On the physics case of a SFF in the TDR phase

and a brief update of exclusive and inclusive $b \to s$ transitions

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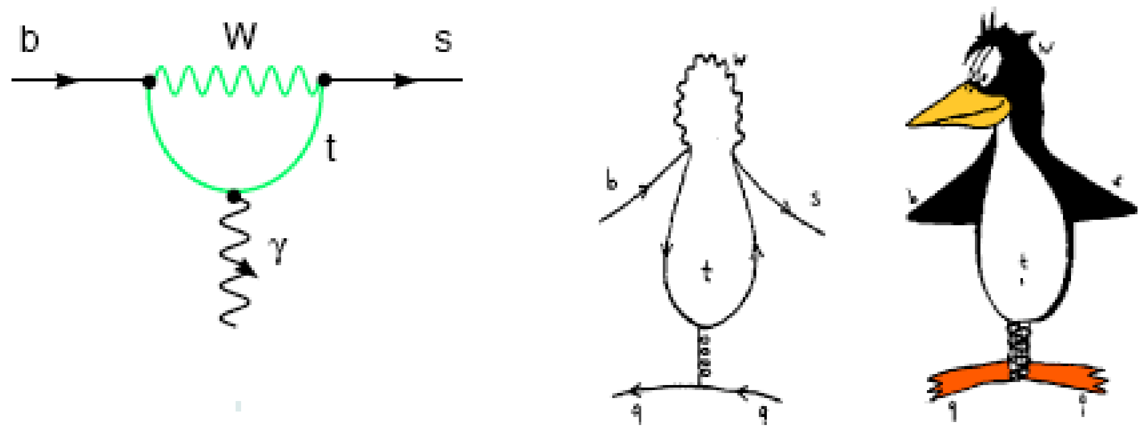
SuperB plenary meeting, LAL, Orsay, 15.-18.2.2009

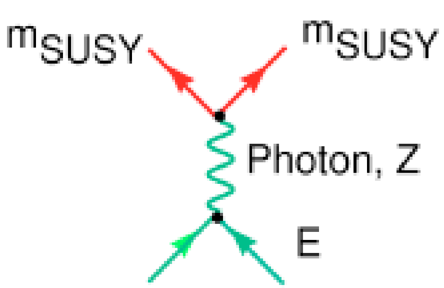
Independent approach to new physics

- Flavour changing neutral current processes like $b \to s\,\gamma$ or $b \to s\,\ell^+\ell^-$ directly probe the SM at the one-loop level.

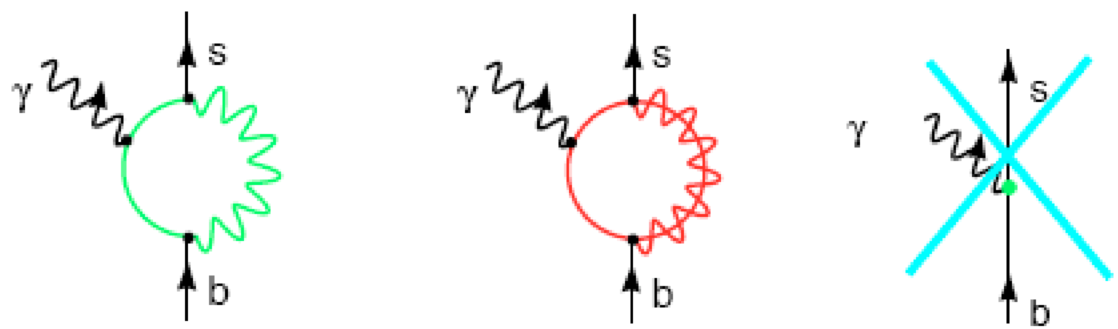


- Indirect search strategy for new degrees of freedom beyond the SM

Direct:



Indirect:



- High sensitivity for 'New Physics' ($\leftrightarrow$ electroweak precision data, 10% $\leftrightarrow$ 0.1%)

- Large potential for synergy and complementarity between collider (high-p_T) and flavour physics within the search for new physics

Flavour problem of New Physics

$$\mathcal{L} = \mathcal{L}_{Gauge} + \mathcal{L}_{Higgs} + \sum_i \frac{c_i^{New}}{\Lambda_{\rm NP}} \mathcal{O}_i^{(5)} + \ldots$$

- SM as effective theory valid up to cut-off scale $\Lambda_{\rm NP}$
- Typical example: $K^0 - \bar{K}^0$-mixing $\mathcal{O}^6 = (\bar{s}\, d)^2$:

  $c^{SM}/M_W^2 \times (\bar{s}\, d)^2 + c^{New}/\Lambda_{\rm NP}^2 \times (\bar{s}\, d)^2$ $\Rightarrow$ $\Lambda_{\rm NP} > 10^4\,\text{TeV}$

  (tree-level, generic new physics)

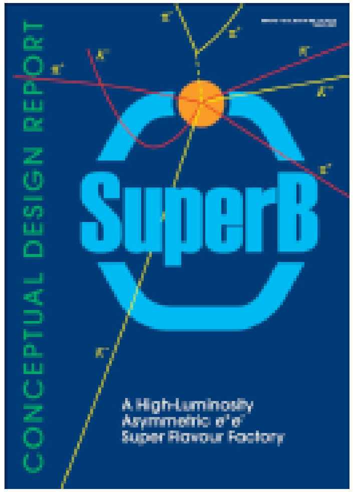
- Natural stabilisation of Higgs boson mass (hierarchy problem)

  (i.e. supersymmetry, little Higgs, extra dimensions) $\Rightarrow$ $\Lambda_{\rm NP} \leq 1\text{TeV}$

- EW precision data $\leftrightarrow$ little hierarchy problem $\Rightarrow$ $\Lambda_{\rm NP} \sim 3 - 10\text{TeV}$

Possible New Physics at the TeV scale has to have a very non-generic flavour structure

Physics case of a Super-B factory



Well explored issue: several studies existing

- SuperKEKb Book: "Physics at a Super B Factory"
  Akeroyd et al., hep-ex/0406071
- SuperBabar Book: "The Discovery Potential of a Super B factory"
  Hewett et al., hep-ph/0503261
- CDR of SuperB: Chapter I "The Physics"
  Bona et al.,arXiv:0709.0451 [hep-ex]
- "On the Physics Case of a Super Flavour Factory"
  Browder,Ciuchini,Gershon,Hazumi,Hurth,Okada,Stocchi,arXiv:0710.3799

Super-B is a Super Flavour factory: besides precise B measurements, CP violation in charm, lepton flavour violating modes $\tau \to \mu\gamma$,...

Estimated sensitivities

Observable	Super Flavour Factory sensitivity
$\sin(2\beta)$ ($J/\psi\, K^0$)	0.005–0.012
γ ($B \to D^{(*)}K^{(*)}$)	1–2°
α ($B \to \pi\pi, \rho\rho, \rho\pi$)	1–2°
$\lvert V_{ub}\rvert$ (exclusive)	3–5%
$\lvert V_{ub}\rvert$ (inclusive)	2–6%
$\bar{\rho}$	1.7–3.4%
$\bar{\eta}$	0.7–1.7%
$S(\phi K^0)$	0.02–0.03
$S(\eta' K^0)$	0.01–0.02
$S(K_S^0 K_S^0 K_S^0)$	0.02–0.04
$\mathcal{B}(B \to \tau\nu)$	3–4%
$\mathcal{B}(B \to \mu\nu)$	5–6%
$\mathcal{B}(B \to D\tau\nu)$	2–2.5%
$\mathcal{B}(B \to \rho\gamma)/\mathcal{B}(B \to K^*\gamma)$	3–4%
$A_{CP}(b \to s\gamma)$	0.004–0.005
$A_{CP}(b \to (s+d)\gamma)$	0.01
$S(K_S^0 \pi^0 \gamma)$	0.02–0.03
$S(\rho^0 \gamma)$	0.08–0.12
$A^{FB}(B \to X_s \ell^+\ell^-)\ s_0$	4–6%
$\mathcal{B}(B \to K\nu\bar{\nu})$	16–20%
$\mathcal{B}(\tau \to \mu\gamma)$	$2\text{–}8 \times 10^{-9}$
$\mathcal{B}(\tau \to \mu\mu\mu)$	$0.2\text{–}1 \times 10^{-9}$
$\mathcal{B}(\tau \to \mu\eta)$	$0.4\text{–}4 \times 10^{-9}$

Browder, Ciuchini, Gershon, Hazumi, Hurth, Okada, Stocchi, arXiv:0710.3799

Sensitivities τ decays

$\mathrm{BR}(l_j^- \to l_i^- \gamma)|_{\mathrm{SM}_R} \approx (m_\nu/M_W)^2 \sim \mathcal{O}(10^{-54})$

$\mathcal{B}(\tau \to \mu\gamma)$	2–8×10^{-9}
$\mathcal{B}(\tau \to \mu\mu\mu)$	0.2–1×10^{-9}
$\mathcal{B}(\tau \to \mu\eta)$	0.4–4×10^{-9}

Example: Little Higgs Models

M. Blanke et al., hep-ph/0605214 hep-ph/0702136

decay	$f = 500\mathrm{GeV}$
$\mu \to e\gamma$	$1.2 \cdot 10^{-11}$
$\mu^- \to e^-e^+e^-$	$1.0 \cdot 10^{-12}$
$\tau \to e\gamma$	$1 \cdot 10^{-8}$
$\tau \to \mu\gamma$	$2 \cdot 10^{-8}$
$\tau^- \to e^-e^+e^-$	$2 \cdot 10^{-8}$
$\tau^- \to \mu^-\mu^+\mu^-$	$3 \cdot 10^{-8}$

ratio	LHT	MSSM (dipole)	MSSM (Higgs)
$\frac{Br(\mu^- \to e^-e^+e^-)}{Br(\mu \to e\gamma)}$	$0.4 \ldots 2.5$	$\sim 6 \cdot 10^{-3}$	$\sim 6 \cdot 10^{-3}$
$\frac{Br(\tau^- \to e^-e^+e^-)}{Br(\tau \to e\gamma)}$	$0.4 \ldots 2.3$	$\sim 1 \cdot 10^{-2}$	$\sim 1 \cdot 10^{-2}$
$\frac{Br(\tau^- \to \mu^-\mu^+\mu^-)}{Br(\tau \to \mu\gamma)}$	$0.4 \ldots 2.3$	$\sim 2 \cdot 10^{-3}$	$0.06 \ldots 0.1$

T.Goto et al.,arXiv:0809.4753 [hep-ph]

What is left over for the TDR phase?

