From Nobel Prize 2008

to New Physics

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National Taiwan University

Colloquium at Tsing-Hua University

March 11, 2009

Outline

- Symmetry breaking – Nobel Prize 2008
- Standard Model
- New physics from Heaven
- Results from collider in 2008.
- What's next?

Broken Symmetry

"for the discovery of the mechanism of spontaneous broken symmetry in subatomic physics"

"for the discovery of the origin of the broken symmetry which predicts the existence of at least three families of quarks in nature"

CP Violation in SM

Photo: Universtity of Chicago

Yoichiro Nambu

- 1/2 of the prize

Photo: KEK

Makoto Kobayashi

- 1/4 of the prize

Photo: Kyoto University

Toshihide Maskawa

- 1/4 of the prize

B Factory

What's the origin of mass?

"for the discovery of the mechanism of spontaneous broken symmetry in subatomic physics"

Nambu's background
Y. Nambu, preliminary Notes for the Nobel Lecture

I will begin by a short story about my background. I studied physics at the University of Tokyo. I was attracted to particle physics because of the three famous names, Nishina, Tomonaga and Yukawa, who were the founders of particle physics in Japan. But these people were at different institutions than mine. On the other hand, condensed matter physics was pretty good at Tokyo. I got into particle physics only when I came back to Tokyo after the war. In hindsight, though, I must say that my early exposure to condensed matter physics has been quite beneficial to me.

Nobel Prize 1972

"for their jointly developed theory of superconductivity, usually called the BCS-theory"

John Bardeen	Leon Neil Cooper	John Robert Schrieffer
1/3 of the prize	1/3 of the prize	1/3 of the prize
USA	USA	USA
University of Illinois Urbana, IL, USA	Brown University Providence, RI, USA	University of Pennsylvania Philadelphia, PA, USA
b. 1908 d. 1991	b. 1930	b. 1931

Cooper pair condense (lower E);

Computable

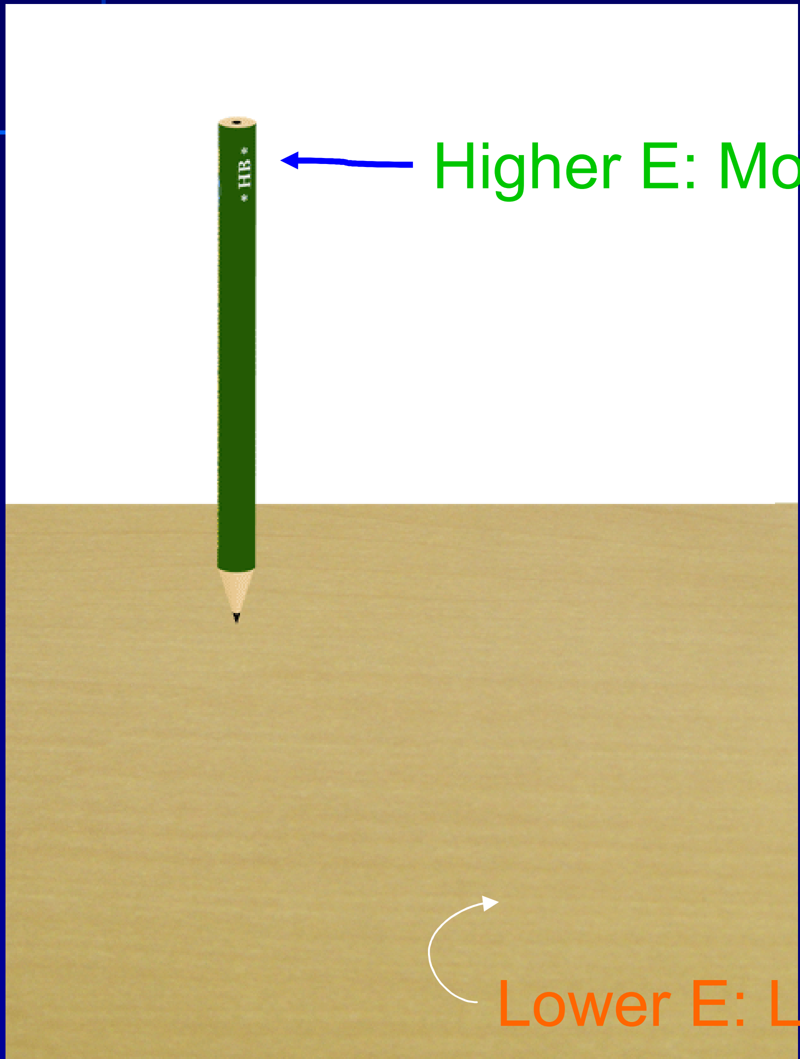
Source of Observation

Meanwhile Nambu had heard J. Robert Schrieffer describe the theory of superconductivity ... with John Bardeen and Leon N. Cooper. The talk disturbed Nambu: the superconducting fluid did not conserve the number of particles, violating an essential symmetry of nature. It took him two years to crack the puzzle.

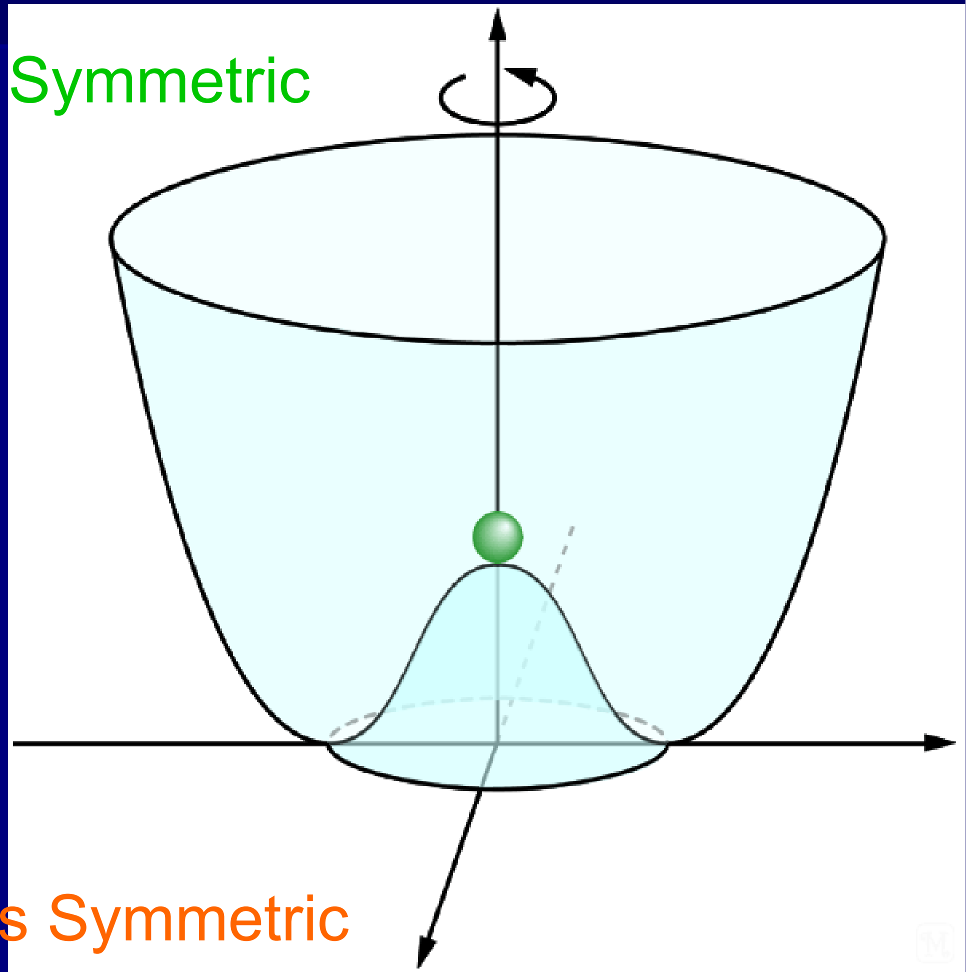
Imagine a dog faced with two bowls of equally enticing food. Being identical, the bowls present a twofold symmetry. Yet the dog arbitrarily picks one bowl. *Unable to accept that the symmetry is entirely lost*, Nambu *discovered* that the dog, in effect, cannot make up her mind and constantly switches from one bowl to the other. By the laws of quantum physics, the oscillation comes to life as a new particle, a boson.

... others, ..., also saw that a superconductor should have such a particle. It was Nambu, however, who detailed the circumstances and significance of its birth and **realized that the pion**, as well, **was born in like manner** (by breaking the chiral, or leftright, symmetry of quarks). ...

Illustration of SSB



Higher E: More Symmetric



Lower E: Less Symmetric

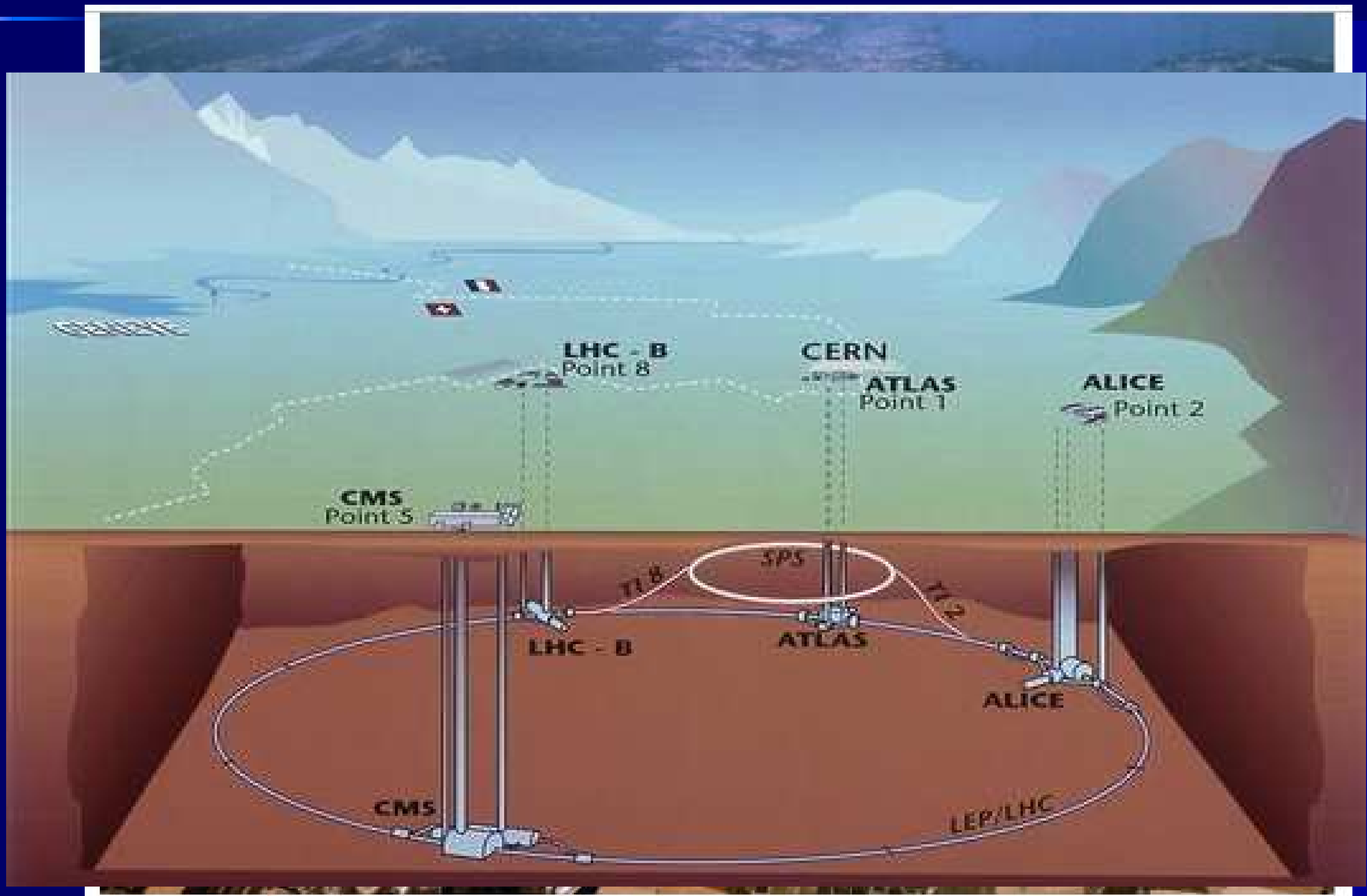
Nambu-Golstone Boson

- ... Being identical, the bowls present a twofold symmetry. Yet the dog arbitrarily picks one bowl. *Unable to accept that the symmetry is entirely lost*, Nambu *discovered* that the dog, in effect, cannot make up her mind and constantly switches from one bowl to the other. By the laws of QM, the oscillation comes to life as a new particle, a boson.

- ... others, ..., also saw that a superconductor should have such a particle. It was Nambu, however, who detailed the circumstances and significance of its birth and **realized that the pion**, as well, **was born in like manner** (by breaking the chiral, or leftright, symmetry of quarks). ...

- Jeffrey Goldstone, then a postdoc at CERN, ..., realized the import ... and soon published a simpler derivation, noting that the result was general. Thereafter ... dubbed the Goldstone boson. ("At the very least, it should be called the Nambu-Goldstone boson,“ Goldstone comments.) When Nambu finally published ... in 1960, ... showed how the initially massless particle mixes with a magnetic field in a superconductor to become heavy. Recognized by Anderson, Peter Higgs, then at the IAS, and others as general ... became the **Higgs Mechanism** of the **Standard Model** ....

LHC – Higgs and new physics



The origin of CP Violation

"for the discovery of the origin of the broken symmetry which predicts the existence of at least three families of quarks in nature"

Only three types of quarks were found before 1972.

Discovery of CP Violation

Phys. Rev. Lett. 13, 138 (1964
)

VOLUME 13, NUMBER 4 PHYSICAL REVIEW LETTERS 27 JULY 1964

EVIDENCE FOR THE 2π DECAY OF THE K_2^0 MESON*†

J. H. Christenson, J. W. Cronin,‡ V. L. Fitch,‡ and R. Turlay§
Princeton University, Princeton, New Jersey

(Received 10 July 1964)

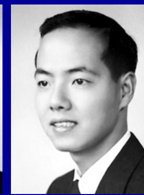
This Letter reports the results of experimental studies designed to search for the 2π decay of the K_2^0 meson. Several previous experiments have served[1,2] to set an upper limit of 1/300 for the fraction of K_2^0's which decay into two charged pions. The present experiment, using spark chamber techniques, proposed to extend this limit.

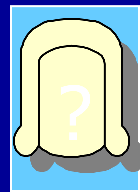
In this measurement, K_2^0 mesons were produced at the Brookhaven AGS in an internal Be target bombarded by 30-BeV protons. A neutral beam was defined at 30 degrees relative to the circulating protons by a $1\frac{1}{2}$-in.$\times 1\frac{1}{2}$-in.$\times$ 48-in. collimator at an average distance of 14.5 ft. from

The analysis program computed the vector momentum of each charged particle observed in the decay and the invariant mass, m^*, assuming each charged particle had the mass of the charged pion. In this detector the K_{e3} decay leads to a distribution in m^* ranging from 280 MeV to ~536 MeV; the $K_{\mu 3}$, from 280 to ~516; and the $K_{\pi 3}$, from 280 to 363 MeV. We emphasize that m^* equal to the K^0 mass is not a preferred result when the three-body decays are analyzed in this way. In addition, the vector sum of the two momenta and the angle, θ, between it and the direction of the K_2^0 beam were determined. This

C P T …

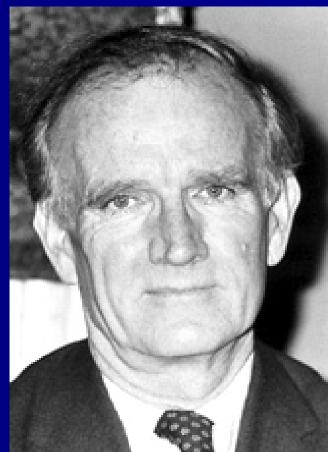
- Charge Conjugation: particle ↔ antiparticle
- Parity: x ↔ -x
- Time reversal: t ↔ -t





