Precision measurement of the oscillation frequency in the B_s^0-$\overline{B_s^0}$ system

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On behalf of the LHCb collaboration

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B-oscillation

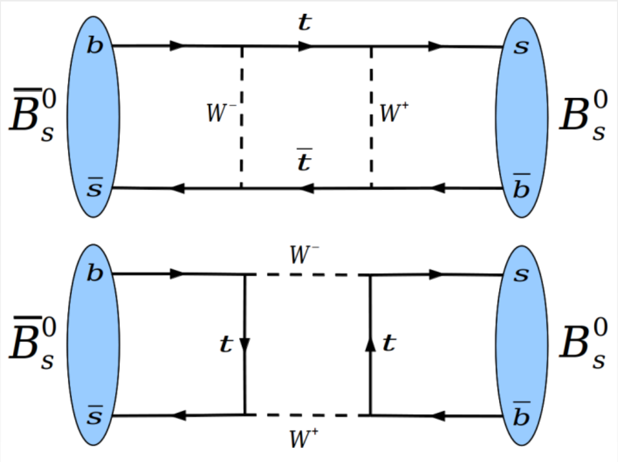
Simplified Schroedinger equation describing oscillation and decay

$$i\frac{d}{dt}\begin{pmatrix} B_s^0 \\ \overline{B_s^0} \end{pmatrix} = \left(M - \frac{i}{2}\Gamma\right)\begin{pmatrix} B_s^0 \\ \overline{B_s^0} \end{pmatrix} \qquad \mathrm{M} = \begin{pmatrix} M_{11} & M_{12} \\ M_{12}^* & M_{22} \end{pmatrix}; \Gamma = \begin{pmatrix} \Gamma_{11} & \Gamma_{12} \\ \Gamma_{12}^* & \Gamma_{22} \end{pmatrix}$$

Mass eigenstates ≠ flavour eigenstates → mass difference ∝ osc. frequency

$$|B_L\rangle = k|B_s^0\rangle + l|\overline{B_s^0}\rangle$$
$$|B_H\rangle = k|B_s^0\rangle - l|\overline{B_s^0}\rangle$$

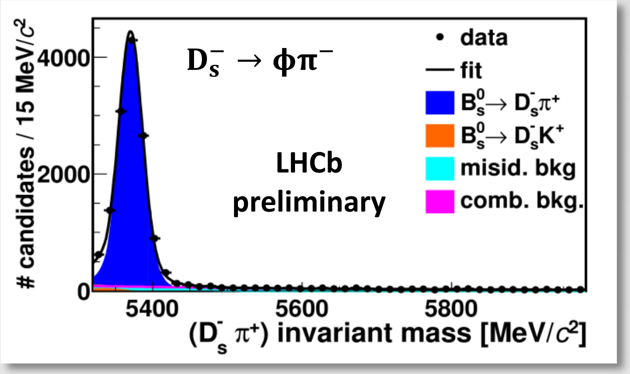
$$\Delta m_q = m_H - m_L = 2|M_{12}^q|$$

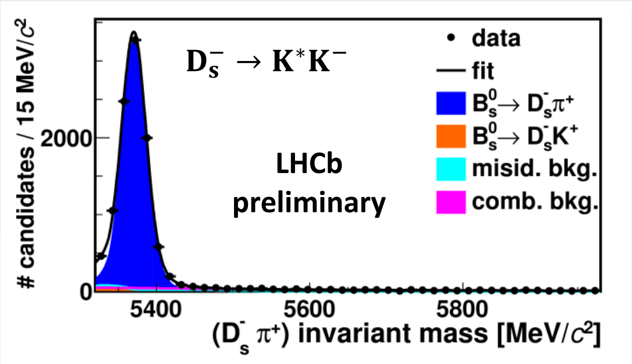


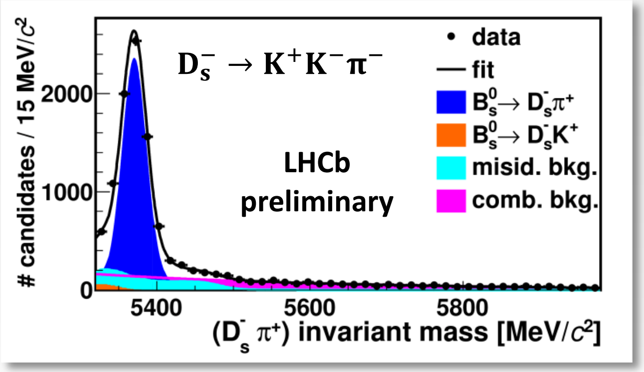
Dominant Feynman diagrams
(Standard Model)

