Search for NP in penguins

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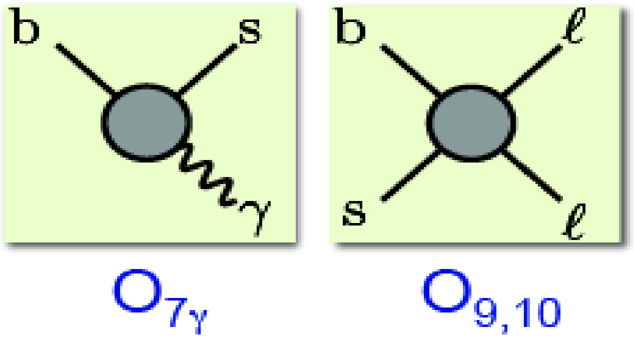
The penguin laboratory

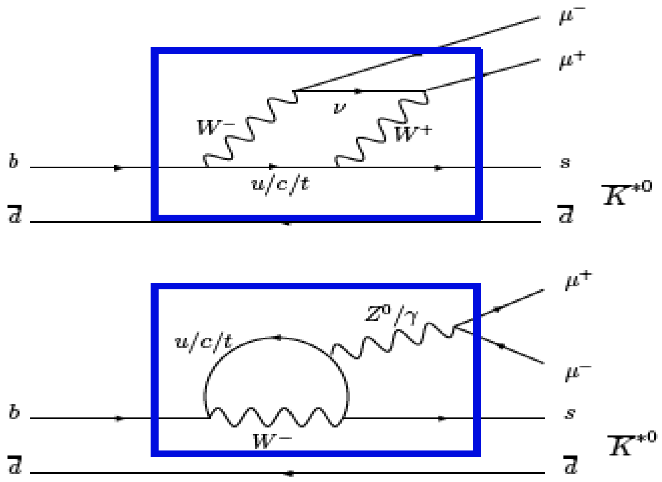
The decay $B^0 \rightarrow K^{*0}\mu^+\mu^-$, $K^{*0} \rightarrow K^-\pi^+$ is in the SM only possible at loop level

- On the other hand NP can show up at either tree or loop level

Angular analysis of 4-body $K^-\pi^+\mu^+\mu^-$ final state brings large number of observables

