SPD collaboration meeting
13-15 December 2021

Status of track reconstruction for SPD experiment

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Introduction

- Track reconstruction is usually divided into separate sub-tasks:

  - track finding
  - track fitting (in general on the base of Kalman filter method)

- Track finding (or pattern recognition):

  - division set of measurements in a tracking detectors into subsets
  - each subset contains measurements believed to originate from the same particle

- Track fitting:

  - starts with the measurements inside one subset as provided by the track finder

Track reconstruction (general scheme)

1. event generation (Pythia8 or another particle generators)

2. simulation => produce sim-hits in vertex and straw-tracker detectors using SPDroot

3. produce digi-hits => apply smearing for vertex and straw hits

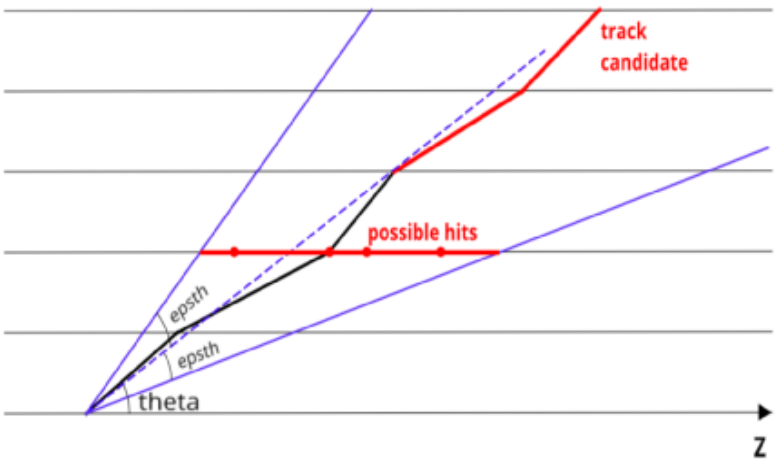
4. pattern recognition => find track candidates with the set of vertex and straw hits:

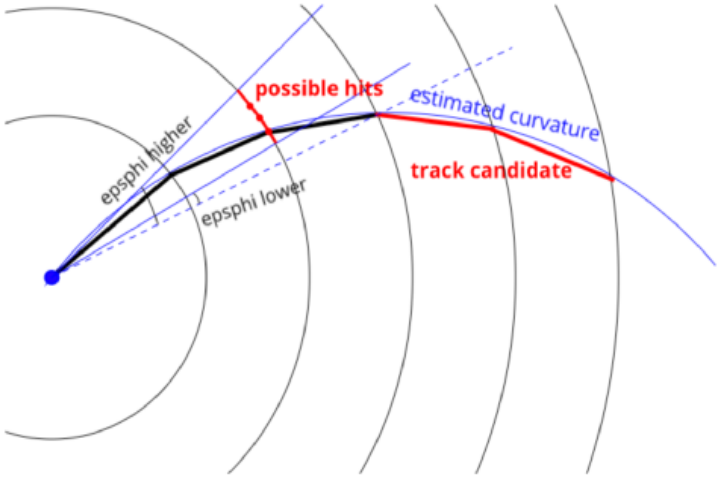
   - construct track seeds using hits in vertex detector;
   - add consistently straw-hits from tracker detector to track candidate;
   - finally create track candidates which contains as vertex and straw tracker hits;
   - apply some cleaning procedure (remove duplicates).

5. do Kalman fit of remaining track candidates

6. write reconstructed track with the set of parameters to output root-file

Track seeds in vertex detector





1. produce 2-points seeds using 2-hits combination in the different vertex layers

2. produce 3-points, 4-points and 5-points seeds from 2-points adding new point from another layer with taking into account the next conditions:

   - theta-angle compatibility => all hits should be inside some δθ - range
   - use 3-hits for track curvature estimation in XY - plane (for 2-points seeds zero point is used)
   - phi-angle compatibility => new hit should be inside some δφ - range

3. then next merging procedure is applied:

   a) if 3-points seed contains all points of some 2-points seed => 2-points seed is removed
   b) if 4-points seed contains all points of some 3-points seed => 3-points seed is removed
   c) if 5-points seed contains all points of some 4-points seed => 4-points seed is removed

Track seeds in vertex detector (2)

4. z-coordinate of primary vertex (or vertices) can be estimated using this set of seeds

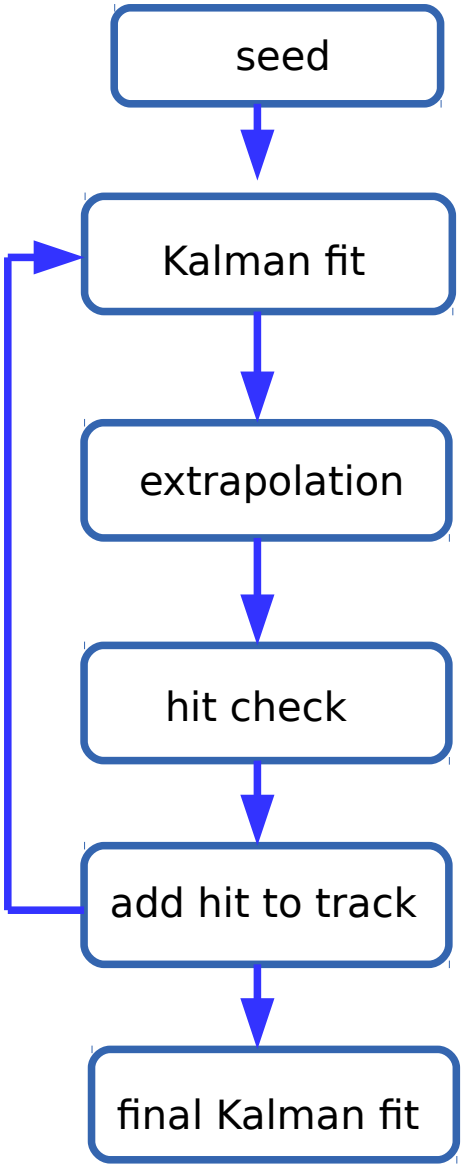
5. check all seeds on compatibility with the “primary” vertices

6. finally produce => 2-points, 3-points, 4-points and 5-points seeds

7. seed finding procedure also provides the next track seed parameters:

    a) seed charge
    b) seed curvature or radius
    c) seed theta
    d) seed phi (phi in 1-st seed point)
    e) estimated z-coordinate of track seed

Track reconstruction (adding straw hits)



input seed as defined with vertex detector hits

do Kalman fit and define primary track parameters

track extrapolation to the plane with straw tubes and define hit position on the plane

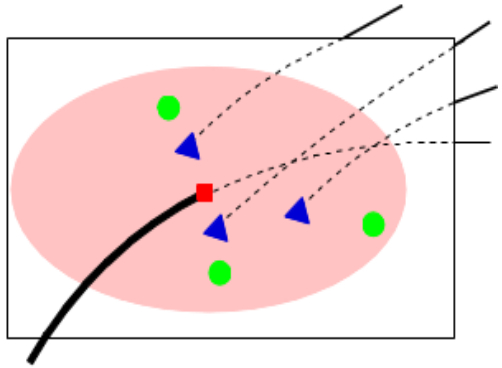
check distance and chi2 between hit point position and “fired” straw tubes on this plane

add “good” straw hits to track candidate and update track parameters (do new Kalman fit)

do final Kalman fit

Track reconstruction (adding straw hits) (2)

1. if 2 or more straw hits (blue triangle on picture) on detector layer are compatible with the track candidate, the next reconstruction options could be used:



   a) use the best hit with minimum chi2 (only one);
   b) the track parameters are updated using all straw hits which are compatible with the track candidate;
   c) for each new hit the new track candidate is created, all previous hits are copied to the new track candidate and then extrapolation and fitting procedures are applied for all new candidates => so called Kalman tree method;

   d) last two options are implemented in present track reconstruction program.

2. finally, “big” number of track candidates are produced and each candidate contains vertex and straw detector hits

3. then cleaning procedure is applied for track candidates (remove duplicates):

   a) check common number of vertex and straw detector hits;
   b) define track quality value => q = Nhits – coeff * chi2 (where chi2 of track fit);
   c) if common number of hits is greater than some value (~40%) => remove low quality track candidate.

4. do final Kalman fit of remaining track candidates

5. write reconstructed track parameters in SpdTrackRC with the same set of track parameters as for the usual SpdTrackMC

Performance of track reconstruction

1. the next MC samples are simulated:
   a) 10 muons of 1 GeV/c momentum (5 with positive and 5 with negative charge)
      and uniform distributed in theta and phi angles;
   c) Minimum Bias events;
   d) Open charm events.

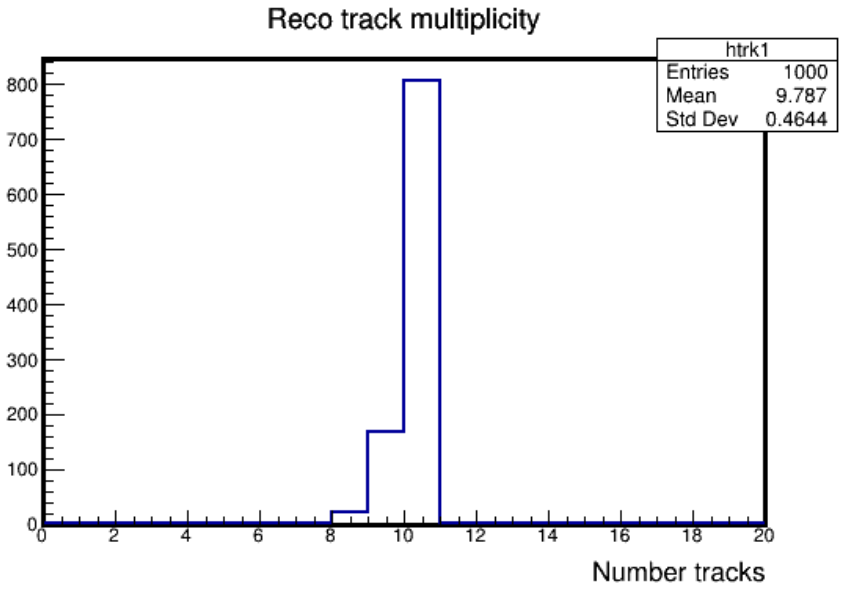
2. “ideal” track reconstruction – Kalman track fit using exact MC information about hits
   which are belonged to this track

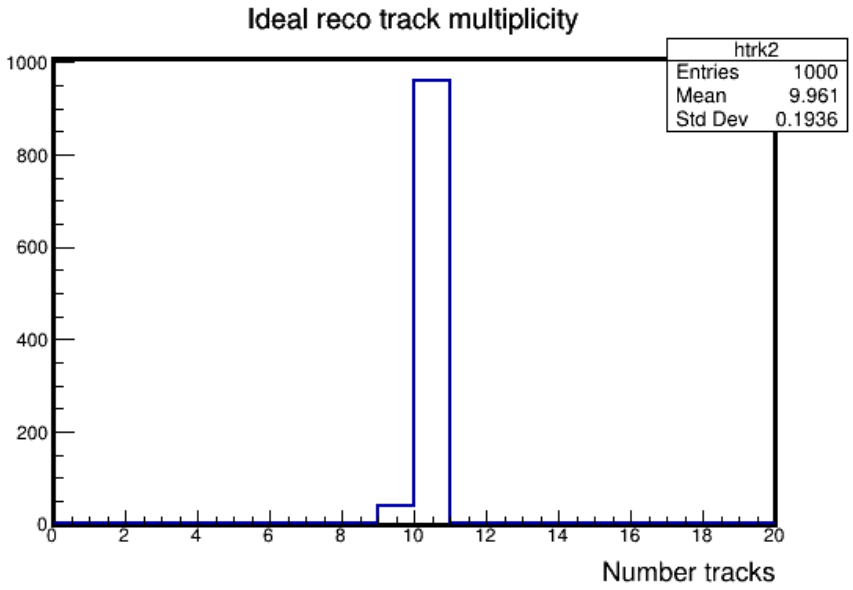
3. “ideal” track reconstruction can be applied to the different particle generation level:
   a) 1-st generation - only primary particles from interaction vertex are considered;
   b) 2-nd generation – primary and secondary particles are considered;
   c) 3-d generation - primary, secondary and further particles are considered.

