Instrumental asymmetries for $B^+ \to h^+\pi^0$

M. Dorigo, D. Ghosh, M. Mantovano, S. Raiz
(University and INFN Trieste)

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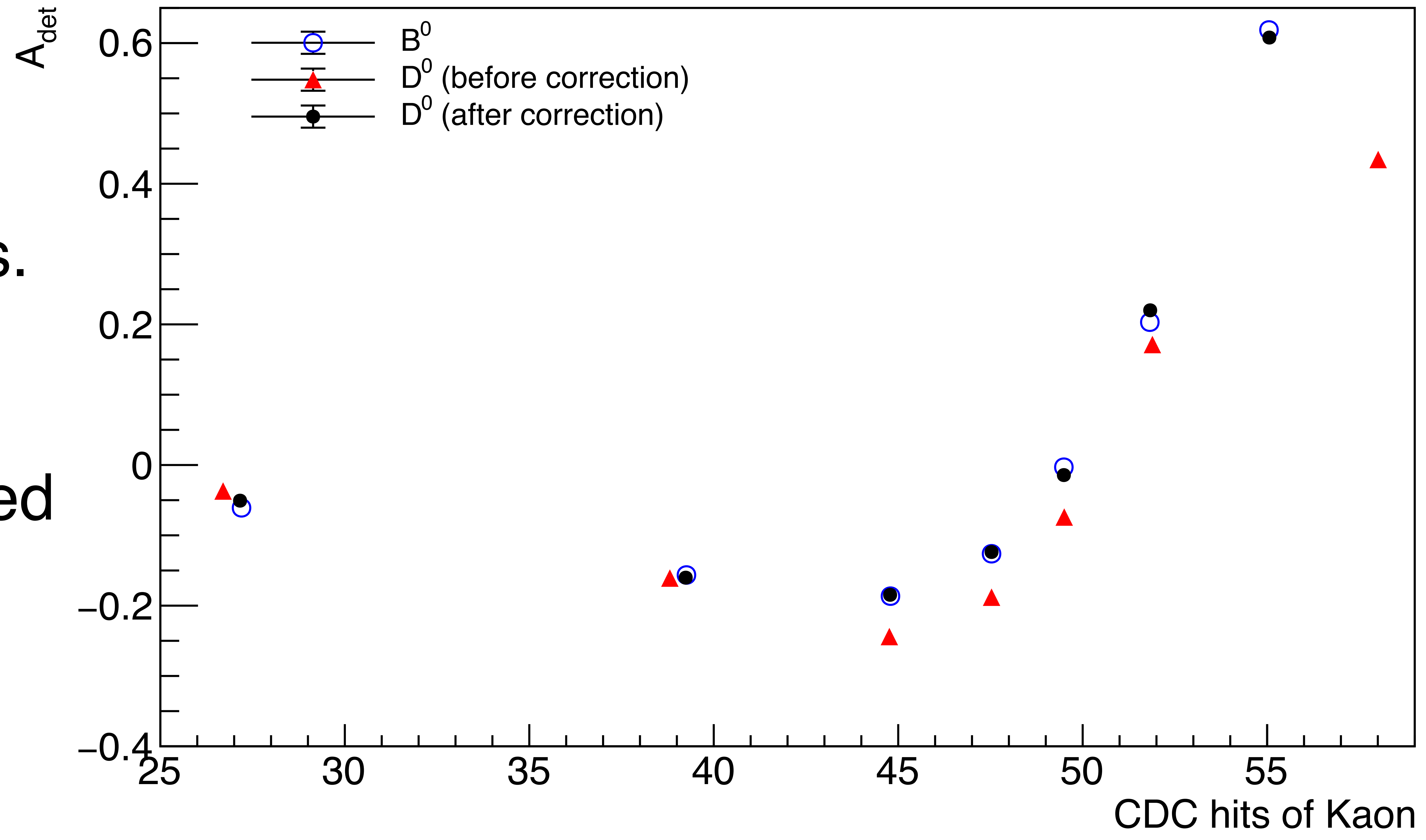
Reminder

- To measure $\mathscr{A}_{CP}$, need to subtract instrumental asymmetry, $\mathscr{A}_{det}$.
- Measured $\mathscr{A}_{det}(K\pi, K, \pi)$ using $D^0 \to K^-\pi^+$ and $D^+ \to K_s^0\pi^+$ decays.
- Studied sample-dependence of $\mathscr{A}_{det}$. Proposed a method to obtain $\mathscr{A}_{det}$ based on reweighing $(p, cos(\theta), \mathrm{CDC\ hits})$ distributions.
- Tested in several cases in MC $(B^0 \to K^+\pi^-, B^+ \to \rho^+\rho^0, B^+ \to D^0\pi^+)$.



