Time-integrated CP violation in Charm decays

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On behalf of LHCb collaboration
(including results also from CLEO-c, Belle and CDF)

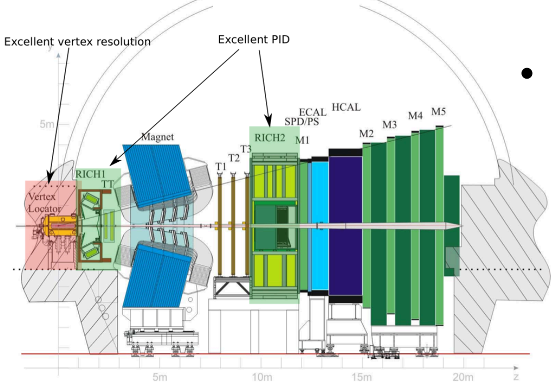
LHCb

INFN Istituto Nazionale di Fisica Nucleare

ALMA MATER STUDIORUM A.D. 1088

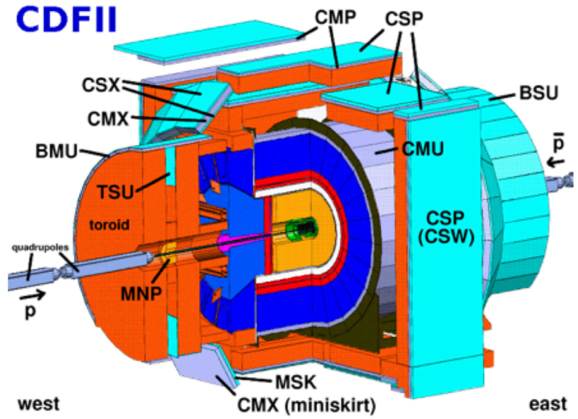
Covered experiments

LHCb

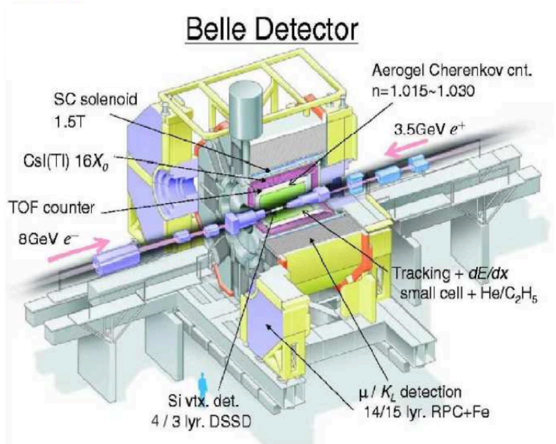


- Very large sample of HF hadrons in pp collisions at LHC:
  - $\sigma_{c\bar{c}}$ = 1419 ± 134μb @ 7 TeV [Nucl. Phys. B871, 1-20]
  - 1 fb^{-1} @ 7 TeV + 2 fb^{-1} @ 8 TeV
  - ~2 kHz of charm events stored on disk

CDFII

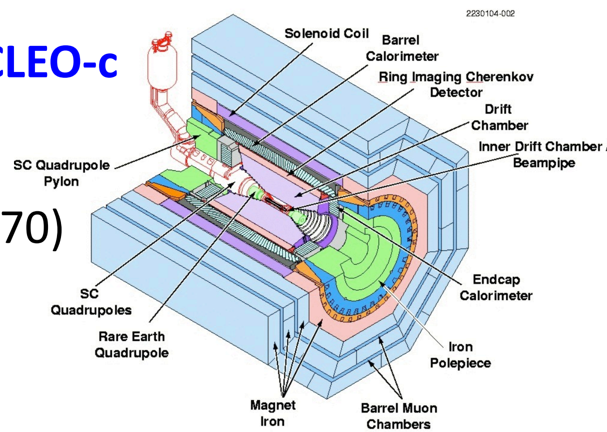


- Exploiting final statistics collected after 10 years at TeVatron
  - general purpose experiment
  - ~10^{13} $p\bar{p}$ collisions @ 1.96 TeV
  - ~ 1% of collisions yields a D meson



- Collected e^+-e^- asymmetric collisions at KEKB:
  - More than 1 ab^{-1} of integrated luminosity at various Υ resonances
  - $\sigma_{c\bar{c}} \approx$ 1.3 nb @ Υ(4S) resonance

CLEO-c



- Collected e^+-e^- collisions at Ψ(3770) resonance:
  - Full sample is 818 pb^{-1}
  - very clean environment

Experimental observable

- Quintessential observable in time-integrated CPV is

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

- A_{RAW} is related to CPV parameters by

$$A_{RAW} \approx A_{CP} + A_P + A_D + A_T$$

$$A_{CP} = \frac{\Gamma(D \to f) - \Gamma(\bar{D} \to \bar{f})}{\Gamma(D \to f) + \Gamma(\bar{D} \to \bar{f})}$$

CP asymmetry related to CKM parameters (A_{CP})

Different production rates between D and D̄ (A_P)

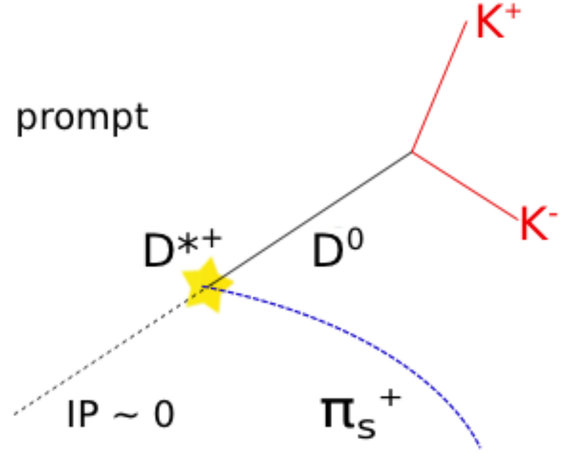
Different detection efficiencies between f and f̄ (A_D)

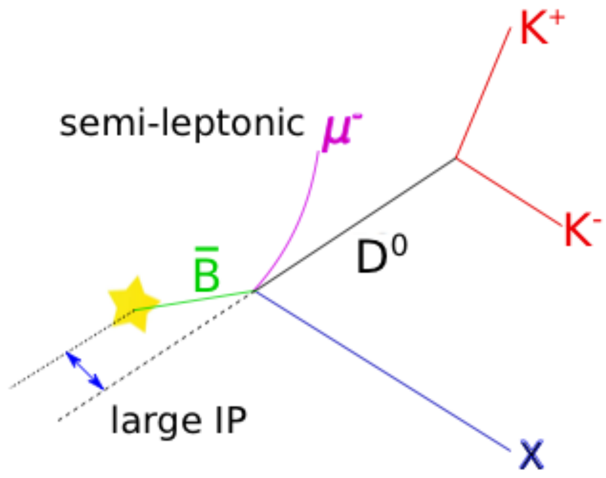
Asymmetry in determination of D flavour (A_T)

- Experimental issues
  - determine the corrections to A_{RAW}
  - general strategy is to measure A_{RAW} in Cabibbo-favoured decays where CPV is very unlikely

Tag asymmetry

- Correction peculiar of neutral D^0 mesons
- Two strategies:
  - D^*-prompt:
    - reconstruct $D^{*+} \rightarrow D^0 \pi_s^+$ decays
    - π_s^+ charge denotes D^0 flavour
    - A_T comes from π_s^+ detection asymmetry
    - used by all the experiments
  - Semi-leptonic:
    - reconstruct $B \rightarrow D^0 \mu^\pm X$ decays
    - $\mu^\pm$ charge denotes D^0 flavour
    - A_T comes from m detection asymmetry
    - completely independent of the D^*-prompt sample
    - peculiar of LHCb





Production asymmetry

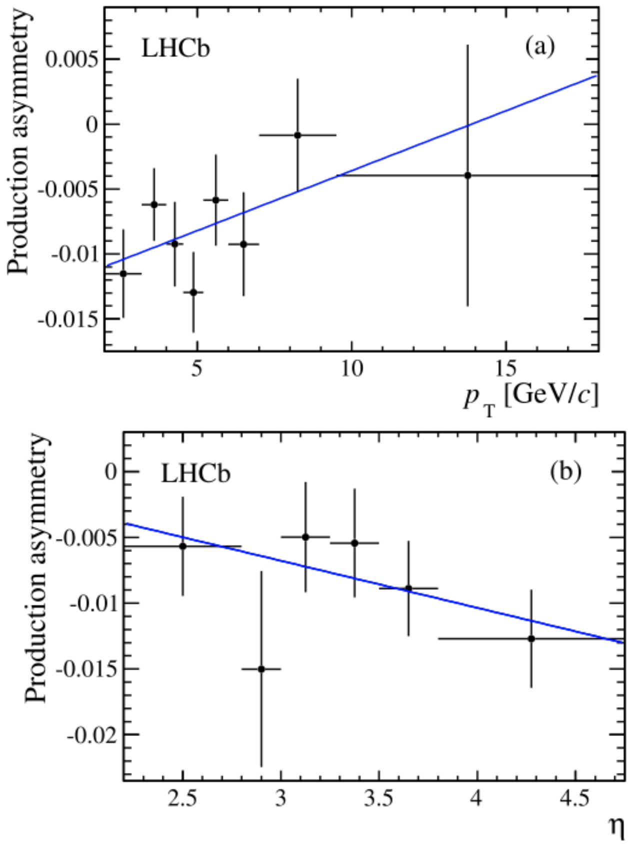
- Depends on several factors
- Tag of D^0:
  - D^*-prompt → A_P of D^*
  - Semi-leptonic → A_P of B mesons
- Environment
  - p-p collisions:
    - initial imbalance between q and q̄
    - different hadronization probabilities for D and D̄
    - may depend on kinematic
  - p-p̄ collisions:
    - expect A_P to vary as a function of η
    - D (D̄) production may be favourite in the direction of p̄ (p)
  - e^+-e^- collisions:
    - function of CMS polar angle

$$A_P \equiv A_{FB}\left(\cos\theta^*\right)$$

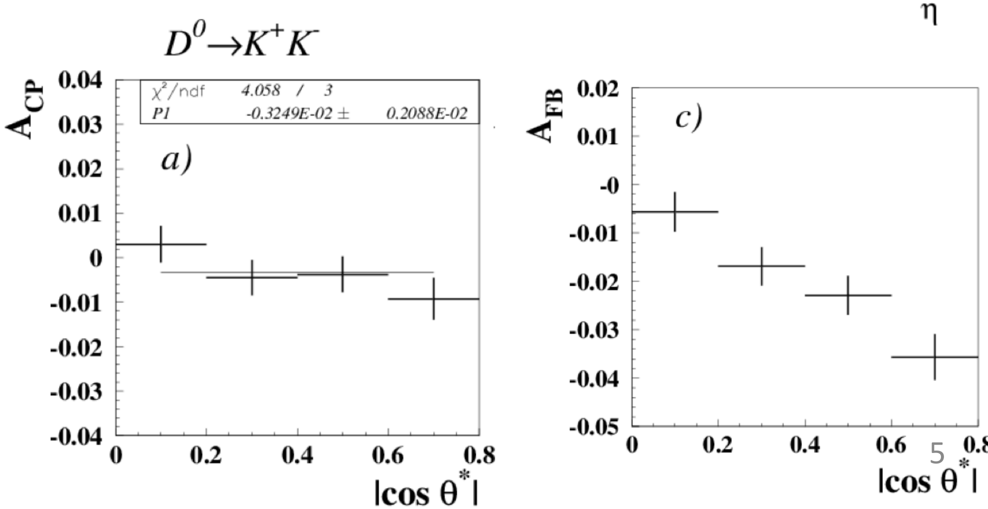
    - can be easily disentangled

$$A_{CP} = \frac{A^{\rm cor}_{\rm raw}(cos\theta^*) + A^{\rm cor}_{\rm raw}(-cos\theta^*)}{2}$$

$$A_{FB} = \frac{A^{\rm cor}_{\rm raw}(cos\theta^*) - A^{\rm cor}_{\rm raw}(-cos\theta^*)}{2}$$



