Exclusive Radiative B decays at BaBar

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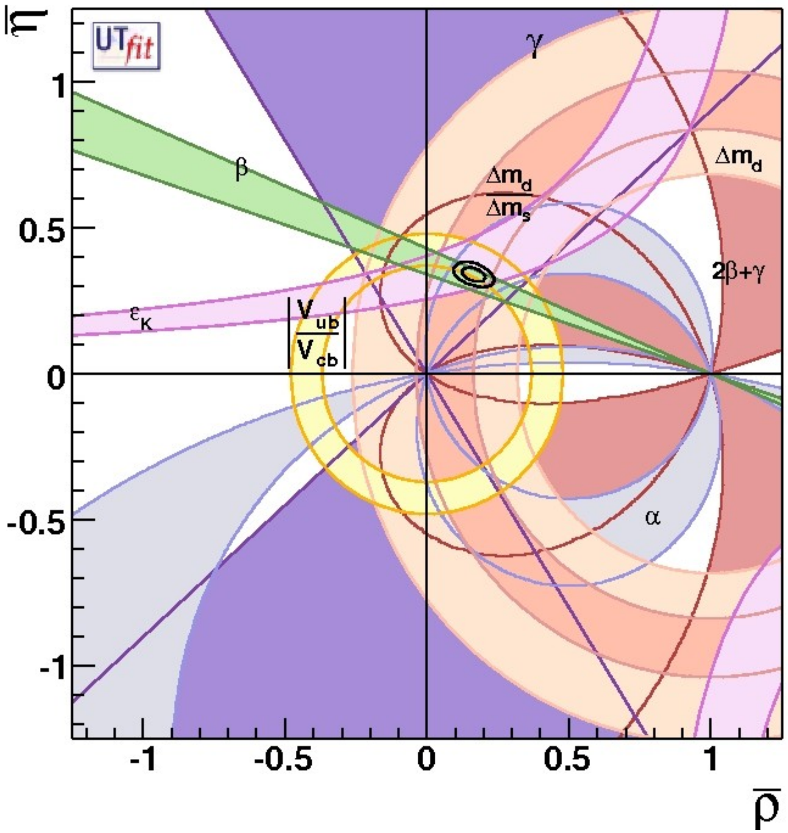
on behalf of BaBar Collaboration

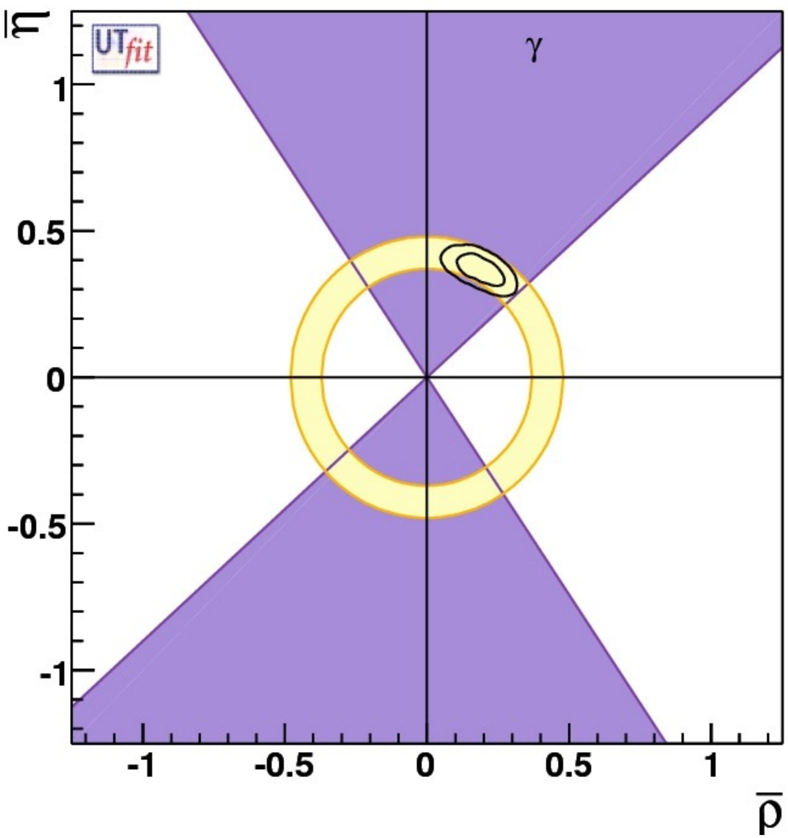
Current Situation of Flavor Physics



CP violation in the Standard Model is consistently accounted for by the CKM matrix

Allowing for the presence of NP increases the error on CKM elements but does not change the picture

NP has to be MFV or close to it if NP scale is at ~ 1 TeV



Minimal Flavor Violation

In the Minimal Flavor Violation Lagrangian

- The only source of Flavor Mixing is the CKM
- NP is flavor blind at a certain scale (e.g. the GUT scale for mSugra, 1/R scale for EDM)

At energy scale ~ m_b

- All CP violation effects are induced by the CKM couplings, i.e. the measurement of phases in charmless decays cannot show deviations from the SM
- NP has effects on the rates, since the flavor-blindness condition is broken by the RGE in the evolution of the Lagrangian from high scale to low scale

