PID purity study on simulation tracks

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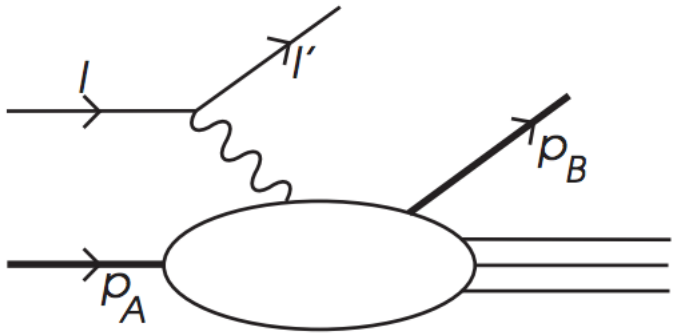
Goal and definition

- Goal: check PID purity for tracks in jets and observe how the purity change with different track energy and the track momentum fraction (z) from the jet.
- PID purity: $\frac{number\ of\ correctly\ identified\ track\ in\ PID\ system}{number\ of\ all\ track\ within\ PID\ system\ coverage}$ for certain kind of particle (Pion, Kaon, proton).
  - "Correctly identified track": 4-momentum and PID of the track are same (matched) between the track in PID system and track from jet.
  - dualRICH_aerogel: $1 < \eta < 3.5$, $P < 12\ GeV$
  - dualRICH_c2f6: $1 < \eta < 3.5$, $P > 12\ GeV$
  - barrelDIRC: $-1 < \eta < 1$
  - mRICH: $-3.5 < \eta < -1$

Data set

- Use Pythia8 and Delphes to simulate DIS process
- Delphes card: **delphes_card_allsilicon_3T.tcl** . Based on EIC Delphes card.
- Number of event generated: 200 k
- E_{proton} = 100 GeV
- $E_{electron}$ = 10 GeV
- Q^2 > 100 GeV
- Jet finding: Anti-kT algorithm, R<1



- The input track list for jet finding is: Eflow track.
  - Include Ecal photons, Hcal tracks and Hcal neutral hadrons.
- The input track list for PID system is: Smearing Track

Basic idea for PID system

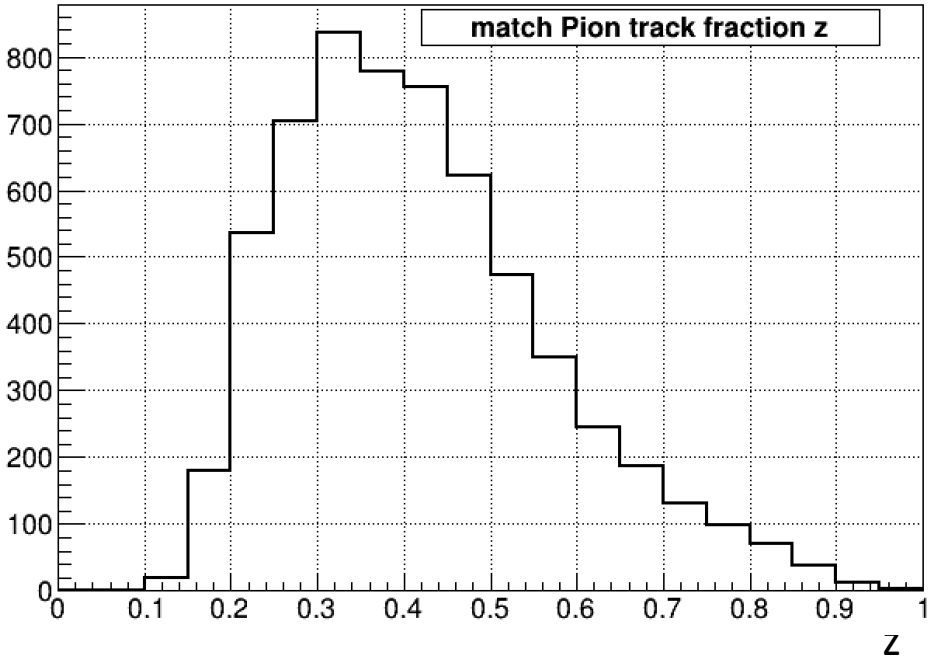
- For tracks, they have given the PID number for common particles to indicate their particle species.
- Implemented using Yellow Report-era EICUG tools ("PID Code") which returns nSigma separation for a particle with a given (P , eta) under a certain hypothesis pair (e.g. K/pi or K/proton).
  - This nSigma separation for particle pair give us the identification efficiency, which is probability that species A to identify as same species A. These have already set in Delphes simulation card.
- Check 4 different PID system purity:
  - mRICH , barrelDIRC , dualRICH_aerogel , dualRICH_c2f6

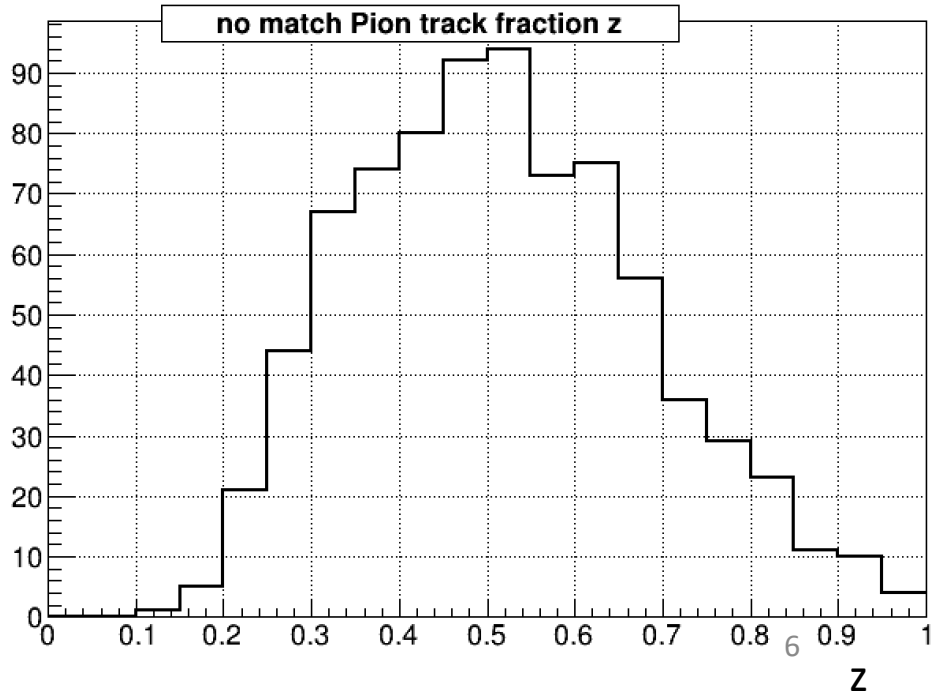
PID system dualRICH_c2f6

- dualRICH_c2f6: $1 < \eta < 3.5$, $P > 12\ GeV$
- PID efficiency: (obtain from Delphes simulation card, the exact identification efficiency is various by different η and E)
  - Pion to Pion: > 80%
  - Kaon to Kaon: > 80%
  - Proton to proton: ≈100%

(no) match Pion track distribution with fraction z

- PID system: dualRICH_c2f6 ($1 < \eta < 3.5$, $P > 12\ GeV$)
- Match track: find out track in PID system with the same track in the simulation track list.
- No match track: can NOT find out track in PID system for the track within coverage with same type in the simulation track list.
  - However, the no match pion track are those not collected in PID system.
  - No pion track are misidentified by the PID system.

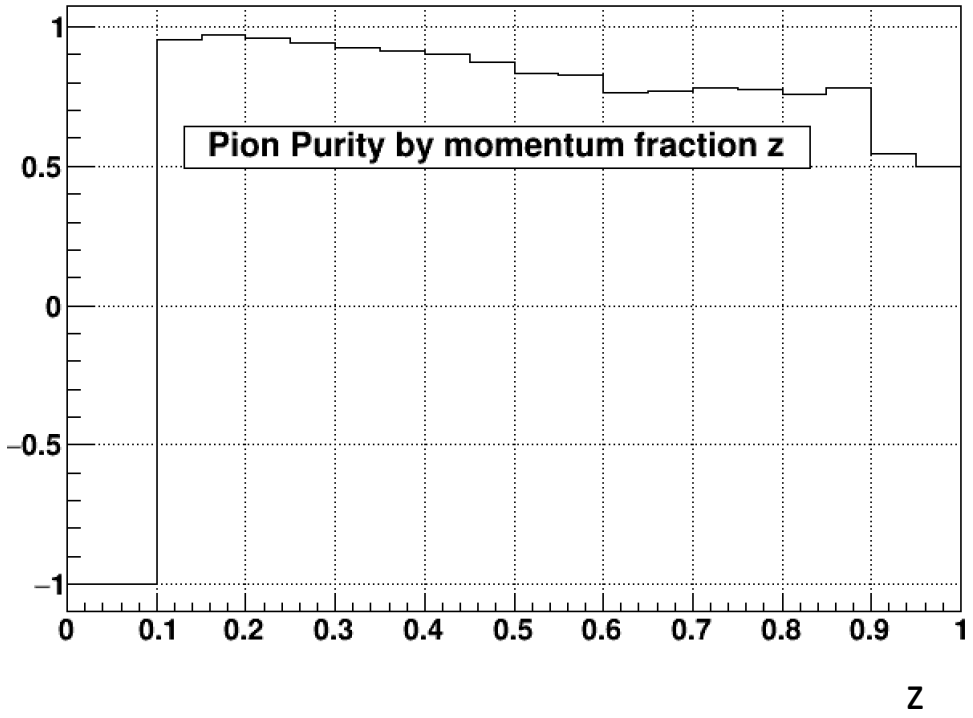




Pion purity by momentum fraction z

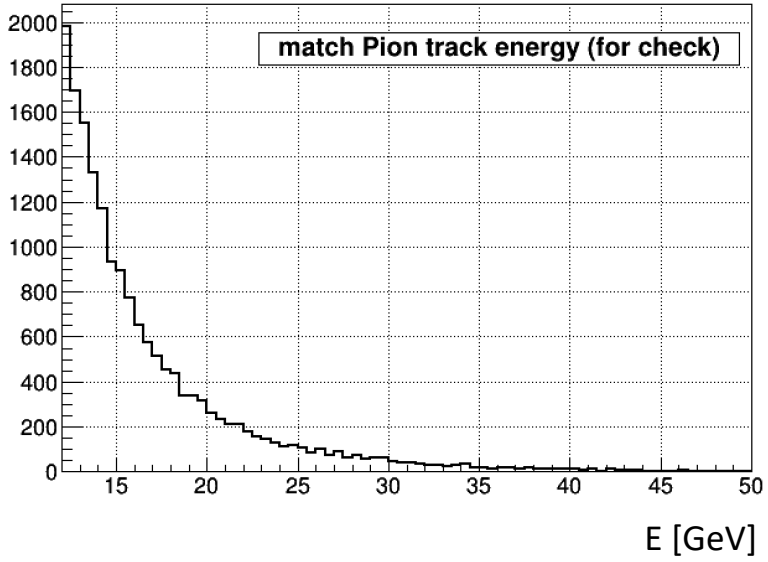
PID system: dualRICH_c2f6

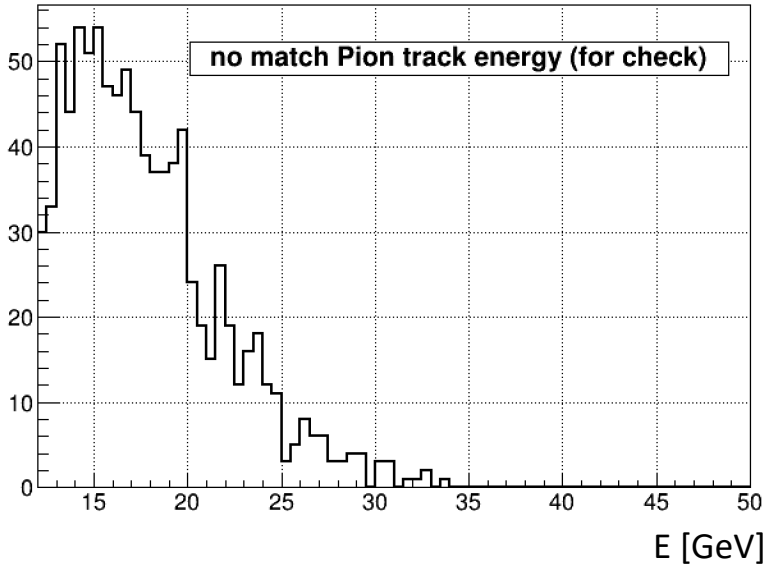
- $purity = \frac{number\ of\ matched\ track\ within\ z\ range}{total\ number\ of\ track\ within\ z\ range}$
- The purity should be within [0,1] , if purity is shown as -1 means no tracks are within this z range.



