Beyond the Standard Model

Searches for New Physics at the B-Factories

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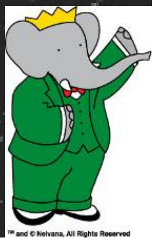
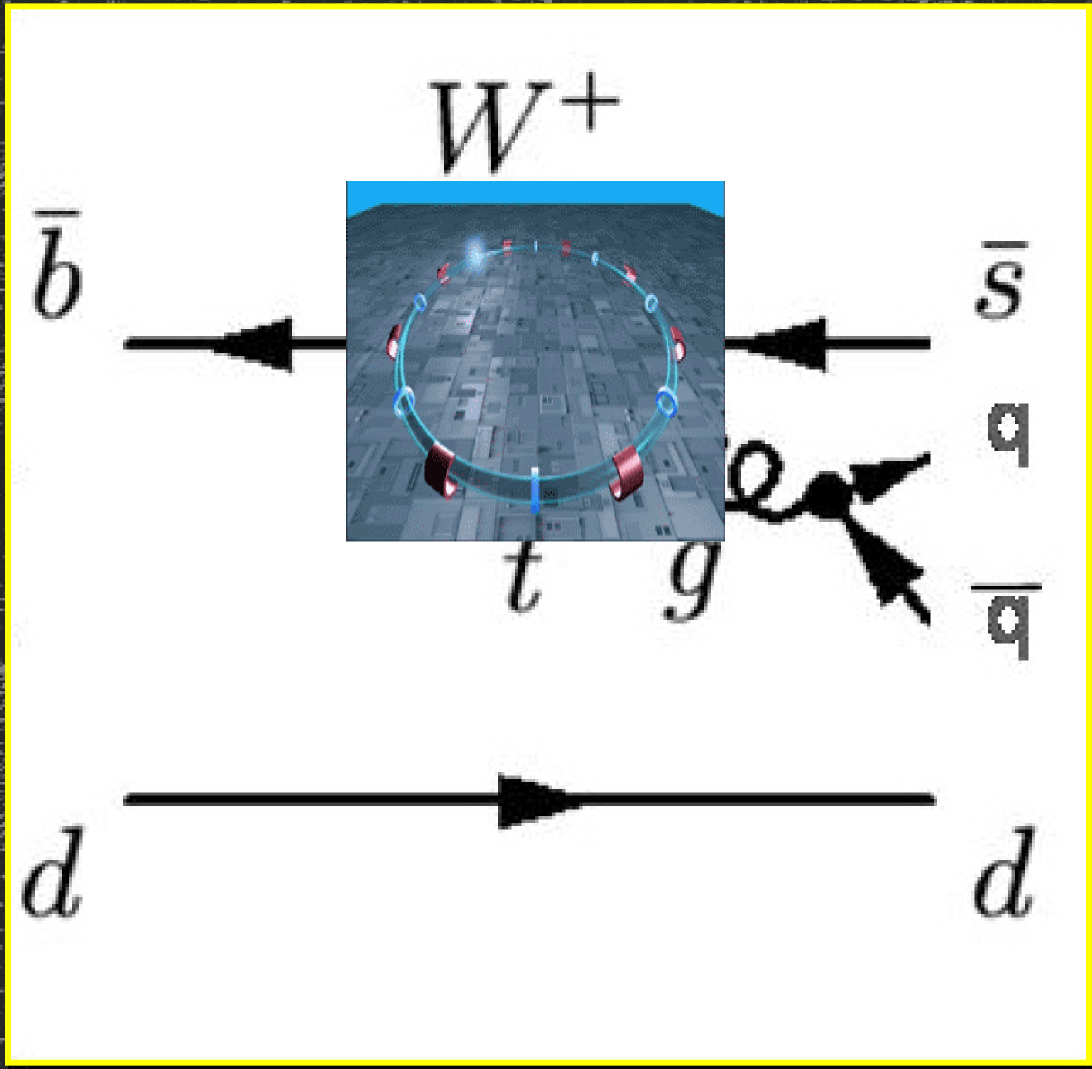
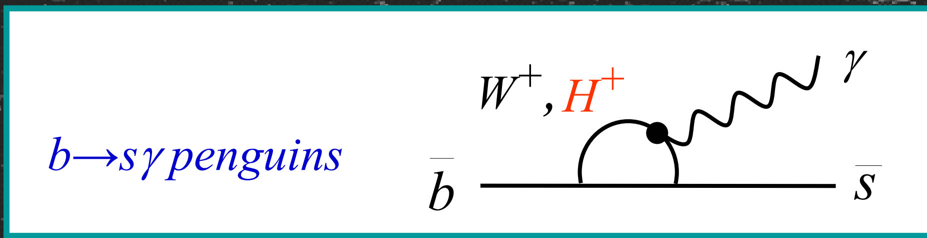
Ohio State University
Aspen 2006

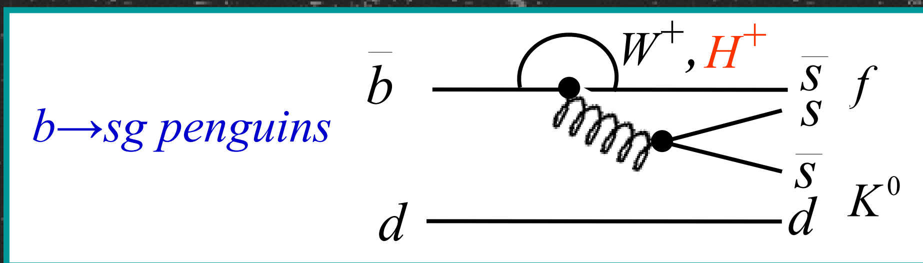


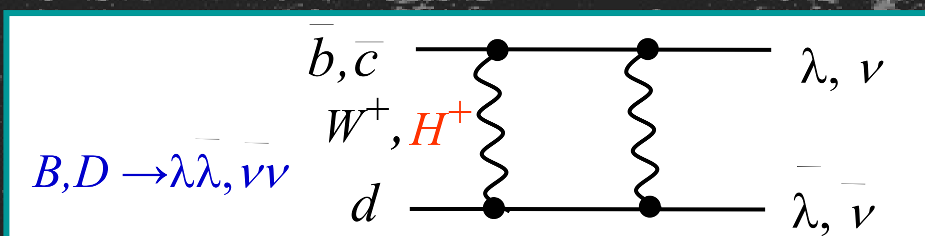
Where to look for New Physics?

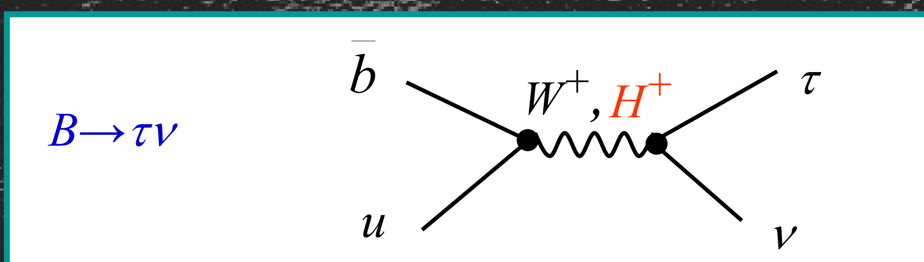


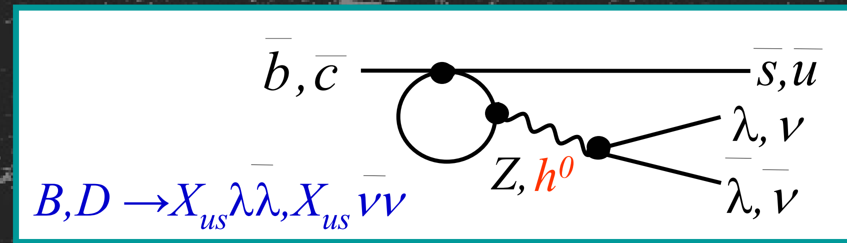
Experimental Strategies

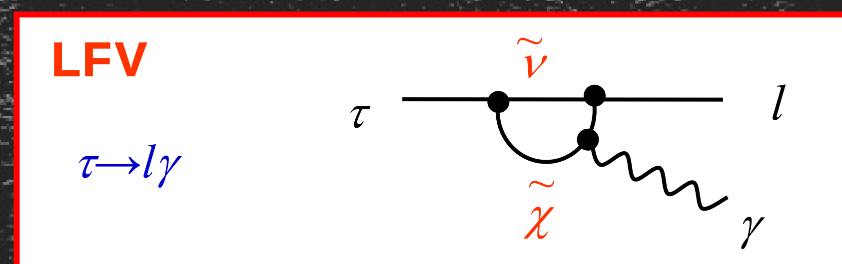






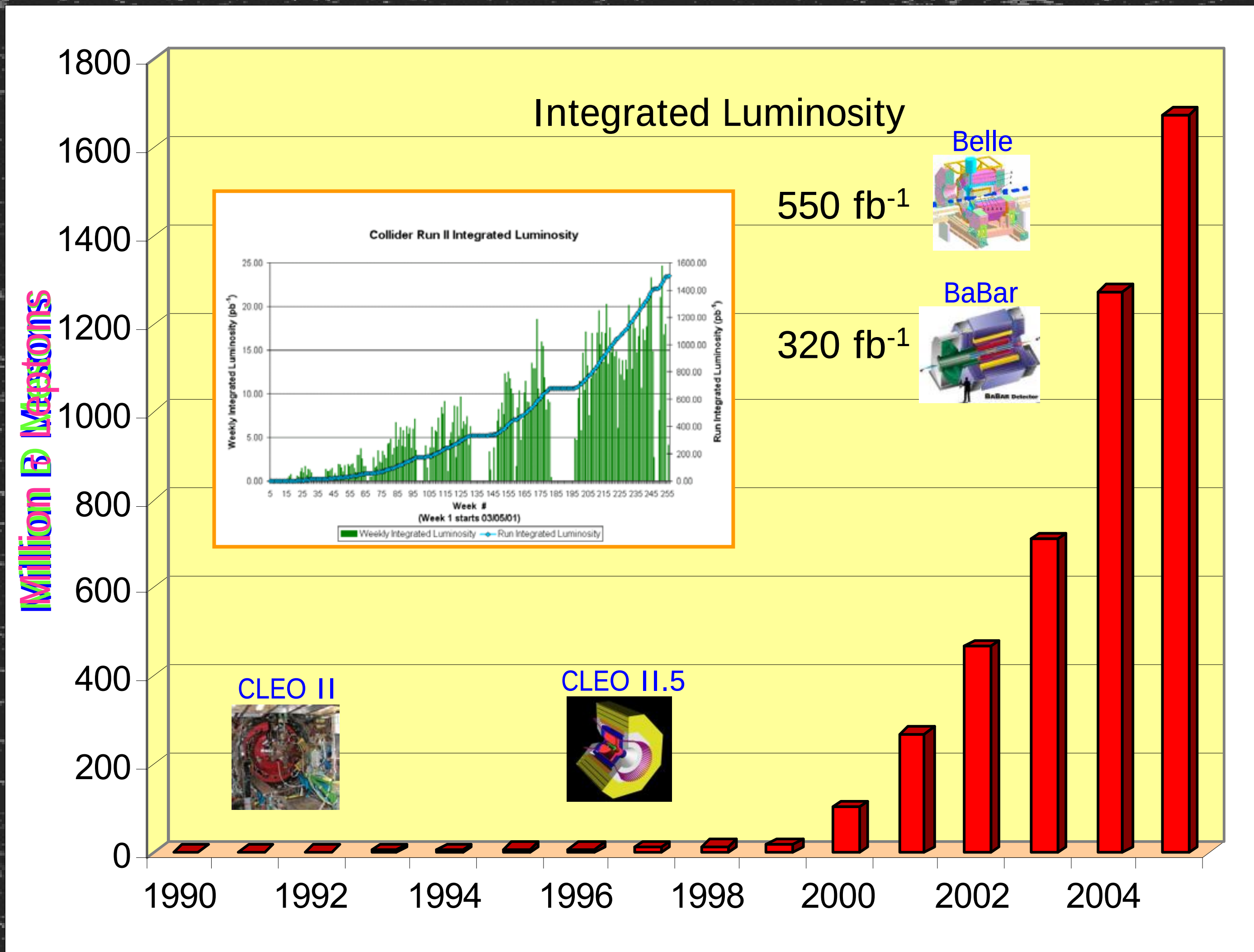






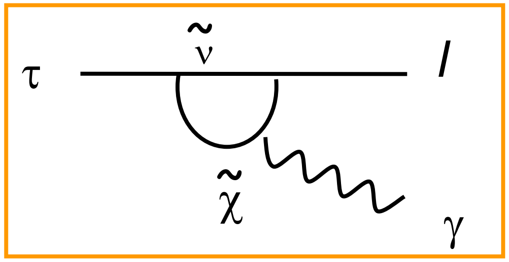
From Hitlin, LHC Lavor Workshop

Experimental Landscape (ca 2006)



Search for Lepton Flavor Violation in τ Decays

- Lepton flavor is conserved in the Standard Model
  - not protected by an underlying conserved current symmetry
  - Neutrino Masses
- Many SM extensions include LF violation

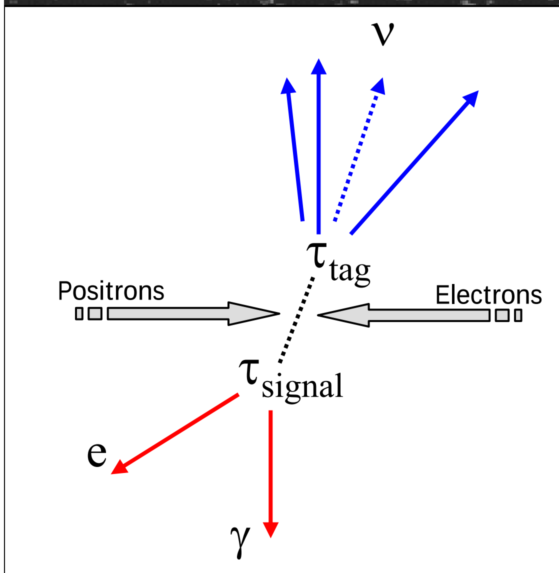


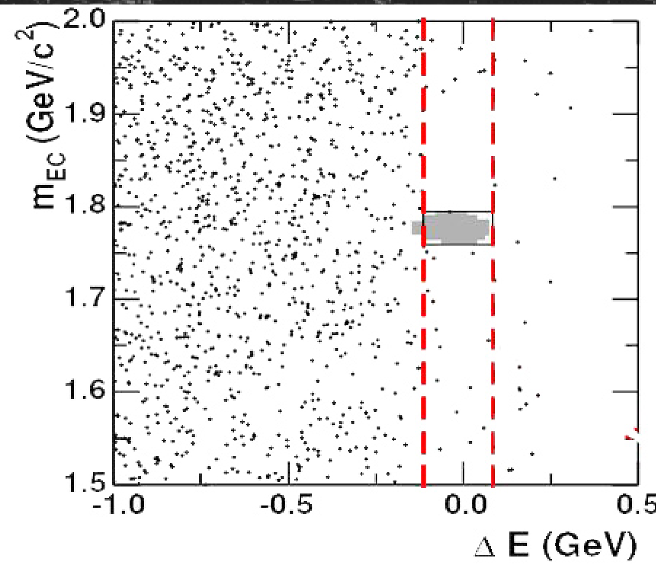
Model	$\tau \to \ell\gamma$	Reference
SM + lepton mixing	10^{-40}	hep-ph/9810484
SM + rh heavy Majorana neutrino	$<10^{-9}$	PRD66(2002)034008
mSUGRA + seesaw	$<10^{-7}$	hep-ph/0206110, hep-ph/9911459
SUSY $SU(5)$	$<10^{-4}$	hep-ph/0303071
SUSY $SO(10)$ + seesaw	$<10^{-5}$	hep-ph/0209303, hep-ph/0304190, hep-ph/0405017
SUSY anomalous $U(1)$	$<10^{-7}$	hep-ph/0308093
neutral SUSY Higgs	$<10^{-10}$	hep-ph/0304081)
MSSM+nonuniversal soft SUSY breaking	$<10^{-10}$	hep-ph/0305290
Non universal Z' (technicolor)	$<10^{-9}$	PLB547(2002)252
extra dimensions	$<10^{-11}$	hep-ph/0210021

