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Performance of the realistic seeding code with ACTS in DD4HEP/juggler

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Fun4All vs DD4HEP

	Fun4All	DD4HEP
Geometry variations	Easy, quick to implement	Requires more steps and coordination (e.g. new material maps)
Pattern recognition algorithm	Mainly truth seeding + Kalman filter (some incomplete ACTS implementation)	Significant work on ACTS and realistic pattern recognition
Magnetic field maps	Multiple field maps (i.e. BaBar) available + capability of scaling these maps to other B values	
Future use	Short-term	Official EPIC software

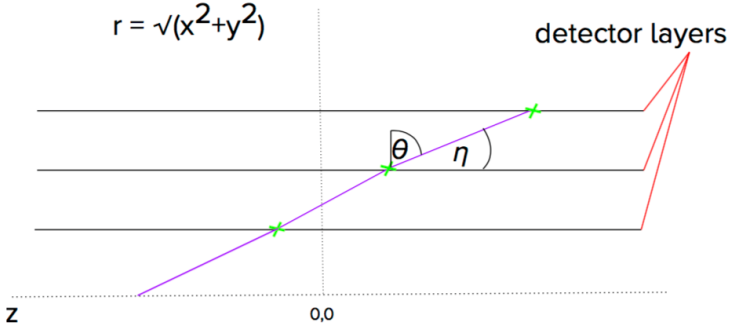
Realistic seeding in DD4HEP/juggler

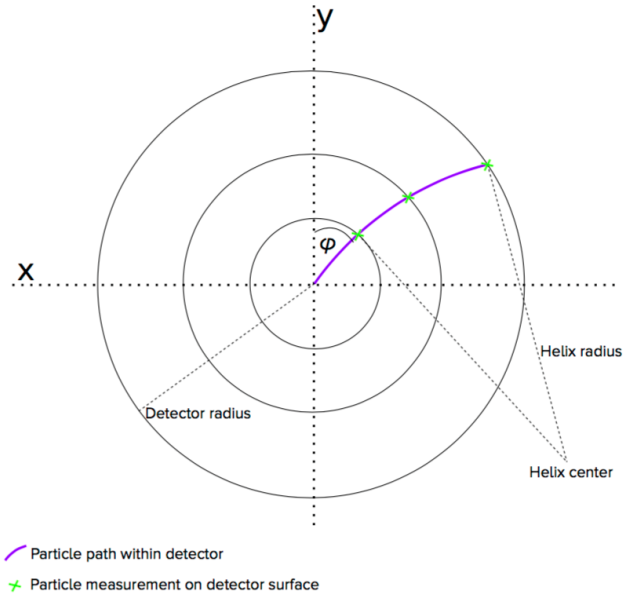
- Realistic seeding code developed by Yue Shi (slides) now available in DD4HEP/juggler (ATHENA software framework)

ACTS Seeding

Figures from https://acts.readthedocs.io/en/latest/core/seeding.html

- Triplet generation (not limited to 3 layers, and works for forward configuration)



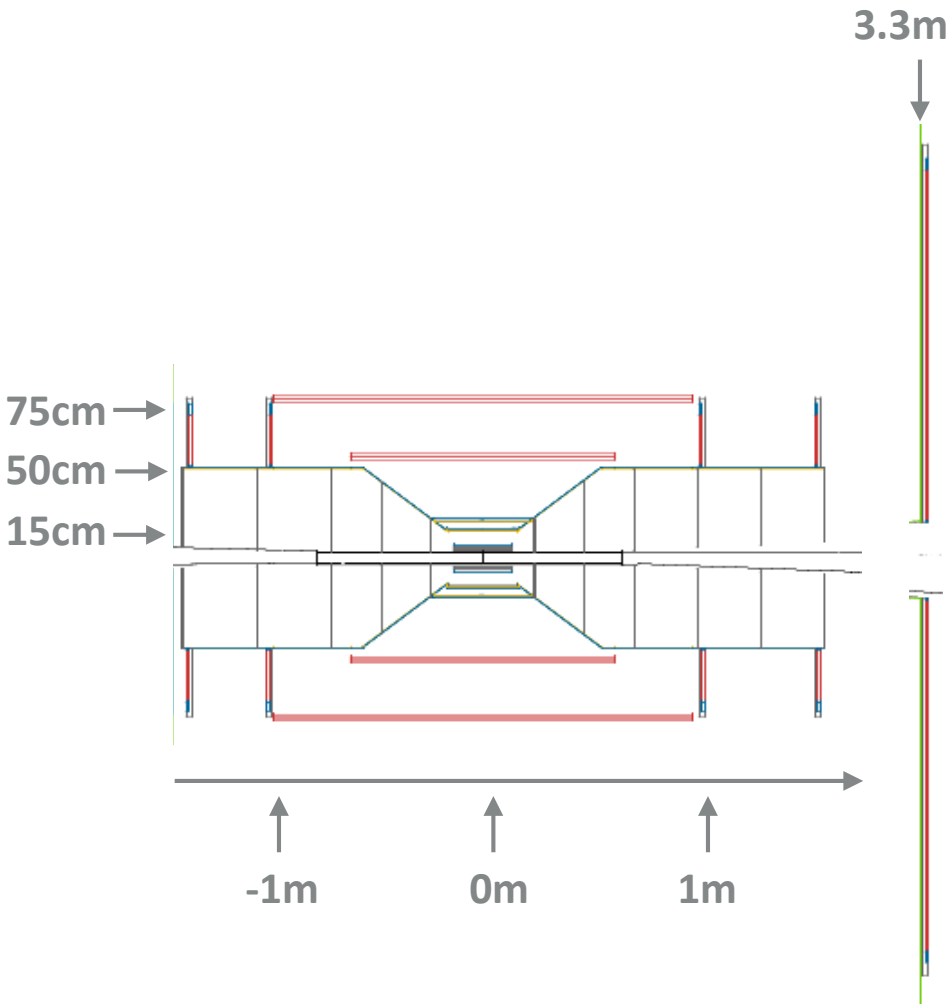


- Triple-loop filtering based on reasonable curvature, compatible η, backprojection to the vertex z range, etc.
- Double-loop filtering, weighting seeds based on mergeability of seed groups (ideally merge to seeds with 5 space points), backprojection to the lowest vertex z and ρ possible
- Single-loop filtering to only retain the highest quality N seeds per middle space point

Realistic seeding in DD4HEP/juggler

- Realistic seeding code developed by Yue Shi (slides) now available in DD4HEP/juggler (ATHENA software framework)

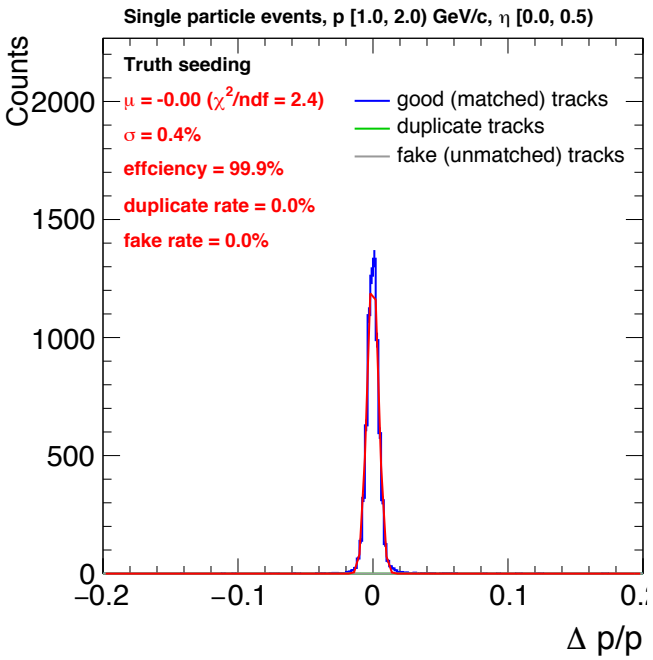
- Performance test
  - ATHENA hybrid tracking geometry + 3T field
  - Single pion events: uniform p_T, ϕ, η distribution (p_T range: 0 to 30GeV, η range: -3.5 to 3.5)
  - **Switch to ePIC geometry when it's ready (geometry+material map) in DD4HEP**

