

WOJCIECH KRUPA  
ON BEHALF OF THE  
LHCb COLLABORATION  
AGH UST KRAKÓW



# BEAUTY TO OPEN CHARM FINAL STATES AT LHCb

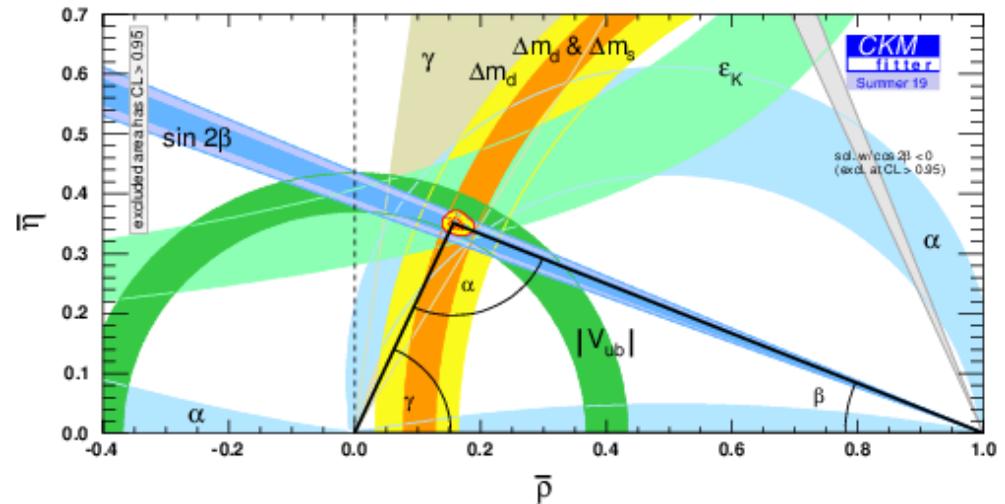
ICHEP 2020, 40TH INTERNATIONAL CONFERENCE  
ON HIGH ENERGY PHYSICS, PRAGUE 2020



# Motivation

- Goals of beauty to open charm studies:
  - Measurement of  $\gamma$  from  $B \rightarrow DK$  type processes
  - b hadron lifetime measurements
  - Searches of rare hadronic B decays
  - Studies of B decays to double charm
  - Studies of  $B \rightarrow DDh$  decays, including searches for exotic structure

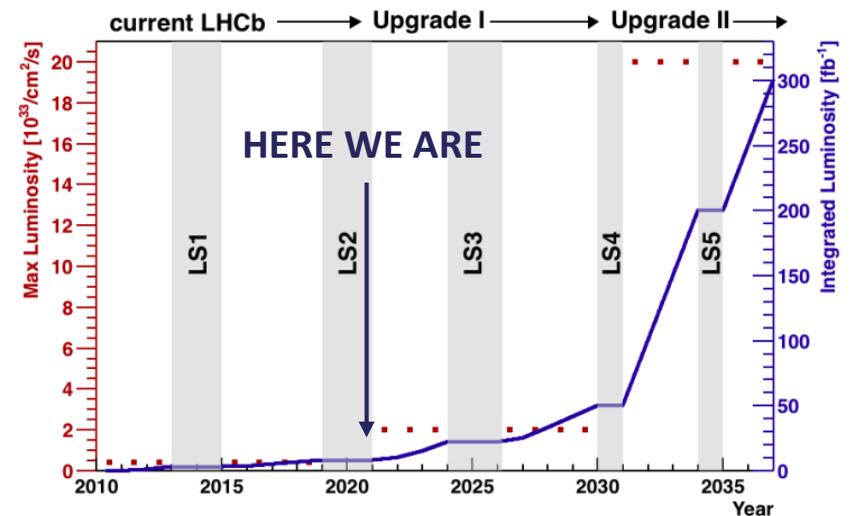
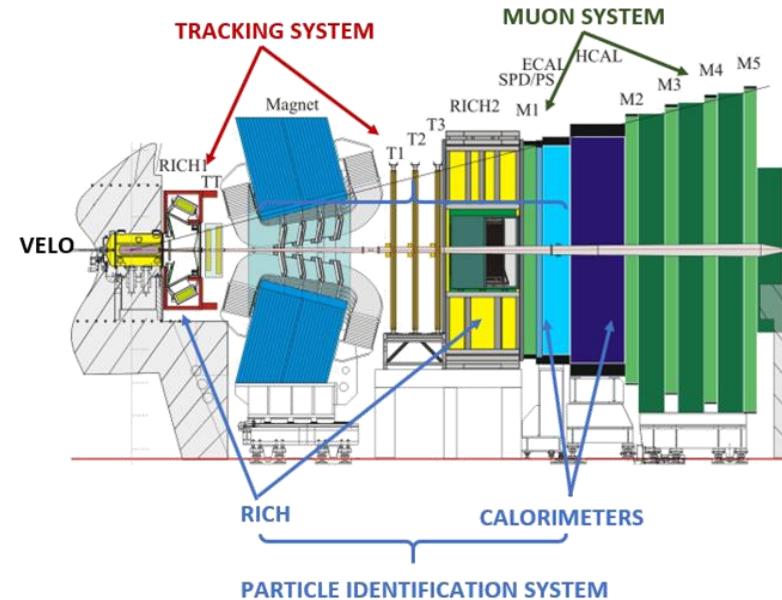
$$\begin{pmatrix} |V_{ud}| & |V_{us}| & |V_{ub}|e^{-i\gamma} \\ -|V_{cd}| & |V_{cs}| & |V_{cb}| \\ |V_{td}|e^{-i\beta} & -|V_{ts}|e^{-i\beta_s} & |V_{tb}| \end{pmatrix}$$



# LHCb spectrometer

LHCb detector designed for decays of hadrons with a  $b$  or  $c$  quarks:

- Covering the pseudorapidity range ( $2 < \eta < 5$ ).
- Identification:  $\varepsilon(h \rightarrow h) \sim 90\%$   $\varepsilon_\mu \sim 97\%$
- IP resolution:  $\sigma_{IP} = 20 \mu\text{m}$
- Momentum resolution:  $\frac{\Delta p}{p} = 0.5 - 0.8 \%$
- Mass resolution:  $\sigma(m_{B \rightarrow hh}) \approx 22 \text{ MeV}$
- Time resolution 45 – 55  $f\text{s}$



# Outline

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New 2020 results (Run 1 & 2 data):