Flavor physics is an interesting search field even in this constrained scenario

Radiative Penguin Decays

The leading contribution in radiative penguin decays is at loop level

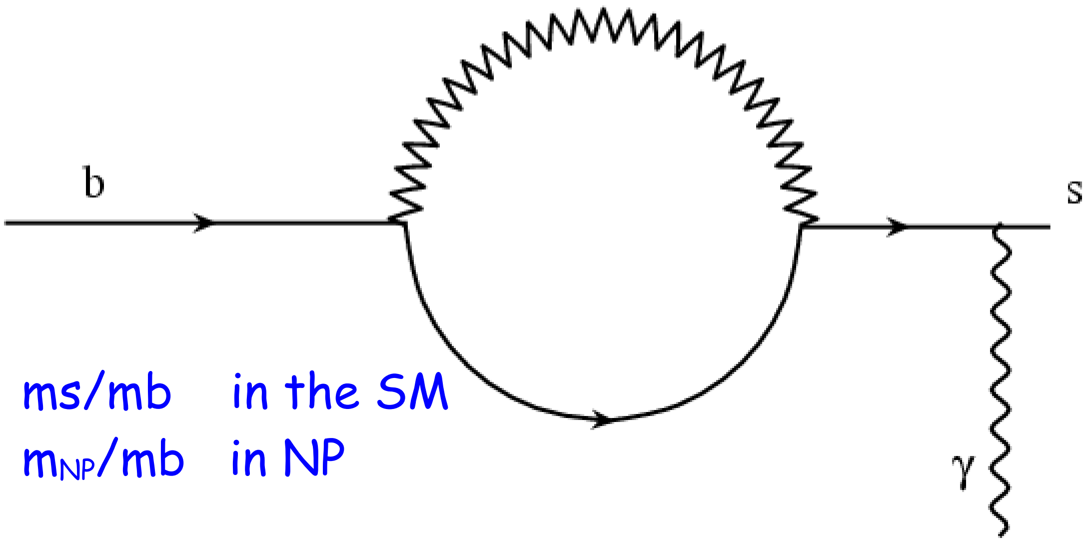
- suppressed in the Standard Model
- (maybe) comparable to NP effects

Similar situation is shared by B_q-meson mixing (q=d,s)

common sensitivity to NP in $b \to q$ transitions

The uniqueness of radiative penguin:

the suppression factor of the "opposite" chirality in the Standard Model does not have any effect if there are heavy-states contribution



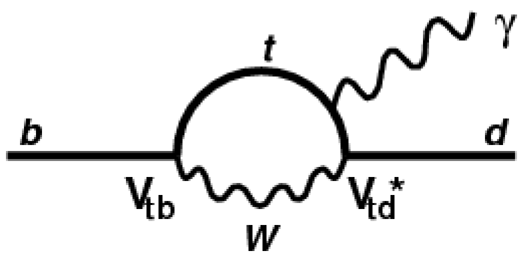
ms/mb in the SM

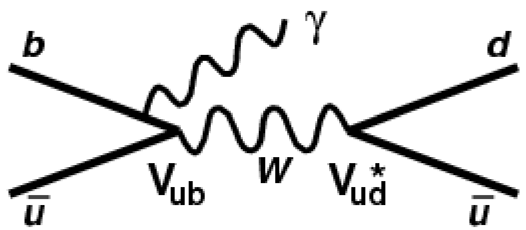
m_{NP}/mb in NP

The comparison of radiative decays and B_q mixing allows to disentangle NP effects. The example: $\Delta md/\Delta ms$ vs $BR(b \to d\gamma)/BR(b \to s\gamma)$

Exclusive $b \to d\gamma$ Decays

- SM branching fraction suppressed by $|V_{td}/V_{ts}|^2 \sim 0.04$ w.r.t. $b \to s\gamma$
- Second (sizable?) SM diagram
  - Good: additional observables (expect significant (~10%) SM A_{CP})
  - Bad: theoretical error to go from ratios of BR to the CKM factor





