Measurement of the semileptonic CP asymmetry in B^0–$\overline{B}^0$ mixing

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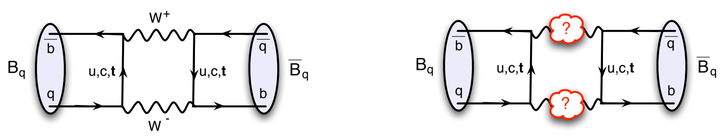
New physics?

- Universe is matter-dominated
- CP-asymmetry in Standard Model (SM) too small
- New particles could enhance the asymmetry
- Search for deviations from SM in loop processes

Mixing

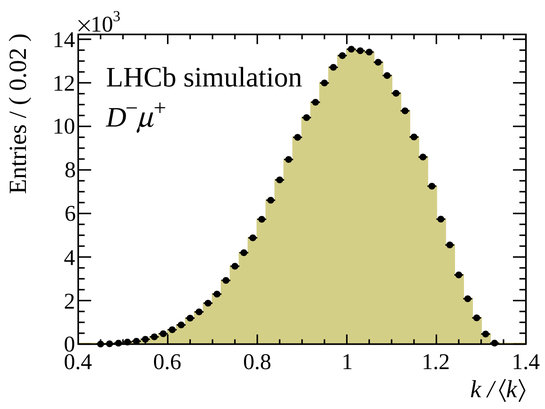
- Mass states $\neq$ flavour eigenstates
- $B^0_{d,s}$ and $\overline{B}^0_{d,s}$ mix over time!



$$i\frac{d}{dt}\begin{pmatrix} |B_q(t)\rangle \\ |\overline{B}_q(t)\rangle \end{pmatrix} = \begin{pmatrix} M_{11} - i\frac{\Gamma_{11}}{2} & M_{12} - i\frac{\Gamma_{12}}{2} \\ M^*_{12} - i\frac{\Gamma^*_{12}}{2} & M_{22} - i\frac{\Gamma_{22}}{2} \end{pmatrix}\begin{pmatrix} |B_q(t)\rangle \\ |\overline{B}_q(t)\rangle \end{pmatrix}$$

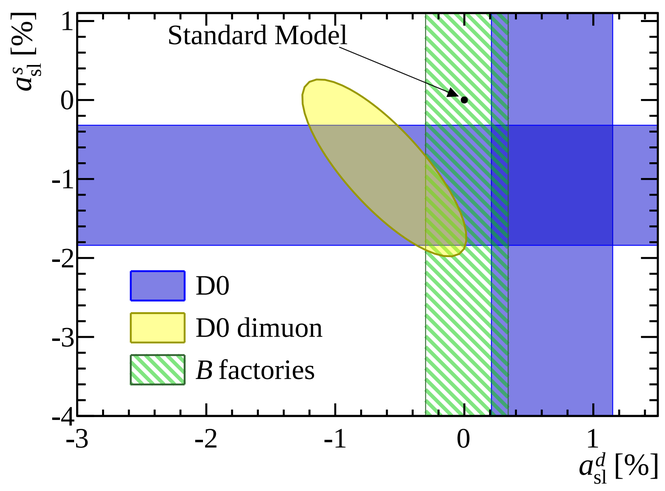
- Mass eigenstates:
  - $\left|B_q^{H,L}\right\rangle = p\left|B_q\right\rangle \pm q\left|\overline{B}_q\right\rangle$
  - $\Delta m_q = m_q^H - m_q^L$
  - $\Delta\Gamma_q = \Gamma_q^L - \Gamma_q^H$
- CP-Violation in mixing: $P(B_q \to \overline{B}_q) \neq P(\overline{B}_q \to B_q)$

K-factors



- $t = \frac{M(B)L}{p(B)c}$
- Neutrino: missing momentum in system
- Correction from simulation: $k = \frac{p_{\text{rec}}}{p_{\text{true}}}$

