The

Fermilab theory group

presents:

A B-Movie

by

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Fermilab

February 2002

featuring

The B_d meson	$\sim$	$\bar{b}d$
The B^+ meson	$\sim$	$\bar{b}u$
The B_s meson	$\sim$	$\bar{b}s$
The K^0 mesons	$\sim$	$\bar{s}d$

The top quark t

The W boson

The Leptons e^-, μ^-, τ^-

The Charged Higgs H^+

The Pseudoscalar Higgs A^0

The Chargino $\tilde{\chi}^+$

The stop squark $\tilde{t}$

the gluon, the photon, the Higgs, ...

Special effects: Madoka Nishimura

The Beauty and the Beast

b-quark

???

Outline

1. Setting the Scene
2. The Unitarity Triangle
3. New Physics and Rare Decays
4. Summary

1. Setting the Scene

K-physics
$K^0 \sim \overline{s}d$

charm physics
$D^0 \sim c\overline{u}$

$\boxed{\text{flavour physics}}$

b-physics
$B^0 \sim \overline{b}d$

top-physics

Flavour physics is the physics of flavour-changing decays.
In the Standard Model it is the physics of the Yukawa sector.

Parameters of the Standard Model:

Gauge sector:

3 couplings of $G = SU(3) \times SU(2) \times U(1)_Y$

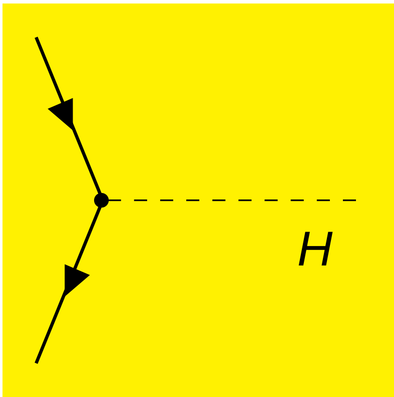
Higgs sector: 2 parameters: VEV $<H>=v$,self-coupling λ

breaks spontaneously $G \to SU(3) \times U(1)_{em}$

dynamics governed by gauge principle

Flavour sector: Higgs Yukawa interactions:

$y_{ij}\overline{f}_i f_j(v+H)$



$\Rightarrow$ quark mass matrix:

$$m_{ij} \quad = \quad y_{ij}v$$

Diagonalization $\Rightarrow$ fermion masses and CKM-matrix.

y_{ij} complex $\Rightarrow$ CP-violation

Understanding of flavour unsatisfactory:

- 21 of the Standard Model's 26 free parameters are in the Yukawa sector.
- Why don't we observe CP-violation in flavour-conserving transitions (electric dipole moments)?
- The CKM CP-violation is too small to explain the baryon asymmetry.
- Why are the fermion masses (except for the top mass) so small?
- Why are the off-diagonal CKM-elements so small?
- Are there only three generations? If yes, why?

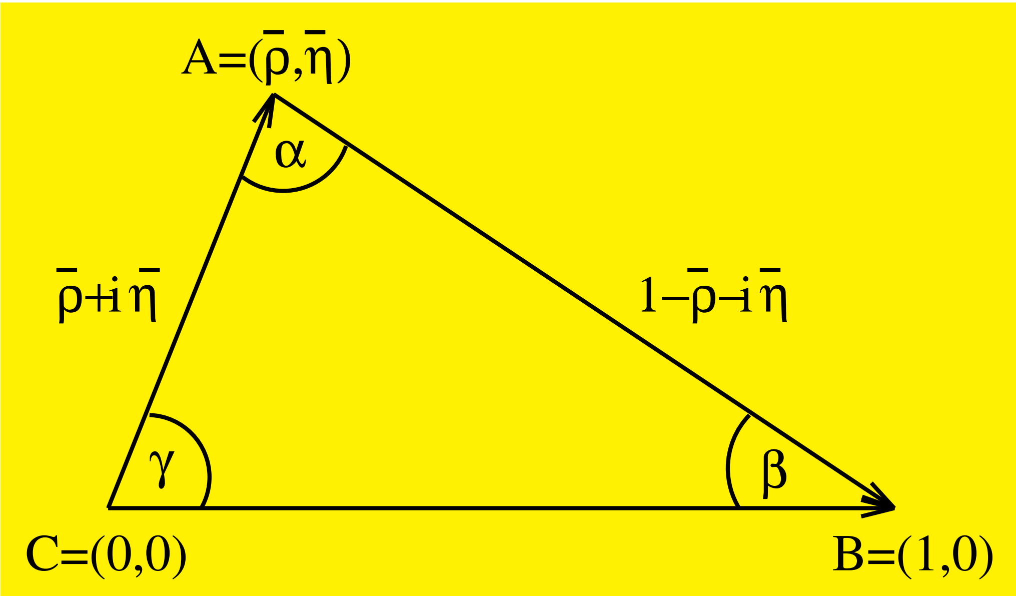
Aim of flavour physics:

- determine CKM-matrix parametrized by (λ, A, $\overline{\rho}$, $\overline{\eta}$)
- to search for new physics
  - by overconstraining the unitarity triangle
  - probing "zero predictions" of the Standard Model
  - measuring highly suppressed rare decays

$$V = \begin{pmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3\left(1+\frac{\lambda^2}{2}\right)(\overline{\rho}-i\overline{\eta}) \\ -\lambda - iA^2\lambda^5\overline{\eta} & 1-\frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1-\overline{\rho}-i\overline{\eta}) & -A\lambda^2 - iA\lambda^4\overline{\eta} & 1 \end{pmatrix}$$

Wolfenstein; Buras, Lautenbacher, Ostermaier

expansion in $\lambda \simeq 0.22$.



In the LEP/SLD/Fermilab-Run-I era precision tests of the gauge sector have confirmed the Standard Model.

