α, β, γ
from charmless *B* decays

Summary of WG-4 contributions to San Diego CKM Workshop

Andreas Höcker
Laboratoire de l'Accélérateur Linéaire, Orsay

BaBar Wednesday meeting

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hoecker@lal.in2p3.fr

Outline

WG-4 sessions / themes:

conveners: M. Beneke, Y. Grossman, M. Hazumi, AH

1) $\sin(2\beta_{\text{eff}})$ from *s*-penguin decays
   - determine $\Delta S = \sin(2\beta_{\text{eff}}) - \sin(2\beta_{\text{SM}})$ for the various modes
2) Extraction of α
   - theory: isospin violation in $\pi\pi$, $\rho\pi$, $\rho\rho$
   - experiment: isospin and Dalitz analyses
3) $B \to \pi\pi$, $K\pi$ decays
   - discussion on theoretical and phenomenological interpretations
4) Theoretical methods
   - QCD-improved and flavor-symmetry approaches
5) Other charmless decays
   - $B \to VV$, *Q2B*
   - charmless *B* decays at hadron machines

mainly discuss things we know less:
Belle's analyses, theory talks

BABAR speakers: please forgive !

sin(2β_{eff}) from *s*-penguin decays

Experimental talks by

- Hara (ϕK_S, $\eta' K_S$, $f_0 K_S$): for all modes: Belle [275m] and BABAR[227m]
  - "strange" first slide:

    113 fb^{-1} (SVD-1), 140 fb^{-1} (SVD-2)

    Belle: separate simple fits; use high S/N sample; easy to handle systematics

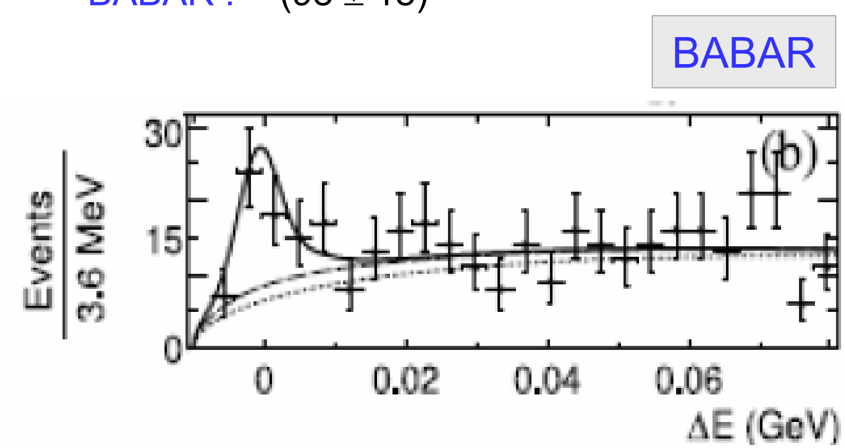
    BABAR: single MV fit; use as may events as possible; checks of validity of PDFs and correlations between variables are important

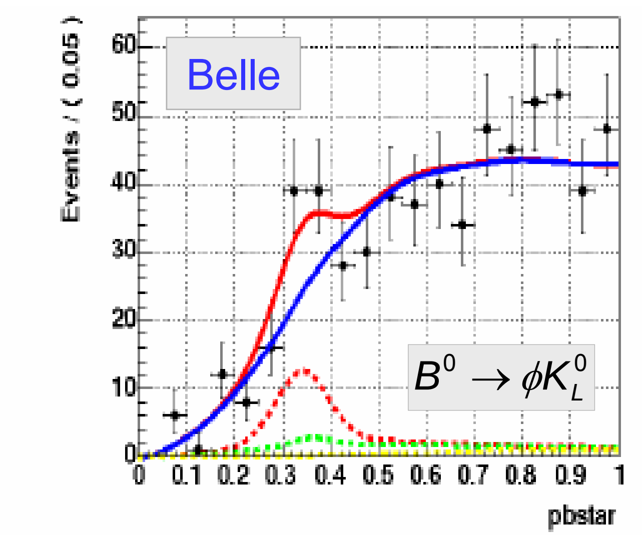
  - continuum bkg: Belle L/ratio cut (P_B*[cont] in ϕK_L from MC), BABAR: *PDF* in fit
  - ϕK_S: Belle : use $\pi^+\pi^-$ (N_S=139 $\pm$ 14) and $\pi^0\pi^0$ (13 $\pm$ 5)

    BABAR : use $\pi^+\pi^-$ (114 $\pm$ 12)

  - ϕK_L: Belle : (N_S = 36 $\pm$ 15)

    BABAR : (98 $\pm$ 18)





- B background : $K^+K^-K^0$ with opposite CP

  Belle: obtained from sideband in ϕK^+ (find 6.7 ± 1.2 %, but no f_0)

  BABAR: from moments analysis < 6.6 % (@ 95% CL)

- other B bkgs obtained from MC and fixed in fit, varied for systematics

  most important in ϕK_L : $\phi K^{*0}(\to K_L\pi^0)$; take into account CP-even fraction (~24%)

- ML fit:

  Belle: 2 vars in fit (CP)

  BABAR: 35 parameters (CP, yields, PDF shapes)

- systematics (ϕK^0):

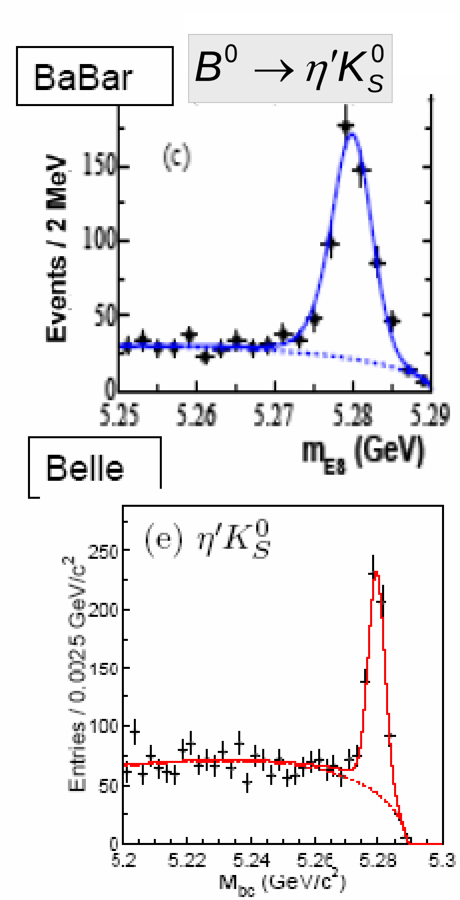
  Belle: control samples ? resolution function; tag-side CPV: $\sigma(A)$ = 0.06 !; vertex: $\sigma(A)$ = 0.03

- $\eta' K_S$: $\eta' \to \eta\pi^+\pi^-$, $\rho^0\gamma$ and $\eta \to \gamma\gamma$, $\pi^+\pi^-\pi^0$ and $K_S \to \pi^+\pi^-$
  BABAR also: $\pi^0\pi^0$

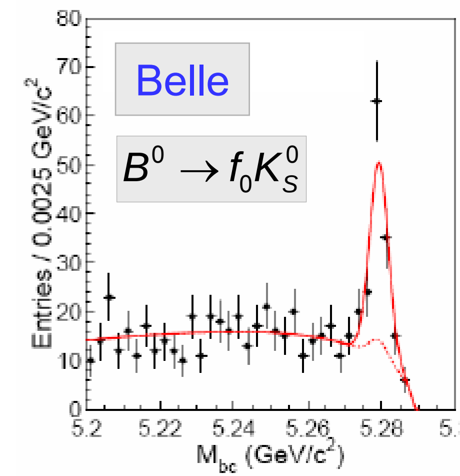
  Belle: cont. fighting with L/ratio cut → N_S= 512 ± 27

  BABAR: 804 ± 40

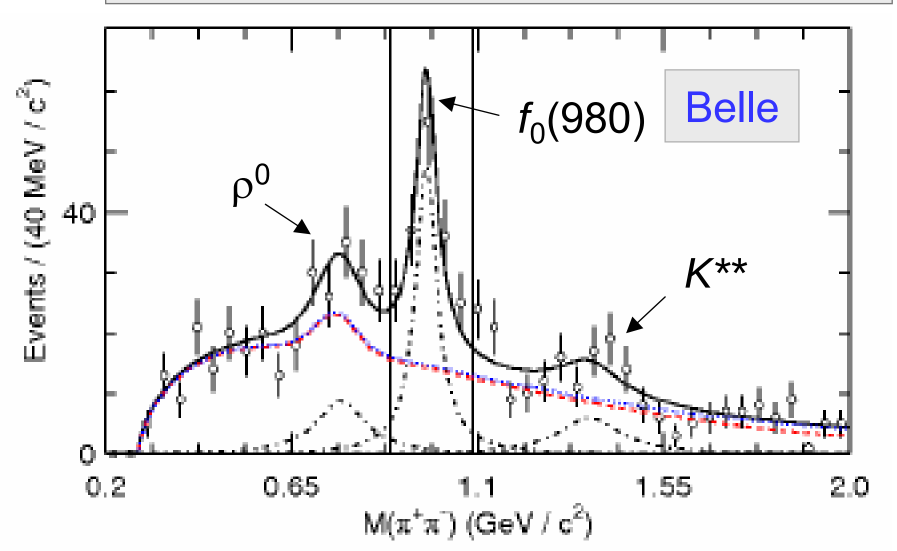
- fit strategy as in ϕK^0 : Belle floats CP parameters only, BABAR has 98 free parameters

