$B_s^0 \rightarrow D_s K$ benchmark with IDEA

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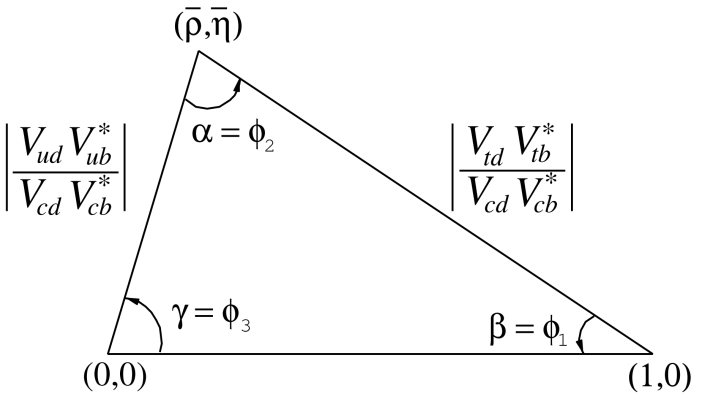
Flavor Physics at FCC-ee

CKM unitarity triangle is a stepping stone for flavor physics

- Any deviation from unitarity would lead to physics beyond standard model
- At the end of HL-LHC and Belle2 programs, γ angle will be known with ~1° error

FCC-ee will be a **Tera-Z factory**

- CKM analyses can be performed by studying **$Z \rightarrow b\bar{b}$**
- This will result in:
  - 75 Billions B_s^0,
  - 310 Billions B^0



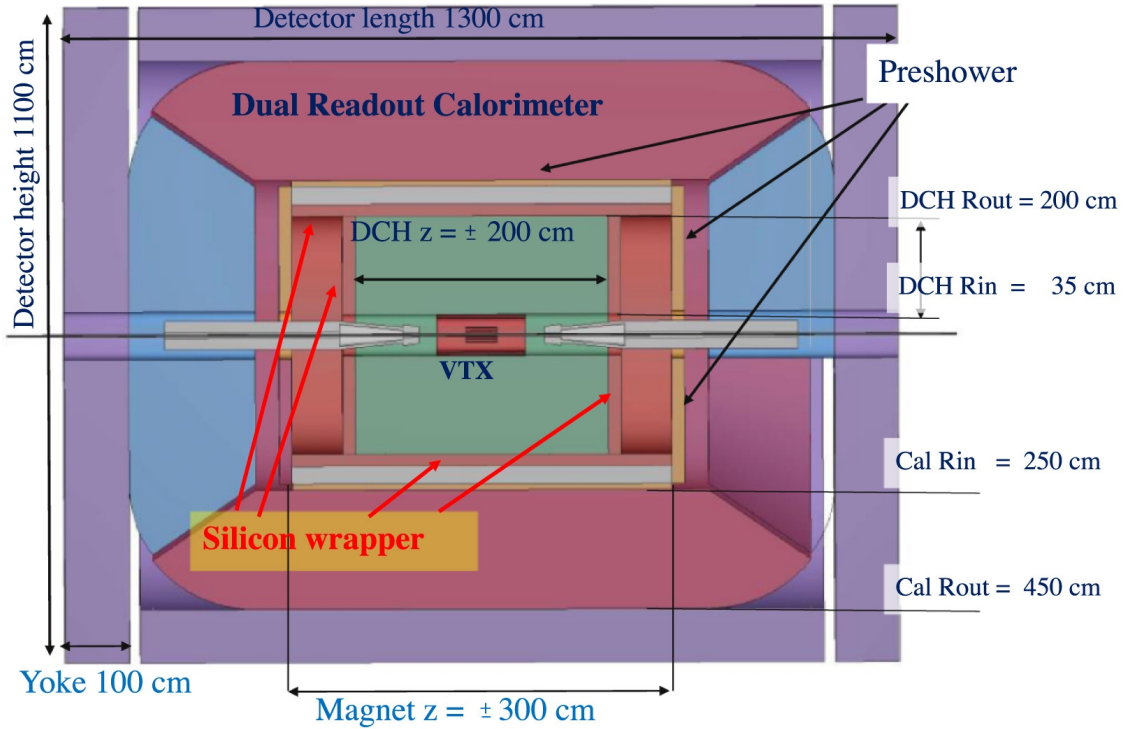
This work aims to understand the feasibilty of

1. **$B_s^0 \rightarrow D_s K$**
2. $B_s^0 \rightarrow J/\psi\Phi$ (*later*)

