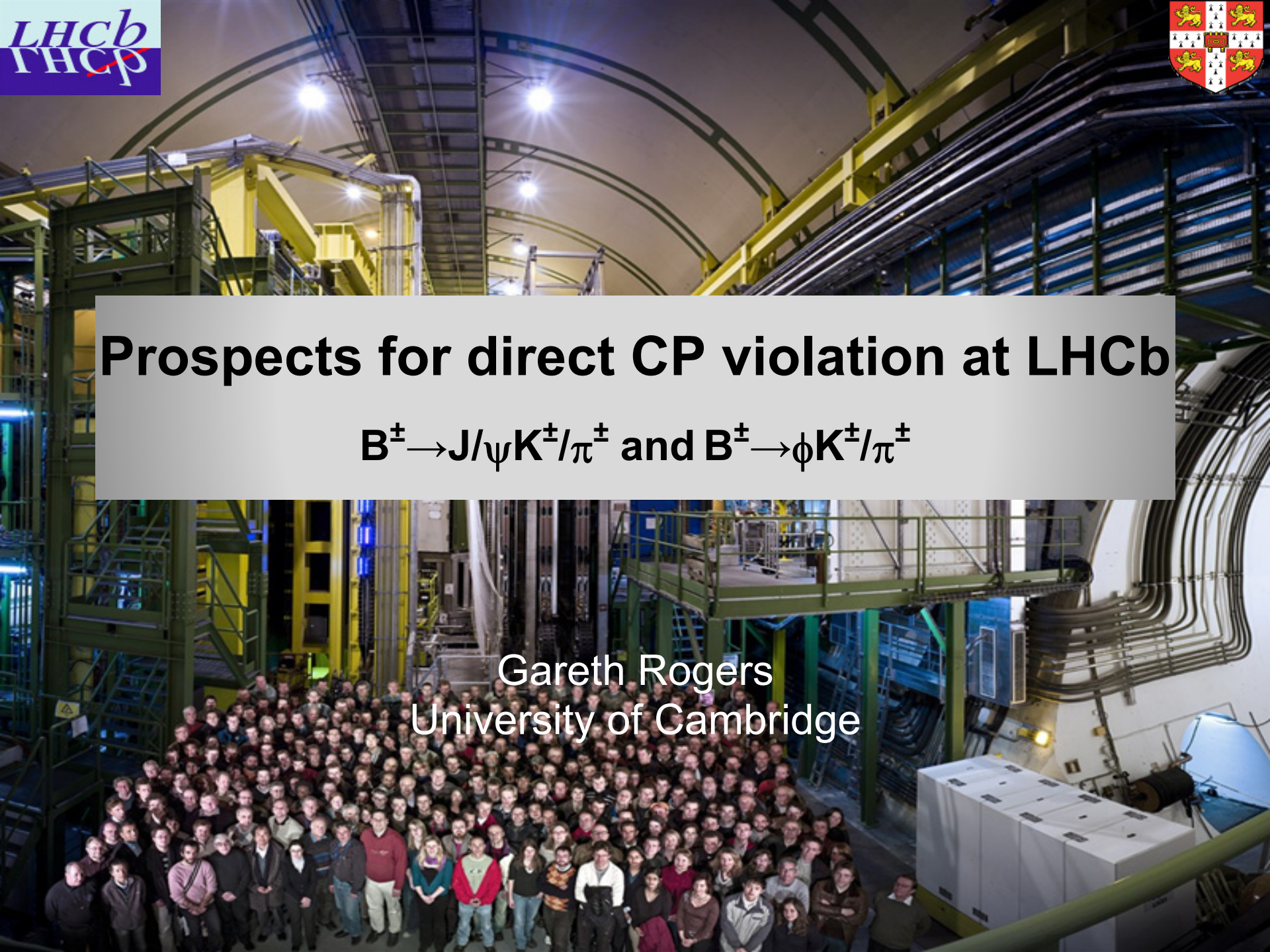


Prospects for direct CP violation at LHCb

$B^{\pm} \to J/\psi K^{\pm}/\pi^{\pm}$ and $B^{\pm} \to \phi K^{\pm}/\pi^{\pm}$

Gareth Rogers
University of Cambridge

Contents

- Theory overview
- Measuring direct CP violation
- LHCb detector
- Monte Carlo studies

Theory overview

- We live in a universe dominated by matter → CP violation necessary.
- Direct CPV is generated by the interference between tree and penguin diagrams.
- Standard model predictions for direct CPV compare the life times of charge conjugate modes.

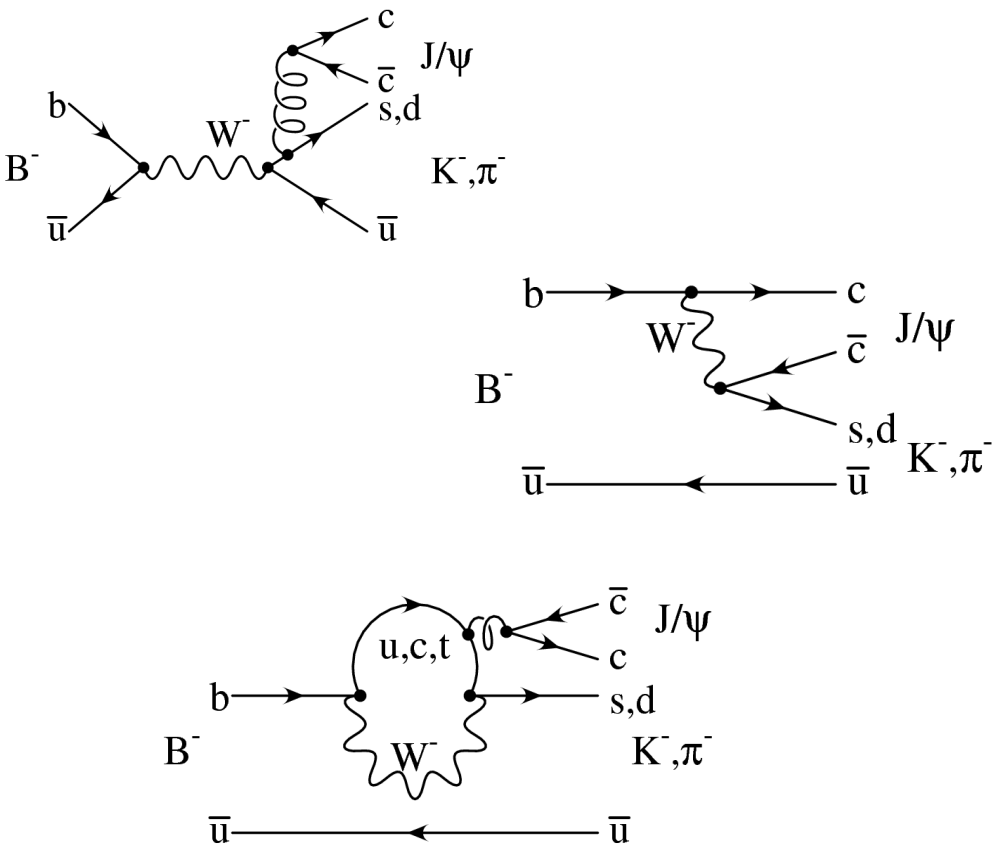
$$A_{CP} = \frac{\Gamma(B^- \to f) - \Gamma(B^+ \to f)}{\Gamma(B^- \to f) + \Gamma(B^+ \to f)}$$

