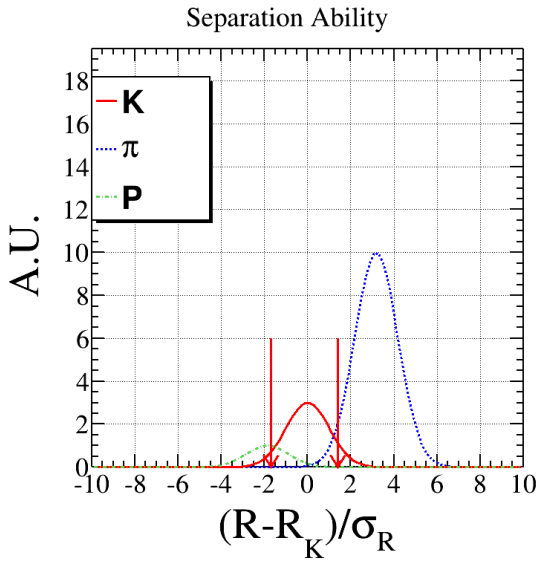
PID efficiency study

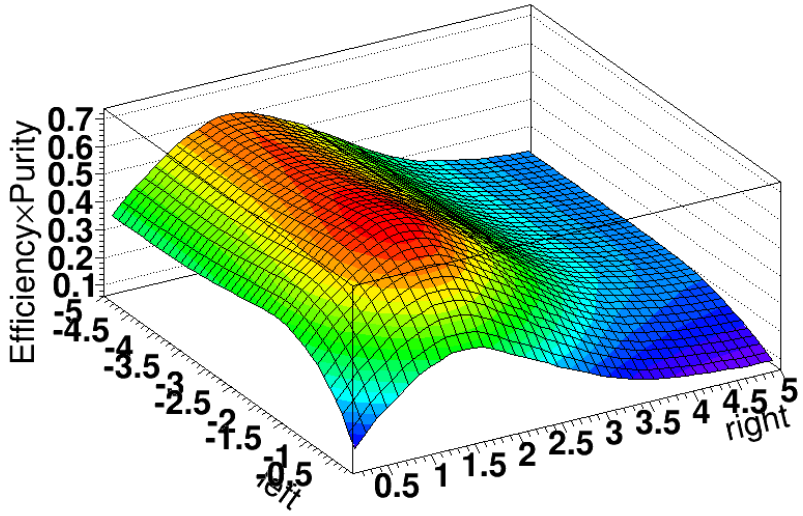
- TPC PID workflow in SW

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 $(\cos\theta, p) = (0.3, 12\mathrm{GeV})$
    - Release version: CEPCSW_tdr24.10.0
    - Samples: single $\pi/K/p$ samples at $p(12\mathrm{GeV})$ and $\theta(72^\circ)$, 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 $(\cos\theta, p) = (0.3, 12\text{GeV})$
  - Maximize efficiency times purity for $\chi_{TPC}(i \to K)$ distribution to select K
  - R is $(dN/dx)_{\text{meas}}$, R_K is $(dN/dx)^K_{\text{exp}}$, σ is $\sigma_{(dN/dx)_{\text{meas}}}$, 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

Backup

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

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

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

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

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

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

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

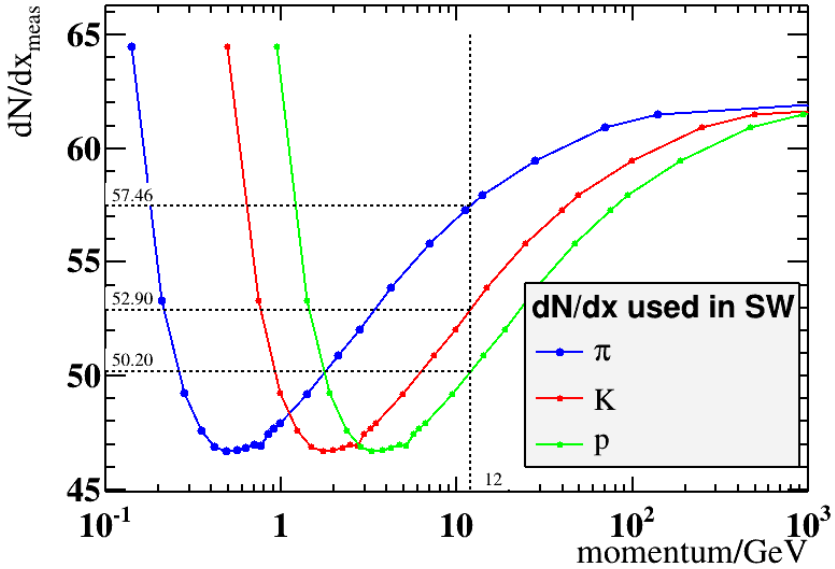
$$\mathrm{purity}(K) = \frac{N_{K\to K}}{N_{K\to K} + N_{\pi\to K} + N_{p\to K}}$$

