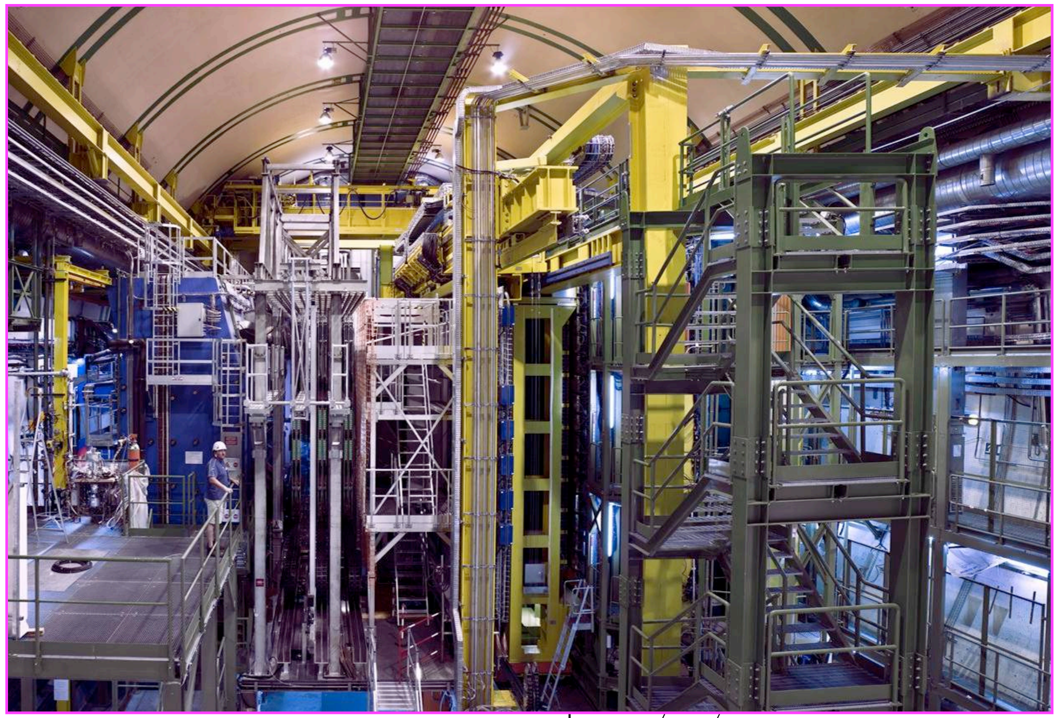
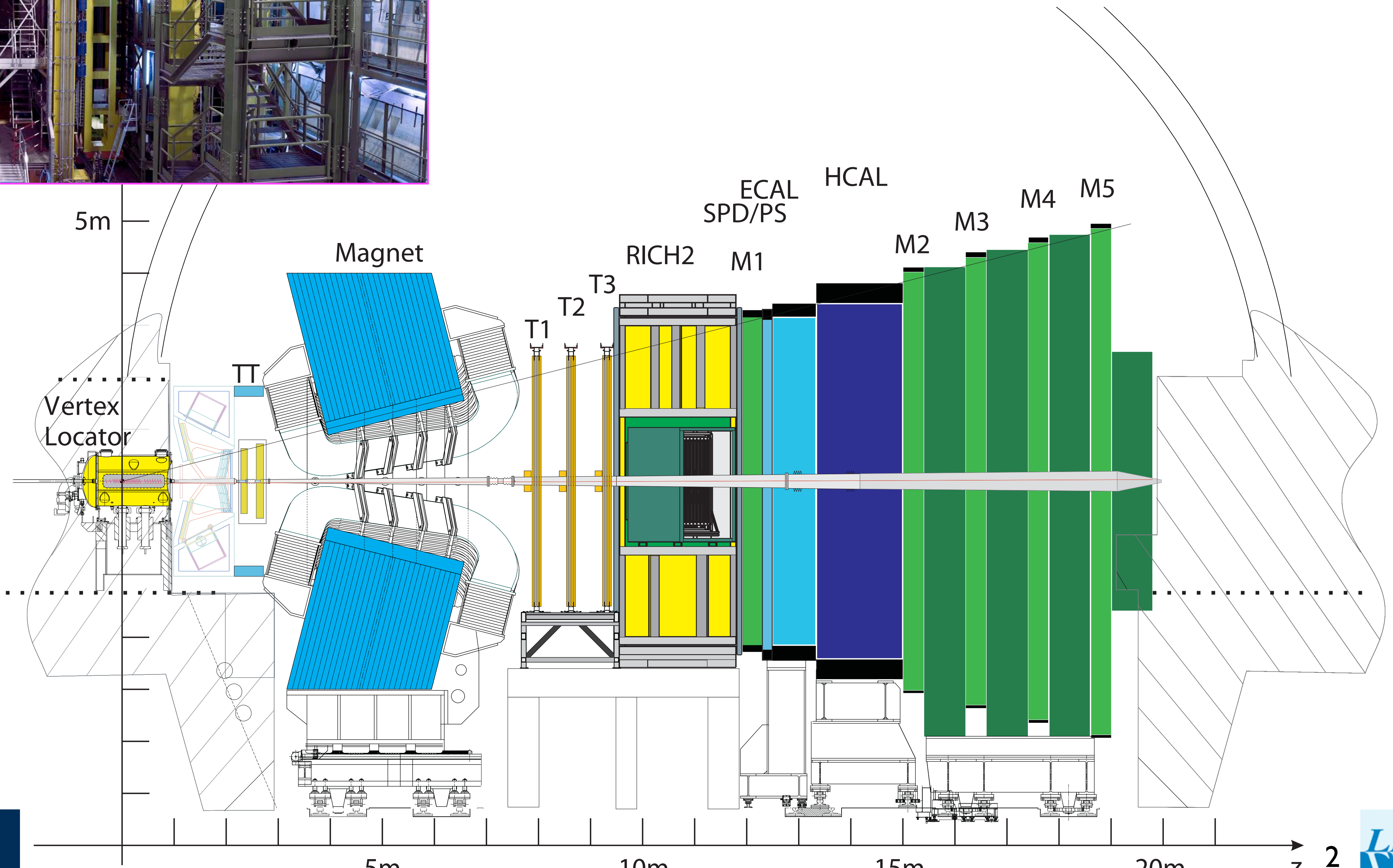
Searches for CP Violation in Charm Decays at LHCb

Mat Charles (Oxford)
on behalf of the LHCb collaboration

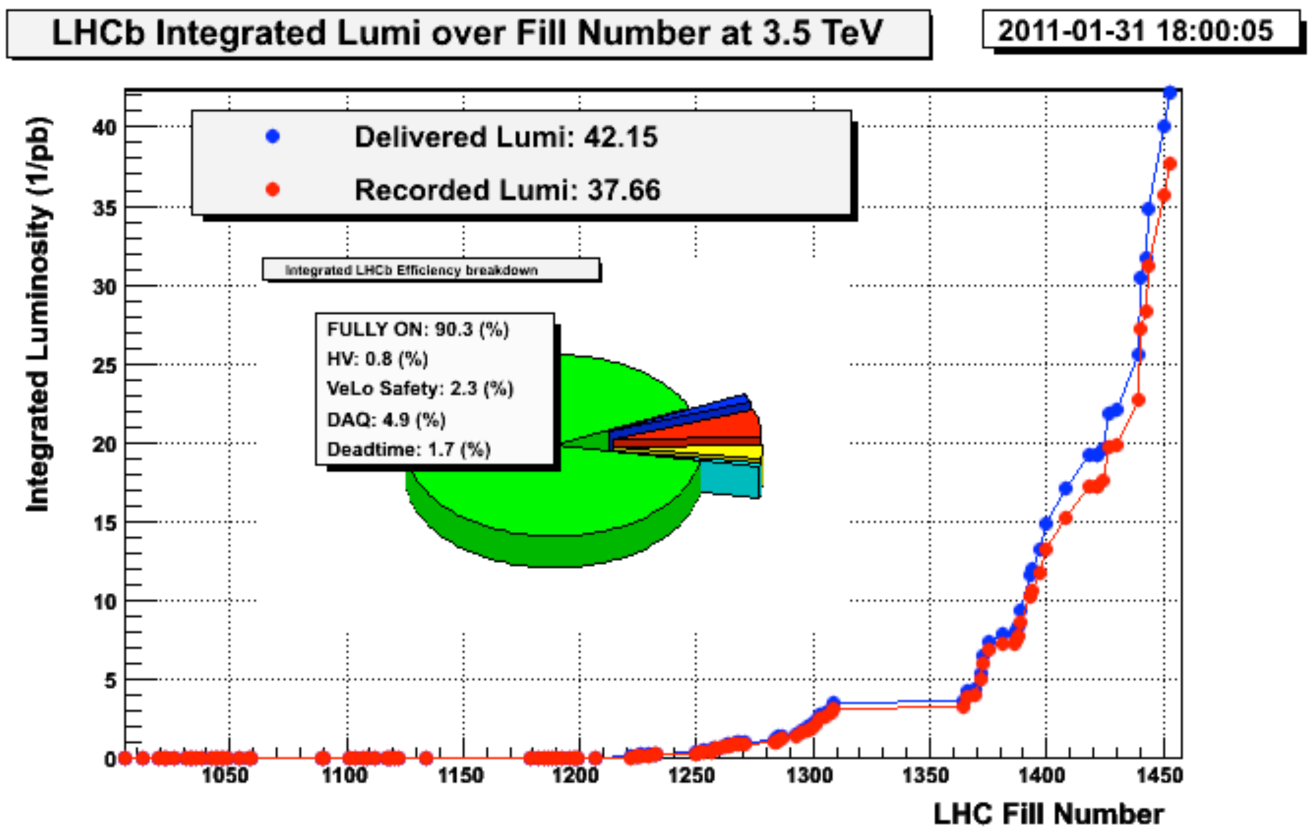
Disclaimer: All results are preliminary

The LHCb detector

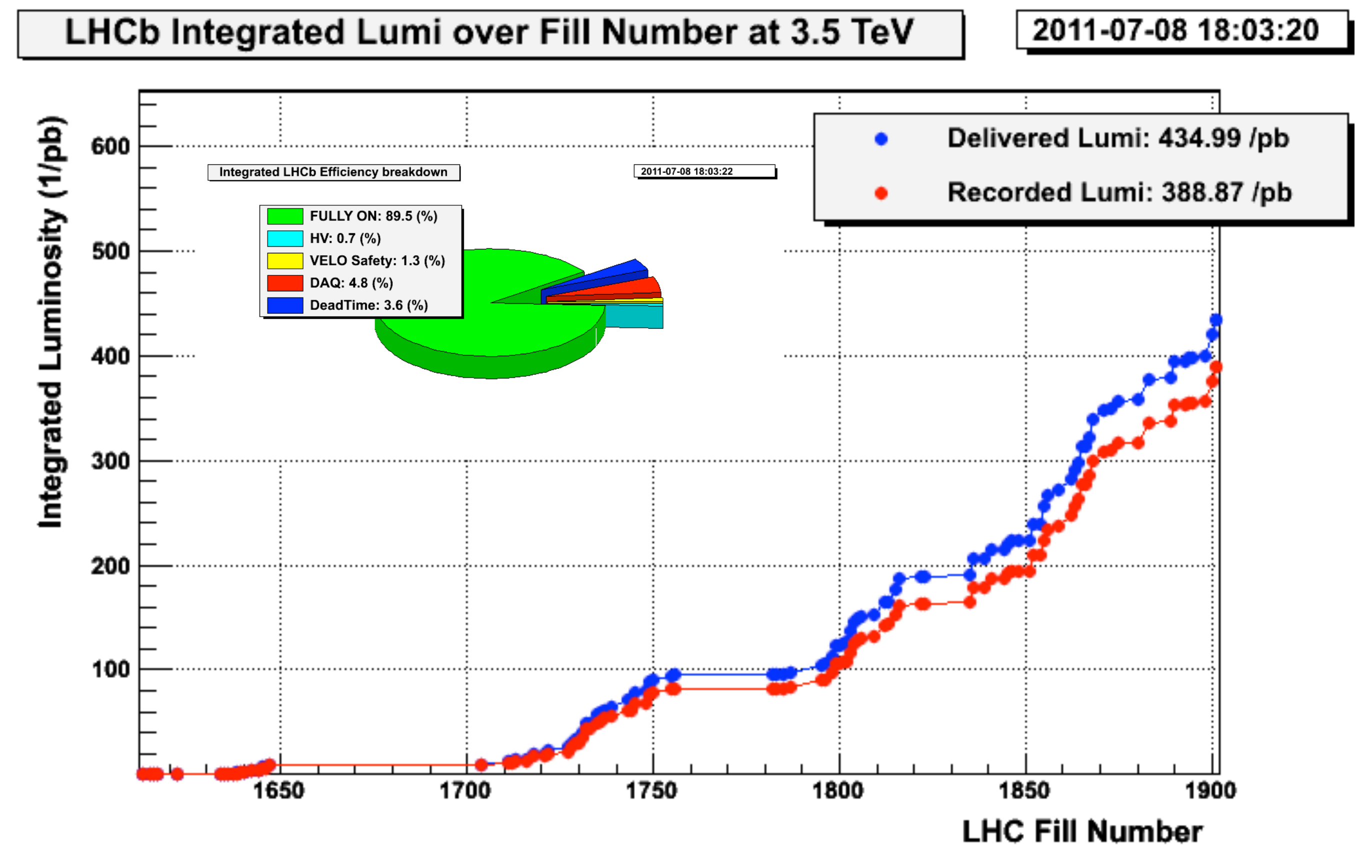




Data-taking



2010: 38 pb^{-1}



2011: 389 pb^{-1} so far...