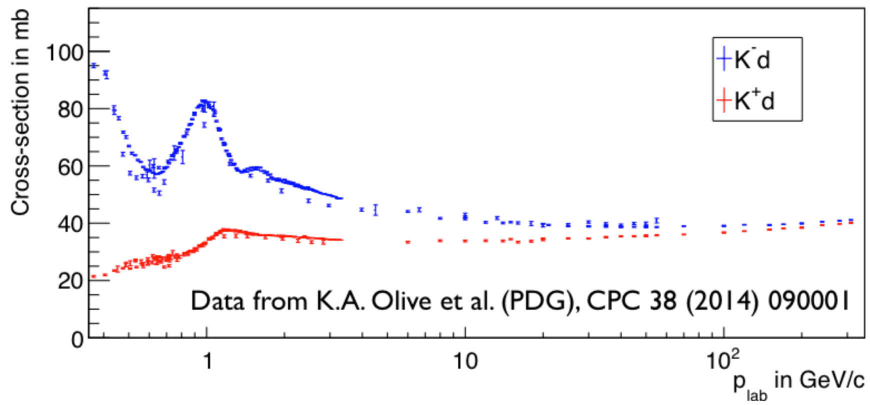
PLB 718 (2013) 902

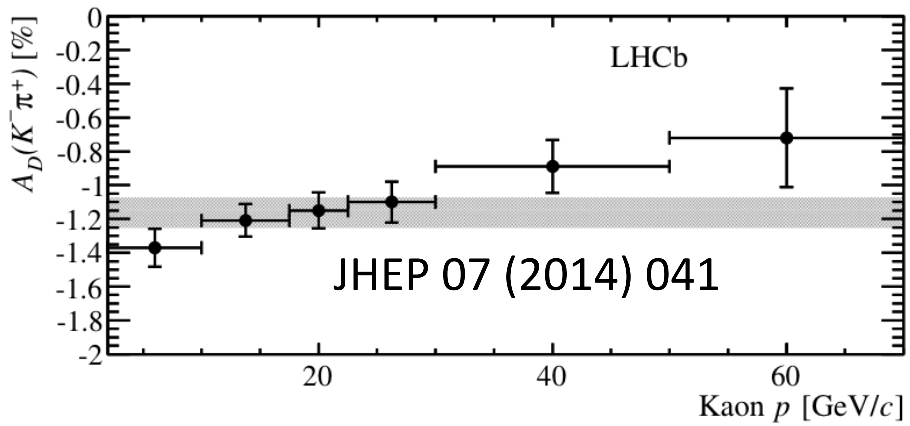


arXiv:1212.1975

Detection asymmetry

- Charge conjugate final states can have different detection efficiency
- Asymmetry in particle interaction with material
  - e.g.: K^- has larger inelastic cross-section with detector material with respect to K^+
- Asymmetry in detector response
  - e.g.: different efficiency with respect to bending direction of charged tracks
  - regularly revert magnet polarity





CP asymmetries in D^0 and $D^{\pm}$ decays

PRD 89 (2014) 072002

CP asymmetries in D^0 and $D^{\pm}$ decays

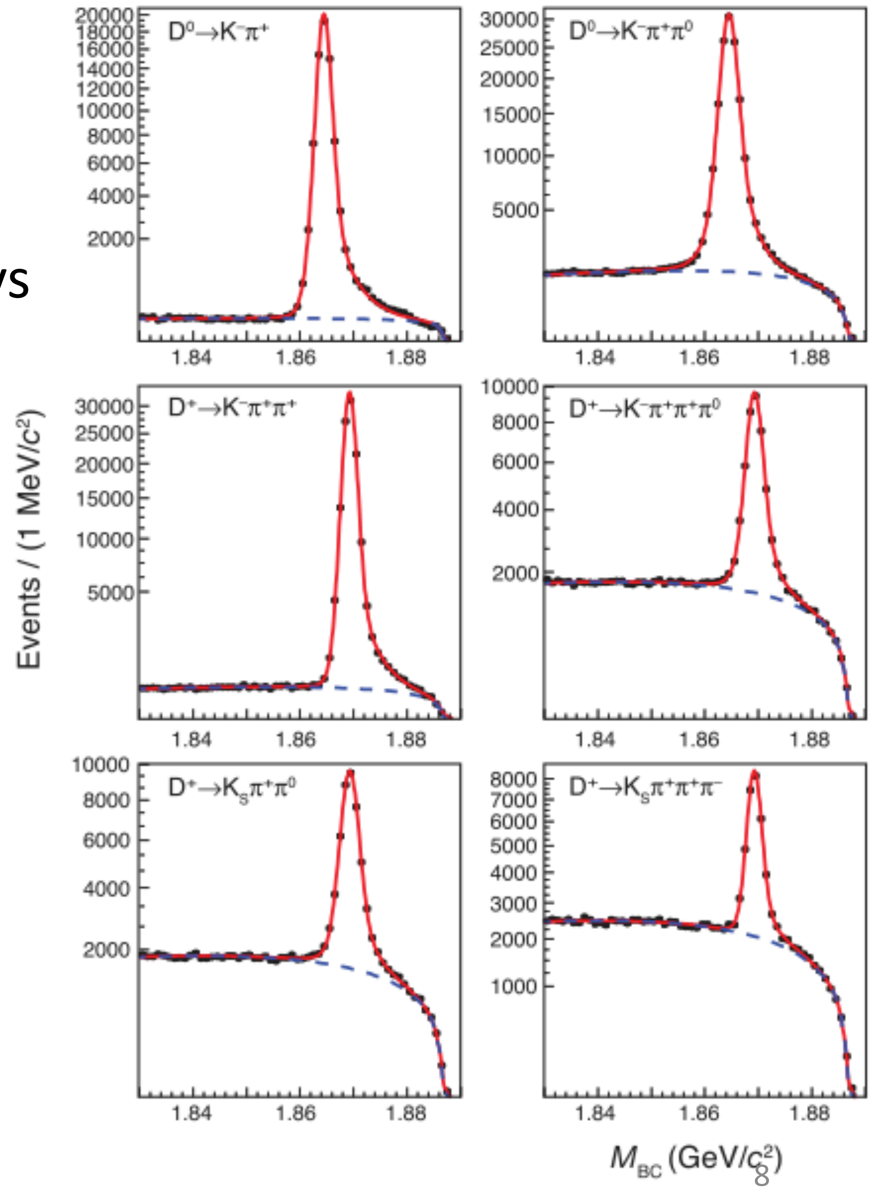
[PRD 89 (2014) 072002]

- D-D̄ pairs produced in the decay of Ψ(3770) resonance:
  - very clean environment
- Detection asymmetries are estimated using partially reconstruction of D decays
  - fits of missing mass in regions of the kinematic of missing track

Mode	*CP* asymmetry (%)
$D^0 \to K^-\pi^+$	$0.3 \pm 0.3 \pm 0.6$
$D^0 \to K^-\pi^+\pi^0$	$0.1 \pm 0.3 \pm 0.4$
$D^0 \to K^-\pi^+\pi^+\pi^-$	$0.2 \pm 0.3 \pm 0.4$
$D^+ \to K^-\pi^+\pi^+$	$-0.3 \pm 0.2 \pm 0.4$
$D^+ \to K^-\pi^+\pi^+\pi^0$	$-0.3 \pm 0.6 \pm 0.4$
$D^+ \to K_S^0\pi^+$	$-1.1 \pm 0.6 \pm 0.2$
$D^+ \to K_S^0\pi^+\pi^0$	$-0.1 \pm 0.7 \pm 0.2$
$D^+ \to K_S^0\pi^+\pi^+\pi^-$	$0.0 \pm 1.2 \pm 0.3$
$D^+ \to K^+K^-\pi^+$	$-0.1 \pm 0.9 \pm 0.4$

No evidence for CPV

818 pb^{-1}



Search for CP violation in the decay $D^+ \to \pi^-\pi^+\pi^+$

PLB 728 (2014) 585-595

Search for CP violation in the decay $D^+ \rightarrow \pi^- \pi^+ \pi^+$

(PLB 728 (2014) 585-595)

- Model independent Dalitz Plot analysis to look for local CP asymmetries
  - define a test statistic
    - binned method

parameter used to remove global asymmetries (A_P, A_D or A_{CP})

$$\mathcal{S}^i_{CP} \equiv \frac{N_i^+ - \alpha N_i^-}{\sqrt{\alpha(N_i^+ + N_i^-)}}, \quad \alpha \equiv \frac{N^+}{N^-},$$

