CP violation and CPT invariance in charmless B decays

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General question about CP violation

C̸P violation and the CPT Theorem

Valid to any Lorentz invariant theory where the observables are represented for hermitian operators. (Greengerg PRL89 (2002) 231602).

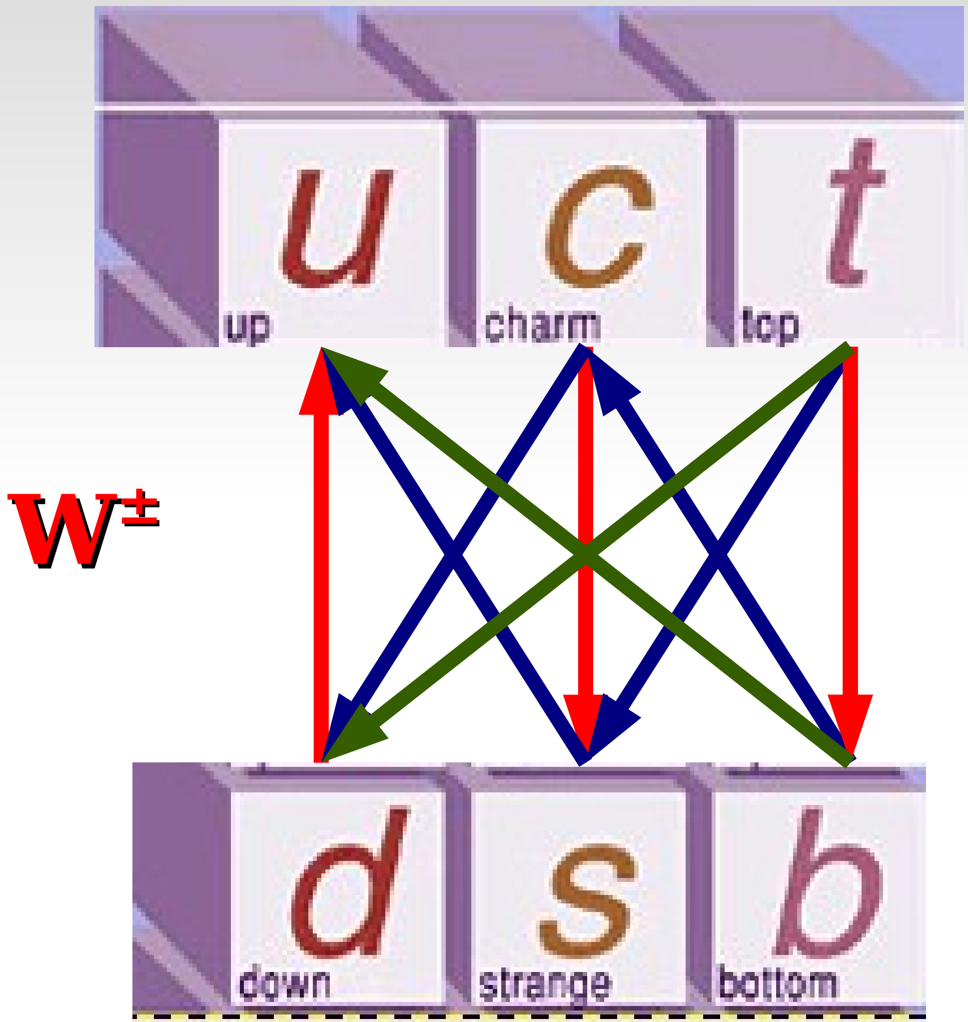
CPT conservation → same lifetime for both, particle and anti-particle.

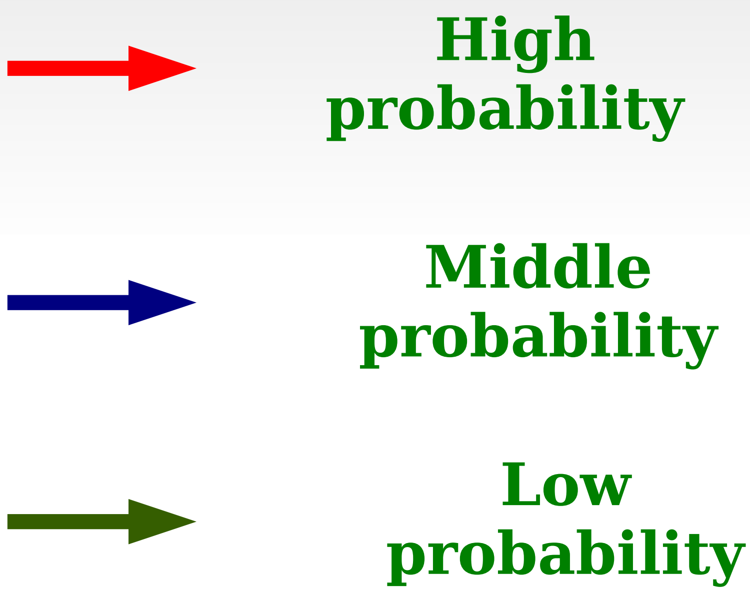
Sum of the partial width from particle and anti-particle must be the same:

$$\Gamma(M^{+} \to f^{+}_{1}) + \ldots\ldots + \Gamma(M^{+} \to f^{+}_{n}) = \Gamma(M^{-} \to f^{-}_{1}) + \ldots\ldots + \Gamma(M^{-} \to f^{-}_{n})$$

C̸P violation → presence of weak phase

CabbiboKobayashiMaskawa Matrix



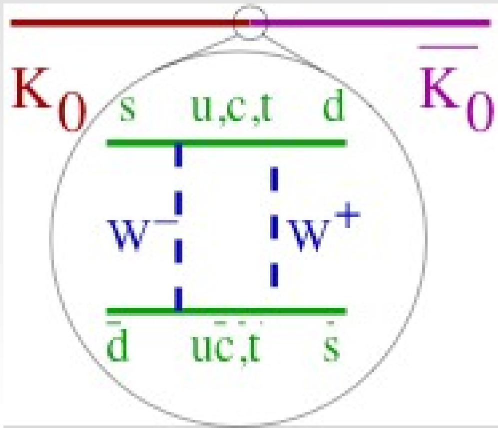


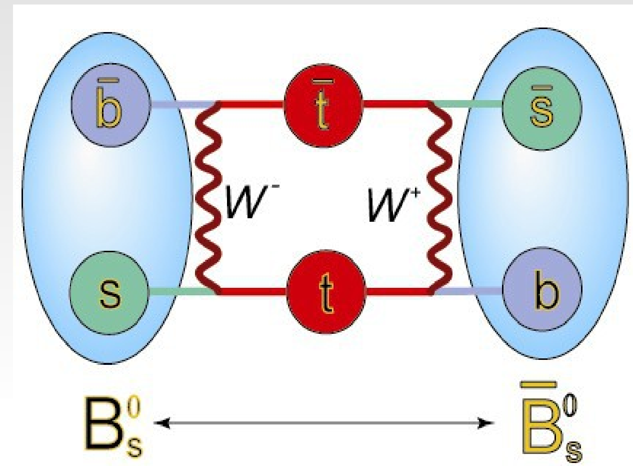
$$
\begin{array}{c|ccc|c}
 & d & s & b & \\
\hline
 & V_{ud} & V_{us} & V_{ub} & u \\
 & V_{cd} & V_{cs} & V_{cb} & c \\
 & V_{td} & V_{ts} & V_{tb} & t
\end{array}
$$

Cabibbo Kobayashi-Maskawa:
4 parameters, 3 angles and one phase.

Interferometer to observe $\not{C}P$ in neutral particles

$K^0 \rightleftarrows \bar{K}^0$ $\qquad\qquad$ $B_s^0 \rightleftarrows \bar{B}_s^0$





If M^0 e $\bar{M}^0$ decays in a same final state (P.ex. $\pi^+\pi^-$ ou K^+K^-):

Master Equation

$$\langle\alpha \mid T(t) \mid P^0\rangle = e^{-(\Gamma/2 - i\Delta m t)} [\, T(P^0 \to \alpha) \cos \Delta m t + q/p \; T(\bar{P}^0 \to \alpha) \sin \Delta m t]$$

$$\langle\alpha \mid T(t) \mid \bar{P}^0\rangle = e^{-(\Gamma/2 - i\Delta m t)} [\, T(\bar{P}^0 \to \alpha) \cos \Delta m t + p/q \; T(P^0 \to \bar{\alpha}) \sin \Delta m t]$$

If $q/p \neq p/q \rightarrow$ CP violation.

Δm oscillation parameter

Short distance

CP asymmetry,

Direct C̸P violation charged particles:
Different disintegration behavior from particle and anti-particle

Two contribution to a same final state.

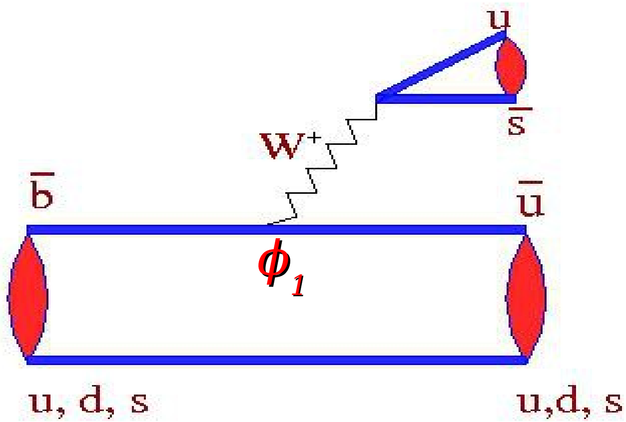
With different strong phases (δ_1 and δ_2) and weak phases (ϕ_1 and ϕ_2).

$$\langle f|T|i\rangle = A_1 e^{i(\delta_1+\phi_1)} + A_2 e^{i(\delta_2+\phi_2)},$$
$$\langle \bar{f}|T|\bar{i}\rangle = A_1 e^{i(\delta_1-\phi_1+\theta)} + A_2 e^{i(\delta_2-\phi_2+\theta)}$$

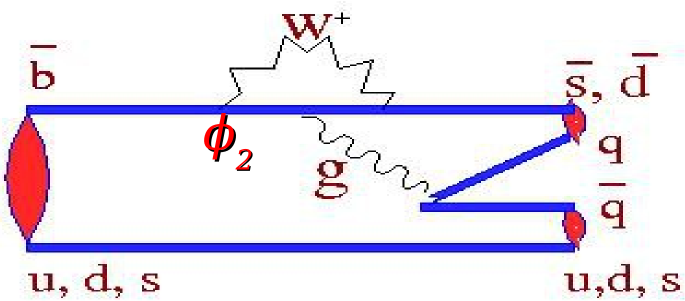
CP Violation:
Branco, Lavoura e Silva

$$\Gamma\,(i\rightarrow f) - \Gamma\,(\overline{i}\rightarrow\overline{f}) = \left|\langle f|T|i\rangle\right|^2 - \left|\langle \bar{f}|T|\bar{i}\rangle\right|^2 = -4A_1A_2 \sin(\delta_1-\delta_2)\sin(\phi_1-\phi_2)$$

So CP Violation needs: different strong δ_1 and δ_2 and weak phases ϕ_1 and ϕ_2.



Interference=>C̸P



Short distance: BSS Model Bander Silverman and Soni PRL 43 (1979) 242

The weak coming from **CKM** and the strong from **Penguin with time-like gluon.**

CPT constraint
for direct CP asymmetry,

CPT Invariance

- *CPT invariance ⇒ Same lifetime and same mass to particle and anti-particle.*

$$\text{Lifetime} \quad \tau = 1 / \Gamma_{total} = 1 / \bar{\Gamma}_{total}$$

$$\Gamma_{total} = \Gamma_1 + \Gamma_2 + \Gamma_3 + \Gamma_4 + \Gamma_5 + \Gamma_6 + \dots\dots\dots\dots\dots\dots$$

$$\bar{\Gamma}_{total} = \bar{\Gamma}_1 + \bar{\Gamma}_2 + \bar{\Gamma}_3 + \bar{\Gamma}_4 + \bar{\Gamma}_5 + \bar{\Gamma}_6 + \dots\dots\dots\dots\dots\dots$$

- ~~C~~P violation ⇒ $\Gamma_1 > \bar{\Gamma}_1$.
- For CPT conservation:

$$\Gamma_2 + \Gamma_3 + \Gamma_4 + \Gamma_5 + \Gamma_6 + \dots\dots\dots < \bar{\Gamma}_2 + \bar{\Gamma}_3 + \bar{\Gamma}_4 + \bar{\Gamma}_5 + \bar{\Gamma}_6 + \dots\dots\dots\dots$$

In a exact proportion.

- We have to include final state interaction in the CP violation calculation.

Direct CP violation :

Different disintegration behavior from particle and anti-particle

Two contribution to a same final state.

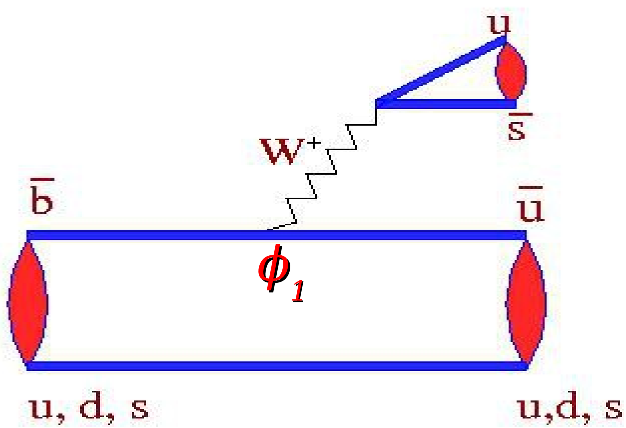
With different strong, δ_1 and δ_2 and weak phases, ϕ_1 and ϕ_2.

