Rare B decays and Universal Extra Dimensions

Flavour in the era of the LHC
9-11 October 2006

Fulvia De Fazio
INFN-Bari

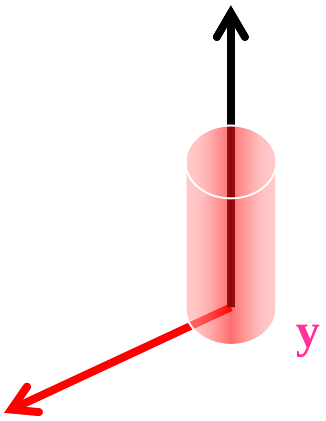
- Brief introduction to extra dimensions
- Universal Extra Dimensions: the ACD model
- Consequences on rare FCNC B decays
- Conclusions and perspectives

Based on P. Colangelo, R. Ferrandes, T.N. Pham, FDF,
PRD73 (06) 115006
and
hep-ph/0610044 (October 06)

Extra dimensions

Assume the space-time described by the usual (1+3) dims x^{μ} + other extra dimensions ⇒ the whole is ***the bulk***

We do not observe extra dimensions ⇒ maybe they are compactified



→ Curved compactification

Why extra dimensions?

- Address the hierarchy problem
- Produce EW symmetry breaking without the Higgs boson
- Provide new dark matter candidates
- Coupling unification
- ….

Arkani-Hamed, Dimopoulos, Dvali
Antoniadis
Randall, Sundrum
Dienes, Dudas, Gherghetta
…

Several scenarios:

- **Large extra dimensions** Arkani-Hamed, Dimopoulos, Dvali
- **Warped extra dimensions** Randall, Sundrum

} I will not discuss these

- **Universal extra dimensions** Appelquist, Cheng, Dobrescu

A single compact extra dimension

In 5D consider the 5th dimension (y) compactified on a circle of radius R $-\pi R \leq y \leq \pi R$

with periodic boundary conditions (geometry= unidimensional sphere S^1)

⇒ fields are periodic functions in y

$$F(x,y) = \sum_{n=-\infty}^{\infty} F_n(x) e^{i\frac{n \cdot y}{R}}$$

Equation of motion: $(\partial_\mu \partial^\mu - \partial_y \partial^y) F(x,y) = 0 \quad \Rightarrow$

$$\left(\partial_\mu \partial^\mu + \frac{n^2}{R^2} \right) F_n(x) = 0$$

$$m_n = \frac{n}{R}$$

→ **Tower of states**

n=0: zero modes - ordinary particles

n≠0: Kaluza Klein excitations (KK)

Universal extra dimensions

Appelquist, Cheng, Dobrescu
PRD 64 (01) 035002

Universal Extra Dimensions are compact dimensions accessible to all SM particles

KK parity $(-1)^j$ (j=KK number) conservation in the equivalent 4D theory

no vertices involving a single non zero KK mode

→ no tree level contribution to the EW observables

non zero KK modes may be produced at colliders only in groups of 2 or more

Present bounds from EW data analysis and direct production

$$\frac{1}{R} \geq \begin{cases} 250 \quad \text{GeV} \quad (M_H > 250 \quad \text{GeV}) \\ 300 \quad \text{GeV} \quad (M_H < 250 \quad \text{GeV}) \end{cases}$$

Appelquist-Cheng-Dobrescu model (ACD) with a single ED

A single additional free parameter: $\frac{1}{R}$

- Minimal extension of the SM in 4+1 dimensions containing:

  - KK excitations of the SM fields
  - KK modes having no SM partner

- Gauge group $SU(3)_c \times SU(2)_L \times U(1)_Y$

- gauge couplings $\rightarrow$ $\hat{g} = g\sqrt{2\pi R}$

The ACD model belongs to the class of ***Minimal Flavour Violation***
since there are neither new operators with respect to the SM, nor new phases beyond the CKM phase

Appelquist-Cheng-Dobrescu model (ACD) with a single ED

Combine the geometry S^1 with a parity operation for $y \in [-\pi R, \pi R]$: $Z_2 : y \to -y$

Require that fields have definite behaviour under the corresponding parity operation P_5

Even fields

$$F(x,y) = \frac{1}{\sqrt{2\pi R}} F_{(0)}(x) + \frac{1}{\sqrt{\pi R}} \sum_{n=1}^{\infty} F_{(n)}(x) \cos\left(\frac{ny}{R}\right)$$

There is a zero mode

Odd fields

$$F(x,y) = \frac{1}{\sqrt{\pi R}} \sum_{n=1}^{\infty} F_{(n)}(x) \sin\left(\frac{ny}{R}\right)$$

no zero mode

SM fields (zero KK modes)

Corresponding non-zero KK modes

} **Even under P_5**

Additional physical scalars (KK modes starting from n=1)
No zero mode!

} **Odd under P_5**

Universal extra dimensions: signatures at hadron colliders

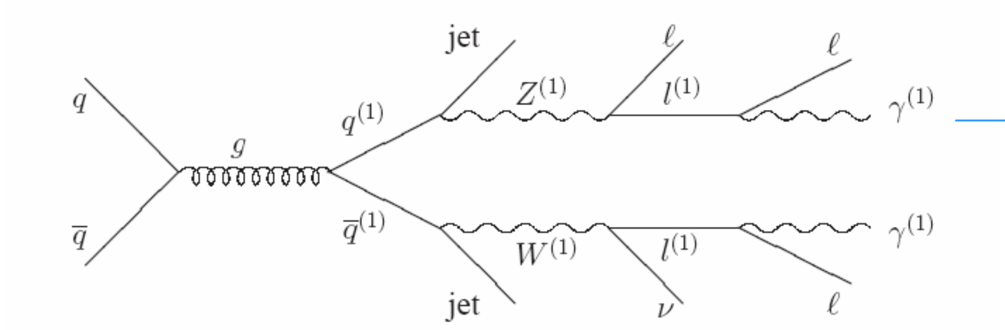
Discovery of KK modes

Since masses are roughly $\approx \frac{n}{R}$ particles with $n \geq 3$ would be very heavy and hence difficult to detect

→ look for modes with n=1 and n=2

1-modes

May be produced in pairs at colliders



→ Escapes the detection
Good dark matter candidate

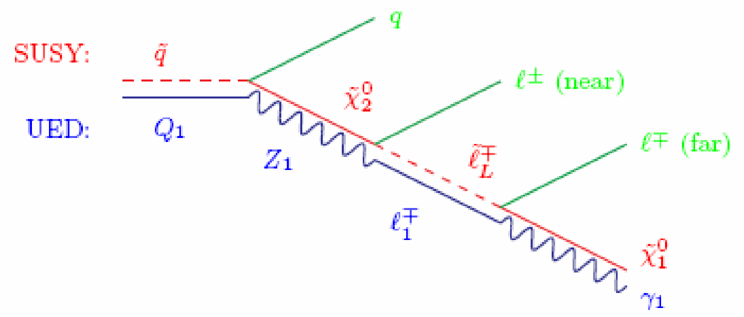
Problem: how to distinguish these processes from SUSY :
1-modes are analogous to superpartners in SUSY
(KK parity resambles R parity …)

Comparison of UED and SUSY

	SUSY	UED
Number of predicted partners	1 superpartner for each SM particle	A tower of KK states (though cross sections for the production of higher modes are kinematically suppressed)
Spin of partners	Differs of ½	SM particles and their KK partners have the same spin
Couplings	the same as for SM particles	the same as for SM particles
Collider signature	missing energy (In models with a WIMP LSP)	missing energy

Common features

Example: twin processes



SUSY: $\tilde{q} \to q\tilde{\chi}_2^0 \to q\ell^{\pm}\tilde{\ell}^{\mp} \to q\ell^{+}\ell^{-}\tilde{\chi}_1^0$

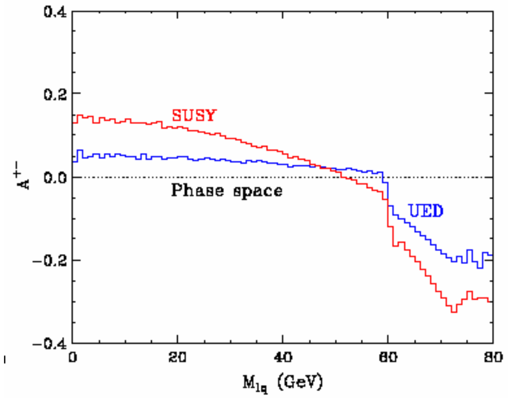
UED: $Q_1 \to qZ_1 \to q\ell^{\pm}\tilde{\ell}_1^{\mp} \to q\ell^{+}\ell^{-}\gamma_1$

In both cases the observed final state is the same $q\ell^{+}\ell^{-}\not{E}_T$

Barr, PLB 596 (04) 205
Datta et al., PRD 72 (05) 096006
Smillie and Webber, JHEP 510 (05) 69

Proposal

consider the charge asymmetry $A^{+-} = \frac{s^{+} - s^{-}}{s^{+} + s^{-}}$ $\quad s^{\pm} = \frac{d\sigma}{d(m_{\ell_{\pm}q})}$



The shape is slightly different in the two cases

challenging!

