LHCb status and charm physics program

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On behalf of the LHCb collaboration

Outline

- LHCb status
- LHCb's trigger
- CP violation searches in D decays at LHCb
- Charm mixing measurements at LHCb

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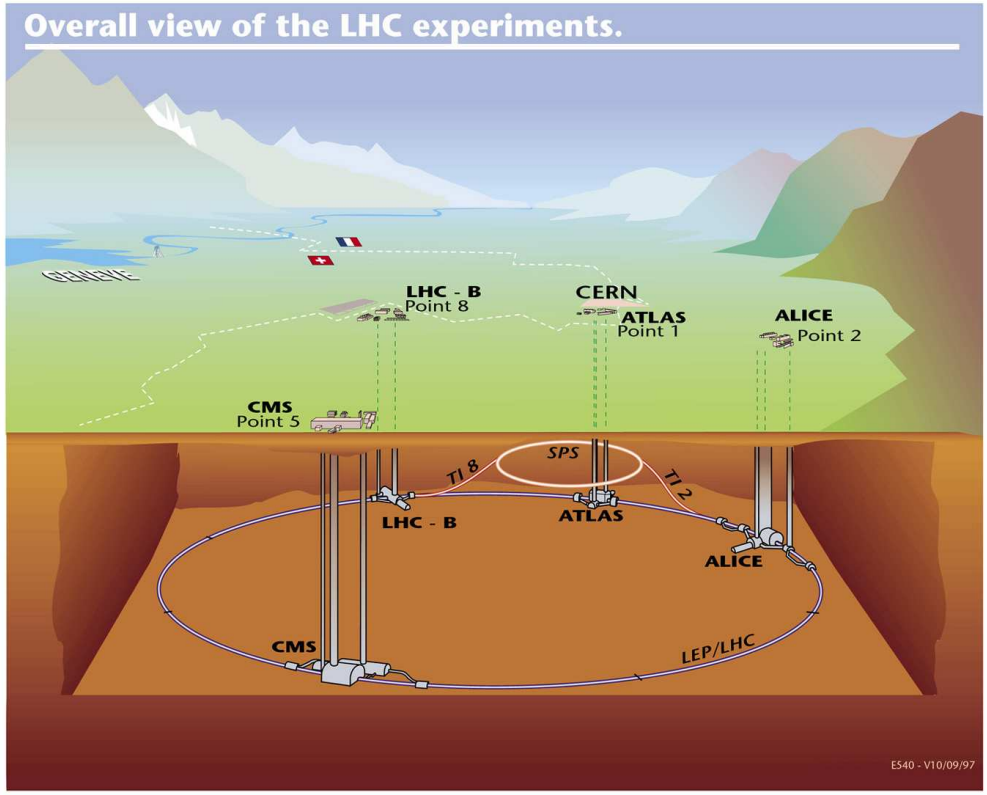
Large Hadron Collider



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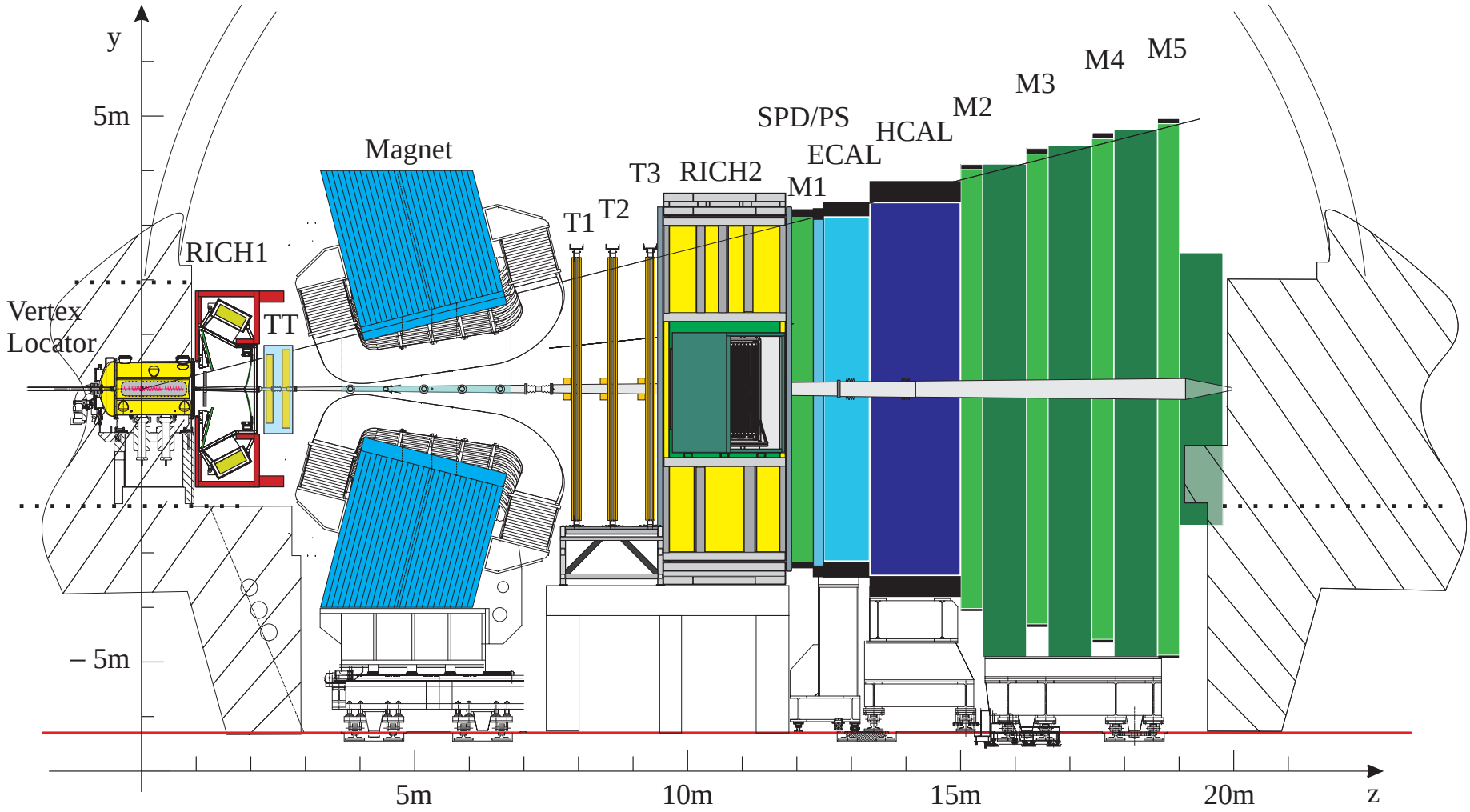
LHCb detector



