The B_s as a Piece of the New Physics Puzzle

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Assumption

- we will have already discovered beyond the SM Physics at the Tevatron/LHC

Question to address at next generation exp's

- How can B-physics contribute to our understanding of the nature of the new physics

Specific questions to ask

1) What is the discriminating power of b-measurements to different beyond the SM flavors?
2) What are the projected sensitivities of upcoming exp's?
3) What are their limiting experimental and theoretical errors?

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any mistakes are purely due to me !

New Physics in the B System*

Class	Properties	Example
SM	• CP & Flavor violation only CKM $H_{eff}^{\Delta F=2} \propto \sum V_{CKM}^{i} C_i(\mu) Q_i \quad (Q_i = \text{VLL in SM})$ • 1 CPV phase	depressingly many
A (MFV)	• Wilson coeff's of SM op's modified by new particles	SHDM(II), CMSSM • tanβ = small
B	• new op's possible • CPV & FV still only in CKM	SHDM(II), CMSSM • tanβ = large
C	• new CPV phases in SM op's • no new op's	MSSM • tanβ = small • non-diag M(sqrk)
D	• new CPV phases • new op's • new Flavor changing contrib's	• multi-Higgs • SUSY: spont. CPV • LR Symmetric
E	• CKM not unitary	4 Generations • tree FCNCs

* Buras, hep-ph/0101336

Models & Their Consequences

Class A (Minimal Flavor Violation) Ali & London, hep-ph/0002167

– $C_1^{Wtt} = C_1^{Wtt}(SM)\ [1 + f]$

Class B (General MFV) Buras, et al, hep-ph/0107048

– $C_1^{Wtt} = C_1^{Wtt}(SM)\ [1 + f_q]$ (q = d,s,ε)

– $f_d \neq f_s \neq f_\varepsilon$

– $\Delta M_q = \Delta M_q(SM)\ [1 + f_q]$

– $\sin 2\beta \sim \sin 2\beta(SM)\ F\ [(1 + f_d),(1 + f_s),(1 + f_\varepsilon)]$

More Models…

Class C (Minimal Insertion Approx) Ali & Lunghi, hep-ph/0105200

- all M(gluino,squark) ~ TeV except lightest stop
- only 1 unsuppressed off-diagonal elem's in squark mass matrix
  - $c_L - t_2$ ~excluded by $b \to s\gamma$
- ΔM_s: $C_1^{Wtt} = C_1^{Wtt}(SM)\,[1 + f]$
- ε_K, ΔM_d, $\sin 2\beta$: $C_1^{Wtt} = C_1^{Wtt}(SM)\,[1 + f + g]$ $(g = g_R + i g_I)$

Class D (LR Sym + Spont CPV) Ball, et al, hep-ph/9910211

- very restrictive model
  - generally: sign[ε] opp. sign[$a(\psi K_s)$] (same in SM)
- $M_{12} = M_{12}^{SM}(1 + \kappa e^{i\sigma_q})$ $q = d, s$
  - κ, σ_q related mainly to (2) param's governing spont CPV

