contribution to discussion: shape of resonances in isobar model fit

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Future challenged in hadronic B decay
14 - 18 January 2019 - Mainz

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2-body x 3-body phase

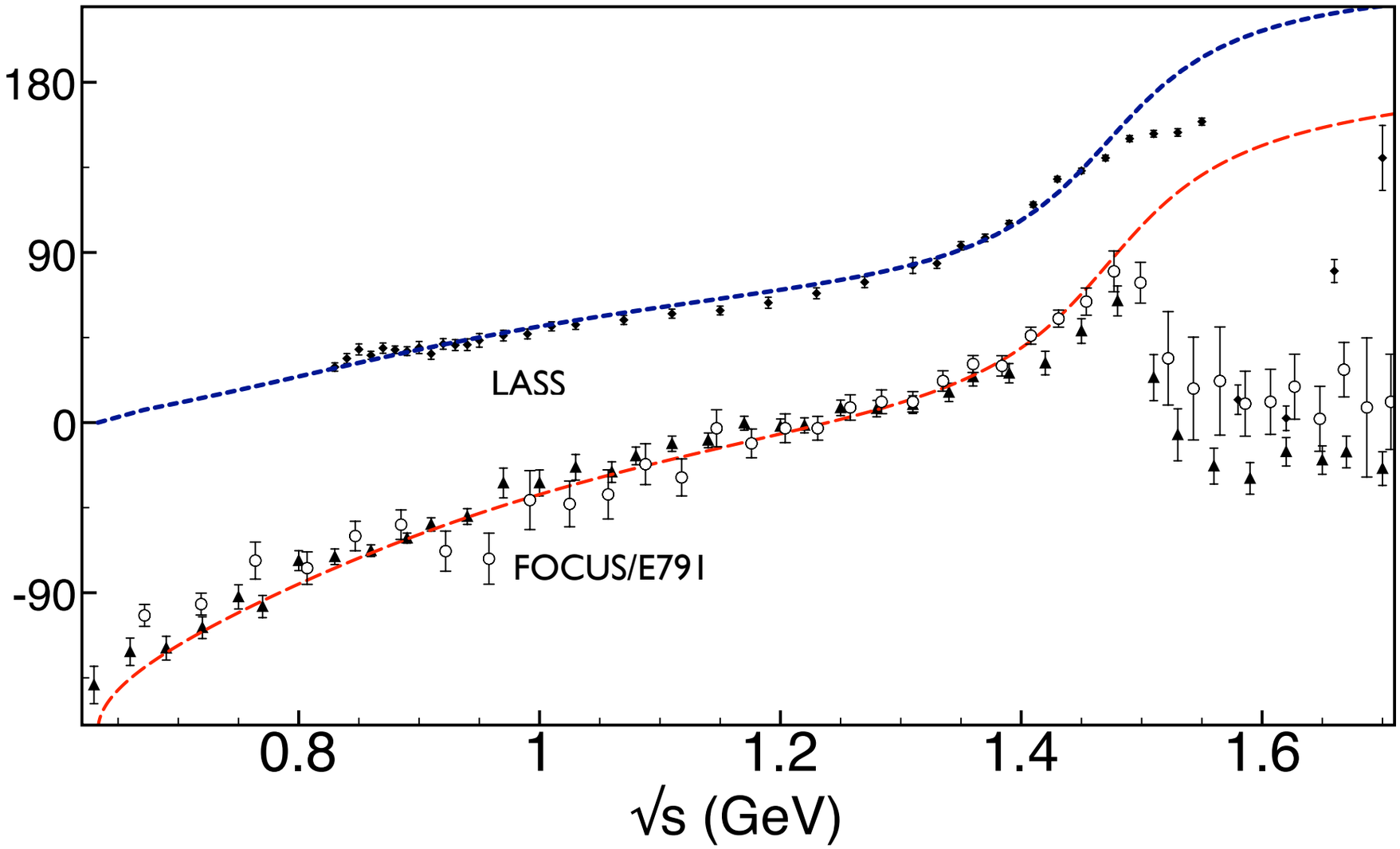
- $D^+ \to K^-\pi^+\pi^+$

PHYSICAL REVIEW D **84,** 094001 (2011)

Towards three-body unitarity in $D^+ \to K^-\pi^+\pi^+$

P. C. Magalhães, M. R. Robilotta, K. S. F. F. Guimarães, T. Frederico, W. de Paula, I. Bediaga, A. C. dos Reis, C. M. Maekawa, and G. R. S. Zarnauskas

arXiv:1504.06346
PRD 92 (2015) no.9, 094005



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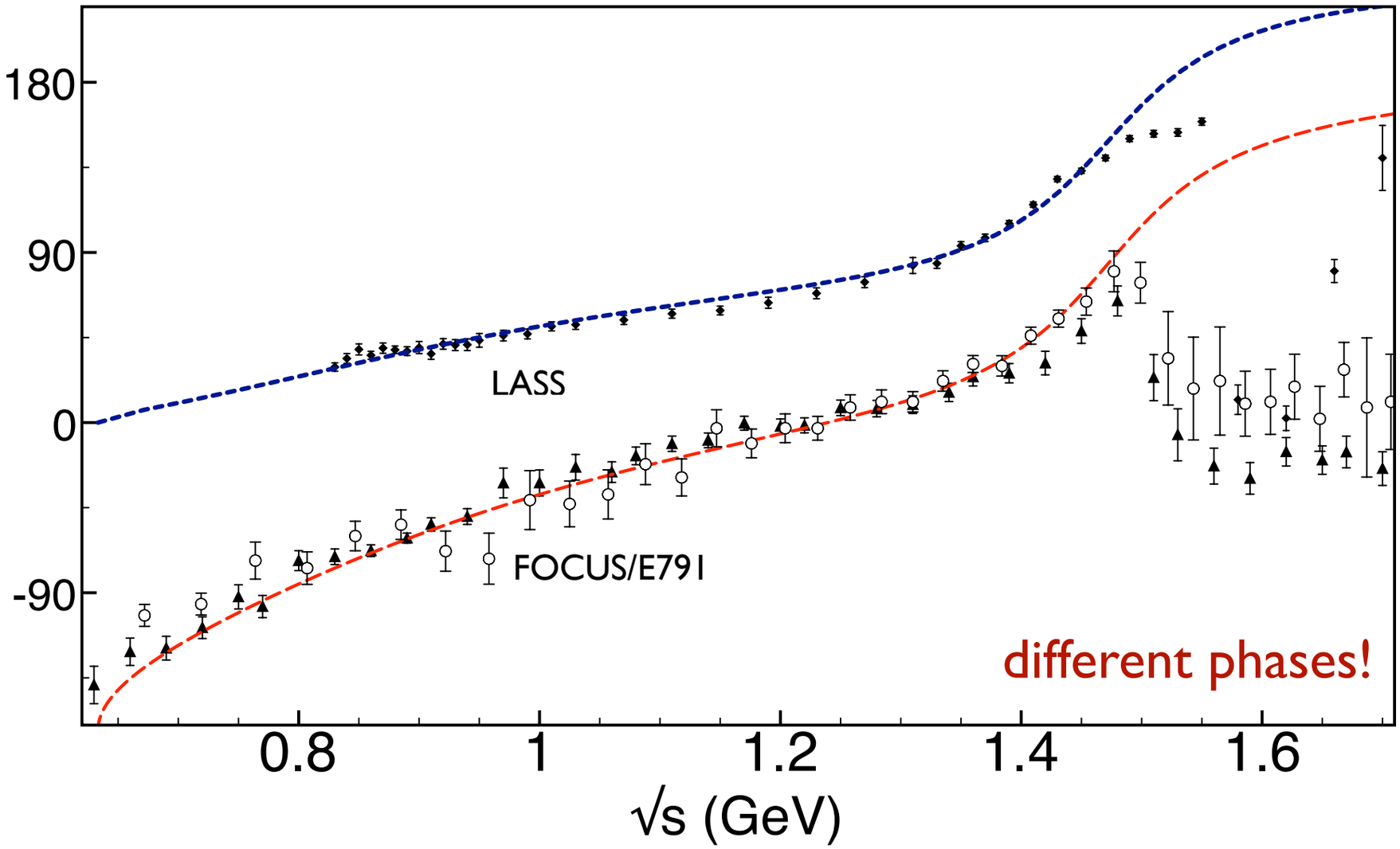

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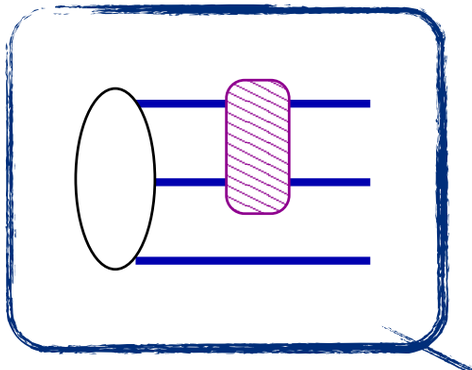
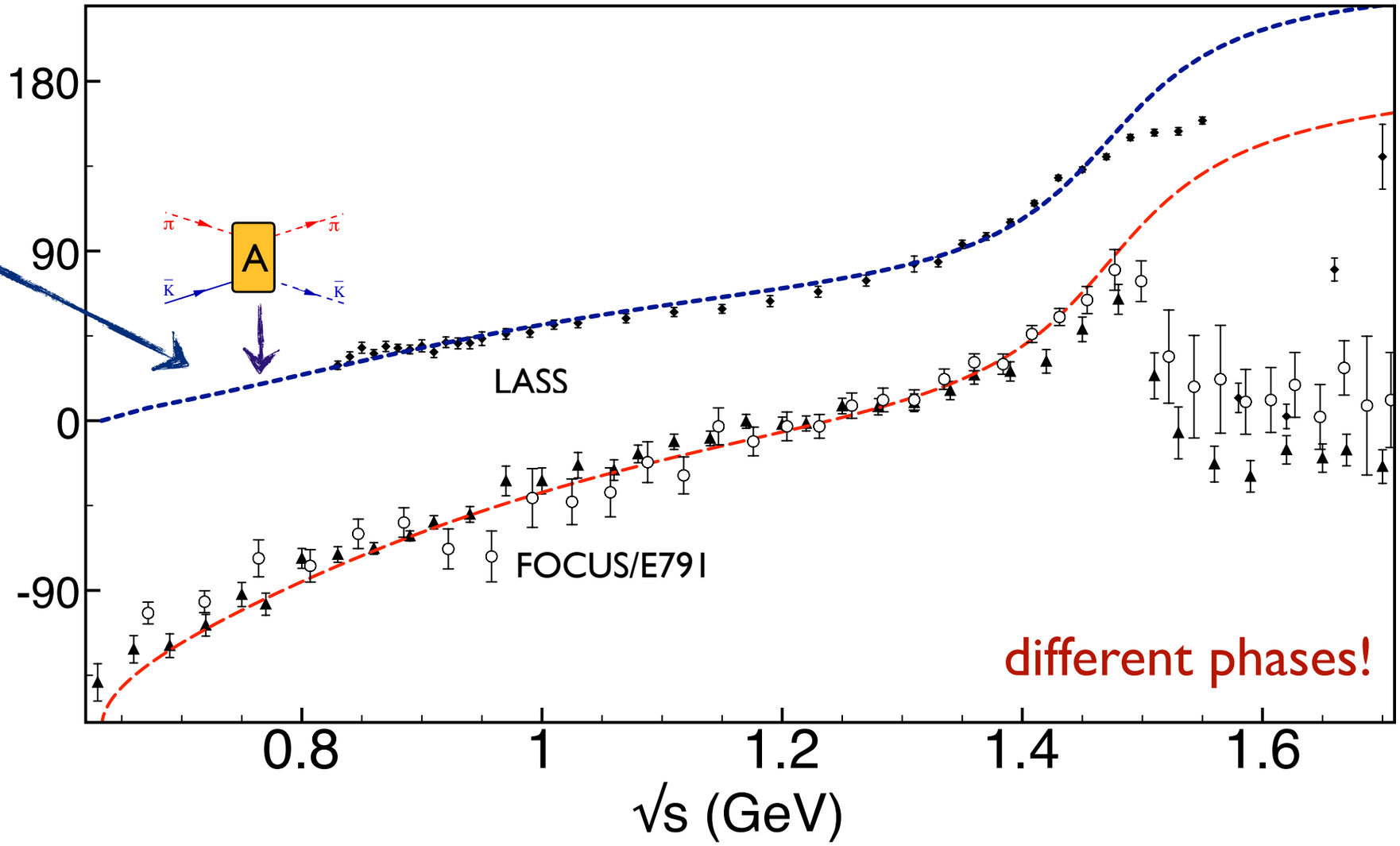


2+1



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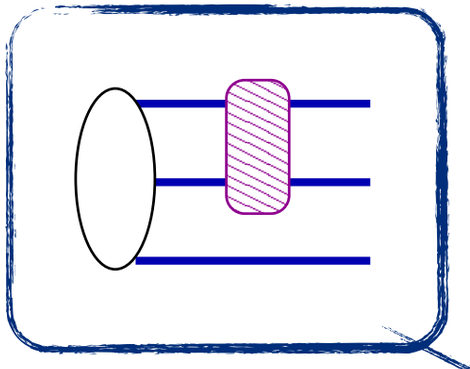

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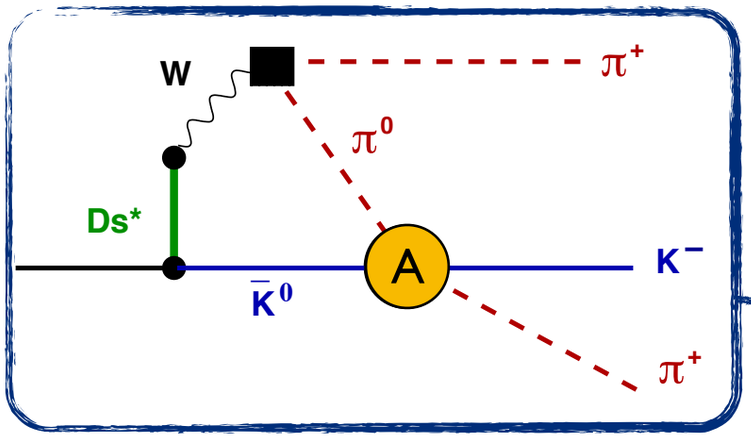
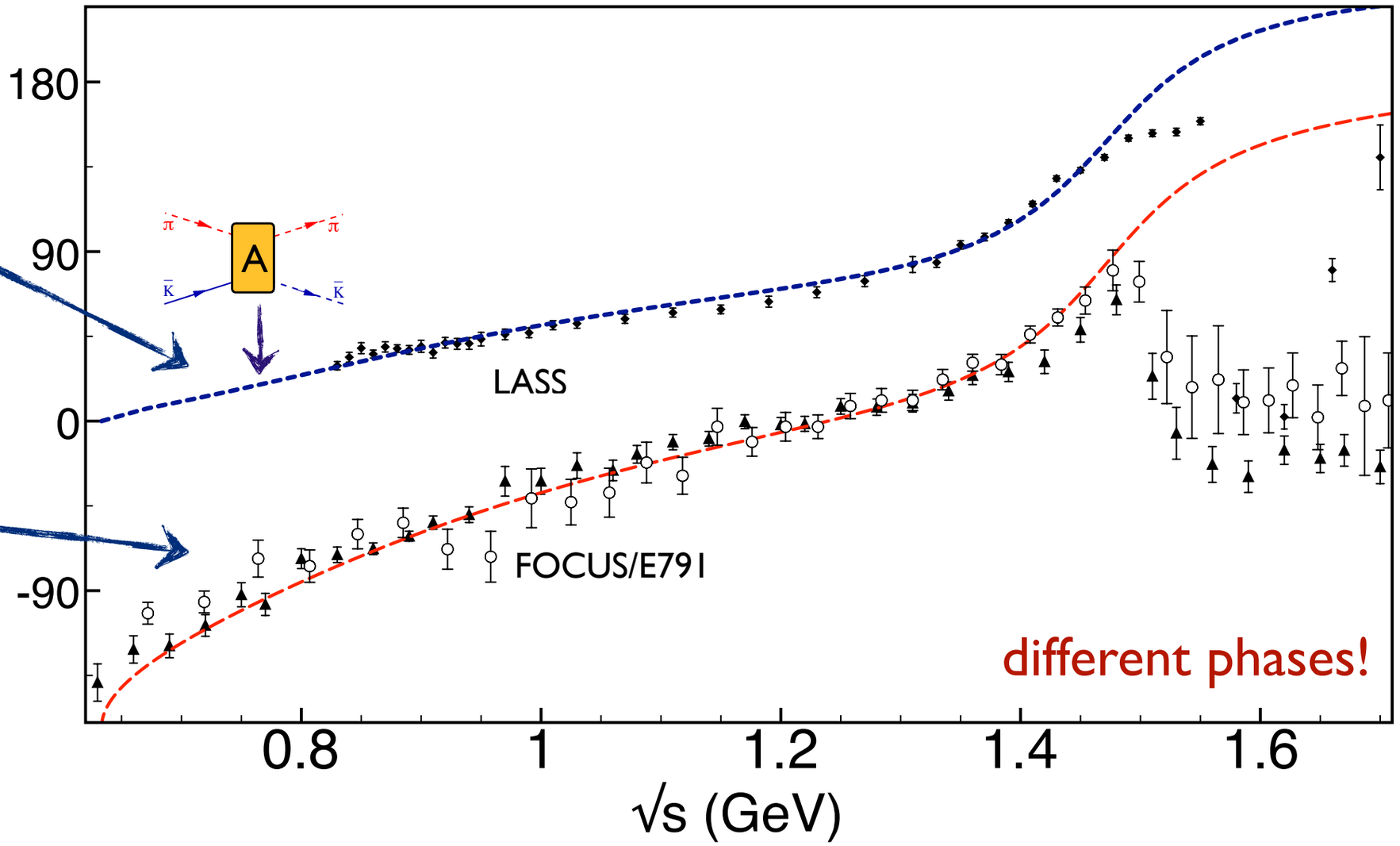


