Third Lecture

- Clean determination of angles

  ... $B_s \to D_s K$ or $B \to D^{(*)}\pi$

  ... $B \to \pi\pi$ with isospin analysis, etc.

- Factorization in $B \to D^{(*)}X$ decay

  ... How / why to test it

- Factorization in charmless decays

  ... different approaches

  ... some predictions / applications

- Summary / Conclusions

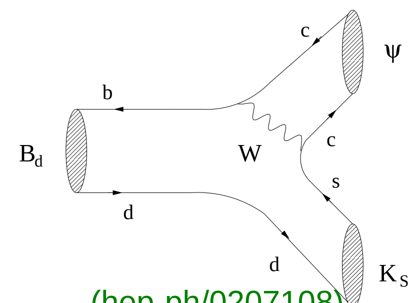
Angles — cleanly

$B \to \psi K_{S,L}$ — saw this before

- Clean measurement possible because $|\lambda_{\psi K_{S,L}}| - 1 \ll 1$

$$a_{f_{CP}} = \frac{\Gamma[\overline{B}^0(t) \to f] - \Gamma[B^0(t) \to f]}{\Gamma[\overline{B}^0(t) \to f] + \Gamma[B^0(t) \to f]} = S_f \sin(\Delta m\, t) - C_f \cos(\Delta m\, t)$$

$$\lambda_{f_{CP}} = \frac{q}{p}\frac{\overline{A}_{f_{CP}}}{A_{f_{CP}}} = \eta_{f_{CP}}\frac{q}{p}\frac{\overline{A}_{\overline{f}_{CP}}}{A_{f_{CP}}}, \quad S_f = \frac{2\mathrm{Im}\,\lambda_f}{1+|\lambda_f|^2}, \quad C_f = \frac{1-|\lambda_f|^2}{1+|\lambda_f|^2}$$

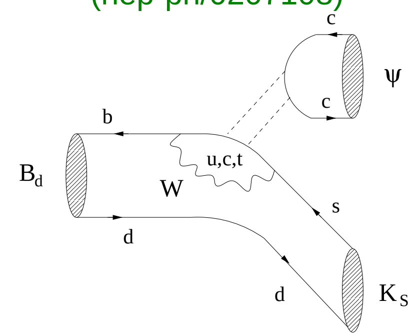


(hep-ph/0207108)

Tree: $\overline{A}_T \sim V_{cb}V_{cs}^*$

Penguin: $\overline{A}_P \sim \underbrace{V_{tb}V_{ts}^*}_{[\lambda^2]} f(m_t) + \underbrace{V_{cb}V_{cs}^*}_{[\lambda^2]} f(m_c) + \underbrace{V_{ub}V_{us}^*}_{[\lambda^4]} f(m_u)$

$$= \underbrace{V_{cb}V_{cs}^*}_{\text{same as Tree phase}}[f(m_c)-f(m_t)] + \underbrace{V_{ub}V_{us}^*}_{\text{suppressed by } \lambda^2}[f(m_u)-f(m_t)]$$

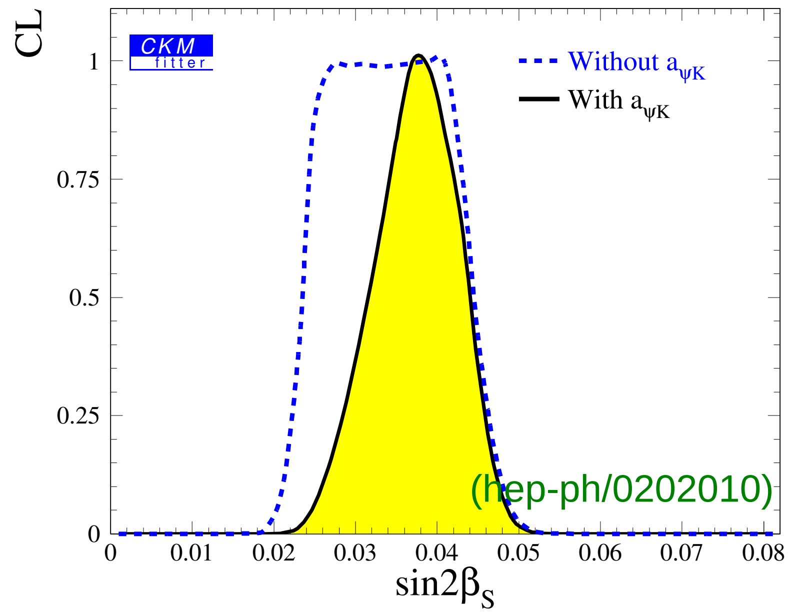


$$\lambda_{\psi K_{S,L}} = \mp\left(\frac{V_{tb}^*V_{td}}{V_{tb}V_{td}^*}\right)\left(\frac{V_{cb}V_{cs}^*}{V_{cb}^*V_{cs}}\right)\left(\frac{V_{cs}V_{cd}^*}{V_{cs}^*V_{cd}}\right) = \mp e^{-2i\beta} \quad \Rightarrow \mathrm{Im}\lambda_{\psi K_{S,L}} = \pm\sin 2\beta$$

$B_s \to \psi\phi$ and $B_s \to \psi\eta^{(\prime)}$

- Analog of $B \to \psi K_S$ in B_s decay — determines the phase between B_s mixing and $b \to c\bar{c}s$ decay, β_s, as cleanly as the determination of β

β_s is a small angle (of order λ^2) in one of the "squashed" UT's



- $\psi\phi$ is a VV final state, so the asymmetry will be diluted by the CP-odd component

$\Rightarrow$ A large asymmetry would clearly signal NP

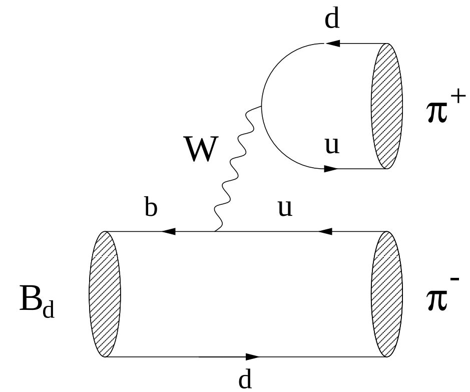
$\psi\eta^{(\prime)}$, on the other hand, is pure CP-even

