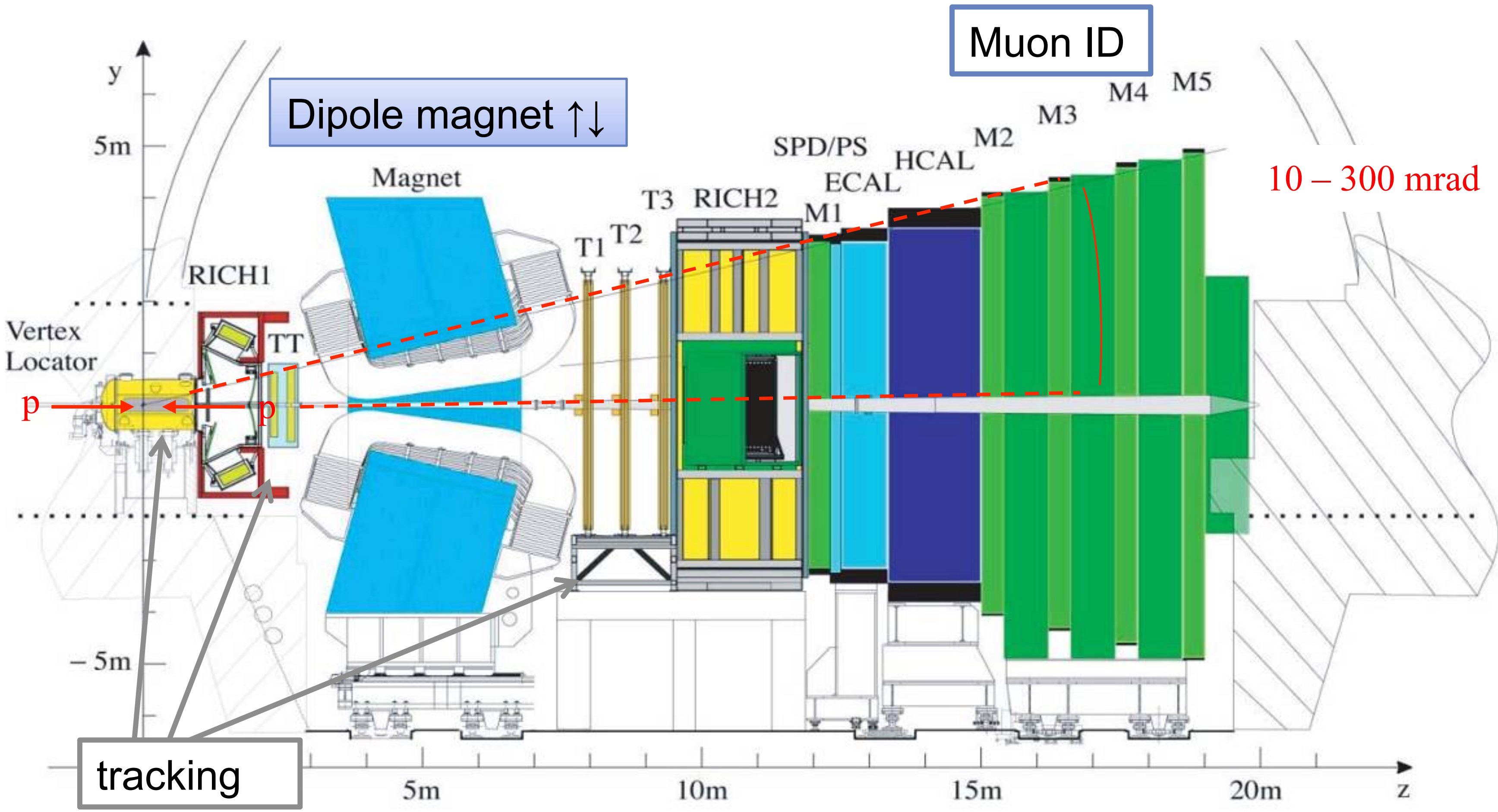
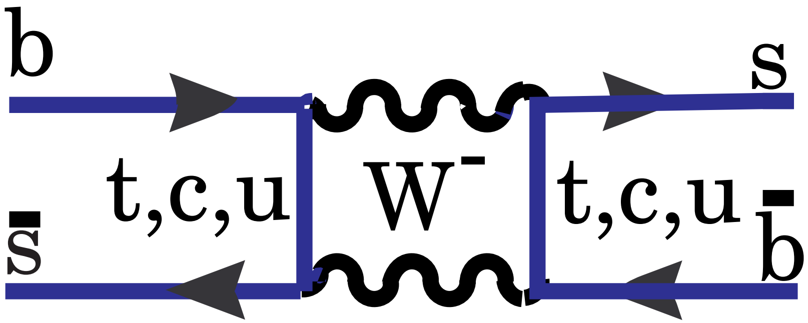
MEASUREMENT FOR THE FLAVOUR-SPECIFIC CP a_{sl}^{s} VIOLATING ASYMMETRY IN $\overline{B}_s^0$ DECAYS