3-body



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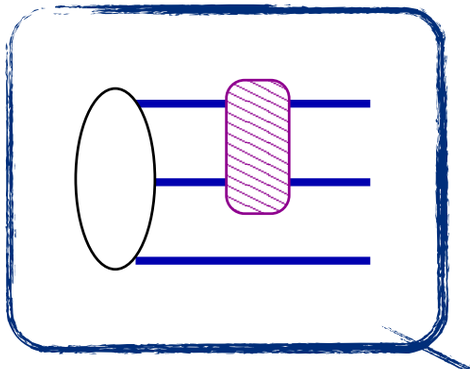

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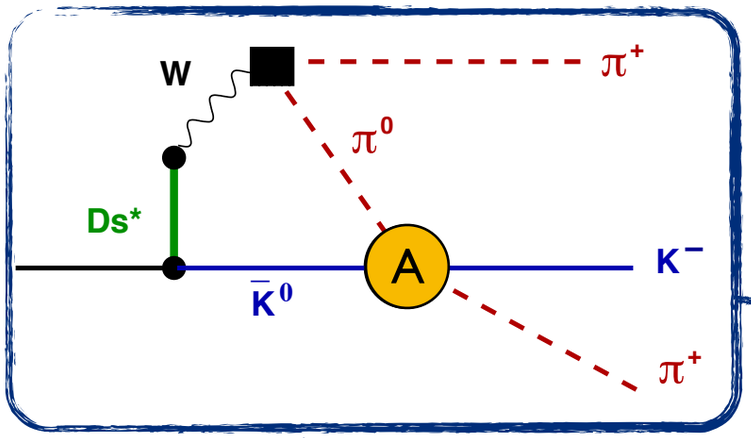
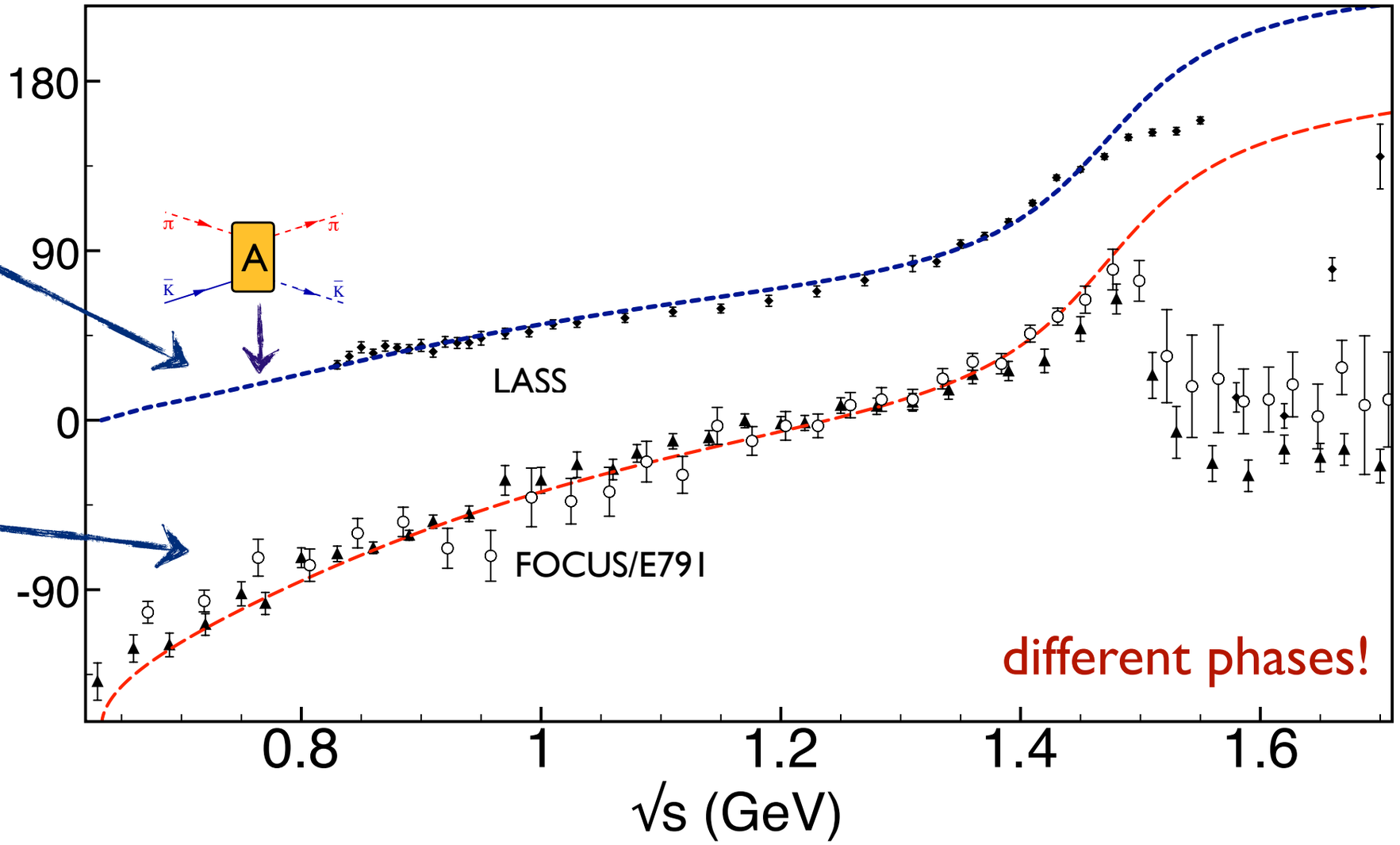


3-body

different dynamic!



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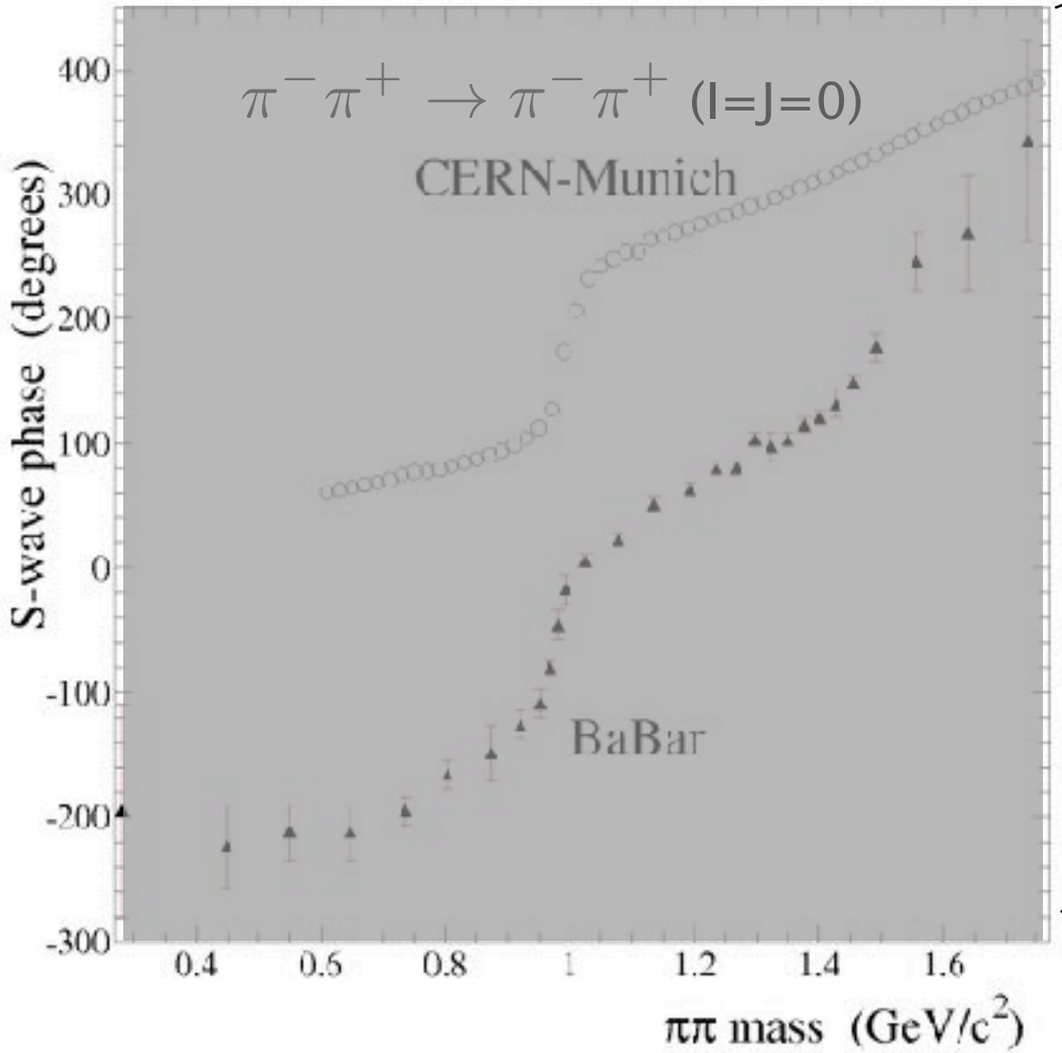
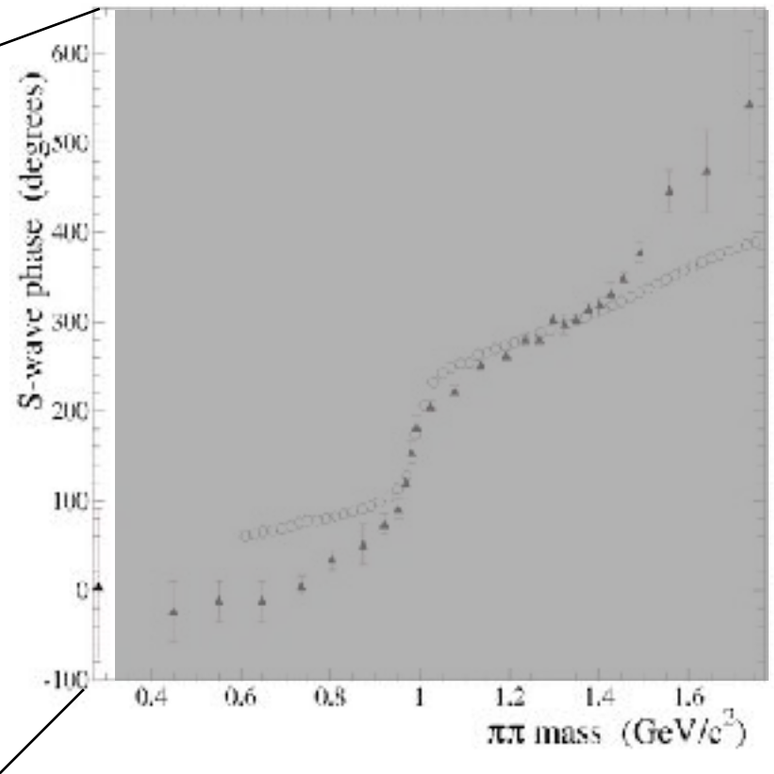
2-body x 3-body phase

- $D_s^+ \to \pi^+\pi^-\pi^+$





Phys.Rev. D 79 (2009) 032003

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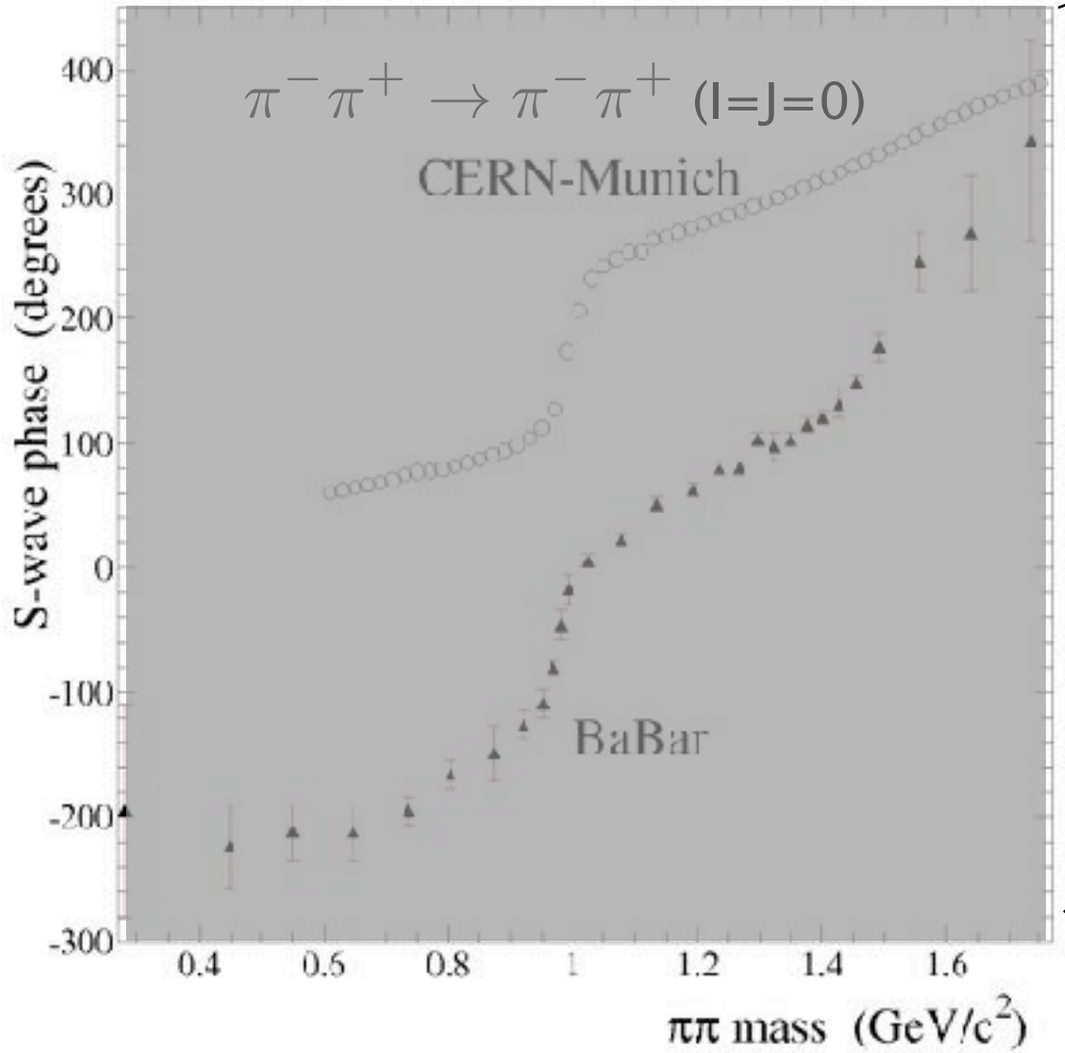

