

LHCb status and charm physics program

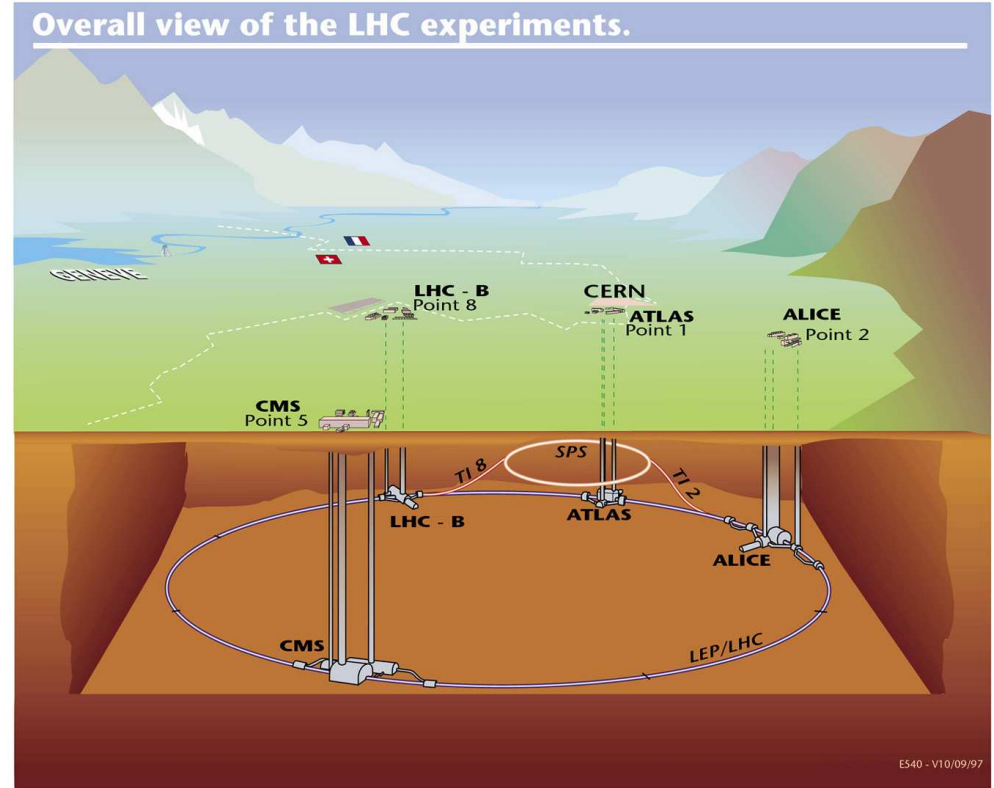