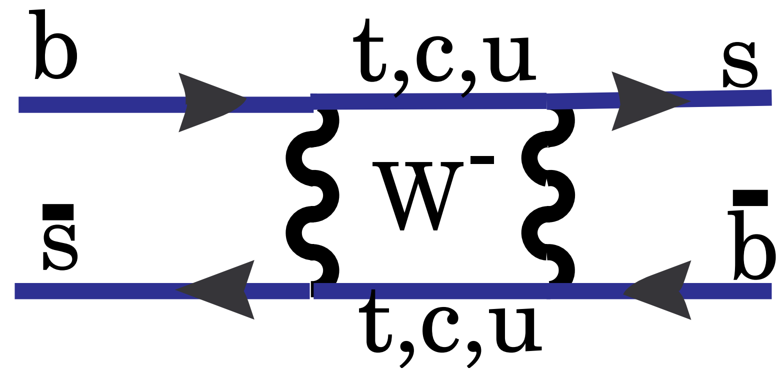
M.ARTUSO ON BEHALF OF THE LHCb COLLABORATION

THE LHCb DETECTOR



A LITTLE BIT OF THEORY





Time evolution of Flavor Eigenstates

$$i\frac{d}{dt}\begin{pmatrix} B_s^0 \\ \overline{B}_s^0 \end{pmatrix} = \begin{pmatrix} M_{11}^s - i\frac{\Gamma_{11}^s}{2} & M_{12}^s - i\frac{\Gamma_{12}^s}{2} \\ M_{12}^{s*} - i\frac{\Gamma_{12}^{s*}}{2} & M_{22}^s - i\frac{\Gamma_{22}^s}{2} \end{pmatrix}\begin{pmatrix} B_s^0 \\ \overline{B}_s^0 \end{pmatrix}$$

Mass eigenstates

$$\left|B_{sL}^0\right\rangle = p\left|B_s^0\right\rangle + q\left|\overline{B}_s^0\right\rangle$$

$$\left|B_{sH}^0\right\rangle = p\left|B_s^0\right\rangle - q\left|\overline{B}_s^0\right\rangle$$

A LITTLE BIT OF THEORY II

Observable quantities are masses and differences in decay widths. In addition, we have the quantity

$$a_s = 1 - \left|\frac{q}{p}\right|^2 = \mathrm{Im}\left(\frac{\Gamma_{12}^s}{M_{12}^s}\right) + O\left(\left(\mathrm{Im}\frac{\Gamma_{12}^s}{M_{12}^s}\right)^2\right) = \left|\frac{\Gamma_{12}^s}{M_{12}^s}\right| \sin\phi_{12}^s$$

$$\phi_{12}^s = \arg\left(-\frac{M_{12}^s}{\Gamma_{12}^s}\right)$$

We can access a_s by measuring asymmetries in flavor specific final states, for example semileptonic decays.

$$a_{sl}^s \equiv \frac{\Gamma(\bar{B}_s^0 \to D_s^- \mu^+) - \Gamma(B_s^0 \to D_s^+ \mu^-)}{\Gamma(\bar{B}_s^0 \to D_s^- \mu^+) + \Gamma(B_s^0 \to D_s^+ \mu^-)} = \frac{1-(1-a_s)^2}{1+(1-a_s)^2} \sim a_s$$

Standard Model predictions

$$\begin{cases} a_{sl}^s = (1.9 \pm 0.3) \times 10^{-5} \\ a_{sl}^d = (-4.1 \pm 0.6) \times 10^{-4} \end{cases}$$

A.Lenz arXiv:1205.1444

WHAT WE MEASURE

Untagged semileptonic asymmetry

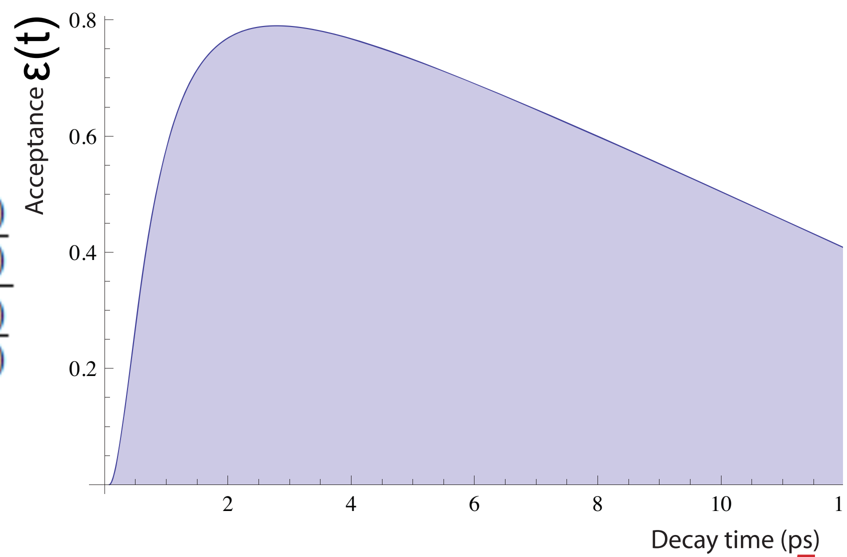
B_s^0 / $\overline{B}_s^0$ Production asymmetry

0.2% in our case

$$A_{meas} \equiv \frac{\Gamma[D_s^- \mu^+] - \Gamma[D_s^+ \mu^-]}{\Gamma[D_s^- \mu^+] + \Gamma[D_s^+ \mu^-]} = \frac{a_{sl}^s}{2} + \left(a_p - \frac{a_{sl}^s}{2} \right) \frac{\int_{t=0}^{\infty} e^{-\Gamma_s t} \cos(\Delta m_s t) \varepsilon(t)\, dt}{\int_{t=0}^{\infty} e^{-\Gamma_s t} \cosh(\frac{\Delta\Gamma_s t}{2}) \varepsilon(t)\, dt}$$

