CP violation in charmless three body B decays

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Behalf LHCb collaboration

QCD22 25th HIGH-ENERGY PHYSICS INTERNATIONAL CONFERENCE IN QUANTUM CHROMODYNAMICS

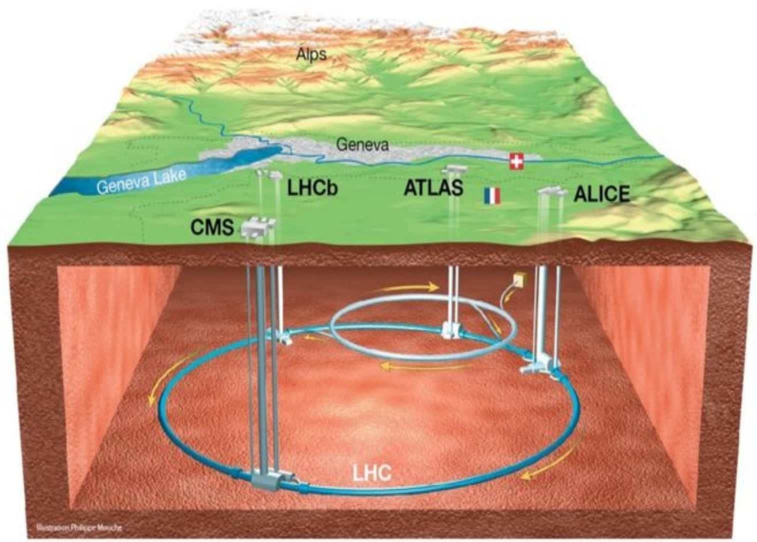
MONTPELLIER · 4-7 july 2022 ·

Based in two recent LHCb papers

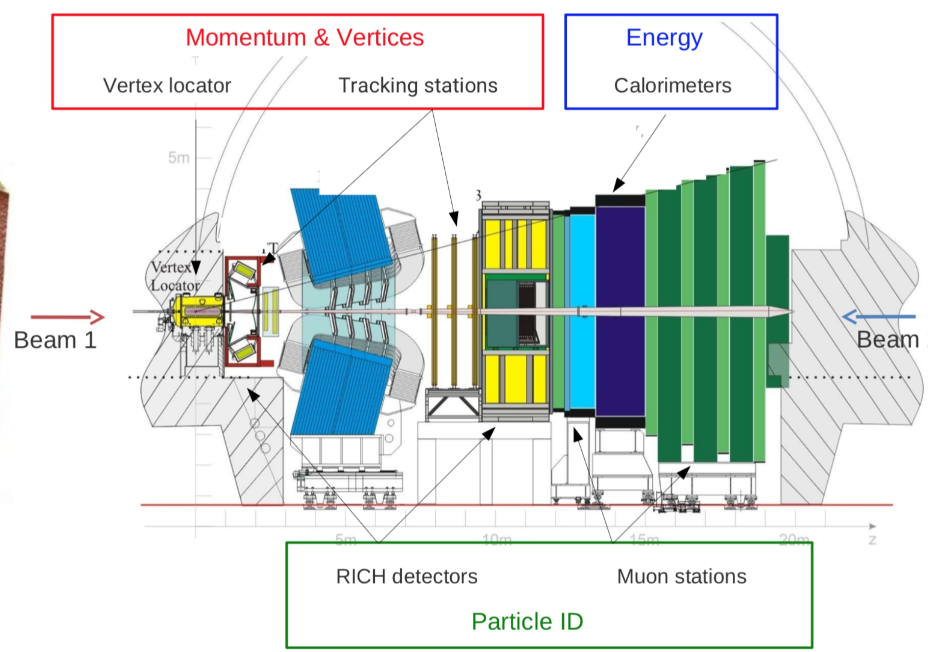
LHCb Collaboration hep/ex-2206-07622

LHCb Collaboration hep/ex-2206-02038

LHCb in LHC accelerator

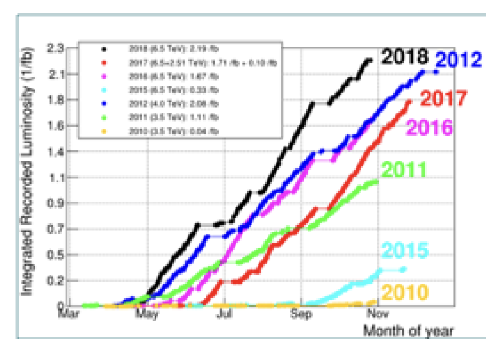


forward arm spectrometer for precision measurements ($2<\eta<5$)



- good vertex and impact parameter resolution ($\sigma(IP)= 15 \pm 29/p_T$ μm)
- excellent momentum resolution ($\sigma(m_B) \sim 25$ MeV/c^2 for 2-body decays)
- excellent particle ID (μ ID 97% for ($\pi \to \mu$) misID of 1-3%)
- stable running conditions constant μ
- trigger on small p_T and low mass objects
- real time analysis alignment and calibration fully automated

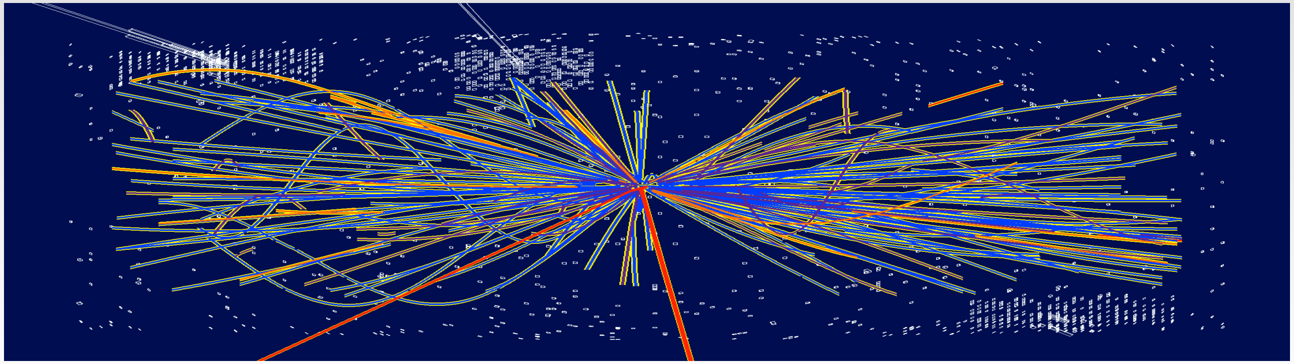
- Excellent performance of LHC and LHCb
- 9 fb^{-1} recorded over Run 1 + Run 2
- Run I with 7 and 8 TeV and Run II with 13 TeV
- p-Pb, Pb-Pb and p–gas (fixed target) runs
- LHCb is a multi-purpose forward detector



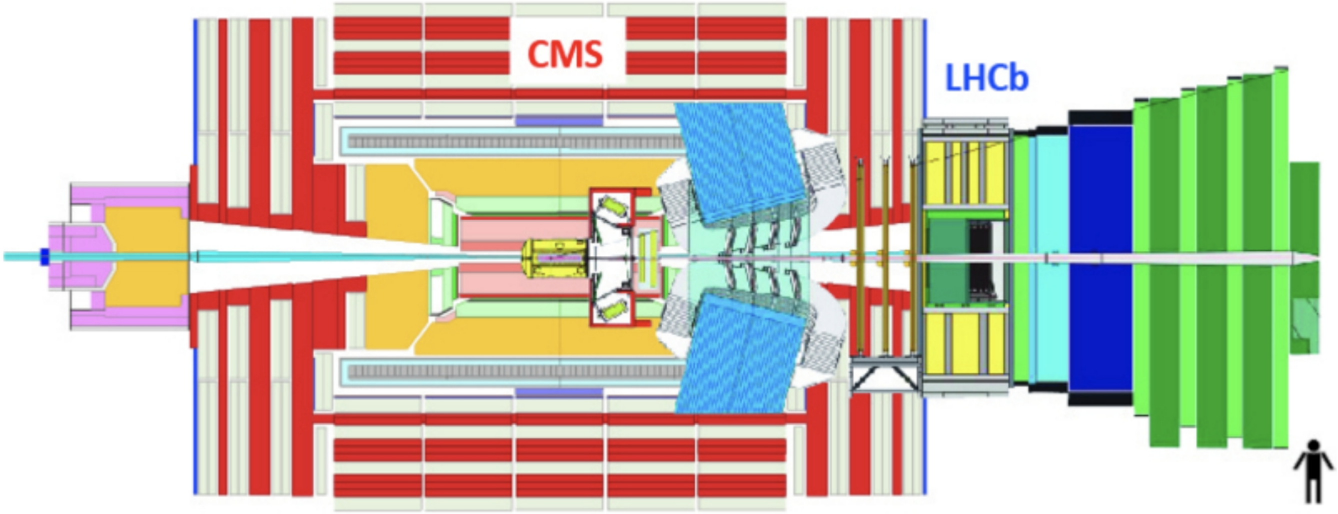
Got exactly the target luminosity that was hinted at the times of the Technical Proposal~1998

LHCb vs CMS

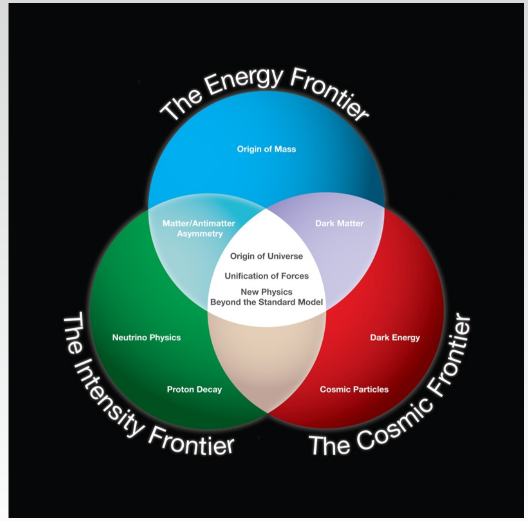
Typical LHC event



high pt vs forward physics



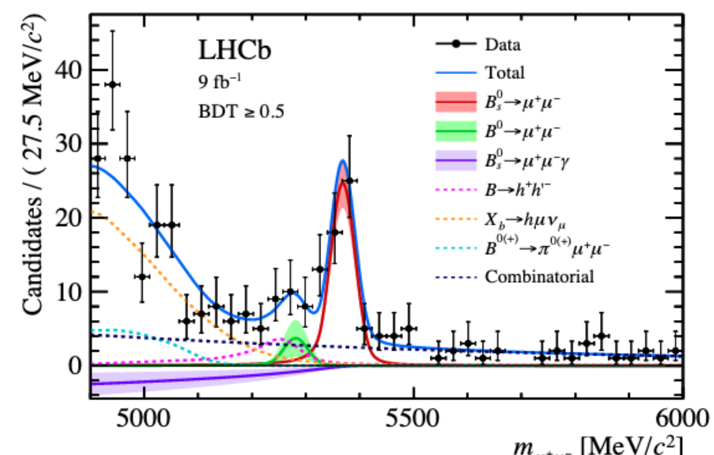
Key questions about the laws of nature and the cosmos



$Br(B_s^0 \to \mu^+\mu^-) = 3.09 \pm 0.5 \times 10^{-9}$

The Intensity Frontier in LHCb

- Flavour Physics
- Matter-Antimatter asymmetry and CP violation
- Rare decays
- Exotics



