Results and Prospects for Charm Physics at LHCb

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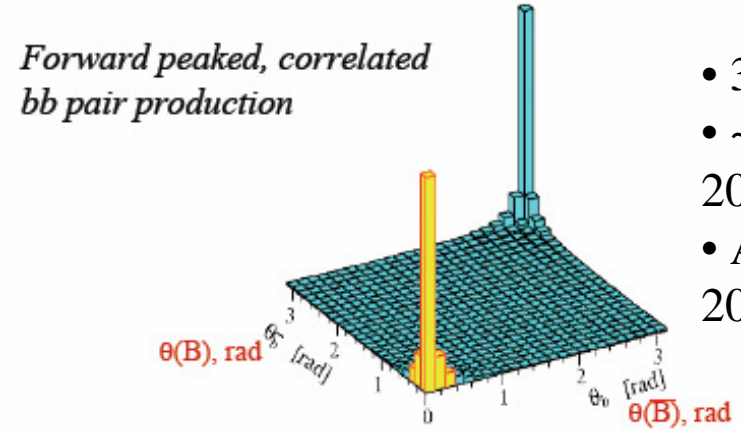
On behalf of the LHCb Collaboration

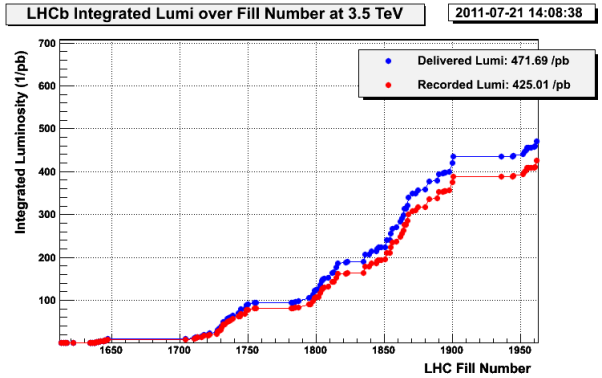
Overview

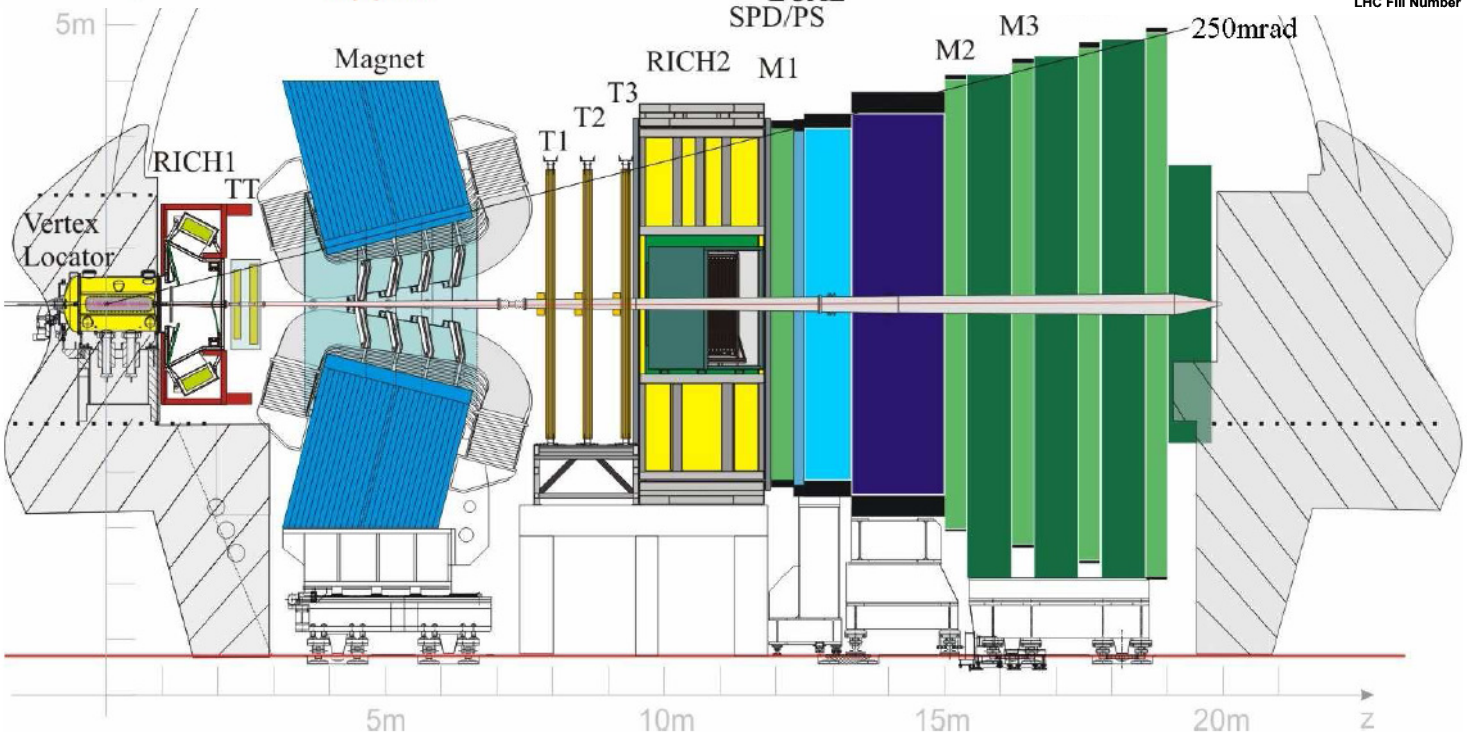
- The LHCb detector.
- Search for CPV in $D^+ \rightarrow K^-K^+\pi^+$
- ΔA_{CP} with $D^0 \rightarrow KK, \pi\pi$
- A_Γ with $D^0 \rightarrow KK$ – New LHCb Result!

