BEAUTY 2006

THE UNIVERSITY OF WARWICK

CONFERENCE SUMMARY
&
FUTURE PROSPECTS

Tim Gershon, University of Warwick

September 29th 2006

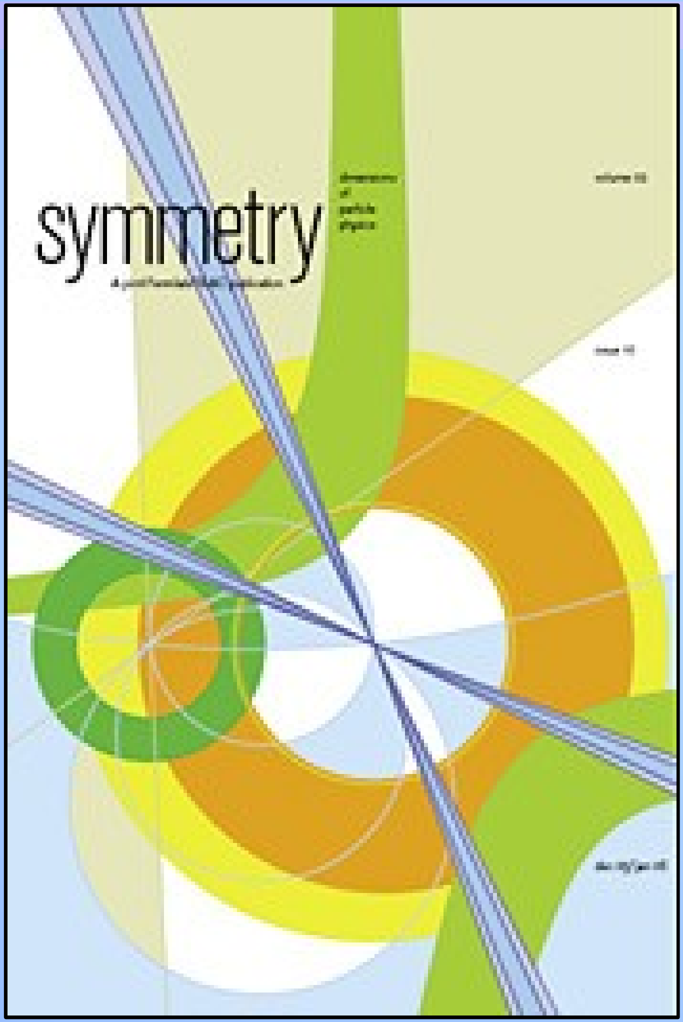
Disclaimer

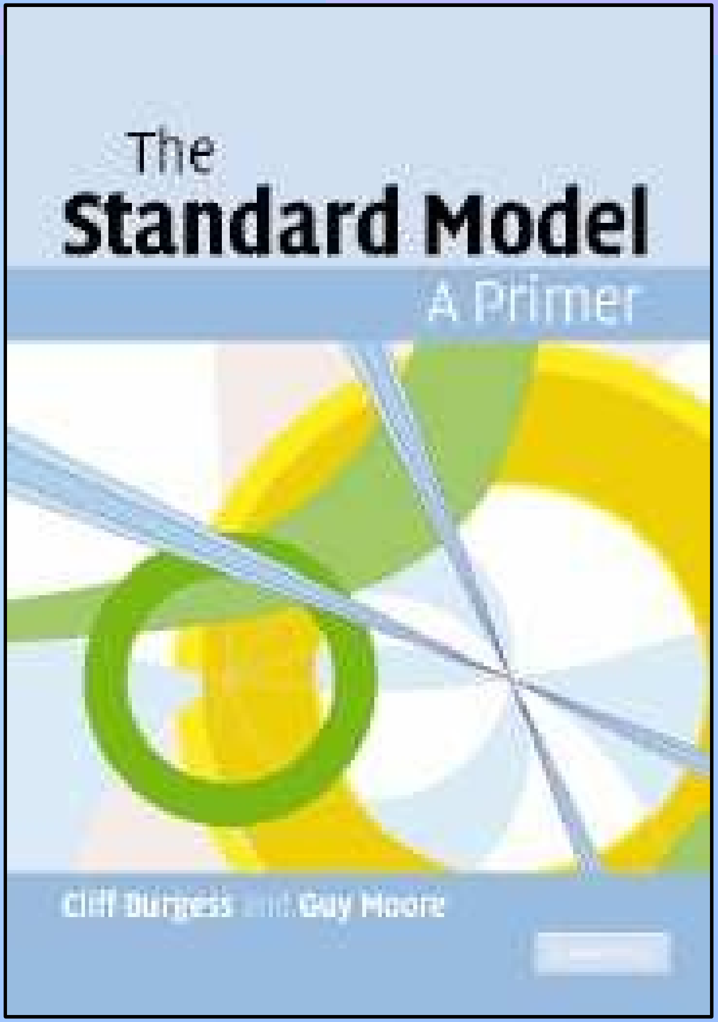
- Far too many interesting talks and impressive results to cover everything …
- Sorry if I miss your favourite topic

Beauty 2006: The 11th International Conference on B Physics at Hadron Machines

- Will mostly focus on B physics (not c, cc, τ, …)
- … will also mention lepton machines!

The Ubiquitous Unitarity Triangle



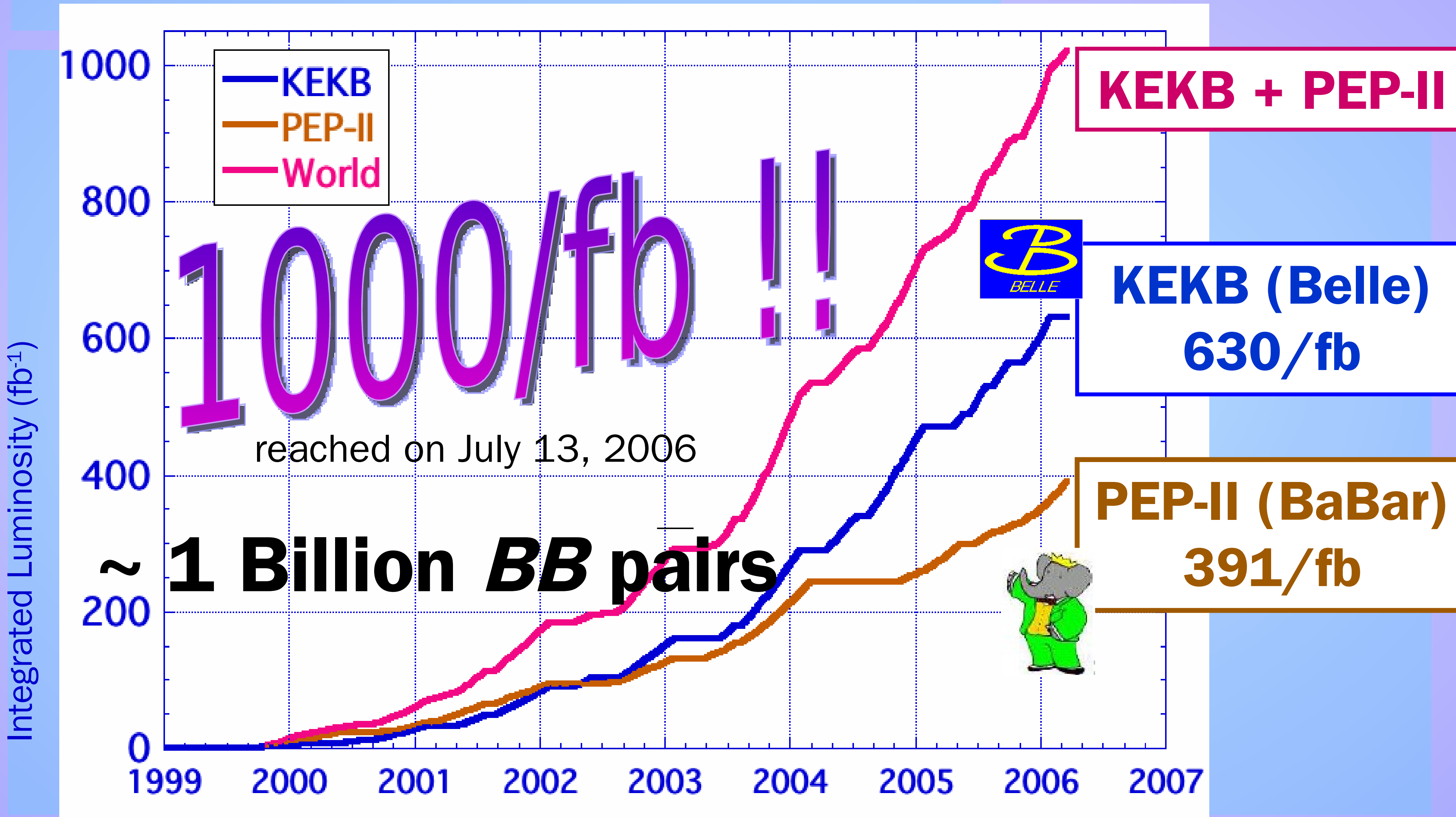


B Physics Highlights 2006

- Huge amounts of statistics at the B factories
- Enormous numbers of conference papers
  - BaBar 114
    http://www-public.slac.stanford.edu/babar/ICHEP06_papers.htm
  - Belle 38 (still increasing)
    http://belle.kek.jp/conferences/ICHEP2006/

- Yet 2006 is the year of the Tevatron …

Atoworld! (© K.Peach)

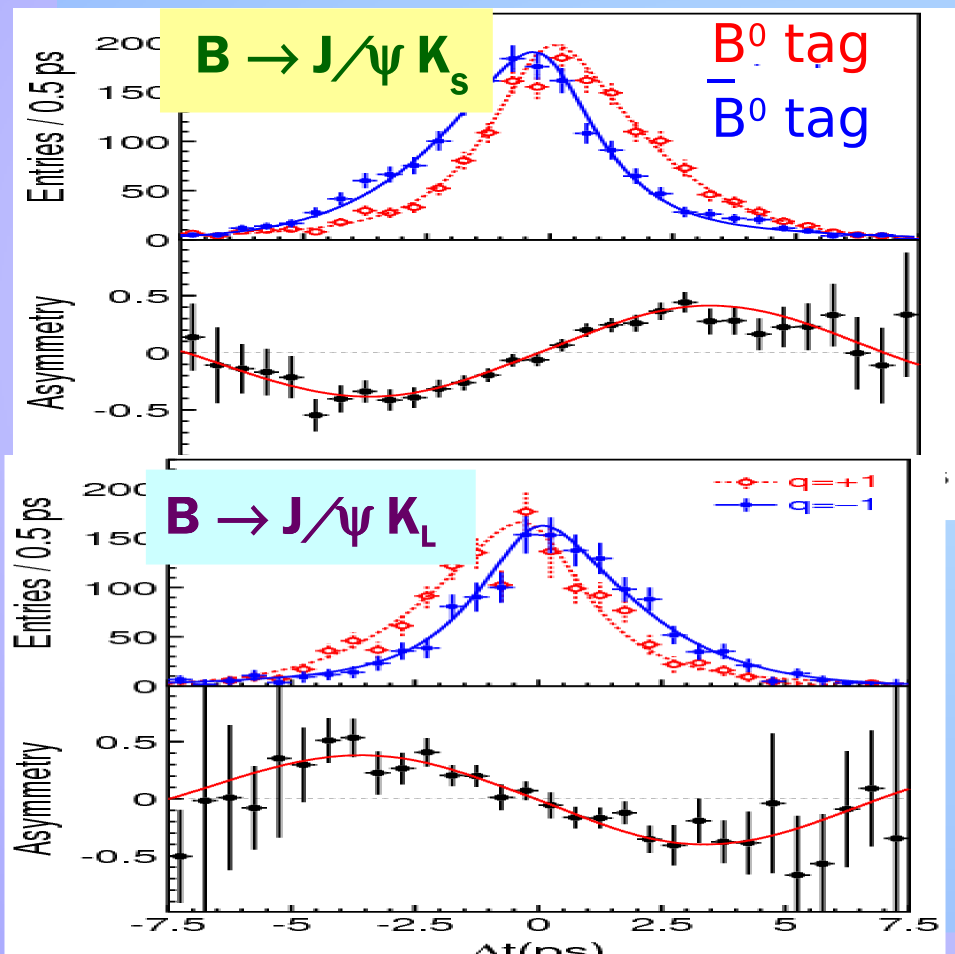


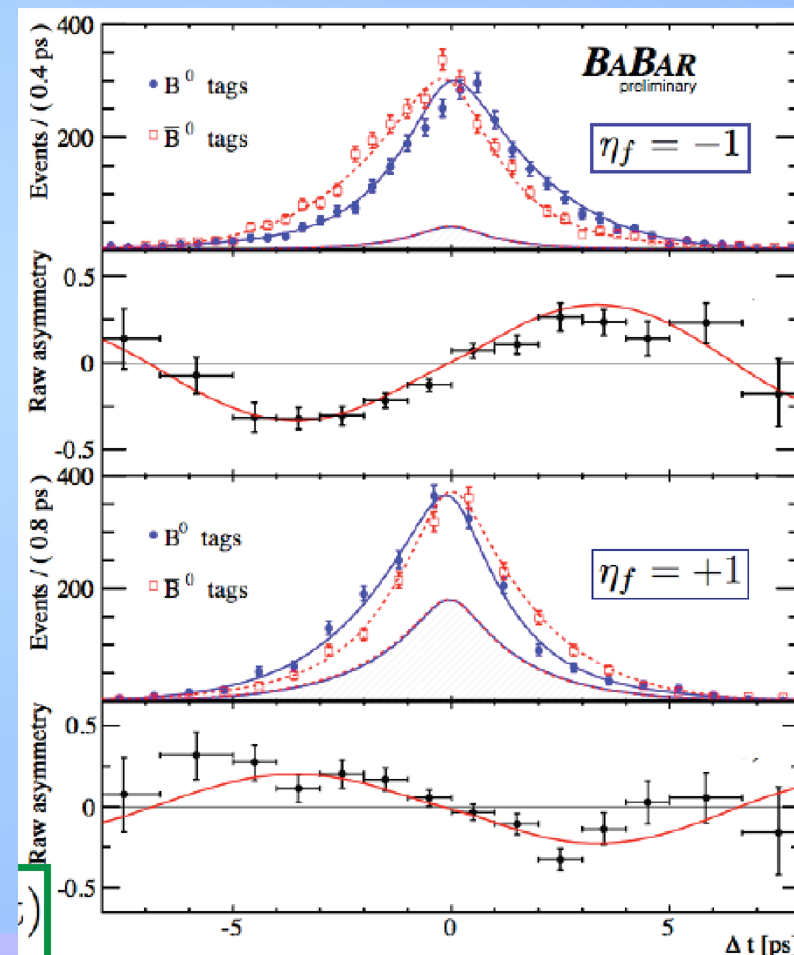
NB. Not all luminosity is on Υ(4S)!

The Golden Mode: $J/\psi\ K_S$, etc

BELLE hep-ex/0608039 N(BB)=532m

BABAR hep-ex/0607107 N(BB)=348m

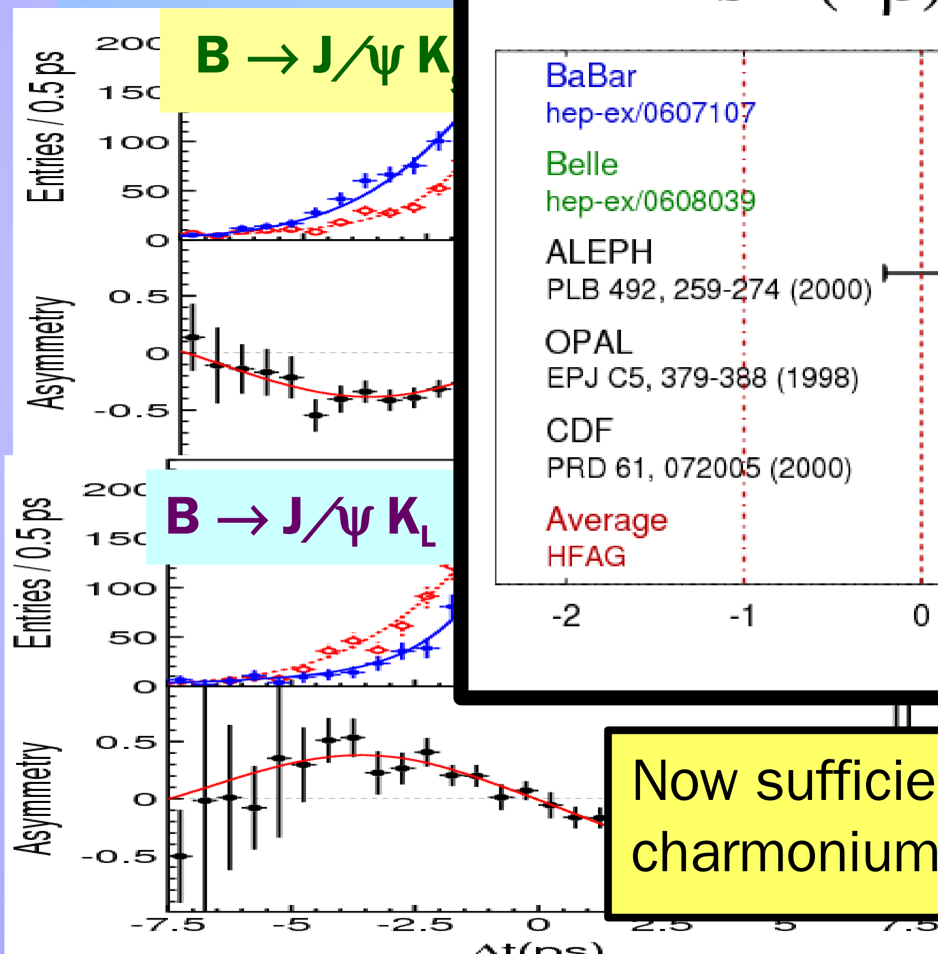


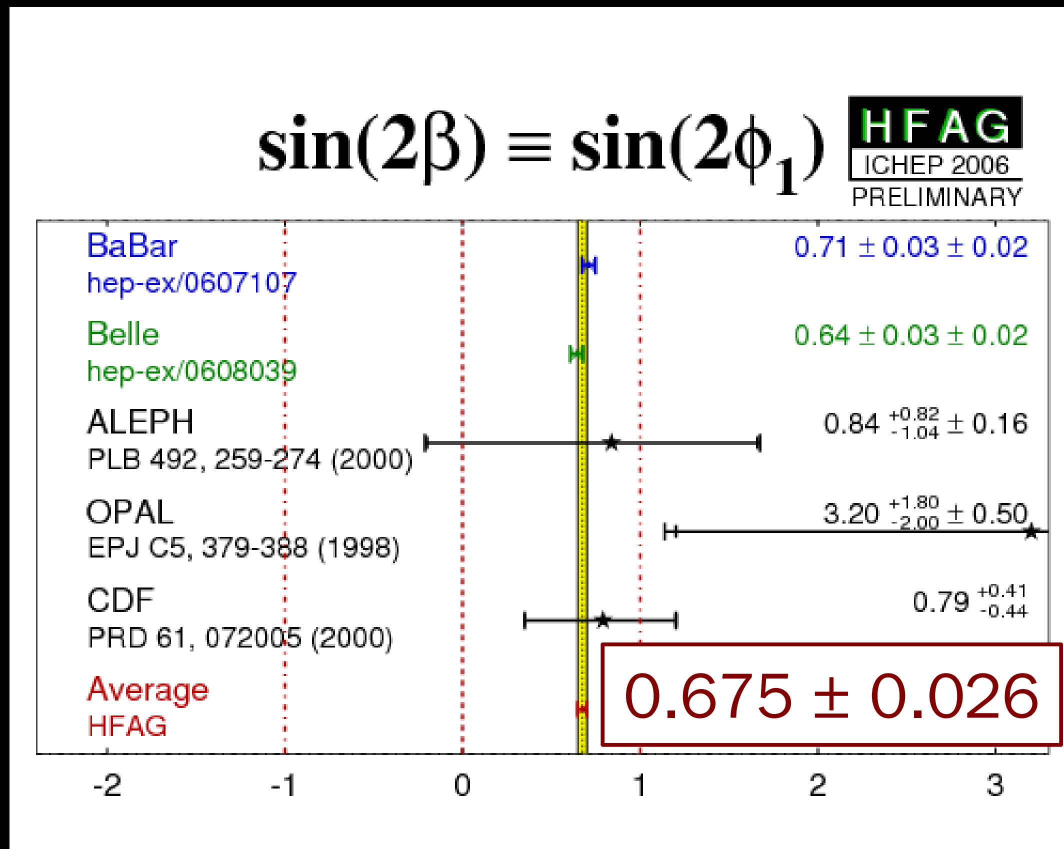


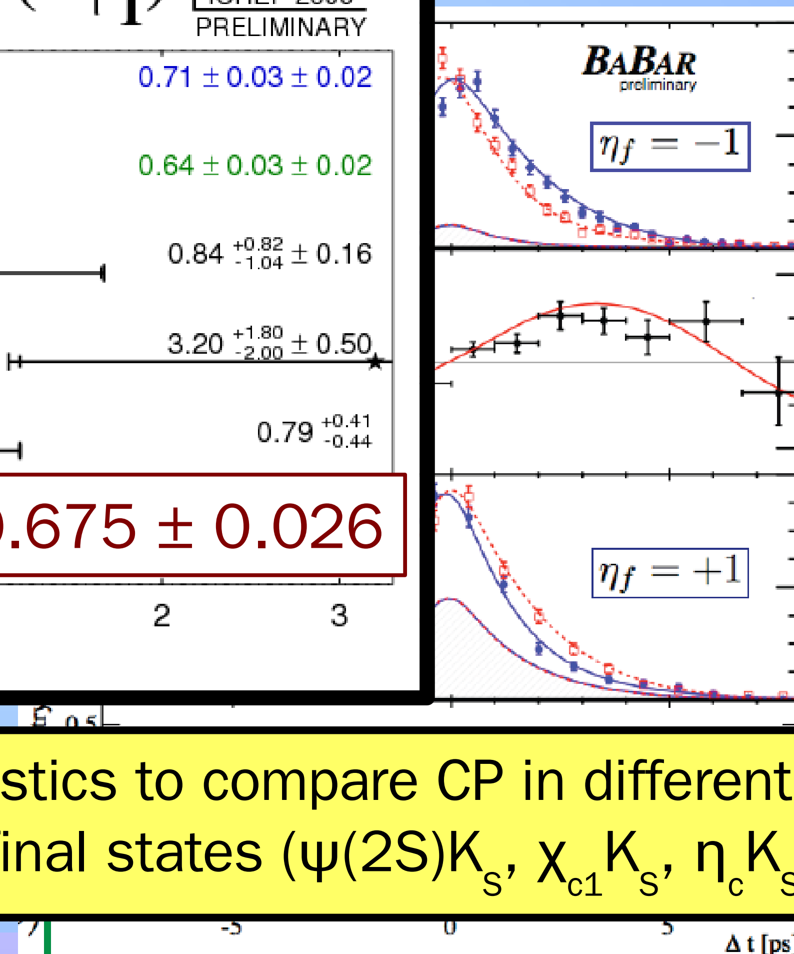
LACKER

The Golden Mode: J/ψ K_S, etc

BELLE hep-ex/ …07 N(BB)=348m







Now sufficient statistics to compare CP in different charmonium kaon final states ($\psi(2S)K_S$, $\chi_{c1}K_S$, $\eta_c K_S$)