CPV
1964

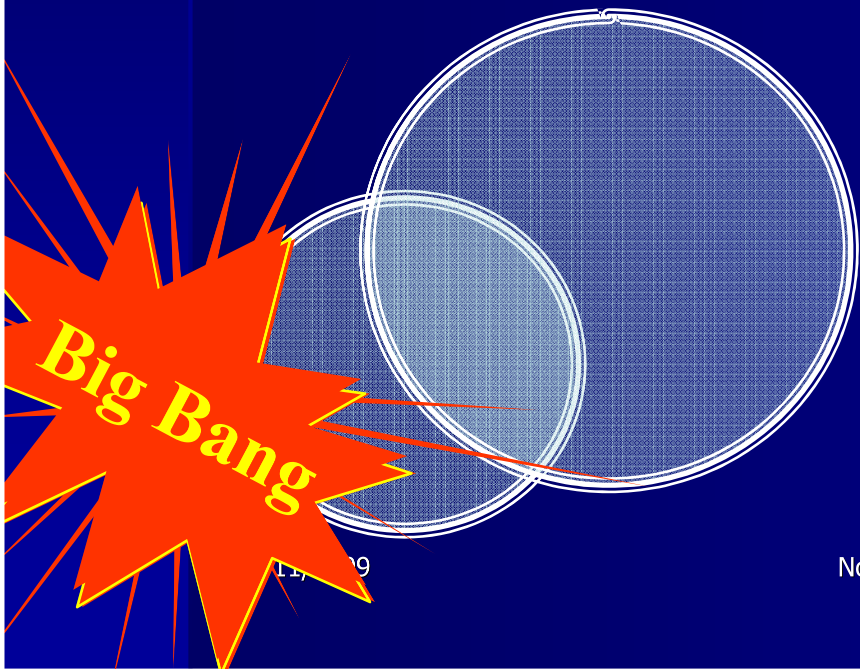
1980 NOBEL PRIZE



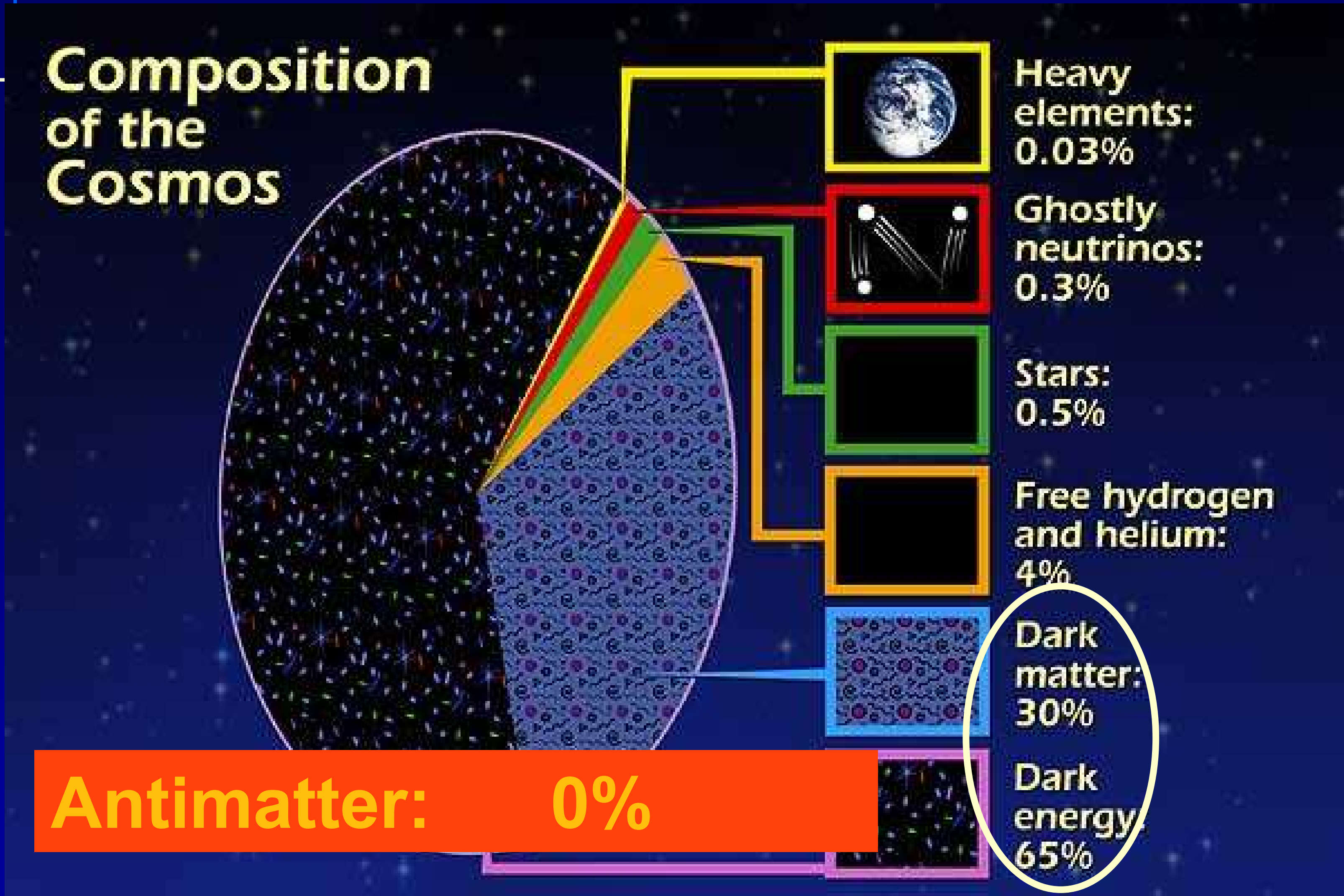
V. Fitch

J.Cronin

Evolution of the Universe



Universe now



Antimatter: 0%

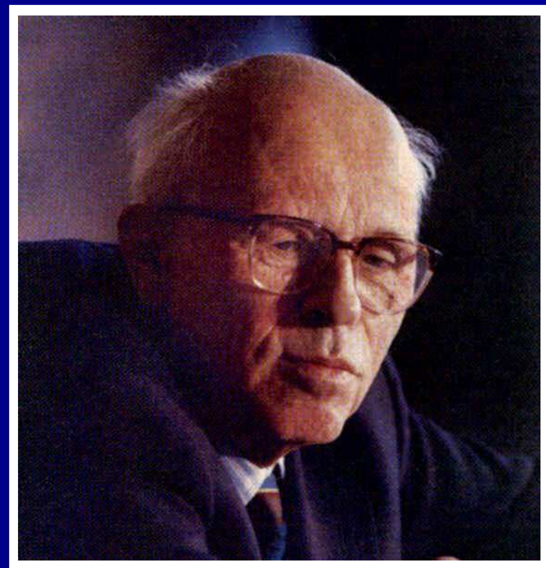
The Sakharov conditions

Antimatter can turn into matter if:

(a) proton decay occurs (baryon # violation)

(b) there is a matter-antimatter asymmetry (CP violation)

(c) there is thermal non-equilibrium



Particle Physics  **Astrophysics**

Must Understand CP Violation

Birth of KM Mechanism

1973

KM Mechanism

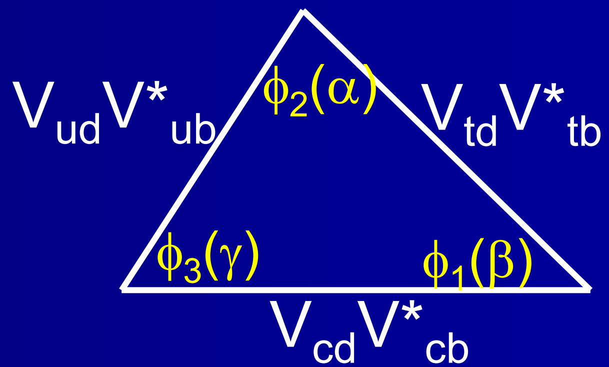
CP violation is due to a complex phase in quark mixing matrix

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} V_{us} V_{ub} \\ V_{cd} V_{cs} V_{cb} \\ V_{td} V_{ts} V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

$$\begin{pmatrix} 1-(\lambda^2/2) & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-(\lambda^2/2) & A\lambda^2 \\ A\lambda^3(1-\rho - i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

Unitarity Matrix

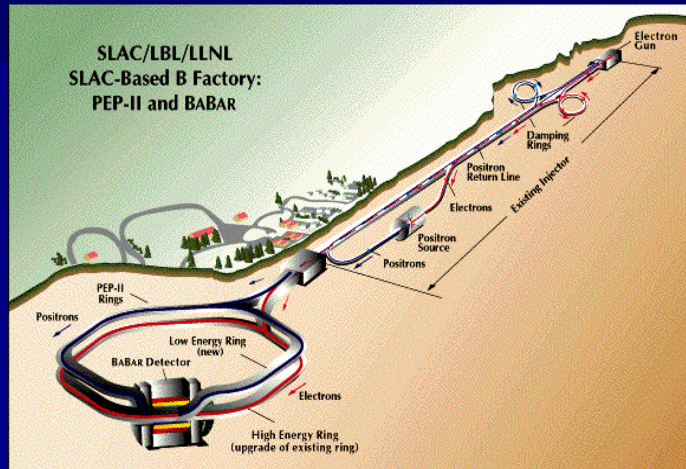
$$V_{ud}V^*_{ub} + V_{cd}V^*_{cb} + V_{td}V^*_{tb} = 0$$

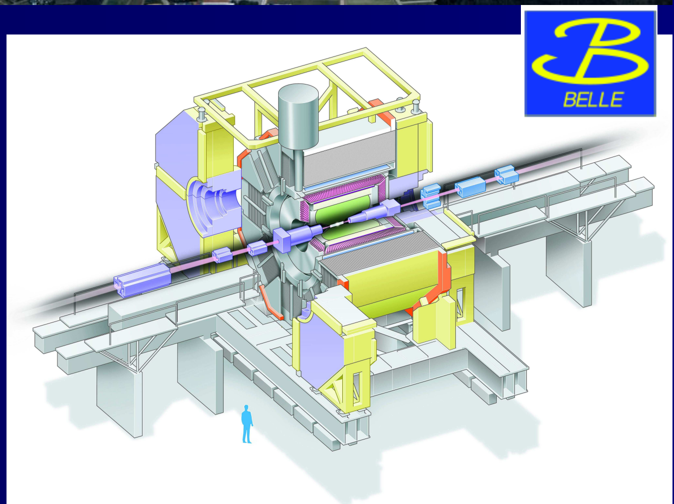


B factories in early 21 centery

KEK

SLAC





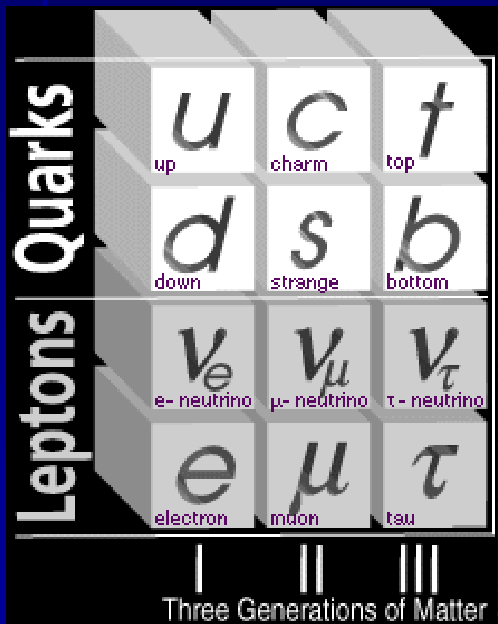
Belle

BaBar

The Standard Model

- Understand fundamental interactions using field theory.
  SU(3)⊗SU(2)⊗U(1) ⇒ strong ⊗ weak ⊗ EM (Standard Model)

- Elementary particles + Interactions + CKM matrix



BOSONS

force carriers
spin = 0, 1, 2,...

Unified Electroweak spin = 1	Mass GeV/c²	Electric charge
γ photon	0	0
W^-	80.22	–1
W^+	80.22	+1
Z^0	91.187	0

Strong or color spin = 1	Mass GeV/c²	Electric charge
g gluon	0	0

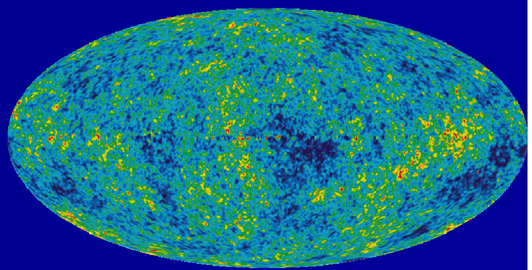
Do we understand everything?

Beyond the SM from Heaven

- Baryon-antibaryon asymmetry is $\sim 10^{10}$, but KM phase contribute only $\sim 10^{20}$

$\frac{n(B)}{n(\gamma)} = (5.1^{+0.3}_{-0.2}) \times 10^{-10}$ (WMAP) $\quad \frac{n(\overline{B})}{n(\gamma)} \simeq 0$ $\Rightarrow$Needs o(10) improvemt.

- What is dark matter? (22%)
- What is dark energy? (74%)
- Neutrinos are massive?



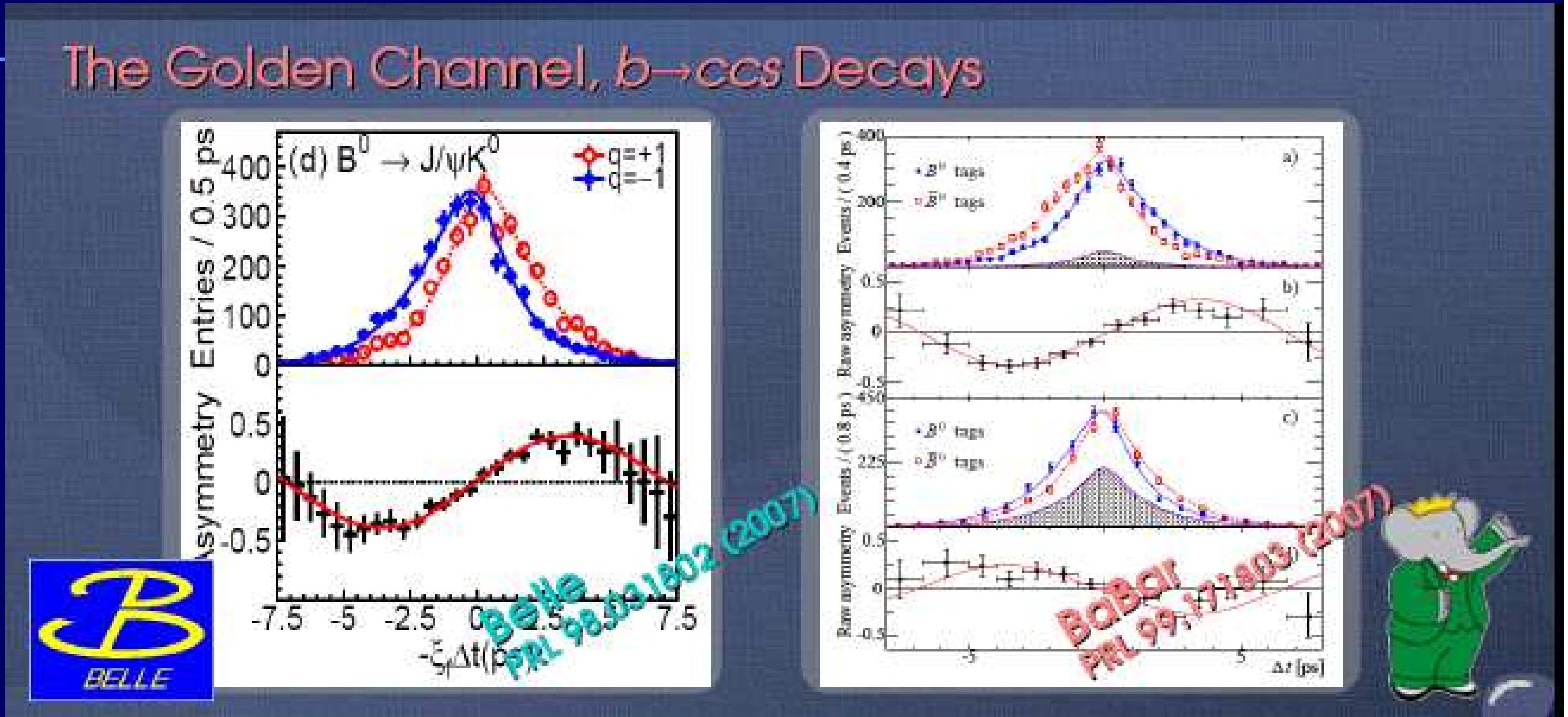
Maping of the Universe

Search for New Physics

Results for 2008

- Results of direct searches for new physics at Tevatron are negative, limited by statistics and collision energy.
- Focus on flavor physics that may show hints or provide clean probe of new physics.

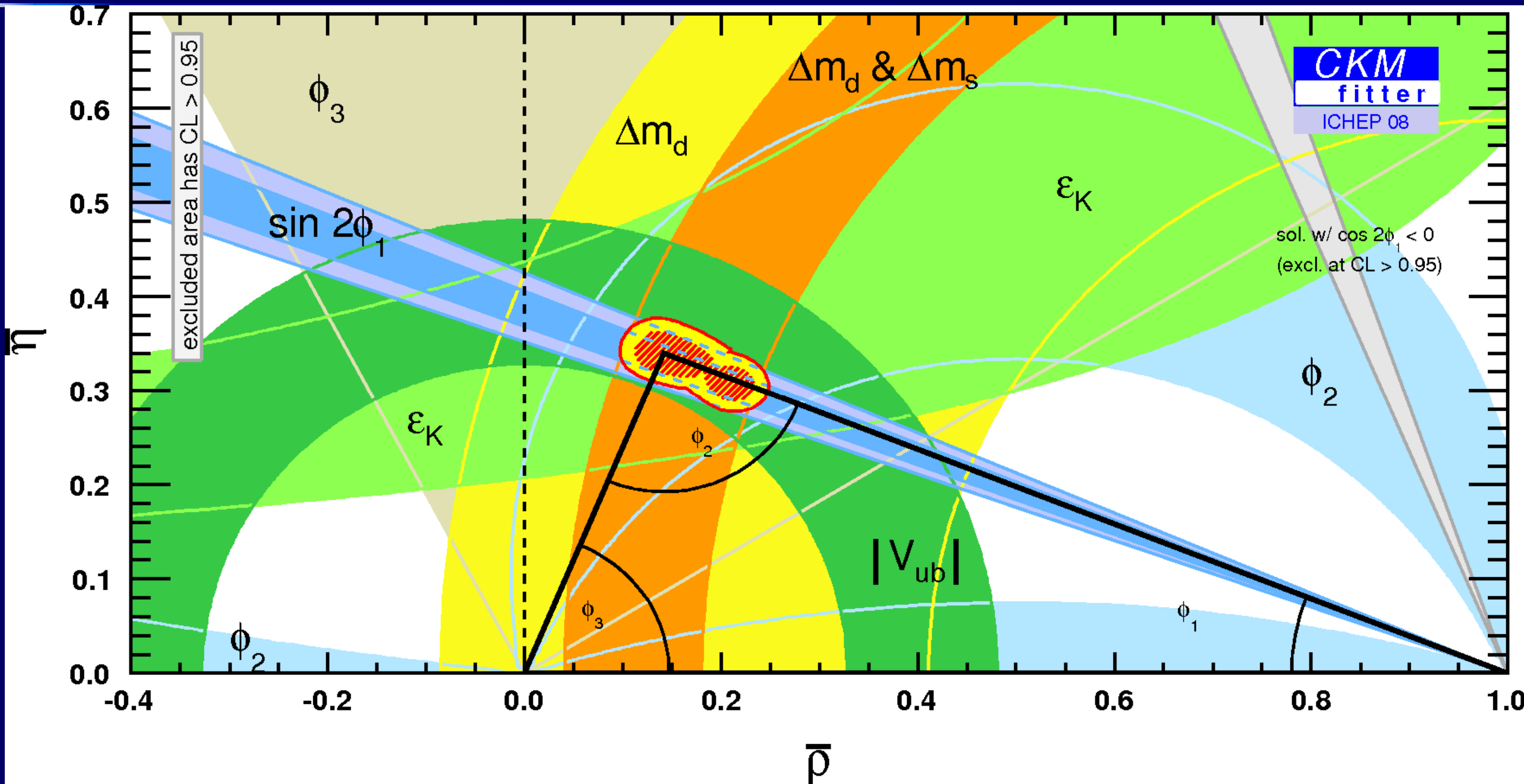
Measurement of ϕ_1/β



HFAG (b→ccs): S_{ccs} = 0.672 ± 0.024
(A_{ccs} = 0.005 ± 0.020, consists of no DCPV)

CP violation in the B system was already established.