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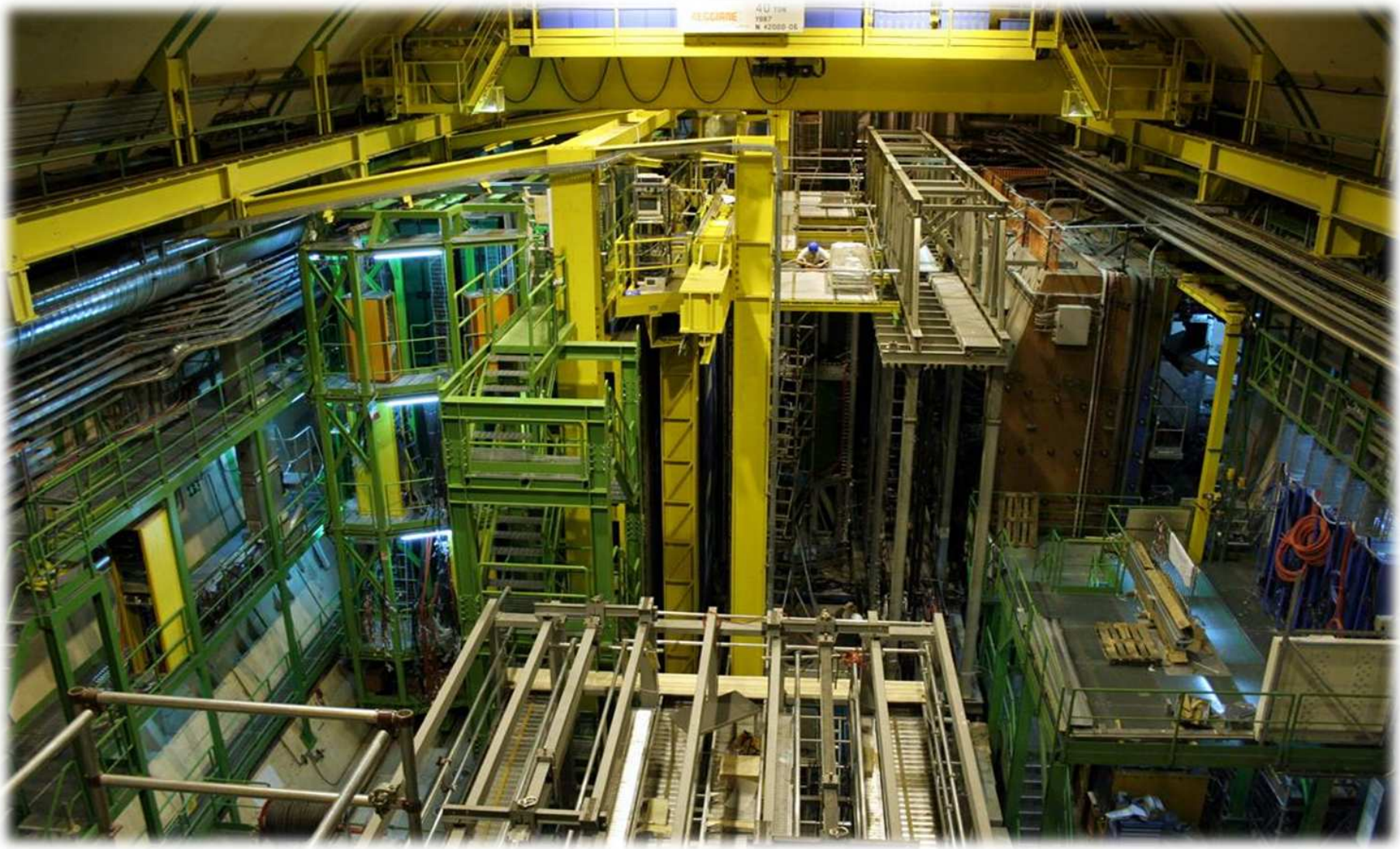
LHCb status