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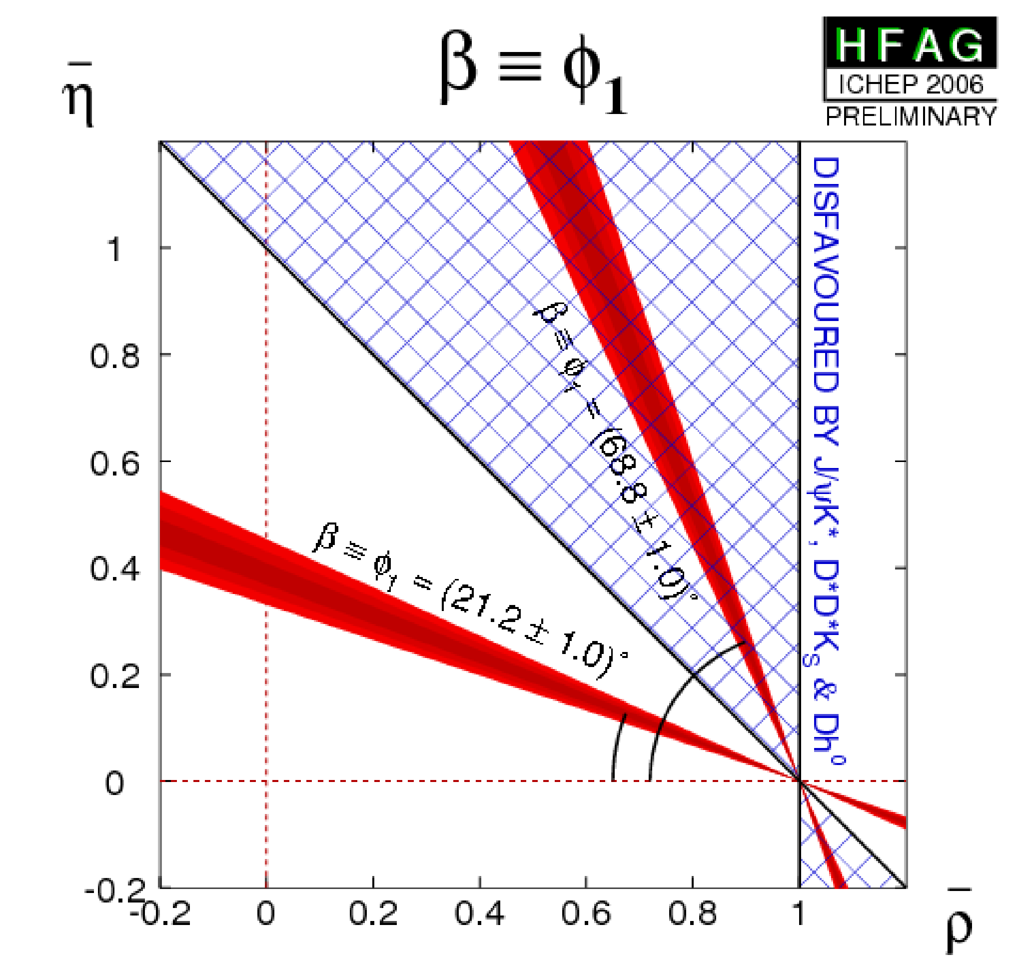
The ambiguity



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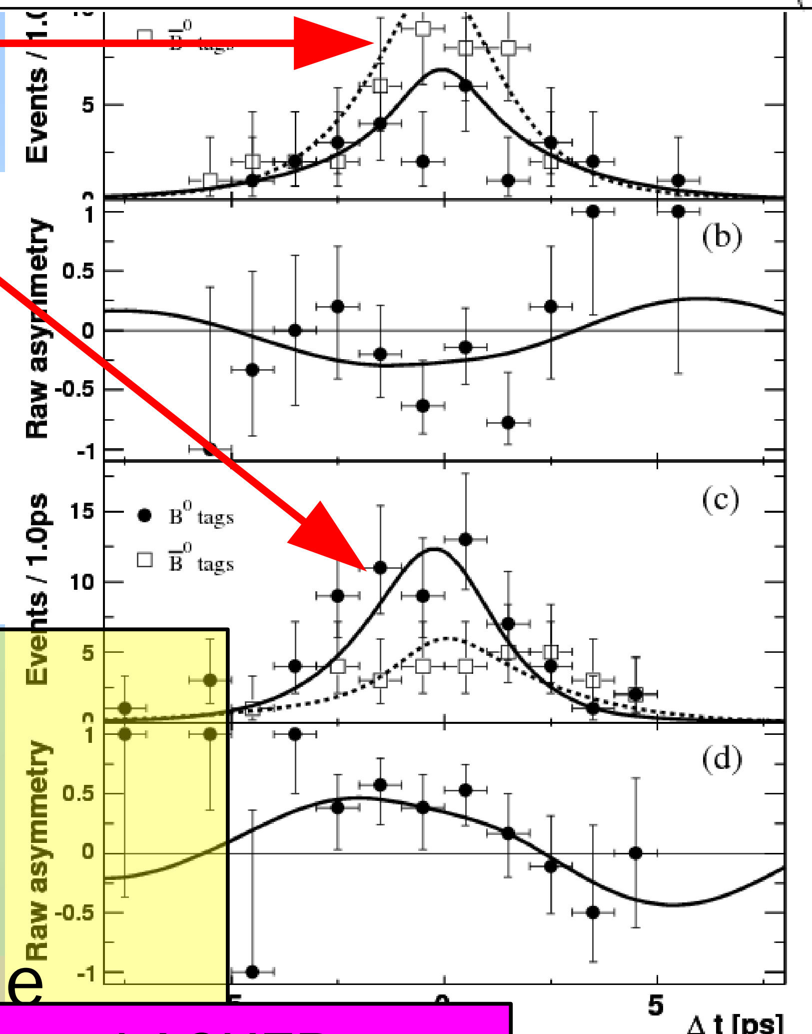
Browder et al., PRD 61 (2000) 054009

The ambiguity – $D^*D^*K_S$

$$f_\pm(\Delta t) \propto e^{-|\Delta t|/\tau_{B^0}} \left\{ (1 \mp \Delta\omega) \pm (1-2\omega) \times \left[\eta_y \frac{J_c}{J_0} \cos(\Delta m_d \Delta t) - \left(\frac{2J_{s1}}{J_0} \sin 2\beta + \eta_y \frac{2J_{s2}}{J_0} \cos 2\beta \right) \sin(\Delta m_d \Delta t) \right] \right\}, \quad (4)$$

η_y (Dalitz half-plane) +1 -1



$$\frac{J_c}{J_0} = 0.76 \pm 0.18(\text{stat}) \pm 0.07(\text{syst})$$

$$\frac{2J_{s1}}{J_0} \sin 2\beta = 0.10 \pm 0.24(\text{stat}) \pm 0.06(\text{syst})$$

$$\frac{2J_{s2}}{J_0} \cos 2\beta = 0.38 \pm 0.24(\text{stat}) \pm 0.05(\text{syst})$$

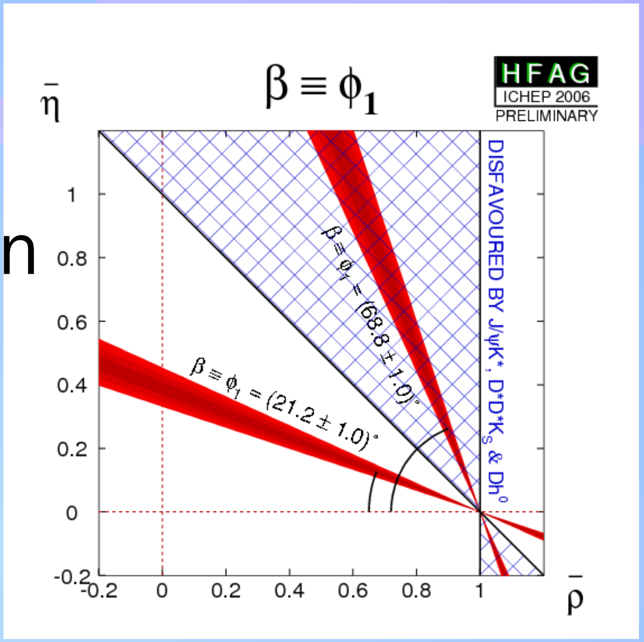
>0 from theory, but ...

- structure in D^*D^*?
- structure in D^*K_S?

theoretical re-examination desirable

LACKER

The ambiguity



All three modes point to SM solution

- Qualitative conclusion easy, but
- Quantitatively very difficult!

To do a really good job need some hard work on hadronic phenonema

- Kπ S-wave in J/ψ K*
- contributions to $D^*D^*K_S$ Dalitz plot
- $D\to K_S\pi^+\pi^-$ model

These & very similar questions reoccur

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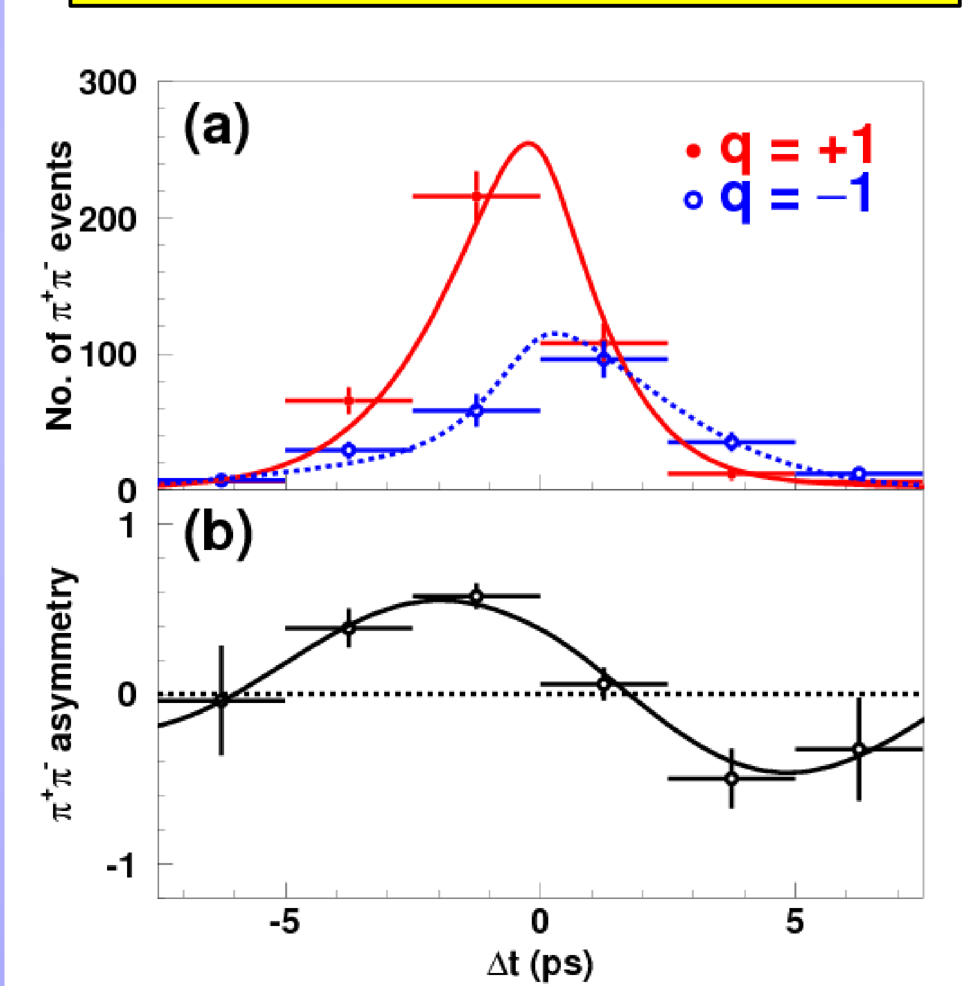
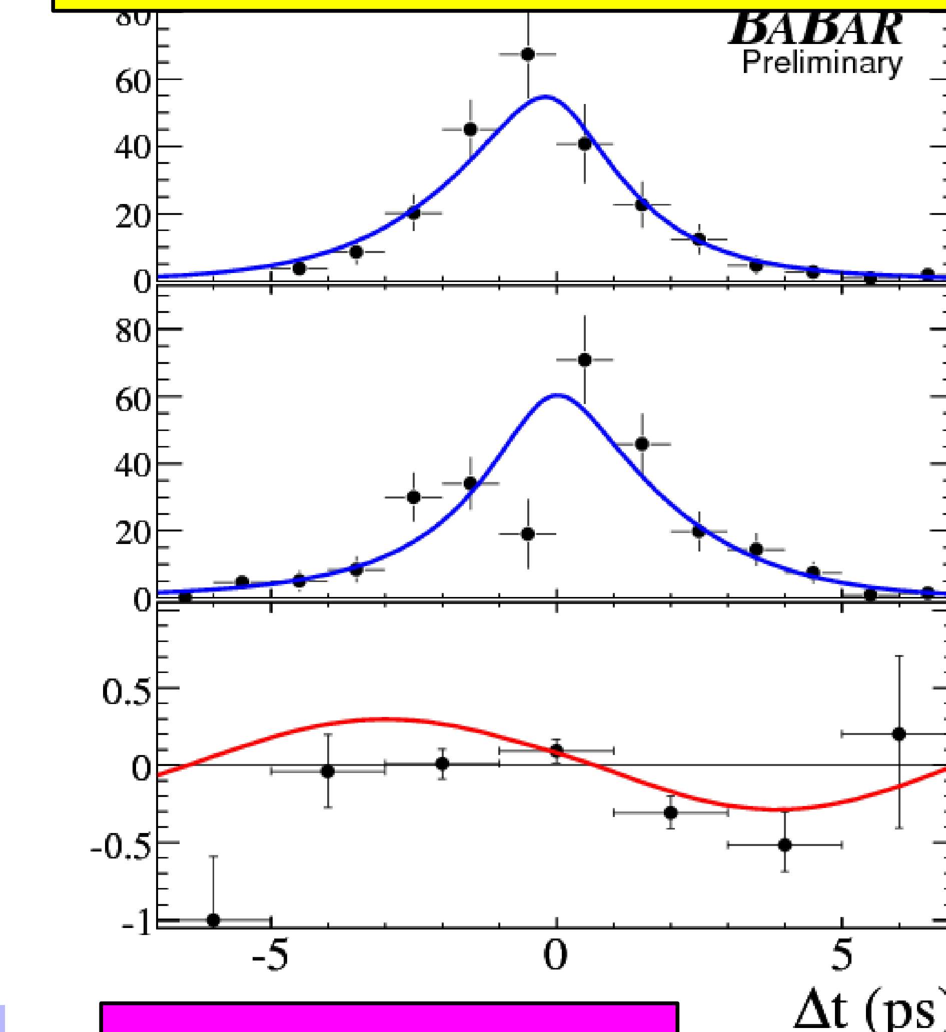
$\alpha \equiv \varphi_2$ —— ππ

BELLE hep-ex/0608035 N(BB)=532m



BABAR hep-ex/0607106 N(BB)=350m

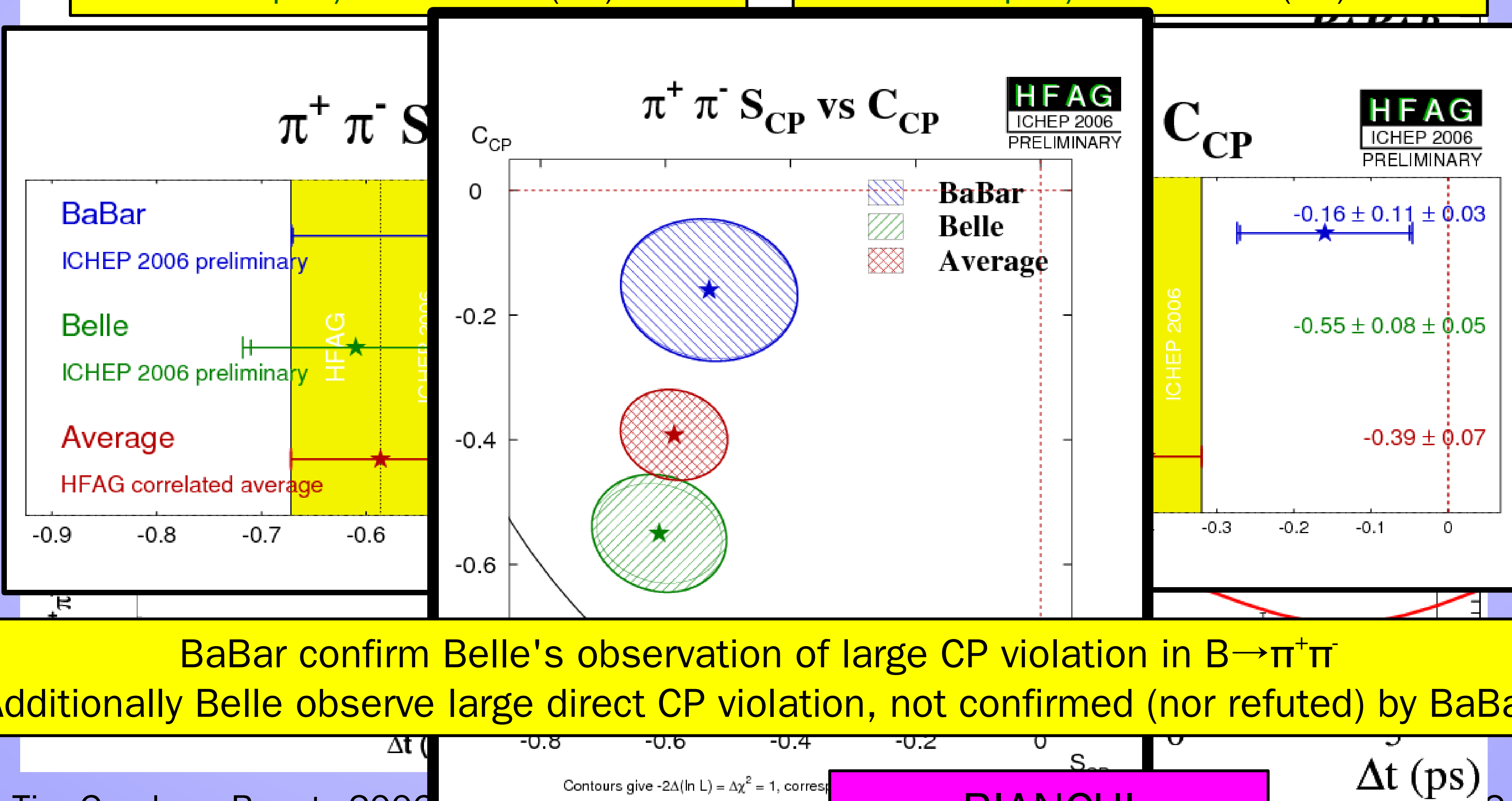


BIANCHI

$\alpha \equiv \varphi_2$ —— ππ

BELLE hep-ex/0608035 N(BB)=532m

BABAR hep-ex/0607106 N(BB)=350m



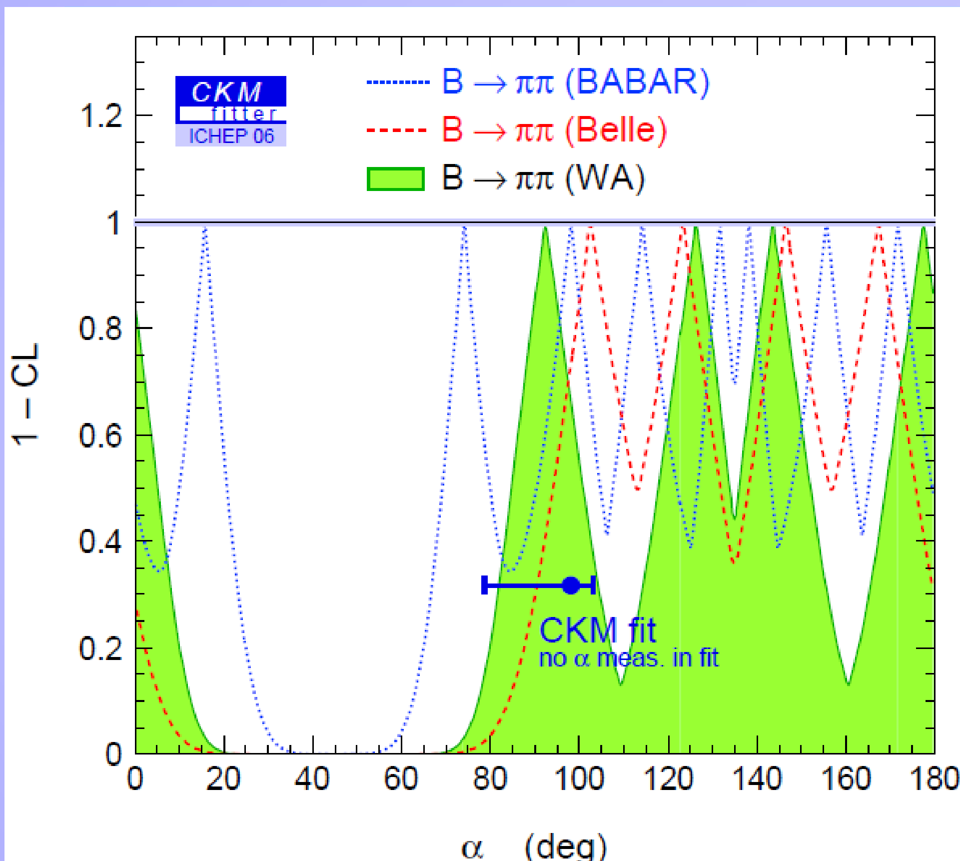
BaBar confirm Belle's observation of large CP violation in $B \rightarrow \pi^+\pi^-$

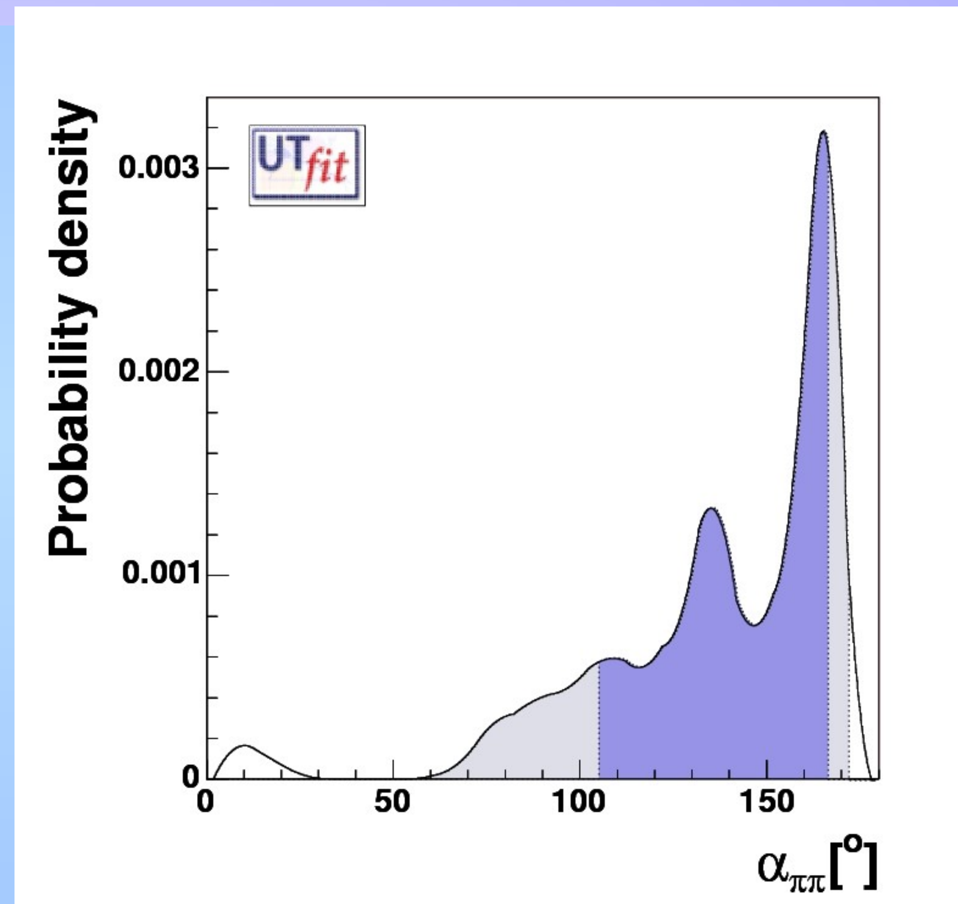
Additionally Belle observe large direct CP violation, not confirmed (nor refuted) by BaBar

BIANCHI

M.Gronau & D.London, PRL 65 (1990) 3381

$\alpha \equiv \varphi_2$ —— ππ Isospin analysis





Different statistical treatments ⇔ surprisingly different answers

BIANCHI, T'JAMPENS

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Statistics

Frequentist: probability **about the data** (randomness of measurements), given the model

$$P(\text{data}|\text{model})$$

[only repeatable events (Sampling Theory)]

Hypothesis testing: given a model, assess the **consistency** of the data with a particular parameter value → 1-CL curve (by varying the parameter value)

Bayesian: probability **about the model** (degree of belief), given the data

$$P(\text{model}|\text{data}) \propto \text{Likelihood}(\text{data},\text{model}) \times \textbf{Prior(model)}$$

$P(\text{data}|\text{model}) \neq P(\text{model}|\text{data})$:

model: Male or Female
data: pregnant or not pregnant

P (pregnant | female) ~ 3%

but

P (female | pregnant) >>>3%

OTHER "PRIOR" EVENTS IMPORTANT!

Sir Francis Bacon

Father of the scientific method:
inductive reasoning & hypothesis testing

"Histories make men wise; poets, witty;
the mathematics, subtile;
natural philosophy, deep;
moral, grave;
logic and rhetoric, able to contend."

