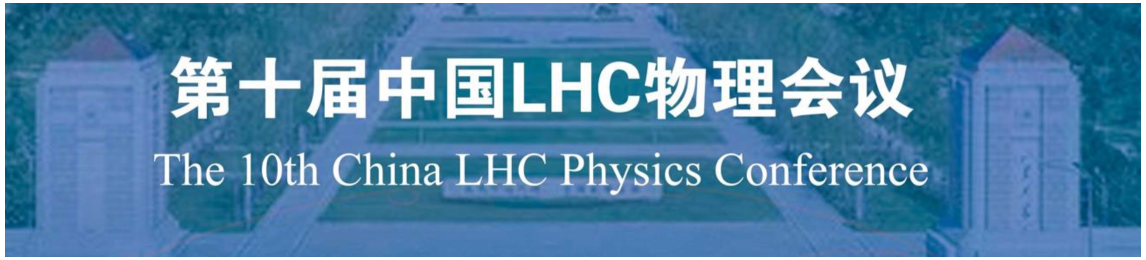

Amplitude analysis of $B^+ \to D^+ \overline{D}^0 K_S^0$ decays

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Outline

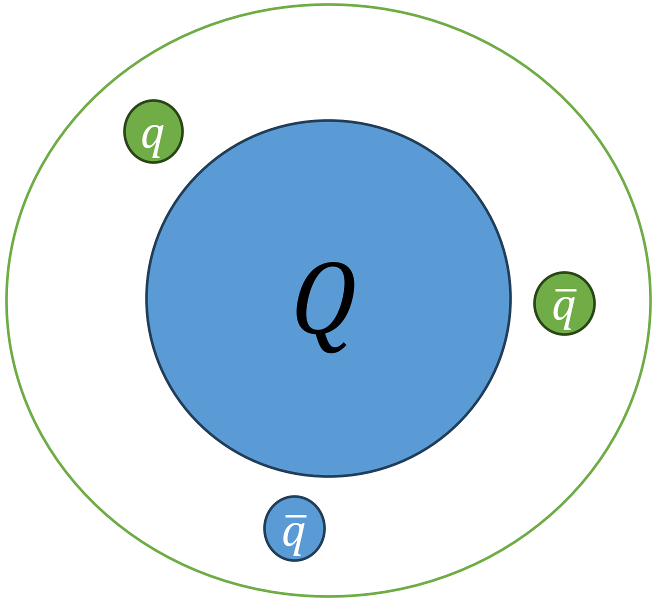
- Introduction
- Analysis Method
- Analysis Results
- Summary

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:

- $T_{b\bar{s}}(5568)^+$ $(b\bar{s}u\bar{d})$ PhysRevD.97.092004
- $T^*_{cs0}(2870)^0, T^*_{cs1}(2900)^0$ $(\bar{c}\bar{s}ud)$ PhysRevD.102.112003

$T^*_{cs0}(2870)^0$ & $T^*_{cs1}(2900)^0$

- Discovered by LHCb in $B^+ \to D^+ D^- K^+$ decays ($D^- K^+$ final state)

Charge conjugate implied

- Minimal quark content ($\bar{c}\bar{s}ud$)

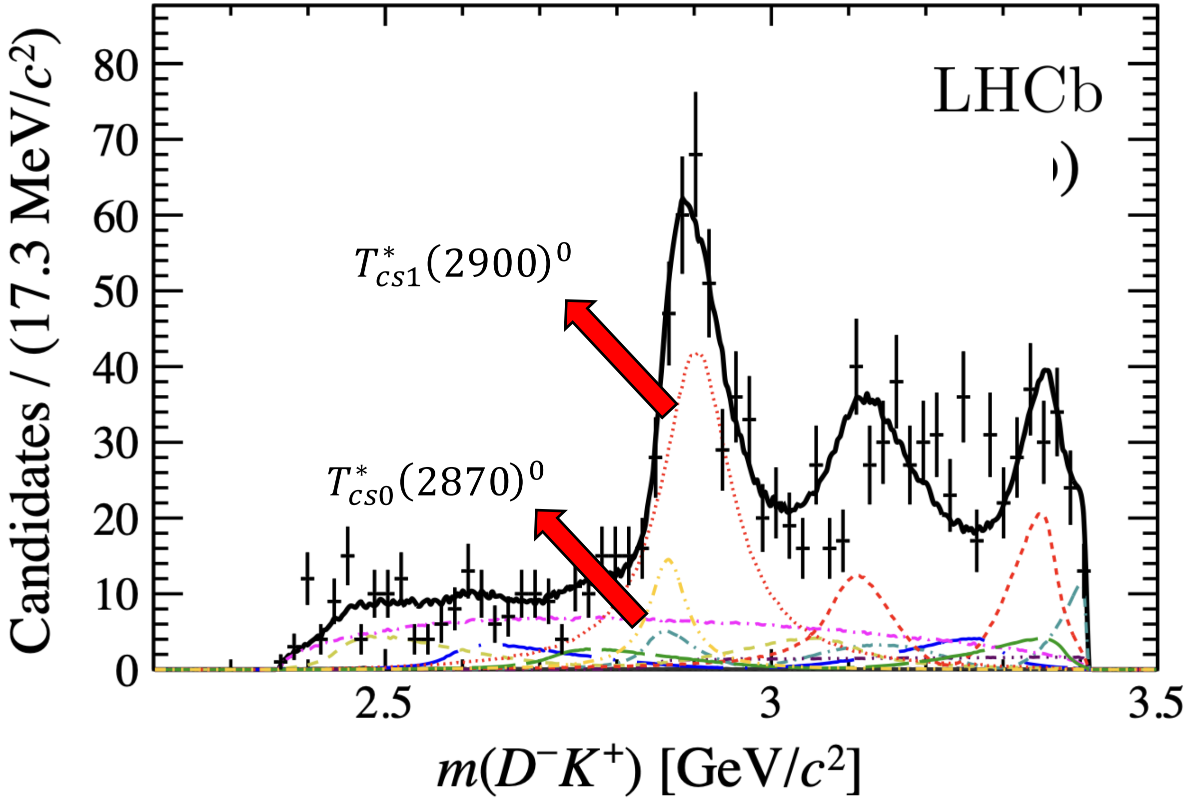
Resonance	Mass (GeV/c^2)	Width (MeV)
$T^*_{cs0}(2870)^0$	$2.866 \pm 0.007 \pm 0.002$	$57 \pm 12 \pm 4$
$T^*_{cs1}(2900)^0$	$2.904 \pm 0.005 \pm 0.001$	$110 \pm 11 \pm 4$