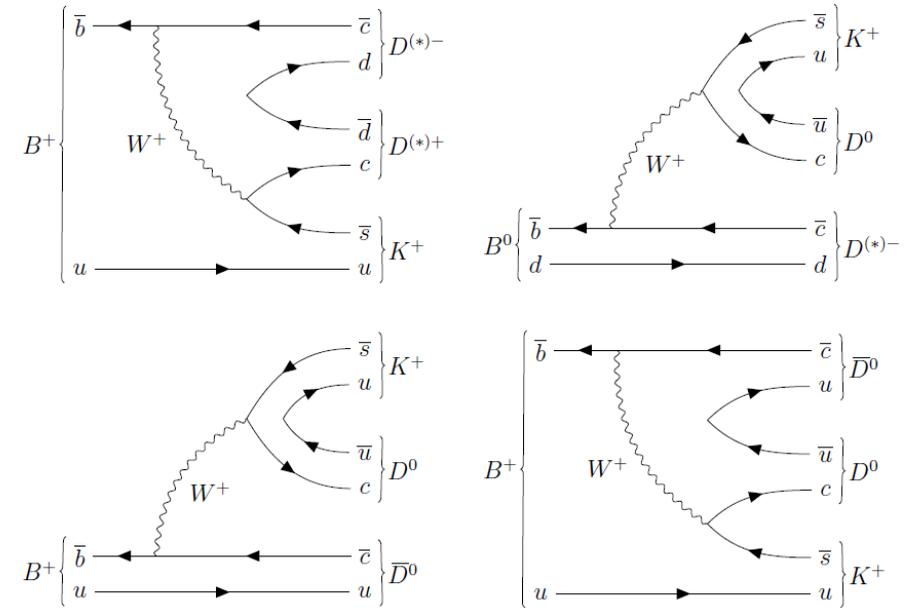
- $B \rightarrow D^*DK$   $B^0 \rightarrow D^*D^0K$  LHCb-PAPER-2020-006 (JHEP)
- $B^0 \rightarrow D^0\overline{D^0}K^+\pi^-$  LHCb-PAPER-2020-015 (JHEP) submitted 9.07 !
- $B^0 \rightarrow D_s^+\pi^-$  LHCb-PAPER-2020-021 (Eur.Phys.J.C) approved 29.07 !!

Other related talks during ICHEP20:

- Evelina Mihova Gersabeck - Time-dependent measurement from beauty to open charm at LHCb
- Sneha Malde - Time-integrated measurements of the CKM angle  $\gamma$  at LHCb
- Daniel Johnson - Exotic baryon- & meson- like states at LHCb

# $B \rightarrow D^* DK \quad B^0 \rightarrow D^* D^0 K$

- Long history of studies (CLEO/  
ALEPH/BaBar)
- LHCb Run 1 & 2 data sample:  $9 \text{ fb}^{-1}$
- The BF's are calculated using  
signal yields correction
- Good consistency with previous  
results
- Good prospect for future  
spectroscopy studies



- LHCb measurements:

$$B^+ \rightarrow D^{*-} D^+ K^+$$

$$B^+ \rightarrow D^{*+} D^- K^+$$

$$B^0 \rightarrow D^{*-} D^0 K^+$$

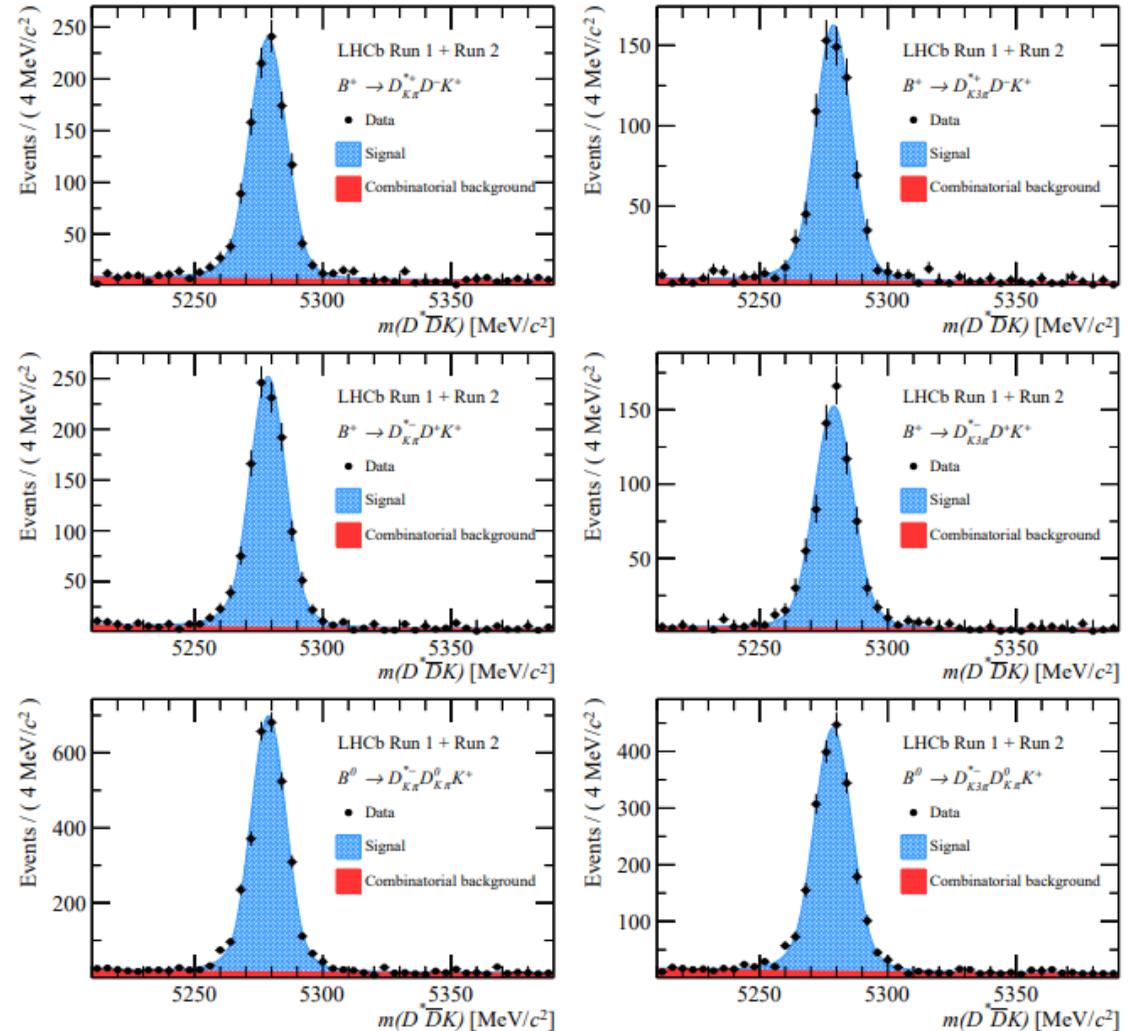
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LHCb-PAPER-2020-006 Submitted to JHEP  
 CLEO coll., EPS97 337 (1997)  
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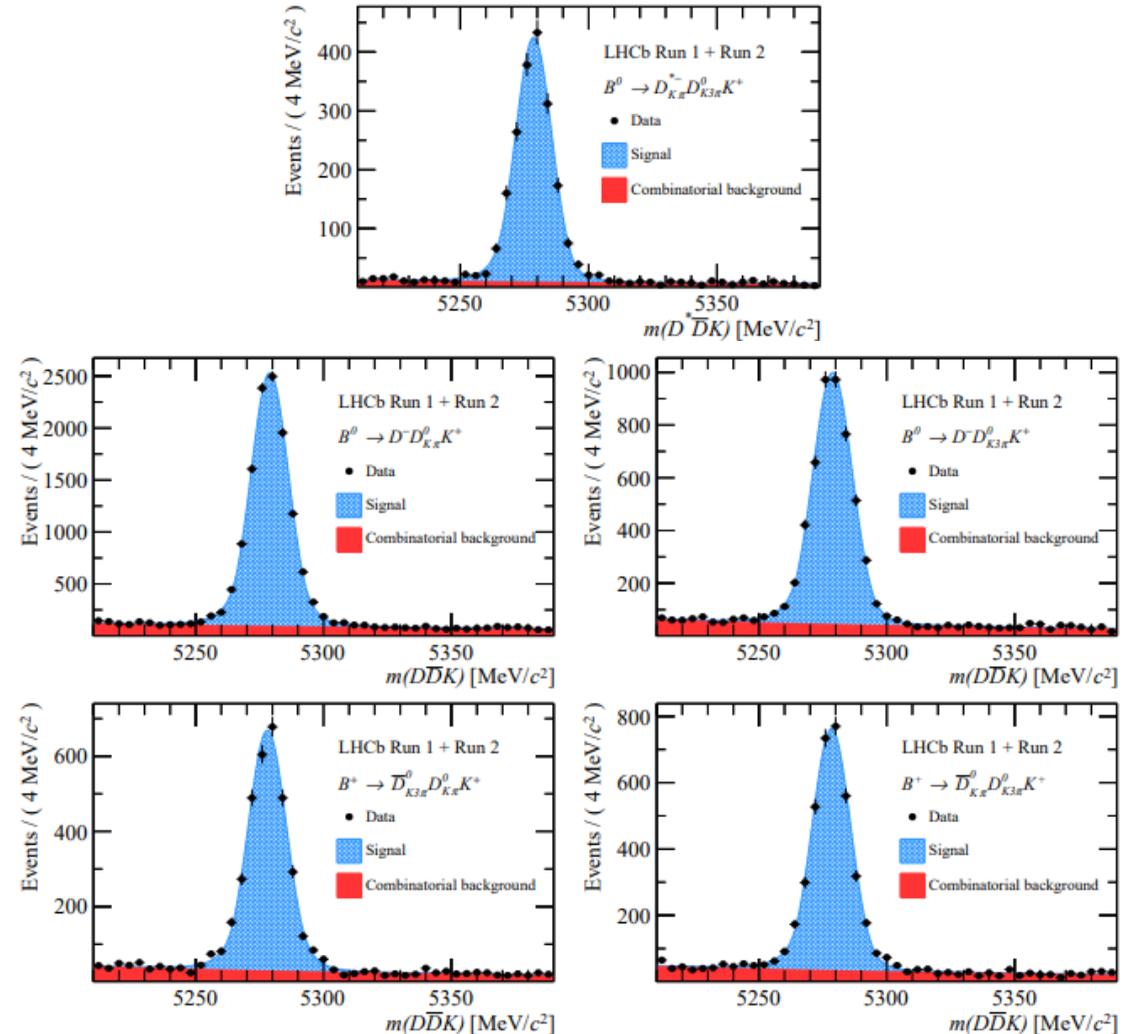
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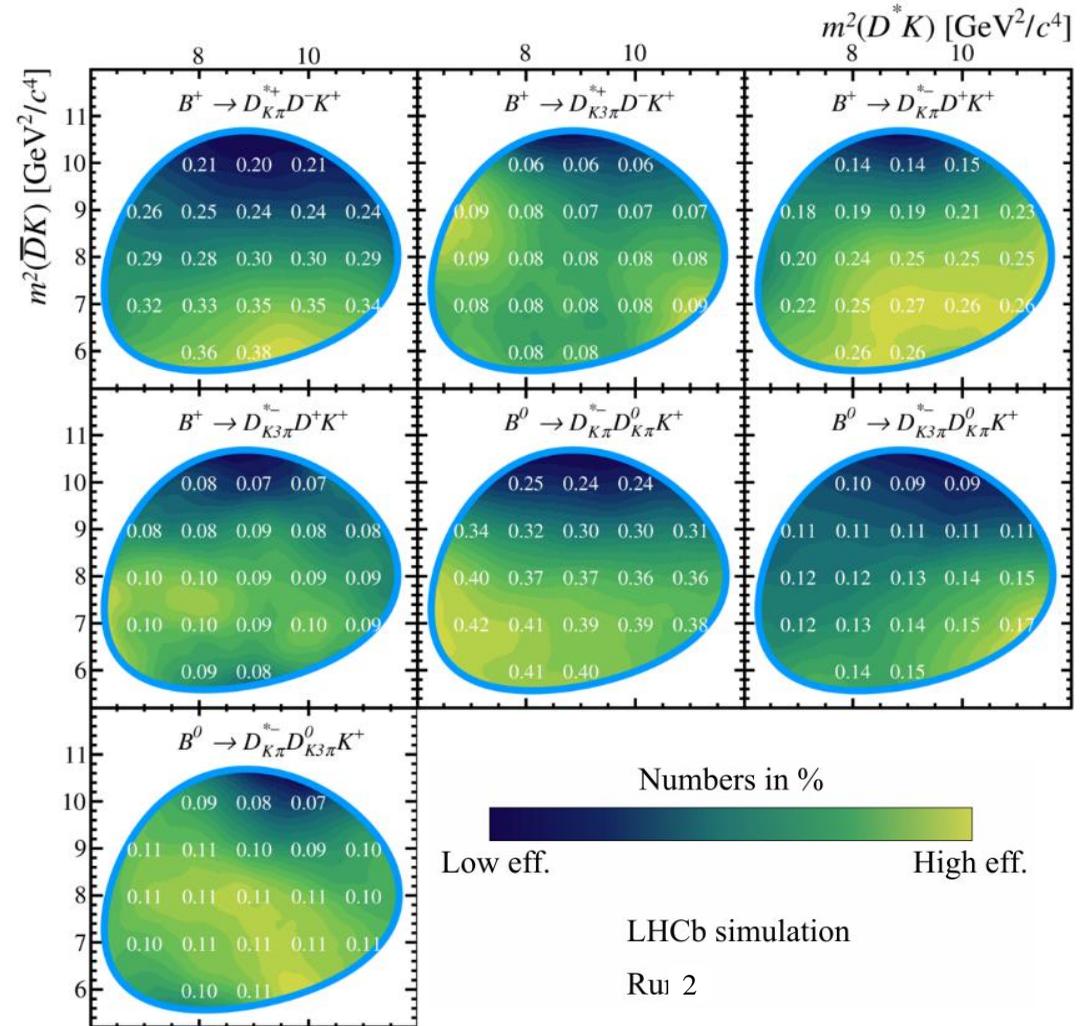
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Phys. Rev. D83 (2011) 032004  
Phys. Rev. Lett. 100 (2008) 092001

