The contributions of $\rho \to \omega\pi$ *in* $B \to \overline{D}^{(*)}\omega\pi$ *decays*

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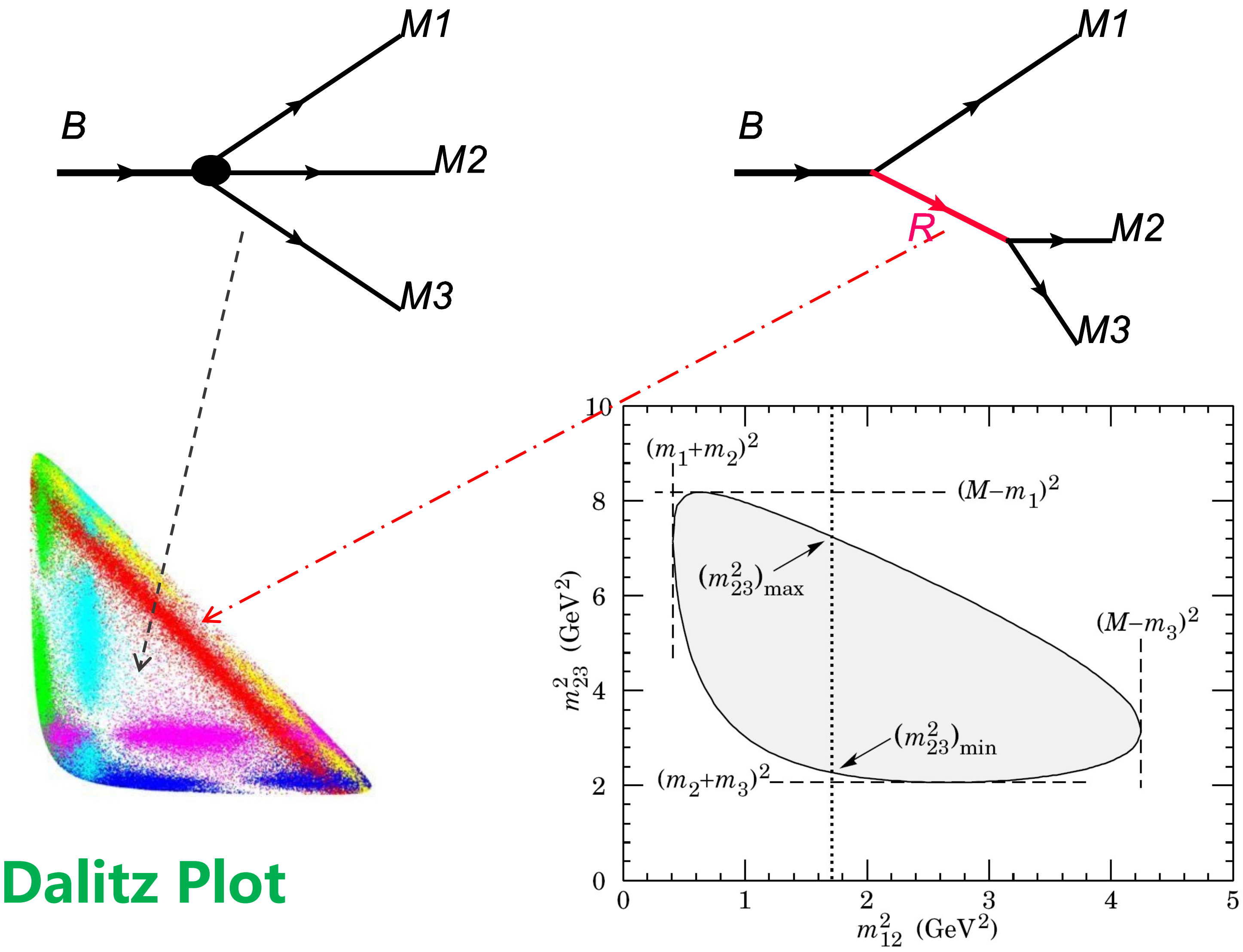
Based on JHEP 01 (2024) 047 with Yu-Shan Ren & Ai-Jun Ma

Outline

- A brief introduction for 3-body B meson decays
- Contributions of the $\rho(770, 1450) \to \omega\pi$ in $B \to \bar{D}^{(*)}\omega\pi$
- Results and discussions
- Summary

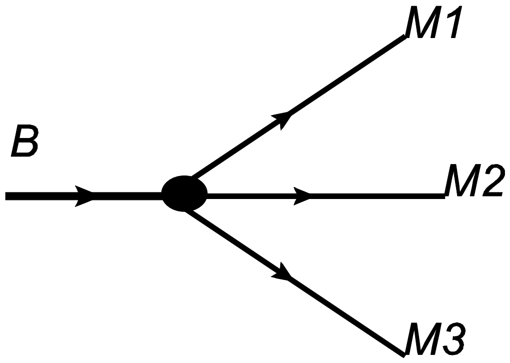
A brief introduction for 3-body B meson decays

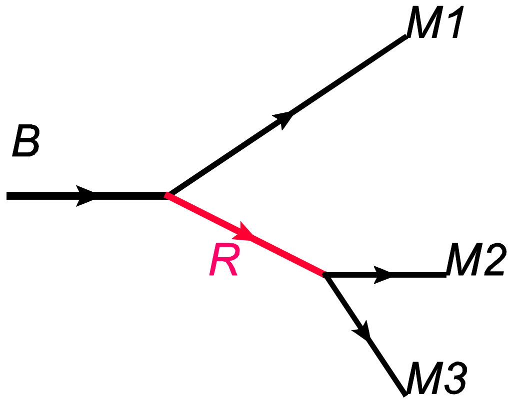
$B \to M1\ M2\ M3$



Dalitz Plot

$B \to M1\ M2\ M3$





The weak effective Hamiltonian:

1.

$$\mathcal{H}_{\text{eff}} = \frac{G_F}{\sqrt{2}} \Big\{ V_{ub} V_{uq}^* [C_1(\mu) Q_1^u(\mu) + C_2(\mu) Q_2^u(\mu)] - V_{tb} V_{tq}^* \Big[\sum_{i=3}^{10} C_i(\mu) Q_i(\mu) \Big] \Big\} + \text{H.c.}, \qquad (2)$$

where $q = d, s$. The functions Q_i $(i = 1, \ldots, 10)$ are the local four-quark operators:

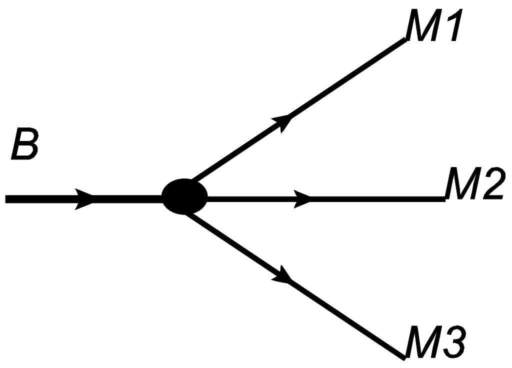
The total amplitude within isobar approach:

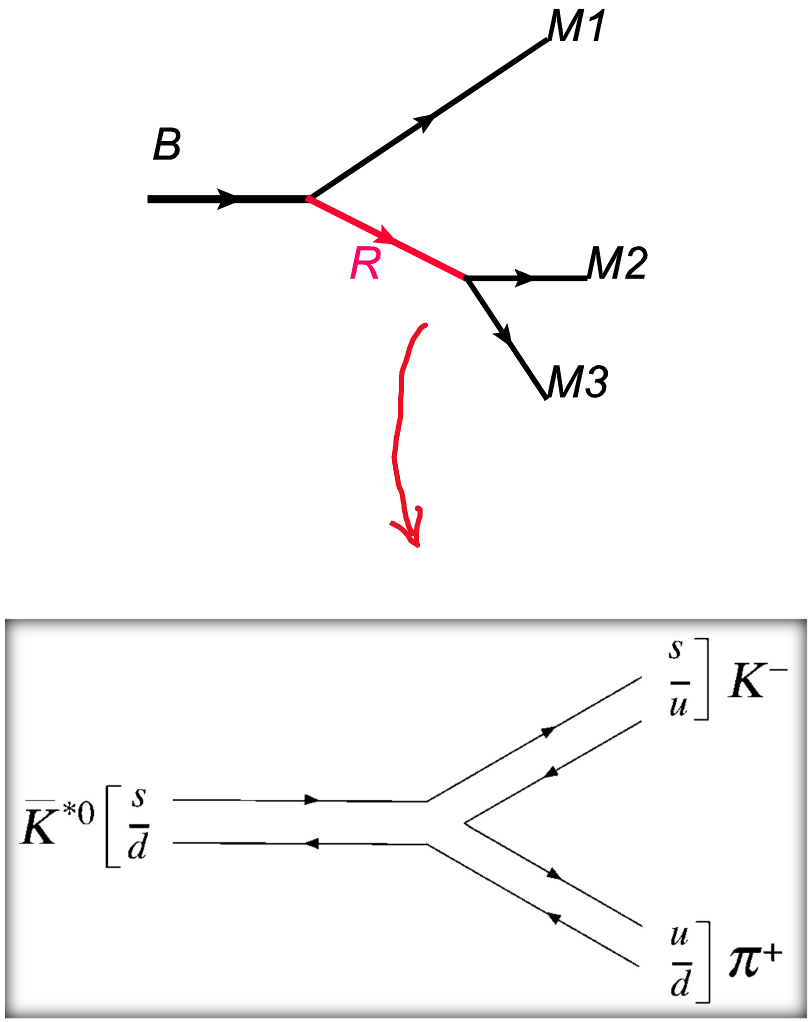
2.

$$\mathcal{A}_{total} = \sum_i \mathcal{A}_{NR}^i + \sum_j \mathcal{A}_R^j$$

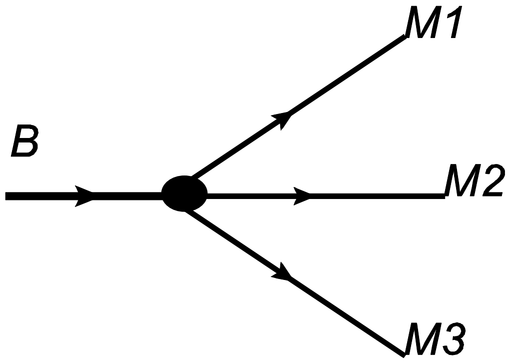
A brief introduction for 3-body B meson decays

