WGVI summary

"Angles from penguin dominated $B_{s/d}$ decays"

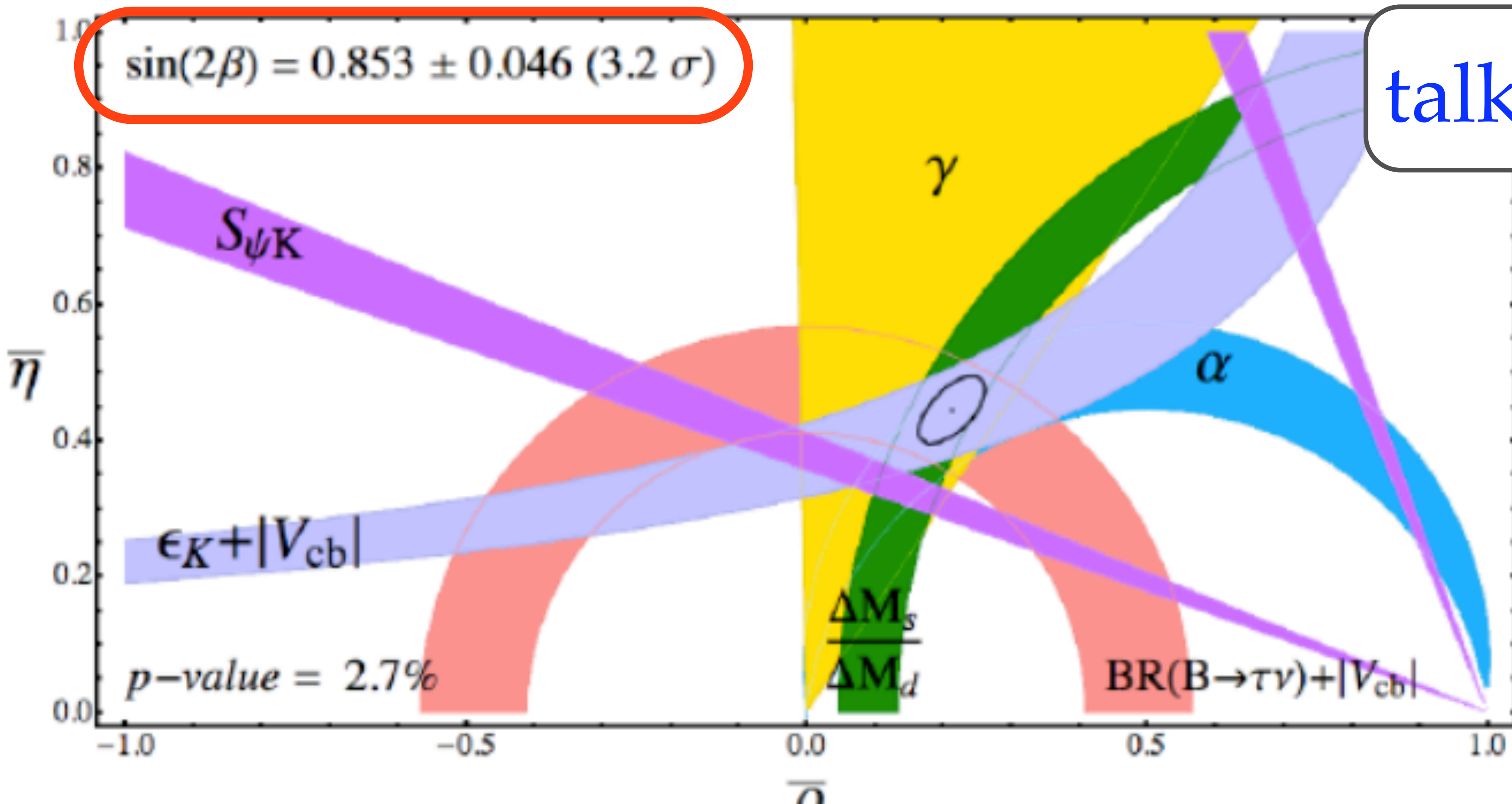
conveners:
Mathew Graham, Diego Tonelli, Jure Zupan

WHAT WAS COVERED

- charmless hadronic B decays
- theory
  - progress on SCET/QCDF and PQCD talks by G. Bell, S. Jager, A. Kagan, S. Mishima
  - use of SU(3)/U-spin for γ extr. talk by Fleischer
  - CKM fits talk by Soni
- experiment (present and future) talk by E. Manoni
  - angles:
    - β from penguins talks by T. Aushev, K. Miyabayashi
    - α from tree talks by J. Dalseno, S. Stracka
    - γ from charmless talks by E. Puccio, A. Carbone
  - Br and direct CP asymmetries in $B_{(s)}\to hh$ talks by Y. Unno, C. Lee
  - polarizations in $B_{(s)}\to VV$ talks by M. Dorigo, G. Vasseur

The rise & demise of the CKM-paradigm

$\sin(2\beta)$ - ε_K - $\Delta M_{Bs}/\Delta M_{Bd}$ - $|V_{cb}|$ - $B\to\tau\nu$ - α - γ



talk by A. Soni

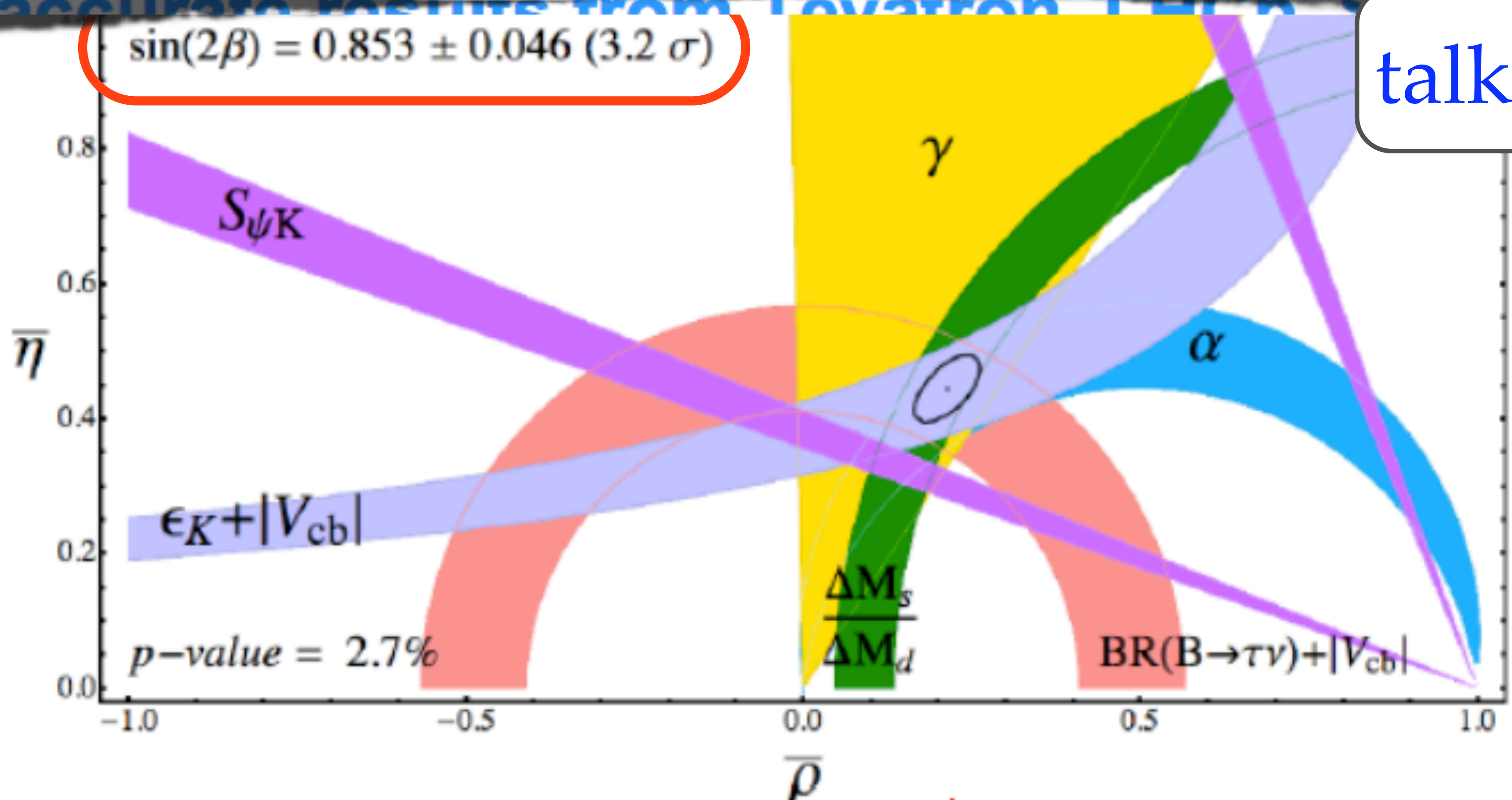
INCLUDE τ to predict Sin2β

- Though CKM works ~15-20% accuracy, several ~2-3 σ deviations have been revealed..These need to be vigorously pursued.

  Taking these hints seriously, model independent analysis suggests new physics with CP-odd phase with scale below ~few TeV is most likely needed.

- SM4 offers a rather simple explanation…
- More accurate results from Tevatron, LHCb, S

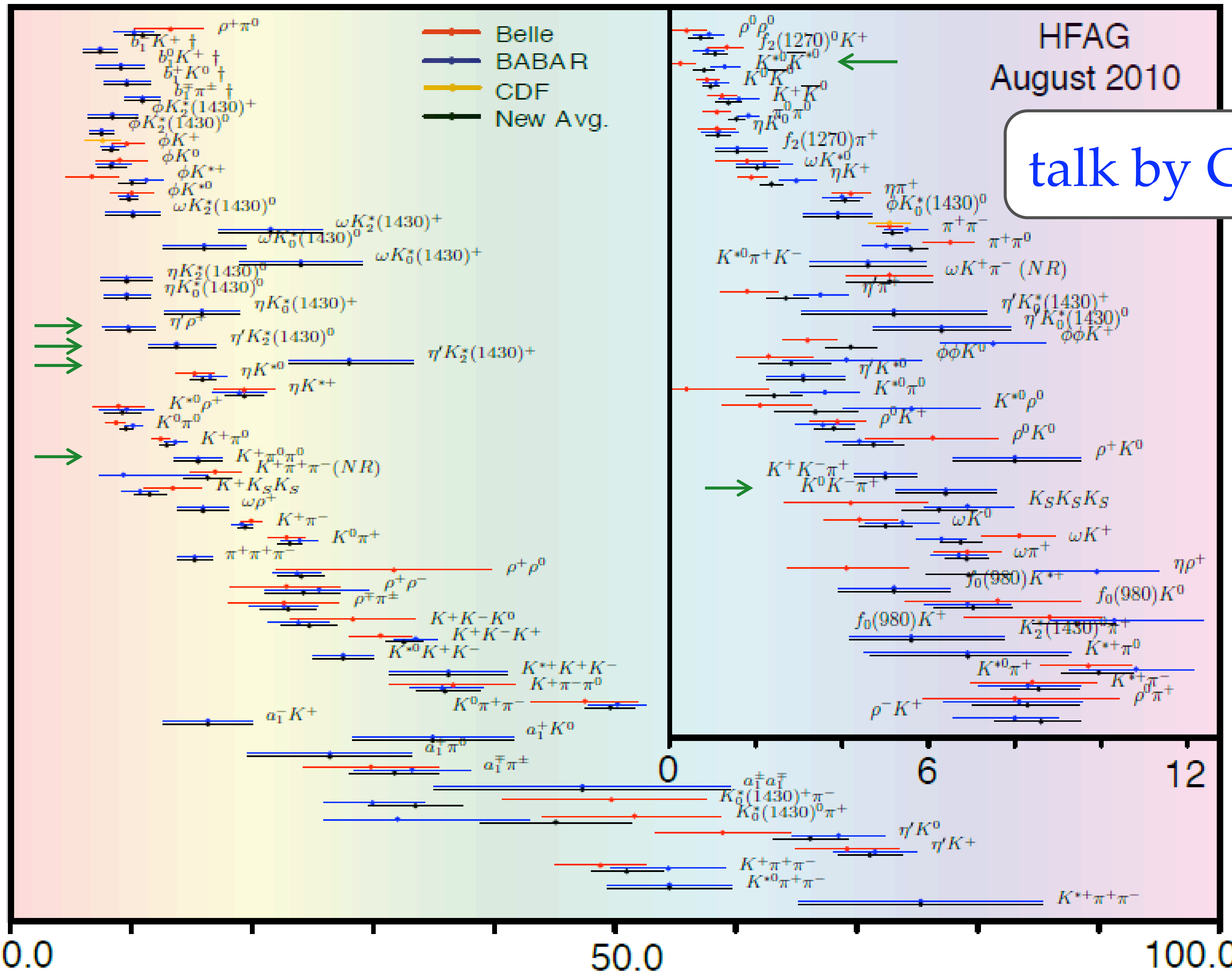
talk by A. Soni



INCLUDE τ to predict Sin2β

Charmless B Decays Overview

- ~100 charmless B decays have been measured with $> 4\sigma$ significance.



talk by C. Lee

Charmless B Decays Overview

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Experimental Results from 2010

talk by C. Lee

BABAR

- $B \to \eta' \rho, \eta' f_0$, and $\eta' K^*$, where $K^* = K^*(892)$, $K_2^*(1430)$, and $K_0^*(1430) + (K\pi)$ S–wave
- $B^+ \to a_1^+(1260) K^{*0}(892)$
- Inclusive $B^0 \to K_S^0 K^\pm \pi^\mp$
- Inclusive $B^+ \to K^+ \pi^0 \pi^0$

BELLE

- $B^0 \to K^{*0} \overline{K^{*0}}, K^{*0} K^{*0}, K^+ \pi^- K^\mp \pi^\pm$
- $B_S^0 \to hh$ $(h = K^+, K^0, \pi^+)$

0.0 50.0 100.0

QCDF,SCET,PQCD

THEORY OF $B \to hh$

talk by G. Bell

QCDF / SCET / pQCD

	BBNS (QCDF)	BPRS (SCET)	pQCD
$\alpha_s(\sqrt{\Lambda m_b})$	perturbative	non-perturbative	perturbative
charm loops	perturbative (small phase)	non-perturbative (large phase from fit to data)	perturbative (small phase)
weak annihilation (power correction)	non-perturbative (crude model, arbitrary phase)	perturbative (with zero bins, small phase)	perturbative (large phase)
strong phases	generically small ($\sim \alpha_s, 1/m_b$)	can be sizeable (charm loops)	can be sizeable (annihilation, Glaubers)
perturbative calculation	partially NNLO	NLO	partially NLO
hadronic input	from lattice + QCD sum rules	from QCD sum rules + data, model $\xi_J^{BM}(z)$	from QCD sum rules + data, model $\phi_B(x, b)$