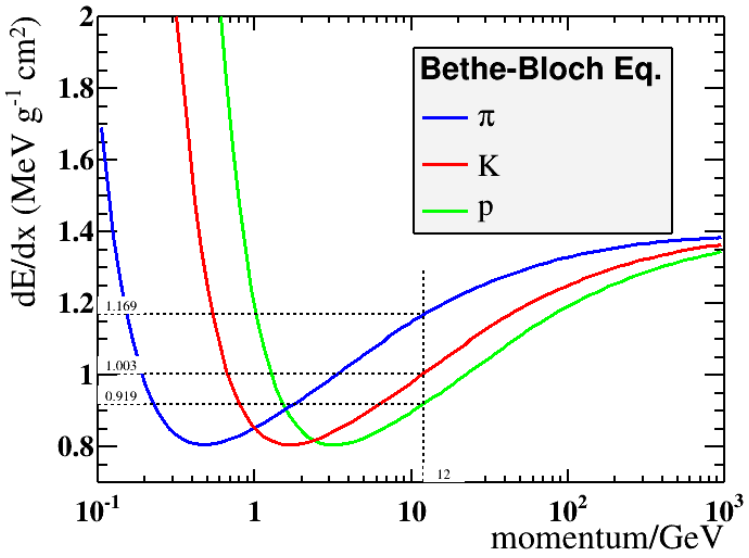
$$= \frac{3 \times \mathrm{Efficiency}_{K\to K}}{3 \times \mathrm{Efficiency}_{K\to K} + 10 \times \mathrm{Efficiency}_{\pi\to K} + 1 \times \mathrm{Efficiency}_{p\to K}}$$

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

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

Comparison in dN/dx and dE/dx





dN/dx curves from the LUT in SW

dE/dx curves from the Bethe-Bloch equation

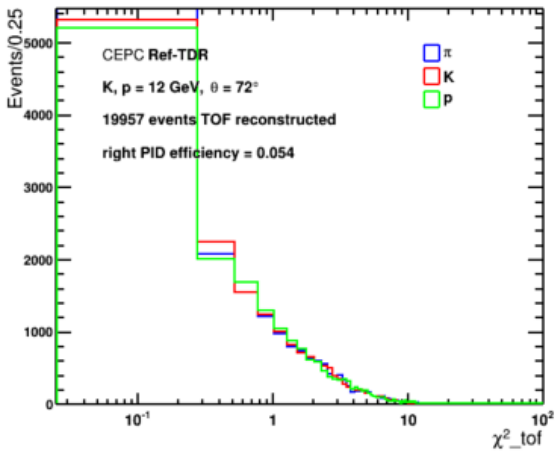
- Bethe equation $$\left\langle -\frac{dE}{dx} \right\rangle = Kz^2 \frac{Z}{A} \frac{1}{\beta^2} \left[\frac{1}{2} \ln \frac{2m_e c^2 \beta^2 \gamma^2 W_{\max}}{I^2} - \beta^2 - \frac{\delta(\beta\gamma)}{2} \right] . \quad (33.5)$$
  - K=0.3071, Z/A=18/39.948, z=1, me=0.511*10^6, bg=p/m0(GeV), c=1, beta=bg/sqrt(1+bg*bg)
  - Tmax=851
  - I=188.0
  - delta=0(x<1.7635),

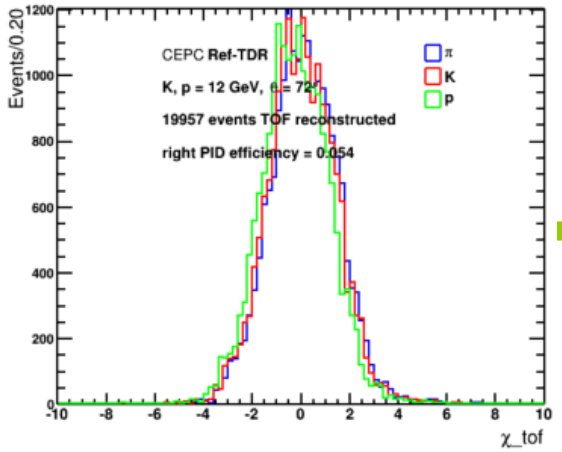
    2ln(bg)+0.19714*(4.4855-x)^2.9618-11.9480(1.7635<x<4.4855),