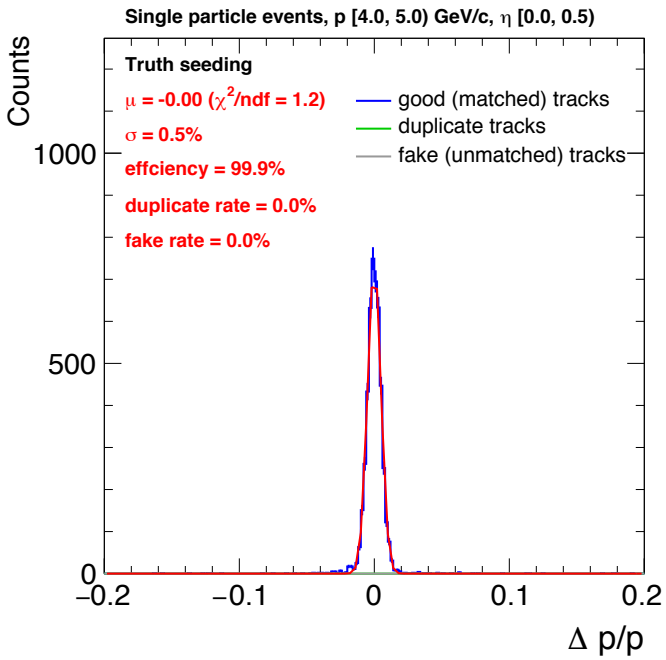


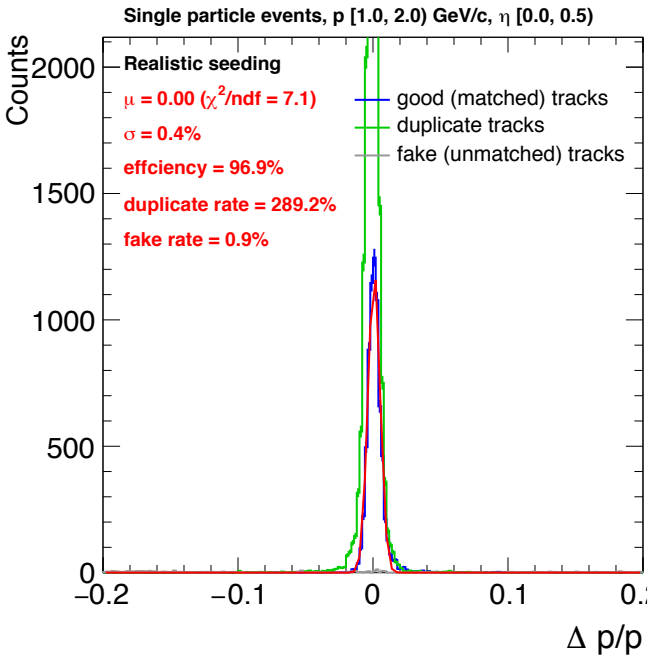
Efficiency, fake rate, duplicate rate

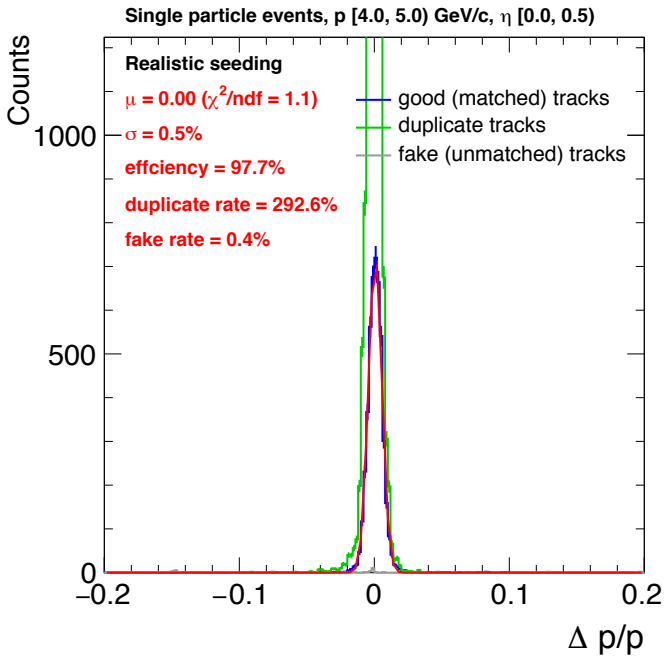
- Currently looking at single particle events
- Good/Matched track definition
  - ☑ Reconstructed charge/momentum has the same sign (charge) as the generated particle
  - ☐ Reconstructed momentum in reasonble range from the truth momentum (magnitude and angle), minimum # of hits, etc.
- Efficiency/duplicate rate/fake rate definition
  - Loop through all the reconstructed particles which are matched to generated particles (charged, stable) → # of matched reconstructed particles
  - If >1 matched tracks are found, choose the one with smallest $|\Delta p/p|$ as the best match
  - Loop through all the generated particles (charged, stable) → # of generated particles
  - Efficiency = # of best-matched reconstructed particles/# of gen particles
  - Duplicate rate = # of matched recontructed particles/# of gen particles
  - Fake rate = # of unmatched reconstructed particles/# of gen particles

Midrapidity (turth seeding vs maxSeedsPerSpM = 10)







