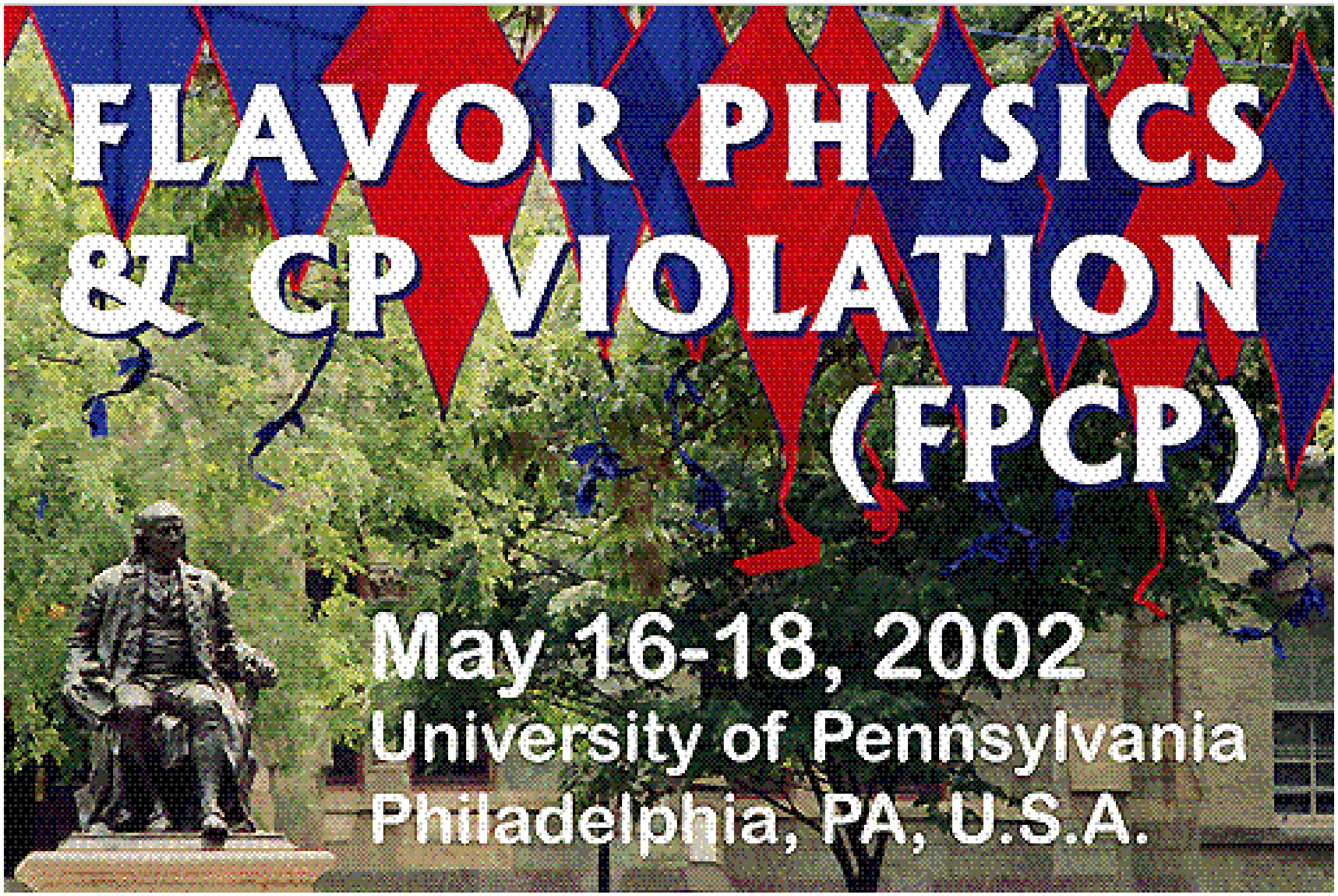


Conference Summary

Ritchie Patterson
Cornell University

Outline

- Finding New Physics via CKM overconstraint
- Finding New Physics via Rare B Decays
- Finding New Physics via Charm

Outline

- Finding New Physics via CKM over-constraint
- Finding New Physics via Rare B Decays
- Finding New Physics via Charm Decay

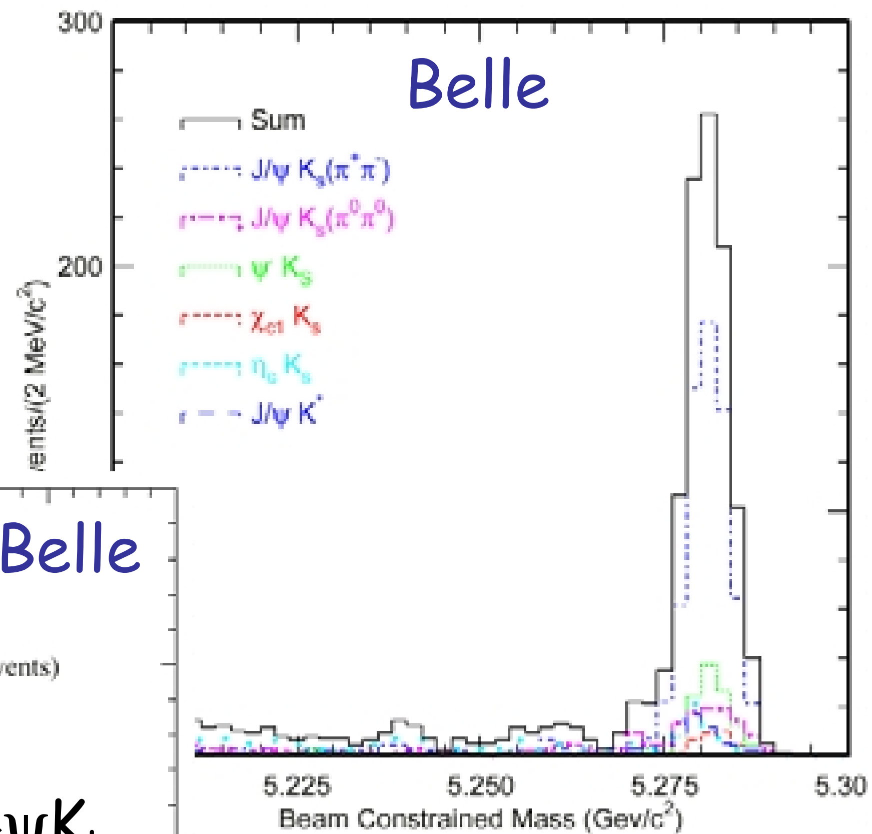
Finding New Physics requires:

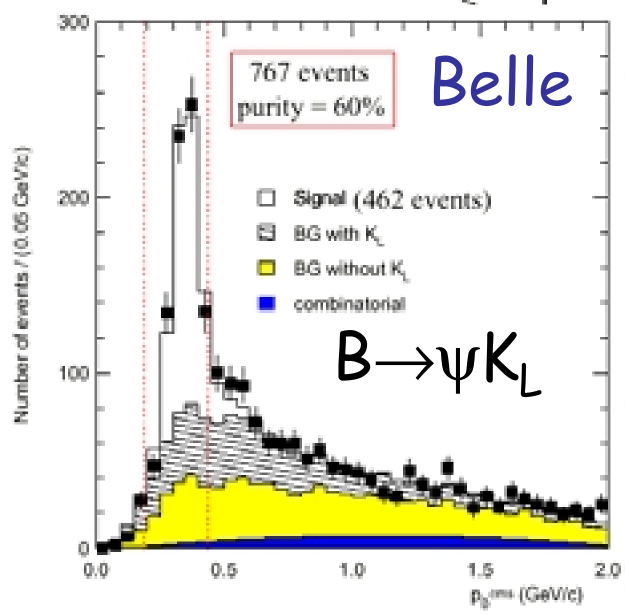
- That we pin down the CKM matrix as precisely as possible and search for deviations from the SM everywhere where New Physics might plausibly enter, particularly in the magnitude and phase of all loop processes SCORCHED EARTH
- That we understand theoretical uncertainties so that we can distinguish new physics from uncontrolled QCD

β or ϕ_1

$\sin 2\phi_1$

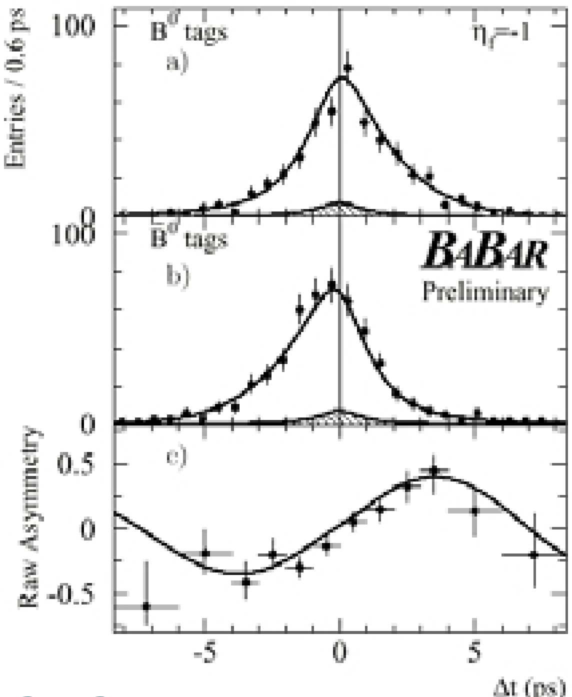
- Multiple modes
  - Very clean!
- Multiple tags
- Multiple crosschecks
  - B Lifetime
  - BB mixing
  - $B \to \psi K_L$
  - Null Modes



