Status of collectivity studies in ep collisions with ZEUS

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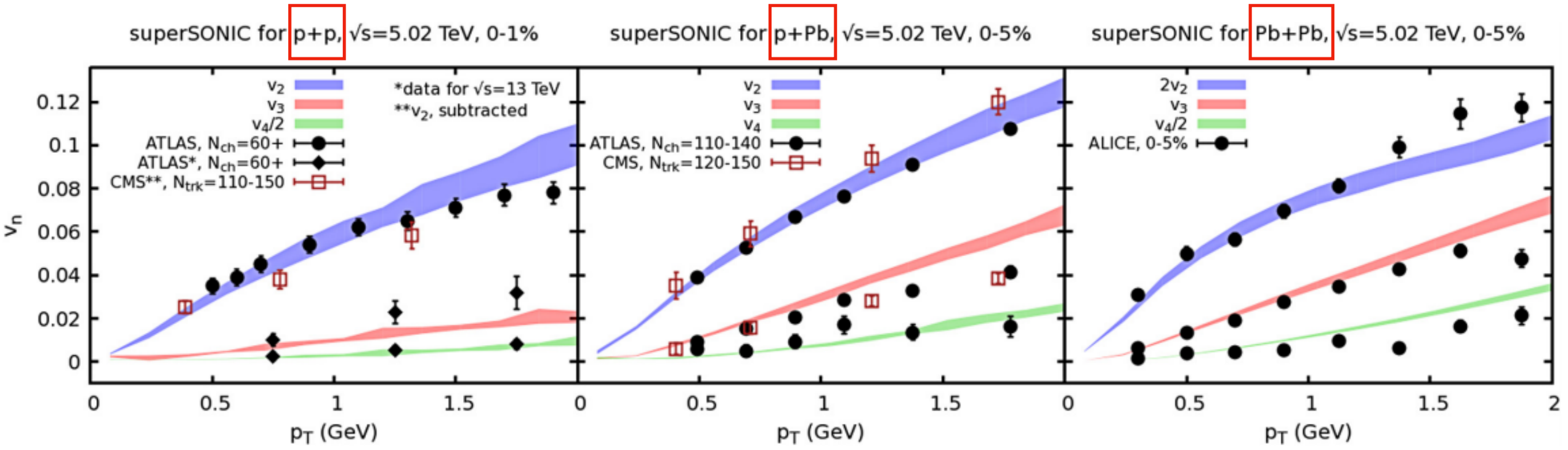
- Joined ZEUS in October 2018.
- Taking over the study from Jaap Onderwaater.

Brief reminder of the motivation for this study

Collectivity observed in all collision systems available at the LHC.
Central question: Can similar effects be seen with ZEUS data?

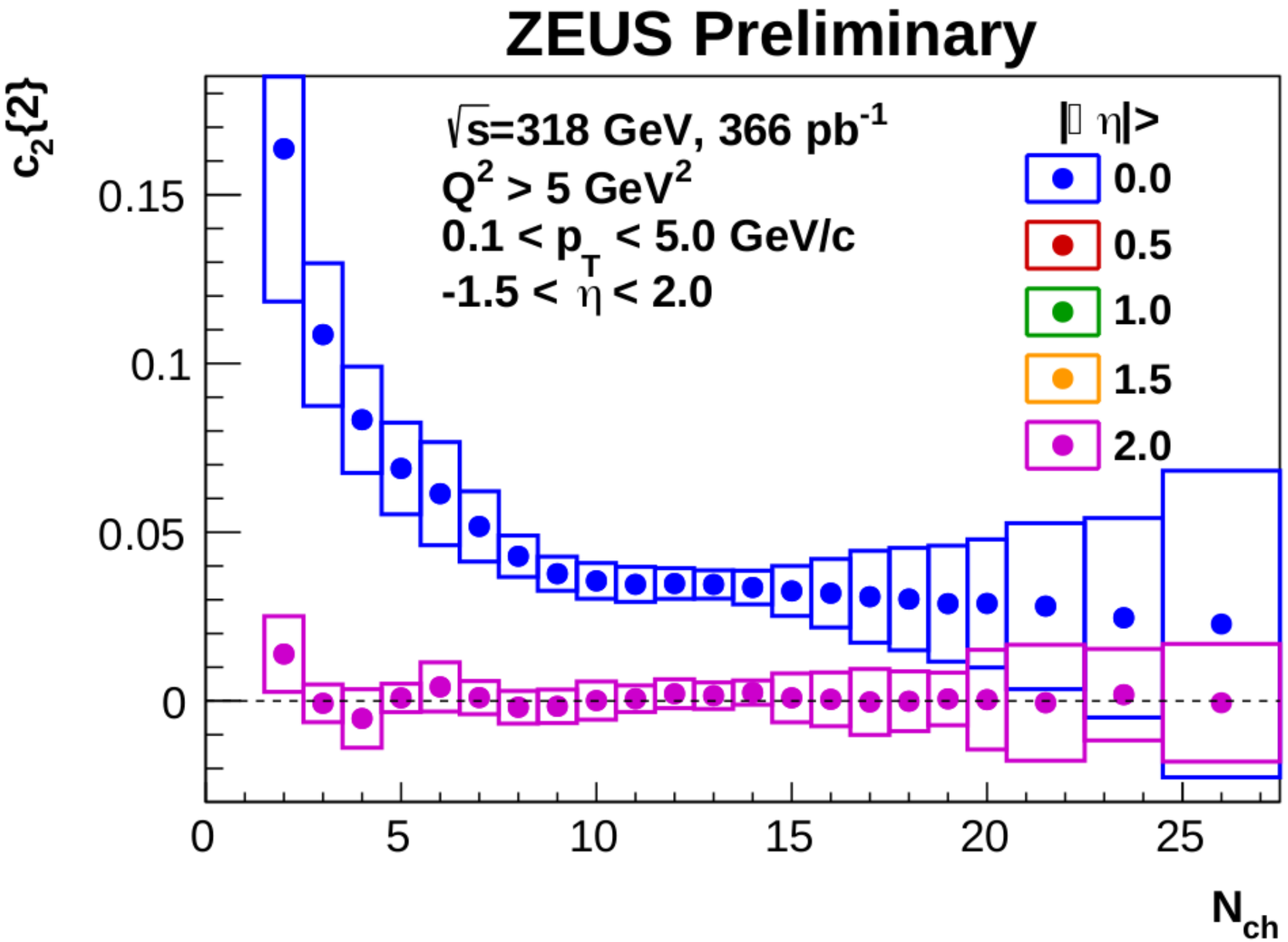


Our probes of collectivity are the Fourier coefficients (v_n)
of the azimuthal particle distribution.
They can be measured in the following way:

$$c_n\{2\} = \langle\langle e^{in(\phi_a - \phi_b)}\rangle\rangle = v_n^2$$

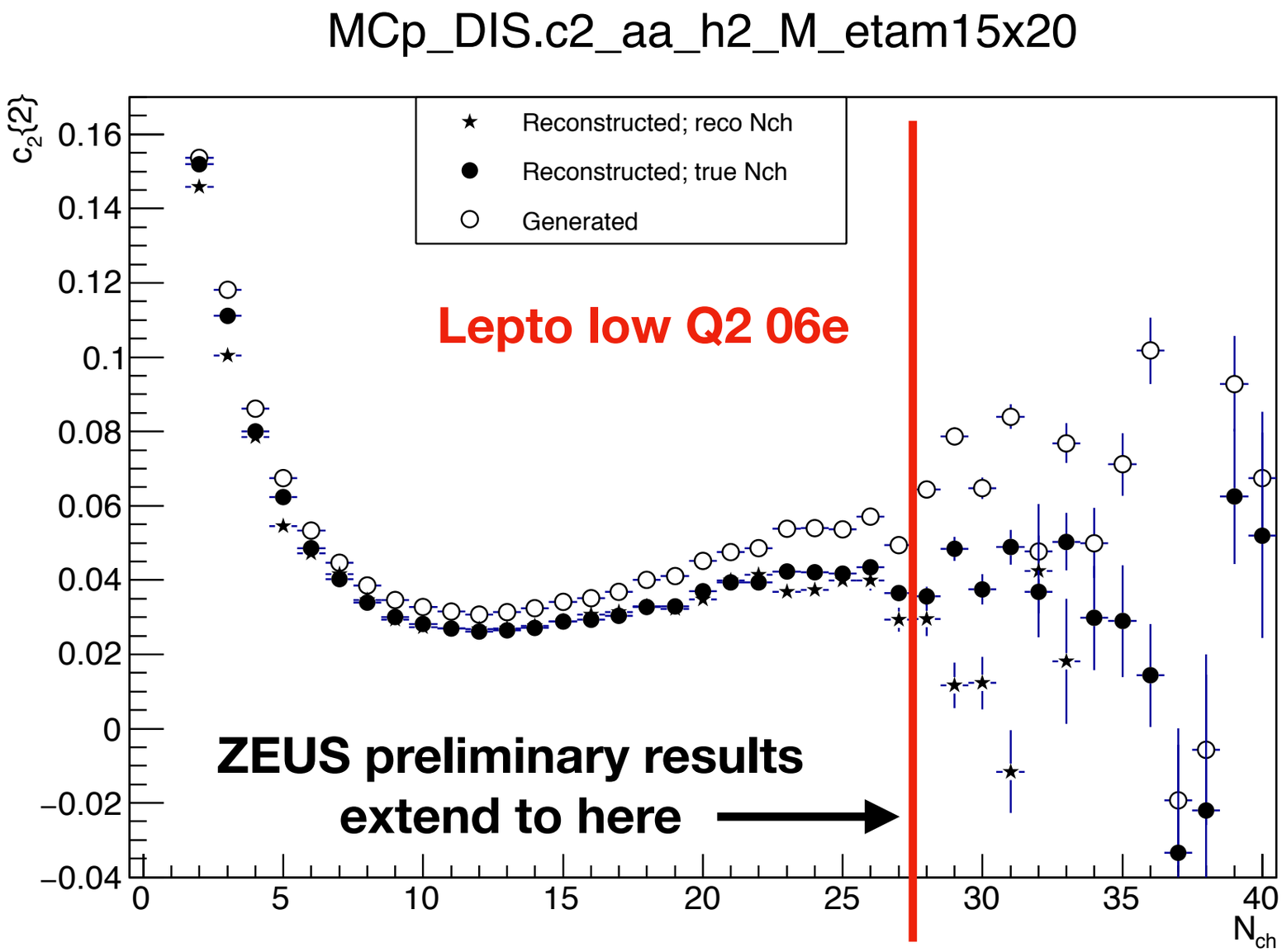
In this presentation I'll be focusing on $c_2\{2\}$ vs. N_{ch}.

Preliminary result



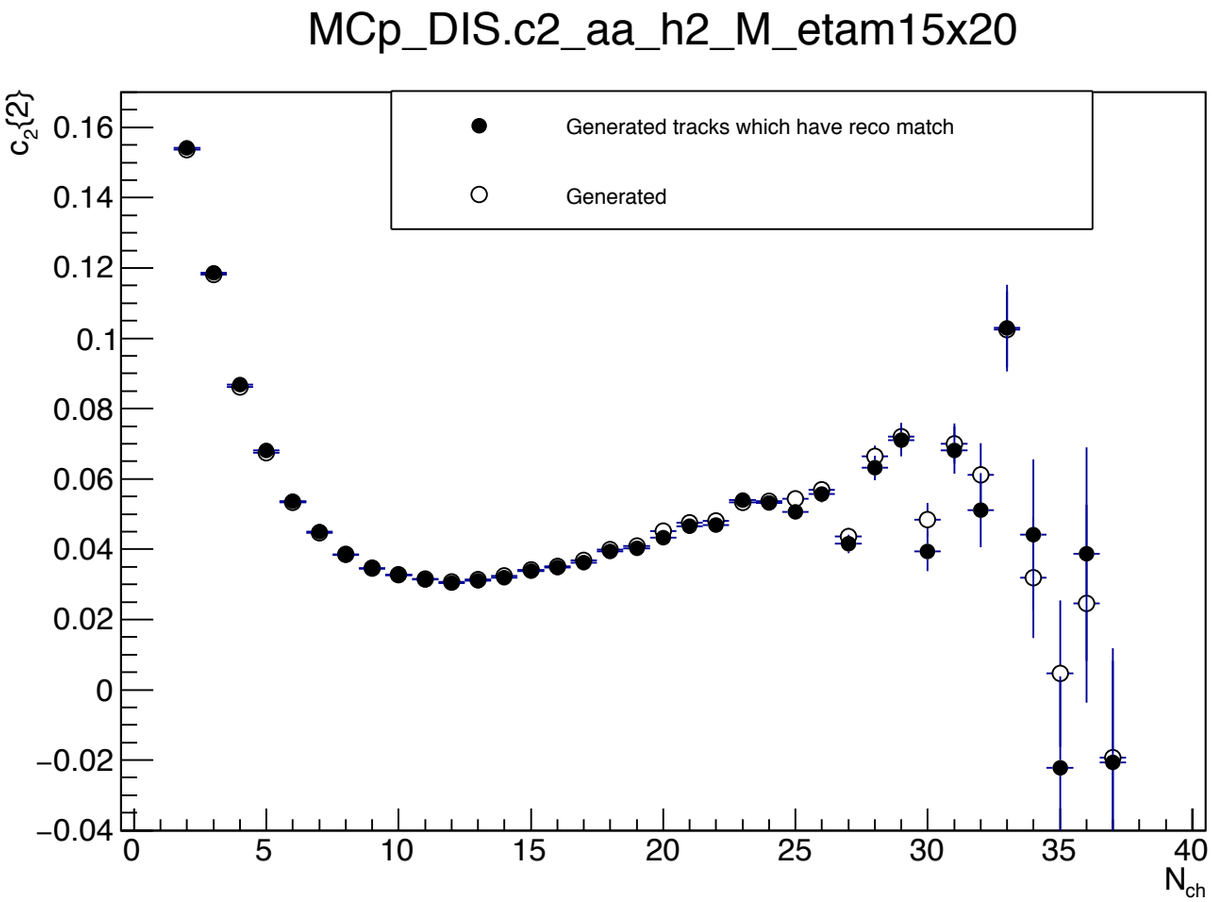
- **We are interested in the high Nch region.**
- **However, the systematics are very large here.**
- **The dominant source of uncertainty here is due to the MC closure test failure.**