We need to account for detection asymmetries

$$A_{\rm meas} = \frac{N(D_s^- \mu^+) - N(D_s^+ \mu^-) \times \frac{\epsilon(D_s^- \mu^+)}{\epsilon(D_s^+ \mu^-)}}{N(D_s^- \mu^+) + N(D_s^+ \mu^-) \times \frac{\epsilon(D_s^- \mu^+)}{\epsilon(D_s^+ \mu^-)}}$$



KEY ELEMENTS OF THE ANALYSIS

- B_s production asymmetry does not affect the measurement (fast oscillations suppress this effect by 0.2% of the ~1% initial asymmetry)
- Prompt D_s have negligible asymmetry (~0.3%) and represent a small fraction of the signal
- Backgrounds are small and have negligible asymmetries
- We have MAGNET UP and MAGNET DOWN data samples of almost equal size, which allow to average out residual charge asymmetries in detection efficiency.

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Note: Small means ~ 1%

ANALYSIS METHOD

PHILOSOPHY: DATA DRIVEN ANALYSIS, ALL CORRECTIONS ARE DERIVED FROM DATA, WITH TWO INDEPENDENT METHODS, WHENEVER POSSIBLE.

- **Determination of the signal yields $D_s^{\pm}\mu^{\mp}, D_s^{\pm} \to \varphi\pi^{\pm}$ with 2011 full data set: 447 pb^{-1} collected with magnet polarity UP and 595 pb^{-1} collected with magnet polarity DOWN**
- **$\varphi \to K^{+}K^{-}$ mass cut provides almost equal kaon momentum spectra.**
- **Detailed analysis of background sources, mostly data based on data.**
- **Efficiency ratio derived from calibration samples, can be expressed as**

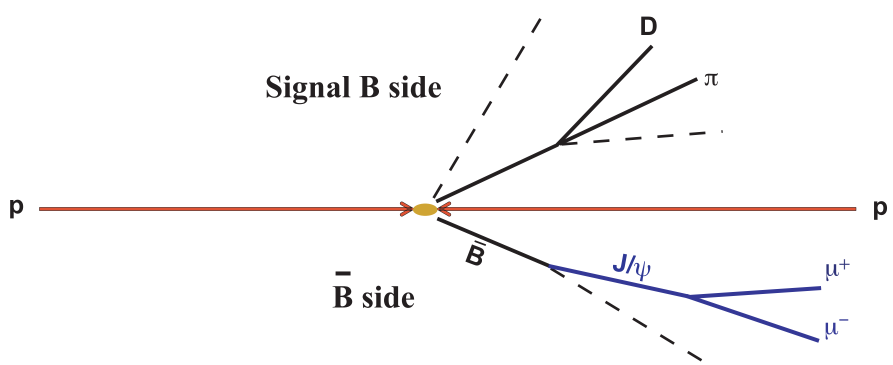
$$\epsilon(D_s^- \mu^+) = \epsilon_{\rm id}(\mu^+) \times \epsilon_{\rm Trigger}(D_s^- \mu^+)\,,$$

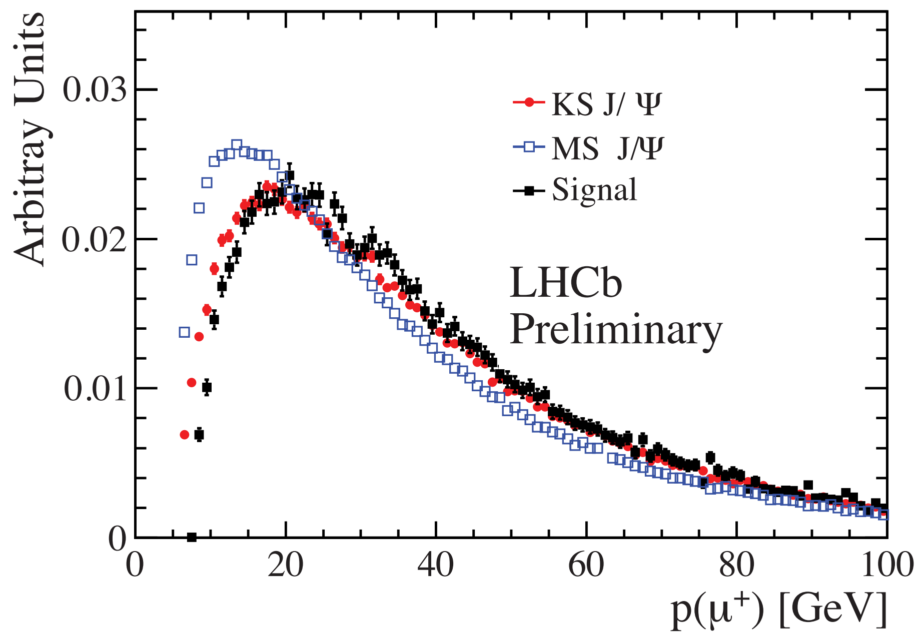
4 CALIBRATION SAMPLES

1. Partially reconstructed $D^{*+} \to \pi^+ D^0, D^0 \to K^- \pi^- \pi^+ (\pi^+)$ demonstrated that tracking efficiency ratio $\varepsilon(\pi^+)/\varepsilon(\pi^-)$ does not depend upon particle momentum. Since π and μ have opposite charges in $D_s^{\mp}\mu^{\pm}$, the tracking efficiencies cancel out.
2. Kinematically selected $J/\psi \to \mu^+\mu^-$ in samples triggered by hadronic B decays not including J/ψ in the final state
3. Muon selected $J/\psi \to \mu^+\mu^-$ where one detached J/ψ track is found by combining it with an opposite sign track that is well identified as a muon (tag muon)
4. $B \to D^+\mu^- X$ with $D^+ \to K^-\pi^+\pi^+$ for software trigger checks

