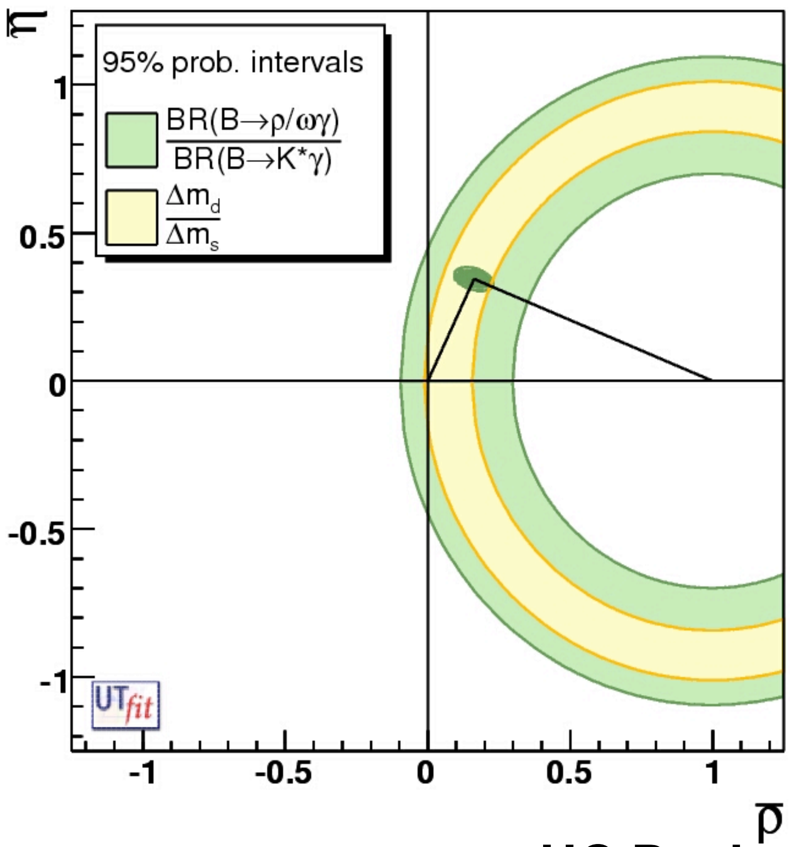
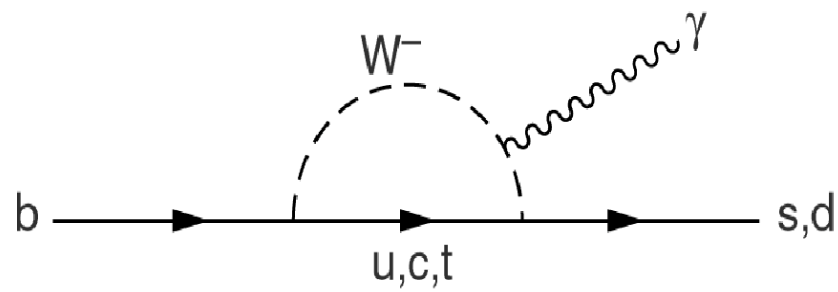
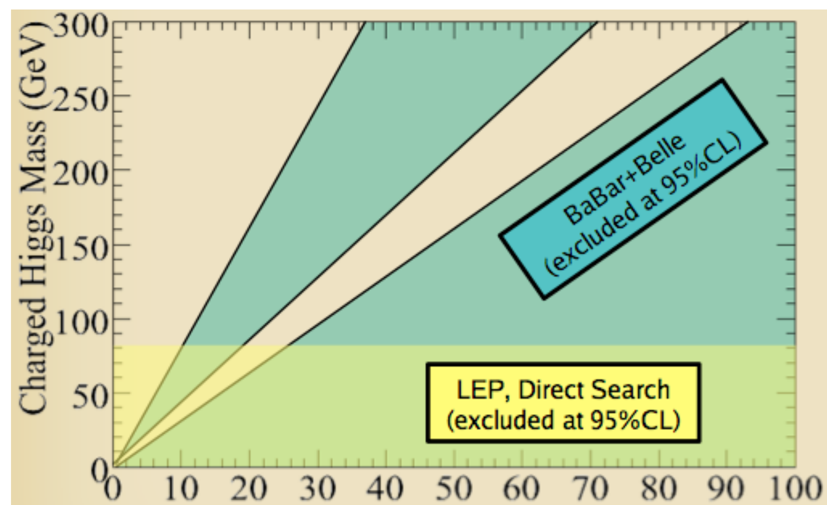
Searching for New Physics in B Decays

Gabriella Sciolla (MIT)







UC Davis - March 6, 2007

What is "New Physics"

- Standard Model: 1971-present
  - 35 years of success with no major failure
    - Minor failure: neutrinos have mass
- Reasons to believe SM is incomplete
  - Hierarchy problem / Fine tuning…
- Many extensions have been proposed
  - SUSY, Extra dimensions,... → New Physics
- The roads to New Physics
  - Direct searches (Tevatron → LHC)
  - Indirect searches
    - Study of CP violation and rare B decays
    - Electric Dipole Moment
    - g-2,…

Outline

- Constraints on New Physics from CP violation
  - CP violation in the Standard Model
    - Why should we expect New Physics?
  - The beauty of the Unitarity Triangle
    - Measurements of angles
    - Measurements of sides

      ** New measurement of R_t in $B \to \rho\gamma$ from BaBar**

      (recently accepted by PRL)

- Constraints to New Physics from rare B decays
  - Example: $B \to \tau\nu$ and $B \to s\gamma$

- Summary and conclusion

CP violation

- What is CP?

$$CP = C \times P$$

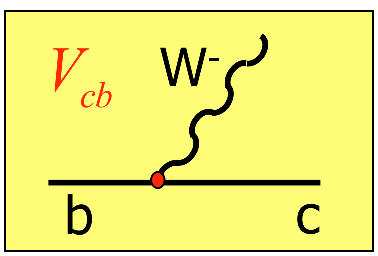
C: Charge Conjugation	P: Parity
Particle → Anti-particle	Inverts space coordinates

- Why is CP violation interesting?
  - Crucial ingredient to explain the matter-dominated universe
    - A. Sakharov (1967)
  - Measures two fundamental parameters of Standard Model
    - ρ and η
  - May hold the key to uncover the first signs of New Physics
    - e.g.: MSSM has 43 new CP violating phases!

CP violation in the Standard Model

- Discovered by Fitch and Cronin in 1964 in K_L decays
- Introduced in Standard Model in 1973 by Kobayashi and Maskawa
- In KM mechanism, CP violation originates from a complex phase in the quark mixing matrix (CKM matrix)

$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-\frac{1}{2}\lambda^2 & \lambda & A\lambda^3(\bar{\rho}-i\bar{\eta}) \\ -\lambda & 1-\frac{1}{2}\lambda^2 & A\lambda^2 \\ A\lambda^3(1-\bar{\rho}-i\bar{\eta}) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^6)$$



A,λ (Cabibbo angle): very well measured
ρ,η: poorly known until recently

Going beyond CKM

The (many) strengths of CKM

- ✓ Simple explanation of CPV in SM
- ✓ It is very predictive: only one CPV phase
- ✓ It accommodates all experimental results
  - Indirect CP violation in $K \rightarrow \pi\pi$ and $K_L \rightarrow \pi l \nu$
  - Direct CP violation in $K \rightarrow \pi\pi$
  - CP violation in the B system

New Physics models have several sources of CP violation

- Exploit CKM prediction power -->use CPV as probe for New Physics

Measure CP violation in channels <u>theoretically well understood</u> and look for deviations w.r.t. SM expectations

The Unitarity Triangle

Unitarity of CKM implies: $V^{\dagger}V = 1$ → 6 unitarity conditions

Of particular interest:

$$\mathbf{V_{ud}V_{ub}^{*} + V_{cd}V_{cb}^{*} + V_{td}V_{tb}^{*} = 0}$$

$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

All sides are ~ O(1) → possible to measure both sides and angles!

- CP asymmetries in B meson decays measure α, β and γ
- Sides from semileptonic B decays, B mixing, rare B decays

The Unitarity Triangle

Unitarity of CKM implies: $V^\dagger V = 1$ → 6 unitarity conditions

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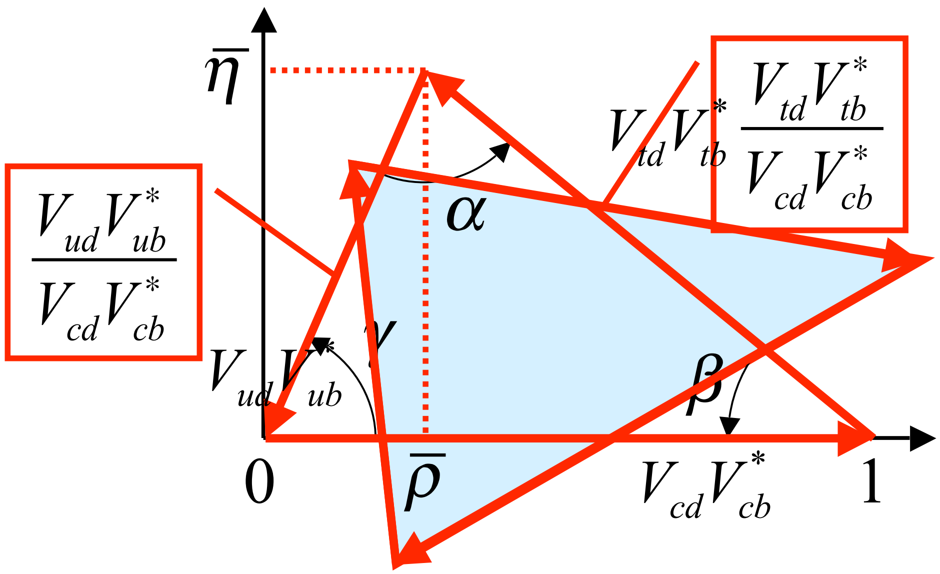

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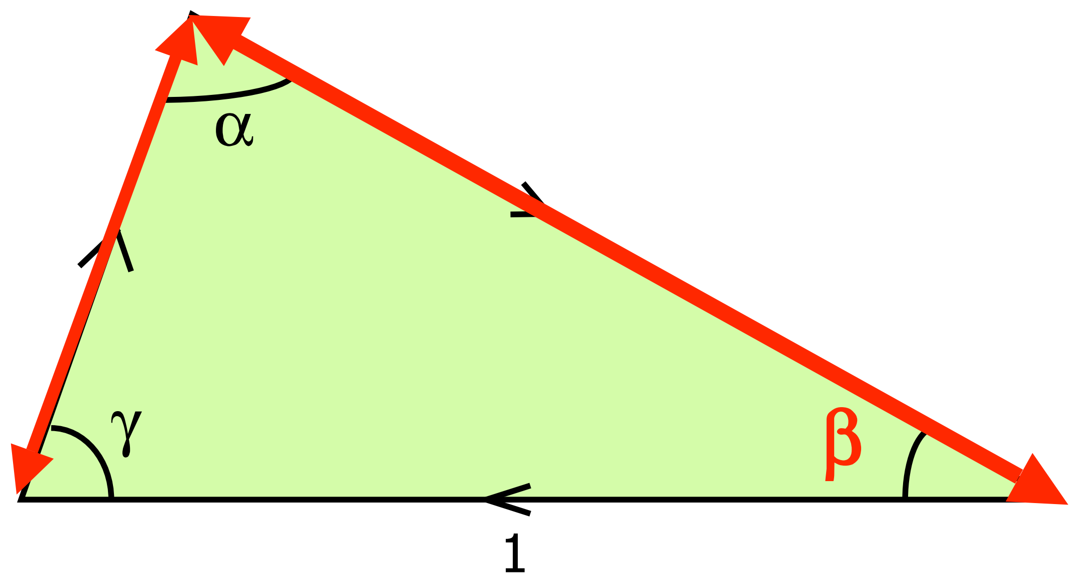
Standard Model parameters (ρ,η)

To precisely determine the parameters of the Standard Model (ρ,η), all we need is a precise measurement of 2 quantities, e.g.: 2 sides.



But additional measurement are essential to look for New Physics

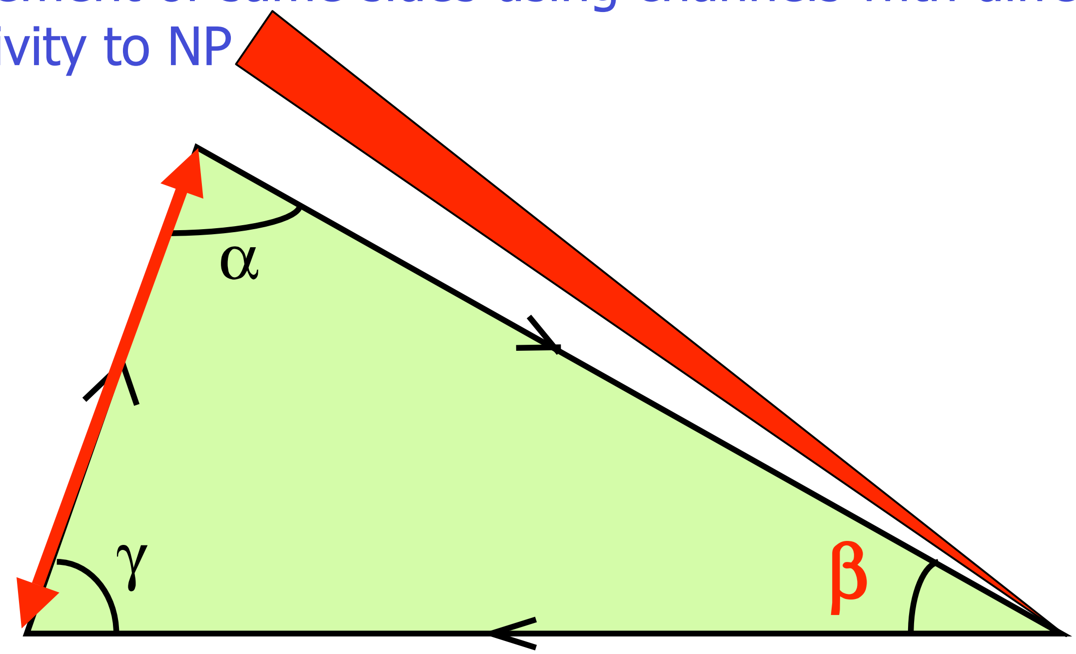
Redundancy, redundancy, redundancy!

3 ways to look for New Physics:

a) Sides vs angles

b) Measurement of same angle using channels with different sensitivity to NP

c) Measurement of same sides using channels with different sensitivity to NP



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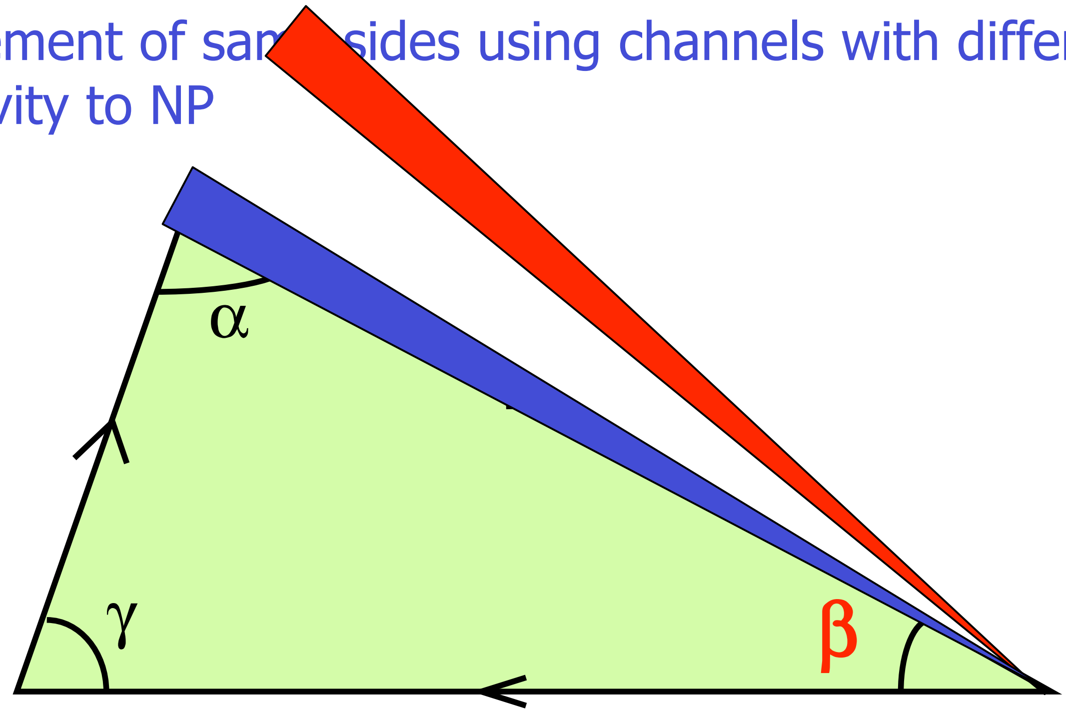

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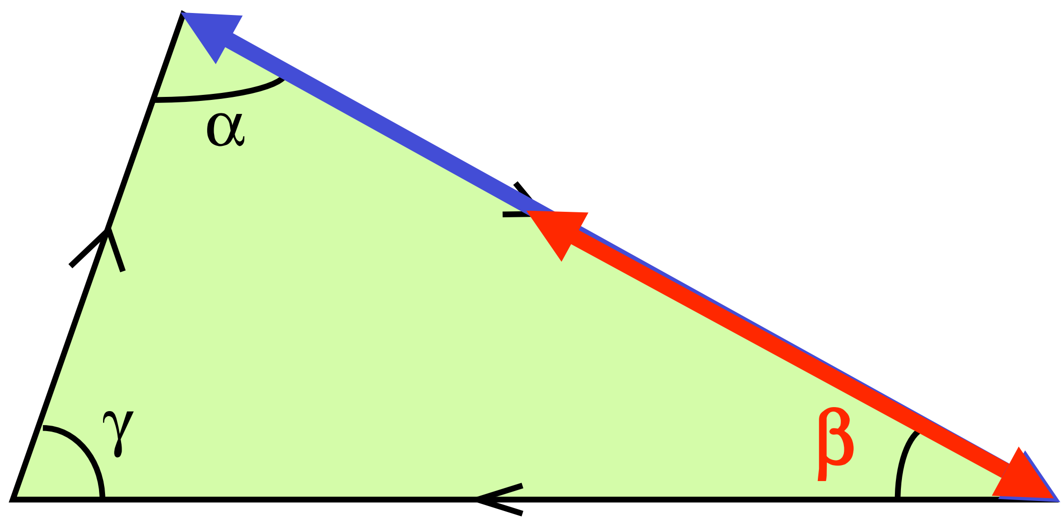
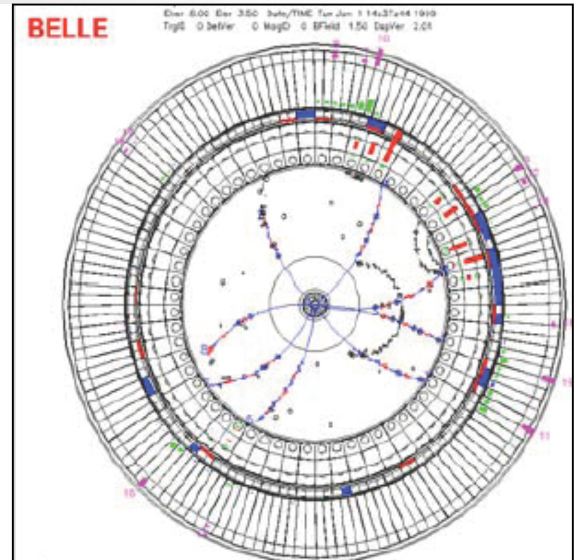
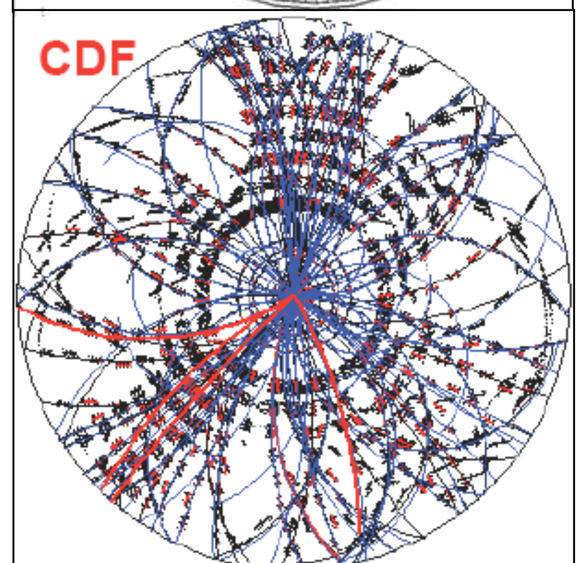


