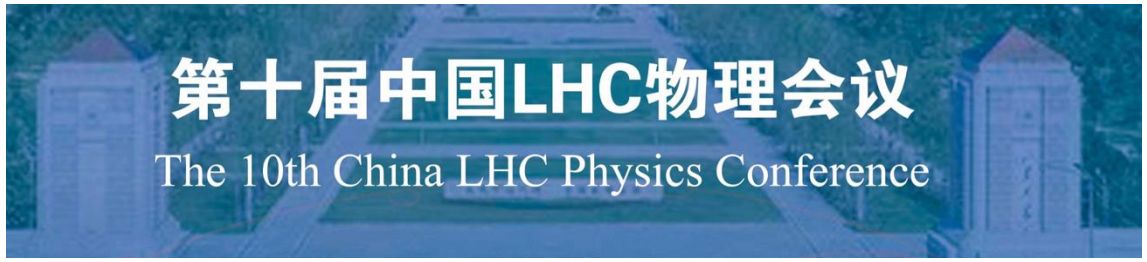

Amplitude analysis of $B^+ \to D^+\overline{D}^0 K_S^0$ decays

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on behalf of LHCb collaboration
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Outline

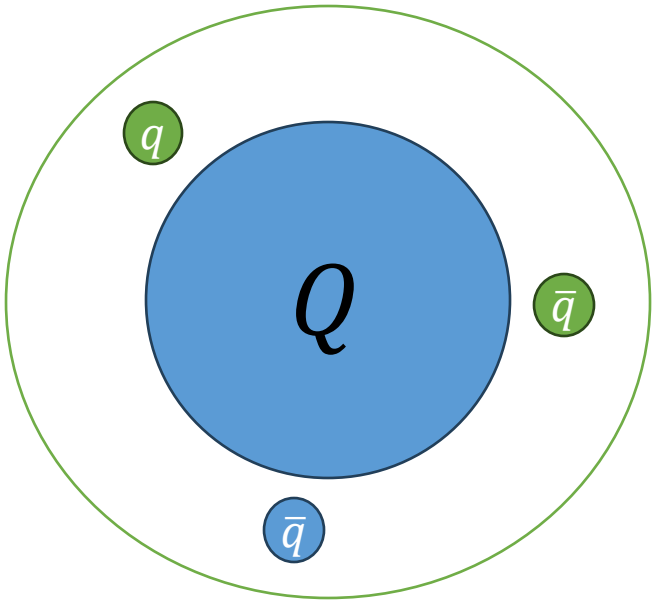
- Introduction
- Analysis Method
- Analysis Results
- Summary

Introduction

Exotics with single heavy quark

Heavy quark effective theory (HQET)

$$\mathcal{L}_Q = \bar{Q}(i\not{D} - m_Q)Q = \bar{Q}_v(iv \cdot D)Q_v + \mathcal{O}\left(m_Q^{-1}\right)$$



Abundant symmetries:

- Heavy quark spin symmetry (HQSS)
- Heavy quark flavor symmetry (HQFS)

Experimental information:

- $X(5568)$ $(b\bar{s}u\bar{d})$ PhysRevD.97.092004
- $X_0(2900), X_1(2900)$ $(\bar{c}\bar{s}ud)$ PhysRevD.102.112003

$X_0(2900)$ & $X_1(2900)$

- Discovered by LHCb in $B^+ \to D^+D^-K^+$ decays (D^-K^+ final state)
- Named as $T^*_{cs0}(2870)^0$ and $T^*_{cs1}(2900)^0$ respectively in PDG
- Minimal quark content ($\bar{c}\bar{s}ud$)

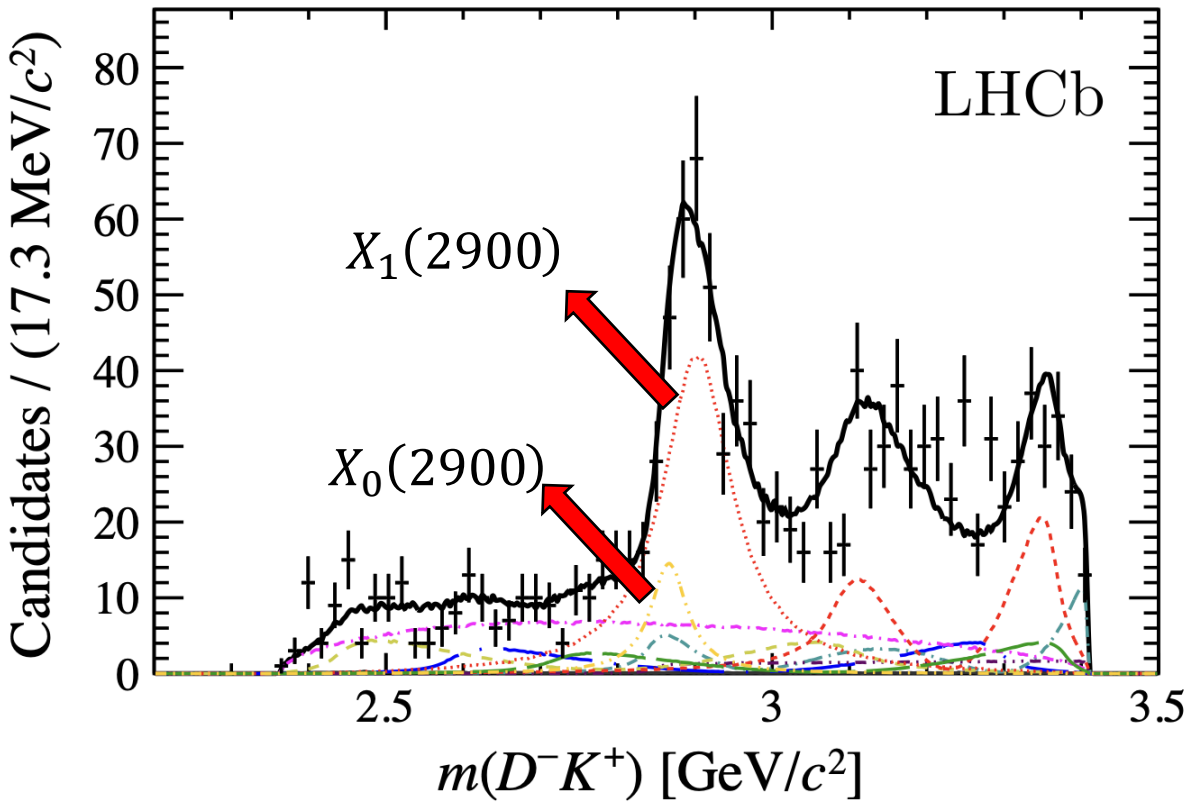
Resonance	Mass (GeV/c^2)	Width (MeV)
$X_0(2900)$	$2.866 \pm 0.007 \pm 0.002$	$57 \pm 12 \pm 4$
$X_1(2900)$	$2.904 \pm 0.005 \pm 0.001$	$110 \pm 11 \pm 4$