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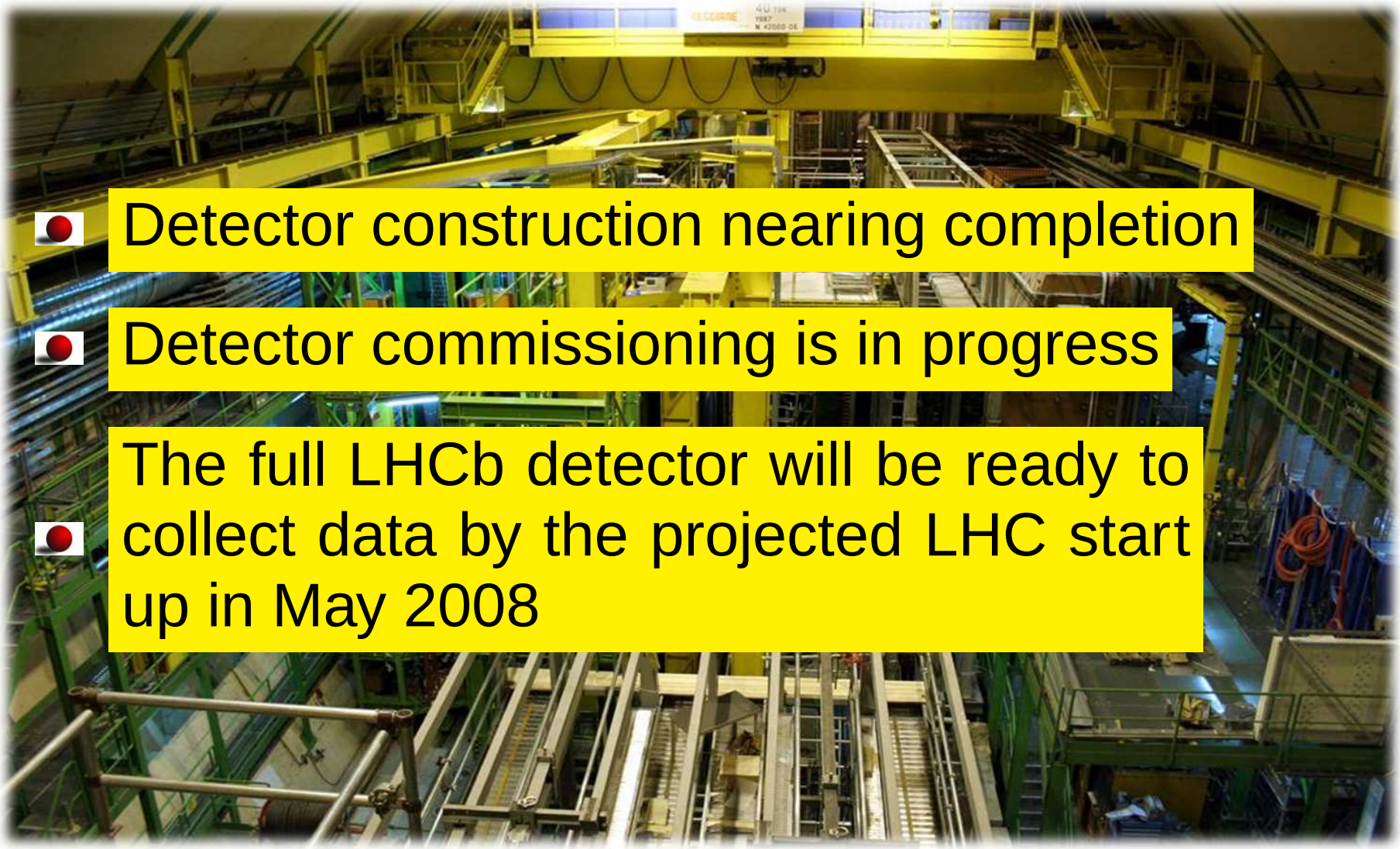
LHCb status



- Detector construction nearing completion
- Detector commissioning is in progress
- The full LHCb detector will be ready to collect data by the projected LHC start up in May 2008

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LHCb features

- The features that make LHCb excellent for B physics also make it a good charm physics experiment
- High event rate
- Excellent vertexing and proper time resolution: $\sim 45\,\mathrm{fs}$ for secondary D^0
- Good tracking and momentum resolution: $\sim 6\,\mathrm{MeV}$ D^0 mass
- Excellent K-π discrimination