MC closure test problem



- **Discrepancy between generated and reconstructed grows with Nch.**
- **This problem has held up the analysis.**
- **Resulted in large systematic uncertainties for ZEUS preliminaries.**
- **All subsequent plots in this presentation are from Lepto low Q2 06e**

Start with a simple question:
Does the full reconstructed pool of tracks contain the essential tracks??



Reconstructed track pool is basically set equal to the entire ZTT track subset.

Retain only matched tracks which are associated with a true MC primary.

<u>Answer:</u> Yes, at least the reconstructed pool is “complete”.

Now, try to find the track cuts which caused the MC closure problem.

Reconstructed Track Selection used for preliminary results

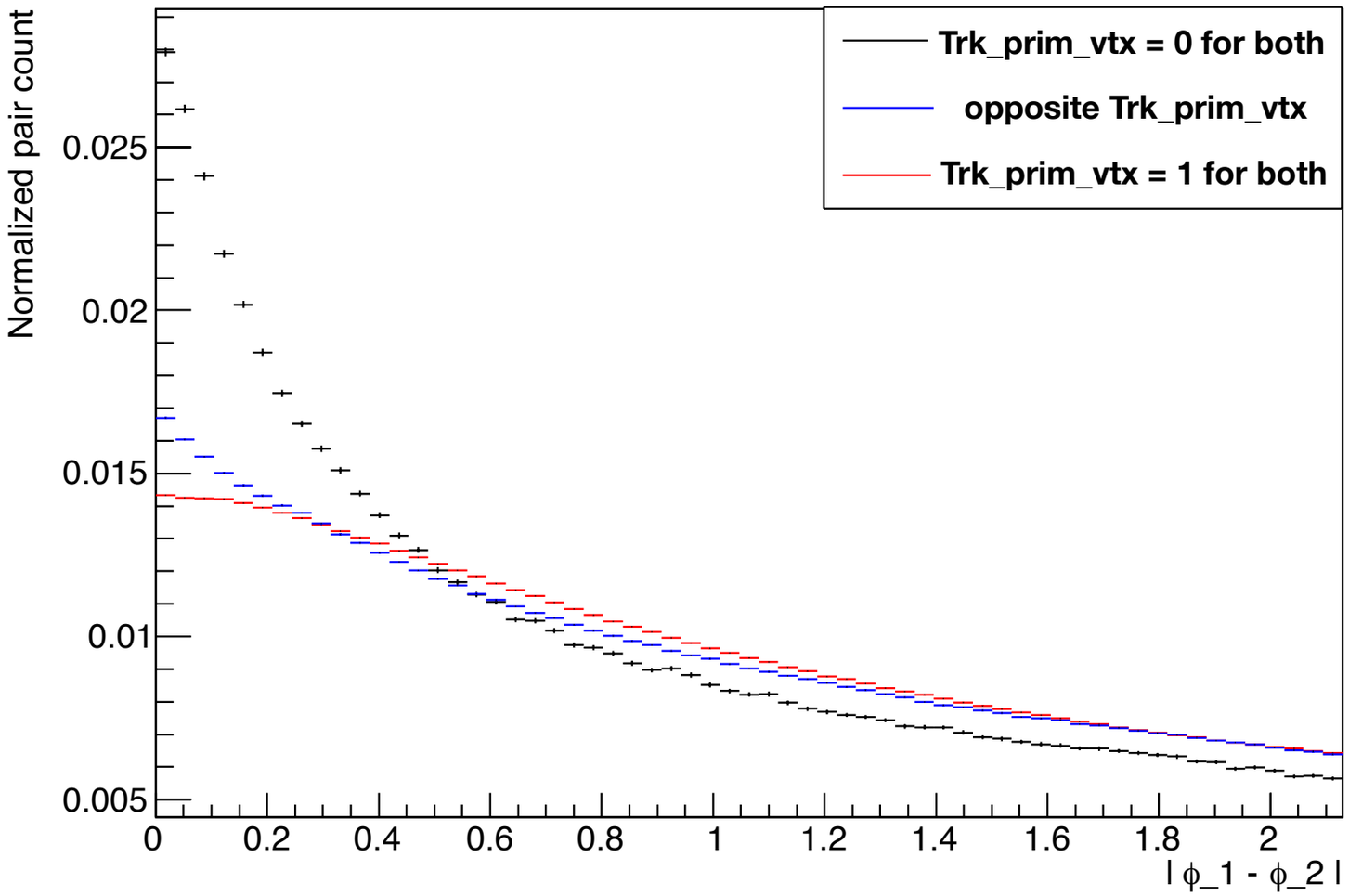
- **ZTT tracks**
- **Remove Sinistra candidate**
- **0.1 < pT < 5.0 GeV/c**
- **-1.5 < eta < 2.0**
- **MVD hits > 0**
- **Trk_prim_vtx = 1**
- **dca_xy < 0.5 cm**

Variations were tried for all of these.

Trk_prim_vtx=1 was found to cause most of the MC closure problem.

This flag is set by vertex pattern recognition algorithm.

Delta Phi distributions for different pair categories

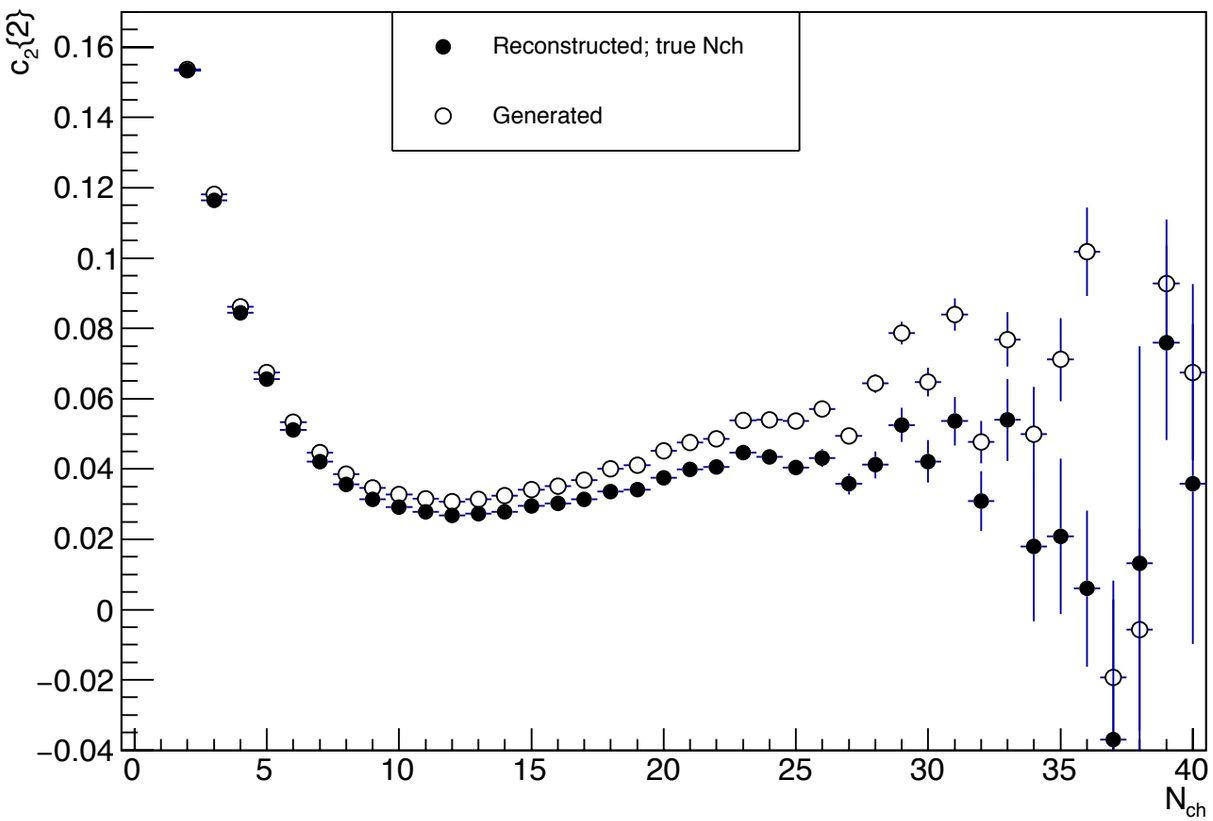


These distributions are from true MC primary tracks which have a match in the Reconstruction pool.

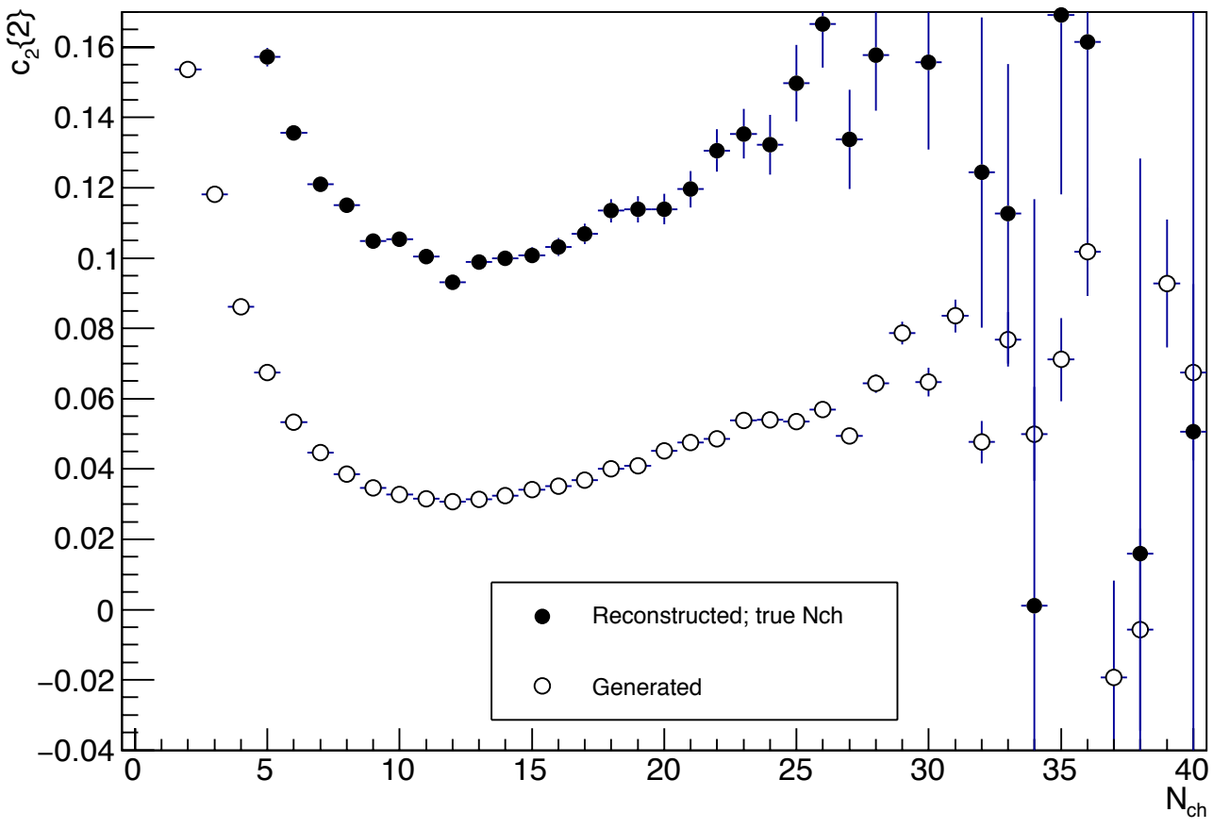
Large difference!! This will have a large effect on our correlation function.