We are now facing the era of precision tests of the flavour sector:

quarks:

b and c physics:
BaBar, BELLE, CLEO-III, Fermilab Run-II (CDF/D0), LHCb/ATLAS/CMS, BTeV

K physics:
DAΦNE, BNL-E926-KOPIO, BNL-E949, KEK-391a, CERN-NA48, CKM, JHF

leptons:

ν oscillations/ν mass:
Super-K, BooNE, SNO, Borexino, KamLAND, K2K, MINOS, OPERA, AMANDA, ICECUBE, ANTARES, KATRIN

$\mu \to e$ transition:
SINDRUM II (PSI), MECO (BNL), ...

Why is CP-violation so interesting?

- Standard Model: only one CP-violating parameter: CKM-phase γ
  $\Rightarrow$ SM is higly predictive.
- Some CP asymmetries (such as $a_{CP}(B_d \to J/\psi K_S)$) are theoretically very clean, hadronic uncertainties drop out.
- There must be new sources of CP-violation to explain the baryon asymmetry of the universe (though not necessarily relevant at low energies).
- Extensions of the Standard Model usually have (too) many sources of CP violation, if they break CP explicitly. E.g.: The minimal supersymmetric standard model (MSSM) has 44 CP-violating phases.
- New sources of flavour-changing transitions which do not come from the Higgs-Yukawa sector a priori involve different phases than the SM amplitudes.
  $\Rightarrow$ CP-violating observables change

Quark mass matrix:

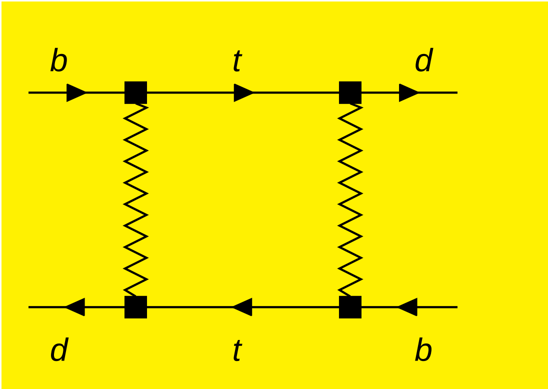
$$m_{ij} \quad = \quad y_{ij} v$$

CP explicitly broken (as in SM, MSSM): y_{ij} complex, v real

CP spontaneously broken: y_{ij} real, v complex,
requires more Higgs multiplets.

Which possibility is realized in nature?

B^0-$\overline{\mathrm{B}}^0$-mixing



$\mathrm{B}^0_\mathrm{d} \sim \bar{b}d$
$\overline{\mathrm{B}}^0_\mathrm{d} \sim b\bar{d}$

Standard Model box diagram
$\Rightarrow$ $|\Delta B| = 2$-hamiltonian

flavour eigenstates

(same for $\mathrm{B}^0_\mathrm{s} \sim s\bar{b}$ and $\overline{\mathrm{B}}^0_\mathrm{s} \sim \bar{s}b$)

The mass eigenstates B_H and B_L are linear combinations of the flavour eigenstates B^0_d and $\overline{\mathrm{B}}^0_\mathrm{d}$. An initially identified (*tagged*) B^0_d oscillates between B^0_d and $\overline{\mathrm{B}}^0_\mathrm{d}$.
Observables:

- their mass difference

$$\Delta m_{B_d} \quad \propto \quad \left|\langle B^0_d | H^{|\Delta B|=2} | \overline{B}^0_d \rangle\right| \quad \stackrel{\mathrm{SM}}{\propto} \quad \left|V_{tb}V^*_{td}\right|^2$$

- their (small) width difference
- the relative phase between $\langle B^0_d | H^{|\Delta B|=2} | \overline{B}^0_d \rangle$ and a chosen b-decay amplitude
  $\Rightarrow$ mixing-induced CP violation.

The Beast

Big problem in flavour physics: quarks are bound into hadrons by non-perturbative QCD, which is hard to compute.

↙ ↘

b-quark

Hadronic physics

Taming the Beast

QCD is perturbatively calculable at short distances.
$\Rightarrow$ separate short from long distance physics.

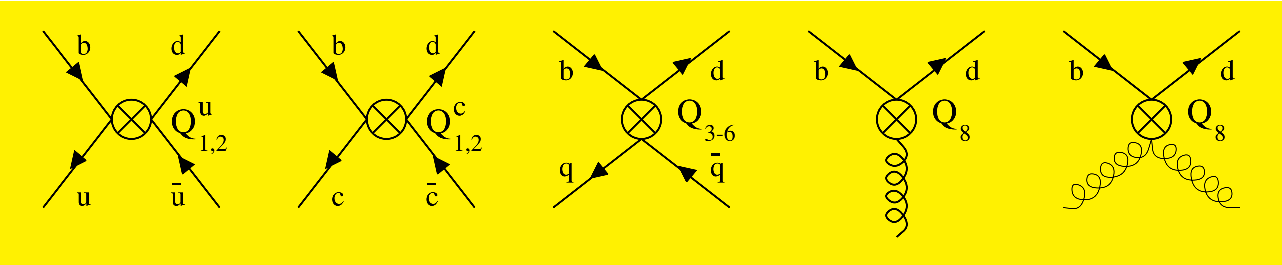
First exploit the hierarchy $M_W, m_t, M_{\rm new} \gg m_b$:
Interactions mediated by these heavy particles look point-like at the energy scale $m_b \approx 5\,\rm GeV$.