(able to contend ~ contentious)

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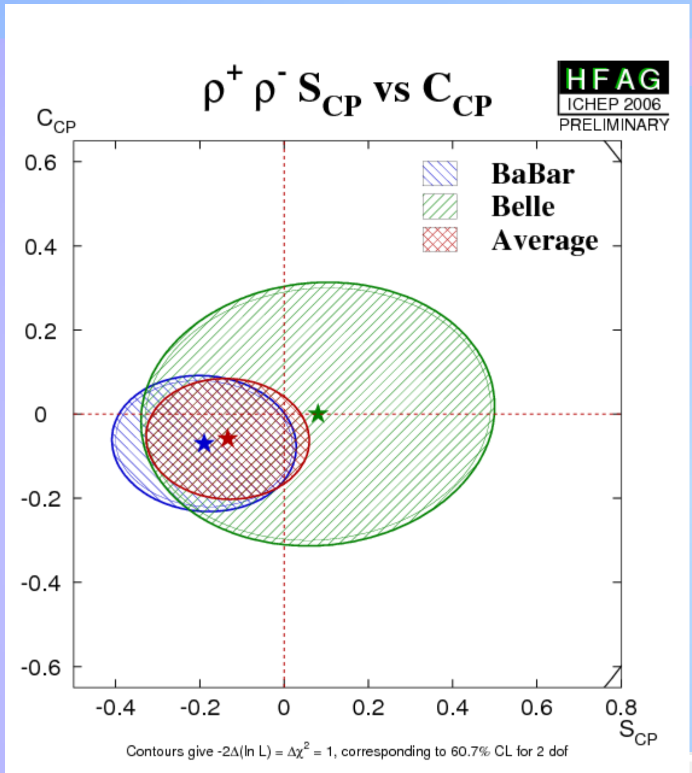
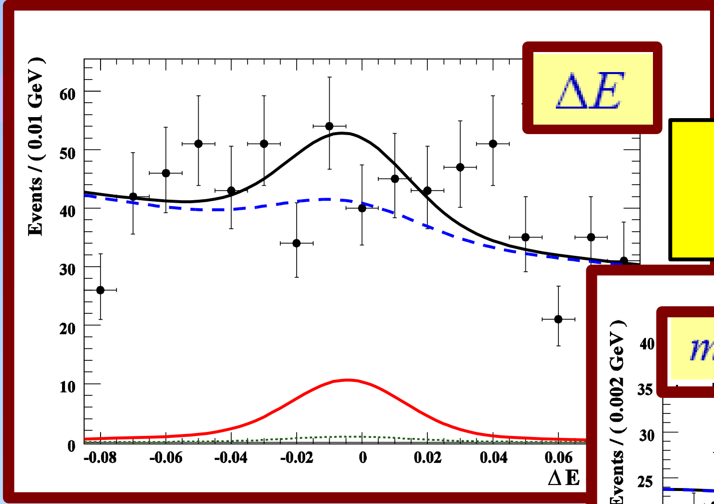
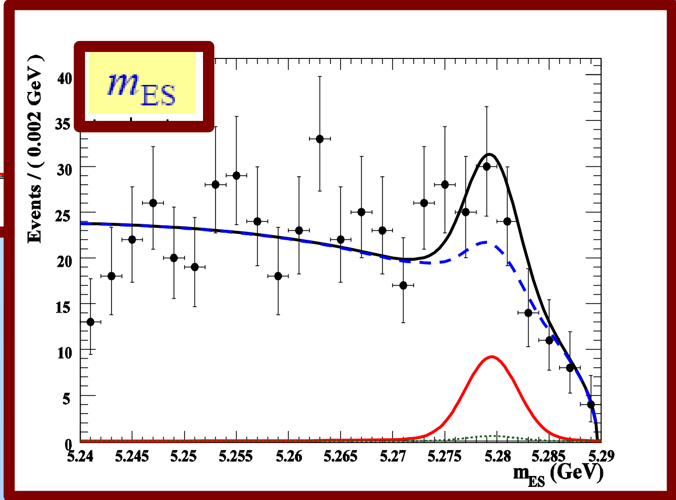
$\alpha \equiv \phi_2$ —— ρρ Isospin analysis





BABAR hep-ex/update
N(BB)=XXXm



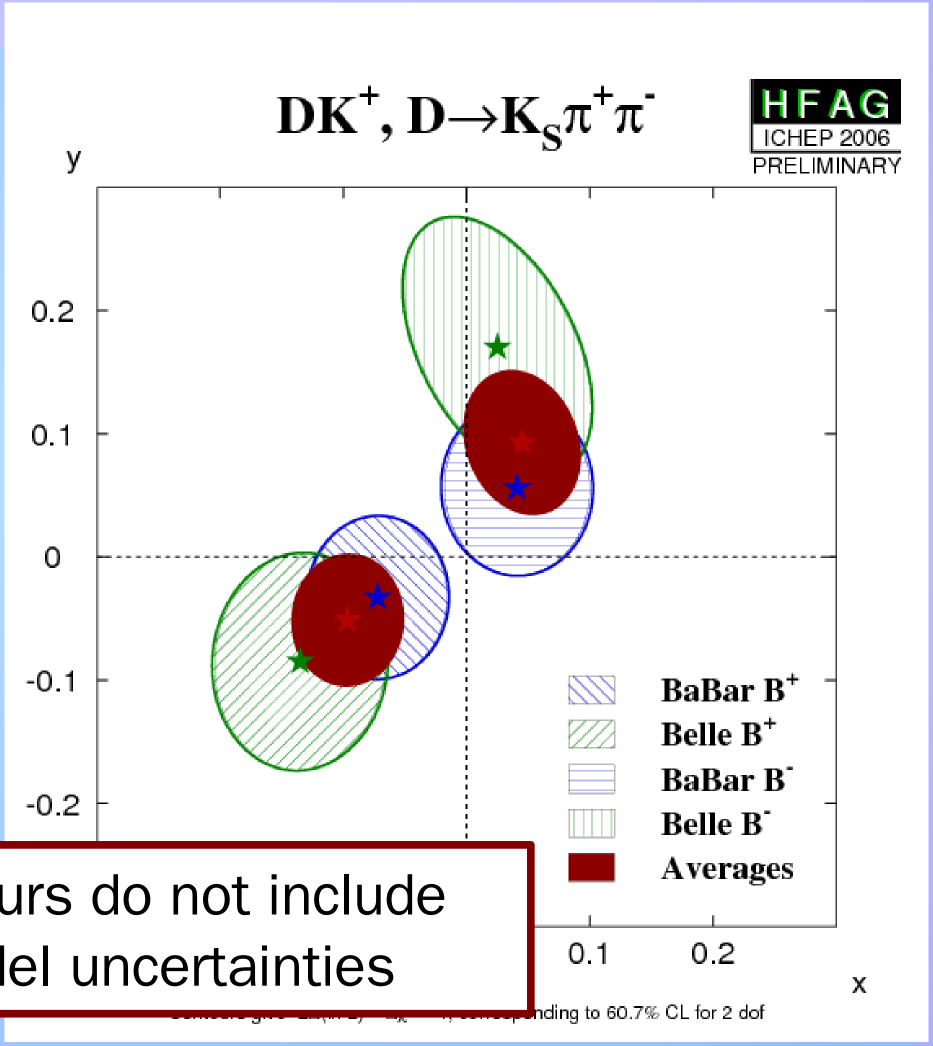
Input from HFAG – rare decays

$BR(B^0 \to \rho^+\rho^-) = 23.1^{+3.1}_{-3.2}$	
$BR(B^+ \to \rho^+\rho^0) = 18.2 \pm 3.0$	$A_{CP}(B^+ \to \rho^+\rho^0) = -0.08 \pm 0.13$
$BR(B^0 \to \rho^0\rho^0) = 1.2 \pm 0.5$	$A_{CP}(B^0 \to \rho^0\rho^0)$ NOT MEASURED YET

BIANCHI, ZUPAN

$\gamma \equiv \varphi_3$ —— DK methods

- Current best precision from $D \rightarrow K_s \pi^+ \pi^-$ (Dalitz method)
- Associated model uncertainty
- Very difficult to reduce without information from CP tagged D mesons (CLEO-c)



Contours do not include model uncertainties

TRABELSI, ZUPAN

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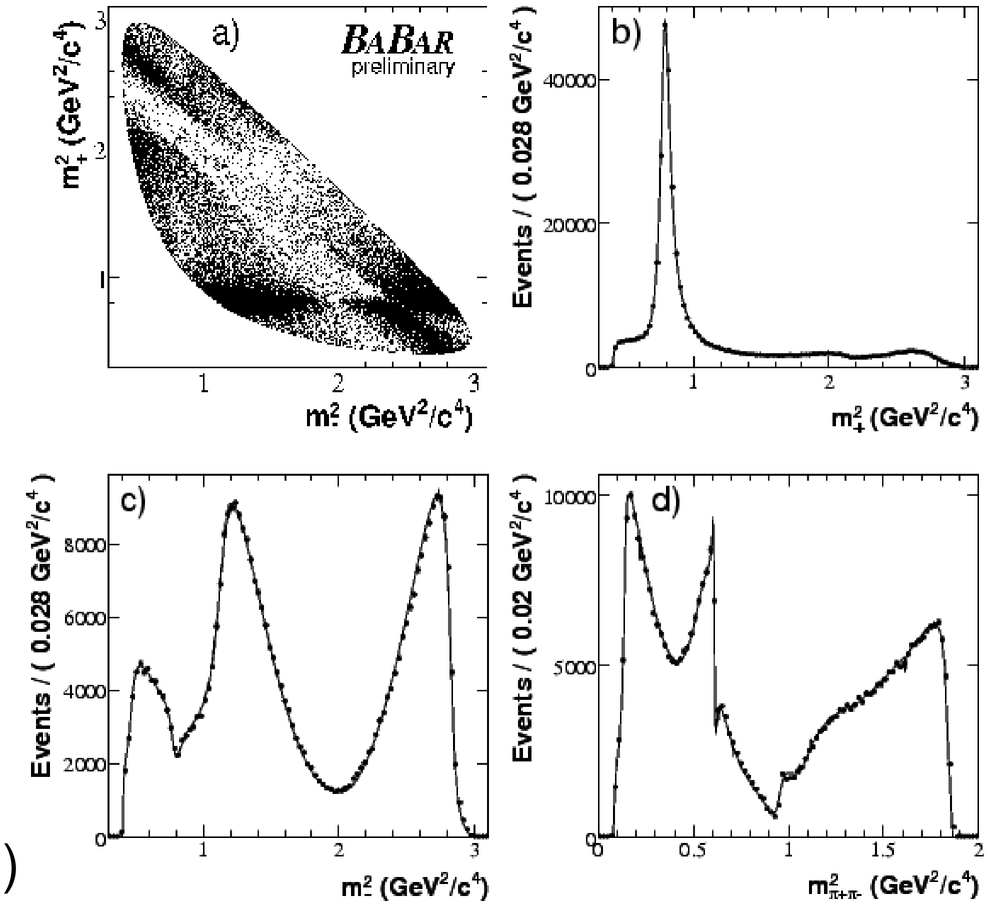
$\gamma \equiv \varphi_3$ —— $K_S\pi^+\pi^-$ model

BABAR hep-ex/0607104 N(BB)=347m

Component	$Re\{a_r e^{i\phi_r}\}$	$Im\{a_r e^{i\phi_r}\}$	Fit fraction (%)
$K^*(892)^-$	-1.223 ± 0.011	1.3461 ± 0.0096	58.1
$K_0^*(1430)^-$	-1.698 ± 0.022	-0.576 ± 0.024	6.7
$K_2^*(1430)^-$	-0.834 ± 0.021	0.931 ± 0.022	3.6
$K^*(1410)^-$	-0.248 ± 0.038	-0.108 ± 0.031	0.1
$K^*(1680)^-$	-1.285 ± 0.014	0.205 ± 0.013	0.6
$K^*(892)^+$	0.0997 ± 0.0036	-0.1271 ± 0.0034	0.5
$K_0^*(1430)^+$	-0.027 ± 0.016	-0.076 ± 0.017	0.0
$K_2^*(1430)^+$	0.019 ± 0.017	0.177 ± 0.018	0.1
$\rho(770)$	1	0	21.6
$\omega(782)$	-0.02194 ± 0.00099	0.03942 ± 0.00066	0.7
$f_2(1270)$	-0.699 ± 0.018	0.387 ± 0.018	2.1
$\rho(1450)$	0.253 ± 0.038	0.036 ± 0.055	0.1
Non-resonant	-0.99 ± 0.19	3.82 ± 0.13	8.5
$f_0(980)$	0.4465 ± 0.0057	0.2572 ± 0.0081	6.4
$f_0(1370)$	0.95 ± 0.11	-1.619 ± 0.011	2.0
σ	1.28 ± 0.02	0.273 ± 0.024	7.6
σ'	0.290 ± 0.010	-0.0655 ± 0.0098	0.9

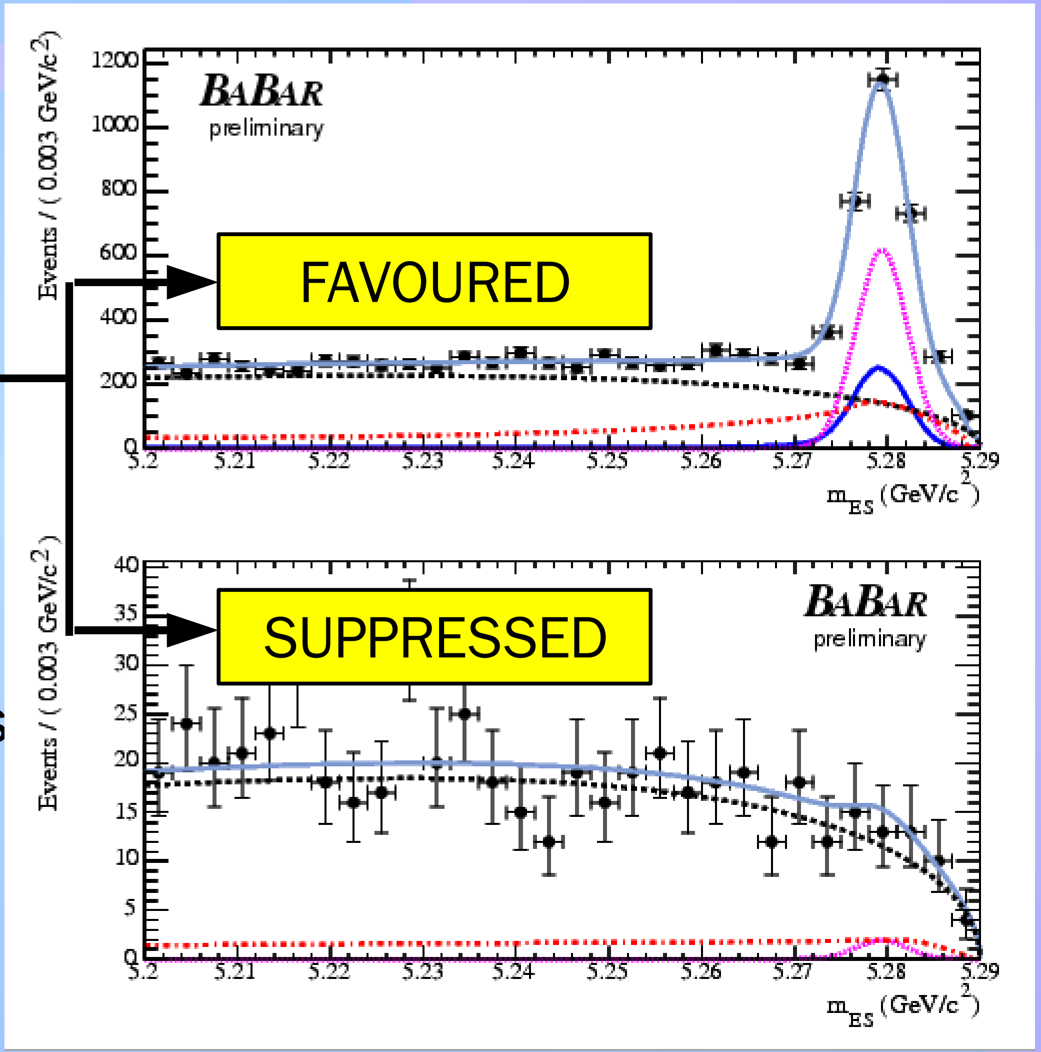


~390,000 $D^{*+} \to D\pi^+$ decays (270/fb)

χ^2/ndf ~ 1.3

$\gamma \equiv \varphi_3$ —— DK methods

- Best approach is to combine many different B & D decays
- New BaBar results with $D \to K^+\pi^-\pi^0$
- No signal for suppressed amplitude yet ⇔ r_B smaller than expected?
- Await results on new channels



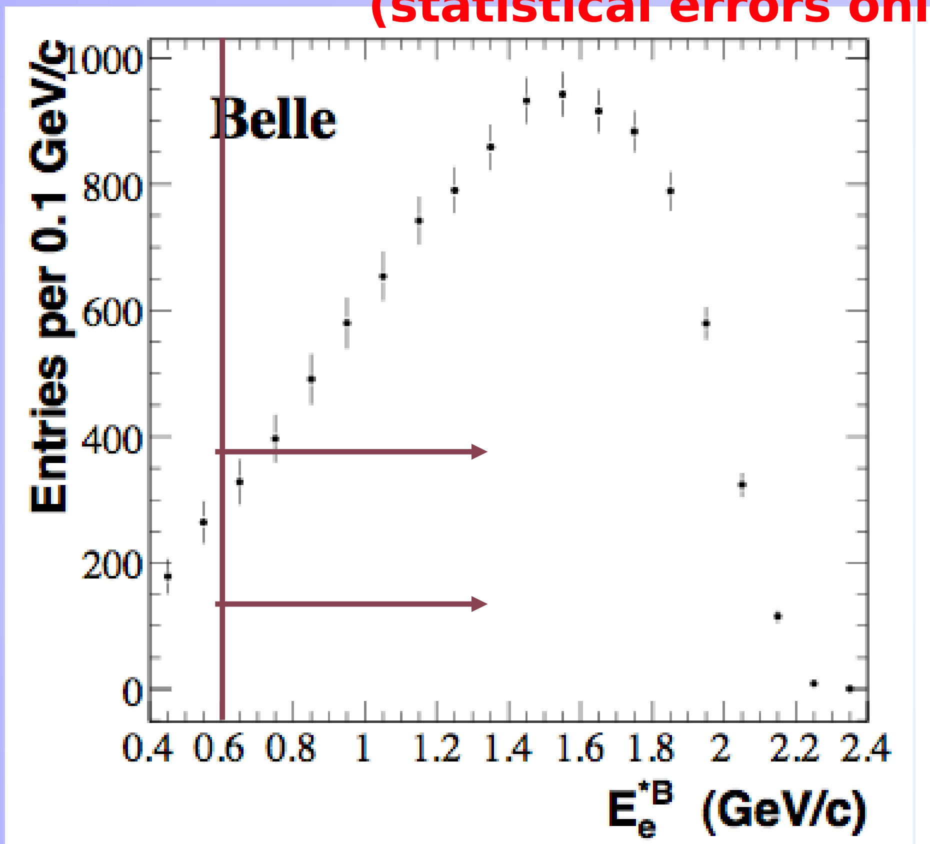
TRABELSI, XIE, ZITO, ZUPAN

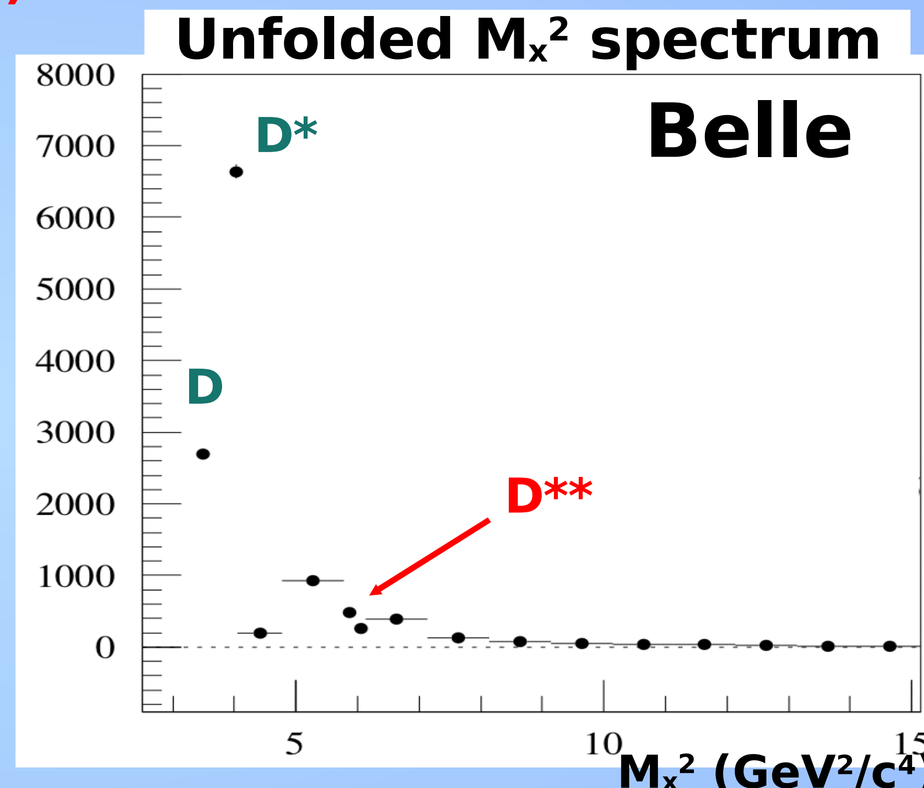
V_{cb} & V_{ub}

"If a man's wit be wandering, let him study the mathematics"

V_{cb} – Inclusive

(statistical errors only)





$|V_{cb}| = (41.93 \pm 0.65_{fit} \pm 0.48_{\alpha_s} \pm 0.63_{th})\times 10^{-3}$ Kinetic scheme

$|V_{cb}| = (41.5 \pm 0.5_{fit} \pm 0.2)\times 10^{-3}$ 1S scheme

Error: 1–2%

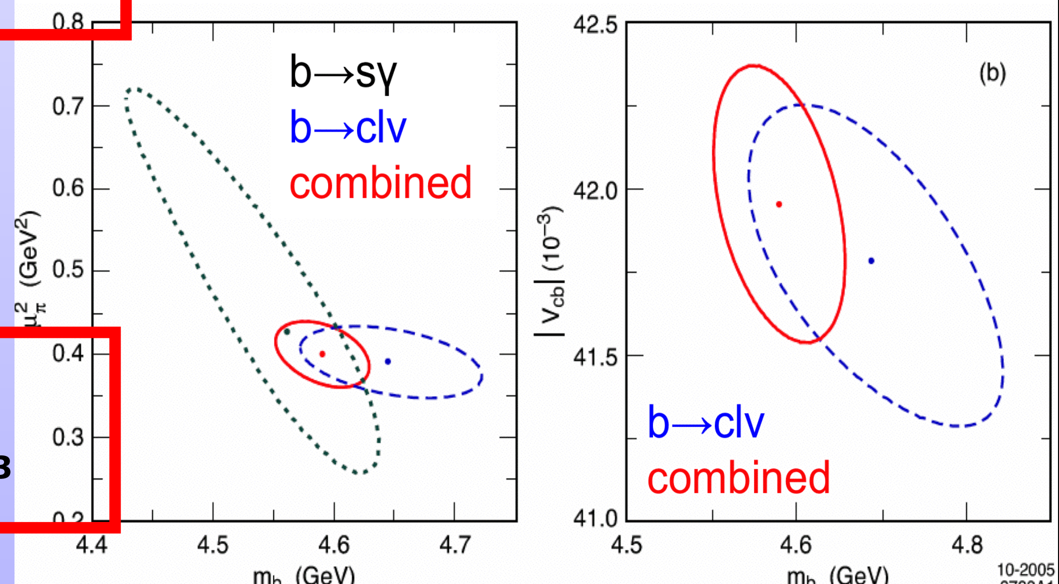
V_{cb} – Inclusive

Global fit Kinetic scheme expansion - all experiments
(Buchmuller, Flaecher PRD73:073008 (2006))
Belle new measurements missing

			Exp	HQ	Γ_{sl}
$\|V_{cb}\|$	=	(41.96	± 0.23	± 0.35	± 0.59) 10^{-3}
m_b	=	4.590	± 0.025	± 0.030	GeV
m_c	=	1.142	± 0.037	± 0.045	GeV
μ_π^2	=	0.401	± 0.019	± 0.035	GeV^2
μ_G^2	=	0.297	± 0.024	± 0.046	GeV^2
ρ_D^3	=	0.174	± 0.009	± 0.022	GeV^3
ρ_{LS}^3	=	-0.183	± 0.054	± 0.071	GeV^3
BR_{clv}	=	10.71	± 0.10	± 0.08	%