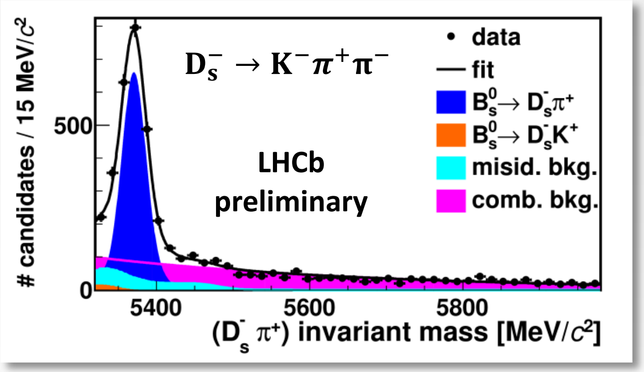
Analysis strategy

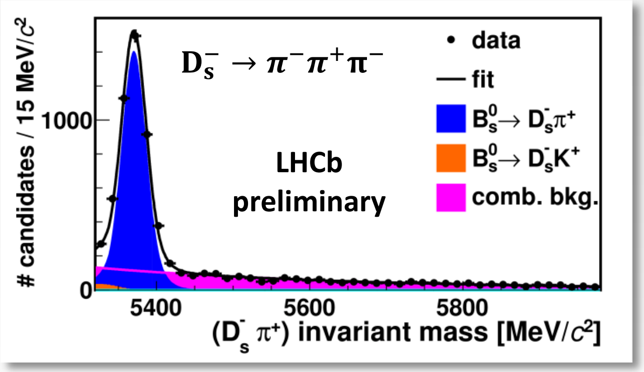
- Use data set taken in 2011
  (integrated luminosity 1 fb^{-1})
- Reconstruct $B_s^0 \to D_s^- \pi^+$ in 5 different D_s^- decay modes
- ~ 34000 signal candidates
- Mean decay time resolution 44 fs
- Need flavour at production
  → flavour tagging algorithms
- Use invariant mass to separate signal from background
- Unbinned maximum likelihood fitter in mass and decay time
- Blinded analysis