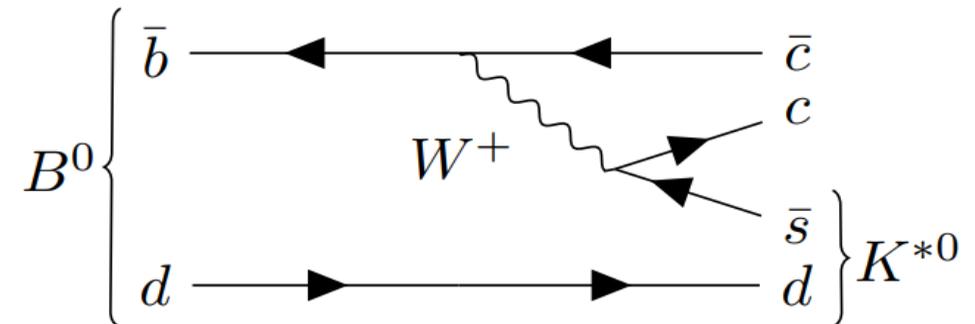
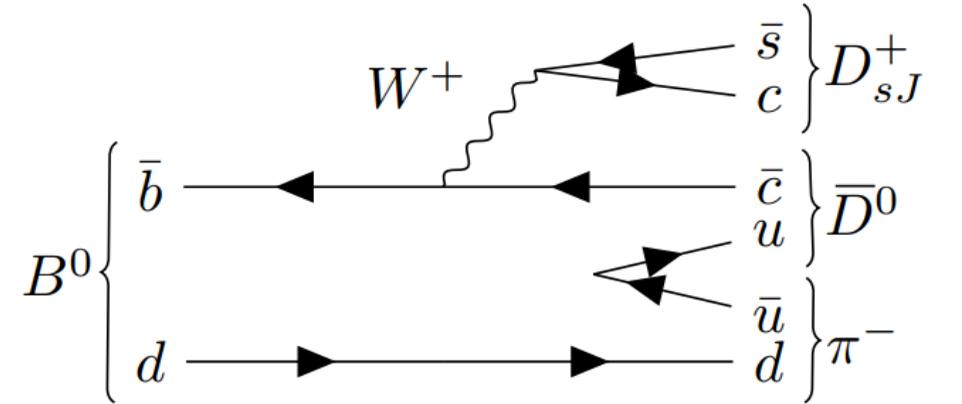
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$$\frac{\mathcal{B}(B^+ \rightarrow D^{*+} D^- K^+)}{\mathcal{B}(B^+ \rightarrow \bar{D}^0 D^0 K^+)} = 0.517 \pm 0.015 \pm 0.013 \pm 0.011,$$
$$\frac{\mathcal{B}(B^+ \rightarrow D^{*-} D^+ K^+)}{\mathcal{B}(B^+ \rightarrow \bar{D}^0 D^0 K^+)} = 0.577 \pm 0.016 \pm 0.013 \pm 0.013,$$
$$\frac{\mathcal{B}(B^0 \rightarrow D^{*-} D^0 K^+)}{\mathcal{B}(B^0 \rightarrow D^- D^0 K^+)} = 1.754 \pm 0.028 \pm 0.016 \pm 0.035,$$
$$\frac{\mathcal{B}(B^+ \rightarrow D^{*+} D^- K^+)}{\mathcal{B}(B^+ \rightarrow D^{*-} D^+ K^+)} = 0.907 \pm 0.033 \pm 0.014,$$

# $B^0 \rightarrow D^0 \bar{D}^0 K^+ \pi^-$

- Very recent result (submitted 09.07)
- The  $b \rightarrow c\bar{c}s$  transition  $\rightarrow$  input to further spectroscopy studies of  $c\bar{s}$  and  $c\bar{c}$  states
- Relative branching fraction measurement in reference to  $B^0 \rightarrow D^{*-} D^0 K^+$  and branching fraction measurement.
- Branching fraction calculation using:

$$R = B(D^{*-} \rightarrow D^0 \pi^-) \times \frac{N_{sig} \epsilon_{con}}{N_{con} \epsilon_{sig}}$$



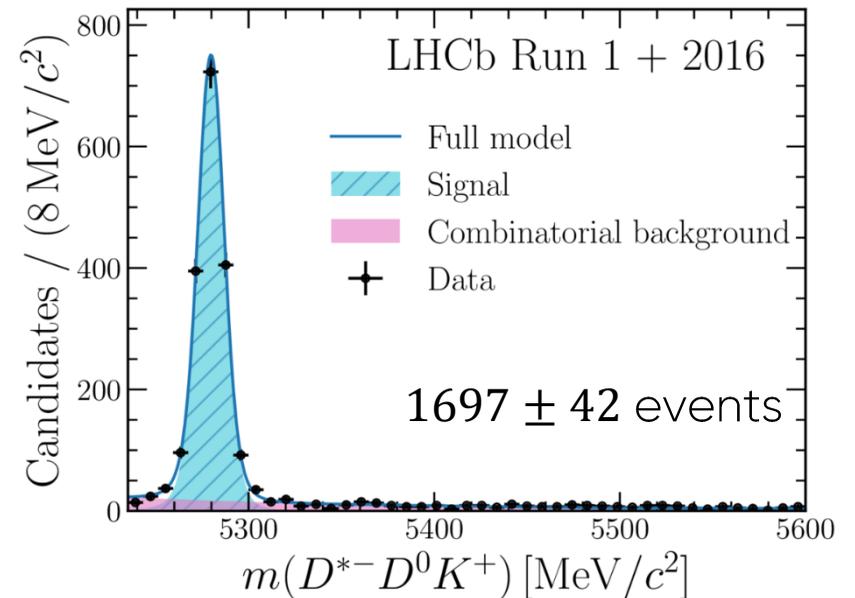
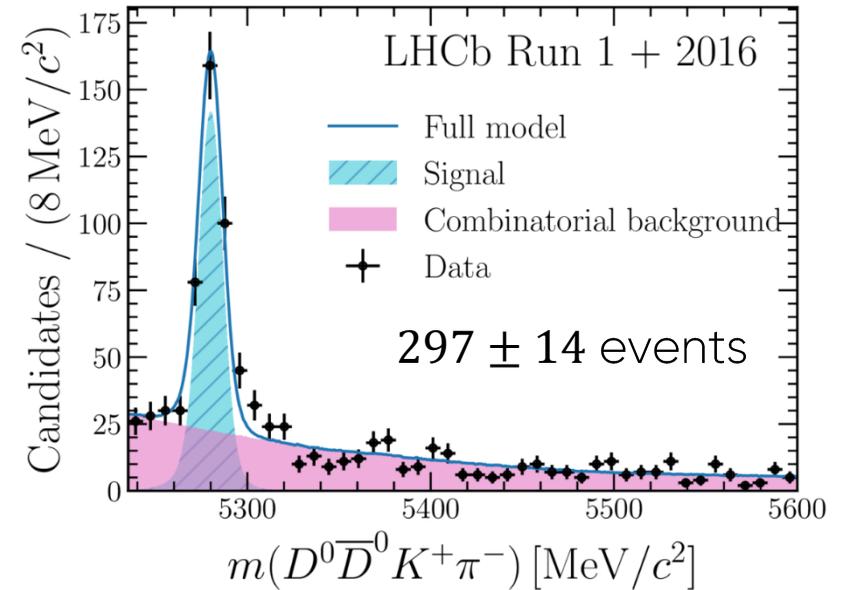
# $B^0 \rightarrow D^0 \bar{D}^0 K^+ \pi^-$