This formulation is at least incomplete

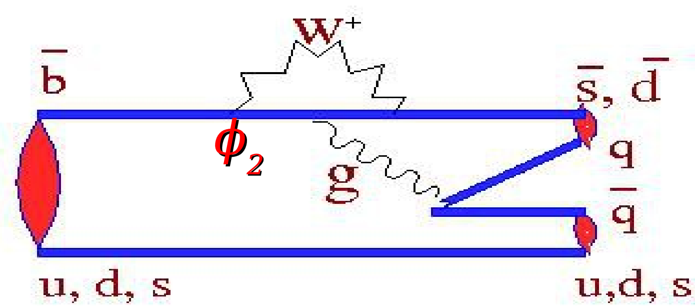
CP Violation:
Branco, Lavoura e Silva

$$\Gamma(i\to f) - \Gamma(\bar{i}\to\bar{f}) = |\langle f|T|i\rangle|^2 - |\langle \bar{f}|T|\bar{i}\rangle|^2 = -4A_1A_2\sin(\delta_1-\delta_2)\sin(\phi_1-\phi_2)$$

CP Violation needs: different strong δ_1 and δ_2 and weak phases ϕ_1 and ϕ_2.



Interference=>CP



Short distance: BSS Model Bander Silverman and Soni PRL 43 (1979) 242

The weak coming from **CKM** and the strong from **Penguin with time-like gluon.**

The common believe: *Ikaros Bigi hep-ph 1503-07719*

' The CKM suppressed weak decays for beauty hadrons produce FS with more hadrons than two, three & four ones. Therefore one expects that CPT invariance is not a “practical“ tool in *beauty decays* '

For ex. the $B^+ \rightarrow K^+ \pi^+ \pi^-$ can have many B decay channels with accessible FSI

- $B^+ \to K^0 \pi^+$
- $B^+ \to K^+ \pi^0$
- $B^+ \to K^+ \eta$
- $B^+ \to K^0 \pi^+ \pi^0$
- $B^+ \to K^+ K^0 K^0$
- $B^+ \to K^+ K^+ K^-$
- $B^+ \to K^0 \pi^+ \eta^0$
- $B^+ \to K^+ \pi^0 \eta^0$
- *Plus 4 bodys*

Has really hadronic interaction many degrees of freedom ???

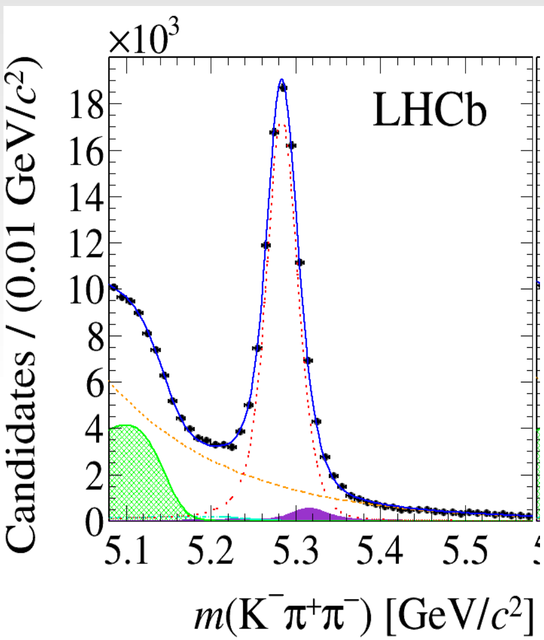
$B^+ \rightarrow K^+ \pi^+ \pi^-$ events distribution.

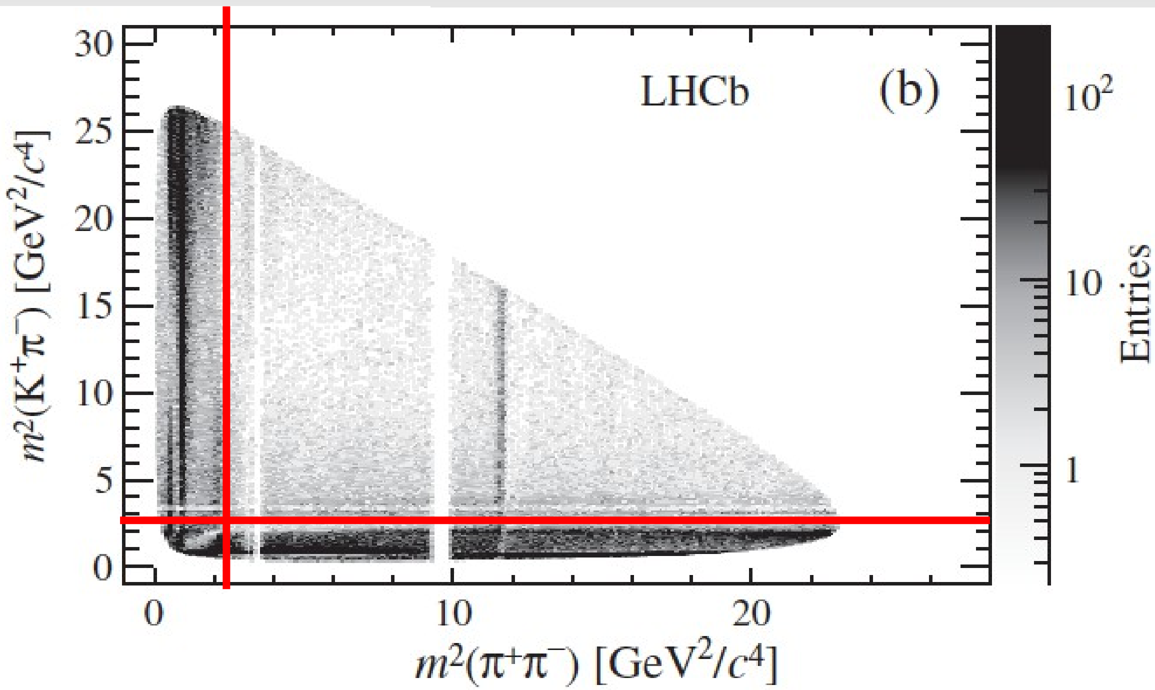
PHYSICAL REVIEW D 90, 112004 (2014)

Measurements of *CP* violation in the three-body phase space of charmless $B^{\pm}$ decays

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

LHCb: 181 074 ± 556 events





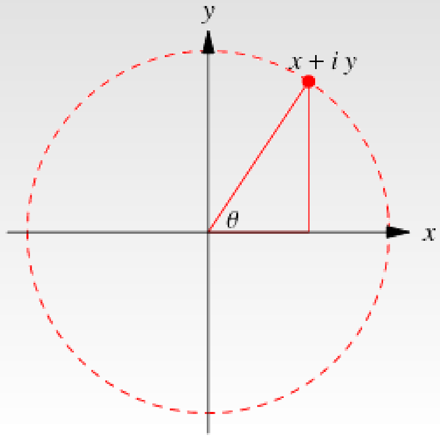
- ***More than 90% of the events has $M^2_{K+\pi-}$ e $M^2_{\pi+\pi-} < 2.5GeV^2$ supporting the 2+1 first order approximation.***
- ***2+1 approximation → use elements of elastic scattering***

Elastic scattering: $K^+\pi^- \rightarrow K^+\pi^-$

Inelasticity: $\eta = 1 \Rightarrow$ 100% of hh going hh,

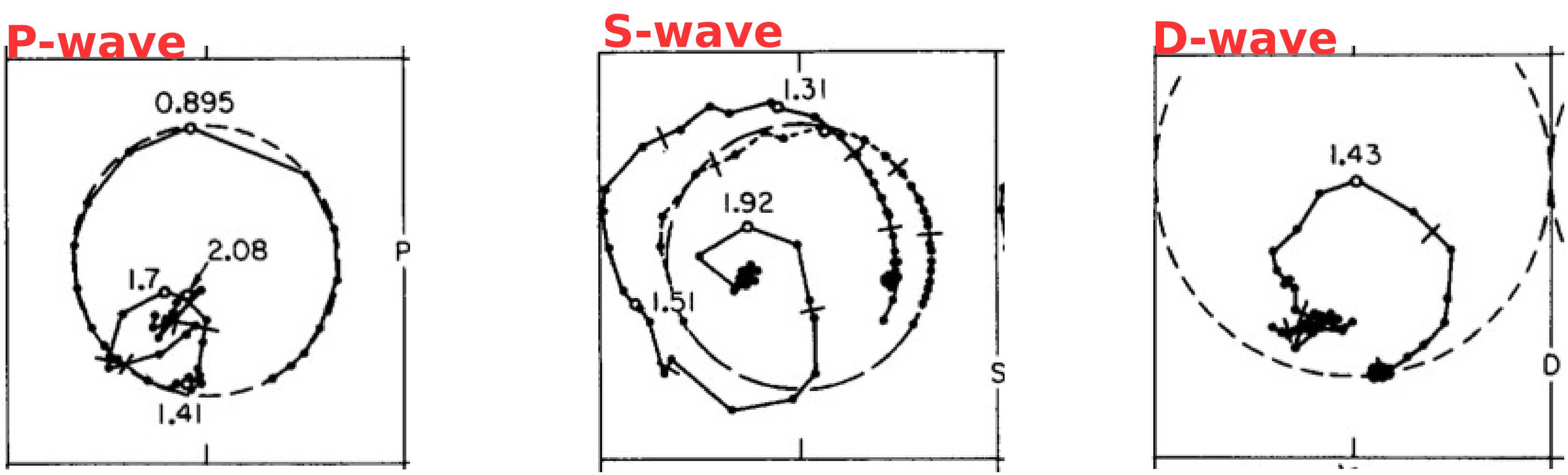
$\eta = 0 \Rightarrow$ 0% going to other final states.

Argand circle.



LASS collaboration $K^+\pi^- \rightarrow K^+\pi^-$ (1988)

Nuclear Physics B296 (1988) 493–526



No deviation of the unitary circle to P-wave till 1.6GeV.
S-wave is also in the unitary circle, if one exclude I=3/2 contribution.

Elastic scattering $\pi^+\pi^- \rightarrow \pi^+\pi^-$.

CERN-Munich collaboration $\pi^+\pi^- \rightarrow \pi^+\pi^-$ (1973)

Nuclear Physics B64 (1973) 134–162.

S-wave **D-wave**

P-wave **F-wave**

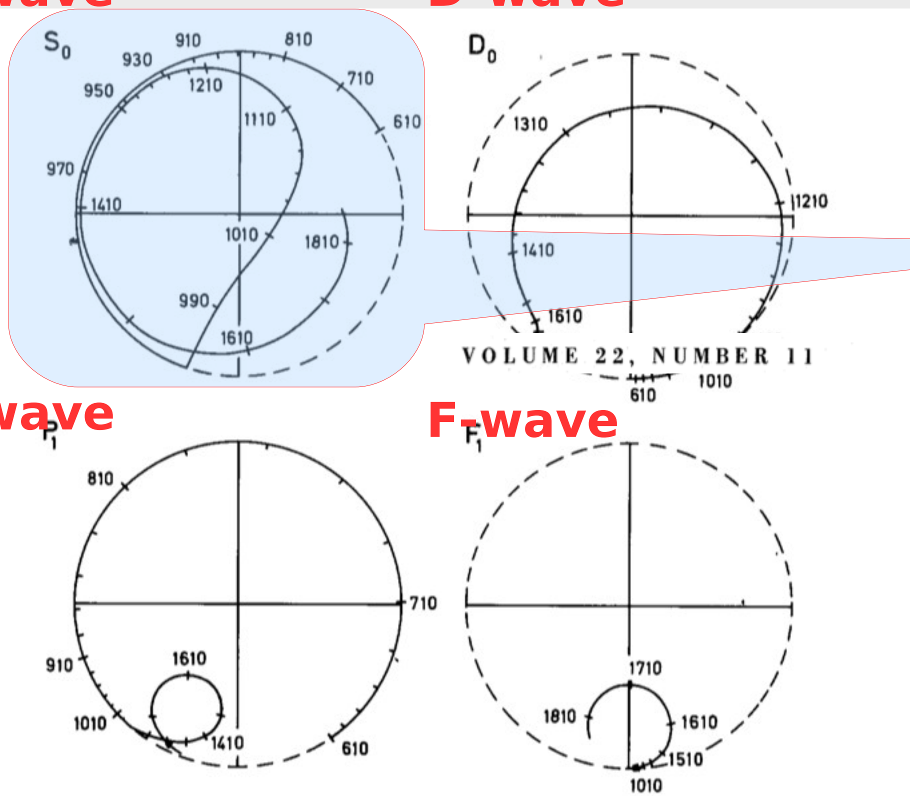


Fig. 6. Argand diagrams (Im T_l^I *versus* Re T_l^I) for the partial wave amplitudes from the energy-dependent fit. Numbers indicate the $\pi\pi$ energy.