Phys. Rev. Lett.128 (2022) 041801

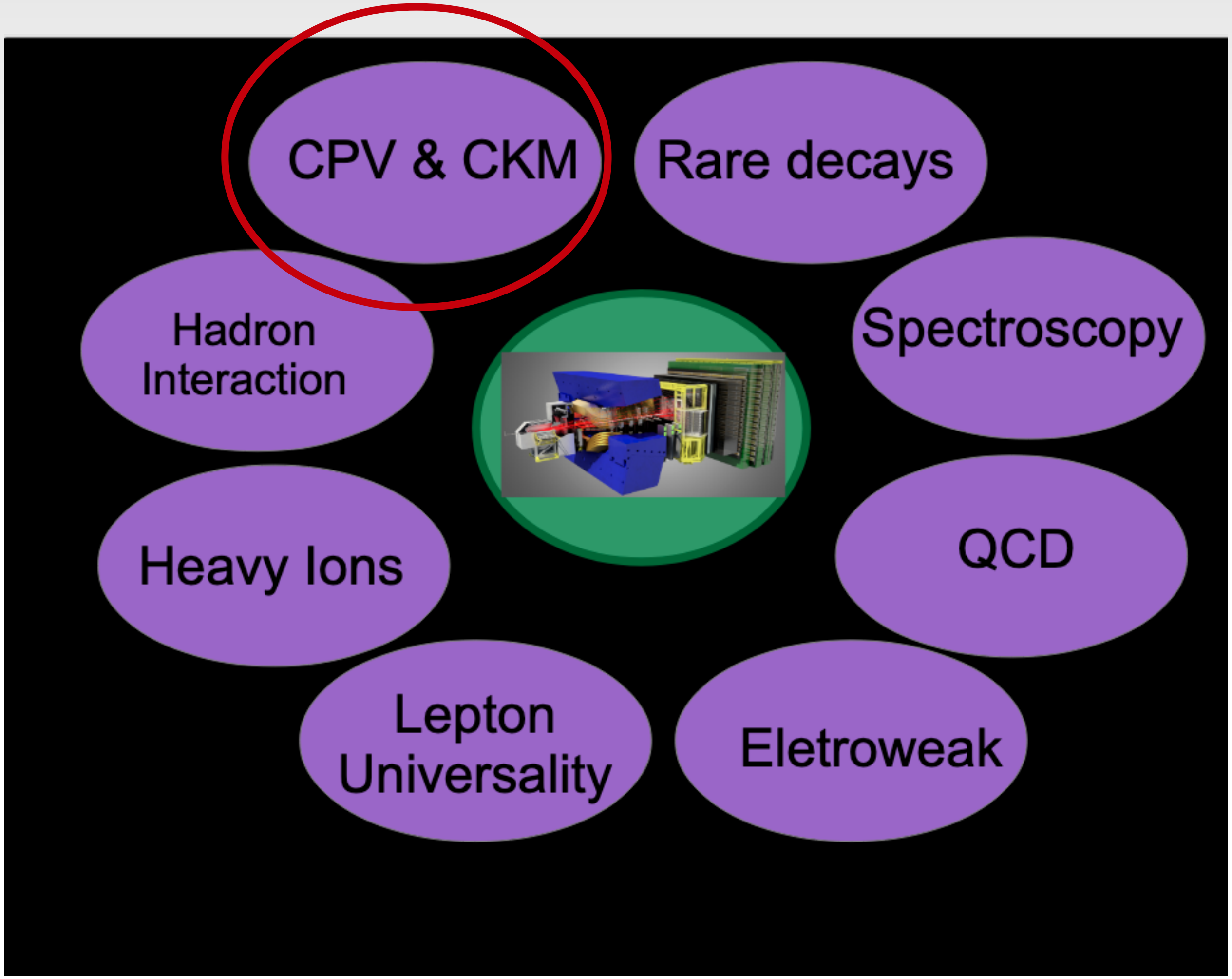
High statistics

Measurements in B and D decays, with branching fraction of **10^{-9}**.
(Next challenge observation of the **$B^0 \to \mu^+\mu^-$ with a Br < 3.4×10^{-10}**)

Recent physics highlights

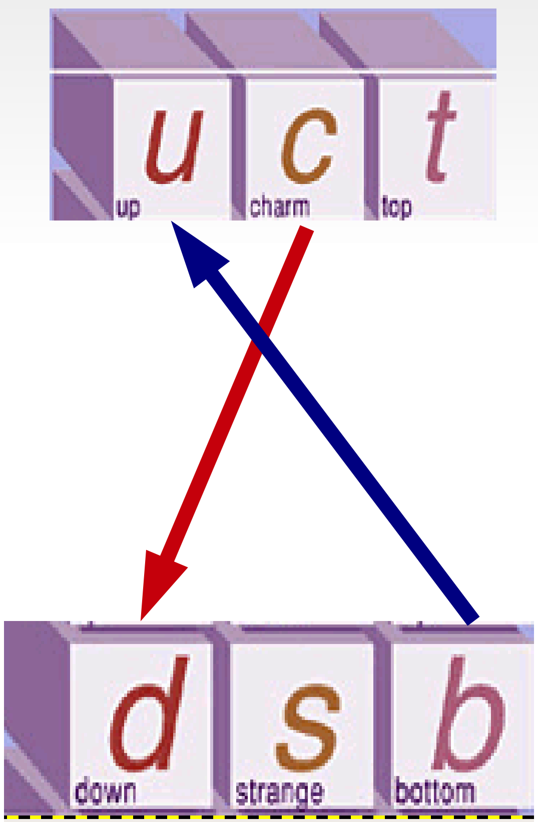
Paper production: 624 papers in total, almost 50.000 citations

- Many new results being published
- Several already using the full Run I and Run II data set.

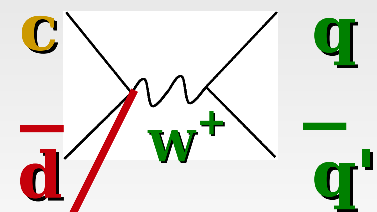


General questions about direct ~~CP~~ Violation.

Direct CP violation in the CKM matrix.



Suppressed weak phase in charm decays

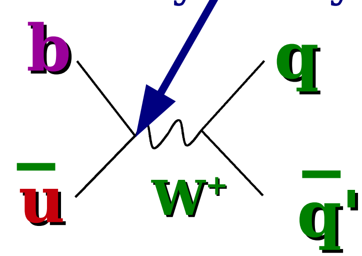


(Sin θ_c ~λ ~0.23)

$$V_{\mathrm{CKM}} = \begin{pmatrix} 1-\frac{1}{2}\lambda^2-\frac{1}{8}\lambda^4 & \lambda & A\lambda^3(\rho-i\eta) \\ -\lambda+\frac{1}{2}A^2\lambda^5[1-2(\rho+i\eta)] & 1-\frac{1}{2}\lambda^2-\frac{1}{8}\lambda^4(1+4A^2) & A\lambda^2 \\ A\lambda^3[1-(1-\frac{1}{2}\lambda^2)(\rho+i\eta)] & -A\lambda^2+\frac{1}{2}A\lambda^4[1-2(\rho+i\eta)] & 1-\frac{1}{2}A^2\lambda^4 \end{pmatrix}$$

Wolfenstein representation

High weak phase in beauty decays



Direct $\cancel{C}P$ violation

Two amplitudes with same initial and final state,

but with different

weak ϕ_i and strong δ_i phases

Phases ϕ_i change sign with charge conjugate operation: weak phase.

Phases δ_i don't change sign with charge conjugate operation: strong phase.

$$A(P \to f) = e^{i\phi_1^{\text{weak}}} e^{i\delta_1^{\text{FSI}}} |\mathcal{A}_1| + e^{i\phi_2^{\text{weak}}} e^{i\delta_2^{\text{FSI}}} |\mathcal{A}_2|,$$

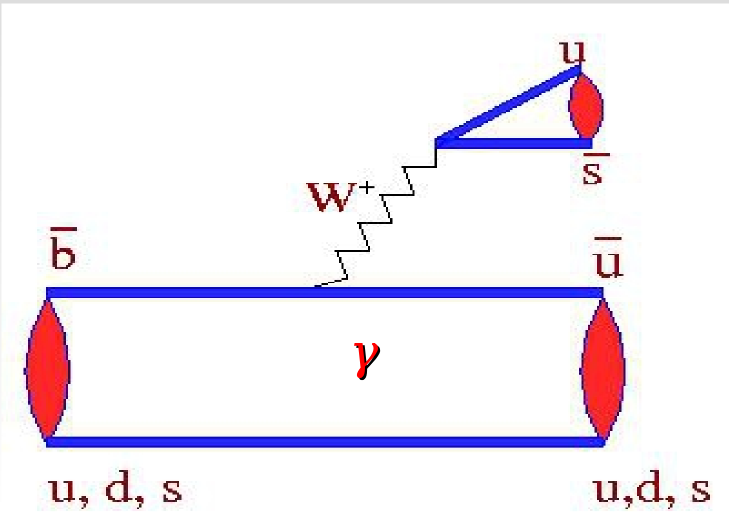
$$A(\overline{P} \to \overline{f}) = e^{-i\phi_1^{\text{weak}}} e^{i\delta_1^{\text{FSI}}} |\mathcal{A}_1| + e^{-i\phi_2^{\text{weak}}} e^{i\delta_2^{\text{FSI}}} |\mathcal{A}_2|,$$

$$\Gamma(P \to f) - \Gamma(\overline{P} \to \overline{f}) = 2\mathcal{A}_1\mathcal{A}_2 \quad \text{Im}(\Delta\phi_i) \; \text{Im}\,(\Delta\delta_i)$$

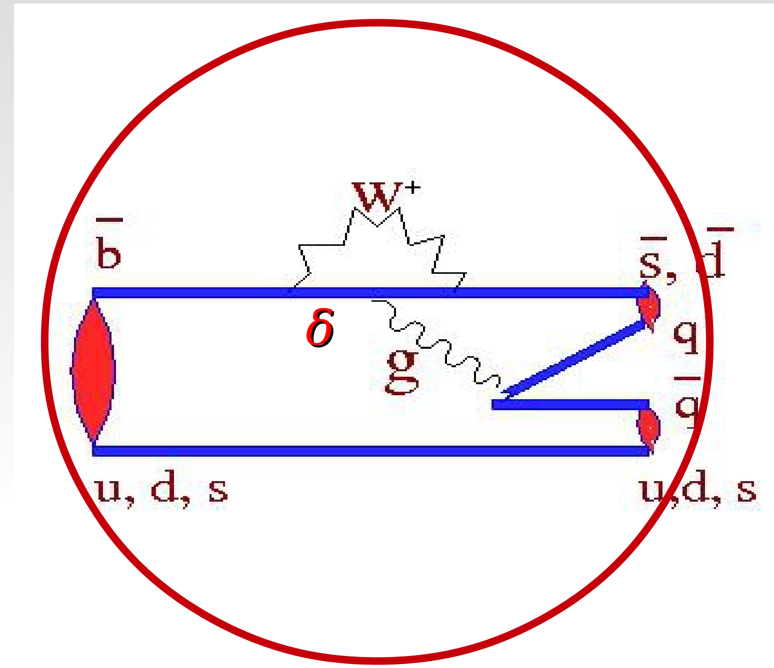
The weak phase come from CKM matrix

Bander-Silverman-Soni (BSS) quark level mechanism

Phys. Rev. Lett. 43, 242 (1979)



