Status of the $B^0_s \to D^{\pm}_s K^{\mp}$ benchmark analysis

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RD_FCC Collaboration Meeting
December 2021

Outline:

- Brief comment on the analysis tools
  - Tools
  - Troubleshooting

- Analysis
  - Motivation
  - Status
  - Outlook

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This section will be tailored around my experience

This implies that anyone else can find other problems or difficulties, or not find them at all

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Starting an analysis…

DISCLAIMER
Just discussing analysis and fast-sim related problems
(i.e., involving k4SimDelphes)

Ramping up and getting acquainted

key4hep/EDM4hep

Producing datasets

Mostly followed the "FCC Starterkit"
Quite self-explanatory

A Doxygen might be of help, but digging around on GitHub (HEP-FCC/FCCAnalyses) helps fine either

Might be a bit tricky as it subdivided into 3 parts

Preselection → Event selection on your samples
Selection → Produce ntuples
Plotting → Well, it's just plotting

Other bits of information can be found in
hep-fcc.github.io/FCCeePhysicsPerformance

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That's where I had a bit more of a trouble

Just because I did not know where to look for decay cards (i.e, CHANNEL.DEC)

Ask to those-who-know (they exist!)

HEP-FCC/FCC-config/tree/dev/FCCee/Generator/EvtGen

NB wrt what's written in the "FCC Starterkit" is outdated some updates can be found in Ref. [1]

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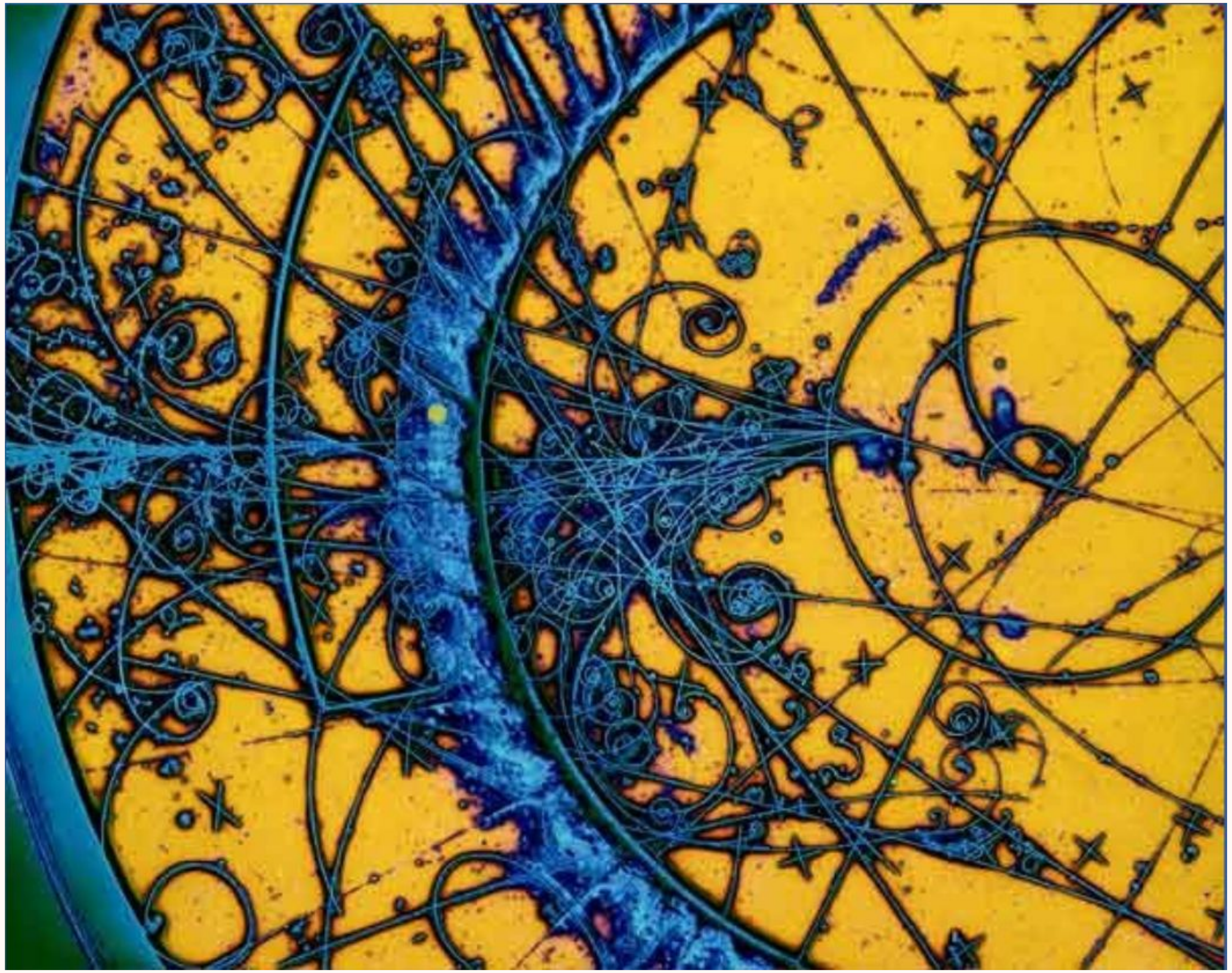
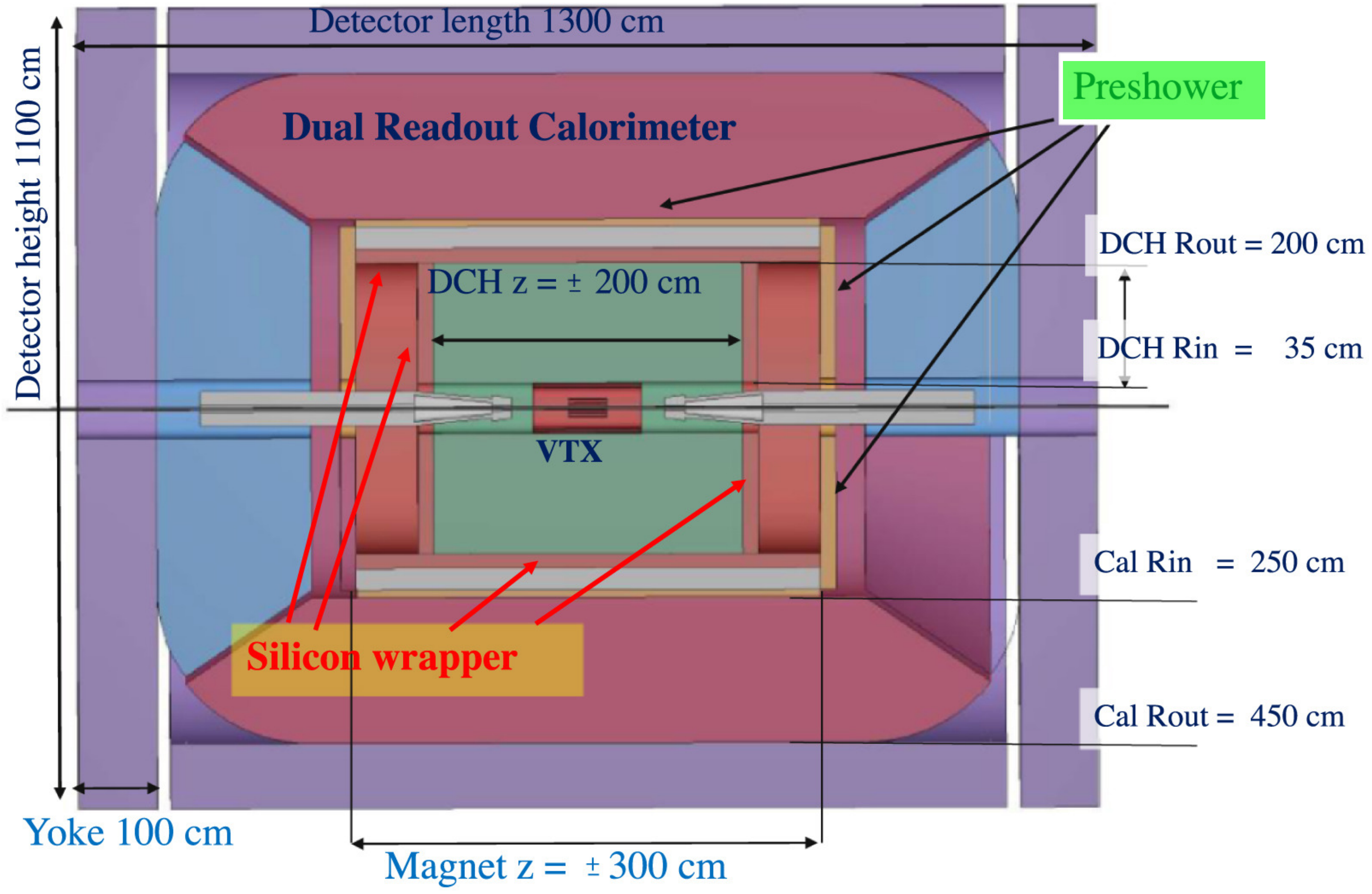
[1] indico.cern.ch/event/979164/contributions/4125123/attachments/2197698/3716029/Evtgen_interface1.pdf

