$B^0_s \to D^{\pm}_s K^{\mp}$ Benchmark Analysis

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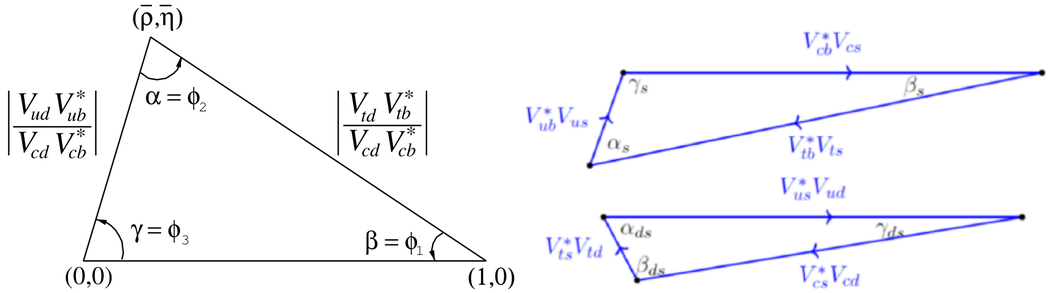
Physics Performance Monthly Meeting

July 2022

Motivation

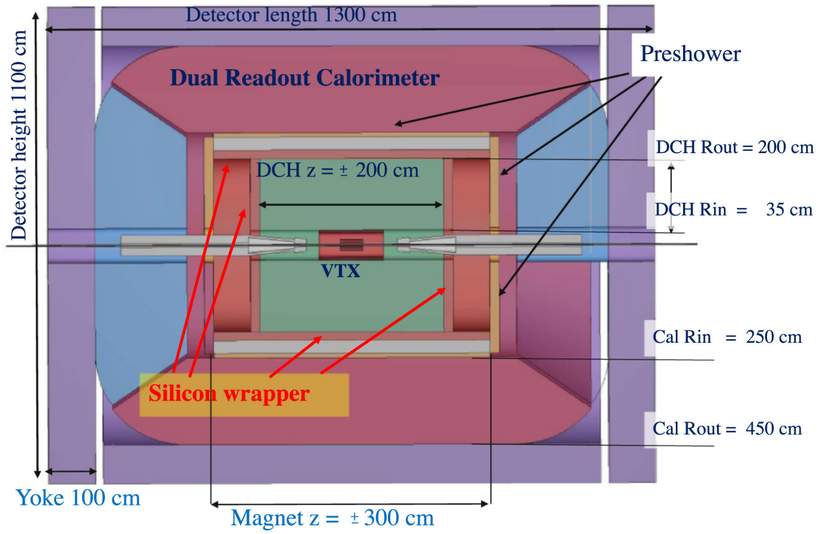


Study of the decay(s):

1. $B^0_s \rightarrow D^{\pm}_s K^{\mp}$
2. $(B_s \rightarrow J/\psi\ \varphi)$

With 75 (310) billion of B^0_s (B^0),
$\sigma(\gamma) \sim 0.4°$ and $\sigma(\beta_s) \sim (3.4\ x\ 10^{-2})°$

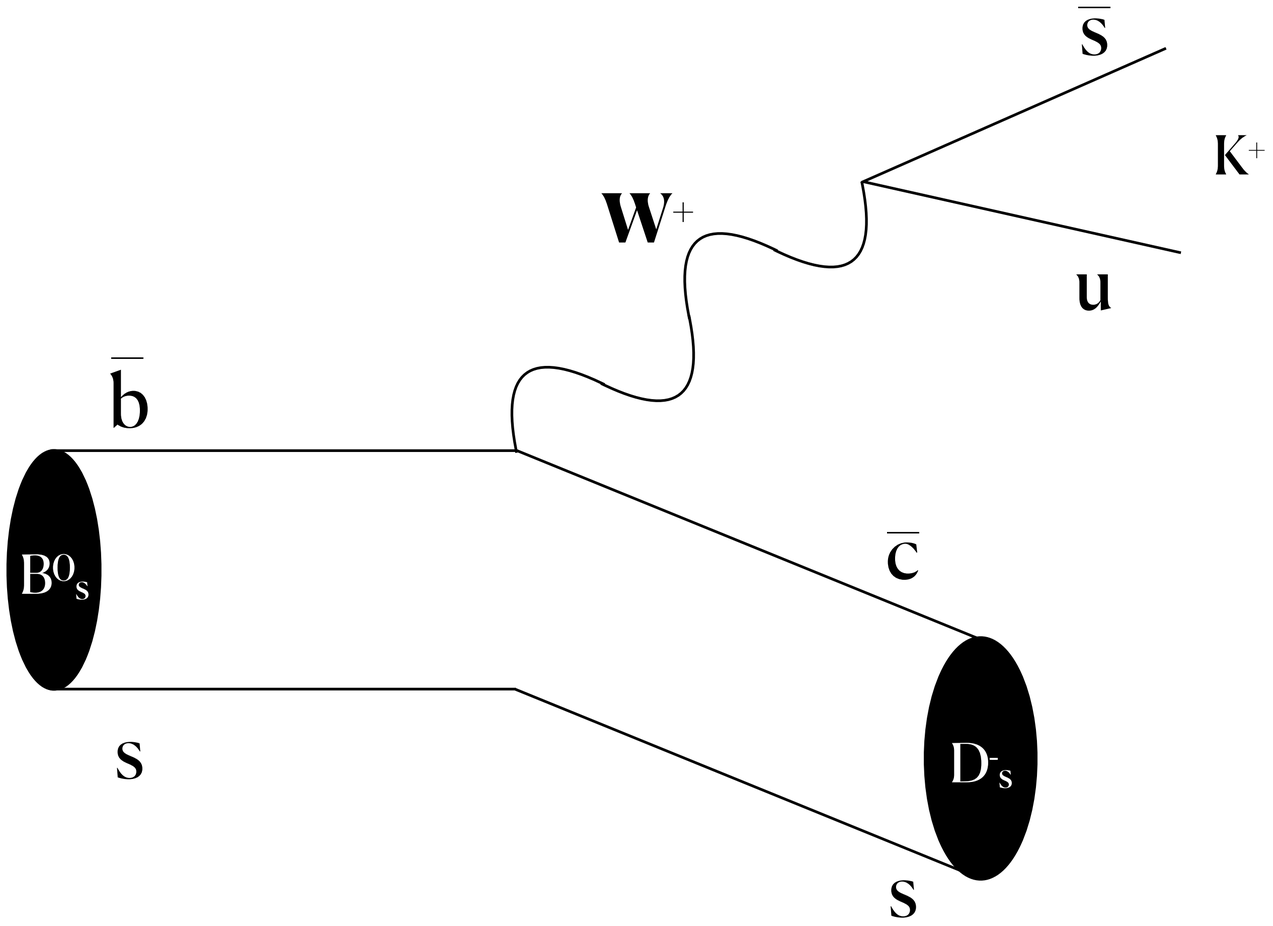
Goal



Defining IDEA's tracking features (full-sim) and estimate (fast-sim) $\varphi_{CKM}(D_sK) = \gamma_{CKM} + \gamma_{ds} - 2\beta_s$ e $2\beta_s$

Using HEP-FCC/FCCAnalyses framework
–> key4hep/EDM4hep

$B^0_s \to D^{\pm}_s K^{\mp} \to (KK\pi^{\pm})\, K^{\mp}$



Signal MC samples

$$B^0_s \to D^{\pm}_s K^{\mp} \to (KK\pi^{\pm})\, K^{\mp}$$

$$\begin{cases} \text{Exclusive } Z \to b\bar{b} \text{ with} \\ 10\text{k events} \,@\, \sqrt{s} = 91.188\ \text{GeV} \end{cases} \longrightarrow$$

```
#
Decay B_s0
  1.000 MyD_s- K+ PHSP;
Enddecay
CDecay anti-B_s0
#
Decay MyD_s-
  1.000 Myphi pi- PHSP;
Enddecay
CDecay MyD_s+
#
Decay Myphi
      1.000  K+ K-  VSS;
Enddecay
#
End
```

NB

Sample was privately produced with an old (Winter '21) version of Delphes generator

MC
Truth Matching

Status

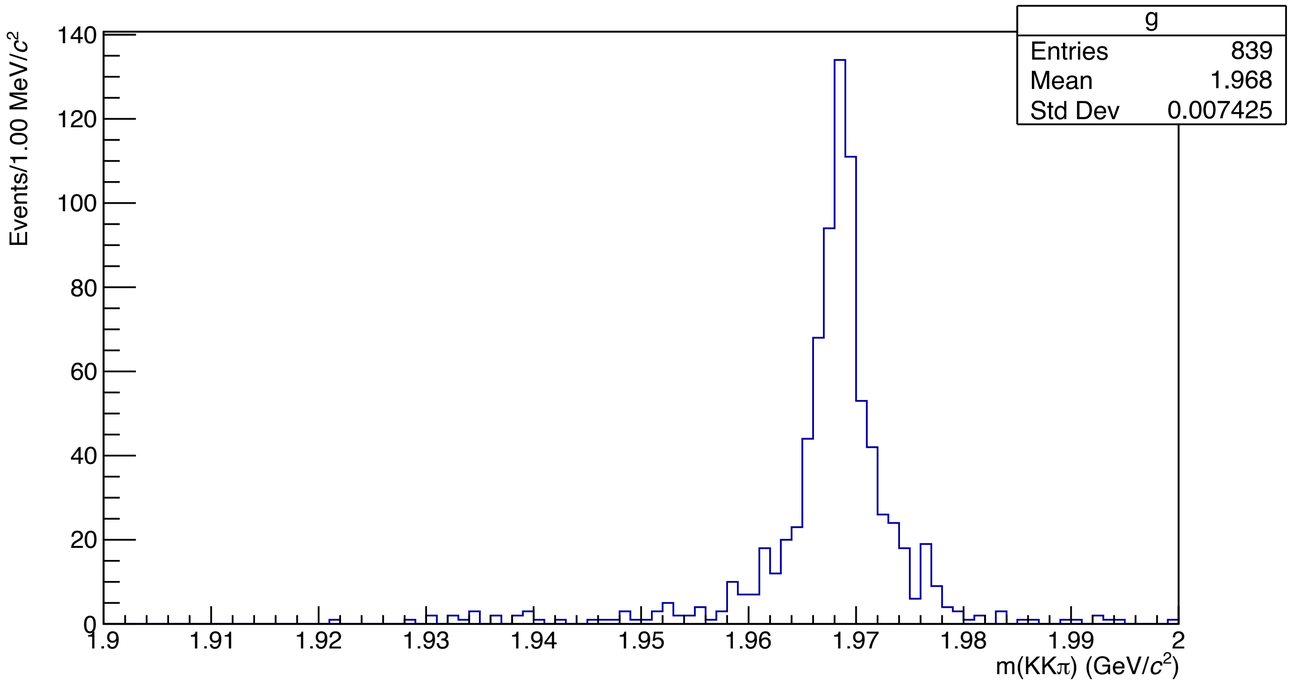
$$B^0_s \rightarrow D^{\pm}_s K^{\mp} \rightarrow (KK\pi^{\pm})\, K^{\mp}$$