KINEMATICALLY SELECTED

$J/\psi \to \mu^+\mu^-$

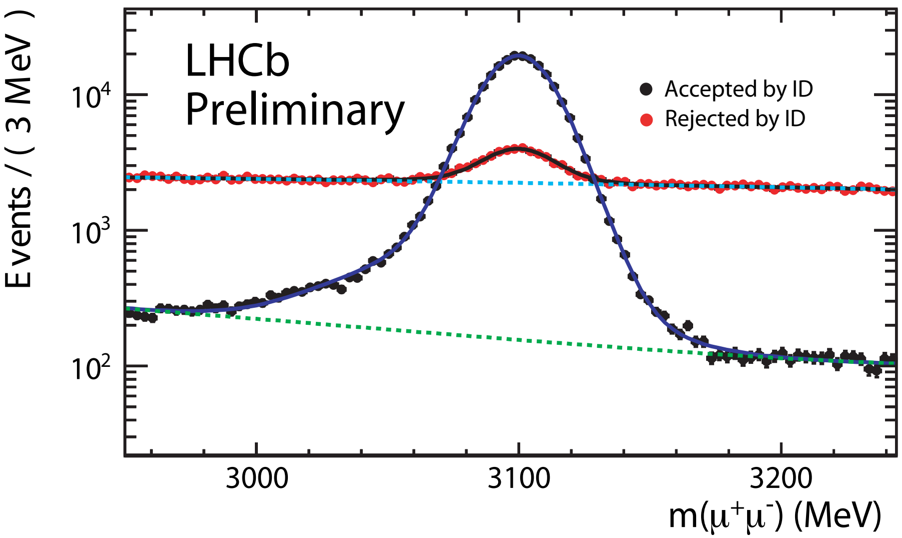




- $J/\psi \to \mu^+\mu^-$ selected in events triggered by b-hadron not decaying into a J/ψ
- We divide calibration and signal samples into 50 p-p_x-p_y bins to reduce sensitivity to kinematic biases

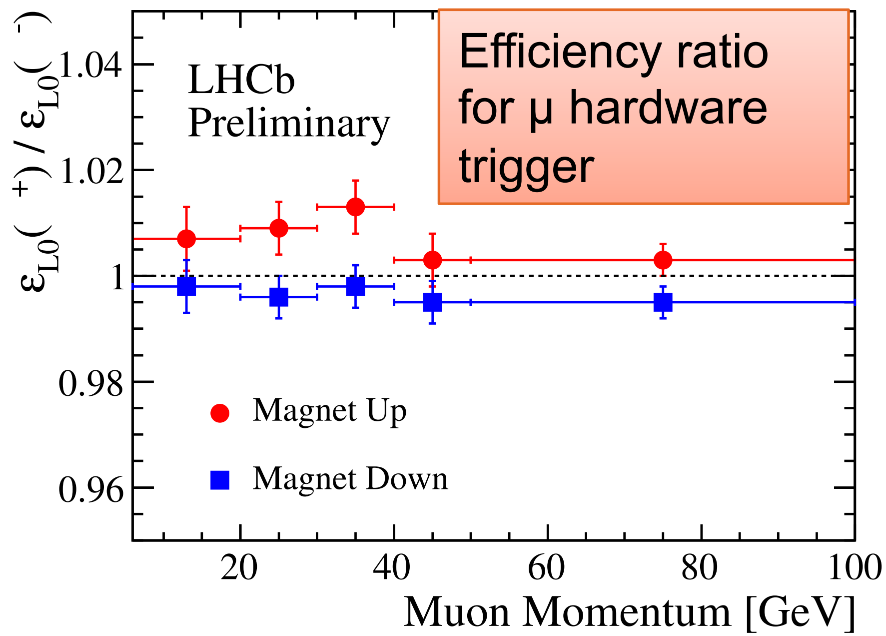
EFFICIENCY RATIOS

Magnet up,muon identification



The KS J/ψ is used to determine $\varepsilon(\mu^+)/\varepsilon(\mu^-)$ for the muon identification algorithm and muon dependent triggers

