B Physics: Standard Model and beyond

A biased sampling

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B Physics at the LHC
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Flavor physics: a wall of the SM edifice

Building up the Standard Model

- $\tau - \theta$ puzzle ⇒ Parity violation
- Cabibbo angle ⇒
  weak coupling universality $\oplus$ quark mixing
- GIM mechanism ⇒ no FCNC at tree level, charm
- CKM paradigm ⇒ (at least) three quark families
- Large B–$\overline{B}$ mixing ⇒ heavy top quark
- Rate of radiative B decay ⇒ top quark mass

Precision tests of the Standard Model

- CKM elements: do they explain all CP violation ?
- Rare decays: new particles contribute through loops ?
- Asymmetries: are the predicted SM relations obeyed ?
- What are the features of New Physics (if any) ?

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Window to New Physics beyond the SM

Puzzles in B physics that may lead directly to NP

- Direct vs indirect measurements of $\sin 2\beta$
- $B \to \tau\nu_\tau$: abnormally large branching ratio
- Anomalous like-sign-dimuon asymmetry
- Lifetime difference and CP phase in B_s mixing and decay
- Forward-backward asymmetry in $B \to K^*\mu^+\mu^-$
- The $K - \pi$ isospin asymmetry puzzle

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A typical B-decay rate calculation

The effective Hamiltonian: Operator Product Expansion

$$\mathcal{H}_{\text{eff}}^{SM} \quad \sim \quad G_F \sum_i \lambda_i^{\text{CKM}} C_i(\mu) O_i(\mu)$$

λ_i^{CKM}: some combination of CKM elements,
C_i: Wilson coefficients corresponding to effective operators O_i

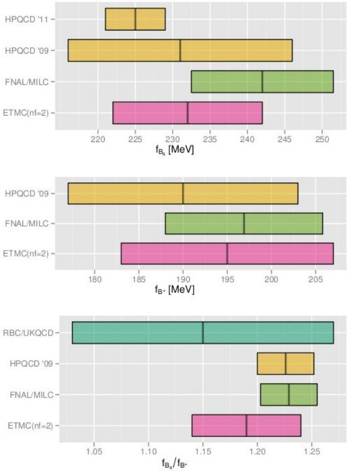
Decay rate:

$$\Gamma(B \to f) = \int [\text{phase space}] \; \left| \langle f | H_{\text{eff}}^{SM} | B \rangle \right|^2$$

Quantities involved:

• Masses, • Decay constants, • Bag parameters,
• Wilson coefficients, • Hadronic matrix elements (form factors),
• CKM elements

Decay constants f_B and f_{B_s} from lattice



$\boxed{N_f = 2 + 1 \text{ results}}$

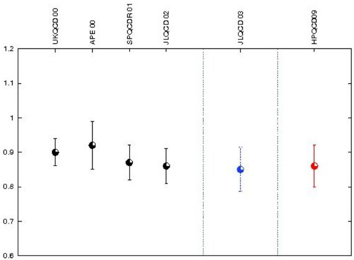
- $f_B = 196.9 \pm 8.9$ MeV ($\sim 5\%$)
- $f_{B_s} = 242.0 \pm 9.5$ MeV ($\sim 5\%$)
- $f_{B_s}/f_B = 1.229 \pm 0.026$ ($\sim 1.5\%$)

Fermilab Lattice $\oplus$ MILC, 2011

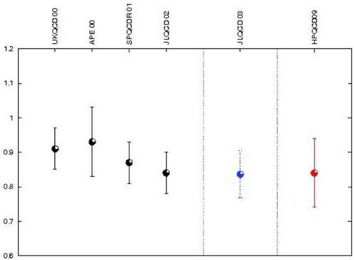
$\oplus$ See Talk by Nilmani Mathur

Bag parameters from lattice

B_{B_d}



B_{B_s}



$N_f = 2+1$ calculation, combined with F_{B_q}:

- $F_{B_s}\sqrt{B_{B_s}} = 233(14)$ MeV $\quad$ ($\sim 6\%$)
- $\xi_B = (f_{B_s}\sqrt{B_{B_s}})/(f_{B_d}\sqrt{B_{B_d}}) = 1.237(32)$ $\quad$ ($\sim 2.5\%$)

N. Tantalo, EPS 2011

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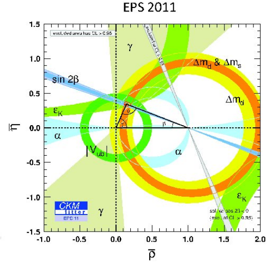
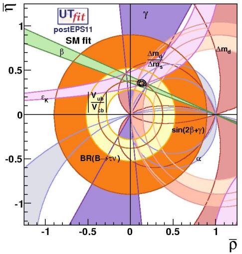
Global fits to CKM elements

CKMfitter:



UTfit:



Constraints in the $\bar{\rho}$–$\bar{\eta}$ plane:

- the ratio $|V_{ub}/V_{cb}|$
- ϵ_K from $K \to \pi\pi$
- Mass differences ΔM_d and ΔM_s
- Angles α, β, γ (or ϕ_2, ϕ_1, ϕ_3) of the unitarity triangle

KM paradigm mostly vindicated !