ANALISI DATI



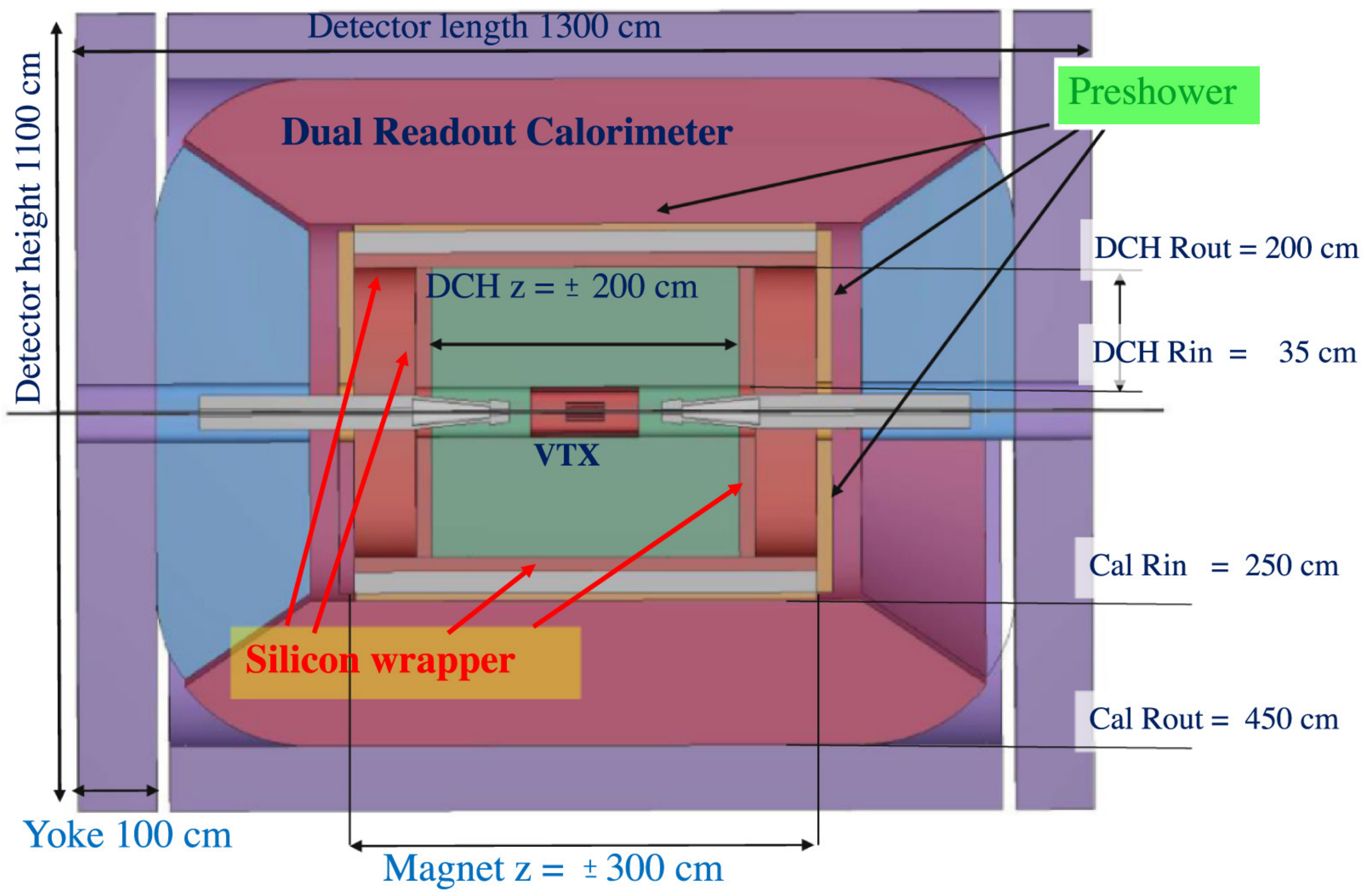
Motivation (1)



Analyse a physics benchmark channel connected with the interests of the PiFE group

Starting with a fast-sim,
and then (in a far far away future?)
move to a full-sim

Motivation (1)