- New physics can modify these predictions, precision measurements constrain these models.

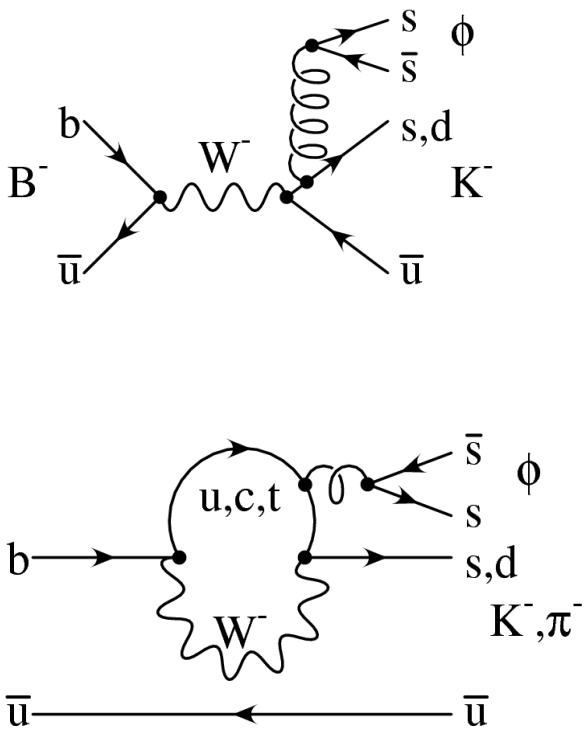
Theory Overview

- My interest is in direct CP asymmetry in the following four charged B decays:

$$B^{\pm} \to J/\psi\, K^{\pm} / \pi^{\pm}$$



$$B^{\pm} \to \phi\, K^{\pm} / \pi^{\pm}$$



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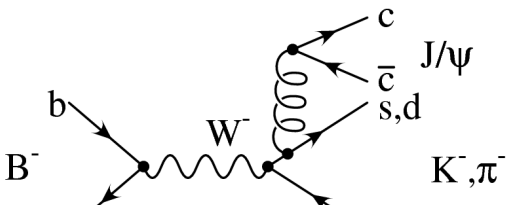
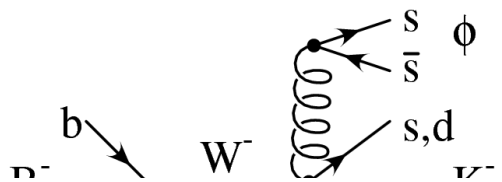
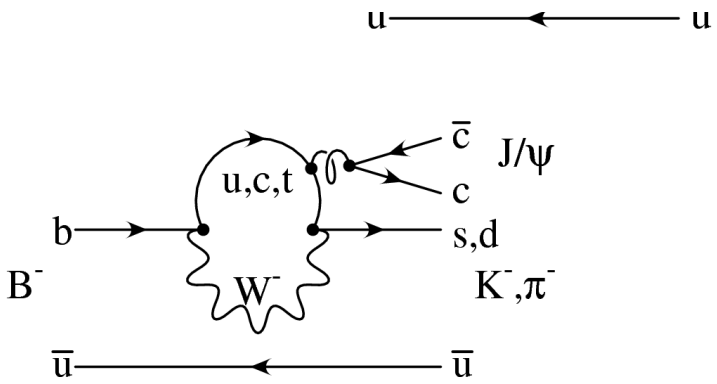
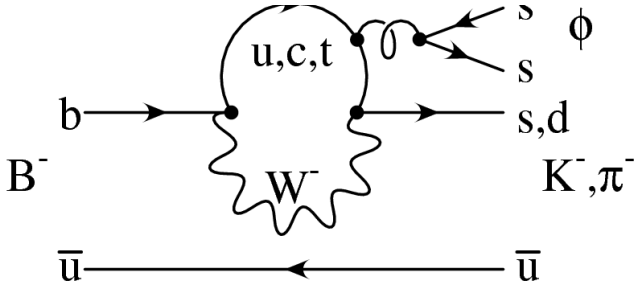


$$B^{\pm} \to \phi\, K^{\pm} / \pi^{\pm}$$



	$B^{\pm}\to J/\psi K^{\pm}$	$B^{\pm}\to J/\psi \pi^{\pm}$	$B^{\pm}\to \phi K^{\pm}$	$B^{\pm}\to \phi \pi^{\pm}$
Standard model, A_{CP}	~0.3%•	~few%†	0.6-1%‡	0-10%‡





• Hou et. al. hep-ph/0605080v1 † Hou hep-ph/9905541 ‡ Cheng et. Al. Physical Review D 80, 114008 (2009)

Measuring direct CP violation

- Simple! reconstruct decays → count number of B^+ and B^- → calculate asymmetry ☺

$$A_{meas} = \frac{N(B^- \to f) - N(B^+ \to f)}{N(B^- \to f) + N(B^+ \to f)}$$

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- Real world a little bit more complicated → CP violation not the only asymmetry.