The experiments:

B factories vs Tevatron

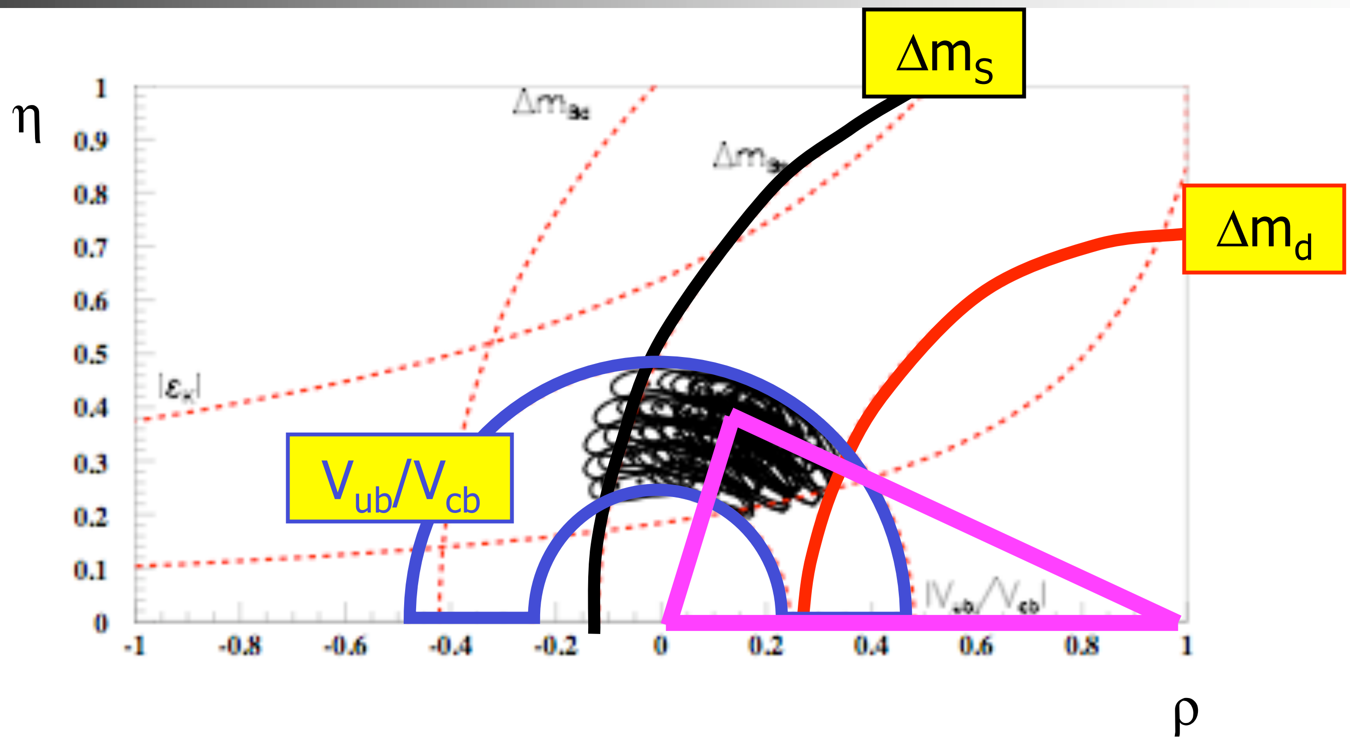
	B factories	Tevatron
Experiments	BaBar at SLAC Belle at KEK	D0 and CDF $p\bar{p}$ @ $\sqrt{s} \sim 2$ TeV
Multiplicity	$e^+e^- \rightarrow \Upsilon(4s) \rightarrow B\bar{B}$	High!
Trigger	$\sigma_{b\bar{b}} : \sigma_{q\bar{q}} \sim 1:4$	$\sigma_{b\bar{b}} : \sigma_{inelastic} \sim 1:10^3$
Luminosity	L > 10^{34} cm^{-2}s^{-1} 400/700 fb^{-1} (BaBar/Belle)	L~10^{32} cm^{-2}s^{-1} high x-sections →high rates
B hadrons	B^0,B^+ with $\beta\gamma$~0.5	B_S , Λ_b , B_C ,…





Complementary capability

The Unitarity Triangle in 1999



3 ways to look for New Physics:

a) Sides vs. angles

b) Angle vs. angle

c) Side vs. side

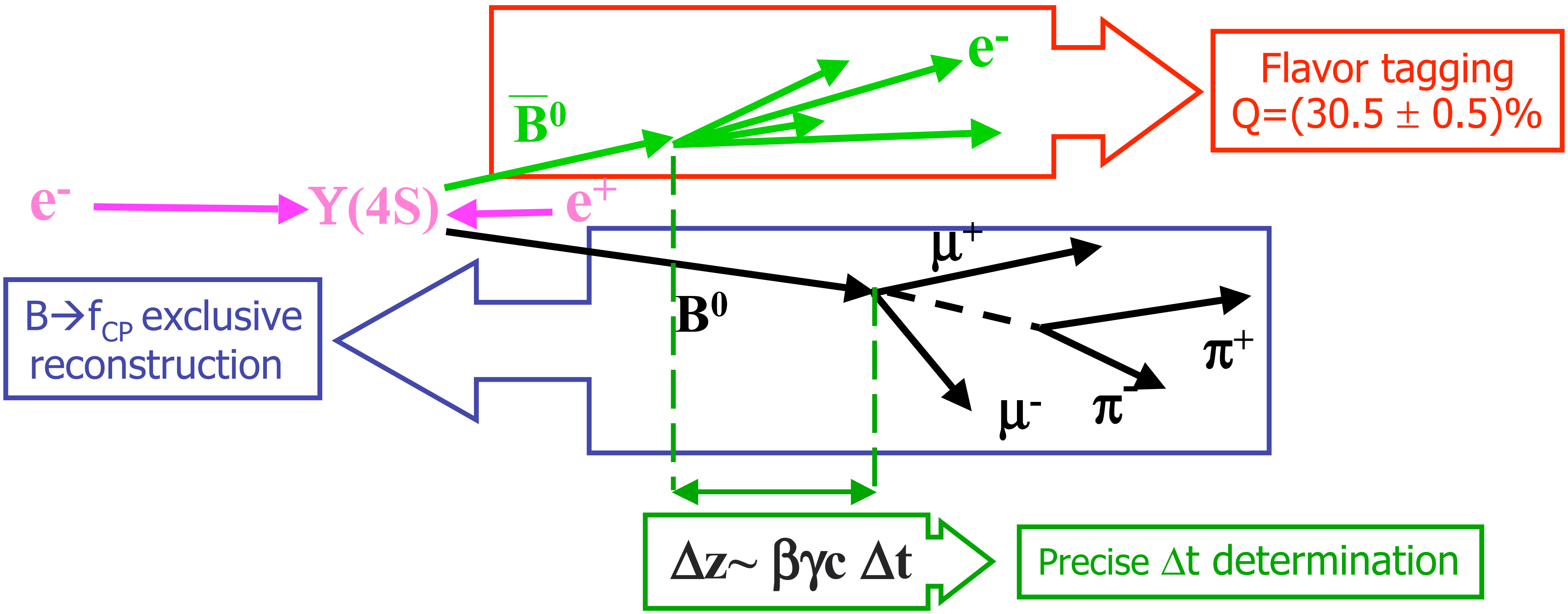
Some measurement of the sides, but no angles!

First goal of the B factories:

measure the angles of UT

Time dependent CP asymmetry:

$$A_{CP}(t) = \frac{N(\overline{B}^0(t) \to f_{CP}) - N(B^0(t) \to f_{CP})}{N(\overline{B}^0(t) \to f_{CP}) + N(B^0(t) \to f_{CP})}$$

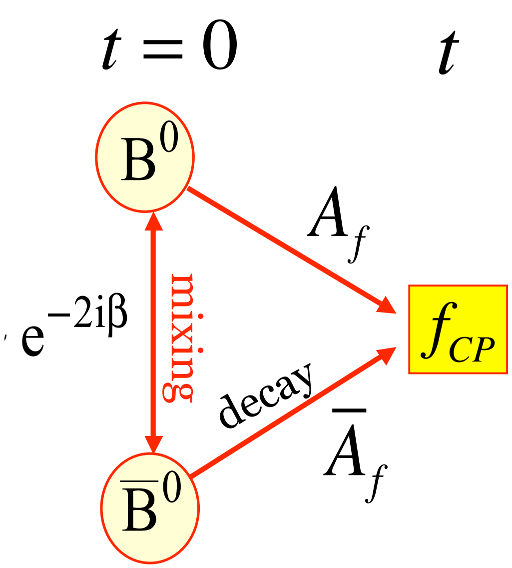


CP violation at the B factories

When only one diagram contributes to the decay B-->f_{CP}

$$A_{CP}(t) = \frac{N(\bar{B}^0(t) \to f_{CP}) - N(B^0(t) \to f_{CP})}{N(\bar{B}^0(t) \to f_{CP}) + N(B^0(t) \to f_{CP})} = \pm \ \mathrm{Im}\,\lambda \ \sin(\Delta m t)$$

CP eigenvalue of final state



$$\lambda_f = \frac{q}{p} \cdot \frac{\bar{A}_f}{A_f}$$

$$\begin{cases} |B_L\rangle = p|B^0\rangle + q|\bar{B}^0\rangle \\ |B_H\rangle = p|B^0\rangle - q|\bar{B}^0\rangle \end{cases}$$

$$\Delta m = m_{B_H} - m_{B_L}$$

(CP violation in interference between mixing and decays)

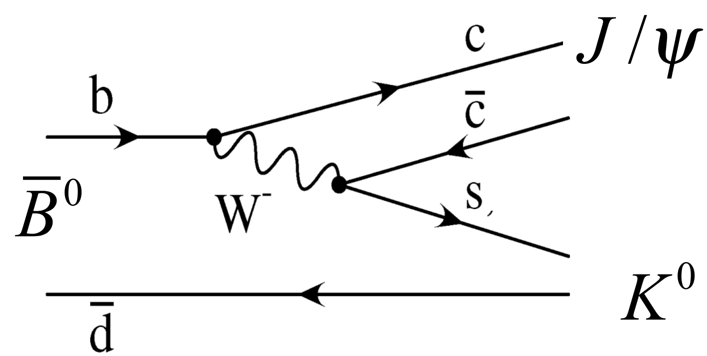
CP violation in B^0 decays: $\sin 2\beta$

For some modes, Imλ is directly and simply related to the angles of the Unitarity Triangle.

Example:

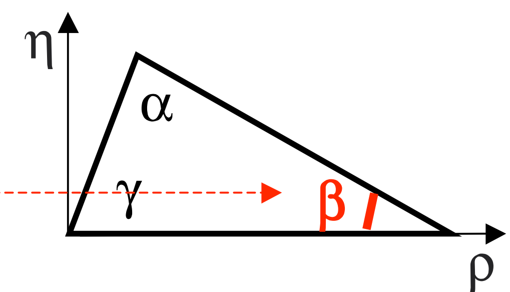
$B^0 \rightarrow J/\Psi K_S$: the "golden mode"

- Theoretically clean
- Experimentally clean
- Relatively large BF ($\sim 10^{-4}$)



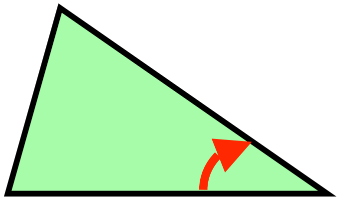
$$\lambda = \left(\frac{V_{tb}^* V_{td}}{V_{tb} V_{td}^*}\right)_{B^0_{mix}} \left(\frac{V_{cs}^* V_{cb}}{V_{cs} V_{cb}^*}\right)_{decay} \left(\frac{V_{cd}^* V_{cs}}{V_{cd} V_{cs}^*}\right)_{K^0_{mix}} = e^{-i2\beta}$$

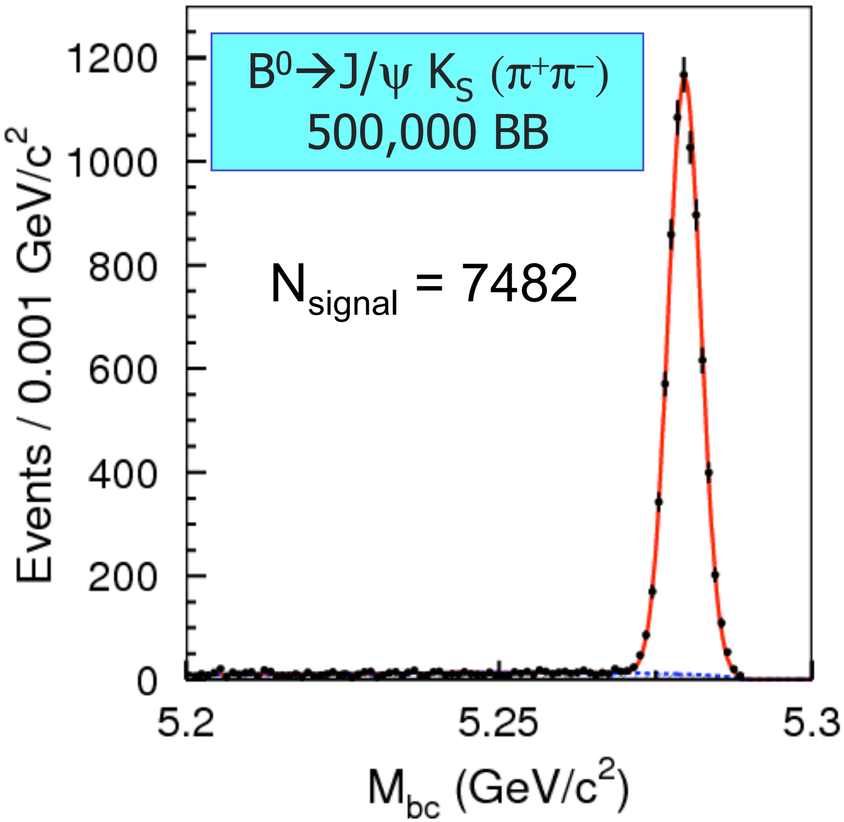
$$A_{CP}(t) = \sin 2\beta \, \sin \Delta m t$$

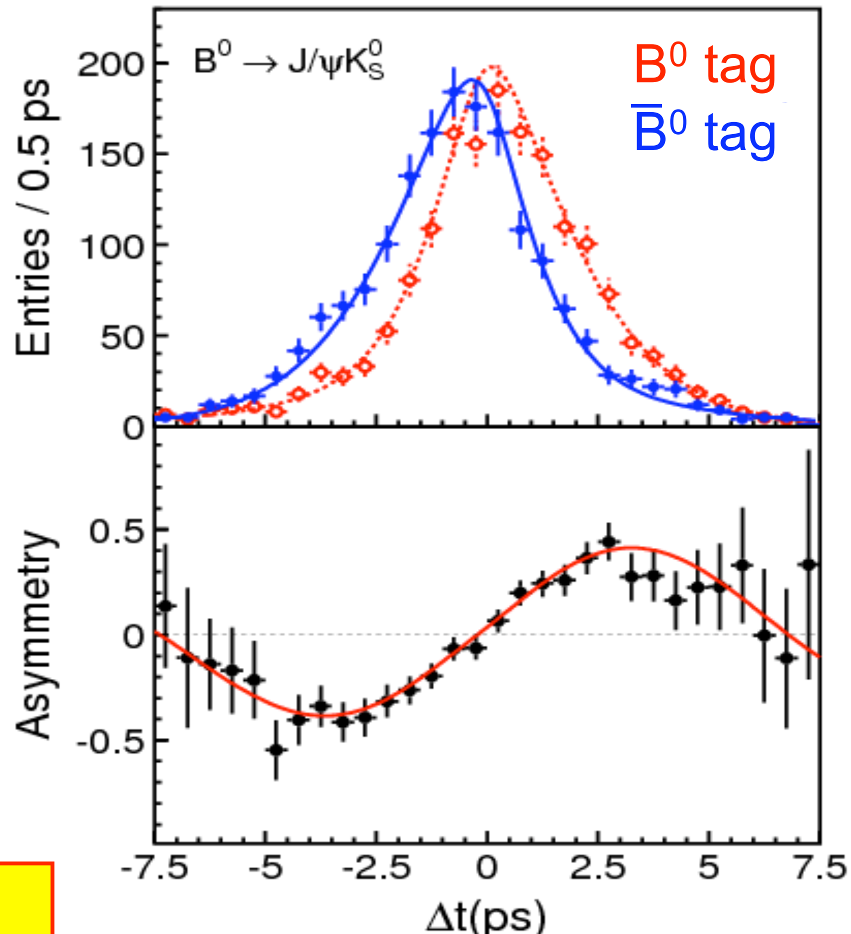


The golden mode for sin2β:

