Search of CPV in the charm sector at LHCb

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On behalf of the LHCb collaboration

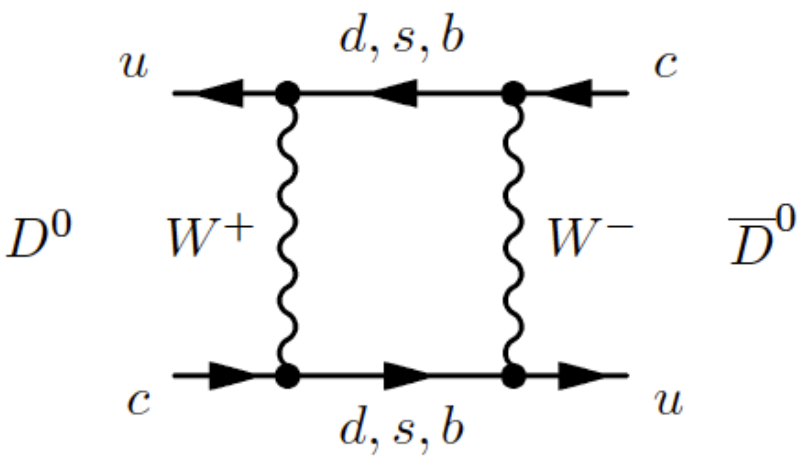
Outline

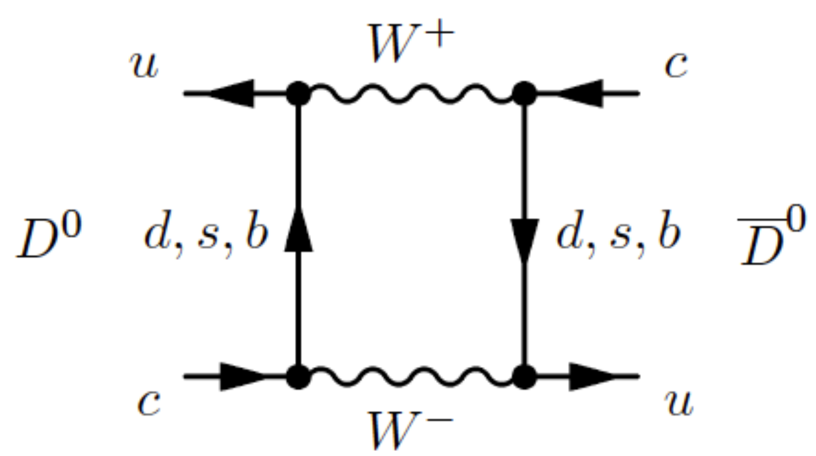
- Introduction
- 1st evidence CP violation in the charm sector at LHCb → ΔA_{CP} measurement
- Other measurements of direct and indirect CPV
- Prospects on 2011 data
- Conclusion

D0 mixing

- D mesons give exclusive access to up-type dynamics
- D^0 mixing
  - observed for the first time in 2007 by BaBar and Belle [arXiv:hep-ex/0703020; arXiv:hep-ex/0703036]
  - well established at >10 σ in HFAG average [HFAG arXiv:1010.1589]
  - No single measurement at 5 σ

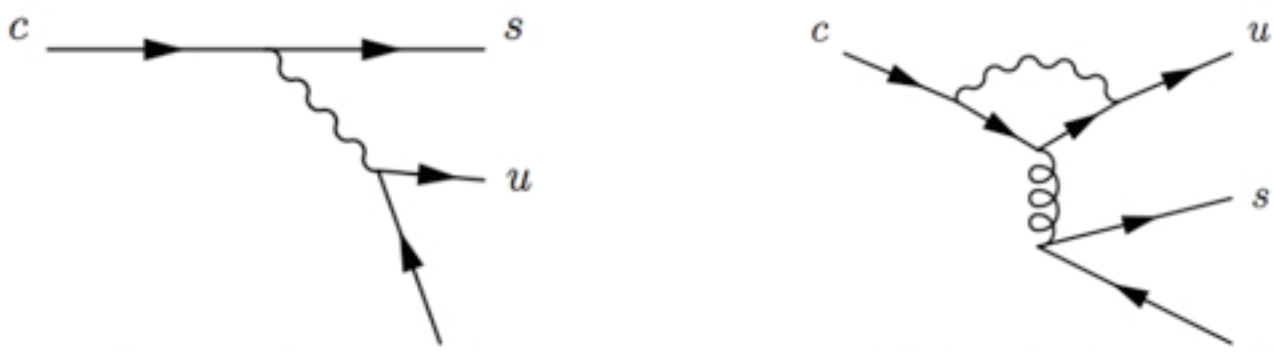
  LHCb potentially can provide the 1st 5σ measurement [not covered in this talk]





CP violation in charm

- CP violation contributions:
  - Direct contribution → in decay
  - Indirect contributions → in mixing and in interference
- In the SM CP violation is conserved to first approximation (dominance of 2 generations)
- New Physics can enhance CP violating observables
- Cabibbo-favoured modes not interesting
  - Tree-level SM contribution swamps everything else
- Singly-Cabibbo-suppressed modes with gluonic penguin diagrams very promising
- Interference between Tree and Penguin can generate direct CP asymmetries
  - Several classes of NP can contribute
  - but also non-negligible SM contribution



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

Measurement of ΔA_{CP} $(D^0 \rightarrow K^-K^+ - D^0 \rightarrow \pi^-\pi^+)$

LHCb-PAPER-2011-023; arXiv:1112:09838 submitted to PRL

Measurement of ΔA_{CP} ($D^0 \to K^-K^+$ - $D^0 \to \pi^-\pi^+$)

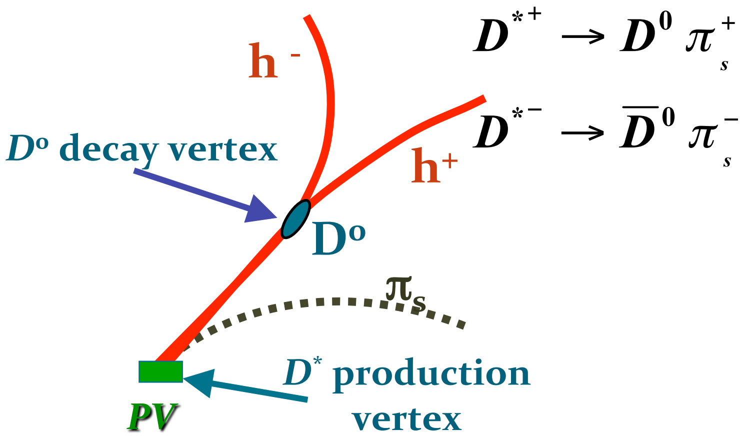
- The time-integrated CP asymmetry is defined as:

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

  where f is the final state K^-K^+ or $\pi^-\pi^+$

- Two contributions due to direct and indirect CPV

- The D^0 flavour is determined by the sign of the slow pion in the decays $D^{*+} \to D^0(f)\pi_s^+$



Measurement of ΔA_{CP} ($D^0 \to K^- K^+$ - $D^0 \to \pi^- \pi^+$)

- The measured asymmetry is

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

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

- At first order expansion with the assumption of small individual asymmetries O(%)

Measurement of ΔA_{CP} ($D^0 \to K^- K^+$ - $D^0 \to \pi^- \pi^+$)

- The measured asymmetry is:

$$A_{RAW}(f)^* = \frac{N\left(D^{*+} \to D^0(f)\pi_s^+\right) - N\left(D^{*-} \to \bar{D}^0(\bar{f})\pi_s^-\right)}{N\left(D^{*+} \to D^0(f)\pi_s^+\right) + N\left(D^{*-} \to \bar{D}^0(\bar{f})\pi_s^-\right)}$$

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

Physics CP asymmetry

Production asymmetry

Detection asymmetry of D^0 and of slow pion

- Detection asymmetry $A_D(f)$ for self-conjugate final states is 0
- D^{*+}/D^{*-} production asymmetries need to be taken into account in proton-proton interaction at LHC

Measurement of ΔA_{CP} ($D^0 \to K^- K^+$ - $D^0 \to \pi^- \pi^+$)

- The measured asymmetry is:

$$A_{RAW}(f)^* = \frac{N\left(D^{*+} \to D^0(f)\pi_s^+\right) - N\left(D^{*-} \to \bar{D}^0(\bar{f})\pi_s^-\right)}{N\left(D^{*+} \to D^0(f)\pi_s^+\right) + N\left(D^{*-} \to \bar{D}^0(\bar{f})\pi_s^-\right)}$$

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

Physics CP asymmetry

Production asymmetry

Detection asymmetry of slow pion

- Taking $A_{RAW}(f)^*$ - $A_{RAW}(f')^*$ the **production** and **slow pion detection** asymmetries will cancel.