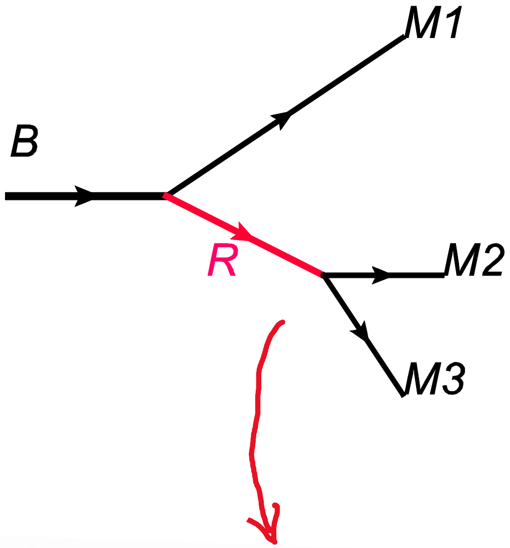
$$B^+ \to K^+ K^- \pi^+$$



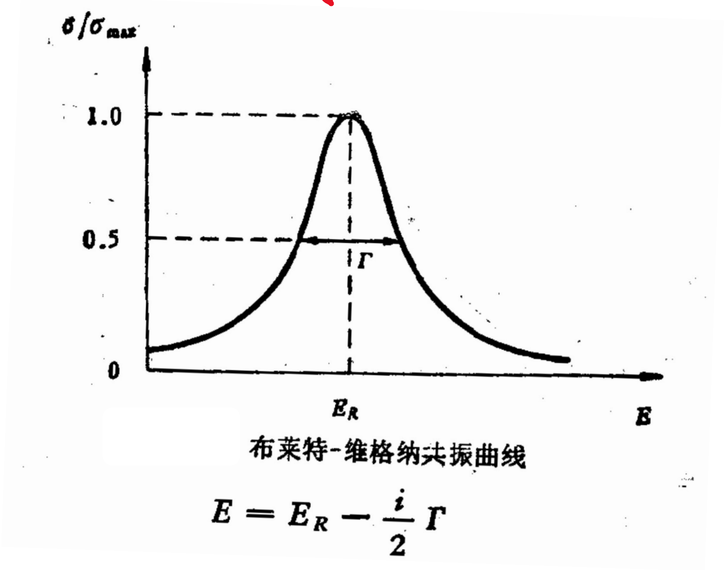


$$B^+ \to K^+ K^- \pi^+$$

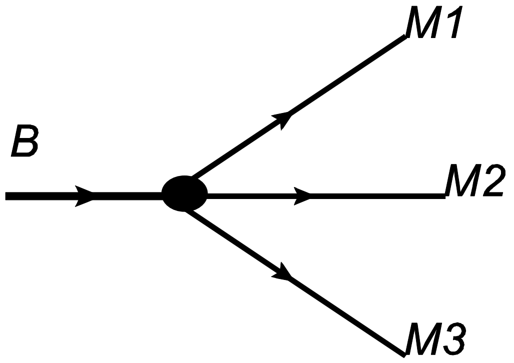


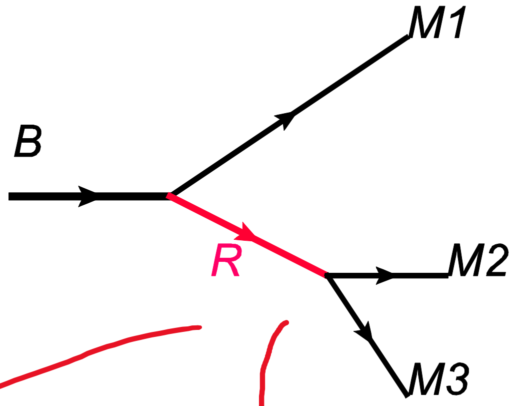


$$\mathrm{BW}_R = \frac{m_R^2}{m_R^2 - s - i m_R \Gamma_R(s)},$$



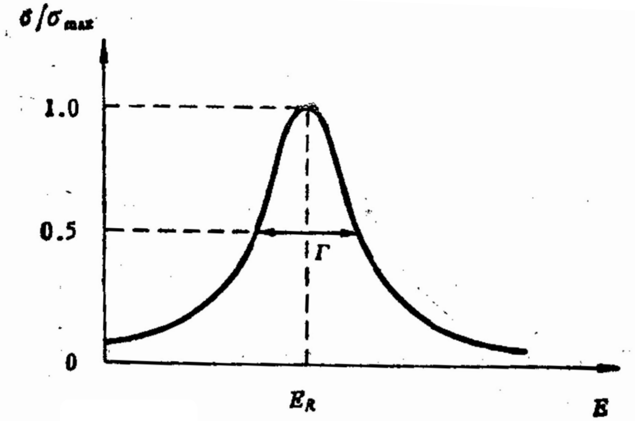
$B^+ \to K^+ K^- \pi^+$





$\rho(770)^0 \to K^+ K^-$?

$$\mathrm{BW}_R = \frac{m_R^2}{m_R^2 - s - i m_R \Gamma_R(s)},$$



布莱特-维格纳共振曲线

$E = E_R - \frac{i}{2}\Gamma$

A brief introduction for 3-body B meson decays

PHYSICAL REVIEW D VOLUME 15, NUMBER 11 1 JUNE 1977

High-statistics study of the reactions $\pi^- p \to K^- K^+ n$ and $\pi^+ n \to K^- K^+ p$ at 6 GeV/c*

A. J. Pawlicki, D. S. Ayres, D. Cohen, R. Diebold, S. L. Kramer, and A. B. Wicklund
Argonne National Laboratory, Argonne, Illinois 60439

(Received 23 December 1976; revised manuscript received 15 March 1977)

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BW-Tail

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Further study of the $I = 1 K\bar{K}$ structure near threshold

A. Astier, J. Cohen-Ganouna, M. Della Negra, B. Maréchal, L. Montanet, M. Tomas †, M. Baubillier, J. Duboc

3) The $I = 1$ $K\bar{K}$ channel is dominated, at threshold, by a virtual bound state resonance

Page-4

PHYSICAL REVIEW D **94,** 072001 (2016)

Amplitude analysis of $B^- \to D^+\pi^-\pi^-$ decays

R. Aaij *et al.*[*]
(LHCb Collaboration)

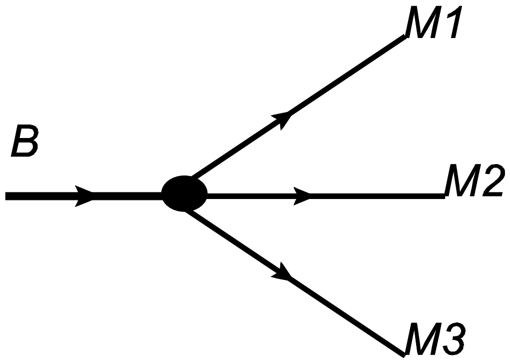
(Received 4 August 2016; published 5 October 2016)

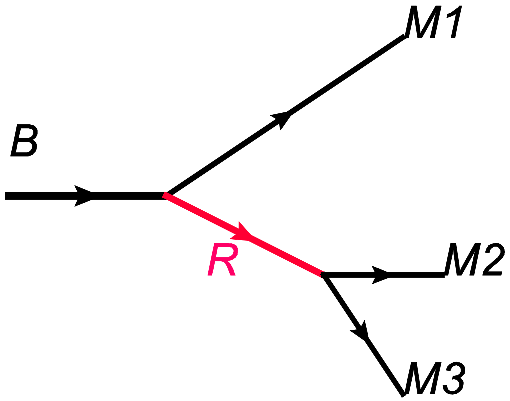
虚 (共振态粒子的) 贡献

Contribution	Fit fraction (%)
$D_2^*(2460)^0$	35.7 ± 0.6
$D_1^*(2680)^0$	8.3 ± 0.6
$D_3^*(2760)^0$	1.0 ± 0.1
$D_2^*(3000)^0$	0.23 ± 0.07
$D_v^*(2007)^0$	10.8 ± 0.7
B_v^{*0}	2.7 ± 1.0
Total S wave	57.0 ± 0.8
Total fit fraction	115.7

A brief introduction for 3-body B meson decays

$B \to M1\ M2\ M3$





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Contributions of the $\rho(770, 1450) \to \omega\pi$ in $B \to \bar{D}^{(*)}\omega\pi$

Motivations:

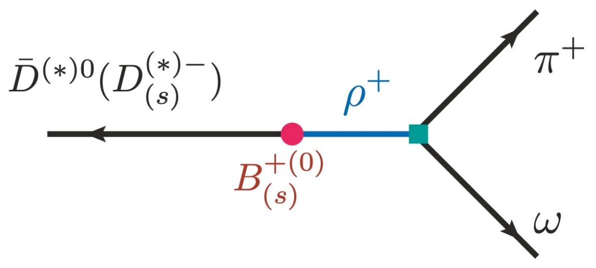
- $B^+ \to \bar{D}^{(*)0}\omega\pi^+$ and $B^0 \to D^{(*)-}\omega\pi^+$ have been measured but without any theoretical predictions [PRD64-092001, PRD74-012001, PRD92-012013]

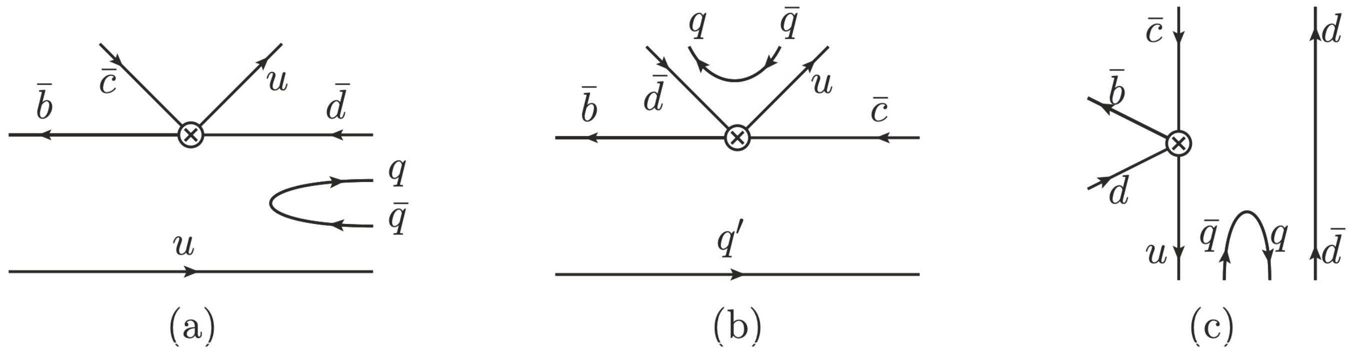
- The $\omega\pi^+$ is related to the resonances $\rho(1450)$ and $\rho(770)$

