Inclusive Rare B Decays

Workshop on `Rare B Decays´
University of Sussex
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Question?

The super flavour factories (and maybe LHCb) will in the future provide new inclusive (and exclusive) measurements. If the statistical accuracy is poorer than in the exclusive modes at LHCb, what is most important to pursue here?

Observables with:

smaller theoretical (and experimental) uncertainties

complementary information on wilson coefficients/ non-perturbative uncertainties

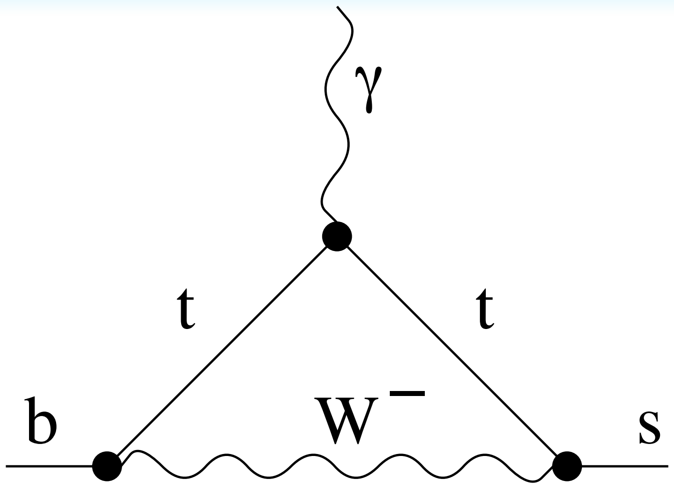
sensitivity to different (exotic) types of new physics

Rare B-decay Workshop

I will discuss on

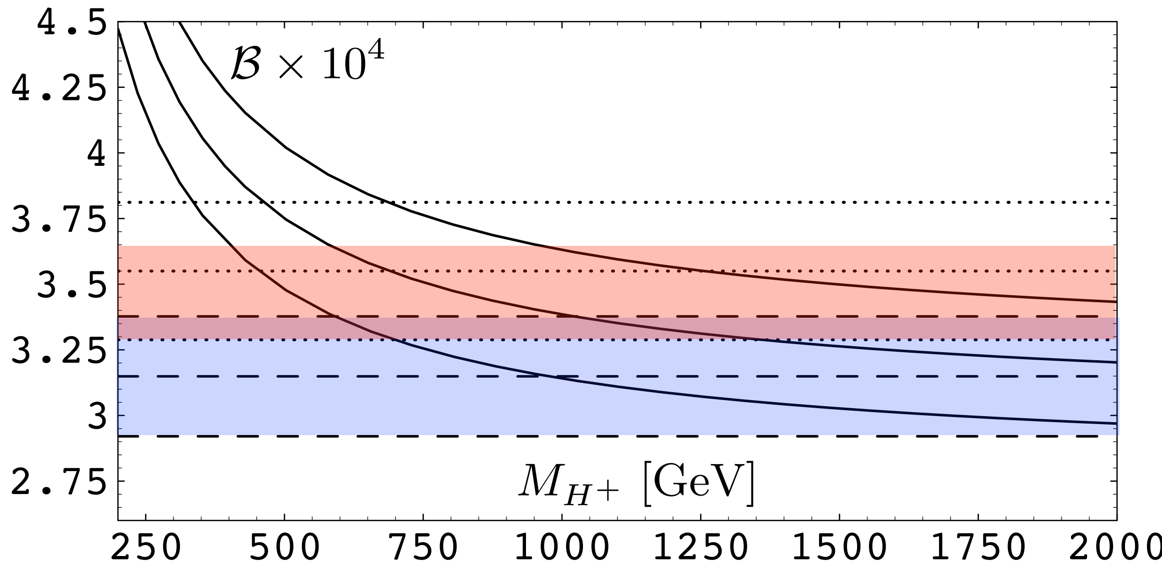
$\overline{B} \to X_s \gamma$, $\overline{B} \to X_s l^+ l^-$, $\overline{B} \to X_s \bar{\upsilon}\, \upsilon$ & $\overline{B} \to K^{(*)} \bar{\upsilon}\, \upsilon$

$\bar{B} \to X_s \gamma$ @ NNLO



$\bar{B} \to X_s \gamma$ is an (approximately) inclusive decay and as such well approximated by the partonic decay

It is sensitive to chirality flipping new interactions (h^+, A-terms)



[Misiak et. al. \`07]

Partial NNLO [Misiak et. al. \`07]:

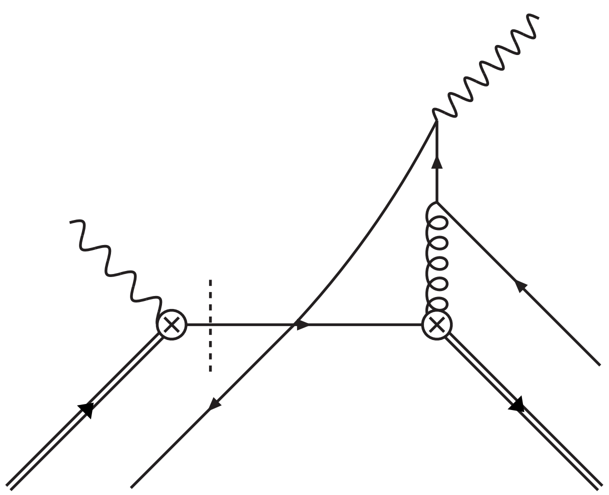
$$\mathrm{BR_{th}}(\bar{B} \to X_s \gamma) = 3.15\ (23) \cdot 10^{-4}$$

$$\mathrm{BR_{exp}}(\bar{B} \to X_s \gamma) = 3.43\ (21)\ (7) \cdot 10^{-4}$$

[HFAG \`12]