- Today's results use just the 2010 sample.
- Already an order of magnitude more integrated luminosity in 2011.
  - Writing out events with fully reconstructed charm hadrons at a rate of 1 kHz

CP violation

- 3 types of CP violation:
  - In mixing: rate of $D^0 \to D^0$bar and D^0bar $\to D^0$ differ
  - In decay: amplitudes for a process and its conjugate differ
  - In interference between mixing and decay diagrams

Indirect

Direct

- In the SM, indirect CP violation in charm is expected to be very small and universal between CP eigenstates
  - Exactly how small is a matter of debate... but for sure well below present limit of several x 10^{-3}
- Direct CP violation can be larger in SM, very dependent on final state (therefore we must search wherever we can)
  - In singly-Cabibbo-suppressed modes (10^{-4}) plausible, $O(10^{-3})$ possible
- Both can be enhanced by NP, in principle up to O(%)

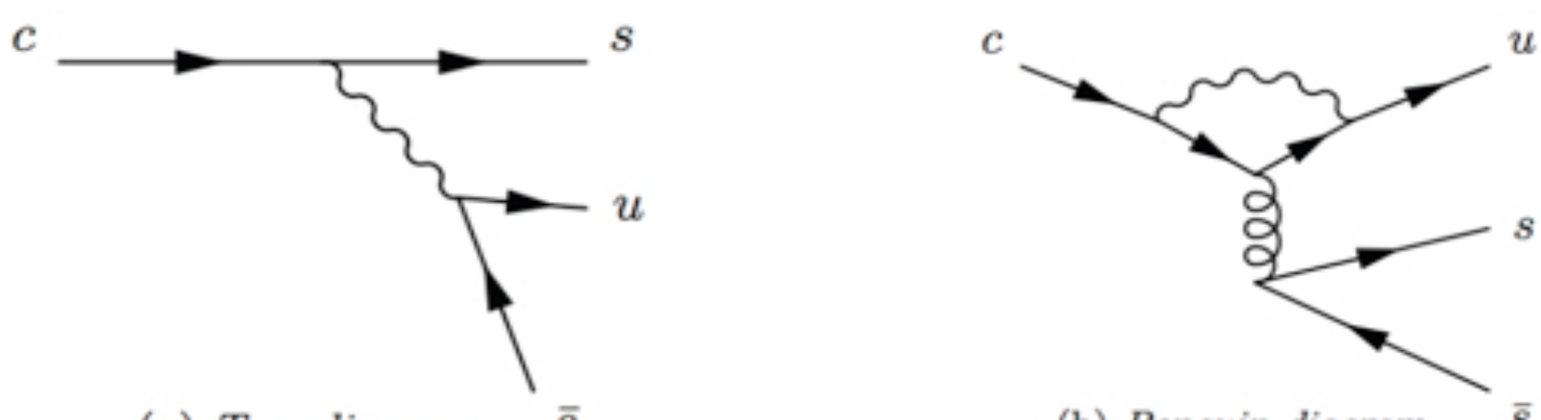
Bianco, Fabbri, Benson & Bigi, Riv. Nuovo. Cim 26N7 (2003)
Grossman, Kagan & Nir, PRD 75, 036008 (2007)
Bigi, arXiv:0907.2950

Bobrowski, Lenz, Riedl & Rorhwild, JHEP 03 009 (2010)
Bigi, Blanke, Buras & Recksiegel, JHEP 0907 097 (2009)

CPV in charm not yet seen experimentally

Where to look for direct CPV

- Remember: need (at least) two competing amplitudes with different strong and weak phases to get CPV.
- Cabibbo-favoured modes not interesting
  - Tree-level SM contribution swamps everything else
- Singly-Cabibbo-suppressed modes with gluonic penguin diagrams very promising



(a) *Tree diagram.* (b) *Penguin diagram.*

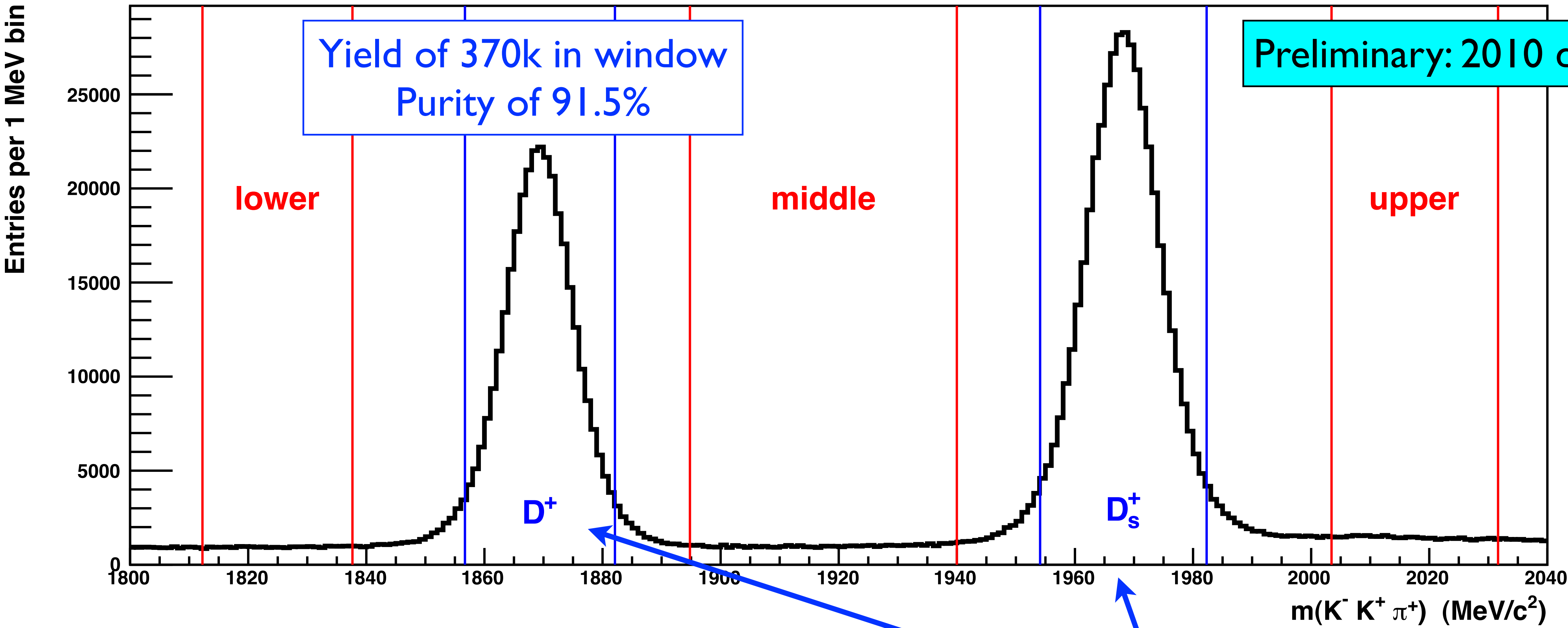
CLEO-c study with 818 pb^{-1}: Phys. Rev. D78 (2008) 072003

BABAR study of 80 fb^{-1}: Phys. Rev. D71 (2005) 091101 (R)

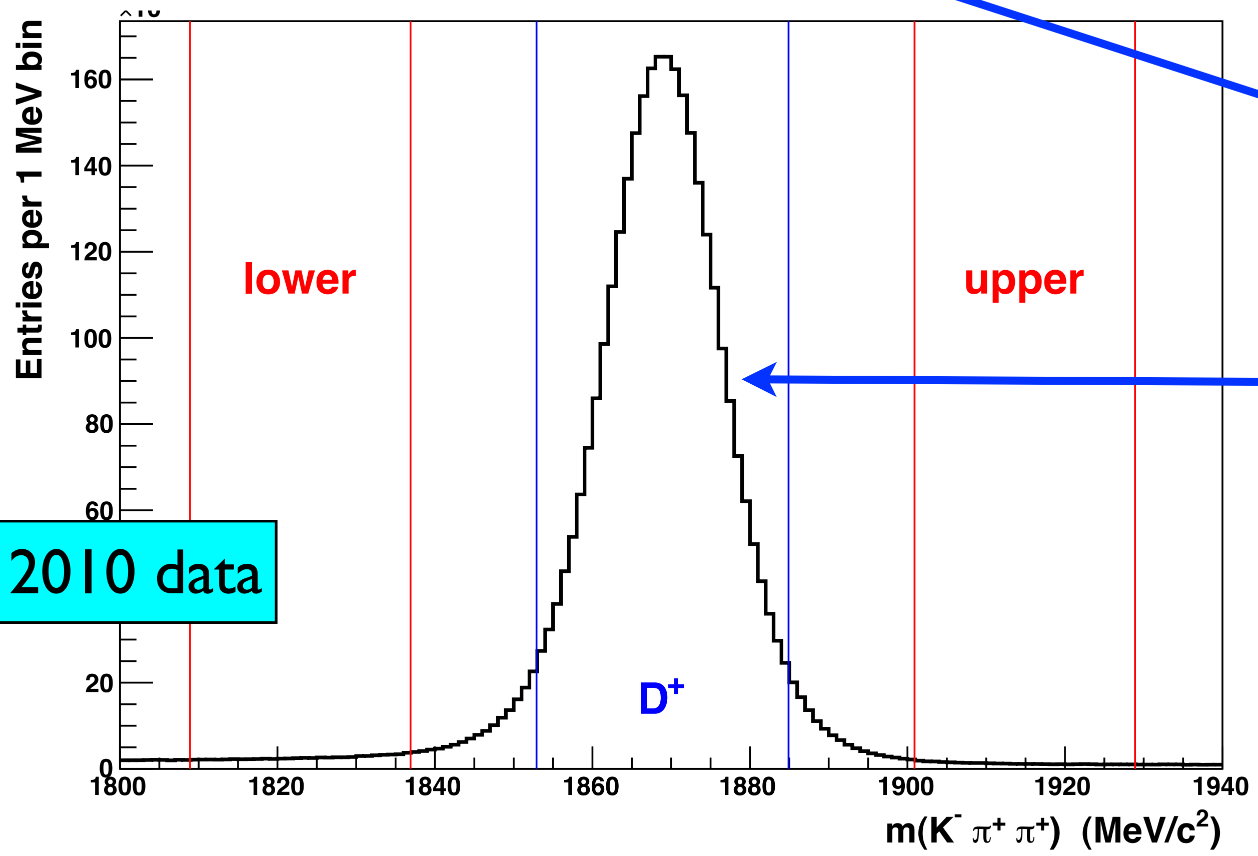
$D^+ \rightarrow K^- K^+ \pi^+$

Paper in preparation.

Mass spectra after selection



KKπ signal (D^+) and control mode (D_s^+)



Preliminary: 2010 data

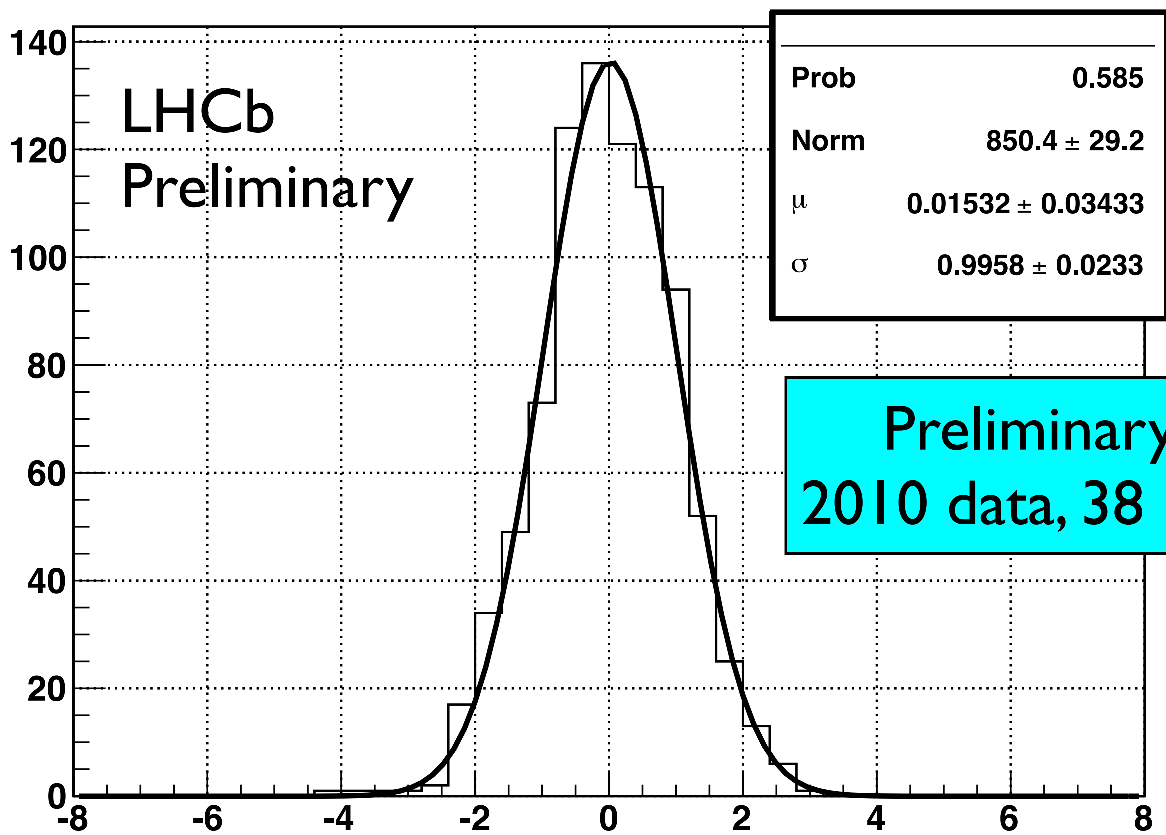
Kππ control mode (D^+) purity ~ 98%

About 6/pb omitted from these mass spectra for technical reasons, but still used in analysis.

Technique

- Model-independent search for CPV in Dalitz plot distribution
- Compare binned, normalized Dalitz plots for D^+, D^-
  - Production asymmetry etc cancels completely after normalization.
  - Efficiency asymmetries that are flat across Dalitz plot also cancel.
- Method based on “Miranda” approach -- asymmetry significance
  - In absence of asymmetry, values distributed as Gaussian($\mu=0$, $\sigma=1$)
  - Figure of merit for statistical test: sum of squares of Mirandas is a χ^2.