sin2β in $B^0 \rightarrow J/\psi\ K^0$



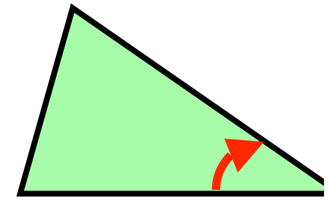


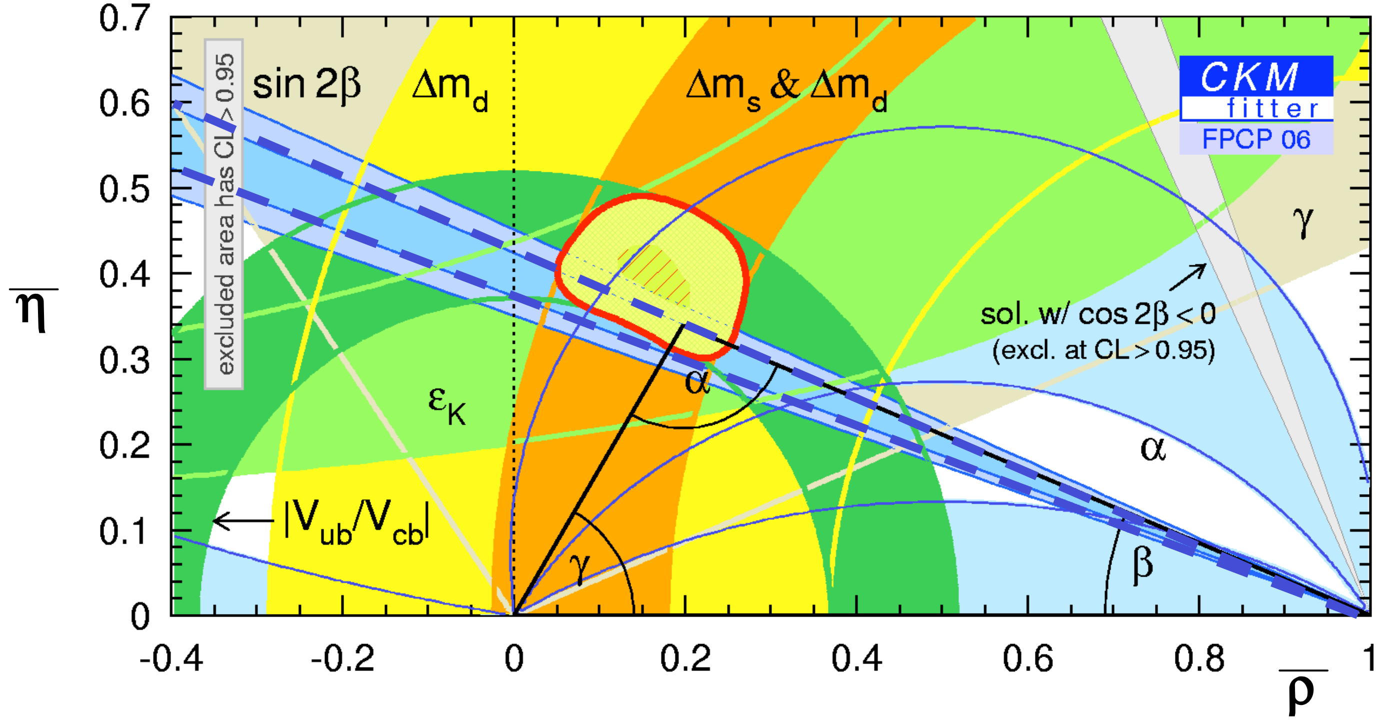


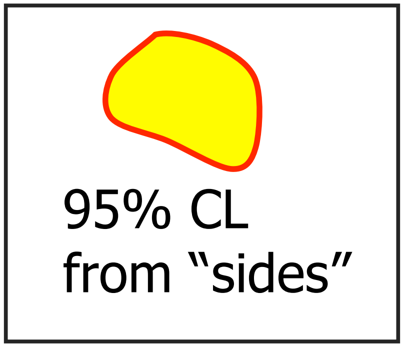
$\sin(2\beta) = 0.674 \pm 0.026$

WA ICHEP 2006

NP test #1: sides vs. angles





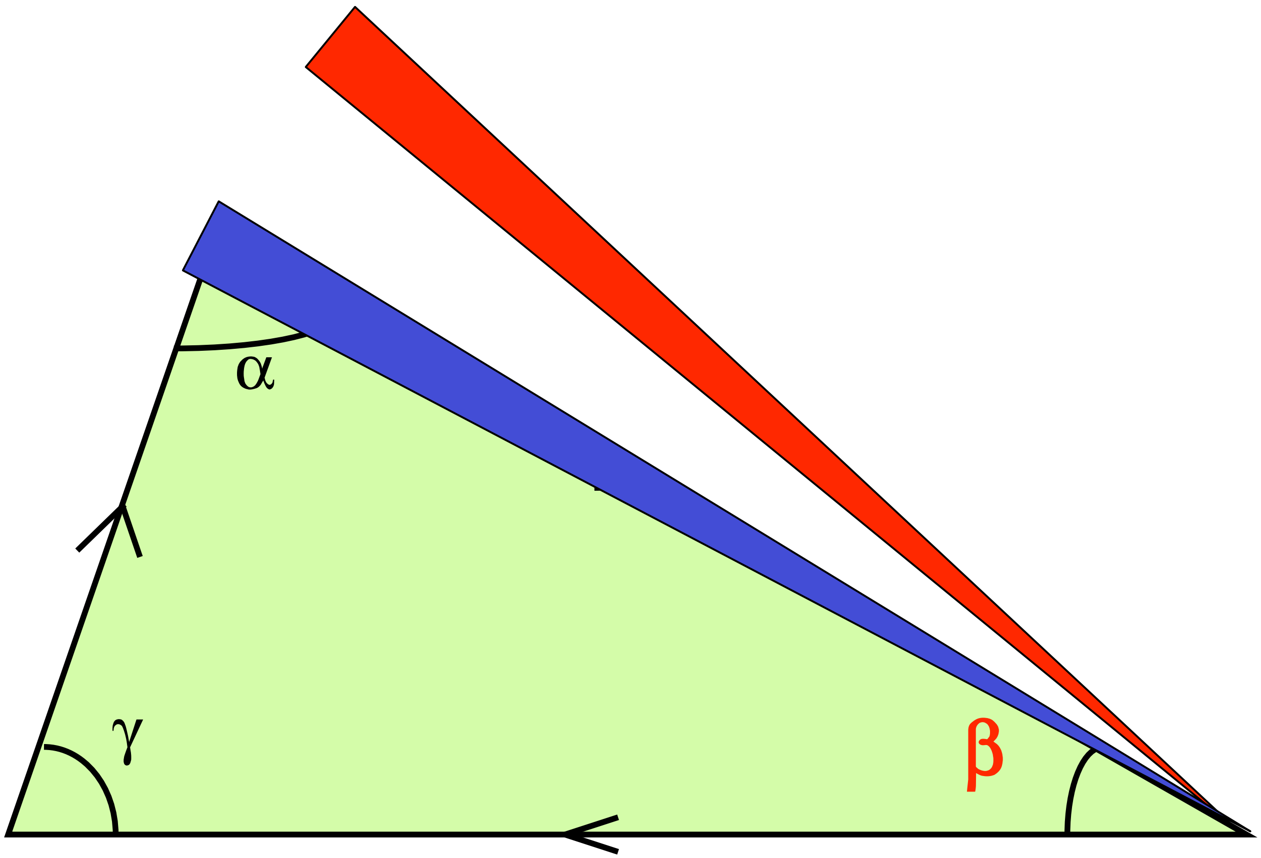


sin2β vs indirect UT constraints: pretty good agreement!

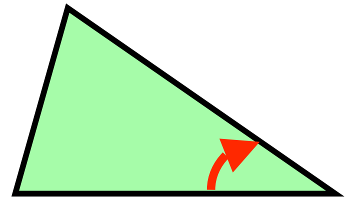
CKM mechanism is the dominant source of CPV in this decay

- New Physics does not show up in the golden mode →SM reference
  - Compare with sin2β in independent modes with different sensitivity to NP

NP test #2: angles vs angles

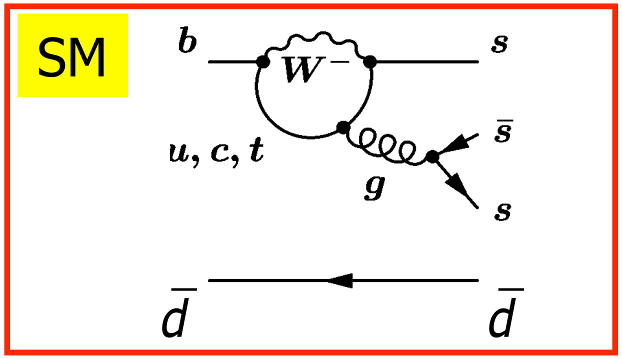


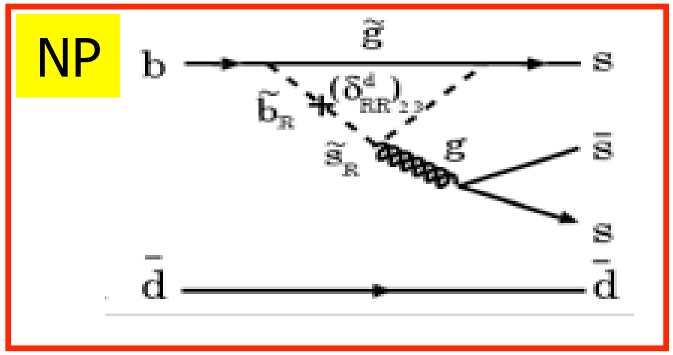
An independent measurement of β:
The Penguin Modes



Decays dominated by gluonic penguin diagrams

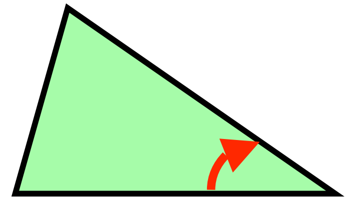
- The typical example: $B^0 \rightarrow \phi K_S$

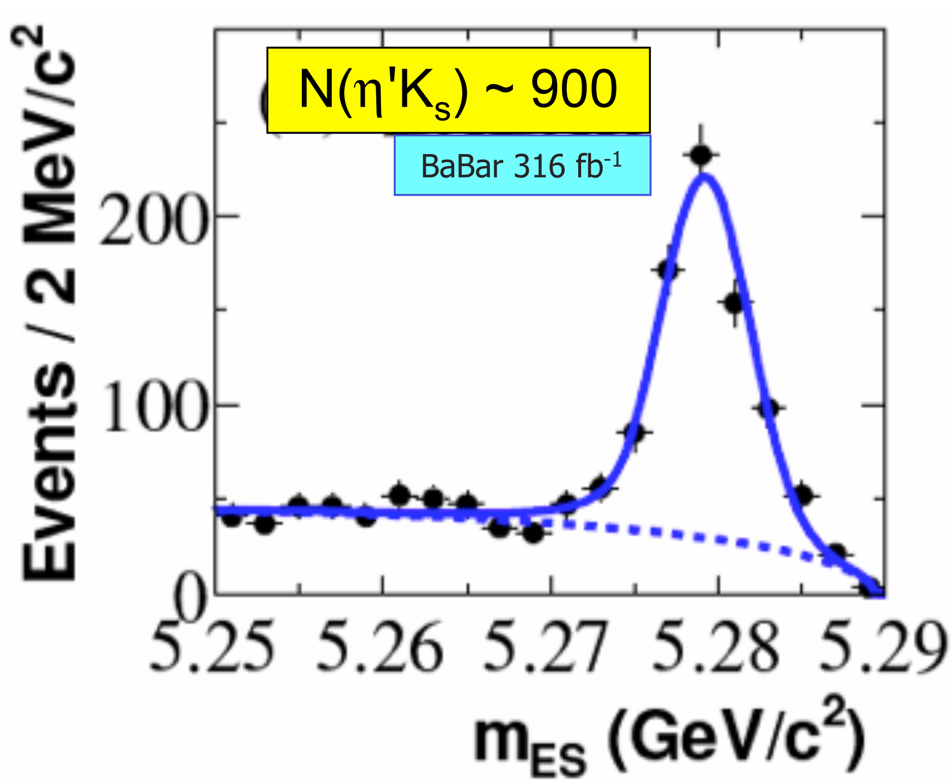


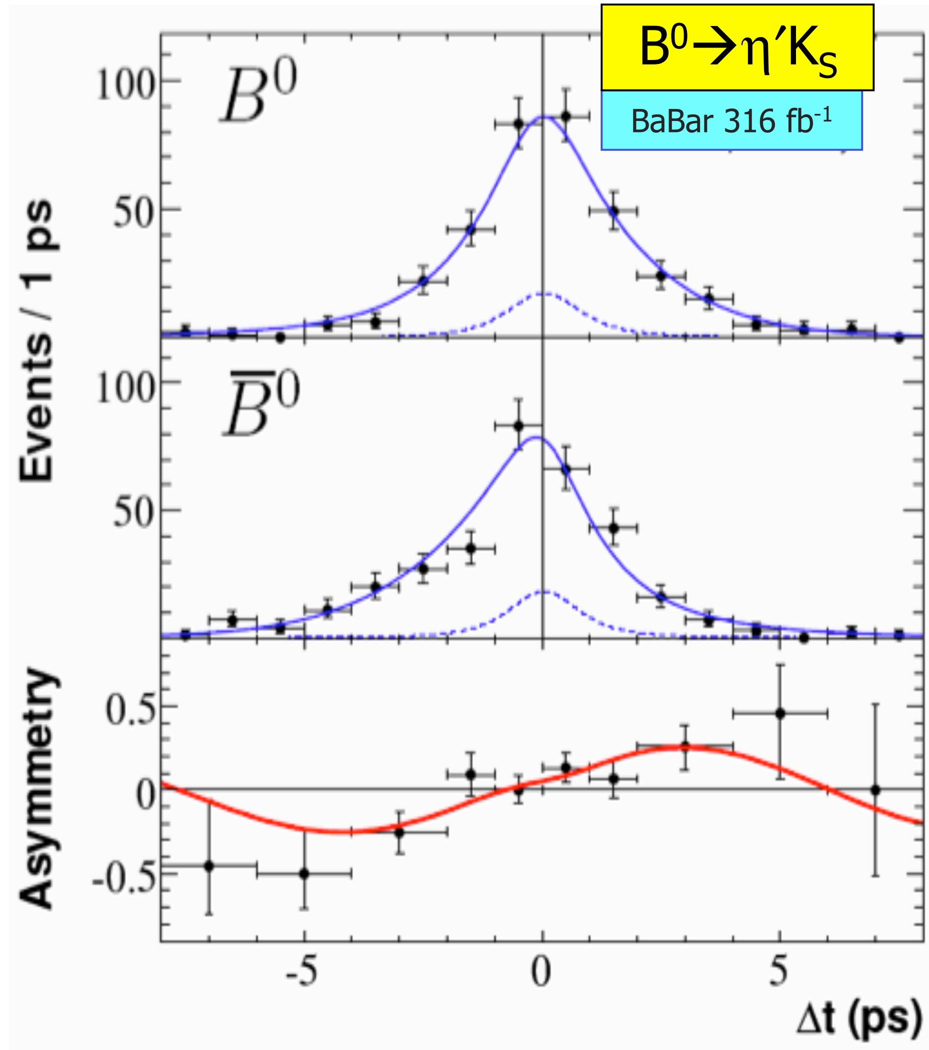


  - No tree level contributions: theoretically clean
  - SM predicts: $A_{CP}(t) = \sin 2\beta \sin(\Delta m t)$
- Impact of New Physics could be significant
  - New particles could participate in the loop → new CPV phases
- Low branching fractions (10^{-5})
  - Measure A_{CP} in as many $b \rightarrow s q\bar{q}$ penguins as possible!
    - φK^0, $K^+ K^- K_S$, $\eta' K_S$, $K_S \pi^0$, $K_S K_S K_S$, ωK_S, $f_0(980) K_S$