Efficiency ratio for μ hardware trigger

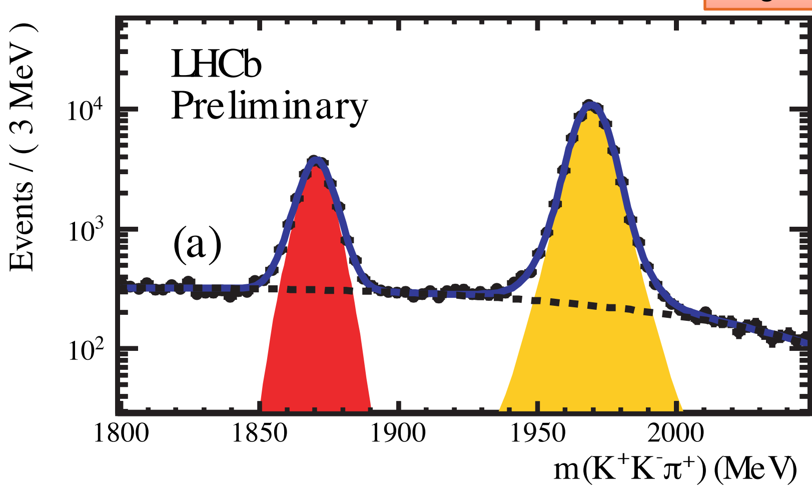


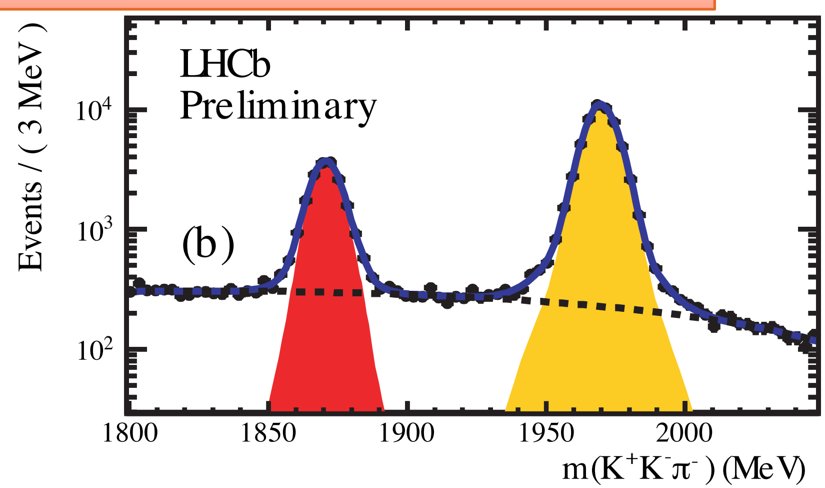
THE SIGNAL YIELDS

- Signal yields are extracted through invariant mass fits.
- Default method includes PDFs for D_s and D^+ signals, and 2nd order Chebyshev polynomials for combinatorial background.
- Alternative PDFs used both for signal and background for sys. checks.

	Magnet UP	Magnet Down
$D_s^- \mu^+$	40,945±285	55,755±278
$D_s^+ \mu^-$	39,849±239	56,447±294