The LHCb Detector



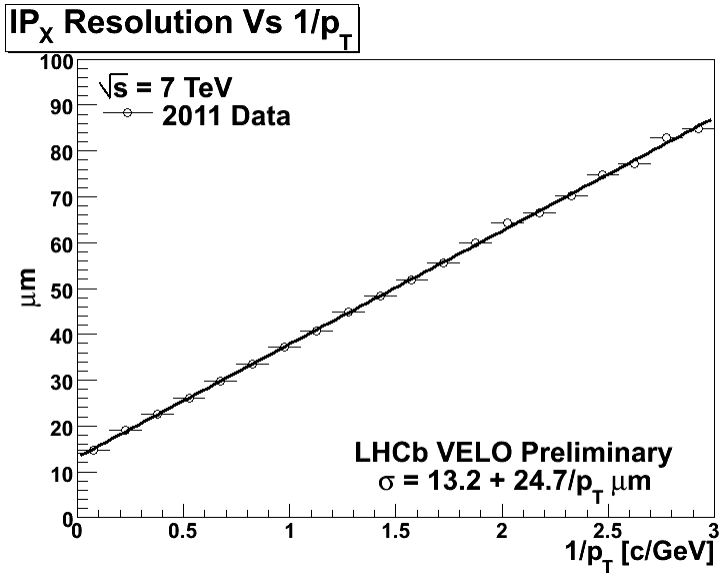
- 38 pb^{-1} taken in 2010.
- ~425 pb^{-1} taken in 2011 so far!
- All results shown from 2010 data.

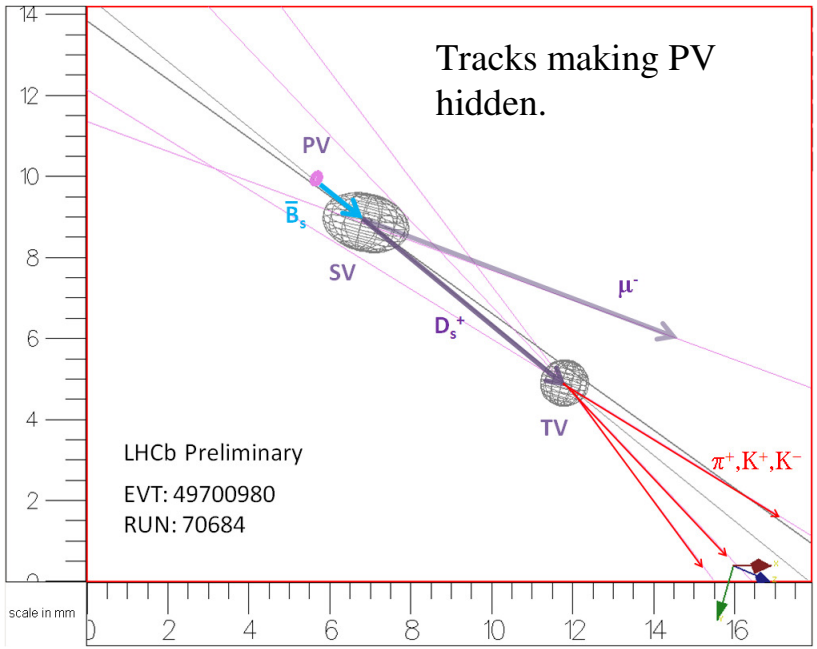




Detector Performance

- VErtex LOcator (VELO) provides excellent impact parameter resolution: 38 μm @ 1 GeV.
- Reflected in vertex resolution: 13 μm in x & y, 69 μm in z, from 25 tracks.
- And proper time resolution: ~50 fs (3% of τ(B), 12% of τ(D)).





- Two Ring Imaging CHerenkov (RICH) detectors provide excellent PID.
- Clean separation of π & K over broad momentum range.

Search for CPV in $D^+ \to K^-K^+\pi^+$

Paper in preparation

Search for CPV in $D^+ \to K^-K^+\pi^+$

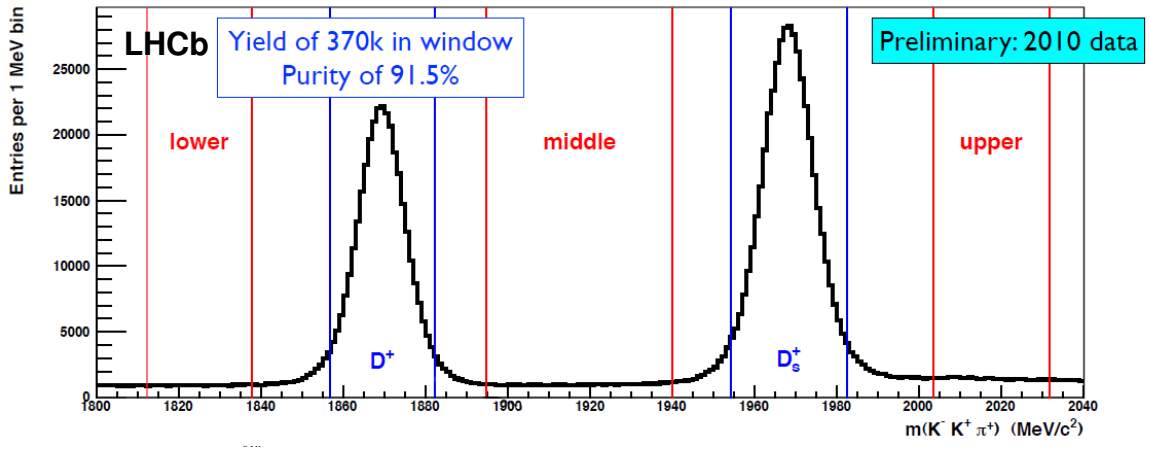
- Model-independent search for CPV in Dalitz plot.
- Compare binned, normalised Dalitz plots for D^+, D^-.
- χ^2 test for asymmetry – "Miranda" method:

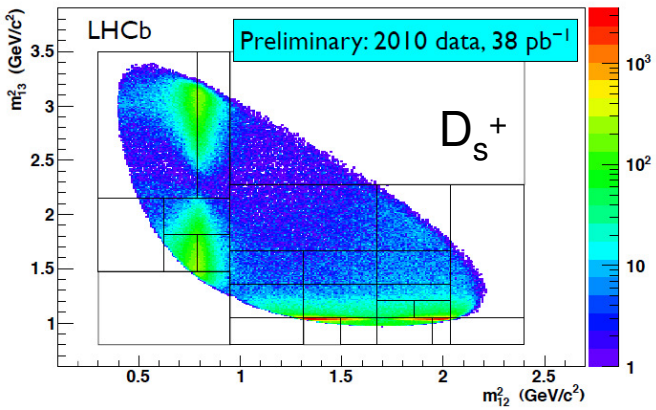
$$\chi^2_{bin} = \frac{(N(D^+) - N(D^-))^2}{\sigma(N(D^+))^2 + \sigma(N(D^-))^2}$$

- Evaluate $P(\chi^2 \mid ndf)$ to check consistency with 0.
- Check for false asymmetries on control samples:
  - Simulation.
  - $D_s^+ \to K^+K^-\pi^+$.
  - Mass sidebands.
  - $D^+ \to K^-\pi^+\pi^+$.
- Combine data with opposite magnet polarities to cancel left-right asymmetries.

"Miranda" method: Phys. Rev. D80 (2009) 096006

$K^-K^+\pi^+$ Control Modes

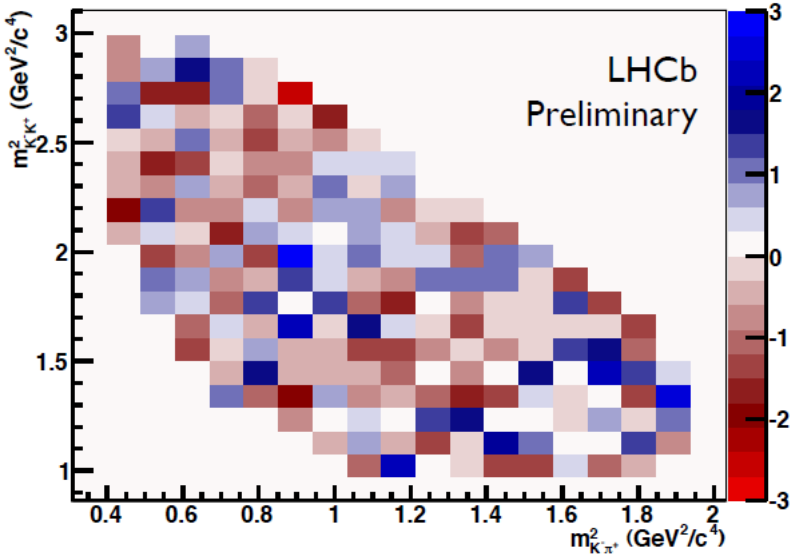


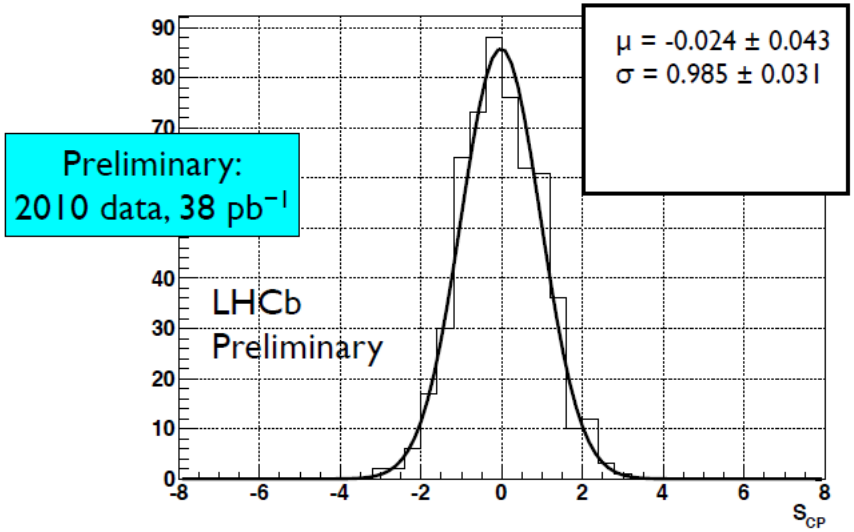


Window	MagUp	MagDown	Combined
Lower sideband	32.7%	10.1%	8.7%
Middle sideband	31.4%	27.7%	50.8%
D_s^+ window	88.9%	15.5%	34.4%
Upper sideband	1.3%	50.7%	26.5%

- No evidence of fake asymmetries.
- Method very robust against systematic effects.