Cohen, D et al PRD 22 (1980) 2595

VOLUME 22, NUMBER 11 1 DECEMBER 1980

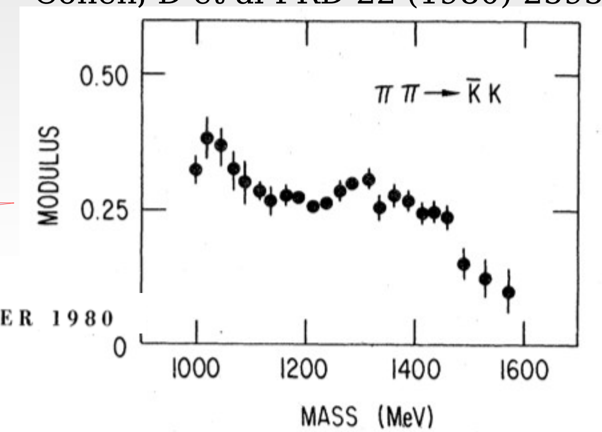


FIG. 27. Modulus of the $\pi\pi \rightarrow \overline{K}K$ scattering amplitude $|T(\pi\pi \quad \overline{K}K)|$ from solution I(b).

Strong coupling:

$\pi^+\pi^- \rightarrow K^+K^-$

Big deviation of the unitary circle in the S wave between 1 to 1.5GeV.

$B^+ \rightarrow K^+ \pi^+ \pi^-$ events distribution.

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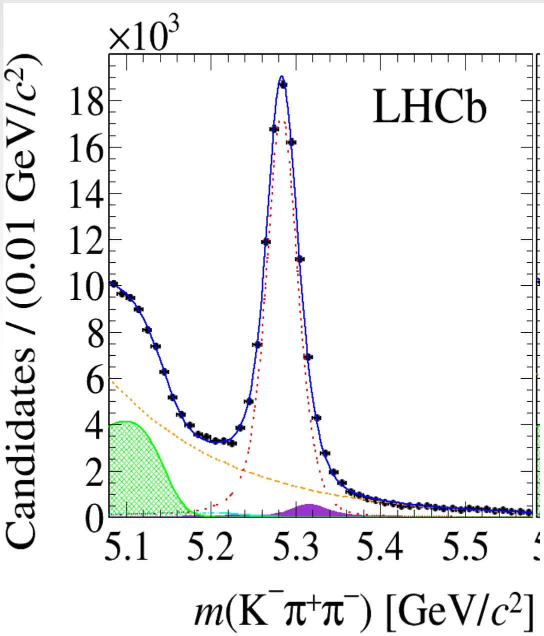

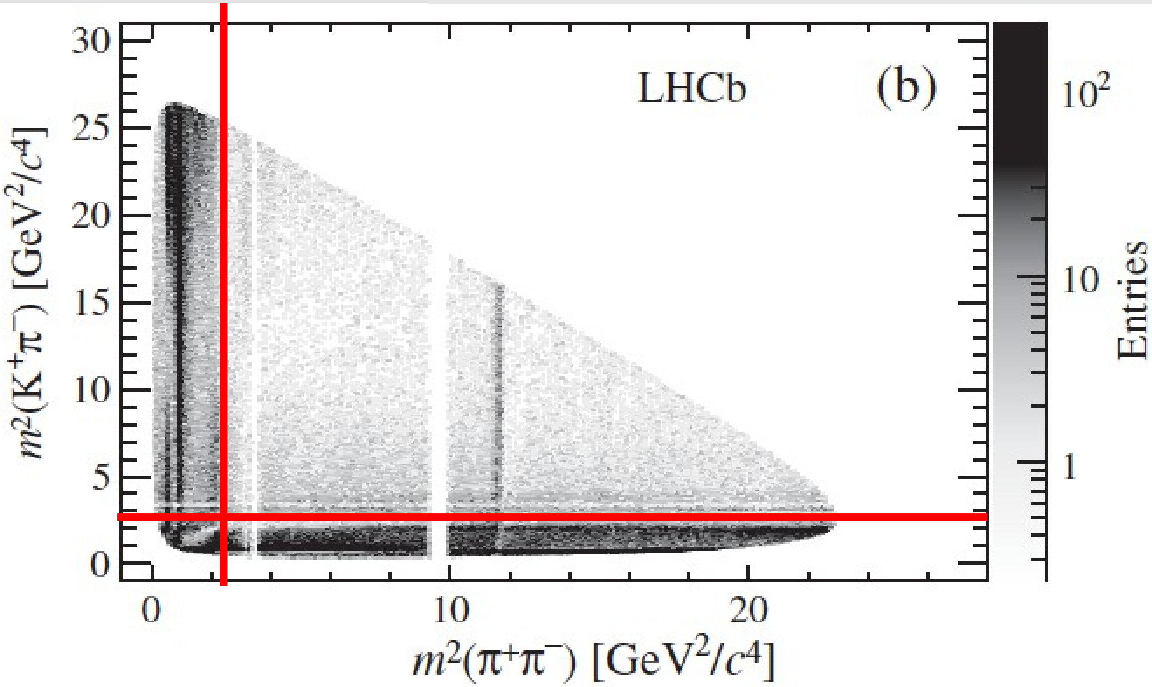

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Long distance CP asymmetry:

S and P wave interference

CP violation in $B^{\mp} \rightarrow \pi^{\mp}\pi^{+}\pi^{-}$ decay.

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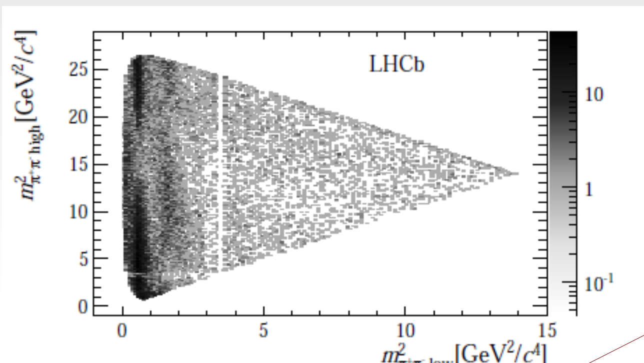
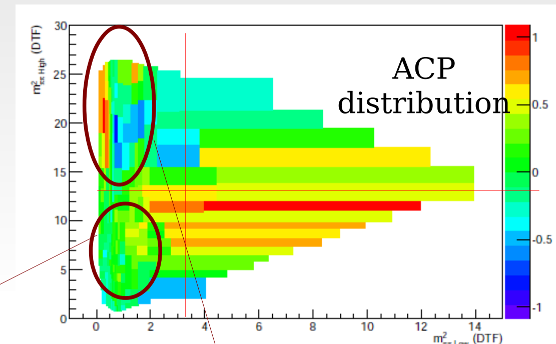
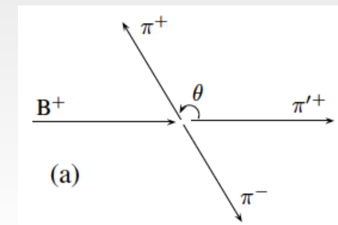
2011 + 2012 data: about 25K$B^{\mp} \rightarrow \pi^{\mp}\pi^{+}\pi^{-}$

Division related with angular distribution of vector resonances.

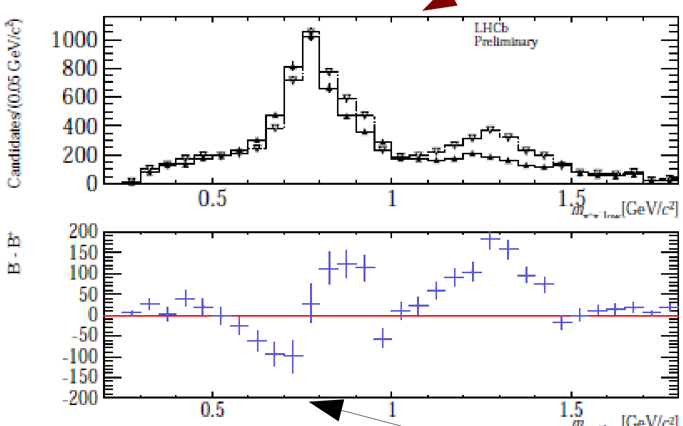


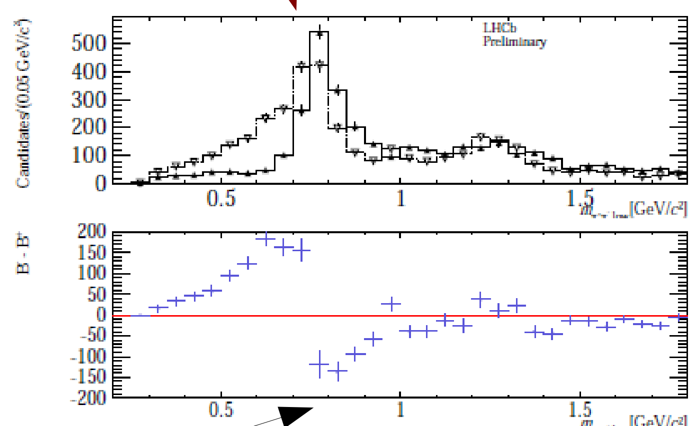




COS Θ < 0

COS Θ > 0





ρ^0(770) invariant mass

CP asymmetry from S and P wave interference in same hadronic final state.

I.B., G. Guerrer, J. Miranda -Phys.Rev. D76 (2007) 073011
I.B., I.I. Bigi, A. Gomes, G. Guerrer, J. Miranda and A.C. Dos Reis-Phys. Rev. D80, 096006 (2009)
I.B., I.I. Bigi, A. Gomes, J. Miranda, J. Otalora, A.C. Dos Reis and A. Veiga- Phys. Rev. D86, 036005 (2012)

Simplest amplitude of $B^{\mp} \rightarrow \pi^{\mp}\pi^{+}\pi^{-}$ to low $\pi^{+}\pi^{-}$ invariant mass: one vector resonance and a scalar non resonant amplitudes.

B positive
$$\mathcal{M}_+ = a_+^\rho e^{i\delta_+^\rho} F_\rho^{\rm BW} \cos\theta + a_+^{nr} e^{i\delta_+^{nr}} F^{\rm NR}$$

B negative
$$\mathcal{M}_- = a_-^\rho e^{i\delta_-^\rho} F_\rho^{\rm BW} \cos\theta + a_-^{nr} e^{i\delta_-^{nr}} F^{\rm NR}$$

$$F_R^{\rm BW}(s) = \frac{1}{m_R^2 - s - i m_R \Gamma_R(s)}$$

$F^{NR} = 1$

θ is the Gottfried-Jackson angle to spin 1 resonances: COS Θ change from -1 to +1

$$\Delta|\mathcal{M}|^2 = |\mathcal{M}_+|^2 - |\mathcal{M}_-|^2 = [(a_+^\rho)^2 - (a_-^\rho)^2]|F_\rho^{\rm BW}|^2\cos^2\theta + [(a_+^{nr})^2 - (a_-^{nr})^2]|F^{\rm NR}|^2$$
$$+2\cos\theta|F_\rho^{\rm BW}|^2|F^{\rm NR}|^2 \times$$

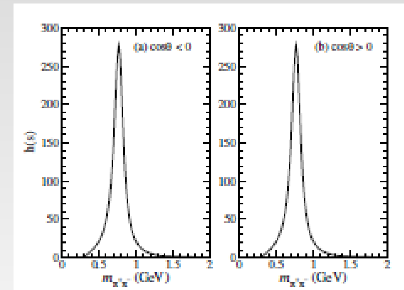
R $$\{(m_\rho^2 - s)[a_+^\rho a_+^{nr}\cos(\delta_+^\rho - \delta_+^{nr}) - a_-^\rho a_-^{nr}\cos(\delta_-^\rho - \delta_-^{nr})]$$

I $$-m_\rho\Gamma_\rho[a_+^\rho a_+^{nr}\sin(\delta_+^\rho - \delta_+^{nr}) - a_-^\rho a_-^{nr}\sin(\delta_-^\rho - \delta_-^{nr})]\}$$

Short and Long distance signatures in Dalitz plot.