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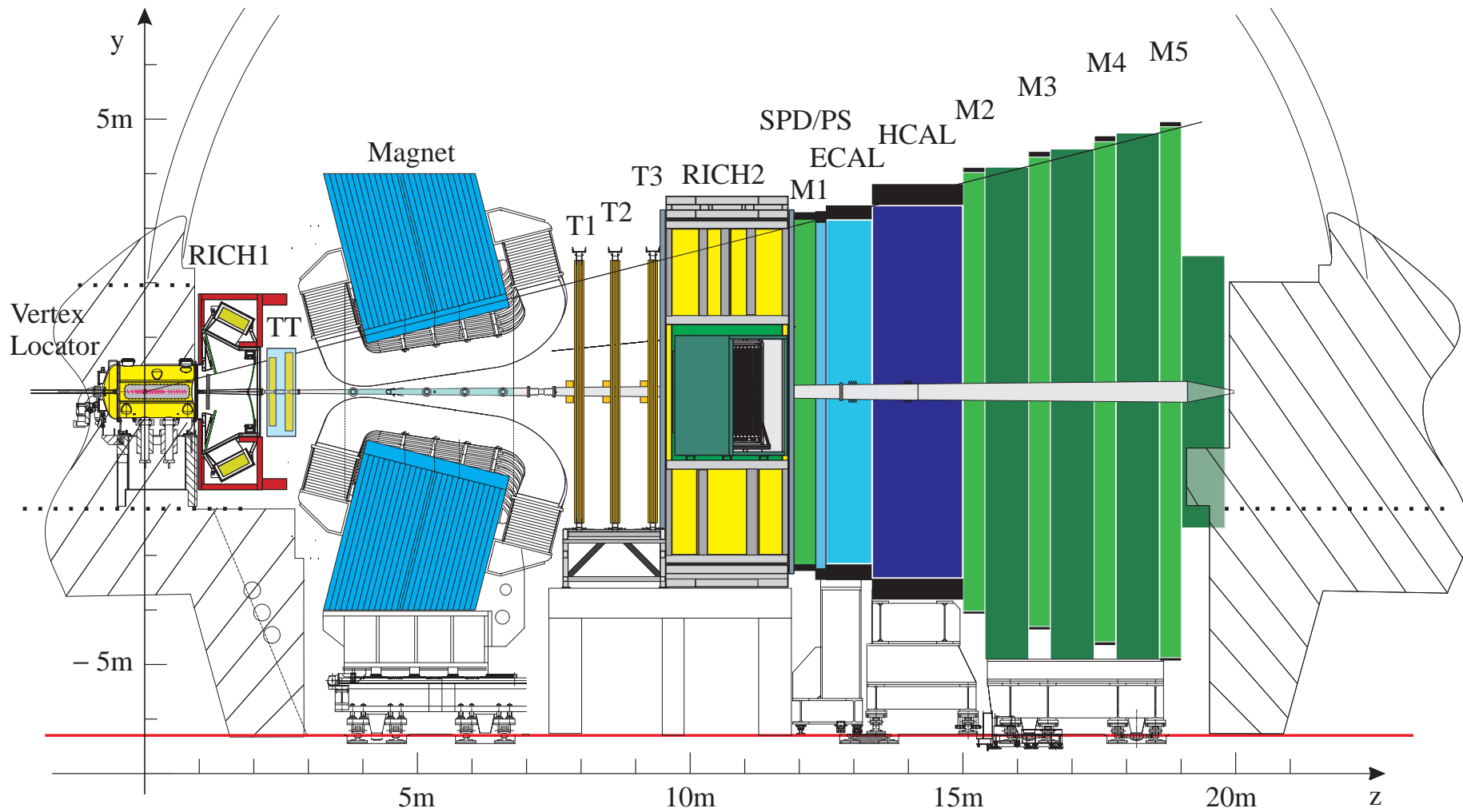
Outline