    - unbinned method (**k-nearest neighbour, kNN**)

$$T = \frac{1}{n_k(N_+ + N_-)} \sum_{i=1}^{N_+ + N_-} \sum_{k=1}^{n_k} I(i,k)$$

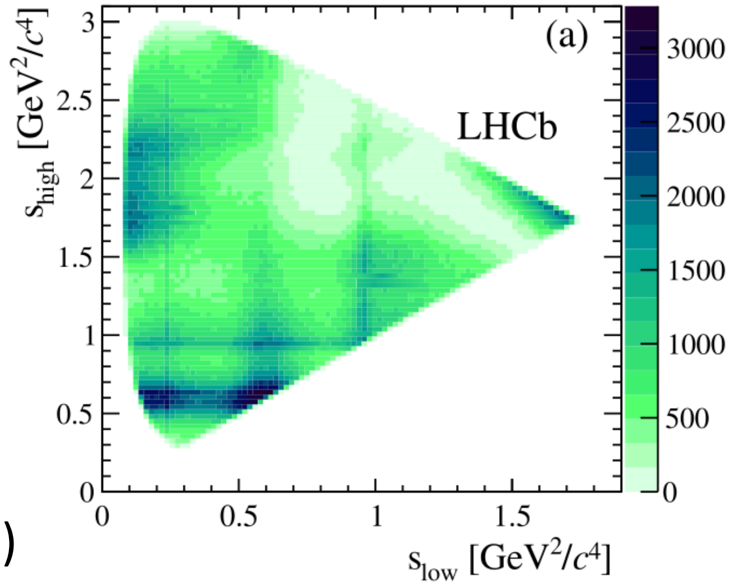
computed in different regions of DP to take into account resonance structure

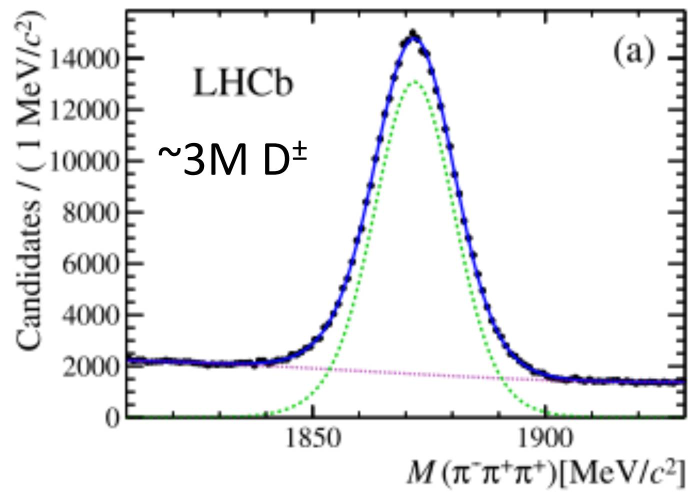
  - both S_{CP} and T have well defined distributions in the no-CPV hypothesis

$$f(S_{CP}) = G(0,1)$$

$$f(T) = G(\mu_T, \sigma_T)$$

1 fb^{-1} @ 7 TeV

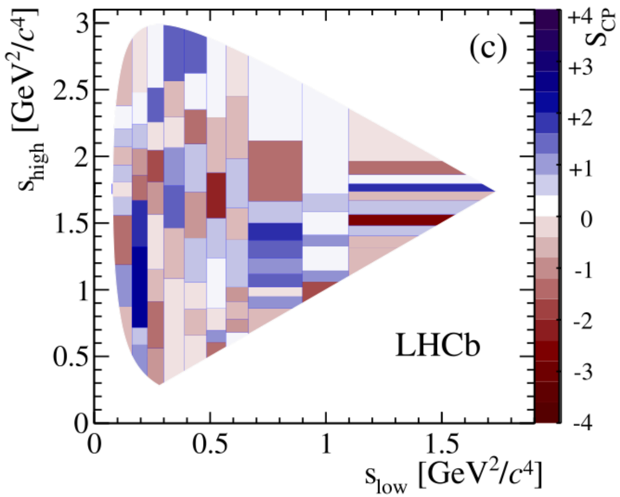


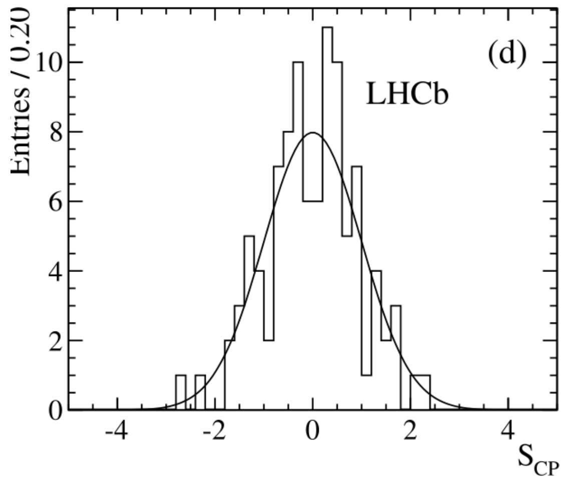


Search for CP violation in the decay $D^+ \rightarrow \pi^- \pi^+ \pi^+$

(PLB 728 (2014) 585-595)

BINNED METHOD

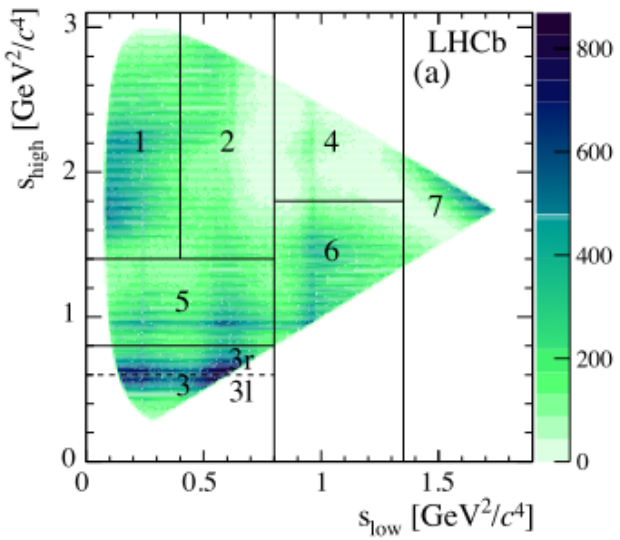


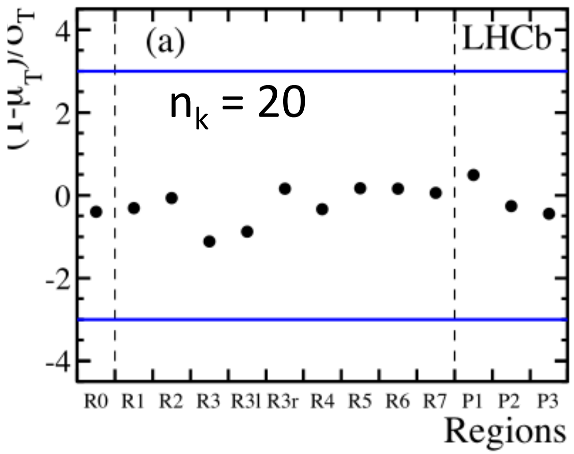


Binned method

- p-value for no-CPV always > 50% for different binning schemes

UNBINNED METHOD





Unbinned method

- p-value for no-CPV always > 30% in different regions of DP

No evidence of CP violation is observed

Search for CP violation in $D^0 \rightarrow \pi^- \pi^+ \pi^0$ decays with the energy test

[PLB 740 (2015) 158–167]

Search for CP violation in $D^0 \rightarrow \pi^-\pi^+\pi^0$ decays with the energy test

[PLB 740 (2015) 158–167]

- Model independent Dalitz Plot analysis to look for CPV
  - method is unbinned and is based on test statistic $T = \Sigma_i (T_i + \bar{T}_i)$

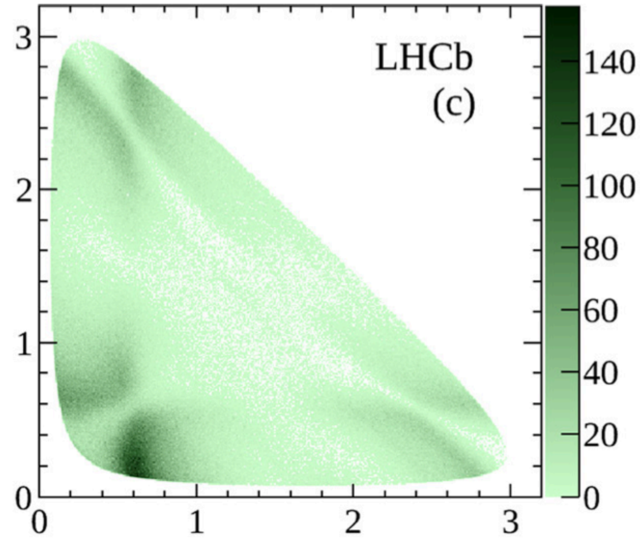
“Energy Test”
[PRD 84 (2011) 054015]

$$T_i = \frac{1}{2n(n-1)} \sum_{j \neq i}^{n} \psi_{ij} - \frac{1}{2n\bar{n}} \sum_{j}^{\bar{n}} \psi_{ij},$$ → contribute of a single D^0

$$\bar{T}_i = \frac{1}{2\bar{n}(\bar{n}-1)} \sum_{j \neq i}^{\bar{n}} \psi_{ij} - \frac{1}{2n\bar{n}} \sum_{j}^{n} \psi_{ij}.$$ → contribute of a single $\bar{D}^0$

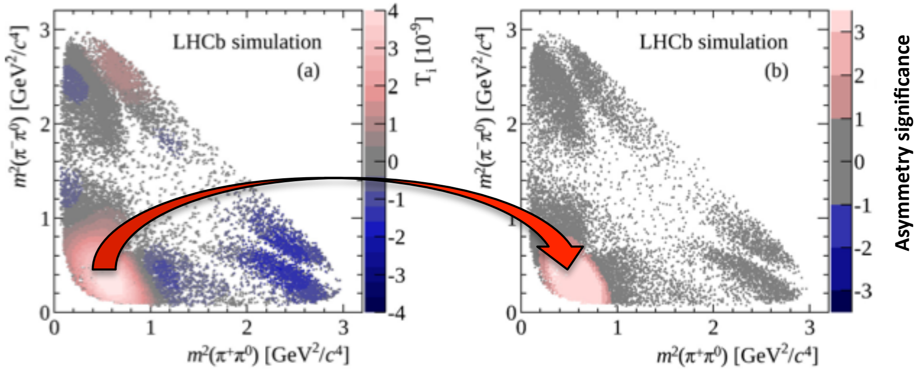
Ψ_{ij}: gaussian metric decreasing with ij-distance in the DP