$D_s\mu$ candidates – magnet DOWN data

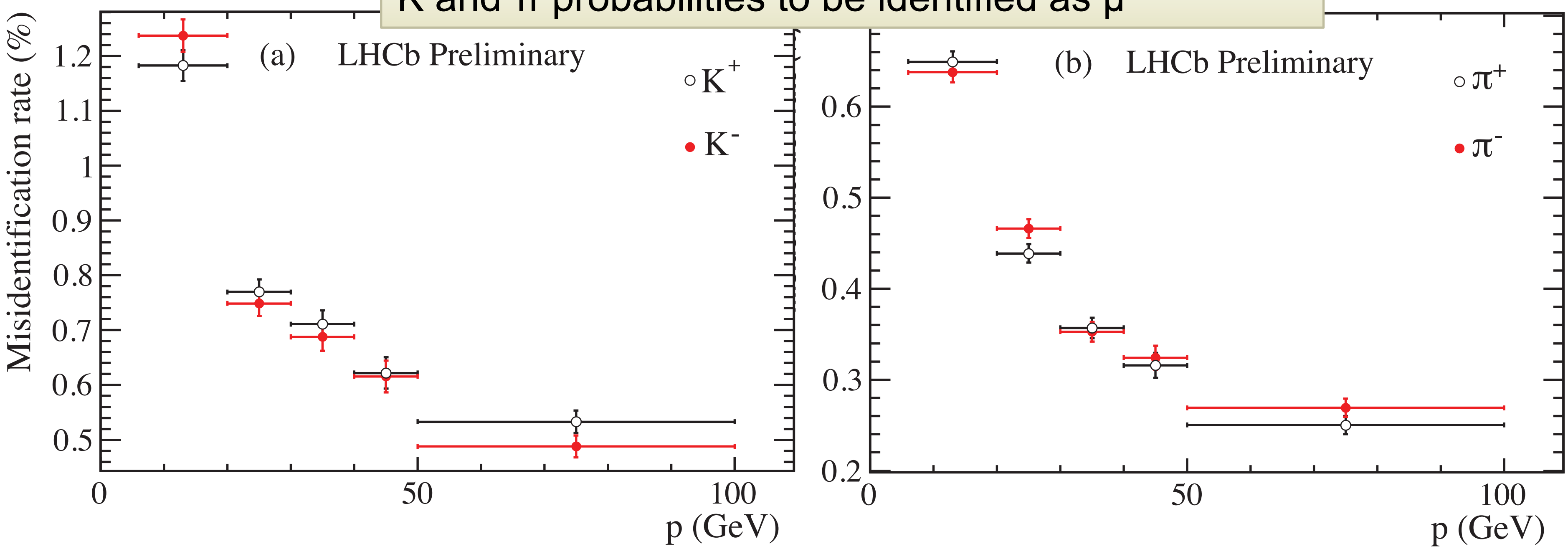




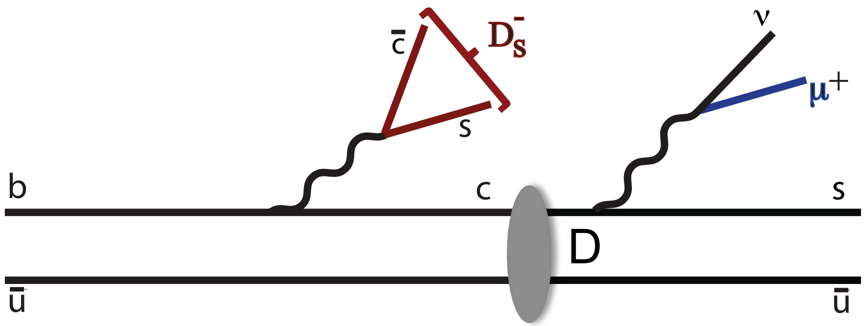
MISIDENTIFIED MUON BACKGROUND

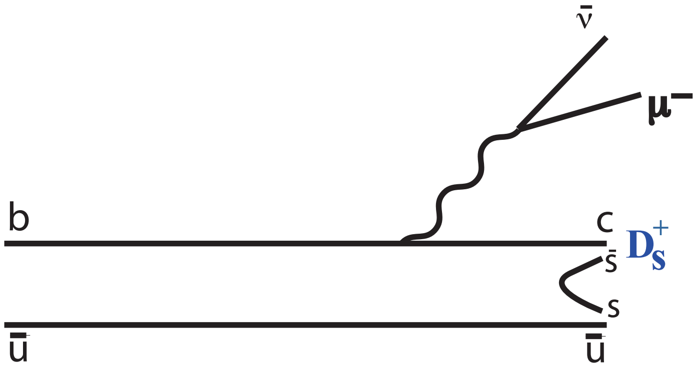
- This background is assessed with $B \to D_s \pi X$ and $D_s K X$ samples
- K & π probabilities to be identified as μ derived from $D^{*+} \to D^0 \pi^+$, $D^0 \to K^- \pi^+$ calibration sample
- For each momentum bin this background <1% of signal
- Asymmetry in $K^\pm(\pi^\pm) \to \mu^\pm$ fake rates ~1%, so product is ~10^{-4}

K and π probabilities to be identified as μ



BACKGROUND FROM $B \to D_s DX$ & $B \to D_s K \mu \nu X$





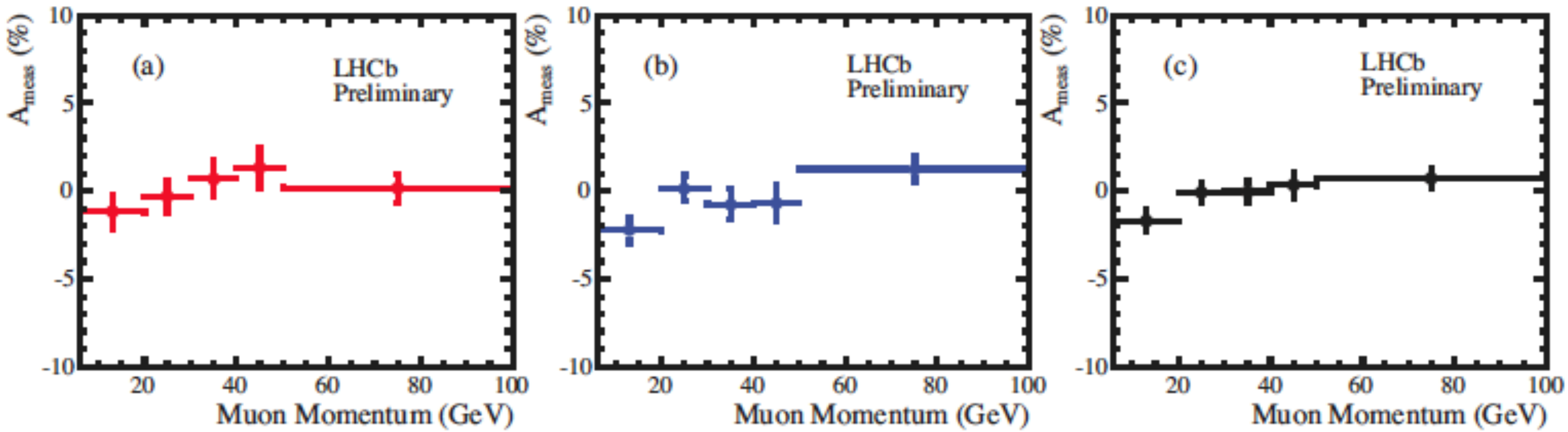
- Background $D_s\mu$ combinations produced by $b \to c\bar{c}s$ where D_s originates from $W \to \bar{c}s$ and the charmed hadron decays semileptonically
- Taking into account 33% suppression factor due to B^0 mixing, we get an overall background fraction of (3.5±0.9)%
- Assuming 1.5% production asymmetry, we assign 0.05% uncertainty to this source
- Background from $B \to D_s K \mu \nu X$ is (3.3±0.9)% and production asymmetry tend to cancel with previous contribution ⇨ we do not assign additional systematic uncertainty.

THE MEASURED ASYMMETRY

Magnet Up
Preliminary A_{meas}=
(0.10±0.41±0.15)%

Magnet Down
Preliminary A_{meas}=
(-0.34±0.35±0.13)%

Average
Preliminary A_{meas}=
(-0.12±0.27±0.10)%



SYSTEMATIC UNCERTAINTIES (PRELIM.)