$B \to \pi\pi$ — the problem

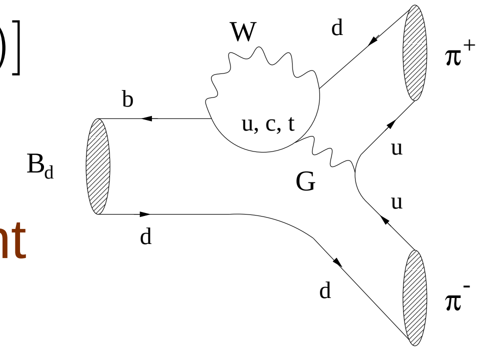
- There are tree and penguin amplitudes, just like for ψK_S

"Tree" ($b \to u\bar{u}d$): $\quad \overline{A}_T \sim \overset{[\lambda^3]}{V_{ub}V_{ud}^*}$

"Penguin": $\quad \overline{A}_P \sim \overset{[\lambda^3]}{V_{tb}V_{td}^*}\, f(m_t) + \overset{[\lambda^3]}{V_{cb}V_{cd}^*}\, f(m_c) + \overset{[\lambda^3]}{V_{ub}V_{ud}^*}\, f(m_u)$



(unitarity) $\quad \sim \underbrace{\overset{[\lambda^3]}{V_{ub}V_{ud}^*}}_{\text{same as Tree phase}}[f(m_u) - f(m_t)] + \underbrace{\overset{[\lambda^3]}{V_{cb}V_{cd}^*}}_{\text{not suppressed}}[f(m_c) - f(m_t)]$



Two amplitudes with different weak- and possibly different strong phases; their values not known model independently

Define P and T by: $A_{\pi^+\pi^-} = T(V_{ub}V_{ud}^*) + P(V_{cb}V_{cd}^*)$

Ratio of $K\pi$ and $\pi\pi$ rates indicates $|P/T| \sim 0.2 - 0.4$, i.e., $|P/T| \not\ll 1$

- Possible solutions: (1) eliminate P; or (2) attempt to calculate P

$B \to \pi\pi$ — isospin analysis

$(u,\, d)$: I-spin doublet

other quarks and gluons: $I = 0$

$\gamma,\, Z$: mixtures of $I = 0, 1$

$(\pi\pi)_{\ell=0} \quad \to \quad I_f = 0$ or $I_f = 2$

$(1 \times 1) \qquad (\Delta I = \frac{1}{2}) \qquad (\Delta I = \frac{3}{2})$

$I = 0$ final state forbidden by Bose symmetry

Hamiltonian has two parts: $\Delta I = \frac{1}{2} \;\Rightarrow\; I_f = 0$

$\Delta I = \frac{3}{2} \;\Rightarrow\; I_f = 2$ ... only two amplitudes

3 rates: $\overline{B}^0 \to \pi^+\pi^-$, $\overline{B}^0 \to \pi^0\pi^0$, and $B^- \to \pi^0\pi^-$ determine magnitudes and relative phase of two amplitudes ... similarly for B^0 and B^+ decay

In practice, need all (tagged) rates $+$ time dependent asymmetry in $B \to \pi^+\pi^-$

Note: γ and Z penguins violate isospin and yield some (small) uncertainty

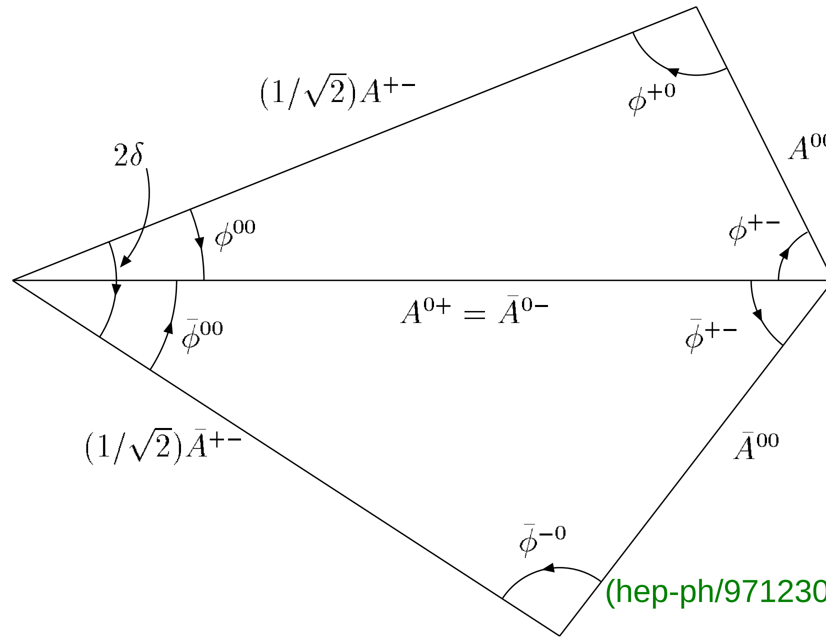
Isospin analysis (cont.)

$$A^{+-} \equiv A(B^0 \to \pi^+\pi^-), \qquad \bar{A}^{+-} \equiv A(\bar{B}^0 \to \pi^+\pi^-),$$
$$A^{00} \equiv A(B^0 \to \pi^0\pi^0), \qquad \bar{A}^{00} \equiv A(\bar{B}^0 \to \pi^0\pi^0),$$
$$A^{+0} \equiv A(B^+ \to \pi^+\pi^0), \qquad \bar{A}^{-0} \equiv A(B^- \to \pi^-\pi^0).$$

Isospin symmetry implies that 6 amplitudes form two triangles with a common base

$$\frac{1}{\sqrt{2}} A^{+-} + A^{00} = A^{+0}, \quad \frac{1}{\sqrt{2}} \bar{A}^{+-} + \bar{A}^{00} = \bar{A}^{-0}$$

$$|A^{+0}| = |\bar{A}^{-0}|$$



(hep-ph/9712306)

$2\delta =$ difference between $\arg \lambda_{\pi^+\pi^-}$ and 2α

(constrained by any limit on $\pi^0\pi^0$ rate – later)