Identification the D^-_s state

D_s identification through the KKπ vertex reconstruction

PID is 100%
(i.e. made via PDGid)

Reconstructed $D^{\pm}_s$ mass



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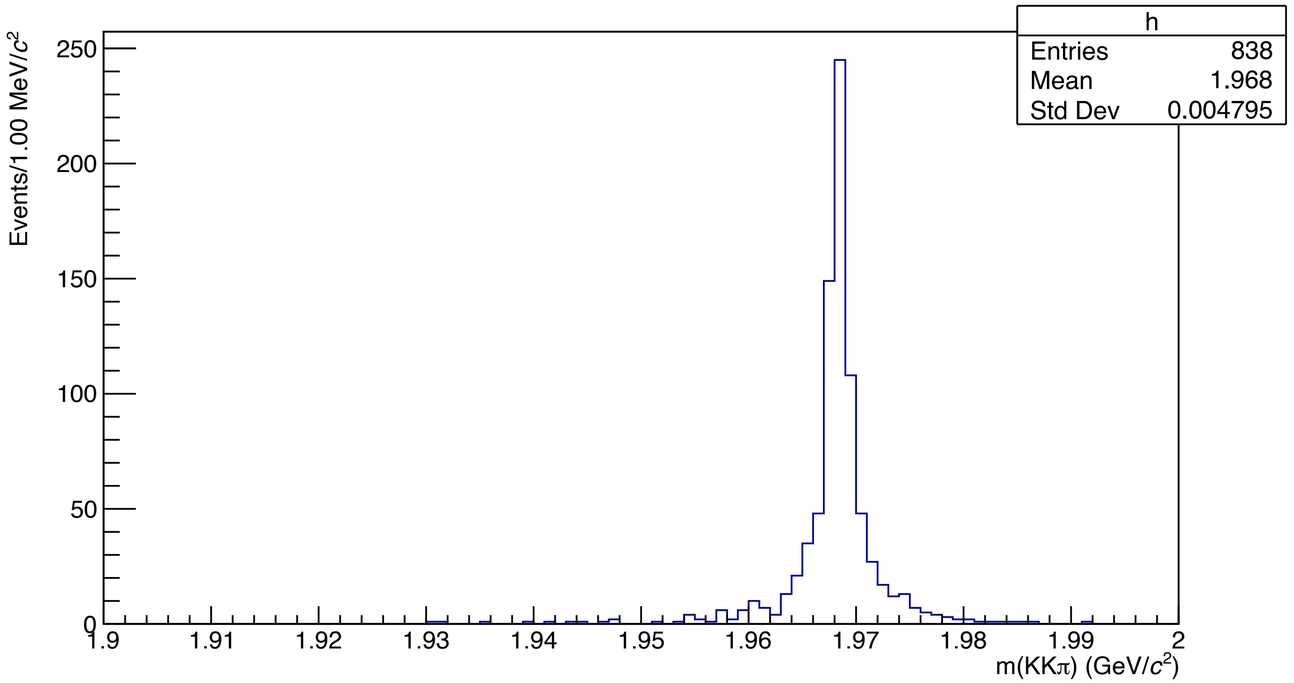


MC
Truth Matching

Status

$B^0_s \rightarrow D^{\pm}_s K^{\mp} \rightarrow (KK\pi^{\pm})\, K^{\mp}$

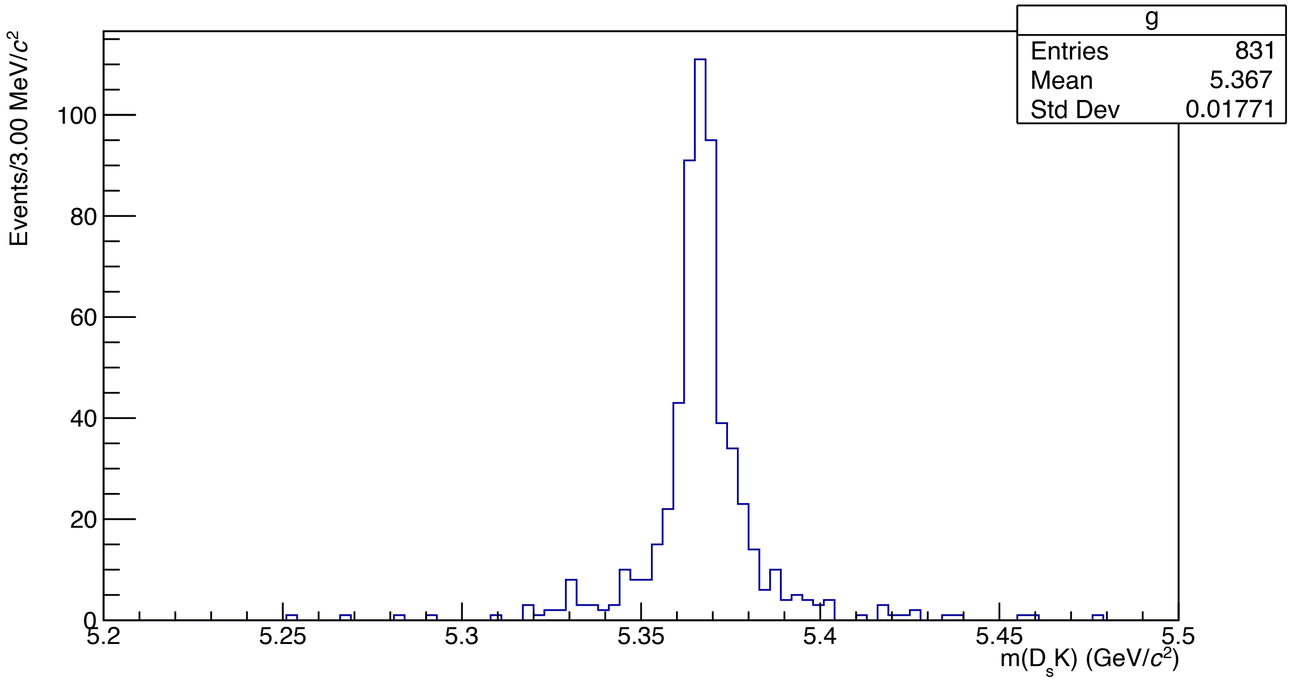
Identification the **B^0_s** state

Combine the **D^-_s** candidates with the bachelor **K^+**

~~B^0_s identification through the D_sK vertex reconstruction~~

PID is 100%
(i.e. made via PDGid)

Reconstructed B^0_s mass



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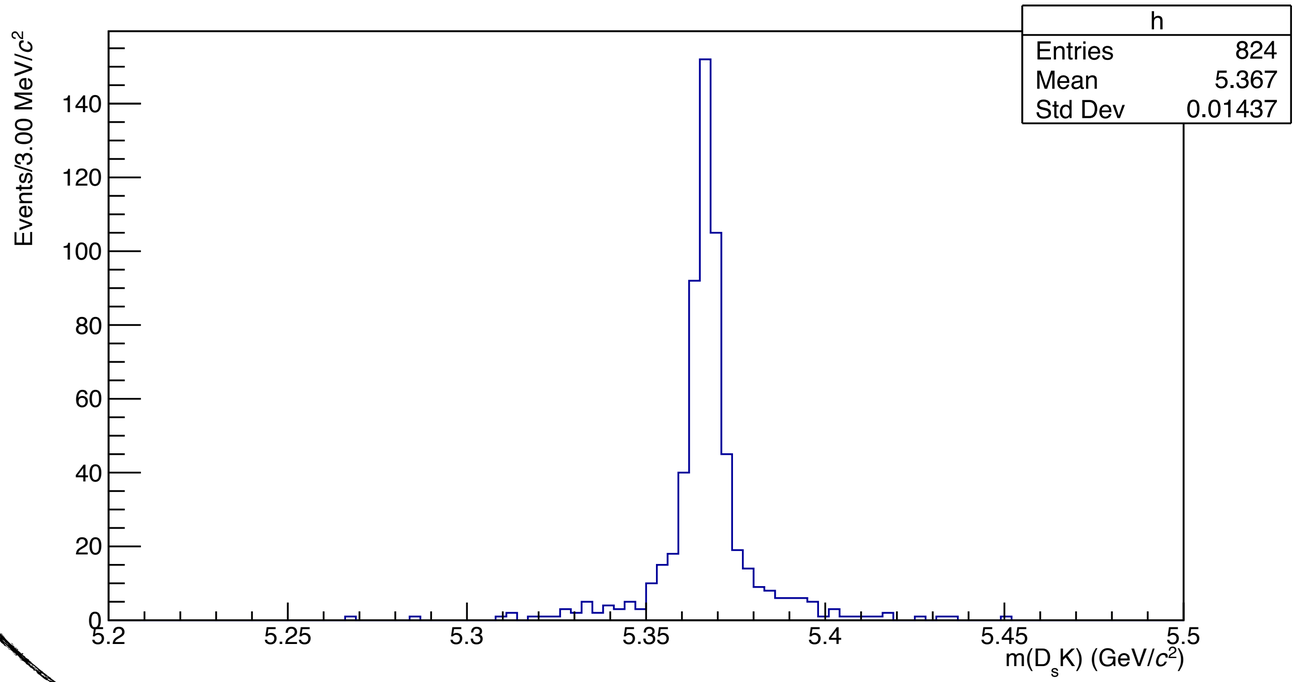
Reconstructed B^0_s mass