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

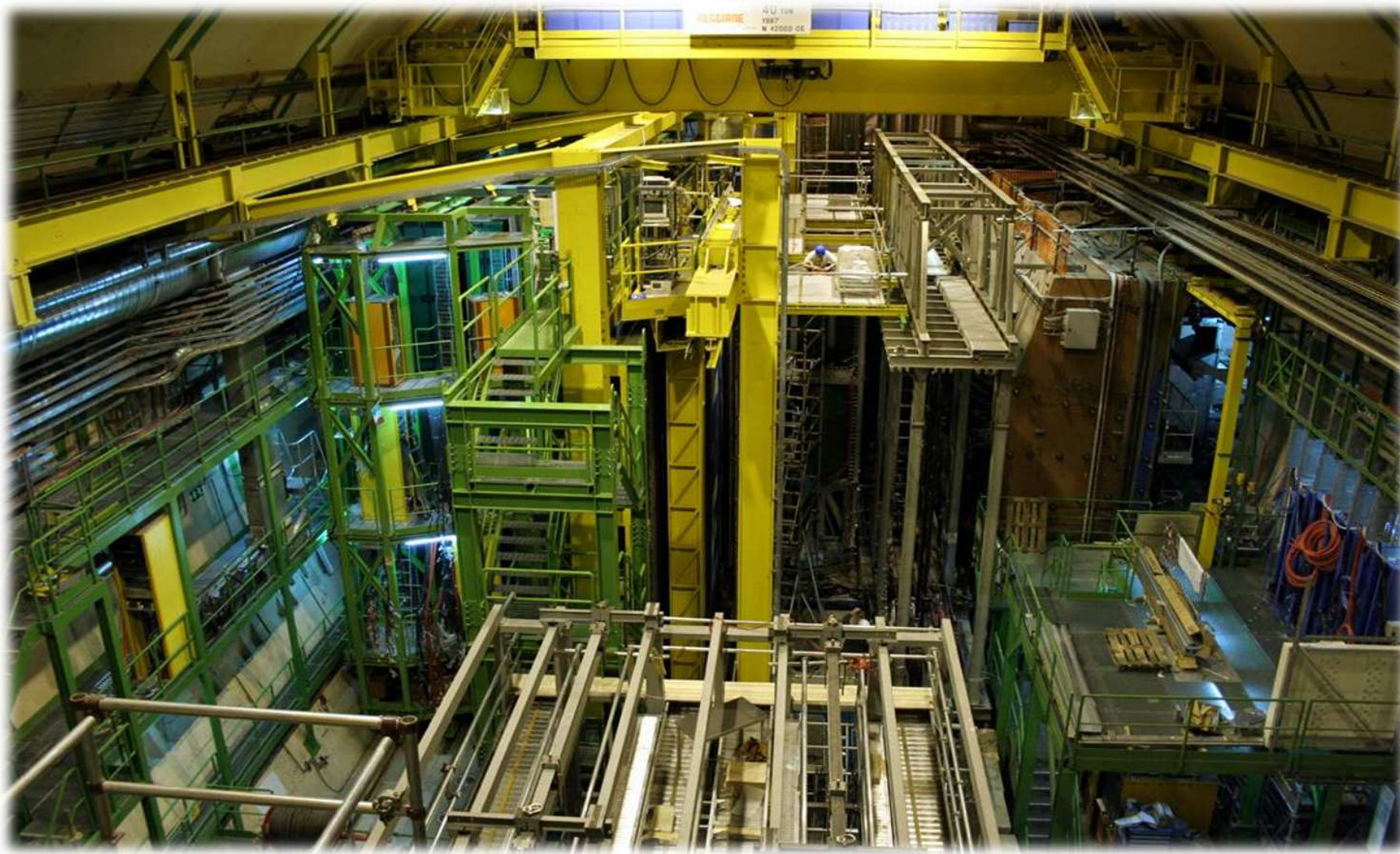
Large Hadron Collider



LHCb detector



LHCb status



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

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: ~ 45 fs for secondary D^0
- Good tracking and momentum resolution: ~ 6 MeV D^0 mass
- Excellent K - π discrimination



LHCb trigger

● L0 hardware trigger — high p_t particles

- Including Calorimeter hadrons $E_t > \sim 3.6$ GeV; Muon $p_t > \sim 1.5$ GeV
- Input 40 MHz \rightarrow 1 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