$B \to \rho\pi$: 4 isospin amplitudes $\Rightarrow$ pentagon relations

Dalitz plot analysis would allow considering $\pi^+\pi^-\pi^0$ final state only

Implications of current data

- Babar and Belle measured:

$$S_{\pi^+\pi^-} = \frac{2\,\mathrm{Im}\,\lambda_{\pi\pi}}{1+|\lambda_{\pi\pi}|^2} \equiv \sin 2\alpha_{\mathrm{eff}}\,, \qquad C_{\pi^+\pi^-} = \frac{1-|\lambda_{\pi\pi}|^2}{1+|\lambda_{\pi\pi}|^2}$$

$$\lambda_{\pi\pi} = e^{-2i\beta}\,\frac{e^{-i\gamma}+P/T}{e^{i\gamma}+P/T}$$

If P/T were small, then $|\lambda_{\pi\pi}| \simeq 1$ and $S_{\pi^+\pi^-} = \mathrm{Im}\lambda_{\pi\pi} \simeq -\sin 2(\beta+\gamma) = \sin 2\alpha$

$C_{\pi^+\pi^-}$ measures: $|\lambda_{\pi\pi}|^2 = \dfrac{1-C_{\pi^+\pi^-}}{1+C_{\pi^+\pi^-}}$ (note: $S^2+C^2 \le 1$, and $=1$ iff $\mathrm{Re}\lambda = 0$)

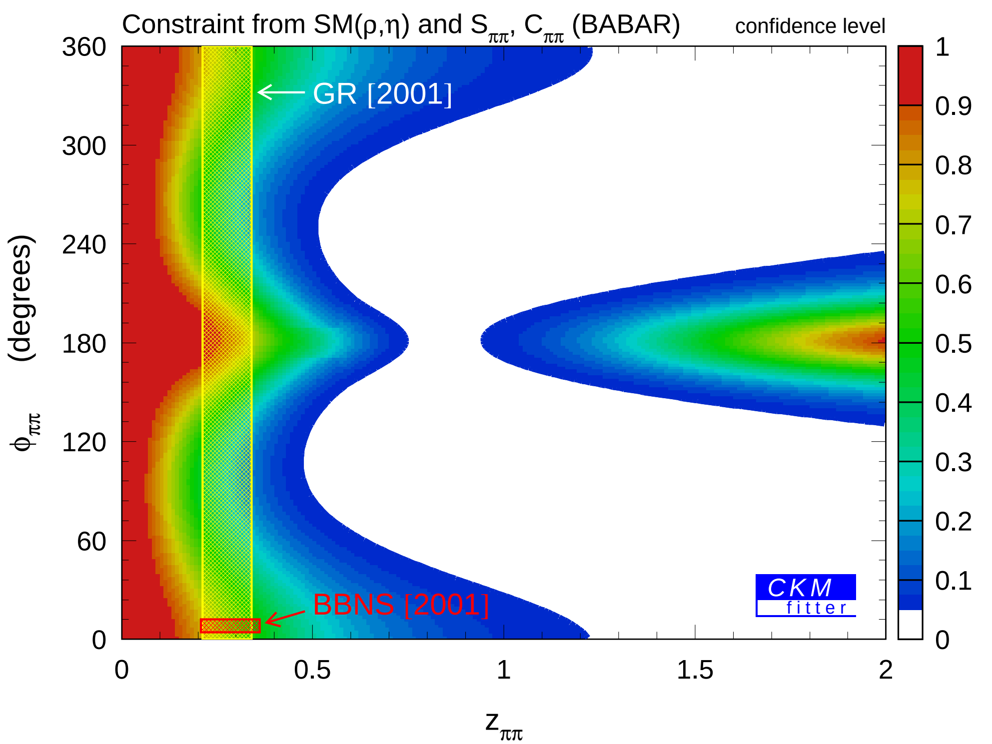
Central values of $C_{\pi^+\pi^-}$ imply Babar: $-0.30 \pm 0.25 \pm 0.04$ $\Rightarrow$ modest P/T

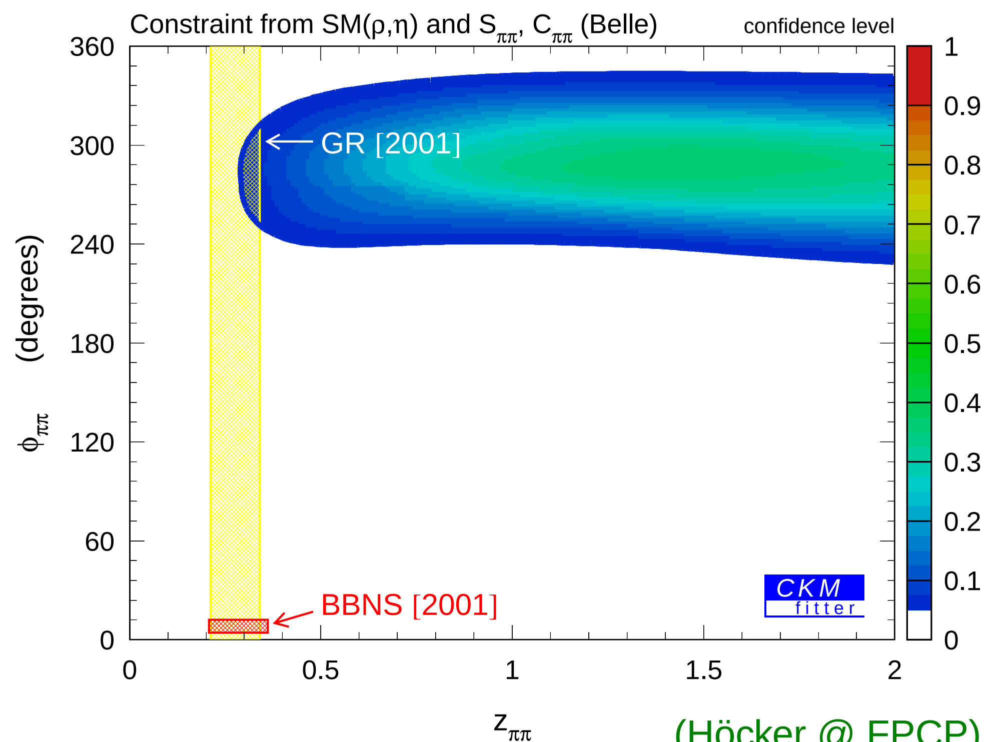
Belle: $-0.94^{+0.31}_{-0.25} \pm 0.09$ $\Rightarrow$ **large P/T**

- To extract α from $S_{\pi^+\pi^-}$ alone, need to know magnitude and phase of P/T