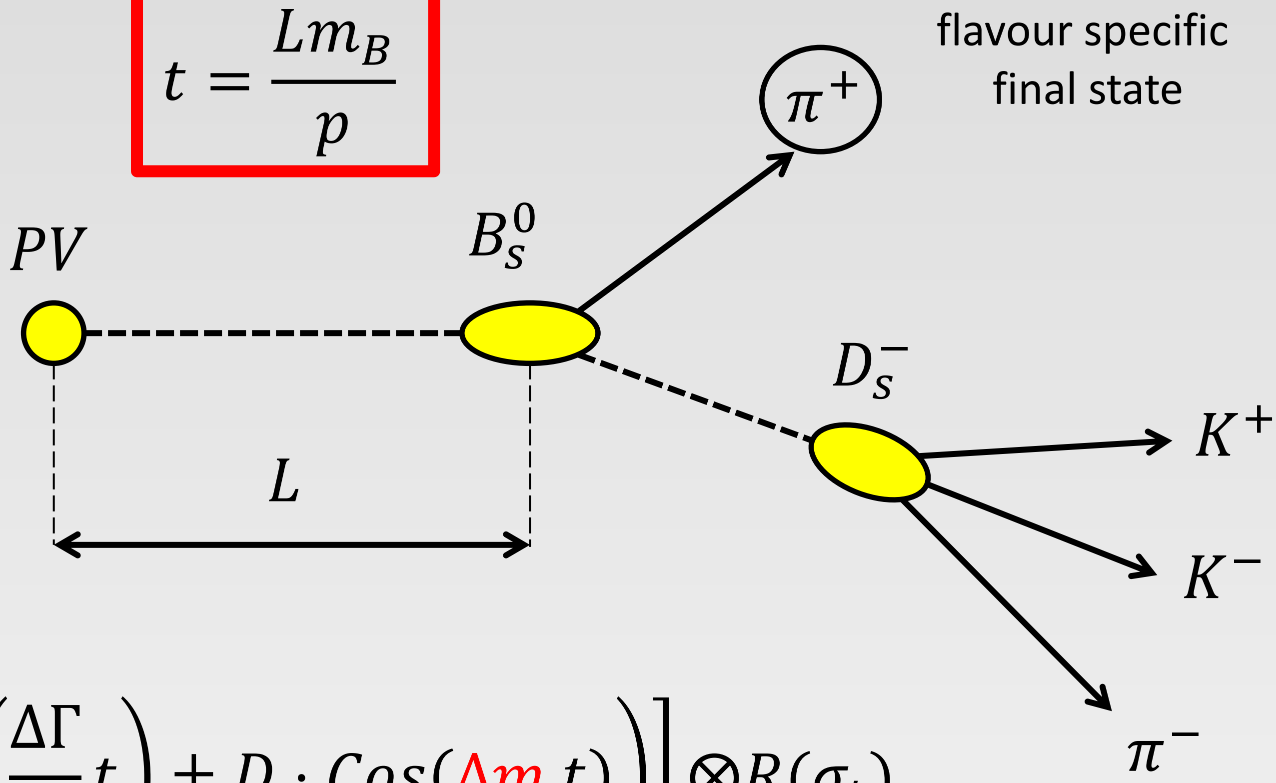




Decay time

Need decay time dependent analysis

$$\boxed{t = \frac{L m_B}{p}}$$



Decay time PDF:

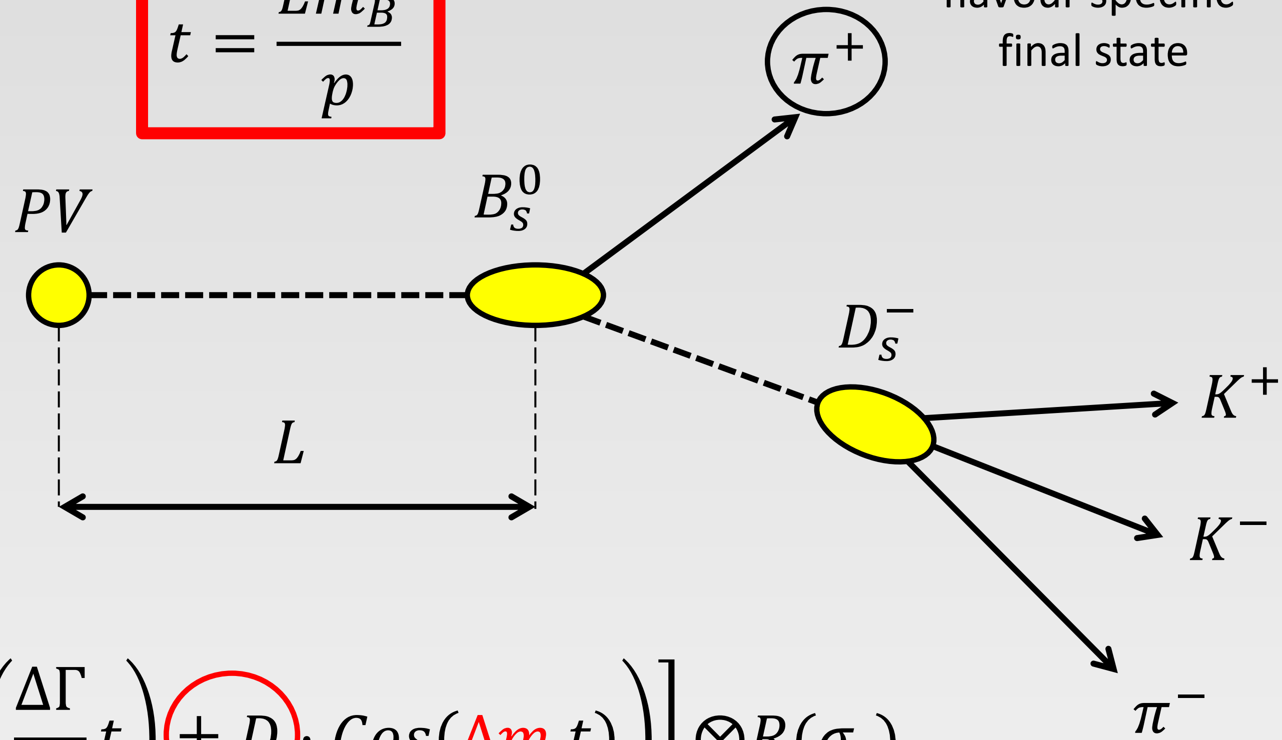
$$PDF \propto \left[e^{-\Gamma t} \cdot \left(Cosh\left(\frac{\Delta\Gamma}{2} t \right) \pm D \cdot Cos(\Delta m\ t) \right) \right] \otimes R(\sigma_t)$$