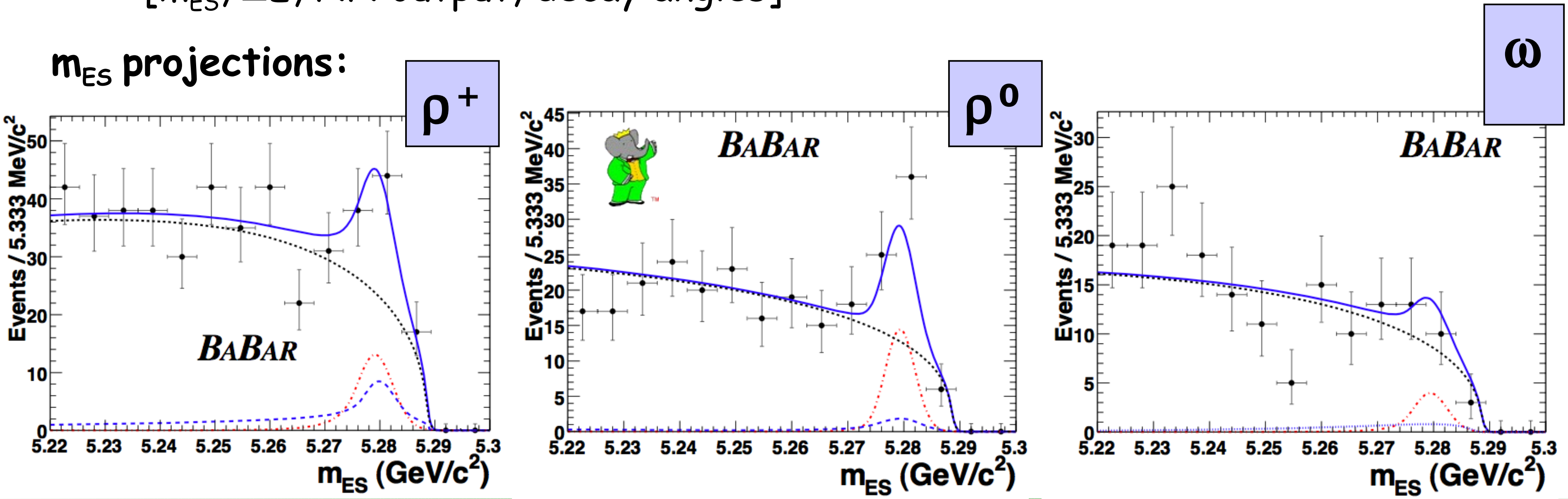
- First observed by Belle ($B \to \rho^0\gamma$)
  PRL 96, 221601 (2006)
- Here: recent BaBar measurement
  PRL 98, 151802 (2007)

Effect >10%
(depending on the channels)

$B \to (\rho,\omega)\gamma$: Analysis [316 fb^{-1}]

- Reconstruct $\rho^{+/0} \to \pi^+\pi^{0/-}$, $\omega \to \pi^+\pi^-\pi^0$
- Background suppression/discrimination is key:
  - continuum [Neural Net with event shape, B tagging information, …]
  - $B \to K^*\gamma$ [particle ID]
  - $B \to (\rho^{\pm,0},\omega)(\pi^0,\eta)$ [helicity angle, invariant mass, energy of the "other" photon]
- Perform 4D (5D) likelihood fits for ρ (ω) channels
  - [m_{ES}, ΔE, NN output, decay angles]

m_{ES} projections:



$B \to (\rho,\omega)\gamma$: Branching Ratios

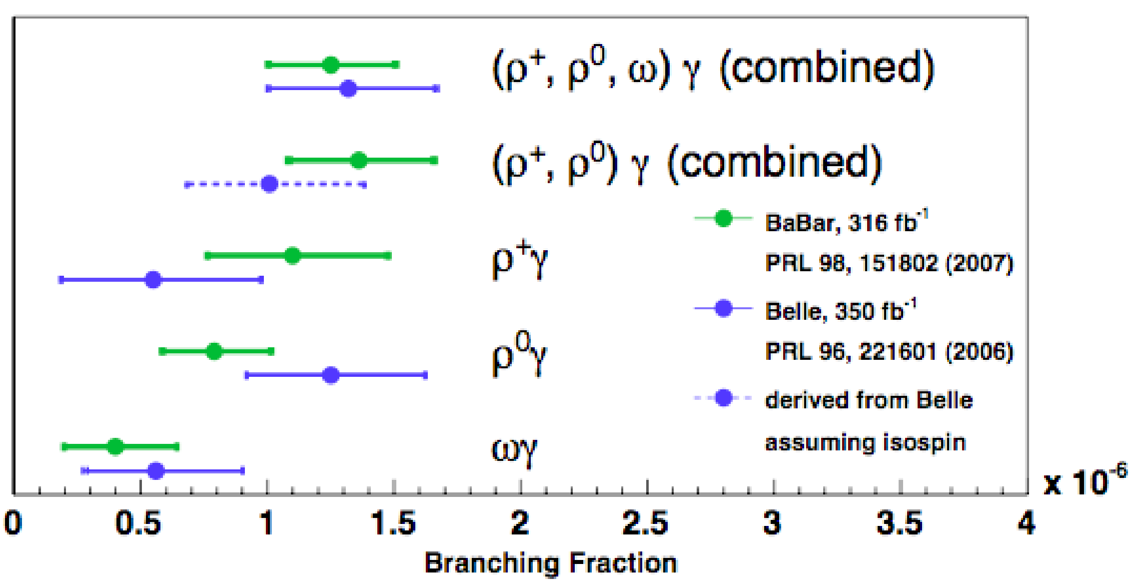
Mode	N_{signal}	*Significance*	$BF(10^{-6})$
$B^+ \to \rho^+\gamma$	$42.0^{+14.0}_{-12.7}$	3.8σ	$1.10^{+0.37}_{-0.33} \pm 0.09$
$B^0 \to \rho^0\gamma$	$38.7^{+10.6}_{-9.8}$	4.9σ	$0.79^{+0.22}_{-0.20} \pm 0.06$
$B^0 \to \omega\gamma$	$11.0^{+6.7}_{-5.6}$	2.2σ	$0.40^{+0.24}_{-0.20} \pm 0.05$
Combined	**simultaneous fit**	6.4σ	$1.25^{+0.25}_{-0.24} \pm 0.09$