Perform an operator product expansion (OPE) resulting in:
Effective hamiltonian for $|\Delta B| = 1$ transitions:

$$H^{|\Delta B|=1} = \frac{G_F}{\sqrt{2}} \left[\sum_{i=1}^{2} C_i \left(V_{\it CKM}\, Q_i^u + V'_{\it CKM}\, Q_i^c \right) + V''_{\it CKM} \sum_{i\geq 3} C_i Q_i \right]$$

yields an expansion in $(m_b/M_W)^2$ with

- Q_i: effective $|\Delta B| = 1$ operators, e.g. $Q_2^c = \overline{c}\gamma_\mu(1-\gamma_5)b\ \overline{d}\gamma^\mu(1-\gamma_5)c$
- C_i: Wilson coefficients = effective couplings, contain short distance structure, perturbative QCD corrections, depend on m_t/M_W.
- $V_{\it CKM}^{(\prime\prime)}$: product of CKM elements



Important: CP-violating phases only appear in the short-distance piece, because QCD conserves CP.

Consider a B^0 decay into a final CP eigenstate f_{CP}, where only a single CKM-element appears in the $B^0 \to f$ amplitude. Then hadronic matrix elements like $\langle f|Q_i|B^0\rangle$ drop out of mixing-induced CP asymmetries:

$$a_{f_{CP}}(B^0 \to f) = \frac{\Gamma\left(B^0(t) \to f_{CP}\right) - \Gamma\left(\overline{B}^0(t) \to f_{CP}\right)}{\Gamma\left(B^0(t) \to f_{CP}\right) + \Gamma\left(\overline{B}^0(t) \to f_{CP}\right)}$$

meson which was a B^0 at time $t = 0$

For $f_{CP} = J/\psi K_S$ one finds:

$$a_{f_{CP}}(B_d^0 \to J/\psi K_S) \stackrel{\mathrm{SM}}{=} -\sin(2\beta)\,\sin(\Delta m_B t)$$

and $\beta = \arg(-V_{cd}V_{cb}^*/(V_{td}V_{tb}^*))$ is one angle of the unitarity triangle.

$a_{CP}(B_s^0 \to (J/\psi\phi)_{L=0})$ is also very clean, but small ($\mathcal{O}(2\%)$) in the SM.

$\Rightarrow$ ideal for searching new non-CKM sources of CP violation.

...still taming the beast

Often the isospin symmetry can be used to relate B_d^0 decays to B^+ decays or U-spin symmetries to relate B_d^0 to B_s^0.

Importantly, in many places one can exploit $m_b \gg \Lambda_{QCD}$ to control hadronic uncertainties:

- in inclusive ($\Rightarrow$ infrared-safe) decays use an OPE to expand in Λ_{QCD}/m_b (Heavy Quark Expansion)

  Shifman, Voloshin

- in exclusive semileptonic $b \to c$ transitions use heavy quark symmetries to constrain formfactors

  Isgur, Wise

- in $B \to \pi\pi, \pi K, KK \ldots$ decays one can use an expansion in $1/m_b$ to express the amplitudes in terms of formfactors.

  Beneke, Buchalla, Neubert, Sachrajda

$1/m_b$-expansion

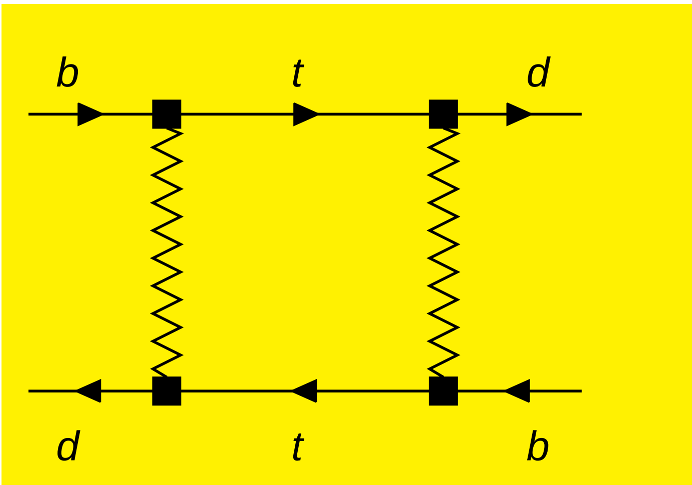
Summary: Why B physics?

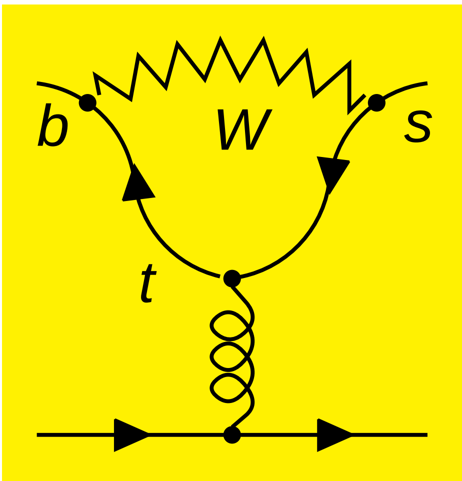
$\mathrm{B}^0_\mathrm{d} \sim \bar{b}d \qquad \mathrm{B}^+ \sim \bar{b}u \qquad \mathrm{B}^0_\mathrm{s} \sim \bar{b}s$

B-physics:

- determine A, $\bar{\rho}$, $\bar{\eta}$,
- measure V_{td} and V_{ts},
- $m_t \gg m_c \Rightarrow$ no GIM-suppression in top-loops,
- CP-violation largest in $b \to d$-transitions,
- compare with K-physics, test CKM-mech. of CP-violation
- $m_b \gg \Lambda_{QCD} \Rightarrow$ QCD theoretically clean,
- Standard Model:
  FCNC transitions in B-physics are small:
  - electroweak loop
  - small CKM factors
    $V_{cb}, V_{ts} = \mathcal{O}(\lambda^2)$, $V_{ub}, V_{td} = \mathcal{O}(\lambda^3)$,
    GIM suppression in charm loops
  - helicity-suppression, because FCNC transitions only involve left-handed fields.

  $\Rightarrow$ constrain or find new physics.