Decay time

Need decay time dependent analysis

$$\boxed{t = \frac{L m_B}{p}}$$

flavour specific final state



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Production flavour from tagging algorithms

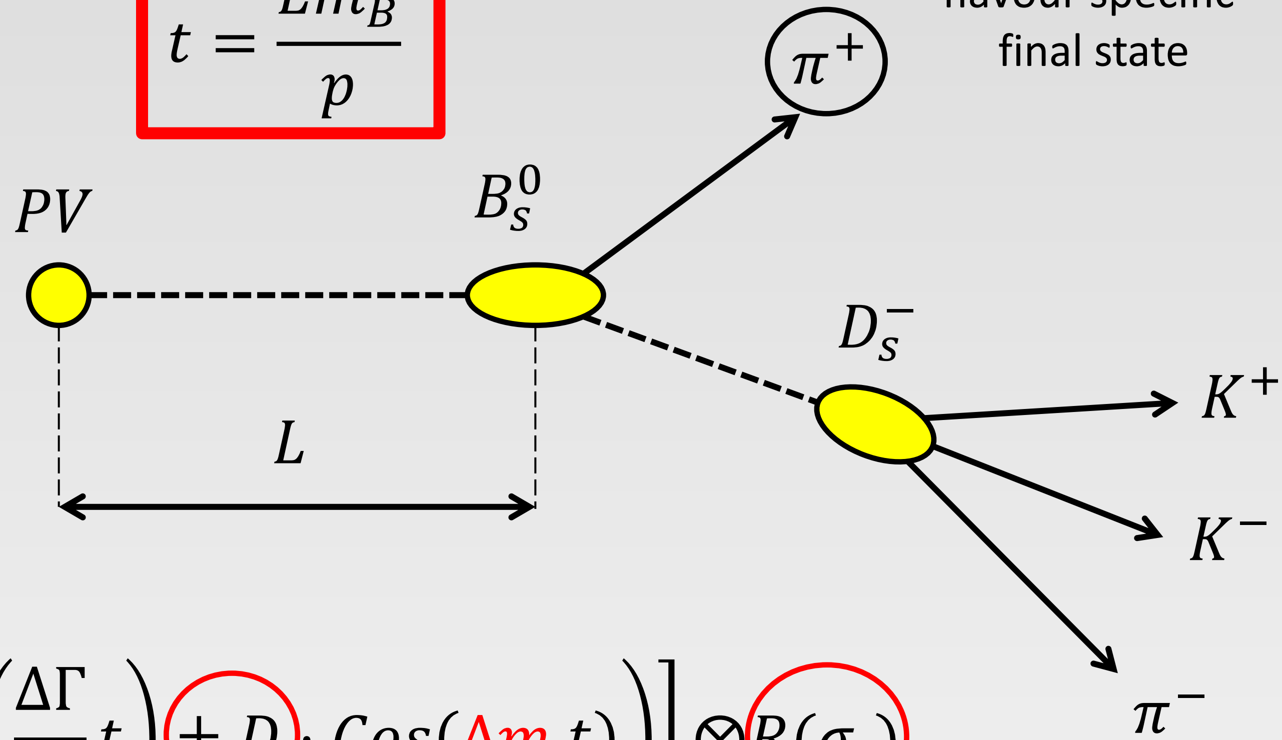
$D = (1 - 2\omega_{mistag})$

Decay time

Need decay time dependent analysis

$$\boxed{t = \frac{L m_B}{p}}$$

flavour specific final state



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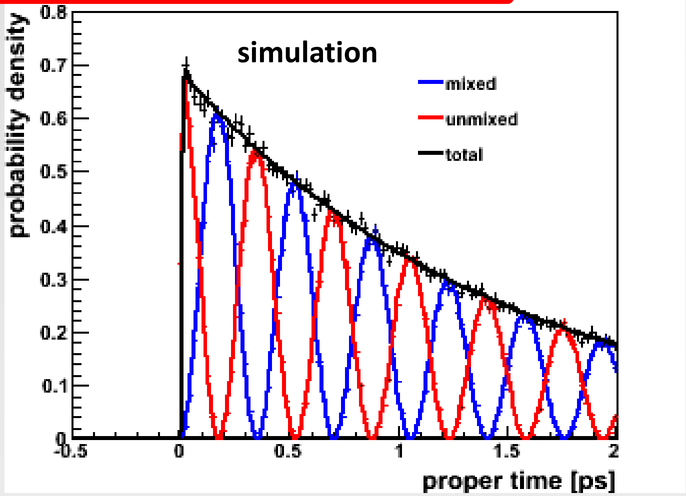