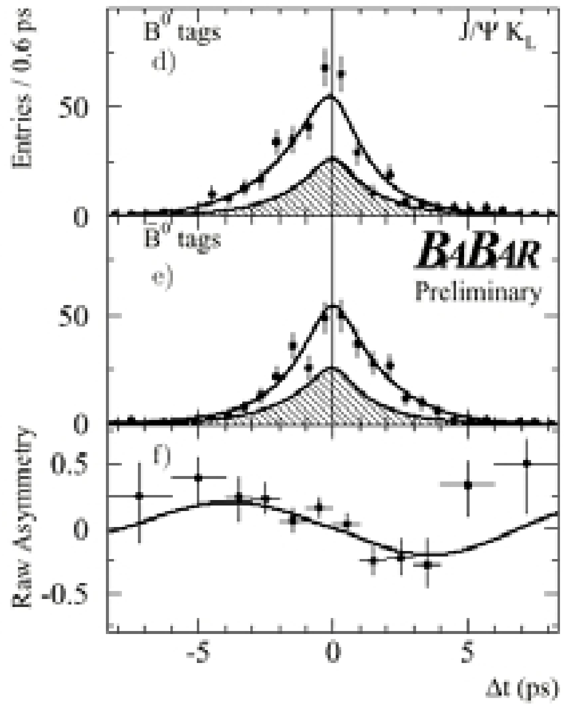


Time Asymmetry Measurement

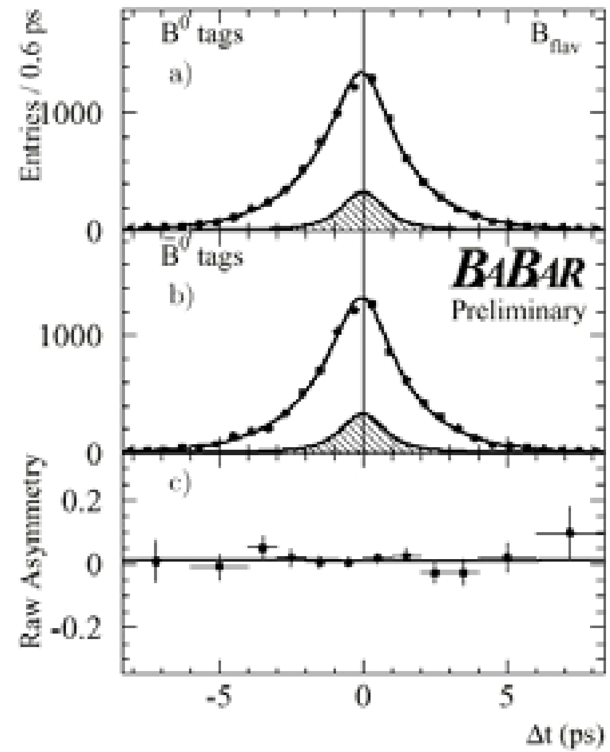
CP odd



CP even



Null sample



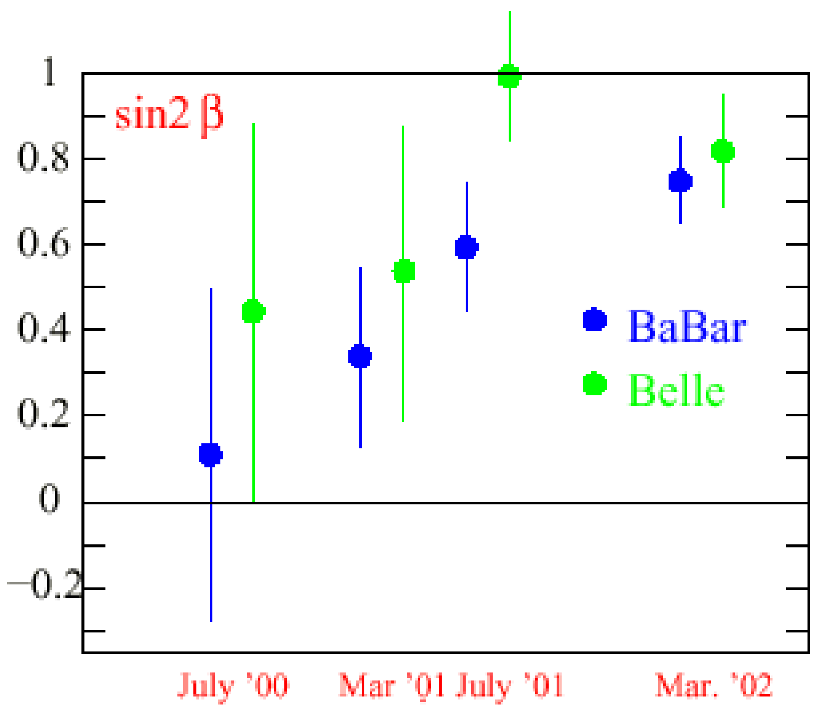
BaBar

$\sin 2\beta = 0.75 \pm 0.09 \pm 0.04$ (62 M BB)

Belle

$\sin 2\beta = 0.82 \pm 0.12 \pm 0.05$ (44 M BB)

sin2β Summary

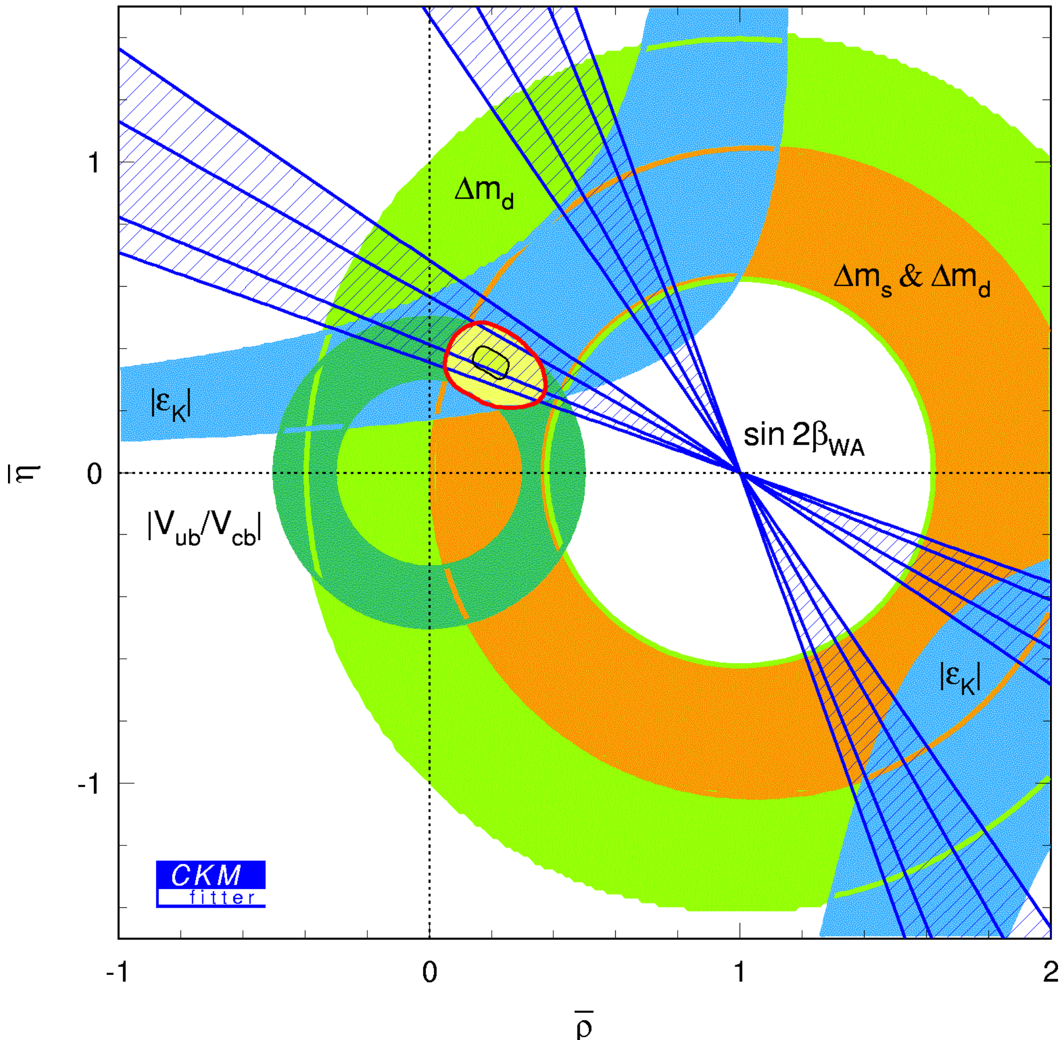


Current world average:

$\sin 2\beta = 0.78 \pm 0.08$

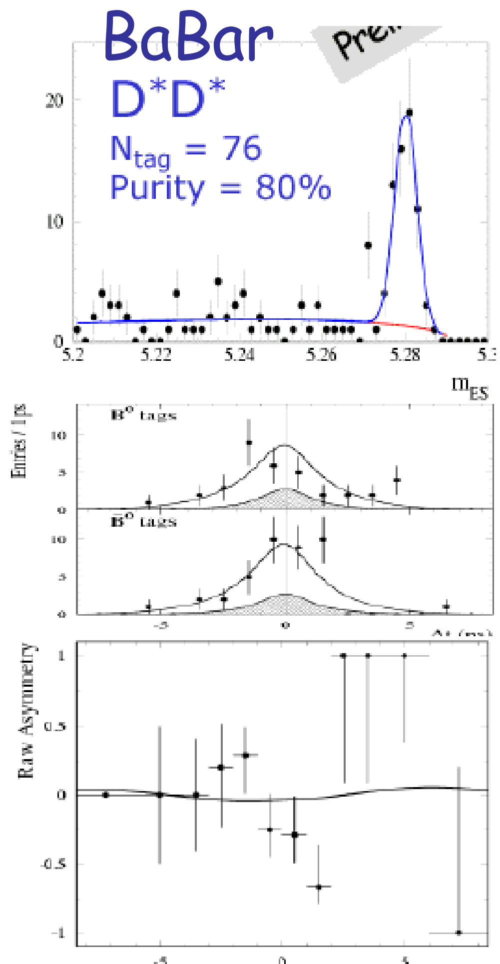
Unitarity Constraints

Hoecker



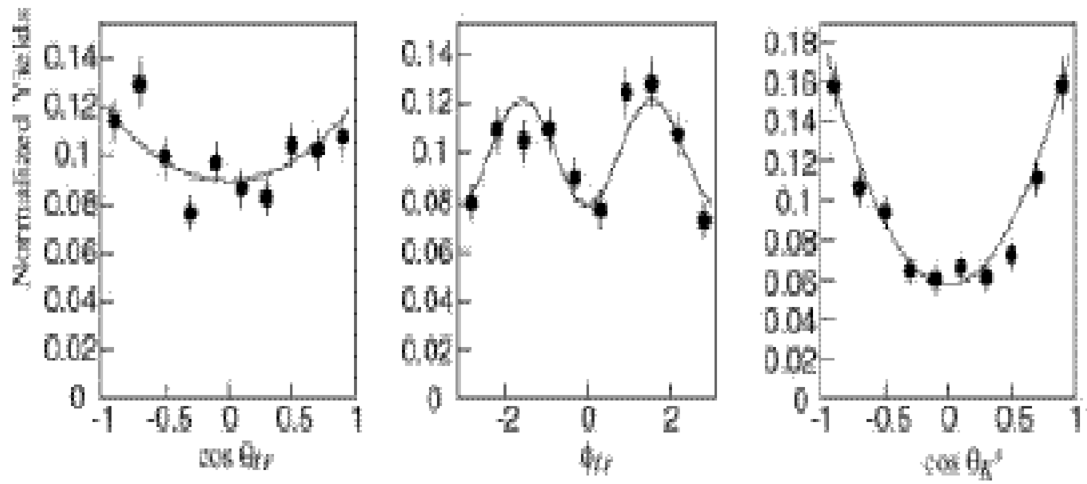
"It is a triumph that after 15 years of effort, we now have established the CKM triangle using two independent methods, one using rates and the other using CP violation in K's and B's." Fred Gilman

Other Routes to sin2β



B→J/ψK* Fang

Belle (to be published in PLB)



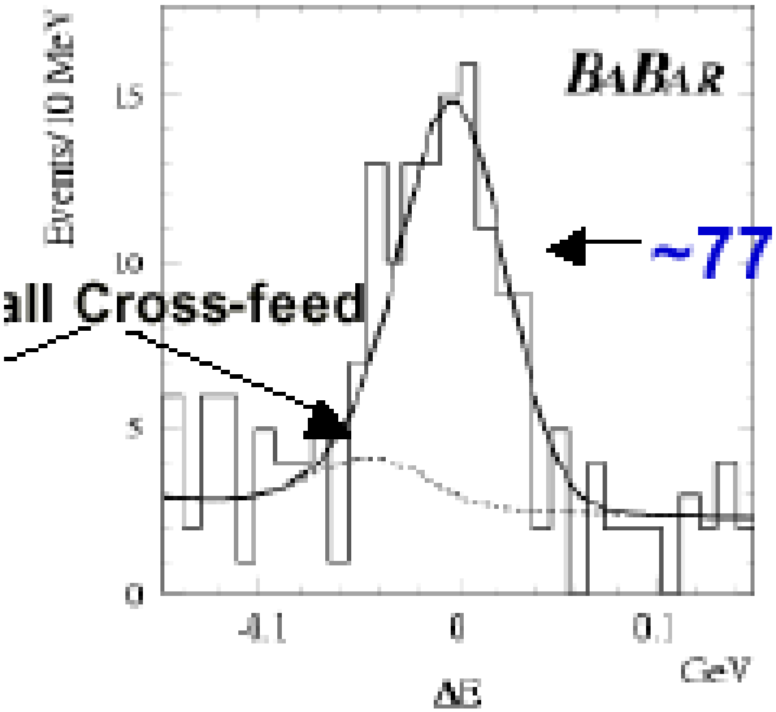
Also B→J/ψρ (hard!!)

