FPCP Experimental Summary

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Experimental Techniques

Hadrons and Hadronic Decays

Measurements of CKM sides

CP Violation + Rare Decays

The Future.

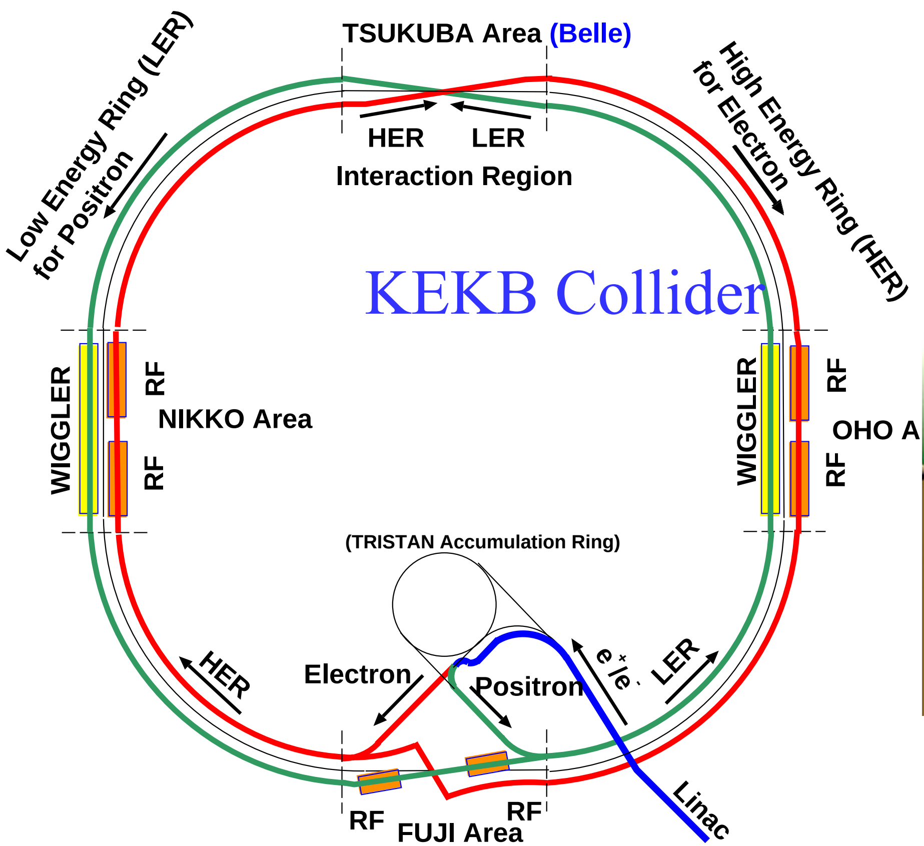
Developments in accelerator physics and detector technology make progress in flavor physics and CP violation possible.

Two especially notable ones with a profound impact at FPCP03:

B-factory storage rings have integrated over 100 fb^{-1} (KEKB achieved L>1 x $10^{34}/cm^2/sec$)

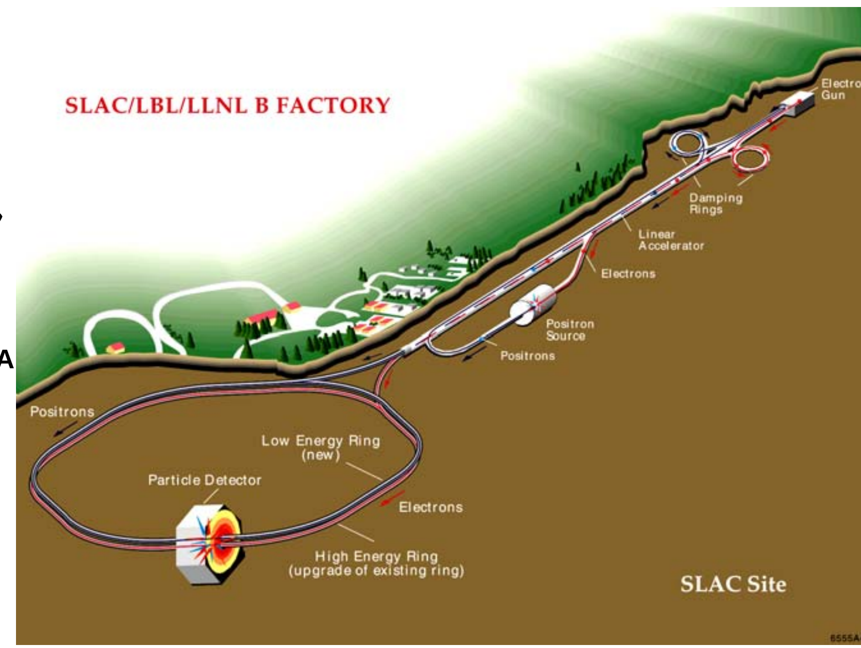
CDF: detached vertex trigger allows selection of hadronic B+D decay modes (coming for D0): Blocker, Shapiro, Martin, Boca, Jain

KEKB (8 x 3.5 GeV, ±11 mrad X angle)

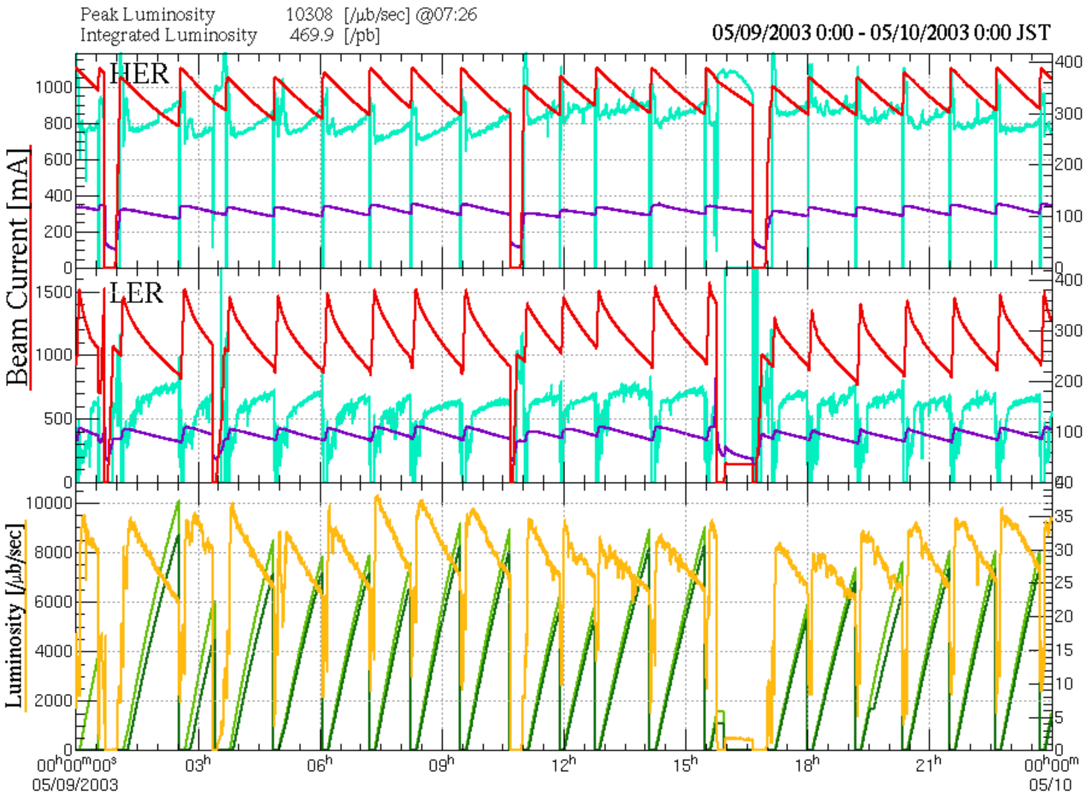


150 fb^{-1}/ 78 fb^{-1} used so far

PEPII (9 x 3.0 GeV, magnetic sep.)



125 fb^{-1}/ 81 fb^{-1} used so far



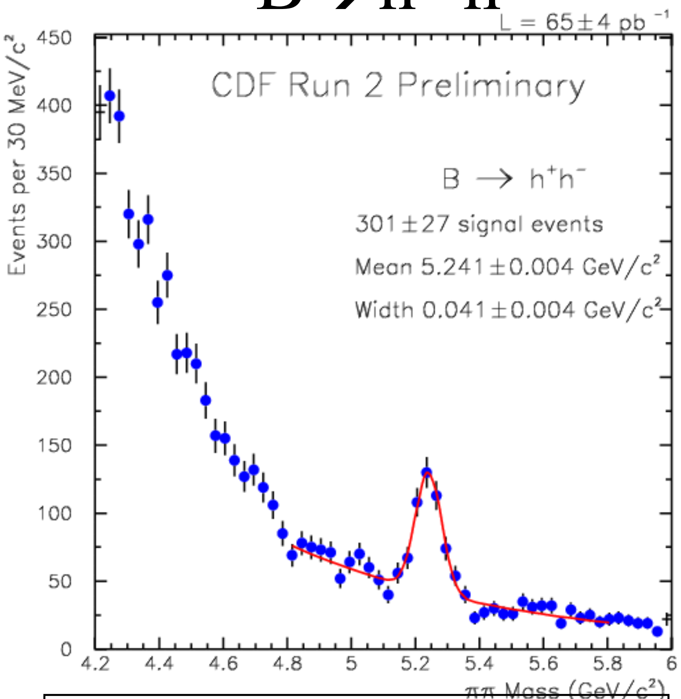
$$Int(L\ dt) = 0.149\ ab^{-1}$$

New Daily Record May 13: 595 pb^{-1}/24 hr

$$L = (1.05 \times 10^{34})/cm^2/sec$$

Hadronic B Decays at CDF

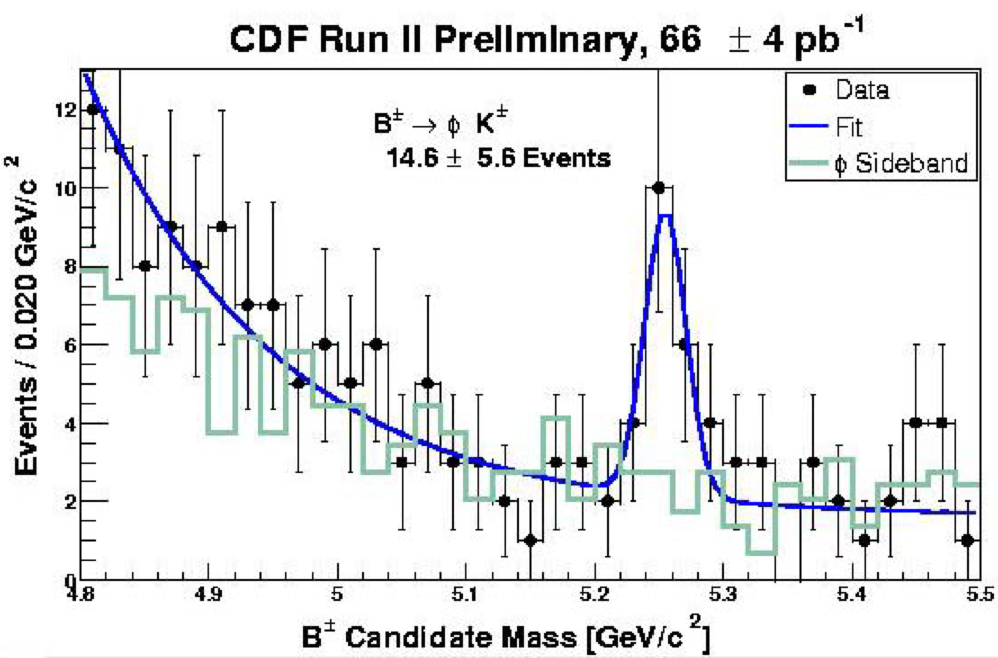
B→h⁺ h⁻



$B_d \rightarrow \pi^+ \pi^-$: 39±14
$B_d \rightarrow K^- \pi^+$: 148±17
$B_s \rightarrow K^+ \pi^-$: 3±11
$B_s \rightarrow K^+ K^-$: 90±17

Disentangle $\mathbf{B_d \rightarrow \pi\pi}$ $\mathbf{B_d \rightarrow K\pi}$ $\mathbf{B_s \rightarrow KK}$ $\mathbf{B_s \rightarrow K\pi}$ **with kinematics & dE/dx**

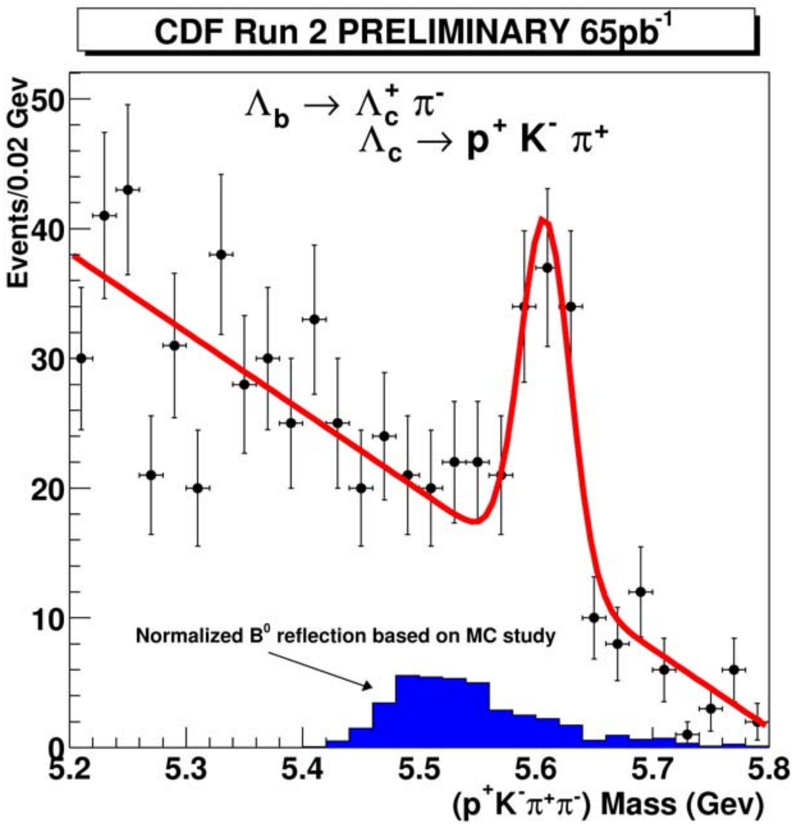
$B^{\pm} \rightarrow \phi K^{\pm}$



B_s Mesons and Λ_b Baryons (CDF vertex trigger)

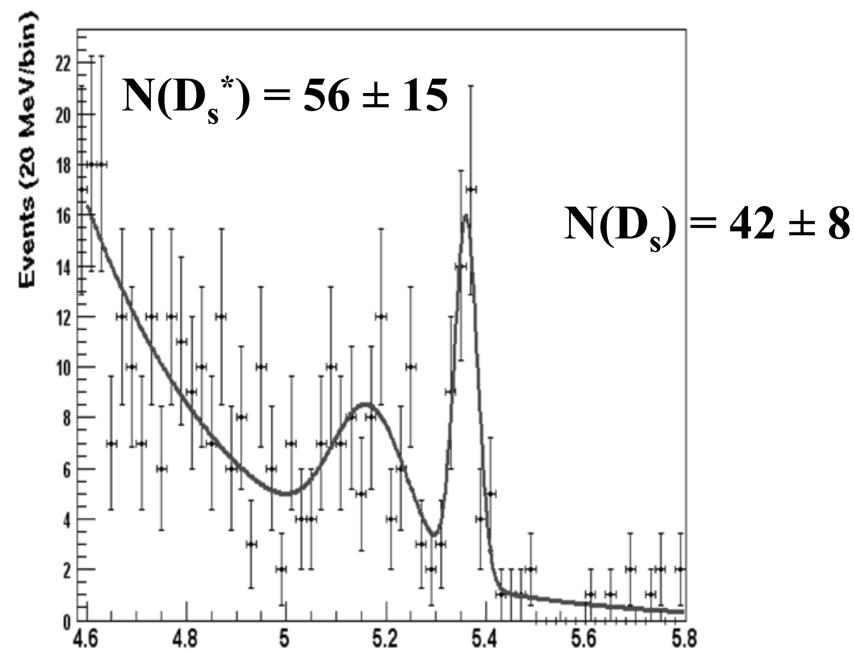
$\Lambda_b \rightarrow \Lambda_c\, \pi$

$\quad\quad \hookrightarrow$ **p K** π



$B_s \rightarrow D_s\pi,\ D_s \rightarrow \phi\pi$ **:**

golden mode for B_s oscillations



But 10^3 events required for a competitive B_s mixing meas !

Selected Topics in "Brown Muck"

N.Isgur

(*Le Romantisme de la Boue*)

New Charm Mesons (D_{sJ} and all that)

Hot topics by Barlow, Stone, Shapiro; Chistov, Trabelsi

Mystery of $e^+e^- \rightarrow J/\psi$ (c cbar) production

Hot topic Bondar

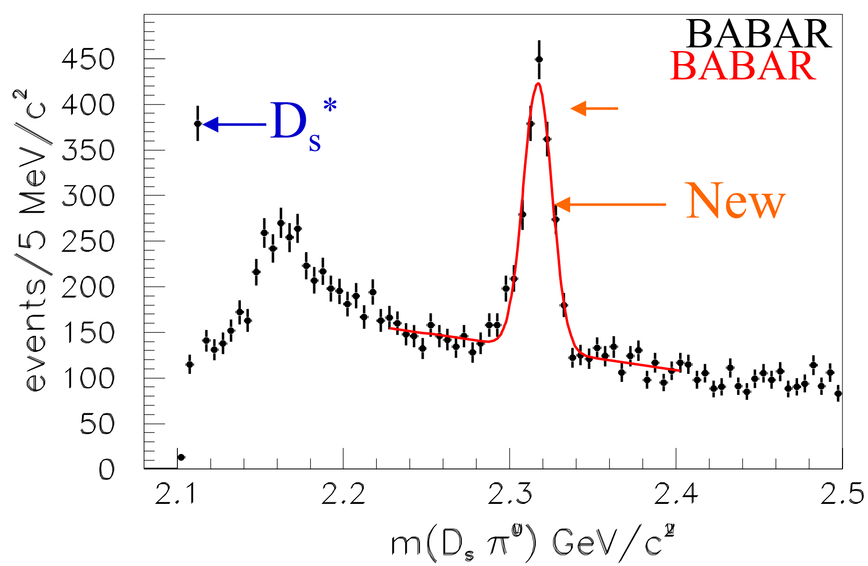
New $D_s^{(*)}\pi^o$ Resonances (A. Palano et al.)

"Le hasard favorise l'esprit prepare"*

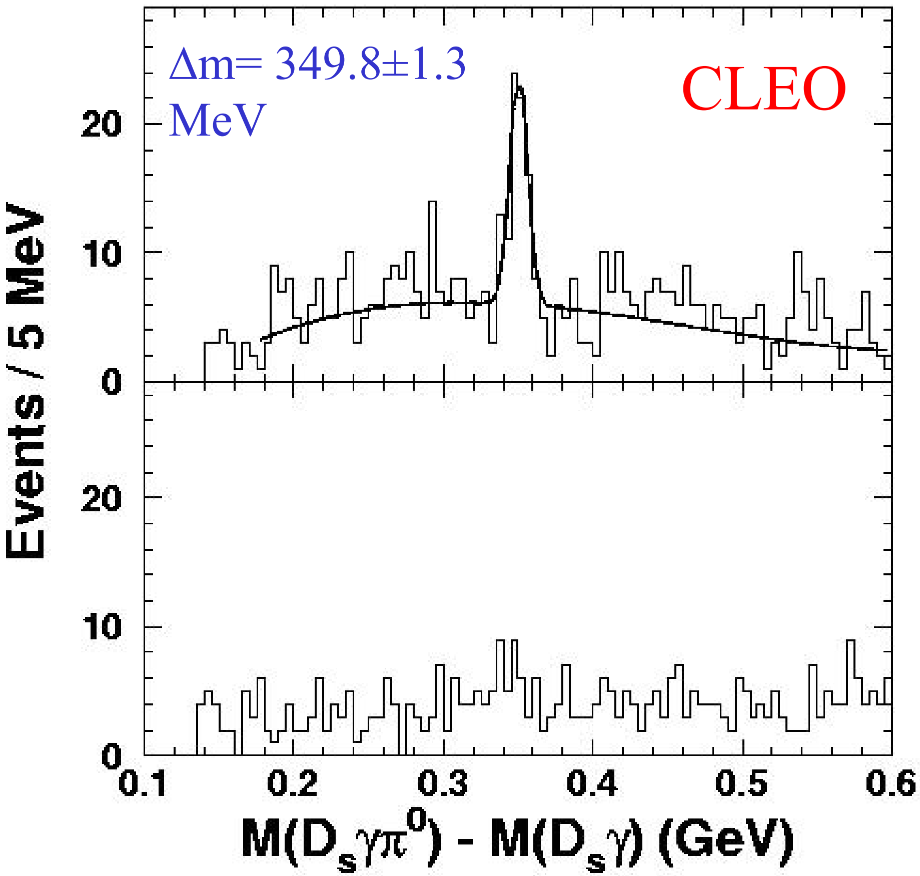
"Narrow" state, mass

2316.8±0.4±3.0 MeV

$D_s\pi^o$

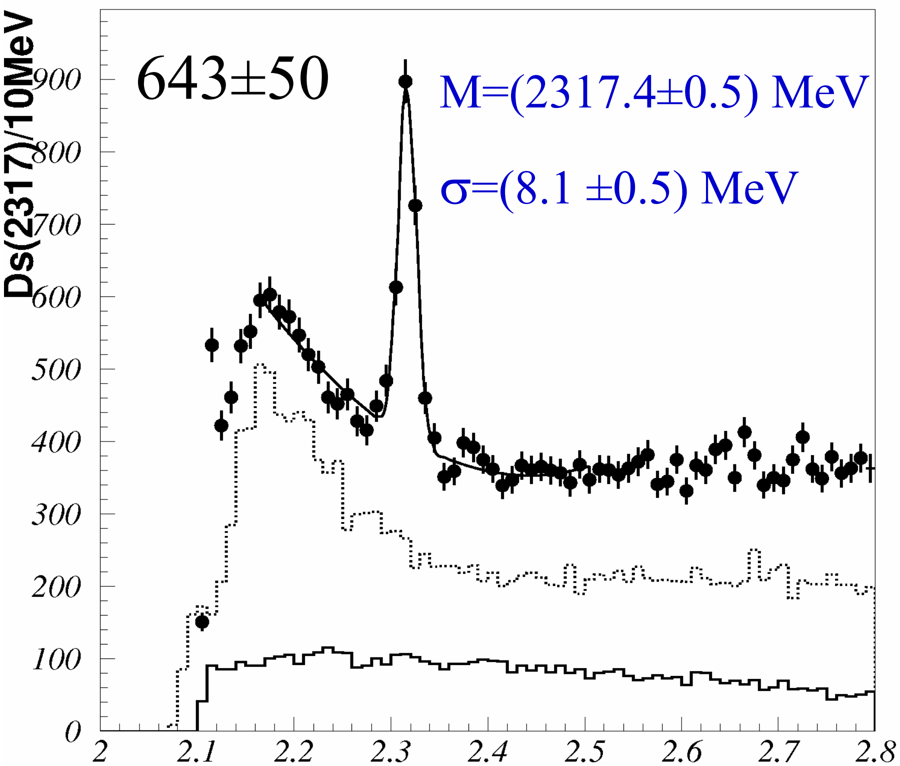


$D_s^*\pi^o$

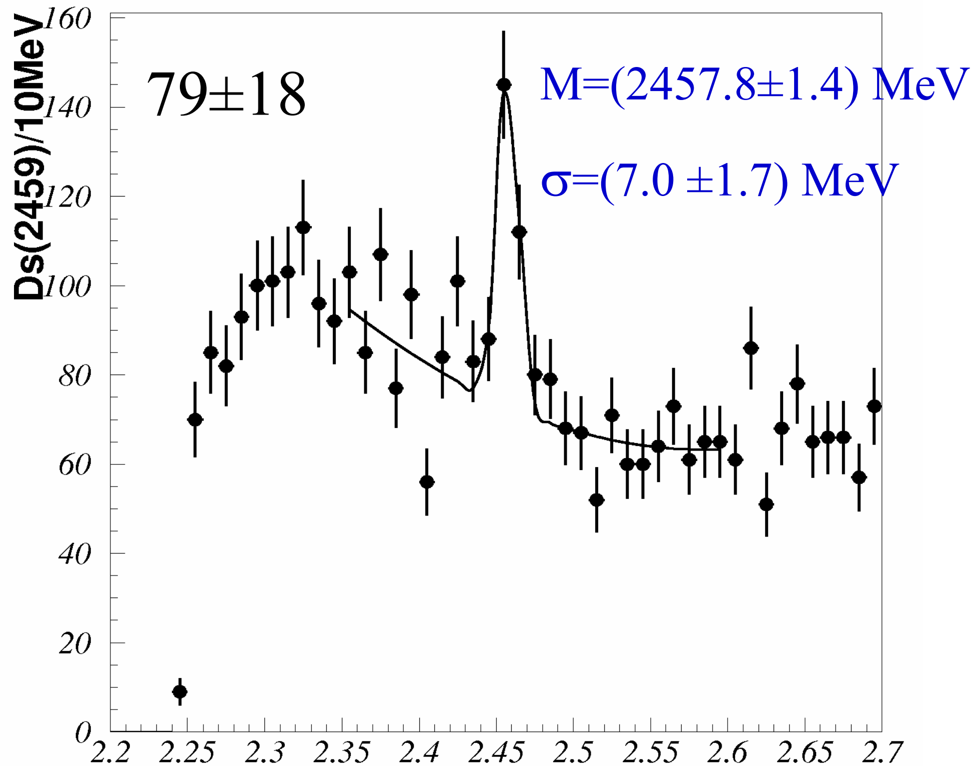


*"Chance favors the prepared mind"-L.Pasteur

Belle Confirms Both States



$M(D_s^+ \pi^0)$



$M(D_s^{*+} \pi^0)$

Interpretation

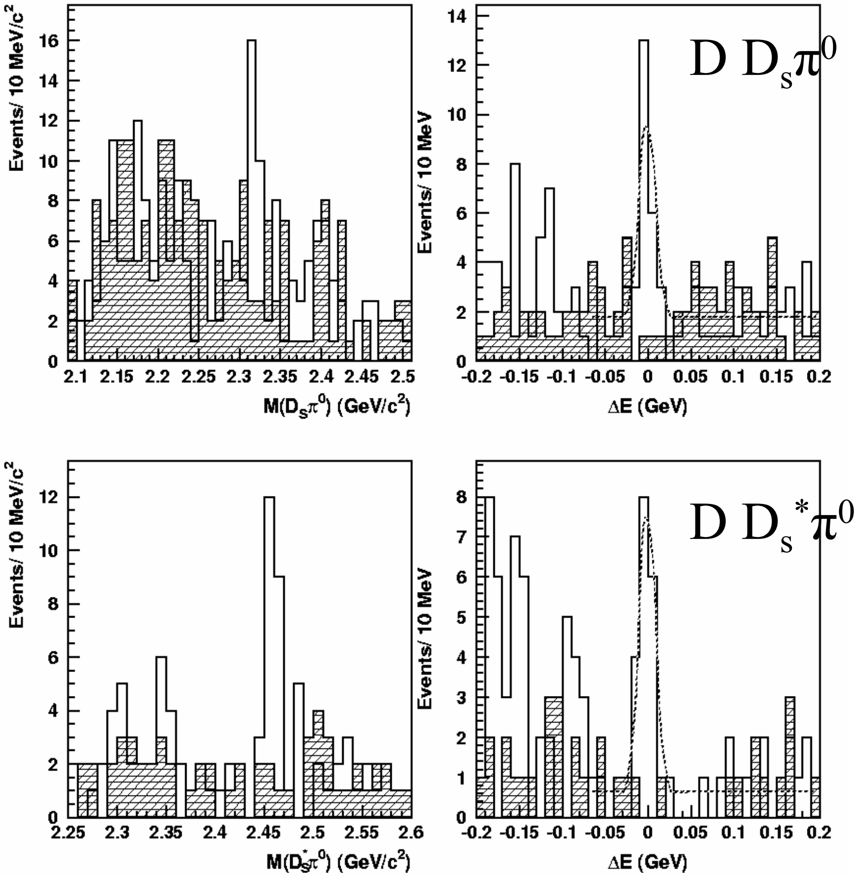
What are these new states: a DK molecule or a 4-quark state ? e.g. Barnes, Close and Lipkin, hep-ph/0305025

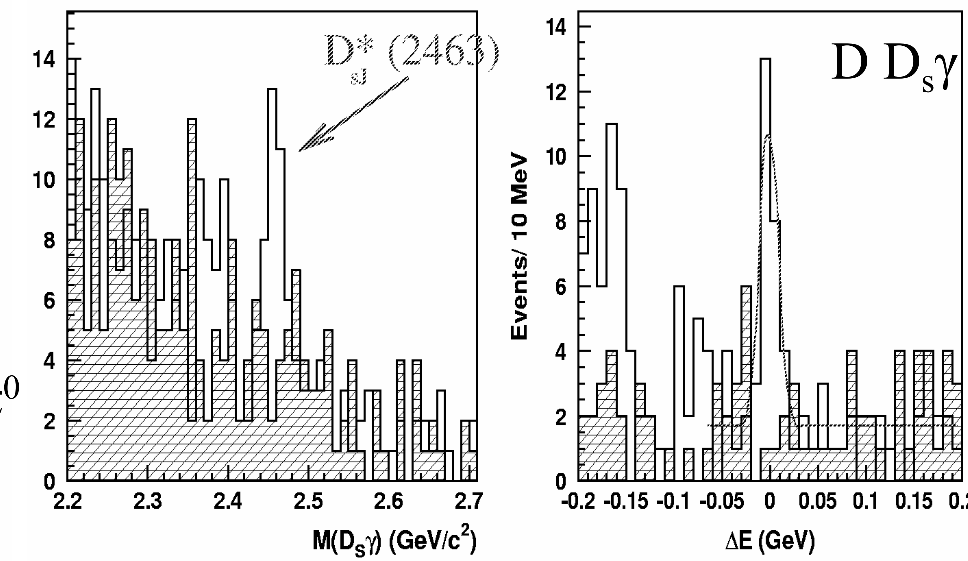
"Ordinary" excited p-wave c-sbar states: D_s** ?

*D_s** predicted J^P: 0^+, 1^+, 1^+ & 2^+. Two narrow 1^+ & 2^+ found long ago by ARGUS and CLEO. Others predicted to be above DK threshold and have large ~200 MeV widths, but this state is far below DK threshold.*

The $D_s^+ \pi^o$ decay from an initial c-sbar state violates isospin, this suppresses the decay width and makes it narrow. Thus, the low mass ensures the narrow width.