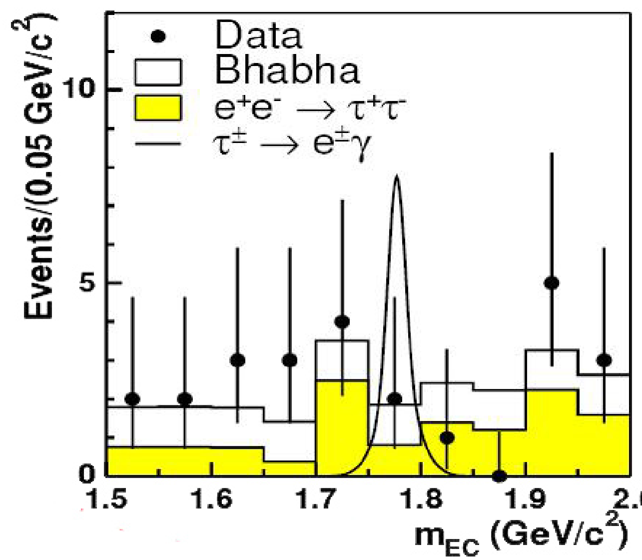
- Observation of LF violation would be a clear signature for new physics

Search for $\tau^- \rightarrow e^- \gamma$

PRL 96, 041801 (2006)







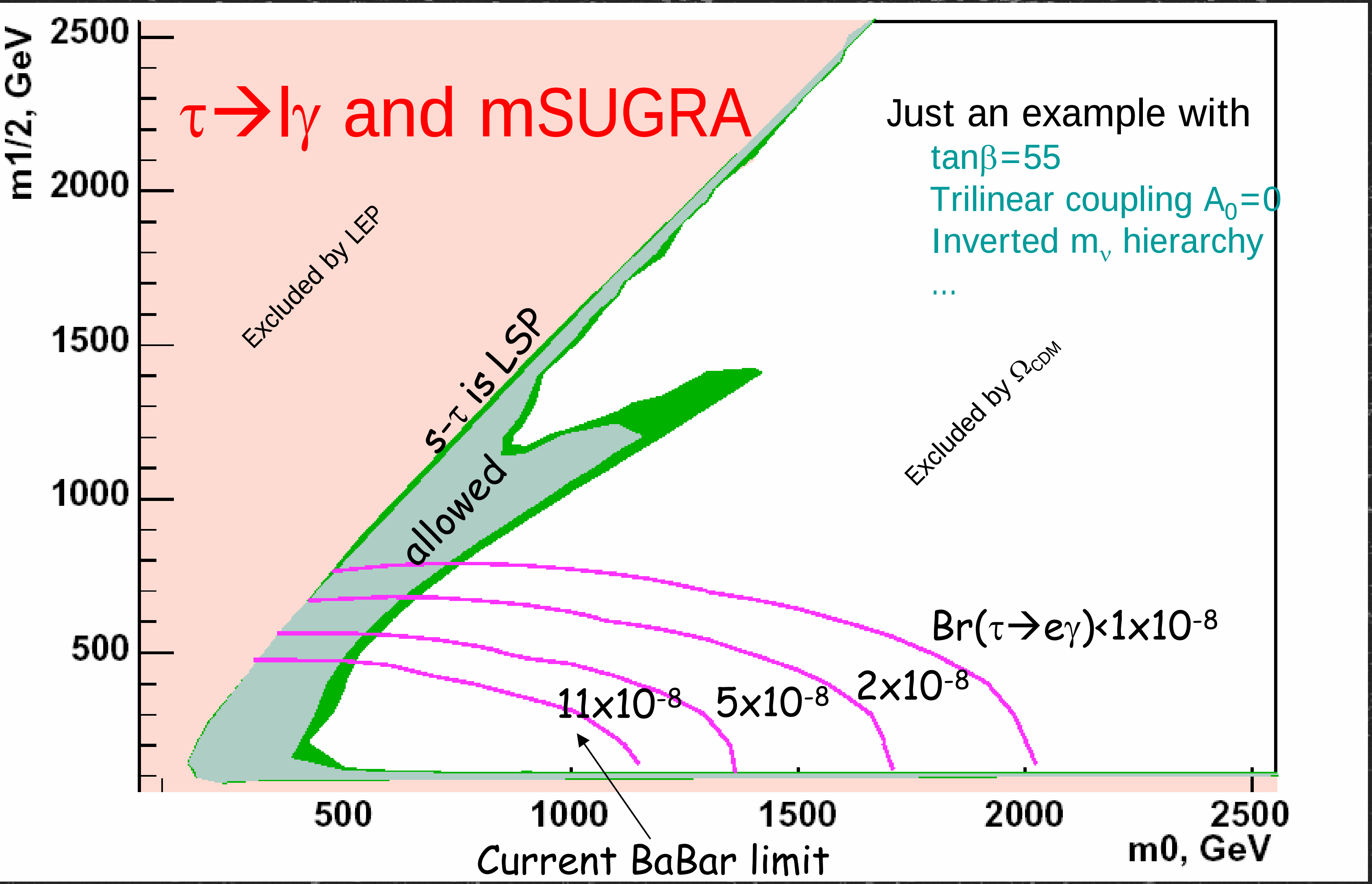
- 207×10^6 $e^+e^- \rightarrow \tau^+\tau^-$ events
- Observe 1 event in a $2\sigma\times2\sigma$ signal box on 1.9±0.4 expected background

$$Br(\tau^- \rightarrow e^-\gamma) < 1.1 \times 10^{-7} \text{ at 90\% C.L.}$$

Previous limits (all @ 90% CL):

$Br(\tau^- \rightarrow \mu^-\gamma) < 0.68 \times 10^{-7}$	(BaBar, PRL 95 041802)
$Br(\tau^- \rightarrow \mu^-\gamma) < 3.1 \times 10^{-7}$	(Belle, PRL 92 171802)
$Br(\tau^- \rightarrow e^-\gamma) < 3.8 \times 10^{-7}$	(Belle, PLB 613 22)

Limits on New Physics – An Example



O. Igonkina, SUSY 2005

Search for New Physics in the Charm Sector

- D^0 Mixing
  Flavor eigenstates are not mass eigenstates
  $|D^0_{1,2}\rangle = p|D^0\rangle \pm q|\overline{D}^0\rangle$ with $M_{1,2}$ and $\Gamma_{1,2}$

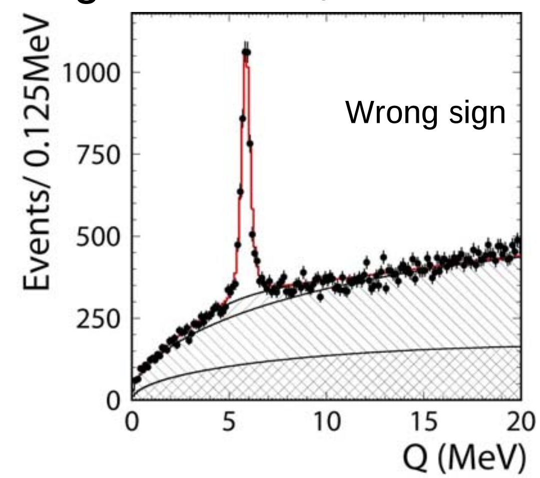
$$x \equiv \frac{\Delta m}{\Gamma},\ y \equiv \frac{\Delta\Gamma}{2\Gamma}$$

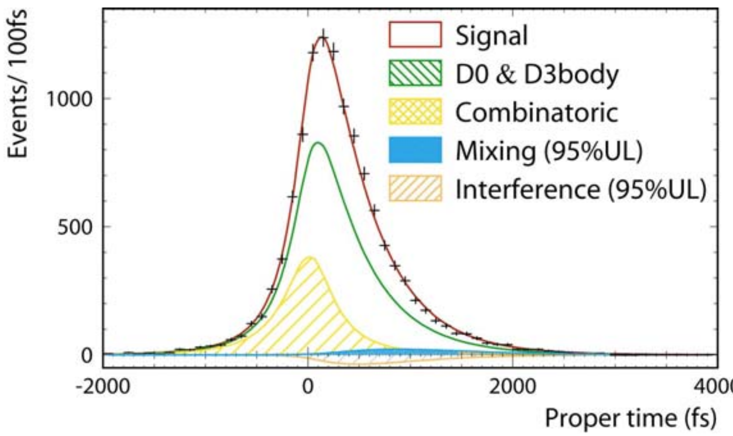
$$\text{mixing rate: } R_M = \frac{x^2+y^2}{2}$$

- D^0 Mixing is small in the SM
  box diagram: x,y, < few x 10^{-5}
  long distance: x ~ 10^{-3}, y ~ 10^{-2}
- Strong phase in hadronic decays
  $x' = x\cos\delta + y\sin\delta$
  $y' = y\cos\delta - x\sin\delta$
- Proper Time Fit

$$\text{WS signal: } \left[R_D + \sqrt{R_D}y't + \frac{x'^2+y'^2}{4}t^2\right]e^{-t}$$

Using $D^0 \to K^+\pi^-$, 400 fb^{-1}

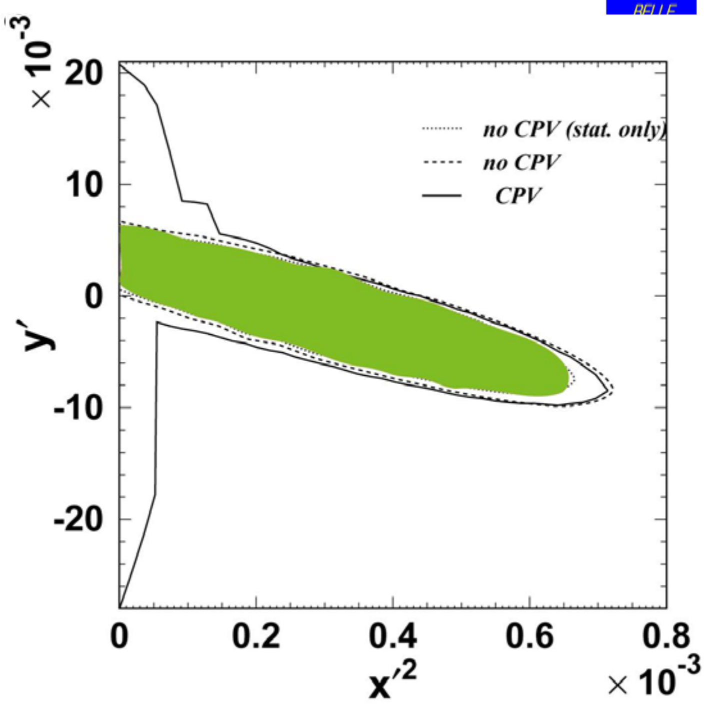




hep-ex/0601029

Experimental Limits on D^0 mixing

hep-ex/0601029

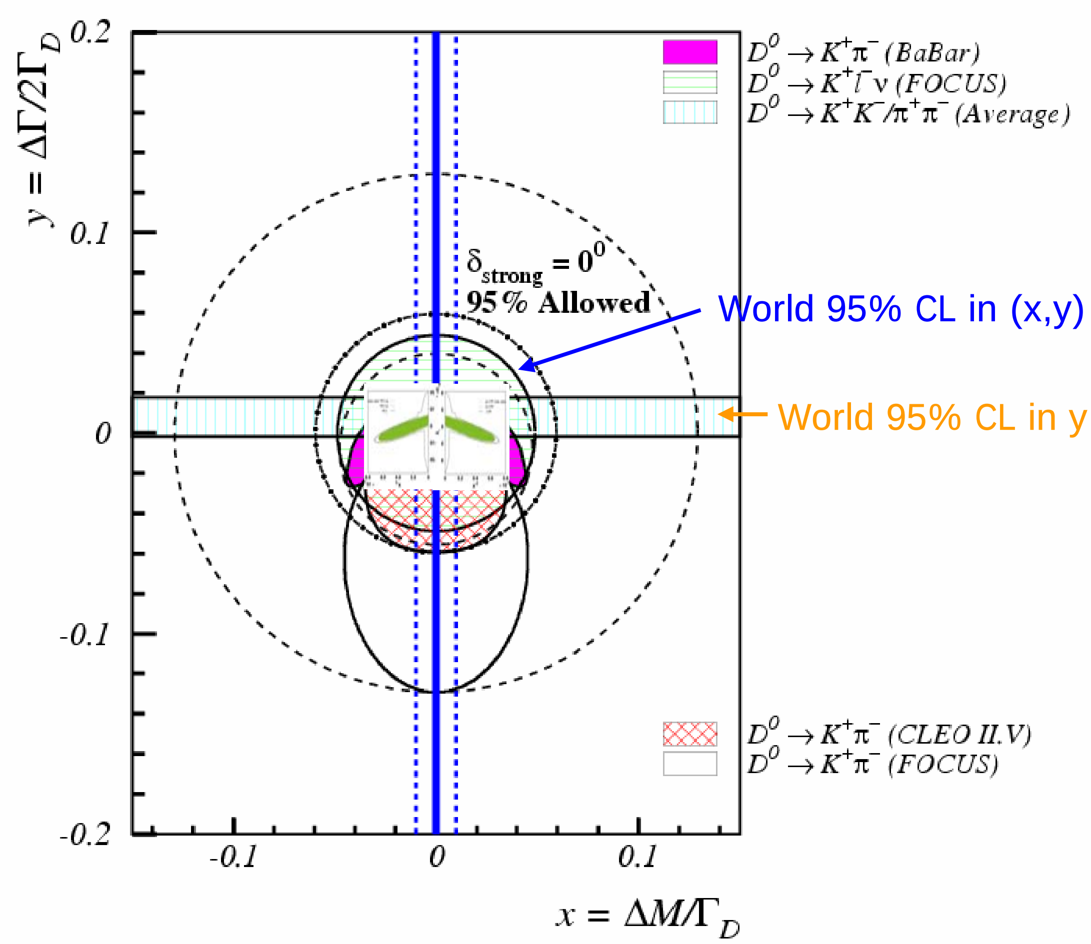


95% CL Limits (assuming CP)

$x'^2 < 0.72 \times 10^{-3}$

$-9.9 \times 10^{-3} < y' < 6.8 \times 10^{-3}$

Note: No-Mixing (0,0) has only 3.9% CL



G. Burdman and I. Shipsey, Ann. Rev. Nucl. Part. Sci. 53, 431 (2003)

[arXiv:hep-ph/030076]

(assuming δ = 0, CPV = 0)

Rare Charm Decays and CP Violation

Experiment	Decay mode	A_{CP} (%)	Notes
BaBar	$D^+ \to K^- K^+ \pi^+$	1.4±1.0 ±0.8	
BaBar	$D^+ \to \phi^+ \pi^+$	0.2±1.5±0.6	Res. Substr. Of $D^+ \to K^- K^+ \pi^+$
BaBar	$D^+ \to K^{*0} K^+$	0.9±1.7±0.7	
CLEO II.V	$D^0 \to \pi^+ \pi^- \pi^0$	1 ±8	Dalitz plot analysis
CDF	$D^0 \to K^+ K^-$	2.0 ±1.2 ± 0.6	Direct CPV
CDF	$D^0 \to \pi^+ \pi^-$	1.0 ±1.3 ± 0.6	Direct CPV
FOCUS	$D^0 \to K^+ K^- \pi^+ \pi^-$	1.0 ±5.7±3.7	T violation through triple product correlations
FOCUS	$D^+ \to K^o K^+ \pi^+ \pi^-$	2.3 ±6.2±2.2	
FOCUS	$D_S \to K^o K^+ \pi^+$	-3.6 ±6.7±2.3	

from S. Stone

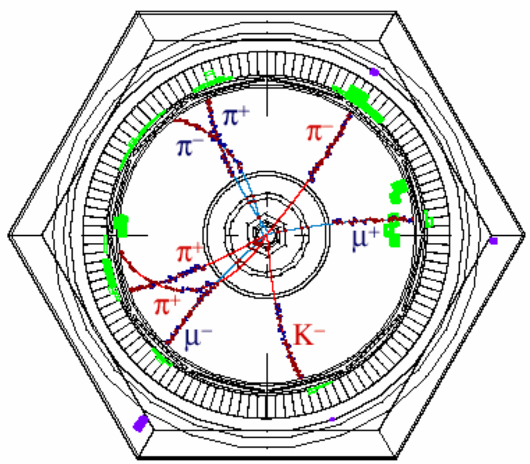
Experimental Aside: Single B Meson Beams

Lots of interesting modes include one or more neutrinos.