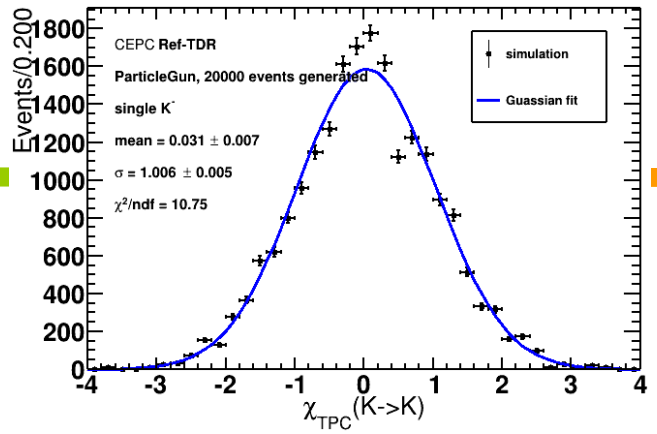
    2ln(bg)-11.9480(x>4.4855), x=ln(bg)/ln(10)

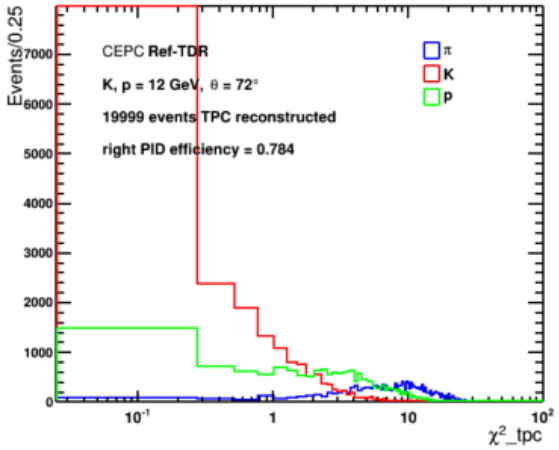
10.1016/0092-640X(84)90002-0

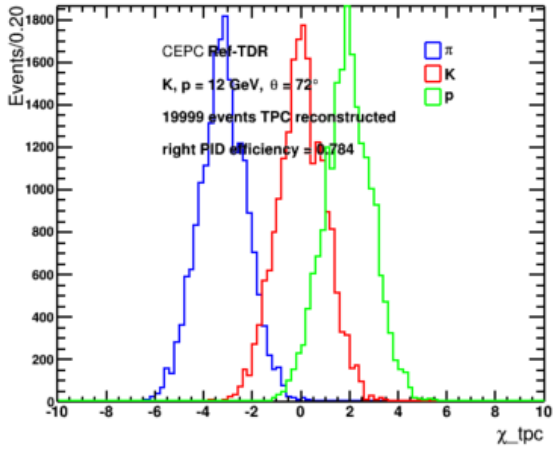
PhysRev.88.851

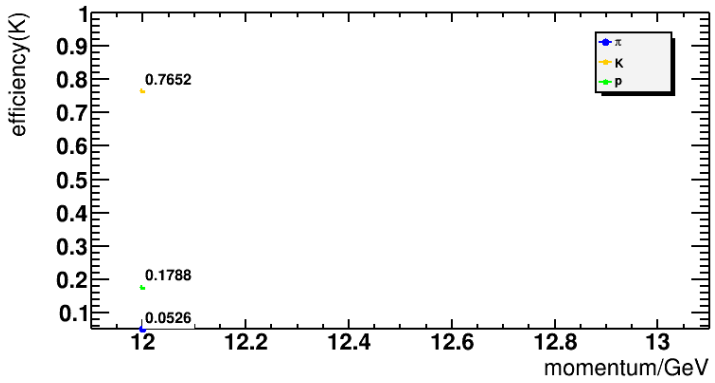

CEPC Ref-TDR
K, p = 12 GeV, θ = 72°
19957 events TOF reconstructed
right PID efficiency = 0.054
π
K
p
Events/0.25
χ²_tof

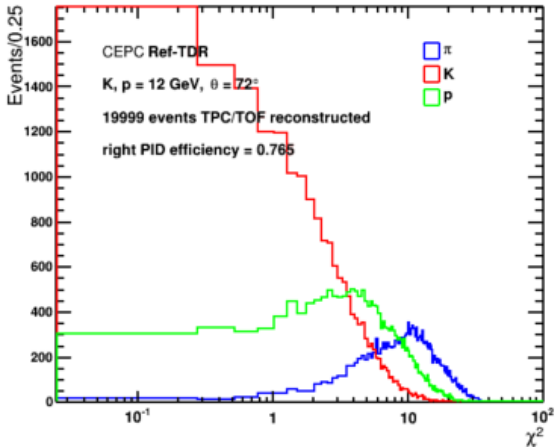

CEPC Ref-TDR
K, p = 12 GeV, θ = 72°
19957 events TOF reconstructed
right PID efficiency = 0.054
π
K
p
Events/0.20
χ_tof

