

HLT performance using embedded muons

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Motivation

- HLT algorithm is not as selective as desired in Run14. But it is critically needed for Run16.
- Use the embedding data
 - Find out the problem of the current algorithm
 - Evaluate HLT efficiency in tracking and in selecting J/psi events

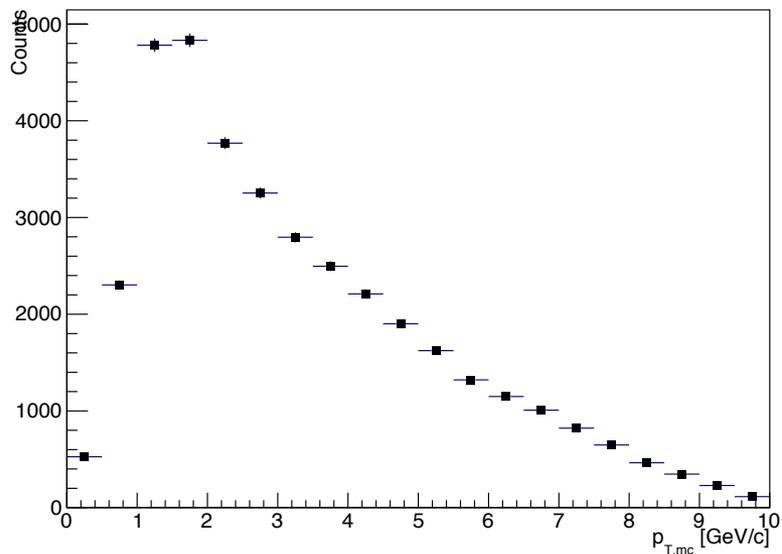
Analysis setup

- Embedding data: embed $J/\psi \rightarrow \mu^+\mu^-$ into Run14 AuAu 200 GeV data.
 - All the J/ψ 's are embedded at the default primary vertex.
 - Flat in p_T , eta, phi
- Select the events in which at least one embedded J/ψ is reconstructed offline both in TPC and MTD.
- Import all the TPC hits (real data + MC) into HLT for tracking
- All MTD hits (real data + MC) are migrated to HLT directly
- Match reconstructed tracks to MTD hits using the matching algorithm implemented in HLT