Experimental status before LHCb

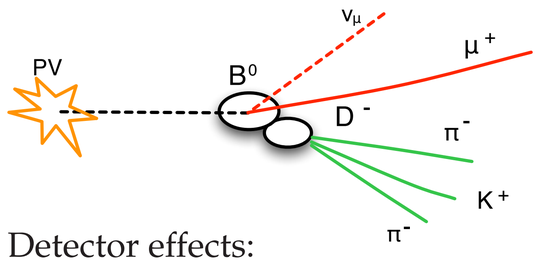


- **Standard Model:** $a_{sl} = 0$**!** [1]
  $a^d_{sl} = (-4.1 \pm 0.6) \times 10^{-4}$
  $a^s_{sl} = (1.9 \pm 0.3) \times 10^{-5}$
- Best measurements by B-factories (green) [2] and D0 (blue) [3]
- D0 dimuon result:
  3.6σ deviation from SM [4]

ASLD

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

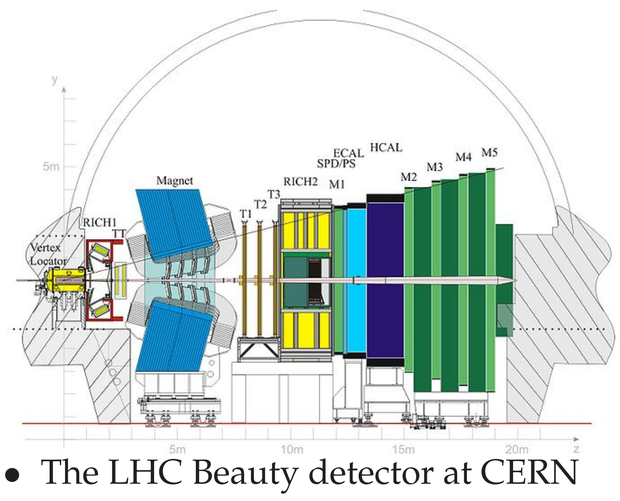
- Use abundant semileptonic decays
- CP Violation in B^0 mixing: a^d_{sl}



- Detector effects:

$$A_{\text{meas}}(t) = \frac{N(f,t) - N(\bar{f},t)}{N(f,t) + N(\bar{f},t)} = \frac{a^d_{sl}}{2} + A_D - \left(A_P + \frac{a^d_{sl}}{2}\right)\frac{\cos(\Delta m_d)}{\cosh\left(\frac{\Delta\Gamma_d t}{2}\right)}$$

LHCb



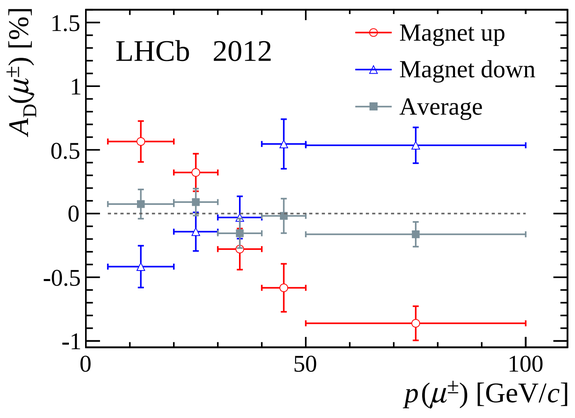
- The LHC Beauty detector at CERN
  - Forward spectrometer specialized in B decays
  - Momentum resolution: $\Delta p/p$ = (0.4-0.6)%
  - Proper time resolution $\sim$ 45 fs
- Production asymmetry A_P: $N(B) \neq N(\bar{B})$
- Detection asymmetry A_D: $\epsilon(f) \neq \epsilon(\bar{f})$