Production flavour from tagging algorithms
$D = (1 - 2\omega_{mistag})$

Need excellent decay time resolution

Measuring Δm_s

significance: $\sigma(\Delta m_s) \propto \sqrt{\varepsilon D^2} e^{-\frac{(\Delta m_s \sigma_t)^2}{2}}$

perfect tagging + resolution



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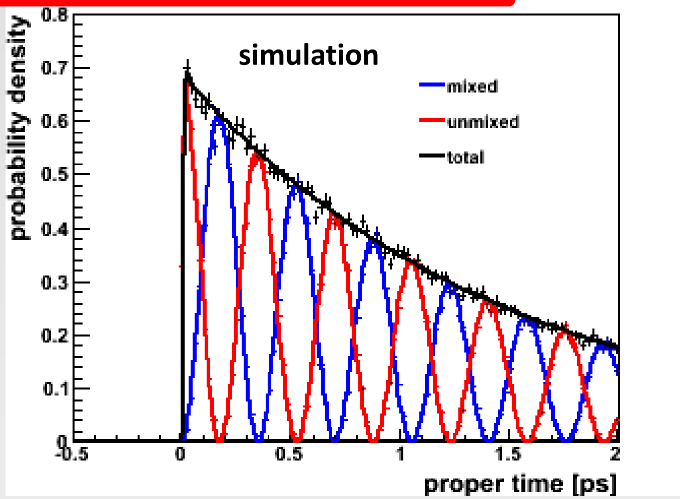
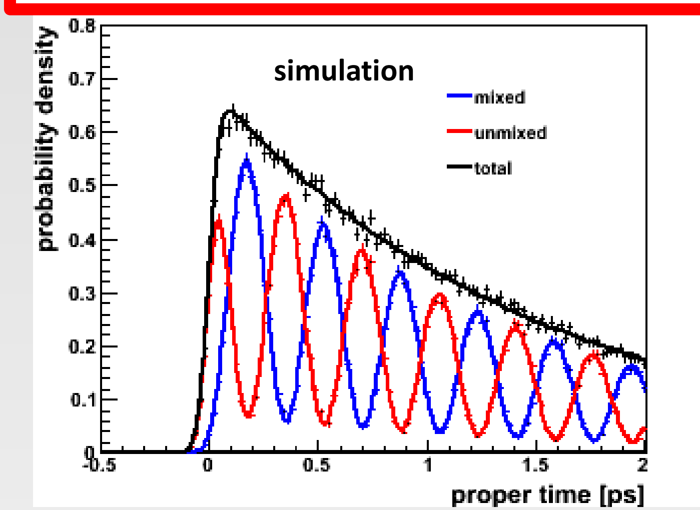


