Model Independent Constraints on the $\mathcal{C}_i$

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Workshop on the physics reach of rare an exclusive B decays

University of Sussex, Brighton
September 2012

N Groups, $N + 1$ Methods

Objective

- sample the probability distribution of the Wilson Coefficients $\mathcal{C}_i$
- use inputs from various sources, perform a global fit
- find credibility regions for $\mathcal{C}_i$

N Groups, $N+1$ Methods

Objective + Issues

- sample the probability distribution of the Wilson Coefficients $\mathcal{C}_i$
  issue: which operators should be considered? increasing complexity!
- use inputs from various sources, perform a global fit
  issue: which inputs to select? increasing duration of analyses
- find credibility regions for $\mathcal{C}_i$
  issue: how to present? $\mathcal{C}_i(\mu_b)$? $\mathcal{C}_i(M_W)$? numbers vs expansion in α_s?

N Groups, $N+1$ Methods

Sampling

- Grid-based Sampling
  Evaluate pdf on equidistantly spaced grid [0805.2525], [1006.5013], [1104.3342]
- Importance Sampling
  Markov Chains[1111.1257],[1207.2753] or Markov Chains + Population Monte Carlo[1205.1838] are used to explore parameter space

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Personal Conclusion

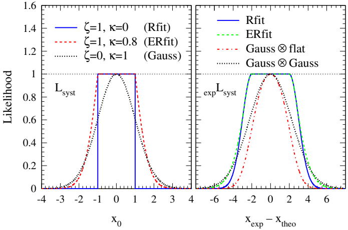
Importance sampling is step in the right direction, but beware of pitfalls!
MC might miss modes of the pdfs (convergence criteria important).
MCMC + PMC large step towards "black box" Monte Carlo.

N Groups, $N+1$ Methods

Theory Uncertainties

Treat theory uncertainties via

- combination [1111.1257] [1207.2753]
  $\sigma^2 = \sigma_{\text{th}}^2 + \sigma_{\text{exp}}^2$
- Rfit [hep-ph/0104062], used in [1006.5013]
  within theory unc.: max. likelihood, outside: gauss w/ exper. error
- Bayesian approach [1205.1838]
  introduce nuisance parameters to treat uncertainties, marginalise



from [hep-ph/0104062]

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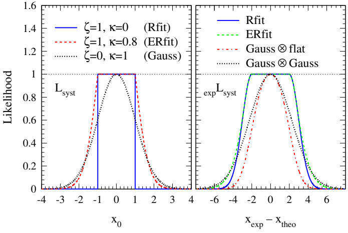


from [hep-ph/0104062]

Personal Conclusion

Results currently comparable for all methods. Bayesian approach also yields information re uncertainties! Important check of theory inputs (hadronic matrix elements, unknown $1/m_b$ contributions, ...)

Results

Results of groups are hard to compare

(A) Altmannshofer et al. [1111.1257]

- fit NP contributions at high scale $\mu_0 \simeq 2M_W$
- $\mathcal{C}_i(\mu_0) = \delta\mathcal{C}_i + \sum_{n=0}^{2} \left(\frac{\alpha_s}{4\pi}\right)^n \mathcal{C}_i^{\mathrm{SM},(\mathrm{n})}$

(B) Bobeth et al. [1205.1838]

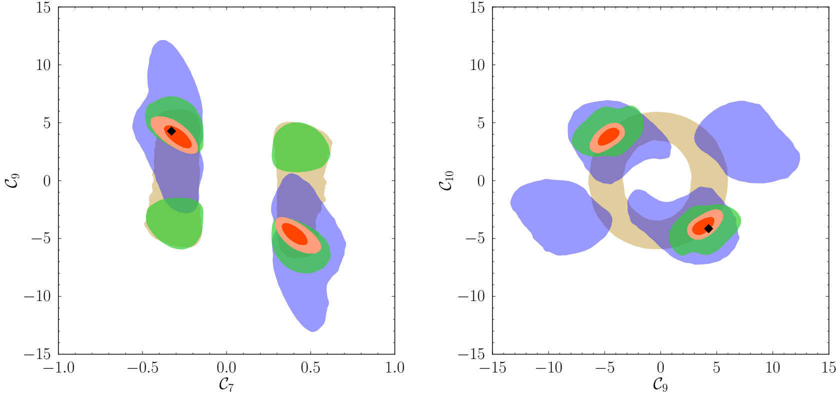
- fit NP contributions at low scale $\mu_b \simeq m_b$
- fit full wilson coefficient $\mathcal{C}_i(\mu_b)$ as a number, not as a series in α_s
- only exclusive decays: $B \to K^*\gamma$, $B \to K^{(*)}\ell^+\ell^-$, $B_s \to \ell^+\ell^-$