- Interesting feature:

  $X_1(2900)$ wider than $X_0(2900)$

⇓

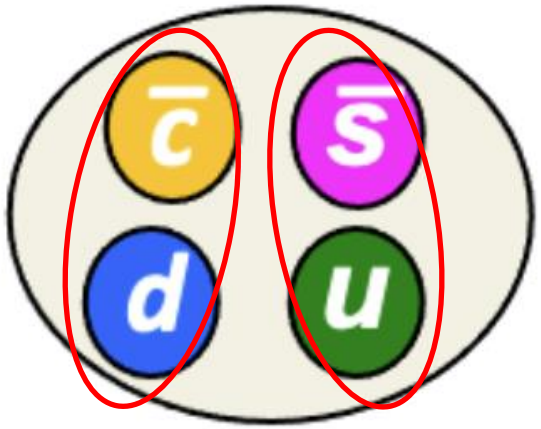
Different nature



Theoretical interpretations

$X_0(2900)$ (0^+)

- Close to D^*K^* threshold
- Most popular interpretation is D^*K^* hadron molecule



$X_1(2900)$ (1^-)

- Compact tetraquark

Isospin eigenstate

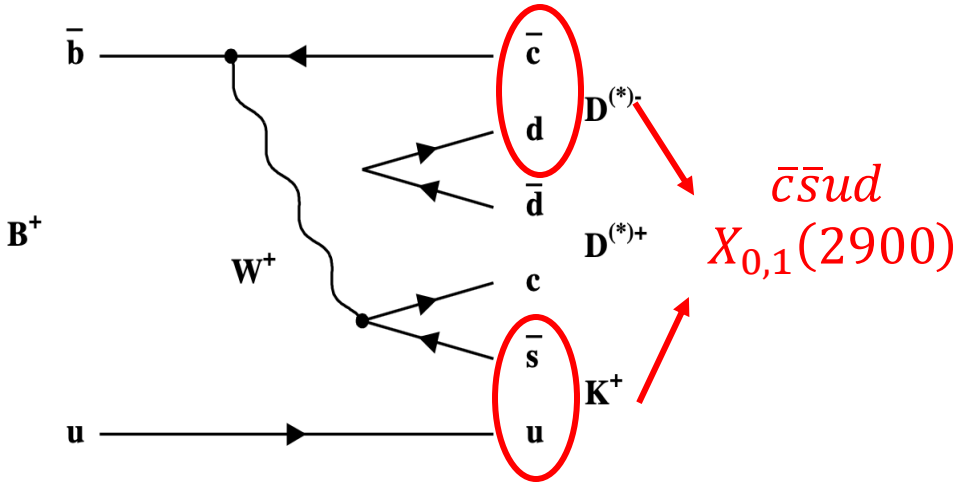
- P-wave D^*K^* hadron molecule with dipole structure
- Kinematical effects (cusp, TS)

