If ever any beauty I did see,

Which I desired, and got, was but a dream of thee.

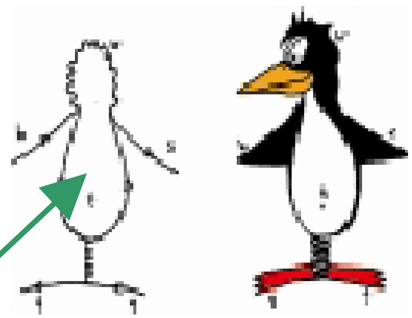
John Donne, *The Good Morrow*

B – decay as a tool to search for physics extending the Standard Model

Penguin decays

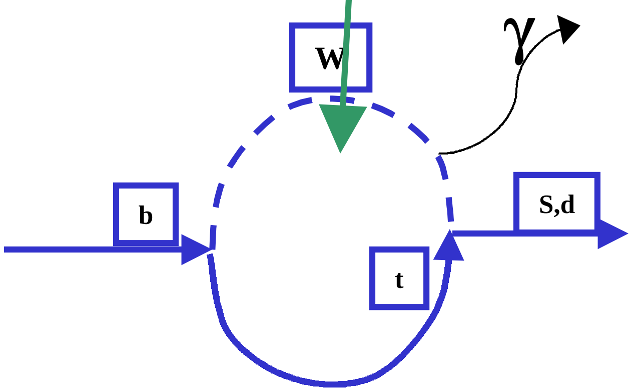
SM forbids direct FCNC

FCNC proceed via a "penguin" loop



Weak decay vertices are governed by the CKM matrix.

The off diagonal elements are small as shown in the wolfenstein parameterization. The factor of $\lambda \sim 0.22$.



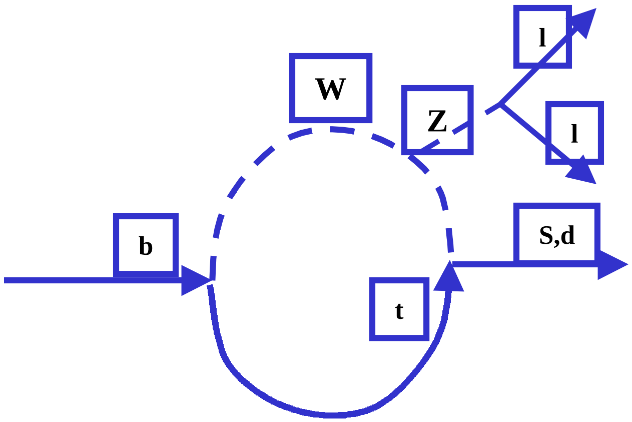
$$V_{CKM} = \begin{vmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{vmatrix} \sim \begin{vmatrix} 1-0.5\lambda & \lambda & A\lambda^3(\rho-i\eta) \\ -\lambda & 1-0.5\lambda & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & A\lambda^2 & 1 \end{vmatrix}$$

Why b-penguins?

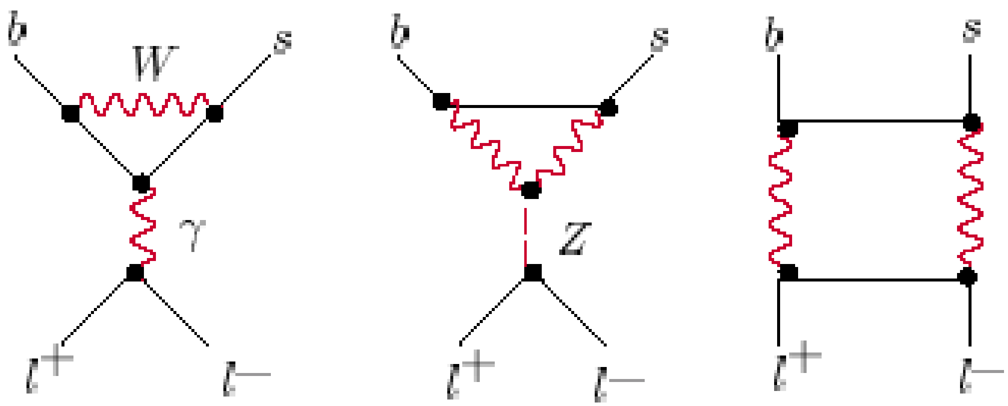
The b-quark and s-quark have no kinematically allowed CKM-favored decays. So tree level decays to lighter quarks are CKM suppressed.