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

➔ CP asymmetry difference very robust against systematics

Experimental Status: individual A_{CP}

Year	Experiment	CP Asymmetry in the decay mode $D^0 \to \pi^+\pi^-$	
2010	CDF	T. Aaltonen, et al(CDF Collab.), arXiv:1111.5023 (2011)	$+0.0022 \pm 0.0024 \pm 0.0011$
2008	BELLE	M. Staric et al. (BELLE Collab.), Phys. Lett. B 670, 190 2008).	$+0.0043 \pm 0.0052 \pm 0.0012$
2008	BABAR	B. Aubert et al. (BABAR Collab.), Phys. Rev. Lett. 100, 061803 (2008).	$-0.0024 \pm 0.0052 \pm 0.0022$
2002	CLEO	S.E. Csorna et al. (CLEO Collab.), Phys. Rev. D 65, 092001 (2002).	$+0.019 \pm 0.032 \pm 0.008$
2000	FOCUS	J.M. Link et al. (FOCUS Collab.), Phys. Lett. B 491, 232 (2000).	$+0.048 \pm 0.039 \pm 0.025$
1998	E791	E.M. Aitala et al. (E791 Collab.), Phys. Lett. B 421, 405 (1998).	$-0.049 \pm 0.078 \pm 0.030$
		COMBOS average	**$+0.0020 \pm 0.0022$**

Year	Experiment	CP Asymmetry in the decay mode $D^0 \to K^+K^-$	
2011	CDF	T. Aaltonen, et al(CDF Collab.), arXiv:1111.5023 (2011)	$-0.0024 \pm 0.0022 \pm 0.0010$
2008	BELLE	M. Staric et al. (BELLE Collab.), Phys. Lett. B 670, 190 (2008).	$-0.0043 \pm 0.0030 \pm 0.0011$
2008	BABAR	B. Aubert et al. (BABAR Collab.), Phys. Rev. Lett. 100, 061803 (2008).	$+0.0000 \pm 0.0034 \pm 0.0013$
2002	CLEO	S.E. Csorna et al. (CLEO Collab.), Phys. Rev. D 65, 092001 (2002).	$+0.000 \pm 0.022 \pm 0.008$
2000	FOCUS	J.M. Link et al. (FOCUS Collab.), Phys. Lett. B 491, 232 (2000).	$-0.001 \pm 0.022 \pm 0.015$
1998	E791	E.M. Aitala et al. (E791 Collab.), Phys. Lett. B 421, 405 (1998).	$-0.010 \pm 0.049 \pm 0.012$
1995	CLEO	J.E. Bartelt et al. (CLEO Collab.), Phys. Rev. D 52, 4860 (1995).	$+0.080 \pm 0.061$
1994	E687	P.L. Frabetti et al. (E687 Collab.), Phys. Rev. D 50, 2953 (1994).	$+0.024 \pm 0.084$
		COMBOS average	**-0.0023 ± 0.0017**

Dominated by CDF, especially for $D^0 \to \pi^+\pi^-$

$A_{CP}(K^+K^-)$ and $A_{CP}(\pi^+\pi^-)$ values consistent with zero but have opposite sign

ΔA_{CP} extraction strategy

- ΔA_{CP} robust against systematics, however detector effect could induce different fake asymmetries for KK and $\pi\pi$
  - Dependence of $A_P(D^*)$ and $A_D(\pi_s)$ on kinematics
  - Different kinematic distribution for KK and $\pi\pi$

➔ Kinematic binning needed to suppress second-order effects of correlated asymmetries:

  ➔ Divide data into kinematic bins of (p_T and η of $D^{*\pm}$, p of slow pion, left and right hemisphere)

  ➔ Treat each bin independently

- Along similar lines:
  - Split by magnet polarity (B field up/down)
  - Split into two run groups

➔ 216 independent measurement of ΔA_{CP}

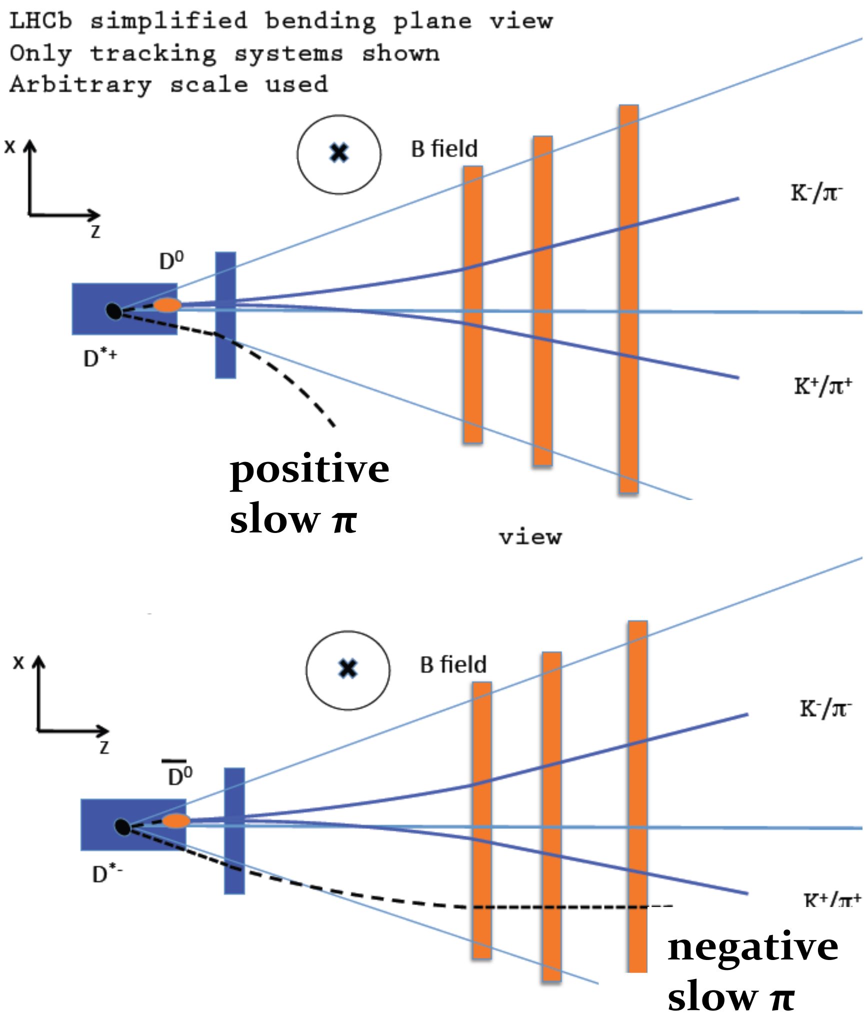
Event selection

- Offline selection
  - Track fit quality for all the tracks
  - $D^{*\pm}$ and D^0 vertex fit quality
  - Transverse momentum of D^0: $p_T > 2$ GeV/c
  - Kaon and pion ID cuts imposed with RICH information
  - Proper lifetime of D^0: $ct_{min}= 100$ μm
  - Helicity angle of of D^0 decay: $|\cos\theta|<0.9$
  - D^0 must point back to primary vertex: $\chi^2(IP)<9$
  - D^0 daughter track must not point back to the primary vertex
  - D^0 mass window: $1844 < m(D^0) <1884$ MeV/c^2
  - Fiducial cuts to exclude edges where the B-field caused large $D^{*\pm}$ and D^0 acceptance asymmetry

Fiducial cut

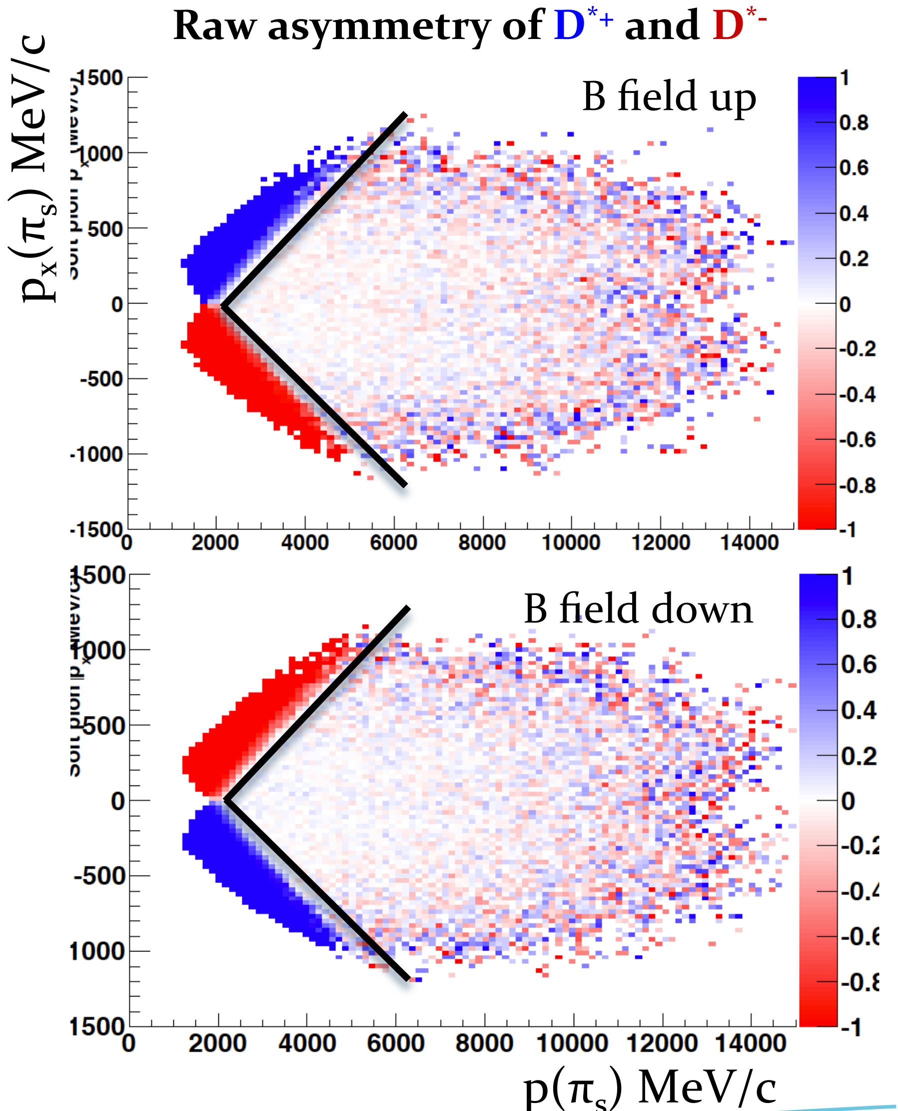
- Magnetic field induces a left/right differences between the D^{*+} and D^{*-} due to the slow pion acceptance

- Two effects:
  - *Acceptance at edges of the detector*
  - *Beam-pipe downstream of the magnet*