- Input to further spectroscopy studies of  $c\bar{s}$  and  $c\bar{c}$  states
- $c\bar{c}$  inputs for  $b \rightarrow s\ell^+\ell^-$  processes such as  $B^0 \rightarrow K^{*0}\mu^+\mu^-$  sensitive to BSM physics
- Relative branching fraction measured in reference to  $B^0 \rightarrow D^{*-}D^0K^+$ :

$$R = 14.2 \pm 1.1 \pm 1.0$$

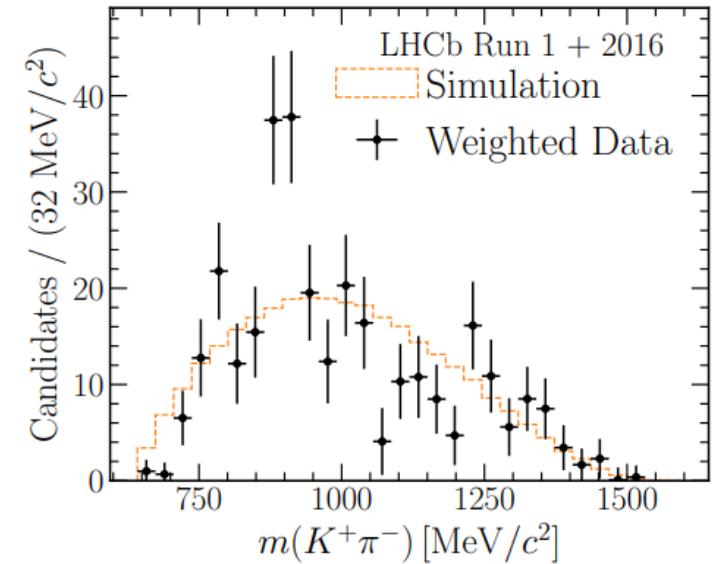
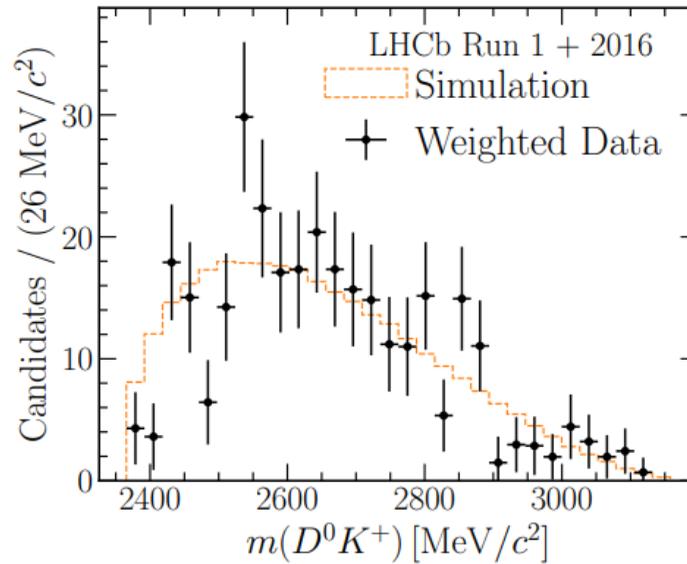
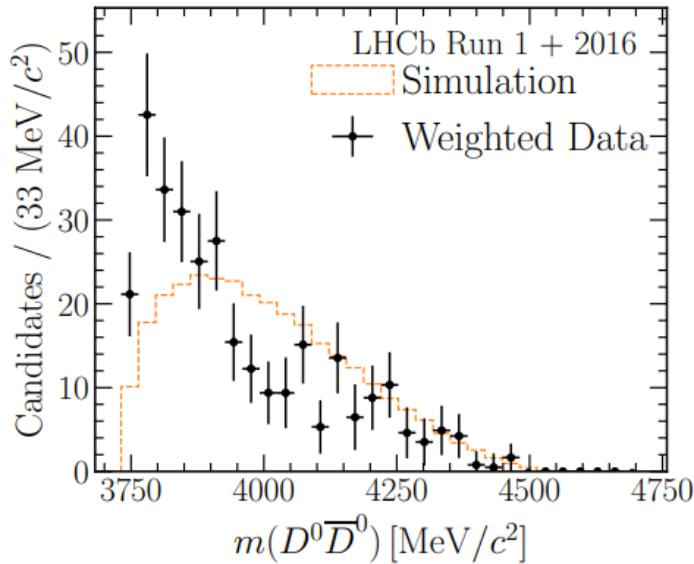
- Branching fraction:

$$B(B^0 \rightarrow D^0 \bar{D}^0 K^+ \pi^-) = (3.50 \pm 0.27 \pm 0.26 \pm 0.30) \times 10^{-4}$$



# $B^0 \rightarrow D^0 \bar{D}^0 K^+ \pi^-$

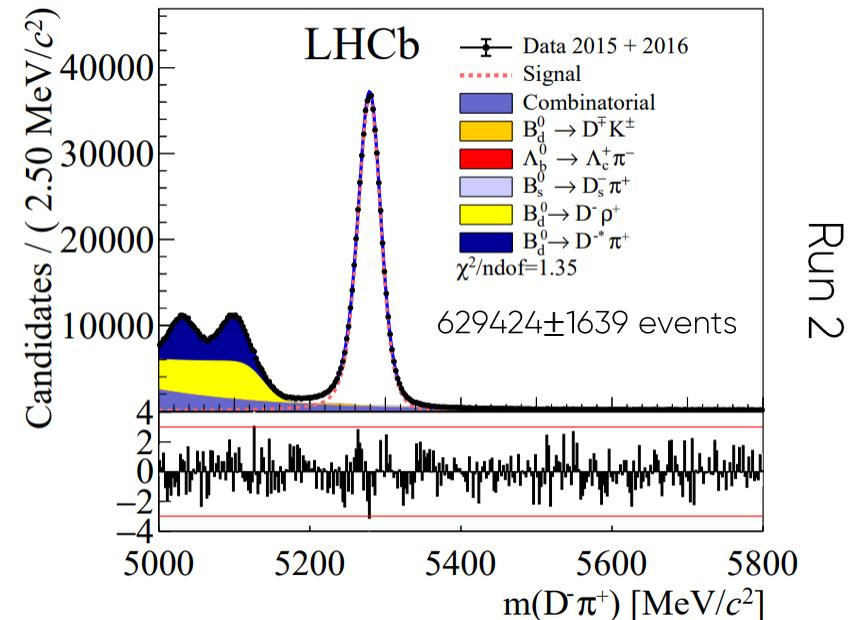
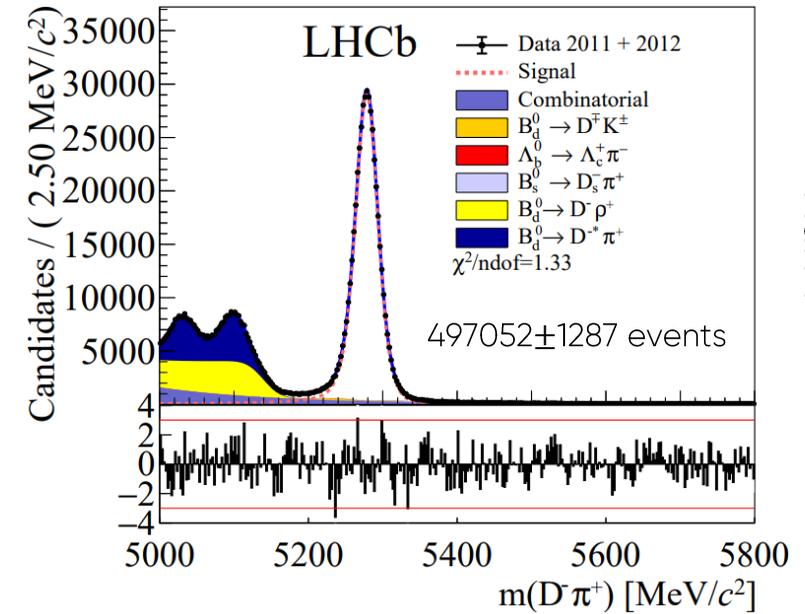
- Analysis of  $m(D^0 \bar{D}^0)$ ,  $m(D^0 K^+)$  and  $m(K^+ \pi^-)$
- Hints of structures:  $\psi(3770)$ ,  $D_{s2}^*(2573)^+$ ,  $D_{s1,3}^*(2860)^+$  and  $K^*(892)^0$