Source	$\sigma(A_{meas})$(%)
Signal modelling in D_s mass fit	0.06
Background from other *b* hadrons	0.05
Momentum difference between π and μ	0.06
Momentum differencee between same sign and opposite sign kaons	0.02
Varying run conditions between field-up and field-down	0.01
Muon corrections	0.05
Muon misidentification	0.01
Muon related software trigger biases	0.05
Statistical uncertainty on the efficiency ratios	0.10
Total	**0.16**

RESULTS [LHCb-CONF-2012-022]

a_{sl}^{s} =2A_{meas} ➪ we obtain the preliminary result

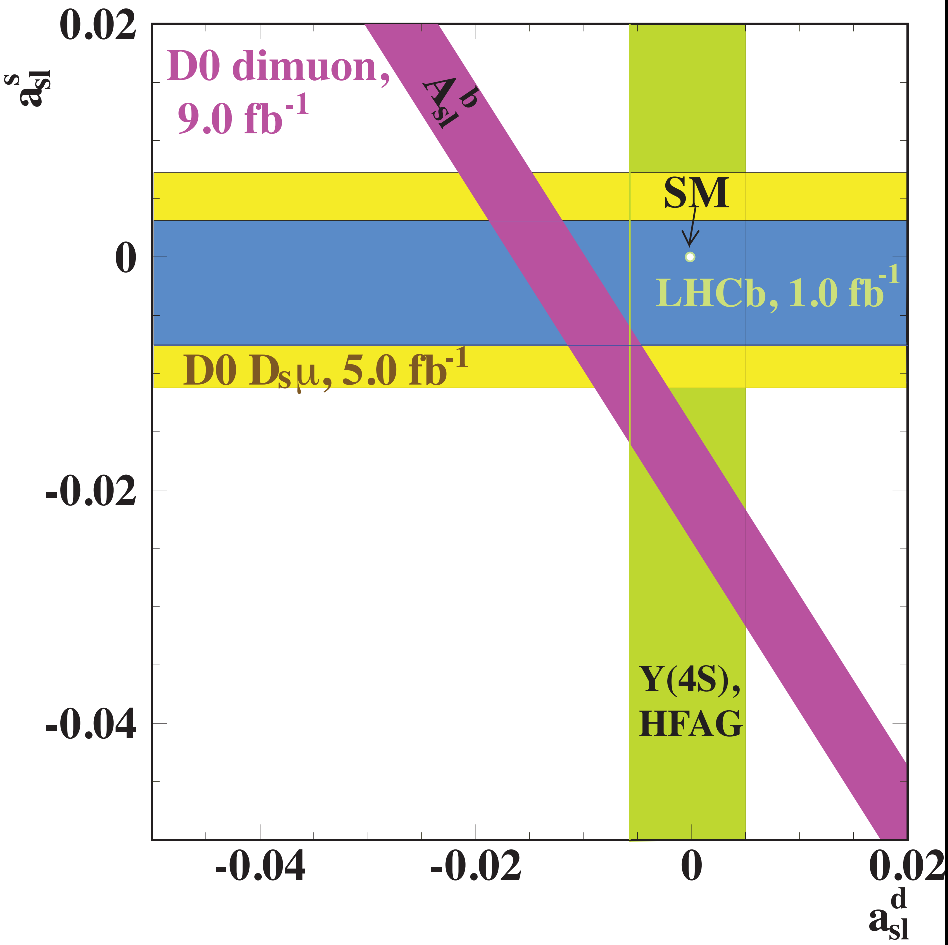
$$a_{sl}^{s} = (-0.24 \pm 0.54 \pm 0.33)\%$$

➪ Most precise measurement of a_{sl}^{s}

➪ In agreement with Standard Model's prediction (Lenz, arXiv:1205.1444)

$$a_{sl}^{s} = (0.0019 \pm 0.0003)\%$$

$$a_{sl}^{d} = (-0.041 \pm 0.0006)\%$$



LHCb, b-FACTORIES AND D0 [PHYS.REV.D84(2011)052007]

D0 result $A_{sl}^{b} = (-0.787 \pm 0.172 \pm 0.093)\% = 0.594 a_{sl}^{s} + 0.406 a_{sl}^{d}$

a) a_{sl}^{d} **is consistent with SM** ⇨ $a_{sl}^{s}(\mathrm{D0}) = (-1.94 \pm 0.49)\%$

(compatible at 1.8 σ with our result)

b) a_{sl}^{s} **is consistent with SM** ⇨ $a_{sl}^{d}(\mathrm{D0}) = (-1.32 \pm 0.33)\%$

(compatible with Y(4S) at 1.6 σ)

c) $a_{sl}^{s} = a_{sl}^{d}$ ⇨ $a_{sl}^{s}(\mathrm{D0}) = a_{sl}^{d}(\mathrm{D0}) = (-0.79 \pm 0.20)\%$

(compatible with Y(4S) and LHCb results at 1.4 σ)