Inclusive modes:

$$|V_{cb}|=(41.96\pm0.23_{exp}\pm0.35_{HQE}\pm0.59_{\Gamma_{SL}})10^{-3}$$



δV_{cb} @ 2%

m_b < 1% ← crucial for V_{ub}

m_c @ 5%

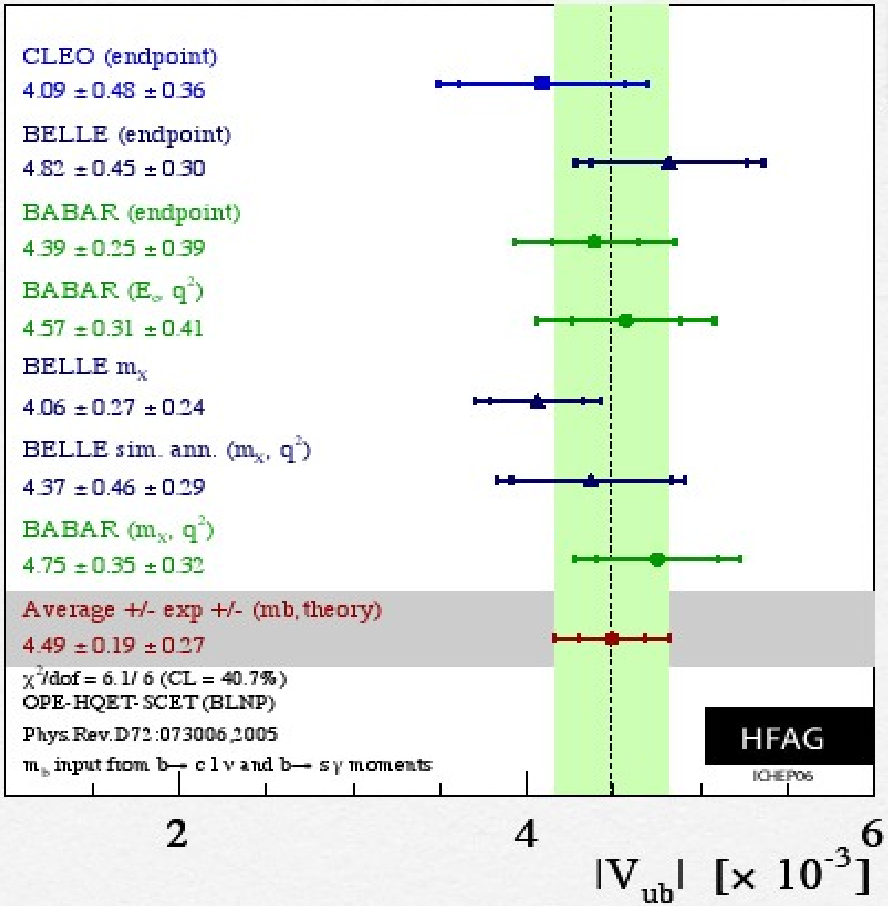
Exclusive modes:

$$|V_{cb}|^{excl}=(39.4\pm0.9_{exp}\pm1.5_{theo})10^{-3}$$

BARBERIO, PAZ

V_{ub} – Inclusive

Inclusive $|V_{ub}|$

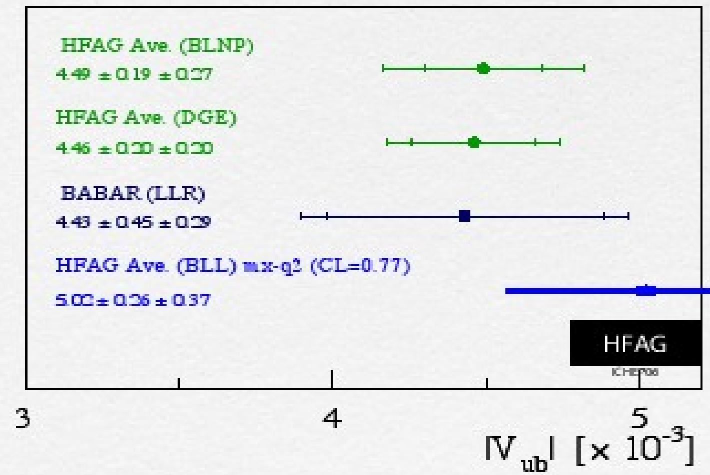


BLNP

$$|V_{ub}| = (4.49 \pm 0.19 \pm 0.27) \times 10^{-3}$$

- C.L. = 41%
- 7.3% uncertainty

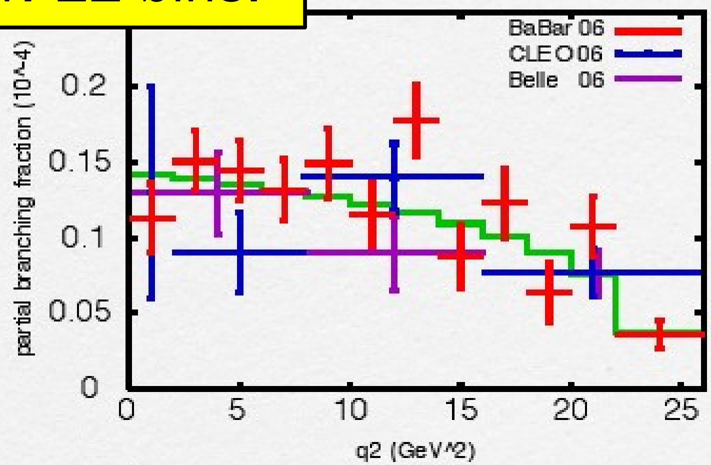
$\pm 2.2_{stat} \pm 2.8_{exp} \pm 1.9_{b\to c} \pm 1.6_{b\to u}$
$\pm 4.2_{HQE} \pm 3.8_{sub\ SF} \pm 1.9_{WA}$ — more exp'tal scrutiny



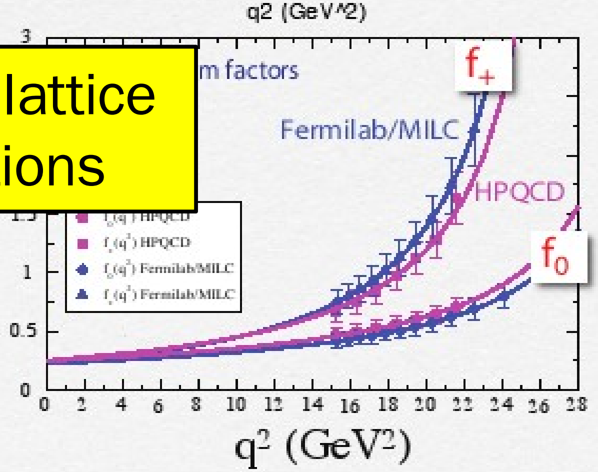
V_{ub} – Exclusive ($B \to \pi l \nu$)

Exclusive: $|V_{ub}|$

BaBar: 12 bins!



Improved lattice calculations



Leverage larger data range?

Arnesen, Grinstein, Rothstein, Stewart
Becher, Hill

- data already constrains ff shape

Lattice statistical uncertainties:

- correlations clear, coeff's unknown
- quark mass (chiral) extrapolation procedure)

Combine chiral extrapolation + data fit

- $|V_{ub}|$ = normalization!
- preliminary indications (HPQCD ff's)
  - $\sigma_{expt} \oplus \sigma_{latt\_stat} \lesssim 5\%$

$\Rightarrow$ once 2 loop pert th'y in hand comparable precision to inclusive

GIBBONS, DAVIES, PAZ

Discovery Mantra

Hadron colliders are discovery machines, lepton colliders are for precision measurements

Δm_s

Sensitivity 31.3/ps

>5σ

Limits

- $[17.56, 17.96]\mathrm{ps}^{-1}$ @ 90% C.L.
- $[16.51, 18.00]\mathrm{ps}^{-1}$ @ 95% C.L.

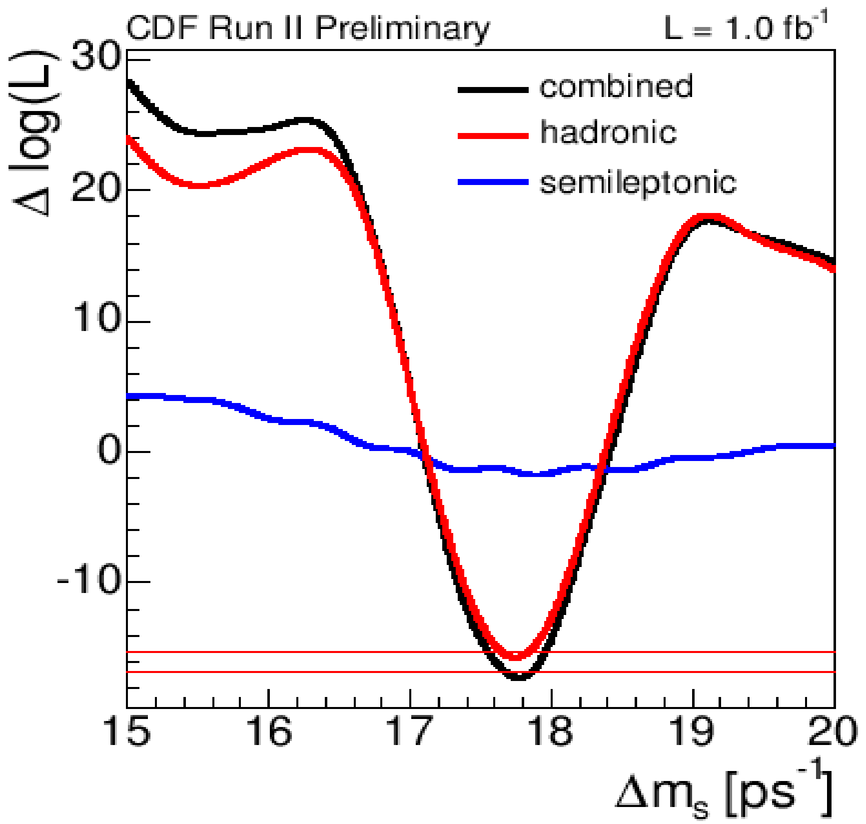
Consistent with SM

- $18.3^{+6.5}_{-1.5}\ \mathrm{ps}^{-1}$ EPS 2005

Agrees with 1^{st} measurement

- $17.31^{+0.33}_{-0.18} \pm 0.07\ \mathrm{ps}^{-1}$

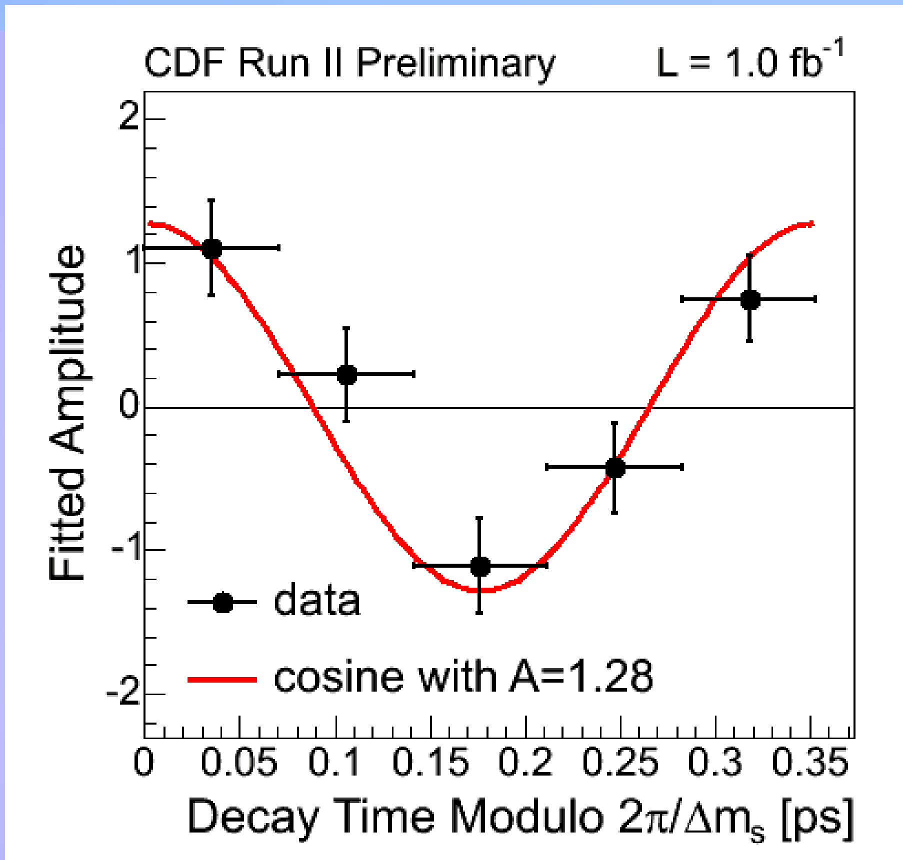
PRL **97**, 062003 (2006)

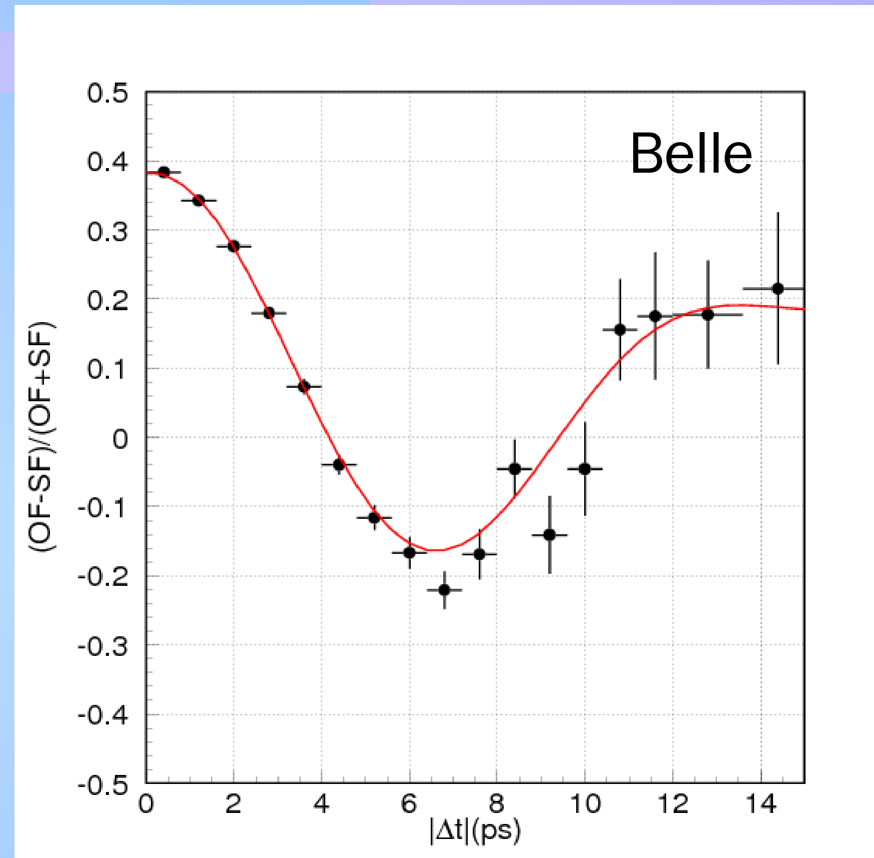


$$\Delta m_s = 17.77 \pm 0.10(stat.) \pm 0.07(syst.)\ \mathrm{ps}^{-1}$$

Systematic dominated by the *ct* scale, any other effect very small

Δm_s & Δm_d





$\Delta m_s = (17.77 \pm 0.10 \pm 0.07)\ \mathrm{ps}^{-1}$

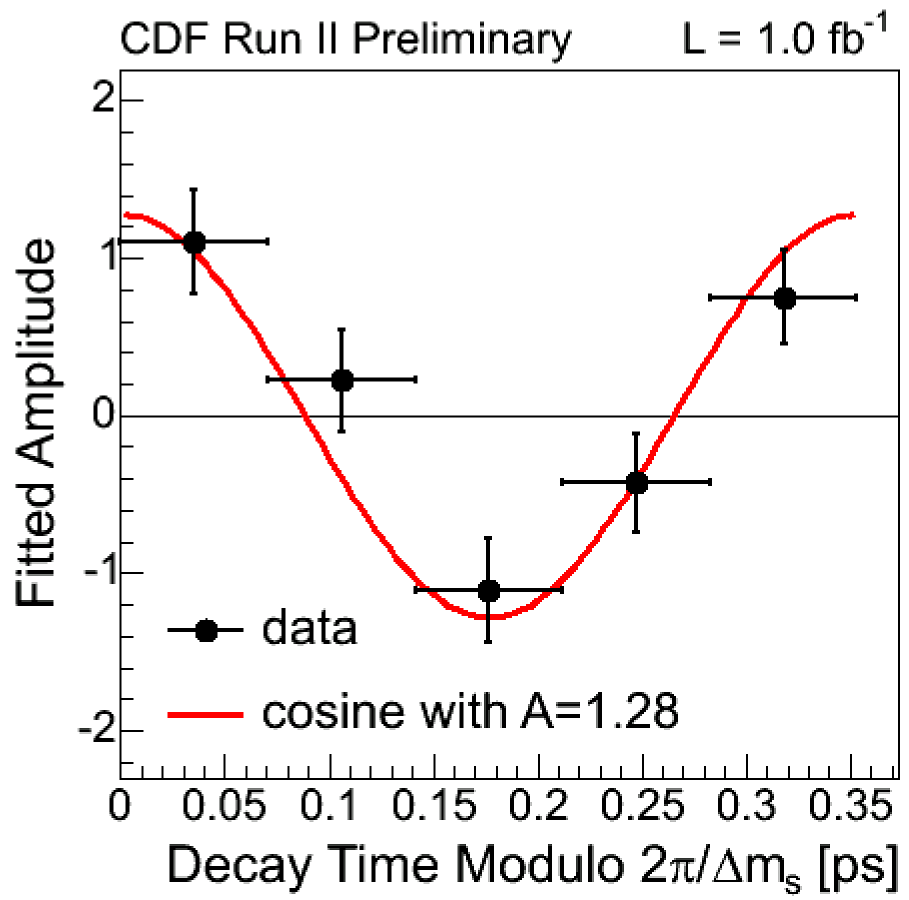
$\Delta m_d = (0.507 \pm 0.005)\ \mathrm{ps}^{-1}$ (PDG 2006)

$|V_{td}/V_{ts}| = 0.2060 \pm 0.0007\ (\mathrm{exp})\ {}^{+0.0081}_{-0.0060}\ (\mathrm{th})$

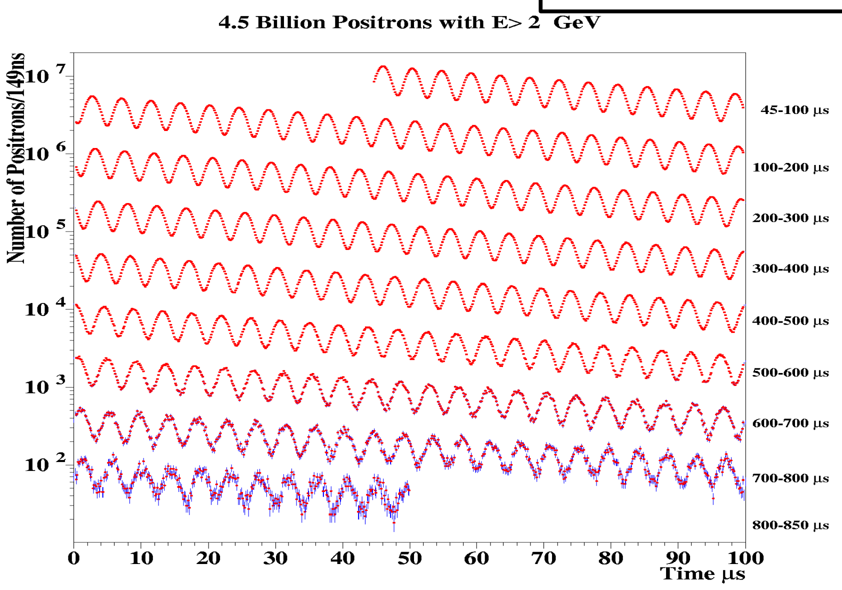
BELLONI, DAVIES

Δm_s – The end of the line?

Yes, this is very pretty ....



μ (g – 2)



... but why not aim for this?

Obviously, same precision not necessary
yet Δm_s poster child for B physics at hadron machines

What comes next?

- We have measurements (to varying degrees of precision) of all UT sides and angles
- No clear discrepancy with the SM

<u>Success of CKM description</u>

- Why should we improve the precision?

- We still have all the unsolved problems of the SM
  - hierarchy problem → TeV scale NP → flavour problem
  - baryon asymmetry of the universe
  - neutrino masses
  - 3 quark & lepton generations

Are surprises possible?

