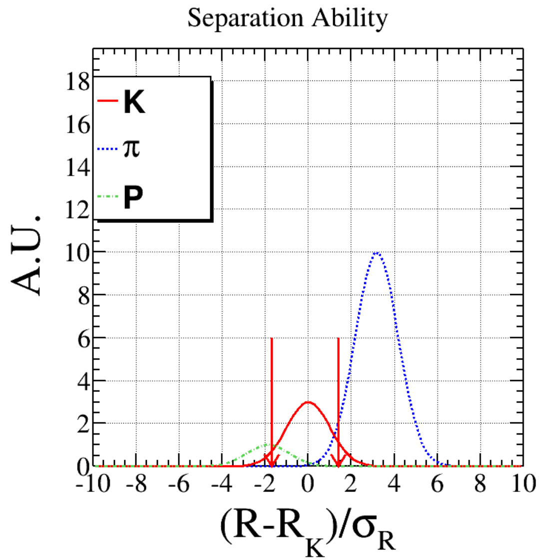
PID efficiency study

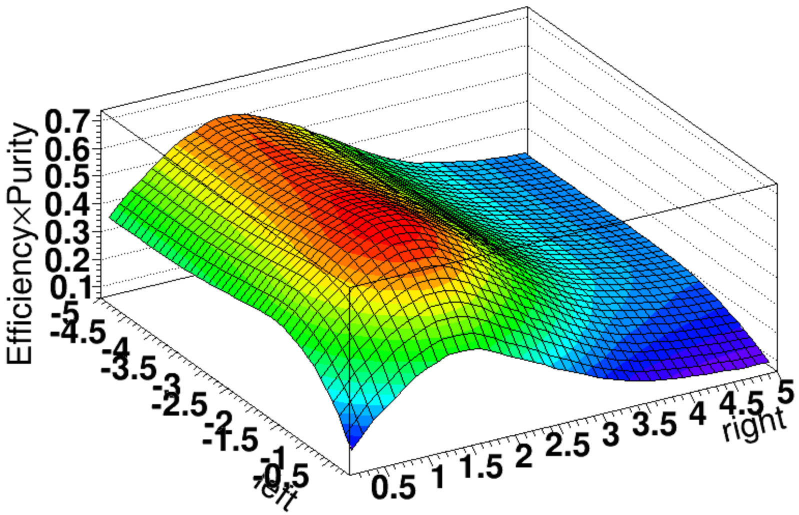
- TPC PID workflow in SW

j.nima.2022.167835

- Apply optimal cut with maximum efficiency times purity
- Cut optimization method in Reference improves K efficiency a lot (0.11), improves K purity a little (0.01) at $(\cos\theta, p) = (0.3, 12\text{GeV})$
- Apply this method to other samples
  - Release version: CEPCSW_tdr24.10.0
  - Samples: single $\pi/K/p$ samples at $p((1-10\text{GeV}), 12\text{GeV})$ and $\theta((45°,\ 85°), 72°)$, (10000, 20000) events generated by ParticleGun

Optimal cut with maximum efficiency times purity





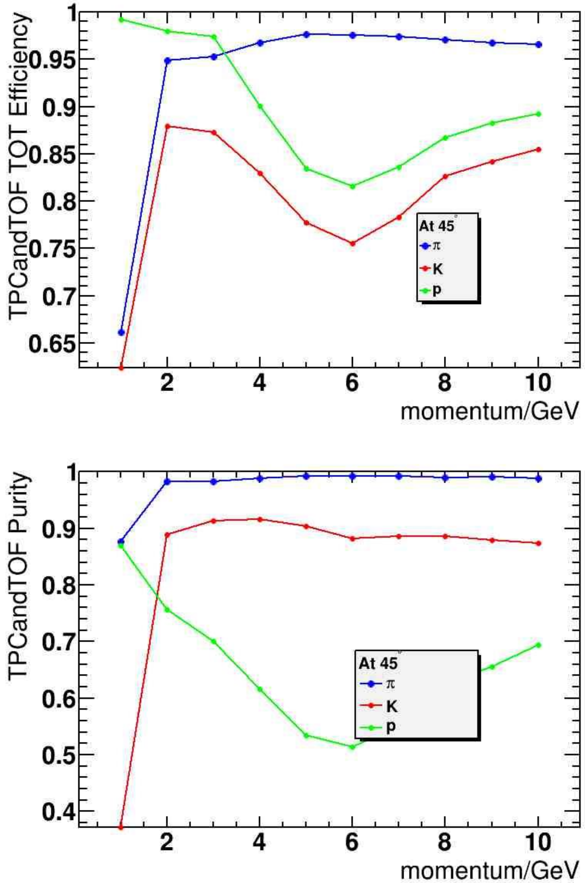
Ideal weighted $\chi_{TPC}(i \to K)$ distribution