Implications for P/T — another way

Assume the SM is correct, use $S_{\pi\pi}$ and $C_{\pi\pi}$ measurements to constrain magnitude and phase of $P/T (\equiv z_{\pi\pi}\, e^{i\phi_{\pi\pi}})$

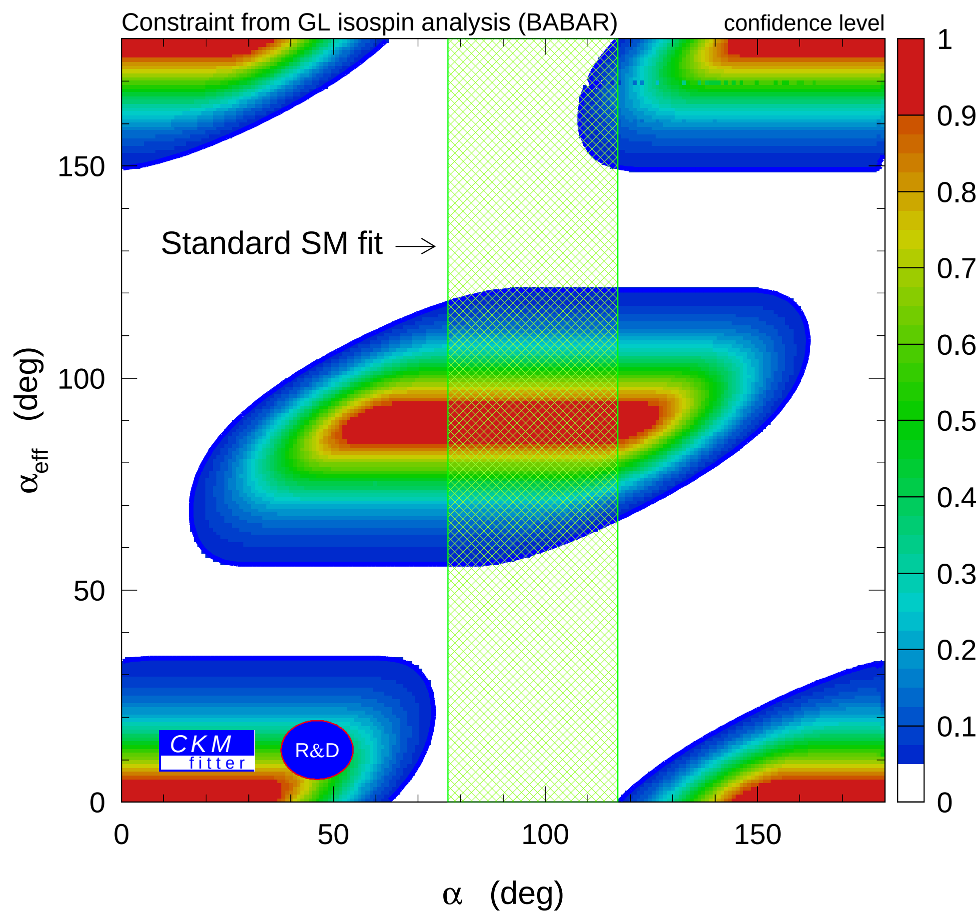




(Höcker @ FPCP)

need more data...

Bounding $\alpha - \alpha_{\text{eff}}$



Isospin relations + branching ratios + limit on $B \to \pi^0\pi^0 \Rightarrow$ bound on $\alpha - \alpha_{\text{eff}}$

No strong constraint from present bound on $B \to \pi^0\pi^0$

$B_s \to D_s^{\pm} K^{\mp}$ — a different story

- Interference between B_s and $\overline{B}_s$ decay — only one tree amplitude in each case

Four amplitudes: $\overline{B}_s \overset{A_1}{\to} D_s^+ K^- \quad (b \to c\bar{u}s)\,, \qquad \overline{B}_s \overset{A_2}{\to} K^+ D_s^- \quad (b \to u\bar{c}s)$

$$B_s \overset{A_1}{\to} D_s^- K^+ \quad (\bar{b} \to \bar{c}u\bar{s})\,, \qquad B_s \overset{A_2}{\to} K^- D_s^+ \quad (\bar{b} \to \bar{u}c\bar{s})$$

$$\frac{\overline{A}_{D_s^+ K^-}}{A_{D_s^+ K^-}} = \frac{A_1}{A_2} \left(\frac{V_{cb} V_{us}^*}{V_{ub}^* V_{cs}} \right), \qquad \frac{\overline{A}_{D_s^- K^+}}{A_{D_s^- K^+}} = \frac{A_2}{A_1} \left(\frac{V_{ub} V_{cs}^*}{V_{cb}^* V_{us}} \right)$$

Relative strong phase and magnitudes of A_1 and A_2 are unknown, still theory error is eliminated if four time dependent rates are measured:

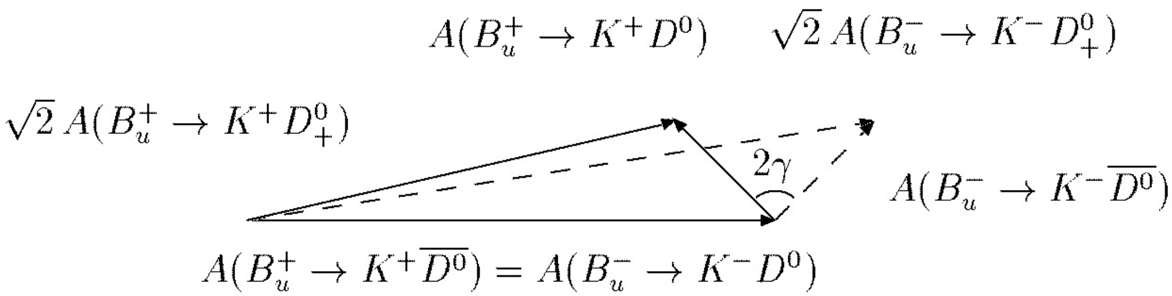
$$\lambda_{D_s^+ K^-}\, \lambda_{D_s^- K^+} = \left(\frac{V_{tb}^* V_{ts}}{V_{tb} V_{ts}^*} \right)^2 \left(\frac{V_{cb} V_{us}^*}{V_{ub}^* V_{cs}} \right) \left(\frac{V_{ub} V_{cs}^*}{V_{cb}^* V_{us}} \right) = e^{-2i(\gamma - 2\beta_s - \beta_K)}$$