NDF = (#bins−1) → p-value



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

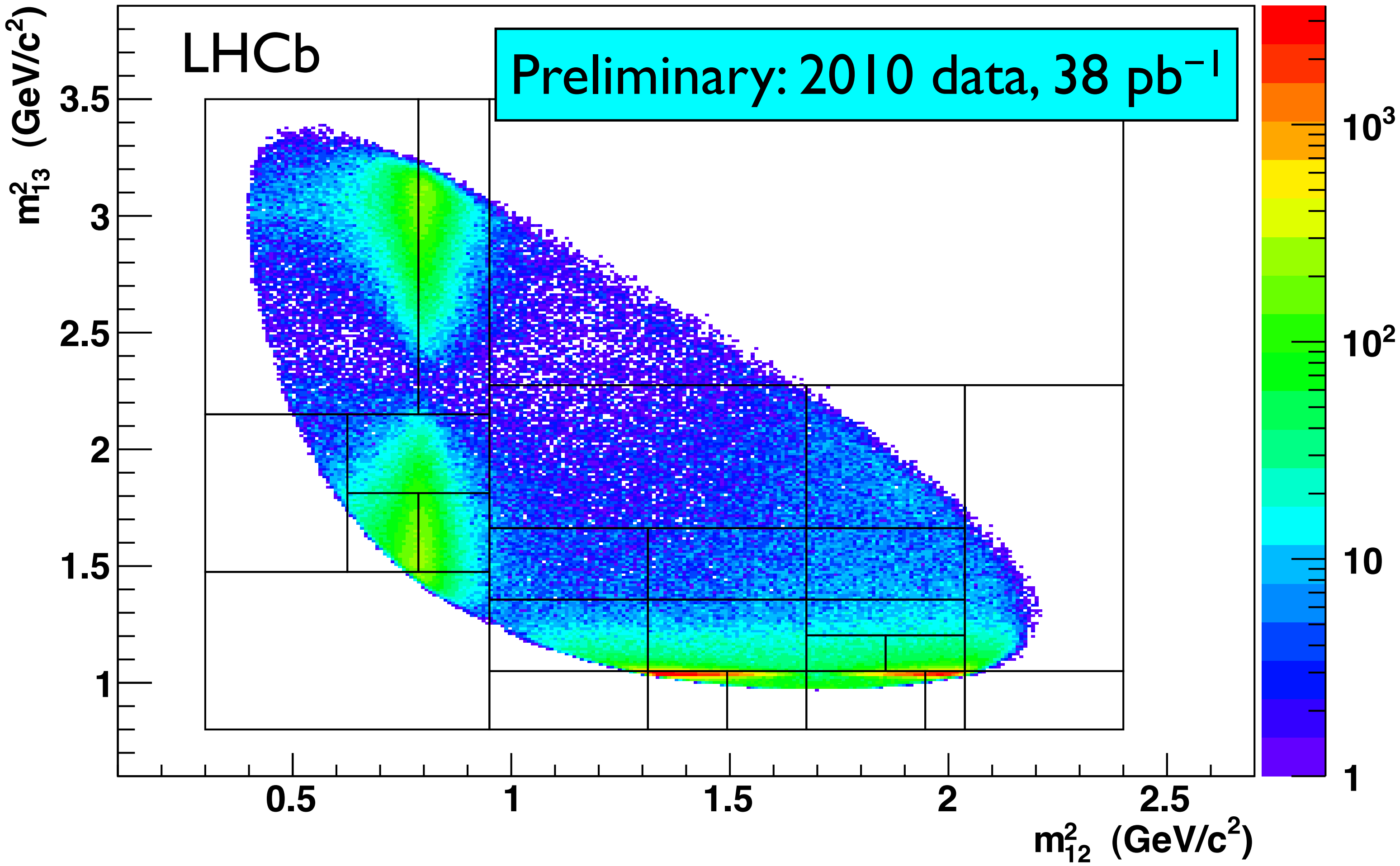
Example: distribution for $D^+ \to K^- \pi^+ \pi^+$ control mode follows prediction very nicely.

Miranda paper: Phys. Rev. D80 (2009) 096006
See also BaBar: Phys.Rev. D78:051102 (2008)

Strategy

- Blind analysis: check no fake asymmetries in control modes, simulation before looking in signal box.
- Verify with toy studies that statistical procedure is sound
  - When generating events with no CP asymmetry, none is detected.
  - When generating with an asymmetry, it is detected (if large enough)
- Key control samples:
  - $D_s^+ \to K^- K^+ \pi^+$ control mode (very powerful!)
  - $K^- K^+ \pi^+$ sidebands
  - $K^- \pi^+ \pi^+$ control mode (much uglier & harder than our signal mode)
- Combine the two magnet polarities to cancel various small left-right asymmetries.
- Try a variety of binnings (sensitive to range of CPV scenarios).

$D_s^+ \to K^- K^+ \pi^+$ control mode



Verify no problem with:

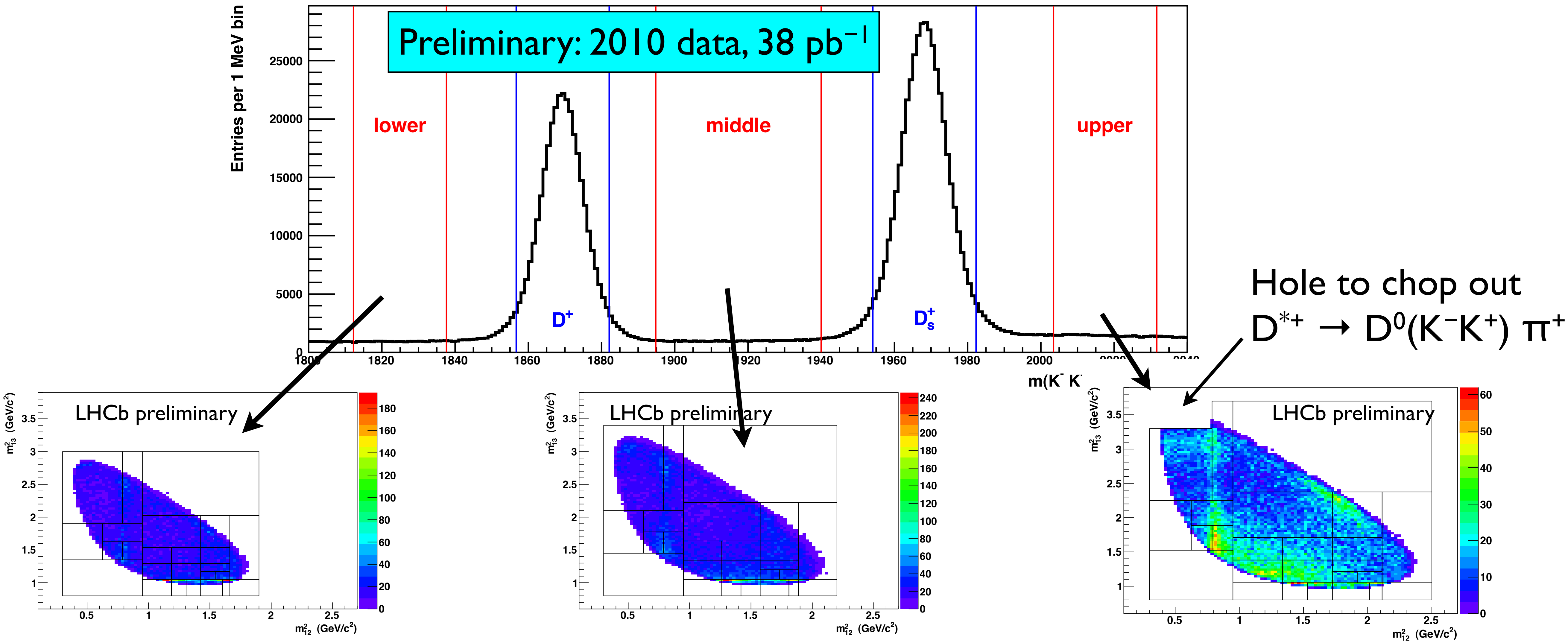
- efficiency asymmetry
- nonpeaking backgrounds (e.g. inclusive ϕ, K^*)
- charm reflections in general

- For MagUp: χ^2/NDF = 16.0 / 24 (88.9%)
- For MagDown: χ^2/NDF = 31.0 / 24 (15.5%)
- Combined: χ^2/NDF = 26.2 / 24 (34.4%)

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

- Great! No evidence of any fake asymmetry in control mode.

Other $K^- K^+ \pi^+$ control modes

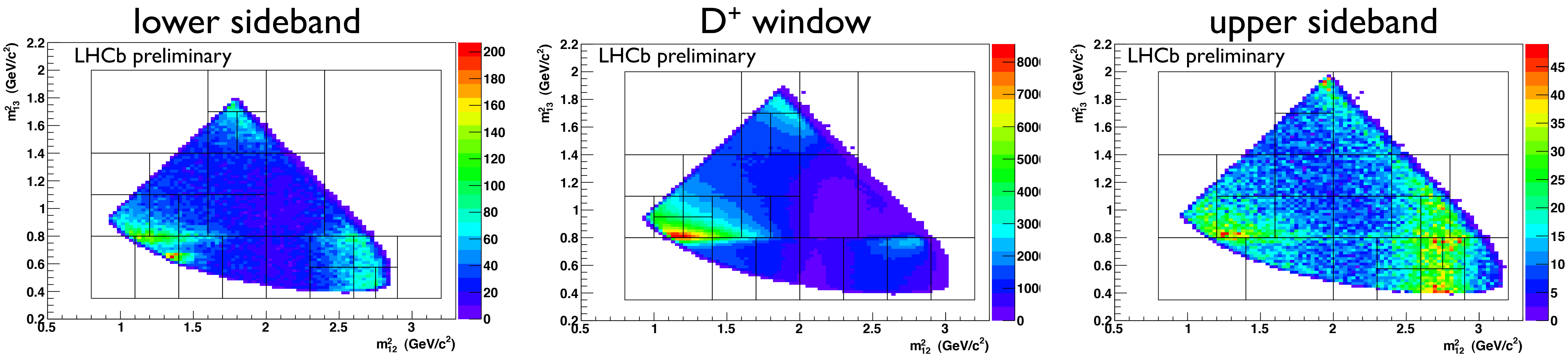


Window	MagUp	MagDown	Combined
lower sideband	32.7%	10.1%	8.7%
middle sideband	31.4%	27.7%	50.8%
D_s^+ window	88.9%	15.5%	34.4%
upper sideband	1.3%	50.7%	26.5%

Sidebands around the D^+ signal peak look completely fine!

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

$K^- \pi^+ \pi^+$ control modes



Window	MagUp	MagDown	Combined
lower sideband	99.7%	18.2%	91.0%
D^+ window	49.2%	0.15%	9.2%
upper sideband	66.2%	56.1%	35.3%

Preliminary
2010 data, 38 pb^{-1}

- $D^+ \rightarrow K^- \pi^+ \pi^+$ behaves amazingly well. Remember:
  - there is a mechanism for a fake asymmetry that doesn't apply to the signal mode (kaon efficiency)
  - the statistics are 10x larger than in the signal mode

Method of comparing normalized Dalitz plots very robust against systematic effects.

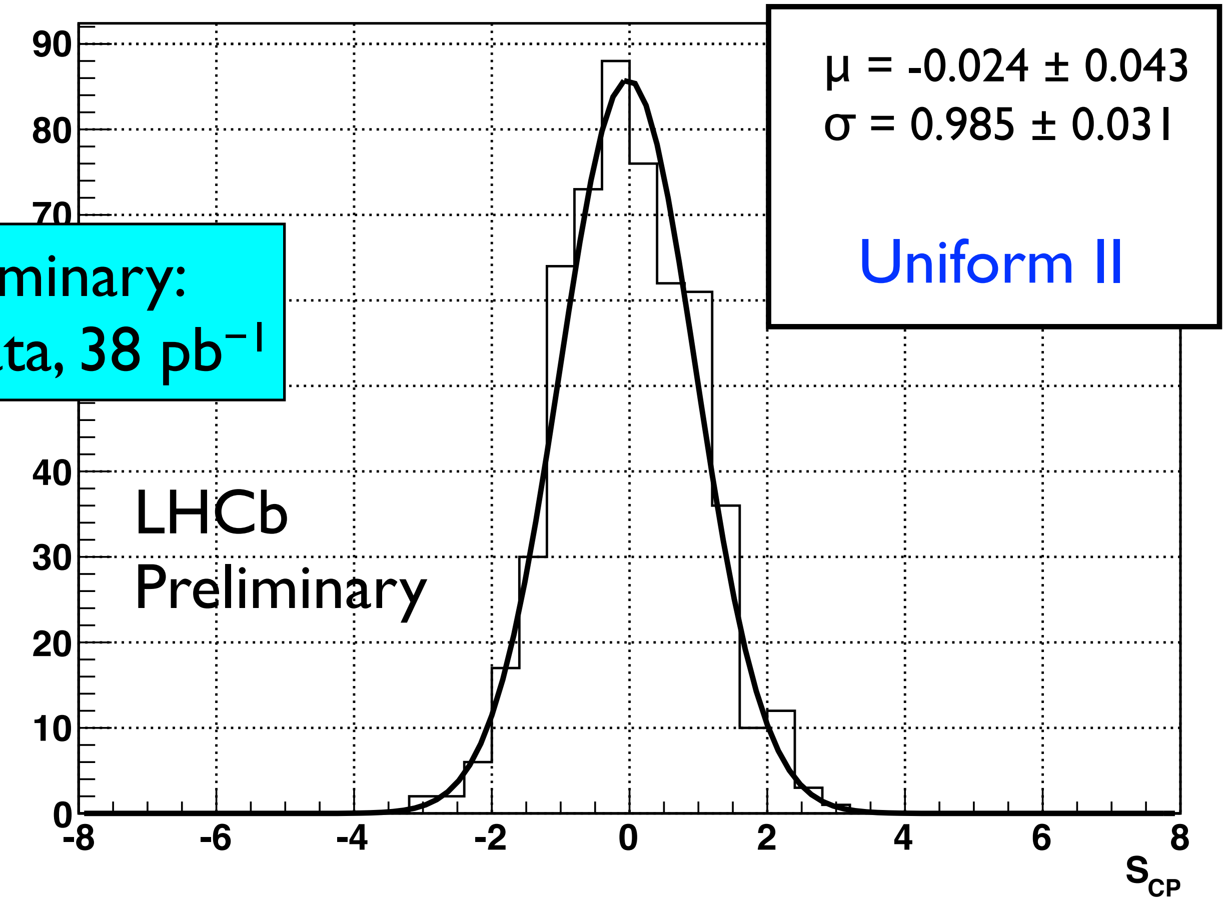
Further tests

- Toy study with simulated K^+/K^- efficiency asymmetry
- Numerous other binning schemes
  - ... in particular using uniform (square) binnings
  - Understand stability, check for highly local asymmetries
- Check for background effects with cut variation:
  - Tighten hadron ID cuts to probe charm backgrounds
  - Vary D pointing cut to probe D-from-B contamination
  - Vary trigger criteria
  - Test subsamples with different running conditions
- Run analysis on GEANT4 Monte Carlo events
  - Caveat: we have much more abundant data than full MC!
- Everything checks out.
- Any asymmetry seen in $D^+ \to K^- K^+ \pi^+$ Dalitz plot is likely to be a real physics effect.