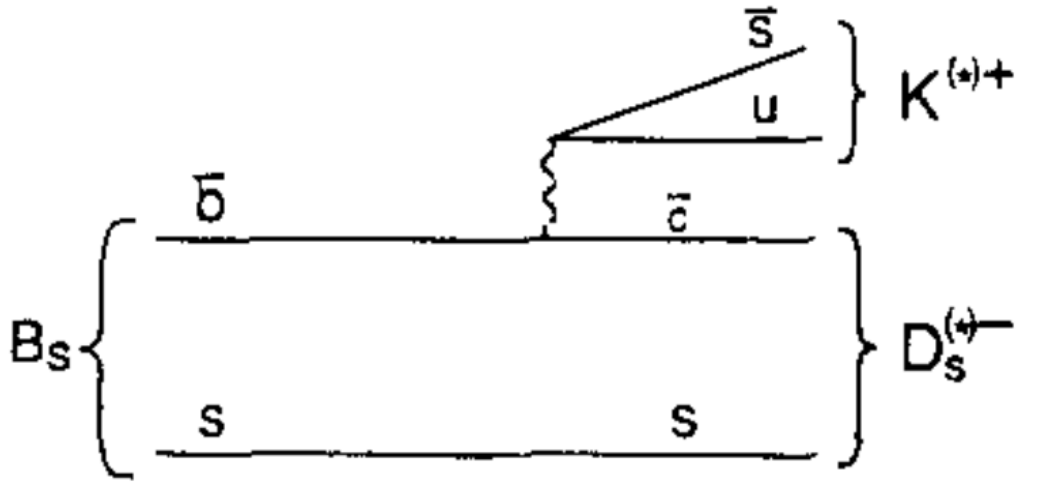
$B^0_s \rightarrow D^{\pm}_s K^{\mp}$

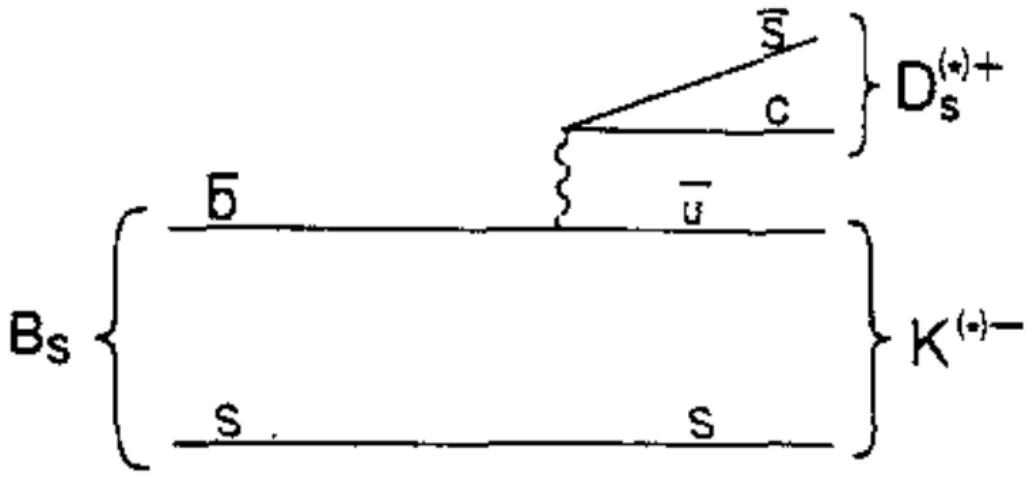
$B_s \rightarrow J/\psi\ \varphi$

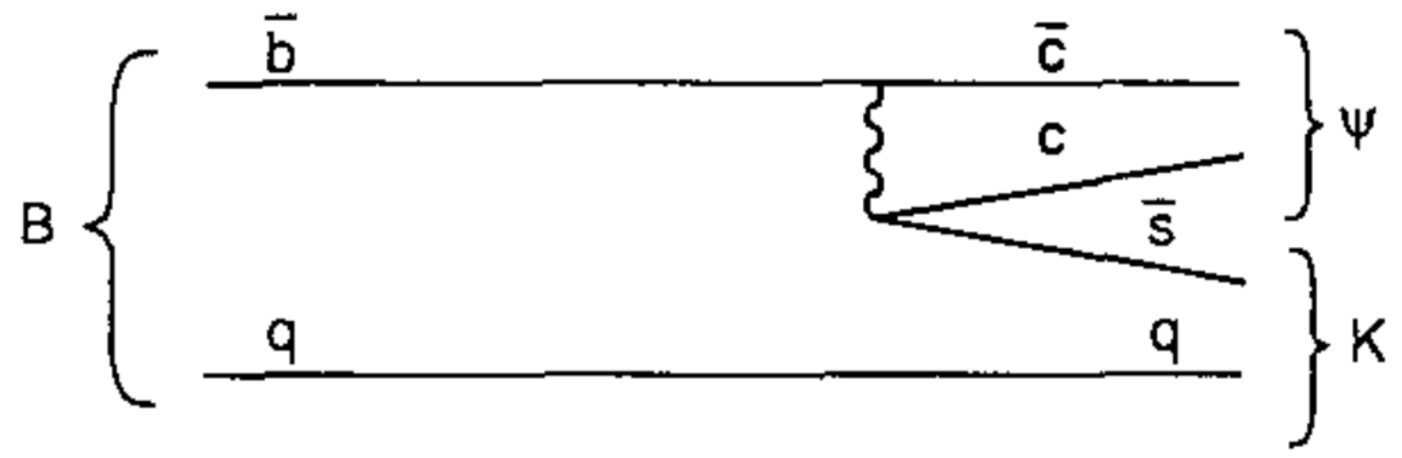
These will give me the possibility to test the IDEA tracking system features with a full simulation

The channels have as well the potential to investigate the properties of the calorimeter

Motivation (2)