$D^+ \rightarrow K^-K^+\pi^+$ Results





- **No evidence of CP violation in 2010 data (38 pb^{-1}).**

LHCb Preliminary

MagUp	6.0%
MagDown	28.5%
Combined	**12.7%**

ΔA_{CP} with $D^0 \rightarrow KK, \pi\pi$

LHCb-CONF-2011-023

ΔA_{CP} Formalism

$$A_{RAW}(f) = \frac{N(D^0 \to f) - N(\overline{D^0} \to \overline{f})}{N(D^0 \to f) + N(\overline{D^0} \to \overline{f})}$$

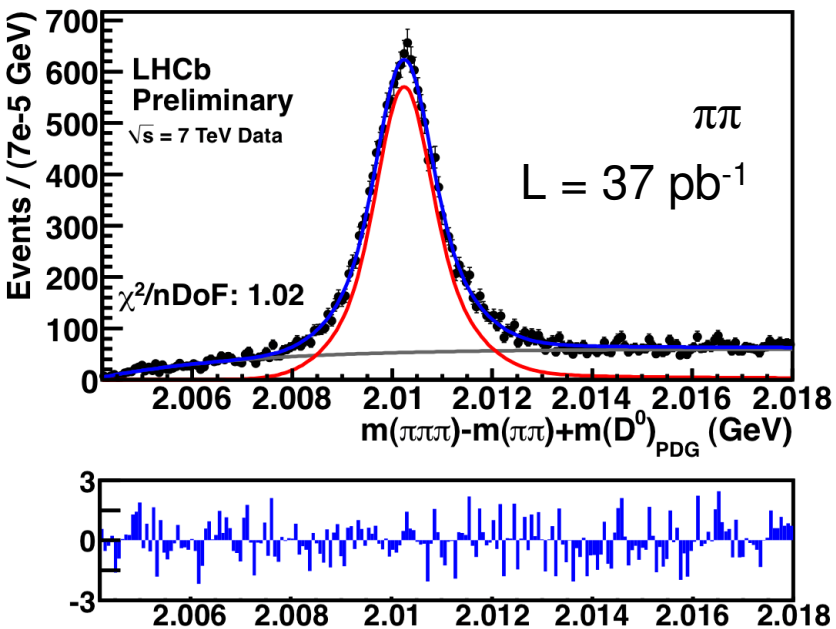
$$A_{RAW}(f)^* = \frac{N(D^{*+} \to D^0(f)\pi^+) - N(D^{*-} \to \overline{D^0}(\overline{f})\pi^-)}{N(D^{*+} \to D^0(f)\pi^+) + N(D^{*-} \to \overline{D^0}(\overline{f})\pi^-)}$$

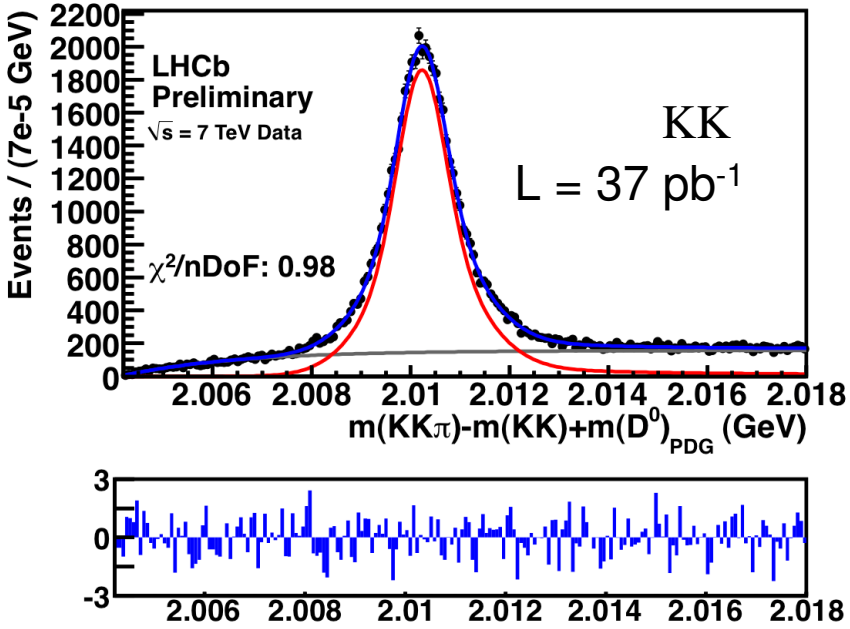
$$= \underbrace{A_{CP}(f)}_{\text{Physics asymmetry}} + \underbrace{A_D(f) + A_D(\pi_s)}_{\text{Detection asymmetries}} + \underbrace{A_P(D^{*+})}_{\text{Production asymmetry}}$$

- Taking $A_{RAW}(f)^*$ - $A_{RAW}(f')^*$ production & π_s detection asymmetries cancel.
- Detection asymmetry for self-conjugate final states is 0.

$$A_{RAW}(K^-K^+)^* - A_{RAW}(\pi^-\pi^+)^* = A_{CP}(K^-K^+) - A_{CP}(\pi^-\pi^+)$$
$$\equiv \Delta A_{CP}$$

ΔA_{CP} with $D^0 \rightarrow KK, \pi\pi$





- Fits to m(D*) - m(D^0).
- Yields:
  - 116k tagged $D^0 \rightarrow K^-K^+$
  - 36k tagged $D^0 \rightarrow \pi^-\pi^+$

$$\mathbf{A_{CP}(KK) - A_{CP}(\pi\pi) = (-0.28 \pm 0.70 \pm 0.25) \%}$$

LHCb Preliminary

A_Γ with $D^0 \rightarrow KK$

LHCb-CONF-2011-046 in preparation

New LHCb Result – First Public Presentation!