Production $\dfrac{f\left(b \to B^-\right)}{f\left(\bar{b} \to B^+\right)} - 1$

Detector $\varepsilon_{K^+} \neq \varepsilon_{K^-}$

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- Modify the formula to collate these asymmetries with an ***r*** parameter.

$$A_{meas} = \frac{r \cdot Br(B^- \to f) - Br(B^+ \to f)}{r \cdot Br(B^- \to f) + Br(B^+ \to f)} \qquad r = \frac{f(b \to B^-) \cdot \varepsilon_{K^-/\pi^-}}{f(\bar{b} \to B^+) \cdot \varepsilon_{K^+/\pi^-}}$$

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- **First data:**

Measuring direct CP violation

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- **First data:**

$$A_r^{K^\pm(\pi^\pm)} = A_{CP}^{B^\pm \to J/\psi K^\pm(\pi^\pm)} - A_{meas}^{B^\pm \to J/\psi K^\pm(\pi^\pm)}$$

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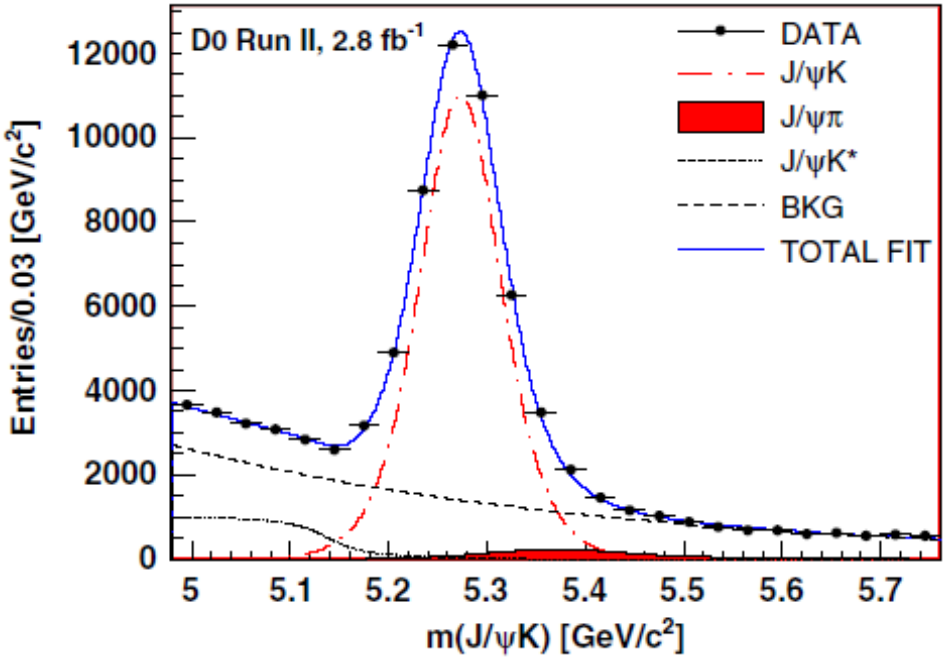
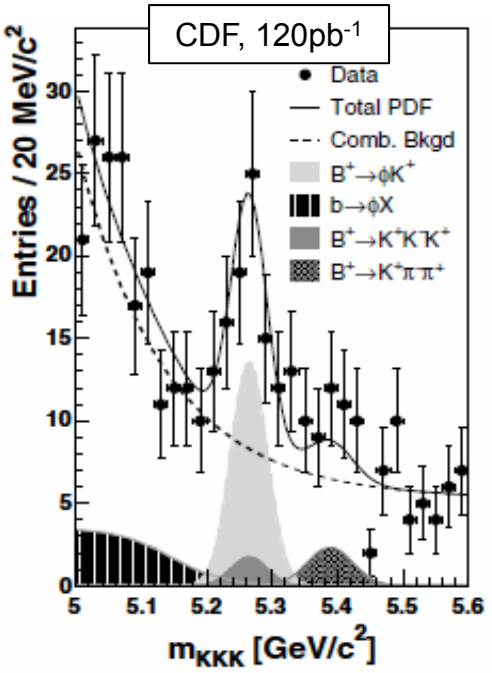
$$A_{CP}^{B^\pm \to \phi K^\pm(\pi^\pm)} = A_{meas}^{B^\pm \to \phi K^\pm(\pi^\pm)} + A_r^{K^\pm(\pi^\pm)}$$

