Direct CPV in charm hadron decays

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Charm@LHC

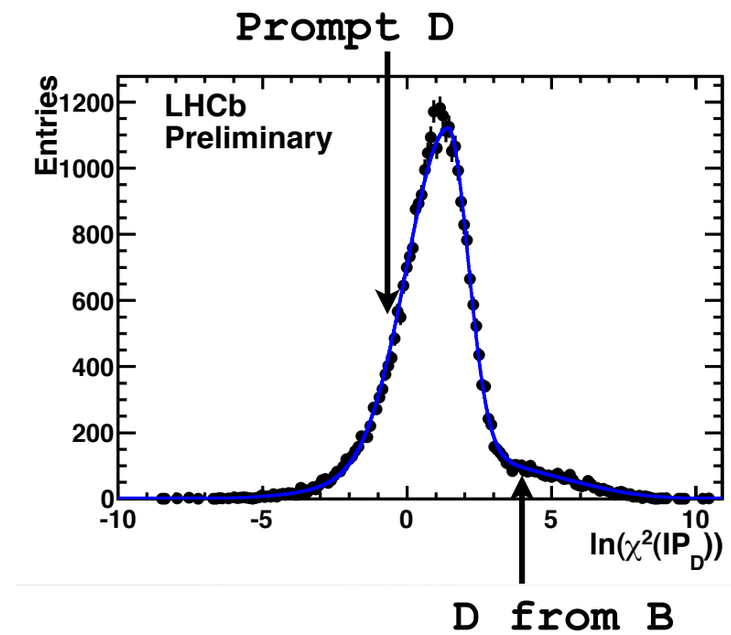
Two types of charm production:

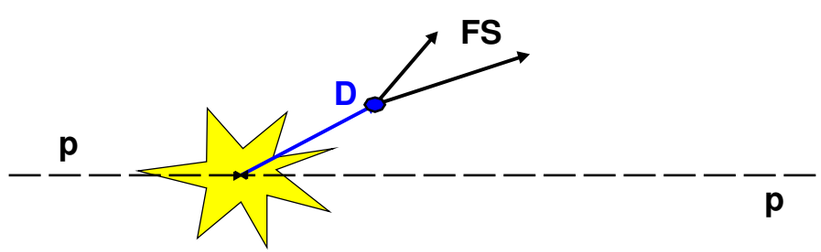
Prompt : Charm produced directly in the primary interaction

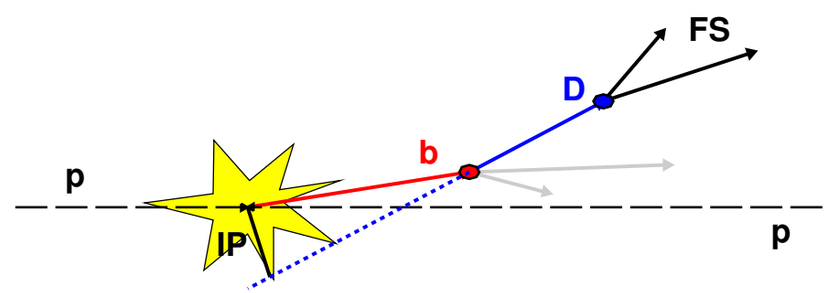
Secondary : Charm produced in B decays [$\mathcal{B}$(B->DX) > 50%]

Prompt charm is much more abundant because the LHC charm cross-section is ~20x higher than the B cross-section

Must discriminate between the two for analyses : use the D impact parameter χ^2







Direct CPV in SCS decays

Raw measurements : time integrated CP asymmetries in $D^0 \to KK$ and $D^0 \to \pi\pi$ decays

Result : Direct CPV through difference in individual CP asymmetries

Measuring difference in CPV asymmetries enables production and detector effects to be cancelled.