Combined BR($\rho\gamma$)
$1.36^{+0.29}_{-0.27} \pm 0.10$

PRL 98, 151802 (2007)

- First evidence of $B^+ \to \rho^+\gamma$
- First BaBar observation of $B \to (\rho/\omega)\gamma$
- Consolidated experimental picture; BaBar and Belle results agree well

BR($\rho^+\gamma$)~2BR($\rho^0\gamma$) ~2BR($\omega\gamma$)
from isospin relations



$B \to (\rho,\omega)\gamma$: from BR to CKM

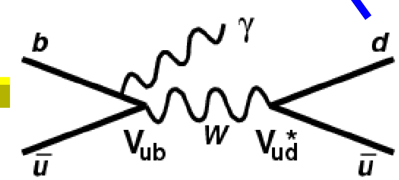
[Ali, Parkhomenko; Beneke, Feldmann, Seidel; Bosch, Buchalla

isospin factor

ratio of factorized amplitudes

SU(3) breaking in the form factor

$$\frac{BR(B\to\rho\gamma)}{BR(B\to K^*\gamma)} = c_\rho \left(\frac{m_B^2 - m_\rho^2}{m_B^2 - m_{K*}^2}\right)^2 \left|\frac{a_7^c(\rho\gamma)}{a_7^c(K^*\gamma)}\right|^2 \frac{1}{\xi^2}(1+\Delta R)\left|\frac{V_{td}}{V_{ts}}\right|^2$$



x CKM factors ~cosα

- ΔR is channel dependent
- Expected to be small in $B^0\to\rho^0\gamma$
- Larger in other channels
- CKM suppression in the SM and in MFV, not general

This is a **crucial test of NP models** if a reliable **calculation of ΔR** is provide. Otherwise use only $B^0\to\rho^0\gamma$

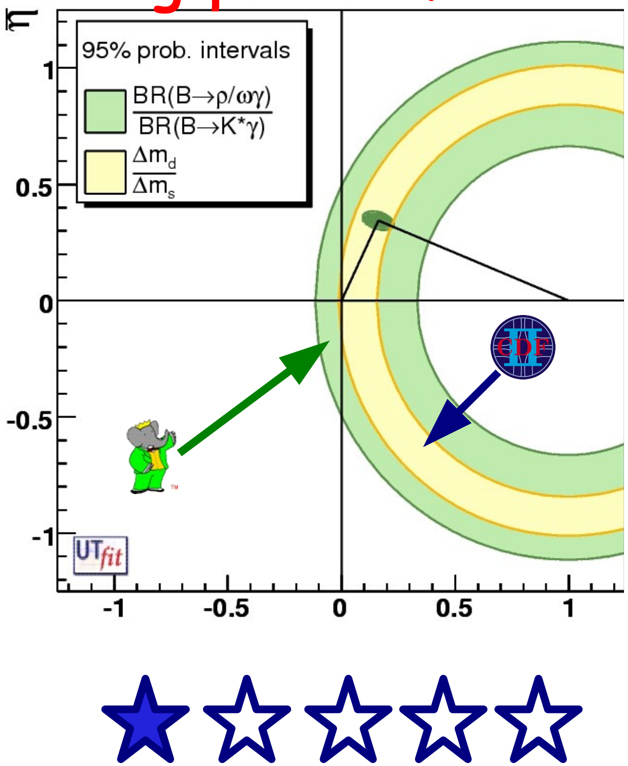
Alternatives

- **Inclusive $b\to d\gamma$ over $b\to s\gamma$**
- $B_s\to K^{*0}\gamma$ from Υ(5S) runs ($\Delta R=0$) Baracchini et al. hep-ph/0703258

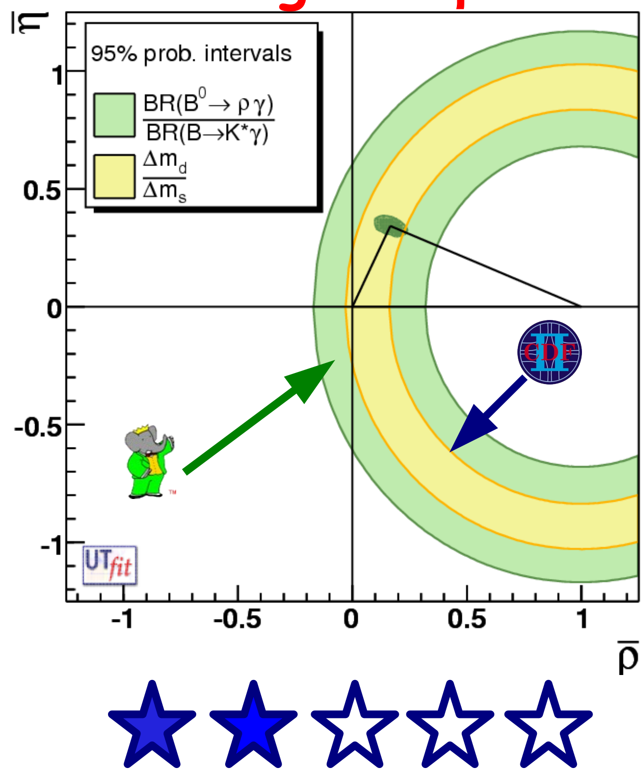
The interpretation of the exp. average is questionable because of different theoretical errors