Check with PID system tracks

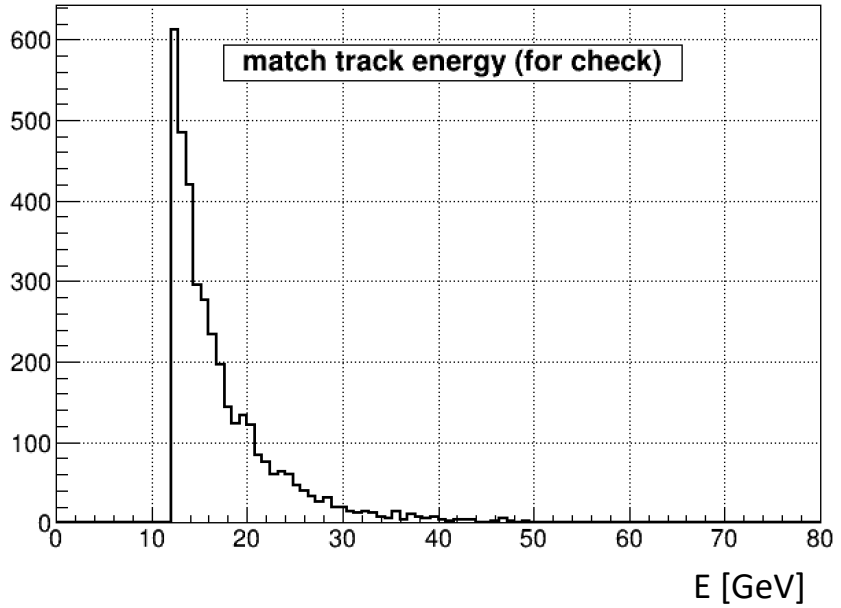
- In order to make sure the PID system in simulation work well, we compare the track in PID system with **Smearing tracks**.
  - Result: we all tracks in Smearing track list can find out in tracks in PID system (regardless of PID value)
  - We can also see some tracks are misidentified as other type of tracks in PID system.
- So the PID system in simulation works well as we expected.

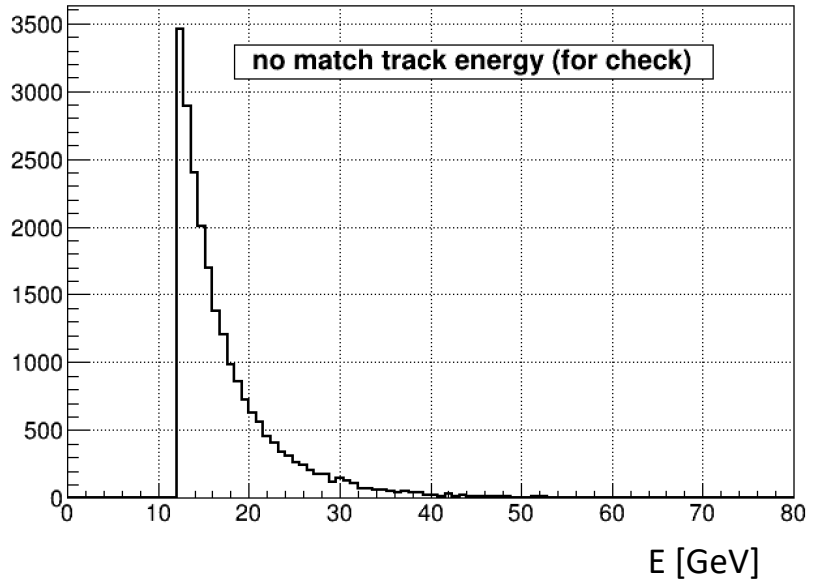




Check with Eflow tracks

- We also check with PID tracks with **Eflow tracks**.
  - We can see the a lot of Eflow tracks can't match with PID tracks (right plot). Note: the tracks below not consider type of PID but only consider 4-momentum.
  - We only focus on Eflow tracks in Pion, Kaon and proton, since these are the main type of tracks in PID system.
  - We also don't see any misidentified tracks (e.g. Pion misidentified as Kaon)
  - We assume some of these no match track are not in Smear track.





Comments and discussion

- The PID system work well.
- If we only compare with Eflow tracks and PID tracks, there are a lot of Eflow tracks can’t match with PID tracks, even though 4-momentum only.
- We don’t see any mismatch Eflow tracks in PID system. Don’t know why?

Results for purity study

PID system dualRICH_c2f6

- dualRICH_c2f6: $1 < \eta < 3.5$, $P > 12\ GeV$
- PID efficiency: (obtain from Delphes simulation card, the exact identification efficiency is various by different η and E)
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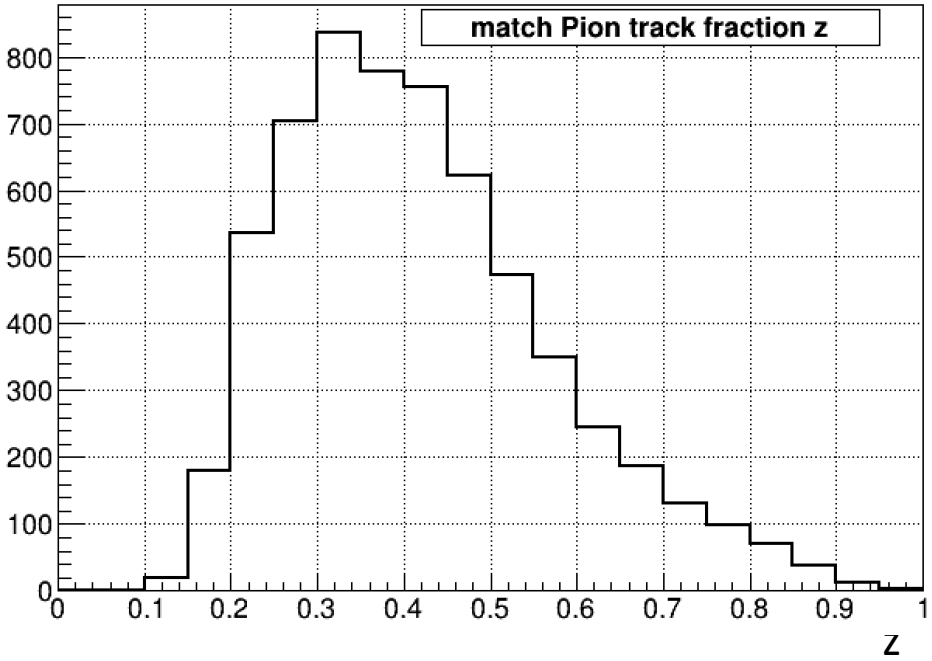
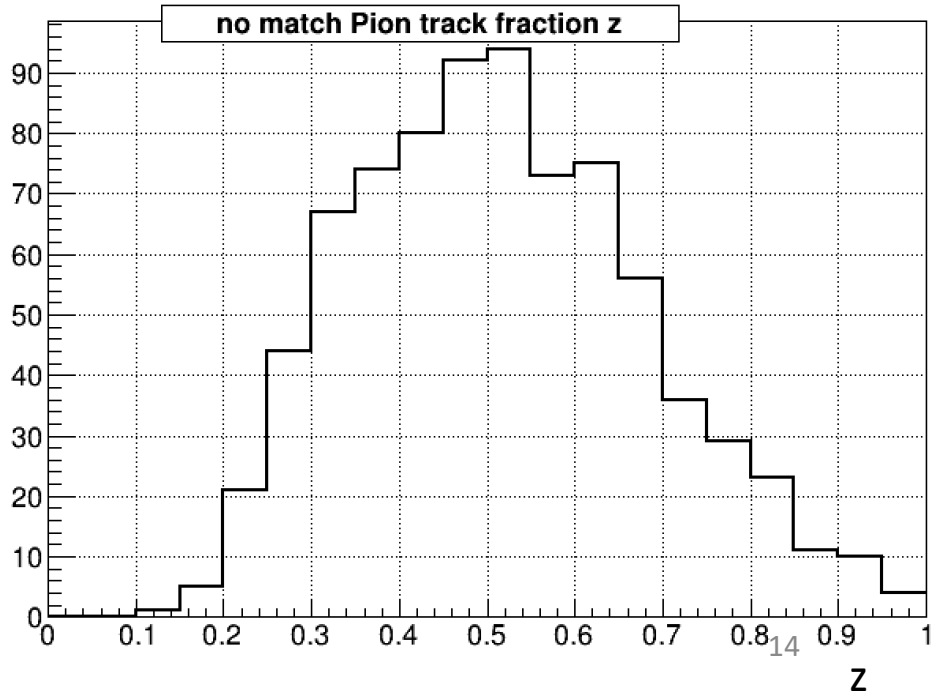
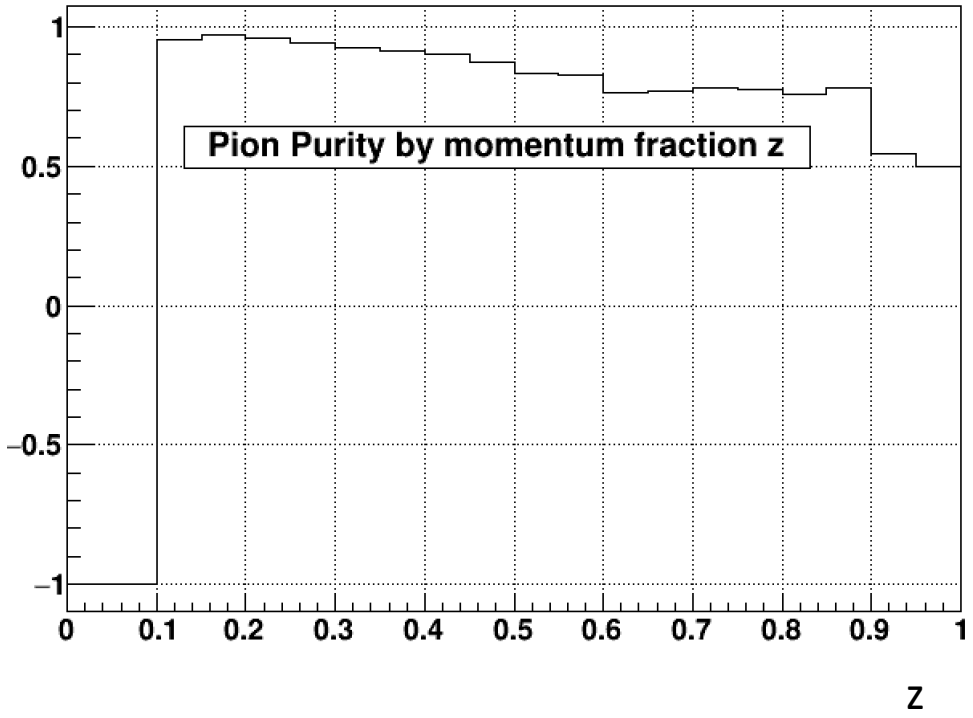




Pion purity by momentum fraction z

PID system: dualRICH_c2f6

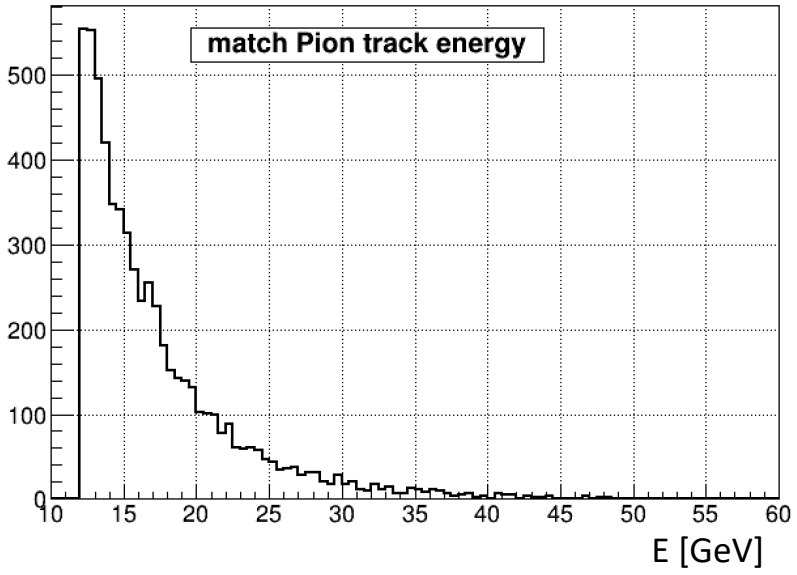
- $purity = \frac{number\ of\ matched\ track\ within\ z\ range}{total\ number\ of\ track\ within\ z\ range}$
- The purity should be within [0,1] , if purity is shown as -1 means no tracks are within this z range.