Interference=>~~CP~~



Phase γ *CKM phase: weak phase.*

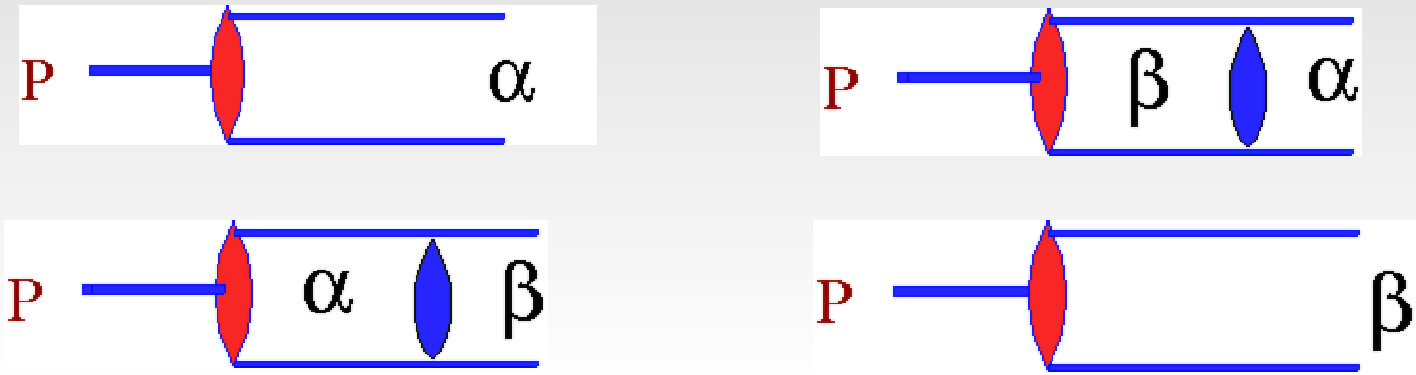
Phase δ *strong phase: from the penguin loop*

$$\Gamma(P \to f) - \Gamma(\overline{P} \to \overline{f}) = 2\mathcal{A}_1\mathcal{A}_2 \quad \sin\gamma \sin\delta$$

CP violation through a strong phase from hadronic re-scattering.

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

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



Phase γ CKM phase: weak phase.

Phase δ strong phase: from S-Matrix

$$S_{matrix} = \begin{pmatrix} e^{i2\,\delta\alpha} & t_{\alpha\beta} e^{i(\delta\alpha+\delta\beta)} \\ t_{\alpha\beta} e^{i(\delta\alpha+\delta\beta)} & e^{i2\,\delta\beta} \end{pmatrix} \Rightarrow \begin{array}{l} \langle\alpha \,|\, T \,|\, P\rangle = e^{i\delta\,\alpha}\,[\,T_\alpha + i t_{\alpha\beta} T_\beta] \\ \langle\beta \,|\, T \,|\, P\rangle = e^{i\delta\,\beta}\,[\,T_\beta + i t_{\alpha\beta} T_\alpha] \end{array}$$

Direct CP violation in

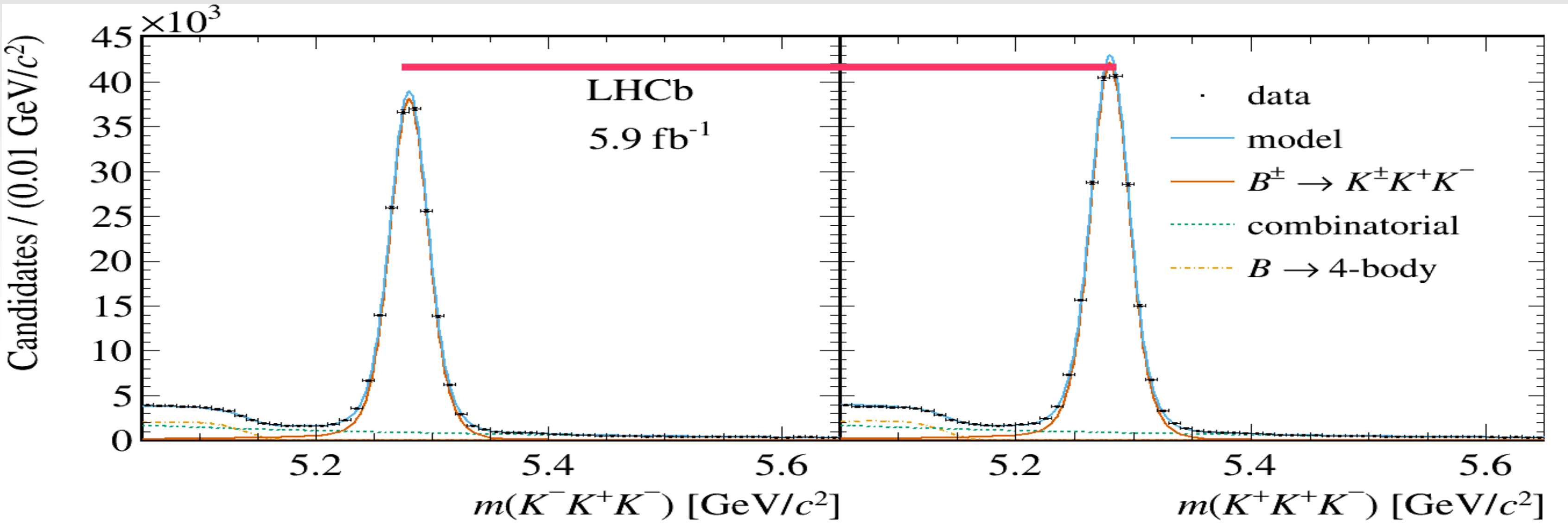
$B \to K \pi \pi$ and $B \to K K K$

$B \to \pi \pi \pi$ and $B \to K K \pi$

Total charge asymmetry for $B^{\mp} \to K^{\mp} K^{+} K^{-}$

LHCb Collaboration hep/ex-2206-07622

$N(B^-) + N(B^+) = 365.000 \pm 1000$



Total charge asymmetry:

$$A_{CP} = \frac{N(B^-) - N(B^+)}{N(B^-) + N(B^+)} = -3.7 \pm 0.2(\text{sta}) \pm 0.2(\text{sys})\%$$

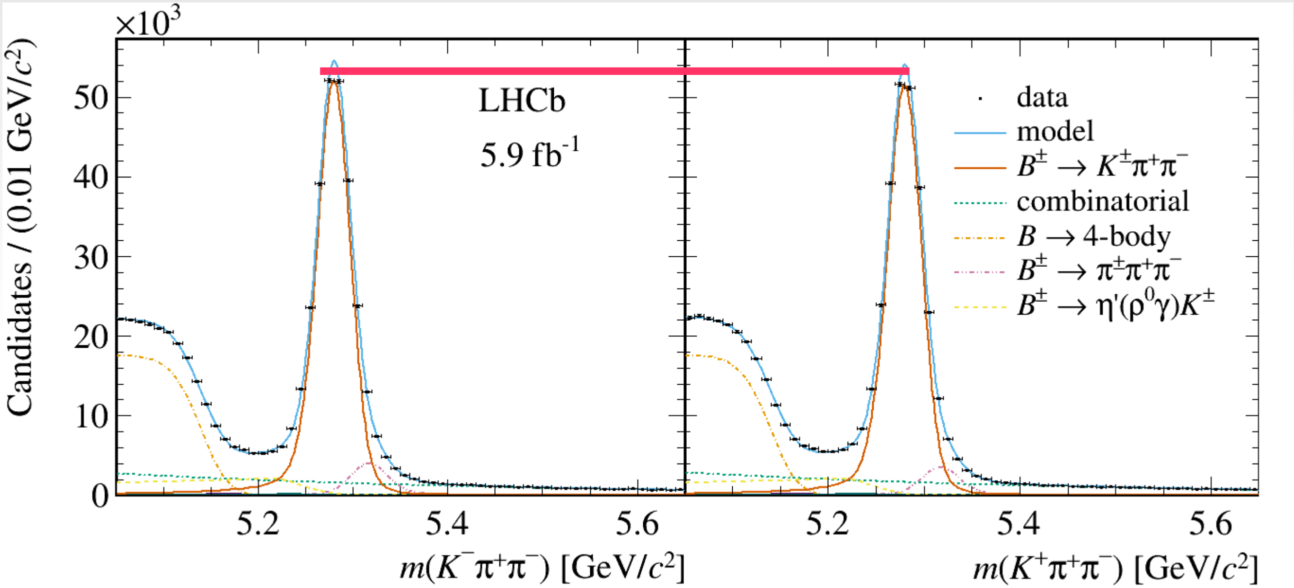
Plus an error of 0.3% from the control channel $B^- \to J/\Psi\ K^-$

CP asymmetry with 8.5 standard deviation

Total charge asymmetry for $B^{\mp} \rightarrow K^{\mp}\ \pi^{-}\pi^{+}$

LHCb Collaboration hep/ex-2206-07622

$N(B^{-}) + N(B^{+}) = 499.200 \pm 900$



Total charge asymmetry:

$$A_{CP} = \frac{N(B^{-}) - N(B^{+})}{N(B^{-}) + N(B^{+})} = 1.1 \pm 0.2(sta) \pm 0.3(sys)\%$$

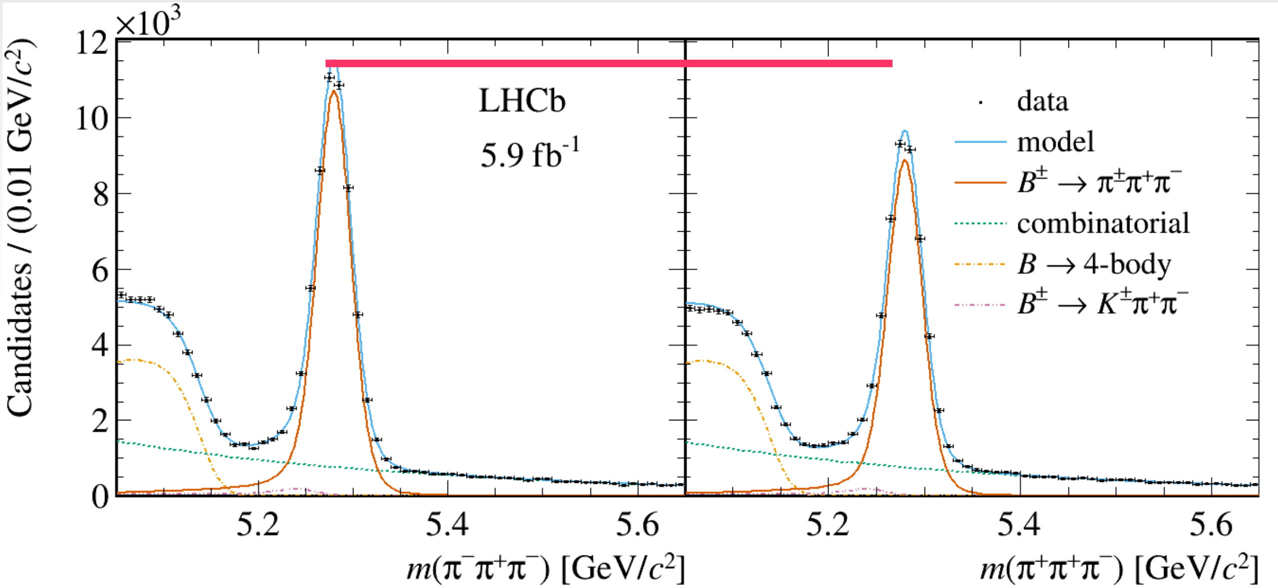
Plus an error of 0.3% from the control channel $B^{-} \rightarrow J/\Psi\ K$