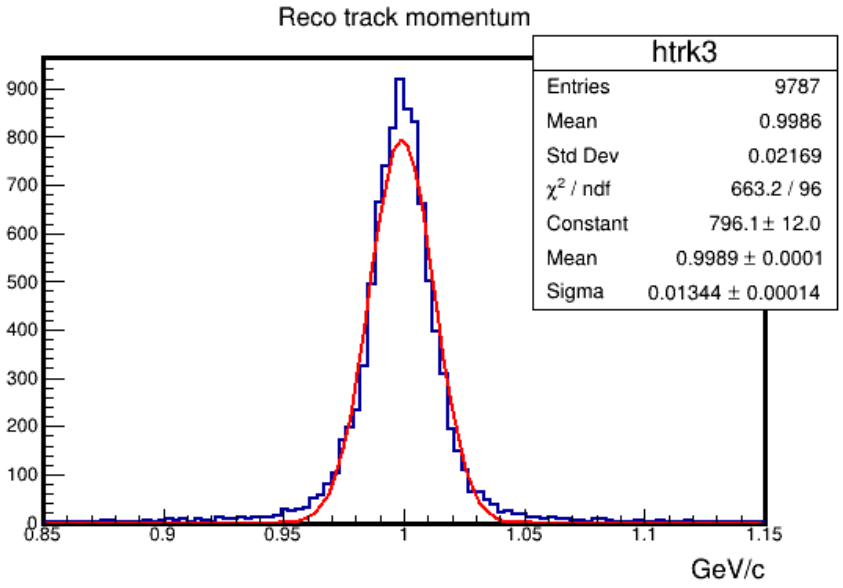
4. estimation of track reconstruction efficiency:
   a) consider “ideal” reconstructed track;
   b) try to find among reconstructed tracks such track which can be considered as identical
      to “ideal” reconstructed track => that means both tracks have the same vertex hits
      and also have 50 % same “straw” hits.

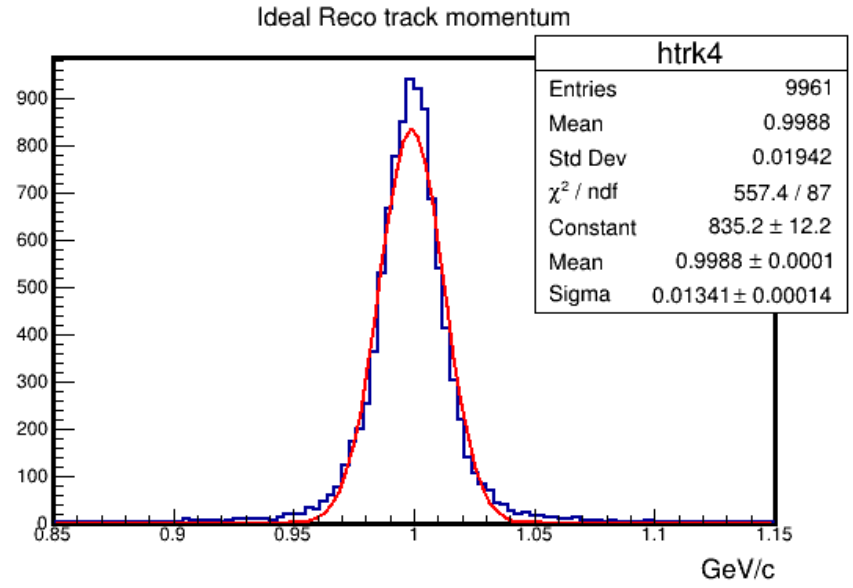
5. estimation of fake reconstruction rate:
   a) consider reconstructed track;
   b) try to find among “ideal” reconstructed tracks such track which can be considered as
      identical to reconstructed track => that means both tracks have the same vertex hits
      and also have 50% same “straw” hits;
   c) if such “ideal” reconstructed track is not found => this reconstructed track is
      considered as fake track

General properties (muon sample)

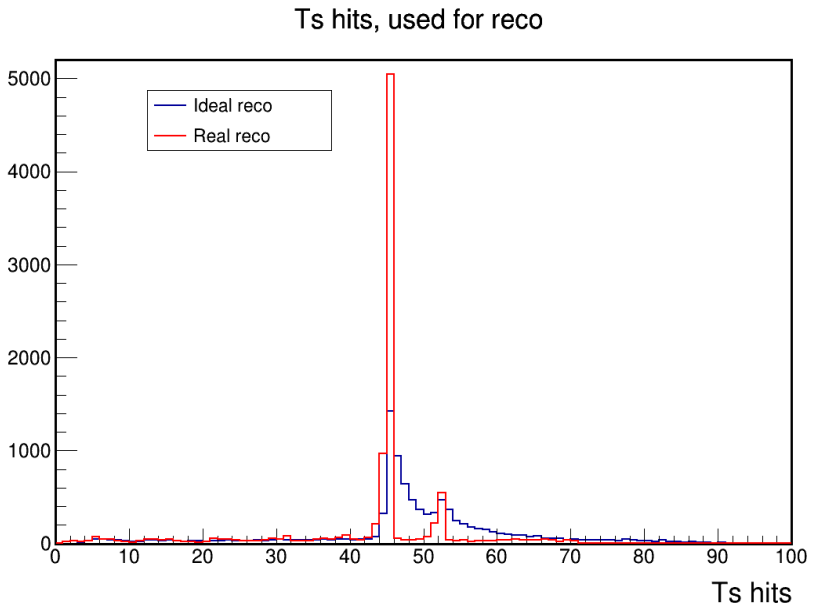


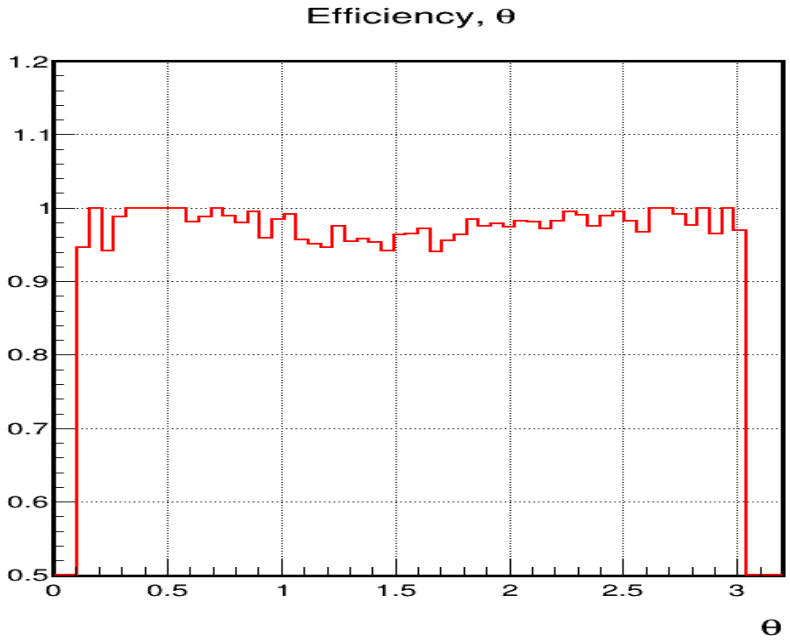


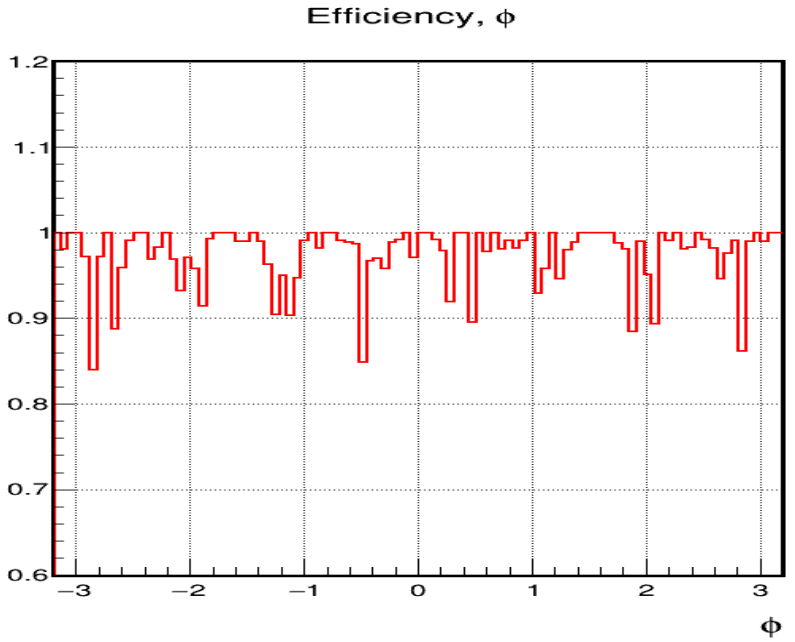




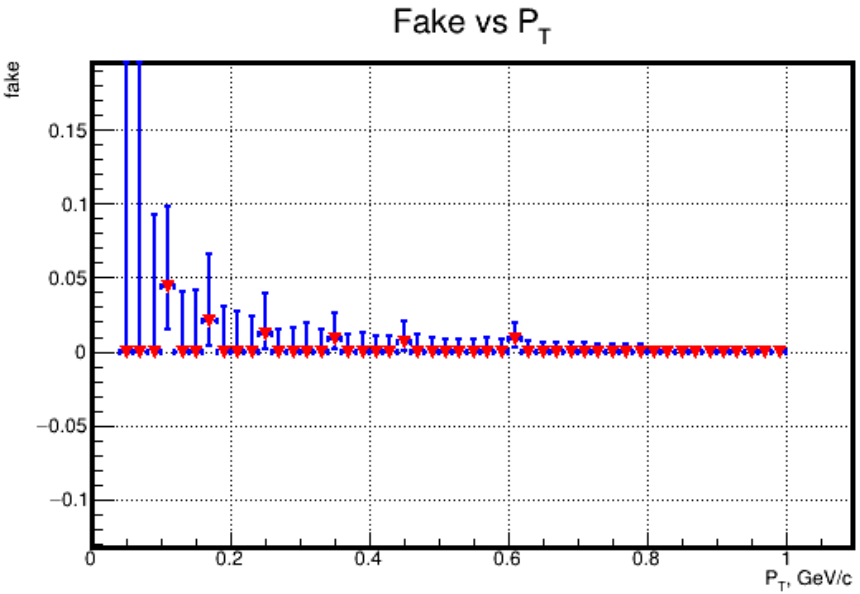
Reconstruction efficiency (muon sample)