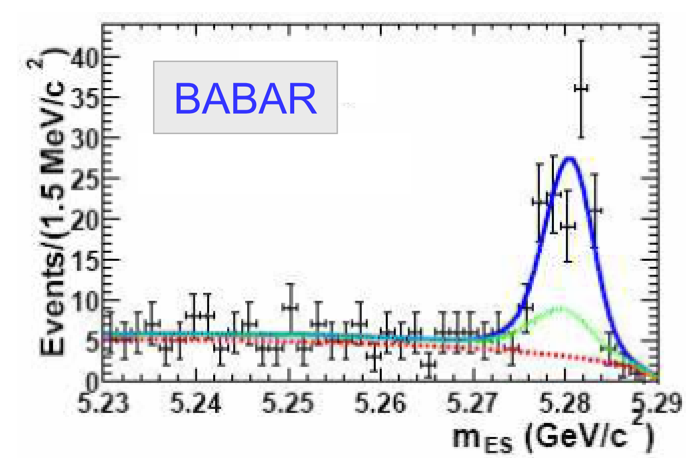


- systematics ($\eta' K_S$)
  - Belle: control samples ? resolution function; tag-side CP: $\sigma(A) = 0.03$!; vertex: $\sigma(A) = 0.03$
  - Big "?": what type of MC fits is Belle doing ? Certainly toy; how about full MC ?
- $f_0 K_S : f_0 \to \pi^+\pi^-, K_S \to \pi^+\pi^-$
- similar analysis/fit strategies as before
  - Belle: N_S= 94 ± 14, 2 params. (CP); BABAR: 152 ± 19, 41 params.
  - 2.7σ difference on S between Belle and BABAR
- systematics: similar; both account for Q2B approximation
  - BABAR: large syst. from fitting procedure!



B-bkg fractions obtained from fit to $m(\pi^+\pi^-)$ spectrum





- Wagner ($K^+K^-K_S$, $K_SK_SK_S$, π^0K_S, ωK_S): for all modes: Belle [275m] and BABAR[227m]
  - $K^+K^-K_S$ (excluding ϕ)
  - similar analysis/fit strategies as before

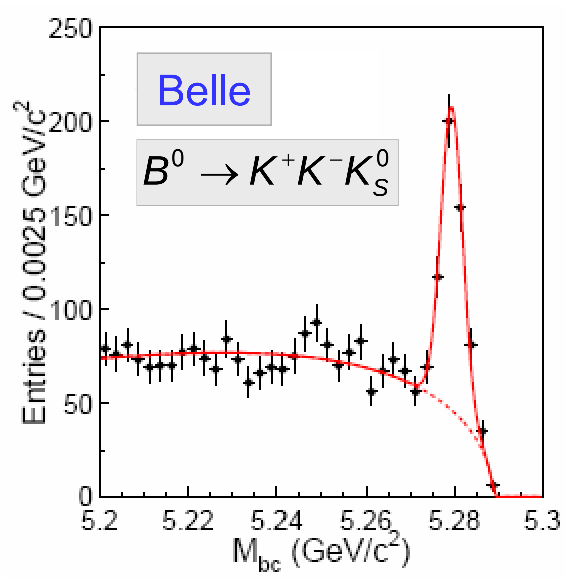
    Belle: N_S= 399 ± 28, 2 params. (*CP*); BABAR: 452 ± 28, 34 params.
  - determination of *CP*-even fraction [$S = -(2f_{CP\text{-even}} - 1) \times \sin 2\beta$]

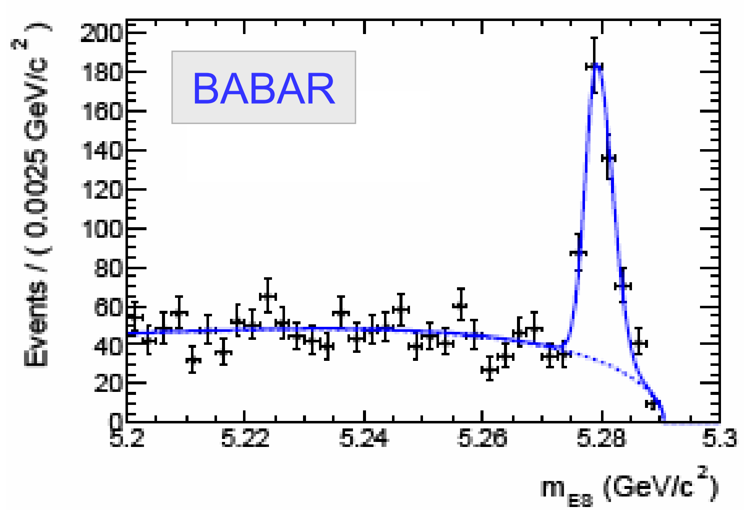
    Belle: isospin relation: $f_{CP\text{-even}} = 2\,\Gamma(B^+ \to K^+K_SK_S) / \Gamma(B \to K^+K^-K_S) = 1.03 \pm 0.15 \pm 0.05$

    (neglects tree contributions and isospin violation from EW penguins)

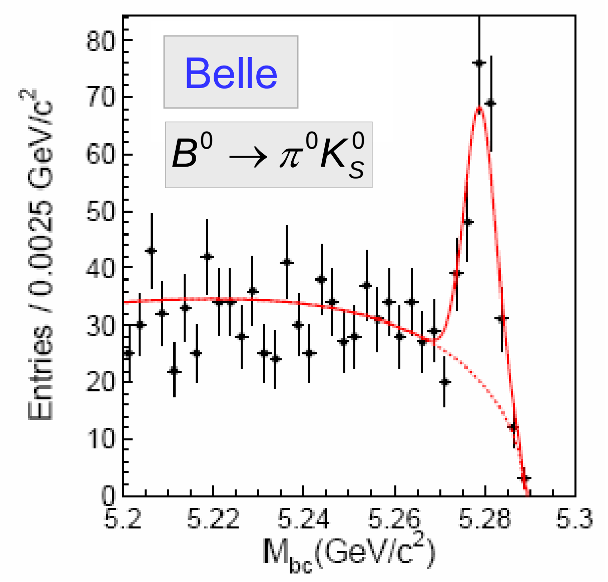
    now (hep-ex/0504023): $0.83 \pm 0.10 \pm 0.04$

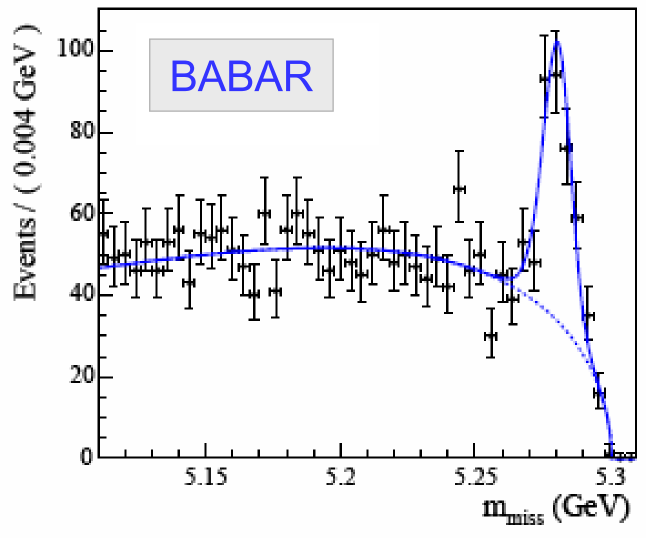
    BABAR: moments analysis: $f_{CP\text{-even}} = 0.89 \pm 0.08 \pm 0.06$ (the method of choice!)