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LHCb trigger

- L0 hardware trigger — high p_t particles
  - Including Calorimeter hadrons $E_t >\sim 3.6\,\mathrm{GeV}$; Muon $p_t >\sim 1.5\,\mathrm{GeV}$
  - Input $40\,\mathrm{MHz} \rightarrow 1\,\mathrm{MHz}$ output
  - Efficiently favors $b\bar{b}$ events over prompt charm
- HLT software trigger
  - Parallel trigger paths: 'alleys'
    - Partial reconstruction of limited detector information
    - Quickly identify general B event features
      - High p_t particles (hadrons, muons, electrons, and photons)
      - Charged tracks with sizable impact parameter
  - Followed by channels for specific interesting decays
    - Fast final state candidate reconstruction
    - Composite decay chain reconstruction, e.g., $D^{*+} \rightarrow \pi_s^+ D^0 (h^- h^+)$
  - 2 kHz total output rate
    - 300 Hz $D^{*+} \rightarrow \pi_s^+ D^0 (h^- h^+)$
    - 600 Hz Di-muon events
    - 200 Hz Exclusive physics channels
    - 900 Hz Single muon inclusive

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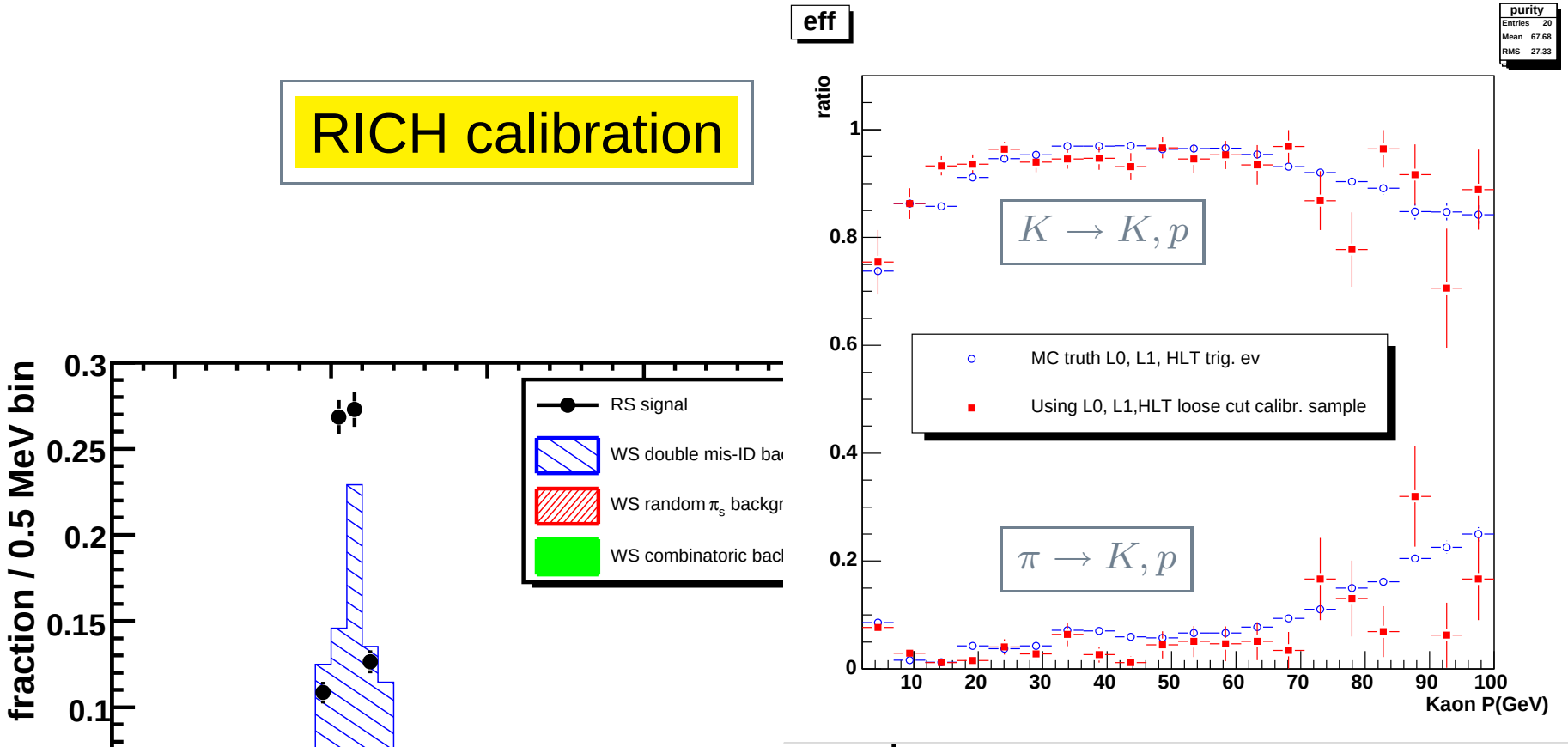
Uses of LHCb D^{*+} trigger