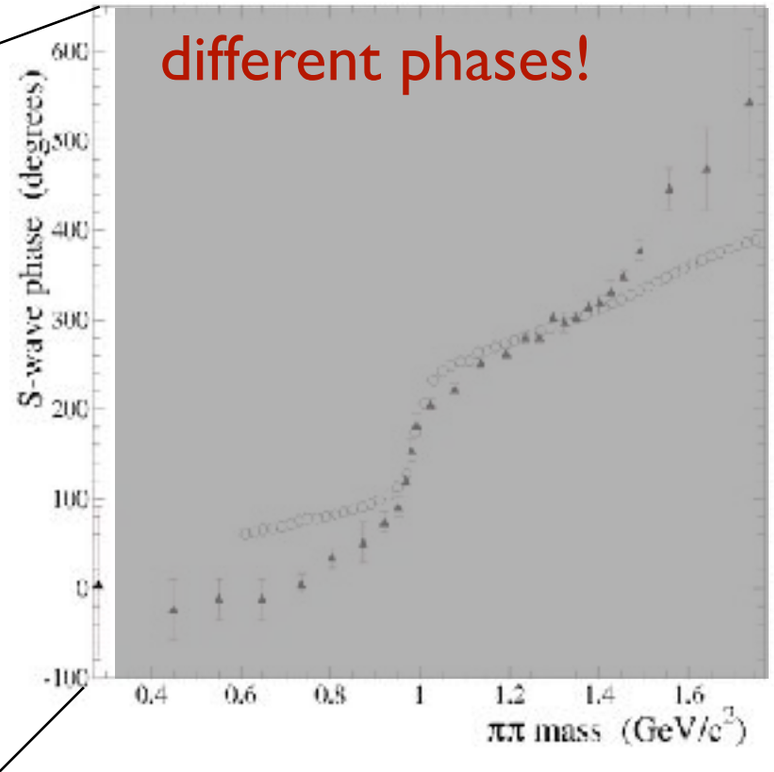

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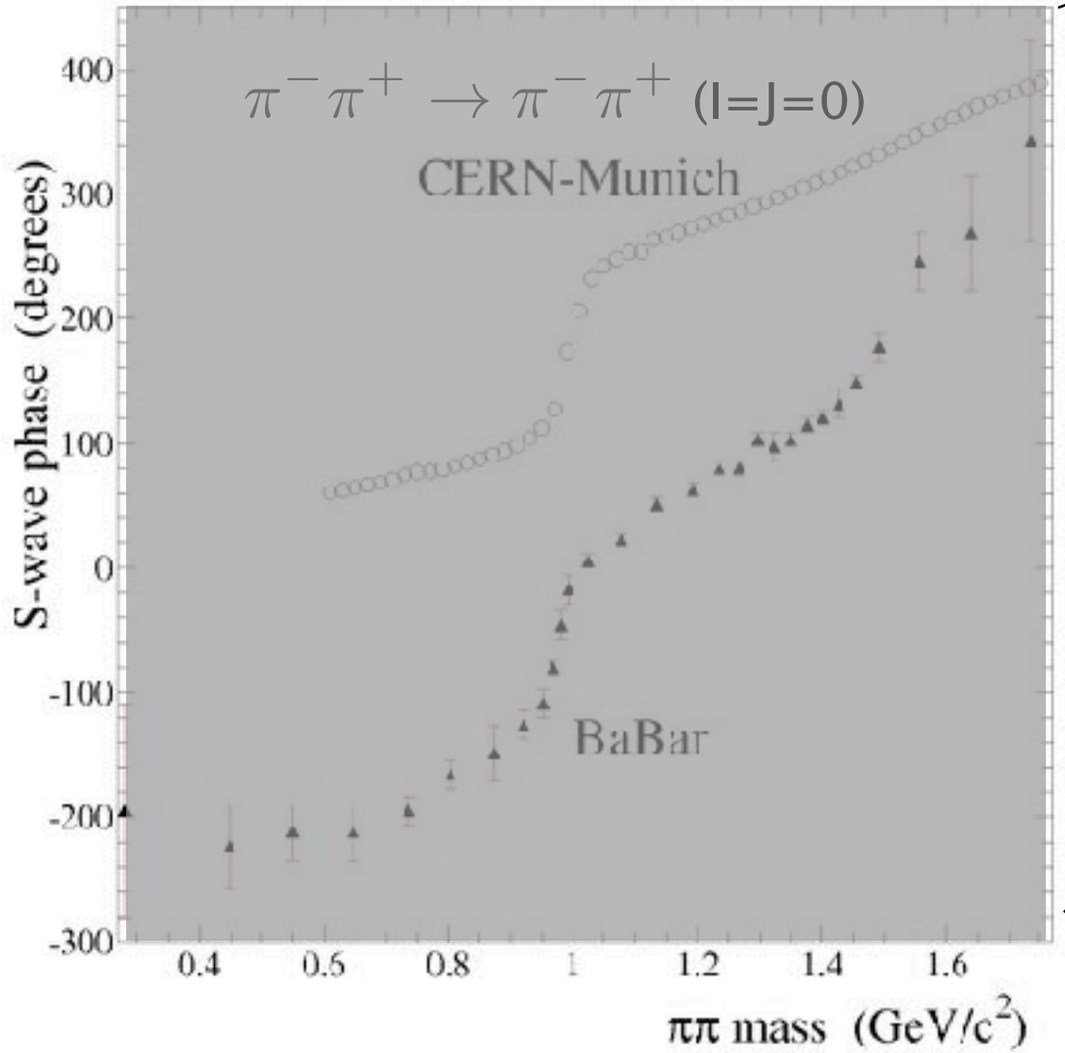

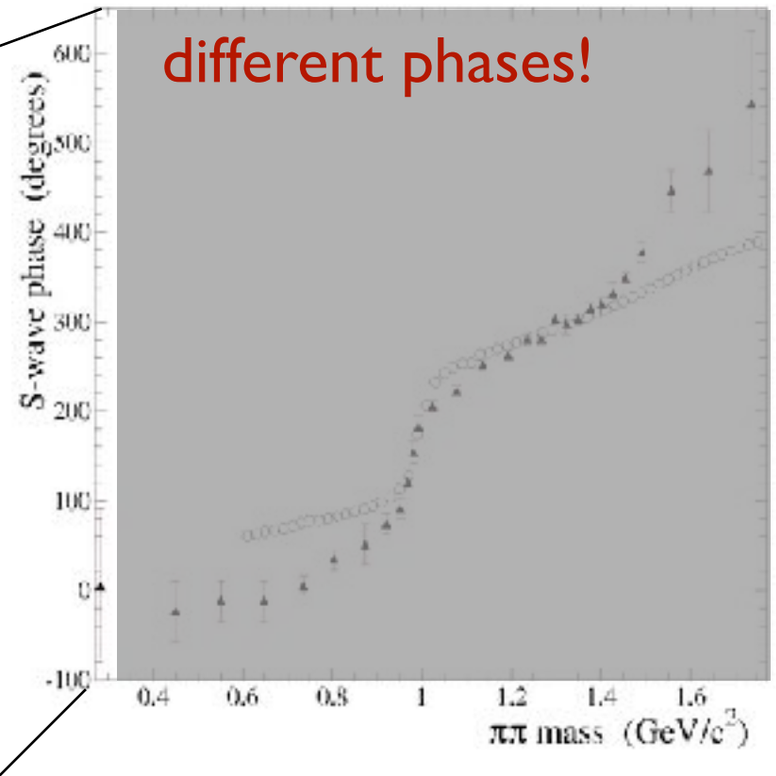

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- 2-body amplitude: spin and isospin well defined!
- 3-body data: only spin! $\&$ $\neq$ dynamics (weak vertex, FSI, 3rd particle, …)

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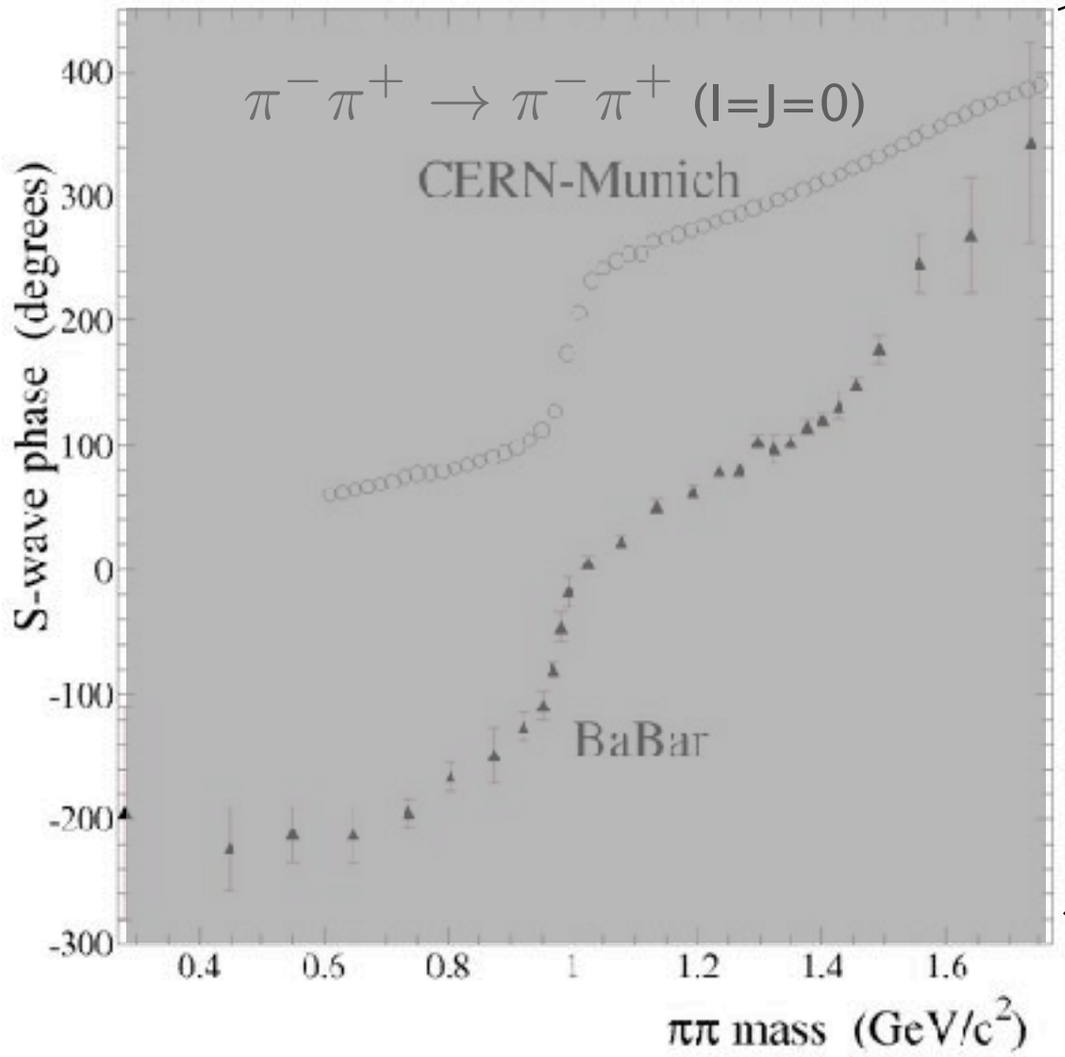

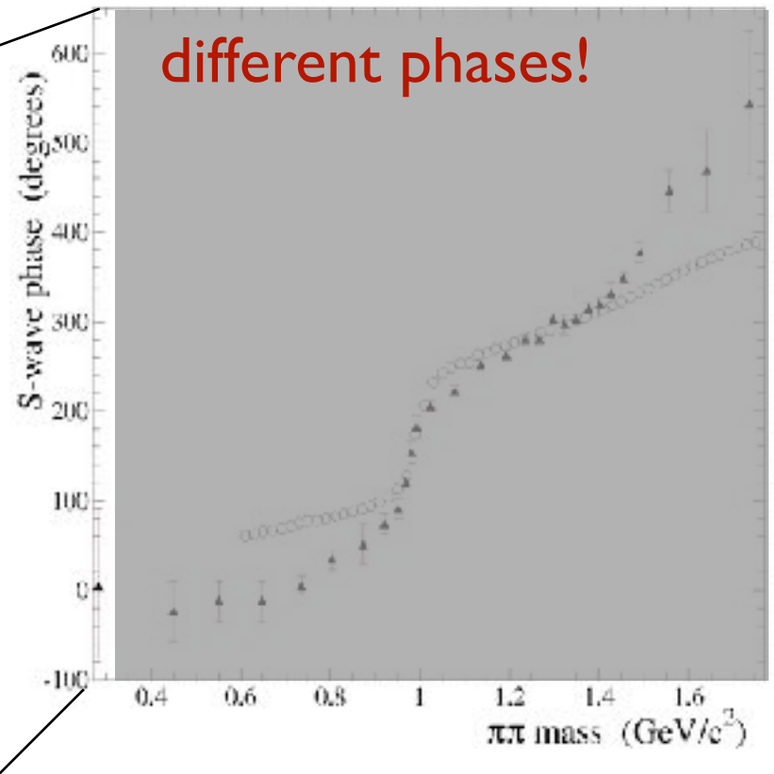

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- 2-body amplitude: spin and isospin well defined!
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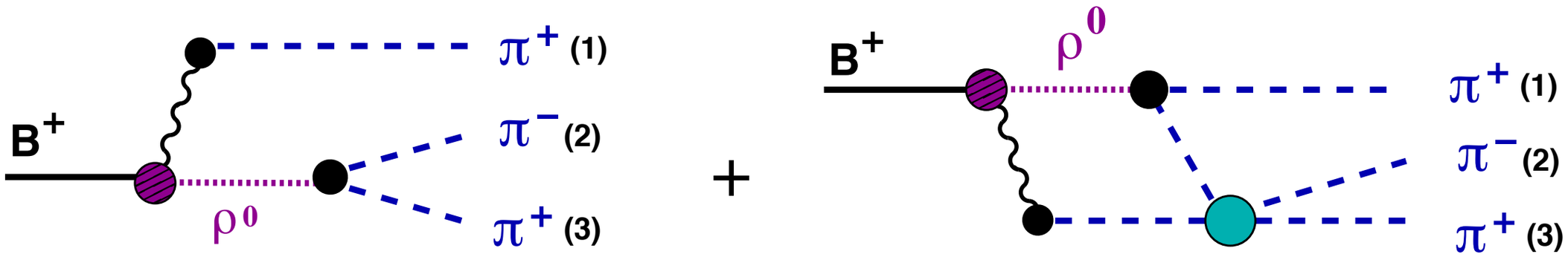
There is no direct connection between phases of the 3-body decay amplitudes and two-body scattering amplitudes

rescattering effects



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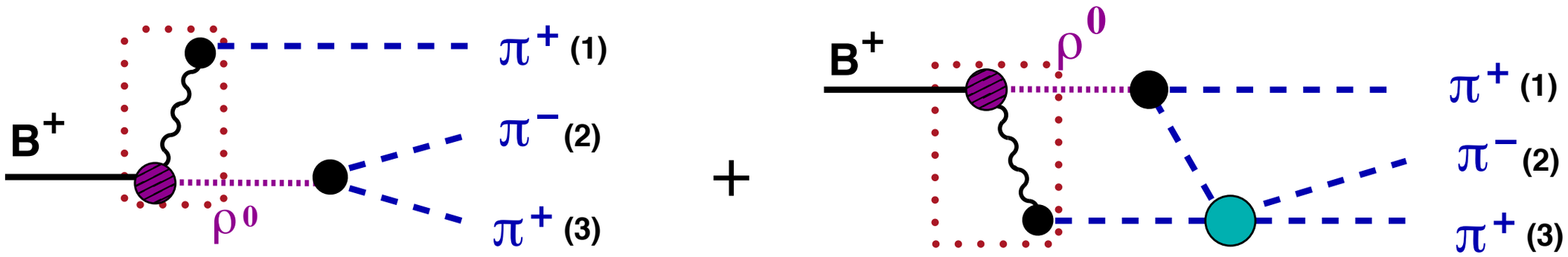
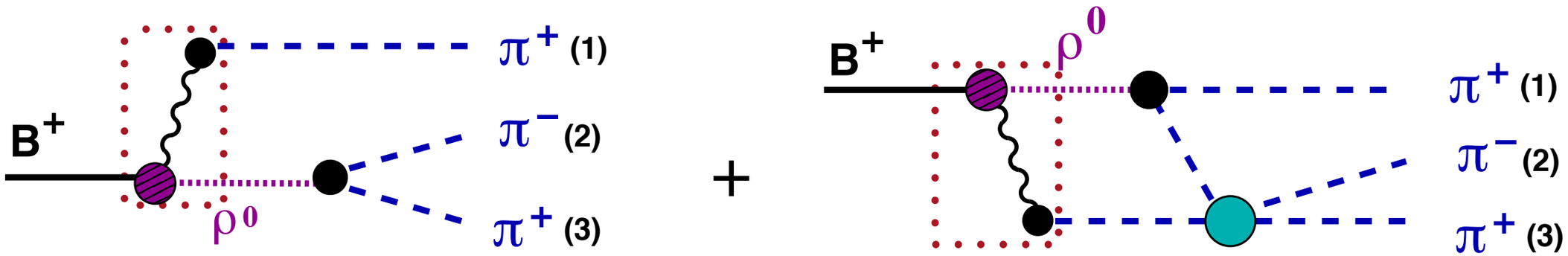