NB Not back propagated to **B^0_s** vertex

MC
Truth Matching

Status

$$B^0_s \rightarrow D^{\pm}_s K^{\mp} \rightarrow (KK\pi^{\pm})\, K^{\mp}$$

Identification the **B^0_s** state

Combine the **D^-_s** candidates with the bachelor **K^+**

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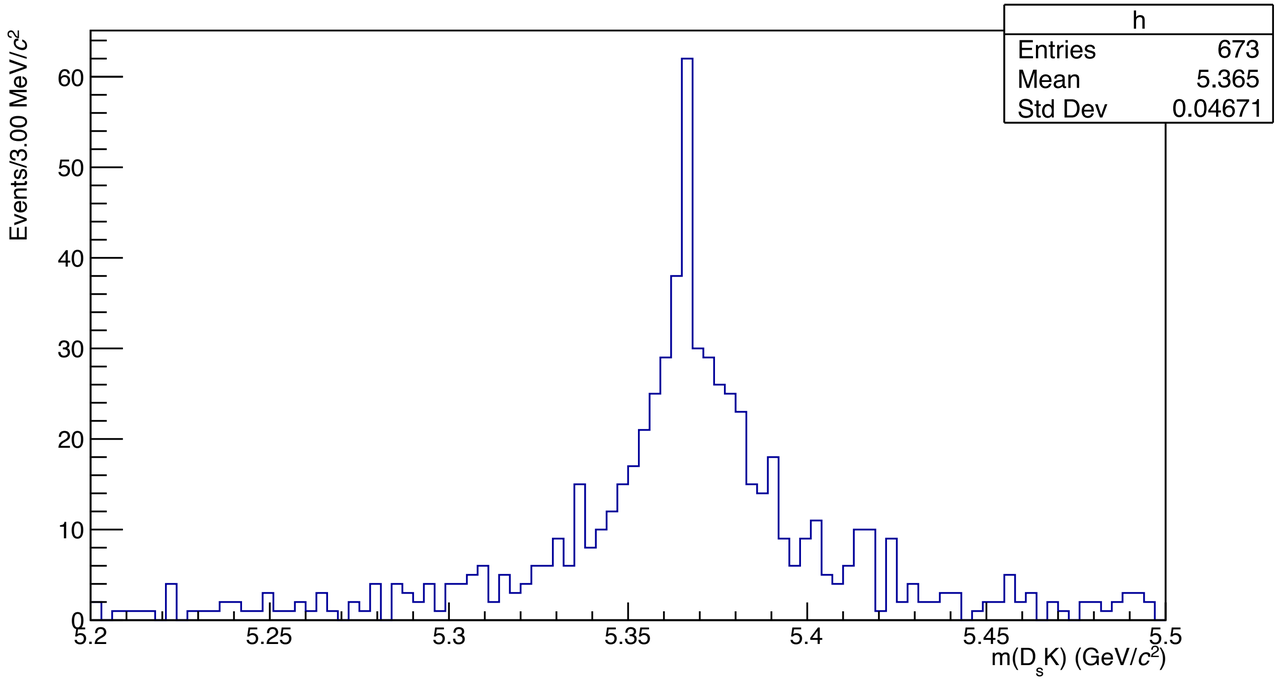
Reconstructed B^0_s mass



MC
Truth Matching

Status

$$B^0_s \rightarrow D^{\pm}_s K^{\mp} \rightarrow (KK\pi^{\pm})\, K^{\mp}$$

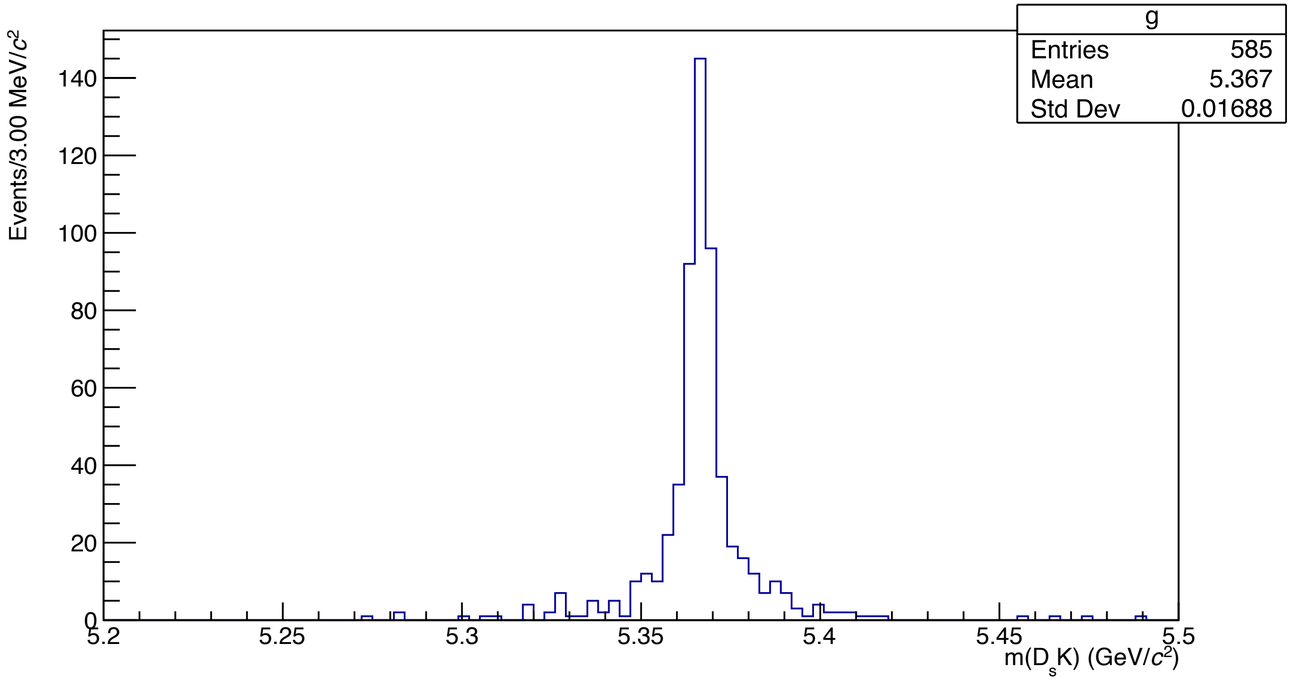
Identification the **B^0_s** state

Combine the **D^-_s** candidates with the bachelor **K^+**

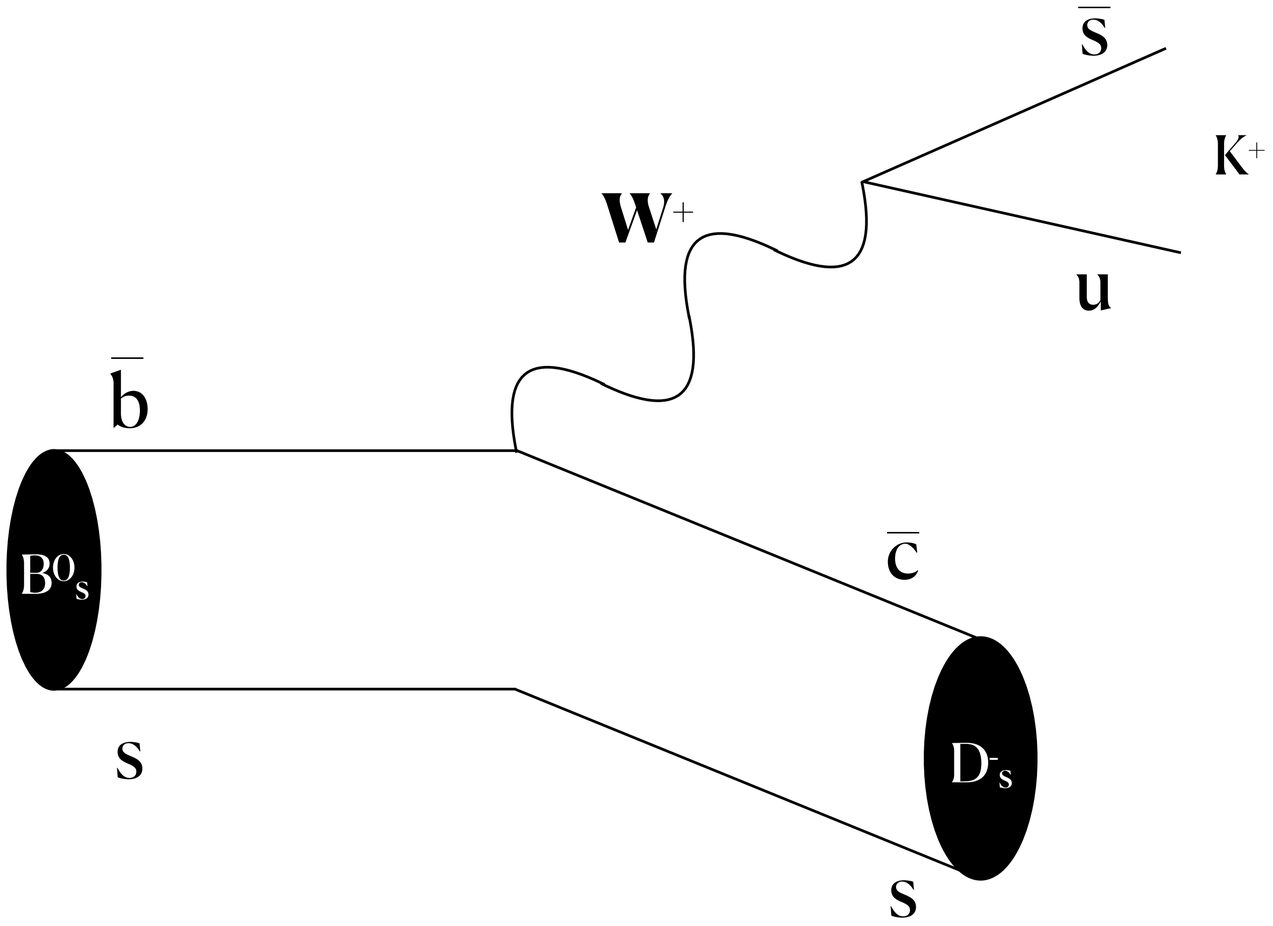
B^0_s ID through the D_sK vertex reco, but the D_s CovMat is re-estimated via a ToyMC