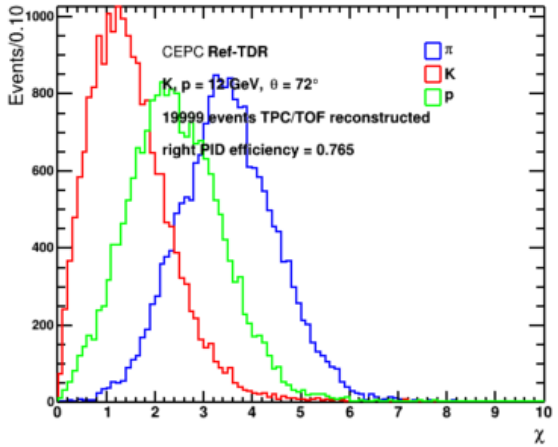

CEPC Ref-TDR
ParticleGun, 20000 events generated
single K⁻
mean = 0.031 ± 0.007
σ = 1.006 ± 0.005
χ²/ndf = 10.75
simulation
Guassian fit
Events/0.200
χ_TPC(K->K)

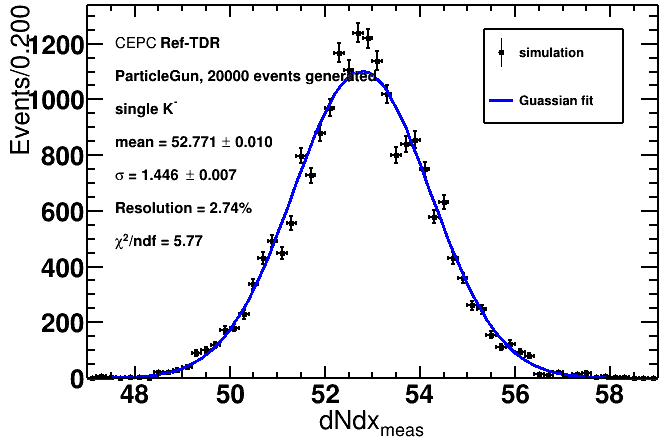

CEPC Ref-TDR
K, p = 12 GeV, θ = 72°
19999 events TPC reconstructed
right PID efficiency = 0.784
π
K
p
Events/0.25
χ²_tpc

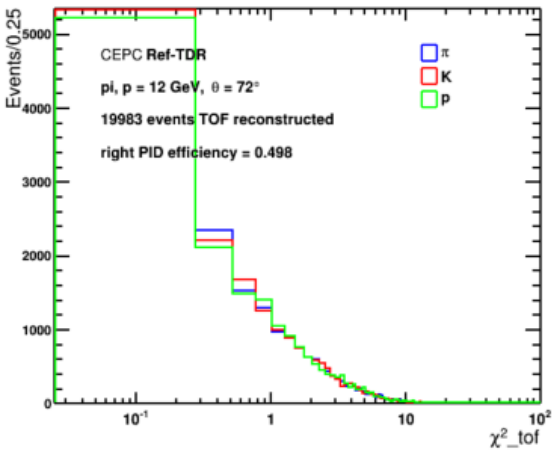

CEPC Ref-TDR
K, p = 12 GeV, θ = 72°
19999 events TPC reconstructed
right PID efficiency = 0.784
π
K
p
Events/0.20
χ_tpc