Are FCNC rare B decays sensitive to UED?

FCNC rare B decays offer the opportunity to reveal new physics before gaining direct evidence since they are loop-induced processes and hence

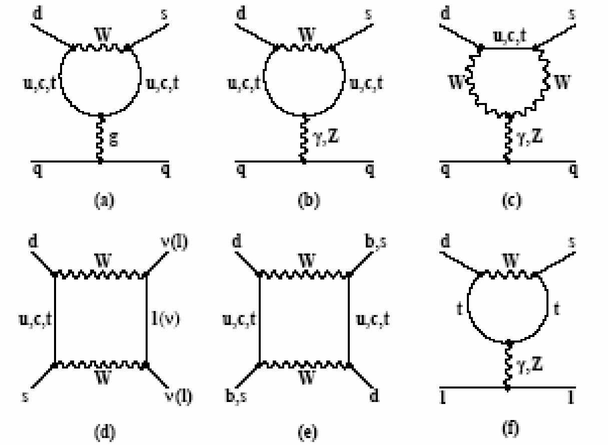
- suppressed in the SM
- sensitive to the contribution of new particles circulating in the loops

I consider:

$$B \to K^{(*)}\ell^+\ell^- , \quad B \to K^{(*)}\tau^+\tau^-$$

$$B \to K^*\gamma , \quad B \to K^{(*)}\nu\nu$$

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



In the SM, the effective hamiltonian for $b \to s\ell^+\ell^-$ is:

$$H_W = 4\frac{G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_{i=1}^{10} C_i(\mu) O_i(\mu)$$

$$O_1 = (\bar{s}_{L\alpha}\gamma^\mu b_{L\alpha})(\bar{c}_{L\beta}\gamma_\mu c_{L\beta})$$
$$O_2 = (\bar{s}_{L\alpha}\gamma^\mu b_{L\beta})(\bar{c}_{L\beta}\gamma_\mu c_{L\alpha})$$

Current-current operators – do not contribute if one neglects long distance effects

$$O_3 = (\bar{s}_{L\alpha}\gamma^\mu b_{L\alpha})[(\bar{u}_{L\beta}\gamma_\mu u_{L\beta}) + ... + (\bar{b}_{L\beta}\gamma_\mu b_{L\beta})]$$
$$O_4 = (\bar{s}_{L\alpha}\gamma^\mu b_{L\beta})[(\bar{u}_{L\beta}\gamma_\mu u_{L\alpha}) + ... + (\bar{b}_{L\beta}\gamma_\mu b_{L\alpha})]$$
$$O_5 = (\bar{s}_{L\alpha}\gamma^\mu b_{L\alpha})[(\bar{u}_{R\beta}\gamma_\mu u_{R\beta}) + ... + (\bar{b}_{R\beta}\gamma_\mu b_{R\beta})]$$
$$O_6 = (\bar{s}_{L\alpha}\gamma^\mu b_{L\beta})[(\bar{u}_{R\beta}\gamma_\mu u_{R\alpha}) + ... + (\bar{b}_{R\beta}\gamma_\mu b_{R\alpha})]$$

QCD penguins - have small Wilson coefficients

$$O_7 = \frac{e}{16\pi^2}\left[m_b(\bar{s}_{L\alpha}\sigma^{\mu\nu} b_{R\alpha}) + m_s(\bar{s}_{R\alpha}\sigma^{\mu\nu} b_{L\alpha})\right] F_{\mu\nu}$$
$$O_8 = \frac{g_s}{16\pi^2} m_b \left[\bar{s}_{L\alpha}\sigma^{\mu\nu}\left(\frac{\lambda^a}{2}\right)_{\alpha\beta} b_{R\beta}\right] G^a_{\mu\nu}$$

magnetic penguins - O_7 induces $B \to K^*\gamma$

$$O_9 = \frac{e^2}{16\pi^2}(\bar{s}_{L\alpha}\gamma^\mu b_{L\alpha})\ \bar{\ell}\gamma_\mu \ell$$
$$O_{10} = \frac{e^2}{16\pi^2}(\bar{s}_{L\alpha}\gamma^\mu b_{L\alpha})\ \bar{\ell}\gamma_\mu\gamma_5 \ell$$

Semileptonic EW penguins

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

No other operators appear in the effective hamiltonian in the ACD model.
The values of the Wilson coefficients are modified because particles not present in the SM can contribute as intermediate states in penguing and box diagrams.
The resulting Wilson coefficients are functions of 1/R and of the top mass $x_t = \frac{m_t^2}{M_W^2}$

$$C\left(x_t, \frac{1}{R}\right) = C_{(0)}(x_t) + \sum_{n=1}^{\infty} C_n(x_t, x_n) \qquad x_n = \frac{m_n^2}{M_W^2}$$

A.J. Buras et al. NPB 660 (03) 225
NPB 678 (04) 455

SM result

The sum over infinite tower of states is finite!!

The main effect of KK contribution consists in the enhancement of C_{10} and the suppression of C_7

A lower bound on 1/R might be established studying various observables in $B \to K^{(*)}\ell^+\ell^-$ (as well as in the modes to be considered afterwards)

Inclusive modes

A.J. Buras et al. NPB 660 (03) 225
NPB 678 (04) 455

UED have an important impact on inclusive BR.
For example, for $\frac{1}{R} = 300$ GeV it is found that there is

- enhancement of $BR(B \to X_s \mu^+ \mu^-)$ by $12\,\%$
  $BR(B \to X_s \nu \bar{\nu})$ by $22\,\%$

- suppression of $BR(B \to X_s \gamma)$ by $20\,\%$

- sizable downward shift in the forward backward asymmetry in $BR(B \to X_s \mu^+ \mu^-)$

The comparison of $BR(B \to X_s \gamma)$ with exp data allows to bound $\frac{1}{R} \geq 250$ GeV

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

- theoretically less clean than inclusive modes (requires $B \to K^{(*)}$ form factors)
- experimentally easier to detect

$$< K(p')|\bar{s}\gamma_\mu b|B(p) >= (p+p')_\mu F_1(q^2) + \frac{M_B^2 - M_K^2}{q^2} q_\mu \left(F_0(q^2) - F_1(q^2)\right)$$

$$< K(p')|\bar{s}\ i\ \sigma_{\mu\nu}q^\nu b|B(p) >= \left[(p+p')_\mu q^2 - (M_B^2 - M_K^2)q_\mu\right] \frac{F_T(q^2)}{M_B + M_K}$$

$$< K^*(p',\epsilon)|\bar{s}\gamma_\mu(1-\gamma_5)b|B(p) >= \epsilon_{\mu\nu\alpha\beta}\epsilon^{*\nu}p^\alpha p'^\beta \frac{2V(q^2)}{M_B + M_{K^*}}$$

$$- \ i\left[\epsilon^*_\mu(M_B + M_{K^*})A_1(q^2) - (\epsilon^*\cdot q)(p+p')_\mu \frac{A_2(q^2)}{(M_B + M_{K^*})} - (\epsilon^*\cdot q)\frac{2M_{K^*}}{q^2}(A_3(q^2) - A_0(q^2))q_\mu\right]$$

$$< K^*(p',\epsilon)|\bar{s}\sigma_{\mu\nu}q^\nu \frac{(1+\gamma_5)}{2} b|B(p) >= i\epsilon_{\mu\nu\alpha\beta}\epsilon^{*\nu}p^\alpha p'^\beta\ 2\ T_1(q^2) +$$

$$+ \ \left[\epsilon^*_\mu(M_B^2 - M_{K^*}^2) - (\epsilon^*\cdot q)(p+p')_\mu\right] T_2(q^2) + (\epsilon^*\cdot q)\left[q_\mu - \frac{q^2}{M_B^2 - M_{K^*}^2}(p+p')_\mu\right] T_3(q^2)\ .$$