Related to potential isospin breaking

$B^+ \to D^+\overline{D}^0 K_S^0$ decays

Discriminate different interpretations via isospin symmetry

$\boldsymbol{B^+ \to D^+ D^- K^+}$

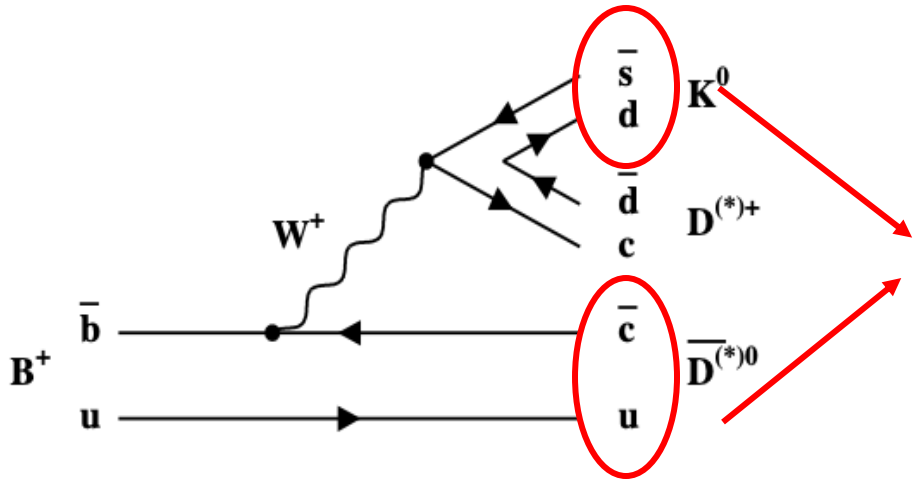


$\bar{c}\bar{s}ud$

$X_{0,1}(2900)$

$B^+ \to D^+ X_{0,1}(2900), X_{0,1}(2900) \to D^- K^+$

$\boldsymbol{B^+ \to D^+ \overline{D}^0 K^0}$



$\bar{c}\bar{s}ud$

$X_{0,1}(2900)$

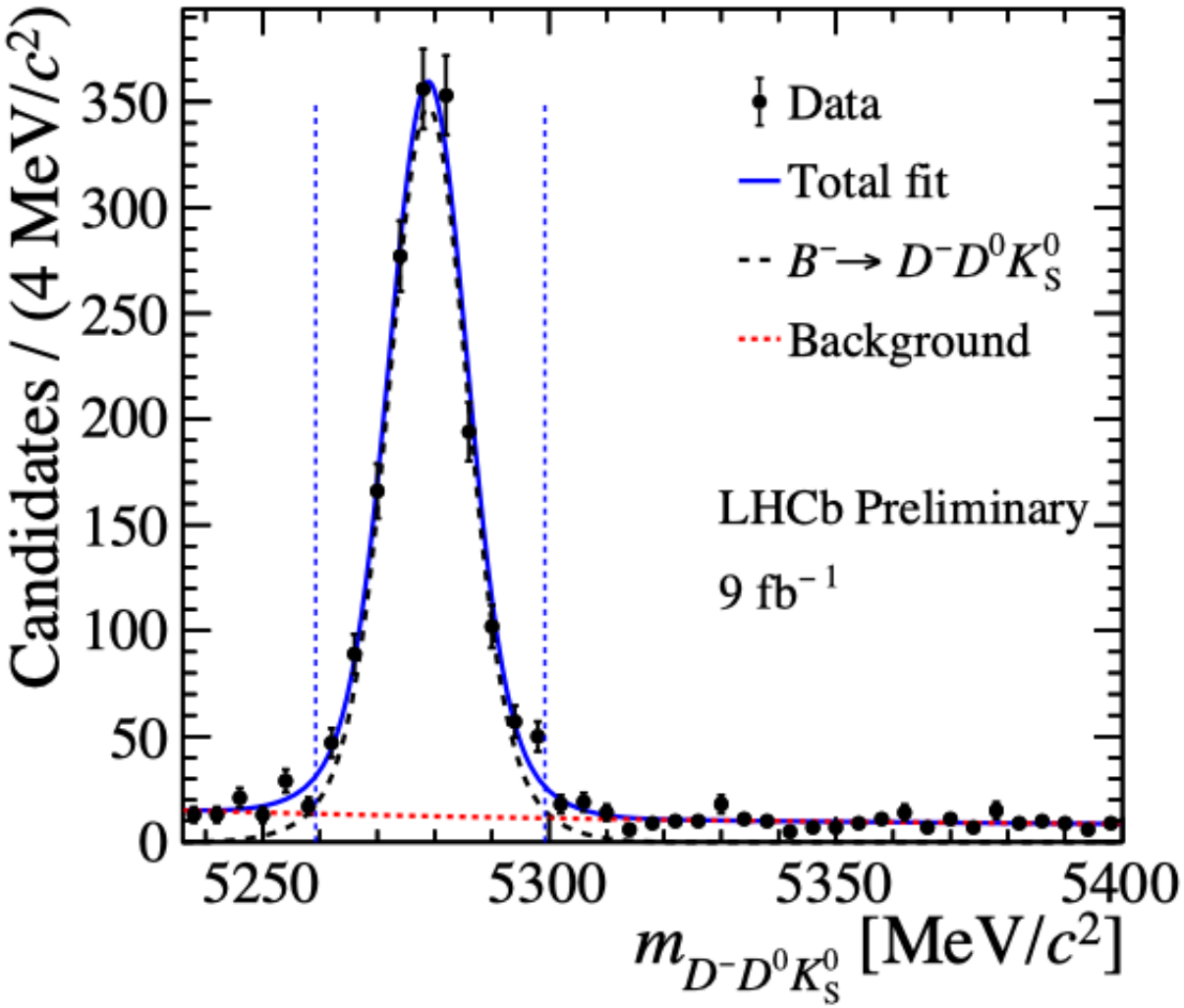
$B^+ \to D^+ X_{0,1}(2900), X_{0,1}(2900) \to \overline{D}^0 K^0$

Similar decay width based on compact tetraquark interpretation

Analysis Method

Signal extraction

- LHCb Run1+Run2 data
- Signal: 2 Gaussian function
  Background: exponential function
- Signal yield: 1540 ± 40
- Similar statistics compared with $B^+ \to D^+ D^- K^+$ decays