- Are there measurements which could have a comparable impact to $K_L \to \pi^+\pi^-$?
  - Inconsistent CPV phenomena in (eg.) $b \to sss$
  - New FCNCs
  - Unpolarised photons in (eg.) $b \to s\gamma$
  - Large CPV in $A_{SL}(B_s)$ &/or φ_s
  - Enhanced v. rare decays, (eg.) $B_s \to \mu\mu$
  - CP violation in charm
  - τ lepton flavour violation &/or CP violation
  - …

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The FCNC Matrix

th. error $\lesssim 10\%$
(grey oval) = exp. error $\lesssim 10\%$
(white oval) = exp. error $\sim 30\%$

FLAVOUR COUPLING:

ELECTROWEAK STRUCTURE	$b \to s$ $(\sim\lambda^2)$	$b \to d$ $(\sim\lambda^3)$	$s \to d$ $(\sim\lambda^5)$
$\Delta F=2$ box	ΔM_{Bs}, $A_{CP}(B_s \to \psi\phi)$	ΔM_{Bd}, $A_{CP}(B_d \to \psi K)$	ΔM_K, ε_K
$\Delta F=1$ 4-quark box	$B_d \to \phi K$, $B_d \to K\pi$, ...	$B_d \to \pi\pi$, $B_d \to \rho\pi$, ...	ε'/ε, $K \to 3\pi$, ...
gluon penguin	$B_d \to X_s \gamma$, $B_d \to \phi K$, $B_d \to K\pi$, ...	$B_d \to X_d \gamma$, $B_d \to \pi\pi$, ...	ε'/ε, $K_L \to \pi^0 l^+ l^-$, ...
γ penguin	$B_d \to X_s l^+ l^-$, $B_d \to X_s \gamma$, $B_d \to \phi K$, $B_d \to K\pi$, ...	$B_d \to X_d l^+ l^-$, $B_d \to X_d \gamma$, $B_d \to \pi\pi$, ...	ε'/ε, $K_L \to \pi^0 l^+ l^-$, ...
Z^0 penguin	$B_d \to X_s l^+ l^-$, $B_s \to \mu\mu$, $B_d \to \phi K$, $B_d \to K\pi$, ...	$B_d \to X_d l^+ l^-$, $B_d \to \mu\mu$, $B_d \to \pi\pi$, ...	ε'/ε, $K_L \to \pi^0 l^+ l^-$, $K \to \pi\nu\nu$, $K \to \mu\mu$, ...
H^0 penguin	$B_s \to \mu\mu$	$B_d \to \mu\mu$	$K_{L,S} \to \mu\mu$

kaon physics

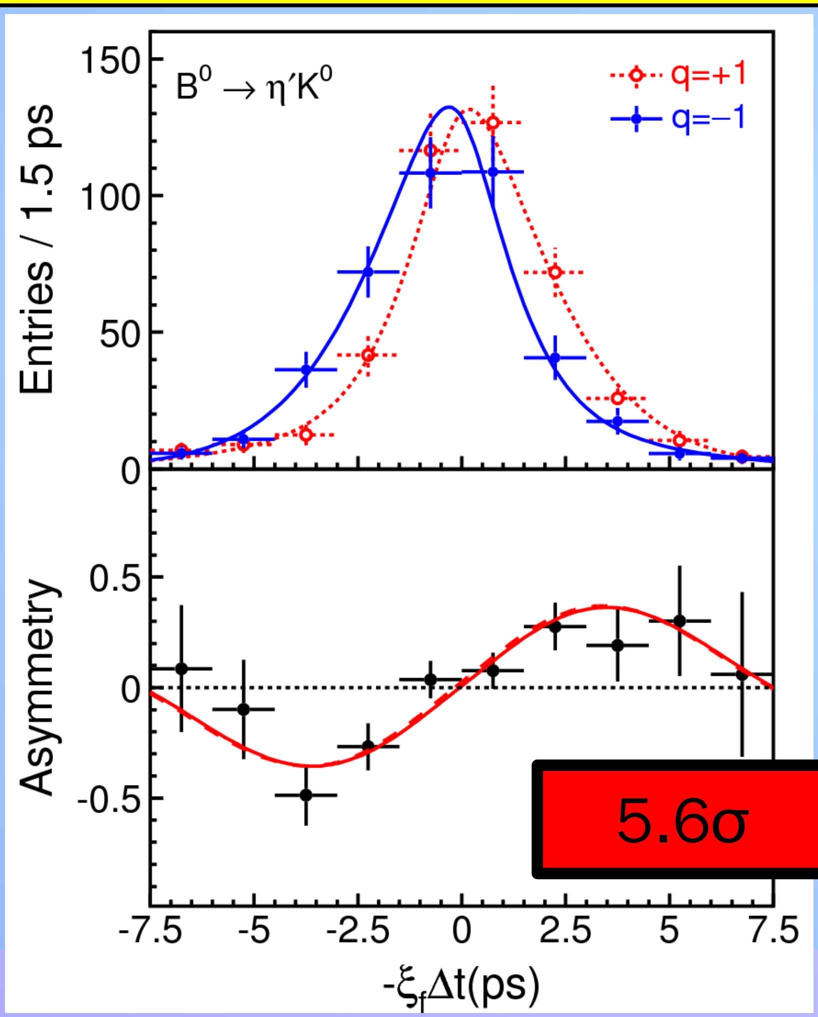
From G.Isidori, via O.Schneider

BEAUTY2003 panel discussion

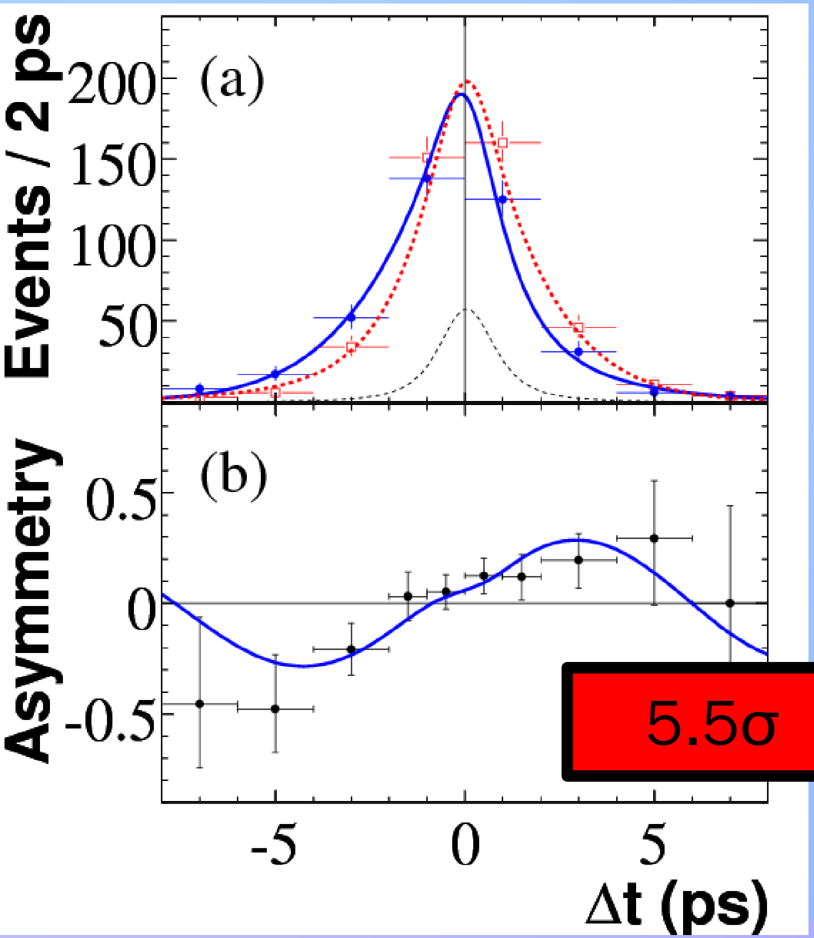
A Goldish Mode: $\eta' K_S$, etc

NEW!

BELLE hep-ex/0608039 N(BB)=532m



BABAR hep-ex/0609052 N(BB)=384m



USHIRODA

CP violation

CP violation has now been seen in

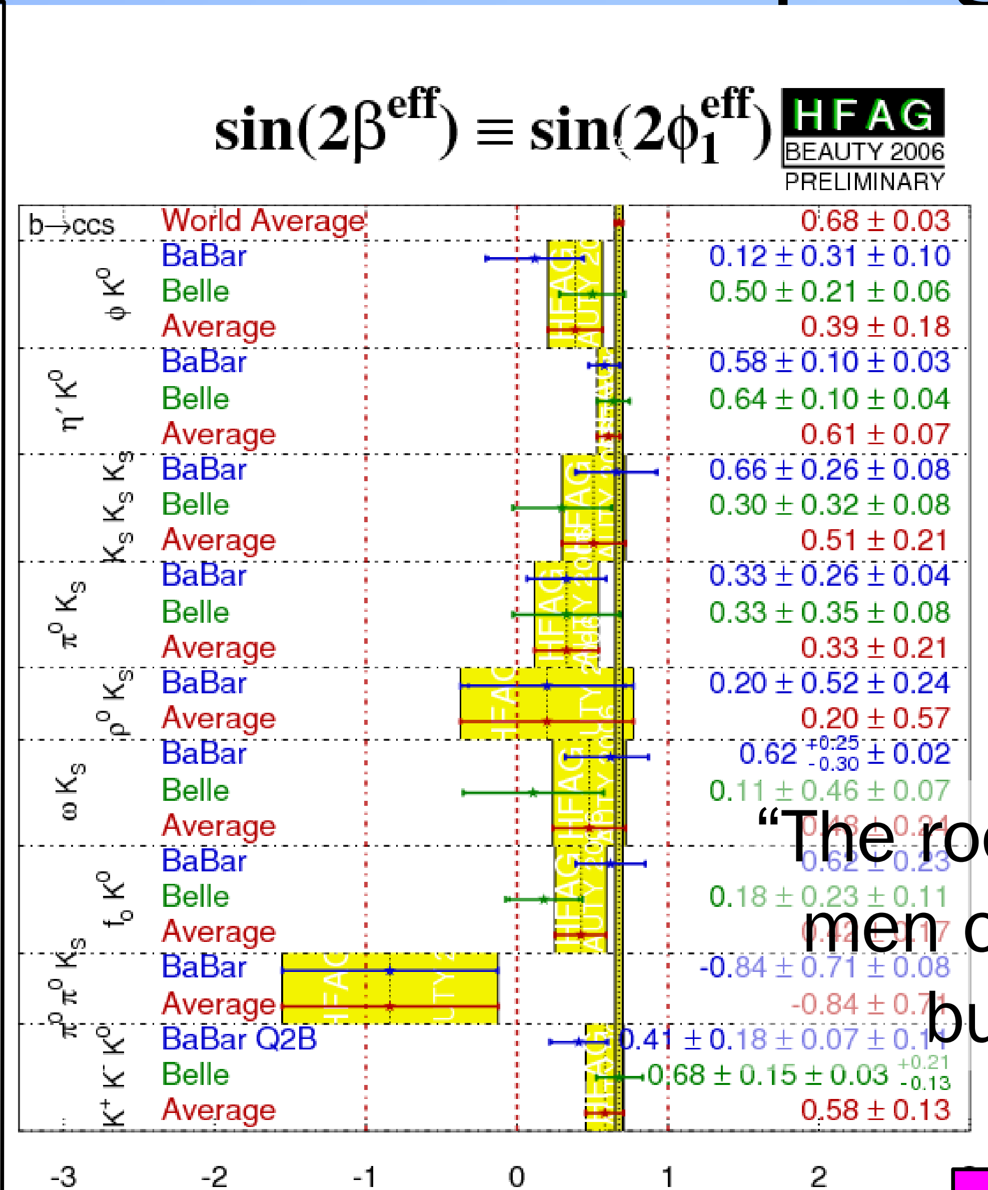
- $K^0\bar{K}^0$ mixing (ϵ_K)
- interference between s→uud and s→ddd decay amplitudes (ϵ')
- interference between $B^0\bar{B}^0$ mixing and
  - b→ccs decay amplitudes ($J/\psi K^0$)
  - b→uud decay amplitudes ($\pi^+\pi^-$)
  - b→sss decay amplitudes ($\eta' K^0$)
- interference between b→uud and b→duu decay amplitudes ($\pi^+\pi^-$)
- interference between b→suu and b→uus decay amplitudes ($K^+\pi^-$)

ALL CONSISTENT WITH KM MECHANISM

[Not yet seen in charged particle decays, baryons, leptons, ...]

Hadronic b → s penguins

BABAR: Time-dependent DP analysis of $B \to K^+K^-K^0$

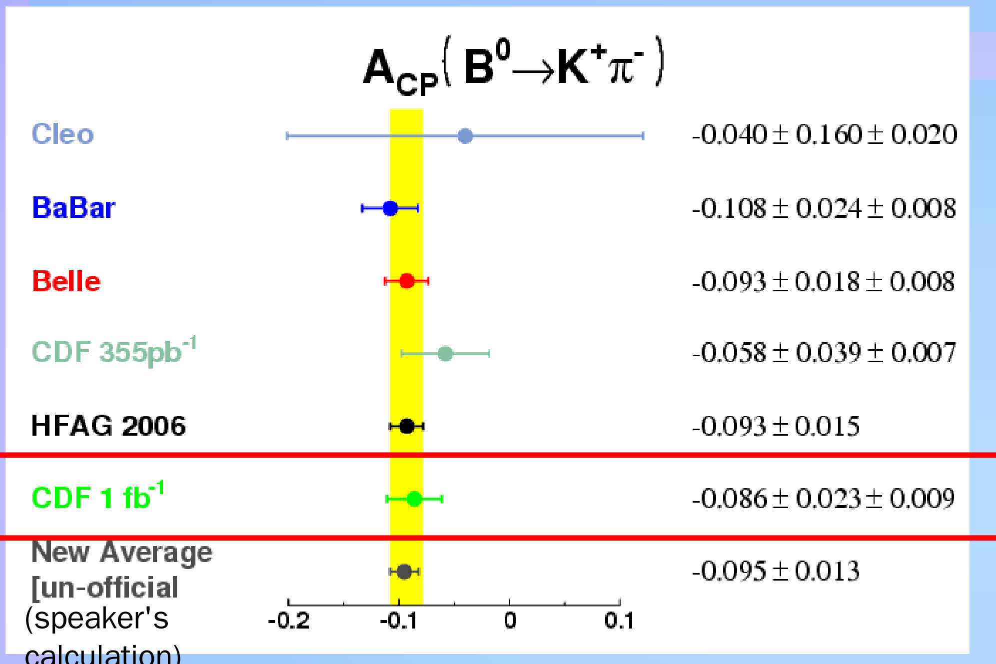


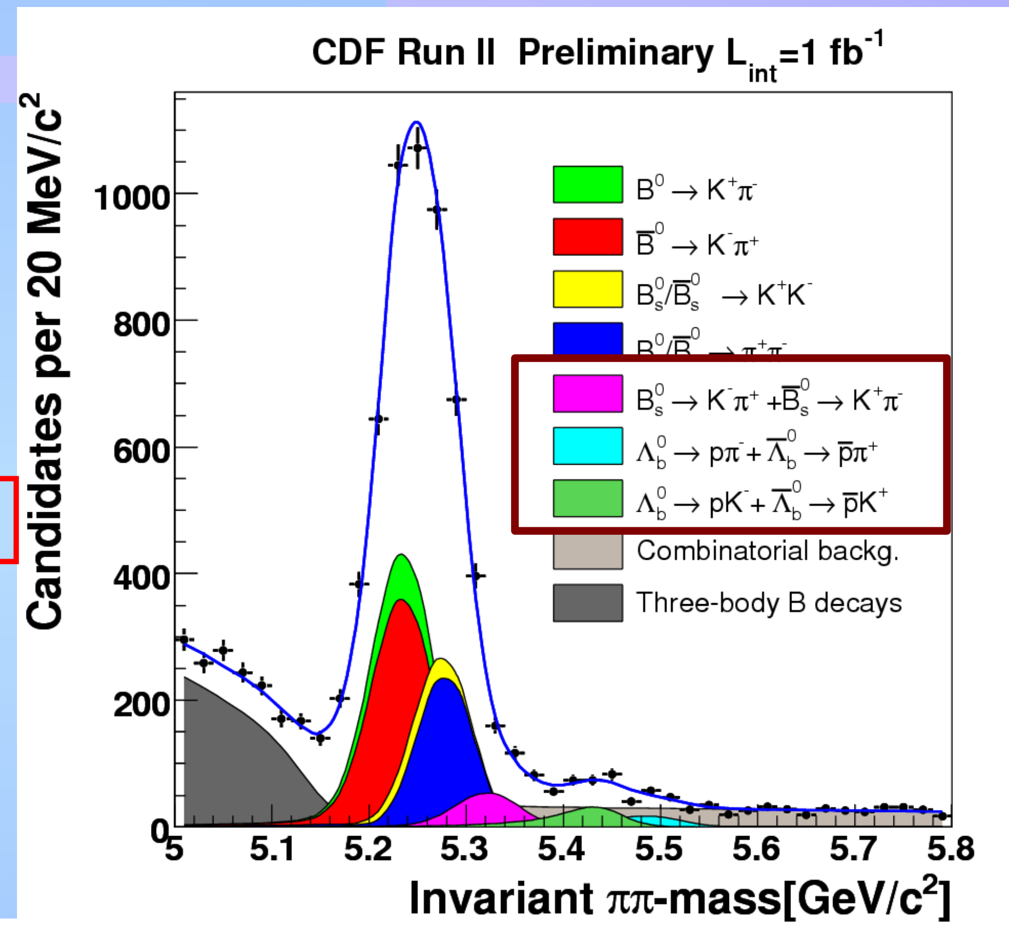
"The root of all superstition is that men observe when a thing hits, but not when it misses"

WE NEED MORE DATA

USHIRODA

$B_{(s)} \rightarrow h^+h'^-$





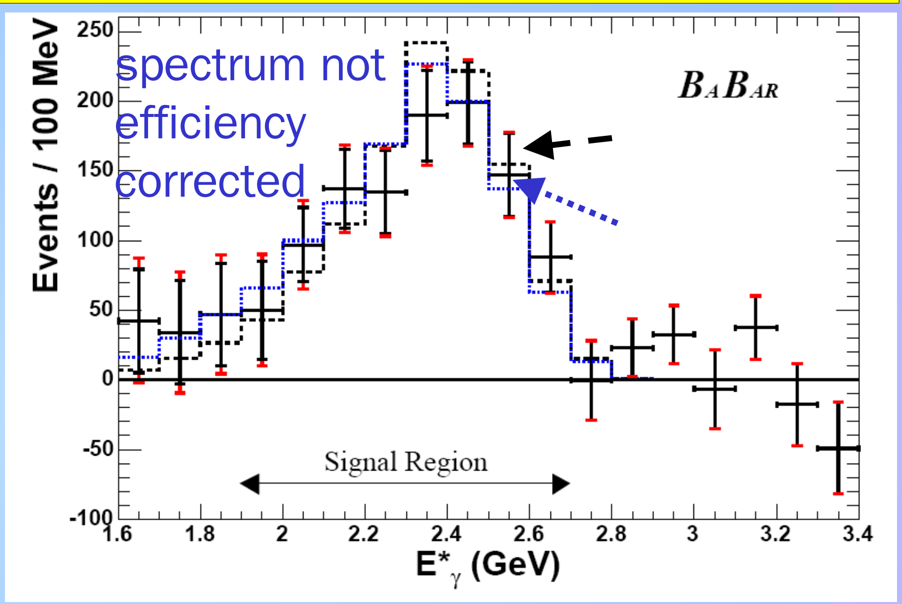
$A_{CP}(B_s \rightarrow K\pi) = 0.39 \pm 0.15\ (stat.) \pm 0.08\ (syst.)$

New light on the "Kπ puzzle" from B_s decays – $B_s \rightarrow K_S\pi^0$ important?

BENEKE, MORELLO

Radiative B decays

hep-ex/0607071 (preliminary, sub. to PRL)



Four of Standard Model predictions:

- No tree-level FCNC
- top & W (Z,H) heaviest particles
- weak interactions are V-A
- only one CP violating phase

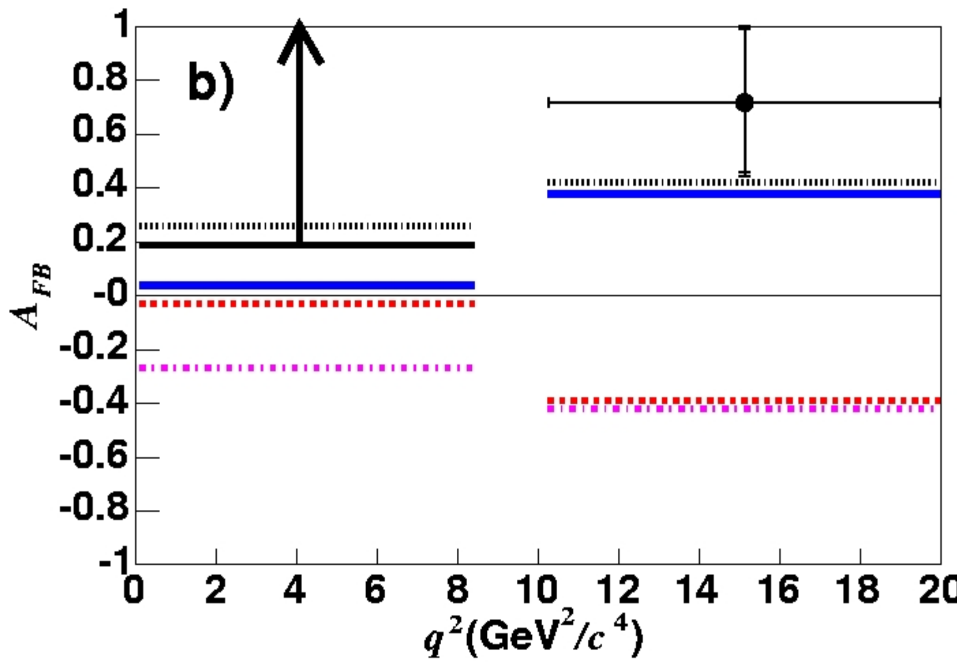
Can experimentally probe each and all of these

- rates (new NNLL calculation)
- asymmetries
  - direct CP, isospin, forward-backward, time-dependent
- polarization

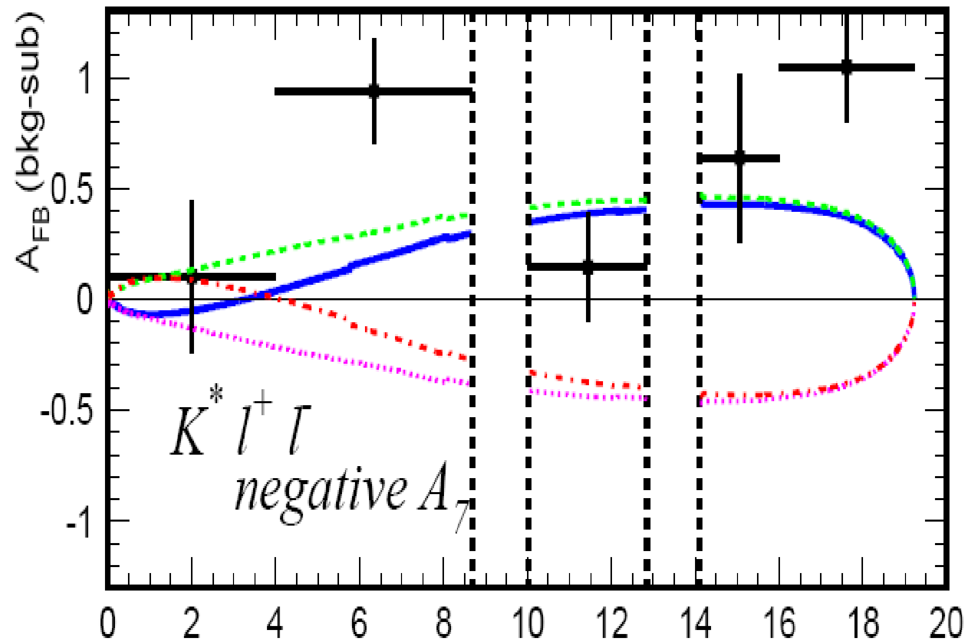
HURTH, LIN, RICHMAN

A_{FB} in $K^*l^+l^-$

BaBar, PRD 73, 092001 (2006)



Belle, PRL 96, 251801 (2006)



One of most interesting hints … <u>NEED MORE DATA!</u>

Inclusive A_{FB} in $X_s l^+l^-$ theoretically (even) cleaner

HURTH, LIN, RICHMAN

CP in B_s mixing

Important measurements:

- $\Delta\Gamma_s$, Γ_s, φ_s, A_{SL}^s, (Δm_s)

New prediction: $\Delta\Gamma_s = (0.090 \pm 0.017)\ \mathrm{ps}^{-1}$

cf. $\tau_s = (1.461 \pm 0.040)$ ps

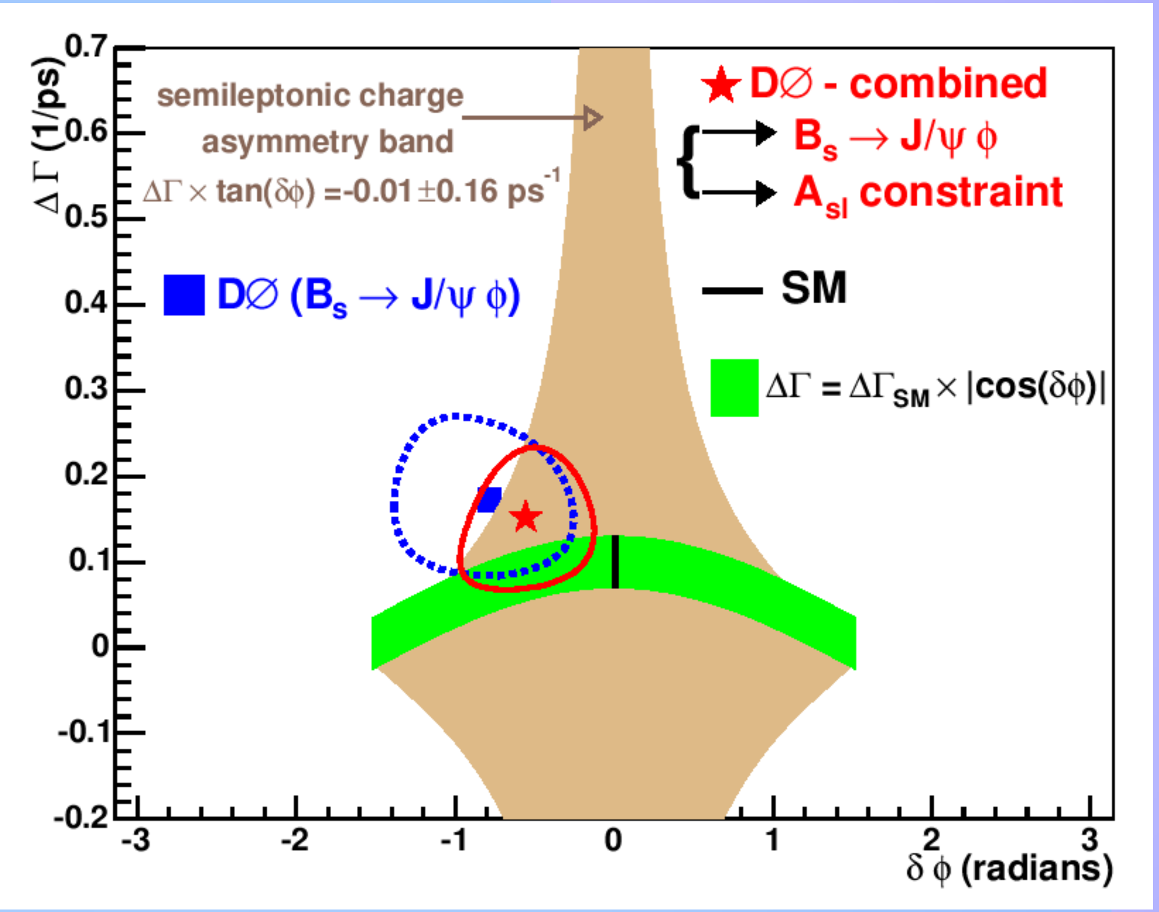
Size of $\Delta\Gamma_s$ crucially important for untagged measurements of φ_s (also possible at Υ(5S))

$$\Gamma(B_s(t) \to f) = \mathcal{N}_f\, |A_f|^2\, \frac{1+|\lambda_f|^2}{2}\, e^{-\Gamma t} \times \left[\cosh\frac{\Delta\Gamma\, t}{2} + \mathcal{A}_{\rm CP}^{\rm dir}\cos(\Delta m\, t) + \mathcal{A}_{\Delta\Gamma}\sinh\frac{\Delta\Gamma\, t}{2} + \mathcal{A}_{\rm CP}^{\rm mix}\sin(\Delta m\, t)\right]$$

$$\Gamma(\overline{B}_s(t) \to f) = \mathcal{N}_f\, |A_f|^2\, \frac{1+|\lambda_f|^2}{2}\,(1+a)\, e^{-\Gamma t} \times \left[\cosh\frac{\Delta\Gamma\, t}{2} - \mathcal{A}_{\rm CP}^{\rm dir}\cos(\Delta m\, t) + \mathcal{A}_{\Delta\Gamma}\sinh\frac{\Delta\Gamma\, t}{2} - \mathcal{A}_{\rm CP}^{\rm mix}\sin(\Delta m\, t)\right].$$