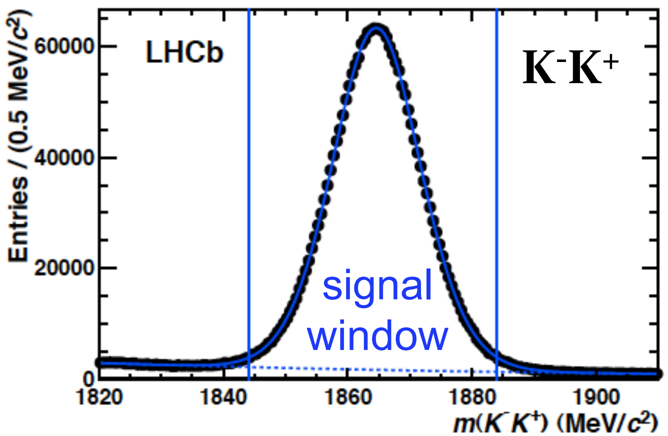
Fiducial cut

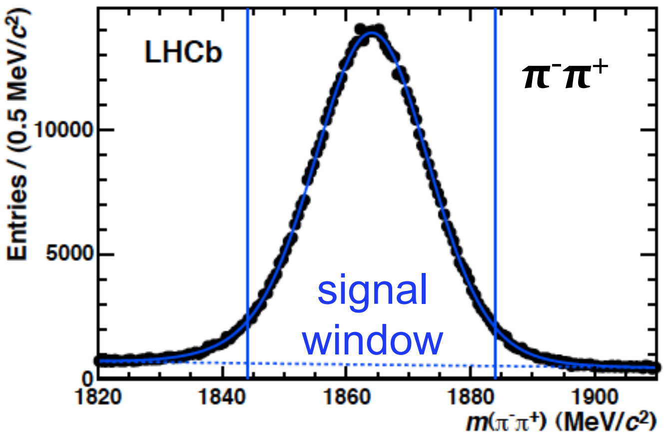
- Magnetic field induces a left/right differences between the D^{*+} and D^{*-} due to the slow pion acceptance
- Two effects:
  - Acceptance at edges of the detector
  - Beam-pipe downstream of the magnet
- There are regions of phase space where on D^{*+} or D^{*-} are reconstructed ➔ large raw asymmetries (up to 100%)
- Fiducial cut to exclude the edge regions with cuts in the slow pion (p_x, p) plane



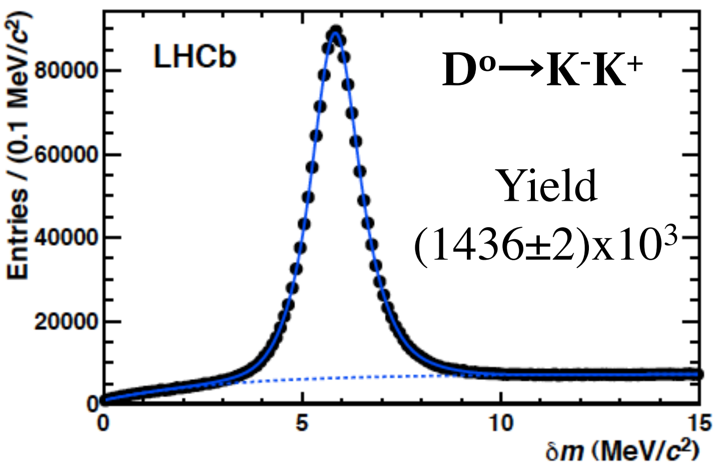
Measurement of ΔA_{CP} ($D^0 \rightarrow K^-K^+$ - $D^0 \rightarrow \pi^-\pi^+$)

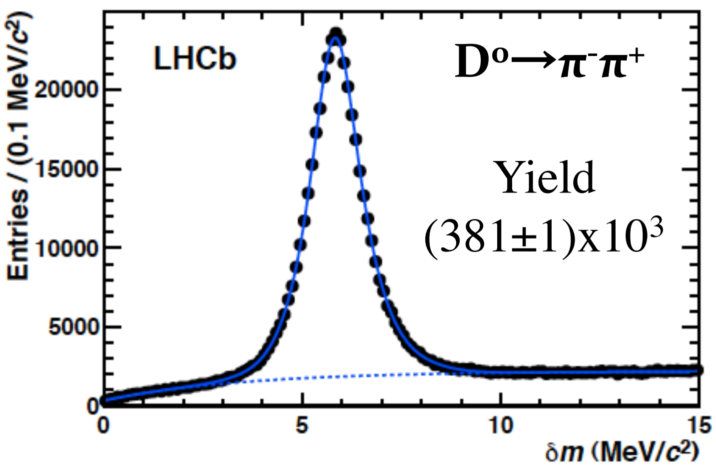
- Total signal yield with an integrated luminosity of 0.6 fb^{-1}: 1.4M tagged $D^0 \rightarrow K^-K^+$ and 381k tagged $D^0 \rightarrow \pi^-\pi^+$





Fit the $\delta m = m(D^{*+}) - m(D^o) - m(\pi^+)$





Fit procedure

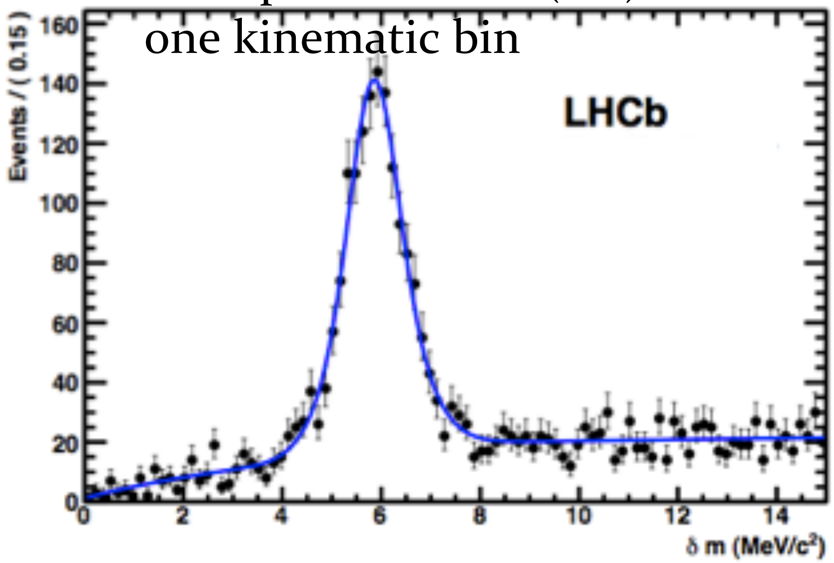
- Use 1D fits to mass difference:

  $\delta m = m(D^{*+}) - m(D^0) - m(\pi^+)$

- Signal model: double Gaussian convolved with a function accounting for the asymmetric tail
- Background model:

$$h(\delta m) = B\left[1 - \mathbf{exp}\left(-\frac{\delta m - \delta m_0}{c}\right)\right]$$

Example fit $D^* \rightarrow D^o(KK)\pi$ one kinematic bin



- Consistency for ΔA_{CP} among 216 kinematic bins:

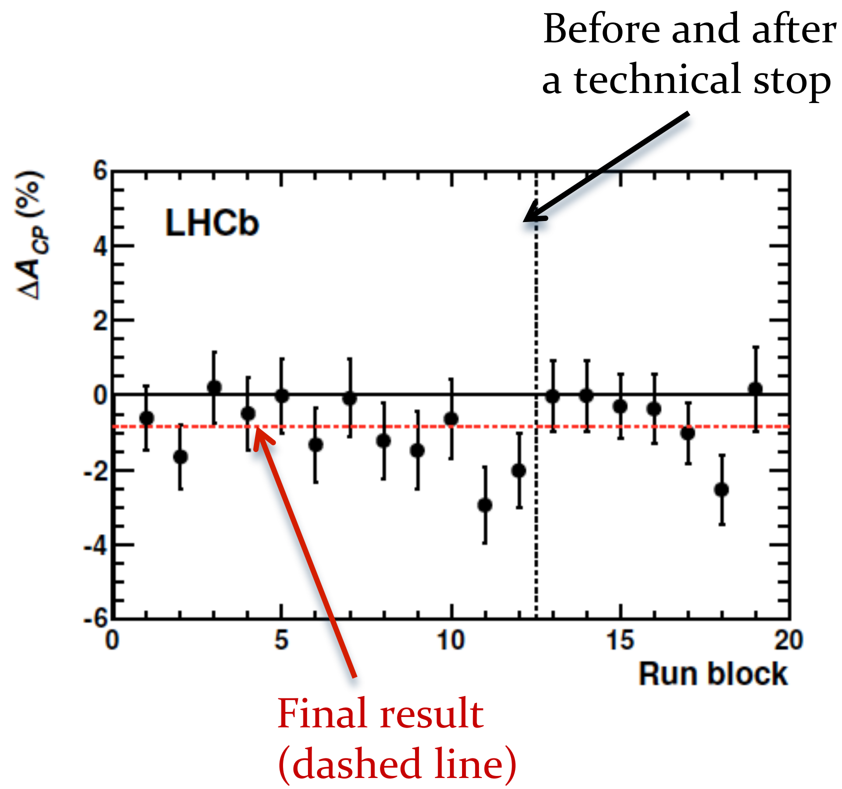
  χ^2/ndof =211/215 (χ^2 prob. 56%)

- A weighted average of the kinematic bins yields the results:

  ΔA_{CP} = −0.82 ± 0.21 (stat) %

Cross-checks

- Several cross-checks, e.g.
  - Stability of result vs data taking runs
  - Stability vs kinematic variables
  - Tightening of PID cuts on D^0 daughters
  - Internal consistency between subsamples (splitting left/right, field up/ field down, etc.)