The silver penguin: $B^0 \rightarrow \eta' K^0$



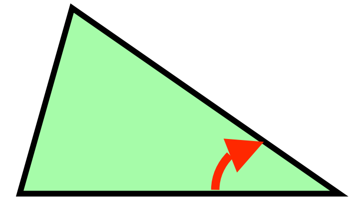


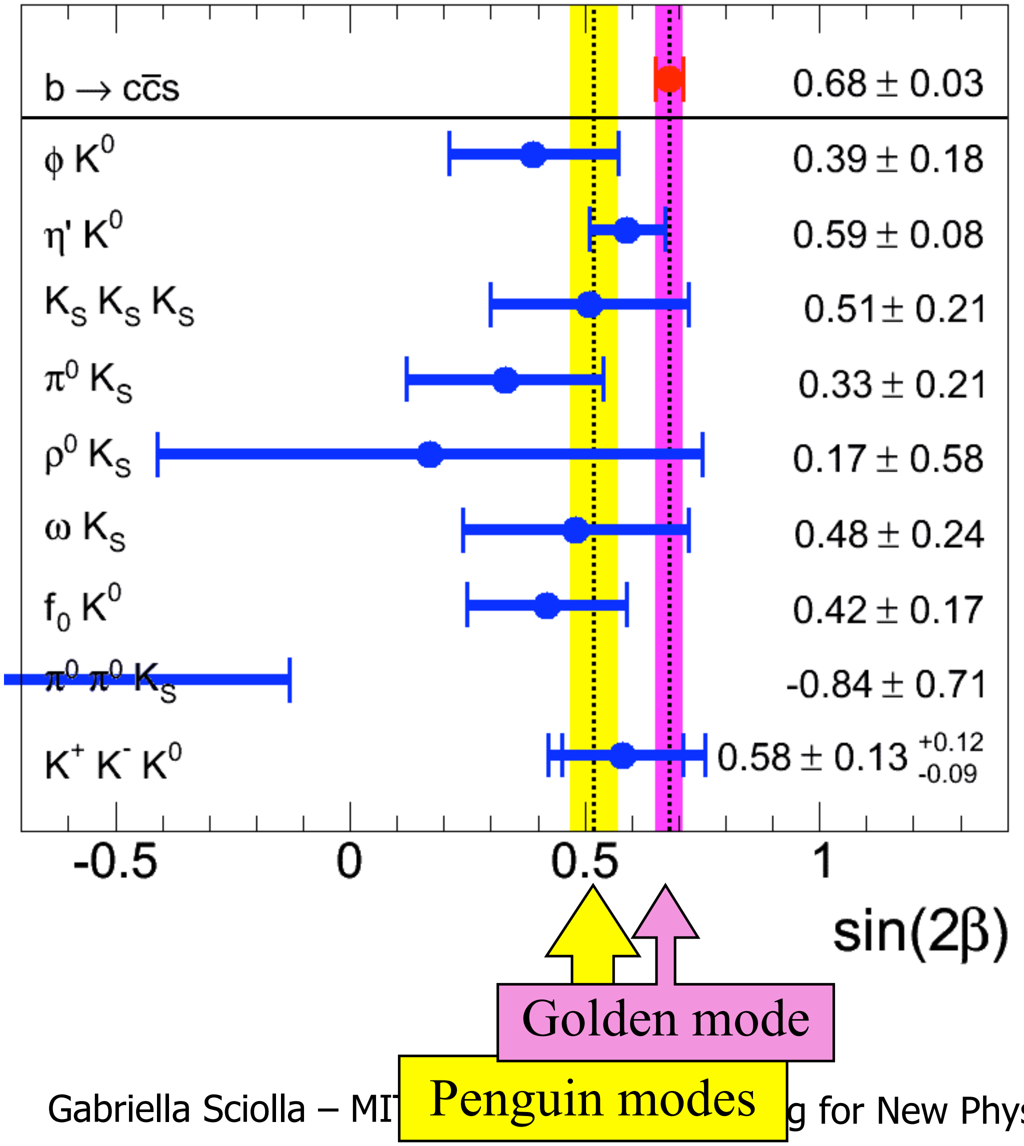


$$S_{\eta' K^0} = 0.55 \pm 0.11 \pm 0.02$$

BaBar 316 fb^{-1}

NP test #2:
β in penguins vs golden mode





BaBar + Belle average

A trend is visible

- although each measurement is compatible with $J/\Psi K_S$…

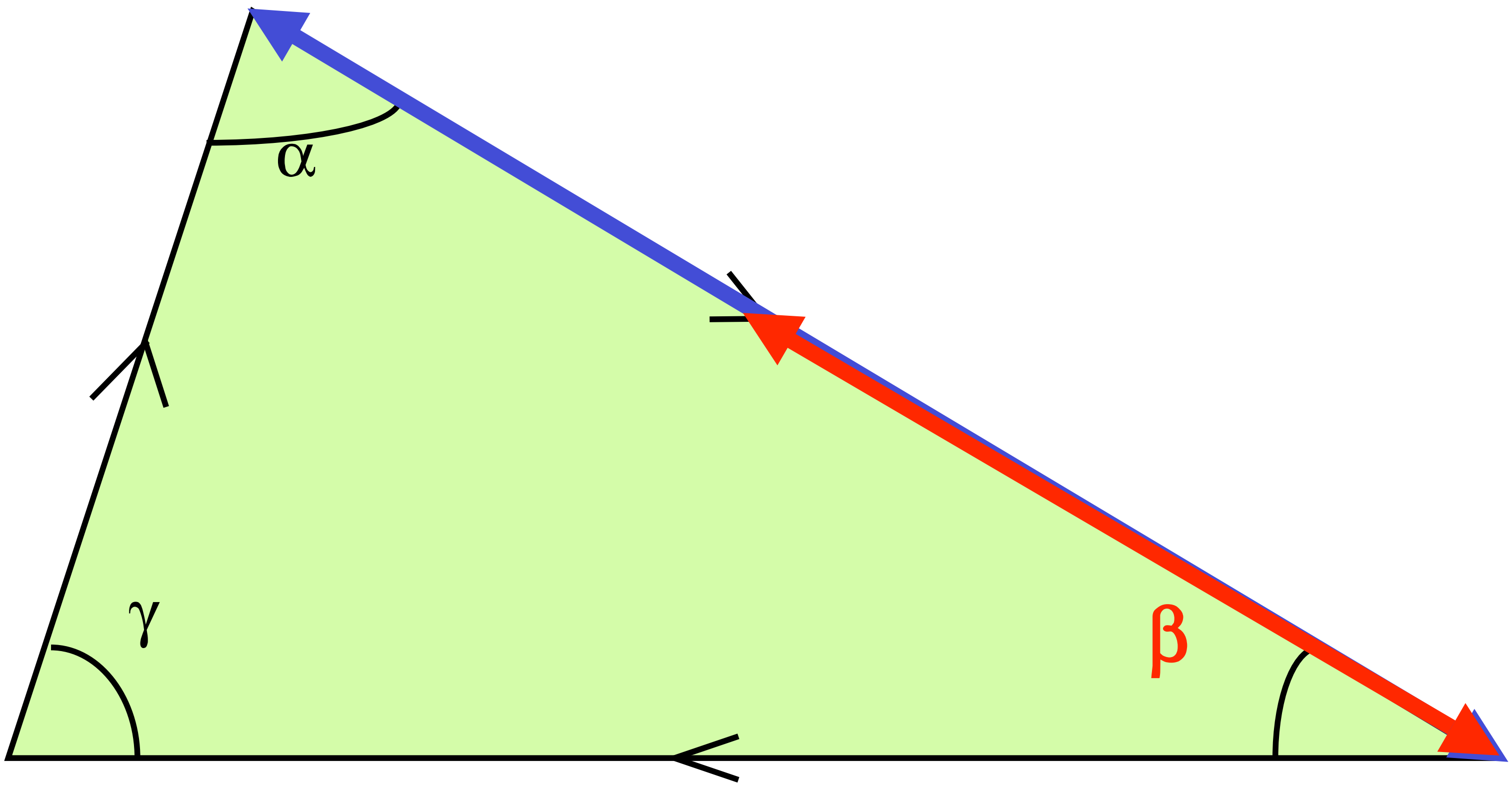
Naïve average: 0.52±0.05

- ~2.6σ

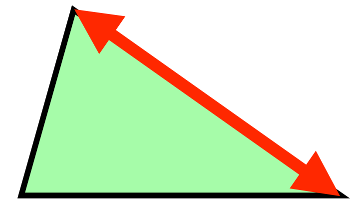
Statistical errors still large…

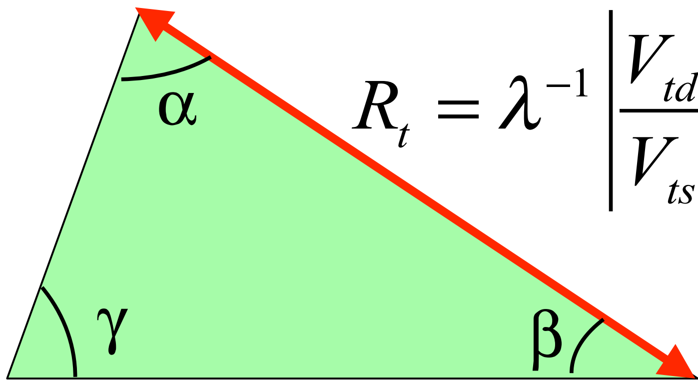
- More statistics will help

NP test #3: sides vs. sides

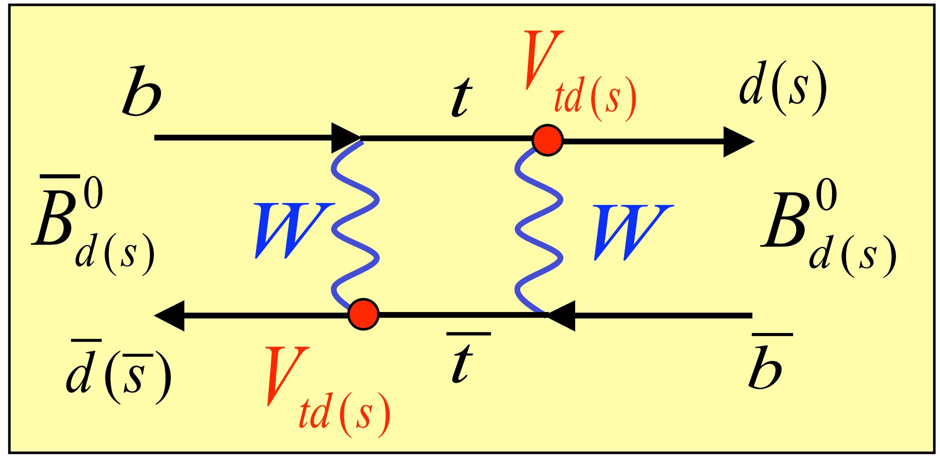


The measurement of R_t





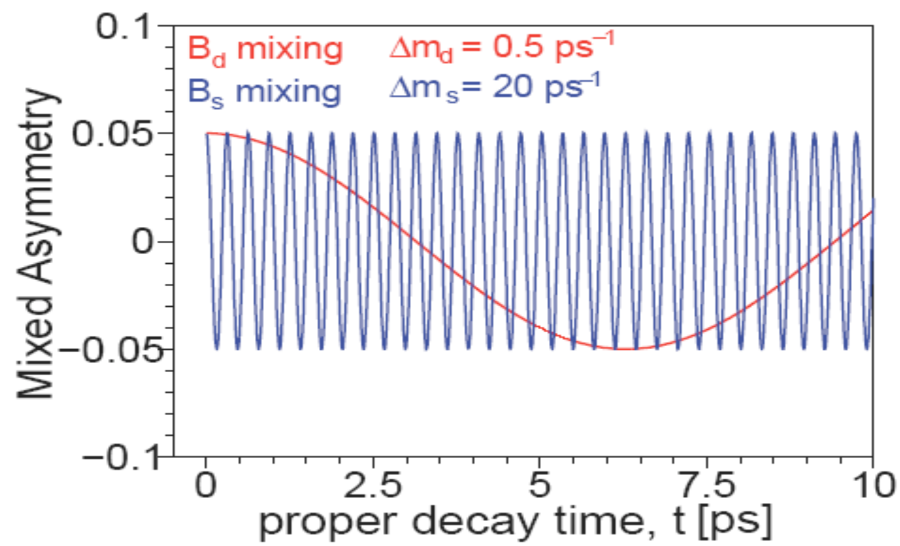
$$R_t = \lambda^{-1} \left| \frac{V_{td}}{V_{ts}} \right|$$



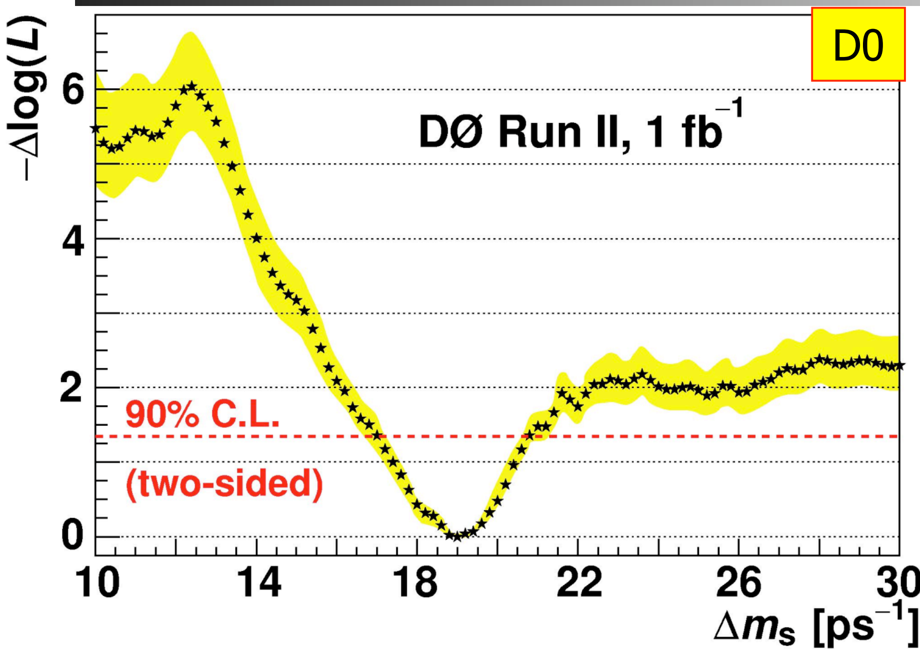
- B_s/B_d oscillations

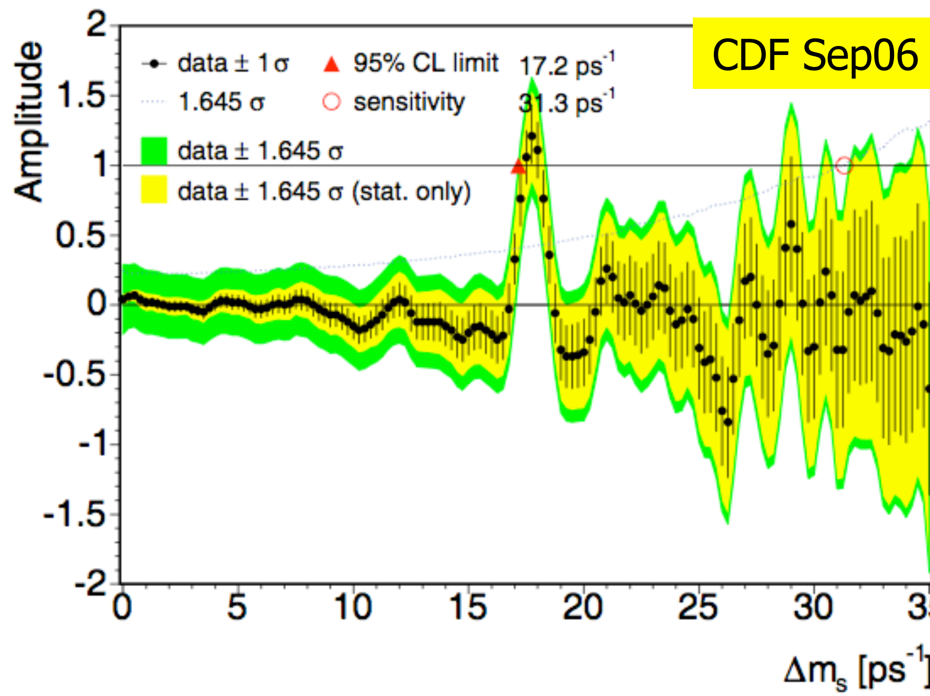
$$\frac{\Delta m_d}{\Delta m_s} \propto \left| \frac{V_{td}}{V_{ts}} \right|^2$$

  - Theory error ~4% (Lattice)
  - Δm_d is precisely measured
  - But B_s mixing is very hard…



Recent Tevatron results





$17 < \Delta m_s < 21\ \mathrm{ps}^{-1}$ @ 90% CL

D0

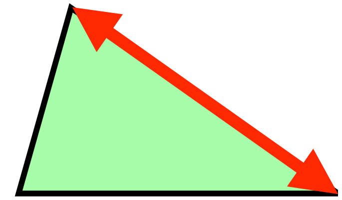
$$\Delta m_S = 17.77 \pm 0.10 \pm 0.07\ \mathrm{ps}^{-1}$$

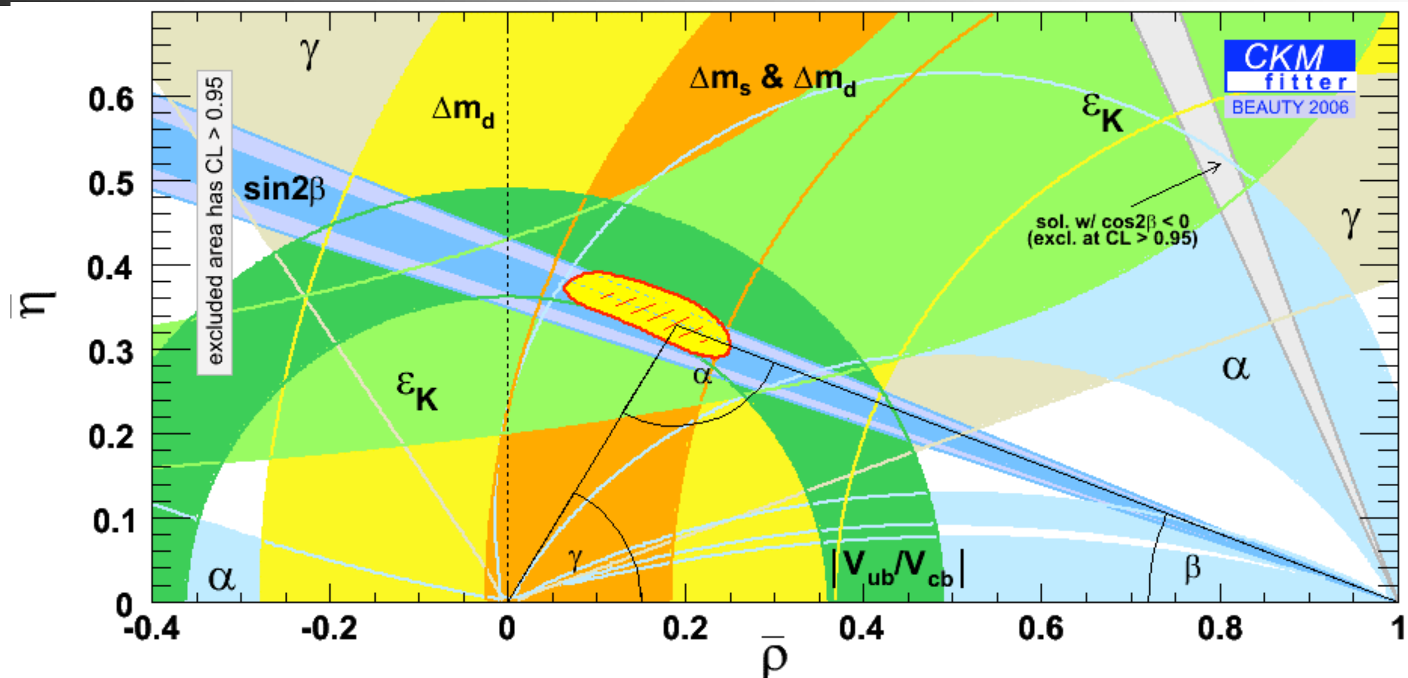
CDF

$$\Rightarrow \quad \left|\frac{V_{td}}{V_{ts}}\right| = 0.2060 \pm 0.0007^{+0.0081}_{-0.0060}$$

Precision ~4%
dominated by theory error

What do we learn from mixing?

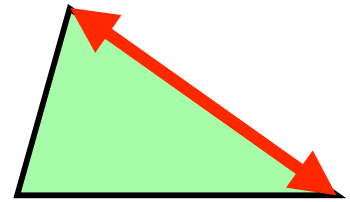




- One precise measurement of R_t improves our knowledge of the SM parameters (ρ,η)
- To go beyond the SM we need to be able to compare this measurement with independent constraints
  - Measurements of angle γ not mature enough for meaningful comparison

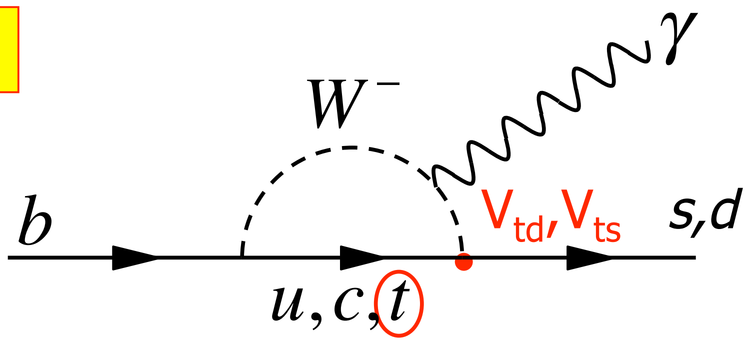
Need for independent measurement of V_{td}/V_{ts} with different sensitivity to New Physics

R_t from $B\to\rho\gamma$ and $B\to K^*\gamma$

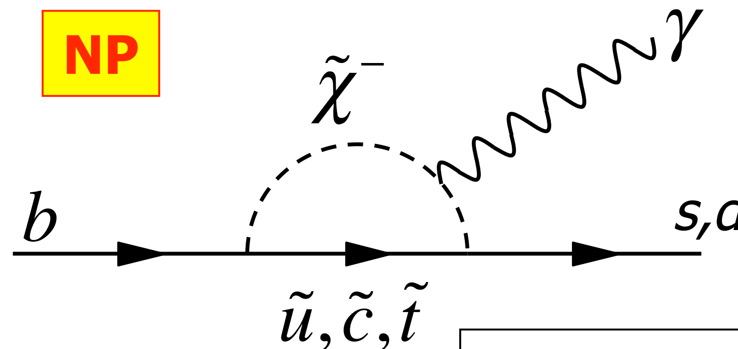


- Radiative penguin decays with $b\to d\gamma$ and $b\to s\gamma$

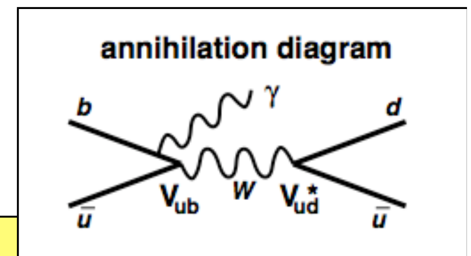
SM



NP



- In the SM, the ratio of BFs measures $|V_{td}/V_{ts}|$
  - Theory errors on $|V_{td}/V_{ts}|$~7.4%

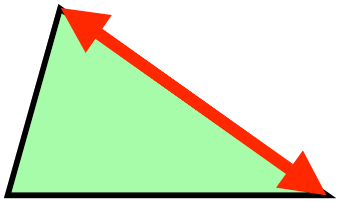


$$\frac{BF(B\to(\rho/\omega)\gamma)}{BF(B\to K^*\gamma)} = \left|\frac{V_{td}}{V_{ts}}\right|^2 \left(\frac{m_B^2 - m_\rho^2}{m_B^2 - m_{K^*}^2}\right)^3 \zeta^2 (1+\Delta R)$$

Light Cone Rum Rules

- New Physics Beyond the SM could take part in the loop and modify BFs…

$B \to \rho\gamma$: analysis overview

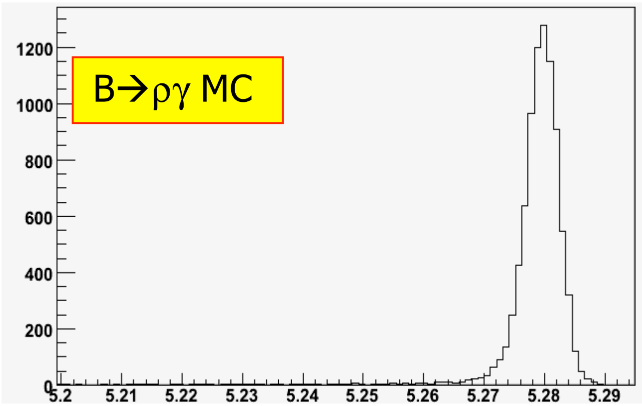


- Two body decay
  - $p_\gamma^{CM} \sim m_B/2$
- Exclusive meson reconstruction
  - $\rho^0 \to \pi^+\pi^-$
  - $\rho^+ \to \pi^+\pi^0$
  - $\omega \to \pi^+\pi^-\pi^0$
- Exclusively reconstruct B meson
  - Beam energy constrained mass m_{ES}

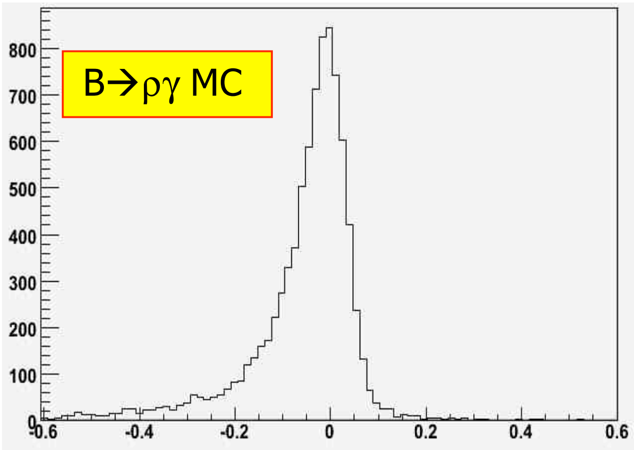
$$m_{ES} = \sqrt{E_{beam}^{*2} - p_B^{*2}}$$