PID is 100%
(i.e. made via PDGid)

Reconstructed B^0_s mass



$B^0_s \to D^{\pm}_s K^{\mp} \to (\varphi\pi^{\pm}) K^{\mp}$



Reco
10k Events

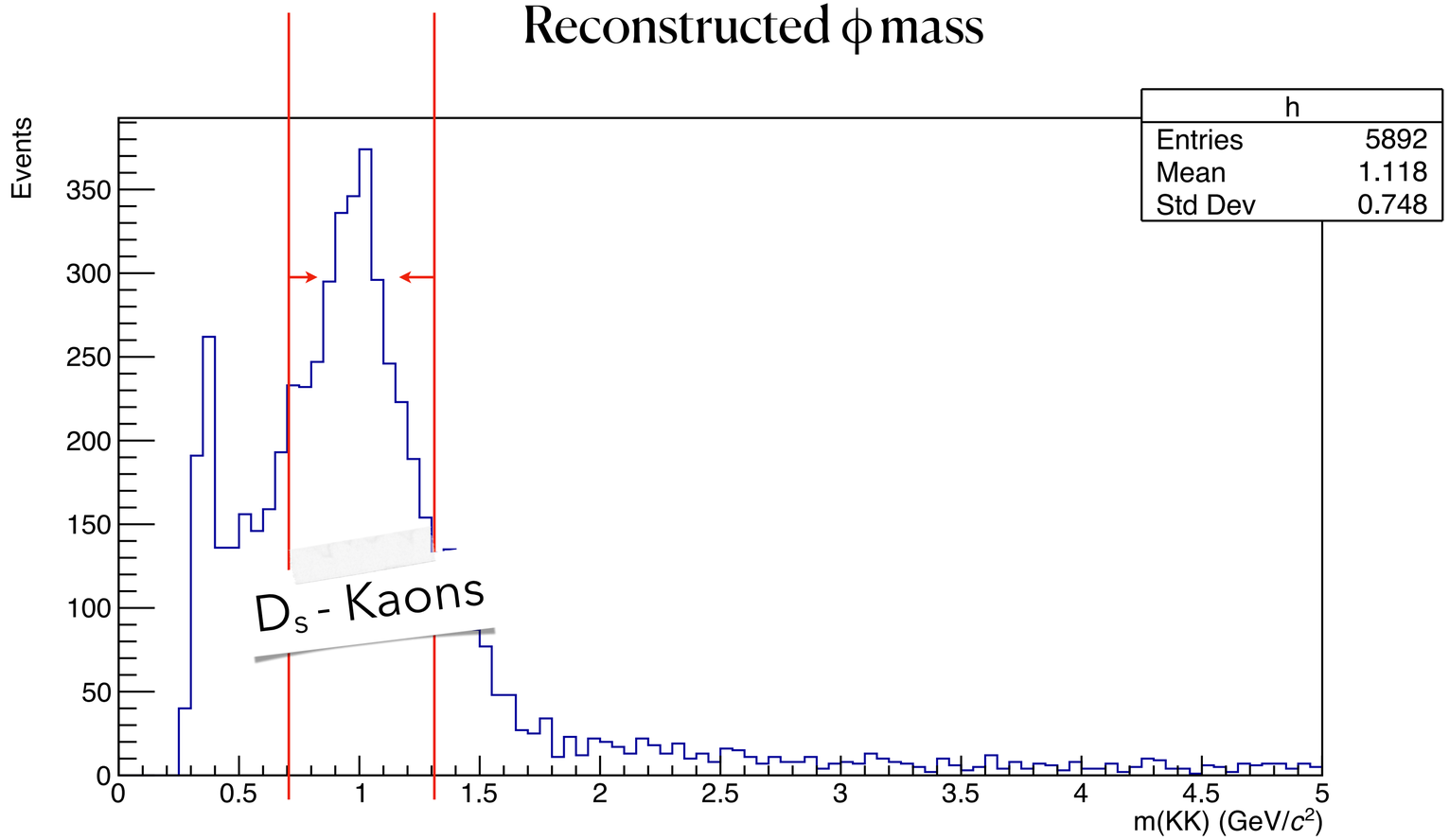
Status

$$B^0_s \rightarrow D^{\pm}_s K^{\mp} \rightarrow (\varphi\pi^{\pm})\, K^{\mp}$$

Divide the K
into 2 sub-groups

D_s - Kaons
Bachelor-Kaons

Using φ(1020) mass as
discriminating values



Reco
10k Events

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Identification the D^-_s state

D_s identification through the KKπ vertex reconstruction

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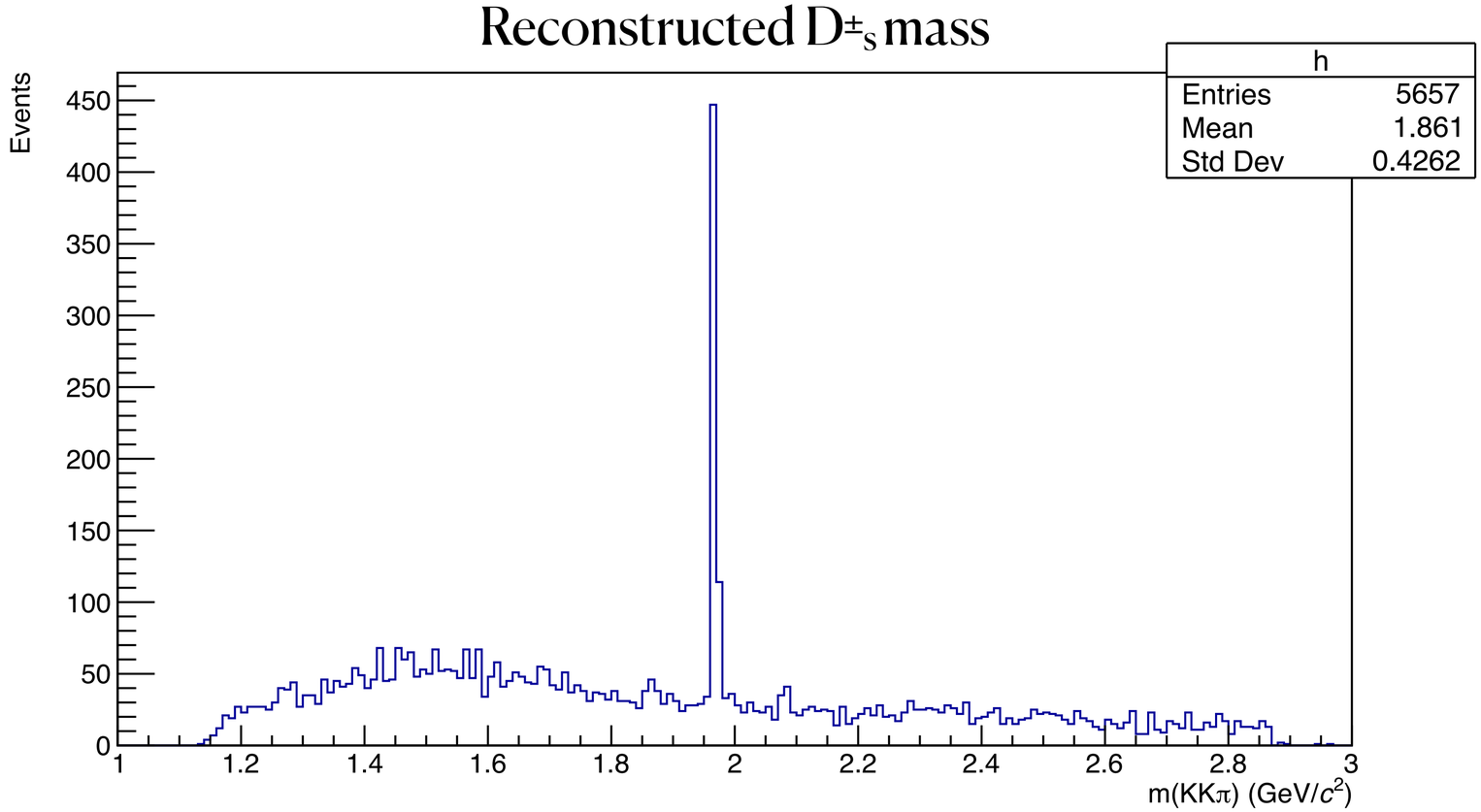

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10k Events

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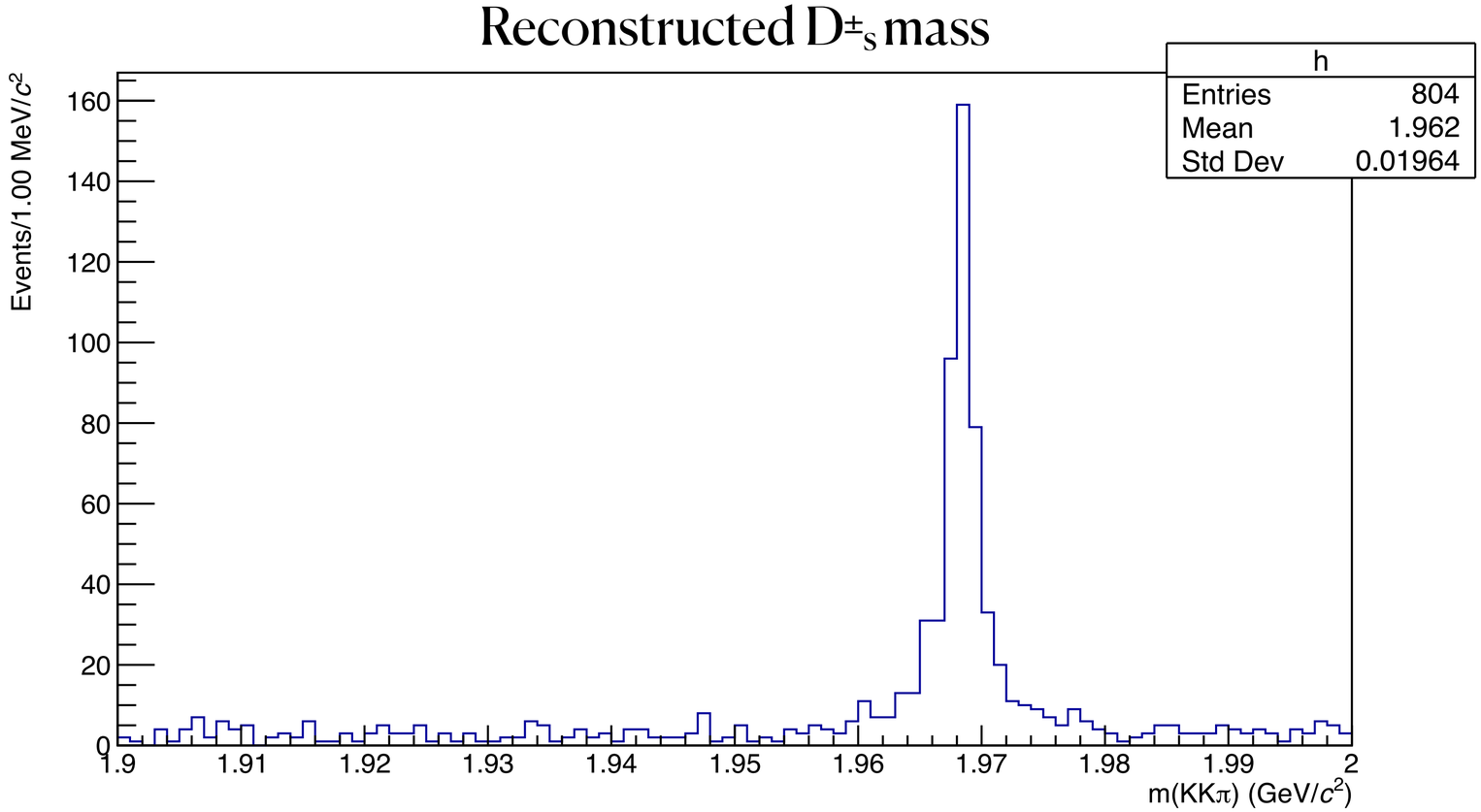