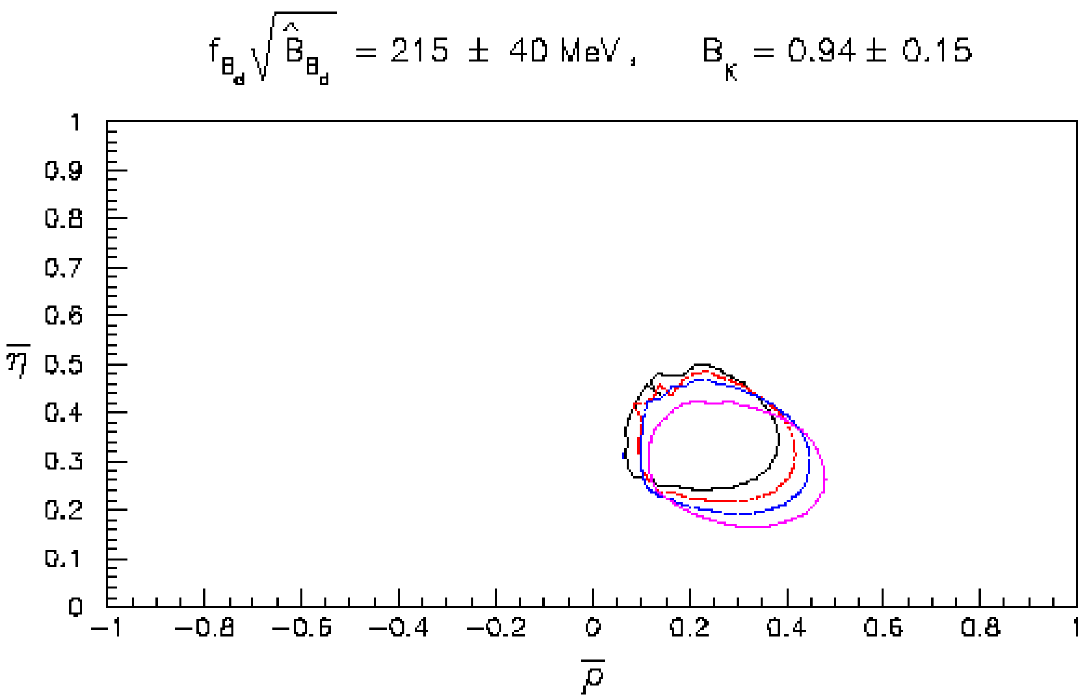
Unitarity Triangle Predictions

Model	ε_K	ΔM_d	ΔM_s / ΔM_d	$\sin 2\beta_{eff}$	γ
A (MFV)	≠ SM	≠ SM	= SM	~ SM	< SM
B (GMVF)	≠ SM	≠ SM	> SM < SM	≠ SM	> SM < SM
B (2HDM-II)	~ SM	~ SM	~ SM	~ SM	?
B (MSSM)	~ SM	~ SM	< SM	~ SM	< SM
C (MIA)	≠ SM	≠ SM	≠ SM	≠ SM	≠ SM
D (SB LR) fit	~ SM	~ SM	(0.61.1)SM	< 0.1	?

- **Measurements & constraints included in fits to specific models**
  - λ, $|V_{cb}|$, $|V_{ub}/V_{cb}|$, B_q, f_{Bi}, m_t,…
  - ε_K, ΔM_d, $b\rightarrow\gamma$,…
- **Other B measurements also see effects:**
  - $b\rightarrow s\gamma$, $b\rightarrow d\gamma$: rates and asymmetries
  - $b\rightarrow s l^+ l^-$: asymmetries
  - $B_s\rightarrow J/\psi\phi$ asymmetry
  - …