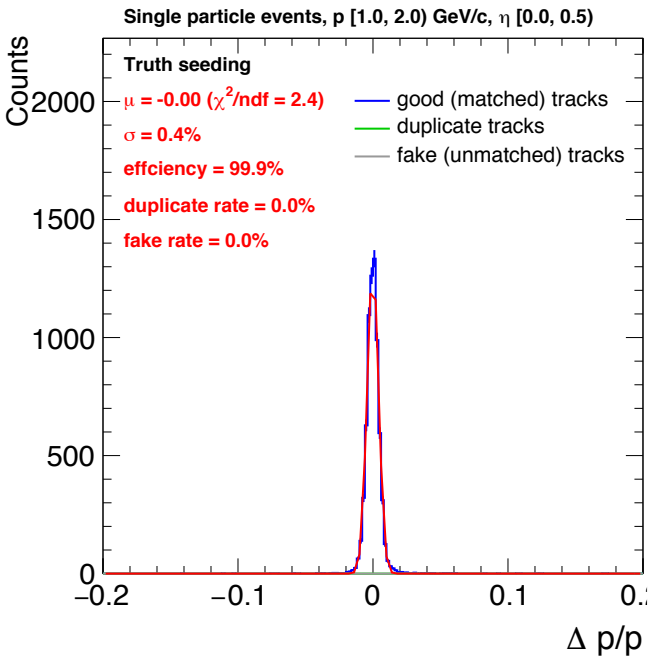


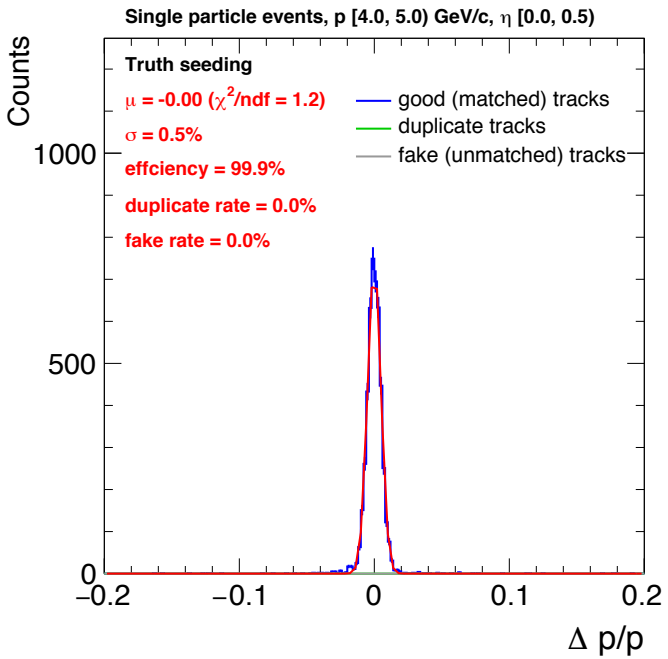
Good efficiency from realistic seeding

Consistant resolution with the truth seeding results

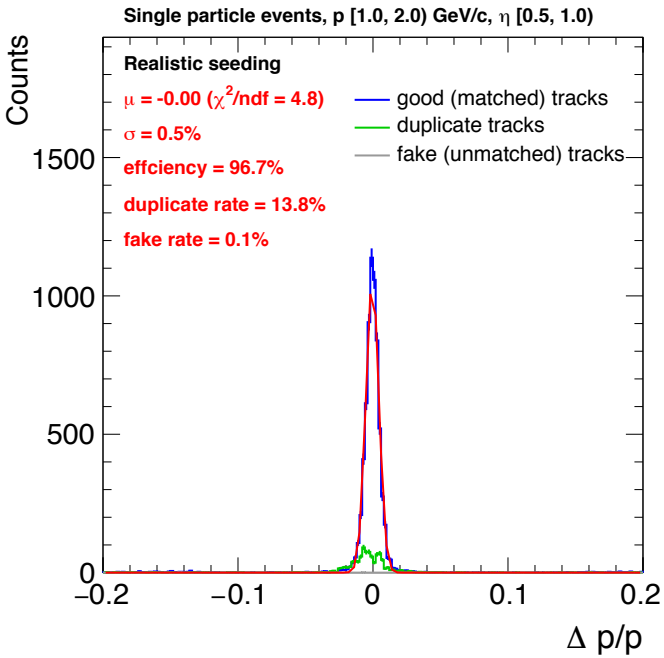
Significant number of fake tracks

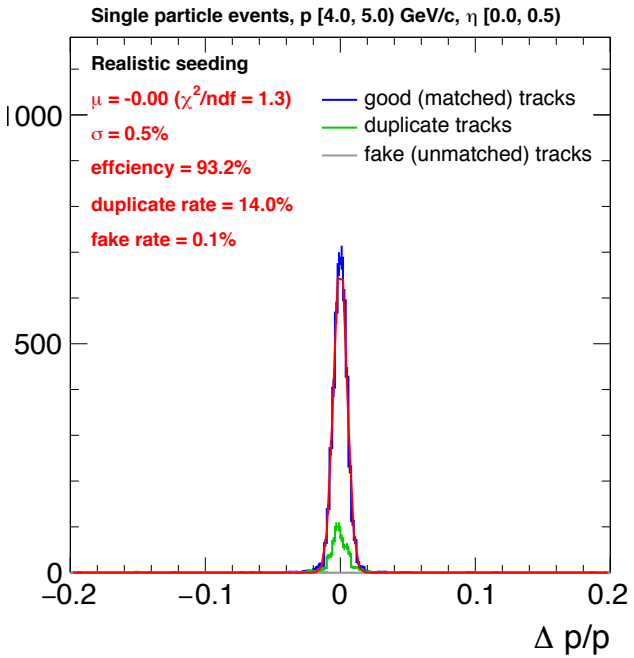
Midrapidity (turth seeding vs maxSeedsPerSpM = 1)





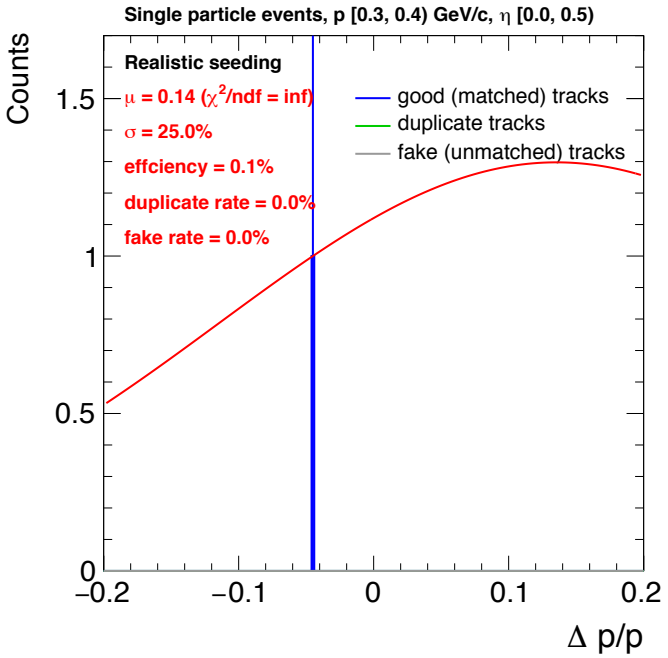
Number of fake tracks greatly reduced (<15% for maxSeedsPerSpM=1 and <35% for maxSeedsPerSpM=5)

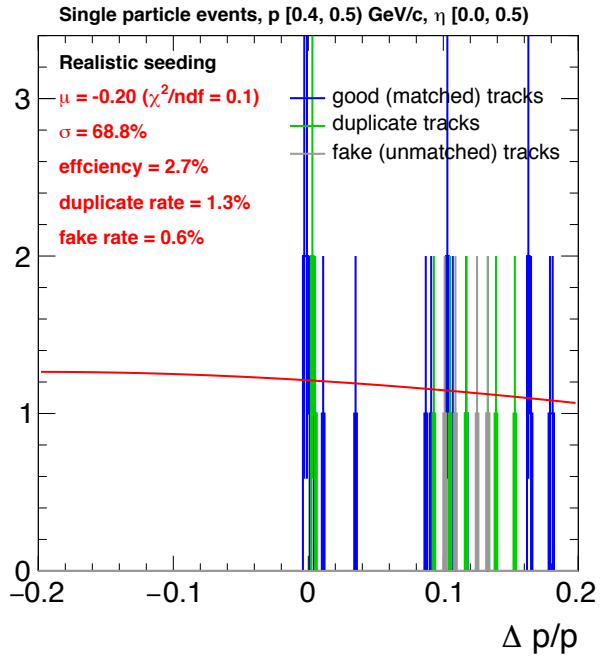


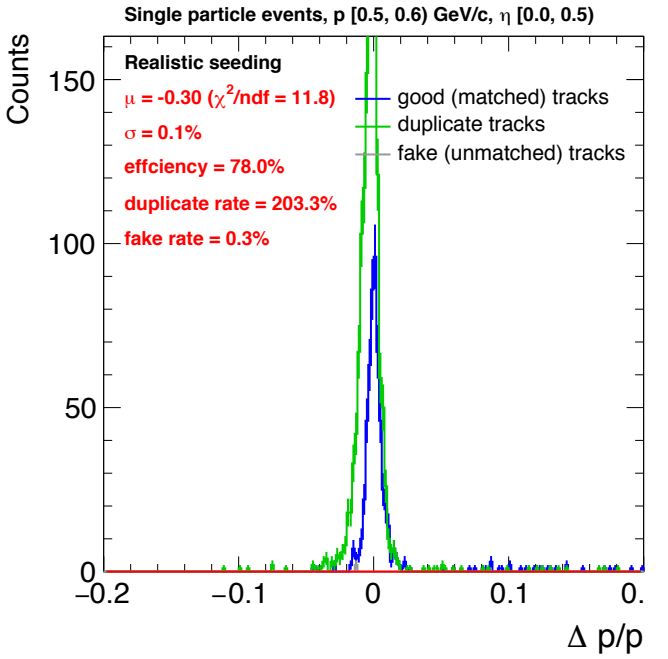


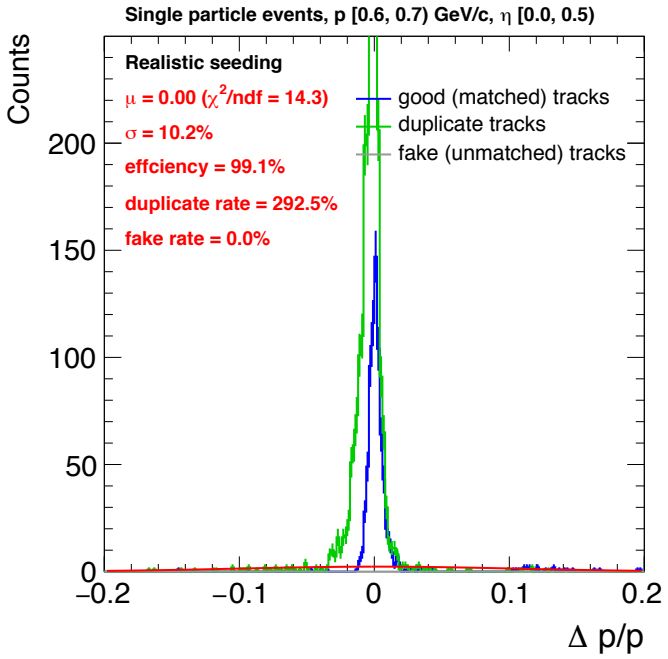
A very small decrease of efficiency

Threshold at midrapidity (maxSeedsPerSpM = 10)