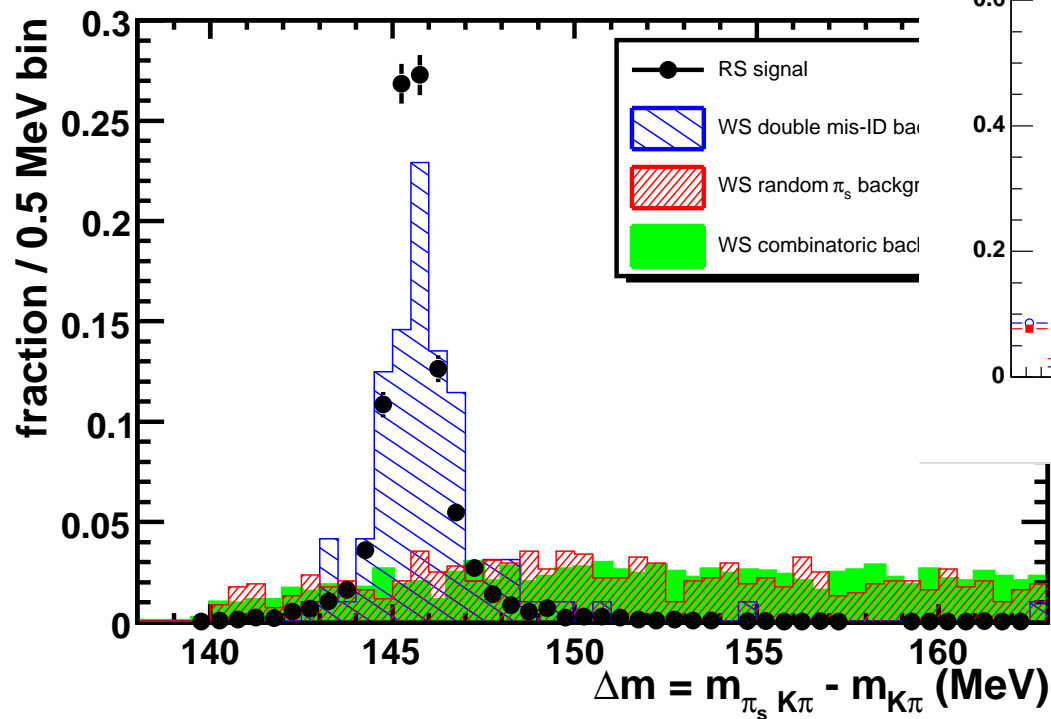
- Fast final state candidate reconstruction
- Composite decay chain reconstruction, e.g., $D^{*+} \rightarrow \pi_s^+ D^0(h^- h^+)$

● 2 kHz total output rate

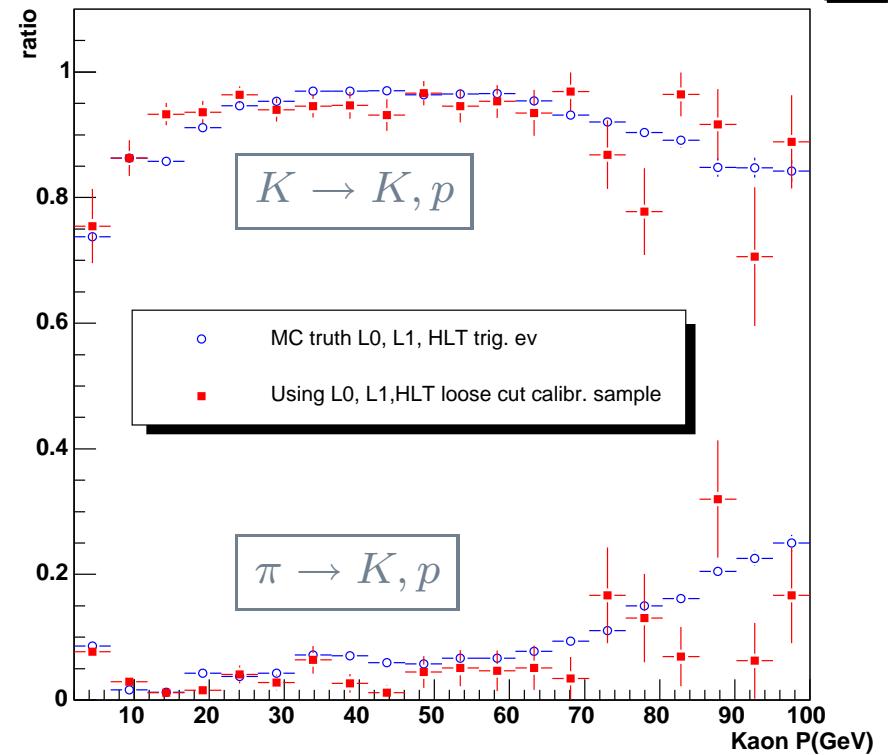
- 300 Hz $D^{*+} \rightarrow \pi_s^+ D^0(h^- h^+)$
- 600 Hz Di-muon events
- 200 Hz Exclusive physics channels
- 900 Hz Single muon inclusive