From all Measurements

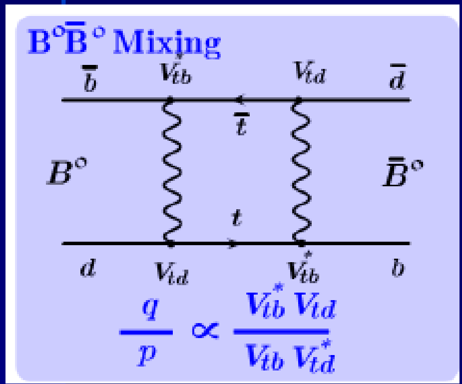


B factories: $\delta\phi_1$~2^o, $\delta\phi_2$ ~10^o, $\delta\phi_3$ ~15^o-30^o

Time dependent CPV in b→s Penguin

$$A_f(t) = \frac{\Gamma(\overline{B}^0(t) \to f) - \Gamma(B^0(t) \to f)}{\Gamma(\overline{B}^0(t) \to f) + \Gamma(B^0(t) \to f)} = -S_f \sin(\Delta m_B t) + C_f \cos(\Delta m_B t)$$

$S_f = \sin 2\phi_1$; $C_f = -A$



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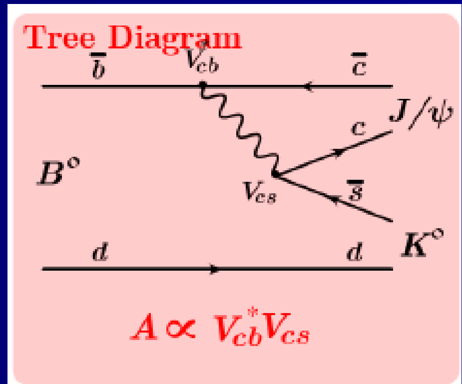


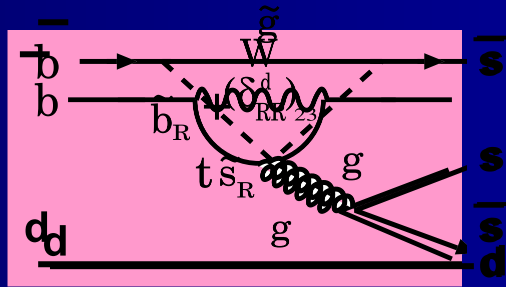
⇒

golden mode

$\sin 2\phi_1 / \sin 2\beta$

$\Delta S = \sin 2\phi_1(s\bar{q}q) - \sin 2\phi_1(c\bar{c}s)$

- **May have tree pollution.**
- **Theoretical expectation: for penguin dominant modes ΔS>0 within 0.05**
- **Clean signals for new physics**



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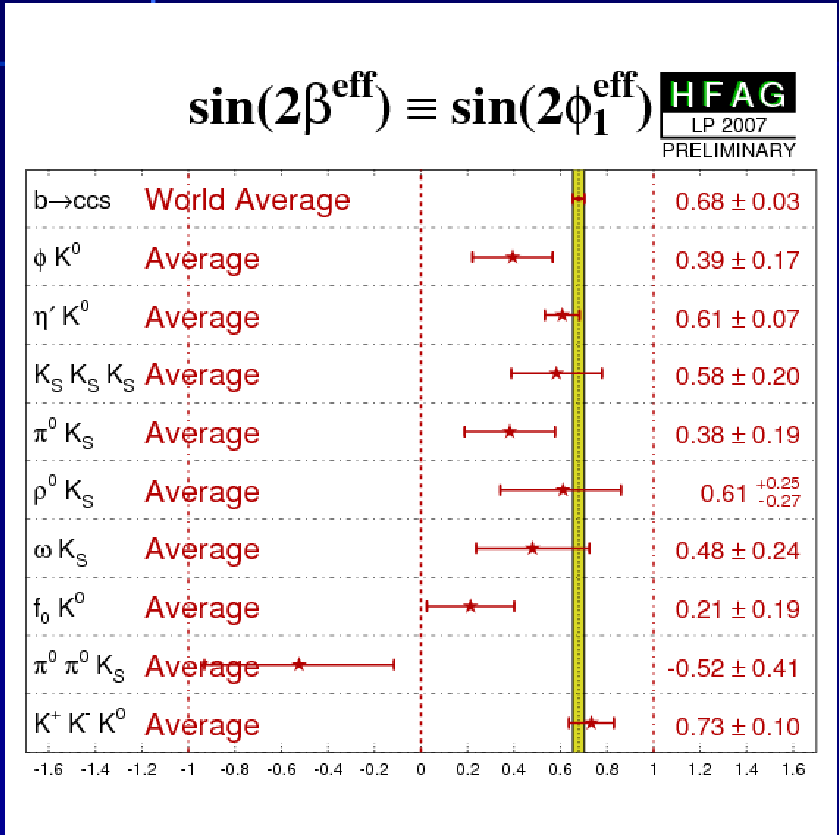
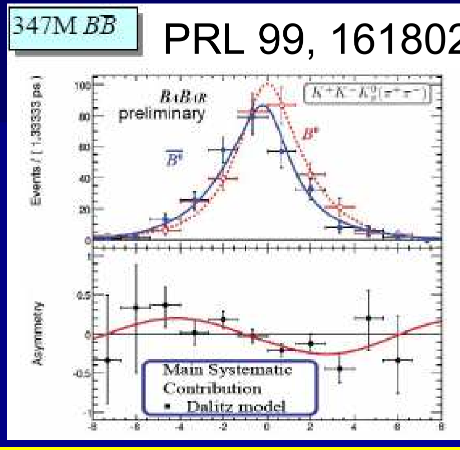
New physics phase in the loop causes deviation

ΔS results before ICHEP 2008



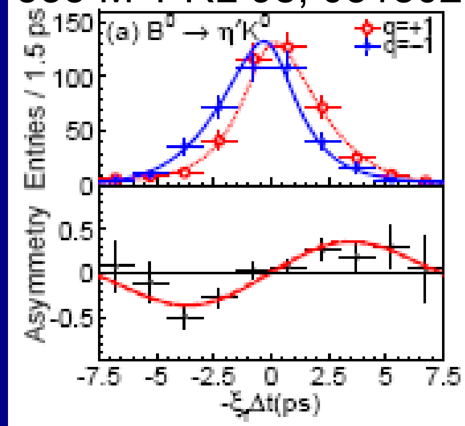


PRL 99, 161802 (2007)

Based on KKK Dalitz analysis

ϕK^0: $\sin 2\beta_{eff} = +0.12 \pm 0.31(stat) \pm 0.10\ (syst)$

535 M PRL 98, 031802 (2007)

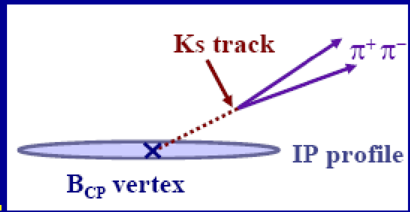


For most modes, ΔS(SM) is positive.

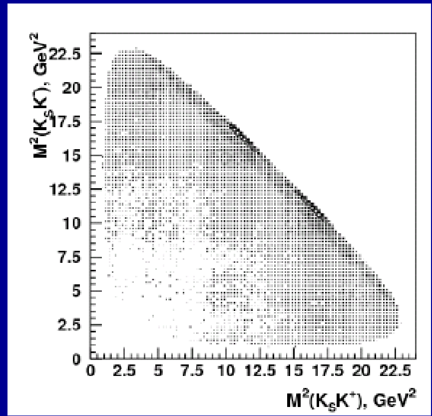
$\eta' K^0$: $\sin 2\phi_{1eff}$: +0.64 ± 0.10 ± 0.04

Decay Modes with Updated Results

- Class A: $\eta' K^0$, $\omega K_S \Rightarrow$ Same method as $J/\Psi\ K^0$
- Class B: $K^0\pi^0$
  - No tracks on B decay vertex. Require tacks with SVD hits.
  - Perform fit by constraining C.



- Class C: $\pi^+\pi^- K_S$, $K^+K^-K_S$
  - Model the Dalitz distributions.
  - Many parameters: phase, S and C for each mode ….



- Class D: $\phi K_S\pi^0$:

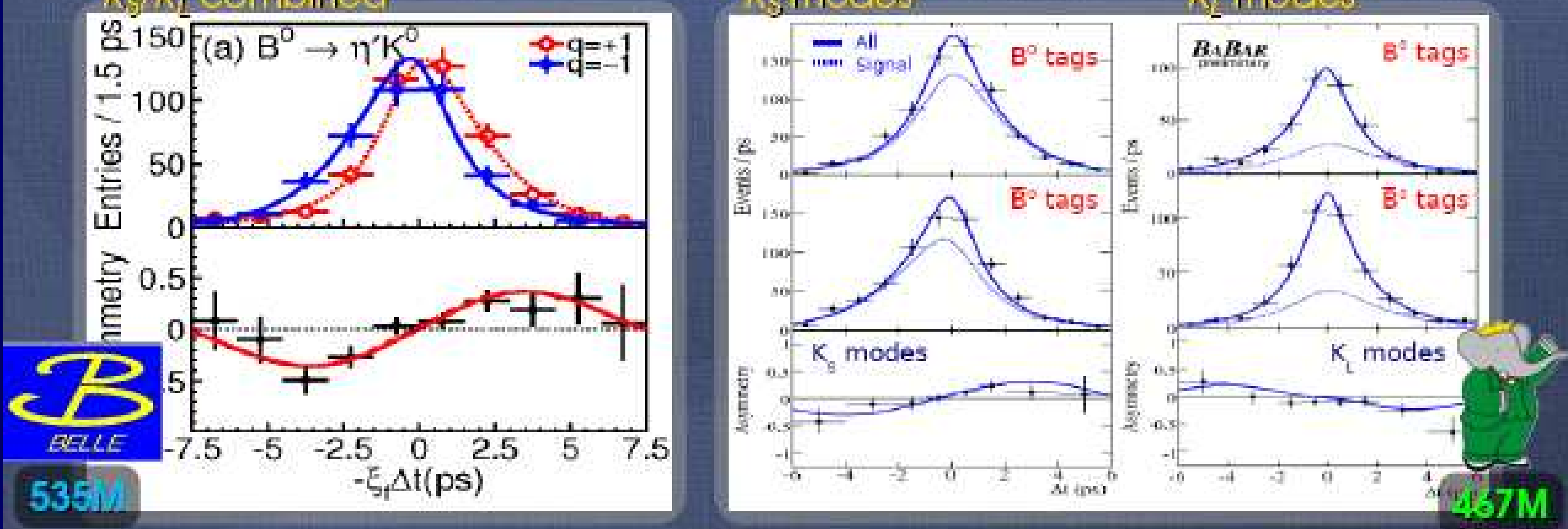
Low statistics. Need to know the CP content. Use results from $\phi K^+\pi^-$.

Class is characterized by the analysis complexity.

ϕ_1 measured with penguins

Single Mode with the Highest Precision: $B \to \eta' K^0$

K_S/K_L combined — K_S modes — K_L modes

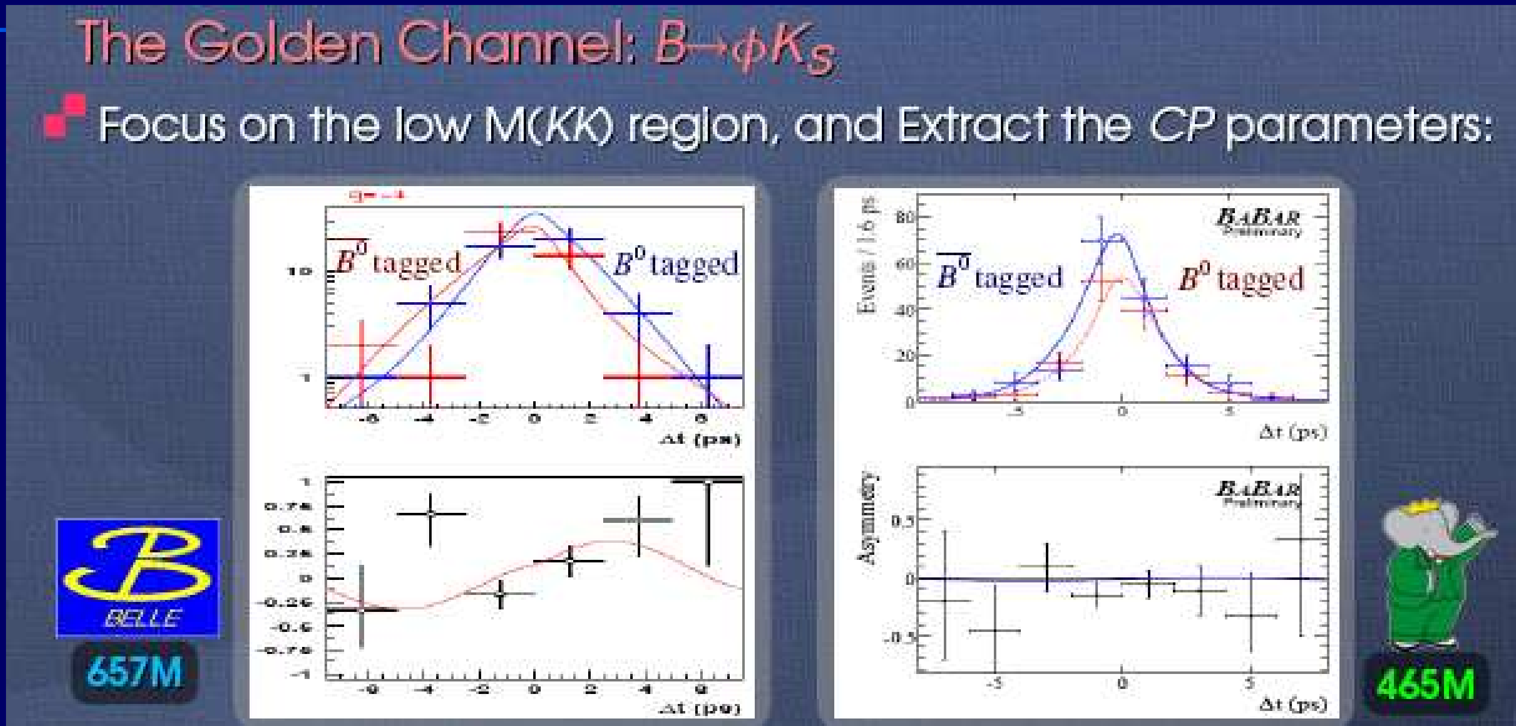


$S(\eta' K^0) = 0.64 \pm 0.10 \pm 0.04$
$A(\eta' K^0) = -0.01 \pm 0.07 \pm 0.05$

$S(\eta' K^0) = 0.57 \pm 0.08 \pm 0.02$
$-C(\eta' K^0) = 0.08 \pm 0.06 \pm 0.02$

- Observation of TCPV in a single well-defined penguin mode!
- Results are consistent with $J/\psi K$ average.

Time dependent Dalitz



$A_{CP} = +0.31^{+0.21}_{-0.23} \pm 0.04 \pm 0.09$
$\phi_1^{eff} = 21.2^{+9.8}_{-10.4} \pm 2.0 \pm 2.0°$
($\sin 2\phi_1^{eff} = 0.67 +0.22/-0.32$)

$A_{CP} = +0.14 \pm 0.19 \pm 0.02$
$\phi_1^{eff} = 7.4 \pm 7.4 \pm 1.1°$
($\sin 2\phi_1^{eff} = 0.26 \pm 0.26 \pm 0.03$)

ϕ_1/β with all penguin modes

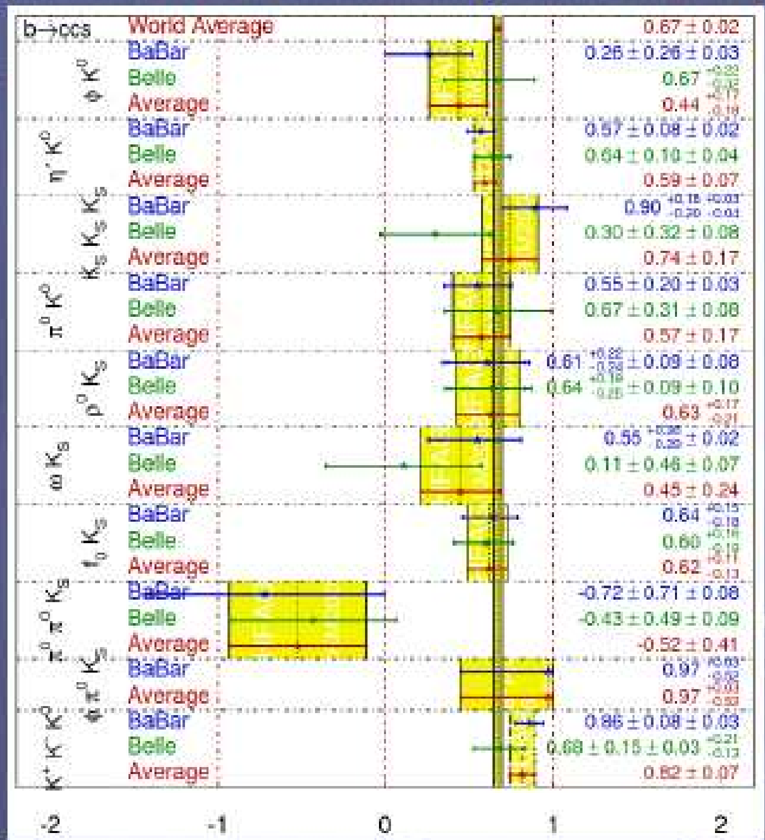
$b \to sqq$ Penguins Summary

HFAG CKM 2008 results →

All measurements now are more or less consistent with the *S* value from *b* → *ccs* decays:
S(*b*→*ccs*) = 0.672±0.024

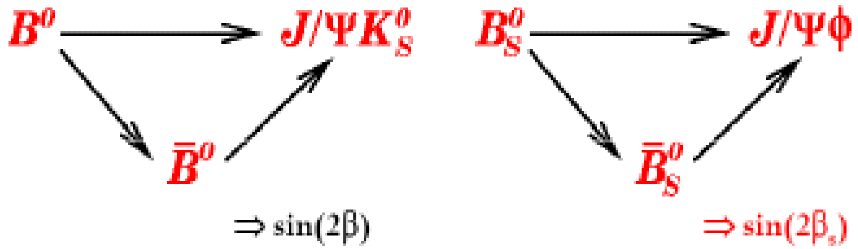
HFAG naïve average:
S(penguins) = 064 ± 0.04

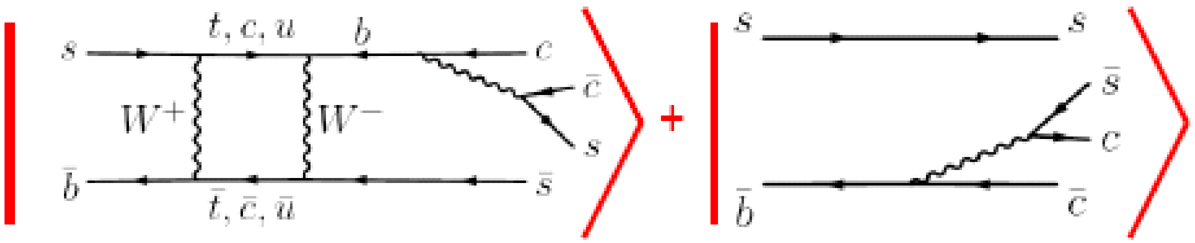
- Measurement with penguin modes are still an excellent test for NP.
- More statistics are required for mode-by-mode studies.