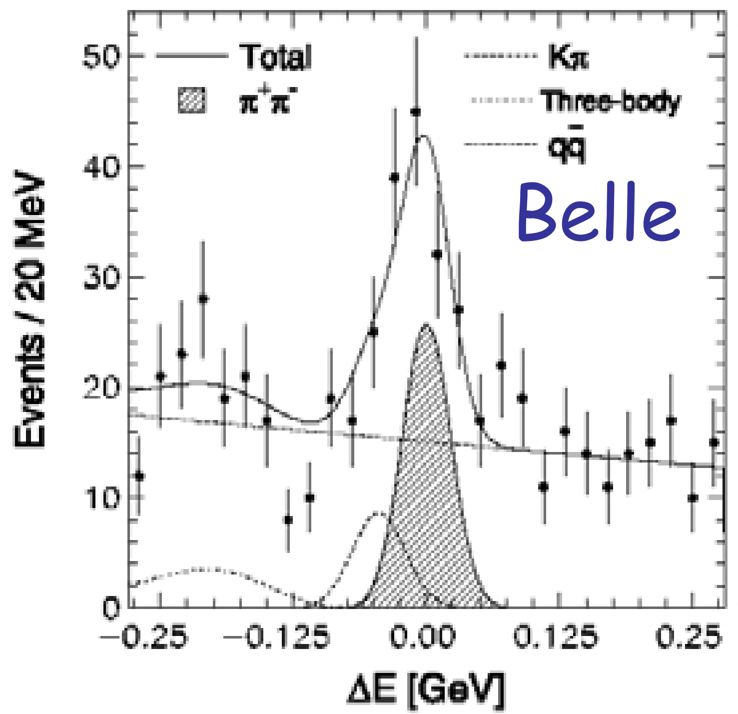
Goal: strengthen the sin2β constraint

- No asymmetry observed
- Angular analysis next

α or ϕ_2

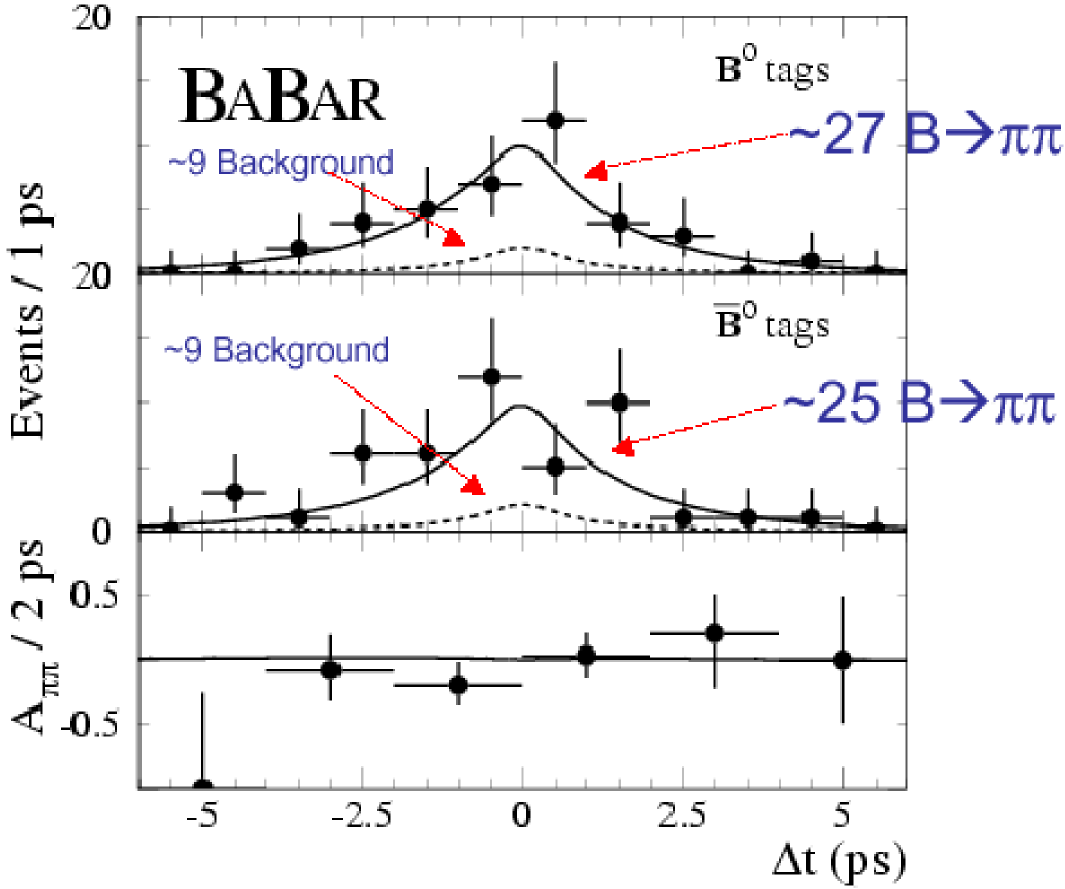
CP Violation in B $\rightarrow \pi^+ \pi^-$

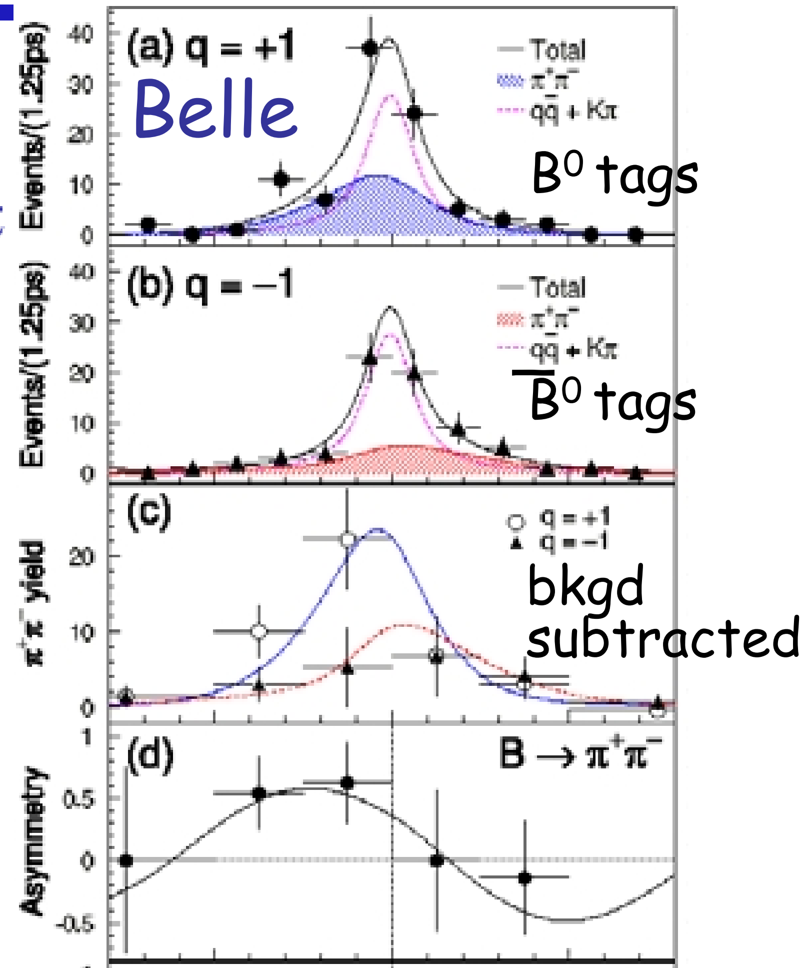




Superb B⟶Kπ suppression is a triumph of both Particle ID systems!

CP Violation in $B \to \pi^+ \pi^-$





$S_{\pi\pi} = -0.01 \pm 0.37 \pm 0.07$

$C_{\pi\pi} = -0.02 \pm 0.29 \pm 0.07$

$S_{\pi\pi} = -1.21\,^{+0.38}_{-0.27}\,^{+0.16}_{-0.13}$

$C_{\pi\pi} = -A_{\pi\pi} = -0.94\,^{+0.25}_{-0.31} \pm 0.07$

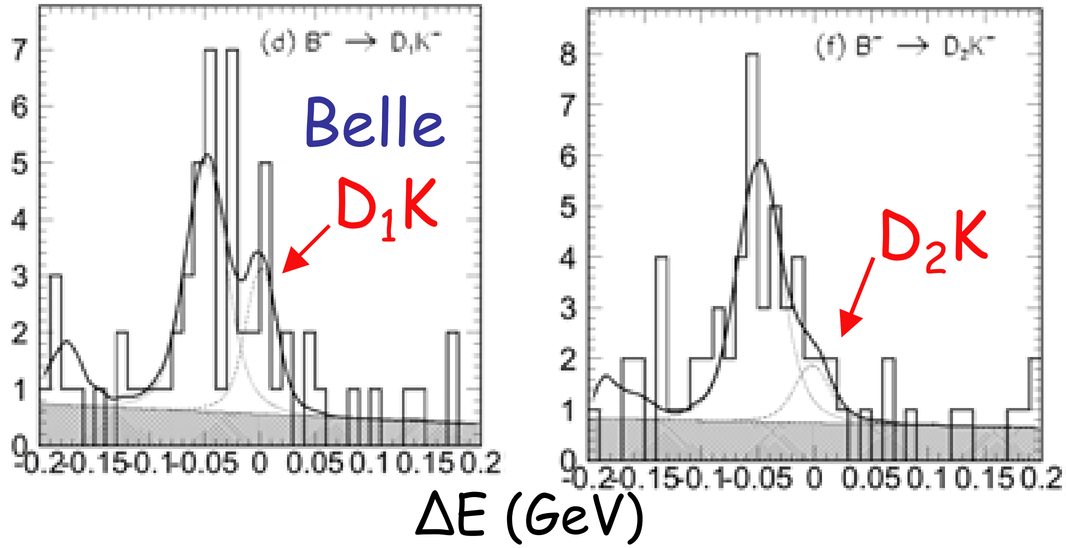
Prospects for α (ϕ_2)

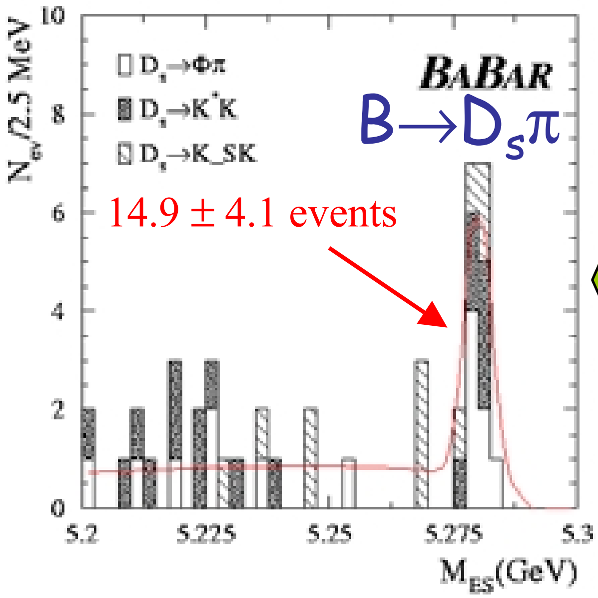
- Improved sin2α statistics (~100 fb^{-1} by summer)
- New bound on α-α_{eff} using isospin constraints
  N. Sinha
  Current $B \to \pi\pi$ BR's imply:
  α-α_{eff} < 57° or α-α_{eff} > 123° 90%CL
  Gronau,London,Sinha,Sinha
  cf α-α_{eff} < 61° or α-α_{eff} > 119° 90%CL
  Grossman,Quinn
- Dalitz analysis of 3-body final states begun
  Garmach, Shelkov

γ **or** ϕ_3

Routes to γ

- Belle $B \to D_{CP} K$
- Gronau, London, Wyler approach





- BaBar $B \to D_s \pi$
- Engineering for $\sin(2\beta + \gamma)$ from $B^0 \to D^- \pi^+$

Atwood

"You need more observables than unknowns."

