SPD S&C meeting,
7 December 2021

Status of track reconstruction for SPD experiment (update)

V. Andreev

Track reconstruction (general scheme)

1. 1-step => event generation

2. 2-st step (simulation) => produce sim-hits in vertex and straw-tracker using SPDroot

3. 3-d step => produce digi-hits (apply smearing for vertex and straw hits)

4. 4-th -step (pattern recognition) => find track candidates with the set of vertex and straw hits

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

5. do Kalman fit of remaining track candidates

6. write reconstructed track to output root-file

Summary and plans (from 23.11.2021 meeting)

1. 1-st version of track reconstruction is ready and added in SPDroot (thanks Artur)

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

3. time for track reconstruction of Minimum Bias events ~12 times greater than for “ideal” track fit (~25 sec/event comparison with ~2 sec/event on my notebook)

Future plans:

1. main task – to decrease the reconstruction time:

   a) study possibility for analytic track propagation in non-uniform magnetic field (example HERA-B, LHC-B, CBM experiments)

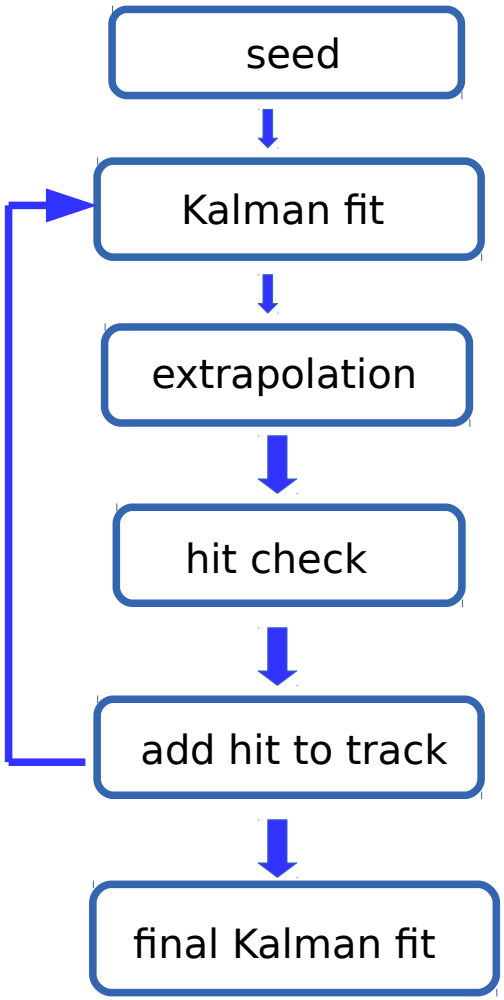
   b) change track fitting procedure (Genfit – program)

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

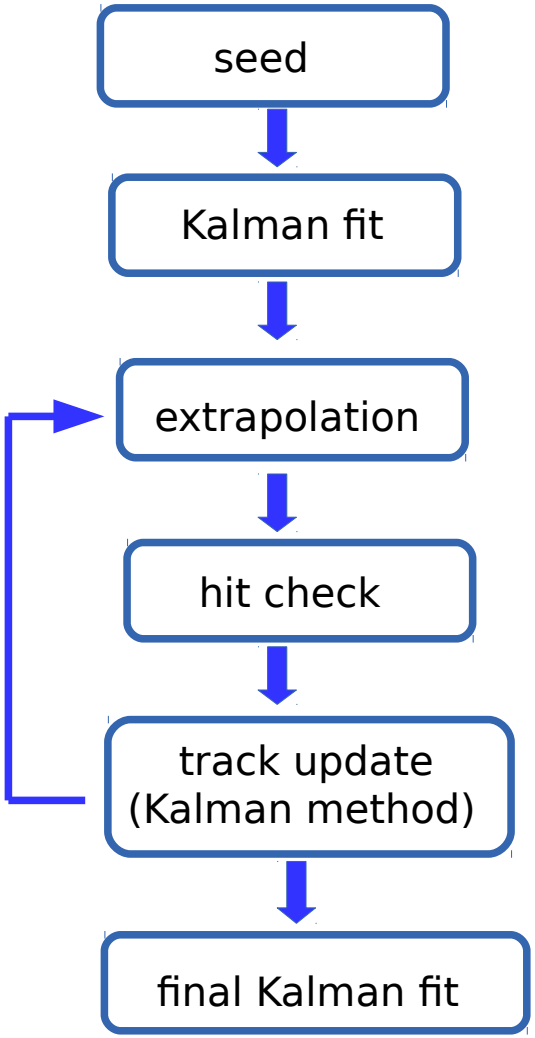
3. develop the finding algorithm for secondary interaction

New track finding procedure (adding straw hits)

Present track finding procedure



New track finding procedure



Results with new approach

Many thanks Igor Denisenko who provides very useful example !!

1. It updates track parameters using Kalman filter procedure (Genfit program)

2. It works inside SPDroot (uses standard SPDroot track parameters)

3. track reconstruction program was updated with this new approach

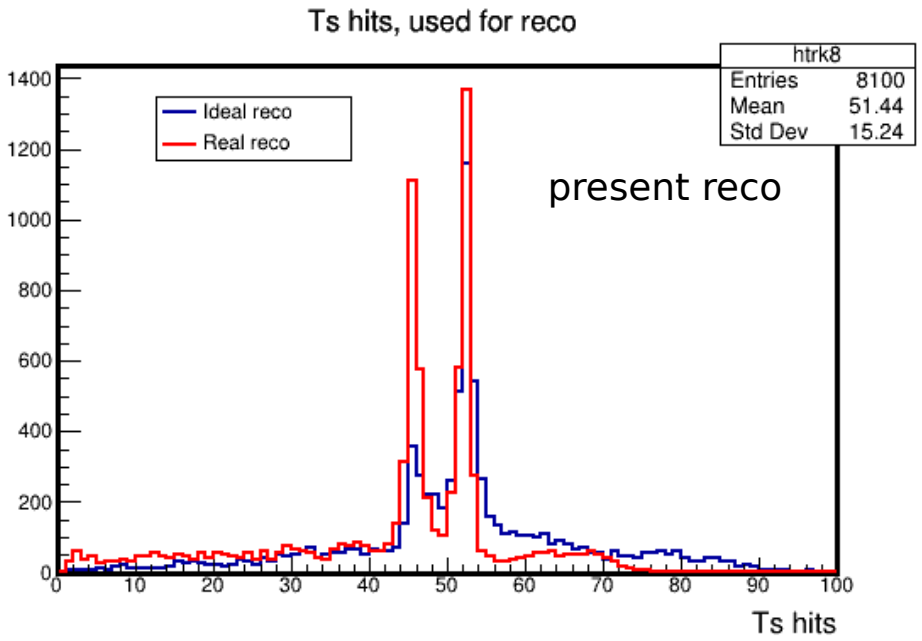
4. time estimation => Minimum Bias events (2 generation is considered => primary+secondary interaction) on my notebook 2.8 GHz:

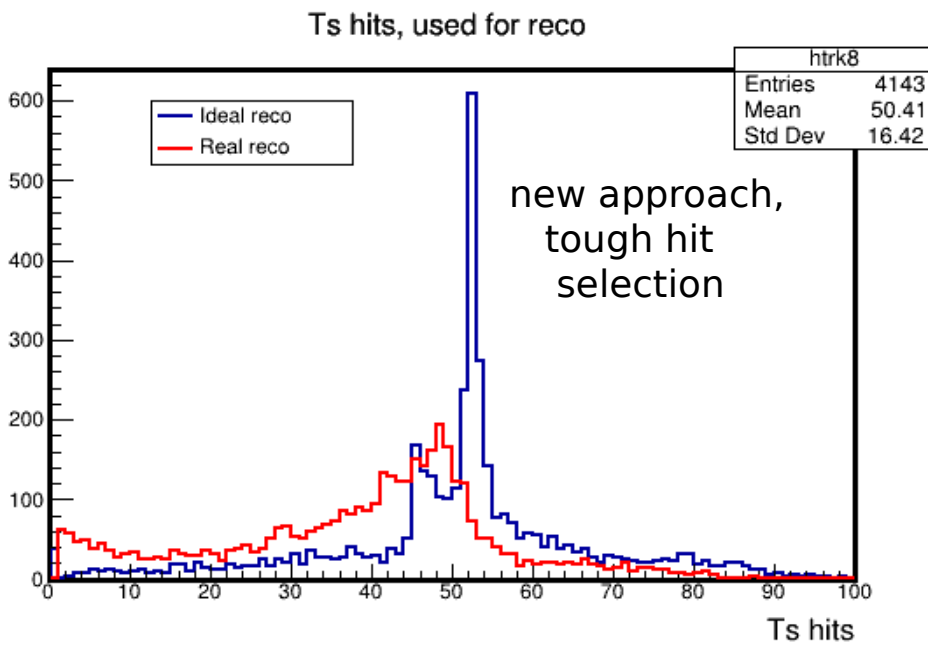
   a) “ideal” track reconstruction => ~2.9 sec/event
   b) present track reconstruction => ~25 sec/event
   c) new approach => ~3.9 sec/event

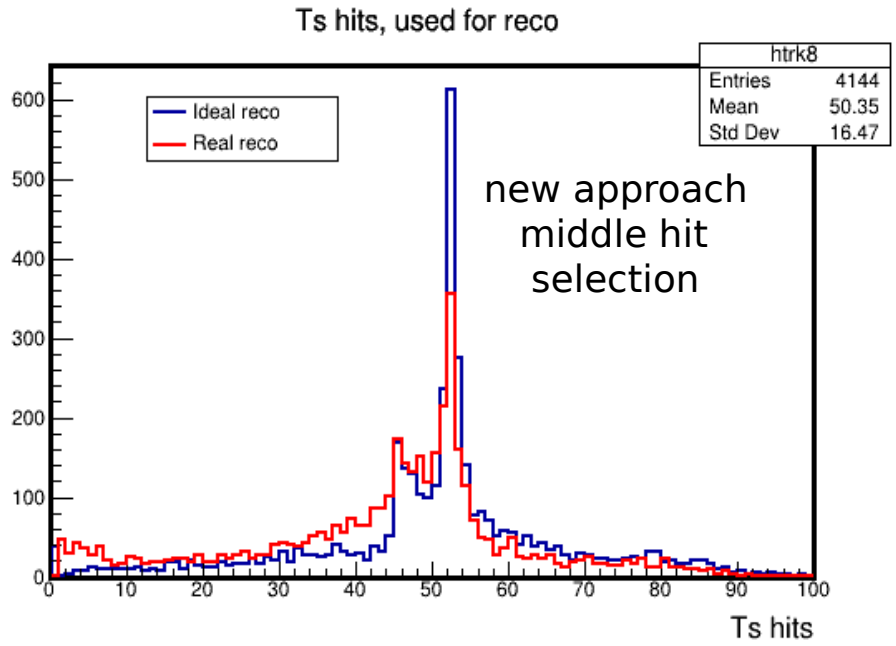
5. reconstructed track parameters with new approach looks the same as for present version

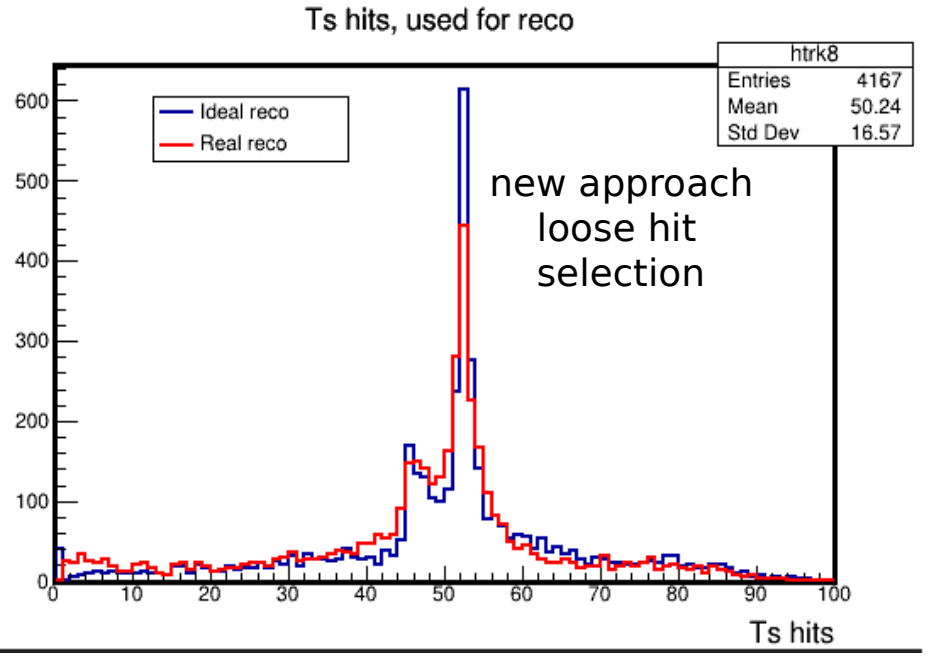
6. need some program reorganization and additional tuning (debugging)

Straw hits associated with reconstructed track



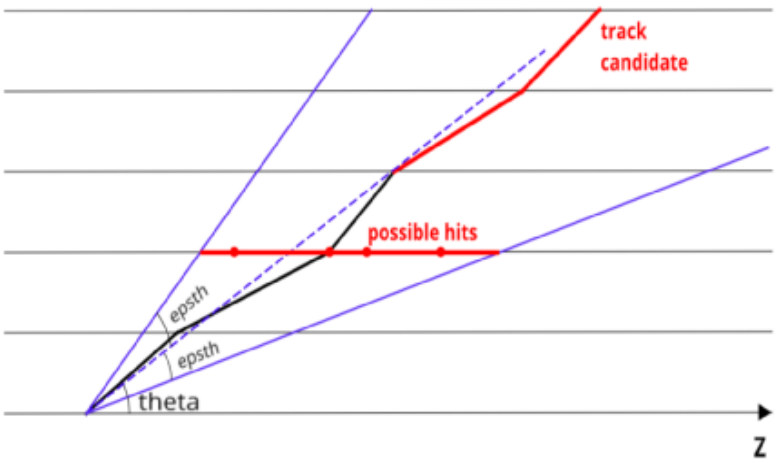


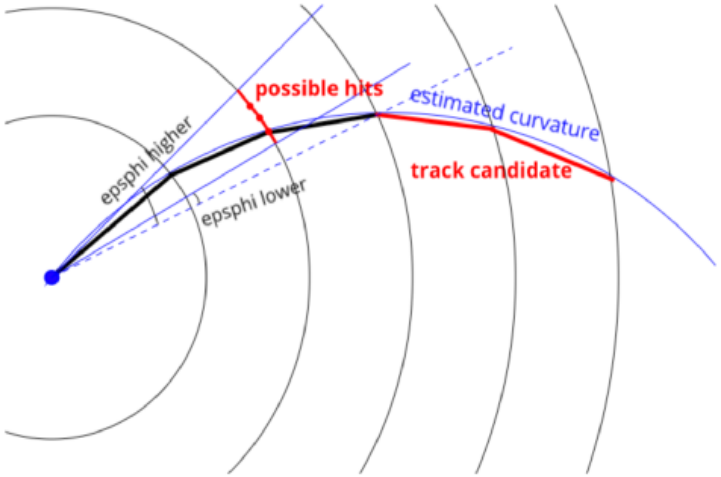




Backup

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 additional point with taking into account the next conditions:

   a) check theta-angle consistence – all hits should be inside some δθ - range
   b) use 3-hits for track curvature estimation in XY - plane (for 2-points seeds zero point is used)
   c) check phi-angle consistence – new hit should be inside some δφ - range