cut optimization

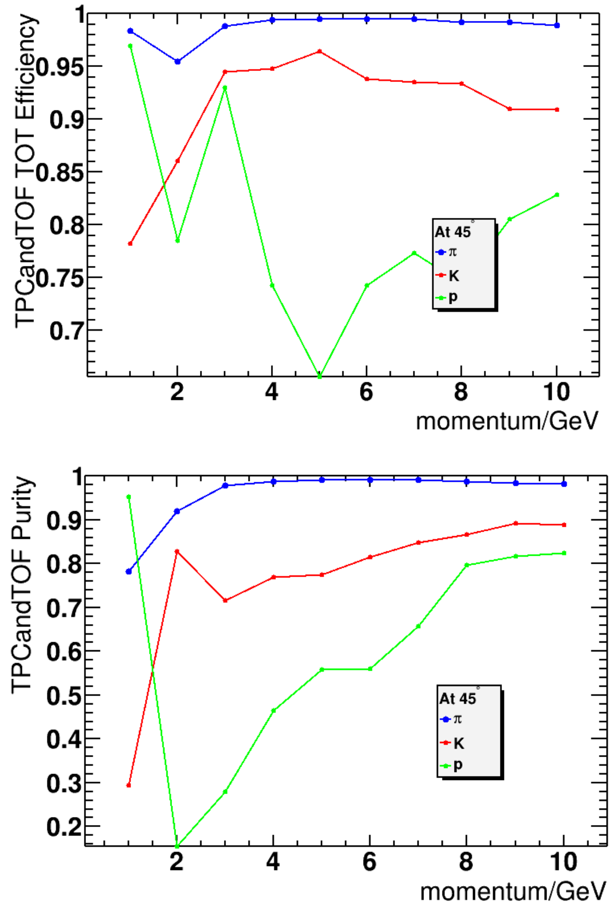
❖ Cut optimization at $(\cos\theta, p) = (0.3, 12\mathrm{GeV})$

- Maximize efficiency times purity for $\chi_{TPC}(i \to K)$ distribution to select K
- R is $(dN/dx)_{\mathrm{meas}}$, R_K is $(dN/dx)^K_{\mathrm{exp}}$, σ is $\sigma_{(dN/dx)_{\mathrm{meas}}}$, π: K: p = (10: 3: 1)
- Maximum point at $-1.7 < \chi_{TPC}(K) < 1.4$, corresponding K efficiency is 0.874, K purity is 0.775, K efficiency improves a lot (+0.11), K purity improves a little (+0.01)
- If we choose the minimum χ^2 to select K, K efficiency is 0.765, K purity is 0.765