- Interesting feature:

$T^*_{cs1}(2900)^0$ wider than $T^*_{cs0}(2870)^0$

↓

Different nature

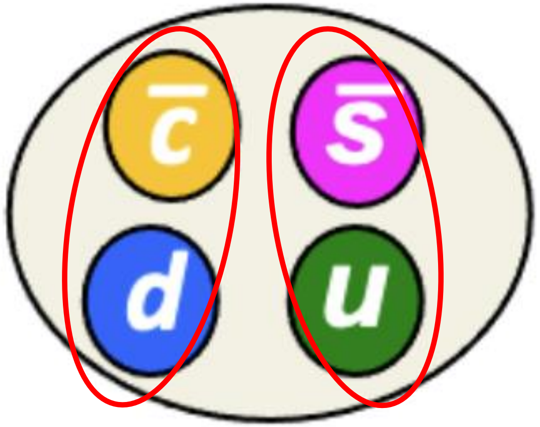


PhysRevD.102.112003

Theoretical interpretations

$T^*_{cs0}(2870)^0\ (0^+)$

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



$T^*_{cs1}(2900)^0\ (1^-)$

- Compact tetraquark

Isospin eigenstate

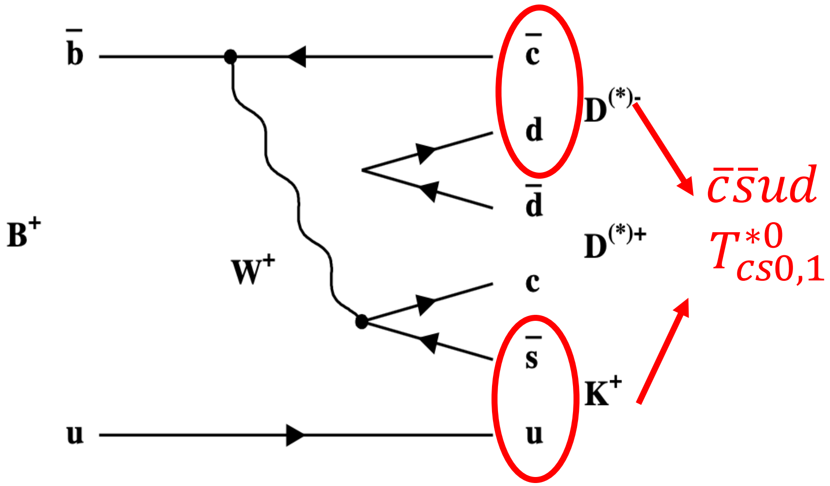
- P-wave D^*K^* hadron molecule with dipole structure
- Kinematical effects (cusp, TS)

Related to potential isospin breaking

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

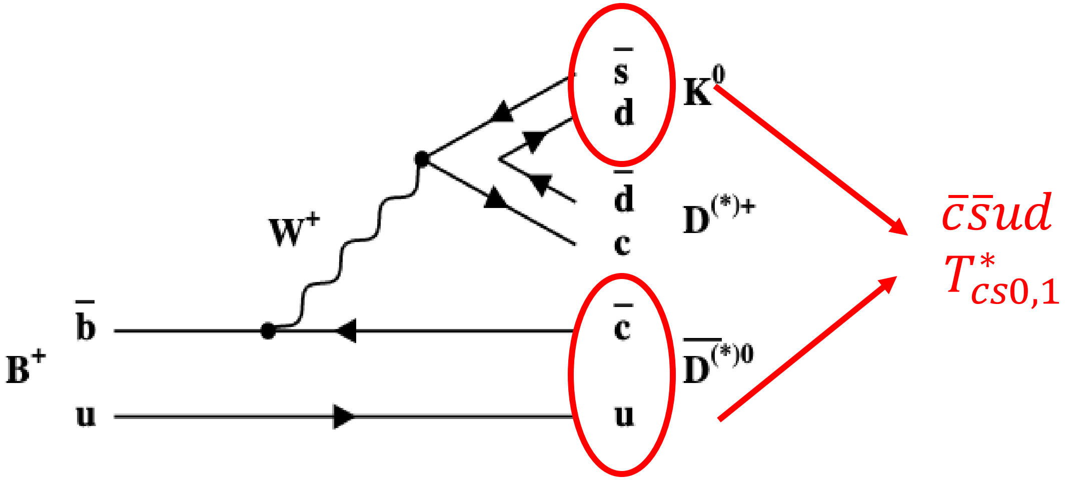
Discriminate different interpretations via isospin symmetry