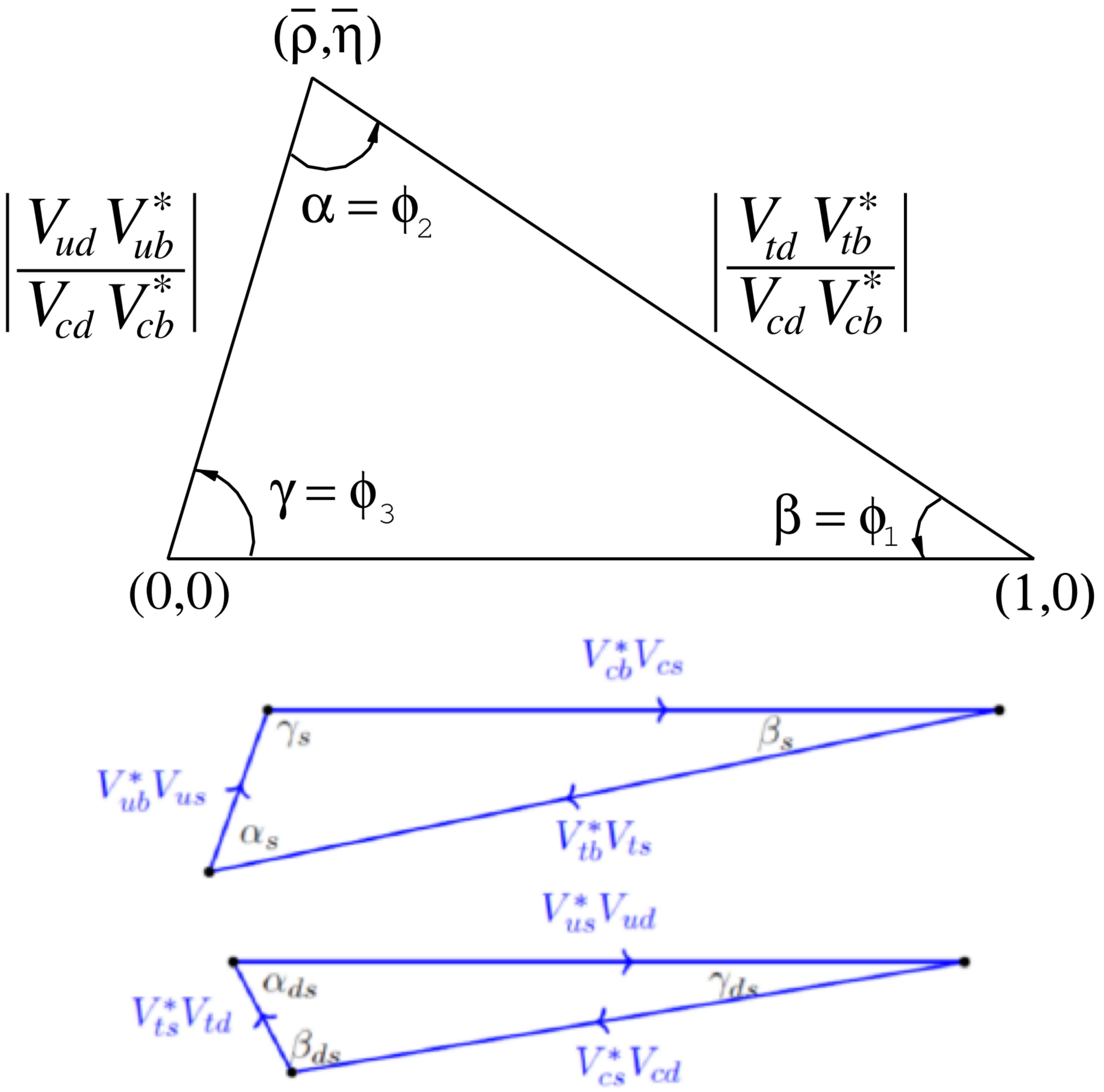




As already mentioned the studied decays are:

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

Motivation (2)



As already mentioned the studied decays are:

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

with the final objective (for the fast-sim) to estimate $\varphi_{CKM} = \gamma\ (+\ \gamma_{ds}) - 2\beta_s$ and $2\beta_s$

From 2., $\varphi_{CP}(J/\psi\varphi) = \pi + 2\beta_s$

From 1., $\varphi_{CKM}(D_sK) = \pi - (\alpha_s - \beta_s)$

Using $\alpha_s = \gamma - \beta_s + \gamma_{ds}$

Approximating $\gamma_{ds} \sim 0$ (properly, $O(10^{-3})$)

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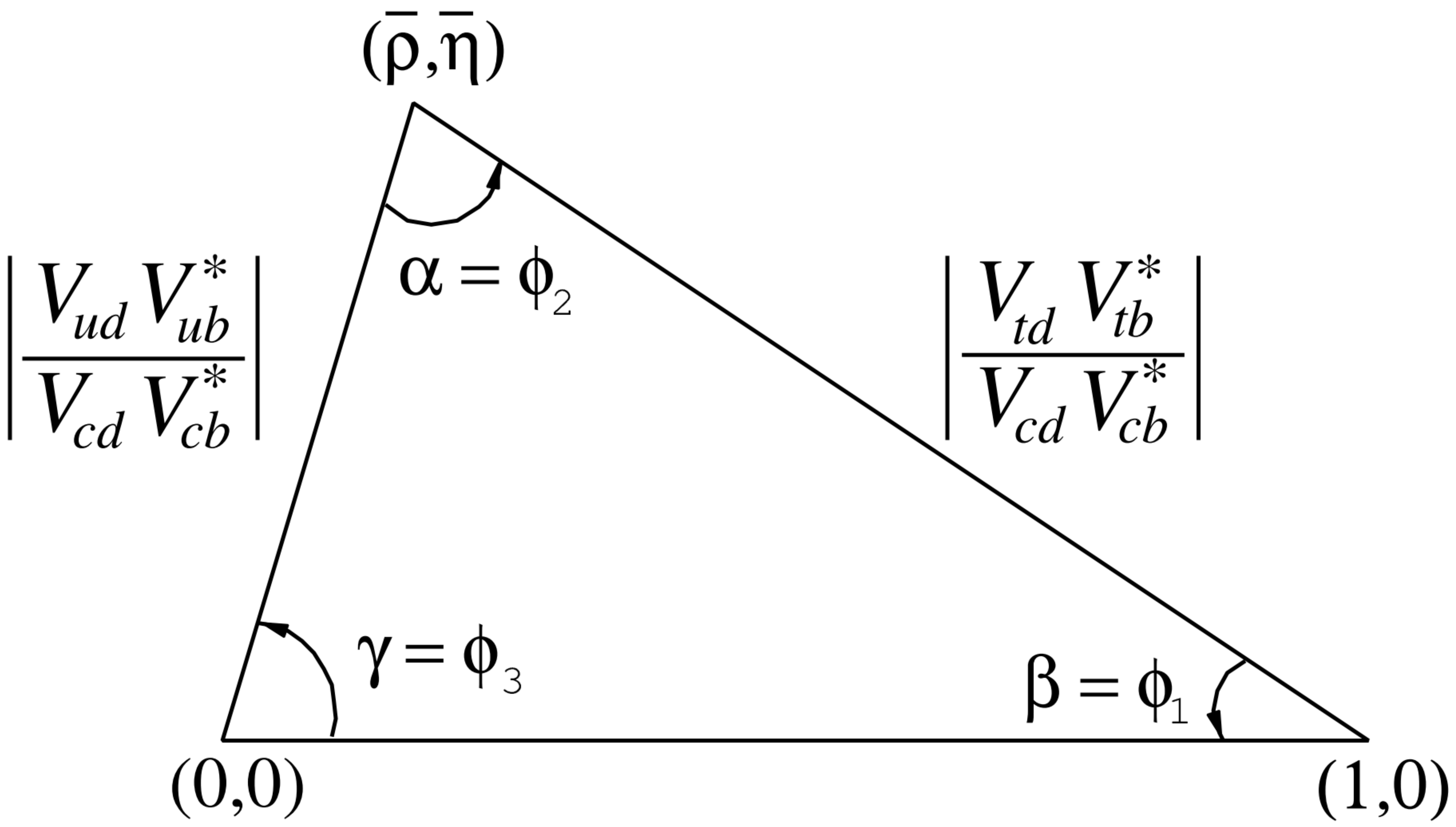
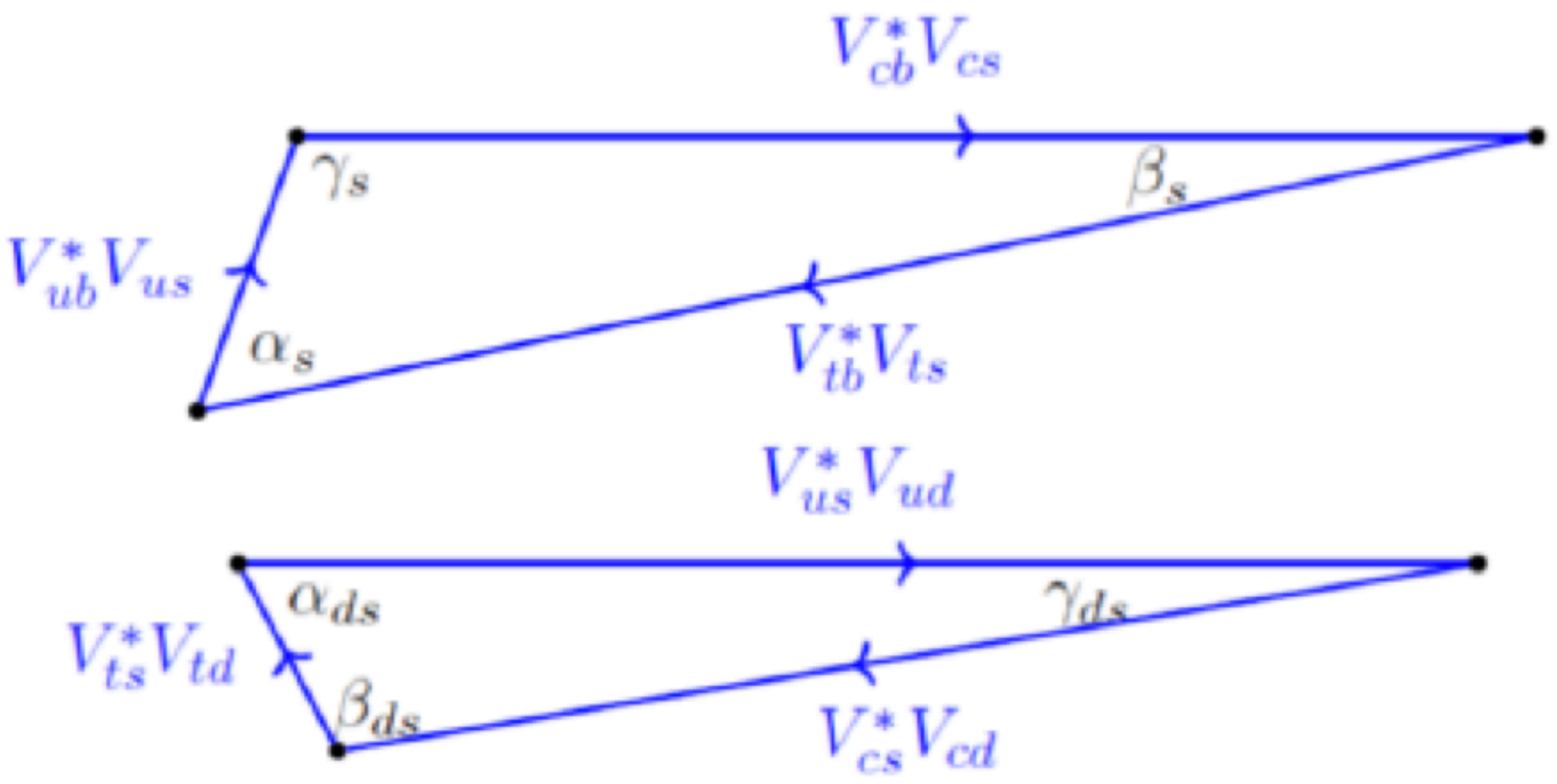