Comparison of optimal cut results and former results



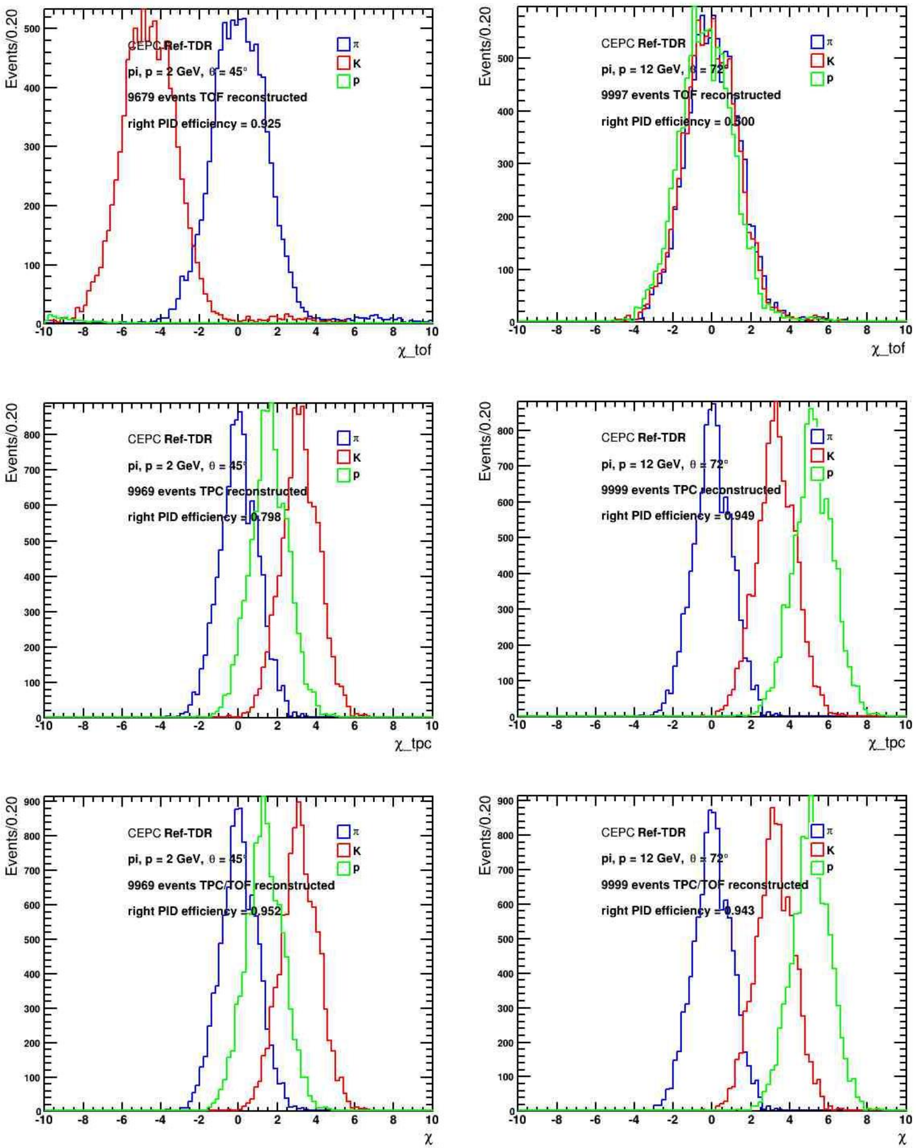
former efficiency and purity



optimal cut results

- Optimal cut maximizes efficiency times purity for $\chi_{TPC}(i \to K)$ distribution to select K
- Former results choose the minimum χ^2 to select K

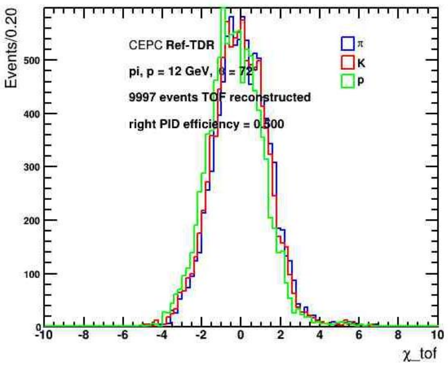
Combined chi distribution – test1

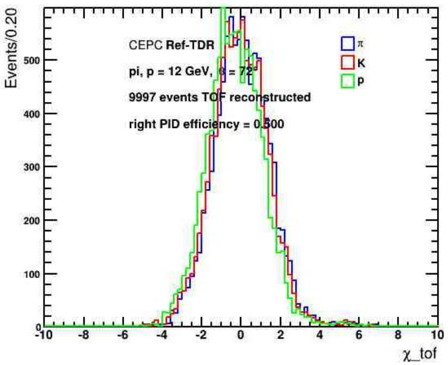


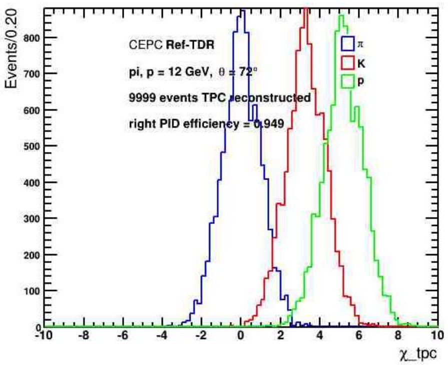
- Find a better way to combine? We cannot get ideal gaussian distributions
- Fow now, four combined χ_i tests are worser than combined TPC and TOF's separation power
- Or we just calculate the efficiency and purity as the article did: calculated combined separation power and integrated the gaussian functions