The effect of Trk_prim_vtx on the correlation function

Trk_prim_vtx = 1



Trk_prim_vtx = 0



For Reconstructed correlations:
Only tracks with a match to a true primary are retained

Huge difference in correlation strengths. So, both track types should be retained.

Reconstructed Track Selection

Jaap's cut list
(used for the preliminary results)

- **ZTT tracks**
- **Remove Sinistra candidate**
- **0.1 < pT < 5.0 GeV/c**
- **-1.5 < eta < 2.0**
- **MVD hits > 0**
- **Trk_prim_vtx = 1**
  - **dca_xy < 0.5 cm**

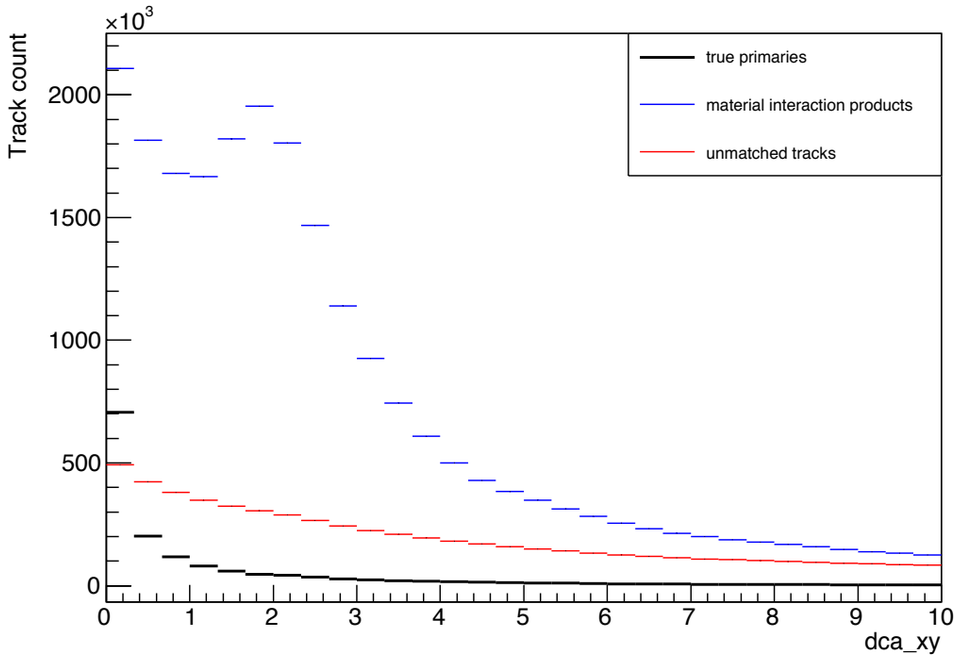
Proposed new cut list

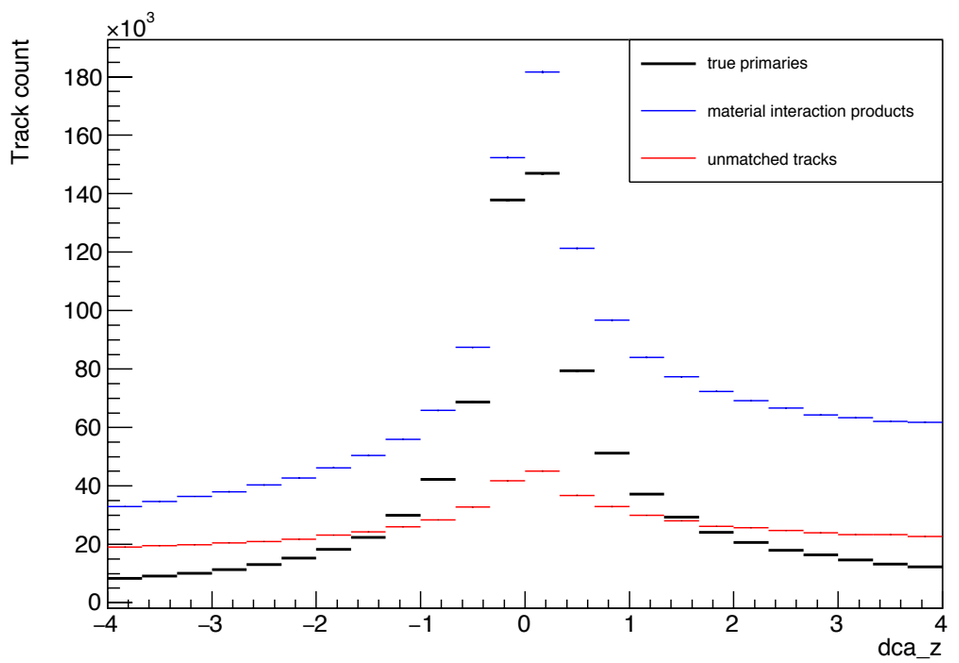
- **ZTT tracks**
- **Remove Sinistra candidate**
- **0.1 < pT < 5.0 GeV/c**
- **-1.5 < eta < 2.0**
- **MVD hits > 0**
- **Trk_prim_vtx = 1**
  - **dca_xy < 1.0 cm**
  - **dca_z < 1.0 cm**
- **Trk_prim_vtx = 0**
  - **dca_xy < 2.0 cm**
  - **dca_z < 4.0 cm**

DCA distributions for 3 track categories

Nch < 5

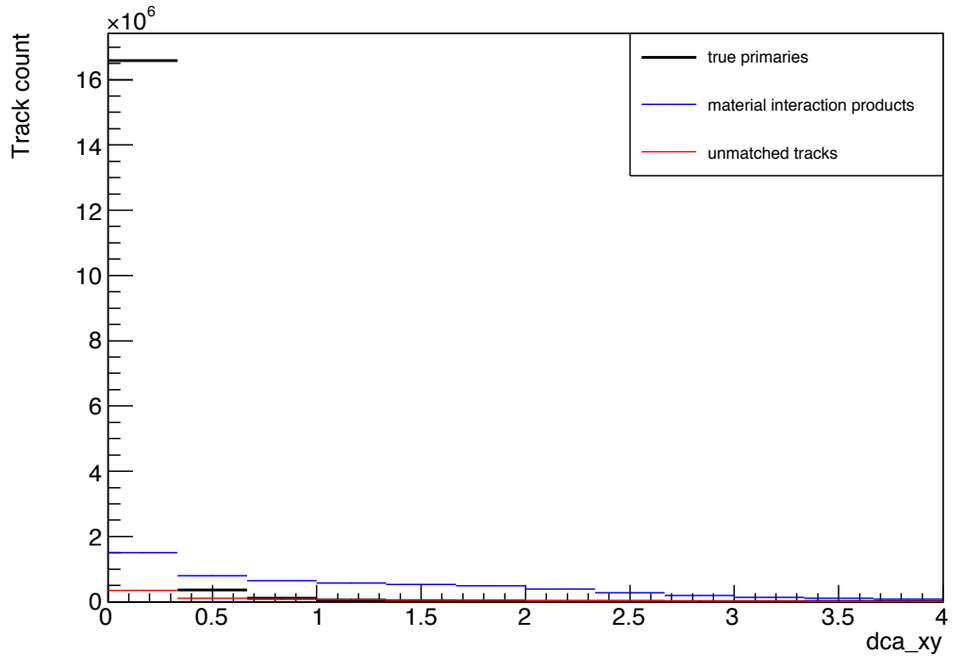
Trk_prim_vtx = 0

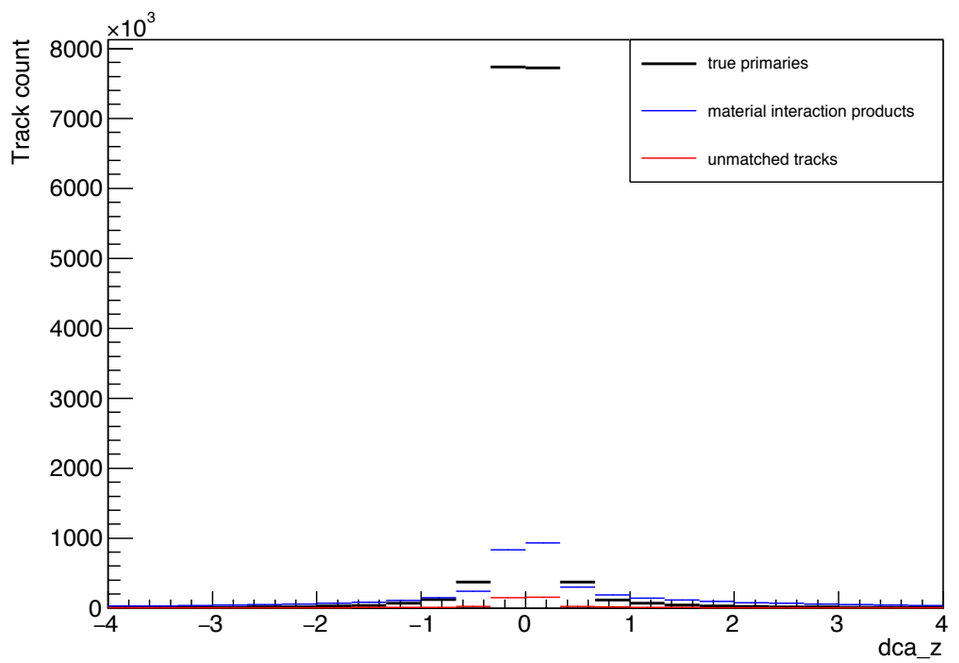




True primary tracks: 1.5M,
Material Interaction tracks: 24.5M
Unmatched tracks: 8.2M

Trk_prim_vtx = 1





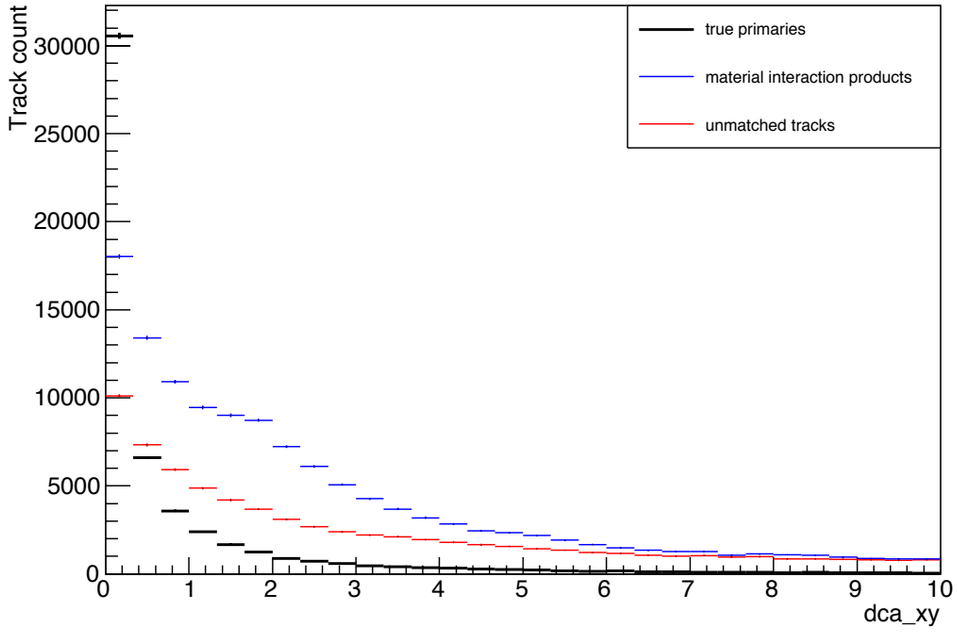
True primary tracks: 17.2M,
Material Interaction tracks: 5.9M
Unmatched tracks: 0.8M