Reco
10k Events

Status

$$B^0_s \rightarrow D^{\pm}_s K^{\mp} \rightarrow (\varphi\pi^{\pm})\, K^{\mp}$$

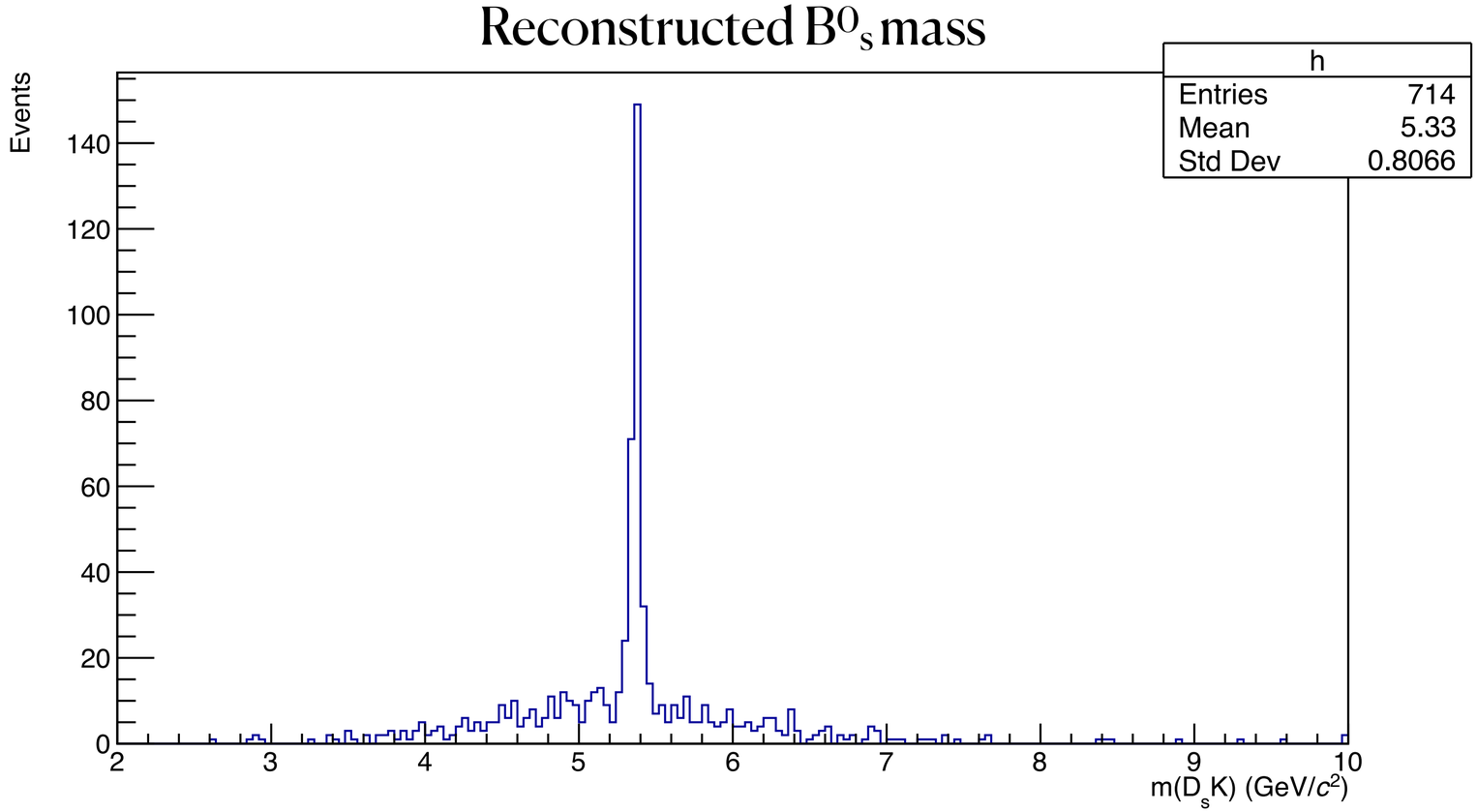
Identification the **B^0_s** state

Combine the **D^-_s** candidates with the bachelor **K^+**

B^0_s identification through the D_sK vertex reconstruction and requesting

$1.9\ \text{GeV}/c^2 < m(D_s) < 2.0\ \text{GeV}/c^2$

PID is 100%
(i.e. made via PDGid)



Reco
10k Events

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$$B^0_s \rightarrow D^{\pm}_s K^{\mp} \rightarrow (\varphi\pi^{\pm})\, K^{\mp}$$

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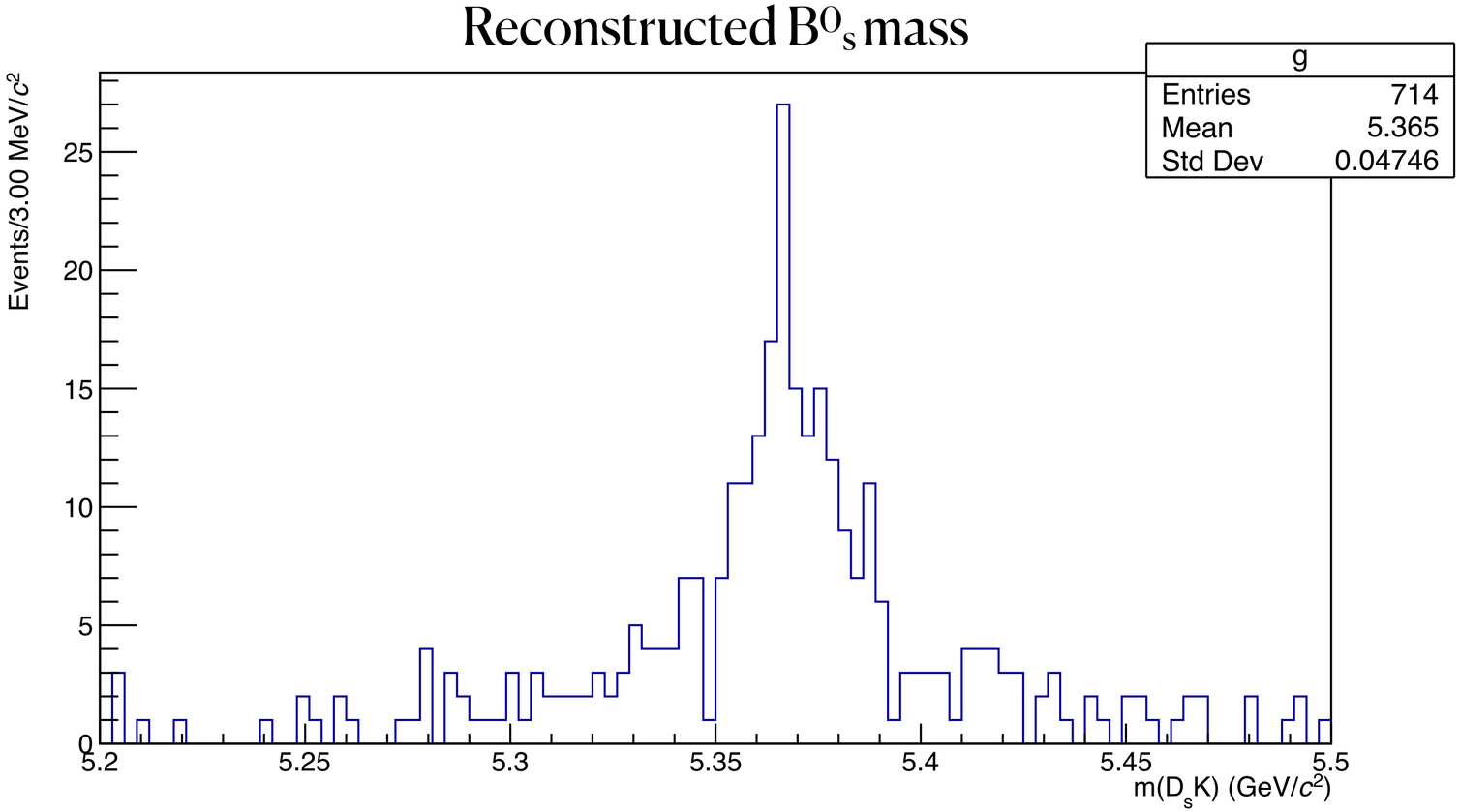


Reco
1M Events

$B^0_s \to D^{\pm}_s K^{\mp} \to (\varphi\pi^{\pm})\, K^{\mp} \to (KK\pi^{\pm})\, K^{\mp}$