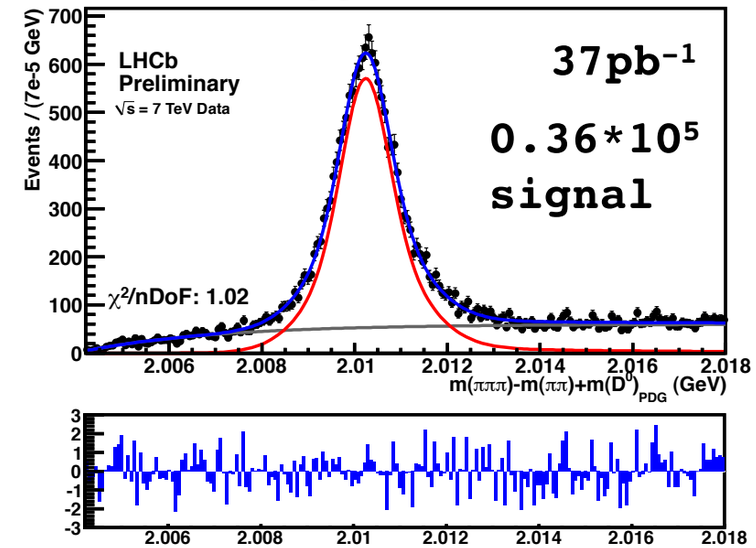
Individual CPV measurements coming later.

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

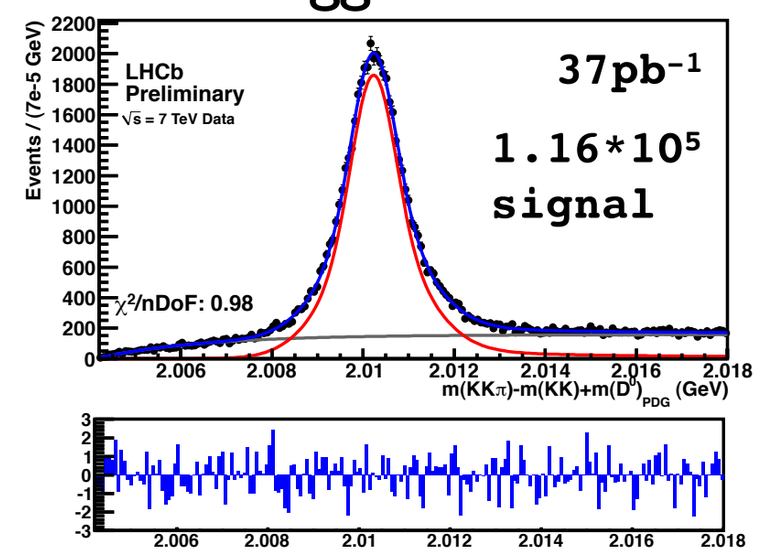
$$A_{RAW}(f)^* \equiv \frac{N(D^{*+} \to D^0(f)\pi^+) - N(D^{*-} \to \overline{D}^0(\bar{f})\pi^-)}{N(D^{*+} \to D^0(f)\pi^+) + N(D^{*-} \to \overline{D}^0(\bar{f})\pi^-)}$$

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

Tagged ππ



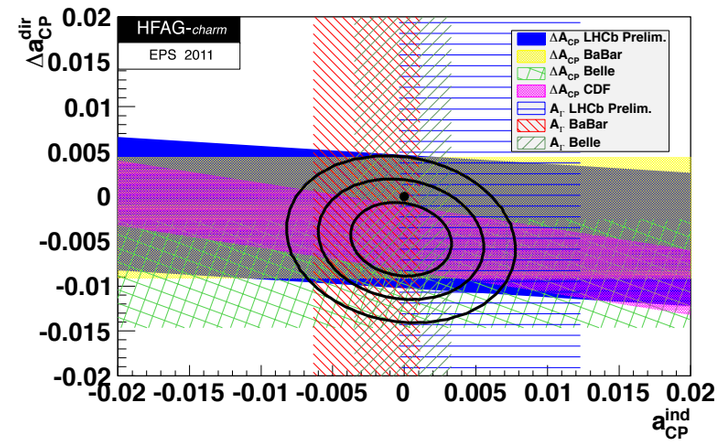
Tagged KK



Direct CPV in SCS decays

LHCb-CONF-2011-02

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 %



LHCb preliminary

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

Systematics expected to track the statistical uncertainty.

Interplay with time dependent measurements critical.