- Similarly, $B_d \to D^{(*)\pm} \pi^{\mp}$ determines $\gamma + 2\beta$: $\quad \lambda_{D^+\pi^-}\, \lambda_{D^-\pi^+} = e^{-2i(\gamma + 2\beta)}$

... ratio of amplitudes $\mathcal{O}(\lambda^2) \Rightarrow$ expected asymmetries are small

$B^\pm \to (D^0, \overline{D}^0) K^\pm \to f_i\, K^\pm$

- $B^\pm \to K^\pm D$: theoretically clean, experimentally very hard (Gronau-Wyler)



$$\frac{|A(B^+ \to K^+ D^0)|}{|A(B^+ \to K^+ \overline{D}^0|} \sim \frac{\lambda}{N_c}$$

- $B^\pm \to K^\pm (D^0, \bar{D}^0) \to K^\pm f_i \qquad (i = 1, 2)$ (Atwood, Dunietz, Soni)

  make use of large final state interaction in D decay

  Idea: $B^+ \to K^+ \overline{D}^0 \to K^+ f_i$ in doubly Cabibbo suppressed $\overline{D}^0$ decay

  $B^+ \to K^+ D^0 \to K^+ f_i$ in Cabibbo allowed D^0 decay (e.g.: $f_i = K^- \pi^+ / \rho^+$)

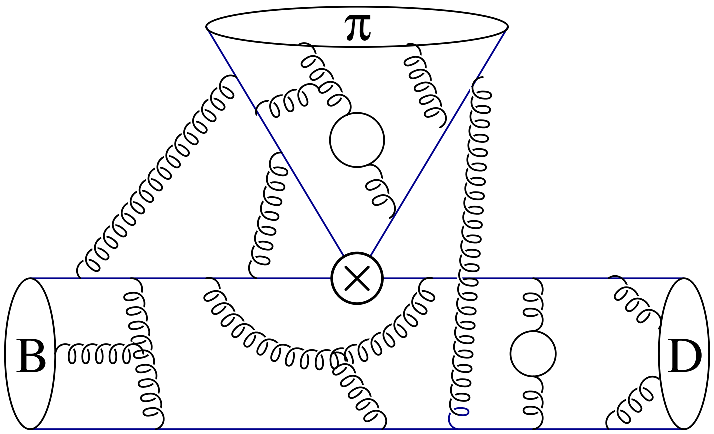
  Need at least 2 final states

  Total Br's $\sim 10^{-7}$ — statistics?

- Many ideas on the market would become a lot simpler if some of the hadronic decay amplitudes were understood

Factorization in $b \longrightarrow c$

Factorization in $b \to c$ exclusive decays



Start from OPE; estimate matrix elements of four-quark operators by grouping the quark fields into two that mediate $B \to D$, and two that can describe vacuum $\to \pi$ — Are gluons connecting B & D to π either calculable or power suppressed?

- "Naive" factorization: $\langle D\pi|\bar{c}b\bar{u}d|B\rangle \sim F_{B\to D}\, f_\pi$

Since B and D are "soft" and π is "collinear", "color transparency" provides a physical picture for factorization (early 90's: Bjorken; Dugan, Grinstein)

Configuration of brown muck in D changes only slightly, π is a fast color dipole

This picture expected to hold for $B \to D^{(*)}X$, as long as $E_X/m_X \gg 1$

Cannot be the full story: Wilson coefficients (of $\bar{c}b\bar{u}d$ operators) scale dependent

Factorization in $b \to c$ (cont.)

- "Generalized" factorization: $\langle D\pi|\bar{c}b\bar{u}d|B\rangle \sim F_{B\to D} \int_0^1 \mathrm{d}x\, T(x,\mu)\, \phi_\pi(x,\mu) f_\pi$

  (proposed: Politzer, Wise; 2-loop proof: Beneke, Buchalla, Neubert, Sachrajda; all orders proof: Bauer, Pirjol, Stewart)

  Fully consistent formulation, scale and scheme dependence cancels order-by-order between Wilson coefficients $C_i(\mu)$ and matrix elements $\langle O_i(\mu)\rangle$

  No OPE — corrections presumed to be $\mathcal{O}(\Lambda/m_b)^n$ but this is not firmly established (Depends on details of B, D, π wave-functions)

  Proof applies when meson that inherits the spectator quark from the B is heavy and the other is light

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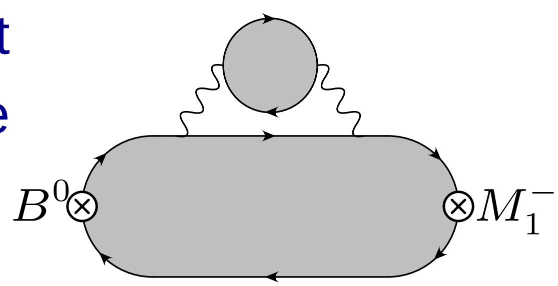
- Factorization also holds in the large number of colors limit ($N_c \to \infty$ with $\alpha_s N_c =$ const.) in all $B^0 \to M_1^- M_2^+$ type decays, corrections $\propto 1/N_c^2$



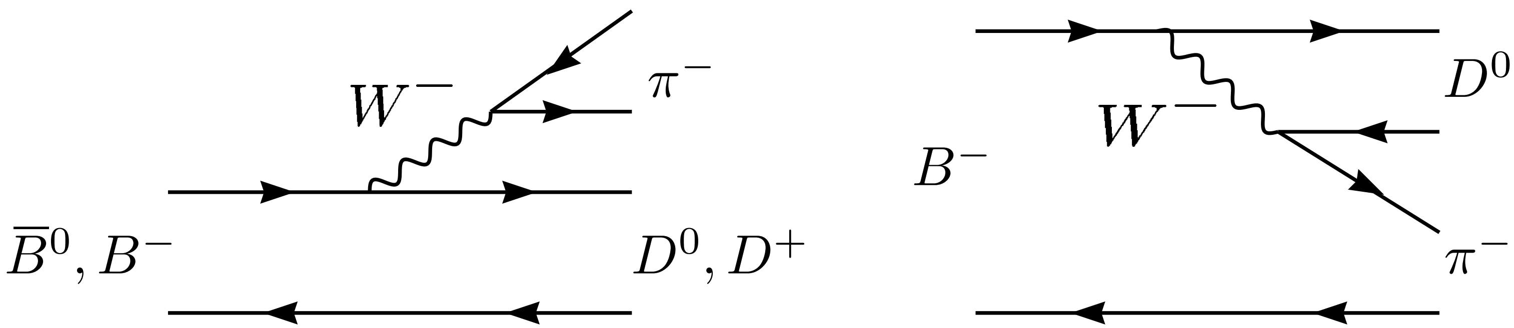
Factorization tests

- Factorization has been observed to work in $\overline{B}^0 \to D^{(*)+}\pi^-$ decays at the $\lesssim 10\%$ level (in amplitudes) ...it gets really interesting just below this ($\sim 1/N_c^2$)