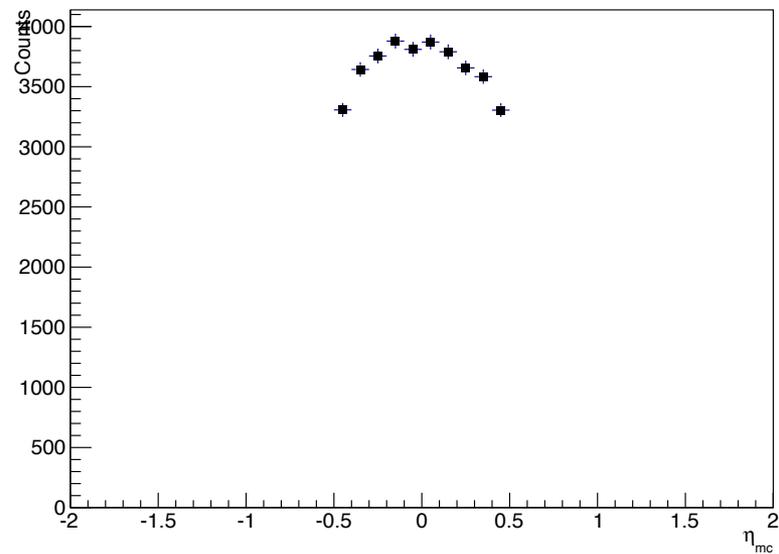
Input MC muon tracks

- $|\eta| < 0.5$
- $n\text{Hits} > 10$

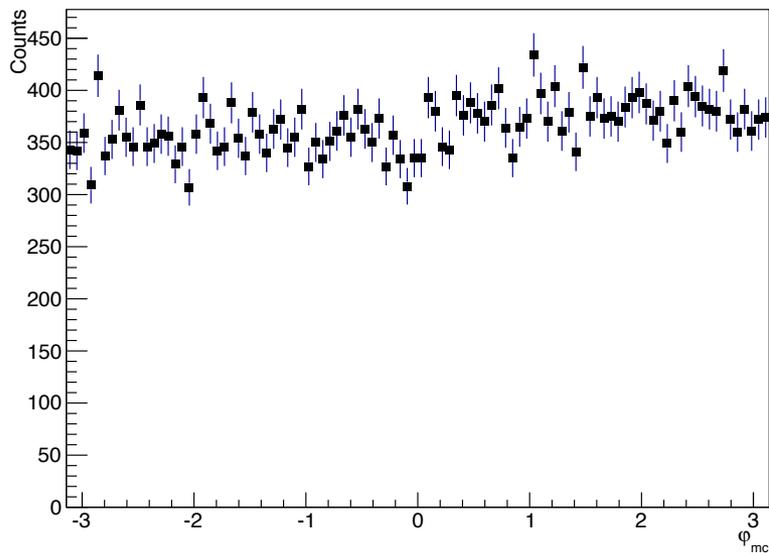
p_T distribution of MC muons



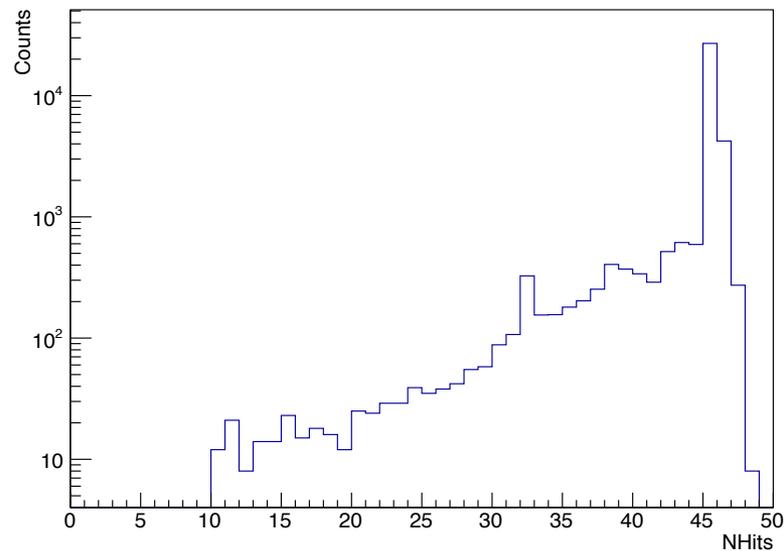
η distribution of MC muons



ϕ distribution of MC muons



Distribution of # of TPC hits for MC muons



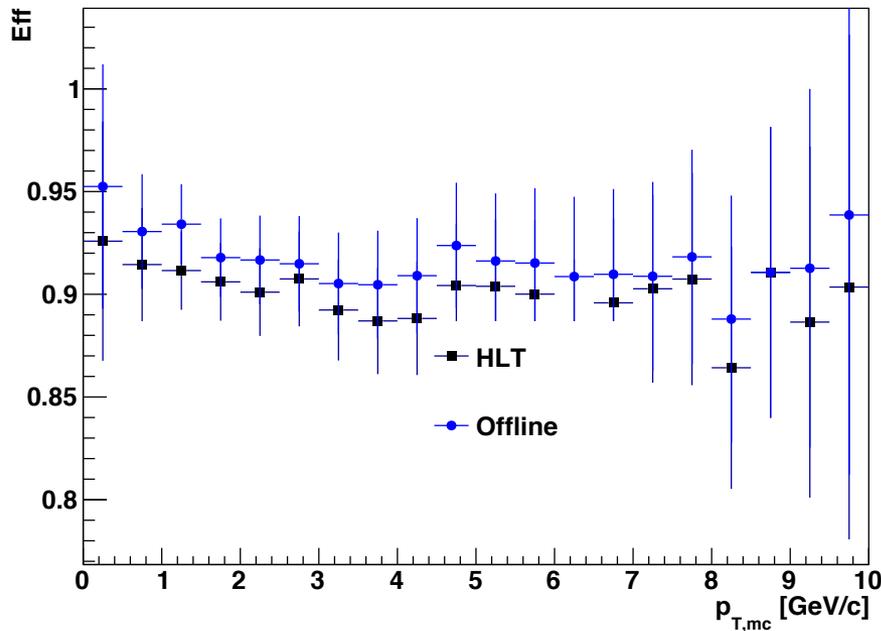
Track match: reconstruction vs MC

- A HLT track is matched to a MC track if they have at least 10 common hits
 - When multiple HLT tracks are matched to the same MC track, the one with the most TPC hits is selected.
- The same criteria is used to match tracks reconstructed offline with MC tracks.
- A HLT track is matched an offline track if they are matched to the same MC track

Compare tracking performance

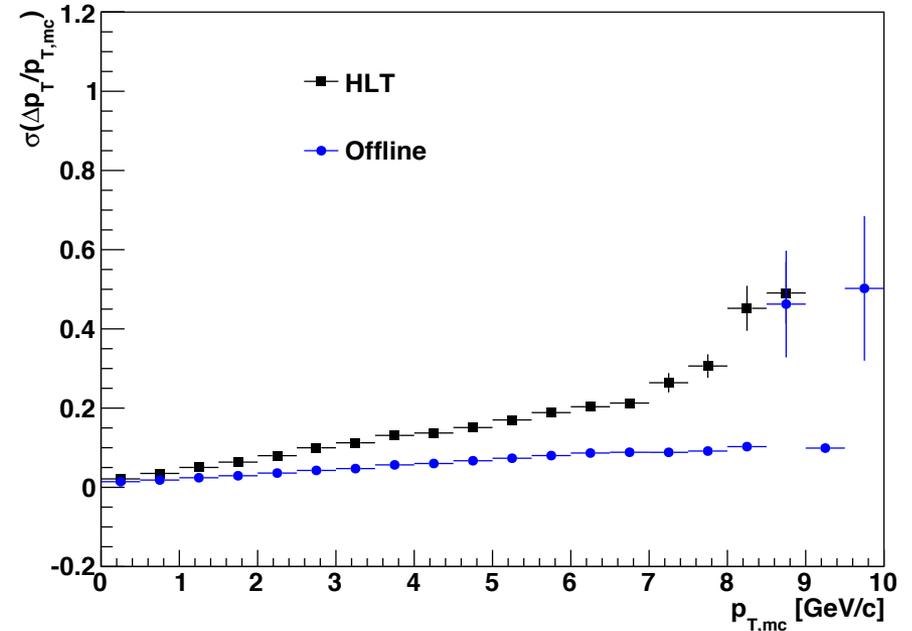
Tracking efficiency

Efficiency of reconstructing MC muons vs p_T



Track momentum resolution

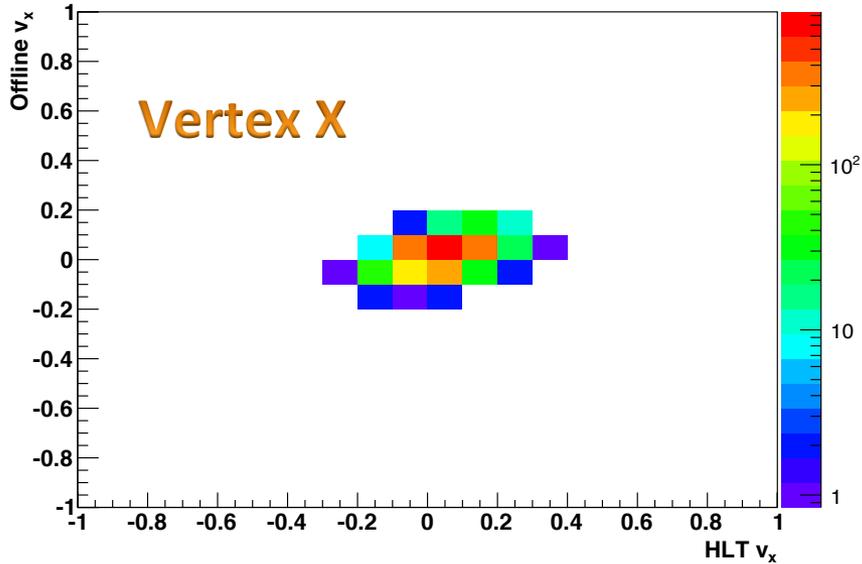
p_T resolution of reconstructed MC muons vs p_T



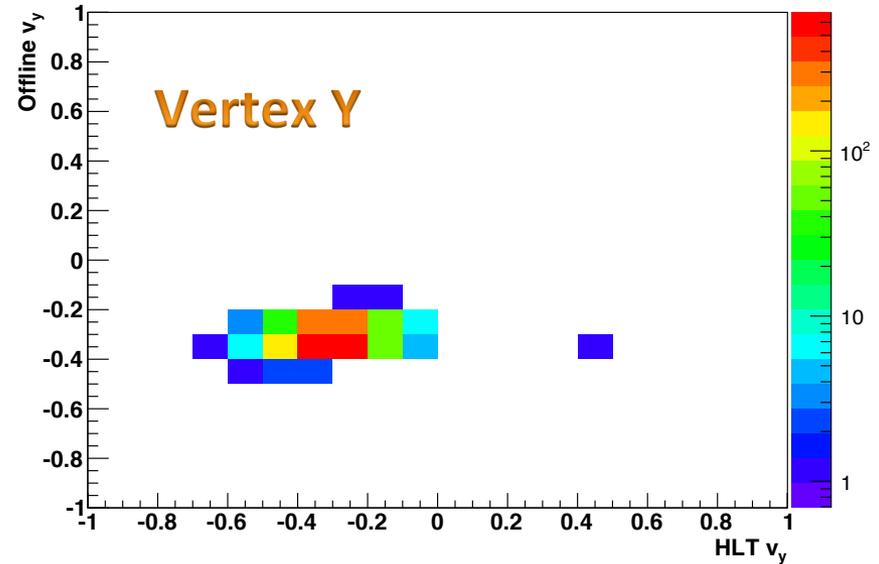
- Slightly higher efficiency and better resolution for offline
- *The actual value of tracking efficiency is biased due to the selection of embedded events used in the study.*

Vertex matching

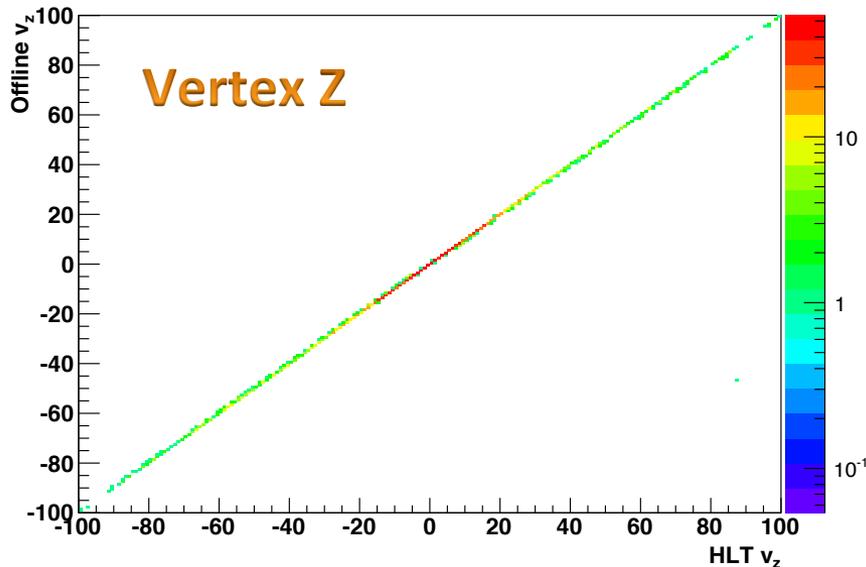
Correspondance of reconstructed vertex x