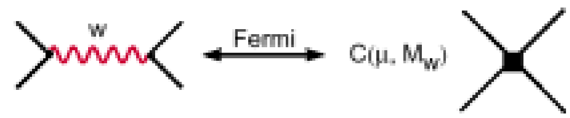
$$V_{CKM} = \begin{vmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{vmatrix} \sim \begin{vmatrix} 1-0.5\lambda & \lambda & A\lambda^3(\rho-i\eta) \\ -\lambda & 1-0.5\lambda & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & A\lambda^2 & 1 \end{vmatrix}$$

The massive t-quark is the main contributor to the loop (V_{tb}>> V_{cb}, V_{ub}). This creates high sensitivity to processes beyond the SM which occur at high energies.



Electroweak Penguins *(B→X$_s$l$^+$l$^-$)*



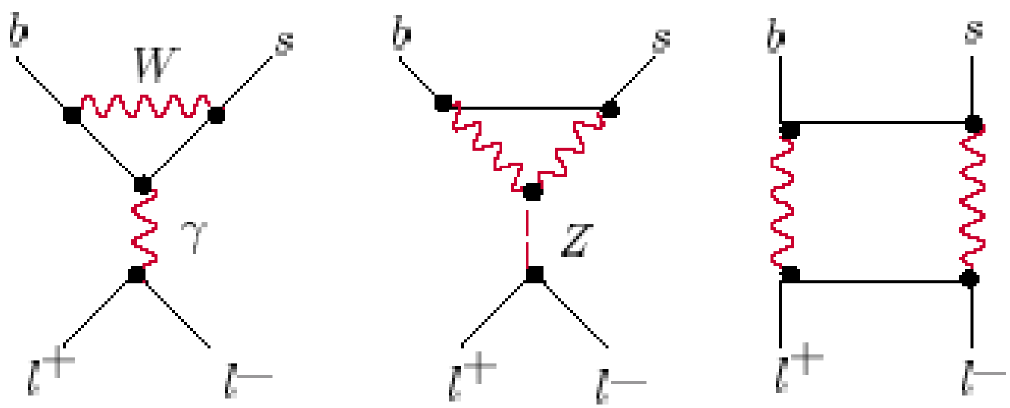


$$H_{eff}(B \to X_s l^+ l^-) = -\frac{4G_F}{\sqrt{2}} \lambda_t \sum_{i=1}^{10} C_i(\mu)\, \mathcal{O}_i(\mu)$$

Where $\lambda_t = V_{ts}^* V_{tb}$ and $C_i(\mu)$ are the wilson coefficients which represent the relative weights of the loops whose local operators at each interaction are $O_i(\mu)$.

The effective hamiltonian comes from reducing the loop diagrams to the corresponding effective point theory similar to the operator product expansion leading to the four point fermi theory.

Electroweak Penguins $(B \rightarrow X_s l^+ l^-)$



The wilson coefficients that contribute to the decay are C_7, C_9 and C_{10}. These are adjusted in models beyond the SM, to take high energy effects of new physics into account.

The magnitude and sign of the wilson coefficients are determined by:

- the invariant dilepton mass spectrum $d\Gamma(B \to X_s l^+ l^-) \,/\, d\hat{s}$,
- the forward-backward charge asymmetry

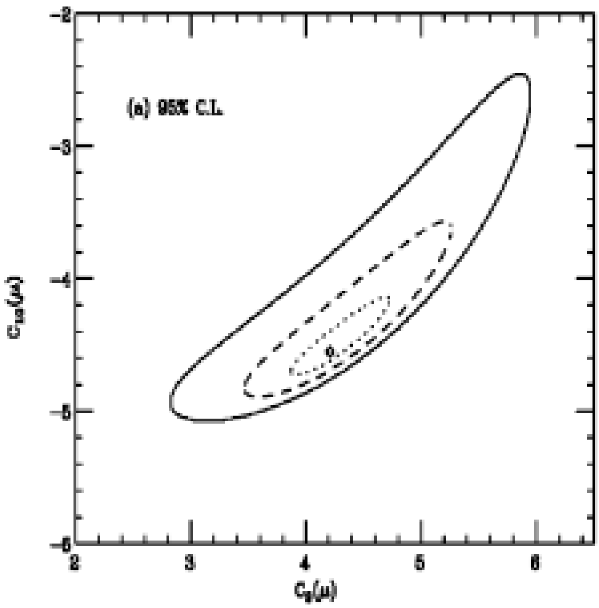
$$A(s) = \int_{-1}^{1} d\cos\theta \; d^2\Gamma(B \to X_s l^+ l^-) \,/\, d\hat{s}\, d\cos\theta \;\; \mathrm{sgn}(\cos\theta)$$