$B^+ \to D^+ D^- K^+$



$B^+ \to D^+ T^{*0}_{cs0,1}, T^{*0}_{cs0,1} \to D^- K^+$

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



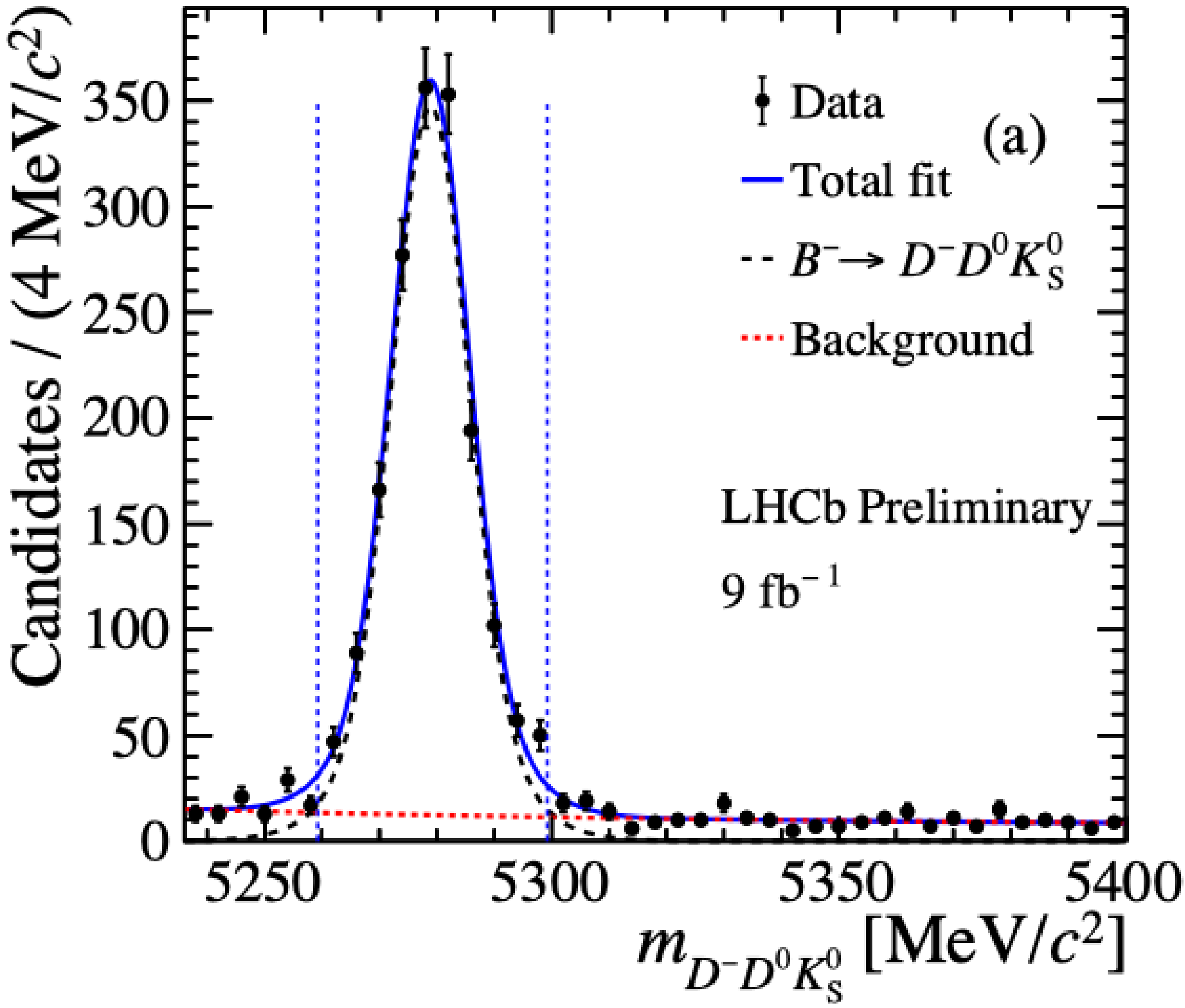
$B^+ \to D^+ T^{*0}_{cs0,1}, T^{*0}_{cs0,1} \to \overline{D}^0 K^0$