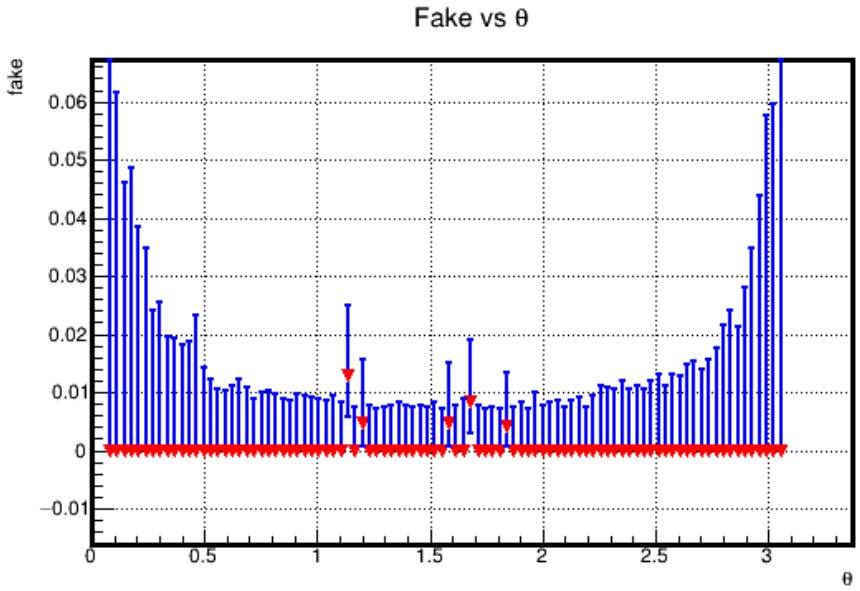


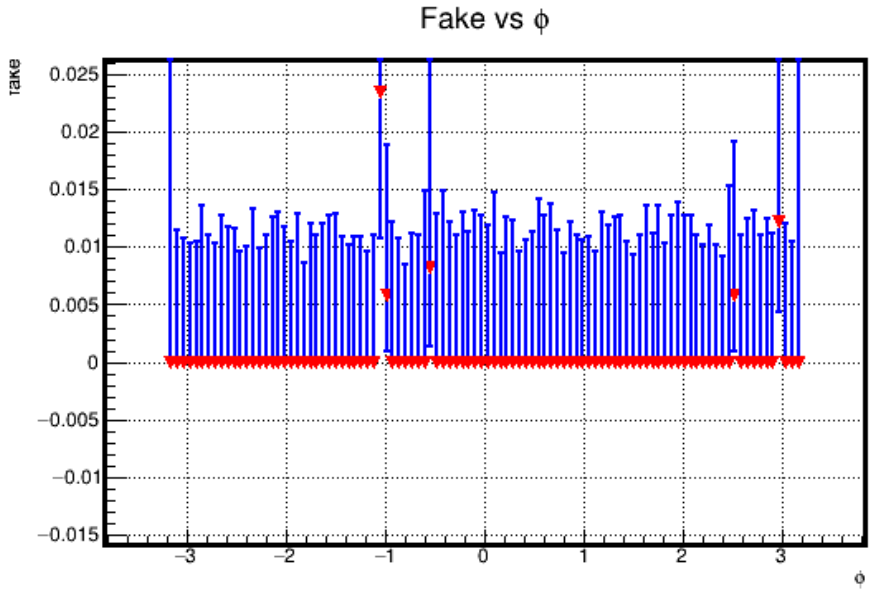




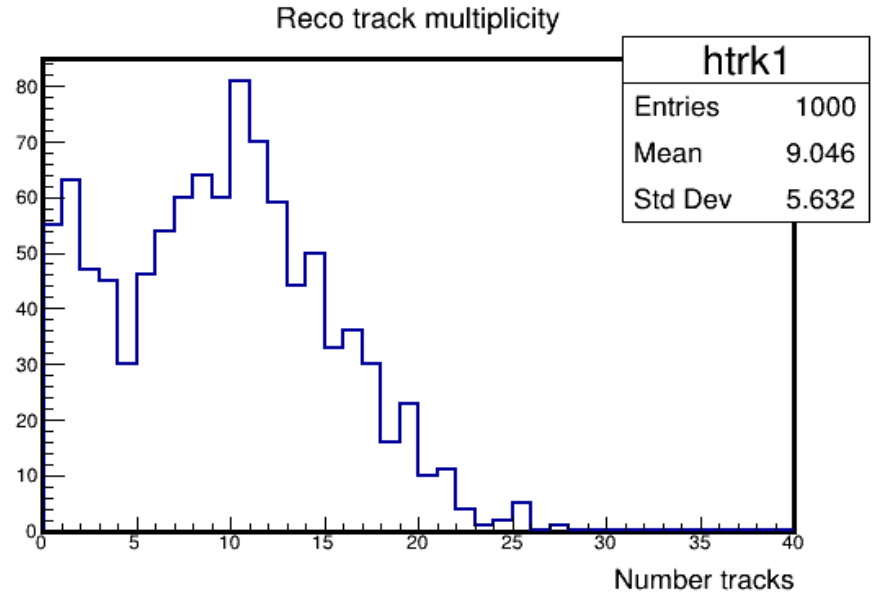
Fake rate (muon sample)

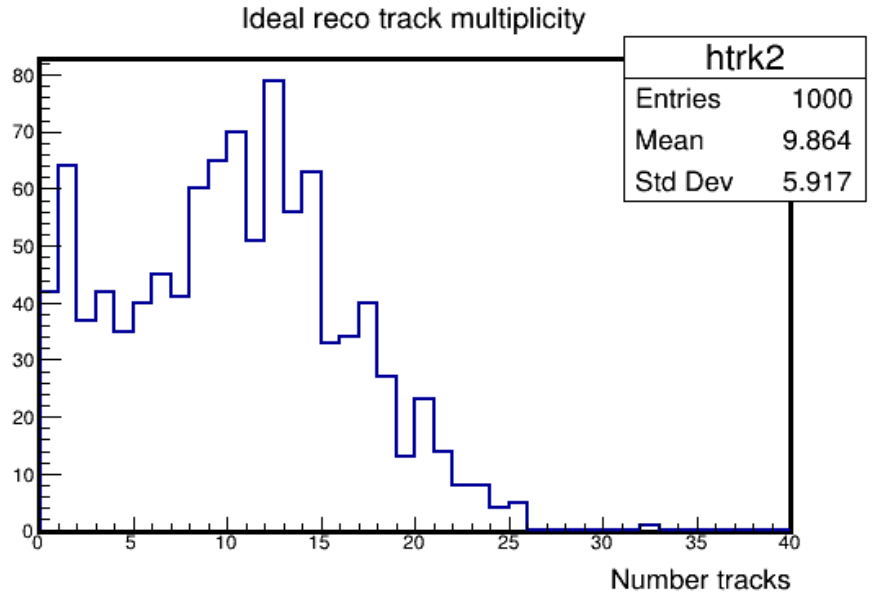


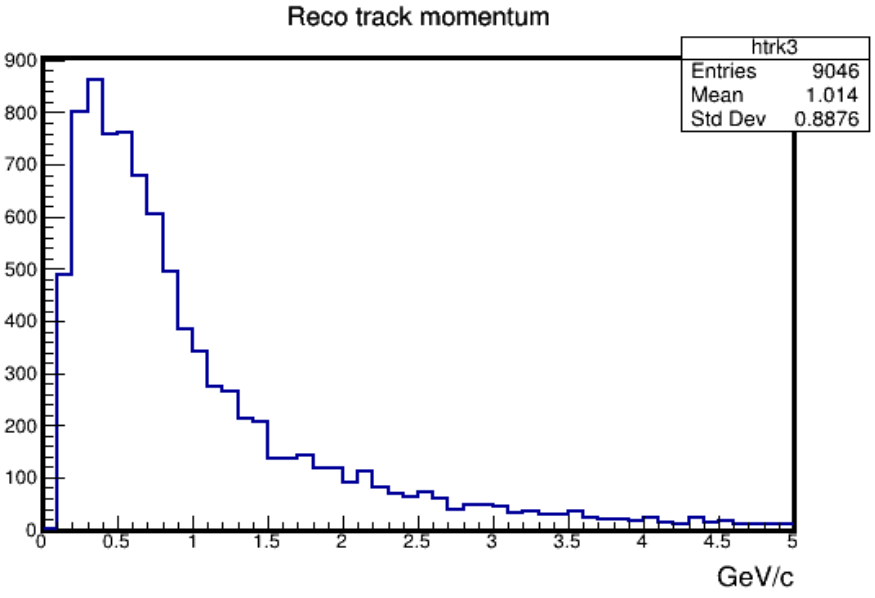


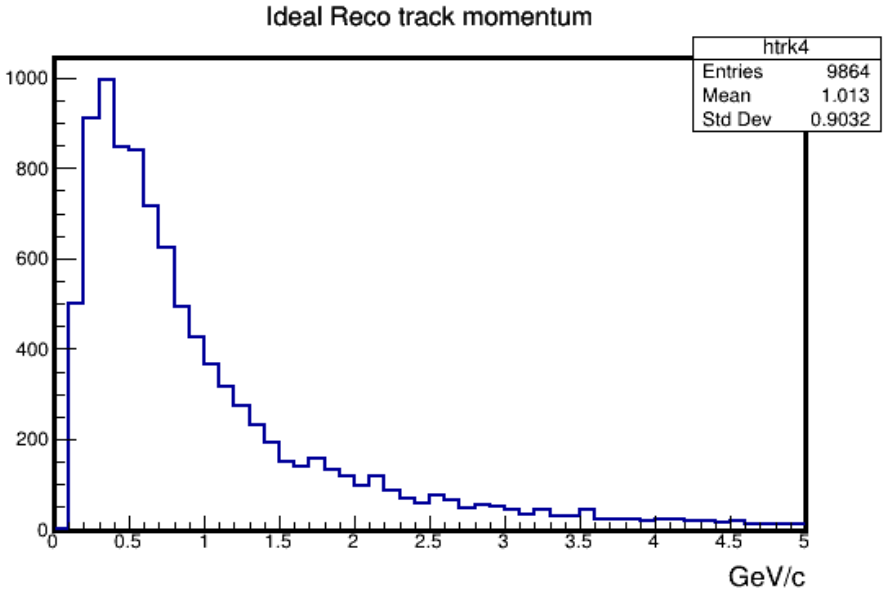


General properies (MB sample)

