Measurement of D meson mixing with semileptonic decays at LHCb

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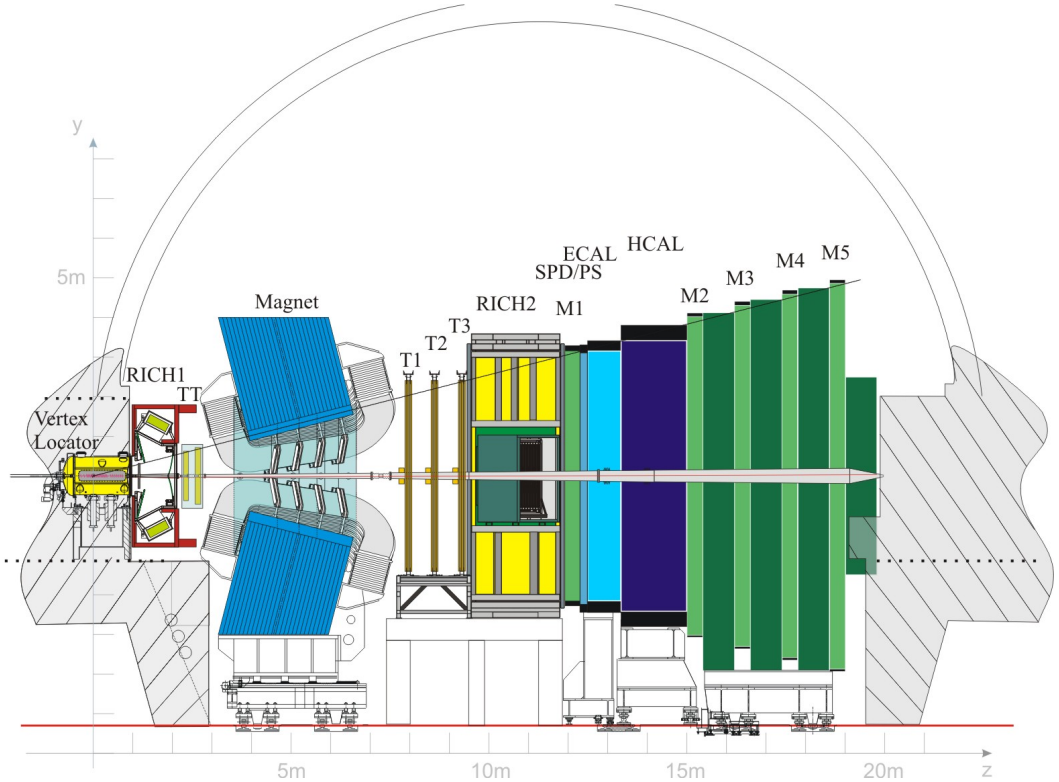
LHCb



- Velo + tracking systems
- RICH detector: kaon-pion separation
- Muon detectors

Figure 1: An overview of the LHCb detector

Proper time resolution of 50 fs. $\tau_D = 410$ fs, so $\sim 10\%$

Charm Mixing

Meson Mixing

- Mixing: the change from a neutral meson into its anti-particle and the other way around, as a function of time
- Charm mixing only recently established