- No evidence of dependence and consistent with the baseline results

Systematic errors

- Fit procedure: 0.08%
  - Evaluated as change in ΔA_{CP} between baseline and not using any fitting at all (just sideband subtraction in δm for KK and $\pi\pi$ modes)
- Multiple candidates: 0.06%
  - Evaluated as mean change in ΔA_{CP} when removing multiple candidates, keeping only one per event chosen at random.
- Peaking background: 0.04%
  - Evaluated with toy studies injecting peaking background with a level and asymmetry set according to D^0 mass sidebands (removing signal tails).
- Kinematic binning: 0.02%
  - Evaluated as change in ΔA_{CP} between full 54-bin kinematic binning and "global" analysis with just one giant bin.
- Fiducial cuts: 0.01%
  - Evaluated as change in ΔA_{CP} when cuts are significantly loosened.
- Sum in quadrature: 0.11%

ΔA_{CP} measurement

- Result with $L = 0.6\ fb^{-1}$ of data collected in 2011:

$$\Delta A_{CP} = -0.82 \pm 0.21\ (\text{stat}) \pm 0.11\ (\text{sys})\ \%$$

- First evidence of *CP* violation in charm with significance 3.5σ (incl. statistical and systematic uncertainties)

ΔA_{CP} interpretation

- A_{CP} of each final state may be written at first order as

$$A_{CP} \approx a_{CP}^{dir}\left(1 + y\cos\phi\frac{\langle t\rangle}{\tau}\right) + a_{CP}^{ind}\frac{\langle t\rangle}{\tau}$$

where $\langle t\rangle$ is the average decay time ➔ experiment dependent and τ is the D^0 lifetime

- To good approximation the indirect asymmetry is universal, i.e. independent of the final state.
- ΔA_{CP} may be written as

$$\Delta A_{CP} \approx \Delta a_{CP}^{dir}\left(1 + y\cos\phi\frac{\overline{\langle t\rangle}}{\tau}\right) + \left(a_{CP}^{ind} + \overline{a_{CP}^{dir}}\, y\cos\phi\right)\frac{\Delta\langle t\rangle}{\tau}$$

$$\Delta X \equiv X\left(K^+K^-\right) - X\left(\pi^+\pi^-\right) \quad \text{and} \quad \overline{X} \equiv \frac{X\left(K^+K^-\right) + X\left(\pi^+\pi^-\right)}{2}$$

- Interpretation of ΔA_{CP} depends on the experiment

Y. Grossman et al., Phys. Rev. D75, 2007
M. Gersabeck et al., arXiv:1111.6515
CDF Collaboration arXiv:1111.5023

Lifetime acceptance

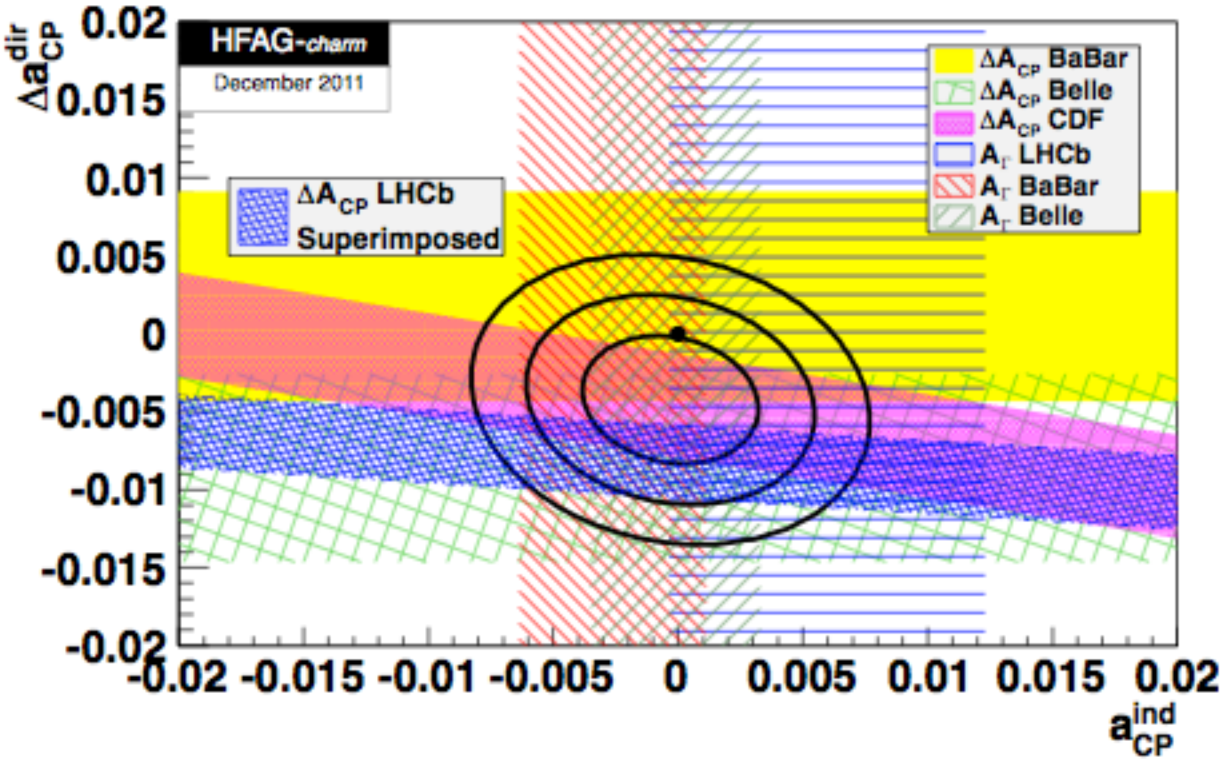
- Lifetime acceptance differs between $D^0 \to K^- K^+$ and $D^0 \to \pi^- \pi^+$
  - e.g. smaller opening angle ➔ short-lived $D^0 \to K^- K^+$ more likely to fail cut requiring daughters not to point to PV than $D^0 \to \pi^- \pi^+$
- Background-subtracted average decay time of D^0 candidates passing the selection is measured for each final state, and the fractional difference with respect to world average D^0 lifetime is obtained:

$$\Delta\langle t\rangle/\tau = [9.83 \pm 0.22(\text{stat.}) \pm 0.19(\text{syst})]\%$$

- Systematics:
  - World-average D^0 lifetime 0.04%
  - Fraction of charm from B-hadron decays 0.18%
  - Background-subtraction procedure 0.04%

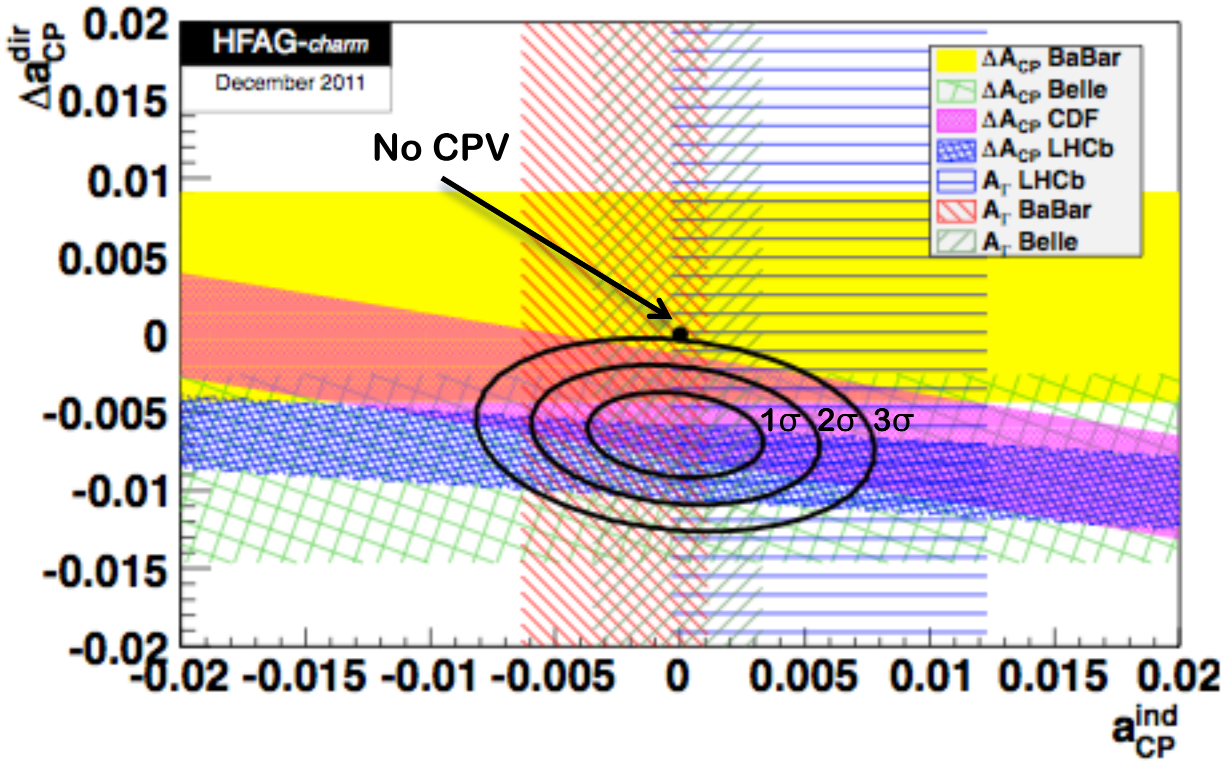
➔ indirect CP violation contribution to ΔA_{CP} mostly cancel

Comparison with the world average



LHCb measurement is consistent with HFAG averages based on previous results (1.1 sigma)

Comparison with the world average



Consistent with no CP violation at 0.13% C.L.

- Central value:

  a_{CP}^{ind} = (−0.019 ± 0.232)% and Δa_{CP}^{dir} = (−0.645 ± 0.180)%

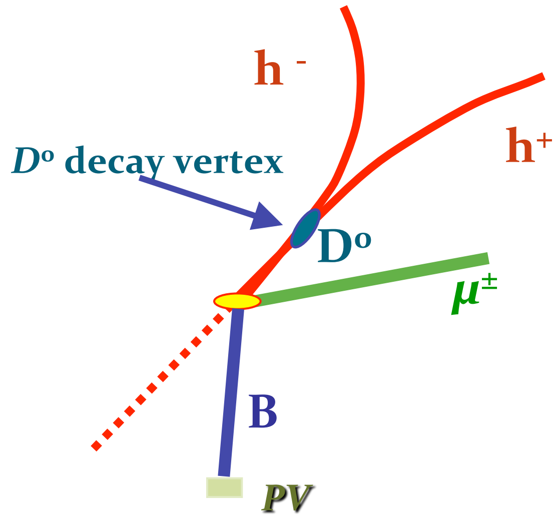
Prospect of ΔA_{CP} measurement

- Current measurement of ΔA_{CP} performed with 60% of 2011 recorded sample
  - work in progress on the full 2011 data sample with 1.1 fb^{-1} of integrated luminosity
- Expected precision 0.1 - 0.2 %
- Measure ΔA_{CP} with D^0 from B semileptonic decays

Charm Physics with semileptonic B decays

- LHCb is an experiment dedicated to study the decays of **beauty** and charm hadrons
- High rate of B hadrons decays into DX
  - Collect large sample thanks to LHCb trigger
- Selection of B semileptonic decays $B \to D\mu\nu X$:
  - $\mathbf{B \to D^0 X \mu\nu}$, $B \to D^+ X \mu\nu$, $B \to D_s^+ X \mu\nu$
- Charge of μ is used to tag the D^0 flavour
- Different data samples for studies in the charm sector:
  - **Evaluation of ΔA_{CP}**; CPV searches in $K_s hh$, $K_s h$, $hh\pi^0$ etc.