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At least two issues

- Experimental sensitivity studies beyond simple extrapolation of statistical errors
- Super-B physics case in view of the LHCb and Super-LHCb

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- Experimental sensitivity studies beyond simple extrapolation of statistical errors
- Super-B physics case in view of the LHCb and Super-LHCb

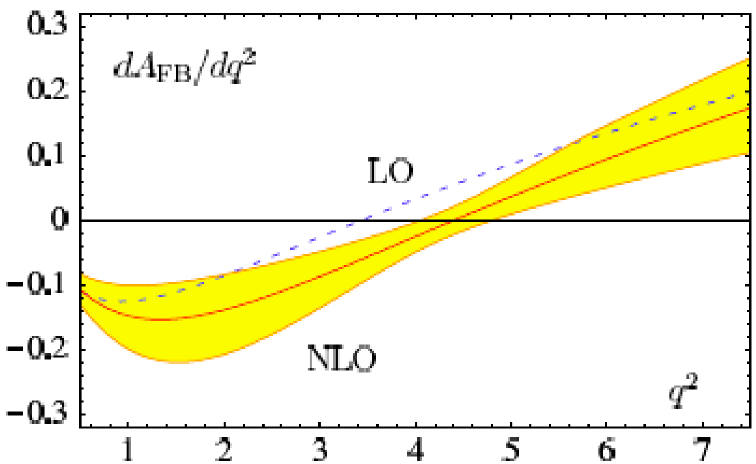
The physics case of a SFF has to be established beyond LHCb reach !

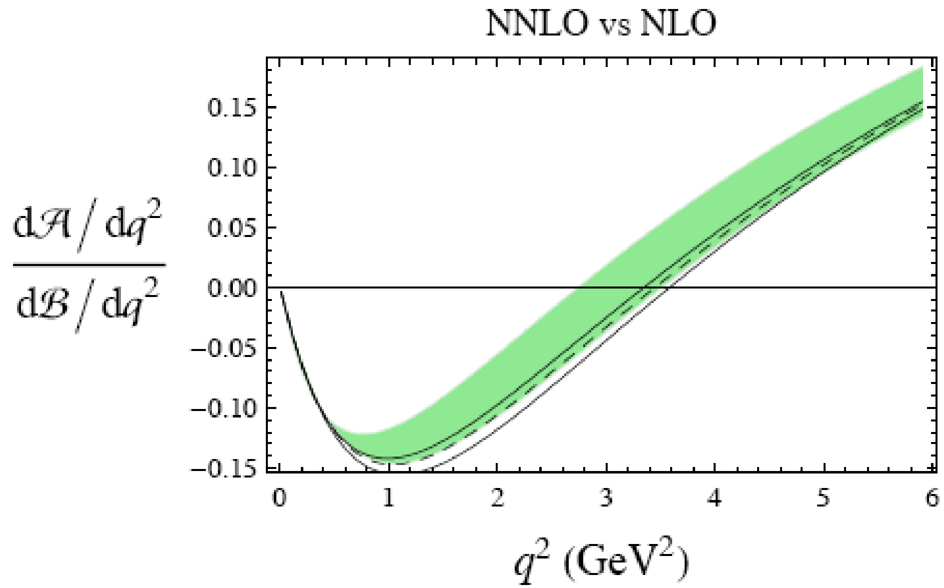
- Comparison of measurable channels is not sufficient
- One needs clear reasons why higher precision of a SFF is necessary when the possible new physics structures can already be tested at LHCb
- One needs new physics structures which cannot be tested at LHCb
- Possible upgrade of LHCb: $10 fb^{-1} \rightarrow 100 fb^{-1}$

SLHCb versus SFF   Important role of Λ/m_b corrections

Measurement of inclusive modes restricted to e^+e^- machines.
(S)LHC experiments: Focus on theoretically clean exclusive modes necessary.

Well-known example: Zero of forward-backward-charge asymmetry in $b \to s\ell^+\ell^-$





Exclusive Zero:

Theoretical error: 9% $+ O(\Lambda/m_b)$ uncertainty   Egede,Hurth,Matias,Ramon,Reece arXiv:0807.2589

Experimental error at SLHC: 2.1% Libby

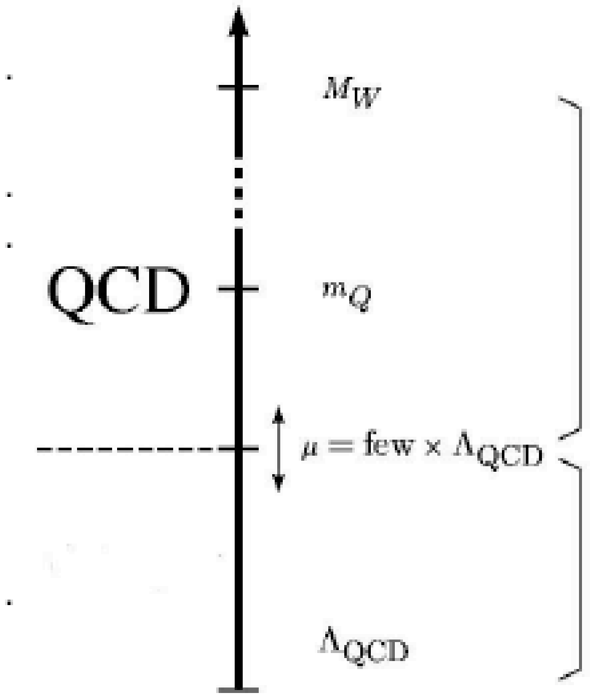
Inclusive Zero:

Theoretical error: $O(5\%)$ Huber,Hurth,Lunghi,arXiv:0712.3009

Experimental error at SFF: $4-6\%$ Browder,Ciuchini,Gershon,Hazumi,Hurth,Okada,Stocchi arXiv:0710.3799

Brief update on $b \to s\gamma$ and $b \to s\ell^+\ell^-$

How to separate new physics effects from hadronic uncertainities?



short-distance physics
perturbative

long-distance physics
nonperturbative

Operator product expansion: Factorization of short- and long-distance physics

- $\mu^2 \approx M_W^2$: C_i: effective couplings, $< \mathcal{O}_i >$: matrix elements

$$H_{eff} = -\frac{4G_F}{\sqrt{2}} \sum C_i(\mu, M_{heavy})\ \mathcal{O}_i(\mu)$$

- $\Lambda_{QCD} << m_Q = m_b$: $1/m_b$ expansion allows for separation of effects
$\mu^2 \approx m_b^2,\ m_b\Lambda_{QCD}$ $\Rightarrow$ effective theories (HQET, SCET)

- $\mu^2 \approx \Lambda_{QCD}^2$: long-distance hadronic parameters (lattice-QCD , U-spin symmetry, QCD sum rules, chiral perturbation theory, ...)

- $\mu^2 \approx M_{New}^2 >> M_W^2$: 'new physics' effects: $C_i^{SM}(M_W) + C_i^{New}(M_W)$

Factorization theorems: separating long- and short-distance physics

- Electroweak effective Hamiltonian: $H_{eff} = -\frac{4G_F}{\sqrt{2}} \sum C_i(\mu, M_{heavy})\ \mathcal{O}_i(\mu)$

- Heavy mass expansion for inclusive modes (in general restricted to e^+e^-)

$$\Gamma(\bar{B} \to X_s\gamma) \stackrel{m_b\to\infty}{\longrightarrow} \Gamma(b \to X_s^{parton}\gamma)\,, \quad \Delta^{nonpert.} \sim \Lambda^2_{QCD}/m_b^2$$

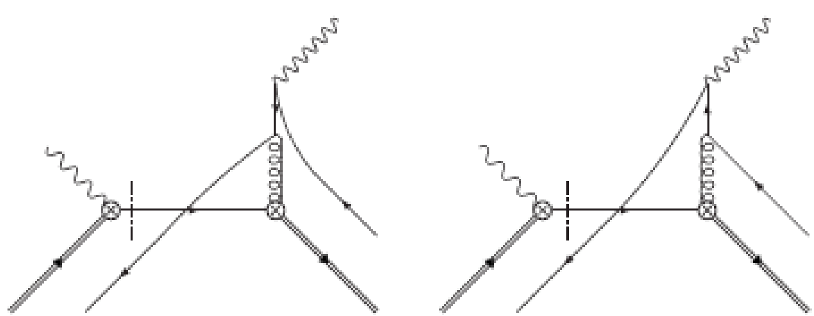
No linear term Λ_{QCD}/m_b (perturbative contributions dominant)

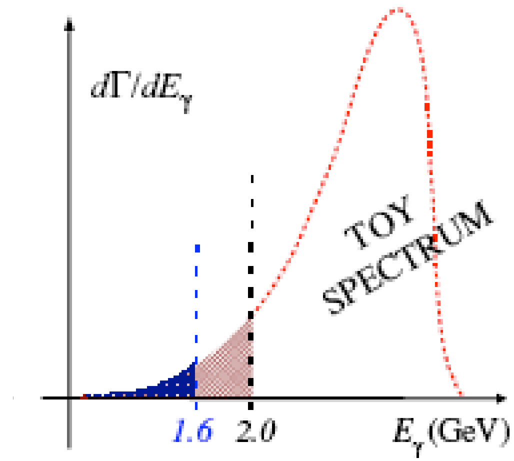
– More sensitivities to nonperturbative physics due to kinematical cuts: shape functions; multiscale OPE (SCET) with $\Delta = m_b - 2E_\gamma^0$

Becher,Neubert,hep-ph/0610067

– Breakdown of local expansion: class of nonlocal power corrections identified; naive estimates lead to 5% uncertainty.