Correspondance of reconstructed vertex y



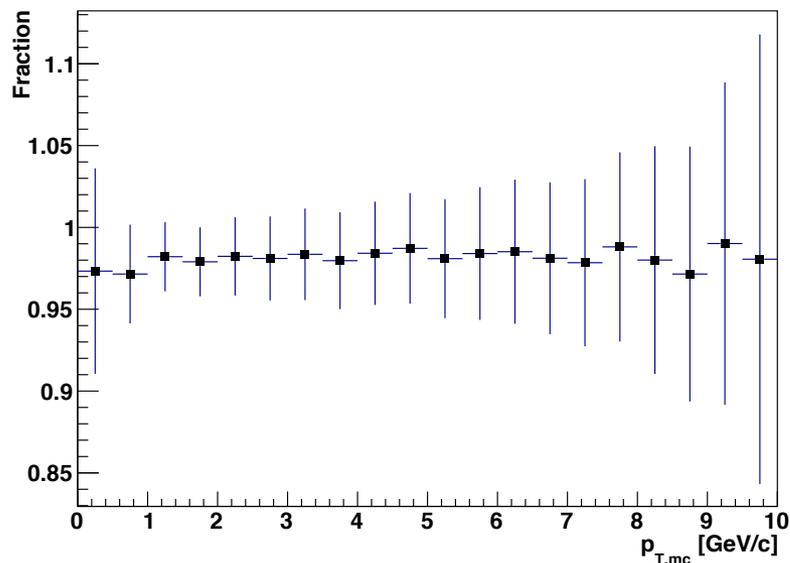
Correspondance of reconstructed vertex z



- Good correspondence between offline and HLT in terms of vertex reconstruction

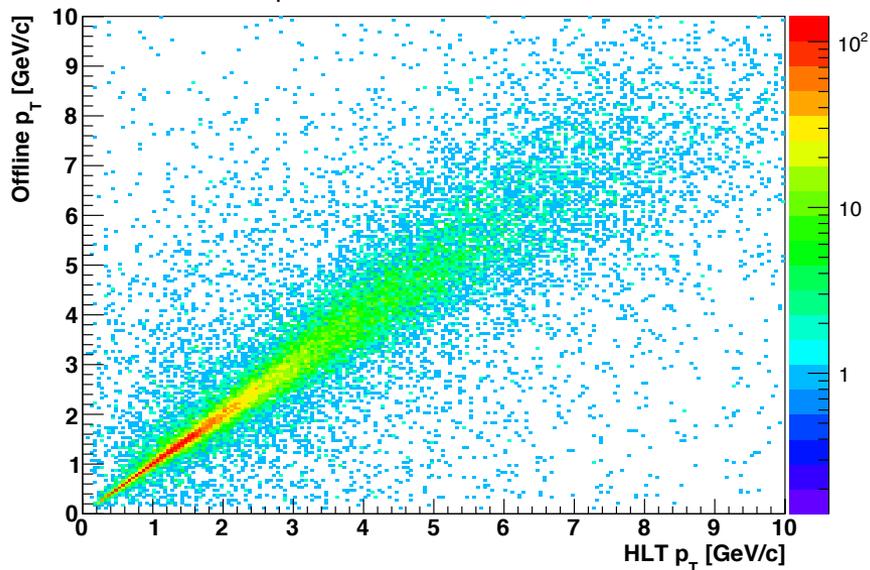
HLT matches to offline

Fraction of HLT tracks matched with offline for MC muons

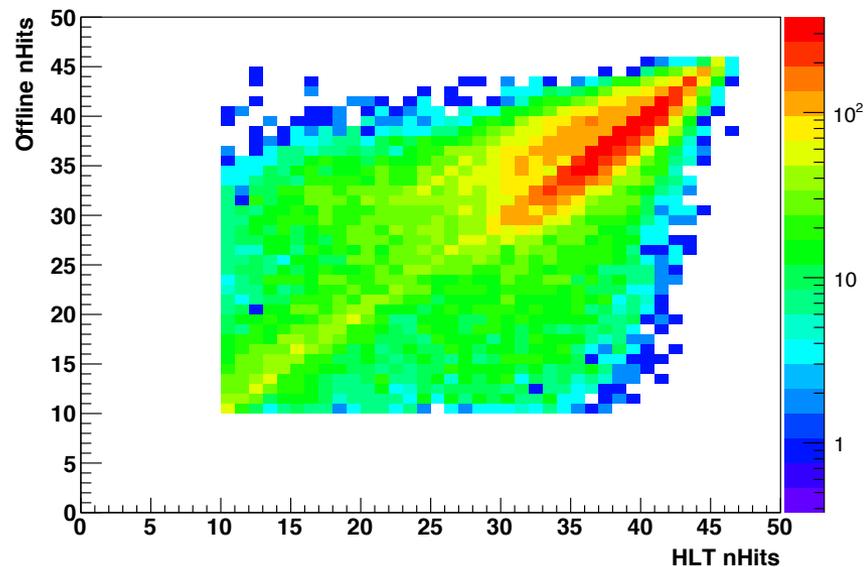


- ~98% of the HLT tracks that are matched MC tracks can be matched with offline tracks.

MC muons: p_T correspondance between HLT and offline



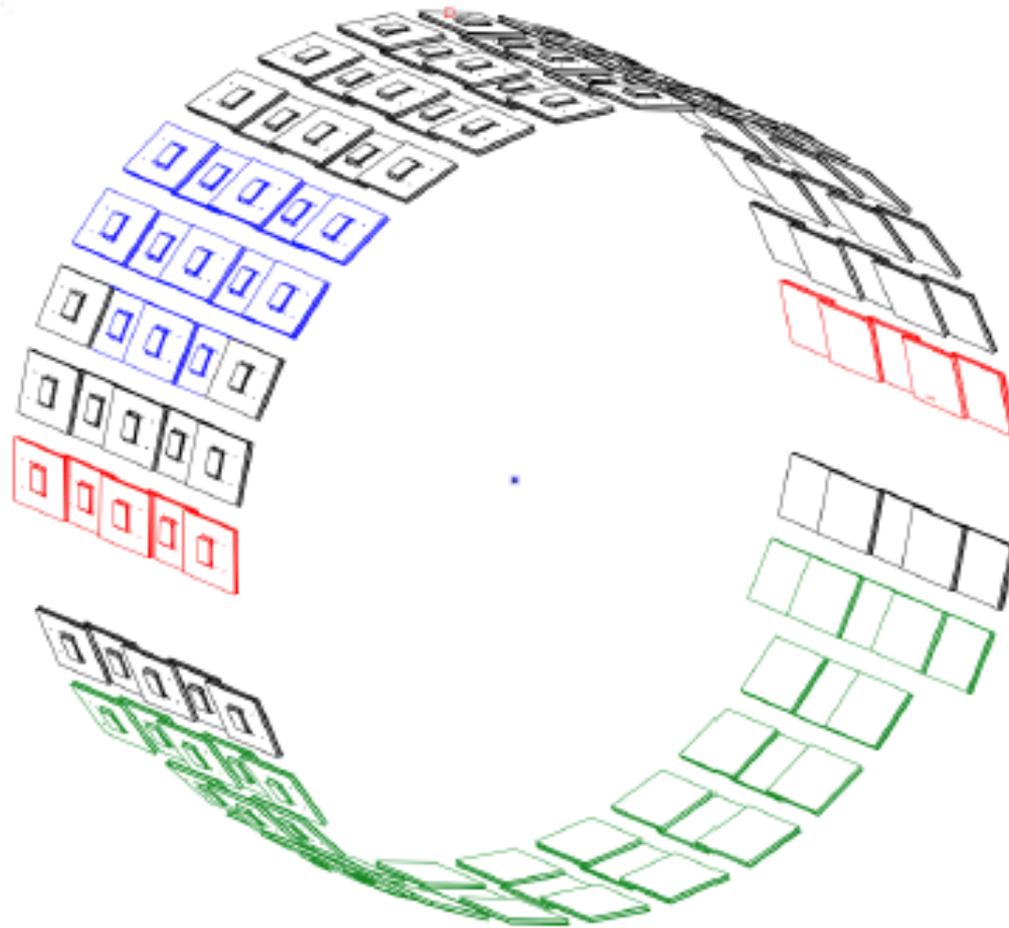
MC muons: nHits correspondance between HLT and offline



