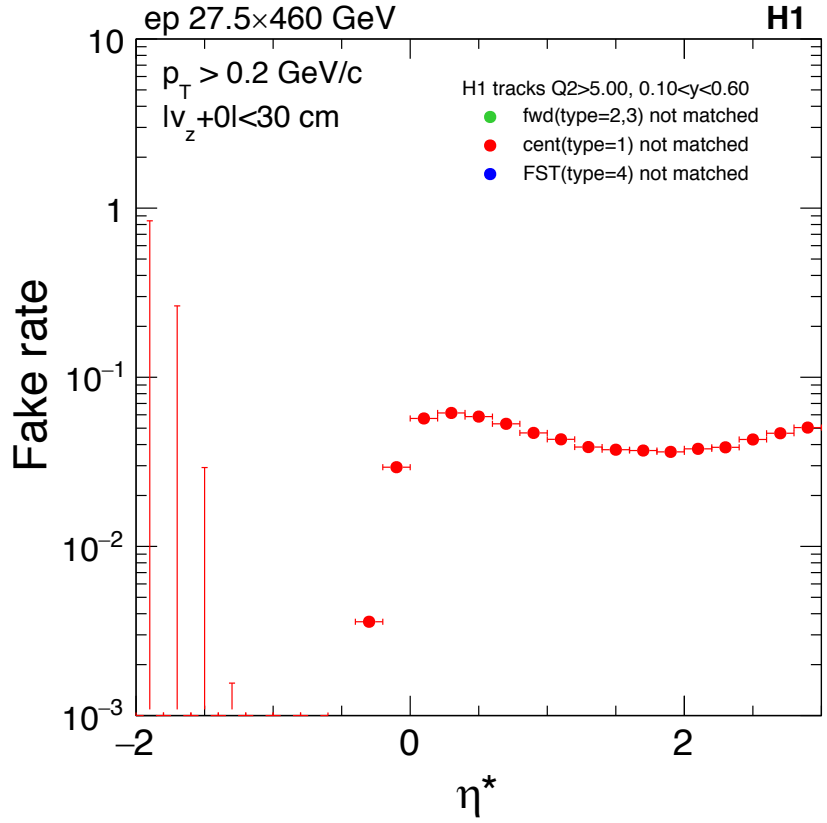
1. chi2nTrackCut < 10.0;
2. chi2nVtxCut < 7.0;
3. fabs(dcaCut) < 5.0;
4. nHits > 10, but is found to be not sensitive
5. track lengths > 2., found not sensitive
6. pT > 200 MeV for both FST and cent tracks. For FST tracks, only 1. has been applied where other cut variables are not available for FST tracks.

FST tracks:
Q2 > 5 && Q2 < 100 && y > 0.1 && y < 0.6 with shifted vertices (70cm)

The best track selection now is the following:
chi2nTrackCut<10.0;