A_Γ Formalism

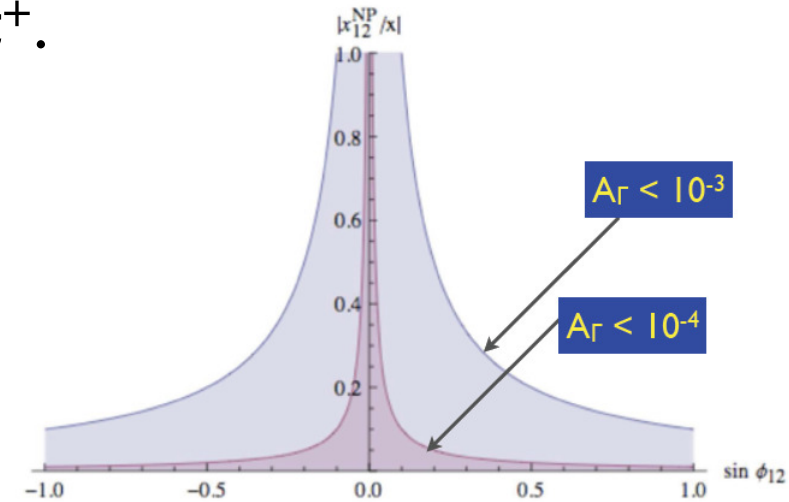
- Direct measure of CPV in D^0 mixing:

$$A_\Gamma = \frac{\tau(\overline{D^0} \to K^- K^+) - \tau(D^0 \to K^- K^+)}{\tau(\overline{D^0} \to K^- K^+) + \tau(D^0 \to K^- K^+)}$$

$$\approx \frac{A_M}{2} y \cos\phi - x \sin\phi$$

- Flavour tag using $D^{*+} \to D^0\pi^+$.
- Control mode: $D^0 \to K\pi$.

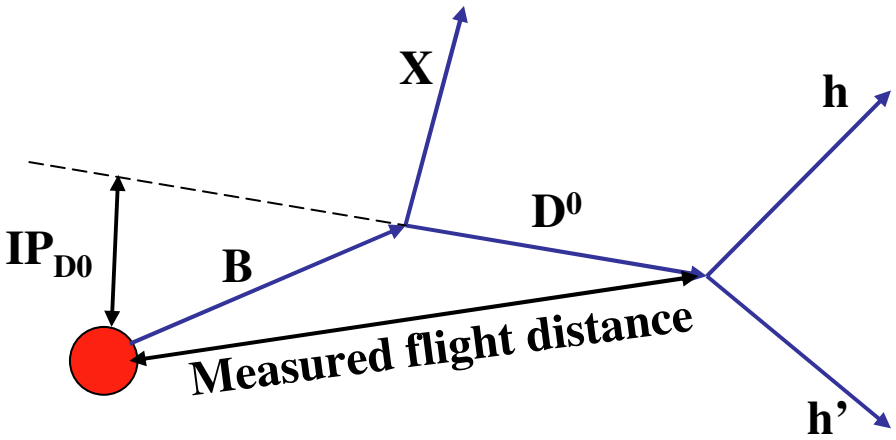
- Predicted very near 0 by SM.
- Observation of non-zero value clear sign of new physics.