2011 dataset 30-40 times larger => ~0.1% precision

Direct CPV in $K_S h$

$D_{(s)}^+ \to K_S h$:

Clean signals observed (modulo $D_s^+ \to K_S \pi$)

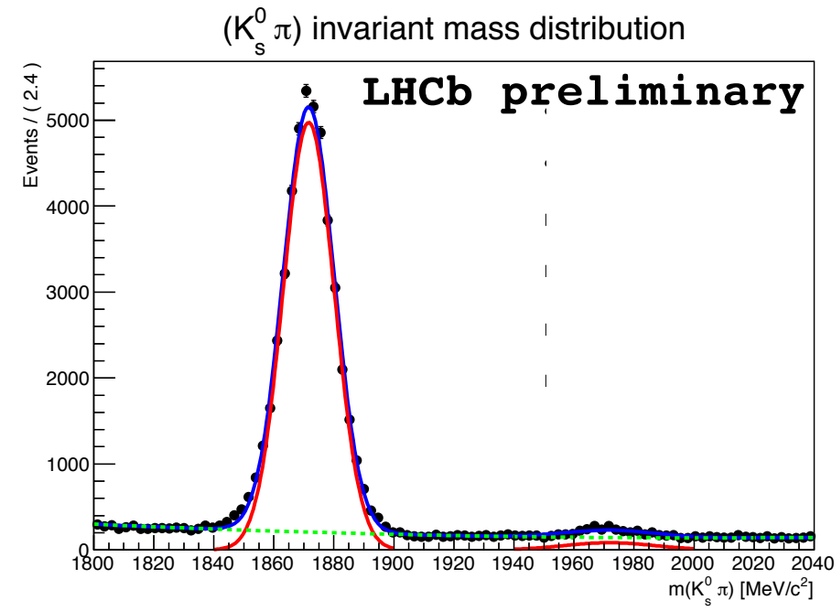
Expected sensitivities :

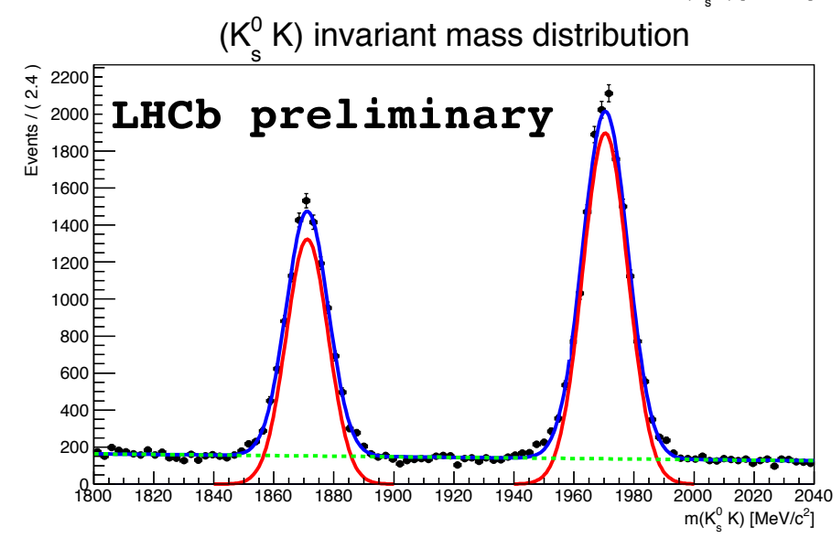
$D^+ \to K_S \pi$	~0.1%
$D^+ \to K_S K$	~0.2%
$D_s^+ \to K_S K$	~0.2%
$D_s^+ \to K_S \pi$	~0.5%

Need to decide on optimal combination of raw asymmetries for which

Production/detection asymmetries cancel

We have a precise SM target to aim at.