Measuring direct CP violation



DOI:10.1103/PhysRevLett.100.211802

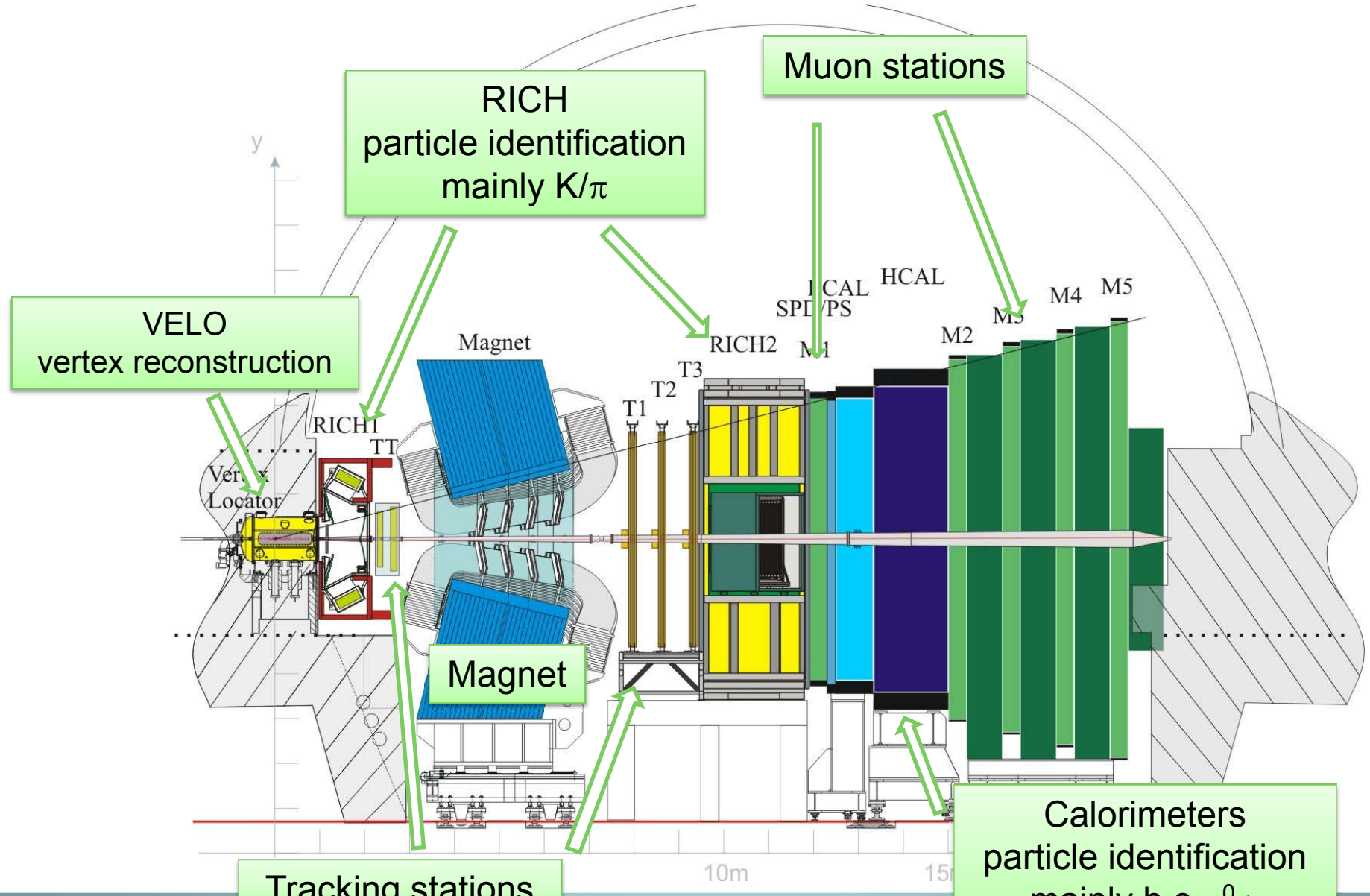


DOI:10.1103/PhysRevLett.95.031801

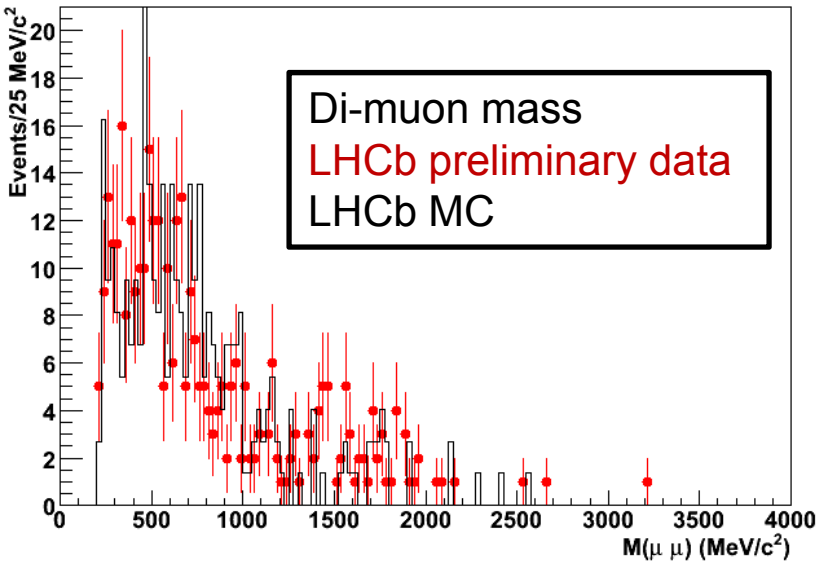
BABAR have latest limit on $B^{\pm}\to\phi\pi^{\pm}$ A_{CP} DOI:10.1103/PhysRevD.74.011102.

	$B^{\pm}\to J/\psi K^{\pm}$	$B^{\pm}\to J/\psi \pi^{\pm}$	$B^{\pm}\to \phi K^{\pm}$	$B^{\pm}\to \phi \pi^{\pm}$
Branching ratio (PDG live)	$(1.007\pm0.035)\times10^{-3}$	$(4.9\pm0.6)\times10^{-5}$	$(8.3\pm0.7)\times10^{-6}$	$<0.24\times10^{-3}$ (90%CL)
A_{CP} (PDG live)	0.009±0.008	0.01±0.07	-0.01±0.06	Unknown

LHCb

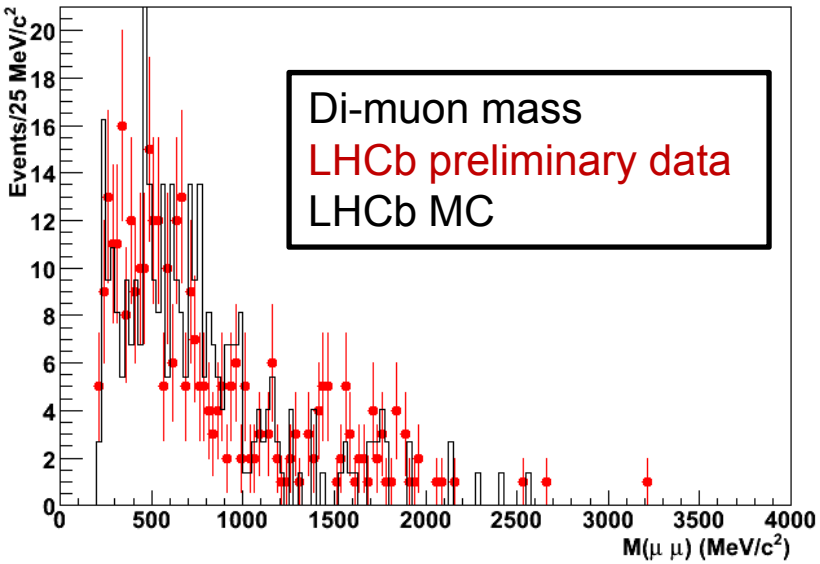

Muon stations
RICH
particle identification
mainly K/π
VELO
vertex reconstruction
Magnet
Tracking stations
Calorimeters
particle identification
mainly h,e,π0,γ
RICH1
TT
RICH2
T1
T2
T3
M1
M2
M4
M5
HCAL
Magnet
10m

Muon performance



- Muon ID is very important, J/ψ's...
- Muon detector commissioned with cosmics and 900GeV run from last year.
- A first measure of the muon mis-id rate from the $K_s \rightarrow \pi\pi$ has been performed.