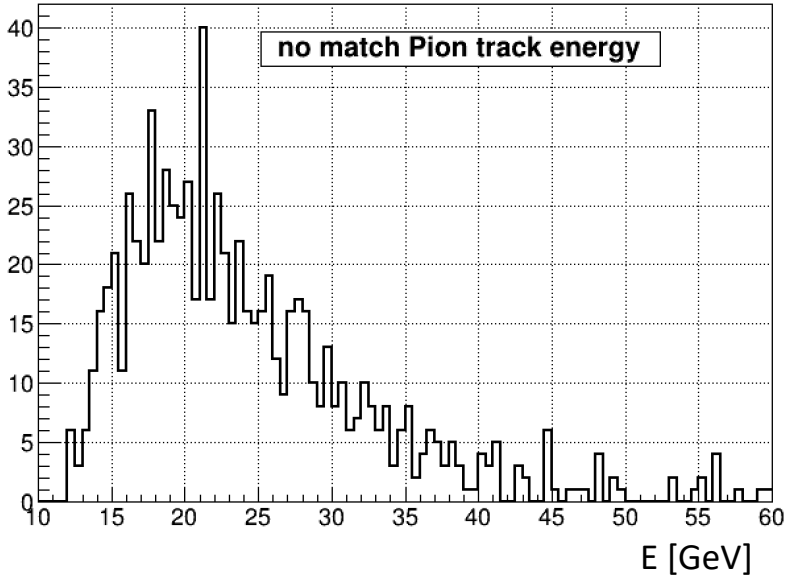


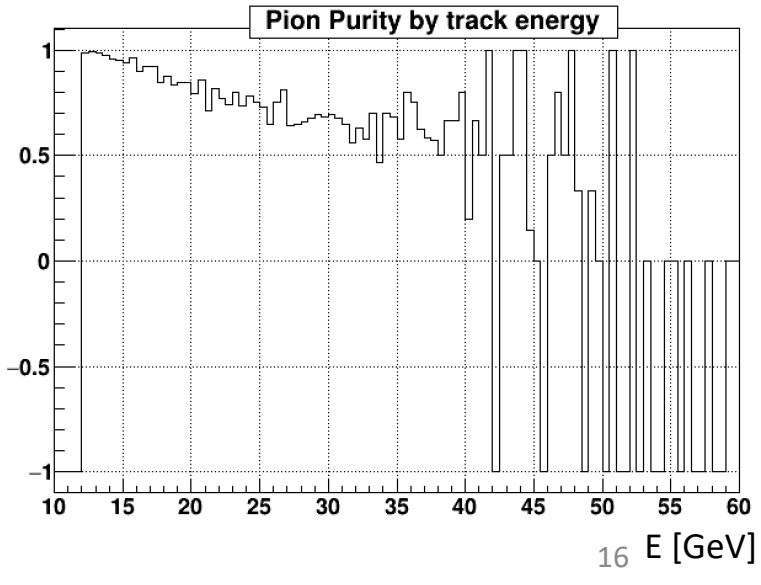
Pion purity by track energy

PID system: dualRICH_c2f6

- $purity = \frac{number\ of\ matched\ track\ within\ track\ energy\ range}{total\ number\ of\ track\ within\ track\ energy\ range}$
- The purity should be within [0,1] , if purity is shown as -1 means no tracks are within this jet energy range.
- For the relatively low purity at E > 20 GeV, there are still some tracks in jets that not match with PID system. (The no match pion track are those not collected in PID system.)

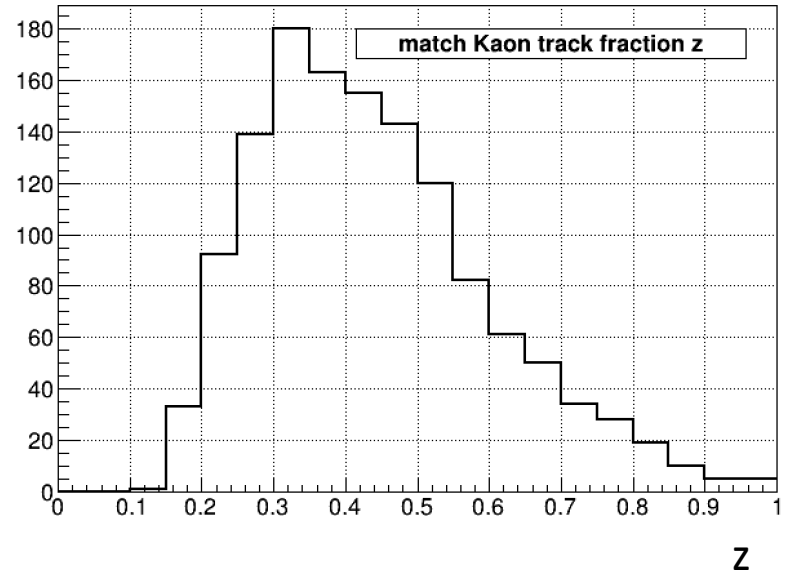


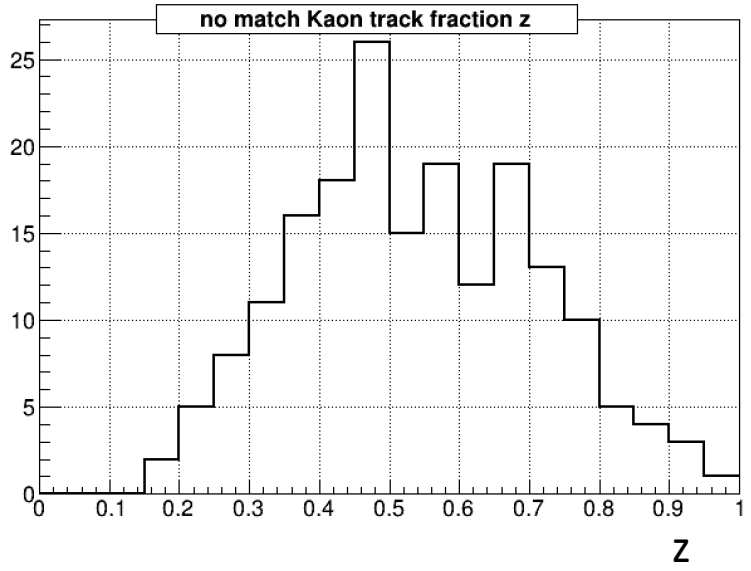


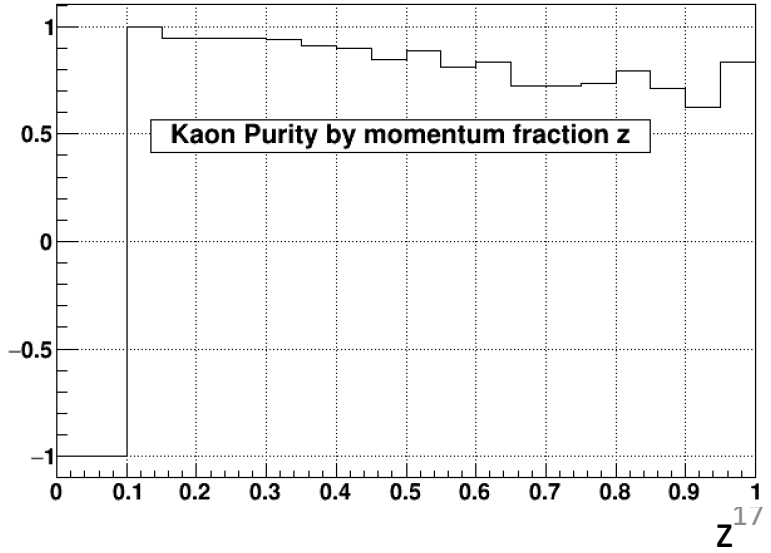


Kaon purity by momentum fraction z

- $purity = \frac{number\ of\ matched\ track\ within\ z\ range}{total\ number\ of\ track\ within\ z\ range}$
- The purity should be within [0,1] , if purity is shown as -1 means no tracks are within this z range.



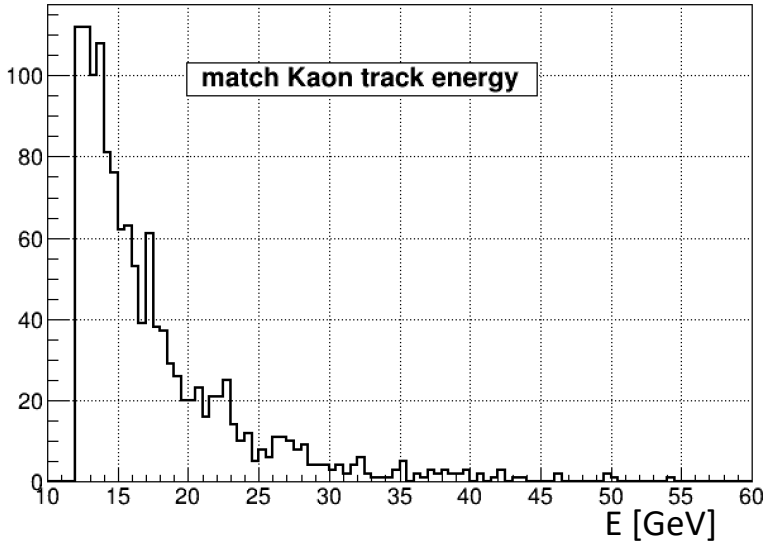


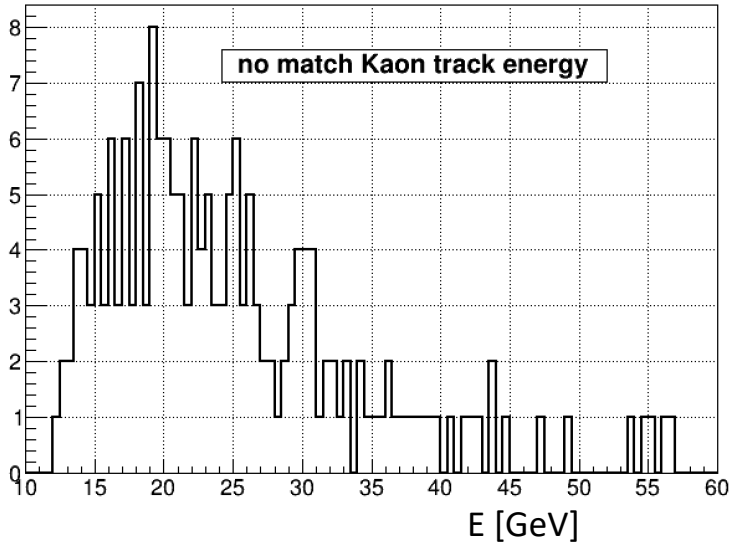


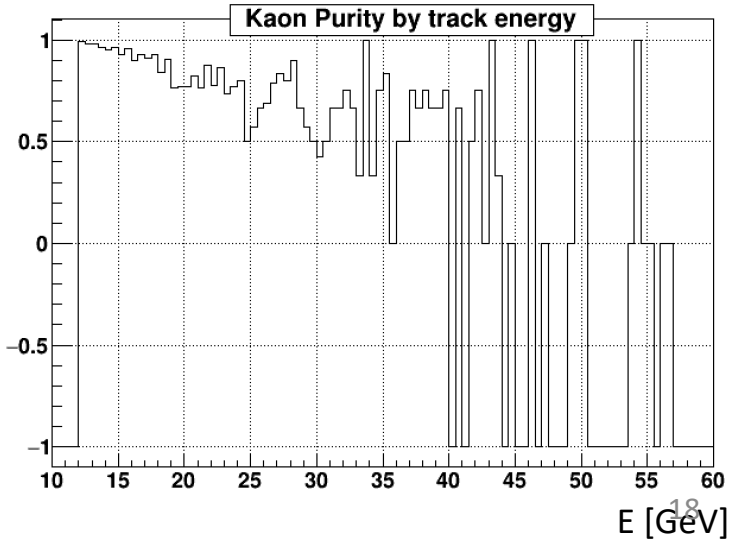
Kaon purity by track energy

PID system: dualRICH_c2f6

- $purity = \frac{number\ of\ matched\ track\ within\ energy\ range}{total\ number\ of\ track\ within\ energy\ range}$
- The purity should be within [0,1] , if purity is shown as -1 means no tracks are within this energy range.