$\sim$ 70% for
$\sigma_t = 44$ fs

perfect tagging, realistic resolution

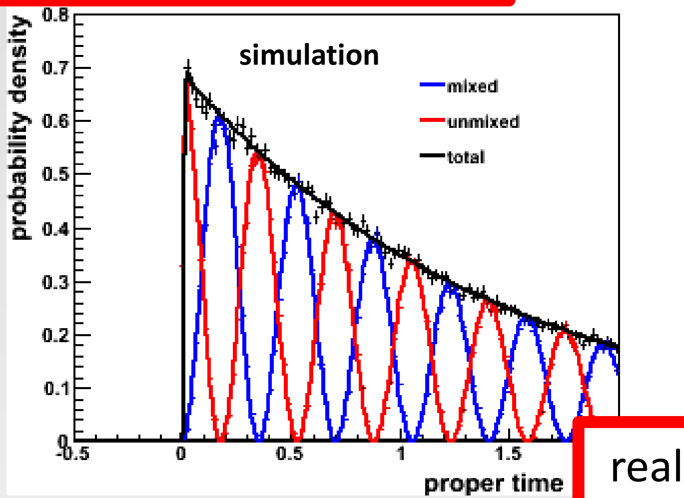


Measuring Δm_s

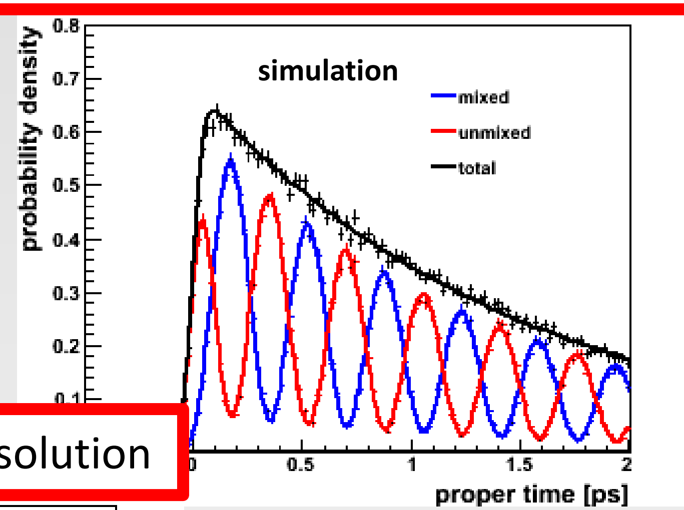
significance: $\sigma(\Delta m_s) \propto \sqrt{\varepsilon D^2} e^{-\frac{(\Delta m_s \sigma_t)^2}{2}}$