Commercial Break

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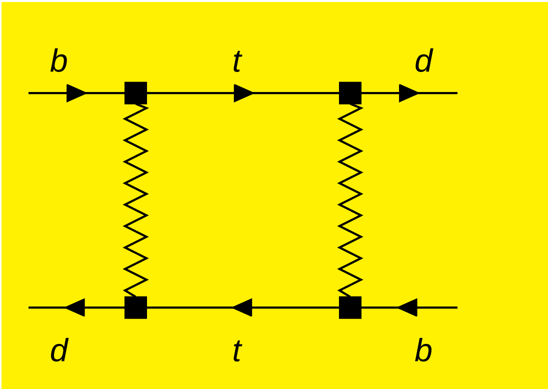
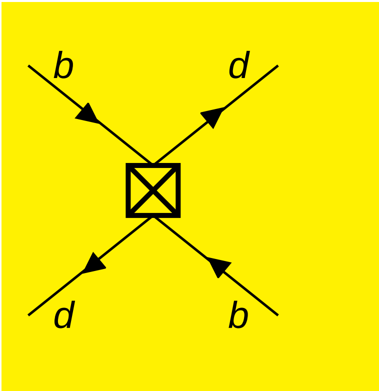
2. The Unitarity Triangle

Physical input for the determination of the unitarity triangle:

Input no. 1: Δm_{B_d}



Standard Model box diagram



effective $|\Delta B| = 2$– operator Q

$$\mathrm{B}_\mathrm{d}^0 \sim \overline{b}d \qquad \overline{\mathrm{B}}_\mathrm{d}^0 \sim b\overline{d}$$

$$H^{|\Delta B|=2} = \frac{G_F^2}{16\pi^2}(V_{tb}V_{td}^*)^2 C(m_t, M_W) Q$$

The mass difference is

$$\Delta m_{B_d} = \frac{\left|\langle B_d^0 | H^{|\Delta B|=2} | \overline{B}_d^0 \rangle\right|}{m_B}$$

$$\propto \left|V_{tb}V_{td}^*\right|^2 \langle B_d^0 | Q | \overline{B}_d^0 \rangle$$

$\Rightarrow$ information on $|V_{td}| = A\lambda^3\sqrt{(1-\overline{\rho})^2 + \overline{\eta}^2}$.

But big hadronic uncertainties:

$$\langle B_d^0 | Q | \overline{B}_d^0 \rangle \quad \propto \quad \widehat{B}_d f_{B_d}^2$$

$$f_{B_d}\sqrt{\widehat{B}_d} \quad = \quad (230 \pm 40) \text{ MeV}$$

Present world average:

$$\Delta m_{B_d} \quad = \quad (0.487 \pm 0.014)\ \mathrm{ps}^{-1} \ = \ 320\ \mu\mathrm{eV}$$

LEP B Oscillation WG

Input no. 2: Δm_{B_s}

Big improvement, once Δm_{B_s} is also measured.

$$\frac{\Delta m_{B_d}}{\Delta m_{B_s}} \quad = \quad \left|\frac{V_{td}}{V_{ts}}\right|^2 \frac{f_{B_d}^2 \widehat{B}_d}{f_{B_s}^2 \widehat{B}_s}$$

In the $SU(3)_F$ limit the hadronic factor is 1.

$$\frac{f_{B_s}\sqrt{\widehat{B}_s}}{f_{B_d}\sqrt{\widehat{B}_d}} \quad = \quad 1.15 \pm 0.06^{+0.07}_{-0}$$

S. Ryan (Lattice 2001)

$\dfrac{\Delta m_{B_d}}{\Delta m_{B_s}}$ determines one side of the unitarity triangle:

$$\left|\frac{V_{td}}{V_{ts}}\right| \quad = \quad \lambda\, R_t \;\equiv\; \lambda \sqrt{(1-\overline{\rho})^2 + \overline{\eta}^2}$$

$$\Delta m_{B_s} \quad \geq \quad 14.9\;\mathrm{ps}^{-1} \quad @95\%\,\mathrm{C.L.} \quad \text{LEP}$$

The rapid oscillations in the B_s system make the measurement of Δm_{B_s} difficult. This measurement has a high priority in the B-physics program of Fermilab Run-II. CDF/D0 can reach $\Delta m_{B_s} \approx 40\mathrm{ps}^{-1}$.

Input no. 3: CP asymmetry $a_{CP}(B_d^0 \to J/\psi K_S)$:

$$a_{CP}(B_d^0 \to J/\psi K_S) \quad = \quad -\sin(2\beta)\;\sin(\Delta m_{B_d} t)$$

Experiment:

$$\sin(2\beta) \quad = \quad 0.59 \pm 0.14 \pm 0.05 \qquad \text{BaBar 2001}$$

$$\sin(2\beta) \quad = \quad 0.99 \pm 0.15 \pm 0.06 \qquad \text{BELLE 2001}$$

Input no. 4: CP violation in $K - \overline{K}$ –mixing:

$\epsilon_K \quad \Rightarrow \quad$ hyperbola in $(\overline{\rho}, \overline{\eta})$ plane:

$$5.3 \cdot 10^{-4} = \widehat{B}_K A^2 \overline{\eta} \left[(1 - \overline{\rho}) A^2 \lambda^4 \eta_2 S_{tt} + \eta_3 S_{ct} - \eta_1 S_{cc} \right]$$

with $\quad S_{tt} = 2.5, \qquad S_{ct} = x_c (0.6 - \log x_c),$

$\qquad S_{cc} = x_c, \qquad x_c = m_c^2 / M_W^2$

Inami,Lim

Next-to-leading order QCD in

$\eta_2 = 0.57 \pm 0.01$ Buras,Jamin,Weisz

$\eta_1 = 1.4 \pm 0.2, \quad \eta_3 = 0.47 \pm 0.04$ Herrlich,U.N.

hadronic parameter

$\widehat{B}_K = 0.85 \pm 0.10 \quad \Rightarrow$ need more effort in lattice QCD

Input no. 5: $b \to u \ell \overline{\nu}_\ell$:

From $\overline{B} \to X_u \ell^- \overline{\nu}_\ell$, $B \to \pi \ell^- \overline{\nu}_\ell$ and $B \to \rho \ell^- \overline{\nu}_\ell$ find

$$|V_{ub}| \propto R_b = \sqrt{\overline{\rho}^2 + \overline{\eta}^2}$$

Important: Precision studies of the unitarity triangle require precision calculations of the theoretical input. One must know the observables involved in the next-to-leading order (NLO) of QCD.