Proton purity by fraction z

PID system: dualRICH_c2f6

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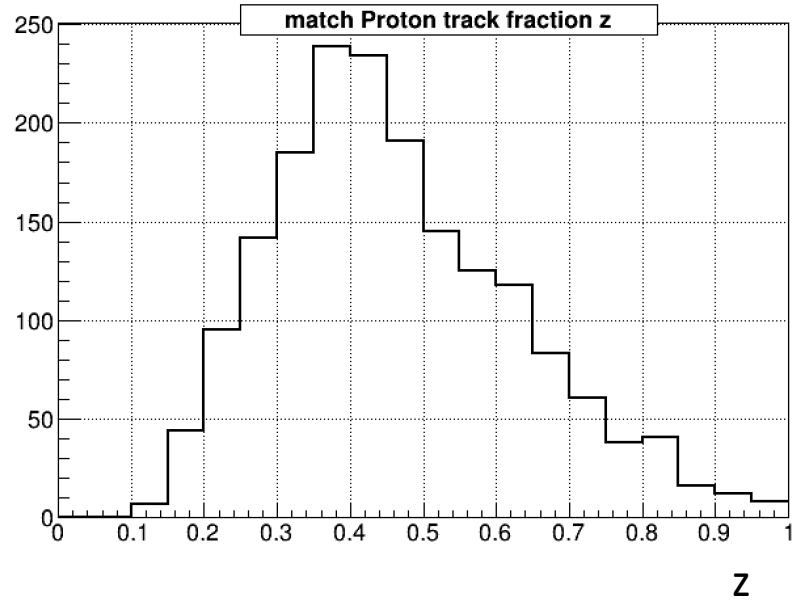
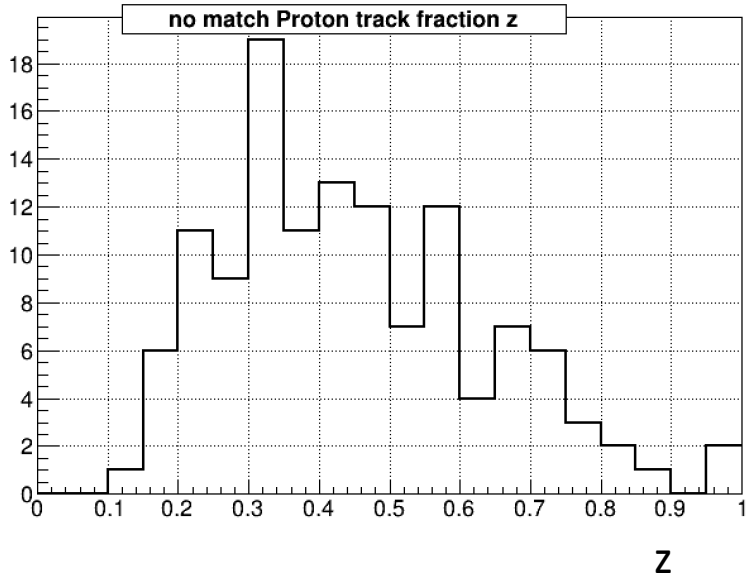
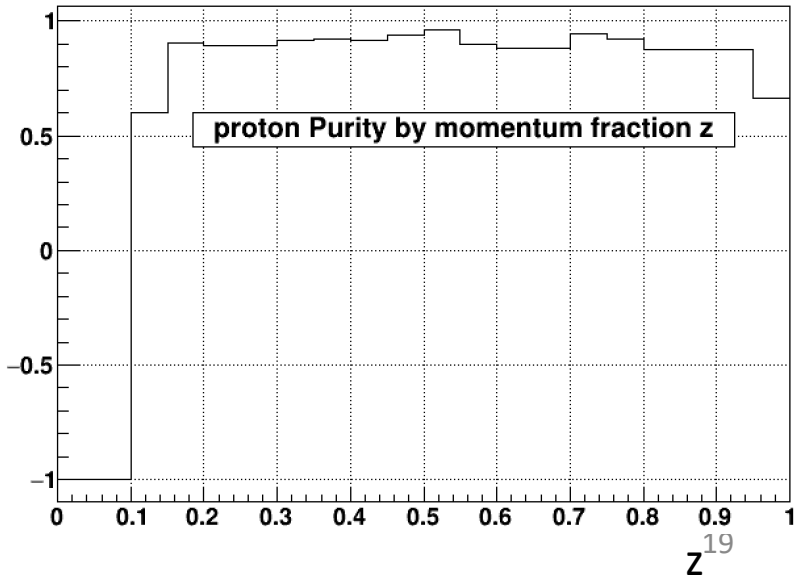
- The purity should be within [0,1] , if purity is shown as -1 means no tracks are within this energy range.
- The no match tracks are those tracks in jet that can not find out in PID system. Instead, we do not see any misidentified proton track. (reasonable)



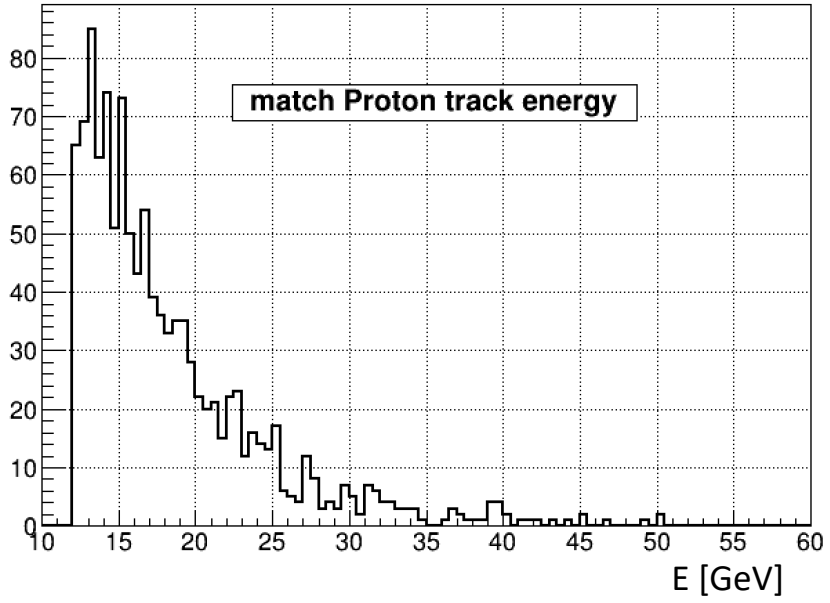


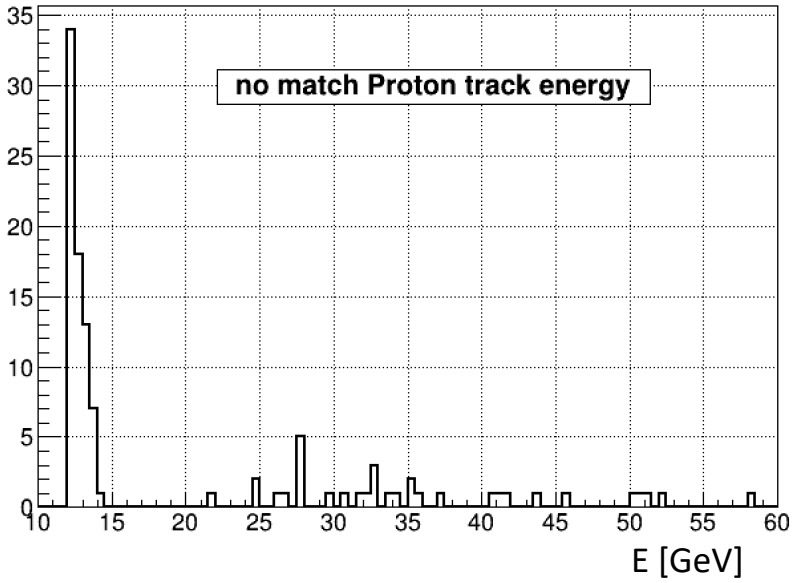


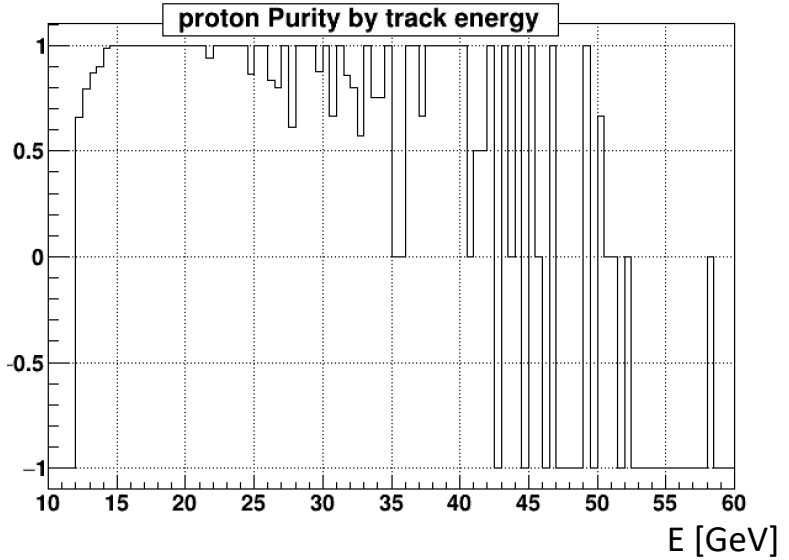
Proton purity by energy

PID system: dualRICH_c2f6

- $purity = \frac{number\ of\ matched\ track\ within\ energy\ range}{total\ number\ of\ track\ within\ energy\ range}$
- The purity should be within [0,1] , if purity is shown as -1 means no tracks are within this energy range.
- The no match tracks are those tracks in jet that can not find out in PID system. Instead, we do not see any misidentified proton track. (reasonable)





