Review of direct CP violation in charmless two and three-body B-decays at LHCb

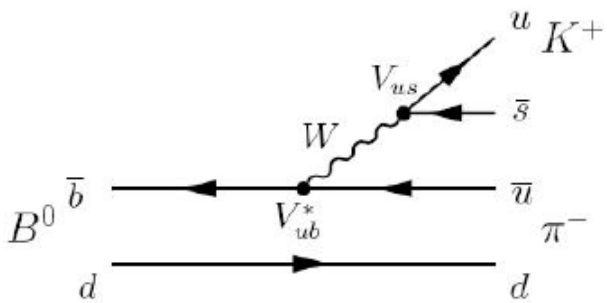
Marc Grabalosa
On behalf of the LHCb Collaboration

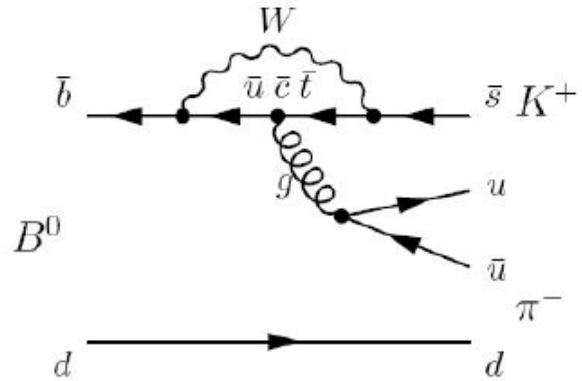
LPC - ClermontFerrand

- Motivation/LHCb
- 2-body charmless decays
- 3-body charmless decays
- VV decays

Charmless B decays

- Motivation
  - Contribution from Tree and Penguin diagrams





  - Tree processes (b→u) can be used to test SM looking for deviation in the CKM structure
  - Loop processes (b→s, b→d) are FCNC and new particles may appear in the loops

- CP violation may arise from the interference of both T and P contributions (2 amplitudes with different weak and strong phases)

- Improvement of the CKM matrix elements (angles) from CP violation observables and BR

- LHCb

$2 < \eta < 5$ coverage

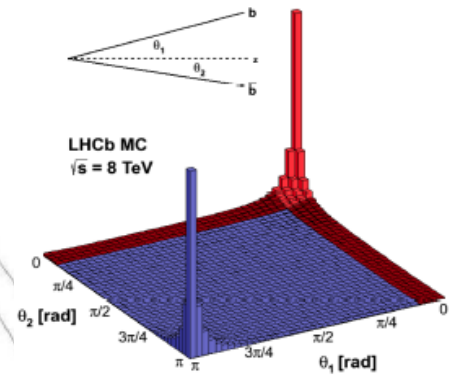
Single arm spectrometer

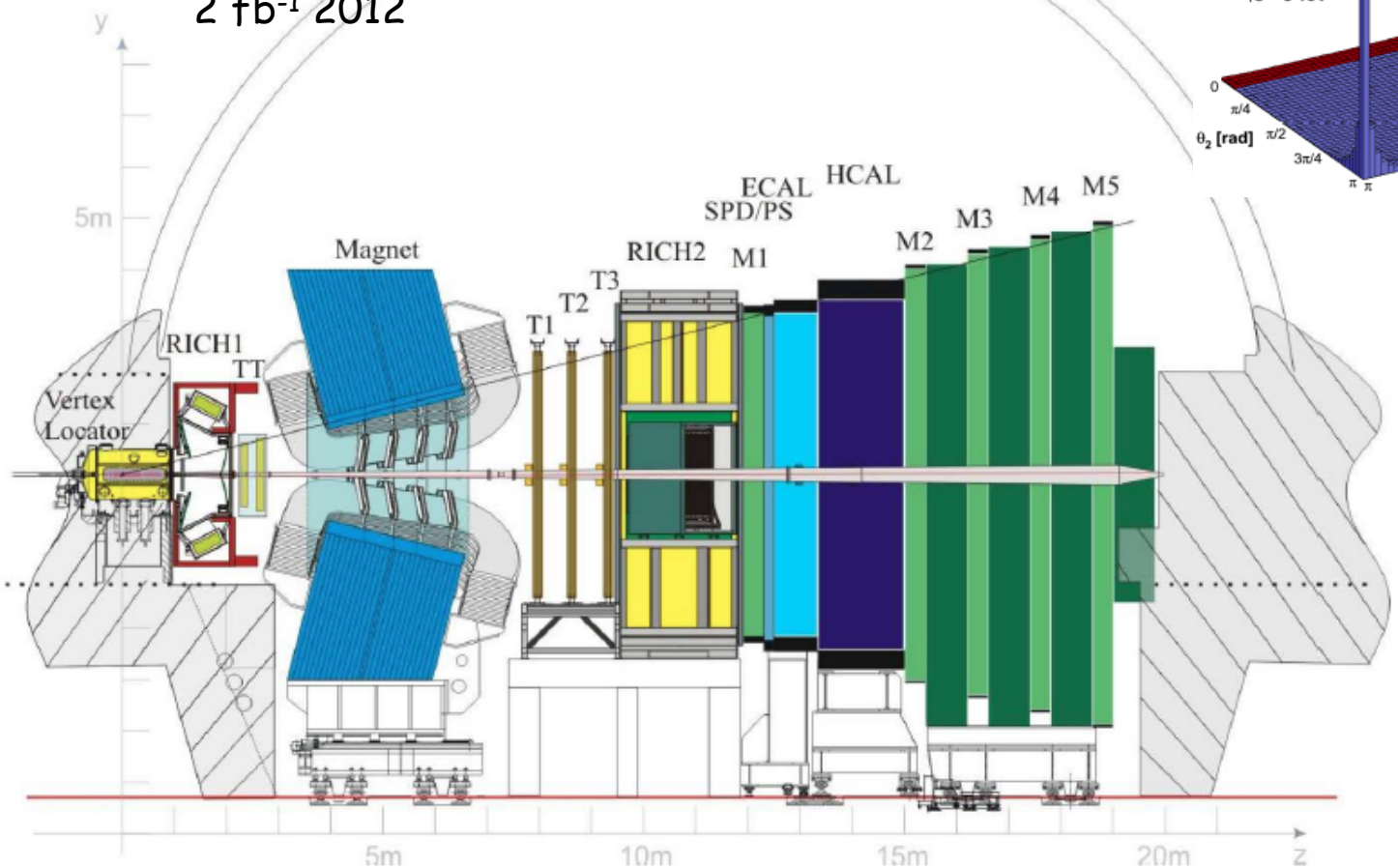
~3fb^{-1} data in run I

37 pb^{-1} 2010

1 fb^{-1} 2011

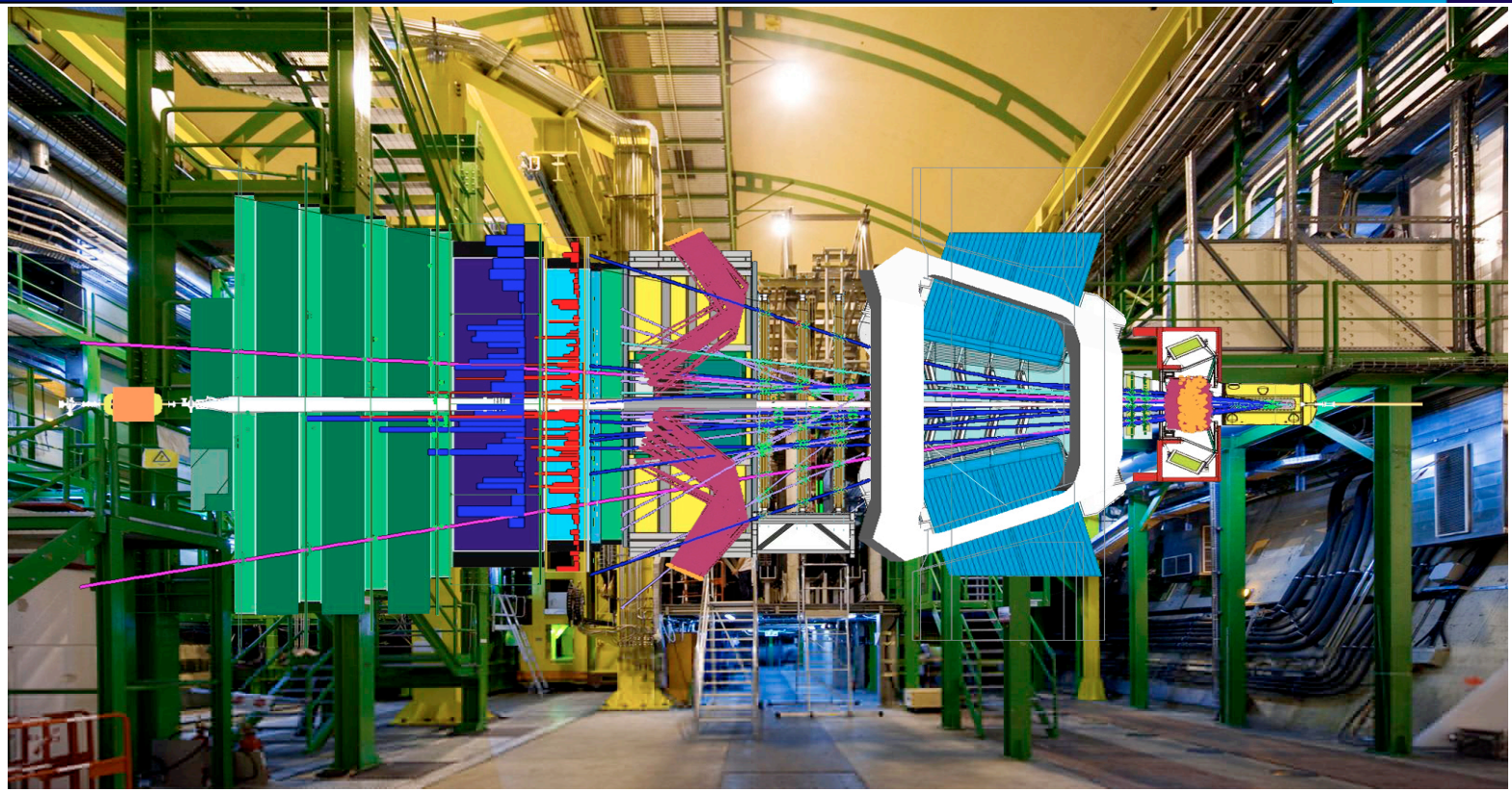
2 fb^{-1} 2012





LHCb

- LHCb



High trigger efficiency

Use of calorimeter and muon stations information at hardware level
Software High Level Trigger (HLT) give flexibility and high efficiency

Excellent tracking system

Decay time, impact parameter and mass resolution
Excellent PV-SV separation

Excellent Particle Identification

Charmless 2 body decays ($B_{d,s} \to K\pi$)

- Direct CP violation ($B^0 \to K\pi$)