Matching efficiency

$$\text{Matching efficiency} = \frac{\text{MC tracks that leave matched track-hit pairs in HLT}}{\text{MC tracks that leave matched track-hit pairs in offline}}$$

MTD geometry



Current matching algorithm in offline

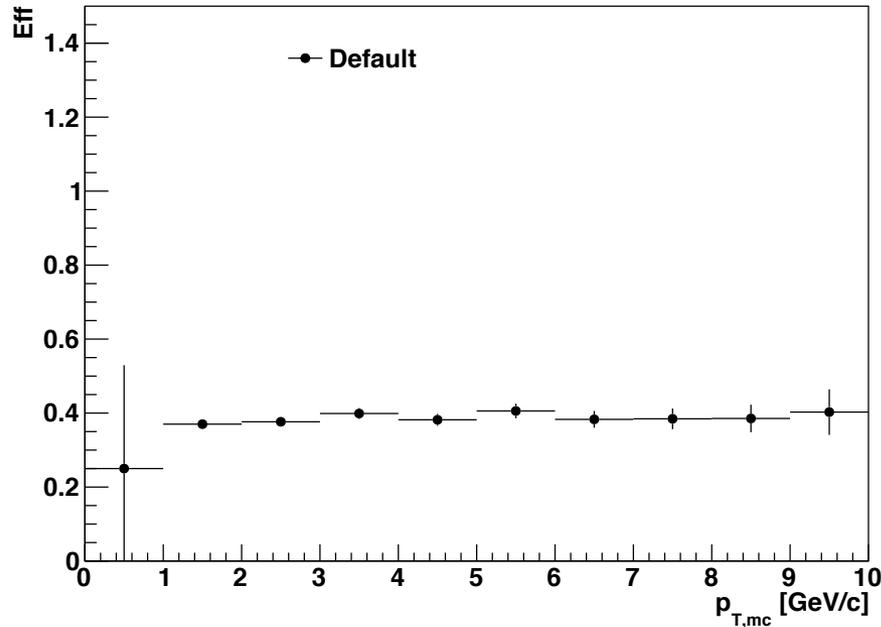
- Track cuts
 - Global tracks
 - $p_T \geq 1 \text{ GeV}/c$
 - $|\eta| \leq 0.8$
 - $n\text{Hits} \geq 15$; $n\text{HitsDedx} \geq 10$
 - $n\text{Hits}/n\text{HitsPoss} \geq 0.52$
- Matching algorithm
 - Tracks are propagated from vertex to MTD **with** energy loss, and the closest MTD hit is chosen as a match.
 - Match window: same backleg, same or adjacent modules
 - **If more than one tracks are matched to the same MTD hit, the closest track is chosen as a match.**

Current matching algorithm in HLT

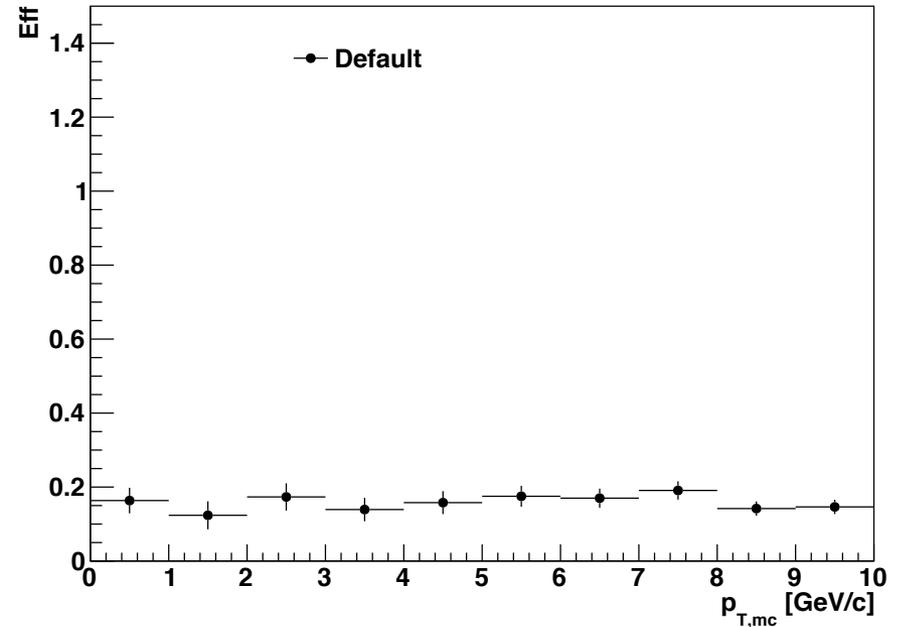
- Track cuts
 - Global tracks
 - $p_T \geq 1 \text{ GeV}/c$
 - $|\eta| \leq 0.8$
 - $n\text{Hits} \geq 15$; $n\text{HitsDedx} \geq 10$
 - $\text{DCA} \leq 10 \text{ cm}$
- Matching algorithm
 - Tracks are propagated from vertex to MTD without energy loss, and the closest MTD hit is chosen as a match.
 - Match window: same backleg, same or adjacent modules
 - If more than one tracks are matched to the same MTD hit, this hit is marked as *unmatched*.