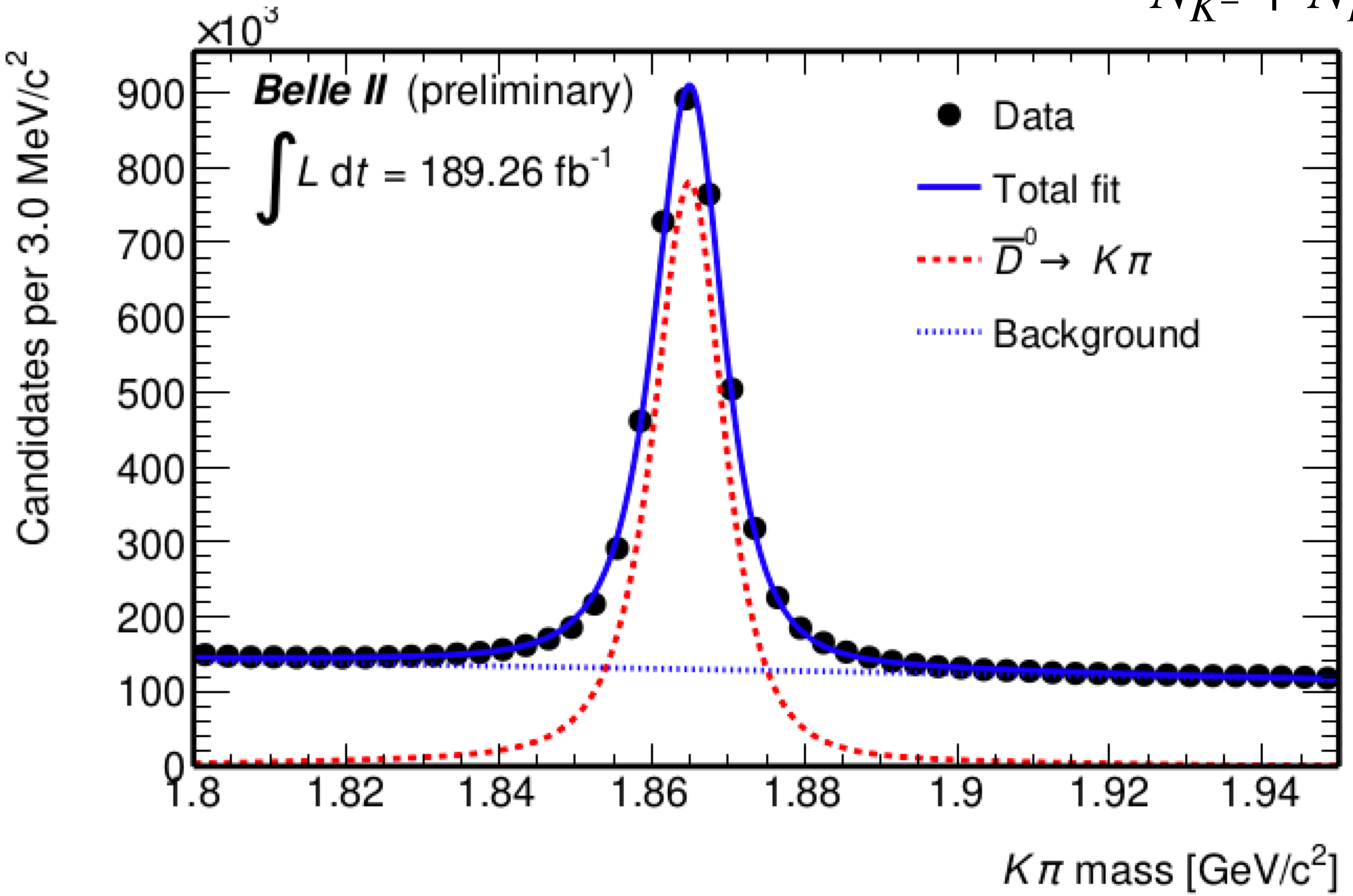
Link: https://indico.belle2.org/event/6872/contributions/37443/attachments/17110/25481/instr_asym_B2GM.pdf

$\mathscr{A}_{det}$ for $B^+ \to h^+\pi^0$

- We tested our method on $B^+ \to h^+\pi^0$ MC: failed to obtain target $\mathscr{A}_{det}$.
- Use a conservative approach:
    - Take $\mathscr{A}_{det}$ measured in control channel from data.
    - Assign a systematic uncertainty to account for the sample-dependence from MC
- While we cannot fully trust MC to obtain $\mathscr{A}_{det}$, we can use it to obtain relative differences of $\mathscr{A}_{det}$.
  (Data-MC comparison showed here:
  https://indico.belle2.org/event/6708/contributions/34844/attachments/16322/24370/Tracking_instr.pdf)

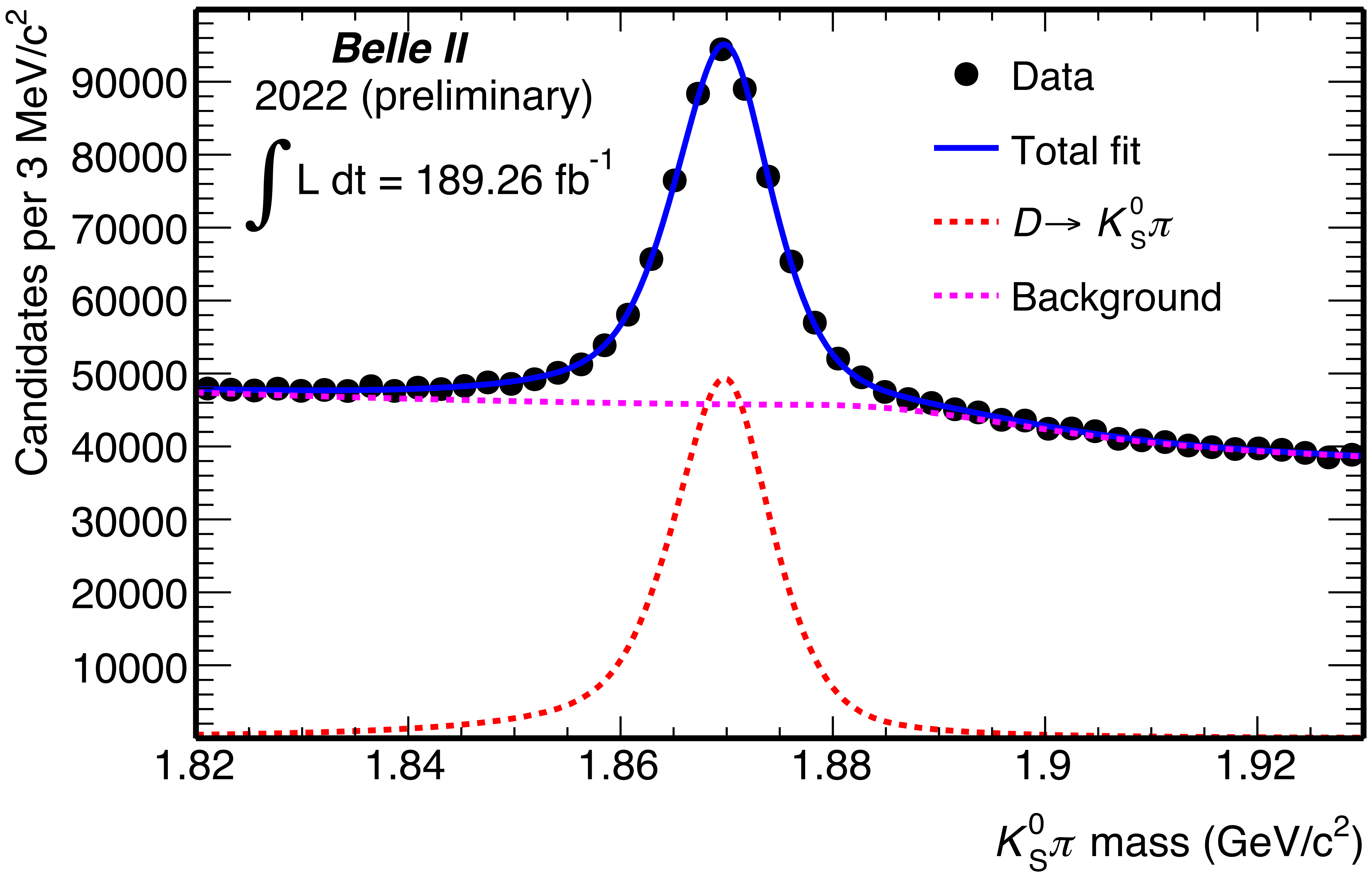
$\mathscr{A}_{det}$ from control samples