  - Impose energy conservation: $\Delta E \sim 0$

$$\Delta E = E_B^* - E_{beam}^*$$

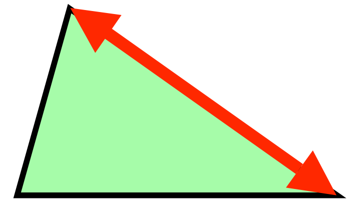


m_{ES} (GeV)/c^2

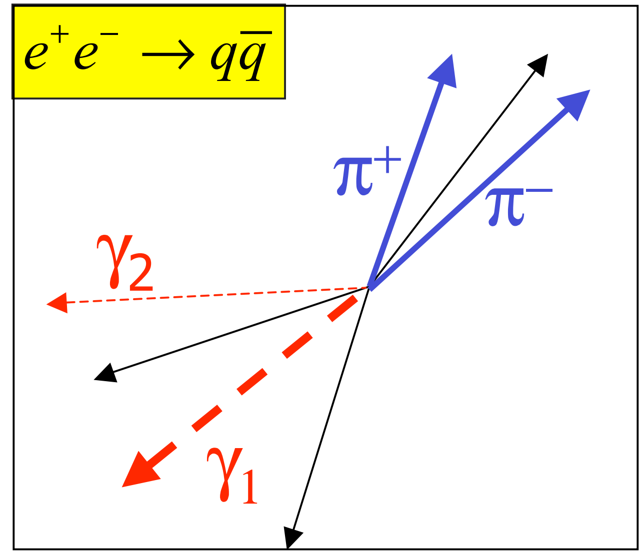


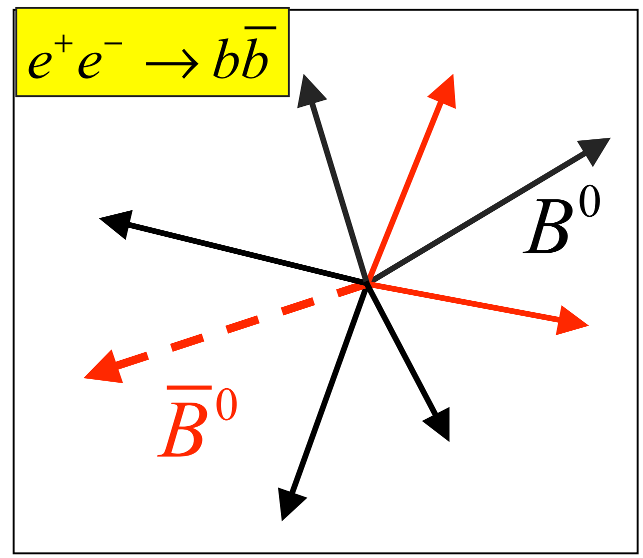
ΔE (GeV)/c^2

$B\to\rho\gamma$: challenges



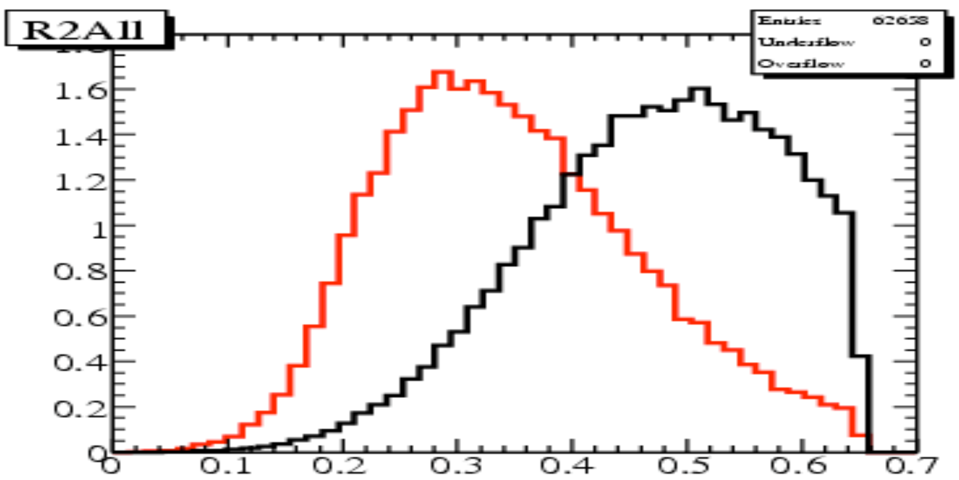
- Very small Branching Fractions
  - $B^0\to\rho^0\gamma \sim 0.5 \times 10^{-6}$
  - $B^+\to\rho^+\gamma \sim 1 \times 10^{-6}$
- Combinatorics from random pions
  - $\Gamma(\rho) \sim 150$ MeV
- Background from $B\to K^*\gamma$
  - Pion identification is a must
- Huge continuum background due γ from $\pi^0\,(\eta)\to\gamma_1\gamma_2$
  - NN for continuum suppression is key
  - Veto photons from $\pi^0\,(\eta)$ decays

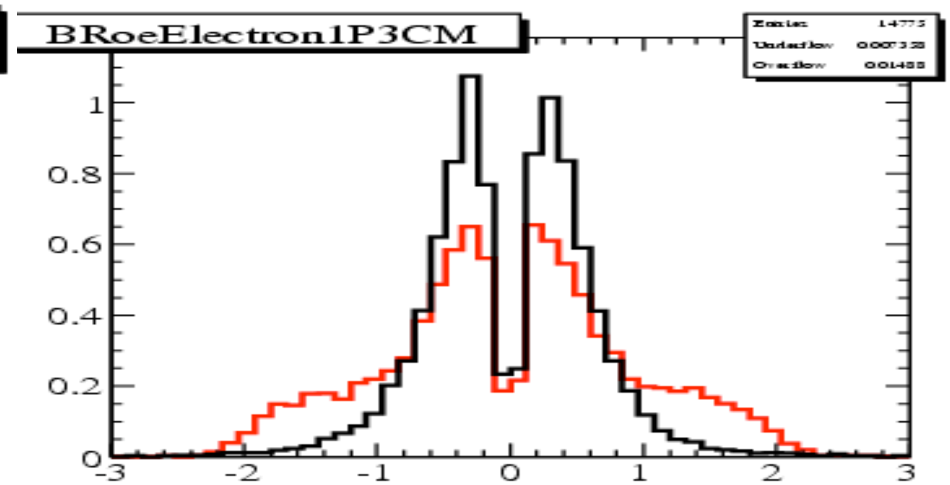




NN for continuum suppression

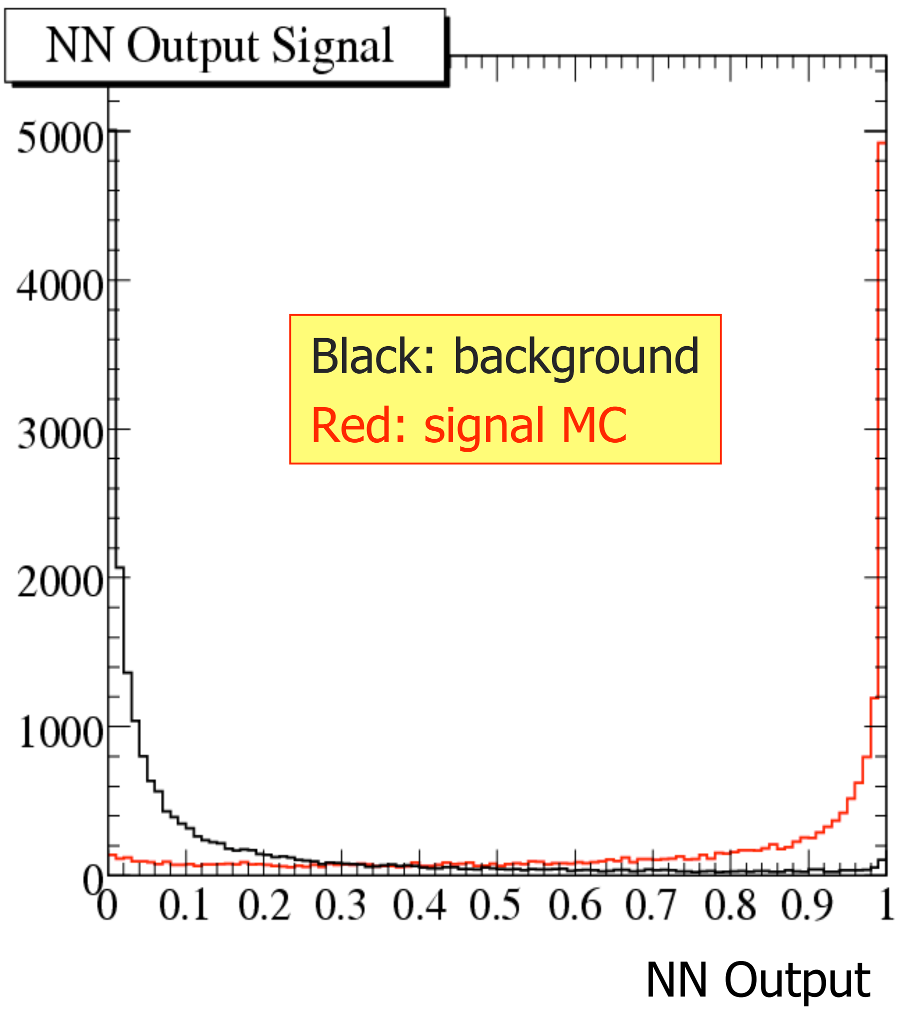
- Identify discriminating variables (30+)
  - Shape variables (e.g.: R2)
  - Properties of B decays (e.g.: Δz)
  - Decay products of other B (e.g.: p_{CMS} of leptons)

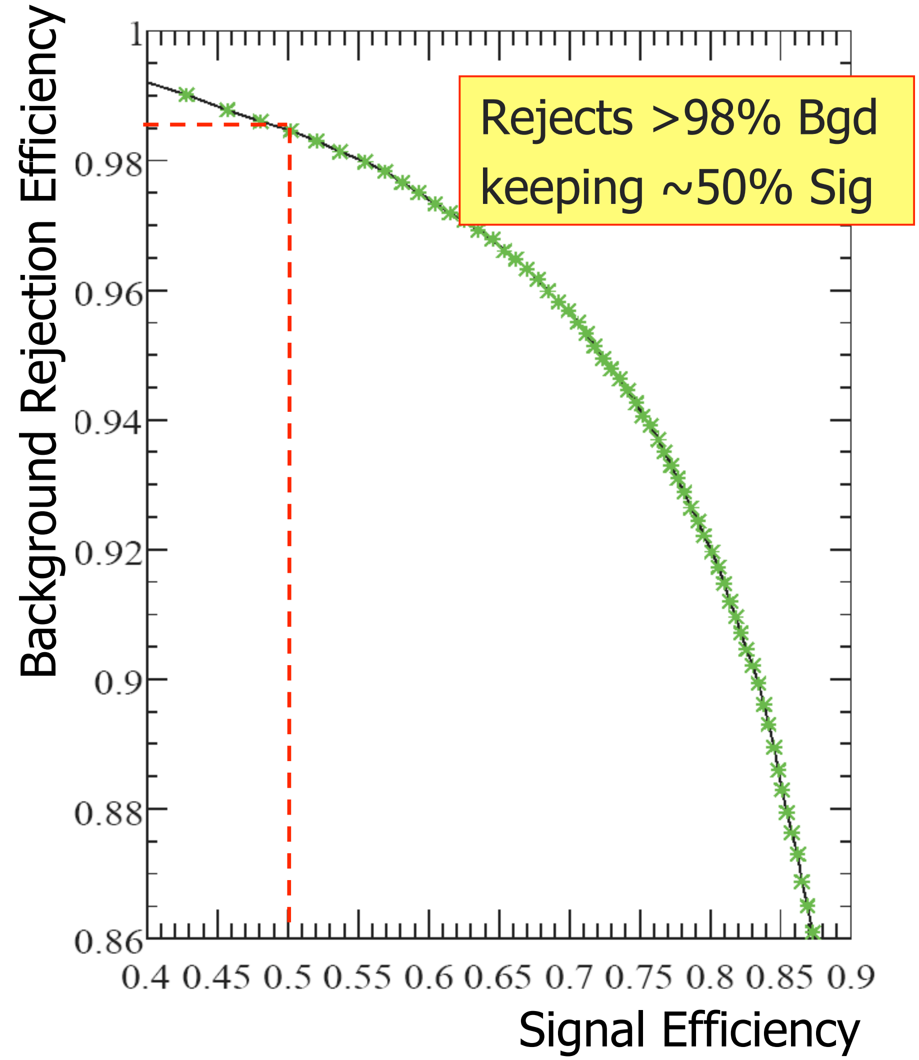




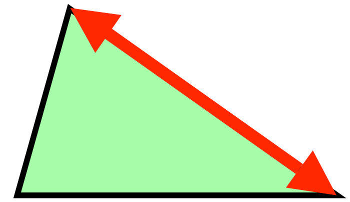
Black: Continuum MC
Red: Signal MC

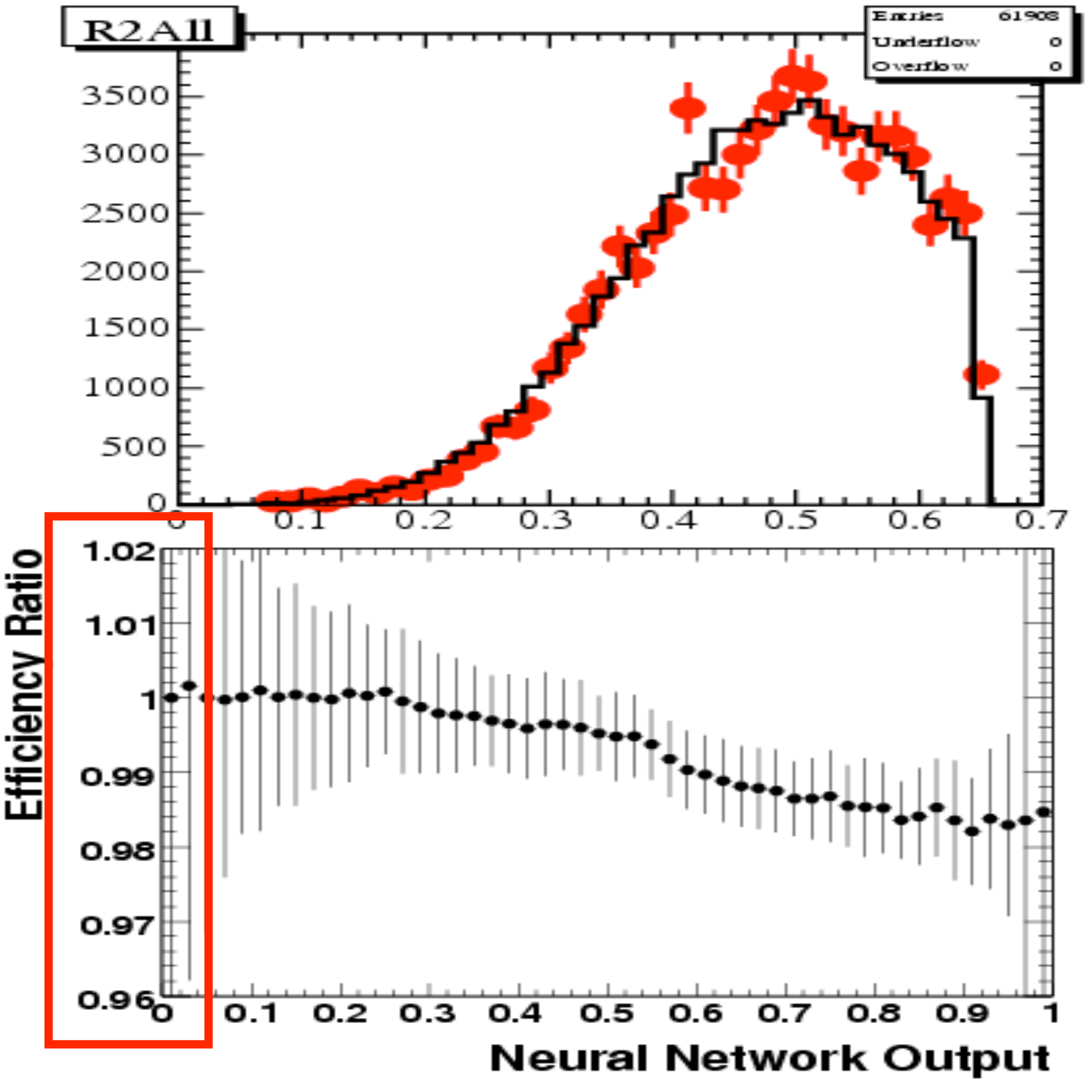
NN Output and performance





NN systematics





Background control sample:
Black: continuum MC
Red: off-peak DATA

Signal NN shape validation:
B→Dπ control sample: N_{nsig}/NN_{Back}

Systematics: ~1 %

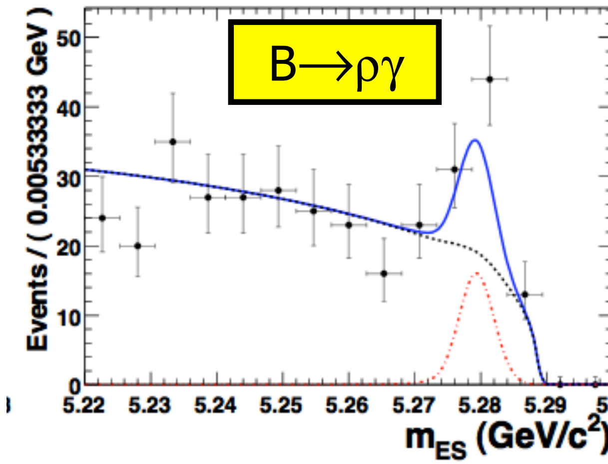
hep-ex/0612017

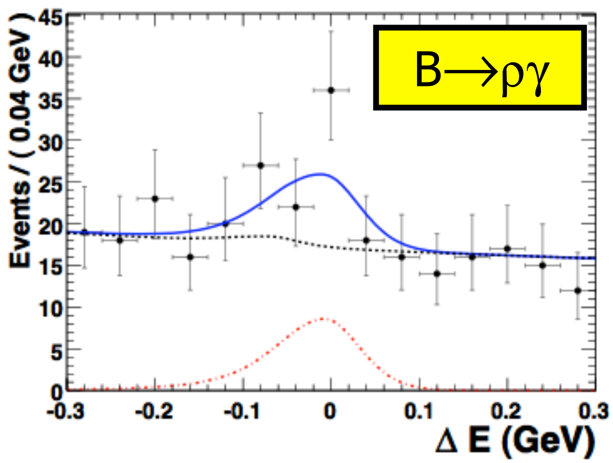
Signal extraction - BaBar

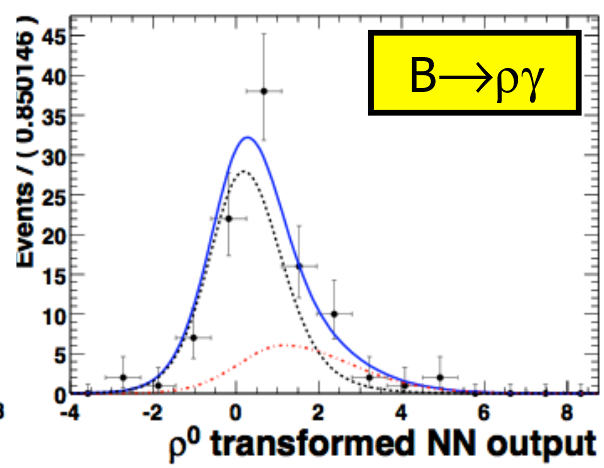
Maximum likelihood fit to signal + background (continuum + B)

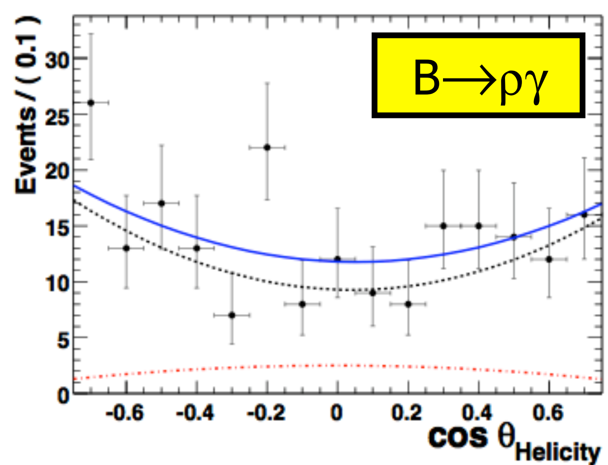
- $B \to \rho\gamma$: 4D fit to m_{ES}, ΔE, NN, $\theta_{helicity}$
- $B \to \omega\gamma$: 5D fit includes Dalitz angle