- theory predictions for direct CP asymmetries can differ a lot!
- measurements (even bounds) of pure annihilation decays highly appreciated:
  $B_d \to K^- K^+, B_s \to \pi\pi/\pi\rho/\rho\rho$

THEORY OF $B \to hh$

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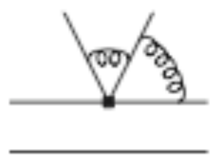
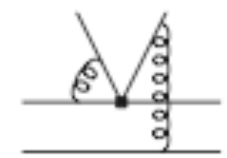
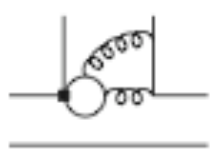
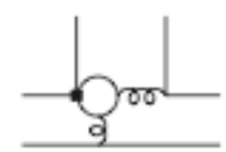
PROGRESS ON QCDF/SCET

- tree amplitudes: talk by G. Bell
- penguin amplitudes: talk by S. Jager

Status	2-loop vertex corrections (T_i^I)	1-loop spectator scattering (T_i^{II})
Trees	 [GB 07, 09] [Beneke, Huber, Li 09]	 [Beneke, Jäger 05] [Kivel 06] [Pilipp 07]
Penguins	 [in progress]	 [Beneke, Jäger 06] [Jain, Rothstein, Stewart 07]

- factorization found to hold (as expected) at highly non-trivial order
- direct CP asymmetries not yet available at NNLO
- first NNLO results for CP-averaged branching ratios of tree-dominated decays

[GB, Pilipp 09; Beneke, Huber, Li 09]

talk by G. Bell

PROGRESS ON QCDF/SCET

- tree amplitudes: talk by G. Bell
- penguin amplitudes: talk by S. Jager

▶ colour-allowed tree α_1: precise prediction, supported by data

▶ colour-suppr. tree α_2: suffers from hadronic uncertainties

data seem to prefer larger values (smaller λ_B?)

Further refinements possible with experimental input

▶ λ_B from $B \to \gamma\ell\nu$ with energetic photon

▶ $B \to \rho\ell\nu$ spectrum to determine $|V_{ub}|A_0^{B\rho}(0)$

▶ tree-dominated B_s decays

▶ pure annihilation decays $B_d \to K^-K^+$, $B_s \to \pi\pi/\pi\rho/\rho\rho$

talk by G. Bell

PROGRESS ON QCDF/SCET

Summary

penguin amplitudes

- Dynamical description of penguin amplitudes

  - well-defined $1/m_b$ expansion, leading terms factorize with a stable perturbation expansion

  - one potentially large missing piece (in a_6)

  - leading-power long-distance charm penguin dead

- Data

  - clearly respects the hierarchies predicted by the HQ expansion (PP, VP versus PV, VV)

  - on direct CP asymmetries doesn't fit well with theory: either higher orders in a_6 are important, or annihilation terms are large, or there is new physics in some amplitudes, or a combination of these

talk by S. Jager

THE SIZE OF POWER CORRECTIONS?

- the puzzles in the data:

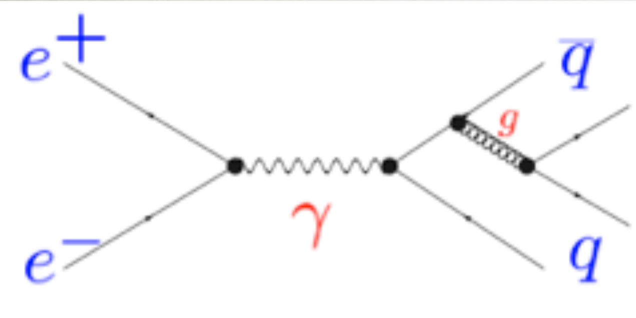
- in $B \to PP$:
  - $\mathrm{Br}(K^0\pi^0)$, $\mathrm{Br}(\pi^0\pi^0)$ too small
  - $A_{CP}(\pi^+\pi^-)$ too small; $A_{CP}(K^+\pi^-)$ has wrong sign and magnitude too small
  - $A_{CP}(K^+\pi^-) \approx A_{CP}(K^+\pi^0)$ contrary to observation

talk by A. Kagan

- in $B \to VP$:
  - $B \to \phi K$ and $B \to K^*\pi$ rates too small
- in $B \to VV$
  - $B \to \phi K^*$, $B \to K^*\rho$ longitudinal polarization fractions (≈ 1) much larger than observed ($\approx 50\%$)

- A. Kagan: soft overlaps can be large

USING INFO FROM $e^+e^- \to hh$



$\propto \langle M_1 M_2 | \bar{q}\gamma_\mu q | 0 \rangle$

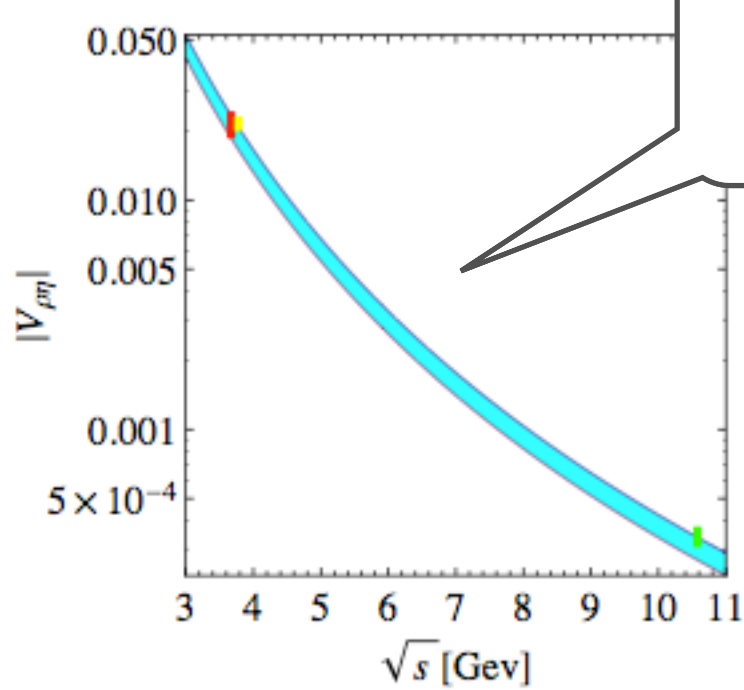
talk by A. Kagan

CLEO-c data implies

$$\frac{\delta F_\pi^{\text{non-pert.}}}{\delta F_\pi^{\text{pert.}}} = O(10), \qquad \frac{\delta F_K^{\text{non-pert.}}}{\delta F_K^{\text{pert.}}} = O(10)$$

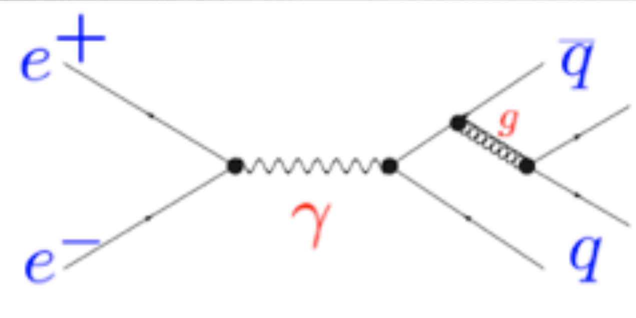
$\Rightarrow$ very large soft-overlaps !

check $\sqrt{s}$ dependence of $e^+e^- \to M_1 M_2$ form factors, e.g.,
$V_{\rho\eta} \propto 1/s^2$ (CLEO-c, BELLE):



really p.c. dominated,
the scaling is right

USING INFO FROM $e^+e^- \to hh$



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talk by A. Kagan

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B physics fits: power.c. of order leading pow.

check $\sqrt{s}$ dependence of $e^+e^- \to M_1 M_2$ form factors, e.g., $V_{\rho\eta} \propto 1/s^2$ (CLEO-c, BELLE):

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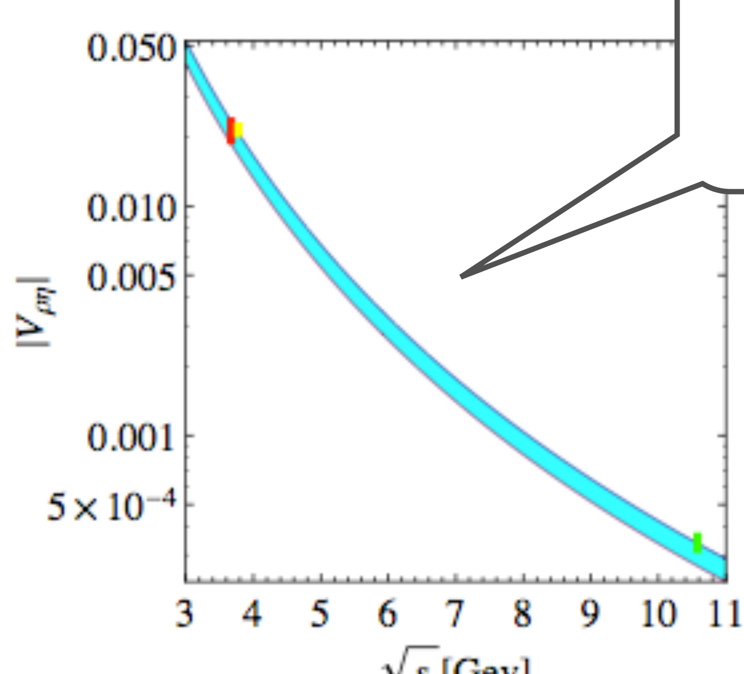
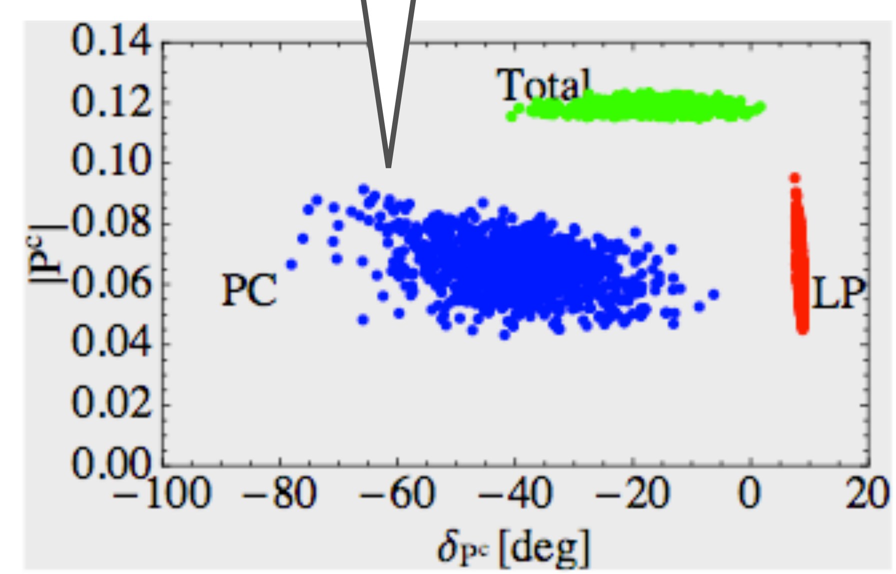




$K\pi$ scatter plot for $|\delta P^c|$ vs. δ_{P^c}

PQCD

- S. Mishima diff. resolution: resummed Glabuer gluons

Soft contribution to C

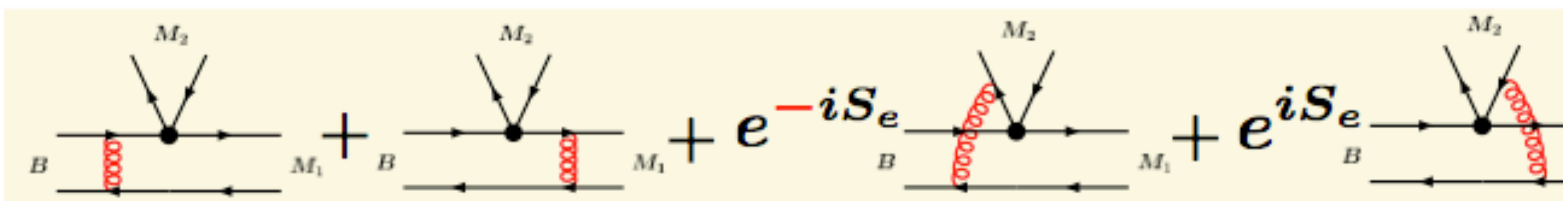
Li,

talk by S. Mishima

- "Modified" factorization formula:

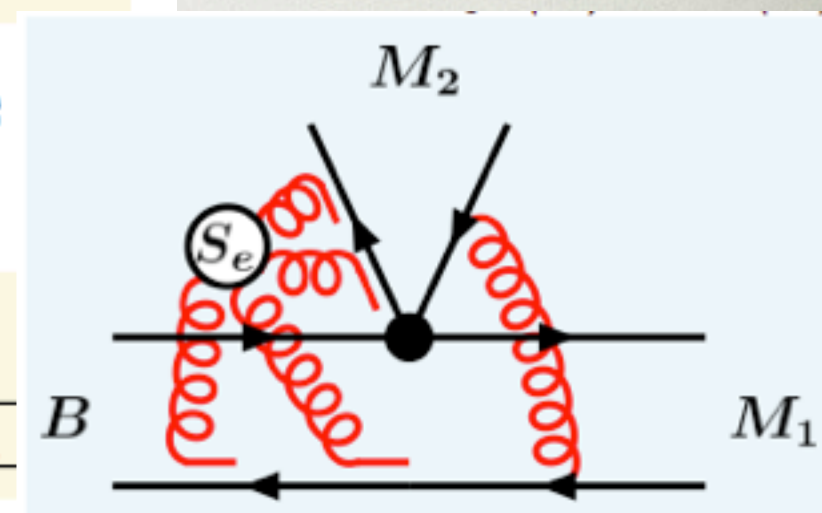
$$\mathbf{Amp.} \sim \Phi_{M_1} \otimes \Phi_{M_2} \otimes H \otimes \Phi_B \otimes (\mathbf{Sudakov}) \otimes e^{\pm i S_e}$$