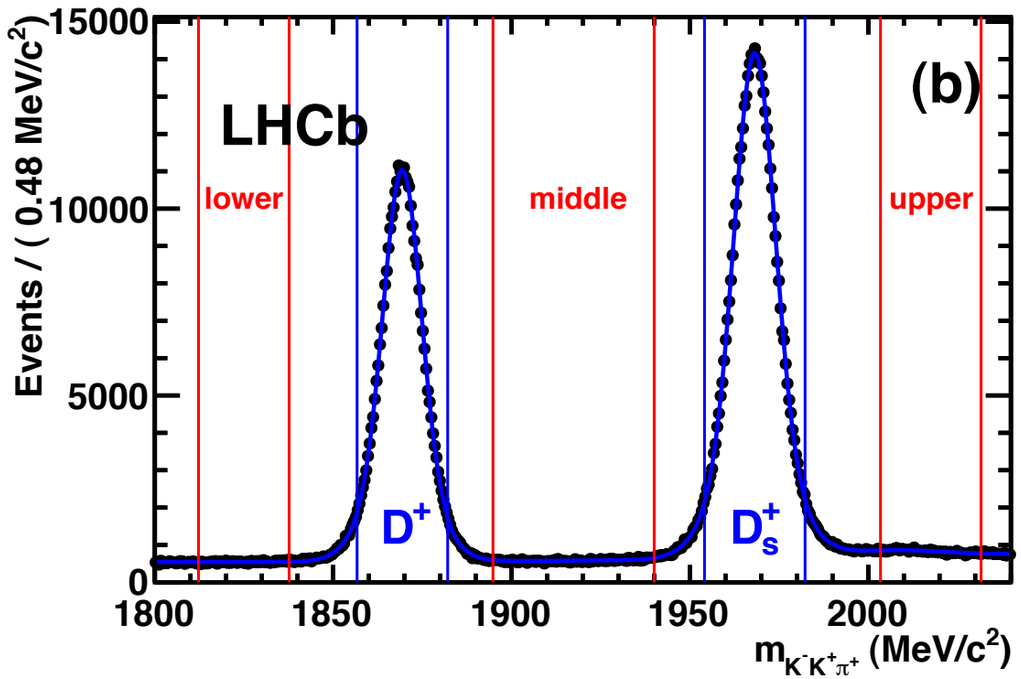


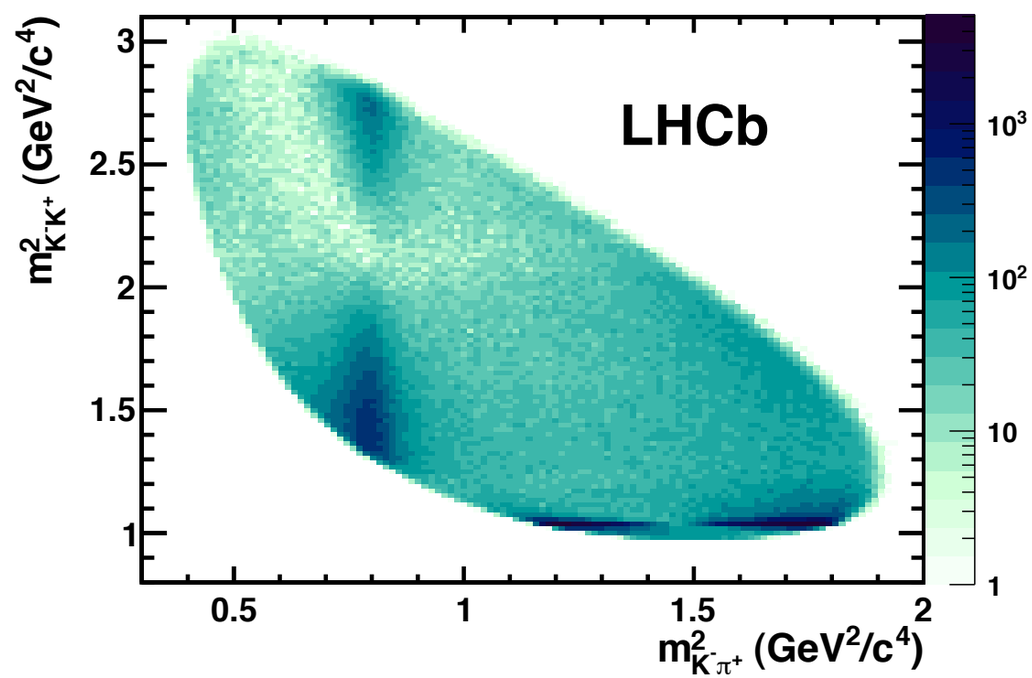
Direct CPV in multi-body decays

Model-independent method (PRD **80** 096006, PRD **78** 051102)