Uses of LHCb D^{*+} trigger

RICH calibration



eff



Charm physics

Two sources of charm

● B decays ($B \rightarrow D^{(*)} X$)

- + 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 fb^{-1} from $B \rightarrow D^{*+} X$

(Similar yields expected from prompt production)

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

CP violation searches

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

(A vital part of any charm physics program)

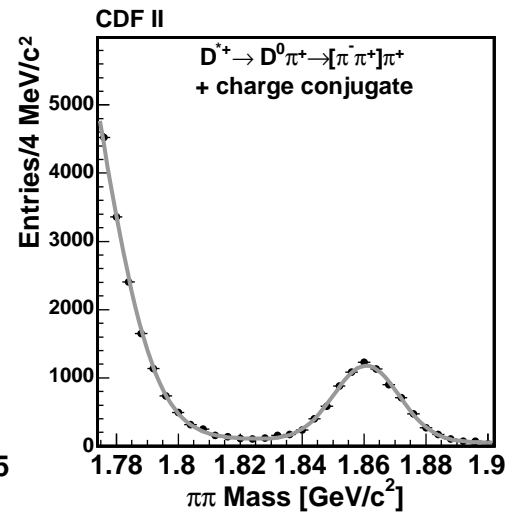
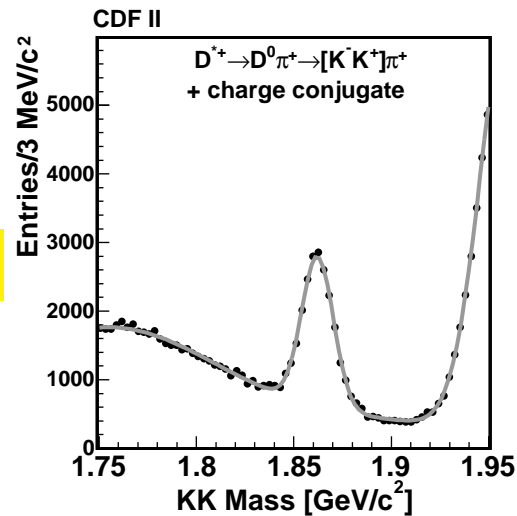
- Both time integrated and time dependent CPV searches
- Two body $K\pi$, K^-K^+ , and $\pi^-\pi^+$ modes
- Three body charged and neutral decays
 - Amplitude analyses
 - $D^0 \rightarrow K_S\pi^+\pi^-, K_S K^+K^-, K_S K\pi; D^+ \rightarrow K^+K^-\pi^+, K\pi\pi$
- Four body decays
 - Quantities odd under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

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

	Data set	$N(K^- K^+)$	$A_{CP}(K^- K^+)(\%)$	$A_{CP}(\pi^- \pi^+)(\%)$
CDF	123 pb ⁻¹	16220	$2.0 \pm 1.2 \pm 0.6$	$1.0 \pm 1.3 \pm 0.6$
Belle ^a	540 fb ⁻¹	109000	$0.15 \pm 0.35 \pm 0.15$	$-0.28 \pm 0.52 \pm 0.15$
BaBar ^a	91 fb ⁻¹	26084	$-1.3 \pm 0.8 \pm 0.2$	$0.3 \pm 1.1 \pm 0.2$
LHCb	10 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 $D^0 \rightarrow \pi^- K^+$ 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_{CP}

- SCS $D^0 \rightarrow K^- K^+$ and $\pi^- \pi^+$
- Belle 3.2σ evidence Phys.Rev.Lett.98:211803,2007 (hep-ex/0703036)