"Beams" with a single, monochromatic B and without c, QED etc would be very useful for : $B \rightarrow \tau\nu$, $B \rightarrow \nu\nu$, $B \rightarrow K\nu\nu$,...

Fully reconstruct one of the Bs and study the remaining of the event ➔ closed kinematics, missing energy reconstruction

$\overline{B}^0 \rightarrow D^{*+}\pi^-$ $B^0 \rightarrow \psi(2S)K^0_s$



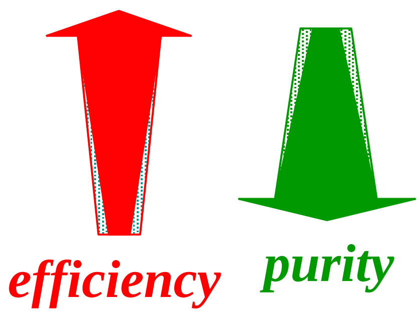
$D^{*+} \rightarrow D^0\pi^+$ $\psi(2S) \rightarrow \mu^+\mu^-$

$D^0 \rightarrow K^-\pi^+$ $K^0_s \rightarrow \pi^+\pi^-$

Tag types

Semileptonic $D^{(*)}l(\nu\pi)$
5K/fb^{-1}

Hadronic $D^{(*)}X$
3K/fb^{-1}



$X = n\pi + m\pi^0 + pK + qK_s$

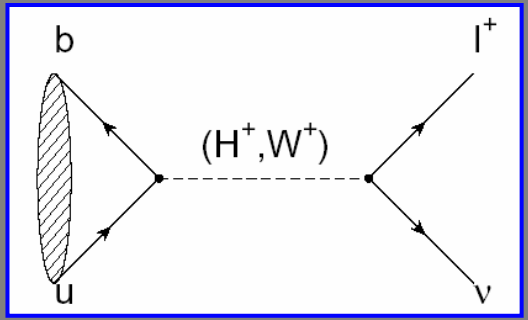
Search for B→ $\tau\nu$

hep-ex/0507069

- SM decay proceeds via W-annihilation diagram

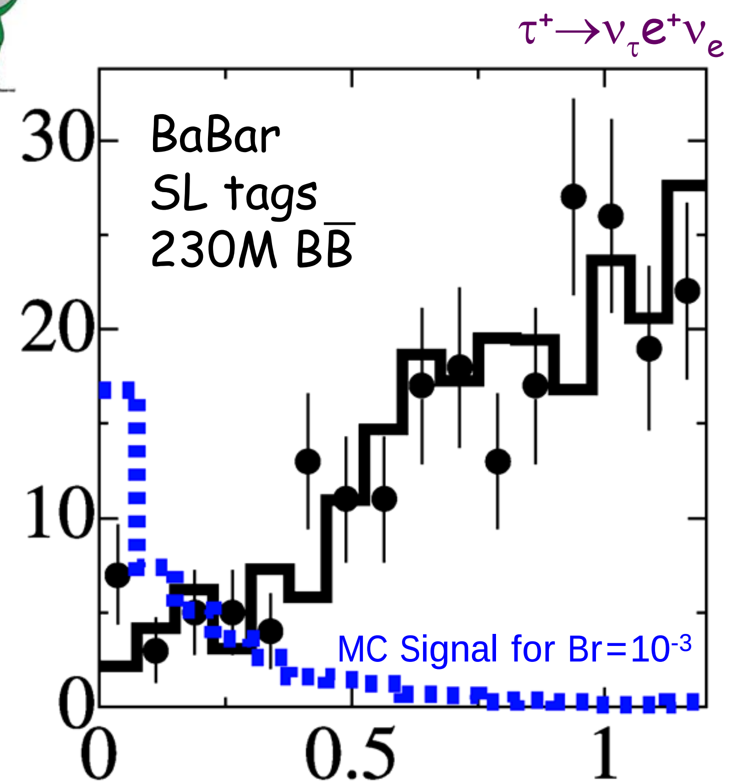
$$\mathcal{B}^{SM}(B^+ \to \tau^+\nu_\tau) = 9.3\times 10^{-5}\left[\frac{f_{B^+}}{196\, MeV}\right]^2\left[\frac{|V_{ub}|}{0.00367}\right]^2$$

- Sensitive to new physics charged current



- Analysis:
  - Undetected neutrinos result in large missing energy and few kinematic constraints – high background.
  - Reduce the background by reconstructing the second B ("tag B") in the event in the copious decay mode $B^- \to D^{*0} l^- \nu_l$
  - Reconstruct $B^+ \to \tau^+ \upsilon_\tau$ with $\tau^+ \to l^+ \nu\nu_{bar}$ or $\tau^+ \to h^+ \nu$, where h = π, ρ, or a_1
  - Require no additional charged tracks in the event

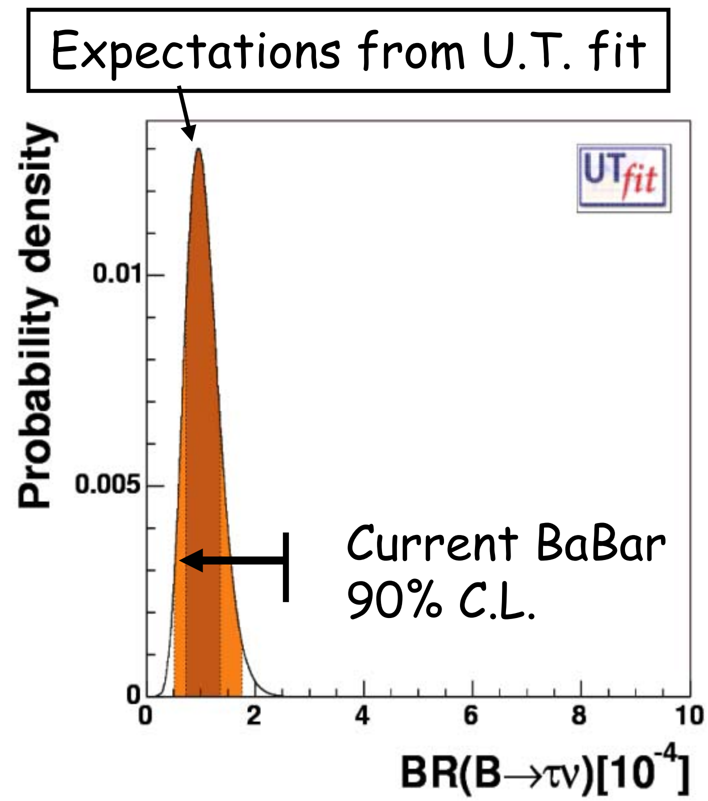
Results for B→τν



Energy in addition to signal candidate (GeV)

No signal in 230 M $B\bar{B}$ events
90% CL Upper Limit
(Combined with hadronic tags)

$Br(B^+ \to \tau^+ \upsilon_\tau) < 2.6 \times 10^{-4}$



Close to the discovery of this mode or NP

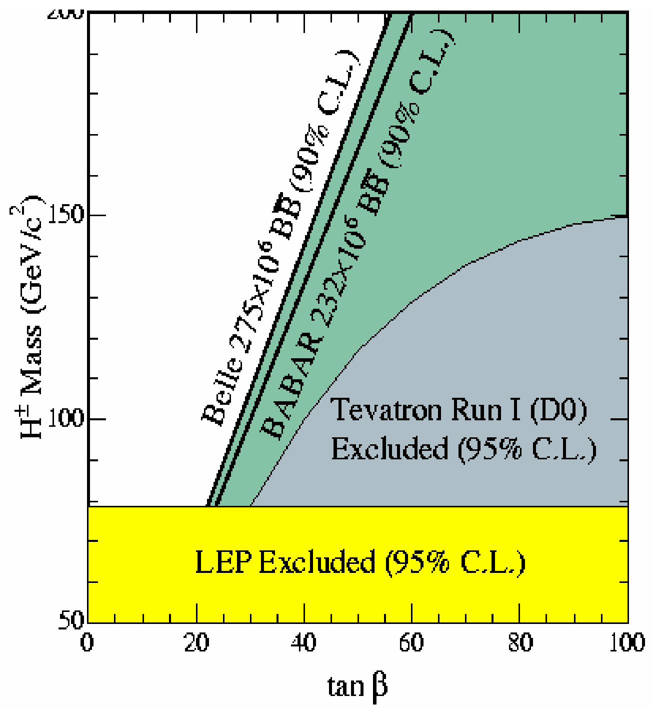
...even closer hep-ex/0507034

New Belle analysis using 250 fb^{-1}

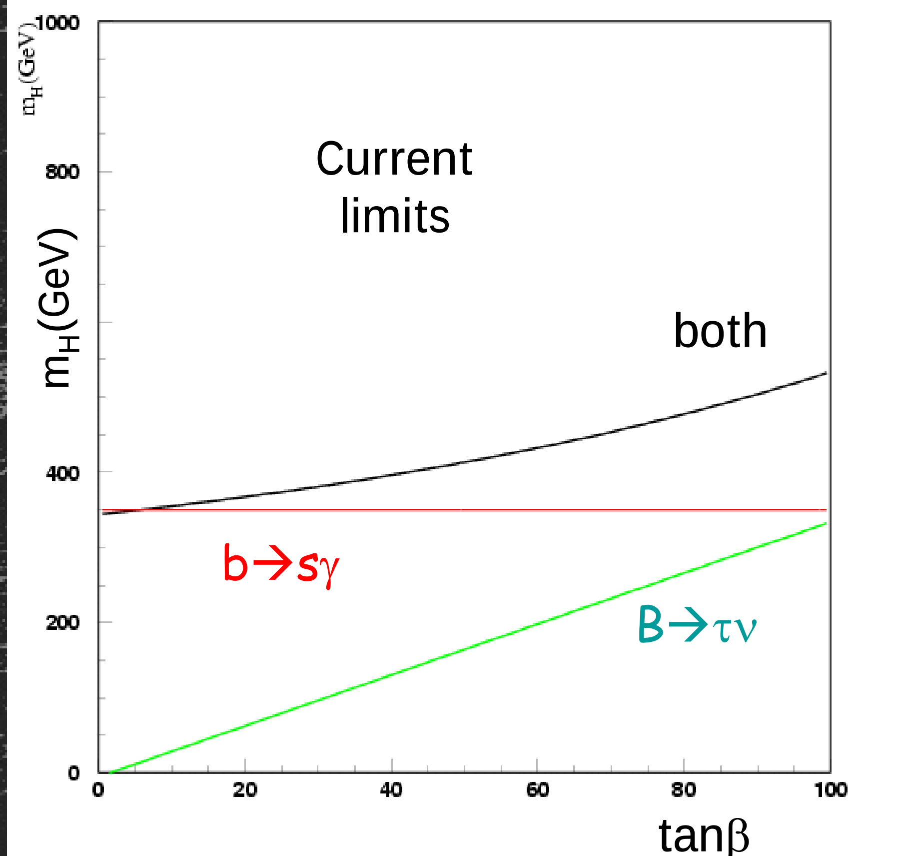
$$BF(B \to \tau\nu) < 1.8 \times 10^{-4}$$

Higgs sensitivity

Limits on 2-Higgs Models from $B \to \tau\nu$



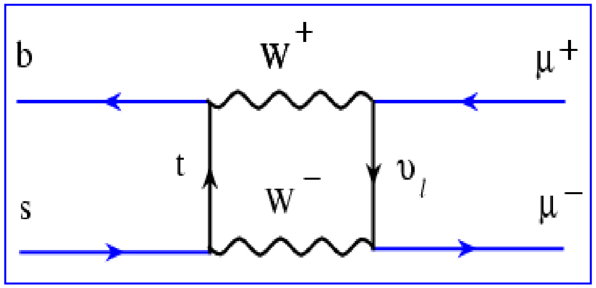
2HDM
Gambino, Misiak Nucl. Phys. B611 338
Hou Phys.Rev.D48:2342-2344,1993

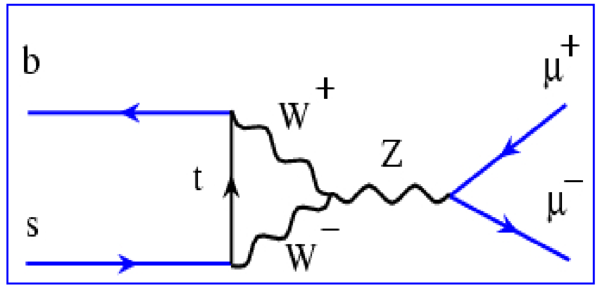


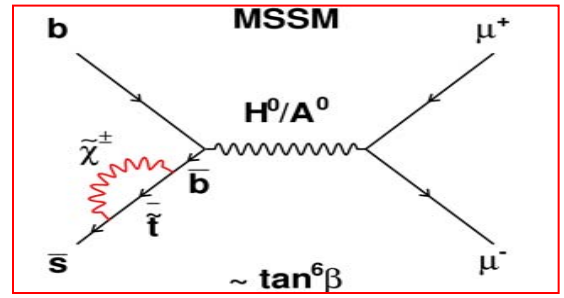
Search for $B_s \to \mu+\mu-$ at the Tevatron

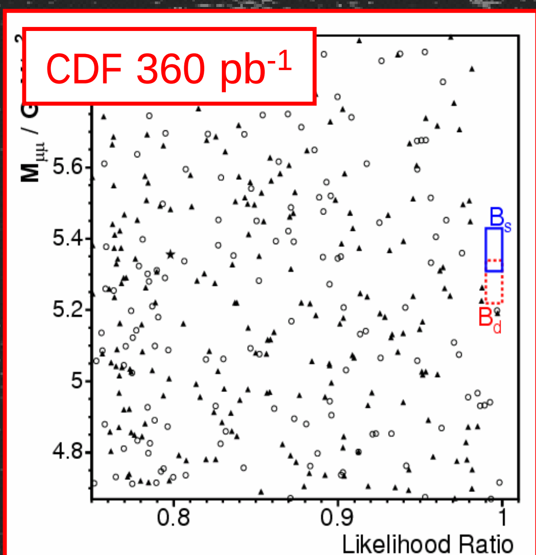
hep-ex/0508058

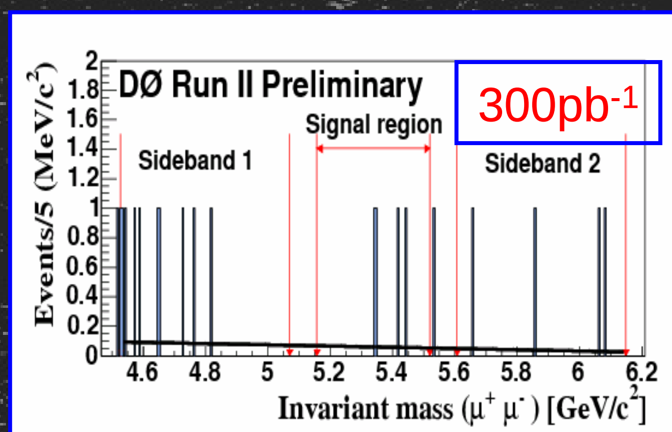
Standard model prediction: $Br(B_s \to \mu^+\mu^-) = (3.5 \pm 0.9) \times 10^{-9}$











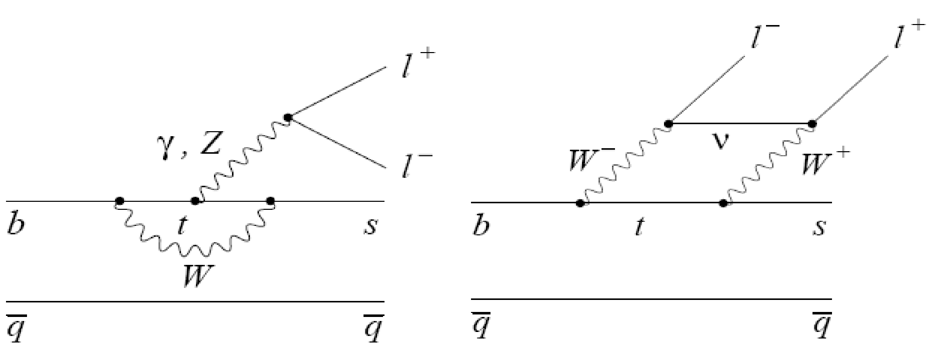
No Signal found

$B_s \to \mu+\mu- < 2.0 \times 10^{-7}$ CDF
$B_s \to \mu+\mu- < 3.9 \times 10^{-7}$ D0