  Want to understand quantitatively accuracy of factorization in different processes

- $\sim 35\%$ corrections for B^- matrix elements have been observed

  Spectator in B going into π expected to be power suppressed



$$\frac{\mathcal{B}(B^- \to D^0\pi^-)}{\mathcal{B}(\overline{B}^0 \to D^+\pi^-)} = 1 + \mathcal{O}(\Lambda_{\rm QCD}/m_{c,b})\,, \qquad \text{data: } \sim 1.8 \pm 0.2$$

Ratio appears universal across channels (D/D^*, π/ρ)

Isospin again: $B \to D\pi$

- Classify amplitudes in terms of isospin (conserved by strong interaction) instead of "tree" and "color suppressed tree", etc.

  Two isospin amplitudes for B decay to $(D\pi)$ in $I_f = \frac{1}{2}$ or $I_f = \frac{3}{2}$
  Three measurable rates $\Rightarrow$ 1 relation:

$$A(B^- \to D^0\pi^-) = A(\overline{B}^0 \to D^+\pi^-) + \sqrt{2}\, A(\overline{B}^0 \to D^0\pi^0)$$

- Three rates determine $|A_{1/2}|$, $|A_{3/2}|$ and their relative strong phase

$$\delta \sim 30^\circ$$ (CLEO, Belle, Babar)

  QCD factorization predicts $\delta \sim \mathcal{O}(\Lambda_{\rm QCD}/m_{c,b})$

  Not clear yet what sets the scale for the size of corrections

Origin of factorization?

- The color transparency argument relies on M_2 being fast ($m/E \ll 1$); the large-N_c argument is independent of this

  Would be nice to observe deviations that clearly distinguish between expectations

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– At the level of existing data, factorization also works in $B \to D_s^{(*)} D^{(*)}$ when both particles are heavy

– Check if factorization is worse in $\overline{B}^0 \to D_s^{(*)-}\, \pi^+$ than in $\overline{B}^0 \to D^{(*)+}\, \pi^-$?

  Need $B \to \pi$ form factor $\nwarrow$ should be $|V_{ub}/V_{cb}|^2 \times$ power suppressed

– "Designer mesons": Study factorization breaking in decays that vanish in naive factorization (so α_s & $1/m$ corrections important), e.g, $B^0 \to D^{(*)+} a_0/b_1/\pi_2$

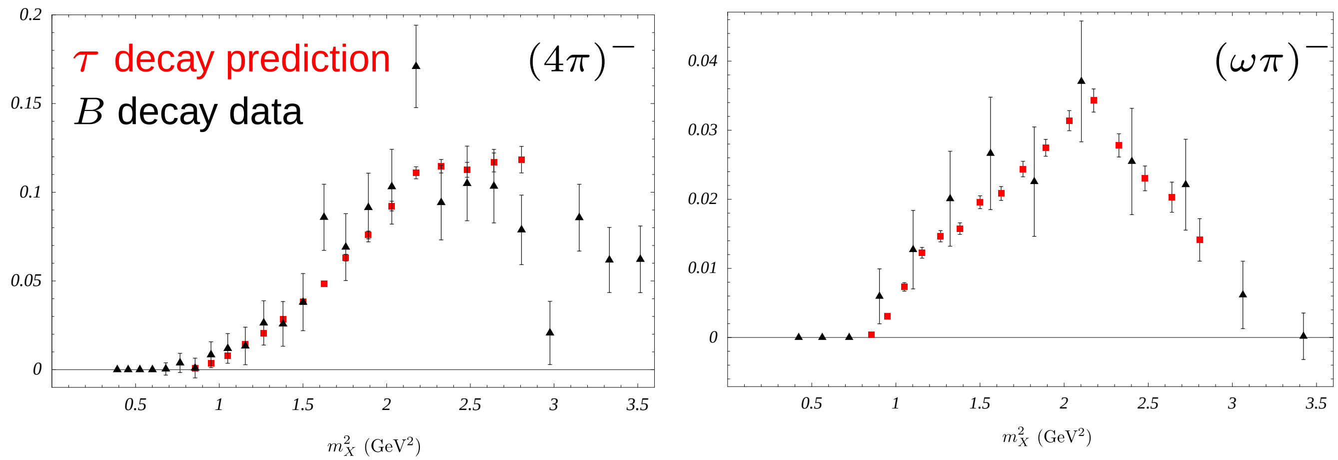
  Rates at 10^{-6} level — soon accessible? (Diehl & Hiller)

Factorization in $B \to D^{(*)}X$

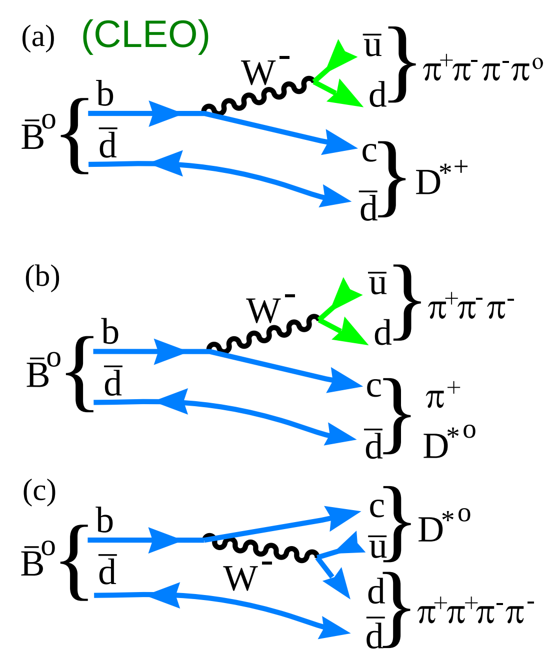
- Study accuracy as a function of the kinematics, with fixed multi-body final states

Expect some nonperturbative corrections to grow as m_X increases (ZL, Luke, Wise)

Compare $B \to D^* 4\pi$ with $\tau \to 4\pi$ (allows $0.4 \lesssim m_X/E_X \lesssim 0.7$)



Different charge modes can disentangle backgrounds from D^{**}, etc.