CP Violation in $B_s \rightarrow J/\psi\ \phi$

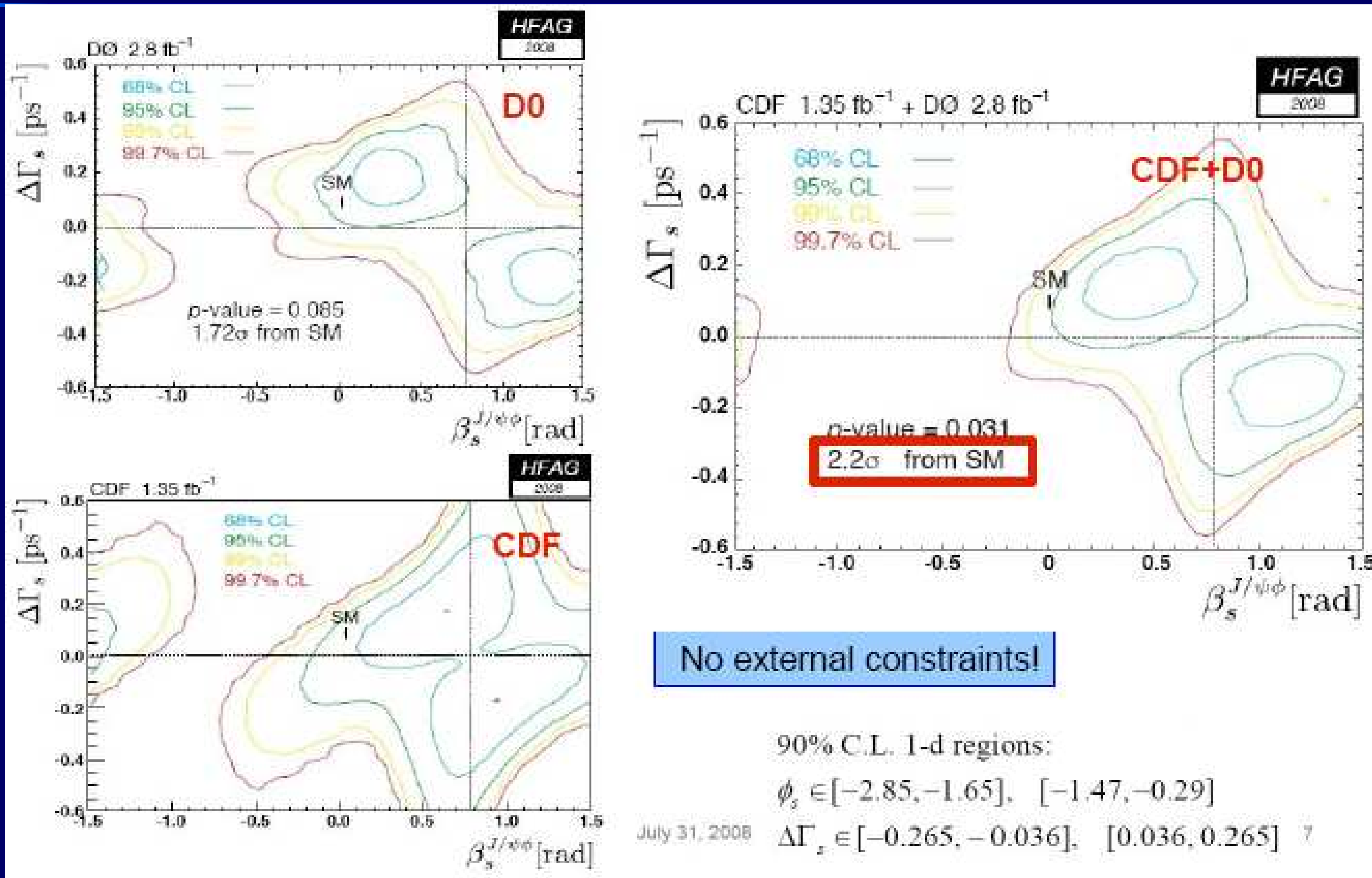
- Analogously B^0, CP violation in B_s occurs through interference of decay with and without mixing:





- β_s in SM is predicted to be very small: $\beta_s^{\mathrm{SM}} = \arg\left(-\frac{V_{ts}V_{tb}^*}{V_{cs}V_{cb}^*}\right) \approx 0.02$
- New Physics affects the CP violation phase as: $2\beta_s = 2\beta_s^{\mathrm{SM}} - \phi_s^{\mathrm{NP}}$
- If NP phase ϕ_s^{NP} dominates $\rightarrow$ $2\beta_s = -\phi_s^{\mathrm{NP}}$ $\phi_s^{\mathrm{SM}} = \arg\left(-\frac{M_{12}}{\Gamma_{12}}\right)$

Results before Summer 2008



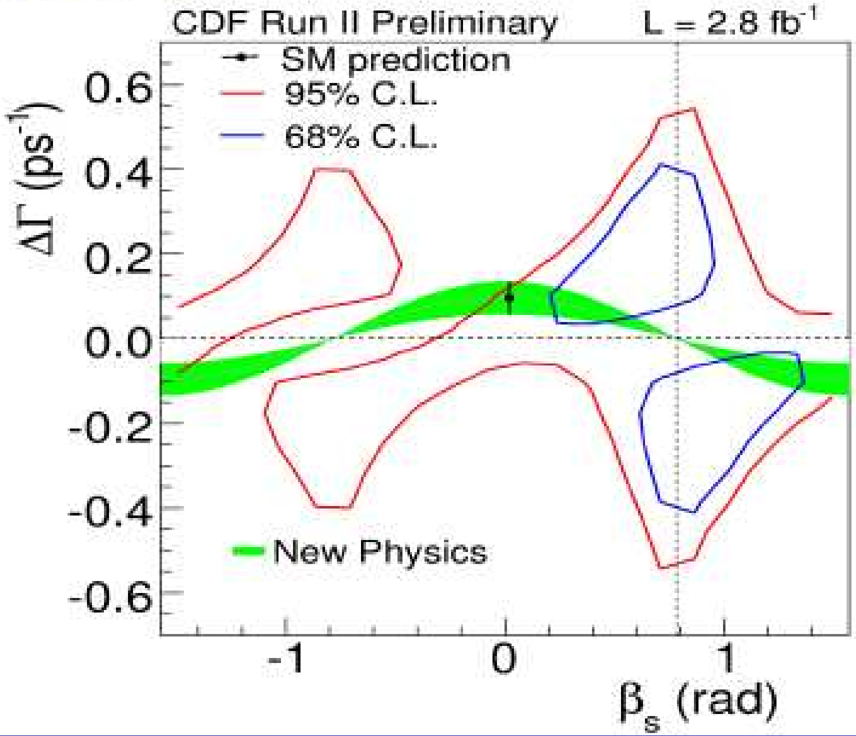
CDF update in summer

- This summer, CDF updated up to 2.8 /fb ==> ~ 3200 events
- However, Same Side Tagging not used in 2nd half of sample

  ==> statistically equivalent to 2.0 /fb

- Consistency with SM decreased: 15% → 7% (~1.8σ)

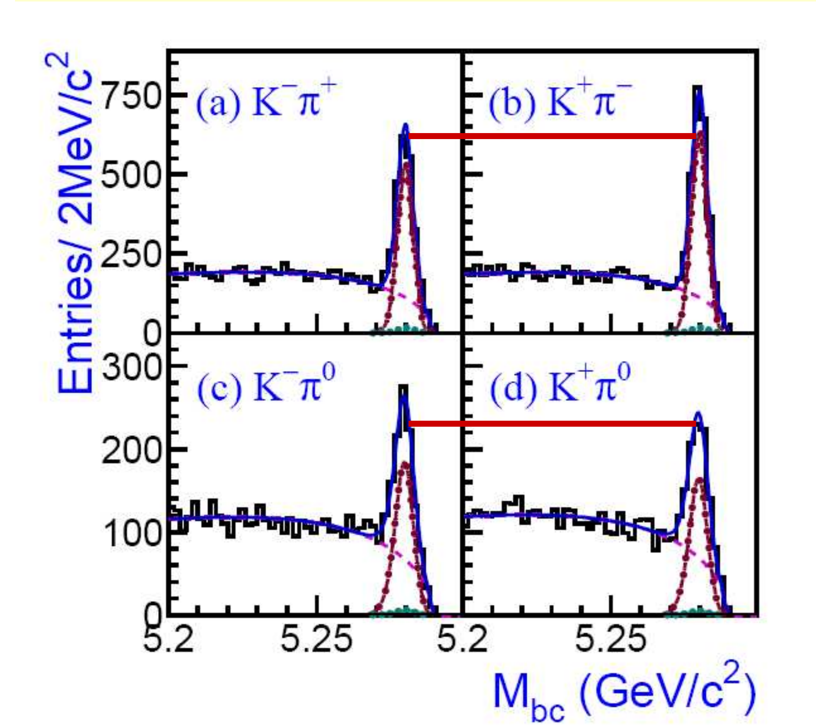
- D0 and CDF will keep updating measurement of $\phi_s^{J/\psi\phi}$ as one of the Tevatron flagship measurements!



Direct CP Violation in B→Kπ Decays

$$\mathcal{A}_{CP}(B \to f) = \frac{|\overline{A}|^2 - |A|^2}{|\overline{A}|^2 + |A|^2} \propto \sum_{i,j} A_i A_j \sin(\delta_i - \delta_j)\sin(\phi_i - \phi_j)$$

Belle Results: Nature 452, 332 (2008)



New Update

$A_{cp}(K^+\pi^-)$ =
- $-0.107 \pm 0.016 ^{+0.006}_{-0.004}$ BaBar
- $-0.094 \pm 0.018 \pm 0.008$ Belle
- $-0.086 \pm 0.023 \pm 0.009$ CDF
- $-0.04 \pm 0.16 \pm 0.02$ CLEO

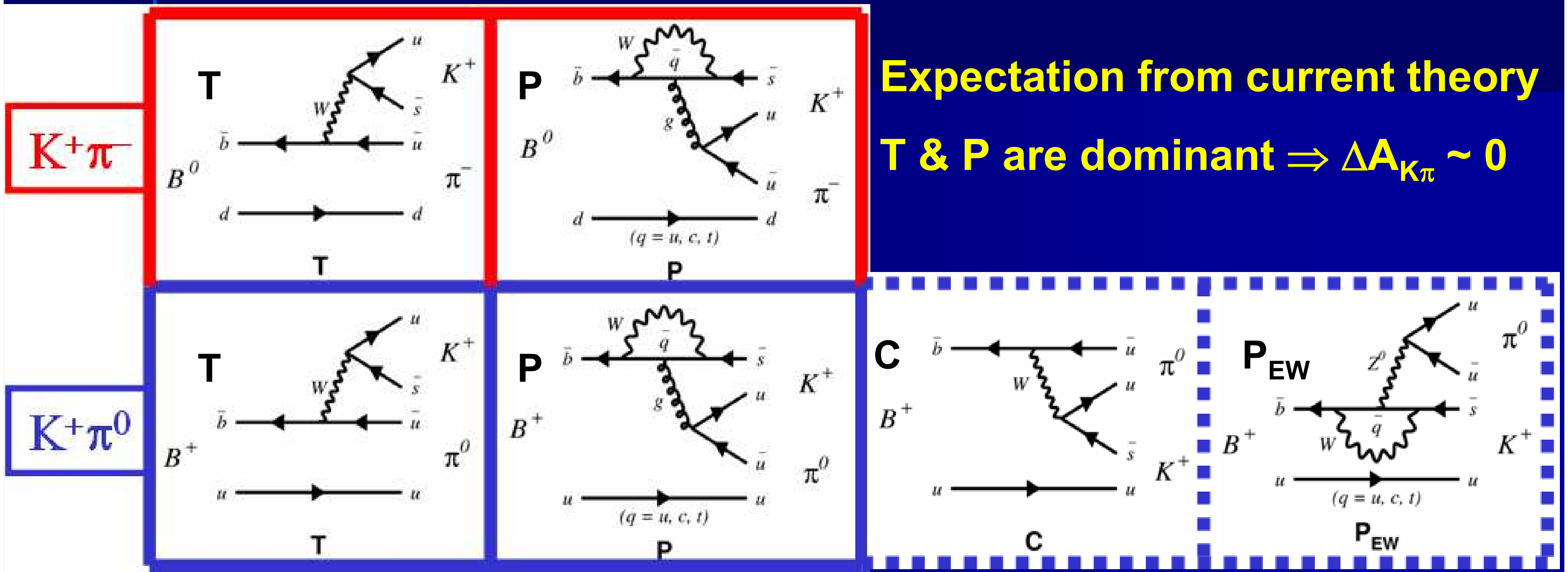
$\Rightarrow -0.098 ^{+0.012}_{-0.011}$ @ 8.1σ AVG

$A_{cp}(K^+\pi^0)$ =
- $+0.030 \pm 0.039 \pm 0.010$ BaBar
- $+0.07 \pm 0.03 \pm 0.01$ Belle
- $-0.29 \pm 0.23 \pm 0.02$ CLEO

$\Rightarrow +0.050 \pm 0.025$ @ 2.0σ AVG

$\Delta A_{K\pi} = A_{cp}(K^+\pi^-) - A_{cp}(K^+\pi^0)$
$= -0.147 \pm 0.028$ @ 5.3σ

$\Delta A_{K\pi}$ Puzzle



Expectation from current theory

T & P are dominant $\Rightarrow \Delta A_{K\pi} \sim 0$

- **Enhancement of large C with large strong phase to T $\Rightarrow$ strong inter. !?**

Chiang et. al. 2004
Li, Mishima & Sanda 2005

- **Enhancement of large P_{EW} $\Rightarrow$ New physics**

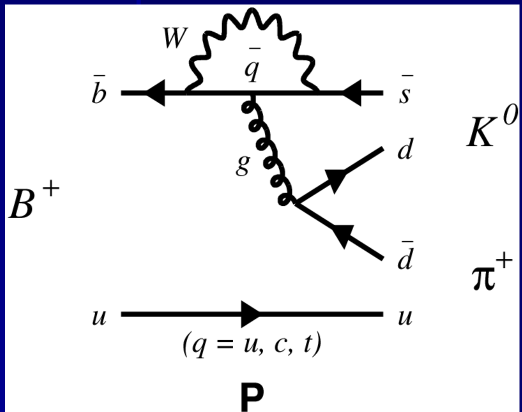
Yoshikawa 2003; Mishima & Yoshikawa 2004;
Buras et. al. 2004, 2006; Baek & London 2007;
Hou et. al. 2007; Feldmann, Jung & Mannel 2008

Model independent checks for NP

M. Gronau, PLB 627, 82 (2005); D. Atwood & A. Soni, Phys. Rev. D 58, 036005(1998).

$$\mathcal{A}_{CP}(K^+\pi^-) + \mathcal{A}_{CP}(K^0\pi^+)\frac{\mathcal{B}(K^0\pi^+)}{\mathcal{B}(K^+\pi^-)}\frac{\tau_0}{\tau_+} = \mathcal{A}_{CP}(K^+\pi^0)\frac{2\mathcal{B}(K^+\pi^0)}{\mathcal{B}(K^+\pi^-)}\frac{\tau_0}{\tau_+} + \mathcal{A}_{CP}(K^0\pi^0)\frac{2\mathcal{B}(K^0\pi^0)}{\mathcal{B}(K^+\pi^-)}$$

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



P dominants. $\Rightarrow A_{cp}(K^0\pi^+) \sim 0$

World Average

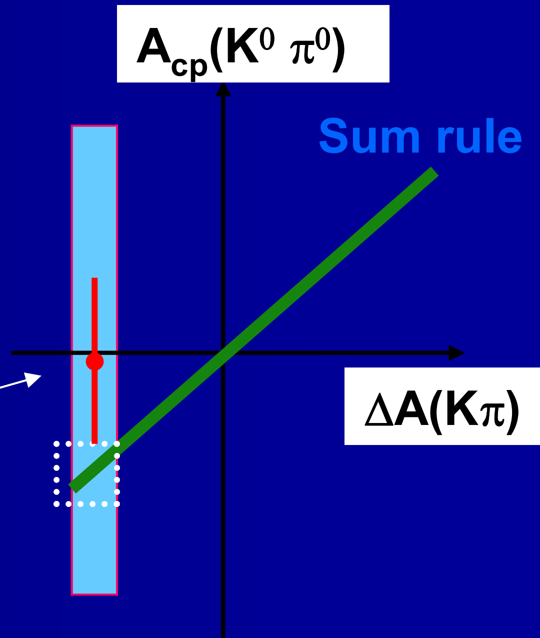
$A_{cp}(K^0\pi^+) = 0.009 \pm 0.025$

$B^0 \to K^0\pi^0$ **New**

A = $-0.13 \pm 0.13 \pm 0.03$

A = $+0.14 \pm 0.13 \pm 0.06$

HFAG AVG: -0.01 ± 0.10



Important topic for Super B factory

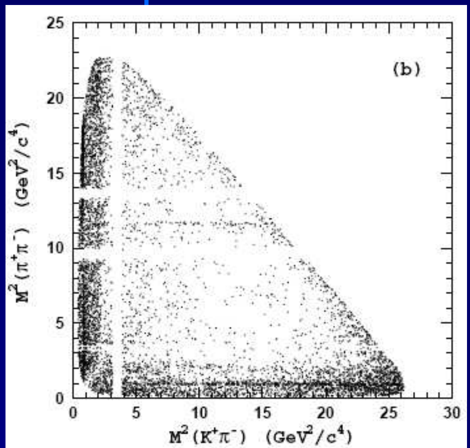
Sum rule predicts
$A_{cp}(K^0\pi^0) = -0.151 \pm 0.043$