Short distance :

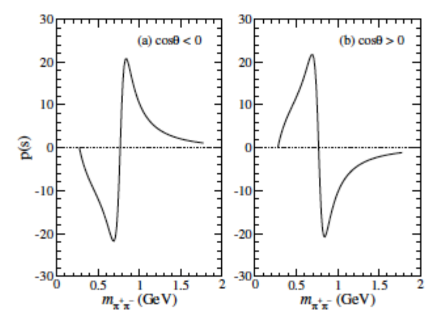
$$\Delta|\mathcal{M}|^2 \propto [(a_+^\rho)^2 - (a_-^\rho)^2]|F_\rho^{\rm BW}|^2 \cos^2\theta$$



Long distance interference S and wave interaction:

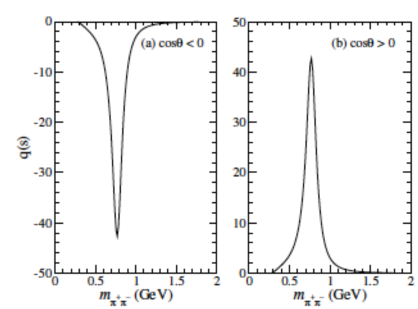
Real part of Dalitz CP asymmetry

$$\Delta^R|\mathcal{M}|_I^2 \propto \frac{\cos\theta(m_\rho^2 - s)}{(m_\rho^2 - s)^2 + m_R^2\Gamma_R^2}$$



Imaginary part of Dalitz CP asymmetry

$$\Delta^I|\mathcal{M}|_I^2 \propto \frac{\cos\theta m_\rho^2\Gamma_\rho^2}{(m_\rho^2 - s)^2 + m_R^2\Gamma_R^2}$$

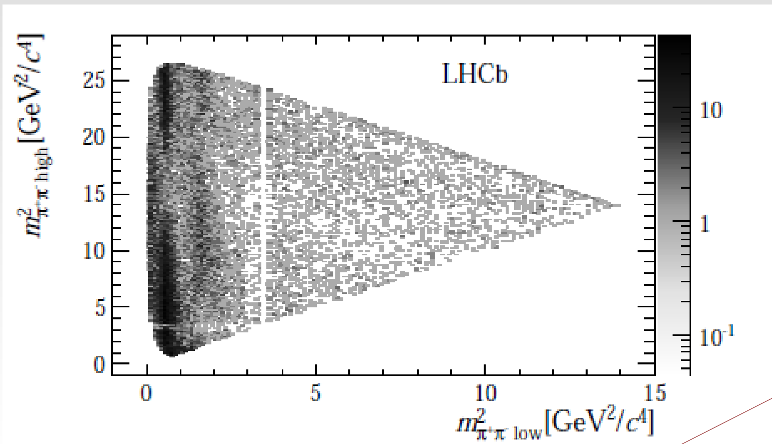


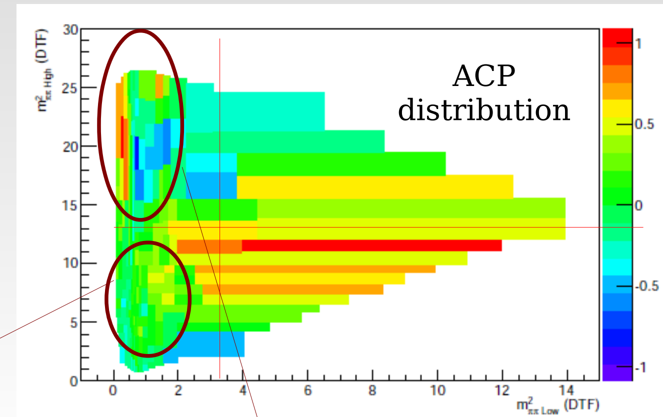
In the last cases CPT is naturally conserved

CP violation in $B^{\mp} \to \pi^{\mp}\pi^{+}\pi^{-}$ decay.

2011 + 2012 data: about 25K $B^{\mp} \to \pi^{\mp}\pi^{+}\pi^{-}$ events

Division related with angular distribution of vector resonances.





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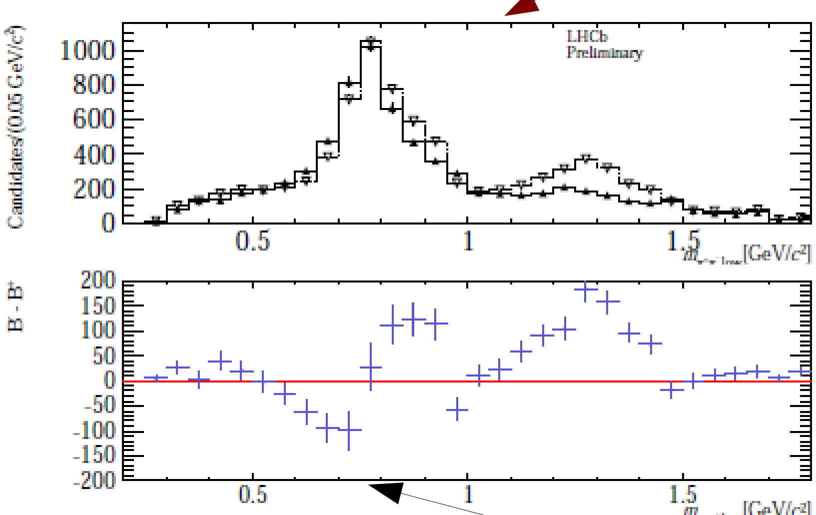
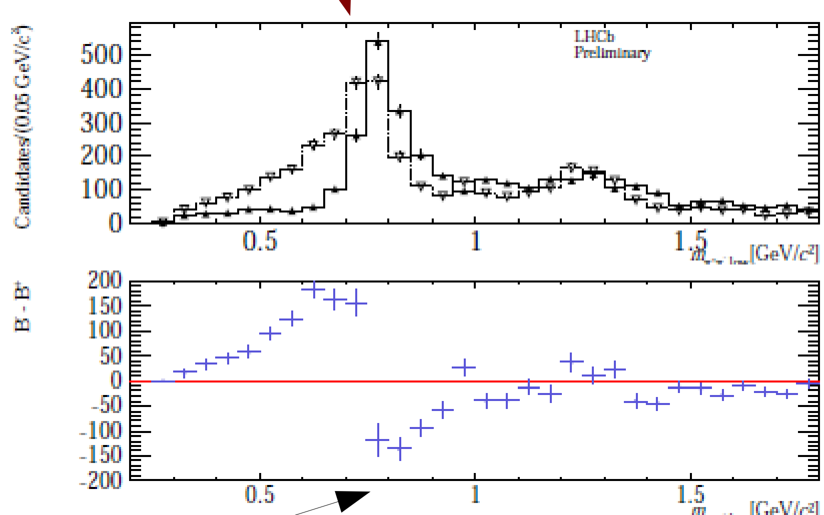




ρ^0(770) invariant mass

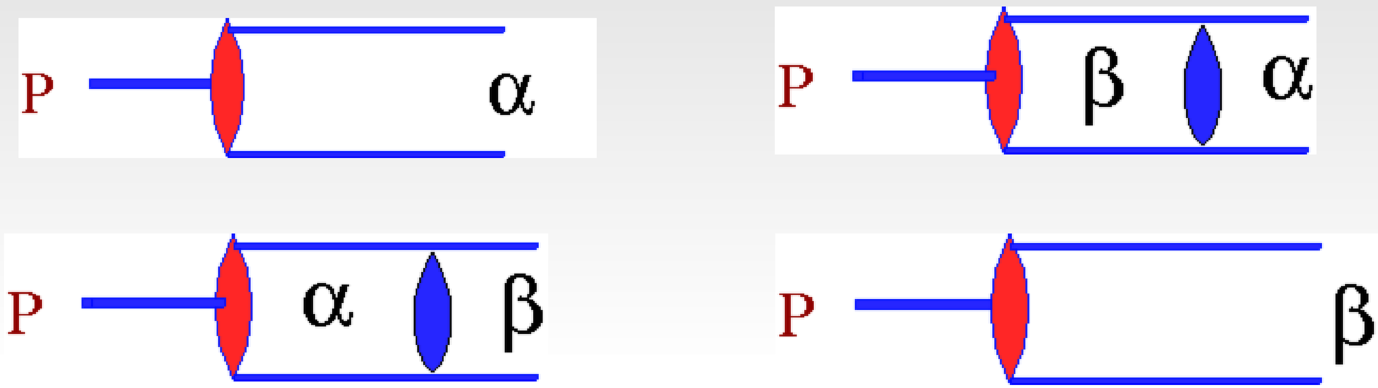
Long distance CP asymmetry:

Re-scattering $\pi^+ \pi^- \longrightarrow K^+ K^-$

CP violation through a different hadronic final state.

Wolfenstein (Phys.Rev. D43 (1991) 151-156)

In a simplified formulation: P particle decay in a family of only two final states **α** e **β** and **η=1**



$$S = \begin{pmatrix} e^{i2\delta\alpha} & t_{\alpha\beta} e^{i(\delta\alpha+\delta\beta)} \\ t_{\alpha\beta} e^{i(\delta\alpha+\delta\beta)} & e^{i2\delta\beta} \end{pmatrix} \Rightarrow \begin{array}{l} <\alpha | T | P> = e^{i\delta\alpha} [T_\alpha + i t_{\alpha\beta} T_\beta] \\ <\beta | T | P> = e^{i\delta\beta} [T_\beta + i t_{\alpha\beta} T_\alpha] \end{array}$$

Where the replacement of P by $\overline{P}$ correspond to changing T_i to T_i^*.

The subtracted square amplitudes is given by:

$$\left.\begin{array}{l} \Delta\alpha = |<\alpha | T | P>|^2 - |<\overline{\alpha} | T | \overline{P}>|^2 = 4 \,\mathrm{Im}\, T^*_\alpha T_\beta \\ \Delta\beta = |<\beta | T | P>|^2 - |<\overline{\beta} | T | \overline{P}>|^2 = -4 \,\mathrm{Im}\, T^*_\alpha T_\beta \end{array}\right\}$$

Satisfying CPT:

$$\Delta\alpha + \Delta\beta = 0$$

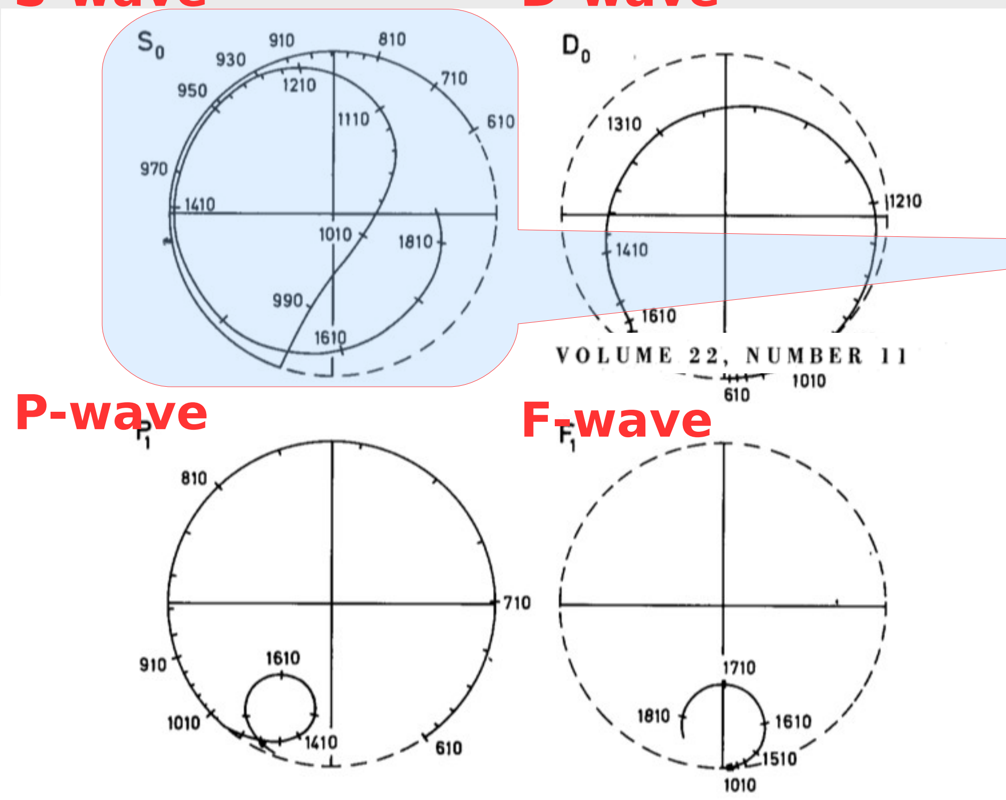
Elastic scattering $\pi^+\pi^- \rightarrow \pi^+\pi^-$.

CERN-Munich collaboration $\pi^+\pi^- \rightarrow \pi^+\pi^-$ (1973)

Nuclear Physics B64 (1973) 134–162.

S-wave **D-wave**

P-wave **F-wave**



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Cohen, D et al PRD 22 (1980) 2595

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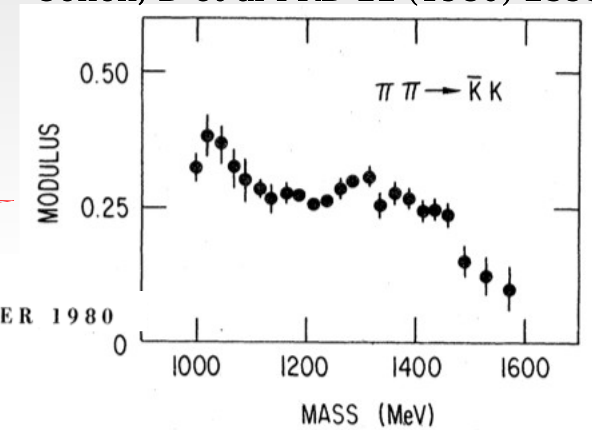

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Strong coupling:

$\pi^+\pi^- \rightarrow K^+K^-$

Big deviation of the unitary circle in the S wave between 1 to 1.5GeV.

