Study PID performance

by $B_s^0 \to \phi\phi$ with Delphes_CEPC

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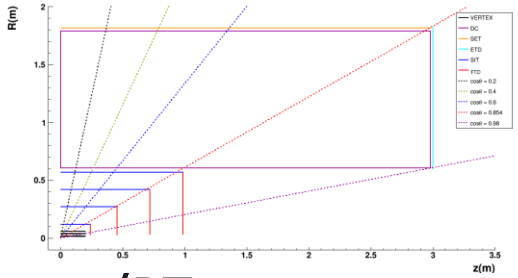
Outline

- Introduction
- Delphes_CEPC
  - Resolution of tracker
  - PID
- $B_s^0 \to \phi\phi \to K^+K^-K^+K^-$
  - Sample
  - Event selection
  - Physics impact of PID

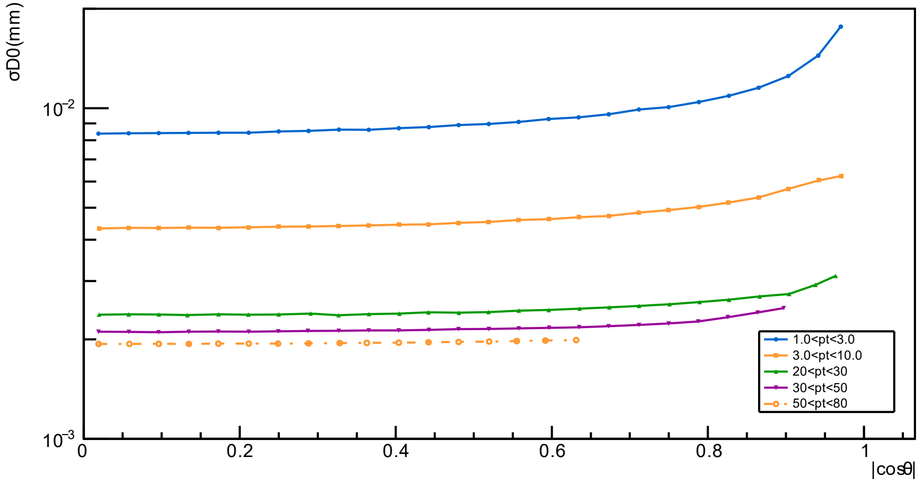
Introduction

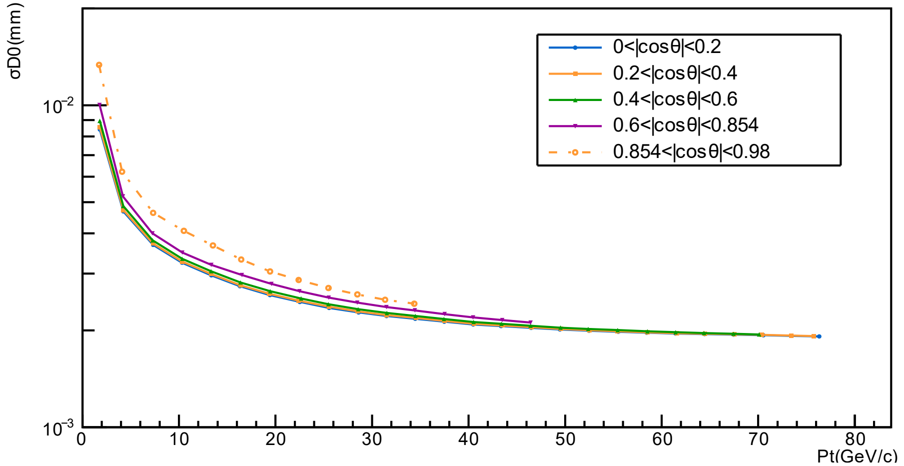
- Delphes is a modular framework that simulates the response of a multipurpose detector
- Delphes_CEPC is a fast simulation tool for CEPC 4^{th} detector based on Delphes
  - New detector layout for CEPC
  - Dedicated PID with dN/dx and TOF
  - Jets with ee-kt
- And then, study physics impact of PID by $B_s^0 \rightarrow \phi\phi \rightarrow K^+K^-K^+K^-$