B → (ρ,ω)γ vs. the UT*fit*

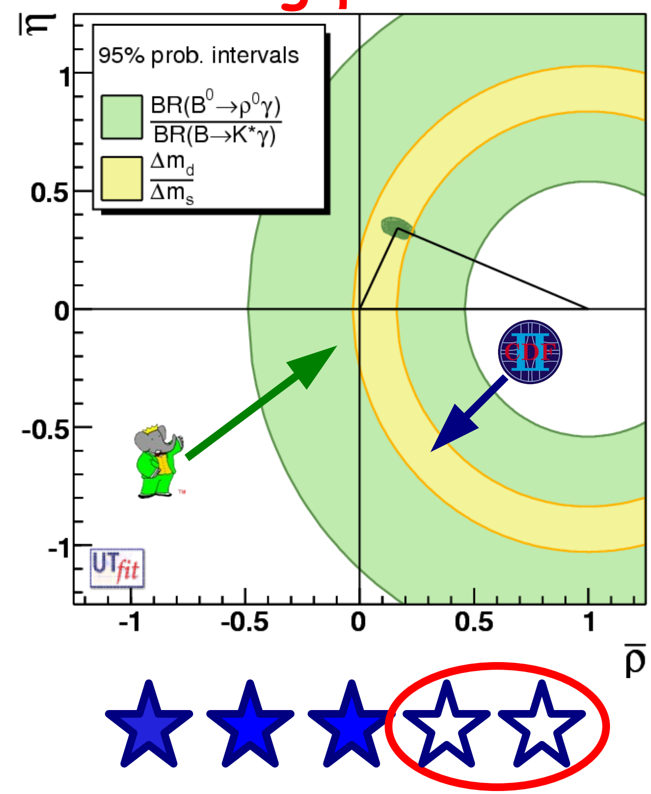
using ρ/ω combination



using the $\rho^{+/0}$



using ρ^0 alone



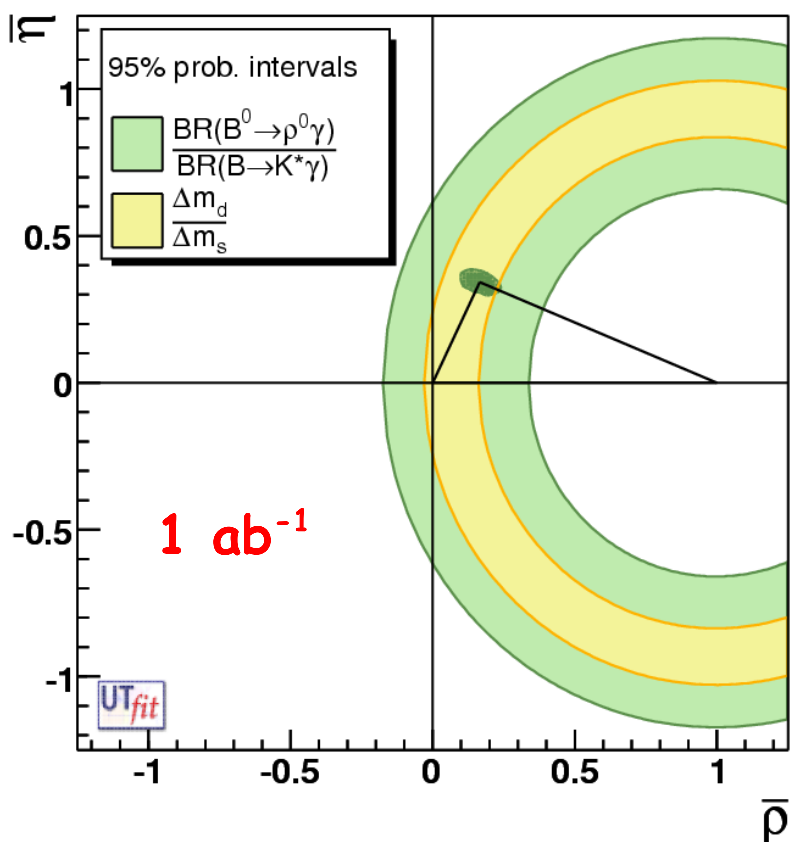
It is still true that perturbative predictions of $B \to K^*\gamma$ are off by a factor ~1.5. Is the penguin ratio safe enough, i.e. are non-perturbative penguin contributions SU(3) conserving?