Final state interaction

$\pi^+ \pi^- \rightarrow K^+ K^-$

2011 +2012 data

PHYSICAL REVIEW D 90, 112004 (2014)

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

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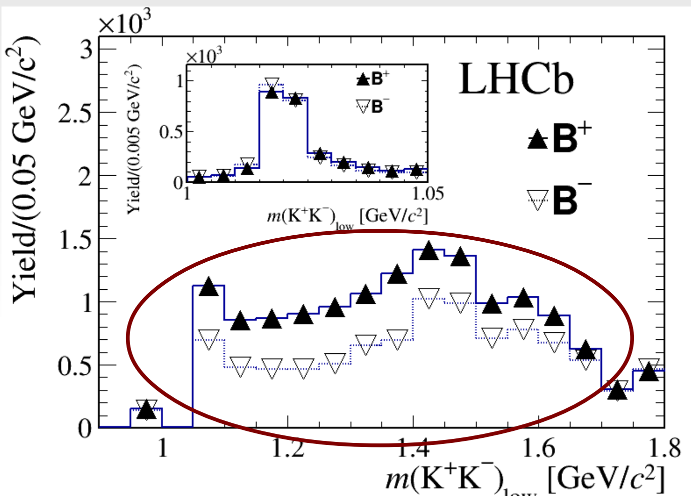

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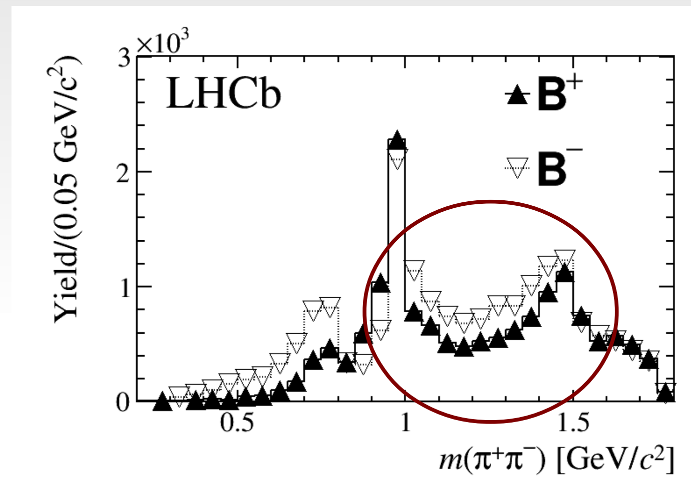

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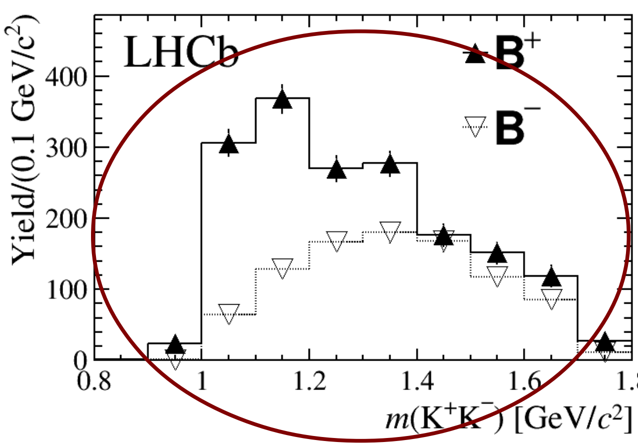
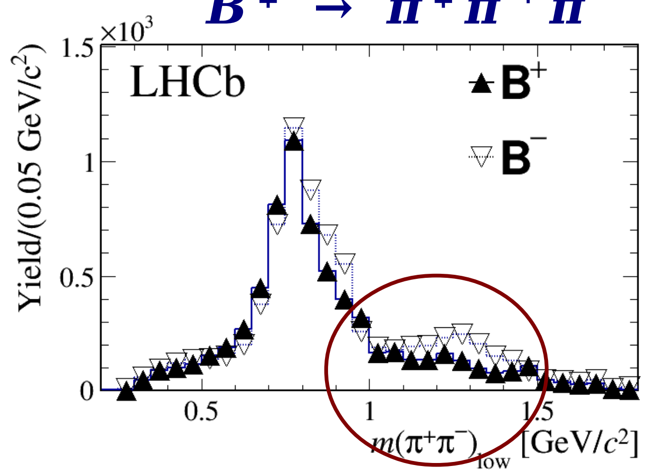


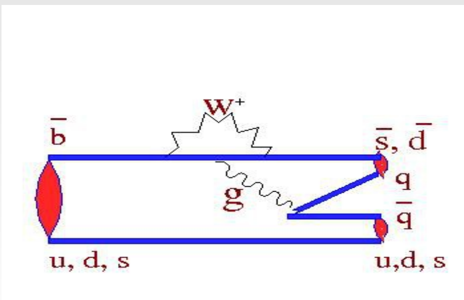
$B^\mp \rightarrow \pi^\mp \pi^+ \pi^-$



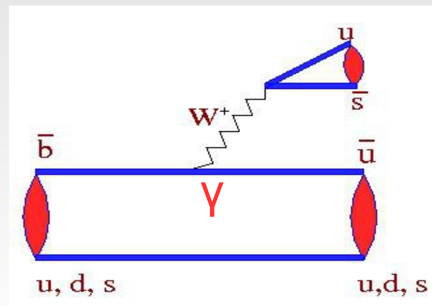
Scattering $\pi^+\pi^- \to K^+K^-$ and CP violation
$B^+ \to K^+\pi^+\pi^-$ e $B^+ \to K^+K^+K^-$.

I. B., T. Frederico and O. Lourenço -Phys. Rev. D 89, 094013 (2014)

The dominant amplitudes for these charmless three body decay can be write down as a sum :



+



$$M^{\pm} = A + B\, e^{\pm i\gamma}$$

CP operation changes signal of the weak phase **γ. Penguin doesn't need to have a strong phase, or does not need to take only the time-like contribution gluon.**

Taking **α** as final state K^+K^- and **β** the couple channel $\pi^+\pi^-$, with an appropriated S-Matrix for the re-scattering given by the asymmetry is given by::

$$\Delta\Gamma_\alpha = 4 \sin\gamma\ (\zeta_0 + \sqrt{(1-\eta^2)}\zeta_1$$

$$\zeta_0 = \mathrm{Imag}[B^*_{0\alpha} A_{0\alpha} (1+i(t_{\alpha\alpha} - t^*_{\alpha\alpha}))]$$ BSS term

$$\zeta_1 = \mathrm{Real}[B^*_{0\alpha} A_{0\beta}\, e^{i(\delta\alpha+\delta\beta)} - B^*_{0\beta} A_{0\alpha}\, e^{i(\delta\alpha+\delta\beta)}]$$ Wolfenstein

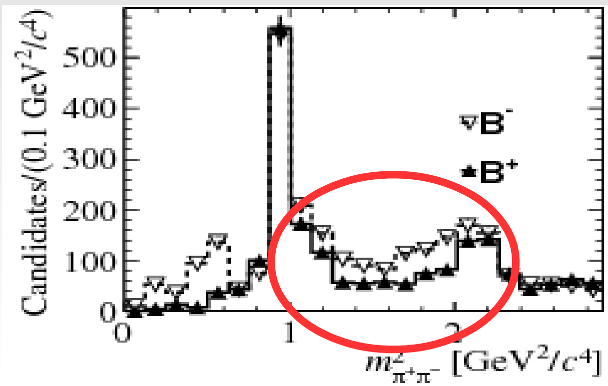
$\boldsymbol{\delta_\alpha}$ and $\boldsymbol{\delta_\beta}$ are strong phase associated to the $\boldsymbol{\pi^+\pi^- \to K^+K^-}$ scattering and **η** the $\pi^+\pi^-$ inelasticity.

Scattering $\pi^+\pi^- \to K^+K^-$ and CP violation
$B^+ \to K^+\pi^+\pi^-$ e $B^+ \to K^+K^+K^-$.

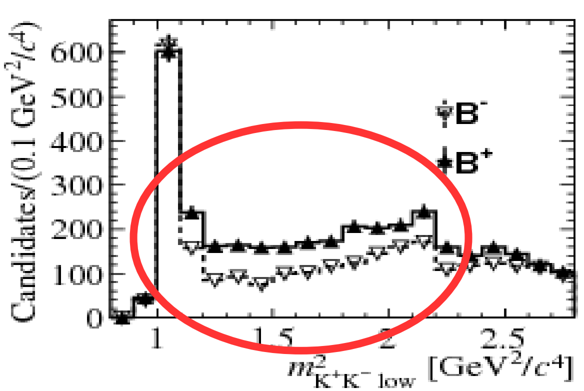
I. B., T. Frederico and O. Lourenço Phys. Rev. D 89, 094013 (2014)-

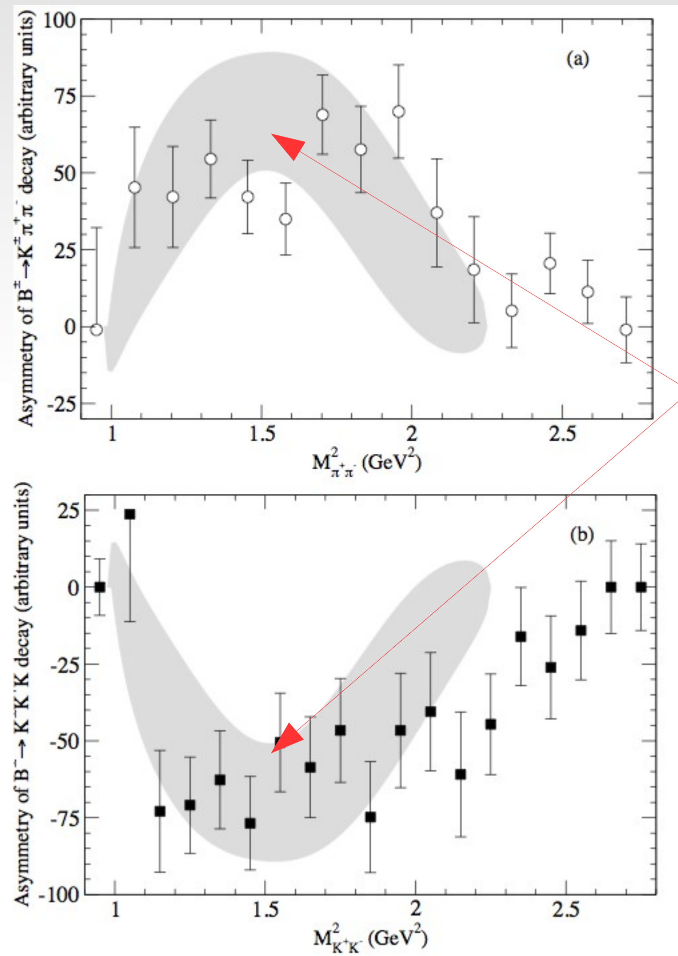
LHCb collaboration
Phys. Rev. Lett. 111 (2013) 101801

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



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





Inelasticity η:compilation
of $\pi^+\pi^- \to K^+K^-$
experimental results.

J. R. Pelaez, and F. J. Ynduráin, Phys. Rev. D **71**, 074016 (2005).

$$\delta_{KK} = \delta_{\pi\pi}$$

BSS term = 0

Putting together re-scattering and S and P interference

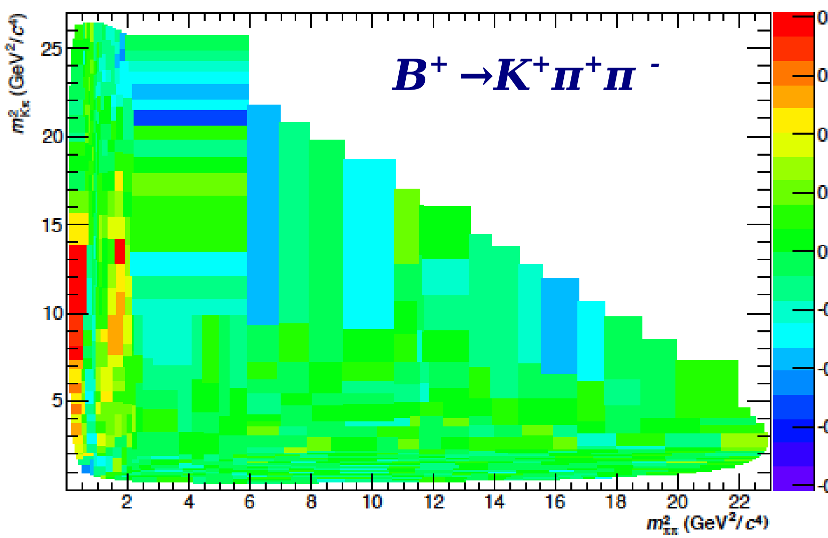
PHYSICAL REVIEW D **90**, 112004 (2014)

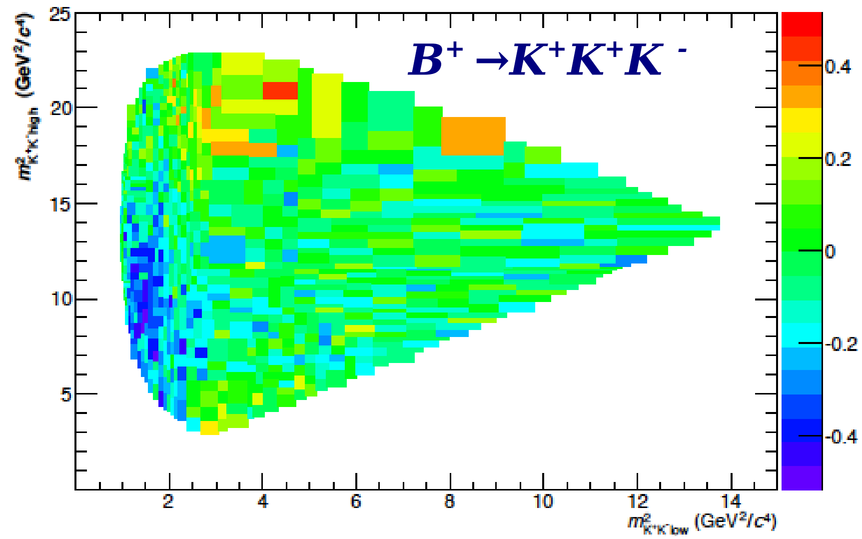
Measurements of *CP* violation in the three-body phase space of charmless $B^{\pm}$ decays