Lee,Neubert,Paz,hep-ph/0609224





- QCD factorization/SCET analysis for exclusive decays with fast light particles in final state; for example $B \to K\pi$:

$$\langle \pi K | Q_i | B \rangle = F_0^{B\to\pi}\, T^{\rm I}_{K,i} * f_K \Phi_K + F_0^{B\to K}\, T^{\rm I}_{\pi,i} * f_\pi \Phi_\pi + T^{\rm II}_i * f_B \Phi_B * f_K \Phi_K * f_\pi \Phi_\pi + O(\Lambda/m_b)$$

  – Separation of perturbative hard kernels from process-independent nonperturbative functions like form factors

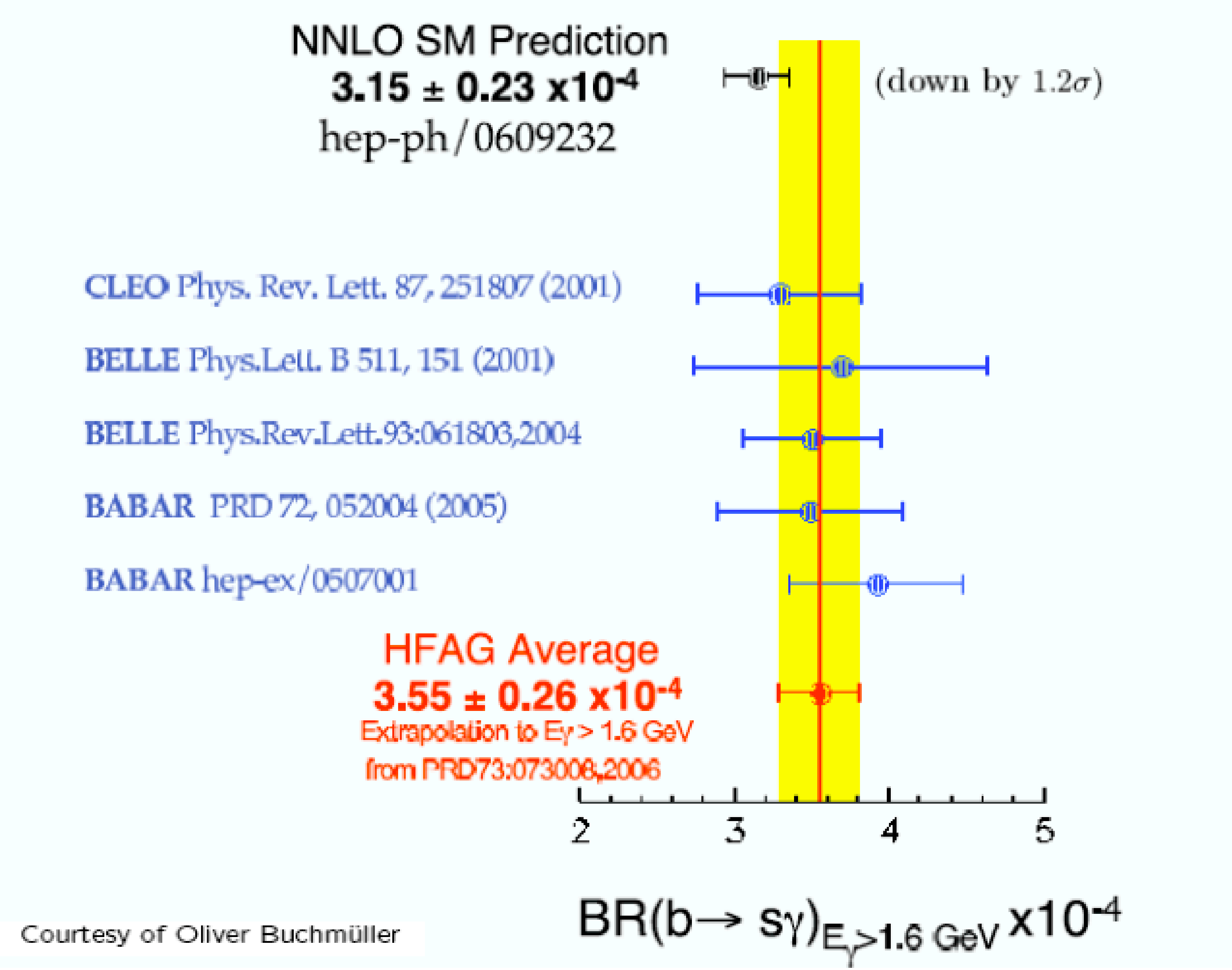
  – Relations between formfactors in large-energy limit

  – Limitation: insufficient information on power-suppressed Λ/m_b terms (breakdown of factorization: 'endpoint divergences')

Phenomenologically highly relevant issue:

general strategy of LHCb to look at ratios of exclusive modes

- Inclusive $b \to s\gamma$ branching ratio



- Belle $(E_0 = 1.7\text{GeV}, 605 fb^{-1})$ $\Rightarrow$ $\text{BR}(1.6\text{GeV}) = (3.52 \pm 0.23 \pm 0.09) \times 10^{-4}$

HFAG

Currently known contributions $\mathcal{B}(\bar{B} \to X_s \gamma)$ that have not been included in the estimate $\underset{(\pm 7.3\%)}{(3.15 \pm 0.23)} \times 10^{-4}$ in hep-ph/0609232:

- New/old large-β_0 bremsstrahlung effects [Ligeti, Luke, Manohar, Wise, 1999] [Ferroglia, Haish, 2007, to be published] $\Rightarrow$ $+2.0\%$ in the BR
- Four-loop mixing into the $b \to sg$ operator Q_8 [Czakon, Haisch, MM, hep-ph/0612329] $\Rightarrow$ -0.3% in the BR
- Charm mass effects in loops on gluon lines in K_{77} [Asatrian, Ewerth, Gabrielyan, Greub, hep-ph/0611123] [Czarnecki, Pak, to be published] $\Rightarrow$ $+0.3\%$ in the BR
- Charm and bottom mass effects in loops on gluon lines in the three-loop $b \to s\gamma$ matrix elements of Q_1 and Q_2 [Boughezal, Czakon, Schutzmeier, arXiv:0707.3090] $\Rightarrow$ $+1.1\%$ in the BR
- Non-perturbative $\mathcal{O}\left(\alpha_s \frac{\Lambda}{m_b}\right)$ effects in the term $\sim C_7 C_8$ [Lee, Neubert, Paz, hep-ph/0609224] $\Rightarrow$ -1.5% in the BR

Total: $+1.6\%$ in the BR

Courtesy of Mikolaj Misiak

- The semileptonic phase factor:

$$\mathrm{BR}_\gamma(E_0) \equiv \mathrm{BR}[B \to X_s\gamma]_{E_\gamma > E_0} = \frac{\mathrm{BR}_{c\ell\nu}}{C}\left(\frac{\Gamma[B \to X_s\gamma]_{E_\gamma>E_0}}{|V_{cb}/V_{ub}|^2\,\Gamma[B \to X_u e\bar\nu]}\right)$$

$$C = \left|\frac{V_{ub}}{V_{cb}}\right|^2 \frac{\Gamma[\bar B \to X_c e\bar\nu]}{\Gamma[\bar B \to X_u e\bar\nu]} = \begin{cases} 0.582 \pm 0.016, \\ 0.546^{+0.023}_{-0.033}, \end{cases}$$

1S scheme has to be updated!
Trott et al.,hep-ph/0408002
kinetic scheme
Gambino,Giordano,arXiv:0805.0271

Enhancement of BR_γ in kinematic scheme

+4.8%!? $\frac{\delta}{\delta m_c}Pert(E_0) \prec 0$, $\bar m_c(\bar m_c)_{1S} \prec \bar m_c(\bar m_c)_{kinetic}$

- Multiscale OPE: Becher,Neubert,hep-ph/0610067

Misiak et al.	BR_γ(1GeV)	BR_γ(1.6GeV)
hep-ph/0609232 'fixed order'	3.27 10^{-4}	(3.15±0.23) 10^{-4}
hep-ph/0610067 multisc. OPE	3.27 10^{-4} (adapted from above)	(2.98±0.26) 10^{-4}

without
−1.5% of $\mathcal{O}(\alpha_s\Lambda/m_b)$
3.05 10^{-4}

Ongoing discussion on cut-effects

Misiak,talk at HQL,Melbourne,arXiv:0808

- General folklore: With $E_\gamma^0 \leq 1.9 GeV$ local OPE of the rate is valid again.