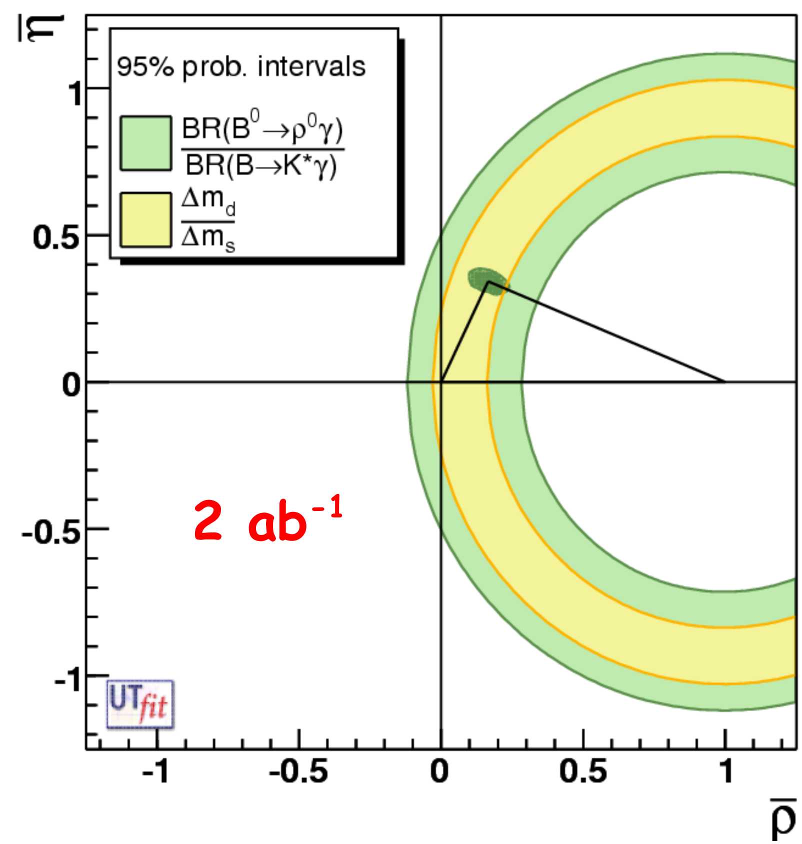
Future Perspectives(I)

The 5σ level could be reached already with a statistics of 500 fb^{-1}. A prediction of the expected precision depends on the assumptions (BR and luminosity)

using $B^0 \to \rho^0 \gamma$ only

	$\vert V_{td}/V_{ts}\vert$ precision (%)		
	500 fb^{-1}	1000 fb^{-1}	2000 fb^{-1}
$\mathcal{B} = 0.33 \times 10^{-6}$	24	18	14
$\mathcal{B} = 0.43 \times 10^{-6}$	19	14	11
$\mathcal{B} = 0.55 \times 10^{-6}$	15	11	8





Search for $B \to \pi \ell\ell$ (I)

Rare decays: expected 10^{-8} in the SM

Possible effects from new physics in the loop

Main sources of background

γ conversions in $B \to \pi\pi^0$ decays

removed imposing m(ee)>30 MeV/c2

charmonium events

removed imposing

$2.90 < m(ee) < 3.20$ GeV/c^2	**J/ψ**
$3.00 < m(\mu\mu) < 3.20$ GeV/c^2	**J/ψ**
$3.60 < m(\ell\ell) < 3.75$ GeV/c^2	**ψ(2S)**

misidentified hadrons after imposing PID requirements

<1% (4%) residual background to electrons (muons)

<5% residual background to pions

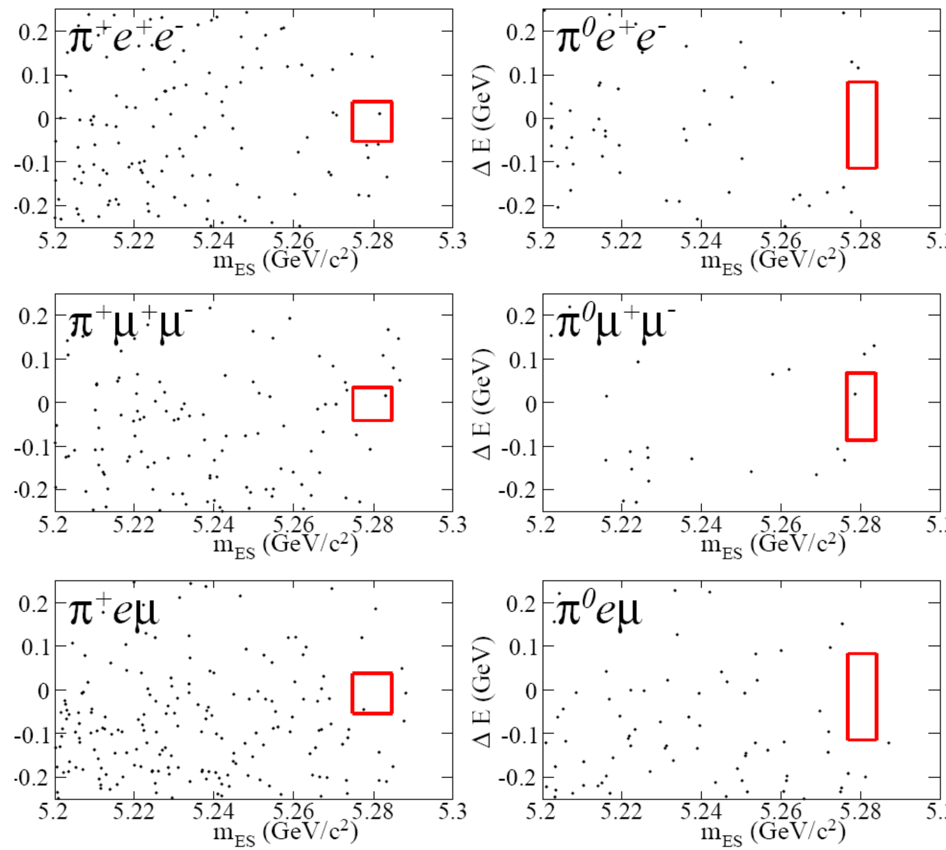
Signal events characterized by $m_{ES} = \sqrt{E_b^{*} - |p_B^{*}|}$ and $\Delta E = E_B^* - E_b^*$