$$\text{Combined } \chi_i = \frac{\sqrt{\left(\frac{dN}{dx}\right)^2_{\text{meas}} + t^2_{\text{meas}}} - \sqrt{\left(\frac{dN}{dx}\right)^{i\ 2}_{\text{exp}} + t^{i\ 2}_{\text{exp}}}}{\sqrt{\sigma^2_{(dN/dx)_{\text{meas}}} + \sigma^2_{t_{\text{meas}}}}}$$

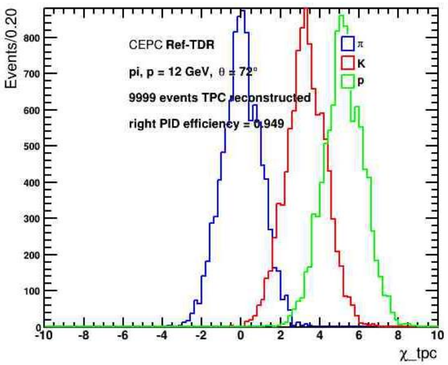
Combined chi distribution – test2&3



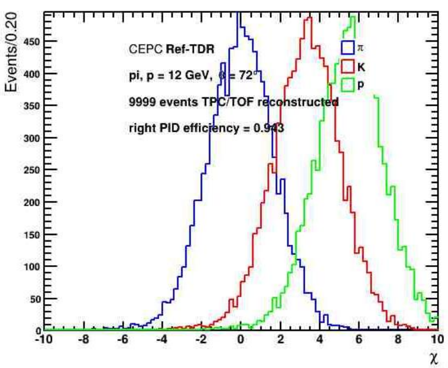


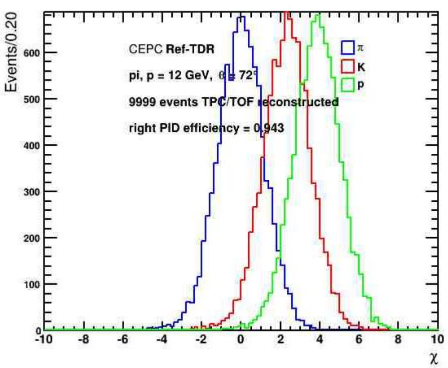


Combined $\chi_i = \chi_{\mathrm{TPC}} - \chi_{\mathrm{TOF}}$

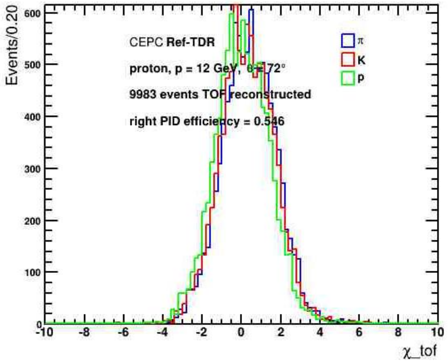


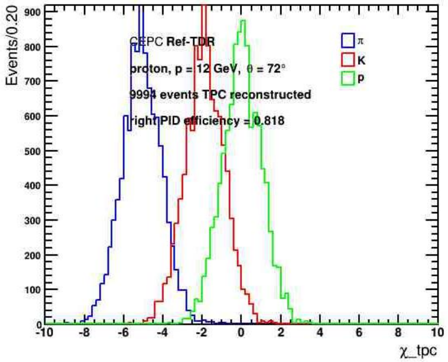
Combined $\chi_i = \dfrac{\chi_{\mathrm{TPC}} - \chi_{\mathrm{TOF}}}{\sqrt{\sigma^2_{(dN/dx)_{\mathrm{meas}}} + \sigma^2_{t_{\mathrm{meas}}}}}$