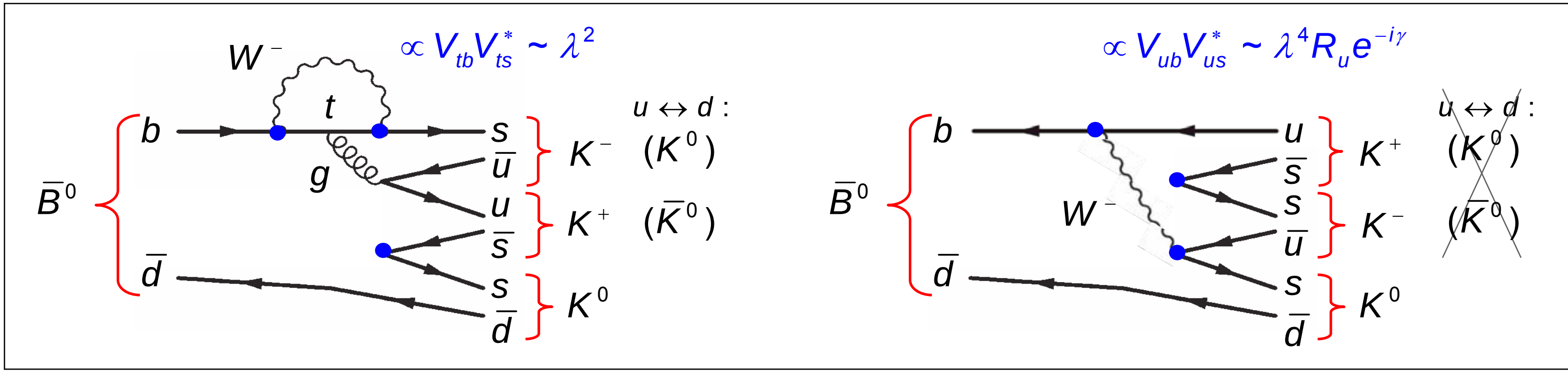


- $\pi^0 K_S$:
- similar analysis/fit strategies as before
  - Belle: N_S= 168 ± 16, 2 params. (*CP*); BABAR: 300 ± 23, 34 params.
  - Belle looses large SVD-1 event fraction due to vertexing fiducial cuts
- both experiments use $J/\psi K_S$ events *ignoring* J/ψ tracks as *CP* control sample
- systematics:
  - Belle: dominated by resolution function (0.05) and background fraction (0.07): sum is 0.11
  - BABAR: dominated by res fcn, CVT align., other *B*'s: sum is 0.04



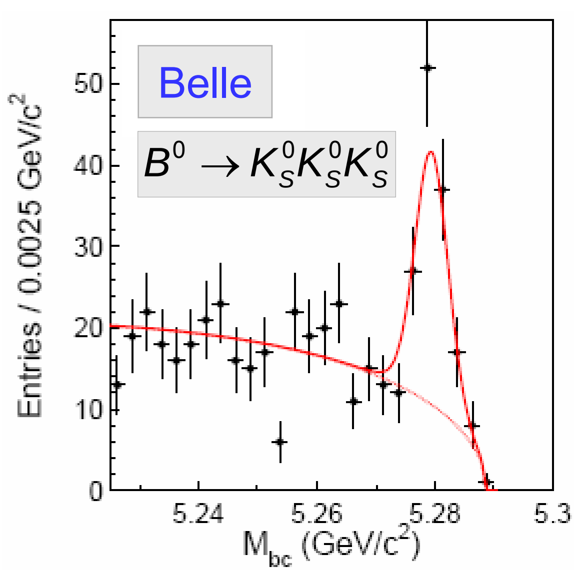


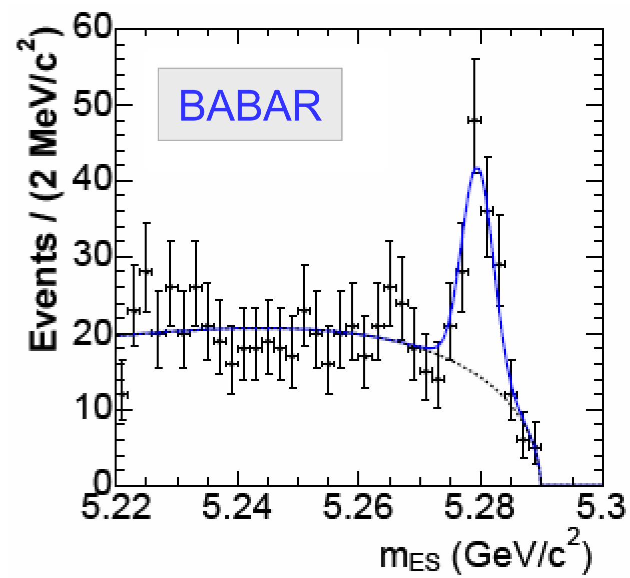
$K_S K_S K_S$ (CP-even eigenstate, new golden mode)



- Belle also allows one $K_S \to \pi^0\pi^0$

Belle: N_S[tot]= 88 ± 13 [16 ± 8 $K_S \to \pi^0\pi^0$] (CP measurement); BABAR: 88 ± 10 (CP and BR)





both experiments exclude (χ_{c0}, D^0) → $K_S K_S$ events

2.5σ difference on S between Belle and BABAR

Statistical error factor 1.9 better for BABAR

Large systematic error on S for Belle: 0.20 (resolution fcn and bkg); BABAR: 0.04

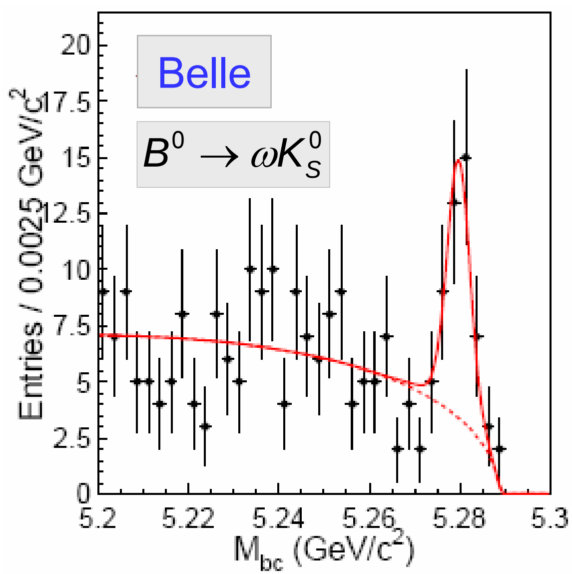
- ωK_S (new *s*-penguin mode; possibly somewhat larger tree pollution than other modes → see later)
- similar analysis/fit strategies as before

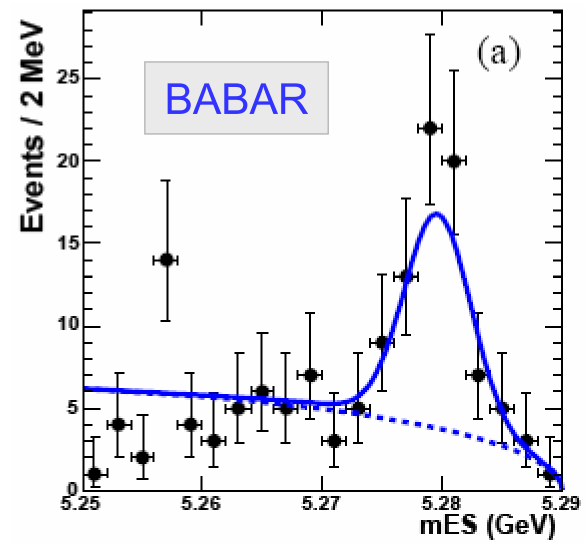
  Belle: N_S= 31 ± 7; BABAR: 96 ± 14

  BABAR more than 3 times more signal events with less data → analysis strategy !!
- systematics:

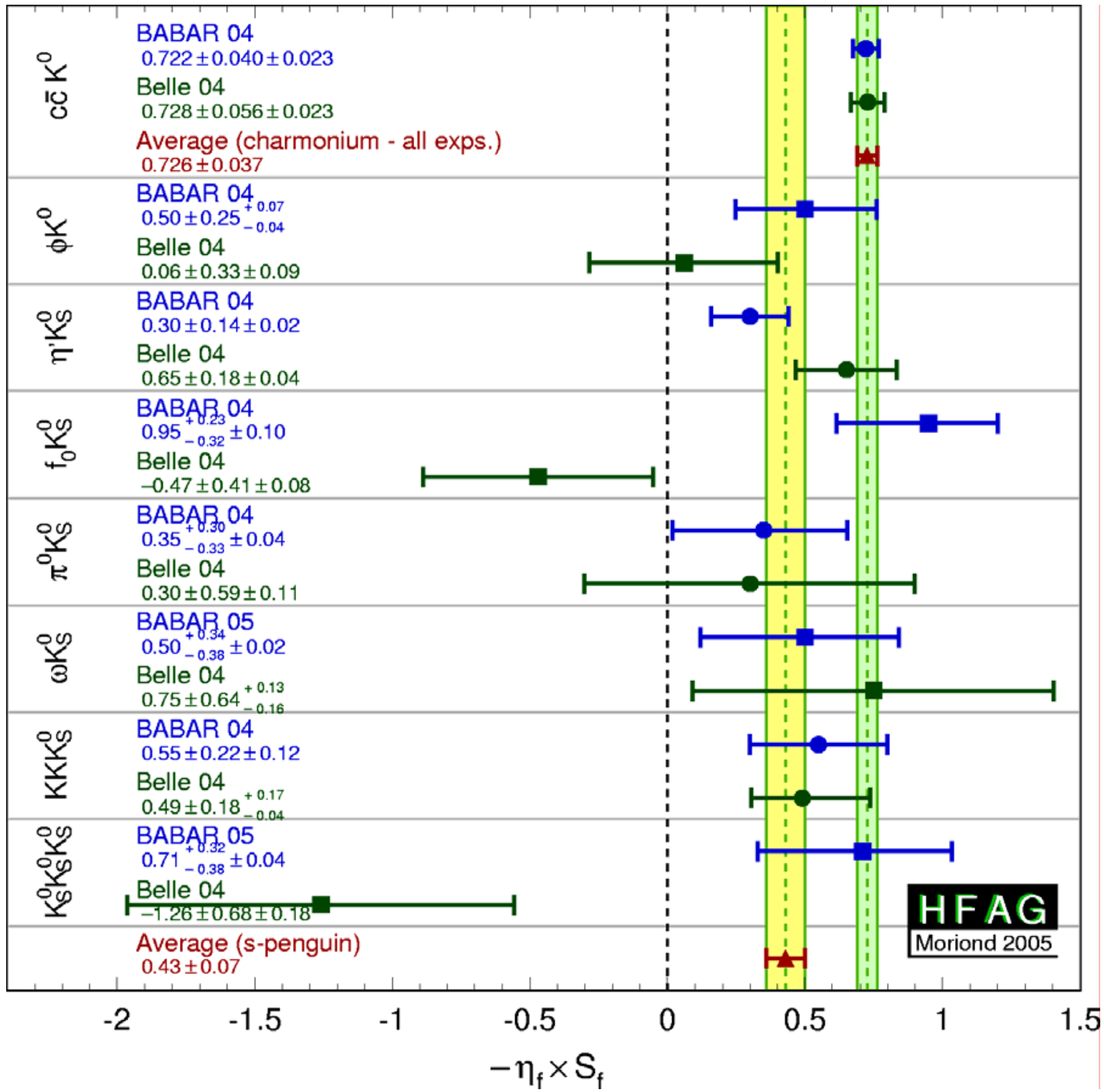
  Belle: ~0.15 (dominated by bkg, fit bias (!) and resolution fcn)