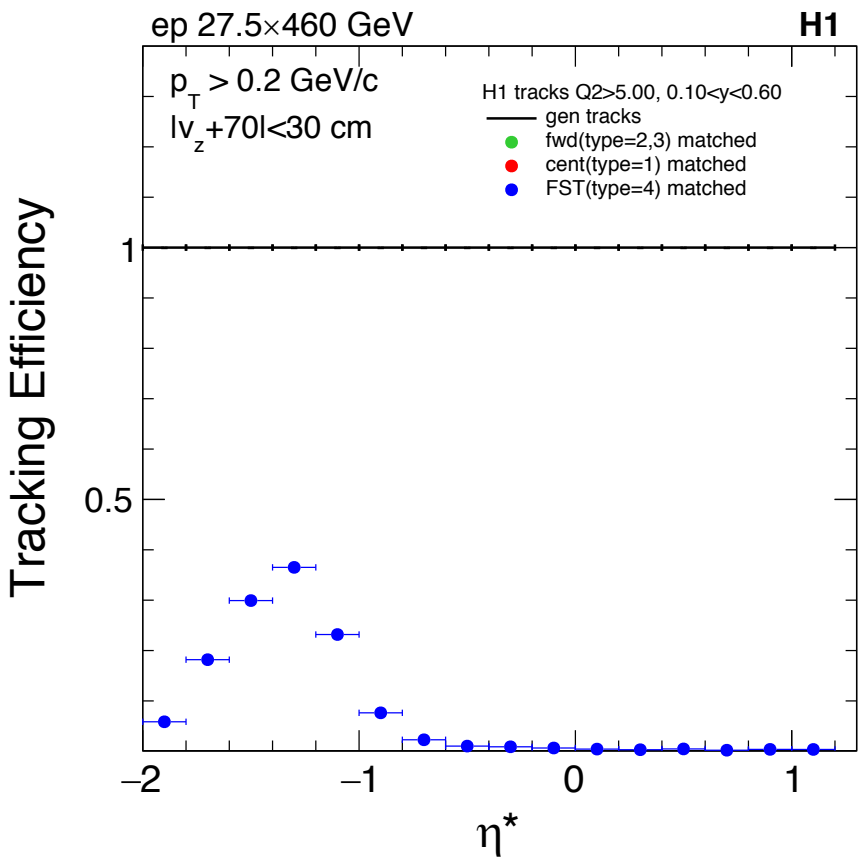
Track performance

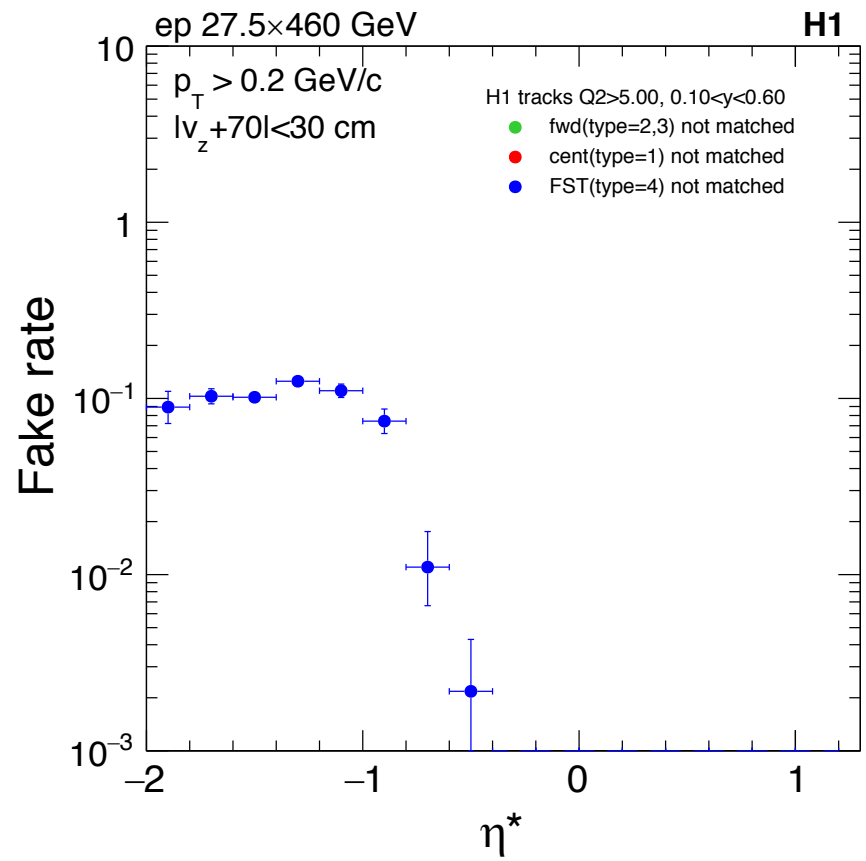




Central tracks with nominal vertex, only good for current region

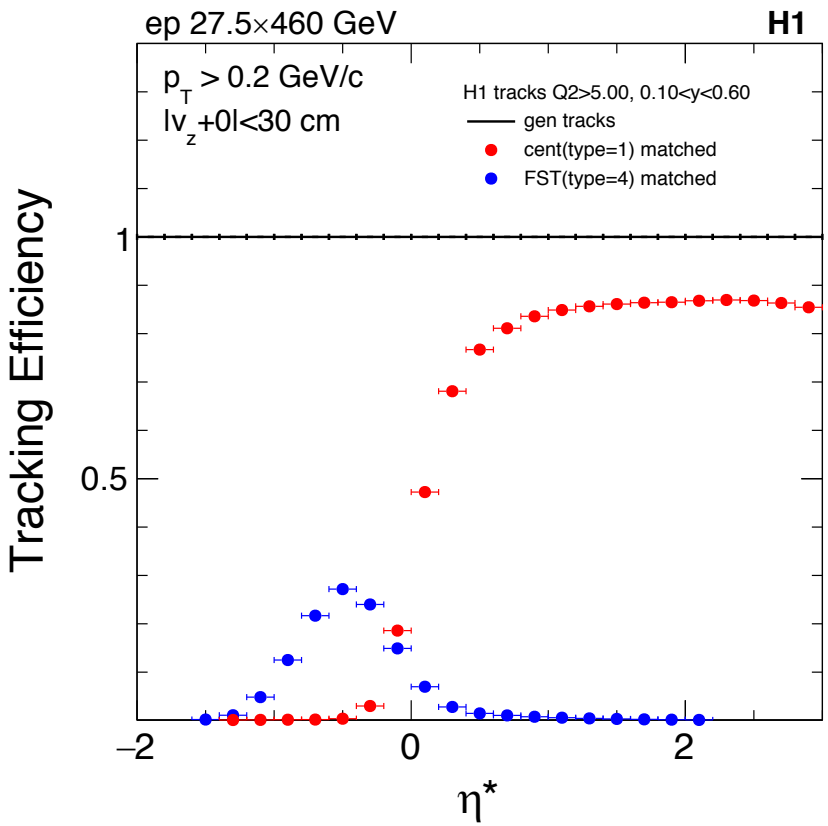
Track performance