CONCLUSIONS

- LHCb reports the preliminary result

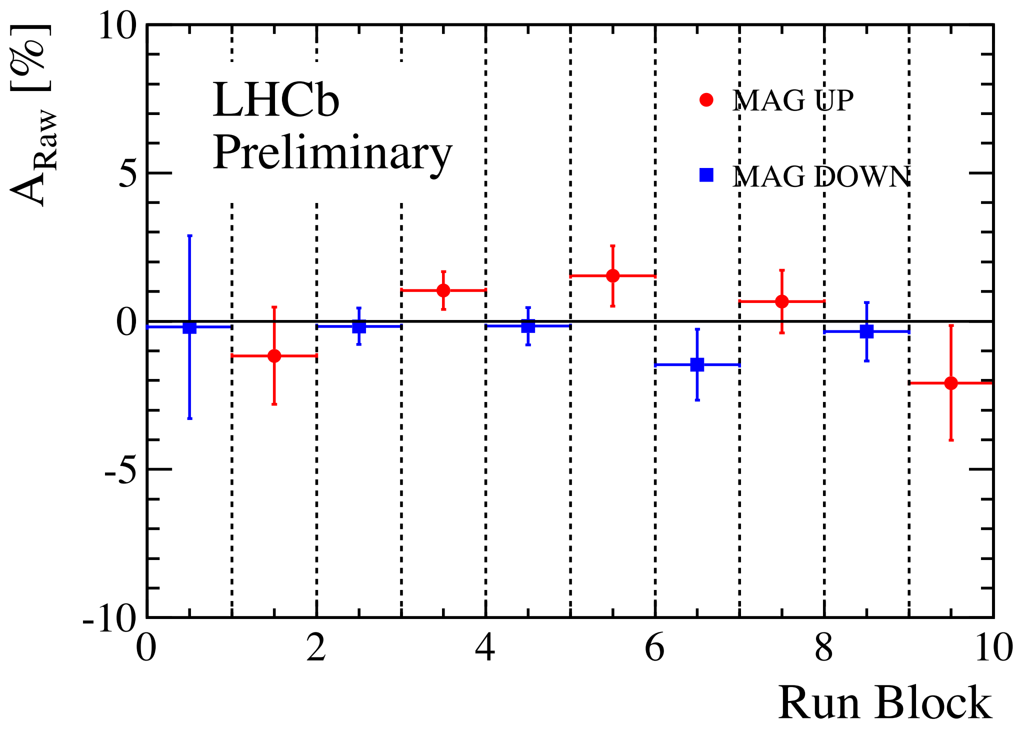
$$a_{sl}^{s} = (-0.24 \pm 0.54 \pm 0.33)\%$$

- This result is consistent with the SM prediction of ~0
- Not the end of the story: more D_s decay modes will be added soon and additional ~2 fb^{-1} expected by the end of the year

THE END

SYSTEMATIC CHECKS

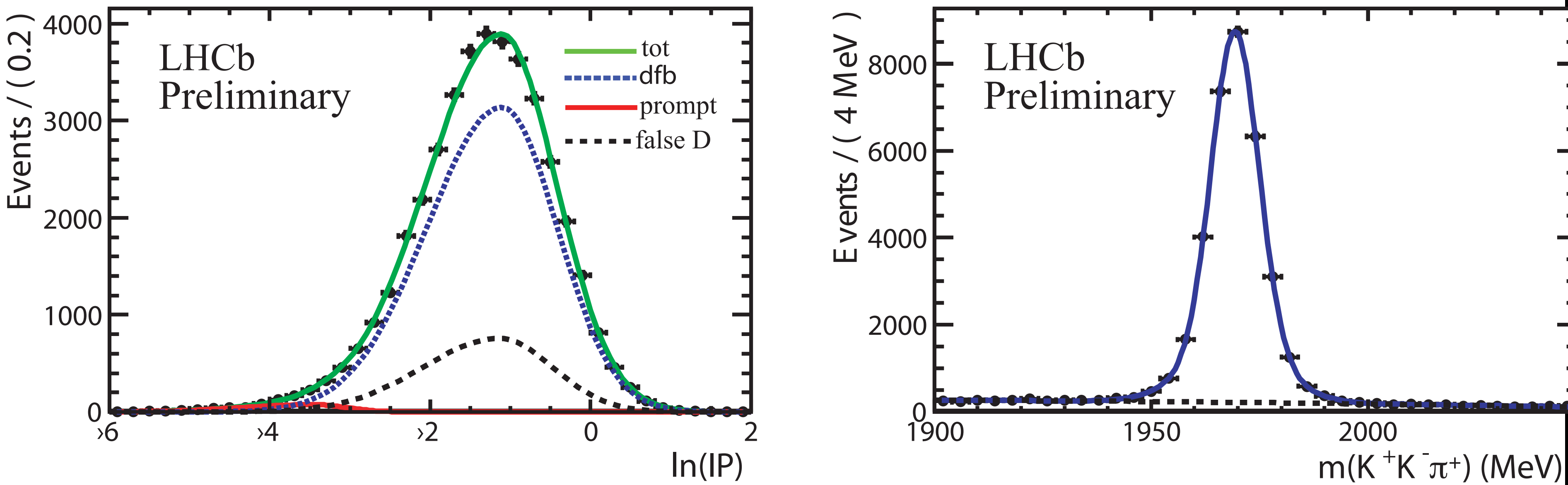
We have studied the sensitivity of the raw asymmetry (not corrected for efficiency ratios) as a function of several variables (time, muon pt, event multiplicity) and we found no evidence of systematic biases.



PROMPT D_s BACKGROUND

Small prompt D_s fraction (1.4±0.01)% & D_s production asymmetry (-0.33±0.22±0.10)% **arXiv:1205.0897 [hep-ex]**➔it can be neglected

$D_s^+ \mu^-$, magnet down



MISIDENTIFIED MUON BACKGROUND

Hadrons identified as K
Full μ momentum range