(C) Descotes-Genon et al. [1207.2753]

- fit NP contributions at low scale $\mu_b \simeq m_b$
- do not consider the same scenarios as (B)

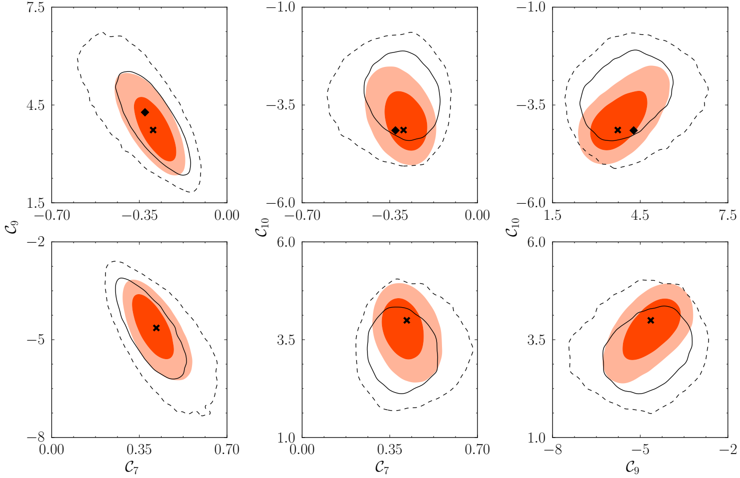
Results from (B) at low scale

95% credibility regions



all regions include $B \to K^*\gamma$ inputs brown incl. $B \to K\ell^+\ell^-$ (high + low)
blue incl. $B \to K^*\ell^+\ell^-$ (low) green incl. $B \to K^*\ell^+\ell^-$ (high)
light red all data + $B_s \to \mu^+\mu^-$ dark red same at 65%

Results from (B) at low scale



color: normal priors (dark: 68%, light: 95%)
lines: wide priors (solid: 68%, dashed: 95%) diamond: SM, cross: MAP

Results from (B) at low scale

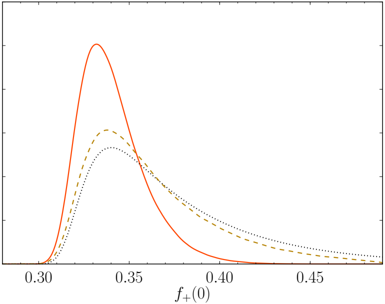
	$\mathcal{C}_7$	$\mathcal{C}_9$	$\mathcal{C}_{10}$
68%	$[-0.34, -0.23] \cup [0.35, 0.45]$	$[-5.2, -4.0] \cup [3.1, 4.4]$	$[-4.4, -3.4] \cup [3.3, 4.3]$
95%	$[-0.41, -0.19] \cup [0.31, 0.52]$	$[-5.9, -3.5] \cup [2.6, 5.2]$	$[-4.8, -2.8] \cup [2.7, 4.7]$
max	$-0.28 \cup 0.40$	$-4.56 \cup 3.64$	$-3.92 \cup 3.86$
68%	$[-0.39, -0.19] \cup [0.30, 0.48]$	$[-5.6, -3.8] \cup [2.9, 5.1]$	$[-4.0, -2.5] \cup [2.6, 3.9]$
95%	$[-0.53, -0.13] \cup [0.24, 0.61]$	$[-6.7, -3.1] \cup [2.2, 6.2]$	$[-4.7, -1.9] \cup [2.0, 4.6]$
max	$-0.30 \cup 0.38$	$-4.64 \cup 3.84$	$-3.24 \cup 3.30$

upper: normal priors
lower: wide priors

Very good agreement with the SM!
From 59 exper. inputs, only one pull $> 2\sigma$! ($\mathcal{B}[B \to K^*\ell^+\ell^-]_{>16}$ Belle)

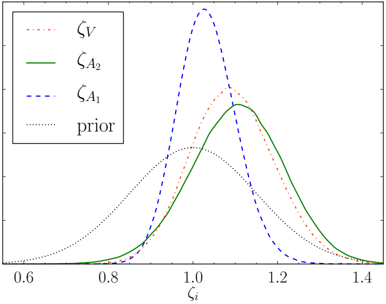
Results from (B) for nuisance parameters

$B \to K\ell^+\ell^-$



$f_+(q^2)$ form factor, two parameters, z parametrisation
dotted: prior
dashed: only $B \to K\ell^+\ell^-$ data
solid: all data

$B \to K^*\ell^+\ell^-$



$V(q^2) \to \zeta_V V(q^2)$, etc.
considerable shifts ($\sim 10\%$) in V and A_2!