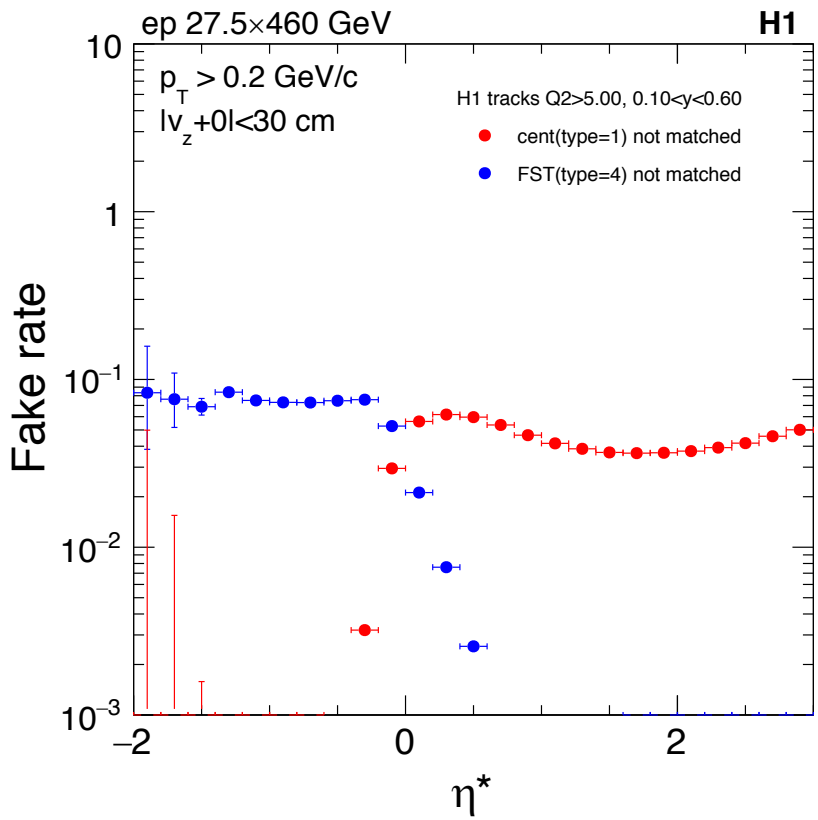




FST tracks with shifted vertex, some target regions

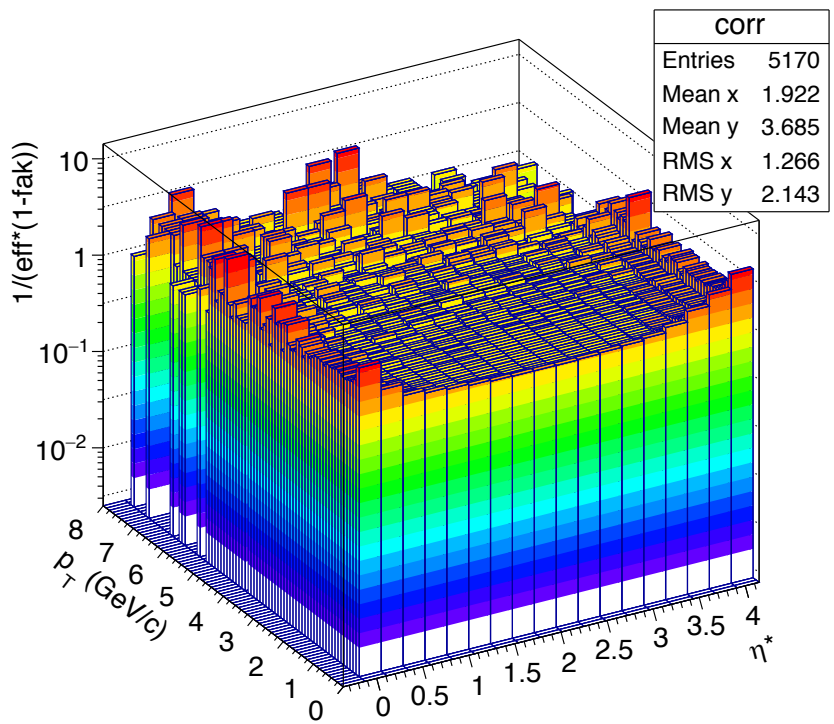
Track performance



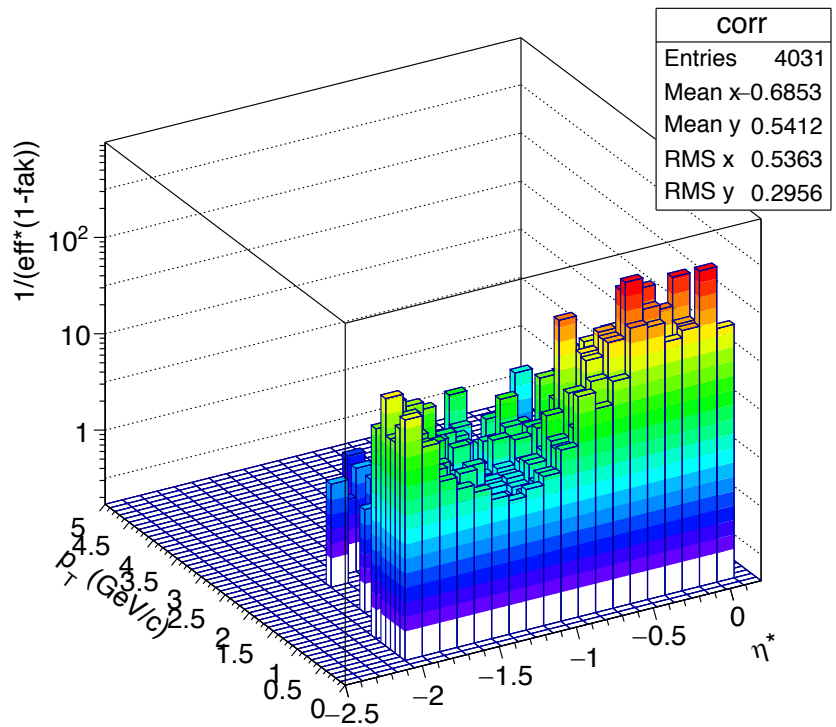


FST tracks with nominal vertex, some target regions

1/eff*(1-fak) factors