Secondary from B decays



ΔA_{CP} measurement with semileptonic B decays

- The measured asymmetry is:

$$A_{RAW}(f)^* = \frac{\mathrm{N}\left(B \to D^0(f)\mu^+\nu_\mu\right) - \mathrm{N}\left(B \to \overline{D}^0(\bar{f})\mu^-\overline{\nu}_\mu\right)}{\mathrm{N}\left(B \to D^0(f)\mu^+\nu_\mu\right) + \mathrm{N}\left(B \to \overline{D}^0(\bar{f})\mu^-\overline{\nu}_\mu\right)}$$

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

Physics CP asymmetry

Detection asymmetry of D^0 and of muon

Production asymmetry

B CP asymmetry

- Taking $A_{RAW}(f)^* - A_{RAW}(f')^*$ all the detection, production and B CP effects cancel
- Measurement of $\Delta A_{CP} = \Delta A_{RAW}$
- Expected statistical precision with the semileptonic sample ~ 0.3% with 1.1. fb^{-1}

Other searches of CPV:
Measurement of A_Γ

LHCb-PAPER-2011-032; arXiv:1112.4698 submitted to JHEP

Search of CPV: y_{CP} and A_Γ measurements

- A measurement of CP violation in D^0 mixing can be evaluated by the asymmetry of the proper-time of flavour-tagged decays:
  - Decays to CP eigenstates: $f=K^-K^+$, $\pi^-\pi^+$

$$A_\Gamma = \frac{\tau(\overline{D}^0 \to K^-K^+) - \tau(D^0 \to K^-K^+)}{\tau(\overline{D}^0 \to K^-K^+) + \tau(D^0 \to K^-K^+)} \approx \frac{A_M}{2} y\cos\phi - x\sin\phi \boxed{+\frac{A_D}{2} y\cos\phi}$$

Including Direct CPV contribution

$$A_\Gamma \approx -a_{CP}^{ind} - a_{CP}^{dir}\, y\cos\phi$$

[M. Gersabeck et al., arXiv:1111.6515]

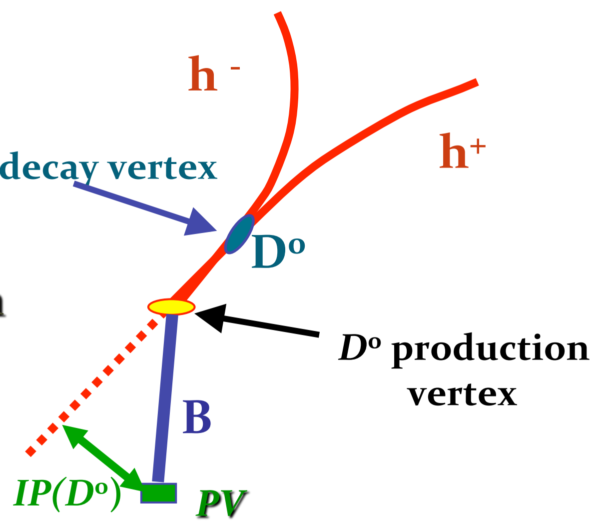
where ϕ is a weak (CP violating) phase, x and y are the mixing parameters A_m represents a CP violation contribution from mixing and A_d from direct CP violation

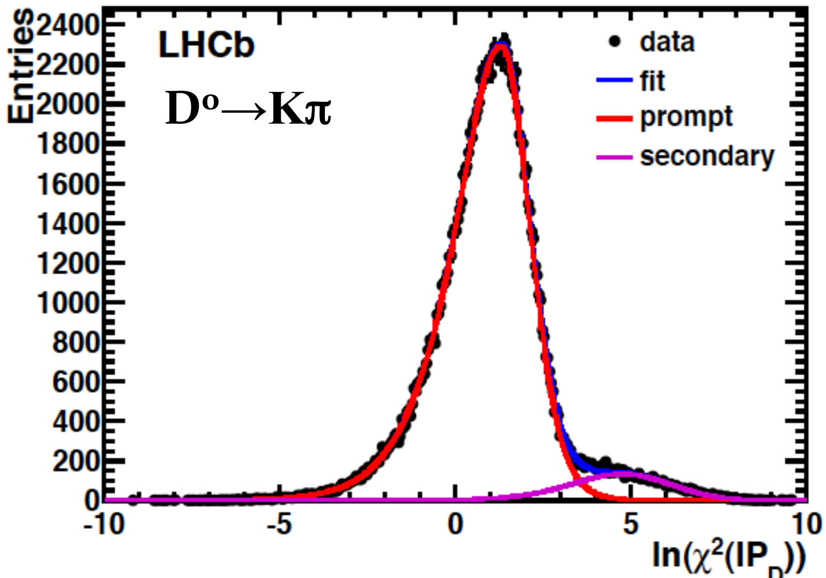
➔ A non-zero value of A_Γ would be a clear measurement of CP violation and a sign of new physics contribution.

A_Γ measurement: Method

- Unbinned likelihood fit m_{D0} for the determination of signal yield
- Main background due to secondary D^0
  - Dangerous background ➔ bias the lifetime measurement
  - Not distinguishable by the invariant mass distribution
  - Difference direction: large IP wrt PV and large angle between p_{D0} and dir. pointing to PV
  - Need statistical separation by $\ln(\chi^2_{IP})$
- Simultaneous fit of proper time and $\ln(\chi^2_{IP})$ to distinguish between prompt and secondary
- Acceptance evaluated by a data driven method, the so called “swimming method”
- Evaluation of the mis-tag rate from $\Delta m(D^*\text{-}\ D^0(hh))$

Secondary from B decays



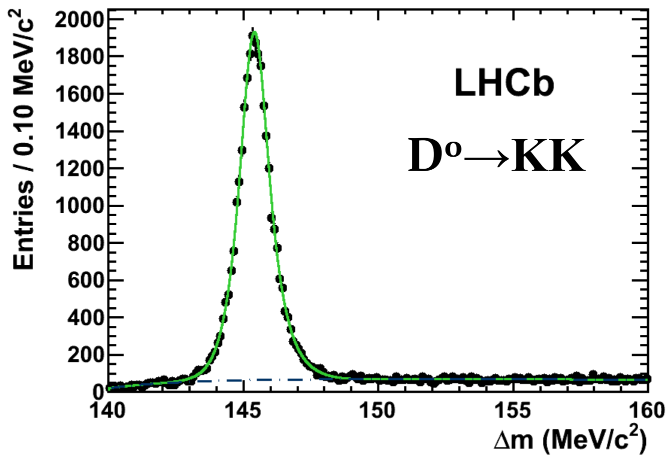


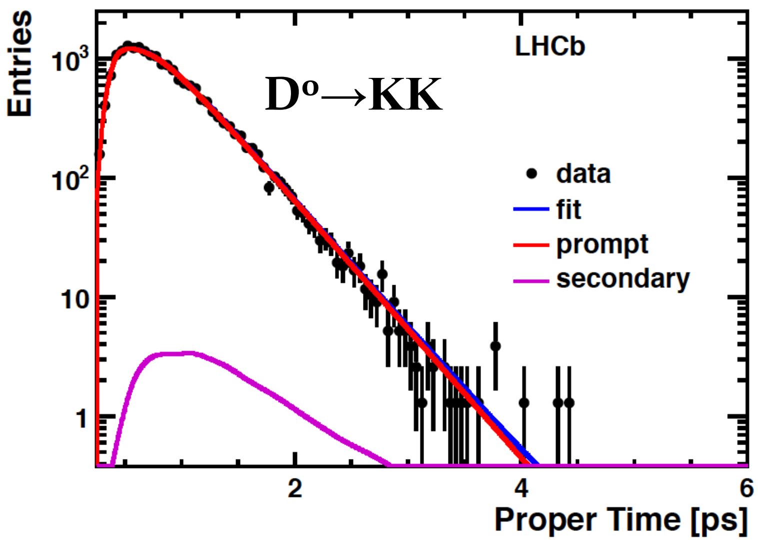
A_Γ measurement

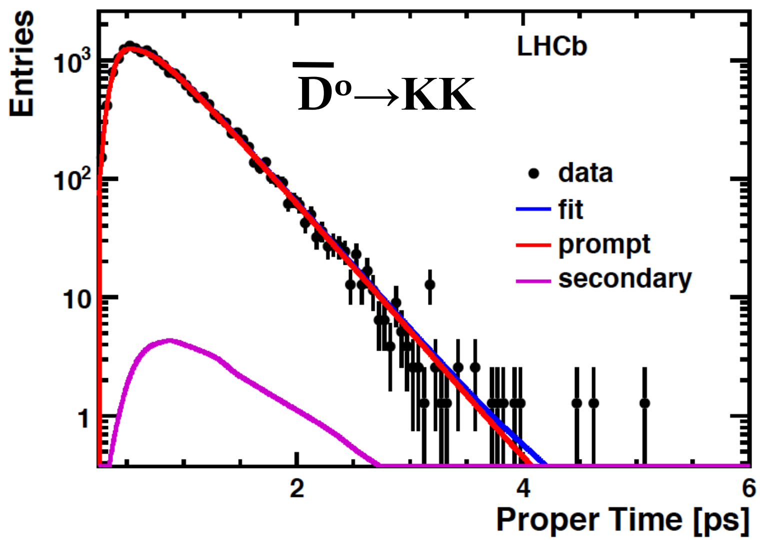
- Data sample of $D^0 \rightarrow K^+K^-$ with 0.03 fb^{-1}
  - ~15k events of each flavour tag.