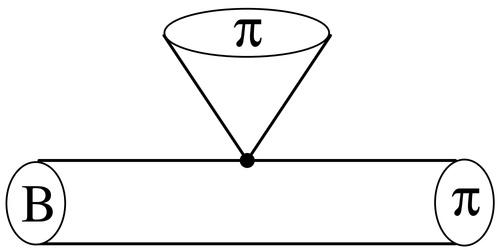


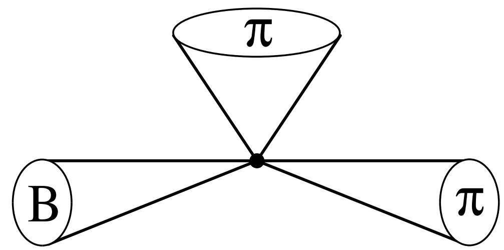
Observing deviations that grow with m_X would provide evidence that perturbative QCD is an important part of the success of factorization in $B \to D^* X$

Factorization in charmless decays

Factorization in charmless B decays

- Two contributions:





Two proposals:

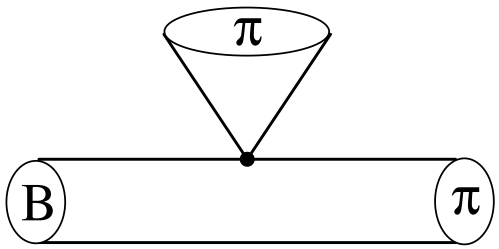
(1) "QCD factorization:" (Beneke, Buchalla, Neubert, Sachrajda)

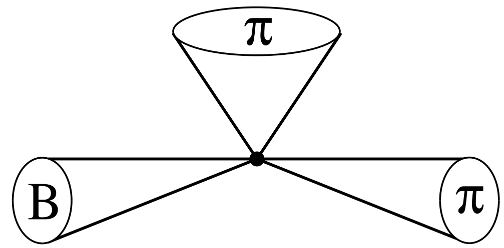
$$\langle \pi\pi | O_i | B \rangle \sim \; F_{B\to\pi}\, T(x) \otimes \phi_\pi(x) \; + \; T(\xi, x, y) \otimes \phi_B(\xi) \otimes \phi_\pi(x) \otimes \phi_\pi(y)$$

- Sudakov suppression at the b mass scale is not effective in the endpoint regions of quark distributions
- Two terms have same size in $\Lambda_{\rm QCD}/m_b$ power counting
- Second term suppressed by $\alpha_s(m_b)$
- Small strong phases

Factorization in charmless B decays

- Two contributions:





Two proposals:

(2) "Perturbative QCD:" (Keum, Li, Sanda)

$$\langle \pi\pi | O_i | B \rangle \sim \; 0 \; + \; T(x_i, b_i) \otimes \phi_B(x_3, b_3) \otimes \phi_\pi(x_2, b_2) \otimes \phi_\pi(x_1, b_1)$$

– Sudakov suppression effective in the regions $x_i \sim \Lambda_{\mathrm{QCD}}/m_b$ and $1/b_i \sim \Lambda_{\mathrm{QCD}}$

– k_T factorization, $1/b_i \sim \sqrt{\Lambda_{\mathrm{QCD}} m_b}$ dominates

– Larger strong phases, annihilation & penguin contributions

Main issues

Huge body of literature due to importance for CP violation

– Power counting depends on treatment of Sudakovs

BBNS: form factors are nonperturbative inputs

KLS: Sudakov suppression renders form factors calculable

– Some formally $\mathcal{O}(\Lambda_{\rm QCD}/m_b)$ terms in BBNS are known to be large

Chirally enhanced terms: $2m_K^2/m_b m_s \sim 1$

– Other issues raised:

Charming penguins (Ciuchini *et al.*)

Intrinsic charm (Brodsky & Gardner)

Scale where π form factor becomes asymptotic $\sim x(1-x)$

It very hard to test the assumptions ... need large variety of rates and direct CPV, for some of which the predictions differ

$B \longrightarrow hh$ rates vs. predictions

- BBNS and KLS predictions vs Experiment (CLEO, BELLE, BABAR):

	BBNS	KLS	World Average
$\frac{\mathcal{B}(\pi^+\pi^-)}{\mathcal{B}(\pi^\mp K^\pm)}$	$0.3-1.6$	$0.30-0.69$	0.28 ± 0.04
$\frac{\mathcal{B}(\pi^\mp K^\pm)}{2\mathcal{B}(\pi^0 K^0)}$	$0.9-1.4$	$0.78-1.05$	1.0 ± 0.3
$\frac{2\mathcal{B}(\pi^0 K^\pm)}{\mathcal{B}(\pi^\pm K^0)}$	$0.9-1.3$	$0.77-1.60$	1.3 ± 0.2
$\frac{\tau_+}{\tau_0}\frac{\mathcal{B}(\pi^\mp K^\pm)}{\mathcal{B}(\pi^\pm K^0)}$	$0.6-1.0$	$0.70-1.45$	1.1 ± 0.1
$\frac{\tau_+}{\tau_0}\frac{\mathrm{B}(\pi^+\pi^-)}{2\mathrm{B}(\pi^\pm\pi^0)}$	$0.6-1.1$		0.56 ± 0.14