Details in the talk by Rahul Sinha

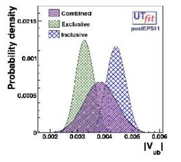
Not so fast: Devil in the details

V_{us}: semileptonic K decays vs. hadronic τ decays

- Semileptonic K decays $\Rightarrow |V_{us}| = 0.2254 \pm 0.0013$
- Strange vs. non-strange hadronic τ decays
  $\Rightarrow |V_{us}| = 0.2166 \pm 0.0019 \pm 0.0005$
- More than 3σ discepancy !

V_{ub}: inclusive vs. exclusive

- $|V_{ub}|(\mathrm{excl}) = (3.38 \pm 0.36) \times 10^{-3}$
- $|V_{ub}|(\mathrm{incl}) = (4.27 \pm 0.38) \times 10^{-3}$

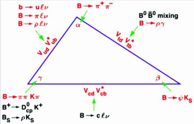


Tests of unitarity

With magnitudes of elements

- $|V_{ud}| = 0.97425 \pm 00022 \quad , |V_{us}| = 0.2254 \pm 0.0013$
- Unitarity holds to one part in 10^{-3}

With unitarity angles



- The trivial unitarity relation (more a test of our calculations):

$$\alpha + \beta + \gamma = \pi$$

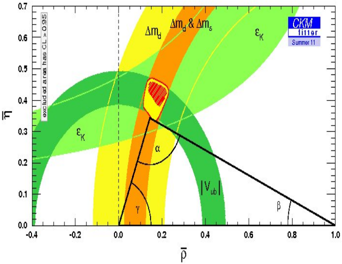
- The nontrivial unitarity relation:

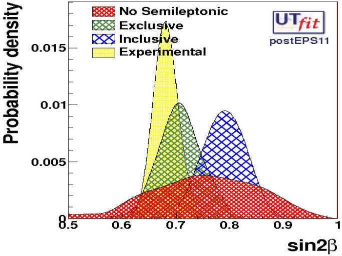
$$\sin\beta_s = \left|\frac{V_{us}}{V_{ud}}\right|^2 \frac{\sin\beta\ \sin(\gamma+\beta_s)}{\sin(\beta+\gamma)}\ [1 + \mathcal{O}(\lambda^4)]$$

Aleksan et al, 1994

- We will soon be close to testing this

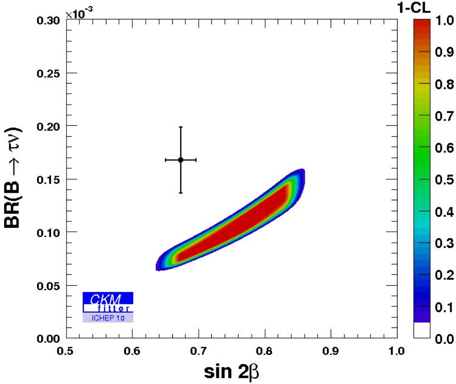
sin 2β: direct measurement vs global fit





- $\sin 2\beta(\text{direct}) = 0.691 \pm 0.020$
- $\sin 2\beta(\text{fit}) = 0.830^{+0.013}_{-0.033}$
- More than 2σ deviation

$\sin 2\beta$, $B \to \tau\nu$, and V_{ub}: correlations



- Branching ratio of $B^+ \to \tau^+\nu$ too large
- Effective V_{ub} needs to be larger
- Correlation with the best-fit value of the unitarity triangle vertex

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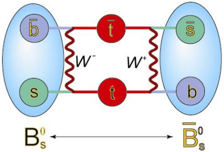
B_q–$\overline{B_q}$ mixing: parameterization



- Oscillation and decay of $a|B_q\rangle + b|\overline{B}_q\rangle$:

$$i\frac{d}{dt}\begin{pmatrix} a \\ b \end{pmatrix} = \left(\mathbf{M} - \frac{i}{2}\Gamma\right)\begin{pmatrix} a \\ b \end{pmatrix}$$

$$\mathbf{M} \equiv \begin{pmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{pmatrix} \quad , \quad \Gamma \equiv \begin{pmatrix} \Gamma_{11} & \Gamma_{12} \\ \Gamma_{21} & \Gamma_{22} \end{pmatrix}$$

$$\mathcal{CP}|B_q\rangle = e^{i\varphi}|\bar{B}_q\rangle,\ \mathcal{CP}|\bar{B}_q\rangle = e^{-i\varphi}|B_q\rangle$$

- CPT invariance : $M_{11} = M_{22}, \quad \Gamma_{11} = \Gamma_{22}$
- Hermiticity : $M_{21} = M_{12}^*, \quad \Gamma_{21} = \Gamma_{12}^*$