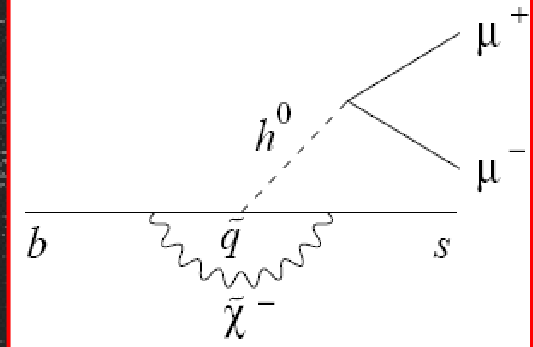
Combined (90% CL)

$B_s \to \mu+\mu- < 1.5 \times 10^{-7}$

EW Penguins: $B \to Kl^+l^-$, $B \to K^*l^+l^-$, and $B \to X_s l^+l^-$



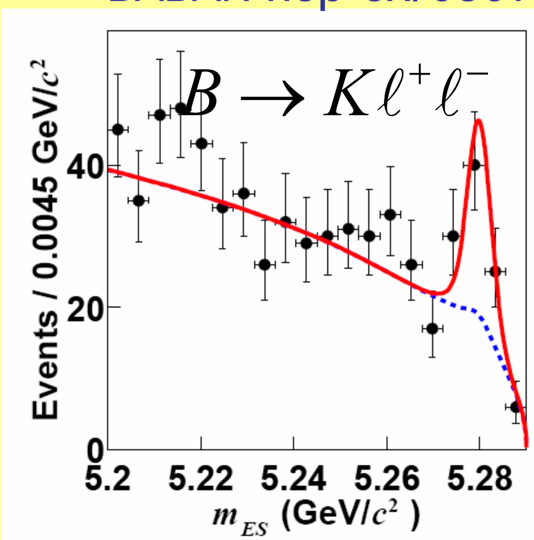
- With l^+l^- pair, can produce both pseudoscalar and vector mesons
- SM: Br($B \to K l^+ l^-$) ~ 4×10^{-7} (± 30% theory) ~3 times that for K*

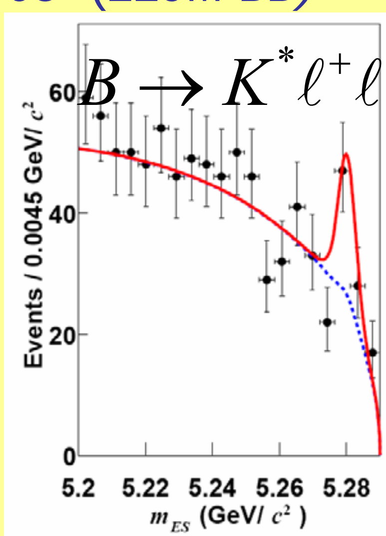


New Physics affects

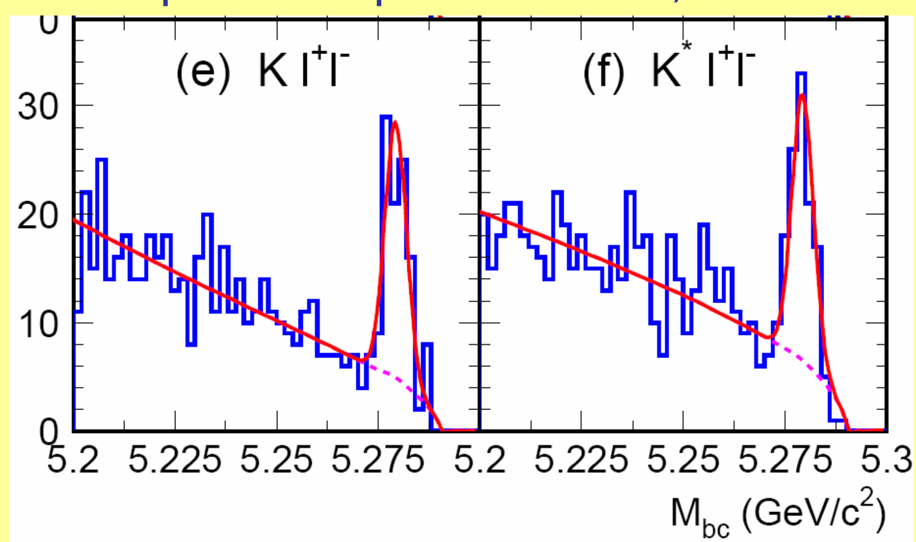
- Rates
- Asymmetries (A_{FB}, CP)
- μμ/ee ratio

BABAR hep-ex/0507005 (229M *BB*)

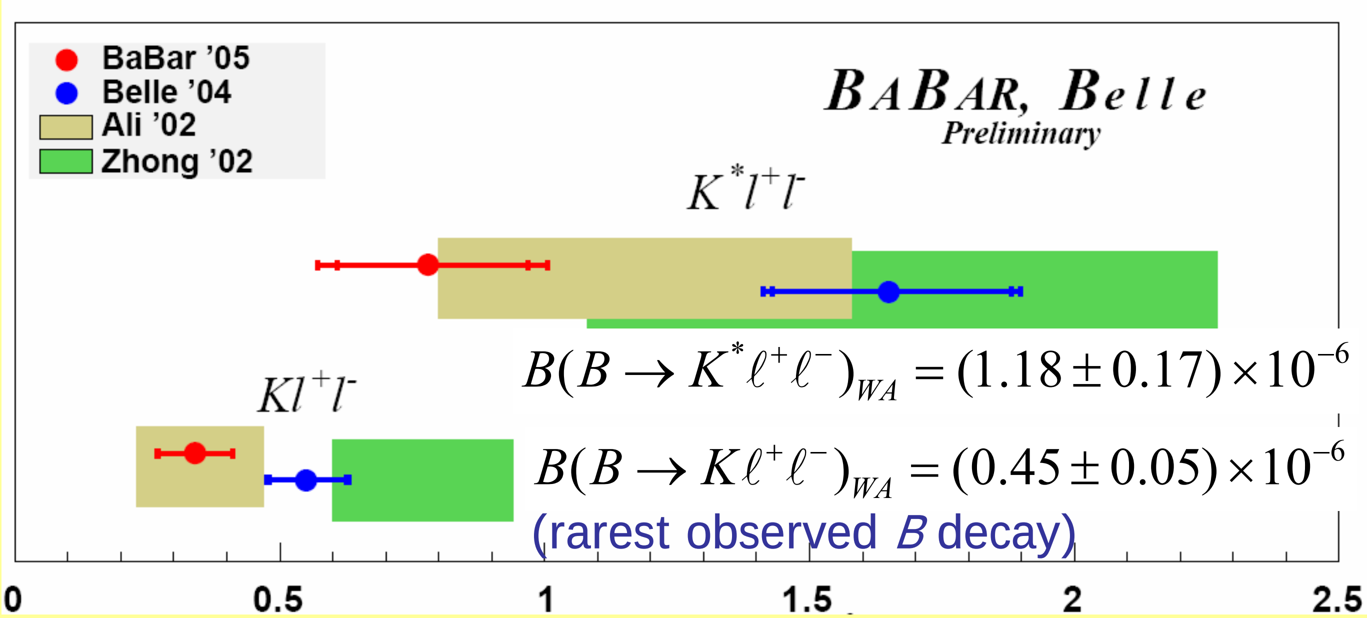




Belle prelim. hep-ex/0410006, 0508009



B→Kl^+l^- and B→K*l^+l^- : branching fractions



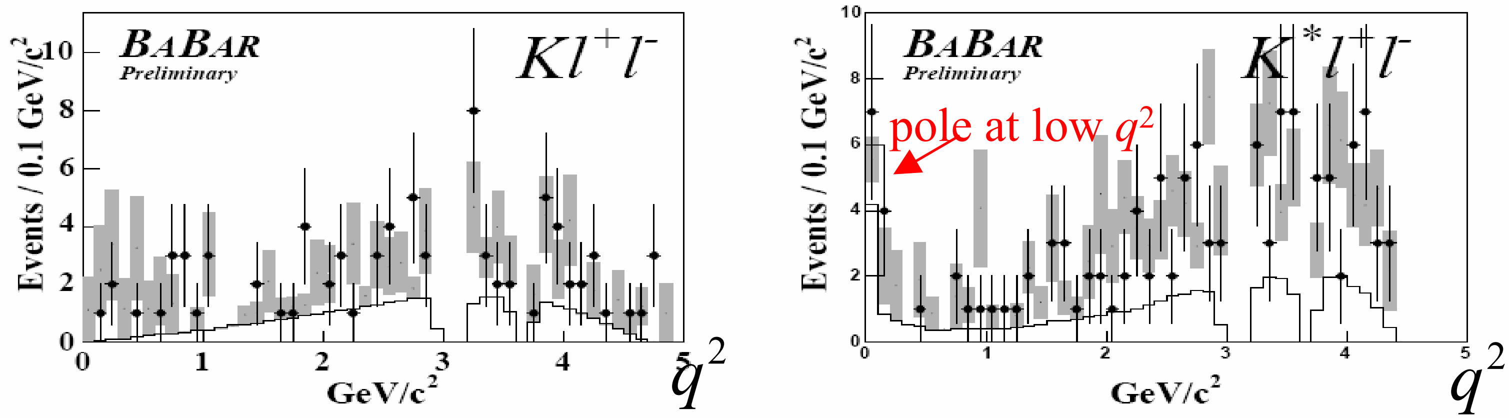
$$B(B \to K^* \ell^+ \ell^-)_{WA} = (1.18 \pm 0.17) \times 10^{-6}$$

$$B(B \to K \ell^+ \ell^-)_{WA} = (0.45 \pm 0.05) \times 10^{-6}$$

(rarest observed *B* decay)

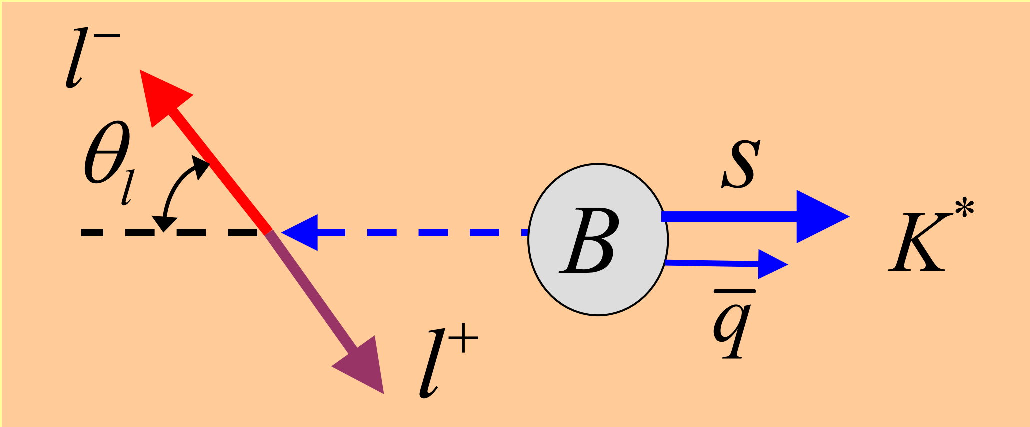
Theory errors mainly due to form factors.

(10^{-6})