  BABAR: 0.04





$\sin(2\beta_{eff})$ from *s*-penguin decays: experimental summary



no indication for direct CPV

Theory: $\Delta S \equiv \sin(2\beta_{\rm eff}) - \sin(2\beta)$

- Most urgent theoretical question: determine ΔS for the various s-penguin modes

  approaches: SU(3) flavor symmetry (Ligeti)

  QCD-improved (Beneke, Pierini)

- Ligeti: Grossman-Ligeti-Nir-Quinn, hep-ph/0303171
  - also discusses: CKM phase from eff. tree processes (same ρ-η point as in standard CKM fit)

    photon polarization in $B \to X\,\gamma$: concludes that $S(f_s\gamma) \sim O(0.1)$ possible (RH photons)
  - SU(3) analysis: recalls that estimates are not optimal, and theory errors <u>not</u> statistical

$$\underbrace{A(B^0 \to f_s)}_{b\to q\bar{q}s} = \underbrace{V_{cb}^*V_{cs}}_{[\lambda^2]}\, a_{f_s}^c + \underbrace{V_{ub}^*V_{us}}_{[\lambda^4]}\, a_{f_s}^u = V_{cb}^*V_{cs} a_{f_s}^c (1+\xi_{f_s})$$

naïve: $\xi_f \sim O(0.03)$

$$\underbrace{A(B^0 \to f_d)}_{b\to q\bar{q}d} = \underbrace{V_{cb}^*V_{cd}}_{[\lambda^3]}\, b_{f_d}^c + \underbrace{V_{ub}^*V_{ud}}_{[\lambda^3]}\, b_{f_d}^u = V_{ub}^*V_{ud} b_{f_d}^u (1+\lambda^2 \xi_{f_d}^{-1})$$

more sensitive to ξ_f

SU(3) relates a_{fs} to b_{fd}: $a_f^u = \sum_{f_d} x_{f_d} b_{f_d}^u$

Branching ratios constrain $\left|\dfrac{V_{ub}^*V_{ud}}{V_{cb}^*V_{cs}}\dfrac{b_{f_d}^u}{a_{f_s}^c}\right| \sim \sqrt{\dfrac{B(f_d)}{B(f_s)}}$

Combine SU(3) and data for <u>conservative</u> upper limit: $\left|\xi_{f_s}\right| = \left|\dfrac{V_{ub}^*V_{us}}{V_{cb}^*V_{cs}}\dfrac{a_{f_s}^u}{a_{f_s}^c}\right| < \lambda \sum_{f_d} \left|x_{f_d}\right| \sqrt{\dfrac{B(f_d)}{B(f_s)}}$

- numerical results (limits at 90% CL)

$$\left|\xi_{\eta' K^0}\right| < 0.17 \qquad (< 0.08 \text{ with } \eta' K^+ \text{ assuming equal trees, and } m_d = m_s)$$

$$\left|\xi_{\phi K^+}\right| < 0.23 \qquad \text{(assumptions as above)}$$

- Denis D. and I found (using CKMfitter for proper error propagation):

(see Denis' talk at: http://www.slac.stanford.edu/BFROOT/www/Physics/WednesdayMeetings/W020205/sin2b-penguin_Uncertainty.pdf)

$$\left|\xi_{\eta' K^0}\right| < 0.14 \qquad (< 0.07 \text{ with } \eta' K^+ \text{ assuming equal trees, and } m_d = m_s)$$

$$(< 0.10 \text{ simplified - ignoring some suppressed modes})$$

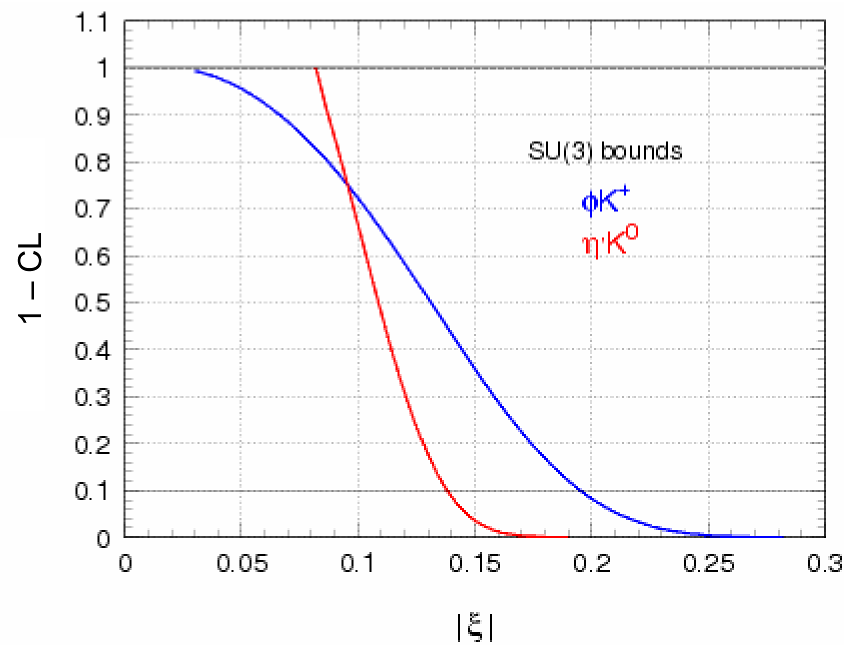
$$\left|\xi_{\phi K^+}\right| < 0.19$$

- also limits on

$|\xi_{K+K-Ks}|$ < 0.19

$|\xi_{\pi^0 Ks}|$ < 0.15

- measurement of K^*K^0 (and others) required



- Beneke: Beneke-Neubert, hep-ph/0308039
  - nicely responded to the Q's from the workshop
  - discusses all modes, but f_0K^0 (unclear quark content) and KKK^0 (3-body modes, no theory)
  - ansatz:

$$A(\bar{B}^0 \to f) = \underbrace{V_{cb}^* V_{cs}}_{[\lambda^2]} a_{f_s}^c + \underbrace{V_{ub}^* V_{us}}_{[\lambda^4]} a_{f_s}^u \propto 1 + e^{-i\gamma} d_f$$

$$\Delta S \propto \mathrm{Re}(d_f)\underbrace{\cos(2\beta)\sin\gamma}_{\sim 0.6} \quad \text{and} \quad C \propto \mathrm{Im}(d_f)\underbrace{\sin\gamma}_{0.9}$$

➡ if d_f is small: S_f and C_f involve independent hadronic parameters

Remarks:

- final state rescattering included
- uncertainties: form factors, power corrections, weak annihilation, light-cone fcns, …
- hierarchies (in relevance for *s*-penguin modes) for topological amplitudes
  - *rather certain:* T irrelevant, P_{EW} contribute
  - *less certain:* $P^{c,u}$ for PP very important, $P_{\mathrm{EW,C}}$ negligible
  - *uncertain:* $P^{c,u}$ for PV+VP very important, C important, $S^{c,u}$ contribute

- pattern, neglecting unimportant modes:

of order one, corrected for CKM suppression

$$\pi K_S \quad \hat{d}_f \sim \frac{[-P^u]+[C]}{[-P^c]} \qquad \rho K_S \quad \hat{d}_f \sim \frac{[P^u]-[C]}{[P^c]}$$

$$\eta' K_S \quad \hat{d}_f \sim \frac{[-P^u]-[C]}{[-P^c]} \qquad \phi K_S \quad \hat{d}_f \sim \frac{[-P^u]}{[-P^c]}$$

$$\eta K_S \quad \hat{d}_f \sim \frac{[P^u]+[C]}{[P^c]} \qquad \omega K_S \quad \hat{d}_f \sim \frac{[P^u]+[C]}{[P^c]}$$

[Quantities in square brackets have positive real part.]