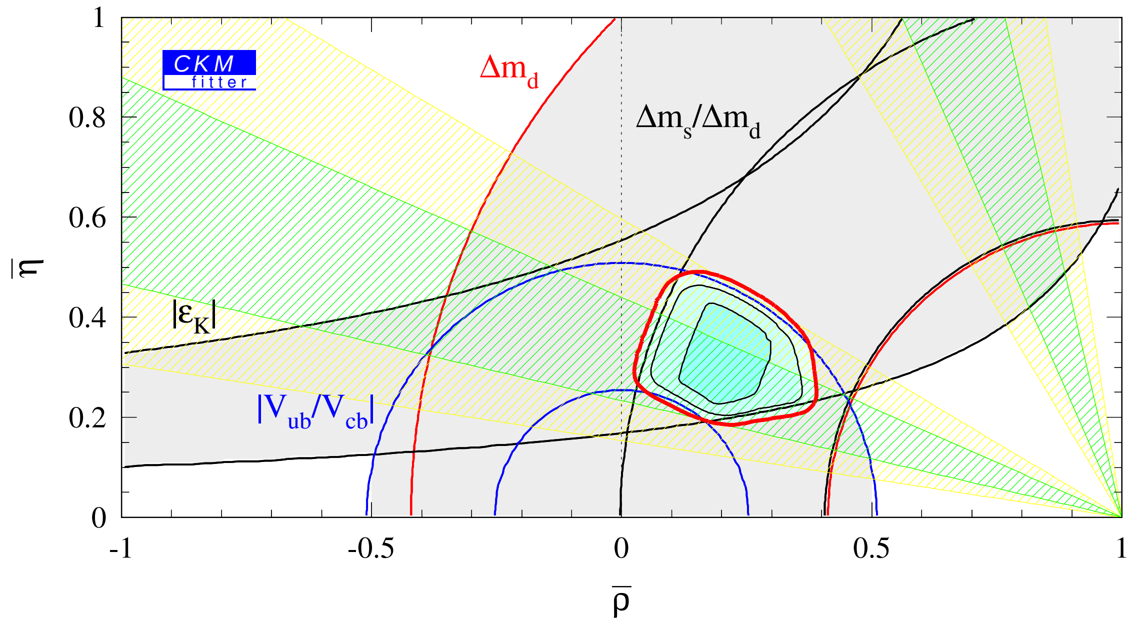
Since 1995 all quantities are known with NLO accuracy. The 1995 prediction for $\sin(2\beta)$ from ϵ_K, $b \to u\ell\overline{\nu}_\ell$ and Δm_{B_d} was

$$\sin(2\beta) = 0.60 \pm 0.19$$

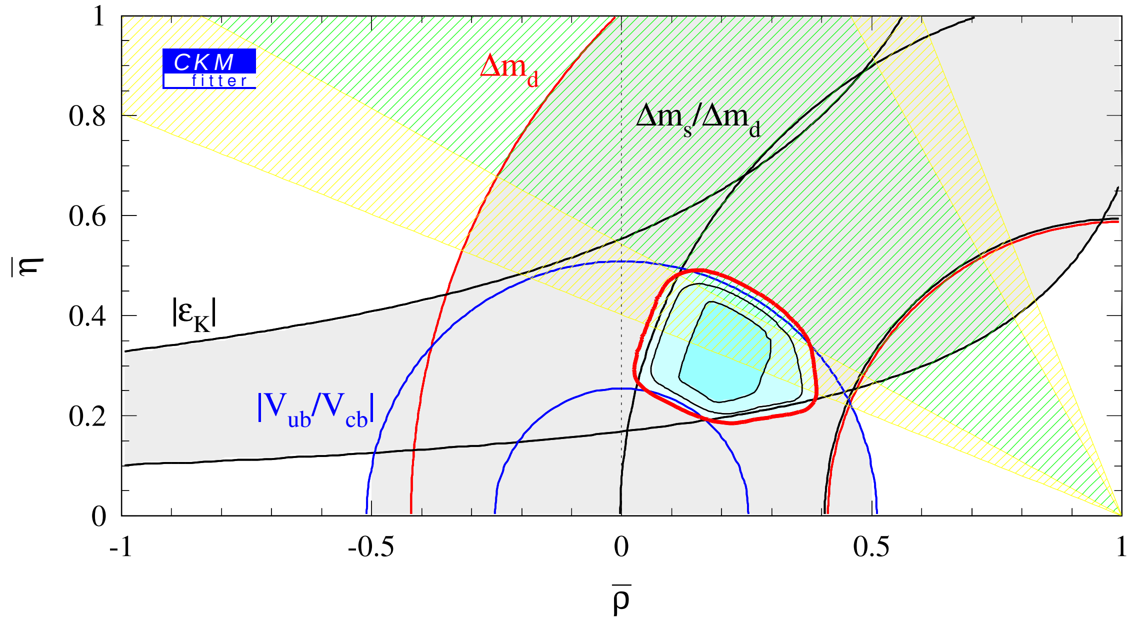
Herrlich, U.N.

Unitarity triangle fit

$\sin(2\beta)$ from BaBar:



$\sin(2\beta)$ from BELLE:



The apex $(\overline{\rho}, \overline{\eta})$ of the unitarity triangle will be completely fixed from $\sin(2\beta)$ and $\Delta m_{B_d}/\Delta m_{B_s}$, ...

... if new physics is absent from $B-\overline{B}$ mixing.