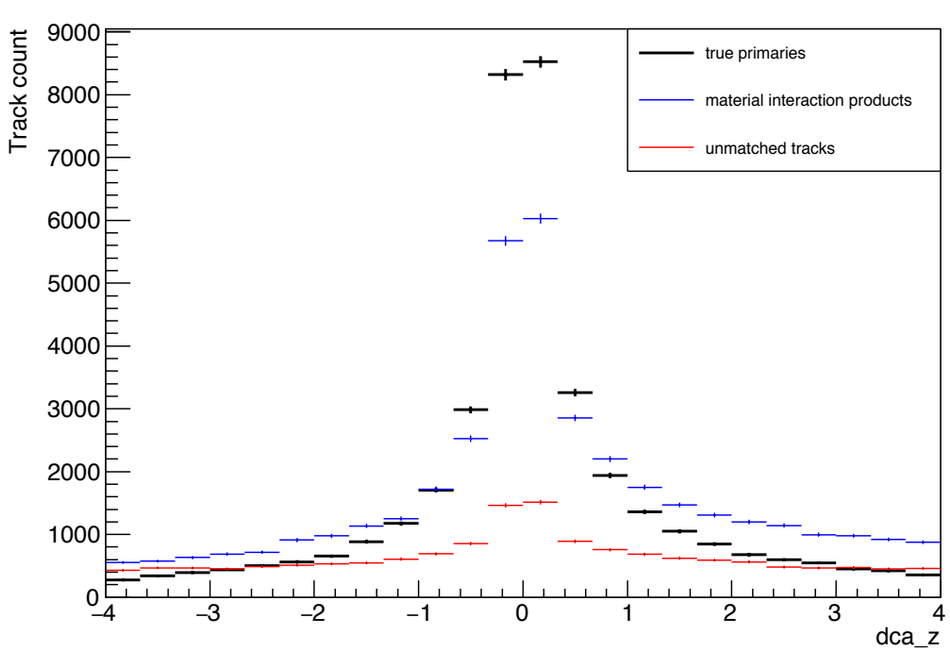
DCA distributions for 3 track categories

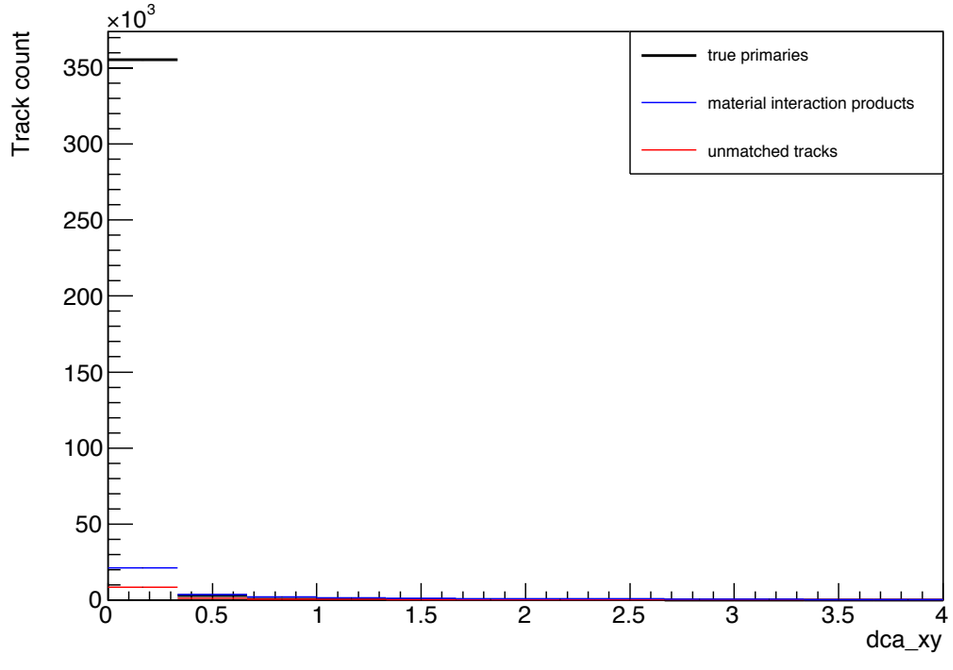
Trk_prim_vtx = 0

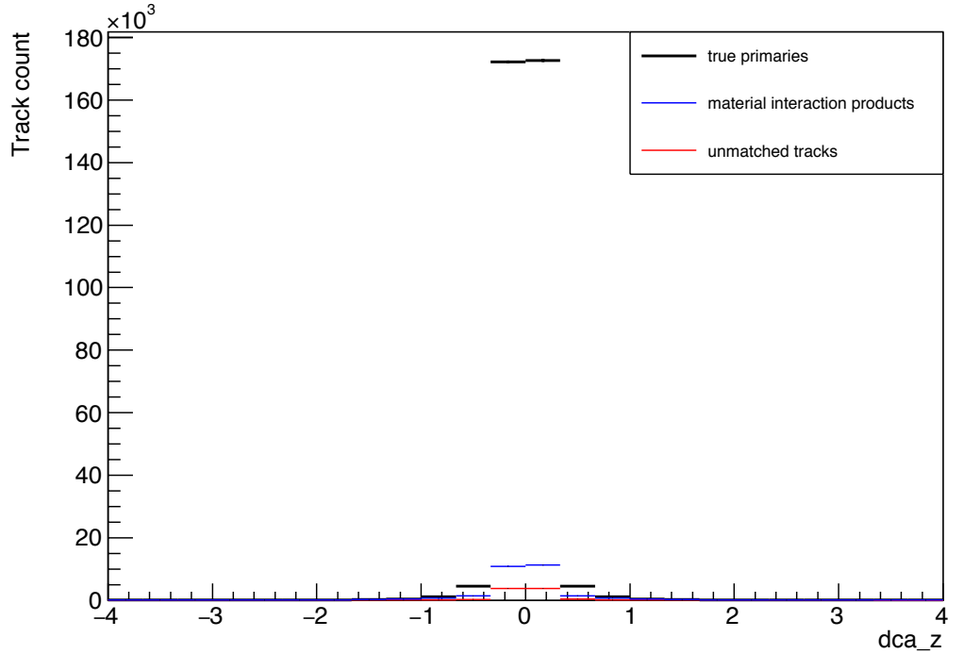
Nch > 20

Trk_prim_vtx = 1







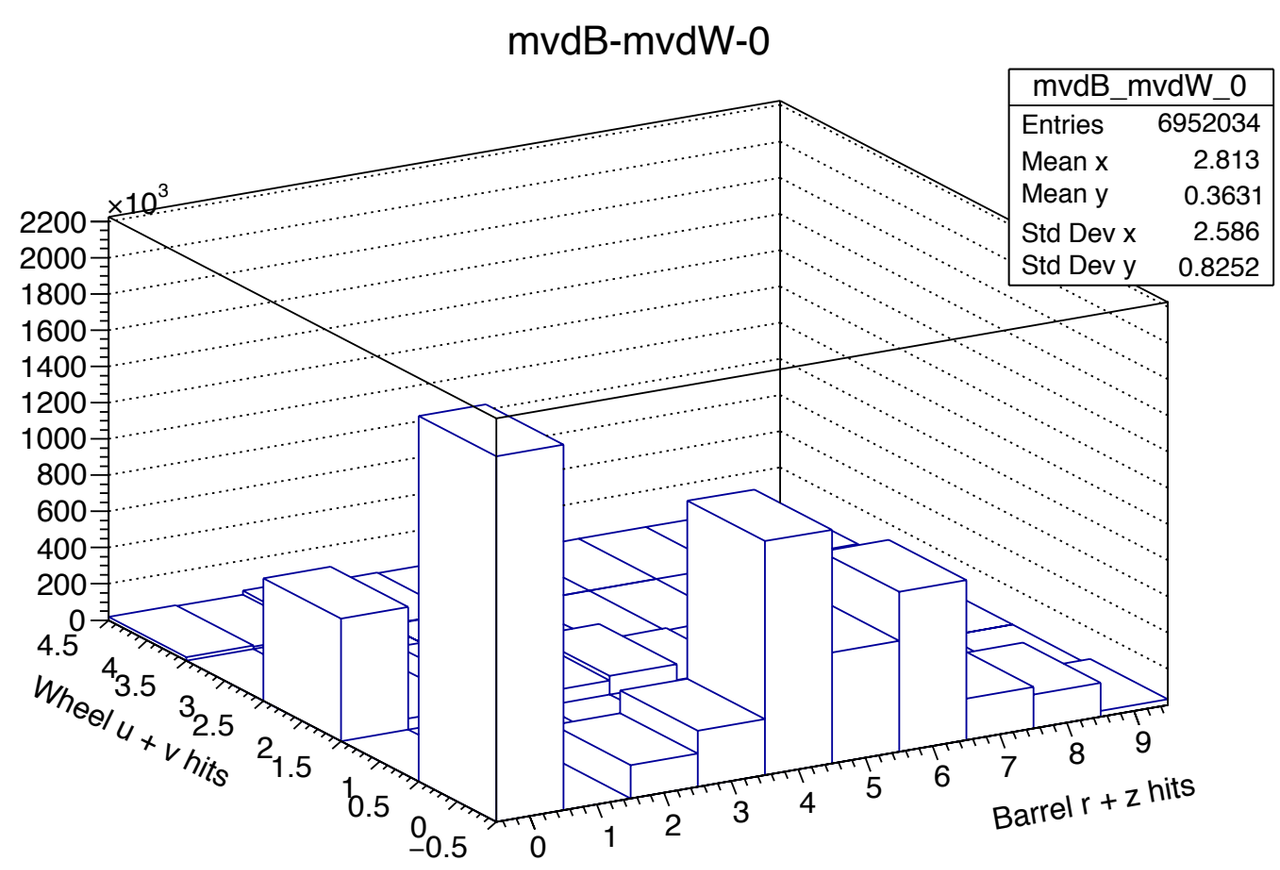


True primary tracks: 0.05M,
Material Interaction tracks: 0.14M
Unmatched tracks: 0.1M

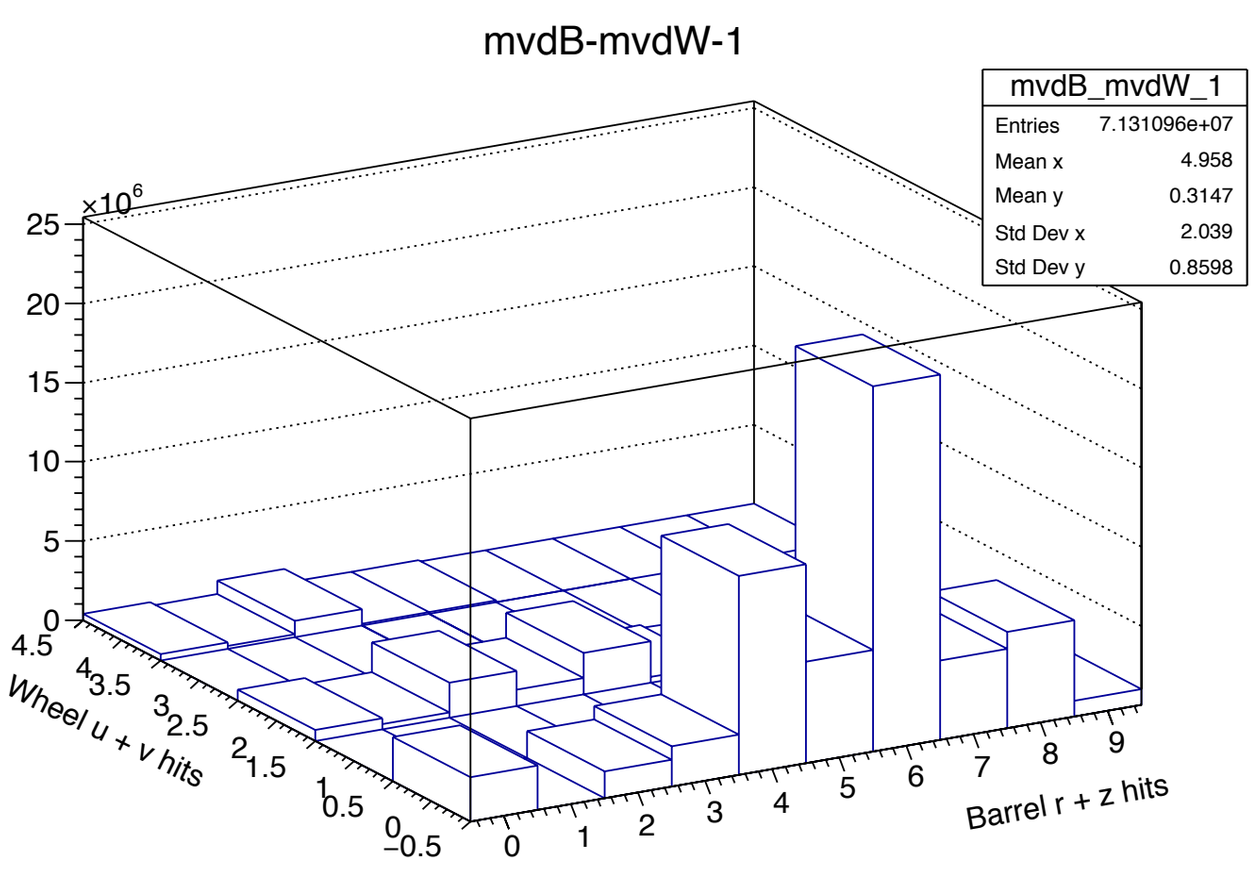
True primary tracks: 0.36M,
Material Interaction tracks: 0.03M
Unmatched tracks: 0.01M