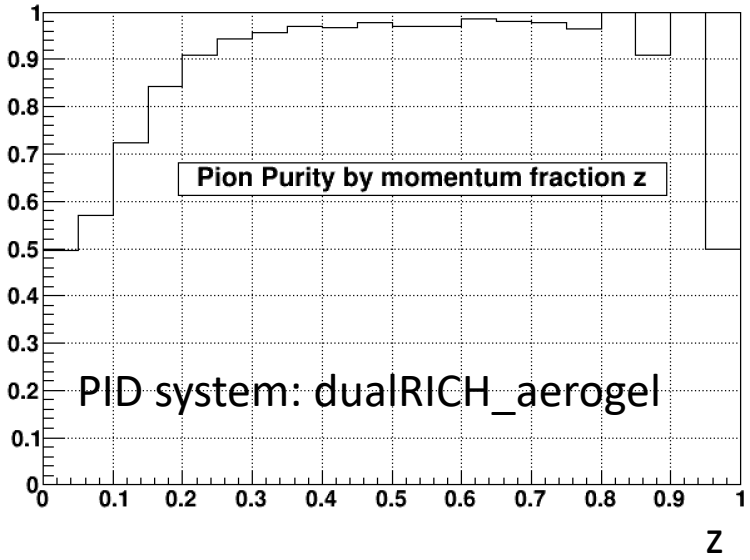


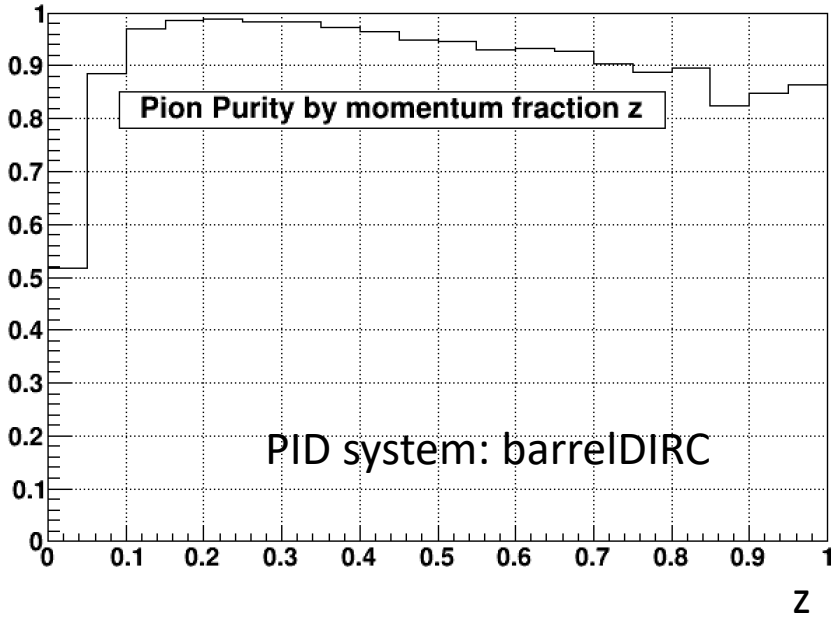
Compare with other PID system

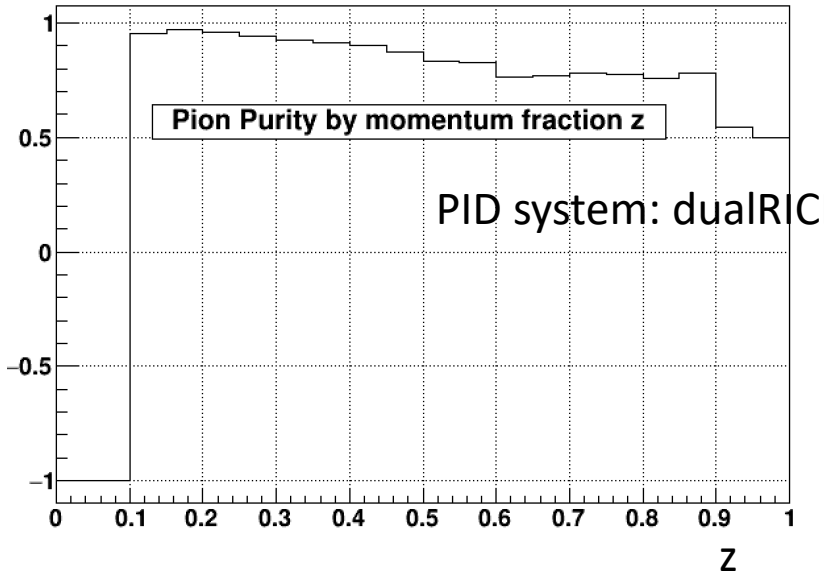
- PID system track range:
  - dualRICH_aerogel: $1 < \eta < 3.5$, $P < 12\ GeV$
  - dualRICH_c2f6: $1 < \eta < 3.5$, $P > 12\ GeV$
  - barrelDIRC: $-1 < \eta < 1$
  - mRICH: $-3.5 < \eta < -1$

- All the track from jets need to satisfy for corresponding range when calculate for purity with each PID system.

Pion purity by z for different PID systems



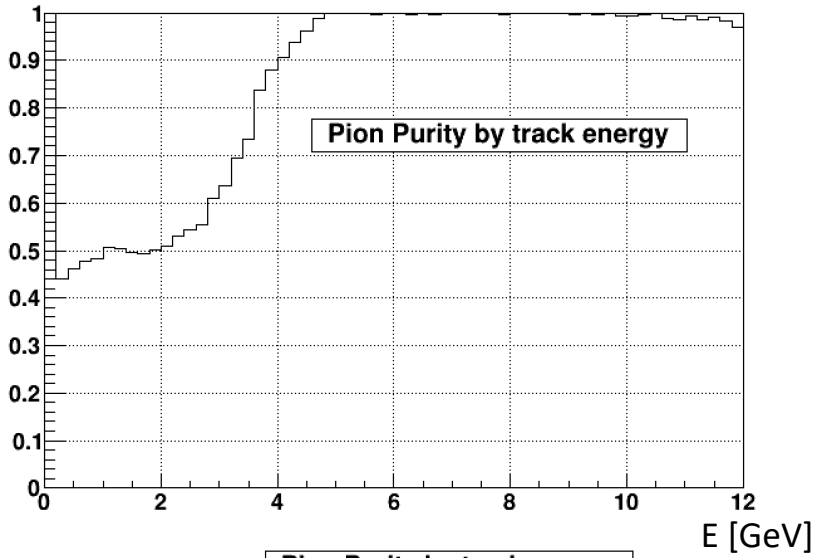




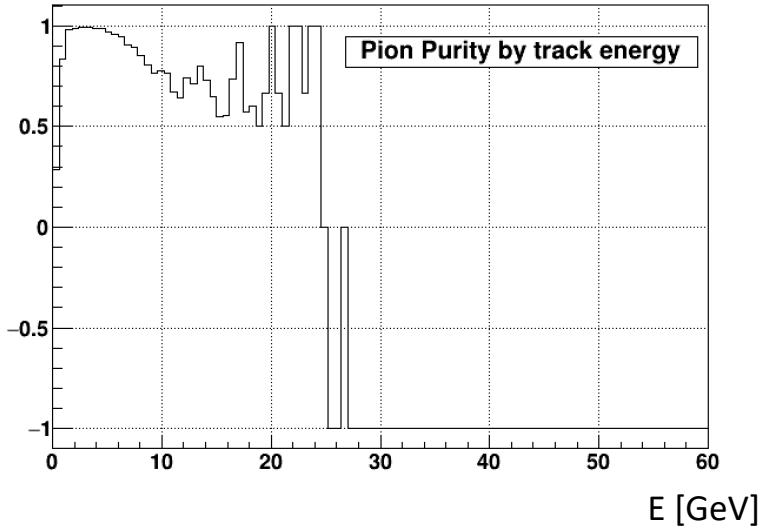
Not many tracks are within PID system mRICH coverage, so the purity is very low (close to 0).

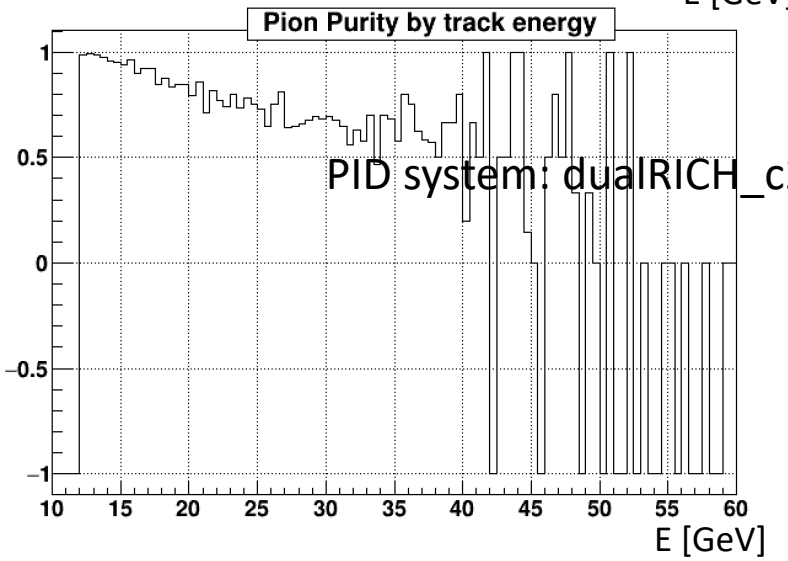
Pion purity by jet energy for different PID systems

PID system: dualRICH_aerogel



PID system: barrelDIRC





PID system: dualRICH_c2f6

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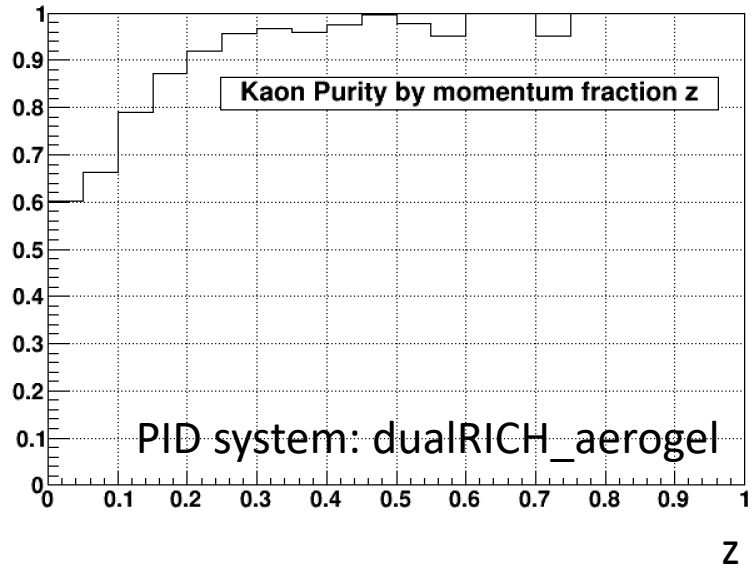
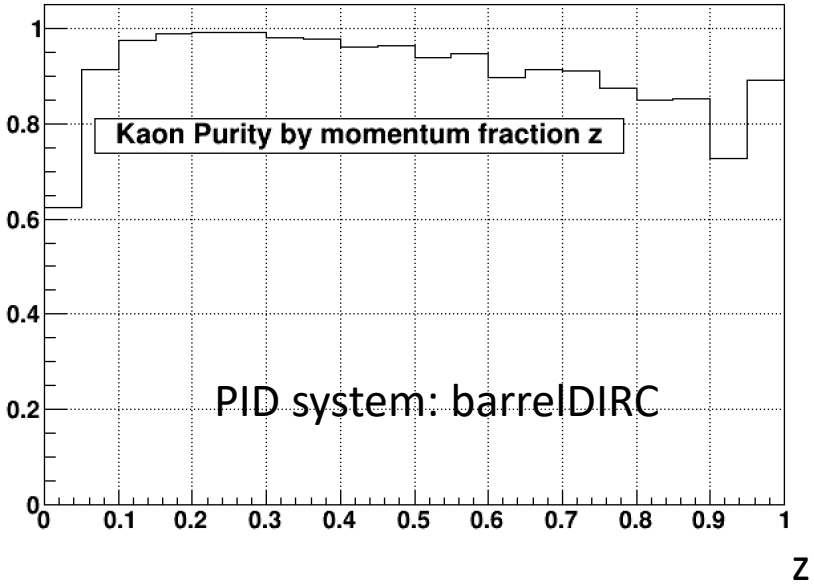
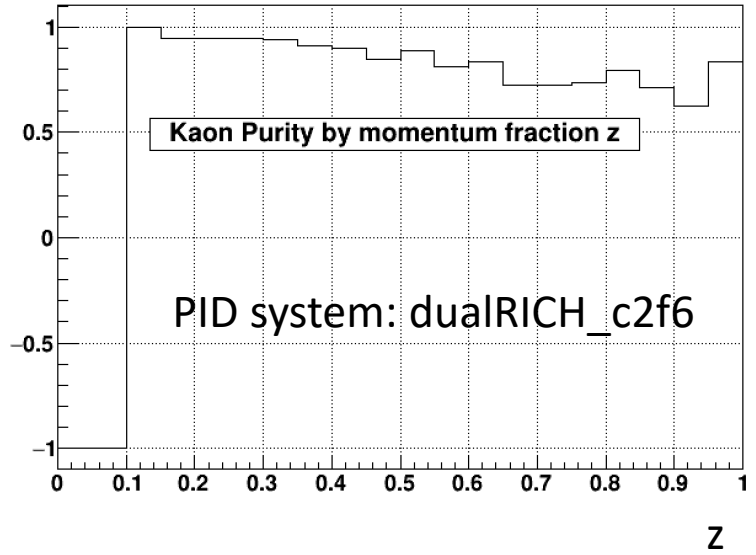
Kaon purity by z for different PID systems