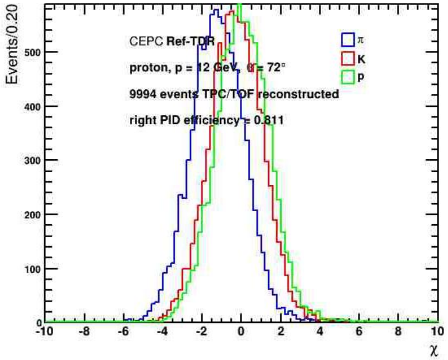




Combined chi distribution – test4







$$\text{Combined } \chi_i = \sqrt{\frac{\left(\frac{dN}{dx}\right)^2_{\text{meas}}}{\sigma^2_{(dN/dx)_{\text{meas}}}} + \frac{t^2_{\text{meas}}}{\sigma^2_{t_{\text{meas}}}}} - \sqrt{\frac{{\left(\frac{dN}{dx}\right)^i_{\text{exp}}}^2}{\sigma^2_{(dN/dx)_{\text{meas}}}} + \frac{{t^i_{\text{exp}}}^2}{\sigma^2_{t_{\text{meas}}}}}$$

Backup

$$\chi_{\mathrm{TPC}}(i) = \frac{(dN/dx)_{\mathrm{meas}} - (dN/dx)^{i}_{\mathrm{exp}}}{\sigma_{(dN/dx)_{\mathrm{meas}}}}, i = \pi/K/p$$

$$\chi_{\mathrm{TOF}}(i) = \frac{t_{\mathrm{meas}} - t^{i}_{\mathrm{exp}}}{\sigma_{t_{\mathrm{meas}}}}, \sigma_{t_{\mathrm{meas}}} = \sqrt{0.05^2 + 0.02^2}$$

$$\chi^2(i) = \chi^2_{\mathrm{TOF}}(i) + \chi^2_{\mathrm{TPC}}(i)$$

$$\chi(i) = \sqrt{\chi^2(i)}$$

$$\mathrm{Efficiency}_{\mathrm{tot}}(i) = \mathrm{Efficiency}_{\mathrm{trk}}(i) \times \mathrm{Efficiency}_{\mathrm{PID}}(i)$$

$$\mathrm{Efficiency}_{\mathrm{trk}}(i) = \frac{N_i^{\mathrm{reco}}}{N_i^{\mathrm{gen}}}$$

$$\mathrm{Efficiency}_{\mathrm{PID}}(i) = \frac{N_i^{\mathrm{reco}}\left(\chi^2(i) < \chi^2(j)\right)}{N_i^{\mathrm{reco}}} (j \neq i)$$