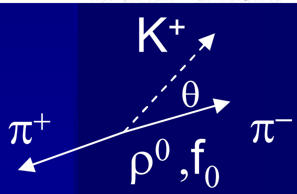
First observation of direct CP violation in charged B decays

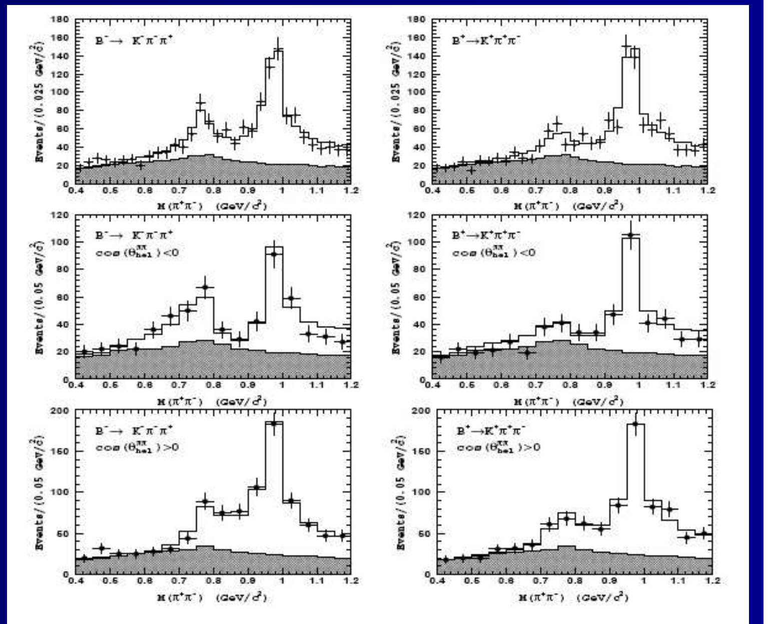
- Dalitz analysis on $B^+ \to K^+\pi^+\pi^-$

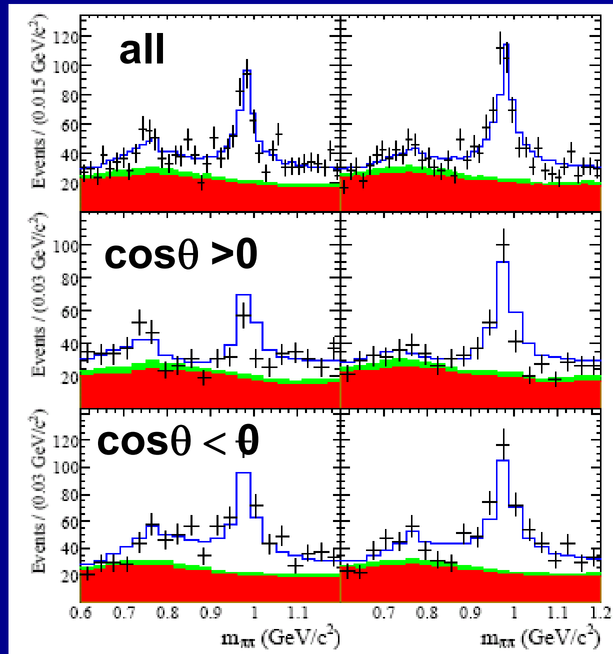
657M $B\bar{B}$, BELLE-CONF-0827

383M $B\bar{B}$, PRD78, 012004, 08





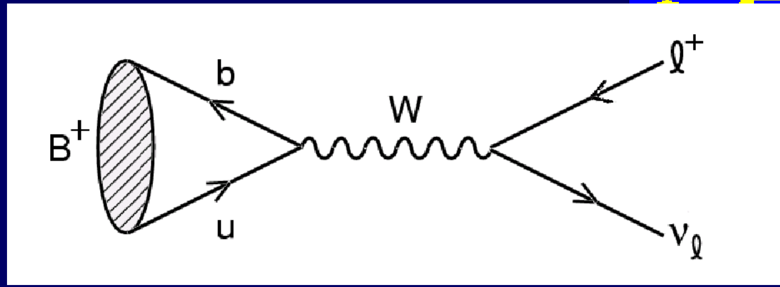




$A_{CP}(B^\pm \to \rho^0 K^\pm) = (+41 \pm 10 \pm 3\ ^{+3}_{-7})\%$ @4.0σ

$A_{CP}(B^\pm \to \rho^0 K^\pm) = (+44 \pm 10 \pm 4\ ^{+5}_{-13})\%$ @3.7σ

$B^+ \to \tau^+ \nu$



- In SM, decay rate related to decay constant and V_{ub}

$$\mathcal{B}(B \to \ell\nu) = \frac{G_F^2 m_B}{8\pi} m_\ell^2 \left(1 - \frac{m_\ell^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

$$\Rightarrow \mathcal{B}(B \to \tau\nu) = (0.78^{+0.09}_{-0.13}) \times 10^{-4}$$

(CKM fitter 2008 prediction)

- Charged Higgs may contribute to BF.

$$\mathcal{B}(B \to \tau\nu) = \mathcal{B}(B \to \tau\nu)_{SM} \times r_H$$

W.S. Hou, PRD 48, 2342 (1993)

destructive

$$r_H = \left(1 - \frac{m_B^2}{m_H^2} \tan^2\beta\right)^2$$

- Previous results:

Belle hadronic tag

$$\mathcal{B}(B \to \tau\nu) = (1.79^{+0.56+0.46}_{-0.49-0.51}) \times 10^{-4}$$

447 M $B\bar{B}$ with 3.5σ

BaBar hadronic & semileptonic tags

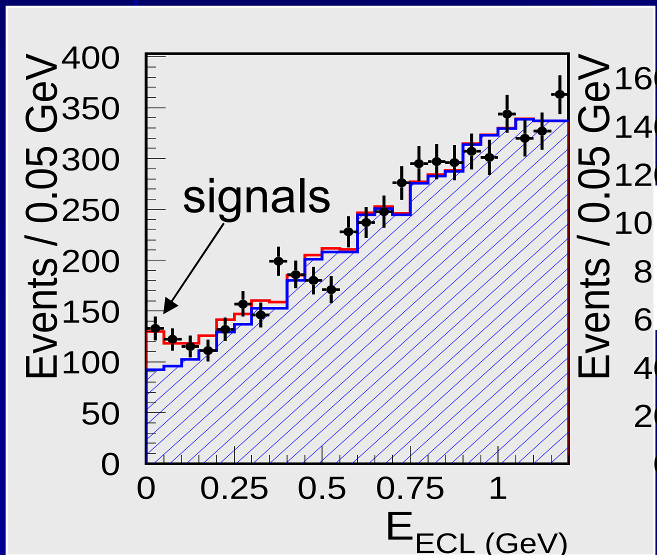
$$\mathcal{B}(B \to \tau\nu) = (1.2 \pm 0.4 \pm 0.3 \pm 0.2) \times 10^{-4}$$

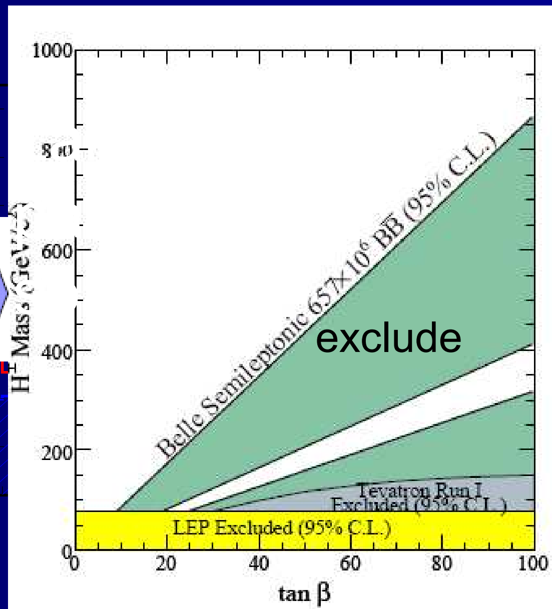
383 M $B\bar{B}$ with 2.6σ

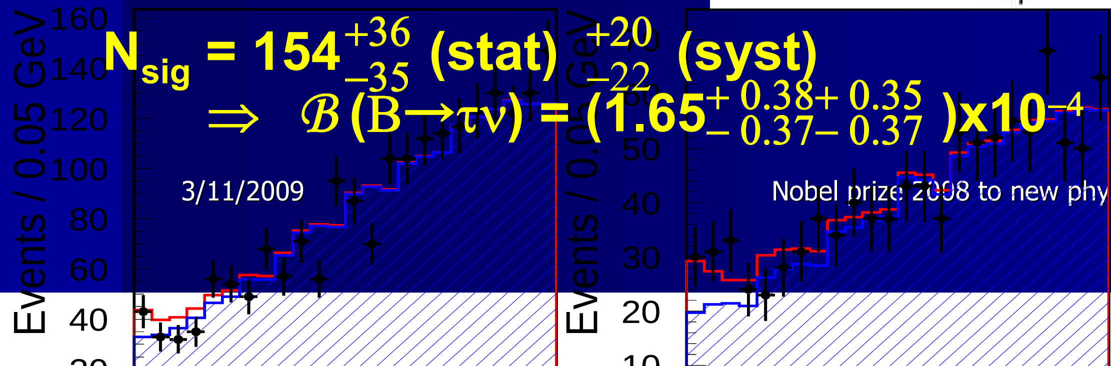
New Belle Result on $B^+ \to \tau^+ \nu$

NEW with 3.8σ

657 M $B\bar{B}$ with $D^{(*)} l \nu$ tag







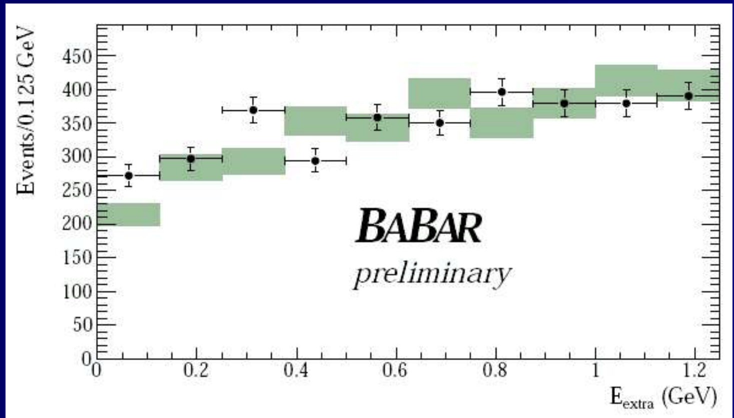
$N_{sig} = 154^{+36}_{-35}$ (stat) $^{+20}_{-22}$ (syst)

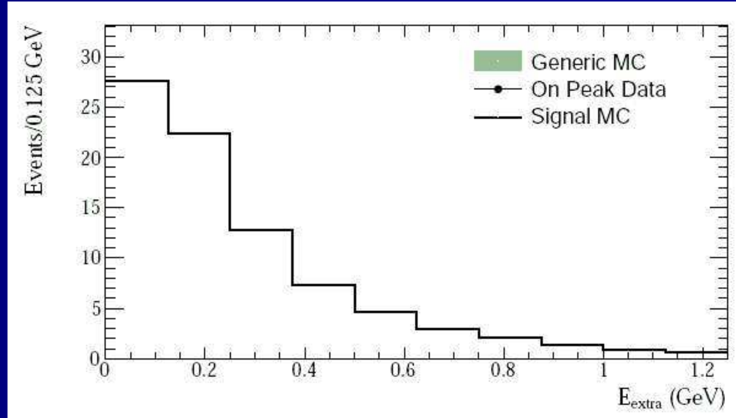
$\Rightarrow \mathcal{B}(B\to\tau\nu) = (1.65^{+0.38}_{-0.37}{}^{+0.35}_{-0.37})\times10^{-4}$

- Tag on $D^{(*)} l \nu$
- Search for $\tau \to e\upsilon\upsilon$, $\mu\nu\nu$, $\pi\nu$
- Check extra energy in ECAL
- Understand background from the control sample

New BaBar Result on $B^+ \rightarrow \tau^+ \nu$

Tag on $D^{(*)}l\nu$, look for $\tau \rightarrow e\nu\nu$, $\mu\nu\nu$, $\pi\nu$, $\rho\nu$





Mode	Expected Background (N_{BG})	Observed Events (N_{obs})	Overall Efficiency (ε)	Branching Fraction
$\tau^+ \rightarrow e^+\nu_e\overline{\nu}_\tau$	91 ± 13	148	$(3.08 \pm 0.14) \times 10^{-4}$	$(4.0 \pm 1.2) \times 10^{-4}$
$\tau^+ \rightarrow \mu^+\nu_\mu\overline{\nu}_\tau$	137 ± 13	148	$(2.28 \pm 0.11) \times 10^{-4}$	$\left(1.0^{+1.2}_{-0.9}\right) \times 10^{-4}$
$\tau^+ \rightarrow \pi^+\overline{\nu}_\tau$	233 ± 19	243	$(3.89 \pm 0.15) \times 10^{-4}$	$\left(0.6^{+1.1}_{-0.5}\right) \times 10^{-4}$
$\tau^+ \rightarrow \pi^+\pi^0\overline{\nu}_\tau$	59 ± 9	71	$(1.30 \pm 0.07) \times 10^{-4}$	$\left(2.0^{+1.4}_{-1.3}\right) \times 10^{-4}$
$B^+ \rightarrow \tau^+\nu_\tau$	521 ± 31	610	$(10.54 \pm 0.41) \times 10^{-4}$	$(1.8 \pm 0.8 \pm 0.1) \times 10^{-4}$

Tension in the CKM fit

	Belle ($\mathcal{B}$x10^4)	BaBar ($\mathcal{B}$x10^4)
Had. Tags	$1.79^{+0.56+0.46}_{-0.49+0.51}$	$1.8^{+0.9}_{-0.8}\pm0.4$
D$l\nu$ Tags	$1.65^{+0.38+0.35}_{-0.37-0.37}$	$1.8\pm0.8\pm0.1$

My Avg. $\mathcal{B}$ = $(1.73\pm0.35)\mathrm{x}10^{-4}$

- CKM fitter obtained $\mathcal{B} = (0.78^{+0.09}_{-0.13})\ \mathrm{x}10^{-4}$ deviation = 2.6 σ
- B = (1.2 ± 0.4) x10^{-4} using

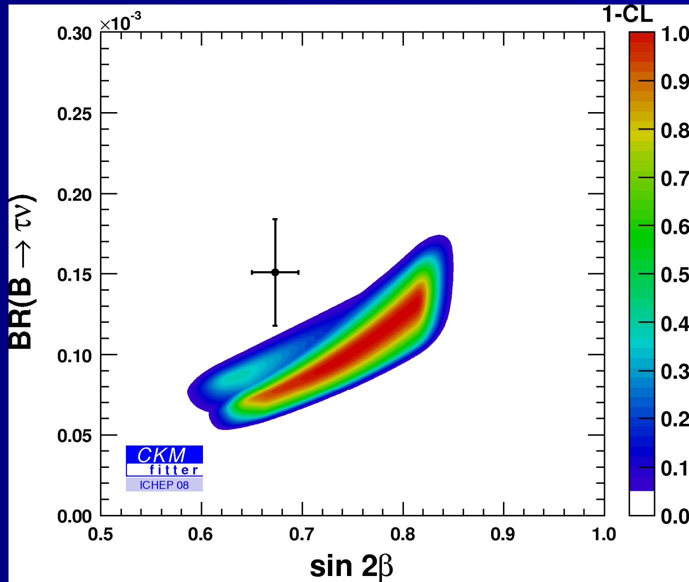
$|V_{ub}| = (4.39 \pm 0.54)\times10^{-3}$, $f_B = 0.189 \pm 0.027$ GeV

Note that interference is destructive in 2HDM (type II). $\mathcal{B} > \mathcal{B}_{SM}$ implies that H^+ contribution dominates

$\mathcal{B}$(B→τν) vs sin2ϕ_1/2β

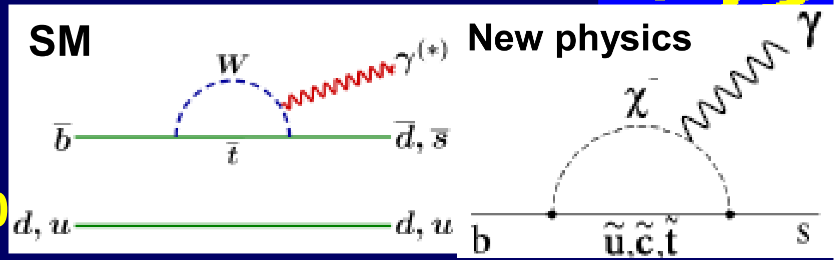
$$\frac{BR(B\to\tau\nu)}{\Delta m_d} = \frac{3\pi}{4}\,\frac{m_\tau^2}{m_W^2\,S(x_t)}\left(1-\frac{m_\tau^2}{m_B^2}\right)^2 \tau_{B^+}\,\frac{1}{B_{Bd}}\,\frac{1}{|V_{ud}|^2}\left(\frac{\sin\beta}{\sin\gamma}\right)^2$$

- Using ratio, the relation is independent of f_B and Vub
- Belle and BaBar will have new updates soon.
- Good topics for the future Super B factory