T = 0 → no-CPV
T > 0 → CPV

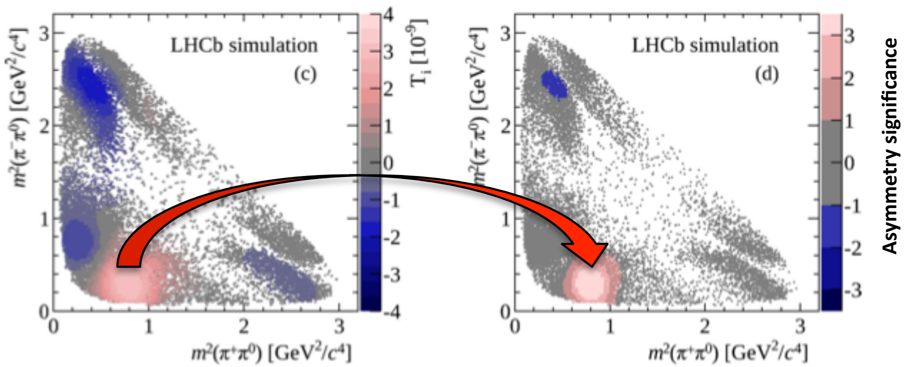


Examples from simulation

introducing 2% direct CPV in ρ^+ resonance



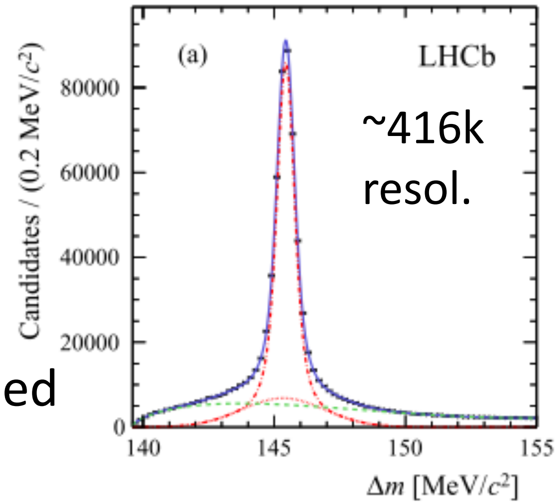
introducing 1° CPV phase in ρ^+ resonance



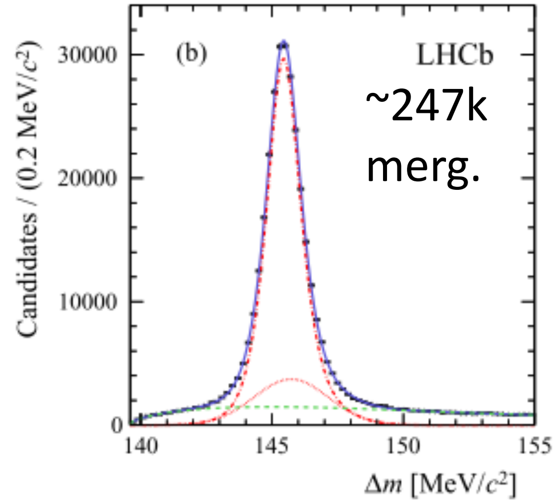
Search for CP violation in $D^0 \rightarrow \pi^-\pi^+\pi^0$ decays with the energy test

[PLB 740 (2015) 158–167]

2 fb^{-1} @ 8 TeV

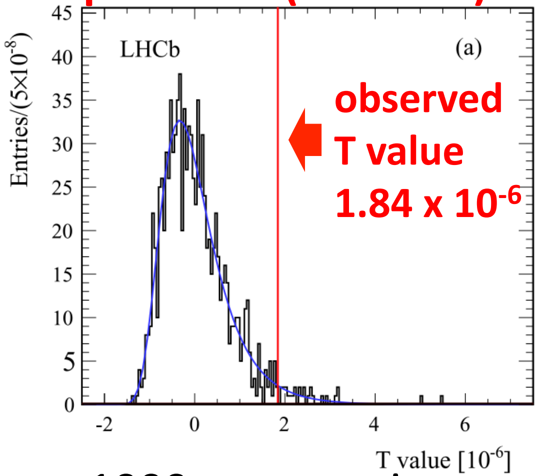


- D^0 flavour determined using D*-prompt
- Two different reconstruction of π^0
  - merged: worse mass resolution but larger p_T
  - resolved: better mass resolution but lower p_T
- Reference distribution of T for no-CPV case is obtained using permutation with randomly assigned flavour
  - p-value is the fraction of permutations above nominal T value

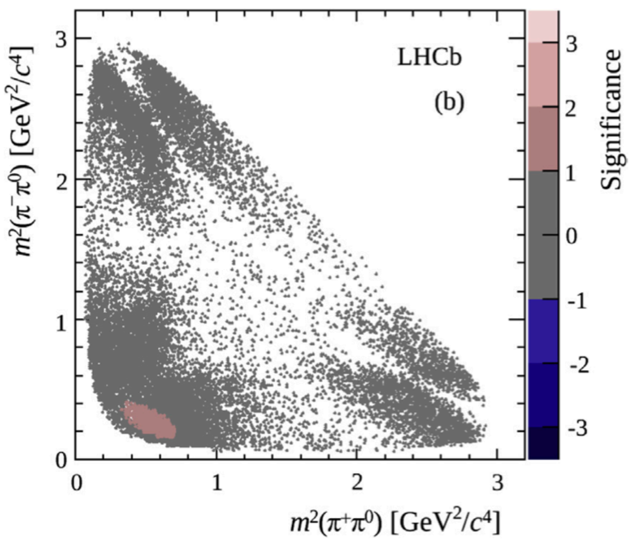


Consistent with no-CPV

p-value = (2.6 ± 0.5)%



1000 permutation



Search for direct CPV in $D^+ \rightarrow K^0_S K^+$ and $D^+_s \rightarrow K^0_S \pi^+$ decays

JHEP 10 (2014) 025

Search for direct CPV in $D^+_{(s)} \rightarrow K^0_S h^+$

[JHEP 10 (2014) 025]

- CPV observable is

$$\mathcal{A}_{\rm meas}^{D^\pm_{(s)}\to K^0_S h^\pm} = \frac{N_{\rm sig}^{D^+_{(s)}\to K^0_S h^+} - N_{\rm sig}^{D^-_{(s)}\to K^0_S h^-}}{N_{\rm sig}^{D^+_{(s)}\to K^0_S h^+} + N_{\rm sig}^{D^-_{(s)}\to K^0_S h^-}}$$

$$\mathcal{A}_{\rm meas}^{D^\pm_{(s)}\to K^0_S h^\pm} \approx \mathcal{A}_{CP}^{D^\pm_{(s)}\to K^0_S h^\pm} + \mathcal{A}_{\rm prod}^{D^\pm_{(s)}} + \mathcal{A}_{\rm det}^{h^\pm} + \boxed{\mathcal{A}_{K^0/\bar{K}^0}}$$

- Two sources of asymmetry
  - **interaction asymmetry** of $K^0/\bar{K}^0$
  - presence of **mixing and CPV** in the K^0-$\bar{K}^0$ system

$A_{K/\bar{K}}$ = (+0.07 ± 0.02)%

- Assuming negligible CPV in CF decays

$$\mathcal{A}_{CP}^{D^\pm_s\to K^0_S \pi^\pm} = \mathcal{A}_{\rm meas}^{D^\pm_s\to K^0_S \pi^\pm} - \mathcal{A}_{\rm meas}^{D^+_s\to \phi\pi^+} - \mathcal{A}_{K^0}$$

$$\mathcal{A}_{CP}^{D^\pm\to K^0_S K^\pm} = \left[\mathcal{A}_{\rm meas}^{D^\pm\to K^0_S K^\pm} - \mathcal{A}_{\rm meas}^{D^\pm_s\to K^0_S K^\pm}\right] - \left[\mathcal{A}_{\rm meas}^{D^\pm\to K^0_S \pi^\pm} - \mathcal{A}_{\rm meas}^{D^+_s\to \phi\pi^+}\right] - \mathcal{A}_{K^0}$$

Detection and production asymmetries cancel in the difference of raw asymmetries

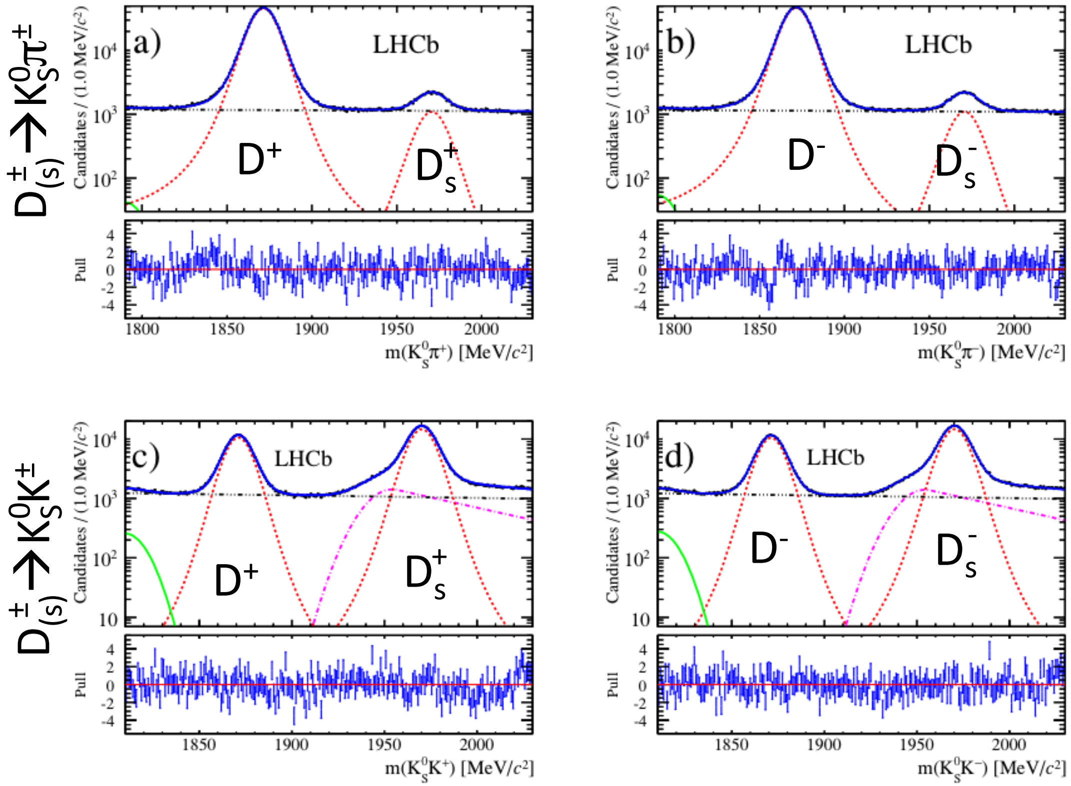
Search for direct CPV in $D^+_{(s)} \rightarrow K^0_S h^+$