-- Signal
-- Background
— S+B



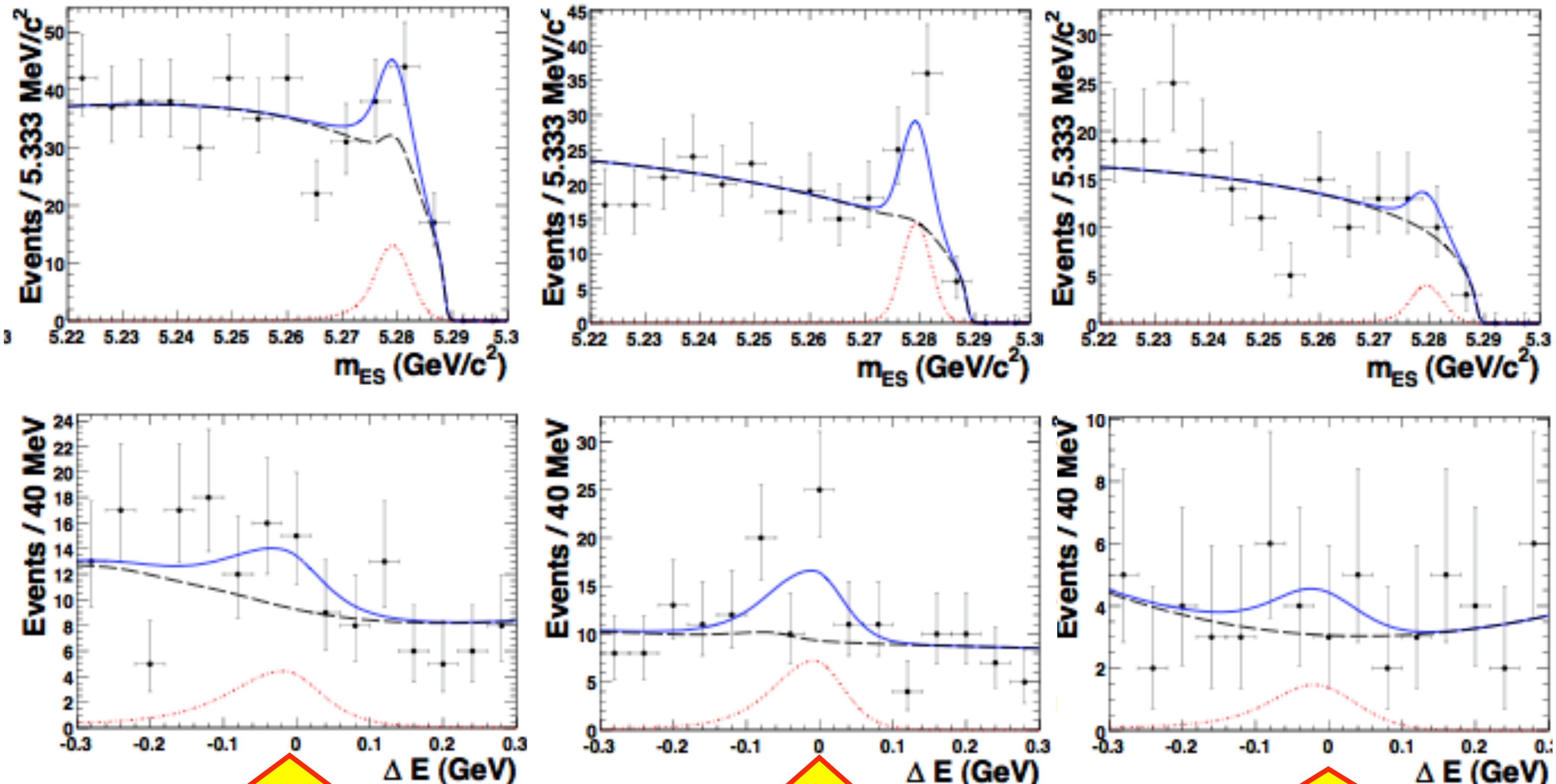






hep-ex/0612017

BaBar new results (316 fb^{-1})



$B^+ \to \rho^+\gamma$
3.8σ

$B^0 \to \rho^0\gamma$
4.9σ

$B^0 \to \omega\gamma$
2.1σ

hep-ex/0612017

BaBar new results (316 fb^{-1})

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 BF		6.4σ	$1.25^{+0.25}_{-0.24} \pm 0.09$

19%

- First evidence of $B^+ \to \rho^+\gamma$
- Best measurement of all of these BFs
- Isospin test:

$$\frac{\Gamma(B^+ \to \rho^+\gamma)}{2\Gamma(B^0 \to \rho^0\gamma)} - 1 = -0.35 \pm 0.27$$

✓ Consistent with 0: isospin symmetry

Phys.Rev.Lett.96:221601,2006

Belle's results (370 fb^{-1})

$Mode$	N_{signal}	$Significance$	$BF(10^{-6})$
$B^+ \to \rho^+ \gamma$	8.5	1.6σ	$0.55^{+0.42+0.09}_{-0.36-0.08}$
$B^0 \to \rho^0 \gamma$	20.7	5.2σ	$1.25^{+0.37+0.07}_{-0.33-0.06}$
$B^0 \to \omega \gamma$	5.7	2.3σ	$0.56^{+0.34+0.05}_{-0.27-0.10}$
Combined	36.9	5.1σ	$1.32^{+0.34+0.10}_{-0.31-0.09}$

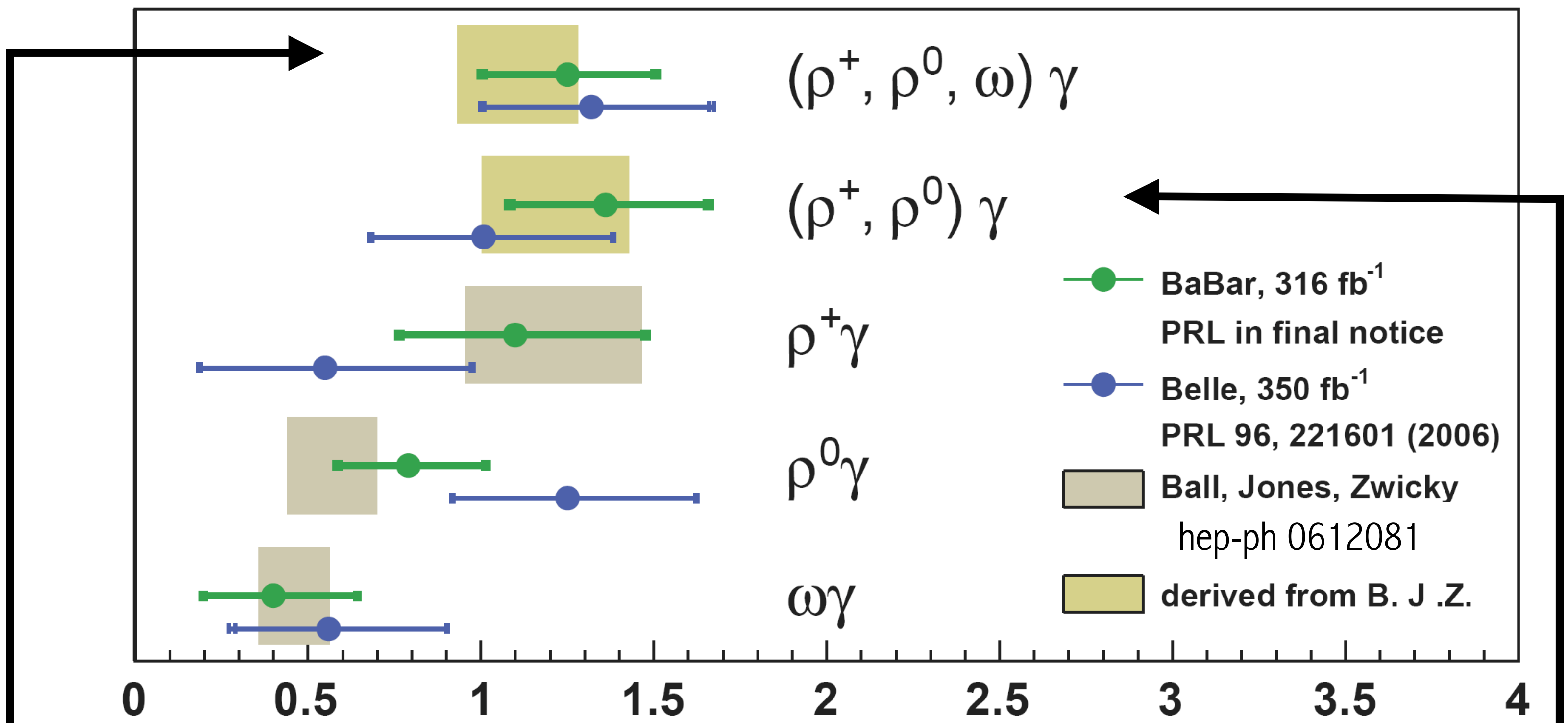
25%

- First observation of $B^0 \to \rho^0 \gamma$
- Isospin test
  - Important because isospin conservation is assumed in combined fit
  - Probability of a larger isospin violation <4.9%

SM expectation

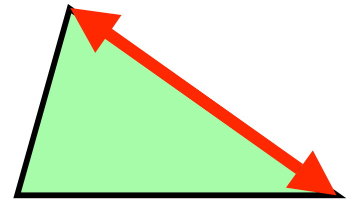
$B^+ \sim 1.0 \times 10^{-6}$
$B^0 \sim 0.5 \times 10^{-6}$

Summary of results: BaBar vs Belle



Isospin-constrained combined fits:
- Combine 3 modes to reduce stat. error
- Combine only ρ modes to reduce theory error
  - ω not a member of iso-triplet!

What do we learn? B→(ρ/ω)γ



	$BaBar(10^{-6})$	$Belle(10^{-6})$	$Average(10^{-6})$
$BF[B \to (\rho/\omega)\gamma]$	$1.25^{+0.25}_{-0.24} \pm 0.09$	$1.32^{+0.34+0.10}_{-0.31-0.09}$	$1.28^{+0.20}_{-0.19} \pm 0.06$

B→(ρ/ω)γ

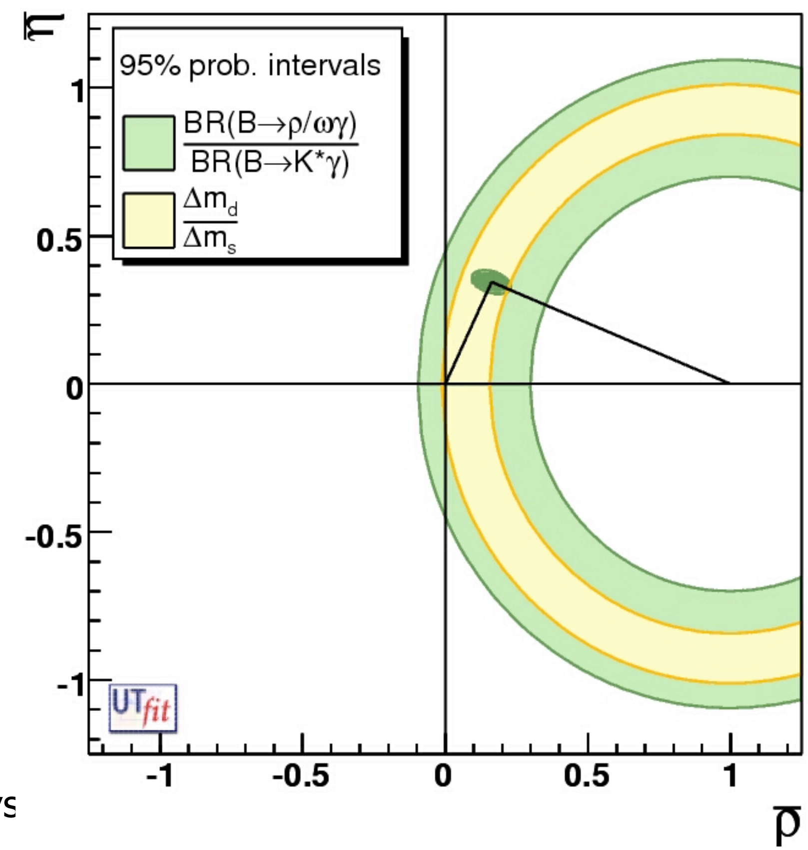
$$\left|\frac{V_{td}}{V_{ts}}\right|_{\rho/\omega\gamma} = 0.202^{+0.017}_{-0.016}(\exp) \pm 0.015(\text{th})$$

8.2% 7.4%

Note:

- BaBar+Belle average
- Ball, Jones, Zwicky (hep-ph 0612081)

In excellent agreement with mixing



What do we learn? B→ργ

	$BaBar(10^{-6})$	$Belle(10^{-6})$	$Average(10^{-6})$
$BF(B \to \rho\gamma)$	$1.36^{+0.29}_{-0.27} \pm 0.10$	$1.01^{+0.37}_{-0.32} \pm 0.07$	$1.22^{+0.23}_{-0.21} \pm 0.05$

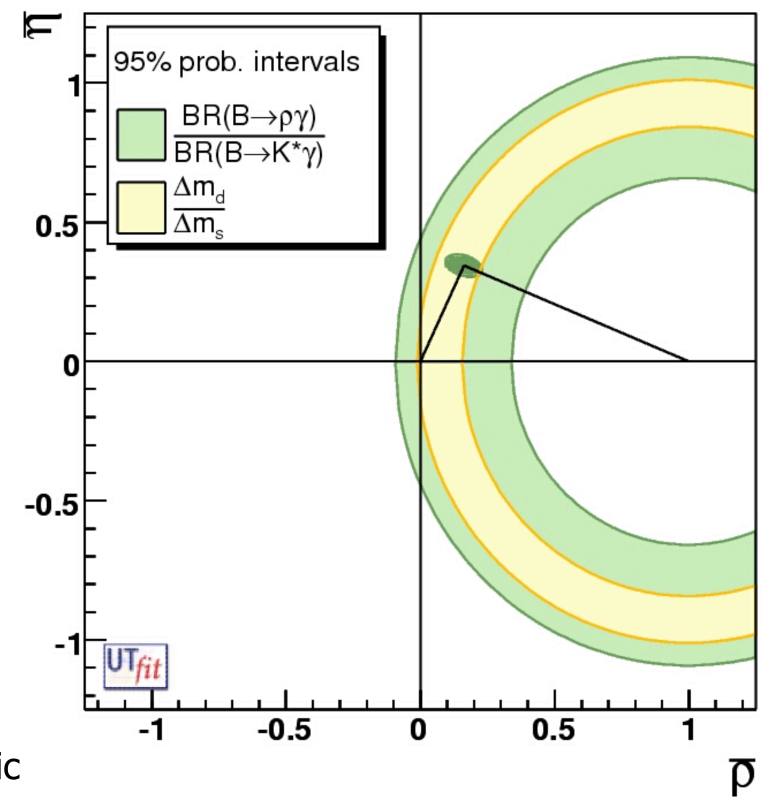
B→ργ

$$\left|\frac{V_{td}}{V_{ts}}\right|_{\rho\gamma} = 0.197^{+0.019}_{-0.018}(\text{exp}) \pm 0.015(\text{th})$$

9.4% 7.5%

Note:

- BaBar's BF(B→ργ) from combined fit
- Belle's BF(B→ργ) from isospin average
- Ball, Jones, Zwicky (hep-ph 0612081)

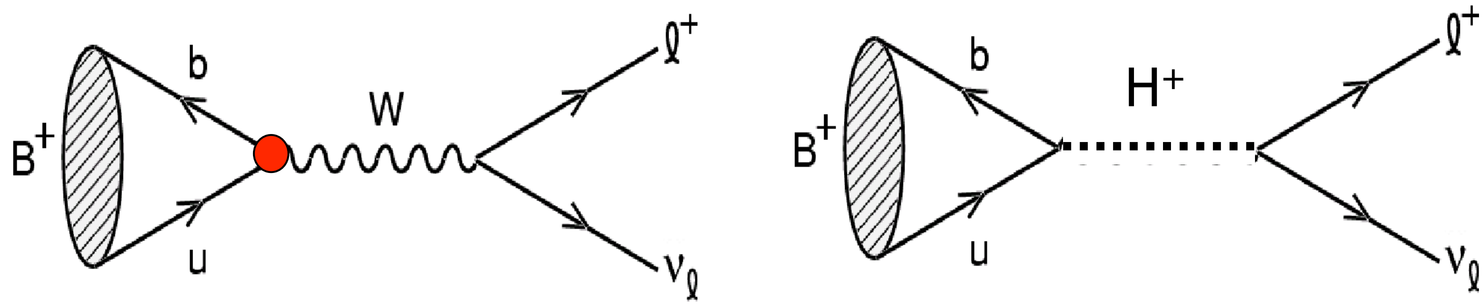


Still in good agreement with mixing

New Physics at the B factories outside the UT

$B^+ \to \tau^+ \nu_\tau$

- Standard Model



$$BF(B^+ \to \tau^+ \nu) = \frac{G_F{}^2 m_B m_\tau^2}{8\pi}\left(1 - \frac{m_\tau^2}{m_B^2}\right) f_B^2 |V_{ub}|^2 \tau_B \sim 10^{-4}$$

f_B^2 → Lattice QCD

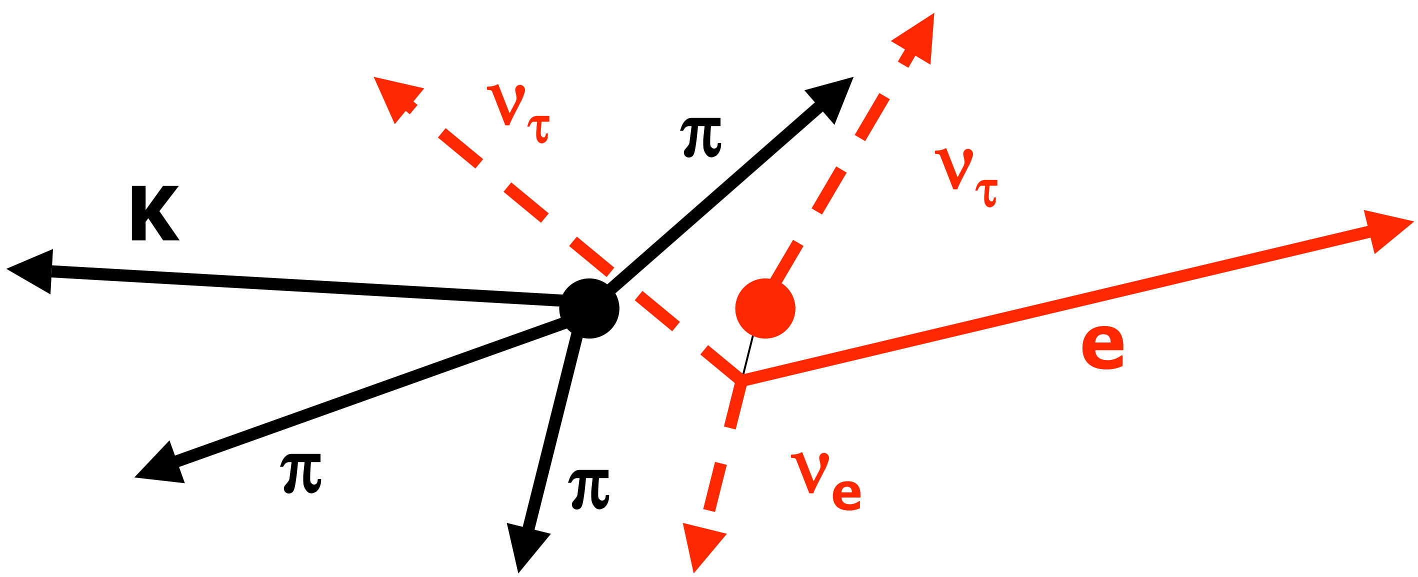
- New Physics, e.g. Type II 2 Higgs Doublet Model

$$BF(B^+ \to \tau^+ \nu) = BF(B^+ \to \tau^+ \nu)_{SM} \times \left(1 - \tan^2\beta \frac{m_{B^+}^2}{m_{H^+}^2}\right)^2$$