Interference between these

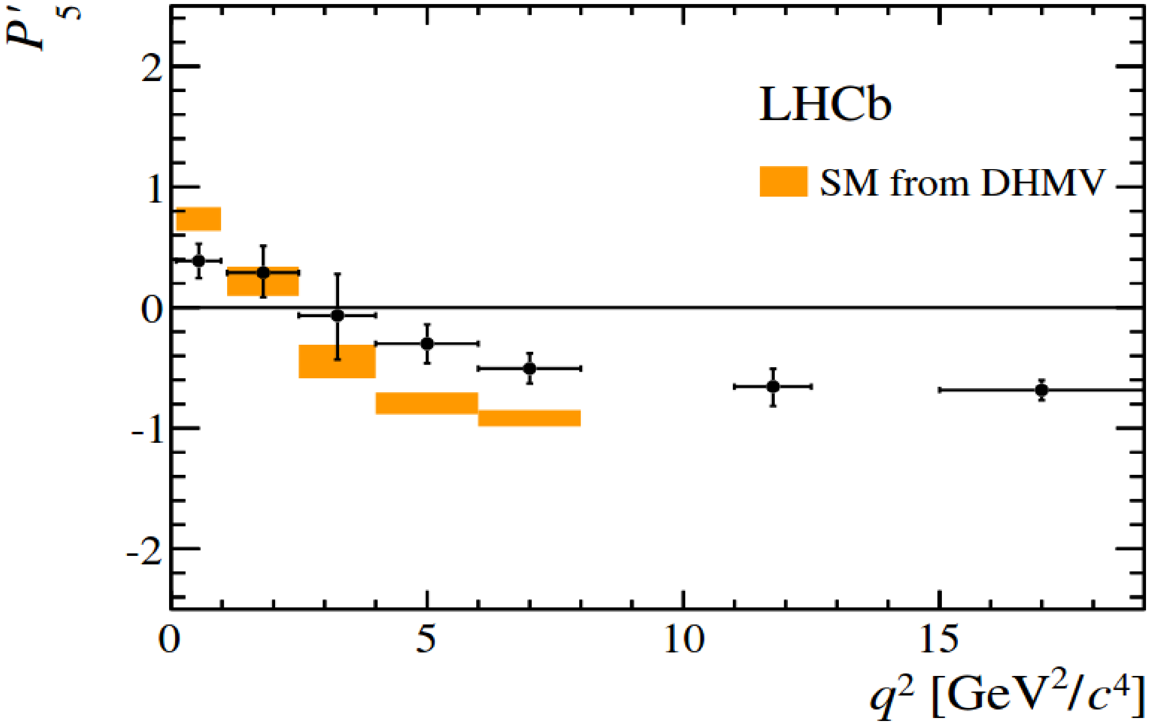




$B^0 \to K^{*0}\mu^+\mu^-$ angular analysis

Results based on 3 fb^{-1} from LHCb

JHEP 02 (2016) 104



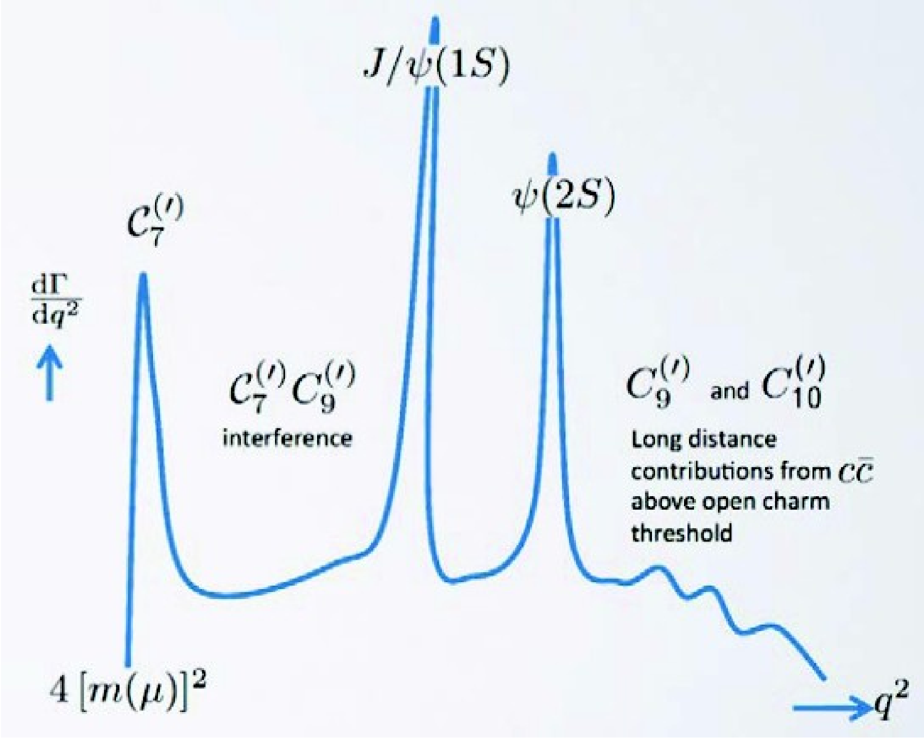
Topology of $B^0 \rightarrow K^{*0}\mu^+\mu^-$

The loop (SM) loop level diagram interferes with tree level $B \rightarrow (c\bar{c})K^{*0}$ followed by $(c\bar{c}) \rightarrow \mu^+\mu^-$

- Gives multiple regions in $q^2 = m^2_{\mu\mu}$

In addition three angles in 4-body decay

Specific observables can reduce effects from this, but approach has reached then end of the road