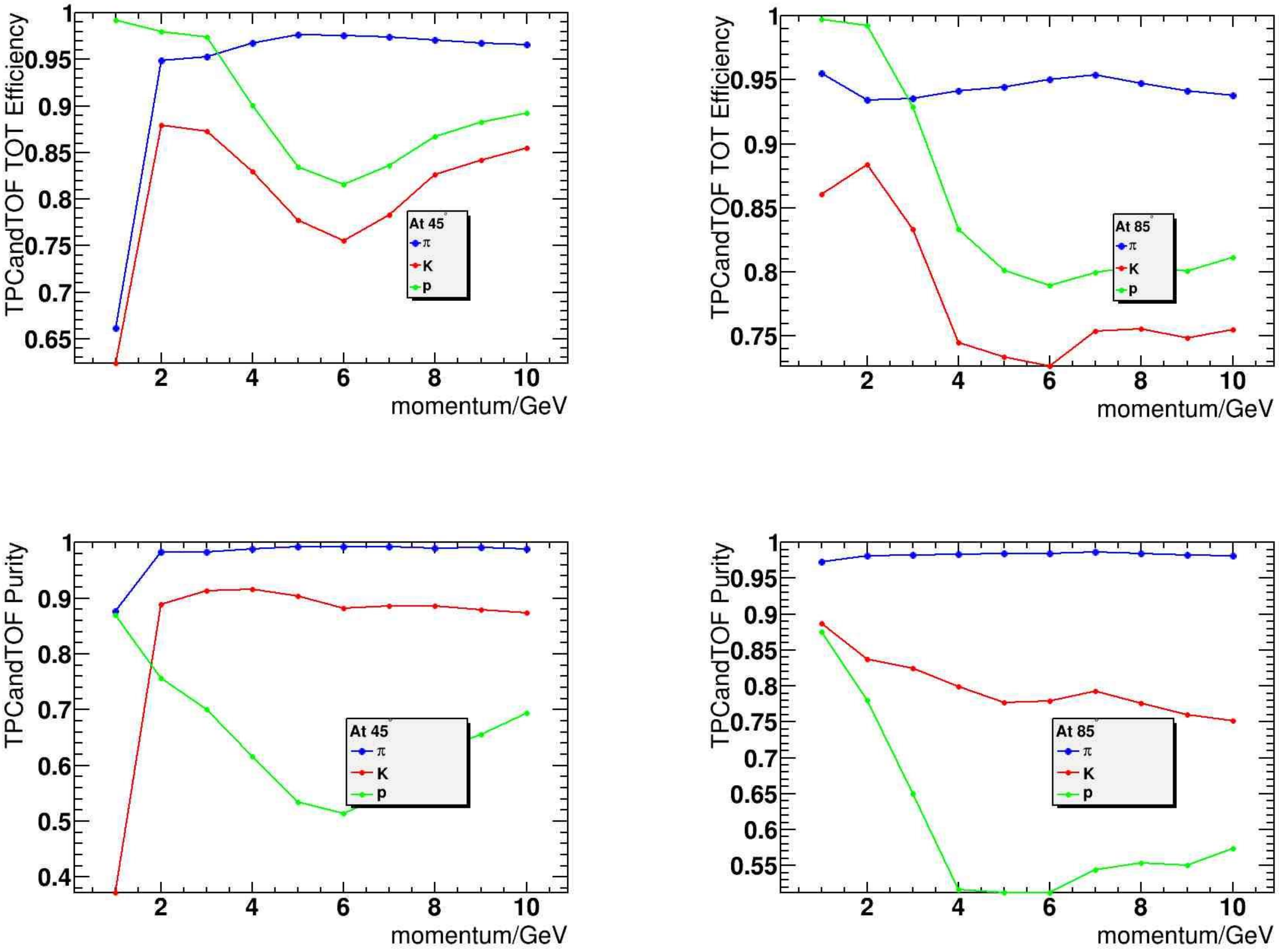
$$\mathrm{purity}(K) = \frac{N_{K\to K}}{N_{K\to K} + N_{\pi\to K} + N_{p\to K}}$$

$$= \frac{3 \times \mathrm{Efficiency}_{K\to K}}{3 \times \mathrm{Efficiency}_{K\to K} + 10 \times \mathrm{Efficiency}_{\pi\to K} + 1 \times \mathrm{Efficiency}_{p\to K}}$$