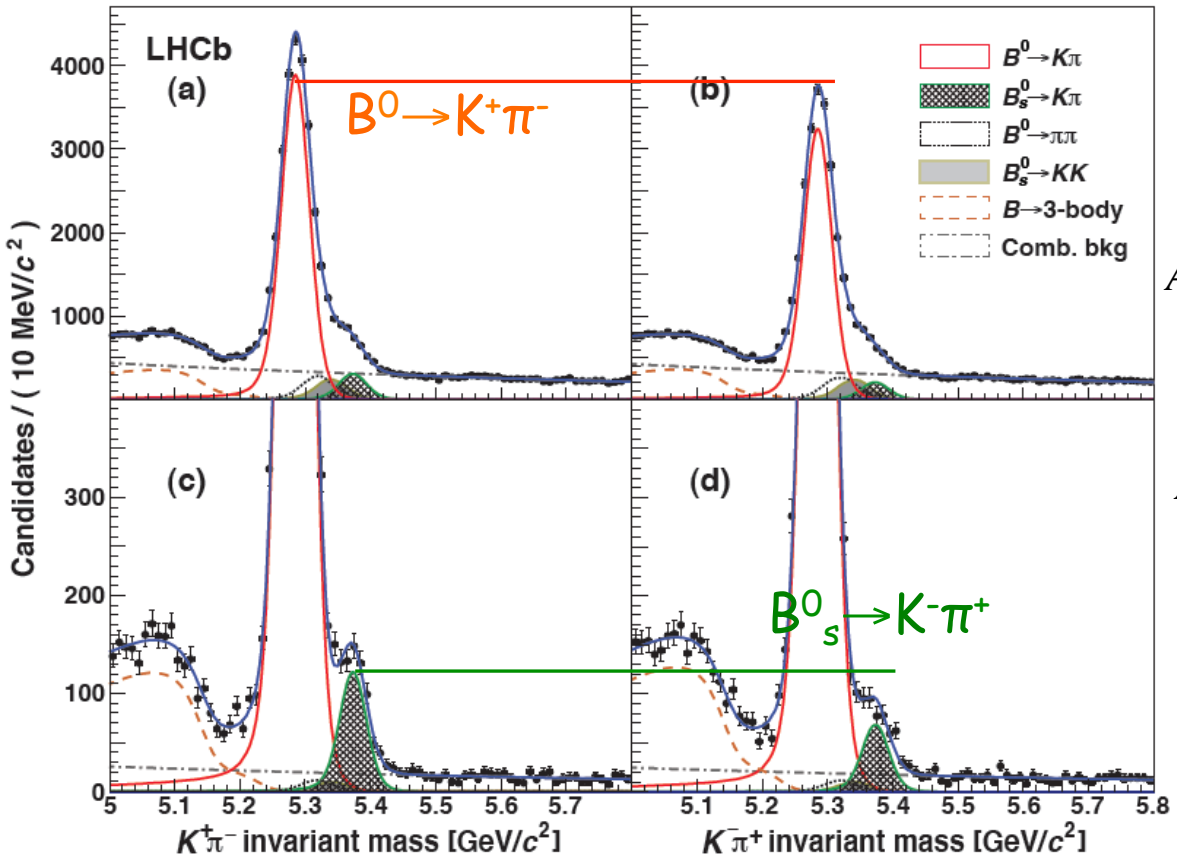
$$A_{CP}(B_s^0 \to \pi K) = \frac{\Gamma(\bar{B}_s^0 \to \pi^- K^+) - \Gamma(B_s^0 \to \pi^+ K^-)}{\Gamma(\bar{B}_s^0 \to \pi^- K^+) + \Gamma(B_s^0 \to \pi^+ K^-)}.$$

$$A_{CP}(B^0 \to K\pi) = \frac{\Gamma(\bar{B}^0 \to K^- \pi^+) - \Gamma(B^0 \to K^+ \pi^-)}{\Gamma(\bar{B}^0 \to K^- \pi^+) + \Gamma(B^0 \to K^+ \pi^-)}$$

Phys. Rev. Lett.110 (2013) 221601
LHCb-PAPER-2013-018
arXiv: 1304.6173

1.0 fb^{-1}

A_{CP} corrected for detection and production asymmetries (~1%) $\mathcal{A}_{CP} = \mathcal{A}_{Raw} - (\mathcal{A}_{Det.} + \kappa \mathcal{A}_{Prod.})$



$$A_{CP}\left(B^0 \to K^+\pi^-\right) = -0.080 \pm 0.007 \pm 0.003$$

(Most precise measurement 10.5 σ)

$$A_{CP}\left(B_S^0 \to K^-\pi^+\right) = 0.027 \pm 0.04 \pm 0.01$$

(First observation CP violation in B_s decays, 6.5 σ)

Charmless 3-body decays ($B^{\pm} \to h^{+} h^{-} h^{\pm}$)

- Direct CP violation

- Evidence of CP violation on $B^{\pm} \to h^{+} h^{-} h^{\pm}$ (1.0 fb^{-1}) [PRL 111 (2013) 101810] [PRL 112 (2014) 011801]

  - Large CP violation in certain regions of the phase space
  - Rich interference patterns
  - Source of strong phase differences not well understood

Submitted to PRD
LHCb-PAPER-2014-044
arXiv: 1408.5373

3.0 fb^{-1}

- New selection w.r.t old analysis
(multivariate selection and new PID variables)

- Measurement of inclusive and phase space CP asymmetries

$$A_{CP} \equiv \frac{\Gamma[B^- \to f^-] - \Gamma[B^+ \to f^+]}{\Gamma[B^- \to f^-] + \Gamma[B^+ \to f^+]}$$

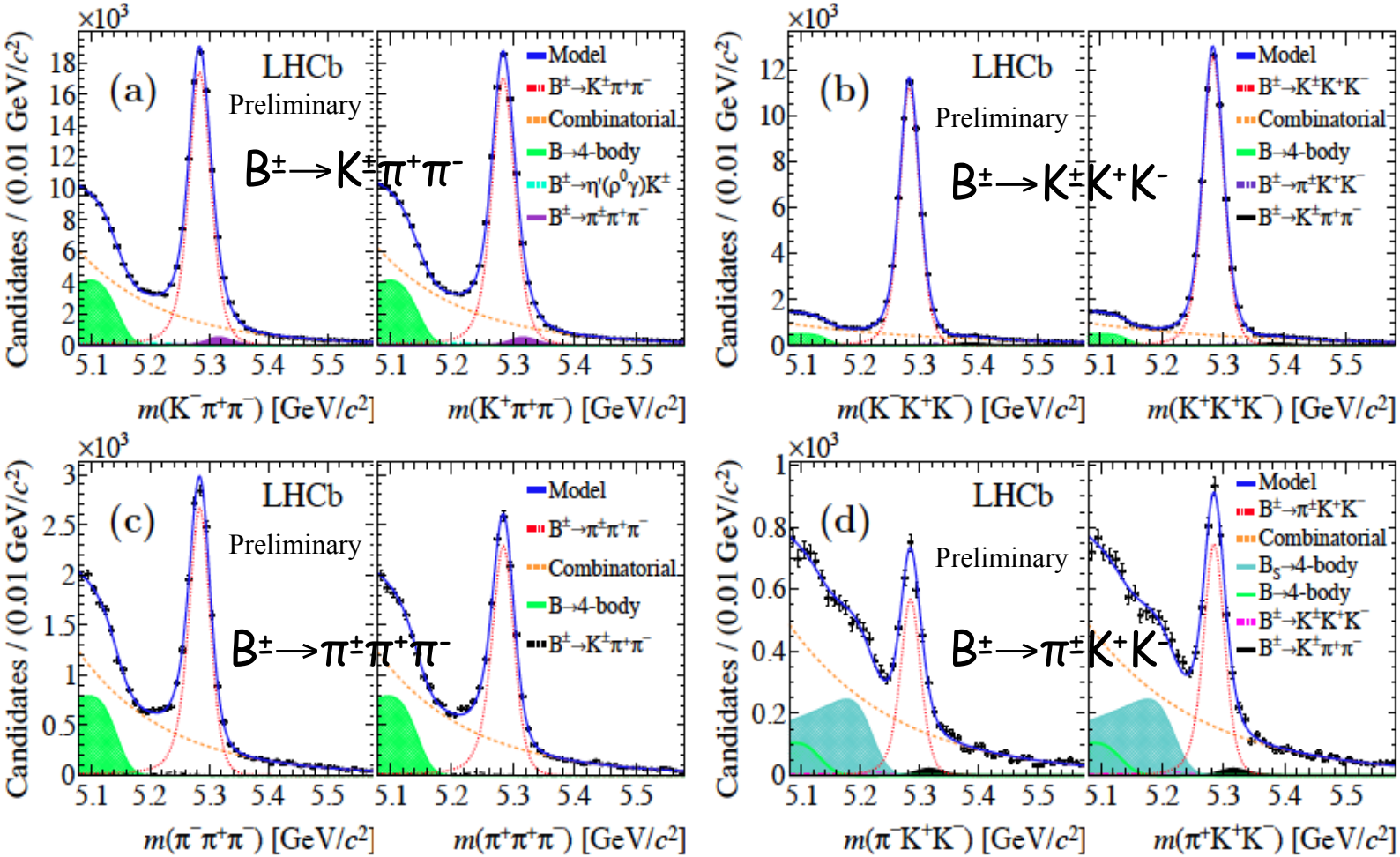
CP violation in $B^{\pm} \to h^{+} h^{-} h^{\pm}$

- Raw asymmetry $\mathcal{A}_{raw} = [N_{B^-} - \overline{N}_{B^+}] / [N_{B^-} + \overline{N}_{B^+}]$

arXiv: 1408.5373

$(N + \overline{N}) = 181069 \pm 404\ (stat.)$

$(N + \overline{N}) = 109240 \pm 354\ (stat.)$



Penguin dominated

Tree dominated

$(N + \overline{N}) = 24907 \pm 222\ (stat.)$

$(N + \overline{N}) = 6161 \pm 172\ (stat.)$

CP violation in $B^\pm \to h^+ h^- h^\pm$

- Raw asymmetry has to be corrected for detection asymmetries and B meson production

arXiv: 1408.5373

for small asymmetries $A_{\rm raw} \approx A_{CP} + A_{\rm P} + A_{\rm D}^{h'}$

$$A_{CP}(Khh) = A_{\rm raw}(hhK) - A_{\rm P} - A_{\rm D}^{K} = A_{\rm raw}(hhK) - A_{\Delta}\,,$$
$$A_{CP}(\pi hh) = A_{\rm raw}(hh\pi) - A_{\rm P} - A_{\rm D}^{\pi} = A_{\rm raw}(hh\pi) - A_{\Delta} + A_{\rm D}^{K} - A_{\rm D}^{\pi}$$

- A_Δ using $B^\pm \to J/\psi K^\pm$ control sample. $A_\Delta = A_{\rm raw}(J/\psi K^\pm) - A_{CP}(J/\psi K^\pm)$

- $A_D(\pi^\pm) = (0.00 \pm 0.25)\%$ from studies of prompt $D^\pm$ decays [PLB 713 (2012) 186].

- $A_D(K^\pm) = (-1.26 \pm 0.18)\%$ using $D^{*+} \to D^0(K^-\pi^+\pi^-\pi^+)\pi^+$, with prompt $D^\pm$ decays [PLB 713 (2012) 186]