$B^+ \to K^+\mu^+\mu^-$ branching fraction

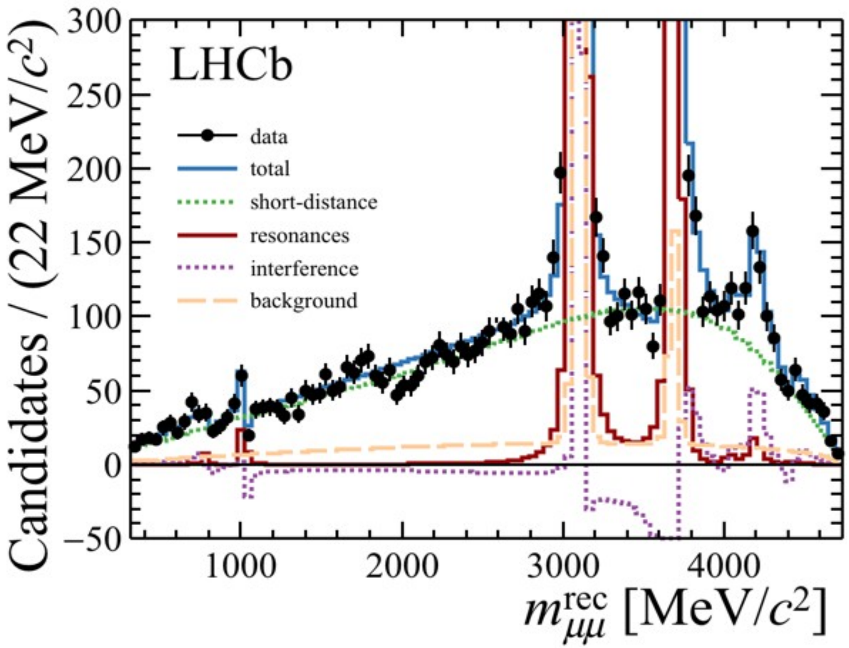
With knowledge of the form factors, the branching fraction can tell about the Wilson coefficients

$$\frac{d\Gamma}{dq^2} = \frac{G_F^2 \alpha^2 |V_{tb}V_{ts}^*|^2}{128\pi^5} |\boldsymbol{k}|\beta \left\{ \frac{2}{3}|\boldsymbol{k}|^2 \beta^2 \left| \mathcal{C}_{10} f_+(q^2) \right|^2 + \frac{4m_\mu^2(m_B^2 - m_K^2)^2}{q^2 m_B^2} \left| \mathcal{C}_{10} f_0(q^2) \right|^2 + |\boldsymbol{k}|^2 \left[1 - \frac{1}{3}\beta^2\right] \left| \mathcal{C}_9 f_+(q^2) + 2\mathcal{C}_7 \frac{m_b + m_s}{m_B + m_K} f_T(q^2) \right|^2 \right\}$$

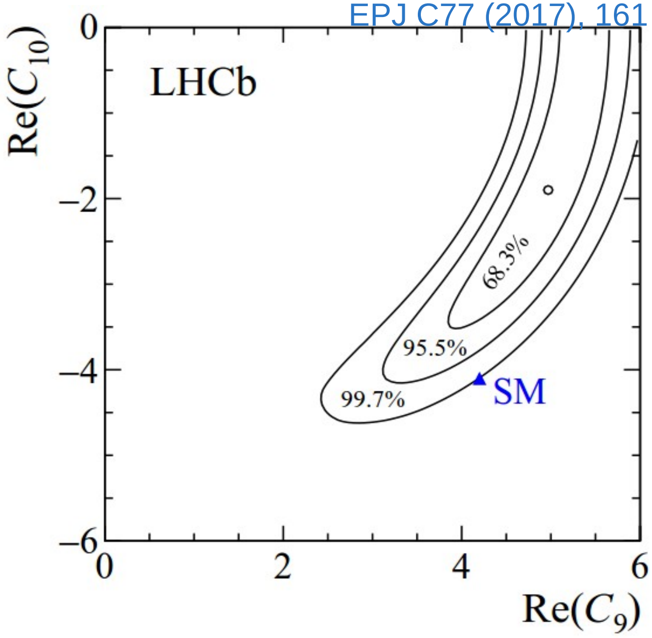
The C_9 we measure has interference from vector resonances

$$\mathcal{C}_9^{\text{eff}} = \mathcal{C}_9 + \sum_j \eta_j e^{i\delta_j} A_j^{\text{res}}(q^2)$$