$D^0 \to K^-\pi^+$ $\qquad \mathscr{A}_{det} = \frac{N_{K^-} - N_{K^+}}{N_{K^-} + N_{K^+}}$



$$\mathscr{A}_{det}(K^-\pi^+) = -0.0061 \pm 0.0009$$

$D^+ \to K_S^0\pi^+$ $\qquad \mathscr{A}_{det} = \frac{N_{\pi^-} - N_{\pi^+}}{N_{\pi^-} + N_{\pi^+}}$



$$\mathscr{A}_{det}(K_S^0\pi^-) = -0.0047 \pm 0.0043$$

Selection details reported in backup

Determination of $\mathscr{A}_{det}(\pi)$

$$\mathscr{A}_{det}(\pi^-) = \frac{N_{\pi^-} - N_{\pi^+}}{N_{\pi^-} + N_{\pi^+}}$$

- Measure $\mathscr{A}_{det}(\pi)$ in data using $D^+ \to K_s^0\pi^+$ decays: assume $\mathscr{A}_{det}(K_S^0) = 0$

$$\mathscr{A}_{det}(\pi^-)(D^+ \to K_s^0\pi^+, \text{data}) = \mathscr{A}_{det}(K_S^0\pi^-) = -0.0047 \pm 0.0043\,(\text{stat})$$

- Sample-dependence uncertainty: difference between $\mathscr{A}_{det}$ of $D^+ \to K_s^0\pi^+$ and $B^+ \to \pi^+\pi^0$ in MC.

$$\mathscr{A}_{det}(\pi^-)(D^+ \to K_s^0\pi^+, \text{MC}) - \mathscr{A}_{det}(\pi^-)(B^+ \to \pi^+\pi^0, \text{MC}) = -0.0079 \pm 0.0030$$

taking $\sqrt{0.0079^2 + 0.0030^2} = 0.0085$

(0.85 % syst)

$$\mathscr{A}_{det}(\pi^-)(D^+ \to K_s^0\pi^+, \text{data}) = -0.0047 \pm 0.0095\,(\text{stat} + \text{syst})$$

Determination of $\mathscr{A}_{det}(K)$

$$\mathscr{A}_{det}(K^-) = \frac{N_{K^-} - N_{K^+}}{N_{K^-} + N_{K^+}}$$

- Measure $\mathscr{A}_{det}(K\pi)$ in data using $D^0 \to K^-\pi^+$ decays and subtract the $\mathscr{A}_{det}(\pi)$ determined before:

$$\mathscr{A}_{det}(K^-)(D^0 \to K^-\pi^+, \text{data}) = -0.0108 \pm 0.0044\,(\text{stat})$$

- Assign $0.85\,\%$ systematic uncertainty for the $\mathscr{A}_{det}(\pi)$

- Assign an additional systematics uncertainty ($0.32\,\%$) evaluated in MC as the difference in $\mathscr{A}_{det}(K)$ between $D^0 \to K^-\pi^+$ and $B^+ \to K^+\pi^0$ channels.

$$\mathscr{A}_{det}(K^-)(D^0 \to K^-\pi^+, \text{MC}) - \mathscr{A}_{det}(K^-)(B^+ \to K^+\pi^0, \text{MC}) = -0.0007 \pm 0.0031$$

0.0032 $(0.32\,\%\ \text{syst})$

$$\mathscr{A}_{det}(K^-)(D^0 \to K^-\pi^+, \text{data}) = -0.0108 \pm 0.0101\,(\text{stat} + \text{syst})$$

Summary

- We measure $\mathscr{A}_{det}(\pi)$ and $\mathscr{A}_{det}(K)$ for $B^+ \to h^+\pi^0$ using control channels: $D^0 \to K^-\pi^+$ and $D^+ \to K_s^0\pi^+$

- Considered a systematic uncertainty for the sample-dependence of $\mathscr{A}_{det}$.

$$\mathscr{A}_{det} = \frac{N_{\pi^-} - N_{\pi^+}}{N_{\pi^-} + N_{\pi^+}}$$

$$\mathscr{A}_{det} = \frac{N_{K^-} - N_{K^+}}{N_{K^-} + N_{K^+}}$$

$\mathscr{A}_{det}(\pi^-)$	-0.005 ± 0.010
$\mathscr{A}_{det}(K^-)$	-0.011 ± 0.010

Backup

$\mathscr{A}_{det}$ from D control channels

- Observed charge asymmetries $\mathscr{A}_{\text{obs}}$:

$$\mathscr{A}_{obs} = \frac{N_D - N_{\bar{D}}}{N_D + N_{\bar{D}}} = \mathscr{A}_{CP} + \mathscr{A}_{det} + \mathscr{A}_{\text{FB}}$$

Observed asymmetry — CP-violating asymmetry — Instrumental asymmetry — Forward-backward asymmetry