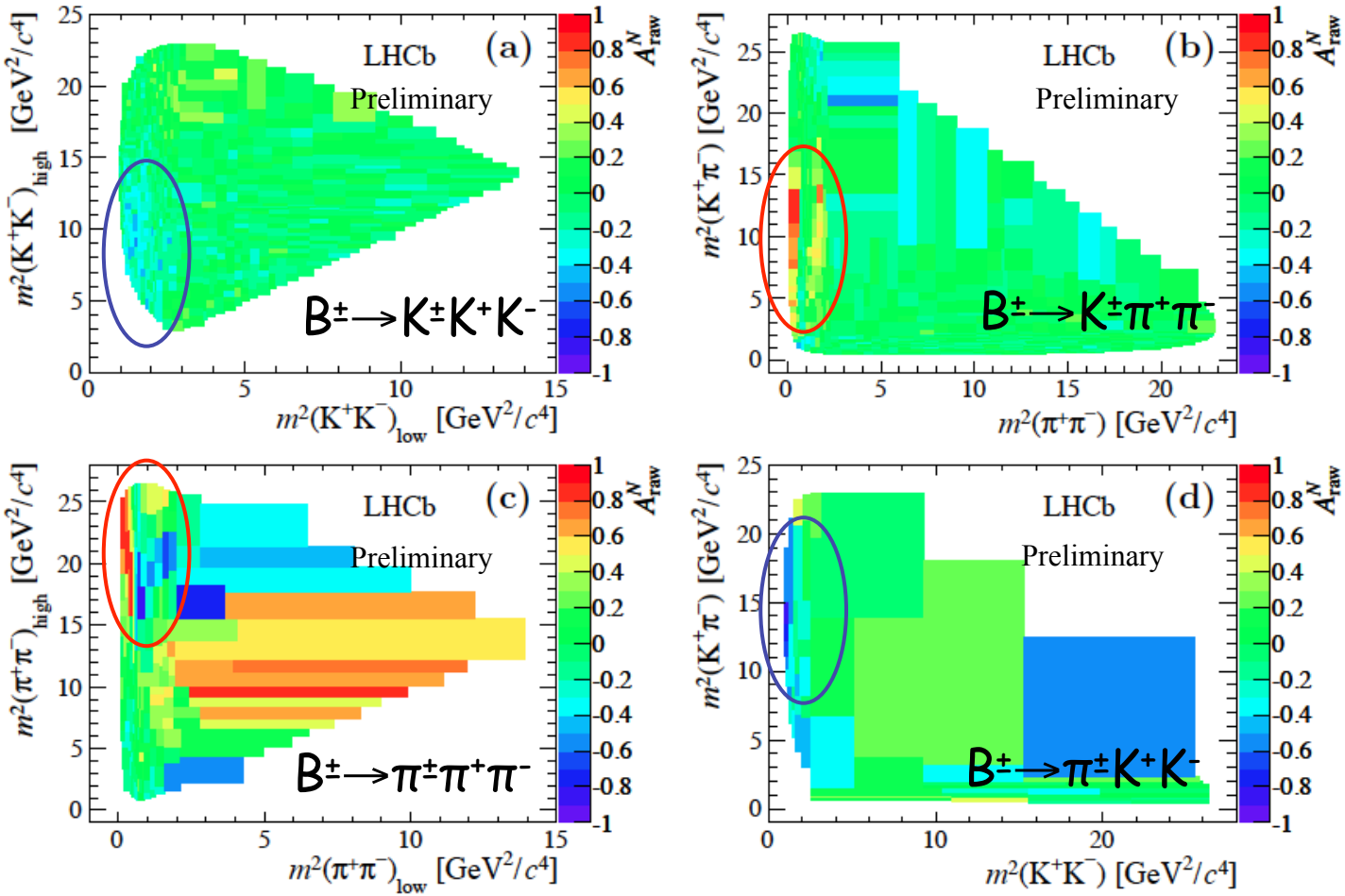
Acceptance correction to take into account non uniformity of efficiencies

$A_{CP}(B^\pm \to K^\pm\pi^+\pi^-)$	$=$	$+0.025 \pm 0.004 \pm 0.004 \pm 0.007$	2.8 σ
$A_{CP}(B^\pm \to K^\pm K^+K^-)$	$=$	$-0.036 \pm 0.004 \pm 0.002 \pm 0.007$	4.3 σ
$A_{CP}(B^\pm \to \pi^\pm\pi^+\pi^-)$	$=$	$+0.058 \pm 0.008 \pm 0.009 \pm 0.007$	4.2 σ
$A_{CP}(B^\pm \to \pi^\pm K^+K^-)$	$=$	$-0.123 \pm 0.017 \pm 0.012 \pm 0.007$	5.6 σ

CP violation in $B^{\pm} \to h^{+} h^{-} h^{\pm}$

- CP asymmetries in local region of Dalitz plots

- Adaptative binning to keep the same events per bin
- Background subtracted with sPlots and acceptance corrected
- Observed large local raw asymmetries in certain regions of the phase space



positive asymmetries
negatve asymmetries

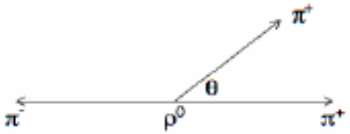
arXiv: 1408.5373

CP violation in $B^{\pm} \to h^{+} h^{-} h^{\pm}$

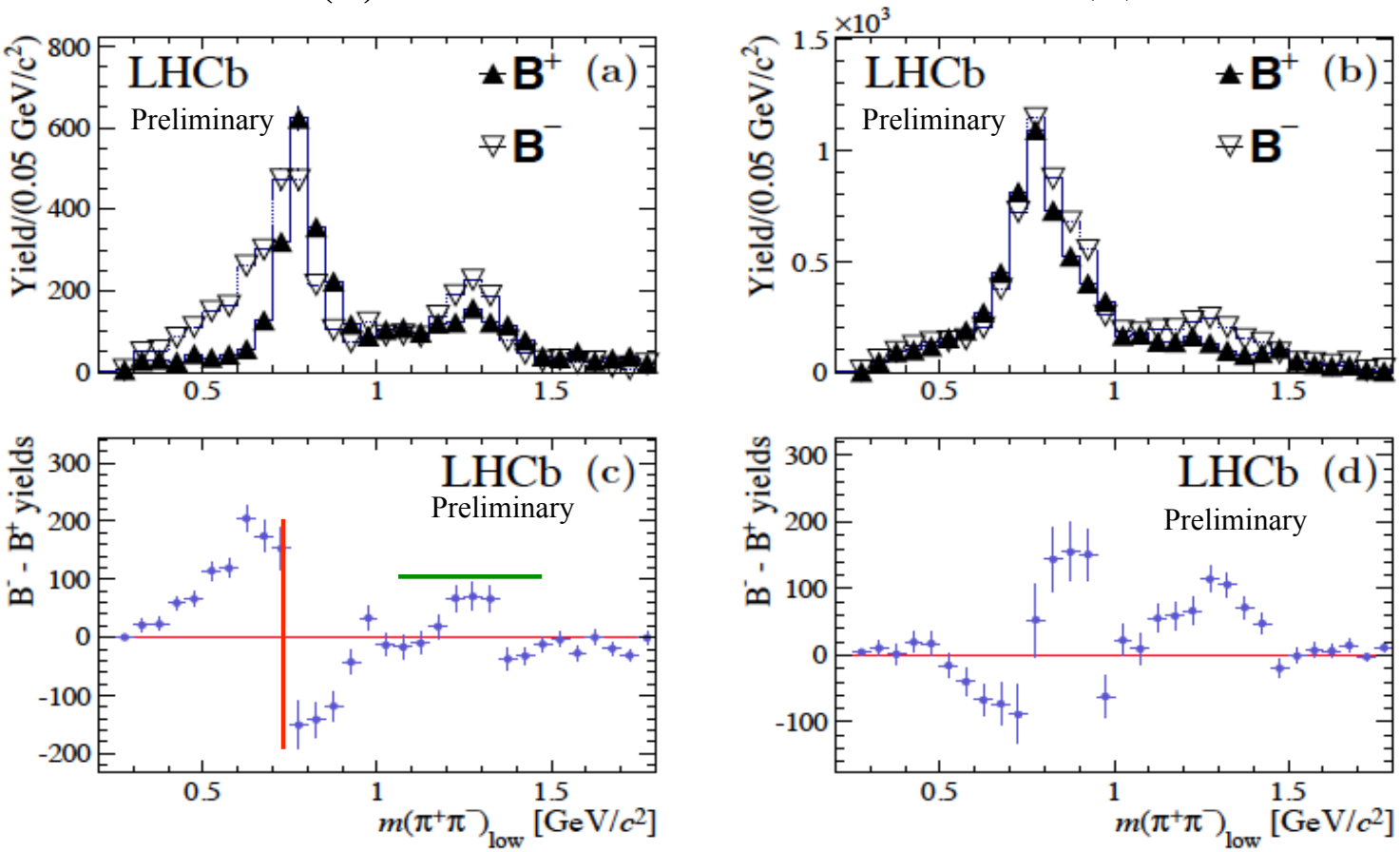
- CP violation measurements in local region of Dalitz plots

- Projections on the m_{hh} divided according to the sign of the cosine of the angle between the momenta of the unpaired hadron and the resonant daughter with the same-sign charge

$B^{\pm} \to \pi^{\pm}\pi^{+}\pi^{-}$ (more in backup)



$\cos(\theta) < 0$ $\cos(\theta) > 0$



$\rho^{0}(770)$ pole

Rescattering region ($1 < m_{hh} < 1.5$ GeV/c^2)

arXiv: 1408.5373

CP violation in $B^{\pm} \to h^{+} h^{-} h^{\pm}$

- CP violation measurements in local region of Dalitz plots

- The charge asymmetry changes sign near the resonances: dominance of the long-distance interference (size of the asymmetry up to ~60% in the regions around the resonances)

- For all the $B^{\pm} \to h^{\pm} h^{+} h^{-}$, charge asymmetry in the scattering region :

arXiv: 1408.5373

$1 < (m_{\pi\pi}$ or $m_{KK}) < 1.5$ GeV/c^2

Decay	N_S	A_{CP}
$B^{\pm} \to K^{\pm}\pi^{+}\pi^{-}$	$15\,562 \pm 165$	$+0.121 \pm 0.012 \pm 0.017 \pm 0.007$
$B^{\pm} \to K^{\pm}K^{+}K^{-}$	$16\,992 \pm 142$	$-0.211 \pm 0.011 \pm 0.004 \pm 0.007$
$B^{\pm} \to \pi^{\pm}\pi^{+}\pi^{-}$	4329 ± 76	$+0.172 \pm 0.021 \pm 0.015 \pm 0.007$
$B^{\pm} \to \pi^{\pm}K^{+}K^{-}$	2500 ± 57	$-0.328 \pm 0.028 \pm 0.029 \pm 0.007$

- **CPT** : the sum of the partial width of a family of final states related by strong rescattering should be the same for particles and antiparticles. → positive and negative asymmetries.

- BackUp: Projections from Dalitz plot to $m_{\pi\pi}$ or m_{KK} for the other three decays and invariant mass fits to events with m_{hh} in the rescattering region

CP violation in $B^+ \to p\bar{p}K^+$ decays

Accepted by PRL
LHCb-PAPER-2014-034
arXiv: 1407.5907

- Large CP asymmetries observed in $B^\pm \to h^\pm h^+ h^-$
  - Since rescattering in $pp \leftrightarrow h^+h^-$ is expected smaller than in $\pi^+\pi^- \leftrightarrow K^+K^-$, smaller CP asymmetries are expected
  - Threshold enhancement at low m_{pp} observed in many B decays to baryon-antibaryon pair plus meson(s)
    - need to study better the dynamics of these decays

- Analysis of CPV based on the 3 fb^{-1} sample (2011+2012)
  - Similar strategy then in $B^\pm \to h^\pm h^+ h^-$ decay
  - Measurement of the BR of the $B^+ \to \bar{\Lambda}(1520)(\to \bar{p}K^+)p$ decay
  - A_{FB} of light meson (π, K) in the pp rest frame
  - Study of CPV across the Dalitz plane
    - <u>First evidence of CPV in baryonic B decays in $B^+ \to p\bar{p}K^+$</u>

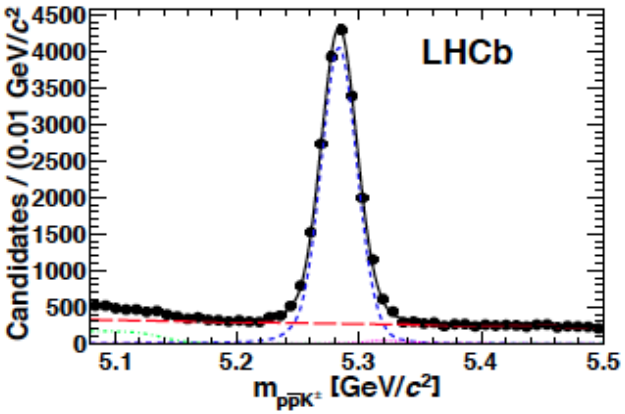
CP violation in $B^+ \to p\bar{p}K^+$ decays