Similar decay widths 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



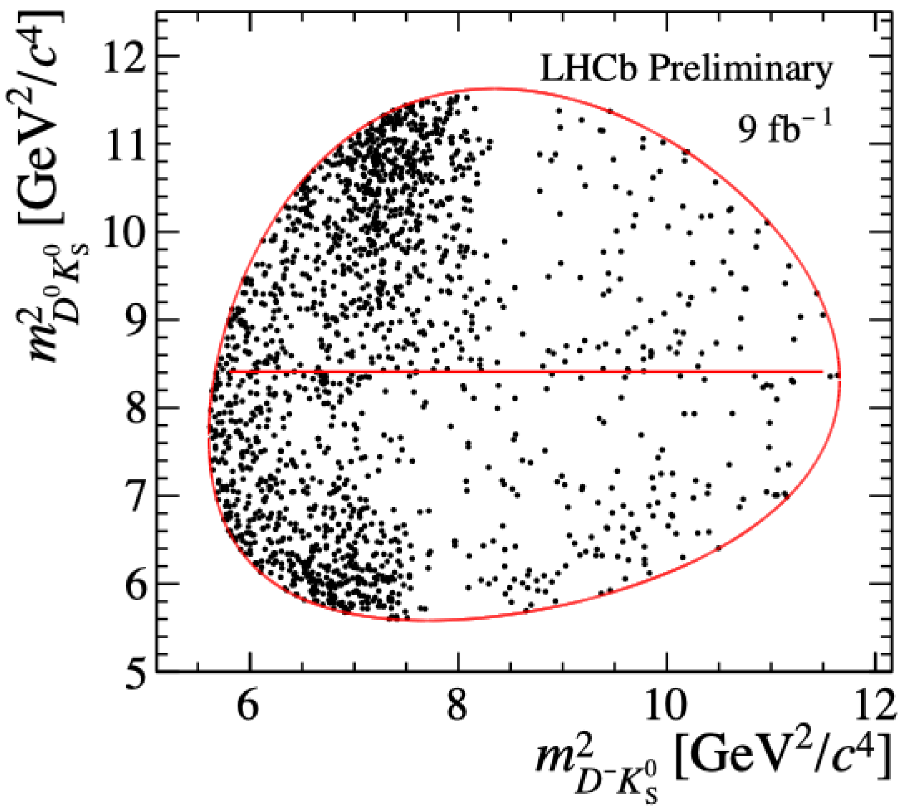
Amplitude construction

- Helicity formalism in model construction

- Potential resonances:
  - $D^+K_S^0$ final state: $D_{s1}^*(2700)^+, D_{s1}^*(2860)^+, D_{s2}^*(2573)^+, D_{s3}^*(2860)^+$
    Relativistic Breit-Wigner lineshape, parameters fixed to PDG
  - $\overline{D}^0K_S^0$ final state: potential $T_{cs0}^*(2870)^0, T_{cs1}^*(2900)^0$