- Test the factorization hypothesis for B decays with $B^0 \to D^{(*)-}\omega\pi^+$ and $B_s^0 \to D_s^{*-}\omega\pi^+$ with the longitudinal polarization Γ_L/Γ [PLB89-105]

Contributions of the $\rho(770,1450) \to \omega\pi$ in $B \to \bar{D}^{(*)}\omega\pi$

Approach:



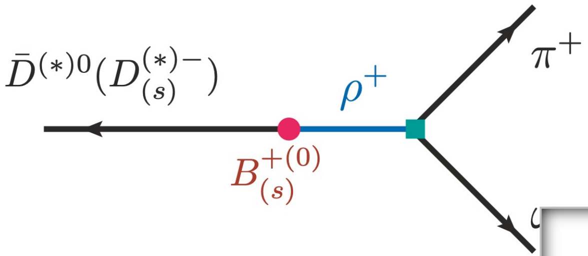


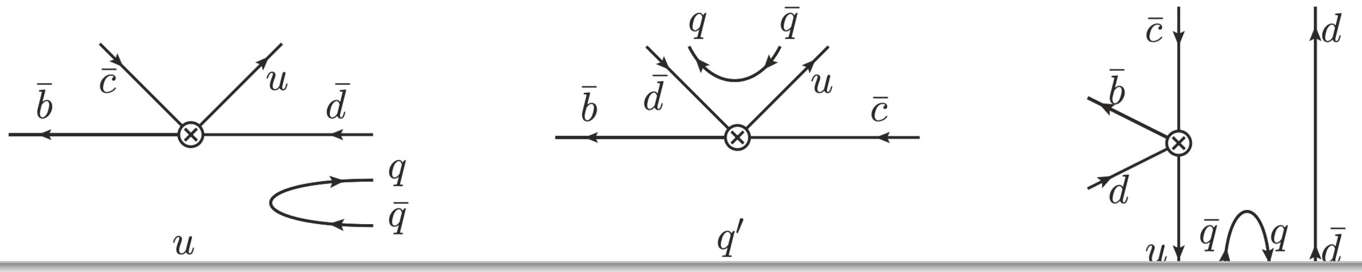
With PQCD approach

$$\mathcal{A} = \langle(\omega\pi)_{P\text{-wave}} D^{(*)}|\mathcal{H}_{\text{eff}}|B\rangle$$
$$= \phi_B \otimes \mathcal{H} \otimes \phi_{\omega\pi}^{P\text{-wave}} \otimes \phi_{D^{(*)}}$$

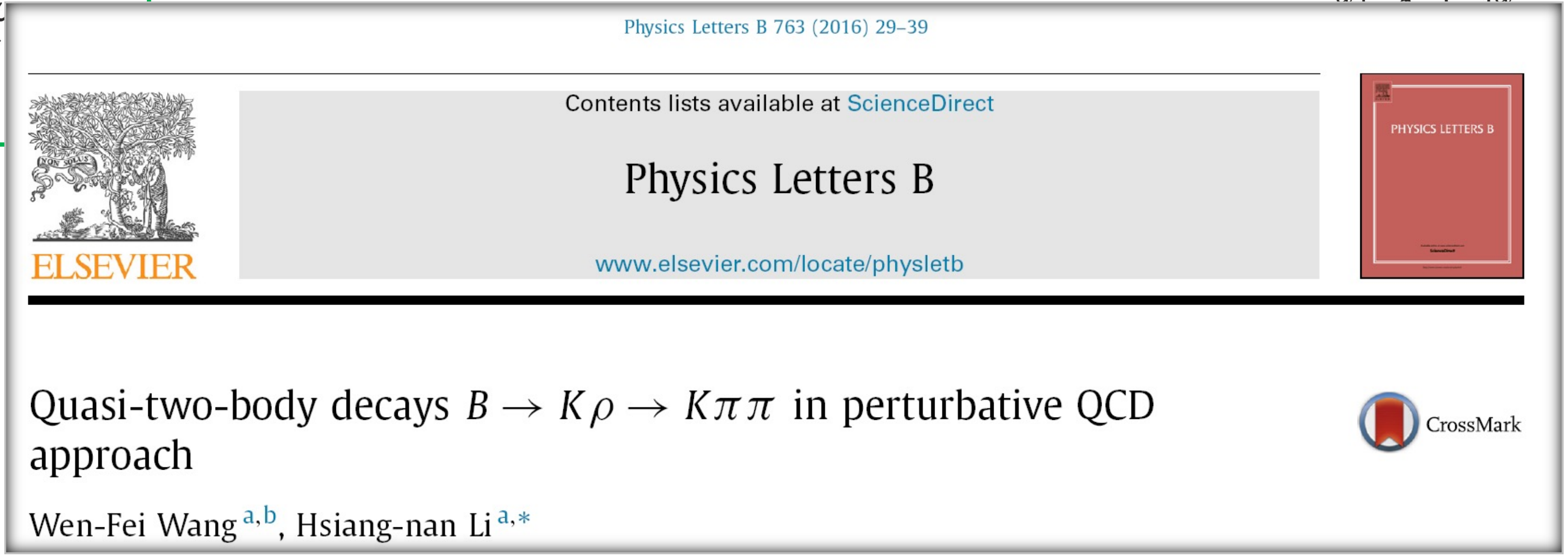
Contributions of the $\rho(770,1450) \to \omega\pi$ in $B \to \bar{D}^{(*)}\omega\pi$

Approach:





With PQCD approach


Physics Letters B 763 (2016) 29–39

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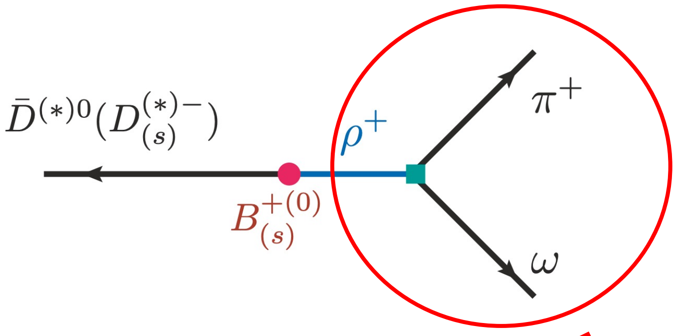
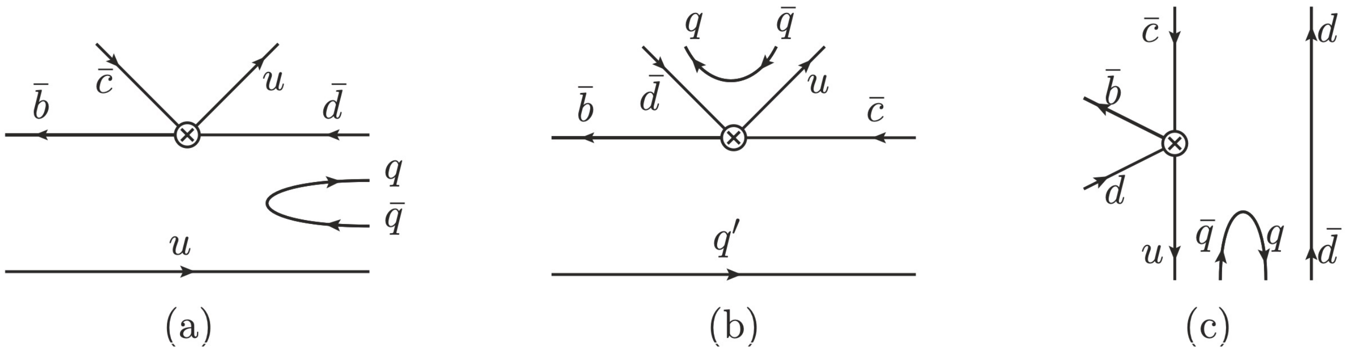
Quasi-two-body decays $B \to K\rho \to K\pi\pi$ in perturbative QCD approach

CrossMark

Wen-Fei Wang [a,b], Hsiang-nan Li [a,*]

Approach:



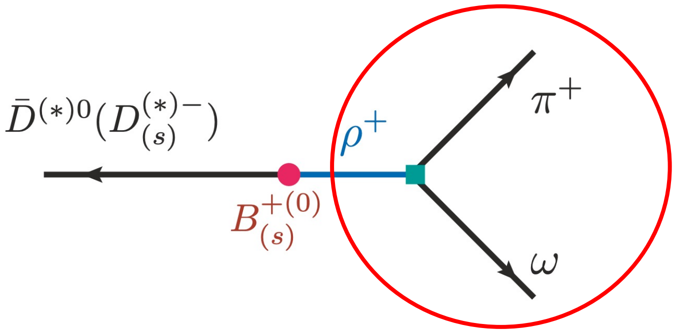


With PQCD approach

$$\phi^{P\text{-wave}}_{\omega\pi,L}(x,s) = \frac{-1}{\sqrt{2N_c}}[\sqrt{s}\,\not\epsilon_L\phi^0(x,s) + \not\epsilon_L\not p\phi^t(x,s) + \sqrt{s}\phi^s(x,s)],$$

$$\phi^{P\text{-wave}}_{\omega\pi,T}(x,s) = \frac{-1}{\sqrt{2N_c}}[\sqrt{s}\,\not\epsilon_T\phi^v(x,s) + \not\epsilon_T\not p\phi^T(x,s) + \sqrt{s}\,i\epsilon_{\mu\nu\rho\sigma}\gamma_5\gamma^\mu\epsilon_T^{*\nu}n^\rho v^\sigma\phi^a(x)],$$

Approach:



$$\mathcal{L}_{\rho\omega\pi}=g_{\rho\omega\pi}\epsilon_{\mu\nu\alpha\beta}\partial^\mu\rho^\nu\partial^\alpha\omega^\beta\pi$$

$\Downarrow$

$$\langle\omega(p_a,\lambda)\pi(p_b)|j_\mu(0)|0\rangle=i\epsilon_{\mu\nu\alpha\beta}\varepsilon^\nu(p_a,\lambda)p_b^\alpha p^\beta F_{\omega\pi}(s)$$

$\Downarrow$

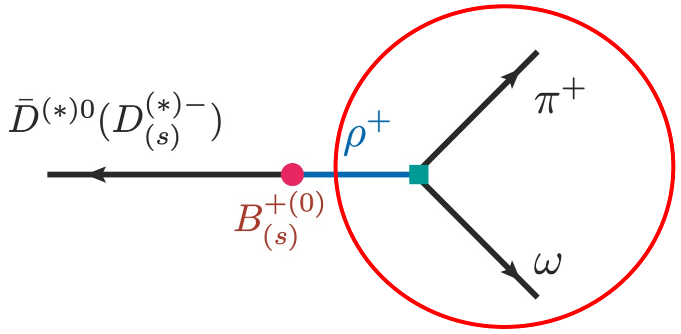
$$F_{\omega\pi}(s)=\frac{g_{\rho\omega\pi}}{f_\rho}\sum_{\rho_i}\frac{A_i e^{i\phi_i}m_{\rho_i}^2}{D_{\rho_i}(s)}$$

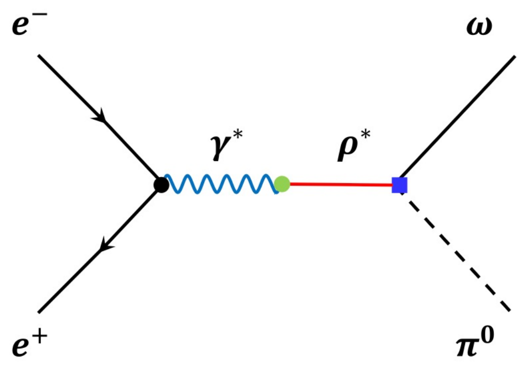
$$D_{\rho_i}(s)=m_{\rho_i}^2-s-i\sqrt{s}\,\Gamma_{\rho_i}(s)$$

one has $A=1$ and $\phi=0$ for $\rho(770)$

Contributions of the $\rho(770, 1450) \to \omega\pi$ in $B \to \bar{D}^{(*)}\omega\pi$

APPROACH:





$$\langle\omega(p_a,\lambda)\pi(p_b)|j_\mu(0)|0\rangle = i\epsilon_{\mu\nu\alpha\beta}\varepsilon^\nu(p_a,\lambda)p_b^\alpha p^\beta F_{\omega\pi}(s)$$

$\Downarrow$

$$F_{\omega\pi}(s) = \frac{g_{\rho\omega\pi}}{f_\rho}\sum_{\rho_i}\frac{A_i e^{i\phi_i} m_{\rho_i}^2}{D_{\rho_i}(s)}$$