Muon performance



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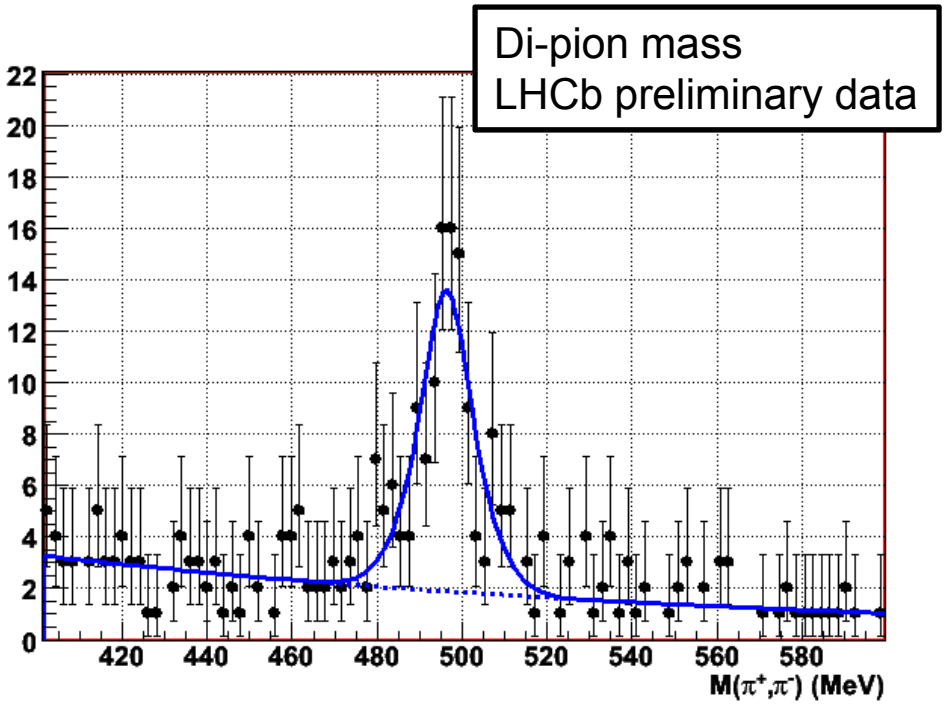
- Right, $K_s \rightarrow \pi\pi$ with one π in muon acceptance and identified as a μ.

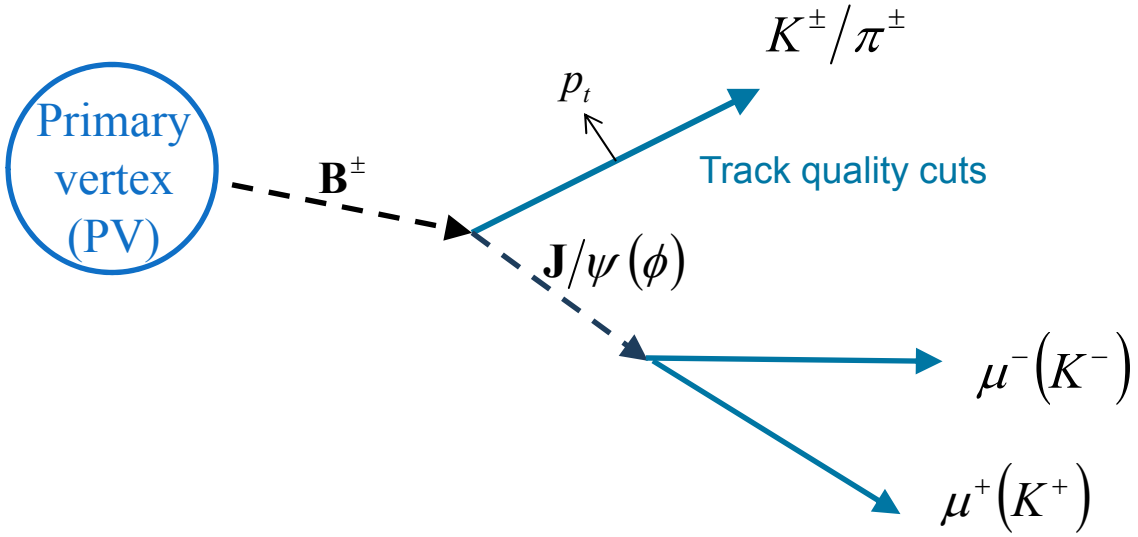
LHCb 2009 data (preliminary):
$\varepsilon(\pi \rightarrow \mu) = 3.8 \pm 0.7\%$

LHCb MC (preliminary):
$\varepsilon(\pi \rightarrow \mu) = 2.3 \pm 0.4\%$

- Preliminary performance worse on data
  - → Likelihood not yet calibrated.



Monte Carlo studies



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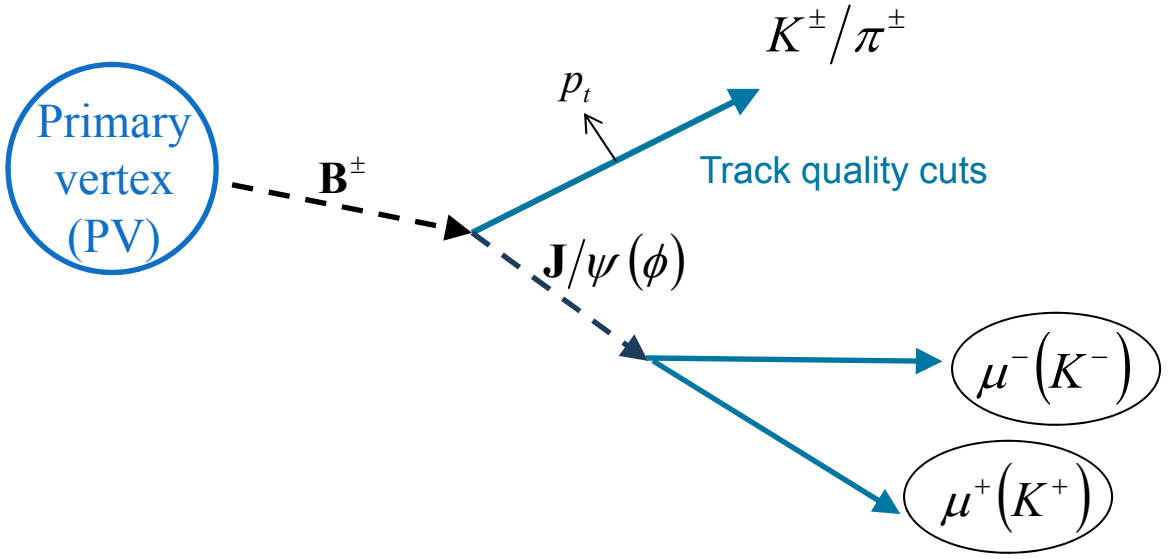
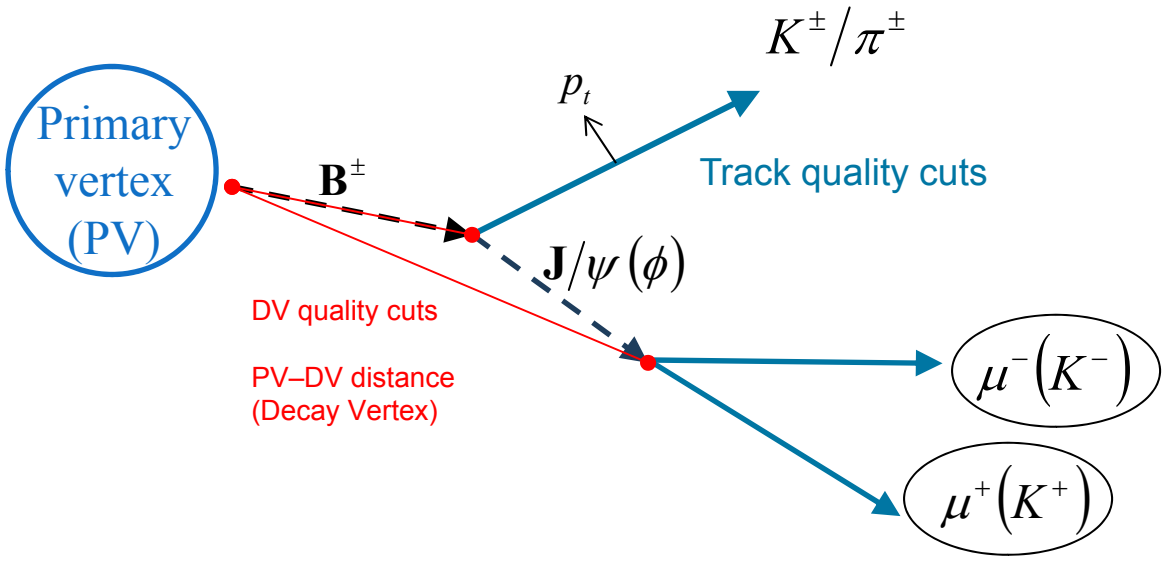