Mass and width differences

Form of M_{12} and Γ_{12}

$$\begin{aligned} M_{12}^q &= \frac{G_F^2 M_W^2}{12\pi^2} m_{B_q} B_{B_q} f_{B_q}^2 \eta_{QCD} (V_{tq}^* V_{tb})^2 S(x_t) \,, \\ \Gamma_{12}^q &= -\mathcal{N} \times [(V_{cb}^* V_{cq})^2 f(z,z) \\ &+ (V_{cb}^* V_{cq})(V_{ub}^* V_{uq}) f(z,0) + (V_{ub}^* V_{uq})^2 f(0,0) \ ] \end{aligned}$$

$$(z = m_q^2/m_t^2)$$

ΔM and $\Delta\Gamma$ in terms of M_{12} and Γ_{12}

If $|\Gamma_{12}^q| \ll |M_{12}^q|$ (valid for B_d and B_s),

$$\begin{aligned} \Delta M &= 2|M_{12}| + O(m_b^4/m_t^4) \\ \Delta\Gamma &= -2\mathrm{Re}(M_{12}^* \Gamma_{12})/|M_{12}| + O(m_b^4/m_t^4) \end{aligned}$$

Mass and width differences: theory and experiment

ΔM Measurements

- $\Delta M_d/\Gamma_d = 0.771 \pm 0.008 \Rightarrow |V_{td}|$
- $\Delta M_s/\Gamma_s = 26.92 \pm 0.15 \pm 0.10 \Rightarrow |V_{ts}|$ (only CDF. New LHCb measurement not included)

$\Delta\Gamma_s$ and $\Delta\Gamma_d$: theoretical predictions

- For Γ_{12}^d, the $(V_{cb}V_{cd}^*)^2$ term dominates, $\Gamma_{12}^d \propto (V_{cb}V_{cd}^*)^2$
- $\Delta\Gamma_d/\Gamma_d = (42 \pm 8) \times 10^{-4}$
- For Γ_{12}^s, the u-u and c-u intermediate states also contribute. $\mathrm{Arg}(\Gamma_{12}^s) \neq \mathrm{Arg}[(V_{cb}V_{cs}^*)^2]$
- $\Delta\Gamma_s/\Gamma_s = 0.137 \pm 0.027$

Lenz et al, 2011

- $\Delta\Gamma_d/\Delta\Gamma_s \approx |V_{td}/V_{ts}|^2 \approx 0.04$

$\Delta\Gamma_s$: Can new physics increase it ?

Measurement from $B_s \to J/\psi\phi$

- $\Delta\Gamma_s/\Gamma_s = 0.154^{+0.067}_{-0.065}$
- Values much larger than predictions are still allowed
  (This point will be useful soon)

NP contribution to $\Delta\Gamma_s$

- $\Delta\Gamma_s$ can only decrease by new physics effects !!

  Grossman 1996

  Caveat: Flavor-dependent NP contributions to Γ_{12} ?
- Third generation scalar leptoquark models

  AD, Kundu, Nandi, 2007
- Left-right symmetric models

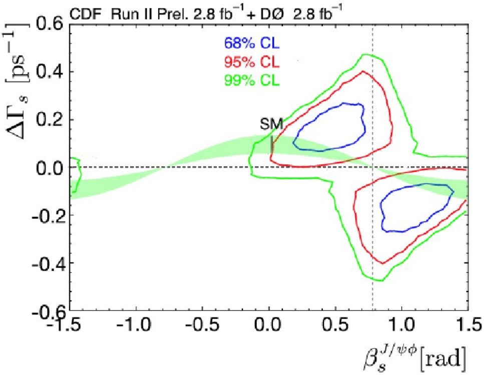
  Badin, Gabbiani, Petrov, 2007

Width difference in B_d system

$\Delta\Gamma_d$ measurement: possible? worthwhile?

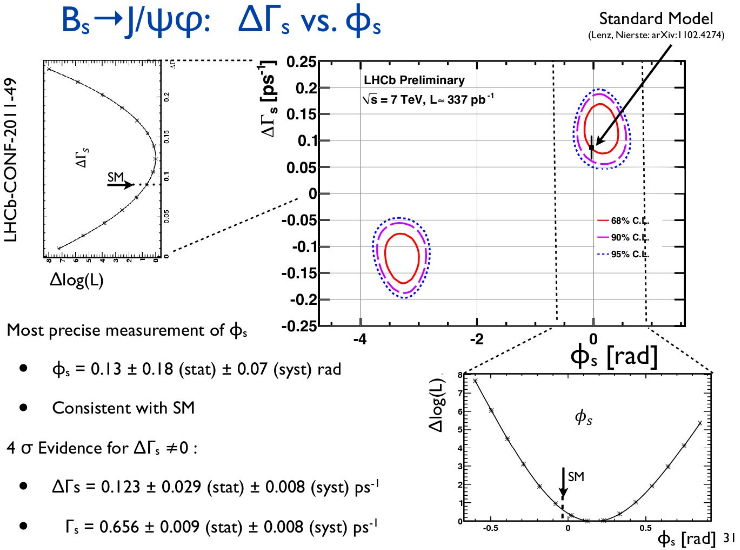
- $\Delta\Gamma_d/\Gamma_d = 0.009 \pm 0.037$ (BaBar + Delphi)
- $\Delta\Gamma_d/\Gamma_d = 0.017 \pm 0.018 \pm 0.11$ (Belle)
- May increase upto 2% with new physics
- $\Delta\Gamma_d$ neglected in theoretical calculations – OK as long as the accuracy of experiments is below per cent level.