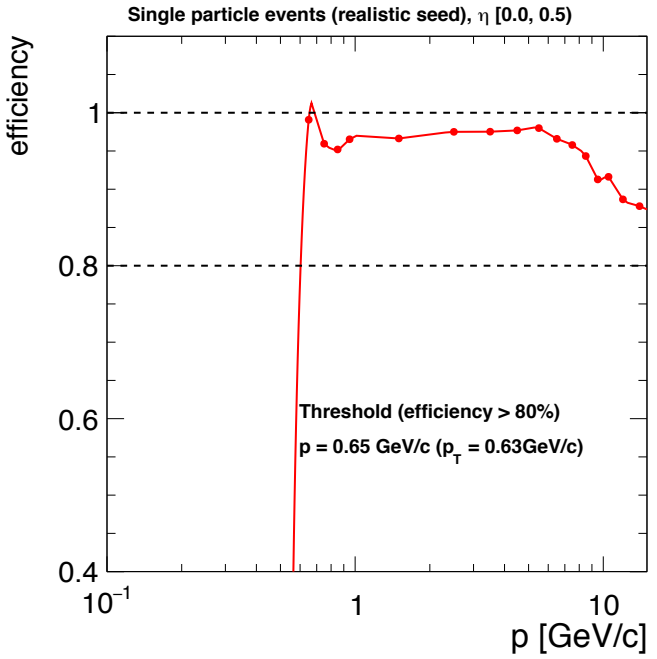




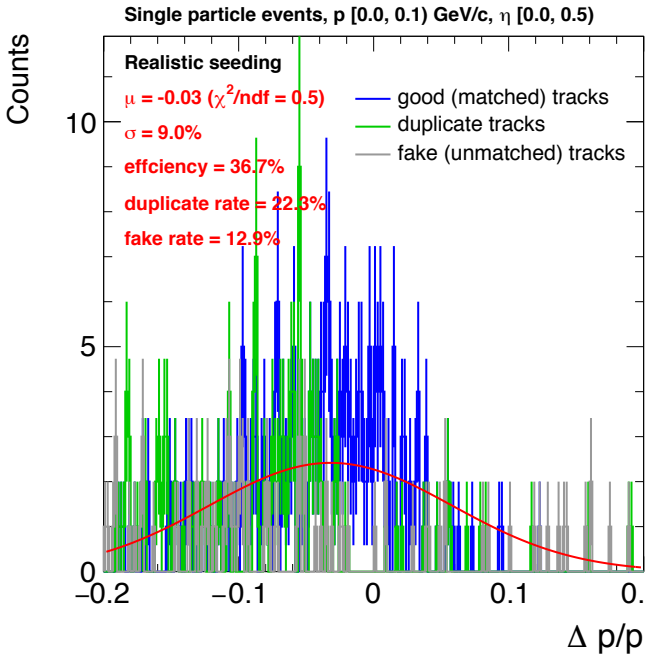


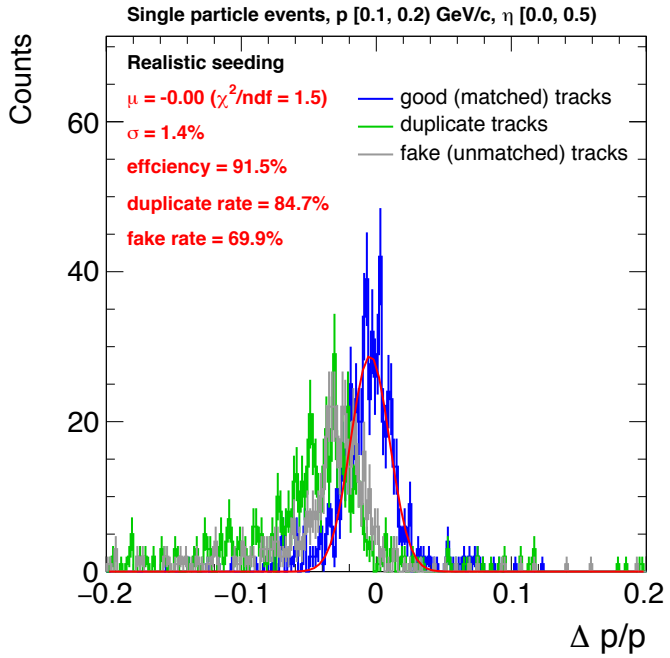


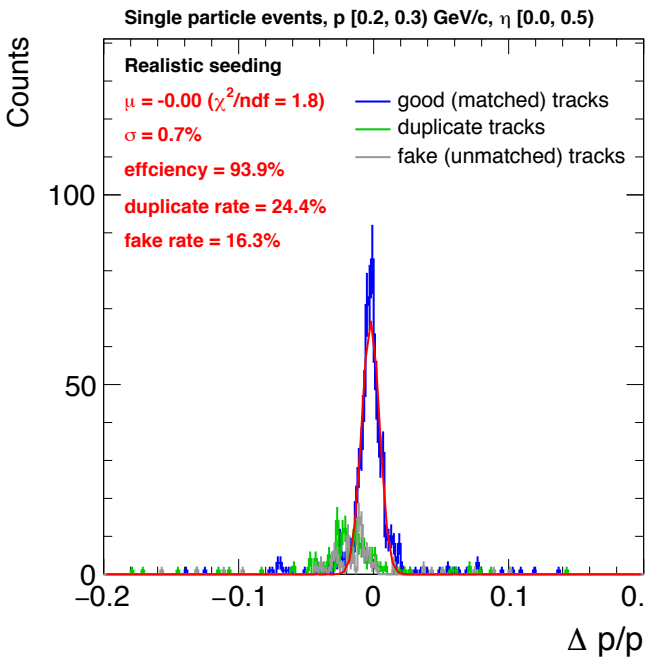
With maxSeedsPerSpM = 10, threshold much higher than the expectation (truth seeding ~0.15GeV)

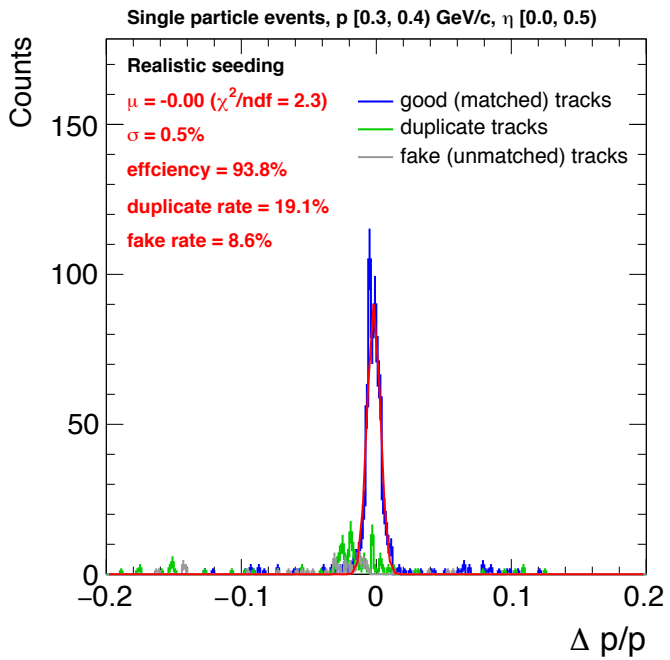


Threshold at midrapidity (maxSeedsPerSpM = 1)