With **75 (310) billion** of **B^0_s (B^0)**,
$\sigma(\gamma) \sim 0.4°$ and $\sigma(\beta_s) \sim (3.4° \times 10^{-2}$ on $\beta_s)$
These can be compared with the present measurements…

$$\gamma = (72.1^{+4.1}_{-4.5})^\circ \qquad 2\beta_s = 0.051 \pm 0.023$$

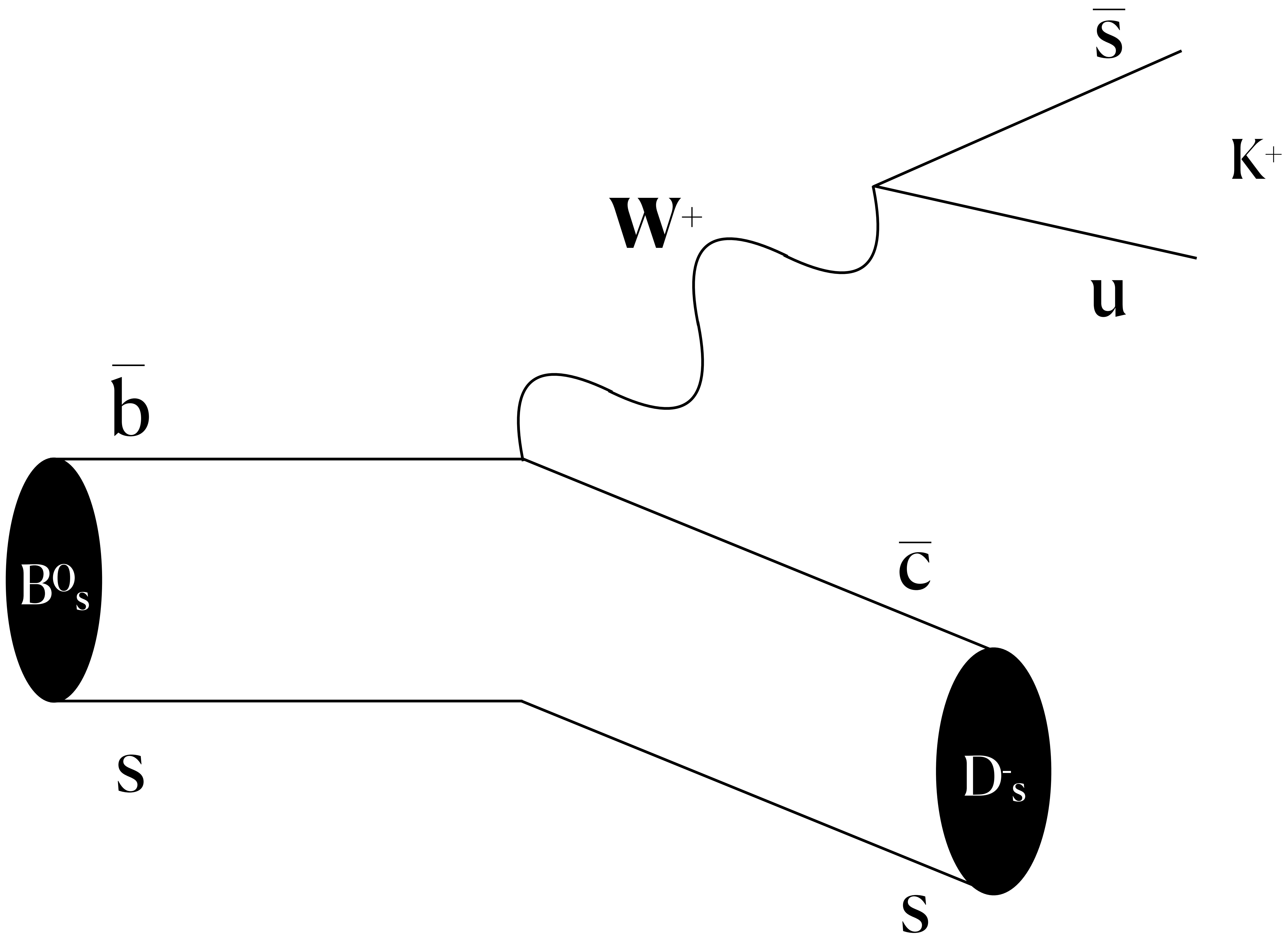
From $B_s \to J/\psi\ \varphi$, $\varphi_{CP}(J/\psi\varphi) = \pi + 2\beta_s$