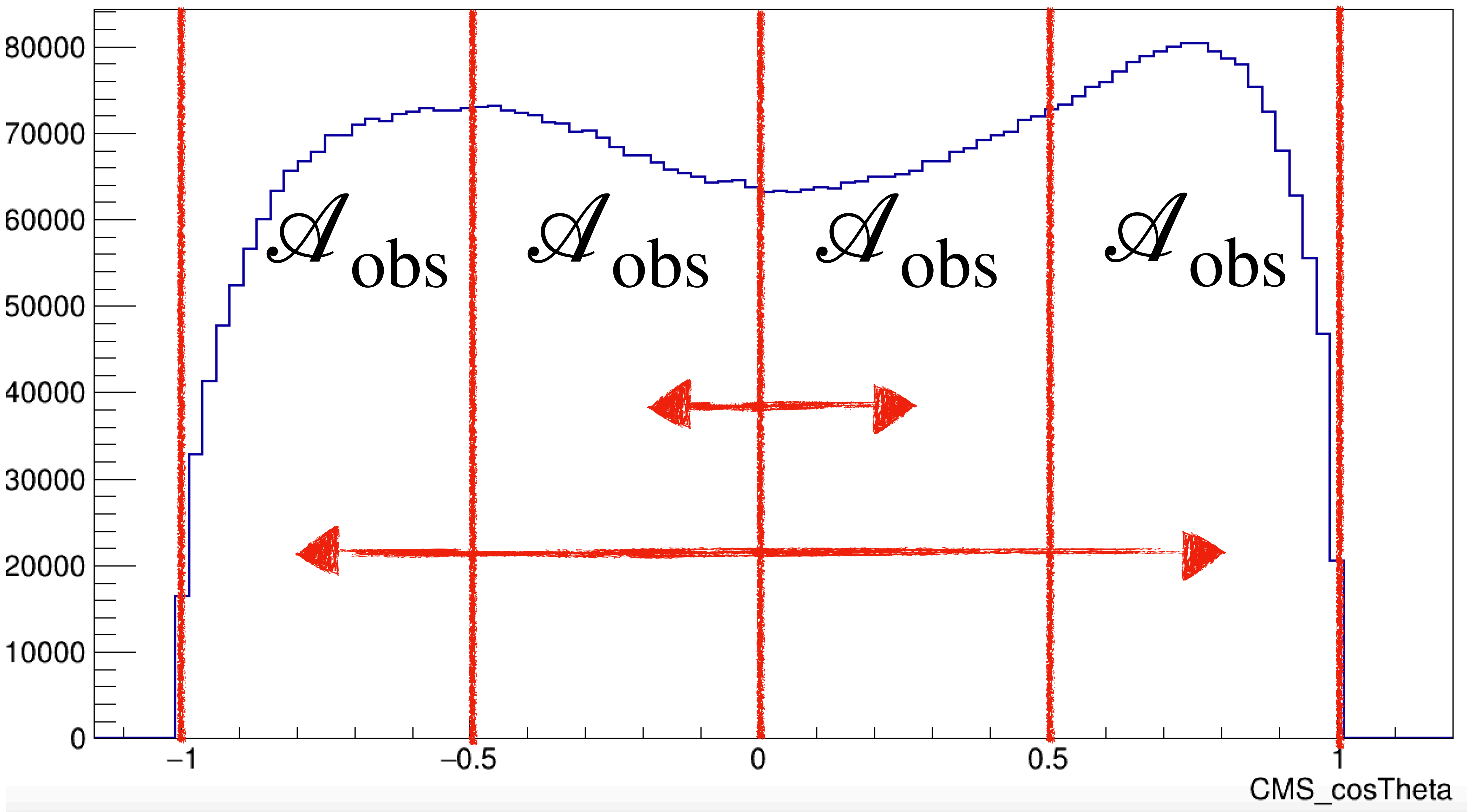
- $\mathscr{A}_{\text{CP}}$ known for $D^0 \to K^-\pi^+$ and $D^+ \to K_s^0\pi^+$:

$$\mathscr{A}_{CP}(K\pi) = 0 \quad \text{and} \quad \mathscr{A}_{CP}(K_s^0\pi) = (-0.41 \pm 0.09)\,\%$$

- We already showed how to subtract $\mathscr{A}_{FB}$ (backup)

Forward-backward production asymmetry

- $\mathscr{A}_{FB}$ contribution due to $\gamma^* - Z^0$ interference in $e^+e^- \to c\bar{c}$.
- $\mathscr{A}_{FB}$ is antisymmetric as a function of $cos(\theta^*)$ (angle of D momentum in the CMS). https://arxiv.org/abs/1406.6311
- Cancel $\mathscr{A}_{FB}$ by combining measurement of $\mathscr{A}_{obs}$ in opposite bins of $cos(\theta^*)$:



$$\mathscr{A}_{det} = \frac{\mathscr{A}_{obs}(cos(\theta^*)) + \mathscr{A}_{obs}(-cos(\theta^*))}{2}$$

NB: Assume that $\mathscr{A}_{det}$ is not antisymmetric as a function of $cos(\theta^*)$.

Sample and selection

Data: Proc12 + buckets16-25 (189.26 fb^{-1}).

SignalMC: from MC14ri-a (300 fb^{-1}).

Vertex fit on D: treefit

Applied the latest beam energy and momentum corrections.