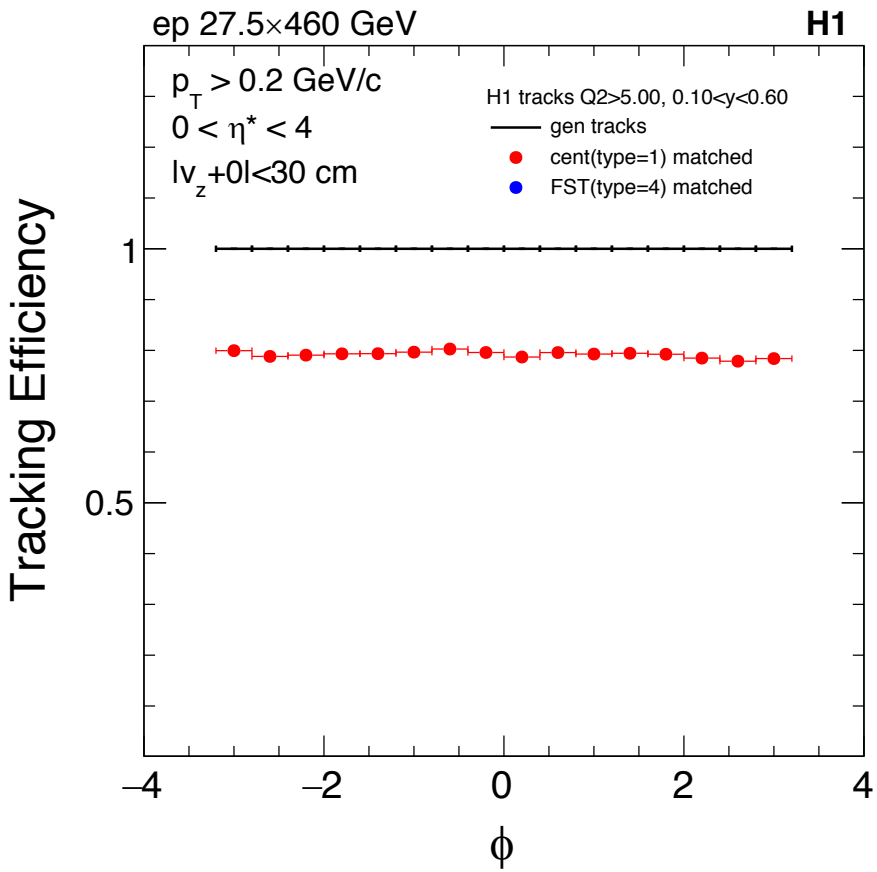
Current region

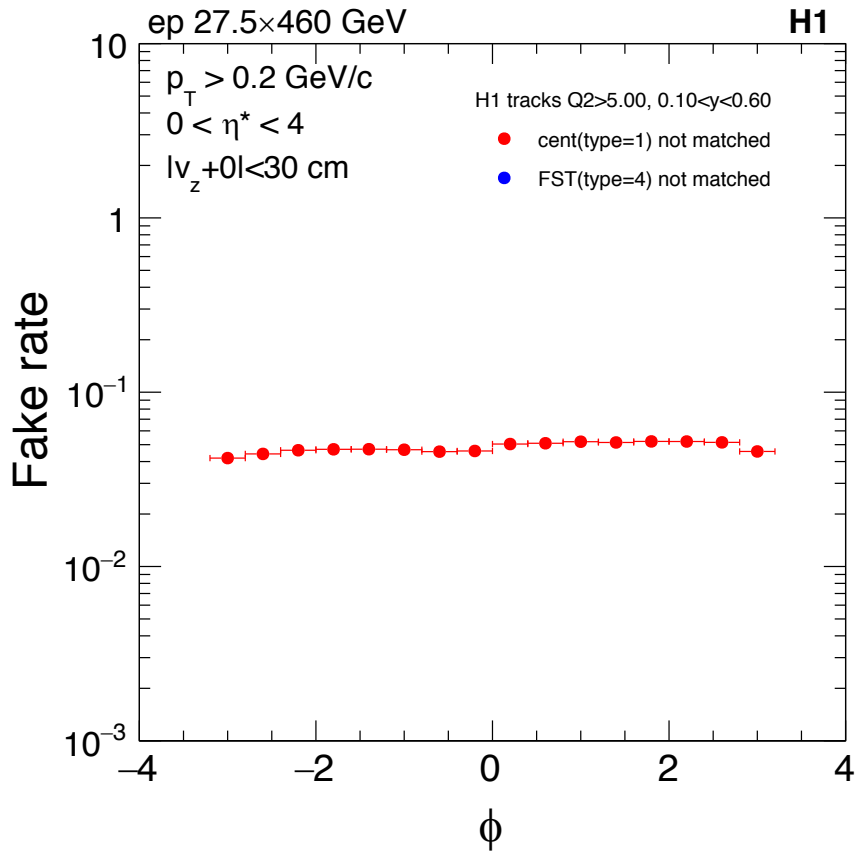


Target region

Target region is extremely challenging

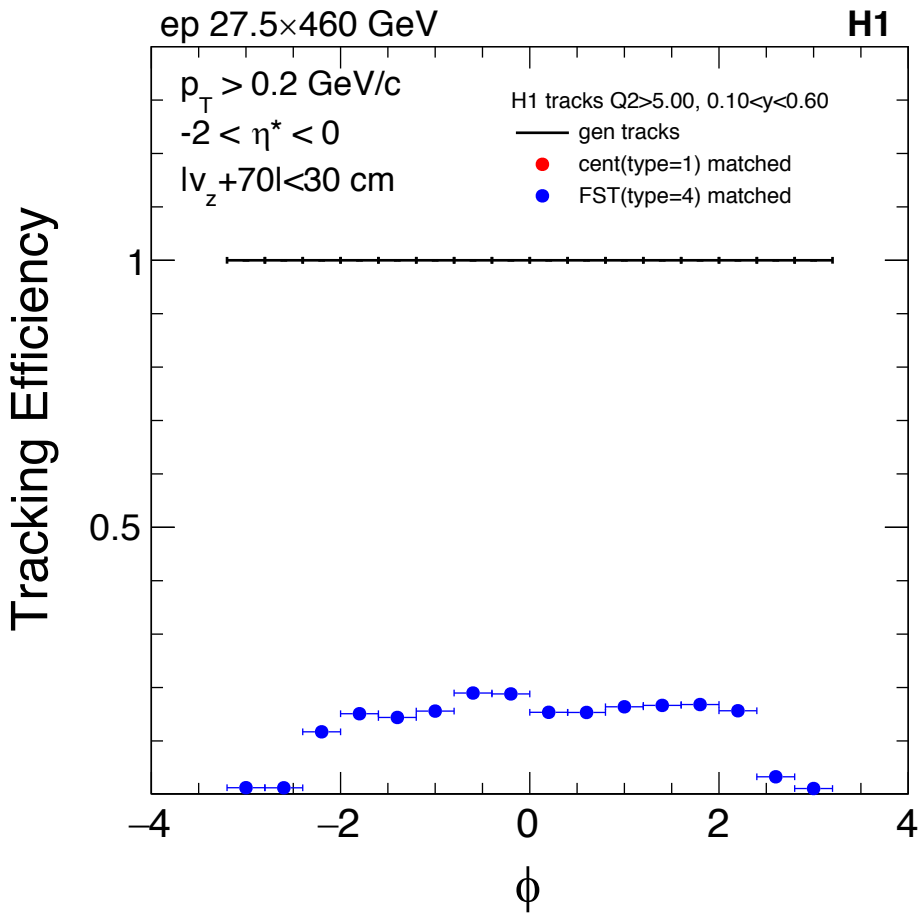
Central tracks efficiency and fake (~phi)