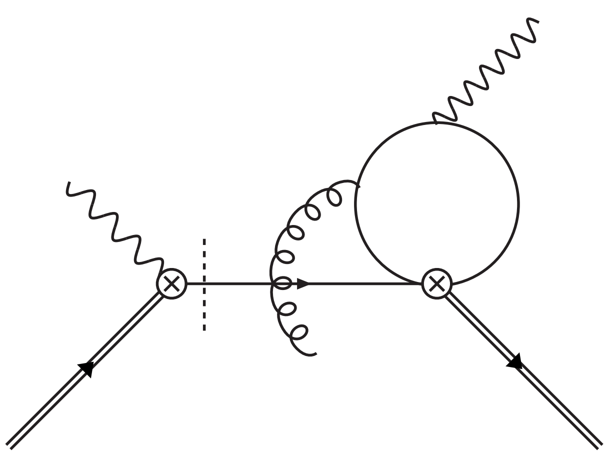
Perturbative Improvements [Czakon et al \`07, Asatrian et. al. \`07, Boughezal et.al. \`07, Ewerth \`08, Pak et al. \`08, Haisch et.al. \`10, Misiak et. al.\`10, Misiak et. al.\`12]

$\bar{B} \to X_s \gamma$ Theory Uncertainty



For the integrated rate of only Q_7 use optical theorem and OPE: corrections of $O(\Lambda_{QCD}{}^2/m_b{}^2)$

Resolved photon contributions are $O(\Lambda_{QCD}/m_b)$ for Q_1Q_7, Q_7Q_8 & Q_8Q_8 [Benzke, Lee, Neubert, Paz `10]



Agrees with 5% uncertainty assigned in [Misiak `07]

$A_{CP}(b \to s\gamma) = [-0.6, 2.8]\%$ [Benzke, Lee, Neubert, Paz `11]

Theory & Experimental uncertainty of same size

$b \to d\gamma$: $Q_1^u Q_7$ vanishes at $O(\Lambda_{QCD}/m_b)$ in CP averaged

$\overline{\mathrm{B}} \to \mathrm{X_s}\,\gamma$ Further Comments

$$\mathcal{B}(\bar{B} \to X_s\gamma)_{E_\gamma > E_0} = \mathcal{B}(\bar{B} \to X_c e\bar{\nu})_{\rm exp} \left|\frac{V_{ts}^* V_{tb}}{V_{cb}}\right|^2 \frac{6\alpha_{\rm em}}{\pi\, C} \left[P(E_0) + N(E_0)\right]$$

The value of $C = \left|\frac{V_{ub}}{V_{cb}}\right|^2 \frac{\Gamma(\bar{B} \to X_c e\bar{\nu})}{\Gamma(\bar{B} \to X_u e\bar{\nu})}$ and m_c depends on the

scheme (1S or kinetic) [Gambino et.al. \`08] 3% shift [Misiak \`08]

In the perturbative cut-off dependent term $P(E_0)$ a log appears: $\log(\delta) = \log(1 - 2\, E_0/m_b)$

Summing this log for small cut-off/logs leads to an unnatural behaviour in the perturbative theory [Misiak \`08]
This results in the theory prediction of Becher & Neubert

$\bar{B} \to X_s\, l^+ l^-$ @ NNLO

For $b \to s\, l^+ l^-$ Q_7, Q_9, Q_{10} contribute and the effective Hamiltonian [Bobeth et. al.] and matrix elements [Asatryan et.al, Ghinculov et. al., Huber et. al.] are known at NNLO+EW/QED

For low q^2 region the expansion is similar to $b \to s\, \gamma$

$$\mathcal{B}(B \to X_s \ell^+ \ell^-)_{\text{low}} = \begin{cases} (1.59 \pm 0.11) \times 10^{-6} & (\ell = \mu) \\ (1.64 \pm 0.11) \times 10^{-6} & (\ell = e)\,, \end{cases}$$

[Hurth, Nakao `11]

$$(q_0^2)[X_s \ell^+ \ell^-] = \begin{cases} (3.50 \pm 0.12)\ \text{GeV}^2 & (\ell = \mu) \\ (3.38 \pm 0.11)\ \text{GeV}^2 & (\ell = e)\,, \end{cases}$$

experimentally there is a cut on $M_X < M$: suppressed shape function [Tackmann et. al. `08] & NNLO hard scattering [Beneke et. al. `10]

reduces $q_0 \; = \; \left[(3.34 \ldots 3.40)^{+0.22}_{-0.25}\right] \text{GeV}^2 \quad \text{for} \quad m_X^{\text{cut}} = (2.0 \ldots 1.8)\ \text{GeV}$

$\bar{B} \to X_s \bar{\upsilon}\, \upsilon$ & $\bar{B} \to K^{(*)} \bar{\upsilon}\, \upsilon$

Inclusive mode cleanest $BR(B^0 \to X \bar{\upsilon}\, \upsilon) = 2.7(2) \cdot 10^{-5}$ [Altamanshofer et. al.] – with a 5% residual theory error, but experimentally hardest

Exclusive mode suffer from the uncertainty in the form factors

For the K^+ background from $B^+ \to \tau^+ \upsilon$ – 3-4% uncertainty [Kamenik, Smith]

Normalisation to $K \to \pi\, l\, l$ reduces uncertainty clean [Bartsch et. al.]

What will we learn beyond the Z-Penguin with 20% exp accuracy?
→ Constraints on extra light new (bs)-coupling particles

Conclusion

Super flavour factories: plenty observables

Inclusive modes are at least as precise as the exclusive ones

different new physics sensitivity & test of theoretical methods

potentially new channels e.g. missing energy are possible