same weak source for both → focus on FSI

rescattering effects

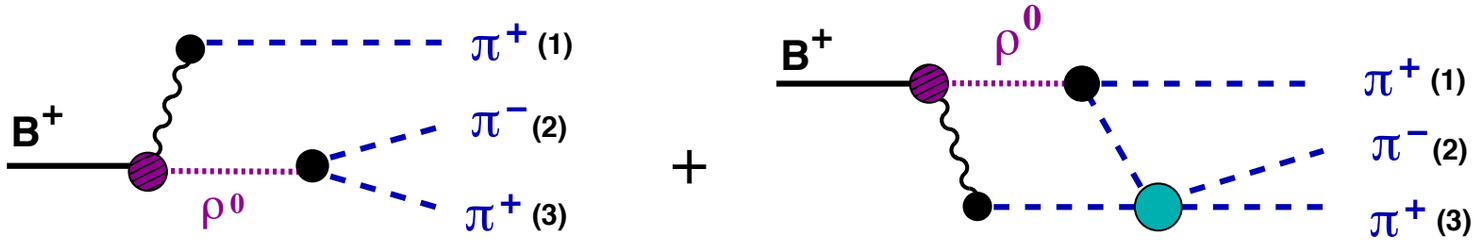


same weak source for both → focus on FSI

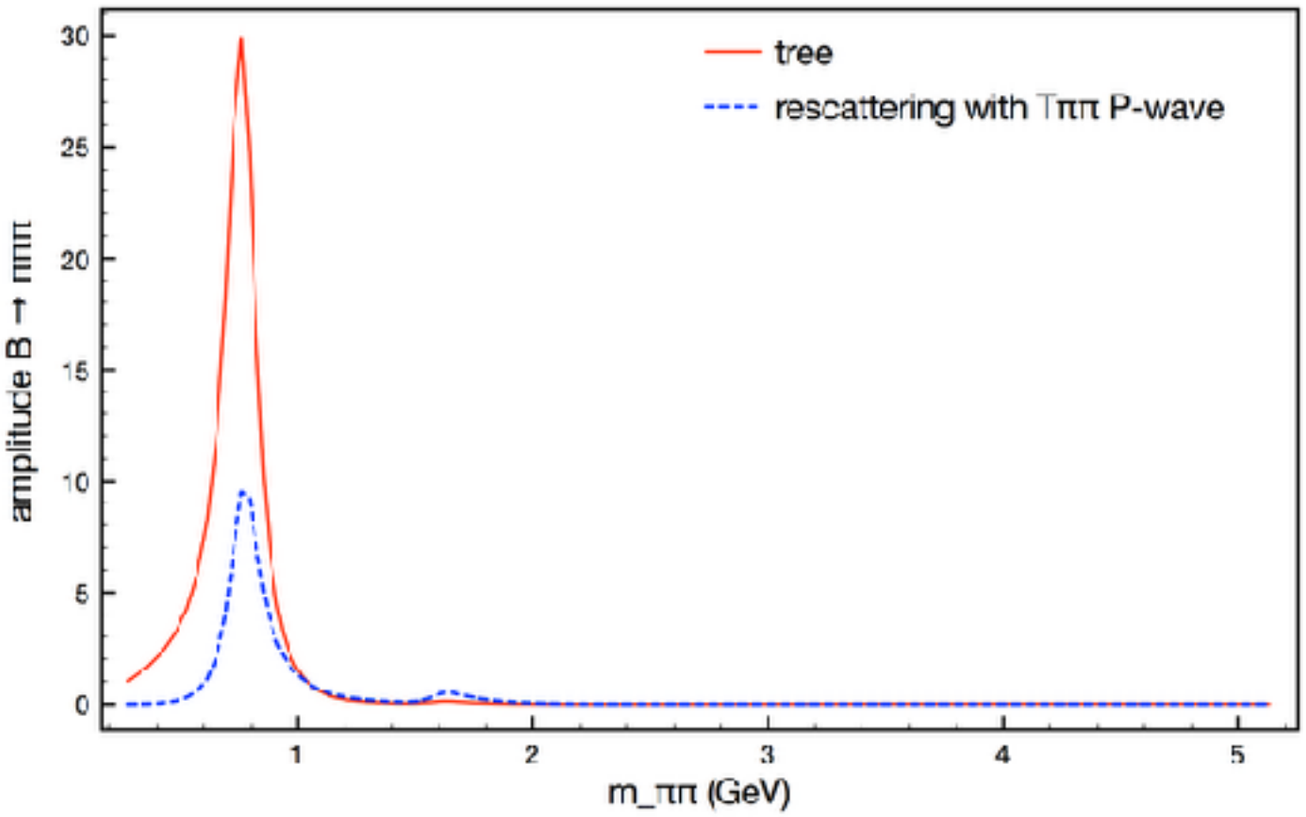
What the relevance of rescattering?

It changes the phase-space distribution on Dalitz plot?

rescattering effects



- two ρ-meson



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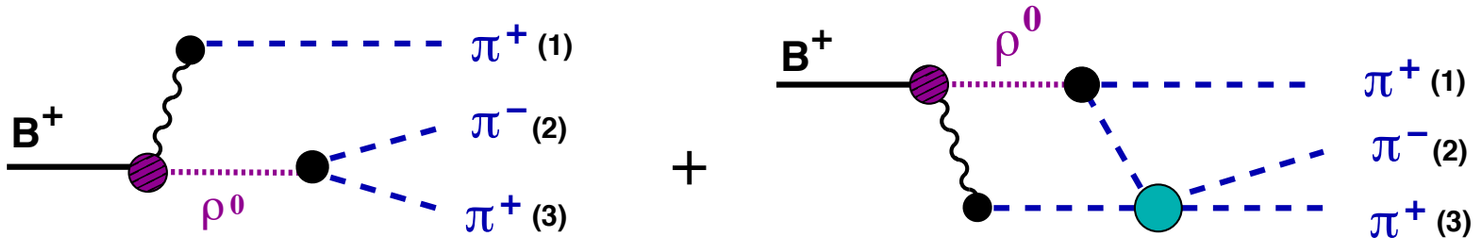

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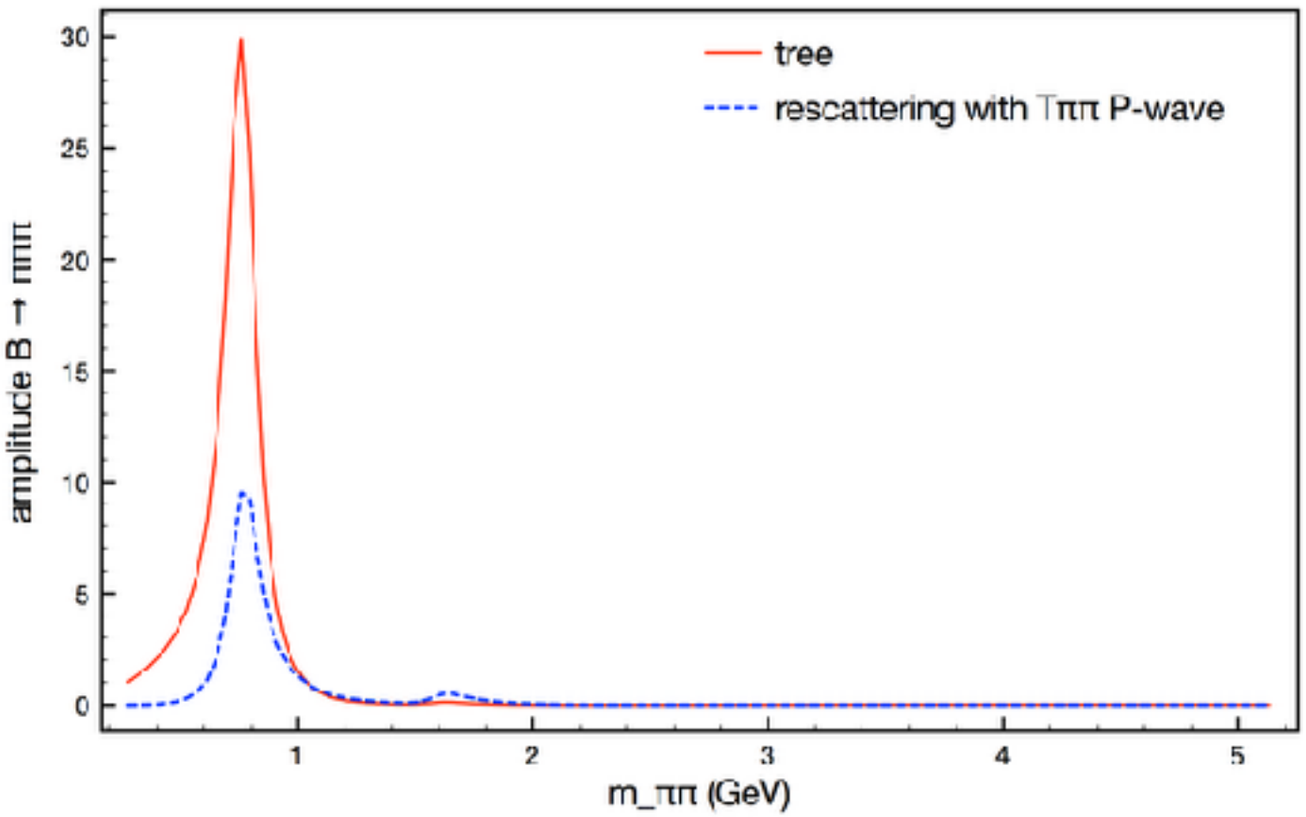

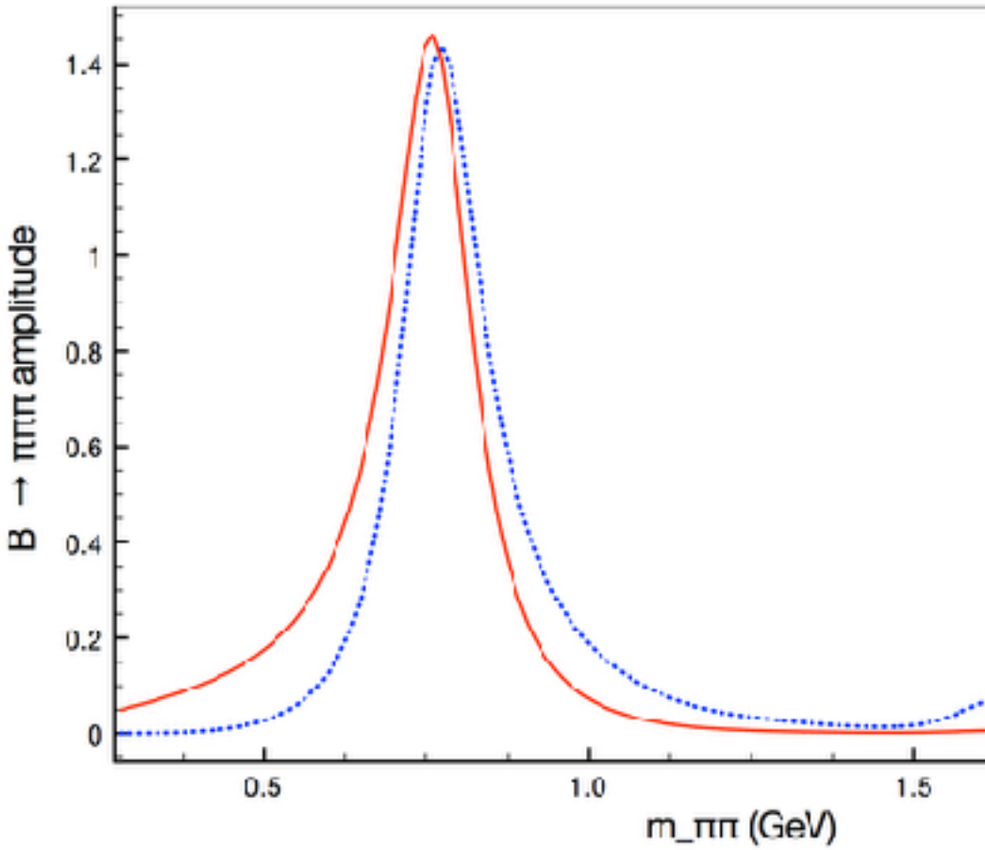

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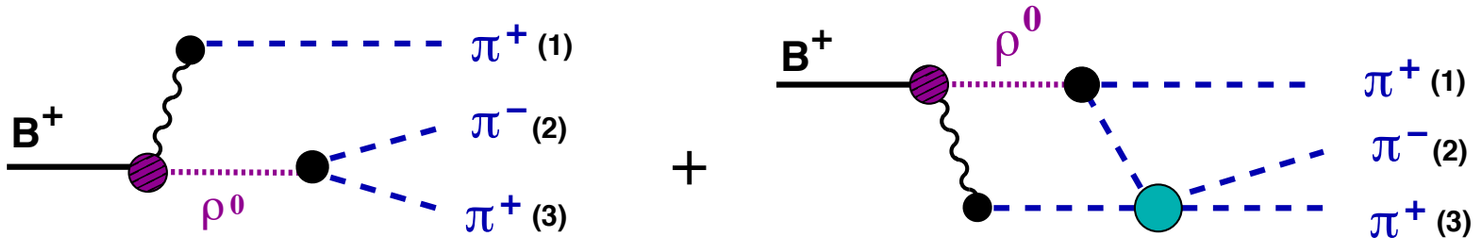

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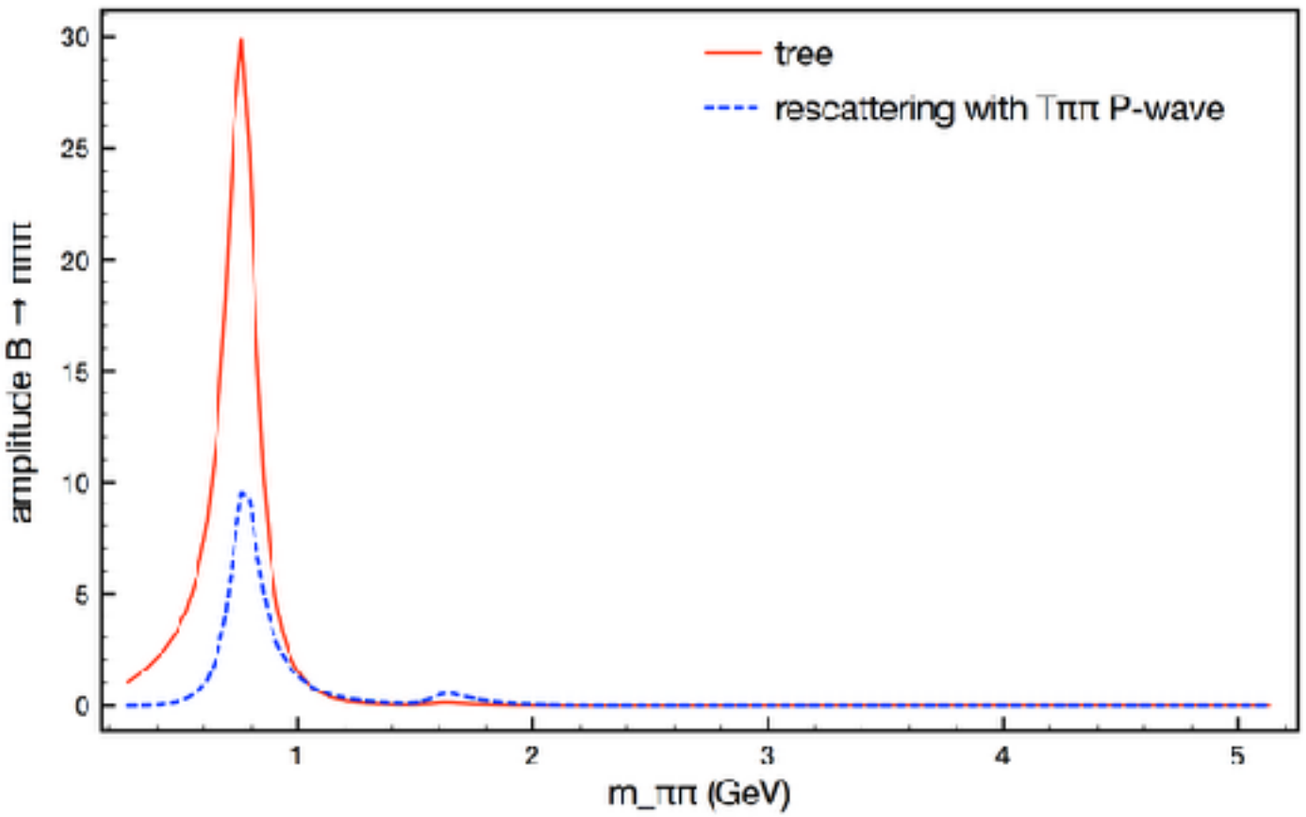
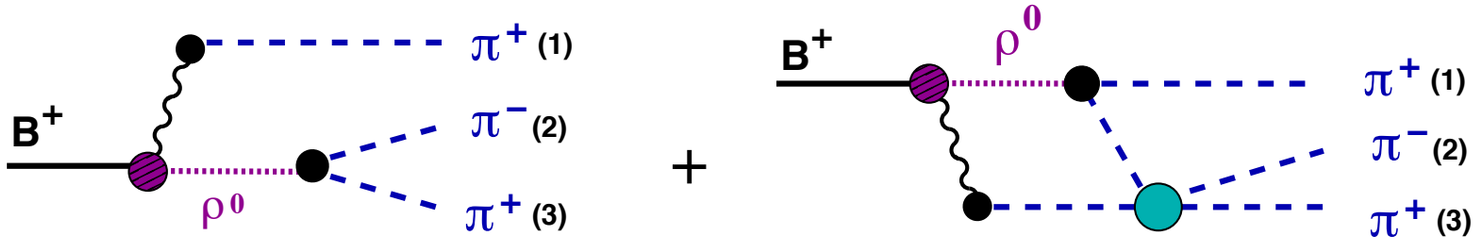
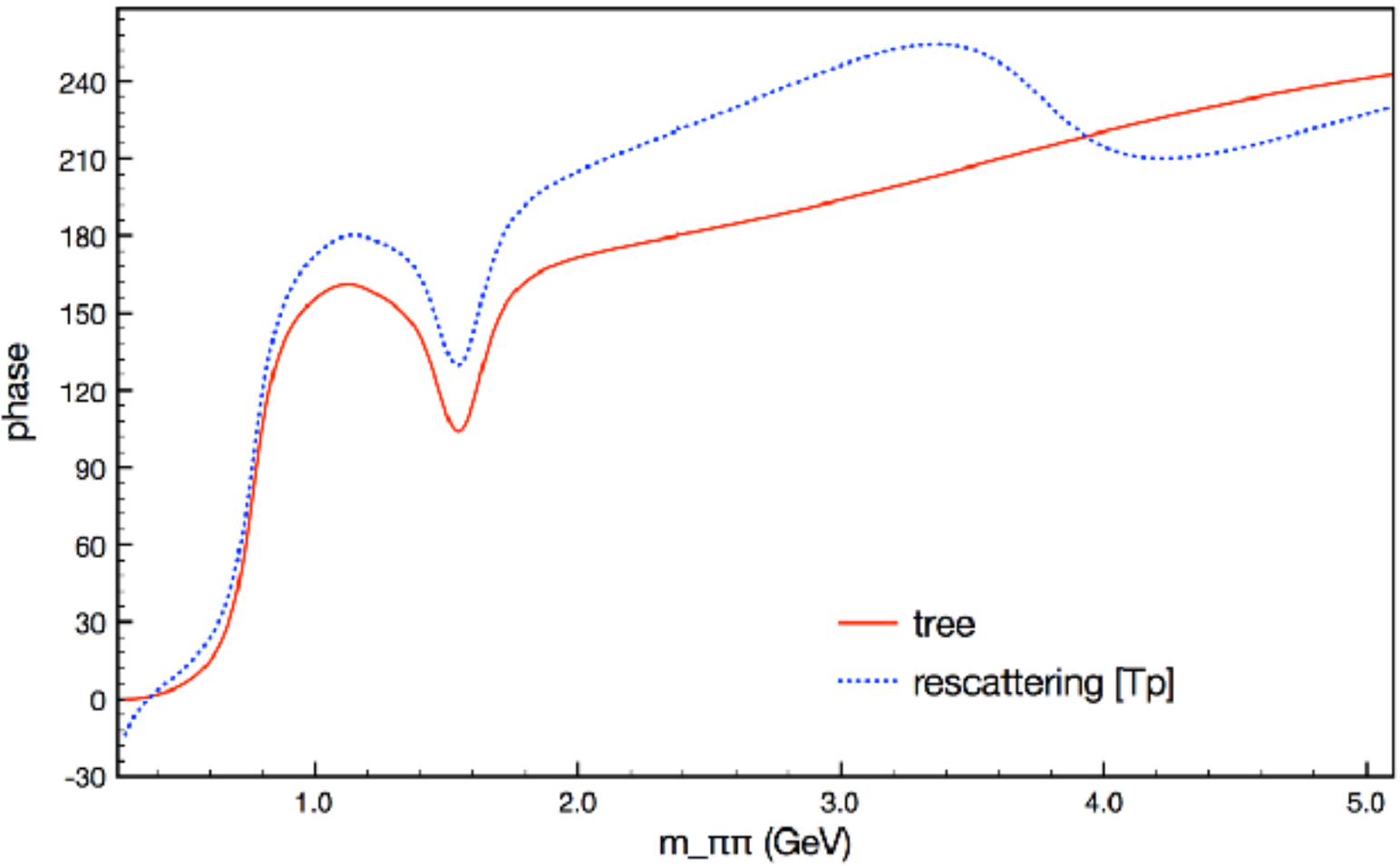