$B^0 \to J/\psi(\ell\ell)\,\pi^0$ and $B^+ \to J/\psi(\ell\ell)\,K^+$ used as control samples

Search for B→πℓℓ (II)

hep-ex/0703018, subm. to PRL **209 fb^{-1}**

Mode	Observed Events	Expected Background	Signal Efficiency	$\mathcal{B}$ U.L. 90% C.L.
$B^+ \to \pi^+ e^+ e^-$	1	0.90 ± 0.24	$7.1 \pm 0.3\%$	1.8
$B^0 \to \pi^0 e^+ e^-$	0	0.44 ± 0.23	$5.7 \pm 0.5\%$	1.4
$B^+ \to \pi^+ \mu^+ \mu^-$	1	0.96 ± 0.29	$4.7 \pm 0.3\%$	2.8
$B^0 \to \pi^0 \mu^+ \mu^-$	1	0.27 ± 0.20	$3.1 \pm 0.3\%$	5.1
$B^+ \to \pi^+ e^\pm \mu^\mp$	1	1.55 ± 0.49	$6.3 \pm 0.3\%$	1.7
$B^0 \to \pi^0 e^\pm \mu^\mp$	0	1.22 ± 0.50	$3.7 \pm 0.3\%$	1.4
$B^+ \to \pi^+ \ell^+ \ell^-$				1.2
$B^0 \to \pi^0 \ell^+ \ell^-$				1.2
$B \to \pi \ell^+ \ell^-$				0.91
$B \to \pi e^\pm \mu^\mp$				0.92



No evidence of signal
Translated into 90% C.L.
upper limits (in units of 10^{-7})

Future Perspectives(II)