Using B→D $D_s^{(*)}\pi^0$ (γ) to find new D_s ** resonances





Belle also a continuum signal for Ds(2460)→Ds γ

Belle:

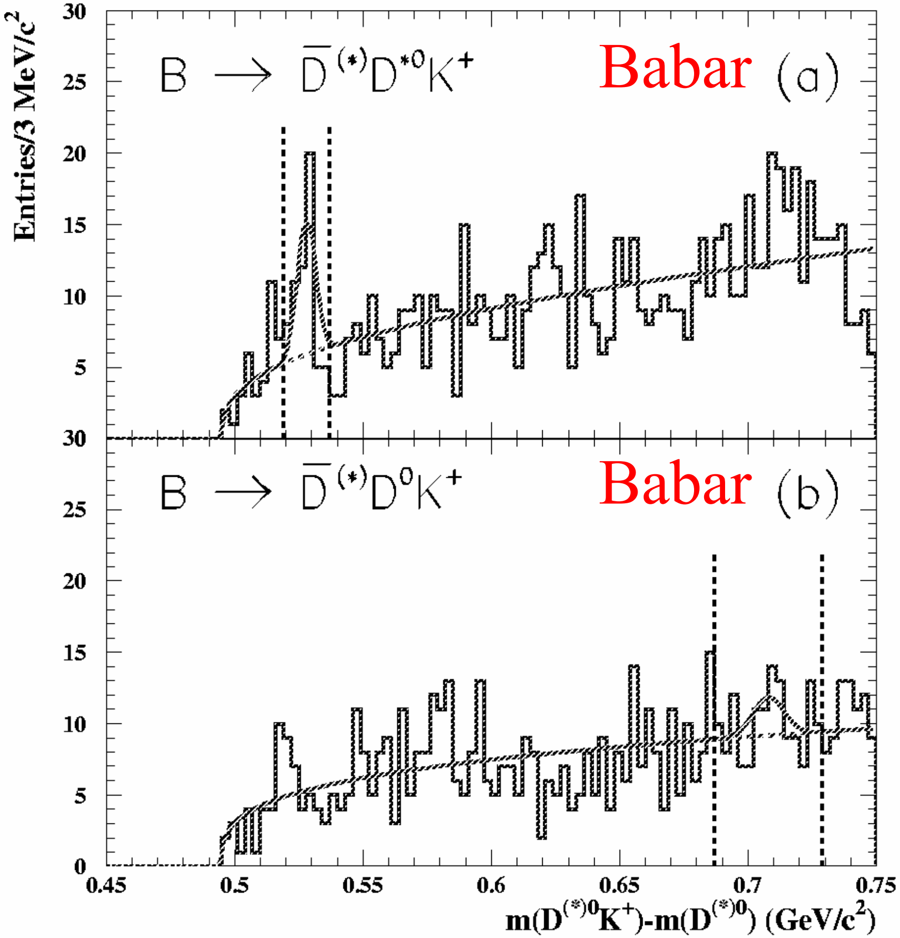
$$\frac{B(D^*_{sJ}(2460)\to D_s\gamma)}{B(D^*_{sJ}(2460)\to D^*_s\pi^0)} = 0.21 \pm 0.07 \pm 0.03$$

Search for orbitally excited D_s^{**} mesons in B decay

$\underline{D^+_{s1}(2536)}$

$J^P = 1^+,\ j_q = 3/2$

look in $B \to D^{(*)} D^{*0} K^-$



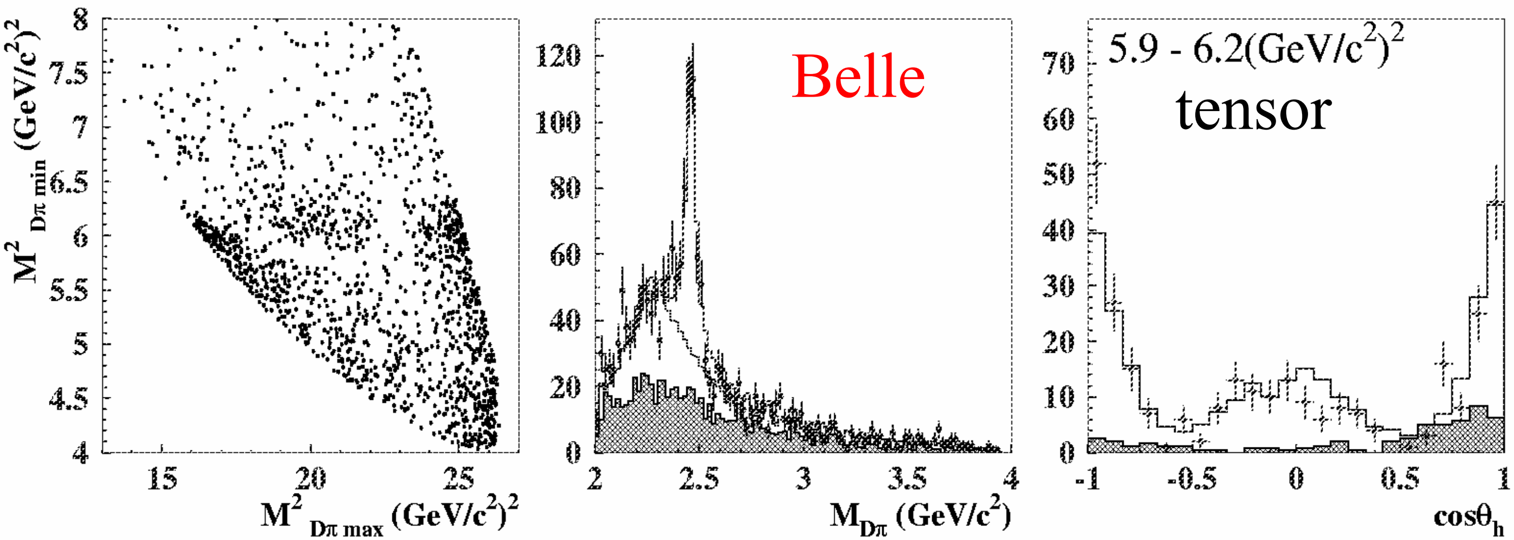
$\underline{D^+_{sJ}(2573)}$

$J^P = 2^+,\ j_q = 3/2$

look in $B \to D^{(*)} D^0 K^-$

No $j_q = 3/2$ states ($D^+_{s1}(2536)$ and $D^+_{sJ}(2573)$) found in $D\bar{D}K$

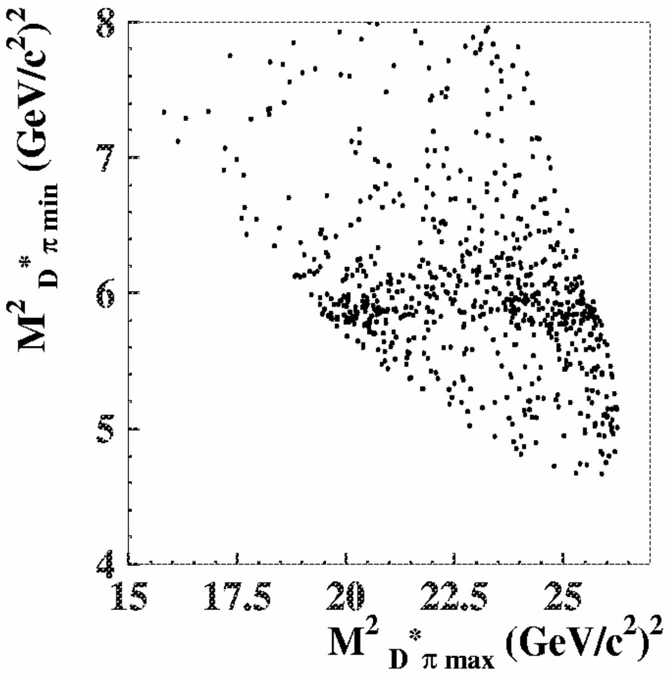
Using $B^- \rightarrow D^+ \pi^- \pi^-$ to find broad D^{**} resonances.

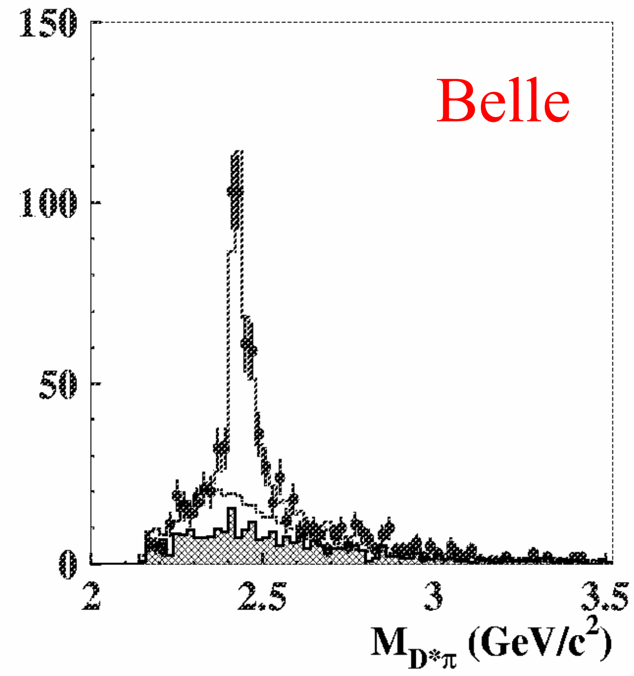


$$M_{D_2^{*0}} = (2461.6 \pm 2.1 \pm 0.5 \pm 3.3) MeV/c^2,$$
$$\Gamma_{D_2^{*0}} = (45.6 \pm 4.4 \pm 6.5 \pm 1.6) MeV/c^2$$
$$B(B^- \to D_2^{*0}\pi^-) \times (D_2^{*0} \to D^+\pi^-) = (3.4 \pm 0.3 \pm 0.6 \pm 0.4) \times 10^{-4}$$

$$M_{D_0^{*0}} = (2308 \pm 17 \pm 15 \pm 20) MeV/c^2,$$
$$\Gamma_{D_0^{*0}} = (276 \pm 21 \pm 18 \pm 60) MeV/c^2$$
$$B(B^- \to D_0^{*0}\pi^-) \times (D_0^{*0} \to D^+\pi^-) = (6.1 \pm 0.6 \pm 0.9 \pm 1.6) \times 10^{-4}$$

Using $B^- \rightarrow D^{*+} \pi^- \pi^-$ to find broad D^{**} resonances.

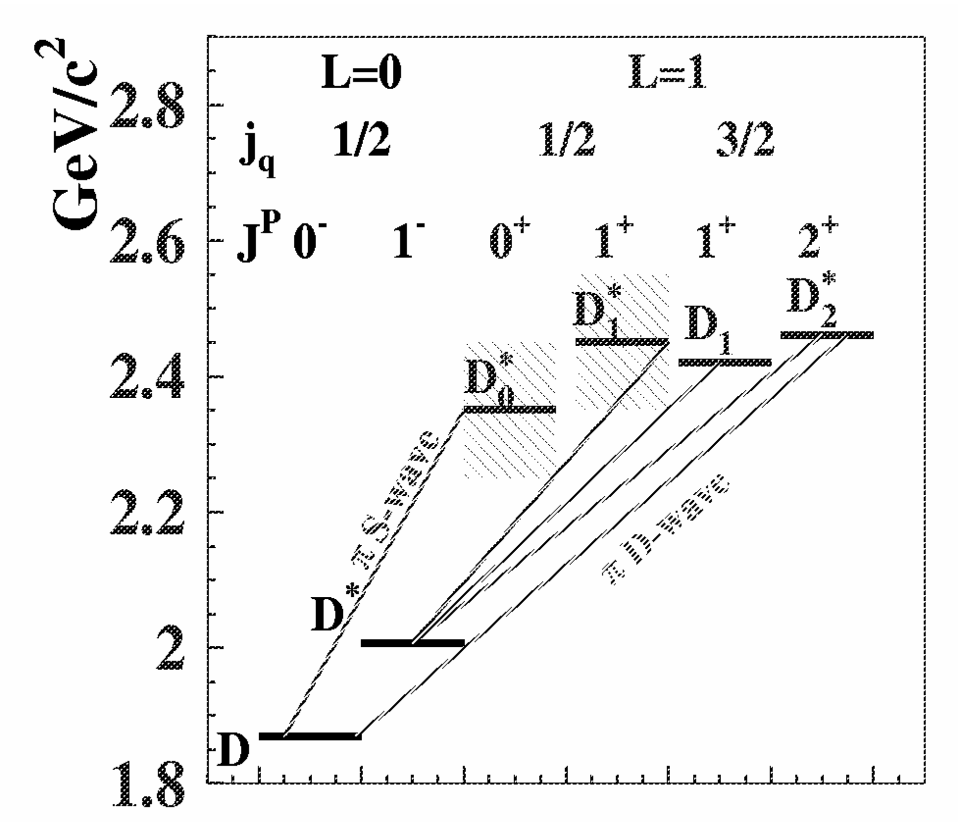




$$M_{D_1^0} = (2421.4 \pm 2.0 \pm 0.4 \pm 0.8) MeV/c^2,$$
$$\Gamma_{D_1^0} = (23.7 \pm 2.7 \pm 0.2 \pm 4.0) MeV/c^2$$
$$B(B^- \to D_1^0 \pi^-) \times (D_1^0 \to D^{*+}\pi^-) = (6.8 \pm 0.7 \pm 1.3 \pm 0.3) \times 10^{-4}$$
$$B(B^- \to D_2^{*0} \pi^-) \times (D_2^{*0} \to D^{*+}\pi^-) = (1.8 \pm 0.3 \pm 0.3 \pm 0.2) \times 10^{-4}$$

$$M_{D_1^{*0}} = (2427 \pm 26 \pm 20 \pm 15) MeV/c^2, \Gamma_{D_1^{*0}} = (384^{+107}_{-75} \pm 24 \pm 70) MeV/c^2$$
$$B(B^- \to D_1^{*0} \pi^-) \times (D_1^{*0} \to D^{*+}\pi^-) = (5.0 \pm 0.4 \pm 1.0 \pm 0.4) \times 10^{-4}$$

More twists or the end of the $D_s^{(*)}\pi^0$ tale ?



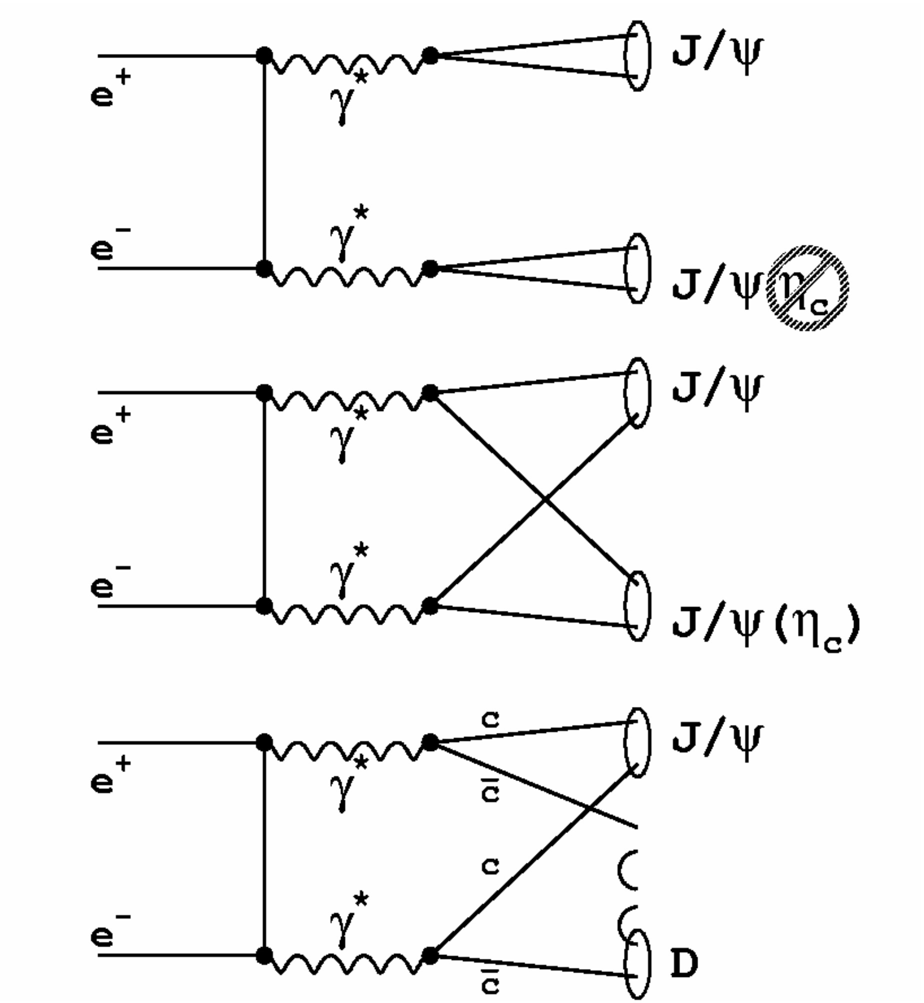
Ds(2460)→Ds γ observed by Belle. This establishes that this is a 1^+ state.

Belle finds that Ds(2420), Ds(2460)[j_l=1/2] produced abundantly in B decay, while the other j_l=3/2 states are not.

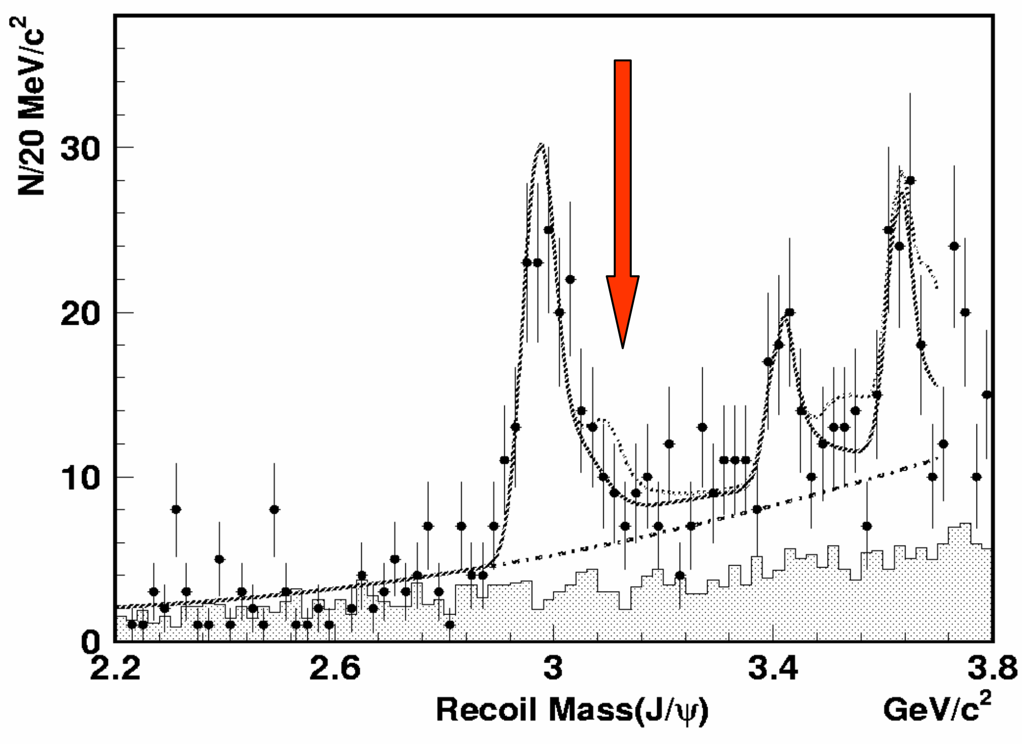
But the masses are unexpected: the new Ds** 0^+ and 1^+ states have nearly the same masses as the D** 0^+ and 1^+ states.

c.f. Baarden, Eichten, Hill

G. Bodwin, J. Lee and E. Braaten (PRL 2003) suggest 2-γ^* processes may explain apparent large and anomalous $e^+ e^- \rightarrow \psi$ (c cbar) signal seen at Belle.



Belle Data vs Braaten et al.

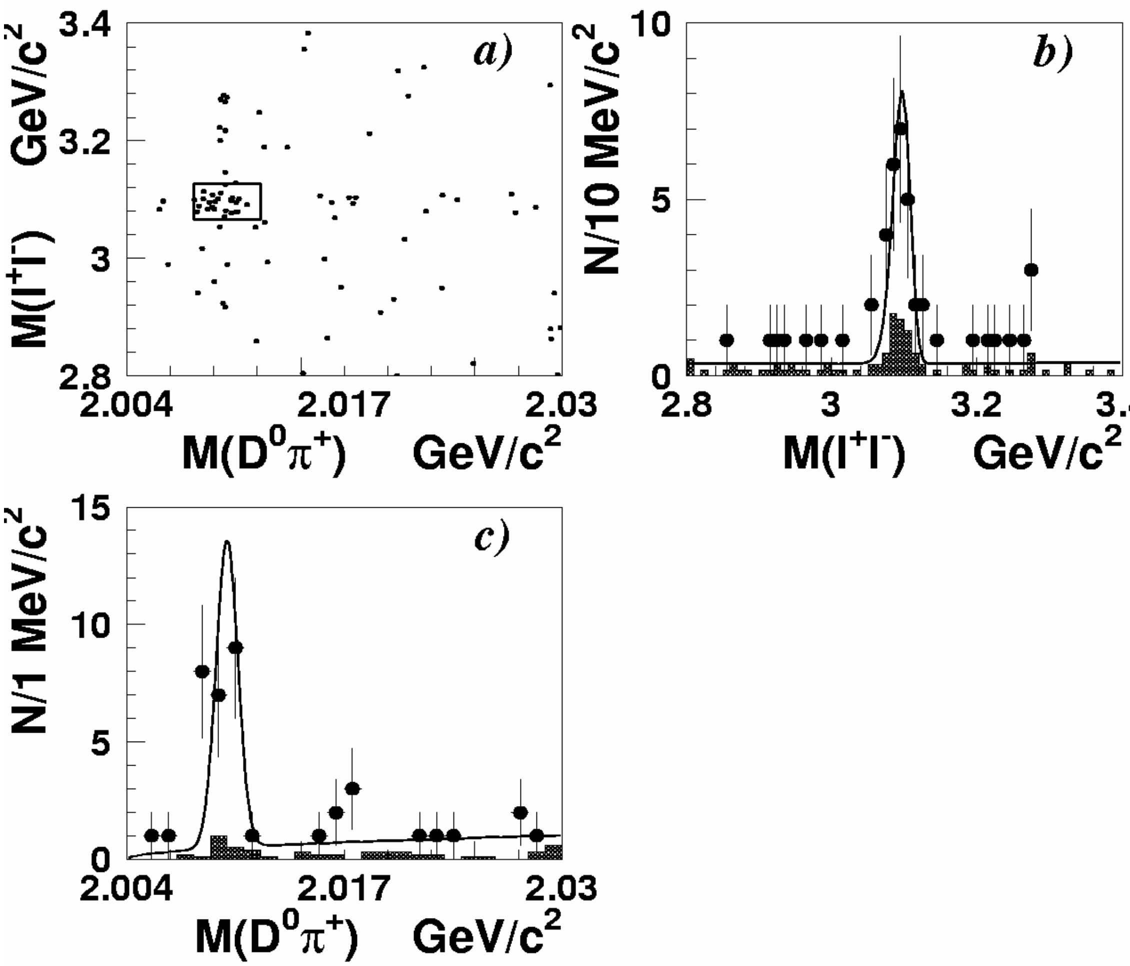


No evidence for $e^+ e^- \rightarrow 2\text{-}\gamma^* \rightarrow J/\psi\ J/\psi$.

[Still have severe disagreement with NRQCD]

Cross section: $\sigma(e^+ e^- \rightarrow J/\psi\ J/\psi)(J/\psi\ J/\psi \rightarrow 2\ \text{charged}) < 8$ fb

Updated signals for $e^+ e^- \rightarrow \psi D^* X$



Belle

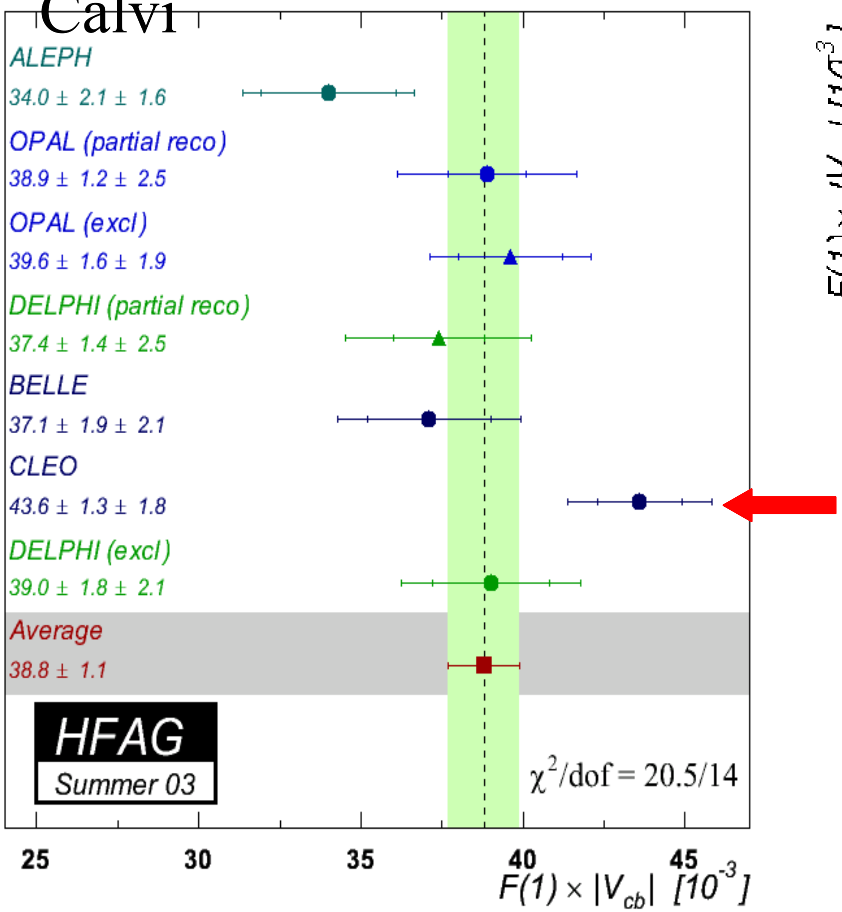
Sum D^0, D^+, D_s^+ and Λ_c yields corrected on the efficiency

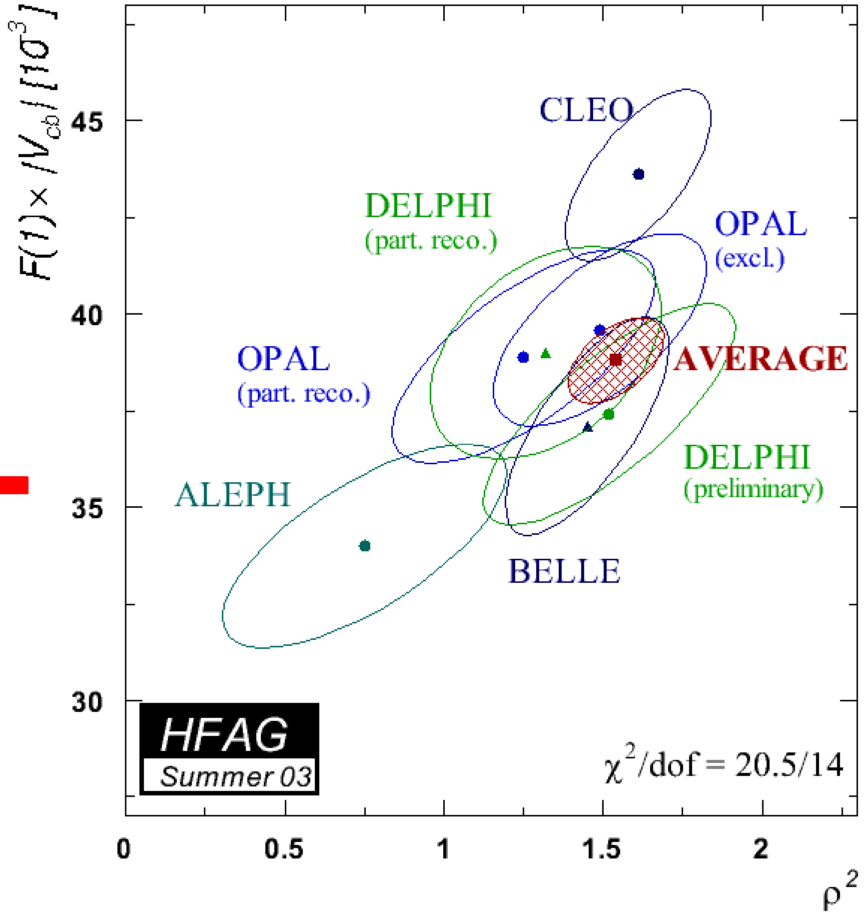
$$\frac{\sigma(e^+e^- \rightarrow J/\psi c\bar{c})}{\sigma(e^+e^- \rightarrow J/\psi X)} = \frac{N_{D^0} + N_{D^+} + N_{D_s^+} + N_{\Lambda_c}}{2 \cdot N_{J/\psi}} =$$

$$\mathbf{0.82 \pm 0.15}$$

CKM Matrix Elements: Length of the sides of the UT (will concentrate on $|V_{ub}|$)

$|V_{cb}|$: Calvi



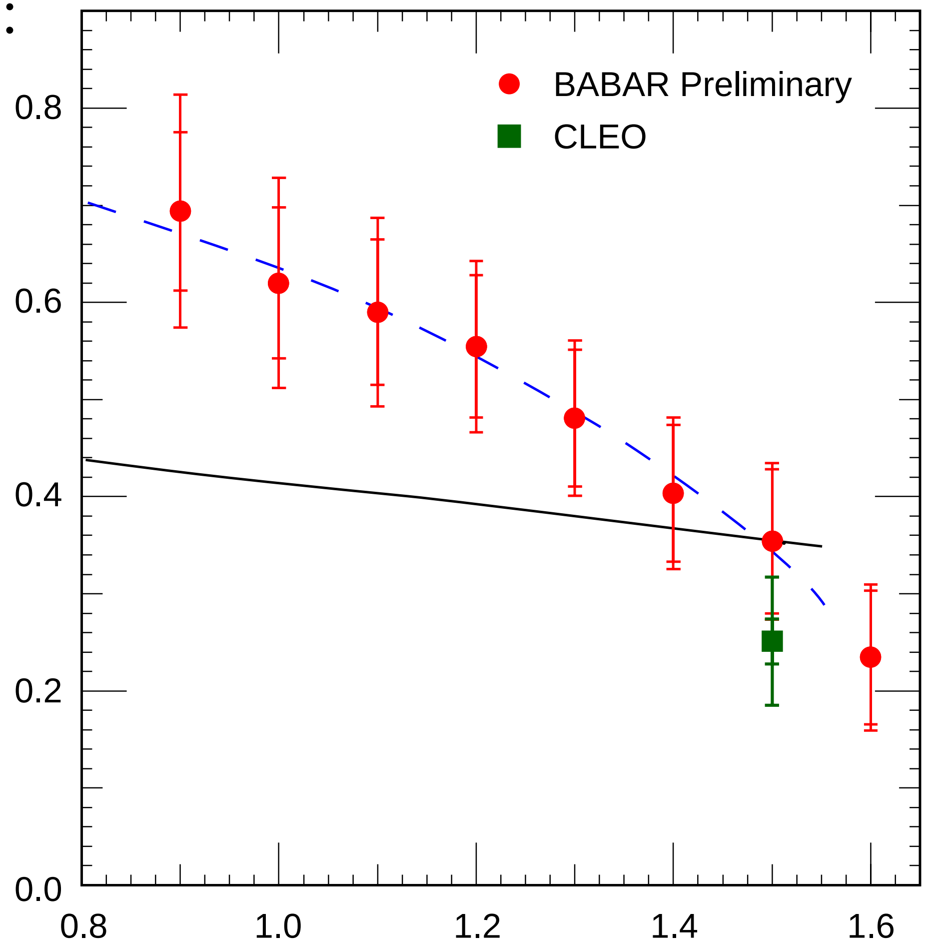


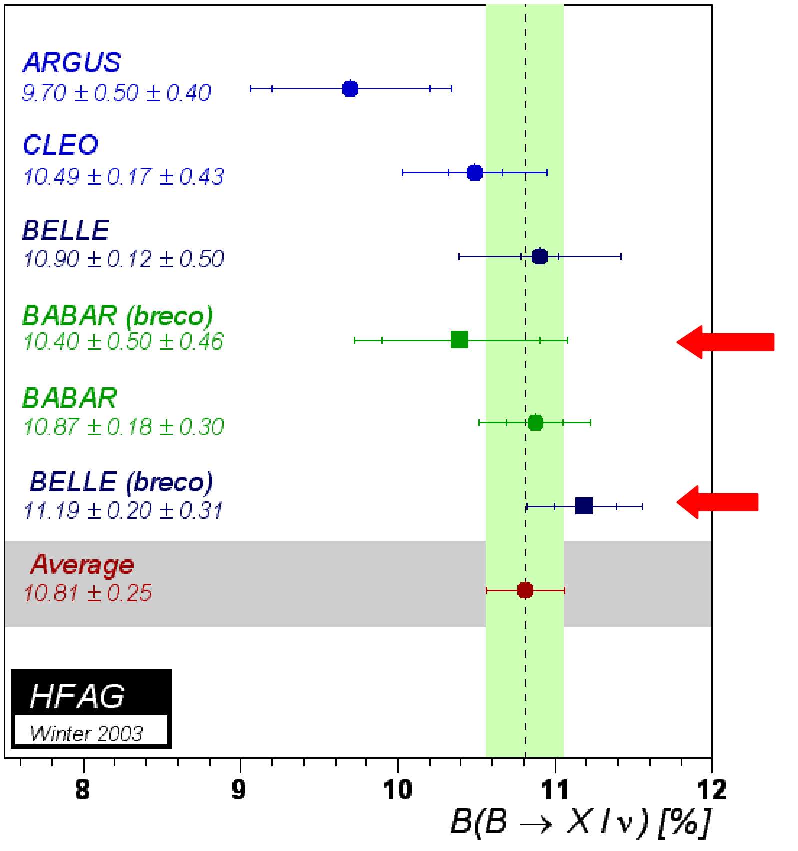
$\mathcal{F}(1)|V_{cb}|=(38.8\pm0.5_{stat}\pm0.9_{syst})\times10^{-3}$ $\rho_A^2=1.54\pm0.05_{stat}\pm0.13_{syst}$