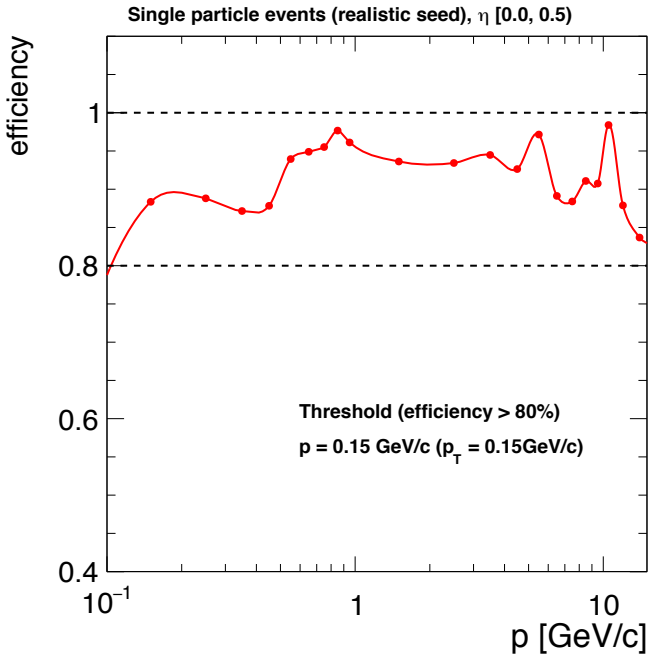




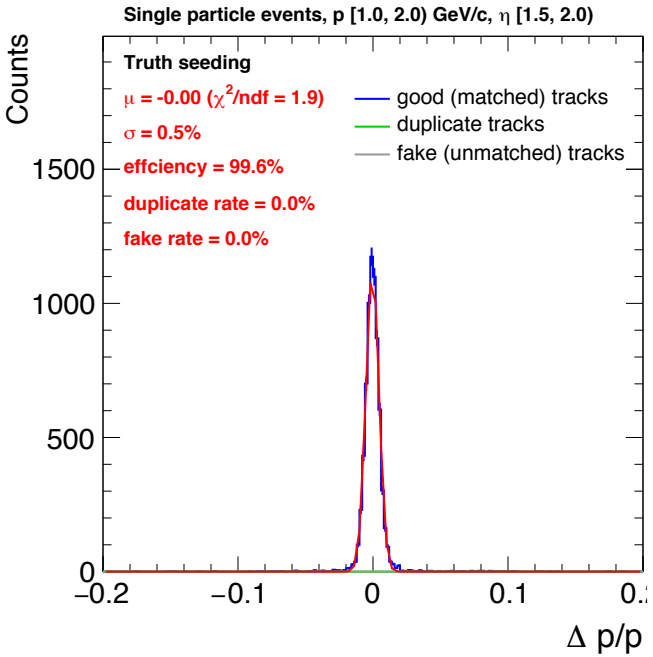


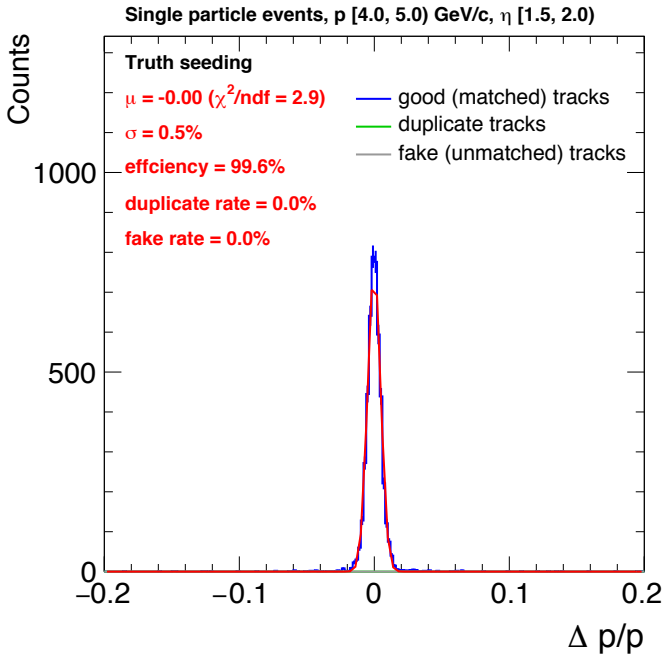


With maxSeedsPerSpM = 1 (or 5), threshold close to the expectation (truth seeding ~0.15GeV)

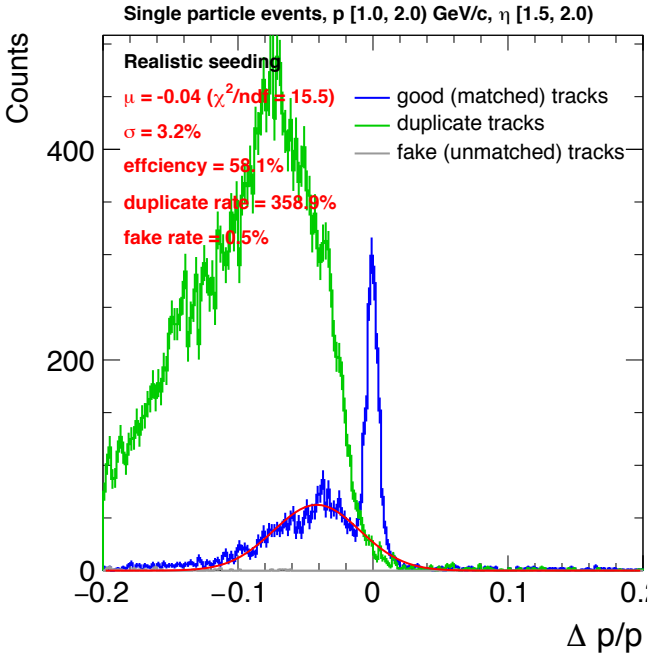


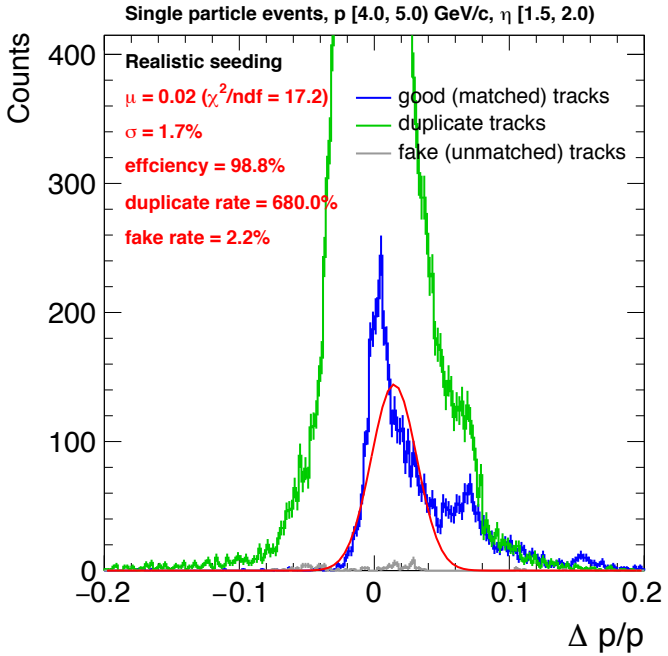
Forward (truth seeding vs maxSeedsPerSpM = 10)





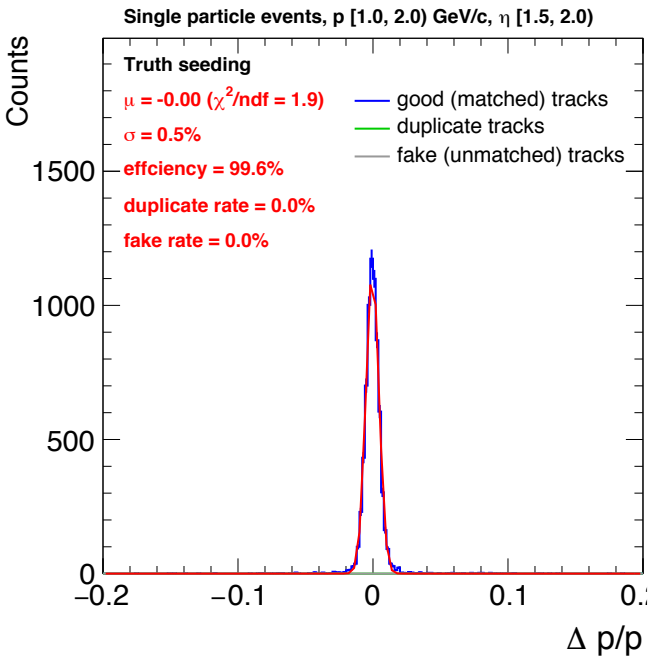
Momentum are not well reconstructed for forward tracks (<10GeV) with realistic seeding