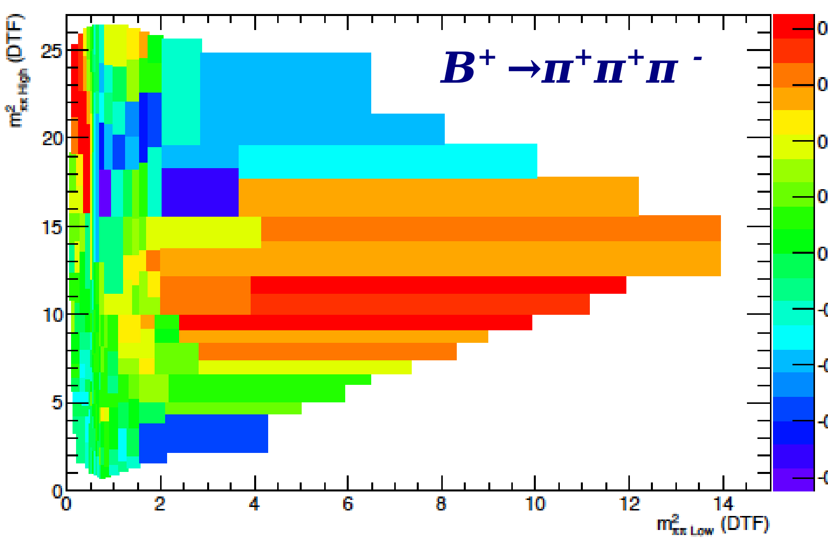
R. Aaij *et al.*[*]
(LHCb Collaboration)

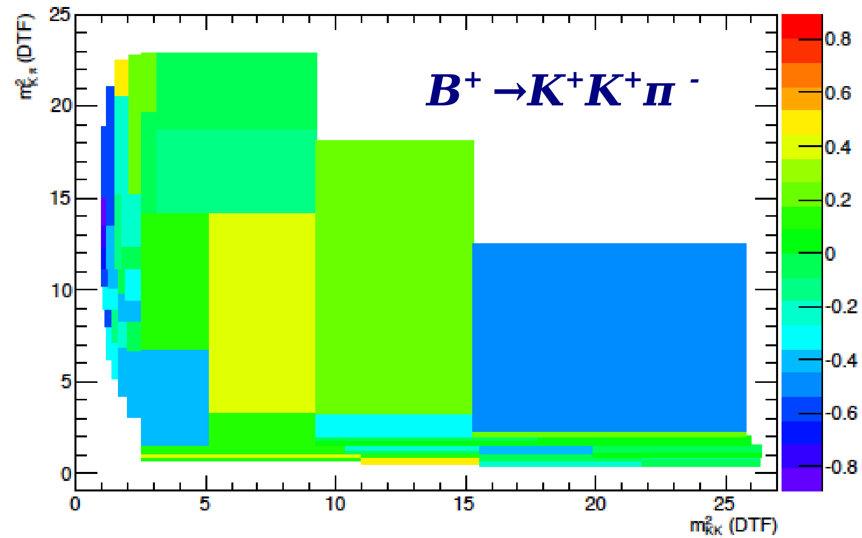
TABLE I. Signal yields of charmless three-body $B^{\pm}$ decays for the full data set.

Decay mode	Yield
$B^{\pm} \to K^{\pm}\pi^{+}\pi^{-}$	181074 ± 556
$B^{\pm} \to K^{\pm}K^{+}K^{-}$	109240 ± 354
$B^{\pm} \to \pi^{\pm}\pi^{+}\pi^{-}$	24907 ± 222
$B^{\pm} \to \pi^{\pm}K^{+}K^{-}$	6161 ± 172



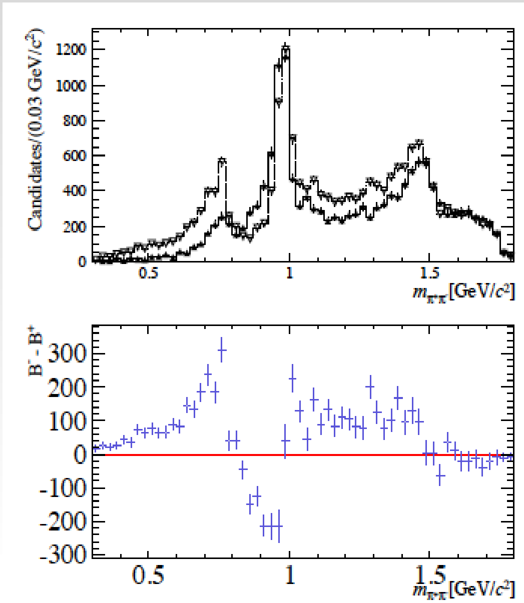




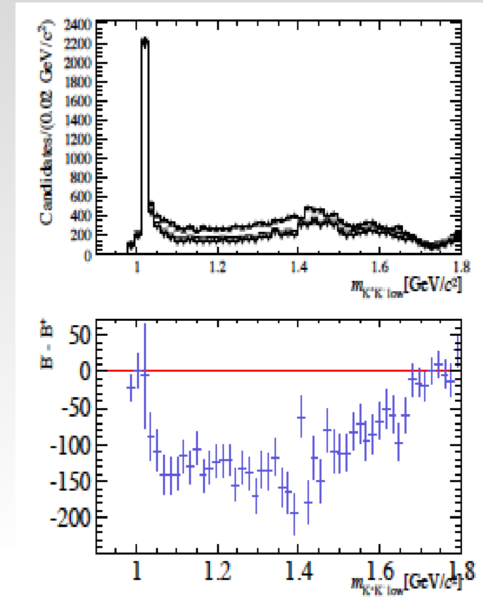


LHCb results: projections

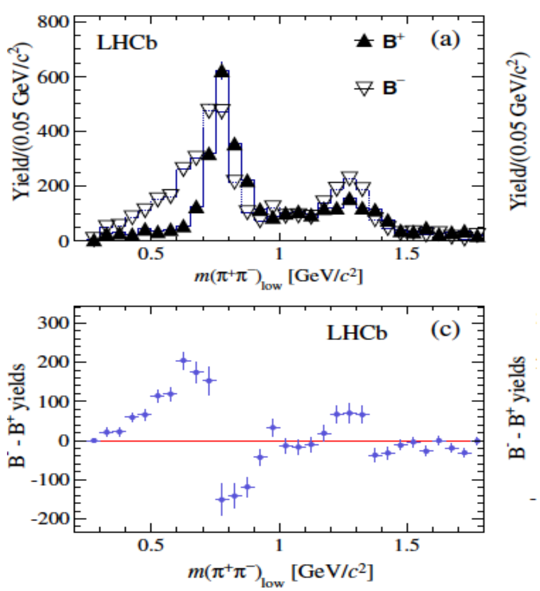
$B^+ \to K^+\pi^+\pi^-$



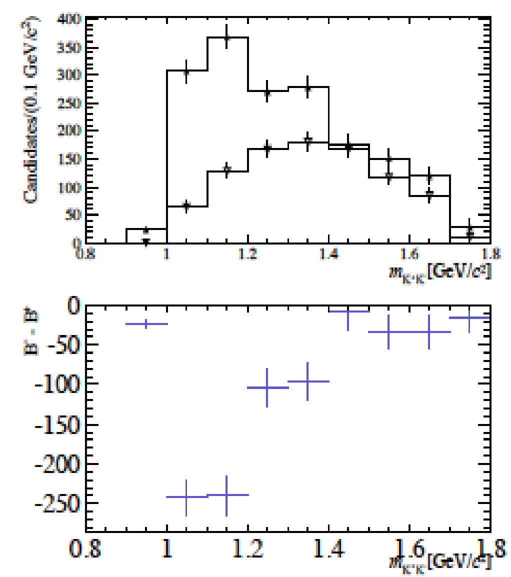
$B^+ \to K^+K^+K^-$



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



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

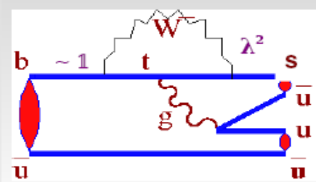


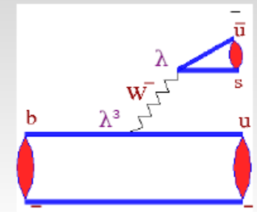
Dalitz interference CP asymmetry between ρ(770), f_0(980), non resonant, $K^+ K^+ \to \pi^+ \pi^-$.

Alvarenga Nogueira et al. arXiv:1506.08332 [hep-ph]

$$\langle \lambda_0 | H_w | h \rangle = A_{0\lambda} + e^{-i\gamma} B_{0\lambda},$$
$$\langle \overline{\lambda}_0 | H_w | \overline{h} \rangle = A_{0\lambda} + e^{+i\gamma} B_{0\lambda},$$

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





$$\mathcal{A}^{\pm}_{0\lambda} = a_0^{\rho} F_{\rho}^{\mathrm{BW}} k(s) \cos\theta + a_0^{f} F_{f}^{\mathrm{BW}} + \frac{a_{0\lambda}^{nr} + b_{0\lambda}^{nr} e^{\pm i\gamma}}{1 + \frac{s}{\Lambda_\lambda^2}} + [b_0^{\rho} F_{\rho}^{\mathrm{BW}} k(s) \cos\theta + b_0^{f} F_{f}^{\mathrm{BW}}] e^{\pm i\gamma},$$

$$+ i \sum_{\lambda', J} t^J_{\lambda', \lambda} \left(A^J_{0\lambda' NR} + e^{\pm i\gamma} B^J_{0\lambda' NR} \right),$$

For our propose we need only these amplitudes in the Isobar mode

$$\mathcal{A}^{\pm}_{0\lambda} = a_0^{\rho} F_{\rho}^{\mathrm{BW}} k(s) \cos\theta + a_0^{f} F_{f}^{\mathrm{BW}} + \frac{a_{0\lambda}^{nr} + b_{0\lambda}^{nr} e^{\pm i\gamma}}{1 + \frac{s}{\Lambda_\lambda^2}} + [b_0^{\rho} F_{\rho}^{\mathrm{BW}} k(s) \cos\theta + b_0^{f} F_{f}^{\mathrm{BW}}] e^{\pm i\gamma},$$

+

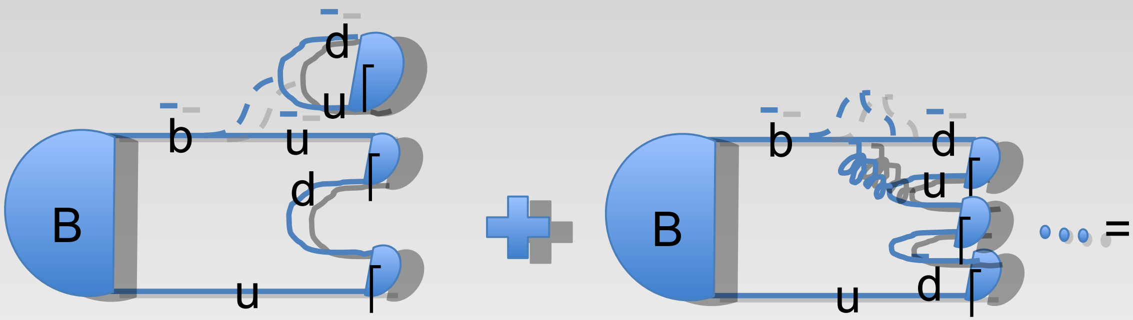
the S matrix

$$S = \begin{bmatrix} \eta e^{2i\delta_{\pi\pi}} & i\sqrt{1-\eta^2}\, e^{i(\delta_{\pi\pi}+\delta_{KK})} \\ i\sqrt{1-\eta^2}\, e^{i(\delta_{\pi\pi}+\delta_{KK})} & \eta e^{2i\delta_{KK}} \end{bmatrix}$$

$$F_R^{\mathrm{BW}}(s) = \frac{1}{m_R^2 - s - i m_R \Gamma_R(s)}$$

Note that in our formalism, the Penguin does not need to have a strong phase

Non-resonant amplitude and $K^+K^+ \to \pi^+\pi^-$ parameters



$$= \frac{a_0 + b_0 e^{\pm i\gamma}}{1 + S/\Lambda^2}$$

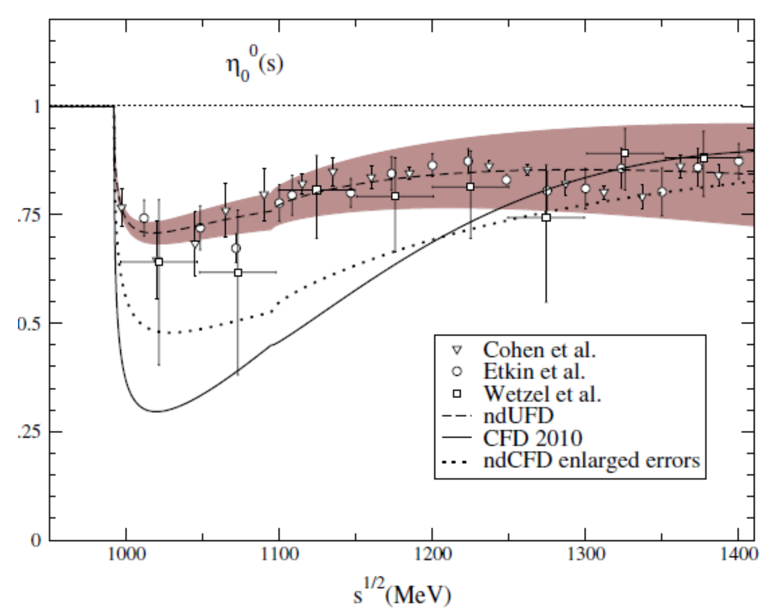
This form factor carries a momentum scale associated with the overlap function between the B and pion states, which should reflect a spatial region with size smaller then the B meson.