Angular analysis of $B_s \to J/\psi\phi$: CDF and D0



- Results getting closer to SM
- Large $\Delta\Gamma_s$ and $\beta_s^{J/\psi\phi}$ still possible

Angular analysis of $B_s \to J/\psi\phi$: LHCb



$B_s \to J/\psi\varphi$: $\Delta\Gamma_s$ vs. ϕ_s

Most precise measurement of ϕ_s

- $\phi_s = 0.13 \pm 0.18$ (stat) ± 0.07 (syst) rad
- Consistent with SM

4 σ Evidence for $\Delta\Gamma_s \neq 0$:

- $\Delta\Gamma_s = 0.123 \pm 0.029$ (stat) ± 0.008 (syst) ps^{-1}
- $\Gamma_s = 0.656 \pm 0.009$ (stat) ± 0.008 (syst) ps^{-1}

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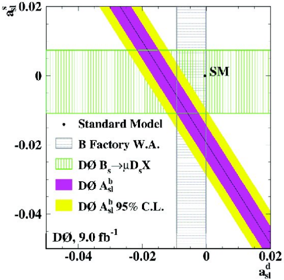
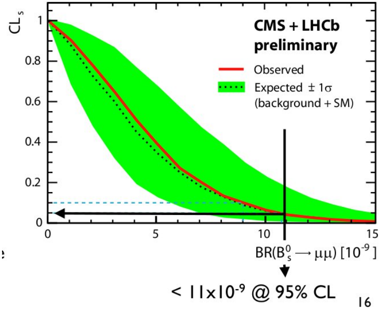
Like-sign dimuon asymmetry



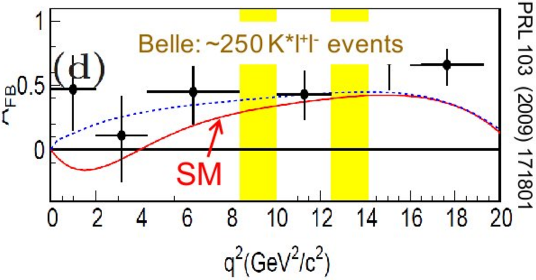
- SM $\Rightarrow A^b_{sl} = (-0.023^{+0.005}_{-0.006})\%$
- $A^b_{sl} = (-0.787 \pm 0.172 \pm 0.093)\%$
  $\Rightarrow 3.9\sigma$ deviation
- B_s sector:
  $a^s_{sl} = (-1.81 \pm 1.06)\%$
- $a^s_{sl} = \frac{\Delta\Gamma_s}{\Delta M_s} \tan \phi^{sl}_s$
- Large $\Delta\Gamma_s$ and/or large ϕ_s !

Branching ratio of $B_s \to \mu^+\mu^-$

- SM: $\mathrm{BR} = (0.32 \pm 0.02) \times 10^{-8}$
- CDF measurement: $\mathrm{BR} = (1.8^{+1.1}_{-0.9}) \times 10^{-8}$
- CMS+LHCb limit: $\mathrm{BR} < 1.1 \times 10^{-8}$



$A_{\rm FB}$ in $B \to K^* \mu^+ \mu^-$: Belle



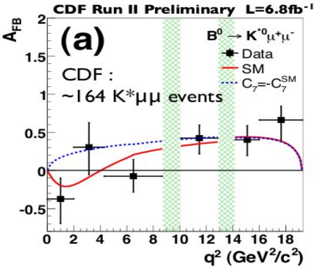
PRL 103 (2009) 171801

- From the interference between γ- and Z-penguin
- Zero of $A_{\rm FB}$ is a clean observable: the form factor dependence cancels at LO to give

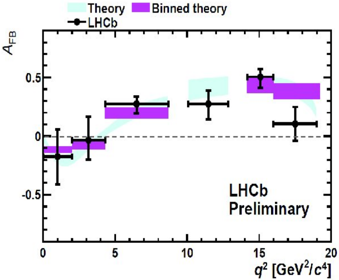
$$\mathrm{Re}[C_9^{\rm eff}(q_0^2)] = -(2 m_B m_b / q_0^2)\, C_7^{\rm eff}$$

- At NLO, $q_0^2 = 3.90 \pm 0.12$ GeV^2
- Zero crossing seems to have disappeared ??

A_{FB} in $B \to K^* \mu^+ \mu^-$: CDF, LHCb



arxiv:1108.0695



LHCb-CONF-2011-038

- Zero crossing seems to be present
- Maybe the Belle observation was just statistical fluctuation

CP asymmetry in $B \to K\pi$ decays

The puzzle

$$\begin{aligned}\Delta_{K\pi} &= A_{CP}(B^+ \to K^+\pi^0) - A_{CP}(B^0 \to K^+\pi^-)\\ &= 0.121 \pm 0.022 \Rightarrow 5.8\sigma \text{ from SM} (P.Chang, EPS2011)\end{aligned}$$

Is it just matrix element calculation ?