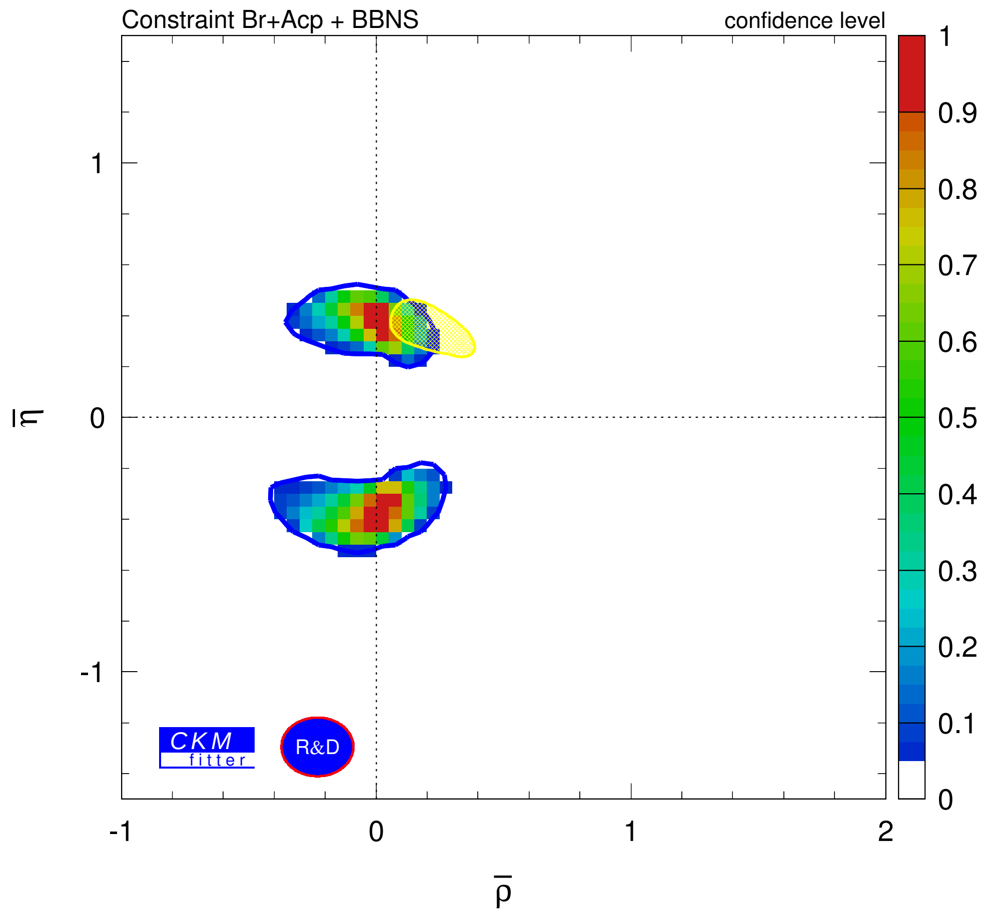
(Nir @ ICHEP)

Although the starting points, and predictions for direct CPV and phases in P/T differ, both BBNS and KLS can reproduce these rates by now

Experimental data is crucial

(ρ, η) using charmless rates

Inputs: $B \to \pi\pi / K\pi$ rates + BBNS



γ from $B_{d,s} \to hh$

- $B \to K\pi/\pi\pi$:   Combination of rates — careful

  Need some assumptions on (some of): rescattering effects, penguins, factorization, $SU(3)$

- $B_d \to \pi^+\pi^-$ vs. $B_s \to K^+K^-$: see: F. Würthwein's talk tomorrow (Fleischer)

  Idea: two decays related by u-spin, that exchanges $d \leftrightarrow s$

  Corrections to the u-spin limit are order m_s/Λ, just as for $SU(3)$
  Need to constrain it somehow from other measurements

  My feeling / hope: measure all possible $B_{d,s} \to \pi\pi$, $K\pi$, KK asymmetries and rates, we'll figure out something, build a case...

Summary — factorization

- In decays such as $\overline{B}^0 \to D^{(*)+}\pi^-$ factorization has become well established
- Some power suppressed corrections (formally order $\Lambda_{\rm QCD}/m_c$) appear sizable
  No evidence yet of factorization becoming a worse approximation in $B \to D^{(*)}X$ as m_X increases
- In charmless decays there are two approaches to factorization, BBNS and KLS
- Different assumptions and power counting, and sometimes different predictions
  Testing the assumptions in a conclusive way does not seem easy
- Theoretical progress in understanding semileptonic form factors in the small q^2 region may help to understand importance of Sudakov effects
- New and more precise data will be crucial to test factorization and tell us about significance of unknown power suppressed terms in various processes

Summary

Final remarks

- To overconstrain CKM, all possible clean measurements are very important, both CP violating and conserving, even if redundant in SM (correlations important)

- The key processes are those which give clean information on short distance parameters ...one theoretically clean measurement is worth ten dirty ones

- It changes with time what is theoretically clean — significant recent progress for:
  - Determination of $|V_{ub}|$ from inclusive B decay
  - Exclusive rare & semileptonic form factors at small q^2
  - Factorization in certain nonleptonic decays

- Studying CKM/CPV and hadronic physics is complementary; except for a few very clean cases several measurements needed to minimize theoretical uncertainties — data will help to get rid of nasty things hard to constrain otherwise

A (near future & personal) best buy list

- $|V_{td}/V_{ts}|$: Tevatron should nail this, hopefully very soon (lattice caveats?)
- Rare decays: $B \to X_s\gamma$ near theory limited; q^2 distribution in $B \to X_s\ell^+\ell^-$ will be very interesting
- $|V_{ub}|$: reaching $\lesssim 10\%$ would be very significant (assumes understanding $|V_{cb}|$; a Babar/Belle measurement that may well survive LHCB/BTeV)
- β: reduce error in ϕK_S, $\eta' K_S$ (and $D^{(*)}D^{(*)}$) modes
- β_s: is CPV in $B_s \to \psi\phi$ small?
- α: how small is $B \to \pi^0\pi^0$? How big are other resonances in $\rho - \pi$ Dalitz plot?
- γ: clean modes hard, test $SU(3)$ relations, factorization and other approaches
- try $B \to \ell\nu$, search for "null observables" [$a_{CP}(b \to s\gamma)$, etc.], for enhancement of $B \to \ell^+\ell^-$, etc.

(apologies for omissions!)

Conclusions

- The CKM picture is predictive and testable — it passed its first nontrivial test and is probably the dominant source of CPV in flavor changing processes
- The point is not only to measure the sides and angles of the unitarity triangle, (ρ, η) and (α, β, γ), but to probe CKM by overconstraining it in as many ways as possible (rare decays, correlations!)
- The program as a whole is a lot more interesting than any single measurement; all possible clean measurements are important, both CPV and CPC
- Many processes can give clean information on short distance physics, and there is progress towards being able to model independently interpret many interesting observables

> "This is not the end. It is not even the beginning of the end.
> But it is, perhaps, the end of the beginning."
>
> — W. Churchill (Nov. 10, 1942)