We choose two sets of form factors, including the relative uncertainties:

3pt QCD sum rules

Light cone sum rules

P. Colangelo et al., PRD 53 (96) 3672

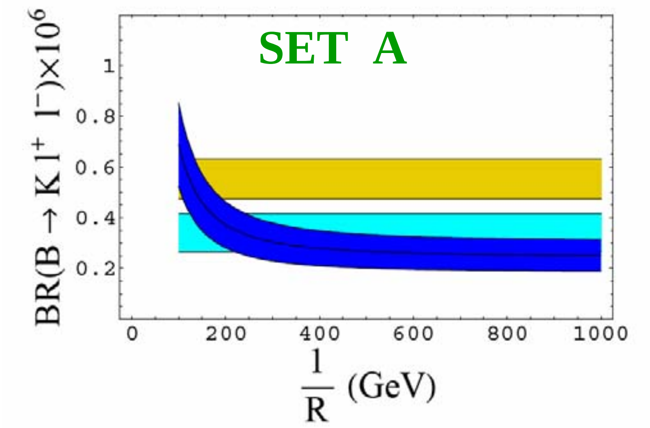
P. Ball and R. Zwicky,
PRD 71 (05) 014015, 014029

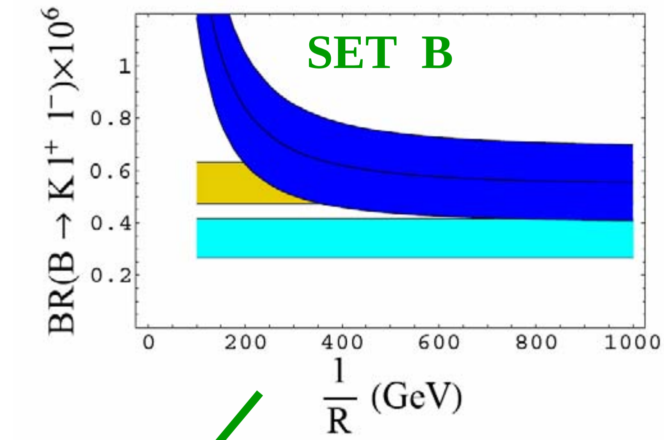
Results

Branching ratio vs 1/R

BELLE BaBar

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



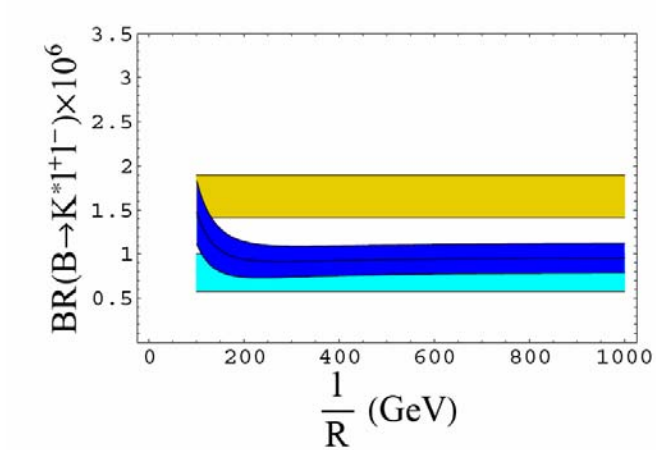


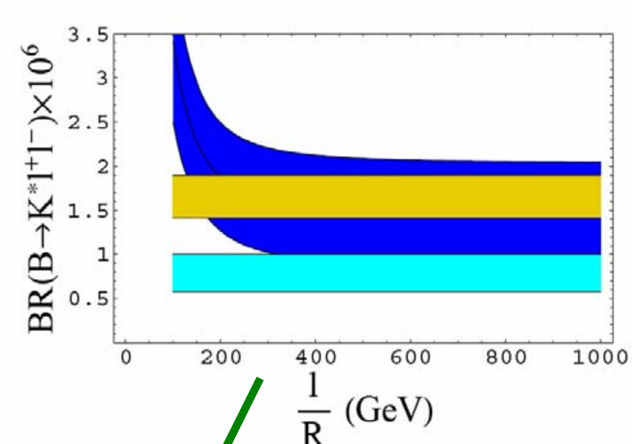
$$B(B \to K\ell^+\ell^-)\Big|_{BELLE} = (5.50 \pm^{0.75}_{0.70} \pm 0.27 \pm 0.02) \times 10^{-7}$$

$$B(B \to K\ell^+\ell^-)\Big|_{BaBar} = (3.4 \pm 0.7 \pm 0.3) \times 10^{-7}$$

This set excludes $\frac{1}{R} \leq 200$ GeV

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





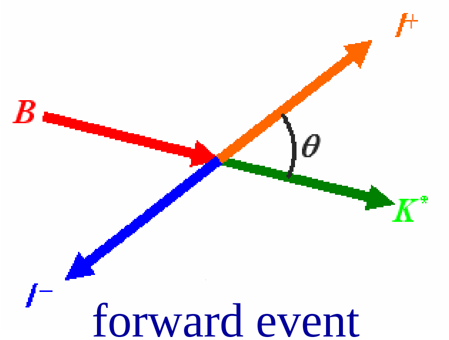
$$B(B \to K\ell^+\ell^-)\Big|_{BELLE} = (16.5 \pm^{2.3}_{2.2} \pm 0.9 \pm 0.4) \times 10^{-7}$$

$$B(B \to K\ell^+\ell^-)\Big|_{BaBar} = (7.8 \pm^{1.9}_{1.7} \pm 1.2) \times 10^{-7}$$

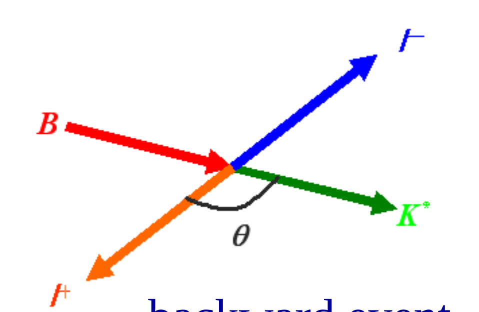
again $\frac{1}{R} \leq 200$ GeV

Forward-backward asymmetry in $B \to K^* \ell^+ \ell^-$

In the rest frame of the (massless) lepton pair



forward event

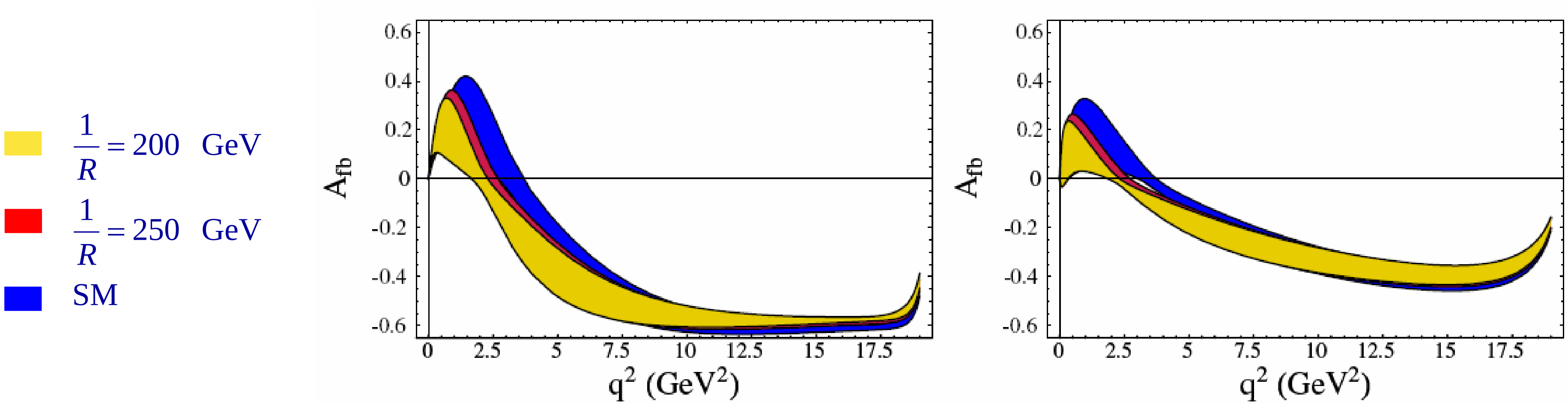


backward event

$$A^{FB}(q^2) = \frac{\int_0^1 \frac{d^2\Gamma}{dq^2 dcos\theta_\ell} dcos\theta_\ell - \int_{-1}^0 \frac{d^2\Gamma}{dq^2 dcos\theta_\ell} dcos\theta_\ell}{\int_0^1 \frac{d^2\Gamma}{dq^2 dcos\theta_\ell} dcos\theta_\ell + \int_{-1}^0 \frac{d^2\Gamma}{dq^2 dcos\theta_\ell} dcos\theta_\ell}$$