Particle ID:
likelihood of μ/K over π.

Monte Carlo studies



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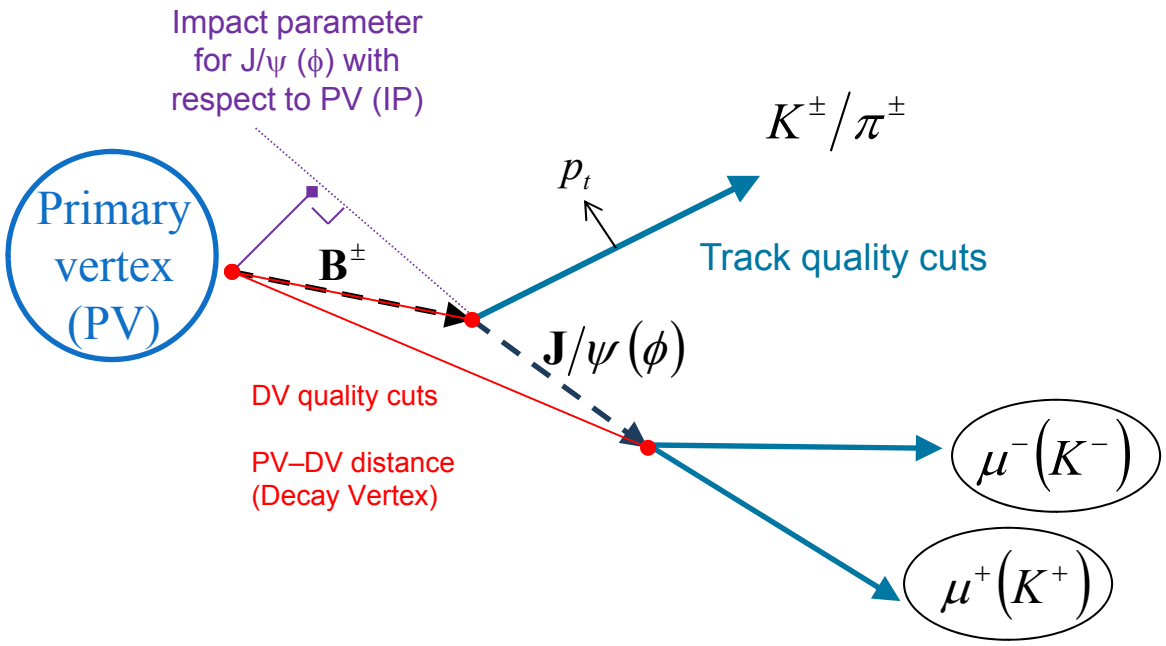

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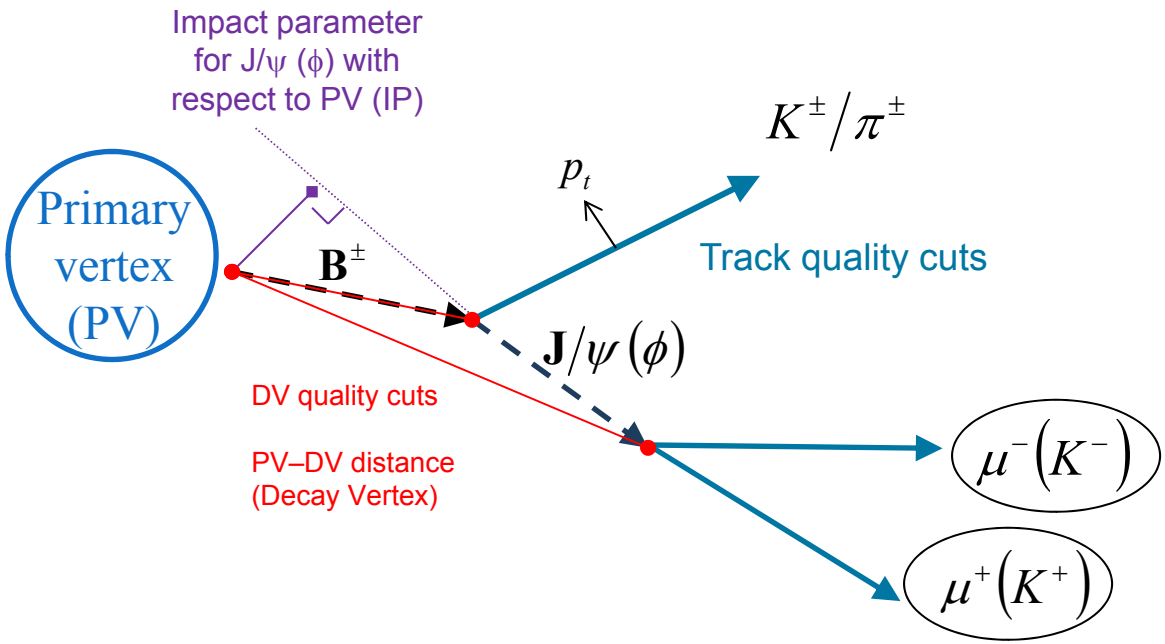