Inclusive semileptonic B Decay

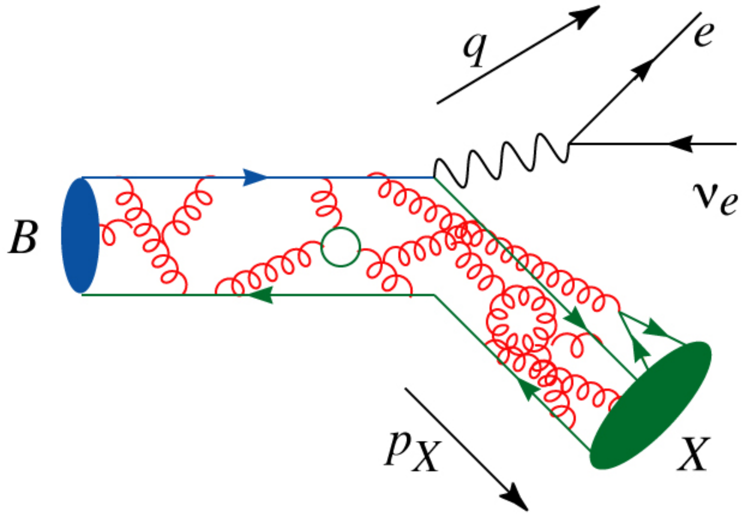
The hottest topic of the conference ! [Artuso, Ligeti, Uraltsev]

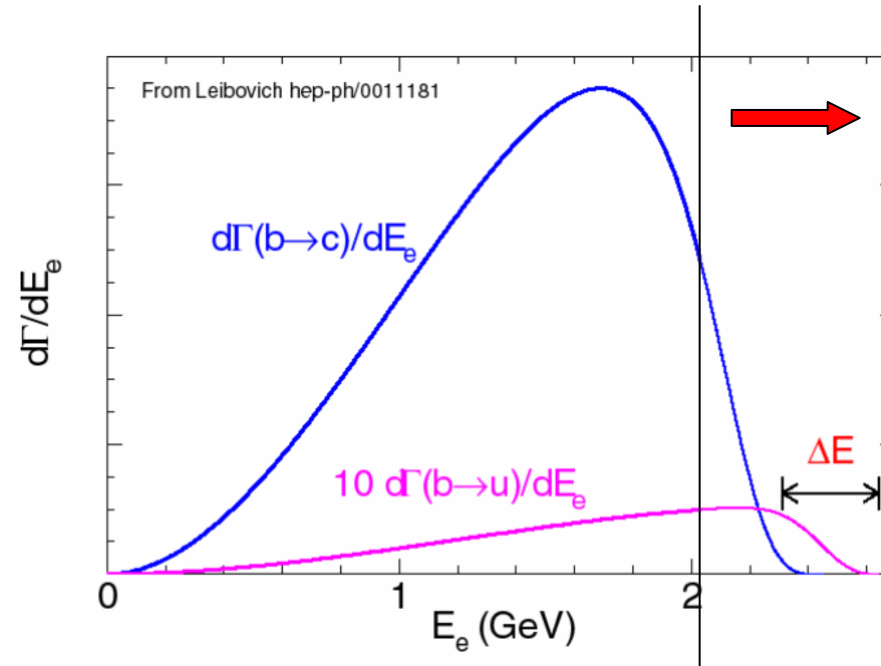
$|V_{cb}|$:





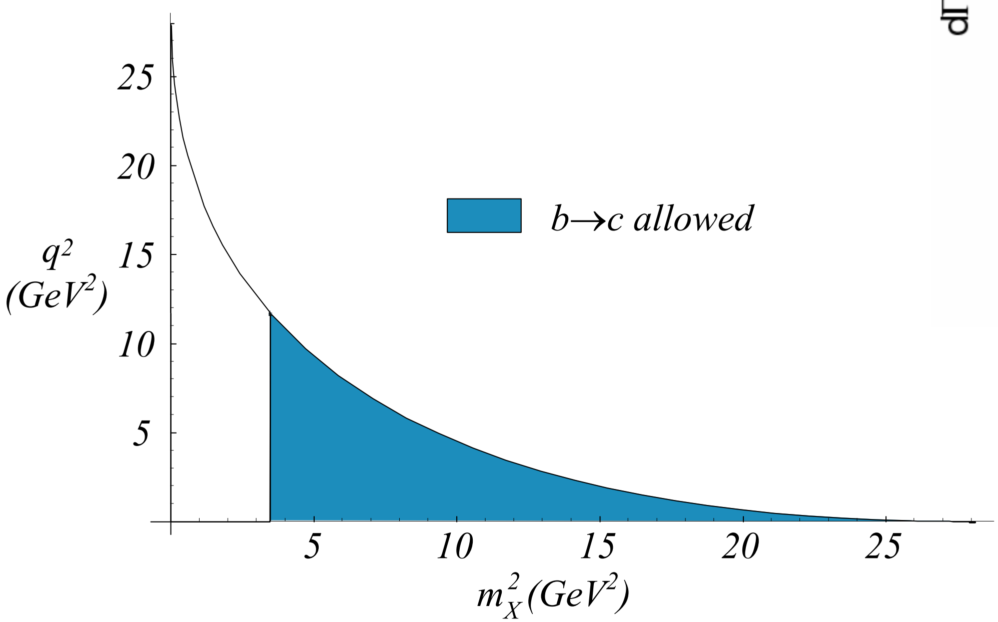
Approaches to $|V_{ub}|$





+ CLEO b→s γ data

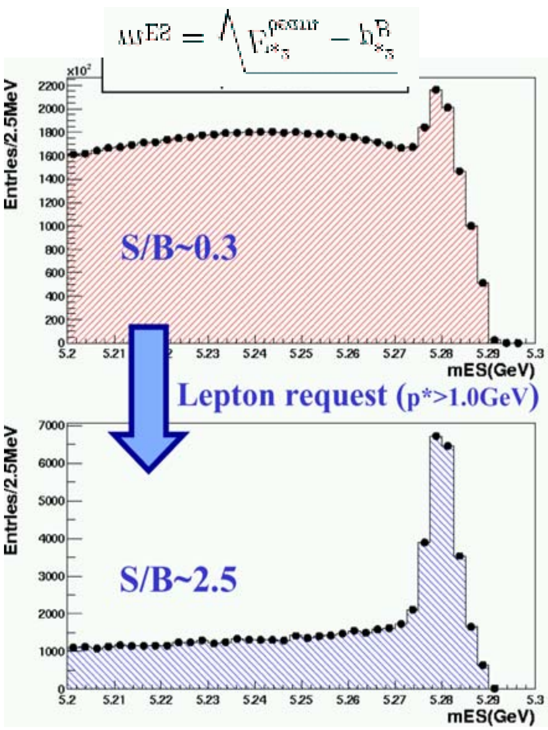
endpoint

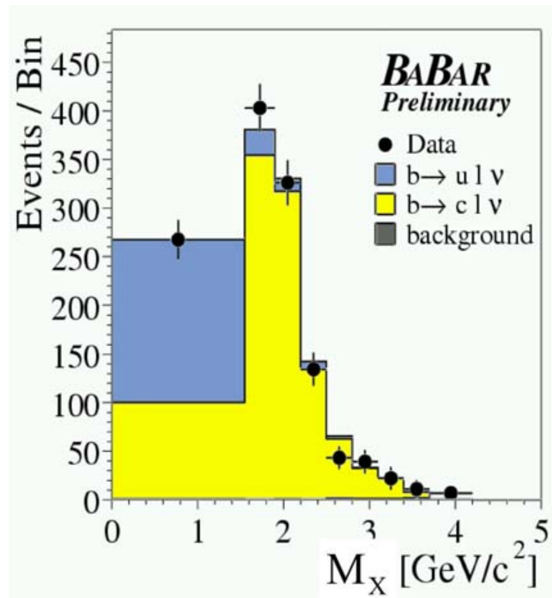


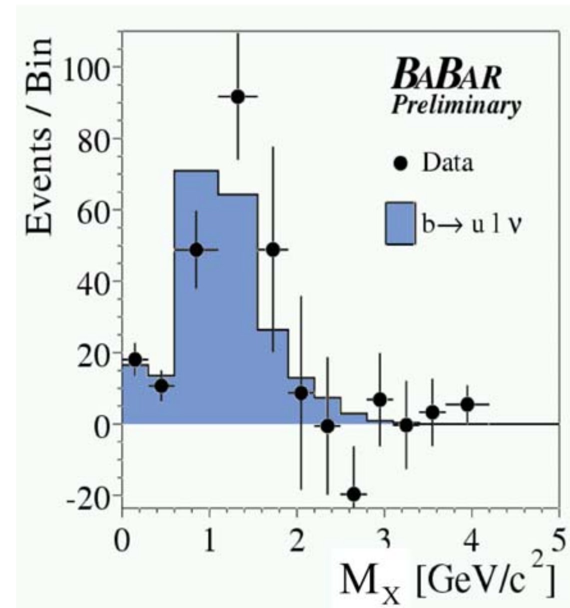
M_X and q^2

$|V_{ub}|$ using reconstructed tags(Babar)

- Use fully reconstructed B tags



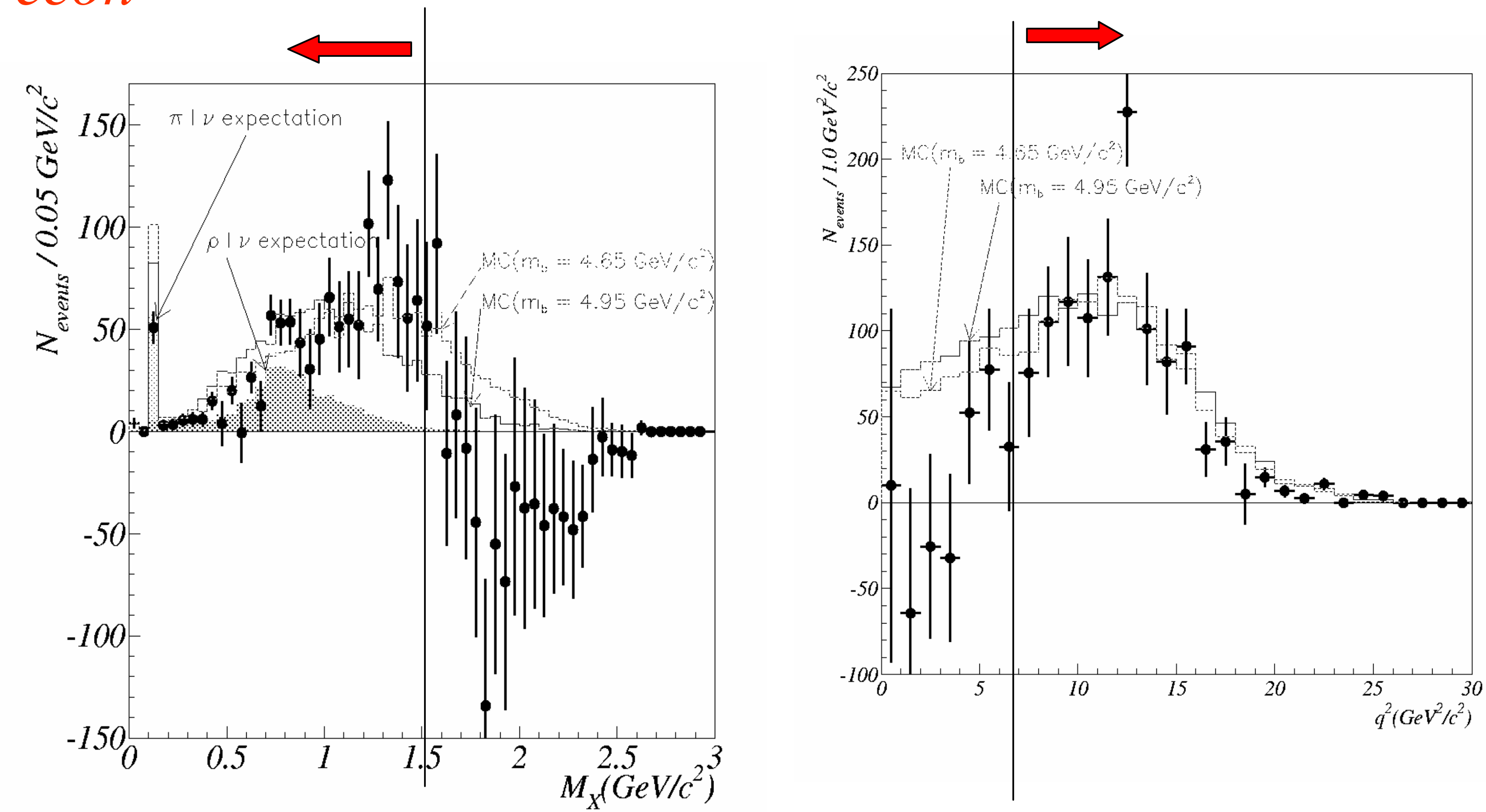




◆ $|V_{ub}|=(4.52\pm0.31(\text{stat})\pm0.27(\text{sys})$
$\pm0.40(\text{thy})\pm0.09(\text{pert})$
$\pm0.27(1/m_b^3))\ \text{x}10^{-3}$

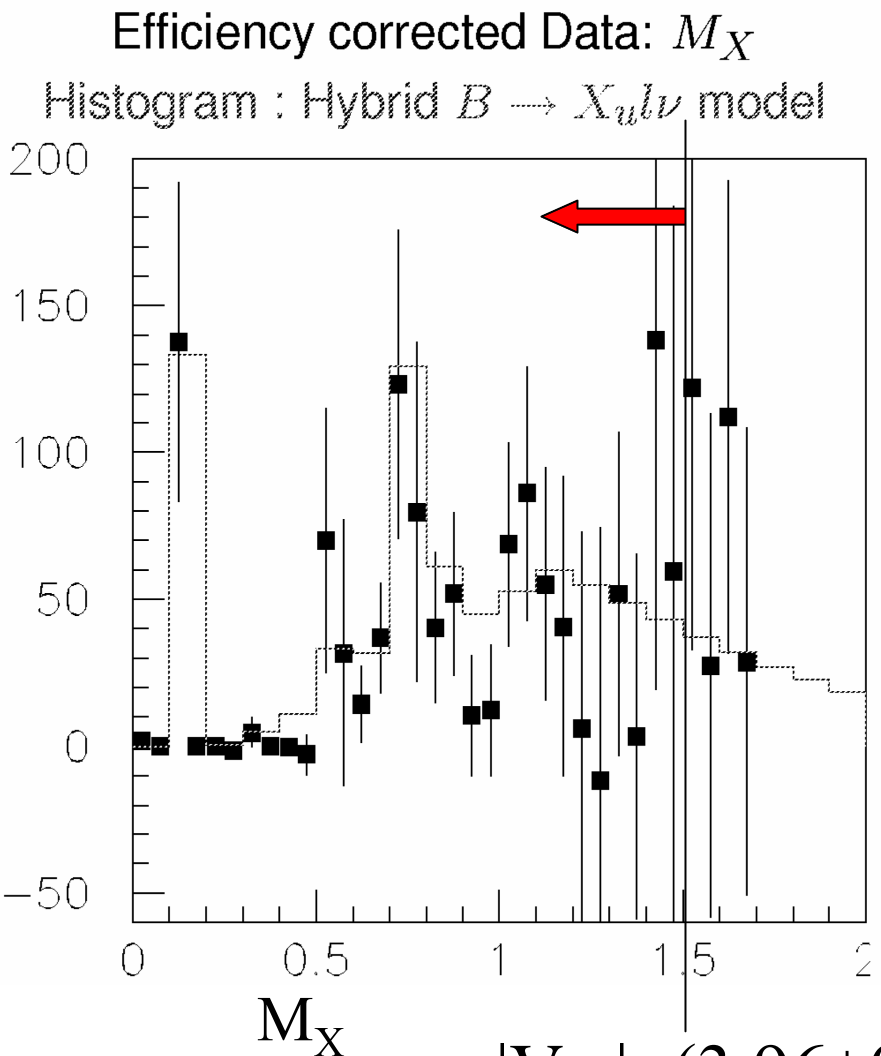
Preliminary

M_X and q^2 spectrum from Belle "advanced neutrino recon"



$|V_{ub}|=(3.96\pm0.17(stat)\pm0.44(sys)\pm0.34(b\rightarrow c)\pm0.26(b\rightarrow u)\pm0.29(theor)) \times 10^{-3}$

Inclusive $|V_{ub}|$ with $D^{(*)} l \nu$ tagging (Belle)



Experimental Systematics	
Tracking	6.0%
Lepton ID	4.0%
$D^{(*)} l \nu$ rec. efficiency	3.2%
π^0 reconstruction	3.0%
Normalisation	2.2%
Kaon ID	2.0%
Total	8.9%

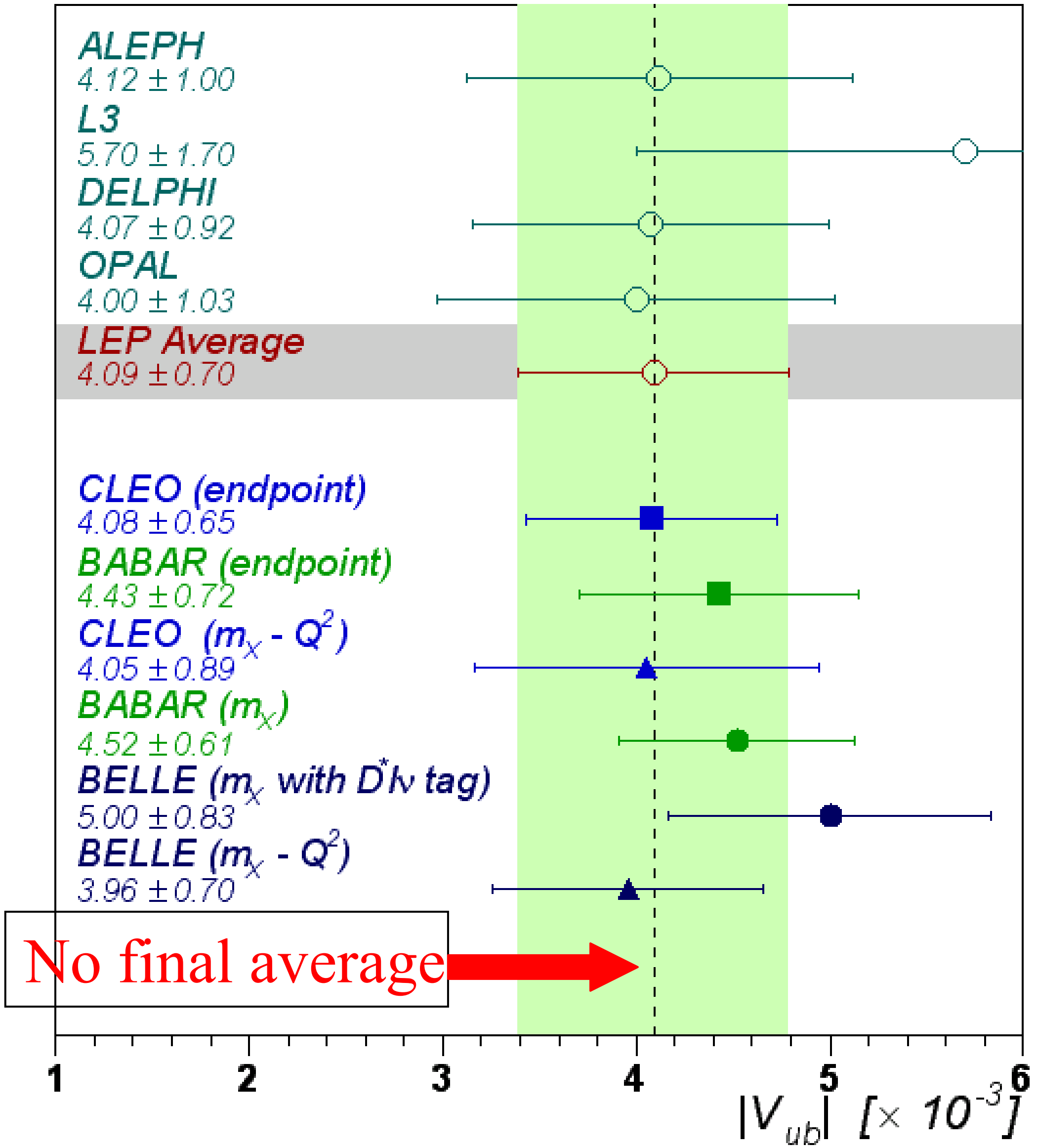
$B \to X_c l \nu$ model	
$b \to c, M_{X_c} < 1.8$ GeV/c^2	2.1%

$B \to X_u l \nu$ model	
M_X rec. efficiency	5.0%

$|V_{ub}|=(3.96\pm0.17(\text{stat})\pm0.44(\text{sys})\pm0.34(b\to c)$

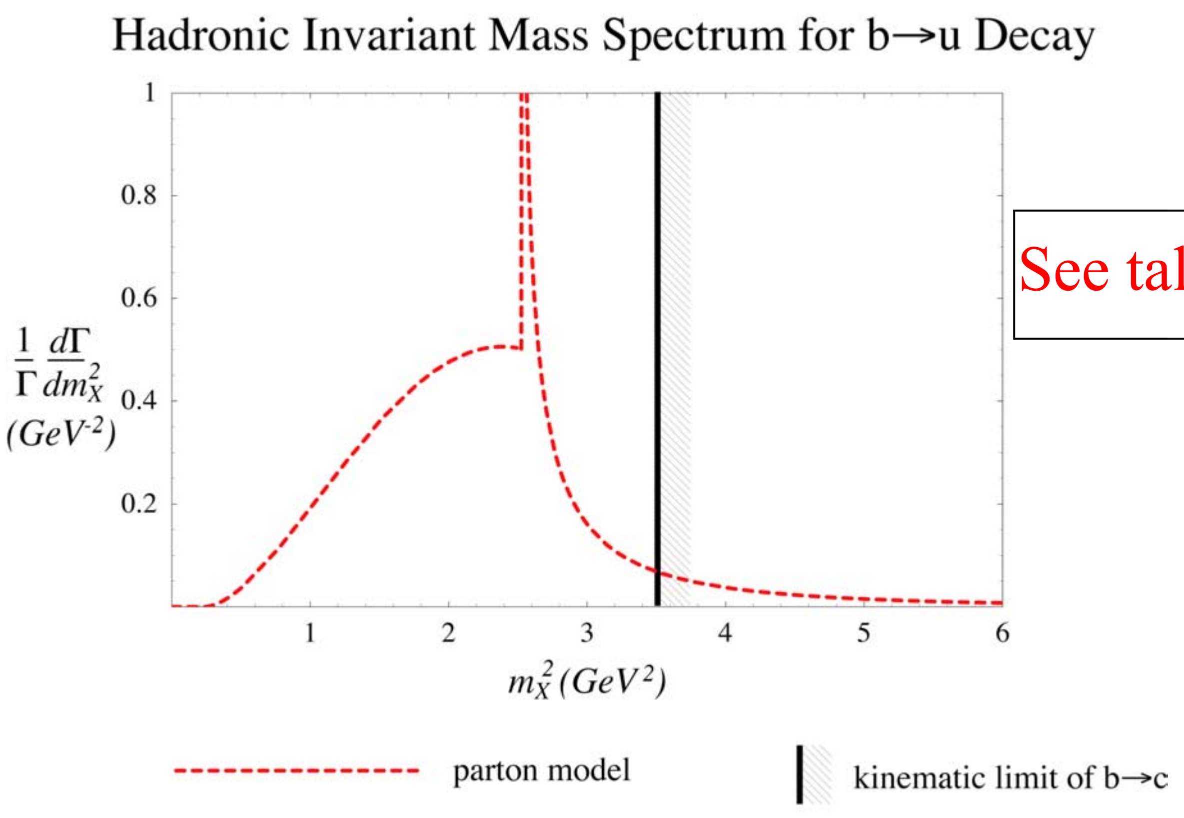
$\pm0.26(b\to u)\pm0.29(\text{theor})) \times 10^{-3}$

Summary of $|V_{ub}|$ (inclusive) from HFAG



Ed Thorndike:
"Systematic errors always dominate."

(Many are theoretical)



See talk by Ligeti

Luke et al: Usually more phase space is better. *Counterintuitive, cut out low M_X and low q^2 where perturbation theory diverges.*

M.Luke:

Representative cuts:

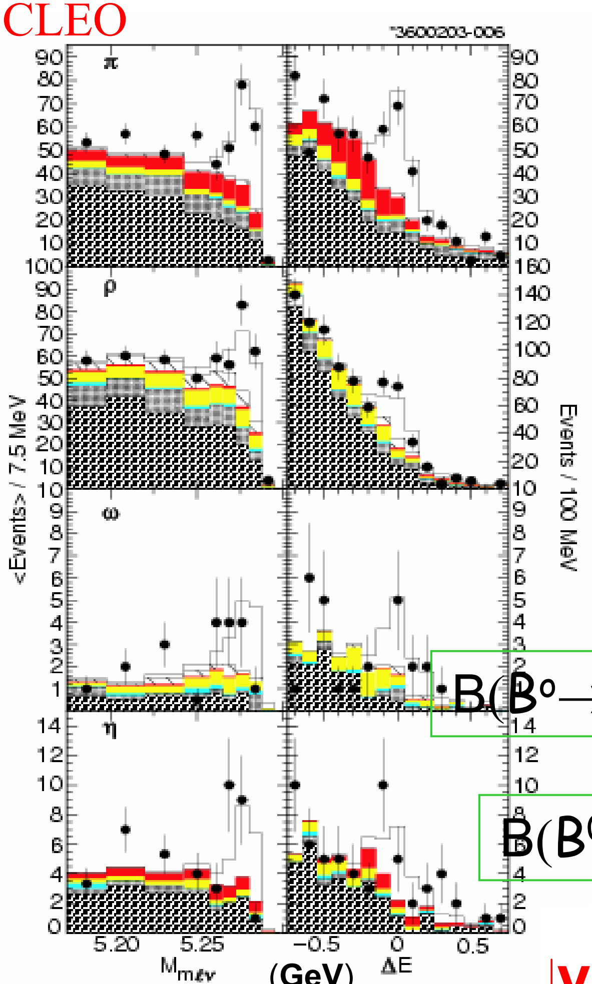
(a)	$q^2 > 6\ \mathrm{GeV}^2,\ m_X < m_D$	46% of rate
(b)	$q^2 > 8\ \mathrm{GeV}^2,\ m_X < 1.7\ \mathrm{GeV}$	33% of rate
(c)	$q^2 > 11\ \mathrm{GeV}^2,\ m_X < 1.5\ \mathrm{GeV}$	18% of rate

Uncertainty	Size (in V_{ub})	Improvement?
Δm_b	±80 MeV: 7%, 8%, 10% ±30 MeV: 3%, 3%, 4%	RG improved Υ sum rules, moments of B decay spectra, lattice
α_s	2%, 3%, 7%	full two-loop calculation
$1/m_b^3$ (weak annihilation)	3%, 4%, 8%	compare $B^{\pm}$, B^0 compare S.L. width of D^0, D_S, lattice

See talk by Ligeti

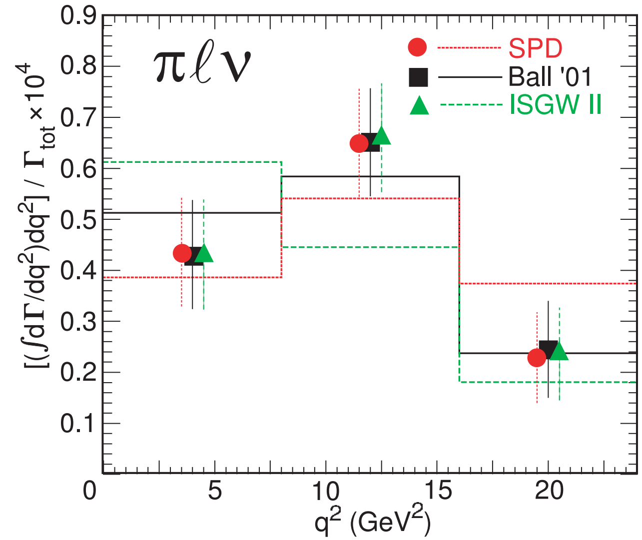
$|V_{ub}|$ (exclusive): $B\to\pi\ell\nu$, $B\to\rho\ell\nu$

CLEO



- Use detector hermeticity to reconstruct ν
- CLEO finds rough q^2 distribution

CLEO



$$B(B^0\to\pi^-\ell\nu)=(1.33\pm0.18|_{stat}\pm0.11|_{exp}\pm0.01|_{ff,sig}\pm0.07|_{ff,cf})\times10^{-4}$$

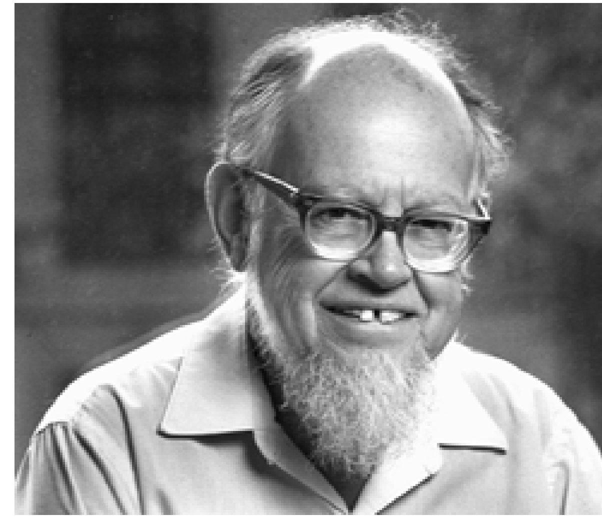
$$B(B^0\to\rho^-\ell\nu)=(2.17\pm0.34|_{stat}{}^{+0.47}_{-0.54}|_{sys}\pm0.41|_{ff,sig}\pm0.01|_{ff,cf})\times10^{-4}$$

$$|V_{ub}|=\left[3.17\pm0.17|_{stat}\ {}^{+0.16}_{-0.17}\Big|^{exp}_{sys}\ {}^{+0.53}_{-0.39}\Big|^{thy}\ \pm0.03\Big|^{theor}_{plv\ FF}\right]\times10^{-3}$$

While Babar finds:

$$|V_{ub}|=\left[3.64\pm0.22|_{stat}\pm0.03|_{syst}\ {}^{+0.39}_{-0.56}\Big|^{thy}\right]\times10^{-3}$$

"I invented ρ and η and I don't care what their values are, so why should you ?? The physics here is to determine if the breadth of CPV phenomena are really described by this simple description."