CP asymmetry with 2.4 standard deviation

Total charge asymmetry for $B^{\mp} \rightarrow \pi^{\mp} \pi^{-} \pi^{+}$

LHCb Collaboration hep/ex-2206-07622

N(B$^-$)   +   N(B$^+$)= 101.000 ± 500



Total charge asymmetry:

$$A_{CP} = \frac{N(B^-) - N(B^+)}{N(B^-) + N(B^+)} = +8.0 \pm 0.4(\mathrm{sta}) \pm 0.3(\mathrm{sys})\%$$

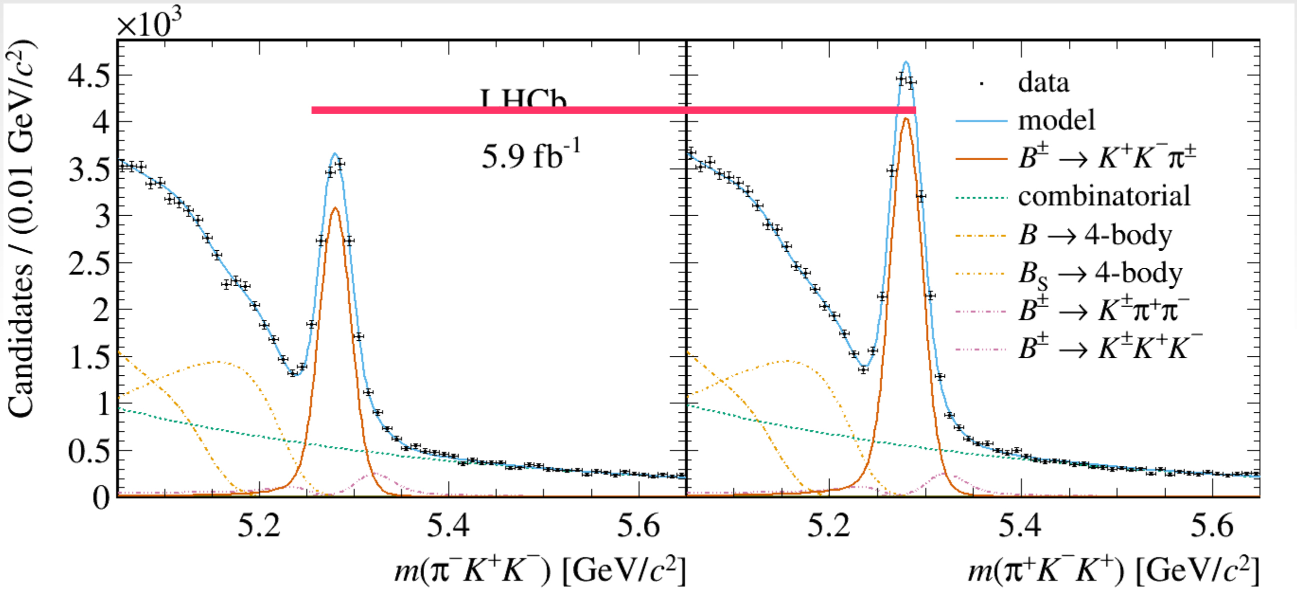
Plus an error of 0.3% from the control channel $B^- \rightarrow J/\Psi\ K$

CP asymmetry with 14.1 standard deviation

Total charge asymmetry for $B^{\mp} \rightarrow K^{\mp} K^{-} \pi^{+}$

LHCb Collaboration hep/ex-2206-07622

N(B^-)   +   N(B^+)= 32.470 ± 300



Total charge asymmetry:

$$A_{CP} = \frac{N(B^-) - N(B^+)}{N(B^-) + N(B^+)} = -11.4 \pm 0.7(\text{sta}) \pm 0.3(\text{sys})\%$$

Plus an error of 0.3% from the control channel $B^- \rightarrow J/\Psi\ K^-$

CP asymmetry with 13.6 standard deviation

Total charge asymmetry

Run II

	(stat)	(syst)	$(J/\psi K^{\pm})$	
$A_{CP}(B^{\pm} \to K^{\pm}\pi^{+}\pi^{-}) = +0.011$	$\pm\, 0.002$	$\pm\, 0.003$	$\pm\, 0.003$	**(2.4σ)**
$A_{CP}(B^{\pm} \to K^{\pm}K^{+}K^{-}) = -0.037$	$\pm\, 0.002$	$\pm\, 0.002$	$\pm\, 0.003$	**(8.5σ)**
$A_{CP}(B^{\pm} \to \pi^{\pm}\pi^{+}\pi^{-}) = +0.080$	$\pm\, 0.004$	$\pm\, 0.003$	$\pm\, 0.003$	**(14.1σ)**
$A_{CP}(B^{\pm} \to \pi^{\pm}K^{+}K^{-}) = -0.114$	$\pm\, 0.007$	$\pm\, 0.003$	$\pm\, 0.003$	**(13.6σ)**

Run I

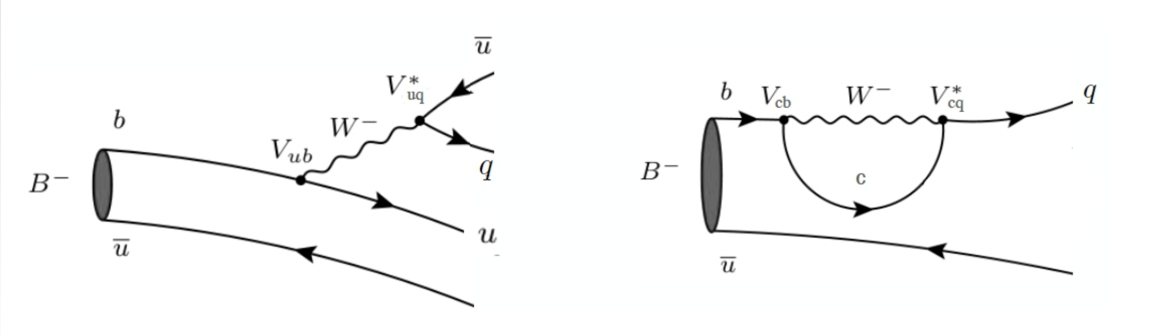
	(stat)	(syst)	$(J/\psi K^{\pm})$
$A_{CP}(B^{\pm} \to K^{\pm}\pi^{+}\pi^{-}) = +0.025$	$\pm\, 0.004$	$\pm\, 0.004$	$\pm\, 0.007$
$A_{CP}(B^{\pm} \to K^{\pm}K^{+}K^{-}) = -0.036$	$\pm\, 0.004$	$\pm\, 0.002$	$\pm\, 0.007$
$A_{CP}(B^{\pm} \to \pi^{\pm}\pi^{+}\pi^{-}) = +0.058$	$\pm\, 0.008$	$\pm\, 0.009$	$\pm\, 0.007$
$A_{CP}(B^{\pm} \to \pi^{\pm}K^{+}K^{-}) = -0.123$	$\pm\, 0.017$	$\pm\, 0.012$	$\pm\, 0.007$

Phys. Rev. D90 (2014) 112004

Relationship between total CP asymmetry in charmless three body B decays

M. Gronau and J. L. Rosner, Phys. Lett. B564 (2003) 90,

Main quark graphic contribution for all channels



$$A(B^+ \to K^+\pi^+\pi^-) = V^*_{ub}V_{us}\,\mathcal{U}_{s_1} + V^*_{cb}V_{cs}\,\mathcal{C}_{s_1},$$
$$A(B^+ \to \pi^+K^+K^-) = V^*_{ub}V_{ud}\,\mathcal{U}_{d_2} + V^*_{cb}V_{cd}\,\mathcal{C}_{d_2},$$
$$A(B^+ \to \pi^+\pi^+\pi^-) = V^*_{ub}V_{ud}\,\mathcal{U}_{d_3} + V^*_{cb}V_{cd}\,\mathcal{C}_{d_3},$$
$$A(B^+ \to K^+K^+K^-) = V^*_{ub}V_{us}\,\mathcal{U}_{s_4} + V^*_{cb}V_{cs}\,\mathcal{C}_{s_4},$$

$\boldsymbol{V^*_{ij}V_{kl}}$ are the CKM parameters

The $\boldsymbol{\mathcal{U}}$ is tree amplitude

$\boldsymbol{\mathcal{C}}$ is the penguin.

Looking at Difference of partial decays

$$\Delta\Gamma_{CP}(h_1^\pm h_2^\pm h_3^\mp) = \Gamma(B^- \to h_1^- h_2^- h_3^+) - \Gamma(B^+ \to h_1^+ h_2^+ h_3^-)\,.$$

Relationship between total CP asymmetry in charmless three body *B* *decays*

$$\begin{aligned}
\Delta\Gamma_{CP}(K^{\pm}\pi^{+}\pi^{-}) &= \boxed{2\,\mathrm{Im}[V_{ub}^{*}V_{us}V_{cb}V_{cs}^{*}]}\,\mathrm{Im}[\mathcal{U}_{s_1}\mathcal{C}_{s_1}^{*} + \bar{\mathcal{U}}_{s_1}\bar{\mathcal{C}}_{s_1}^{*}],\\
\Delta\Gamma_{CP}(\pi^{\pm}K^{+}K^{-}) &= \boxed{2\,\mathrm{Im}[V_{ub}^{*}V_{ud}V_{cb}V_{cd}^{*}]}\,\mathrm{Im}[\mathcal{U}_{d_2}\mathcal{C}_{d_2}^{*} + \bar{\mathcal{U}}_{d_2}\bar{\mathcal{C}}_{d_2}^{*}],\\
\Delta\Gamma_{CP}(\pi^{\pm}\pi^{+}\pi^{-}) &= \boxed{2\,\mathrm{Im}[V_{ub}^{*}V_{ud}V_{cb}V_{cd}^{*}]}\,\mathrm{Im}[\mathcal{U}_{d_3}\mathcal{C}_{d_3}^{*} + \bar{\mathcal{U}}_{d_3}\bar{\mathcal{C}}_{d_3}^{*}],\\
\Delta\Gamma_{CP}(K^{\pm}K^{+}K^{-}) &= \boxed{2\,\mathrm{Im}[V_{ub}^{*}V_{us}V_{cb}V_{cs}^{*}]}\,\mathrm{Im}[\mathcal{U}_{s_4}\mathcal{C}_{s_4}^{*} + \bar{\mathcal{U}}_{s_4}\bar{\mathcal{C}}_{s_4}^{*}]\,.
\end{aligned}$$

$$\boxed{\mathrm{Im}(V_{ub}^{*}V_{us}V_{cb}V_{cs}^{*}) = -\,\mathrm{Im}(V_{ub}^{*}V_{ud}V_{cb}V_{cd}^{*})}$$

U-spin d ⇄ s imply $\mathcal{U}_{s_1} = \mathcal{U}_{d_2}\,,\quad \mathcal{C}_{s_1} = \mathcal{C}_{d_2}\,,\quad \mathcal{U}_{d_3} = \mathcal{U}_{s_4}\,,\quad \mathcal{C}_{d_3} = \mathcal{C}_{s_4}$

B. Bhattacharya, M. Gronau, and J. L. Rosner, Phys. Lett. B726 (2013) 337

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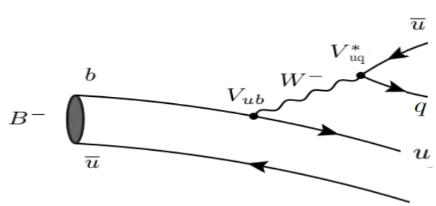
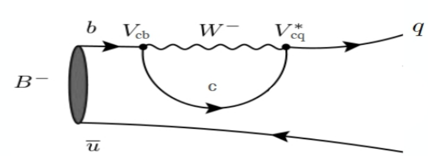