- S-wave and P-wave $\overline{D}^0K_S^0$ non-resonance

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



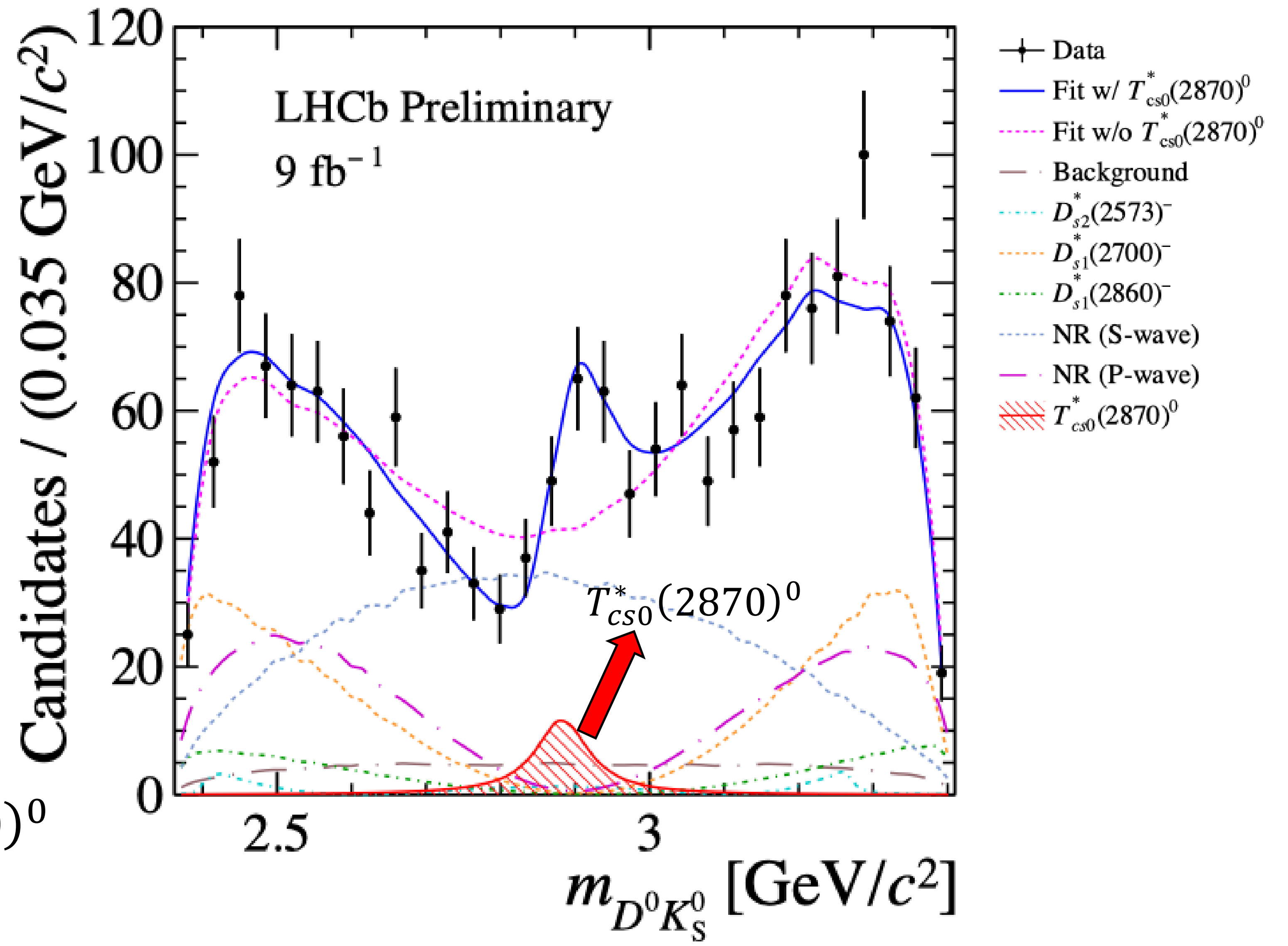
Analysis Results

Amplitude fit result

- Significant $T_{cs0}^*(2870)^0$ signal (5.3σ)

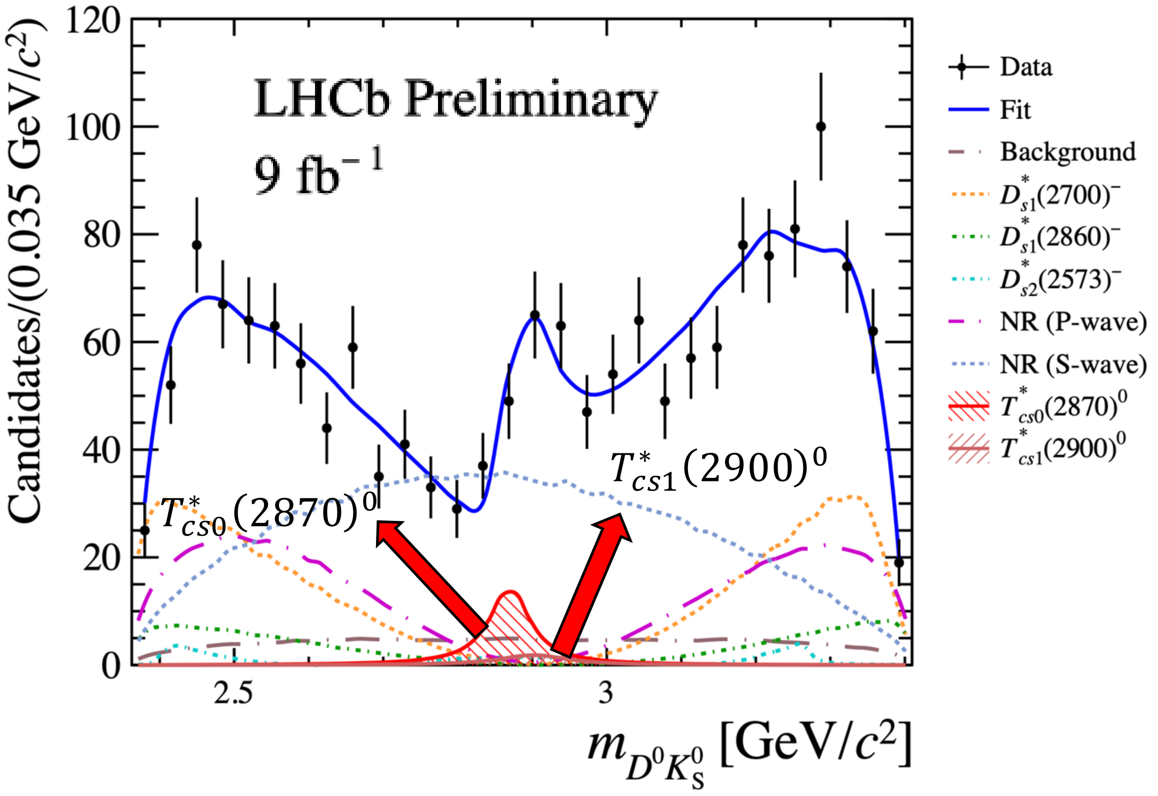
$$M(T_{cs0}^{*0}) = 2883 \pm 11 \pm 7\,\text{MeV}/c^2,$$
$$\Gamma(T_{cs0}^{*0}) = 87^{+22}_{-47} \pm 6\,\text{MeV},$$

- Acceptable description to data even without $T_{cs1}^*(2900)^0$
- Moments analysis agrees with the results above (See backup)
- Bad fit quality with only $T_{cs1}^*(2900)^0$ and no $T_{cs0}^*(2870)^0$