# $B^0 \rightarrow D_S^+ \pi^-$

- **Brand new** result (approved **XX.07**)
- Data sample:  $5.0 \text{ fb}^{-1}$
- Simultaneous measurement of:
  - ratio  $r_{D\pi} = \tan\theta_c \frac{f_{D^+}}{f_{D_S^+}} \sqrt{\frac{B(B^0 \rightarrow D_S^+ \pi^-)}{B(B^0 \rightarrow D^- \pi^+)}}$
  - BR and relative BR measured in reference to  $B^0 \rightarrow D^- \pi^+$
  - Collision energy dependence on the hadronisation fraction on the  $f_s/f_d$  and  $V_{ub}$
- $B(B^0 \rightarrow D_S^+ \pi^-) \propto |V_{ub}|^2 |V_{cs}|^2$   
[LHCb-PAPER-2020-021]

$$|F(B^0 \rightarrow \pi^-)|^2 f_{D_S^+}^2 |a_{NF}|^2$$



# $B^0 \rightarrow D_S^+ \pi^-$

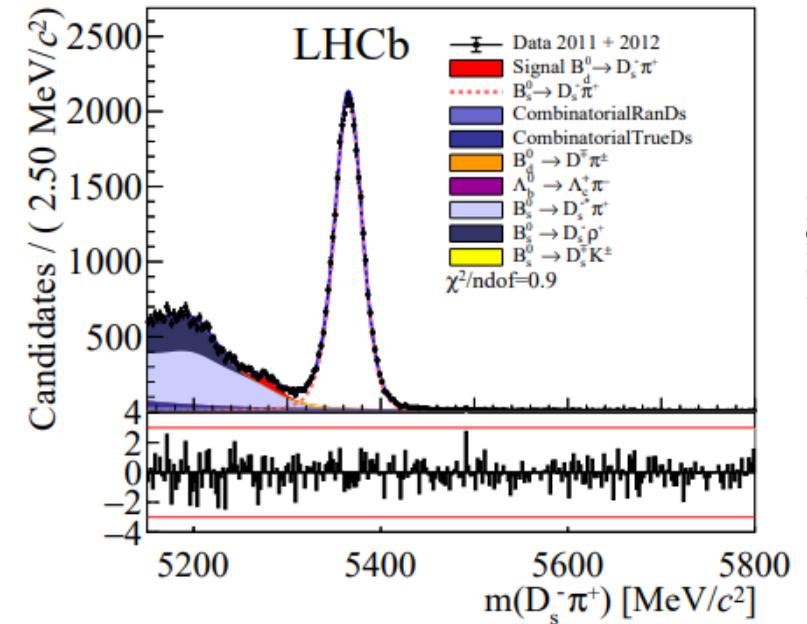
- **Brand new** result (approved **XX.07**)
- Data sample:  $5.0 \text{ fb}^{-1}$
- Relative branching fraction measured in reference to  $B^0 \rightarrow D^+ \pi^-$ :

$$\frac{B(B^0 \rightarrow D_S^+ \pi^-)}{B(B^0 \rightarrow D^+ \pi^-)} = (7.70 \pm 0.70 \pm 0.25) \times 10^{-3}$$

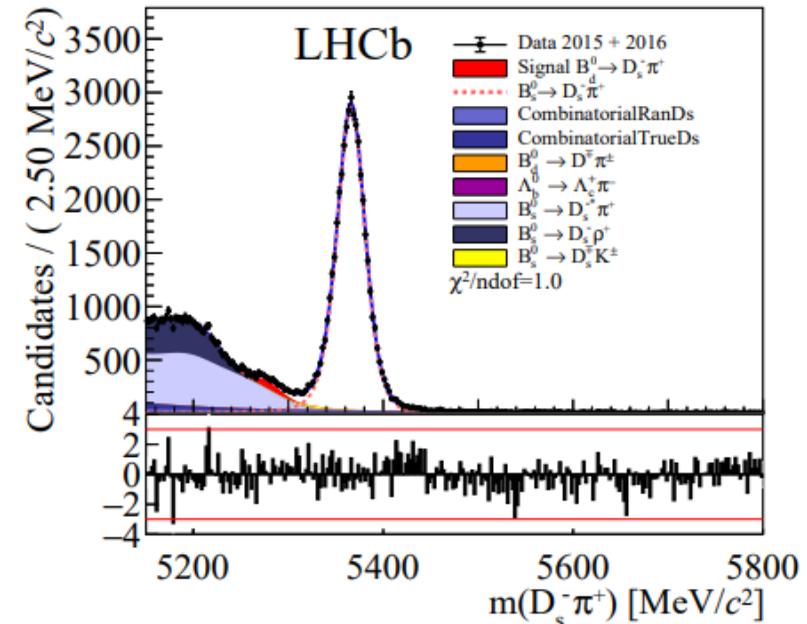
- Branching fraction:

$$\begin{aligned} B(B^0 \rightarrow D_S^+ \pi^-) &= (19.4 \pm 1.8 \pm 1.4 \pm 1.2) \times 10^{-6} \end{aligned}$$