γ from $B \to K\pi$

Branching Fractions   Bartoldus

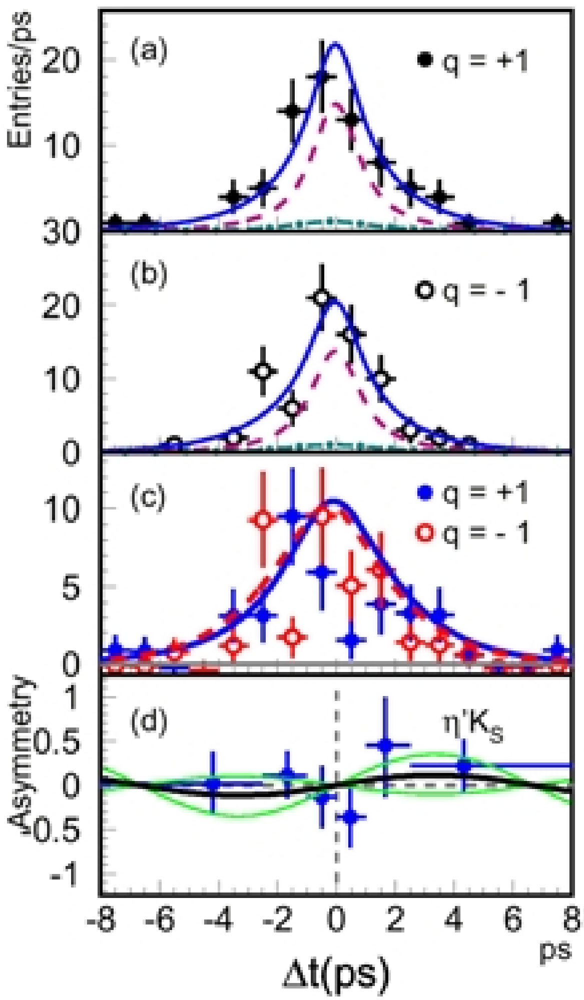
Mode	CLEO	Belle	BABAR	Average	χ^2
$K^+\pi^-$	$17.2^{+2.5}_{-2.4} \pm 1.2$	$21.8 \pm 1.8 \pm 1.5$	$17.8 \pm 1.1 \pm 0.8$	$18.6^{+1.1}_{-1.1}$	2.5
$K^+\pi^0$	$11.6^{+3.0}_{-2.7}{}^{+1.4}_{-1.3}$	$12.5 \pm 2.4 \pm 1.2$	$11.1^{+1.3}_{-1.2} \pm 1.0$	$11.5^{+1.3}_{-1.3}$	0.2
$K^0\pi^+$	$18.2^{+4.6}_{-4.0} \pm 1.6$	$18.8 \pm 3.0 \pm 1.5$	$17.5^{+1.8}_{-1.7} \pm 1.3$	$17.9^{+1.7}_{-1.7}$	0.1
$K^0\pi^0$	$14.6^{+5.9}_{-5.1}{}^{+2.4}_{-3.3}$	$7.7 \pm 3.2 \pm 1.6$	$8.2^{+3.1}_{-2.7} \pm 1.2$	$8.9^{+2.3}_{-2.2}$	1.0
$\pi^+\pi^-$	$4.3^{+1.6}_{-1.4} \pm 0.5$	$5.1 \pm 1.1 \pm 0.4$	$5.4 \pm 0.7 \pm 0.4$	$5.2^{+0.6}_{-0.6}$	0.4
$\pi^+\pi^0$	$5.4^{+2.1}_{-2.0} \pm 1.5\ (< 13)$	$7.0 \pm 2.2 \pm 0.8$	$4.1^{+1.1}_{-1.0}{}^{+0.8}_{-0.7}$	$4.9^{+1.1}_{-1.1}$	1.2
$\pi^0\pi^0$	< 5.2	< 5.6	< 3.4		
K^+K^-	< 1.9	< 0.5	< 1.1		

Fleischer/Mannel; Buras/Fleischer; Neubert/Rosner bounds

Don't yet constrain γ, but almost

Editorial note: Careful quantization of uncertainty in theoretical inputs,if used (eg strong phases), is essential

A Probe for new physics



Belle $B \rightarrow \eta' K_S$

- Sensitive to new physics, eg SUSY GUT-motivated model (Moroi)
- $\sin 2(\phi_1 + \phi_{NP}) = 0.29 \pm 0.54 \pm 0.07$

Other windows onto New Physics

- R. Sinha $B\to\psi K^*$
  - Interference between CP+ and CP- helicity amplitudes is sensitive to NP in b->s penguin "Even CLEO could do this."

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  - $B(B \to \psi K^0)$- $B(B \to \psi K^+)$ and A_{CP}^{dir}-$A_{CP}^{(+)}$ probe new physics in I=1 transition amplitude
  - Direct CPV probes new physics in I=0 transition amplitude

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- Hot Topic $B \to \Omega K$
  - Conference program announces baryon number violation!

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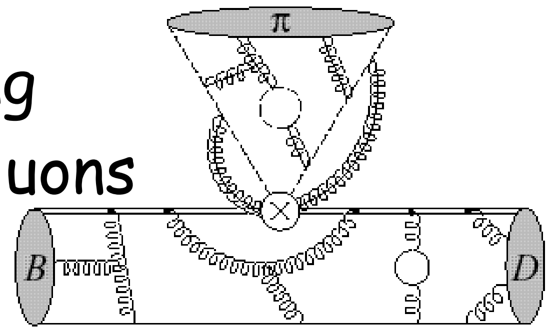
QCD Factorization

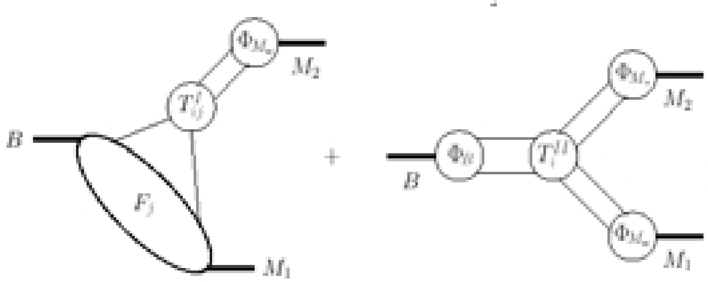
Beneke, Stewart

- Color transparency For a fast moving meson with collinear quarks, soft gluons see zero net color.



- Expansion in Λ/m_b (BBNS) or Λ/Q (BFGPS)

$$\langle M_1 M_2 | \mathcal{O}_i | \bar{B} \rangle = \sum_j F_j^{B\to M_1}(m_2^2) \int_0^1 du\, T_{ij}^I(u)\, \Phi_{M_2}(u) + O(\Lambda/m_b, \Lambda/m_c, \Lambda/E)$$



Proved to all orders in α_s
Bauer, Pirjol, Stewart

This is an important theoretical advance

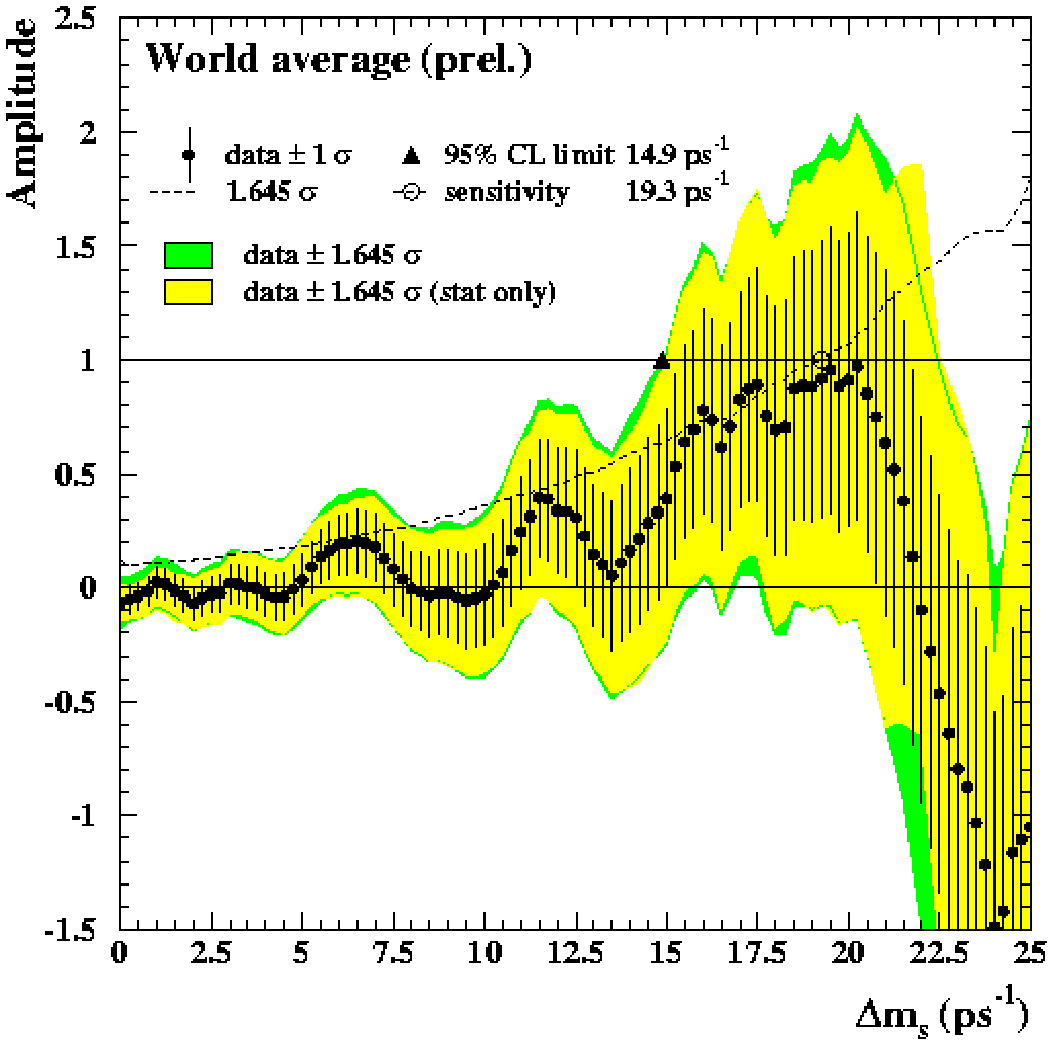
QCD Factorization

Results   Beneke et al

- Resolution of the mysterious $K^{(*)}\eta^{(')}$ branching fractions
- For $B\to K\pi$,
  $|T/P| = 0.24 \pm 0.04$ (pars.) ± 0.04 $(\Lambda/m_b) \pm 0.05$ (V_{ub})
  Consistent with $BR(B^{\pm}\to\pi^{\pm}\pi^{0})/BR(B^{\pm}\to\pi^{\pm}K^{0})$ & SU(3)
- Strong interaction phases mostly suppressed, so
  Small CP violation in $B\to K\pi$
  Current WA is A_{CP}=-0.05±0.05
- $-1 < S_{\pi\pi} < 0$ and $-0.1 < C_{\pi\pi} < 0.25$
  (caveat: my recollection of Beneke plot)

The sides of the triangle

Search for B_s Mixing



ALEPH, CDF, DELPHI, OPAL and SLD

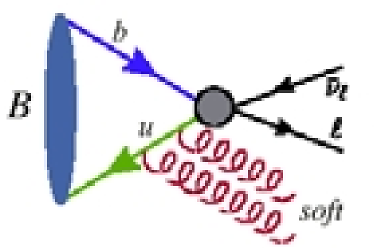
$m_s > 14.9\ ps^{-1}$ 95% cl

(sensitivity is $19.3\ ps^{-1}$)

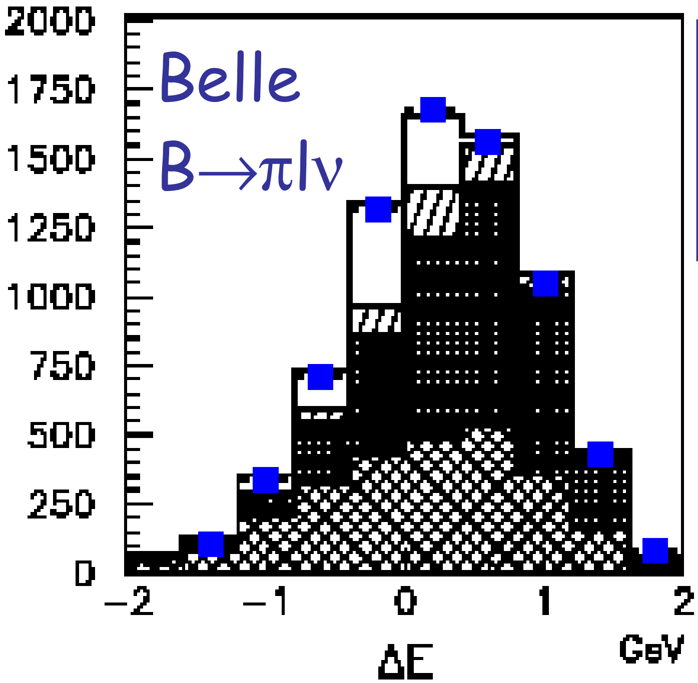
$|V_{ub}|$ from inclusive $b \to u l \nu$

Luke Theoretical issues in $|V_{ub}|$

- 10% or better theoretical uncertainties are possible, but require large data samples and meticulous detector understanding
- Scale of errors is understood
- Shape function f(k) now measured using $b \to s\gamma$
  CLEO
- In general, what's clean theoretically, is tough experimentally… and vice versa
  Murphy's Law of Heavy Flavor Physics!