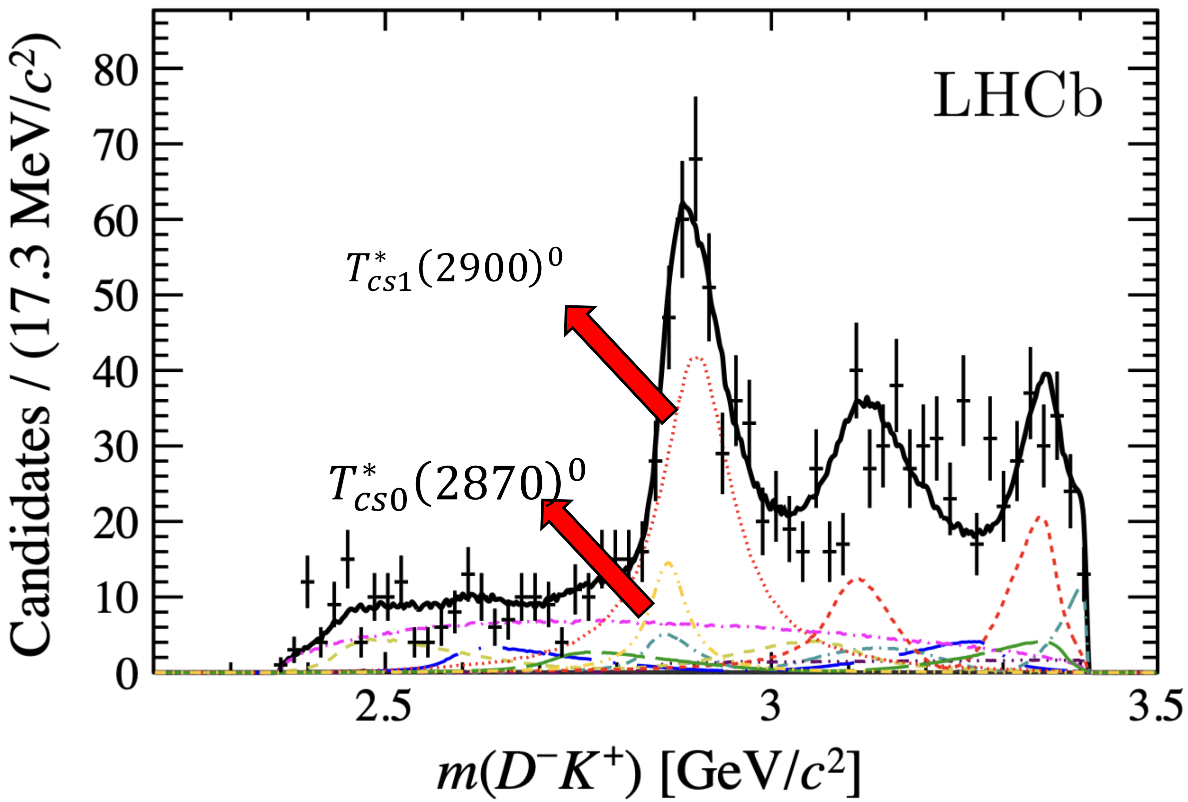


Comparison with previous results

An additional amplitude model:
Add $T^*_{cs0}(2870)^0$ and $T^*_{cs1}(2900)^0$ into amplitude with parameters constrained to PDG values



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

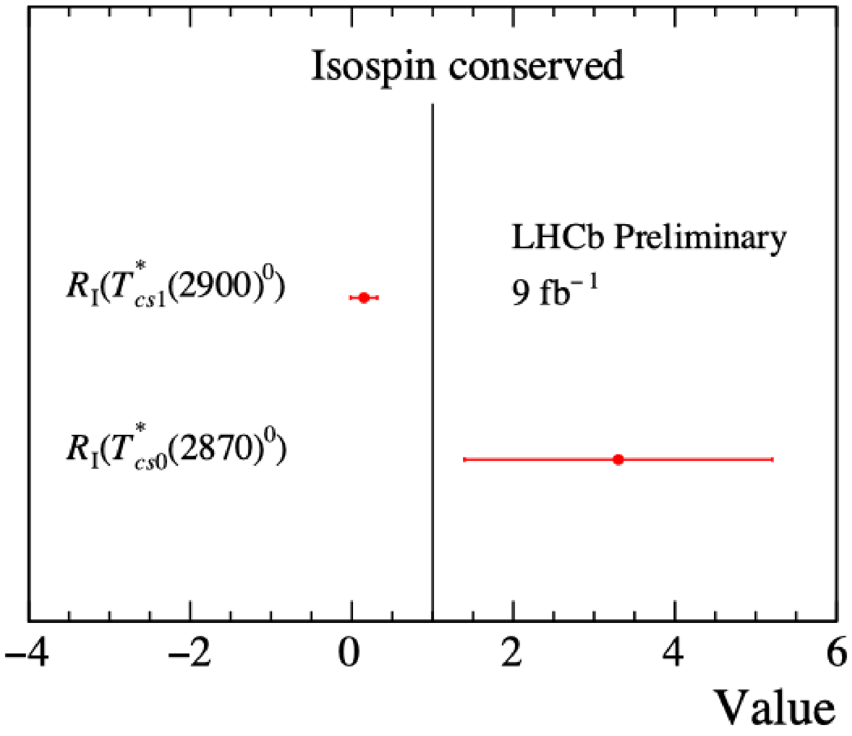


Previous results: $B^+ \to D^+D^-K^+$

Isospin analysis

Isospin symmetry requires:

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



Observable	Result			
$R_{\rm I}(T^*_{cs0}(2870)^0)$	3.3	$\pm\,1.1$	$\pm\,1.1$	$\pm\,1.1$
$R_{\rm I}(T^*_{cs1}(2900)^0)$	0.15	$\pm\,0.15$	$\pm\,0.05$	$\pm\,0.05$

For $T^*_{cs0}(2870)^0$, approximately isospin symmetry

For $T^*_{cs1}(2900)^0$, isospin symmetry is not well preserved

Summary

Summary

- As exotics with single heavy quark, the natures of $T_{cs0}^{*}(2870)^{0}$and $T_{cs1}^{*}(2900)^{0}$ are under heavy debate.