3. then next merging procedure is applied:
   a) if 3-points seed contains all points of 2-points seed => 2-points seed is removed
   b) if 4-points seed contains all points of 3-points seed => 3-points seed is removed
   c) if 5-points seed contains all points of 4-points seed => 4-points seed is removed

Track seeds in vertex detector (2)

4. z-coordinate of primary vertex is very important parameter for track reconstruction => clustering algorithm is applied for z-coordinate estimation which can produce several “primary” vertexes

5. check all seeds on compatibility with the set of “primary” vertexes

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 (=> or Pt)
   c) seed theta
   d) seed phi (phi in 1-st seed point)
   e) estimated z-coordinate of primary vertex

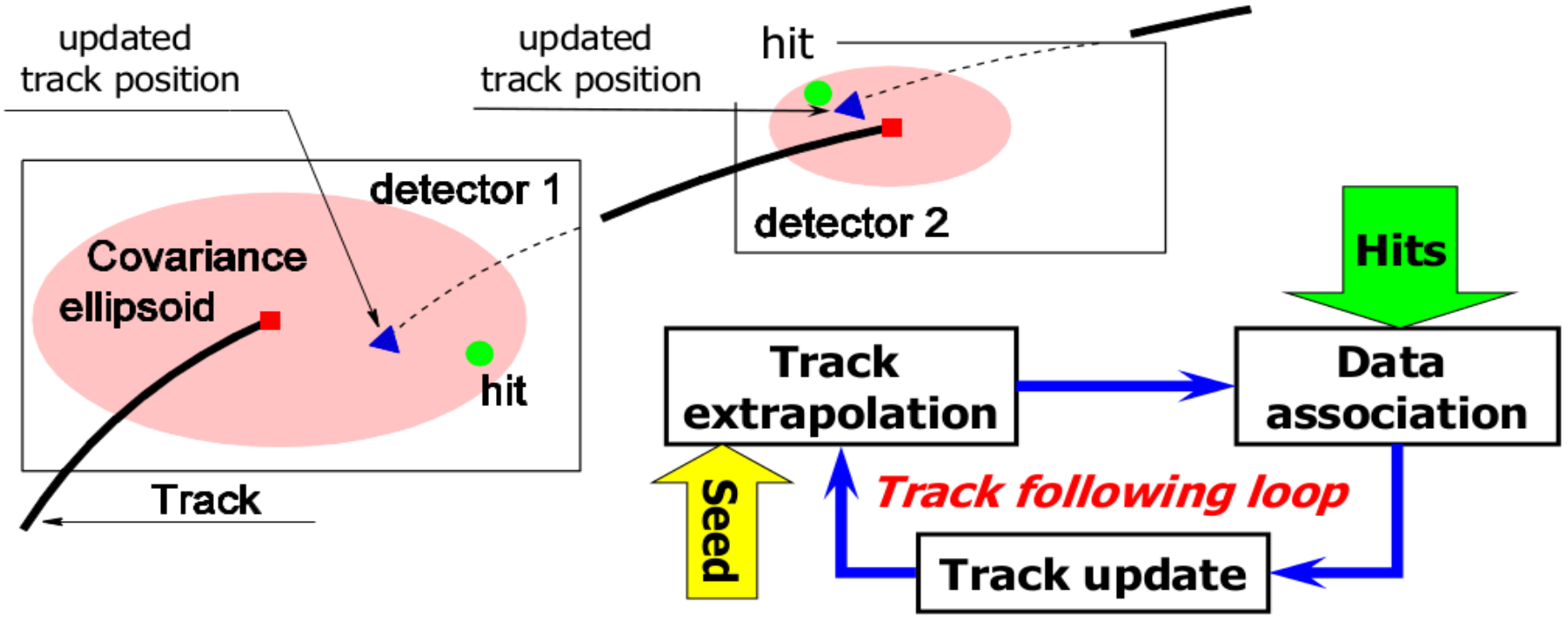
Track reconstruction (add straw hits)

1. do Kalman fit of vertex seed and find primary track candidate parameters

2. extrapolate track to 1-st straw layer of tracker module and find hit position on the plane

3. check distance and chi2 between hit point position and “fired” straw wires on this plane

4. add “good” straw hits to track candidate points, update track parameters (do new Kalman fit) and then extrapolate track to the next straw layer

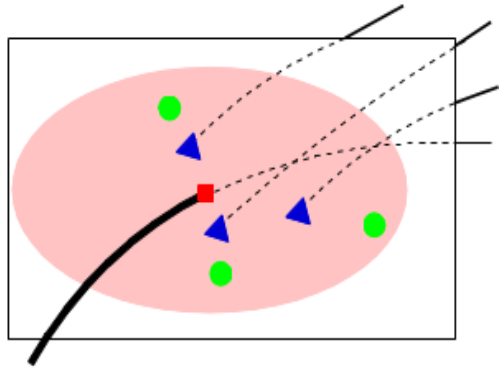


Track reconstruction (2)
(add straw hits)

5. if 2 or more straw hits (blue triangle on picture) on one detector layer are consisted with the track candidate, the next two reconstruction option are foreseen:

   a) 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

   b) the track parameters are updated using all straw hits which are consisted with the track candidate



6. finally, “big” number of track candidates are produced which contains vertex and straw detector hits

7. then cleaning procedure is applied for track candidates:
   a) check common number of vertex and straw detector hits
   b) define track quality value => q = Nhits – coeff * chi2 (chi2 of track fit)
   c) if common number of hits is greater than some value (~50%) -> remove track candidate with low quality

8. do final Kalman fit of remaining track candidates

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

Performance of track reconstruction

1. there were simulated the next samples:

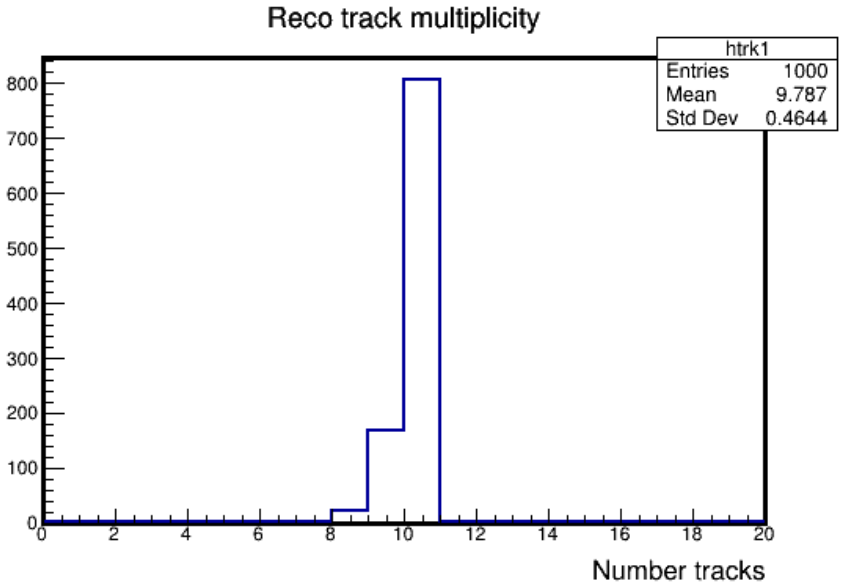
   a) 10 muons of 1 GeV/c momentum (5 with positive and 5 with negative charge) and uniform distributed in theta and phi angles;
   b) 10 pions of 1 GeV/c momentum (5 with positive and 5 with negative charge) and uniform distributed in theta and phi angles;
   c) Minimum Bias events (1-st and 2-nd particle generation);
   d) open charm events (1-st, 2-nd and 3-d particle generations).

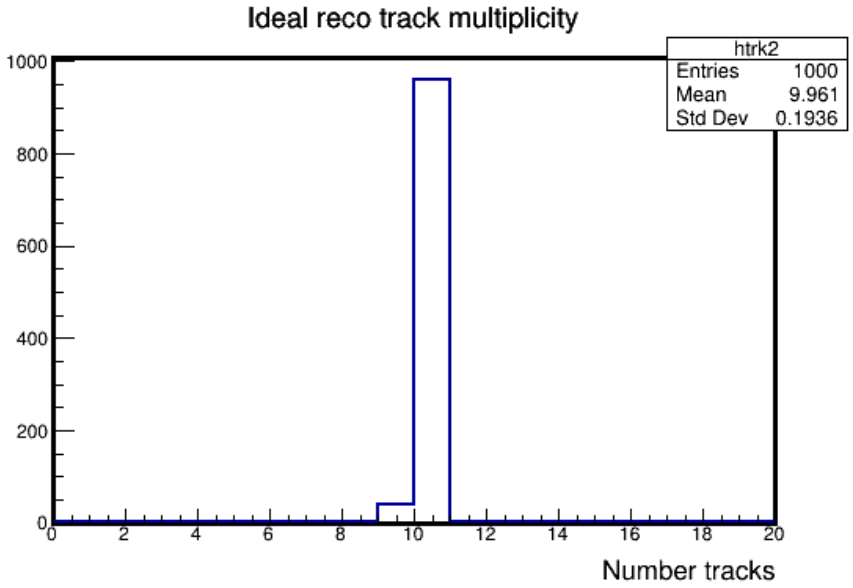
3. “ideal” track reconstruction can be applied to the different particle generation level:
   a) 1-st generation - only to primary vertex particles;
   b) 2-nd generation – to primary and secondary particles;
   c) 3-d generation - to primary, secondary and secondary particles.

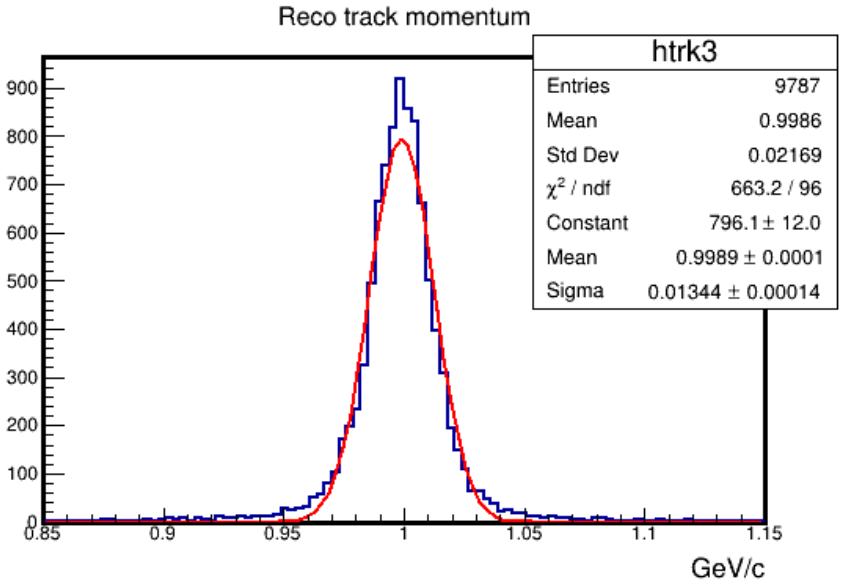
4. estimation of track reconstruction efficiency:
   a) consider “ideal” reconstructed track;
   b) try to find among reconstructed tracks that which can be considered as identical to “ideal” reconstructed track - If both tracks have the same vertex hits and have also 50% same “straw” hits

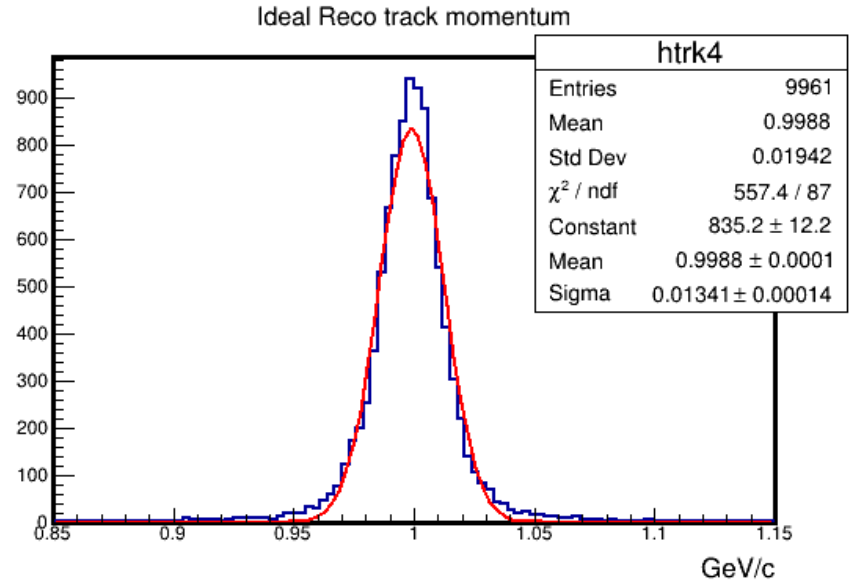
5. estimation of fake reconstruction rate:
   a) consider reconstruction track;
   b) try to find among “ideal” reconstructed tracks that which can be considered as identical to reconstructed track – if both tracks have the same vertex hits and also have 50% same “straw” hits
   c) if such “ideal” reconstructed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

General properties (muon sample)