- The presence of S_e may convert a destructive interference into a constructive one.



small in C (large in T, P)

almost cancel if Se=0

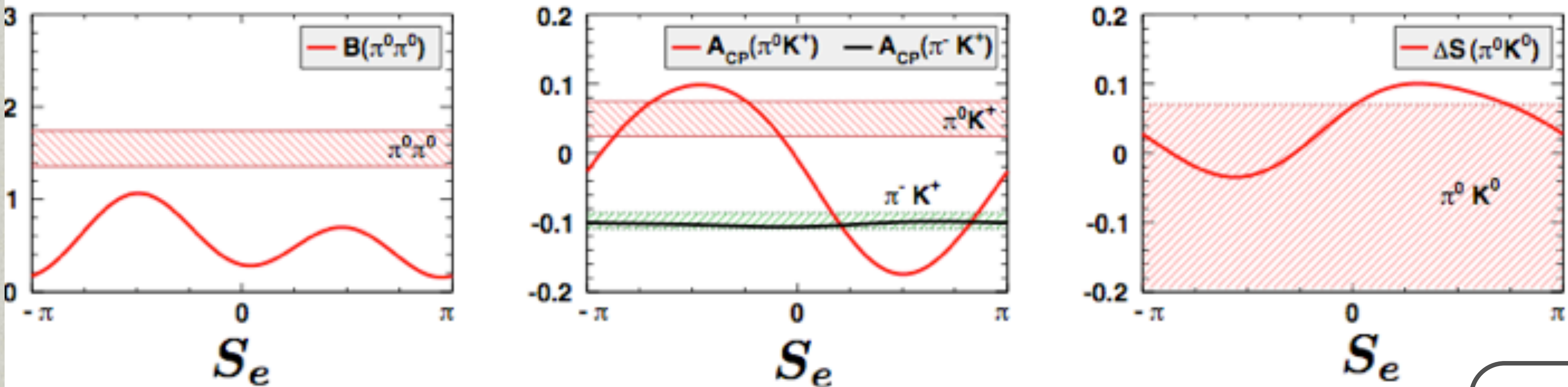


- The soft factor should be studied by nonpert. methods, but we treat it as a parameter.
- C could be enhanced, while T and P are unchanged.

PQCD

Resolution of the $B \to \pi\pi, \pi K$ puzzles

Li, S.M. (09)



- $S_e(\pi\pi) \approx S_e(\pi K)$.
- The $B \to \pi\pi, \pi K$ puzzles can be resolved simultaneously for $S_e \sim -\pi/2$. ⇢ $\frac{C}{T} \approx 0.5\, e^{-2.2i}$
  - $B(\pi^0\pi^0)$ can be enhanced.
  - The difference between $A_{CP}(\pi^\mp K^\pm)$ and $A_{CP}(\pi^0 K^\pm)$ can be enlarged.
- A bit smaller $S(\pi^0 K_S)$ is predicted.

talk by S. Mishima

since vacuum m.el.
will it spoil B→PV, VV?

$$e^{iS_e(\mathrm{b})} = \langle 0 | W_+(0,\mathrm{b};-\infty) W_+(0,\mathrm{b};\infty)^\dagger W_-(0,0_T;\infty) W_-(0,0_T;-\infty)^\dagger | 0 \rangle$$

$$W_\pm(z^\pm, z_T; \infty) = P \exp\left[-ig \int_0^\infty d\lambda n_\pm \cdot A(z+\lambda n_\pm)\right]$$

depends on the transverse separation

15/22 Satoshi Mishima (DESY)

ANGLES

ALPHA

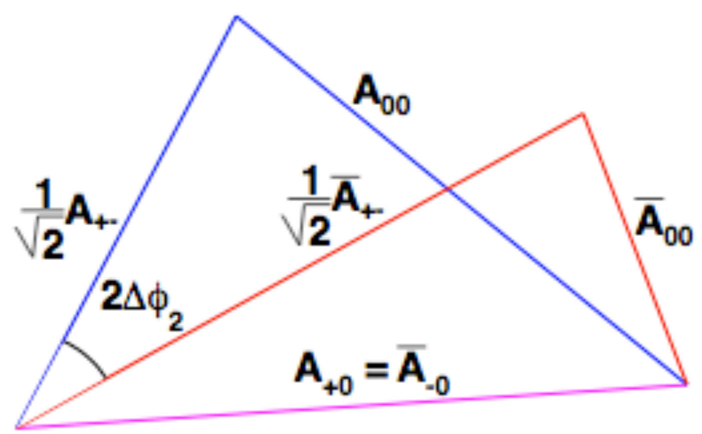
Measurement of ϕ_2 in $B \to \pi\pi$, $\rho\pi$ and $\rho\rho$

Recent results from BaBar

PRL **102** 141802 (2009)

$\mathcal{B}(B^+ \to \rho^+\rho^0) = (23.7 \pm 1.4 \pm 1.4) \times 10^{-6}$

Precise measurement of isospin triangle base



talk by J. Dalseno

$f_L = 0.950 \pm 0.015 \pm 0.006$

Dominantly longitudinally polarised

$\mathcal{A}_{CP} = 0.054 \pm 0.055 \pm 0.010$

No evidence for electroweak penguins

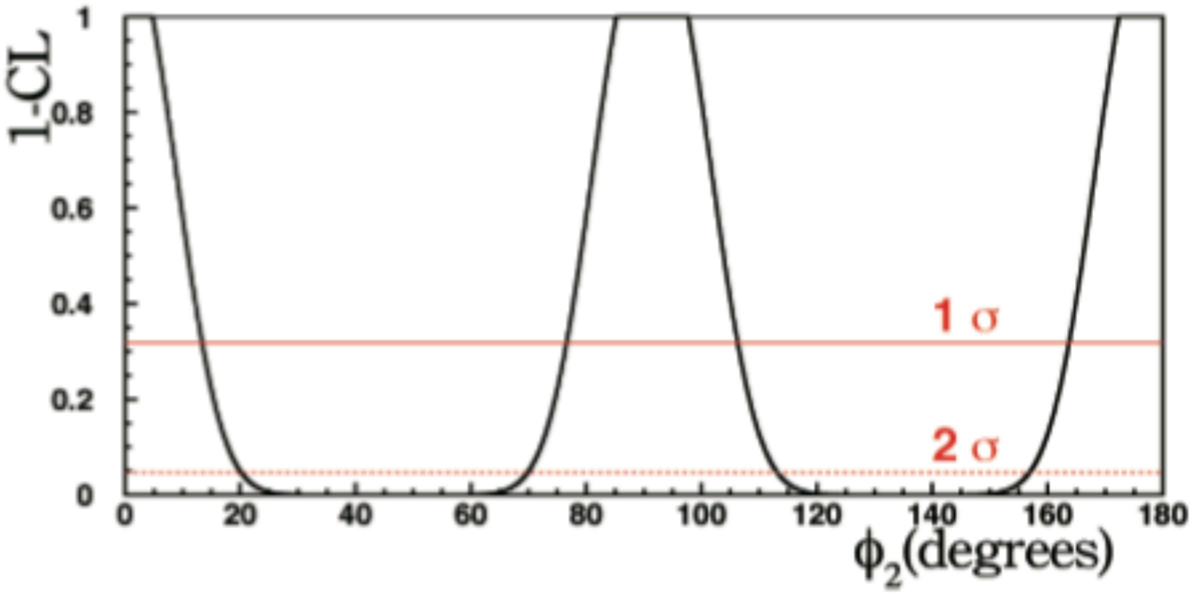
Belle will update this analysis soon with ∼10 times statistics

Measurement of ϕ_2 in $B \to \pi\pi$, $\rho\pi$ and $\rho\rho$

Belle

Use Belle results for $\mathcal{B}(\rho^0\rho^0)$, otherwise WA

Before BaBar's $B^+ \to \rho^+\rho^0$ update



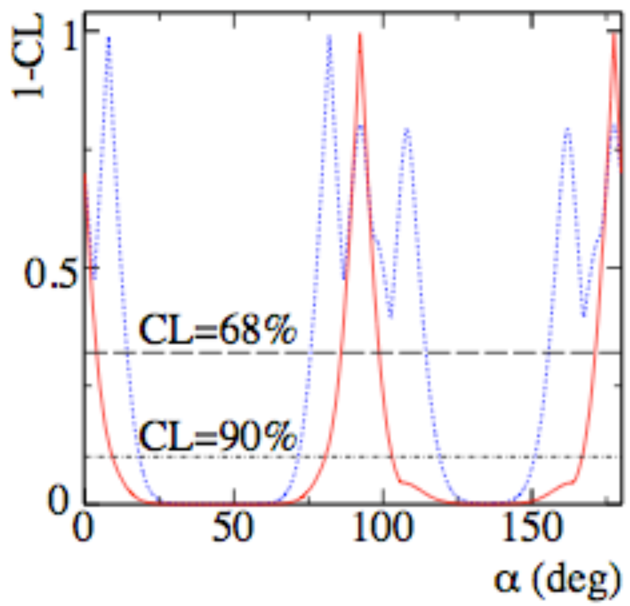
Plateau due to no constraint on $\mathcal{A}_{CP}(\rho^0\rho^0)$

$\phi_2 = (91.7 \pm 14.9)^\circ$

BaBar

PRL **102** 141802 (2009)

Use BaBar results only



Blue: Before $\mathcal{B}(B^+ \to \rho^+\rho^0)$ increase

$\phi_2 = (92.4^{+6.0}_{-6.5})^\circ$

$B \to \rho\rho$ currently the best environment for constraining ϕ_2 because of relatively small penguins

talk by J. Dalseno

Measurement of ϕ_2 in $B \to \pi\pi$, $\rho\pi$ and $\rho\rho$

Summary

talk by J. Dalseno

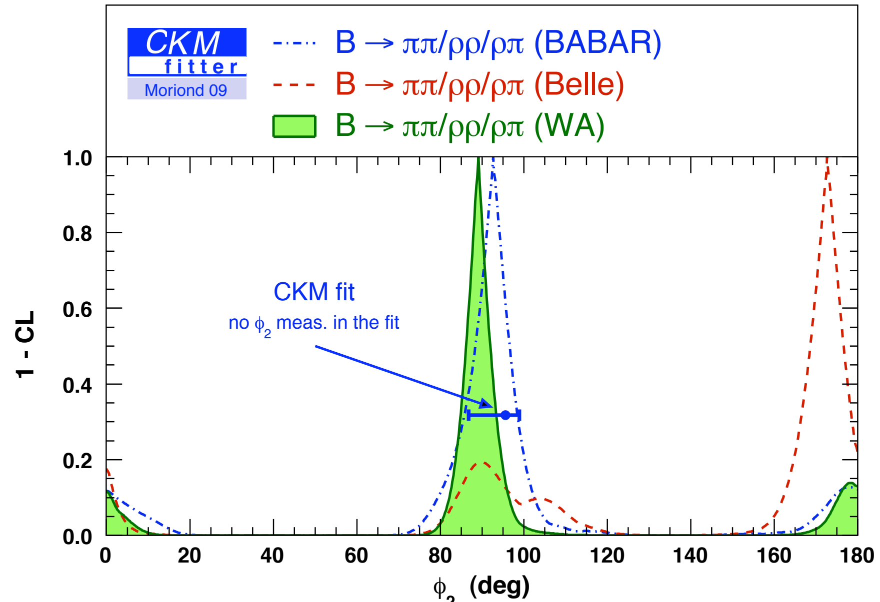
Many measurements of ϕ_2 performed by the B factories

$B \to \rho\rho$ currently gives tightest constraint on ϕ_2

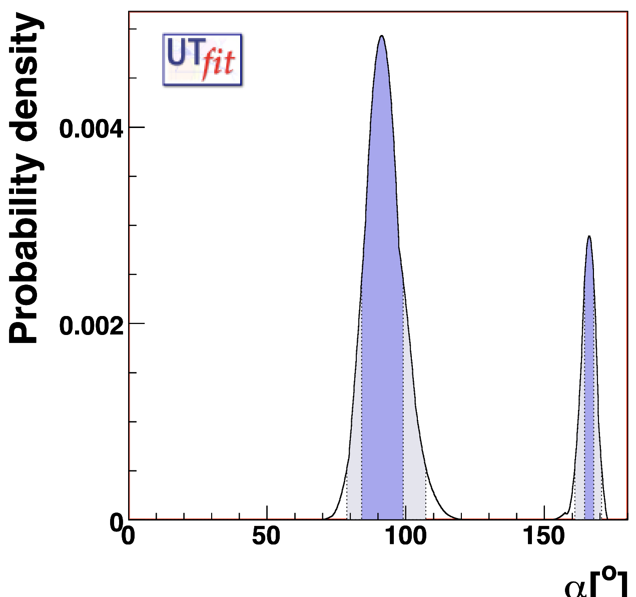
But only $B^0 \to (\rho\pi)^0$ can ultimately constrain ϕ_2 without ambiguity

Both experiments have final data sets taken at $\Upsilon(4S)$ resonance

Many final results from the B factories still anticipated



$\phi_2 = (89.0^{+4.4}_{-4.2})^\circ$



$\phi_2 = (92.0 \pm 3.4)^\circ$

Determination of α/ϕ_2 from $B \to a_1\pi$ and $B \to K_{1A}\pi$ decays

Extraction of bounds on $\Delta\alpha$

PRD 81, 052009 (2010)

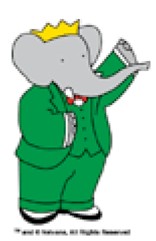
- MC trials: generate quantities from experimental distributions
  - For each set of values, solve system of inequalities for $\Delta\alpha$