● Amplitude analysis of $D^0 \rightarrow K_S \pi^+ \pi^-$

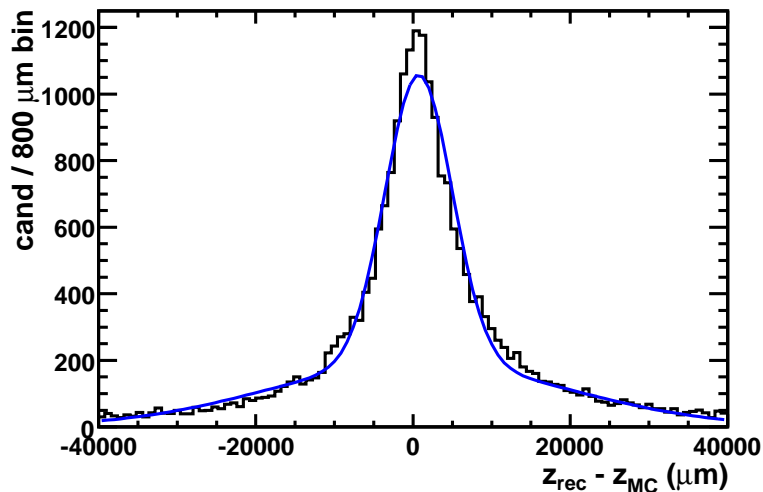
- Sensitive to x and y
- Powerful technique demonstrated by CLEO and Belle

● Mixing measurements in $D^0 \rightarrow 4h$

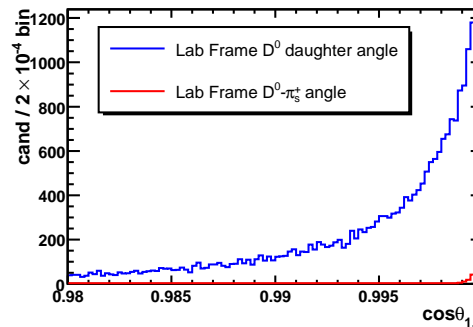
- Technology for 4-body amplitude analysis already exists at LHCb
- Preliminary selection: up to 25×10^6 RS $D^0(4h)$ events per 2 fb^{-1} written to tape

D^* vertex resolution

D^* resolution in z



Signal MC lab frame angles



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

D^0 lifetime τ :
 (0.4101 ± 0.0015) ps

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

Birth vertex improvement

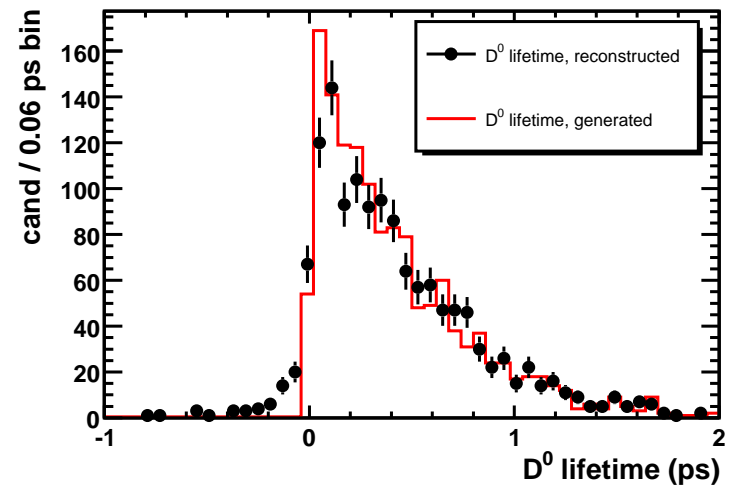
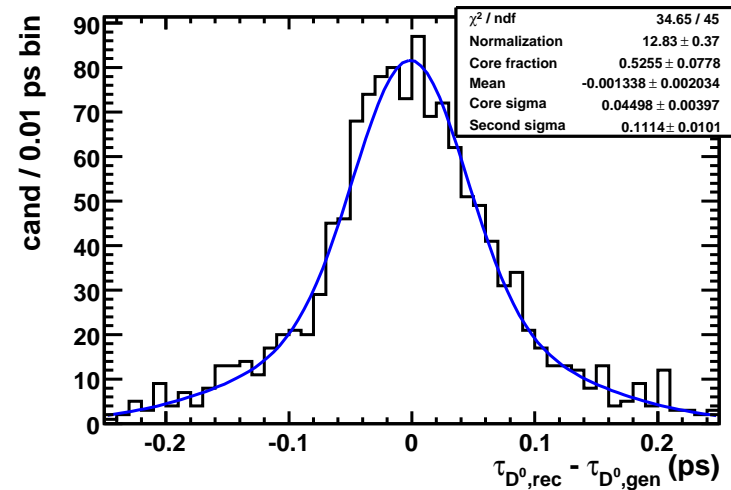
- Use additional tracks at production vertex
- 76% of D^{*+} from B 's have at least one charged sister
- 63% have reconstructed sister tracks that pass some basic criteria
- Use one additional track partially reconstruct parent B_{part}