- But: Becher,Neubert,hep-ph/06100067
  A low cut around $1.8 GeV$ might not guarantee that a theoretical description in terms of a local OPE is sufficient because of the sensitivity to the scale $\Delta = m_b - 2E_\gamma^0$.
  - Multiscale OPE with three short-distance scales m_b, $\sqrt{m_b \Delta}$ and Δ needed to connect the shape function and the local OPE region.
  - Using SCET, effects at the 3%-level found not by power corrections Λ_{QCD}/Δ, but by perturbative ones
  - $BR(\bar{B} \to X_s \gamma)_{E_\gamma > 1.6\,\mathrm{GeV}} = 2.98 \pm 0.26$

- Nevertheless: Misiak, 2.workshop on Flavour Dynamics, Albufeira, 3.-10.11.2007

  For $E_\gamma^0 = 1.6 GeV$ or lower, the cutoff-enhanced perturbative corrections undergo a dramatic cancellation with the so-called power-suppressed terms. Consequently, both types of terms must be treated with the same precision. Until this is done, the fixed-order results should be considered more reliable.

$$\mathrm{const.} + \log(\Delta/m_b) + \log^2(\Delta/m_b) + \ldots$$

versus

$$(\Delta/m_b) + (\Delta/mb)^2 + (\Delta/m_b)\log(\Delta/m_b) + \ldots$$

$\mathcal{O}(\alpha_s)\surd$; $\mathcal{O}(\alpha_s^2)\surd$; but not terms of $\mathcal{O}(\alpha_s^3)$

- Mixing-induced CP asymmetries in $b \to s\gamma$ transitions
  - General folklore: within the SM are small, $O(m_s/m_b)$

$$\mathcal{O}_{7L} \equiv \frac{e}{16\pi^2} m_b\, \bar{s}\sigma_{\mu\nu} P_R\, b F^{\mu\nu} \quad \mathcal{O}_{7R} \equiv \frac{e}{16\pi^2} m_{s/d}\, \bar{s}\sigma_{\mu\nu} P_L\, b F^{\mu\nu}\ .$$

Mainly: $\bar{B} \to X_s \gamma_L$ and $B \to X_s \gamma_R$ $\Rightarrow$ almost no interference in the SM

  - But: within the inclusive case the assumption of a two-body decay is made, the argument does not apply to $b \to s\gamma gluon$

    Corrections of order $O(\alpha_s)$, mainly due operator $\mathcal{O}_2$ $\Rightarrow$ $\Gamma_{22}^{\text{brems}}/\Gamma_0 \sim 0.025$
    $\Rightarrow$ 11% right-handed contamination
    Grinstein,Grossman,Ligeti,Pirjol, hep-ph/0412019

  - QCD sum rule estimate of the time-dependent CP asymmetry in $B^0 \to K^{*0}\gamma$ including long-distance contributions due to soft-gluon emission from quark loops versus dimensional estimate of the nonlocal SCET operator series:
    Ball,Zwicky,hep-ph/0609037 $\leftrightarrow$ Grinstein,Pirjol,hep-ph/0510104

$$S = -0.022 \pm 0.015^{+0}_{-0.01},\ S^{sgluon} = -0.005 \pm 0.01 \leftrightarrow |S^{sgluon}| \approx 0.06$$

    Note: Expansion parameter is Λ_{QCD}/Q where Q is the kinetic energy of the hadronic part. There is no contribution at leading order. Therefore, the effect is expected to be larger for larger invariant hadronic mass, thus, the K^* mode has to have the smallest effect, below the 'average' 10%

    Should be resolved!

    Experiment: $S = -0.28 \pm 0.26$

$$\Delta S = 0.02 - 0.03 \text{ (Super B sensitivity)}$$

    Browder,Ciuchini,Gershon,Hazumi,Hurth,Okada,Stocchi,arXiv:0710.3799

- Untagged direct CP asymmetries in $b \to s/d$ transitions

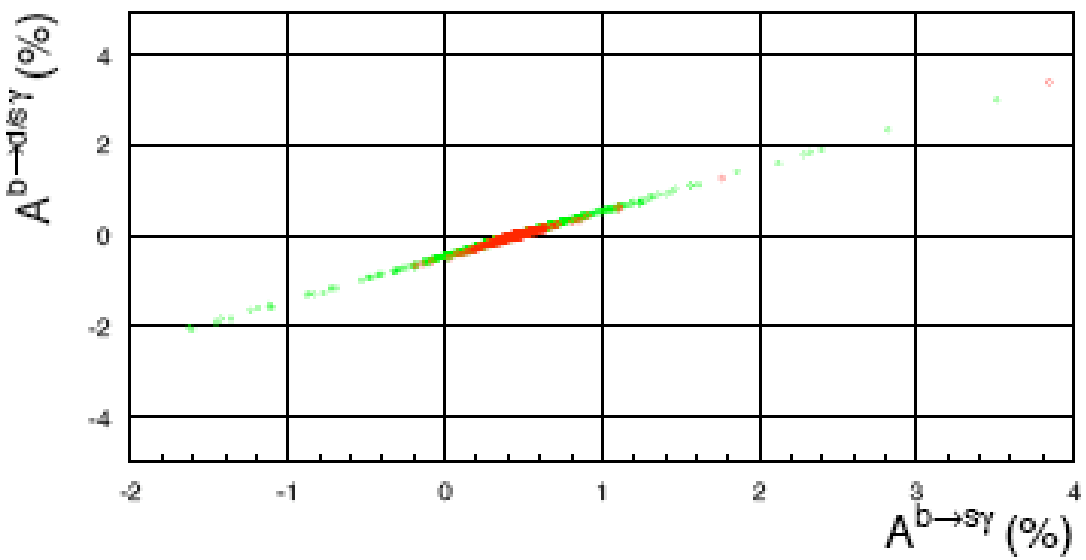
KM mechanism CKM unitarity + U spin symmetry of matrix elements $d \leftrightarrow s$:

$$|\Delta BR_{CP}(B \to X_s\gamma) + \Delta BR_{CP}(B \to X_d\gamma)| \sim 1 \cdot 10^{-9} \approx 0$$

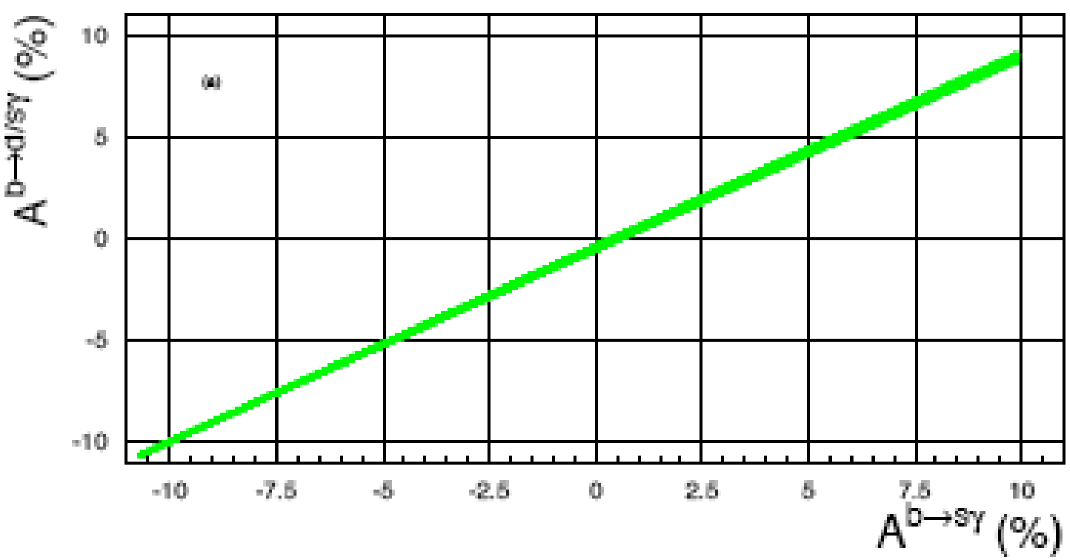
Clean test, whether new CP phases are active or not

Hurth,Mannel,hep-ph/0109041; Hurth,Lunghi,Porod,hep-ph/0312260

Experiment: (Super-) B-factories ±3% (±0.3%) precision possible



MFV with (flavourblind) phases



Model-independent analysis C_7^s;

Theory: $\Delta\Gamma_{CP}(B \to X_{s+d}\gamma) = \Gamma(\bar{B} \to X_{s+d}\gamma) - \Gamma(B \to X_{\bar{s}+\bar{d}}\gamma)$

KM mechanism CKM unitarity

$\Rightarrow \; J = \mathrm{Im}(\lambda_u^{(s)}\lambda_c^{(s)*}) = (-1)\; \mathrm{Im}(\lambda_u^{(d)}\lambda_c^{(d)*})$

+ U spin symmetry of matrix elements $d \leftrightarrow s$:

$$\Delta\Gamma_{CP}(B \to X_{s+d}\gamma) = b_{inc}\Delta_{inc}$$

b_{exc}: 'relative U-spin-breaking'; Δ_{exc}: 'typical size' of CP violating rate difference