NIERSTE, CHEU, BLUSK, CHANDRA, MAGINI

CP in B_s mixing

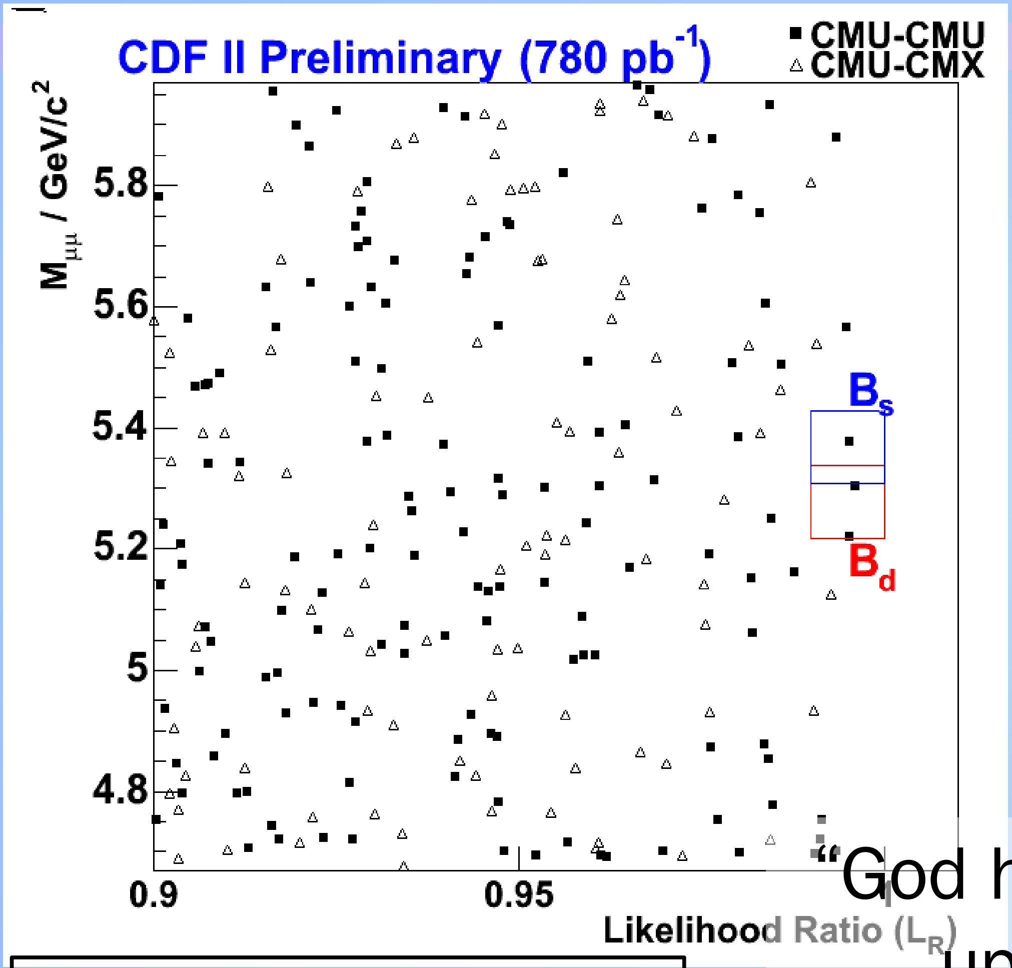


<u>Tagged</u> measurements will be much more sensitive to φ_s

…these are possible **now**!

NIERSTE, CHEU, BLUSK, CHANDRA, MAGINI

$B_s \to \mu^+\mu^-$



"God hangs the greatest weights upon the smallest wires"

$B(B_s \to \mu\mu) < 1.0\ 10^{-7}$

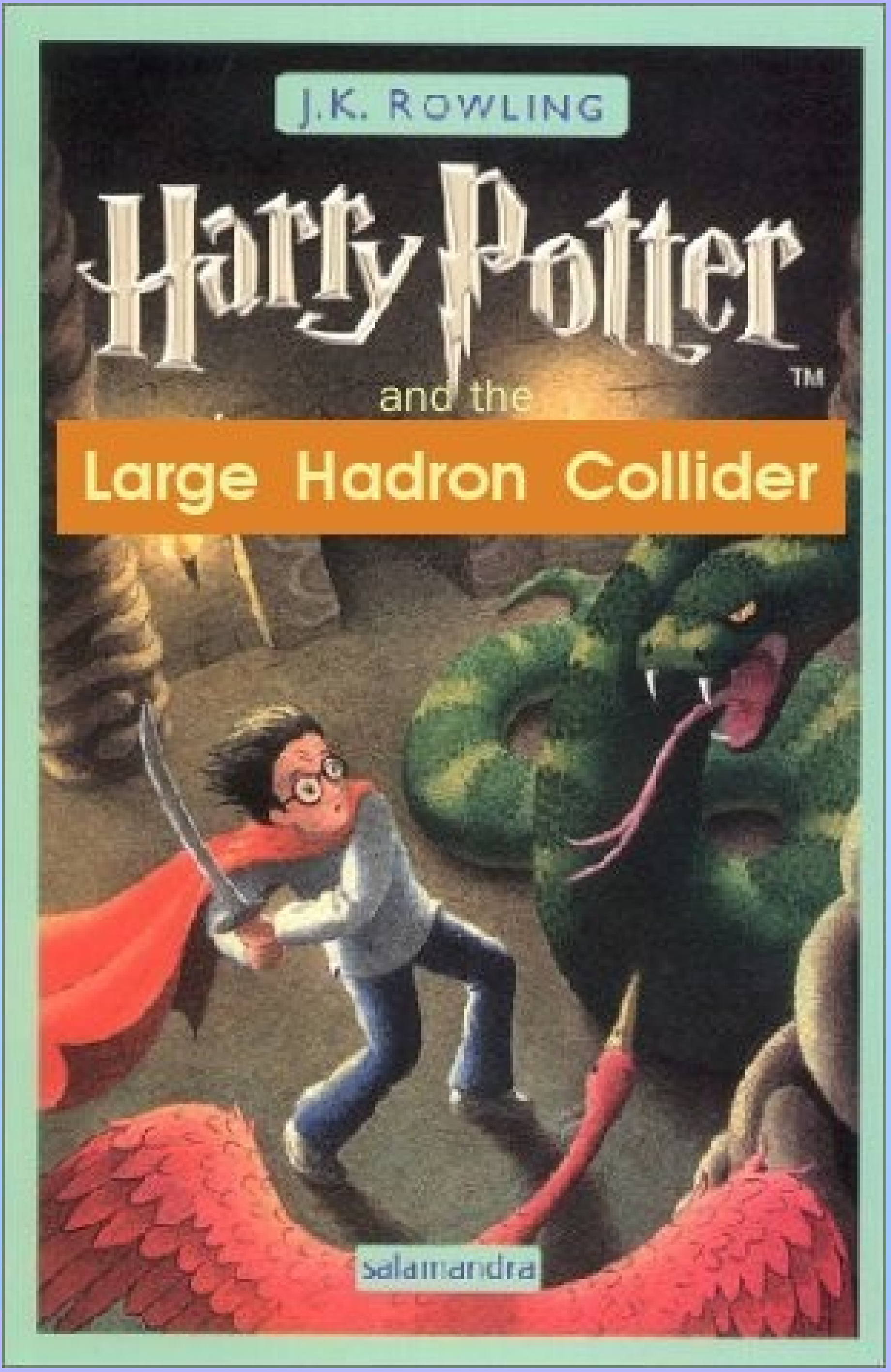
$B(B_d \to \mu\mu) < 3.0\ 10^{-8}$

Also lν(γ), llγ, ττ

IKADO, LIN, SMIZANSKA

The Excitement Mounts

- We are reaching the culmination of a long-running saga
- Many books have been written, films have been made
- The journey has not been without thrills and spills
- Millions of people worldwide are eagerly awaiting the outcome ....


J.K. ROWLING
Harry Potter
TM
and the
Large Hadron Collider
Salamandra

LHC preparation

I will not attempt to summarise details from several excellent status reports

Please refer to slides of

- Burckhart, Eerola, Buchmuller, Schilling, Garrido, Corti, Kirk, Rodrigues, Ruiz

and relevant Tevatron experience in talks of

- Annovi, Bauer, Moulik, and others

Take home message:

Prospects for B physics at the LHC are very exciting …

… but much hard work lies ahead!

LHC(b) Key Measurements

Very rough and incomplete lists

1st year or so ...

- α ($\pi^+\pi^-$)
- γ (DK)
- γ (hh' + U-spin)
- $\Delta\Gamma_s$
- A_{SL}^s
- ϕ_s ($B_s \to J/\psi\ \phi$, etc.)
- $B_s \to \phi\gamma$
- $B_s \to \mu\mu$
- $B \to K^{(*)}ll$, $B_s \to \phi ll$

... and later

- α ($\pi^+\pi^-\pi^0$ & $\rho^0\rho^0$)
- γ (DK)
- γ (D_sK)
- A_{SL}^s
- ϕ_s ($B_s \to J/\psi\ \phi$, etc.)
- $B_s \to \phi\phi$, etc.
- $B_s \to \phi\gamma$
- $B_s \to \mu\mu$
- $B \to K^{(*)}ll$, $B_s \to \phi ll$

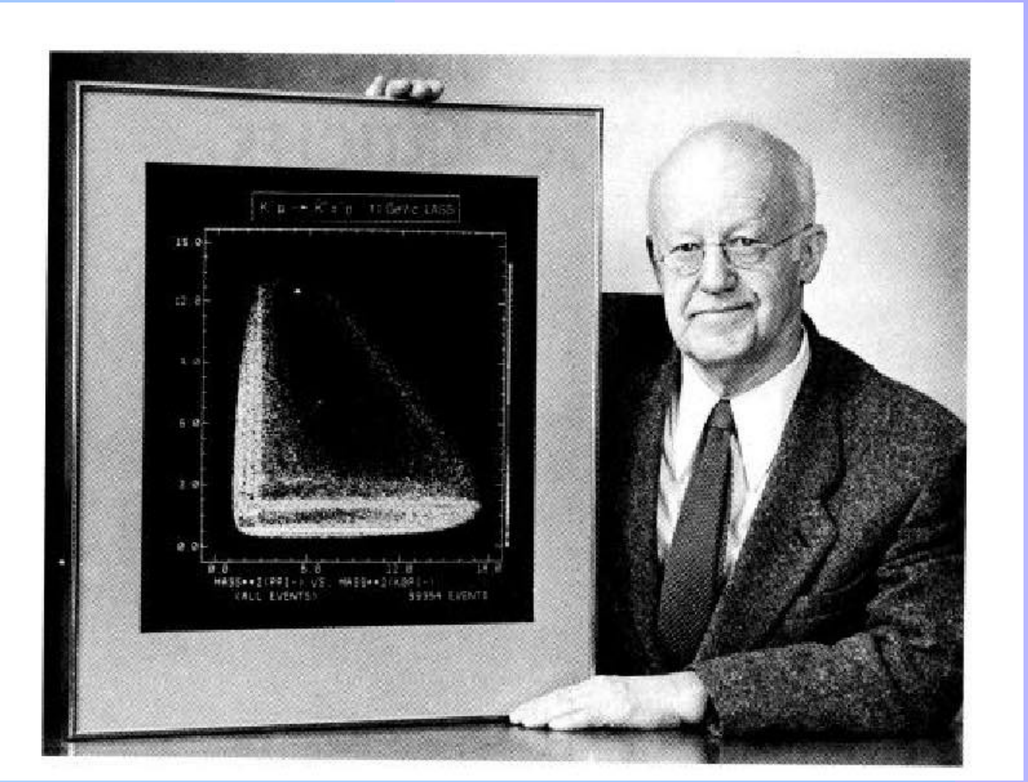
ROBBE, CARBONE, XIE, SMIZANSKA,
DE CAPUA, MAGINI, MUHEIM

Motivation for Super B Factory

- How to beat theoretical (hadronic) uncertainties?
  - Measure ratios, asymmetries, *etc.*
  - Exploit flavour symmetries (isospin, U-spin, SU(3))
    - these approaches key to LHC(b) program
  - Avoid hadrons in the final state
    - neutrinos ← impossible in hadronic environment
    - photons ← difficult in hadronic environment
    - charged leptons
      - e, μ, τ ← e difficult, τ impossible
  - Use inclusive final states
    - X_s, X_d ← impossible in hadronic environment

physics/0603219
Nucl.Phys.A 771, 8 (2006)

Richard Dalitz 1925-2006



- Not nearly enough time to discuss all applications of the Dalitz analysis technique
- Even a small selection enough to demonstrate the profound usefulness of the method

Will continue to throw light on both strong and weak interactions, and perhaps new physics, into the LHC era, and beyond

Thanks to the Organisers

Andy Carslaw

Sue Geddes (Conference Secretary)

Pete Gronbech

Neville Harnew (Local Chair)

Jim Libby

Jonas Rademacker

Guy Wilkinson

Closing thought

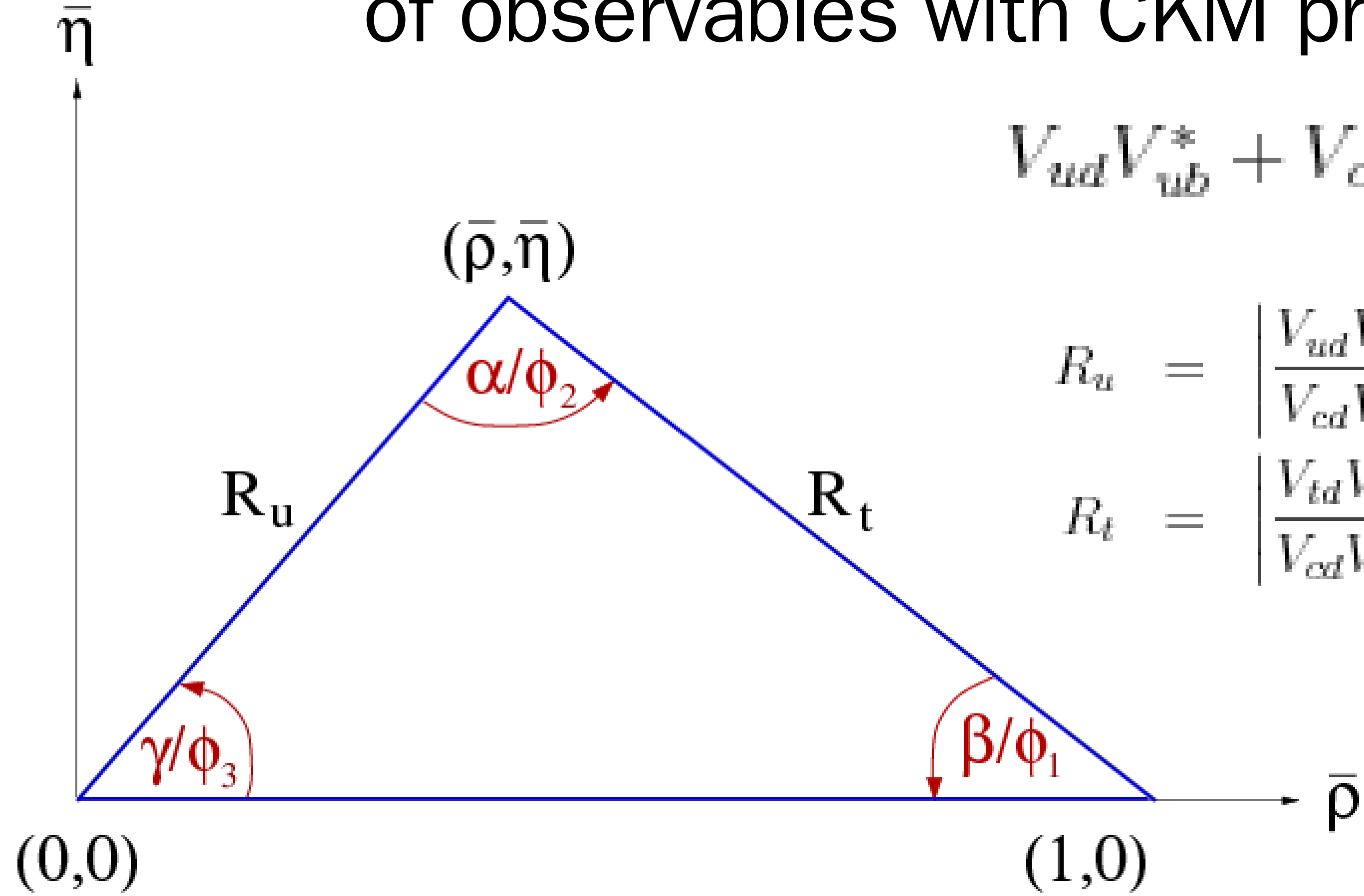
"Reading maketh a full man, conference a ready man, and writing an exact man."

THE END

"Discretion in speech is more than eloquence."

Unitarity Triangle

Convenient method to illustrate (dis-)agreement of observables with CKM prediction



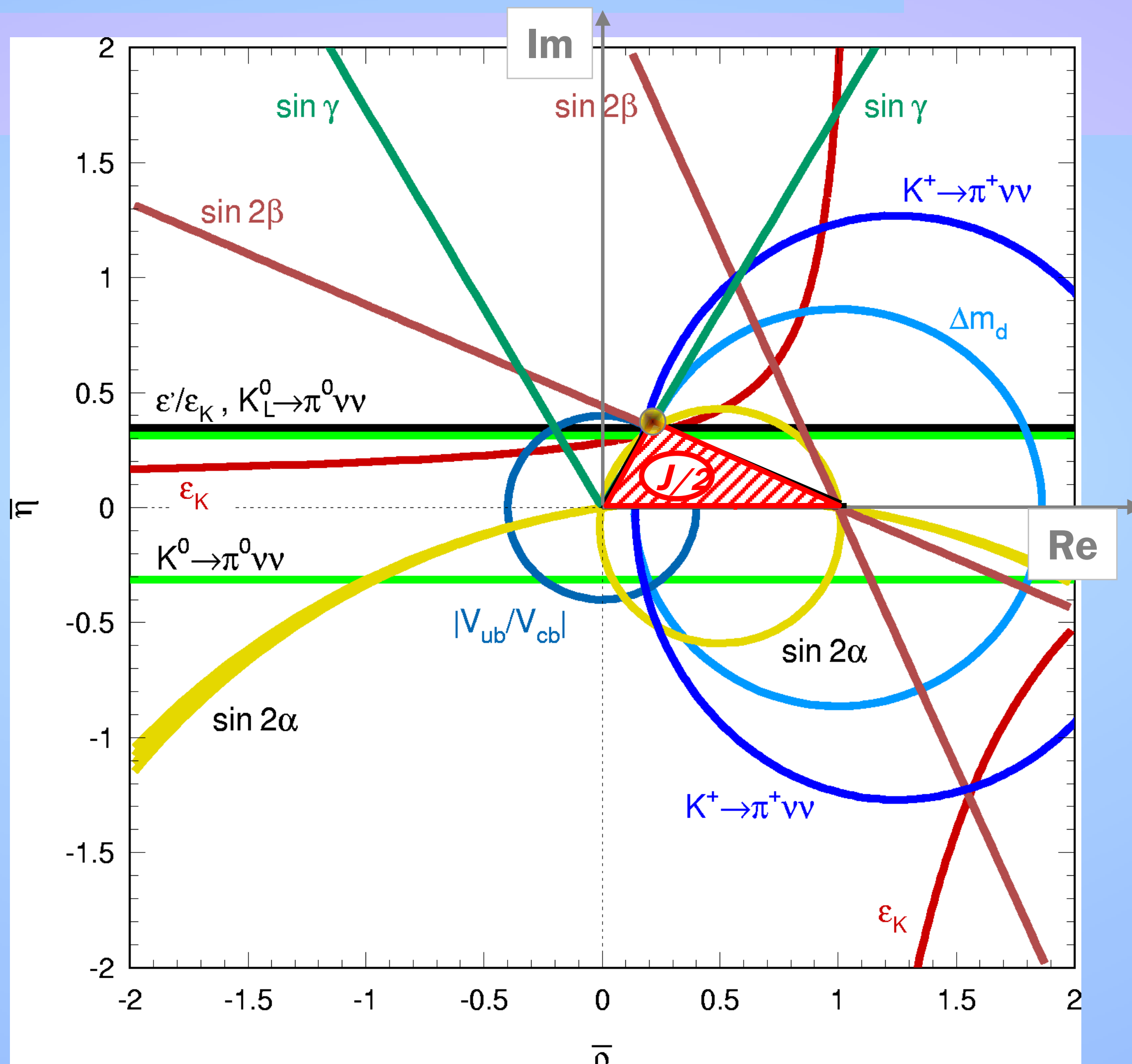
$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0,$$

$$R_u = \left|\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right| = \sqrt{\bar{\rho}^2 + \bar{\eta}^2},$$

$$R_t = \left|\frac{V_{td}V_{tb}^*}{V_{cd}V_{cb}^*}\right| = \sqrt{(1-\bar{\rho})^2 + \bar{\eta}^2}.$$