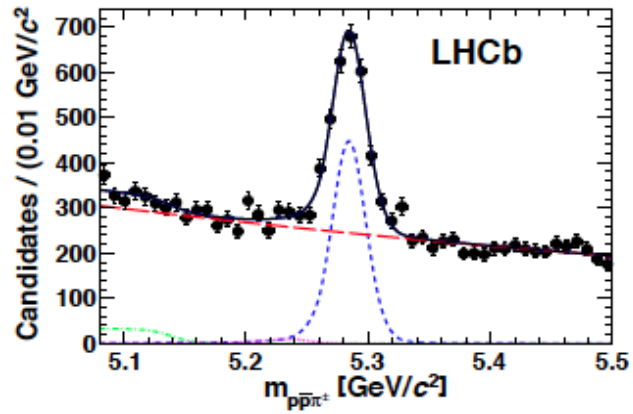
arXiv: 1407.5907

- Yields extracted with an unbinned maximum likelihood fit

$B^+ \to p\bar{p}K^+$

N =18721±142

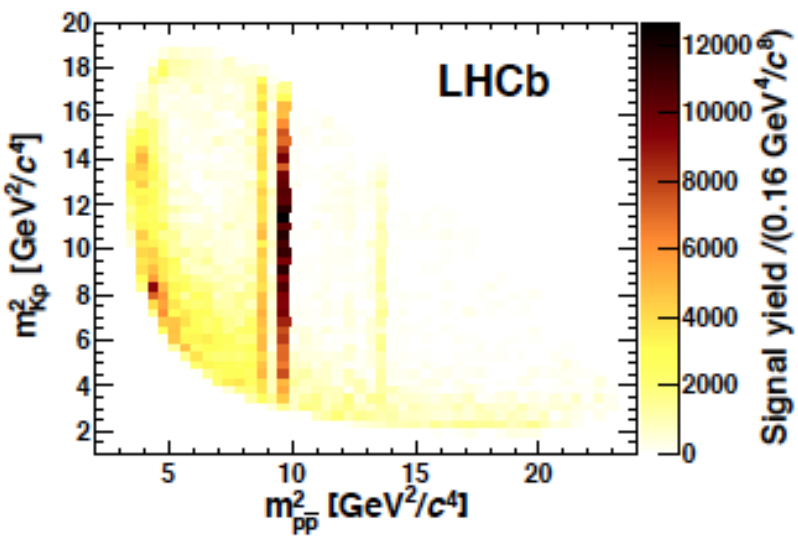


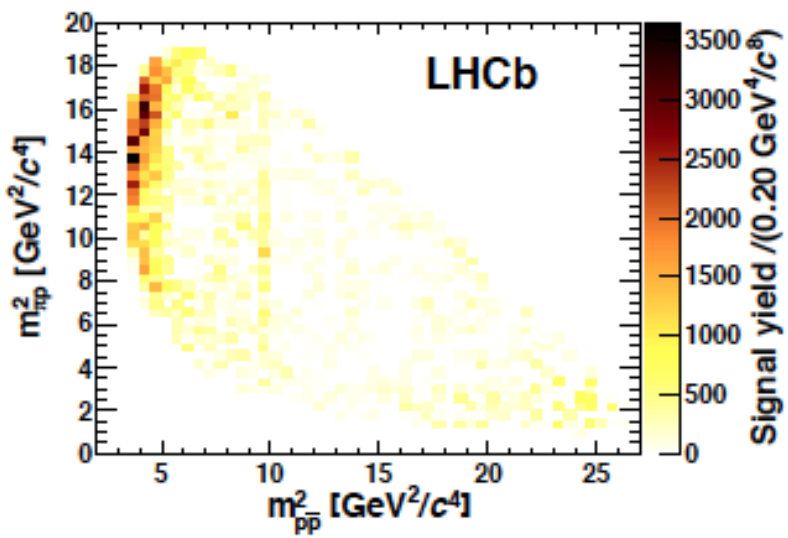


$B^+ \to p\bar{p}\pi^+$

N =1988±74

- Dalitz plots background subtracted (sWeights) and acceptance corrected





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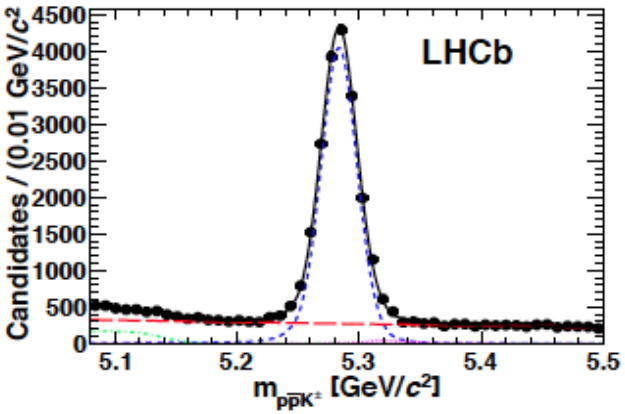

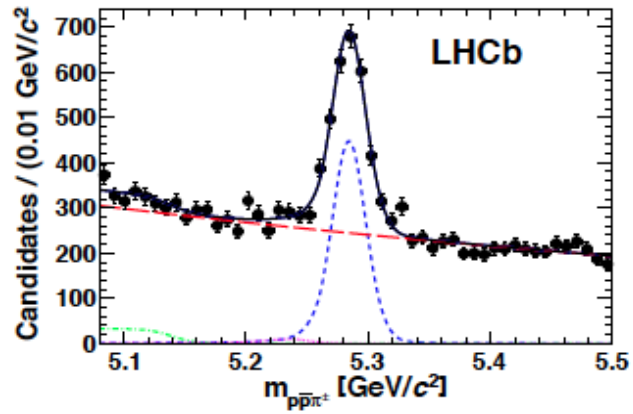

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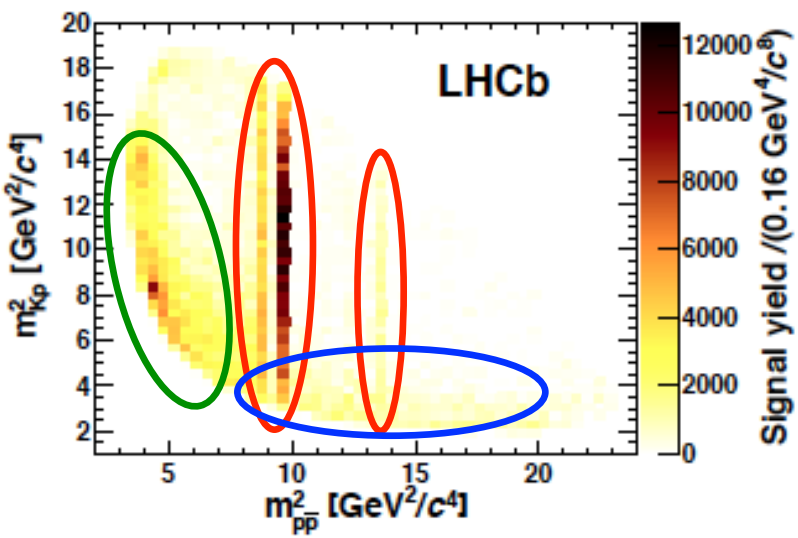
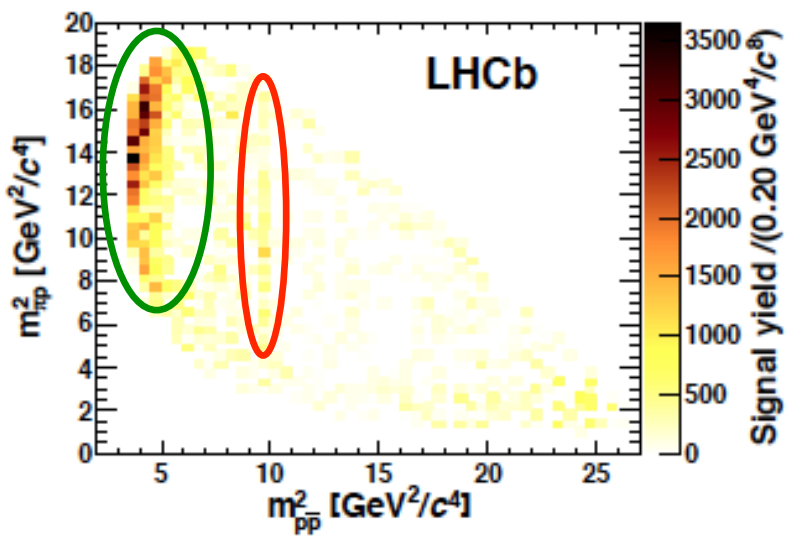




Charmonium resonances (J/ψ, $\psi(2S)$ and η_c)

Enhancement at low m_{pp}^2

$\Lambda(1520) \to pK^-$

CP violation in $B^+ \to p\bar{p}K^+$ decays

arXiv: 1407.5907

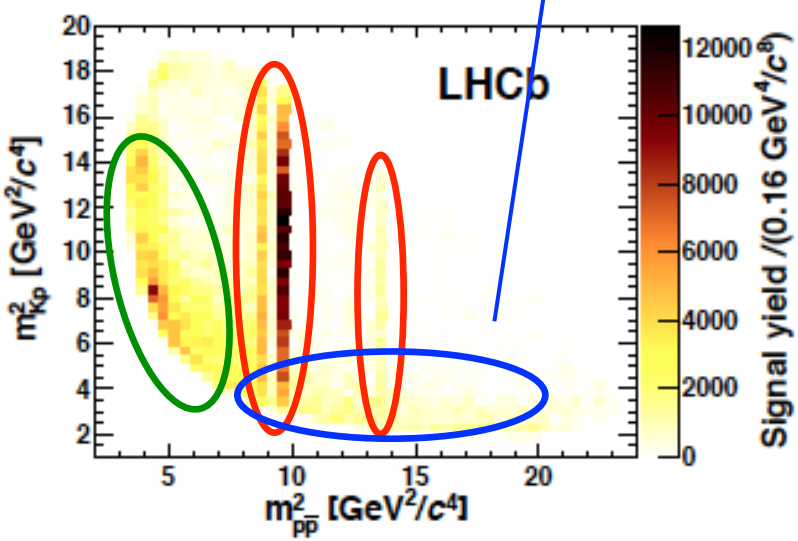
Branching ratio of $\Lambda(1520) \to pK$ using J/ψ, as control channel

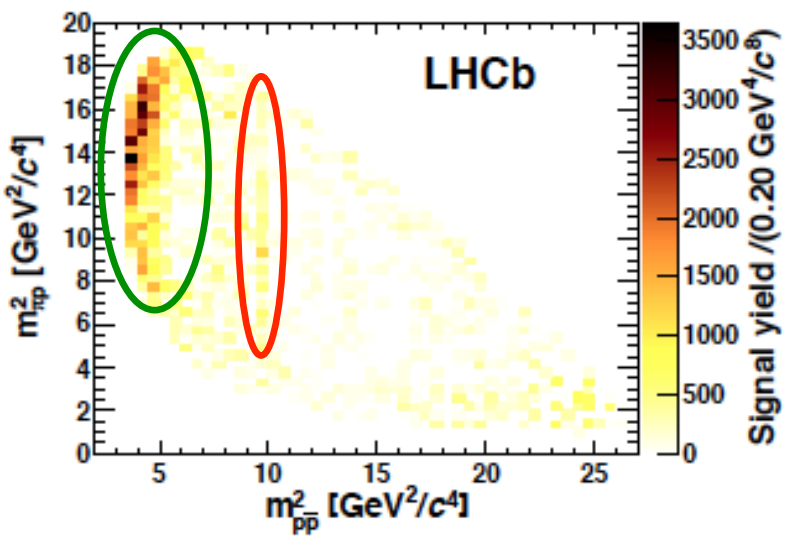
$$\frac{\mathcal{B}(B^+ \to \overline{\Lambda}(1520)(\to K^+\overline{p})p)}{\mathcal{B}(B^+ \to J/\psi(\to p\overline{p})K^+)} = 0.033 \pm 0.005\ (\text{stat}) \pm 0.007\ (\text{syst}),$$

$$\frac{\mathcal{B}(B^+ \to p\overline{p}\pi^+,\ m_{p\overline{p}} < 2.85\,\text{GeV}/c^2)}{\mathcal{B}(B^+ \to J/\psi(\to p\overline{p})\pi^+)} = 12.0 \pm 1.2\ (\text{stat}) \pm 0.3\ (\text{syst}).$$

$$\mathcal{B}(B^+ \to \overline{\Lambda}(1520)p) = (3.15 \pm 0.48\ (\text{stat}) \pm 0.07\ (\text{syst}) \pm 0.26\ (\text{BF})) \times 10^{-7},$$
$$\mathcal{B}(B^+ \to p\overline{p}\pi^+,\ m_{p\overline{p}} < 2.85\,\text{GeV}/c^2) = (1.07 \pm 0.11\ (\text{stat}) \pm 0.03\ (\text{syst}) \pm 0.11\ (\text{BF})) \times 10^{-6}$$