$|P^u/P^c|$ are roughly independent of f but (magnitude of real parts)

$$P^c(\pi K) \sim 2P^c(\rho K) \sim 0.4P^c(\eta' K) \sim 2.3P^c(\eta K) \sim 1.3P^c(\phi K) \sim 2.3P^c(\omega K)$$

hence the influence of C determines the difference between the different modes.

- results:

Mode	Theory $\delta\sin(2\beta)_f$	[Range]*	Experiment
πK_S	$0.07^{+0.05}_{-0.04}$	$[+0.02, 0.13]$	$-0.39^{+0.27}_{-0.29}$
ρK_S	$-0.08^{+0.08}_{-0.12}$	$[-0.24, 0.02]$	—
$\eta' K_S$	$0.01^{+0.01}_{-0.01}$	$[-0.01, 0.03]$	-0.32 ± 0.11
ηK_S	$0.10^{+0.11}_{-0.07}$	$[-1.45, 0.27]$	—
ϕK_S	$0.02^{+0.01}_{-0.01}$	$[+0.01, 0.04]$	-0.39 ± 0.20
ωK_S	$0.13^{+0.08}_{-0.08}$	$[+0.03, 0.19]$	$0.02 \pm 0.64^{+0.13}_{-0.16}$

* range determined with scans requiring the exp. BRs to be within 3σ

- discussion points:
  - expected deviations mostly positive !
  - very small uncertainties for $\eta' K_S$ and ϕK_S
  - direct *CP* measurement of no use, if it is small
  - SU(3) is of no use: n-n' and ω-ϕ mixing are $O(1)$ effects

    $\rightarrow$ roughly, the argument goes like: QCDF is $O(\Lambda_{QCD}/m_b \sim 0.1)$, while SU(3) is $O(0.3)$

- how to obtain large ΔS ? [recall: $\mathrm{Re}(d_f) \sim \varepsilon_{CKM} \times \mathrm{Re}(a^u / a^c)$]
  - suppression of a^c ? cancellation between amplitudes excluded by BR measurements
  - enhancement of a^u ? needs to be several times larger than predicted by QCDF… not possible
  - if to be explained by hadronic effects, possibly large enhancement of *u*-penguin

my comment: note that this scenario is favored by current $\pi\pi$, $K\pi$ data

- Pierini: Ciuchini *et al.*, in preparation
  - introductory remarks:
  - a clear demonstration that penguins *do* factorize is still missing
    - Λ_{QCD}/m_b corrections may be important
  - charming penguin approach:
  - take tree $E_{1,2}$ and pert. LO contributions from QCDF
    - parameterize (RGIq) P^c, P^{c-u}, annhiliation by complex amplitudes (neglect OZI-suppr. terms)

fit for these using data

  - ansatz: $\sqrt{2}\cdot A(B^0 \to K^0\pi^0) = \underbrace{-V_{tb}^* V_{ts}}_{[\lambda^2]} P(c) - \underbrace{V_{ub}^* V_{us}}_{[\lambda^4]}\left(E_2 + P_1^{\mathrm{GIM}}(u-c)\right)$

  - what about EW penguins ? Neglected ?
  - results for fits to all isospin-related modes:

$\Delta S(\pi^0 K^0)$	= + 0.04 ± 0.02, no/small direct CPV
$\Delta S(\pi^0 K^{*0})$	= + 0.05 ± 0.06, no/small direct CPV
$\Delta S(\rho^0 K^0)$	= – 0.02 ± 0.05, no/small direct CPV
$\Delta S(\phi^0 K^0)$	= + 0.03 ± 0.05, no/small direct CPV

s-penguins: my personal conclusions

- "QCD-improved" authors agree quantitatively (also on the sign of ΔS)
- only data-driven fits are predictive when $\Delta S \sim O(0.1)$
- for $\eta' K^0$ and ϕK^0 $\Delta S \sim O(0.01) \rightarrow$ even large errors in the theory would not lead to large ΔS
- why would SU(3) be better than Factorization ?

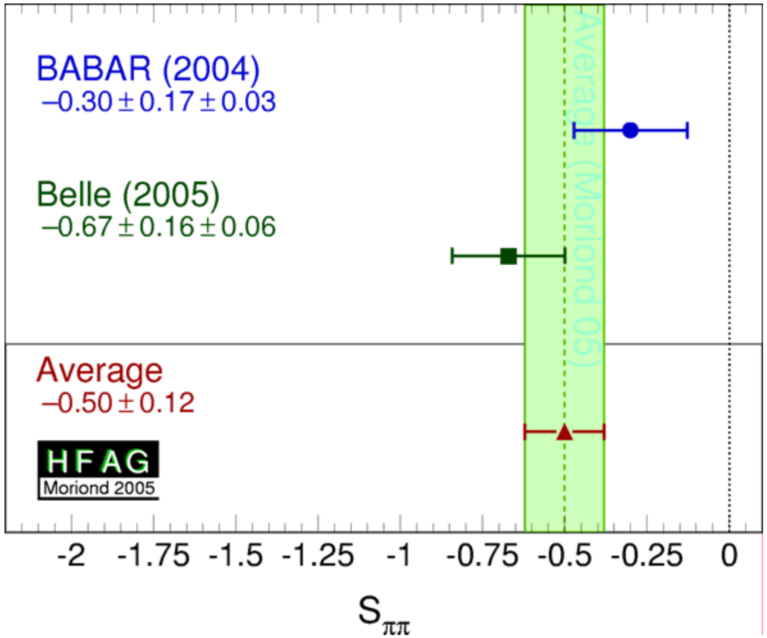
  (only because it produces worse bounds, doesn't make it more reliable ;-))
- what if *u*-penguins are huge ? … and why would that be ?

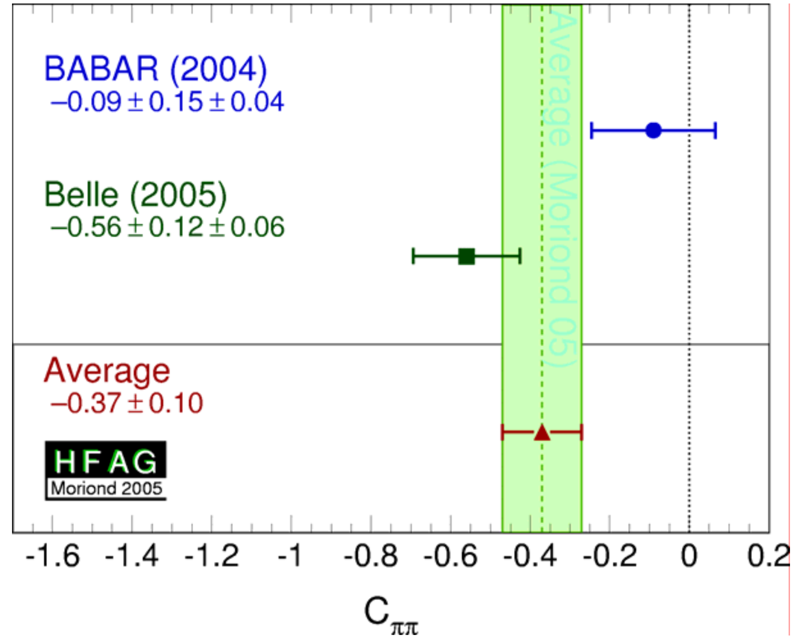
Extraction of α

Experimental talks by

- Ishino ($B \to \pi\pi$) [nice talk!] : Belle [275m] and BABAR[227m] for $\pi^+\pi^-$
  - continuum suppression :
    - Belle uses Super-FW moments: these involve the final B_{CP} state momenta, and hence are different for each final state: how to validate these with BReco events ? Never saw a validation plot !
    - Belle: L/ratio cut; BABAR: Fisher in fit
  - Fit yields :
    - Belle: $N_{\pi\pi}$ = 666 $\pm$ 43, $N_{K\pi}$ = 247 $\pm$ 31 (after PID cut); 2 parameter fit (2820 events in fit)
    - BABAR: $N_{\pi\pi}$ = 467 $\pm$ 33, $N_{K\pi}$ = 1606 $\pm$ 51; 46 parameter fit (two-step fit ☹) (68030 events in fit)
  - Validations :
    - both: tag-cat dependent S & B PDFs; τ_B and Δm_d measurements; similar systematics
    - Belle: Δt(cont) obtained from sideband events
      cont *CP* asymmetries varied for systematics
      full MC fits ?
      no likelihood ratio plot and/or sPlots;
      fits for subsets with different S/N … consistency within stat. errors

Results : S & C combined: 3.2 (ICHEP'04) → 2.3σ discrepancy





- Belle's direct CPV check:
  (time-integrated fit)