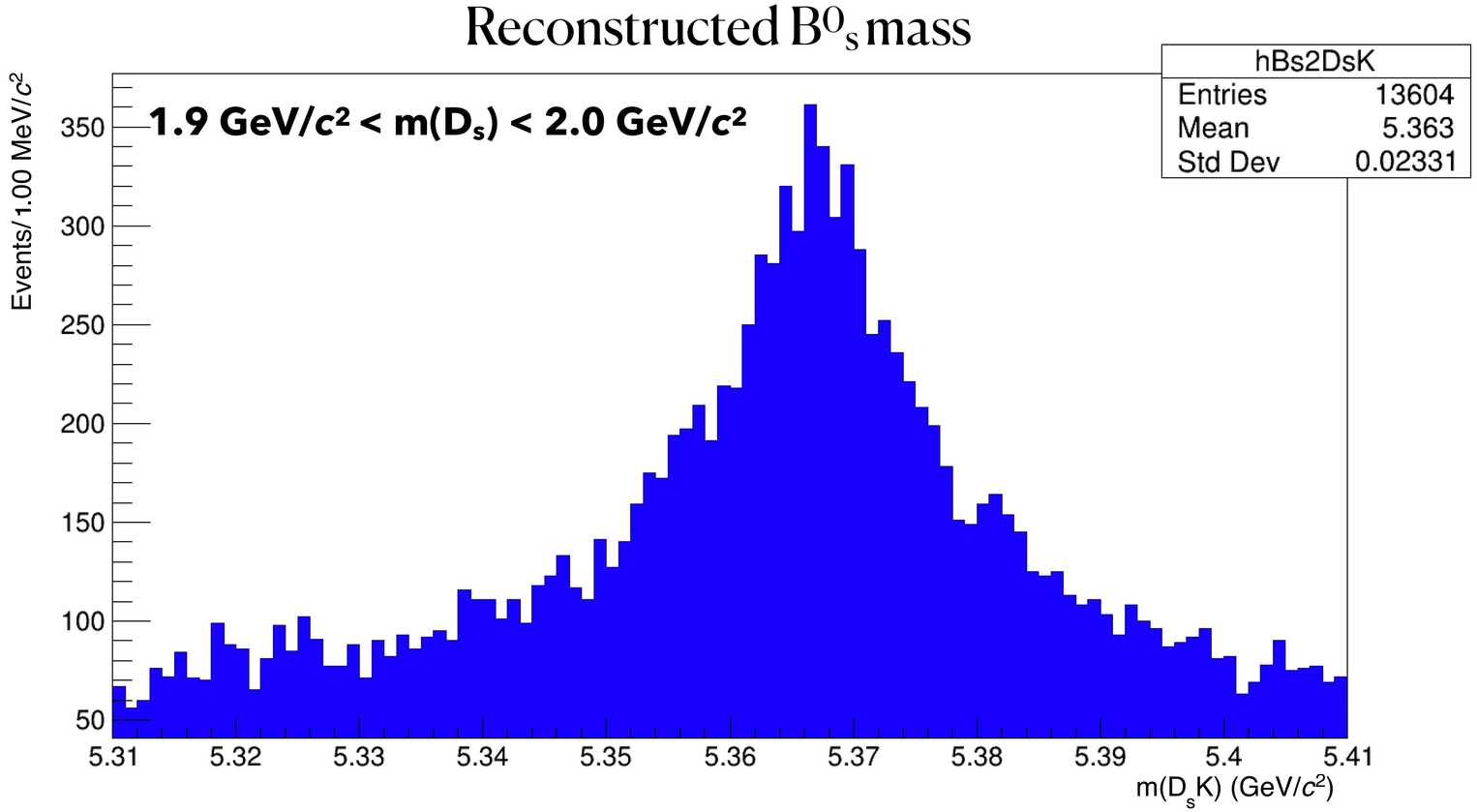
Identification the **B^0_s** state

Combine the **D^-_s** candidates with the bachelor **$K^+ (\to \phi\pi^+)$**

B^0_s ID through the D_sK vertex reconstruction and requesting

$1.9\ \text{GeV}/c^2 < m(D_s) < 2.0\ \text{GeV}/c^2$

PID is 100%
(i.e. made via PDGid)



Reco
0.5M Events

$B^0_s \to D^{\pm}_s K^{\mp} \to (\varphi\pi^{\pm})\, K^{\mp} \to (KK\pi^{\pm})\, K^{\mp}$

Main Background Contributions

Samples run and analysed

Main mode	Decay chain	Background mode	Decay chain
$B_s \to D_s^{\pm} K^{\mp}$	$D_s^{\pm} \to \phi\pi^{\pm}, \phi \to K^+K^-$	$B_s \to D_s^{*\pm} K^{\mp}$	$D_s^{*\pm} \to \gamma\phi\pi^{\pm}, \phi \to K^+K^-$
"	$D_s^{\pm} \to \phi\rho^{\pm}, \phi \to K^+K^-$	"	$D_s^{*\pm} \to \gamma\phi\rho^{\pm}, \phi \to K^+K^-, \rho^{\pm} \to \pi^{\pm}\pi^0$
		$B_s \to D_s^{\pm} K^{*\mp}$	$D_s^{\pm} \to \phi\pi^{\pm}, \phi \to K^+K^-, K^{*\mp} \to K^{\mp}\pi^0$
		"	$D_s^{\pm} \to \phi\rho^{\pm}, \phi \to K^+K^-, \rho^{\pm} \to \pi^{\pm}\pi^0, K^{*\mp} \to K^{\mp}\pi^0$
		$B_s \to D_s^{\pm} \pi^{\mp}$	$D_s^{\pm} \to \phi\pi^{\pm}, \phi \to K^+K^-$
		"	$D_s^{\pm} \to \phi\rho^{\pm}, \phi \to K^+K^-, \rho^{\pm} \to \pi^{\pm}\pi^0$
		$B_s \to D_s^{\pm} \rho^{\mp}$	$D_s^{\pm} \to \phi\pi^{\pm}, \phi \to K^+K^-, \rho^{\mp} \to \pi^{\mp}\pi^0$
		$B^0 \to D_s^{\pm} K^{\mp}$	$D_s^{\pm} \to \phi\pi^{\pm}, \phi \to K^+K^-$
		"	$D_s^{\pm} \to \phi\rho^{\pm}, \phi \to K^+K^-, \rho^{\pm} \to \pi^{\pm}\pi^0$
		$\Lambda_b^0 \to D_s^- p^+$	$D_s^{\pm} \to \phi\pi^{\pm}, \phi \to K^+K^-$
		"	$D_s^{\pm} \to \phi\rho^{\pm}, \phi \to K^+K^-, \rho^{\pm} \to \pi^{\pm}\pi^0$
		$\Lambda_b^0 \to D_s^{*-} p^+$	$D_s^{\pm} \to \gamma\phi\pi^{\pm}, \phi \to K^+K^-$
		"	$D_s^{\pm} \to \gamma\phi\rho^{\pm}, \phi \to K^+K^-, \rho^{\pm} \to \pi^{\pm}\pi^0$

Delphes FCCee Physic events dev production (IDEA with Track Covariance full matrix lower triangle)
http://fcc-physics-events.web.cern.ch/fcc-physics-events/Delphesevents_dev_IDEA.php

Reco
0.5M Events

$B^0_s \to D^{\pm}_s K^{\mp} \to (\varphi\pi^{\pm})\, K^{\mp} \to (KK\pi^{\pm})\, K^{\mp}$

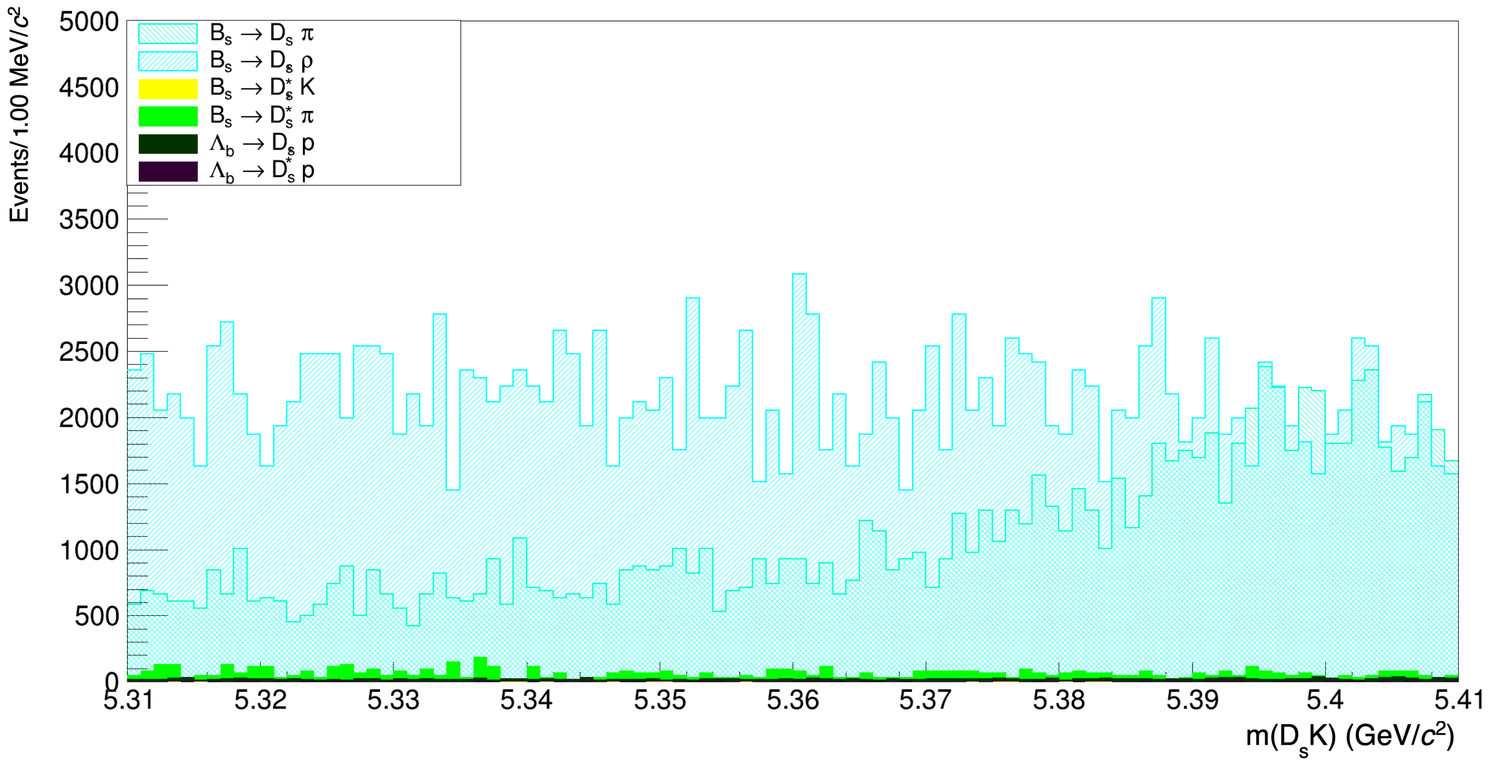
Identification the **B^0_s** state

Combine the **D^-_s** candidates
with the bachelor **$K^+ (\to \phi\pi^+)$**

B^0_s ID through the D_sK
vertex reconstruction and requesting
$1.9\ \text{GeV}/c^2 < m(D_s) < 2.0\ \text{GeV}/c^2$