A_Γ=(-0.59 ± 0.59 ± 0.21) %

- The main systematic is due to the secondary and the combinatorial background
- *Already competitive to existing measurements*







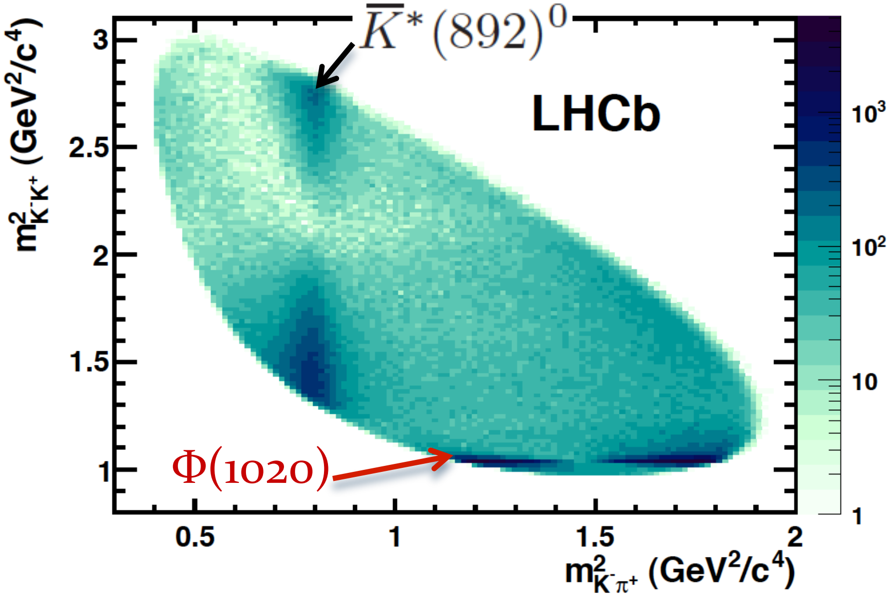
Other searches of CPV:
Search for direct CPV in three-body singly Cabibbo suppressed decay $D^+ \to K^- K^+ \pi^+$

LHCb-PAPER-2011-017; arXiv:1110.3970 submitted to PRD

Search of CP violation in $D^+ \to K^- K^+ \pi^+$

- Search of direct CP violation in three-body decays
  - Dominated by many resonant states visibled in Dalitz plot

- Look for local asymmetries in Dalitz plots of singly Cabibbo suppressed decay $D^+ \to K^- K^+ \pi^+$



- The asymmetry can vary across the Dalitz plot
- Local asymmetries can vanish in the integrated measurement

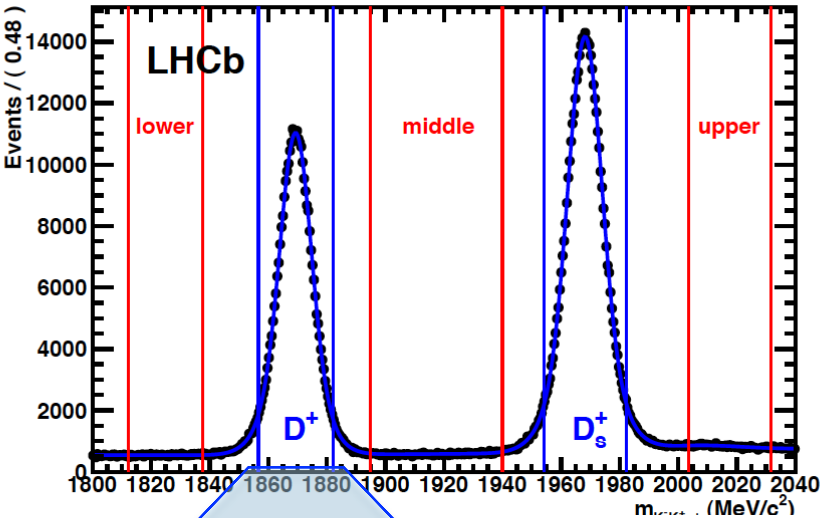
- Model independent method based on a direct comparison on a bin-by-bin basis between D^+ and D^- Dalitz plots

Search of CP violation in $D^+ \to K^- K^+ \pi^+$

- Method based on Miranda approach:
  [Phys. Rev. D80 (2009) 096006]
  - the local asymmetry significance is defined for each bin:

$$S_{CP}^{i} = \frac{N^i(D^+) - \alpha N^i(D^-)}{\sqrt{N^i(D^+) + \alpha^2 N^i(D^-)}} \qquad \text{where} \quad \alpha = \frac{N_{tot}(D^+)}{N_{tot}(D^-)}$$

  - Evaluation of the $\chi^2 = \Sigma (S^i_{CP})^2$ and of the probability value obtained under the assumption of no CPV



Yield of 370k
Purity ~ 90%

- The method is model independent
  - Different binning schemes used (sensitive to range of CPV scenarios)
- Data sample with L~0.04 fb^{-1} of data collected in 2010

⇨ 10 and 20 times more signal events than in previous BaBar and CLEO-c results

Control channels

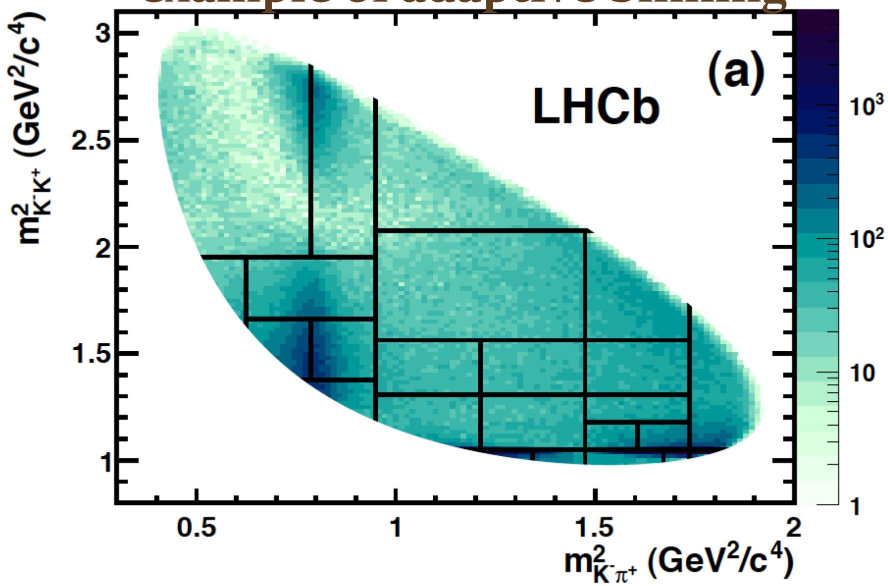
- Investigation of no CP asymmetries (due to detector, production or background asymmetries) by data-driven method
  - Control channel $D_s^+ \to K^- K^+ \pi^+$
  - Sidebands $D^+ \to K^- K^+ \pi^+$
  - Control channel $D^+ \to K^- \pi^+ \pi^+$
- Combine the two magnet polarities to cancel various small left-right asymmetries

✓ No evidence of fake asymmetries in the control mode

✓ Sidebands around the D^+ signal peak look fine

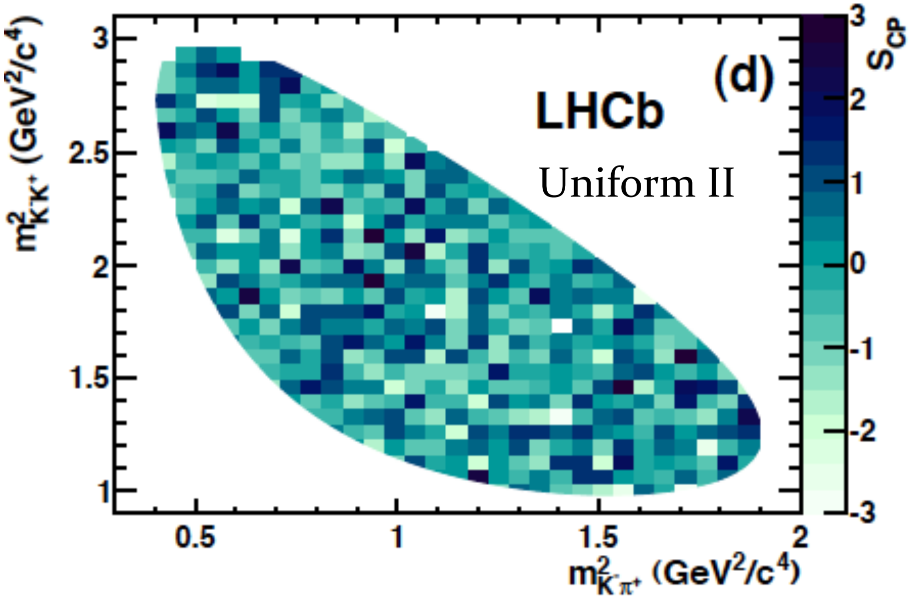
✓ Method very robust against systematic effects