- and the decay rate of $B \to X_s \gamma$, $\quad \Gamma(B \to X_s \gamma)$

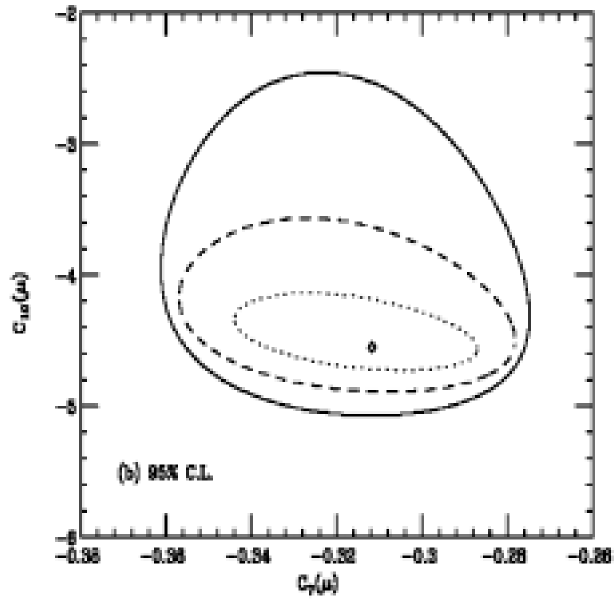
Electroweak Penguins *($B \rightarrow X_s l^+ l^-$)*

Analysis of the supersymmetric contributions to the Wilson coefficients is done in terms of the quantities:

$$R_i = C_i^{SUSY} / C_i^{SM} - 1 = C_i^{new} / C_i^{SM}$$



The 95% C.L. projections in the $C_9 - C_{10}$ and $C_7 - C_{10}$ planes. The solid,dashed and dotted contours correspond to $3x10^7$, 10^8 and $5x10^8$ BBar pairs. The central value of the SM is labeled by the diamond.



Electroweak Penguins $(B \rightarrow X_s l^+ l^-)$

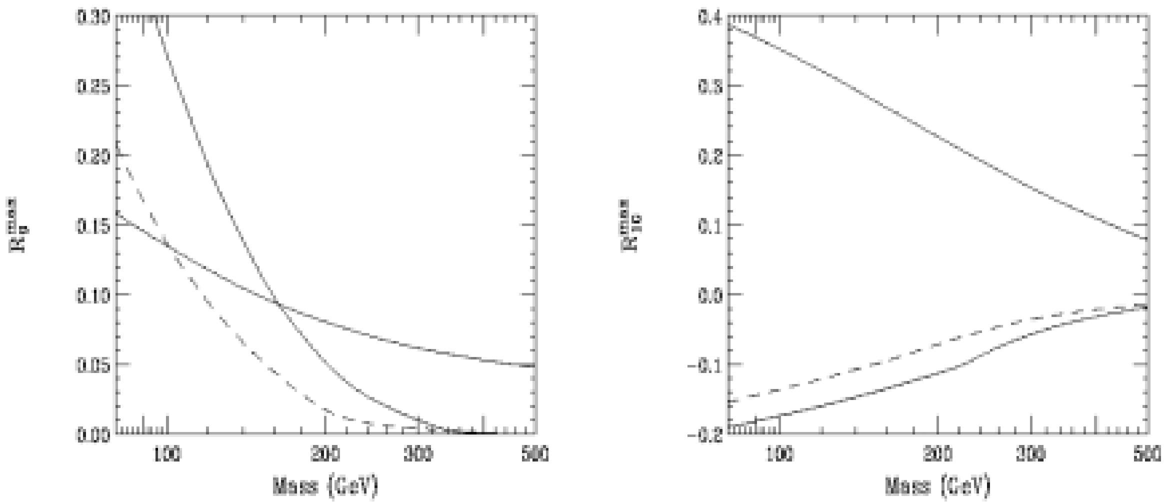


Figure 5: The maximum value of (a) R_9 and (b) R_{10} achievable for general supersymmetric models. The top solid line comes from the $t - H^{\pm}$ contribution and is displayed versus the $H^{\pm}$ mass. The bottom solid line is from the $\tilde{t}_t - \chi_j^{\pm}$ contribution with $\tan\beta = 1$ and is shown versus the $\chi_i^{\pm}$ mass. The dashed line is the $\tilde{t}_t - \chi_j^{\pm}$ contribution with $\tan\beta = 2$. The other mass parameters which are not plotted are chosen to be just above the reach of LEP II and the Tevatron.