From $B^0_s \to D^\pm_s K^\mp$, $\varphi_{CKM}(D_sK) = \pi - (\alpha_s - \beta_s)$

Using $\alpha_s = \gamma - \beta_s + \gamma_{ds}$

Approximating $\gamma_{ds} \sim 0$ (properly, $O(10^{-3})$)

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



Signal MC sample

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

Exclusive $Z \rightarrow b\bar{b}$ with →

10k events @ $\sqrt{s}$ = 91.188 GeV

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

Status

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

Identified the $D^{\pm}_s$ final state

Simple selection

$n_K = 2$

$n_\pi = 1$

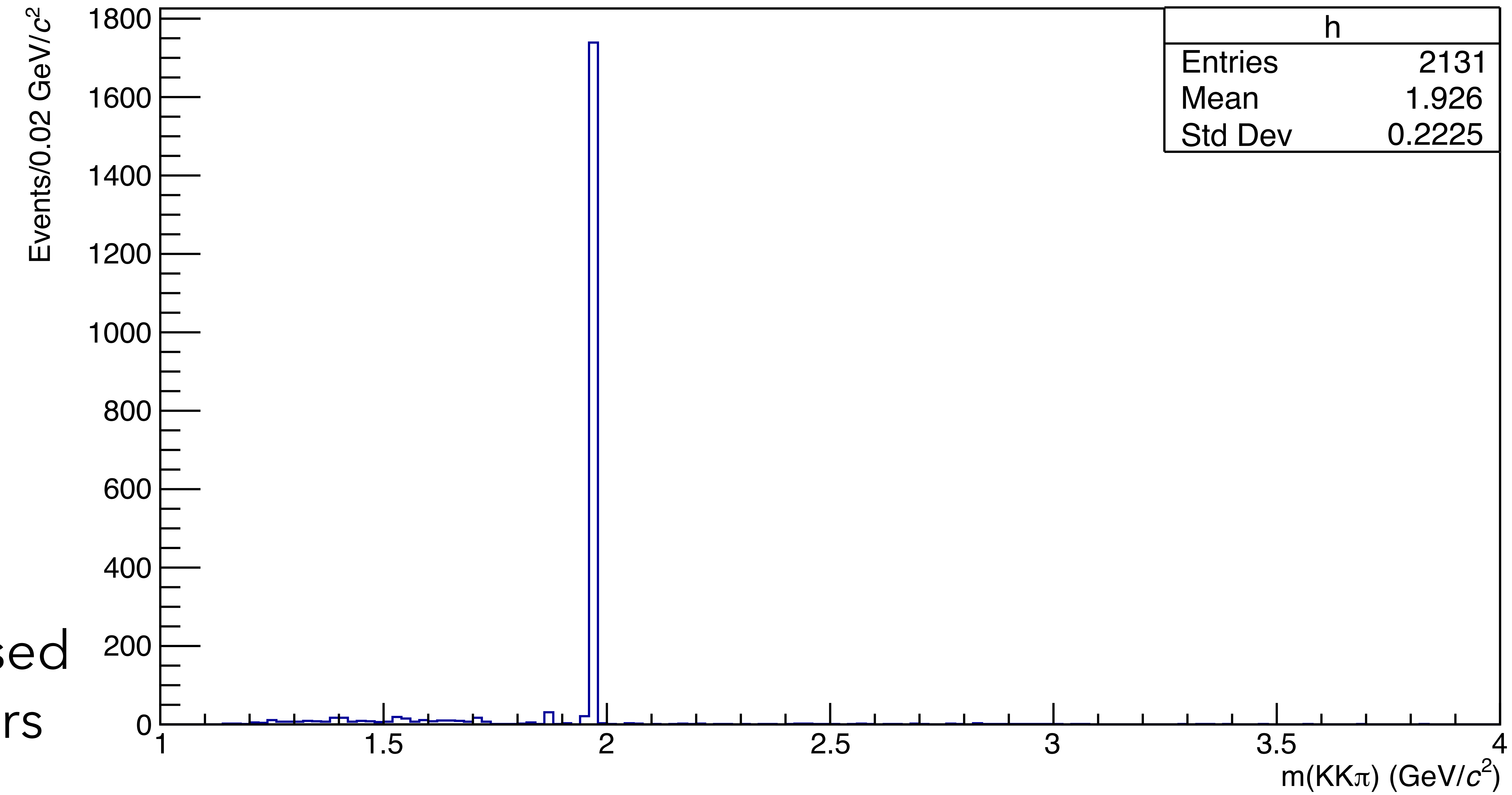
$|Q_{Tot}| = 1$

$Q_{KK} = 0$

NB

Despite the reco, MC truth is still used to identify the $D^{\pm}_s$ meson daughters