$BF(a_1^{\pm}\pi^{\mp})$ $[10^{-6}]$	$BF(a_1^{-}K^{+})$ $[10^{-6}]$	$BF(a_1^{+}K^{0})$ $[10^{-6}]$	$BF(K_{1A}^{+}\pi^{-})$ $[10^{-6}]$	$BF(K_{1A}^{0}\pi^{+})$ $[10^{-6}]$
$33.2 \pm 3.8 \pm 3.0$	$16.3 \pm 2.9 \pm 2.3$	$34.8 \pm 5.0 \pm 4.4$	14^{+9}_{-10}	<36
f_π (MeV)	f_K (MeV)	f_{a1} (MeV)	f_{K1A} (MeV)	θ [°]
130.4 ± 0.2	155.5 ± 0.9	203 ± 18	207 ± 20	72

$$\cos 2(\alpha_{\rm eff}^{\pm} - \alpha) \geq (1 - 2R_{\pm}^{0})/\sqrt{1 - (\mathcal{A}_{CP}^{\pm})^2}$$

$$\cos 2(\alpha_{\rm eff}^{\pm} - \alpha) \geq (1 - 2R_{\pm}^{\pm})/\sqrt{1 - (\mathcal{A}_{CP}^{\pm})^2}$$

$$(P/T)_{\rho\rho} < (P/T)_{a_1\pi} \lesssim (P/T)_{\rho\pi} < (P/T)_{\pi\pi}$$

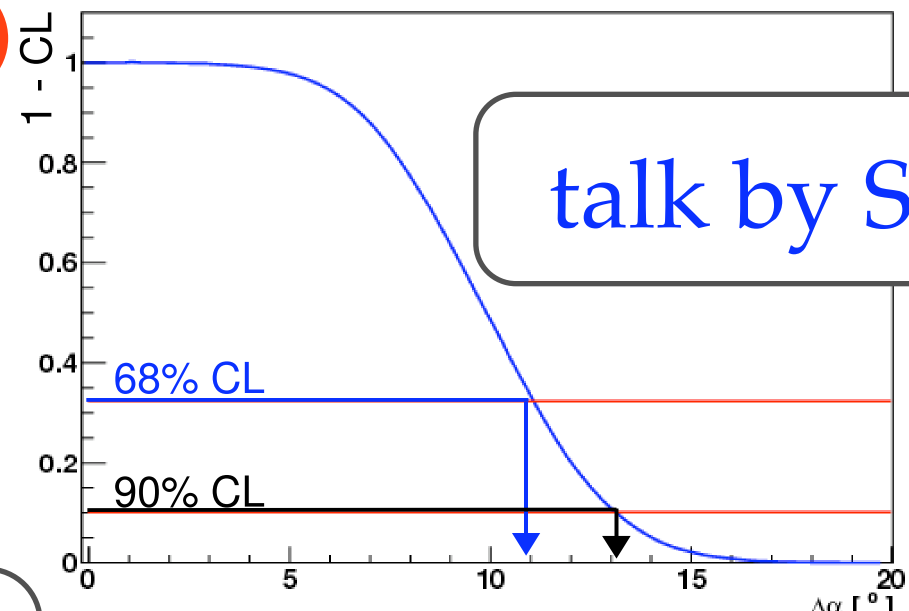


$|\Delta\alpha| < 11^{\circ}$ @ 68% CL

$\Delta\alpha < 13^{\circ}$ @ 90% CL

$\alpha = (79 \pm 7 \pm 11)^{\circ}$

Selected solution compatible with global CKM fits



talk by S. Stracka

SU(3) breaking on the error estimate not in

BETA
(FROM PENGUINS)

$\phi_1(\beta)$ from $B^0 \to K^+K^-K_S$, $\pi^+\pi^-K_S$ and $K_SK_SK_S$

- multiple solutions found with present statistics
  - in $B^0 \to K^+K^-K_S$ 4-fold (Belle), 2-fold(BaBar)
  - in $B^0 \to \pi^+\pi^-K_S$ 2-fold (Belle), 2-fold(BaBar)

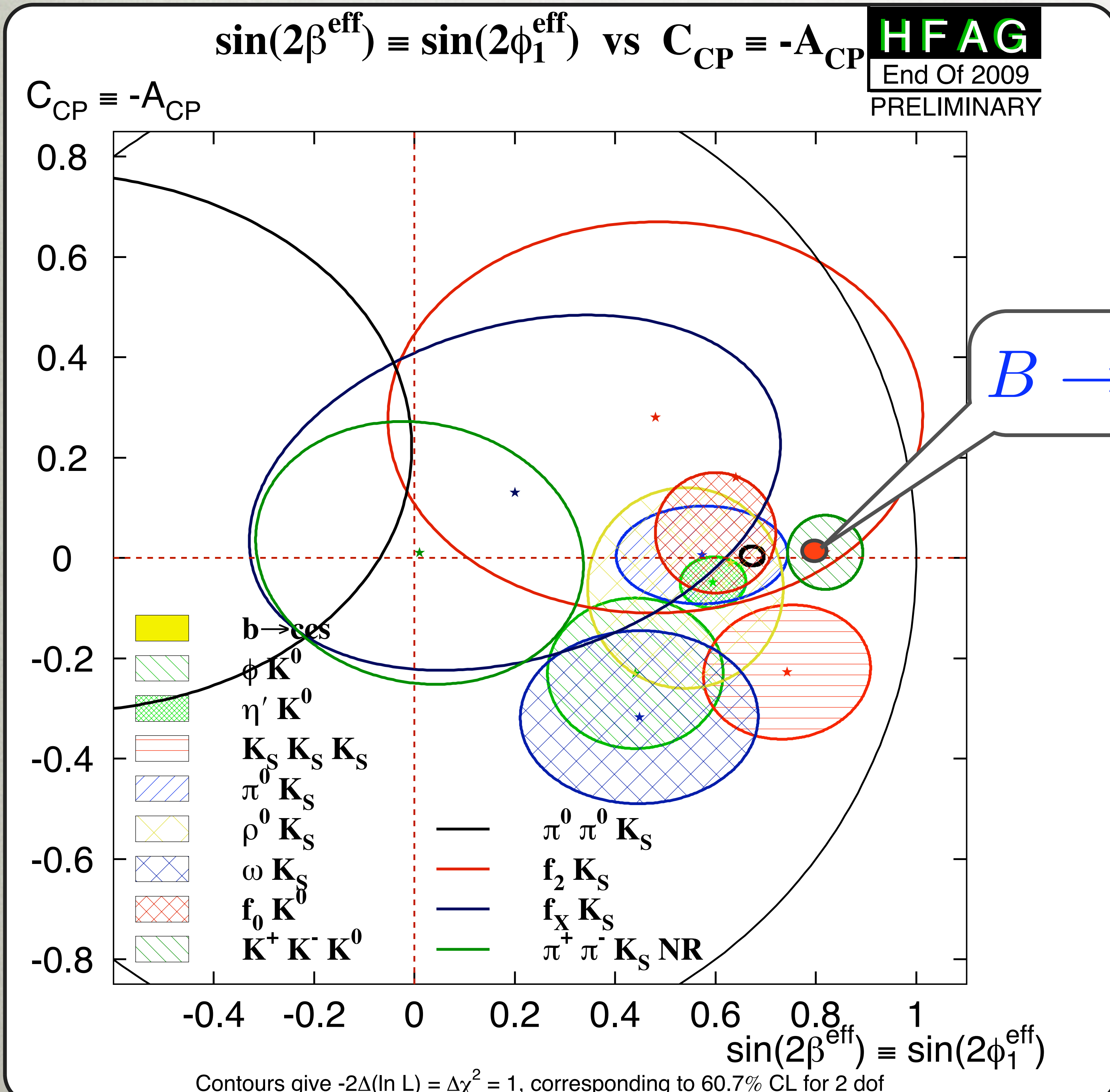
available statistics.

- No significant deviation of effective ϕ_1 with respect to ϕ_1 determined by charmonium modes, so far.
- No significant direct CP violation has been observed so far.
- In Super B-factory statistics (a few×10ab^{-1}), the best solution is supposed to be identified by likelihood value.
- BaBar performed Dalitz analysis for $B^0 \to K_SK_SK_S$.
  - $f_0(1710)$ and $f_2(2010)$ are evident.
  - There would be a chance to measure CP violation parameters for each process with higher statistics.

$BF(B^0 \to K_SK_SK_S) = (6.5 \pm 0.5 \pm 0.4) \times 10^{-6}$

talk by K. Miyabayashi

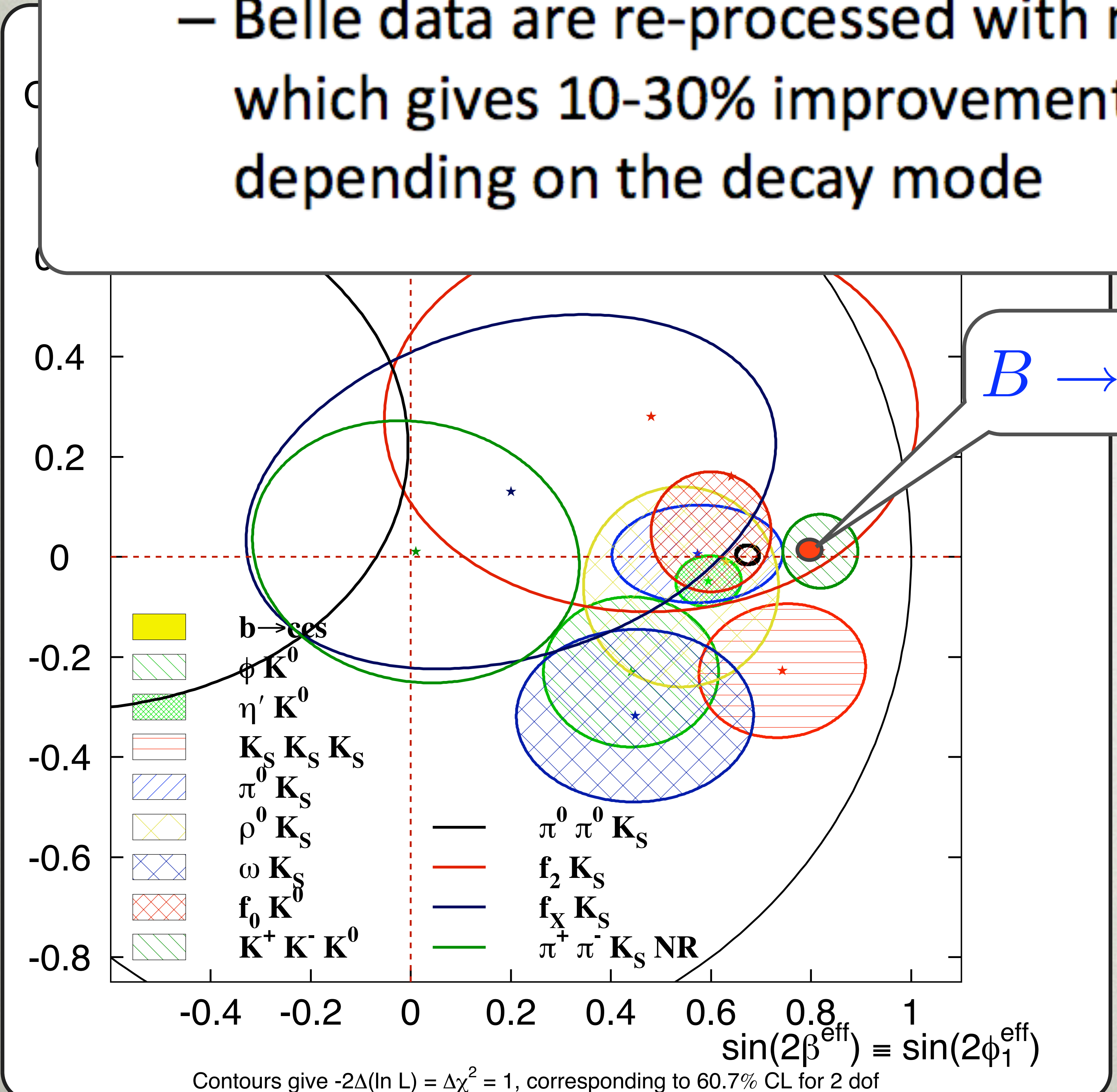
β FROM PENGUINS



$B \to J/\psi K_S$

talk by T. Aushev

- Further improvements are expected from Belle:
  - currently not the whole statistics is used
  - Belle data are re-processed with new reconstruction, which gives 10-30% improvement in the efficiency depending on the decay mode



talk by T. Aushev

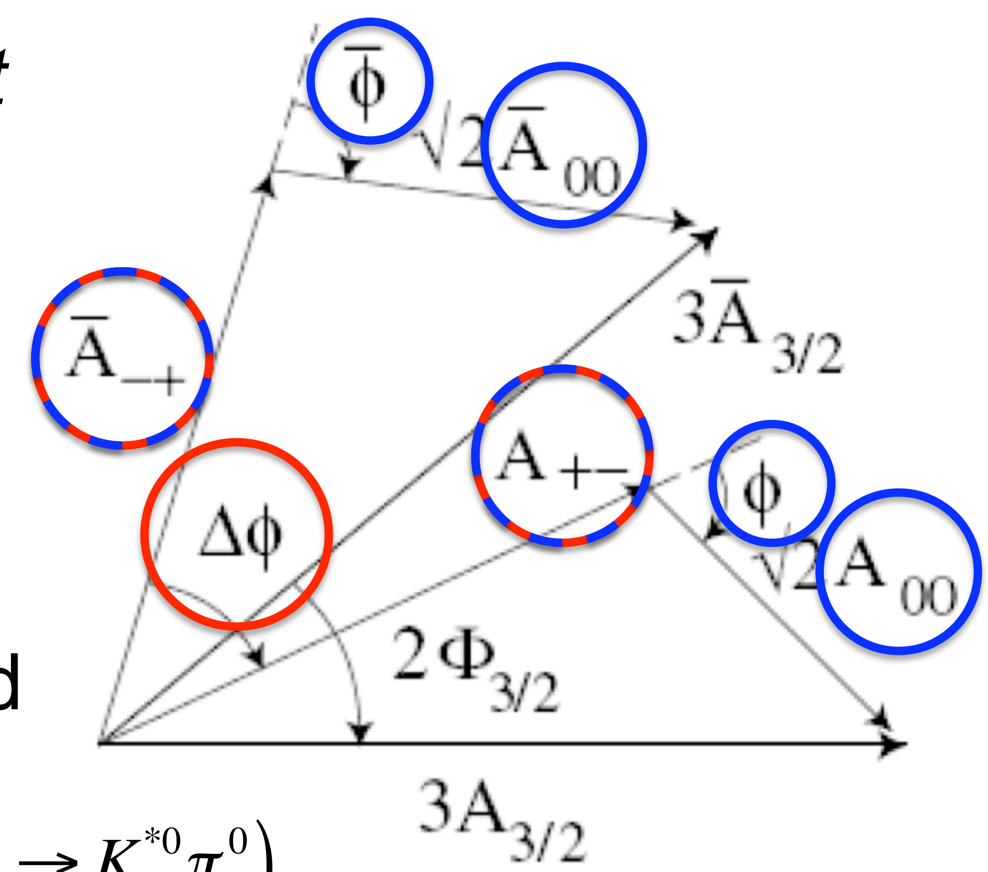
GAMMA
(FROM CHARMLESS)