RICH calibration



Charm physics

Two sources of charm

- B decays ($B \to D^{(*)} X$)
  - \+ Strongly favored by LHCb triggers
  - \+ Potentially less background
  - \- New techniques need to be developed—no published measurements
- Prompt production in primary interaction
  - 0 Triggered less efficiently—compensated by prolific production
  - \- Potentially larger backgrounds—especially random π_s background for D^{*+}
  - \+ CDF has proven that measurements are possible in hadronic environment

Estimated reconstructible yields in $2\,\mathrm{fb}^{-1}$ from $B \to D^{*+} X$

(Similar yields expected from prompt production)

$D^0 \to K^- \pi^+$	50×10^6
$D^0 \to K^- K^+$	5×10^6
$D^0 \to \pi^- \pi^+$	2×10^6
$D^0 \to \pi^- K^+$	0.2×10^6

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CP violation searches

Looking for unambiguous signs of New Physics in as many channels as possible

(A vital part of any charm physics program)

- Both time integrated and time dependent CPV searches
- Two body $K\pi$, K^-K^+, and $\pi^-\pi^+$ modes
- Three body charged and neutral decays
  - Amplitude analyses
  - $D^0 \to K_S\pi^+\pi^-, K_SK^+K^-, K_SK\pi$; $D^+ \to K^+K^-\pi^+, K\pi\pi$
- Four body decays
  - Quantities odd under T
  - Amplitude analyses (analysis code already exists in LHCb)
  - $D^0 \to K^+K^-\pi^+\pi^-, K\pi\pi\pi$

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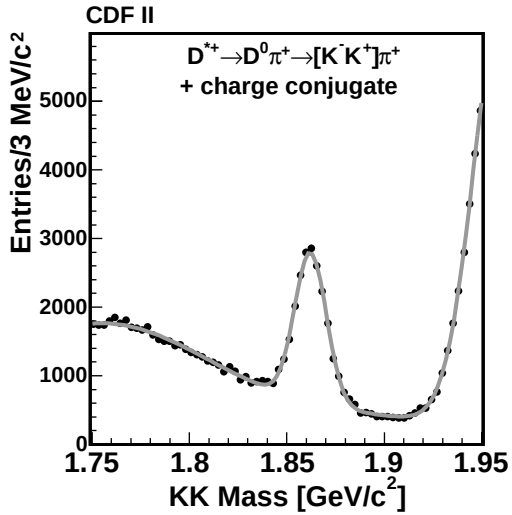
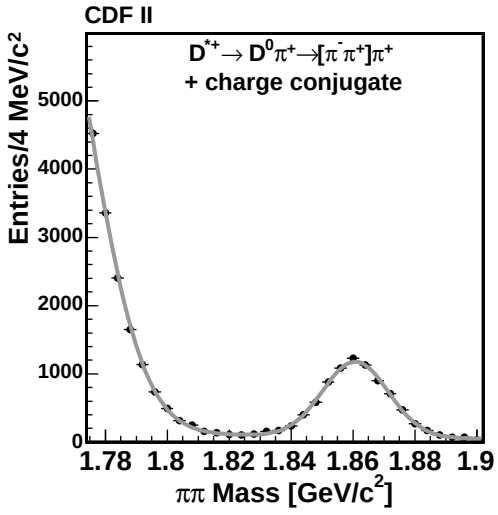
CPV in $D^0 \to K^- K^+$

	Data set	$N(K^-K^+)$	$A_{CP}(K^-K^+)(\%)$	$A_{CP}(\pi^-\pi^+)(\%)$
CDF	$123\,\text{pb}^{-1}$	16220	$2.0 \pm 1.2 \pm 0.6$	$1.0 \pm 1.3 \pm 0.6$
Belle[a]	$540\,\text{fb}^{-1}$	109000	$0.15 \pm 0.35 \pm 0.15$	$-0.28 \pm 0.52 \pm 0.15$
BaBar[a]	$91\,\text{fb}^{-1}$	26084	$-1.3 \pm 0.8 \pm 0.2$	$0.3 \pm 1.1 \pm 0.2$
LHCb	$10\,\text{fb}^{-1}$	8×10^6	Lower limit yield from D^{*+} from B, not optimized for time-independent K^-K^+	

[a] Asymmetries of $\tau(K^-K^+)$ rather than $\Gamma(K^-K^+)$

CDF direct CPV search in K^-K^+





Mixing measurements at LHCb

- Precise mixing measurements
  - Measure CP violation in mixing
  - Determine relative values of x and y—dominant mixing processes
- WS $D^0 \to \pi^- K^+$ mixing analysis
  - Sensitive to x'^2 and y'
  - BaBar 3.9σ evidence Phys.Rev.Lett.98:211802,2007 (hep-ex/0703020)
  - Require measurement of strong phase δ by CLEO / BES-III to relate x', y' to x, y
- Two body lifetime ratio measurement of $y_{\rm CP}$
  - SCS $D^0 \to K^- K^+$ and $\pi^- \pi^+$
  - Belle $3.2\,\sigma$ evidence Phys.Rev.Lett.98:211803,2007 (hep-ex/0703036)
- Amplitude analysis of $D^0 \to K_S \pi^+ \pi^-$
  - Sensitive to x and y
  - Powerful technique demonstrated by CLEO and Belle
- Mixing measurements in $D^0 \to 4h$
  - Technology for 4-body amplitude analysis already exists at LHCb
  - Preliminary selection: up to 25×10^6 RS $D^0(4h)$ events per $2\,\mathrm{fb}^{-1}$ written to tape