PID is 100%
(i.e. made via PDGid)

Reconstructed B^0_s mass



Reco
0.5M Events

$B^0_s \to D^{\pm}_s K^{\mp} \to (\varphi\pi^{\pm})\, K^{\mp} \to (KK\pi^{\pm})\, K^{\mp}$

Main Background Contributions

Samples run and analysed

Their combinatoric contribution needs to be addressed

Tried to restrict possible D_s candidates via $\phi \to KK$ vertexing

Main mode	Decay chain	Background mode	Decay chain
$B_s \to D_s^{\pm} K^{\mp}$	$D_s^{\pm} \to \phi\pi^{\pm}, \phi \to K^+K^-$	$B_s \to D_s^{*\pm} K^{\mp}$	$D_s^{*\pm} \to \gamma\phi\pi^{\pm}, \phi \to K^+K^-$
"	$D_s^{\pm} \to \phi\rho^{\pm}, \phi \to K^+K^-$	"	$D_s^{*\pm} \to \gamma\phi\rho^{\pm}, \phi \to K^+K^-, \rho^{\pm} \to \pi^{\pm}\pi^0$
		$B_s \to D_s^{\pm} K^{*\mp}$	$D_s^{\pm} \to \phi\pi^{\pm}, \phi \to K^+K^-, K^{*\mp} \to K^{\mp}\pi^0$
		"	$D_s^{\pm} \to \phi\rho^{\pm}, \phi \to K^+K^-, \rho^{\pm} \to \pi^{\pm}\pi^0, K^{*\mp} \to K^{\mp}\pi^0$
		$B_s \to D_s^{\pm} \pi^{\mp}$	$D_s^{\pm} \to \phi\pi^{\pm}, \phi \to K^+K^-$
		"	$D_s^{\pm} \to \phi\rho^{\pm}, \phi \to K^+K^-, \rho^{\pm} \to \pi^{\pm}\pi^0$
		$B_s \to D_s^{\pm} \rho^{\mp}$	$D_s^{\pm} \to \phi\pi^{\pm}, \phi \to K^+K^-, \rho^{\mp} \to \pi^{\mp}\pi^0$
		$B^0 \to D_s^{\pm} K^+$	$D_s^{\pm} \to \phi\pi^{\pm}, \phi \to K^+K^-$
		"	$D_s^{\pm} \to \phi\rho^{\pm}, \phi \to K^+K^-, \rho^{\pm} \to \pi^{\pm}\pi^0$
		$\Lambda_b^0 \to D_s^- p^+$	$D_s^{\pm} \to \phi\pi^{\pm}, \phi \to K^+K^-$
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Reco
1M Events

$B^0_s \to D^{\pm}_s K^{\mp} \to (\varphi\pi^{\pm})\, K^{\mp} \to (KK\pi^{\pm})\, K^{\mp}$

Combine the D^-_s candidates with the bachelor $K^+ (\to \phi\pi^+)$ applying $\phi \to KK$ vertexing

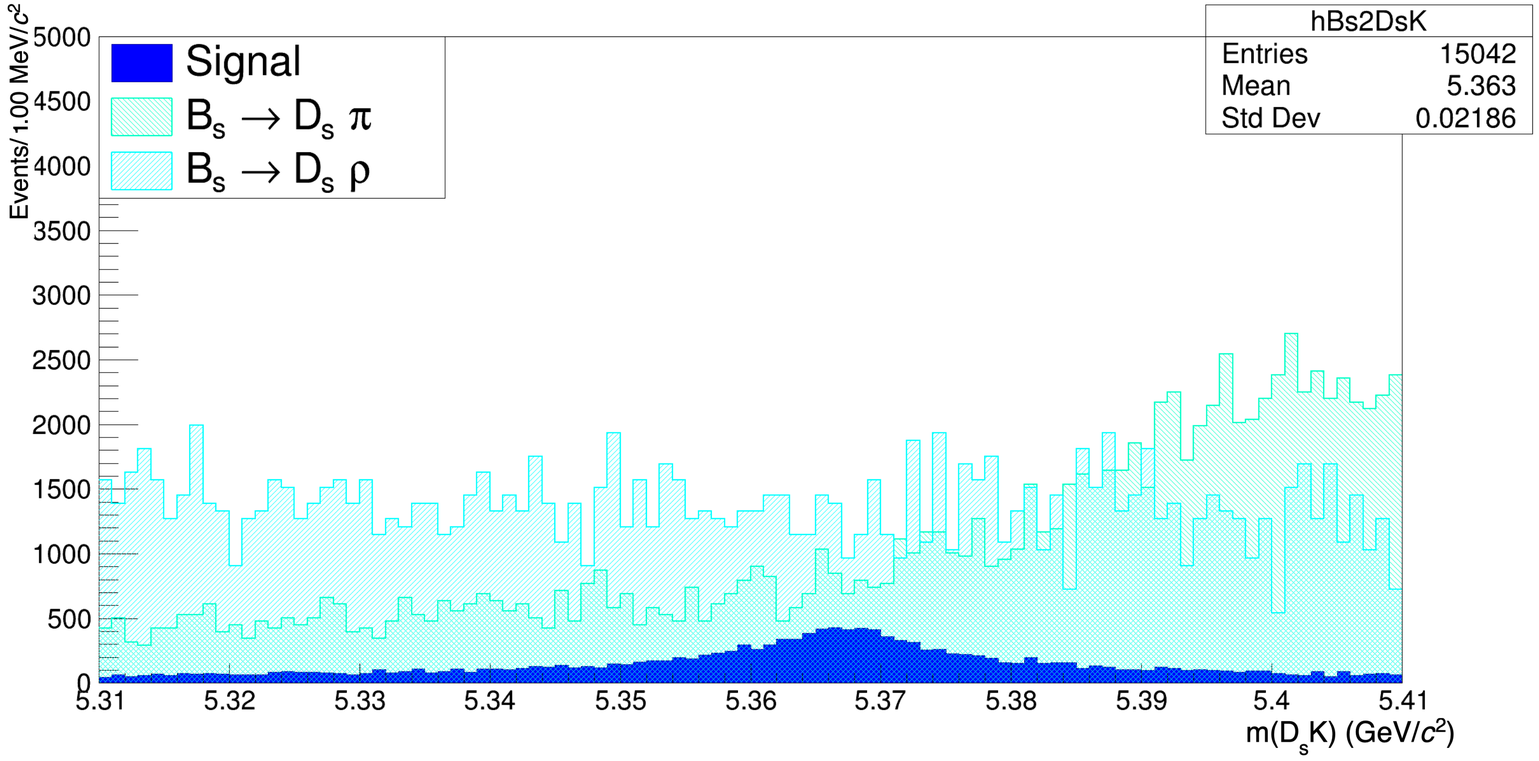
B^0_s ID through the D_sK vertex reconstruction and requesting

$1.9\ \text{GeV}/c^2 < m(D_s) < 2.0\ \text{GeV}/c^2$

PID is 100%

	$B^0_s \to D_sK$	$B^0_s \to D_s\pi$	$B^0_s \to D_s\rho$
Base Selection	13604	109271	214622
$\phi \to KK$ vertexing	15042	103285	136776

Reconstructed B^0_s mass



Conclusion and Outlook

B^0_s & $D^{\pm}_s$ masses are **reconstructed** with 100% correct PID

Background channels need to be addressed, the **SecondaryTrack** method is being **investigated** as well as **hemisphere** selection

Implement the **newest vertexing** method added to EDM4Hep

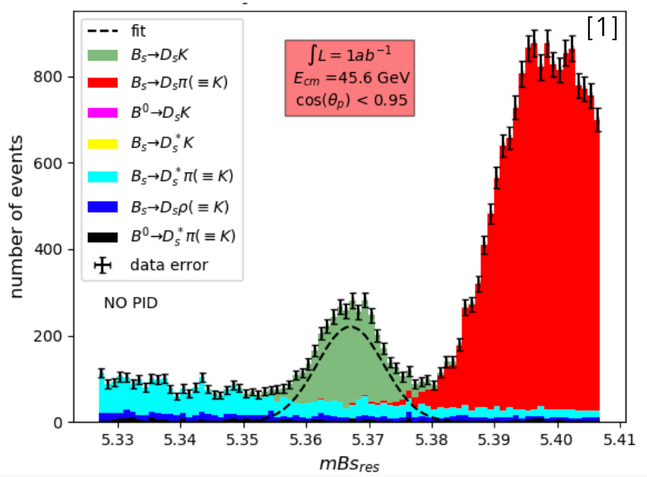
Next Steps

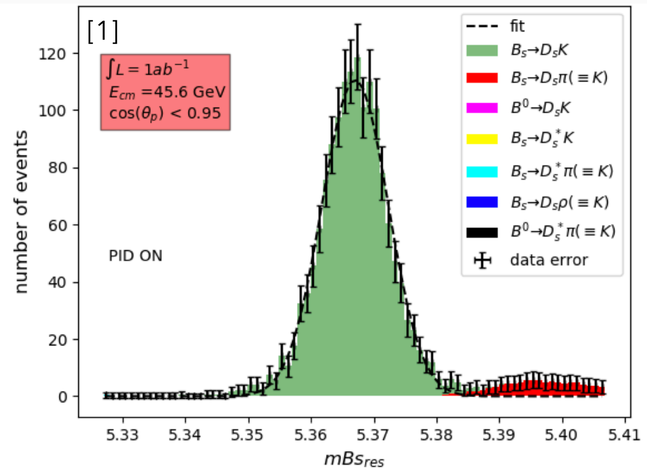
On a longer time-scale

Run over GEANT4 IDEA detector (***full-sim***)
Add a more realistic **PID**

Reproduce the plots of the **B^0_s reconstructed mass** on the right[1]

Ref. [1] describes a generic FCC scenario, so it would be useful to see them within EDM4hep





[1] R. Aleksan, L. Oliver, and E. Perez, arXiv:2107.02002

Thank you for the attention!