Tracks:thetaInCDCAcceptance + |dr| <0.5 + |dz| <3 + chiProb>0 + CDCHits>20

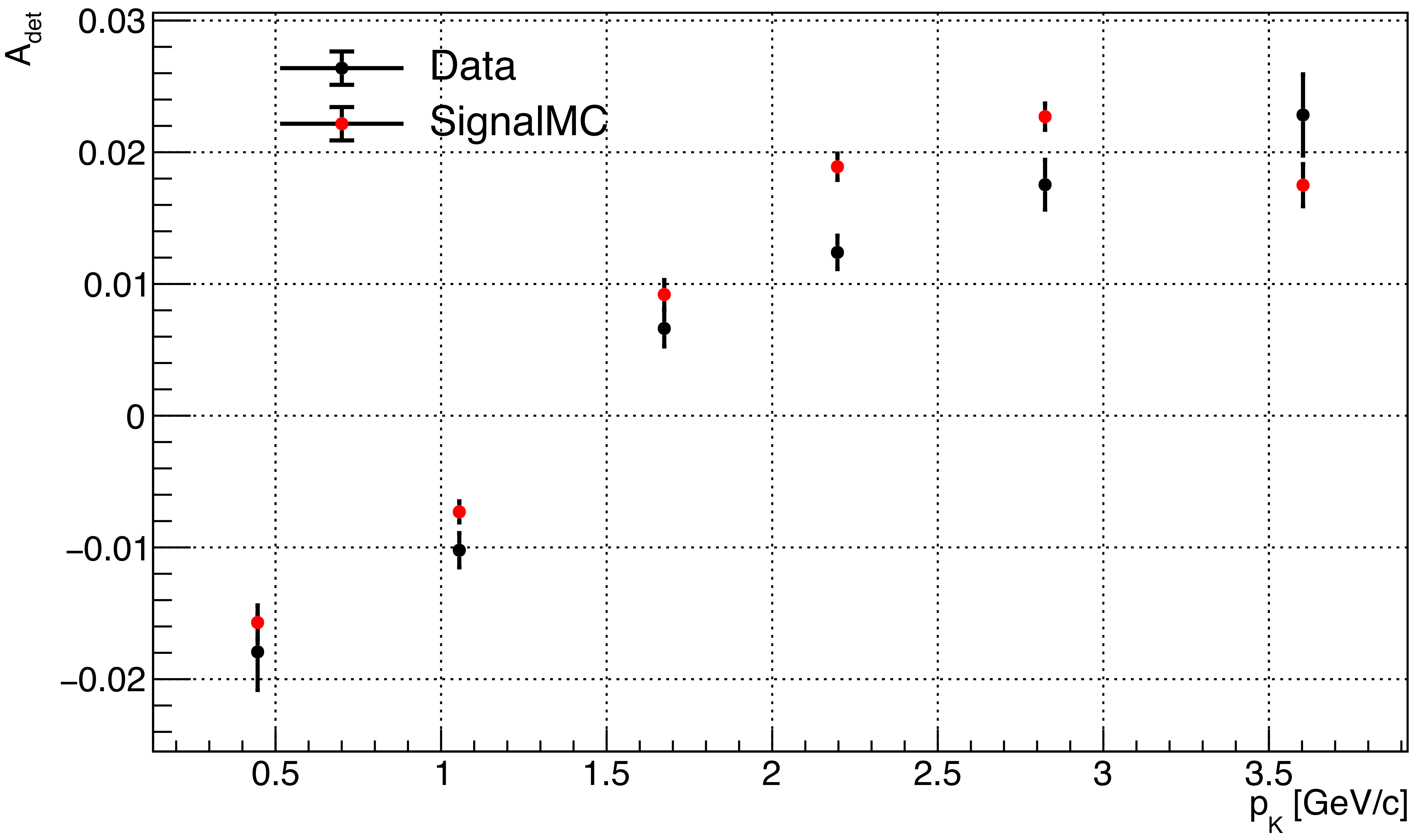
$D^0 \to K^-\pi^+$	$D^+ \to K_s^0\pi^+$
kaonID>0.5 + pionID>0.5 + p_CMS(D) >2.5 GeV/c + CS>0.5	pionID>0.5 + p_CMS(D) >2.5 GeV/c + CS>0.5 + 0.4942GeV/c^2<m(Ks)<0.5014Gev/c^2+ Significance of distance (Ks) >44.5

$\mathscr{A}_{det}(K\pi)$ from $D^0 \to K^-\pi^+$

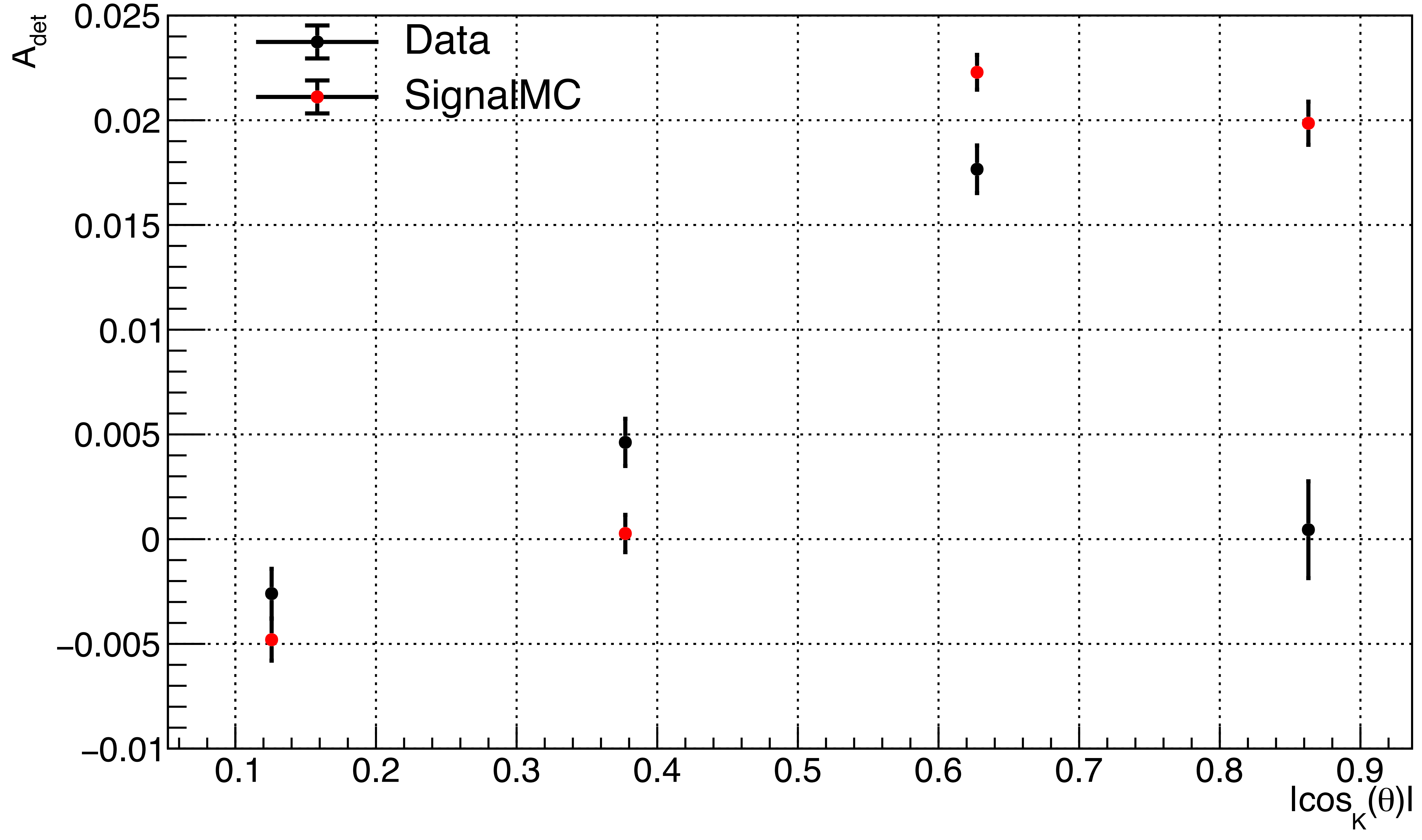
$\mathscr{A}_{\text{det}}(K\pi)$ kinematics dependences: data vs MC

