MEASUREMENT OF MATTER-ANTIMATTER DIFFERENCES IN BARYON DECAYS AT LHCb

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- PHYSICS MOTIVATION
  - LHCb has the unique possibility to search for CPV in b-baryon decays.
  - Large CPV effects are expected within the Standard Model in charmless b-baryon decays, up to $A_{CP} \approx 20\%$.
  - It is important to measure CPV effects in T-odd asymmetries as well as $A_{CP}$-type asymmetries since New Physics contributions could produce different effects in each.

- ANALYSIS STRATEGY
  - Search for CPV using triple product asymmetries in 4-body $\Lambda_c^0$ charmless decays: $\Lambda_c^0 \to p\pi^+\pi^-$ and $\Lambda_c^0 \to p\pi^+K^-K^+$. 
  - Transitions governed by $b \to sW^+\ell^-$ and $b \to sW^-\ell^+$ penguin amplitudes of similar magnitude.
  - Relative weak phase dominated by large CKM phase $\arg(\rho) = \gamma$
  - Perform measurements in regions of phase space for increased sensitivity to localised CPV effects. Different strong phases at play.
  - Use $\Lambda_c^0 \to p(\pi^0\pi^+)\pi^-$, a $F_+$ mediated decay with no CPV expected as control sample to assess main source of systematic uncertainties.

- EXPERIMENTAL TECHNIQUE
  - Triple products in $\Lambda_c^0$ rest frame
    $C_p = \frac{\bar{p}_z \bar{p}_x + \bar{p}_y}{\sqrt{2}} = \sin \Phi$
    $C_t = \frac{\bar{p}_z \bar{p}_x - \bar{p}_y}{\sqrt{2}} = \sin \phi$
  - T-odd asymmetries
    $A_\delta = N_{C>0} - N_{C<0} / N_{C>0} + N_{C<0}$
    $A_\lambda = N_{c>0} - N_{c<0} / N_{c>0} + N_{c<0}$
  - By construction $A_\delta, A_\lambda$, $\alpha^{CP}$, $\alpha^{odd}$ are largely insensitive to
    - particle/antiparticle production asymmetries
    - detector-induced charge asymmetries
    - reduced systematic uncertainties
  - CP-violating observable:
    $a_{CP}^{odd} = \frac{1}{2} (A_\delta - A_\lambda)$
  - P-violating observable:
    $a_{P}^{odd} = \frac{1}{2} (A_\delta + A_\lambda)$

- INTEGRATED OVER PHASE SPACE
  - $A_{CP}$ consistent with $0$.

- IN REGIONS OF PHASE SPACE
  - $X^2$ test:
    - P symmetry: $P^+$ value $=4.3 \times 10^{-2}$ ($2.9 \sigma$ deviation)
    - CP symmetry: $P^+$ value $=4.9 \times 10^{-1}$ ($2.0 \sigma$ deviation)

- SCHEME A
  - Combination of two binning schemes:
    - First evidence of CPV from CP symmetry
    - First evidence of CPV in baryons

- CONCLUSION
  - First evidence of CPV in baryon decays $\Lambda_c^0 \to p\pi^+\pi^-$.
  - Published in Nature Physics doi:10.1038/nphsy4021.
  - Data sample doubled with Run II data.
  - Observation within the sensitivity of the next update.

- BIBLIOGRAPHY