- Dalitz plots background subtracted (sWeights) and acceptance corrected





Charmonium resonances (J/ψ, $\psi(2S)$ and η_c)

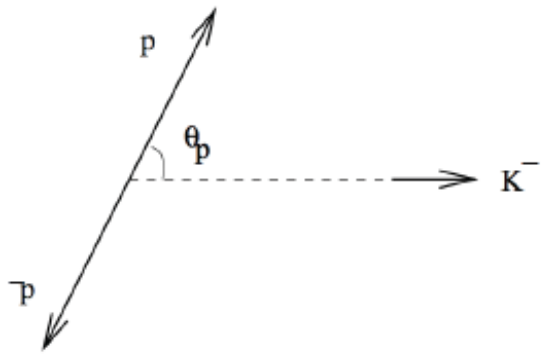
Enhancement at low m_{pp}^2

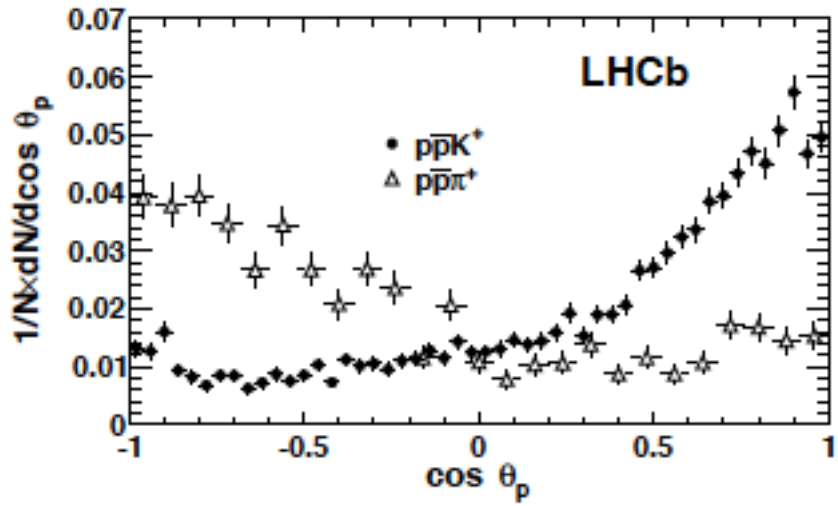
$\Lambda(1520) \to pK^-$

CP violation in $B^+ \to p\bar{p}K^+$ decays

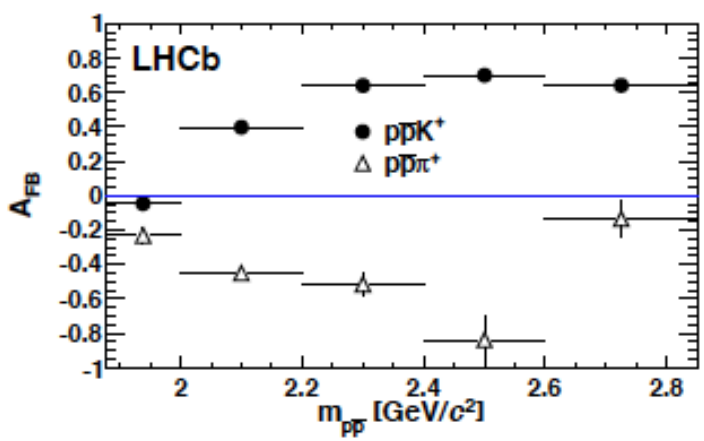
arXiv: 1407.5907

- Dynamics studied in the charmless region $m_{p\bar{p}} < 2.85$ GeV/c^2
- Acceptance-corrected distribution of the cosine of the helicity angle θ_p





- Opposite behaviour of two modes (can be generated by non-resonant scattering)
- Can be used to compute A_{FB} asymmetry



$$A_{FB} = \frac{N_{pos} - N_{neg}}{N_{pos} + N_{neg}}$$

$$A_{FB}\left(p\bar{p}K^{\pm}, m_{p\bar{p}} < 2.85 GeV/c^2\right) = 0.495 \pm 0.012(stat.) \pm 0.007(syst.)$$

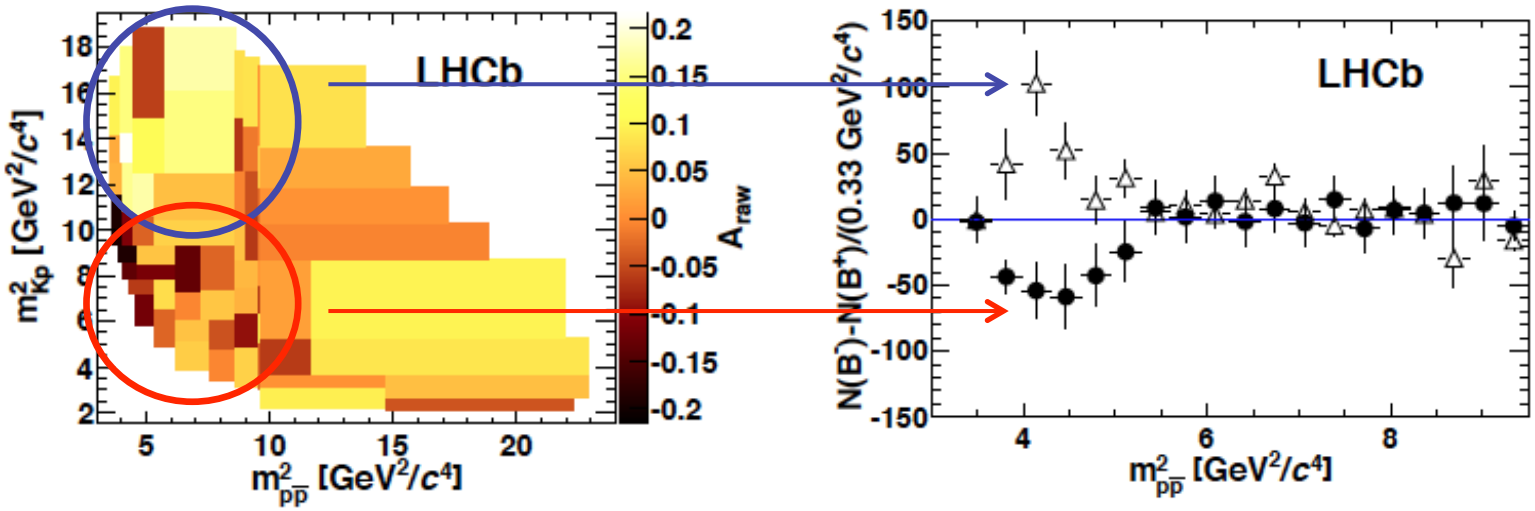
$$A_{FB}\left(p\bar{p}\pi^{\pm}, m_{p\bar{p}} < 2.85 GeV/c^2\right) = -0.409 \pm 0.033(stat.) \pm 0.006(syst.)$$

Significant improvement with respect to Belle [Phys. Lett. B 659 (2008) 80]

CP violation in $B^+ \to p\bar{p}K^+$ decays

- Raw asymmetry in the Dalitz plane for $B^+ \to p\bar{p}K^+$ (adaptive binning)

arXiv: 1407.5907



- Raw asymmetry corrected like in $B^\pm \to h^\pm h^+ h^-$ for production and detection asymmetries

Mode/region	A_{CP}
$\eta_c(p\bar{p})K^\pm$	0.040 ± 0.034 (stat) ± 0.004 (syst)
$\psi(2S)(p\bar{p})K^\pm$	0.092 ± 0.058 (stat) ± 0.004 (syst)
$p\bar{p}K^\pm,\ m_{p\bar{p}} < 2.85\,\mathrm{GeV}/c^2$	0.021 ± 0.020 (stat) ± 0.004 (syst)
$p\bar{p}K^\pm,\ m_{p\bar{p}} < 2.85\,\mathrm{GeV}/c^2,\ m^2_{Kp} < 10\,\mathrm{GeV}^2/c^4$	-0.036 ± 0.023 (stat) ± 0.004 (syst)
$p\bar{p}K^\pm,\ m_{p\bar{p}} < 2.85\,\mathrm{GeV}/c^2,\ m^2_{Kp} > 10\,\mathrm{GeV}^2/c^4$	0.096 ± 0.024 (stat) ± 0.004 (syst)
$p\bar{p}\pi^\pm,\ m_{p\bar{p}} < 2.85\,\mathrm{GeV}/c^2$	-0.041 ± 0.039 (stat) ± 0.005 (syst)

4 σ

First evidence of CPV in baryonic B decays

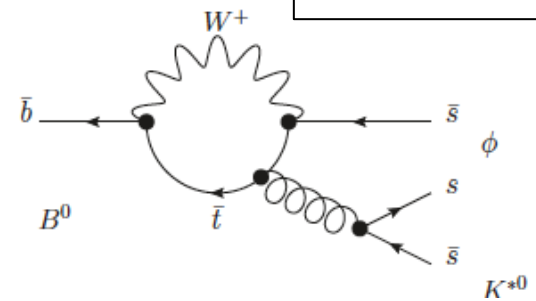
VV decays ($B^0 \to \phi K^*$)

- $B^0 \to \phi K^*$ ($K^+K^-K^+\pi^-$)

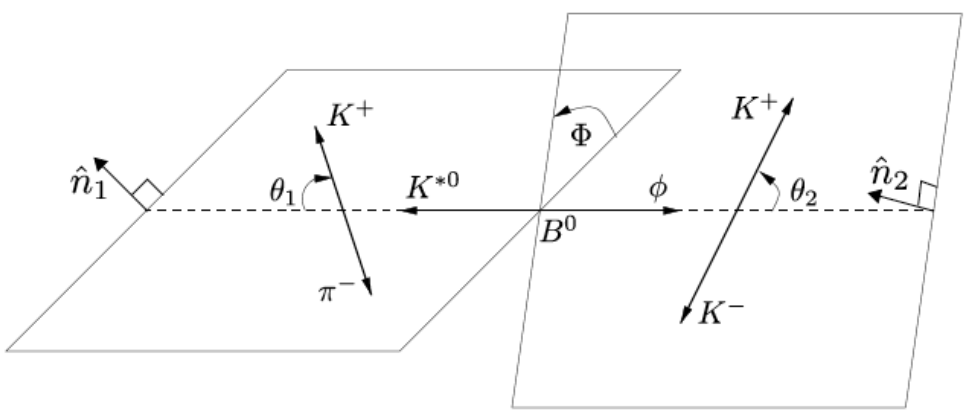
1.0 fb^{-1}

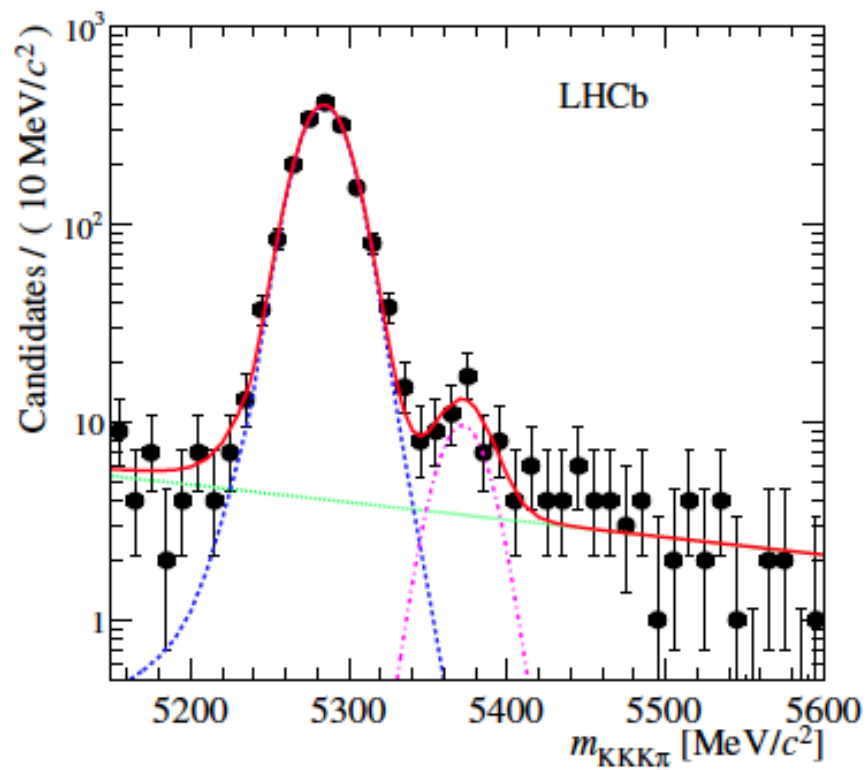
JHEP 05 (2014) 069
LHCb-PAPER-2014-005
arXiv: 1403.2888