Resolution of tracker

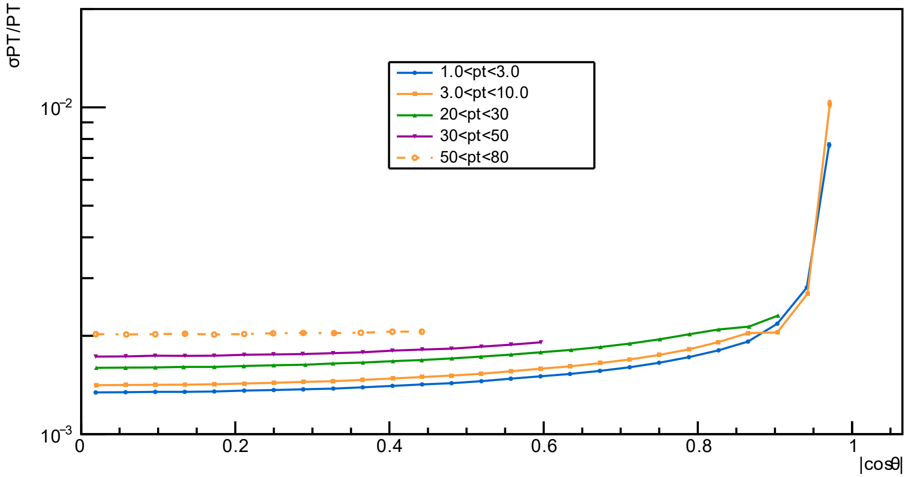


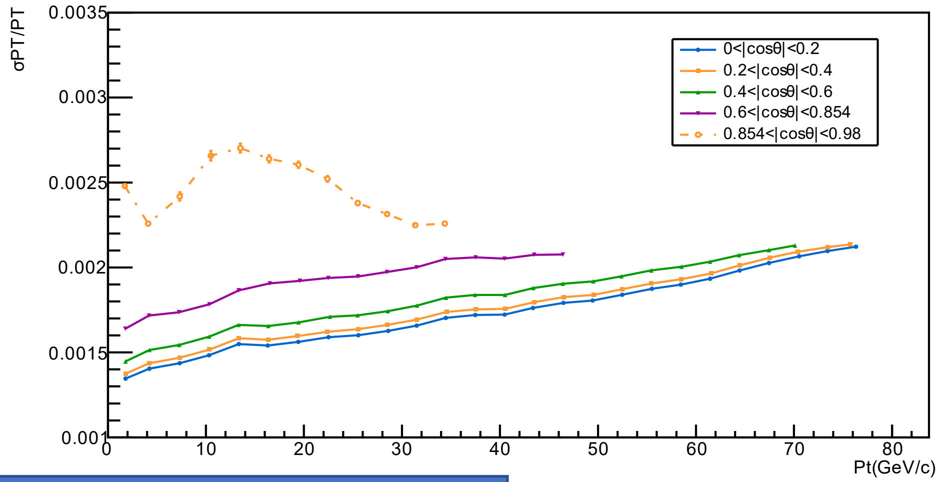
Impact parameter σ_{D0}





Momentum σ_{PT}/PT





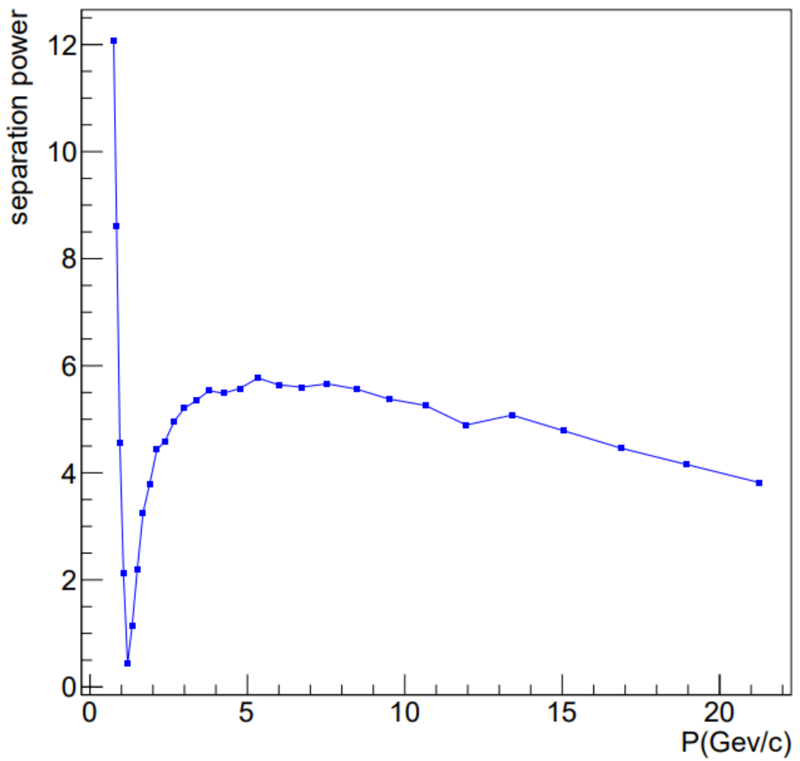
The results are consistent with full simulation

Implementation of PID in Delphes_CEPC

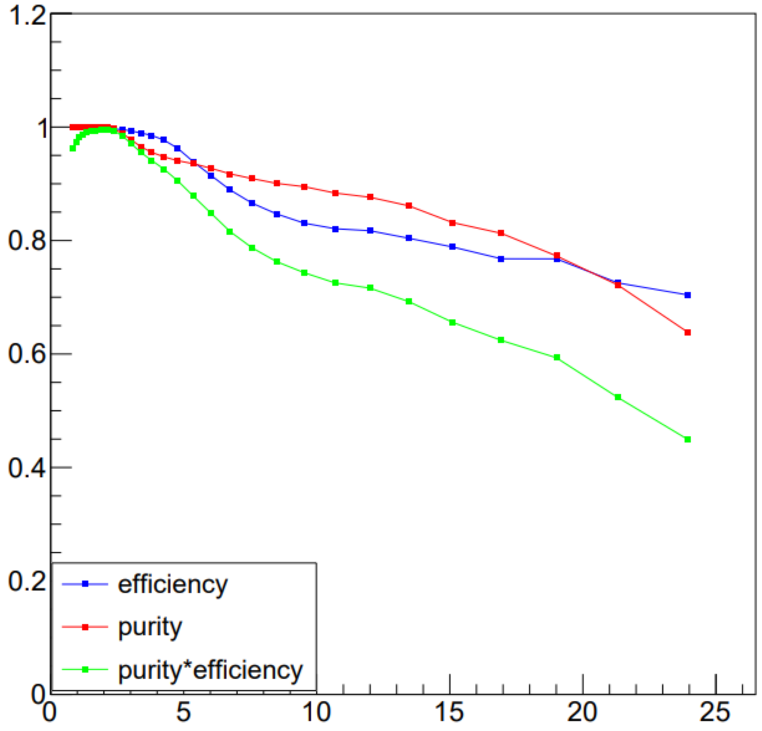
1. Calculate chi-squares for different assumptions
   - $(\chi^2)^i = \left(\chi^2_{dN/dx}\right)^i + \left(\chi^2_{tof}\right)^i$ i represent π, K, p
   - $(\chi^2_{dN/dx})^i \ = \left(\frac{dN/dx_{meas} - (dN/dx)^i_{exp}}{(\sigma)^i_{dN/dx}}\right)^2$, $(\chi^2_{tof})^i \ = \left(\frac{tof_{meas} - (tof)^i_{exp}}{\sigma_{tof}}\right)^2$
   - $(dN/dx)^i_{exp}$, $(\sigma)^i_{dN/dx}$ and $(tof)^i_{exp}$ depend on the particle type assumption
2. Calculate probabilities based on $(\chi^2)^i$ for different assumptions
3. Compare the probabilities , the most likely assumption is taken