- C and P_{EW} corrections may be high
- QCDF: large imaginary values for C and P_{EW} amplitudes
- Evidence for large P_{EW} should have been found from $B(B^+ \to K\pi/\rho)/B(B^0 \to K\pi/\rho)$: not found
- Large C $\Rightarrow$ breakdown of power-counting in SCET
  But SCET seems to hold for all other modes !
- pQCD: higher order corrections? No consensus
- Recent claim using Pauli blocking: $\bar{b} \to \bar{s}u\bar{u}$ is Pauli-suppressed for a spectator u-quark in B^+, not for a spectator d-quark in B^0.

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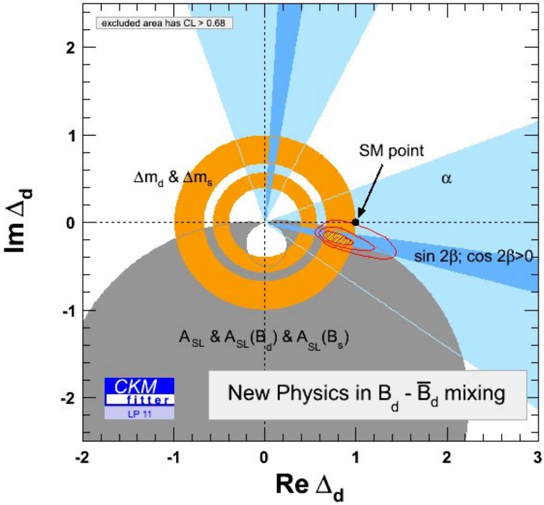
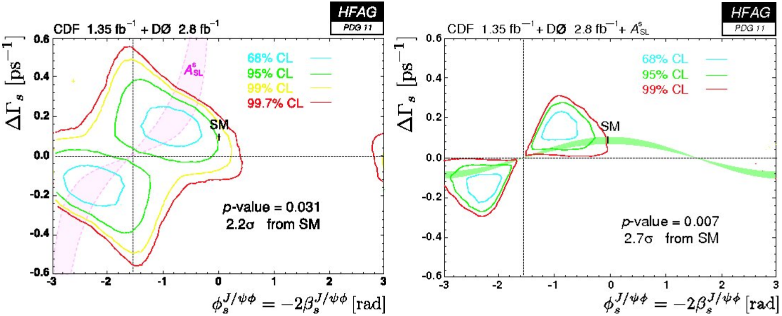
Like-sign dimuon asymmetry and $\sin 2\beta$: for B_d



$$\Delta_d = \frac{M_{12d}}{M_{12d}(SM)}$$

$J/\psi\phi$ and A_{sl}: tension, combined fit, and SM



- The two measurements prefer different values of $(\Delta\Gamma, \phi_s)$
- If forced to ve valid simultaneously, give a best fit far away from the SM

The Tale of Two Betas

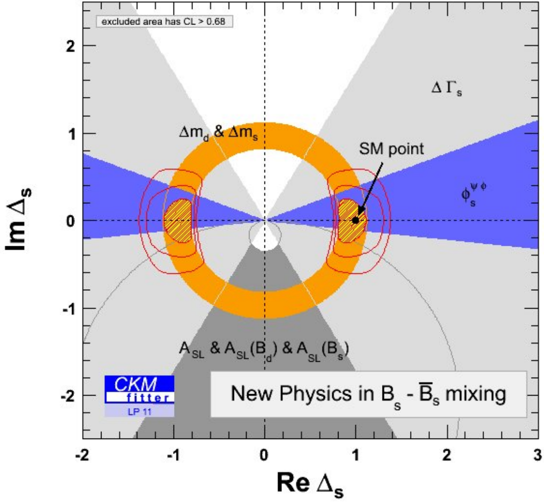
β from $B_s \to J/\psi\phi$

- $\beta_s^{J/\psi\phi} \approx \frac{1}{2}\mathrm{Arg}\left(-\frac{(V_{cb}V_{cs}^*)^2}{M_{12s}}\right)$
- $\beta_s^{J/\psi}(SM) = 0.019 \pm 0.001$

β from a_{sl}

- $a_{sl} = (\Delta\Gamma_s/\Delta M_s)\ \tan\phi_s^{sl}$
- $\phi_s^{sl} = \mathrm{Arg}(-M_{12s}/\Gamma_{12s})$
- $\mathrm{Arg}(\Gamma_{12}) \neq \mathrm{Arg}(V_{cb}V_{cs}^*)^2$ since the (c-u) and (u-u) intermediate states contribute to Γ_{12}.
- $\phi_s^{sl}(SM) = 0.0041 \pm 0.0007$
- $\beta_s^{sl}(SM) = -0.0020 \pm 0.0003$

Like-sign dimuon asymmetry and $B \to J/\psi\phi$: for B_s



$$\Delta_s = \frac{M_{12s}}{M_{12s}(SM)}$$

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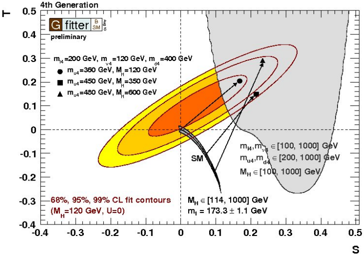
Electroweak constraints