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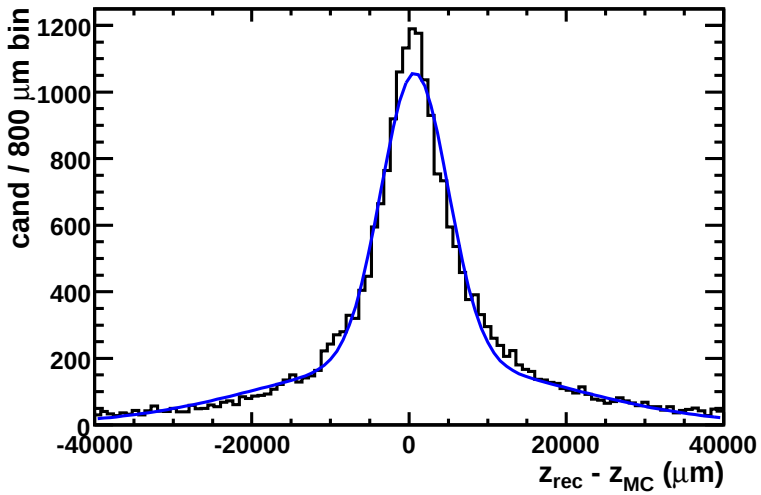
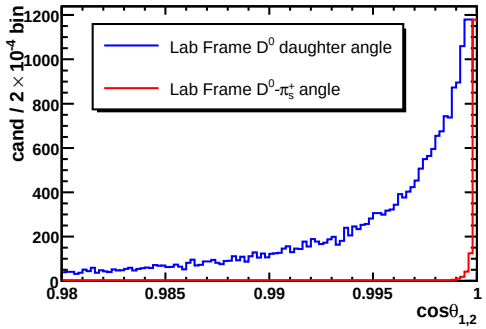
D^* vertex resolution

D^* resolution in z



Signal MC lab frame angles



- D^0 and π_s^+ almost collinear
- Add tracks at birth vertex

Decay vertex resolutions

	D^0	D^{*+}
x	21.6 μm	187. μm
y	16.9 μm	144. μm
z	257. μm	4232. μm
τ	0.465 ps	

D^0 lifetime τ:
(0.4101 ± 0.0015) ps

D^0 flight distance at 60 GeV:
$\beta\gamma c\tau \approx 4$ mm

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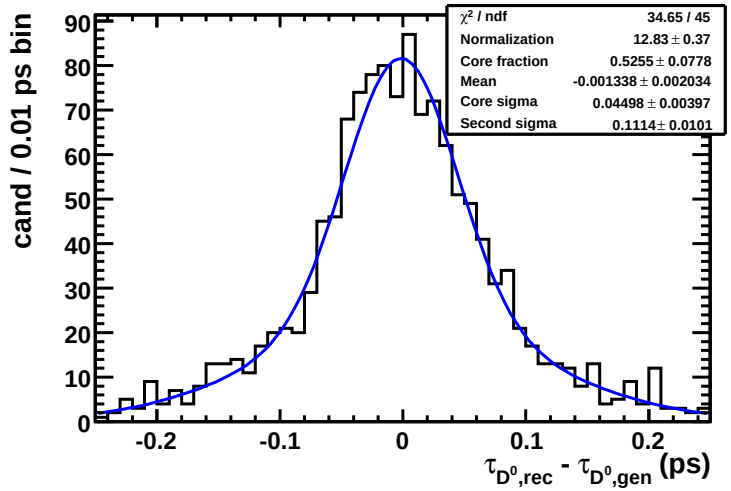
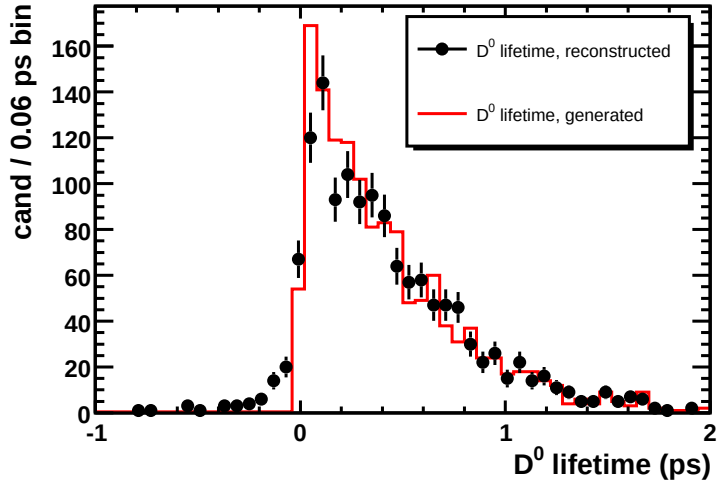
Birth vertex improvement