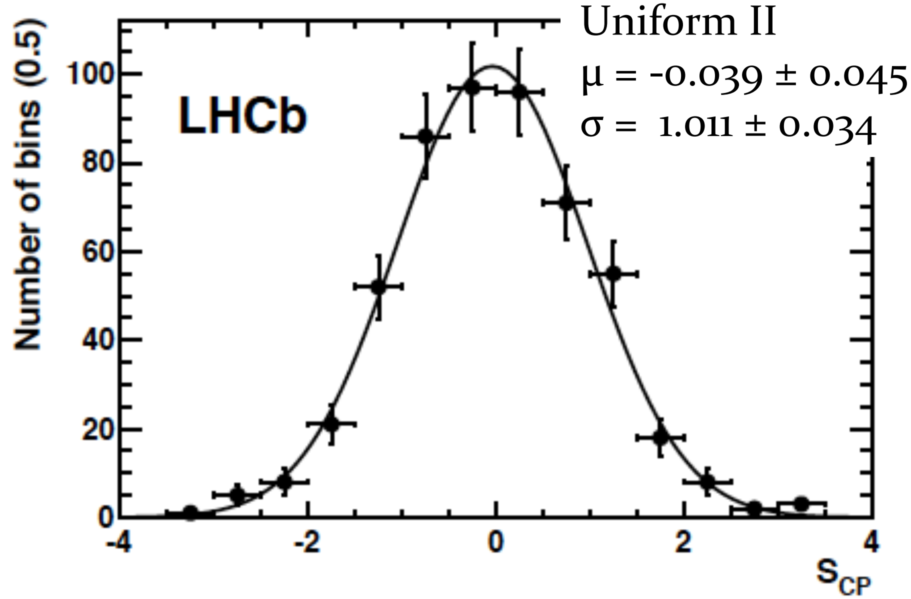
example of adaptive binning



Window	p-value
D_s^+ window	34.4%
Left sideband	8.7 %
Middle sideband	50.8%
Right sideband	36.5%

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





Binning scheme	p-value
Adaptive I (25 bins)	12.7 %
Adaptive II (106 bins)	10.6 %
Uniform I (199 bins)	82.1 %
Uniform II (530 bins)	60.5 %

- S_{CP} distributions consistent with standard Gauss distribution

No evidence for CP violation in the 2010 dataset of 0.04 fb^{-1}

Other searches of CPV:

Search of CP violation in $D^{\pm}_{(s)} \rightarrow K^0_s h^{\pm}$

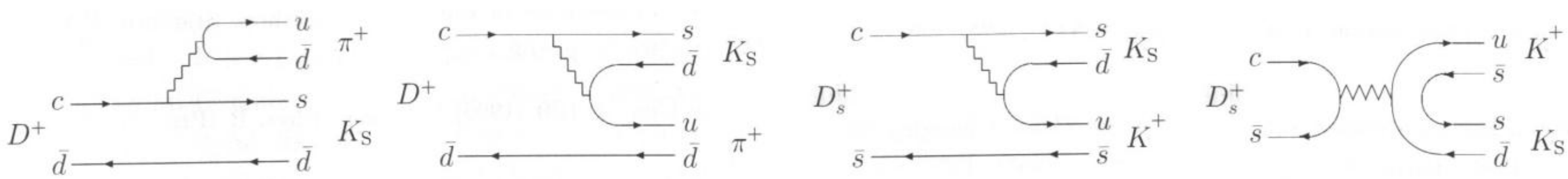
Search CPV in $D^{\pm}_{(s)} \rightarrow K^0_s\ h^{\pm}$

- CPV requires at least 2 different diagrams with different strong and weak phases
- Measurement of direct CP asymmetry in $D^{\pm}_{(s)} \rightarrow K^0_s\ h^{\pm}$:
  - $D^{\pm} \rightarrow K^0_s\ \pi^{\pm}$; in $D^{\pm}_s \rightarrow K^0_s\ K^{\pm}$ mixture of CA and DCS decays
  - $D^{\pm} \rightarrow K^0_s\ K^{\pm}$; in $D^{\pm}_s \rightarrow K^0_s\ \pi^{\pm}$ SCS decays

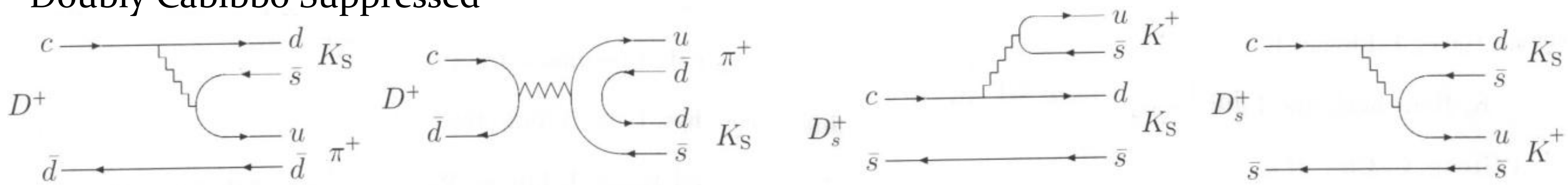
$D^{\pm} \rightarrow K^0_s\ \pi^{\pm}$

$D^{\pm}_s \rightarrow K^0_s\ K^{\pm}$

Cabibbo Allowed



Doubly Cabibbo Suppressed



Search CPV in $D^{\pm}_{(s)} \to K^0_s\ h^{\pm}$

- The asymmetry, including DCS contribution

$$A_q = \frac{\Gamma\left(D_q^- \to K_s h_q^-\right) - \Gamma\left(D_q^+ \to K_s h_q^+\right)}{\Gamma\left(D_q^- \to K_s h_q^-\right) + \Gamma\left(D_q^+ \to K_s h_q^+\right)} \approx \underbrace{\boxed{\delta_K}}_{\text{CPV in K system}} + \overbrace{\boxed{2R_a \tan^2\theta_C \sin\phi \sin\delta_a}}^{\text{CPV in D system}}$$

where θ_C is Cabbibo angle, ϕ is the weak phase, R_q and δ_q the amplitude ratio and strong phase difference of DCS/CA decays

- SM prediction $A_q \cong \delta_k = (3.32 \pm 0.06) \cdot 10^{-3}$
- New Physics affecting the DCS channels might cancel this asymmetry or enhance it up to the percent level