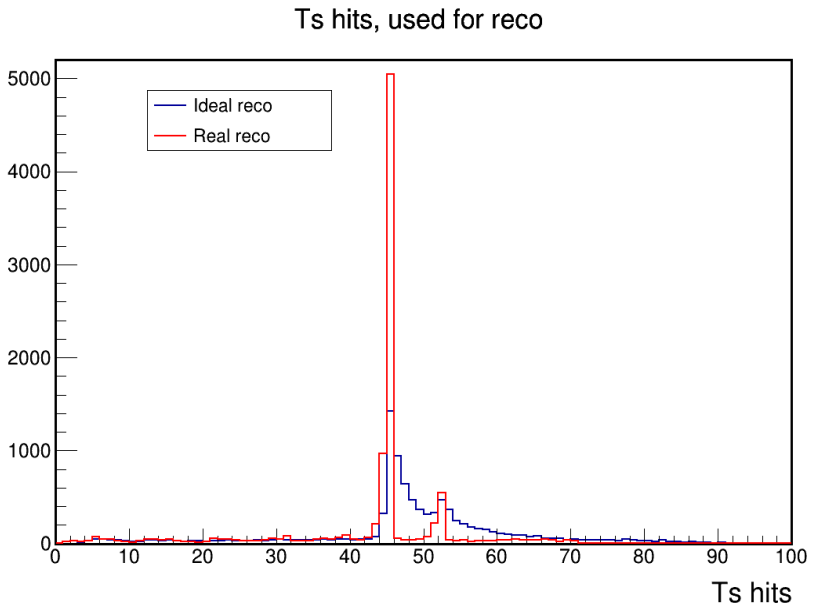


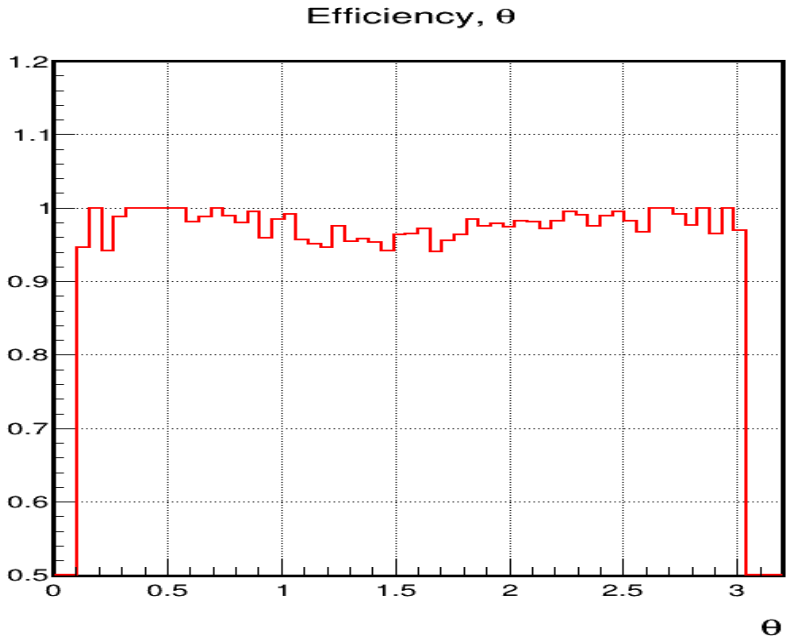


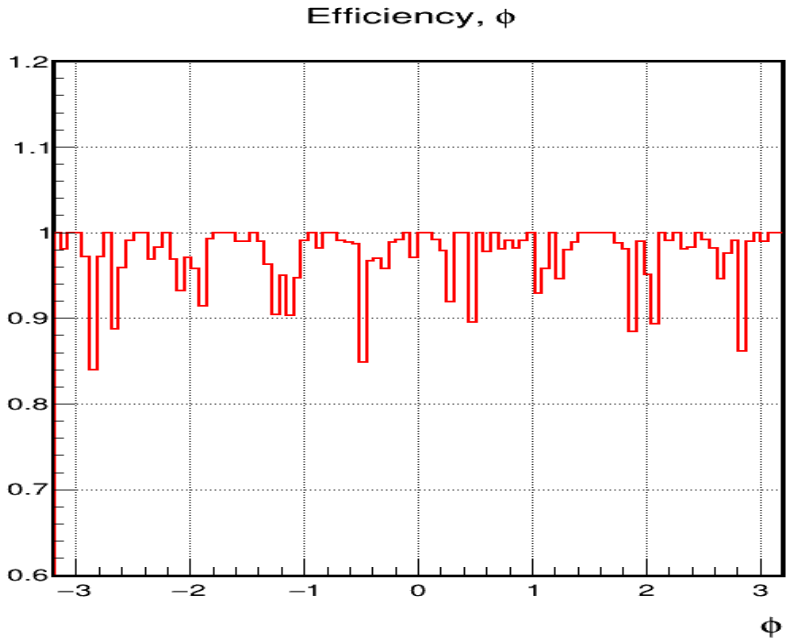




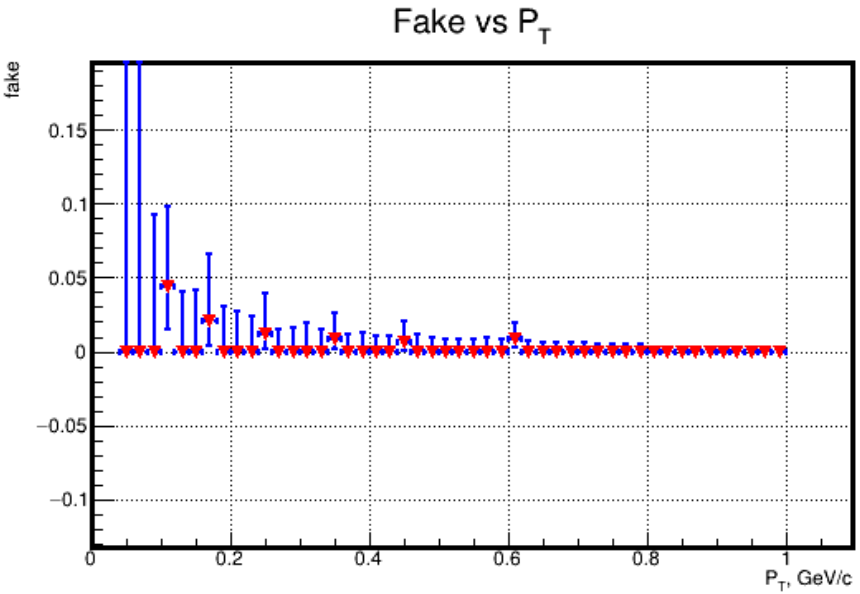
Reconstruction efficiency (muon sample)

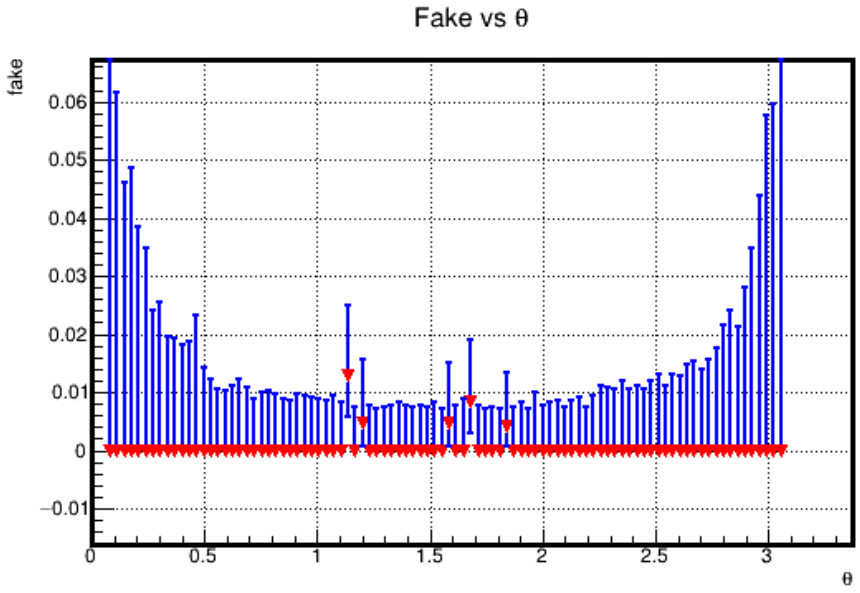


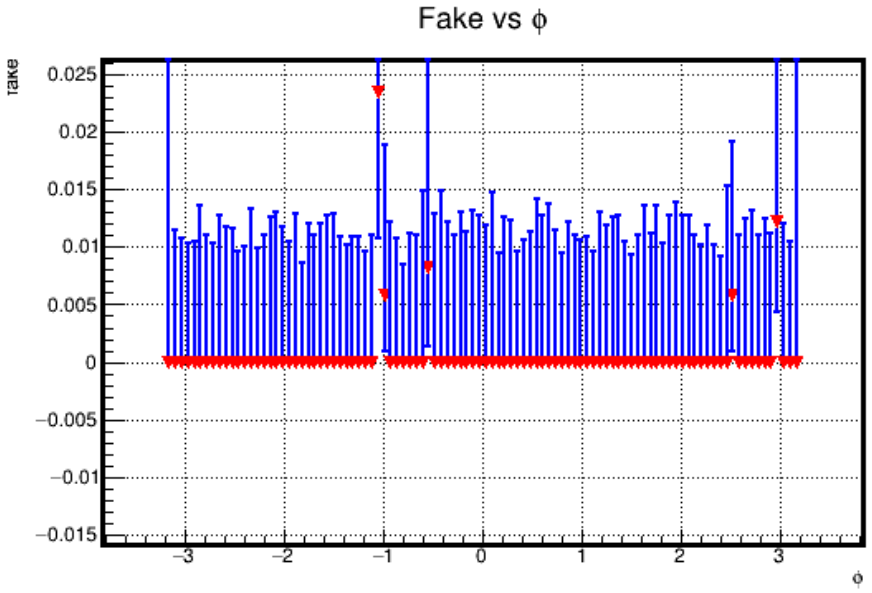




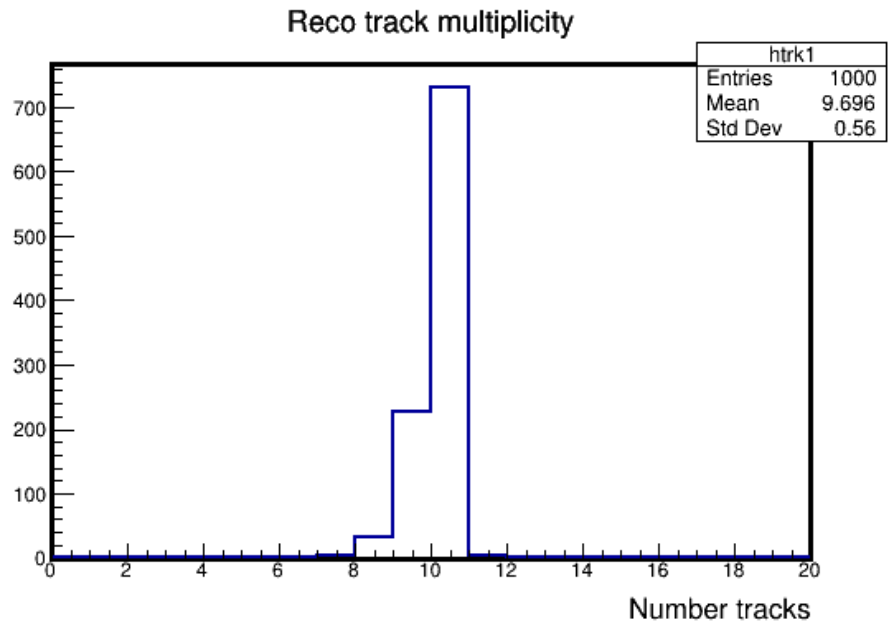
Fake rate (muon sample)

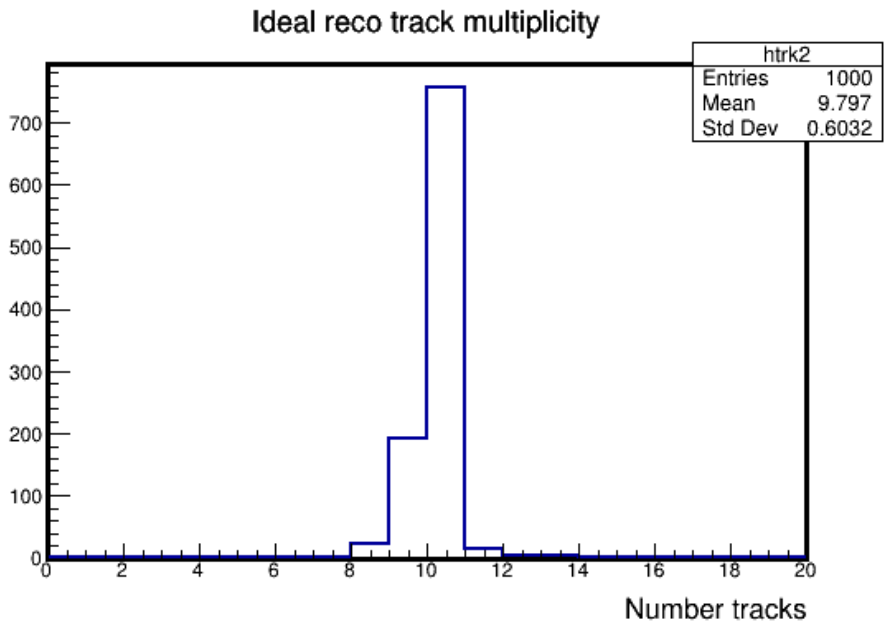


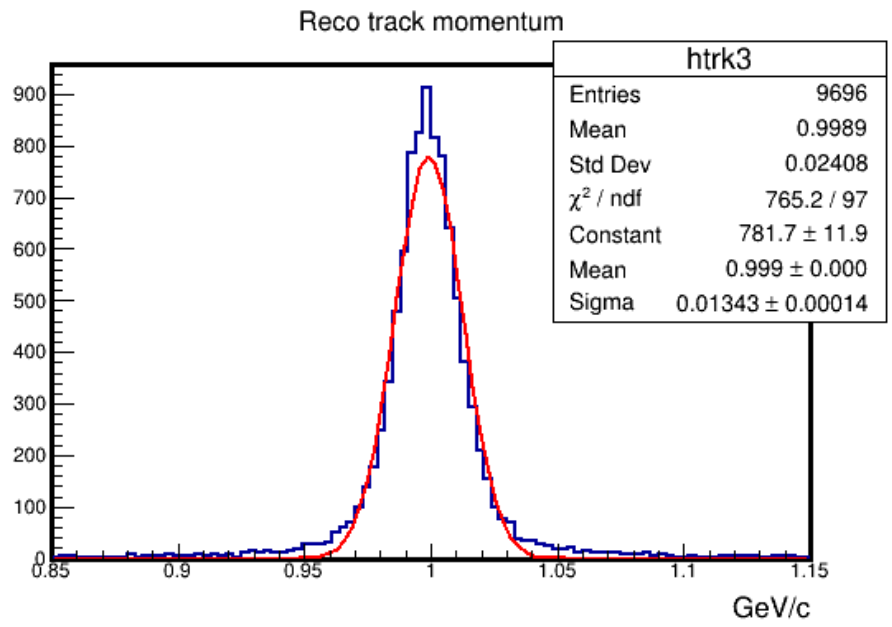


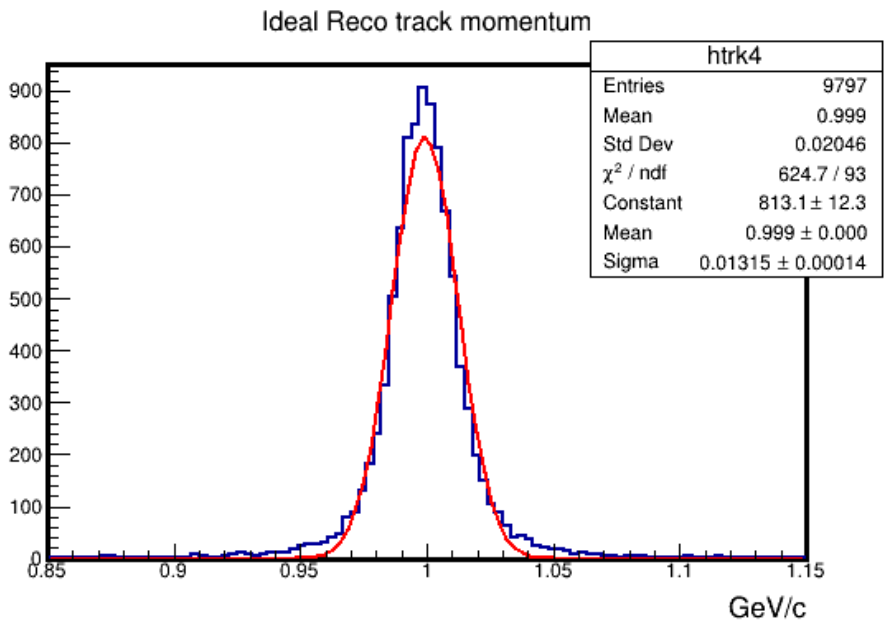


General properties (pions sample)