Amplitude construction

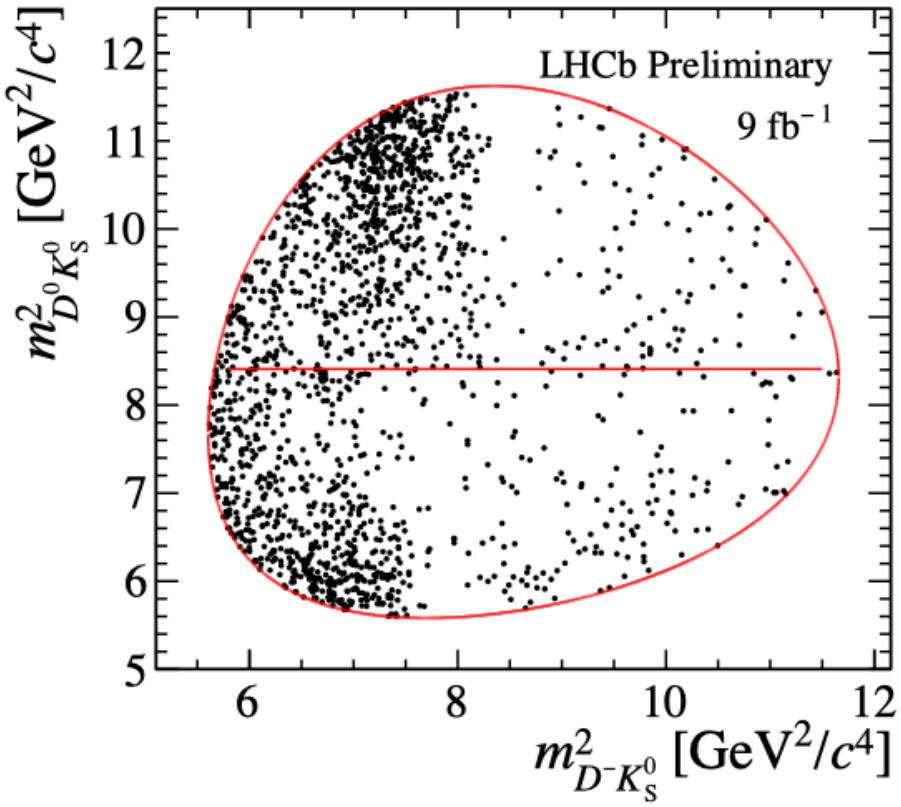
- Helicity formalism in model construction

- Potential resonances:
  - $D^+K_S^0$ final state: $D_{s1}^*(2700)^+, D_{s1}^*(2860)^+, D_{s2}^*(2573)^+, D_{s3}^*(2860)^+$
  - $\bar{D}^0K_S^0$ final state: potential $X_{0,1}(2900)$

  Relativistic Breit-Wigner lineshape, parameters fixed to PDG

- S-wave and P-wave non-resonant contribution

- coherently add different resonant or non-resonant contribution in amplitude



Analysis Results

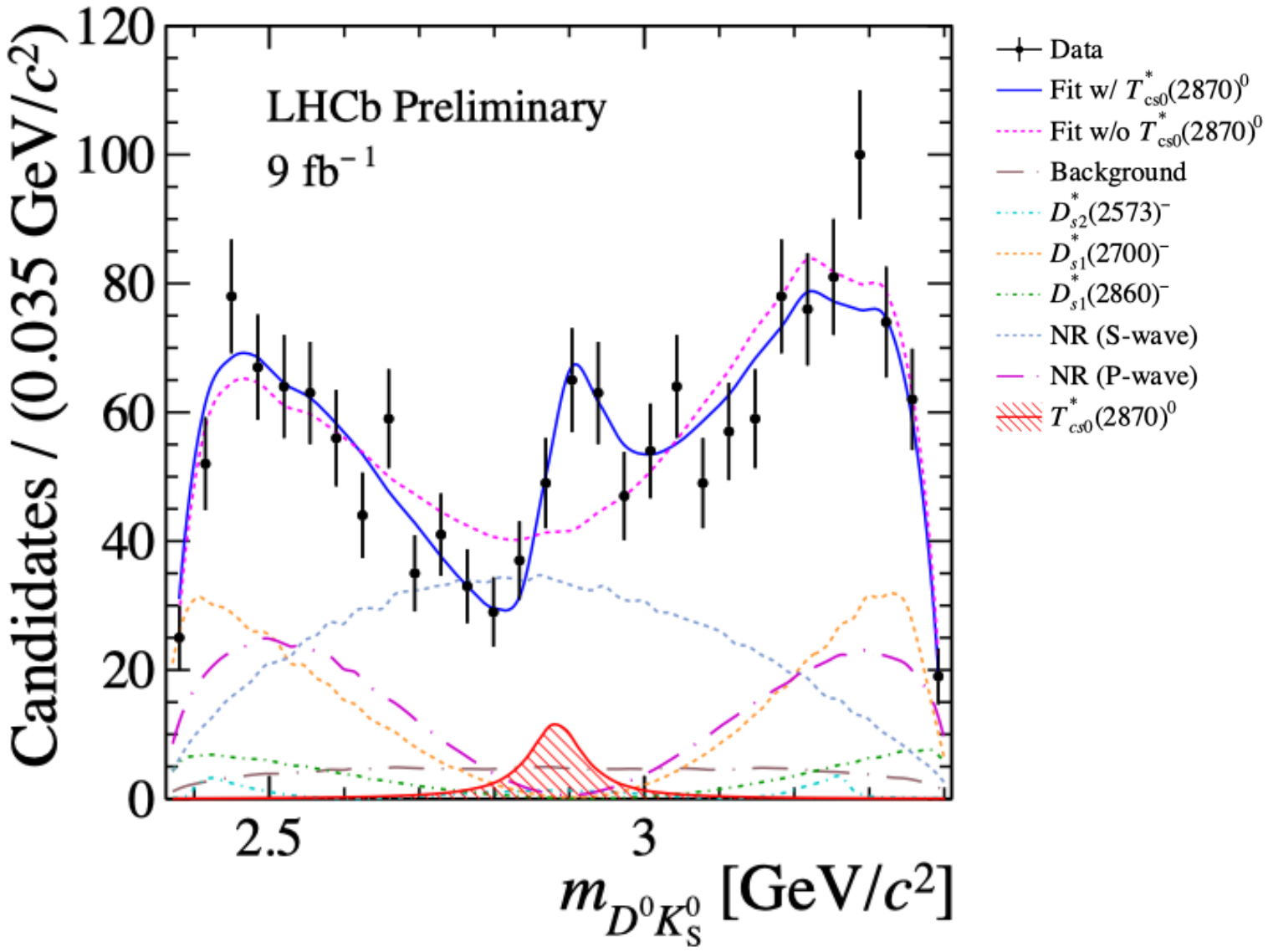
Amplitude fit result

- Significant $X_0(2900)$ signal (5.3σ)

$$M(T^{*0}_{cs0}) = 2883 \pm 11 \pm 7\,\mathrm{MeV}/c^2,$$
$$\Gamma(T^{*0}_{cs0}) = 87^{+22}_{-47} \pm 6\,\mathrm{MeV},$$