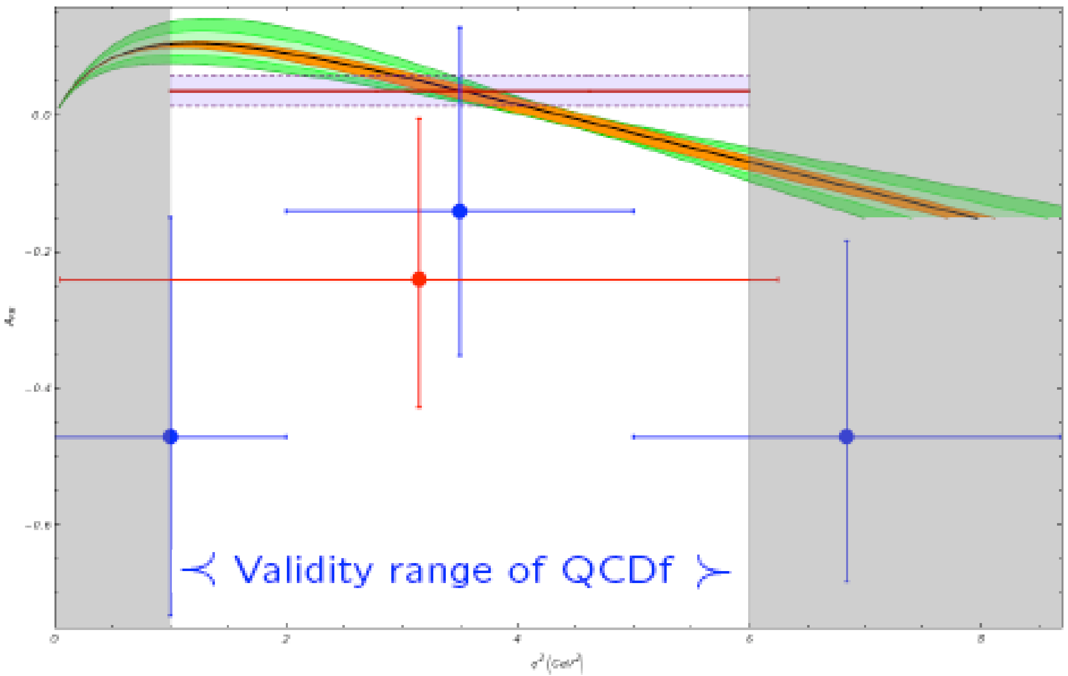
$|b_{inc}| \sim m_s^2/m_b^2 \sim 5 \cdot 10^{-4}$ (also in $1/m_b^2$ and in $1/m_c^2$ corrections)

$$|\Delta\mathcal{B}_{CP}(B \to X_{s+d}\gamma)| \sim 1 \cdot 10^{-9} \approx 0$$

Very clean test, whether new CP phases are active or not

- Exclusive $b \to s\ell^+\ell^-$

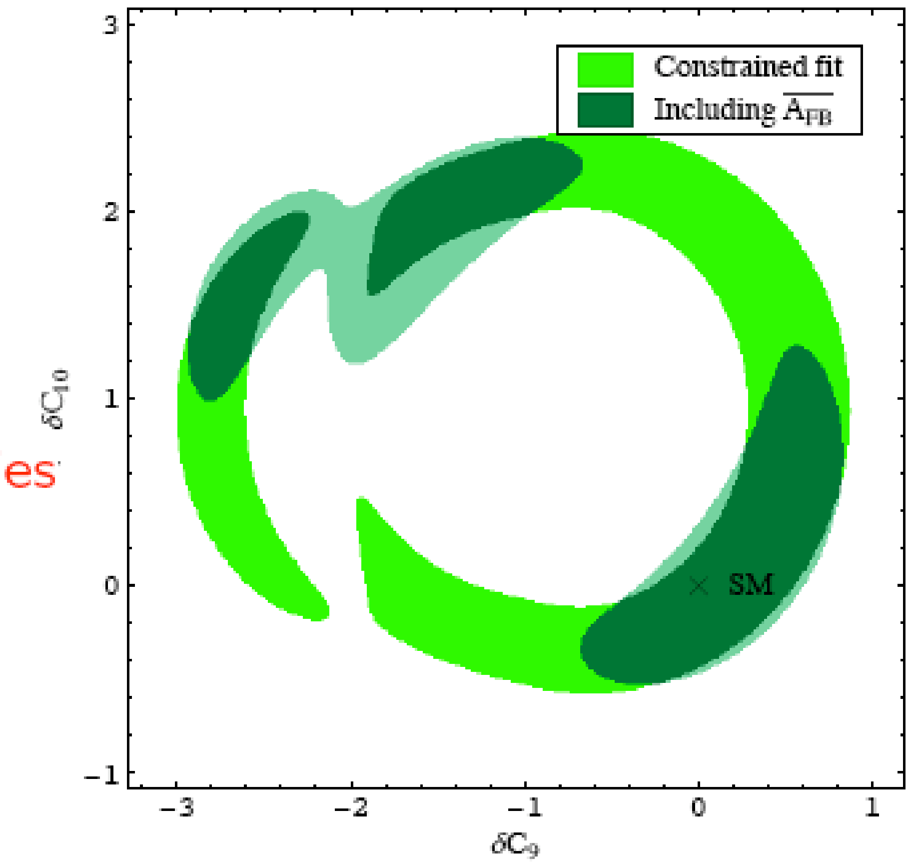
Forward-backward asymmetry: New measurements of Babar and Belle



Babar FPCP 2008

Belle ICHEP 2008

Impact on MFV constraints



(only Babar data included yet)

Hurth,Isidori,Kamenik,Mescia,arXiv:0807.5039

LO: Zero free from hadronic uncertainties

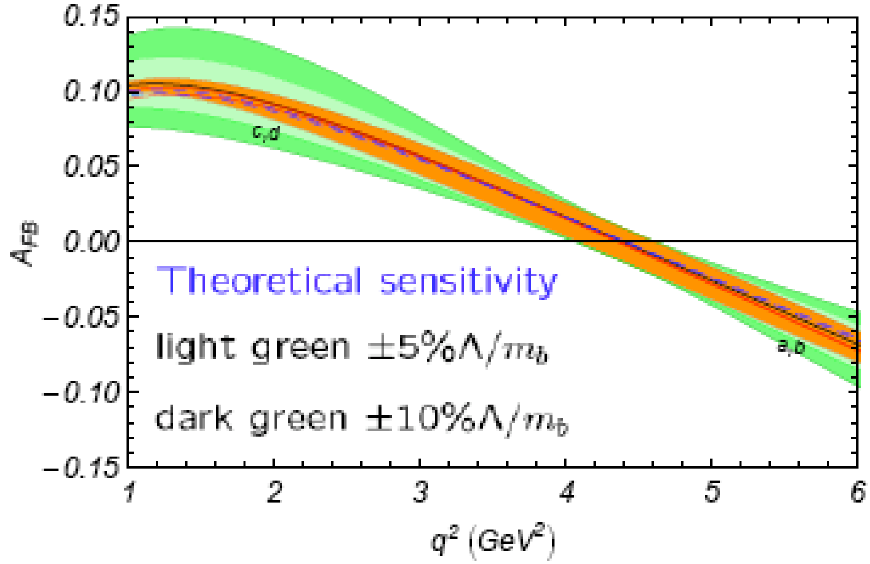
NLO contribution within QCDf

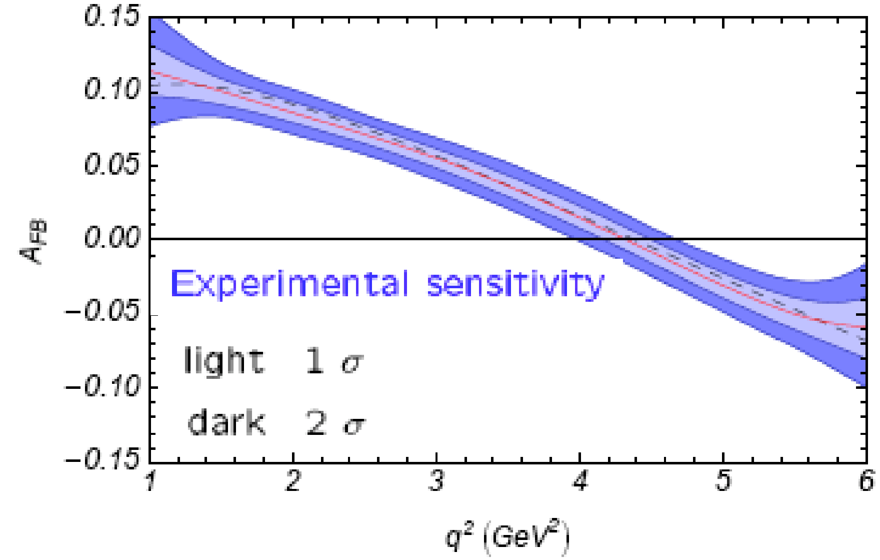
Beneke,Feldmann,Seidel,hep-ph/0412400

Issue of Λ/m_b corrections

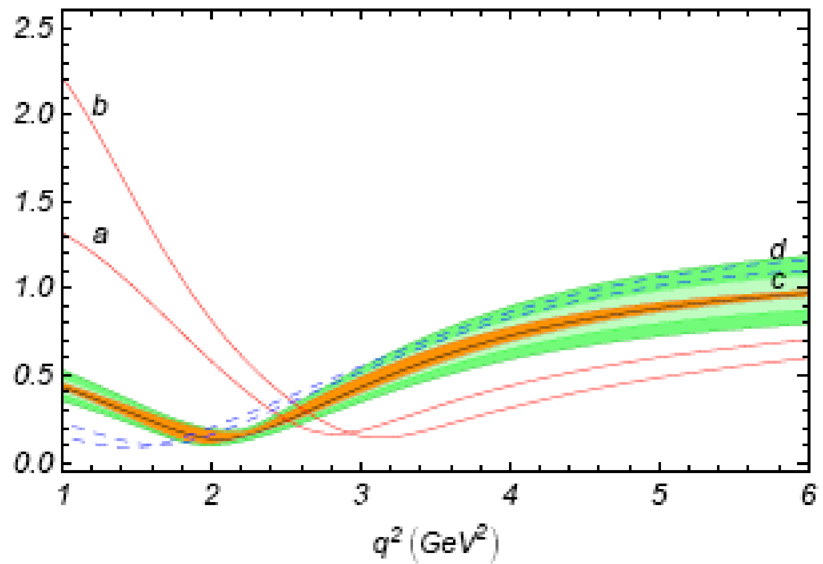
Egede,Hurth,Matias,Ramon,Reece, arXiv:0807.2589