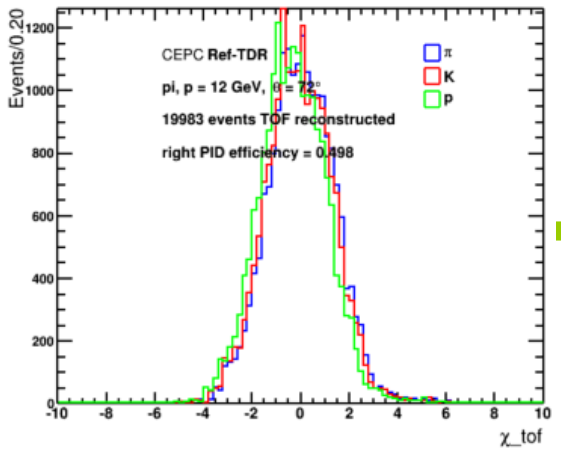

efficiency(K)
0.7652
0.1788
0.0526
π
K
p
momentum/GeV

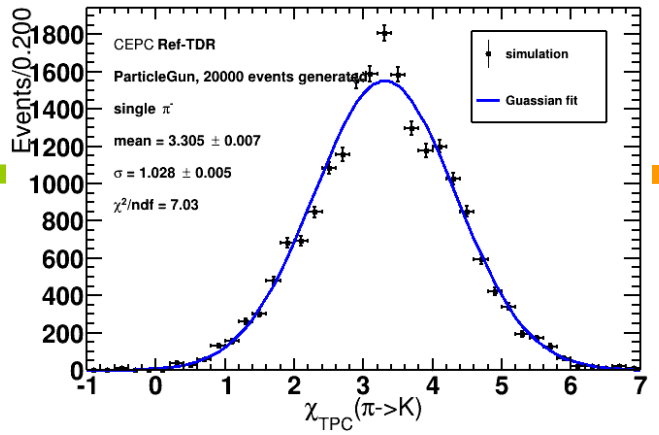

CEPC Ref-TDR
K, p = 12 GeV, θ = 72°
19999 events TPC/TOF reconstructed
right PID efficiency = 0.765
π
K
p
Events/0.25
χ²

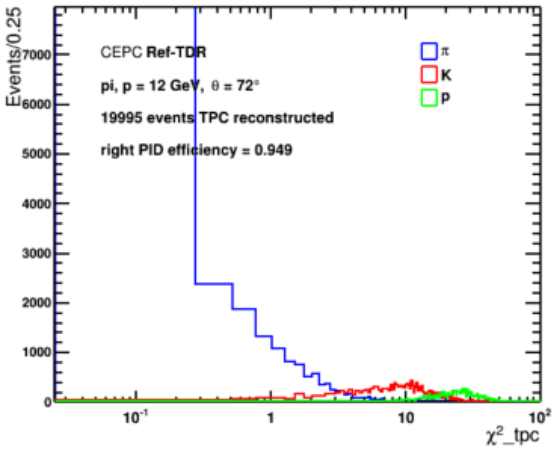

CEPC Ref-TDR
K, p = 12 GeV, θ = 72°
19999 events TPC/TOF reconstructed
right PID efficiency = 0.765
π
K
p
Events/0.10
χ

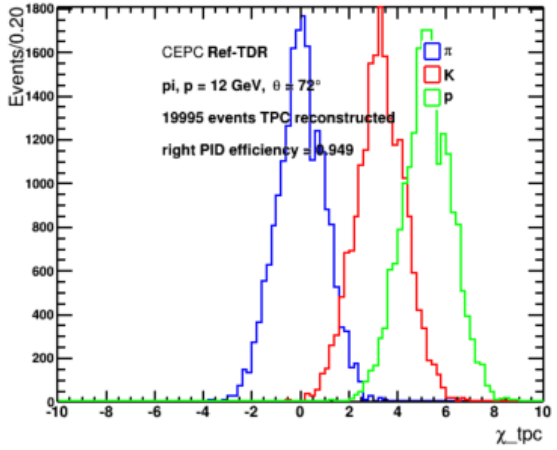

CEPC Ref-TDR
ParticleGun, 20000 events generated
single K⁻
mean = 52.771 ± 0.010
σ = 1.446 ± 0.007
Resolution = 2.74%
χ²/ndf = 5.77
simulation
Guassian fit
Events/0.200
dNdx_meas

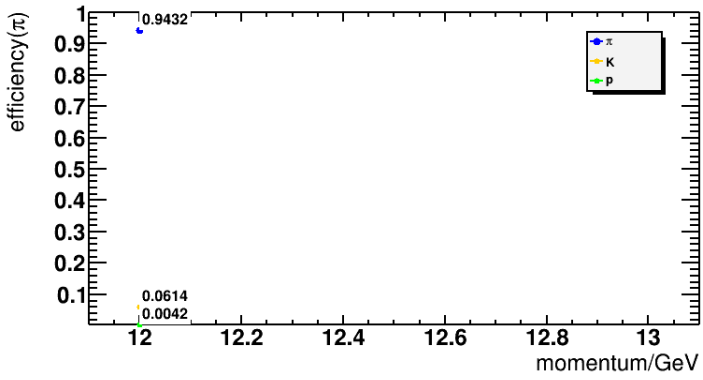

CEPC Ref-TDR
pi, p = 12 GeV, θ = 72°
19983 events TOF reconstructed
right PID efficiency = 0.498
π
K
p
Events/0.25
χ²_tof