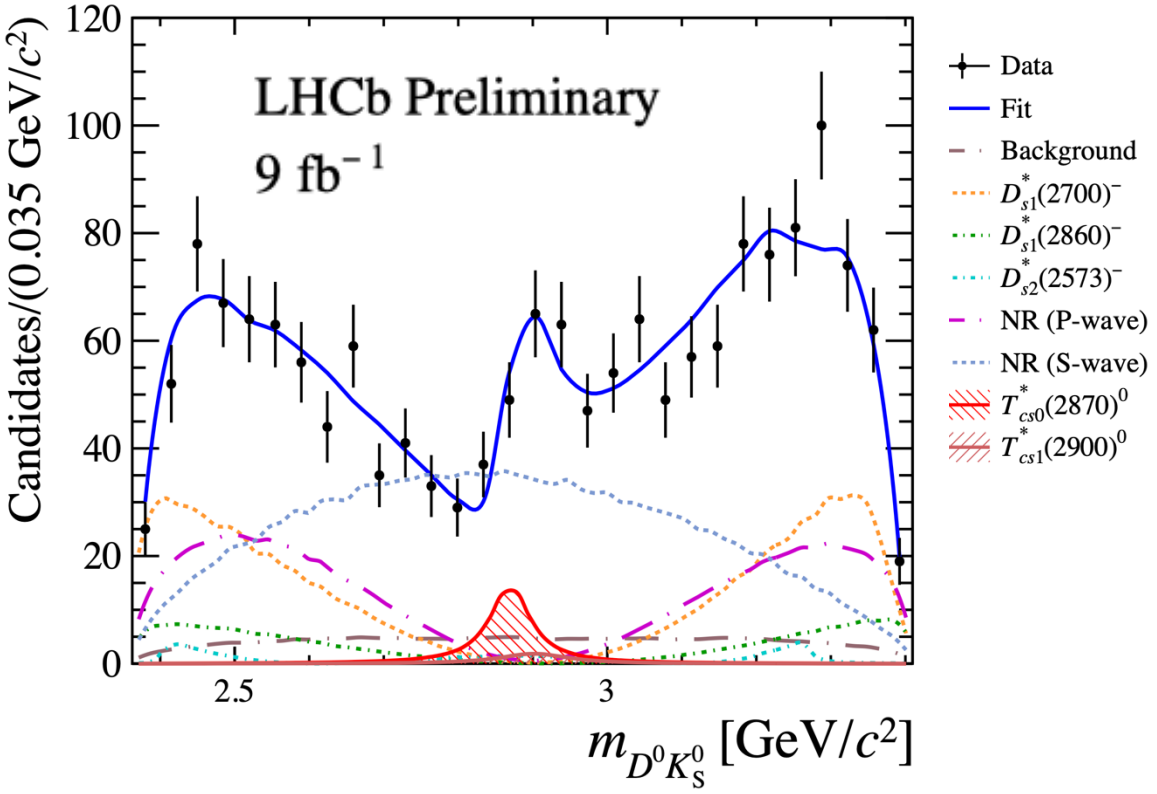
- Acceptable description to data even without $X_1(2900)$

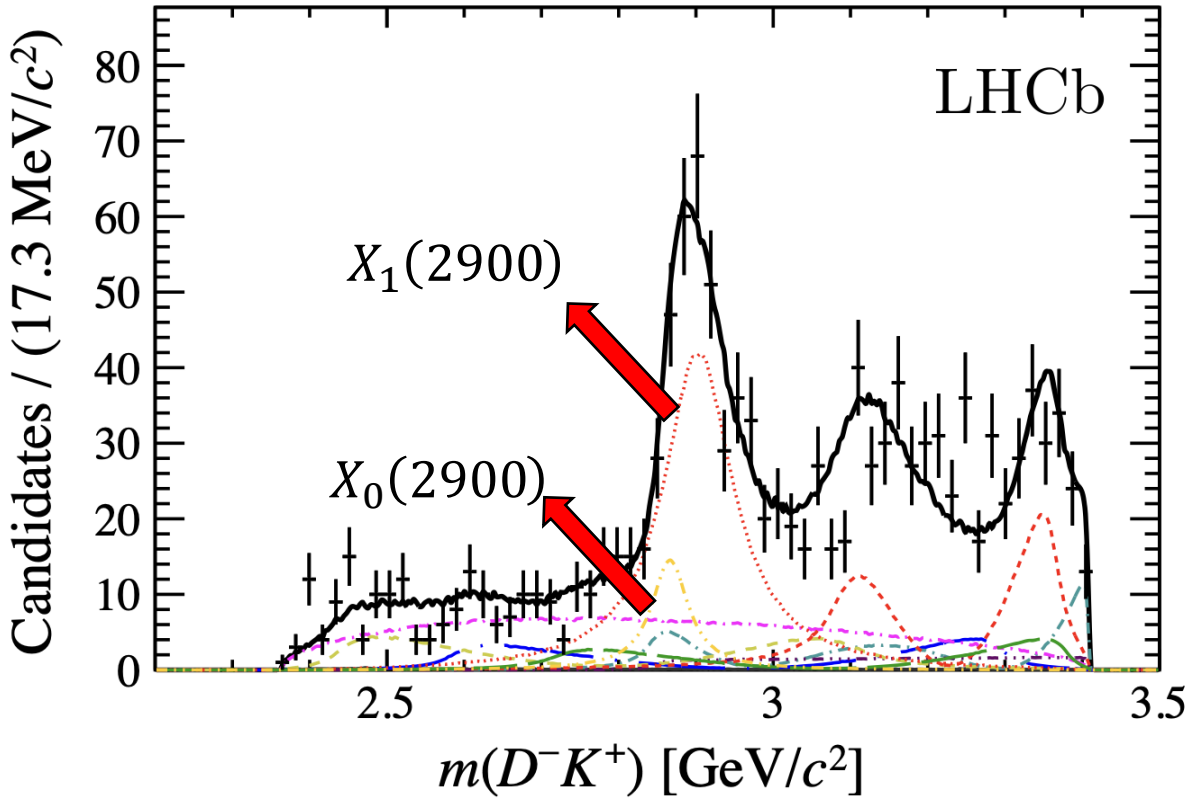
- Moments analysis agrees with the results above (See backup)