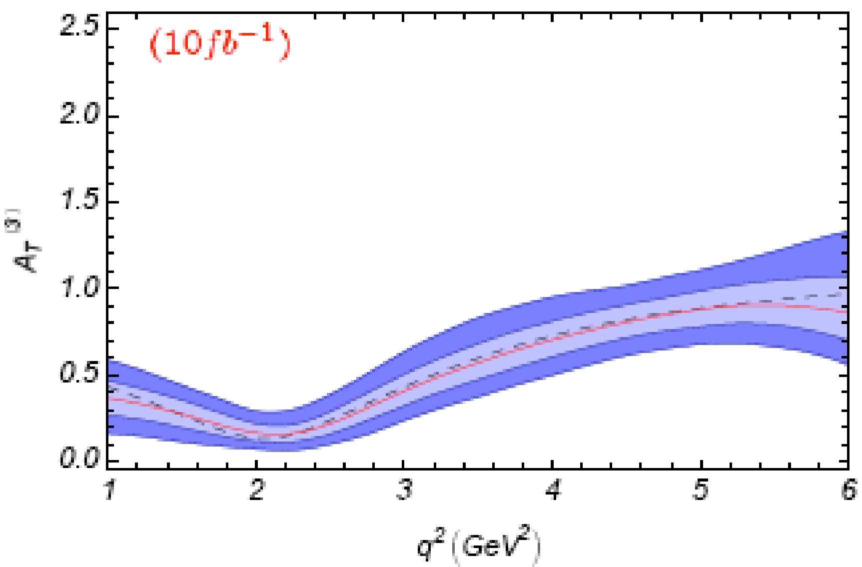
LHCb ($10fb^{-1}$) will clarify the situation





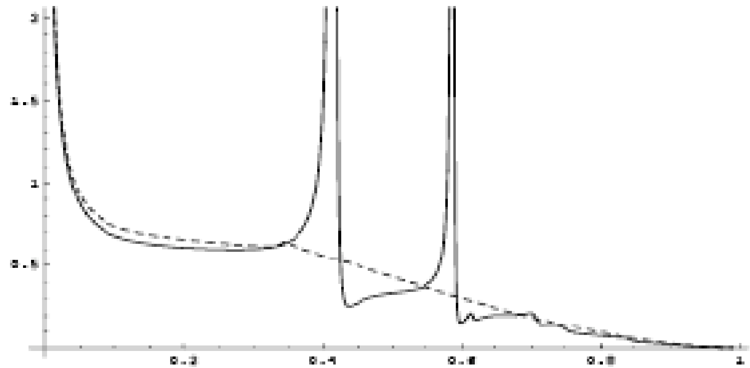
Full angular fit: many theoretical clean observables accessible for LHCb





- Inclusive $b \to s\ell^+\ell^-$

$\frac{d}{d\hat{s}} BR(\bar{B} \to X_s l^+ l^-) \times 10^{-5}$



$\hat{s} = q^2/m_b^2$

NNLL prediction of $\bar{B} \to X_s\ell^+\ell^-$: dilepton mass spectrum
Asatryan,Asatrian,Greub,Walker, hep-ph/0204341;
Ghinculov,Hurth,Isidori,Yao hep-ph/0312128:

NNLL QCD corrections $q^2 \in [1GeV^2, 6GeV^2]$

central value: -14%, perturbative error: $13\% \to 6.5\%$

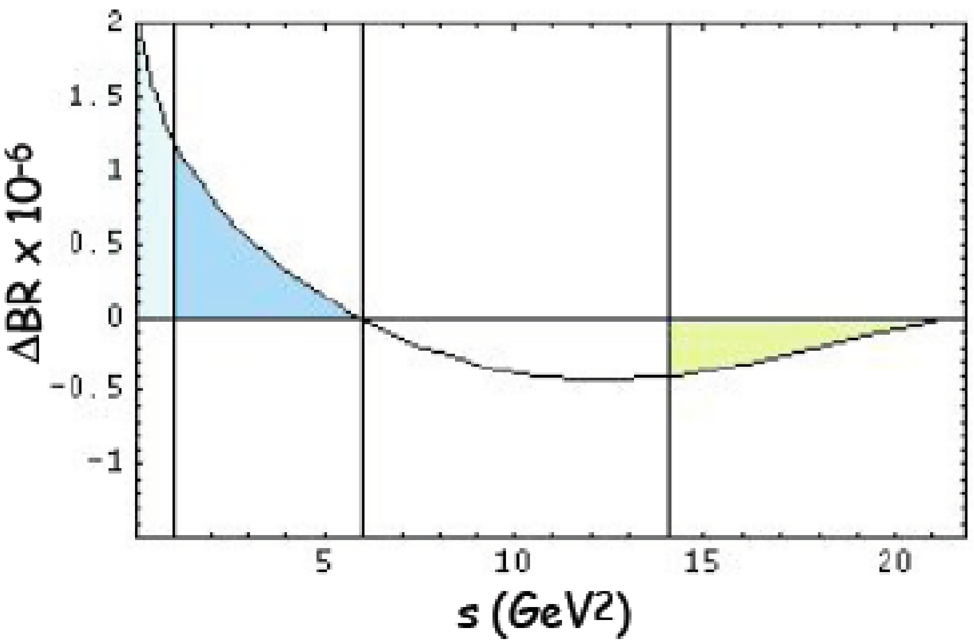
NNLL prediction of $\bar{B} \to X_s\ell^+\ell^-$: forward-backward-asymmetry (FBA)
Asatrian, Bieri, Greub, Hovhannisyan, hep-ph/0209006;
Ghinculov,Hurth,Isidori,Yao, hep-ph/0208088, hep-ph/0312128:

Update with electromagnetic corrections for dilepton mass spectrum
and FBA including the high-q^2 region Huber,Hurth,Lunghi arXiv/0712.3009[hep-ph]

Electromagnetic corrections

Huber,Hurth,Lunghi arXiv/0712.3009[hep-ph]

- Focus on corrections to the Wilson coefficients which are enhanced by a large logarithm $\alpha_{em} Log(m_W/m_b)$
- Corrections to matrix elements lead to large collinear logarithm $Log(m_b/m_\ell)$ which survive intregration if a restricted part of the dilepton mass spectrum is considered
  - $+2\%$ effect in the low-q^2 region for muons, for the electrons the effect depends on the experimental cut parameters:
  - Note that the coefficient of this logarithm vanishes when integrated over the whole spectrum



$\Rightarrow$ Relative effect of this logarithm in the high-q^2 region much larger : we find -8% !

- Our theory predictions correspond to a Super-B measurement not to the present Babar/Belle set-up see Huber,Hurth,Lunghi, arXiv:0807.1940 [hep-ph]

Further refinements:

Recent proposal: normalization to semileptonic $B \to X_u \ell \nu$ decay rate with the same cut reduces the impact of $1/m_b$ corrections in the high-q^2 region significantly. Ligeti, Tackmann, hep-ph/0707.1694

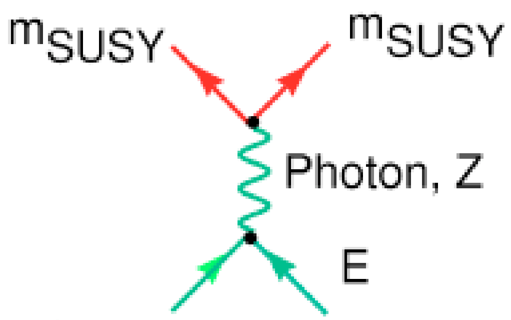
Hadronic invariant-mass cut is imposed in order to eliminate the background like $b \to c\,(\to s e^+ \nu) e^- \bar{\nu} = b \to s e^+ e^- +$ missing energy Lee, Stewart, hep-ph/0511334

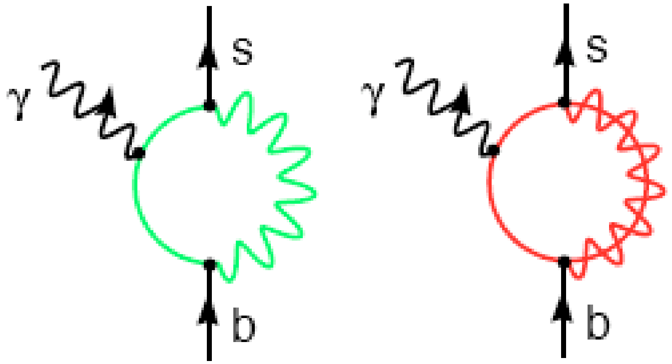
Additional $O(5\%)$ uncertainty due to nonlocal power corrections $O(\alpha_s \Lambda / mb)$

Third independent combination of Wilson coefficents in $\bar{B} \to X_s \ell^+ \ell^-$ $(z = cos\theta)$

$$\frac{d^2\Gamma}{dq^2\,dz} = 3/8\,\left[(1+z^2)\,H_T(q^2) + 2\,z\,H_A(q^2) + 2\,(1-z^2)\,H_L(q^2)\right]$$

$$\frac{d\Gamma}{dq^2} = H_T(q^2) + H_L(q^2)\,, \qquad \frac{dA_{\rm FB}}{dq^2} = 3/4\,H_A(q^2)$$