(JHEP 10 (2014) 025)

1 fb^{-1} @ 7 TeV + 2 fb^{-1} @ 8 TeV

- Sample divided by charge and magnet polarity
- Simultaneous fit of all subsamples
- p_T and η distributions of D in the various channels are equalized using a weighting procedure

Decay mode	Yield
$D^\pm \to K^0_S\pi^\pm$	$4\,834\,440 \pm 2\,555$
$D^\pm_s \to K^0_S\pi^\pm$	$120\,976 \pm 692$
$D^\pm \to K^0_S K^\pm$	$1\,013\,516 \pm 1\,379$
$D^\pm_s \to K^0_S K^\pm$	$1\,476\,980 \pm 2\,354$
$D^\pm \to \phi\pi^\pm$	$7\,020\,160 \pm 2\,739$
$D^\pm_s \to \phi\pi^\pm$	$13\,144\,900 \pm 3\,879$



$$\mathcal{A}_{CP}^{D^\pm \to K^0_S K^\pm} = (+0.03 \pm 0.17 \pm 0.14)\%$$
$$\mathcal{A}_{CP}^{D^\pm_s \to K^0_S \pi^\pm} = (+0.38 \pm 0.46 \pm 0.17)\%,$$

No evidence of CPV

A_{CP} $D^+ \rightarrow K^0_S K^+$	
BaBar [PRD 87 (2013) 052012]	(+0.13 ± 0.36 ± 0.25) %
Belle [JHEP 02 (2013) 098	(-0.25 ± 0.28 ± 0.14) %
CLEO-c [PRD 81 (2010) 052013]	(0.2 ± 1.5 ± 0.9) %

A_{CP} $D^+_s \rightarrow K^0_S \pi^+$	
BaBar [PRD 87 (2013) 052012]	(+0.6 ± 2.0 ± 0.3) %
Belle [PRL 104 (2010) 181602]	(+5.45 ± 2.50 ± 0.33) %
CLEO-c [PRD 81 (2010) 052013]	(+16.3 ± 7.3 ± 0.3) %

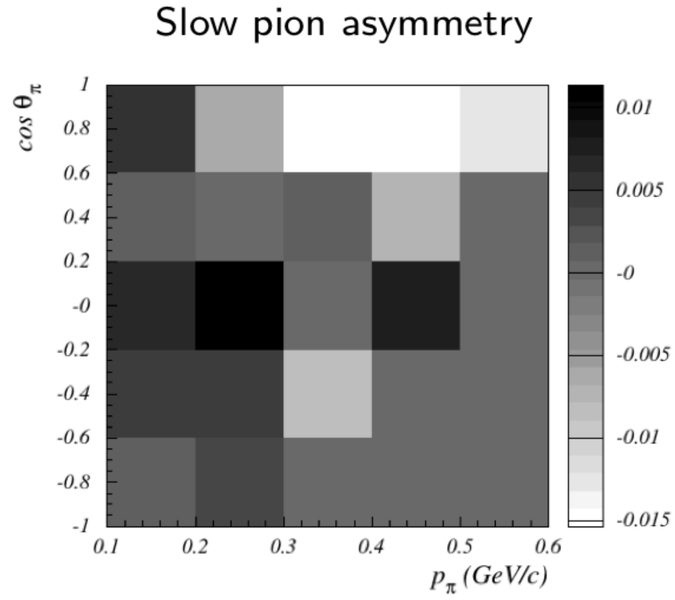
Search for CP Violation in $D^0 \to \pi^0\pi^0$ and $D^0 \to K^0_S\pi^0$ decays

[PRL 112 (2014) 211601]

Search for CP Violation in $D^0 \to \pi^0\pi^0$ and $D^0 \to K_S^0\pi^0$ decays

[PRL 112 (2014) 211601]

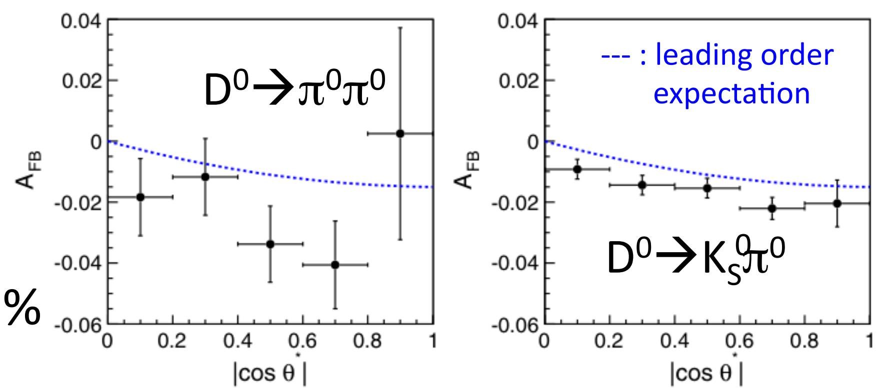
- Initial flavour of the D^0 tagged with D^*-prompt
  - introduce detection asymmetry of π_s^+
  - studied using tagged and untagged samples of $D^0 \to K^-\pi^+$ decays as a function of p_T and $\cos\theta$ of π_s^+



- A_{FB} can be subtracted subtracted thanks to its dependence on $\cos\theta^*$

$$A_{CP} = \frac{A^{\rm cor}_{\rm raw}(cos\theta^*) + A^{\rm cor}_{\rm raw}(-cos\theta^*)}{2}$$

$$A_{FB} = \frac{A^{\rm cor}_{\rm raw}(cos\theta^*) - A^{\rm cor}_{\rm raw}(-cos\theta^*)}{2}$$



- For $D^0 \to K_S^0\pi^0$ decays need to take into account
  - $K^0/\bar{K}^0$ interaction asymmetry: $A_{K/\bar{K}}$ = -0.11% [PRD 84, 111501 (2011)]
  - CPV in K^0-$\bar{K}^0$ mixing: (−0.339 ± 0.007)% [PRL 109, 021601 (2012); 109, 119903(E) (2012)]

Search for CP Violation in $D^0 \to \pi^0\pi^0$ and $D^0 \to K_S^0\pi^0$ decays

[PRL 112 (2014) 211601]

996 fb^{-1}

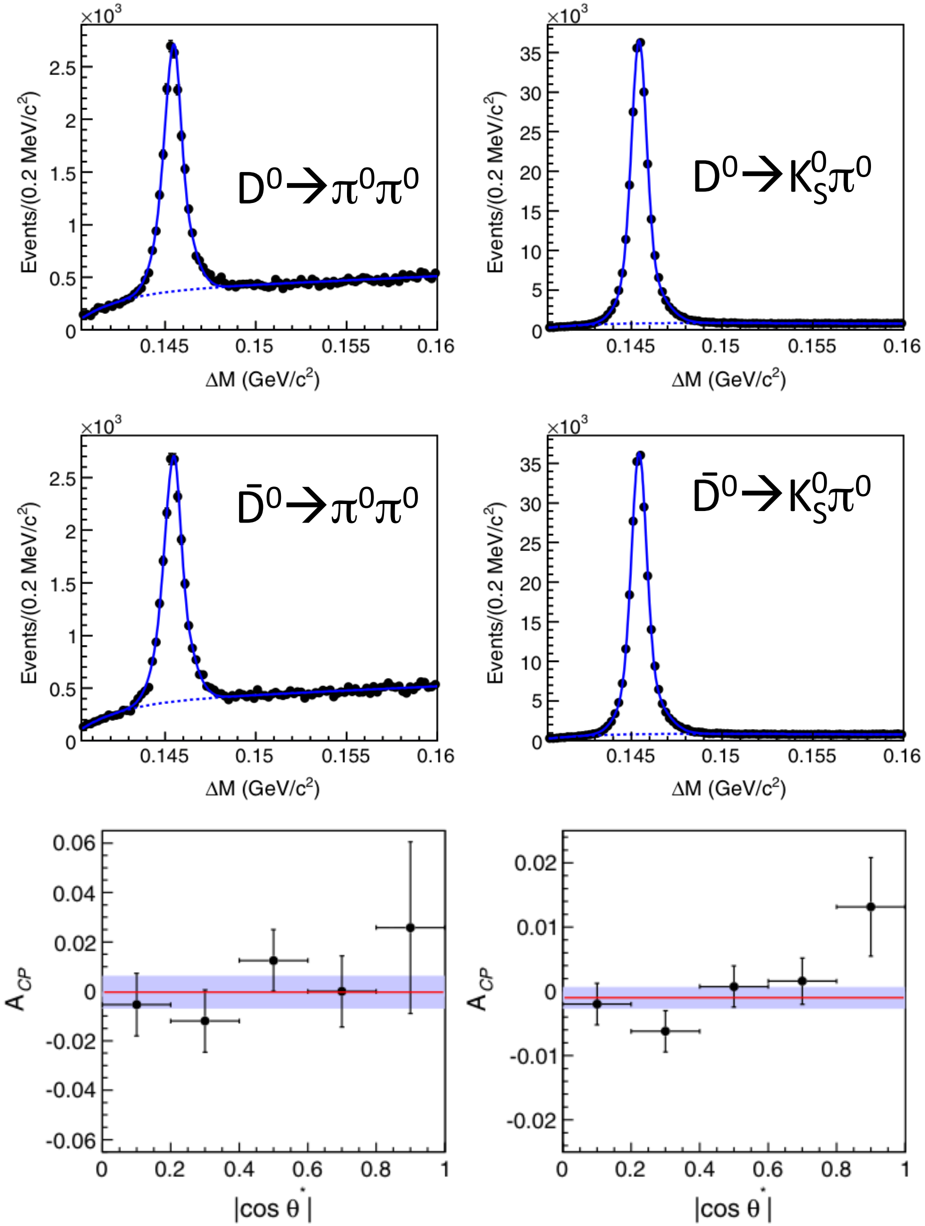
- Using a luminosity of 996 fb^{-1}
  - ~ 345k $D^0 \to \pi^0\pi^0$
  - ~ 470k $D^0 \to K_S\pi^0$)
- In order to take into account all the corrections to A_{RAW} fits are performed in bins of $(\cos\theta^*, p_T, \cos\theta) \to 10 \times 7 \times 8$

$$A_{CP}^{\pi^0\pi^0} = (-0.03 \pm 0.64 \pm 0.10)\%$$
$$A_{CP}^{K_S^0\pi^0} = (-0.21 \pm 0.16 \pm 0.07)\%$$