change the shape of ρ!

rescattering effects



- different P-wave phase



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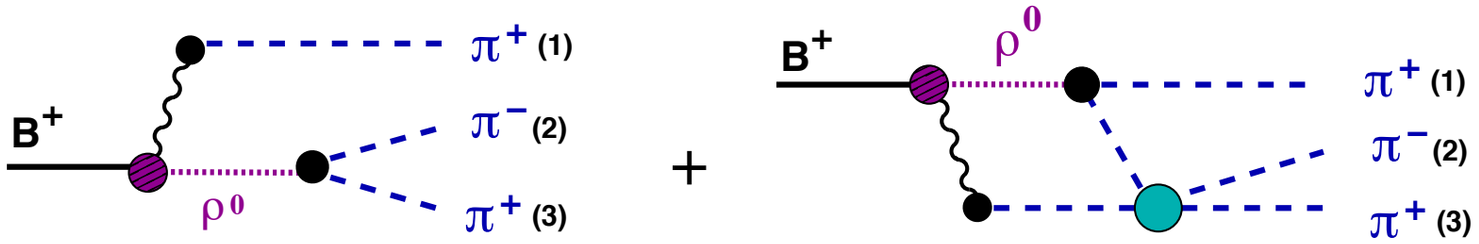

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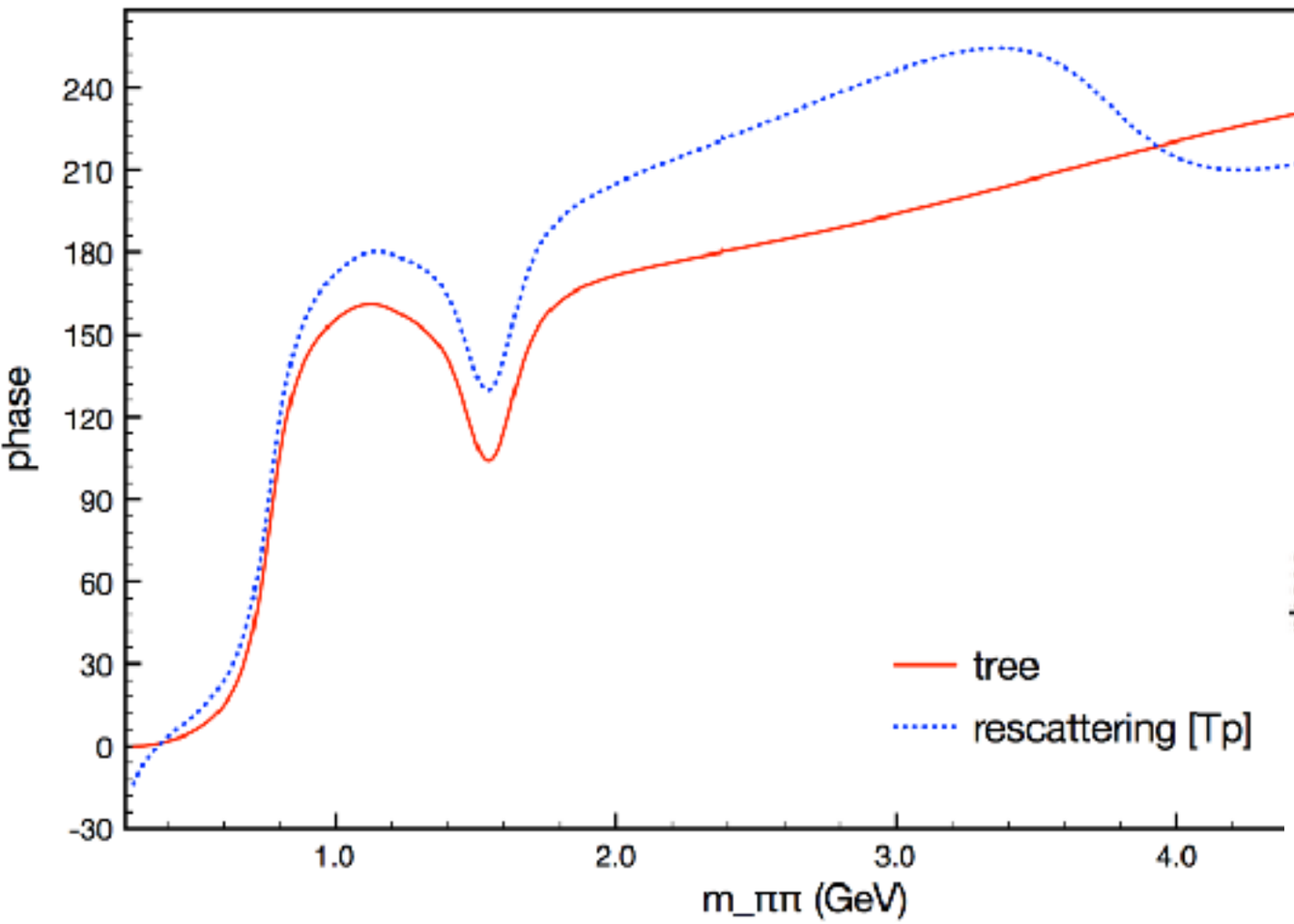
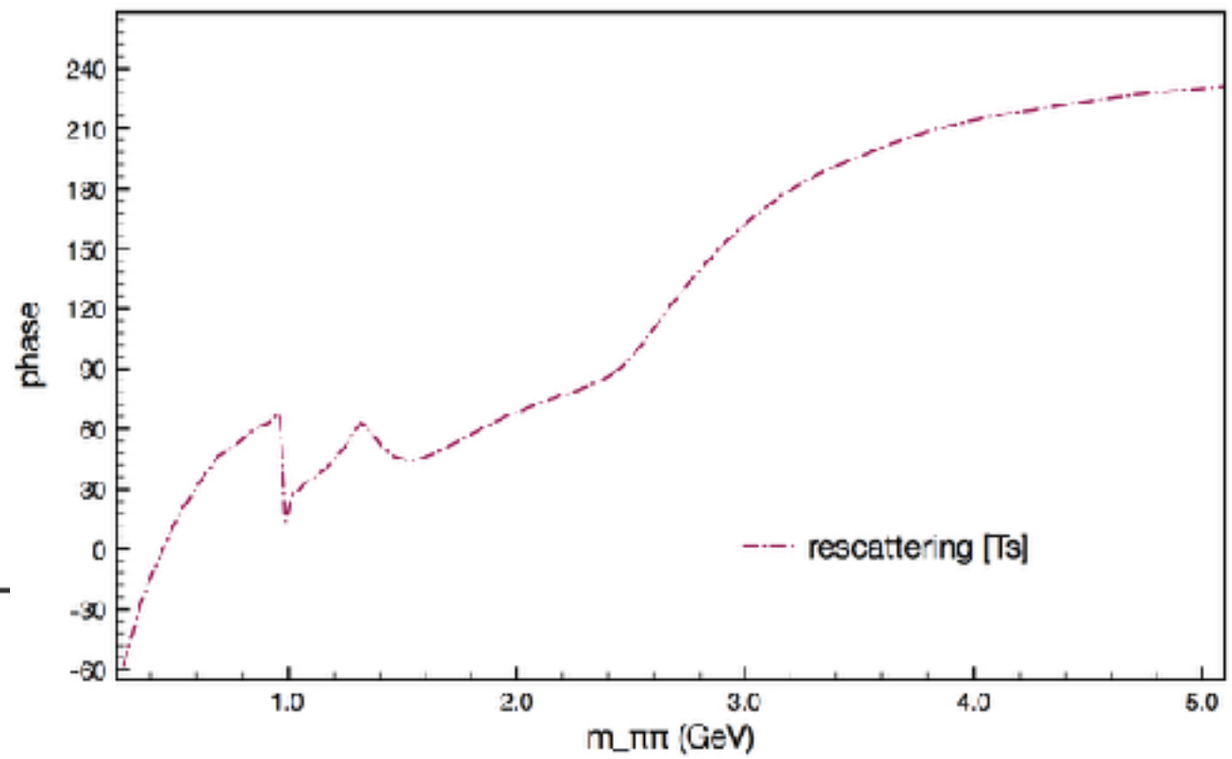
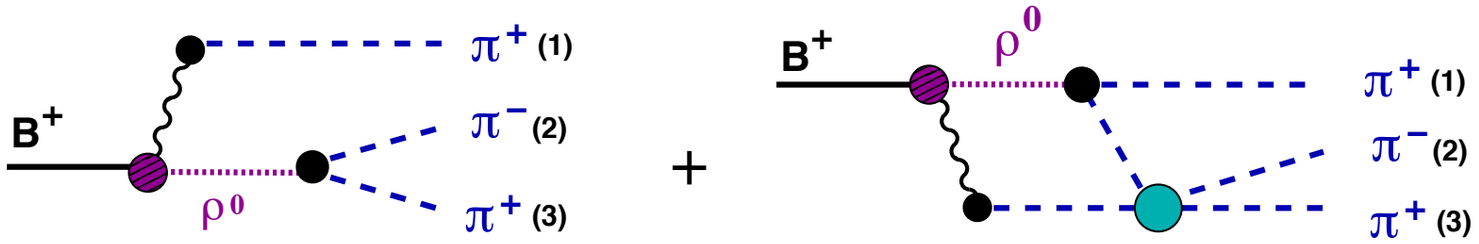


- S-wave phase



rescattering effects



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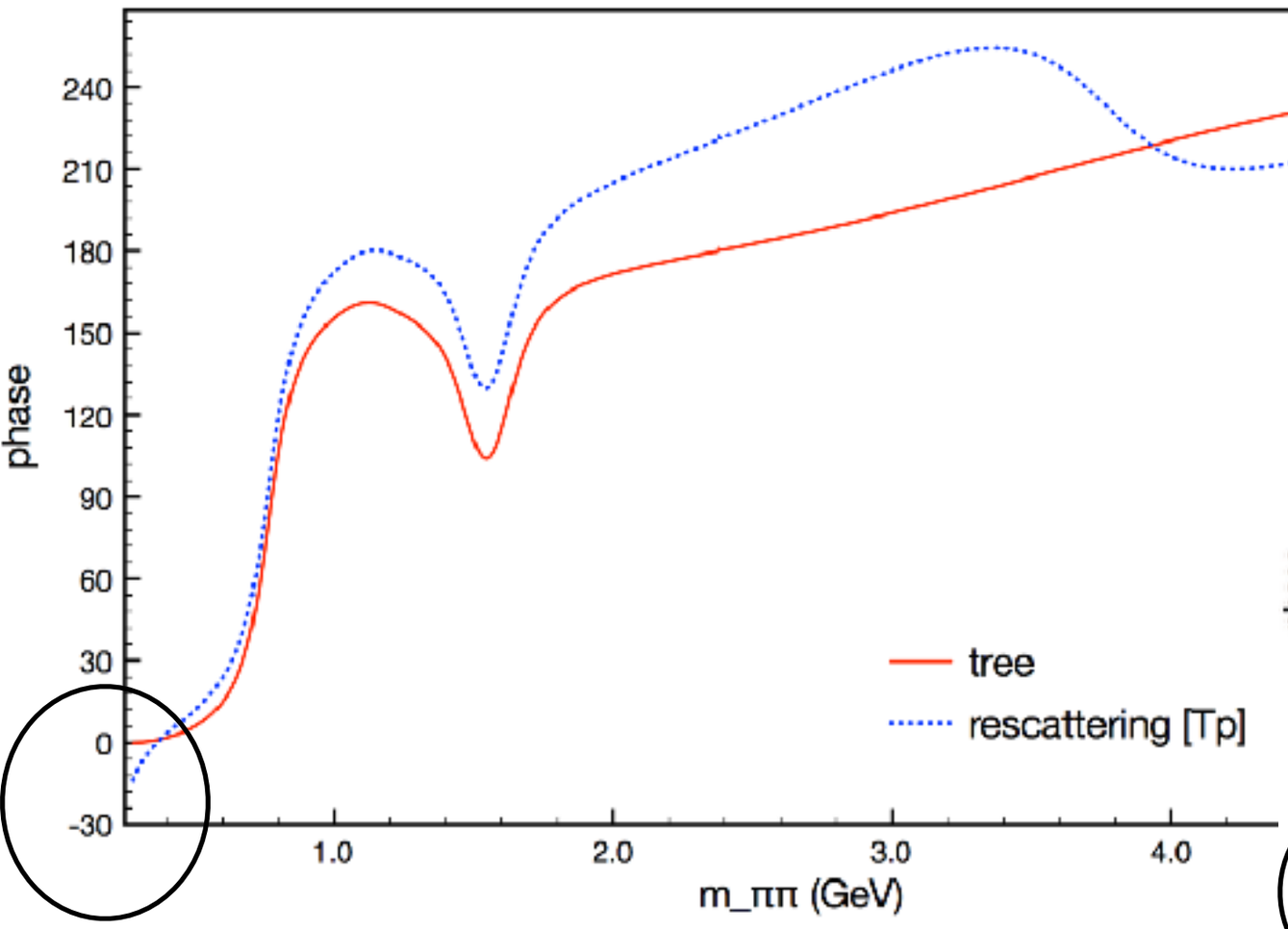
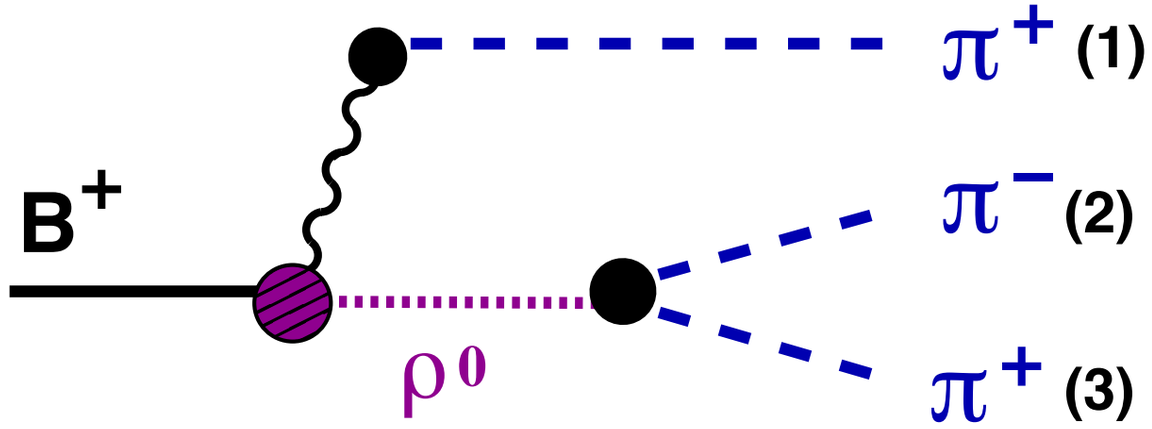