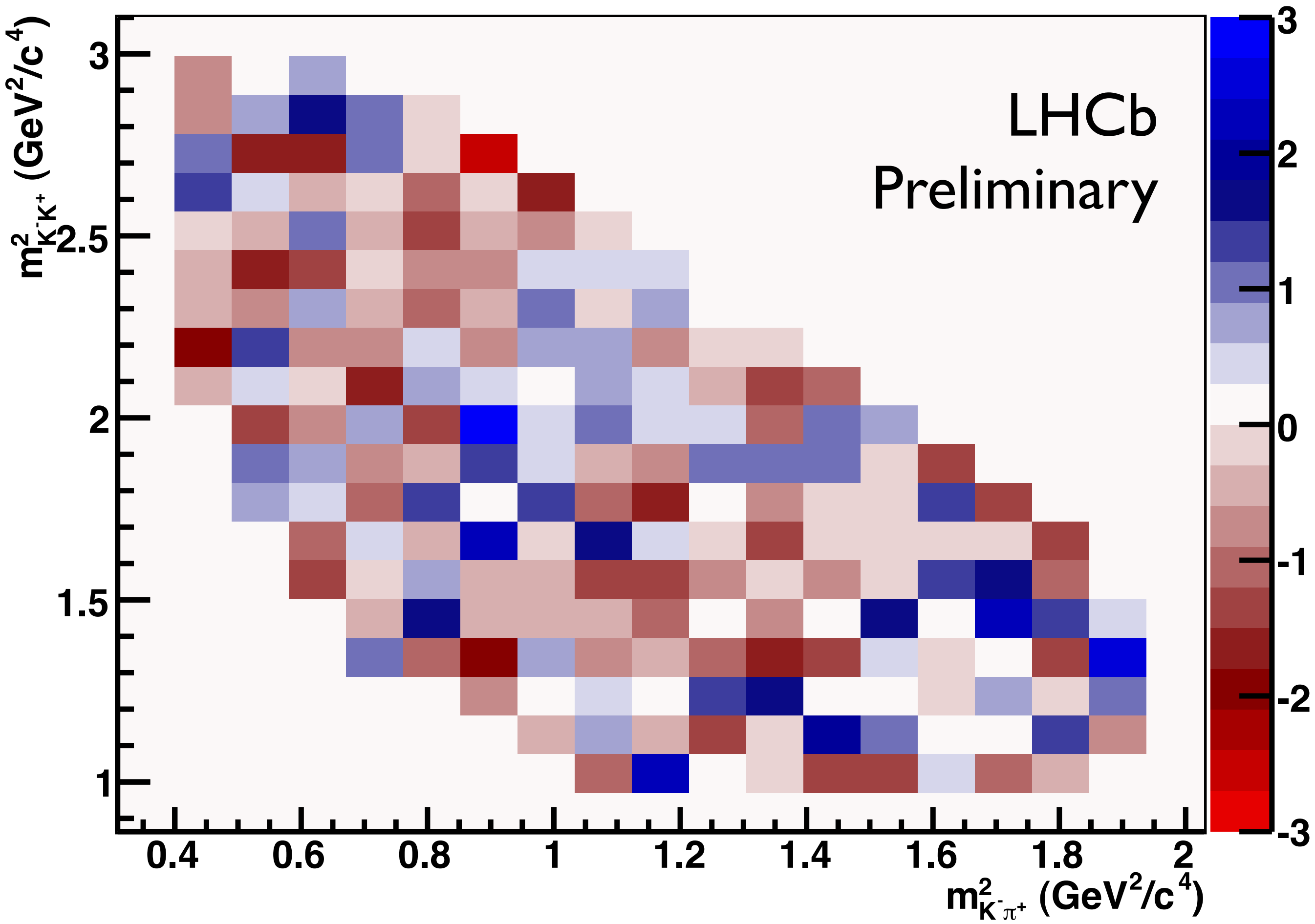
Results for $D^+ \to K^- K^+ \pi^+$

binning	χ^2/ndof	prob (%)
adaptive I	32.0/24	12.7
adaptive II	126.1/105	7.9
uniform I	191.3/198	82.1
uniform II	519.5/529	60.5

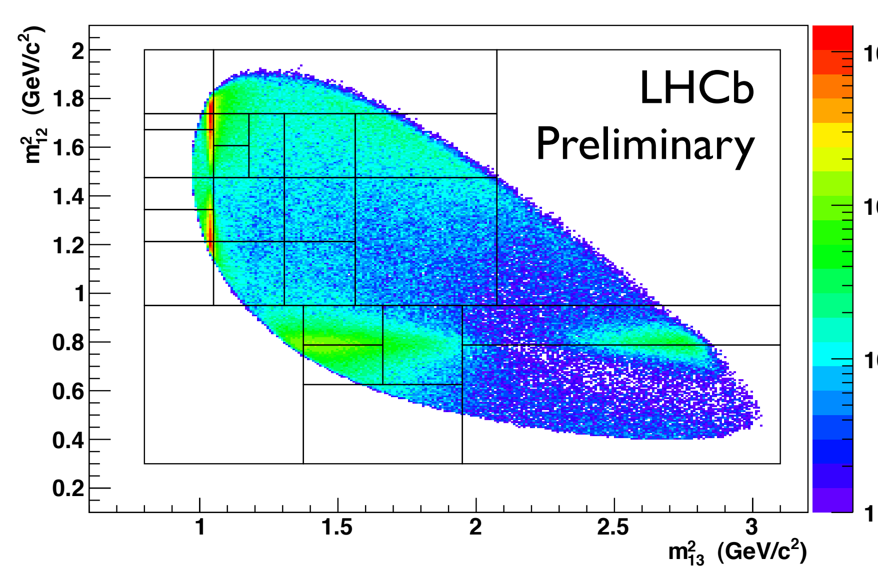
Preliminary: 2010 data, 38 pb^{-1}



Uniform I

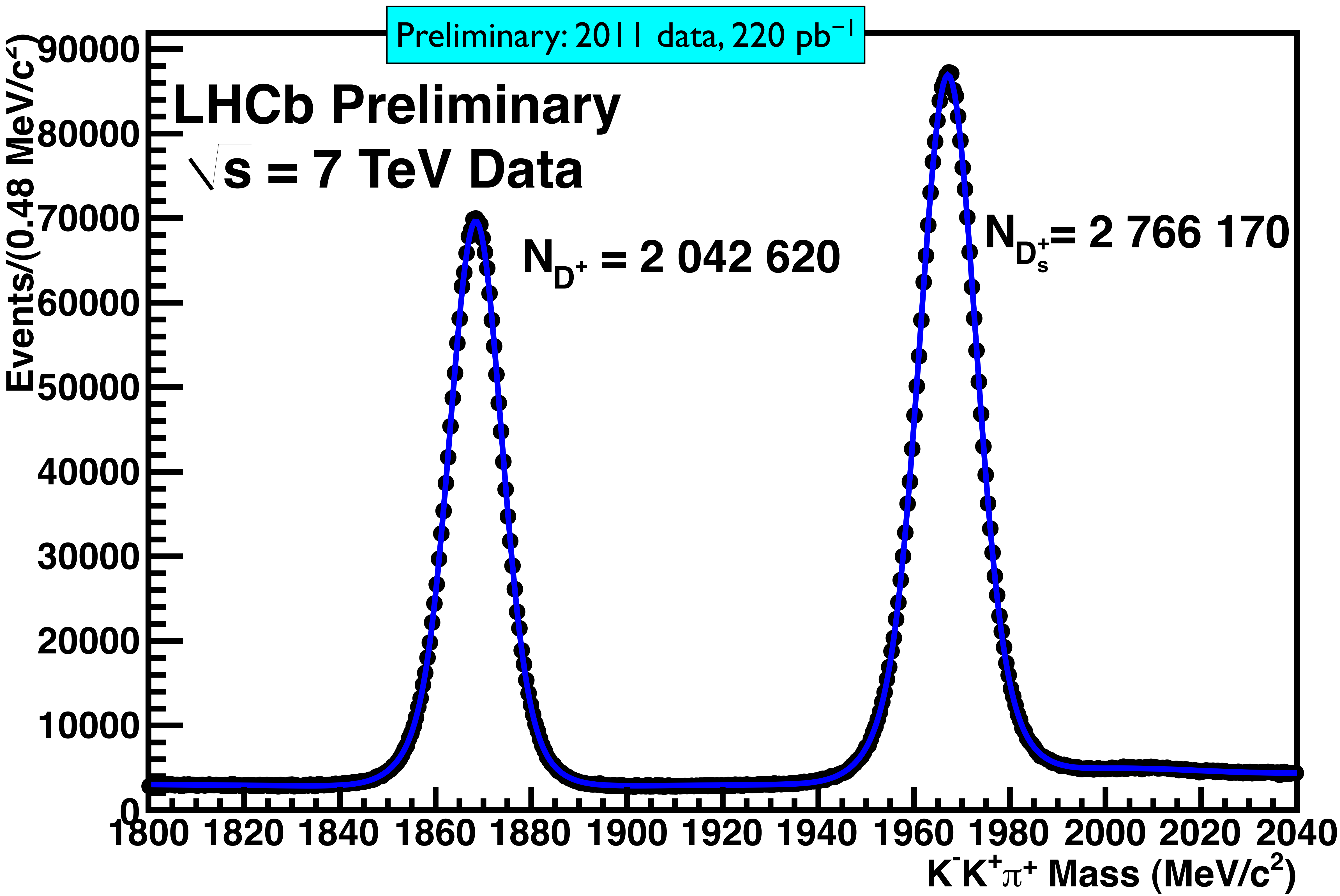


No evidence for CP violation in the 2010 dataset of 38 pb^{-1}



Adaptive I

... but there is much more to come



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$D^0 \rightarrow K^- K^+, \pi^- \pi^+$

Formalism

$$A_{RAW}(f)^* \quad = \quad A_{CP}(f) + A_D(f) + A_D(\pi_s) + A_P(D^{*+})$$

physics CP asymmetry

Detection asymmetry of D^0

Detection asymmetry of soft pion

Production asymmetry

- ... so when we take $A_{RAW}(f)^* - A_{RAW}(f')^*$ the production and soft pion detection asymmetries will cancel. Moreover...
- No detector asymmetry for D^0 decays to $(K^+ K^-)$, $(\pi^+ \pi^-)$

... i.e. all the D^*-related production and detection effects cancel.

This is why we measure the CP asymmetry difference: very robust against systematics.

Shorthand: $\Delta A_{CP} \equiv A_{CP}(K^- K^+) - A_{CP}(\pi^- \pi^+)$

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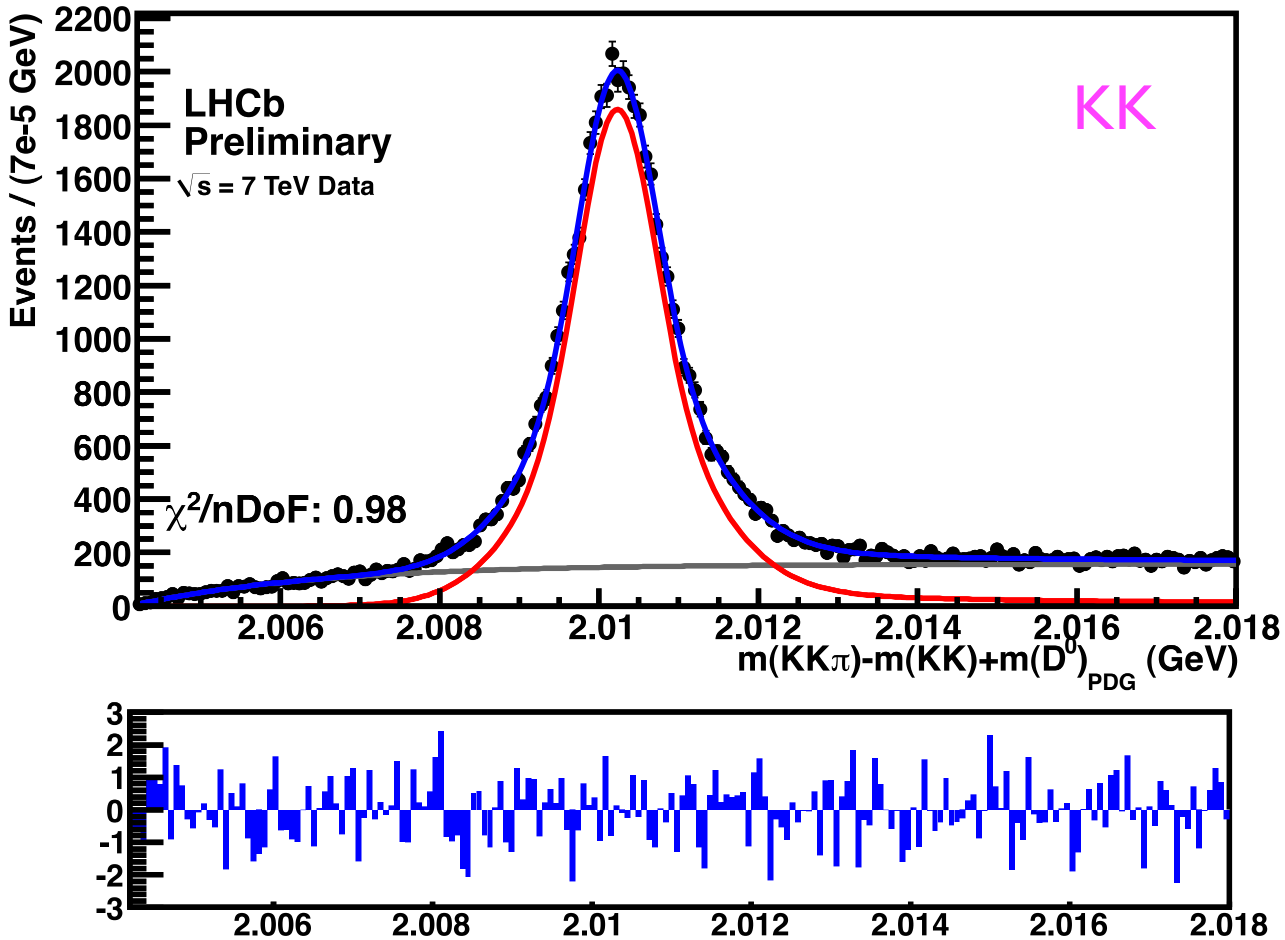
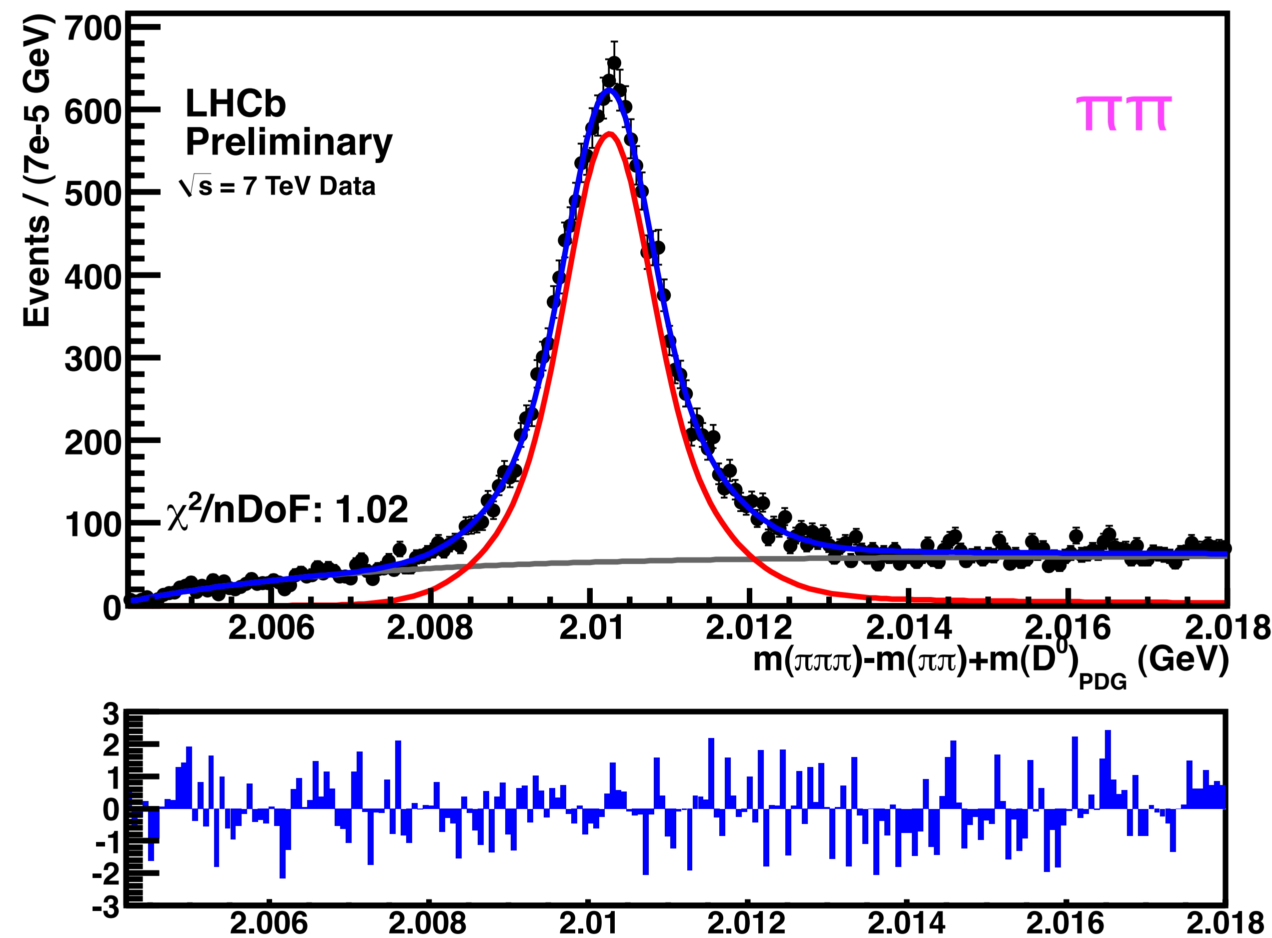
LHCb