With the B_s^0 sample, **FCC can measure:**

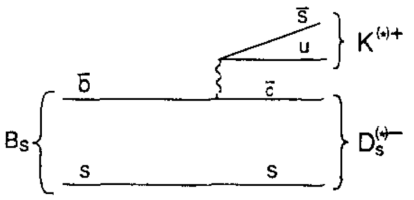
- **γ with a precision of 0.4°**
- β_s with a precision of $(3.4 \times 10^{-2})°$

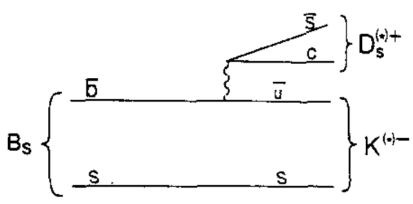
Flavor Physics with IDEA



This work makes use of fast and full simulations of **IDEA detector**:

- to establish impact of **tracking** and **PID** and guide further developments
- to estimate the **sensitivity** of
  - **$\varphi = \gamma_{CKM} + \gamma_{ds} - 2\beta_s$ with $B_s \rightarrow DK$**
  - *$2\beta_s$ with $B_s \rightarrow J/\psi\,\Phi$*





The work is performed in FCC analyses framework: **key4HEP/EDM4HEP**

$B_s \rightarrow D_s K$

- **Final state of interest is $D_s \rightarrow \Phi\pi$ + bachelor K, with $\Phi \rightarrow KK$.**

- Generated 10k events at Z peak, exclusive $Z \rightarrow b\bar{b}$.
  - One b hadronizes in B_s, the other goes inclusively
  - Old (Winter `21) DELPHES generation.

- In order to study the impact, two approaches:
  1) Truth-matching (TM)
  2) Reconstruction

```
#
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
```

- Generated also main backgrounds and tested with the reconstruction routines

Results with TM - D_s

Apply few general selections

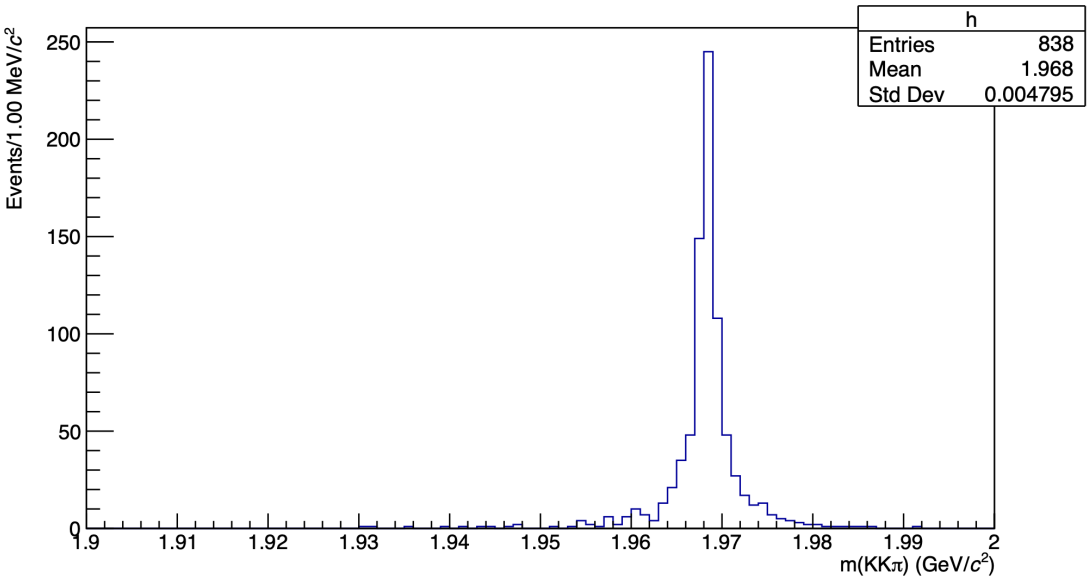
- $Q_{tot} = 0$
- $N_K \geqslant 3$
- $N_\pi \geqslant 1$
- $Q_{KK} = 0$