Fourth generation still allowed with precision constraints

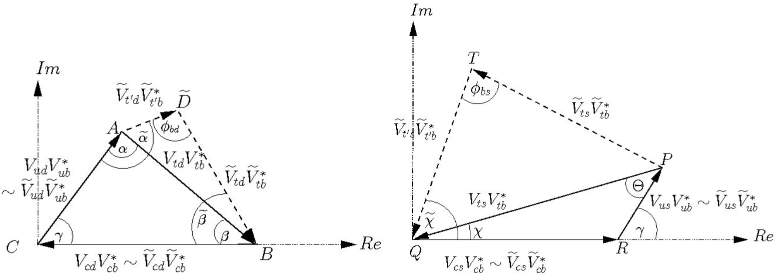


Electroweak constraints on fourth generation

- Masses cannot be too high, unitarity constraints
- Higgs mass and θ_{34} correlated

Chanowitz, Erler, Hou, Kribs, Langacker, Soni et al

Unitarity quadrilaterals



- Deviations in both, β and β_s possible

See talk by Amarjit Soni

Constraints from the flavor data

Observables that impact CKM_4 in a clean manner:

- R_{bb} and A_b from $Z \to b\bar{b}$
- ϵ_K from $K_L \to \pi\pi$
- the branching ratio of $K^+ \to \pi^+\nu\bar{\nu}$
- the mass differences in the B_d and B_s systems
- the time-dependent CP asymmetry in $B_d \to J/\psi K_S$
- γ from tree-level decays
- the branching ratios of $B \to X_s\gamma$ and $B \to X_c e\bar{\nu}$
- the branching ratio of $B \to X_s\mu^+\mu^-$ in the high-q^2 and low-q^2 regions

Constraints and implications

- $|\tilde{V}_{ub'}| < 0.06$, $|\tilde{V}_{cb'}| < 0.027$, $|\tilde{V}_{tb'}| < 0.31$ at 3σ.
- NP signals for B, D and rare K decays are still possible.

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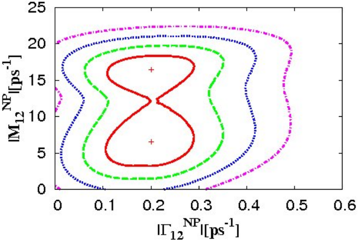
3. Concluding remarks

$\Gamma_{12}^{NP} = 0$ highly disfavored

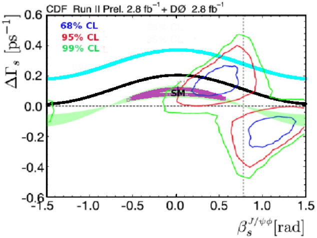


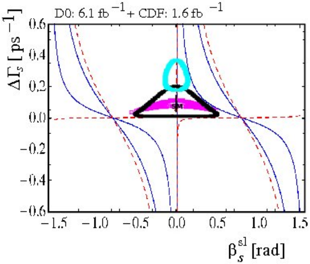
- $B_s \to J/\psi\phi$ and likesign dimuon asymmetry favor different ϕ_s regions
- The tension can be reduced only with larger $\Delta\Gamma_s$
- If no NP contribution to Γ_{12s}, difficult to be consistent with data

AD, Ghosh, Kundu, Patra, 2011

Implications of nonzero Γ_{12}^{NP}

Possible to go outside the “green band”:





Scalar leptoquarks that couple only to τ

AD, Kundu, Nandi, 2010

Z’, RPV SUSY

Deshpande, He, Valencia 2010

- $b \to s\tau\tau$ the only unconstrained operator Bauer et al, 2010
- Enhanced BR for $B_s \to \tau^+\tau^-$ predicted
- $BR(B_s \to \tau\tau) \sim 5\%$ still allowed

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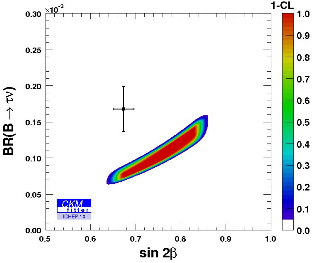
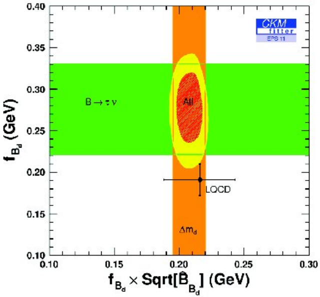
Implications of the $B \to \tau\nu$ anomaly

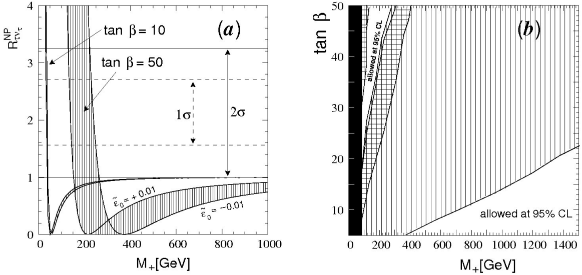




- SM: $\mathrm{BR}(B^+ \to \tau^+\nu_\tau)_{\mathrm{SM}} = (0.81 \pm 0.15) \times 10^{-4}$
- Measured: $\mathrm{BR}(B^+ \to \tau^+\nu_\tau) = (1.68 \pm 0.31) \times 10^{-4}$
- More than 2σ enhancement: difficult to explain by f_{B_d}
- New physics ? large V_{ub} ?
- But $K^+ \to \mu\nu$ looks fine. Universality violation ?
- $B \to D\tau\nu$ and $B \to D^*\tau\nu$ show similar (1.8σ) excess