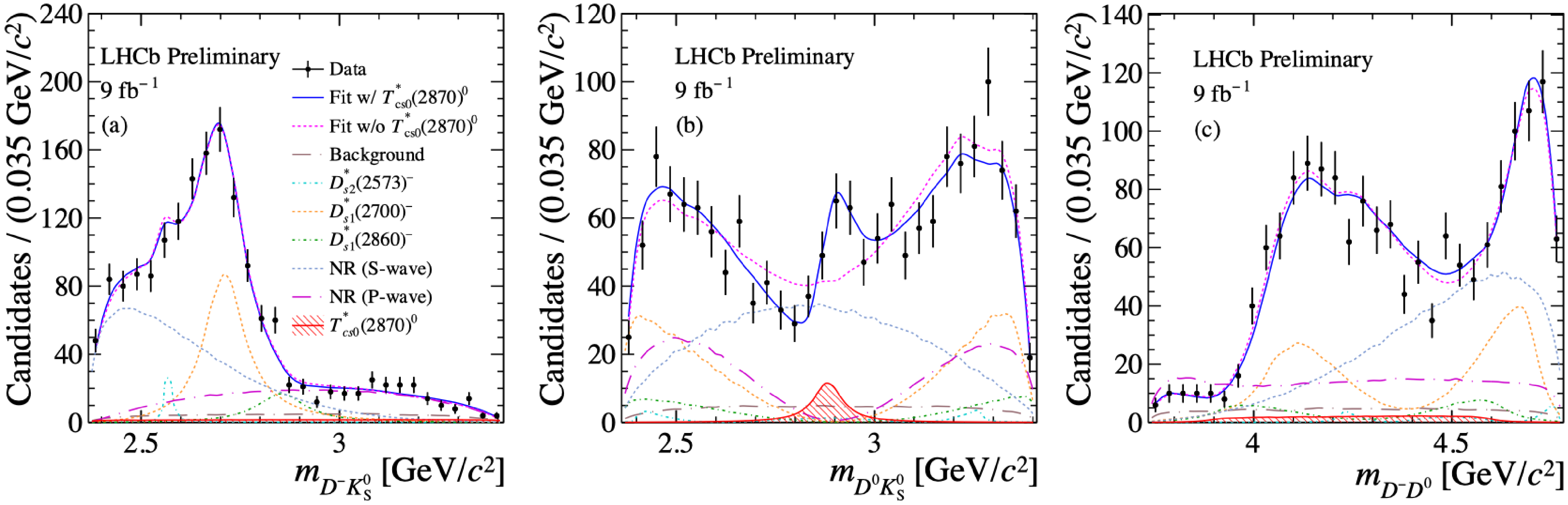
- Amplitude analysis of $B^{+} \to D^{+}\overline{D}^{0}K_{S}^{0}$ decays performed with LHCb data, $T_{cs0}^{*}(2870)^{0}$ is confirmed, while $T_{cs1}^{*}(2900)^{0}$ is not significant.

- Isospin symmetry is not well preserved in $T_{cs1}^{*}(2900)^{0}$ decays.

Thanks for listening!