Detection Asymmetries

- Measure $A_D \to$ leave A_P free in fit

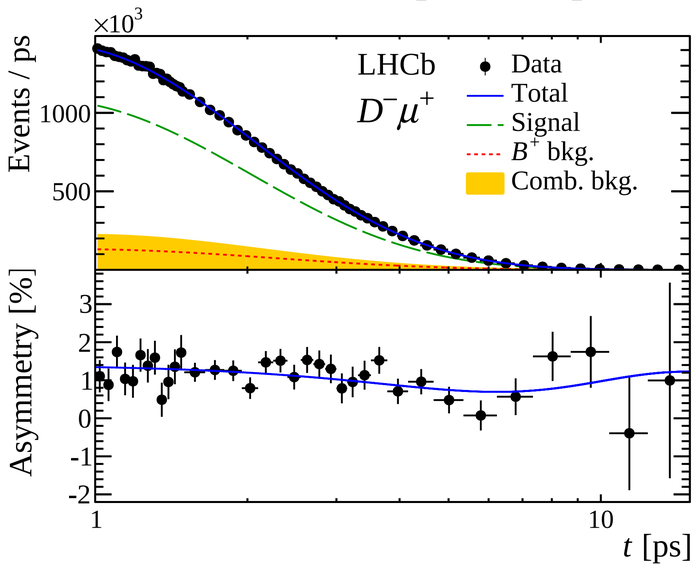
$$A_{\text{D}} = \frac{\epsilon(\mu^+K^+\pi^-\pi^-) - \epsilon(\mu^-K^-\pi^+\pi^+)}{\epsilon(\mu^+K^+\pi^-\pi^-) + \epsilon(\mu^-K^-\pi^+\pi^+)}$$

- Tracking, trigger and selection asymmetries
- Grouped by $A_D(K^+\pi^-) + A_D(\mu^+\pi^-)$
- Use Tag and Probe J/ψ & prompt D decays



LHCb Results: Phys. Rev. Lett. 114, 041601 (2015) [5]

$$\mathcal{P}_{sig}(t,q) = \mathcal{N}e^{-\Gamma_d t}\left(1 \pm A_D \pm \frac{a^d_{sl}}{2} \mp \left(A_P + \frac{a^d_{sl}}{2}\right)\cos(\Delta m_{\text{d}} t)\right)$$



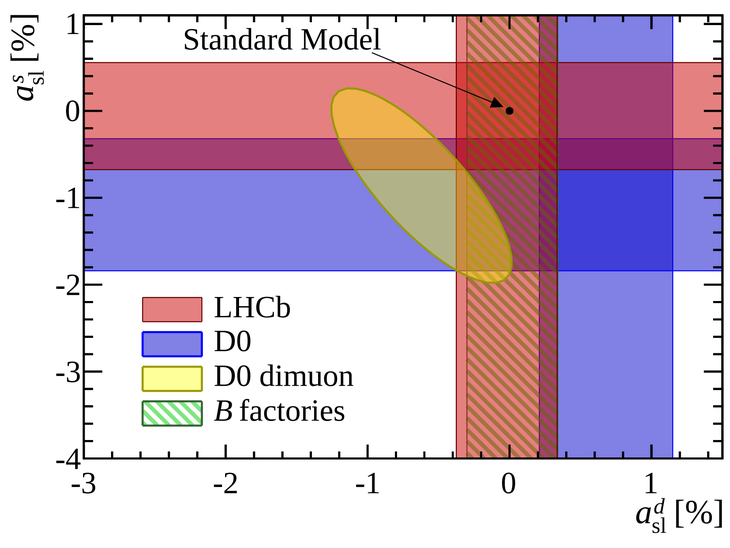
$$\mathbf{a^d_{sl} = (-0.02 \pm 0.19(\text{stat}) \pm 0.30(\text{syst}))\%}$$

$$\mathbf{A_P}(7\text{ TeV}) = (-\mathbf{0.66 \pm 0.26}(\text{stat}) \pm \mathbf{0.22}(\text{syst}))\%$$
$$\mathbf{A_P}(8\text{ TeV}) = (-\mathbf{0.48 \pm 0.15}(\text{stat}) \pm \mathbf{0.17}(\text{syst}))\%$$

- Largest systematics:
  - size of A_D calibration samples
  - B^+ background asymmetry

$\to$ **World's best measurement to date**

a^s_{sl} 1 fb^{-1} result by LHCb: [6]
$(-0.06 \pm 0.50(\text{syst}) \pm 0.36(\text{stat}))\%$



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Special thanks to Lucia Grillo