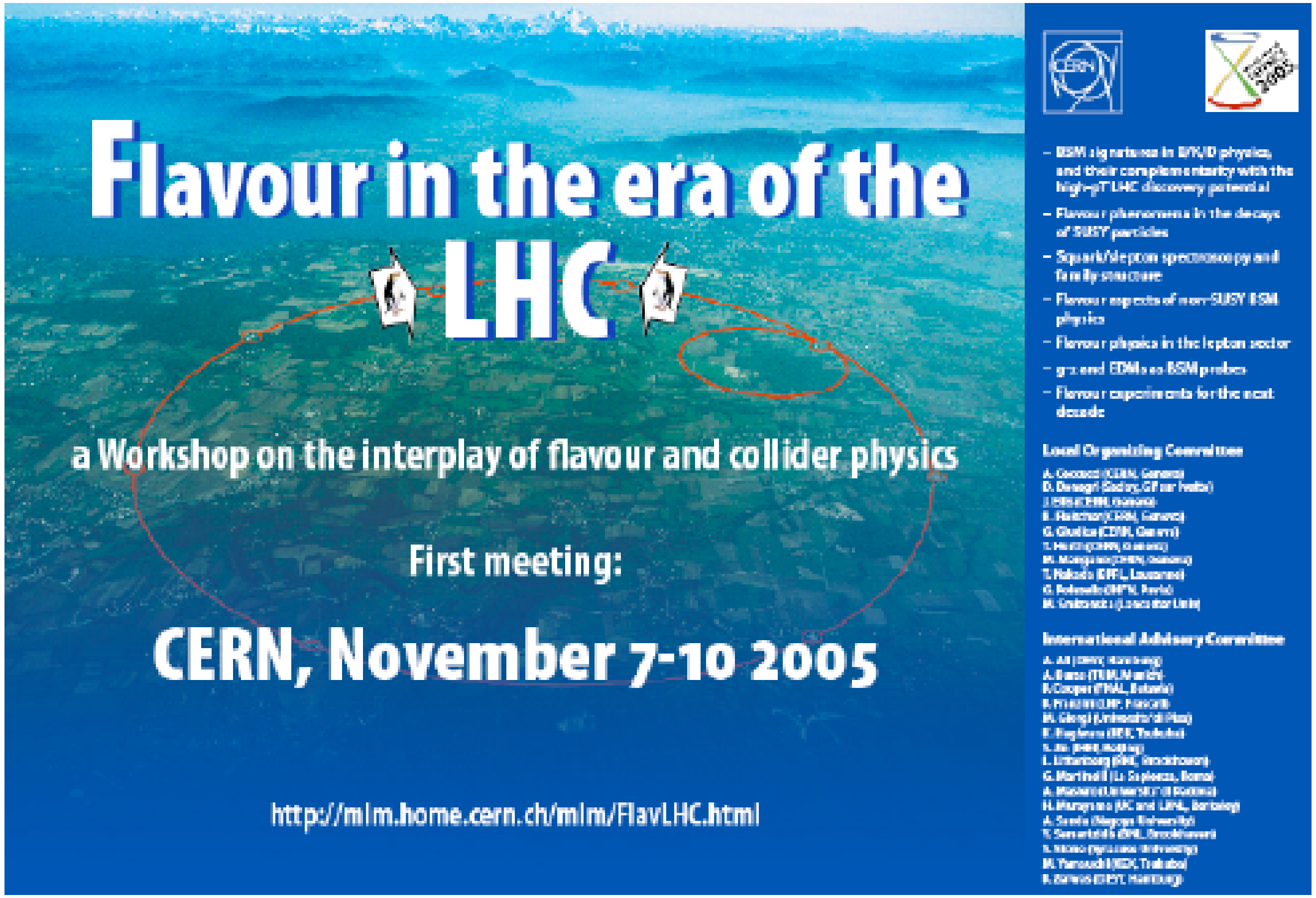
The indirect information will be most valuable when the general nature of new physics will be identified in the direct search.

Immense potential for synergy and complementarity between high-p_T and flavour physics within the search for new physics

Flavour@high-p_T

⇒ CERN workshop on the interplay of flavour and collider physics

Fleischer,Hurth,Mangano see http://mlm.home.cern.ch/mlm/FlavLHC.html



5 meetings between 11/2005 and 3/2007 Yellow Report

arXiv:0801.1800 [hep-ph] “Collider aspects of flavour physics at high Q”

arXiv:0801.1833 [hep-ph] “B, D and K decays”

arXiv:0801.1826 [hep-ph] “Flavour physics of leptons and dipole moments”

published in EPJC 57 (2008) 1-492

Follow-up workshop:

Working Group on the Interplay Between Collider and Flavour Physics

The working group addresses the complementarity and synergy between the LHC and the flavour factories within the new physics search. New collaborations on this topic were triggered by the two recent CERN workshop series Flavour in the Era of the LHC and CP Studies and Non–Standard Higgs Physics at the border line of collider and flavour physics and experiment and theory. This follow–up working group wants to provide a continuous framework for such collaborations and trigger new research work in this direction. Regular meetings at CERN (well–connected by VRVS) are planned in the near future.

https://twiki.cern.ch/twiki/bin/view/Main/ColliderAndFlavour

Kick-off meeting 3.-4.December 2007 at CERN

http://indico.cern.ch/conferenceDisplay.py?confId=22180

Next meeting 16.-18. of March 2009 at CERN

Please feel cordially invited !

Possible future scenarios:

A couple of years after the start of the LHC, may be

1. many new degrees of freedom discovered at ATLAS and CMS, and new FCNCs at LHCb

2. many new particles discovered at ATLAS and CMS, but no new FCNCs at LHCb $\Rightarrow$ important input to understand the New Physics

3. No new particles discovered at ATLAS and CMS (except one Higgs), but new FCNCs at LHCb $\Rightarrow$ tells us something about the mass scale to aim at (modulo flavour problem)

4. ....

5. ....

Note: With flavour observables we measure c_i^{New}/Λ_{NP} :

c_i^{New} may be constrained by symmetry, may depend on different interactions

Extra

 Quark flavour at ATLAS/CMS

- Probing MFV at the LHC   Grossman,Nir,Thaler,Volansky,Zupan,arXiv:0706.1845

MFV: all flavour violation is governed by Yukawa/CKM structures

To an accuracy of $\mathcal{O}(0.05)$ $$V_{\rm LHC}^{\rm CKM} = \begin{pmatrix} 1 & 0.23 & 0 \\ -0.23 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}.$$

New particles (i.e. heavy vector-like quarks) that couple to the SM quarks decay to either 3rd generation quark, or to non-3rd generation quark, but not to both.

If ATLAS/CMS measures $BR(q_3) \sim BR(q_{1,2})$ then this excludes MFV.

MFV prediction for events with B' pair production:

$$\frac{\Gamma(B'\overline{B'} \to X q_{1,2} q_3)}{\Gamma(B'\overline{B'} \to X q_{1,2} q_{1,2}) + \Gamma(B'\overline{B'} \to X q_3 q_3)} \lesssim 10^{-3}$$

Flavour tagging efficiencies are crucial.

- Flavour-violating squark and gluino decays

Hurth,Porod,hep-ph/0311075
arXiv:0801.1833

Squark decays: $\tilde{u}_i \to u_j \tilde{\chi}^0_k \, , \, d_j \tilde{\chi}^+_l \qquad \tilde{d}_i \to d_j \tilde{\chi}^0_k \, , \, u_j \tilde{\chi}^-_l$

These tree decays are governed by the same mixing matrices as the contributions to flavour violating low-energy observables.

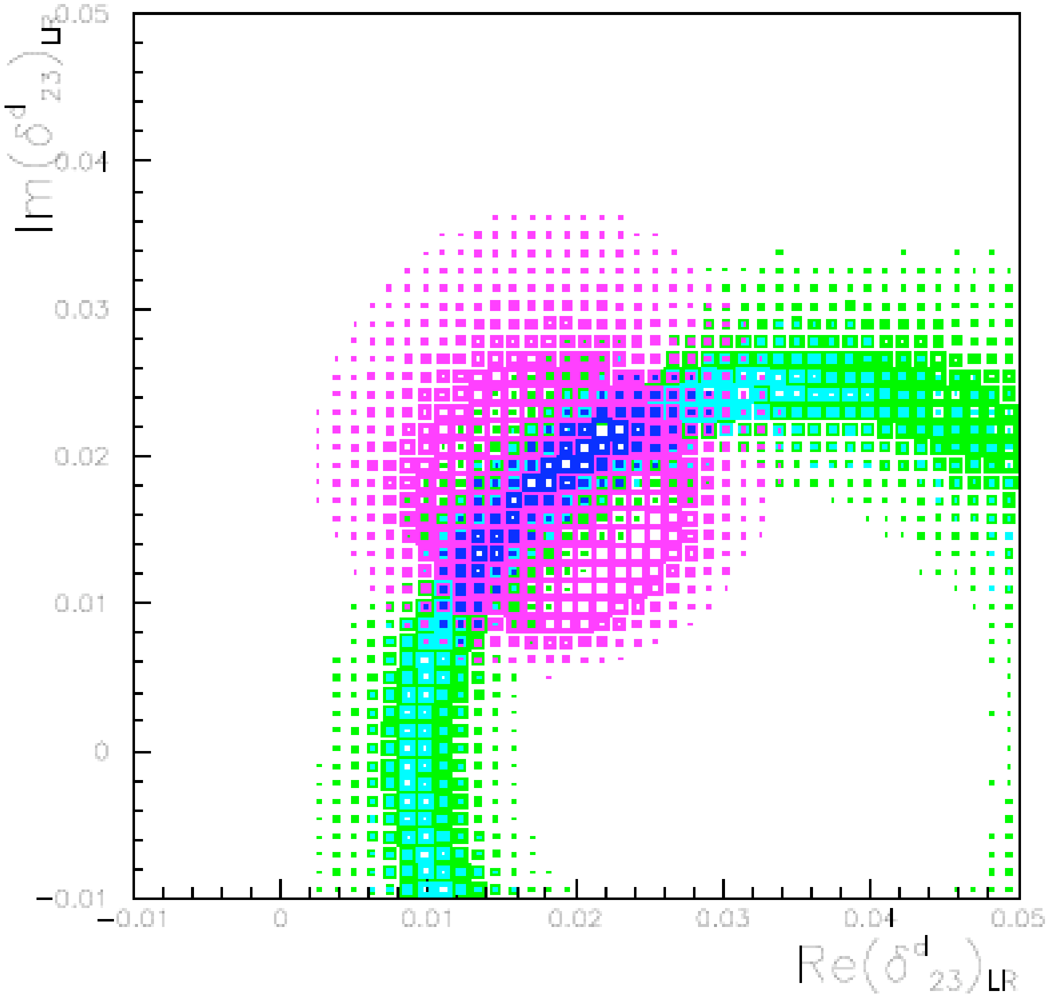
Squarks can have large flavour-violating decay modes ($10\% - 20\%$), which are compatible with present constraints from flavour physics.