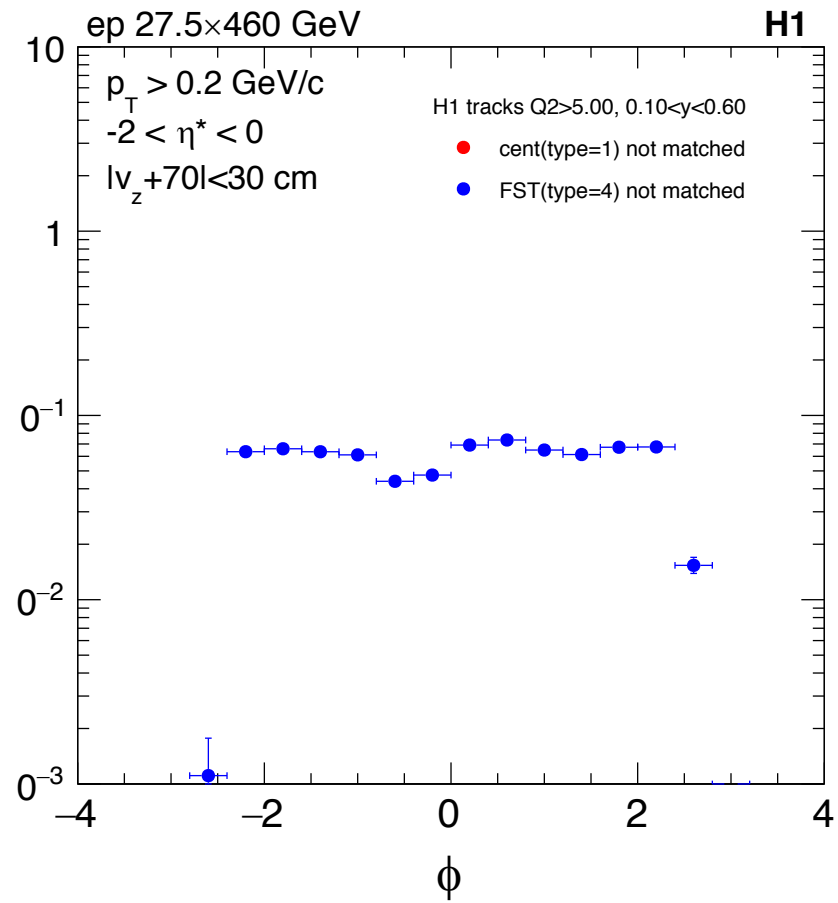




- Pt>0.2 & 0<eta*<4
- Looks good

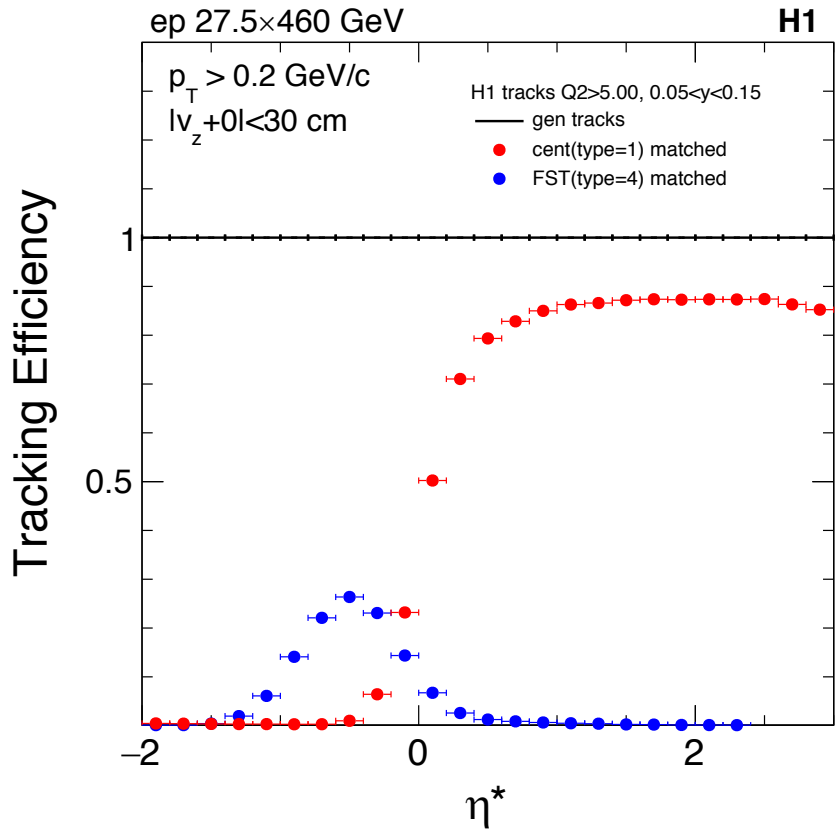
FST tracks efficiency and fake (~phi)

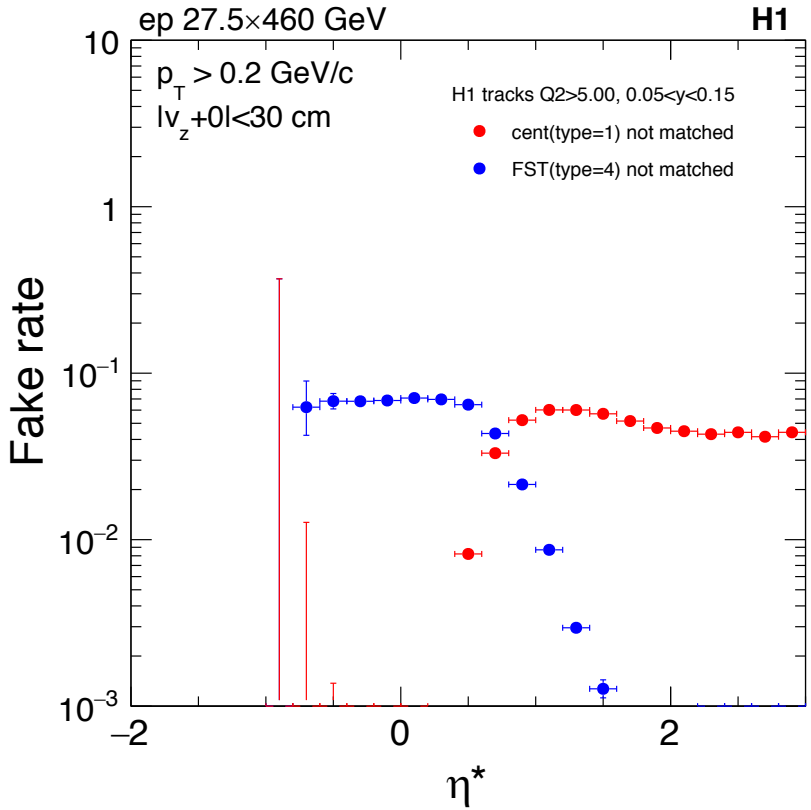




- Pt>0.2 & -2<eta*<0
- Some structure between -1 to 0?
- Missing part of the acceptance in phi is expected