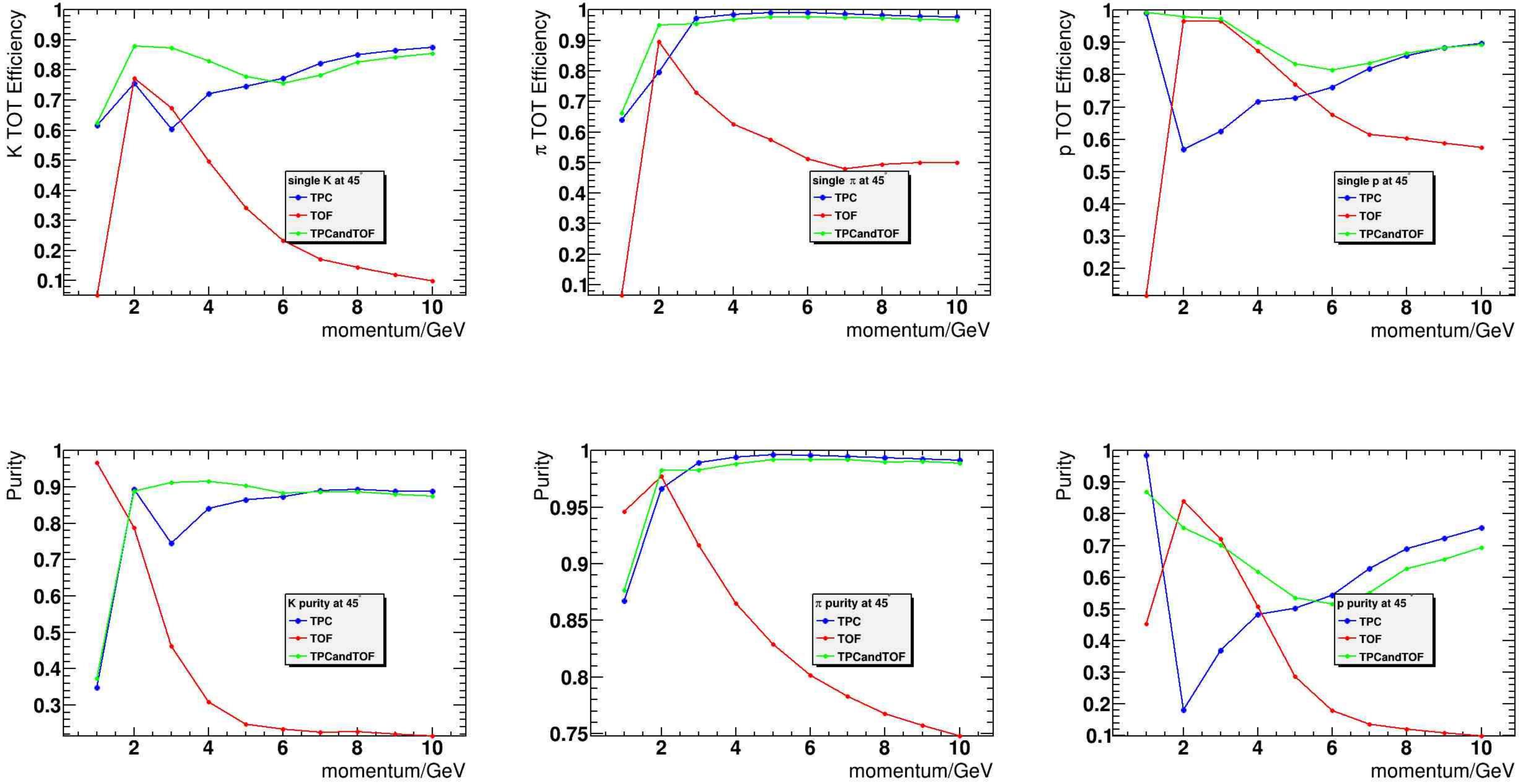
$$\mathrm{Efficiency}_{\mathrm{opti.\ PID}}(i) = \frac{N_i^{\mathrm{reco}}(a < \chi(i \to i) < b)}{N_i^{\mathrm{reco}}}$$