Determination of γ from $B \to K^* \pi$ decays and related modes

talk by E. Puccio

Method for determining γ from $K\pi\pi$

- Method from Ciuchini *et al.* and Gronau *et al.*
- Form isospin triangles from $K^*\pi$ modes:
  - From $B^0 \to K^+\pi^-\pi^0$
  - From $B^0 \to K_S\pi^+\pi^-$
- Resultant amplitude and phase:



$$3A_{\frac{3}{2}} = A\left(B^0 \to K^{*+}\pi^-\right) + \sqrt{2}A\left(B^0 \to K^{*0}\pi^0\right)$$

$$\Phi_{\frac{3}{2}} = \frac{1}{2}\left(\phi - \bar{\phi} - \Delta\phi_{K^*\pi}\right) \approx \gamma$$ up to correction from EW penguins

Determination of γ from $B\to K^*\pi$ decays and related modes

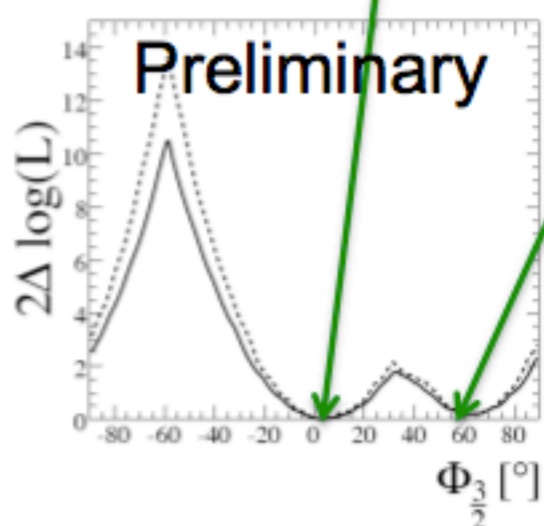
$= \gamma + \mathcal{O}(r_{3/2})$

talk by E. Puccio

From BaBar data of 454 million BB events gives:

- $\Delta\Phi_{3/2} = (-7\,^{+15}_{-18} \pm 15)°$
- $\Phi_{3/2} = (1 \pm 21)°, (60 \pm 18)°$

Stat.
Total



$$\Phi_{\frac{3}{2}} = \frac{1}{2}\arctan\left(\frac{\sin\Delta\Phi}{\frac{|A_{K^{*+}\pi^-}|}{\sqrt{2}|A_{K^{*0}\pi^0}|} + \ldots}\right)$$

- Two bands in $\Phi_{3/2}$ fro…

Conclusion

- BaBar results for $K^+\pi^-\pi^0$ in process of being finalised.
- Results to be combined soon to form CKM constraint.

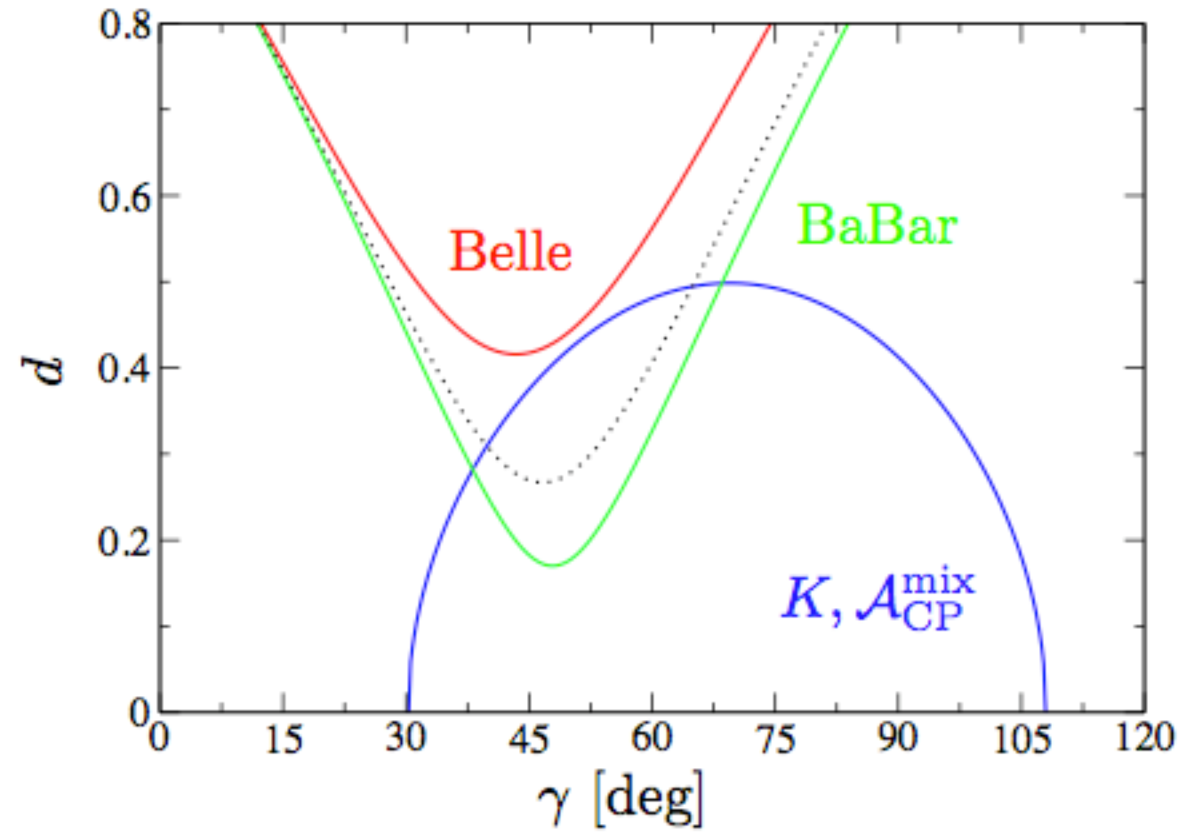
$B_{s,d} \to \pi\pi, \pi K, KK$ Decays

$$A(B_d^0 \to \pi^+\pi^-) = e^{i\gamma}\left(1 - \frac{\lambda^2}{2}\right)\mathcal{C}\left[1 - d\,e^{i\theta}e^{-i\gamma}\right]$$

$$A(B_s^0 \to K^+K^-) = e^{i\gamma}\lambda\,\mathcal{C}'\left[1 + \frac{1}{\epsilon}d'e^{i\theta'}e^{-i\gamma}\right]$$

- Contours in the γ–d plane:
  - $\mathcal{A}_{\rm CP}^{\rm dir}(B_d \to \pi^+\pi^-)$ and $\mathcal{A}_{\rm CP}^{\rm mix}(B_d \to \pi^+\pi^-)$: *theoretically clean;*
  - K and $\mathcal{A}_{\rm CP}^{\rm mix}(B_d \to \pi^+\pi^-)$: U-spin symmetry enters:

talk by R. Fleischer



$B_{s,d} \to \pi\pi, \pi K, KK$ Decays

talk by R. Fleischer

$$\Rightarrow \quad \boxed{\gamma = (68.5^{+4.5}_{-5.8}|_{\rm input}{}^{+5.0}_{-3.7}|_{\xi}{}^{+0.1}_{-0.2}|_{\Delta\theta})^\circ}$$

[UTfit: $\gamma = (69.6 \pm 3.1)^\circ$; CKMfitter: $\gamma = (67.2 \pm 3.9)^\circ$ $\Rightarrow$ excellent agreement!]

- Agreement between $B_d \to \pi^+\pi^-$, $B_s \to K^+K^-$ result for γ and UT fits:

  $\Rightarrow$ *dramatic* NP effects @ amplitude level are *excluded* ...

  – Measurement of $\mathcal{A}_{\rm CP}^{\rm mix}(B_s \to K^+K^-)$ is the next important step:

    $\to$ interesting *correlations* with $(\sin\phi_s)_{B_s \to \psi\phi}$ $\Rightarrow$ probe of NP!

- Detailed analysis of the $B_d \to \pi^\mp K^\pm$, $B_s \to \pi^\pm K^\mp$ system:

  – FM bound $\gamma \leq (71.8^{+5.4}_{-4.3})^\circ$ is effective in an interesting region!

  – Current $B_d \to \pi^\mp K^\pm$, $B_s \to \pi^\pm K^\mp$ data: $\Rightarrow$ $24^\circ \leq \gamma \leq 71^\circ$ ...

CDFII results ($1\ fb^{-1}$)

PRL **103,** 031801 (2009) PHYSICAL REVIEW LETTERS week ending 17 JULY 2009

Observation of New Charmless Decays of Bottom Hadrons

talk by M. Dorigo

	Mode	Relative $\mathcal{B}$	Absolute $\mathcal{B}(10^{-6})$
✓ (blue)	$B_s^0 \to K^-\pi^+$	$\frac{f_s}{f_d}\frac{\mathcal{B}(B_s^0\to K^-\pi^+)}{\mathcal{B}(B^0\to K^+\pi^-)} = 0.071 \pm 0.010 \pm 0.007$	$5.0 \pm 0.7 \pm 0.8$
✓ (red)	$B_s^0 \to \pi^+\pi^-$	$\frac{f_s}{f_d}\frac{\mathcal{B}(B_s^0\to \pi^+\pi^-)}{\mathcal{B}(B^0\to K^+\pi^-)} = 0.007 \pm 0.004 \pm 0.005$	$0.49 \pm 0.28 \pm 0.36$ (<1.2 at 90% C.L.)
	$B^0 \to K^+K^-$	$\frac{\mathcal{B}(B^0\to K^+K^-)}{\mathcal{B}(B^0\to K^+\pi^-)} = 0.020 \pm 0.008 \pm 0.006$	$0.39 \pm 0.16 \pm 0.12$ (<0.7 at 90% C.L.)
✓ (blue)	$\Lambda_b^0 \to pK^-$	$\frac{f_\Lambda}{f_d}\frac{\mathcal{B}(\Lambda_b^0\to pK^-)}{\mathcal{B}(B^0\to K^+\pi^-)} = 0.066 \pm 0.009 \pm 0.008$	$5.6 \pm 0.8 \pm 1.5$
✓ (blue)	$\Lambda_b^0 \to p\pi^-$	$\frac{f_\Lambda}{f_d}\frac{\mathcal{B}(\Lambda_b^0\to p\pi^-)}{\mathcal{B}(B^0\to K^+\pi^-)} = 0.042 \pm 0.007 \pm 0.006$	$3.5 \pm 0.6 \pm 0.9$

▯ world's first
▯ world's best

submitted soon

	Mode	Relative $\mathcal{B}$	Absolute $\mathcal{B}(10^{-6})$
	$B^0 \to \pi^+\pi^-$	$\frac{\mathcal{B}(B^0\to\pi^+\pi^-)}{\mathcal{B}(B^0\to K^+\pi^-)} = 0.259 \pm 0.017 \pm 0.016$	$5.02 \pm 0.33 \pm 0.35$
✓ (red)	$B_s^0 \to K^+K^-$	$\frac{f_s}{f_d}\frac{\mathcal{B}(B_s^0\to K^+K^-)}{\mathcal{B}(B^0\to K^+\pi^-)} = 0.347 \pm 0.020 \pm 0.021$	$24.4 \pm 1.4 \pm 3.5$

	Mode	CP–asymmetry
	$B^0 \to K^+\pi^-$	$\frac{\mathcal{B}(\overline{B}^0\to K^-\pi^+)-\mathcal{B}(B^0\to K^+\pi^-)}{\mathcal{B}(\overline{B}^0\to K^-\pi^+)+\mathcal{B}(B^0\to K^+\pi^-)} = -0.086 \pm 0.023 \pm 0.009$
✓ (blue)	$B_s^0 \to K^-\pi^+$	$\frac{\mathcal{B}(\overline{B}_s^0\to K^+\pi^-)-\mathcal{B}(B_s^0\to K^-\pi^+)}{\mathcal{B}(\overline{B}_s^0\to K^+\pi^-)+\mathcal{B}(B_s^0\to K^-\pi^+)} = +0.39 \pm 0.15 \pm 0.08$
✓ (blue)	$\Lambda_b^0 \to pK^-$	$\frac{\mathcal{B}(\Lambda_b^0\to pK^-)-\mathcal{B}(\overline{\Lambda}_b^0\to \overline{p}K^+)}{\mathcal{B}(\Lambda_b^0\to pK^-)+\mathcal{B}(\overline{\Lambda}_b^0\to \overline{p}K^+)} = +0.37 \pm 0.17 \pm 0.03$
✓ (blue)	$\Lambda_b^0 \to p\pi^-$	$\frac{\mathcal{B}(\Lambda_b^0\to p\pi^-)-\mathcal{B}(\overline{\Lambda}_b^0\to \overline{p}\pi^+)}{\mathcal{B}(\Lambda_b^0\to p\pi^-)+\mathcal{B}(\overline{\Lambda}_b^0\to \overline{p}\pi^+)} = +0.03 \pm 0.17 \pm 0.05$

CDFII results (1 fb^{-1})