Matching efficiency

HLT: MTD matching efficiency for single muon



HLT: MTD matching efficiency for J/psi



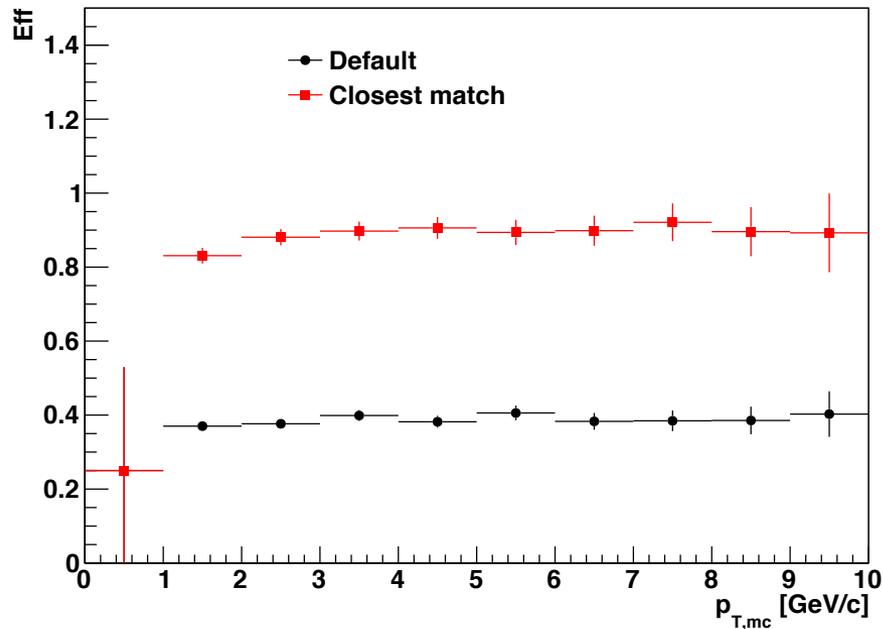
- The matching efficiency is about 40% for single muon and 20% for J/psi. The real efficiency is even lower due to partial tracking.
- Most of the efficiency loss comes from the rejection of MTD hits that get matched multiple times, i.e. a good match can be rejected by any random match.

Improve matching algorithm in HLT

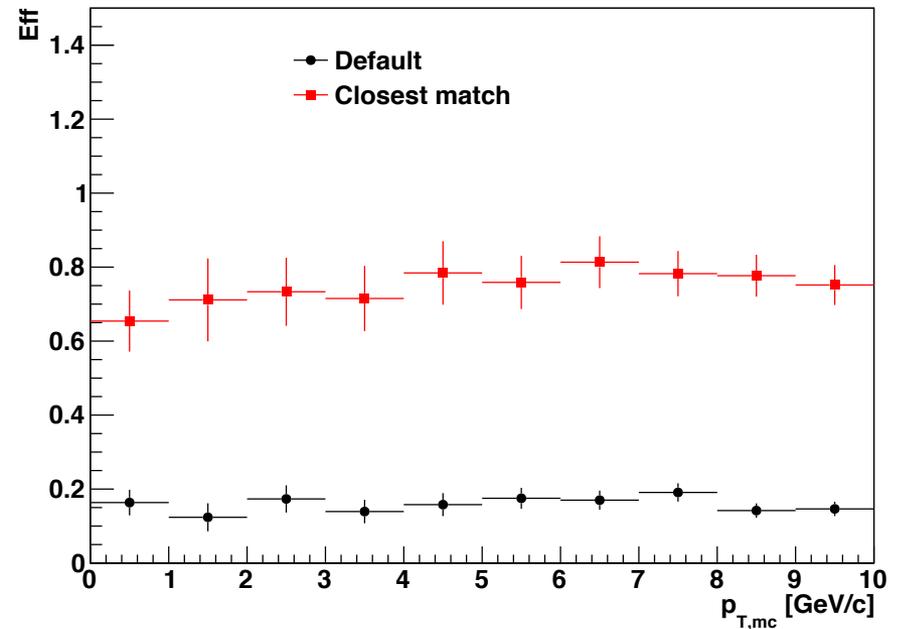
- Matching algorithm
 - Tracks are propagated from vertex to MTD without energy loss, and the closest MTD hit is chosen as a match.
 - If more than one tracks are matched to the same MTD hit, the closest track is chosen as a match.

Matching efficiency

HLT: MTD matching efficiency for single muon

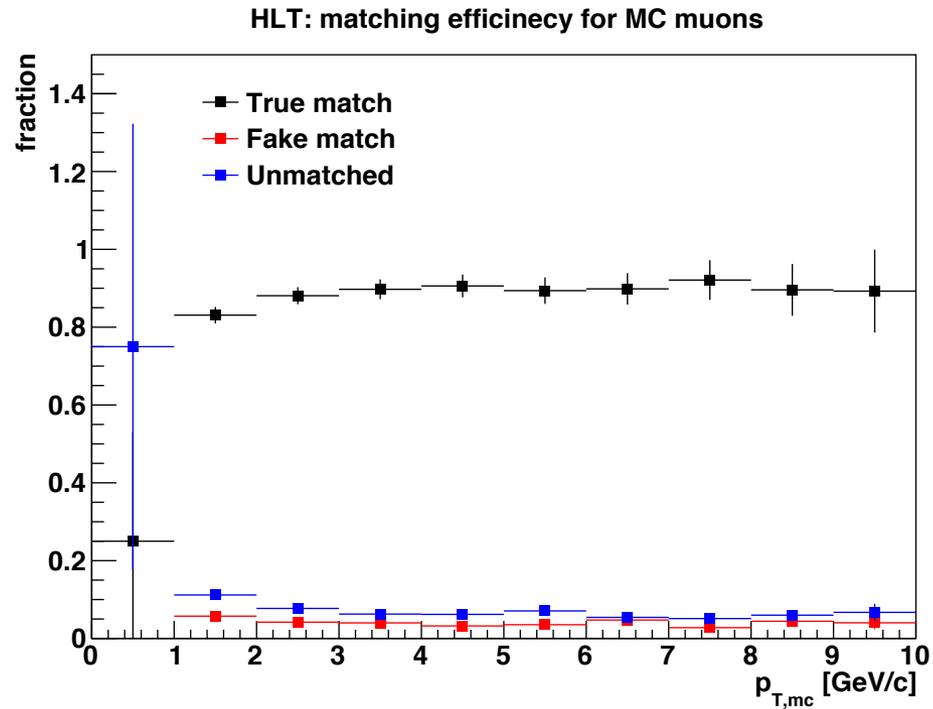


HLT: MTD matching efficiency for J/psi



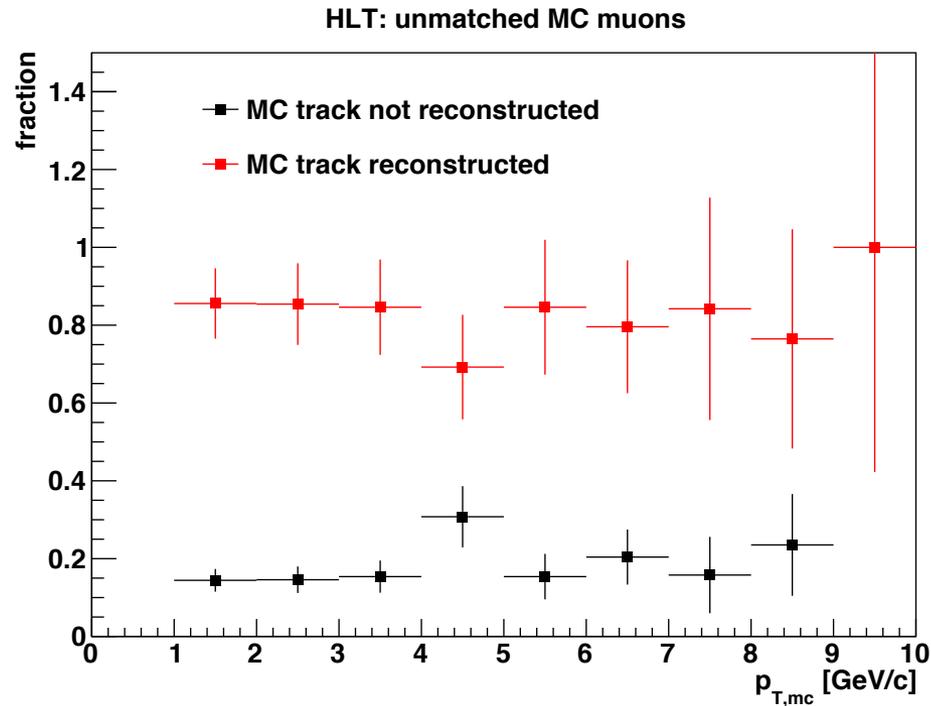
- The matching efficiency is increased by about a factor 2 for single muon and a factor of 4 for J/psi
- Still ~10% loss for single muon