Improvements (Theory)

$1/m_b$ Subleading Contributions (SL)

- So far SL contributions constants, i.e. , no functional dependence on q^2. Room for improvements?
- At high q^2, the SL contributions for different transversity amplitudes are correlated. What about low q^2?
- Is it benefitial to calculate remaining $1/m_b$ corrections?
- At low q^2: self consistency of $X_\perp$ in $B \to K^*\gamma$ vs $B \to K^*\ell^+\ell^-$. For $B \to K^*\gamma$, regularisation is needed, for $B \to K^*\ell^+\ell^-$ there is no need. Leads to problem in limit $q^2 \to 0$ for $B \to K^*\ell^+\ell^-$ observables, e.g. A_I.

Improvements (Theory)

Residual Renormalization Scale Dependence

- binned A_{FB} at low q^2, as well as its zero crossing q_0^2 have large μ dependence in NLO calculations.
- with increasing experimental precision (finer bins), $\mathcal{C}_i$ results will show μ_b dependence.
- NNLO calculation needed?
- Consider μ_b-variation in fits, extract "true" / "intrinsic" value of μ_b?

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Personal Conclusion

Extraction of μ feasible albeit computationally expensive, since running of $\mathcal{C}_{1\ldots6,8}$ must be included.

Improvements (Experiment)

Do not use model assumptions ($J_{1c} \sim J_{2c}$, etc.) for fits! Problem with definitions of F_L, F_T arise. From distribution in $\cos\theta_{K^*}$:

$$\frac{\mathrm{d}\langle\Gamma\rangle}{\mathrm{d}\cos\theta_{K^*}} = \frac{3}{2}\Big(\langle J_{1s} - \frac{1}{3}J_{2s}\rangle \sin^2\theta_{K^*} + \langle J_{1c} - \frac{1}{3}J_{2c}\rangle \cos^2\theta_{K^*}\Big)$$

$$\frac{\mathrm{d}\langle\Gamma\rangle}{\mathrm{d}\cos\theta_{K^*}} = \frac{3}{2}\langle F_L\rangle \cos^2\theta_{K^*} + \frac{3}{4}\langle 1 - F_L\rangle \sin^2\theta_{K^*}$$

However, from distribution in $\cos\theta_\ell$:

$$\frac{\mathrm{d}\langle\Gamma\rangle}{\mathrm{d}\cos\theta_\ell} = \frac{1}{2}\Big(\langle 2J_{1s} + J_{1c}\rangle + \langle 2J_{6s} + J_{6c}\rangle \cos\theta_\ell + \langle 2J_{2s} + J_{2c}\rangle \cos 2\theta_\ell\Big)$$

$$\frac{\mathrm{d}\langle\Gamma\rangle}{\mathrm{d}\cos\theta_\ell} = \frac{3}{4}\langle F_L\rangle(1 - \cos^2\theta_\ell) + \frac{3}{8}\langle 1 - F_L\rangle(1 + \cos^2\theta_\ell) + \langle A_{\mathrm{FB}}\rangle \cos\theta_\ell$$

With scalar/tensor operators and for $m_\ell \neq 0$:

$$F_L(J_{1c}, J_{2c}) \neq F_L(J_{1s}, J_{1c}, J_{2s}, J_{2c})$$

Improvements (Experiment)

- provide correlation between q^2 bins
  (gaussian?) covariance matrix, BaBar do this for $B \to \pi \ell \nu$ bins, see e.g. [1005.3288]
- provide correlation between observables in the same bin
  perhaps as (gaussian?) covariance matrix
  available e.g. for $S_{K^* \gamma}$, $C_{K^* \gamma}$
- ultimately: (marginalised!) likelihood surfaces for all bins of the observables would be appreciated
  Discussion: How to provide it?

Summary

- No NP yet! SM fits very well.
- Model Independent Analysis: real-valued $\mathcal{C}_{7,9,10}$ suffice (so far!).
- More statistics, more inputs, more correlations needed.