Φ and **prompt Kaons** are already **separated**

To reconstruct D_s, apply **vertex fit** to KKπ tracks

PID is 100% via PDG-ID

Reconstructed $D^{\pm}_s$ mass



Results with TM - B_s

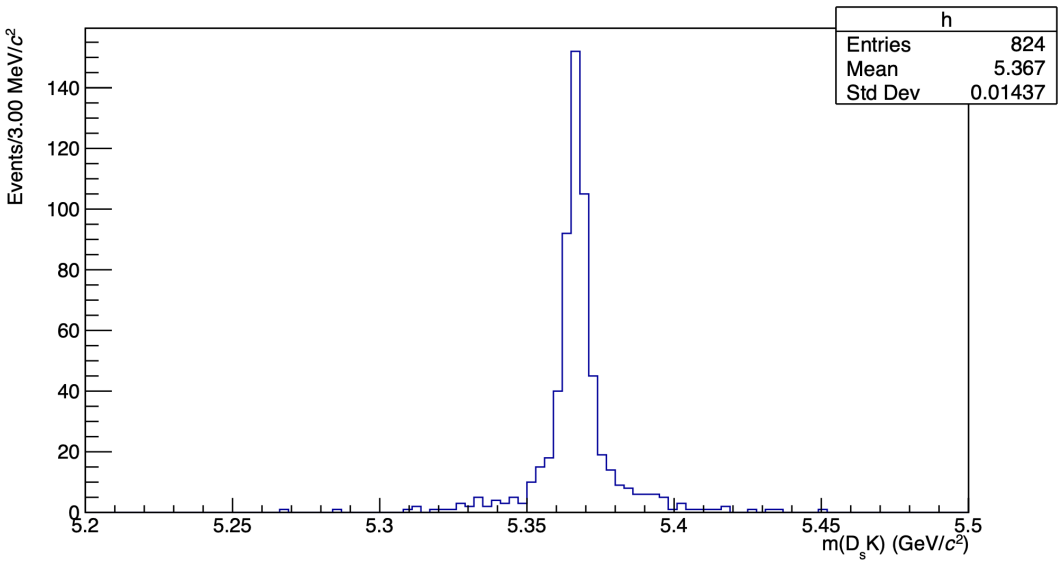
To reconstruct B_s, **vertex fit** of

D_s and bachelor K

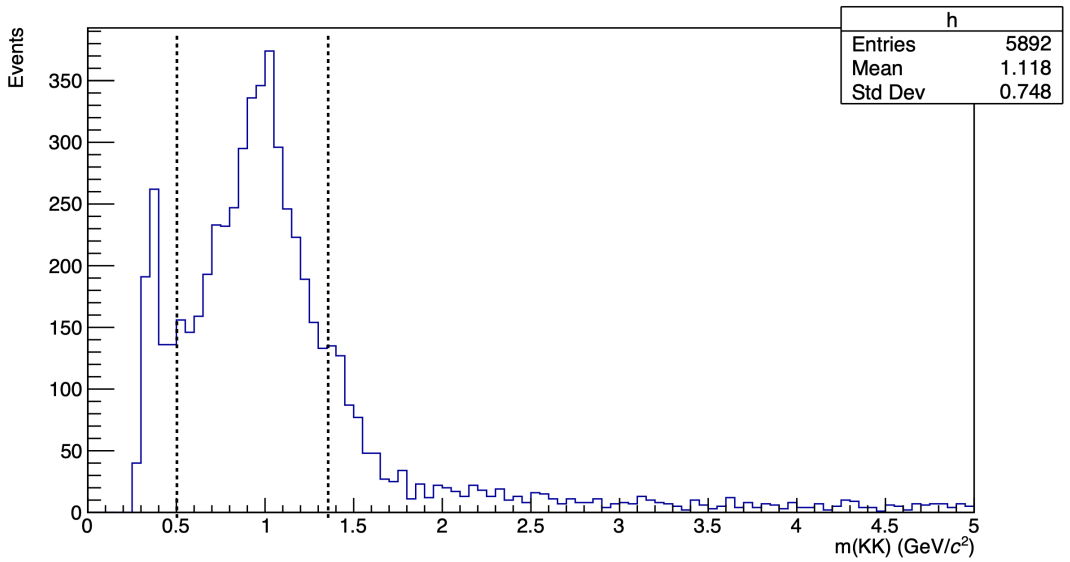
- no study on B_s impact parameter

PID is 100% via PDG-ID

Reconstructed B_s^0 mass



Result with Reconstruction



Apply few general selections