$$\mathscr{A}_{\text{obs}} = \frac{N_{D^0} - N_{\bar{D}^0}}{N_{D^0} + N_{\bar{D}^0}}$$

Check marginal distribution:
integrate over $cos_K(\theta)$ and CDC hits of kaon.



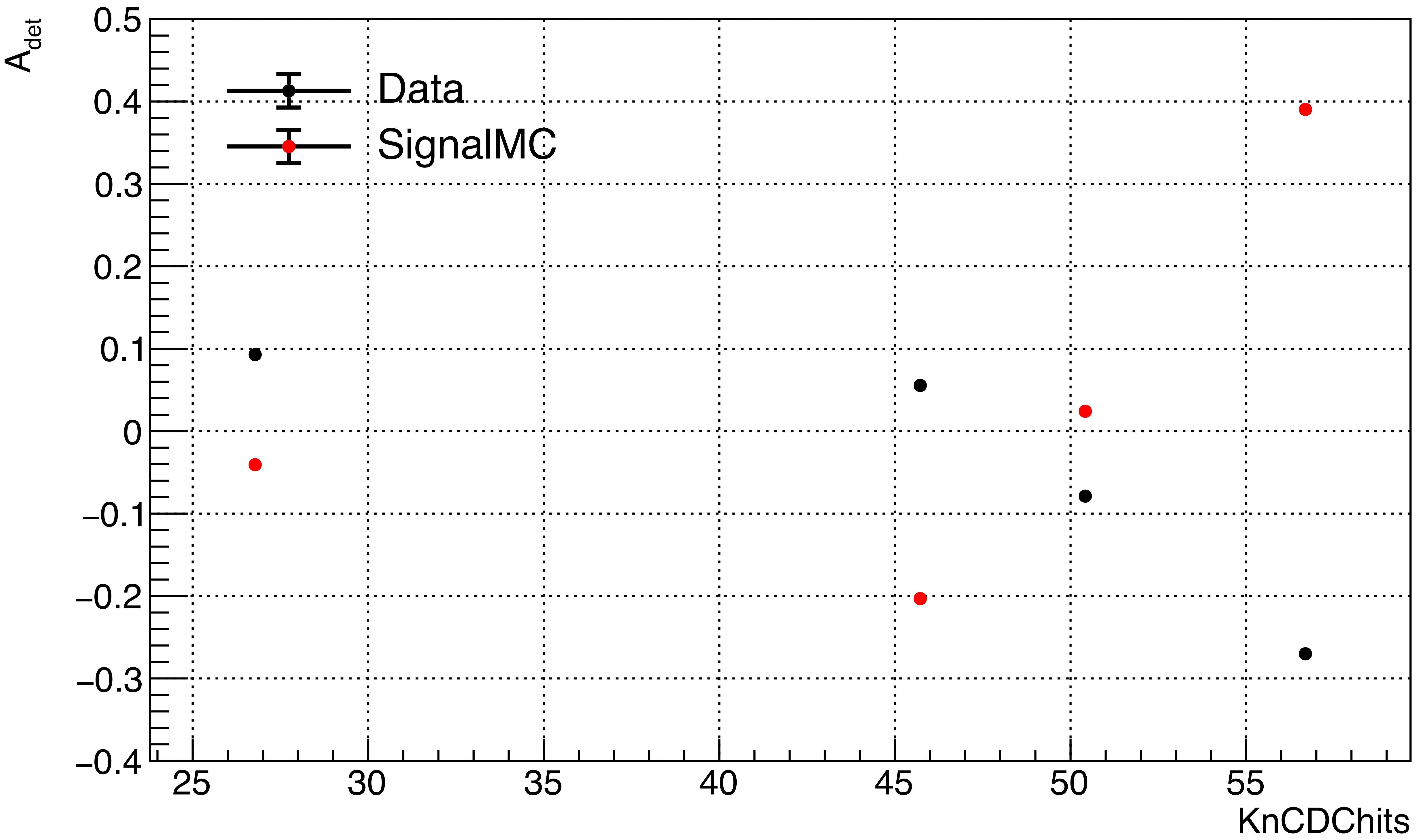
Check marginal distribution:
integrate over $p_K(\theta)$ and CDC hits of Kaon.



$\mathscr{A}_{\rm det}(K\pi)$ dependence on CDC hits: data vs MC

$$\mathscr{A}_{\rm obs} = \frac{N_{D^0} - N_{\bar{D}^0}}{N_{D^0} + N_{\bar{D}^0}}$$

Integrate over all kinematic variables.