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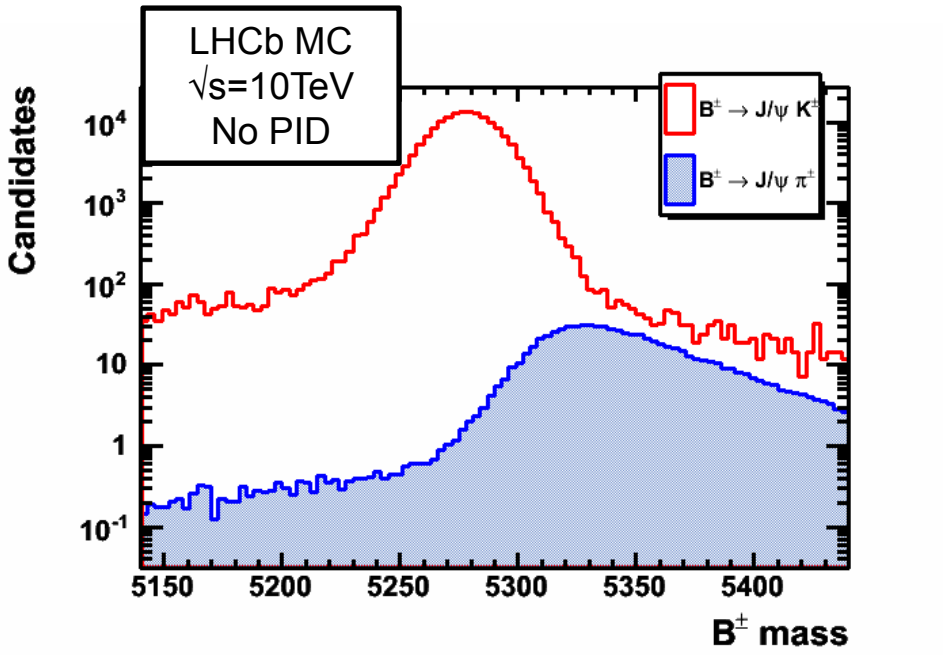
	$B^{\pm}\to J/\psi K^{\pm}$	$B^{\pm}\to J/\psi \pi^{\pm}$	$B^{\pm}\to \phi K^{\pm}$	$B^{\pm}\to \phi \pi^{\pm}$
Efficiency, ε_{Total}	(0.99±0.01)%	(0.97±0.01)%	(1.10±0.01)%	(1.09±0.01)%

$$\varepsilon_{Total} = \varepsilon_{generator} \times \varepsilon_{L0trigger} \times \varepsilon_{selection}$$

Monte Carlo studies

- Determine number of $B^{\pm}$'s from a fit to the $B^{\pm}$ mass peaks in the samples.
- Provide additional information to the fit by utilising the difference in the kaon and pion likelihoods.
- Final fit is a 2D fit to $B^{\pm}$ mass and K-π likelihood difference.



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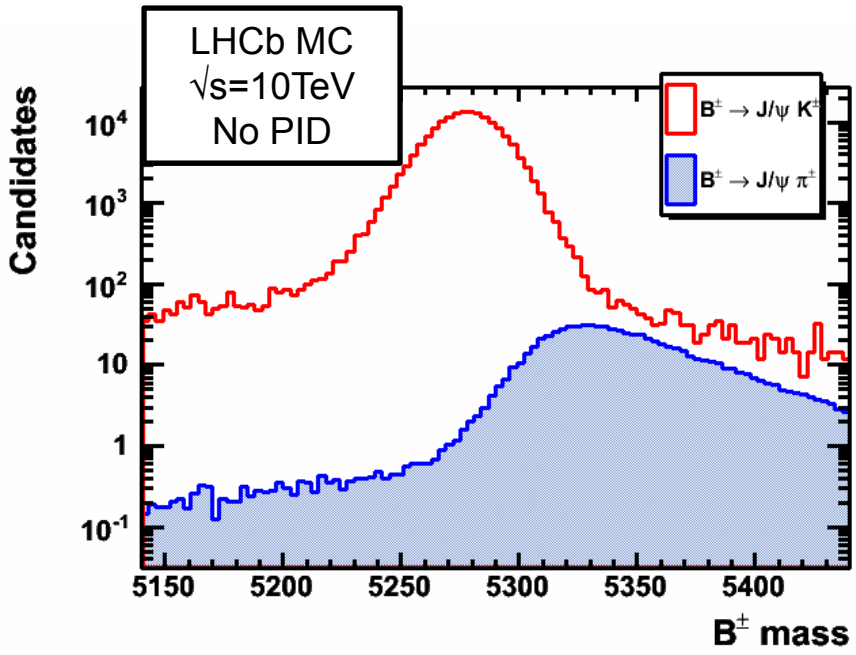