Correcting for K^0-mixing

$$A_{CP}^{K_S^0\pi^0} = (+0.12 \pm 0.16 \pm 0.07)\%$$

No evidence for CPV



Measurement of CP asymmetry in $D^0 \rightarrow K^-K^+$ and $D^0 \rightarrow \pi^-\pi^+$ decays

JHEP 07 (2014) 041

Measurement of CP asymmetry in $D^0 \rightarrow K^-K^+$ and $D^0 \rightarrow \pi^-\pi^+$ decays

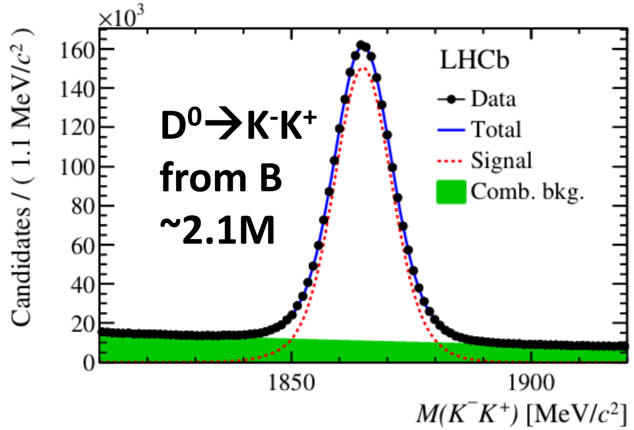
[JHEP 07 (2014) 041]

- Use semi-leptonic B decays to tag D^0 flavour
  - reconstruct $B \rightarrow D^0\mu^\pm X$ decays
  - reconstruct $D^0 \rightarrow K^-K^+$ and $D^0 \rightarrow \pi^-\pi^+$
  - corrections to A_{RAW} are $A_P(B)$ and $A_D(\mu)$
- Measuring ΔA_{CP} corrections cancel in the difference:

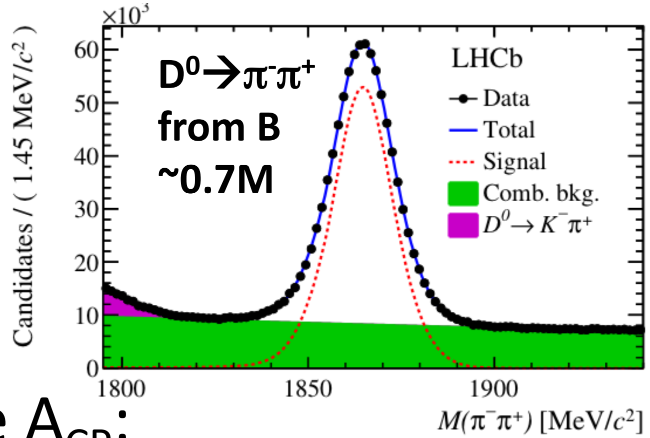
$$\Delta A_{CP} = A_{RAW}(K^+K^-) - A_{RAW}(\pi^+\pi^-) = A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-)$$

  - re-weight of events is used to equalize kinematical distributions
  - sample is separated by magnet polarity to further check removal of corrections
- Experimental challenge is to measure single A_{CP}:
  - need to determine corrections
  - help from CF decays where CPV ≈ 0

1 fb^{-1} @ 7 TeV + 2 fb^{-1} @ 8 TeV



(a)



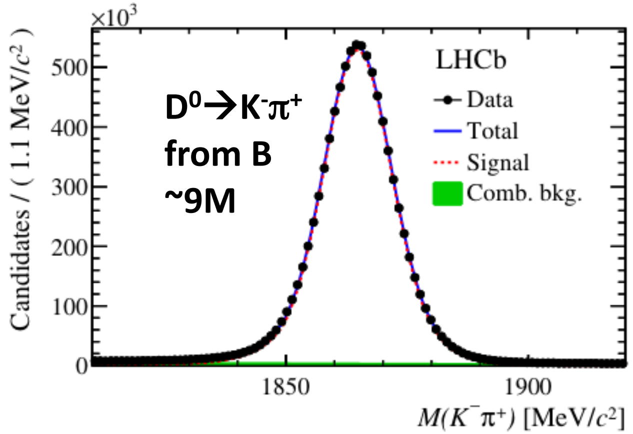
(b)

Measurement of CP asymmetry in $D^0 \rightarrow K^- K^+$ and $D^0 \rightarrow \pi^- \pi^+$ decays

[JHEP 07 (2014) 041]

$$A_{RAW}(K^+K^-) = A_{CP}(K^+K^-) + A_P(B) + A_D(\mu)$$

$$A_{CP}(K^-\pi^+) + A_P(B) + A_D(\mu) + A_D(K^-\pi^+) = A_{RAW}(K^-\pi^+)$$



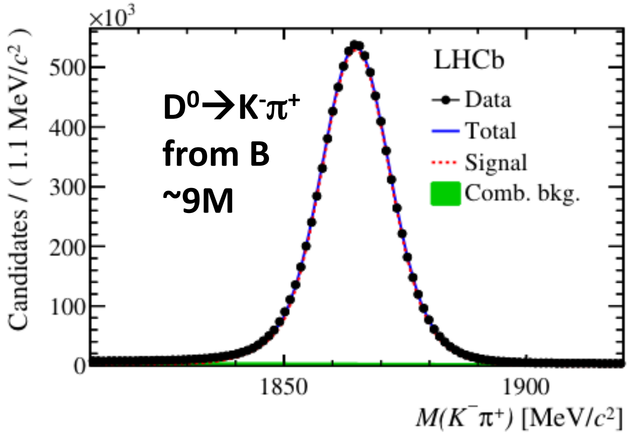
(c)

Measurement of CP asymmetry in $D^0 \to K^-K^+$ and $D^0 \to \pi^-\pi^+$ decays

[JHEP 07 (2014) 041]

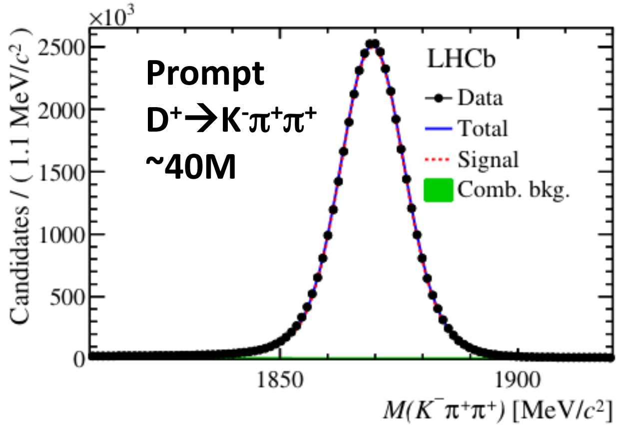
$$A_{RAW}(K^+K^-) = A_{CP}(K^+K^-) + A_P(B) + A_D(\mu)$$

$$A_{CP}(K^-\pi^+) + A_P(B) + A_D(\mu) + A_D(K^-\pi^+) = A_{RAW}(K^-\pi^+)$$



(c)

$$A_{RAW}(D^+ \to K^-\pi^+\pi^+) = A_{CP}(D^+ \to K^-\pi^+\pi^+) + A_D(K^-\pi^+) + A_P(D^+) + A_D(\pi^+)$$



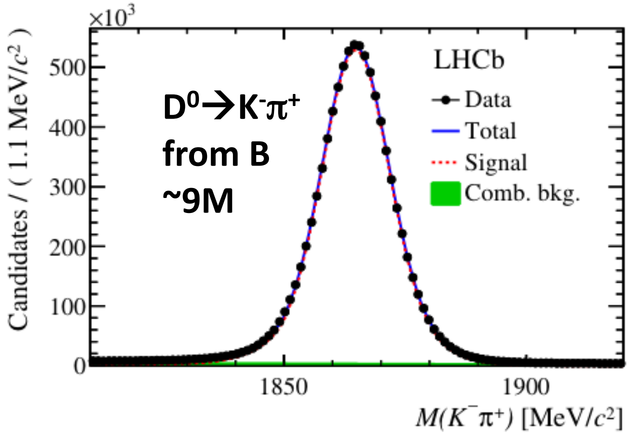
(d)

Measurement of CP asymmetry in $D^0 \rightarrow K^- K^+$ and $D^0 \rightarrow \pi^- \pi^+$ decays

[JHEP 07 (2014) 041]

$$A_{RAW}(K^+K^-) = A_{CP}(K^+K^-) + A_P(B) + A_D(\mu)$$

$$\cancel{A_{CP}(K^-\pi^+)} + A_P(B) + A_D(\mu) + A_D(K^-\pi^+) = A_{RAW}(K^-\pi^+)$$

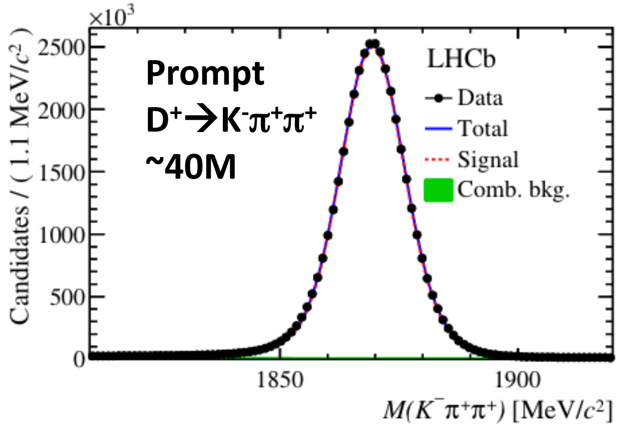


(c)

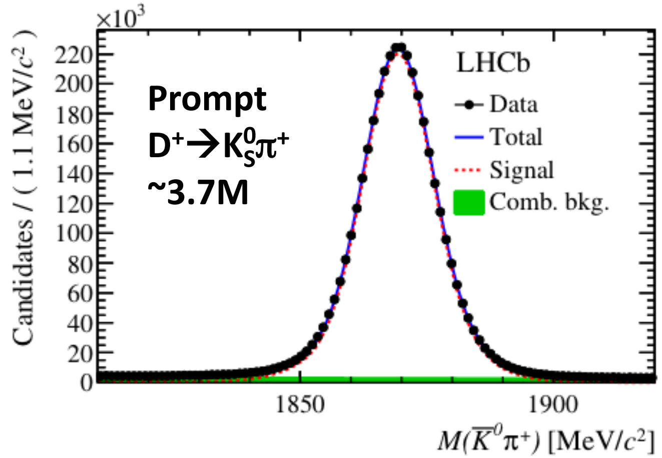
$$A_{RAW}(D^+ \rightarrow K^-\pi^+\pi^+) = \cancel{A_{CP}(D^+ \rightarrow K^-\pi^+\pi^+)} + A_D(K^-\pi^+) + A_P(D^+) + A_D(\pi^+)$$

$$A(K_S^0) + \cancel{A_{CP}(D^+ \rightarrow K_S^0\pi^+)} + A_P(D^+) + A_D(\pi^+) = A_{RAW}(D^+ \rightarrow K_S^0\pi^+)$$