[PRD92-014014, PRD105-074035, PRD108-092012]

$$\frac{d\mathcal{B}}{ds} = \tau_B \frac{s\,|\mathbf{p}_\pi|^3 |\mathbf{p}_D|^3}{24\pi^3 m_B^7} |\mathcal{A}|^2$$

$$|\mathbf{p}_\pi| = \frac{\sqrt{[s-(m_\pi+m_\omega)^2]\,[s-(m_\pi-m_\omega)^2]}}{2\sqrt{s}},$$

$$|\mathbf{p}_D| = \frac{\sqrt{[m_B^2-(s+m_D)^2]\,[m_B^2-(s-m_D)^2]}}{2\sqrt{s}},$$

$$\sum_{\lambda=0,\pm} \varepsilon^\mu(p,\lambda)\varepsilon^\nu(p,\lambda) = -g^{\mu\nu} + \frac{p^\mu p^\nu}{p^2},$$

$$\sum_{\lambda=0,\pm} |\epsilon_{\mu\nu\alpha\beta} p_3^\mu \varepsilon^\nu(p_\omega,\lambda) p_\pi^\alpha p^\beta|^2 = s\,|\mathbf{p}_\pi|^2 |\mathbf{p}_D|^2 (1-\cos^2\theta)$$

Six decay modes with large branching ratios (10^-3)

Decay modes	Units	PQCD	Data [16]
$B^+ \to \bar{D}^0[\rho(770)^+ \to]\pi\pi^+$	%	$1.21^{+0.20}_{-0.21}$	1.34 ± 0.18
$B^0 \to D^-[\rho(770)^+ \to]\pi\pi^+$	10^{-3}	$7.63^{+1.18}_{-0.96}$	7.6 ± 1.2
$B_s^0 \to D_s^-[\rho(770)^+ \to]\pi\pi^+$	10^{-3}	$7.36^{+0.78}_{-0.82}$	6.8 ± 1.4
$B^+ \to \bar{D}^{*0}[\rho(770)^+ \to]\pi\pi^+$	10^{-3}	$9.03^{+1.79}_{-1.74}$	9.8 ± 1.7
$B^0 \to D^{*-}[\rho(770)^+ \to]\pi\pi^+$	10^{-3}	$8.15^{+1.46}_{-1.45}$	6.8 ± 0.9
$B_s^0 \to D_s^{*-}[\rho(770)^+ \to]\pi\pi^+$	10^{-3}	$7.12^{+1.09}_{-1.09}$	9.5 ± 2.0

[16] is PDG2022

Decay modes	$\mathcal{B}$ (in 10^{-3})
$B^+ \to \bar{D}^0[\rho(770)^+ \to]\omega\pi^+$	$1.42^{+0.16+0.15+0.11+0.10}_{-0.16-0.13-0.09-0.10}$
$B^+ \to \bar{D}^0[\rho(1450)^+ \to]\omega\pi^+$	$0.96^{+0.11+0.09+0.08+0.40}_{-0.11-0.09-0.08-0.40}$
$B^0 \to D^-[\rho(770)^+ \to]\omega\pi^+$	$0.80^{+0.06+0.12+0.06+0.07}_{-0.06-0.09-0.02-0.07}$
$B^0 \to D^-[\rho(1450)^+ \to]\omega\pi^+$	$0.52^{+0.03+0.06+0.03+0.22}_{-0.03-0.06-0.03-0.22}$
$B_s^0 \to D_s^-[\rho(770)^+ \to]\omega\pi^+$	$0.88^{+0.05+0.07+0.00+0.06}_{-0.05-0.07-0.01-0.06}$
$B_s^0 \to D_s^-[\rho(1450)^+ \to]\omega\pi^+$	$0.59^{+0.03+0.05+0.00+0.25}_{-0.03-0.04-0.00-0.25}$

Decay modes	$\mathcal{B}$ (in 10^{-3})	Γ_L/Γ
$B^+ \to \bar{D}^{*0}[\rho(770)^+ \to]\omega\pi^+$	$1.21^{+0.17+0.09+0.05+0.07}_{-0.17-0.09-0.03-0.07}$	$0.74^{+0.02}_{-0.02}$
$B^+ \to \bar{D}^{*0}[\rho(1450)^+ \to]\omega\pi^+$	$0.87^{+0.12+0.07+0.03+0.37}_{-0.12-0.07-0.02-0.37}$	$0.67^{+0.02}_{-0.02}$
$B^0 \to D^{*-}[\rho(770)^+ \to]\omega\pi^+$	$1.20^{+0.18+0.09+0.02+0.07}_{-0.18-0.08-0.01-0.07}$	$0.68^{+0.02}_{-0.02}$
$B^0 \to D^{*-}[\rho(1450)^+ \to]\omega\pi^+$	$0.89^{+0.13+0.06+0.02+0.38}_{-0.13-0.06-0.02-0.38}$	$0.63^{+0.01}_{-0.01}$
$B_s^0 \to D_s^{*-}[\rho(770)^+ \to]\pi\pi^+$	$1.03^{+0.11+0.08+0.00+0.05}_{-0.11-0.08-0.00-0.05}$	$0.65^{+0.01}_{-0.01}$
$B_s^0 \to D_s^{*-}[\rho(1450)^+ \to]\pi\pi^+$	$0.77^{+0.08+0.06+0.00+0.32}_{-0.08-0.06-0.00-0.32}$	$0.59^{+0.01}_{-0.01}$

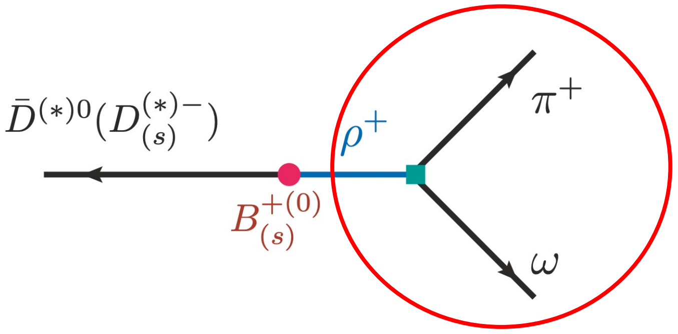
BELLE: PRD92−012013

$$\mathcal{B} = (1.48 \pm 0.27^{+0.15+0.21}_{-0.09-0.56}) \times 10^{-3}$$

$$\mathcal{B} = (1.07^{+0.15+0.06+0.40}_{-0.31-0.13-0.02}) \times 10^{-3}$$

Contributions of the $\rho(770, 1450) \to \omega\pi$ in $B \to \bar{D}^{(*)}\omega\pi$