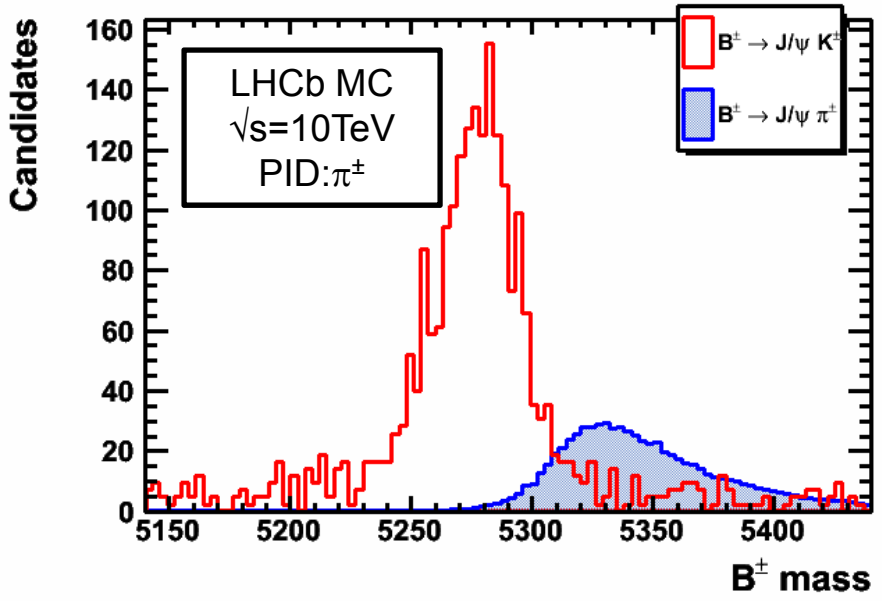

Summary

Conditions		$B^{\pm}\to J/\psi K^{\pm}$ ΔA_r	$B^{\pm}\to J/\psi \pi^{\pm}$ ΔA_r	$B^{\pm}\to \phi K^{\pm}$ ΔA_{CP}	$B^{\pm}\to \phi \pi^{\pm}$ ΔA_{CP}
$0.2fb^{-1}$	3.5+3.5TeV	0.008	0.1	0.03	0.8
$1fb^{-1}$	3.5+3.5TeV	0.008	0.07	0.01	0.3
$2fb^{-1}$	7+7TeV	0.008	0.07	0.008	0.2

- Error in $B^{\pm}\to J/\psi K^{\pm}$ and $B^{\pm}\to J/\psi \pi^{\pm}$ quickly dominated by A_{CP} error.
- Sensitivity in $B^{\pm}\to \phi K^{\pm}$ and $B^{\pm}\to \phi \pi^{\pm}$ dominated by statistics for first data.
- LHCb can improve sensitivity in current A_{CP} measurements for $B^{\pm}\to \phi K^{\pm}$ and $B^{\pm}\to \phi \pi^{\pm}$.

Current sensitivity:
$B^{\pm}\to J/\psi K^{\pm}$: 0.008 (PDG)
$B^{\pm}\to J/\psi \pi^{\pm}$: 0.07 (PDG)
$B^{\pm}\to \phi K^{\pm}$: 0.06 (PDG)
$B^{\pm}\to \phi \pi^{\pm}$: unmeasured

Back up

Yields and efficiencies

- Yield calculation:

$$2 \times \sigma_{b\bar{b}} \times Br(b \to B^{\pm}) \times Br\left(B^{\pm} \to J/\psi\, K^{\pm}\left(\pi^{\pm}\right)\right) \times Br\left(J/\psi \to \mu\mu\right)$$

$$2 \times \sigma_{b\bar{b}} \times Br(b \to B^{\pm}) \times Br\left(B^{\pm} \to \phi K^{\pm}\left(\pi^{\pm}\right)\right) \times Br\left(\phi \to KK\right)$$

Yield	$B^{\pm} \to J/\psi K^{\pm}$	$B^{\pm} \to J/\psi \pi^{\pm}$	$B^{\pm} \to \phi K^{\pm}$	$B^{\pm} \to \phi \pi^{\pm}$
3.5+3.5TeV, 0.2fb^{-1}	21K	98	1.6K	2*
3.5+3.5TeV, 1fb^{-1}	104K	494	8K	9*
7+7TeV, 2fb^{-1}	455K	2K	35K	37*

* Use the predicted branching ratio of 4.45x10^{-9} from arxiv:0804.1231, Mawlong et. al..

Muon

- 5 muon stations in LHCb – M1 before the ECAL and HCAL, M2—M5 after.
- M2—M5 made from a honey comb structure of multi-wire proportional chambers (MWPC).
- M1 inner region made from radiation hard triple-GEMs, where a high particle flux is seen. Outer region made from MWPC.
  - Triple—GEMs use an $Ar/CO_2/CF_4$ (60/20/20) gas mixture.
- Used as part of the level 0 hardware trigger, looking for high p_t muons.

Introduction

- Can use $b \to D^{*+}X$, $D^{*+} \to D^0\pi^+$, $D^0 \to K^-\mu^+\nu$ to measure $r = \frac{f(b \to \bar{B}) \cdot \varepsilon_{K^-}}{f(\bar{b} \to B) \cdot \varepsilon_{K^+}}$ V.Gibson
- includes all B species
- B species have different production ratios R.Lambert

$$\partial p = \frac{f(b \to \bar{B})}{f(\bar{b} \to B)} - 1 = +(3.45 \pm 0.32) \times 10^{-3} \qquad \partial p = \frac{f(b \to B^-)}{f(\bar{b} \to B^+)} - 1 = -(7.23 \pm 0.54) \times 10^{-3}$$

- Extraction of $r = f(b \to B^-) \cdot \varepsilon_{K^-} / f(\bar{b} \to B^+) \cdot \varepsilon_{K^+}$ directly from data probably requires a study of semi-leptonic B± decays e.g.

$B^+ \to \overline{D^0}\mu^+\nu$, $\overline{D^0} \to K^+\mu^-\nu$

$B^+ \to \overline{D^{*0}}X$, $\overline{D^{*0}} \to \overline{D^0}\pi^0$, $\overline{D^0} \to K^+\mu^-\nu$

Difficult to measure due to large backgrounds and missing energy.

- Other methods extract $r_K = \frac{\varepsilon_{K^-}}{\varepsilon_{K^+}}$ M.Adinolfi/M.Patel

First data

What can we do with first data ?

- Use $B^{\pm} \to J/\Psi K^{\pm}$ to measure

$$A_{meas} = \frac{r \cdot B(B^- \to J/\Psi K^-) - B(B^+ \to J/\Psi K^+)}{r \cdot B(B^- \to J/\Psi K^-) + B(B^+ \to J/\Psi K^+)} \qquad r = \frac{f\left(b \to B^-\right) \cdot \varepsilon_{K^-}}{f\left(\bar{b} \to B^+\right) \cdot \varepsilon_{K^+}}$$

$$A_r = \frac{1-r}{1+r} = \frac{A_{CP} - A_{meas}}{A_{CP}\left(1 - A_{meas}\right)} \approx A_{CP} - A_{meas} \qquad A_{CP}\left(B^+ \to J/\Psi K^+\right)$$

- Extract $B^{\pm} \to \Phi K^{\pm}$ using known $A_{meas} = \frac{r \cdot B(B^- \to \Phi K^-) - B(B^+ \to \Phi K^+)}{r \cdot B(B^- \to \Phi K^-) + B(B^+ \to \Phi K^+)}$
- Apply to $A_{CP} \approx A_{meas} + A_r$
- Error on $A_{CP}\left(B^+ \to \Phi K^+(\pi^+)\right)$ given by current error on $A_{CP}\left(B^+ \to J/\Psi K^+(\pi^+)\right)$