Divide Dalitz plot into bins and in each bin i calculate $\mathcal{S}^i_{CP}$:

$$\mathcal{S}^i_{CP} = \frac{N^i(D^+) - \alpha N^i(D^-)}{\sqrt{N^i(D^+) + \alpha^2 N^i(D^-)}}\ , \qquad \alpha = \frac{N_{\rm tot}(D^+)}{N_{\rm tot}(D^-)}$$





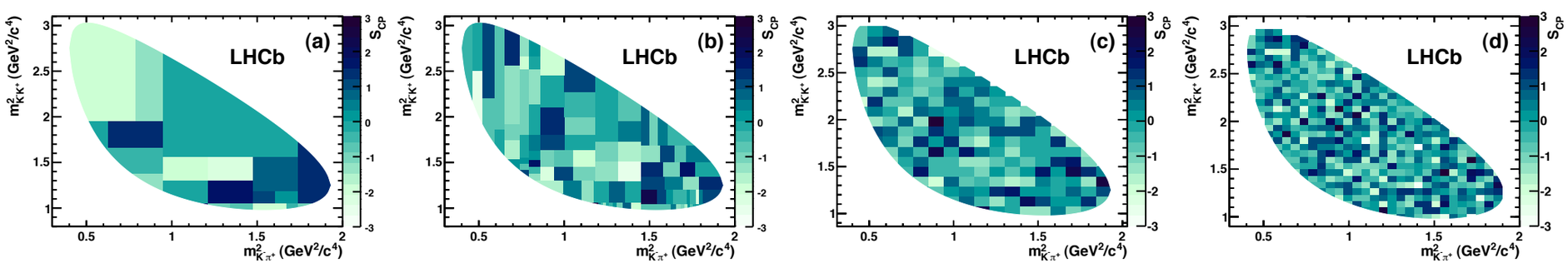
Direct CPV in multi-body decays

We observe no evidence of CPV in the 2010 dataset

- Paper presents results with two adaptive and two uniform binning schemes

Control modes ($D^+ \to K\pi\pi$, $D_S \to KK\pi$) used to check for biases => none found

Binning	Fitted mean	Fitted width	χ^2/ndf	p-value (%)
Adaptive I	0.01 ± 0.23	1.13 ± 0.16	$32.0/24$	12.7
Adaptive II	-0.024 ± 0.010	1.078 ± 0.074	$123.4/105$	10.6
Uniform I	-0.043 ± 0.073	0.929 ± 0.051	$191.3/198$	82.1
Uniform II	-0.039 ± 0.045	1.011 ± 0.034	$519.5/529$	60.5



http://arxiv.org/abs/1110.3970, submitted to PRD

CPV and T-odd moments in D→4h

$D^0 \to 4h$:

Clean signals observed (even in 4π mode!)

Many different analyses underway

5D "Miranda" style Dalitz analysis

In $D \to 4\pi$ expect ~100k events
In $D \to K\pi\pi\pi$ expect 4k DCS, 2M CF
In $D \to KK\pi\pi$ expect ~25k events