PID performance in Delphes_CEPC

dN/dx
k/pi separation powser



dN/dx and TOF
Kaon efficiency and purity



$|cos\theta| < 0.98$

$B_s^0 \to \phi\phi \to K^+K^-K^+K^-$

Process	$\mathcal{B}$	Sample size
$Z \to b\bar{b}$	$(15.12 \pm 0.05)\%$	6×10^7
$b\bar{b} \to B_s^0$	$(0.101 \pm 0.008) \times 2$	1.212×10^7
$B_s^0 \to \phi\phi$	$(1.85 \pm 0.14) \times 10^{-5}$	54
$\phi \to K^+K^-$	$(49.1 \pm 0.5)\%$	

- Signal sample using Pythia8
- Background using Pythia6
- For now, only considering the background of $Z \to b\bar{b}$
- On Tera-Z yield:
    - Z$\sim 10^{12}$, $b\bar{b} \sim 10^{11}$

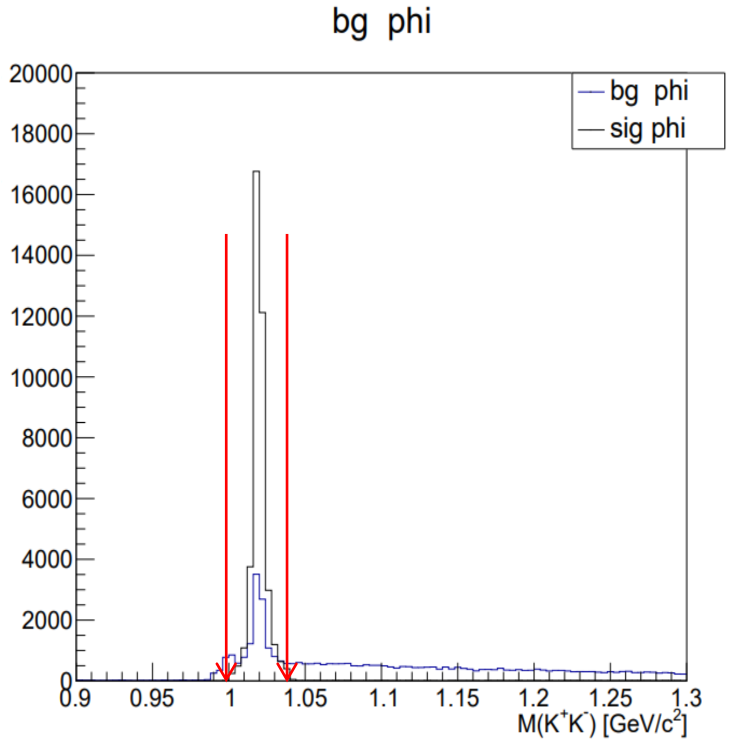
Event selection

- $Z \to b\bar{b} \to di - jets$
- So the following selections is done in one jet
- And the $M_{\phi\phi}$closest to $m_{B_s^0}$ is retained