$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho-\boxed{i\eta}) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-\boxed{i\eta}) & -A\lambda^2 & 1 \end{pmatrix}$$

Makoto Kobayashi

Toshide Maskawa

CP Violation and Rare Decays

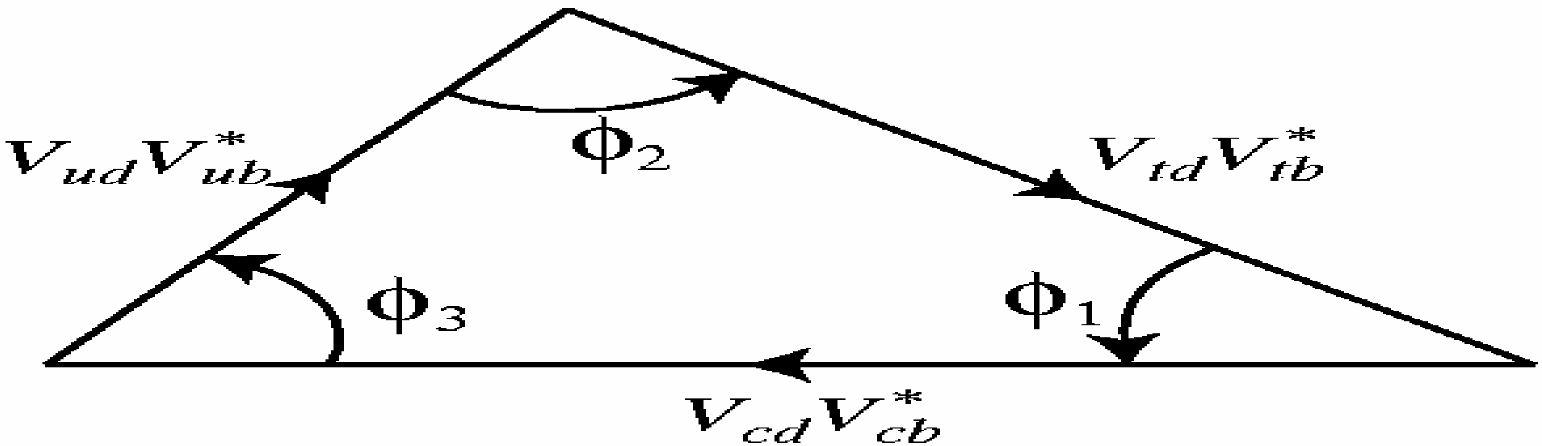
The angles $\varphi_1(\beta)$, $\varphi_2(\alpha)$, prospects for φ_3 (γ) and other forms of CPV: Lacker, Ford, Sagawa, Golutvin, Boca[charm], John[charm], Sozzi[kaons]

Rare Hadronic Decays: Bona, Aihara

Radiative and Electroweak Penguins: Di Lodovico, Ishikawa, Artuso.

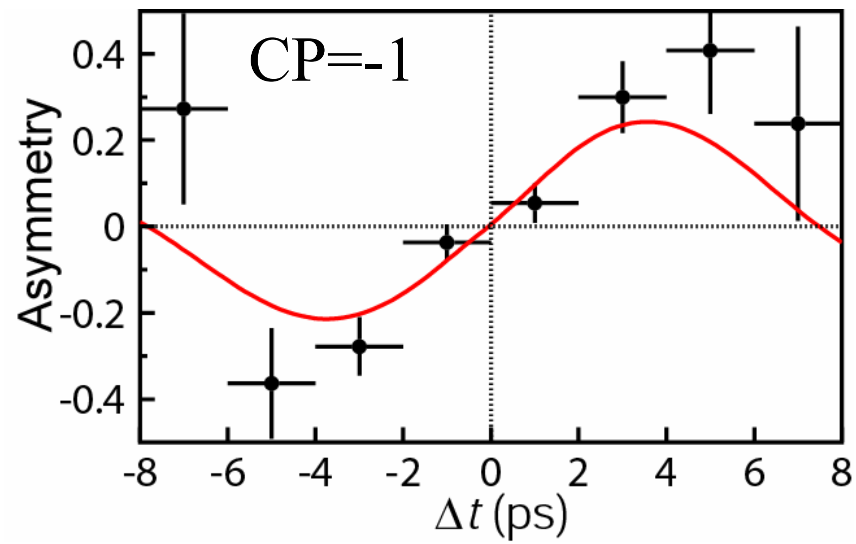
Notational Conventions

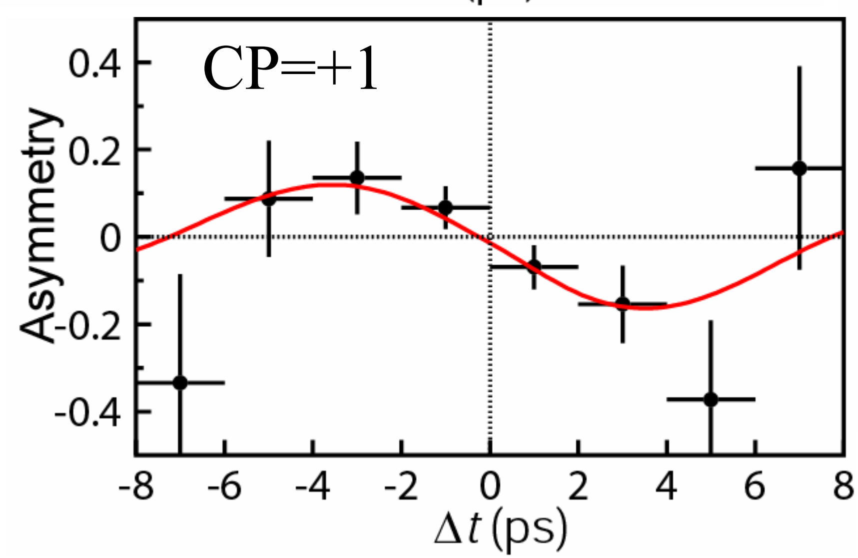
Three Angles: ($\varphi_1, \varphi_2, \varphi_3$) *or* ($\beta$, α, γ)

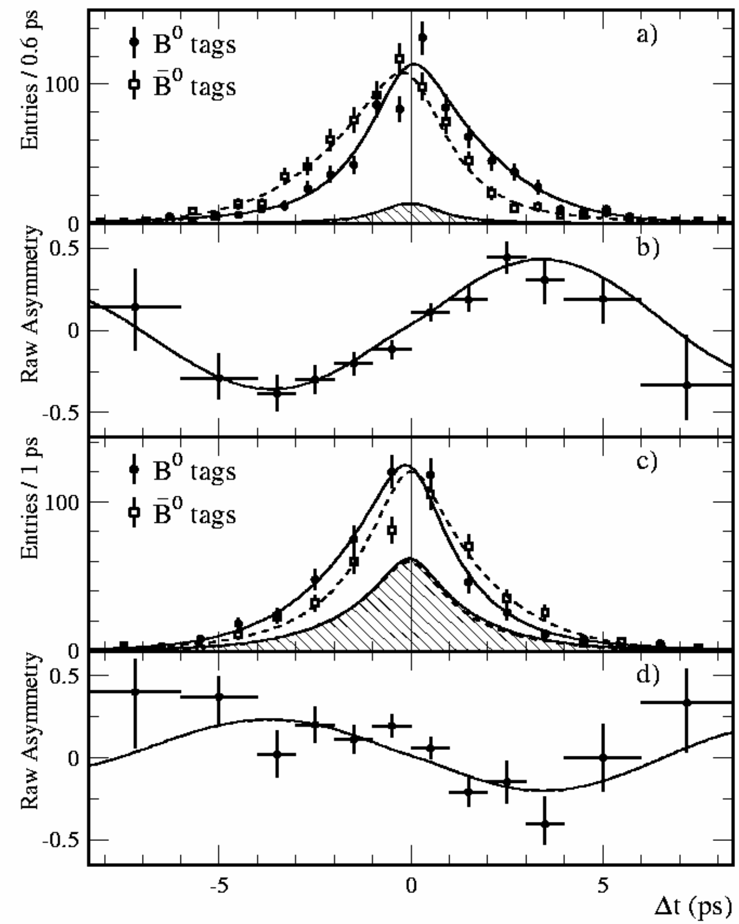


Birthname: Matsui	Nickname: Godzilla
ϕ_1	β
ϕ_2	α
ϕ_3	γ

Belle and Babar measurements of $\sin(2\phi_1)$







CP=-1

CP=+1

hep-ex/020825, PRD 66,071102 (2002)

Status/history of results for $\sin(2\varphi_1)[\sin(2\beta)]$

Belle 2001: $\sin(2\varphi_1) = 0.99 \pm 0.14 \pm 0.06$

Babar 2001: $\sin(2\varphi_1) = 0.59 \pm 0.14 \pm 0.05$

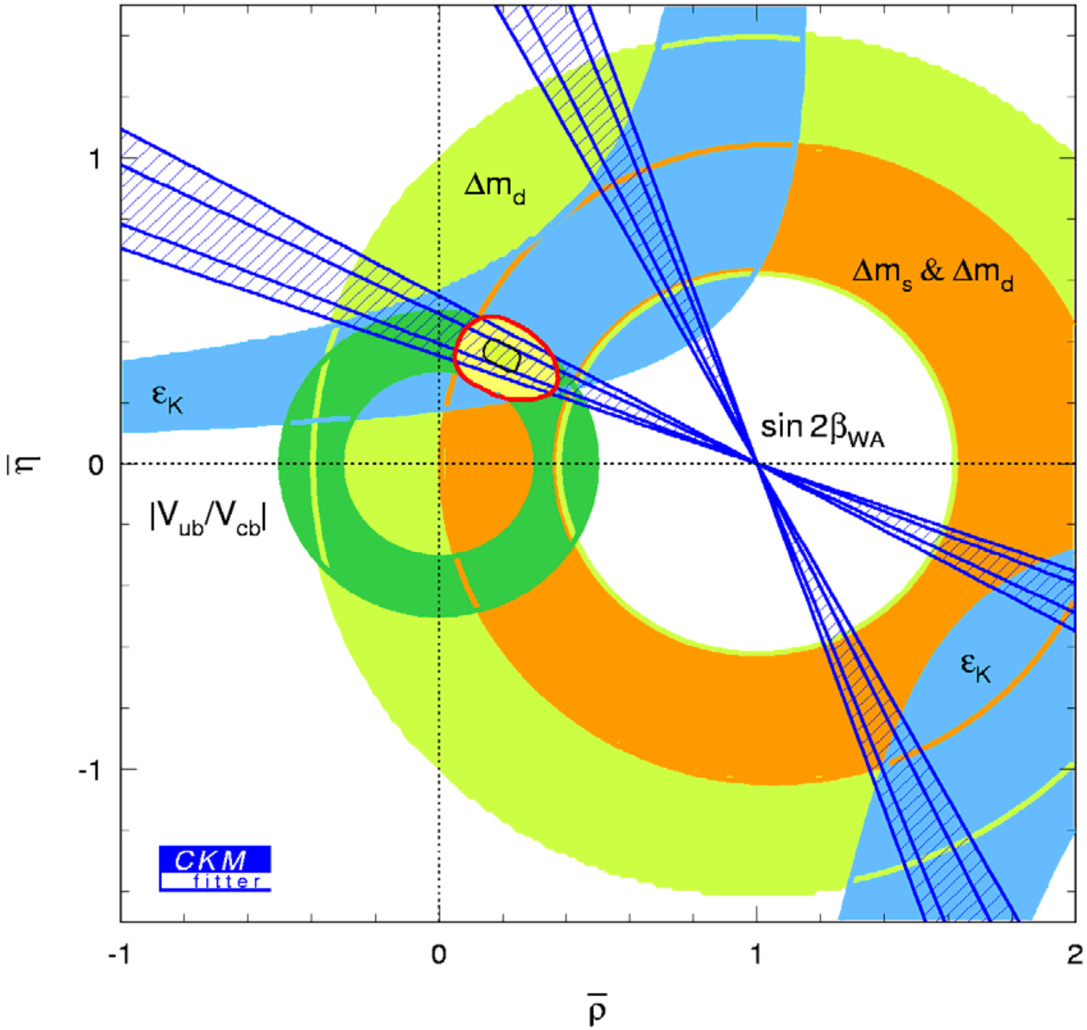
First signals for CPV outside of the kaon sector.

Belle 78 fb^{-1} : $\sin(2\varphi_1) = 0.719 \pm 0.074 \pm 0.035$

Babar 81 fb^{-1}: $\sin(2\varphi_1) = 0.741 \pm 0.067 \pm 0.033$

Now becoming a precision measurement

Current Belle and BaBar Results for sin(2φ₁)



$\sin 2\phi_1$ (Belle)

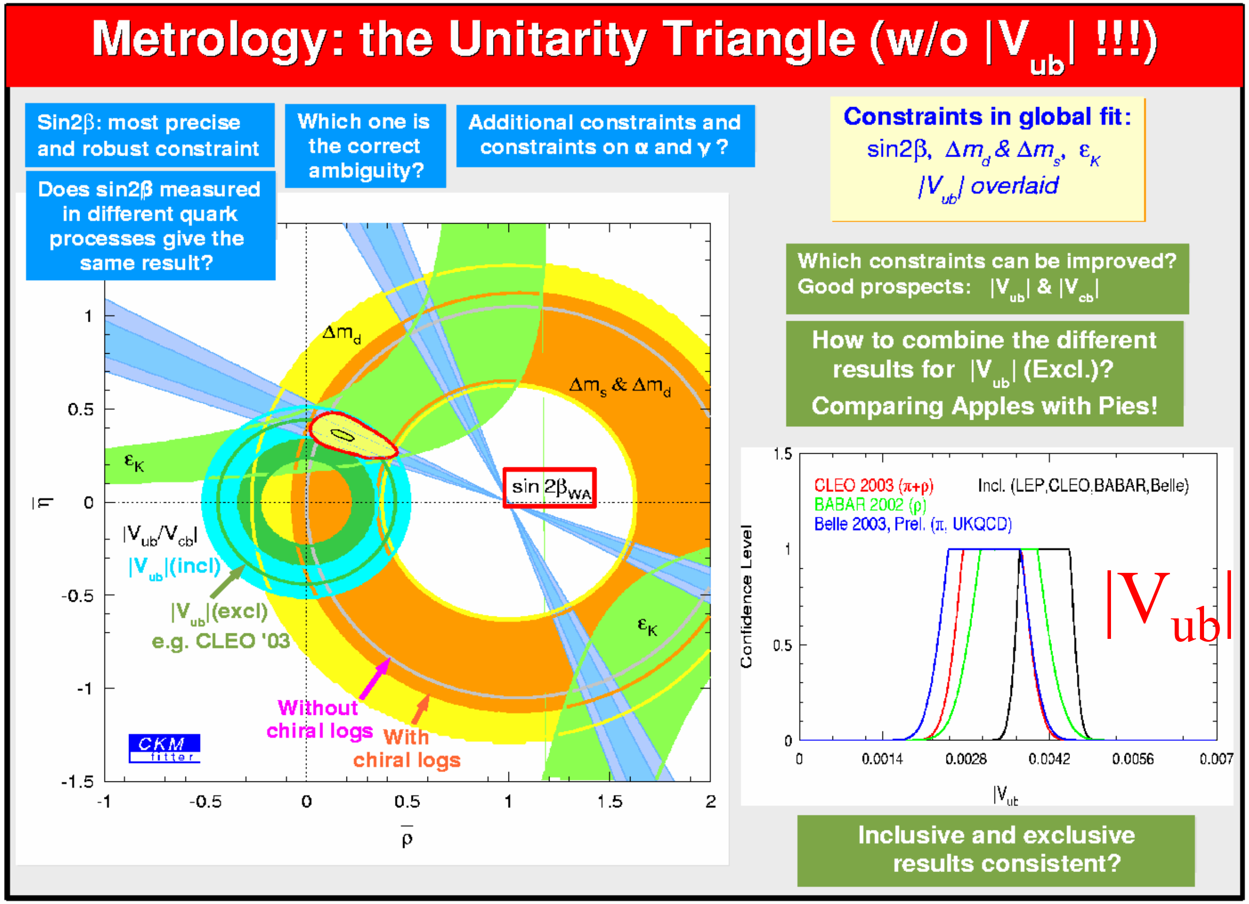
$=0.719 \pm 0.074 \pm 0.035$

$\sin 2\phi_1$ (BaBar)

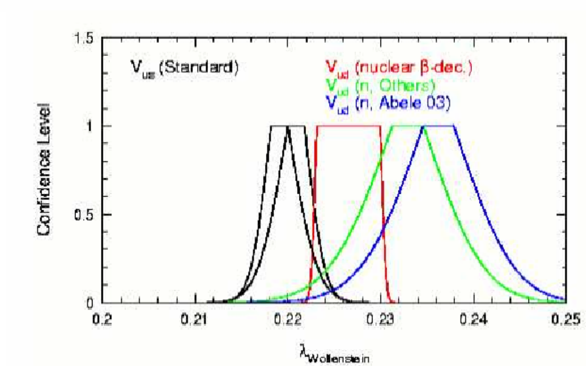
$=0.741 \pm 0.067 \pm 0.033$

$\sin 2\phi_1$ (World Av.)

$=0.734 \pm 0.055$



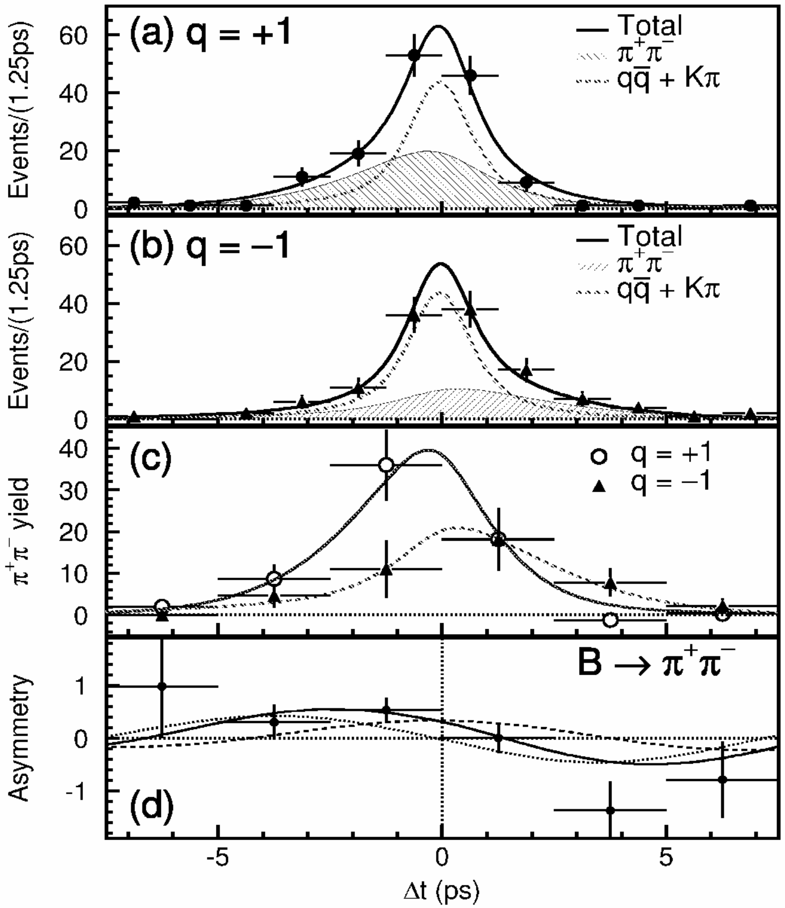
$|V_{us}|$

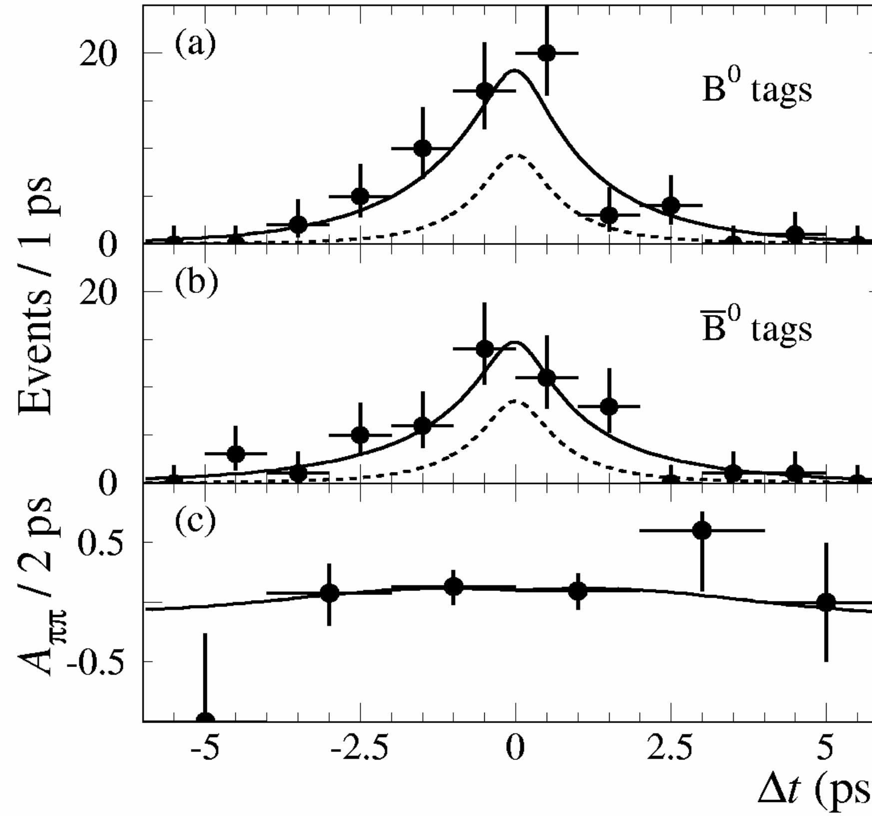


From H. Lacker

$B \rightarrow \pi^+ \pi^-$ CPV CONTROVERSY

Data: Belle (78 fb^{-1}) versus Babar (81 fb^{-1})

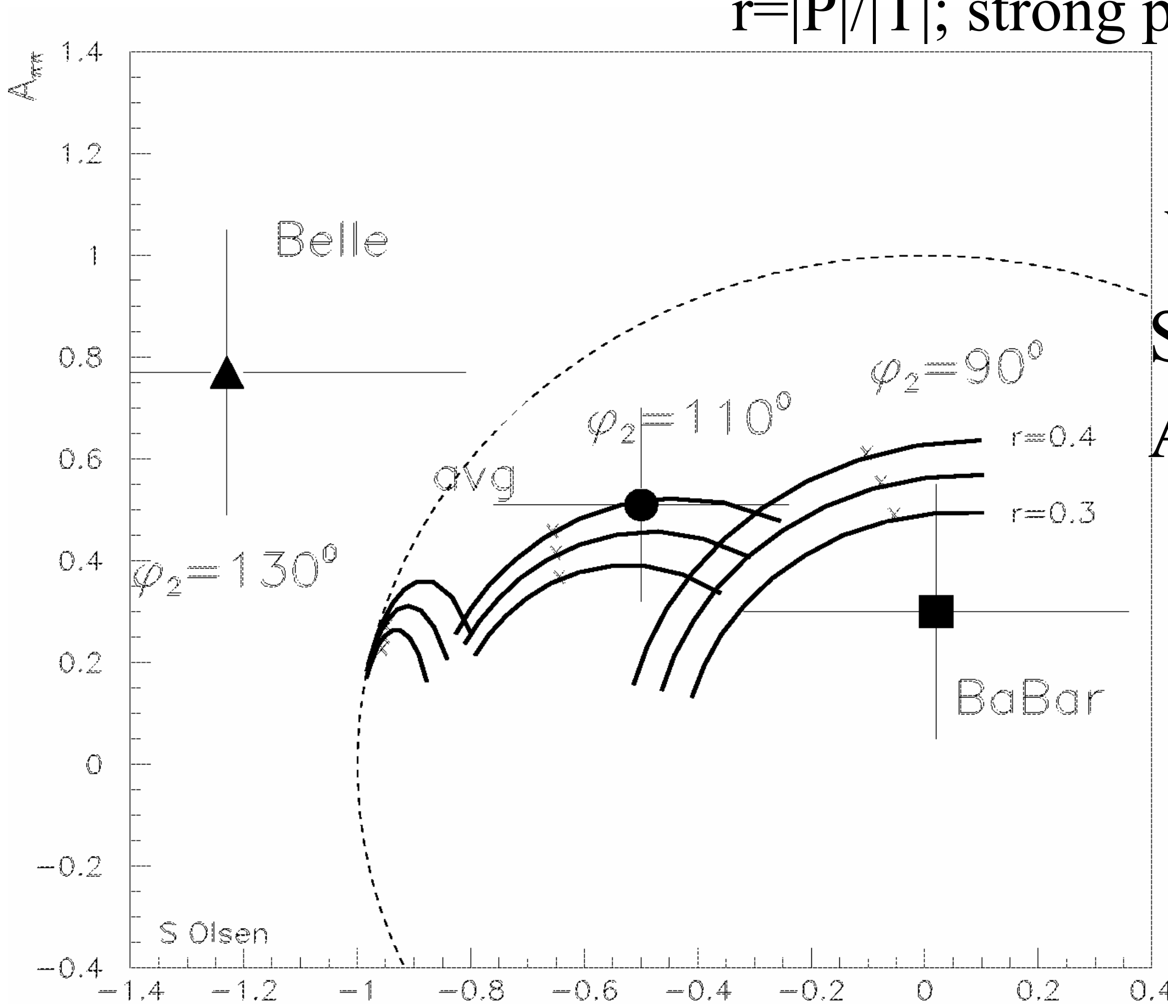




	$C_{\pi\pi}(=-A_{\pi\pi})$	$S_{\pi\pi}$
Belle	$-0.77 \pm 0.27 \pm 0.08$	$-1.23 \pm 0.41^{+0.08}_{-0.07}$
BaBar	$-0.30 \pm 0.25 \pm 0.04$	$+0.02 \pm 0.34 \pm 0.05$

Comparison of Belle and BaBar ($S_{\pi\pi}$,$A_{\pi\pi}$)

r=|P|/|T|; strong phase difference



$A_{\pi\pi}$

$S_{\pi\pi}$

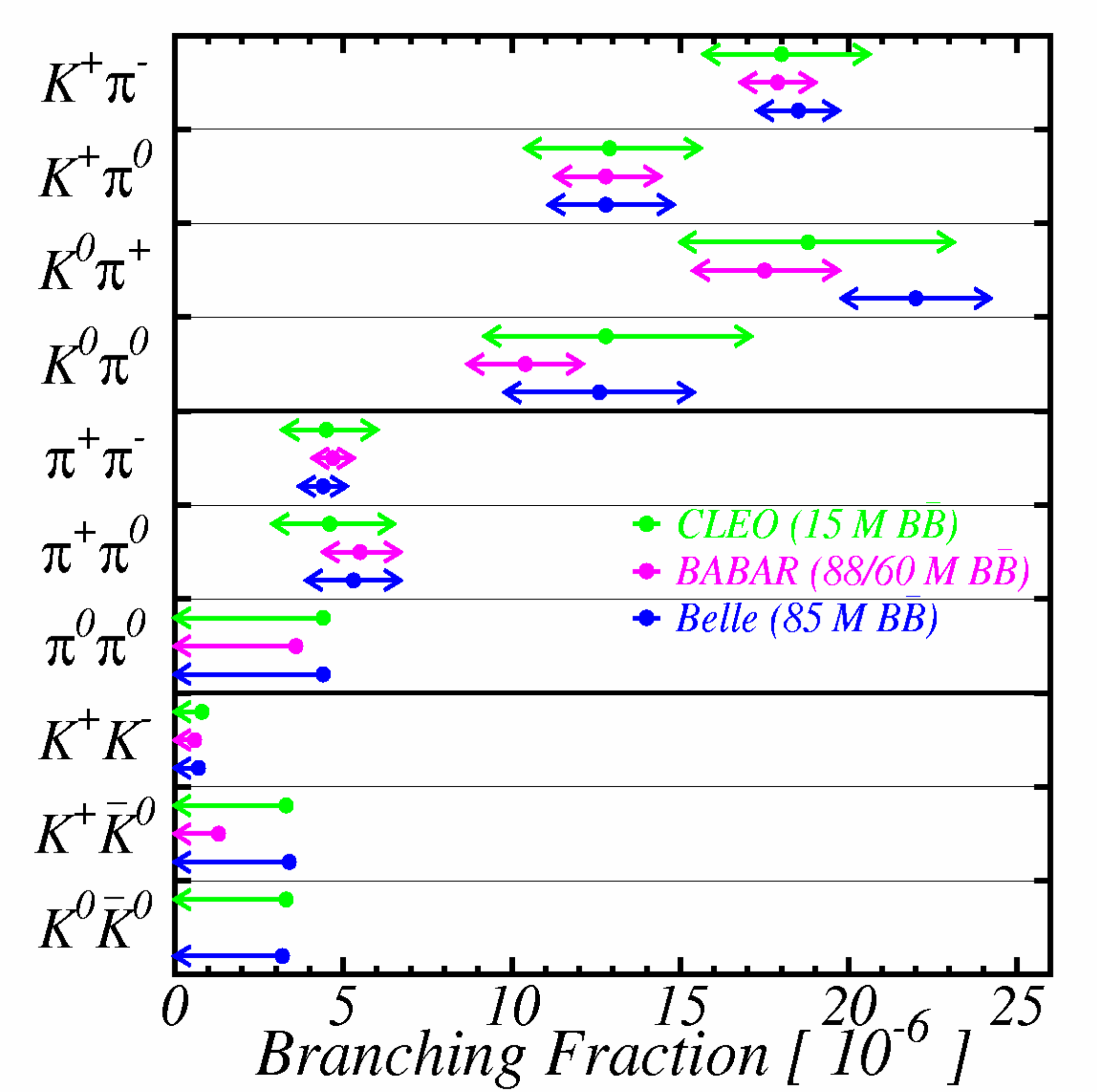
World Average

S=-0.66±0.26

A= 0.49±0.2

2.2 σ difference

Comparison of Results on B→h h BFs



Hints relevant to φ_2 (α) extraction

[Belle:29 fb^{-1} (PRD, B.C.K Casey et al)→78 fb^{-1}]

Ratios of B → h h Branching Fractions

Belle update

Modes	Ratio @78 fb^{-1}	Ratio @29 fb^{-1}
$\Gamma(\pi^+\pi^-)\ /\ \Gamma(K^+\pi^-)$	$0.24 \pm 0.04 \pm 0.02$	$0.24\ ^{+0.06}_{-0.05} \pm 0.02$
$2\Gamma(K^+\pi^0)/\ \Gamma(K^0\pi^+)$	$1.16 \pm 0.16\ ^{+0.14}_{-0.11}$	$1.34 \pm 0.33\ ^{+0.15}_{-0.14}$
$\Gamma(K^+\pi^-)/\ \Gamma(K^0\pi^+)$	$0.91 \pm 0.09 \pm 0.06$	$1.27\ ^{+0.22}_{-0.23} \pm 0.10$
$\Gamma(K^+\pi^-)/2\Gamma(K^0\pi^0)$	$0.74 \pm 0.15 \pm 0.09$	$1.41\ ^{+0.56}_{-0.60}\ ^{+0.28}_{-0.27}$
$\Gamma(\pi^+\pi^-)\ /2\Gamma(\pi^+\pi^0)$	$0.45 \pm 0.13 \pm 0.05$	$0.40 \pm 0.15 \pm 0.05$
$\Gamma(\pi^0\pi^0)\ /\ \Gamma(\pi^+\pi^0)$	< 0.92	< 0.83

The deviation of $\Gamma(\pi^+\pi^-)/2\,\Gamma(\pi^+\pi^0)$ from unity indicates: either $\varphi_3 > 90^0$ or large FSI or a large color suppressed contribution.