Lipkin and Xing, Phys. Lett. B450 (1999) 405

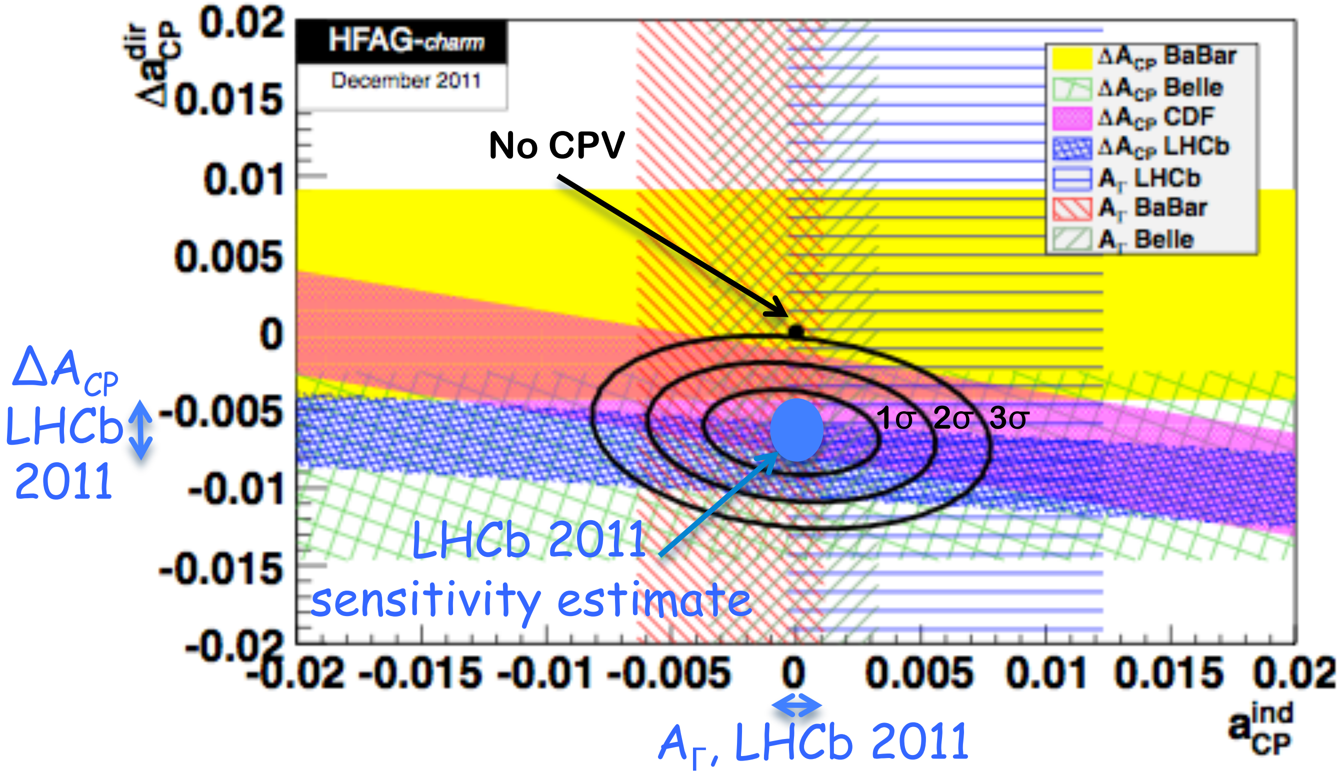
Current Measurements

Year	Experiment	CP Asymmetry in the decay mode $D^+ \to K^0_s \pi^+$	
2011	BABAR	P. del Amo Sanchez et al. (BABAR Collab.), Phys. Rev. D 83, 071103 (2011).	-0.0044 ± 0.0013 ± 0.0010
2010	BELLE	B.R. Ko et al. (BELLE Collab.), hep-ex arXiv:1001.3202v1 (2010).	-0.0071 ± 0.0019 ± 0.0020
2007	CLEO-c	S. Dobbs et al. (CLEO Collab.), Phys. Rev. D 76, 112001 (2007).	-0.006 ± 0.010 ± 0.003
2002	FOCUS	J.M. Link et al. (FOCUS Collab.), Phys. Rev. Lett. 88, 041602 (2002).	-0.016 ± 0.015 ± 0.009
		COMBOS average	**-0.0052 ± 0.0014**
Year	**Experiment**	**CP Asymmetry in the decay mode $D_s^+ \to K^0_s K^+$**	
2010	BELLE	B.R. Ko et al. (BELLE Collab.), Phys. Rev. Lett. 104, 181602 (2010)	+0.0012 ± 0.0036 ± 0.0022
2002	CLEO-c	J.P. Alexander et al. (CLEO Collab.), Phys. Rev. Lett. 100, 161804 (2008)	+0.049 ± 0.021 ± 0.009
		COMBOS average	**-0.0028 ± 0.009**
Year	**Experiment**	**CP Asymmetry in the decay mode $D^+ \to K^0_s K^+$**	
2010	BELLE	B.R. Ko et al. (BELLE Collab.), Phys. Rev. Lett. 104, 181602 (2010)	-0.0016 ± 0.0058 ± 0.0025
2002	FOCUS	J.M. Link et al. (FOCUS Collab.), Phys. Rev. Lett. 88, 041602 (2002)	+0.071 ± 0.061 ± 0.012
		COMBOS average	**-0.0009 ± 0.0063**
Year	**Experiment**	**CP Asymmetry in the decay mode $D_s^+ \to K^0_s \pi^+$**	
2010	BELLE	B.R. Ko et al. (BELLE Collab.), Phys. Rev. Lett. 104, 181602 (2010)	+0.0545 ± 0.0250 ± 0.0033
2007	CLEO-c	G.S. Adams et al. (CLEO Collab.), Phys. Rev. Lett. 99, 191805 (2007)	+0.27 ± 0.11
		COMBOS average	**-0.0653 ± 0.0246**

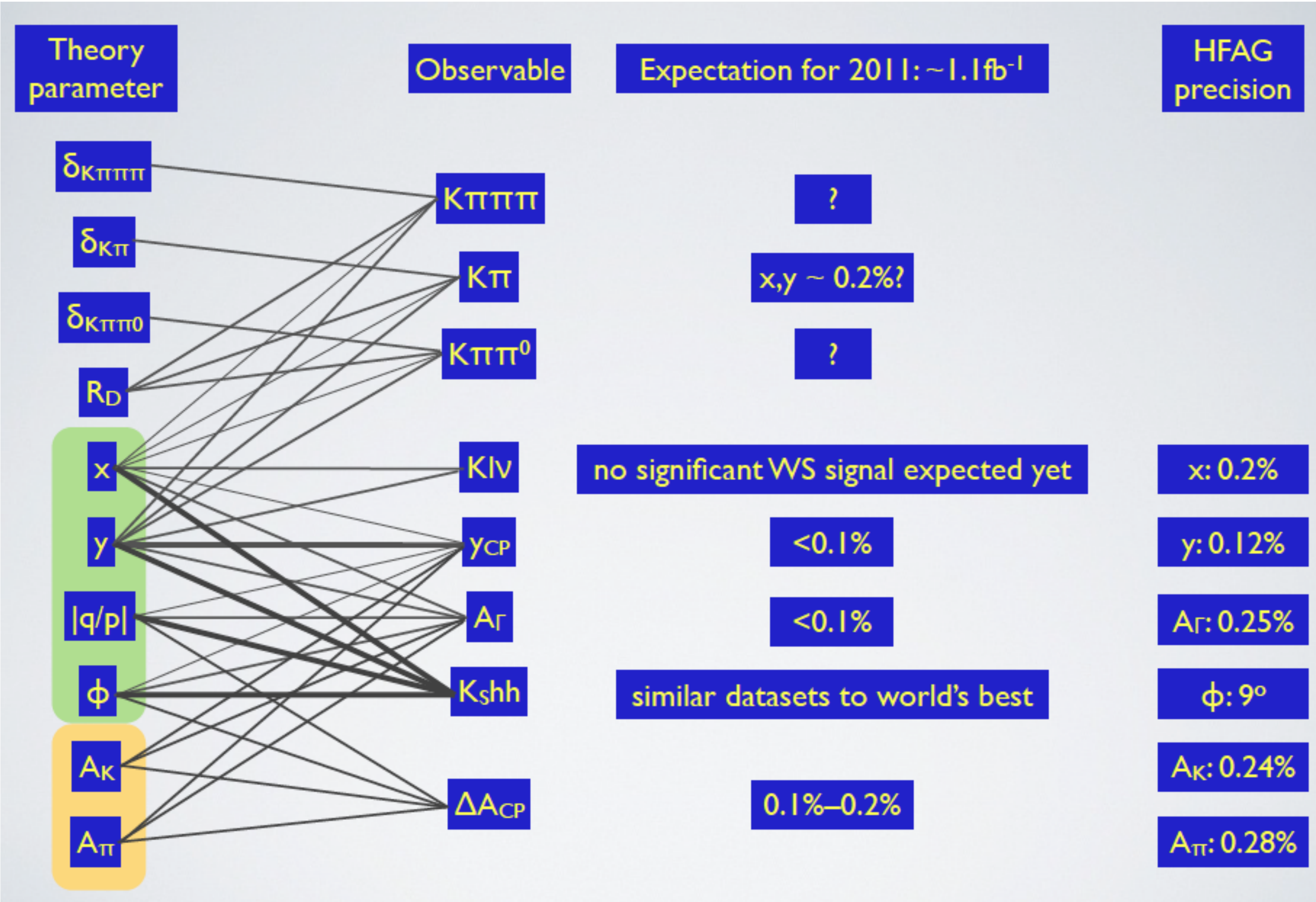
Prospects and conclusions

Expected precision with 1.1 fb^{-1}

- A_Γ and ΔA_{CP} are discovery modes



Expected precision with 1.1 fb^{-1}



Conclusion

- First evidence of CPV at 3.5 σ by LHCb with ΔA_{CP} measurement
- Other searches of CPV in the charm sector
- The 1.1 fb^{-1} data sample collected in 2011 allows 10^{-3} precision
- New results on CPV in the charm sector are expected in the coming months
- Many other results to follow

maybe new surprise in the charm sector

Backup

Measurement of A_{CP}

- The measured asymmetry is:

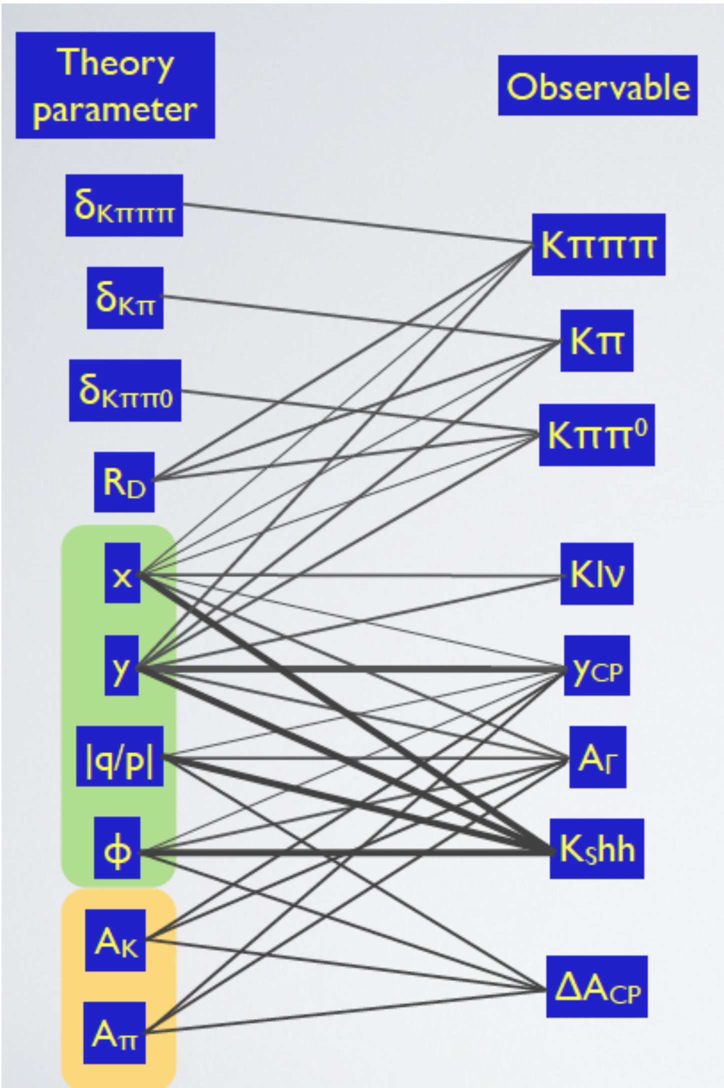
$$A_{RAW}(f)^* = A_{CP}(f) + A_D(f) + A_D(\pi_s) + A_P(D^*)$$

- To extract the A_{CP} it is needed to evaluate the production asymmetry of D^* and the detection asymmetry of slow pion

$$\begin{array}{rcccccc}
A_{CP}^{RAW}(K\pi) & = & & & A_D(K\pi) & & + A_P(D^0) \\
A_{CP}^{RAW}(K\pi)^* & = & & & A_D(K\pi) & + A_D(\pi_s) & + A_P(D^*) \\
A_{CP}^{RAW}(KK)^* & = & A_{CP}(KK) & & & + A_D(\pi_s) & + A_P(D^*) \\
A_{CP}^{RAW}(\pi\pi)^* & = & A_{CP}(\pi\pi) & & & + A_D(\pi_s) & + A_P(D^*)
\end{array}$$

4 observables | 3 CP asymmetries | 2 detection asymmetries | 2 production asymmetries

Current status of LHCb Measurements



Current LHCb measurements

Time-integrated RS/WS ratio

$(0.55 \pm 0.63_{stat} \pm 0.41_{syst})\%$

$(-0.59 \pm 0.59_{stat} \pm 0.21_{syst})\%$

$(-0.82 \pm 0.21_{stat} \pm 0.11_{syst})\%$

Acceptance evaluation

- Determine trigger & selection acceptance on an event-by-event basis, the so called 'Swimming method'
- Evaluate the event acceptance as function of lifetime:

move the PV along the D^0 momentum

Evaluate the trigger & selection decision: accepted or not accepted