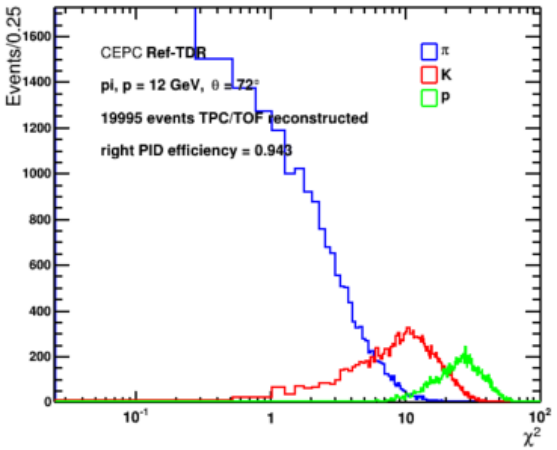

CEPC Ref-TDR
pi, p = 12 GeV, θ = 72°
19983 events TOF reconstructed
right PID efficiency = 0.498
π
K
p
Events/0.20
χ_tof

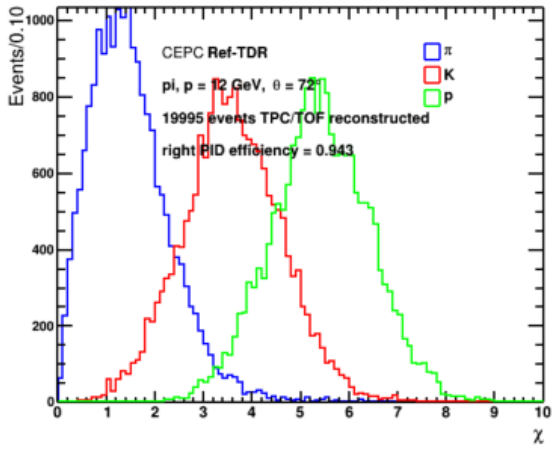

CEPC Ref-TDR
ParticleGun, 20000 events generated
single π⁻
mean = 3.305 ± 0.007
σ = 1.028 ± 0.005
χ²/ndf = 7.03
simulation
Guassian fit
Events/0.200
χ_TPC(π->K)

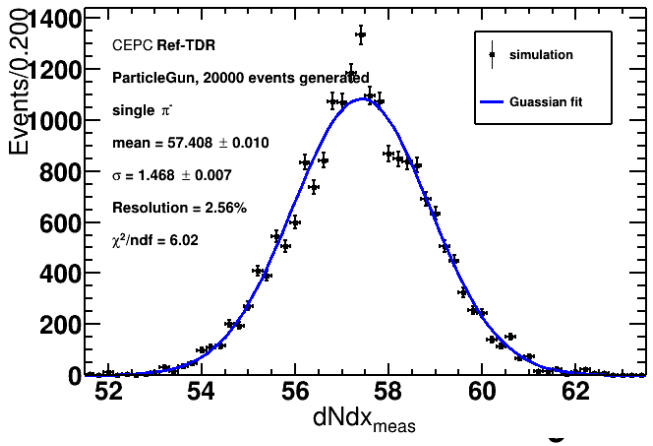

CEPC Ref-TDR
pi, p = 12 GeV, θ = 72°
19995 events TPC reconstructed
right PID efficiency = 0.949
π
K
p
Events/0.25
χ²_tpc

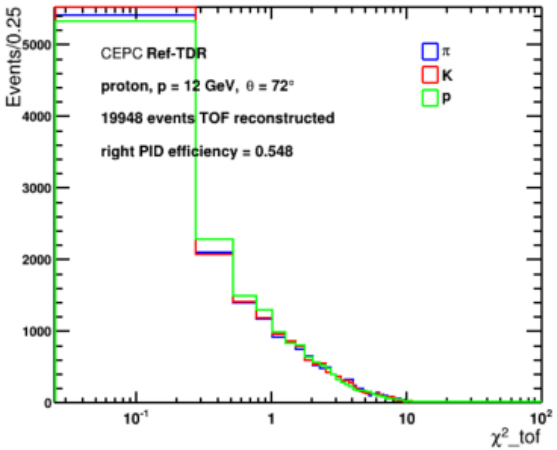

CEPC Ref-TDR
pi, p = 12 GeV, θ = 72°
19995 events TPC reconstructed
right PID efficiency = 0.949
π
K
p
Events/0.20
χ_tpc