Parametrization to the inelasticity factor give big uncertainty

$$\eta_0^{(0)} = 1 - \left(\epsilon_1 \frac{k_2}{s^{1/2}} + \epsilon_2 \frac{k_2^2}{s}\right) \frac{M'^2 - s}{s};$$

$$\epsilon_1 = 2.4 \pm 0.2, \quad \epsilon_2 = -5.5 \pm 0.8;$$

k_2 is a kinematic factor $\quad k_2 = \frac{\sqrt{s - 4m_K^2}}{2},$



J. R. Pelaez, and F. J. Yndurain, Phys. Rev. D **71**, 074016 (2005).

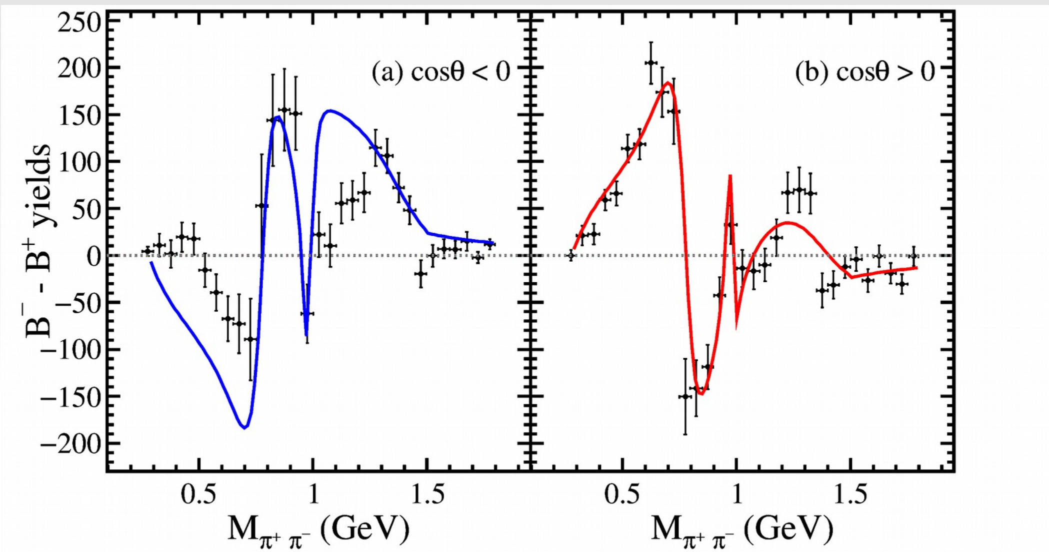
General equation to CP asymmetry

A general equation to describe CP asymmetry for both, long and short distance is given by:

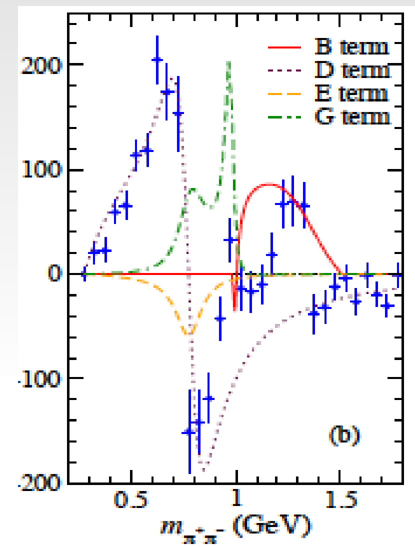
$$
\begin{aligned}
\Delta\Gamma_\lambda = {} & \mathcal{A}\left(1+\frac{s}{\Lambda_\lambda^2}\right)^{-2} + \mathcal{B}\sqrt{1-\eta^2(s)}\cos[2\delta_{\pi\pi}(s)]\left[\left(1+\frac{s}{\Lambda_\lambda^2}\right)\left(1+\frac{s}{\Lambda_{\lambda'}^2}\right)\right]^{-1} + \\
& + \mathcal{C}|F_\rho^{\rm BW}(s)|^2 k^2(s)\cos^2\theta + \\
& + |F_\rho^{\rm BW}(s)|^2 k(s)\cos\theta\Big\{(m_\rho^2 - s)\Big[\mathcal{D}\left(1+\frac{s}{\Lambda_\lambda^2}\right)^{-1} - \mathcal{D}'\left(1+\frac{s}{\Lambda_{\lambda'}^2}\right)^{-1}\sqrt{1-\eta^2(s)}\sin[2\delta_{\pi\pi}(s)]\Big] + \\
& + \mathcal{D}'\left(1+\frac{s}{\Lambda_{\lambda'}^2}\right)^{-1} m_\rho\Gamma_\rho(s)\sqrt{1-\eta^2(s)}\cos[2\delta_{\pi\pi}(s)]\Big\} + \\
& + |F_\rho^{\rm BW}(s)|^2 k(s)\cos\theta\Big\{m_\rho\Gamma_\rho(s)\Big[\mathcal{E}\left(1+\frac{s}{\Lambda_\lambda^2}\right)^{-1} + \mathcal{E}'\left(1+\frac{s}{\Lambda_{\lambda'}^2}\right)^{-1}\sqrt{1-\eta^2(s)}\sin[2\delta_{\pi\pi}(s)]\Big] + \\
& + \mathcal{E}'\left(1+\frac{s}{\Lambda_{\lambda'}^2}\right)^{-1}(m_\rho^2 - s)\sqrt{1-\eta^2(s)}\cos[2\delta_{\pi\pi}(s)]\Big\} + \\
& + \mathcal{F}[(m_\rho^2 - s)(m_f^2 - s) + m_\rho\Gamma_\rho(s) m_f\Gamma_f(s)]|F_\rho^{\rm BW}(s)|^2|F_f^{\rm BW}(s)|^2 k(s)\cos\theta + \\
& + \mathcal{G}[(m_\rho^2 - s) m_f\Gamma_f(s) - m_\rho\Gamma_\rho(s)(m_f^2 - s)]|F_\rho^{\rm BW}(s)|^2|F_f^{\rm BW}(s)|^2 k(s)\cos\theta + \\
& + |F_f^{\rm BW}(s)|^2\Big\{(m_f^2 - s)\Big[\mathcal{H}\left(1+\frac{s}{\Lambda_\lambda^2}\right)^{-1} - \mathcal{H}'\left(1+\frac{s}{\Lambda_{\lambda'}^2}\right)^{-1}\sqrt{1-\eta^2(s)}\sin[2\delta_{\pi\pi}(s)]\Big] + \\
& + \mathcal{H}'\left(1+\frac{s}{\Lambda_{\lambda'}^2}\right)^{-1} m_f\Gamma_f(s)\sqrt{1-\eta^2(s)}\cos[2\delta_{\pi\pi}(s)]\Big\} \\
& + |F_f^{\rm BW}(s)|^2\Big\{m_f\Gamma_f(s)\Big[\mathcal{P}\left(1+\frac{s}{\Lambda_\lambda^2}\right)^{-1} + \mathcal{P}'\left(1+\frac{s}{\Lambda_{\lambda'}^2}\right)^{-1}\sqrt{1-\eta^2(s)}\sin[2\delta_{\pi\pi}(s)]\Big] + \\
& + \mathcal{P}'\left(1+\frac{s}{\Lambda_{\lambda'}^2}\right)^{-1}(m_f^2 - s)\sqrt{1-\eta^2(s)}\cos[2\delta_{\pi\pi}(s)]\Big\} + \mathcal{Q}|F_f^{\rm BW}(s)|^2, \qquad (5.12)
\end{aligned}
$$

CP violation in $B^{\mp} \to \pi^{\mp}\pi^{+}\pi^{-}$ and $B^{\mp} \to \pi^{\mp}K^{+}K^{-}$ Decays

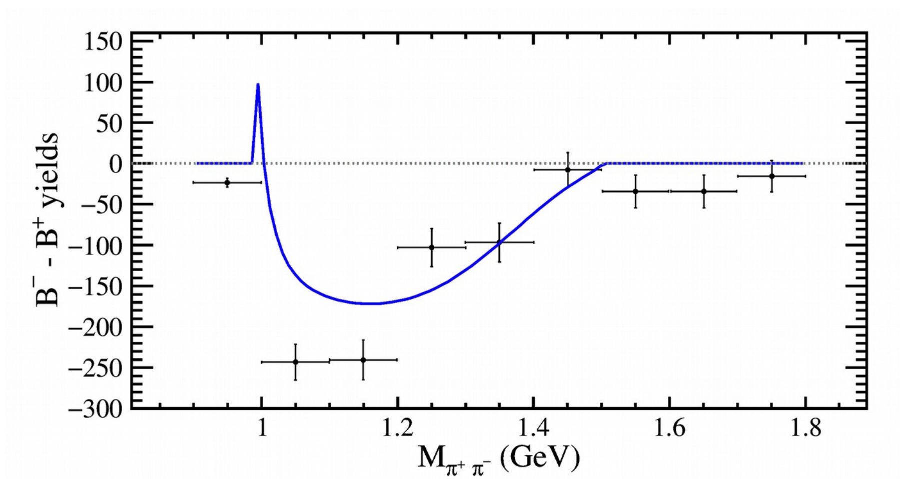
$B^{\mp} \to \pi^{\mp}\pi^{+}\pi^{-}$



S and P wave interference and Re-scattering $K^{+}K^{-} \to \pi^{+}\pi^{-}$



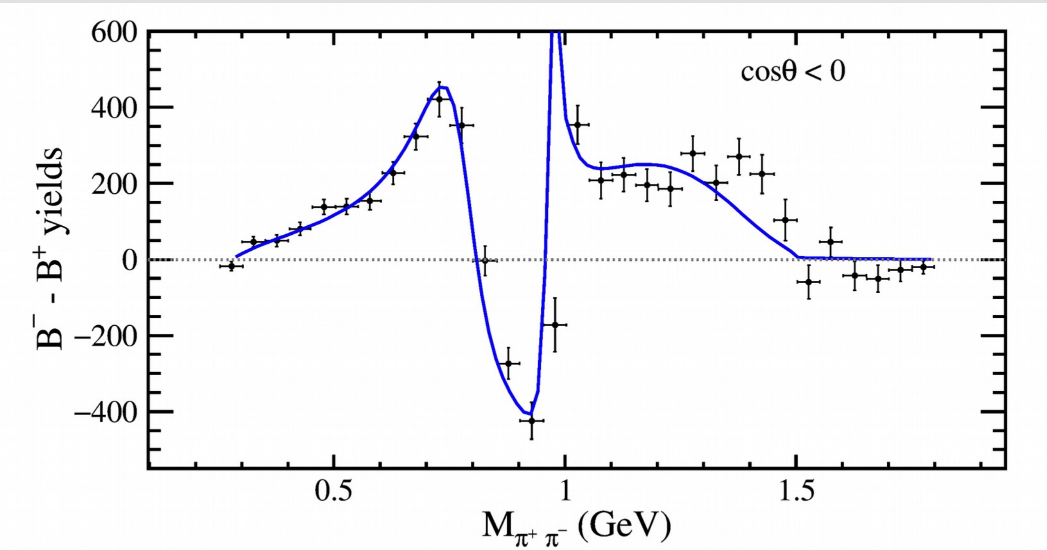
$B^{\mp} \to \pi^{\mp}K^{+}K^{-}$



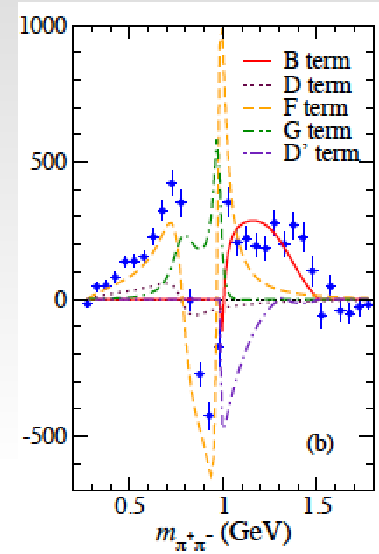
Re-scattering $\pi^{+}\pi^{-} \to K^{+}K^{-}$

CP violation in $B^{\mp} \to K^{\mp}\pi^{+}\pi^{-}$ and $B^{\mp} \to K^{\mp}K^{+}K^{-}$ Decays