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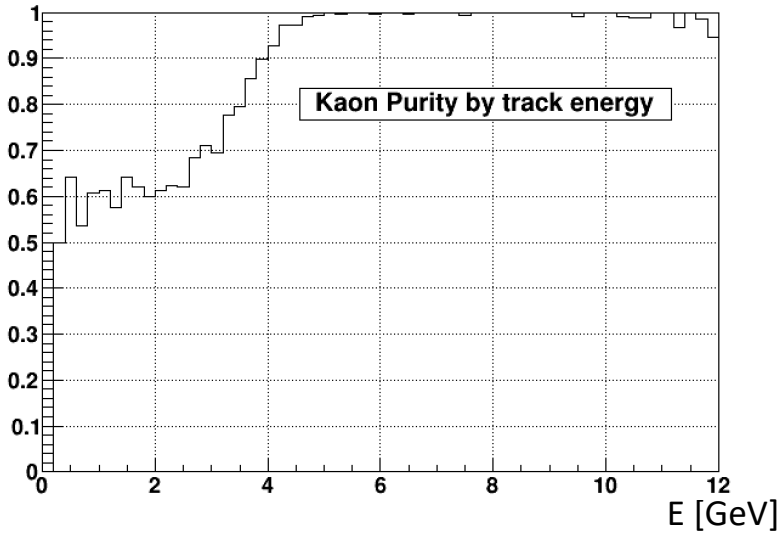
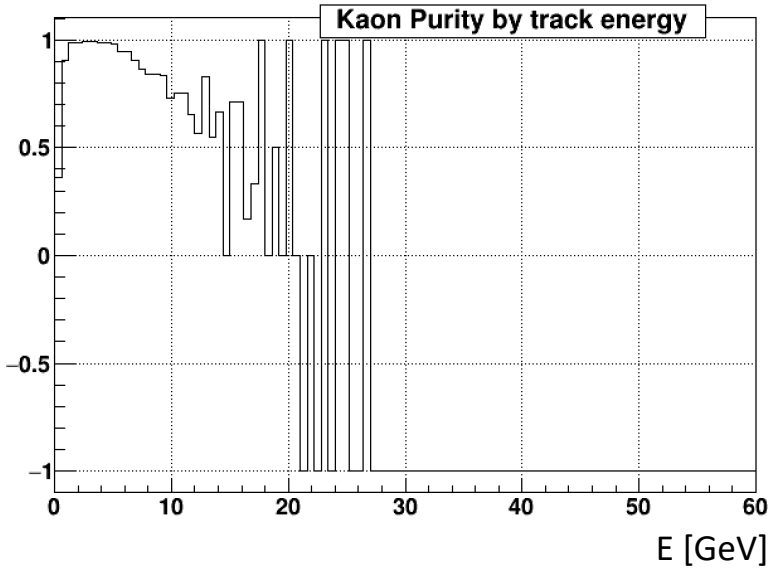
Kaon purity by jet energy for different PID systems

PID system: dualRICH aerogel



PID system: barrelDIRC



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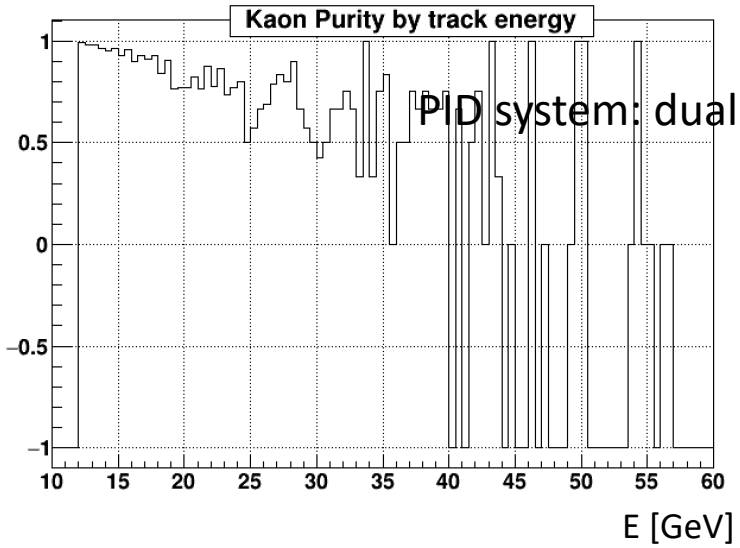

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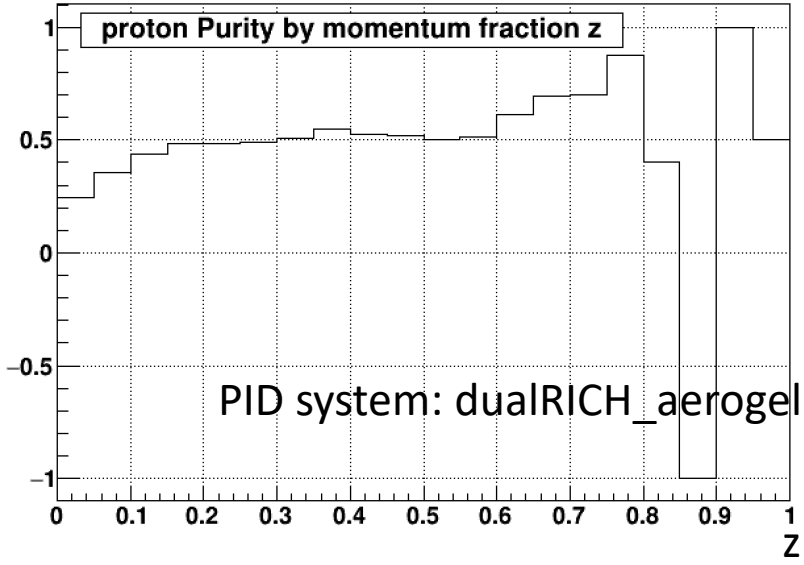
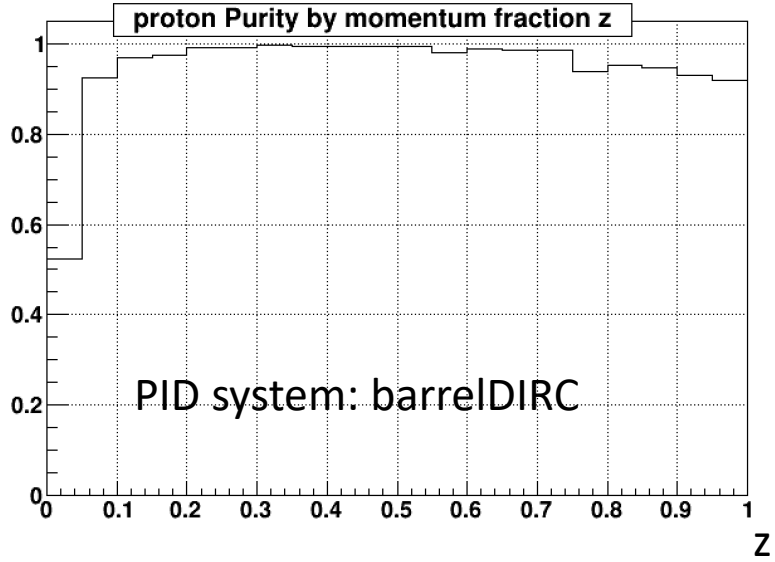
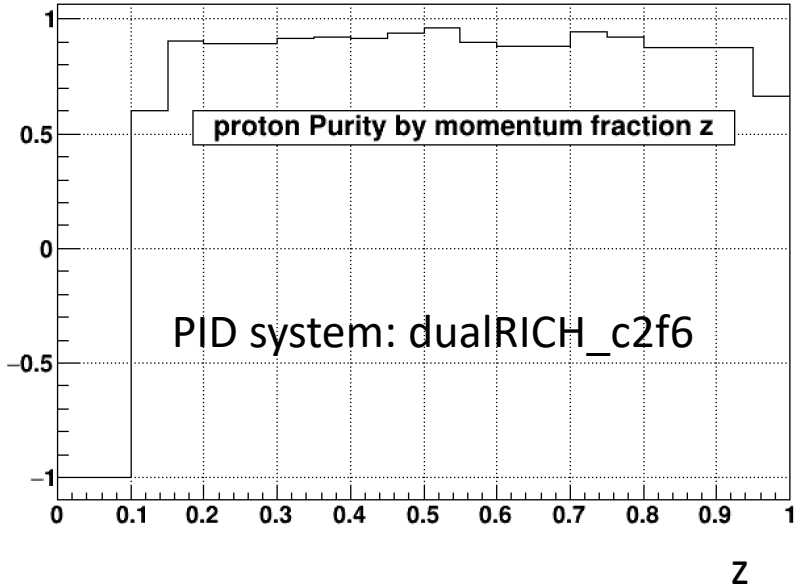
Proton purity by z for different PID systems







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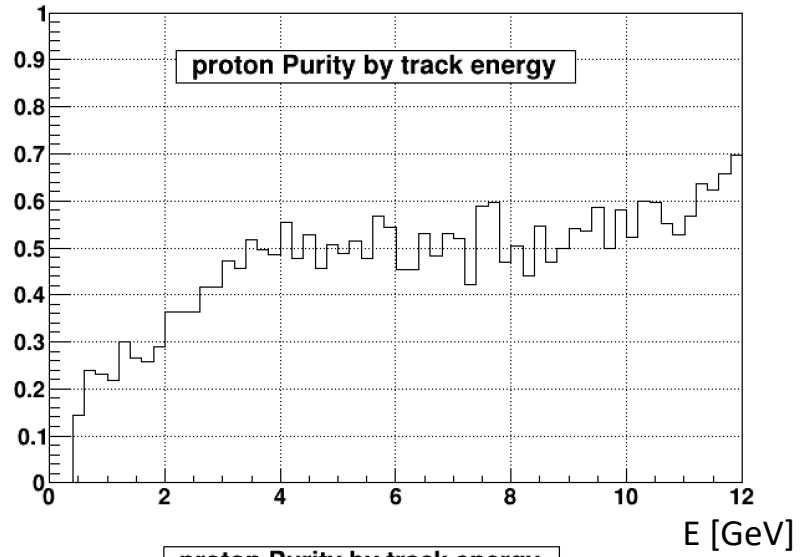
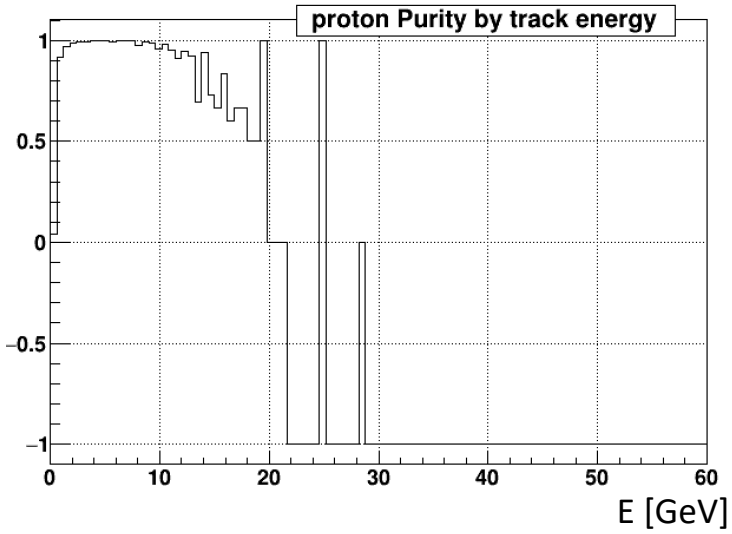
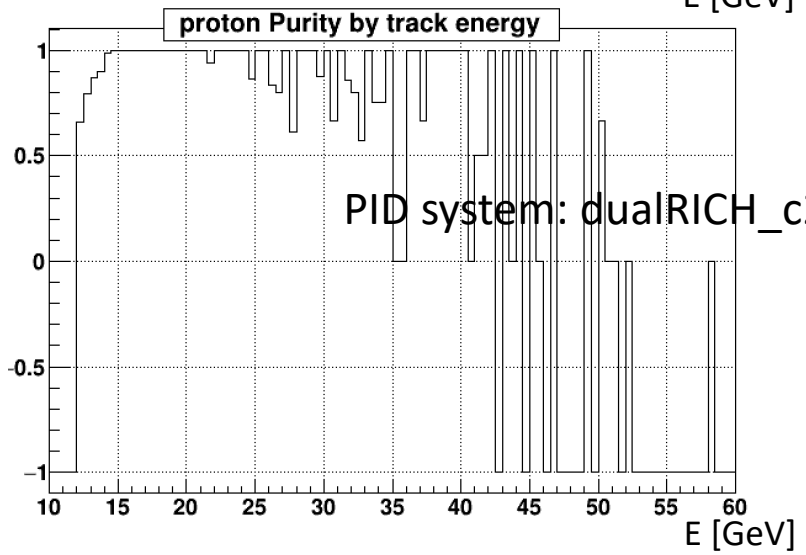


PID system: barrelDIRC





PID system: dualRICH_c2f6

Not many tracks are within PID system mRICH coverage, so the purity is very low (close to 0).