Approach:



$$\mathcal{L}_{\rho\omega\pi} = g_{\rho\omega\pi}\epsilon_{\mu\nu\alpha\beta}\partial^\mu\rho^\nu\partial^\alpha\omega^\beta\pi$$

$$\Downarrow$$

$$\langle\omega(p_a,\lambda)\pi(p_b)|j_\mu(0)|0\rangle = i\epsilon_{\mu\nu\alpha\beta}\varepsilon^\nu(p_a,\lambda)p_b^\alpha p^\beta F_{\omega\pi}(s)$$

$$\Downarrow$$

$$F_{\omega\pi}(s) = \frac{g_{\rho\omega\pi}}{f_\rho}\sum_{\rho_i}\frac{A_i e^{i\phi_i}m_{\rho_i}^2}{D_{\rho_i}(s)}$$

$$D_{\rho_i}(s) = m_{\rho_i}^2 - s - i\sqrt{s}\,\Gamma_{\rho_i}(s)$$

one has $A = 1$ and $\phi = 0$ for $\rho(770)$

$$g_{\rho\omega\pi} = 16.0 \pm 2.0\ \mathrm{GeV}^{-1}$$

$$g_{\rho\pi\pi} \approx 6.0$$

$$g_{\rho\omega\pi} = 16.0 \pm 2.0\ \mathrm{GeV}^{-1}$$

$$F_{\omega\pi}(s) = \frac{g_{\rho\omega\pi}}{f_\rho} \sum_{\rho_i} \frac{A_i e^{i\phi_i} m_{\rho_i}^2}{D_{\rho_i}(s)}$$

The weight A_1 in Eq. (2.23) for the subprocess $\rho(1450) \to \omega\pi$ moves a lot in the literature, it has been measured to be 0.584 ± 0.003 and 0.164 ± 0.003 in [31], 0.175 ± 0.016, 0.137 ± 0.006 and 0.251 ± 0.006 in [28], 0.26 ± 0.01 and 0.11 ± 0.01 in [27]

[31]:PRD108-092012
[28]:PRD94-112001
[27]:PRD88-054013

Results and discussions

$$g_{\rho\omega\pi} = 16.0 \pm 2.0\ \text{GeV}^{-1}$$

$$F_{\omega\pi}(s) = \frac{g_{\rho\omega\pi}}{f_\rho} \sum_{\rho_i} \frac{A_i e^{i\phi_i} m_{\rho_i}^2}{D_{\rho_i}(s)}$$

$$A_1 = \frac{g_{\rho(1450)\omega\pi} f_{\rho(1450)} m_{\rho(770)}}{g_{\rho(770)\omega\pi} f_{\rho(770)} m_{\rho(1450)}}$$

$$A_1 = 0.171 \pm 0.036$$

$$f_{\rho(1450)} g_{\rho(1450)\omega\pi} = \sqrt{12\pi f_{\rho(1450)}^2 \mathcal{B}(\rho(1450) \to \omega\pi) \Gamma_{\rho(1450)} / p_c^3}$$

$$f_{\rho(1450)}^2 \mathcal{B}(\rho(1450) \to \omega\pi) = 0.011 \pm 0.003$$

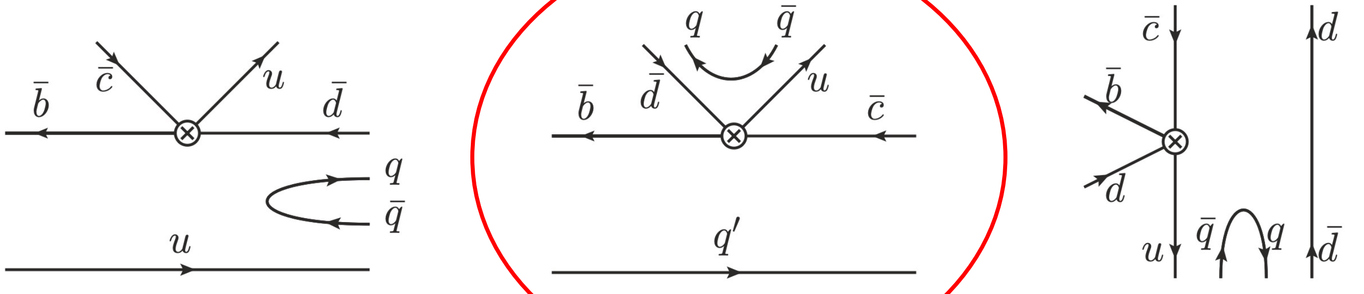
PRD64-092001 CLEO

❖ Test the factorization hypothesis for B decays with $B^0 \to D^{(*)-}\omega\pi^+$ and $B_s^0 \to D_s^{*-}\omega\pi^+$ with the longitudinal polarization Γ_L/Γ [PLB89-105]