- Penguin FCNC in the SM.
- Sensitive to NP contributions in the loop.
- 1655±42 signal candidates with 2011 data.
- 5-dim unbinned maximum likelihood fit
- Angular analysis



$$d^5\Gamma = \frac{9}{8\pi}\sum_{i=1}^{15} h_i\ f_i(\theta_1,\theta_2,\Phi)\mathcal{M}_i(m_{K\pi},m_{KK})d\Omega(KKK\pi)$$



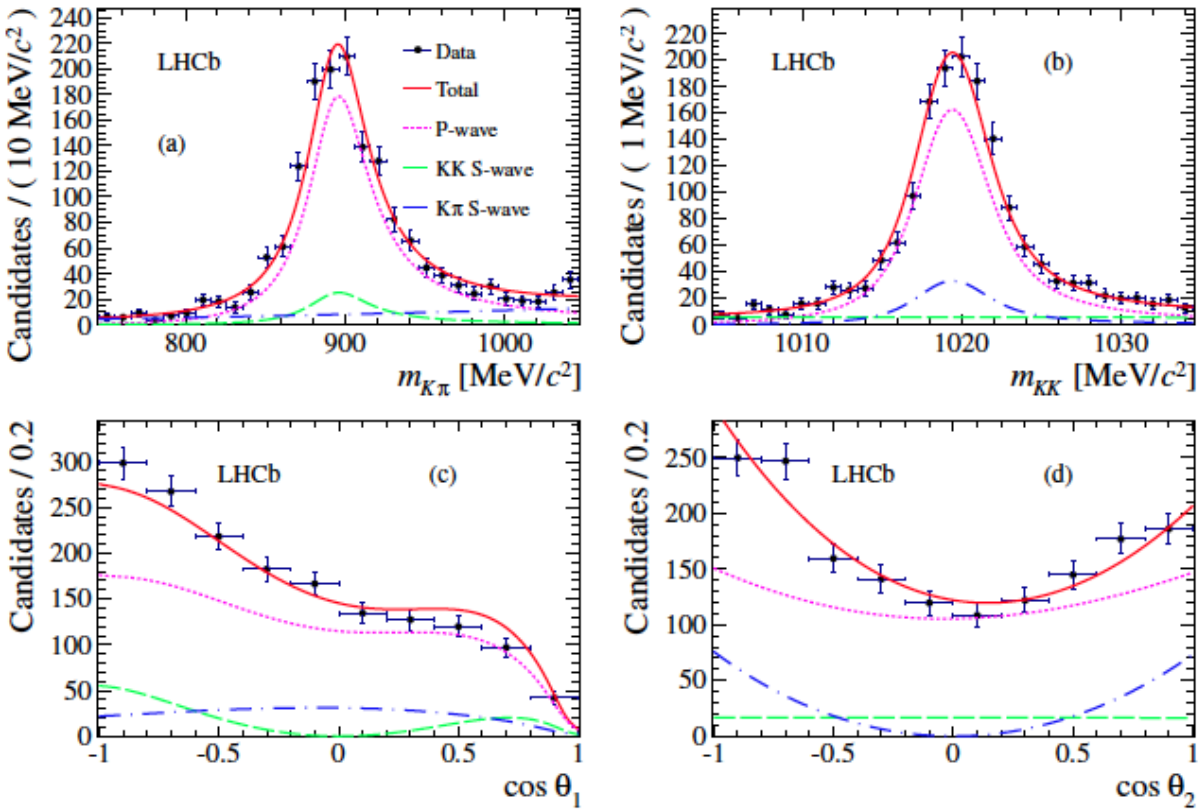


VV decays ($B^0 \to \phi K^*$)

- Polarization $B^0 \to \phi K^*$ ($K^+K^-K^+\pi^-$)

1.0 fb^{-1}

JHEP 05 (2014) 069



Parameter	LHCb
f_L	$0.497 \pm 0.019 \pm 0.015$
$f_\perp$	$0.221 \pm 0.016 \pm 0.013$
$\delta_\perp$	$2.633 \pm 0.062 \pm 0.037$
$\delta_\parallel$	$2.562 \pm 0.069 \pm 0.040$
$\mathcal{A}_0^{CP}$	$-0.003 \pm 0.038 \pm 0.005$
$\mathcal{A}_\perp^{CP}$	$+0.047 \pm 0.072 \pm 0.009$
$\delta_\perp^{CP}$	$+0.062 \pm 0.062 \pm 0.006$
$\delta_\parallel^{CP}$	$+0.045 \pm 0.068 \pm 0.015$

Intermediate long. Polarisation
(~ same amount of longitudinal and transverse polarization)

CP asymmetries compatible with zero

- Direct rate CP asymmetry
  - measured w.r.t $J/\psi\ K^*$

$$A = \frac{N(\overline{B}^0 \to \phi \overline{K}^{*0}) - N(B^0 \to \phi K^{*0})}{N(\overline{B}^0 \to \phi \overline{K}^{*0}) + N(B^0 \to \phi K^{*0})}$$

$$\Delta A_{CP} = (+1.5 \pm 3.2 \pm 0.5)\,\%$$

Consistent with zero
Most precise measurement

Conclusion

- Charmless B decays are very interesting channels to check the SM and look for NP
  - Potential for direct CP violation, sensitive to CKM angles,…

- 2-body
  - Most precise measurement of direct CP violation in $B^0 \to K^+\pi^-$ (10.5σ)
  - First observation of direct CP violation in B^0_s observed in $B^0_s \to \pi^+K^-$ (6.5σ).

- 3-body
  - Measured CP asymmetries in charged three-body decay of $B^\pm \to h^+h^-h^\pm$
    - CP asymmetries not uniform in phase space.
    - $KK \leftrightarrow \pi\pi$ rescattering is apparent.
    - Interference effects seem important, in particular around the $\rho^0(770)$ resonance.
  - Studied the CPV and decay dynamics of baryonic $B^+ \to p\bar{p}K^+$
    - First evidence of CPV in baryonic B decays
    - Opposite behaviour in the helicity distribution for the $p\bar{p}K^+$ and $p\bar{p}\pi^+$ final states

- VV decays
  - $B^0 \to \phi K^*$: Determination of CPV asymmetries and measurement of longitudinal polarization

Conclusion

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- 3-body
  - Measured CP
    - CP asymm
    - $KK \leftrightarrow \pi\pi$
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$h^-h^\pm$

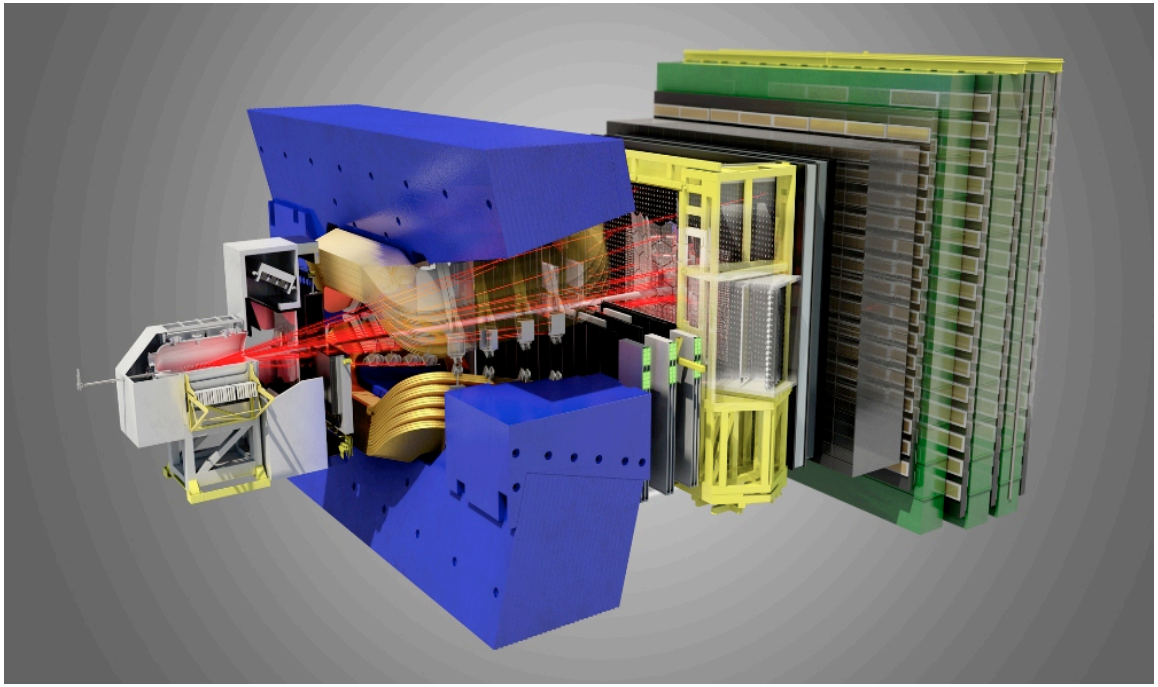
THANKS

- VV decays
  - $B^0 \to \phi K^*$: Determination of CPV asymmetries and measurement of longitudinal polarization

BackUp

Resolution

momentum resolution:
$\Delta p / p = 0.4$ % at 5 GeV/c to 0.6 % at 100 GeV/c
ECAL resolution (nominal):
1 % + 10 % / $\sqrt{(E[GeV])}$
impact parameter resolution:
20 μm for high-pT tracks
invariant mass resolution:
~8 MeV/c2 for $B \rightarrow J/\psi X$ decays with constraint on J/ψ mass
~22 MeV/c2 for two-body B decays
~100 MeV/c2 for $B_s \rightarrow \varphi \gamma$, dominated by photon contribution
decay time resolution:
45 fs for $B_s \rightarrow J/\psi \varphi$ and for $B_s \rightarrow D_s \pi$



Efficiencies

percentage of working detector channels:
~ 99 % for all sub-detectors
data taking efficiency:
> 90 %
data good for analyses:
> 99 %
trigger efficiencies:
~ 90 % for dimuon channels
~ 30 % for multi-body hadronic final states
track reconstruction efficiency:
> 96 % for long tracks
electron ID efficiency:
~ 90 % for ~ 5 % $e \rightarrow h$ mis-id probability
kaon ID efficiency:
~ 95 % for ~ 5 % $\pi \rightarrow K$ mis-id probability
muon ID efficiency:
~ 97 % for 1-3 % $\pi \rightarrow \mu$ mis-id probability

Acceptance

pseudorapidity:
$2 < \eta < 5$

Charmless 2 body decays ($B_{d,s} \to K\pi$)