Fits to the data

- Divide data up according to magnet polarity, trigger conditions.
- Fit (Δm + constant). Here are two example fits:

Preliminary: 2010 data





Total signal yield:

116k tagged $D^0 \to K^+ K^-$

36k tagged $D^0 \to \pi^+ \pi^-$

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Systematics & preliminary result

Effect	Uncertainty
Modeling of lineshapes	0.06%
D^0 mass window	0.20%
Multiple candidates	0.13%
Binning in (p_t, η)	0.01%
Total systematic uncertainty	0.25%
Statistical uncertainty (for comparison)	0.70 %

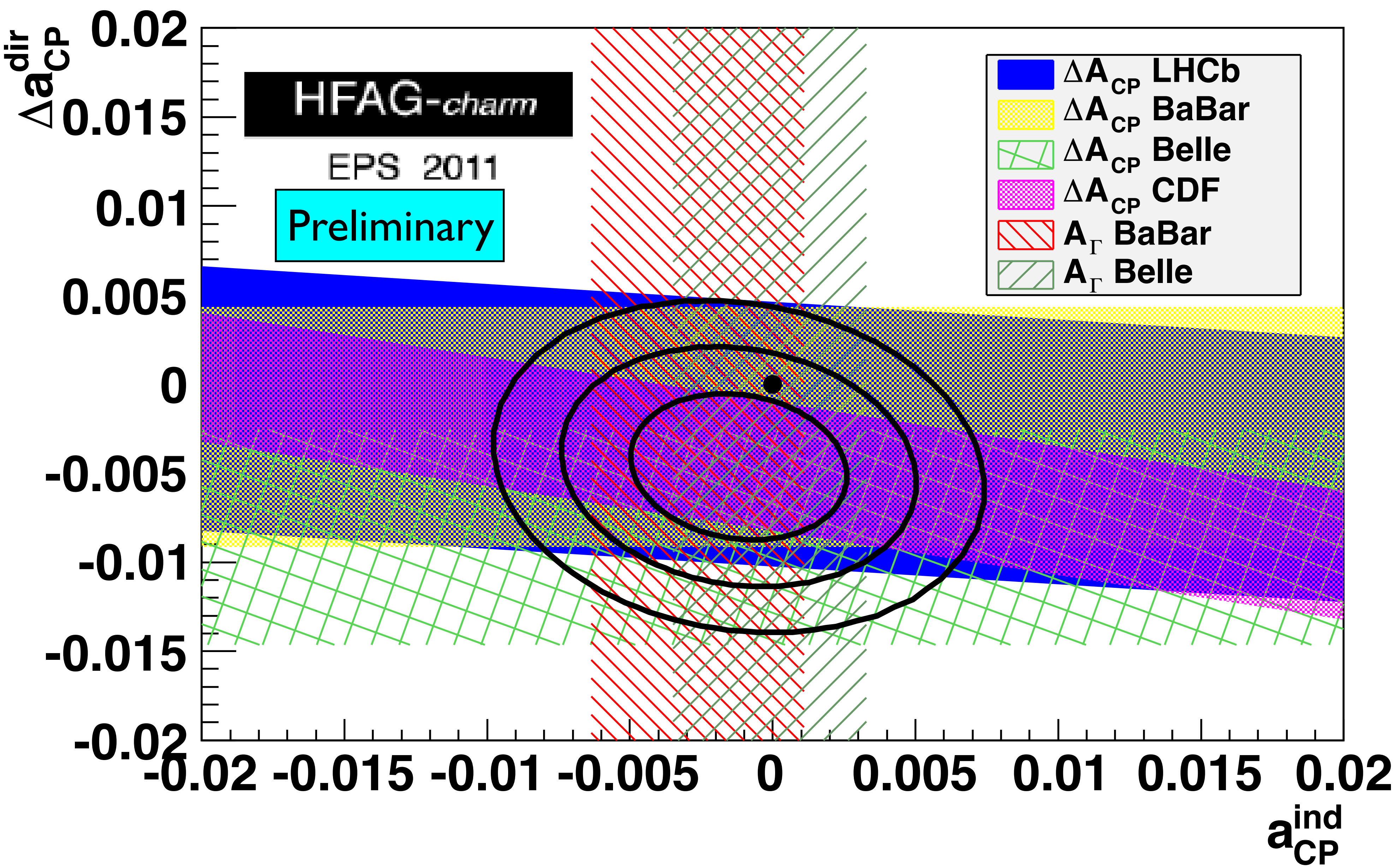
Preliminary: 2010 data, 38 pb^{-1}

$$A_{CP}(KK) - A_{CP}(\pi\pi) = (-0.275 \pm 0.701 \pm 0.25)\%$$

- Note: already competitive with the B-factories!
  - Statistical error for BABAR 0.62%, Belle 0.60%
  - But for CDF: 0.33%
- Expect systematic error to scale well with integrated lumi.
  - Estimates very conservative, with large statistical component.

Interpretation

- PRELIMINARY average courtesy of HFAG (thanks!)
- Slope in LHCb result due to small KK/ππ lifetime acceptance difference: $\Delta\langle t\rangle/\tau = 0.10 \pm 0.01$



See also: Bigi, Paul & Recksiegel, JHEP05 089 (2011)

Mixing & indirect CPV

Time-dependent charm at LHCb

- This is just a teaser!
- Two analyses with public control results:
  - Measurement of mixing parameter y_{CP} and search for indirect CPV (A_Γ) in lifetime of $D^0 \to K^- K^+, K^- \pi^+$
  - Measurement of mixing parameters (y', x'^2) and search for indirect CPV in time-dependent rate of $D^0 \to K^+ \pi^-$ LHCB-CONF-2011-029
- A_Γ unblinded yesterday with 2010 data
  - ... but came too late for this talk -- you will have to wait for Guy's plenary for the result!
- Instead, control measurement...

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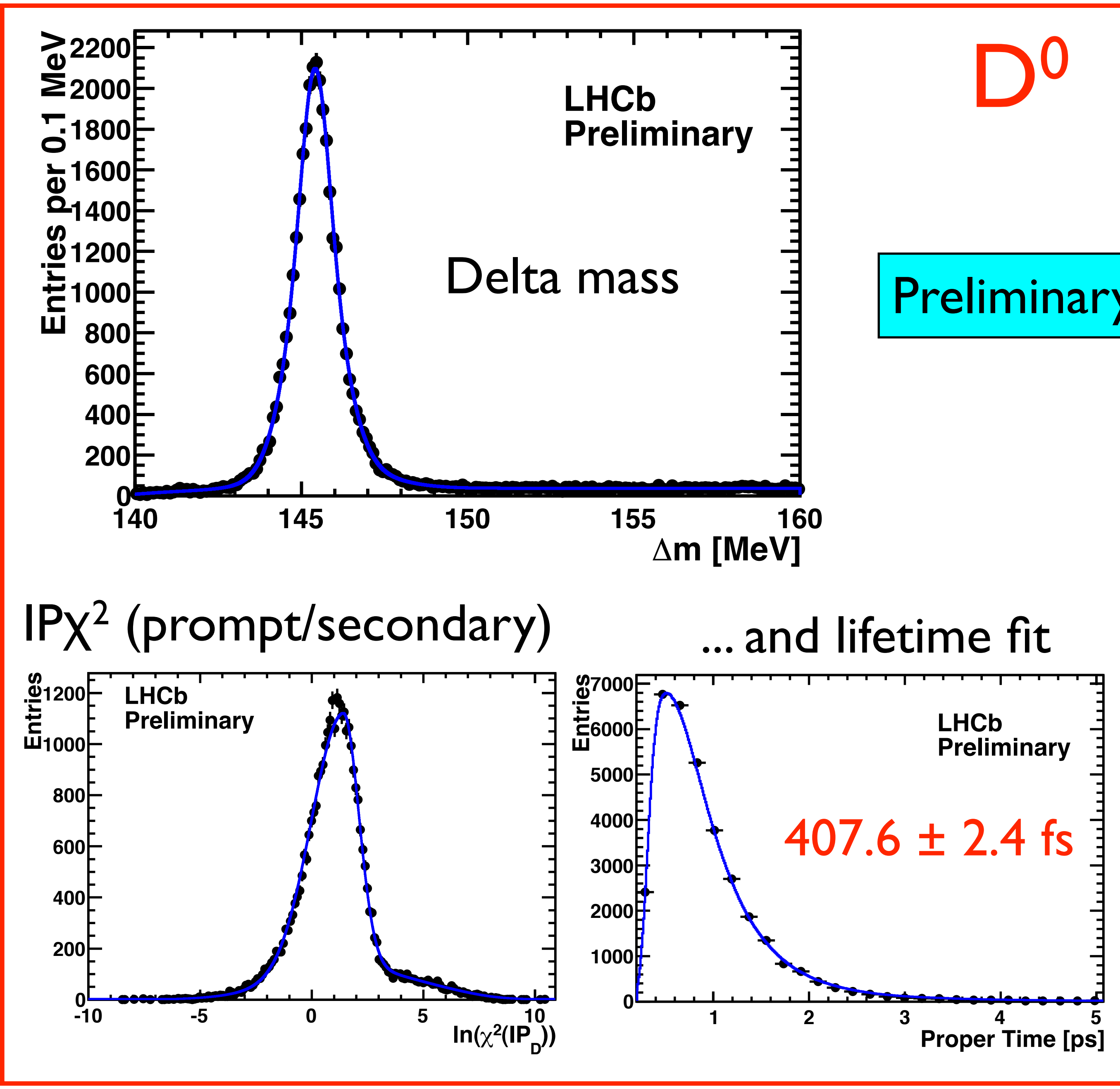
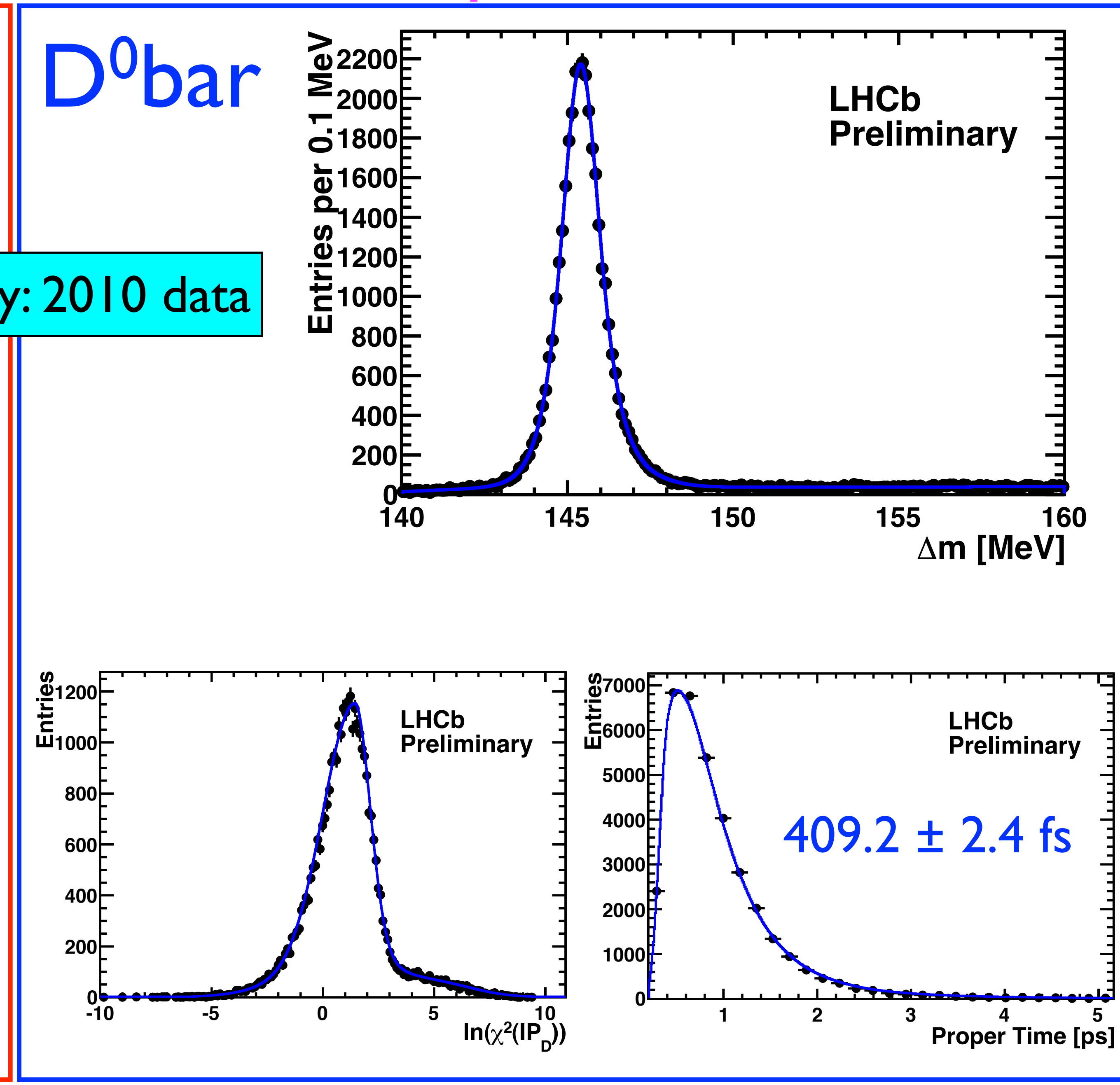
LHCb