- S-wave phase

tree amplitude



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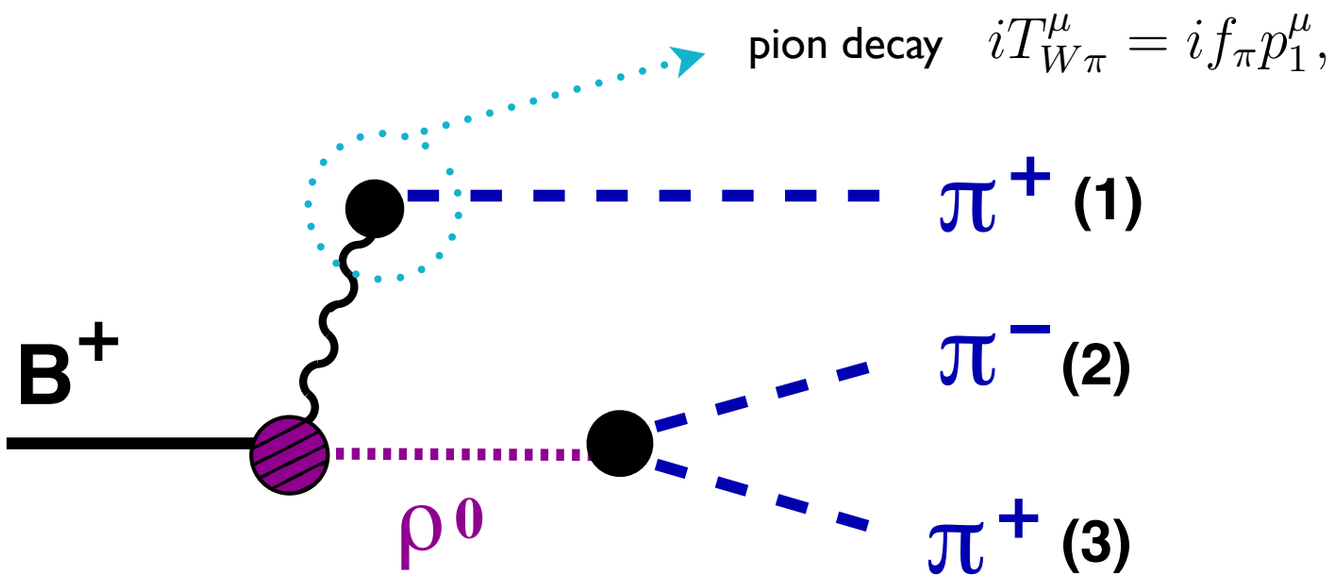

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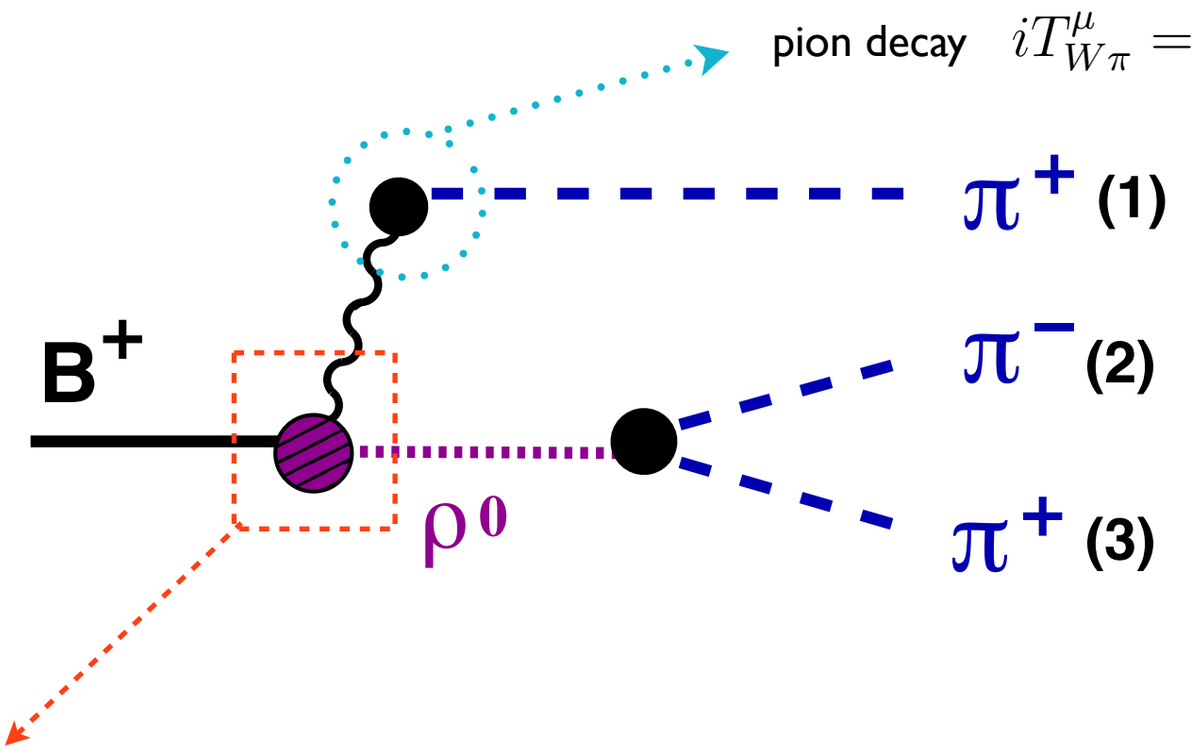
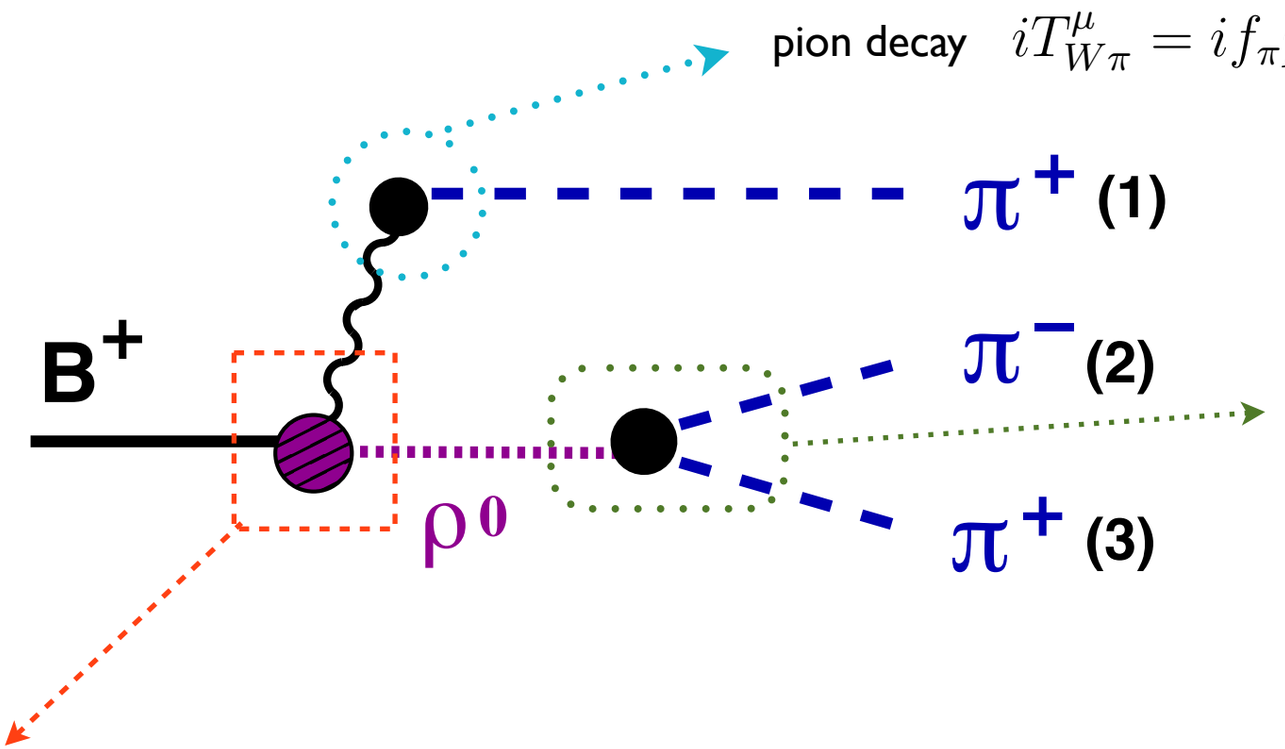


$$iT_{B\rho} = -i\ 2m_\rho\ \frac{\epsilon^* \cdot P_B}{p_1^2}\ p_1\ F_0^{B\rho}(p_1^2)$$

Bρ form factor - constant

$$F_0^{B\rho}(p_1^2) = \frac{F_{B\rho}(0)}{1 - M_\pi^2/m_B^{*2}} \approx F_{B\rho}(0) = 0.372$$

tree amplitude



pion vector FF

$$iT^{\nu}_{\rho\pi\pi} = iC_W(-p_3 + p_2).\epsilon\, F^1_{\pi\pi}(s_{23}),$$

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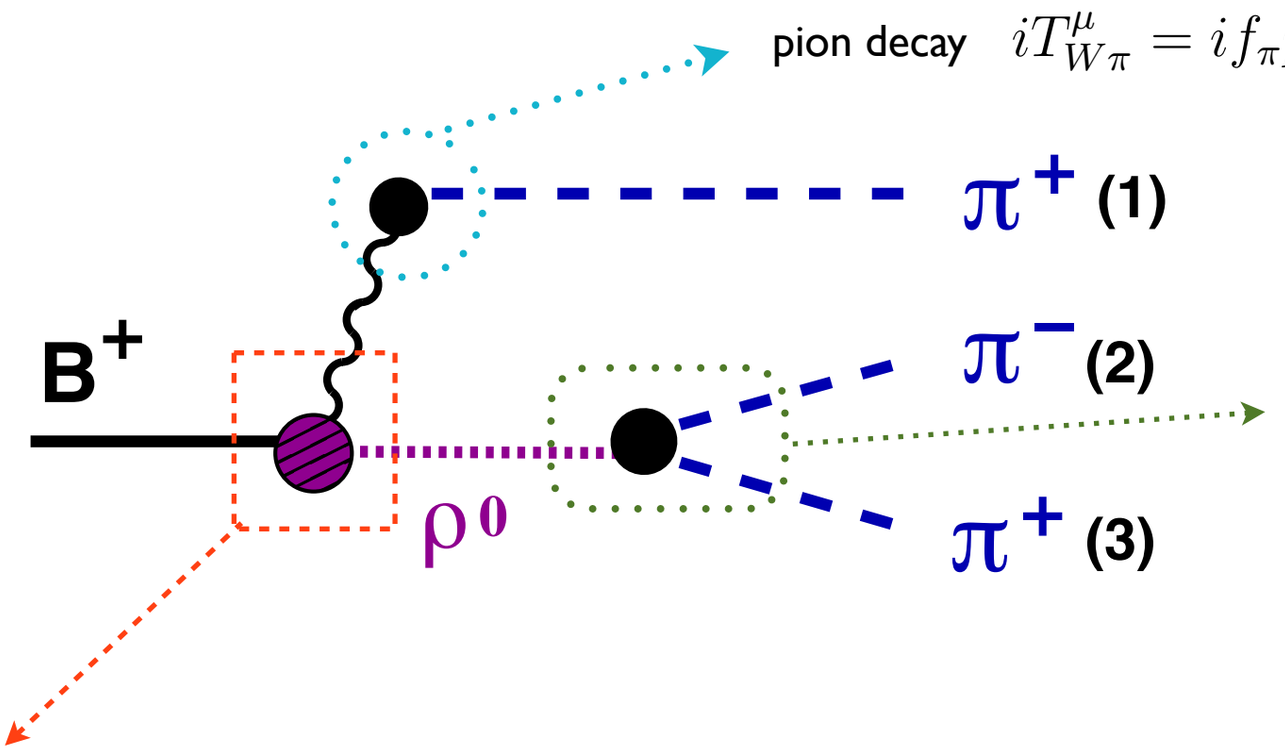

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function of Fππ

$$iT_{B\rho} = -i\ 2m_\rho\ \frac{\epsilon^* \cdot P_B}{p_1^2}\ p_1\ F_0^{B\rho}(p_1^2)$$

$$\boxed{A_0 \ = \ C_0\left[-p_1\ \cdot (p_2 - p_3)\right] F^1_{\pi\pi}(s_{23});}$$

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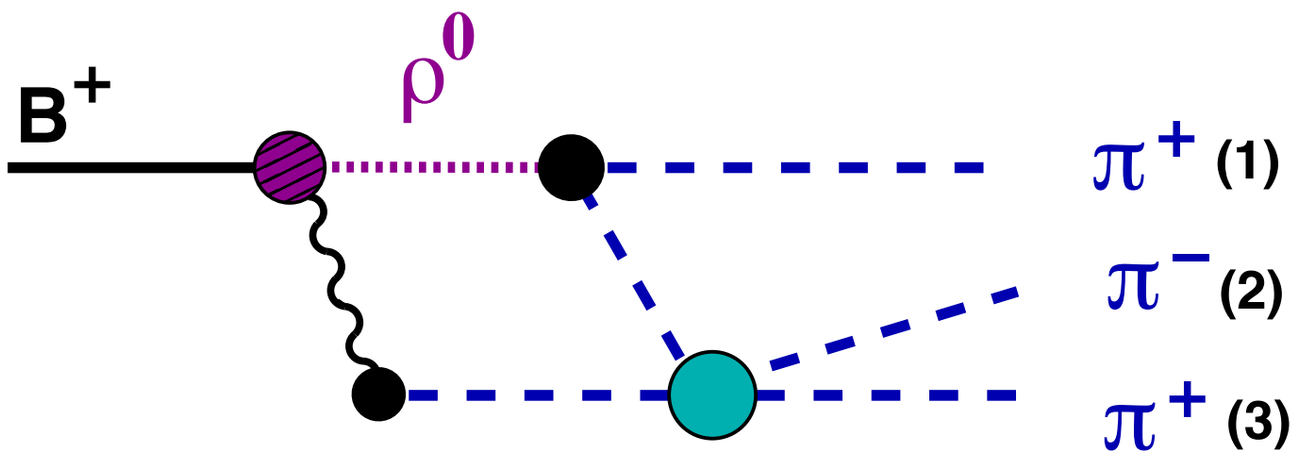
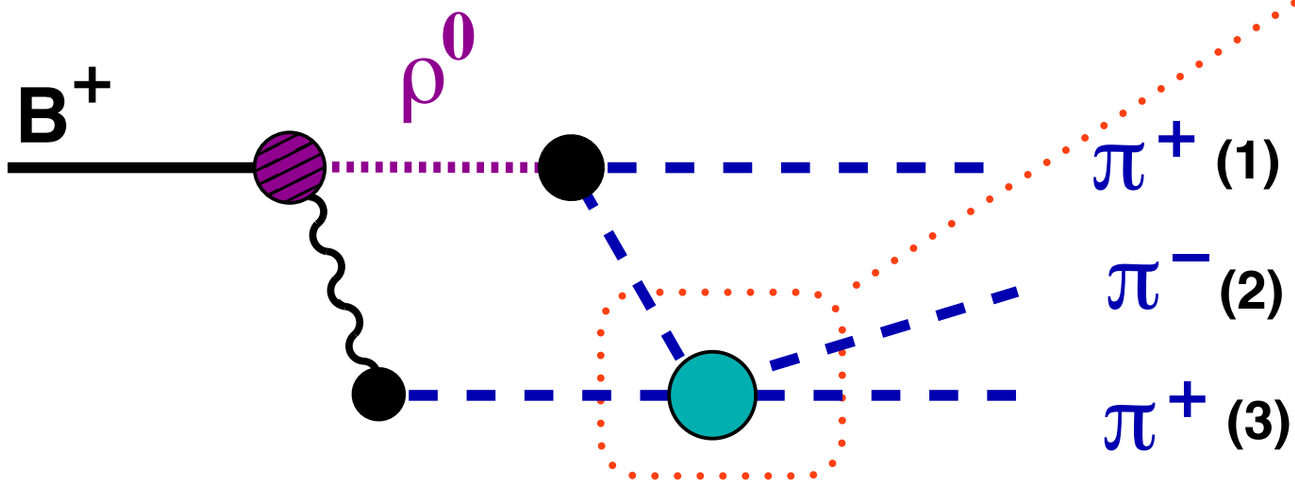
$$C_0 = \ 2\, m_\rho\, f_\pi \frac{C_W}{M_W^2}\, F_{B\rho}(0),$$