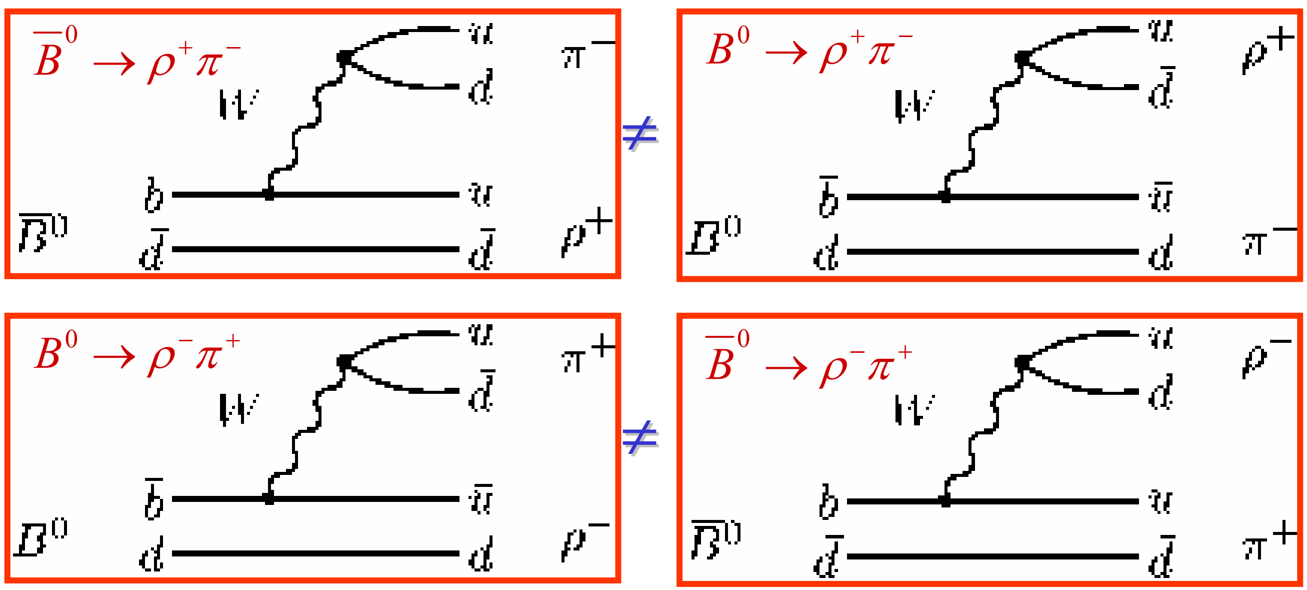
The bound $\Gamma(\pi^0\pi^0)/\ 2\ \Gamma(\pi^+\pi^0)$ gives a weak limit on $|\varphi_{2eff} - \varphi_2| < 51^0$ at 90% C.L. (Babar UL)

CP Violation in $B^0 \to \rho\pi$ decay

Final state is $\pi^+\pi^-\pi^0$: not a CP eigenstate

Four amplitudes contribute:

$$B^0 \to \rho^+\pi^- + \overline{B}^0 \to \rho^-\pi^+ \text{ and } B^0 \to \rho^-\pi^+ + \overline{B}^0 \to \rho^+\pi^-$$

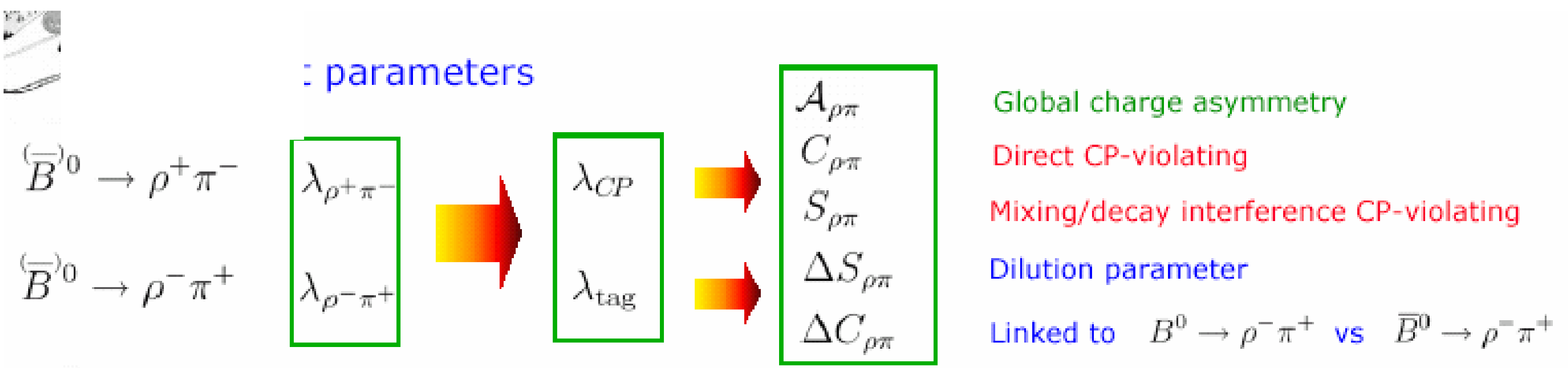


$B^0 \rightarrow \rho\pi$ Time-dependence

Decay rate distribution

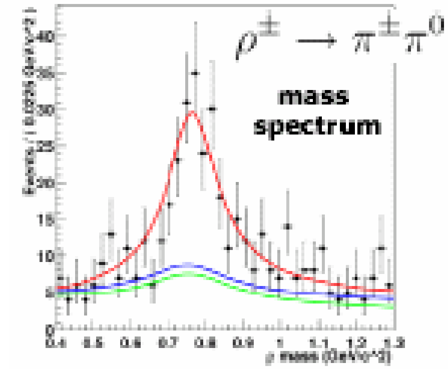
$$f^{\rho^\pm h^\mp}_{B^0\,\mathrm{tag}}(\Delta t) = (1 \pm A^{\rho h}_{CP})\frac{e^{-|\Delta t|/\tau}}{4\tau}\left[1 + \Big((S_{\rho h} \pm \Delta S_{\rho h})\sin(\Delta m_d \Delta t) - (C_{\rho h} \pm \Delta C_{\rho h})\cos(\Delta m_d \Delta t)\Big)\right]$$

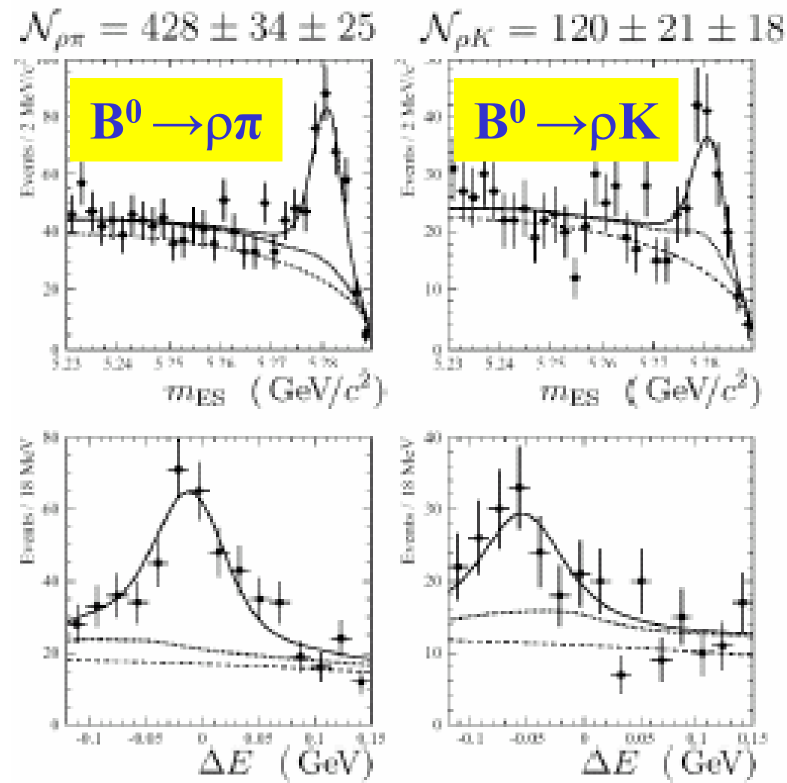
$$f^{\rho^\pm h^\mp}_{\overline{B}^0\,\mathrm{tag}}(\Delta t) = (1 \pm A^{\rho h}_{CP})\frac{e^{-|\Delta t|/\tau}}{4\tau}\left[1 - \Big((S_{\rho h} \pm \Delta S_{\rho h})\sin(\Delta m_d \Delta t) - (C_{\rho h} \pm \Delta C_{\rho h})\cos(\Delta m_d \Delta t)\Big)\right]$$



$B^0 \to \rho\pi/\rho K$ (*BaBar*)

Results based on 89 million BB pairs.





BR of ρπ and ρK

$$\mathcal{B}(B \to \rho^{\pm}\pi^{\mp}) = (22.6 \pm 1.8 \pm 2.2) \times 10^{-6}$$

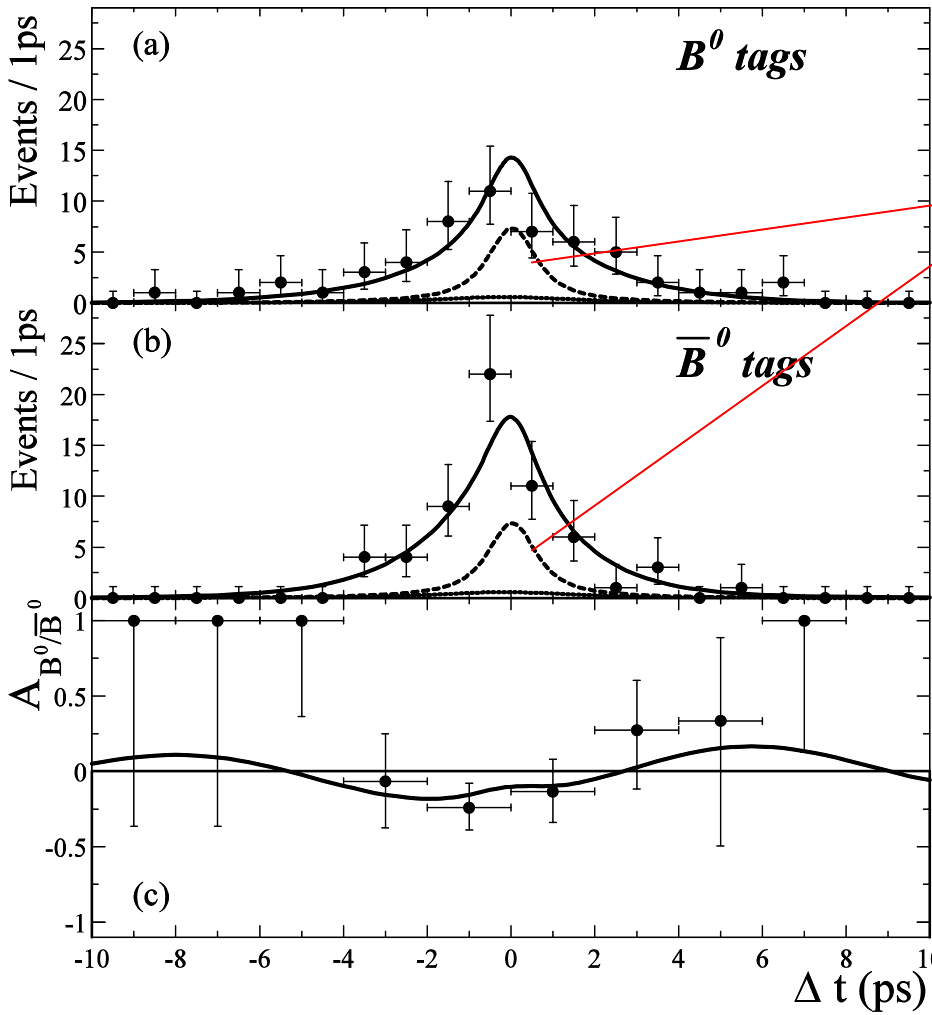
$$\mathcal{B}(B \to \rho^{\pm}K^{\pm}) = (7.3^{+1.3}_{-1.2} \pm 1.3) \times 10^{-6}$$

Charge asymmetry of ρπ and ρK

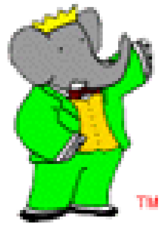
$$A_{\rho K} = +0.28 \pm 0.17 \pm 0.08$$

$$A_{\rho\pi} = -0.18 \pm 0.08 \pm 0.03$$

$B^0 \to \rho\pi/\rho K$ (BaBar) : Δt distributions



B+continuum background



$$\mathcal{A}_{\rho\pi} = -0.18 \pm 0.08 \pm 0.03$$

$$C_{\rho\pi} = +0.36 \pm 0.18 \pm 0.04$$

$$S_{\rho\pi} = +0.19 \pm 0.24 \pm 0.03$$

$$\Delta C_{\rho\pi} = +0.28 \pm 0.19 \pm 0.04$$

$$\Delta S_{\rho\pi} = +0.15 \pm 0.25 \pm 0.03$$

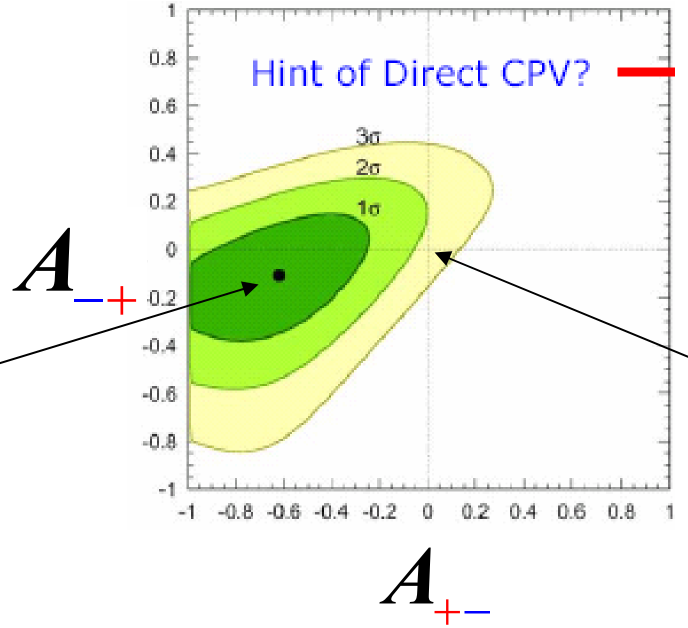
Direct CP violation in $B^0 \to \rho\pi$?

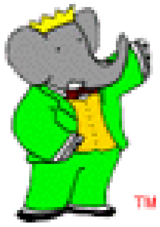
$$A_{+-} \equiv \frac{N(\overline{B}^0_{\rho\pi} \to \rho^+\pi^-) - N(B^0_{\rho\pi} \to \rho^-\pi^+)}{N(\overline{B}^0_{\rho\pi} \to \rho^+\pi^-) + N(B^0_{\rho\pi} \to \rho^-\pi^+)} = \frac{A_{CP}^{\rho\pi} - C_{\rho\pi} - A_{CP}^{\rho\pi} \cdot \Delta C_{\rho\pi}}{1 - \Delta C_{\rho\pi} - A_{CP}^{\rho\pi} \cdot C_{\rho\pi}}$$

$$A_{-+} \equiv \frac{N(\overline{B}^0_{\rho\pi} \to \rho^-\pi^+) - N(B^0_{\rho\pi} \to \rho^+\pi^-)}{N(\overline{B}^0_{\rho\pi} \to \rho^-\pi^+) + N(B^0_{\rho\pi} \to \rho^+\pi^-)} = \frac{A_{CP}^{\rho\pi} + C_{\rho\pi} + A_{CP}^{\rho\pi} \cdot \Delta C_{\rho\pi}}{1 + \Delta C_{\rho\pi} + A_{CP}^{\rho\pi} \cdot C_{\rho\pi}}$$

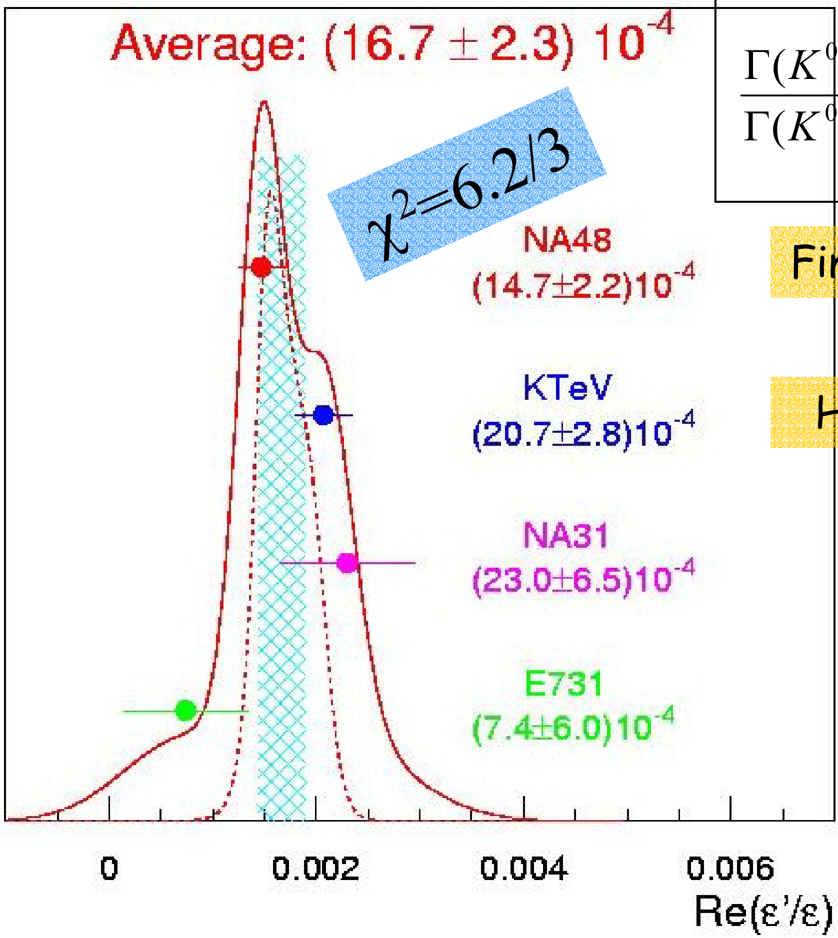
$$A_{+-} = -0.62^{+0.24}_{-0.28} \pm 0.06$$

$$A_{-+} = -0.11^{+0.16}_{-0.17} \pm 0.04$$





Direct CPV in kaons: Re(ε'/ε) Results



$$\frac{\Gamma(K^0 \to \pi^+\pi^-) - \Gamma(\overline{K}^0 \to \pi^+\pi^-)}{\Gamma(K^0 \to \pi^+\pi^-) + \Gamma(\overline{K}^0 \to \pi^+\pi^-)} = (5.04 \pm 0.82) \times 10^{-6}$$

Final result (1997-2001)

Half statistics (1997)

Direct CP violation proved at >7σ level… after 36 years!

Further results will come from KTeV and KLOE

Large Direct CP Asymmetries for B Decay Modes ?

Hint from Belle (~2.2 σ level) of direct CP violation in $B^0 \rightarrow \pi^+ \pi^-$: $A_{\pi\pi} = 0.77 \pm 0.27 \pm 0.08$

Hints from Babar in $B^\pm \rightarrow \eta \pi^\pm$: $A = -0.50 \pm 0.19$ *as well as in* $B \rightarrow \rho^+ \pi^-$.

Belle anomaly (2.9 σ) in the pure penguin mode $B^\pm \rightarrow K_S \pi^\pm$ at 29 fb^{-1} ; fluctuated away at 78 fb^{-1}

Summary of Direct CP violation in B Decays

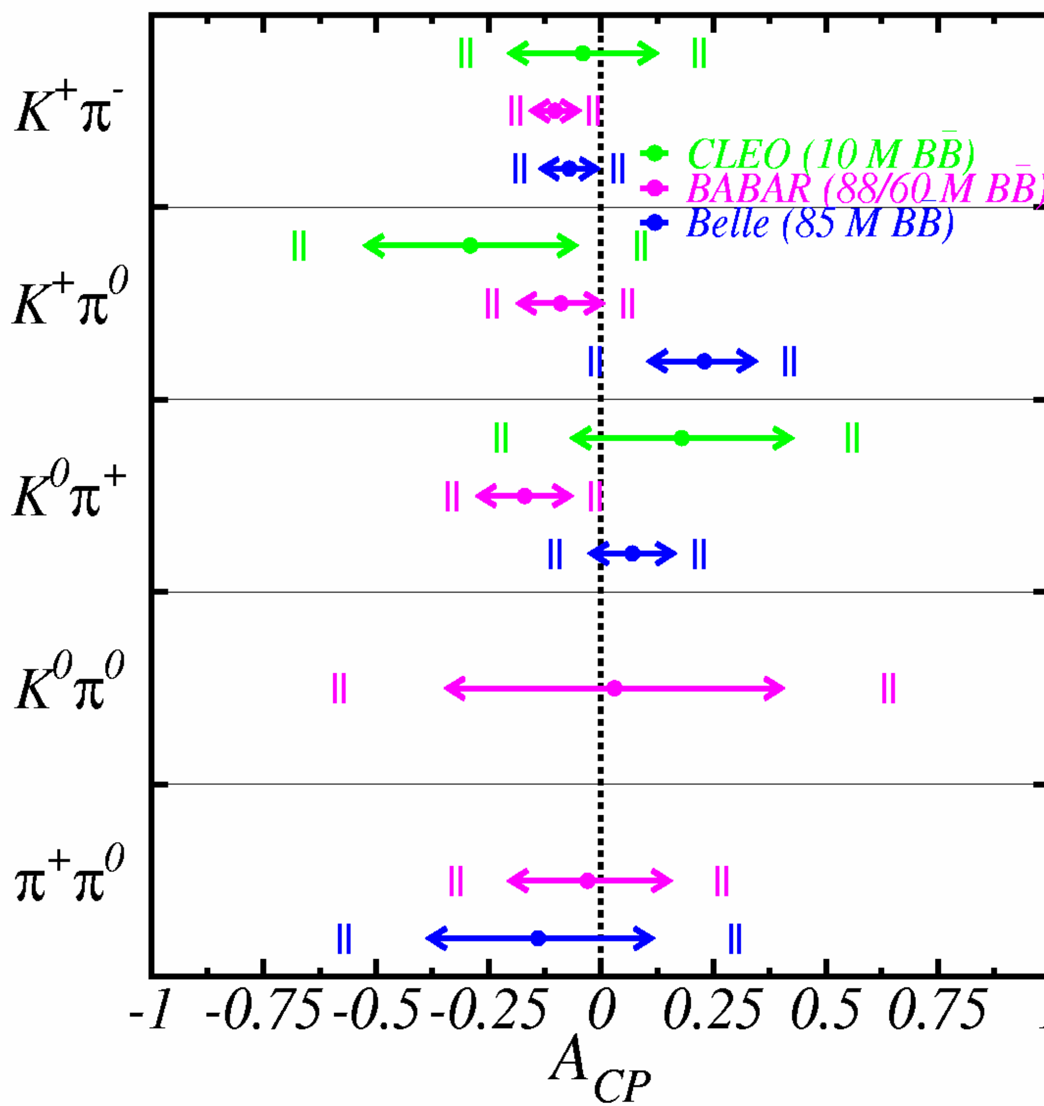
1 exp Sensitivity ±6 %

1 exp Sensitivity ±11 %

Pure penguin

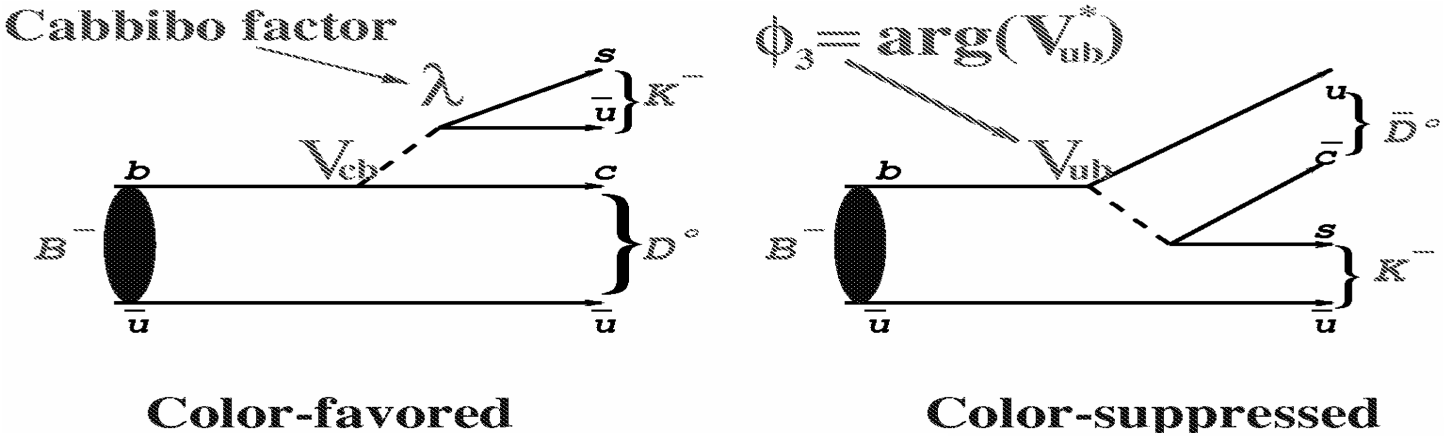
Flavor tag required

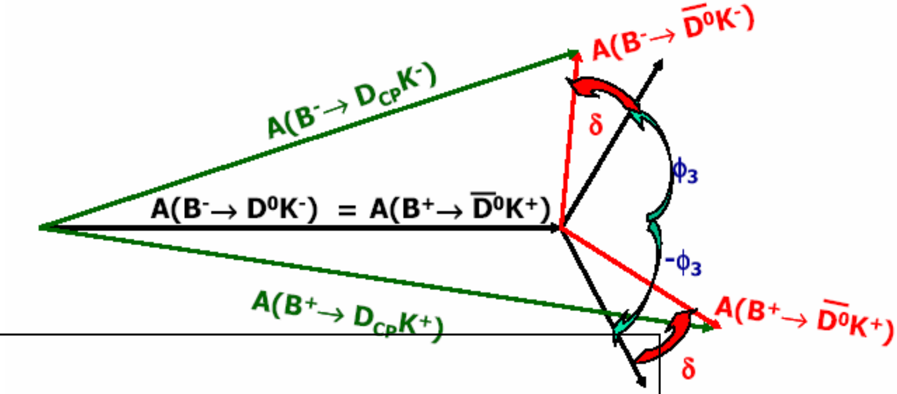
Pure tree



Theoretical Expectations: 5-10 % in QCD Fact or pQCD

Extraction of φ_3 (γ)





Experimental observables:

$$R_{1,2} = \frac{BF(B^- \to D_{1,2}K^-) / BF(B^- \to D_{1,2}\pi^-)}{BF(B^- \to D^0K^-) / BF(B^- \to D^0\pi^-)} \quad , \quad A_1 \text{ and } A_2$$

allow, in principle, to extract R_{DK^-}, δ and γ

Example of B→V V: B→φ K* Angular Analysis

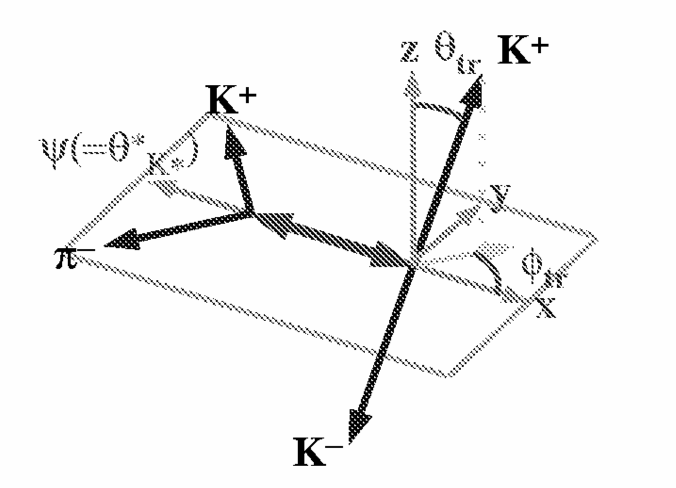
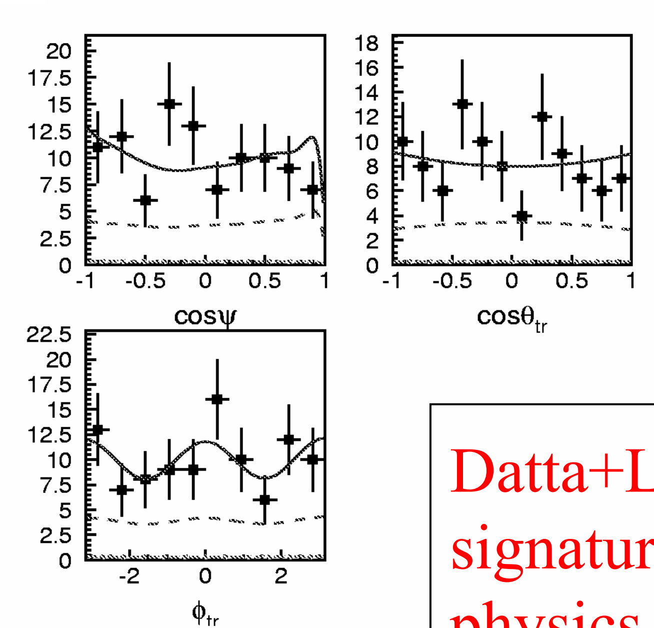


Figure 1: The angles in transversity basis.



$|A_0|^2 = 0.43 \pm 0.09 \pm 0.04$

$|A_{perp}|^2 = 0.41 \pm 0.10 \pm 0.04$

$\arg(A_{par}) = -2.57 \pm 0.39 \pm 0.09$

$\arg(A_{perp}) = 0.48 \pm 0.32 \pm 0.06$

Not a single CP eigenstate.

No clear FSI signal.