In the SM, due to the opposite sign of C_7 and C_9 A_{fb} has a zero.
The position of the zero is almost independent of the form factor model
The presence and the position of the zero may distinguish the different scenarios.
A_{fb} is also sensitive to the value of 1/R

SET A **SET B**



Forward-backward asymmetry in $B \to K^* \ell^+ \ell^-$

The position of the zero is determined by:

$$Re(C_9) + \frac{2m_b}{s} C_7 \left[(M_B + M_{K^*}) \frac{T_1(s)}{V(s)} + (M_B - M_{K^*}) \frac{T_2(s)}{A_1(s)} \right] = 0$$

In the large energy limit of the final light vector meson relations among form factors hold

→ possibility to derive a model independent prediction for the position of the zero

Neglecting $O(\alpha_s)$ effects:

$$\frac{T_1(E)}{V(E)} = \frac{1}{2} \frac{M_B}{M_B + M_{K^*}} \qquad \frac{T_2(E)}{A_1(E)} = \frac{(M_B + M_{K^*})}{2M_B}$$

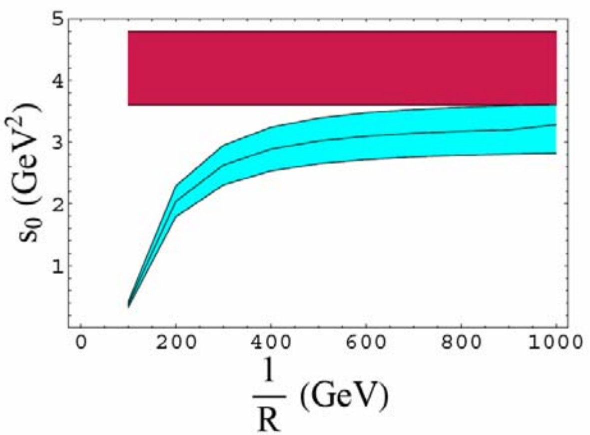
Inclusion of corrections provides the result

$$s_0 = 4.2 \pm 0.6 \quad GeV^2$$

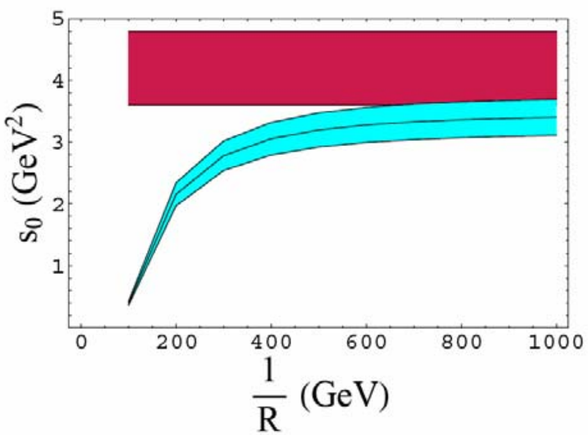
Beneke, Feldmann, Siedel
NPB 612 (01) 25;
EPJ C41 (05) 173

Position of the zero vs 1/R

SET A



SET B

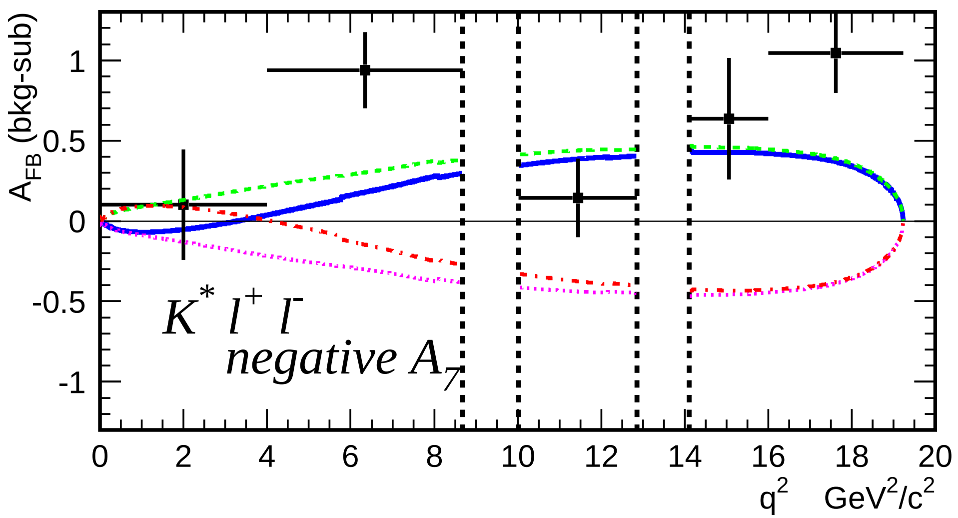


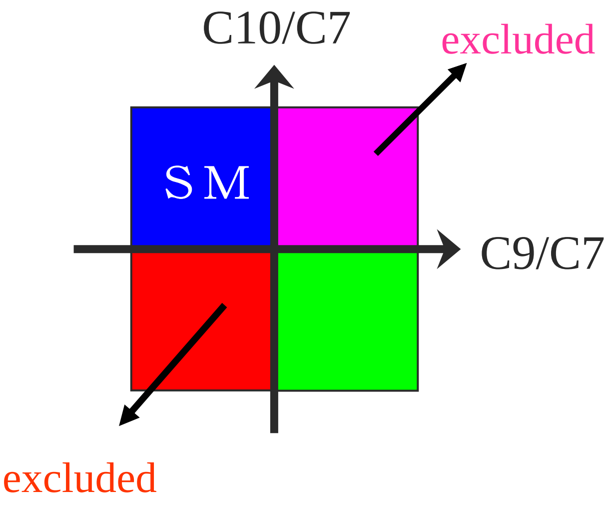
Beneke et al

Forward-backward asymmetry in $B \to K^* \ell^+ \ell^-$

Hishikawa, talk at EPS05

BELLE analysis



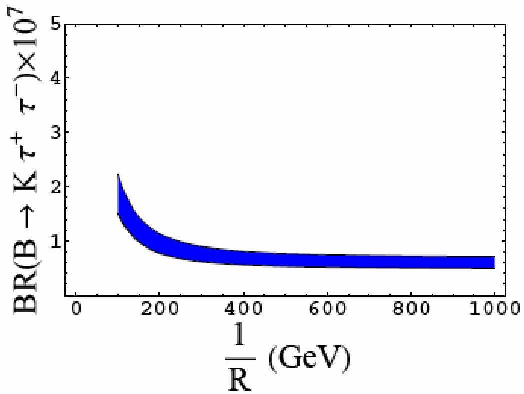


- Large forward-backward asymmetry is observed.
- New physics scenarios with positive C_9C_{10} are excluded.