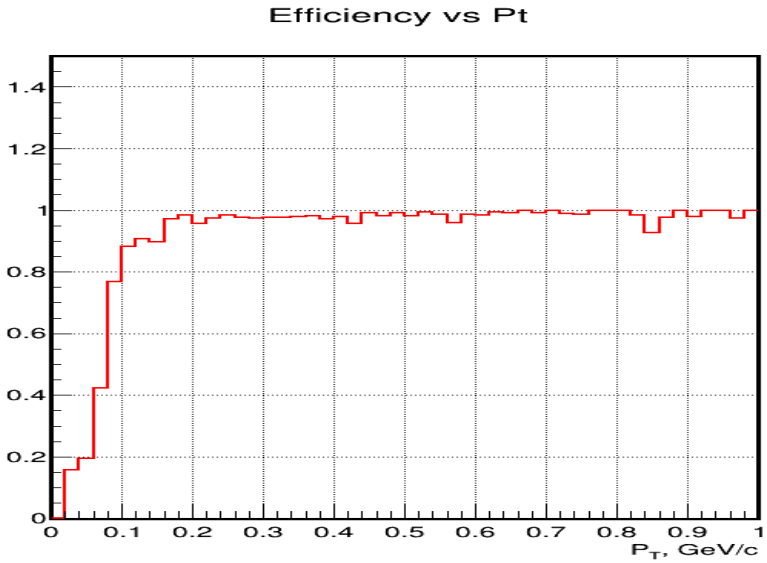


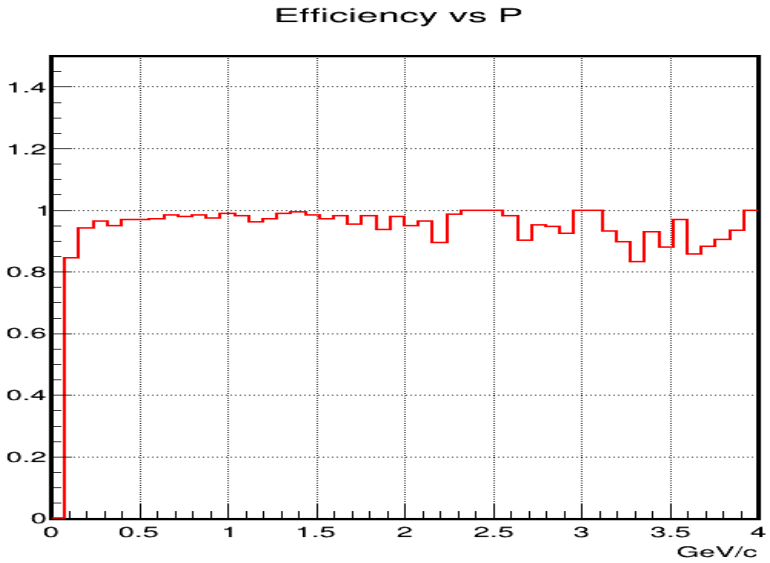


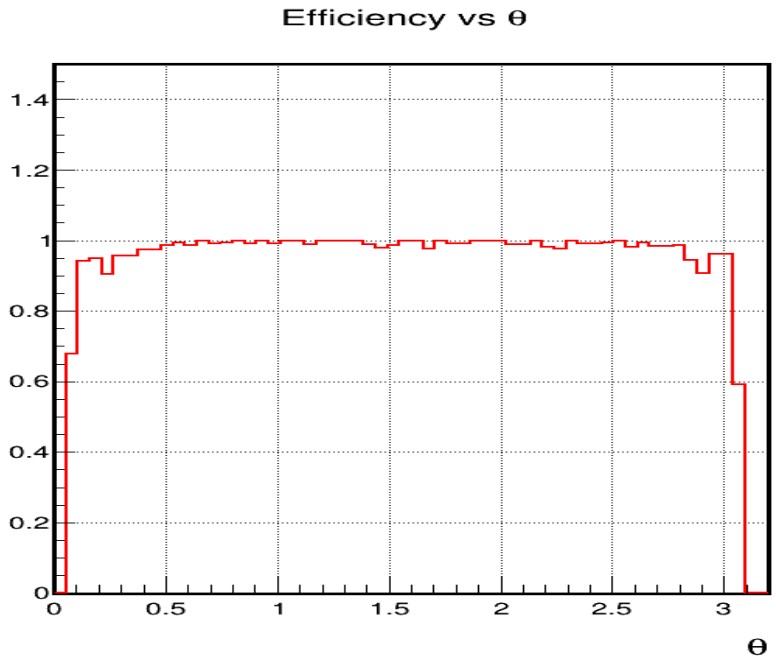


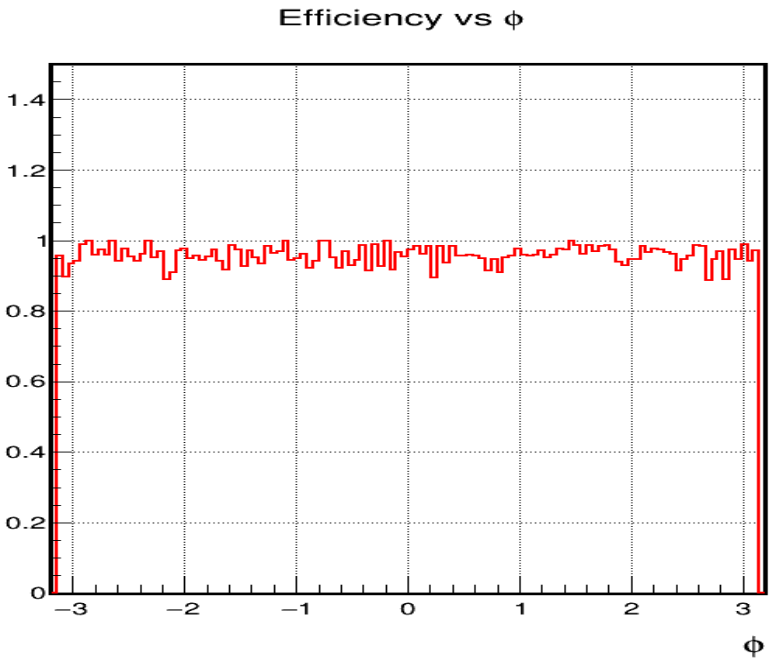


Reconstruction efficiency (Minimum Bias)

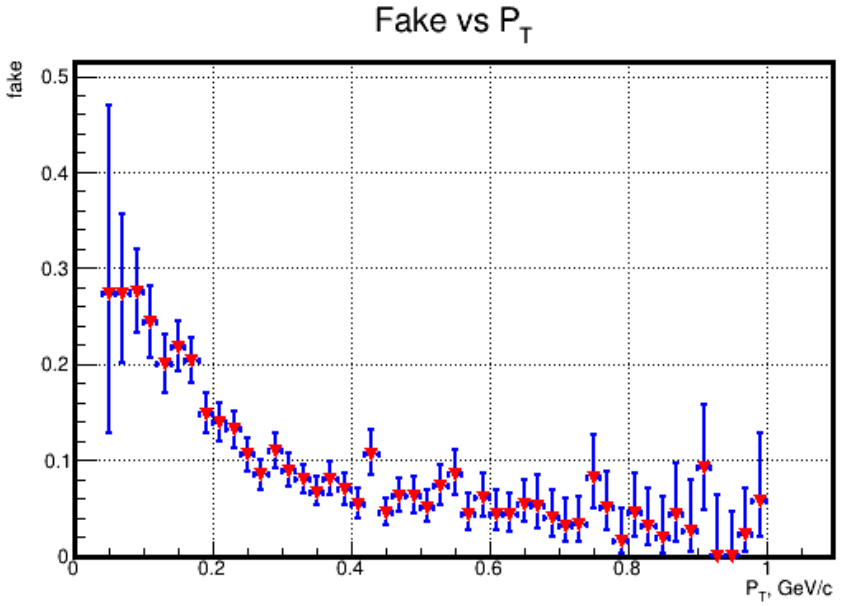


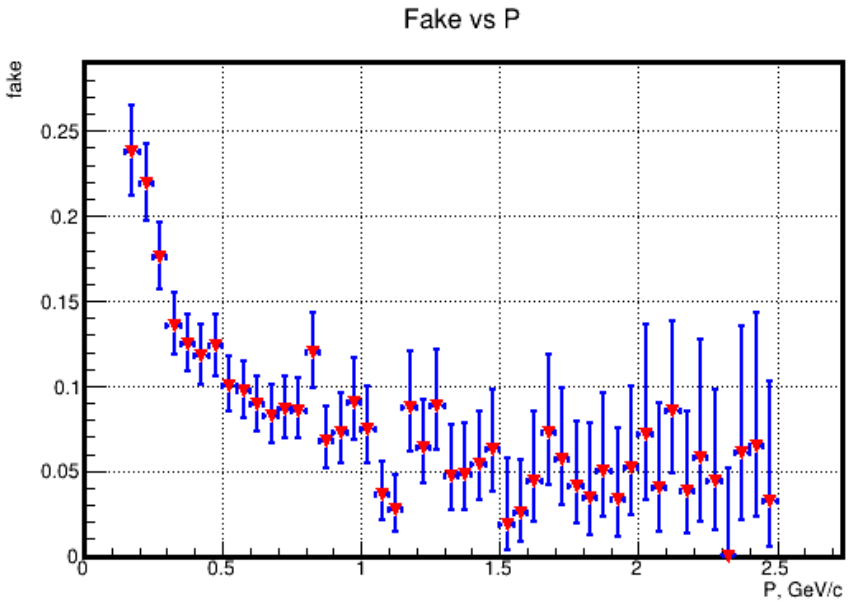


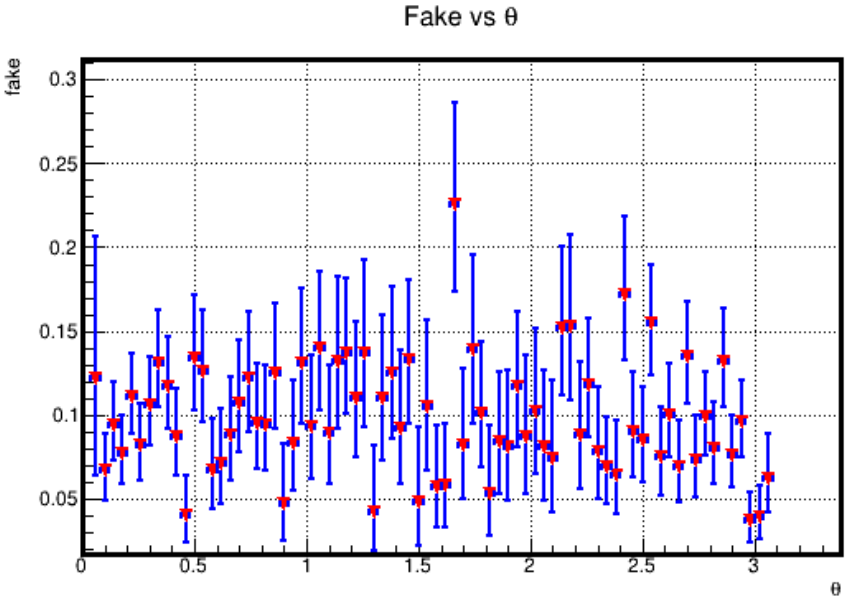


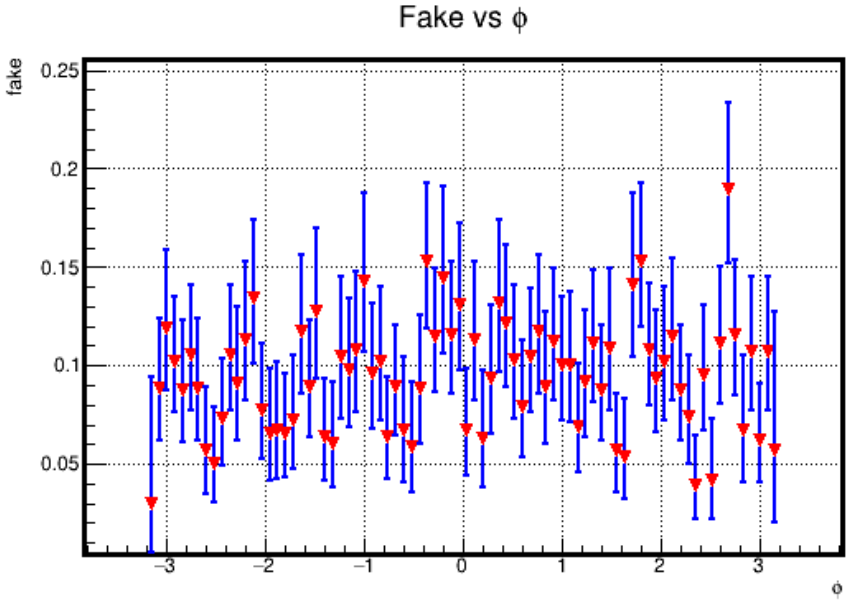


Fake rate (MB, 1-st generation)