Datta+London: A_T signatures of new physics in B→VV

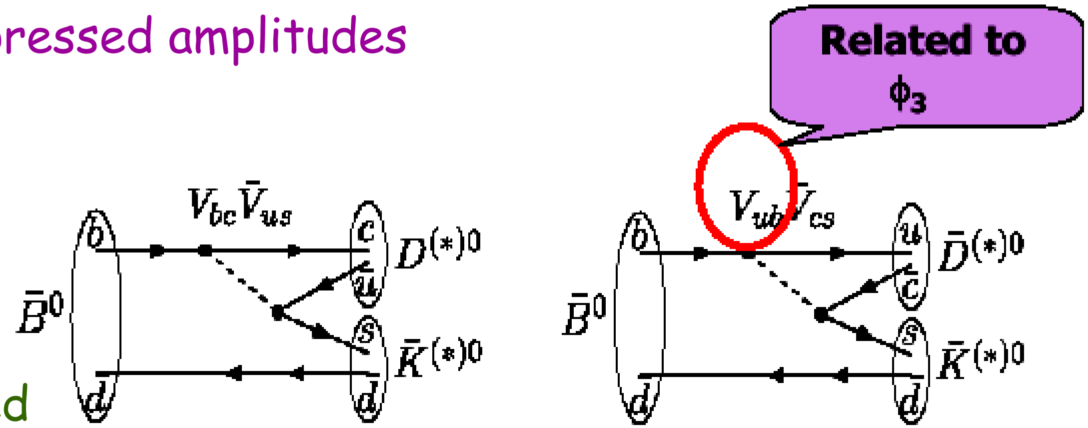
Babar: Observe B→$K^{*+} \rho^0$

Belle: Observe B→$\rho^+ \rho^0$

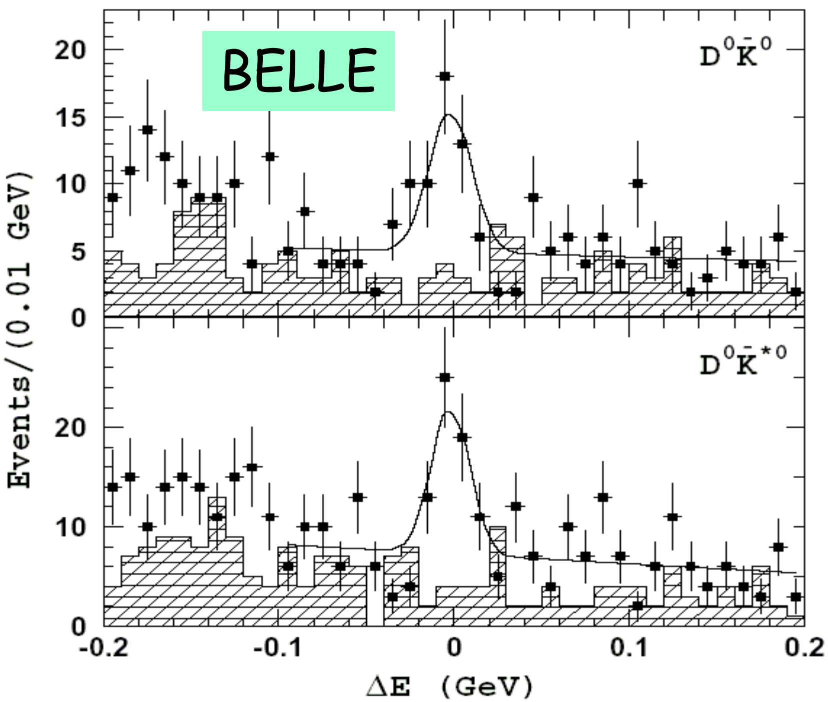
Babar: Observe B→$D^{*0} K^{*-}$

Extraction of γ (φ_3): $B^0 \rightarrow D^0 K^{(*)0}$ Mode

Two comparable color-suppressed amplitudes



Triangles are not as squashed as in $B^{\pm} \rightarrow DK^{\pm}$ case



$BF(\overline{B}^0 \rightarrow D^0\ \overline{K}^0) = (5.0\ ^{+1.3}_{-1.2} \pm 0.6) \times 10^{-5}$

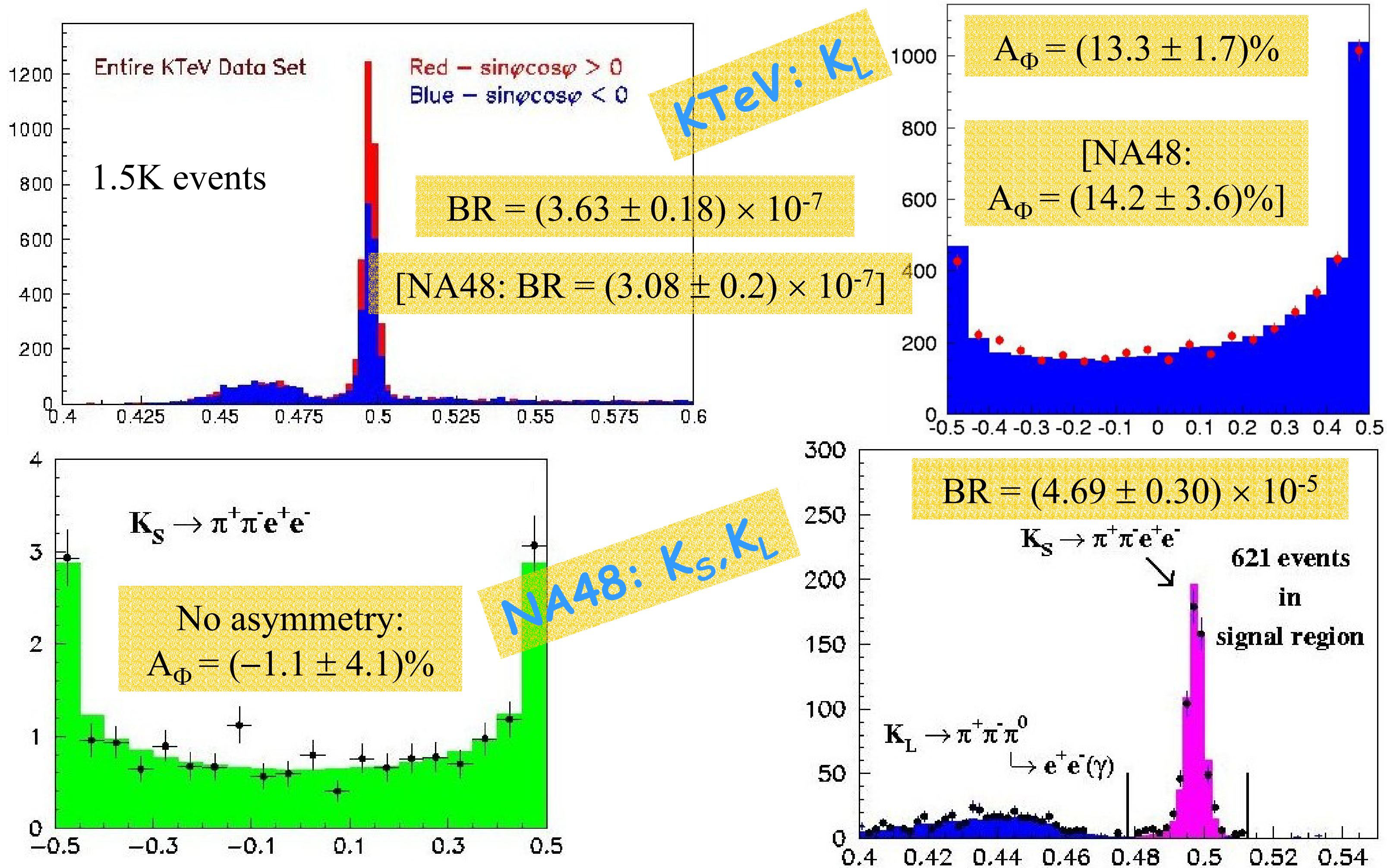
$BF(\overline{B}^0 \rightarrow D^0\ \overline{K}^{*0}) = (4.8\ ^{+1.1}_{-1.0} \pm 0.6) \times 10^{-5}$

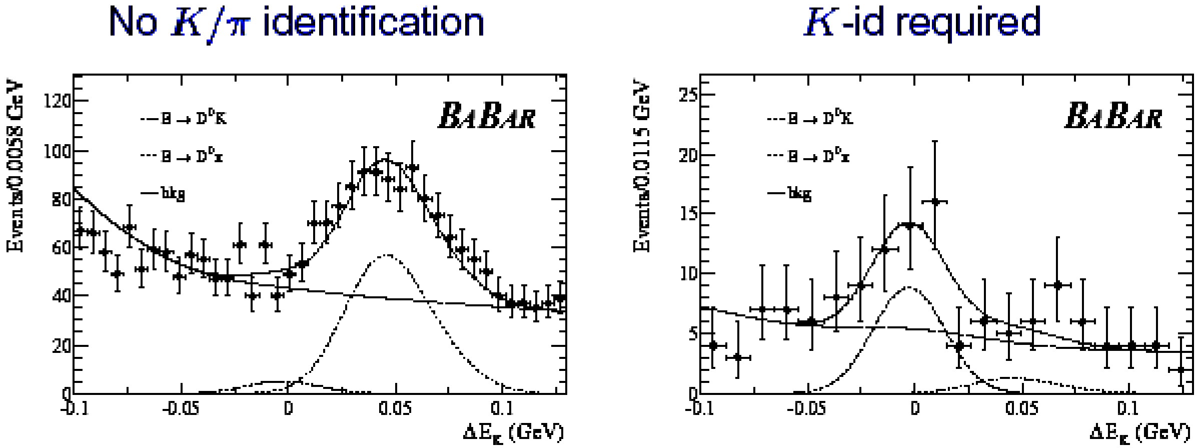
Hope to observe $B^0 \rightarrow D^0\ K^{*0}$ decay

Present Upper Limit is

$BF(B^0 \rightarrow D^0\ K^{*0}) < 1.8 \times 10^{-5}$

T-odd correlations in $K_{L,S} \rightarrow \pi^+\pi^-e^+e^-$



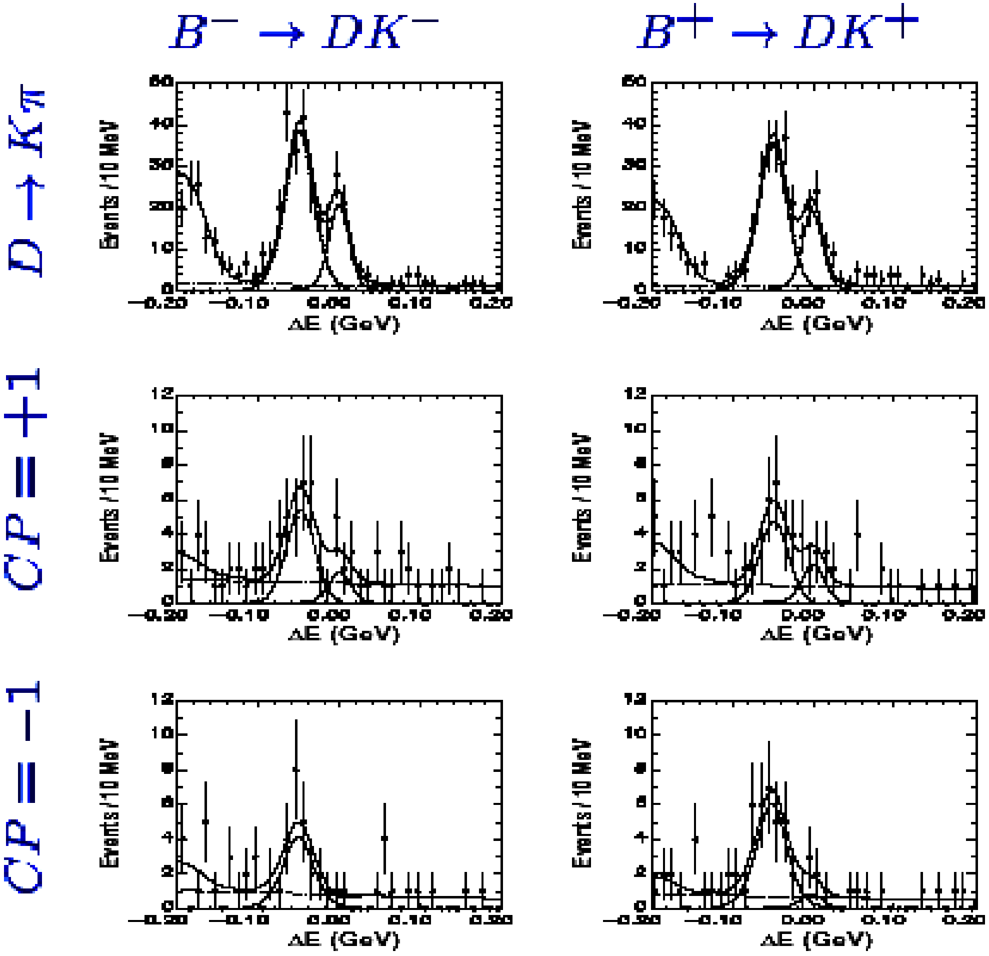


BaBar reconstructed

D_1K^- $\hookrightarrow K^+K^-$

$$R_1 = \frac{(7.4 \pm 1.7 \pm 0.6)\%}{(8.31 \pm 0.35 \pm 0.20)\%}$$

$$A_{D1K^-} = 0.17 \pm 0.23^{+0.09}_{-0.07}$$



BELLE studied both D_1K^- and D_2K^-

$R_1 = 1.21 \pm 0.25 \pm 0.14$
$R_2 = 1.41 \pm 0.27 \pm 0.15$
$A_{D1K^-} = +0.06 \pm 0.19 \pm 0.04$
$A_{D2K^-} = -0.18 \pm 0.17 \pm 0.05$

No constraints on γ possible with this statistics …

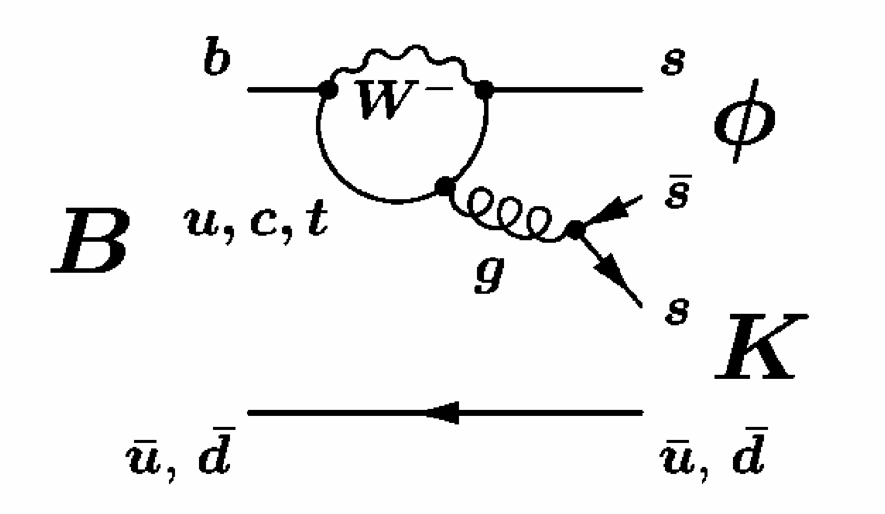
Needed:

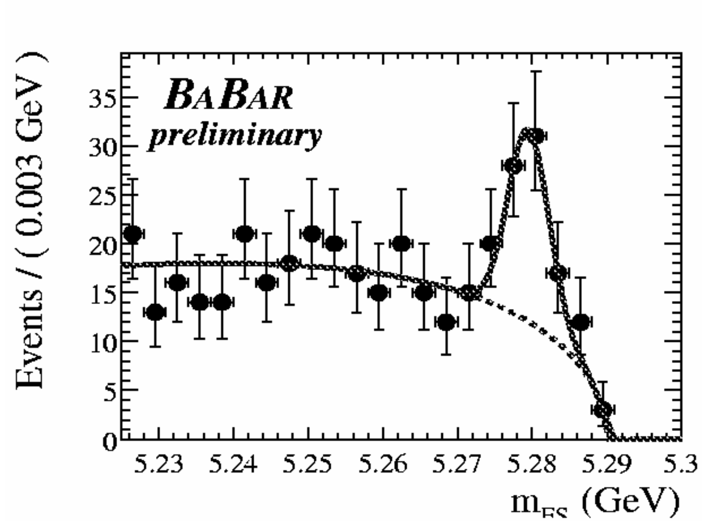
significantly higher statistics
precision measurements of D Branching Fractions

Dreams of New Physics and Other Adventures with rare B decays.

Hunting for phases from new physics

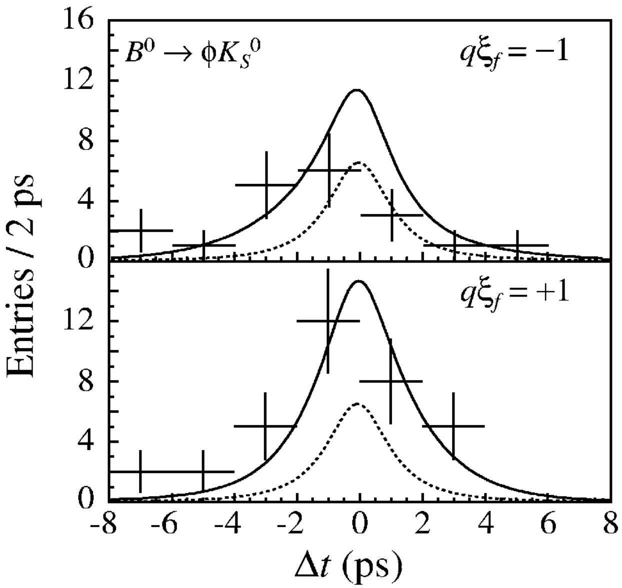
Example:

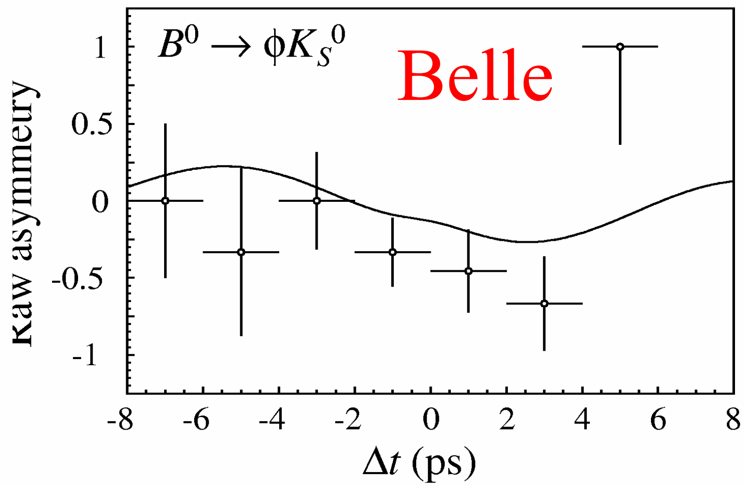




In the SM, $\sin(2\varphi_1)^{\text{eff}} = \sin(2\varphi_1)\ (B \rightarrow \psi\ K_S)$

Hunting for new phases in b→s penguins





(hep-ph/0209290), J-P Lee, K. Y. Lee; (hep-ph/0208226) B. Dutta, C.S. Kim and S. Oh; (hep-ph/0208091), M. Raidal; (hep-ph/0208087), M. Ciuchini, L. Silvestrini; (hep-ph/0208016), A. Datta;(hep-ph/0208005), H. Murayama;(hep-ph/0207356), G. Hiller; (hep-ph/0207070), M-B. Causse; (hep-ph/0208080) Y. Nir ….

Belle: $\sin 2\varphi_{1\mathrm{eff}}$ = -0.73 ±0.64 ±0.22

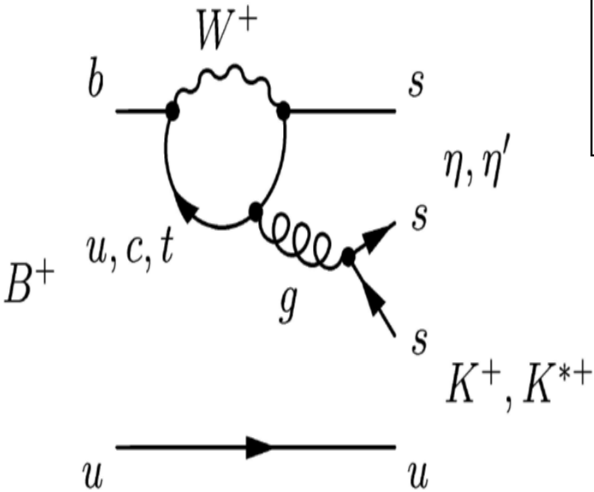
Babar: $\sin 2\varphi_{1\mathrm{eff}}$ = -0.18±0.51 ±0.09

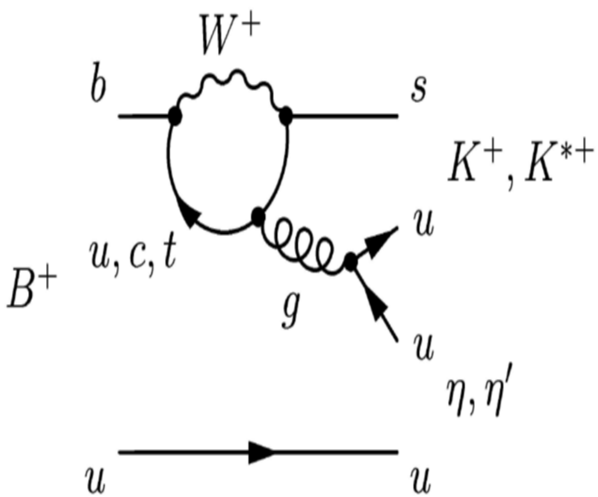
2.7σ off

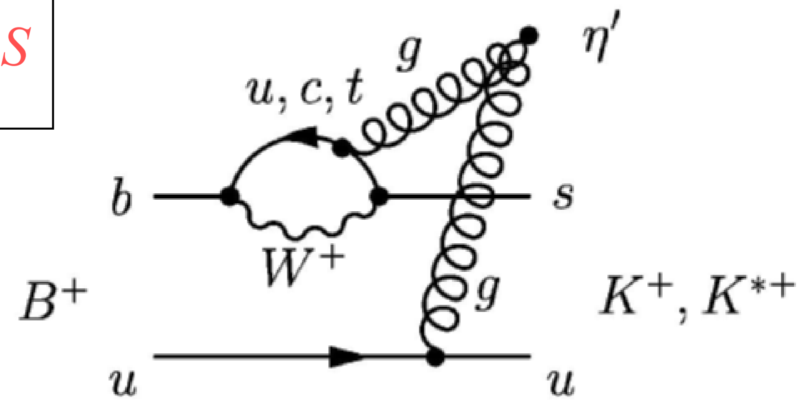
WA: $\sin 2\varphi_{1eff}\,(\varphi\, K_S)$ = -0.38 ±0.41 ←

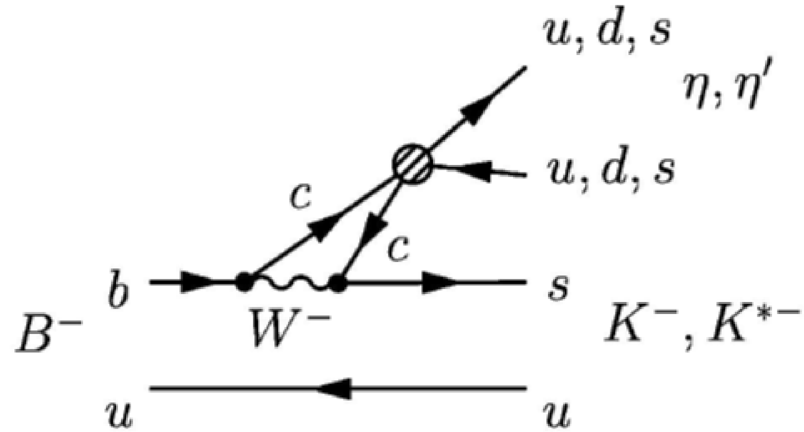
Hunting for new phases in b→s penguins

$B \to \eta' K_S$









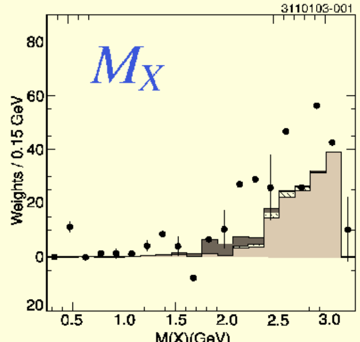
Large rates for exclusive and inclusive $B \to \eta' X_s$ decays.

Mystery of Large Inclusive $B \to \eta' X_s$

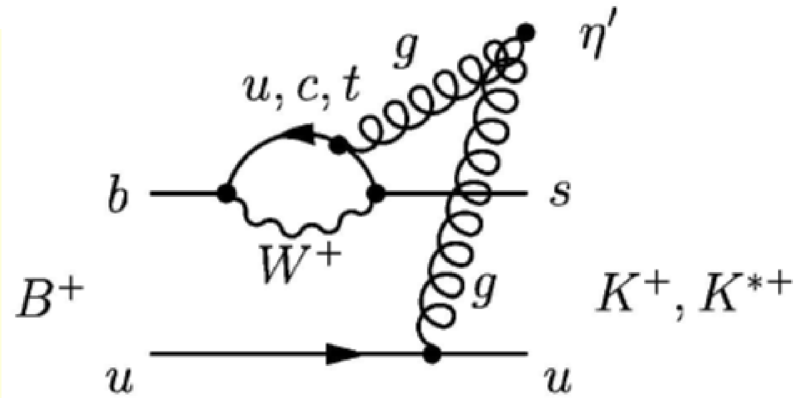
Inclusive $B \to \eta'$

CLEO

hep-ex/0303009, submitted to PRD



- Semi-inclusive reconstruction: $X_s = 1K + (1 \sim 4)\pi$
- Subtract continuum fraction using off-resonant data.
- $\mathcal{B} = (6.2 \pm 1.6 \pm 1.3^{+0.0}_{-1.5}) \times 10^{-4}$ PRL **81**, 1786 (1998)
  $8 \sim 9\times$ larger than $\mathcal{B}(\eta' K)$
- $\mathcal{B} = (4.6 \pm 1.1 \pm 0.4 \pm 0.5) \times 10^{-4}$ New!
- Rising spectrum on recoiled mass.



"gluon anomaly"

c.f. Babar: hep-ex/0109034: $B \to \eta' X_s = (6.8^{+0.7}_{-1.0} \pm 1.0_{-0.5}) \times 10^{-4}$

BaBar: $B \rightarrow \eta' X_s$ *inclusive*

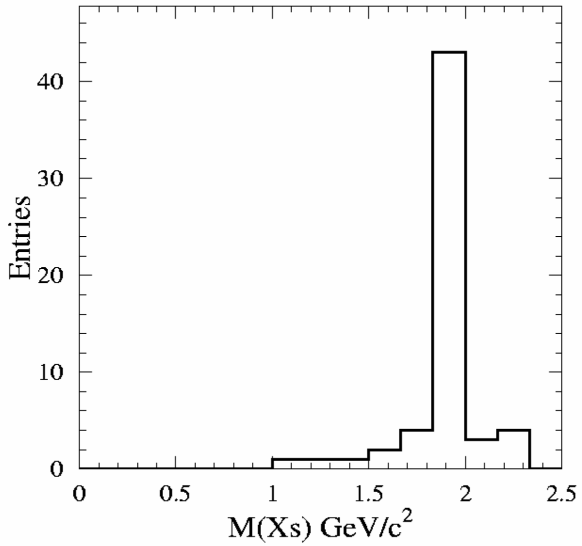
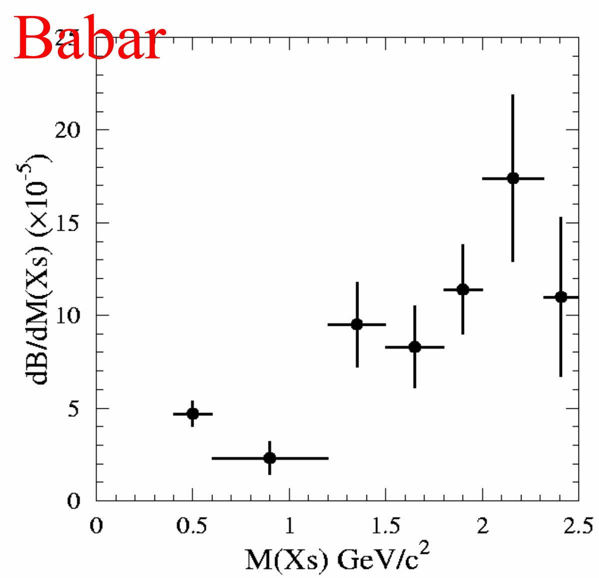


Figure 3: $M(X_s)$ spectrum predicted from simulation of $\overline{B}^0 \rightarrow \eta' D^0$ decays

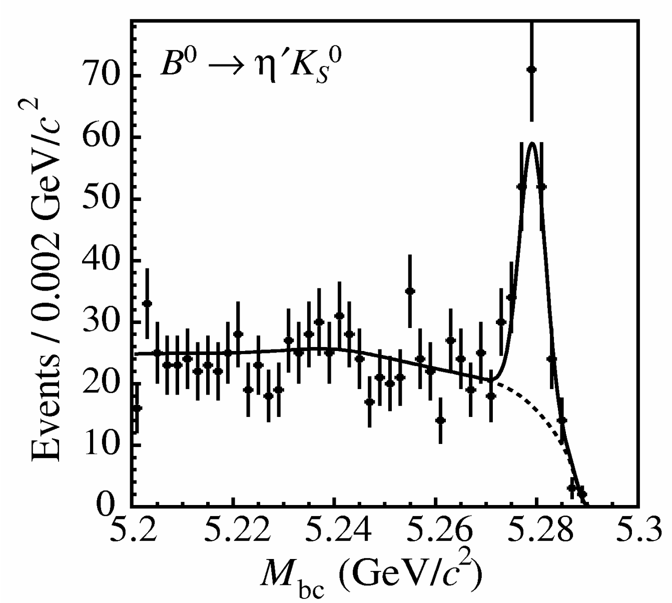
QCD anomaly: **e.g D.Atwood and A.Soni, W.S. Hou and Tseng**

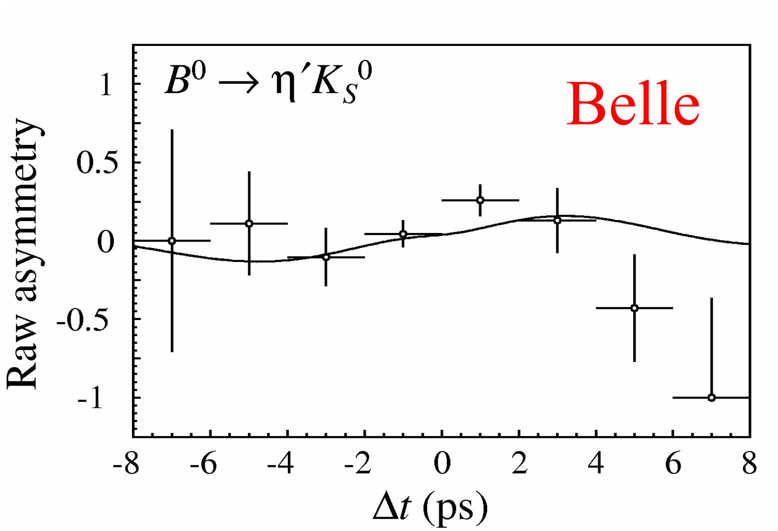


"3-body"

A. Kagan: CLEO Y(1S) data show that the η' gg form factor is much too small. [c.f. Ali+Parkhomenko, E. Kou]

N(η'K_S)=146±12





Search for New Physics in the B→ η'K_S penguin decay.