(0.054 ± 0.014)%



(d)



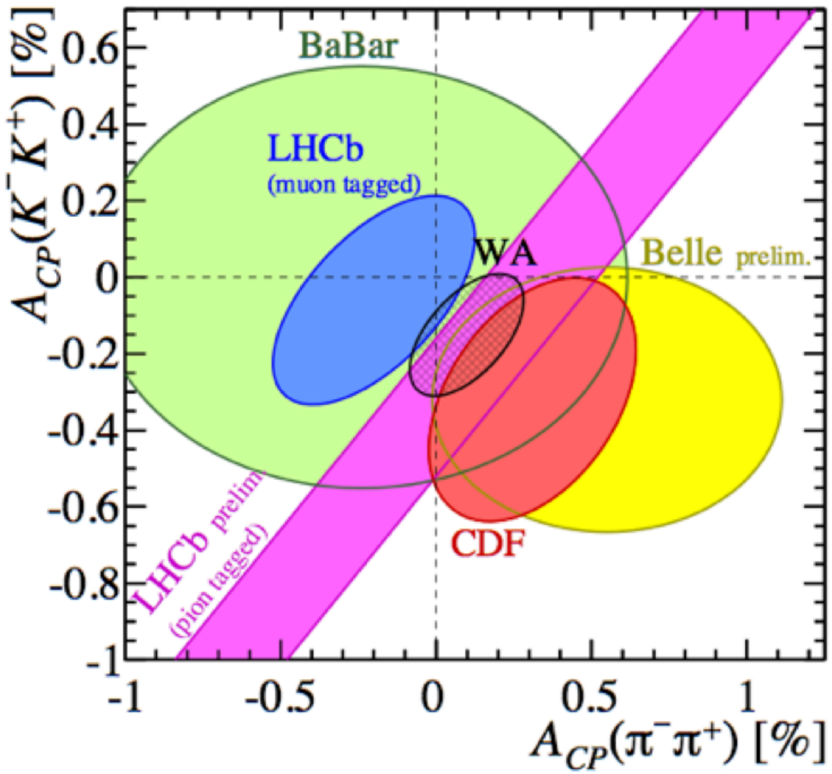
(e)

$$A_{CP}(K^-K^+) = A_{\rm raw}(K^-K^+) - A_{\rm raw}(K^-\pi^+) + A_D(K^-\pi^+)$$

Measurement of CP asymmetry in $D^0 \rightarrow K^- K^+$ and $D^0 \rightarrow \pi^- \pi^+$ decays

[JHEP 07 (2014) 041]

Ignoring contribution from indirect CPV



$$A_{CP}(K^-K^+) = (-0.06 \pm 0.15\,(\mathrm{stat}) \pm 0.10\,(\mathrm{syst}))\%$$
$$A_{CP}(\pi^-\pi^+) = (-0.20 \pm 0.19\,(\mathrm{stat}) \pm 0.10\,(\mathrm{syst}))\%$$

Direct and indirect CPV in ΔA_{CP}

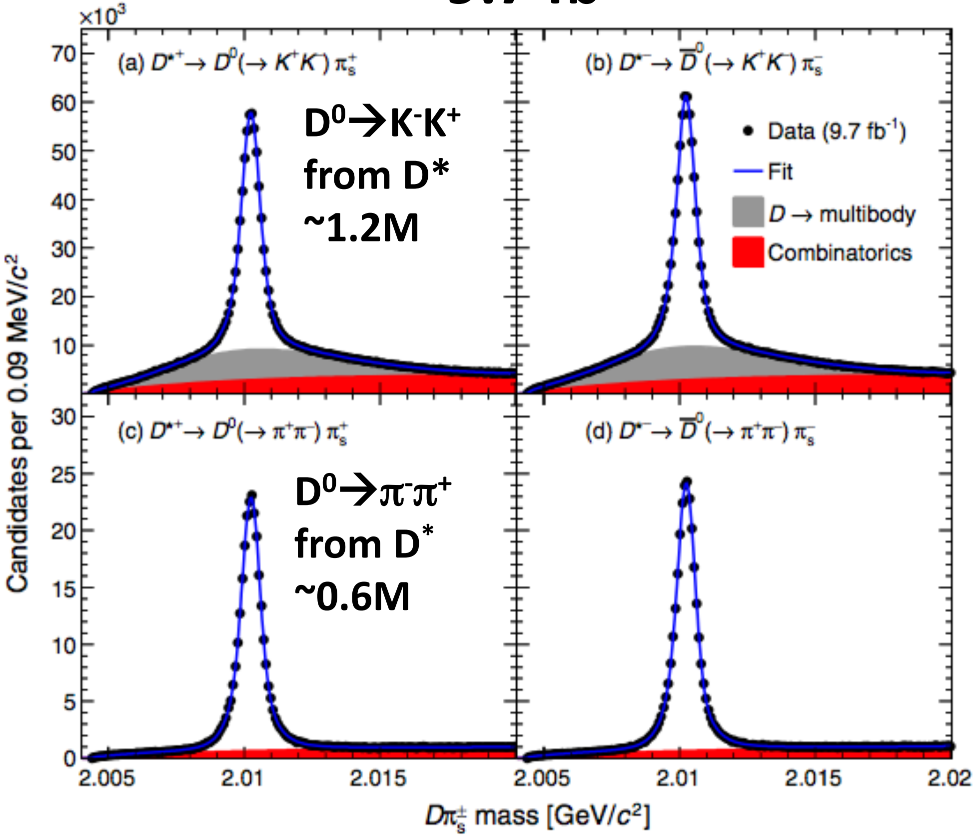
- In D^0 decays one should take into account indirect CPV coming from mixing and interference between mixing and decay
  - ΔA_{CP} does not measure pure direct CPV

$$\Delta A_{CP} \approx \Delta a_{CP}^{dir} - \frac{\Delta\langle t \rangle}{\tau} A_\Gamma \qquad A_\Gamma = \frac{\tau(\overline{D}^0 \to h^+h^-) - \tau(D^0 \to h^+h^-)}{\tau(\overline{D}^0 \to h^+h^-) + \tau(D^0 \to h^+h^-)}$$

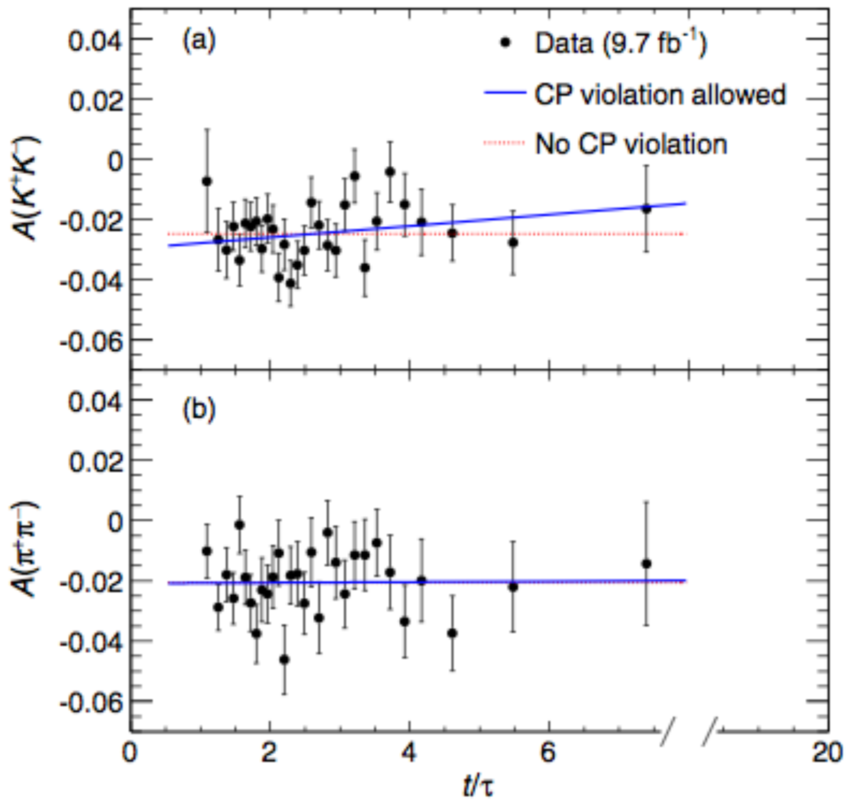
- Two recent measurements of A_Γ:
  - LHCb [JHEP 04 (2015) 043]:
    - use of D^0 from semi-leptonic B decays
  - CDF [PRD 90 (2014) 111103]:
    - use of D^0 tagged with D^*-prompt
  - Same technique
    - measure A_{RAW} in bins of t/τ $\quad A_{RAW}^{CP}(t) \approx A_0 - A_\Gamma \frac{t}{\tau}$
    - A_0 contains A_D, A_P and A_{CP}^{dir} → no effect on the determination of A_Γ
    - independence of A_0 from decay time is controlled using CF $D^0 \to K^-\pi^+$ decays

Measurements of A_Γ

9.7 fb^{-1}



PHYSICAL REVIEW D **90,** 111103(R) (2014)