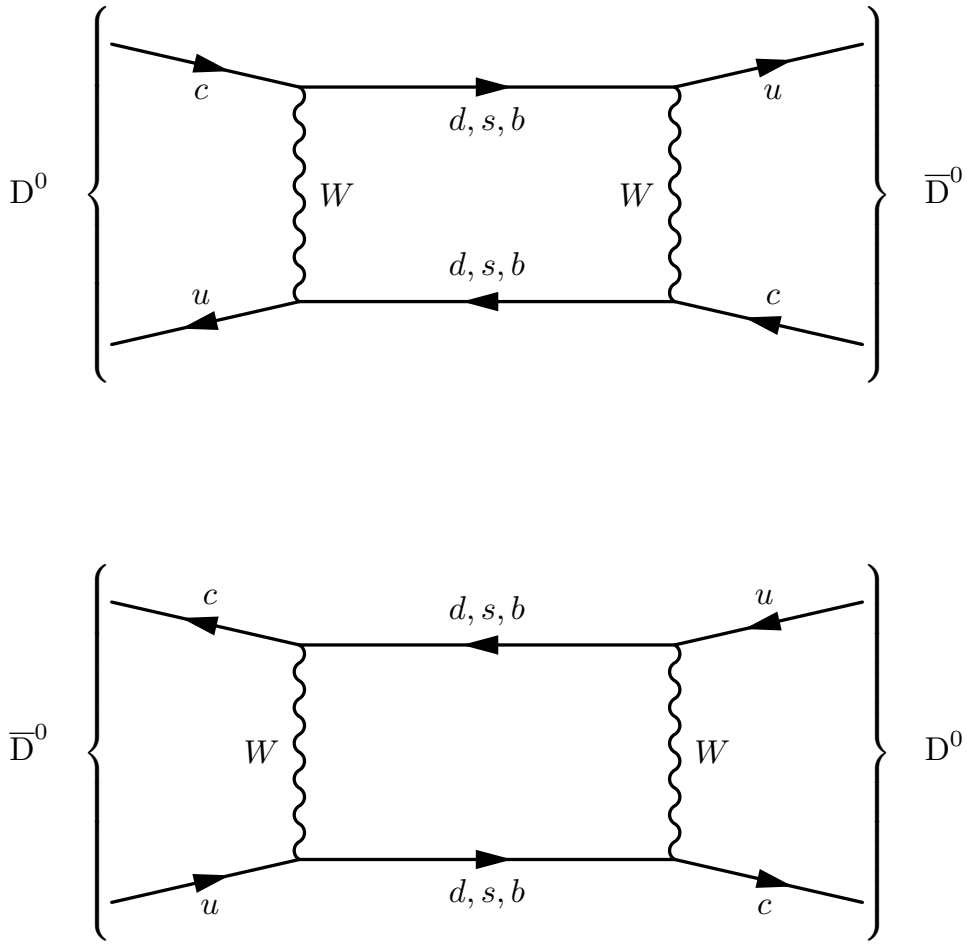


Figure 2: Box diagrams for D mixing

Charm Mixing

Equations

Mixing probability for semileptonic D^0 decays:

$$\mathcal{P}(D^0 \to \overline{D}^0 \to K^+\mu^-\overline{\nu}_\mu) \propto R_M t^2 e^{-\Gamma t}$$

The mixing rate R_M:

$$R_M = \frac{\int_0^\infty dt\mathcal{P}(D^0 \to \overline{D}^0 \to K^+\mu^-\overline{\nu}_\mu)}{\int_0^\infty dt\mathcal{P}(D^0 \to K^-\mu^+\nu_\mu)}$$
$$\propto \frac{x^2+y^2}{2}$$