- $Q_{tot} = 0$
- $N_K \geqslant 3$
- $N_\pi \geqslant 1$
- $Q_{KK} = 0$

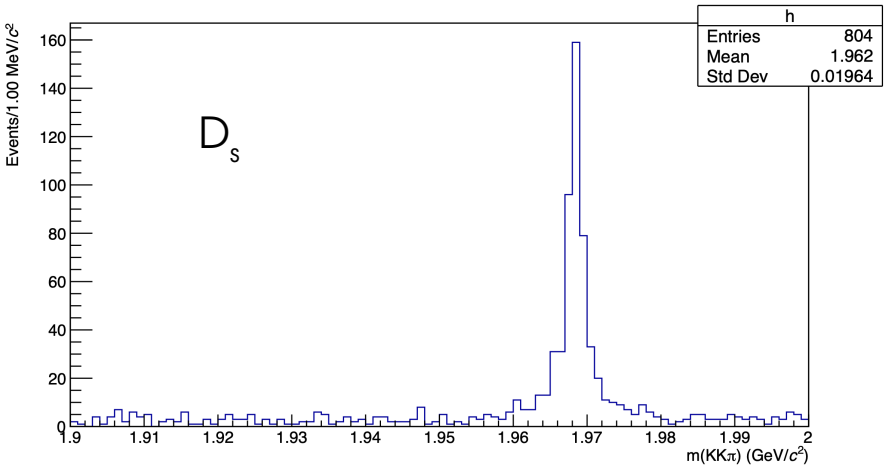
Study the **KK invariant** mass to identify **prompt** and **Φ kaons**

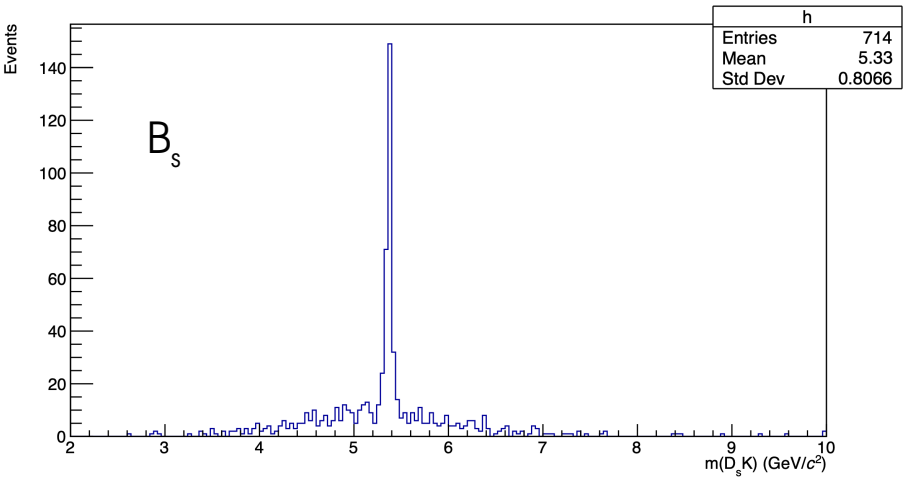
PID is 100% via PDG-ID

Result with Reconstruction – D_s and B_s

By applying a similar procedure as in the TM case, we identify **D_s** and **B_s candidates**.

We add a loose selection on **D_s candidates** mass **1.9 GeV/c^2 < mass(Φπ) < 2 GeV/c^2**