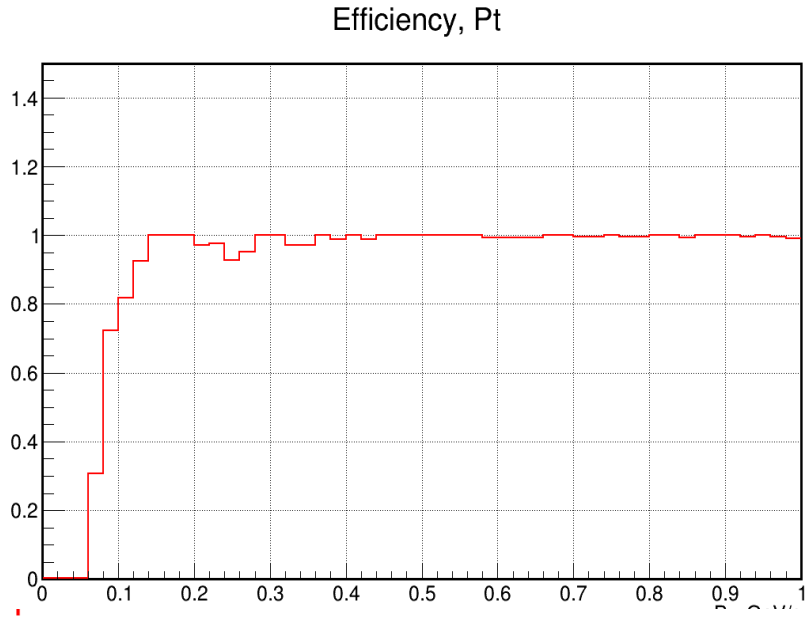


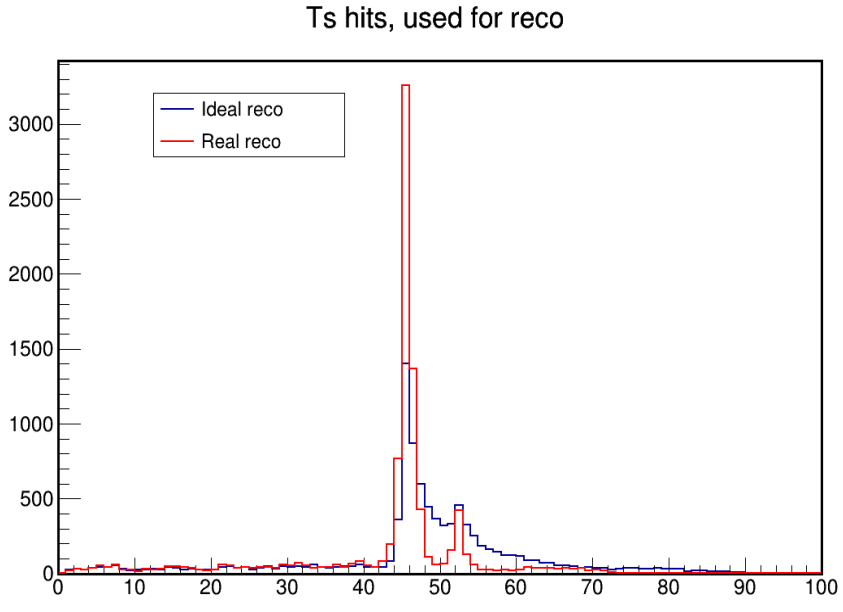


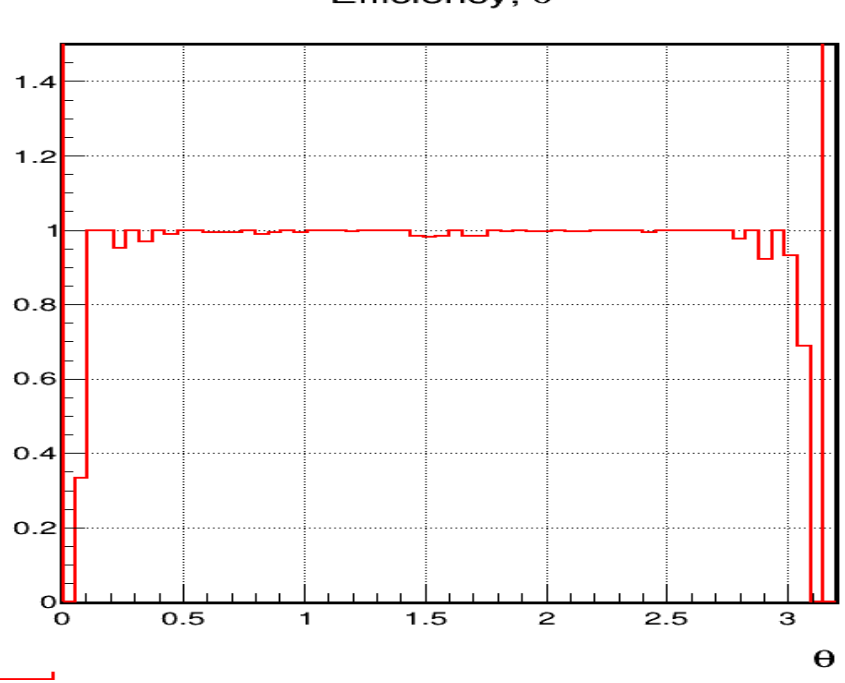


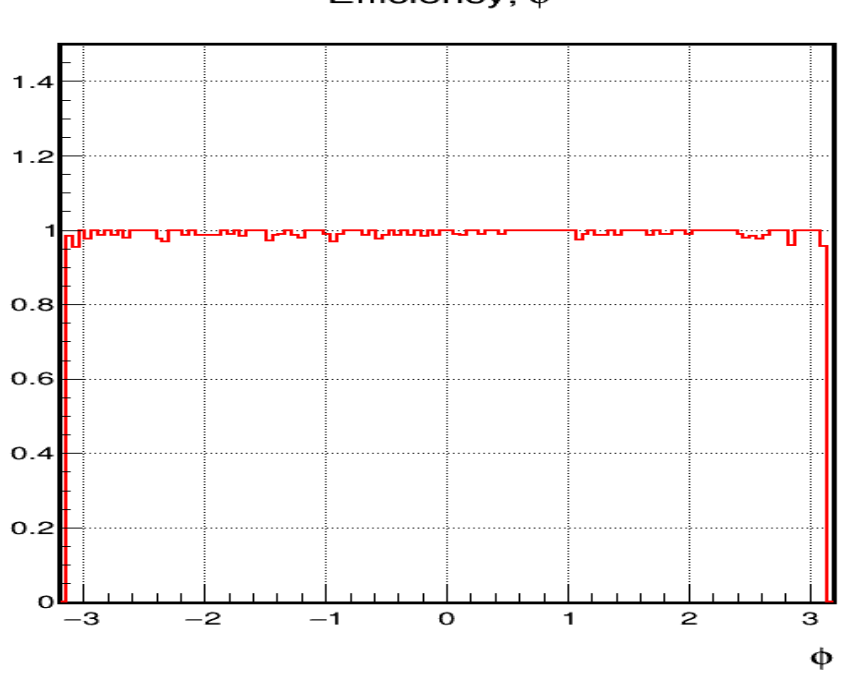


Reconstruction efficiency (pions sample)

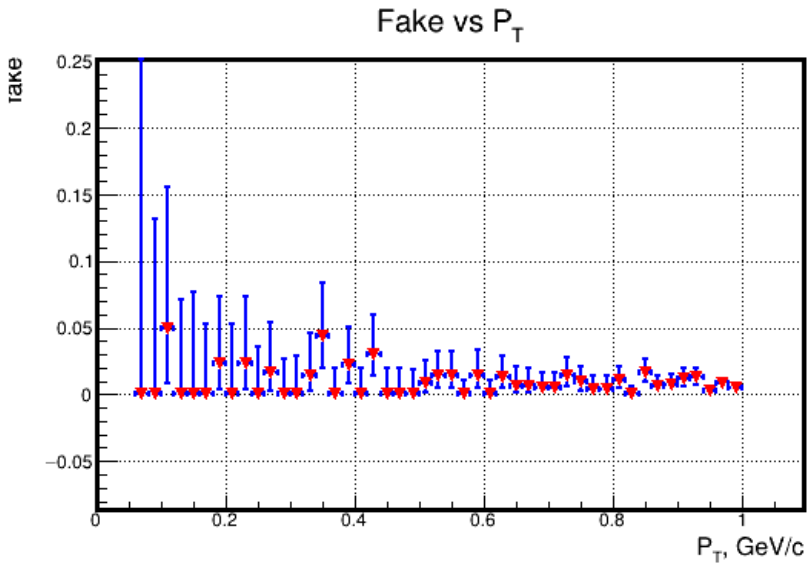


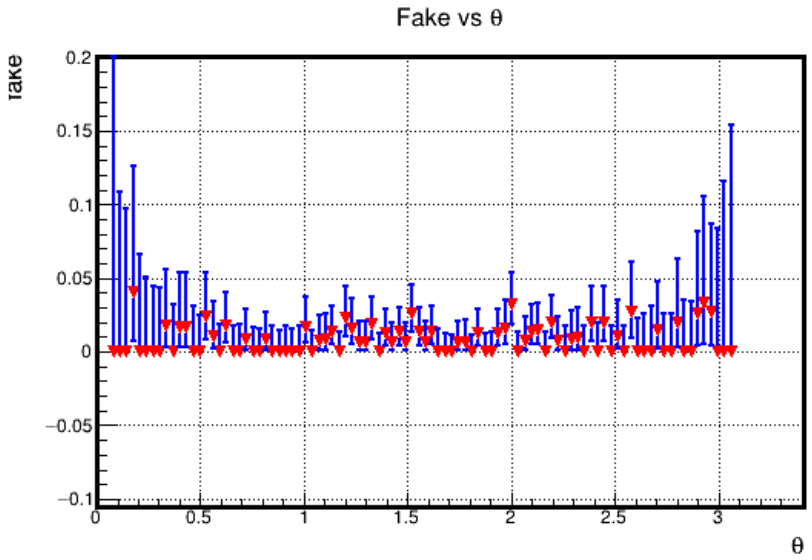


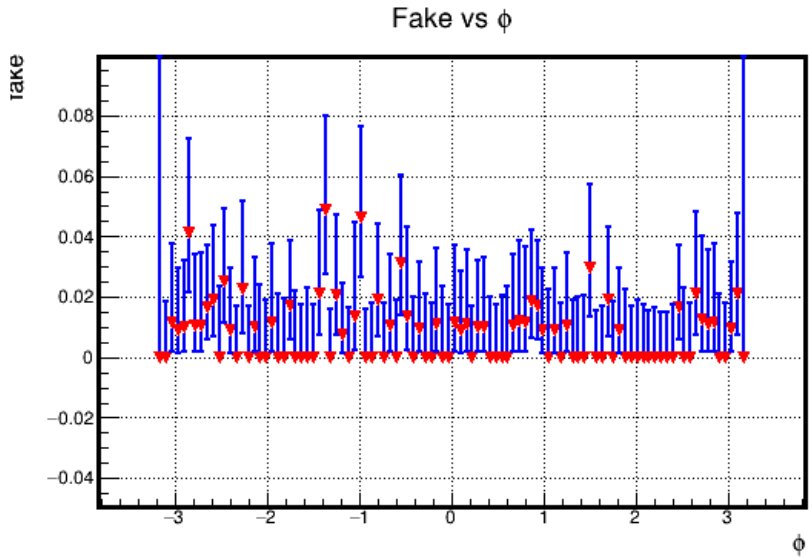




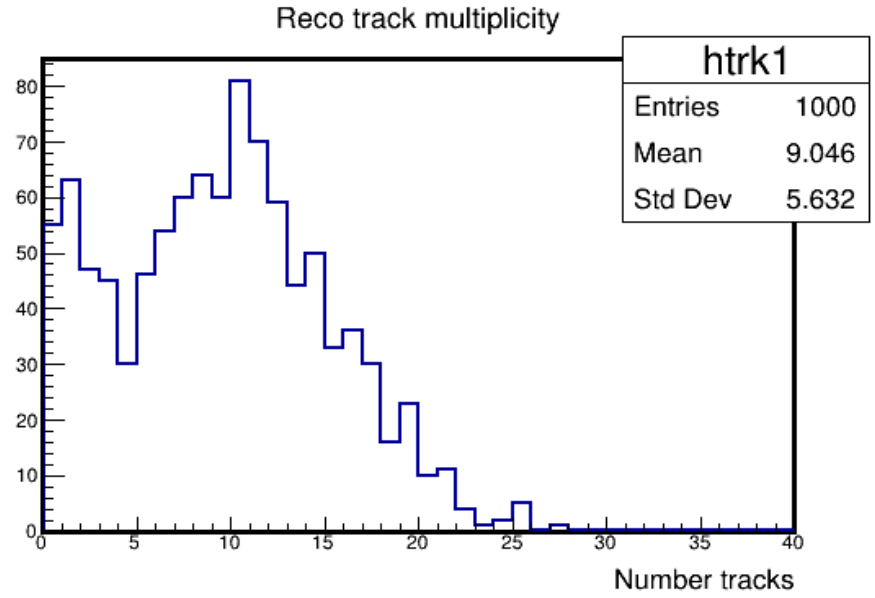
Fake rate (pions sample)

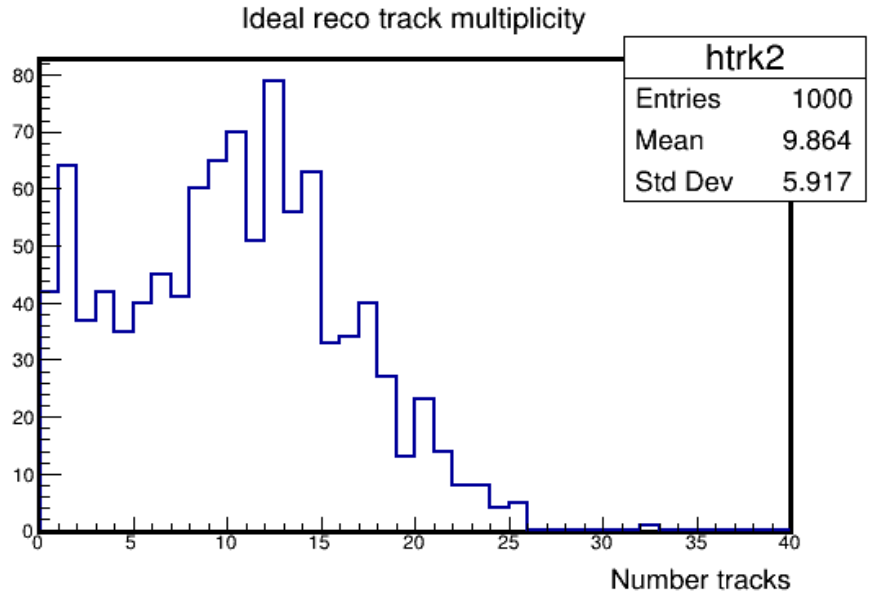


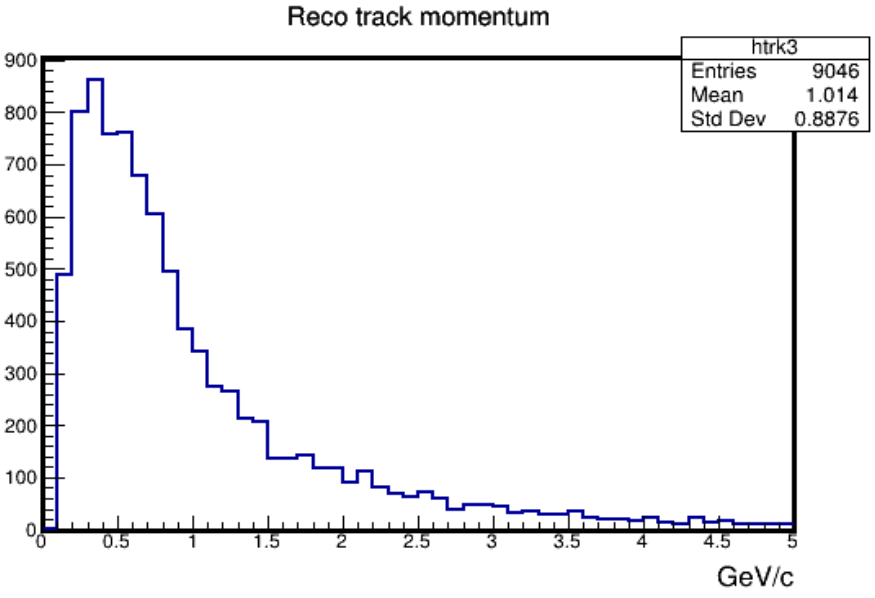


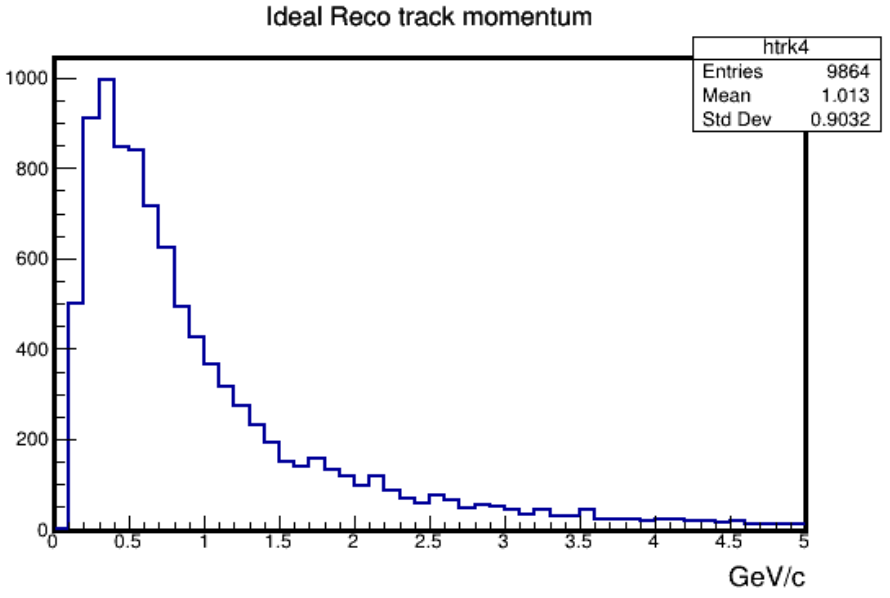


General properies (MB sample)