details if needed

one loop amplitude



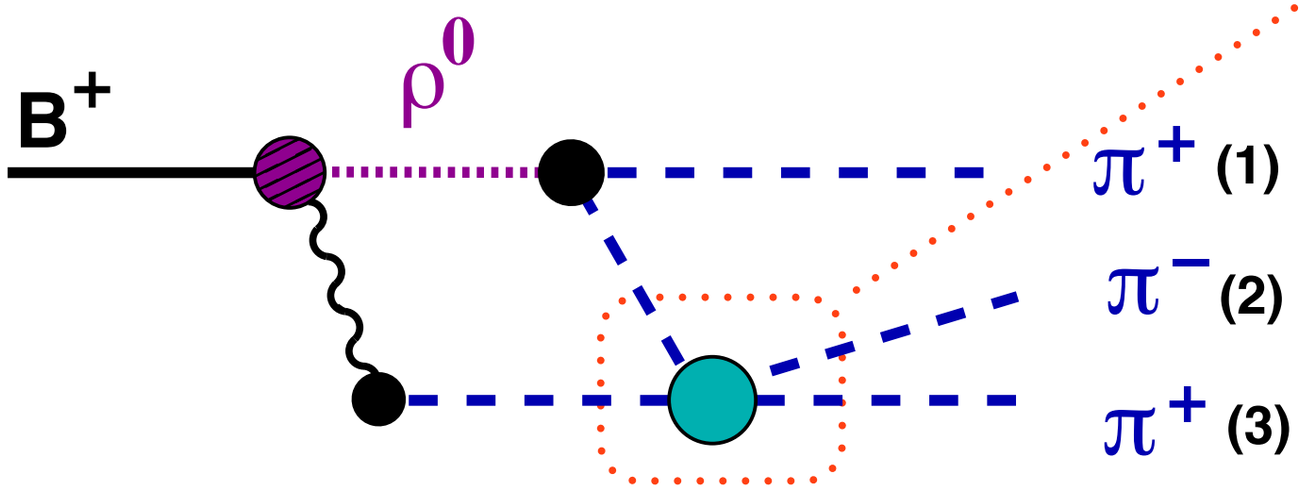
one loop amplitude



ππ scattering

$T^{I}_{\pi\pi}$ with I = 0,1 or 2

one loop amplitude



ππ scattering

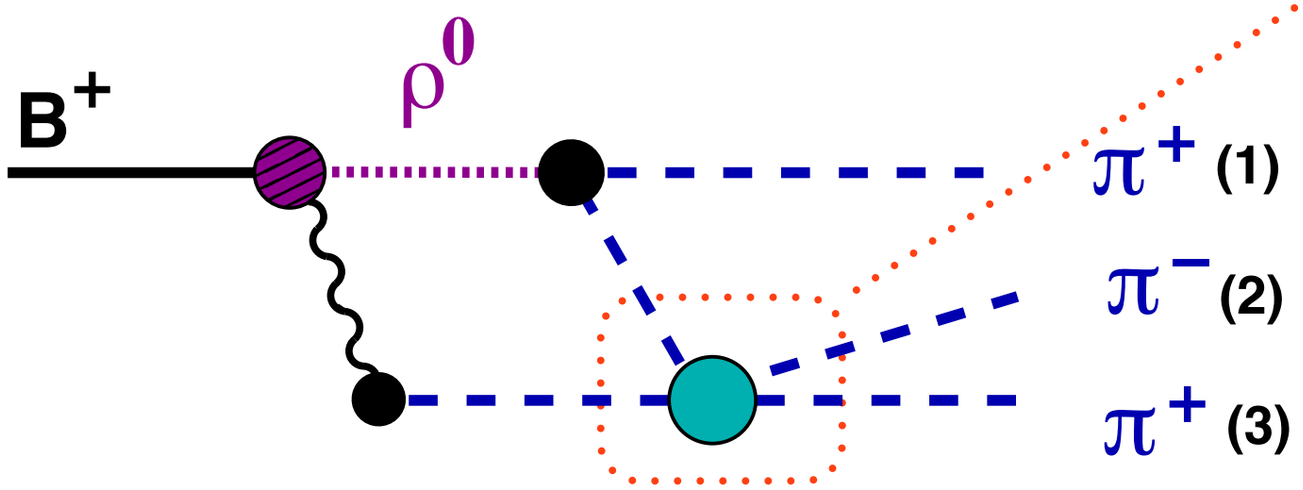
$T^{I}_{\pi\pi}$ with I = 0,1 or 2

$$A_1 = -i \int \frac{d^4\ell}{(2\pi)^4} \frac{T_{\pi\pi}\, A_0}{\Delta_\pi^+ \, \Delta_\pi^-}$$

$$\Delta_\pi^+ = (P_B - l)^2 - M_\pi^2;$$

$$\Delta_\pi^- = (l - p_3)^2 - M_\pi^2;$$

one loop amplitude



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$$\Delta_\pi^+ = (P_B - l)^2 - M_\pi^2;$$

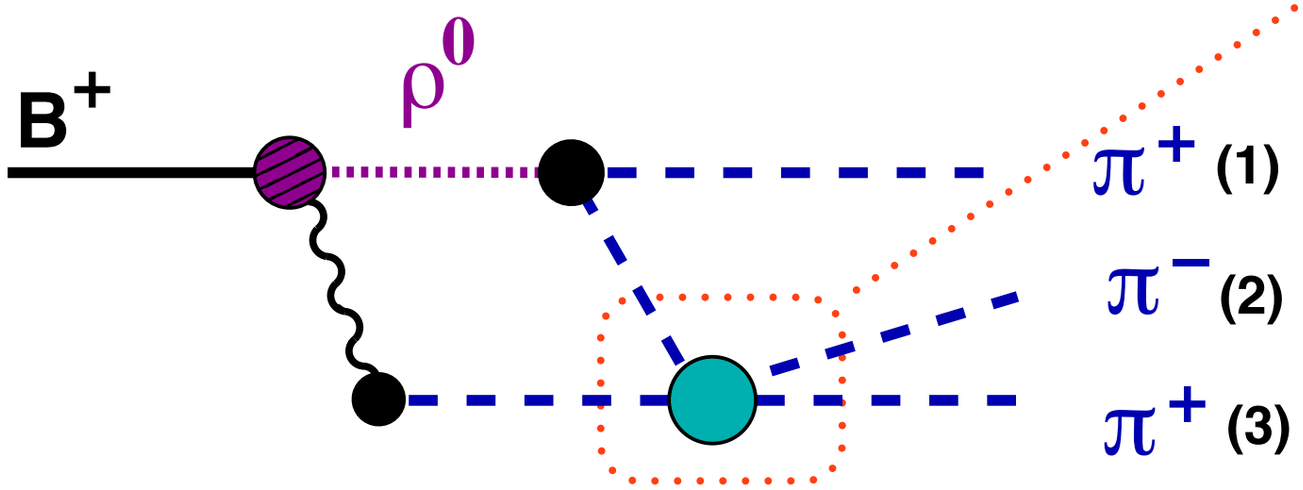
$$\Delta_\pi^- = (l - p_3)^2 - M_\pi^2;$$

$$A_0 = C_0 \left[-p_1 \cdot (p_2 - p_3)\right] F^1_{\pi\pi}(s_{23});$$

$$F^1_{\pi\pi}(s_{23}) = \frac{m_\rho^2}{D_\rho} = \sum_i \frac{N_{\rho i}}{l^2 - \Theta_i}$$

$$-p_1' \cdot (p_2' - p_3) = \frac{1}{2}\left[\, \Delta_{\pi^+} + 2\,\Delta_{\pi^-} - 2\, s_{23} + 3\, M_\pi^2 + M_B^2 - l^2 \,\right]$$

one loop amplitude



ππ scattering

$T^{I}_{\pi\pi}$ with I = 0,1 or 2

$$A_1 = -i \int \frac{d^4\ell}{(2\pi)^4} \frac{T_{\pi\pi}\, A_0}{\Delta_\pi^+ \, \Delta_\pi^-}$$

$$\Delta_\pi^+ = (P_B - l)^2 - M_\pi^2;$$

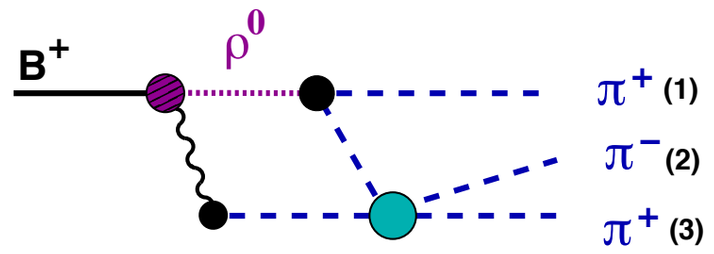
$$\Delta_\pi^- = (l - p_3)^2 - M_\pi^2;$$

$$A_0 = C_0 \left[-p_1 \cdot (p_2 - p_3)\right] F^1_{\pi\pi}(s_{23});$$

$$F^1_{\pi\pi}(s_{23}) = \frac{m_\rho^2}{D_\rho} = \sum_i \frac{N_{\rho i}}{l^2 - \Theta_i} \qquad -p_1' \cdot (p_2' - p_3) = \frac{1}{2}\left[\, \Delta_{\pi^+} + 2\,\Delta_{\pi^-} - 2\, s_{23} + 3\, M_\pi^2 + M_B^2 - l^2 \,\right]$$

$$A_1 = -iC_O \frac{-m_B^{*2}}{2} \int \frac{d^4\ell}{(2\pi)^4}\, T_{\pi\pi}\,(s_{23})\, \frac{(\Delta_{\pi^+} + 2\,\Delta_{\pi^-} - 2\, s_{23} + 3\, M_\pi^2 + M_B^2 - l^2)}{\Delta_\pi^+ \, \Delta_\pi^- \, \Delta_{B*}} \frac{N_\rho}{l^2 - \Theta_\rho}$$

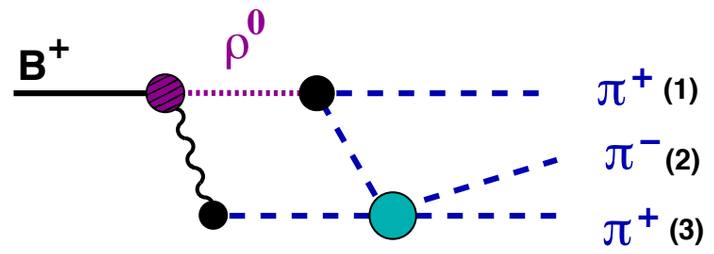
one loop amplitude



$$A_1 = i\frac{C_O\, m_B^{*2}\, N_\rho}{2}\int \frac{d^4\ell}{(2\pi)^4}\left[\frac{3\,(t-u)}{s_{12}-4\,M_\pi^2}\,T_{\pi\pi}^P(s_{23})+\frac{3}{2}T_{\pi\pi}^S(s_{23})\right]\frac{(\Delta_{\pi^+}+2\,\Delta_{\pi^-}-\,2\,s_{23}+3\,M_\pi^2+M_B^2-l^2)}{\Delta_\pi^+\,\Delta_\pi^-\,\Delta_{B*}\,[l^2-\Theta_\rho]}$$

$$t-u \;=\; 2p_3\cdot(p_2-p_1)-2\,l\cdot(p_2-p_1)$$

one loop amplitude



$$A_1 = i\frac{C_O\, m_B^{*2}\, N_\rho}{2}\int \frac{d^4\ell}{(2\pi)^4}\left[\frac{3\,(t-u)}{s_{12}-4\,M_\pi^2}\,T^P_{\pi\pi}(s_{23})+\frac{3}{2}T^S_{\pi\pi}(s_{23})\right]\frac{(\Delta_{\pi^+}+2\,\Delta_{\pi^-}-\,2\,s_{23}+3\,M_\pi^2+M_B^2-l^2)}{\Delta_\pi^+\,\Delta_\pi^-\,\Delta_{B*}\,[l^2-\Theta_\rho]}$$

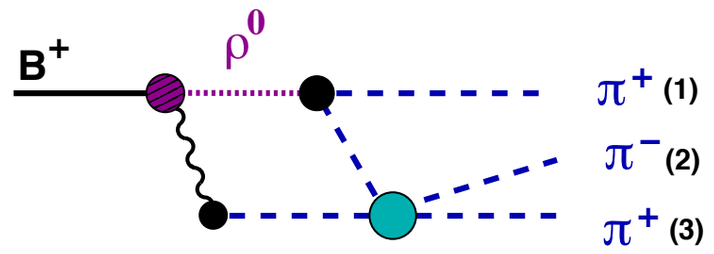
$$t-u \;=\; 2p_3\cdot(p_2-p_1)-2\,l\cdot(p_2-p_1)$$

$$A_1^P \;=\; i\frac{C_O\, m_B^{*2}\, N_\rho}{2}\,T^P_{\pi\pi}(s_{23})\Bigg\{2p_3\cdot(p_2-p_1)\int\frac{d^4\ell}{(4\pi)^2}\,\frac{(\Delta_{\pi^+}+2\,\Delta_{\pi^-}-\,2\,s_{23}+3\,M_\pi^2+M_B^2-l^2)}{\Delta_\pi^+\,\Delta_\pi^-\,\Delta_{B*}\,[l^2-\Theta_i]}$$

$$-\,2\,(p_2-p_1)_\mu\int\frac{d^4\ell}{(4\pi)^2}\,l^\mu\,\frac{(\Delta_{\pi^+}+2\,\Delta_{\pi^-}-\,2\,s_{23}+3\,M_\pi^2+M_B^2-l^2)}{\Delta_\pi^+\,\Delta_\pi^-\,\Delta_{B*}\,[l^2-\Theta_i]}\Bigg\}\,,$$

$$A_1^S \;=\; i\frac{C_O\, m_B^{*2}\, N_\rho}{2}\,T^S_{\pi\pi}(s_{23})\int\frac{d^4\ell}{(4\pi)^2}\,\frac{(\Delta_{\pi^+}+2\,\Delta_{\pi^-}-\,2\,s_{23}+3\,M_\pi^2+M_B^2-l^2)}{\Delta_\pi^+\,\Delta_\pi^-\,\Delta_{B*}\,[l^2-\Theta_i]}$$

one loop amplitude



$$A_1 = i\frac{C_O\, m_B^{*2}\, N_\rho}{2}\int \frac{d^4\ell}{(2\pi)^4}\left[\frac{3\,(t-u)}{s_{12}-4\,M_\pi^2}\,T^P_{\pi\pi}(s_{23})+\frac{3}{2}T^S_{\pi\pi}(s_{23})\right]\frac{(\Delta_{\pi^+}+2\,\Delta_{\pi^-}-\,2\,s_{23}+3\,M_\pi^2+M_B^2-l^2)}{\Delta_\pi^+\,\Delta_\pi^-\,\Delta_{B*}\,[l^2-\Theta_\rho]}$$

$$t-u \;=\; 2p_3\cdot(p_2-p_1)-2\,l\cdot(p_2-p_1)$$

$$A_1^P \;=\; i\frac{C_O\, m_B^{*2}\, N_\rho}{2}\,T^P_{\pi\pi}(s_{23})\Bigg\{2p_3\cdot(p_2-p_1)\int\frac{d^4\ell}{(4\pi)^2}\,\frac{(\Delta_{\pi^+}+2\,\Delta_{\pi^-}-\,2\,s_{23}+3\,M_\pi^2+M_B^2-l^2)}{\Delta_\pi^+\,\Delta_\pi^-\,\Delta_{B*}\,[l^2-\Theta_i]}$$