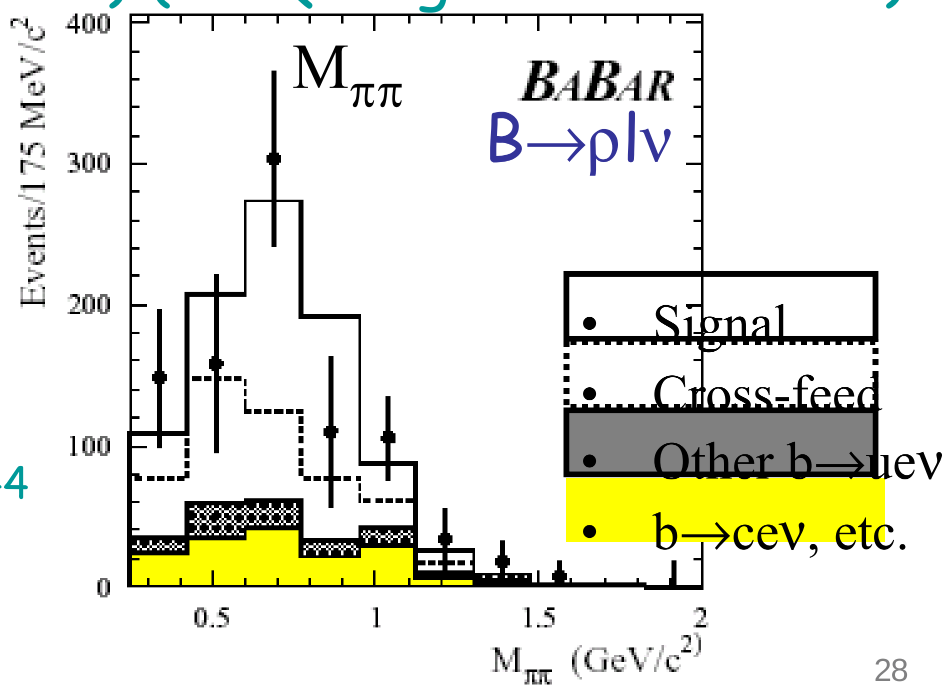


$|V_{ub}|$ using $B\to\pi l\nu$ and $B\to\rho l\nu$



$B\to\pi l\nu$	$B\to\rho l\nu$
•Smaller rate	•Higher rate
•Amenable to lattice	•ρ complications

Belle $B(B\to\pi l\nu)=1.89\pm0.15\pm0.30 \times 10^{-4}$ (LCSR) (UKQCD gives similar BR)

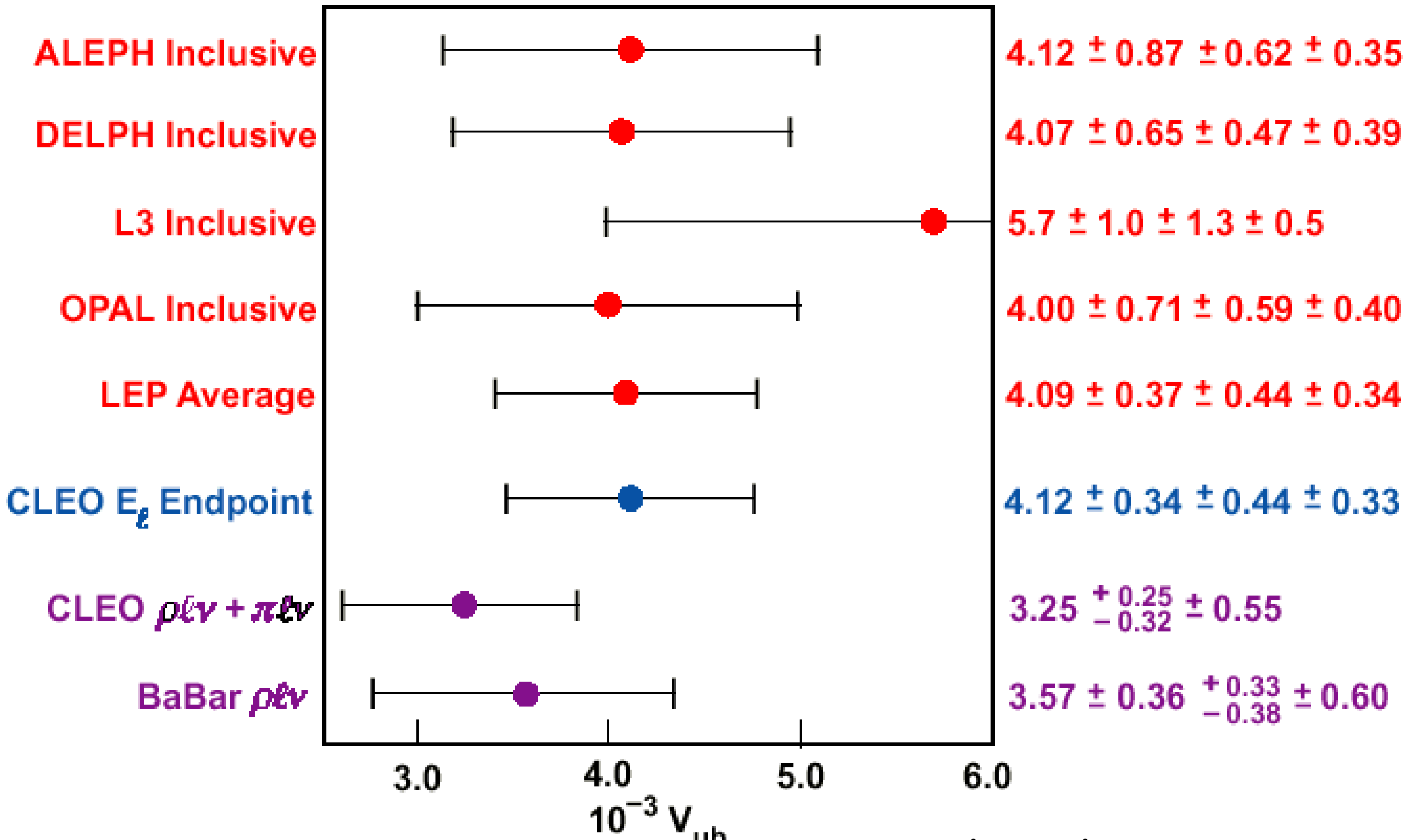


BaBar

$B(B\to\rho l\nu)=$

$3.26\pm0.65^{+0.63}_{-0.65}\pm0.44 \times 10^{-4}$

$|V_{ub}|$ Summary

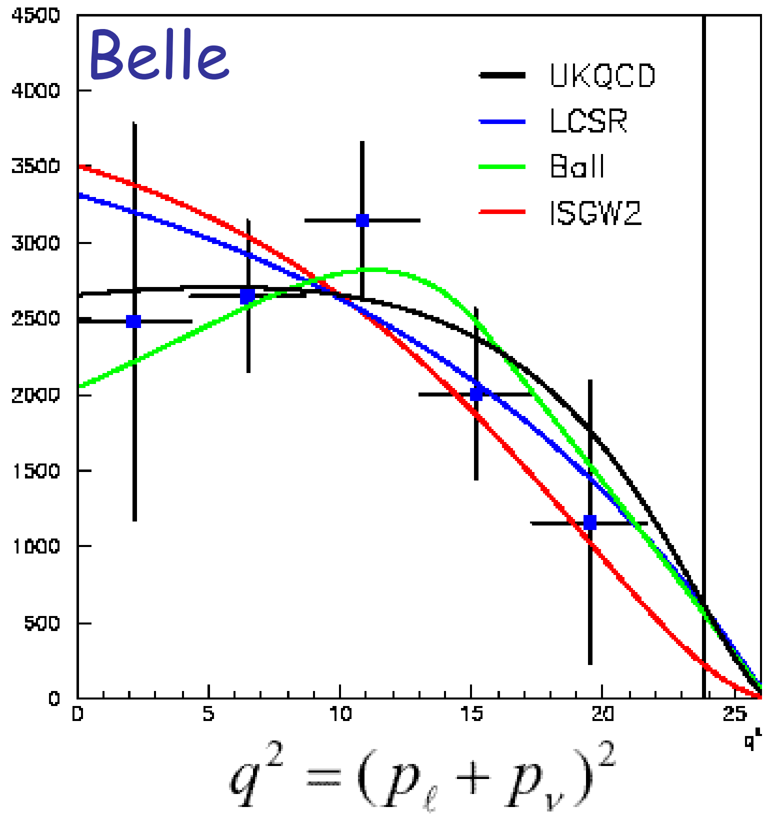


! Non-gaussian theoretical errors

Current uncertainty in $|V_{ub}|$ is ~15-20%

We need to understand better the meaning of the assigned theory errors

$|V_{ub}|$ of the future



- Uses $B \to \pi l \nu$
- Form factor from lattice, verified with data
- Crosschecked by other modes and inclusive analyses

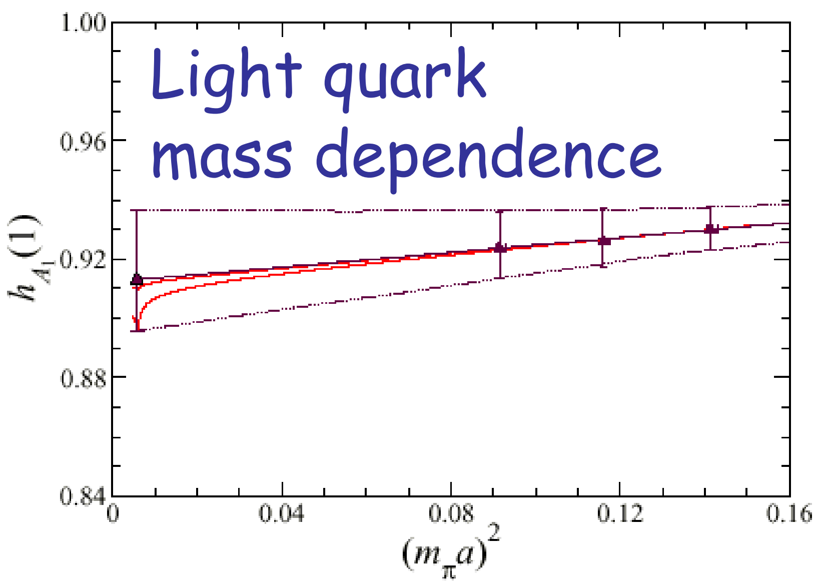
$|V_{cb}|$: Input from the Lattice

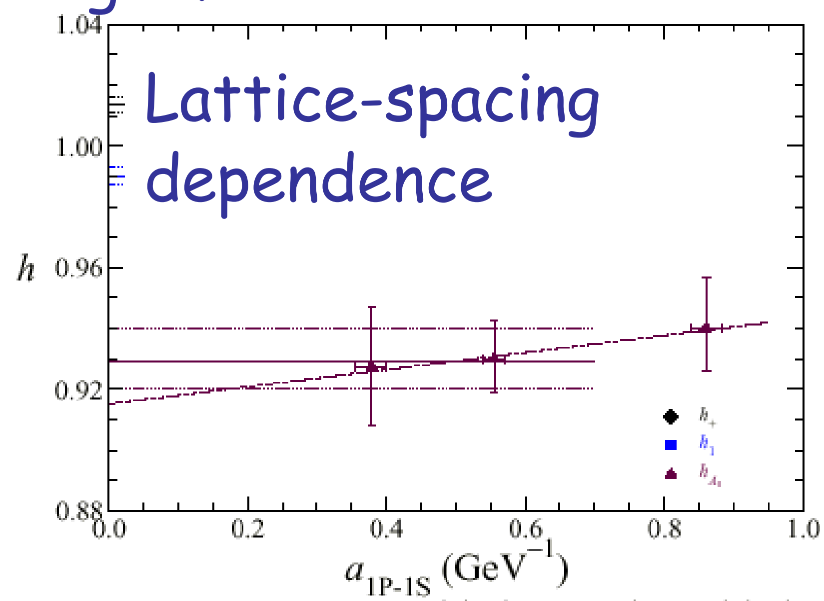
Kronfeld New calculation of form factor normalization, F(1)