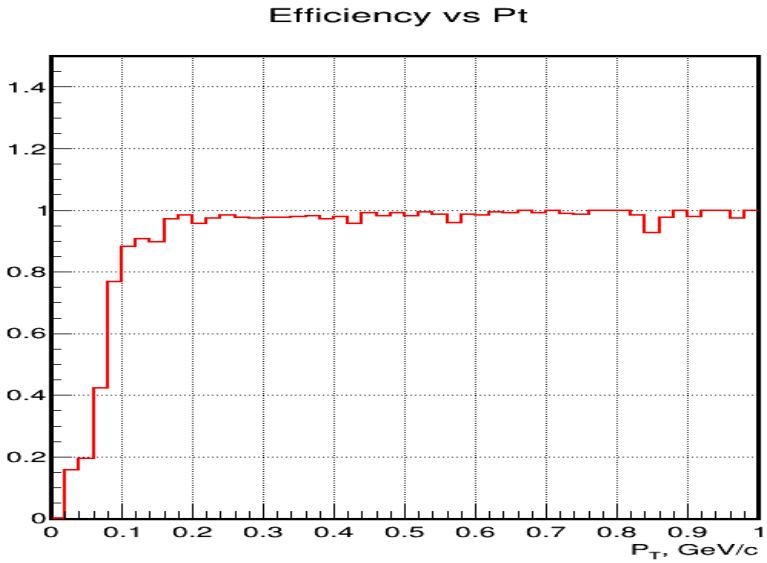


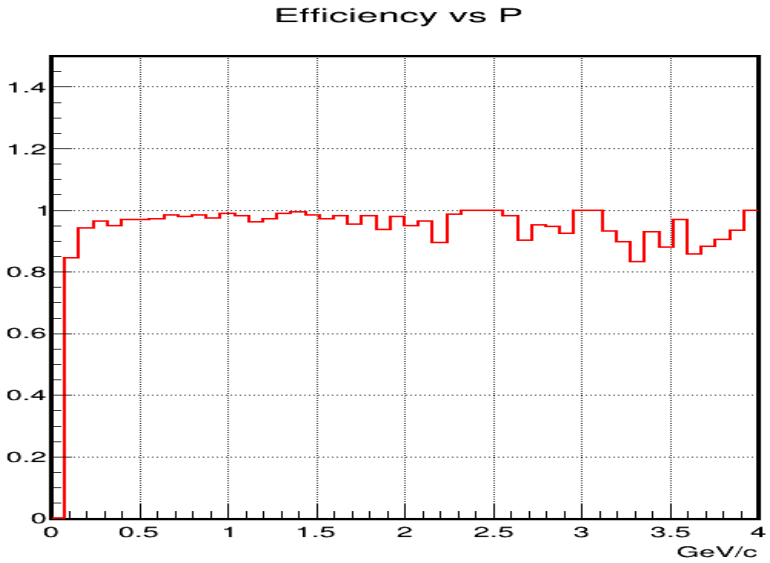


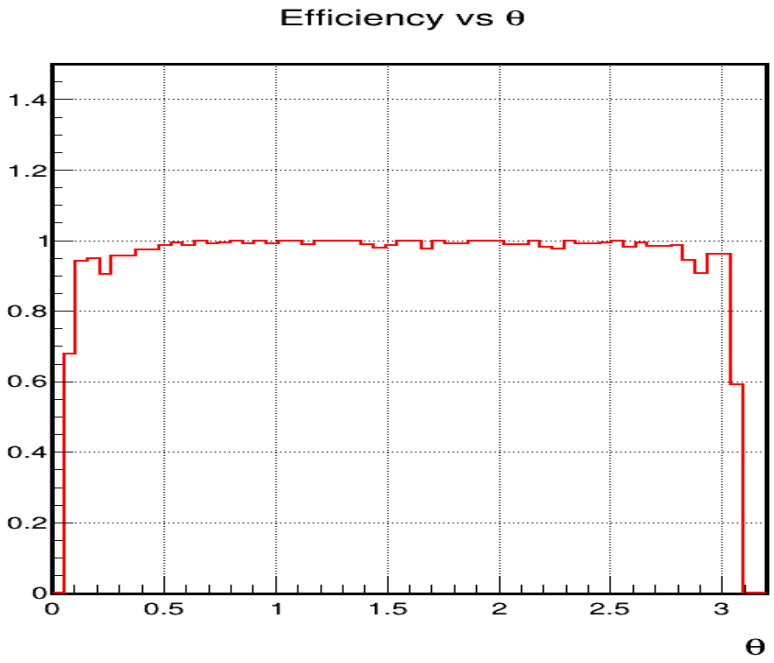


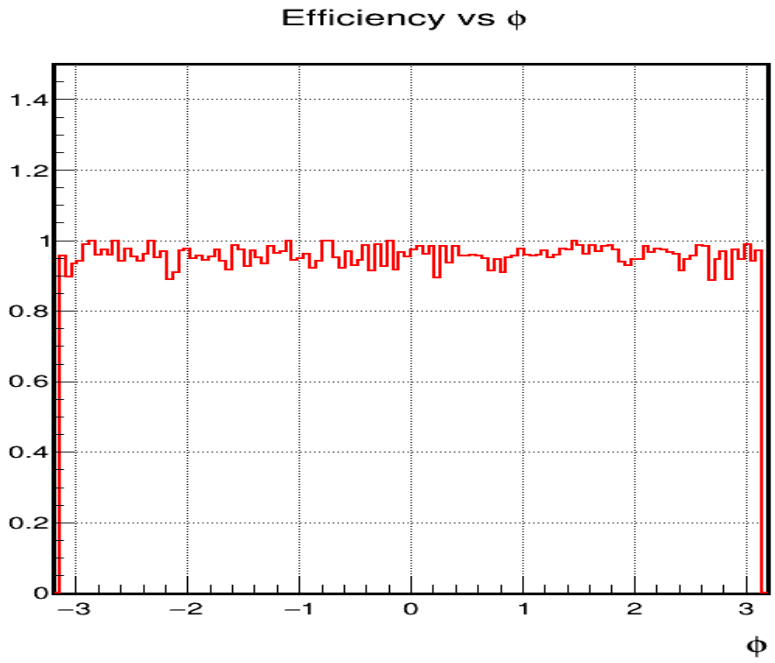


Reconstruction efficiency (MB, 1-st generation)

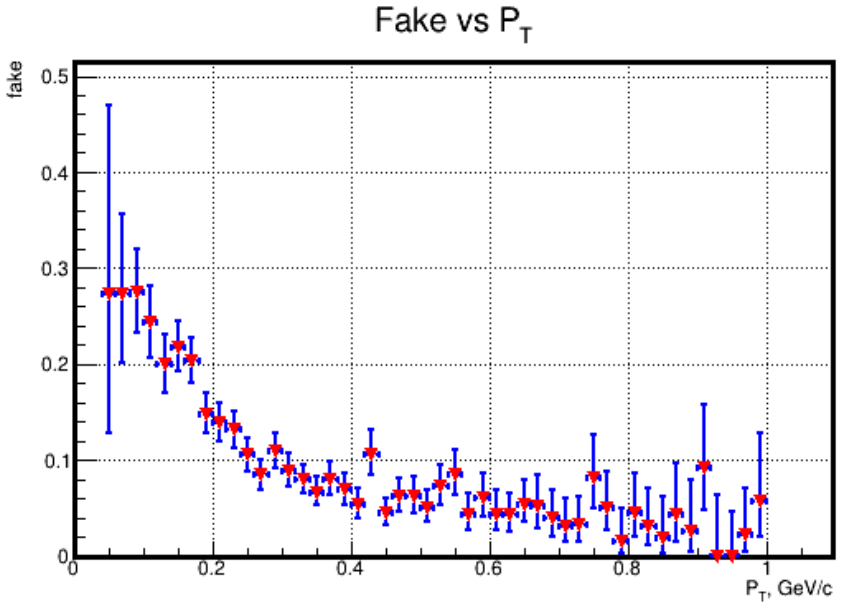


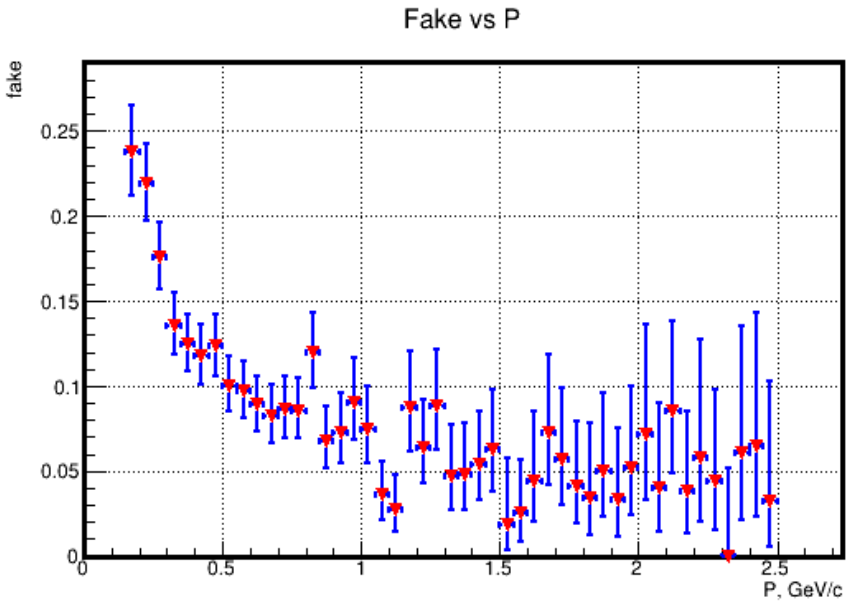


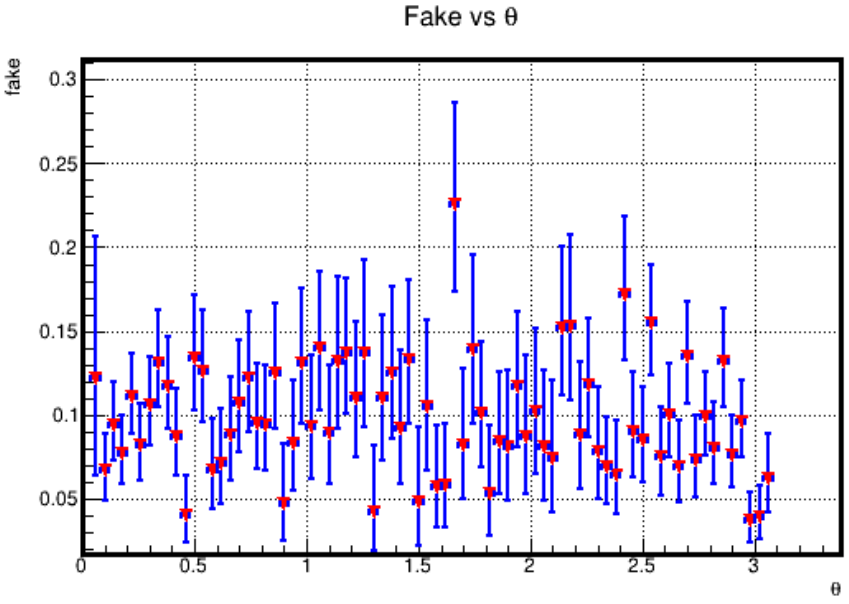


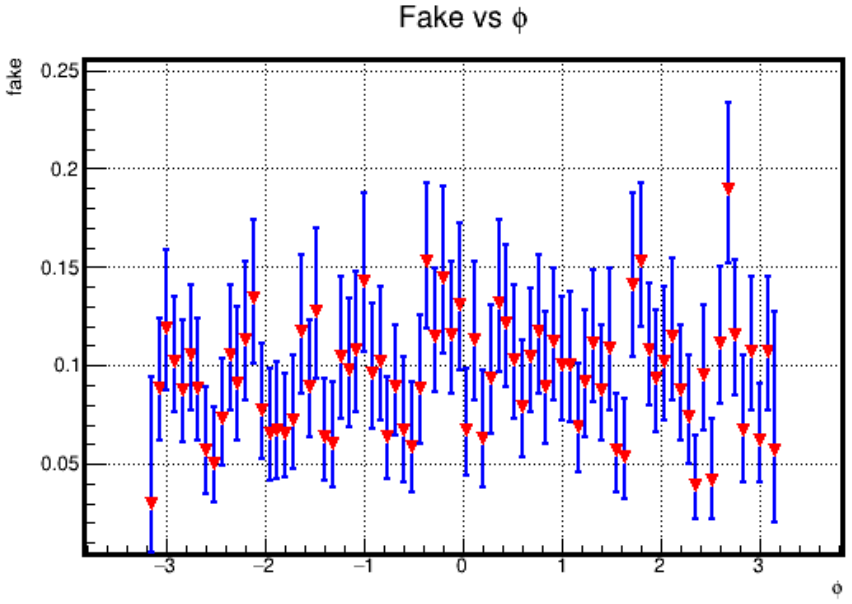


Fake rate (MB, 1-st generation)