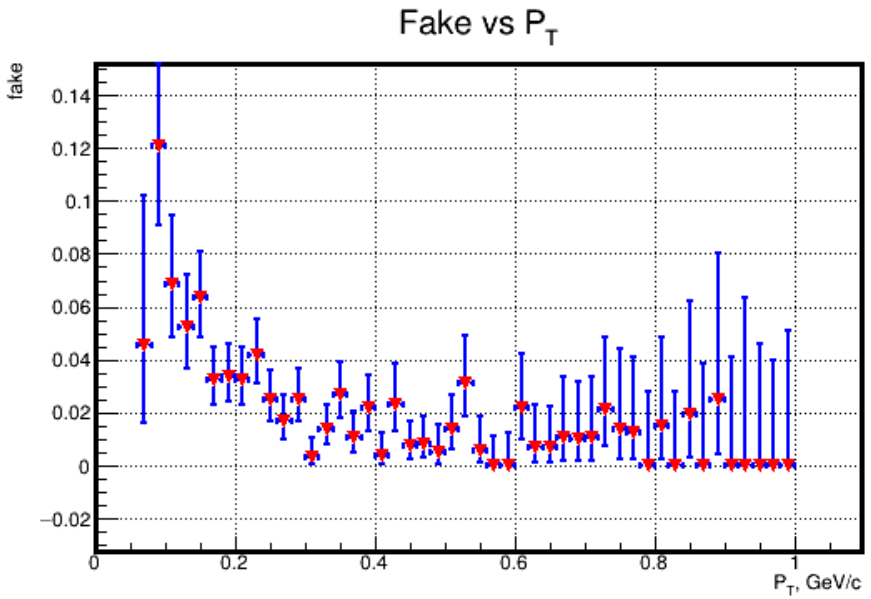


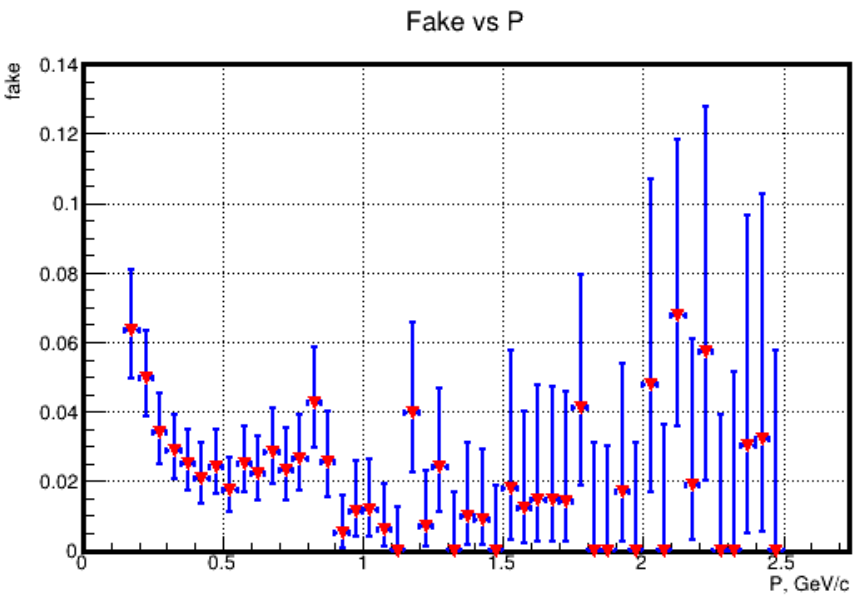


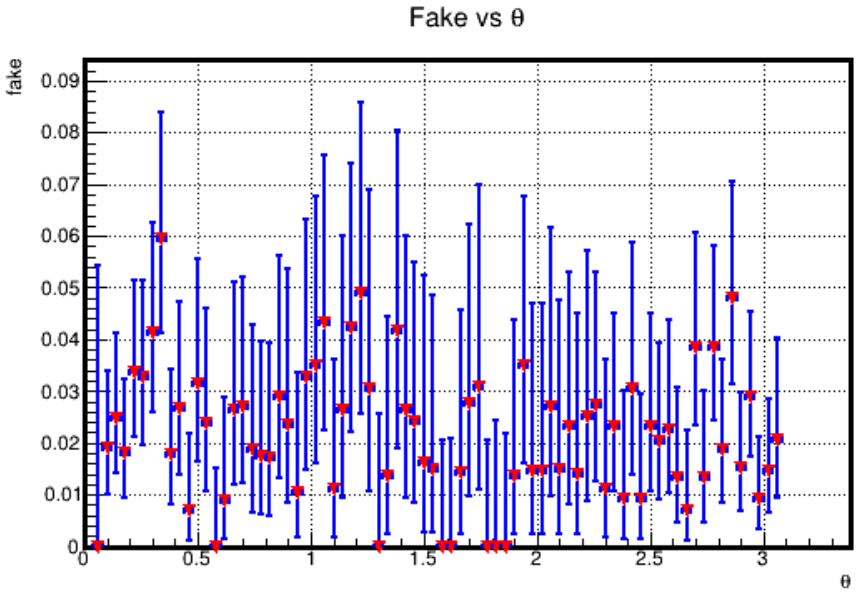


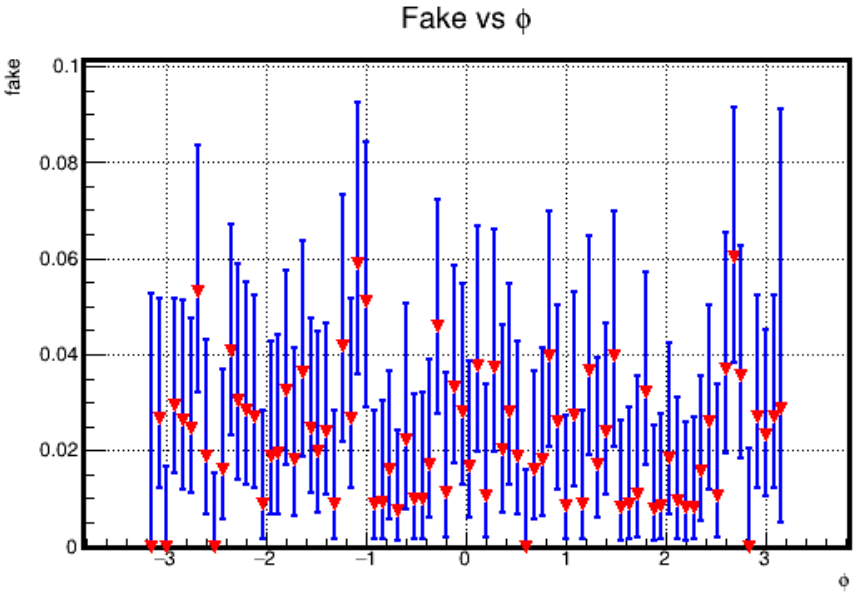


Fake rate (MB, 2-nd generation)