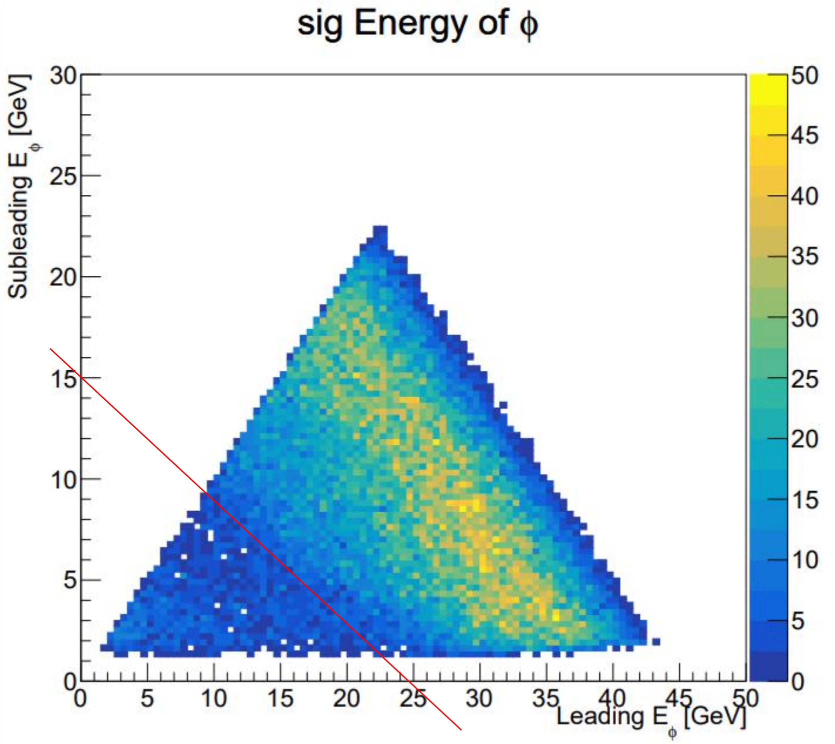
◆Final state:$K^+K^-K^+K^-$

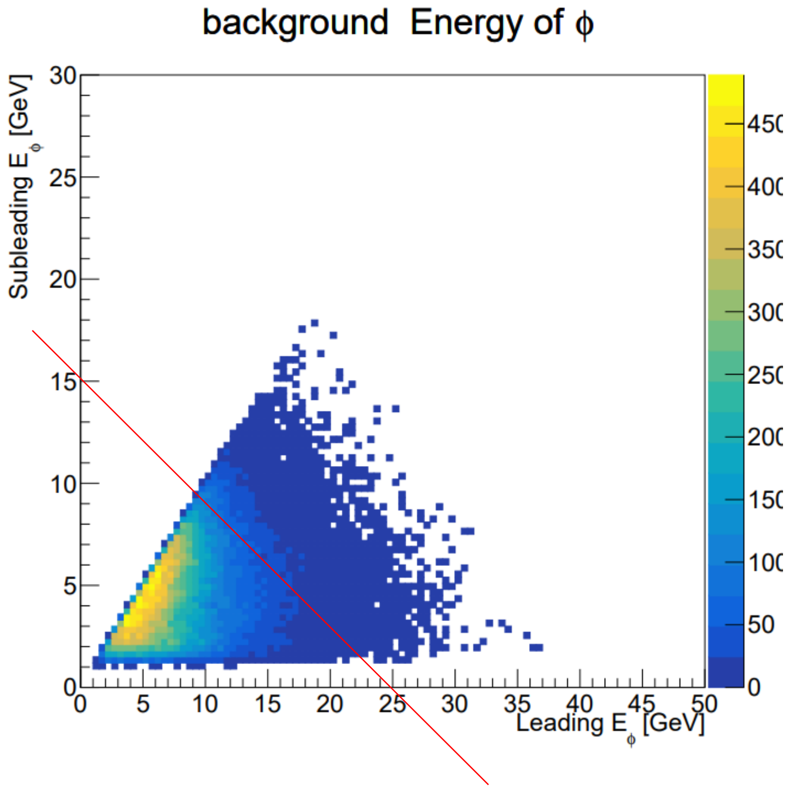
- Kaon PID(dN/dx +TOF)
  - $Prob_K > Prob_\pi \quad \&\& \quad Prob_K > Prob_p$
  - $N(K^+) \geq 2 \quad \&\& \quad N(K^-) \geq 2$
- ϕ reconstruction
  - Select two combinations of $M_{K^+K^-}$ closest m_ϕ
  - $|M_{K^+K^-} - m_\phi| < 0.02\ GeV/c^2$
  - $0.6 \times leading\ E_\phi + subleading\ E_\phi > 15\ GeV$
- B_s^0 reconstruction
  - $|m_{\phi\phi} - m_{B_0^s}| < 0.03\ GeV/c^2$