MVD hit distribution for true primaries

Trk_prim_vtx = 0



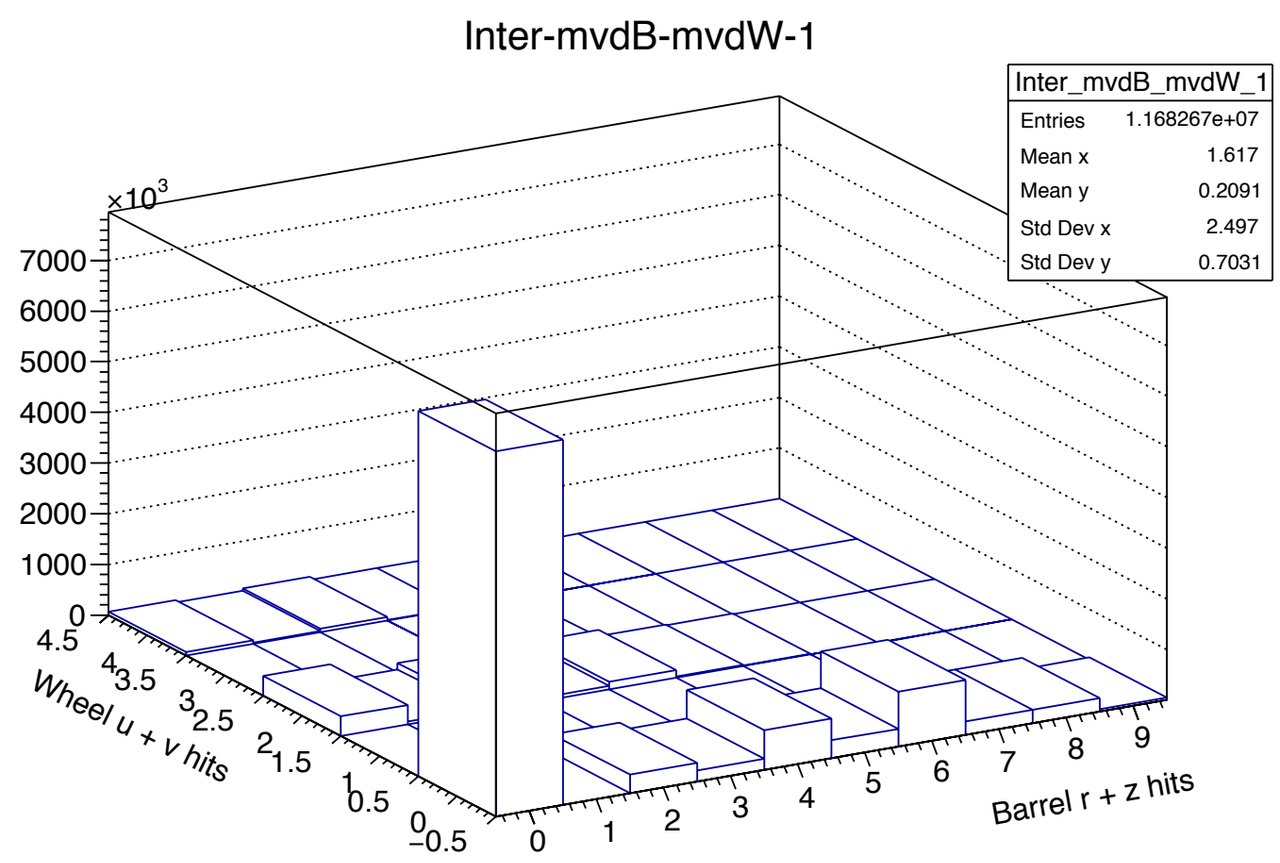
Trk_prim_vtx = 1



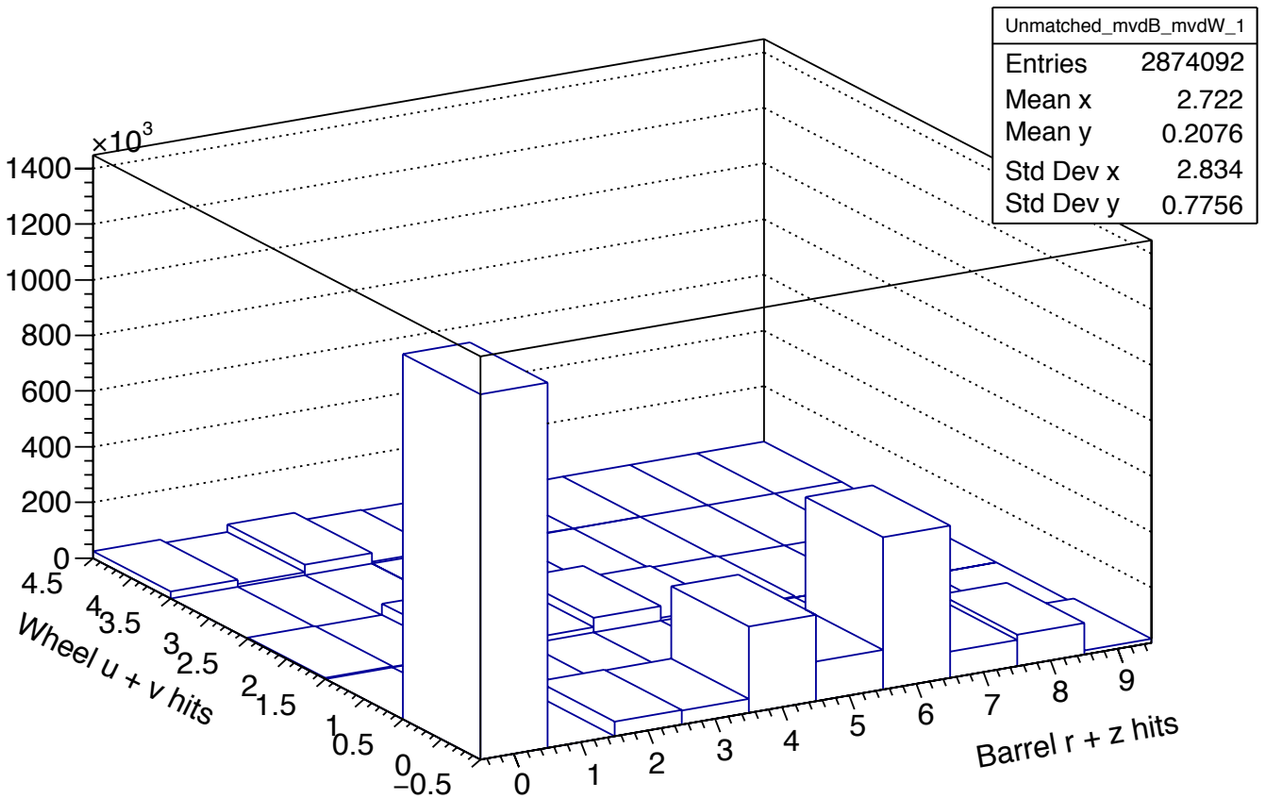
Most true primaries have an MVD hit point.

MVD hit distribution for interaction products and unmatched tracks

Material interaction products



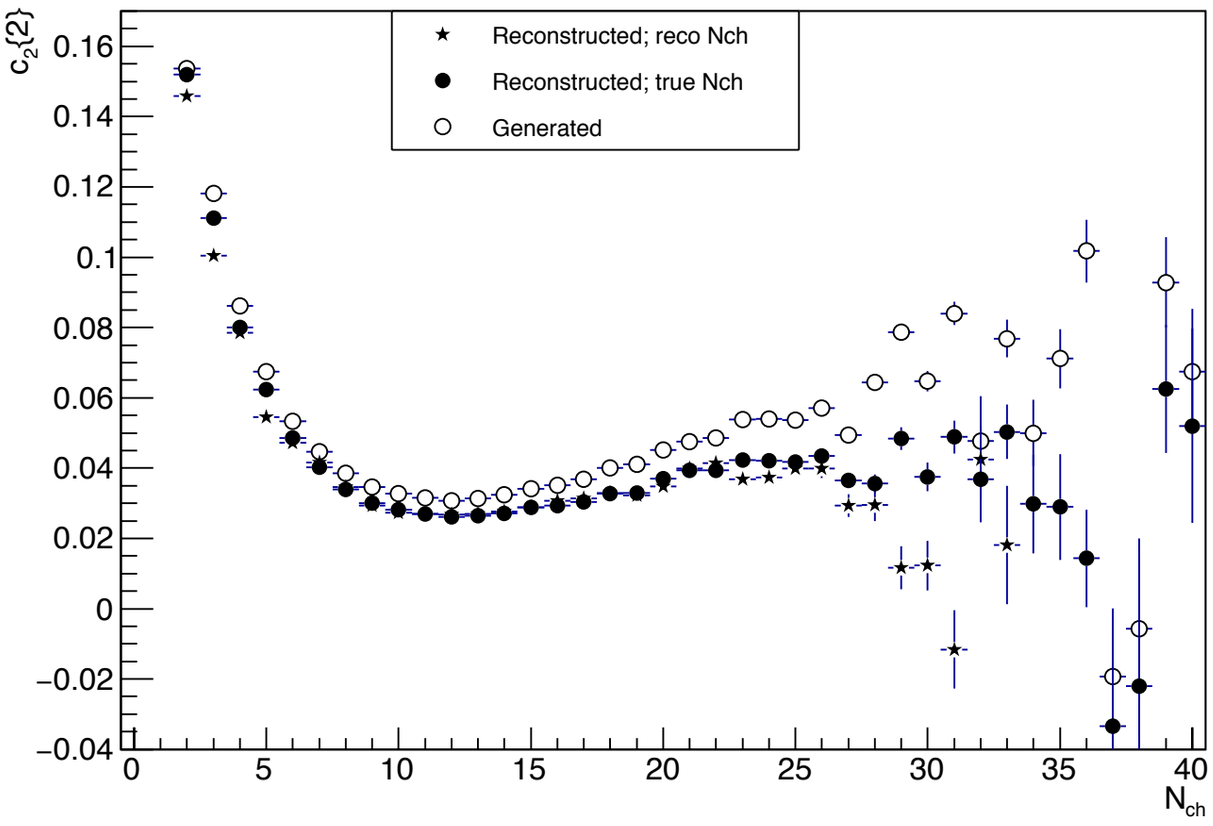
Unmatched tracks



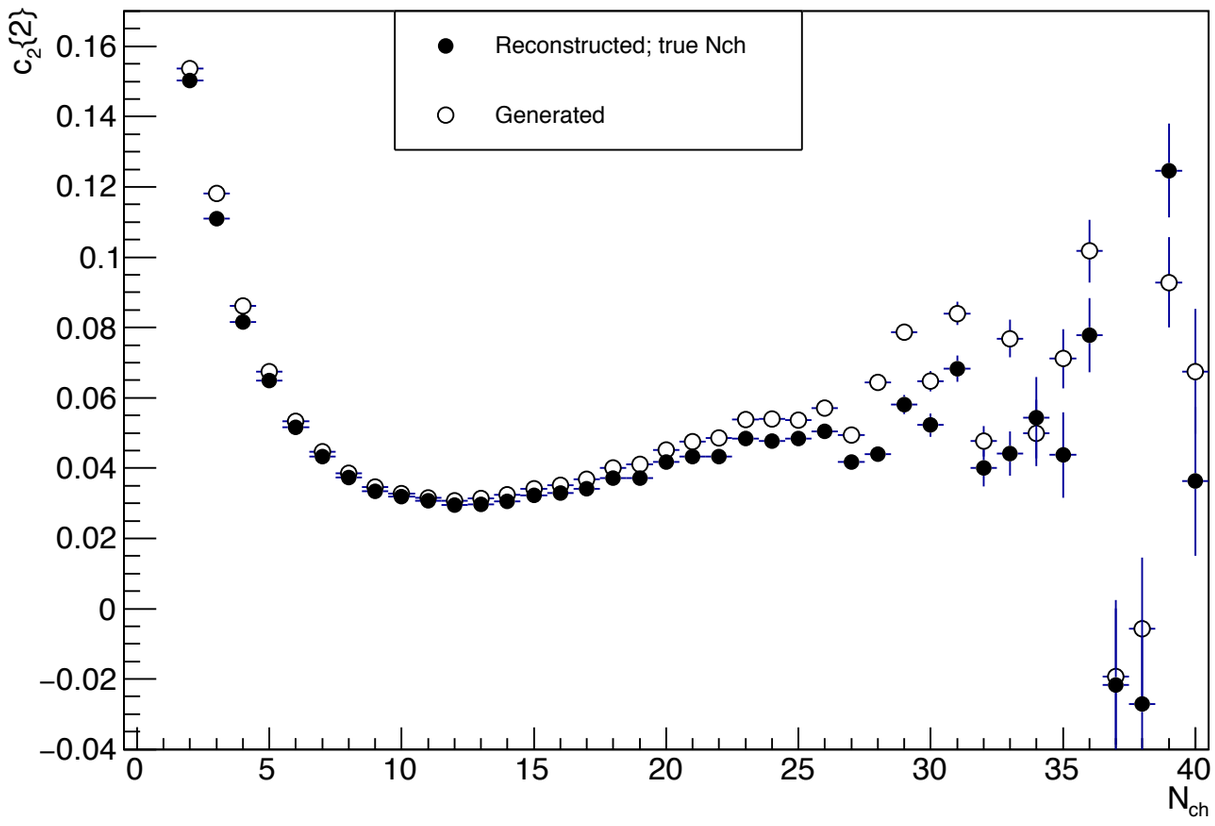
Most unwanted tracks do <u>not</u> have an MVD hit point.
These distributions are for Trk_prim_vtx=1 but similar for the other case.