$B^+ \rightarrow K^+\mu^+\mu^-$ branching fraction



EPJ C77 (2017), 161



Branching fraction is below SM expectation

This is seen in all other electroweak penguin decays with muons

Now take this to the $B^0 \to K^{*0}\mu^+\mu^-$

There are now 3 polarisation states so complexity is rising

$$\mathcal{A}_0^{L,R}(q^2) = -8N\frac{m_B m_{K^*}}{\sqrt{q^2}}\left\{(C_9 \mp C_{10})A_{12}(q^2) + \frac{m_b}{m_B+m_{K^*}}C_7 T_{23}(q^2) + \mathcal{G}_0(q^2)\right\}$$

$$\mathcal{A}_\parallel^{L,R}(q^2) = -N\sqrt{2}(m_B^2 - m_{K^*}^2)\left\{(C_9 \mp C_{10})\frac{A_1(q^2)}{m_B-m_{K^*}} + \frac{2m_b}{q^2}C_7 T_2(q^2) + \mathcal{G}_\parallel(q^2)\right\}$$

$$\mathcal{A}_\perp^{L,R}(q^2) = N\sqrt{2\lambda}\left\{(C_9 \mp C_{10})\frac{V(q^2)}{m_B+m_{K^*}} + \frac{2m_b}{q^2}C_7 T_1(q^2) + \mathcal{G}_\perp(q^2)\right\},$$

Wilson Coefficients — The good

Form Factors — The bad

Non-local hadronic contributions — and the ugly

Modelling the ugly part

$$\mathcal{G}_0 = \frac{m_b}{m_B + m_{K^*}} T_{23}(q^2)\zeta^0 e^{i\omega^0} + A_{12}(q^2)\sum_j \eta_j^0 e^{i\theta_j^0} A_j^{\text{res}}(q^2),$$

$$\mathcal{G}_\parallel = \frac{2m_b}{q^2} T_2(q^2)\zeta^\parallel e^{i\omega^\parallel} + \frac{A_1(q^2)}{m_B - m_{K^*}}\sum_j \eta_j^\parallel e^{i\theta_j^\parallel} A_j^{\text{res}}(q^2),$$

$$\mathcal{G}_\perp = \frac{2m_b}{q^2} T_1(q^2)\zeta^\perp e^{i\omega^\perp} + \frac{V(q^2)}{m_B + m_{K^*}}\sum_j \eta_j^\perp e^{i\theta_j^\perp} A_j^{\text{res}}(q^2),$$