$\Delta\Gamma_{CP}(B^{\mp} \rightarrow \pi^{\mp}\pi^{+}\pi^{-}) = -\,\Delta\Gamma_{CP}(B^{\mp} \rightarrow K^{\mp}K^{+}K^{-})$

$\Delta\Gamma_{CP}(B^{\mp} \rightarrow K^{\mp}\pi^{+}\pi^{-}) = -\,\Delta\Gamma_{CP}(B^{\mp} \rightarrow \pi^{\mp}K^{+}K^{-})$

Results

Putting together the result I presented before and the relative BR measured by LHCb Phys. Rev. D 102, 112010

$$\Delta\Gamma_{CP} = \Gamma(B^-) - \Gamma(B^+) = A_{CP}(B^{\mp})\, BR(B^{\mp}) / \tau(B^{\mp})$$

$$\frac{\Delta\Gamma_{CP}(B^{\mp}\to \pi^{\mp}\pi^{+}\pi^{-})}{\Delta\Gamma_{CP}(B^{\mp}\to K^{\mp} K^{+} K^{-})} = -0.92 \pm 0.18$$

$$\frac{\Delta\Gamma_{CP}(B^{\mp}\to \pi^{\mp}\pi^{+}\pi^{-})}{\Delta\Gamma_{CP}(B^{\mp}\to K^{\mp} K^{+} K^{-})} = -1.06 \pm 0.08$$

In good agreement with the U-spin model

We can go ahead and compare the other two possibles relationship, only taking into account the quark diagrams and CKM elements.

$$\boxed{\begin{aligned}\Delta\Gamma_{CP}(B^{\mp} \to K^{\mp} K^{+}\pi^{-}) &= -\Delta\Gamma_{CP}(B^{\mp} \to K^{\mp} K^{+} K^{-})\\ \Delta\Gamma_{CP}(B^{\mp} \to K^{\mp}\pi^{+}\pi^{-}) &= -\Delta\Gamma_{CP}(B^{\mp} \to \pi^{\mp} \pi^{+}\pi^{-})\end{aligned}}$$

$$\frac{\Delta\Gamma_{CP}(B^{\mp}\to K^{\mp}K^{+}\pi^{-})}{\Delta\Gamma_{CP}(B^{\mp}\to K^{\mp} K^{+} K^{-})} = +0.47 \pm 0.04$$

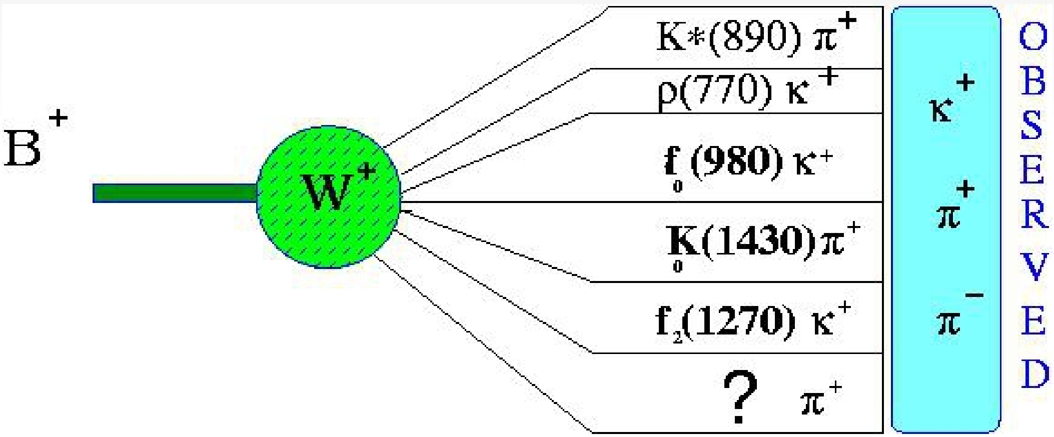
$$\frac{\Delta\Gamma_{CP}(B^{\mp}\to K^{\mp}\pi^{+}\pi^{-})}{\Delta\Gamma_{CP}(B^{\mp}\to \pi^{\mp} \pi^{+} \pi^{-})} = +0.48 \pm 0.09$$

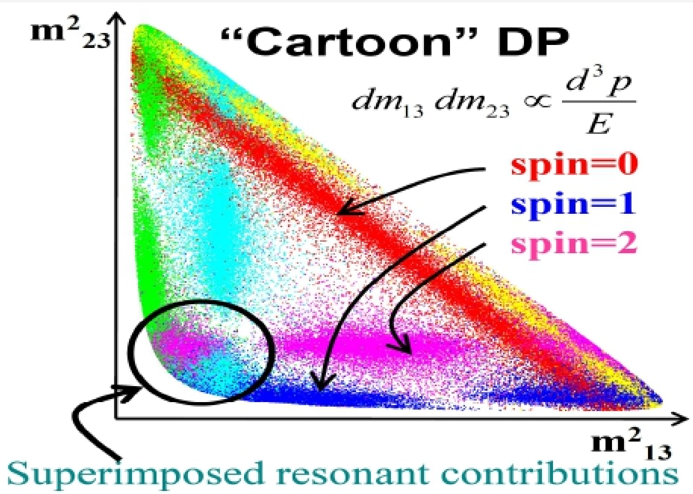
Both relationship are positive, so must have more important elements in the amplitudes other the CKM matrix elements.

I. Bediaga, T. Frederico, P. C. Magalhaes, and D. T. Machado,Physics Letters B, Volume 824 (2022)136824

Charmless three body B charge decays

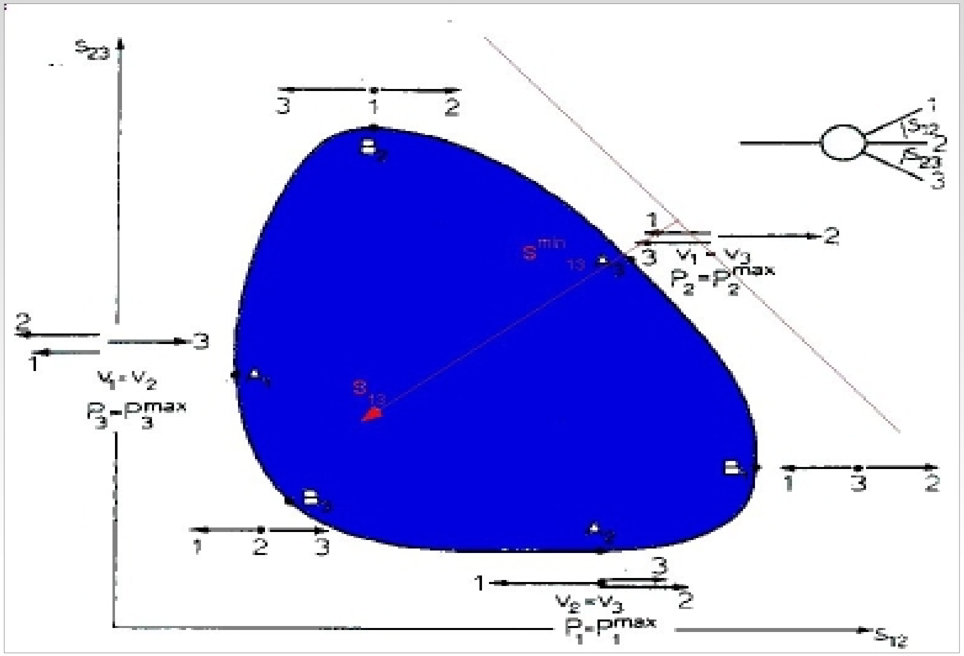
- Study the B decays and their intermediary states
- Coherent sum of amplitudes





Interference between intermediary states with different weak and strong phases implies <u>CP violation.</u>

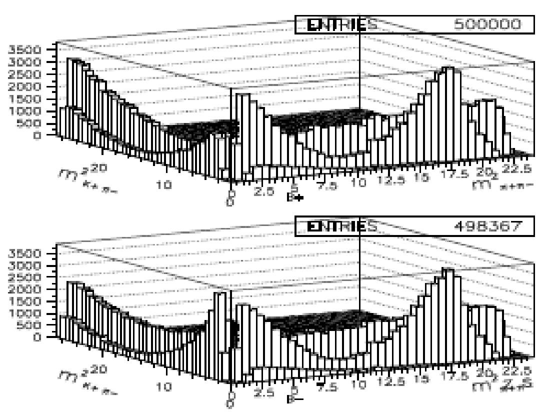
Dalitz Plot



$$s_{12} = M_{12}^2 = (p_1^\nu + p_2^\nu)^2$$
$$s_{13} = M_{13}^2 = (p_1^\nu + p_3^\nu)^2$$
$$s_{23} = M_{23}^2 = (p_2^\nu + p_3^\nu)^2$$

$$d\Gamma(s_{12}, s_{23}) = \frac{1}{(2\pi)^3 32 M_B^3} |\mathcal{M}|^2 \, ds_{12} ds_{23}$$

Flat phase space, resonances and other dynamic effects appear as a bump in the Dalitz plane

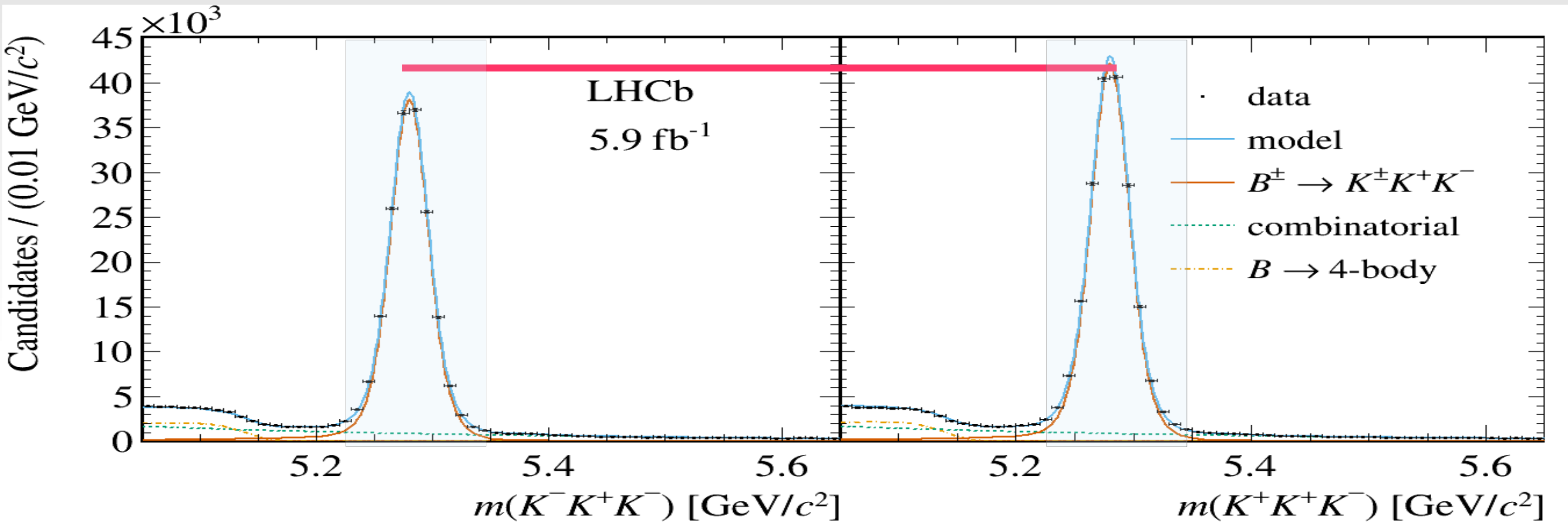


$B^+ \neq B^- \Longrightarrow \cancel{CP}$

Total charge asymmetry for $B^{\mp} \to K^{\mp} K^{+} K^{-}$

LHCb Collaboration hep/ex-2206-07622

$N(B^-) + N(B^+) = 365.000 \pm 1000$



Total charge asymmetry:

$$A_{CP} = \frac{N(B^-) - N(B^+)}{N(B^-) + N(B^+)} = -3.7 \pm 0.2(\text{sta}) \pm 0.2(\text{sys})\%$$