Reconstructed $D^{\pm}_s$ mass



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

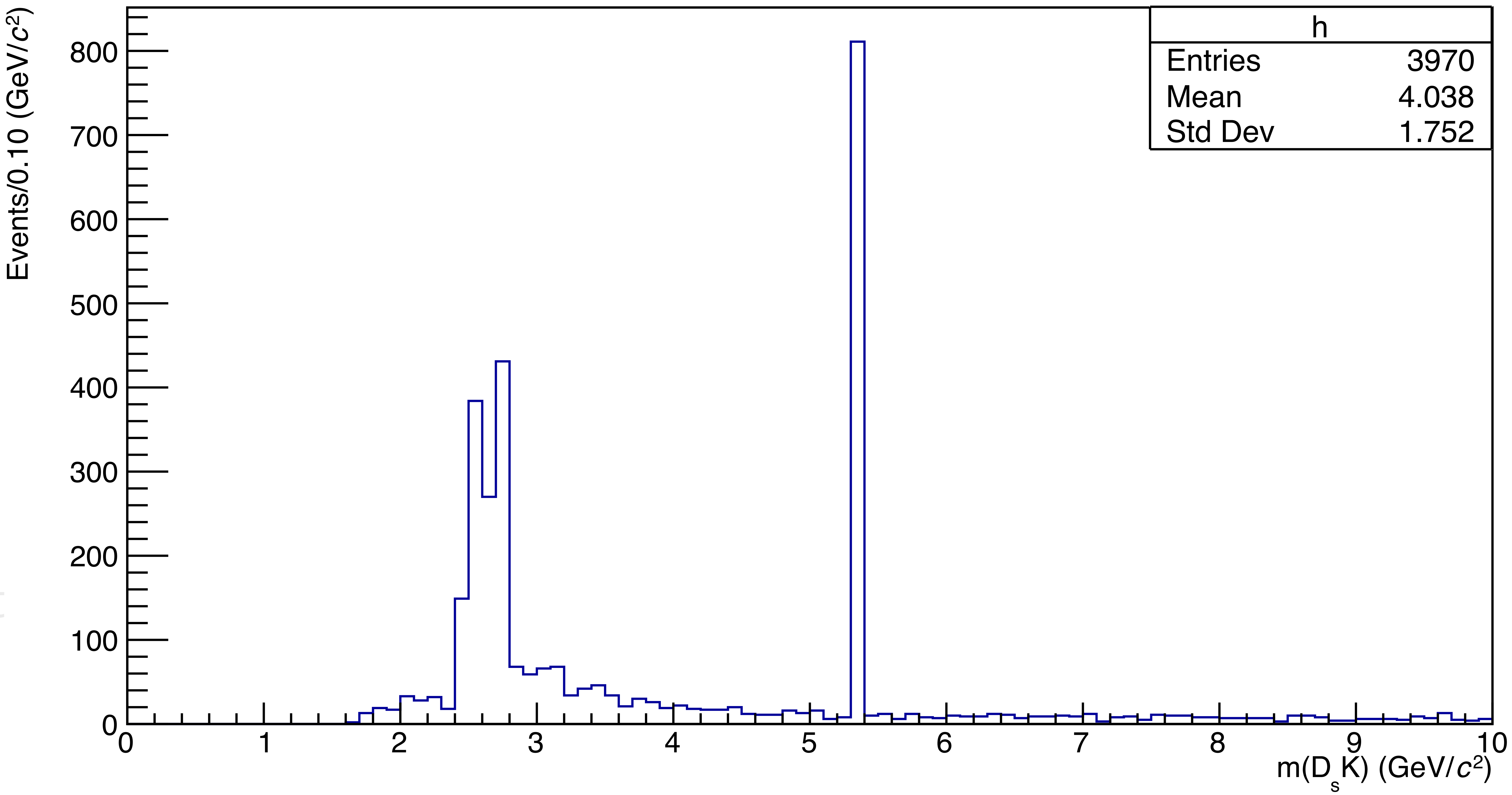
Purely combinatorial

Combine the $\mathbf{D^{\pm}_s}$ candidates with the $\mathbf{K^{\mp}}$ requesting

$|Q_{Tot}| = 1$

Despite main peak clearly visible, there is a heap in the low invariant mass region

Reconstructed B^0_s mass



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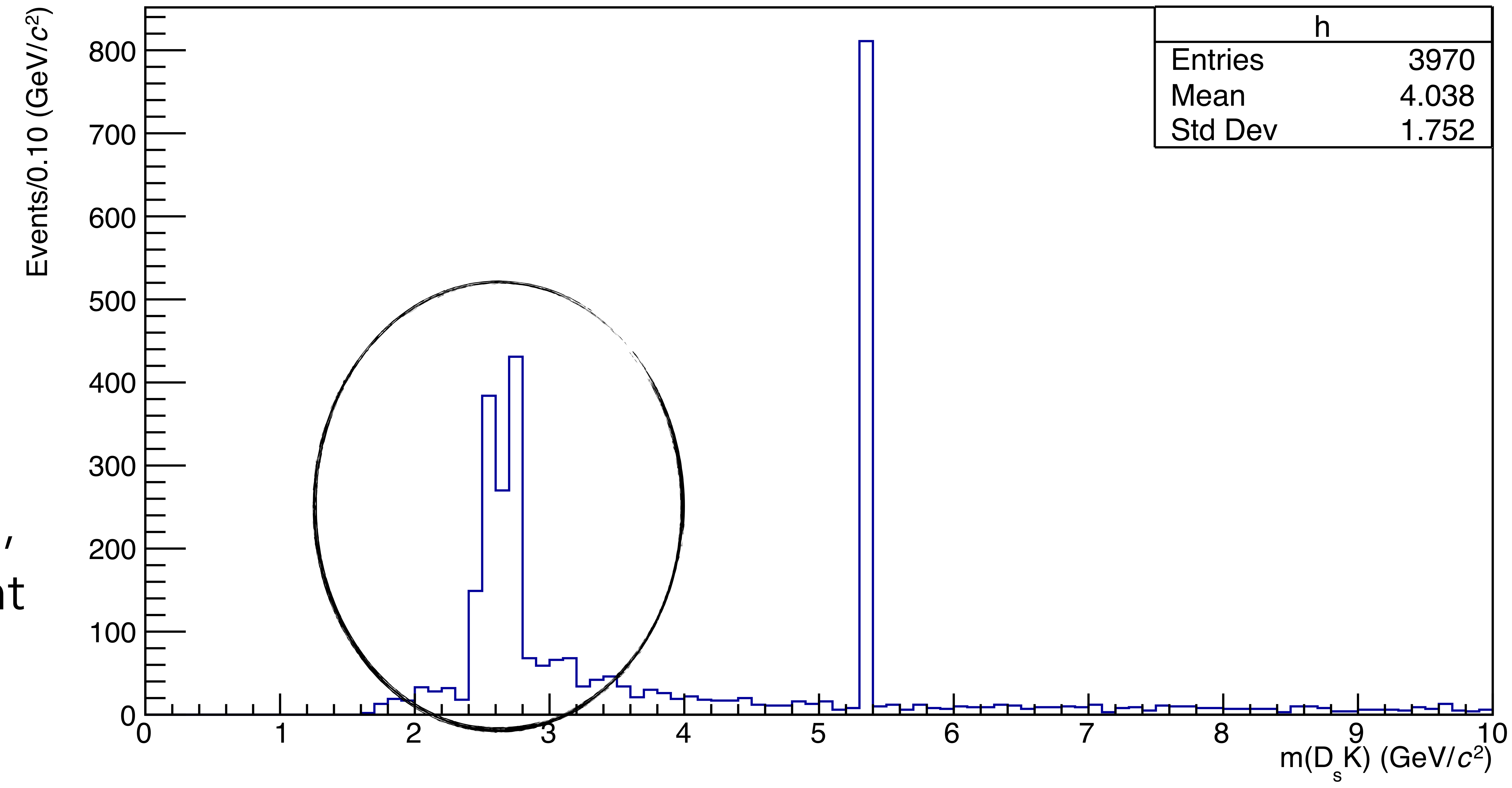

Status

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

Around the end of October had a really fruitful discussion with E. Perez

Defined some objectives and "deliverables"

Prepared some DEC cards and new datasets have been centrally produced[2] (thanks to E. Perez)

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

[2] fcc-physics-events.web.cern.ch/fcc-physics-events/Delphesevents_dev_IDEA.php

Conclusion and Outlook

Finally, **started the analysis** and got used with the FCCSW tools

Still making use of the MC truth **B^0_s & $D^\pm_s$** mass have been **reconstructed**