PRL **103**, 031801 (2009) PHYSICAL REVIEW LETTERS week ending 17 JULY 2009

Observation of New Charmless Decays of Bottom Hadrons

talk by M. Dorigo

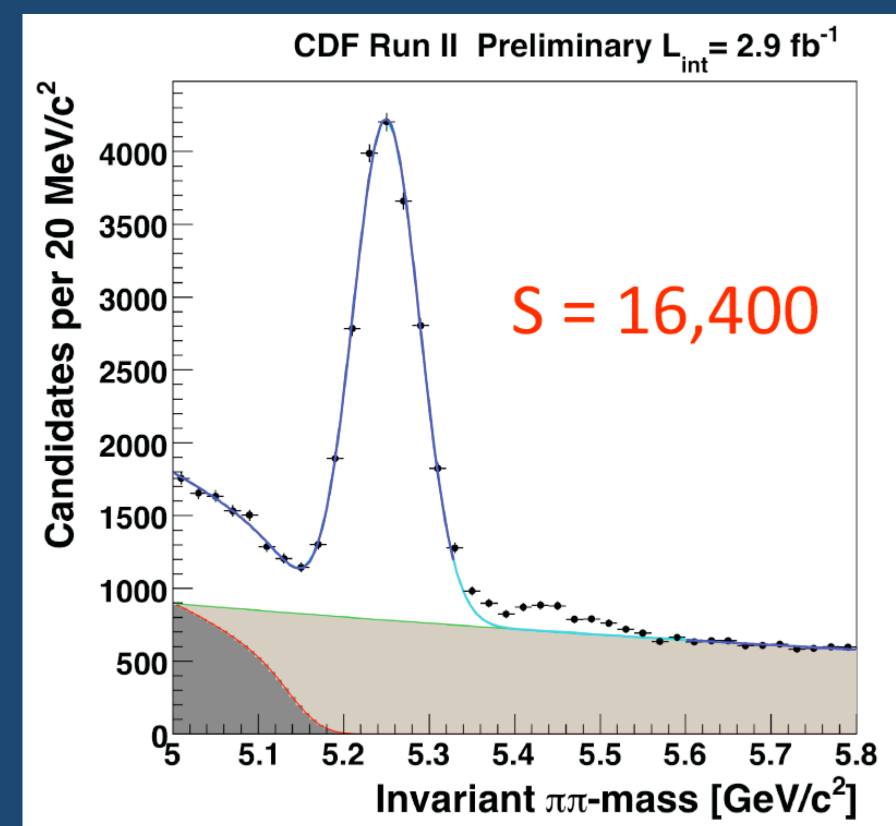
Mode
$B_s^0 \to K^- \pi^+$
$B_s^0 \to \pi^+ \pi^-$
$B^0 \to K^+ K^-$
$\Lambda_b^0 \to p K^-$
$\Lambda_b^0 \to p \pi^-$

world's first
world's best

Next

5 fb^{-1} analysis in progress

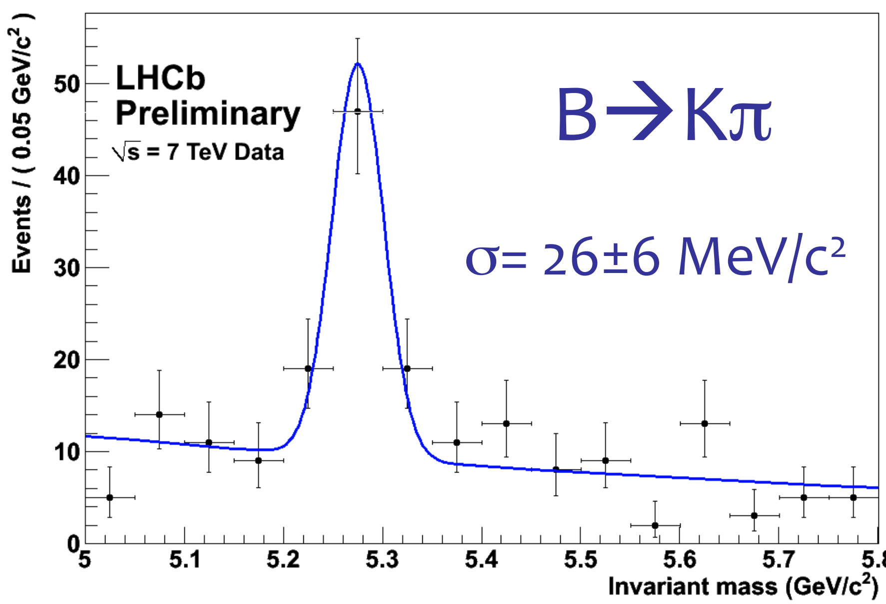
- ✓ Expect observation of DCPV in B^0_s.
- ✓ DCPV in B^0 competitive with Belle.
- ✓ Precision measurement of rare modes' BR.
- ✓ Observe new modes? (aim at $B^0_s \to \pi^+\pi^-$)

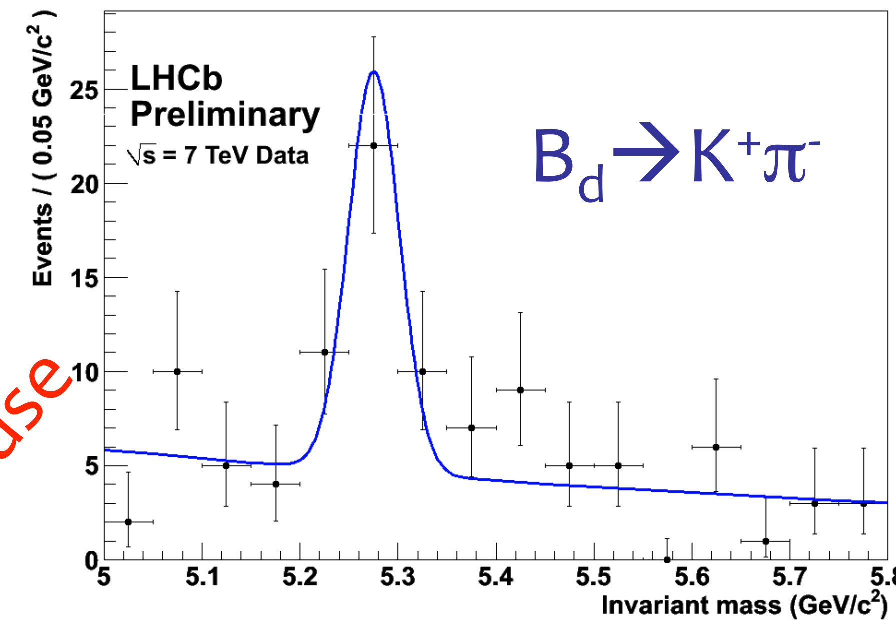


γ from penguin decays at LHCb

talk by A. Carbone

B→hh working in progress with L= 0.9 pb^{-1}



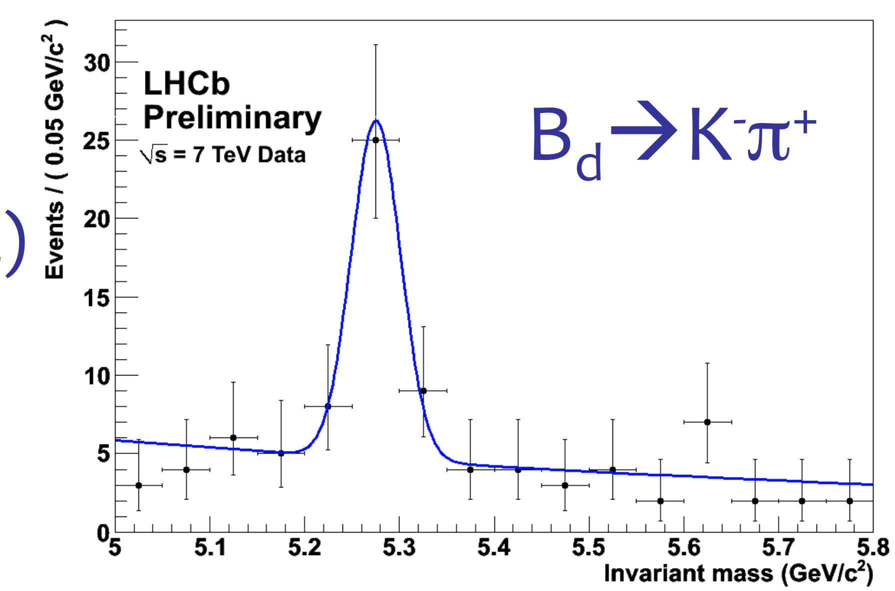


RICH PID in use

Yield: 56±10

$$\frac{N_{\pi+K-} - N_{K+\pi-}}{N_{\pi+K-} + N_{K+\pi-}} = 0.01 \pm 0.16 \text{ (stat)}$$

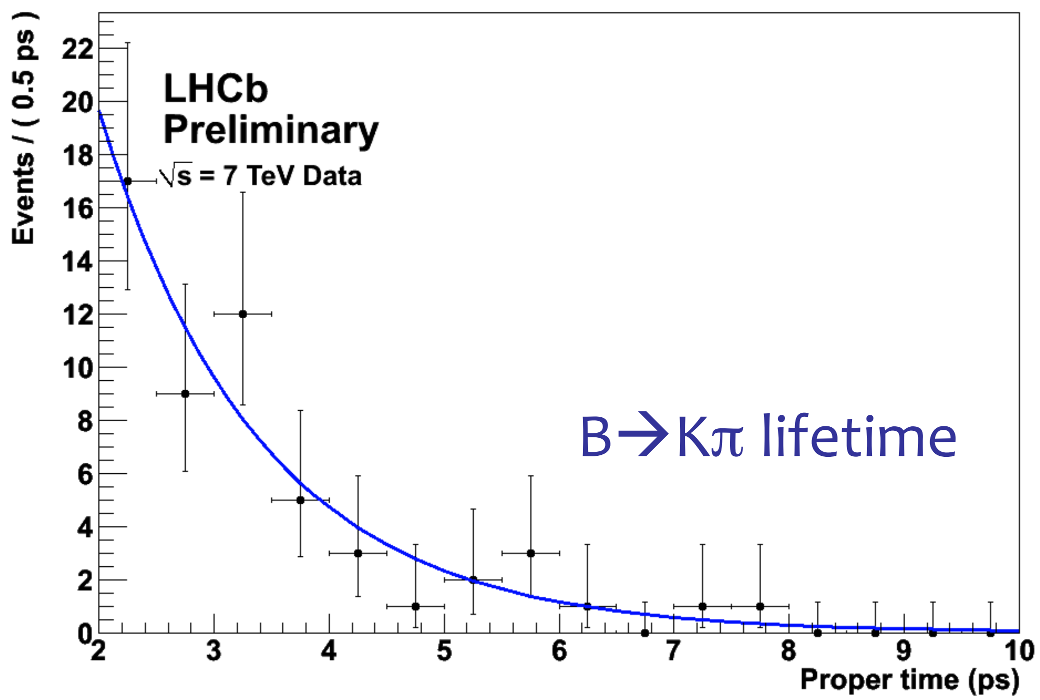
(HFAG: -0.098 ± 0.012)

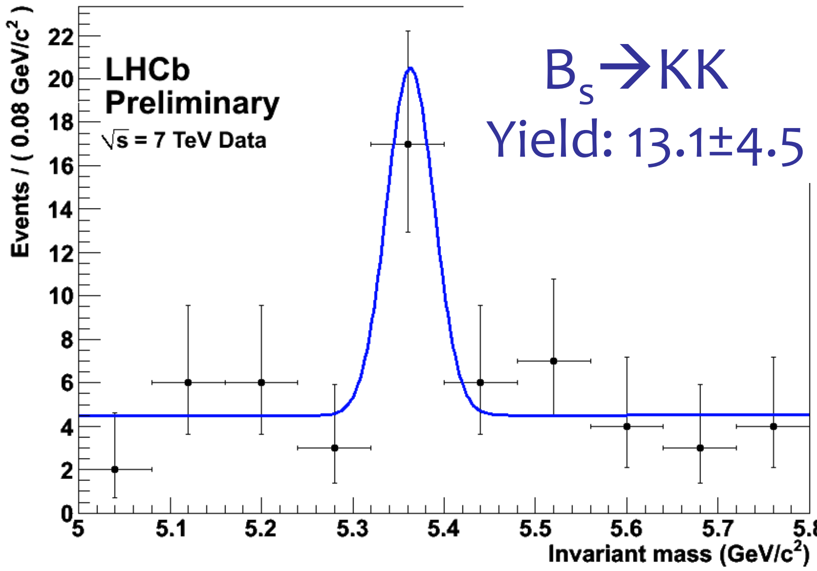


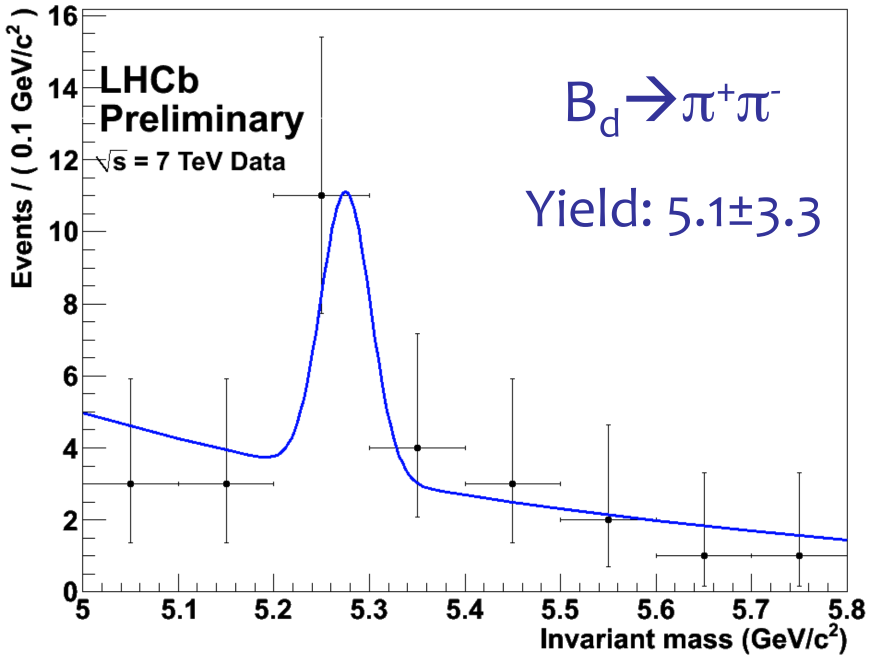
Yield statistically consistent with Monte Carlo expectation