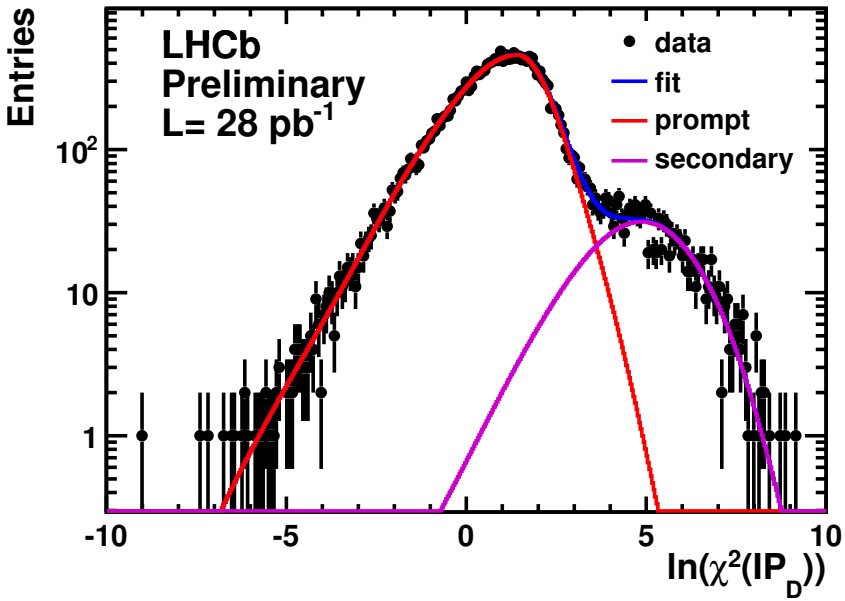


Kagan, FPCP 2011

A_Γ Method

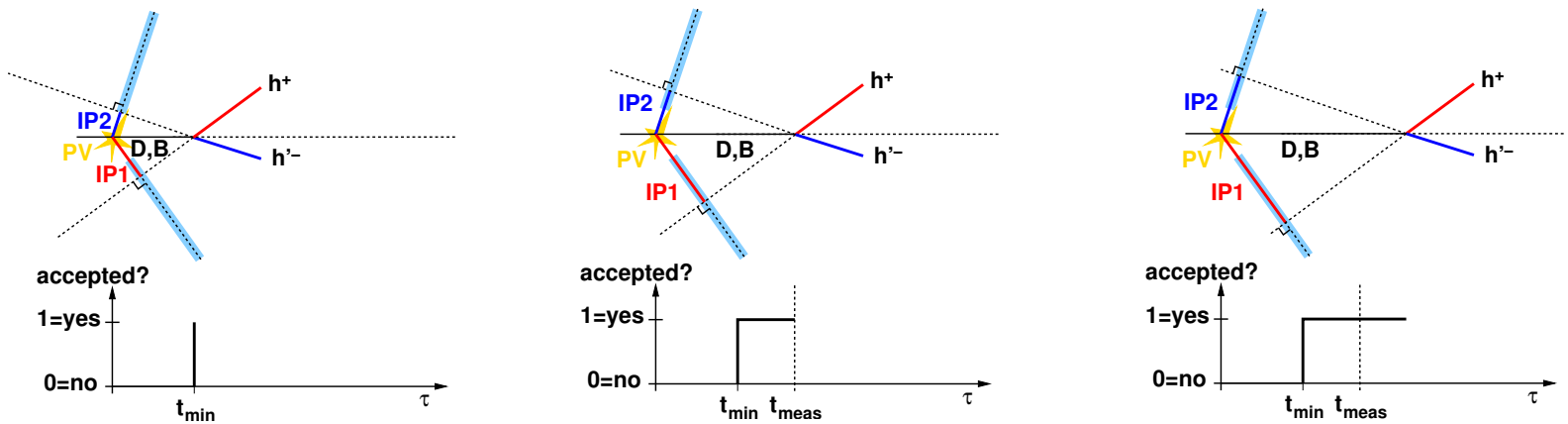
- Unbinned likelihood fit m(D^0) to determine signal yield & m(D*) - m(D^0) to determine mistag.
- Unbinned likelihood fit to proper time to determine τ directly.
- Distinguish prompt D^0 & D^0 from B with simultaneous fit to χ^2(IP(D^0)).



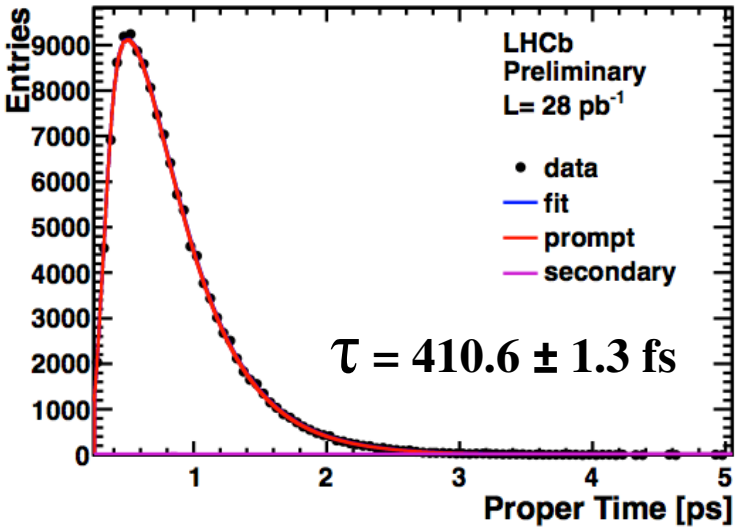


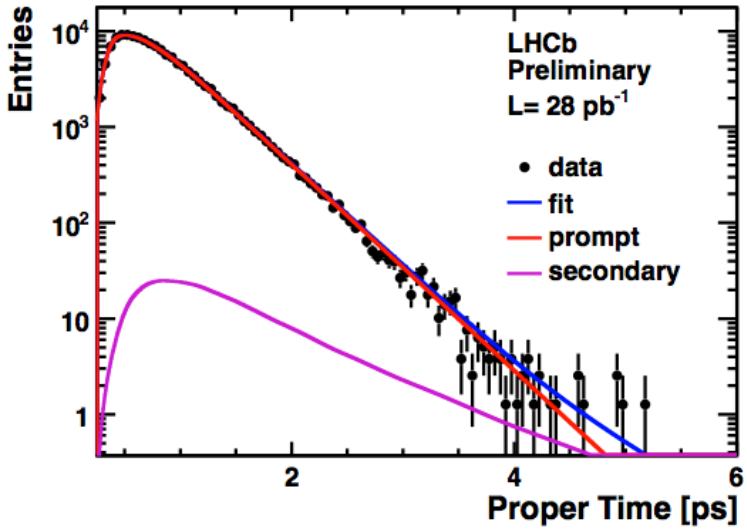
A_Γ Method contd.

- Correct trigger & selection acceptance using per-candidate acceptance functions – 'Swimming method'.
- Move PV along direction of D^0 momentum to artificially change D^0 proper time.
- Store trigger & selection decision for each proper time to build acceptance function.