Unitarity Triangle in MFV Models

95% CL Allowed Contours from Fit



f = 0 SM

f = 0.2 mSUGRA

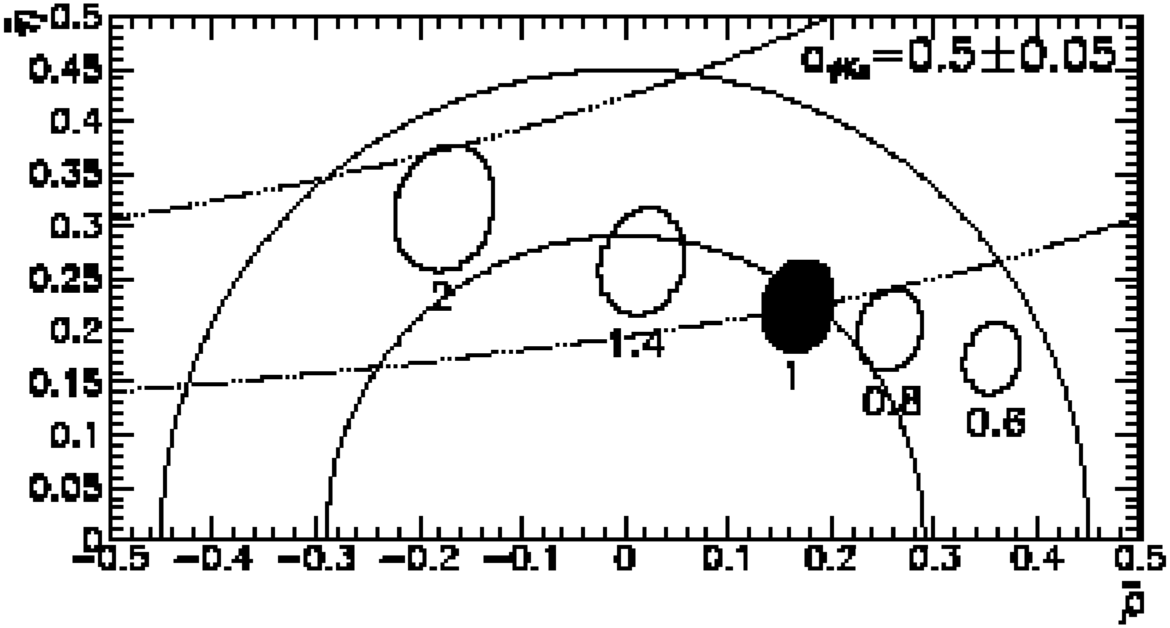
f = 0.45 non-mSUGRA

f = 0.75 non-SUGRA + nEDM

Ali and London: hep-ph/0002167

Unitarity Triangle in GMFV

1σ Allowed Contours from Fit



ΔM_s = 18.0 ± 0.05 ps^{-1}

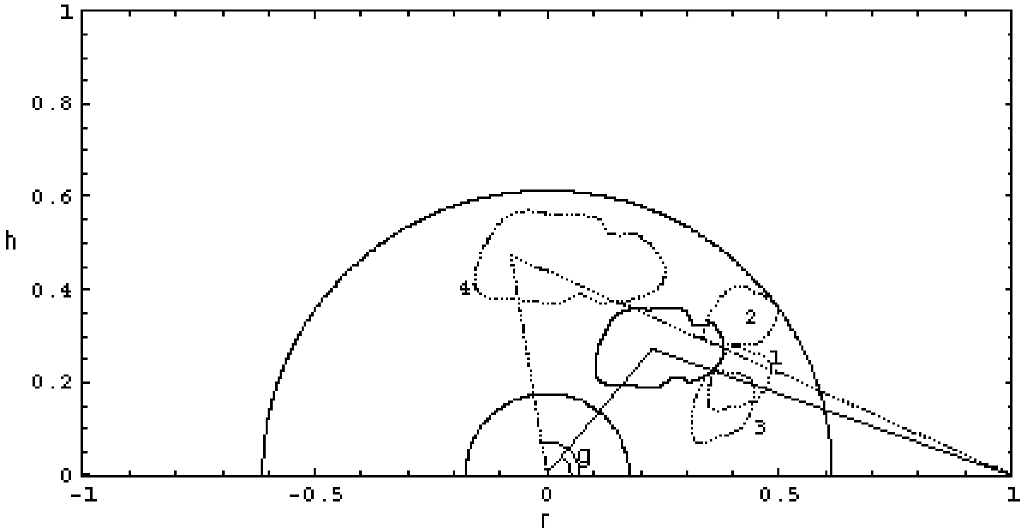
$a(\psi K_s)$ = 0.5 ± 0.05

various $R_{sd} = \dfrac{1+f_s}{1+f_d}$

Buras, Chankowski, Rosiek, Slawianowska: hep-ph/0107048

Unitarity Triangle in MIA

95% CL Allowed Contours from Fit

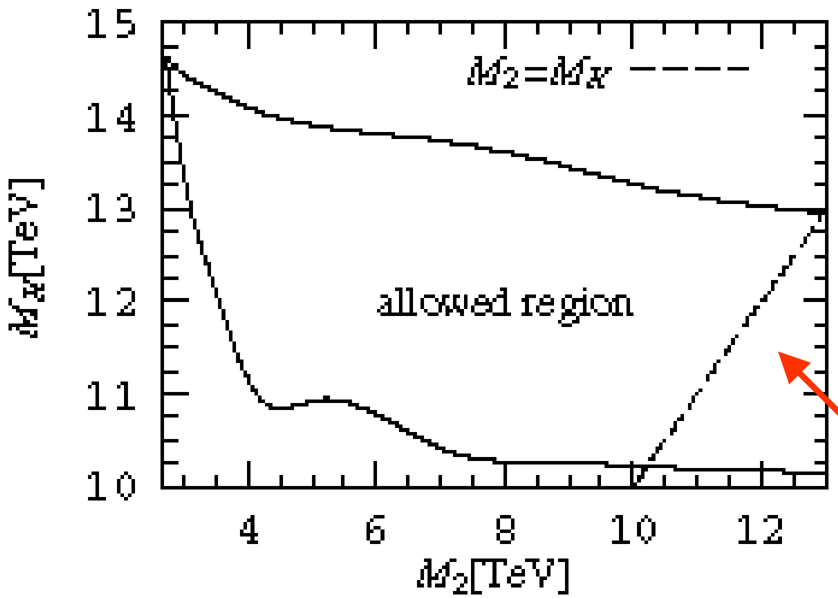


	f	g_R	g_I
SM	0	0	0
1	0	0.9	0
2	0	0.4	-0.8
3	0	0.7	0.5
4	0	-0.5	-0.2

Ali and Lunghi: hep-ph/0105200

Mass Parameters in SB LR

Allowed Region from all Constraints



***M_2* = mass of W_R**

***M_H* = extra Higgs masses**

Decoupling limit (*M_2*,*M_H*$\rightarrow\infty$) excluded

Ball, Frere, Matias: hep-ph/9910211

More Constraints: $\Delta\Gamma_s$ & ϕ_s

- **CPV Phase in B_s**
  - ***A*(*t*)[$B_s \rightarrow J/\psi\, \phi$] $\Rightarrow$ sin ϕ_s**