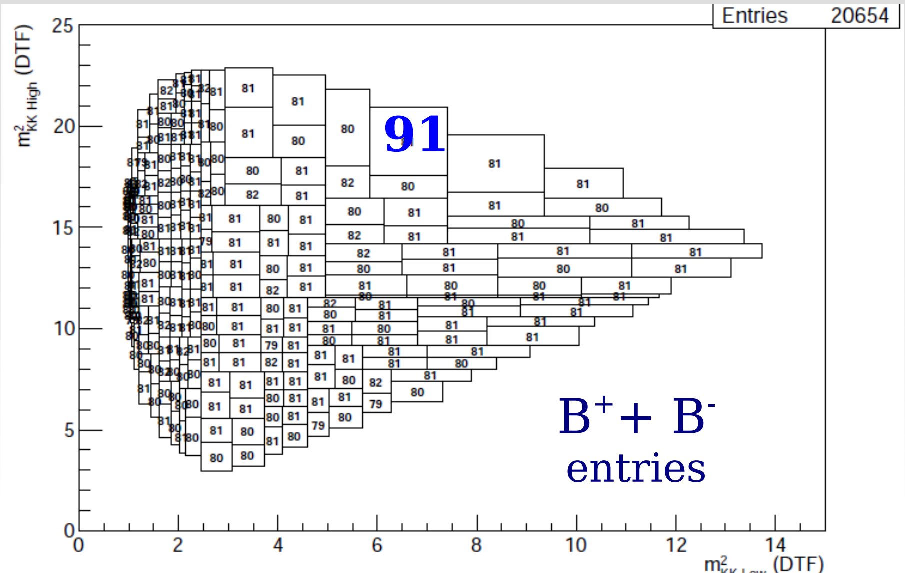
Plus an error of 0.3% from the control channel $B^- \to J/\Psi\ K^-$

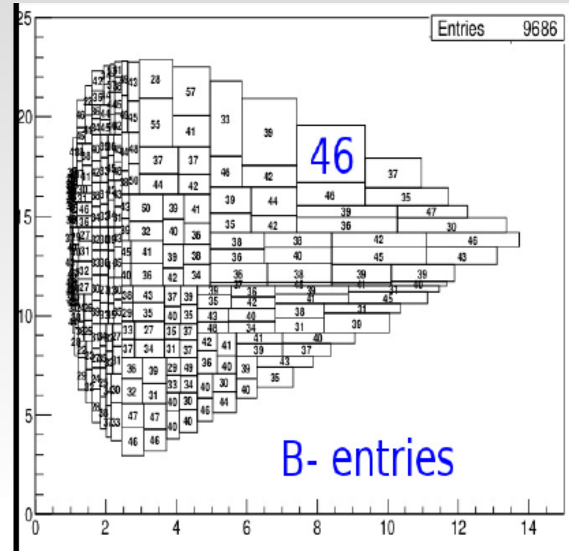
CP asymmetry with 8.5 standard deviation

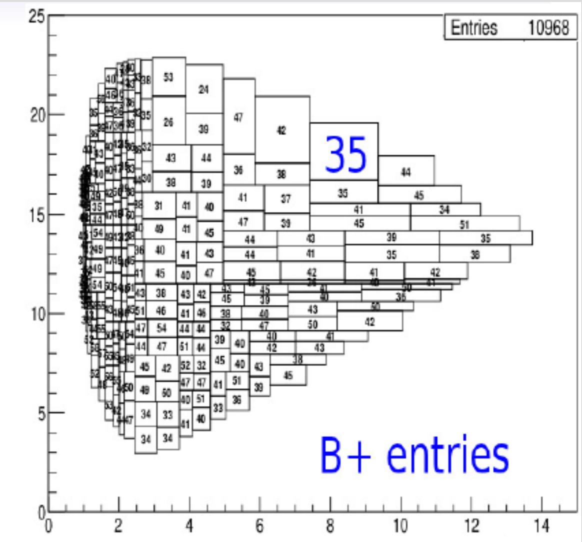
B^+ - B^- Dalitz differences

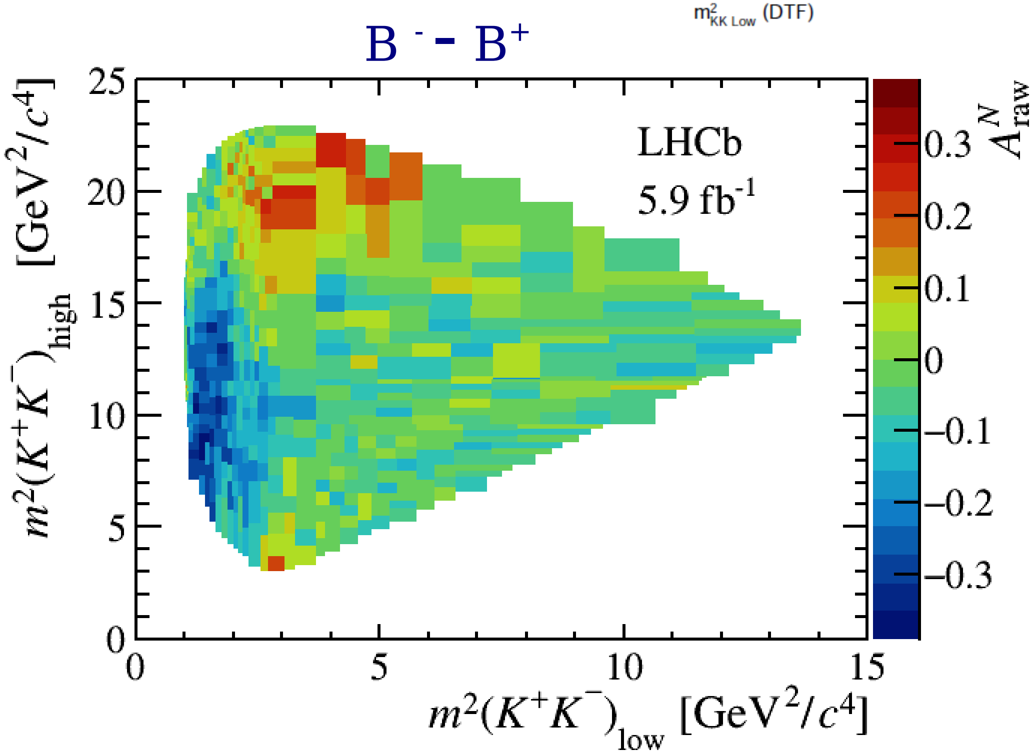
M^2_{K+K-} Vs M^2_{K+K-} phase space distribution

Bins with the same number of events









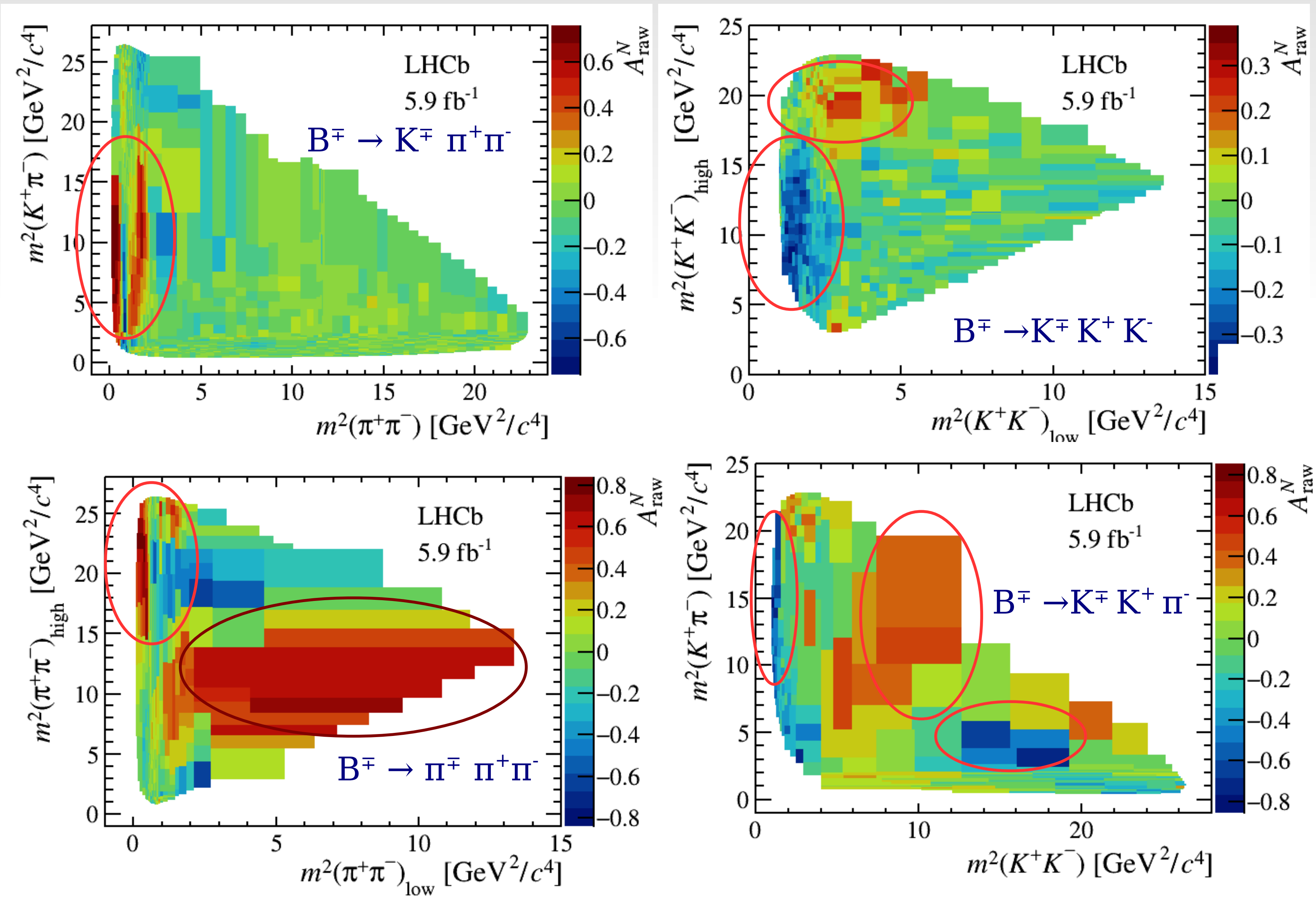
Dalitz Map of the CP violation

Map of the strong phases

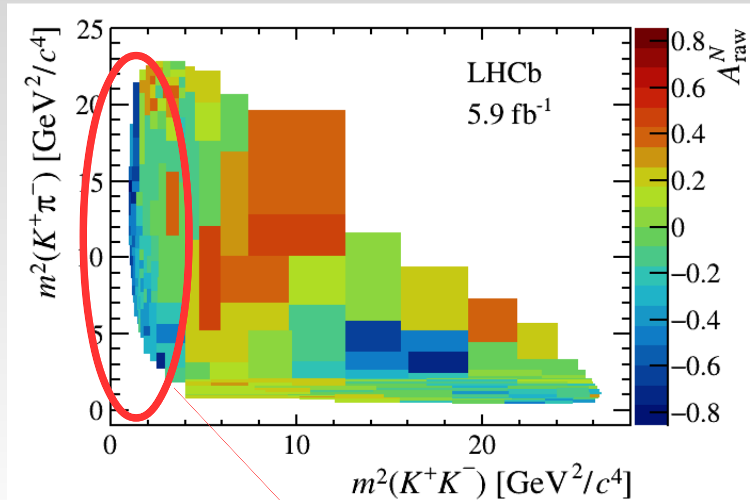
Sources of CP asymmetry in Dalitz phase space