$B^+ \to \tau^+ \nu$: analysis technique

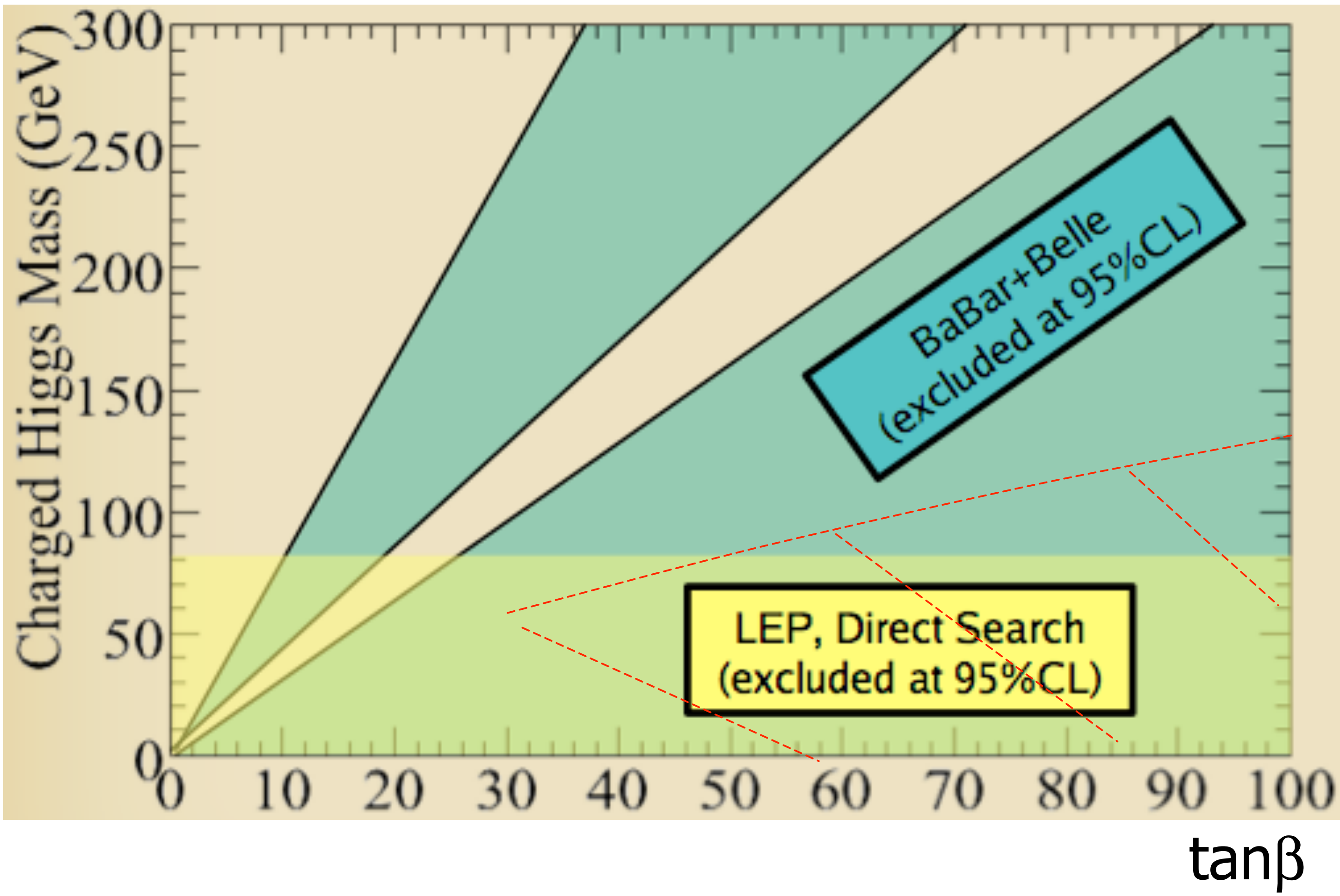
- Exclusive reconstruction of the other B in the event
- All particles left in the event must belong to the other B
- τ^+ reconstructed in the following final states:

$$\tau^+ \to \rho^+ \nu, \mu^+ \nu \nu, e^+ \nu \nu, \pi^+ \nu \nu$$

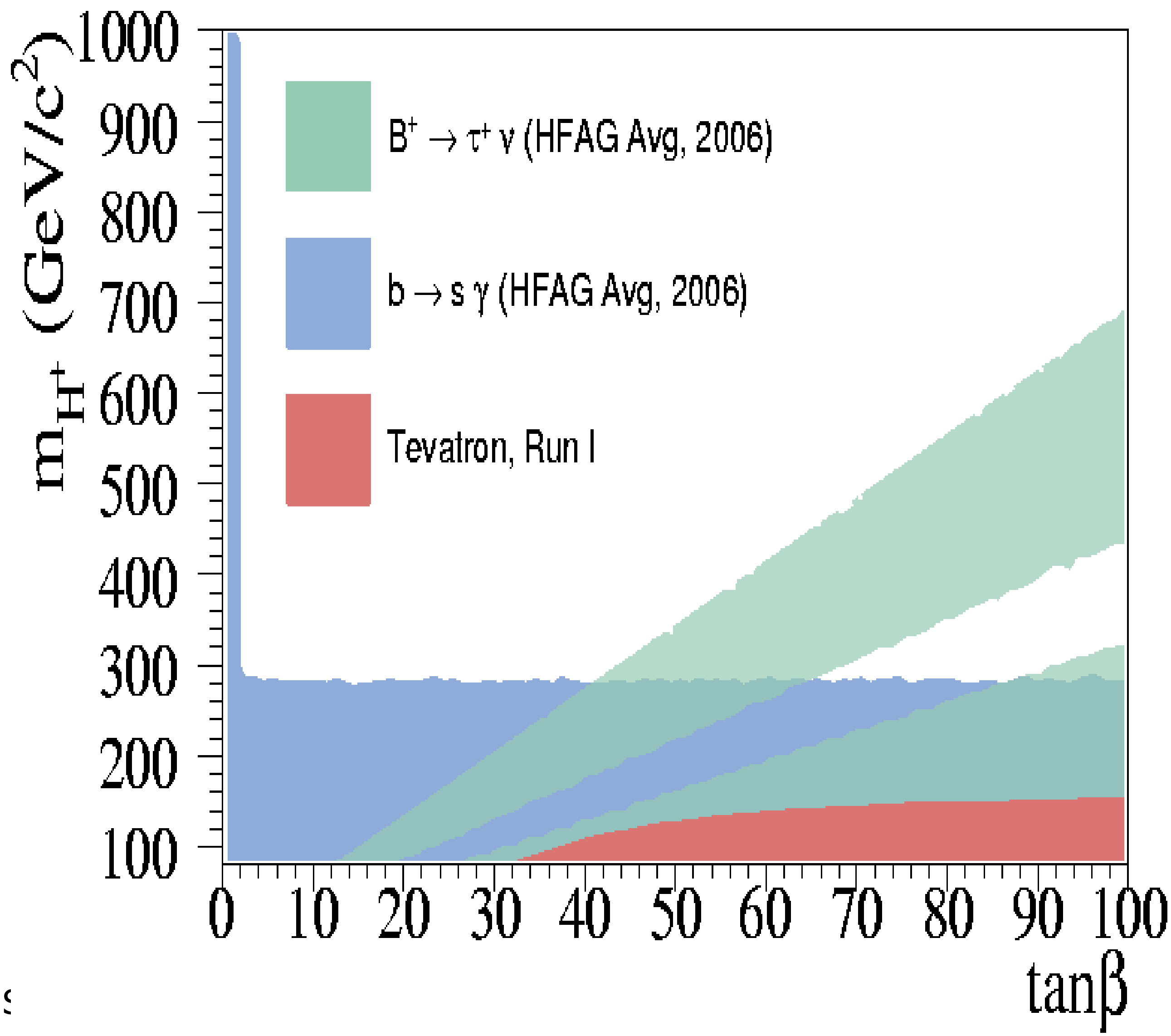


Constraints on NP from B→τν

Average of latest BaBar + Belle results:



Adding constraints from B-->sγ



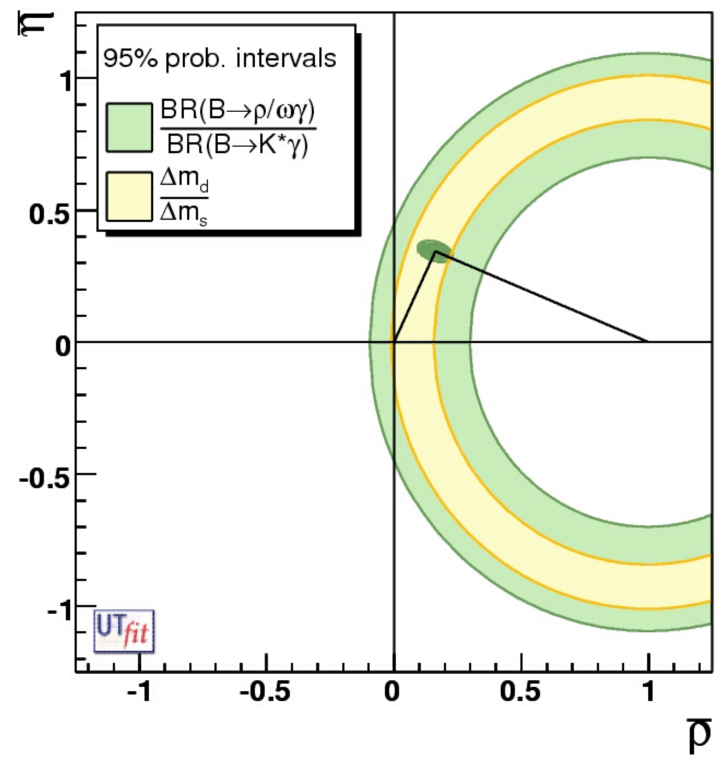
Conclusion

- The abundant and clean dataset from the B factories allows us to test the SM in many different ways
  - Sides vs. Angles
  - Angles: trees vs. penguins
  - Sides: B mixing vs $B \to \rho\gamma$ (New!)
- Rare decays add independent constraints
  - E.g.: $B \to \tau\nu$ or $B \to s\gamma$
- New Physics is still hiding:

  … should we give up hope?

$$\frac{m_W}{\Lambda_{NP}} \sim \frac{100\ \mathrm{GeV}}{1\ \mathrm{TeV}} \sim 10\%$$

  - Precision of ~few% needed

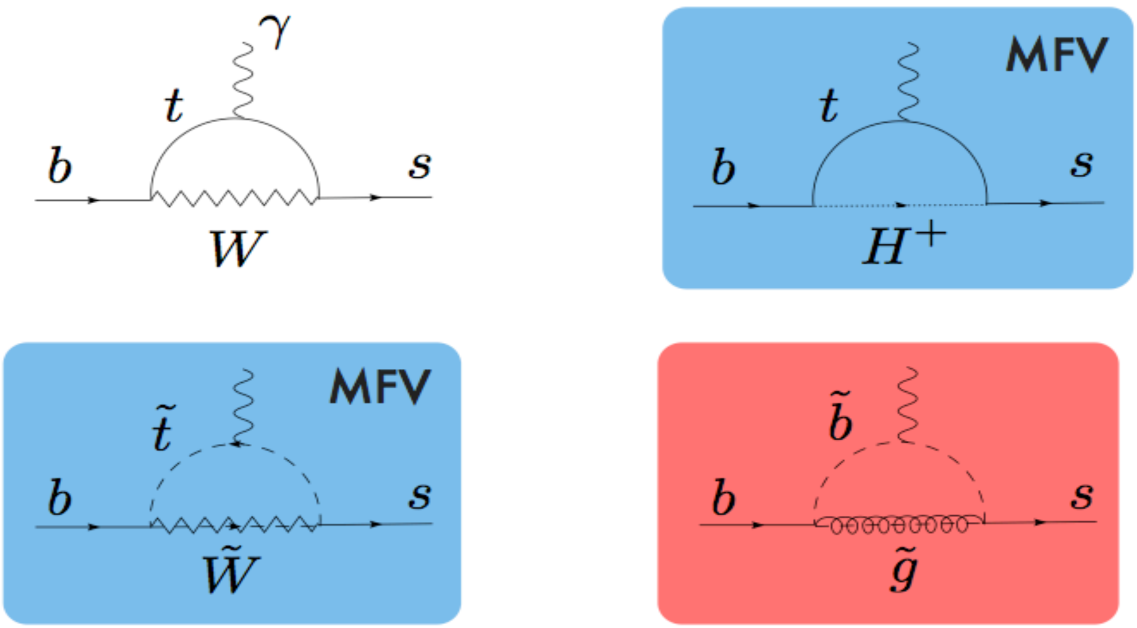


- Can these precisions ever be reached?
  - Almost there for several measurements

… data set will more than double by 2008!

Inclusive BF(b→s γ)

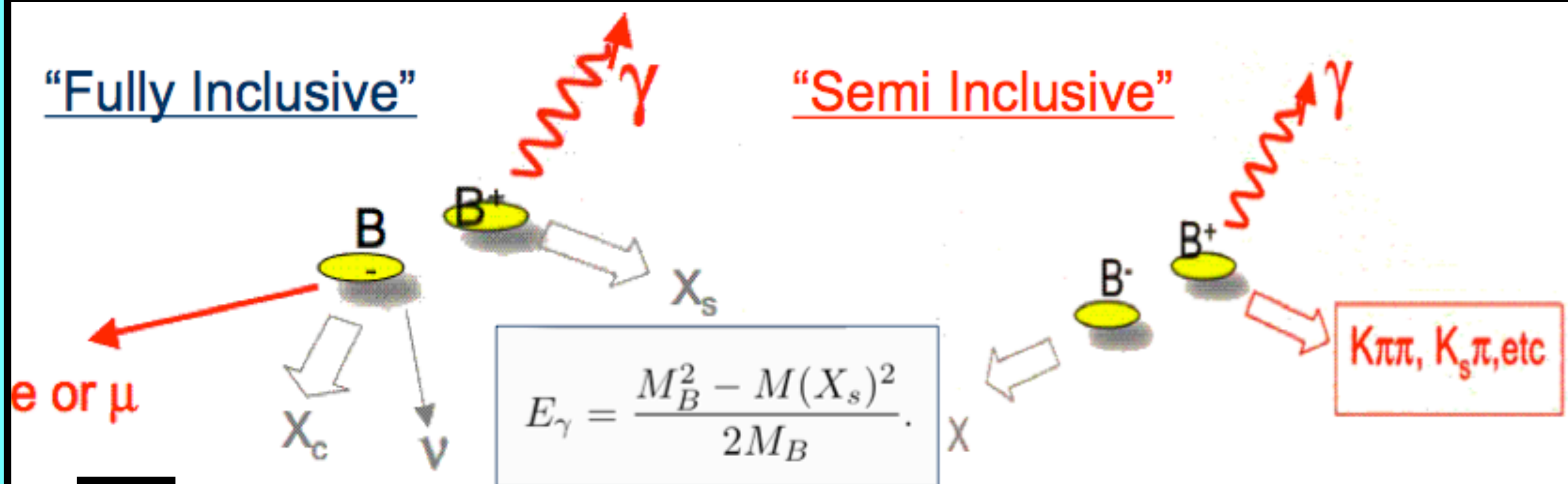
- A sensitive probe of New Physics
  - Example: diagrams contributing in MSSM



- Many variables can be measured
  - Inclusive BF (b→s g), direct A_{CP}, Time Dependent A_{CP}, …

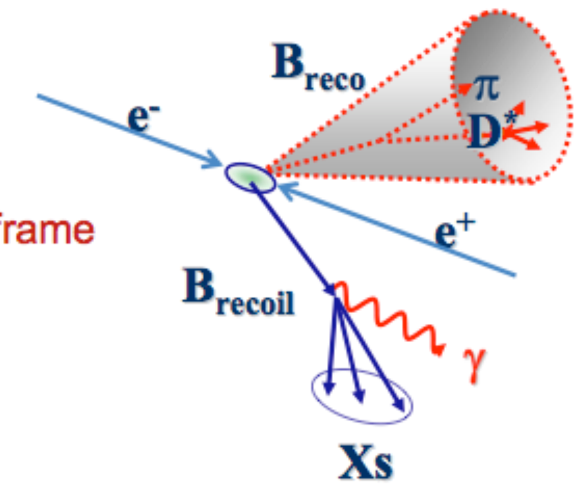
B→sγ: experiment

Present



Future

- Hadronic Decay of one B meson is fully reconstructed
  - 4-momentum, charge and flavour determined
  - Enables measurement of A_{CP}
  - Photon energy measured in B rest frame
- BF normalisation obtained from Breco sample
  - Small efficiency extrapolation



Bounds on M_{H+} in Type II 2HDM

Theory error~ 7%

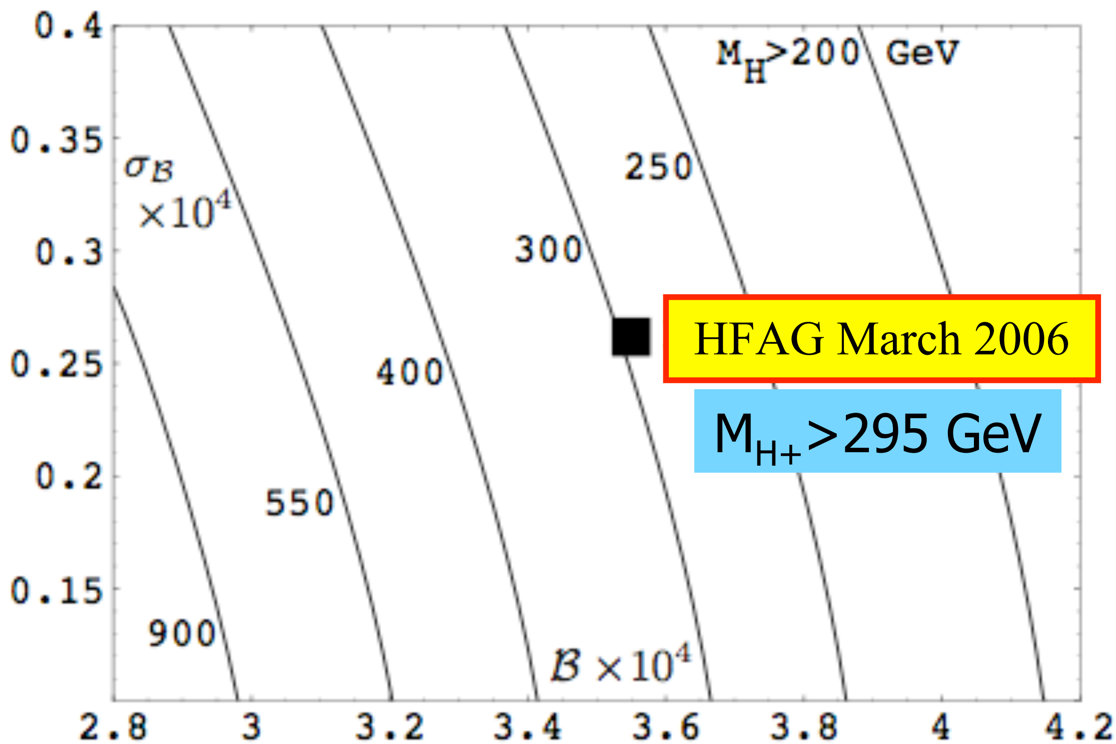
Theory NNLO $B(B \to X_s\gamma) = (3.15 \pm 0.23) \times 10^{-4}$

Experiment $B(B \to X_s\gamma) = (3.55 \pm 0.24 \pm 0.10 \pm 0.03) \times 10^{-4}$