y_{CP} and A_Γ in $D^0 \rightarrow K^- K^+, K^- \pi^+$

- As a test, analysts measured lifetime asymmetry between $D^0 \rightarrow K^- \pi^+$ and D^0bar $\rightarrow K^+ \pi^-$ on a subsample of data...



Preliminary: 2010 data



Avg lifetime 408.4 ± 1.7 fs, (stat only) consistent with PDG: 410.1 ± 1.5 fs.

$$A_\Gamma^{K\pi,eff} = (-2.1 \pm 4.2) \times 10^{-3}$$ ✓ Consistent with zero.

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Conclusions & prospects

- Charm physics at LHCb is off to a great start.
  - Search for CPV in $D^+ \to K^- K^+ \pi^+$
  - Measurement of $[A_{CP}(D^0 \to K^+K^-) - A_{CP}(D^0 \to \pi^+\pi^-)]$
- 2010 data already interesting: even with 38 pb^{-1}, already competitive with B-factories.
- ... and now an order of magnitude more on tape!
  - Many improvements to the software trigger for charm
  - Dedicated lines for key modes: $D \to$ hh, hhh, hhhh, K_Sh, $K_S$hh, μμ, hμμ, hhμμ
- Look forward to more 2010 results
  - A_Γ result next week
  - Time-dependent measurements of mixing, CPV
  - Rare decay searches
- ... and then precision searches for CP violation and new physics with the 2011 data and beyond.

fin

More control channel tests

Sample	Binning	p-value
Ds -> K- K+ π+ (phi region)	335 square bins	20.1%
Ds -> K- K+ π+ (phi region)	124 square bins	41.7%
Ds -> K- K+ π+ (phi region)	30 square bins	66.0%
Ds -> K- K+ π+ (K*(892) region)	360 square bins	25.3%
Ds -> K- K+ π+ (K*(892) region)	116 square bins	84.6%
Ds -> K- K+ π+ (K*(892) region)	32 square bins	62.5%
Ds -> K- K+ π+ (middle region)	350 square bins	14.5%
Ds -> K- K+ π+ (middle region)	105 square bins	89.5%
Ds -> K- K+ π+ (middle region)	28 square bins	24.6%

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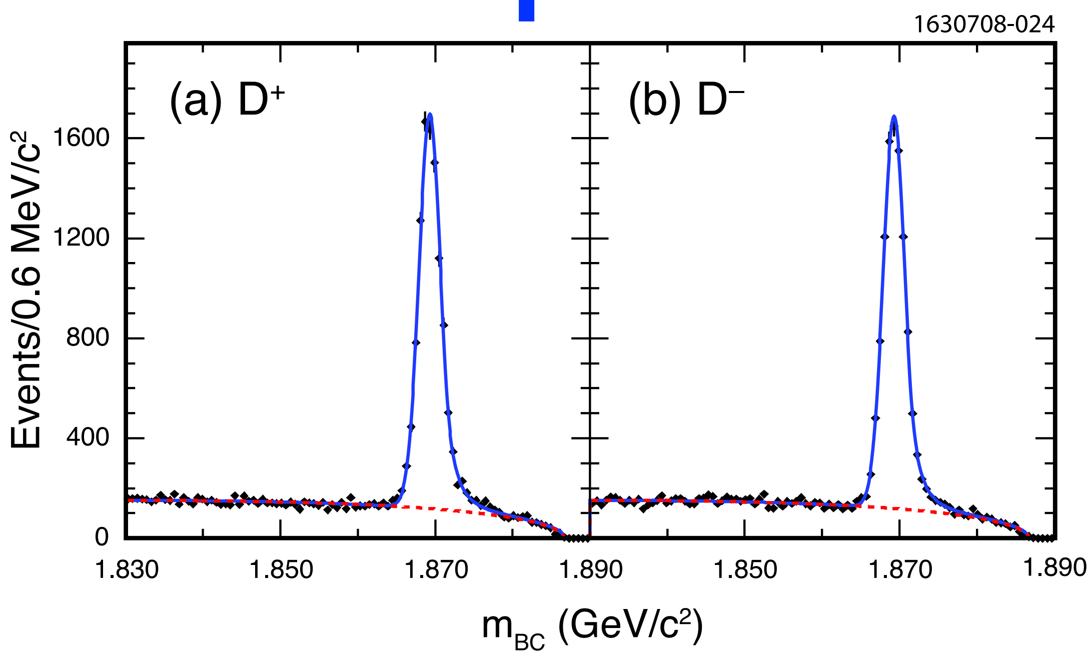
LHCb

More control channel tests

Sample	Binning	p-value
D+ -> K- π+ π+	1381 square bins	73.8%
D+ -> K- π+ π+	865 square bins	17.7%
D+ -> K- π+ π+	438 square bins	72.7%
D+ -> K- π+ π+	118 square bins	54.6%
D+ -> K- π+ π+	1272 adaptive bins	81.7%
D+ -> K- π+ π+	876 adaptive bins	57.4%
D+ -> K- π+ π+	391 adaptive bins	65.8%
D+ -> K- π+ π+	97 adaptive bins	30.0%

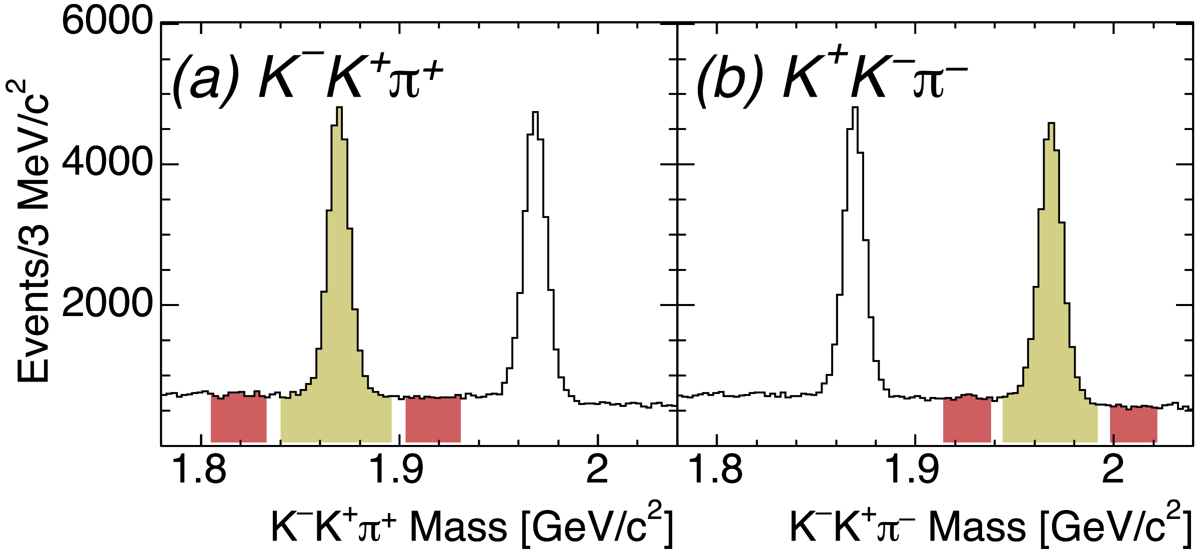
Comparison with CLEO, BABAR



CLEO-c (818/pb)

Yield of 19k

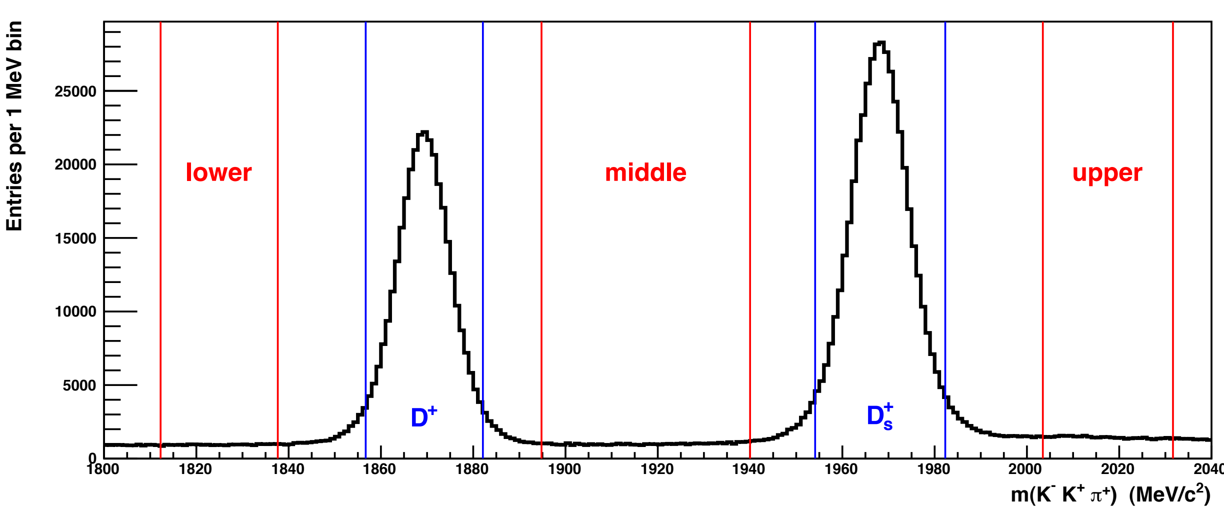
Purity of 84%



BABAR (80/fb)

Yield of 43k

Purity about 66%



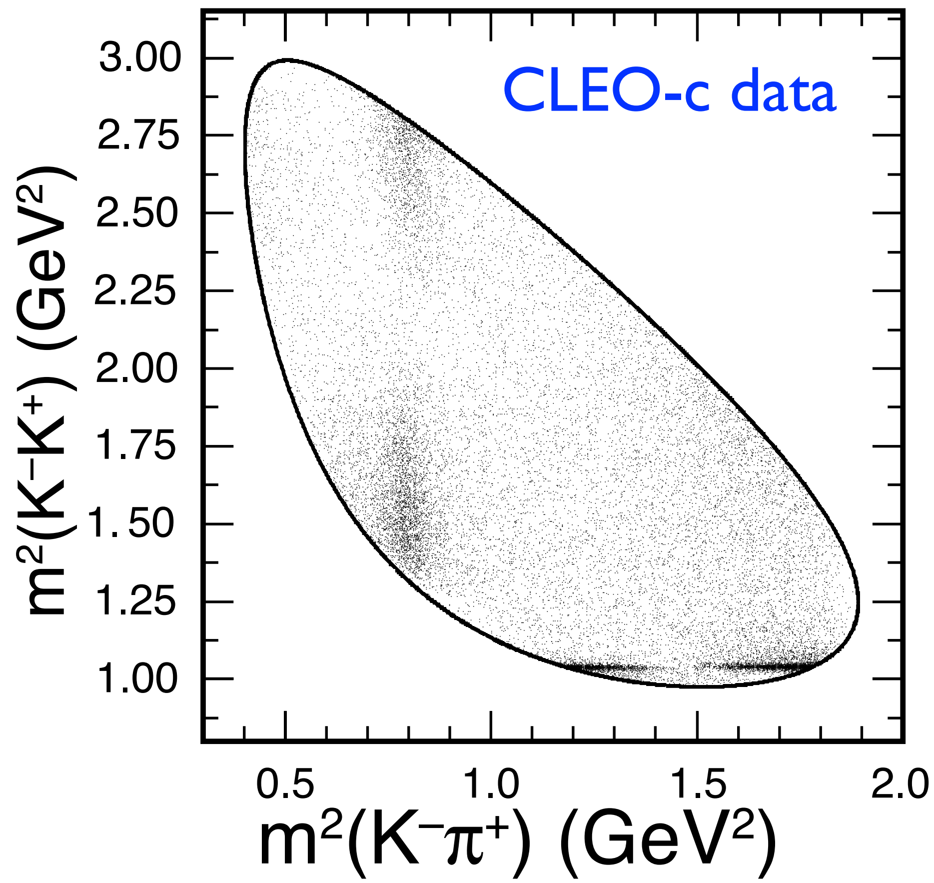
LHCb (38/pb)