Cross check with $D^0 \rightarrow K\pi$





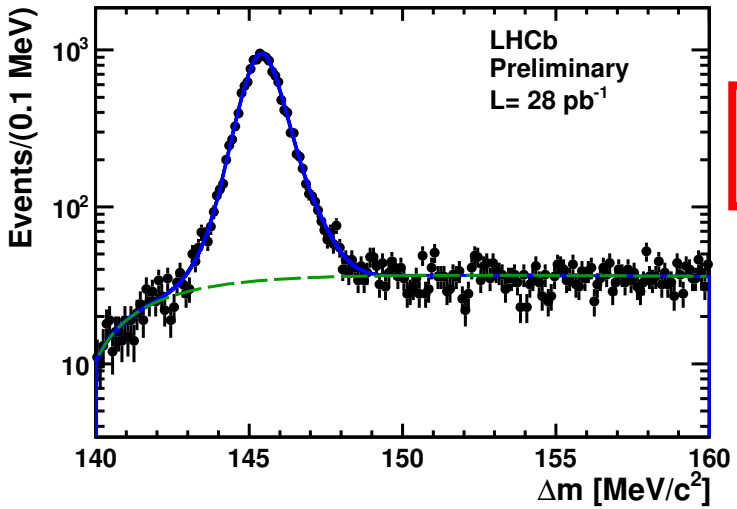
- Proof of principle: apply same procedure to $D^0 \rightarrow K\pi$.
- 110k candidates of each tag.

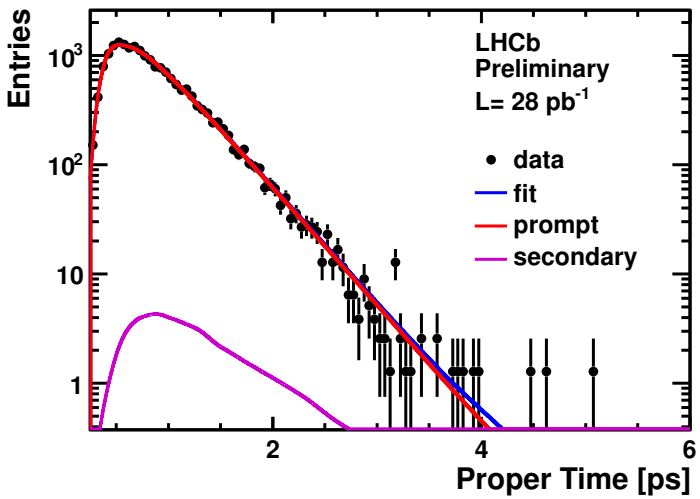
$$\mathbf{A_\Gamma^{K\pi,eff} = (-0.09 \pm 0.22 \pm 1.6) \ \%}$$

LHCb Preliminary

- Consistent with 0 as expected!
- Lifetimes consistent with PDG average of 410.1 ± 1.5 fs.
- Acceptance well modelled by 'Swimming'.

A_Γ with $D^0 \rightarrow KK$



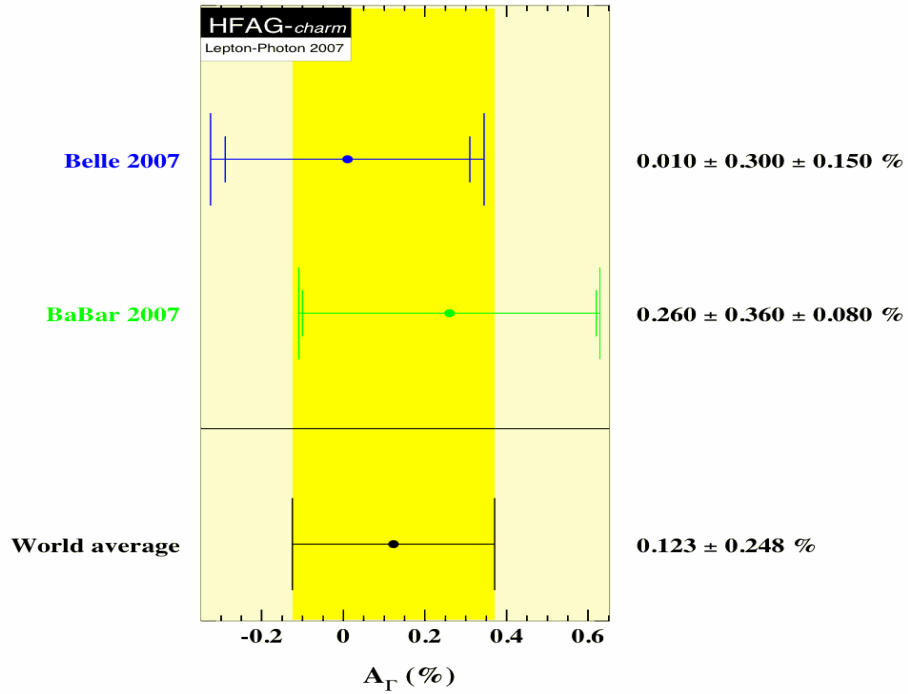


- 15k candidates of each tag.