MC closure before and after

Old track selection criteria



New track selection criteria



The discrepancy is smaller now.

Other effects likely contribute to remaining discrepancy:

- **MVD (in backup)**
- **phi reconstruction smearing (in backup)**
- **contamination from fakes and material interaction products.**

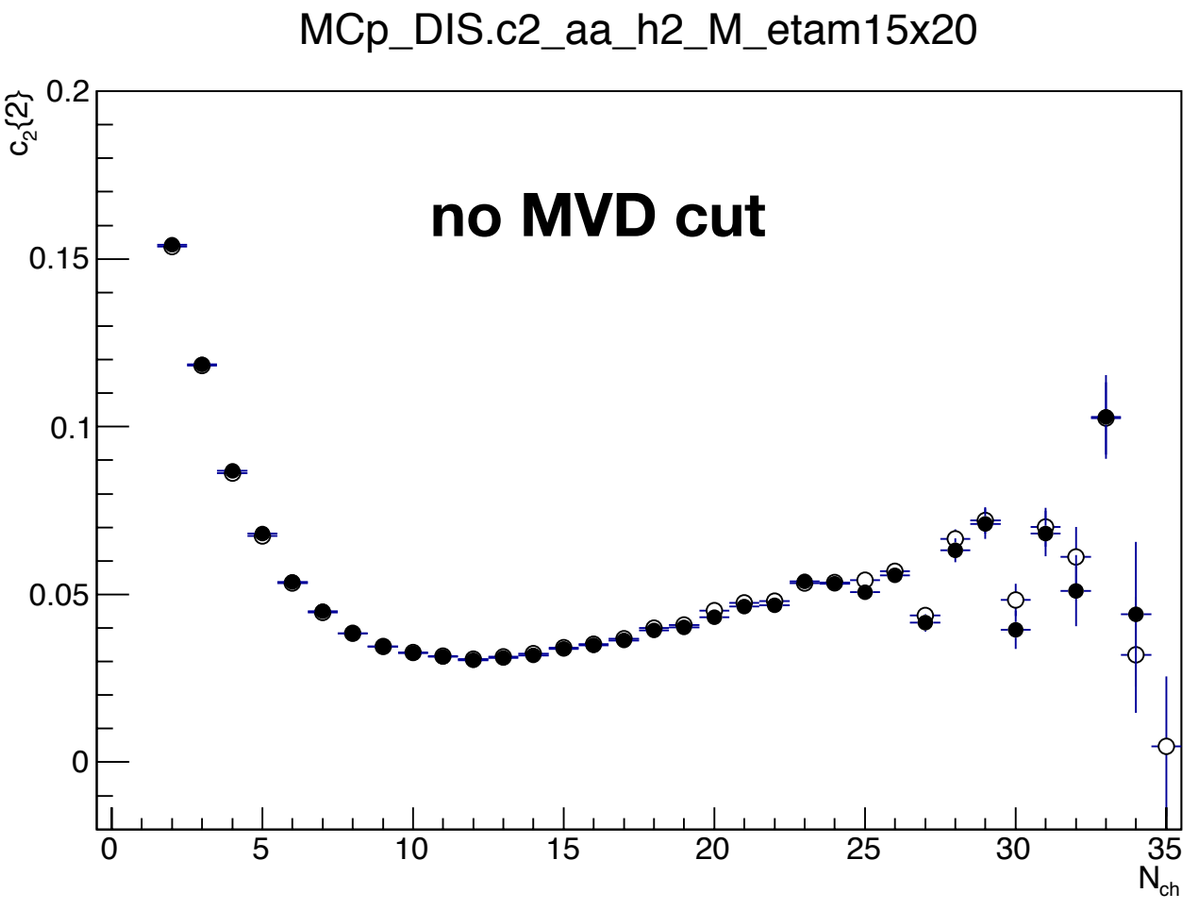
Next Steps

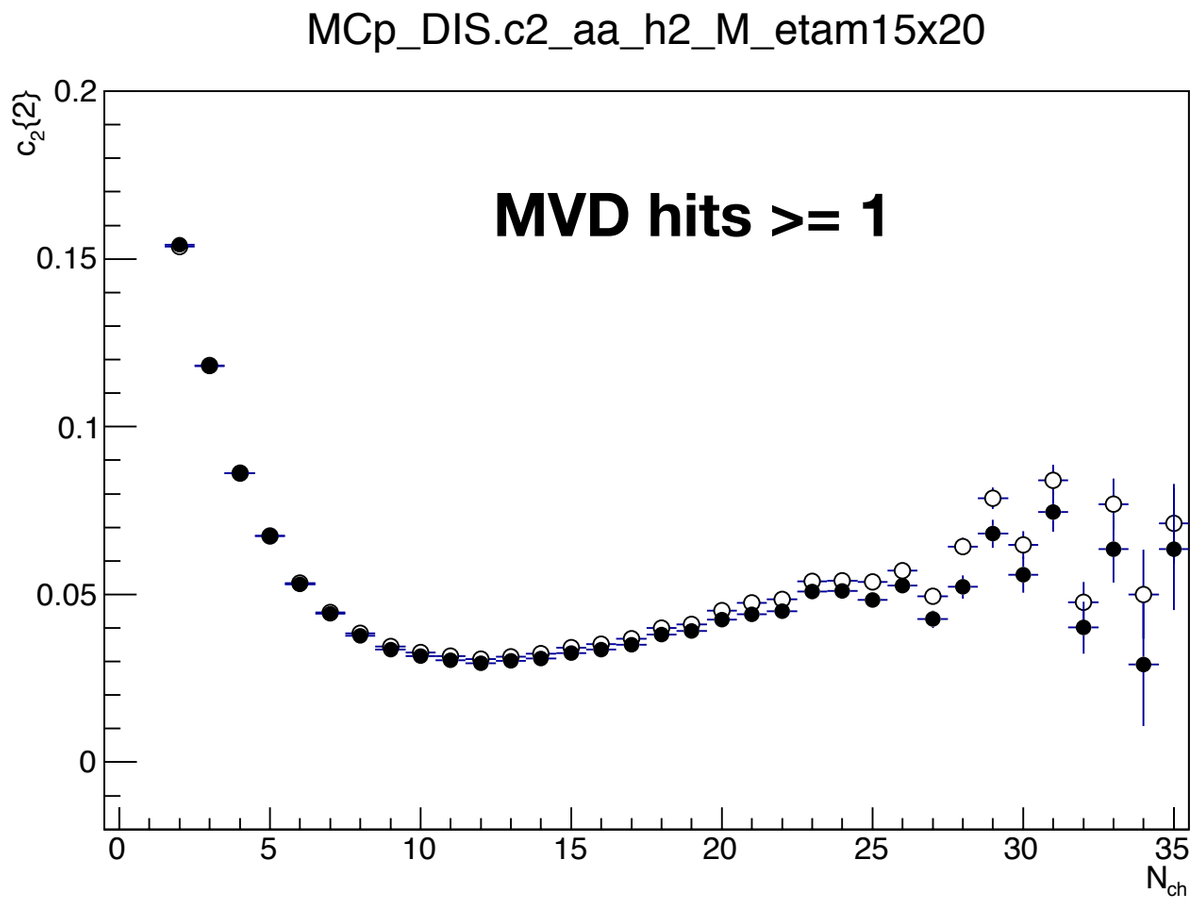
We plan to have the following done by March:

- **Revisit Nch estimation using efficiency corrections.**
- **Re-evaluate final correlations and systematics from all periods (2003 - 2007).**