3. New Physics and Rare Decays

Where to look?

$B_d - \overline{B}_d$ mixing, $B_s - \overline{B}_s$ mixing

Δm_{B_d}, Δm_{B_s}, $\Delta\Gamma_{B_s}$

mixing-induced CP asymmetries

Rare decays:

$b \to s\gamma$: $B \to K^*\gamma$, $B \to X_s\gamma$

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

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

$B_{s,d} \to \ell^+\ell^-$

Kaon physics:

ϵ_K, ϵ'_K/ϵ_K, $K^+ \to \pi^+\nu\overline{\nu}$, $K_L \to \pi^0\nu\overline{\nu}$

General pattern:

$b \to s$ transitions directly probe the SM, because $|V_{ts}| \simeq |V_{cb}| = 0.041 \pm 0.003$ is known from $b \to c\ell\overline{\nu}_\ell$

$b \to u$, $b \to d$, $s \to d$ transitions (over-)constrain the unitarity triangle

What to look for?

Effects of

extra Higgs multiplets

supersymmetry

right-handed W-bosons

isosinglet quarks ($\Rightarrow$ flavour-changing Z-boson couplings)

Extra Higgses

E.g. Two-Higgs-doublet model (2HDM):

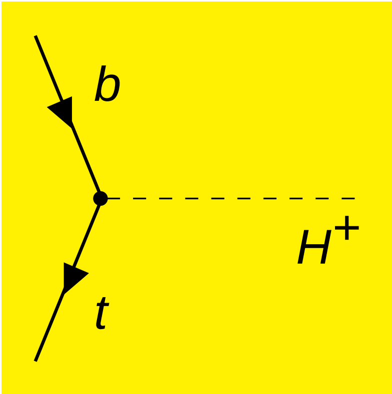
2 VEV's: v_1, v_2, $\tan\beta \equiv v_2/v_1$.

5 Higgs fields:

$H^\pm$	A^0	H^0	h^0
charged	CP-odd	CP-even	CP-even

B-physics is sensitive to effects of the charged Higgs:

$$\frac{g}{\sqrt{2}M_W} V_{tb} \left[m_b \tan\beta \, H^+ \, \overline{t}_L b_R + m_t \cot\beta \, H^+ \, \overline{t}_R b_L \right]$$



The term $\propto m_b$ is probed,

if the SM amplitude is chirality-suppressed, i.e. involves a right-handed b-quark field, $\mathcal{A}_{SM} \propto m_b$,

or

in models with large $\tan\beta$.

In $B \to \ell^+\ell^-$ also diagrams with A^0 and H^0 are relevant for large $\tan\beta$.

But: B physics is insensitive to the Standard Model Higgs.

Supersymmetry

MSSM $=$ Type-II 2HDM

$+$ scalar (fermion) superpartner for each fermion (boson)

Effects on flavour physics:

1. Flavour-changing gluino-squark-quark couplings from SUSY-breaking terms
   $\Rightarrow$ too large FCNC's
   $\Rightarrow$ constrains SUSY-breaking

   Hagelin; Gabbiani,Gabrielli,Masiero,Silvestrini
   Besmer, Greub, Hurth

2. Electroweak loops with superpartners
   (Loop diagrams with charginos, squarks)

3. Loop corrections to the Higgs-Yukawa couplings
   couplings absent at tree-level are loop-induced and can be large, if $\mu \tan \beta$ is large.

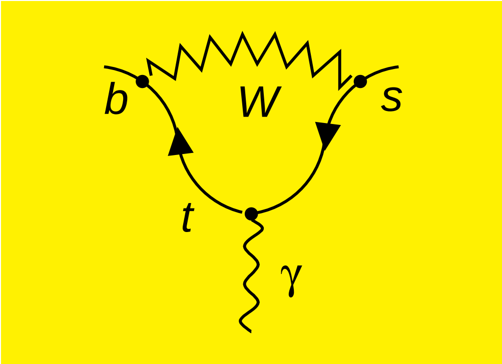
   Hall,Ratazzi,Sarid
   Carena,Olechowski,Pokorski,Wagner
   Carena,Garcia,U.N.,Wagner
   Pospelov

   $B \to \mu^+ \mu^-$ can be substantially enhanced.

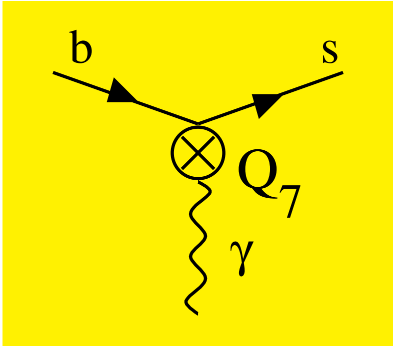
   Babu,Kolda; Chankowski,Slawianowska
   Bobeth,Ewerth,Krüger,Urban
   Dedes,Dreiner,U.N.; Isidori,Retico

$b \to s\gamma$

Standard Model:



$+$ other diagrams $\quad \propto G_F C_7 Q_7$



with $Q_7 = \frac{e}{16\pi^2} m_b \overline{b}_R \sigma_{\mu\nu} s_L F^{\mu\nu}$

Key features:

- Well-measured.
- CKM elements well-known.
- No overall hadronic factor in $Br(\overline{B} \to X_s\gamma)$.
  $\Rightarrow$ cleanly predictable.
- SM branching ratio anomalously small (factor of 10 below naive estimate).
- Chirality suppression: $\Rightarrow$ sensitive to right-handed gauge bosons and supersymmetry with large $\tan\beta$.
- Supersymmetry: Charged Higgs contribution always positive and essentially independent of $\tan\beta$. Chargino-stop contribution $\propto \tan\beta$.