Again: flavour-tagging at LHC important, but difficult

This can complicate determination of sparticle masses: $\tilde{g} \to b \tilde{b}_j \to b \bar{b} \tilde{\chi}^0_k$

Sensitivity of Superflavour factory:

Browder, Ciuchini, Gershon, Hazumi, H., Okada, Stocchi arXiv:0710.3799



Flavour-violating parameter $Re(\delta^d_{23})_{LR} \times Im(\delta^d_{23})_{LR}$

Fig. 8: Density plot of the region in the $\mathrm{Re}(\delta^d_{23})_{LR}$–$\mathrm{Im}(\delta^d_{23})_{LR}$ for $m_{\tilde{q}} = m_{\tilde{g}} = 1$ TeV generated using SFF measurements. Different colours correspond to different constraints: $\mathcal{B}(B \to X_s\gamma)$ (green), $\mathcal{B}(B \to X_s\ell^+\ell^-)$ (cyan), $A_{CP}(B \to X_s\gamma)$ (magenta), all together (blue). Central values of constraints corresponds to assuming $(\delta^d_{23})_{LR} = 0.028e^{i\pi/4}$.

Flavour-violating parameter $Re(\delta^d_{13})_{LL} \times Im(\delta^d_{13})_{LL}$

Bona et al.,arXiv:0709.0451

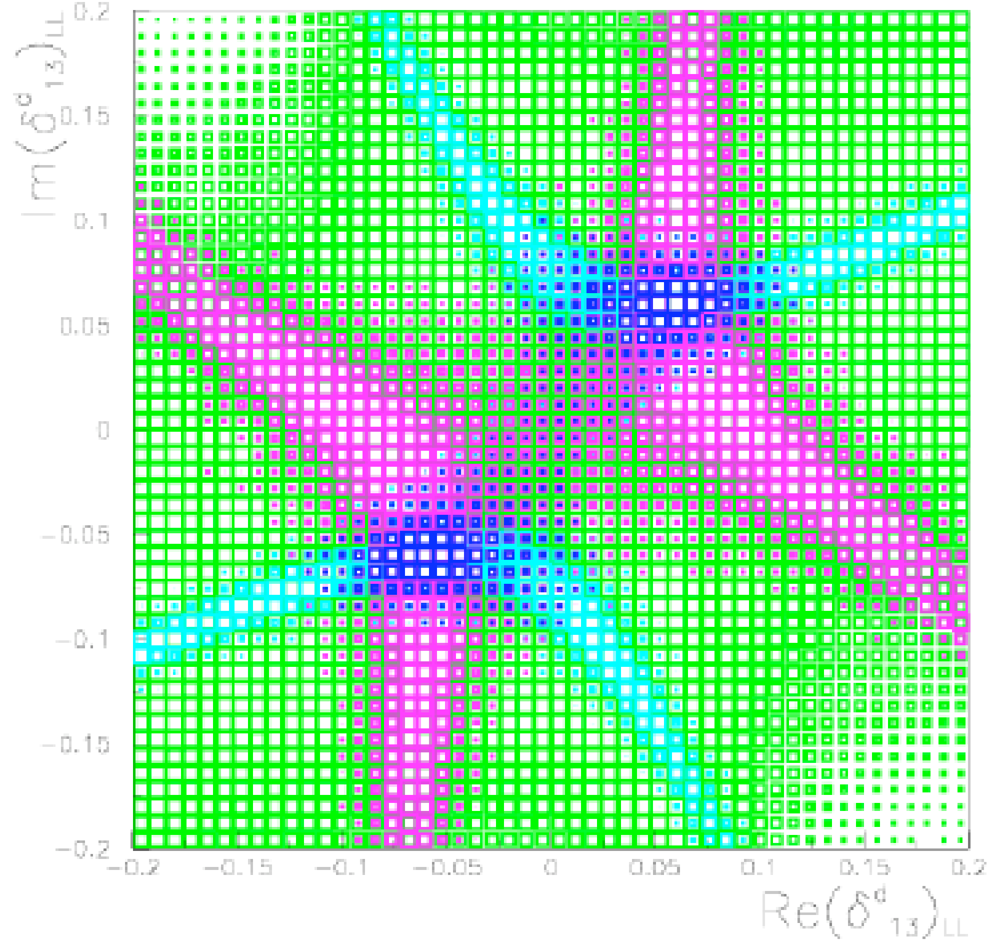
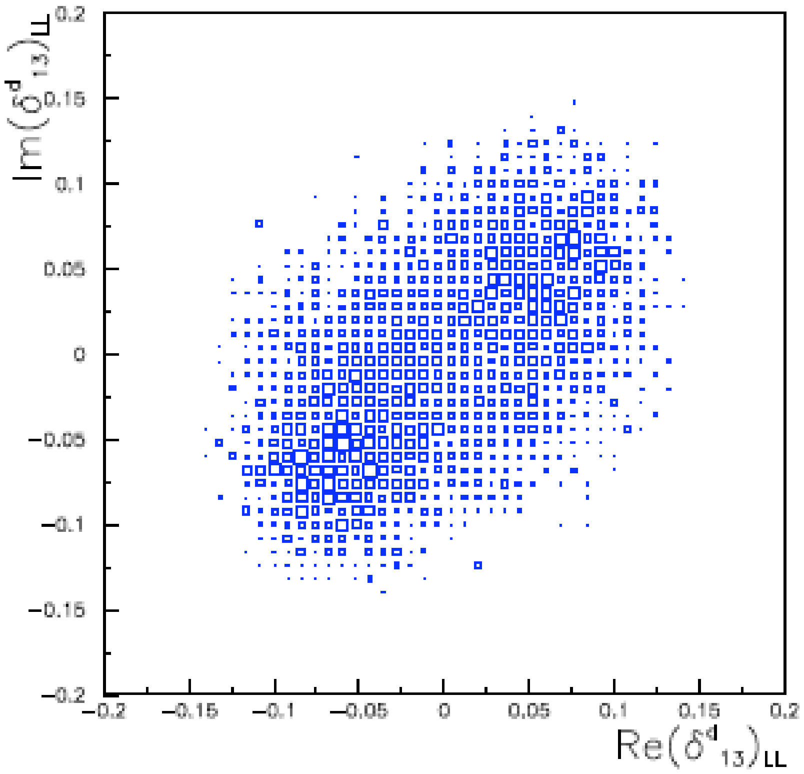


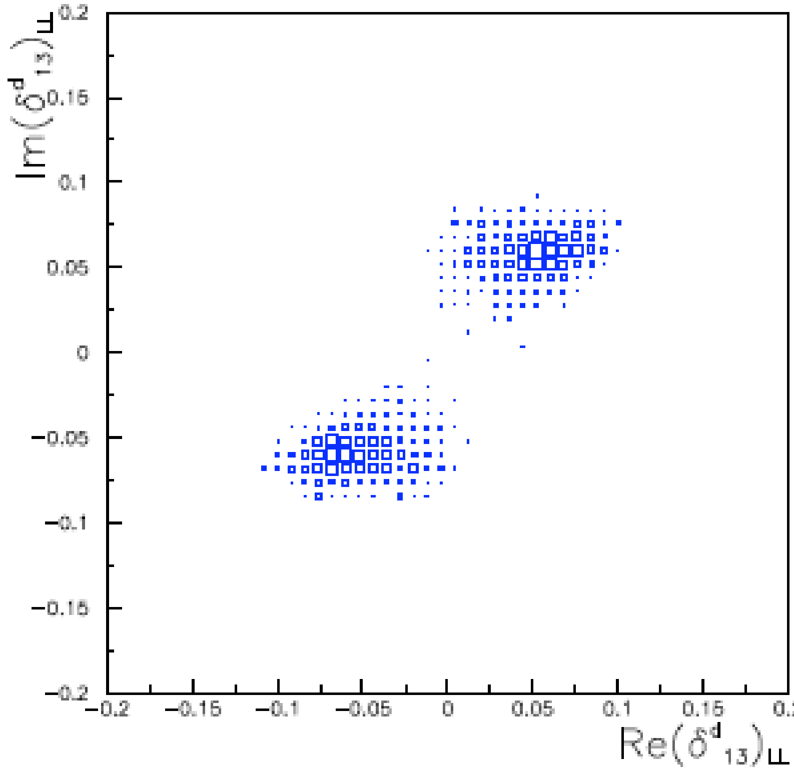
Figure 2-13. *Density plot of the selected region in the* Re $(\delta^d_{13})_{LL}$–Im $(\delta^d_{13})_{LL}$ *for* $m_{\tilde{q}} = m_{\tilde{g}} = 1$ TeV *and* $(\delta^d_{13})_{LL} = 0.085e^{i\pi/4}$ *using* Super*B measurements. Different colours correspond to different constraints:* $A^d_{\rm SL}$ *(green),* β *(cyan),* Δm_d *(magenta), all together (blue).*

Hitlin et al.,arXiv:0810.1312

Comparison

$10ab^{-1}$ $50ab^{-1}$





$Re(\delta^d_{13})_{LL} \times Im(\delta^d_{13})_{LL}$