Backup

Amplitude fit result



Angular distributions

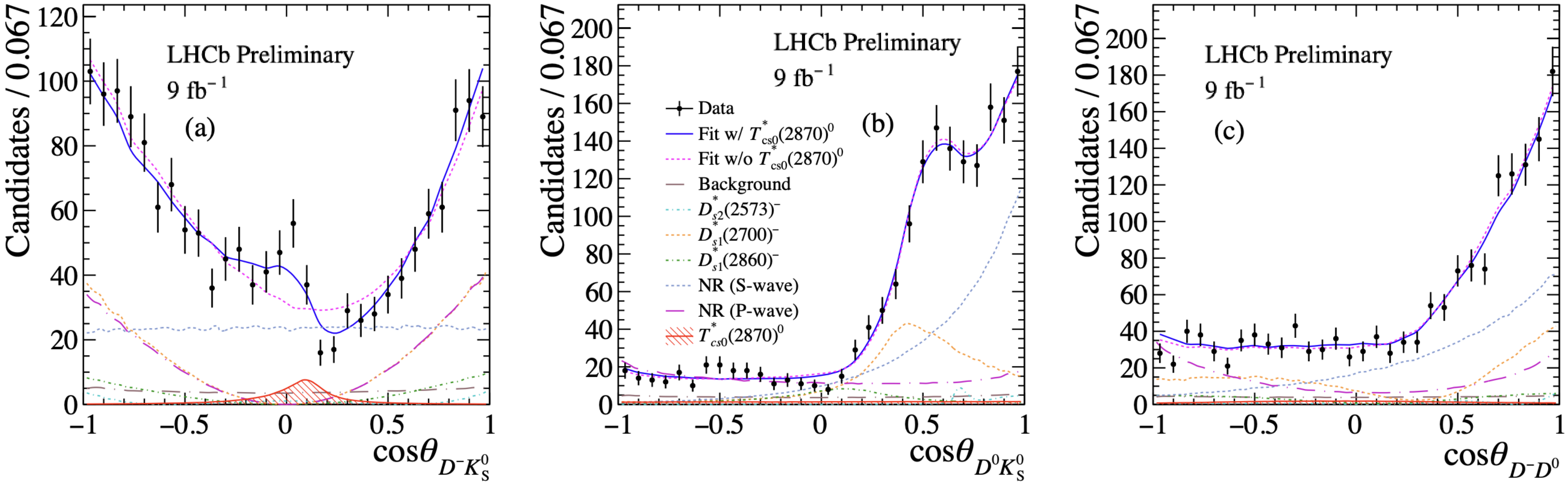


Figure S5: The (a) $\cos\theta_{D^-K^0_S}$, (b) $\cos\theta_{D^0K^0_S}$ and (c) $\cos\theta_{D^-D^0}$ distributions, overlaid by the fit projections (thick blue) with or (dashed magenta) without the $T^*_{cs0}(2870)^0$ state. The subcomponents correspond to the fit including the $T^*_{cs0}(2870)^0$ structure.

Moments analysis

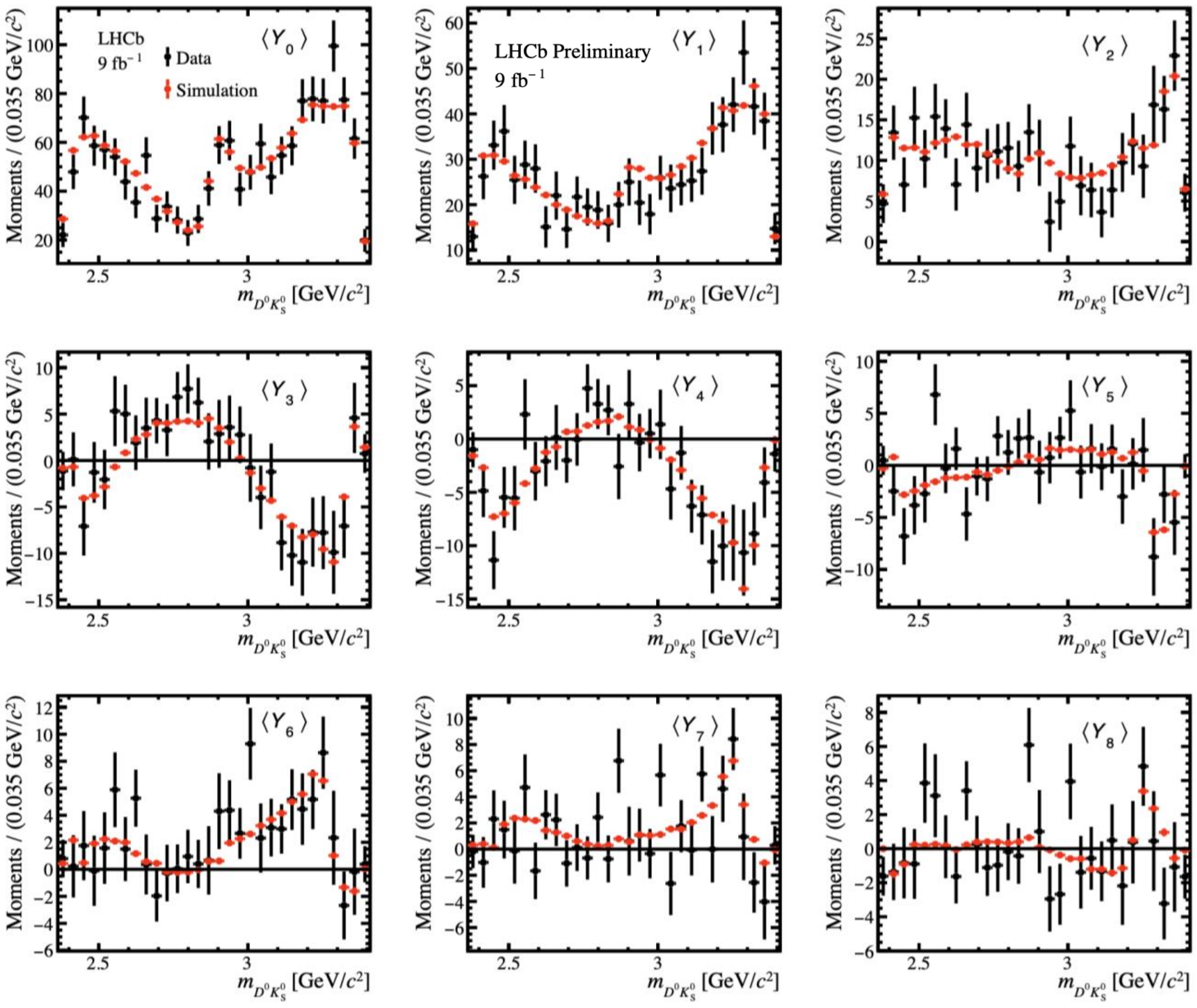


Figure S2: Distributions of the first nine moments as a function of $m_{D^0 K_S^0}$, for data (black dot) and for the sample generated based on the nominal amplitude model (red dot).