Breakdown of matching



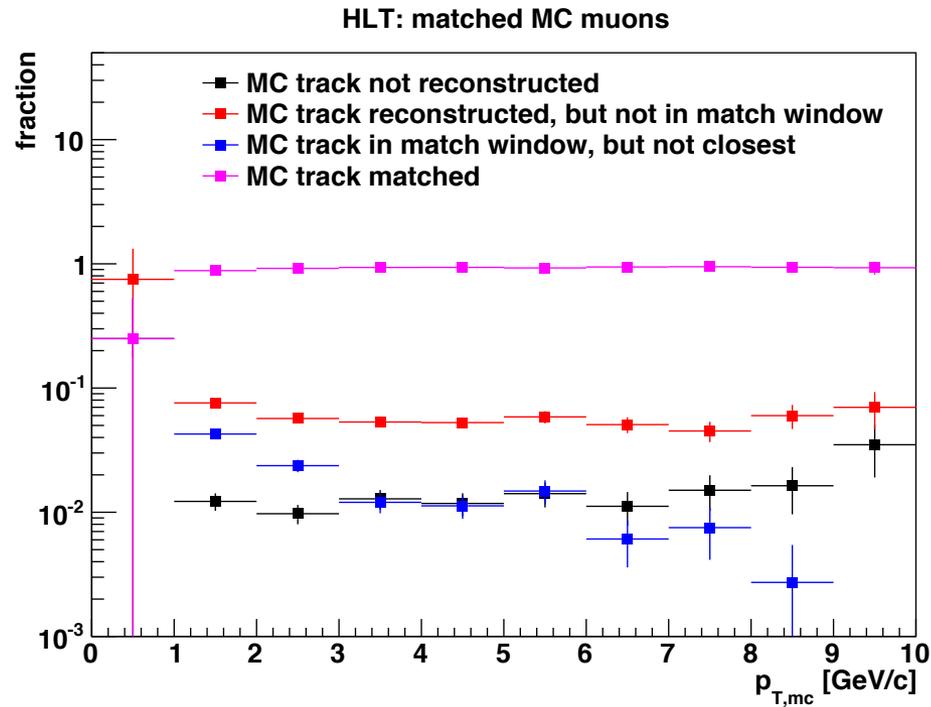
- True match: ~90%
- Fake match: ~4%
- Unmatched: ~6%

Unmatched muons



- ~15%: MC tracks are not reconstructed in HLT
- ~85%: tracks are reconstructed, but not projected to the match window.

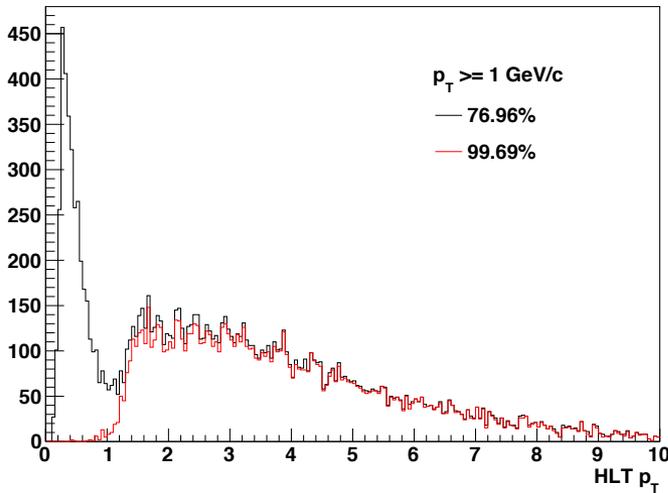
Matched muons



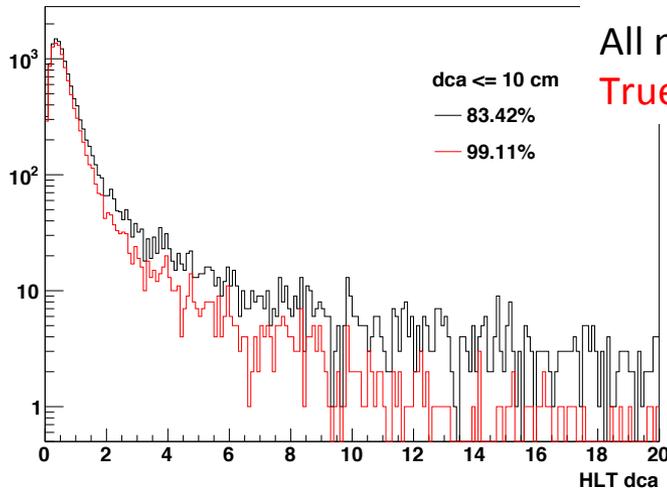
- Majority of the time, fake matches come from that MC tracks are not projected to the match window.

Loss of tracks in HLT due to track quality cuts

HLT: p_T distribution of HLT tracks matched to MC muons

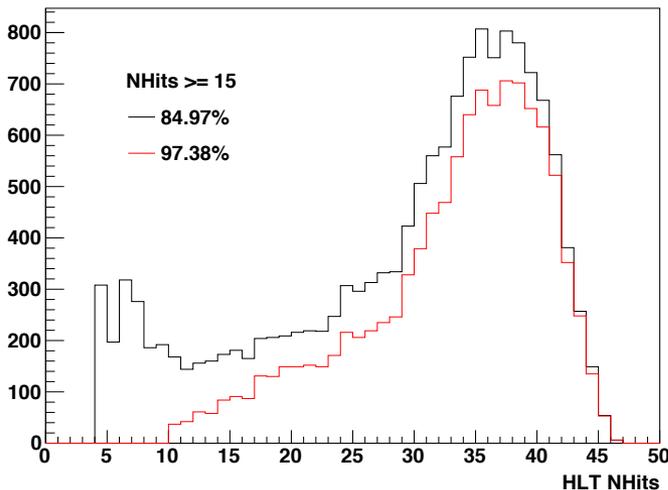


HLT: dca distribution of HLT tracks matched to MC muons

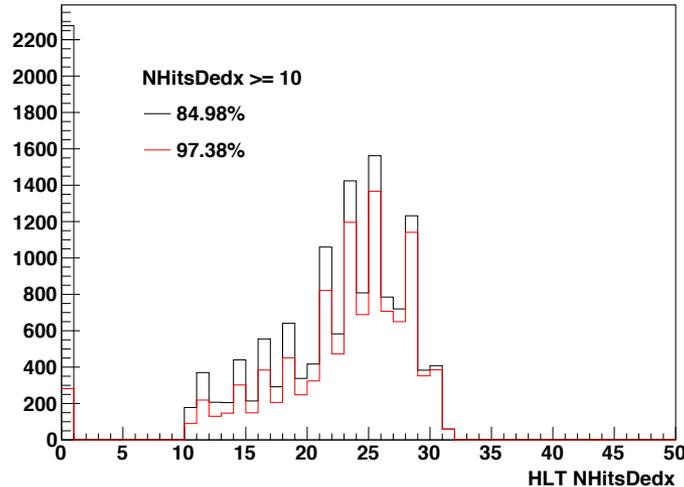


All matched HLT tracks
True matched HLT tracks

HLT: NHits distribution of HLT tracks matched to MC muons



HLT: NHitsDedx distribution of HLT tracks matched to MC muons



- All the plots are made without any track quality cuts
- 2-3% of loss due to hard cuts in NHits