$$\mathrm{purity}_{\mathrm{opti.}}(K)$$

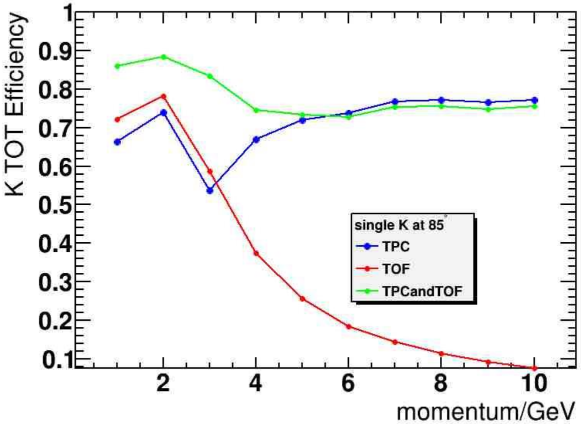
Efficiency and purity

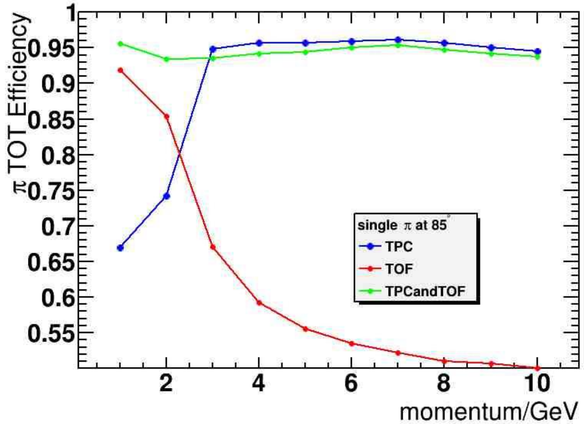


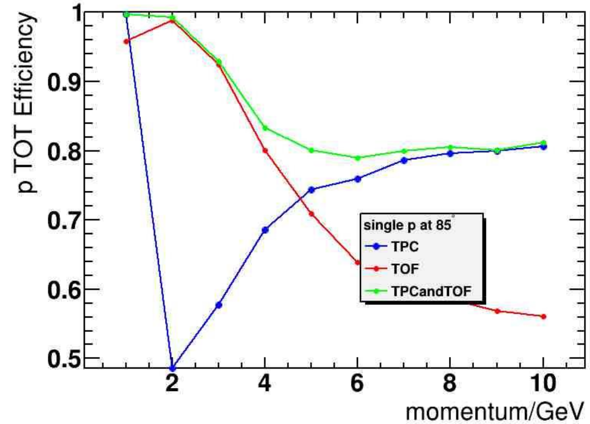
45 degree

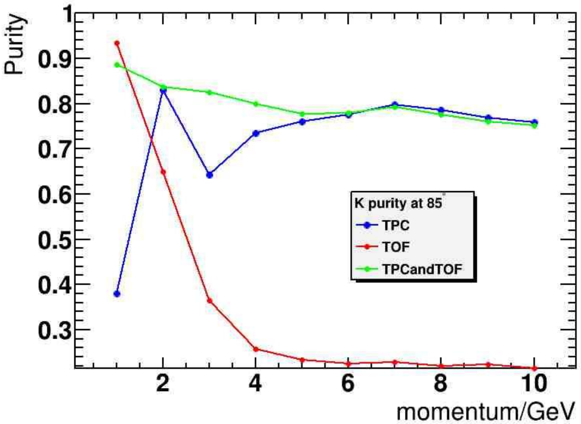

K TOT Efficiency
single K at 45°
TPC
TOF
TPCandTOF
momentum/GeV
π TOT Efficiency
single π at 45°
TPC
TOF
TPCandTOF
momentum/GeV
p TOT Efficiency
single p at 45°
TPC
TOF
TPCandTOF
momentum/GeV
Purity
K purity at 45°
TPC
TOF
TPCandTOF
momentum/GeV
Purity
π purity at 45°
TPC
TOF
TPCandTOF
momentum/GeV
Purity
p purity at 45°
TPC
TOF
TPCandTOF
momentum/GeV

85 degree


K TOT Efficiency
single K at 85°
TPC
TOF
TPCandTOF
momentum/GeV


π TOT Efficiency
single π at 85°
TPC
TOF
TPCandTOF
momentum/GeV


p TOT Efficiency
single p at 85°
TPC
TOF
TPCandTOF
momentum/GeV


Purity
K purity at 85°
TPC
TOF
TPCandTOF
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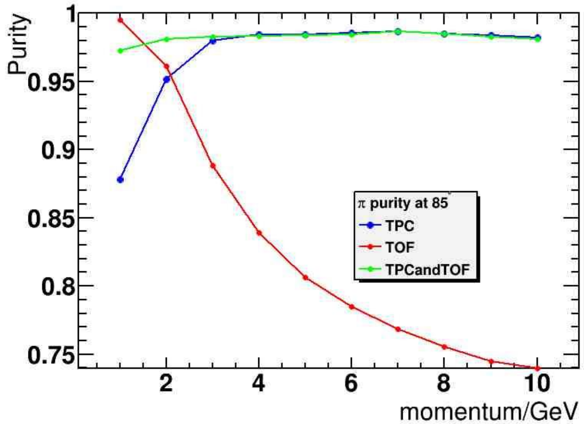
Purity
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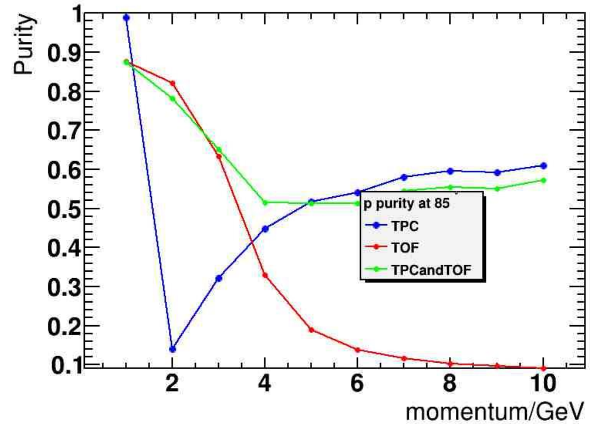
Purity
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