LHCb Collaboration hep/ex-2206-07622

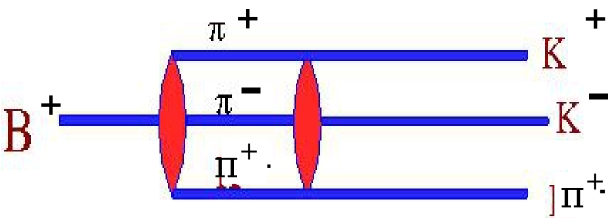
Green NO CPV Blue positive CPV Red negative CPV

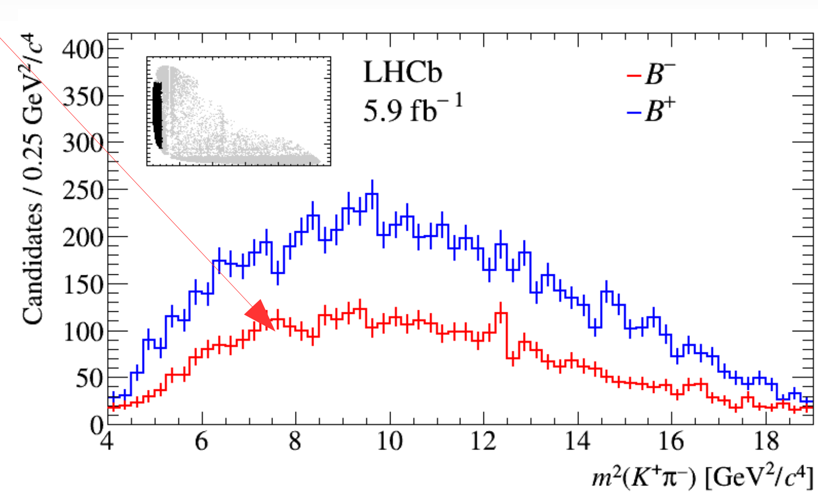


Hadronic re-scattering amplitude $K^- K^+ \rightarrow \pi^- \pi^+$



Rescattering
K- K+ → π- π^+





$K^- K^+ \rightarrow \pi^- \pi^+$ rescattering: **largest ever CP asymmetry for a single amplitude**

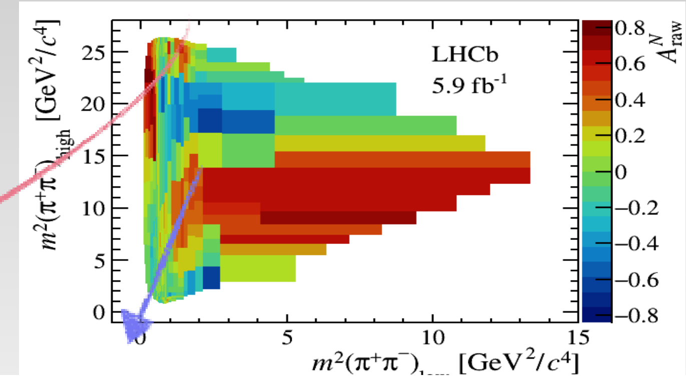
$$\mathbf{A_{CP} = 66.4 \pm 4.0\ \%}$$

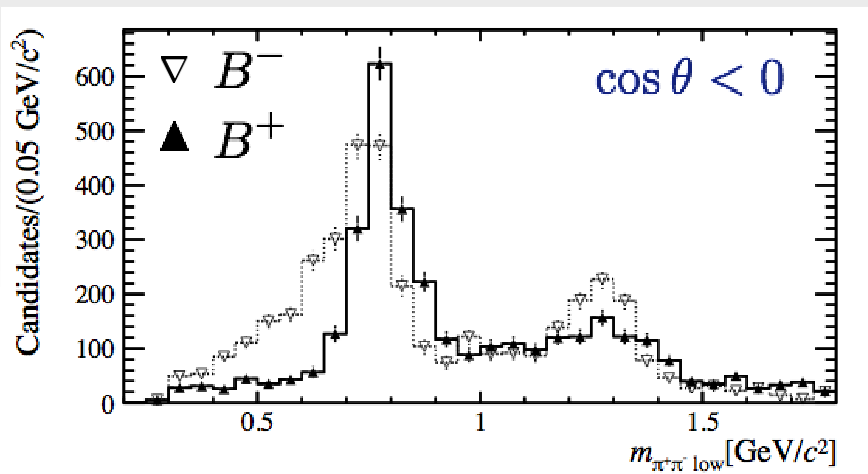
LHCb Collaboration PRL 123 (2019) 231802

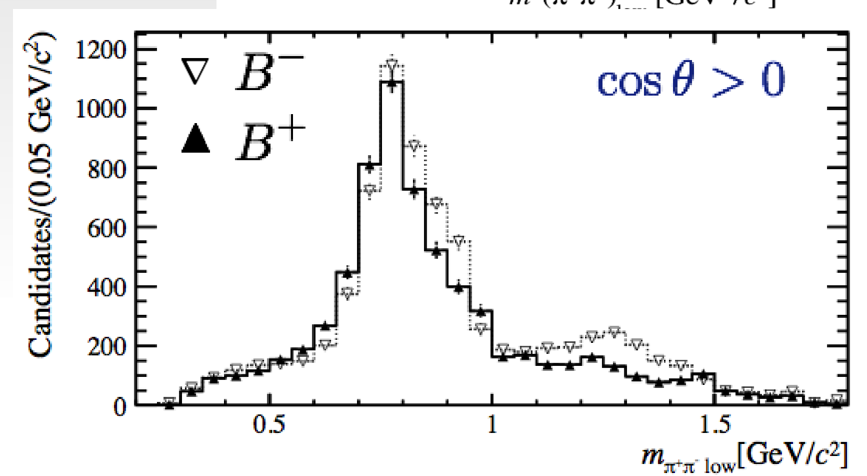
CP violation from S and P wave phase differences

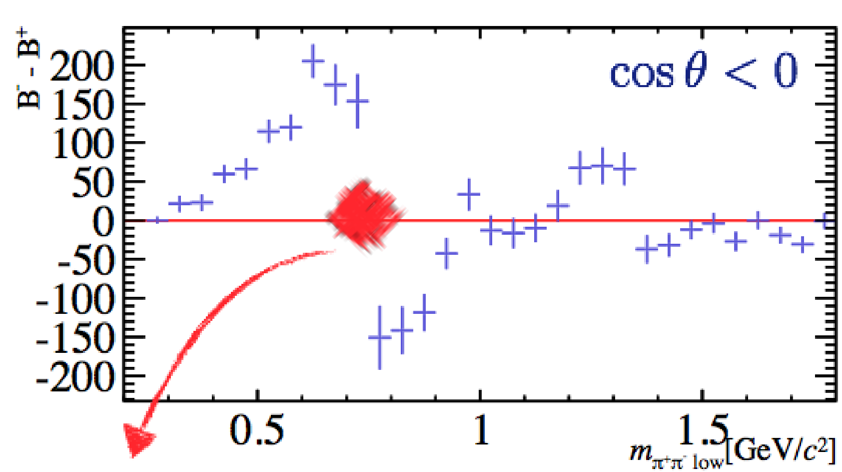
Phys.Rev. D90 (2014) no.11, 112004

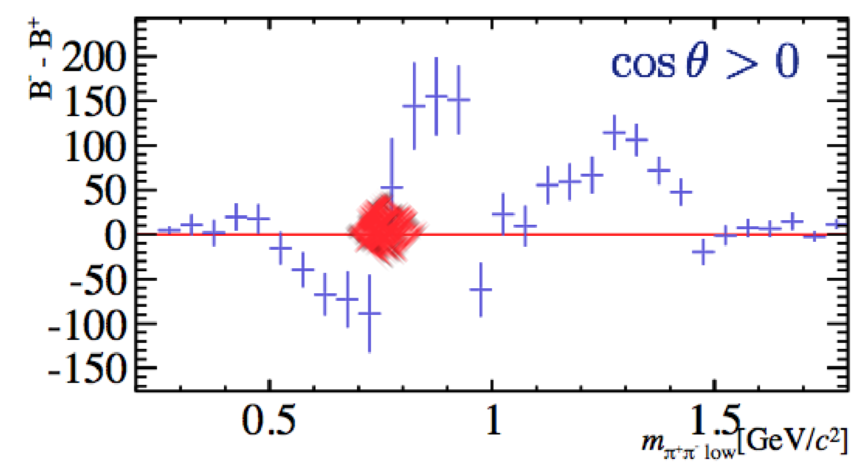
$$B^{\mp} \rightarrow \pi^{\mp}\pi^{+}\pi^{-}$$