Needed to extract $|V_{cb}|$ from $B \to D^* l\nu$

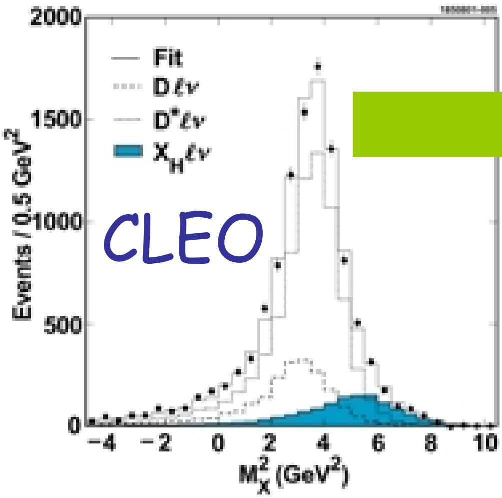
$$F(1) = 0.913^{+0.024}_{-0.017} \pm 0.016^{+0.003}_{-0.014}{}^{+0.000}_{-0.016}{}^{+0.006}_{-0.014}$$

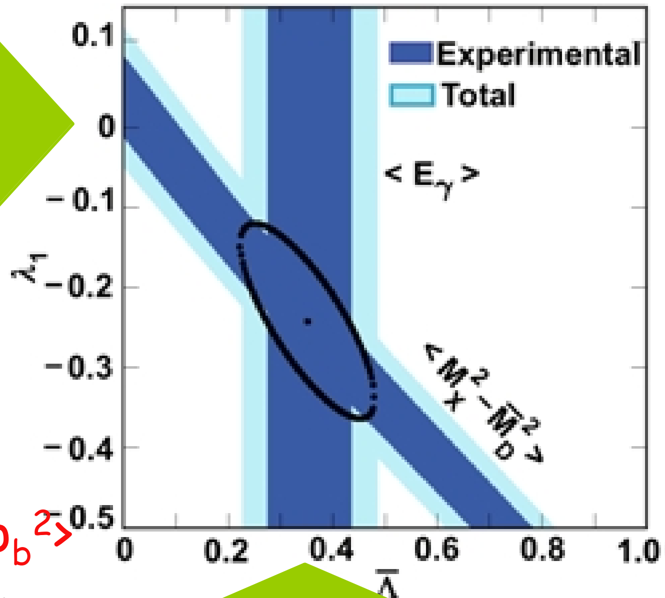
stat | QCD match | lattice spacing | light-quark mass | quenching





$|V_{cb}|$: Constraining the Unknowns

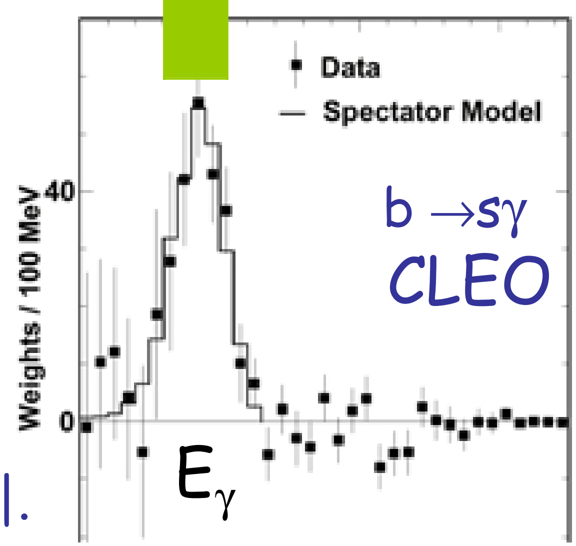




Voloshin; Falk, Luke & Savage; Falk & Luke; Gremm & Kapustin

- Measurements of m_b and $\lambda_1 \sim\!< -p_b^2 >$ reduce theoretical uncertainty in V_{cb} from inclusive $b \to c l \nu$ decay to about 2.5% (neglecting duality).
- m_b also improves V_{ub} from inclusive $b \to u l \nu$ decay

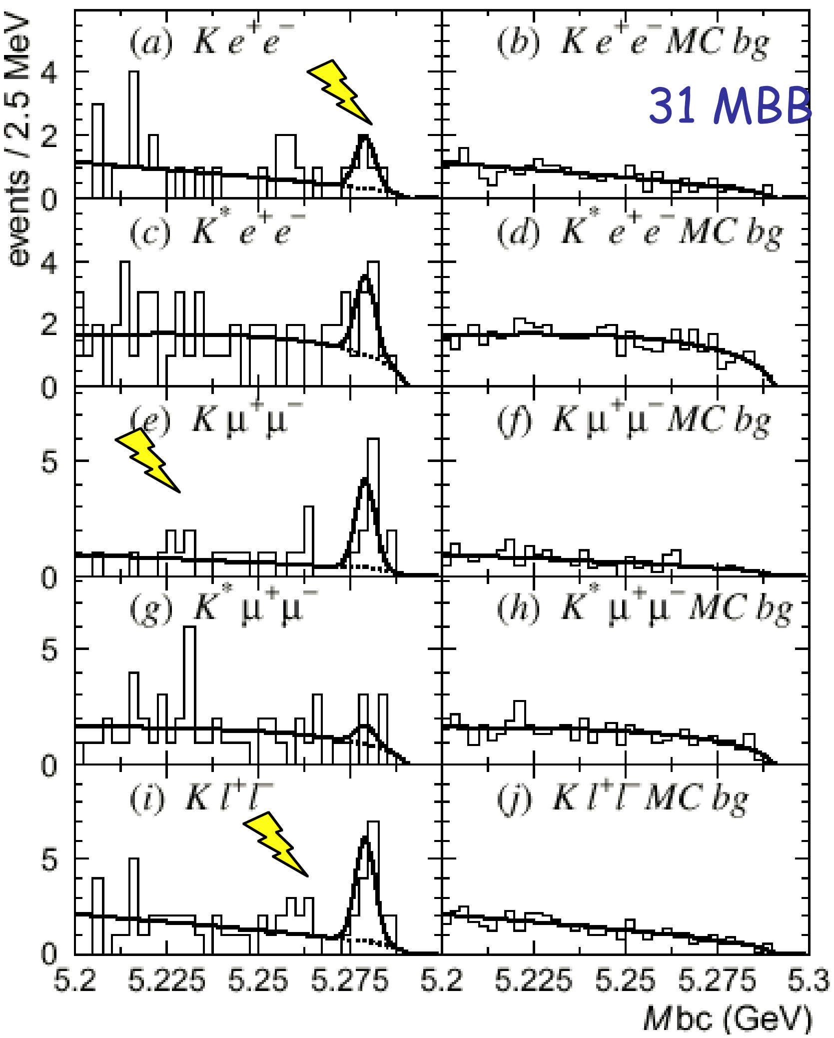
  Most Important: Theory errors are now well-controlled for both the exclusive and inclusive values of $|V_{cb}|$.

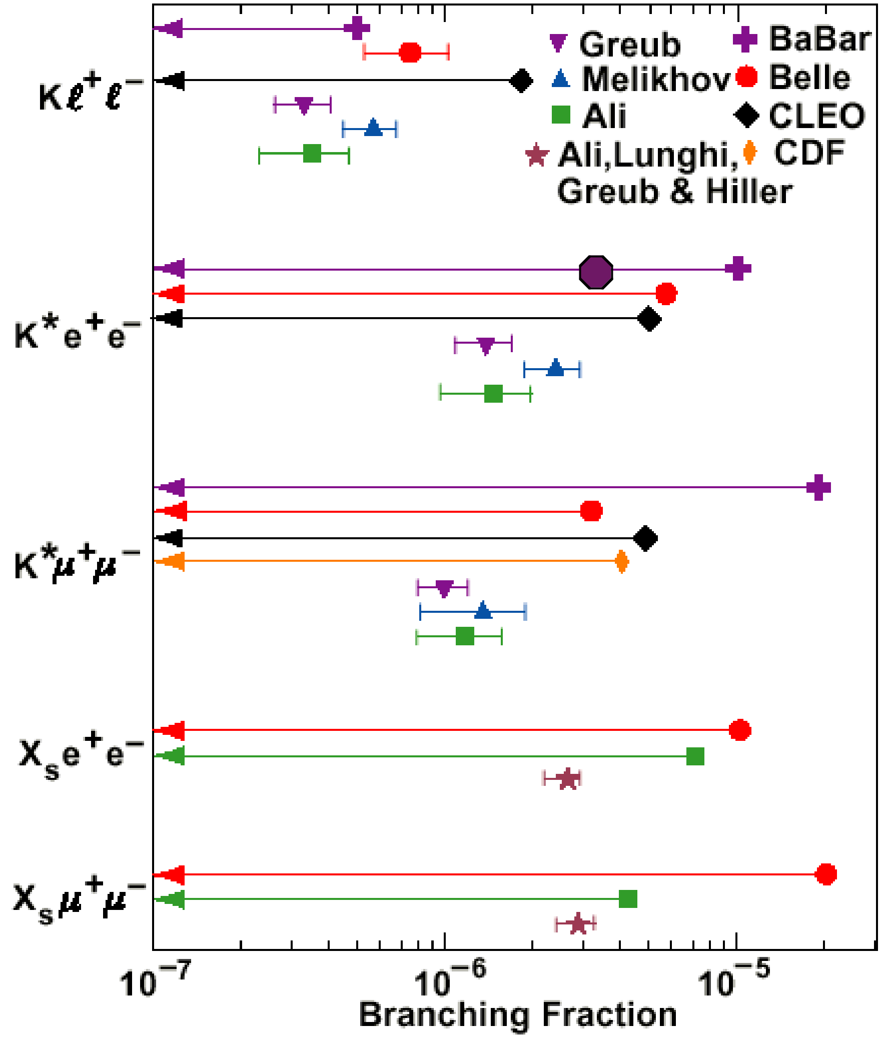


Rare B Decays

Loop Decays: B→K(*)ll

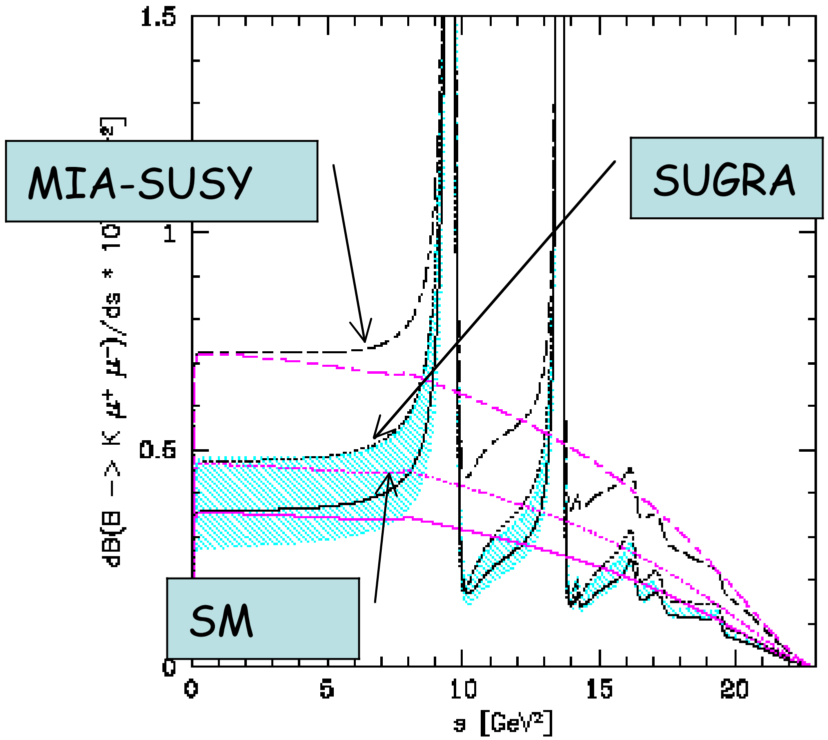
Belle PRL **88**, 021801 (2002)



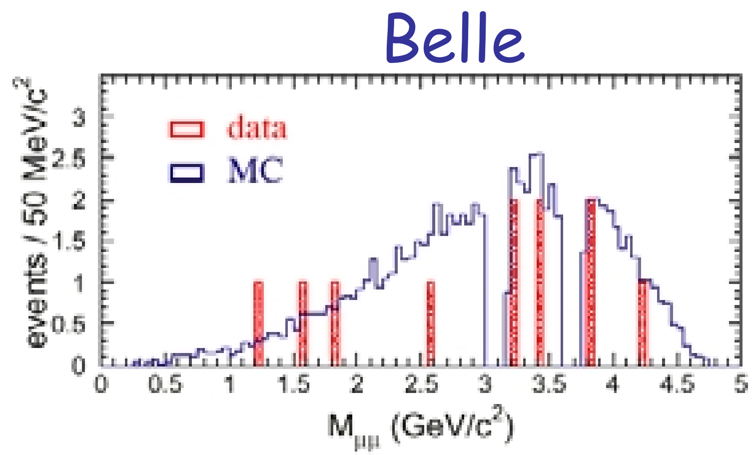


Today: BaBar Kll observation

Probing SUSY: $B \to K^{(*)} ll$



Ali, Ball, Handoko, Hiller
Phys. Rev. D61, 074024 (2000)



Bounds on New Physics

Ali et al. hep-ph/0112300

BF of Kl^+l^- and upper limit of BF of $X_S e^+e^-$ constrain on Wilson coefficiencts C_9 and C_{10}.