$$x = \frac{\Delta m}{\Gamma} \quad y = \frac{\Delta\Gamma}{2\Gamma}$$

Indirect Measurement

parameter	value
$x(\%)$	$0.64^{+0.18}_{-0.19}$
$y(\%)$	0.74 ± 0.12

yields $R_M \approx 4.9 \times 10^{-5}$

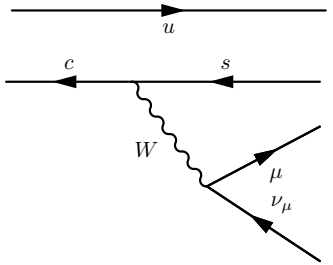


Figure 3: $\overline{D}^0 \to K^+\mu^-\overline{\nu}_\mu$

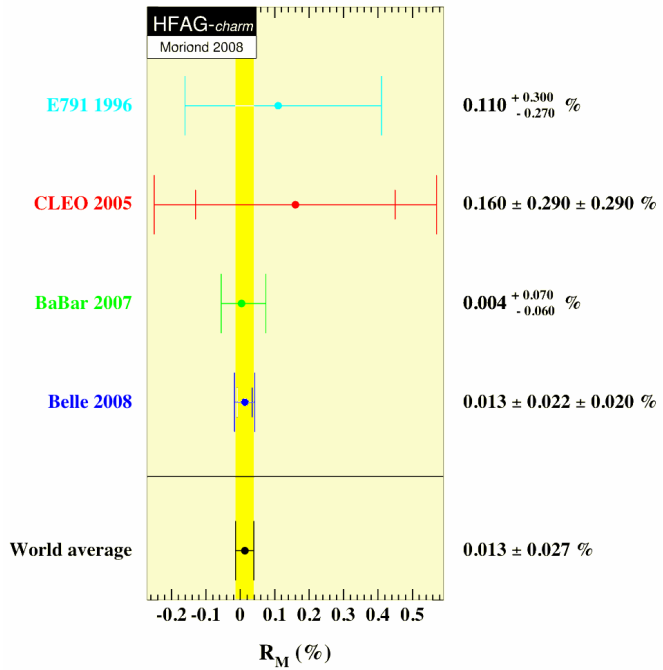


Figure 4: Direct measurement

Tagging Charm

Measuring the sign of the pion:

$$D^{*+} \to D^0 \pi_s^+$$

$$D^{*-} \to \overline{D}^0 \pi_s^-$$

Neutrino cannot be reconstructed, best solution is to measure the mass difference: $\Delta m = m(\pi_s K \mu) - m(K\mu)$

Right-Sign and Wrong-Sign

charge combination	process	name
π_s^+, K^-, μ^+	non-mixed	Right-Sign, RS
π_s^+, K^+, μ^-	mixed	Wrong-Sign, WS
π_s^-, K^+, μ^-	non-mixed	Right-Sign, RS
π_s^-, K^-, μ^+	mixed	Wrong-Sign, WS

Trigger

Trigger Description

- Trigger has 3 stages
- Stage 1: Level-0, hardware, from $\mathcal{O}(10\ \mathrm{MHz})$ to 1 MHz
- Stage 2: HLT1, software, generic selection, reducing to 30 kHz
- Stage 3: HLT2, software, inclusive and exclusive trigger lines, reducing to 3 kHz

HLT2 selection for this measurement

- Desired rate: 50 Hz
- μ^+: $P_T > 800$ MeV
- K^-: $P_T > 600$ MeV
- Combined: $P_T > 1500$ MeV
- Neutrinos are not reconstructed
- π_s^+: $P_T > 300$ MeV and $P > 3000$ MeV
- D^0: flight distance > 10 mm
- First version is running!