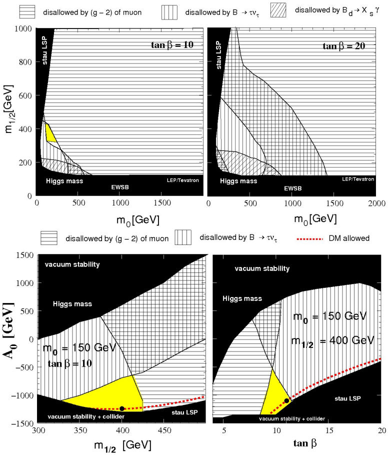
If $B \to \tau\nu$ is indeed enhanced:

$$\mathrm{BR}(B^+ \to \tau^+ \nu_\tau)_{\mathrm{NP}} = \frac{G_F^2 m_B m_\tau^2}{8\pi} \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 f_B^2 \, |\widetilde{V}_{ub}|^2 \, \tau_B \left(1 - \tan^2\beta \, \frac{m_B^2}{M_+^2}\right)^2$$



- Large M_{H^+}, small $\tan\beta$ to barely survive
- Small M_{H^+}, large $\tan\beta$ to explain the anomaly

Constraints on cMSSM



- cMSSM cannot explain the anomaly
- Only a small region in parameter space survives
- This “golden” region is still consistent with neutralino dark matter !

Bhattacharjee et al, 2011

Flavor physics is now encroaching on the territory of high-energy collider physics !

Outline

Lorentz structure of NP models

$$\mathcal{H}_{\text{eff}}(b \to s\mu^+\mu^-) = \mathcal{H}_{\text{eff}}^{SM} + \mathcal{H}_{\text{eff}}^{VA} + \mathcal{H}_{\text{eff}}^{SP} + \mathcal{H}_{\text{eff}}^{T} \,,$$

$$\begin{aligned}
\mathcal{H}_{\text{eff}}^{SM} &= -\frac{4G_F}{\sqrt{2}} V_{ts}^* V_{tb} \Big\{ \sum_{i=1}^{6} C_i(\mu)\mathcal{O}_i(\mu) + C_7 \frac{e}{16\pi^2} (\bar{s}\sigma_{\mu\nu}(m_s P_L + m_b P_R)b)\, F^{\mu\nu} \\
&\quad + C_9 \frac{\alpha_{em}}{4\pi} (\bar{s}\gamma_\mu P_L b)\, \bar{\mu}\gamma_\mu\mu + C_{10} \frac{\alpha_{em}}{4\pi} (\bar{s}\gamma_\mu P_L b)\, \bar{\mu}\gamma_\mu\gamma_5\mu \Big\} \\
\mathcal{H}_{\text{eff}}^{VA} &= \frac{\alpha G_F}{\sqrt{2}\pi} V_{tb}^* V_{ts} \Big\{ R_V\, \bar{s}\gamma_\mu P_L b\, \bar{\mu}\gamma_\mu\mu + R_A\, \bar{s}\gamma_\mu P_L b\, \bar{\mu}\gamma_\mu\gamma_5\mu \\
&\qquad + R_V'\, \bar{s}\gamma_\mu P_R b\, \bar{\mu}\gamma_\mu\mu + R_A'\, \bar{s}\gamma_\mu P_R b\, \bar{\mu}\gamma_\mu\gamma_5\mu \Big\} \,, \\
\mathcal{H}_{\text{eff}}^{SP} &= \frac{\alpha G_F}{\sqrt{2}\pi} V_{tb}^* V_{ts} \Big\{ R_S\, \bar{s}P_R b\, \bar{\mu}\mu + R_P\, \bar{s}P_R b\, \bar{\mu}\gamma_5\mu \\
&\qquad + R_S'\, \bar{s}P_L b\, \bar{\mu}\mu + R_P'\, \bar{s}P_L b\, \bar{\mu}\gamma_5\mu \Big\} \,, \\
\mathcal{H}_{\text{eff}}^{T} &= \frac{\alpha G_F}{\sqrt{2}\pi} V_{tb}^* V_{ts} \Big\{ C_T\, \bar{s}\sigma_{\mu\nu} b\, \bar{\mu}\sigma^{\mu\nu}\mu + i C_{TE}\, \bar{s}\sigma_{\mu\nu} b\, \bar{\mu}\sigma_{\alpha\beta}\mu\, \epsilon^{\mu\nu\alpha\beta} \Big\}
\end{aligned}$$