Decay vertex resolutions

	D^0	D^{*+}	B_{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

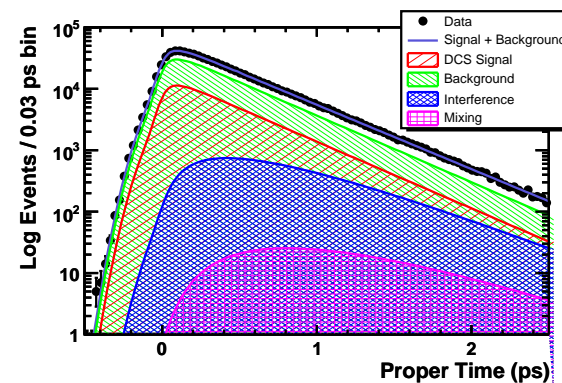


Toy MC study of WS mixing

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

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

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



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

Toy MC of lifetime ratio

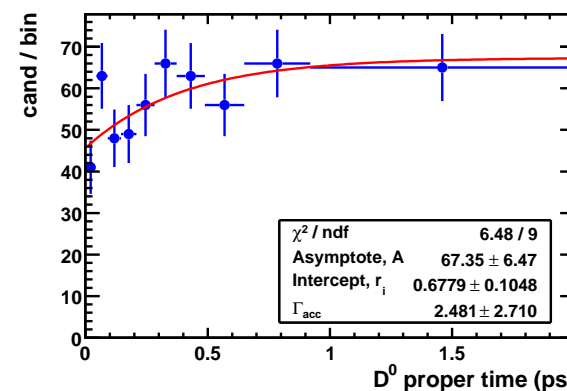
Compare lifetimes of the non-eigenstate RS decay
 $D^0 \rightarrow K^- \pi^+$ and CP even decays $D^0 \rightarrow K^- K^+ (\pi^- \pi^+)$

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

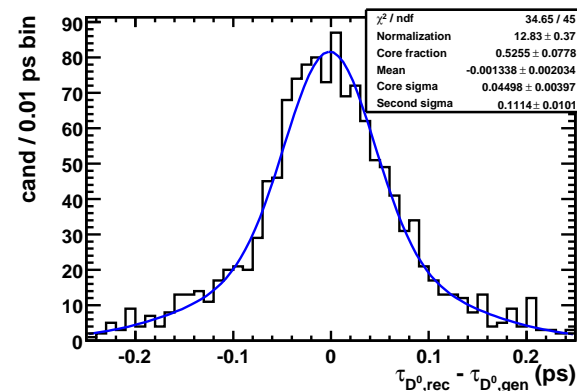
- 2 fb⁻¹ of simulated signal ev/toy
- Exponential background exp(-t/τ_{D⁰})
- Acceptance and resolution effects includes

	Data set	N(K ⁻ K ⁺)	y _{CP} (%)
Belle	540 fb ⁻¹	109000	1.31 ± 0.32 ± 0.25
BaBar	91 fb ⁻¹	26084	1.5 ± 0.8 ± 0.5
HFAG average			1.12 ± 0.32
B factories	2 ab ⁻¹		y _{CP} ± 0.3
LHCb	10 fb⁻¹	8 × 10⁶	y_{CP} ± 0.05 (stat)