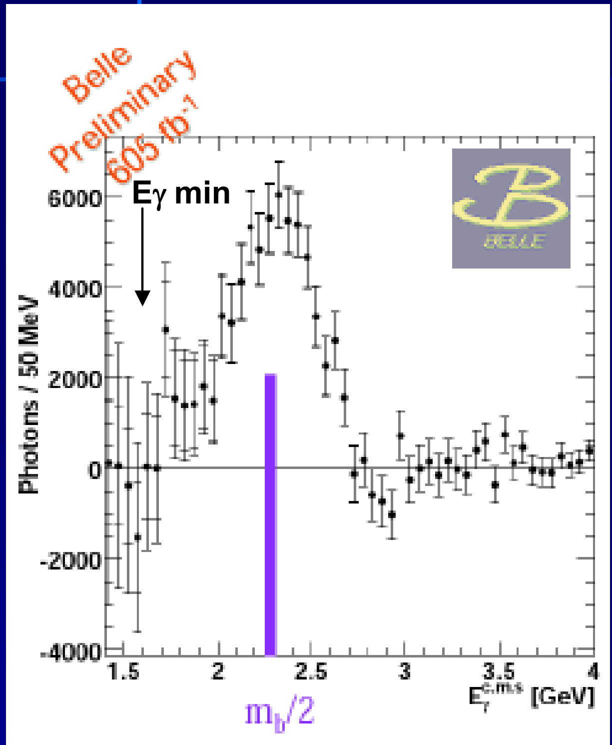


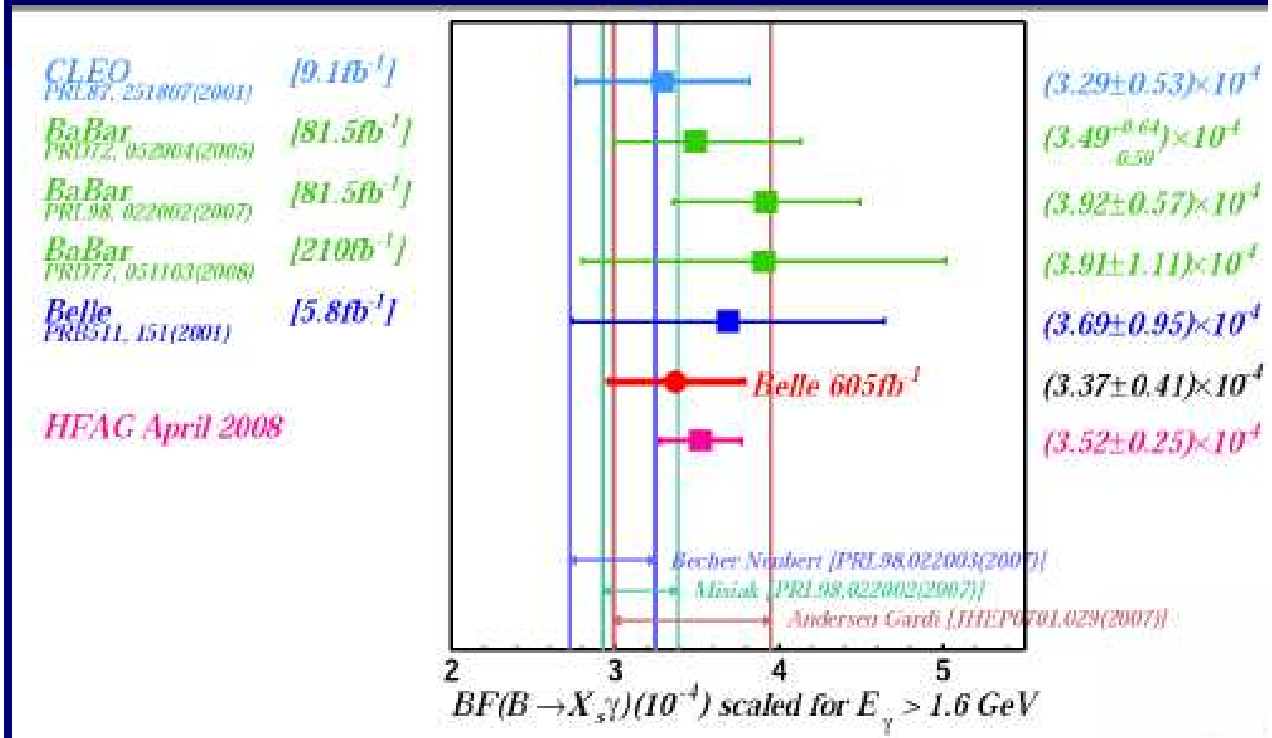
1σ deviation

$B \to X_s \gamma$



Belle update with E_γ >1.7 GeV: arXiv:0804.1580





SM NNLO calculation:

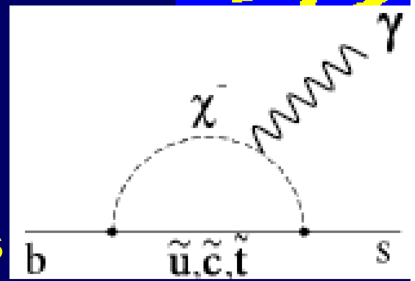
$\mathcal{B}(B \to X_s\gamma)\,|_{E_\gamma > 1.6\ \mathrm{GeV}} =$

- $(3.15\pm0.23)\times10^{-4}$ Misiak et al.
- $(2.98\pm0.26)\times10^{-}$ Becher Neubertv
- $(3.47\pm0.49)\times10^{-4}$ Anderson Gardi

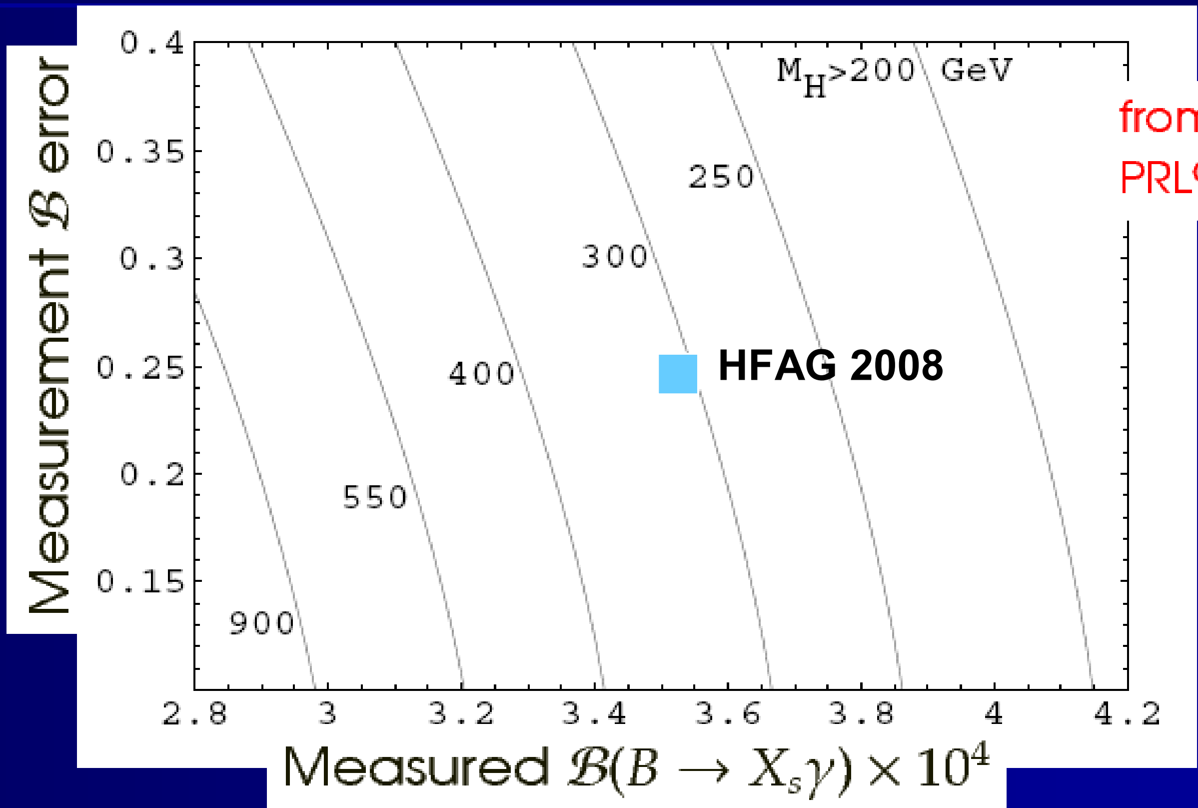
HFAG 2008:

$\mathcal{B}(B \to X_s\gamma)\,|_{E_\gamma > 1.6\ \mathrm{GeV}} = (3.52\pm0.25)\times10^{-4}$

Charged Higgs Bound



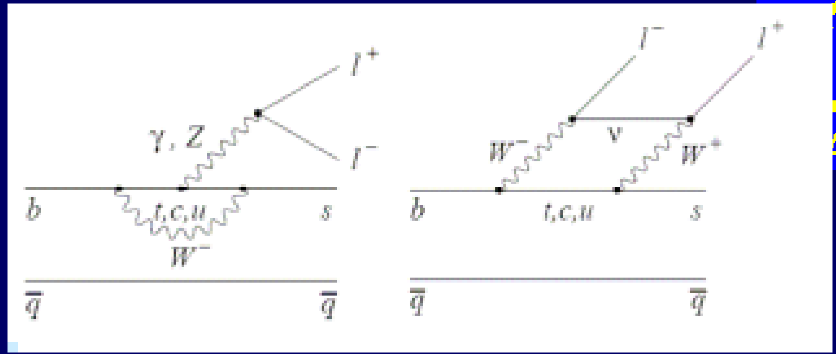
The 95% lower bound of charged Higgs mass as a function of $\mathcal{B}(B \to X_s\,\gamma)$ and its error.



from Misiak et al, PRL98,022002('07)

M_H+ > 300 GeV/c^2 @ 95% C.L. for all tanβ

$b \to s\, l^+ l^-$



- Loop dominant ⇒ Small BF ; good place for new physics!
- Contributions from three coefficients:

  $\mathcal{L}_{eff} = \Sigma\, C_i\, O_i$, C_i (short distance effect). SM expects real C_i

  C_7^{eff}: EM penguin; C_9^{eff}(C_{10}^{eff}): vector (axial vector) part of weak diagrams
- More observables sensitive to NP:

– FB lepton asymmetry, A_{FB}

– K* polarization, FL

– CP asymmetry, A_{CP}

– Isospin asymmetry

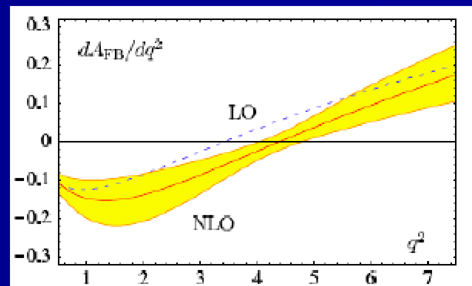
– e/μ ratio

- $A_{FB}(q^2)$:

  $e^+e^- \to \mu^+\mu^-$ indication of Z^0

  $b \to s\, l^+ l^-$:

  SM ⇒



Good agreement with SM BF

657M, NEW

- Obtain partial BF in 6 bins in q^2; extrapolate the total BF.
- $BF(B \to K^*ll) = (10.8 \pm 1.0 \pm 0.9) \times 10^{-7}$
- $BF(B \to Kll) = (4.8^{+0.5}_{-0.4} \pm 0.3) \times 10^{-7}$

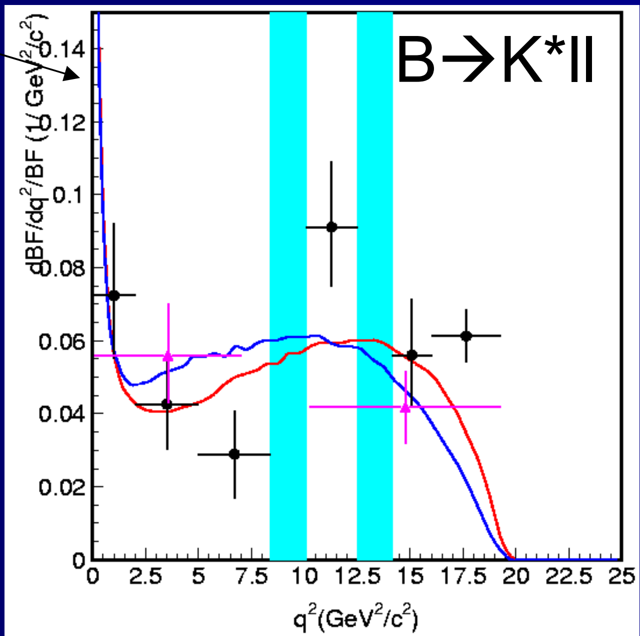
384M FPCP 08

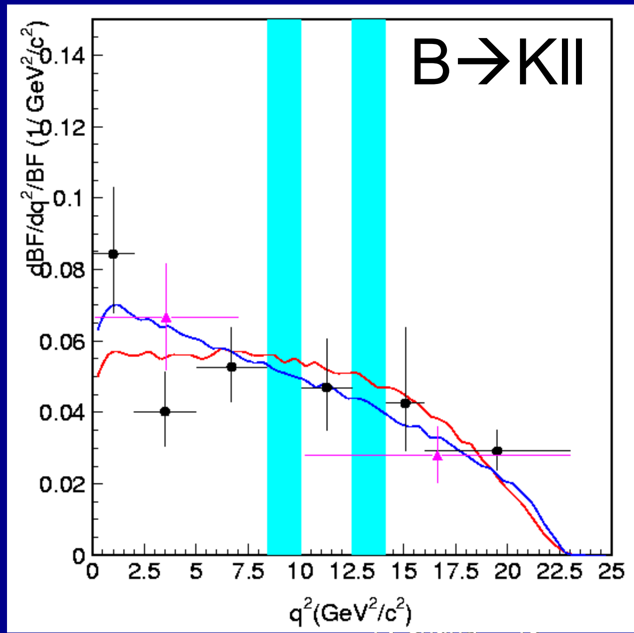
- $BF(B \to K^*ll) = (11.1 \pm 1.9 \pm 0.7) \times 10^{-7}$
- $BF(B \to Kll) = (3.9 \pm 0.7 \pm 0.2) \times 10^{-7}$

photon pole

Veto events in the J/ψ and ψ′ regions

- –•– **Belle, ICHEP 08**
- –•– **BABAR, FPCP 08**
- –– **Melikhov et. al (quark model, PLB 410, 1997)**
- –– **Ali (PRD 66, 034002, 290, 2002)**





Good agreement with SM BF

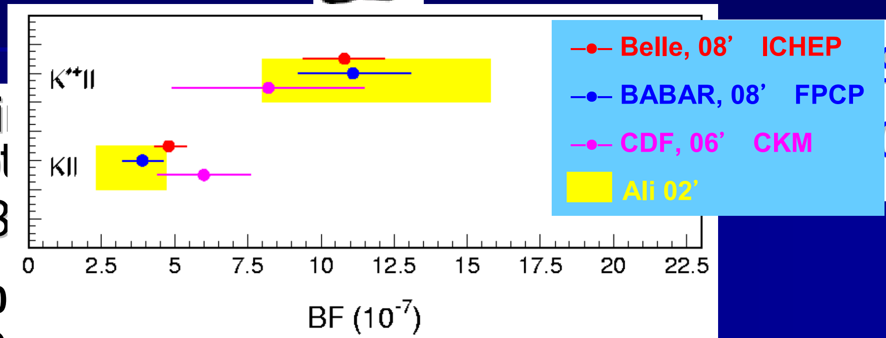
657M, NEW

384M FPCP 08

- Obtain partial BF i… extrapolate the tot…
- BF(B→K*ll)=(10.8… x10^{-7}
- BF(B→Kll)=(4.8 $^{+0}_{-0.4}$…

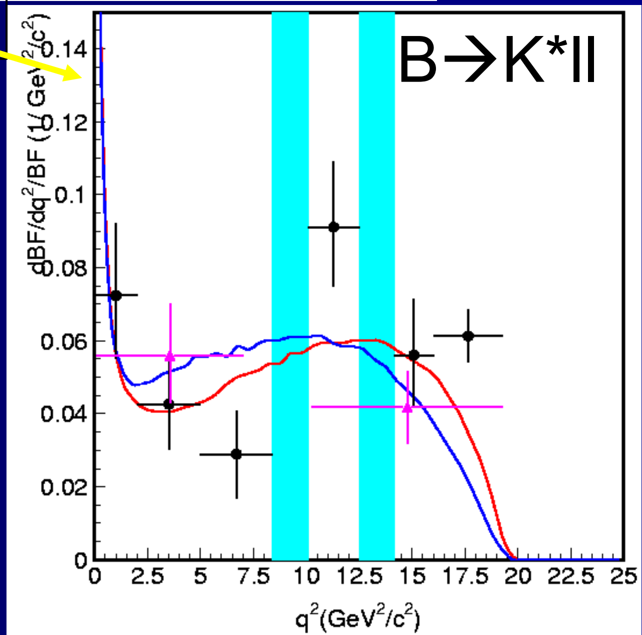
…9±0.7) x10^{-7}

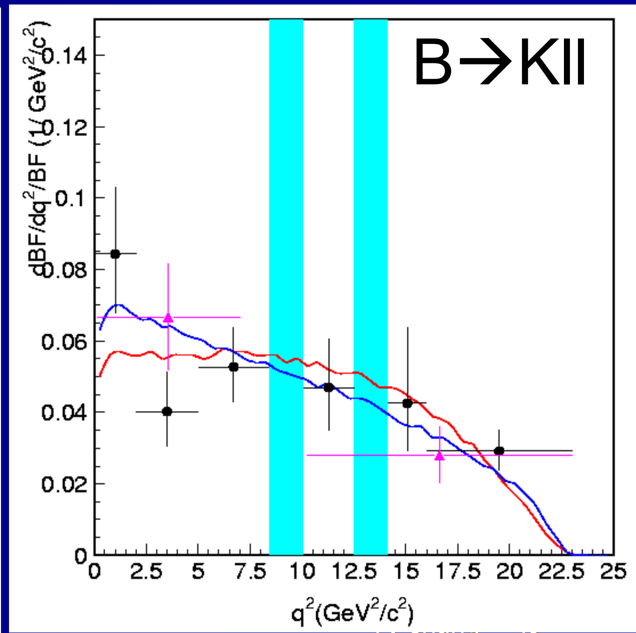
…0.2) x10^{-7}



photon pole

Veto events in the J/ψ and ψ′ regions

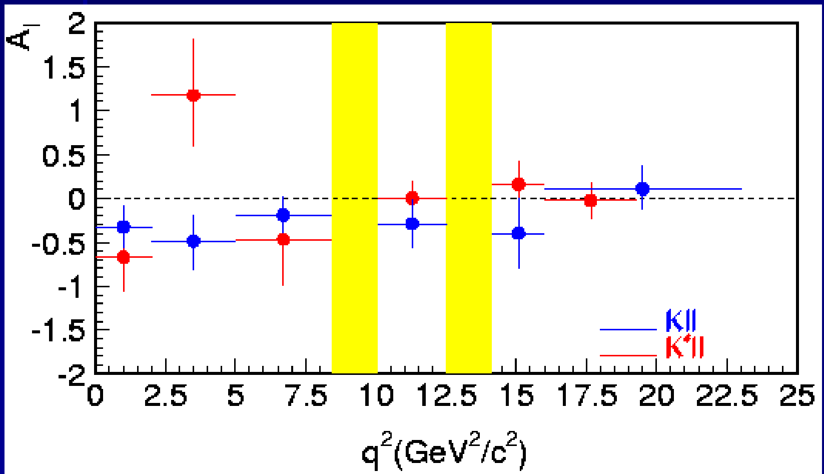


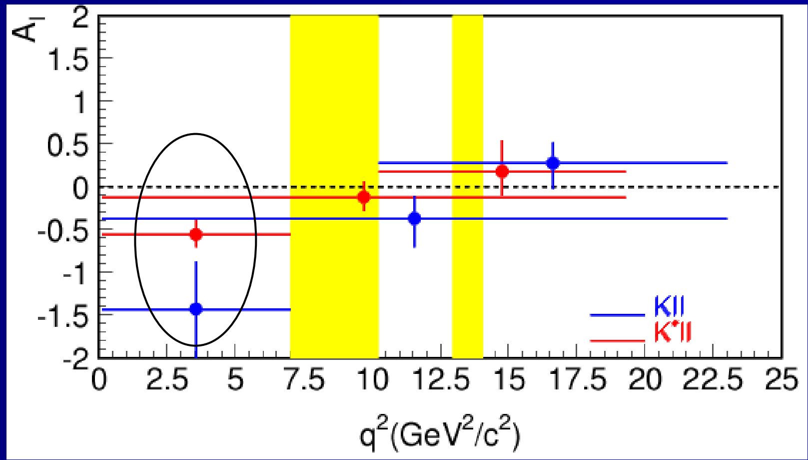


- **Belle, ICHEP 08**
- **BABAR, FPCP 08**
- **Melikhov et. al (quark model, PLB 410, 1997)**
- **Ali (PRD 66, 034002, 290, 2002)**