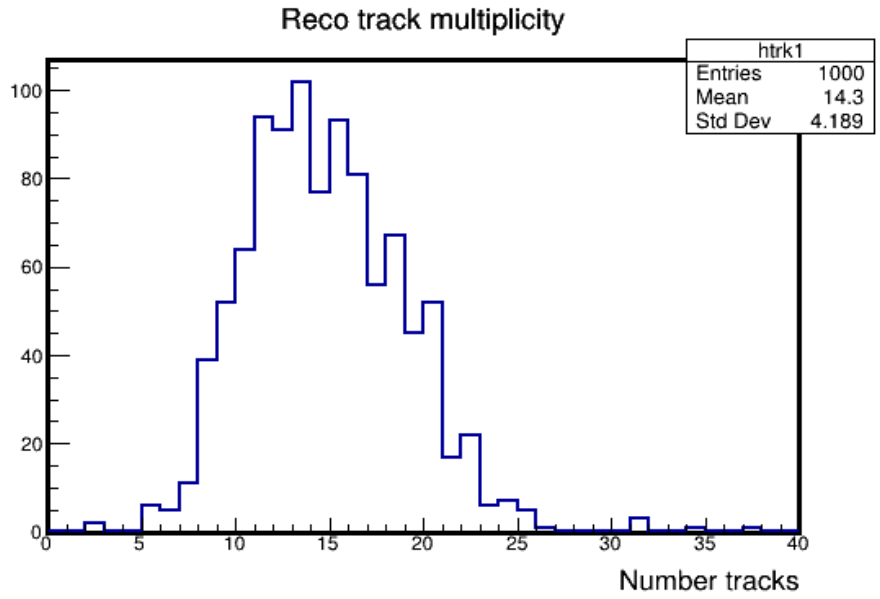


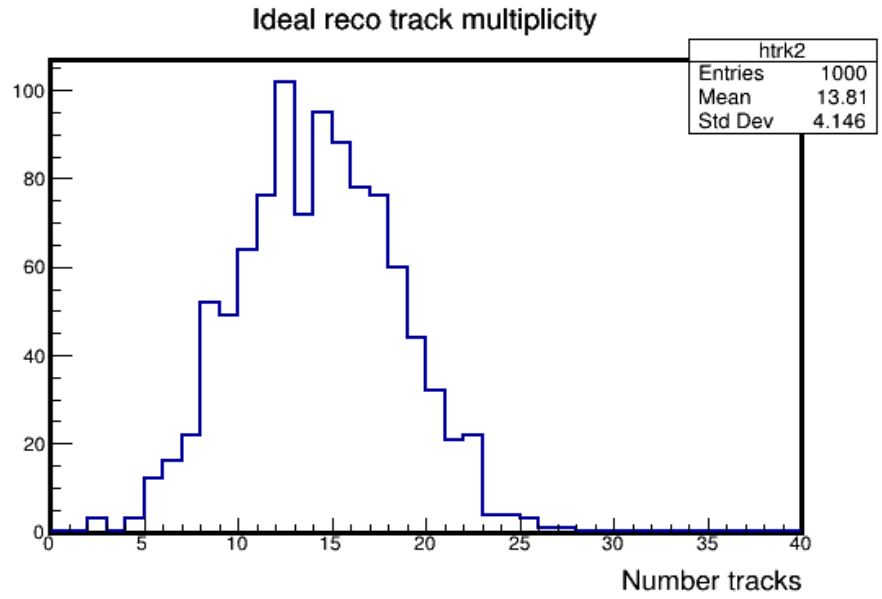


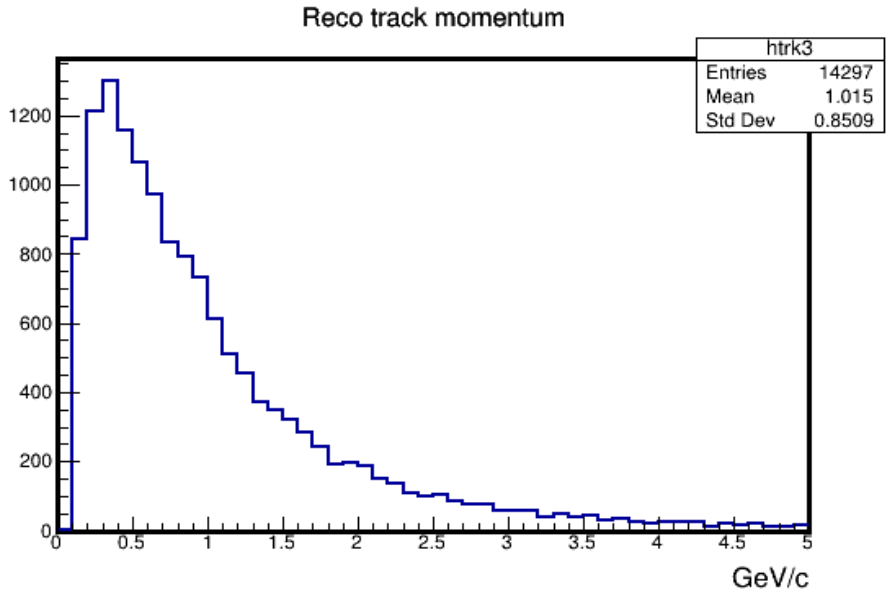


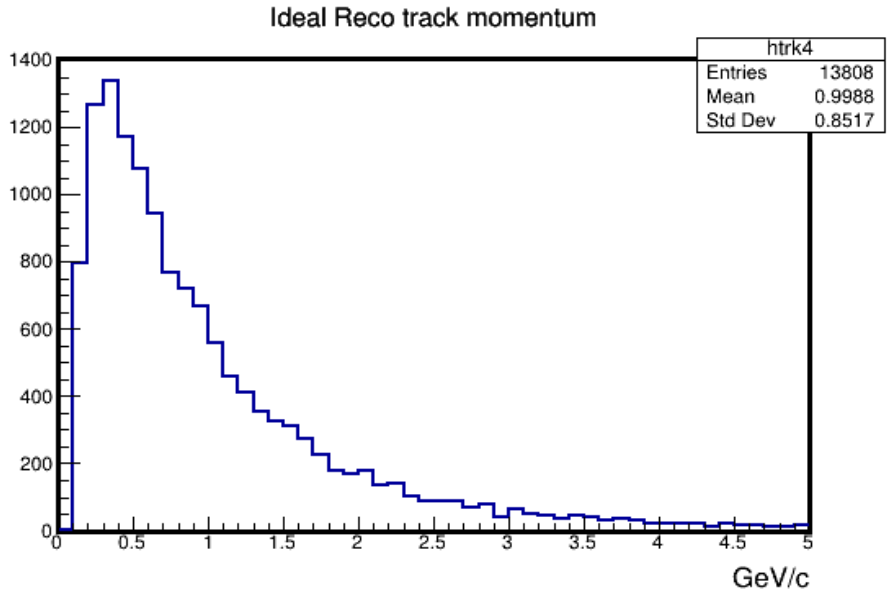


General properties (open charm sample)

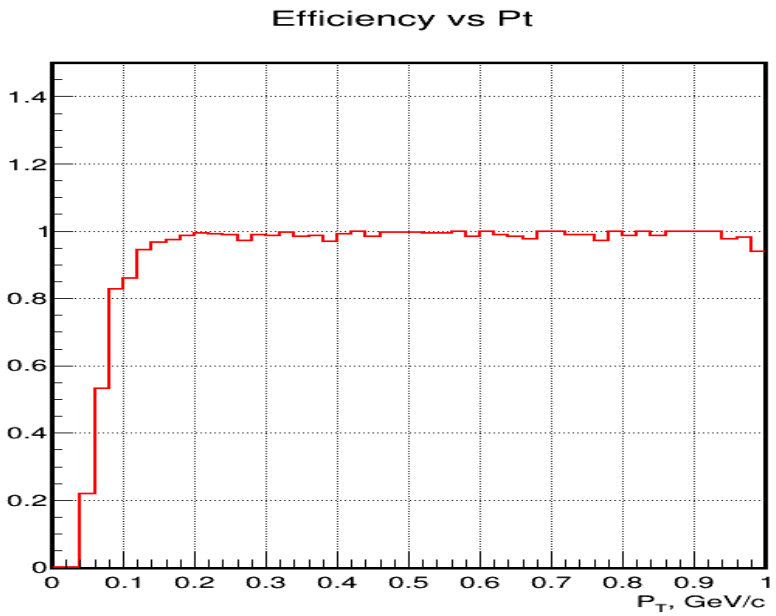


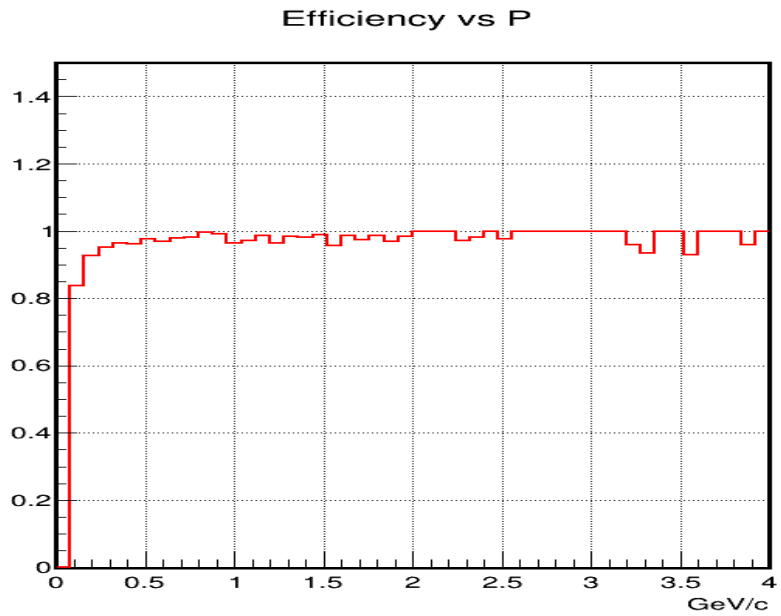


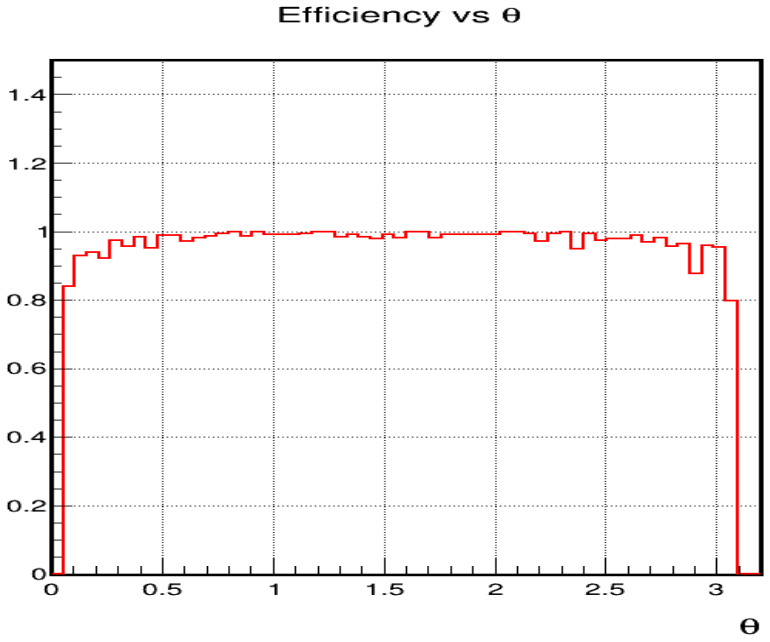


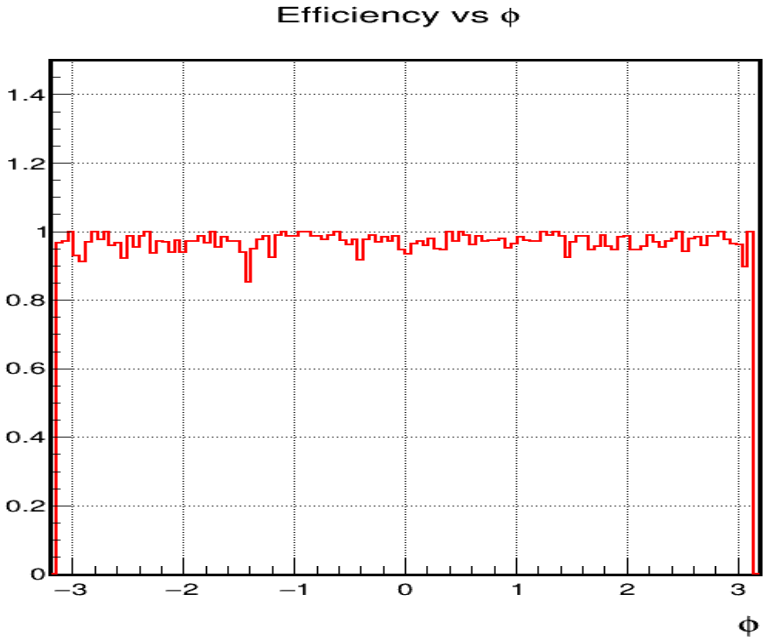


Reconstruction efficiency (open charm)