Electroweak Penguins $(B \rightarrow X_s l^+ l^-)$

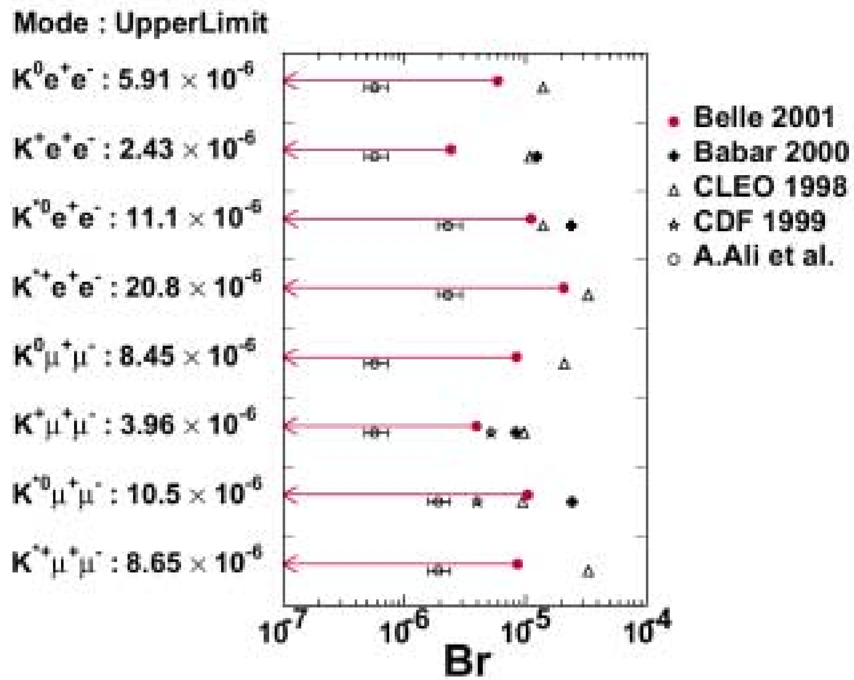
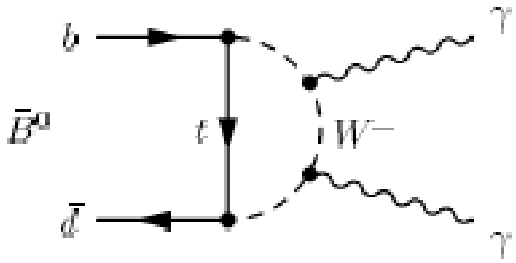
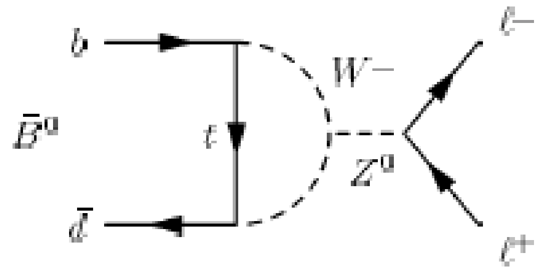


Figure 7: Upper limits on the branching fractions for each $B \rightarrow K^{(*)}\ell\ell$ mode (preliminary). Our results are compared to theoretical predictions and upper limits from previous experiments.

Vertical Electroweak Penguins





B^0 decay mode	Exp.	UL $\mathcal{B}$ (10^{-6})	Theory	B_s decay mode	Exp.	UL $\mathcal{B}$ (10^{-6})	Theory
$\gamma\gamma$	L3	38	10^{-8}	$\gamma\gamma$	L3	148	10^{-7}
e^+e^-	CLEOII	5.9	10^{-15}	e^+e^-	L3	54	10^{-14}
$\mu^+\mu^-$	CDF	0.68	10^{-10}	$\mu^+\mu^-$	CDF	2	10^{-9}
$\tau^+\tau^-$			10^{-8}	$\tau^+\tau^-$			10^{-7}

Present and Future B-Physics Prospects

Expt.	Collider	Beams	$\sqrt{s}$ (GeV)	Year online	$\mathcal{L}$ (10^{33} cm^{-1} s^{-1})	$\sigma(b\bar{b})$ (nb)	$b\bar{b}$ pairs (10^7/yr)	$\beta\gamma c\tau$ (μm)	$\sigma(b\bar{b})$ $/\sigma(q\bar{q})$
CLEO III	CESR	e^+e^-	10	1999	1.2	1	1.2	30	$3 \cdot 10^{-1}$
	CESR-IV		10	?	30	1	30	30	$3 \cdot 10^{-1}$
BaBar	PEP-II	e^+e^- †	10	1999	3-10	1	3-10	270	$3 \cdot 10^{-1}$
Belle	KEK-B	e^+e^- †	10	1999	3-10	1	3-10	200	$3 \cdot 10^{-1}$
HERA-B	HERA	pN	40	1998	—	6-12	50-100	9000	$1 \cdot 10^{-6}$
CDF II	Tevatron	$p\bar{p}$	1800	2000	0.2-1.0	100000	20000	500	$1 \cdot 10^{-3}$
D0									
BTeV ‡				2004	0.2			5000	
LHC-B ‡	LHC	pp	14000	2005	0.15	500000	75000	7000	$5 \cdot 10^{-3}$
Atlas								500	
CMS									

† Asymmetric beam energies. ‡ Forward detector.

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8) T. Iijima, "Study of Rare B Meson Decays at Belle" [hep-ex/0105005].