Update of these and other analyses to the full available dataset. A few examples

BR of b→d channels

$B\to\rho\gamma$

$B\to\pi\ell\ell$

$B\to\gamma\gamma$

BR of b→s channels

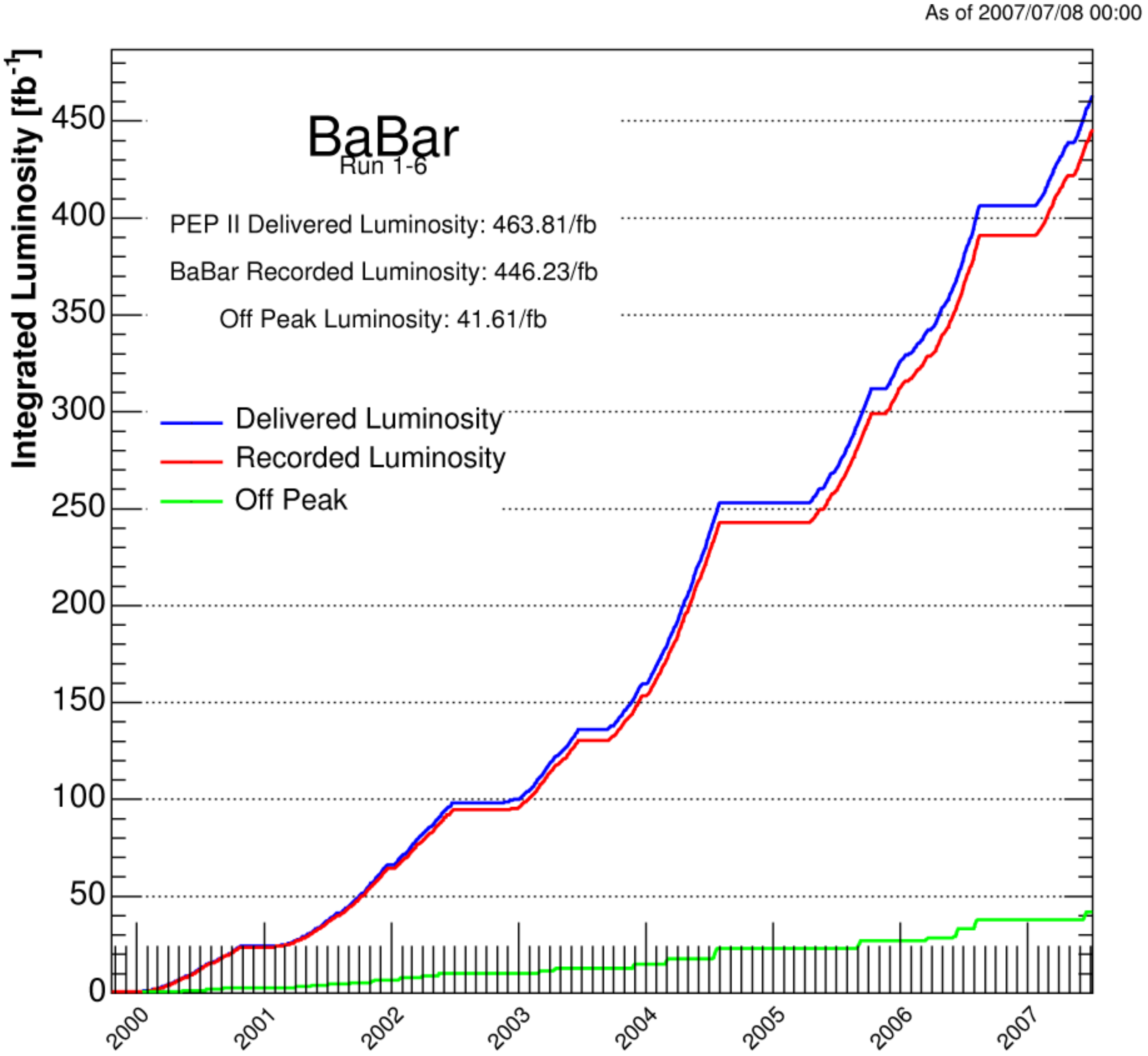
$B\to K^*\gamma$

$B\to K^{(*)}\ell\ell$

TD analyses of

$B\to K^0\pi^0\gamma$

$B\to K^0\eta\gamma$



Conclusions

- Even in the worst (for flavor physics) NP scenario, radiative penguins are an important probe of New Physics
- The statistics of B factories is large enough to constraint $b \to s$ and the almost unexplored $b \to d$ penguin transitions
- The first remarkable example: $B \to \rho/\omega\,\gamma$ and determination of $|V_{td}/V_{ts}|$ from penguin decays

In the next future

- more channels will be added
- the old analyses will be updated to the full dataset

Important constraints on NP models, waiting for the evidence of new heavy states from LHC

Backup Slides

Comparison with data

$$\mathcal{B}_{\rm th}(B \to K^*\gamma) = \tau_B \frac{G_F^2 \alpha |V_{tb}V_{ts}^*|^2}{32\pi^4} m_{b,\rm pole}^2 M^3 \left[\xi_\perp^{(K^*)}\right]^2 \left(1 - \frac{m_{K^*}^2}{M^2}\right)^3 K_{\rm NLO} \left|C_7^{(0)\rm eff}\right|^2$$

$$K_{\rm NLO} = \frac{\left|C_7^{(0)\rm eff} + A^{(1)}(\mu)\right|^2}{\left|C_7^{(0)\rm eff}\right|^2} \quad \text{with} \quad 1.5 \le K \le 1.7$$

$$\mathcal{B}_{\rm th}(B^0 \to K^{*0}\gamma) \simeq (6.9 \pm 1.1) \times 10^{-5} \left(\frac{m_{b,\rm pole}}{4.65\ \rm GeV}\right)^2 \left(\frac{\xi_\perp^{(K^*)}}{0.35}\right)^2$$

$$\mathcal{B}_{\rm th}(B^\pm \to K^{*\pm}\gamma) \simeq (7.4 \pm 1.2) \times 10^{-5} \left(\frac{m_{b,\rm pole}}{4.65\ \rm GeV}\right)^2 \left(\frac{\xi_\perp^{(K^*)}}{0.35}\right)^2$$

- $T_1^{K^*}(0) = (1 + O(\alpha_s))\xi_\perp^{(K^*)}(0)$

[Beneke, Feldmann]

Current Experimental Average

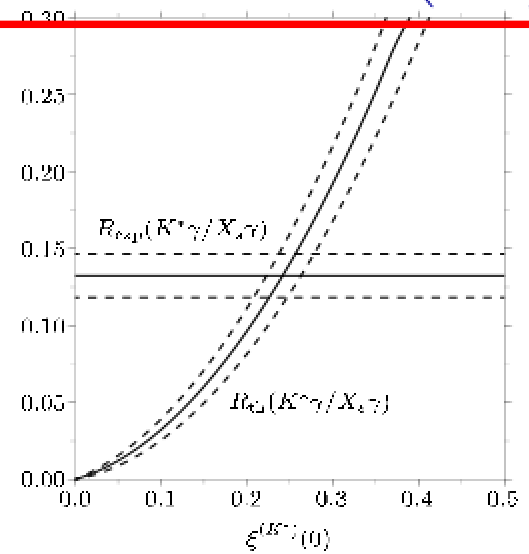
$$\mathcal{B}(B^0 \to K^{*0}\gamma) = (4.01 \pm 0.20) \times 10^{-5}$$

$$\mathcal{B}(B^\pm \to K^{*\pm}\gamma) = (4.03 \pm 0.26) \times 10^{-5}$$

- Using the ratio

$$R_{\rm exp}(K^*\gamma/X_s\gamma) = 0.124 \pm 0.012$$

$$\Longrightarrow \quad T_1^{K^*}(0) = 0.27 \pm 0.02$$



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FPCP 2007