Summary

- HLT tracking performance
 - Good vertex reconstruction
 - Slightly lower tracking efficiency and worse track momentum resolution
- Improved MTD matching algorithm by selecting the closest track as the match can increase the J/psi efficiency by about a factor of 4.
- Source of inefficiency
 - Un-reconstructed HLT tracks
 - Track quality cuts in HLT
 - Mis-match to HLT tracks
 - MC tracks do not point to MTD hits after extrapolation

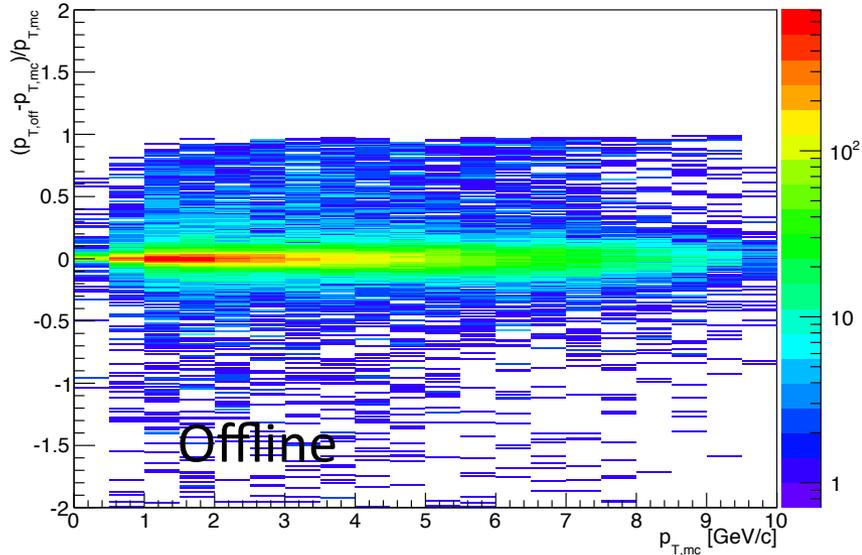
What's next?

- Fine-tune the cuts on tracks
- Estimate the HLT efficiency using real data by comparing to offline reconstruction
 - Additional efficiency loss due to partial tracking