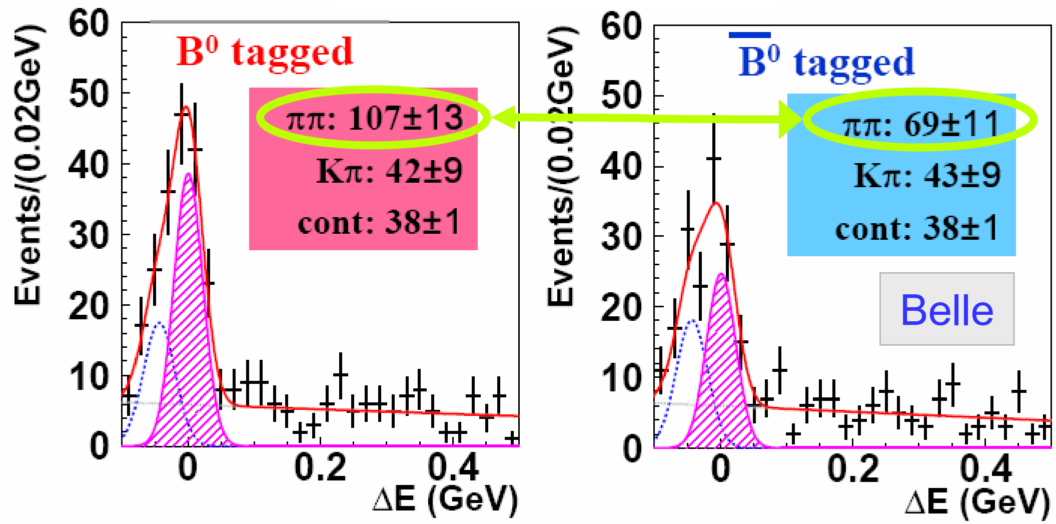
- amusing SU(3) trick:

$$A_{CP}(K^+\pi^-) = -0.11 \pm 0.02$$

$$\approx SU(3)$$

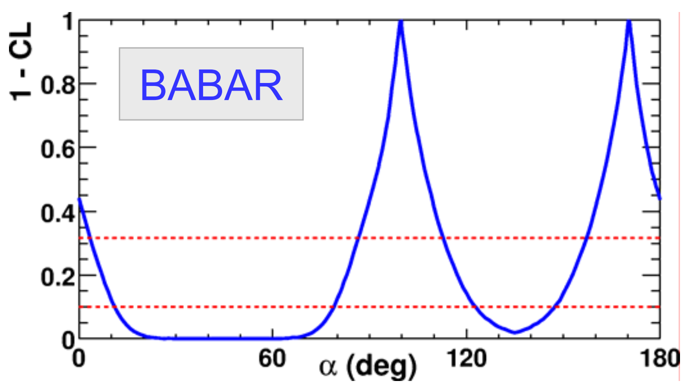
$$\frac{1}{3}C(\pi^+\pi^-) = -0.12 \pm 0.03$$

Gronau-Rosner, hep-ph/0405173



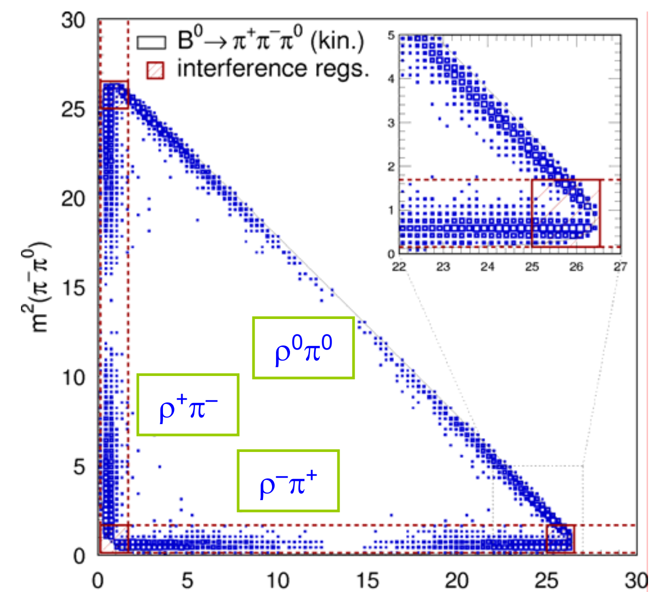
- Bevan ($B \to \rho\rho$) BABAR[227m] for $\rho^+\rho^-$ and $\rho^0\rho^0$ – nothing from Belle yet ☹
  - introduction to isospin analysis and complication with CPV in $B \to VV$ decays
  - presentation of $B^0 \to \rho^0\rho^0$ measurement, and effect on isospin analysis
  - presentation of $B^0 \to \rho^0\rho^0$ pointing out improvements (mainly B-bkg treatment)
    - very nice summary of complicated analysis
    - discussion of interference effects with $\rho\pi\pi$ and $a_1\pi$
  - Isospin analysis predicts that $B^+ \to \rho^+\rho^0$ is somewhat large
    - Belle [93m]: $B(\rho^+\rho^0) = 31.7 \pm 7.1\,^{+3.8}_{-6.7}$
    - BABAR [89m]: $B(\rho^+\rho^0) = 22.5\,^{+5.7}_{-5.4} \pm 5.8$

    are the large B backgrounds correctly subtracted ?
  - New toy-based frequentist determination of α :
    - BABAR and Belle use same (or similar) method for isospin analysis: easy to average



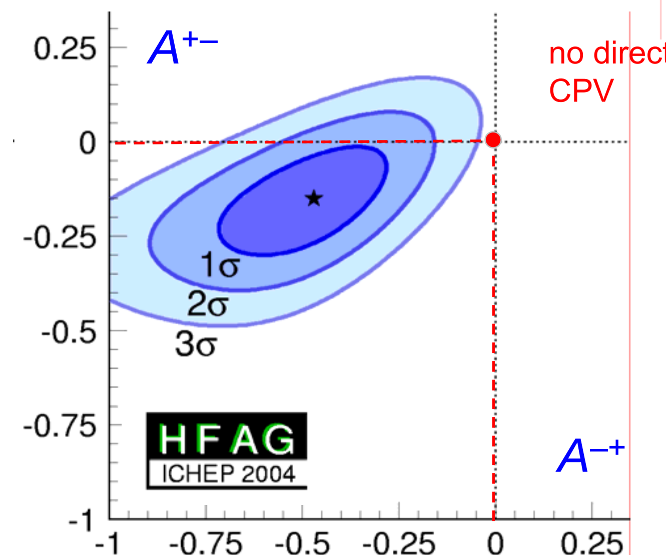
$$\alpha_{[SM]} = (100 \pm 13)^\circ \text{ with } 11^\circ \text{ due to penguins}$$

- Graham ($B \to \rho\pi$) BABAR[213m] for full DP analysis
  - introduction to phenomenological framework, isospin analysis (pentagon)
  - Q2B analysis (only ρ bands on DP): Belle [152m]
    - similar as other charmless analyses
    - tight cut on ρ helicity angle: $|\cos\theta| > 0.5$ to fight cont
    - $E(\pi^0)$ dependent ΔE and m_{bc} (like us)
    - distinguish correct and wrong charge
    - 3 B-bkg components: ρK, generic BB and rare B
    - $N_S = 483 \pm 46$ (BABAR[213m]: 1184 ± 58, full Dalitz)
  - difficulties for Q2B analysis: needs super-B statistics
  - direct CPV: BABAR dominates and Belle agrees
    - QCDF predicts small penguins: very small direct CPV !



Average : BABAR (213m) & Belle (152m)	
A^{+-} -0.15 ± 0.09	A^{-+} $-0.47^{+0.13}_{-0.14}$

$\Delta\chi^2$(no direct CPV) = 14.5 (CL = 0.00070 $\Rightarrow$ 3.4σ)



  - presentation of Dalitz plot analysis with 27 obs., etc
    - see $\rho^0\pi^0$, but do not confirm large BR from Belle !

Theory talks by

- Buchalla ($B^0 \to \pi^+\pi^-$, $\rho^+\pi^-$, $\rho^+\rho^-$)

  Buchalla-Safir, hep-ph/0406016

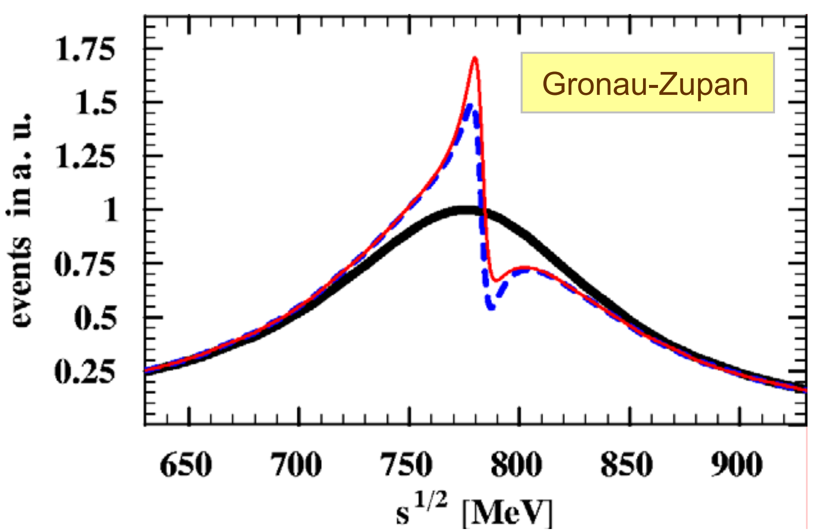
  similar idea in Gronau et al., hep-ph/0410170