Experimental status

Experiment	$Br(\overline{B} \to X_s\gamma)$
ALEPH	$(3.11 \pm 1.08)10^{-4}$
BELLE	$(3.36 \pm 0.87)10^{-4}$
CLEO	$(3.21 \pm 0.41)10^{-4}$
world average	$(3.23 \pm 0.42)10^{-4}$
SM prediction ($E_\gamma > m_b/20$)	$(3.73 \pm 0.31)10^{-4}$

Gambino,Misiak

In supersymmetric scenarios this implies either heavy non-standard particles or $\mu A_t < 0$.

μ, A_t: supersymmetric parameters

mSUGRA

- $A_t M_{gaugino} < 0$ favoured.
- $(g-2)_{\mu,exp} > (g-2)_{\mu,SM} \Rightarrow \mu M_{gaugino} > 0$.
- $Br_{exp}(\overline{B} \to X_s\gamma) \lesssim Br_{SM}(\overline{B} \to X_s\gamma)$
  $\Rightarrow \mu A_t < 0$ favoured.

$\Rightarrow$ consistent picture, yet there are better observables for $\mu A_t < 0$.

$B_s \to \mu^+\mu^-$

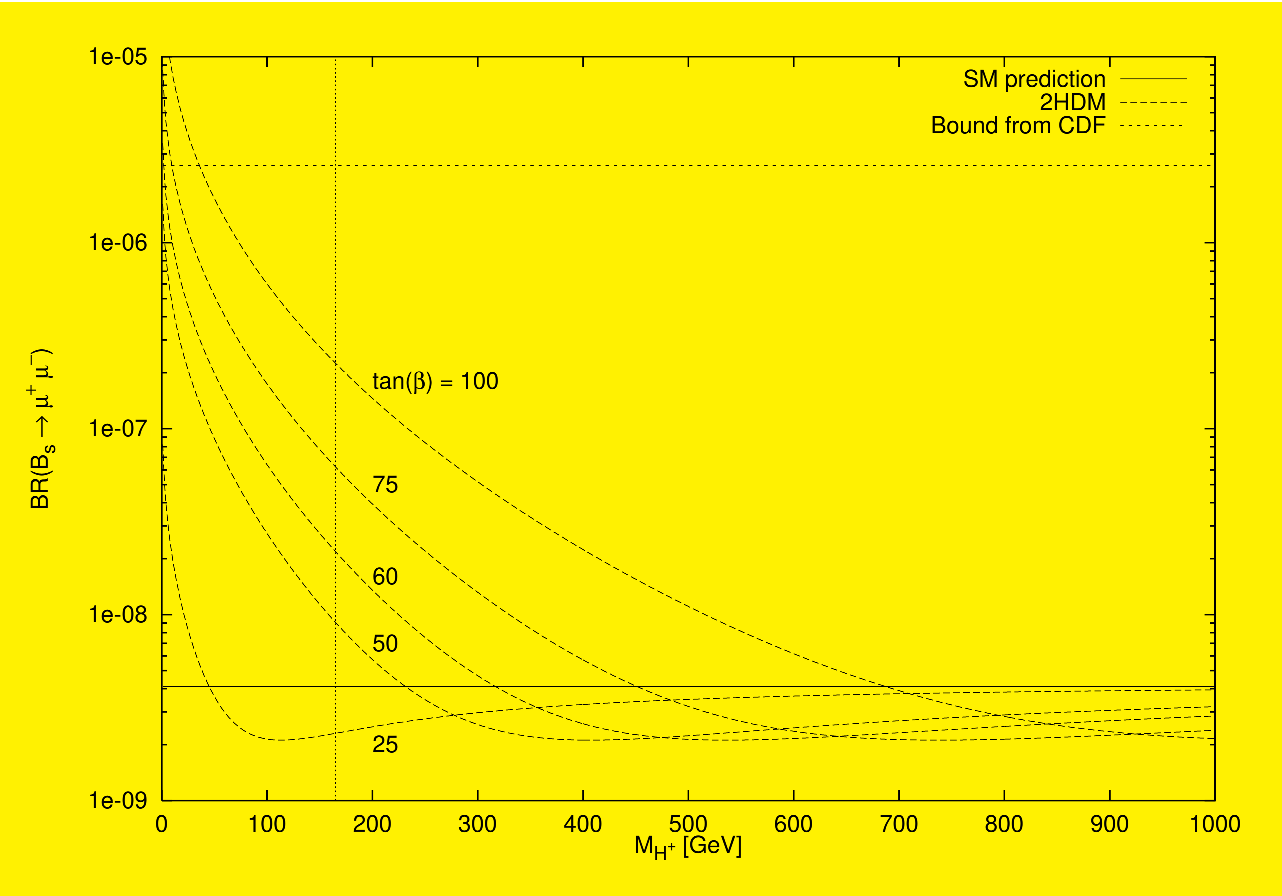
SM amplitude $\propto V_{ts}\dfrac{m_\mu}{M_W}$ Buchalla,Buras; Misiak,Urban

Type-II 2HDM amplitude

$$\propto V_{ts}\frac{m_\mu}{M_W}\frac{m_{B_s}\tan\beta}{2\sqrt{2}M_W}\frac{\log r}{r-1}, \quad \text{with } r = \frac{m^2_{H^+}}{m_t^2}$$

for large $\tan\beta$, Logan,U.N.

Dependence on other parameters drops out.



vertical line: bound from $b \to s\gamma$

MSSM: amplitude of $B_s \to \mu^+\mu^-$ has an extra factor of $\tan\beta$ compared to the 2HDM.

$\Rightarrow$ branching fraction can be enhanced by three orders of magnitude.

Origin: Mixing of the two Higgsinos and Higgsino-Wino mixing.

Pospelov

Babu,Kolda; Chankowski,Slawianowska

Bobeth et al.; Dedes,Dreiner,U.N.

Isidori,Retico

$Br(B \to \ell^+\ell^-) \propto m_b^2 m_\ell^2 \tan^6\beta$ is the observable which is most sensitive to SUSY with large $\tan\beta$. In particular the factor $m_b^2 m_\mu^2 \tan^6\beta$ is a unique feature of a flavour-changing transition.