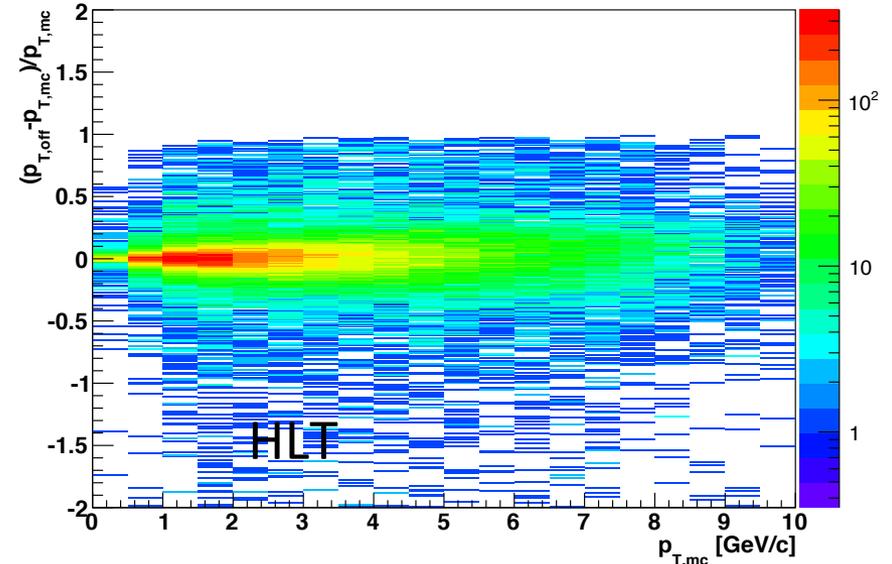
backup

Compare track momentum resolution

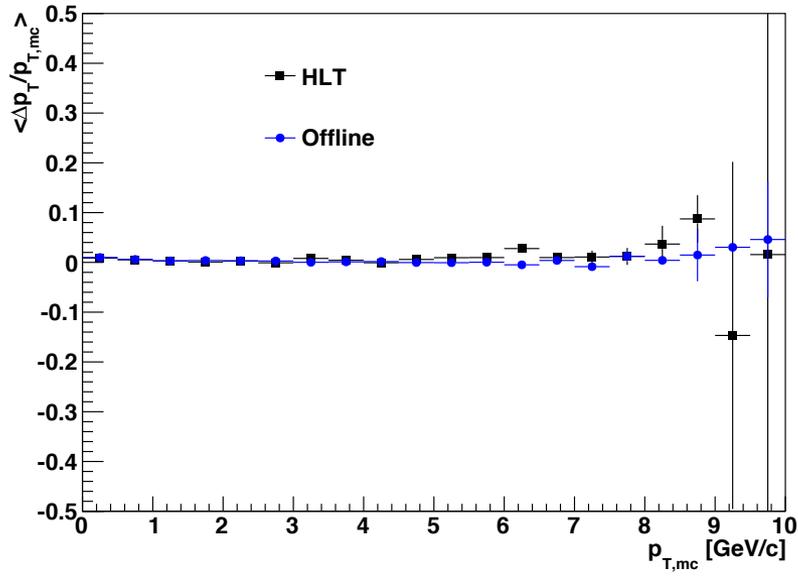
Offline: transverse momentum resolution



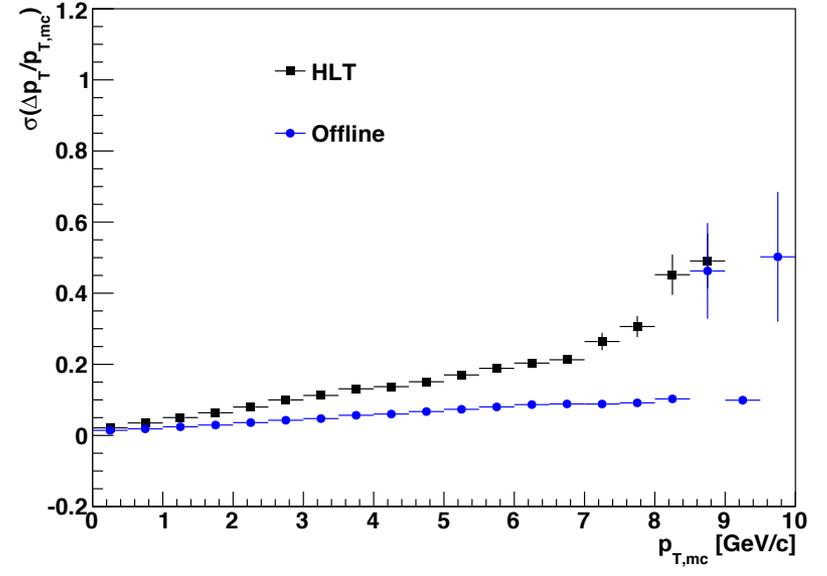
HLT: transverse momentum resolution



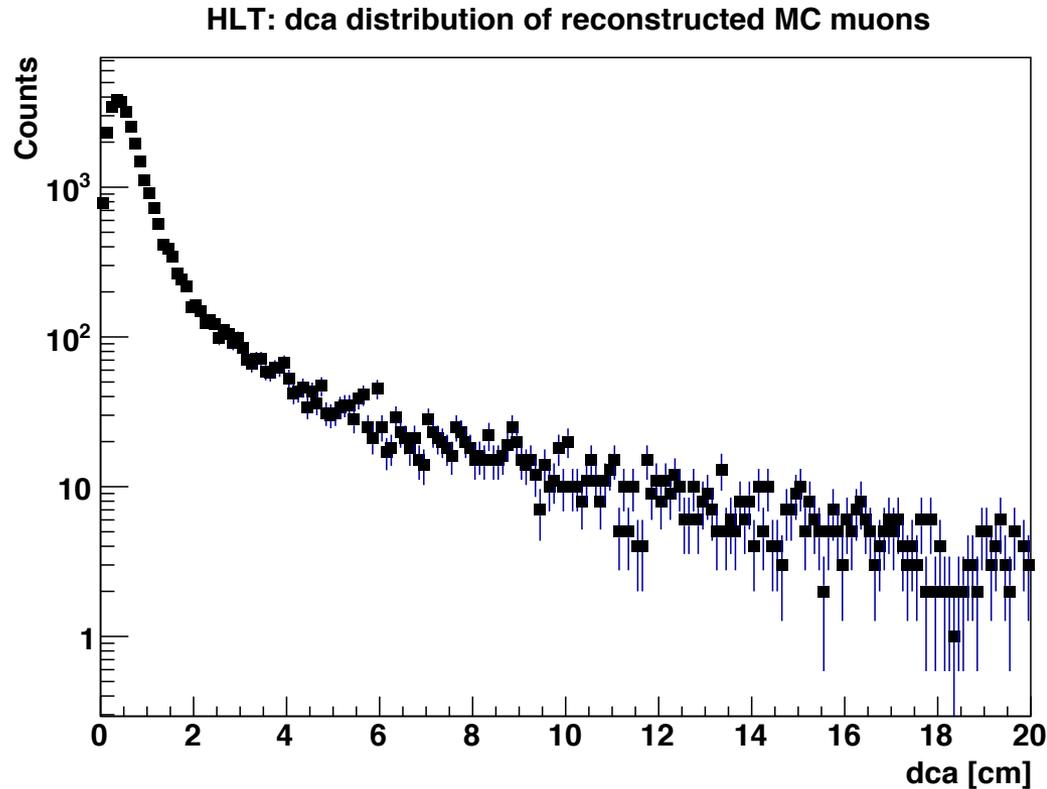
p_T shift of reconstructed MC muons vs p_T



p_T resolution of reconstructed MC muons vs p_T

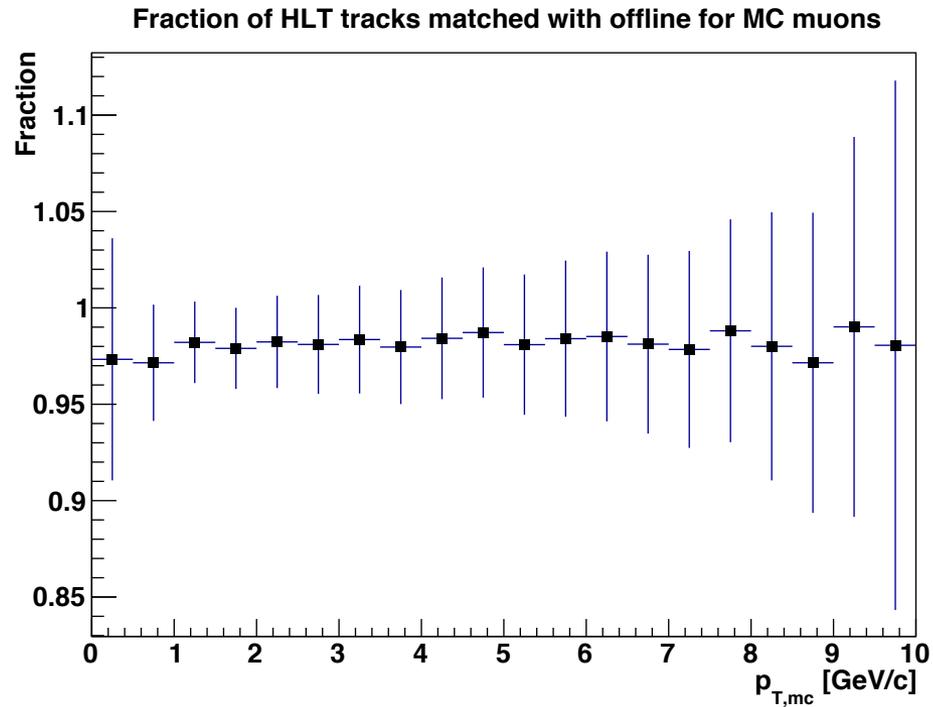


Dca distribution of HLT tracks



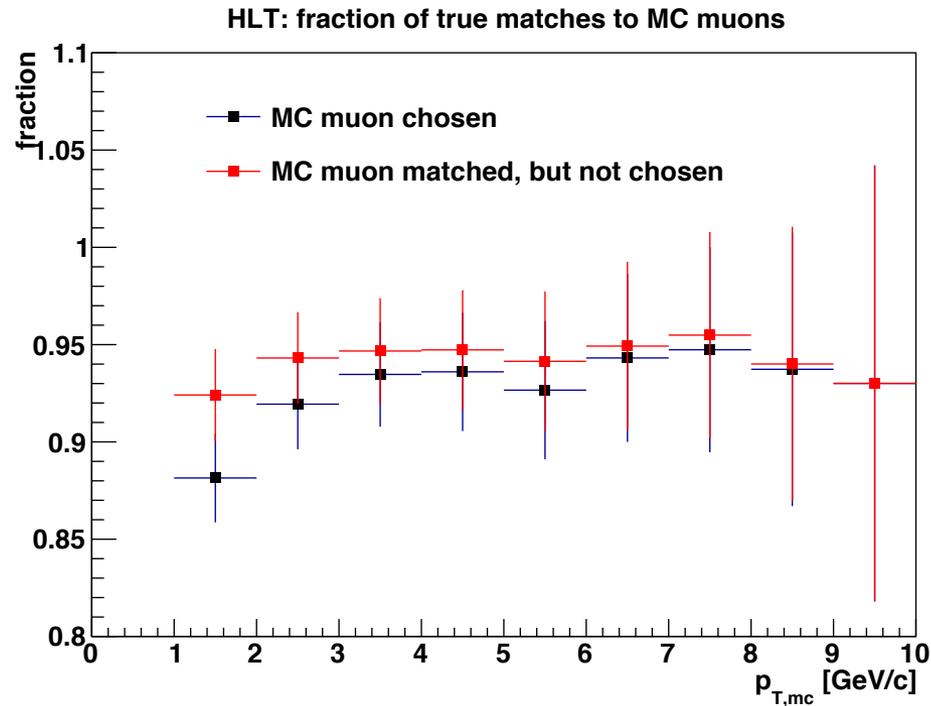
- Given that the MC tracks are embedded at primary vertex, and that the vertex reconstruction in HLT matches that in offline, the DCA distribution of the HLT tracks (matched to MC tracks) is narrowly peaked around 0 as expected.

Source of inefficiency (I)



- ~98% of the HLT tracks that are matched MC tracks can be matched with offline tracks.

Source of inefficiency (II)



- ~5% of MTD hits are **matched** to HLT tracks that do not originate from the corresponding MC tracks which produce the MTD hits as determined in offline.
- A small fraction is due to that another track is closer to the MTD hit even though the MC track is matched to MTD hit as well.