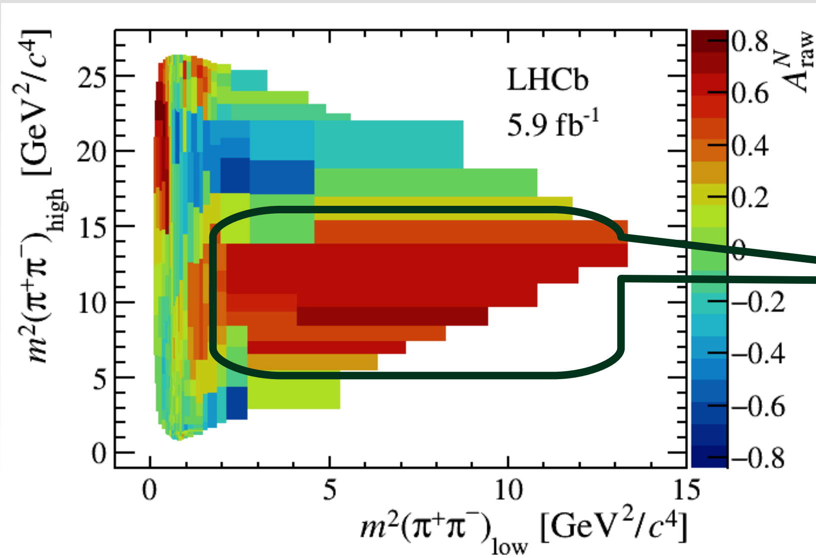


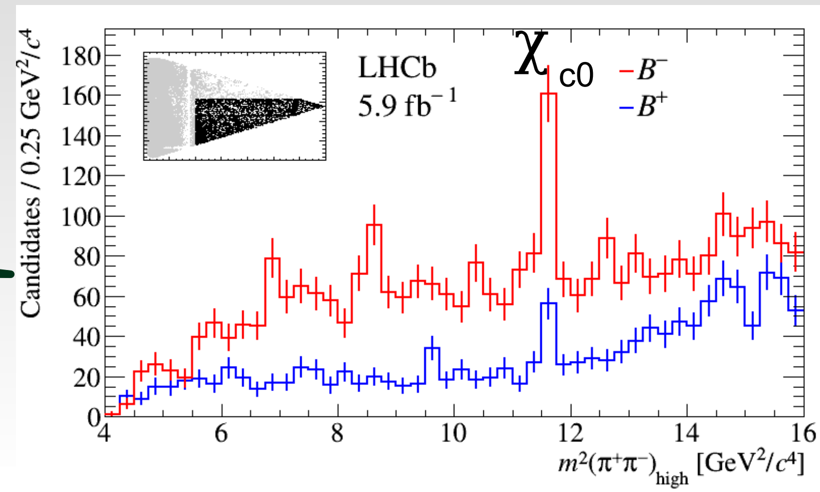
$m_{\pi\pi} \approx 770 MeV/c^2$

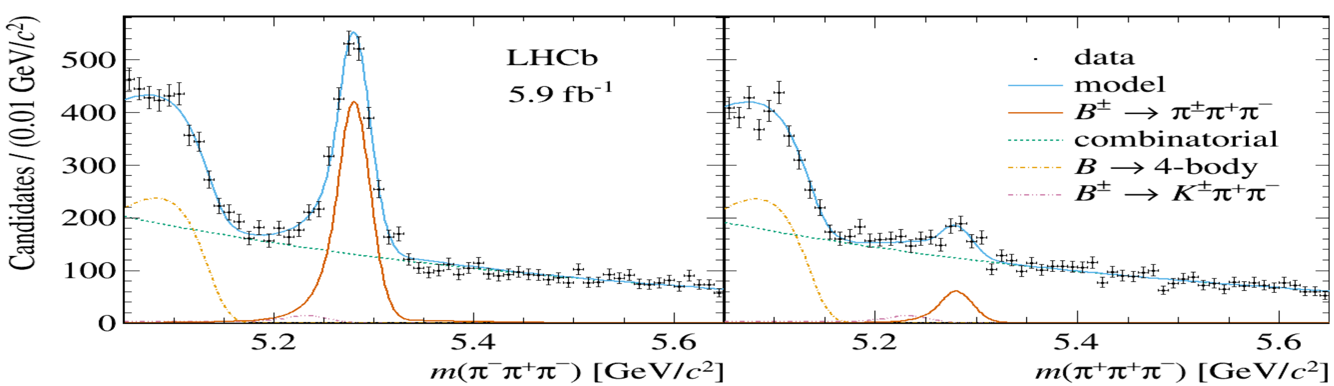
27

CP violation involving $B^{\mp}$ *decays with charmonium*

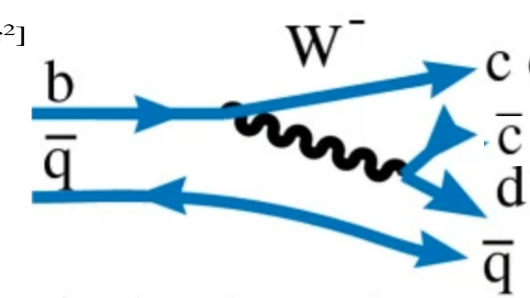
$$B^{\mp} \rightarrow \pi^{\mp} \chi_{c0}$$
$$\hookrightarrow \pi^{+} \pi^{-}$$



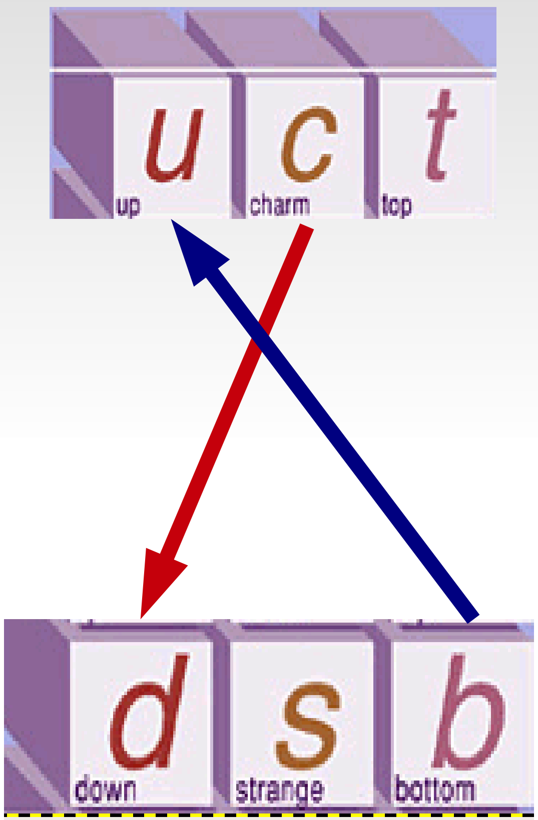




$$\boxed{A_{CP} = 75.5 \pm 3.0\ \%}$$



Direct CP violation in the CKM matrix.



High weak phase in
beauty decays

Wolfenstein representation

$$V_{\mathrm{CKM}} = \begin{pmatrix} 1-\frac{1}{2}\lambda^2-\frac{1}{8}\lambda^4 & \lambda & A\lambda^3(\rho-i\eta) \\ -\lambda+\frac{1}{2}A^2\lambda^5[1-2(\rho+i\eta)] & 1-\frac{1}{2}\lambda^2-\frac{1}{8}\lambda^4(1+4A^2) & A\lambda^2 \\ A\lambda^3[1-(1-\frac{1}{2}\lambda^2)(\rho+i\eta)] & -A\lambda^2+\frac{1}{2}A\lambda^4[1-2(\rho+i\eta)] & 1-\frac{1}{2}A^2\lambda^4 \end{pmatrix}$$

Suppressed weak phase
in charm decays

No weak phase in b → c
Transition

New strong interaction dynamic?

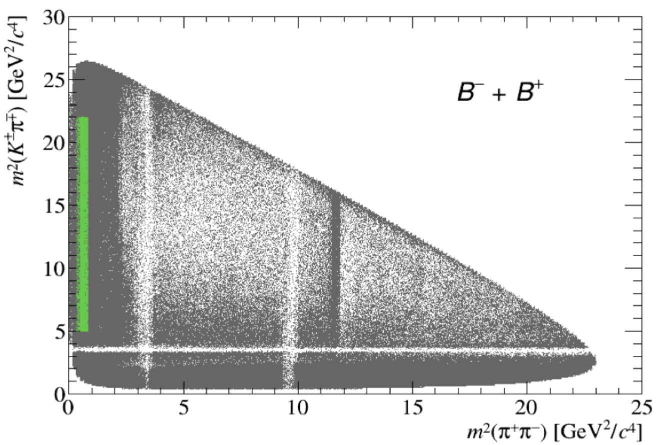
Search for CP violation in $B^{\pm}$ *decays in a Charmless pseudoscalar and a vector final state.*

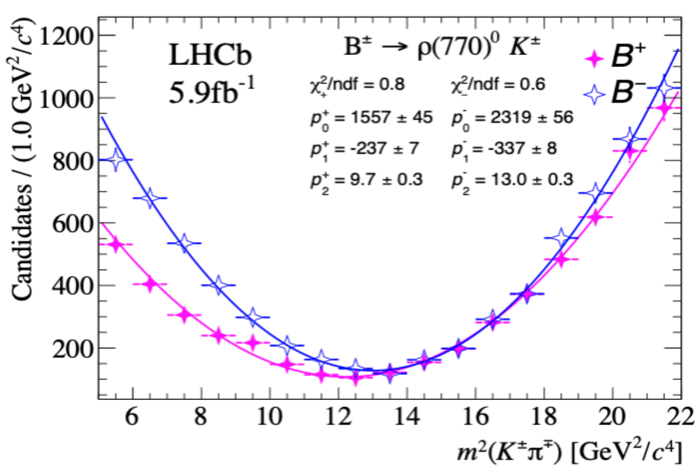
LHCb Collaboration hep-ex - 2206.02038

- Few measurements in the literature and huge theoretical interested
- Model-independent method that explores the angular distribution of these decays.
- This method avoid the long term model dependent amplitude analysis

$$|\mathcal{M}_{\pm}|^2 = p_0^{\pm} + p_1^{\pm}\cos\theta(s_{\perp}, m_v^2) + p_2^{\pm}\cos^2\theta(s_{\perp}, m_v^2) \qquad A_{\mathrm{CP}}^{V} = \frac{p_2^{-} - p_2^{+}}{p_2^{-} - p_2^{+}}$$

where $s_{\perp} \equiv m^2(h_1^- h_3^+)$ and $\theta \equiv$ helicity angle





$$A_{CP} = 0.150 \pm 0.019$$

$A_{CP} = 0.44 \pm 0.10 \pm 0.04^{+0.05}_{-0.13}$
BaBar
Phys. Rev. D78 (2008) 012004

$A_{CP} = 0.30 \pm 0.11 \pm 0.02^{+0.11}_{-0.04}$
Belle
Phys. Rev. Lett. 96 (2006) 251803

Results

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Five independent measurements

$B^{\mp} \rightarrow K^{*0}(890)\ K^{\mp}$, $B^{\mp} \rightarrow \phi(1020)K^{\mp}$

$B^{\mp} \rightarrow K^{*0}(890)\pi^{\mp}$, $B^{\mp} \rightarrow \rho^{0}(770)K^{\mp}$, $B^{\mp} \rightarrow \rho^{0}(770)\pi^{\mp}$

Decay channel	Vector Resonance	$\mathcal{A}_{CP}^{V} \pm\sigma_{\text{stat}} \pm \sigma_{\text{syst}}$
$B^{\pm} \to \pi^{\pm}\pi^{+}\pi^{-}$	$\rho(770)^{0} \to \pi^{+}\pi^{-}$	-0.004 $\pm$ 0.017 $\pm$ 0.009
$B^{\pm} \to K^{\pm}\pi^{+}\pi^{-}$	$\rho(770)^{0} \to \pi^{+}\pi^{-}$	+0.150 $\pm$ 0.019 $\pm$ 0.011
	$K^{*}(892)^{0} \to K^{\pm}\pi^{\mp}$	-0.015 $\pm$ 0.021 $\pm$ 0.012
$B^{\pm} \to \pi^{\pm}K^{+}K^{-}$	$K^{*}(892)^{0} \to K^{\pm}\pi^{\mp}$	+0.007 $\pm$ 0.054 $\pm$ 0.032
$B^{\pm} \to K^{\pm}K^{+}K^{-}$	$\phi(1020) \to K^{+}K^{-}$	+0.004 $\pm$ 0.010 $\pm$ 0.007

From the five decays only
A_{CP} ($B^{\mp} \rightarrow \rho^{0}(770)K^{\mp}$)
different from zero

Remarks

- **LHCb detector**

  Run I and Run II high statistical in order to observe BR of 10^{-9}

  Run III would allow to go ahead with BR of 10^{-10} may be 10^{-11}

  LHCb is able to work in different subjects of “The intensity frontier”

- **CP violation**

  Observed for the first time direct CP violation in $B^{\mp} \to \pi^{\mp} \pi^{-} \pi^{+}$, $B^{\mp} \to K^{\mp} K^{-} K^{+}$

  Relationship between total CP asymmetry in charmless three body *B decays*

  Strong CP violation involving a charmonioum

  Observed for the first time direct CP violation in $B^{\mp} \to \rho^{0}(770)K^{\mp}$

  No CPV for the another four decays involving Pseudoscalar and Vector mesons

Thanks!