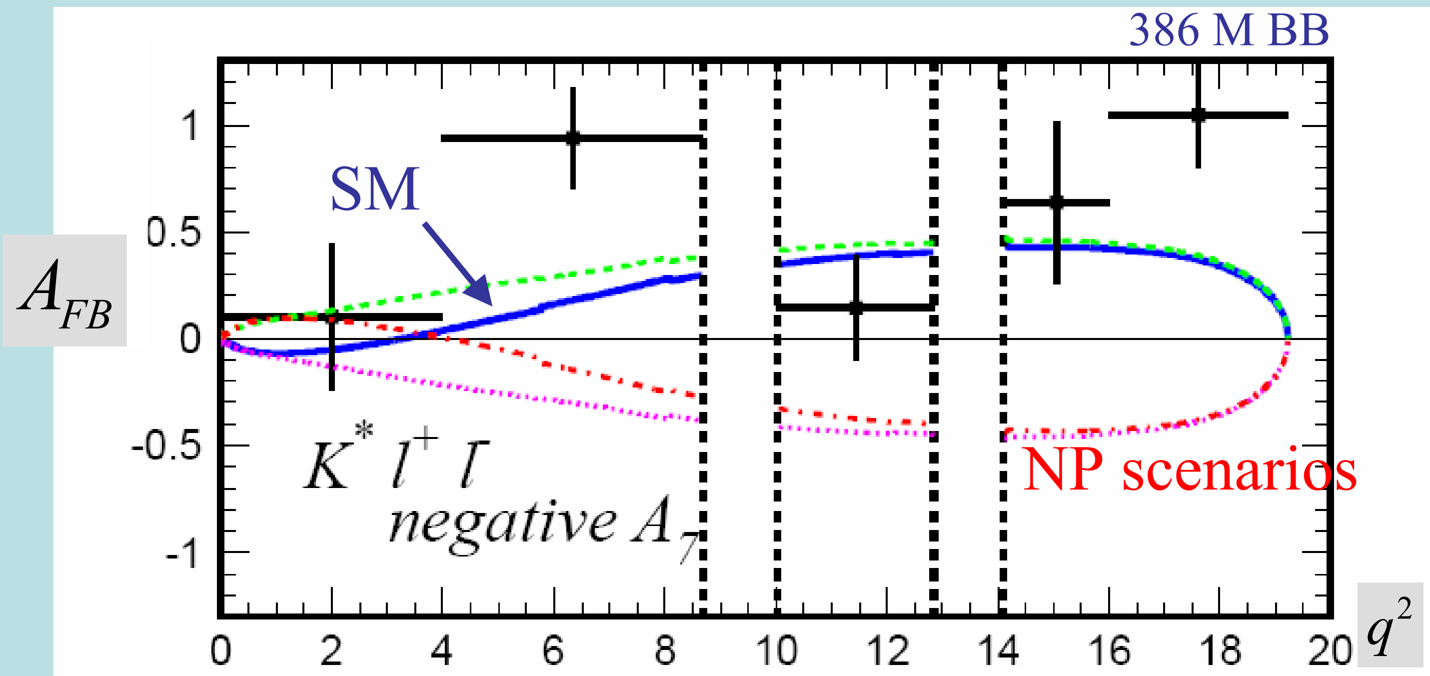


B→K*l^+l^-: Lepton F-B Asymmetry

hep-ex/0508009

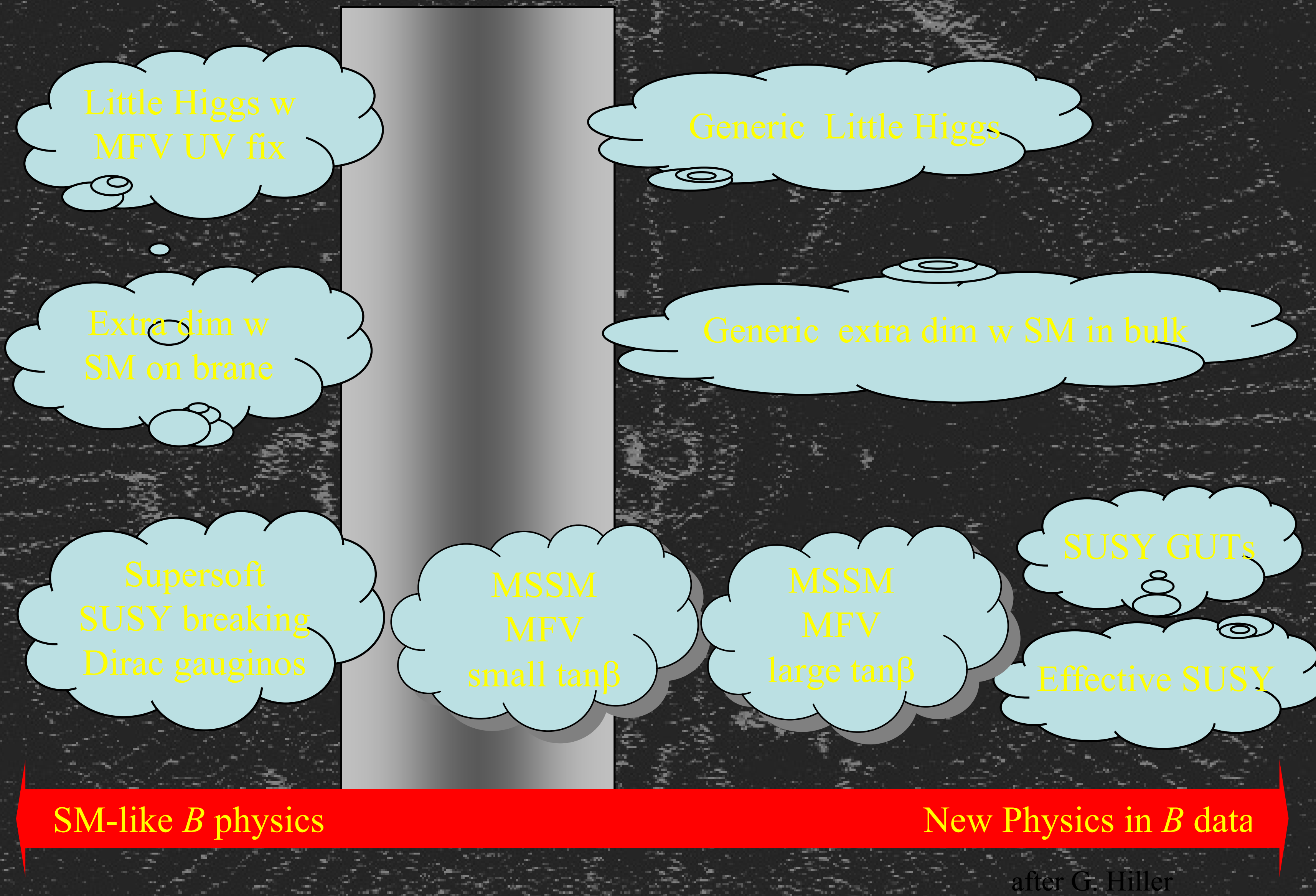


Lepton angular distribution in $l^+ l^-$ rest frame

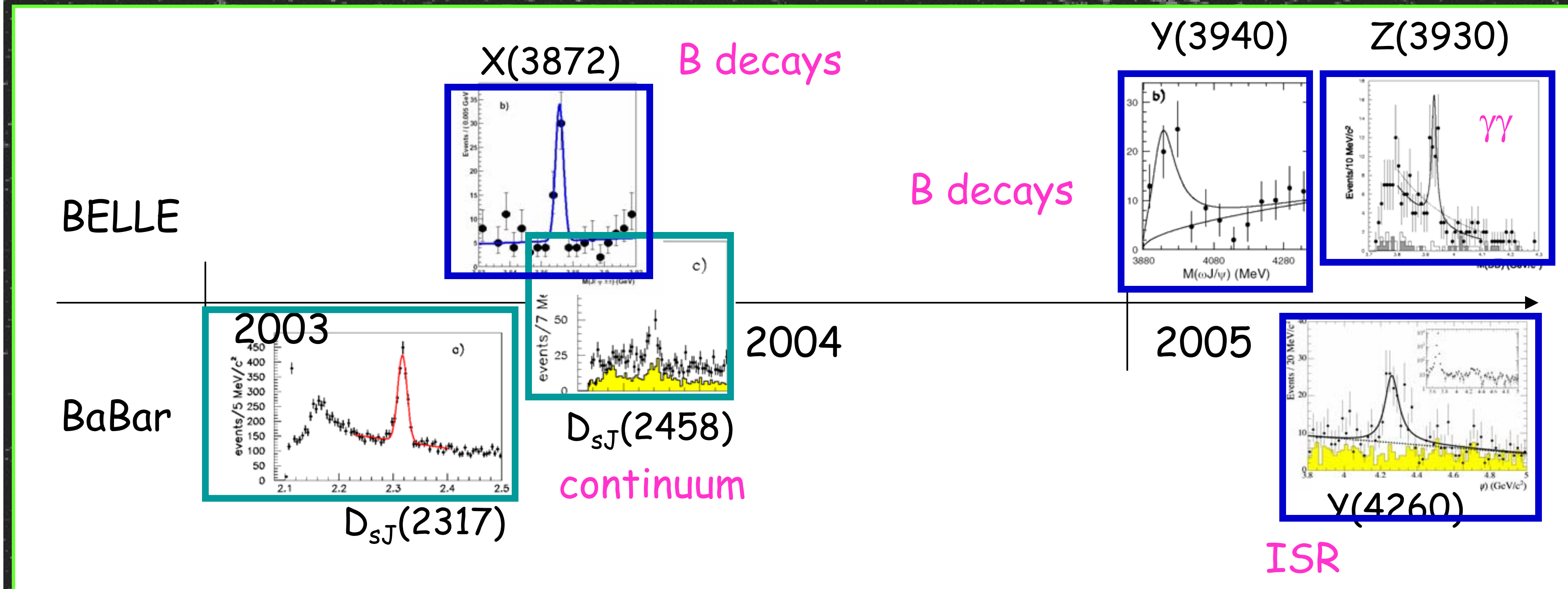


→constraints on Wilson coeffs describing short-distance physics

Getting Lost?



Be ready for surprises

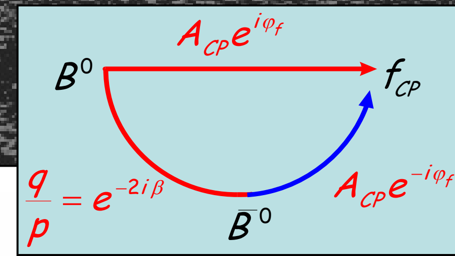


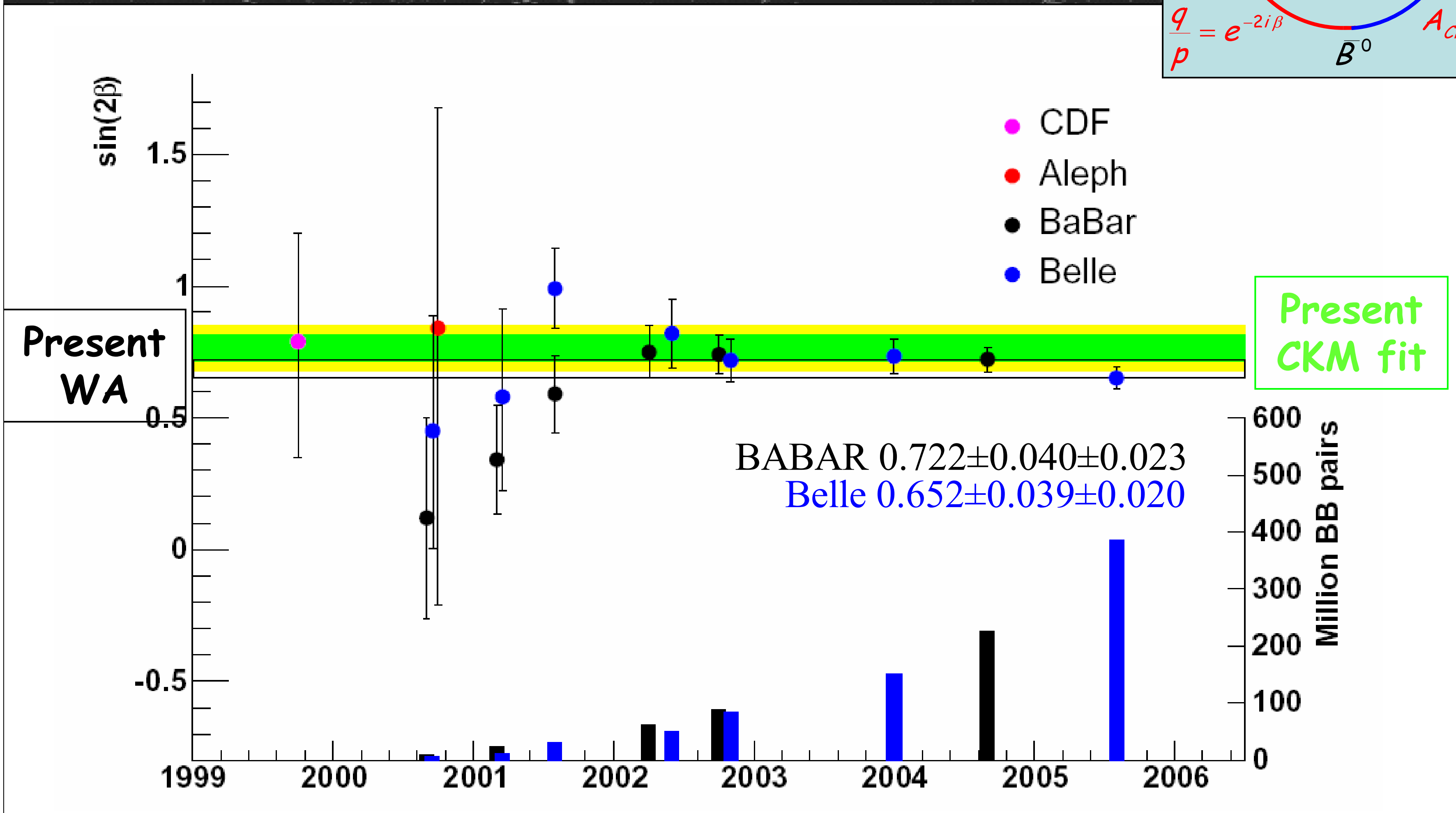
Several new particles have been observed by the B Factories

Different production mechanism ⇨ Different J^{PC}

For a nice review by Swanson see hep-ph/0601110

CP Violation in the B System





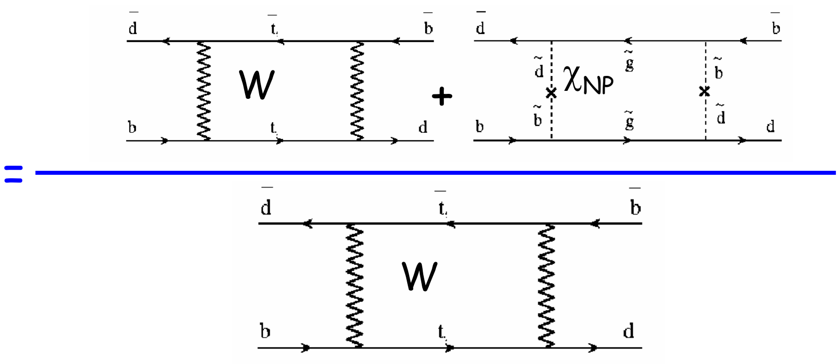
See talk by Aihara for more on CPV

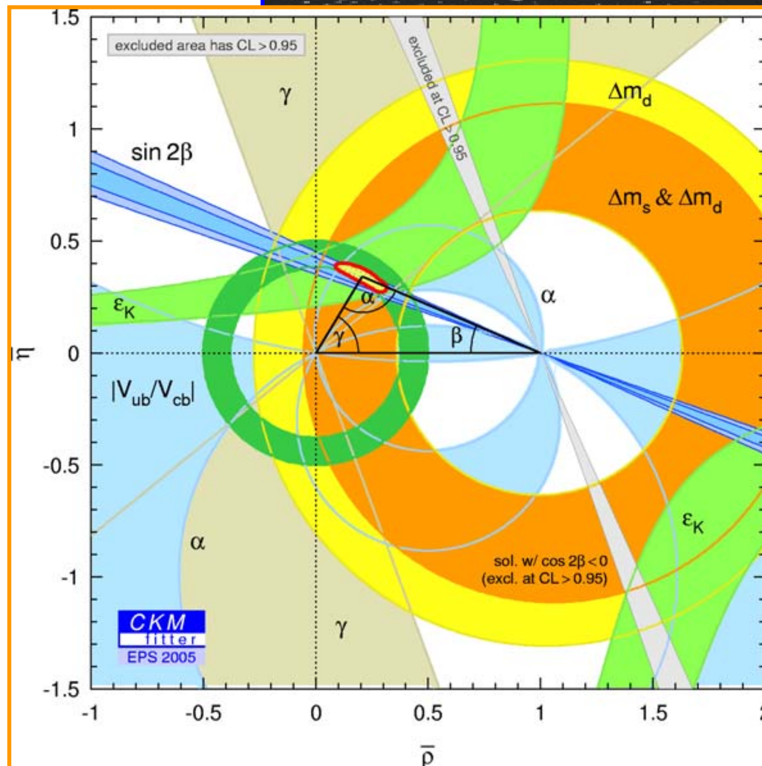
Bounds on new physics from UT fits

CKM Model confirmed by many measurements
Now look for New Physics as correction to CKM Model

The fit to the unitarity triangle constraints:

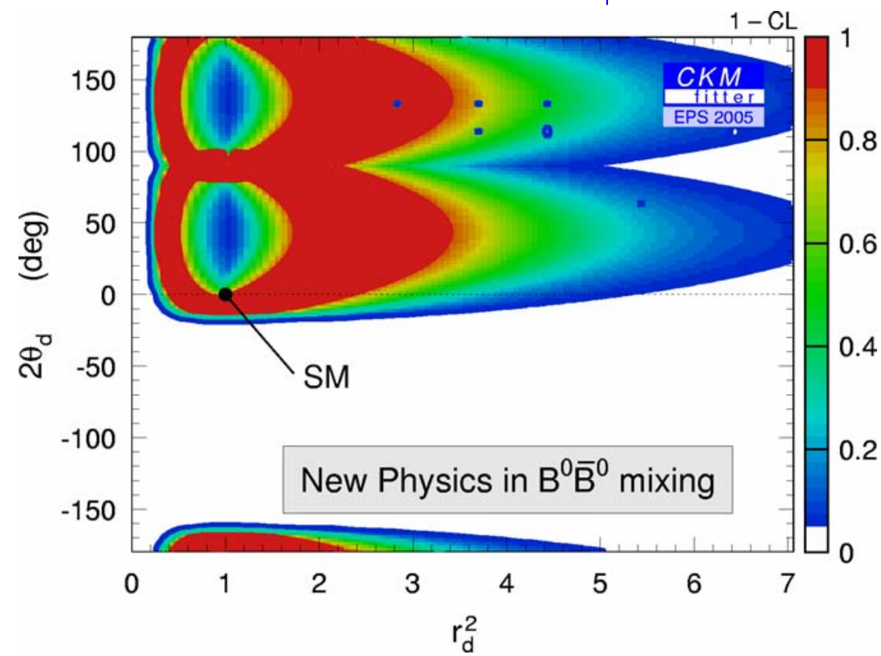
$$C_{B_d} e^{2i\phi_{B_d}} = \frac{A_{\rm SM} e^{2i\beta} + A_{\rm NP} e^{2i(\beta+\phi_{\rm NP})}}{A_{\rm SM} e^{2i\beta}}$$



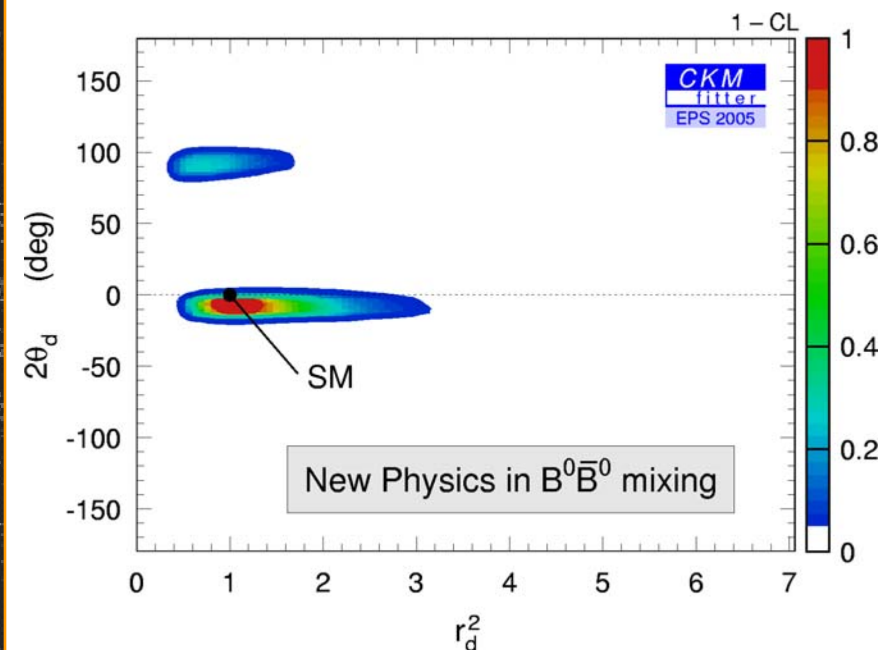


Bounds on new physics from UT fits

Constraints: $|V_{ub}|$, Δm_d, $S_{\psi K}$



add: α, γ



First constraints on Θ_d, C_{Bd}
In terms of probed new physics mass scale (Λ=m(χ_{NP}); g_{NP}=coupling)