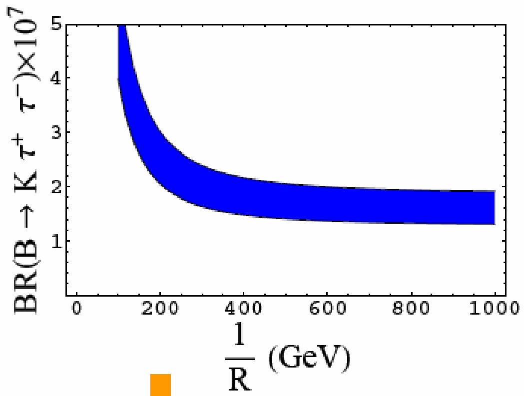
$B \to K\tau^+\tau^-$

Branching ratio vs 1/R

SET A



SET B



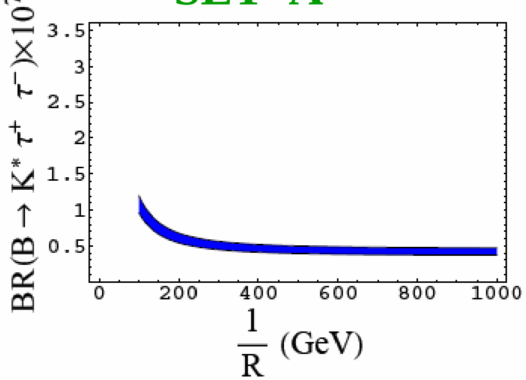
SM predictions:

$$BR(B \to K\tau^+\tau^-) = \begin{cases} 0.6 \pm 0.1 \;\; 10^{-7} & (\text{set A}) \\ 1.6 \pm 0.3 \;\; 10^{-7} & (\text{set B}) \end{cases}$$

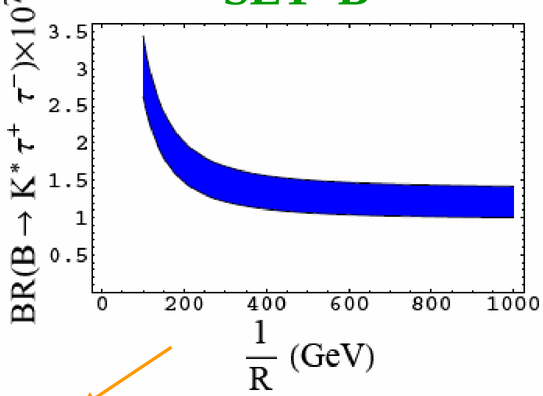
A measurement of $BR > 2\times10^{-7}$ would constrain $\frac{1}{R} \leq 300$ GeV

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

SET A



SET B



A measurement of $BR > 2\times10^{-7}$ would constrain $\frac{1}{R} \leq 250$ GeV

SM predictions:

$$BR(B \to K^*\tau^+\tau^-) = \begin{cases} 4.1 \pm 0.5 \;\; 10^{-8} & (\text{set A}) \\ 1.2 \pm 0.2 \;\; 10^{-7} & (\text{set B}) \end{cases}$$

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

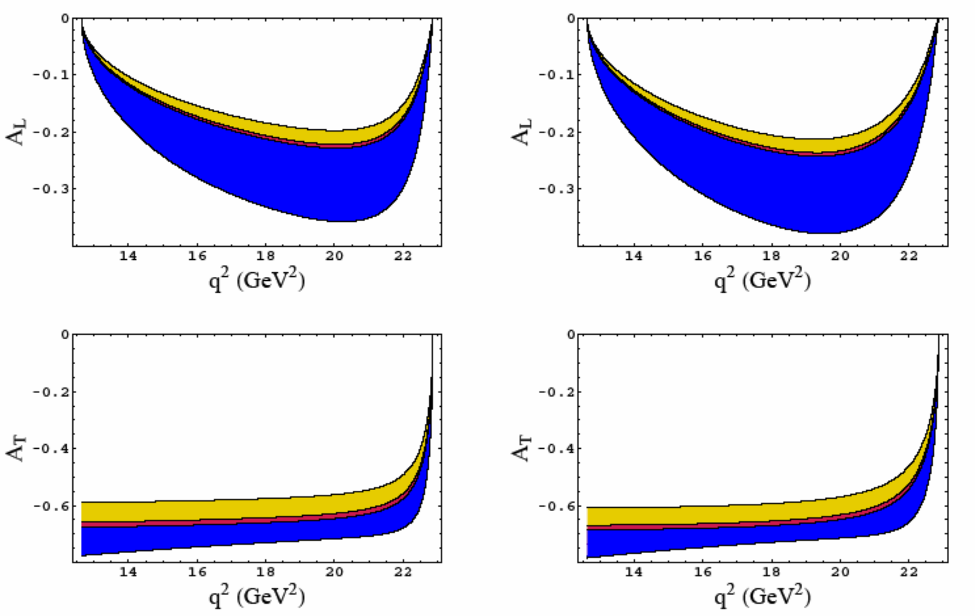
τ^- polarization asymmetry

$$\mathcal{A}_A(q^2) = \frac{\frac{d\Gamma}{dq^2}(s_A) - \frac{d\Gamma}{dq^2}(-s_A)}{\frac{d\Gamma}{dq^2}(s_A) + \frac{d\Gamma}{dq^2}(-s_A)}$$

A=L, T, N
In the rest frame of the lepton pair:

$$s_L = \frac{1}{m_\tau}\left(\left|\vec{k}_1\right|, 0, 0, E_1\right)$$
$$s_T = (0,0,-1,0)$$
$$s_N = (0,1,0,0)$$

SET A **SET B**



$\frac{1}{R} = 200$ GeV

$\frac{1}{R} = 500$ GeV

SM

A_T is more sensitive to the ED scenario

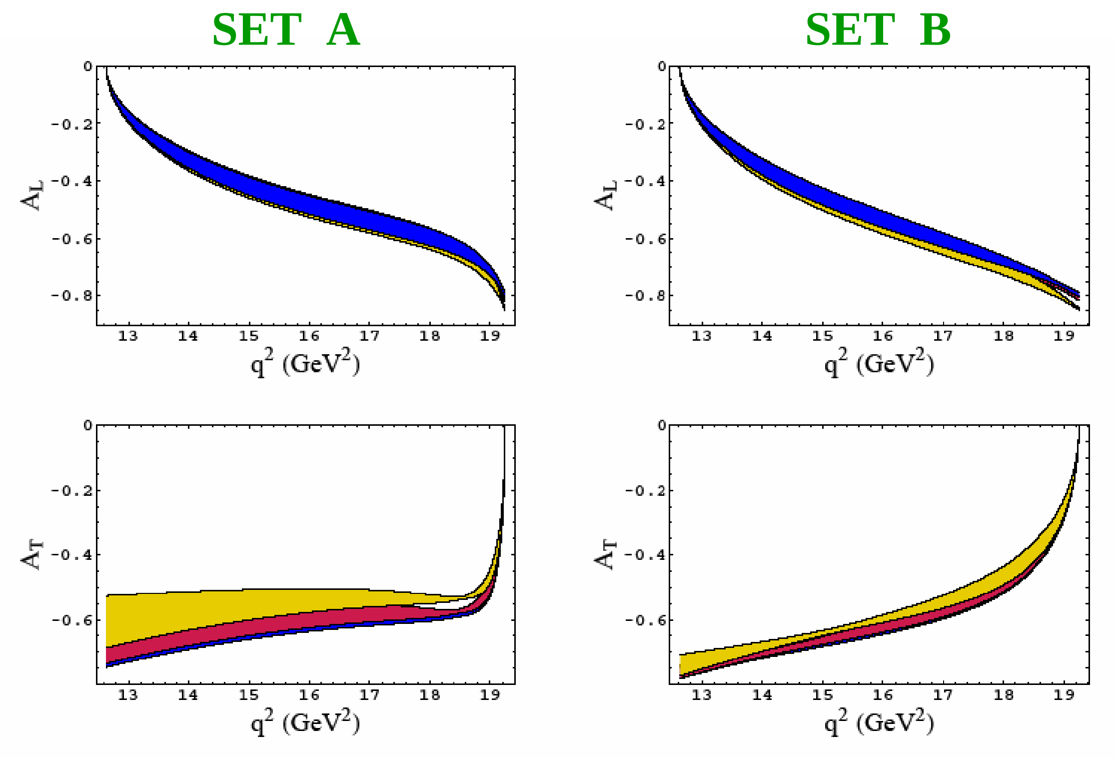
Small values of 1/R simultaneously induce in $B \to K \tau^+ \tau^-$

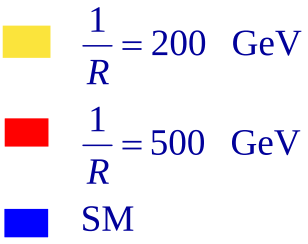
- an increase of the BR
- a decrease of A_T

Observation of such a correlation is an experimental challenge!