Backup

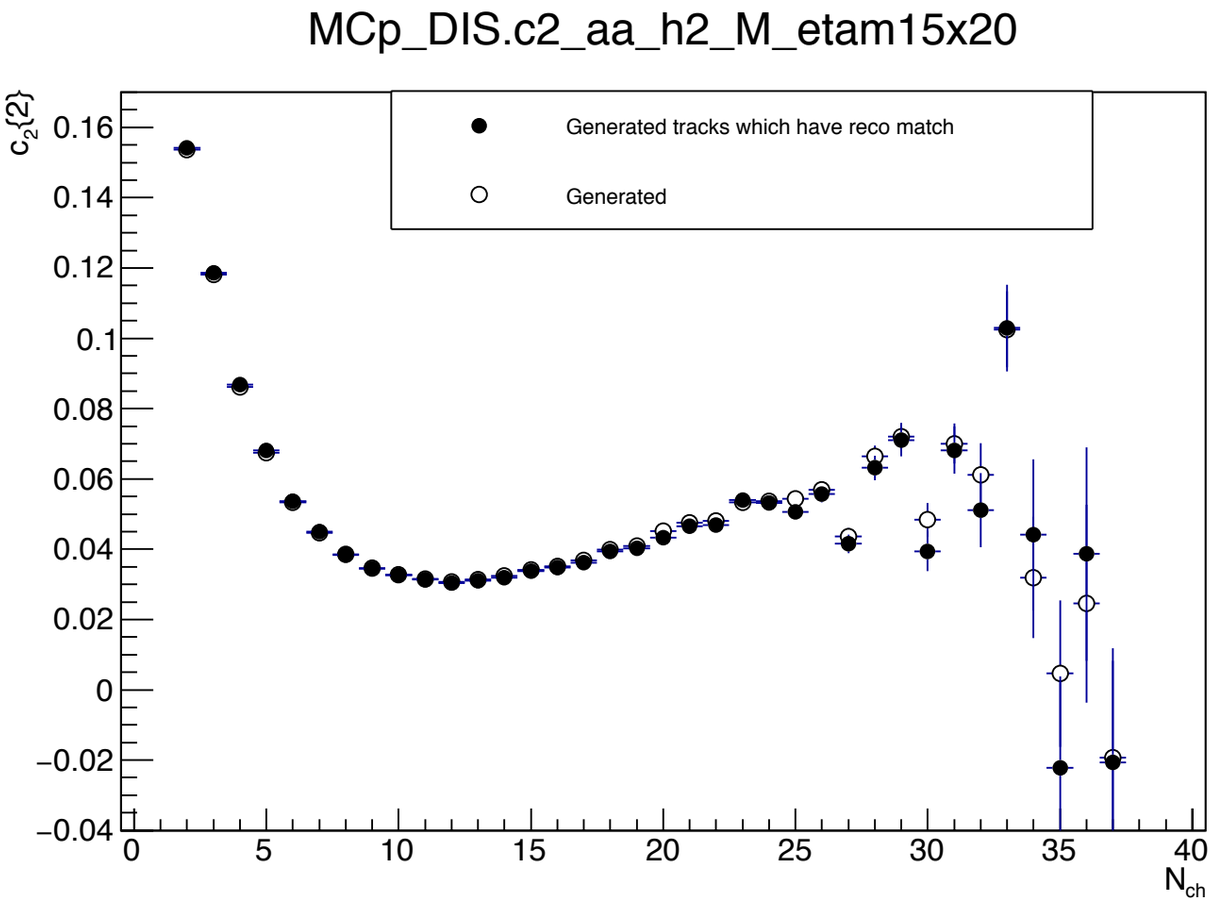
Effect of MVD constraint





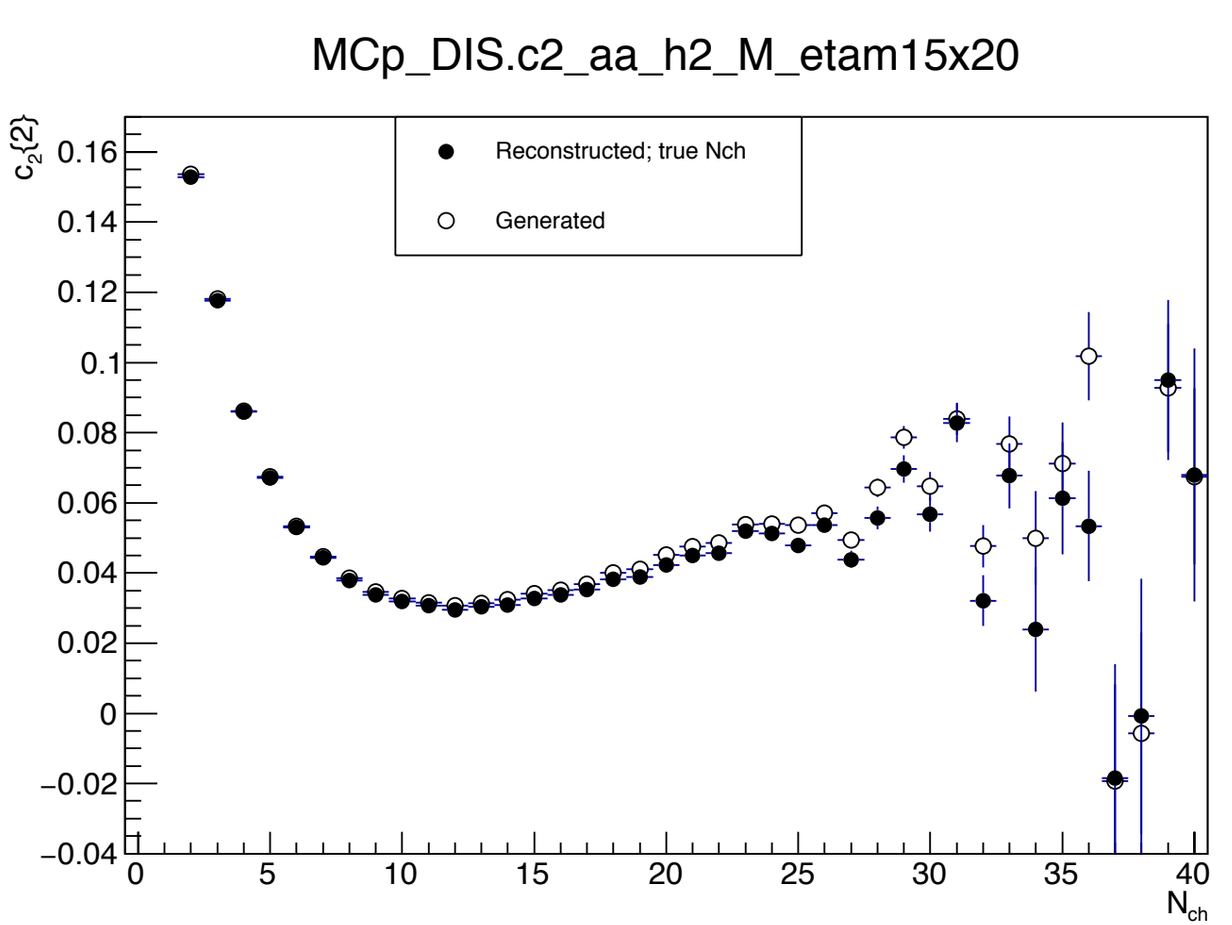
Effect of phi reconstruction smearing

Generator Phi



- **Reconstructed track set basically equal to the entire ZTT track subset.**
- **We look for matched tracks which are then associated with a true MC primary.**

Reconstructed Phi



- **Reconstructed phi used.**
- **Small effect.**

MC Isthep number

The isthep number gives information about the MC generated particle.
http://adamo.web.cern.ch/Adamo/zeusddl/FMCZEvt.html

We define 3 track groups:

True primaries	**Material interaction products**	**Unmatched tracks**
cτ > 1 cm	**UBUF(1) < 0**	**fakes, …**

Fmck_isthep = Tn_isthep*10000 + Generator_isthep
Tn_isthep = UBUF(2)*1000 + (UBUF(1) + 500)

Generator_isthep is basically 1 or 0 in ZEUS data.
It is 1 for final-state particles produced by the generator.

UBUF(2) contains information on the demise of the particle,
i.e. It decayed, it scattered hadronically, …

UBUF(1) corresponds to the parent MC track index.
If it is negative, it means the particle is an interaction or shower product.

Definition of primary particles in this analysis

ALICE definition

A primary particle is a particle with a mean proper lifetime τ larger than 1 cm/c, which is either

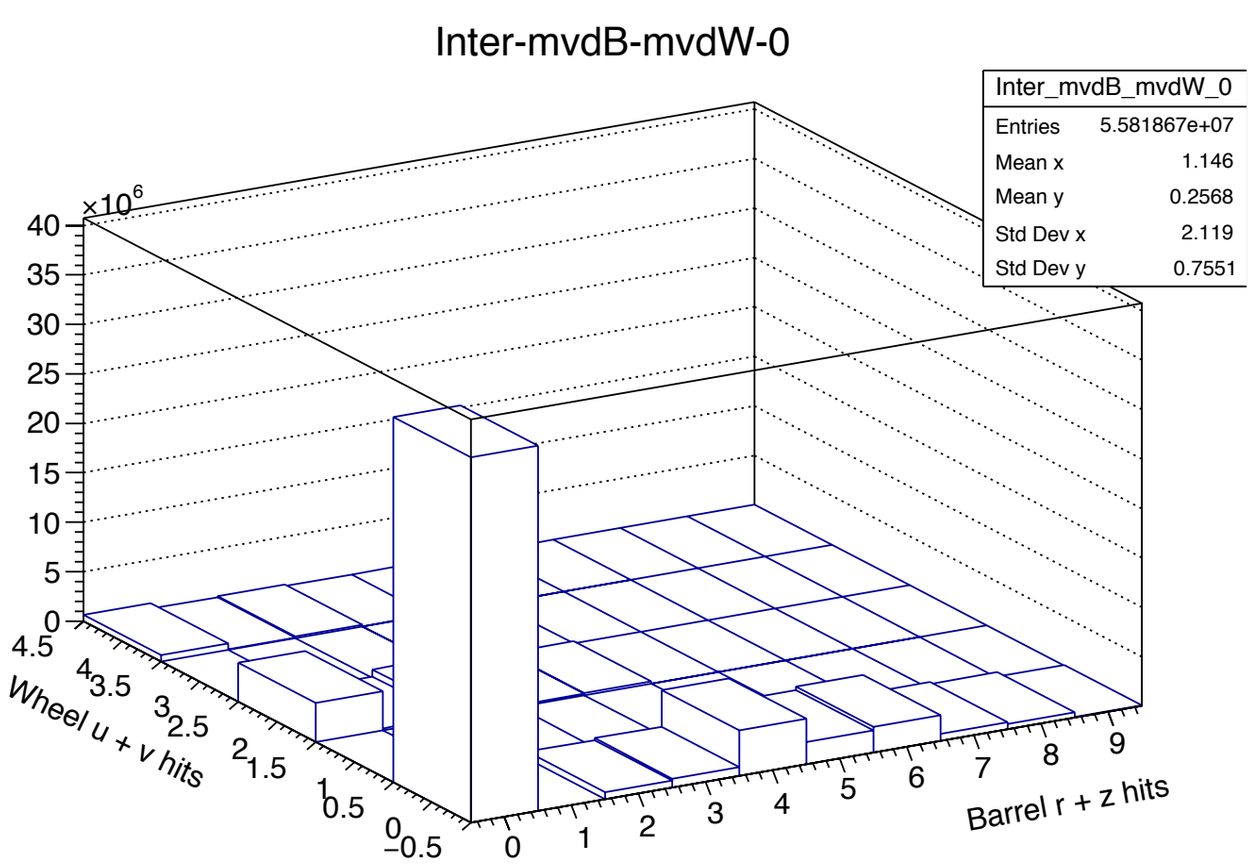
a) produced directly in the interaction, or

b) from decays of particles with τ smaller than 1 cm/c, restricted to the decay chains leading to the interaction.

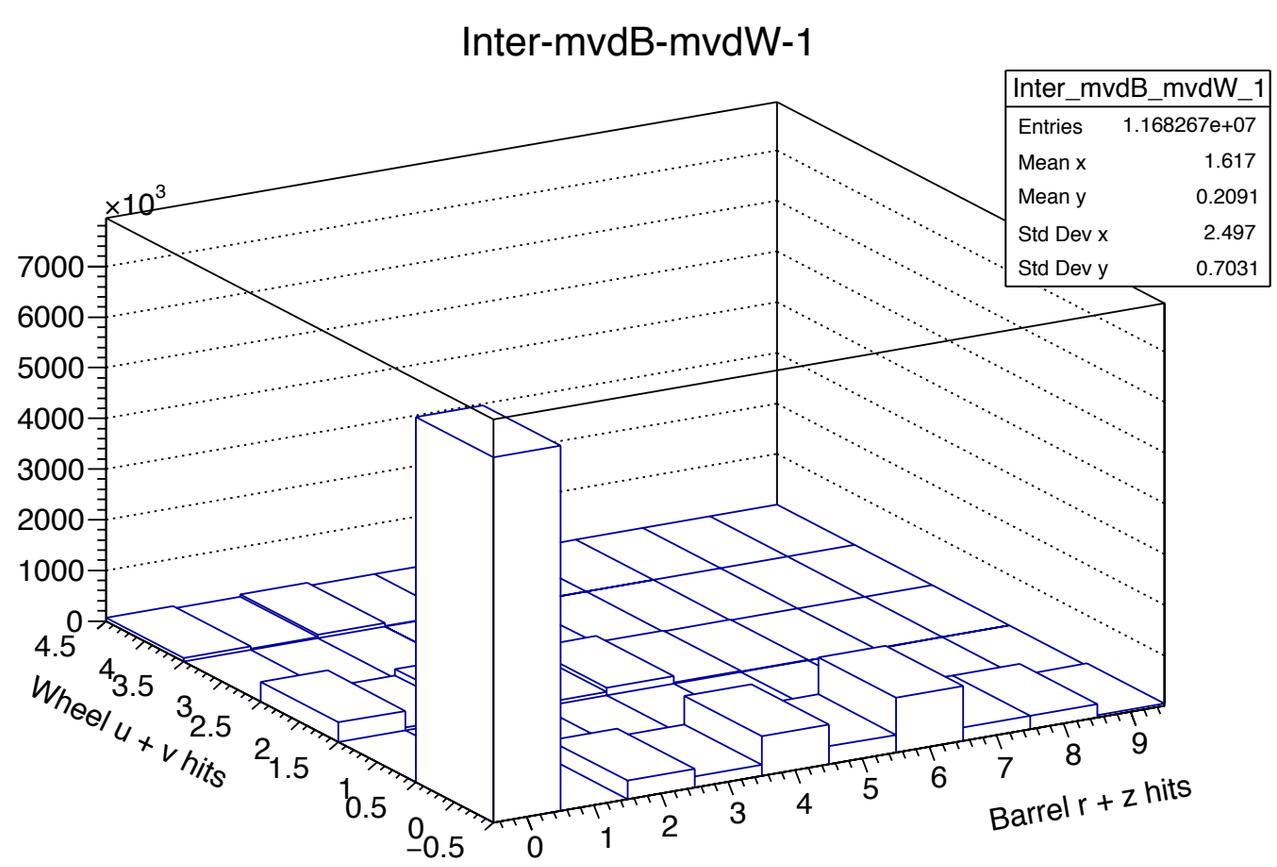
Specie	Width Γ (GeV)	Mean proper lifetime τ (ps)	(cm/c)
p^+	0	∞	∞
γ	0	∞	∞
K^0	0	∞	∞
e^-	0	∞	∞
n	7.478×10^{-28}	$8.861 \times 10^{+14}$	$2.656 \times 10^{+13}$
μ^-	2.996×10^{-19}	$2.212 \times 10^{+06}$	$6.63 \times 10^{+04}$
K_L^0	1.287×10^{-17}	$5.148 \times 10^{+04}$	1543
π^+	2.528×10^{-17}	$2.621 \times 10^{+04}$	785.7
K^+	5.317×10^{-17}	$1.246 \times 10^{+04}$	373.6
Ξ^0	2.27×10^{-15}	291.9	8.751
Λ	2.501×10^{-15}	264.9	7.943
Ξ^-	4.02×10^{-15}	164.8	4.941
Σ^-	4.45×10^{-15}	148.9	4.464
K_S^0	7.351×10^{-15}	90.14	2.702
Ω^-	8.071×10^{-15}	82.1	2.461
Σ^+	8.209×10^{-15}	80.72	2.42