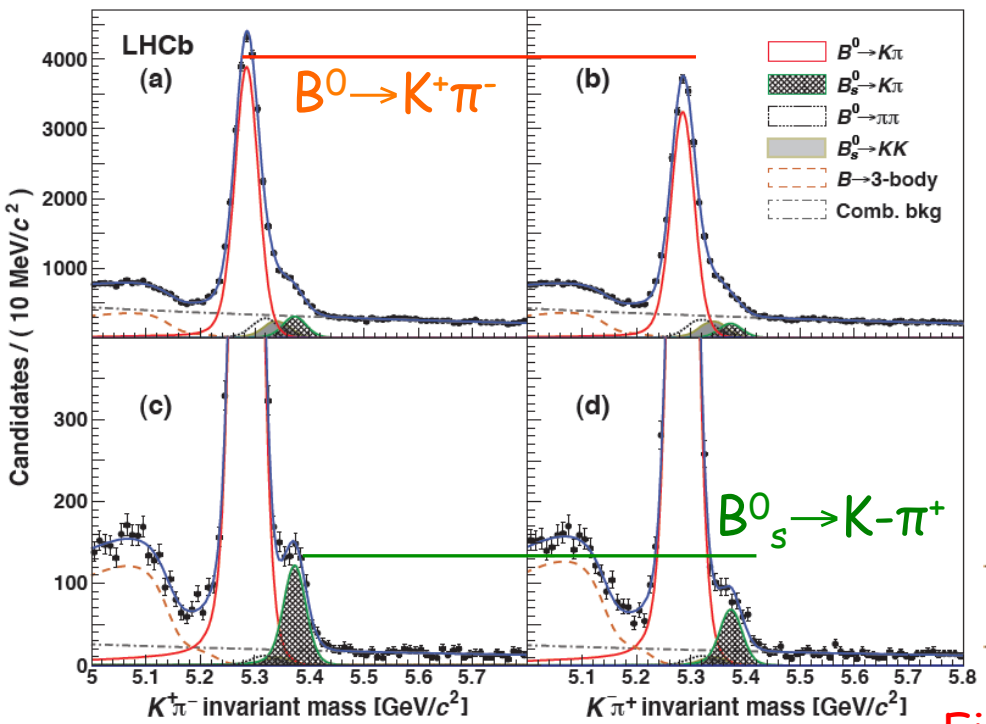
- Direct CP violation ($B^0 \to K\pi$)
  - Compare the decay rates of self-tagged modes
    - Different optimizations for B_d/B_s
    - PID is a keypoint
    - Raw asymmetry must be corrected for detection asymmetry and B production asymmetry

$$A_{CP}(B_s^0 \to \pi K) = \frac{\Gamma(\bar{B}_s^0 \to \pi^- K^+) - \Gamma(B_s^0 \to \pi^+ K^-)}{\Gamma(\bar{B}_s^0 \to \pi^- K^+) + \Gamma(B_s^0 \to \pi^+ K^-)}.$$

$$A_{CP}(B^0 \to K\pi) = \frac{\Gamma(\bar{B}^0 \to K^- \pi^+) - \Gamma(B^0 \to K^+ \pi^-)}{\Gamma(\bar{B}^0 \to K^- \pi^+) + \Gamma(B^0 \to K^+ \pi^-)}$$

1.0 fb^{-1}

$$\mathcal{A}_{\rm CP} = \mathcal{A}_{\rm Raw} - (\mathcal{A}_{\rm Det.} + \kappa \mathcal{A}_{\rm Prod.})$$



1. A_{Det} determined from large D decay samples
2. κ dilution from mixing/acceptance
3. A_{Prod} determined from time dependence

Total correction is small (~1%)

Phys. Rev. Lett.110 (2013) 221601
LHCb-PAPER-2013-018
arXiv: 1304.6173

$$A_{CP}(B^0 \to K^+\pi^-) = -0.080 \pm 0.007\,(\text{stat}) \pm 0.003\,(\text{syst}), \quad 10.5\ \sigma$$

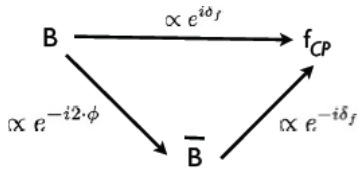
$$A_{CP}(B_s^0 \to K^-\pi^+) = 0.27 \pm 0.04\,(\text{stat}) \pm 0.01\,(\text{syst}). \quad 6.5\ \sigma$$

First observation CP violation in B_s decays

Charmless 2 body decays ($B^0 \to \pi^+\pi^-$ and $B^0_s \to K^+K^-$)

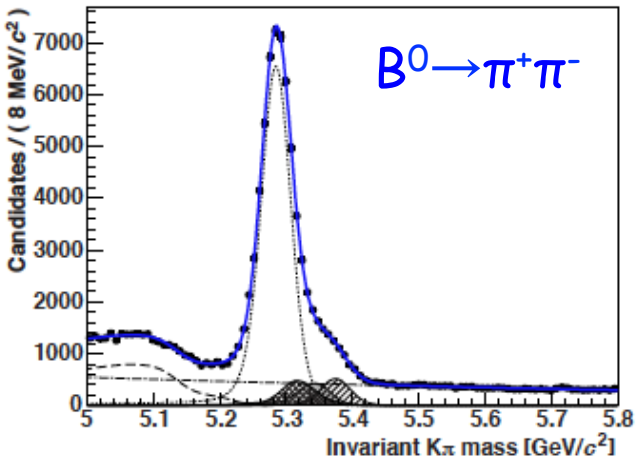
- Mixed-induced CPV

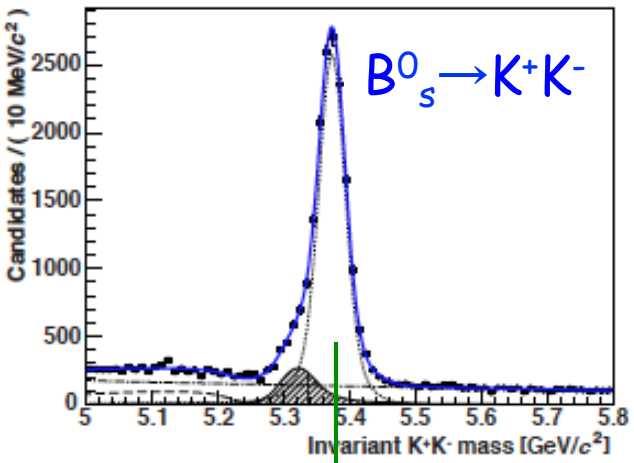
J. High Energy Phys.10 (2013) 183
arXiv: 1308.1428

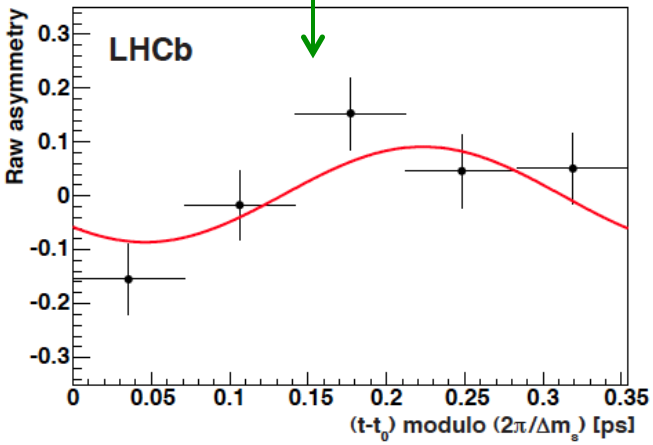


$$A_{CP}(t) = \frac{A_{\rm dir}\cos(\Delta m t) + A_{\rm mix}\sin(\Delta m t)}{\cosh(\frac{\Delta\Gamma}{2}t) - A_\Delta \sinh(\frac{\Delta\Gamma}{2}t)}$$

1.0 fb^{-1}







$A_{\pi\pi}^{dir}$ = 0.38 ± 0.15 ± 0.02
$A_{\pi\pi}^{mix}$ = −0.71 ± 0.13 ± 0.02
$\rho(A_{\pi\pi}^{dir}, A_{\pi\pi}^{mix})$ = −0.38

5.6 σ away from (0,0)

A_{KK}^{dir} = 0.14 ± 0.11 ± 0.03
A_{KK}^{mix} = 0.30 ± 0.12 ± 0.04
$\rho(A_{KK}^{dir}, A_{KK}^{mix})$ = 0.02

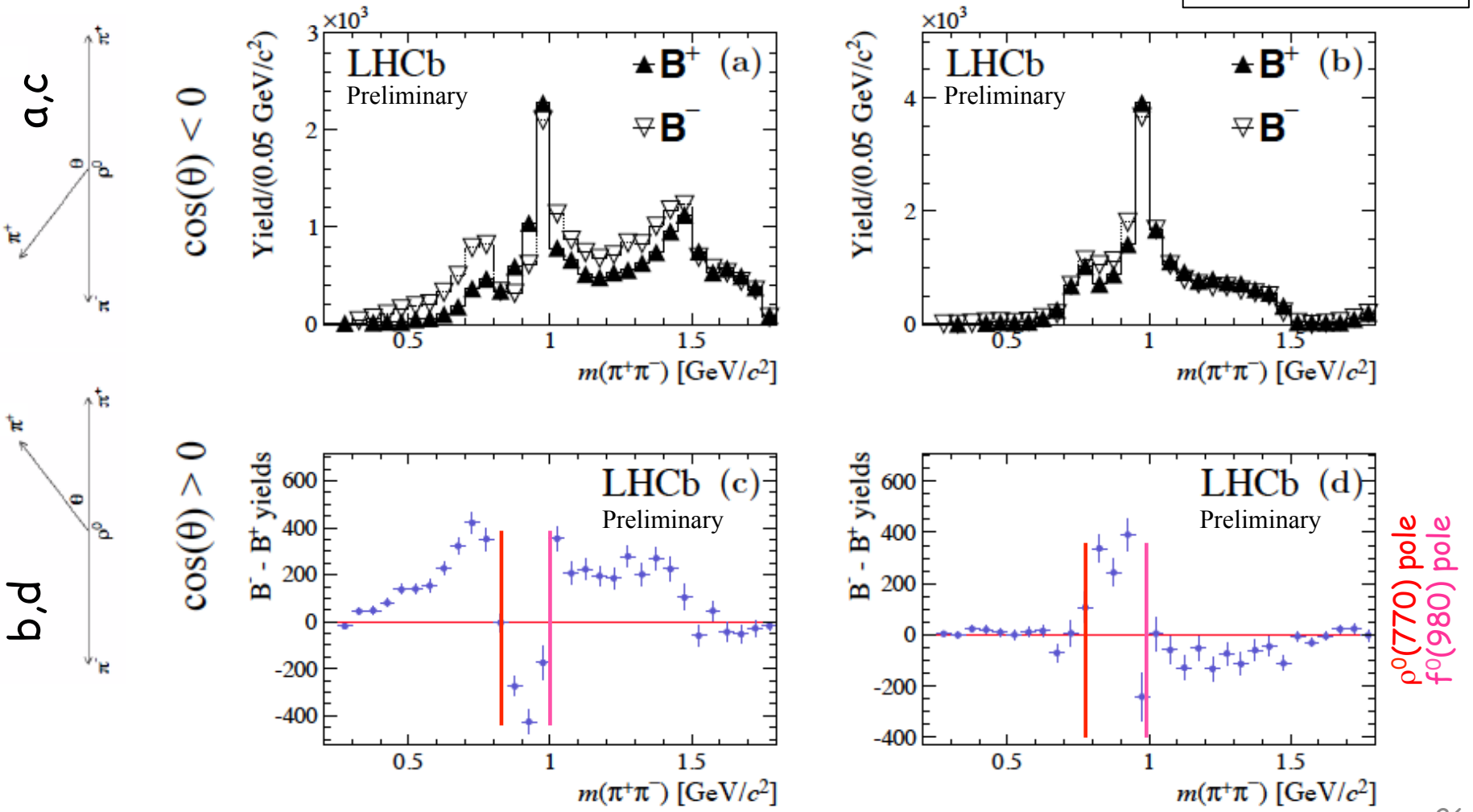
2.7 σ away from (0,0)

Charmless 3-body decays ($B^{\pm} \to h^{+} h^{-} h^{\pm}$)

- CP violation measurements in local region of Dalitz plots

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

arXiv: 1407.5907



Charmless 3-body decays ($B^{\pm} \to h^{+} h^{-} h^{\pm}$)