Unexpectedly Large Isospin Asymmetry?

$$A = \frac{1.071 \times BF(B^0 \to K^{(*)0} ll) - BF(B^\pm \to K^{(*)\pm} ll)}{1.071 \times BF(B^0 \to K^{(*)0} ll) + BF(B^\pm \to K^{(*)\pm} ll)}$$



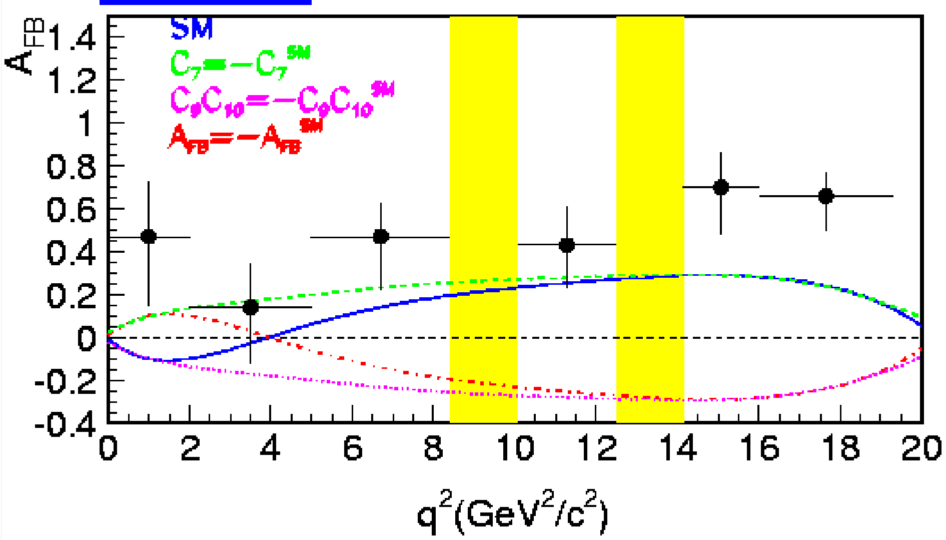


Anomalous $A_{FB}(q^2)$ in $B \to K^{(*)} ll$?

Obtain A_{FB} by a fit: $\frac{3}{4}F_L(1-\cos^2\theta_{Bl})+\frac{3}{8}(1-F_L)(1+\cos^2\theta_{Bl})+A_{FB}\cos\theta_{Bl}$

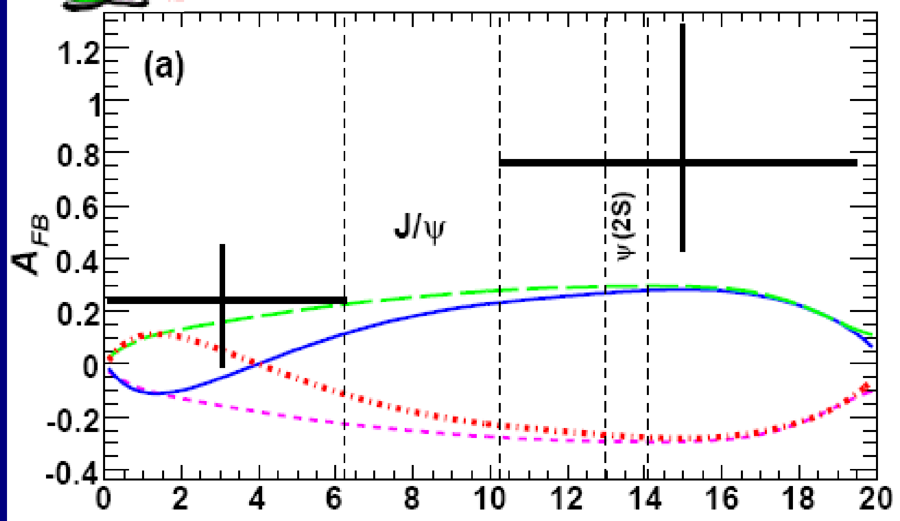
Efficiency corrected

657 M $B\bar{B}$



Data show positive A_{FB} at low q^2, while the SM predicts negative A_{FB}.

384 M $B\bar{B}$

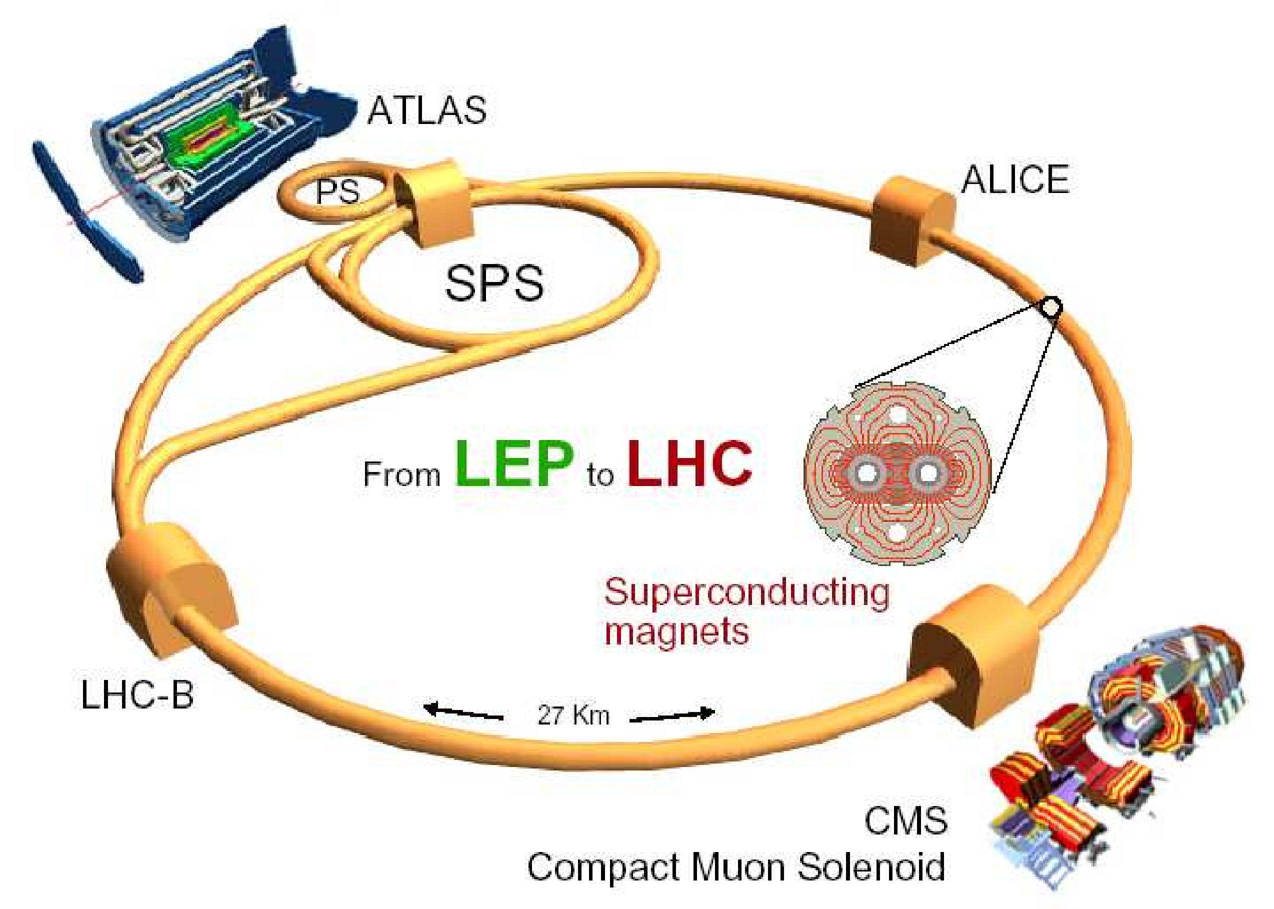


At high q^2, data above the SM expectation.

What’s next?

Four Experiments in LHC

Academia Sinica

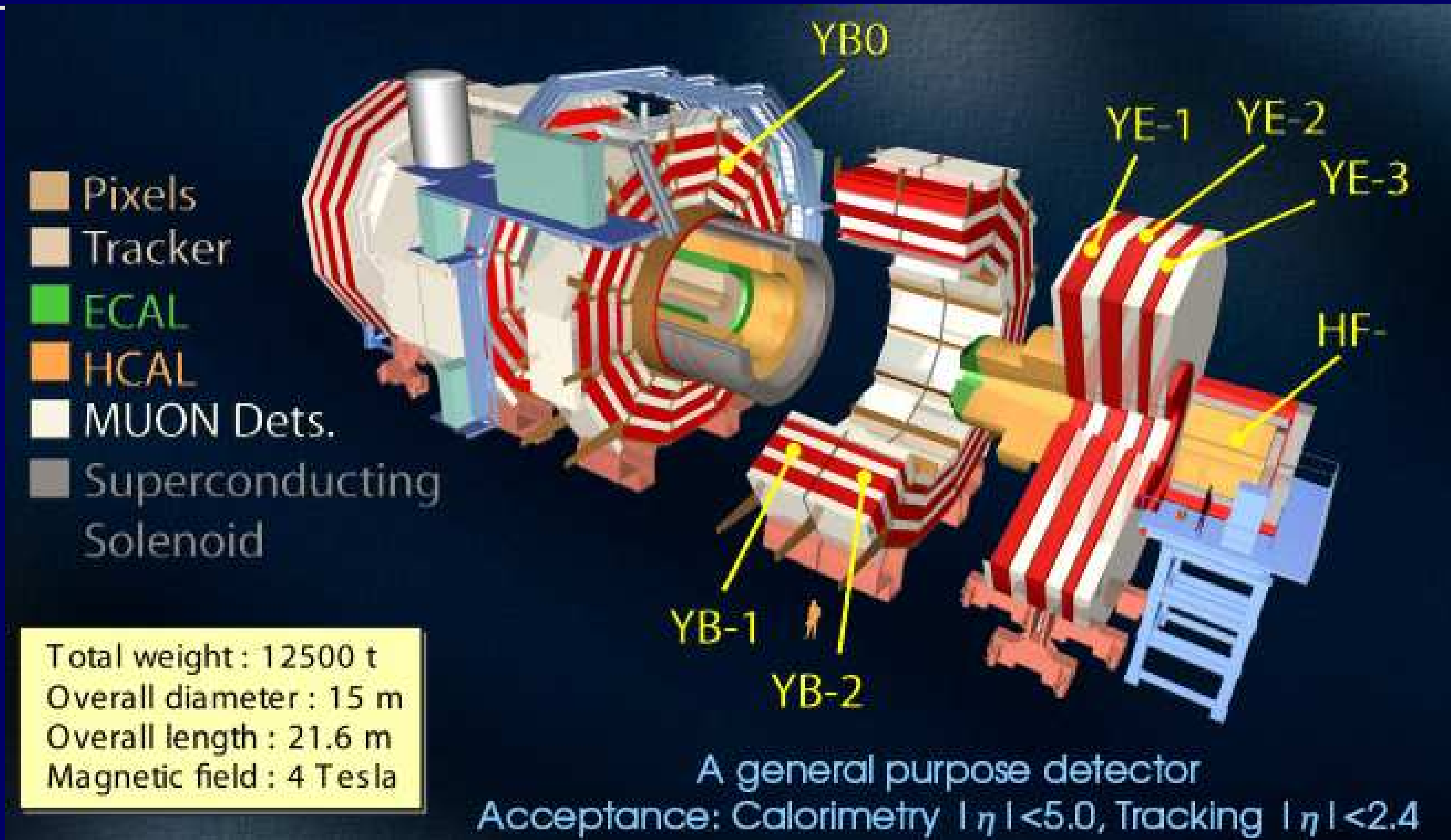


Heavy ions

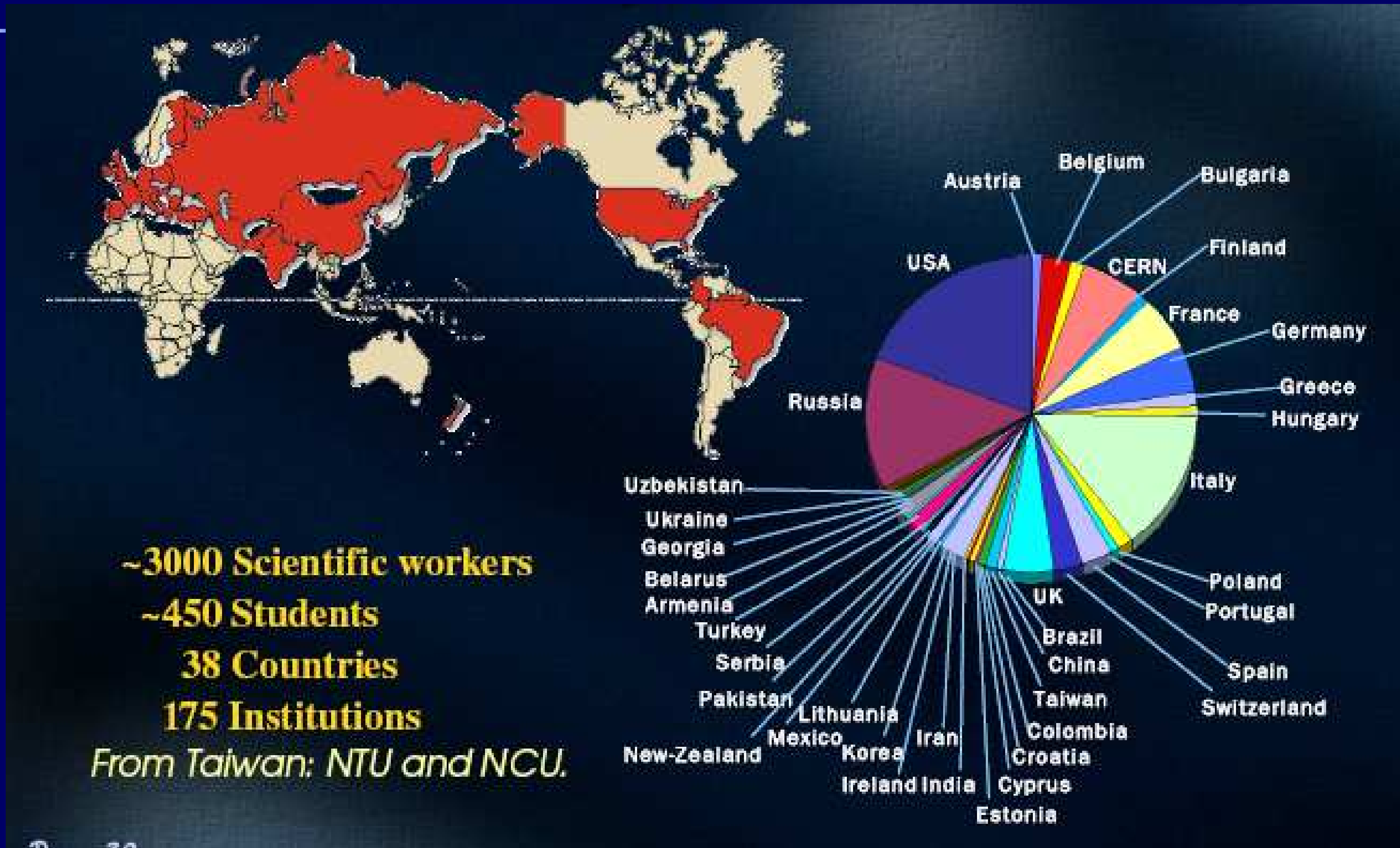
Flavor Physics

NTU & NCU

The CMS detector



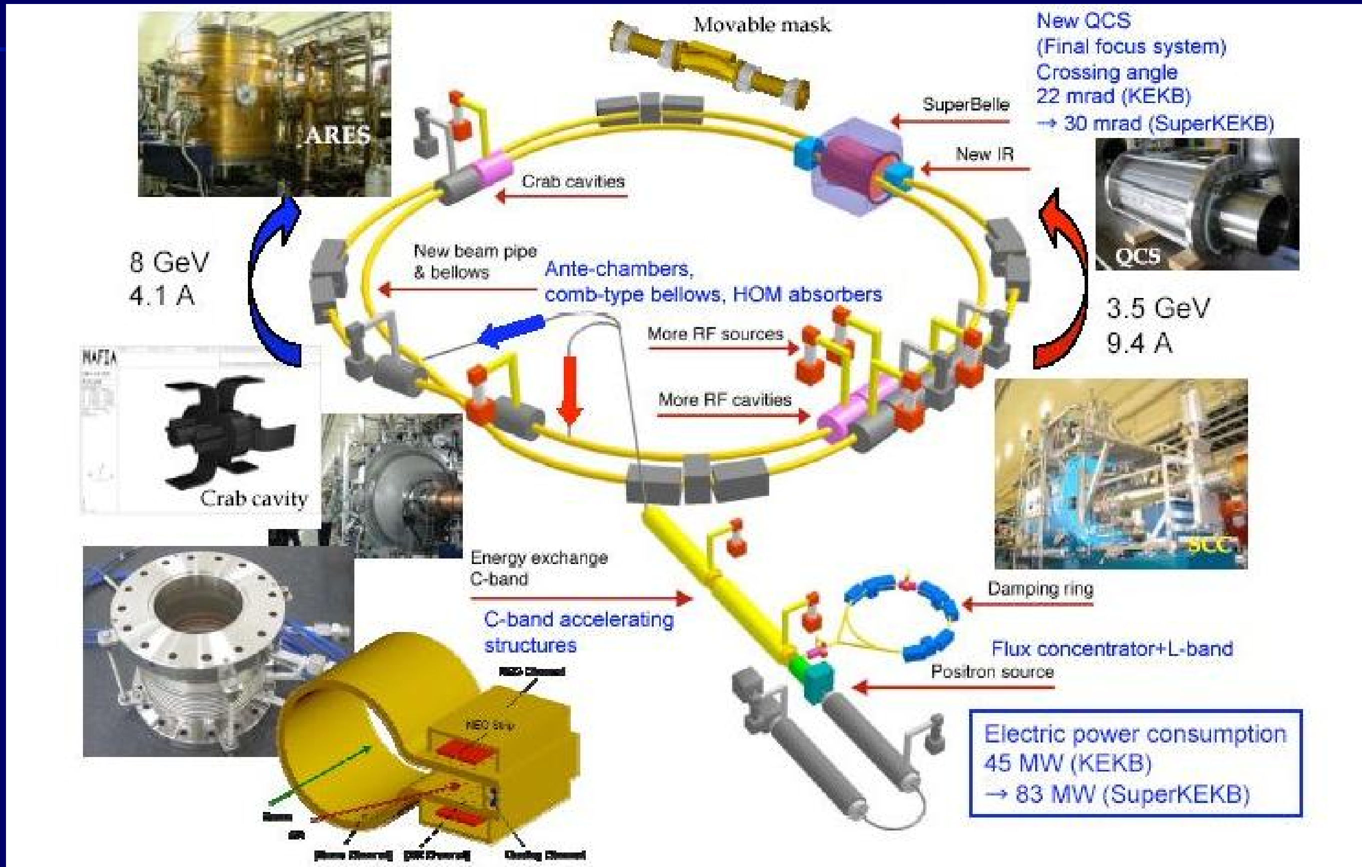
The CMS collaboration



Plan for LHC in 2009-2010

- Repairing 50 magnets and restarting LHC
  in October 2009
- Take data for 44 weeks in 09-10 with
  an extra cost of 8M euros
- A short run with 0.9 TeV first and all
  the way to 10 TeV.
- Expect to collect 300 pb^{-1} of data.