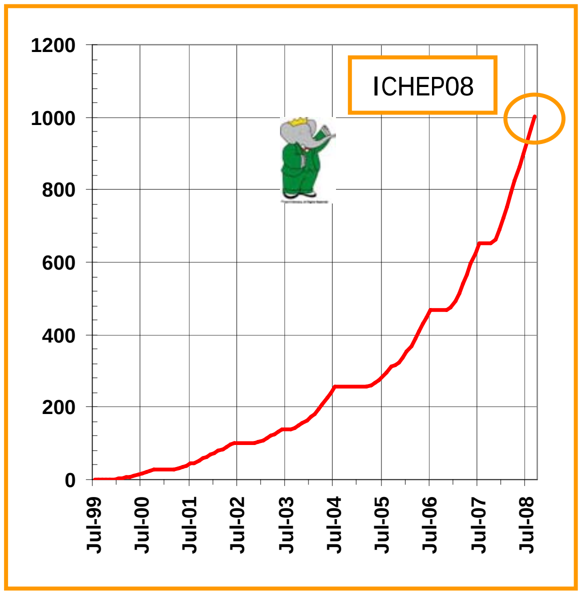
Λ(now)~5g_{NP} TeV

Ligeti, Silvestrini, Agashe et al

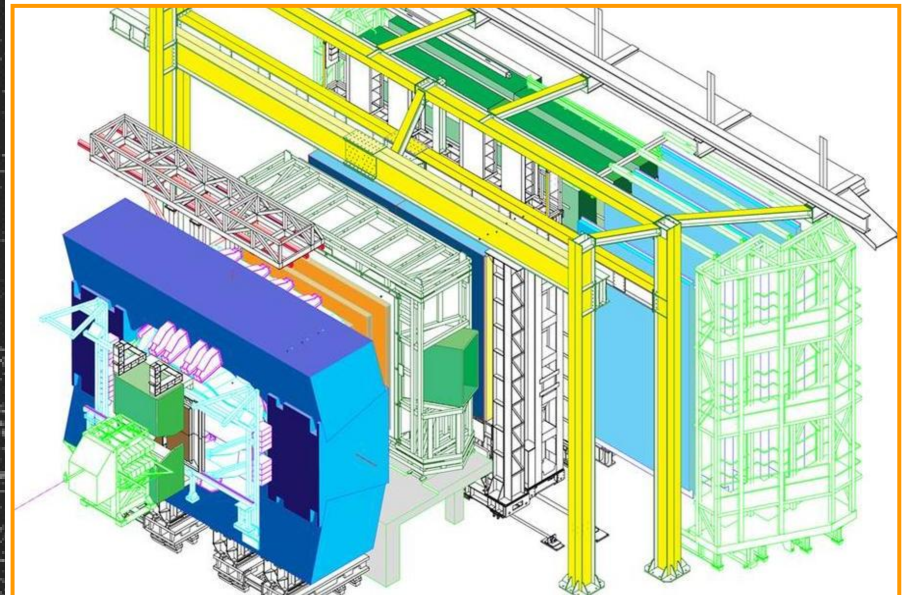
The next few years (2006 – 2008)

- Belle and BaBar
  - 1 ab^{-1} (2006)
  - 2 ab^{-1} (2008)

- Tevatron
  - 2 fb^{-1} (2006)
  - 8 fb^{-1} (2009)



- LHCb is nearing completion

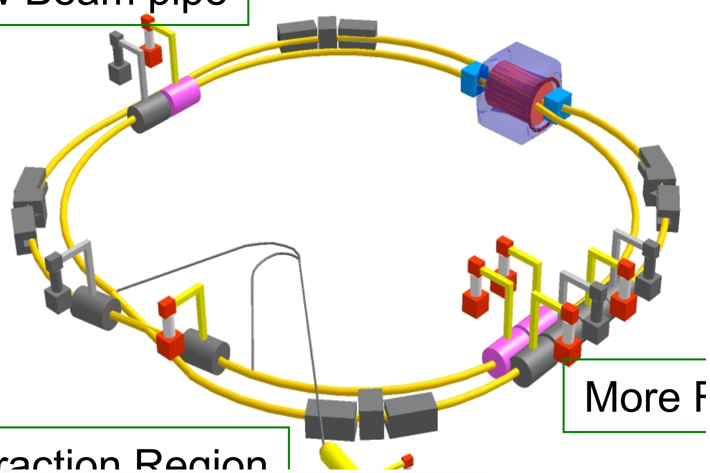


See talk by S. Stone on Thursday

Super B-Factory Plans at KEK and Frascati

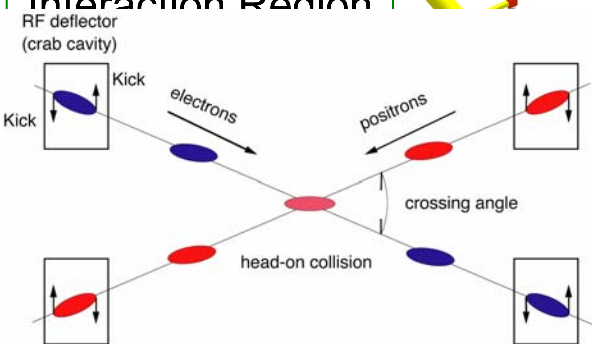
Design Luminosity ~ 1 x 10^{36} /cm^2/sec
Synergy with ILC
Lots of R&D needed

New Beam pipe

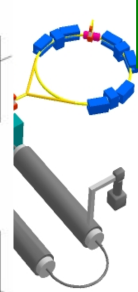


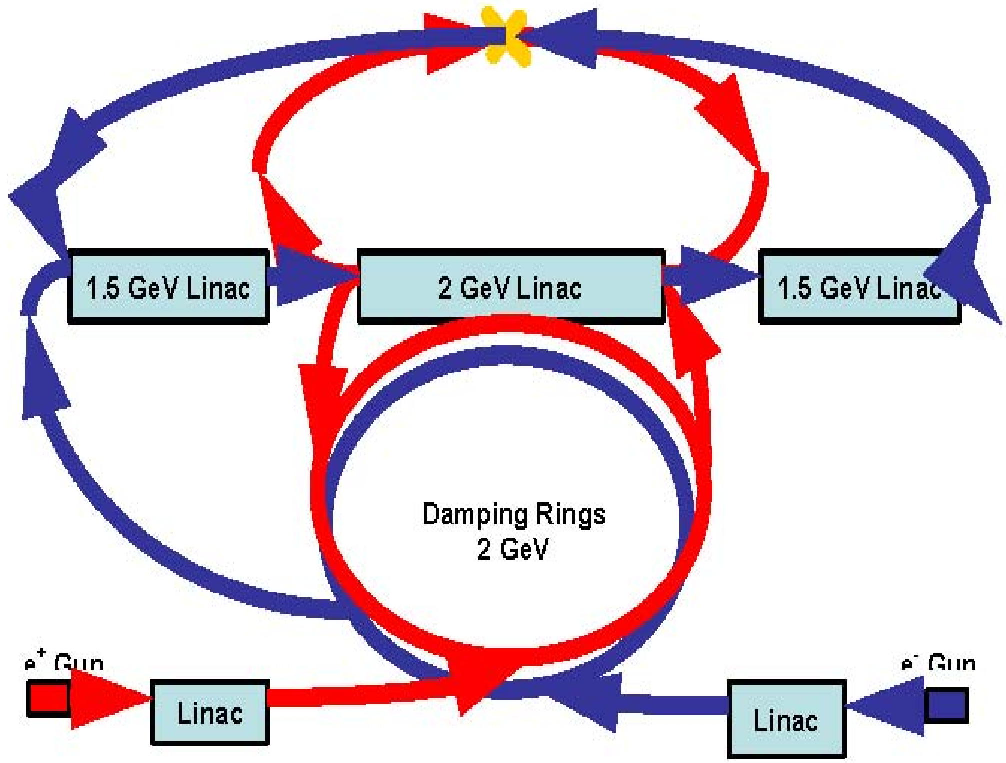
More F

Interaction Region



Dan





$L = 4 \times 10^{35}$/cm^2 /sec

KEK

Frascati

Next Super B Workshop in Frascati, March 16-18, 2006

Have Ideas – Need Statistics

Mode	BR_{SM}	Notes on New Physics
$b \rightarrow s\gamma$	$\sim 3\ 10^{-4}$	BF, $A_{CP,}$ and A_{FB} important
$b \rightarrow sg$	$\sim 10^{-5}$ each	BF not critical. Need events to measure S_{CP}
$B \rightarrow Xll$	$\sim 10^{-6}$ each	BF, $A_{CP,}$ and A_{FB} important
$B \rightarrow X\nu\nu$	$\sim 10^{-6}$ each	Up to 10^{-5} each
$D \rightarrow Xll$	$\sim 10^{-6}$ each	Up to 10^{-5} each
$B \rightarrow \tau\nu$	$\sim 10^{-4}$	Experiments close to SM sensitivity
$\tau \rightarrow l\gamma$	$\sim 10^{-40}$	Up to 10^{-8}
$B \rightarrow ll$	$<10^{-11}$	Up to 10^{-5}
$D \rightarrow ll$	$<10^{-9}$	Up to 10^{-6}

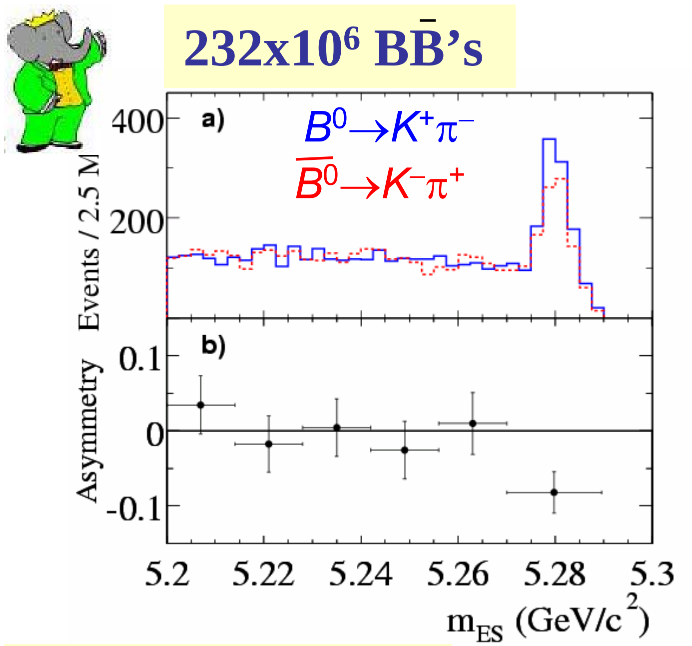
Additional Transparencies

K. Honscheid
Ohio State University
Aspen 2006

Let's rule out at least one NP model

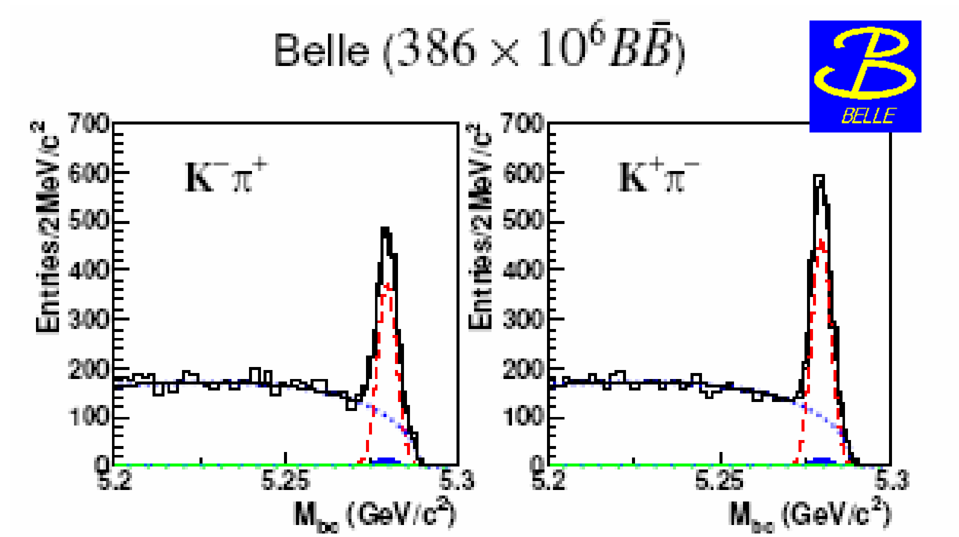
Observation of direct CP violation in $B^0 \rightarrow K^+\pi^-$