Strong dependence of $\mathscr{A}_{det}$ on CDC hits of kaon

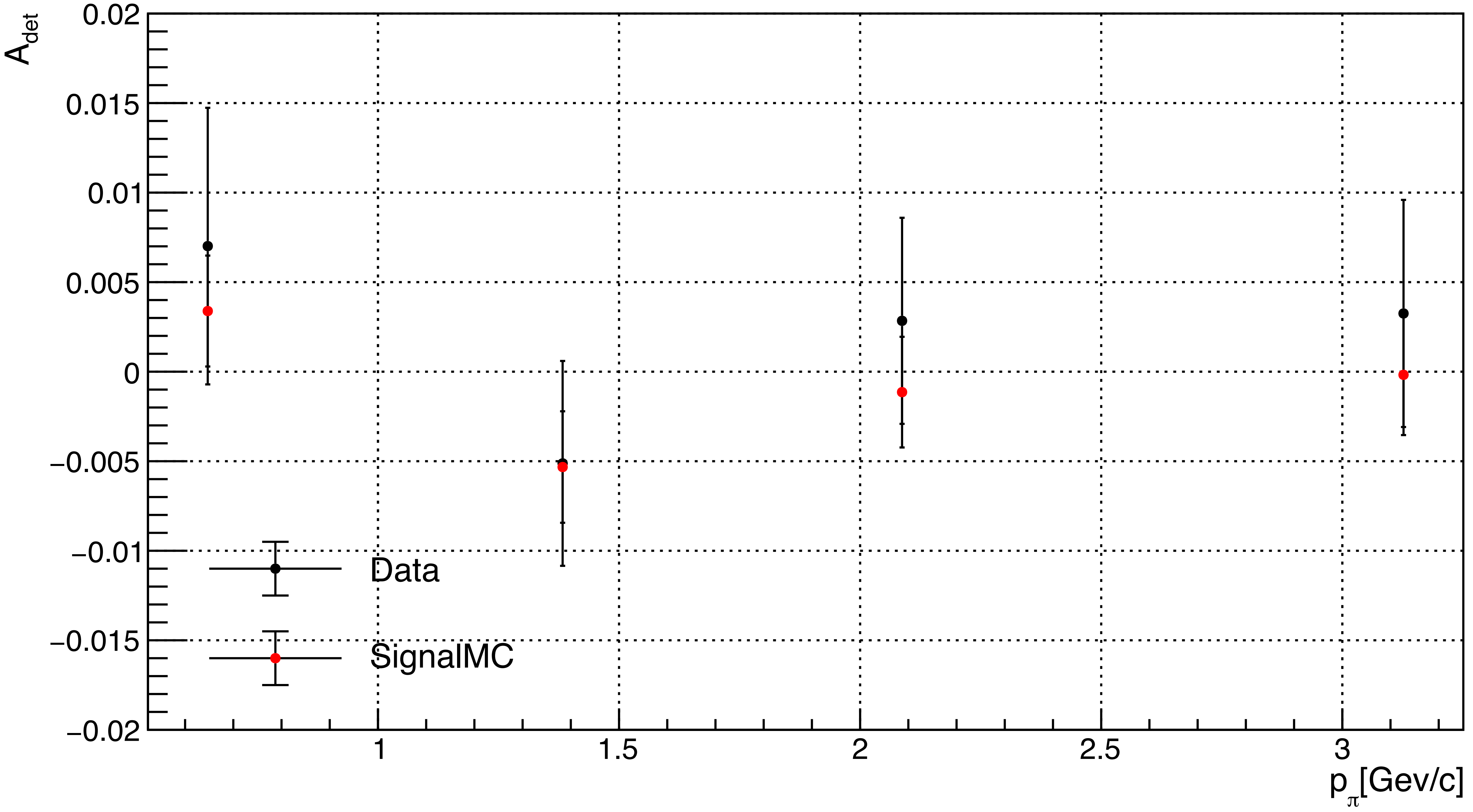
Known Data-MC discrepancy due to CDC drift-time mismodeling.

$\mathscr{A}_{det}(\pi)$ from $D^+ \rightarrow K_s^0\pi^+$

$\mathscr{A}_{\text{det}}(\pi)$ kinematics dependences : data vs MC

$$\mathscr{A}_{\text{obs}} = \frac{N_{D^+} - N_{D^-}}{N_{D^+} + N_{D^-}}$$

Check marginal distribution:
integrate over $cos_\pi(\theta)$ and CDC hits of pion.