Plan for Super KEKB

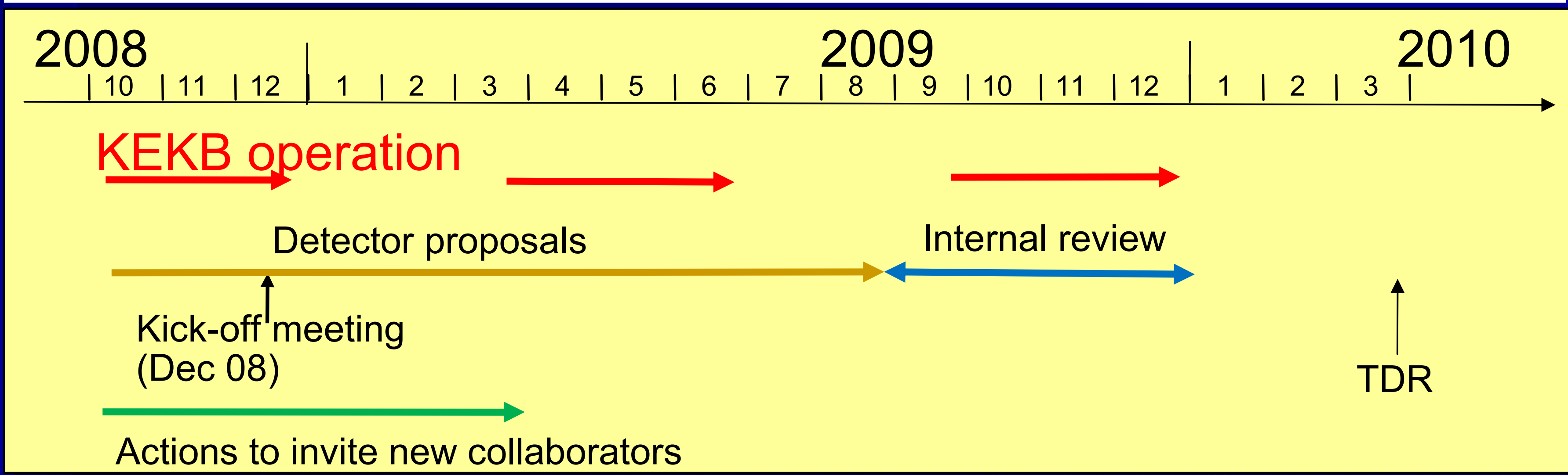


will reach 8×10^{35} cm^{-2}s^{-1}

Expect to start construction in 2010 and take data in 2014

New collaboration (SuperBelle)

- Super Belle will be a new international collaboration.
  - Two proto-collaboration meetings in Mar&Jul, 2008
    - Participation of new people from Germany, India, U.S., Japan,… .
  - Kick-off of the new collaboration: 10th-12th Dec 2008.
    - Still most of the sessions were be open.
- Near-term plan (preliminary)
  - Detector study report has been completed.
  - Detector proposals (by summer 2009).
  - The final detector design by Dec. 2009.



1st open meeting of SuperKEKB Collaboration

KEK, Japan, December 10-12, 2008

Summary

- Nobel prize 2008 – Symmetry breaking
- Human endeavor: achieve a lot but more to explore
- Results start to probe NP but limited by statistics:

  ϕ_{Bs} $B \rightarrow \tau\nu$, A_{FB}, isospin asymmetry

  $\mathcal{B}$(B→Xsγ) strong constraint to NP

  Need much more data to confirm the ΔS puzzle.

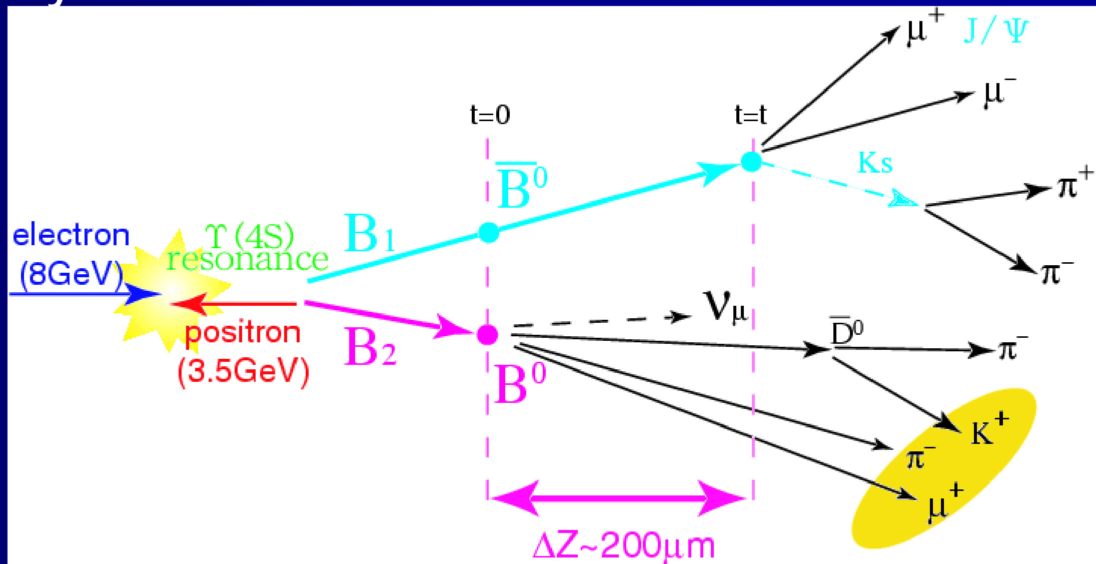
  ΔA explanation ⇒ if from new physics, what is it?
- Future new physics search:

  direct: ATLAS and CMS; indirect: LHCb and Super KEKB

Backup Slides

Measurement in Principle

- Fully reconstruct a CP eigenstate.
- Determine the flavor the tag side.
- From the distance of the two B decay vertices to measure the decay time difference.

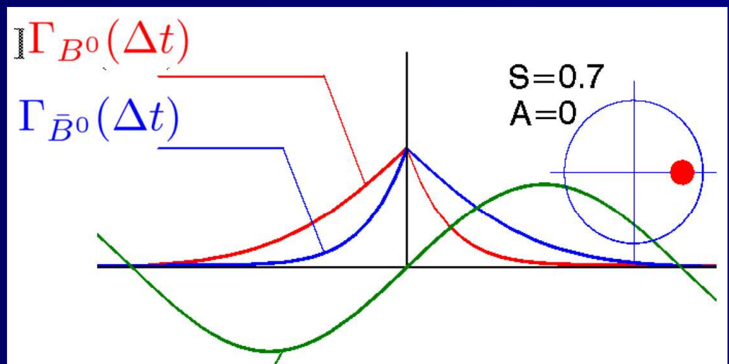


Time dependent CP Asymmetry

$$A_{CP}(t)=\frac{\Gamma(\overline{B}^0\rightarrow f_{CP};t)-\Gamma(B^0\rightarrow f_{CP};t)}{\Gamma(\overline{B}^0\rightarrow f_{CP};t)+\Gamma(B^0\rightarrow f_{CP};t)}=A_f\cos(\Delta m t)+S_f\sin(\Delta m t)$$

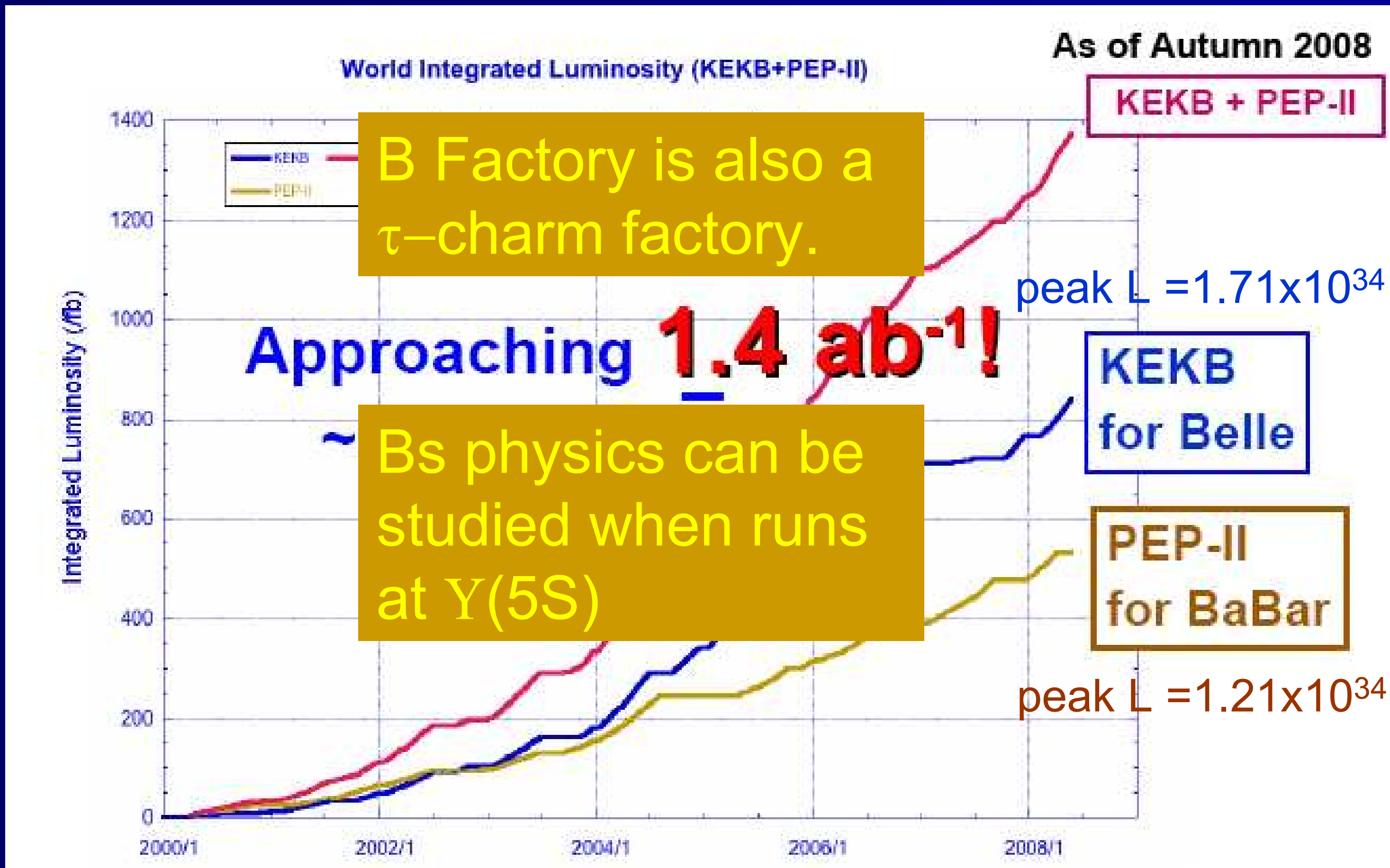
Indicates direct CP violation
$A_f = 0$ if $f_{CP} = J/\psi K_S$
($-A_f = C_f$ in BaBar)

$S_f = \sin 2\phi_1$
if $f_{CP} = J/\psi K_S$

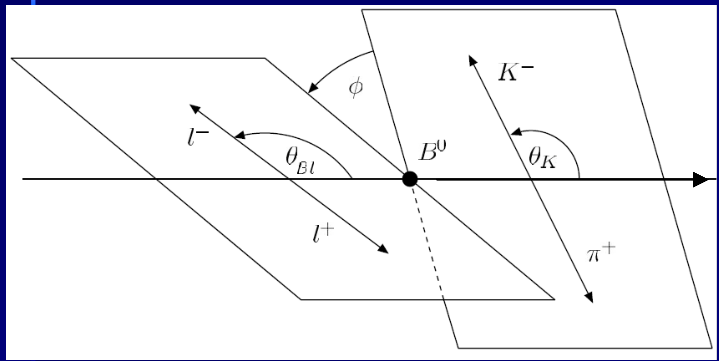


- Asymmetry in Δt shape implies ICPV.
- Difference in area indicates DCPV

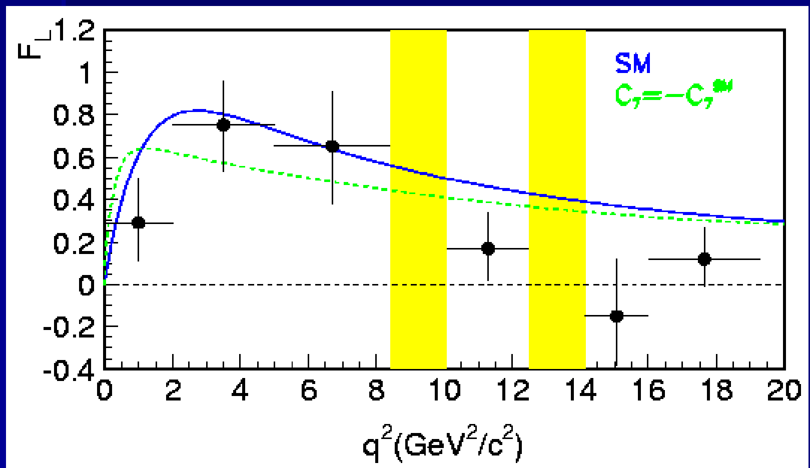
Successful Operation

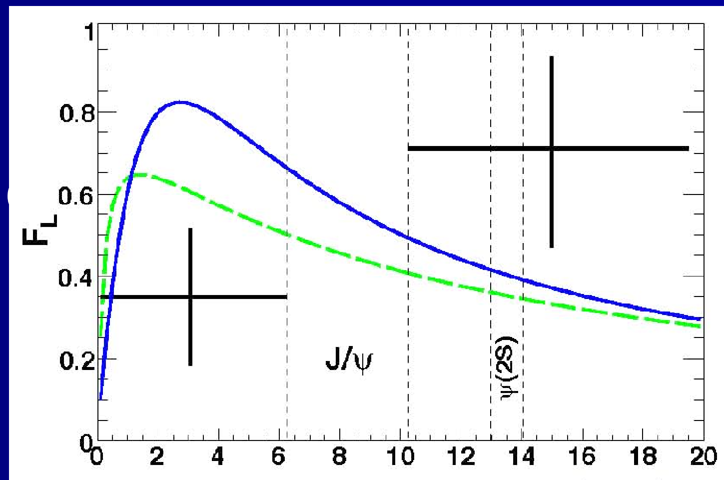


K* Helicity Distribution



$$\frac{3}{2}F_L\cos^2\theta_K+\frac{3}{4}(1-F_L)(1-\cos^2\theta_K)$$





Lepton Flavor & CP Asymmetries

- In SM, R_{K^*} ~ 1.33 and R_K ~1.0.
- R_K is sensitive to the size of photon pole.
- R_K >1.0 in the two Higgs doublet model with large tan β.

(Y. Wang and D. Atwood, PRD 68, 094016, 2003)

$$R_{K^{(*)}} = \frac{\mathcal{B}(B \to K^{(*)} ee)}{\mathcal{B}(B \to K^{(*)} \mu\mu)}$$

A_{CP}

Lepton Asy.	Belle (657M)	BABAR (384M)
$K^*\ell\ell$	1.21±0.25±0.07	$1.37^{+0.53}_{-0.40}$
$K\ell\ell$	0.97±0.18±0.05	$0.96^{+0.44}_{-0.34}$

CP Asy.	Belle (657M)	BABAR (384M)
$K^*\ell\ell$	-0.10±0.10±0.03	-0.02±0.16
$K\ell\ell$	0.04±0.10±0.02	-0.18±0.18

More on A_{FB}

$$\frac{dA_{FB}}{d\hat{s}} \propto -\left\{ \mathrm{Re}(C_9^{eff} C_{10}) V A_1 + \frac{\hat{m}_b}{\hat{s}} \mathrm{Re}(C_7^{eff} C_{10}) \left[V T_2 (1-\hat{m}_{K^*}) + A_1 T_1 (1+\hat{m}_{K^*}) \right] \right\}$$

- $C_7 = -C_7^{SM}$? If yes, $\mathcal{B}$ will change!

The sign of C_7 is constrained by $\mathcal{B}$ (Xsll).

Gambino et. al, PRL94, 061803, 05

- **C may be complex due to new physics.**

Hou et. Al, PRD77, 014016, 08