232×10^6 $B\bar{B}$'s



BaBar 2004

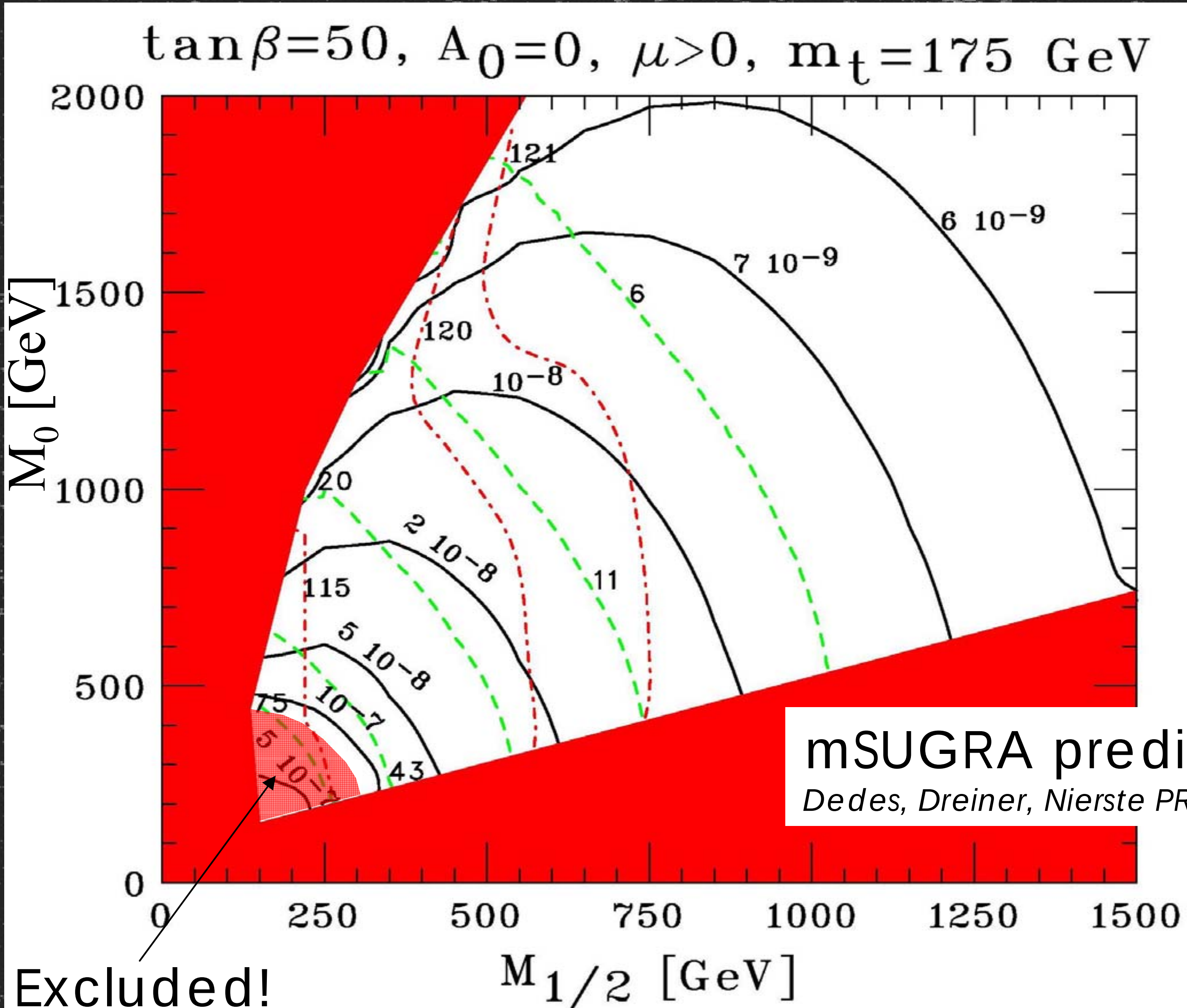
$$A_{CP} = -0.133 \pm 0.030 \pm 0.009$$



New Belle Result:
-0.113+/- 0.022+/- 0.008

➔ Superweak Model (Wolfenstein) is really out

Implications of $B_s \to \mu^+\mu^- < 1.5\times10^{-7}$



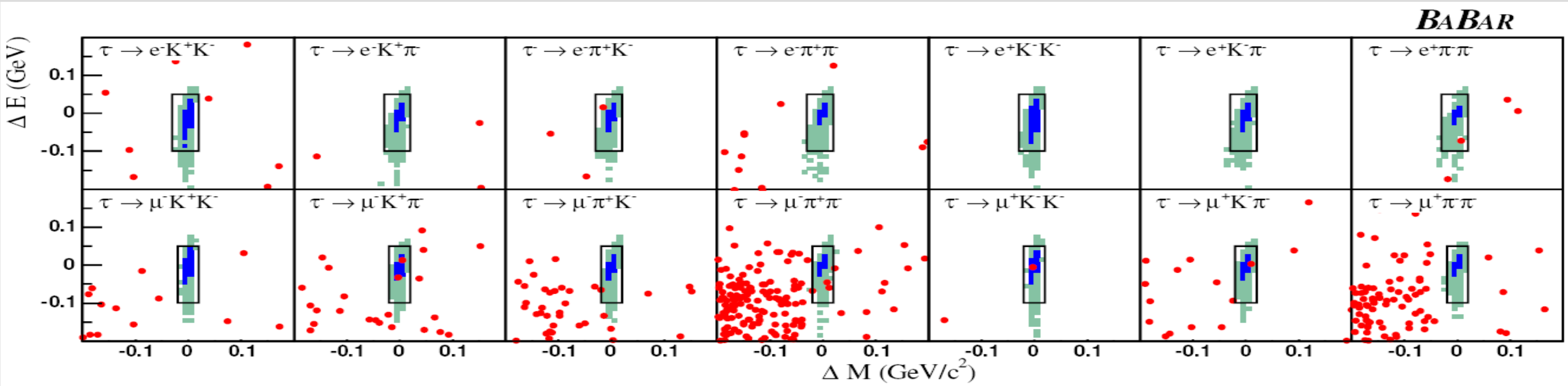
Excluded!

mSUGRA prediction:

Dedes, Dreiner, Nierste PRL87:251804,2001

Search for LFV in $\tau^- \to l^\pm hh'$

PRL 95, 191801 (2005)

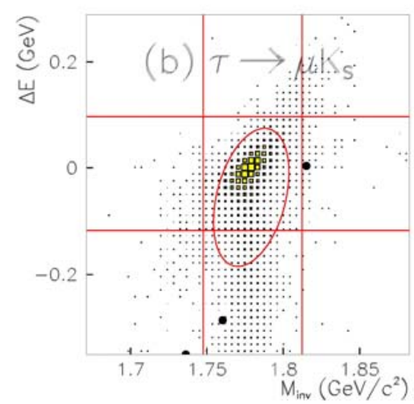


$\tau^- \to$	$e^-K^+K^-$	$e^-K^+\pi^-$	$e^-\pi^+K^-$	$e^-\pi^+\pi^-$	$e^+K^-K^-$	$e^+K^-\pi^-$	$e^+\pi^-\pi^-$
UL($\times 10^{-7}$)	1.4	1.7	3.2	1.2	1.5	1.8	2.7
$\tau^- \to$	$\mu^-K^+K^-$	$\mu^-K^+\pi^-$	$\mu^-\pi^+K^-$	$\mu^-\pi^+\pi^-$	$\mu^+K^-K^-$	$\mu^+K^-\pi^-$	$\mu^+\pi^-\pi^-$
UL($\times 10^{-7}$)	2.5	3.2	2.6	2.9	4.8	2.2	0.7

hep-ex/0509016

$$\mathrm{Br}(\tau^- \to e^- K_s) < 5.6 \times 10^{-8} \text{ at 90\% C.L.}$$

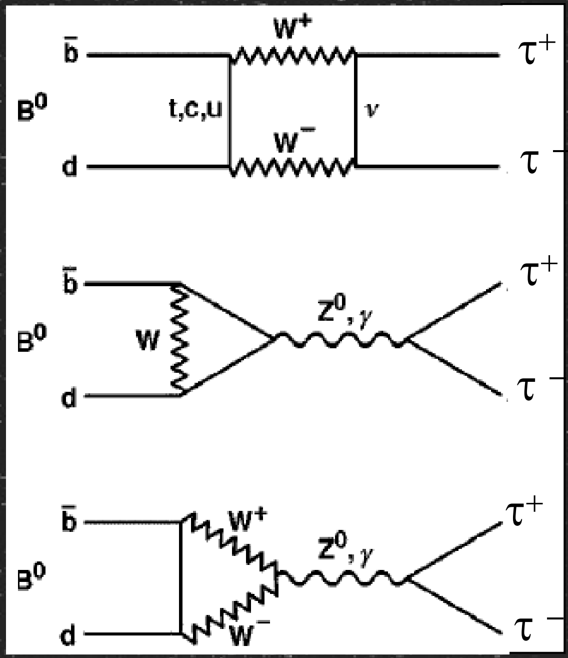
$$\mathrm{Br}(\tau^- \to \mu^- K_s) < 4.9 \times 10^{-8} \text{ at 90\% C.L.}$$



First Search for $B^0 \to \tau^+\tau^-$

hep-ex/0501115

- SM expectation ~ 10^{-7}
  (Compare: 10^{-11} for $\mu^+\mu^-$, 10^{-15} for e^+e^-)
- Helicity $(m_l/m_B)^2$ and Cabibbo $(V_{tb}V_{td}^*)$ suppressed
- Very clean theoretically
- Small SM ➡ Sensitive to new physics in the loops



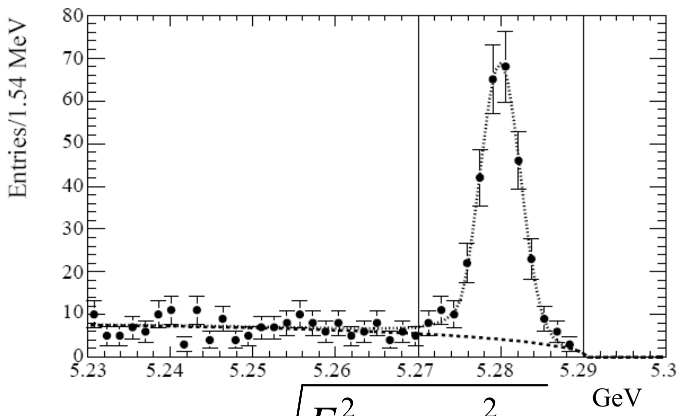
- Analysis
  - Reconstruct the tag B in decays to $D^{(*)}$ and up to 5 kaons and pions
  - Reconstruct the signal decay $B^0 \to \tau^+\tau^-$, with $\tau \to$1-prong decays
  - Require no additional charged tracks in the event
  - Require little remaining energy: $E_{extra} < 0.11$ GeV
  - Use correlations between E_{extra} and the momenta of the reconstructed τ daughters in a neural net to further reduce the background

$B^0 \to \tau^+\tau^-$ Results

hep-ex/0501115

Using 232 × 10⁶ Υ(4S)→B$\overline{B}$ events we observe
263 ± 19 events with 281 ± 40 expected background.

➡ First limit on this mode



$$m_{ES} = \sqrt{E_{beam}^2 - p_{Btag}^2}$$

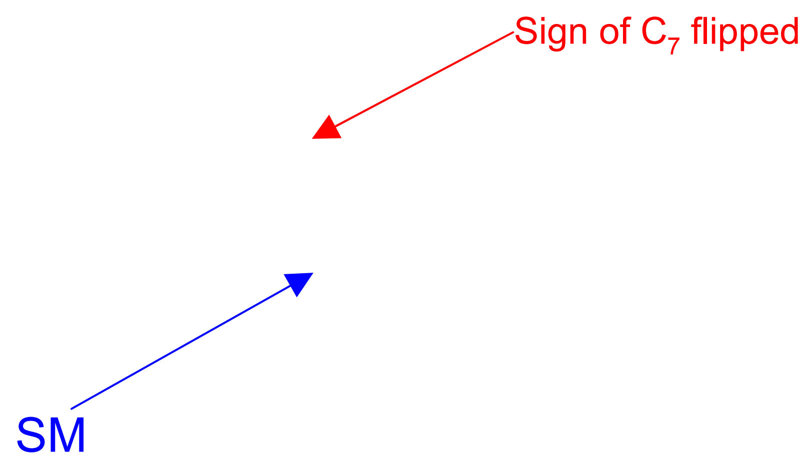
$Br(B^0 \to \tau^+\tau^-) < 3.2 \times 10^{-3}$ at 90% C.L.

Yields a constraint on leptoquark parameter. For example

$$\lambda_R^{33}\lambda_R^{13} \ < \ 1.1 \times 10^{-2} \left[\frac{m_{S_{1/2}}}{100\ \mathrm{GeV}}\right]^2$$

RH coupling to generations i,j

Leptoquark doublet mass


Sign of C_7 flipped
SM

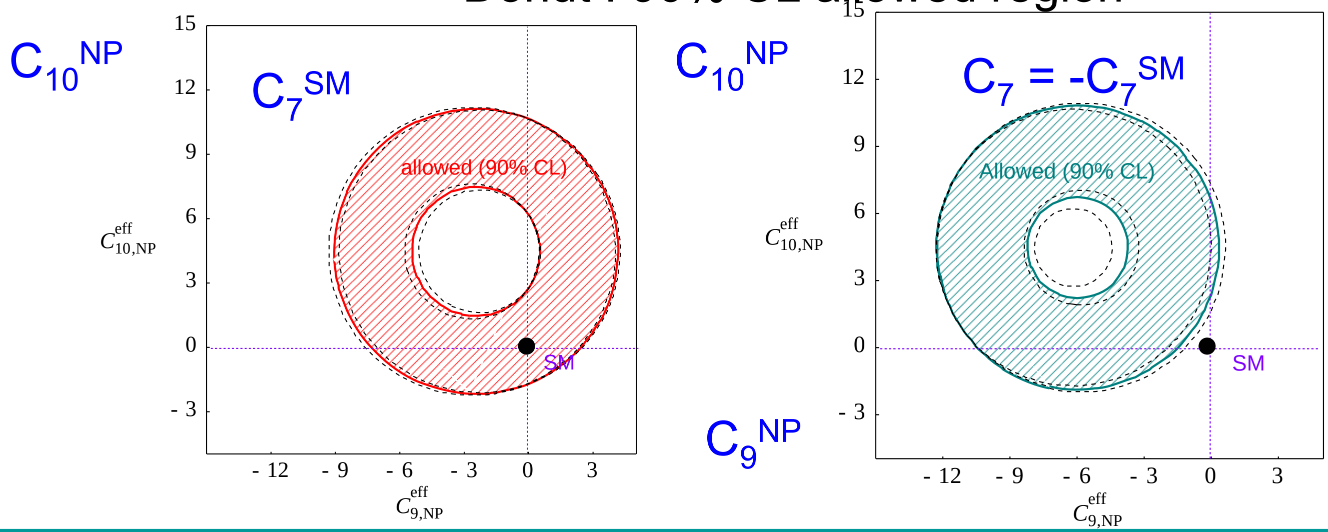
Constraints on C_i from $B(B \rightarrow X_s l^+ l^-)$

P.Gambino, U.Haisch and M.Misiak PRL 94 061803 (2005)

- Clean prediction for $B(B \rightarrow Xsll)$ with $1<q^2<6 GeV^2$ is available.
  - Combine Belle and Babar results
  - Sign of C7 flipped case with SM C9 and C10 values is unlikely.

BF	Belle	Babar	WA	SM	$C_7 = -C_7^{SM}$
$q^2>(2m_\mu)^2$	4.11 ± 1.1	5.6 ± 2.0	4.5 ± 1.0	4.4 ± 0.7	8.8 ± 0.7
$1<q^2<6GeV^2$	1.5 ± 0.6	1.8 ± 0.9	1.60 ± 0.5	1.57 ± 0.16	3.30 ± 0.25

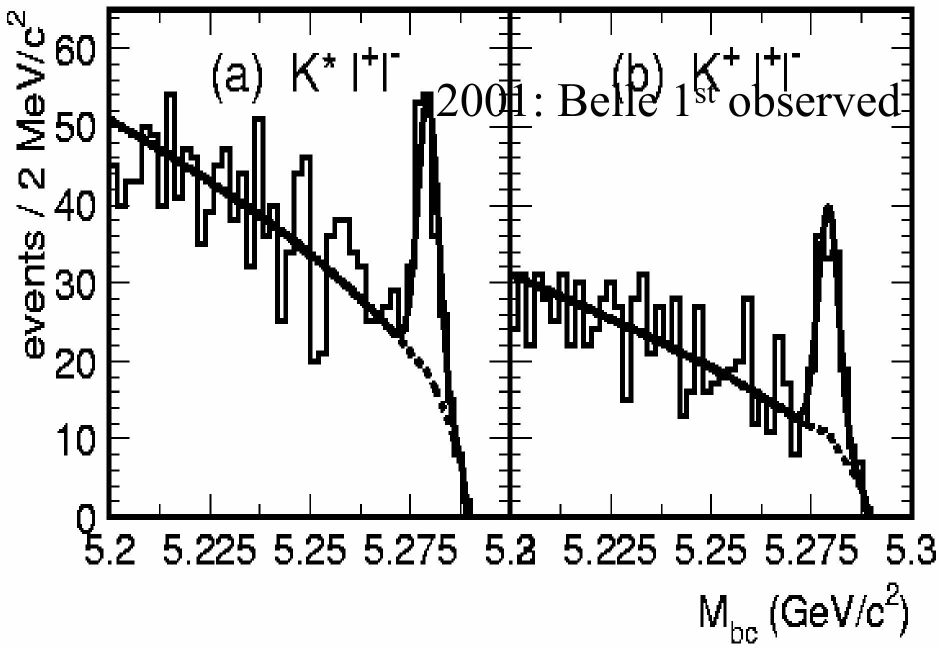
Donut : 90% CL allowed region



2005: Sample used for $A_{FB}(B \rightarrow K^{*}ll)(q^2)$

hep-ex/0503044

2001: Belle 1st observed



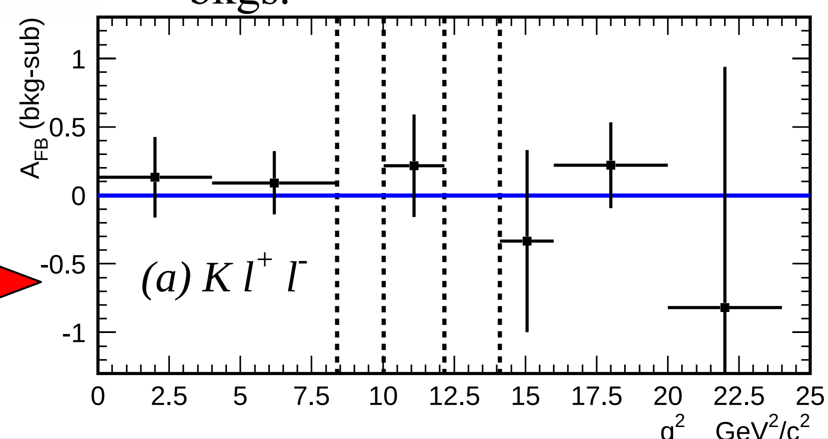
$$
\begin{aligned}
&P(q^2, \cos\theta; A_9/A_7, A_{10}/A_7) \\
&= f_{\rm sig}\epsilon_{\rm sig}(q^2,\cos\theta)\frac{d^2\Gamma}{dq^2 d\cos\theta}(q^2,\cos\theta)/N_{\rm sig} \\
&+ f_{\rm cfcf}\epsilon_{\rm cfcf}(q^2,\cos\theta)\frac{d^2\Gamma}{dq^2 d\cos\theta}(q^2,\cos\theta)/N_{\rm cfcf} \\
&+ f_{\rm ifcf}\epsilon_{\rm ifcf}(q^2,\cos\theta)\frac{d^2\Gamma}{dq^2 d\cos\theta}(q^2,-\cos\theta)/N_{\rm ifcf} \\
&+ f_{X_s\ell\ell}\mathcal{P}_{X_s\ell\ell}(q^2,\cos\theta) \\
&+ f_{\rm dilep}\Big\{(1-f_{K^*\ell h})\mathcal{P}_{\rm dilep}(q^2,\cos\theta) \\
&\quad + f_{K^*\ell h}\mathcal{P}_{K^*\ell h}(q^2,\cos\theta)\Big\} \\
&+ f_{K^*hh}\mathcal{P}_{K^*hh}(q^2,\cos\theta) + f_{\psi}\mathcal{P}_{\psi}(q^2,\cos\theta), \qquad (
\end{aligned}
$$

Treat q^2, $\cos(\theta)$ dependence of bkgs.