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

τ ⁻ polarization asymmetry





Again, the transverse asymmetry is more sensitive to the ED scenario

τ⁻ polarization asymmetry: Large Energy limit

Relations among form factors holding in the large energy limit of the light final state (K or K*)

$$
\begin{aligned}
F_1(q^2) &= \xi_P(E) \\
F_0(q^2) &= \frac{2E}{M_B}\xi_P(E) \\
F_T(q^2) &= -\frac{M_B+M_K}{M_B}\xi_P(E)
\end{aligned}
$$

→ A single function is required to describe B →P modes:

$\xi_P(E)$

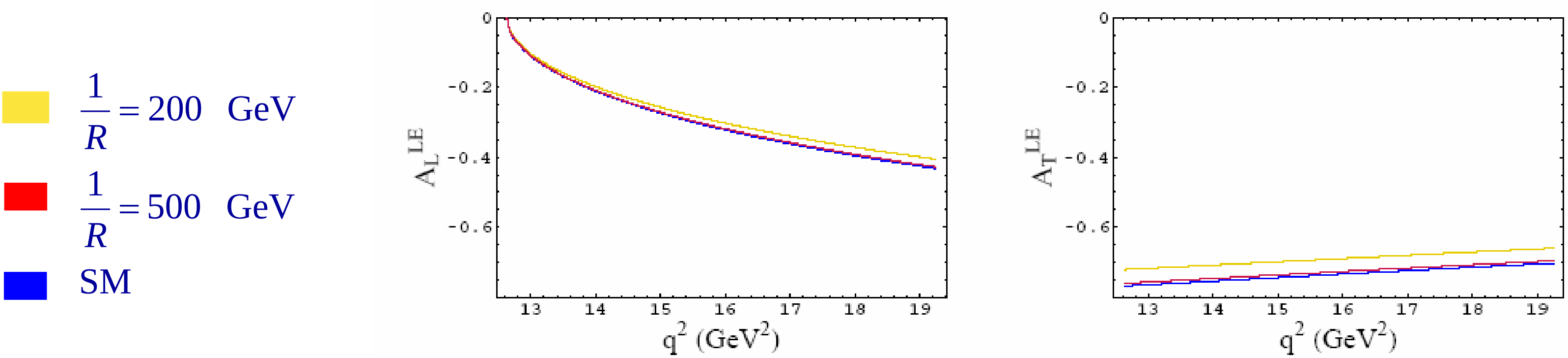
$$
\begin{aligned}
V(q^2) &= -i\frac{M_B+M_{K^*}}{M_B}\xi_\perp(E) \\
A_1(q^2) &= -i\frac{2E}{M_B+M_{K^*}}\xi_\perp(E) \\
A_2(q^2) &= i\frac{M_B}{M_B-M_{K^*}}(\xi_\parallel(E)-\xi_\perp(E)) \\
A_0(q^2) &= -i\frac{E}{M_{K^*}}\xi_\parallel(E)
\end{aligned}
$$

$$
\begin{aligned}
T_1(q^2) &= -\frac{i}{2}\xi_\perp(E) \\
T_2(q^2) &= -i\frac{E}{M_B}\xi_\perp(E) \\
T_3(q^2) &= \frac{i}{2}(\xi_\parallel(E)-\xi_\perp(E))
\end{aligned}
$$

→ Two functions describe B →V modes:

$\xi_\parallel(E),\ \xi_\perp(E)$

In both cases the asymmetries turn out to be **independent** on such functions



K* helicity fractions in $B \to K^* \ell^+ \ell^-$

Definitions:

$$f_L(q^2) = \frac{d\Gamma_L(q^2)/dq^2}{d\Gamma(q^2)/dq^2}$$ → longitudinal

$$f_\pm(q^2) = \frac{d\Gamma_\pm(q^2)/dq^2}{d\Gamma(q^2)/dq^2}$$

$$f_T(q^2) = f_+(q^2) + f_-(q^2)$$ → transverse

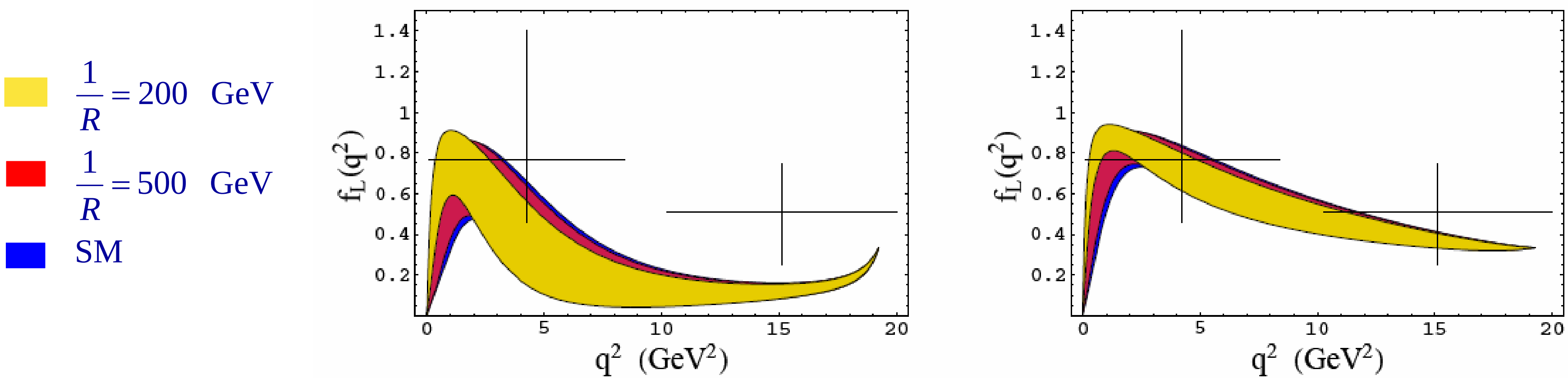
Recent BaBar measurement of the longitudinal K* helicity fraction in $B \to K^* \ell^+ \ell^-$

$$f_L = 0.77^{+0.63}_{-0.30} \pm 0.07 \qquad 0.1 \leq q^2 \leq 8.41 \; GeV^2$$

$$f_L = 0.51^{+0.22}_{-0.25} \pm 0.08 \qquad q^2 \geq 10.24 \; GeV^2 \; ,$$

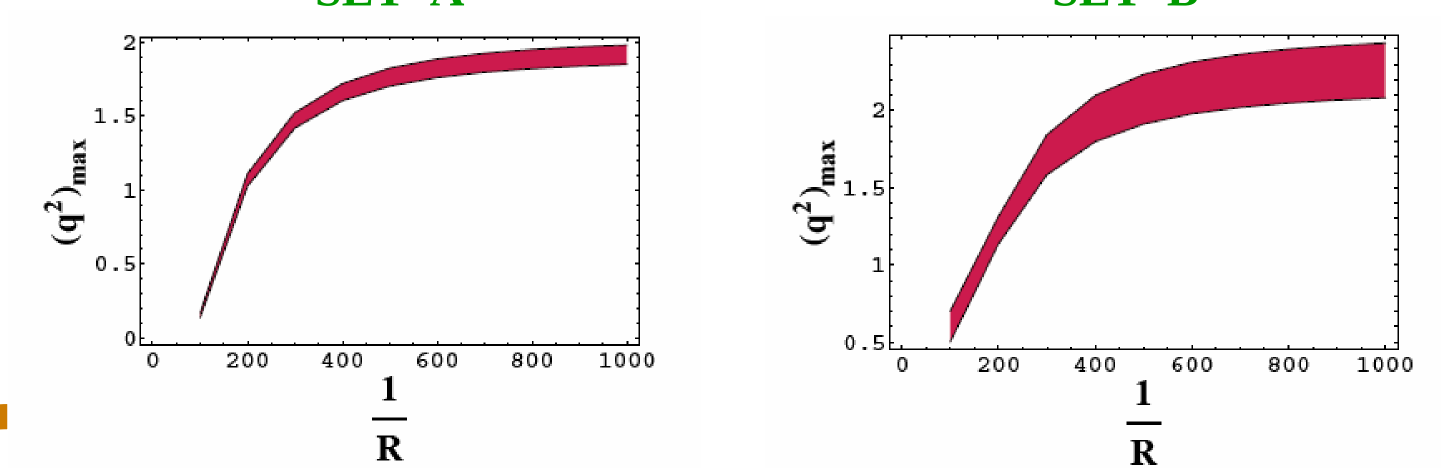
Results

SET A SET B



A higher sensitivity to 1/R is displayed by the value of the momentum transfer q^2_{max} where f_L has a maximum