SUSY-SO(10) models (with $\tan\beta = \mathcal{O}(50)$) are hardly compatible with the upper bound

$$Br(B_s \to \mu^+\mu^-) < 2.6 \cdot 10^{-6}$$

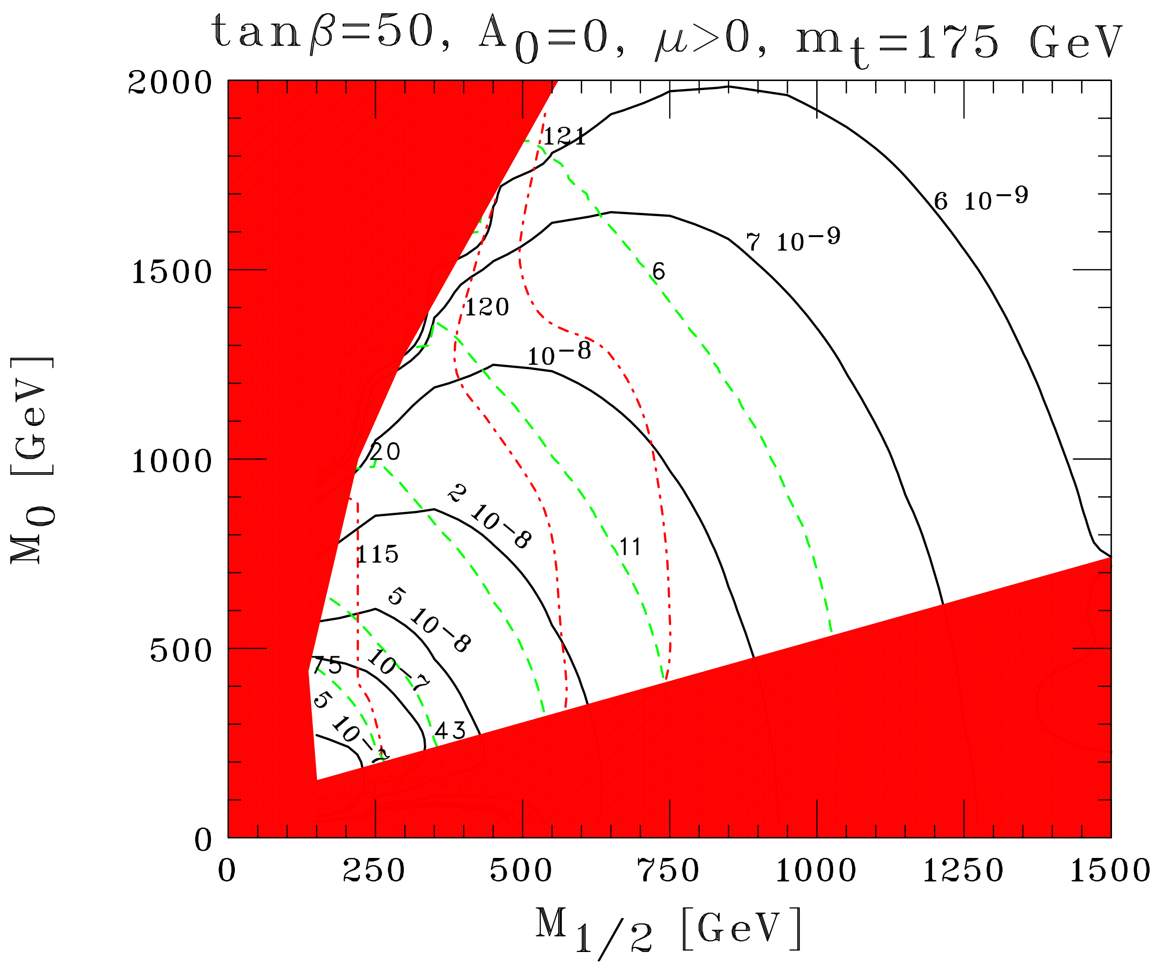
from the Tevatron. Dedes,Dreiner,U.N.

A similar phenomenon occurs in $B_s - \overline{B}_s$ mixing, where 2-loop terms $\propto m_s^2 \tan^4\beta$ occur.

Rosiek

mSUGRA: 5 parameters M_0, $M_{1/2}$, $\tan\beta$, A_0 and sgn μ defined at the GUT scale.

In mSUGRA there is a nice correlation of $Br(B_s \to \mu^+\mu^-)$ with the lightest Higgs boson mass and with $g-2$:



Any measurement of $Br(B_s \to \mu^+\mu^-)$ implies a useful upper bound on the lightest Higgs boson mass.

Summary

1. B-physics is a fertile field to probe short-distance physics.

2. ΔM_{B_s} will dramatically improve our knowledge of the unitarity triangle. Together with $\sin(2\beta)$ from $a_{CP}(B_d \to J/\psi K_S)$ its apex $(\overline{\rho}, \overline{\eta})$ is fixed, ... if there is no non-CKM type new physics.

3. FCNC transitions are sensitive to new physics, especially to non-CKM sources of flavour violation.
   $b \to s$ transitions probe the Standard Model directly:
   $b \to s\gamma$, $b \to s\ell^+\ell^-$, $B_s - \overline{B}_s$ mixing
   $b \to d$, $s \to d$ transitions probe the Standard Model by overconstraining the unitarity triangle.

4. $b \to s\gamma$ plays an important role to constrain low-energy supersymmetry.

5. A unique testing ground for supersymmetry with large $\tan\beta$ is the decay $B_s \to \mu^+\mu^-$, with possible orders-of-magnitude enhancements. It challenges SO(10) GUT models and will constrain the mSUGRA parameter space.

The future ...of the SM?
...of SO(10)?
...or of mSUGRA?

Which theories will sink with the ship?

A B-Movie

The End