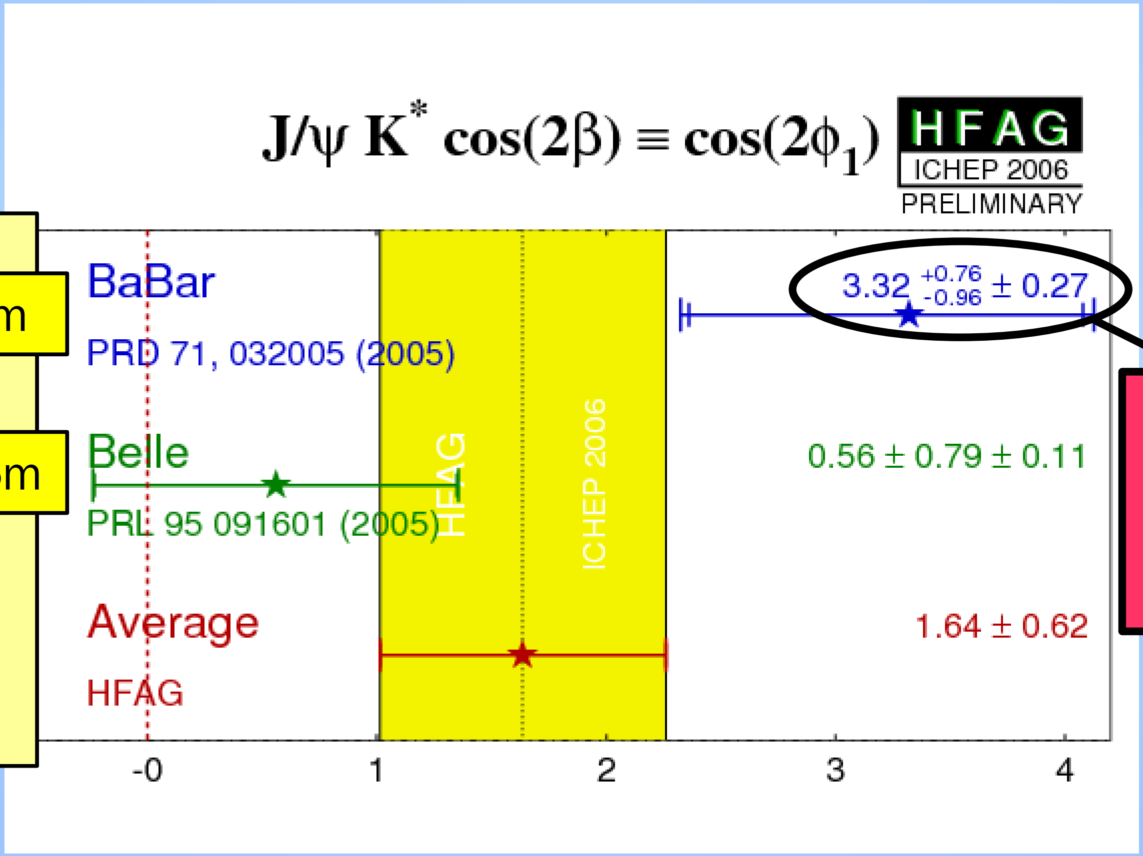
KM Prediction

All measurements must agree



Picture by A.Hoecker

The ambiguity – J/ψ K*



N(BB)=88m

N(BB)=275m

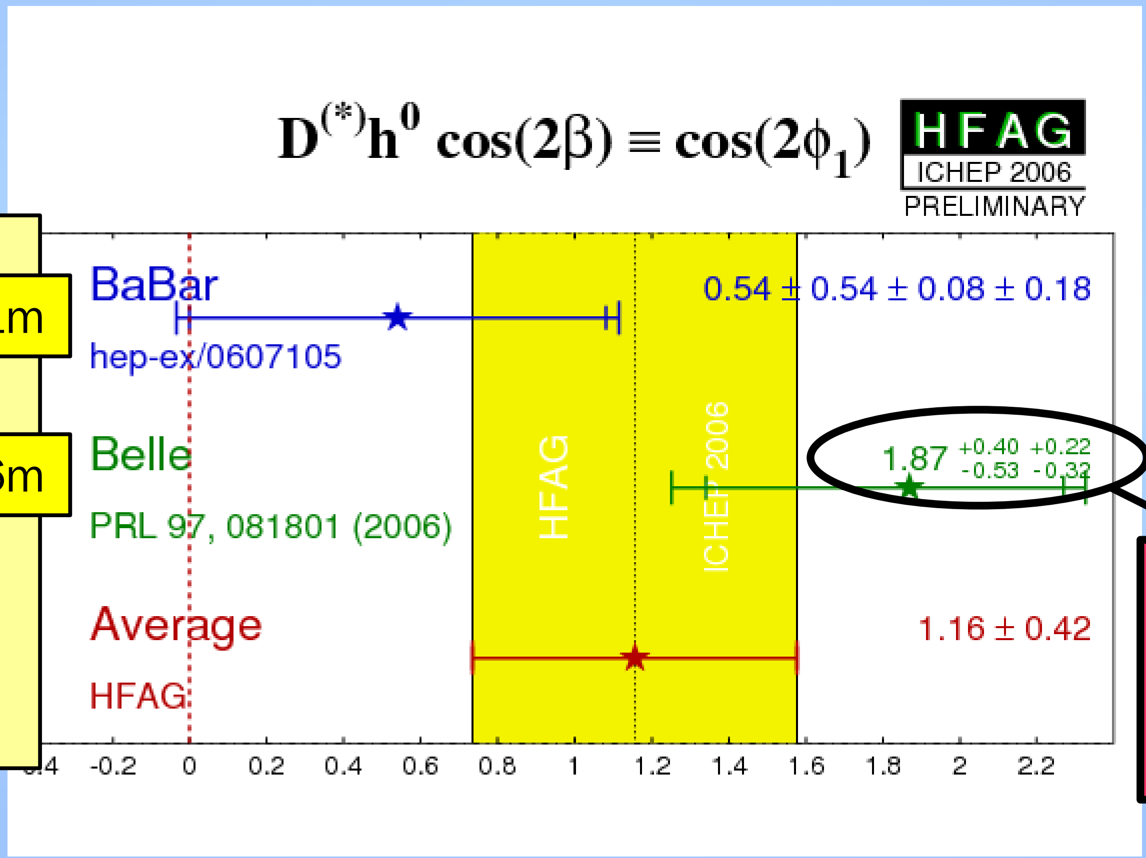
UPDATES NECESSARY

highly non-Gaussian errors

LACKER

Bondar et al., PLB 624 (2005) 1

The ambiguity – $D^{(*)}h^0$



N(BB)=311m

N(BB)=386m

UPDATES NECESSARY

highly non-Gaussian errors

Also constraints on sin(2β) [testing arg(b→cud) = arg(b→ccs)]

- measurements with D→CP eigenstates will improve this test

LACKER

$\alpha \equiv \varphi_2$ — $\pi\pi$

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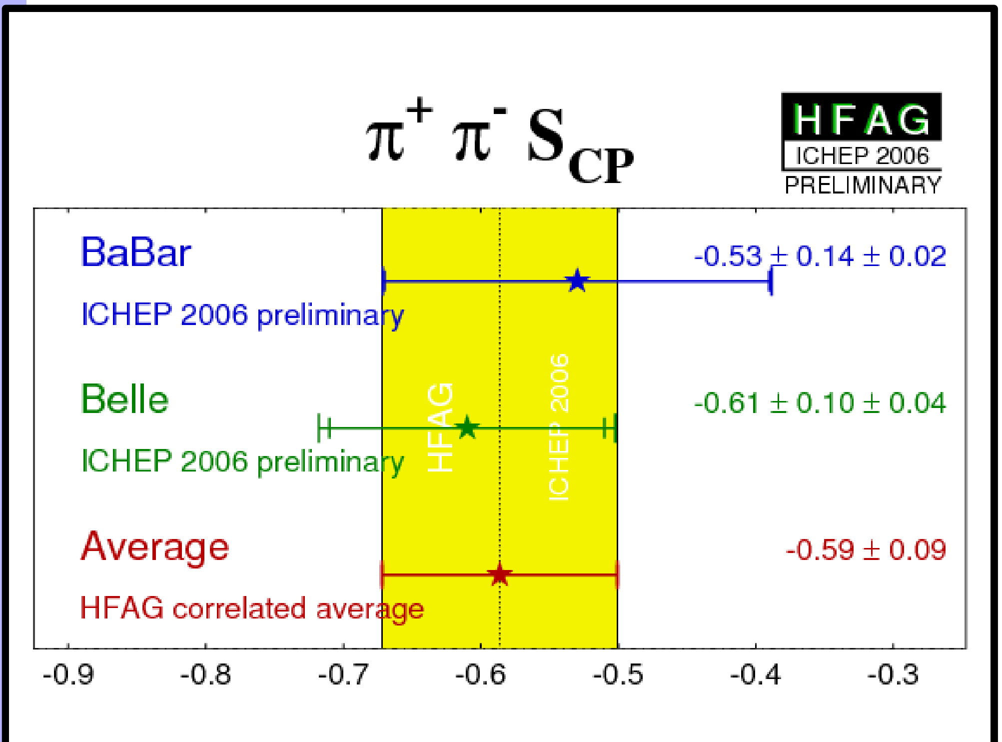
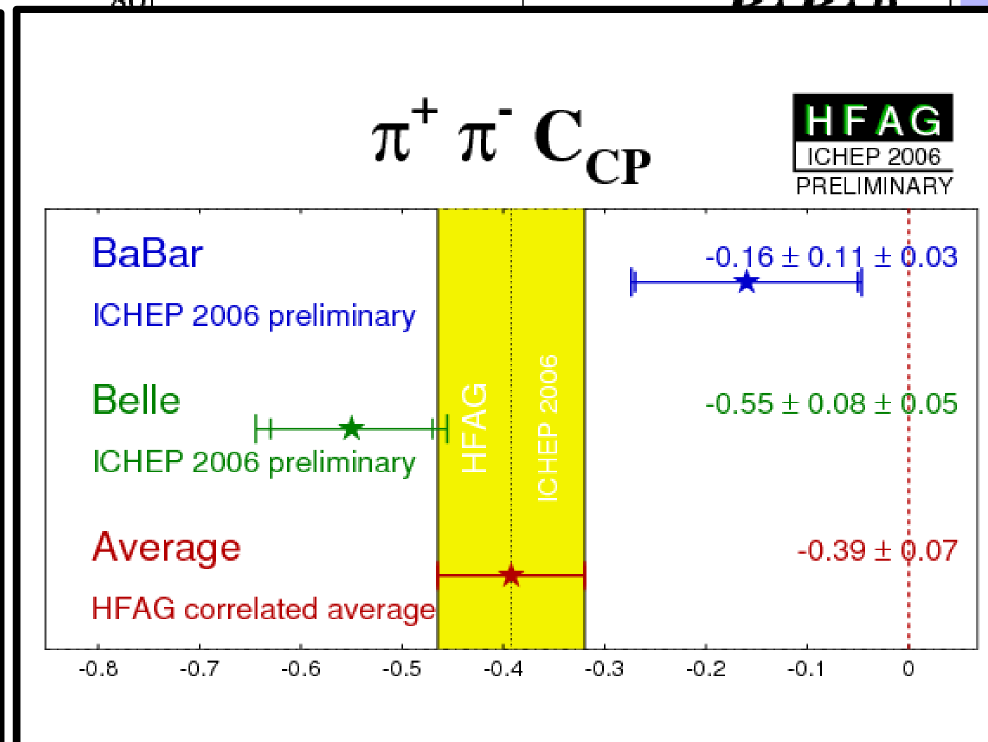
BELLE hep-ex/0608035 N(BB)=532m



BABAR hep-ex/0607106 N(BB)=350m



BaBar confirm Belle's observation of large CP violation in $B \rightarrow \pi^+\pi^-$

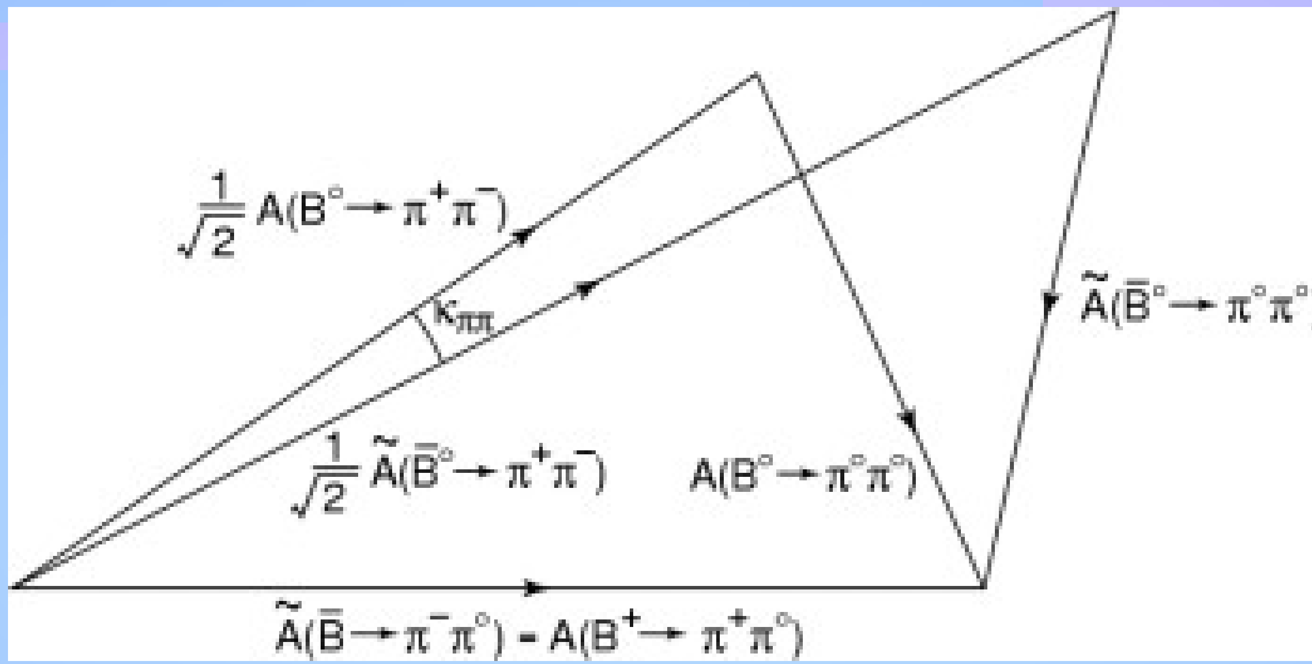
Additionally Belle observe large direct CP violation, not confirmed (nor refuted) by BaBar

BIANCHI

M.Gronau & D.London, PRL 65 (1990) 3381

THE UNIVERSITY OF WARWICK

$\alpha \equiv \varphi_2$ —— $\pi\pi$ Isospin analysis



Input from HFAG – rare decays

$BR(B^0 \to \pi^+\pi^-) = 5.2 \pm 0.2$	-
$BR(B^+ \to \pi^+\pi^0) = 5.7 \pm 0.4$	$A_{CP}(B^+ \to \pi^+\pi^0) = 0.04 \pm 0.05$
$BR(B^0 \to \pi^0\pi^0) = 1.3 \pm 0.2$	$A_{CP}(B^0 \to \pi^0\pi^0) = 0.36^{+0.33}_{-0.31}$

BIANCHI, ZUPAN

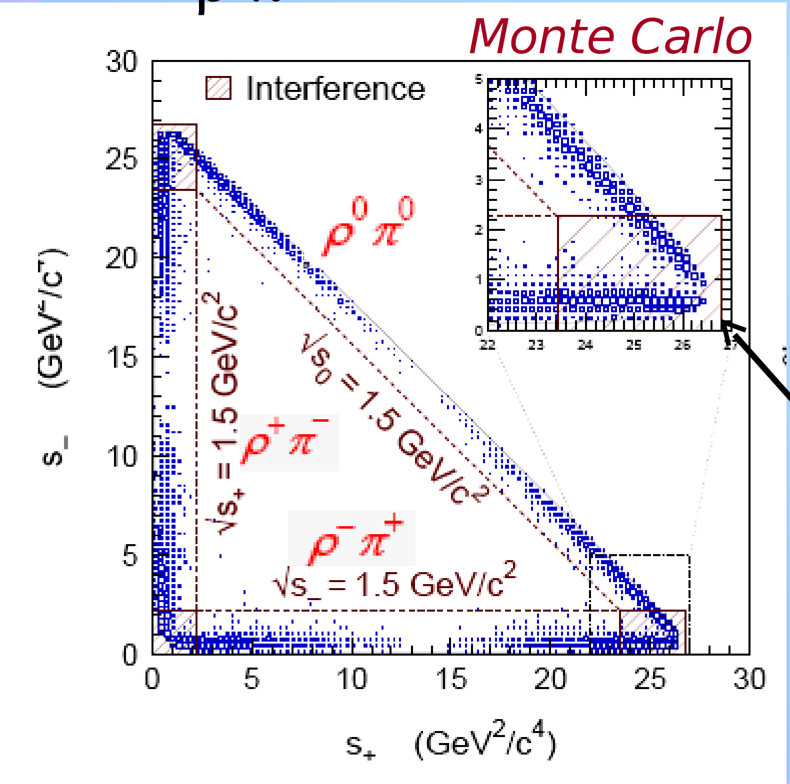
A.Snyder & H.Quinn, PRD 48 (1993) 2139

$\alpha \equiv \phi_2$ —— $\pi^+\pi^-\pi^0$ Dalitz plot analysis

B^0, $\bar{B}^0$ $\longrightarrow$ $\rho^+\pi^-$, $\rho^-\pi^+$, $\rho^0\pi^0$ $\longrightarrow$ $\pi^+\pi^-\pi^0$

$$A(B^0 \to \pi^+\pi^-\pi^0) = f_+ A(\rho^+\pi^-) + f_- A(\rho^-\pi^+) + f_0 A(\rho^0\pi^0)$$

$$\tilde{A}(\overline{B}^0 \to \pi^+\pi^-\pi^0) = f_+ \tilde{A}(\rho^+\pi^-) + f_- \tilde{A}(\rho^-\pi^+) + f_0 \tilde{A}(\rho^0\pi^0)$$



- Time-dependent Dalitz-plot analysis assuming isospin simmetry.
  - 26 coefficients of the bilinear form factor terms occurring in the decay rate are measured with a UML fit.
  - Physically relevant quantities are derived from subsequent fits to these coefficients.

Interference provides information on strong phase difference

BIANCHI, ZUPAN, ROBBE

A.Snyder & H.Quinn, PRD 48 (1993) 2139

$\alpha \equiv \phi_2$ —— $\pi^+\pi^-\pi^0$ Dalitz plot analysis

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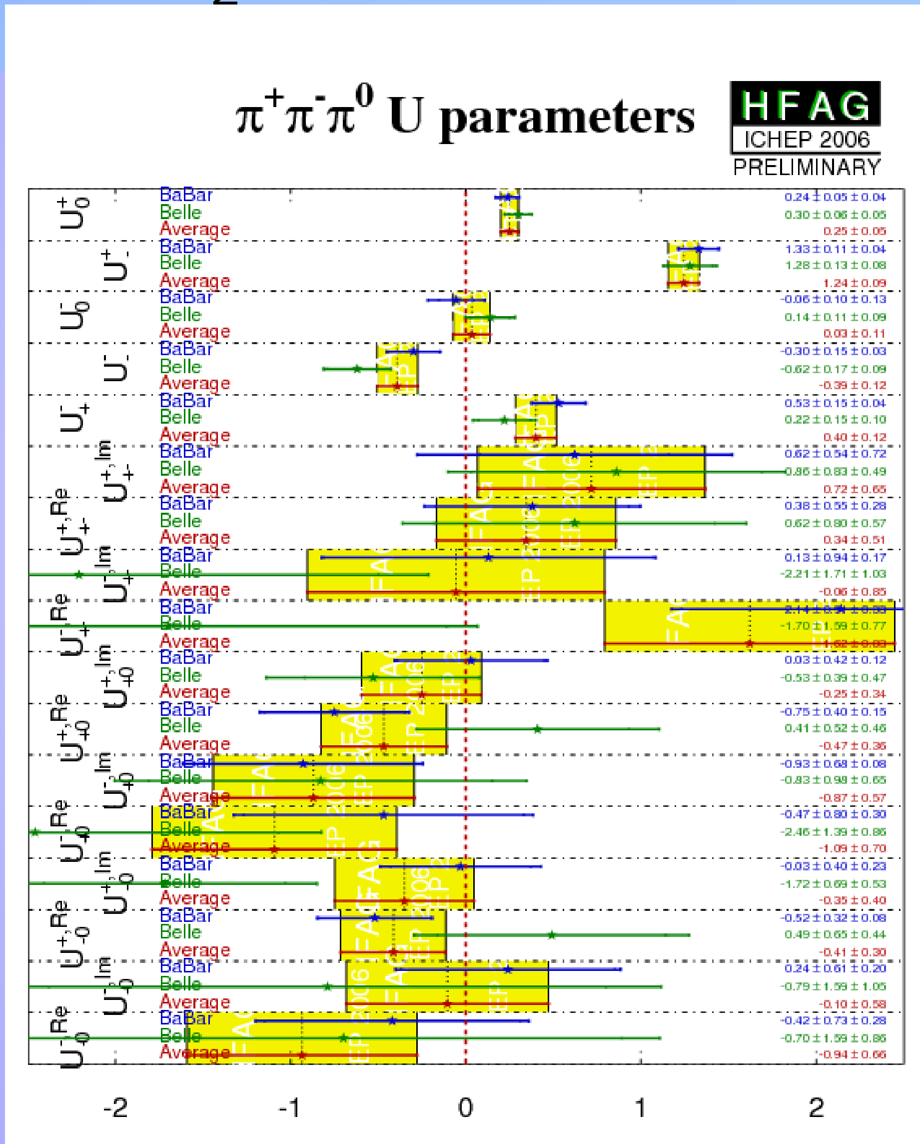
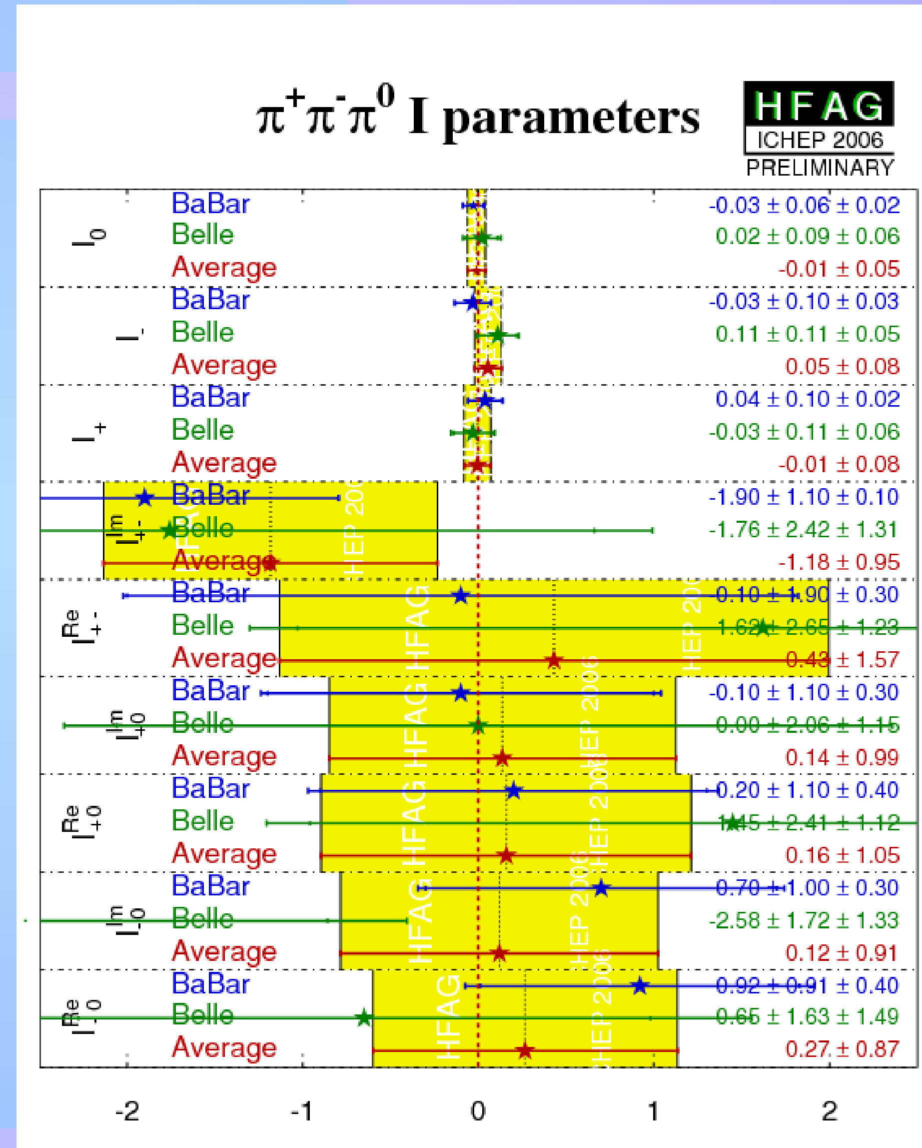
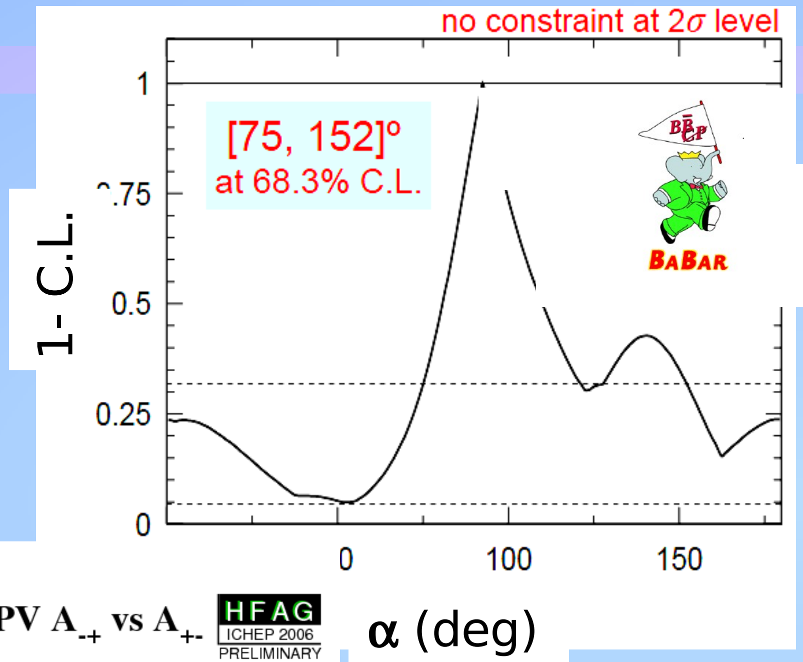




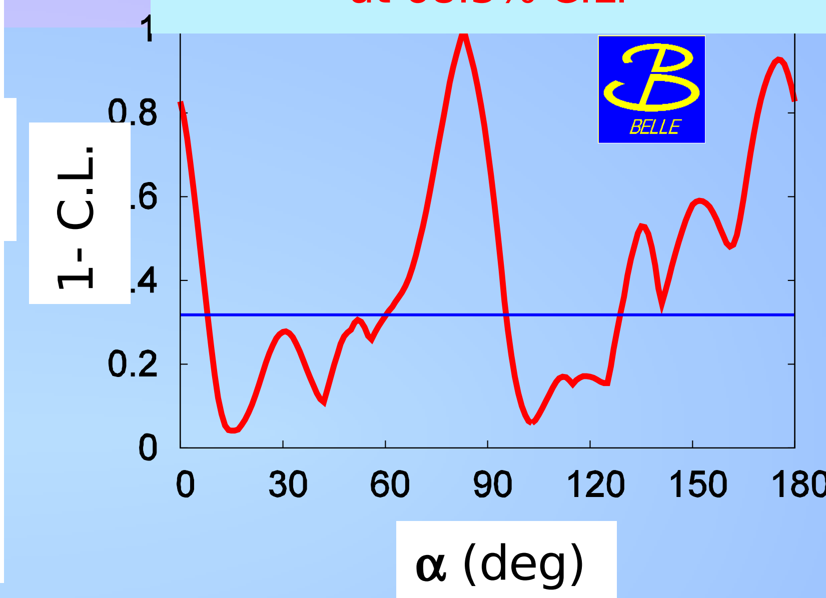
BIANCHI

A.Snyder & H.Quinn, PRD 48 (1993) 2139

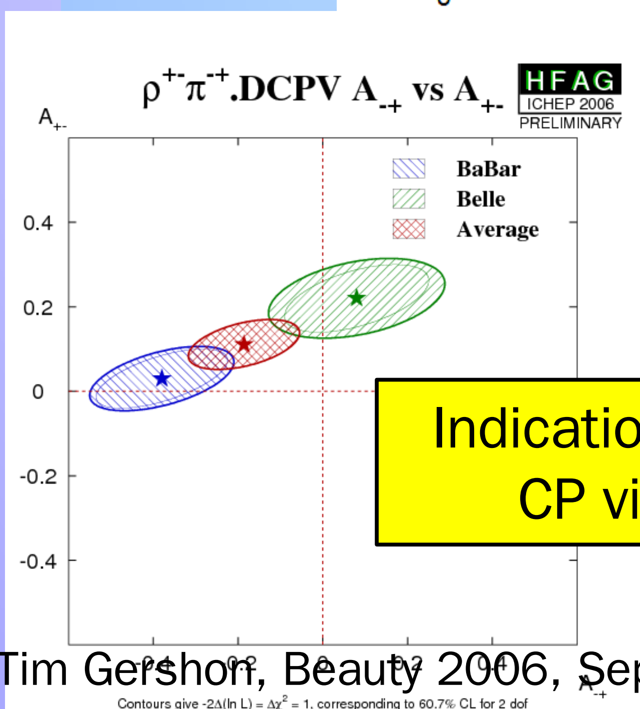
$\alpha \equiv \phi_2$ —— $\pi^+\pi^-\pi^0$ Dalitz plot analysis



[0,8]° U [60,95]° U[129,180]°
at 68.3% C.L.