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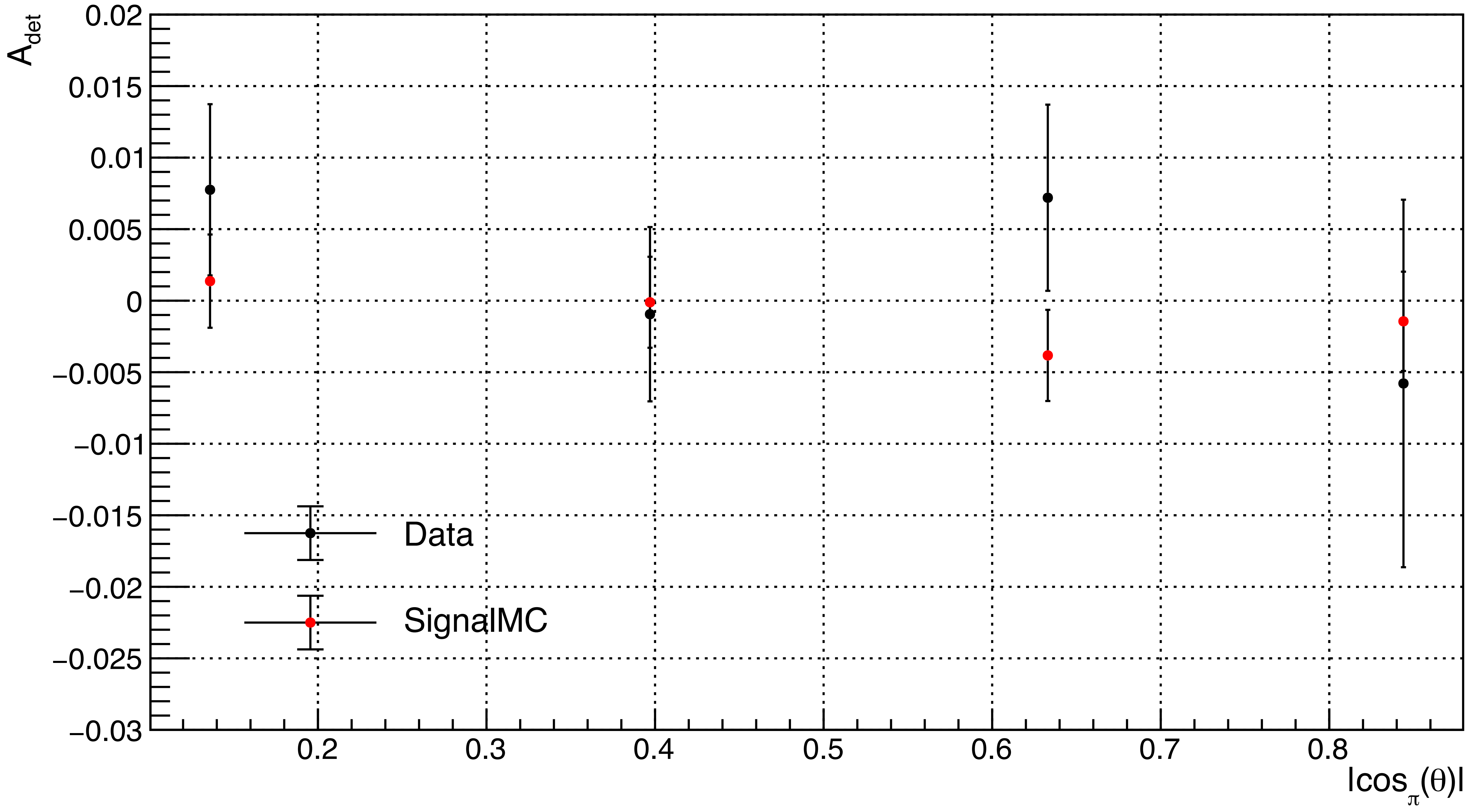

$\mathscr{A}_{\text{det}}(\pi)$ dependence on CDC hits: data vs MC

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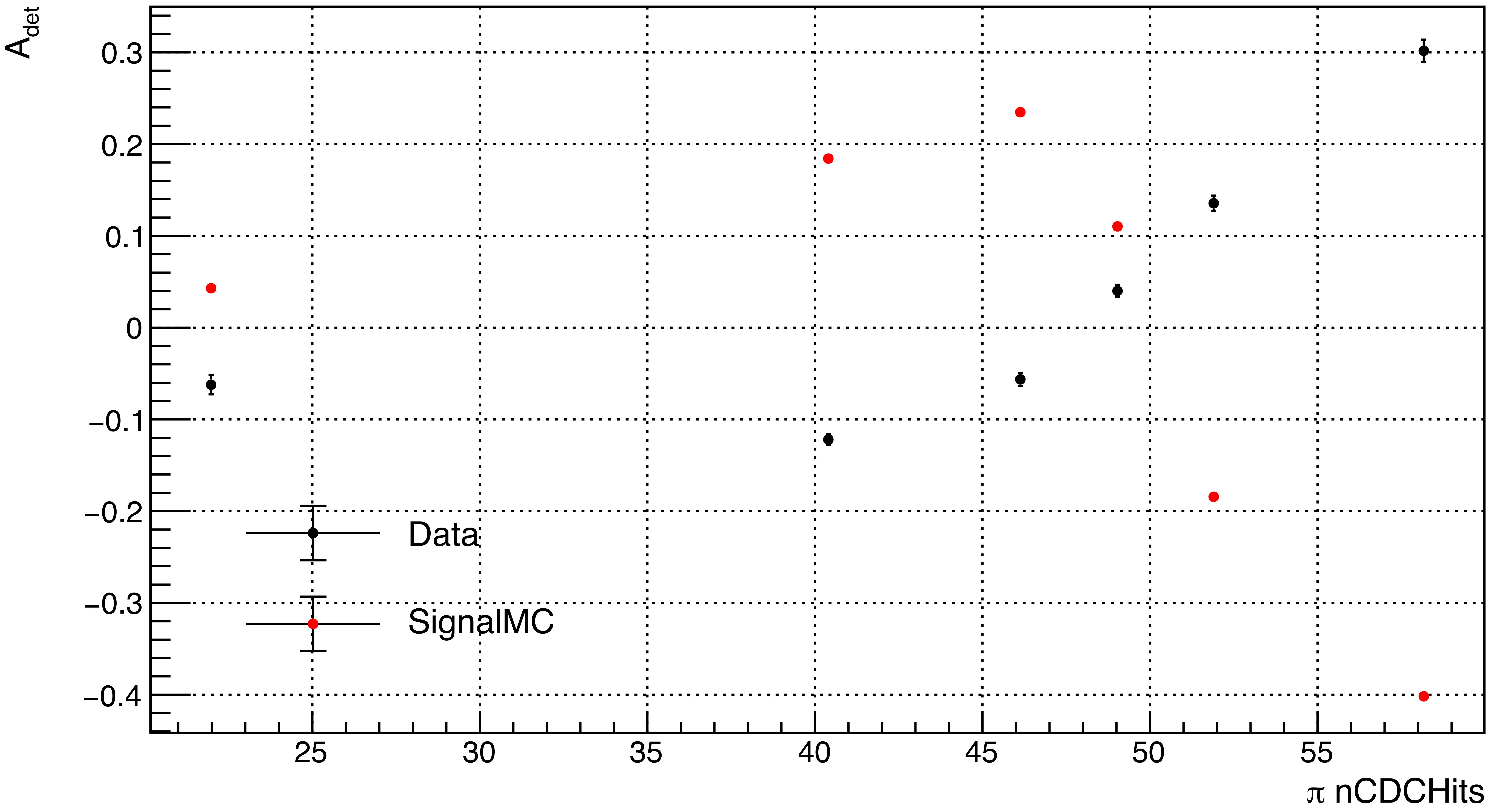
Integrate over all kinematic variables.



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