Conclusion

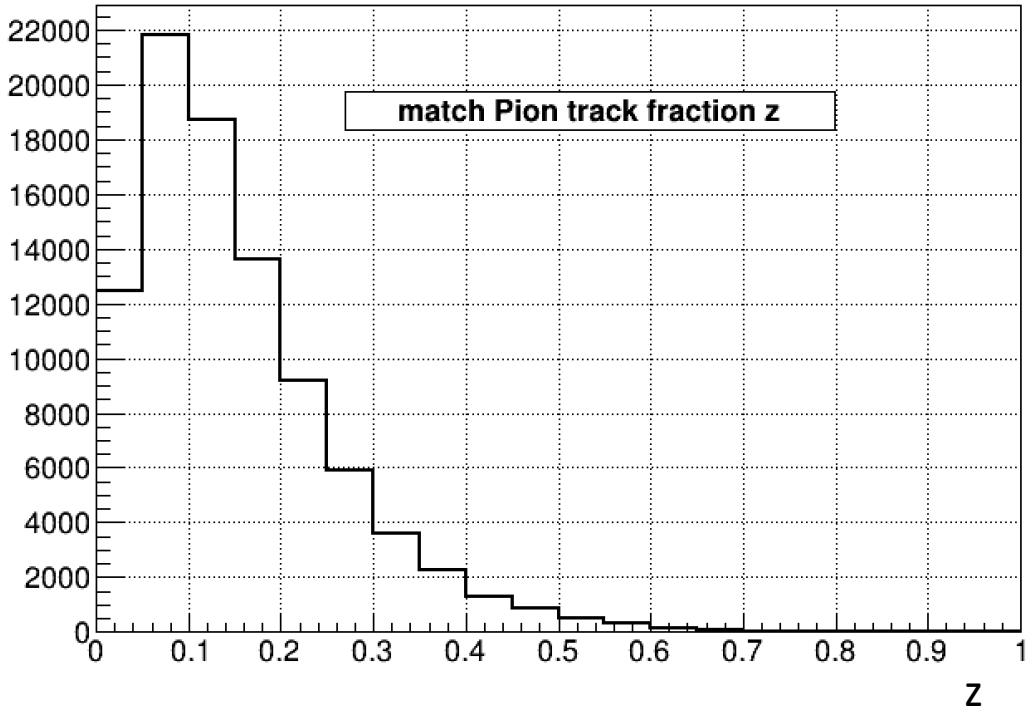
- We figure out that the no match tracks are those tracks in jet that can not find out in the PID system. They are not the misidentify tracks.
- We don’t find out any misidentify track for these PID system. (e.g. pion track identify as kaon track.) Look strange and unreasonable.
- We are not sure if the PID system work well?
- No much track at backward region, so unable to judge the PID system for that region.

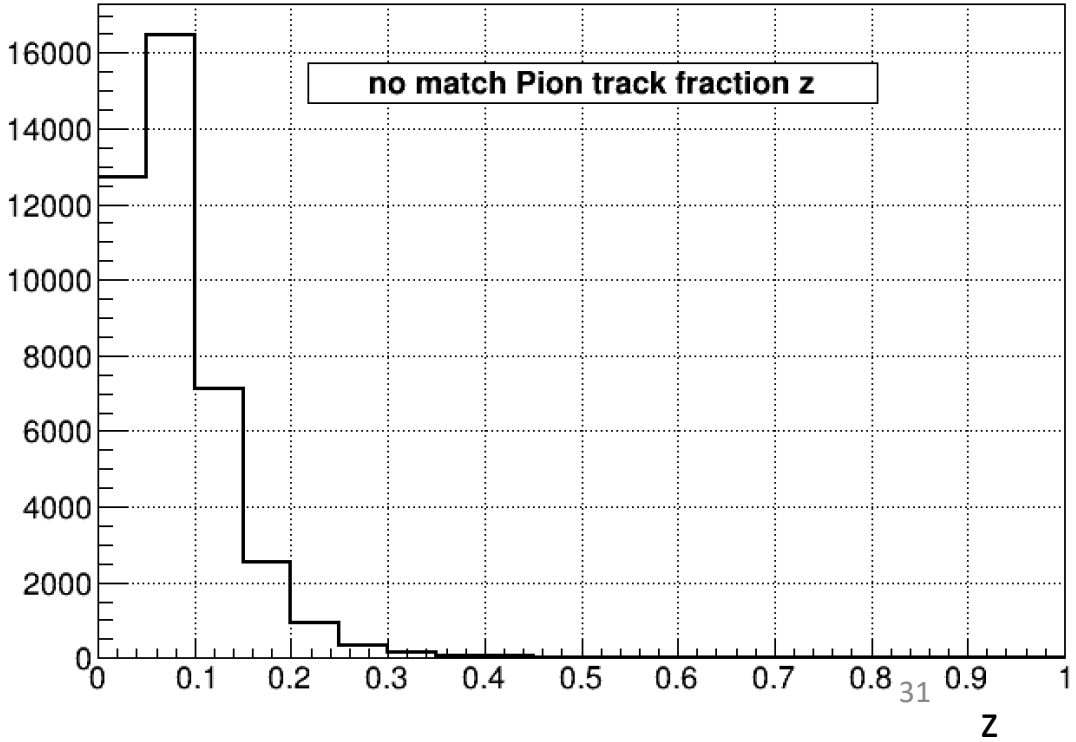
PID system: dualRICH_aerogel

- PID system: dualRICH_aerogel $(1 < \eta < 3.5\ ,\ P < 12\ GeV)$
- PID efficiency:
  - Pion to Pion: > 95%
  - Kaon to Kaon: > 95%
  - Proton to proton: 100% $(2.6 < P < 12\ GeV)$; 60% $(0.4 < P < 2.6\ GeV)$

(no) match Pion track distribution with fraction z

- PID system: dualRICH_aerogel $(1 < \eta < 3.5\ ,\ P < 12\ GeV)$
- Match track: find out track in PID system with the same track in the simulation track list.
- No match track: can NOT find out track in PID system within all the track within PID system coverage with same PID number in the simulation track list.
- Z: momentum fraction of the track from the jet.

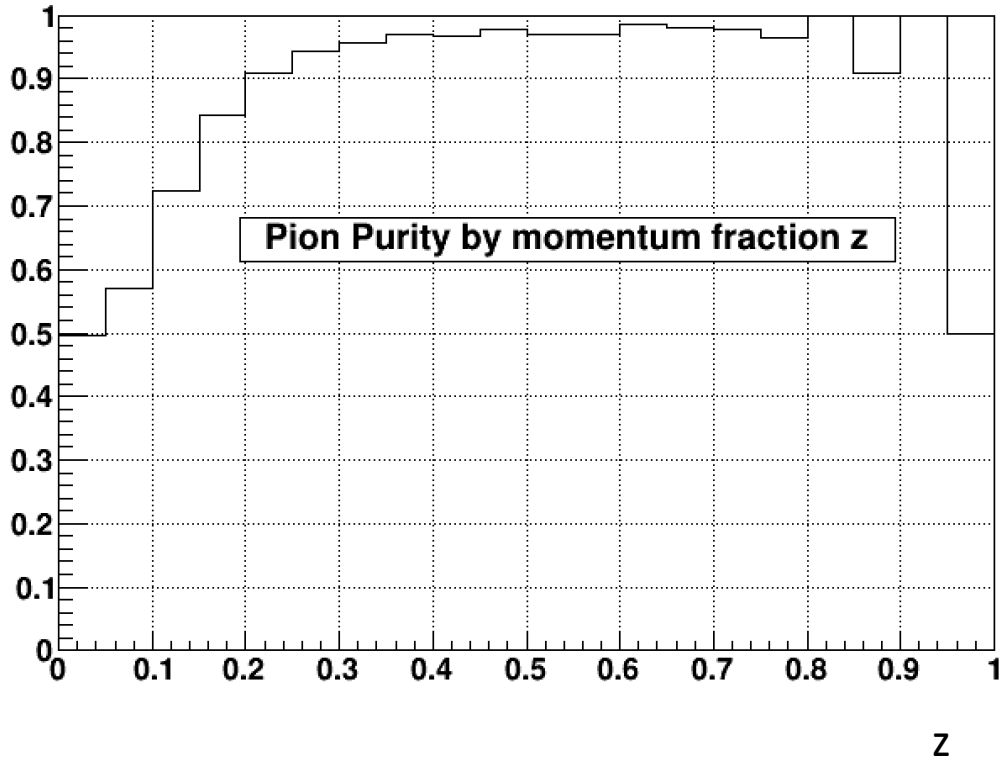




Pion purity by momentum fraction z

PID system: dualRICH_aerogel

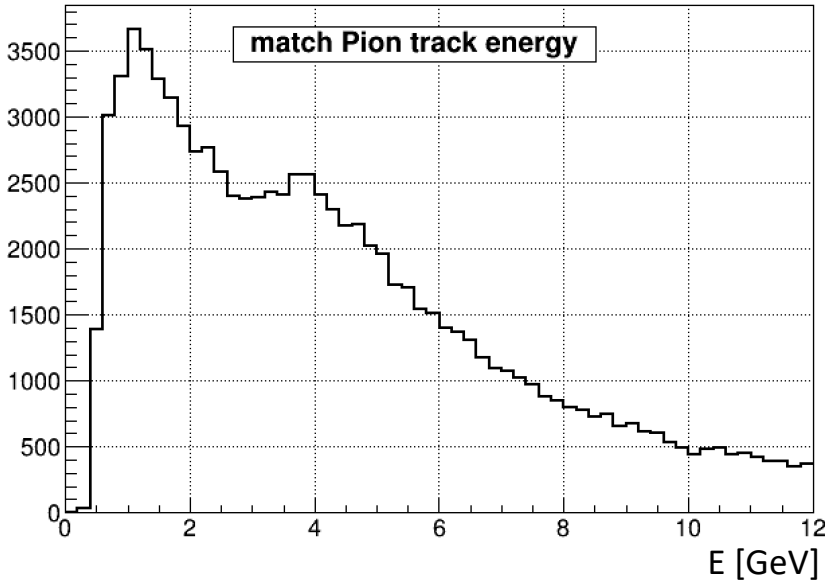
- $purity = \frac{number\ of\ matched\ track\ within\ z\ range}{total\ number\ of\ track\ within\ z\ range}$
- The purity should be within [0,1] , if purity is shown as -1 means no tracks are within this z range.