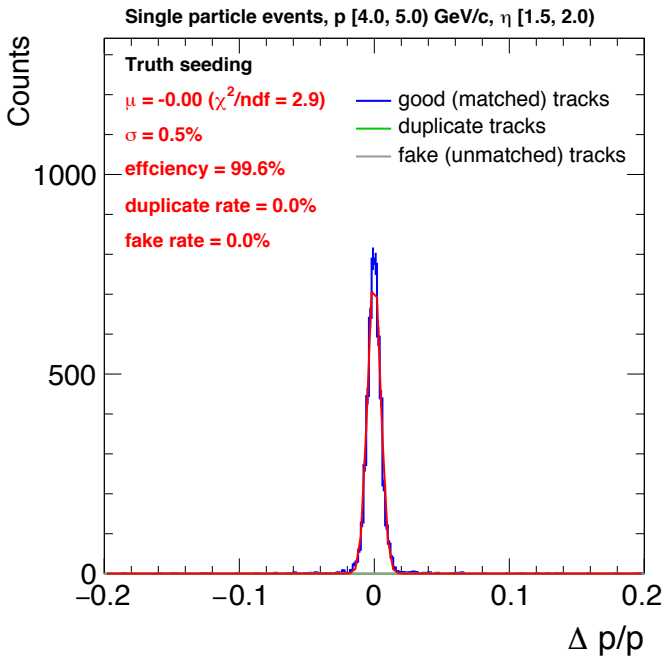


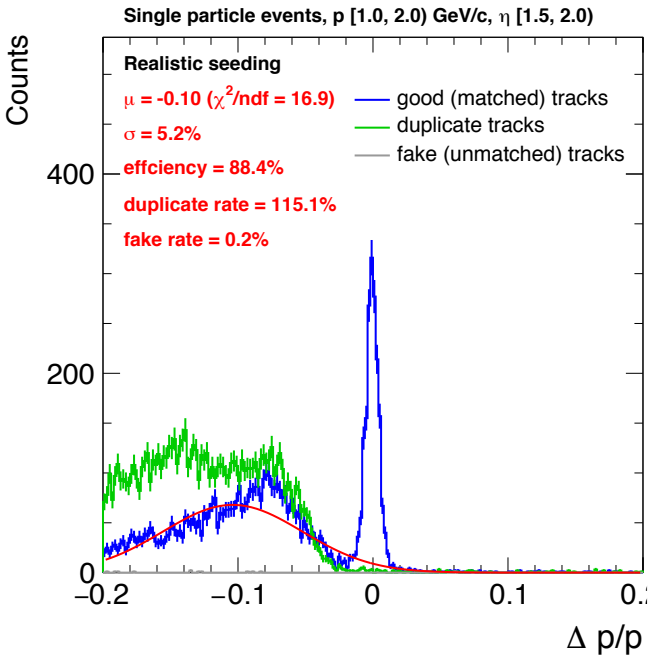


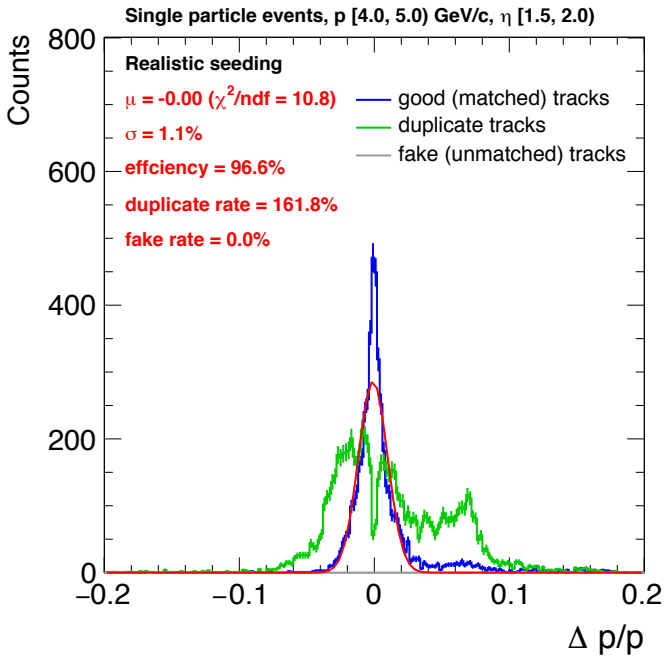
Significant number of fake tracks

Forward (truth seeding vs maxSeedsPerSpM = 1)



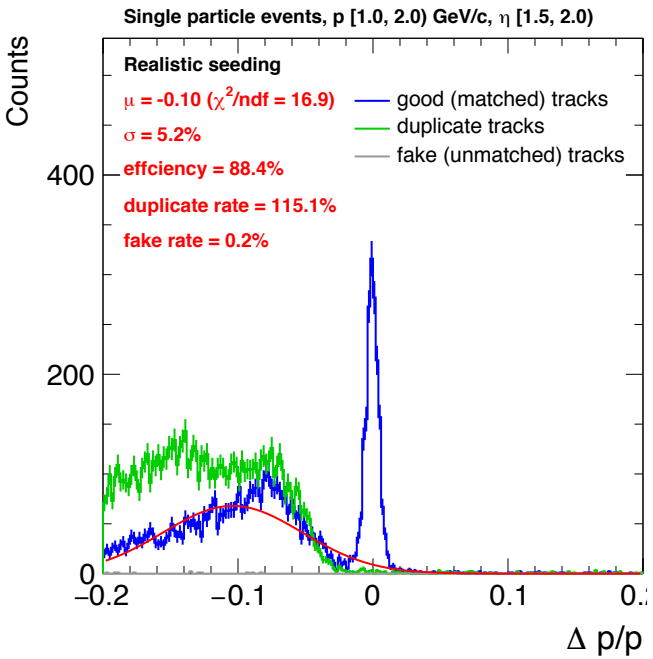


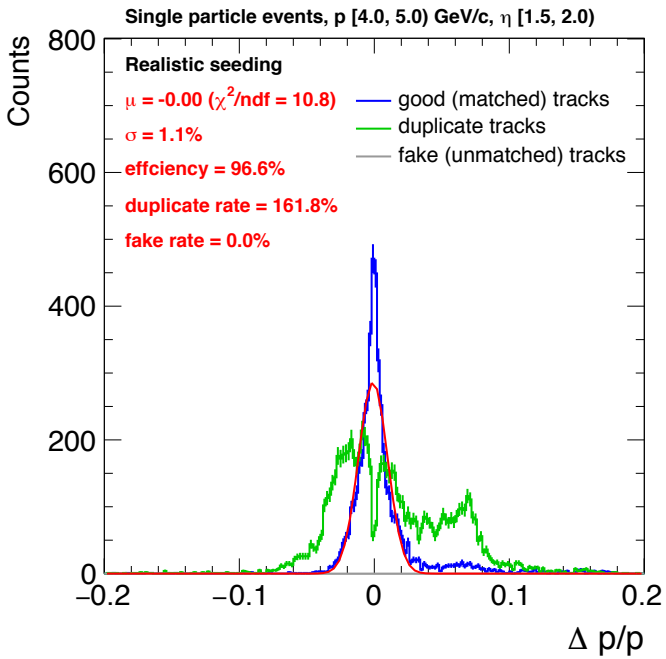




Number of fake tracks greatly reduced also at forward rapidity

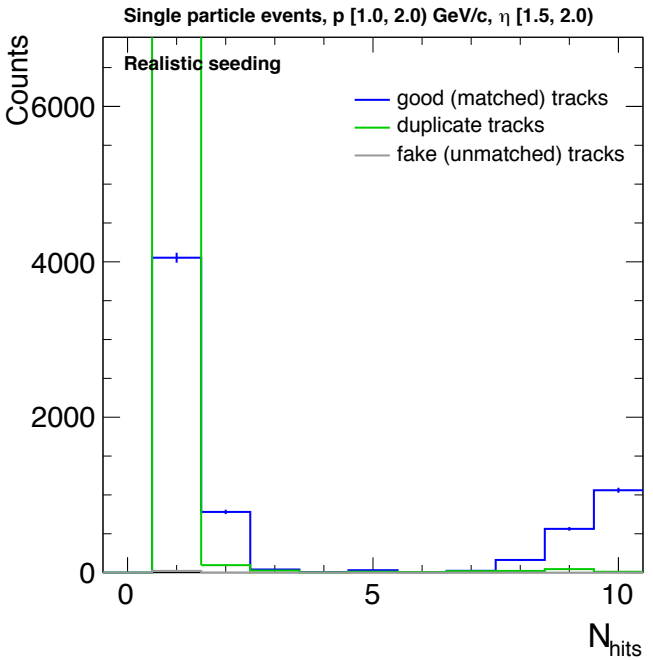
Number of associated hits for the forward tracks