Yet, clearly, more **thoughts** need to be put **into the B^0_s mass**

Next Steps

Remove the MC truth matching and use "real" reconstruction

Implement vertex reconstruction at the B^0_s level too → Many thanks to E. Perez

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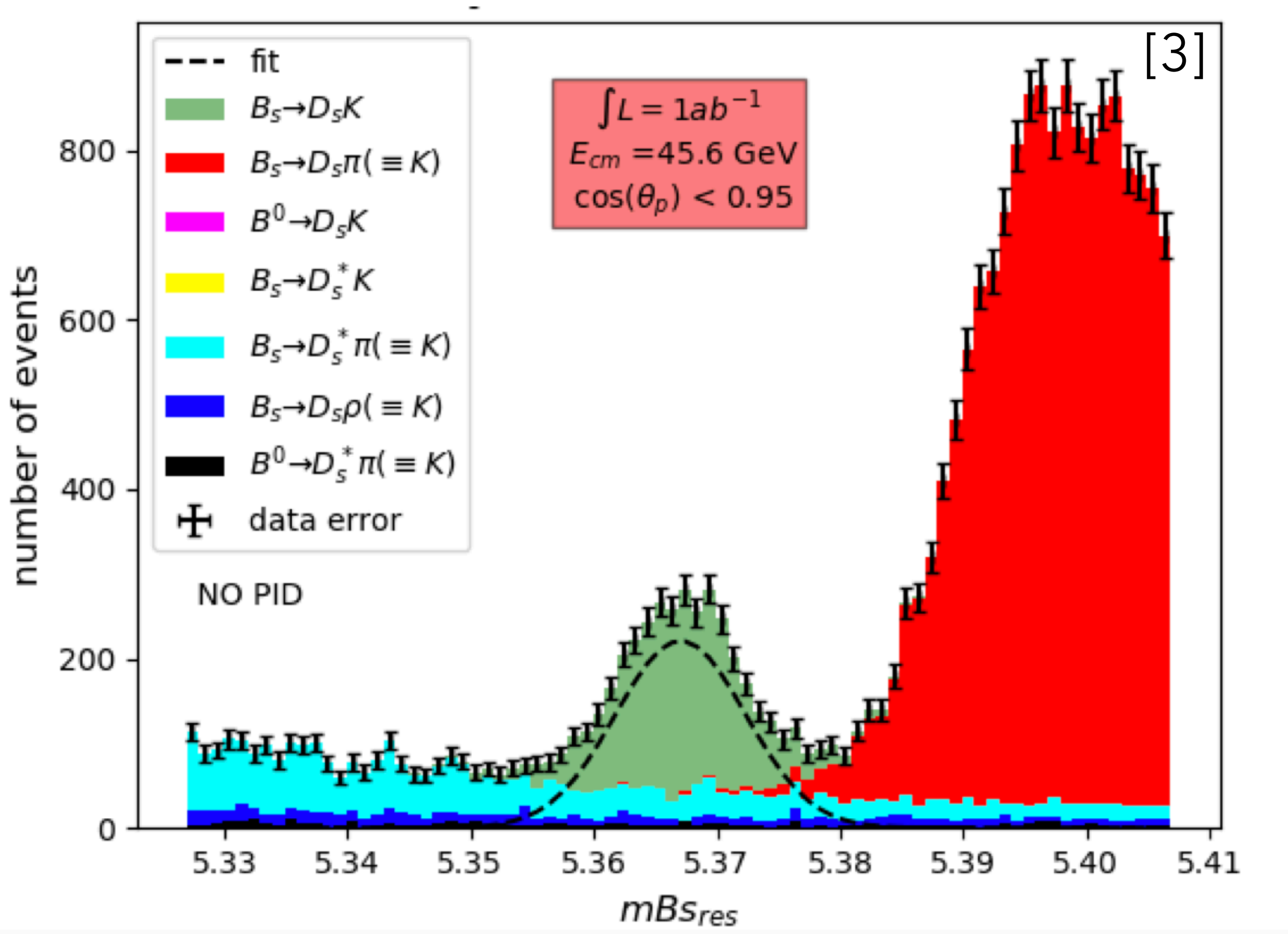
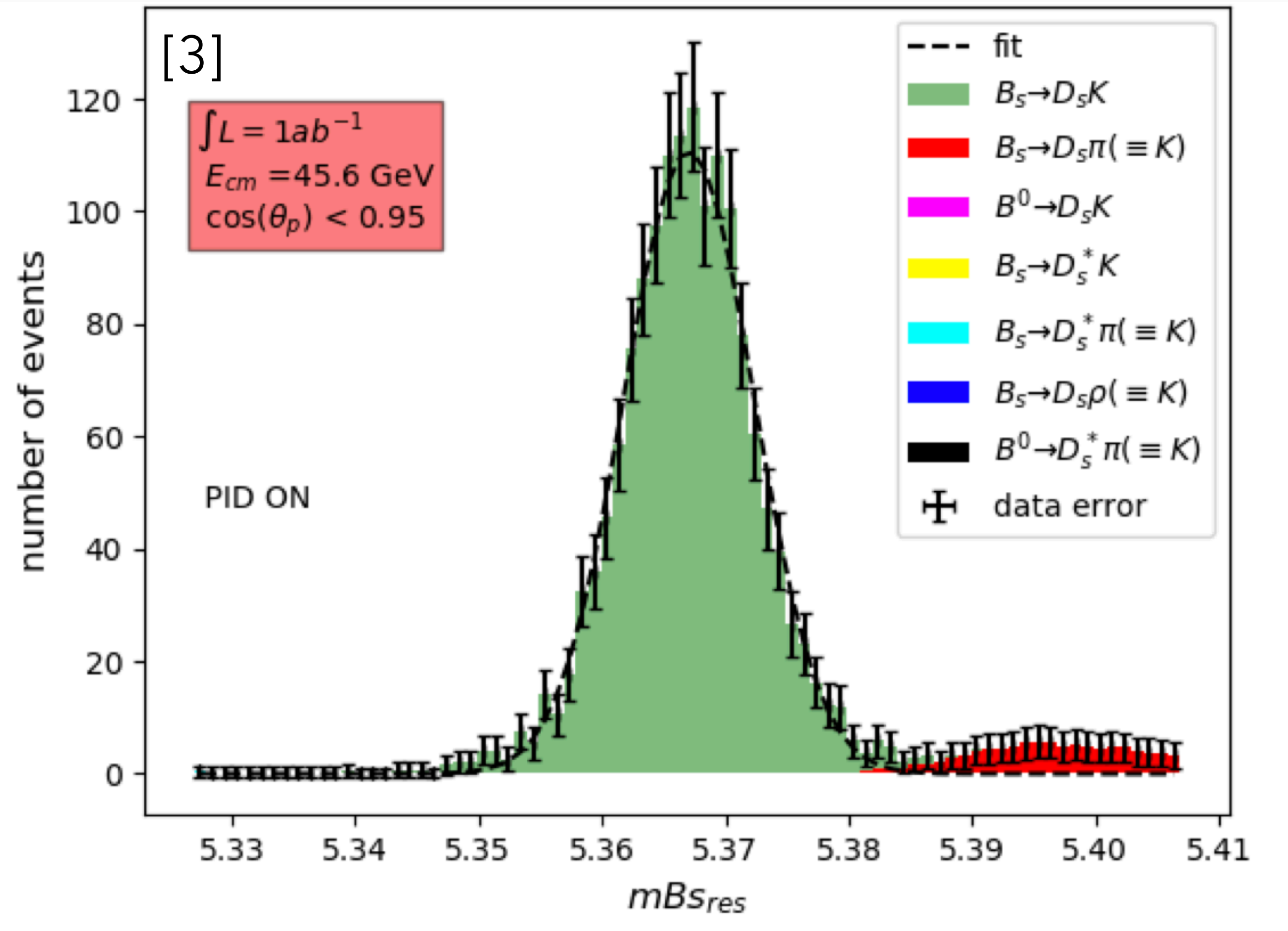
During discussion with E. Perez
(P. Azzi was there too!)

It was decided the would be of help to **reproduce** the plots of the **B^0_s reconstructed mass** on the right[3]

Ref. [3] describes a generic FCC scenario, so it would be useful to see them within EDM4hep





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

Thank you for the attention!