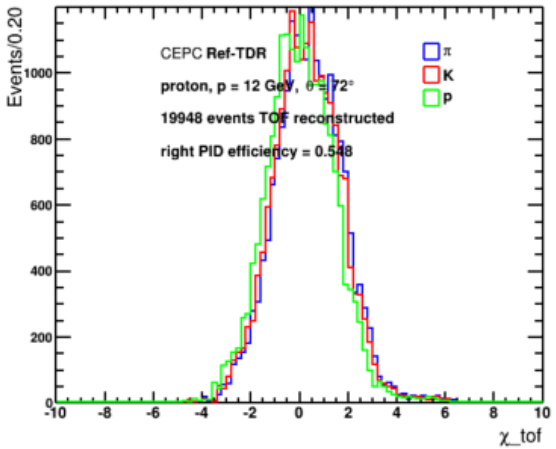

0.9432
0.0614
0.0042
π
K
p
efficiency(π)
momentum/GeV

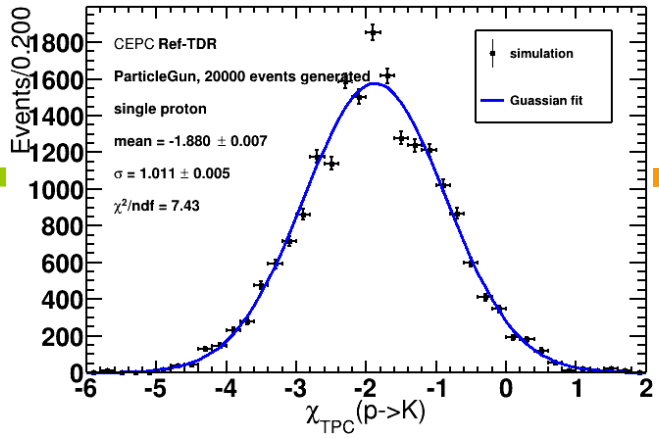

CEPC Ref-TDR
pi, p = 12 GeV, θ = 72°
19995 events TPC/TOF reconstructed
right PID efficiency = 0.943
π
K
p
Events/0.25
χ²

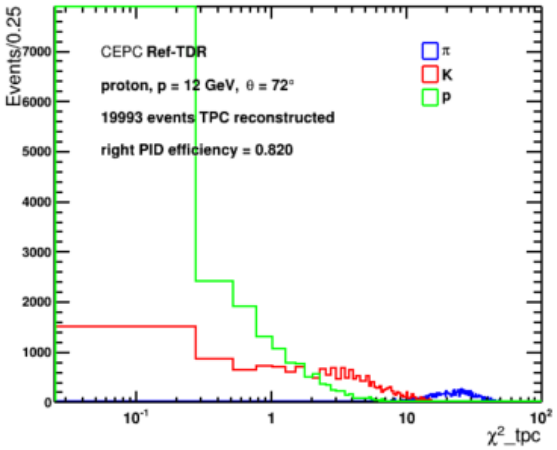

CEPC Ref-TDR
pi, p = 12 GeV, θ = 72°
19995 events TPC/TOF reconstructed
right PID efficiency = 0.943
π
K
p
Events/0.10
χ

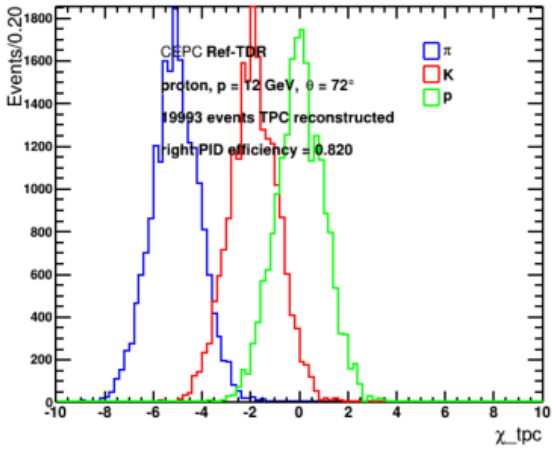

CEPC Ref-TDR
ParticleGun, 20000 events generated
single π⁻
mean = 57.408 ± 0.010
σ = 1.468 ± 0.007
Resolution = 2.56%
χ²/ndf = 6.02
simulation
Guassian fit
Events/0.200
dNdx_meas

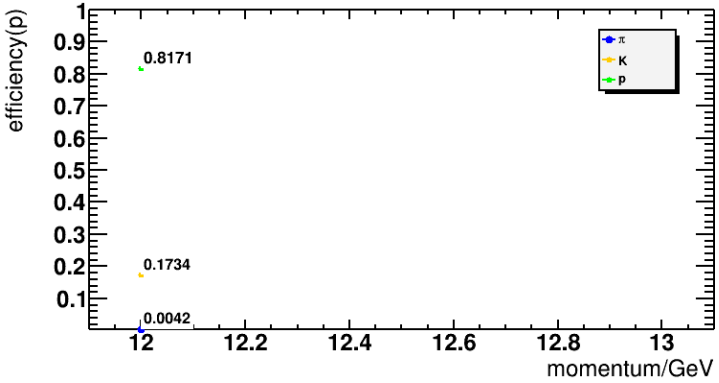

CEPC Ref-TDR
proton, p = 12 GeV, θ = 72°
19948 events TOF reconstructed
right PID efficiency = 0.548
π
K
p
Events/0.25
χ²_tof