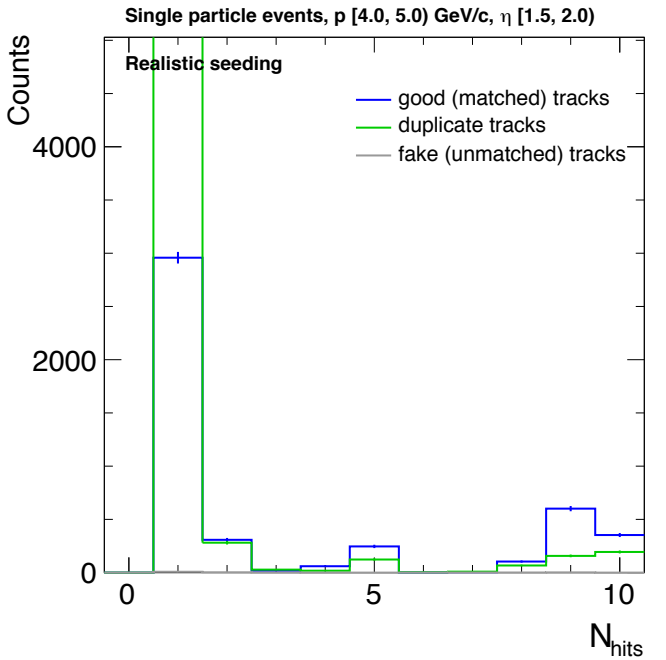




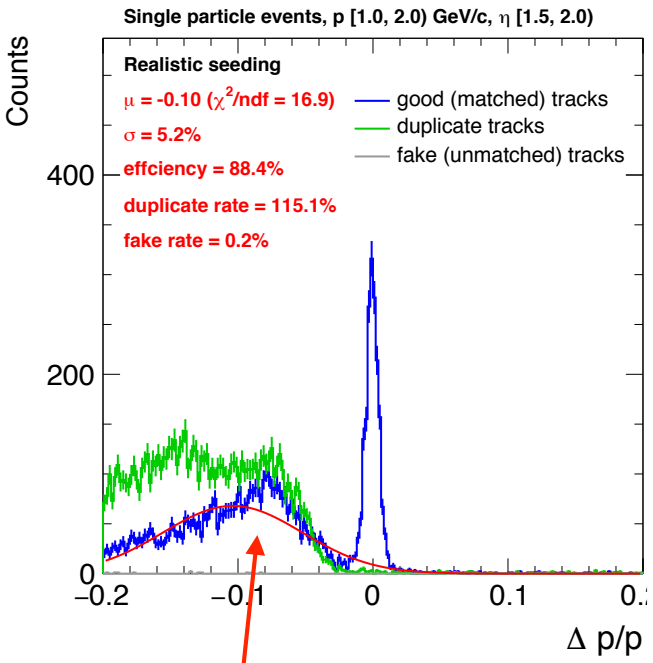
maxSeedsPerSpM = 1

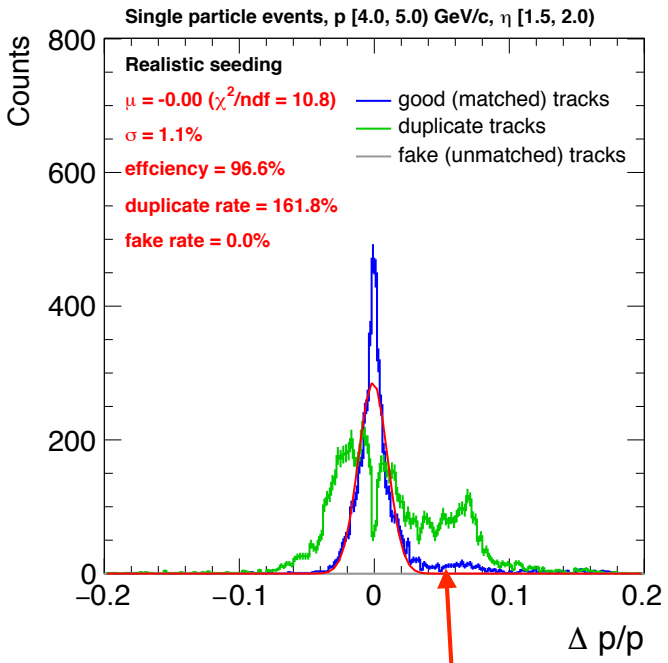
Most of the fake tracks are with only 1 associated hits