- $r_{D\pi} = 0.0163 \pm 0.0011 \pm 0.0033$

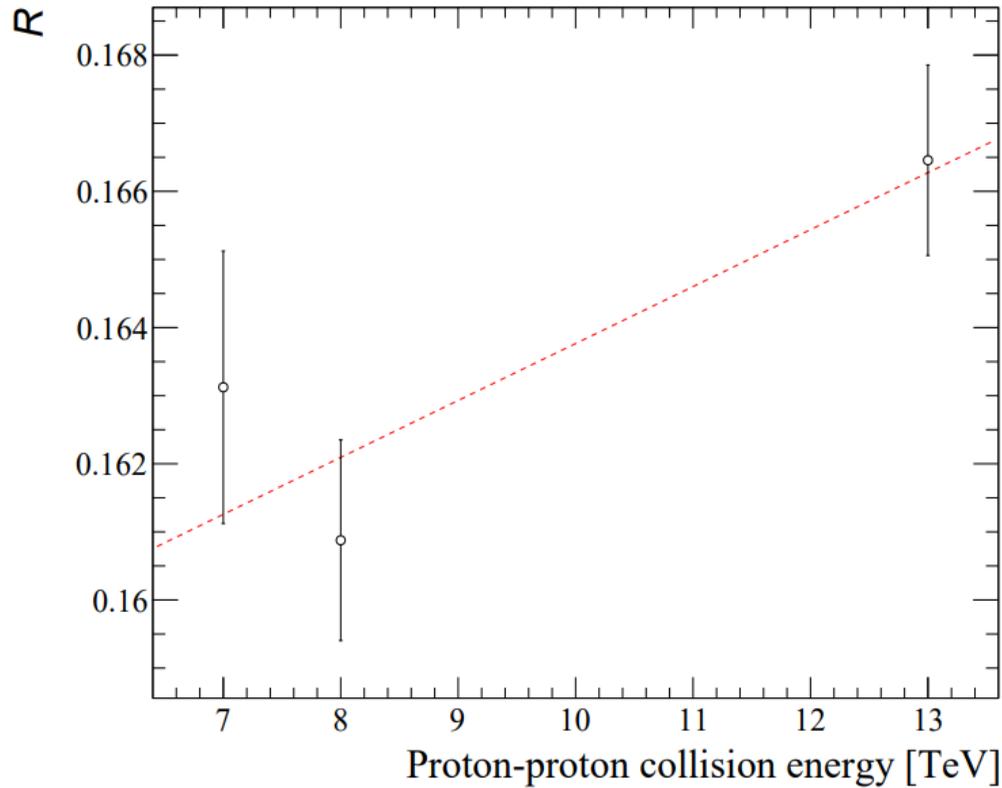


Run 1

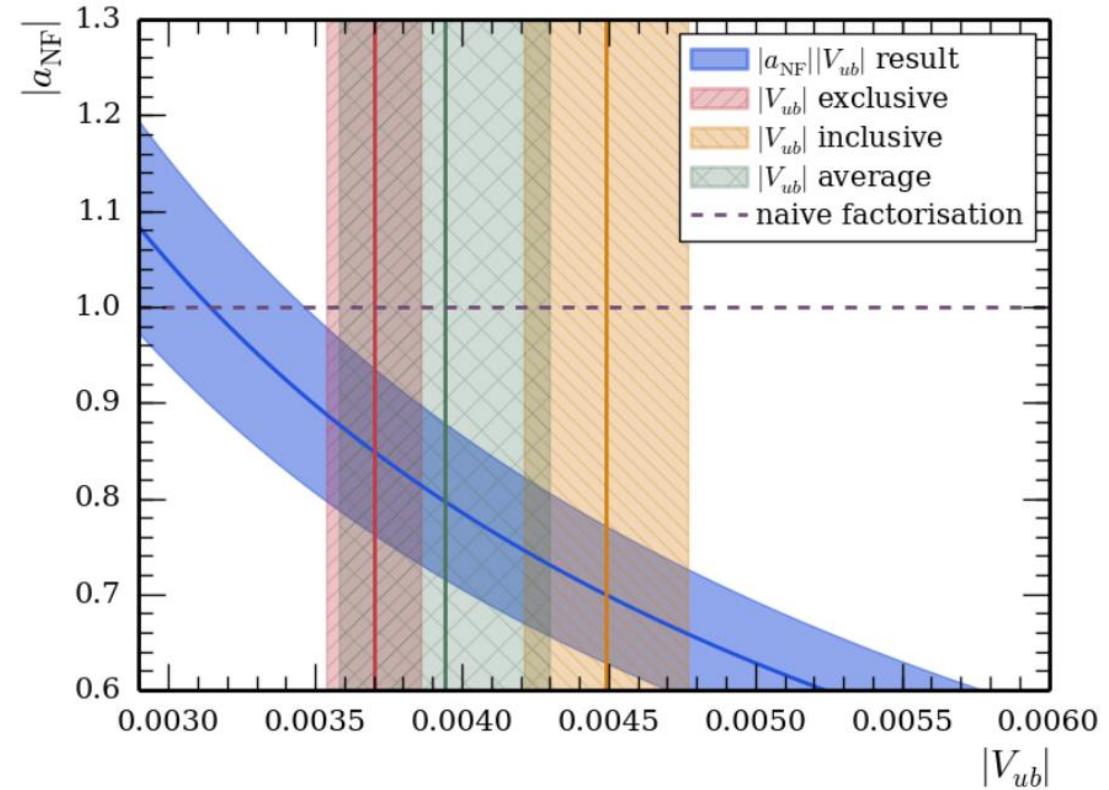


Run 2

# $B^0 \rightarrow D_S^+ \pi^-$



$$R = 0.1554(35) + 0.00083(34)\sqrt{s}$$



$$|V_{ub}||a_{NF}| = (3.14 \pm 0.32) \times 10^{-3}$$

$$\mathcal{R} = \frac{N_{B_S^0 \rightarrow D_S^- \pi^+} \epsilon_{B^0 \rightarrow D^- \pi^+}}{N_{B_S^0 \rightarrow D^- \pi^+} \epsilon_{B^0 \rightarrow D_S^- \pi^+}} \propto \frac{f_S}{f_d}$$