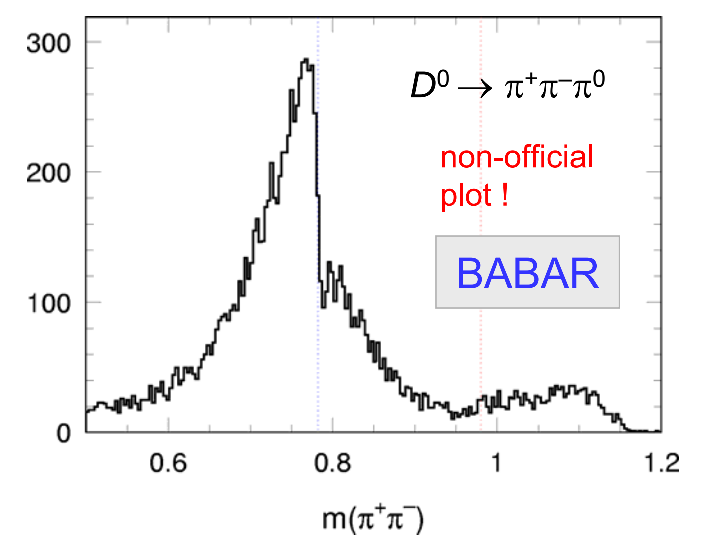
  - bounds on η from *CP* measurements only, ignoring SU(2) partners:
    - assuming strong phase < |90°|
    - use as input $\sin(2\beta)$
  - hmmm …
- Zupan (isospin violation in $B \to \pi\pi$, $\rho\pi$, $\rho\rho$) [nice talk!]

  Gronau-Zupan, hep-ph/0502139

  - isospin breaking:
    - source are *d*,*u* charges different, quark-mass differences
    - typical size: $(m_u - m_d)/\Lambda_{QCD} \sim 1\%$
    - extend basis of operators to P_{EW}: $Q_{7,\ldots,10}$
    - mass eigenstate ≠ isospin eigenstates → mixing (π^0-η-η', ρ-ω)
    - may induce $\Delta I = 5/2$ transitions
  - EW penguins:
    - can be Fierz-related to $\Delta I = 3/2$ (tree) amplitude: $e^{i\gamma}A^{+0} = e^{-i(\gamma+2\delta)}\overline{A}^{+0}$, with $\delta \approx 1.5°$
    - neglects $Q_{7,8}$
    - also holds for $\rho\pi$, $\rho\rho$

- π^0-η-η' mixing :
  - $\left|\pi^0\right\rangle = \left|\pi_3\right\rangle + \varepsilon\left|\eta\right\rangle + \varepsilon'\left|\eta'\right\rangle$, with known ε, ε'
  - would create direct CPV in $\pi^+\pi^0$
  - bound from SU(3): $\Delta\alpha$ < 1.4°; much smaller bound (<0.1°) for $\rho\pi$
- $B \to \rho\rho$
  - $\Gamma_\rho > 0 \to \Delta I = 1$ contributions possible (like in $\rho\pi$)
  - $O(m_\rho / \Gamma_\rho)^2$ effect; can be reduced experimentally by tighter m_ρ cuts
- ρ-ω mixing : must be there ! (also for $B \to \rho\pi$)
  - determined from fits to $\pi^+\pi^-$ spectrum
  - expect large effect, since: $|A(B^+\to\rho^+\omega) / A(B^+\to\rho^+\rho^0)| = 0.69 \pm 0.41$
  - however: integrated effect is small (< 2%)





$B \to \pi\pi$, $K\pi$ decays

Experimental talks by

- Cristinziani (BRs and A_{CP} in $B \to \pi\pi$, $K\pi$) : Belle [275m] and BABAR[227m] for $\pi^+\pi^-$
  - analysis status :
    - Belle: BRs mostly (but $\pi^0\pi^0$) with 85m BB, A_{CP} with 275m
    - BABAR: most with 227m, but BR(h^+h^-)
  - strategies similar as in previous CP analyses
    - I would love to see sPlots from Belle !
  - radiative corrections are major issue for BR measurements
    - copious 2-body BRs are now systematically limited
  - results:
    - no evidence for $B^0 \to K^+K^-$ (need combined limit for phenom. analyses)
    - ~ agreement for $\pi^0\pi^0$ signal (Belle: 82 ± 16, BABAR: 61 ± 17 (twice smaller BR))
    - large BR($K^0\pi^0$) confirmed
    - no K_SK_S signal seen by Belle (BABAR has 4.5σ evidence)
    - approximate Lipkin sum rule (relating A_{CP} and BRs between $K\pi$ modes) satisfied
  - future of $\pi\pi$ isospin analysis is entirely driven by $\pi^0\pi^0$ mode !

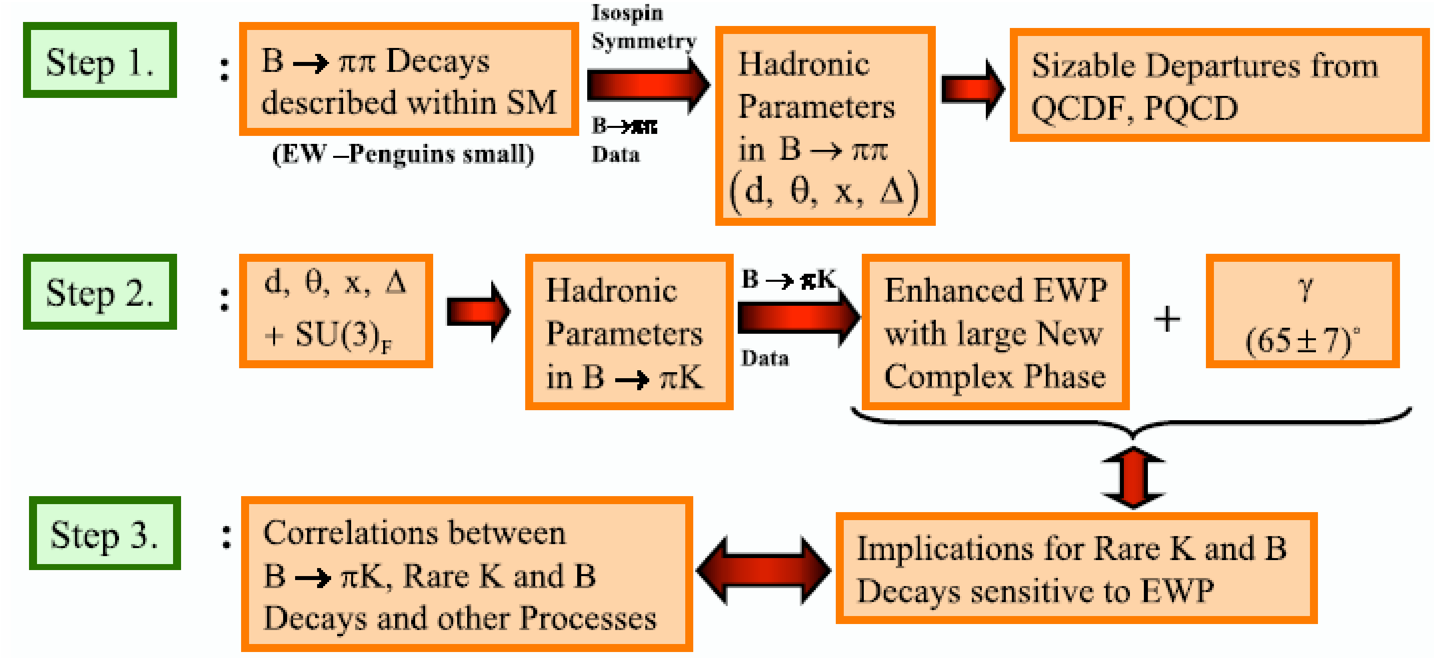
Theory of $B \to \pi\pi$, $K\pi$ decays

- Buras (introduction)
  - confront 16(–1) $\pi\pi$, $K\pi$ observables with theory/flavor symmetry
  - weak effective Hamiltonian: $H_{\mathrm{eff}} = \frac{G_F}{\sqrt{2}} \sum_{i=1...10} C_i(\mu) Q_i$
    - C_i are short-distance Wilson coefficients, mostly known to NNLO pQCD
    - Q_i are long-distance local tree, QCD penguin and EW penguin operators: unknown
  - theoretical strategies:
    - diagrammatic approach and SU(3)-flavor (problem: no explicit relation with H_{eff})
    - calculations of the matrix elements (QCDF, pQCD, SCET, …)
    - admixtures between these
  - $B \to \pi K$ decays:
    - during 90's: lots of sum rules/ratios/… to measure γ; but: γ subleading, uncertaint. not controlled
    - now: input γ from global CKM fit, and study dynamics (mainly EWP sector, NP)
    - is there a puzzle ? Buras et al, hep-ph/0309012

$$R_n = \frac{1}{2}\frac{\mathrm{BR}(B^0 \to \pi^- K^+)}{\mathrm{BR}(B^0 \to \pi^0 K^0)} = 0.79 \pm 0.08 \quad \text{whereas } R_n > 1 \text{ in SM (??)}$$