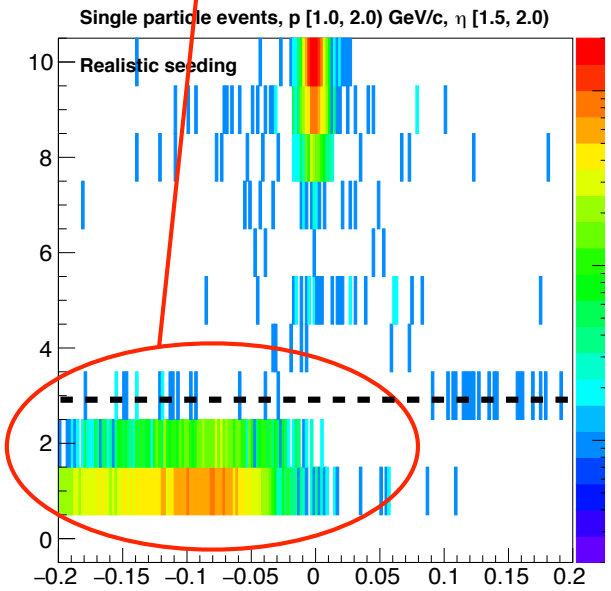


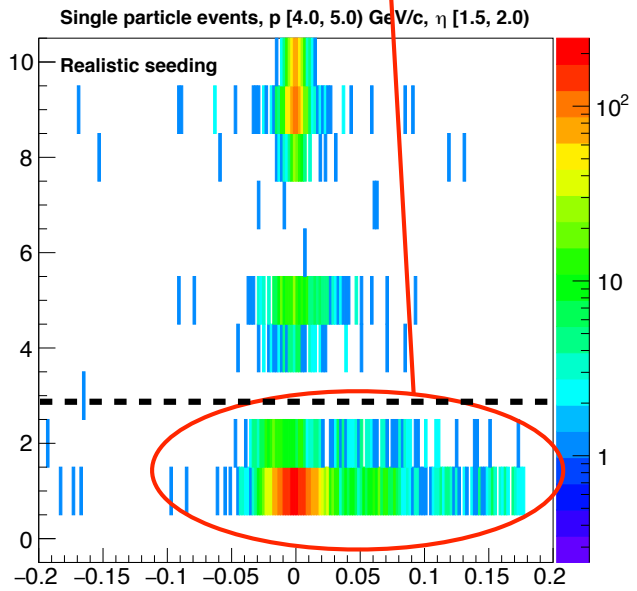


Number of associated hits for the forward tracks





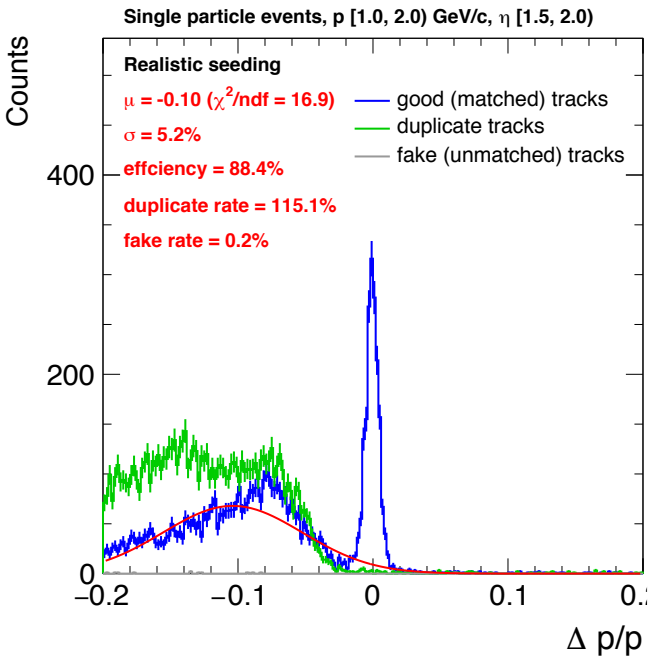


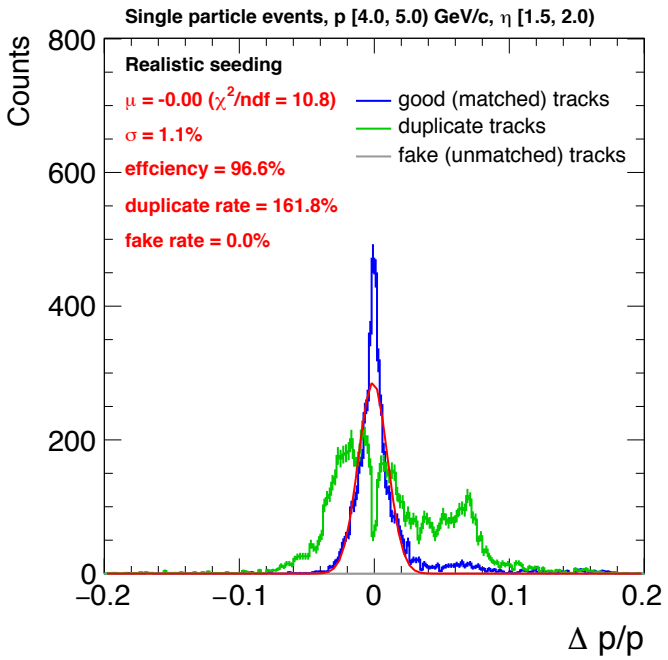


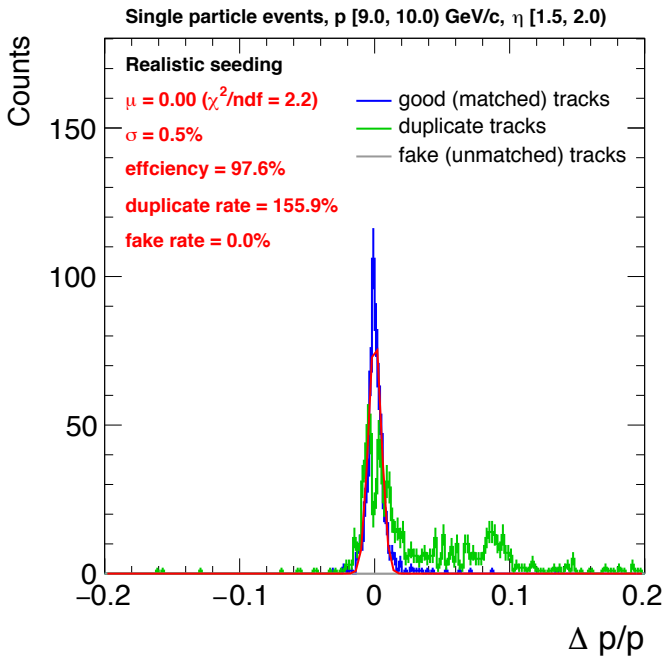
maxSeedsPerSpM = 1

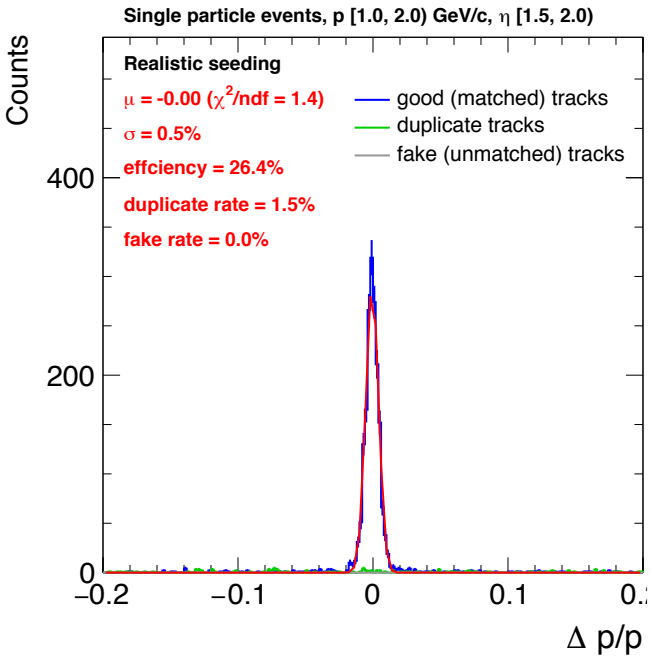
The multi-peak structure come from a mix of low hits (<3) and high hits tracks

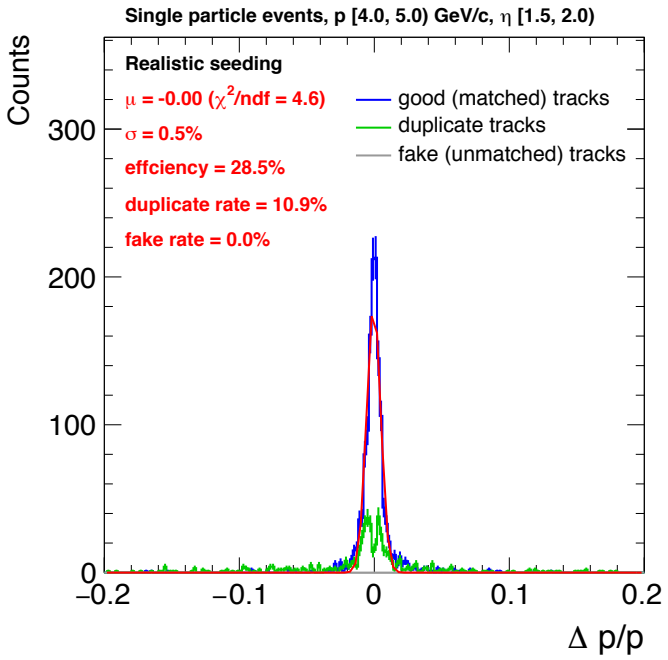
Requiring min # of associated hits for forward tracks (>=3)

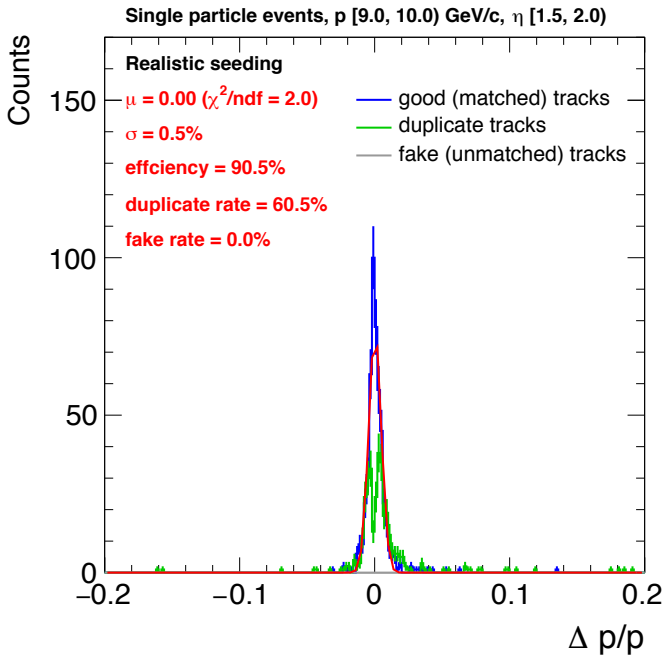












Summary

- Realistic seeding works well in midrapidity w/ “maxSeedsPerSpM = 1”
  - Reduced the number of duplicate tracks without significant loss of efficiency
  - Lower threshold value at midrapidity
  - “maxSeedsPerSpM = 5” gives similar performance
- The multi-peak momentum distribution at forward rapidity is related to tracks with very few hits (<3)
  - Once constrain “good tracks” to be with at least 3 associated hits, momentum distribution looks better (but low efficiency <5GeV)
  - Check what hits are missing (+why) for the tracks with few hits
- Switch to ePIC geometry soon