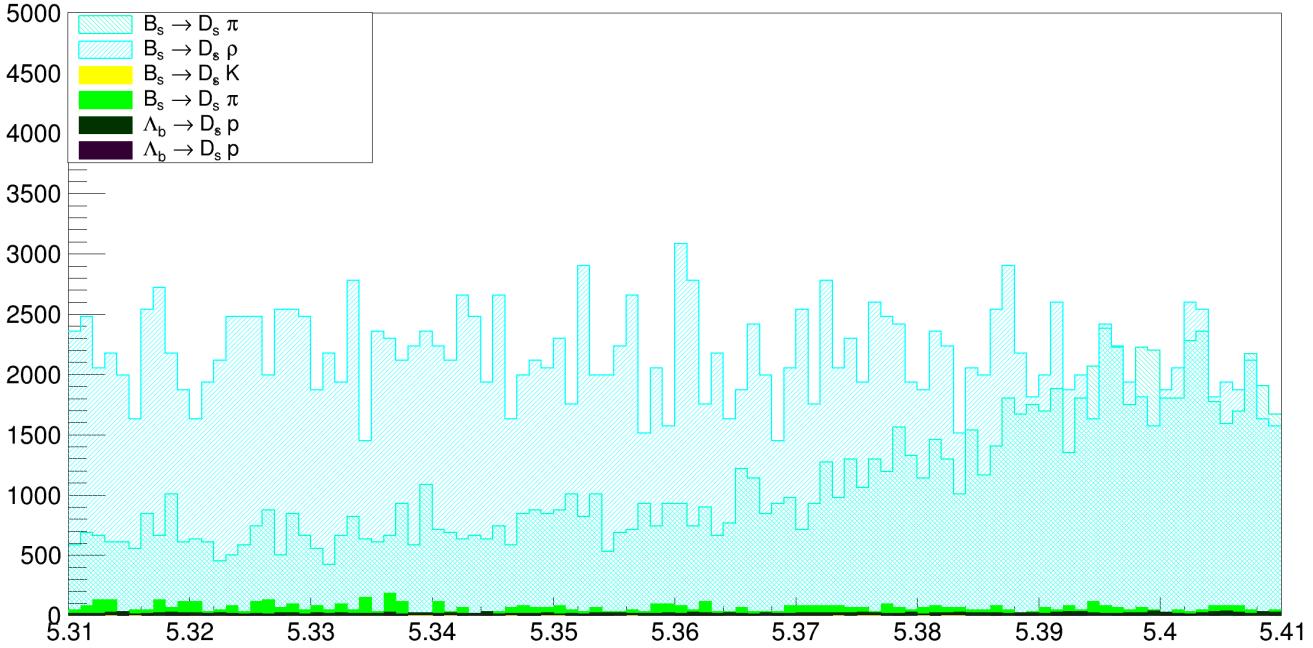
Main backgrounds

500k events generated and analysed with the same routines

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

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

Background results



Largest contribution from:

- $B_s \to D_s \pi$
- $B_s \to D_s \rho$

Mainly from **combinatorial**

Negligible for other cases

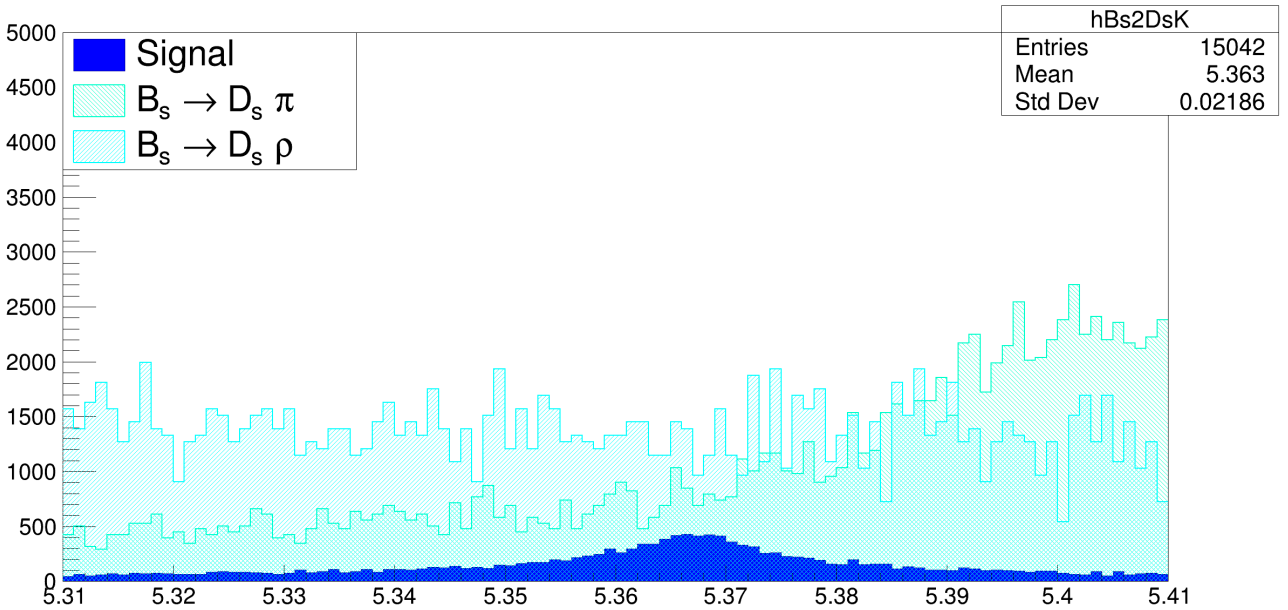
Add an additional selection:

$\Phi \to$ KK vertexing in order to try to reduce the bkgs

Results

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

Signal peaking at correct mass, but background seems higher.



Summary and next steps - I

- First fast simulation of $B_s \rightarrow D_s K$ benchmark for flavor physics prepared

- With perfect PID, preliminary vertexing and tracking:
  - Good reconstruction of B_s candidate
  - Large source of combinatorial background from 2 B_s decays with larger branching ratio
    - Some clever strategy is needed to further suppress those contributions (hemisphere selection, impact parameters)
  - A new version of vertexing is now available to further improve this result

Summary and next steps - II

- Run the full simulation with GEANT4 IDEA detector
- Add a more realistic PID
- Reproduce results of arXiv: 2107.02002 with EDM4HEP

Stay tuned!