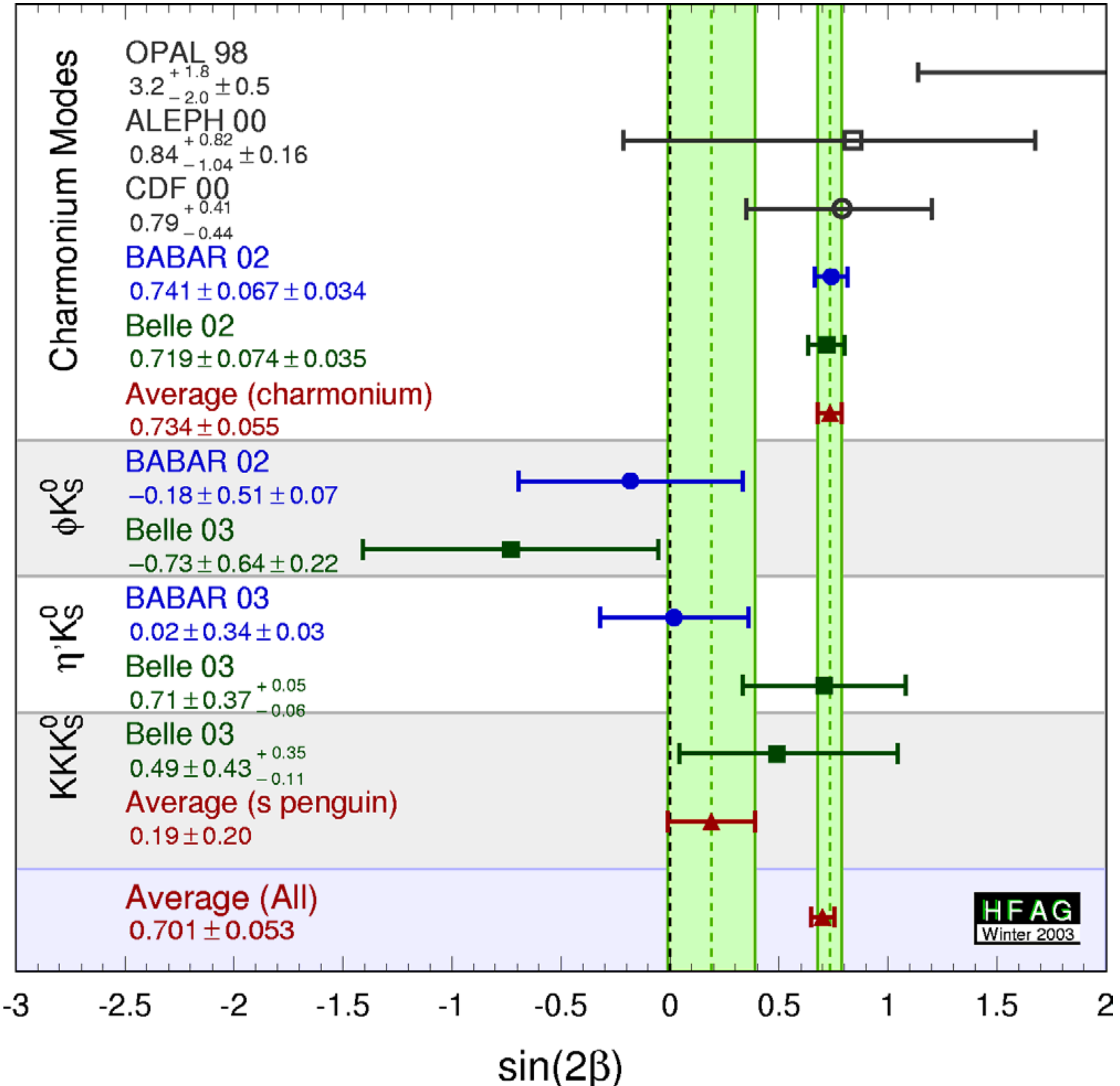
Belle: $S_{\eta' Ks} = 0.71 \pm 0.37^{+0.05}_{-0.06}$

Babar: $S_{\eta' Ks} = 0.02 \pm 0.34 \pm 0.03$

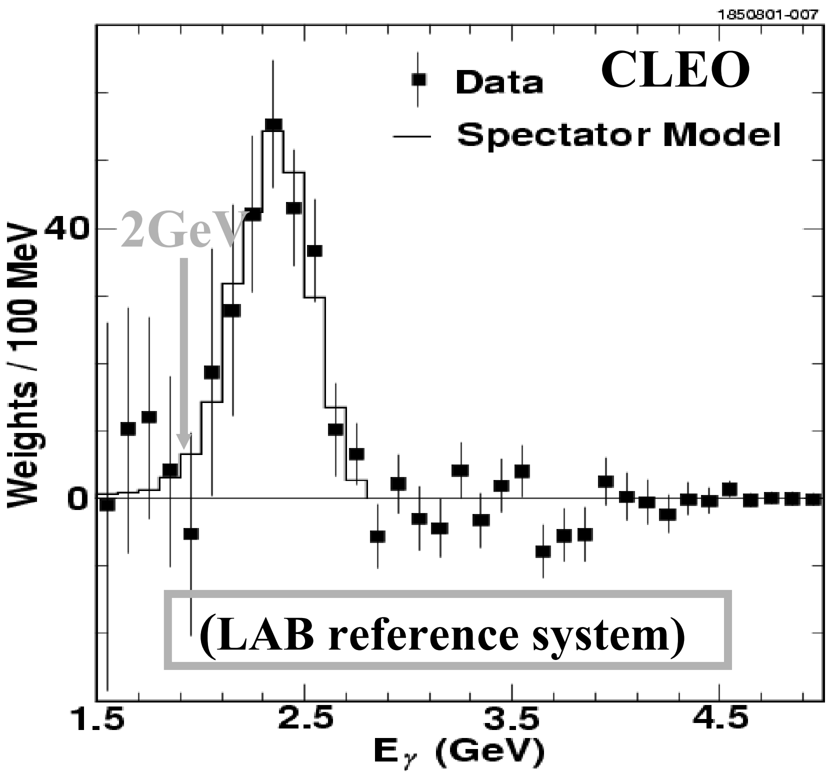
In the absence of New Physics, $S_{\eta' Ks} = \sin(2\varphi_1)$ (a.k.a. sin(2β))

Current WA: $\sin(2\varphi_1)=0.734 \pm 0.055$

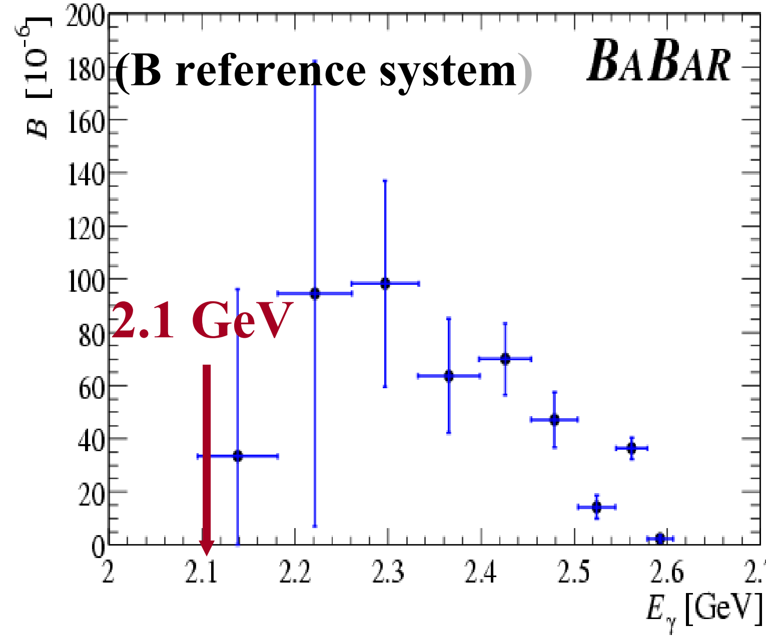
Status of new phases in b→s penguins



γ Energy spectrum in $B \to X_s \gamma$



Inclusive analyses need to boost γ from LAB frame to B frame. Exclusive analyses from M_{Xs} ➔ E_γ in B frame

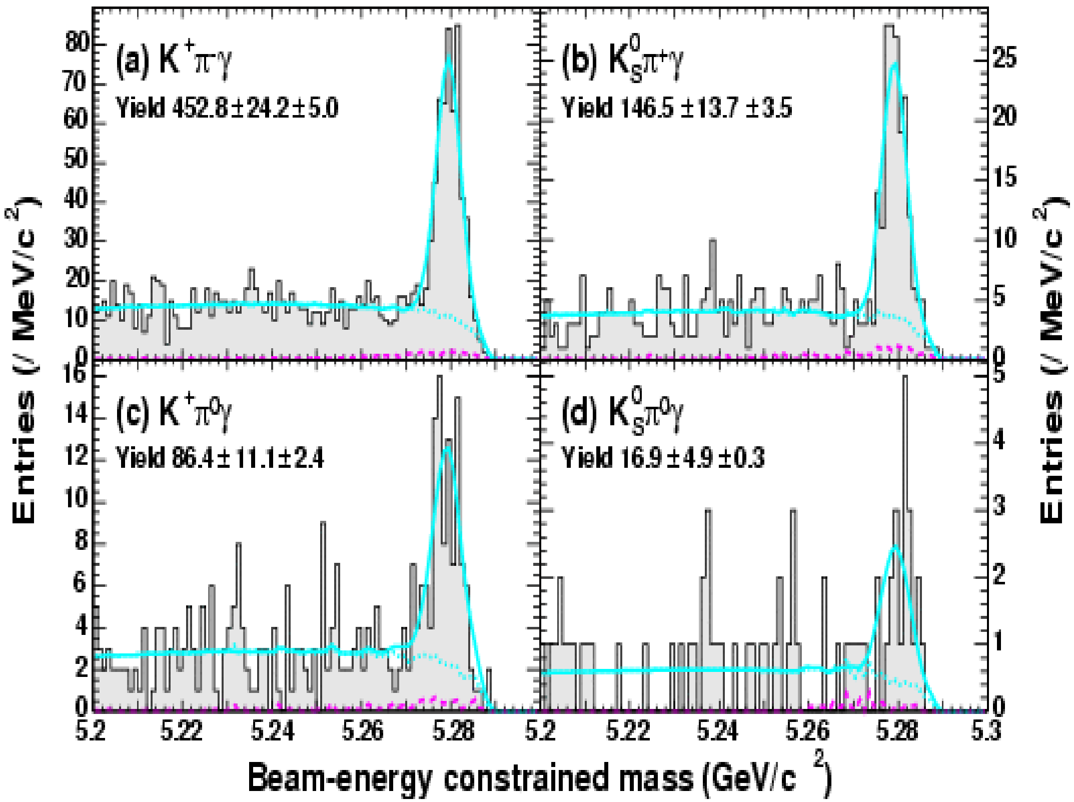


CLEO (PRL 87, 251807, 2001)
E_γ > 2.0 GeV
$\langle E_\gamma \rangle$ = 2.346±0.032±0.011 GeV
$\langle E_\gamma^2 \rangle - \langle E_\gamma \rangle^2$ =
0.0226±0.0066±0.0020 GeV^2

BaBar (hep-ex/0207074)
E_γ > 2.1 GeV
$\langle E_\gamma \rangle$=2.35±0.04±0.04 GeV

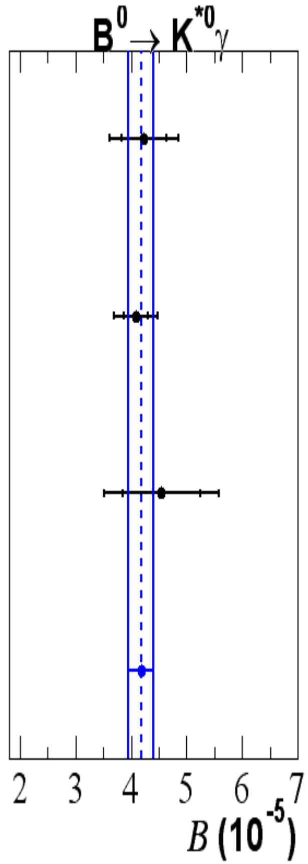
B→K*γ

B→K*(892)γ – BELLE

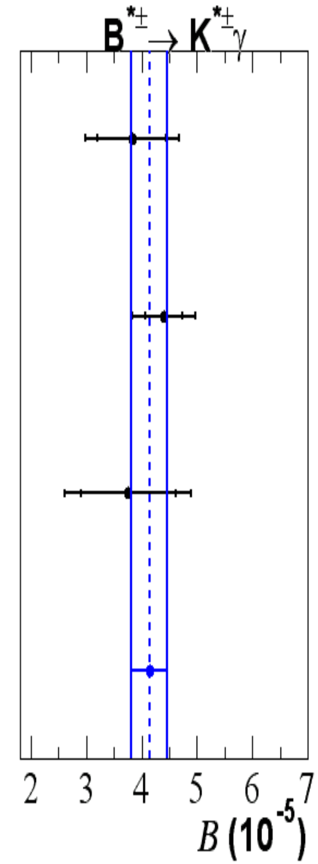


- First observations of B→K*(892)γ and B→K*$_2$(1430)γ by CLEO (1993 and 2000).
- Much higher statistics now. Results close to being systematics limited.
- Measurements of Branching Fractions, CP asymmetries and isospin asymmetry between B^0 and $B^\pm$ decay widths

$\mathcal{B}(B \to K^*\gamma)$ results



	B ± stat ± syst
BaBar PRL 88, 101805, 2002 [20.7 fb^{-1}]	$(4.23 \pm 0.40 \pm 0.22)\,10^{-5}$
BELLE BELLE-CONF-0239 [78 fb^{-1}]	$(4.09 \pm 0.21 \pm 0.19)\,10^{-5}$ New
CLEO PRL 84, 5283, 2000 [9.2 fb^{-1}]	$(4.55 \pm 0.70 \pm 0.34)\,10^{-5}$
Average	$(4.18 \pm 0.23)\,10^{-5}$



	B ± stat ± syst
BaBar PRL 88, 101805, 2002 [20.7 fb^{-1}]	$(3.83 \pm 0.62 \pm 0.22)\,10^{-5}$
BELLE BELLE-CONF-0239 [78 fb^{-1}]	$(4.40 \pm 0.33 \pm 0.24)\,10^{-5}$ New
CLEO PRL 84, 5283, 2000 [9.2 fb^{-1}]	$(3.76 \pm 0.86 \pm 0.28)\,10^{-5}$
Average	$(4.14 \pm 0.33)\,10^{-5}$

New

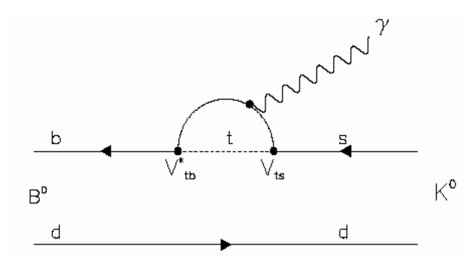
BELLE isospin asymmetry:

$r = \tau_{B\pm}/\tau_{B0} = 1.083 \pm 0.017$

$$\Delta_{0\pm} = \frac{r\mathcal{B}(B^0 \to K^{*0}\gamma) - \mathcal{B}(B^\pm \to K^{*\pm}\gamma)}{r\mathcal{B}(B^0 \to K^{*0}\gamma) + \mathcal{B}(B^\pm \to K^{*\pm}\gamma)} = +0.003 \pm 0.045 \pm 0.018$$

Isospin breaking (Kagan & Neubert hep-ph/0110078) can test Wilson coefficients (C_6/C_7)

The Hunt for the EW Penguin: $B \rightarrow X_s\, l^+ l^-$



Discovered by CLEO in 1994

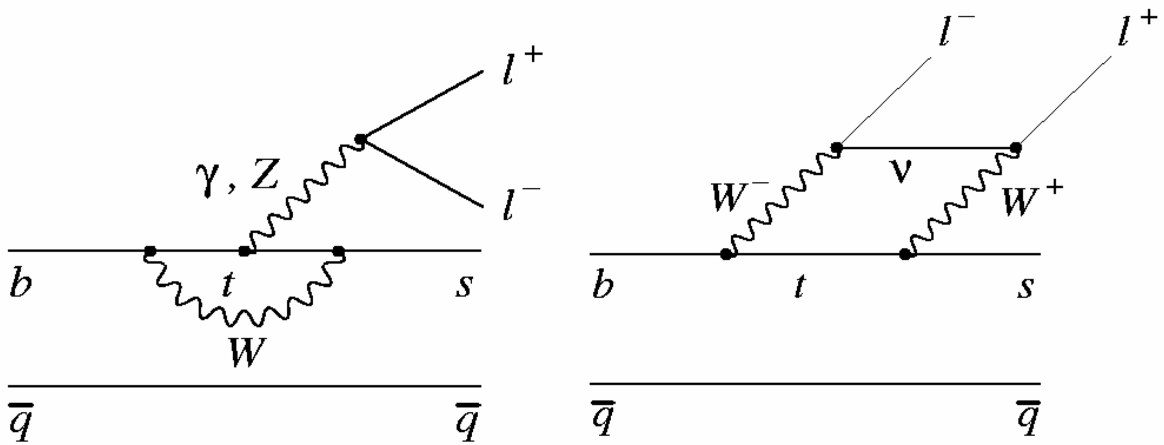


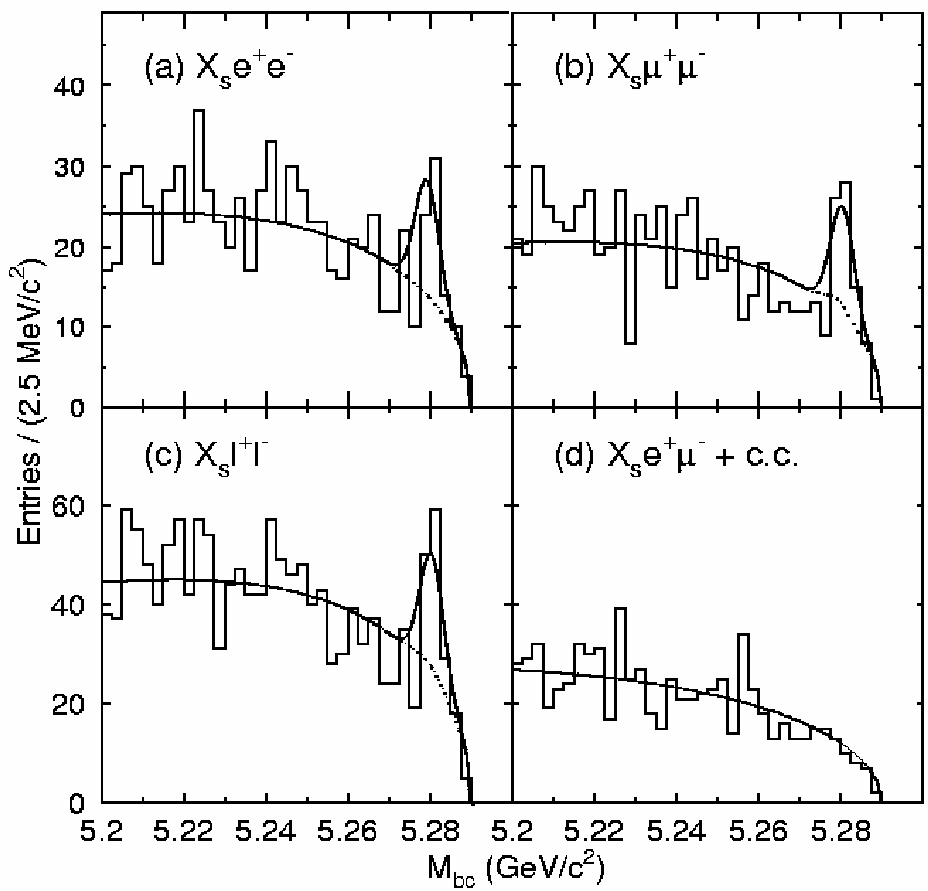
Figure 1: Standard Model diagrams for the decays $B \rightarrow K^{(*)}\ell^+\ell^-$.

As in $b \rightarrow s\,\gamma$, heavy particles in the loops can be replaced with NP particles (e.g. $W^+ \rightarrow H^+$)

Note contributions from virtual γ^*, W, Z^* and internal t quark.

Belle 2002: Observation of *inclusive* $B \to X_s l^+ l^-$

25.5 ± 11.2

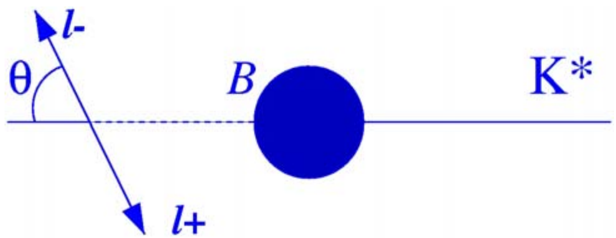


37.3 ± 9.7

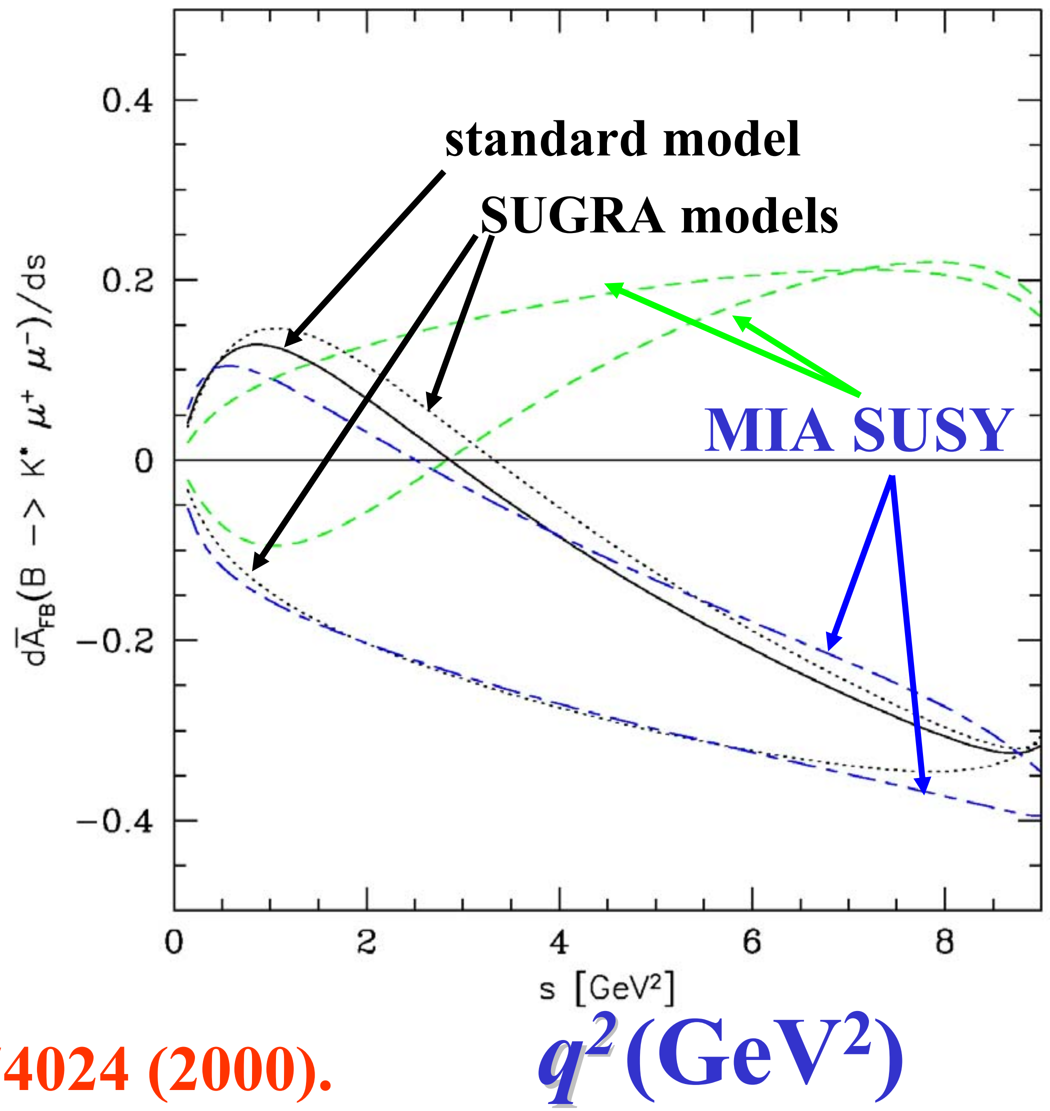
Control sample

$$BF(B \to X_s l^+ l^-) = (6.1 \pm 1.4 ^{+1.3}_{-1.1}) \times 10^{-6}$$

Sensitivity to new physics in A_{FB} ($B \rightarrow K^* l^+ l^-$)



Polar angle of lepton in dilepton rest frame.



A. Ali *et al.*, PRD 61, 074024 (2000).

- A_{FB} statistical uncertainties for pure signal

A_{FB} $X_s\, e^+e^- + X_s\, \mu^+\mu^-$	500 fb^{-1}	1000 fb^{-1}	10 ab^{-1}	50 ab^{-1}
$\hat{s} < \hat{s}_0$	-0.02 ± 0.11	-0.02 ± 0.08	-0.017 ± 0.024	-0.017 ± 0.011
$\hat{s} > \hat{s}_0$	0.17 ± 0.09	0.17 ± 0.07	0.173 ± 0.021	0.173 ± 0.009

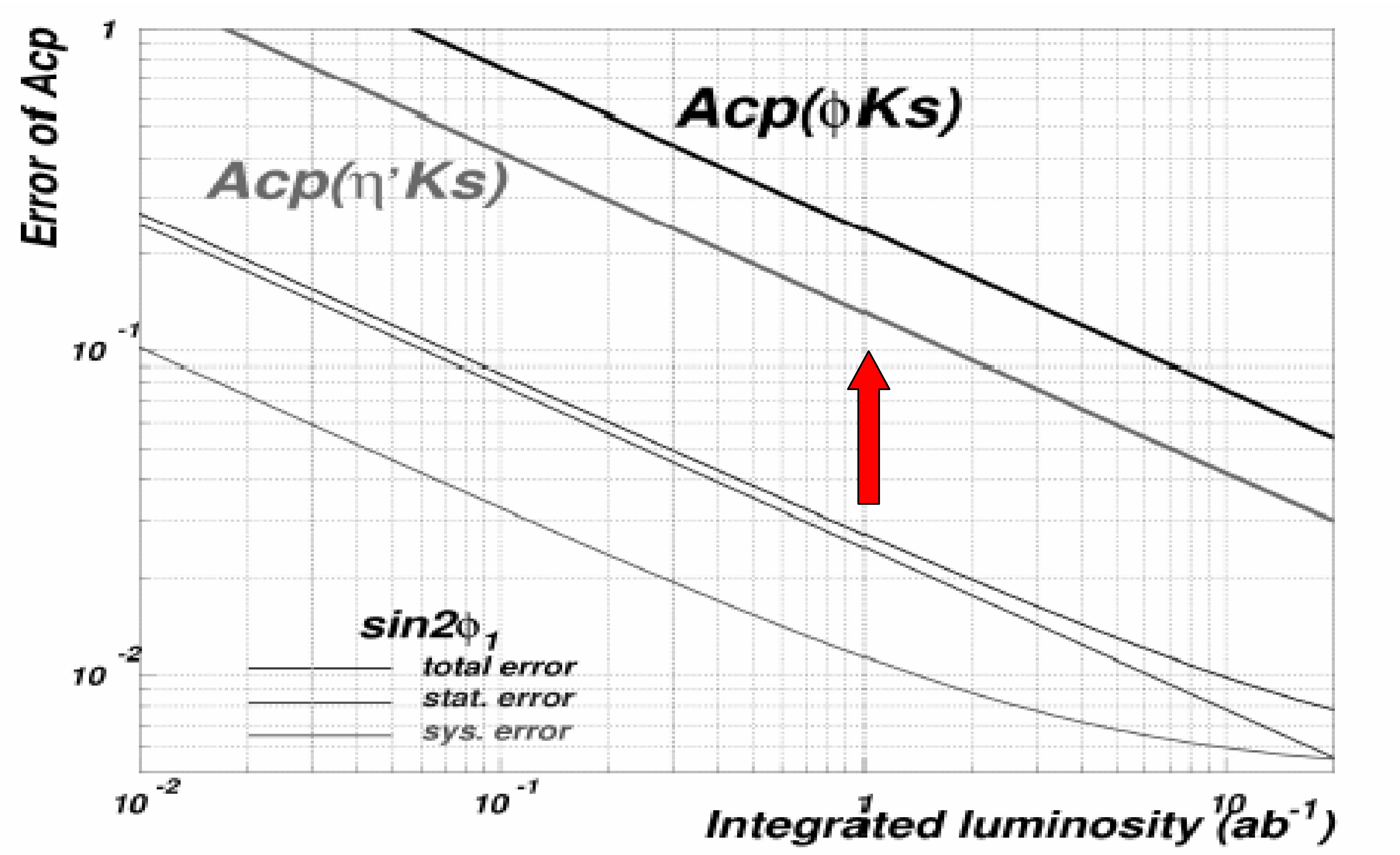
zero point of the asymmetry: $A_{FB} = 0$ for $\hat{s} = \hat{s}_0 = 0.162 \pm 0.008$ (NNLL)

- A_{FB} statistical uncertainties for background-subtracted full sample

A_{FB} $X_s\, e^+e^- + X_s\, \mu^+\mu^-$	500 fb^{-1}	1000 fb^{-1}	10 ab^{-1}	50 ab^{-1}
$\hat{s} < \hat{s}_0$	-0.02 ± 0.17	-0.02 ± 0.12	-0.017 ± 0.039	-0.017 ± 0.017
$\hat{s} > \hat{s}_0$	0.17 ± 0.22	0.17 ± 0.16	0.173 ± 0.050	0.173 ± 0.022

⇒ A_{FB} clearly needs high-luminosity B Factory

Sensitivity to new physics phases

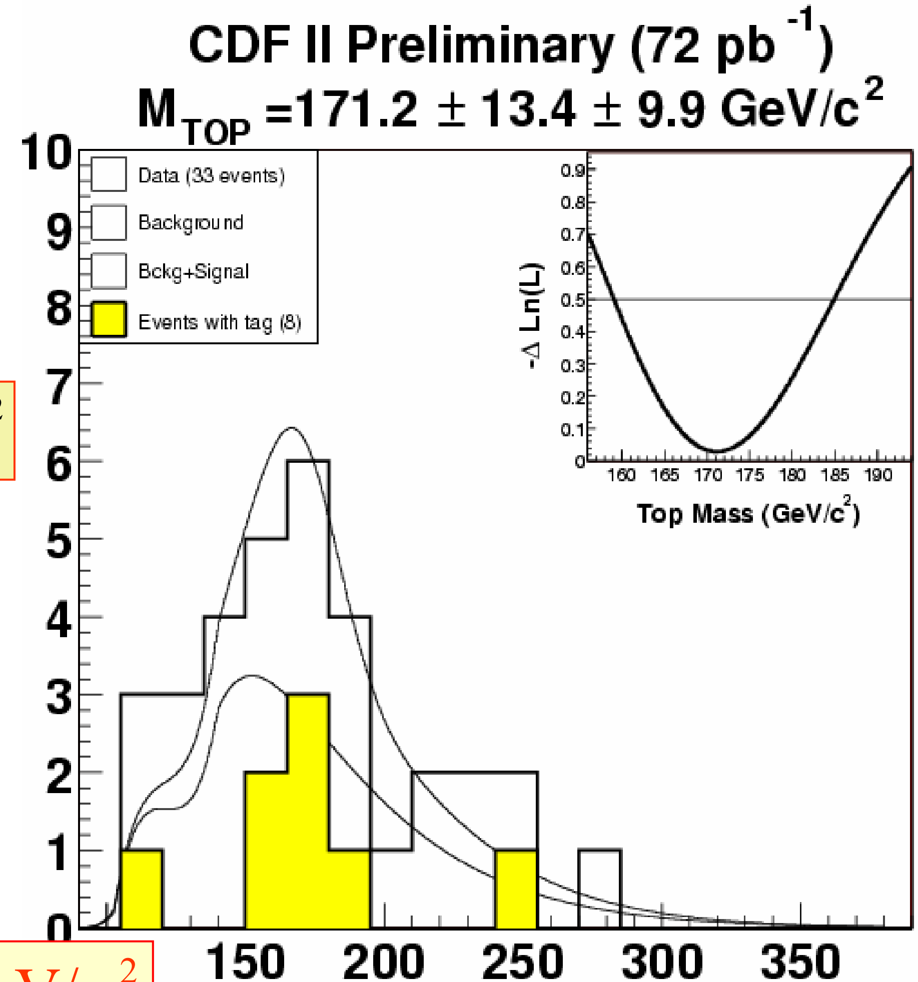


New Top Mass Measurements

- 33 candidates
  - 8 events with a tagged b

$$M_{top} = 171.2^{+14.4}_{-12.5}\,(stat) \pm 9.9(sys)\,GeV/c^2$$

CDF Run 1 combined:
M_{top} = 176.1 ± 6.5 GeV/c^2



$$m_{top} = 180.1 \pm 3.6\ (stat) \pm 4.0(syst)\ GeV/c^2$$

Run I D0 lepton+jets:

173.3± 5.6(stat) ± 5.5 (syst) GeV/c^2.

2-3 GeV for 2 fb^{-1}

Question: Why look for new physics at a super B-factory or LHCB/BTeV when you have the LHC that produces new particles directly ?

Answer: They are complementary; LHC does masses, B Factory does phases (and couplings).