Theory of $B \to \pi\pi$, $K\pi$ decays: series of short talks

- Fleischer: hep-ph/0312259, hep-ph/0402112, hep-ph/0410407
  - analysis strategy:



  - $\pi\pi$ analysis shows
    - agreement with SM (we knew this from isospin analysis already)
    - sizable direct CPV in $\pi^0\pi^0$ expected
    - large non-factorizable contributions (large "color-suppressed" amplitude)

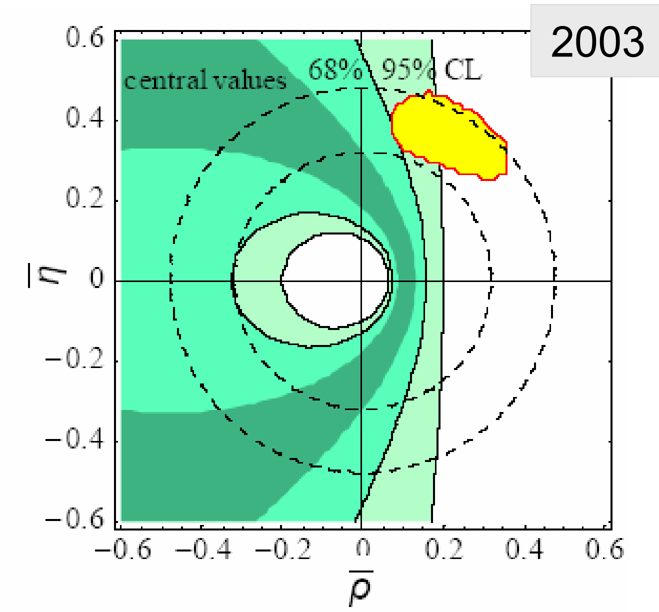
- strategy, ingredients to πK analysis, and results
  - SU(3)-flavor
  - neglect penguin annihilation and exchange topologies
  - use $\pi\pi$ results as input and predict πK
  - $A_{CP}(\pi^- K^+) = -0.13 \,^{+0.10}_{-0.07}$ (in agreement with measurement)
- study observables with sensitivity to EW penguins to search for NP
  - R_c , R_n
  - consider color-allowed EWP, neglect color-suppressed EWP
- conclusions
  - observables with tiny impact of EWP: agreement with SM
  - observables with sizable impact of EWP: discrepancies with SM
  - “puzzle” can be resolved with NP in EWP sector ($\rightarrow$ prediction of CPV effects in πK)

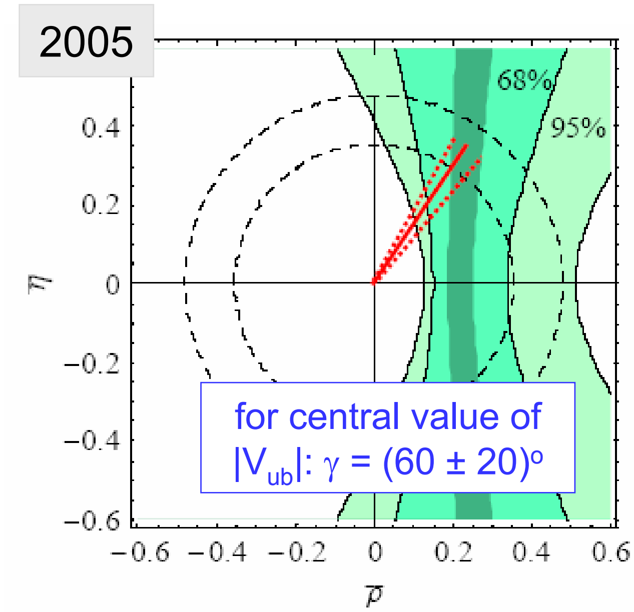
- Charles ($B \to \pi K$ puzzle: how many pieces): hep-ph/0406184, and in preparation
  - point of critique: why should annihilation/exchange diagrams are negligible ?
    - argument: power suppressed & ~ f_B/m_B & small in QCDF (model)
    - annihilation cannot be neglected in charm decays: $|A(B \to D_s K) / A(B \to DK)|$ ~ 10%
    - $BR(K^+K^-) / BR(\pi^+\pi^-)$ weak estimator of annihilation (< 30% for amplitudes)
  - puzzles ?
    - there is a $\pi\pi$ puzzle: why are "color-suppressed" terms so large ?
    - there is no πK puzzle using SU(2) [quadrilateral system not constraining enough]
    - there seems to be a πK puzzle using SU(3) when neglecting annihilation terms and $P_{EW,C}$
    - if one accepts that "color-suppression" has a problem, then $P_{EW,C}$ could be large
    - its inclusion is better than NP $\to$ no new parameters
  - side-remark (CKM information from *CP* and BR measurements, if $BR(K^+K^-)=0$)
    - $\pi^+\pi^-$, π^+K^- measure α (and not γ) in strict SU(3); UL on $BR(K^+K^-)$ gives bound on $|\alpha - \alpha_{eff}|$
    - $\pi^0\pi^0$, π^0K^0 measure β (and not γ) in strict SU(3)
    - $BR(\pi^-K^+)\, C(\pi^-K^+) + BR(\pi^-\pi^+)\, C(\pi^-\pi^+) = 0$ (= 0.3 ± 0.6)
    - $BR(\pi^0K^0)\, C(\pi^0K^0) + BR(\pi^0\pi^0)\, C(\pi^0\pi^0) = 0$ (= 0.6 ± 1.7)

    both satisfied in data
    (note of course: these sum rules neglect annihilation!)
  - main result: without dynamical assumptions, derive significant constraint in ρ-η plane from combined $\pi\pi$, πK fit in strict SU(3) limit. Marginal agreement with global CKM fit.

- Neubert (comments on $B \to \pi K$): using hep-ph/0308039
  - determination of γ
    - get relevant input from data, up to SU(3) breaking corrections, which are calculable for $m_B \to \infty$
    - residual uncertainties small: ~ $O(1/N_C \times m_s/m_b)$

$$R_* = \frac{1}{2}\frac{\mathrm{BR}(B^+ \to \pi^+ K^0)}{\mathrm{BR}(B^+ \to \pi^0 K^+)} = 0.71 \pm 0.14 \;\; (2001);\; 0.80 \pm 0.09 \; (2003);\; 0.99 \pm 0.08 \; (2005)$$





  - on the πK puzzle :
    - defines yet another pair of ratios: R_{00} and R_L
    - weak evidence (< 3σ) for new physics within QCDF approach to the πK puzzle

- Yoshikawa (Large EW penguins): hep-ph/0408090, hep-ph/0306147
  - … it was a nice talk, but no particularly new results
  - general outline:
    - diagrammatic approach (following Gronau-Hernandez-London-Rosner, eg, in hep-ph/9504327)
    - full ansatz including all relevant EW penguins
    - apply hierarchy assumptions
    - fit to $B \to \pi K$ data
  - conclusions:
    - $|P_{EW}/P|$ >~ 0.2 – but not enough to remove all discrepancies
    - large strong phase between EWP and tree required
      $\to$ or: new physics phase, or large "color suppression"
    - new physics phases must appear in direct CPV and $S(\pi^0 K^0)$

- Also two brief discussion contributions from Sivestrini (charming penguins) and Lipkin (SU(3) relations between πK observables)

- Feldman (Naively-, QCD- and non-factorizable effects):

hep-ph//0408188

is really interested in understanding the dynamics

  - Factorization
    - naïve factorizable effects: $A_{M_1M_2} \sim f_{M_1} F^{B\to M_2}$
    - QCD-factorizable: $A^{F}_{M_1M_2} \sim \alpha_S \cdot f(\phi_{M_i}, \phi_B, F^{B\to M_i})$
    - non-factorizable effects (model-dependent)
      - power-suppressed: $A^{NF}_{M_1M_2} \sim O(\Lambda / m_b)$
      - soft / endpoint sensitive effects: $A^{NF}_{M_1M_2} \sim \alpha_S \ln(\Lambda / m_b)$
  - Typical QCD-improved $B \to \pi\pi$ analyses
    - 7(–1) real parameters (isospin)
    - assumptions about size of NF effects, *eg*, EW penguins are neglected
    - ends up with 3-4 adjustable parameters (*eg*, X_A, X_H in BBNS, charm penguins, …)
    - present data show preference for large NF *u*-penguin compared to *c*-penguin
  - Long distance penguins and annihilation must be included when discussing NF effects
  - SU(3) and isospin violation
    - $SU(3)_F$ breaking for NF amplitudes cannot be obtained from F ones
    - can isospin-breaking corrections play a role in πK ? ~ 5% ?
  - better control of power-suppressed effects is the most urgent theoretical issue

$B \to \pi\pi$, $K\pi$ decays: conclusions ?

- before becoming too quantitative, need updates of $\pi\pi$, πK BRs (incl. radiative corrections)
- most phenomenological groups agree on where problems are/may be
- differences about what can be neglected
- certainly, within SU(2) there is no problem at all
- problems start within SU(3), and are also present in QCD-improved analyses
- control of power-suppressed terms is major theoretical challenge
- rather independent of the theoretical framework (QCDF, SCET, pQCD, …)

more next week ☺