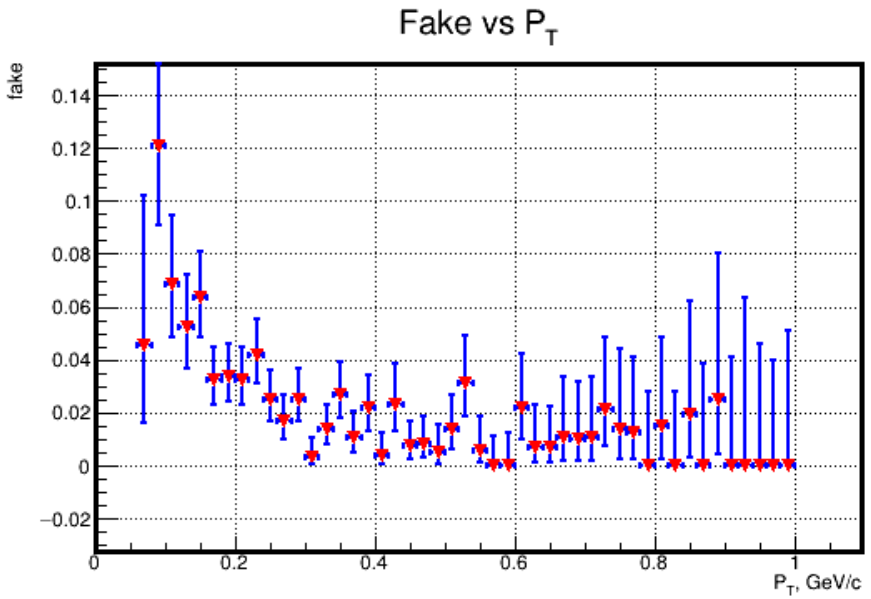


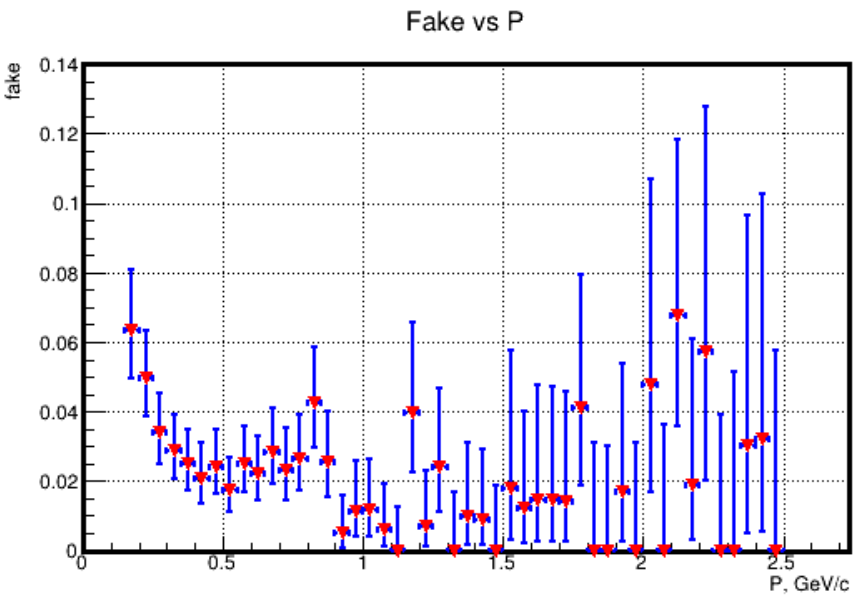


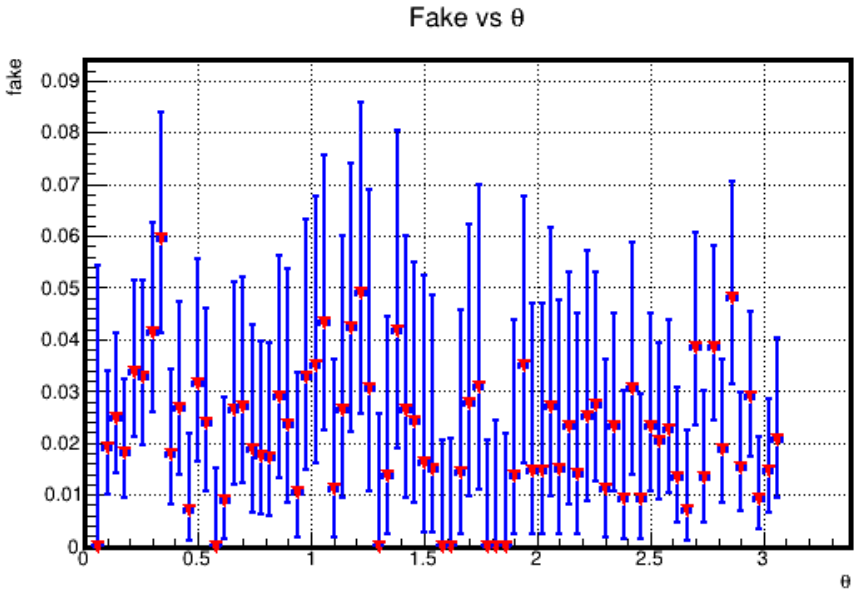


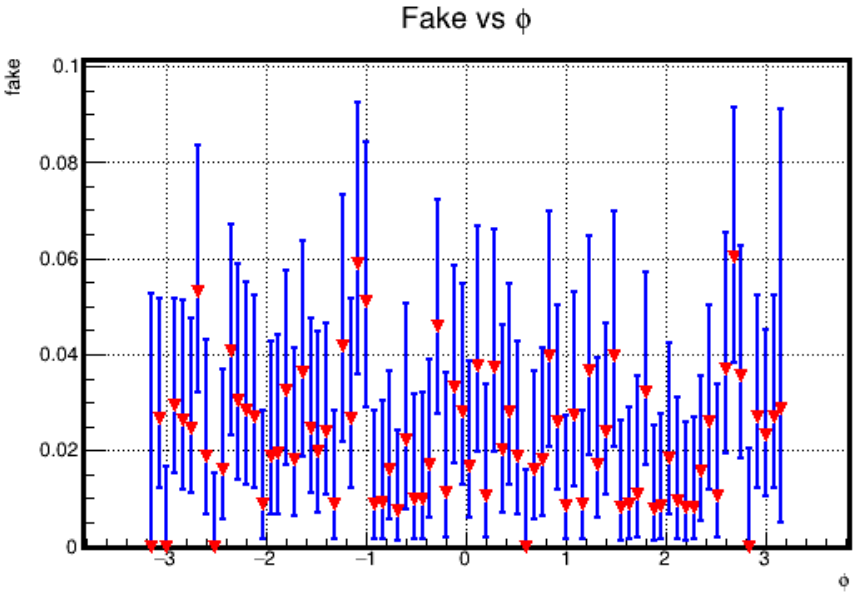


Fake rate (MB, 2-nd generation)

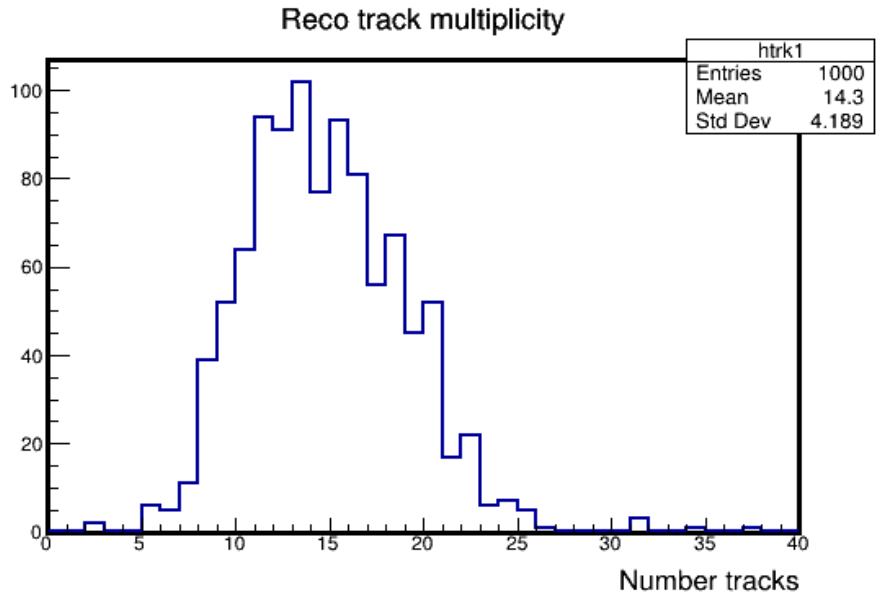


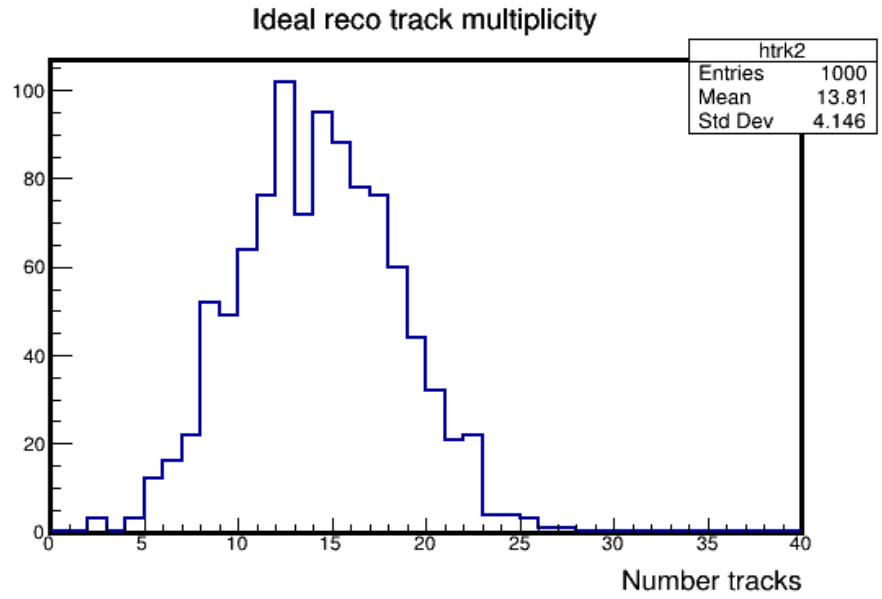


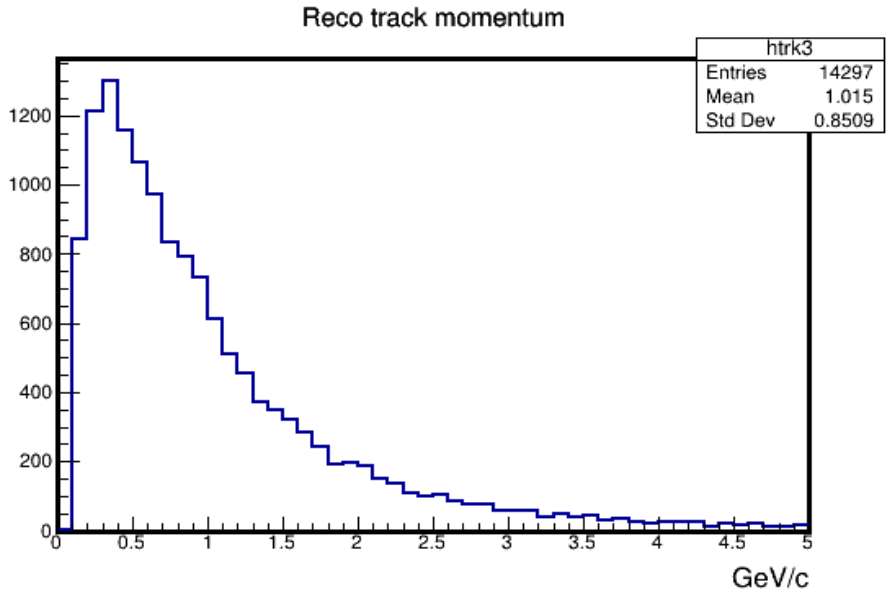


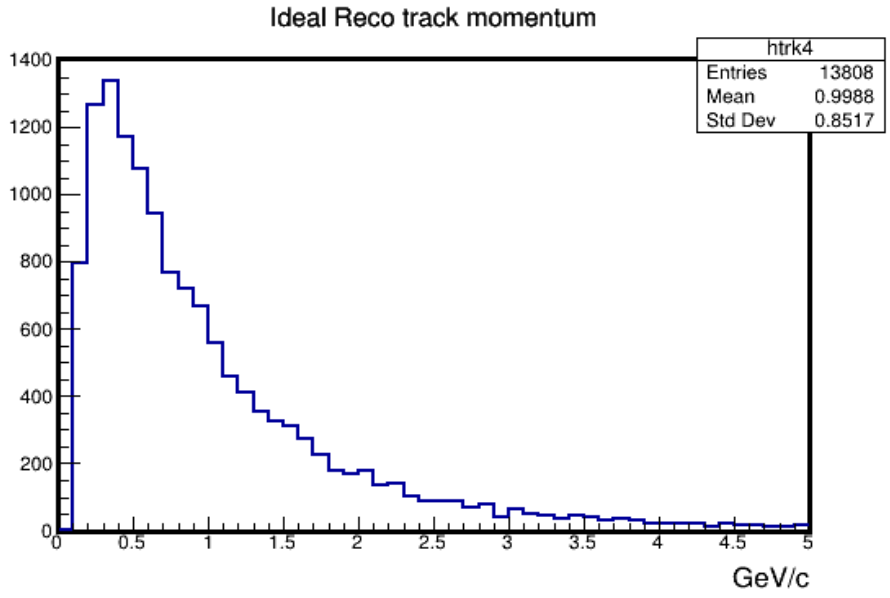


General properties (open charm sample)