pure annihilation decay

$B^0 \to D_s^{*-} K^{*+}$

$\mathcal{B} = (3.2^{+1.5}_{-1.3}) \times 10^{-5}$

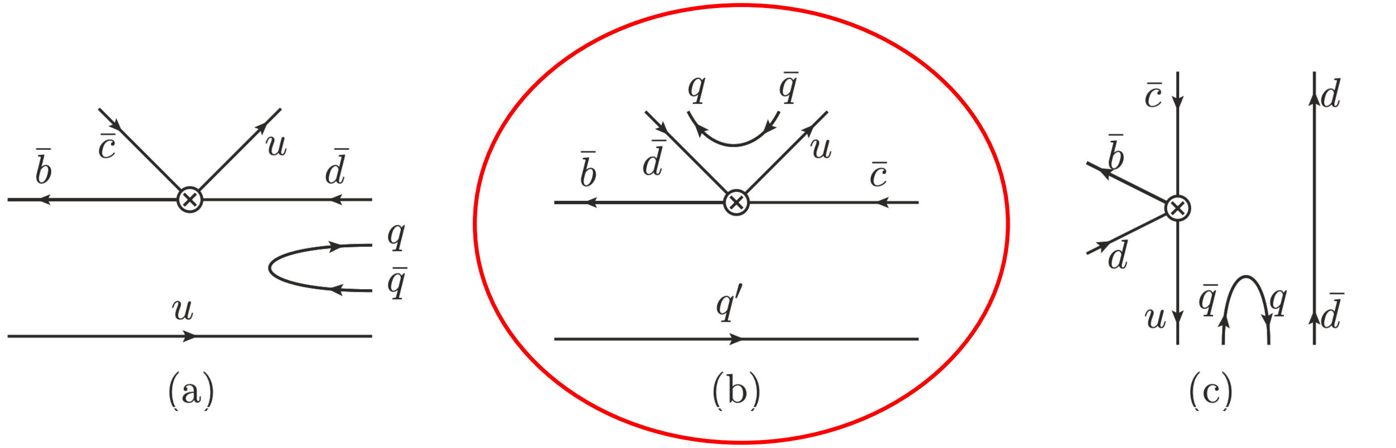


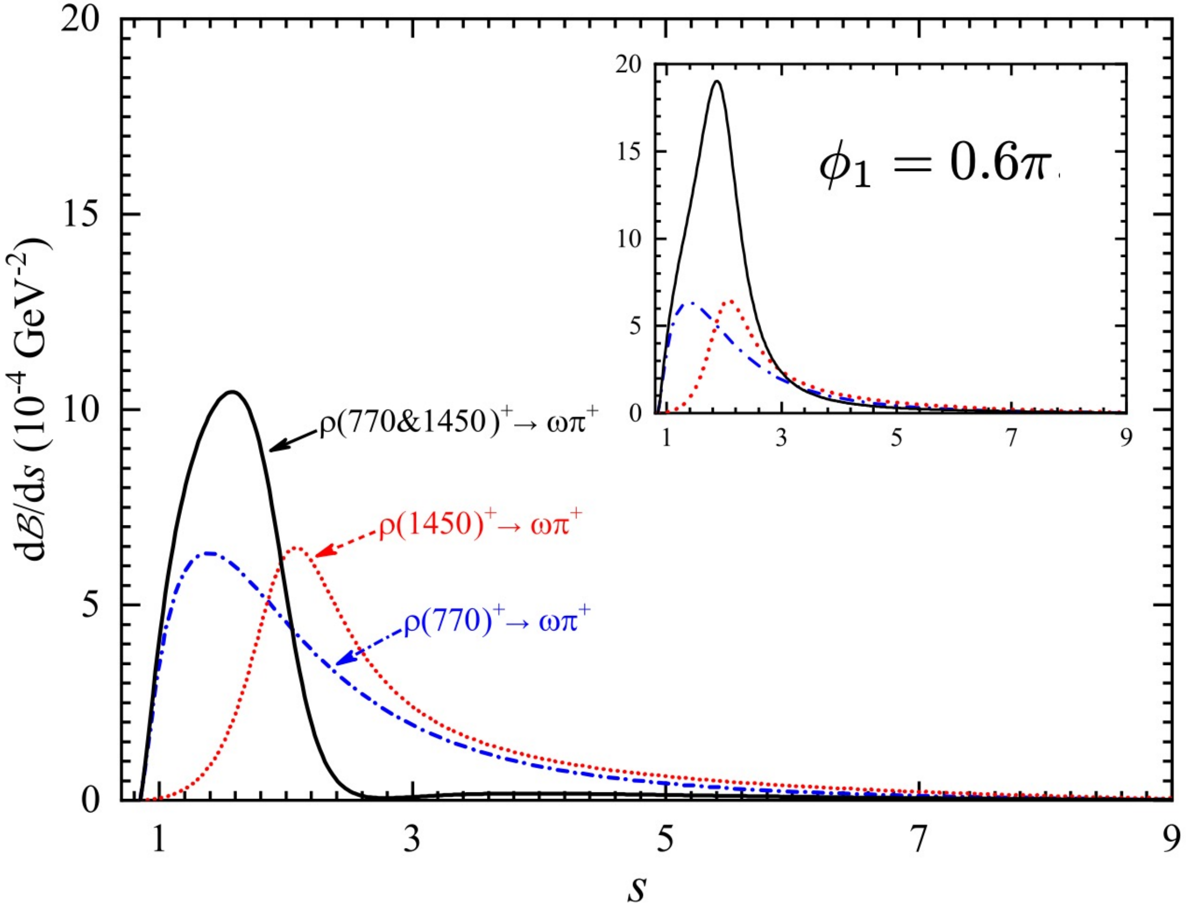
(a) (b) (c)

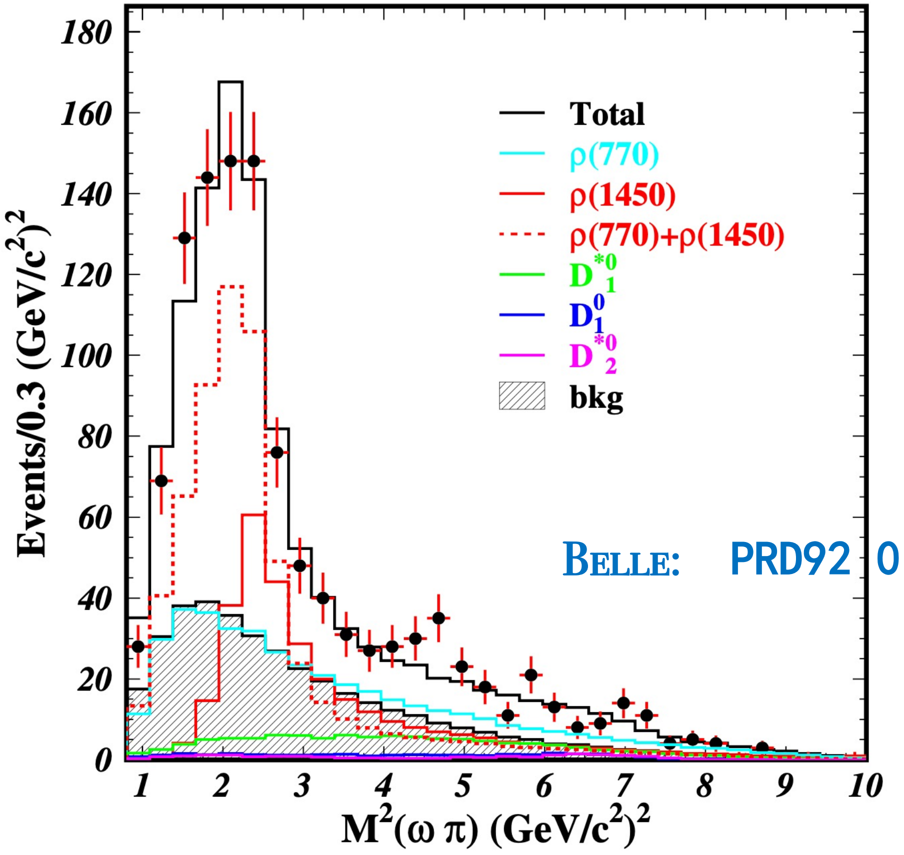
❖ Test the factorization hypothesis for B decays with $B^0 \to D^{(*)-}\omega\pi^+$ and $B_s^0 \to D_s^{*-}\omega\pi^+$ with the longitudinal polarization Γ_L/Γ [PLB89-105]

$$B_s^0 \to D_s^{*-}[\rho(770)^+ \to]\pi\pi^+$$

$$B_s^0 \to D_s^{*-}[\rho(1450)^+ \to]\pi\pi^+$$







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$$B^0 \to D^{*-}\rho^+ \to D^{*-}\omega\pi^+$$

- ✓ **Introduction of the 3-body B decays / Virtual contributions**
- ✓ **Contributions of the $\rho(770, 1450) \rightarrow \omega\pi$ in $B \rightarrow \bar{D}^{(*)}\omega\pi$**
- ✓ **Results and discussions**

Summary

- ✓ Introduction of the 3-body B decays / Virtual contributions
- ✓ Contributions of the $\rho(770, 1450) \to \omega\pi$ in $B \to \bar{D}^{(*)}\omega\pi$
- ✓ Results and discussions

Thank You !