    $$\phi_s = arg(-M_{12}\Gamma_{12}^*) = arg\left[-\frac{V_{cs}V_{cb}^*}{V_{ts}V_{tb}^*}\right] \sim \mathbf{0.03\ \ in\ the\ SM\ (signs?)}$$

  - **like sin 2β this is free of hadronic uncertainties to *O*(10%)**
  - **New Physics $\Rightarrow$ $\phi_s = \phi_s^{SM} + \phi_s^{NP} \sim \phi_s^{NP} = arg(1 + ae^{i\vartheta})$**

- **B_s Width Difference**
  - **$\Delta\Gamma_s$ = $\Gamma_L - \Gamma_H$ = 2 | Γ_{12}| cos ϕ_s**
  - **$\Delta\Gamma_{CP}$ = 2($\Gamma_{CP+} - \Gamma_{CP-}$) = 2 | Γ_{12}| = $\Delta\Gamma_s$ / cos ϕ_s**
    - **Note that $\Delta\Gamma_s$ only *decreases* with New Physics**
  - **various methods to disentangle $\Delta\Gamma_s$ & cos ϕ_s**
    - **Dunietz, Fleischer, Nierste: hep-ph/0012219**
  - **$\Delta\Gamma_s$ coupled to ΔM_s in the SM** $$\frac{\Delta\Gamma_s}{\Delta M_s} \propto \left(\frac{m_b}{m_W}\right)^2$$

ϕ_s in New Physics Models

Model	***a***	θ
Vector d-quarks ($\Rightarrow$ bsZ)	**< 0.25**	**any**
4th Generation	**> 1**	**any**
RPV SUSY	**> 1**	**any**

Grossman: hep-ph/9603244

Experimental Statistics

Exp	Start	$\int L\, dt$ [fb^{-1}]	b-Events	Time [yr]
BaBar/Belle	1999	60-100	$65\text{-}110 \times 10^6$	1
DCF/DØ	2001	2	0.4×10^{12}	2 (run IIa)
		15	3.0×10^{12}	run IIa + IIb
BTeV	2005/6	2	0.2×10^{12}	1
Atlas/CMS	2006	10	5×10^{12}	1
		30	15×10^{12}	3 (low lumi)
LHCb	2006?	2	1×10^{12}	1
		10	5×10^{12}	5

B_s Experimental Sensitivities

Meas	SM	Current	CDF/DØ	BTeV	Atlas/CMS	LHCb
sin 2β	0.71 ± 0.09	0.61 ± 0.12	0.03 (IIa)	0.025	0.015	0.010
t-res [fs]			45/100	43	63	31
ΔM_s [ps^{-1}]	14 – 26	> 14.9	< 20/50 5σ	< 48 0.10	< 30 0.11	< 60 0.011
$\Delta\Gamma_s / \Gamma_s$	(9.3±4.0)%	< 52%	(4-8)%	(1.7-2.6)%	(1.2-1.8)%	
ϕ_s ($J/\psi\phi$)	0.03	$x_s = 20$ $x_s = 40$	— —	0.025 0.035	0.014 (3 y) 0.03 (3 y)	0.02 (3 y) 0.03 (3 y)

all sensitivities per year unless otherwise noted

Main Exp Limitations

- Statistics
- Proper Time Resolution
- Backgrounds

Main Theor Uncertainties

- $f_B \sqrt{B_B}$
- m_q

Gauging the Impact of Flavor Physics

Goal

- Compare discriminating power of Flavor Physics for different new physics models
- Quantifies where Flavor Physics makes an impact

Strategy

- Develop standard tests
- Apply these to current situation and expected future

1) Predictions for benchmark SUSY points
2) Allowed regions for classes of models
   a) Define outputs: $\bar{\rho}, \bar{\eta}$ plots, ϕ_s, model params...?
   b) Define inputs: standard current parameter sets
   c) Improvement path: collect expected sens's vs time

Problems

- do we miss something by narrowing our goals?