Example: Beautiful, sophisticated and precise measurements of the top quark mass at the Tevatron (Coca). However, the couplings $|V_{ts}|$, $|V_{td,}|$ and most importantly the phase of (V_{td}) cannot be measured in direct top production.

The Future

Super/Upgraded $e^+ e^-$ B Factories: Yamauchi, Giorgi

Hadronic B Experiments: Honscheid, Matteuzi, Ohlsson-Malek

Tau-charm: Urheim(presented by Artuso)

Neutrinos: Cavata

Super KEKB, PEP-II, L=$10^{35\text{-}36}$/cm^2/sec; BTeV, LHCb and B physics at ATLAS/CMS

G. Hiller

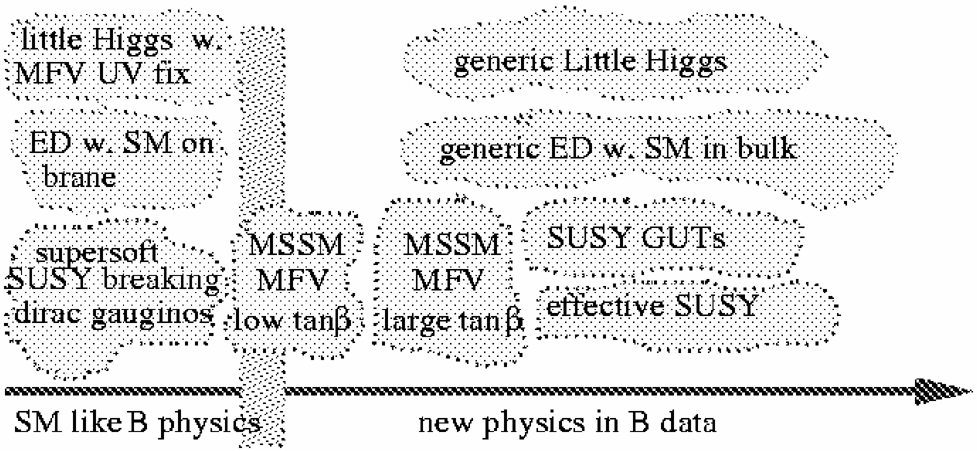


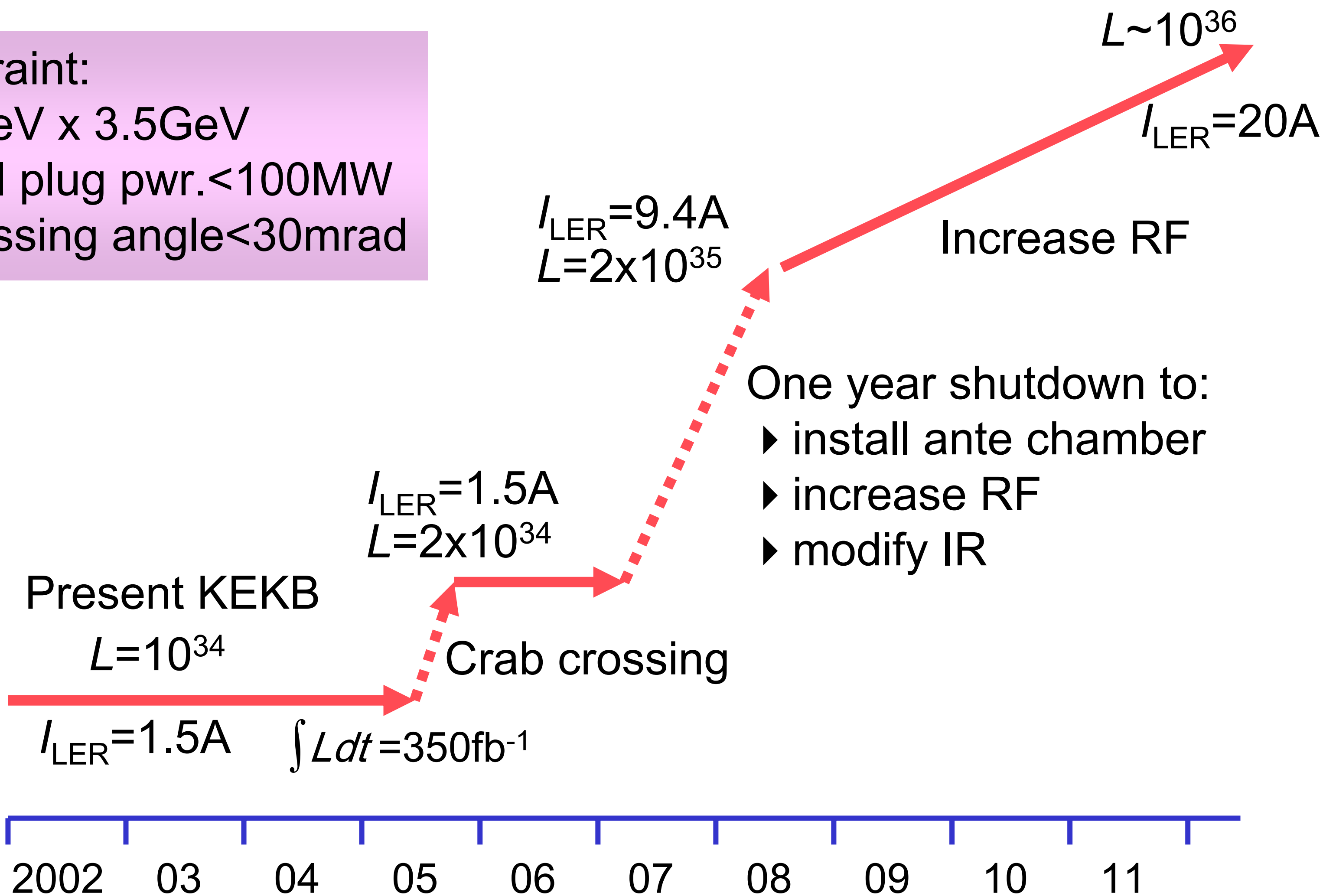
Figure 4. Flavor/CP yield of models of electroweak symmetry breaking.

Scenarios for flavor physics beyond the SM.

Signatures in time-dependent CPV (φ K_S) , rare decays (e.g. b→s l^+ l^- , b→s γ)

KEKB upgrade strategy

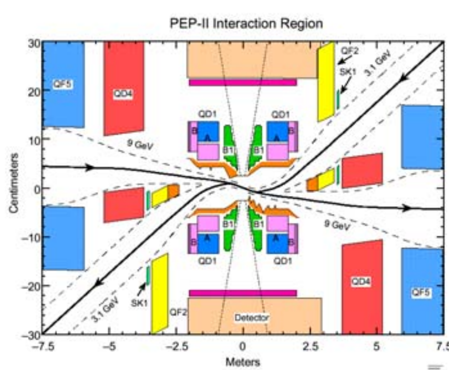
Constraint:
- 8GeV x 3.5GeV
- wall plug pwr.<100MW
- crossing angle<30mrad

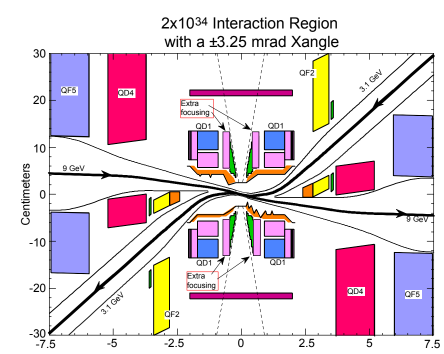


PEP-II Upgrade Plans

	Now	Projected <2005	Upgrade >2005	
LER energy	3.1	3.1	3.1?	GeV
HER energy	9.0	9.0	9.0?	GeV
LER current	1.8	2.4	3.3	A
HER current	1.0	1.4	1.5	A
β_y^*	**12.5**	**9.0**	**5.0**	mm
β_x^*	35	35	35	cm
X emittance	50	50	50	nm-rad
Estimated σ_y^*	5	4.3	3	μm
Bunch spacing	1.89	1.89	1.26	m
Number of bunches	921	1130	1700	
Collision angle	head-on	head-on	**±3.25**	mrads
Beam pipe radius	2.5	2.5	2.5	cm
Luminosity	5×10^{33}	8×10^{33}	$\mathbf{2\times10^{34}}$	$cm^{-2}\ sec^{-1}$

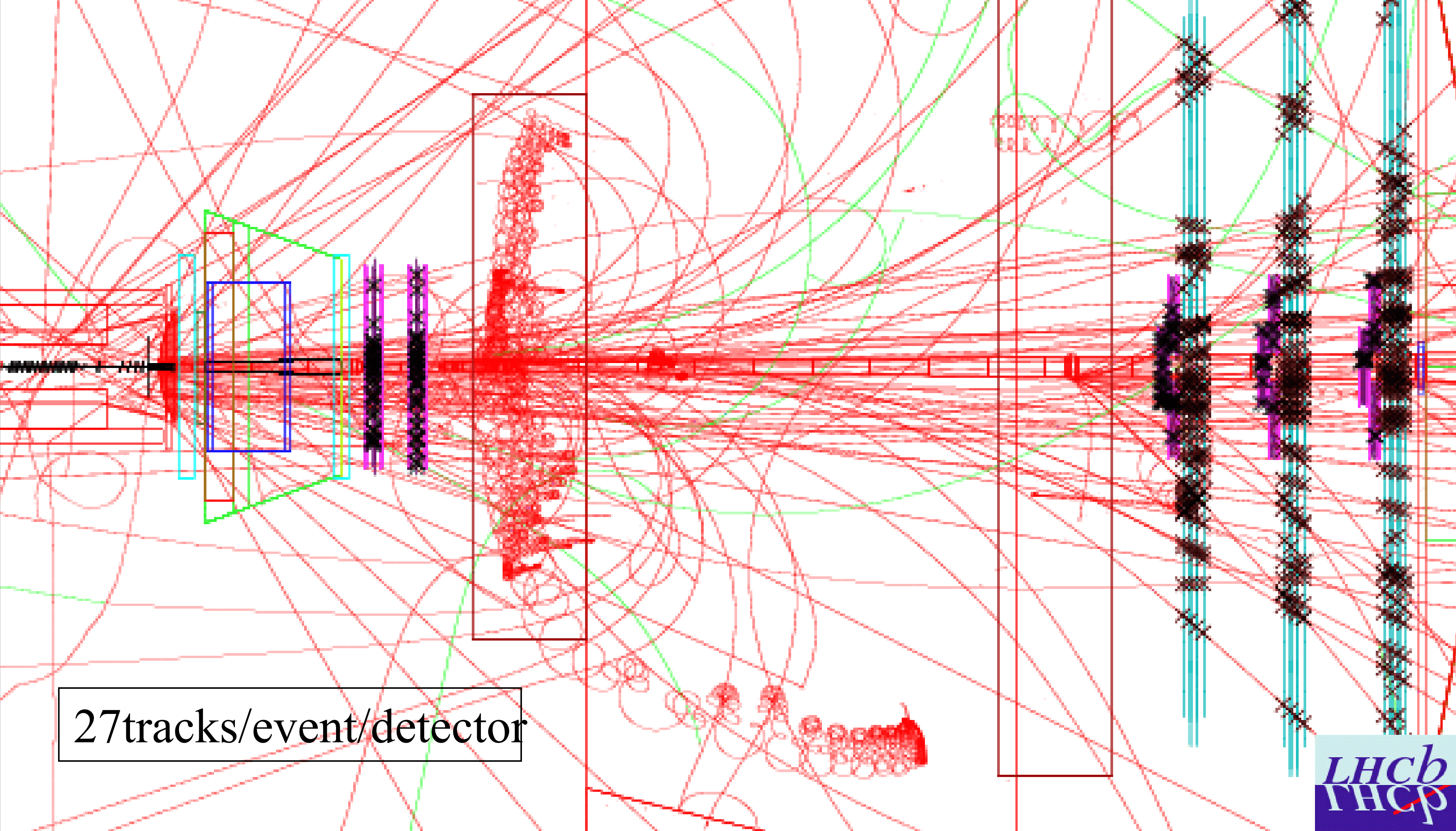
M. Giorgi





Fully simulated $b\bar{b}$ event at LHCB

- incl. multiple scattering, hadronic interactions
- decays in flight
- Kalman fitter



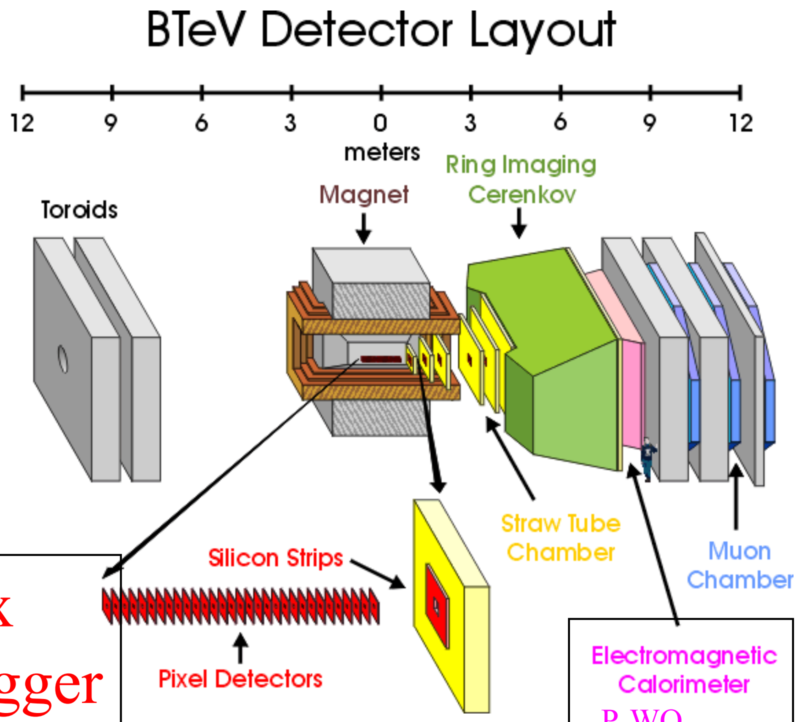
BTeV & LHCb

Dedicated Hadron Collider B experiments

Tevatron

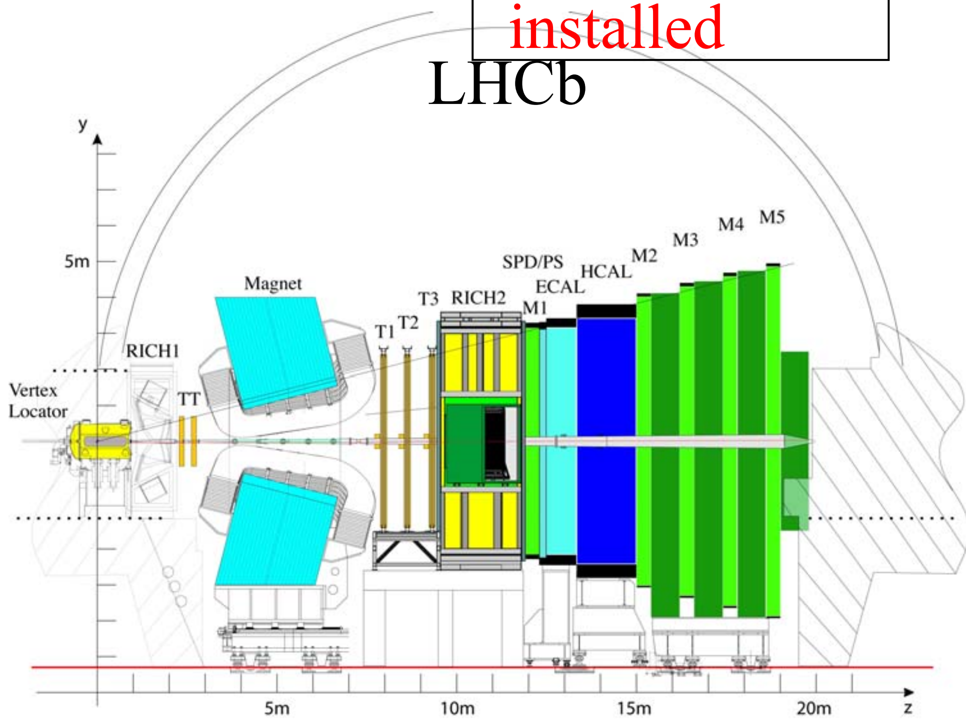
LHC

Magnet being installed



vtx trigger

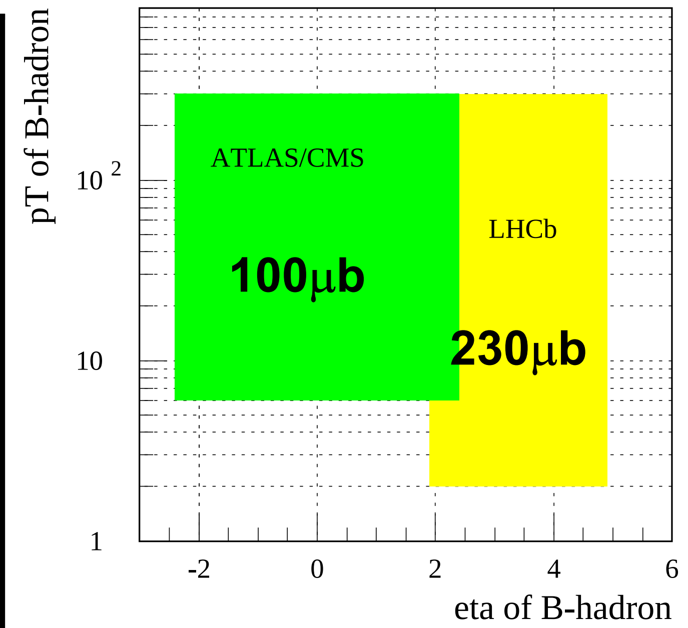
Electromagnetic Calorimeter
P_bWO_4

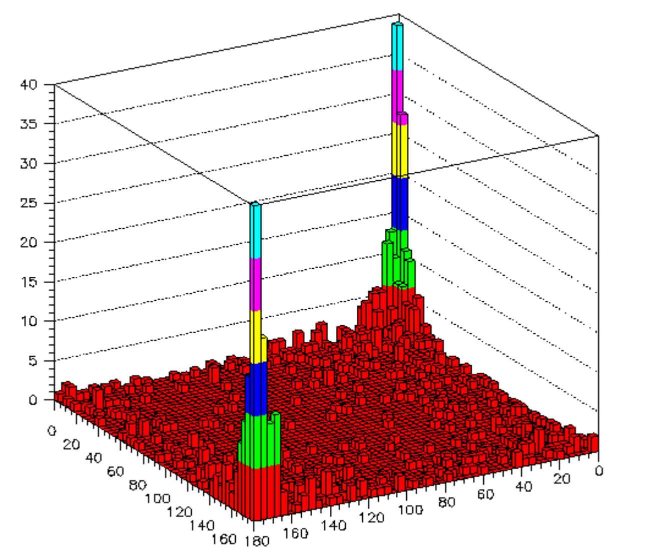


Favorable x-section/background ratio (10^{3}) compared to HERA-B, old FNAL fixed target. Radiation hard technologies.

Overview of the LHC B physics potential

LHC $\sigma_{total} = 100$ mb $\sigma_{inelastic} = 80$ mb $\sigma_{bb} = 500\ \mu b$	
ATLAS & CMS Central detectors	**LHCb** Forward detector
$\lvert\eta\rvert < 2.5$, $p_T > 10$ GeV $\sigma_{B\text{-hadron}} = 100\ \mu b$	$1.9 < \eta < 4.9$, $p_T > 2$ GeV $\sigma_{B\text{-hadron}} = 230\ \mu b$
L = 1-2 x 10^{33} cm^{-2} s^{-1} 10^{34} cm^{-2} s^{-1} for rare decays	L = 2 x 10^{32} cm^{-2} s^{-1}
Exclusive channels ~ 2.8 10^6 Dominated by bb →J/Ψ Hadronic channels: < 10^5 (however all with muon tag)	Exclusive channels ~ 3.4 10^6 1.7 10^6 bb →J/Ψ Hadronic channels ~ 1.7 10^6



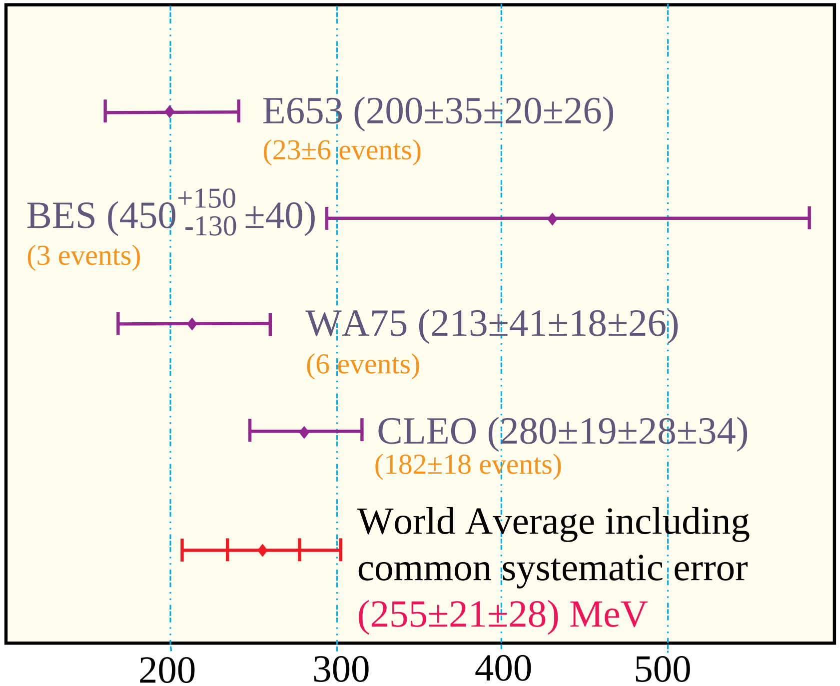


BTeV & LHCb

- Sensitivity to B_s mixing up to x_s ~80
- Large rare decay rates $B^o \rightarrow K^{*o} l^+ l^-$ ~2500 events in 10^7 s
- Measurement of γ to ~7^o using $B_s \rightarrow D_s K^-$
- Measurement of α to ~4^o using $B^o \rightarrow \rho\pi$ (BTeV)
- Measurement of χ[related to the phase of B_s mixing] to ~1^o using $B_s^o \rightarrow J/\psi\eta$ (BTeV) or $B_s^o \rightarrow J/\psi\varphi$

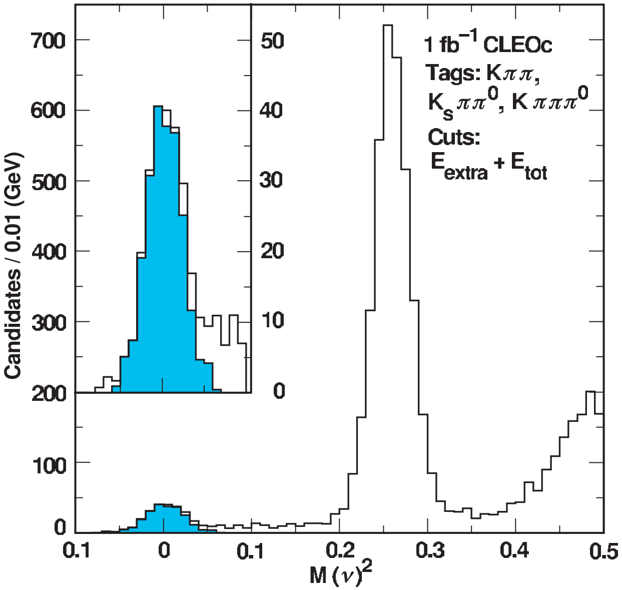
Purely leptonic decays (f_D, f_{Ds}) →CLEO-C is starting

f_{Ds} Values from $D_s \to \mu\upsilon$



f_{D_s} (MeV)

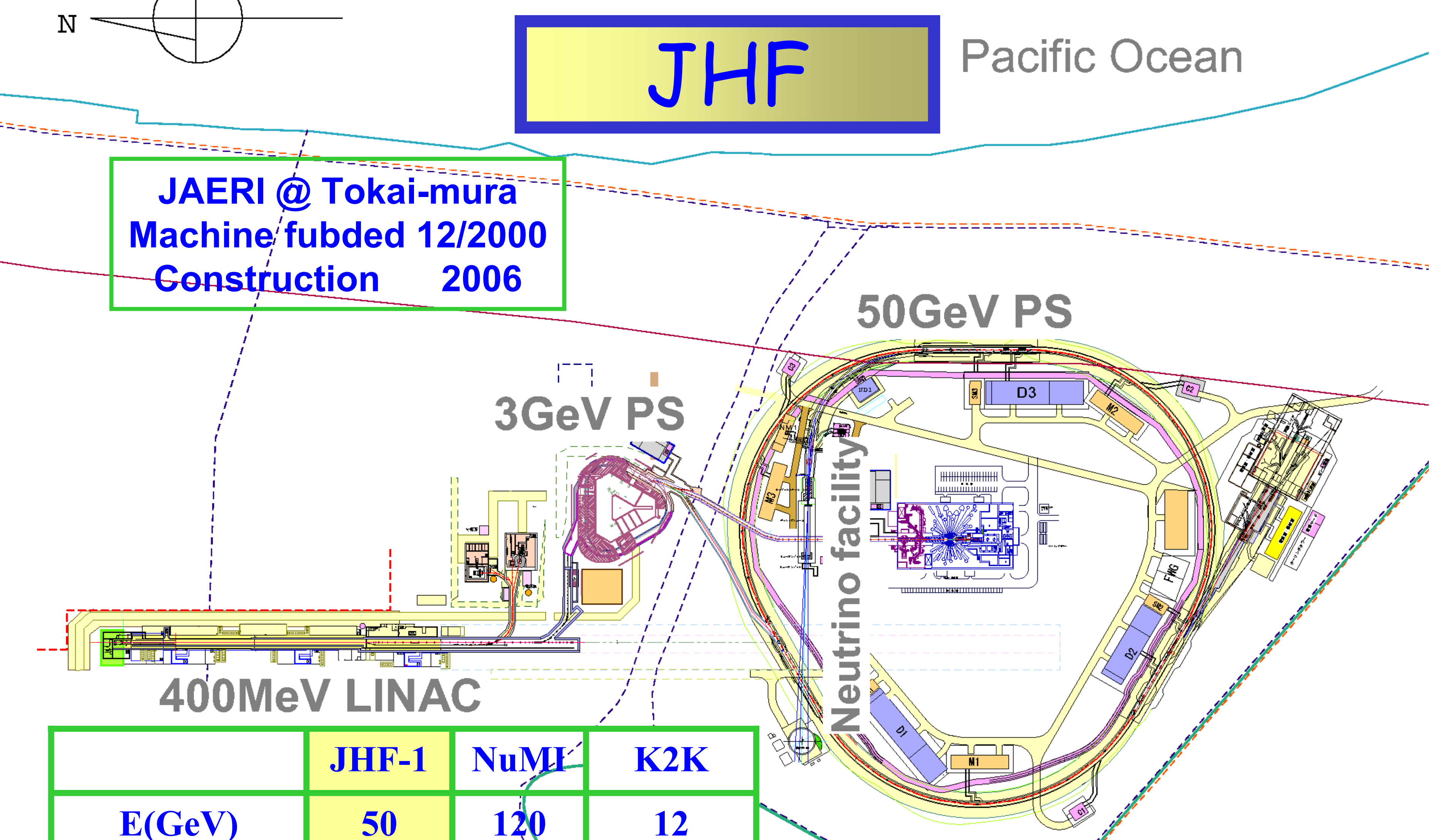
CLEO-C MC



MM² of $D^+ \to \mu^+\nu$ with 1 fb^{-1} of CLEO-C data [2% precision]

JHF

JAERI @ Tokai-mura
Machine fubded 12/2000
Construction 2006



	JHF-1	NuMI	K2K
E(GeV)	50	120	12
Int(10^{12}ppp)	330	40	6
Rate(Hz)	0.275	0.53	0.45
P(MW)	0.75	0.41	0.0052

Measure V_{ub} (θ_{13}) and CPV in neutrinos

Nous remercions les organisateurs

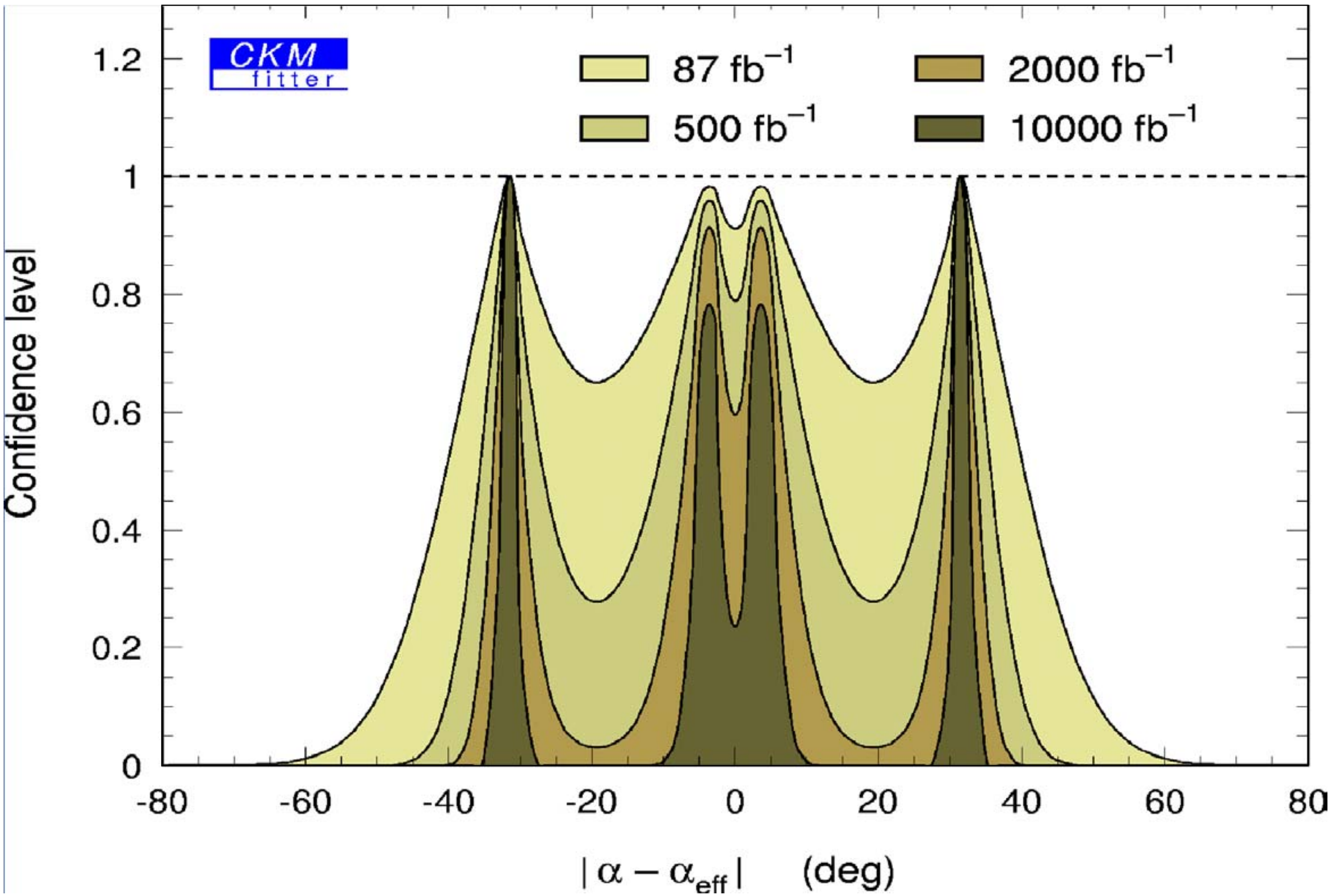
We thank the organizers

どもありがとございました

FPCP2003 **Paris**

BACKUP SLIDES

An independent estimate of the Gronau-Wyler construction



Uses current central values