Yield Extraction

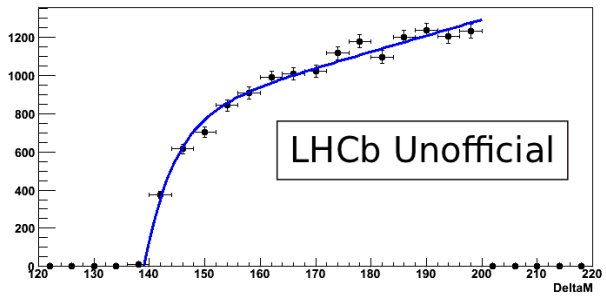


Figure 5: Background fit through same-sign data

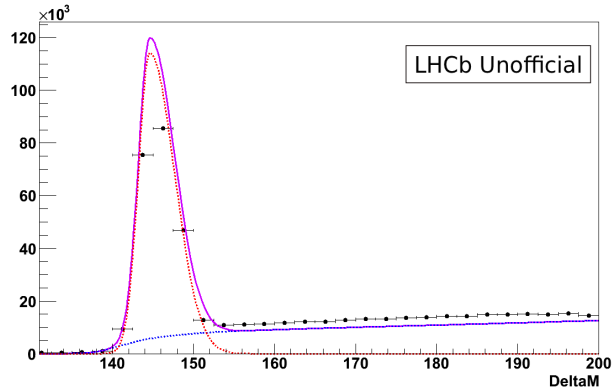


Figure 6: Background and signal fit

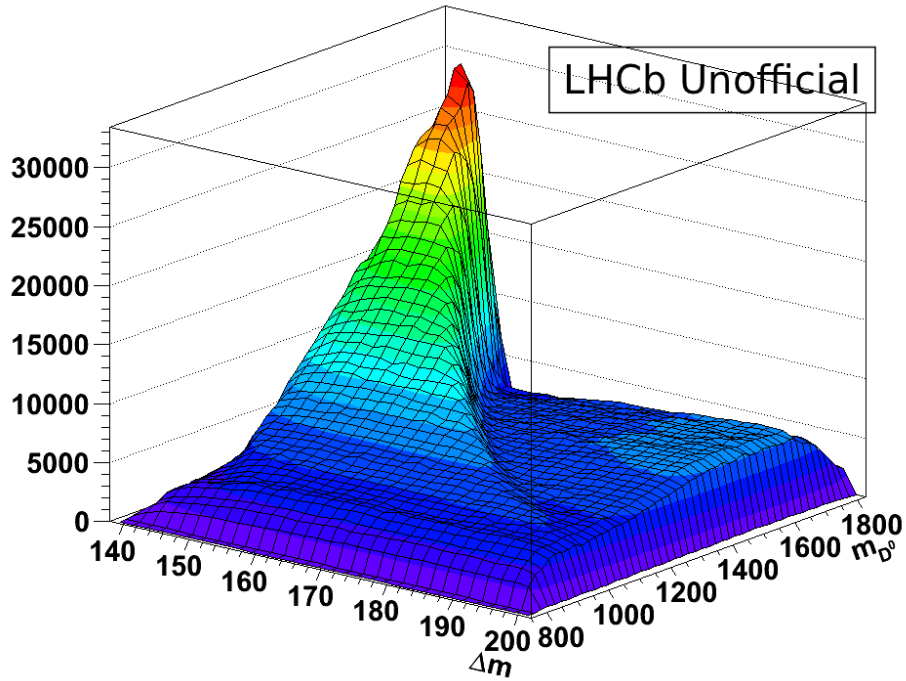


Figure 7: Δm vs. m_{D^0}

Signal-Background

- Measuring the signal to background ratio
- Background should be the same for the WS
- S/B varies as a function of mass

Sensitivity Estimate

Meson Mixing

- Assumptions:
  3σ significance of WS signal and $R_M \approx 5 \times 10^{-5}$
- e.g. RS S/B $= 10$
  requires sample of 4×10^8
- $\approx 2 \times 10^8$/year
- Competitive dataset in 2012

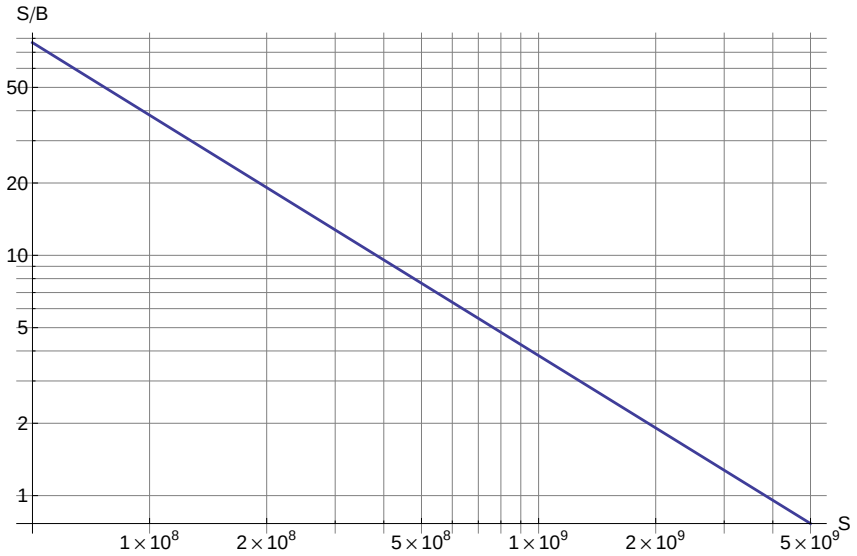


Figure 8: Necessary RS purity for a given RS sample

Conclusion

- Measuring D meson mixing with semileptonic decays by finding the Right-Sign to Wrong-Sign ratio
- Designed a trigger selection
- Set up a signal fit
- Estimated sensitivity $\rightarrow$ possible with 2011 + 2012 data
- Outlook: estimate the impact of the proper time bias on the sensitivity