Same interplay with CPV in mixing as for the 2 body measurements

Search for $KK\mu\mu$, followed by T-odd moments analysis if/once discovered

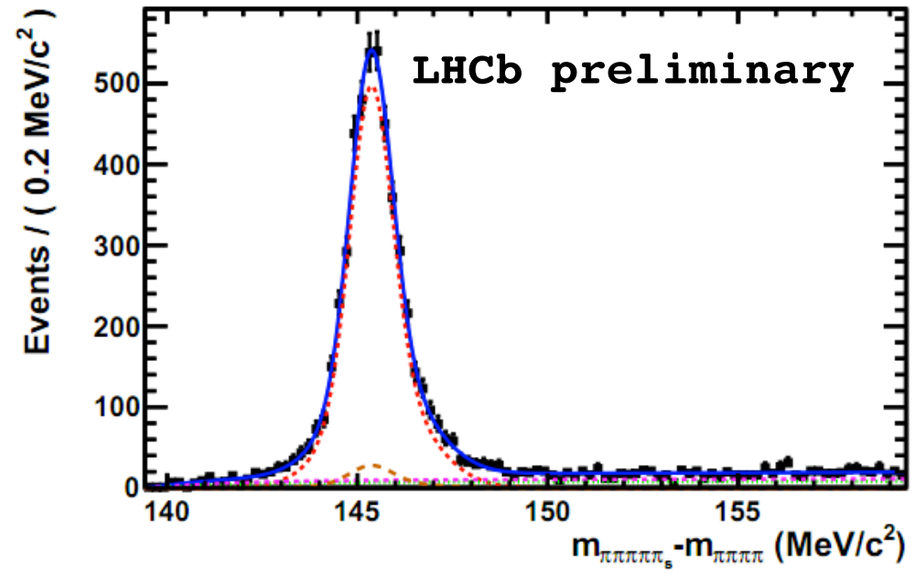


Figure: $D*(2010)$ mass - D^0 mass

Direct CPV in baryon decays

Studies of these modes have only begun recently, so far focusing on observing the $L_c \to pK\pi$ decays and understanding backgrounds etc.

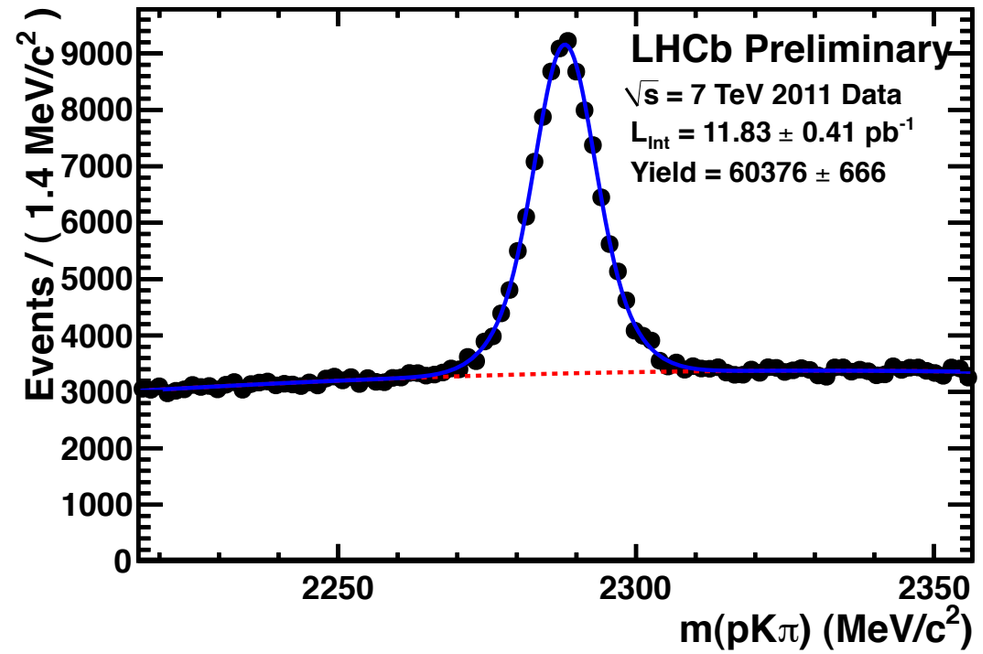
Can expect ~4 M $L_c \to pK\pi$ signal events in $1 fb^{-1}$, sensitivity to direct CPV should be <0.1%

We are only scratching the surface however

Should we look for quasi two-body CPV, such as in $L_c \to p\varphi$? Or do a Dalitz analysis for the CS modes too?

What about other baryons? Rare decays?

The LHC is producing uniquely large samples of charm baryons: we need to fully exploit them!



Session outline

Direct CP violation in the decays of charmed hadrons (90 minutes)

- LHCb introduction
- The theoretical uncertainty on direct CPV in singly cabibbo suppressed SM decays (A. Kagan)
- CP violation in Dalitz plots of multi-body charm decays (I. Bigi)
- Charmed baryons : CP violation and rare decays (A. Khodjamirian)
- Discussion