$|C_7|$ is determined from BF of $X_S\gamma$.

two solution

negative(SM) and positive.

C_9^{NP} - C_{10}^{NP} plane SM = (0,0)

$$C_9^{NP} = C_9 - C_9^{SM}$$
$$C_{10}^{NP} = C_{10} - C_{10}^{SM}$$

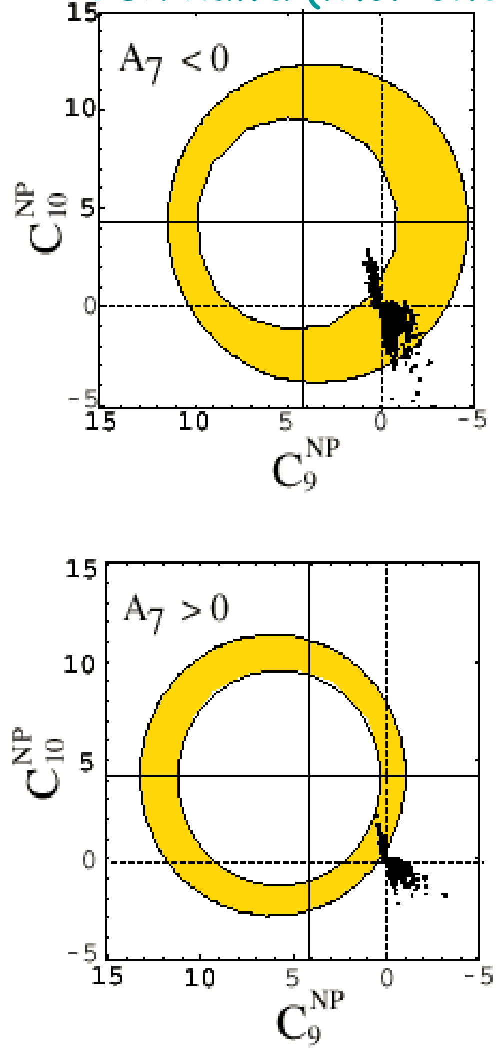
Outer circle is constrained from $X_S e^+e^-$.

Inner circle is constrained from Kl^+l^-.

Points : Extened-MFV resutls.

Exclude some parameter space in EMFV.

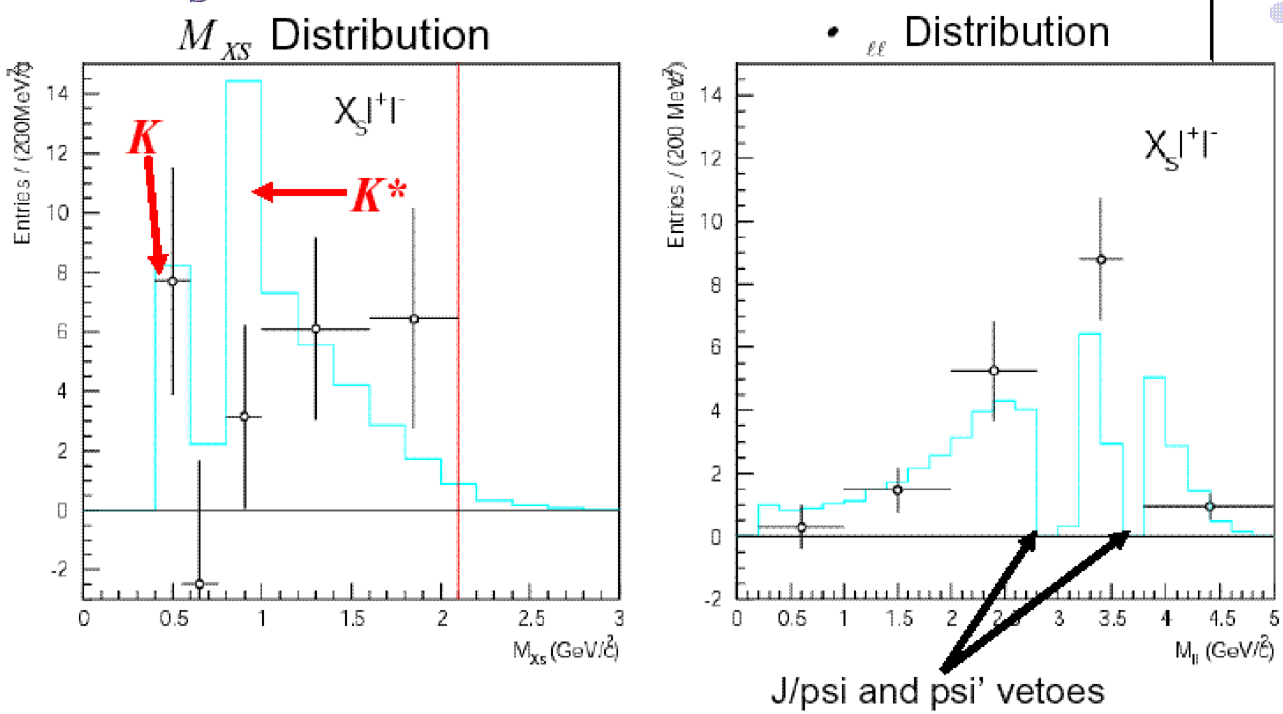
Ishikawa (Moriond)



Observation of b→sll

M_{X_s} and • $_{\ell\ell}$ Distribution

Belle

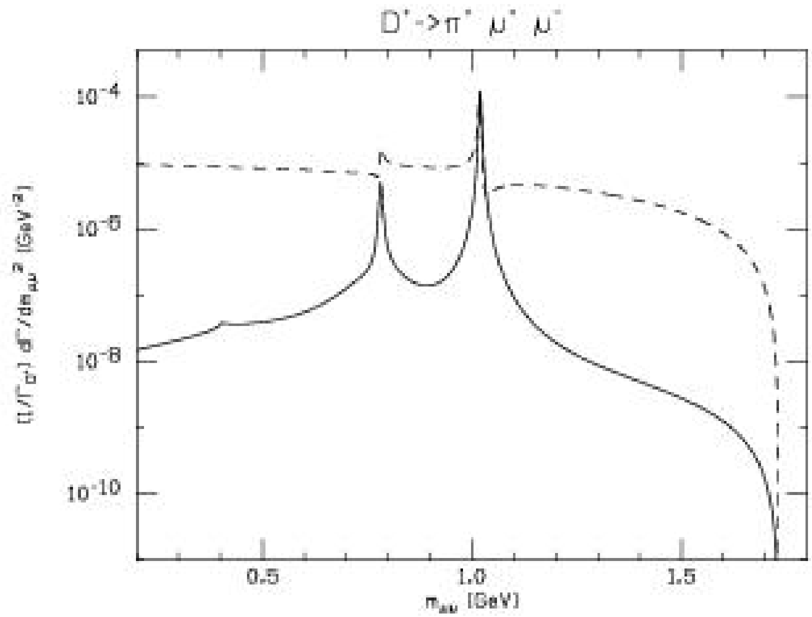


With the higher statistics, more information will be obtained from M(Xs) and M(ll) distribution.

Theoretically cleaner than exclusive Kll

Charm Physics

D→πμμ



Burdman

MSSM R-Parity violating terms enhance D→πμμ rate

FOCUS B(D→πμμ) < 8.8×10^{-6}

Bound compatible with expected sensitivity of 7.6×10^{-6}

DD Mixing

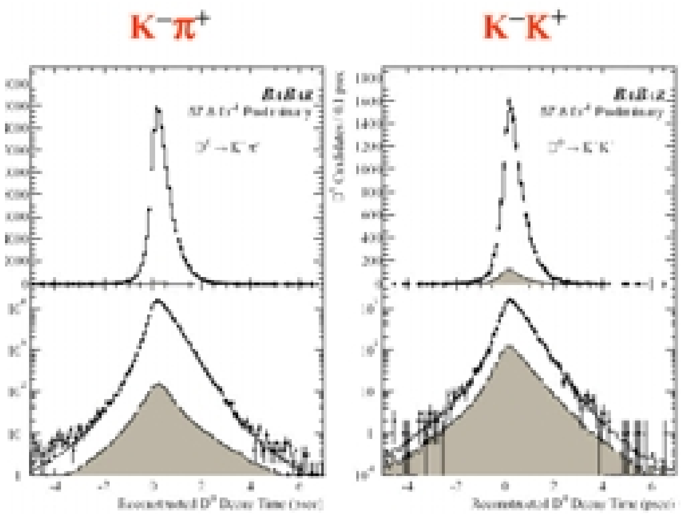
- DD mixing parametrized by $x=\Delta m/\Gamma$ and $y=\Delta\Gamma/2\Gamma$
- Typically, SM gives $x, y <\approx 10^{-3}$

  But, SU(3) breaking from phase space may induce $y\approx1\%$ Petrov

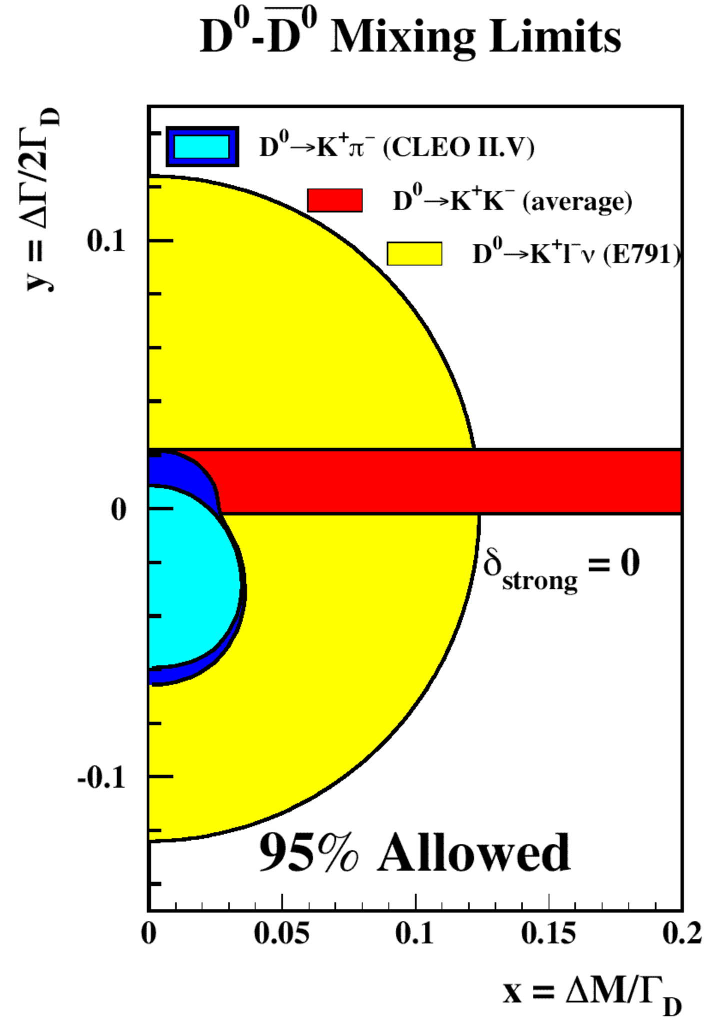
  New physics can enhance x

DD Mixing Results

BaBar 58 fb^{-1}



- New BaBar measurement of $y=2\Delta\Gamma/\Gamma$
- Belle and Focus have done similarly precise m'ments
- World Average:
  $y = 1.0 \pm 0.7$ %