$b \to s\mu^+\mu^-$ decay modes: inter-related observables

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

- Branching ratio

$B \to X_s\mu^+\mu^-$, $B \to \mu^+\mu^-\gamma$, $B \to K\mu^+\mu^-$

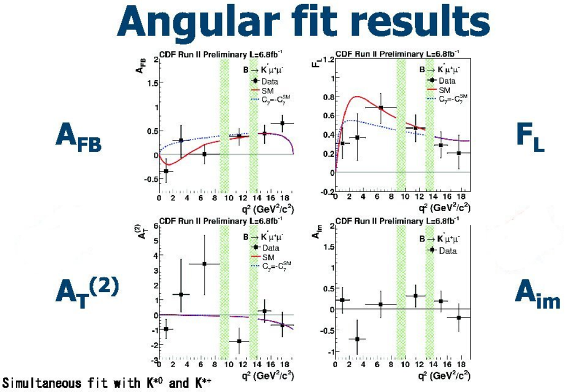
- Branching ratio, Forward-backward asymmetry A_{FB}, CP asymmetry

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

- Branching ratio, longitudinal polarization fraction f_L
- Many angular asymmetries: $A_{FB}, A_T^{(2)}, A_{LT}$
- Triple Product (TP) asymmetries: $A_T^{(im)}, A_{LT}^{(im)}$
- CP asymmetries for all of these

Angular variables in $B \to K^* \mu^+ \mu^-$

CDF results:

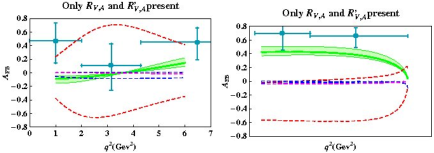


Angular fit results

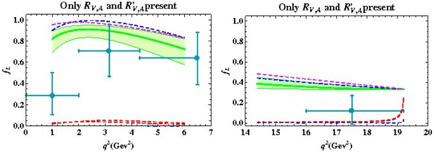
Simultaneous fit with K*0 and K*+

New VA operators: effect on $K^*\mu\mu$ observables

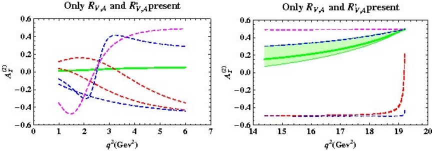
Forward-backward asymmetry



Longitudinal polarization fraction



The angular observable $A_T^{(2)}$:



Alok et al 2011

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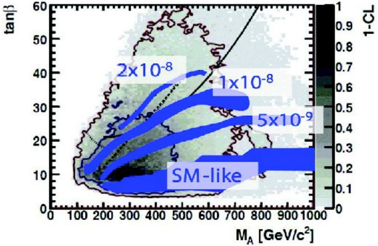
$B_s \to \mu^+\mu^-$ branching ratio

- SM: $\mathrm{BR} = (0.32 \pm 0.02) \times 10^{-8}$
- CDF measurement: $\mathrm{BR} = (1.8^{+1.1}_{-0.9}) \times 10^{-8}$
- CMS+LHCb limit: $\mathrm{BR} < 1.1 \times 10^{-8}$

$$\begin{aligned} B(\bar{B}_s \to \mu^+\mu^-) \quad &= \quad \frac{G_F^2 \alpha_{em}^2 m_{B_s}^5 f_{B_s}^2 \tau_{B_s}}{64\pi^3} |V_{tb} V_{ts}^*|^2 \sqrt{1 - \frac{4m_\mu^2}{m_{B_s}^2}} \times \\ &\left\{ \left(1 - \frac{4m_\mu^2}{m_{B_s}^2}\right) \left| \frac{R_S - R'_S}{m_b + m_s} \right|^2 + \left| \frac{R_P - R'_P}{m_b + m_s} + \frac{2m_\mu}{m_{B_s}^2} (C_{10} + R_A - R'_A) \right|^2 \right\}. \end{aligned}$$

$\Rightarrow$ Strong bounds on Scalar and pseudoscalar operators



Specific model (cMSSM):

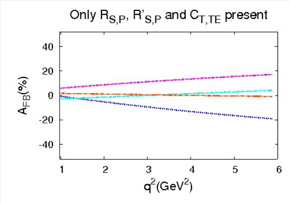
Buchmueller et al

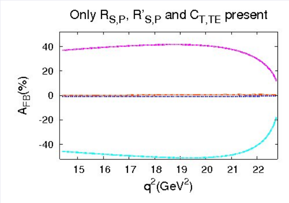
New SP and T operators

Limits (updated pre-EPS 2011):

- $|R_s - R'_S|^2 + |R_P - R'_P|^2 < 0.44$
- $|C_T|^2 + 4|C_{TE}|^2 < 1.0$

Forward-backward asymmetry in $K\mu\mu$:





- Zero everywhere in the SM, new VA operators do not help
- Enhancement at low q^2: due to S, P operators
- Enhancement at high q^2: due to T operators

Alok et al 2011

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- B physics: a window and a magnifying glass (precision measurements)
- Bounds from low-energy data getting significant enough to constrain new physics at the energy frontier
- Hints of NP in A^b_{sl}, $B \to \tau\nu$, $J/\psi\phi$:
    - New universality-breaking $b \to d\tau\nu$ and $b \to s\tau\tau$ operators?
    - Indications of NP that contribute to $\Delta\Gamma_s$?
    - $B_s \to \tau\tau$ may turn out to be crucial
- Data will tell.

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The End of B Physics (talk)

backup slides