3.5% in data

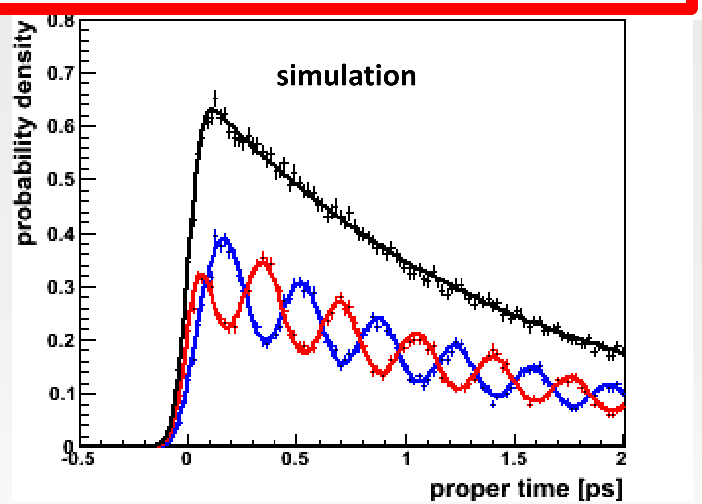
perfect tagging + resolution



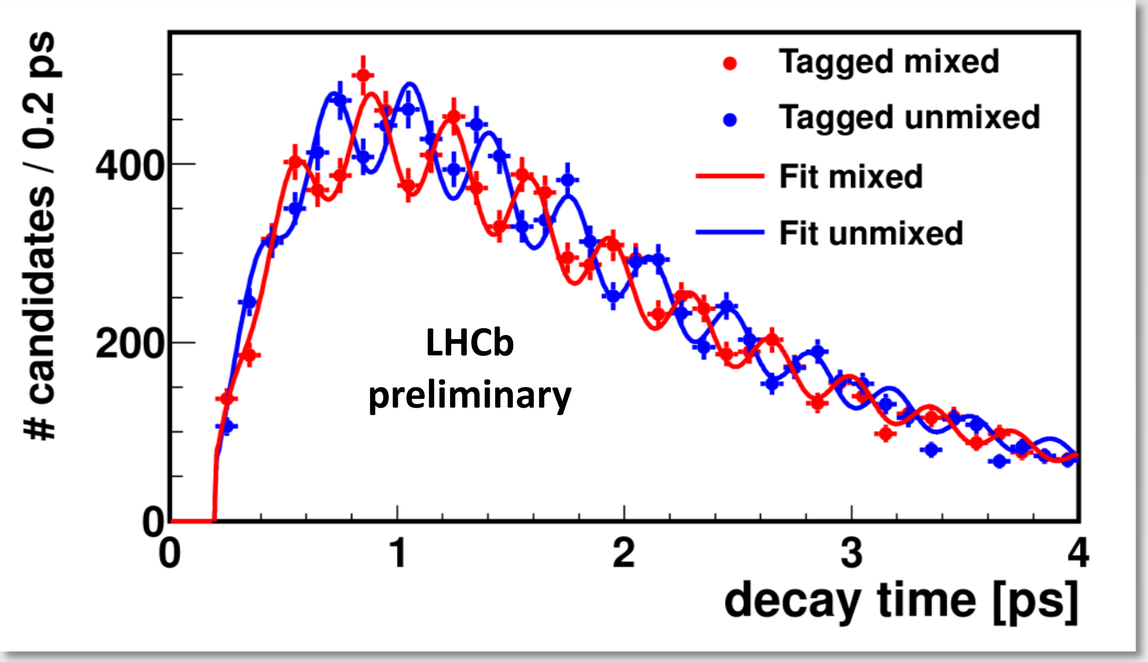
perfect tagging, realistic resolution



realistic tagging, realistic resolution

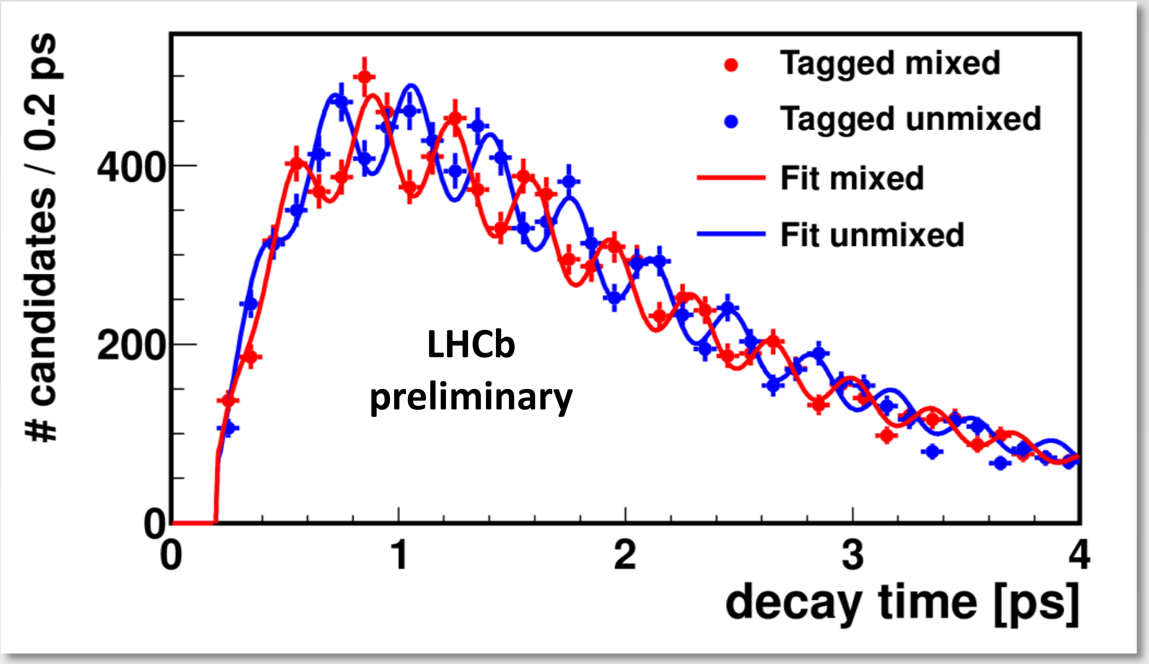


Result



candidates / 0.2 ps
400
200
0
0
1
2
3
4
decay time [ps]
Tagged mixed
Tagged unmixed
Fit mixed
Fit unmixed
LHCb
preliminary