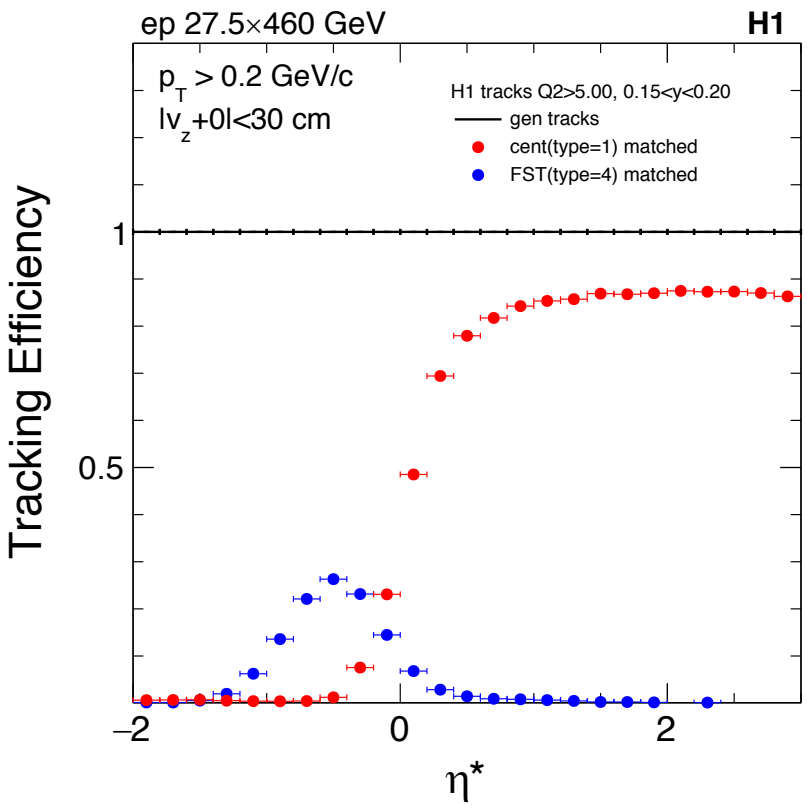
y dependence on tracks

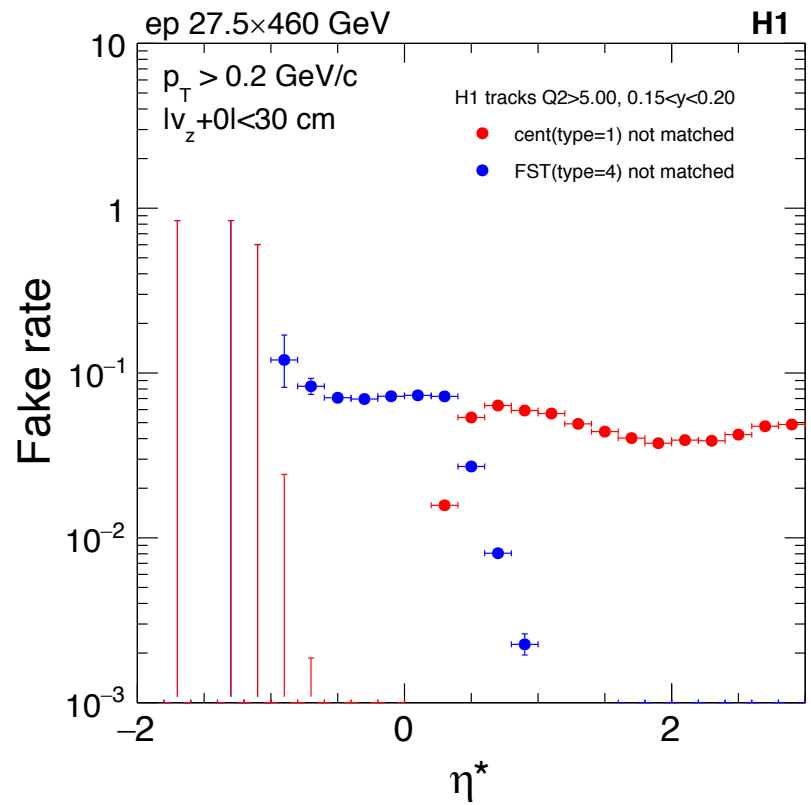




0.05 < y < 0.15, nominal vertex, acceptance ok.

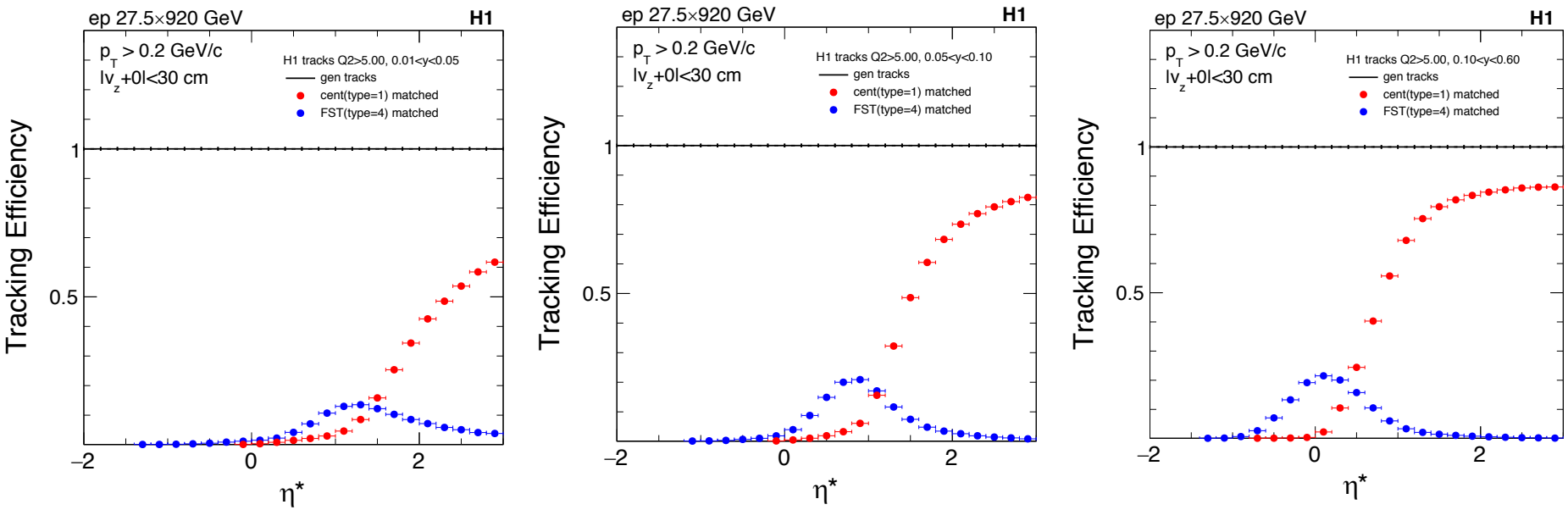
y dependence on tracks





0.15 < y < 0.2, nominal vertex, not much different from previous

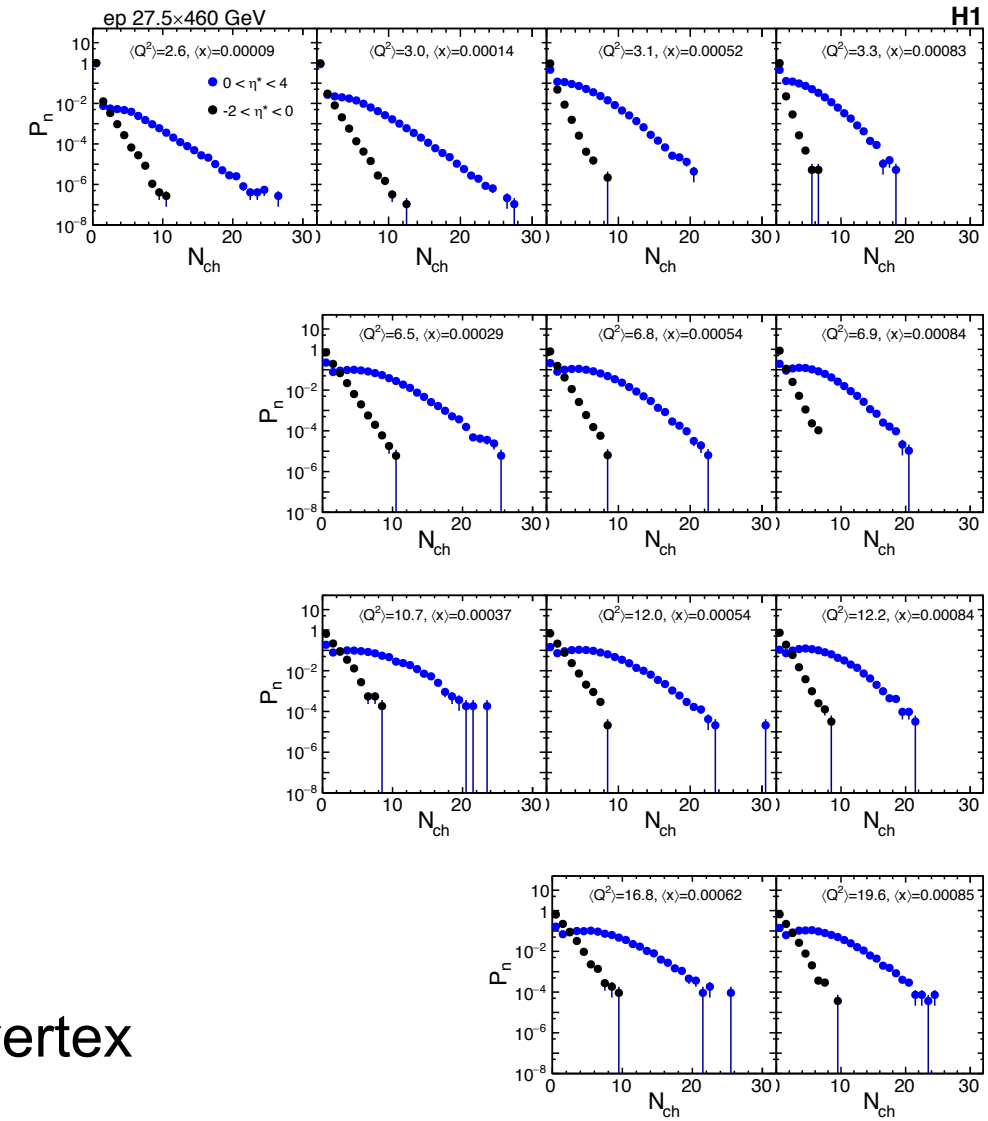
y dependence on tracks



27.5 on 920 GeV ep:
Nominal vertex at higher energy, strong dependence on y

Raw data without corrections

Q2



Q2 (2,5)