SET A SET B



The position of the maximum is shifted towards lower values when 1/R decreases

$B \to K^* \gamma$

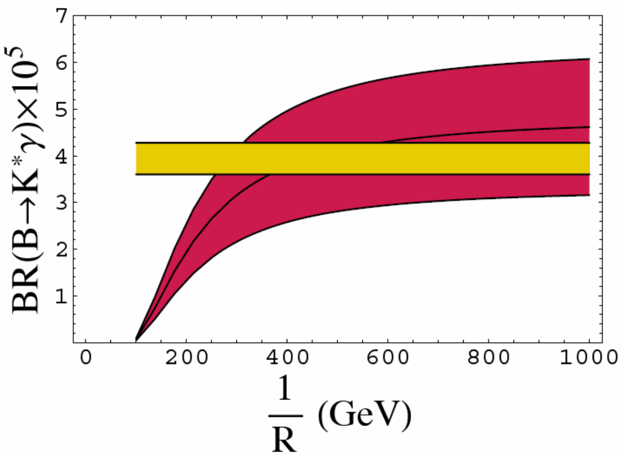
Takes contribution from the operator O_7

Mode	Belle Collab.	BaBar Collab.
$B^0 \to K^{*0}\gamma$	$(4.01 \pm 0.21 \pm 0.17) \times 10^{-5}$	$(3.92 \pm 0.20 \pm 0.24) \times 10^{-5}$
$B^- \to K^{*-}\gamma$	$(4.25 \pm 0.31 \pm 0.24) \times 10^{-5}$	$(3.87 \pm 0.28 \pm 0.26) \times 10^{-5}$

Branching ratio vs 1/R

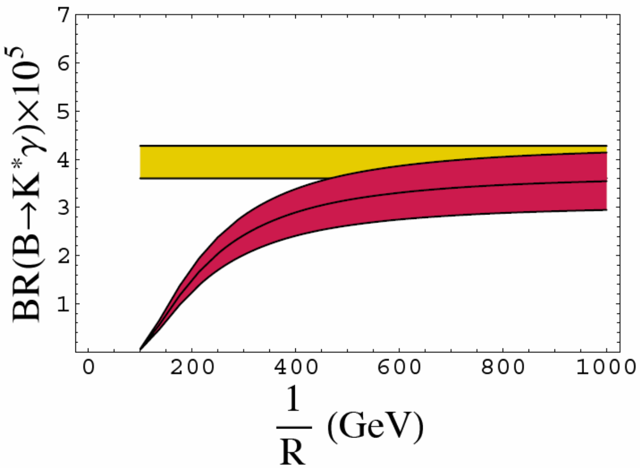
Exp data

SET A



$$\frac{1}{R} \geq 250 \quad \text{GeV}$$

SET B



$$\frac{1}{R} \geq 400 \quad \text{GeV}$$

This channel is the one which allows to put the stronger bounds on 1/R

Exclusive modes: Summary

UED have an important impact on exclusive observables,
though sometimes obscured by form factor dependence.

For $\frac{1}{R} = 300$ GeV there is

- enhancement of
  - $BR(B \to K^{(*)} \ell^+ \ell^-)$ by $\approx 20\,\%$
  - $BR(B \to K^{(*)} \tau^+ \tau^-)$ by $\approx 25\,\%$
  - $BR(B \to K^{(*)} \nu \bar{\nu})$ by $\approx 20\,\%$
- suppression of $BR(B \to K^* \gamma)$ by $\approx 30\,\%$ → Provides the most stringent bound on 1/R
- sizable downward shift in the zero of the forward backward asymmetry in $B \to K^* \ell^+ \ell^-$
- suppression of transverse polarization asymmetries in $B \to K^{(*)} \tau^+ \tau^-$
- downward shift of the maximum of the longitudinal helicity fraction in $B \to K^* \tau^+ \tau^-$

It would be mostly interesting to observe the correlation among the various observables

Backup slides

Universal extra dimensions: signatures at high energy lepton colliders

Example: UED $e^+e^- \to \mu_1^+\mu_1^- \to \mu^+\mu^-\gamma_1\gamma_1$

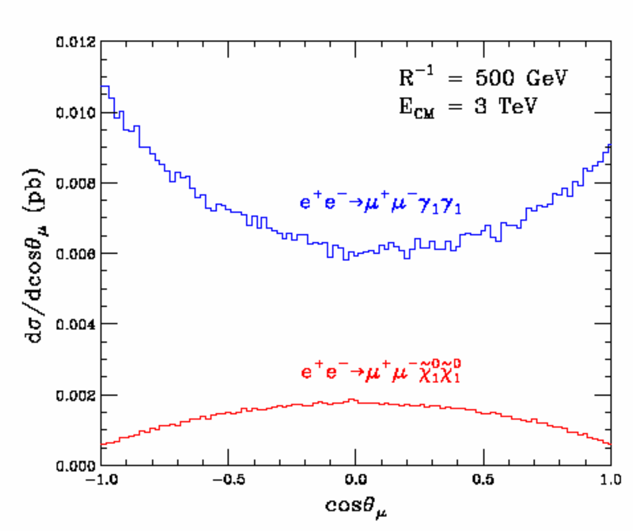
SUSY $e^+e^- \to \tilde{\mu}^+\tilde{\mu}^- \to \mu^+\mu^-\tilde{\chi}_1^0\tilde{\chi}_1^0$

Choosing $\frac{1}{R} = 500$ GeV $\sqrt{s} = 3$ TeV

One can obtain the differential cross section as a function of the muon scattering angle

$$\left(\frac{d\sigma}{d\cos\vartheta}\right)\bigg|_{UED} \approx 1+\cos^2\vartheta$$

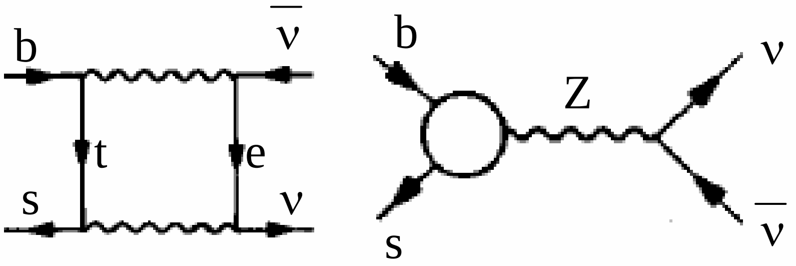
$$\left(\frac{d\sigma}{d\cos\vartheta}\right)\bigg|_{SUSY} \approx 1-\cos^2\vartheta$$



M. Battaglia et al., hep-ph/0507284

$B \to K \nu \bar{\nu},\ B \to K^* \nu \bar{\nu}$

Contributing diagrams



Effective hamiltonian

$$\mathcal{H}_{eff} = \frac{G_F}{\sqrt{2}} \frac{\alpha}{2\pi \sin^2(\theta_W)} V_{ts} V_{tb}^* \, \eta_X X(x_t) \, \bar{b}\gamma^\mu (1-\gamma_5) s \, \bar{\nu}\gamma_\mu (1-\gamma_5)\nu \equiv c_L^{SM} \, \mathcal{O}_L$$

Appealing features

- absence of long distance contributions
- presence of a single operator in the SM
  - ➡ new Physics effects can either modify the value of C_L or introduce an operator O_R

In the ACD scenario no new operator contributes, only the value of the coefficient is modified