- Use additional tracks at production vertex
- 76% of D^{*+} from B's have at least one charged sister
- 63% have reconstructed sister tracks that pass some basic criteria
- Use one additional track partially reconstruct parent $B_{\rm part}$



Decay vertex resolutions

	D^0	D^{*+}	$B_{\rm part}$
x	21.6 μm	187. μm	18.1 μm
y	16.9 μm	144. μm	18.4 μm
z	257. μm	4232. μm	237. μm



Improved proper time resolution $= 0.045$ ps

$1.07 < B/S = 2.56 < 5.28$ at 90% CL

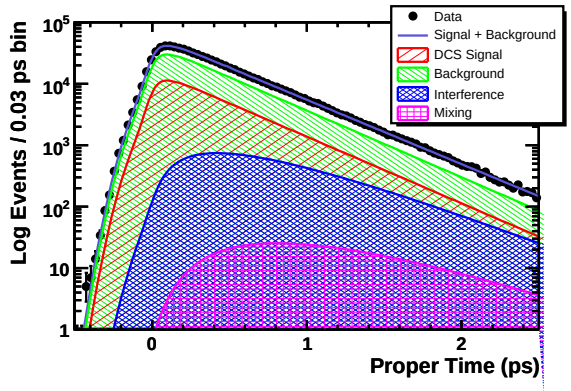
Process detailed in CERN-LHCb-2007-049

Toy MC study of WS mixing

Investigate sensitivity to x'^2 and y' 1-D fit to proper time

$$\Gamma(t; D^0 \to \pi^- K^+) \propto e^{-\Gamma t}\left[R_D + \sqrt{R_D} y' \Gamma t + \tfrac{1}{4}(y'^2 + x'^2)(\Gamma t)^2\right]$$

- $10\,\mathrm{fb}^{-1}$ of simulated signal ev/toy
- Exponential background $\exp\left(-t/\tau_{D^0}\right)$
- Acceptance and resolution effects includes
- Fit to x'^2 and y'



	Data set	N_{WS}	$x'^2(\times 10^{-3})$	$y'(\times 10^{-3})$
BaBar	$384\,\mathrm{fb}^{-1}$	4030	$-0.22 \pm 0.30 \pm 0.21$	$9.7 \pm 4.4 \pm 3.1$
Belle	$400\,\mathrm{fb}^{-1}$	4024	< 0.72	$-9.9 < y' < 6.8$
HFAG average			$-0.01^{+0.20}_{-0.20}$	$5.5^{+2.8}_{-3.7}$
B factories	$2\,\mathrm{ab}^{-1}$		$x'^2 \pm 0.15$	$y' \pm 3.0$
LHCb	$\mathbf{10\,fb^{-1}}$	**232500**	$\boldsymbol{x'^2 \pm 0.064\,(\mathrm{stat})}$	$\boldsymbol{y' \pm 0.87\,(\mathrm{stat})}$

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Toy MC of lifetime ratio

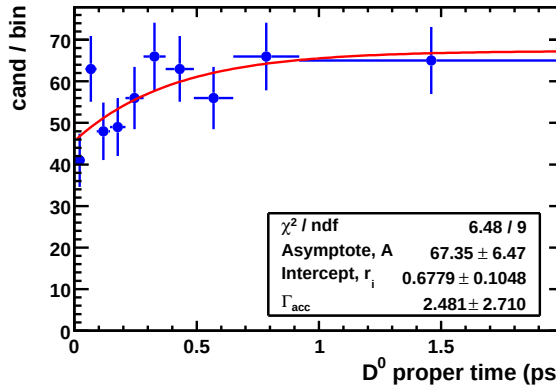
Compare lifetimes of the non-eigenstate RS decay $D^0 \to K^-\pi^+$ and CP even decays $D^0 \to K^-K^+(\pi^-\pi^+)$

$$y_{\rm CP} \equiv \frac{\tau(D^0 \to K^-\pi^+)}{\tau(D^0 \to (K^+K^-, \pi^+\pi^-)} - 1 = y\cos\phi - x\sin\phi \left[\frac{R_m^2 - 1}{2}\right]$$

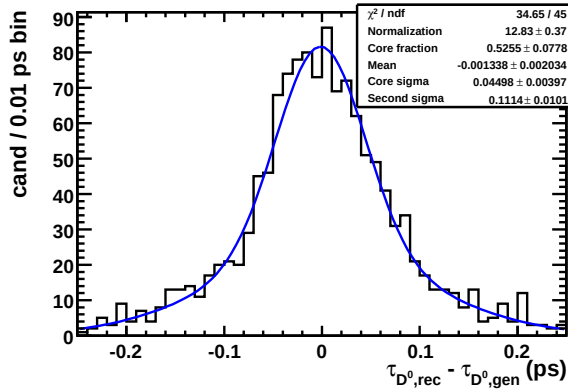
- $2\,\mathrm{fb}^{-1}$ of simulated signal ev/toy
- Exponential background $\exp(-t/\tau_{D^0})$
- Acceptance and resolution effects includes