Magnitude and phase of non-local contribution to dipole form factor

Sum over all resonances

Magnitude and phase for each resonance

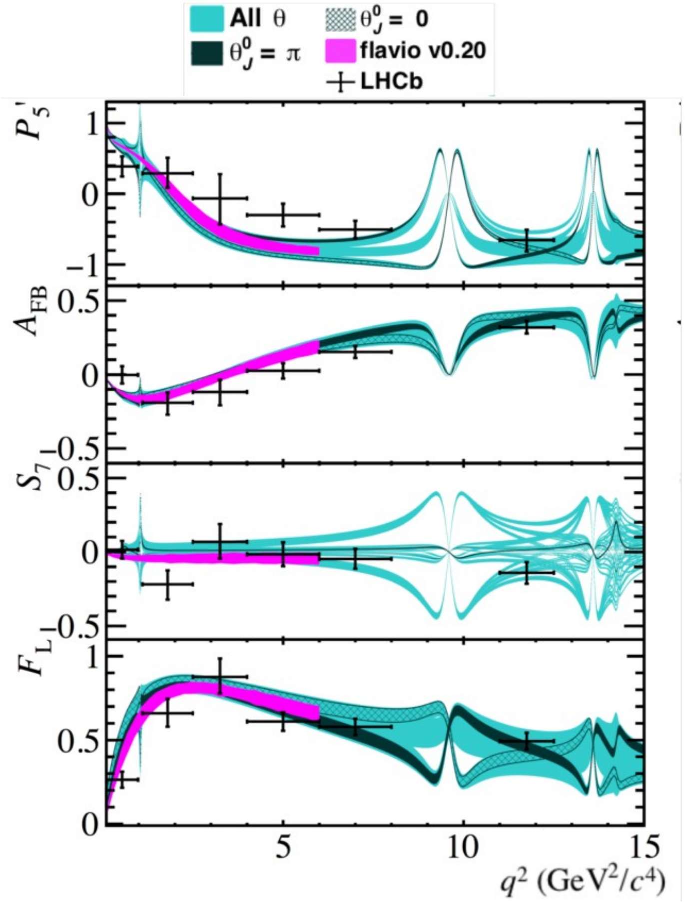
BW Amplitudes

Include φ, ρ, J/ψ, ψ(2S), ψ(3770), ψ(4040), ψ(4160)

Does the model make sense?

We can take model and compare to other predictions outside the resonance regions

- In EPJC78 (2018) 453, arXiv:1709.03921 we did this comparison to Flavio
- See excellent agreement for the SM predictions



Experimental challenges

Acceptance

- The efficiency varies with angles and q^2
- Modelled through simulation amd cross checked with data

Resolution

- Use kinematic constraint to B^0 mass to make q^2 resolution as good as possible