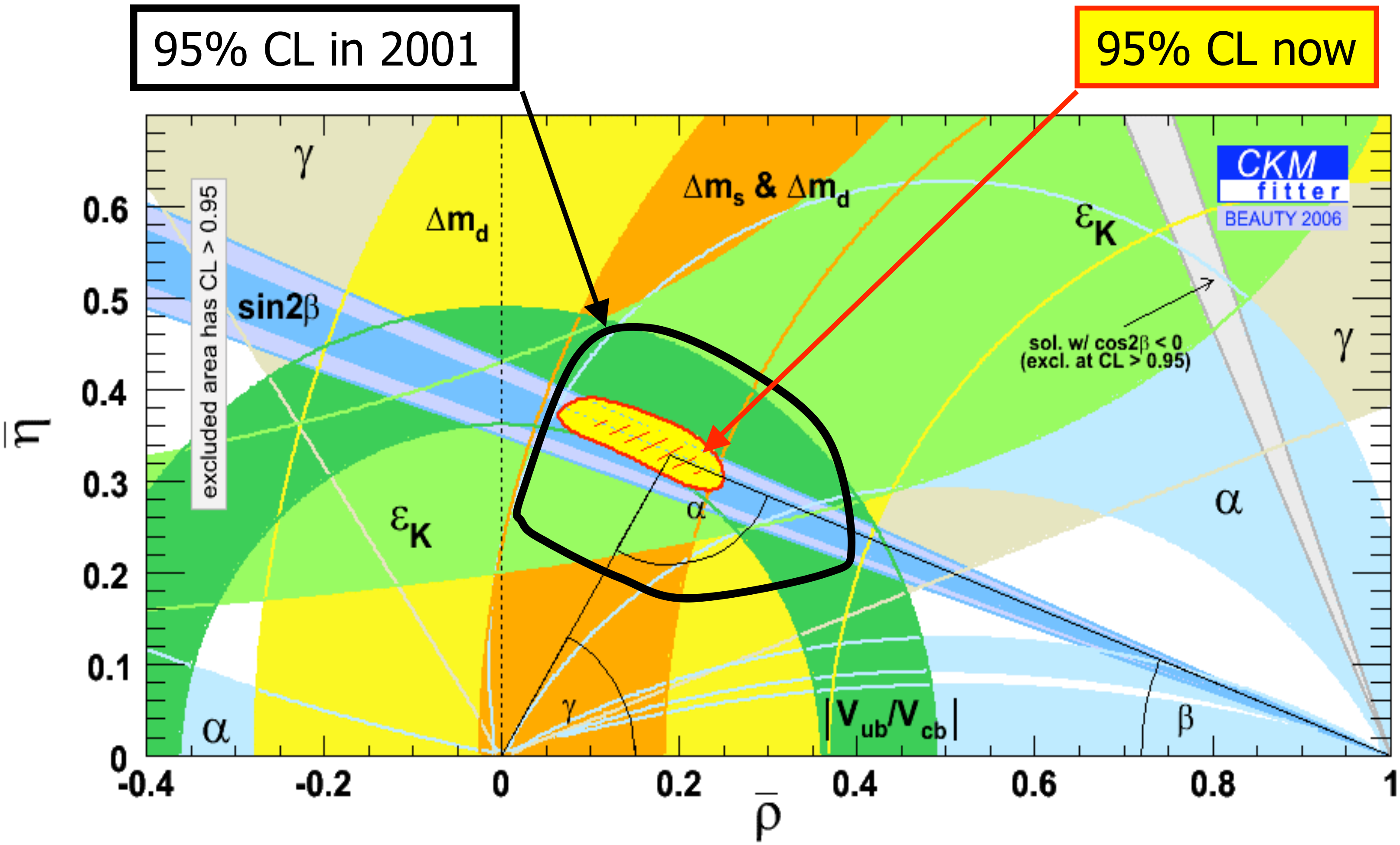
Exp. error ~7%

95% CL lower bound on M_{H+} as a function of experimental central values (x) and errors (y)

Misiak et al, hep-ph/0609232



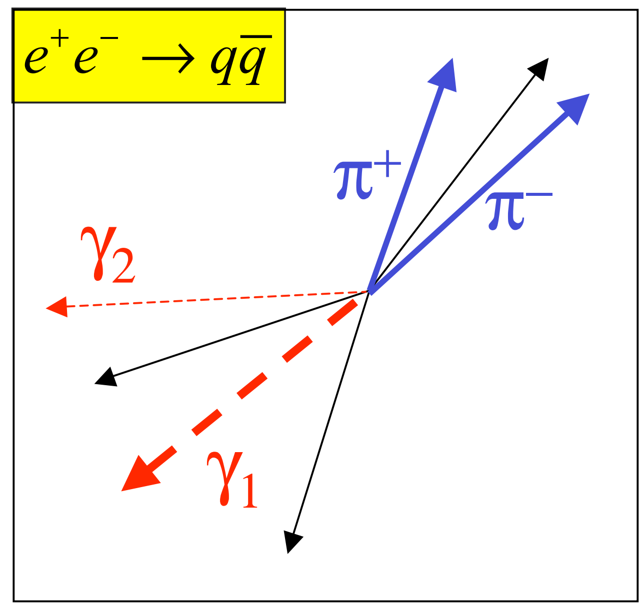
How well do we know SM parameters?



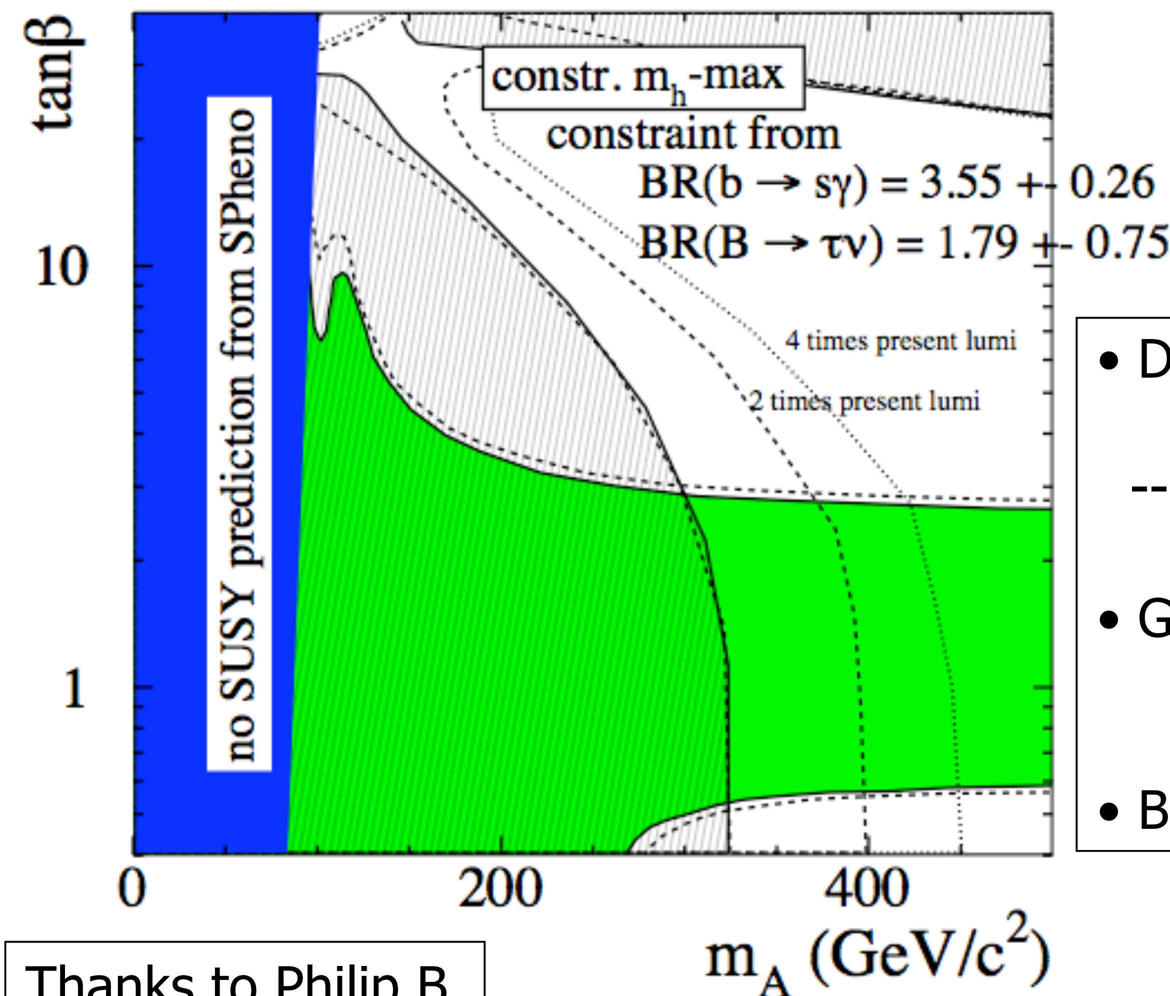
π^0 and η veto

- Explicitly rejects photon coming from $\pi^0\,(\eta) \rightarrow \gamma_1\gamma_2$
  - Suppress both continuum and B backgrounds

- Method
  - Combine γ candidate with all other photons (γ_i) in event
  - Obtain pdf(mass($\gamma\gamma_i$),$E_{\gamma i}$)'s for signal and π^0/η in continuum MC
  - Cut on likelihood ratio



Constraints on MSSM



LEP 2 benchmark:
Max Mixing

- Dashed area: B→τν+B→sγ (2006 Babar +Belle)
  --- is sγ only
- Green: LEP MSSM Higgs (direct searches)
- Blue: temporary s/w problem

Thanks to Philip B.

The Future of $B \rightarrow \rho\gamma$

- How well can we do by 2008?
  - Experimental error on V_{td}/V_{ts}: 8.2% $\rightarrow$ 4.7%
    - Just assuming 1 ab^{-1}/B factory
    - Improvements in analysis technique will help further
  - Theory error on V_{td}/V_{ts}
    - Light Cone Sum Rules: 7.4% (now), 5% in 2008?
    - Anything from Lattice QCD?
  - CFR: Error from mixing ~ 4%, theory dominated

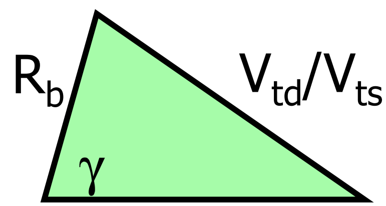
- $BF(B \rightarrow (\rho/\omega)\gamma)$ or $BF(B \rightarrow (\rho/\omega)\gamma$?
  - Is it time to trade a slightly larger experimental error for a slightly better theory error?

Ball, Jones, Zwicky hep-ph/0612081

Another way of looking at $B \to \rho\gamma$

R_b, γ, λ and $|V_{td}/V_{ts}|$ are related by:

$$\left|\frac{V_{td}}{V_{ts}}\right| = \lambda\sqrt{1 - 2R_b\cos\gamma + R_b^2}$$



Using BaBar latest results:

$$\left|\frac{V_{td}}{V_{ts}}\right| = 0.199^{+0.022}_{-0.025}(\text{exp}) \pm 0.014(\text{th}) \quad \Leftrightarrow \quad \gamma = (61.0^{+13.5}_{-16.0}(\text{exp})^{+8.9}_{-9.3}(\text{th}))^{\circ}$$

$$cfr: \gamma^{WA}_{direct} = (60^{+38}_{-24})^{o}$$

- $|V_{td}/V_{ts}|$ depends on $\cos\gamma$
- Measurements in $B \to D^{(*)}K^{(*)}$ depend on $\sin^2\gamma$

Remove discrete ambiguity! γ<180° favored

Comparison of $B \to X_s\gamma$ Methods

	Semi-Incl		Fully-Incl			
			lepton tag		Breco tag	
	stat	syst	stat	syst	stat	syst
BF:						
Current	6%	15%	8%	9%+8%	20%	<10%
with 1ab-1	2%	8%?	<2.5%	~4%?	~10%	~5%
Acp						
Current	5%	1.5%	12%	2%	~30%	~10%
with 1ab-1	1.5%	~1%	3%	2%	~15%	~5%
Isospin						
Current	6%	2.5%			~20%	~10%
with 1ab-1	<2%	~1%			~10%	~5%

- Breco tagged measurement can use all statistics
- For semi-incl it will be difficult to improve on missing fraction systematic
- Model dependence of lepton tagged measurement to improve with statistics

B--> tau nu

Compare the measured branching fractions (x10^{-4}):

$$0.88\,^{+0.68}_{-0.67}\,(stat.) \pm 0.11(syst.)$$ **BABAR (324M BB)**

$$1.79\,^{+0.56}_{-0.49}\,(stat.)^{+0.39}_{-0.46}\,(syst.)$$ **Belle (447M BB)**

The measurements have comparable uncertainty but differing central values (compatible within uncertainty), allowing Belle to claim 3.5σ evidence.

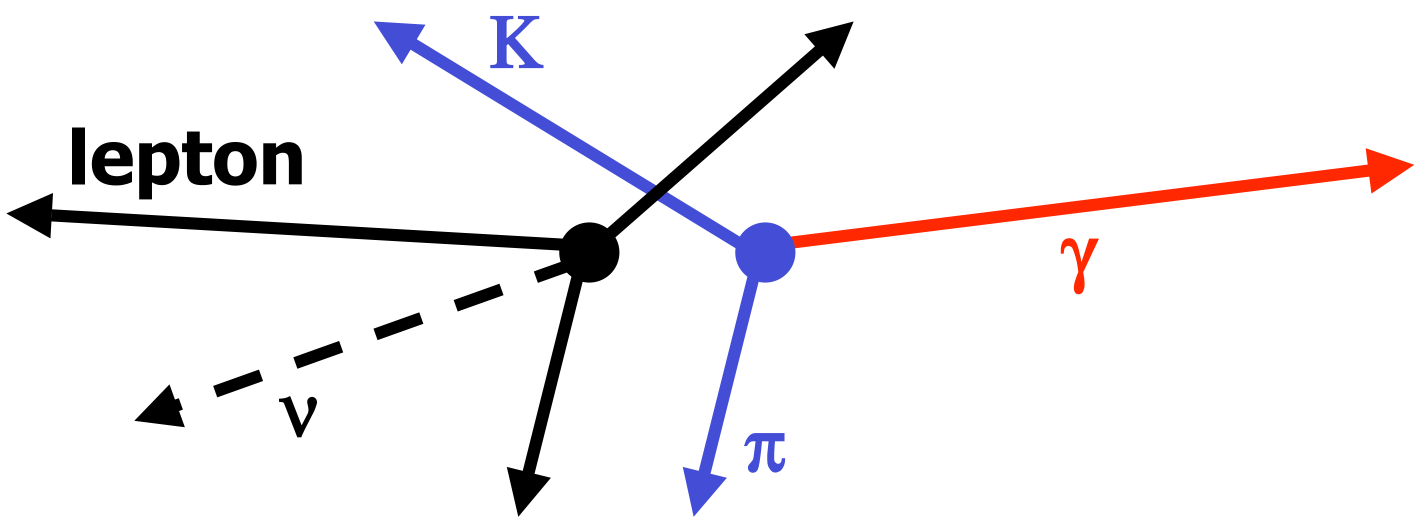
Compare $f_B|V_{ub}|\times 10^{-4}$ GeV:

$$7.0^{+2.3}_{-3.6}\,(stat.)^{+0.4}_{-0.5}\,(syst.)$$ **BABAR (324M BB)**

$$10.1^{+1.6}_{-1.4}\,(stat.)^{+1.1}_{-1.3}\,(syst.)$$ **Belle (447M BB)**

Inclusive B→sγ: experiment

- Fully inclusive approach
  - Focus on the γ properties
  - Suppress continuum by "tagging" other B
- Semi-inclusive approach
  - Reconstruct $B \rightarrow N_1 K + N_2 \pi + \gamma$
    - 38 decay modes: ~50% of the BF

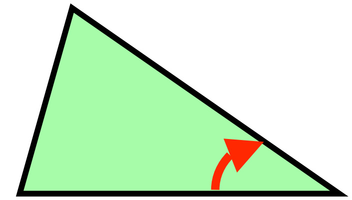


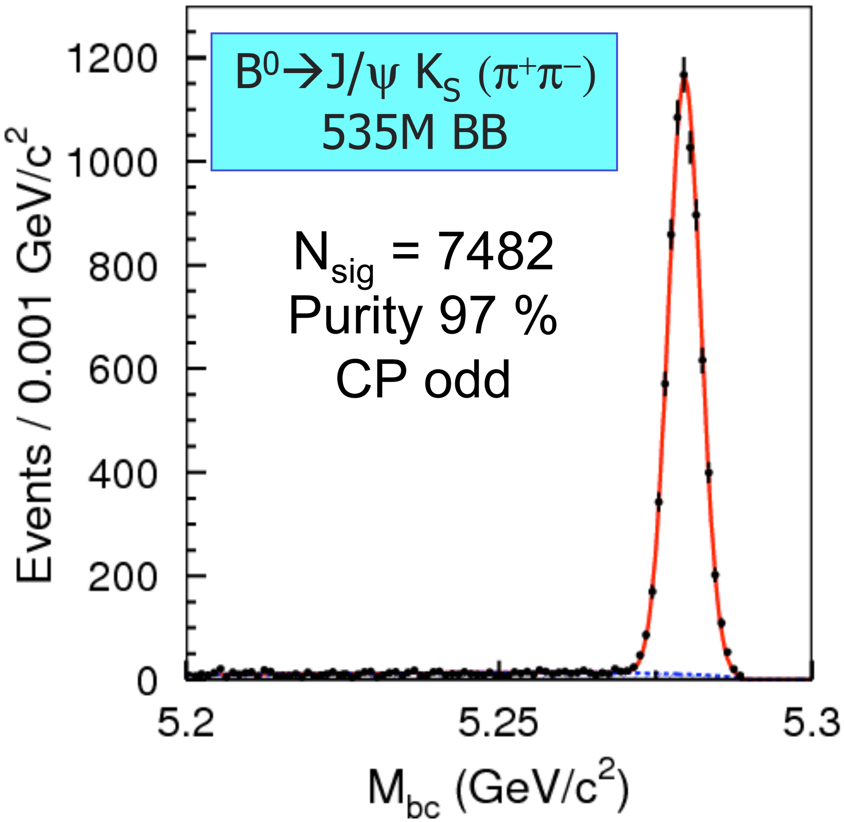
Run 6 and 7

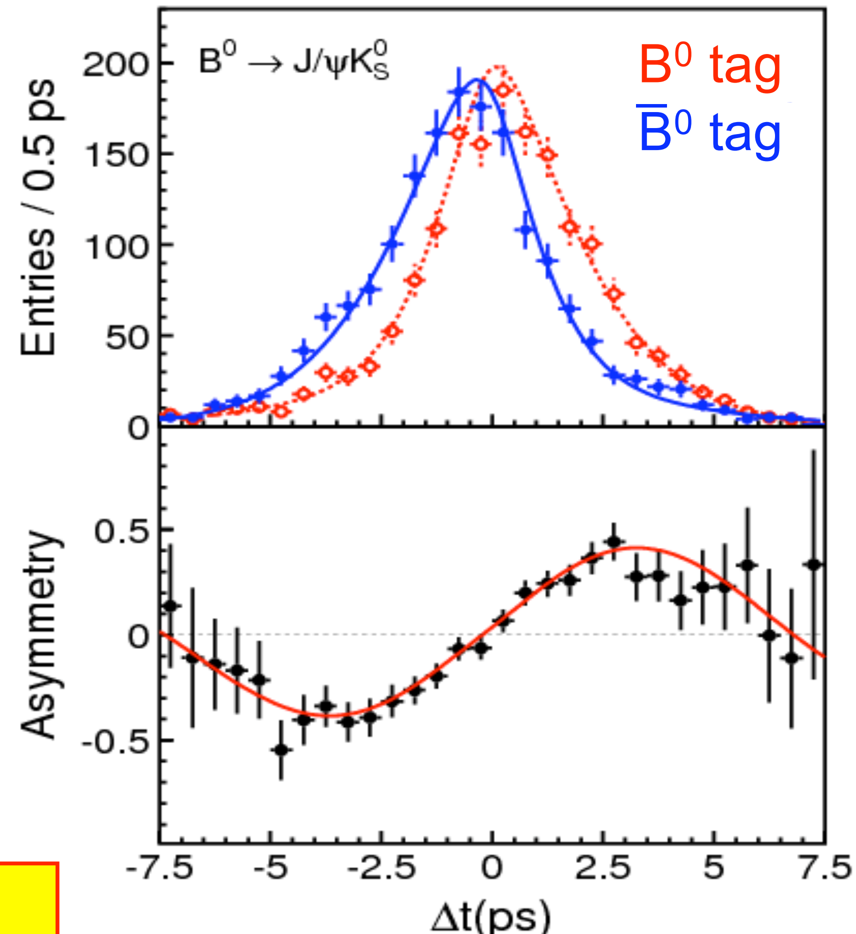
- Run 6: Jan 07-Summer 07 (8 months)
  - ~200fb --> 600 fb
  - Peak Lumi 1.8 10^{34}
- Run 7: Dec 07-Sep 08 (10 months)
  - ~400 fb-1 --> ~1ab
  - Peak 2.1 10^{34}

The golden mode for sin2β:

sin2β in $B^0 \rightarrow J/\psi\ K^0$







sin(2β) = 0.674 ± 0.026

WA ICHEP 2006