	Data set	$N(K^-K^+)$	$y_{\rm CP}(\%)$
Belle	$540\,\mathrm{fb}^{-1}$	109000	$1.31 \pm 0.32 \pm 0.25$
BaBar	$91\,\mathrm{fb}^{-1}$	26084	$1.5 \pm 0.8 \pm 0.5$
HFAG average			1.12 ± 0.32
B factories	$2\,\mathrm{ab}^{-1}$		$y_{\rm CP} \pm 0.3$
LHCb	$\mathbf{10\,fb^{-1}}$	$\mathbf{8 \times 10^6}$	$\boldsymbol{y_{\rm CP} \pm 0.05\,(stat)}$

Acceptance



Resolution



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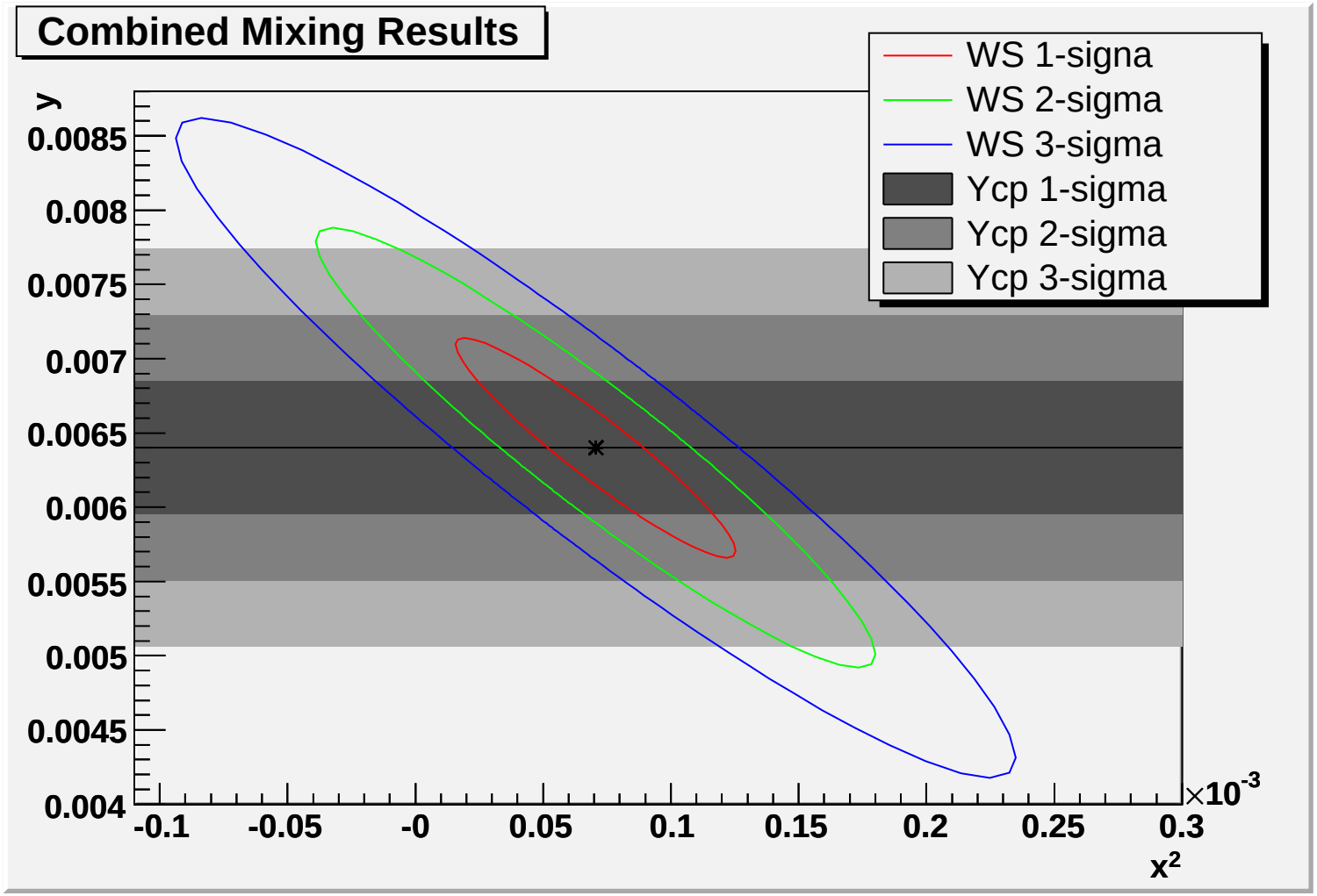
Summary of LHCb at $10\,\mathrm{fb}^{-1}$



Values for x'^2 and y' from David Asner's March 2007 report to *Flavour in the era of the LHC*

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Summary

- LHCb will be complete and ready to take data at LHC start-up in May 2008
- The LHCb experiment has an exciting potential for charm physics studies
- A dedicated D^* trigger will provide 10^8 flavor tagged $D^0 \to hh$ per $2\,\mathrm{fb}^{-1}$
- Unprecedented sensitivity in searches for:

  D^0 mixing

  CP violation

We have only begun to tap LHCb's potential for charm physics

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