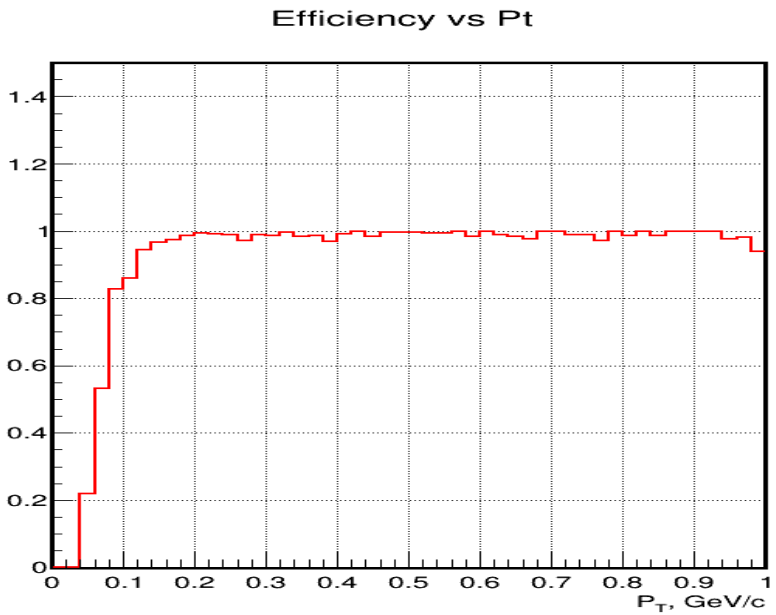


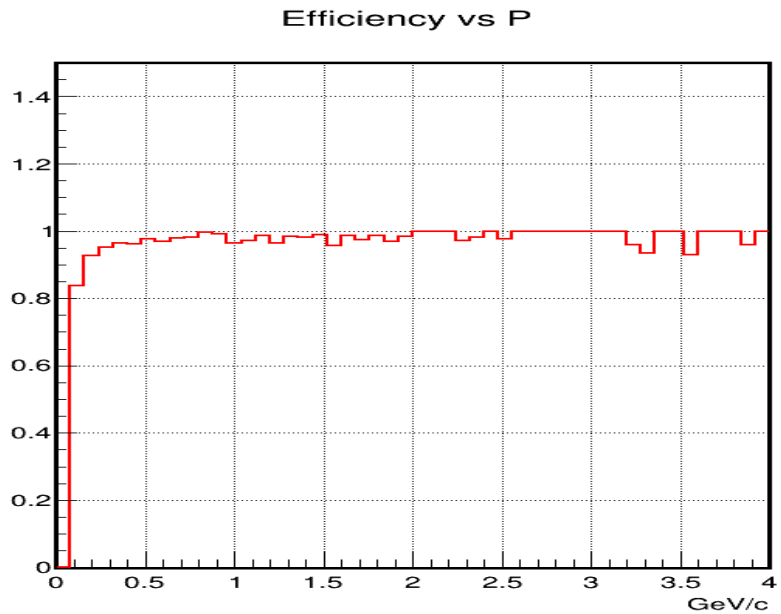


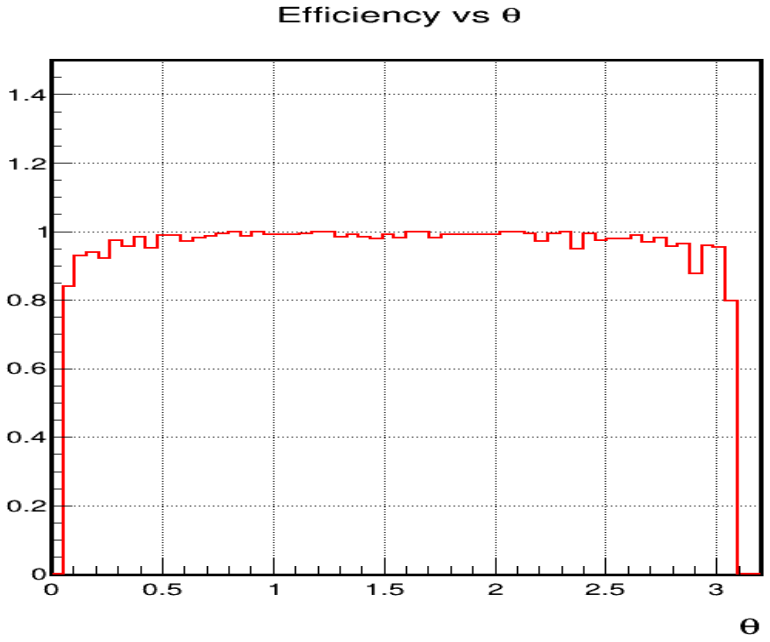


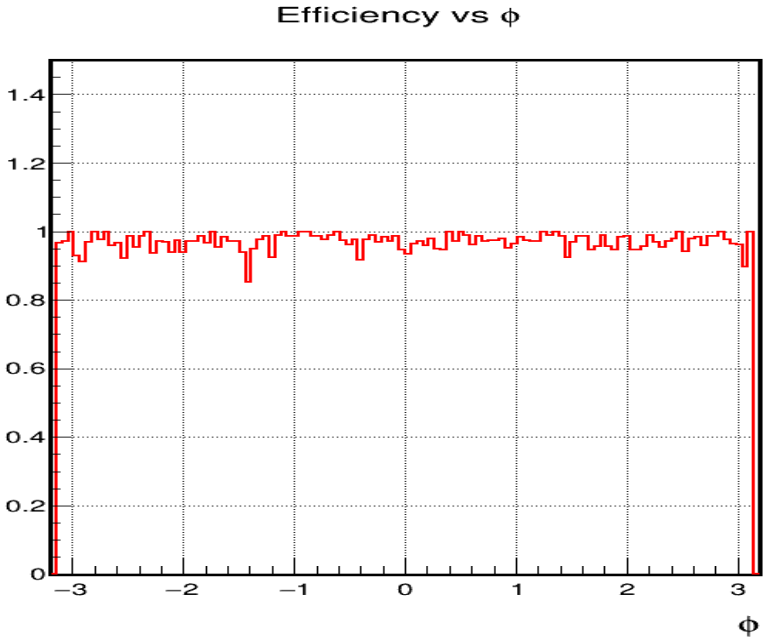


Reconstruction efficiency (open charm, 1-st generation)

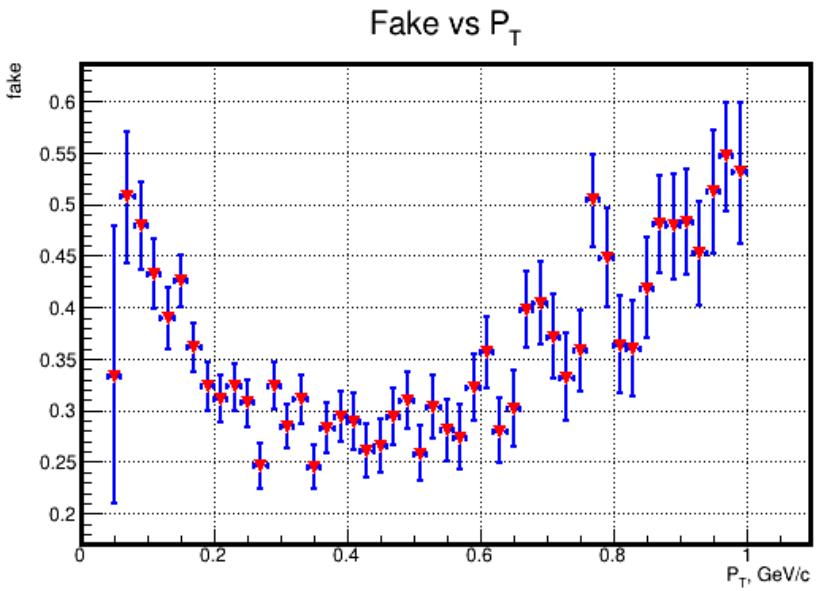


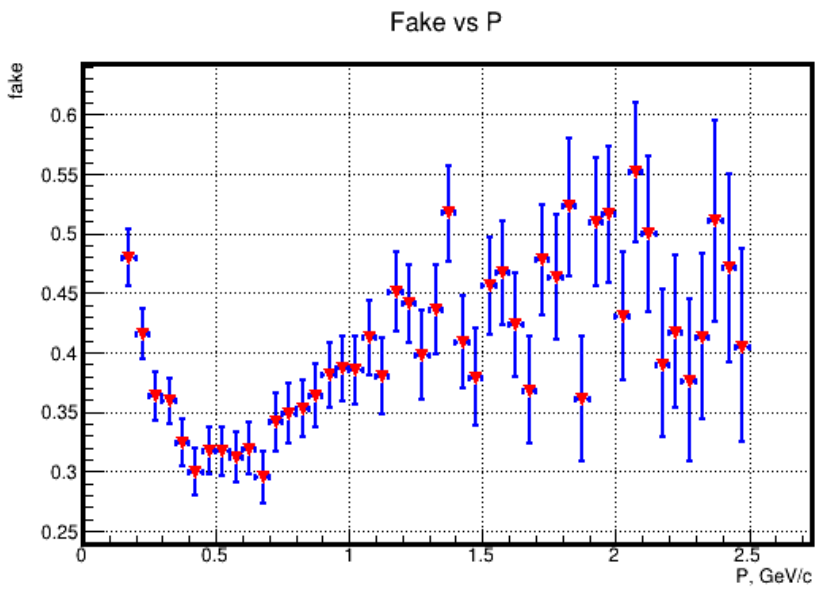


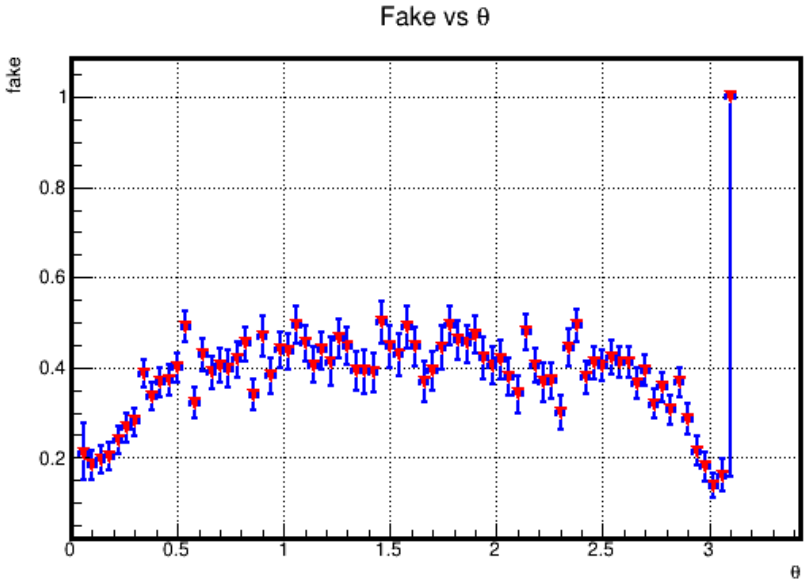


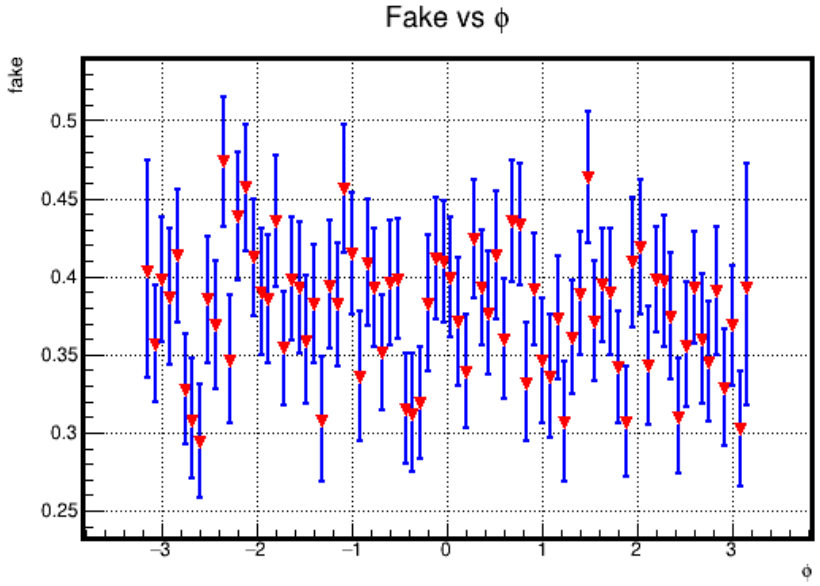


Fake rate (open charm, 1-st generation)

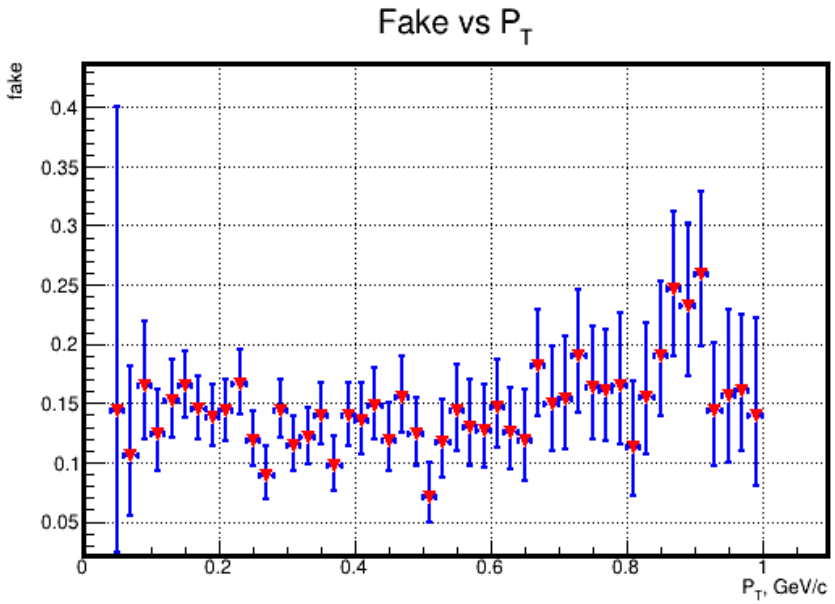


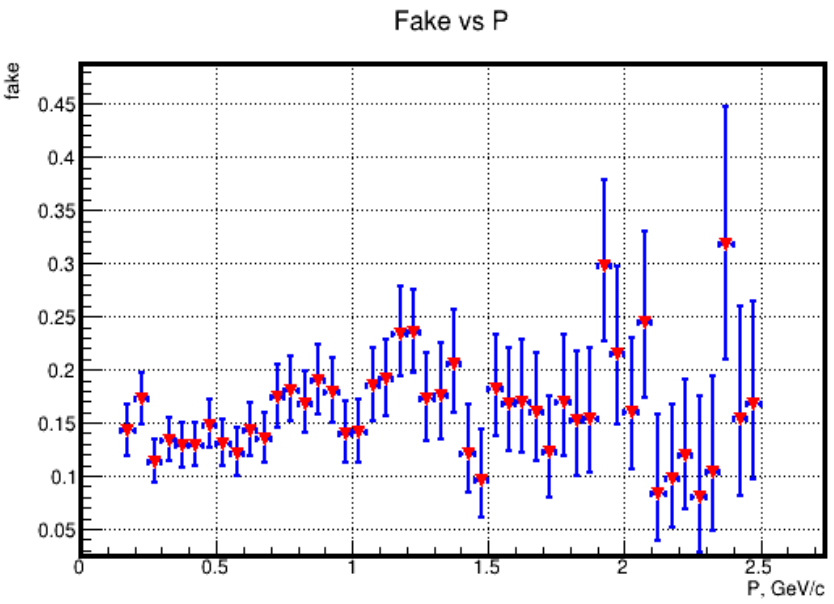


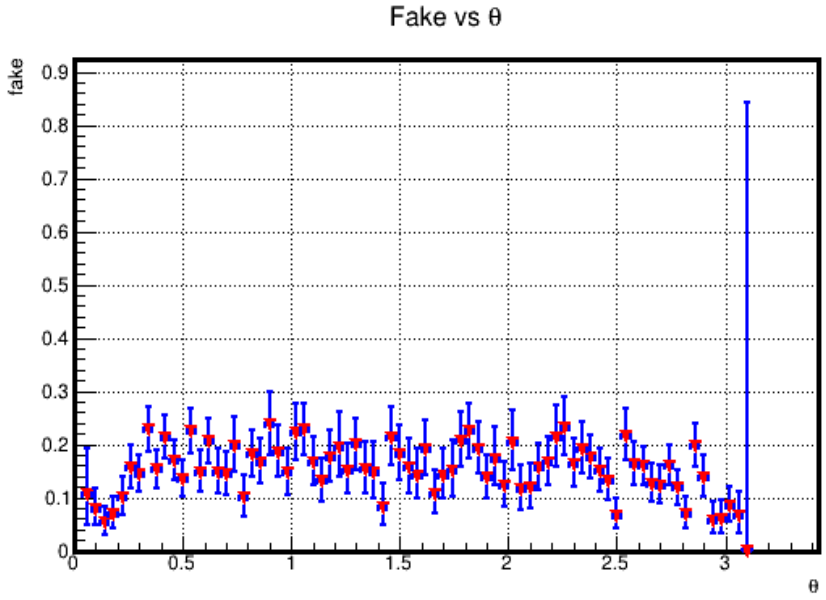


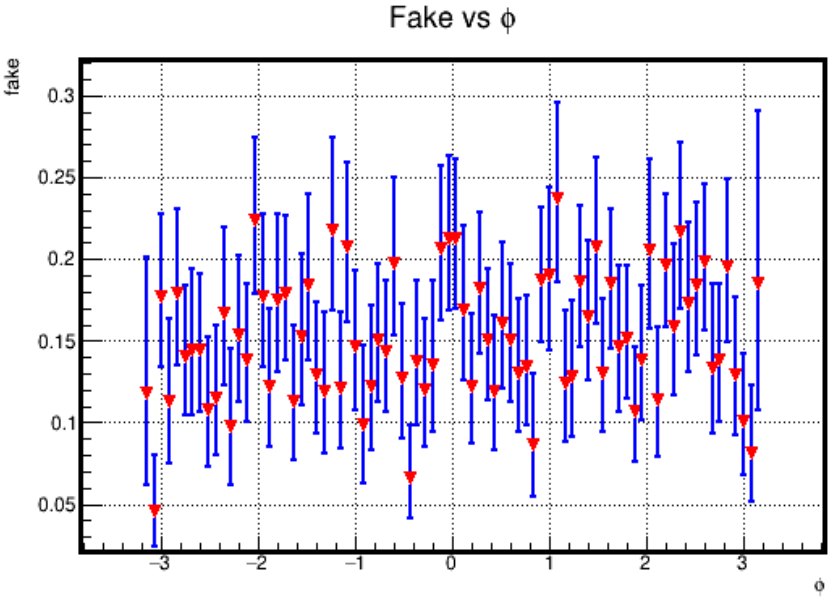


Fake rate (open charm, 2-nd generation)