$$A_\Gamma = (-0.59 \pm 0.59 \pm 0.21) \%$$

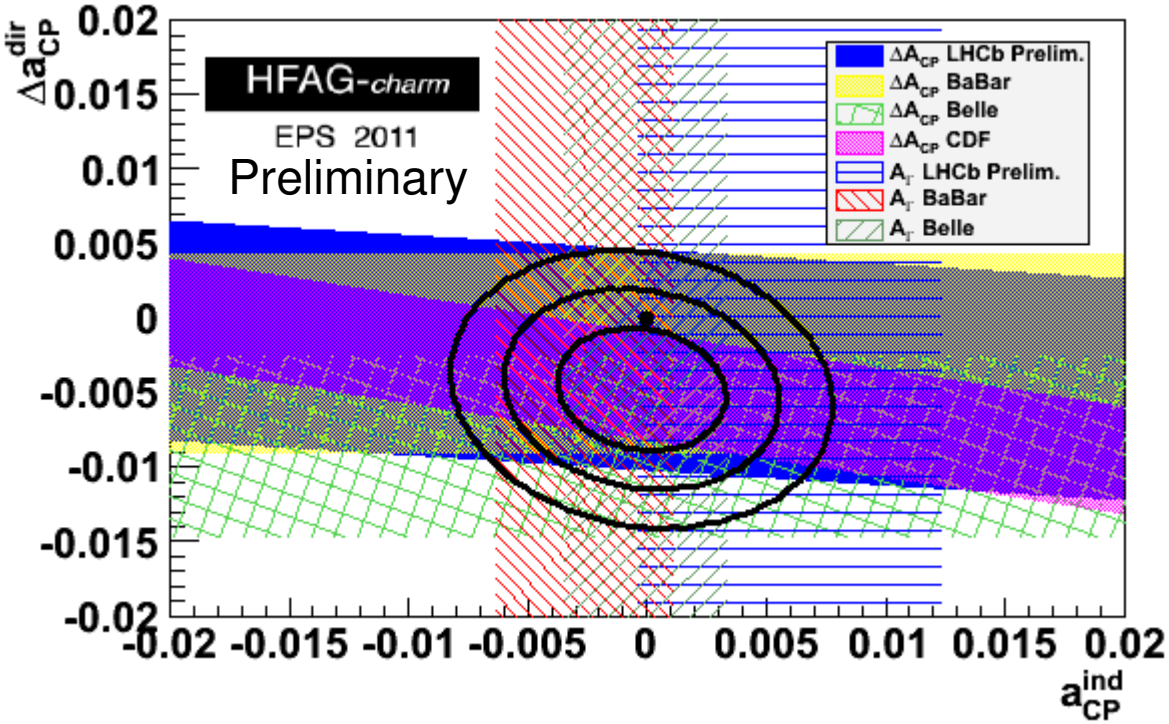
LHCb Preliminary
First public presentation!

- With just 28 pb^{-1} not yet competitive:



HFAG World Average

- Preliminary average courtesy of HFAG.
- Slope in LHCb ΔA_{CP} result due to small KK/ππ lifetime acceptance difference: $\Delta\langle t\rangle/\tau = 0.10 \pm 0.01$



Conclusions & Outlook

- Many charm analyses ongoing at LHCb.

- **LHCb Preliminary Results on 2010 data (~38 pb^{-1}):**
  - **No CPV in $D^+ \rightarrow K^-K^+\pi^+$.**
  - **A_{CP}(KK) - A_{CP}($\pi\pi$) = (-0.28 ± 0.70 ± 0.25) %**
  - **A_Γ = (-0.59 ± 0.59 ± 0.21) % (28 pb^{-1})**

- Study of x'^2 & y' with wrong sign $D^0 \rightarrow K\pi$ well advanced.
- Many production & spectroscopy measurements also being made.

- **425 pb^{-1} collected in 2011 so far!**
- **Sufficient to really probe new physics in many key areas!**

Backup

Slide borrowed from presentation by M. Charles EPS 2011

Time-integrated wrong-sign $D^0 \to K\pi$

Three contributions with different lifetime dependence:

$$\Gamma_{WS}(t) = e^{-\Gamma t}\left(\underbrace{R_D}_{\text{DCS}} + \underbrace{y'\sqrt{R_D}}_{\text{Interference}}(\Gamma t) + \underbrace{\frac{x'^2 + y'^2}{4}}_{\text{Mixing}}(\Gamma t)^2\right)$$

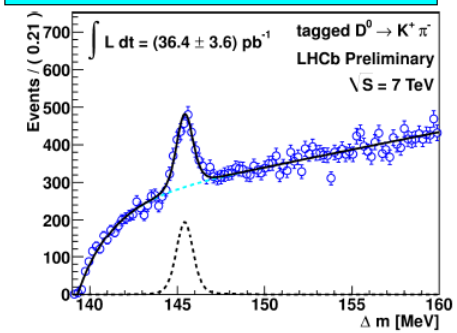
[Limit of $|x| \ll 1$, $|y| \ll 1$, and no CPV.]

Our lifetime acceptance is not flat => affects relative weighting.

- Start with raw WS/RS time-integrated ratio.
- Determine our efficiency(t) using PDG D0 lifetime as input
- Determine correction using HFAG mixing parameters as input
- Compute lifetime-acceptance-corrected WS/RS ratio.

	WS/RS of $D \to K\pi$ decays (%)
$R_{measured}$	$0.442 \pm 0.033\ (stat.)\ \pm 0.042\ (sys.)$
$R_{acc\,cor}$	$0.409 \pm 0.031\ (stat.)\ \pm 0.039(sys.)\ ^{+0.028}_{-0.020}\ (sys.\ mixing)$
$R(PDG)$	0.380 ± 0.018

Preliminary: 2010 data, 38 pb^{-1}



Cross-check consistent with PDG average.

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