Backup Slides

MC
Truth Matching

Status

$B^0_s \rightarrow D^{\pm}_s K^{\mp} \rightarrow (KK\pi^{\pm})\, K^{\mp}$

Identification the **B^0_s** state

Combine the **D^-_s** candidates with the bachelor **K^+**

~~B^0_s identification through the D_sK vertex reconstruction~~

PID is 100%
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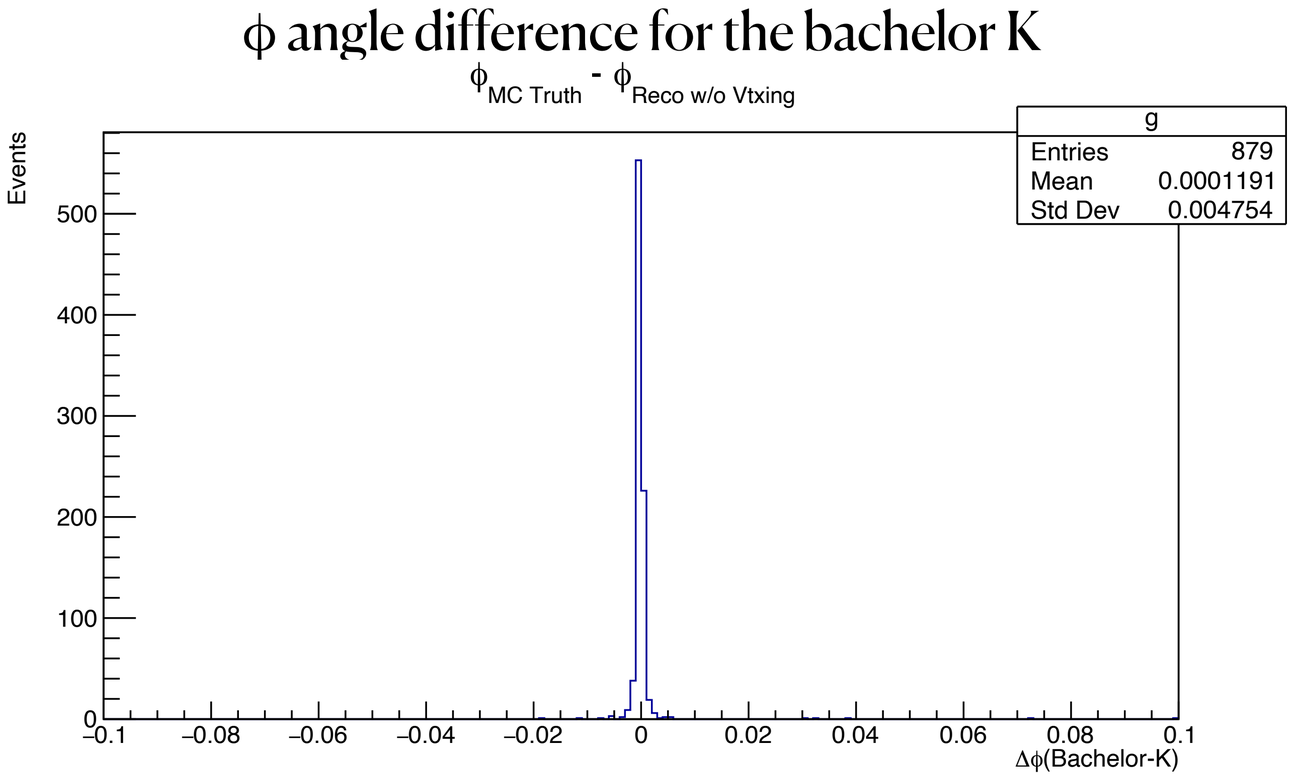

MC
Truth Matching

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$B^0_s \rightarrow D^{\pm}_s K^{\mp} \rightarrow (KK\pi^{\pm})\, K^{\mp}$

Identification the **B^0_s** state

Combine the **D^-_s** candidates with the bachelor **K^+**

B^0_s identification through the D_sK vertex reconstruction

PID is 100%
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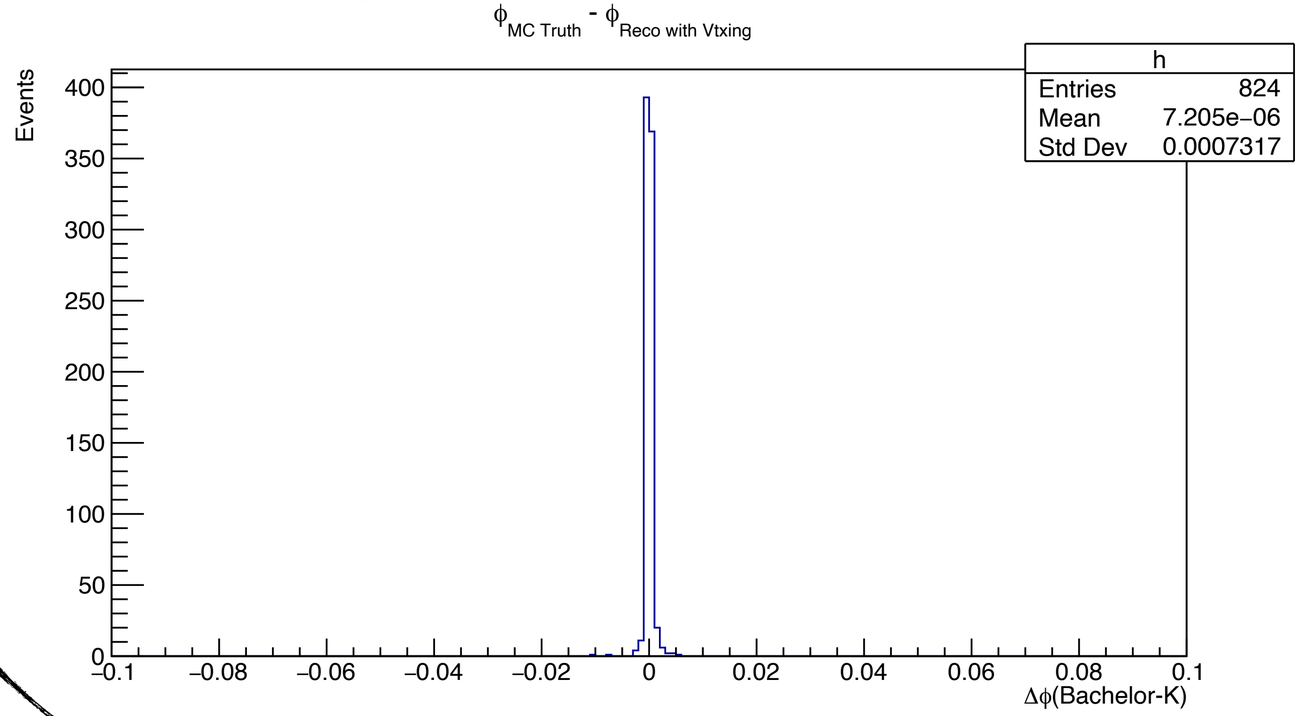
ϕ angle difference for the bachelor K



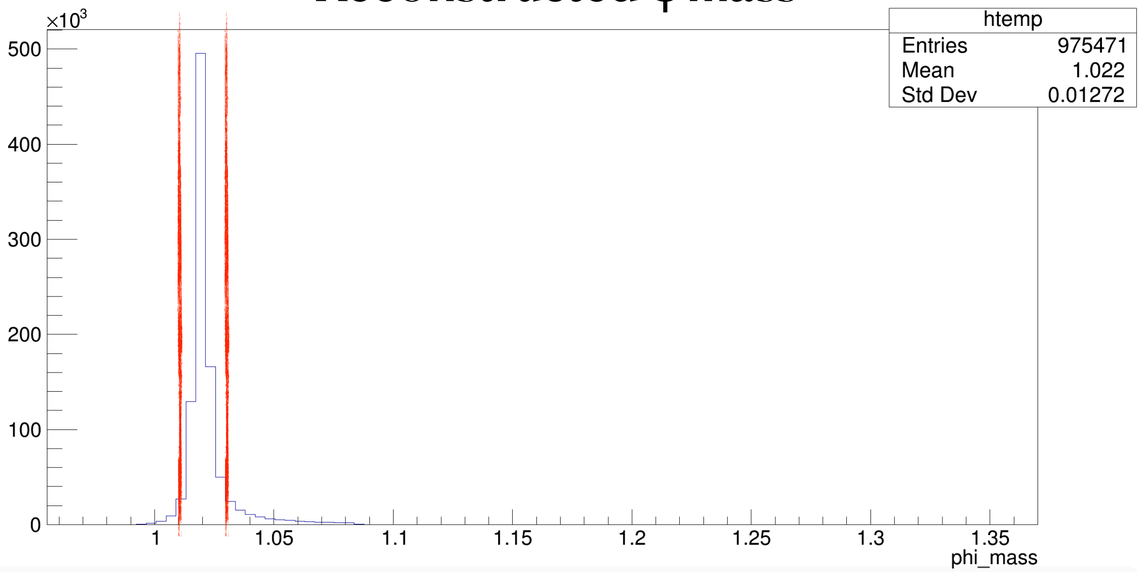
NB Not back propagated to **B^0_s** vertex

Reco
1M Events

$B^0_s \to D^{\pm}_s K^{\mp} \to (\varphi\pi^{\pm})\, K^{\mp} \to (KK\pi^{\pm})\, K^{\mp}$

$\varphi \to$ KK vertexing

Reconstructed φ mass



Reconstructed D_s mass