Belle constraint improved using "isospin pentagon"



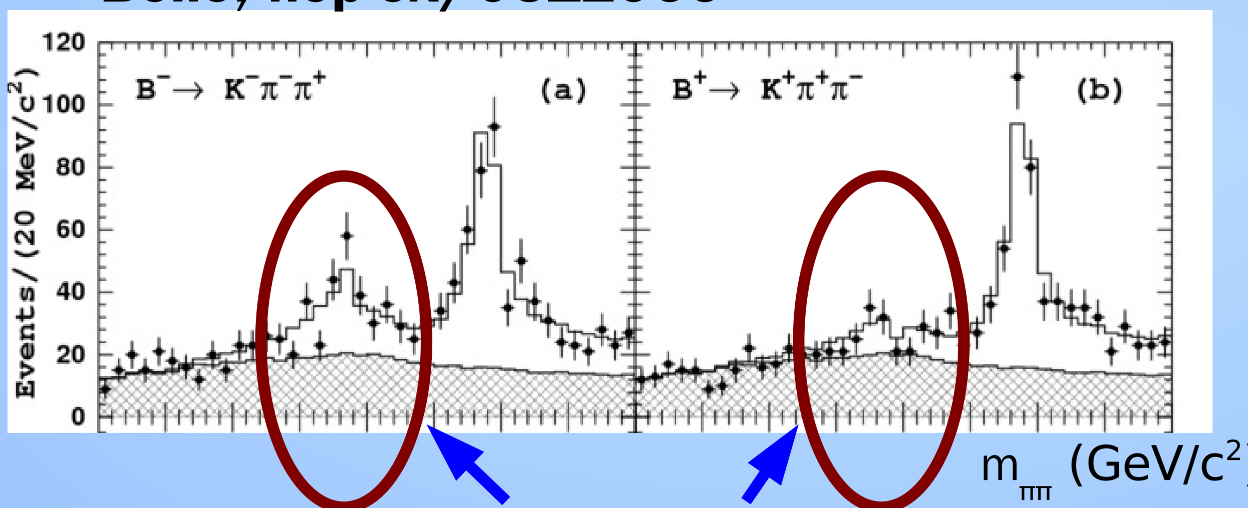
Indication of direct CP violation

BIANCHI

DCPV in 3 body B decay

- Dalitz analysis → measure hadronic parameters
- Search for DCPV in $B^+ \to K^+\pi^+\pi^-$

Belle, hep-ex/0512066



Clear asymmetry in the ρ region

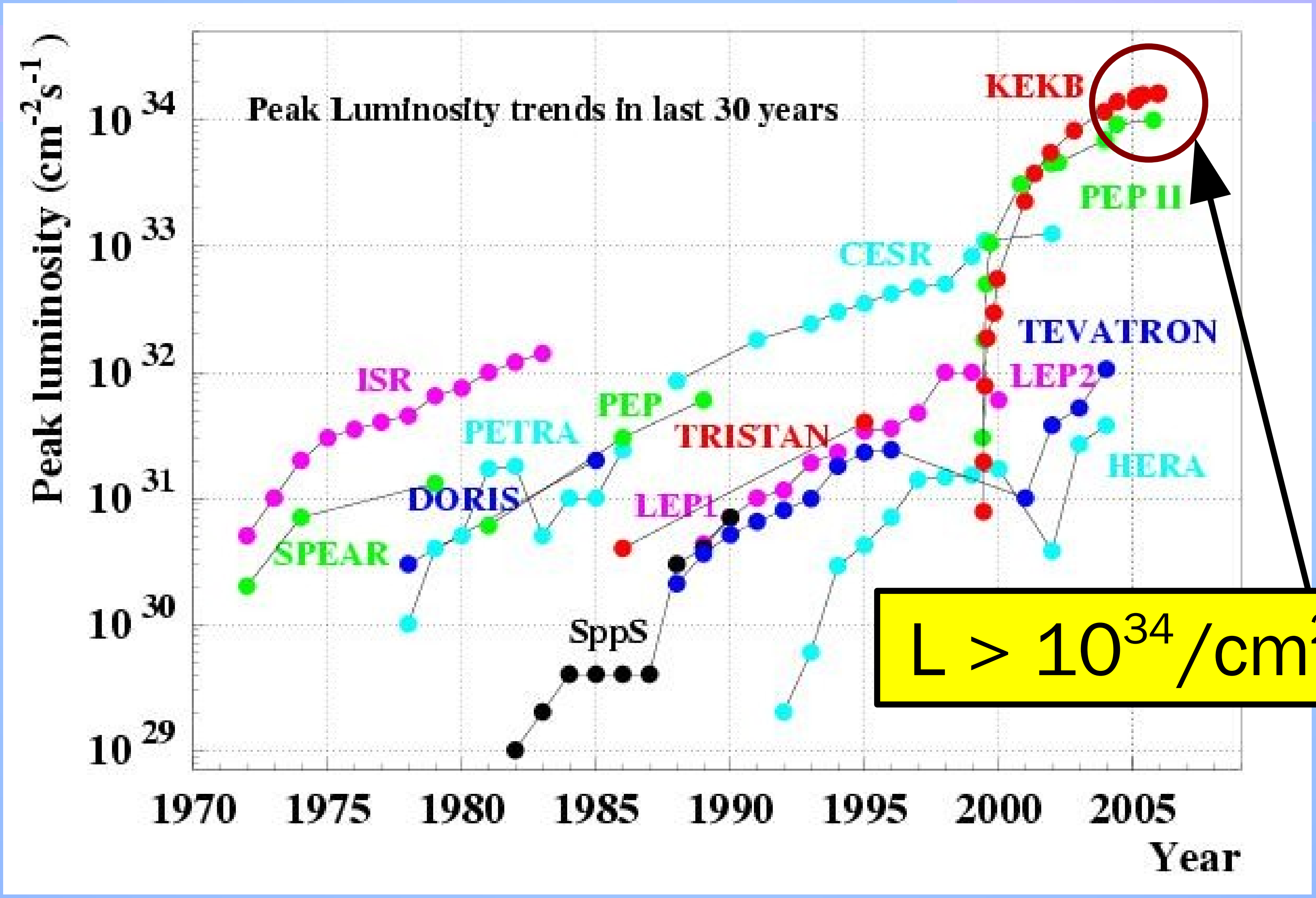
Dalitz analysis → enhanced sensitivity to CPV

$A_{CP}(\rho K^+) = (30 \pm 11 \pm 2\ ^{+11}_{-4})\%$ 3.9σ significance

first evidence for CPV in any charged particle!

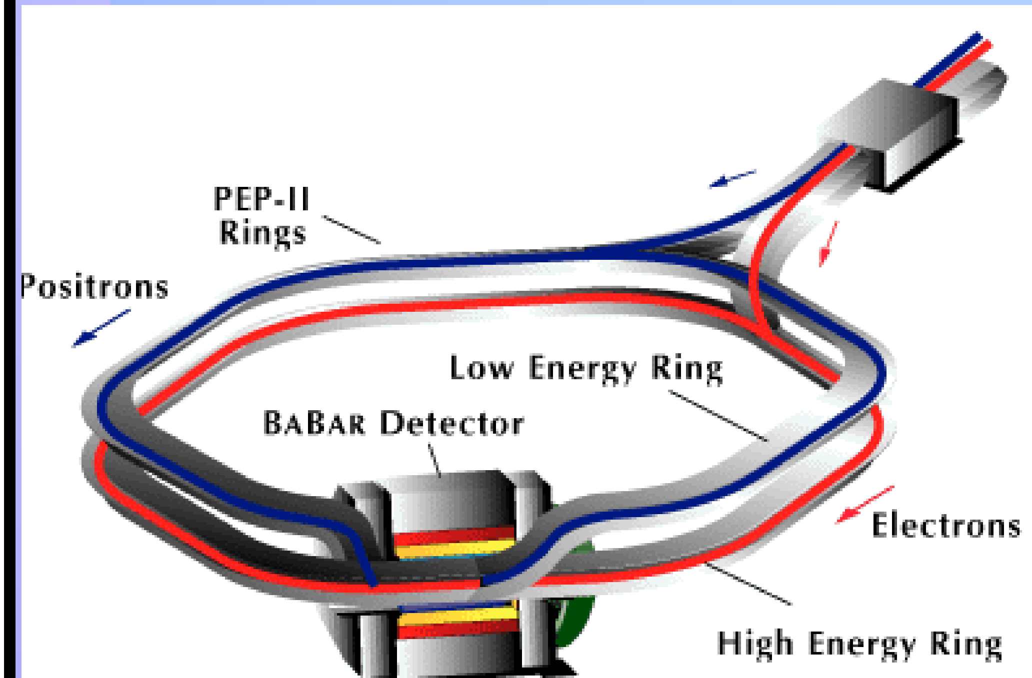
BaBar result not shown here

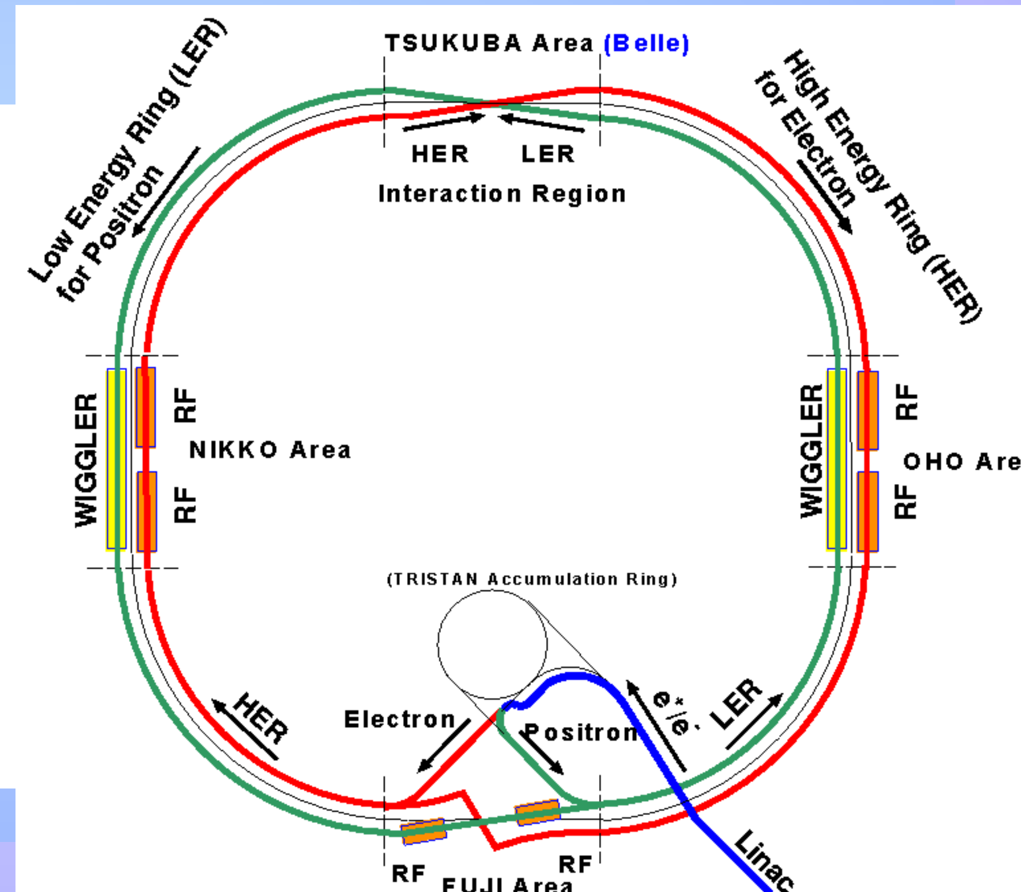
Luminosity trends



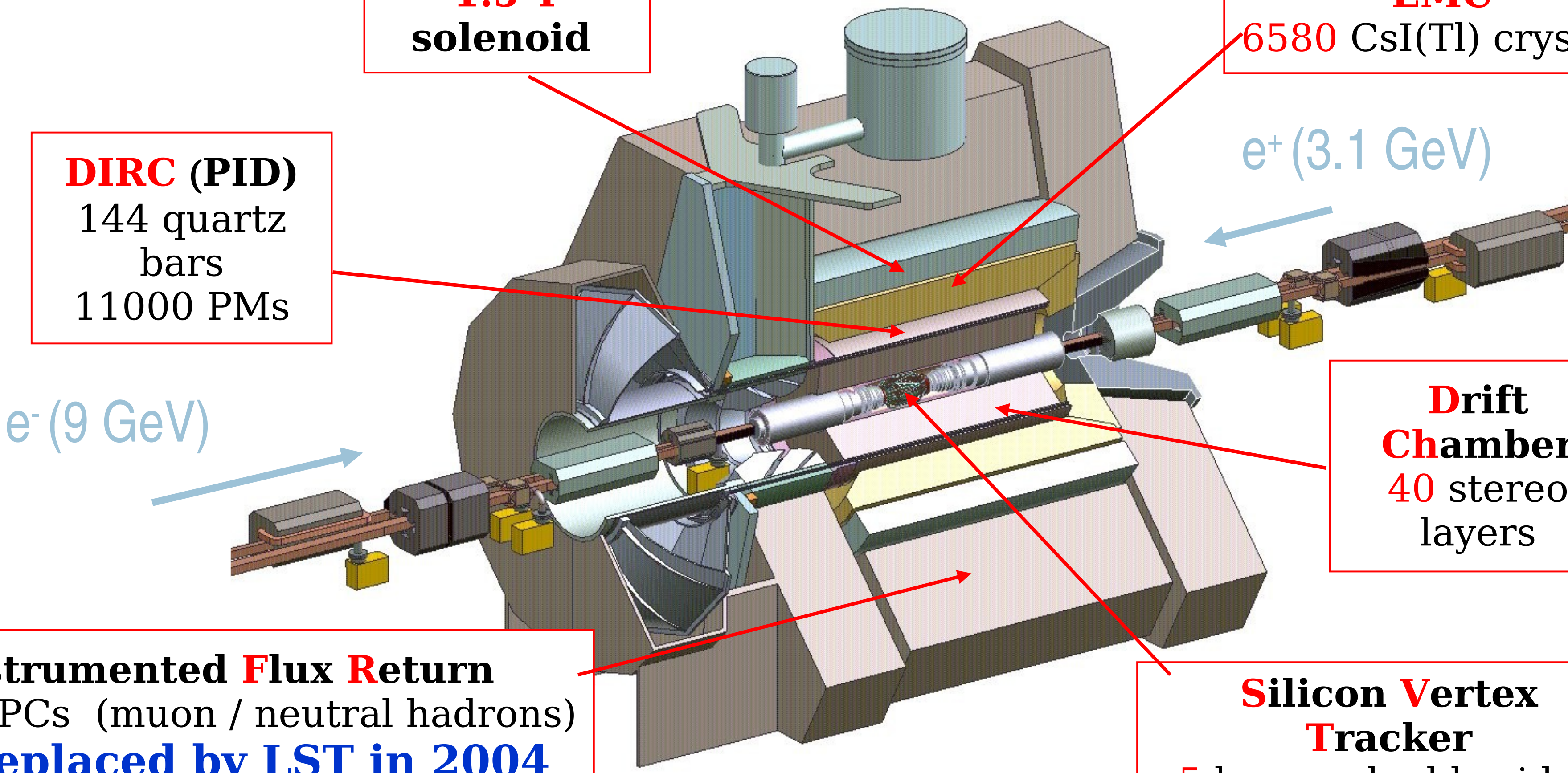
Asymmetric B Factories

PEPII at SLAC	KEKB at KEK
9.0 GeV e^- on 3.1 GeV e^+	8.0 GeV e^- on 3.5 GeV e^+





BaBar Detector



Belle Detector

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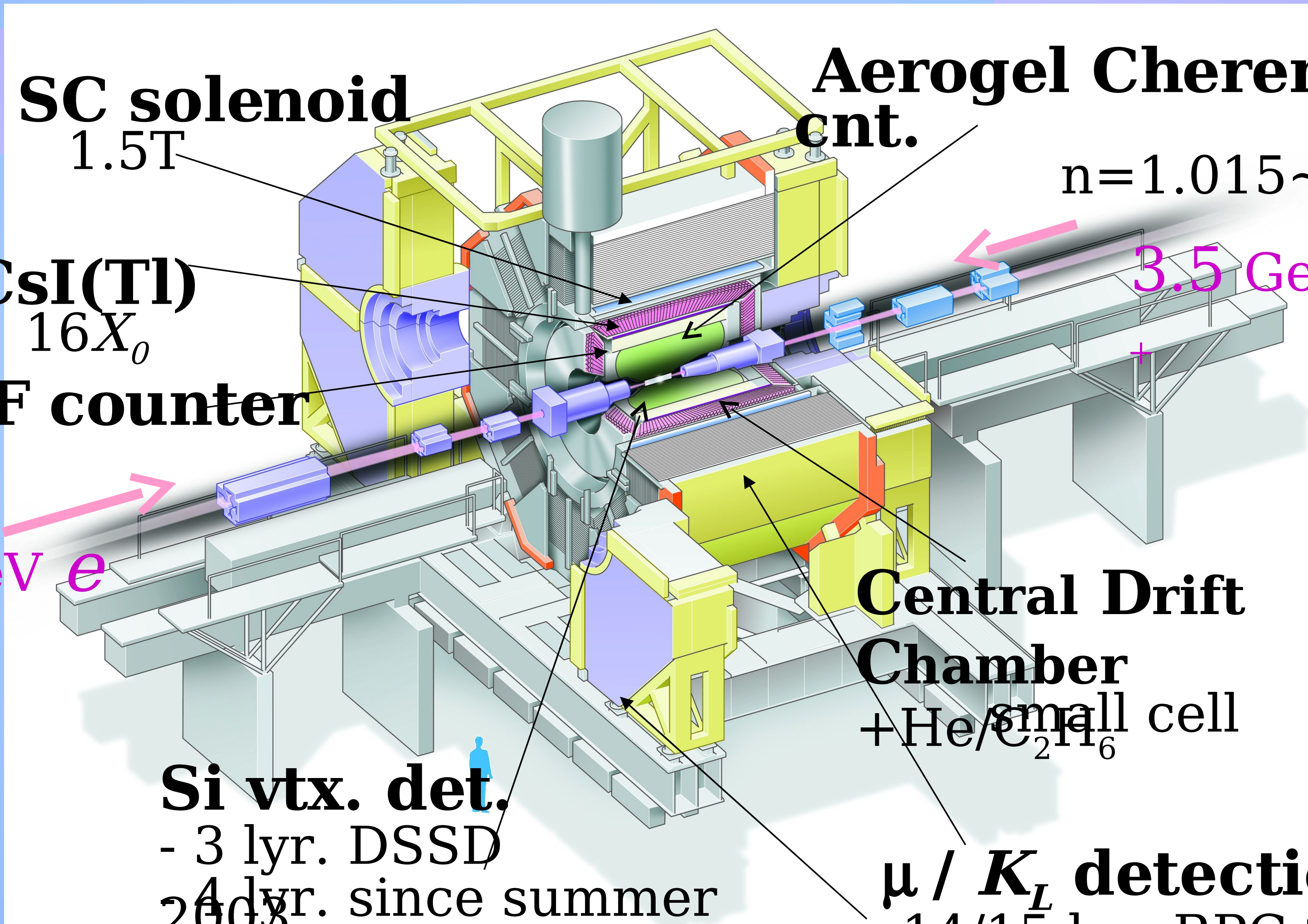

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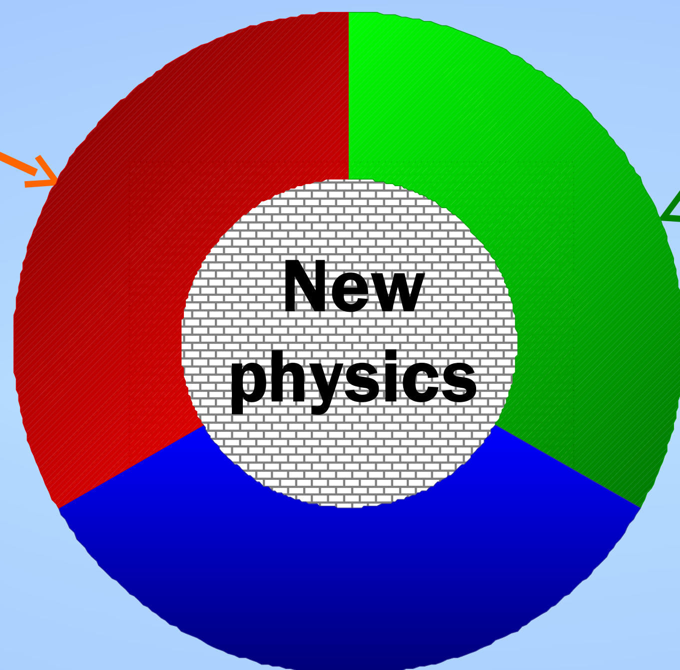
"Unified and Unbiased Attack on New Physics"

LHC, ILC

mass spectrum
interactions

ν experiments,
g_μ–2, $\mu \rightarrow e\gamma$, EDM, …

ν mass and mixing
CPV and LFV



τ LFV
τ CPV

flavour mixing
CPV phases

Super B factory, LHCb, *K* experiments ⋯