B→hh working in progress with L= 0.9 pb^{-1}

talk by A. Carbone





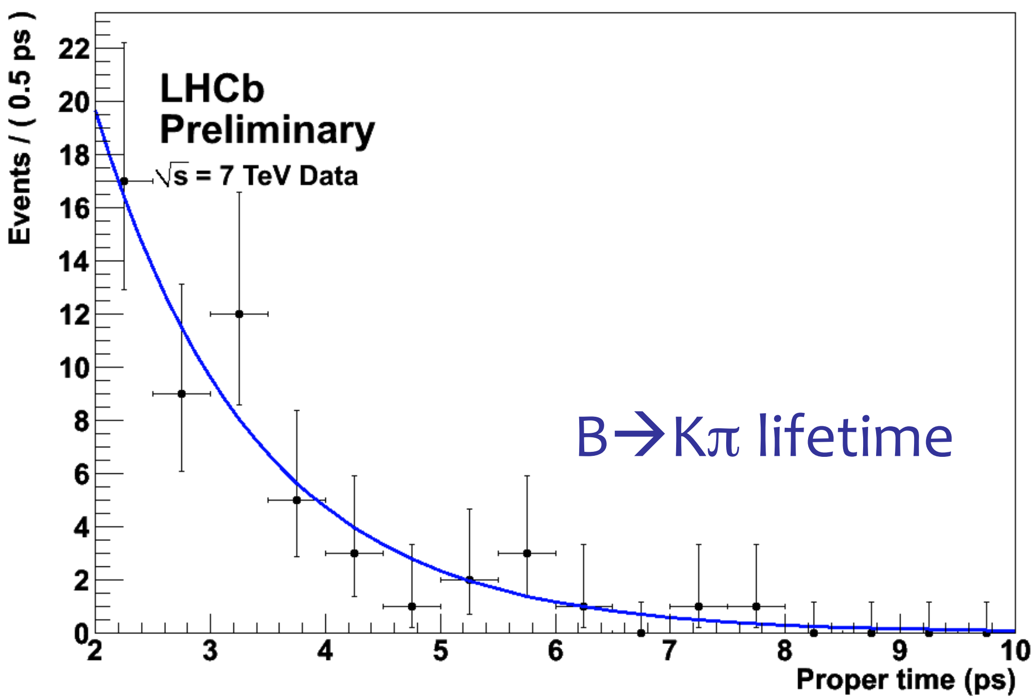


- lifetime fit on early B→Kπ data sample using a cut t>2 ps in order to select a region of flat proper time acceptance

τ_d = (1.5 1± 0.28) ps

B→hh working in progress with L= 0.9 pb^{-1}

talk by A. Carbone



- lifetime fit on early B→Kπ data sample using a cut t>2 ps in order to select a region of flat proper time acceptance

τ_d = (1.5 1± 0.28) ps

	Current knowledge	LHCb stat.
$A^{CP}_{K^+\pi^-}$	$-0.098^{+0.012}_{-0.011}$	0.008
$A^{CP}_{\pi^+K^-}$	$0.39 \pm 0.15 \pm 0.08$	0.05
$A^{CP}_{p\pi^-}$	$0.03 \pm 0.17 \pm 0.05$	0.05
$A^{CP}_{pK^-}$	$0.37 \pm 0.17 \pm 0.03$	0.03
$A^{dir}_{\pi^+\pi^-}$	0.38 ± 0.06	0.13
$A^{mix}_{\pi^+\pi^-}$	-0.65 ± 0.07	0.13
$\mathrm{Corr}(A^{dir}_{\pi^+\pi^-}, A^{mix}_{\pi^+\pi^-})$	0.08	−0.03
$A^{dir}_{K^+K^-}$	Unmeasured	0.15
$A^{mix}_{K^+K^-}$		0.11
$\mathrm{Corr}(A^{dir}_{K^+K^-}, A^{mix}_{K^+K^-})$		0.02
$\frac{\mathcal{BR}(B^0 \to \pi^+\pi^-)}{\mathcal{BR}(B^0 \to K^+\pi^-)}$	0.264 ± 0.011	0.006
$\frac{\mathcal{BR}(B^0 \to K^+K^-)}{\mathcal{BR}(B^0 \to K^+\pi^-)}$	$0.020 \pm 0.008 \pm 0.006$	0.005
$\frac{f_s \mathcal{BR}(B^0_s \to K^+K^-)}{f_d \mathcal{BR}(B^0 \to K^+\pi^-)}$	$0.347 \pm 0.020 \pm 0.021$	0.006
$\frac{f_s \mathcal{BR}(B^0_s \to \pi^+K^-)}{f_d \mathcal{BR}(B^0 \to K^+\pi^-)}$	$0.071 \pm 0.010 \pm 0.007$	0.004
$\frac{f_s \mathcal{BR}(B^0_s \to \pi^+\pi^-)}{f_d \mathcal{BR}(B^0 \to K^+\pi^-)}$	$0.007 \pm 0.004 \pm 0.005$	0.002
$\frac{f_{\Lambda_b} \mathcal{BR}(\Lambda_b \to p\pi^-)}{f_d \mathcal{BR}(B^0 \to K^+\pi^-)}$	$0.0415 \pm 0.0074 \pm 0.0058$	0.0016
$\frac{f_{\Lambda_b} \mathcal{BR}(\Lambda_b \to pK^-)}{f_d \mathcal{BR}(B^0 \to K^+\pi^-)}$	$0.0663 \pm 0.0089 \pm 0.0084$	0.0018

LHCb stat. sensitivity with L=500 pb^{-1}

"PUZZLES" : $B \to K\pi$, $B \to VV$

B→Kπ “PUZZLE”

talk by Y. Unno

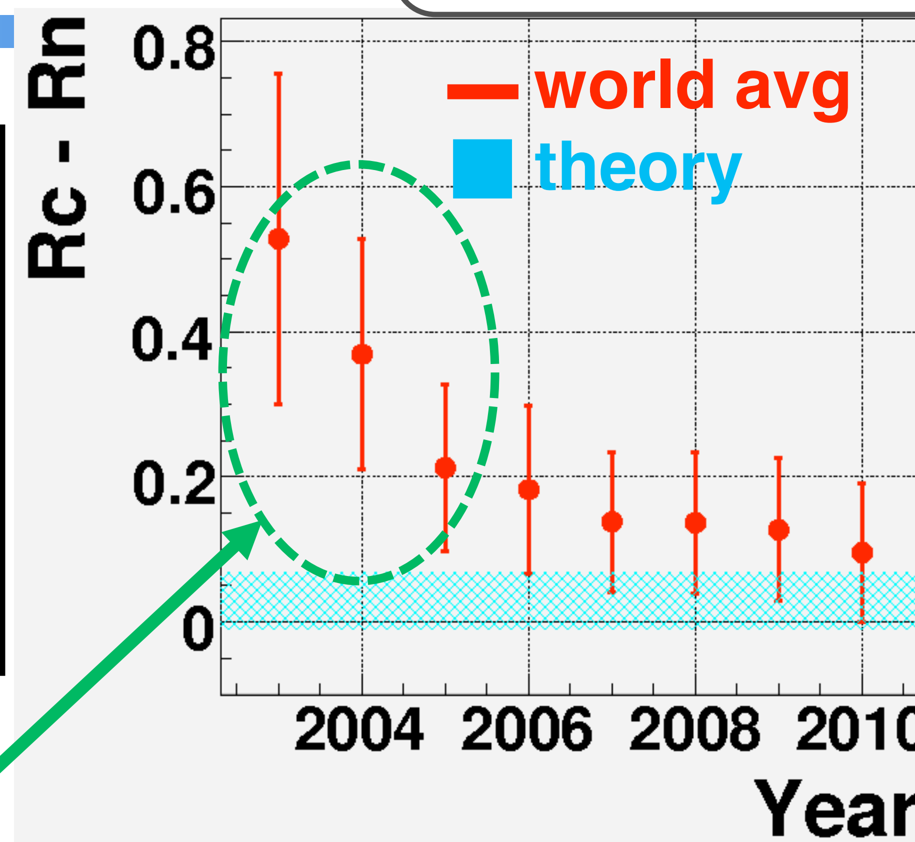
Ratio of Br(B→Kπ)

Naïve world avg.

$$R_c = \frac{2Br(B^+ \to K^0\pi^+)}{Br(B^+ \to K^+\pi^0)} = 1.12 \pm 0.07$$

$$R_n = \frac{Br(B^0 \to K^+\pi^-)}{2Br(B^0 \to K^0\pi^0)} = 1.02 \pm 0.06$$

$$R_c - R_n = 0.10 \pm 0.09$$



World avg. are consistent with theory:

$$R_c = 1.15 \pm 0.03$$

$$R_n = 1.12 \pm 0.03$$

$$R_c - R_n = 0.03 \pm 0.04$$

- Puzzle appears to have disappeared
- For a more precise check, we have to reduce:
  - syst. errors in exp.
  - theory errors.

ΔA_{CP} puzzle is established with 5.3σ

$\Delta A_{CP} = A_{CP}(K^+\pi^0) - A_{CP}(K^+\pi^-)$
$= +0.148 \pm 0.028$

talk by Y. Unno

ΔA_{CP} puzzle

- **Isospin sum rule among B→**

(M.Gronau, PLB 672(2005), 82-88)

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

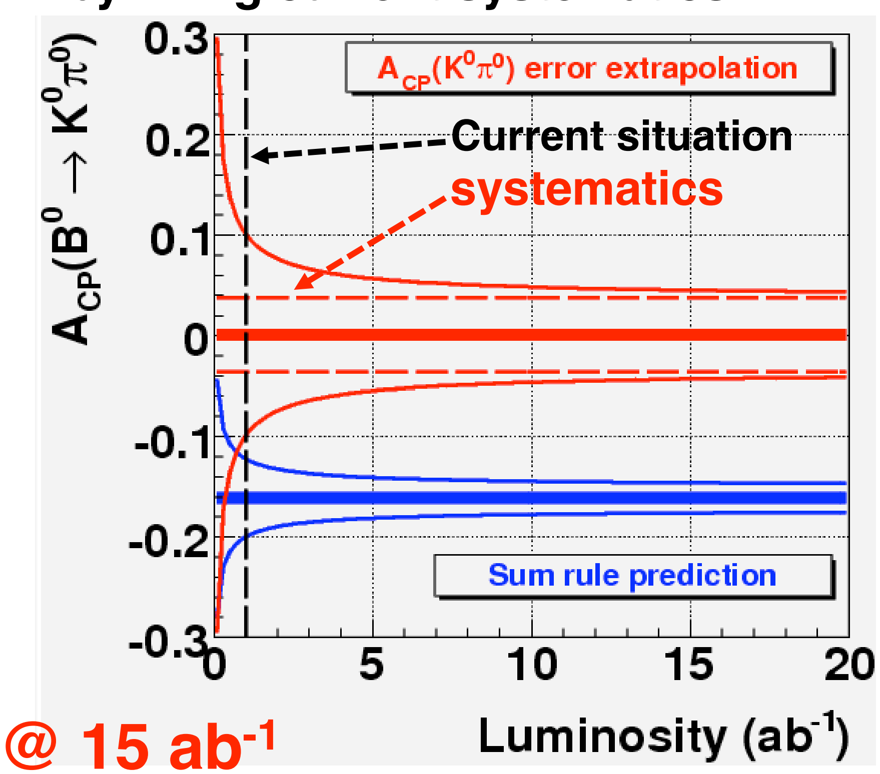
- **Isospin sum rule predicts:**

using world average values(A_{CP}, Br, τ_+, τ_0)

$$A_{CP}(K^0\pi^0) = -0.153 \pm 0.045$$

talk by Y. Unno

Expectation using
- **current world average central values**
- **by fixing current systematics**



@ 15 ab^{-1}
- **$\delta A_{CP}(K^0\pi^0)$ ~ 5%**
- **Sum rule – $A_{CP}(K^0\pi^0)$ > 3σ**
- **But, will be systematics dominant…**

Source (BELLE)	$\Delta\mathcal{A}_{K^0\pi^0}$
Wrong tag fraction	0.005
Physics parameters	0.001
Resolution function	0.007
Background Δt shape	0.006
Background fraction	0.022
Possible fit bias	0.020
Vertex reconstruction	0.022
Tag side interference	0.054
Total	0.064

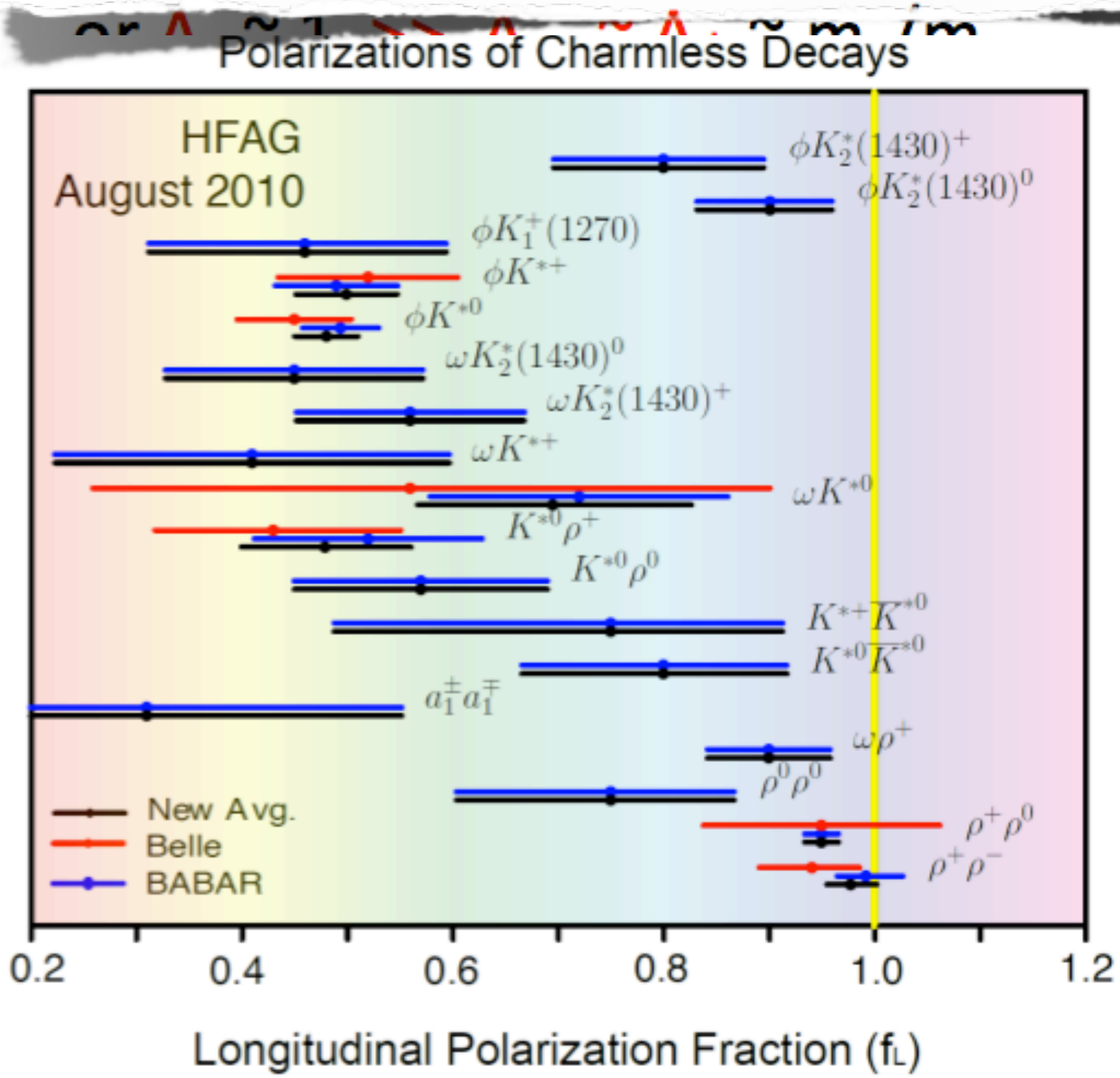
- **Situation is same as Babar**
- **Need to reduce TSI**