$B \to K \nu \bar{\nu}$

Missing energy distributions

$x = \frac{E_{miss}}{M_B}$

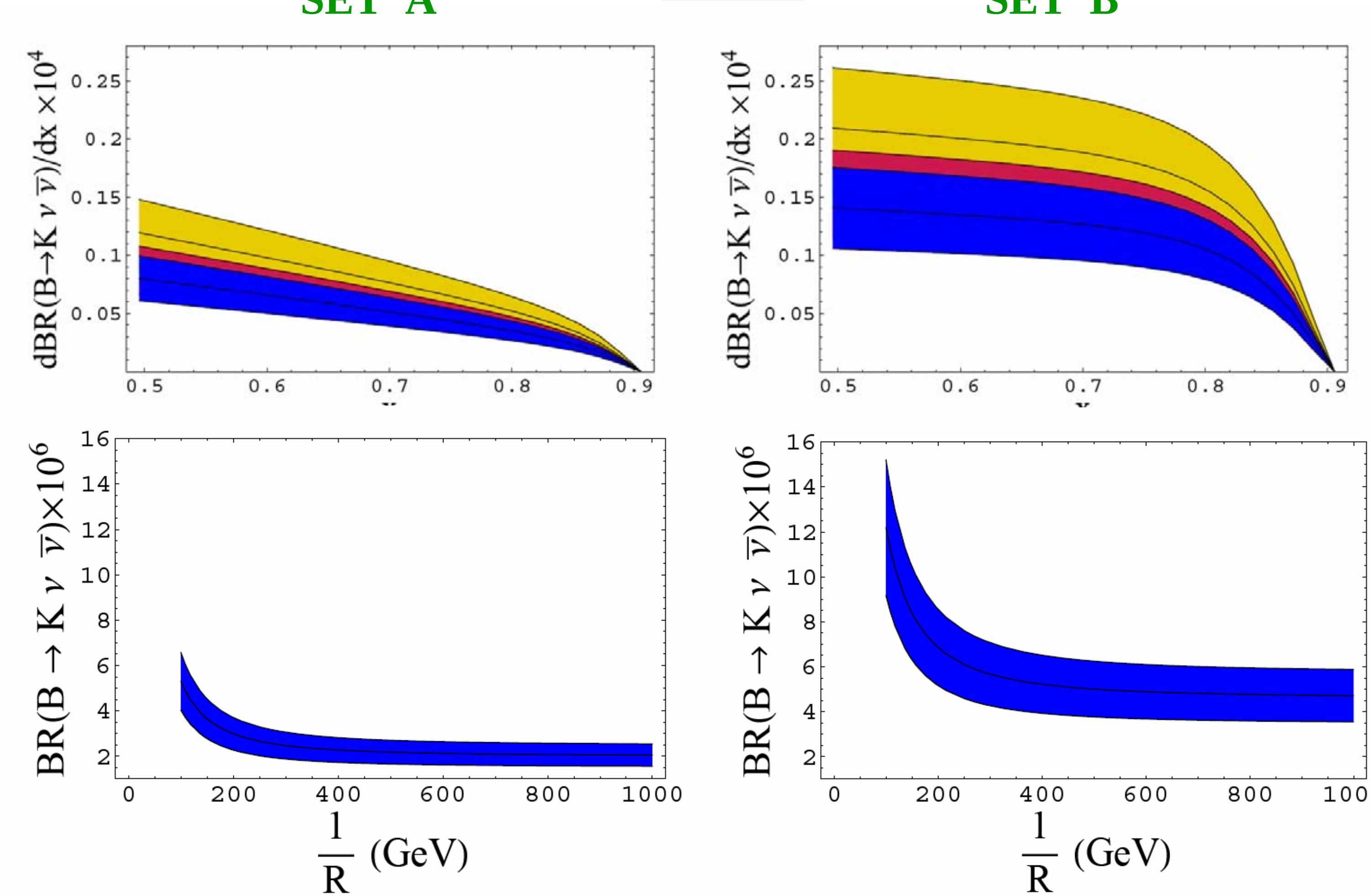
SET A **SET B**

$\frac{1}{R} = 200$ GeV

$\frac{1}{R} = 500$ GeV

SM

Branching fraction vs 1/R



Notice that exp data provide only an upper limit:

$B(B \to K \nu \bar{\nu}) < 3.6 \times 10^{-5}$ (BaBar Collab.)

$< 5.2 \times 10^{-5}$ (BELLE Collab.)

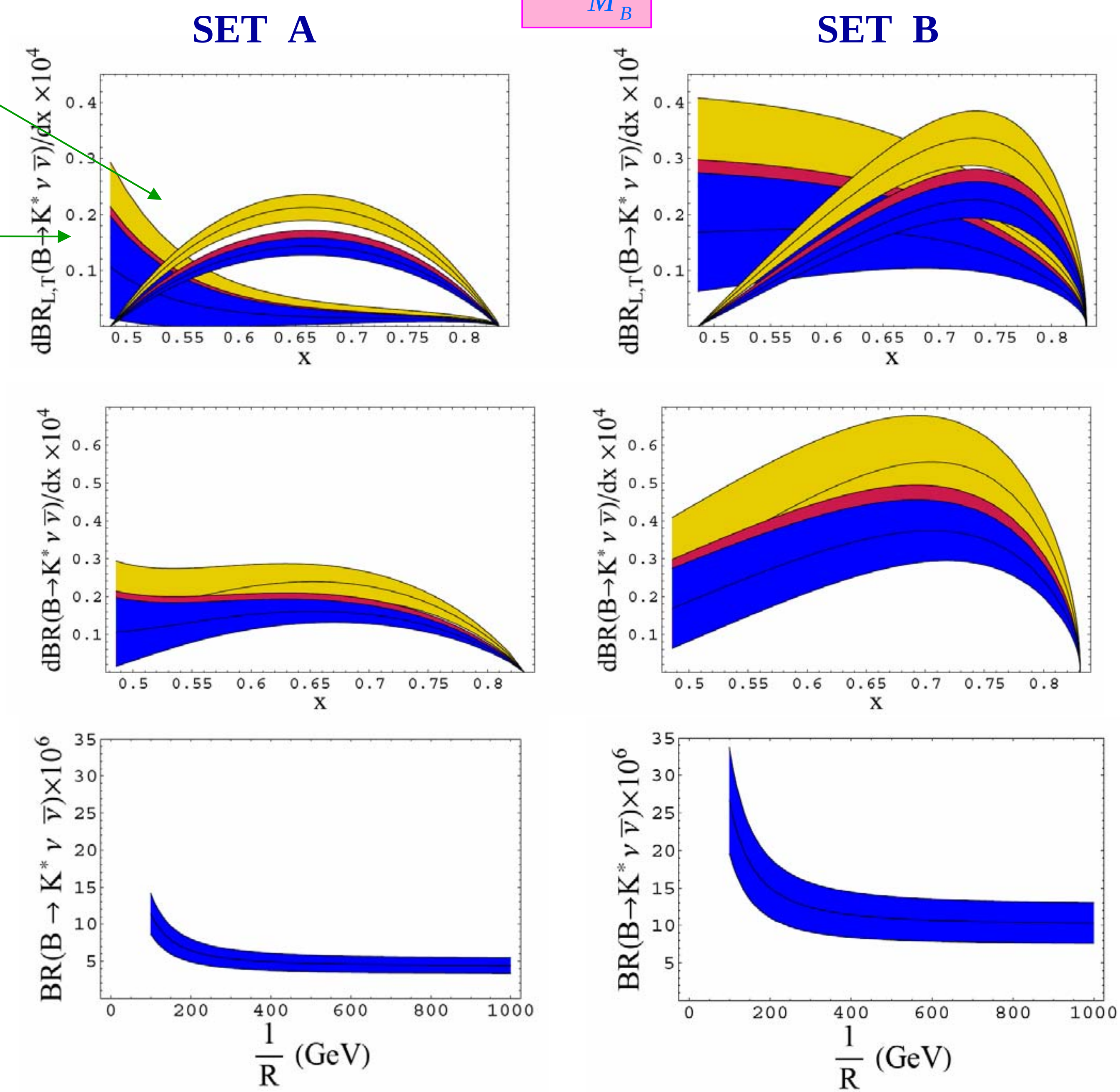
$B \to K^{*} \nu \bar{\nu}$

Missing energy distributions

$x = \frac{E_{miss}}{M_B}$

transversely polarized K*

Longitudinally polarized K*



Branching fraction vs 1/R

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

We choose two sets of form factors, including the relative uncertainties.

SET A

P. Colangelo et al., PRD 53 (96) 3672

3-point QCD sum rules:

- F_1, V, T_1 ⟶ polar behaviour
- A_1, A_2, T_2, T_3 ⟶ linear dependence on q^2
- F_T ⟶ double pole

SET B

P. Ball and R. Zwicky,
PRD 71 (05) 014015, 014029

Light-cone QCD sum rules:

- A_1, T_2 ⟶ simple poles
- V, T_1 ⟶ sum of two poles
- F_1 , F_T, A_2, T_3 ⟶ sum of a pole + a double pole