Comparison with previous results

An additional amplitude model:
Add $X_0(2900)$ and $X_1(2900)$ into amplitude with parameters constrained to PDG values





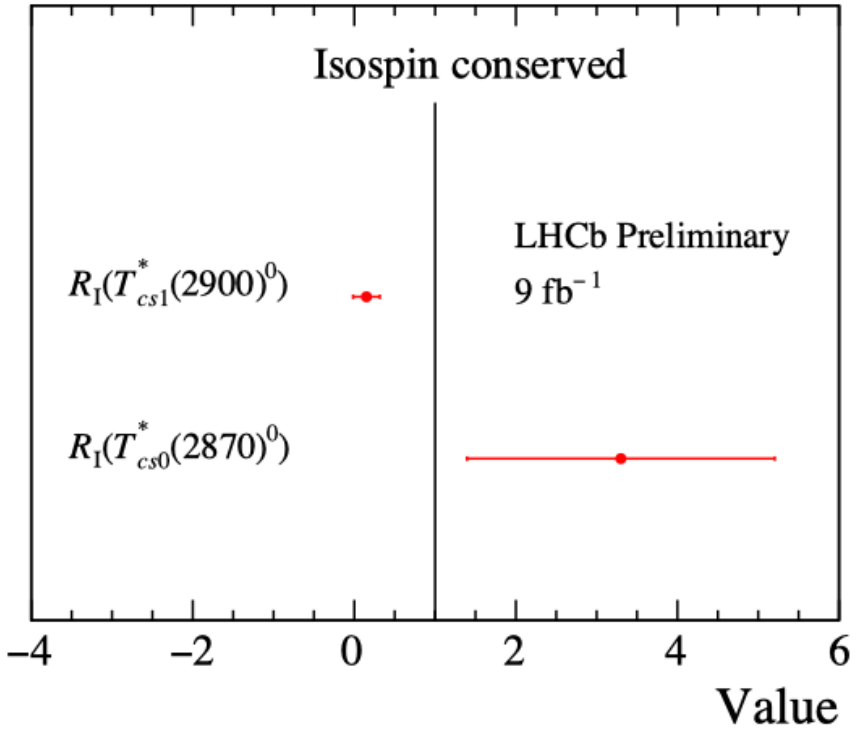
This analysis: $B^+ \to D^+\overline{D}^0K^0_S$

Previous results: $B^+ \to D^+D^-K^+$

Isospin analysis

Isospin symmetry requires:

$$R_I(X) = \frac{B(B^+ \to D^+\bar{D}^0K^0) \times FF(X \to \bar{D}^0K^0)}{B(B^+ \to D^+D^-K^+) \times FF(X \to D^-K^+)} \approx 1$$



Observable	Result			
$R_I(T^*_{cs0}(2870)^0)$	3.3	± 1.1	± 1.1	± 1.1
$R_I(T^*_{cs1}(2900)^0)$	0.15	± 0.15	± 0.05	± 0.05

For $X_1(2900)$, isospin symmetry is not well preserved

Summary

Summary

- As exotics with single heavy quark, the natures of $X_{0,1}(2900)$ are under heavy debate.

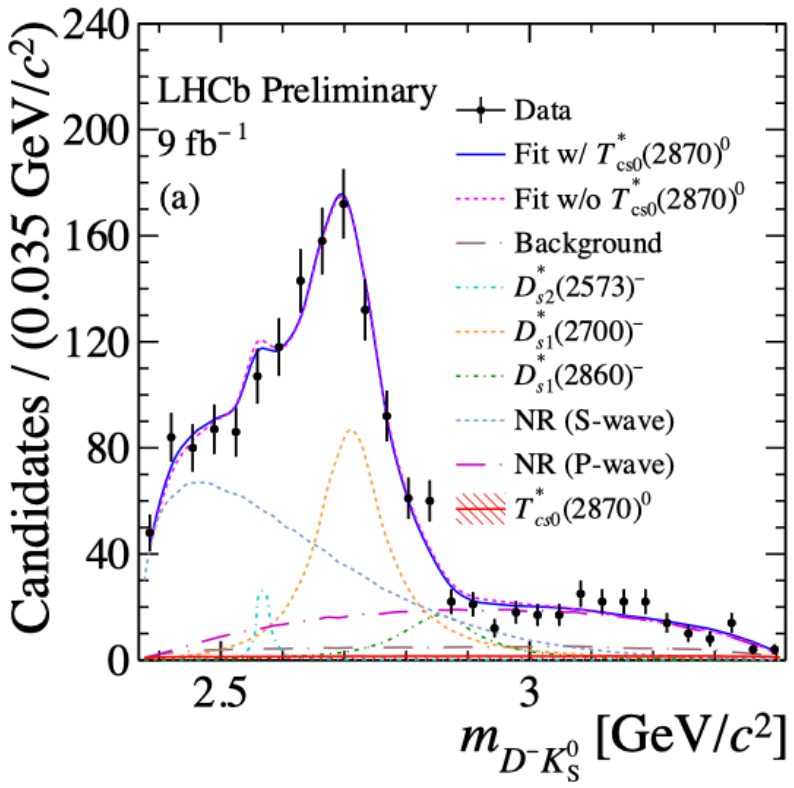
- Amplitude analysis of $B^+ \to D^+\bar{D}^0 K_S^0$ decays performed with LHCb data, $X_0(2900)$ is confirmed.