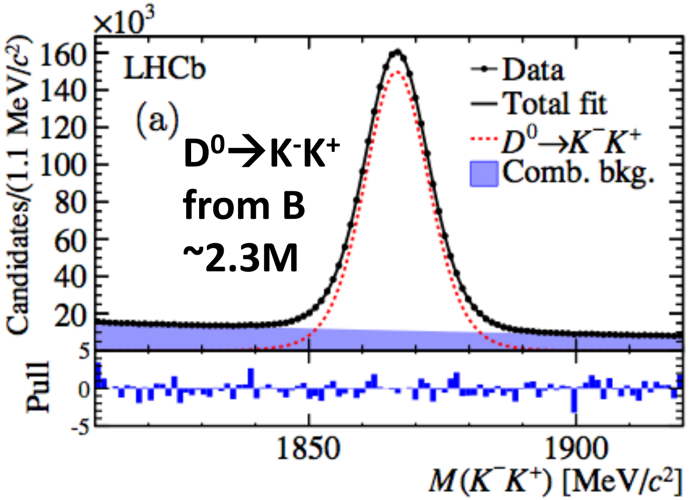


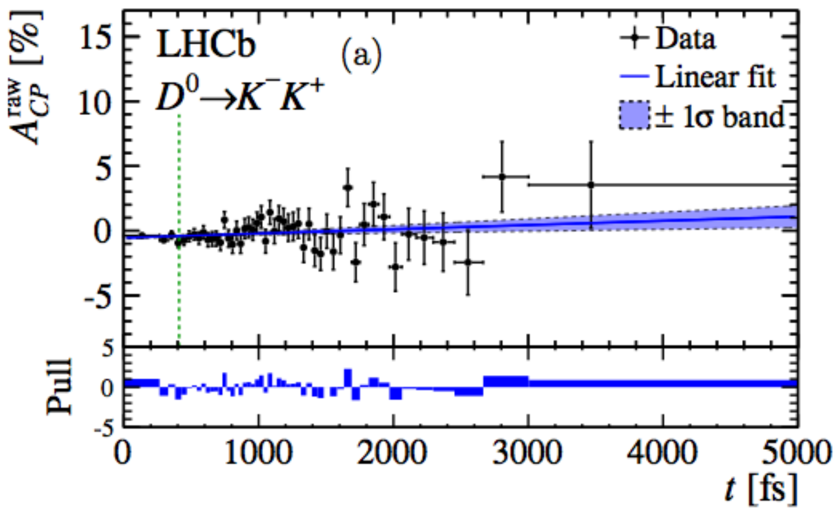
$$A_\Gamma(K^+K^-) = (-0.19 \pm 0.15(\text{stat}) \pm 0.04(\text{syst}))\%,$$
$$A_\Gamma(\pi^+\pi^-) = (-0.01 \pm 0.18(\text{stat}) \pm 0.03(\text{syst}))\%,$$

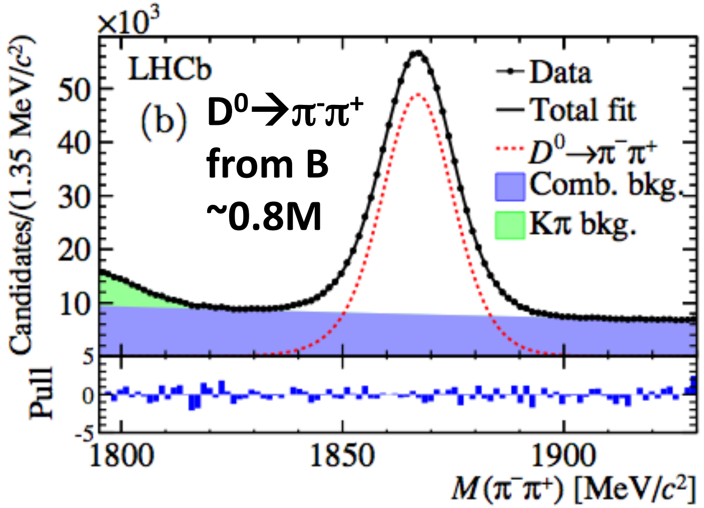
No evidence of CPV

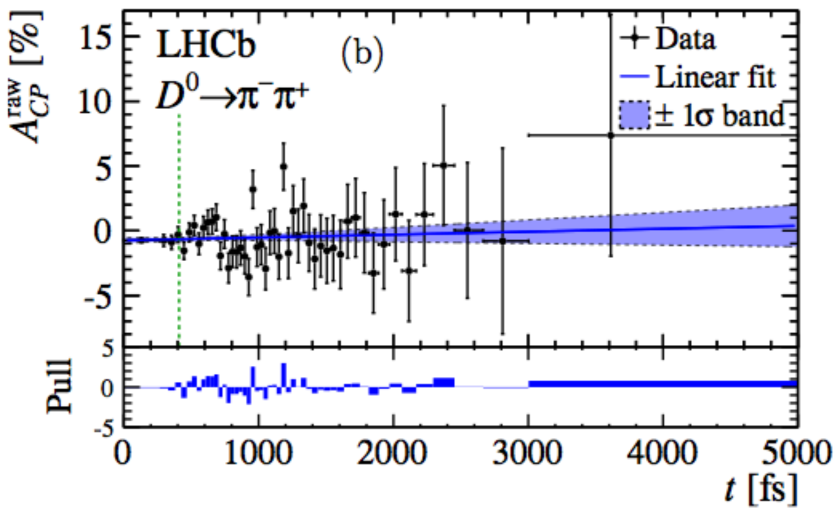
Measurements of A_Γ

JHEP 04 (2015) 043 - 1 fb^{-1} @ 7 TeV + 2 fb^{-1} @ 8 TeV





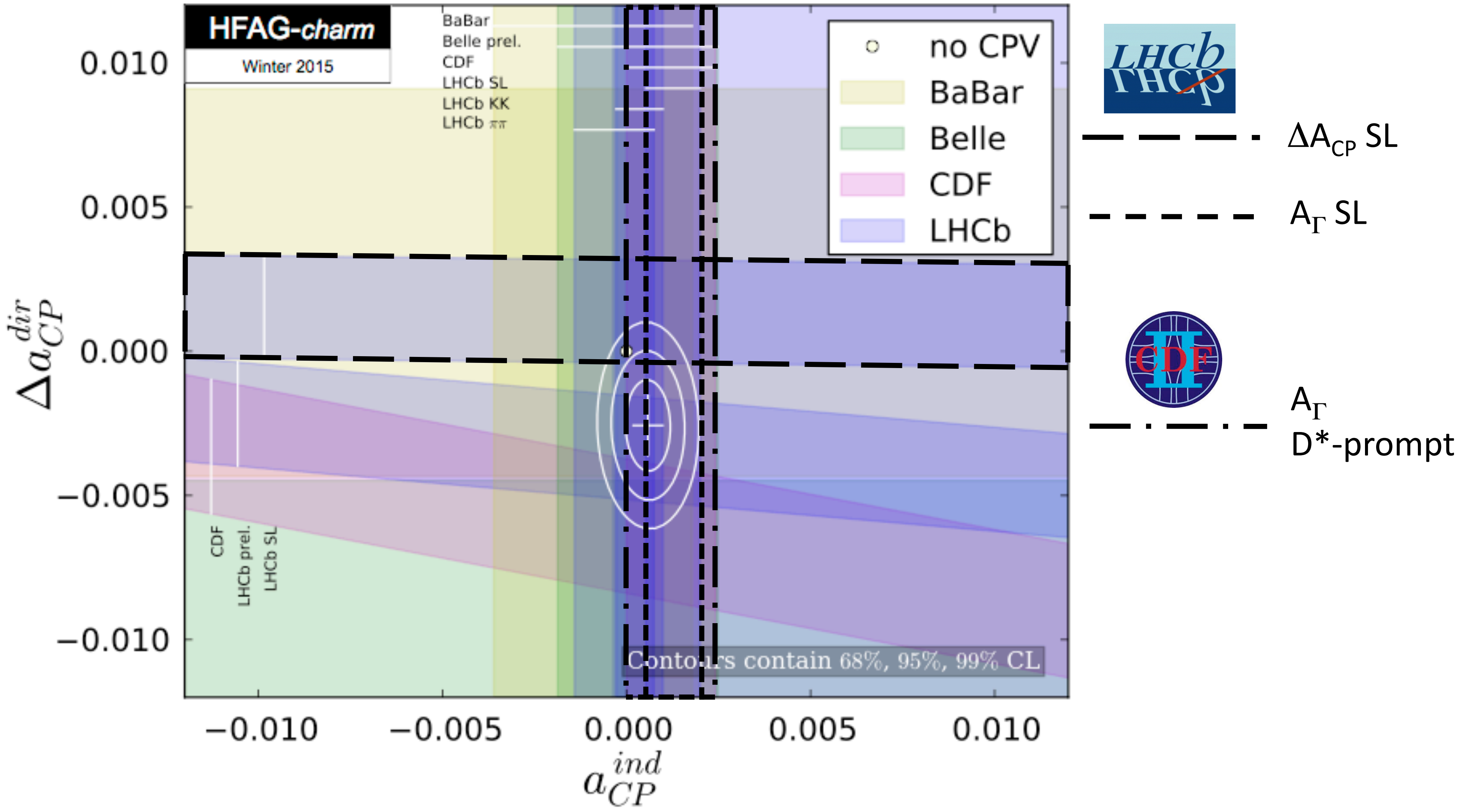




$$A_\Gamma(K^-K^+) = (-0.134 \pm 0.077\ ^{+0.026}_{-0.034})\ \%$$
$$A_\Gamma(\pi^-\pi^+) = (-0.092 \pm 0.145\ ^{+0.025}_{-0.033})\ \%$$

No evidence of CPV

Direct and indirect CPV



Data are consistent with no-CPV at 1.8% CL

Conclusions

- Several measurements of time-integrated CPV in charm decays have been presented
  - model independent search for CPV in Dalitz Plot of multibody D decays
    - $D^{\pm} \rightarrow \pi^{-}\pi^{+}\pi^{+}$, $D^{0} \rightarrow \pi^{-}\pi^{+}\pi^{0}$
    - model-dependent measurements will be the next step to extract all the information from resonance structure
  - Measurements of CPV asymmetries in several D^{0} and $D^{\pm}$ decays
    - D^{0} and $D^{\pm}$ to several modes including π^{0} and K_{S}^{0}
    - $D_{s}^{\pm} \rightarrow K_{S}^{0}\pi^{\pm}$, $D^{\pm} \rightarrow K_{S}^{0}K^{\pm}$
    - $D^{0} \rightarrow \pi^{0}\pi^{0}$ and $D^{0} \rightarrow K_{S}^{0}\pi^{0}$
    - $D^{0} \rightarrow K^{-}K^{+}$ and $D^{0} \rightarrow \pi^{-}\pi^{+}$
    - Measurements entered the regime of $O(10^{-3})$ precision

Conclusions

- No evidence of CPV yet...
- More results will arrive in the near future
  - LHCb still have to exploit the full potential of Run1
  - more data will come from Run2 of LHC → LHCb trigger rate will double
  - Belle II will start to take data soon
  - for longer term prospects see Umberto Marconi's and Matt Barrett's talks on Friday