Q2 (5,10)

Q2 (10,15)

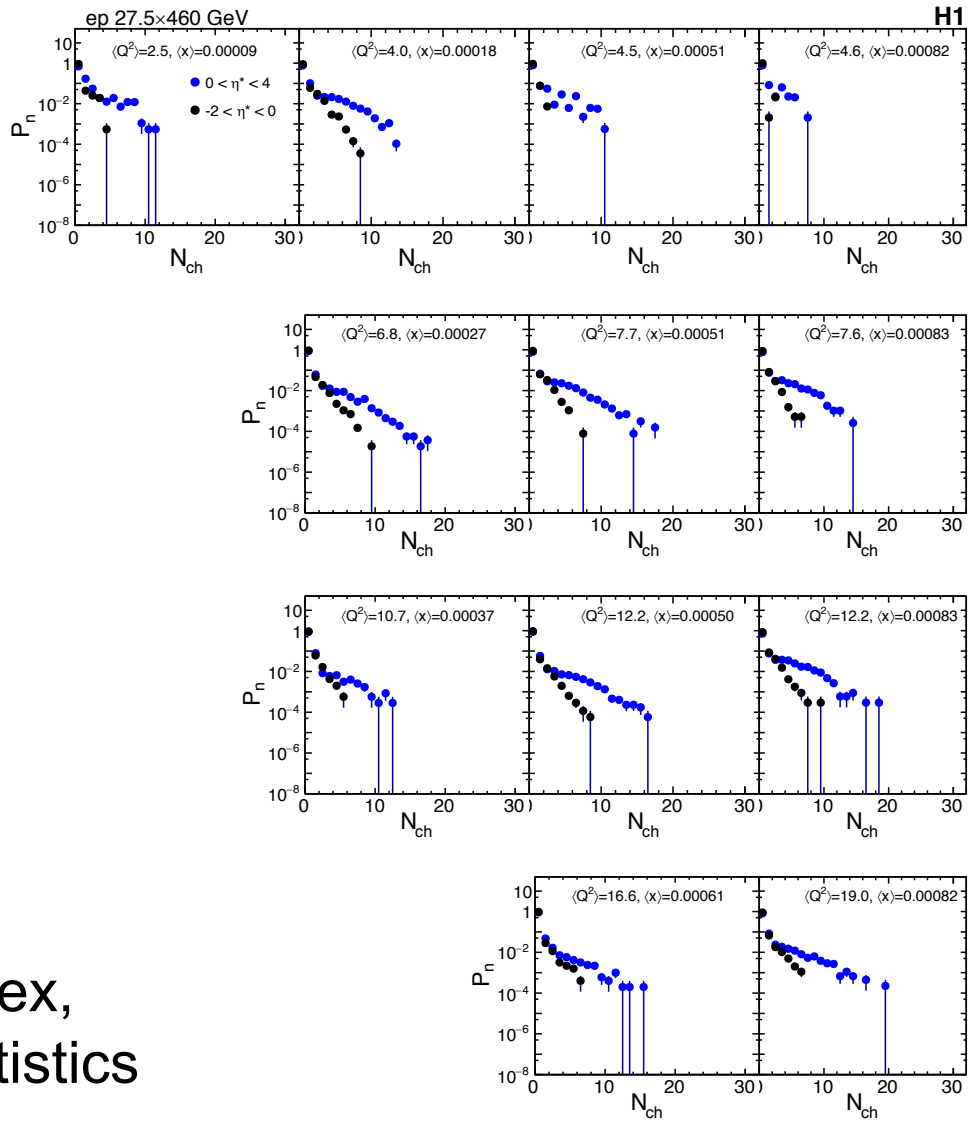
Q2 (15,100)

Nominal vertex

X

Raw data without corrections

Q2



Q2 (2,5)

Q2 (5,10)

Q2 (10,15)

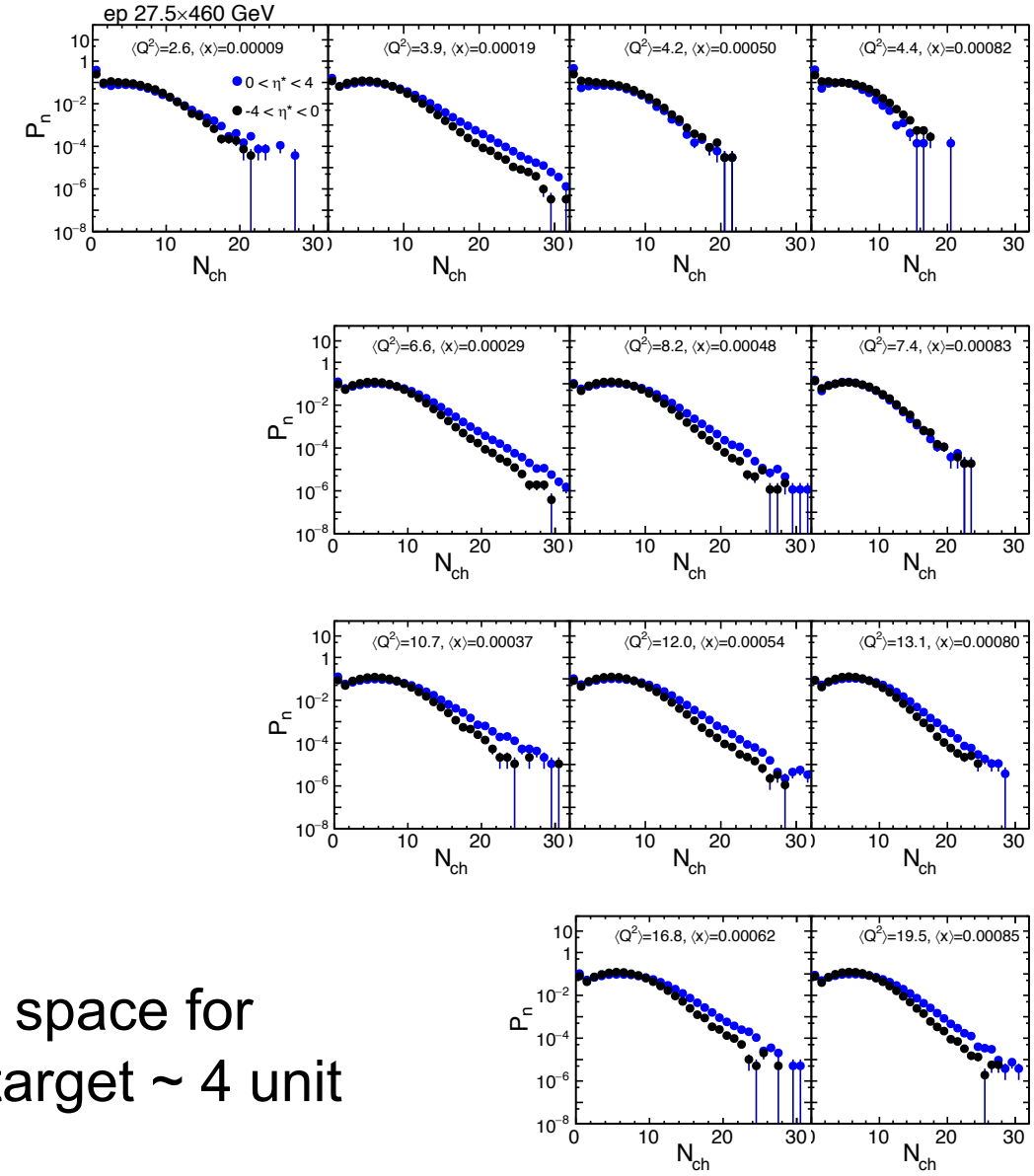
Q2 (15,100)

