Rare b Decays as Probes of New Physics

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Anomalies in Rare b Decays

- Rare decays are well established probes of new physics
- Several anomalies in $b \to s\ell\ell$ decays:
  (1) hints for LFU violation (R_K, R_{K^*}),
  (2) total rates of several decays low compared to SM prediction,
  (3) anomalous angular distribution in $B_d \to K^* \mu\mu$ (P_5').

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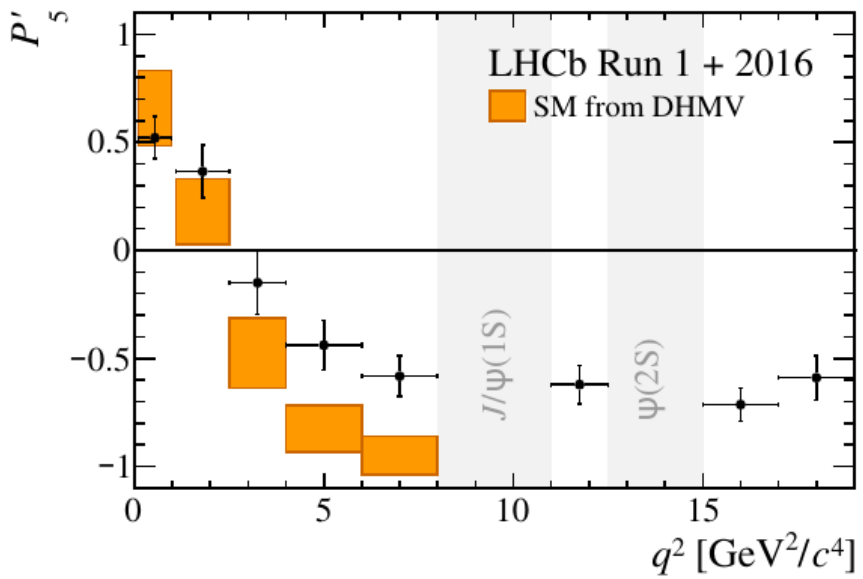
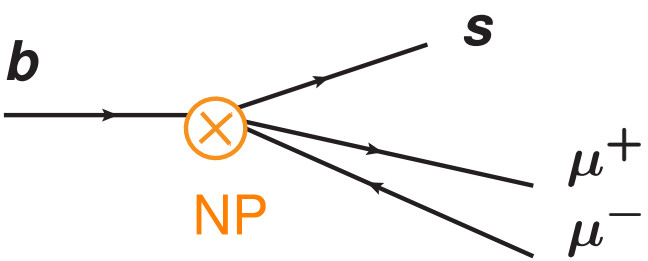
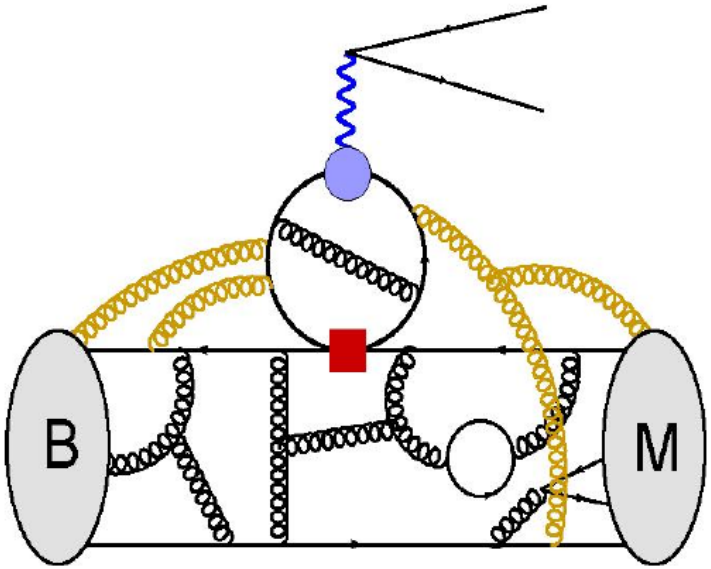
- Latest LHCb result on P_5' has exp. uncertainties that are comparable to the (agressive?) theory uncertainties.
- Will we learn anything from more precise measurements of the angular distribution?



New Physics or Hadronic Effects?



or



$C_9(\bar{s}\gamma_\mu P_L b)(\bar{\mu}\gamma^\mu \mu)$ could be mimicked by hadronic effects

Distinguishing New Physics from Hadronic Effects

(heavy) New Physics	Hadronic Contributions
described by local four fermion operator	a non-local and non-perturbative effect
universal for all processes	could be process dependent
universal for all final state helicities	could be helicity dependent
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independent on q^2	could be q^2 dependent
could be leptonic axial-vector current	leptonic vector current
could be RH quark current	LH quark current
could be CP violating	CP conserving
could violate lepton flavor universality	lepton flavor universal

The Future of Global Fits

- Need robust theory predictions to profit from the expected experimental precision.

- *My point of view*: we should "sacrifice C_9":

  Use completely generic parameterization of hadronic effects (in particular the "charm loops").

  This means any new physics in the form of a lepton-universal real part of C_9 can be absorbed by an hadronic effect.

- However, sensitivity to new physics in everything else should remain:

  C_{10}, right-handed currents, CP violation, lepton-universality violation

- Such a setup is robust with respect to unknown hadronic effects (as long as the parameterization is sufficiently generic).

$\Rightarrow$ More precise measurements lead to better new physics sensitivity.

Rare b Decays at LHCb with 50+ fb^{-1}

- LHCb with 50 fb^{-1} or 300 fb^{-1} will have sufficient statistics to make precision measurements of $b \to d$ transitions, e.g. full angular analysis of $B_s \to K^* \mu^+ \mu^-$ with precision similar to the one we currently have for the $B_d \to K^* \mu^+ \mu^-$ decay.
- Can test lepton flavor universality in $b \to d \ell \ell$ transitions.
- Will have sensitivities to $b \to s \tau \tau$ and $b \to s \tau \mu$ that are interesting given predictions of some new physics models that explain the current anomalies.

Rare b Decays at Belle II

- Inclusive processes $B \to X_s \ell^+ \ell^-$ can be accessed at Belle II. Theoretically under better control than exclusive decays at low q^2. Effect of the hadronic mass cut?
- Also interesting sensitivities to $b \to s\tau\tau$ and $b \to s\tau\mu$.
- Can have access to di-neutrino modes $B \to K\nu\nu$ and $B \to K^*\nu\nu$. Related to $b \to s\ell\ell$ by $SU(2)_L$, but cleaner (no charm loop pollution).

Rare b Decays at FCC-ee or CEPC

- Tera-Z factories (FCC-ee or CEPC) have unique sensitivities to processes with taus in the final state.
- E.g. up to 1000 fully reconstructed $B_d \to K^* \tau^+ \tau^-$ events.

$\Rightarrow$ Ultimate test of $L_\mu - L_\tau$ models (predict that a 25% reduction of $b \to s\mu\mu$ is correlated with a 25% enhancement of $b \to s\tau\tau$)

- Can probably also do $B_s \to \phi\nu\nu$ and $\Lambda_b \to \Lambda\nu\nu$