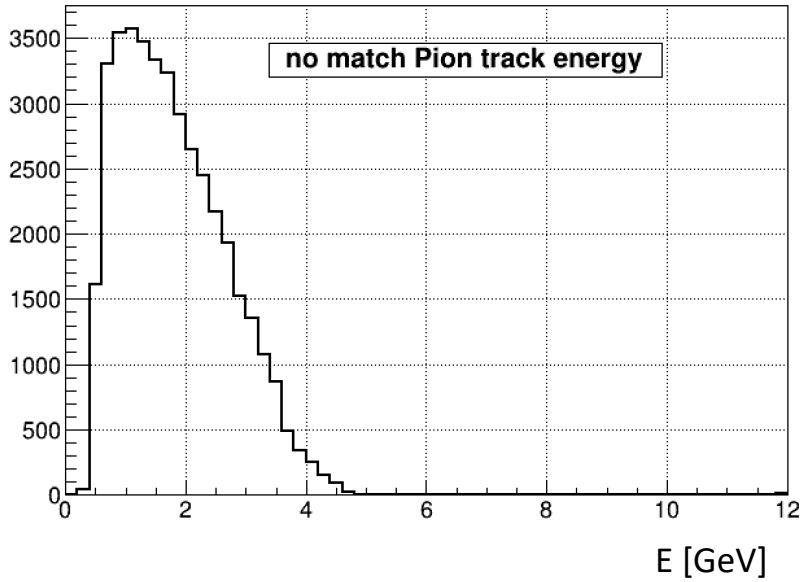


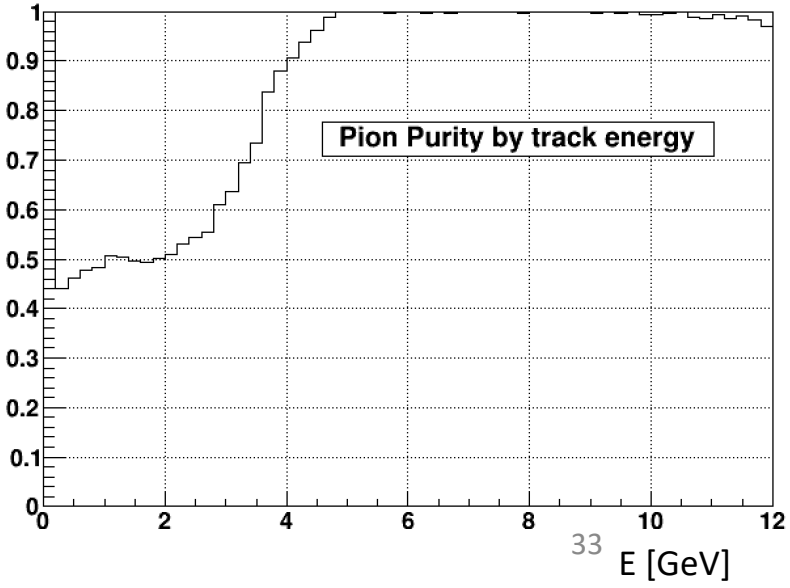
Pion purity by track energy

PID system: dualRICH_aerogel
$(1 < \eta < 3.5\ ,\ P < 12\ GeV)$

- $purity = \frac{number\ of\ matched\ track\ within\ track\ energy\ range}{total\ number\ of\ track\ within\ track\ energy\ range}$
- The purity should be within [0,1] , if purity is shown as -1 means no tracks are within this jet energy range.





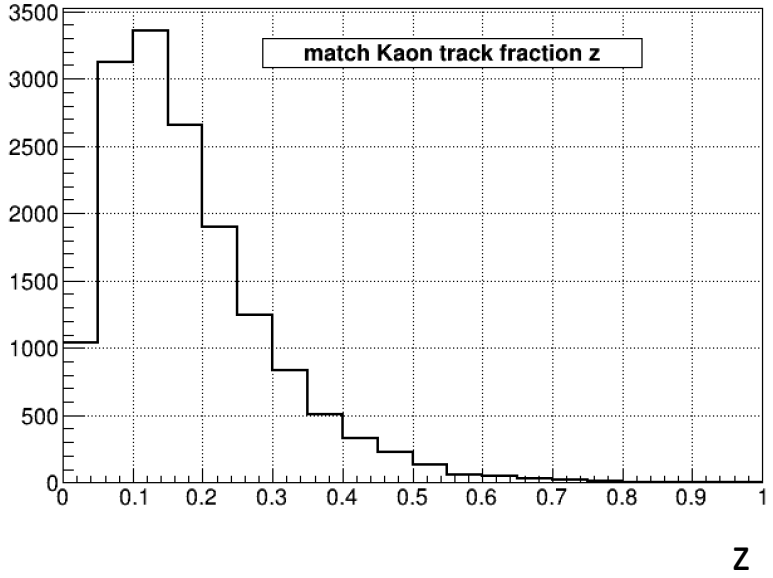


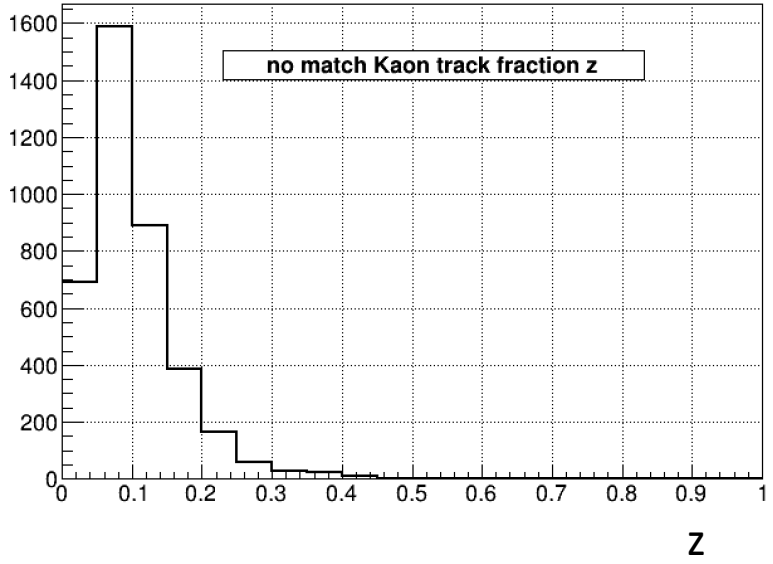
Kaon purity by momentum fraction z

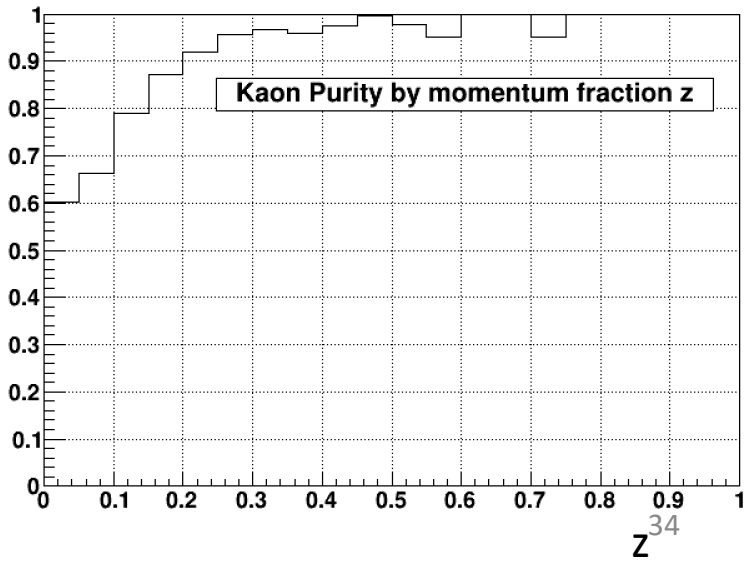
- $purity = \frac{number\ of\ matched\ track\ within\ z\ range}{total\ number\ of\ track\ within\ z\ range}$
- The purity should be within [0,1] , if purity is shown as -1 means no tracks are within this z range.

PID system: dualRICH_aerogel

$(1 < \eta < 3.5\ ,\ P < 12\ GeV)$





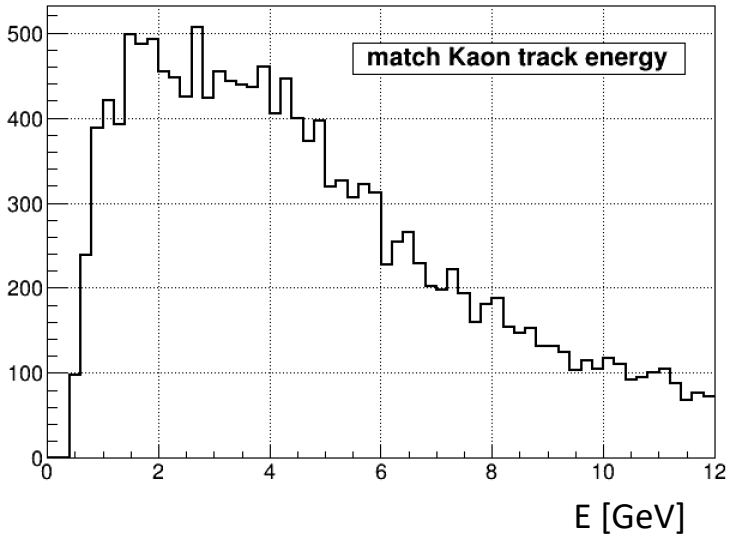


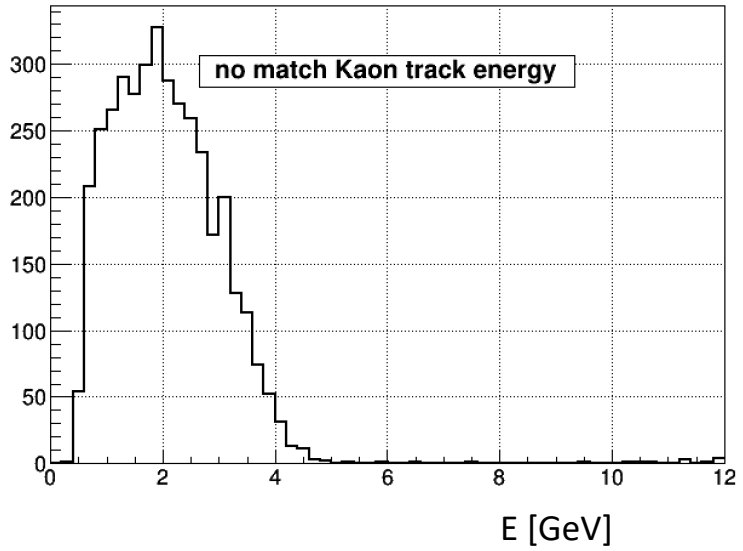
Kaon purity by track energy

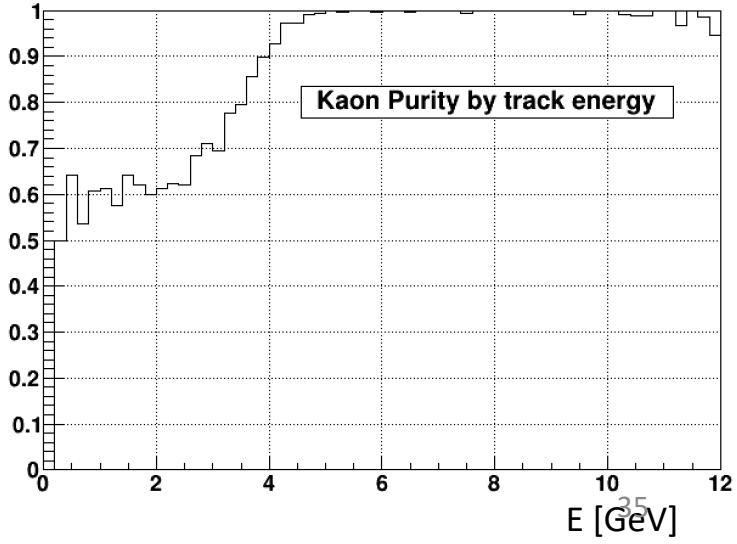
PID system: dualRICH_aerogel

$(1 < \eta < 3.5\ , P < 12\ GeV)$

- $purity = \frac{number\ of\ matched\ track\ within\ energy\ range}{total\ number\ of\ track\ within\ energy\ range}$
- The purity should be within [0,1] , if purity is shown as -1 means no tracks are within this energy range.







Proton purity

PID system: dualRICH_aerogel

$(1 < \eta < 3.5\ ,\ P < 12\ GeV)$

- Proton purity looks lower compared with Kaon and Pion purity.