shifted vertex,
Limited statistics

X

DJANGO14 MC True

Q2



Q2 (2,5)

Q2 (5,10)

Q2 (10,15)

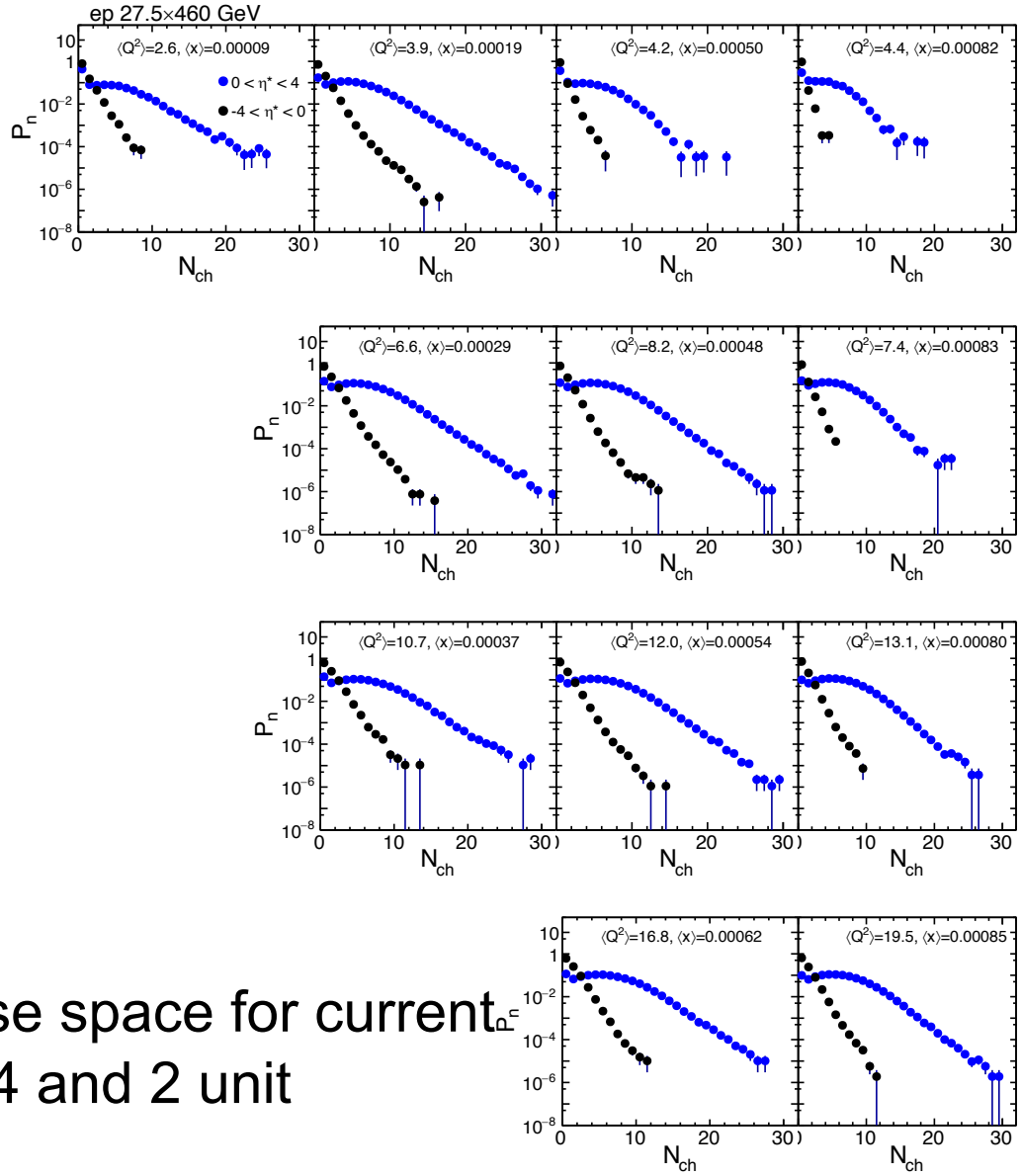
Q2 (15,100)

Equal phase space for current and target ~ 4 unit

X

DJANGO14 MC RECO

Q2



Q2 (2,5)

Q2 (5,10)

Q2 (10,15)

Q2 (15,100)

different phase space for current and target ~ 4 and 2 unit

X

Summary and plans

- Analysis seems reasonable for measurement in the current region. Target regions are still limited by acceptance. From physics point of view (EE), acceptance is the key.
  - **Overall: drop events with shifted vertex? Seems not worth it.**

1. Option 1: Current region only with full correction within our pseudorapidity window (0 < eta* < 4);
2. Option 2: Combine current and a little bit of target region with full correction (-2 < eta* < 4);
3. Option 3: Option 1 + target region (-2 < eta* 0) but need to fully correct to at least 4 unit in eta* (-4 < eta* < 0), will be model dependent.

What's next?

- Finalize kinematic regions in Q2 and x, e.g., drop Q2 (2,5)?
- Unfolding
- Need Trigger bias or trigger efficiency estimates
- No need for overall normalization, e.g., luminosity, only self normalization.