Polarization puzzle

talk by G. Vasseur

- Naïve expectation:

  $A_0 \sim 1 \gg A_{+1} \sim m_V/m_B \gg A_{-1} \sim m_V^2/m_B^2$

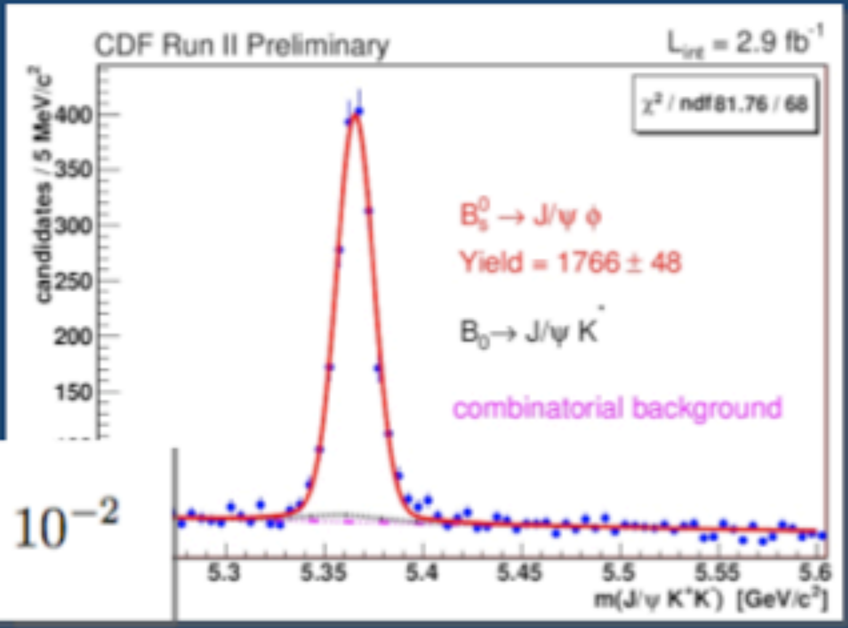


- f_L large (~ 1)
  - ρ ρ, ω ρ (tree VV),
  - K* K* (b→d penguin VV),
  - ϕ K^*_2 (V T).
- f_L smaller (~ 0.5)
  - ϕ K*, ρ K*, ω K* (b→s penguin V V),
  - ω K^*_2 (V T),
  - ϕ K_1 (V A),
  - a_1 a_1 (A A).

$B_s \to \phi\phi$ at CDF-II

Branching Ratio update

Use B^0_s $J/\psi\phi$ with the same trigger selection for normalization, avoid dependence on fragmentation probabilities f_s/f_d



$$\frac{BR(B^0_s \to \phi\phi)}{BR(B^0_s \to J/\psi\phi)} = [1.78 \pm 0.14(stat) \pm 0.20(syst)] \cdot 10^{-2}$$

Using BR(B^0_s $J/\psi\phi$) from PDG, updated to current values of f_s/f_d :

$$BR(B^0_s \to \phi\phi) = [2.40 \pm 0.21(stat) \pm 0.27(syst) \pm 0.82(BR)] \cdot 10^{-5}$$

CDF-PUB-10064 (2010)

Previous CDF result $(1.4^{+0.6}_{-0.5} \pm 0.6)\times 10^{-5}$

Theoretical prediction:

QCDf: $(1.95 \pm 1.0^{+1.31}_{-0.80})\times 10^{-5}$ NPB 774, 64 (2007)

pQCD: $(3.53^{+0.83}_{-0.69}{}^{+1.67}_{-1.02})\times 10^{-5}$ PRD 76, 074018 (2007)

14

talk by M. Dorigo

World's 1° Polarization Measurement

- Systematics dominated by:
  - Non-resonant contributions (B^0_s ϕ(KK) and B^0_s ϕf_0): ~1%
  - Dependence of acceptance on $\Delta\Gamma_s$: ~1%
  - Uncertainties of $\tau_{L(H)}$: ~1%

talk by M. Dorigo

$$|A_0|^2 = 0.348 \pm 0.041(\text{stat}) \pm 0.021(\text{syst}),$$
$$|A_\parallel|^2 = 0.287 \pm 0.043(\text{stat}) \pm 0.011(\text{syst}),$$
$$|A_\perp|^2 = 0.365 \pm 0.044(\text{stat}) \pm 0.027(\text{syst}),$$
$$\cos\delta_\parallel = -0.91^{+0.15}_{-0.13}(\text{stat}) \pm 0.09(\text{syst}).$$

CDF-PUB-10120 (2010)

World's 1° Polarization Measurement

- Systematics dominated by:
  - Non-resonant contributions (B^0_s ϕ(KK) and B^0_s ϕf_0): ~1%
  - Dependence of acceptance on $\Delta\Gamma_s$: ~1%
  - Uncertainties of $\tau_{L(H)}$: ~1%

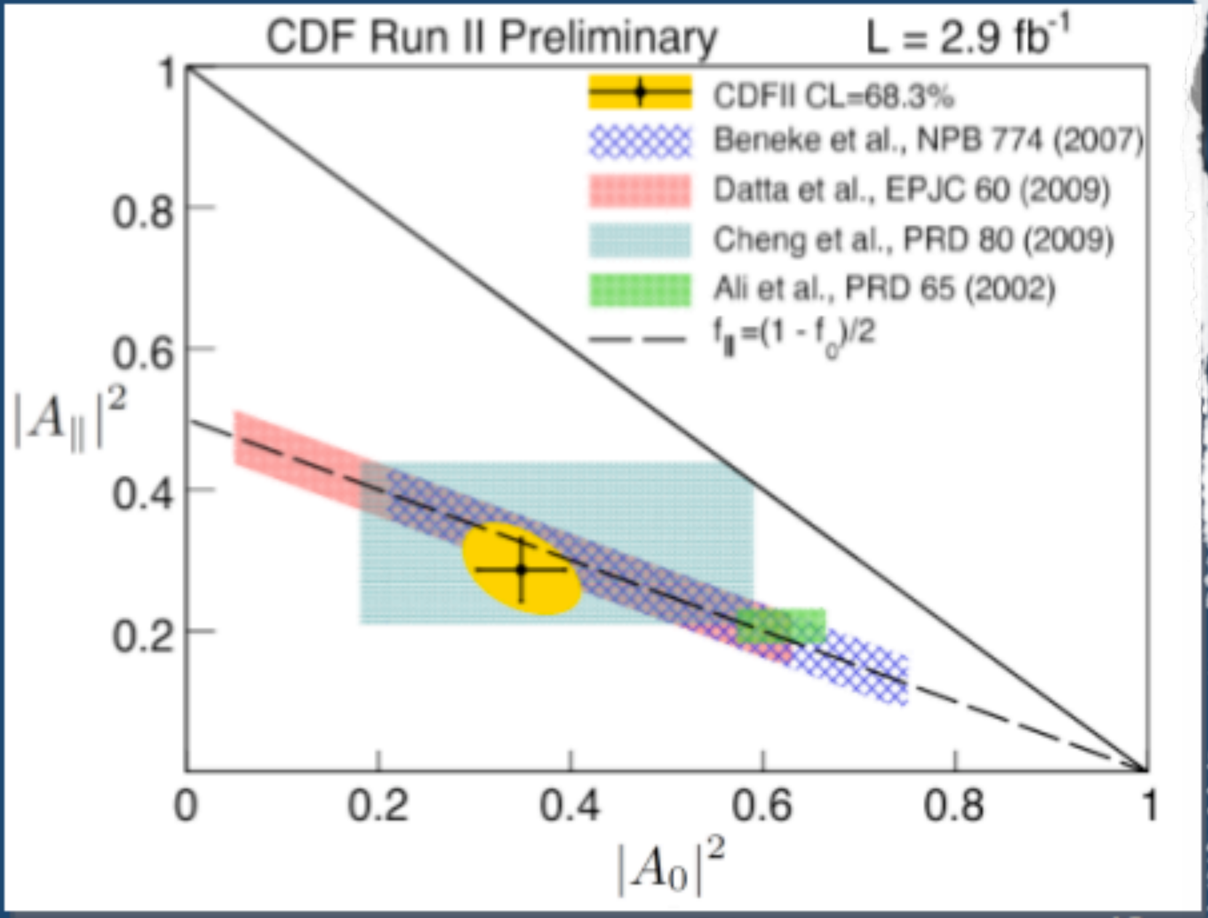
talk by M. Dorigo

$$|A_0|^2 = 0.348 \pm 0.041(\text{stat}) \pm 0.021(\text{syst}),$$
$$|A_\parallel|^2 = 0.287 \pm 0.043(\text{stat}) \pm 0.011(\text{syst})$$

- FSI [PL B597, 291 (2004) + many others]
- NP? [PR D76, 075015 (2007)]

Agreement with QCDf prediction

	$\cos\delta_\parallel$	
CDF	$0.91^{0.15}_{0.13}(stat)$	$0.09(syst)$
QCDf	$0.80^{0.31}_{0.16}$	NP B774 (2007)
QCDp	$0.27^{0.09}_{0.27}$	PR D76 (2007)



CP (and CPT) violation studies at the Super Flavour Factories

- ✓ Super Flavor Factory will allow to make precise tests on CP and CPT violation in B_d, τ, D and B_s system

talk by E. Manoni

- ✓ expected sensitivities @ Superb after 5 years (75ab^{-1})
  - $\sigma(\alpha) \approx$ some degree (statistically dominated)
  - $\sigma(\sin 2\beta) \approx 0.005$ for golden modes (syst dominated), some of the penguin mode measurements are theoretically limited
  - $\sigma(\gamma) \approx 1^\circ$ reducing syst on GGSZ measurement
  - test CPV in mixing and CPTV parameters in B^0 decays down to 10^{-3}
  - potential of SuperB for CPV and CPTV tests in τ decays under study

- ✓ 5 years of SuperB running will allow precise CKM metrology: wide array of measurements of constraint on the CKM mechanism can display inconsistency signaling NP effects (the dream) or confirming our understanding on quark mixing (the nightmare)

THANKS TO EVERYONE

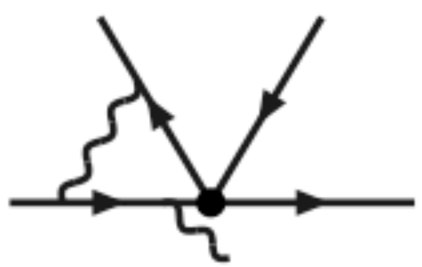
EXTRAS

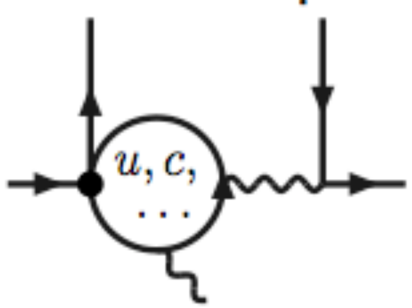
PROGRESS ON QCDF/SCET

- tree amplitudes: talk by G. Bell
- penguin amplitudes: talk by S. Jager

- a_4 computed to $O(\alpha_s)$ (vertex kernel T^I) Beneke et al 1999-2001
  $O(\alpha_s^2)$ (spectator scattering kernel T^{II}) Beneke, SJ 2006
  Jain, Rothstein, Stewart 2007

For the latter one needs to compute (besides simpler terms)





talk by S. Jager

penguin loop could be large because C_1~1 first appears at this order
however, due to a (not understood) cancellation it gives almost no contribution

- a_6 computed to $O(\alpha_s)$ (vertex kernel T^I) Beneke et al 1999-2001
  spectator scattering vanishes at this order

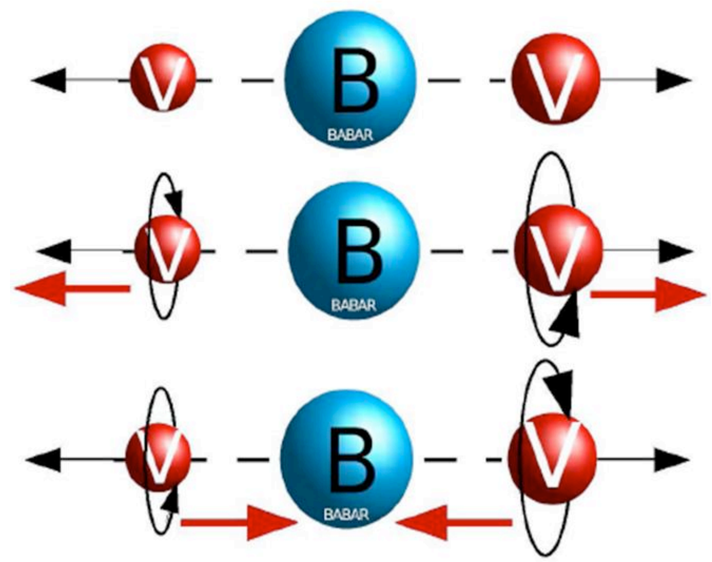
  At $O(\alpha_s^2)$ one needs to compute the same diagrams as above
  could potentially be large contribution for PP and VP final states

Polarization of B → VV experimental status

Polarization in B → VV

talk by G. Vasseur

- Three amplitudes.
- Helicity basis:
  - A_0 (longitudinal: $\lambda_{V1}=\lambda_{V2}= 0$)
  - A_{+1} (transverse: $\lambda_{V1}=\lambda_{V2}= +1$)
  - A_{-1} (transverse: $\lambda_{V1}=\lambda_{V2}= -1$)



- Transversity basis:

$$A_0 \qquad A_{//} = \frac{A_{+1} + A_{-1}}{\sqrt{2}} \qquad A_{\perp} = \frac{A_{+1} - A_{-1}}{\sqrt{2}}$$

CP-even longitudinal — CP-even transverse — CP-odd transverse