Event selection



$$|m_{K^+K^-} - m_\phi| < 0.02\ GeV/c^2$$





$$0.6 \times leading\ E_\phi + subleading\ E_\phi > 15\ GeV$$

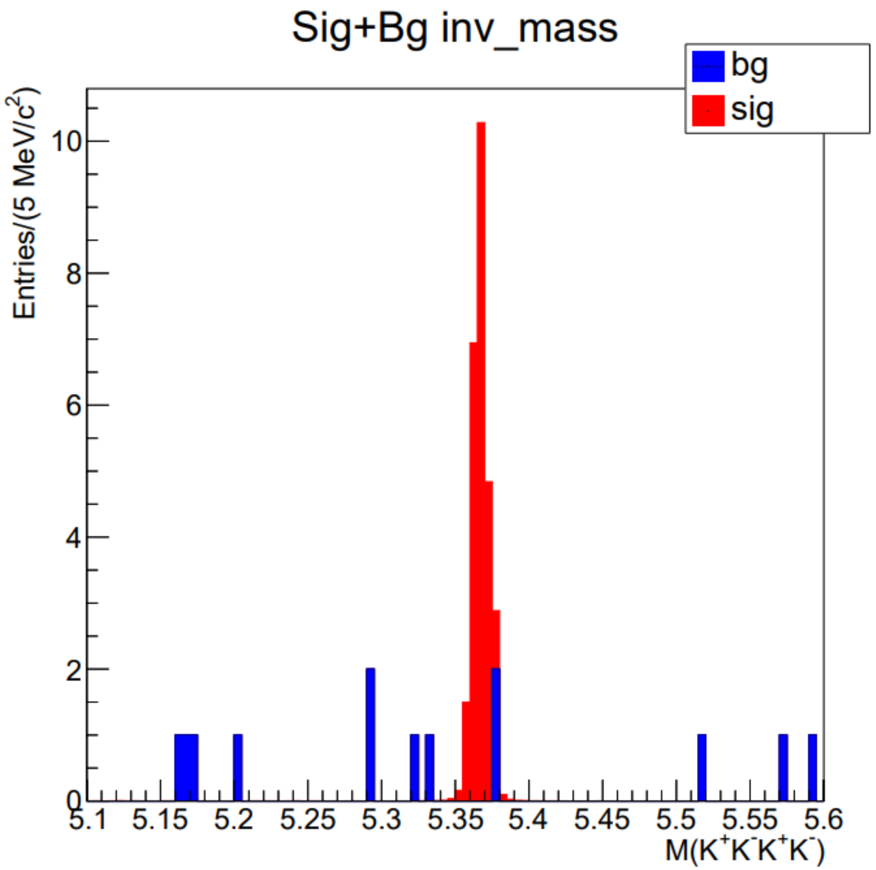
Cut flow

Cut	With PID			Without PID		
	Signal efficiency	background	$\frac{S}{B}$	Signal efficiency	background	$\frac{S}{B}$
No cut	1	6×10^7	9×10^{-7}	1	6×10^7	9×10^{-7}
$N(K^+) \geq 2\ \&\&\ N(K^-) \geq 2$	55.97%	1330420	2.27×10^{-5}	98.12%	57656858	9.19×10^{-7}
$\lvert m_{K^+K^-} - m_\phi \rvert < 0.02\ GeV/c^2$	48.51%	97011	2.70×10^{-4}	83.12%	2394695	1.87×10^{-5}
$0.6 \times leading\ E_\phi + subleading\ E_\phi > 15\ GeV$	46.27%	9318	2.68×10^{-3}	80.23%	208079	2.08×10^{-4}
$\lvert m_{\phi\phi} - m_{B_0^s} \rvert < 0.03$	45.30%	2	12.2	76.91%	35	1.19