MVD for material interaction products

Trk_prim_vtx = 0

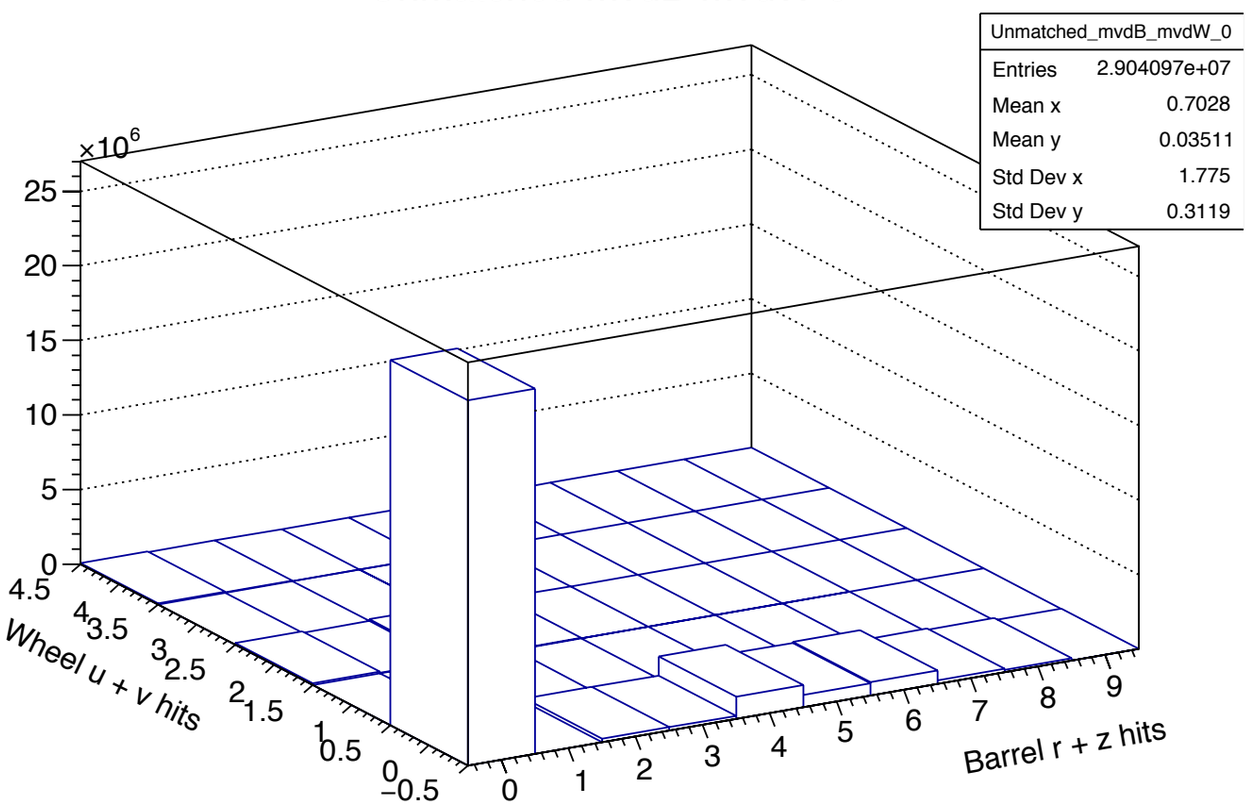


Trk_prim_vtx = 1

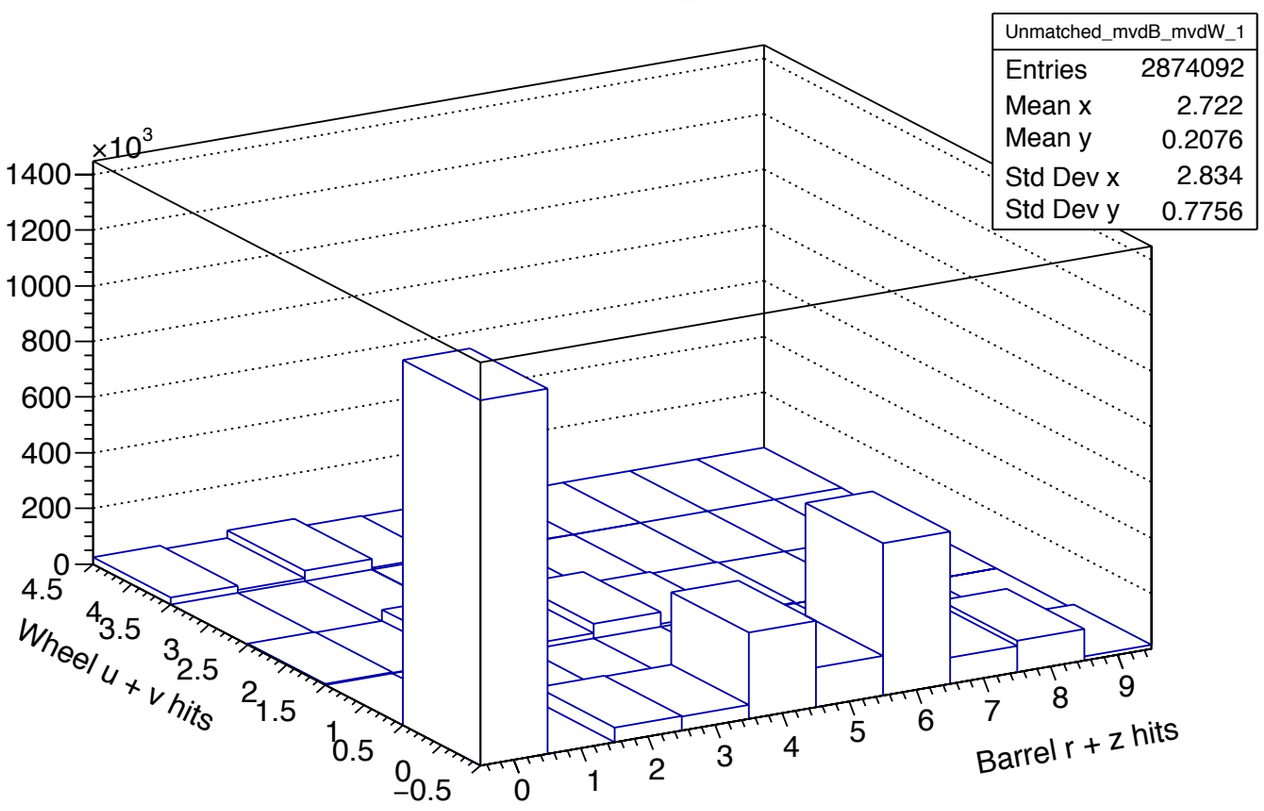


MVD for unmatched tracks

Trk_prim_vtx = 0

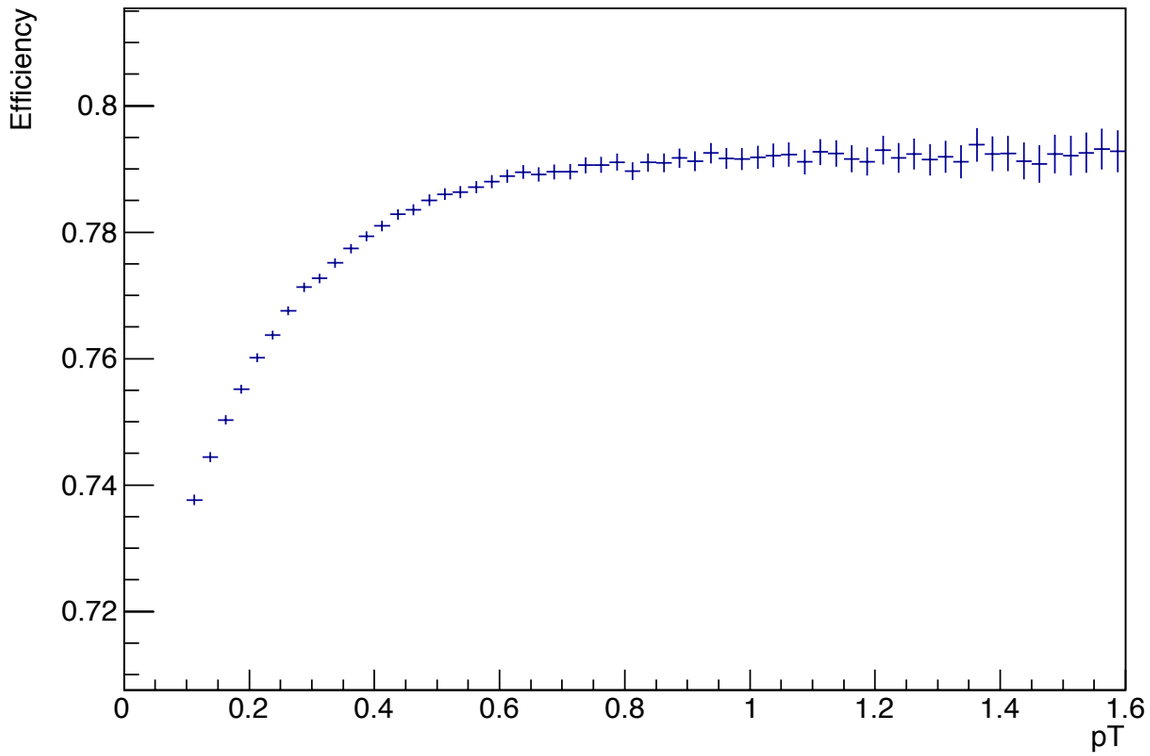


Trk_prim_vtx = 1

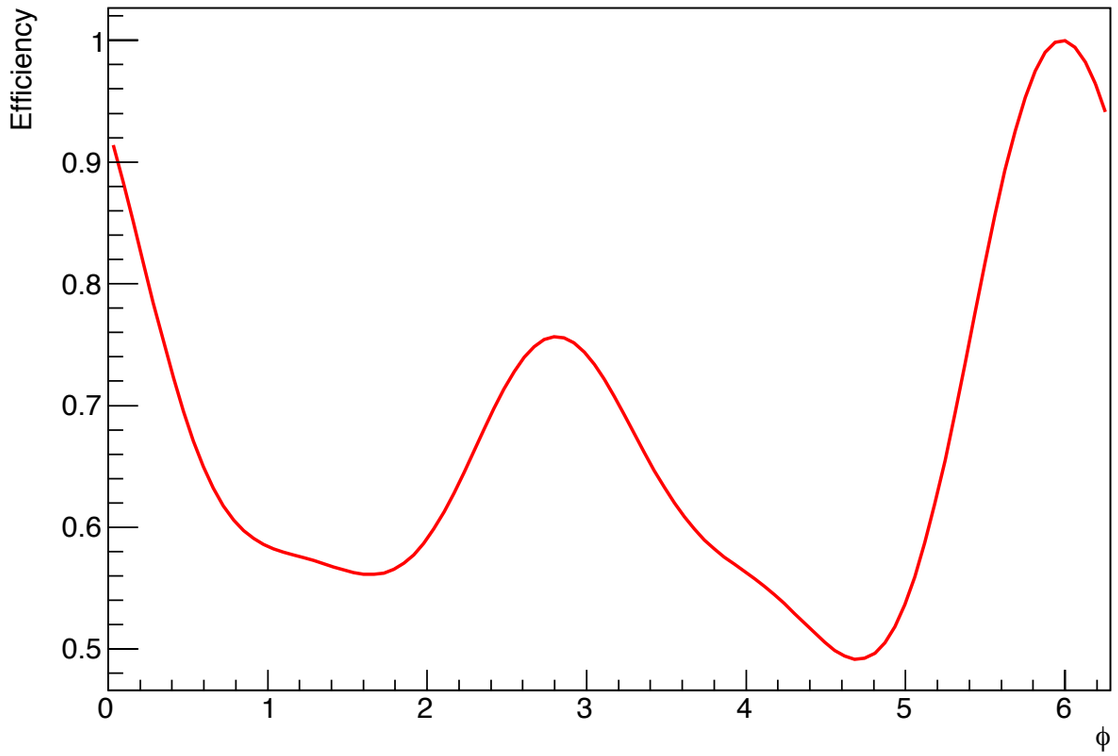


Pt & Phi efficiency correction test

Artificially generated pt efficiency



Artificially generated Phi efficiency



- **The product of these efficiency curves are applied to the generator list of tracks.**
- **Random MC sampling is used to simulate detector inefficiencies.**

Pt & Phi efficiency correction test