Yield of 370k in window

Purity of 91.5%

CLEO-c result

	Magnitude	Phase (°)	Fit Fraction (%)
	Fit A $[\chi^2/\text{d.o.f.} = 898/708]$		
$\overline{K}^{*0}$	1(fixed)	0(fixed)	$25.0 \pm 0.6^{+0.4+0.2}_{-0.3-1.2}$
$\overline{K}^{*}_{0}(1430)^0$	$3.7 \pm 0.5^{+0.5+1.0}_{-0.1-1.0}$	$73 \pm 9^{+6+15}_{-6-38}$	$12.4 \pm 3.3^{+3.4+7.3}_{-0.7-5.8}$
ϕ	$1.189 \pm 0.015^{+0.000+0.028}_{-0.011-0.010}$	$-179 \pm 4^{+3+13}_{-1-5}$	$28.1 \pm 0.6^{+0.1+0.2}_{-0.3-0.4}$
$a_0(1450)^0$	$1.72 \pm 0.10^{+0.11+0.81}_{-0.11-0.28}$	$123 \pm 3^{+1+9}_{-1-15}$	$5.9 \pm 0.7^{+0.7+6.7}_{-0.6-1.8}$
$\phi(1680)$	$1.9 \pm 0.2^{+0.0+1.3}_{-0.1-0.7}$	$-52 \pm 8^{+0+10}_{-5-26}$	$0.51 \pm 0.11^{+0.02+0.85}_{-0.04-0.12}$
$\overline{K}^{*}_{2}(1430)^0$	$6.4 \pm 0.9^{+0.5+1.9}_{-0.4-3.6}$	$150 \pm 6^{+1+28}_{-0-13}$	$1.2 \pm 0.3^{+0.2+0.8}_{-0.1-0.6}$
NR	$5.1 \pm 0.3^{+0.0+0.6}_{-0.3-0.2}$	$53 \pm 7^{+1+18}_{-5-11}$	$14.7 \pm 1.8^{+0.2+3.9}_{-1.6-1.5}$
	Total Fit Fraction $= (88.7 \pm 2.9)\%$		
	Fit B $[\chi^2/\text{d.o.f.} = 895/708]$		
$\overline{K}^{*0}$	1(fixed)	0(fixed)	$25.7 \pm 0.5^{+0.4+0.1}_{-0.3-1.2}$
$\overline{K}^{*}_{0}(1430)^0$	$4.56 \pm 0.13^{+0.10+0.42}_{-0.01-0.39}$	$70 \pm 6^{+1+16}_{-6-23}$	$18.8 \pm 1.2^{+0.6+3.2}_{-0.1-3.4}$
ϕ	$1.166 \pm 0.015^{+0.001+0.025}_{-0.009-0.009}$	$-163 \pm 3^{+1+14}_{-1-5}$	$27.8 \pm 0.4^{+0.1+0.2}_{-0.3-0.4}$
$a_0(1450)^0$	$1.50 \pm 0.10^{+0.09+0.92}_{-0.06-0.33}$	$116 \pm 2^{+1+7}_{-1-14}$	$4.6 \pm 0.6^{+0.5+7.2}_{-0.3-1.8}$
$\phi(1680)$	$1.86 \pm 0.20^{+0.02+0.62}_{-0.08-0.77}$	$-112 \pm 6^{+3+19}_{-4-12}$	$0.51 \pm 0.11^{+0.01+0.37}_{-0.04-0.15}$
$\overline{K}^{*}_{2}(1430)^0$	$7.6 \pm 0.8^{+0.5+2.4}_{-0.6-4.8}$	$171 \pm 4^{+0+24}_{-2-11}$	$1.7 \pm 0.4^{+0.3+1.2}_{-0.2-0.7}$
$\kappa(800)$	$2.30 \pm 0.13^{+0.01+0.52}_{-0.11-0.29}$	$-87 \pm 6^{+2+15}_{-3-10}$	$7.0 \pm 0.8^{+0.0+3.5}_{-0.6-1.9}$
	Total Fit Fraction $= (86.1 \pm 1.1)\%$		
	Fit C $[\chi^2/\text{d.o.f.} = 912/710]$		
$\overline{K}^{*0}$	1(fixed)	0(fixed)	$25.3 \pm 0.5^{+0.2+0.2}_{-0.4-0.7}$
LASS	$3.81 \pm 0.06^{+0.05+0.13}_{-0.05-0.46}$	$25.1 \pm 2^{+1+6}_{-2-5}$	$40.6 \pm 0.8^{+0.4+1.6}_{-0.5-9.1}$
ϕ	$1.193 \pm 0.015^{+0.003+0.021}_{-0.010-0.011}$	$-176 \pm 2^{+0+8}_{-2-8}$	$28.6 \pm 0.4^{+0.2+0.2}_{-0.3-0.5}$
$a_0(1450)^0$	$1.73 \pm 0.07^{+0.14+0.68}_{-0.03-0.38}$	$122 \pm 2^{+1+8}_{-1-10}$	$6.0 \pm 0.4^{+0.9+5.5}_{-0.2-2.4}$
$\phi(1680)$	$1.71 \pm 0.16^{+0.02+0.41}_{-0.02-0.77}$	$-72 \pm 8^{+2+10}_{-2-22}$	$0.42 \pm 0.08^{+0.02+0.19}_{-0.01-0.16}$
$\overline{K}^{*}_{2}(1430)^0$	$4.9 \pm 0.7^{+0.1+2.2}_{-0.4-2.3}$	$146 \pm 9^{+0+34}_{-7-11}$	$0.7 \pm 0.2^{+0.0+0.7}_{-0.1-0.3}$
	Total Fit Fraction $= (101.5 \pm 0.8)\%$		

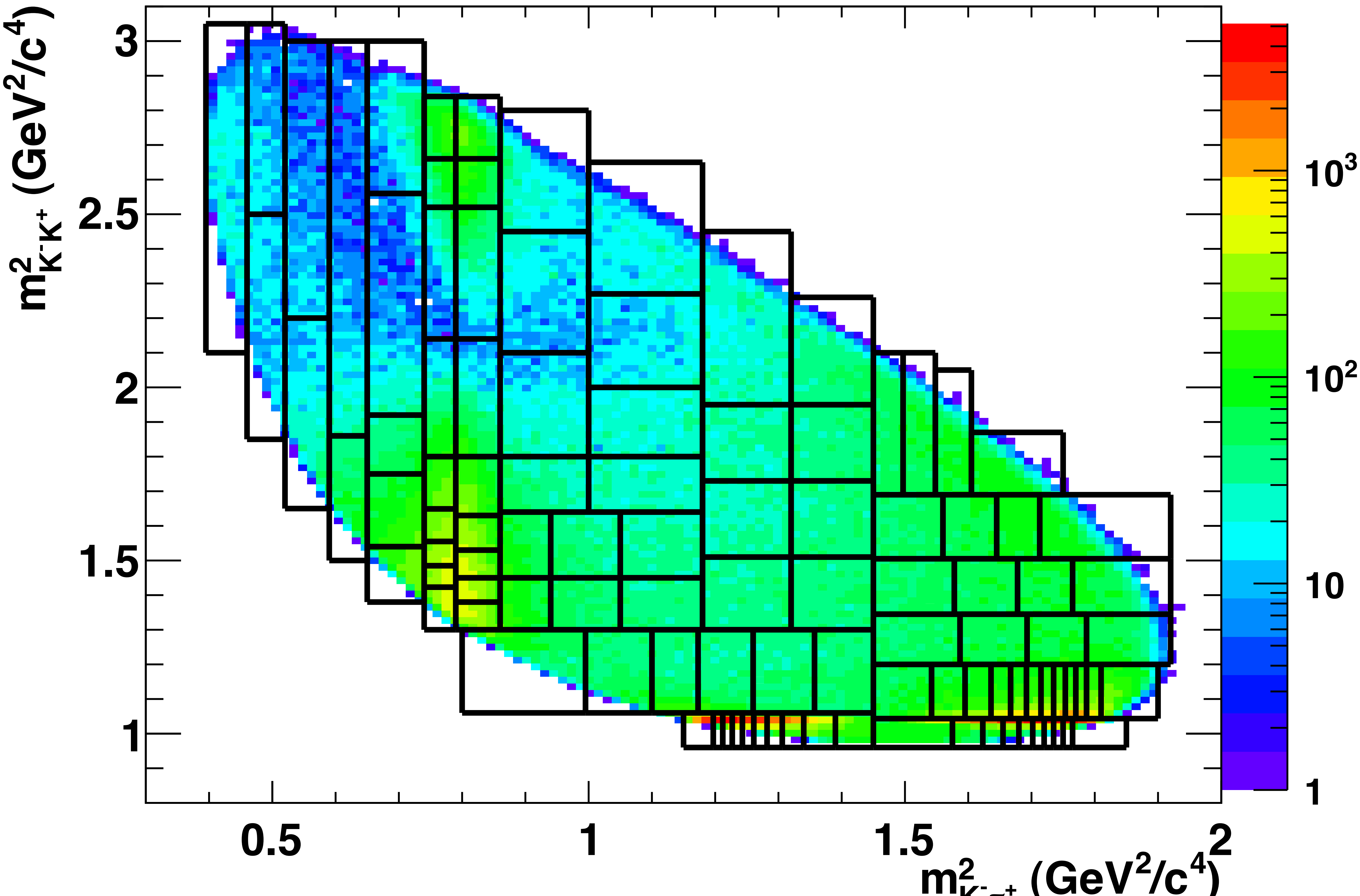


Yield ~ 20k signal
Purity ~ 84%

We use this model for our toy MC

Phys. Rev. D **78** (2008) 072003

Adaptive binning II



Recent measurements (HFAG)

Year	Experiment	CP Asymmetry in the decay mode D0 to π+π-	[Γ(D0)-Γ(D0bar)]/[Γ(D0)+Γ(D0bar)]
2010	CDF	M.J. Morello (CDF Collab.), Preprint (CHARM 2010).	+0.0022 ± 0.0024 ± 0.0011
2008	BELLE	M. Staric et al. (BELLE Collab.), Phys. Lett. B 670, 190 2008).	+0.0043 ± 0.0052 ± 0.0012
2008	BABAR	B. Aubert et al. (BABAR Collab.), Phys. Rev. Lett. 100, 061803 (2008).	-0.0024 ± 0.0052 ± 0.0022
2002	CLEO	S.E. Csorna et al. (CLEO Collab.), Phys. Rev. D 65, 092001 (2002).	+0.019 ± 0.032 ± 0.008
2000	FOCUS	J.M. Link et al. (FOCUS Collab.), Phys. Lett. B 491, 232 (2000).	+0.048 ± 0.039 ± 0.025
1998	E791	E.M. Aitala et al. (E791 Collab.), Phys. Lett. B 421, 405 (1998).	-0.049 ± 0.078 ± 0.030
.	.	COMBOS average	+0.0020 ± 0.0022

Year	Experiment	CP Asymmetry in the decay mode D0 to K+K-	[Γ(D0)-Γ(D0bar)]/[Γ(D0)+Γ(D0bar)]
2011	CDF	A. Di Canto (CDF Collab.), Preprint (BEAUTY 2011).	-0.0024 ± 0.0022 ± 0.0010
2008	BELLE	M. Staric et al. (BELLE Collab.), Phys. Lett. B 670, 190 (2008).	-0.0043 ± 0.0030 ± 0.0011
2008	BABAR	B. Aubert et al. (BABAR Collab.), Phys. Rev. Lett. 100, 061803 (2008).	+0.0000 ± 0.0034 ± 0.0013
2002	CLEO	S.E. Csorna et al. (CLEO Collab.), Phys. Rev. D 65, 092001 (2002).	+0.000 ± 0.022 ± 0.008
2000	FOCUS	J.M. Link et al. (FOCUS Collab.), Phys. Lett. B 491, 232 (2000).	-0.001 ± 0.022 ± 0.015
1998	E791	E.M. Aitala et al. (E791 Collab.), Phys. Lett. B 421, 405 (1998).	-0.010 ± 0.049 ± 0.012
1995	CLEO	J.E. Bartelt et al. (CLEO Collab.), Phys. Rev. D 52, 4860 (1995).	+0.080 ± 0.061
1994	E687	P.L. Frabetti et al. (E687 Collab.), Phys. Rev. D 50, 2953 (1994).	+0.024 ± 0.084
.	.	COMBOS average	-0.0023 ± 0.0017

CDF leads the pack, especially for $D^0 \to \pi^+ \pi^-$

High-energy hadron colliders are great places to produce charm.

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Bonus: D^0 production asymmetry

Assume no real CPV in $D^0 \to K^-\pi^+$. Then:

cancel

cancel

$$
\begin{aligned}
A_{RAW}(K^-\pi^+) &= A_D(K^-\pi^+) + A_P(D^0) \\
A_{RAW}(K^-\pi^+)^* &= A_D(K^-\pi^+) + A_D(\pi_s) + A_P(D^{*+}) \\
A_{RAW}(K^-K^+)^* &= A_{CP}(K^-K^+) + A_D(\pi_s) + A_P(D^{*+}) \\
\Rightarrow A_{RAW}(K^-\pi^+) - A_{RAW}(K^-\pi^+)^* + A_{RAW}(K^-K^+)^* &= A_P(D^0) + A_{CP}(K^-K^+)
\end{aligned}
$$

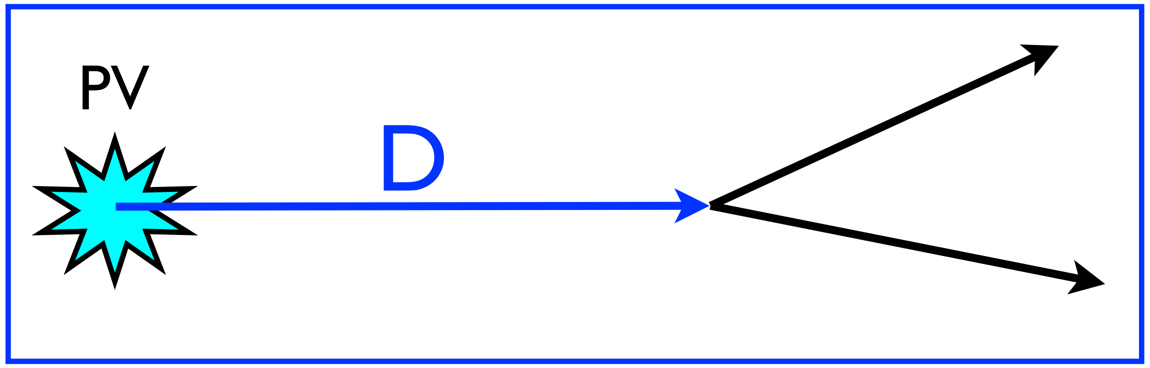
... so if we use measurements of $D^0 \to K^- K^+$ CP asymmetry from other experiments as input, we can extract overall D^0 production asymmetry at LHCb. (Similarly $\pi^- \pi^+$.)