Sample for $B \rightarrow K^{*}\, l\, l$ events 113 ± 13

$B \rightarrow K\, l\, l$ control sample 96 ± 12

Consistent with flat



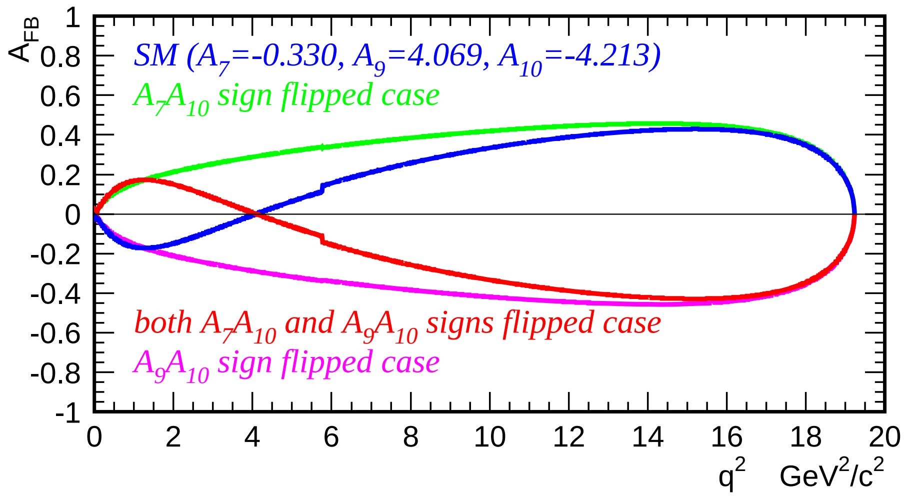
New Measurement of $A_{FB}(q^2)$ in K*ll

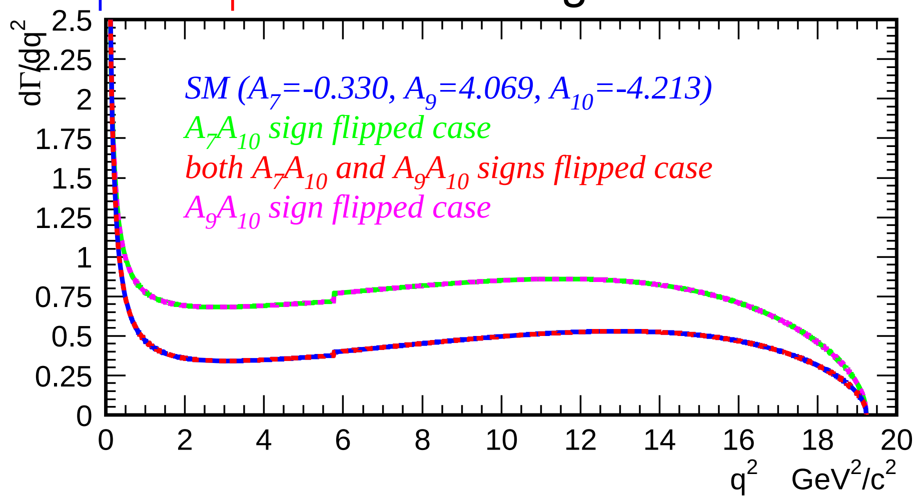
- Forward-backward asymmetry is induced by interference btw virtual photon and Z^0 contributions.
- Relative signs and magnitudes of C_7 to C_{10} and C_9 to C_{10} can be determined from $A_{FB}(B \rightarrow K^*ll)$!!

$$A_{\mathrm{FB}}(q^2) = \frac{\Gamma(q^2, \cos\theta_{B\ell^-} > 0) - \Gamma(q^2, \cos\theta_{B\ell^-} < 0)}{\Gamma(q^2, \cos\theta_{B\ell^-} > 0) + \Gamma(q^2, \cos\theta_{B\ell^-} < 0)}$$

$$\frac{d}{d\hat{s}}(\Gamma_F^{K^*} - \Gamma_B^{K^*}) = -\frac{G_F^2 \alpha^2 m_B^5}{2^8 \pi^5} |V_{ts}^* V_{tb}|^2 \hat{s}\hat{u}(\hat{s})^2 \times \left[\mathrm{Re}(C_9^{\mathrm{eff}}) C_{10} V A_1 + \frac{\hat{m}_b}{\hat{s}} C_7^{\mathrm{eff}} C_{10} (V T_2 (1 - \hat{m}_{K^*}) + A_1 T_1 (1 + \hat{m}_{K^*})) \right] .$$

We do not use C_i but A_i which is leading coefficients.





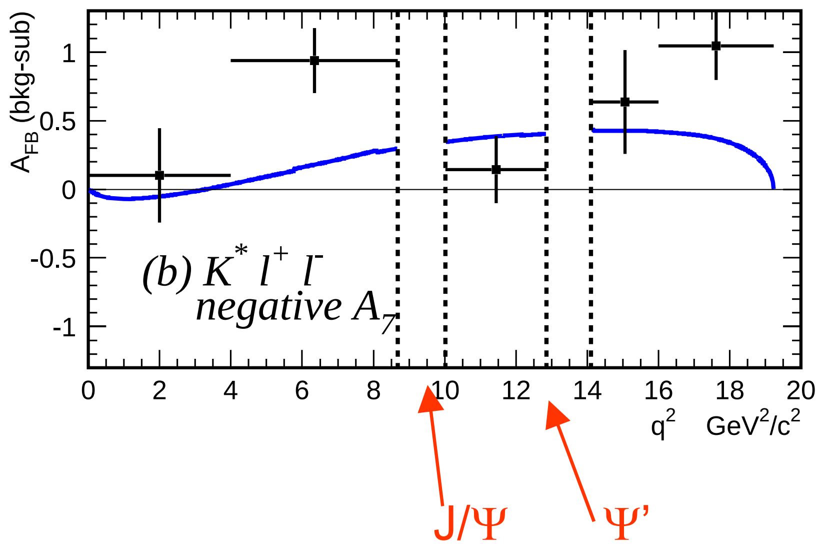
Fit results for ratios of Wilson coefficients

- Null test with K⁺ll

$$A_{FB}^{\text{bkg-sub}}(B \to K^+\ell\ell) = 0.09 \pm 0.14(\text{stat.})$$

- Projection to A_{FB}

$$A_{FB}^{\text{bkg-sub}}(B \to K^*\ell\ell) = 0.56 \pm 0.13(\text{stat.})$$



Best fit for negative A_7 (SM like)

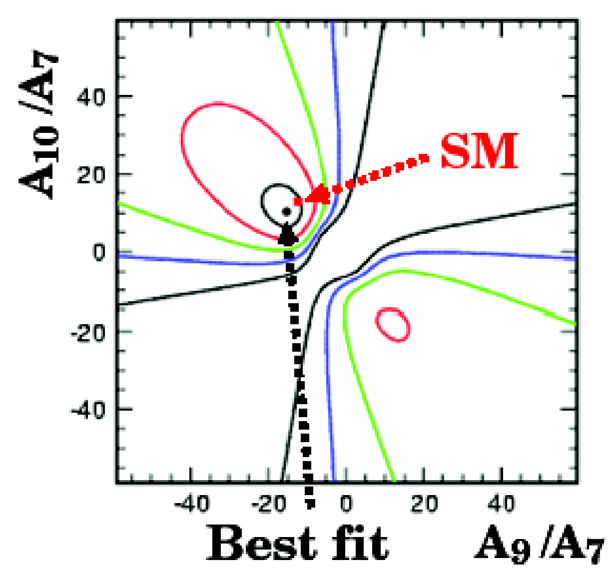
$$A_9/A_7 = -15.3^{+3.4}_{-4.8} \pm 1.1,$$
$$A_{10}/A_7 = 10.3^{+5.2}_{-3.5} \pm 1.8,$$

SM
$$A_9/A_7 = -12.3,$$
$$A_{10}/A_7 = 12.8.$$

Best fit for positive A_7 (non-SM like)

(This solution is also allowed)

$$A_9/A_7 = -16.3^{+3.7}_{-5.7} \pm 1.4,$$
$$A_{10}/A_7 = 11.1^{+6.0}_{-3.9} \pm 2.4,$$



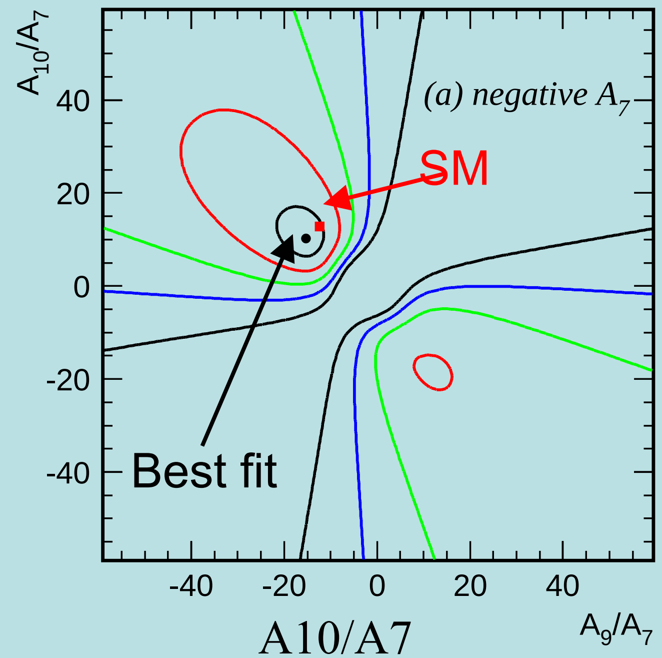
Confidence Level Contours

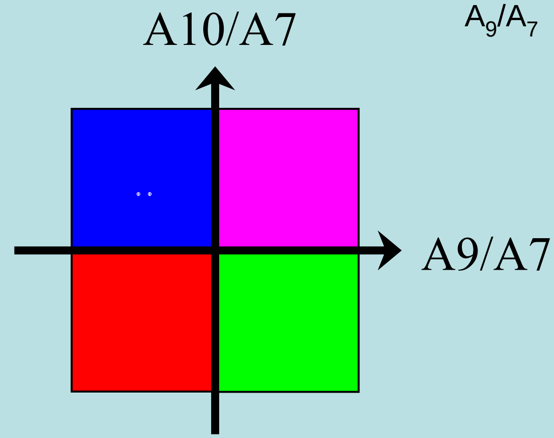
- For any allowed A_7, we obtain 95% CL

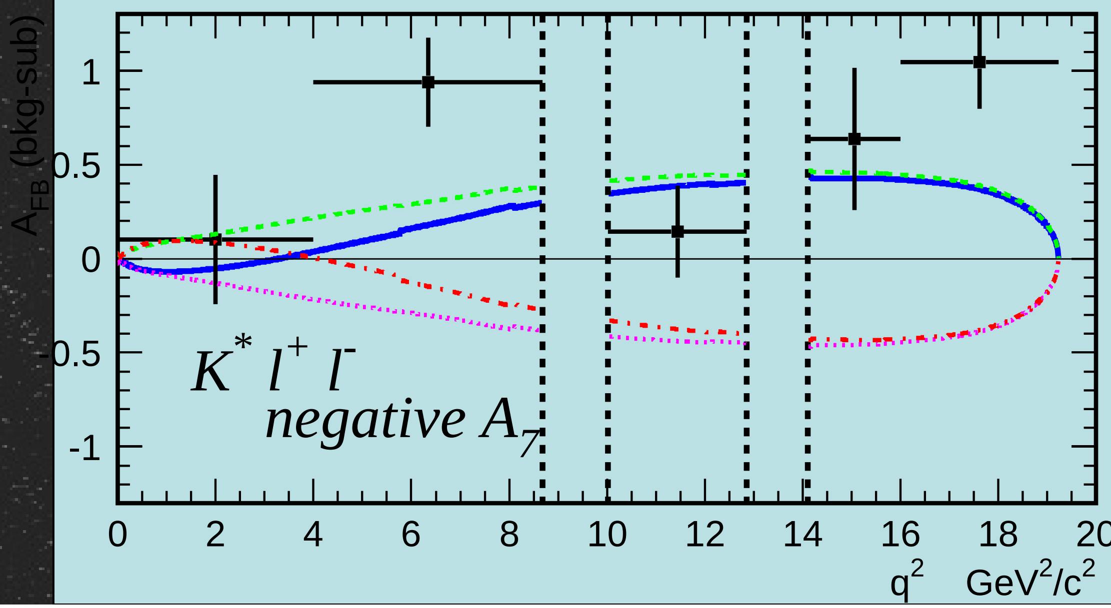
$$-1401 < A_9 A_{10}/A_7^2 < -26.4.$$

SM $A_9 A_{10}/A_7^2 = -157.$

- Sign of A_9A_{10} is negative!!
- Sign of A_9A_{10} flipped case is excluded
  - The first and third quadrants
- Sign of A_7A_{10} is not determined yet.
  - The second and fourth quadrants







fit result

A7A10 sign flipped (to SM)

Both A_7A_{10} and A_9A_{10} signs flipped

A_9A_{10} sign flipped

What is the ultimate possible UT precision?

- Theoretical limits (continuum methods)
  - Many measurements will not be theory-limited for quite some time

Ligeti:

Measurement (in SM)	Theoretical limit	Present error
$B \to \psi K_S$ (β)	$\sim 0.2^\circ$	1.6°
$B \to \phi K_S,\ \eta^{(\prime)} K_S, \ldots\ (\beta)$	$\sim 2^\circ$	$\sim 10^\circ$
$B \to \pi\pi,\ \rho\rho,\ \rho\pi$ (α)	$\sim 1^\circ$	$\sim 15^\circ$
$B \to DK$ (γ)	$\ll 1^\circ$	$\sim 25^\circ$
$B_s \to \psi\phi$ (β_s)	$\sim 0.2^\circ$	—
$B_s \to D_s K$ $(\gamma - 2\beta_s)$	$\ll 1^\circ$	—
$\|V_{cb}\|$	$\sim 1\%$	$\sim 3\%$
$\|V_{ub}\|$	$\sim 5\%$	$\sim 15\%$
$B \to X \ell^+ \ell^-$	$\sim 5\%$	$\sim 20\%$
$B \to K^{(*)} \nu\bar{\nu}$	$\sim 5\%$	—
$K^+ \to \pi^+ \nu\bar{\nu}$	$\sim 5\%$	$\sim 70\%$
$K_L \to \pi^0 \nu\bar{\nu}$	$< 1\%$	—