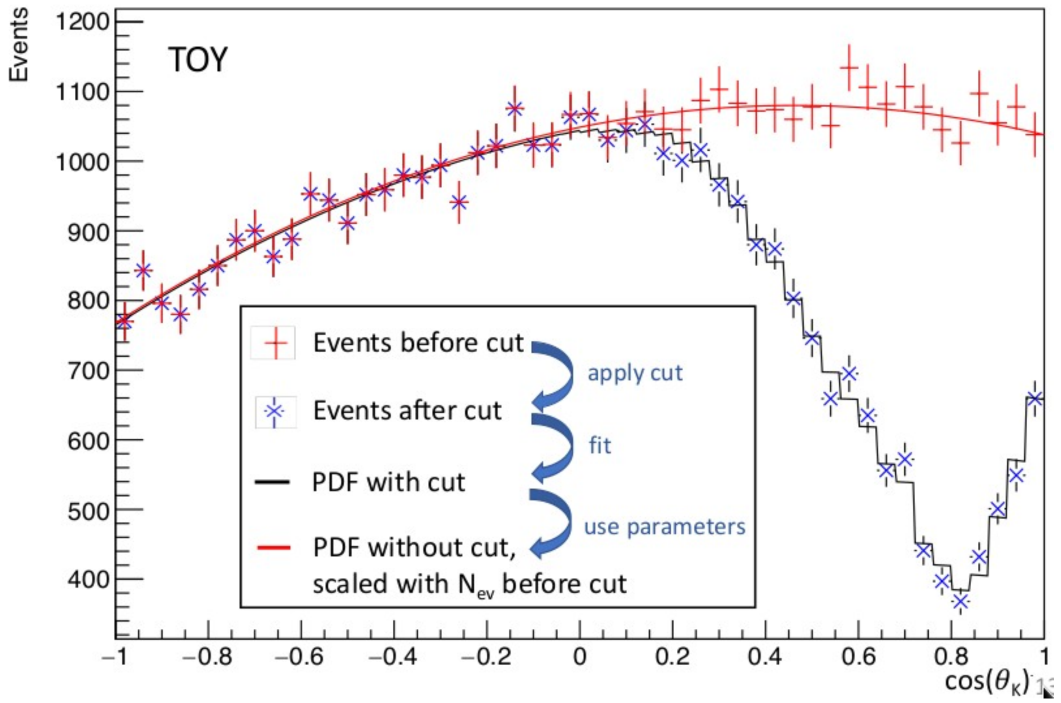
Backgrounds

- A veto on $B^+ \to K^+\mu^+\mu^-$ (+ random π) causes distortion in sideband

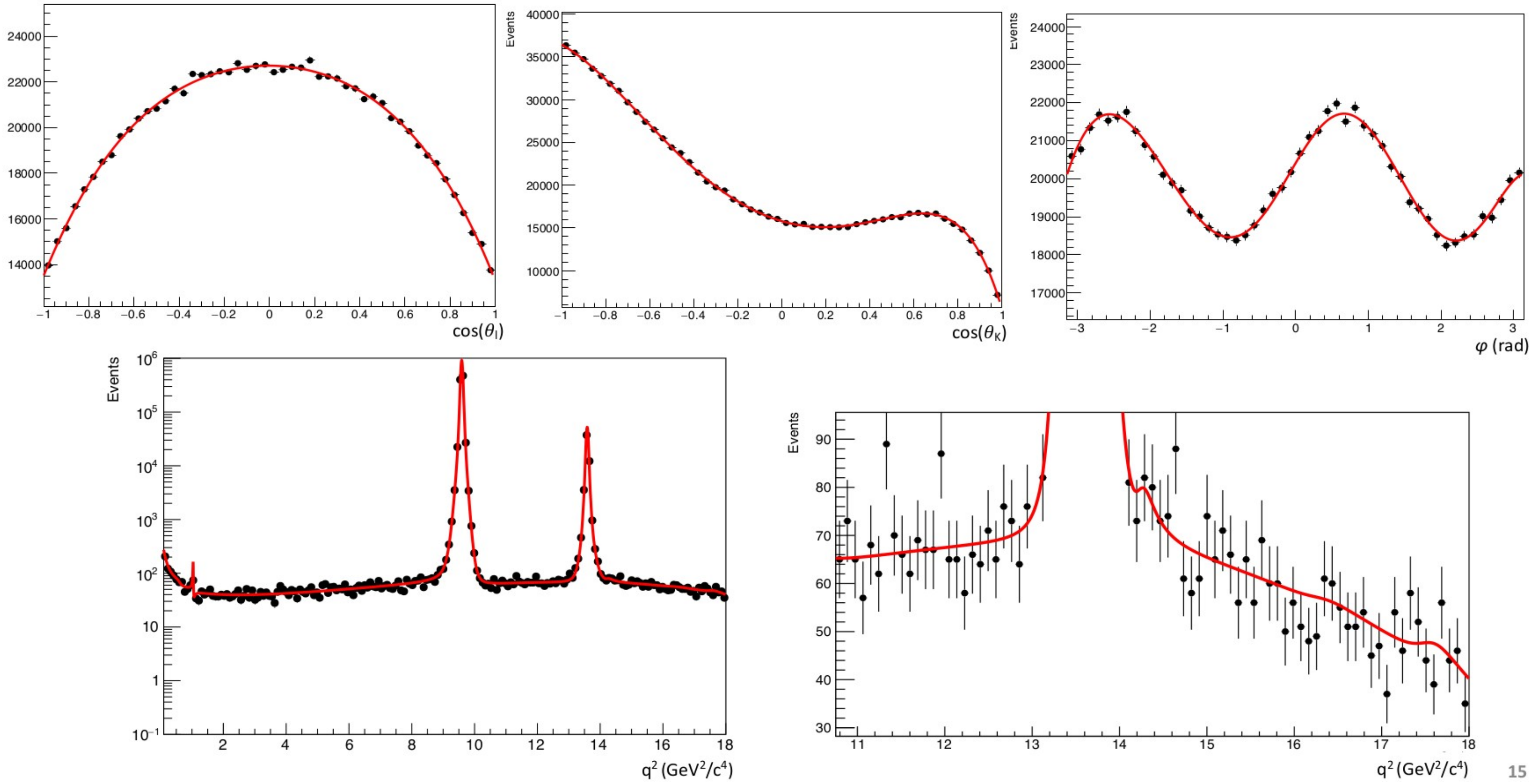
Background fit

The $B^+ \rightarrow K^+\mu^+\mu^-$ (+ random π) veto causes a (known) part of phase space to be missing in sideband

Effect of this can be modelled and then corrected for to predict background in signal region



Signal fit



Expected sensitivity

The sensitivity has so far been modelled in toy models

Use the expected statistics for full LHCb data taking to date

- Hope for ~0.2 on C_9, C_{10} Wilson coefficients
- ~10 mrad on resonance phases

Improvement better than $\sqrt{n}$ expectation on current 0.5 resolution

- Main difference is due to use of full q^2 spectrum
- Will gain knowledge on $c\bar{c}$ loops as well

arXiv:1704.05435