We obtain:

$$A_P(D^0) = (-1.08 \pm 0.32 \pm 0.12)\%.$$

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

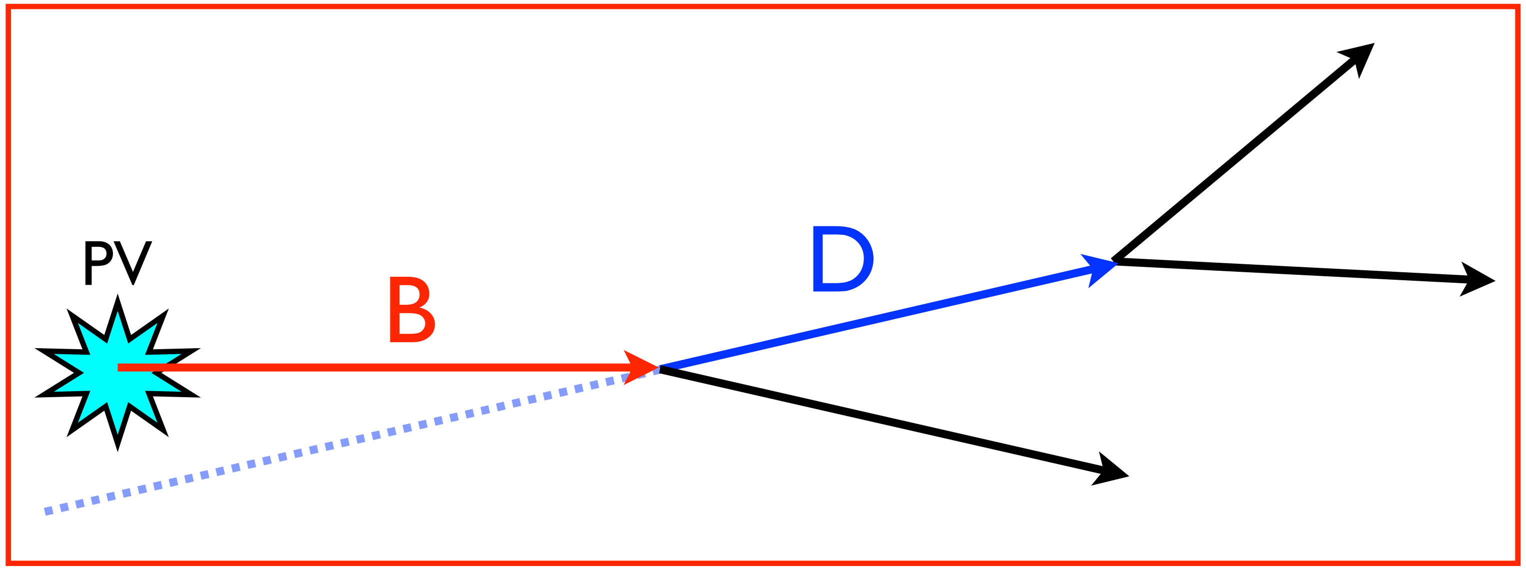
Prompt-secondary discrimination



Prompt charm:

D points to primary vertex

Daughters of D don't in general

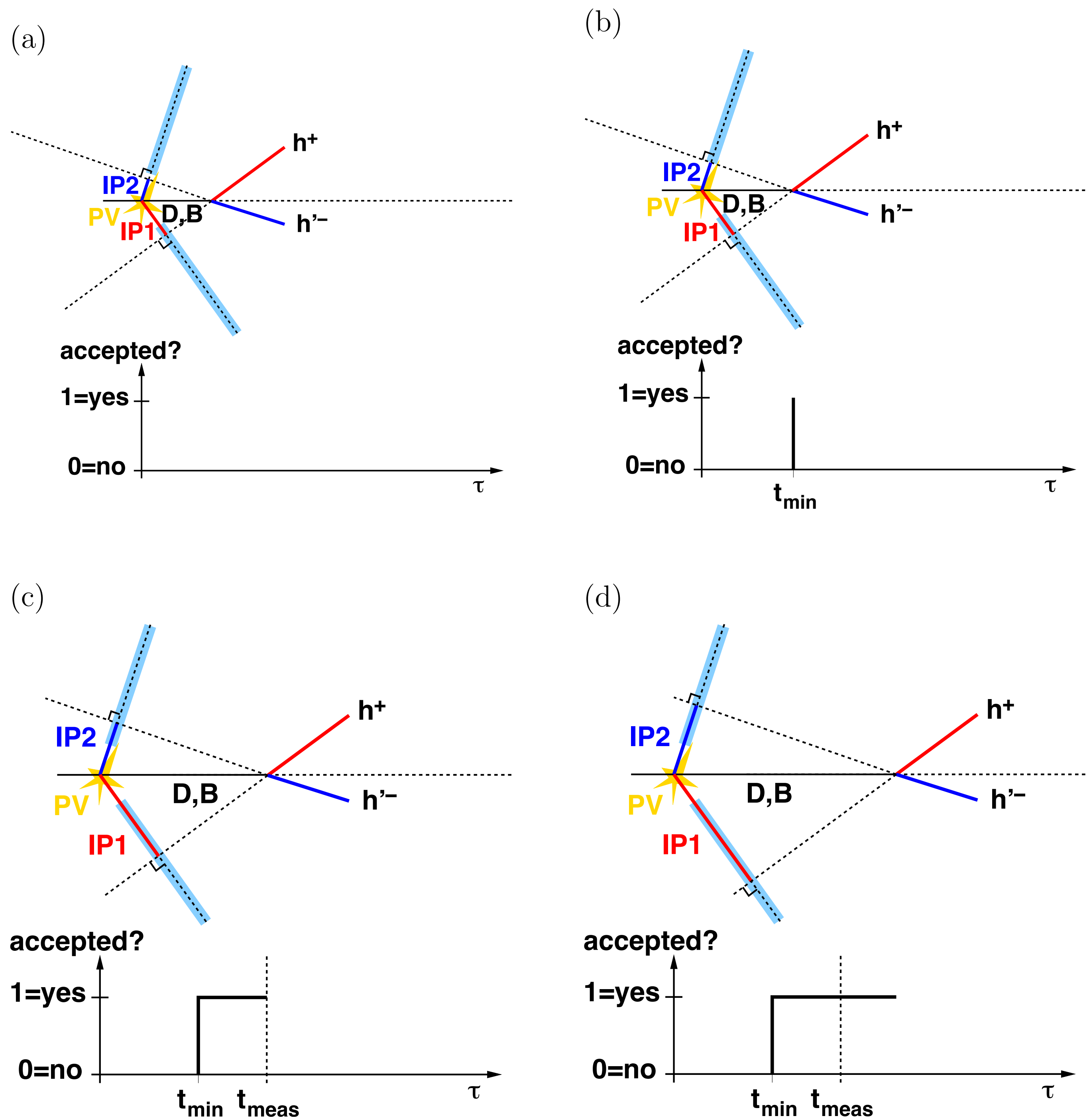


Secondary charm:

D doesn't point to PV in general

y_{CP} and A_Γ in time-dep. $D^0 \to K^- K^+, K^- \pi^+$

- Swimming technique developed at Tevatron.
- Ideally suited to LHCb where our software trigger can be recreated exactly offline.



Trying to measure how acceptance varies with lifetime candidate-by-candidate.

... so that we can pull it directly from the data instead of having to model it on signal MC.

Ideally, would shift D^0 decay vertex, but this is a nightmare (imagine trying to move VELO hits).

Instead, shift primary vertex in opposite sense (*nearly* the same thing; systematic for difference)

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

Three contributions with different lifetime dependence:

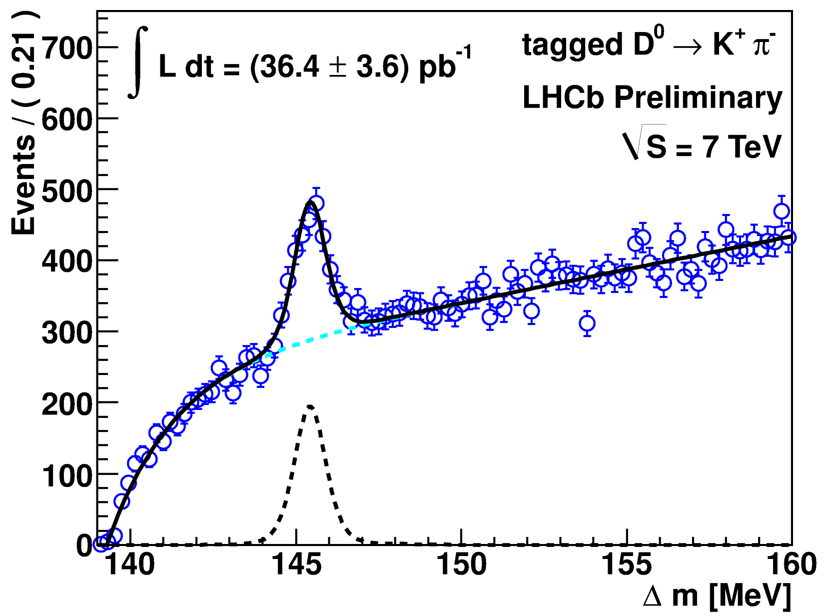
$$\Gamma_{WS}(t) = e^{-\Gamma t}\left(\underbrace{R_D}_{\text{DCS}} + \underbrace{y'\sqrt{R_D}}_{\text{Interference}}(\Gamma t) + \underbrace{\frac{x'^2 + y'^2}{4}}_{\text{Mixing}}(\Gamma t)^2\right)$$

[Limit of |x| ≪ 1, |y| ≪ 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.

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



	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

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Cross-check consistent with PDG average.

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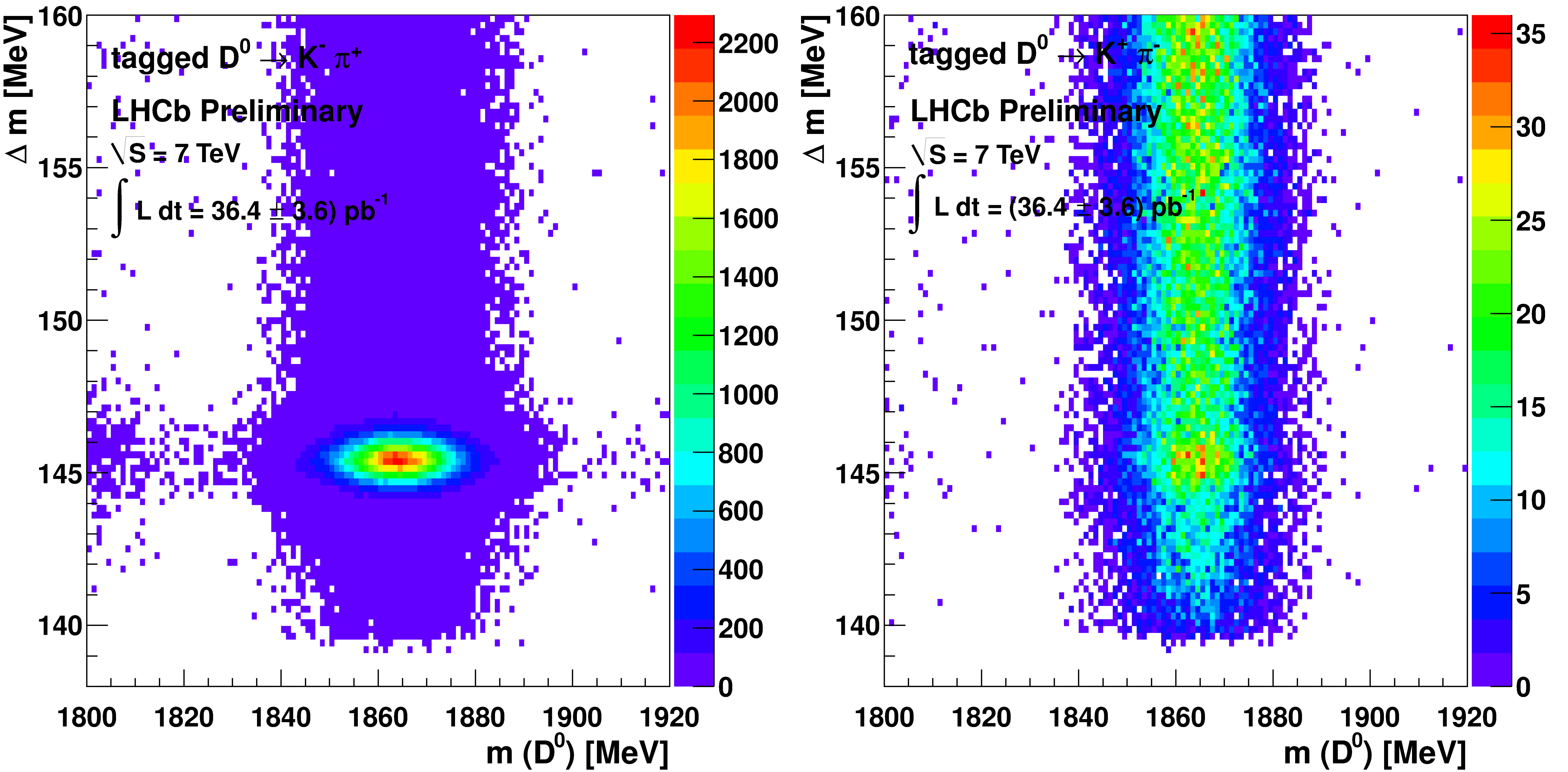
WS/RS in Kπ



tagged $D^0 \to K^- \pi^+$
LHCb Preliminary
$\sqrt{s}$ = 7 TeV
$\int L\,dt = 36.4 \pm 3.6)\ pb^{-1}$
Δ m [MeV]
m (D^0) [MeV]
160
155
150
145
140
1800
1820
1840
1860
1880
1900
1920
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
tagged $D^0 \to K^+ \pi^-$
LHCb Preliminary
$\sqrt{s}$ = 7 TeV
$\int L\,dt = (36.4 \pm 3.6)\ pb^{-1}$
Δ m [MeV]
m (D^0) [MeV]
35
30
25
20
15
10
5
0