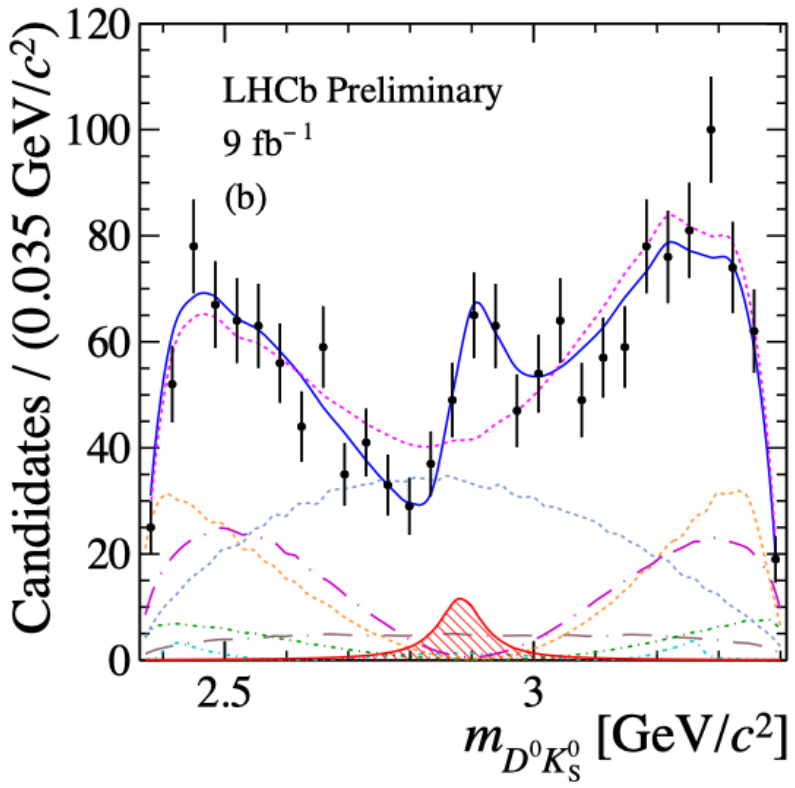
- Isospin symmetry is not well preserved in $X_1(2900)$ decays.

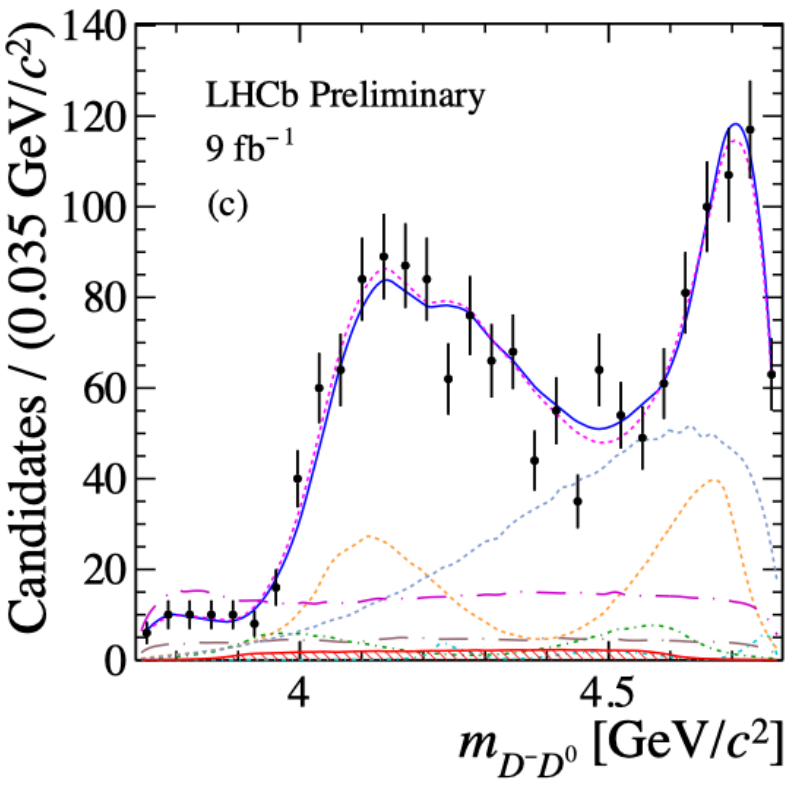
Thanks for listening!