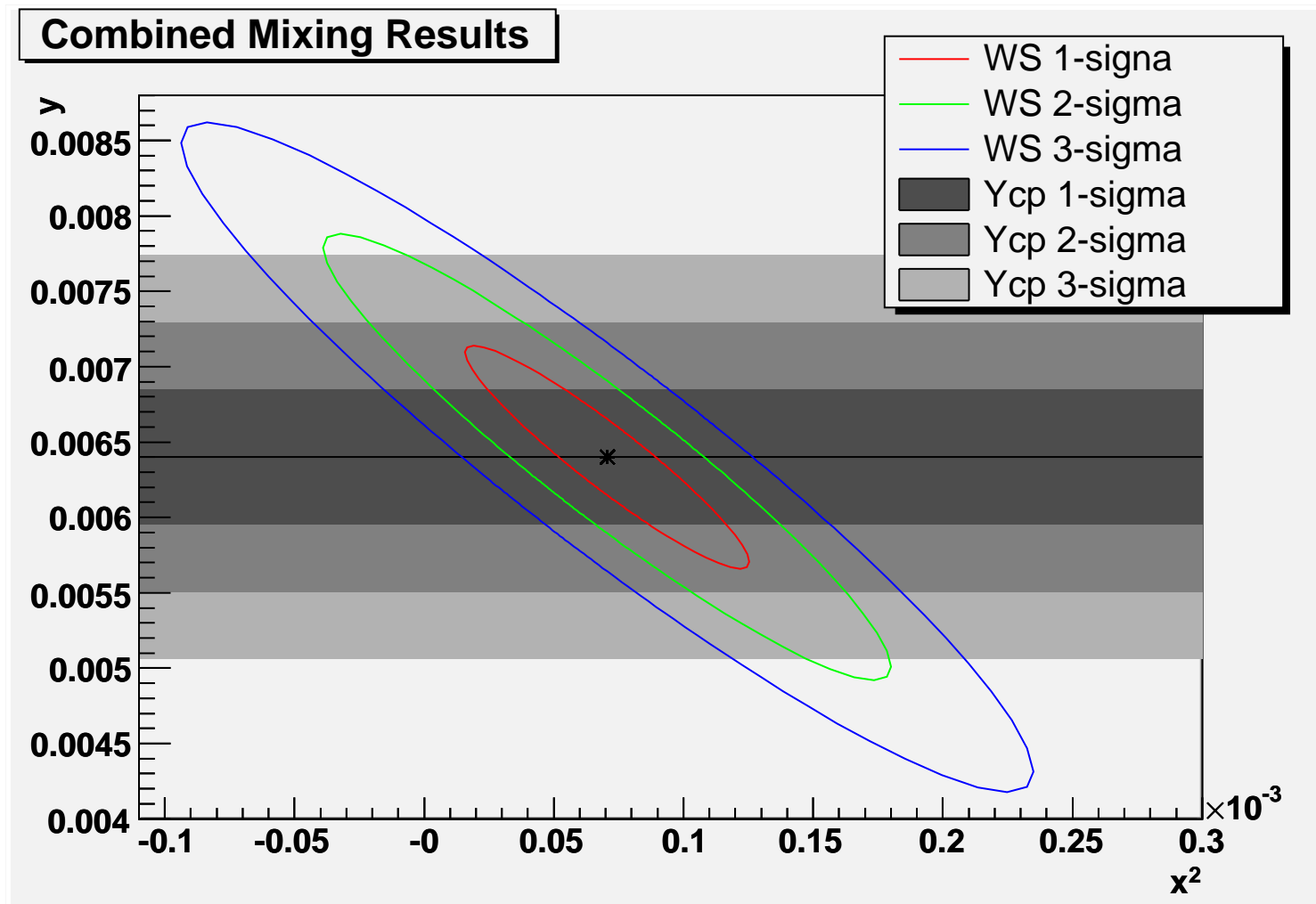
Acceptance



Resolution



Summary of LHCb at 10 fb^{-1}



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

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 $D^0 \rightarrow hh$ per 2 fb^{-1}
- Unprecedented sensitivity in searches for:
 - D^0 mixing
 - CP violation

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