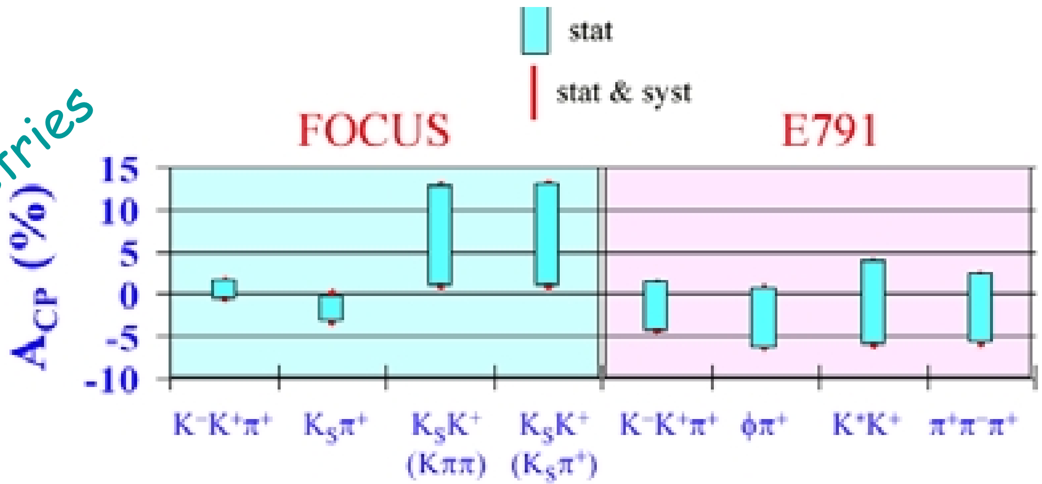
- $x < 6\%$ (95% CL)

no strong phase assumption

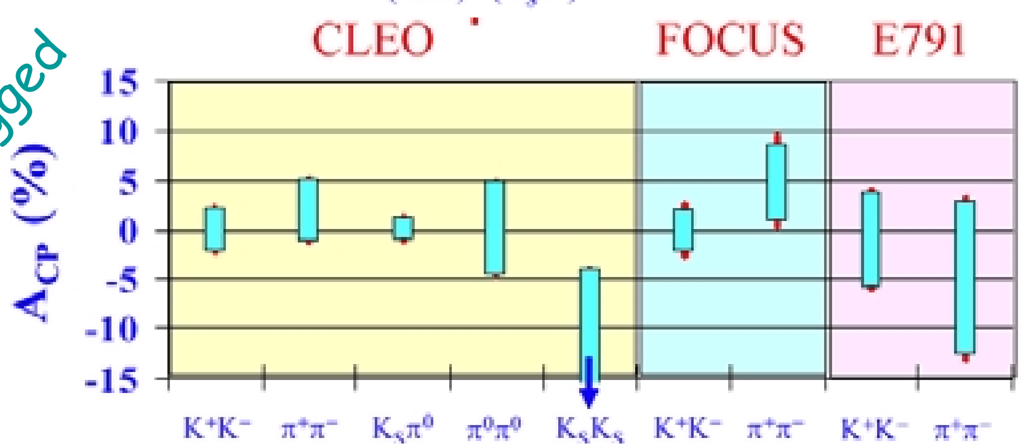
CP Violation in Charm Decay

Expect CP Violation ~0.1%

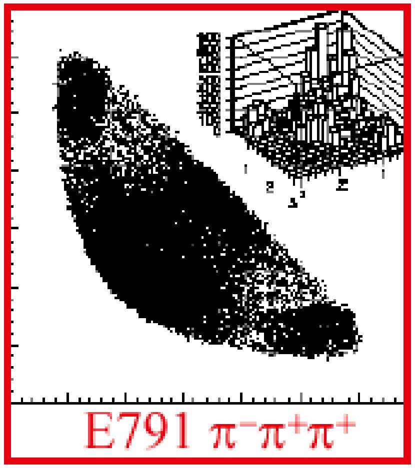
Charge Asymmetries

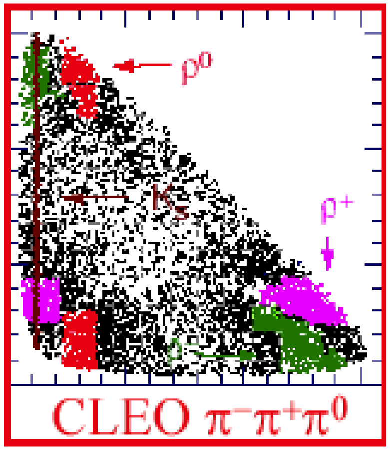


Flavor Tagged



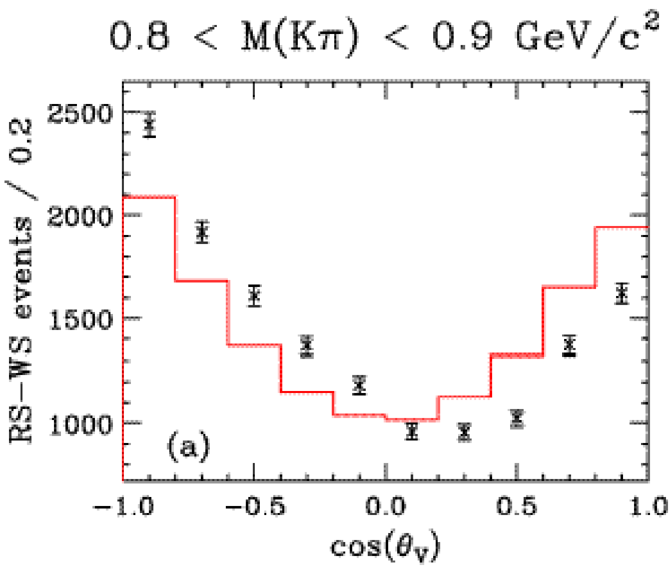
Coming soon to a theatre near you…

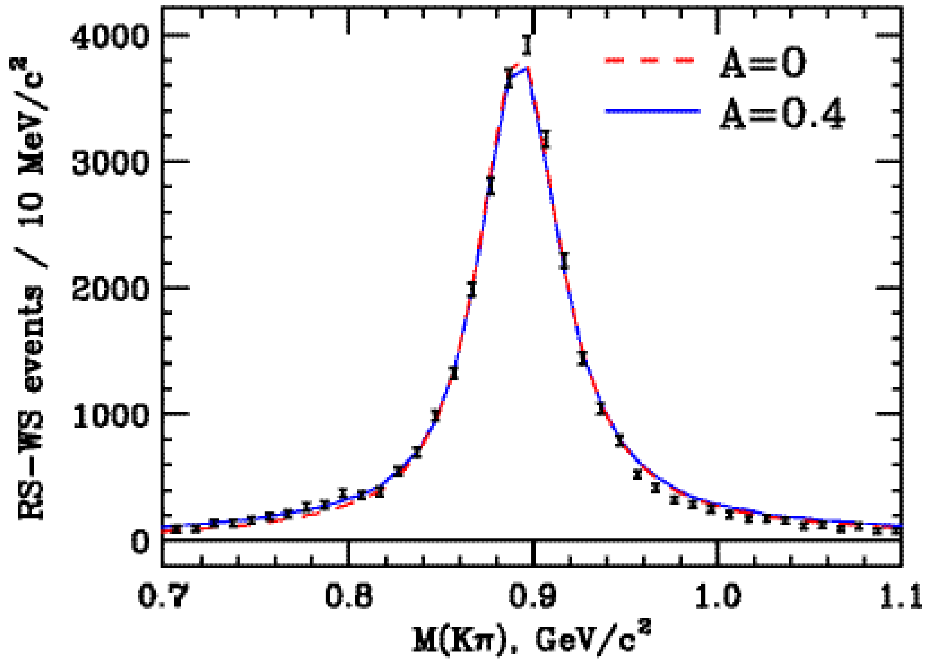




Charm Semileptonic Decay

FOCUS Pretty detective work by uncovers broad s-wave resonance at low Kπ mass in $D \rightarrow K\pi\mu\nu$



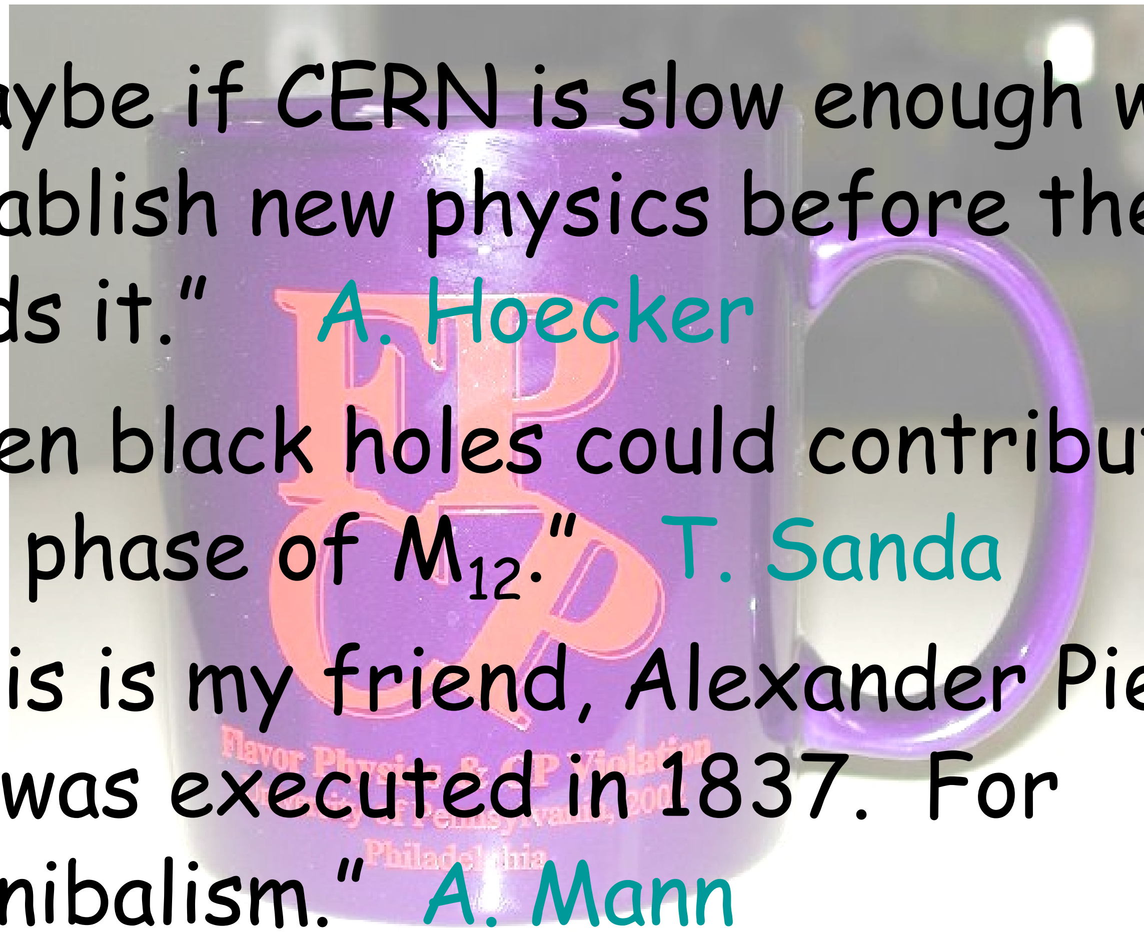


Outlook

These are very exciting times in heavy flavor physics and CP violation

- BaBar and BELLE have unprecedented reach in B_d physics
- CDF and D0 are starting up with huge b production and access to the B_s
- CLEO-c and, if all goes well, BES will provide key BR's and QCD tests
- E949, and later CKM, will constrain $|V_{td}|$ with kaons
- LHCb and BTeV are planning for very high precision studies of the B_d and B_s
- Very high luminosity B-Factories being contemplated

You heard it here



- “Maybe if CERN is slow enough we can establish new physics before the LHC finds it.” A. Hoecker
- “Even black holes could contribute to the phase of M_{12}.” T. Sanda
- “This is my friend, Alexander Pierce. He was executed in 1837. For cannibalism.” A. Mann