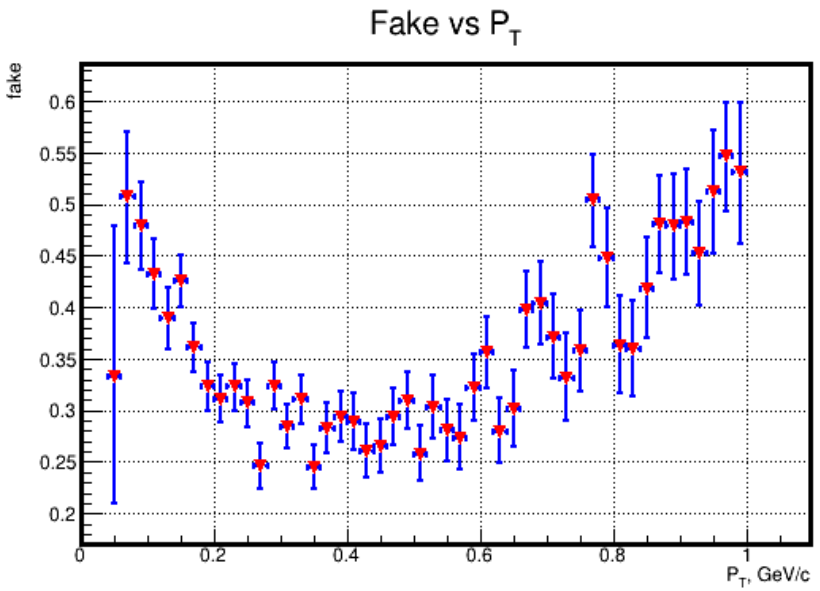


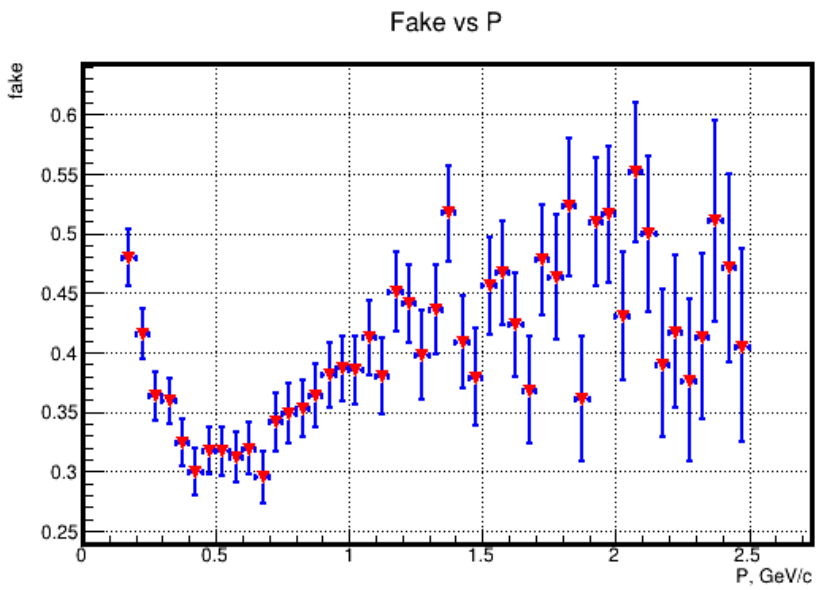


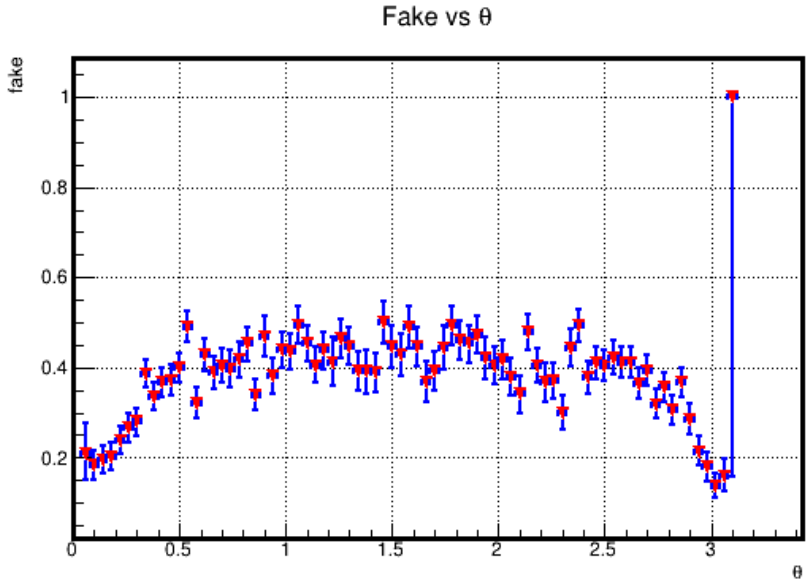


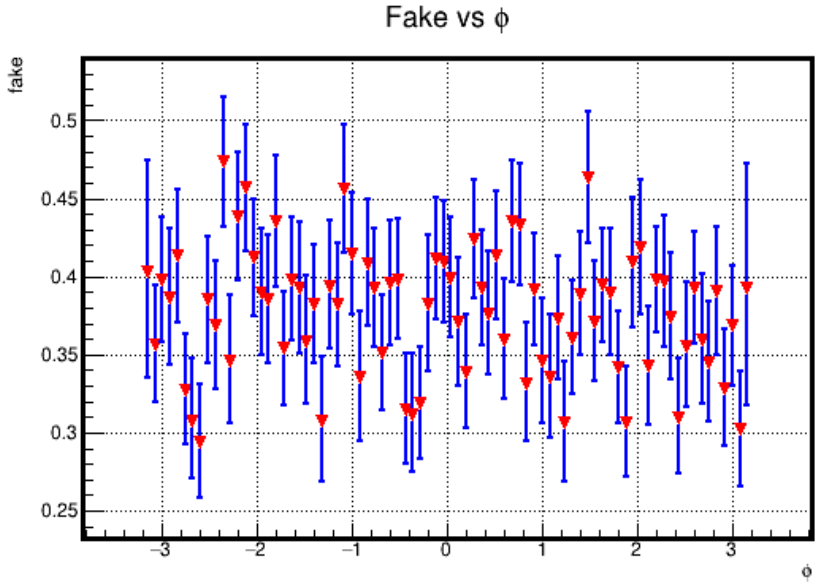


Fake rate (open charm, 1-st generation)

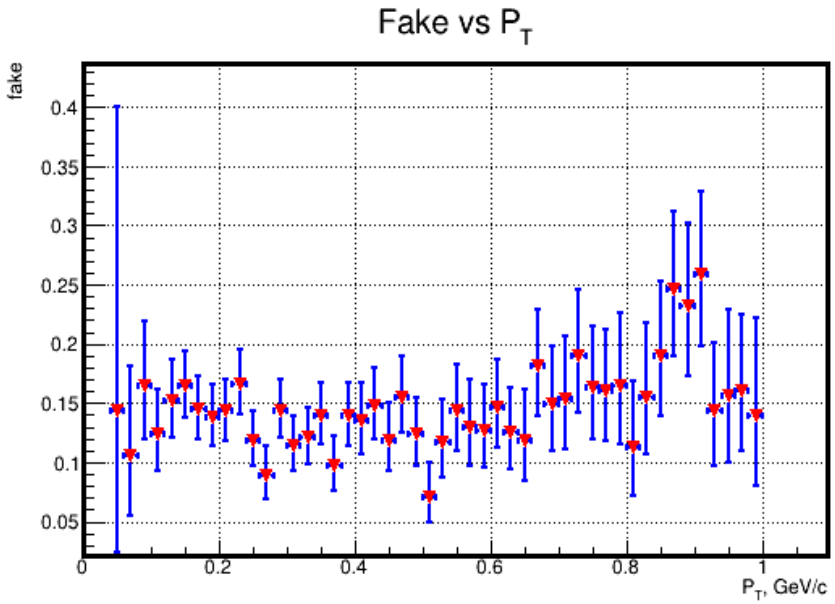


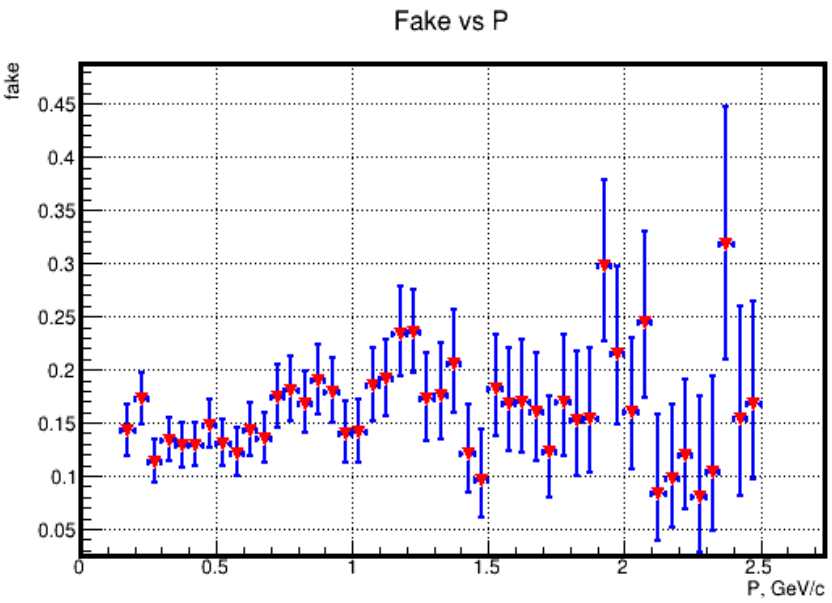


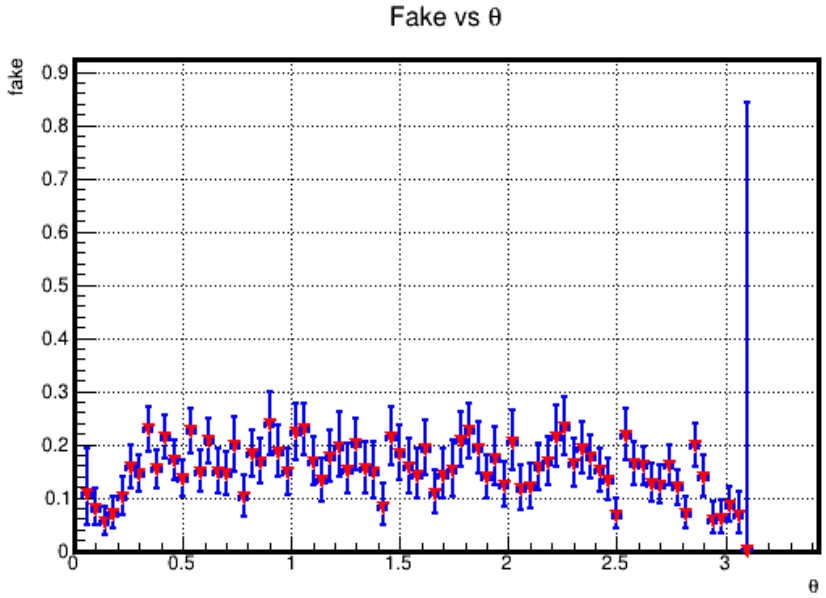


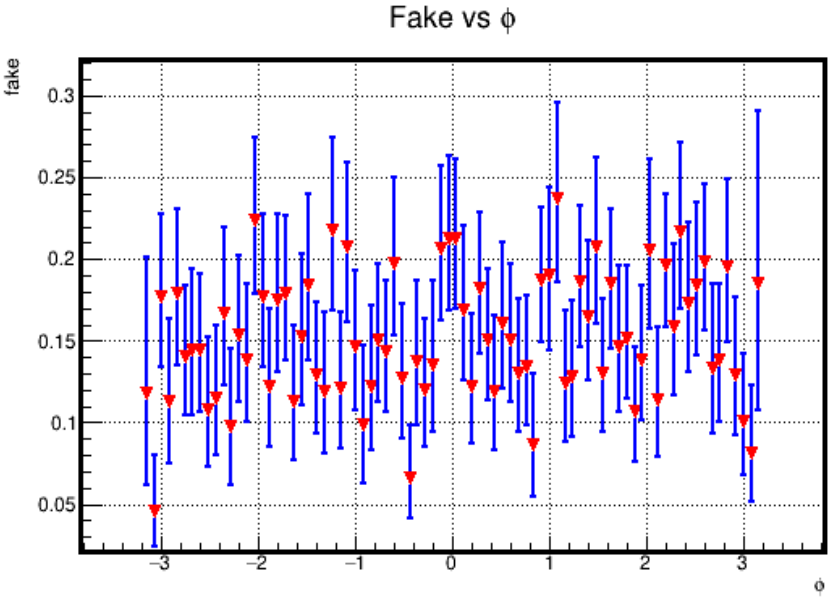


Fake rate (open charm, 2-nd generation)