# Summary

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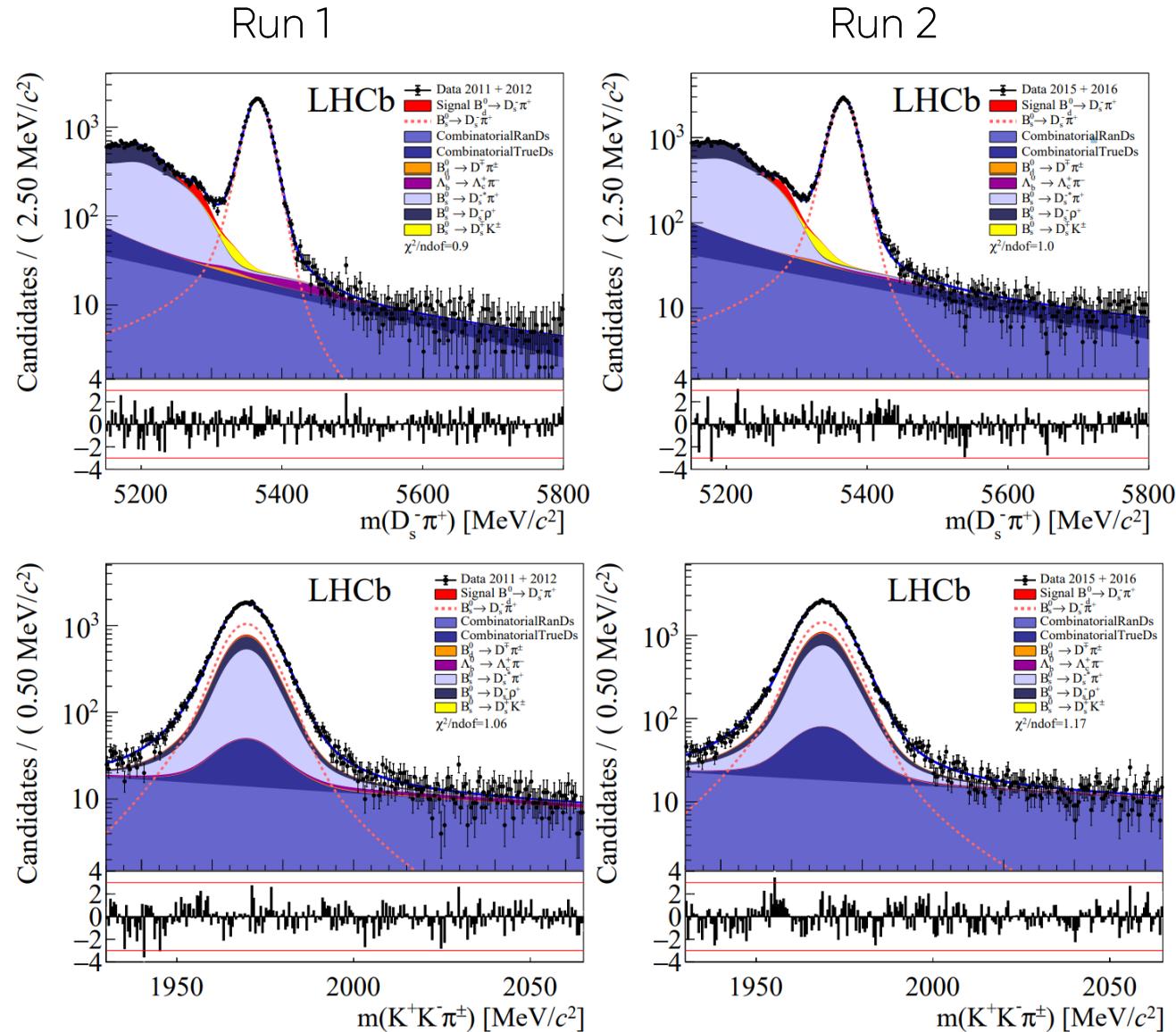
- Many interesting results of analysis over Run 1 and Run 2 data.
- Exploration of decays through resonance states and multibody final states
- All results in agreement with SM
- Still significant discovery potential in studies of beauty to open charm processes
- Good prospects for the precision measurements in Run 3 & 4
- Stay tuned for more to come



# Backup

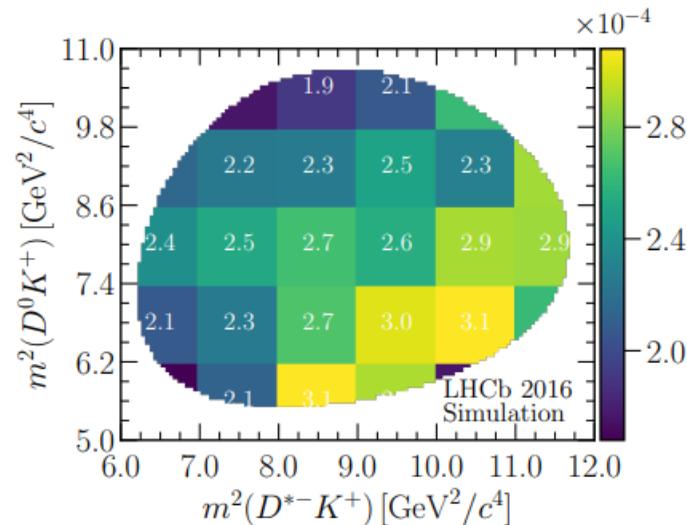
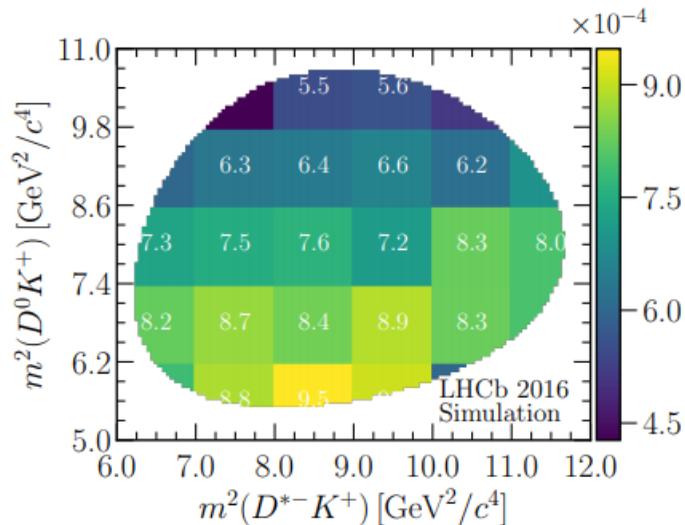
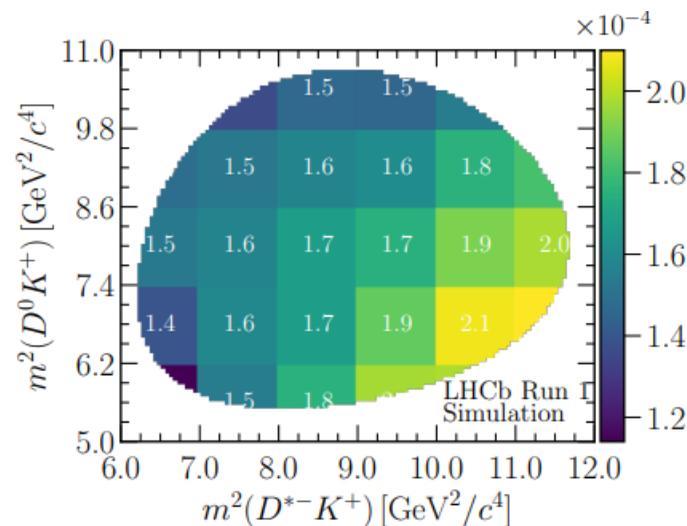
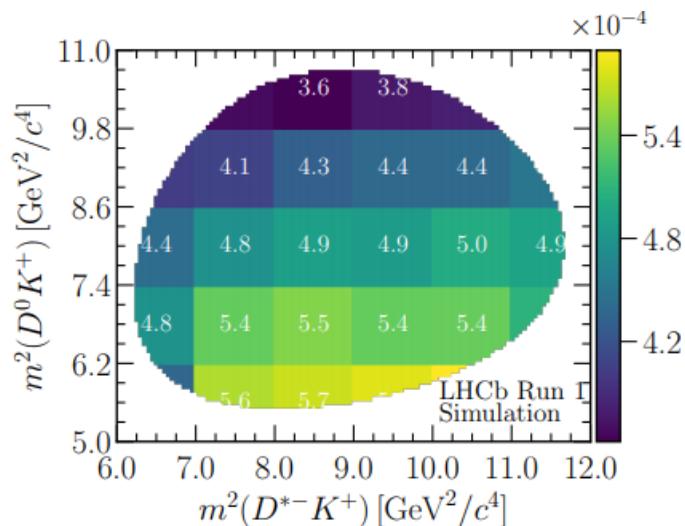


$$B^0 \rightarrow D_s^+ \pi^-$$



Beauty to open charm final states at LHCb

$$B^0 \rightarrow D^0 \overline{D^0} K^+ \pi^-$$



$$B^0 \rightarrow D^0 \bar{D}^0 K^+ \pi^-$$