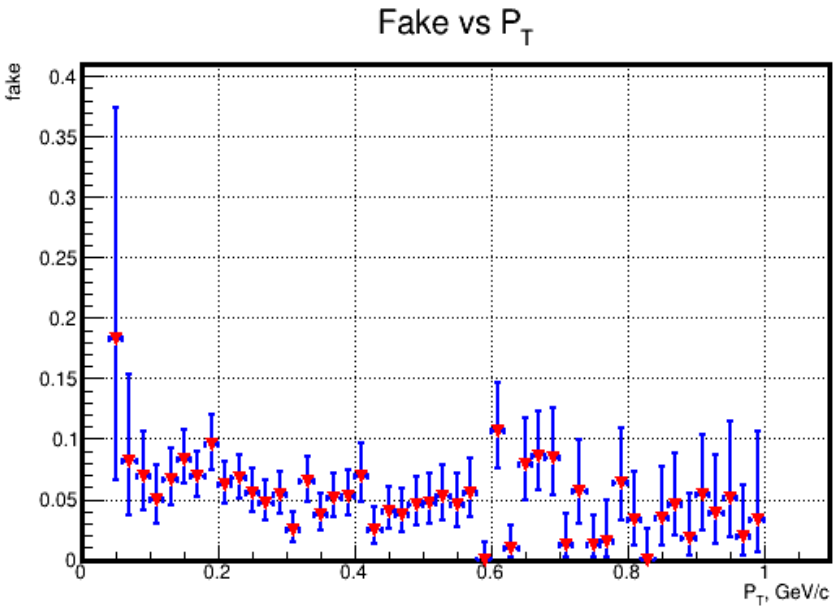


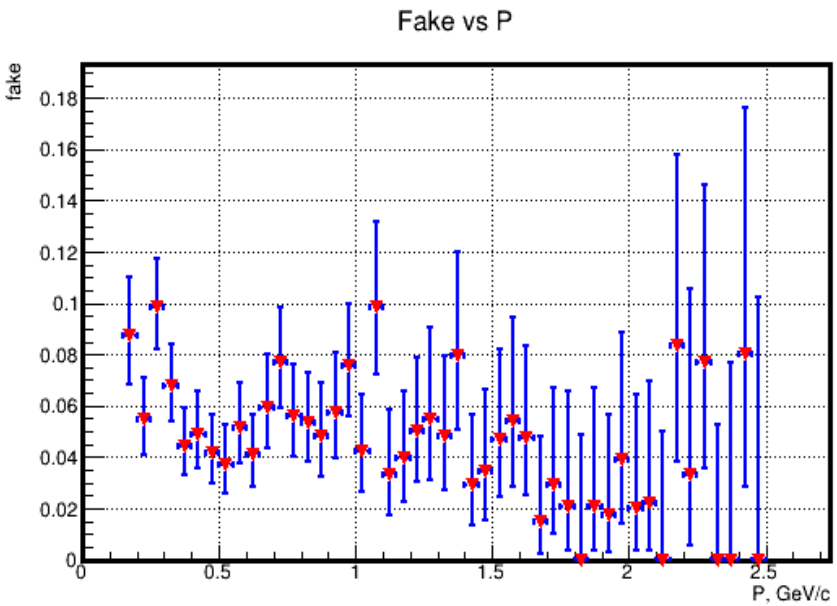


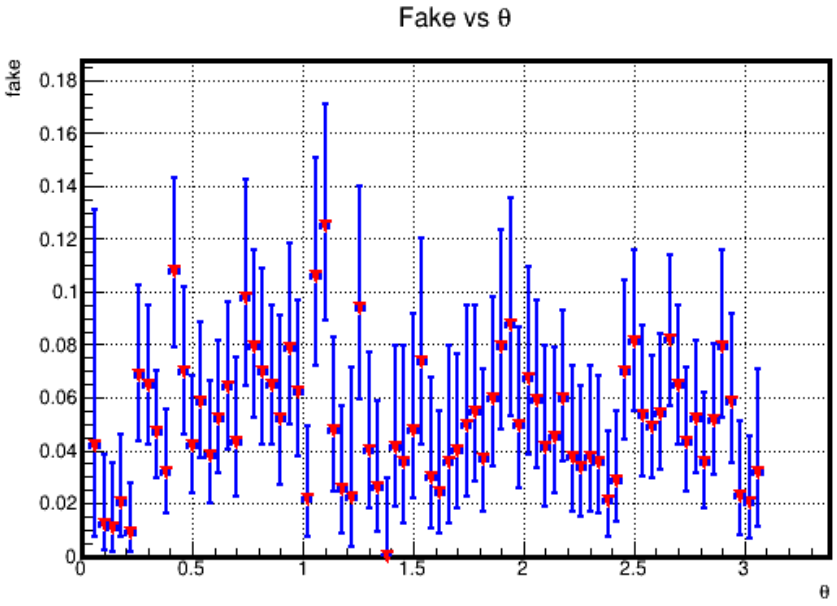


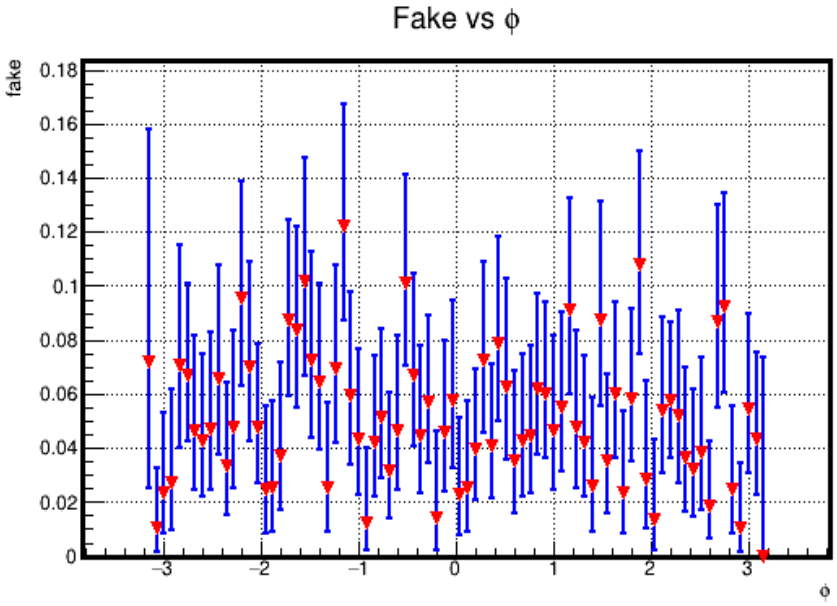


Fake rate (open charm, 3-nd generation)

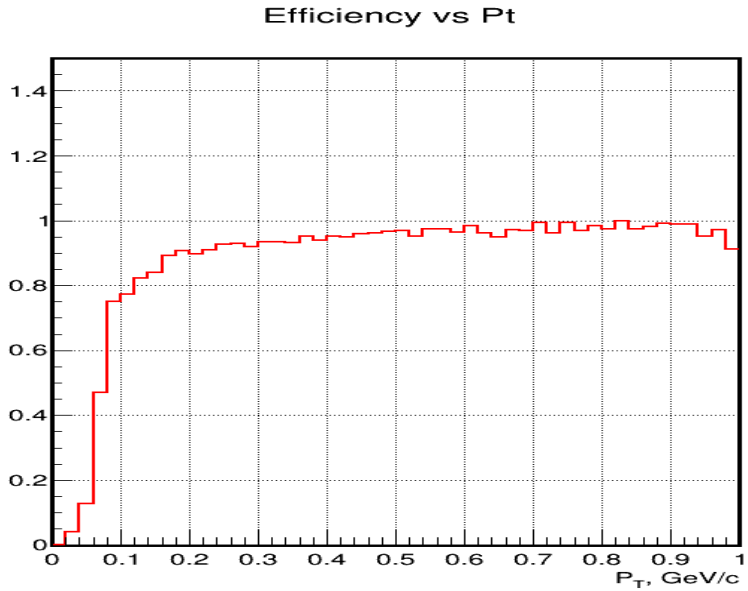


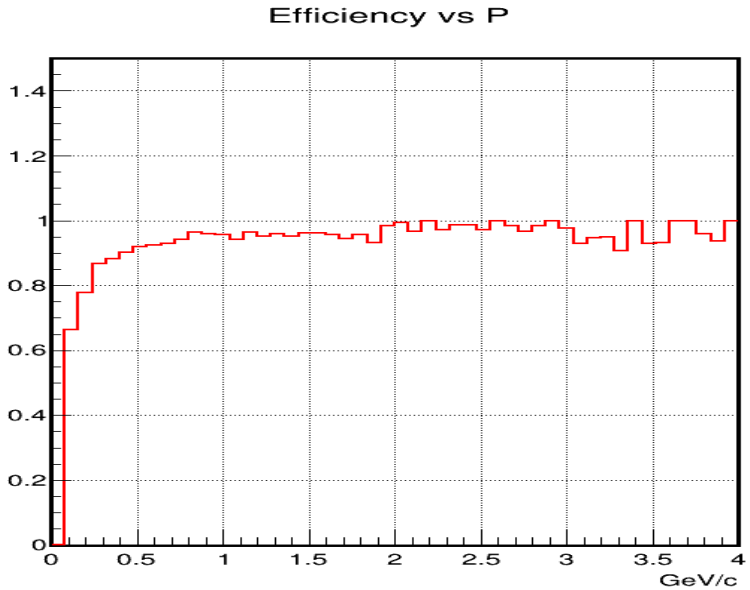


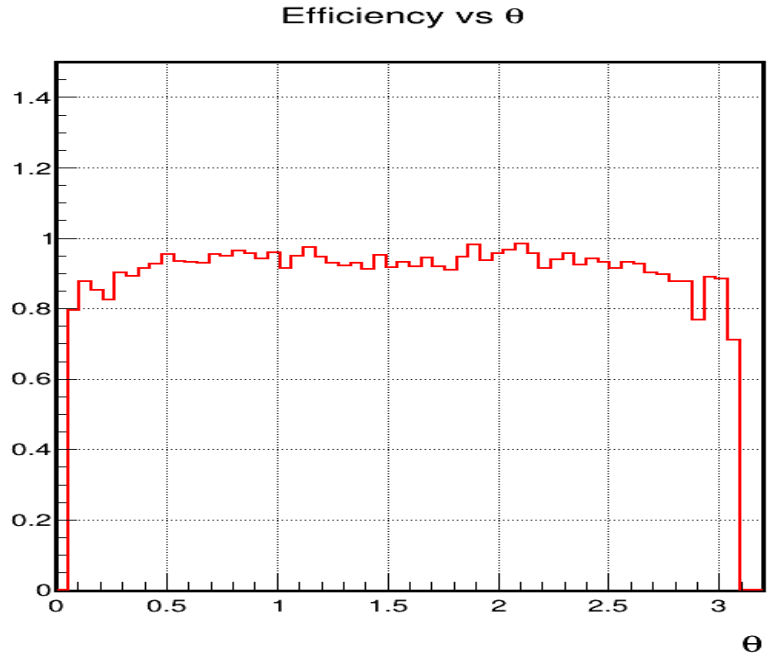


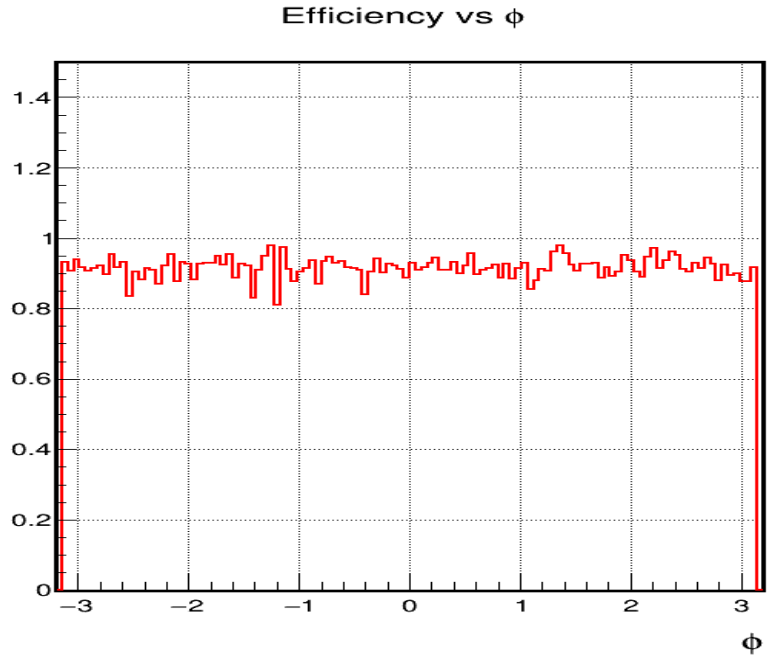


Reconstruction efficiency (open charm, 2-nd generation)

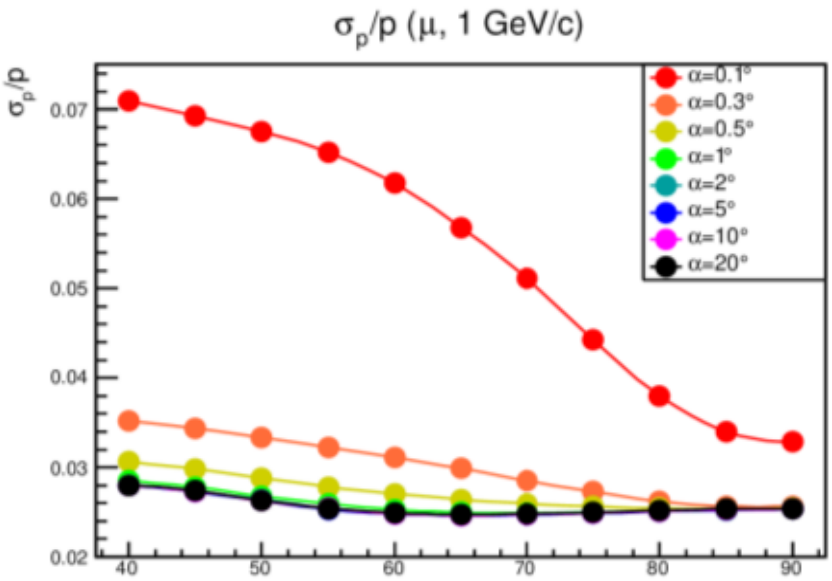








Track momentum resolution vs straw tubes tilt (Ruslan study)



Muons 1 GeV/c, $\theta = 40^0$, $0^0 < \varphi < 360^0$

“ideal” reco
0.1^0 only straw => fit ~7.9 %
1.0^0 only straw => fit ~2.7 %

Reco (its+straw)
0.1^0 => fit ~1.31 %
1.0^0 => fit ~1.30 %