Result



New result (preliminary)

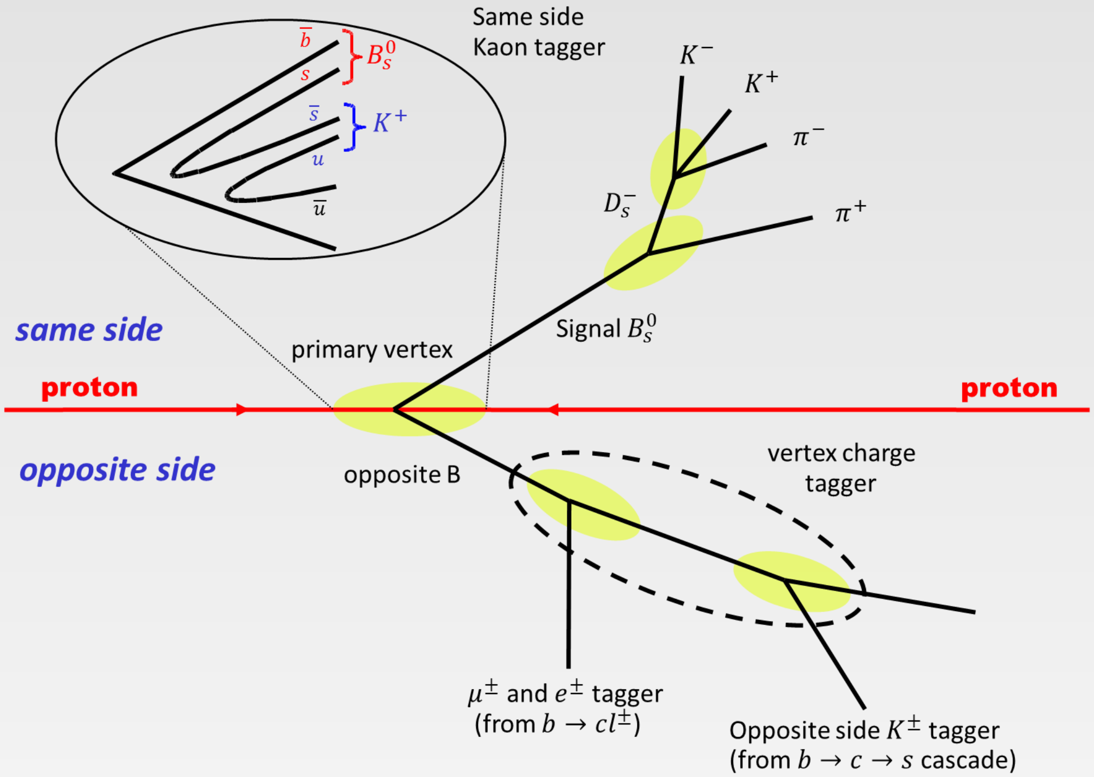
$$\Delta m_s = 17.768 \pm 0.023(stat) \pm 0.006(syst)\ ps^{-1}$$

Dominant systematics from decay length scale and momentum scale

Backup

Flavour Tagging

Tagging efficiency	Mistag probability	Dilution
$\varepsilon = \dfrac{\#\,tagged\ candidates}{\#\,all\ candidates}$	$\omega = \dfrac{\#\,tagged\ wrong}{\#\,tagged}$	$D = (1 - 2\omega)$



- Opposite side taggers
  - exploits $b\bar{b}$ pair production by partially reconstructing the second B-hadron in the event
- Same side kaon tagger
  - exploits hadronization of signal B_s-meson
- Combined tagging power
  - $\varepsilon D^2 = 3.5 \pm 0.5\%$