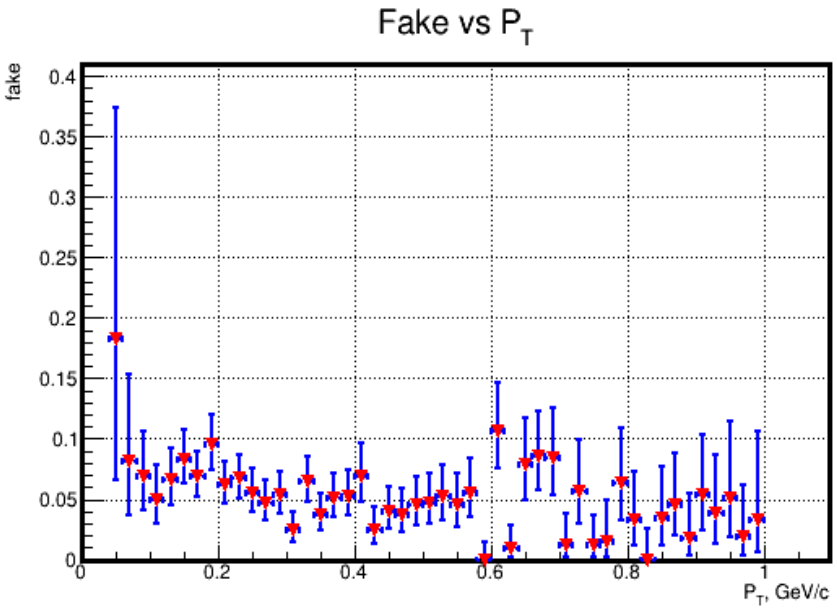


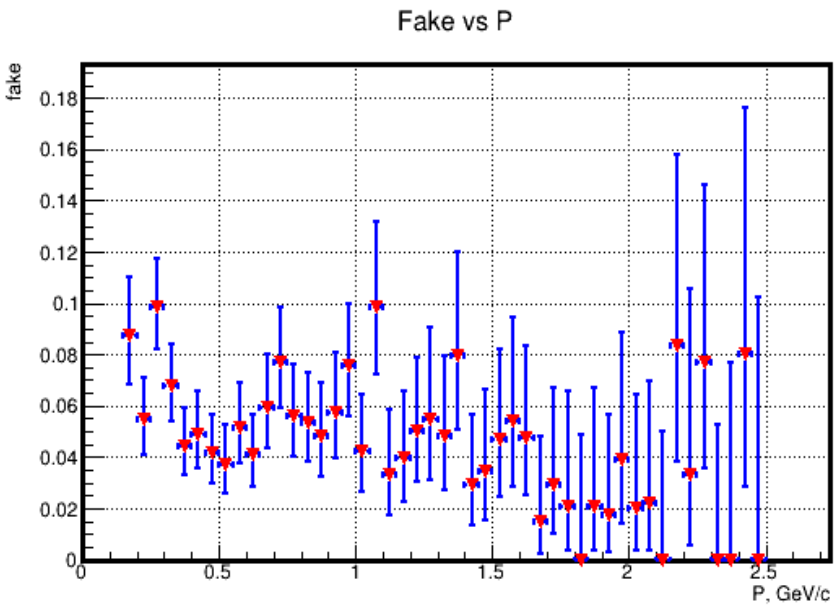


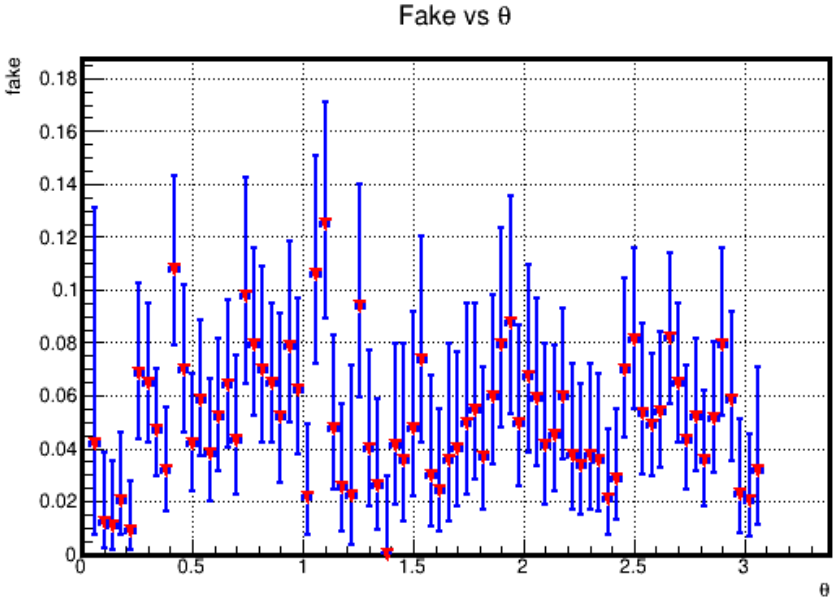


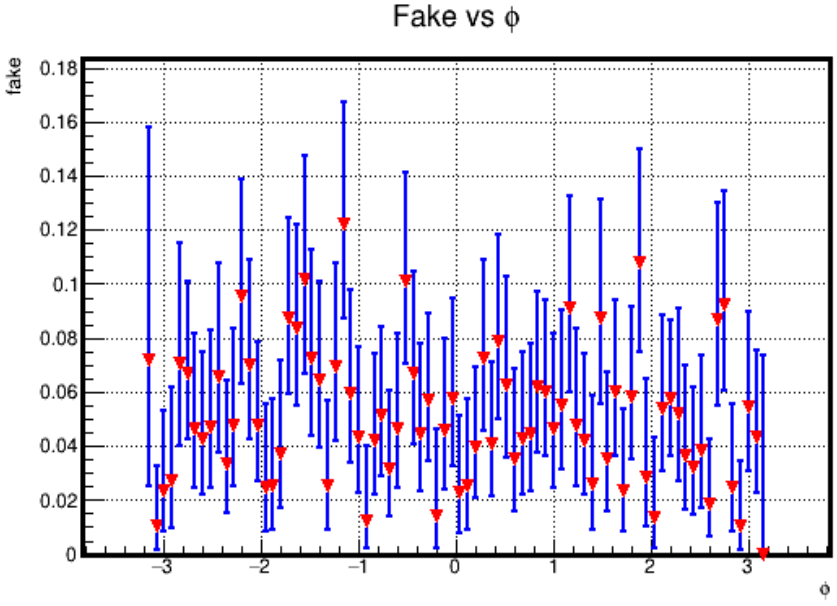


Fake rate (open charm, 3-nd generation)









Summary and plans

1. 1-st version of track reconstruction is ready and implemented to SPDroot

2. reconstruction algorithm shows good track reconstruction efficiency and low fake rate

3. time estimation for Minimum Bias events reconstruction (2.8 GHz notebook):
   a) “ideal” track reconstruction => ~2.9 sec/event
   b) present track reconstruction => ~25 sec/event

Future plans:

1. main task – to decrease the reconstruction time:

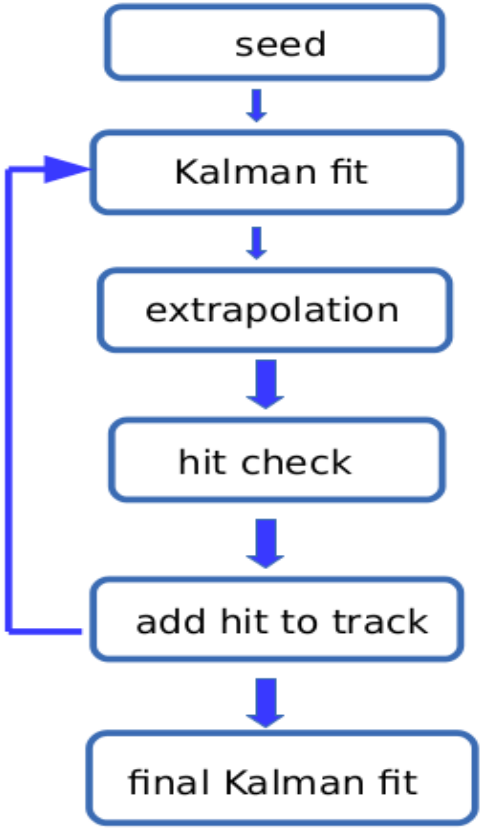
   a) change track fitting procedure (Genfit – program)
   b) study possibility to use analytic track propagation in non-uniform magnetic field (HERA-B, LHC-B, CBM experiments as examples)

2. investigate track reconstruction procedure with several interactions in one events

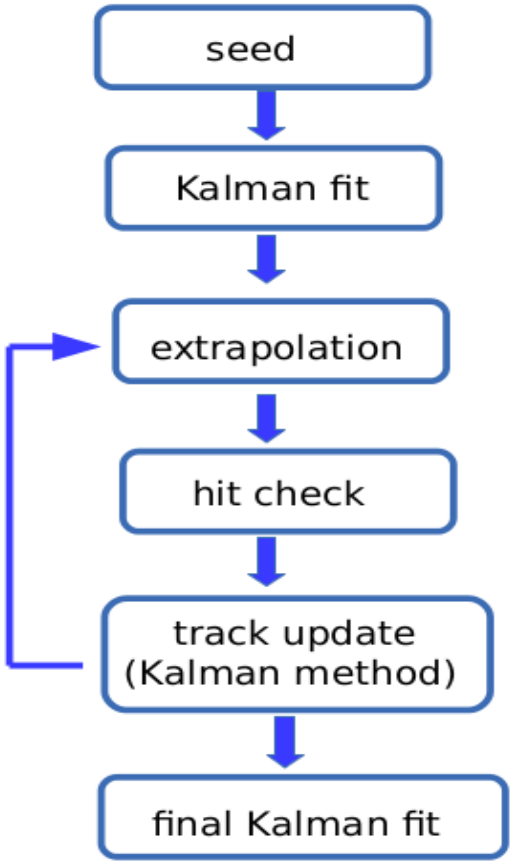
3. develop the finding algorithm for secondary interaction

Future plans (decreasing track reconstruction time)

Present track finding procedure



New track finding procedure



1. time estimation for Minimum Bias events reconstruction (2.8 GHz notebook):
   a) “ideal” track reconstruction => ~2.9 sec/event
   b) present track reconstruction => ~25 sec/event
   c) new approach => ~3.9 sec/event

2. SPDroot release with new track finding procedure is foreseen in 1-2 months