Backup

Amplitude fit result







Angular distributions

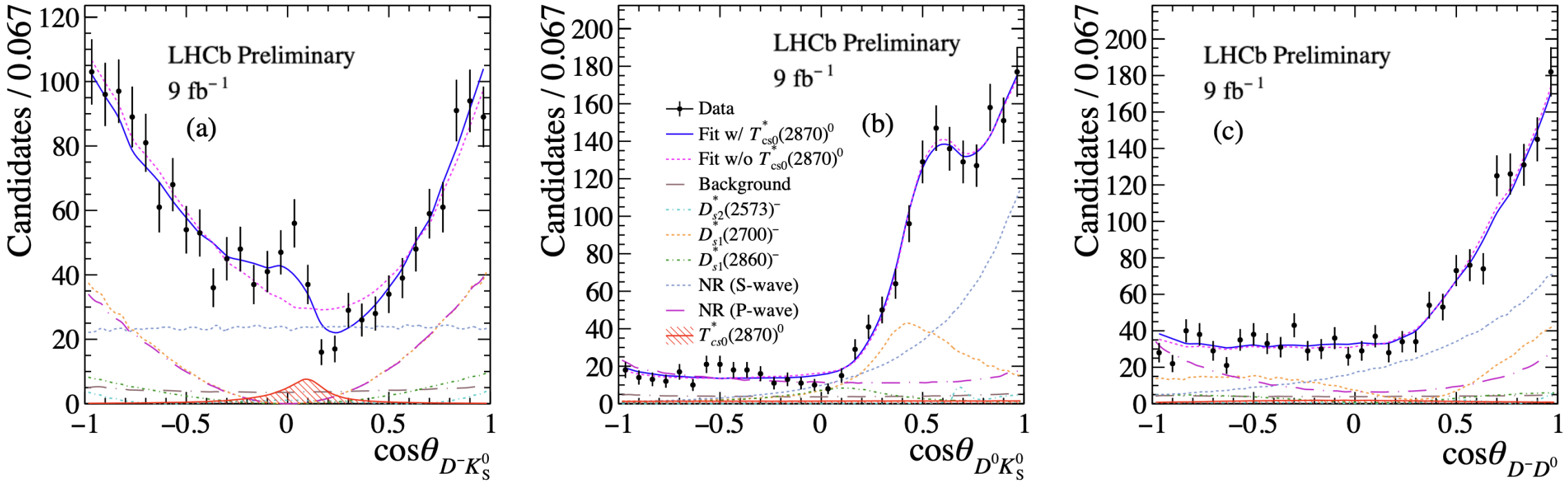


Figure S5: The (a) $\cos\theta_{D^-K_S^0}$, (b) $\cos\theta_{D^0K_S^0}$ and (c) $\cos\theta_{D^-D^0}$ distributions, overlaid by the fit projections (thick blue) with or (dashed magenta) without the $T^*_{cs0}(2870)^0$ state. The subcomponents correspond to the fit including the $T^*_{cs0}(2870)^0$ structure.

Moments analysis

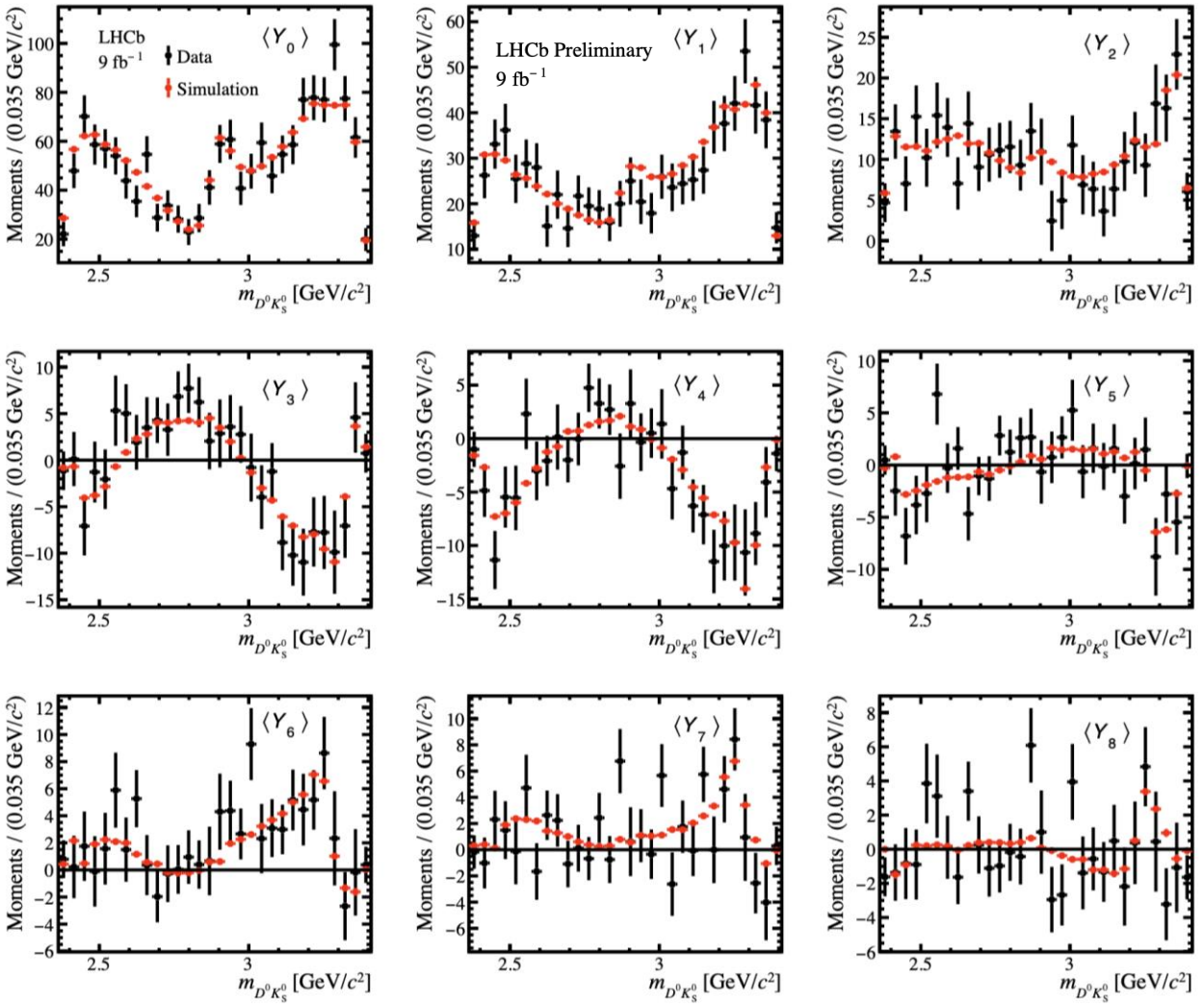


Figure S2: Distributions of the first nine moments as a function of $m_{D^0K^0_S}$, for data (black dot) and for the sample generated based on the nominal amplitude model (red dot).