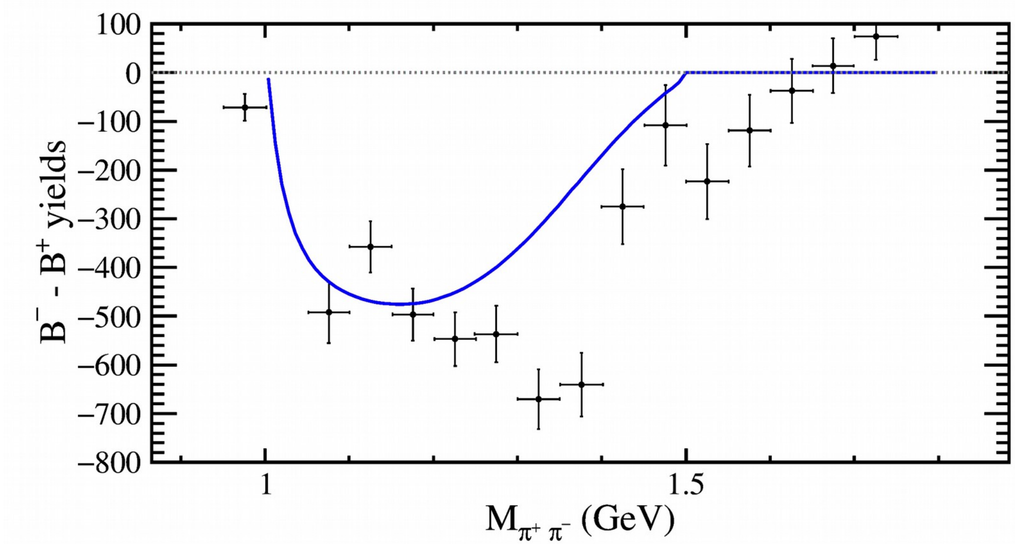
$B^{\mp} \to K^{\mp}\pi^{+}\pi^{-}$



S and P wave interference and Re-scattering $K^{+}K^{-} \to \pi^{+}\pi^{-}$



$B^{\mp} \to K^{\mp}K^{+}K^{-}$



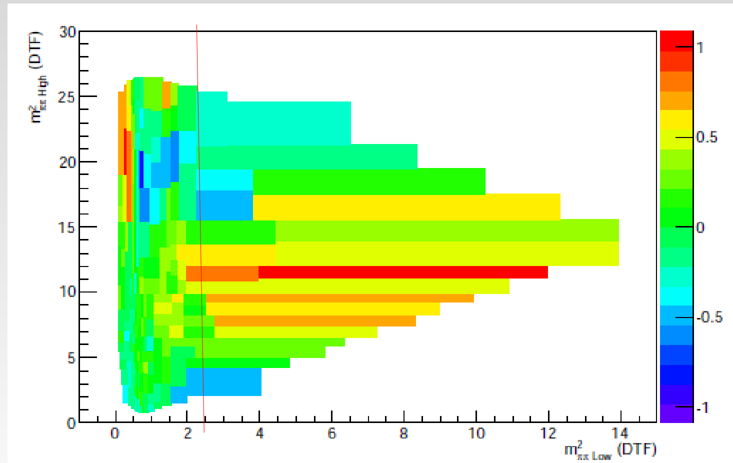
Re-scattering $\pi^{+}\pi^{-} \to K^{+}K^{-}$

Summary

- CPT constraint must be take in account in three body charmless B decay.
- We propose a general formalism using CPT constraint.
- CP violation in $B^{\mp} \rightarrow \pi^{\mp}\pi^{+}\pi^{-}$ and $B^{\mp} \rightarrow \pi^{\mp}K^{+}K^{-}$ decays seems present together compatibility with CPT constraint.
- CP violation in $B^{\mp} \rightarrow K^{\mp}\pi^{+}\pi^{-}$ and $B^{\mp} \rightarrow K^{\mp}K^{+}K^{-}$ decays seems present together compatibility with CPT constraint.
- S and P wave interference has a clear signature in CP violation distributions
- Amplitude $\pi^{+}\pi^{-} \rightarrow K^{+}K^{-}$ play an important rule in these decays.
- Amplitude analysis must improve this preliminary analysis.

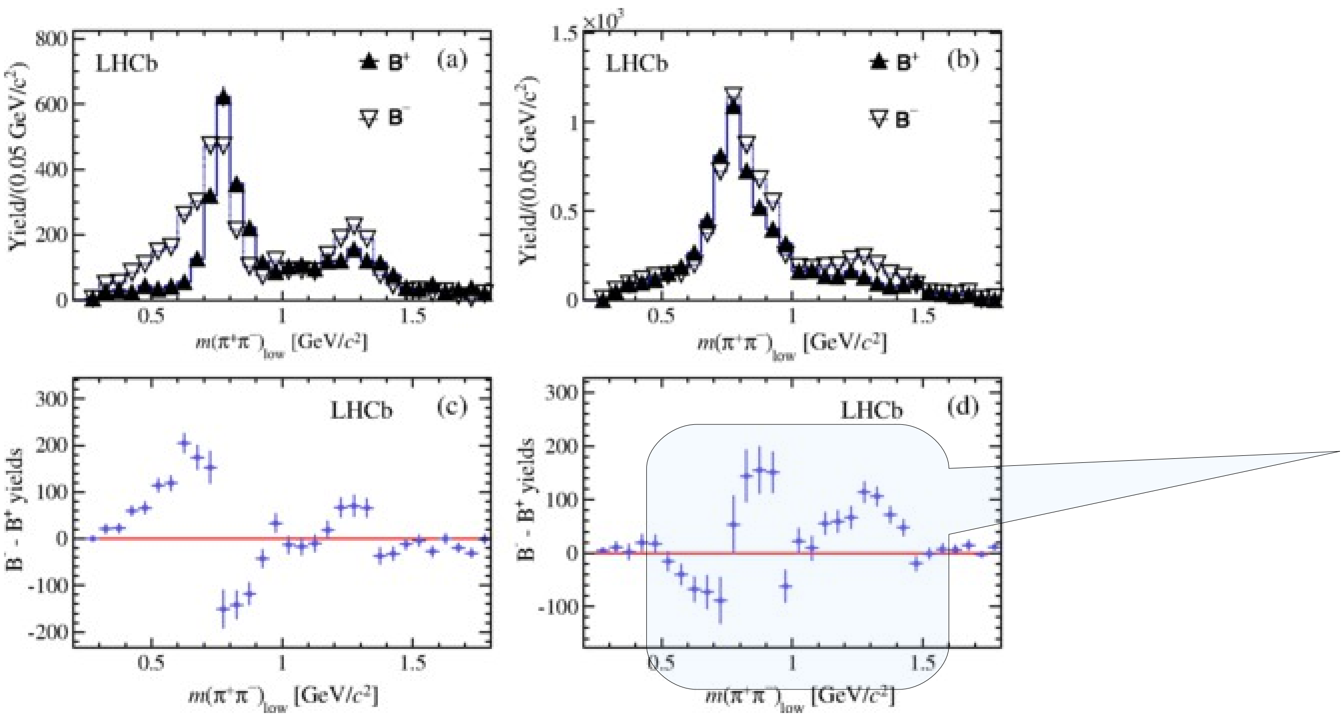
Backcup

CP violation in $B^{\mp} \to \pi^{\mp}\pi^{+}\pi^{-}$ decay.



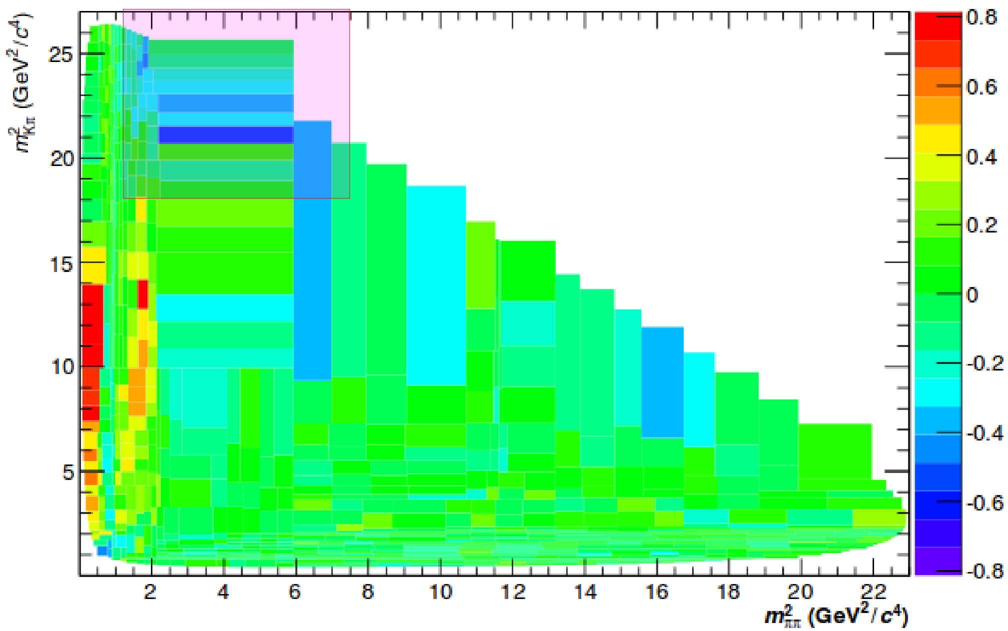
COS Θ >0

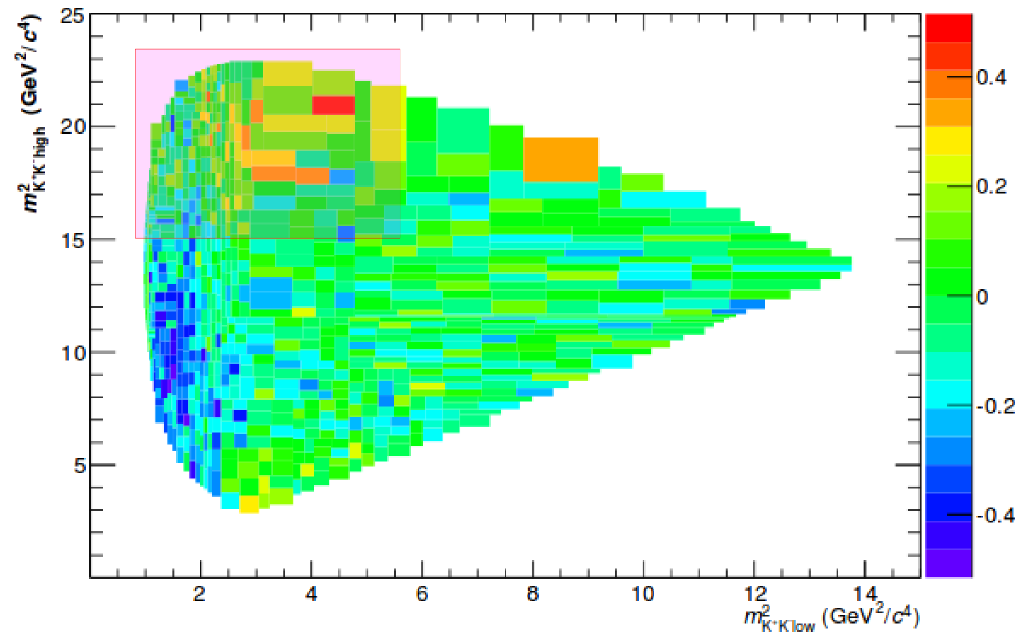
COS Θ<0

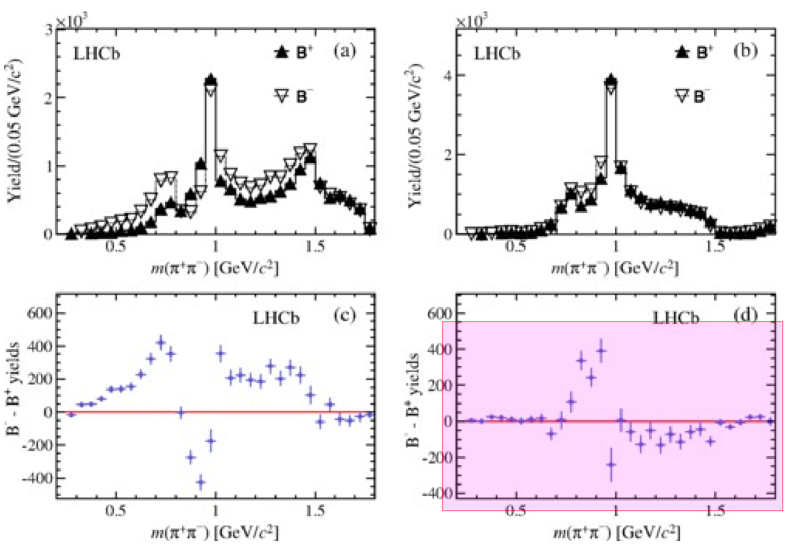


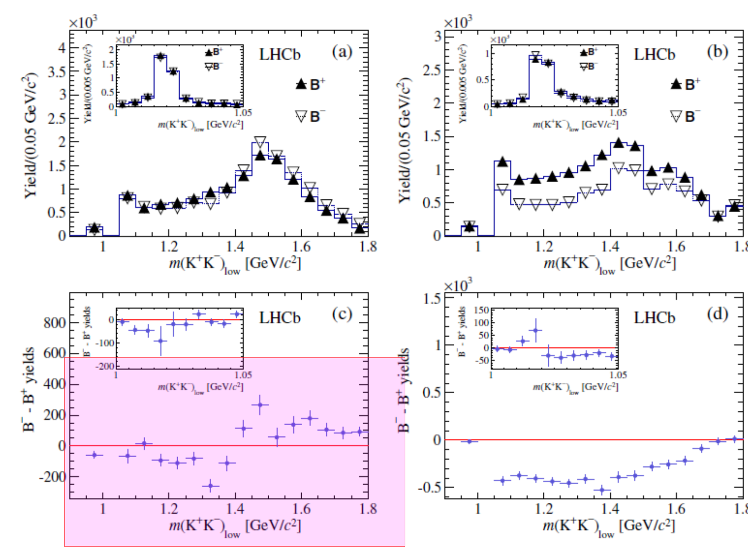
Symmetrize effect

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









$B^+ \to K^+D^+D^-$ $B^+ \to \pi^+D^+D_s^-$?