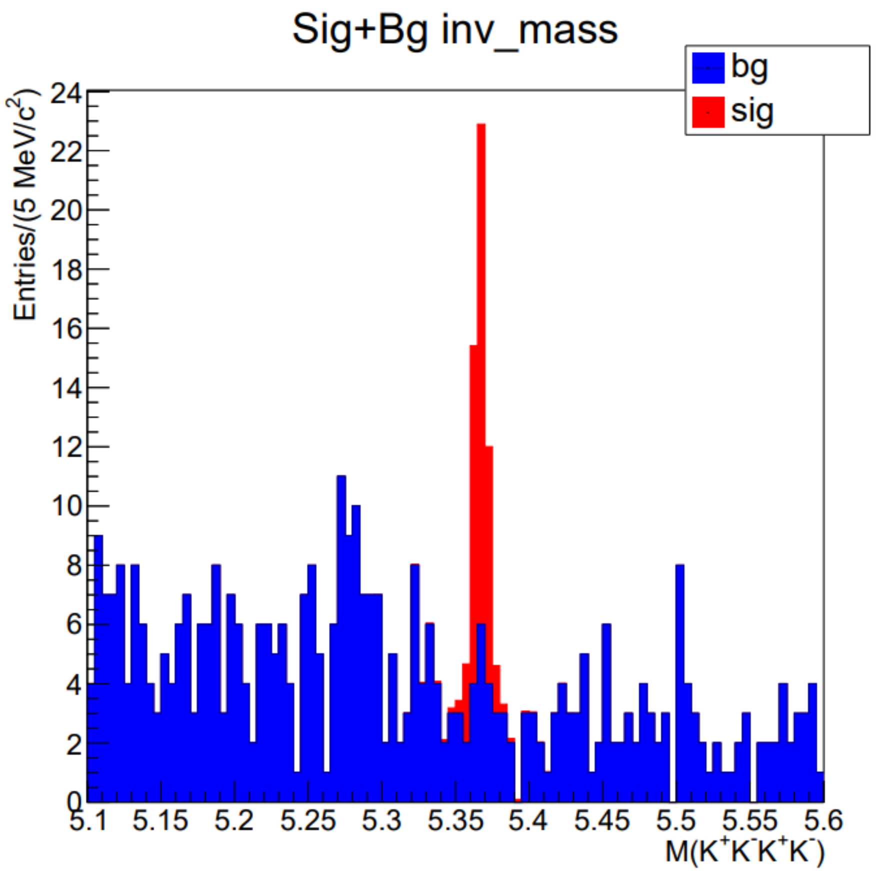
Without PID means not distinguishing between π K p

Distributions after All Cuts

With PID



Without PID



Summary

- PID information is important in physics analysis
- Next to do :
  - More realistic PID
  - More samples
  - Optimized cuts
- A paper on Delphes Card in preparation

Thanks!

Backup

The calculation of χ

◆ dN/dx : $(\chi^2_{dN/dx})^i = \left(\frac{dN/dx_{meas} - (dN/dx)^i_{exp}}{(\sigma)^i_{dN/dx}}\right)^2$

1.

$$(dN/dx)^i_{exp} = f\left((\beta\gamma)^i\right) \qquad (\sigma)^i_{dN/dx} = \sqrt{(dN/dx)^i_{exp}}$$

f is the theoretical function of cluster that only depends on $\beta\gamma$

2. Considering cluster counting efficiency $\varepsilon = \frac{dN/dx_{meas}}{dN/dx_{real}}$
   - Consider effect of ε as a function of dN/dx in xy plane: $\varepsilon = -0.007309 \times (dN/dx)_{xy} + 1.245497$
   - Then:

$$(dN/dx)^i_{exp} = \varepsilon \times f\left((\beta\gamma)^i\right) \qquad (\sigma)^i_{dN/dx} = \sqrt{\varepsilon \times (dN/dx)^i_{exp}}$$

◆ TOF: $(\chi^2_{tof})^i = \left(\frac{tof_{meas} - (tof)^i_{exp}}{\sigma_{tof}}\right)^2$

$$(tof)^i{}_{exp} = \frac{L}{v^i} = \frac{Lm^i}{p} \qquad \sigma_{tof} = 30ps$$