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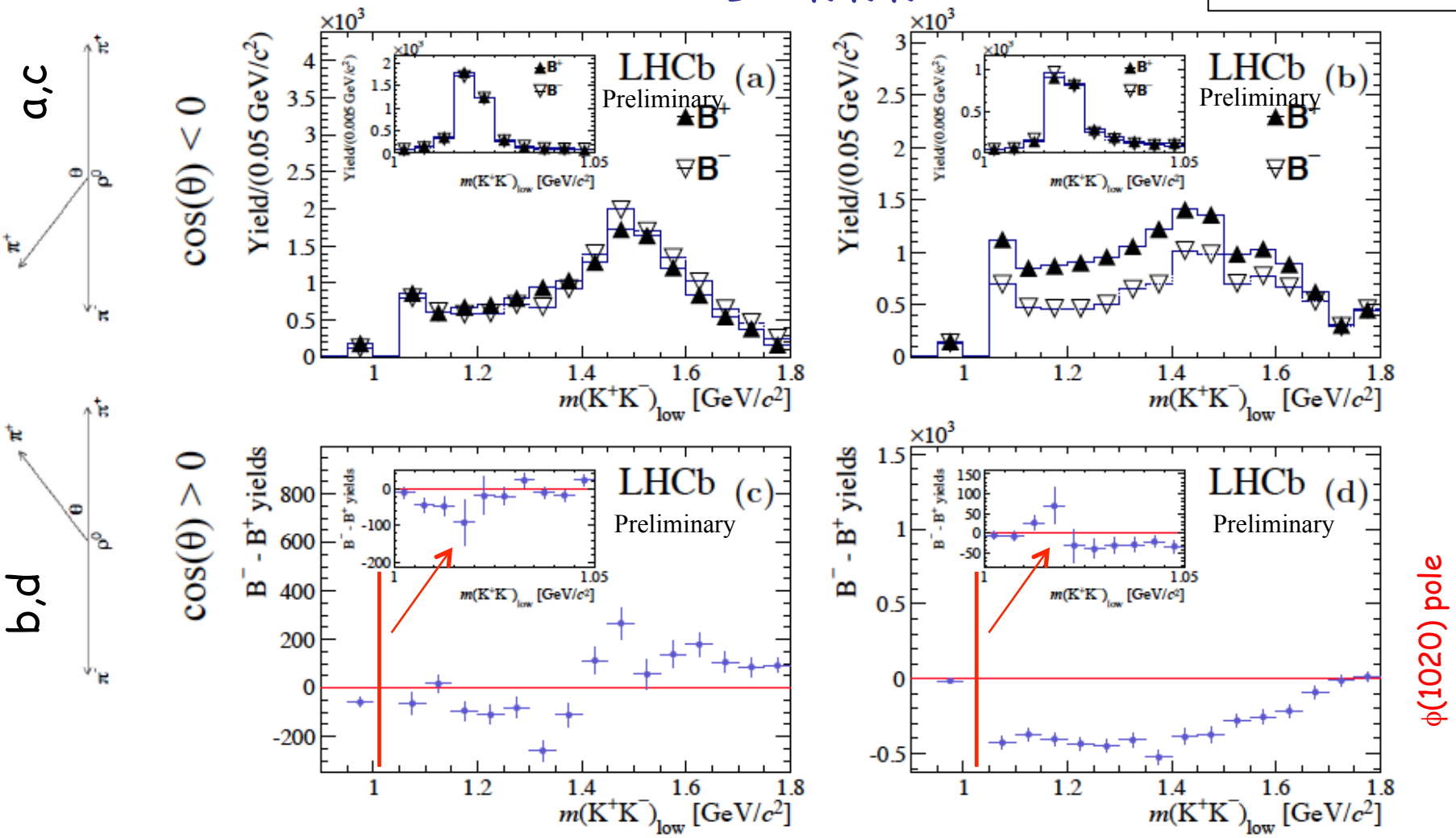
arXiv: 1407.5907

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

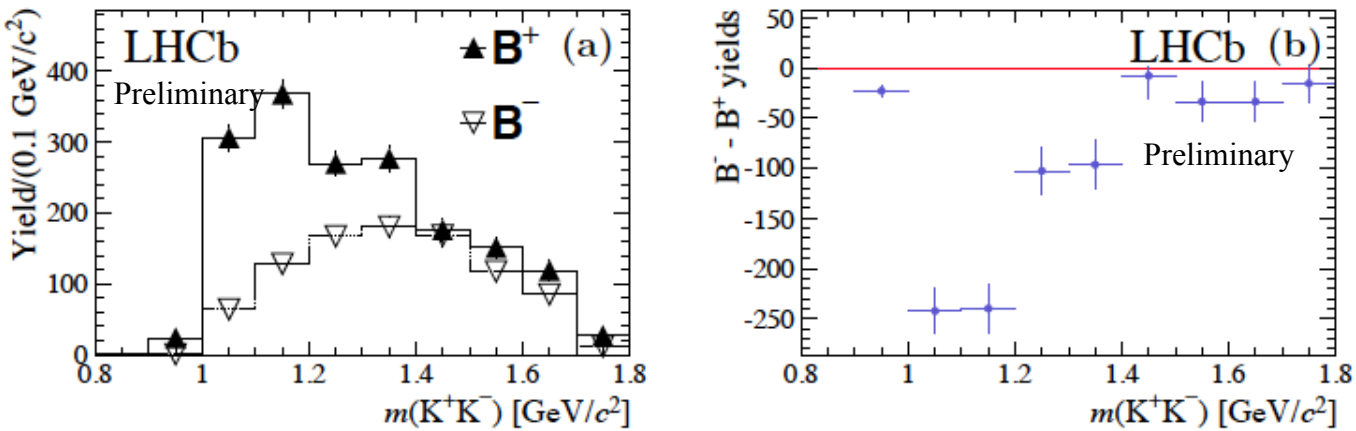


Charmless 3-body decays ($B^{\pm} \to h^{+} h^{-} h^{\pm}$)

- CP violation measurements in local region of Dalitz plots

arXiv: 1407.5907

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



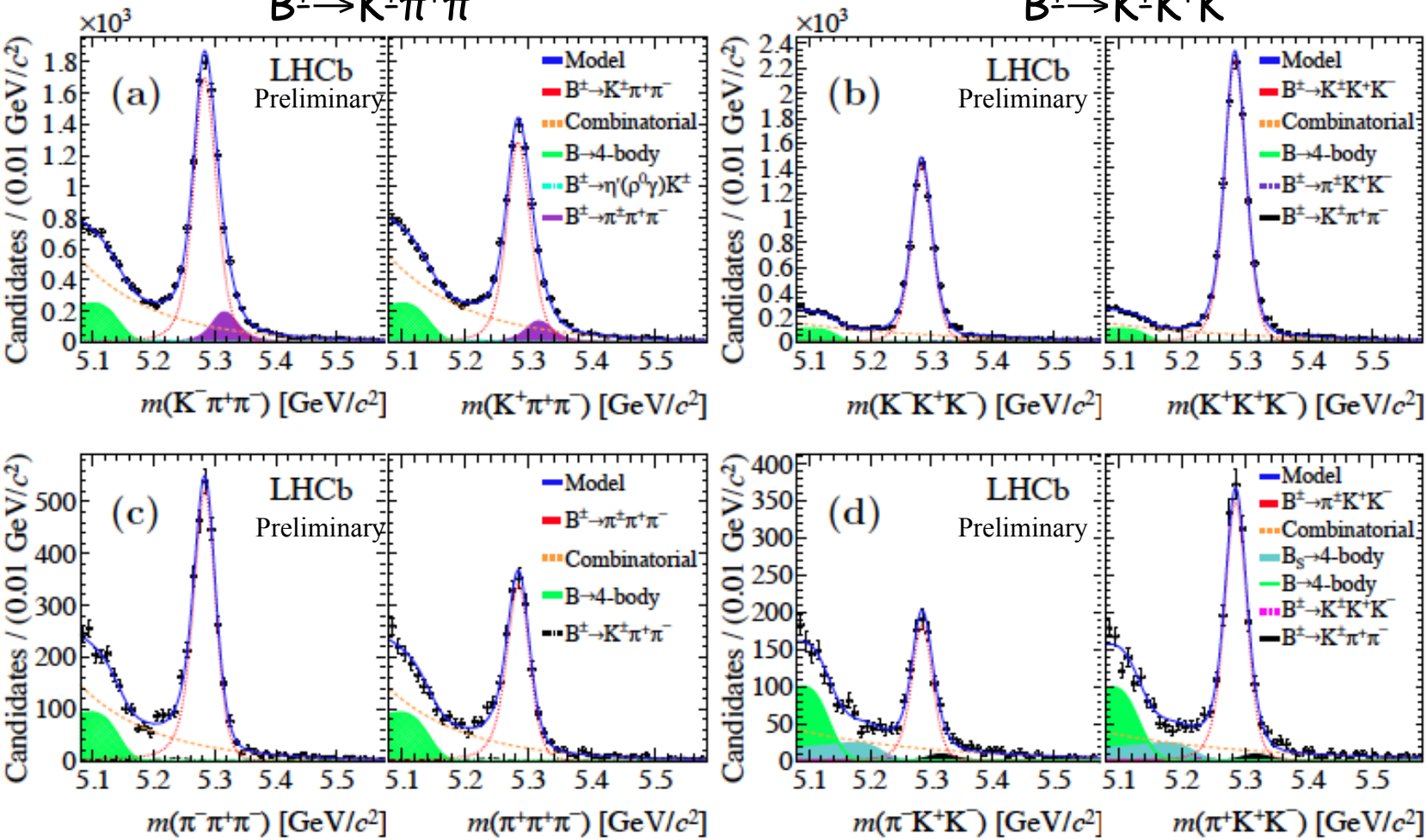
Charmless 3-body decays ($B^\pm \to h^+ h^- h^\pm$)

- CP violation measurements in local region of Dalitz plots

arXiv: 1407.5907

- Invariant mass fits in the rescattering region

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



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

Charmless 3-body decays ($B^{\pm} \to h^{+} h^{-} h^{\pm}$)

- CP violation measurements in local region of Dalitz plots

- Signal yields and charge asymmetries in the regions dominated by the vector resonances
- I, II $\cos\theta > 0$ and III,IV $\cos\theta < 0$
- I, III $0.47 < m_{\pi\pi}$ GeV/c2 < 0.77 and II, IV $0.77 < m_{\pi\pi}$ GeV/c2 < 0.92

arXiv: 1407.5907

Decay mode	Resonance	Sector	N_S	A_{CP}
$B^{\pm} \to K^{\pm}\pi^{+}\pi^{-}$	ρ	I	2909 ± 80	$-0.052 \pm 0.032 \pm 0.047 \pm 0.007$
		II	6136 ± 100	$+0.140 \pm 0.018 \pm 0.034 \pm 0.007$
		III	2856 ± 86	$+0.598 \pm 0.036 \pm 0.079 \pm 0.007$
		IV	2107 ± 55	$-0.208 \pm 0.043 \pm 0.042 \pm 0.007$
$B^{\pm} \to K^{\pm}\pi^{+}\pi^{-}$	K^{*}	I	$11\,095 \pm 115$	$+0.002 \pm 0.013 \pm 0.011 \pm 0.007$
		II	7159 ± 89	$+0.007 \pm 0.016 \pm 0.005 \pm 0.007$
		III	2427 ± 65	$-0.009 \pm 0.031 \pm 0.054 \pm 0.007$
		IV	9861 ± 124	$-0.020 \pm 0.015 \pm 0.010 \pm 0.007$
$B^{\pm} \to \pi^{\pm}\pi^{+}\pi^{-}$	ρ	I	2629 ± 59	$+0.302 \pm 0.026 \pm 0.015 \pm 0.007$
		II	1653 ± 46	$-0.244 \pm 0.034 \pm 0.019 \pm 0.007$
		III	5204 ± 79	$-0.076 \pm 0.019 \pm 0.007 \pm 0.007$
		IV	4476 ± 72	$+0.055 \pm 0.020 \pm 0.013 \pm 0.007$
$B^{\pm} \to K^{\pm}K^{+}K^{-}$	ϕ	I	3082 ± 56	$-0.018 \pm 0.024 \pm 0.008 \pm 0.007$
		II	4119 ± 64	$-0.008 \pm 0.021 \pm 0.004 \pm 0.007$
		III	1546 ± 39	$+0.066 \pm 0.034 \pm 0.010 \pm 0.007$
		IV	2719 ± 53	$+0.015 \pm 0.026 \pm 0.002 \pm 0.007$

Significant CP asymmetry in The decays involving a $\rho(770)$