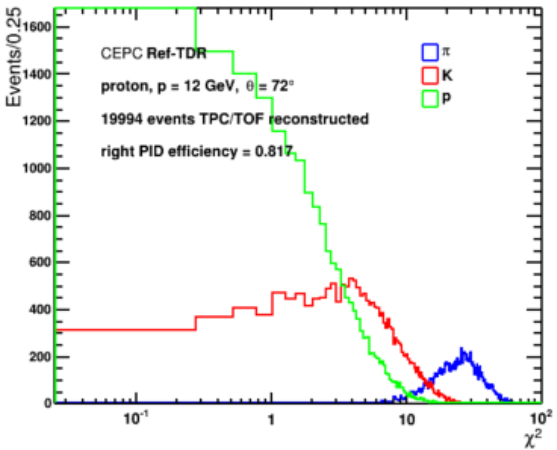

CEPC Ref-TDR
proton, p = 12 GeV, θ = 72°
19948 events TOF reconstructed
right PID efficiency = 0.548
π
K
p
Events/0.20
χ_tof

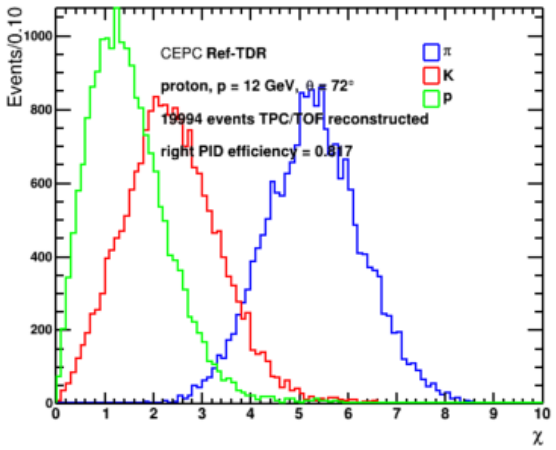

CEPC Ref-TDR
ParticleGun, 20000 events generated
single proton
mean = -1.880 ± 0.007
σ = 1.011 ± 0.005
χ²/ndf = 7.43
simulation
Guassian fit
Events/0.200
χ_TPC(p->K)

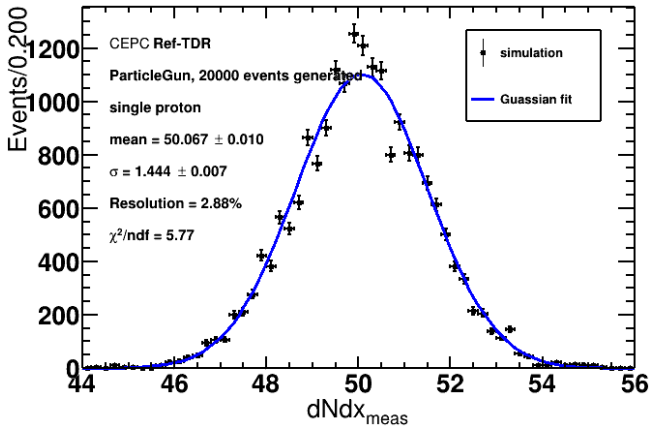

CEPC Ref-TDR
proton, p = 12 GeV, θ = 72°
19993 events TPC reconstructed
right PID efficiency = 0.820
π
K
p
Events/0.25
χ²_tpc


CEPC Ref-TDR
proton, p = 12 GeV, θ = 72°
19993 events TPC reconstructed
right PID efficiency = 0.820
π
K
p
Events/0.20
χ_tpc


efficiency(p)
0.8171
0.1734
0.0042
π
K
p
momentum/GeV


CEPC Ref-TDR
proton, p = 12 GeV, θ = 72°
19994 events TPC/TOF reconstructed
right PID efficiency = 0.817
π
K
p
Events/0.25
χ²


CEPC Ref-TDR
proton, p = 12 GeV, θ = 72°
19994 events TPC/TOF reconstructed
right PID efficiency = 0.817
π
K
p
Events/0.10
χ


CEPC Ref-TDR
ParticleGun, 20000 events generated
single proton
mean = 50.067 ± 0.010
σ = 1.444 ± 0.007
Resolution = 2.88%
χ²/ndf = 5.77
simulation
Guassian fit
Events/0.200
dNdx_meas