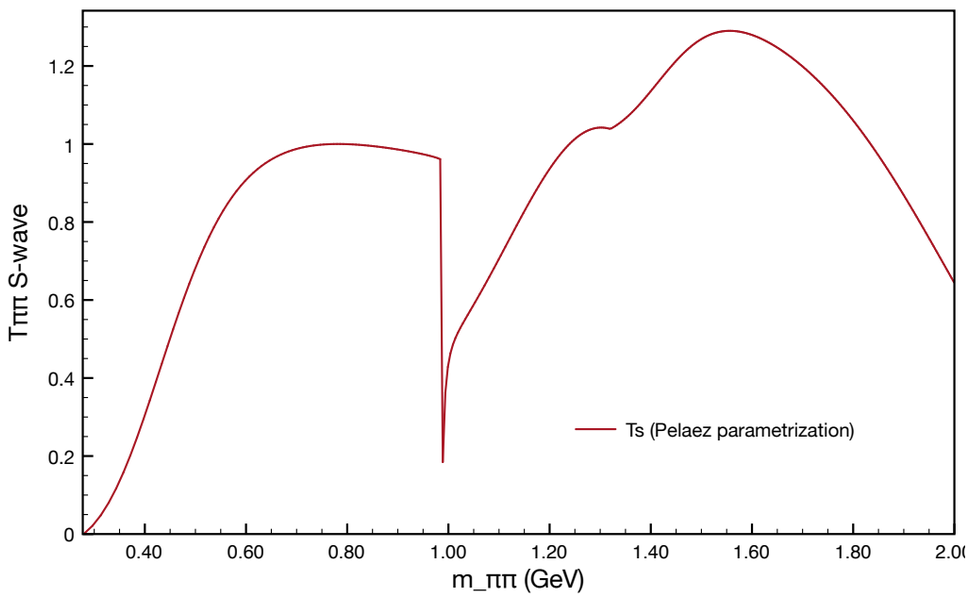
$$-\,2\,(p_2-p_1)_\mu\int\frac{d^4\ell}{(4\pi)^2}\,l^\mu\,\frac{(\Delta_{\pi^+}+2\,\Delta_{\pi^-}-\,2\,s_{23}+3\,M_\pi^2+M_B^2-l^2)}{\Delta_\pi^+\,\Delta_\pi^-\,\Delta_{B*}\,[l^2-\Theta_i]}\Bigg\}\,,$$

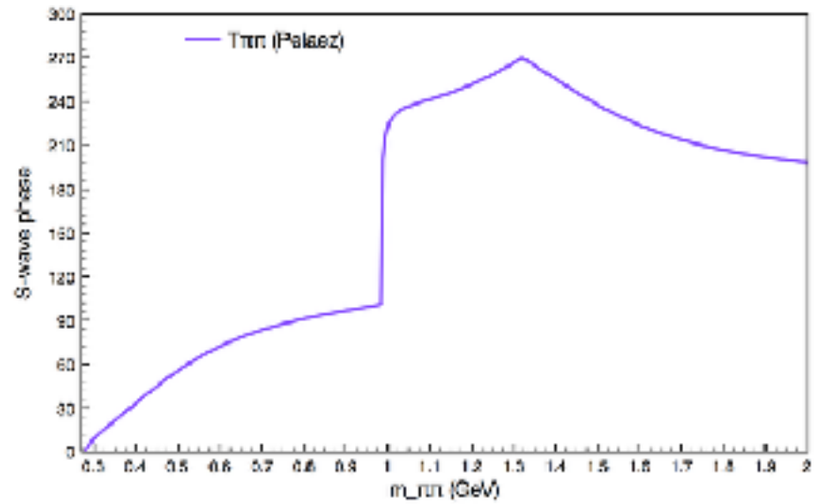
$$A_1^S \;=\; i\frac{C_O\, m_B^{*2}\, N_\rho}{2}\,T^S_{\pi\pi}(s_{23})\int\frac{d^4\ell}{(4\pi)^2}\,\frac{(\Delta_{\pi^+}+2\,\Delta_{\pi^-}-\,2\,s_{23}+3\,M_\pi^2+M_B^2-l^2)}{\Delta_\pi^+\,\Delta_\pi^-\,\Delta_{B*}\,[l^2-\Theta_i]}$$

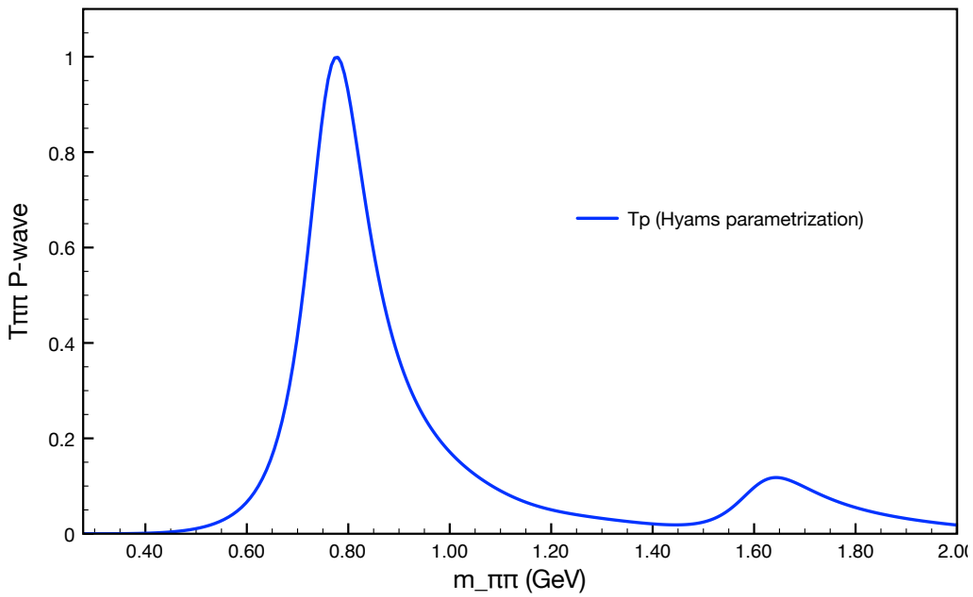
no angular distribution

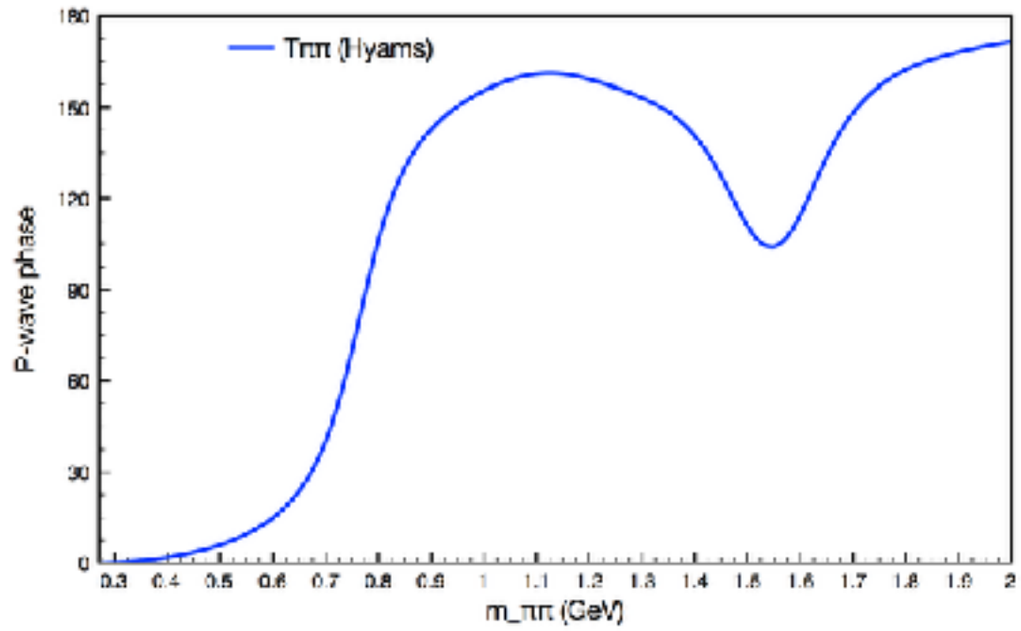
ππ scattering

J. R. Pelaez, F. J. Ynduráin, Phys. Rev. D **71** (2005) 074016.
B. Hyams et. al., Nucl. Phys. B**64**, 134 (1973)



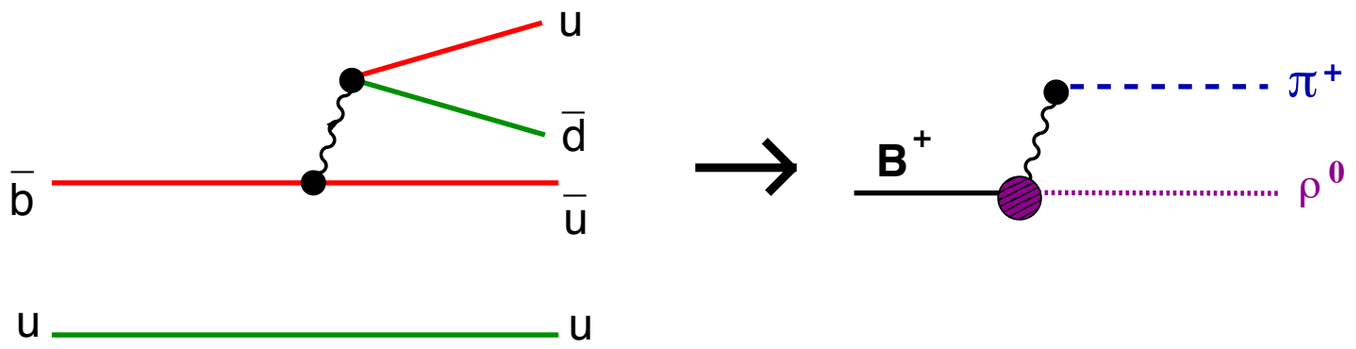




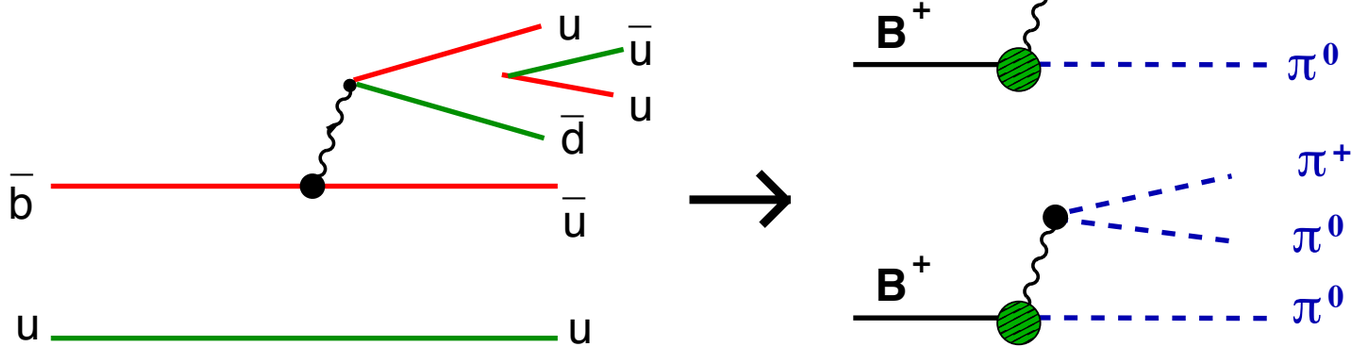


Topologies

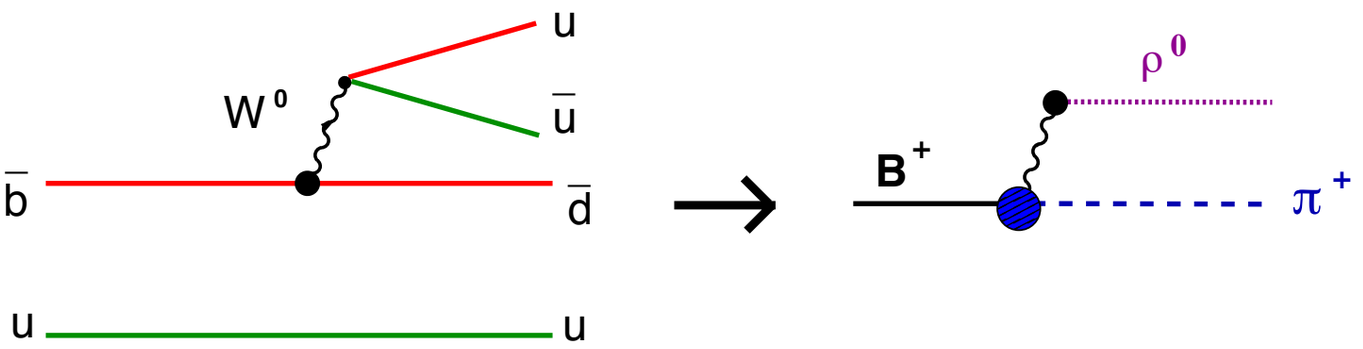
a.1



v.1

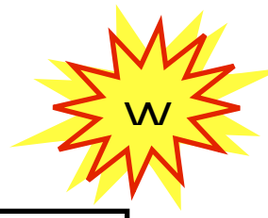


v.2
(Fierz)

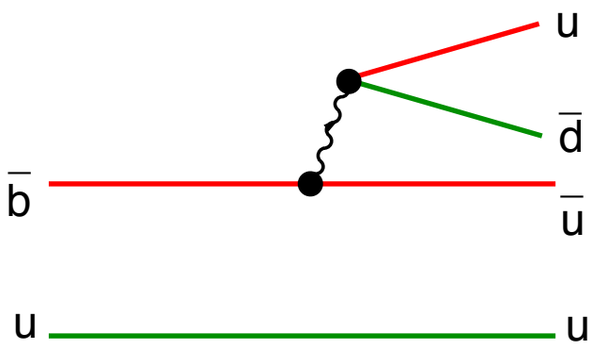


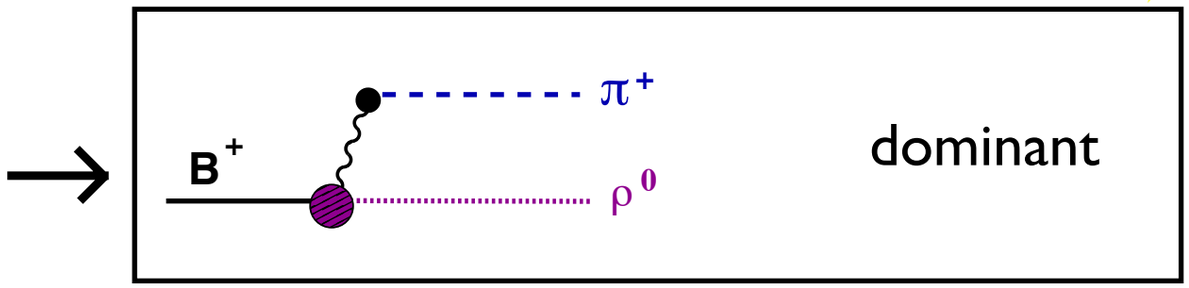
penguin not relevant on this decay

Topologies

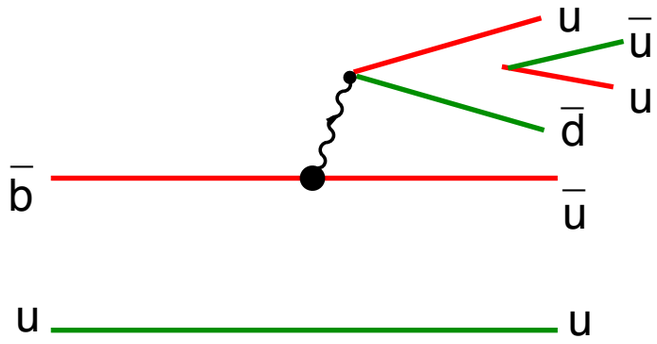


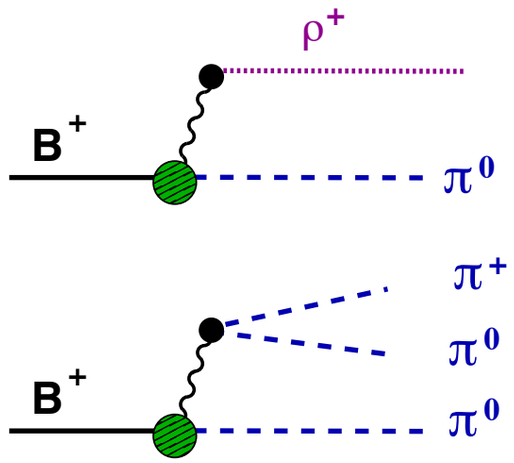
a.1





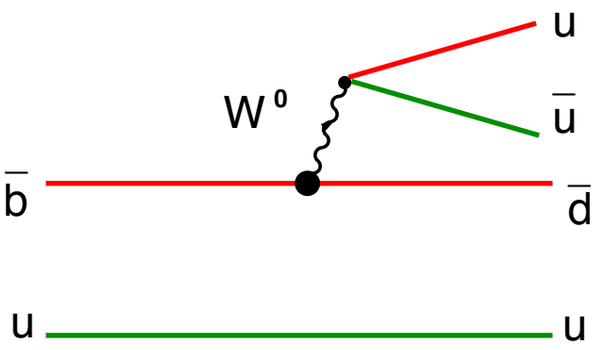
v.1

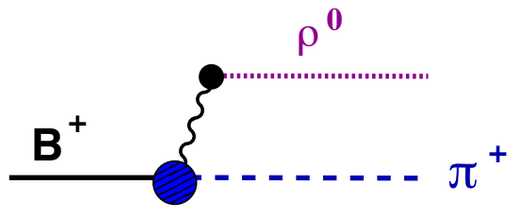




only by rescattering

v.2
(Fierz)





penguin not relevant on this decay