CKM 2008 WGIV Report "Mixing and Lifetimes"

Conveners: C. Tarantino, I.K. Furić

Introduction

- 4 sessions [Wed, Thu, Fri, Fri am], 19 talks
- covered lifetimes, mixing, CP and CPT violation
- spanning kaon, charm and beauty systems
- very lively topic: ϕ_s measurements and implications from global fits
- prompted break-away discussion session on Thursday

The Kaon System

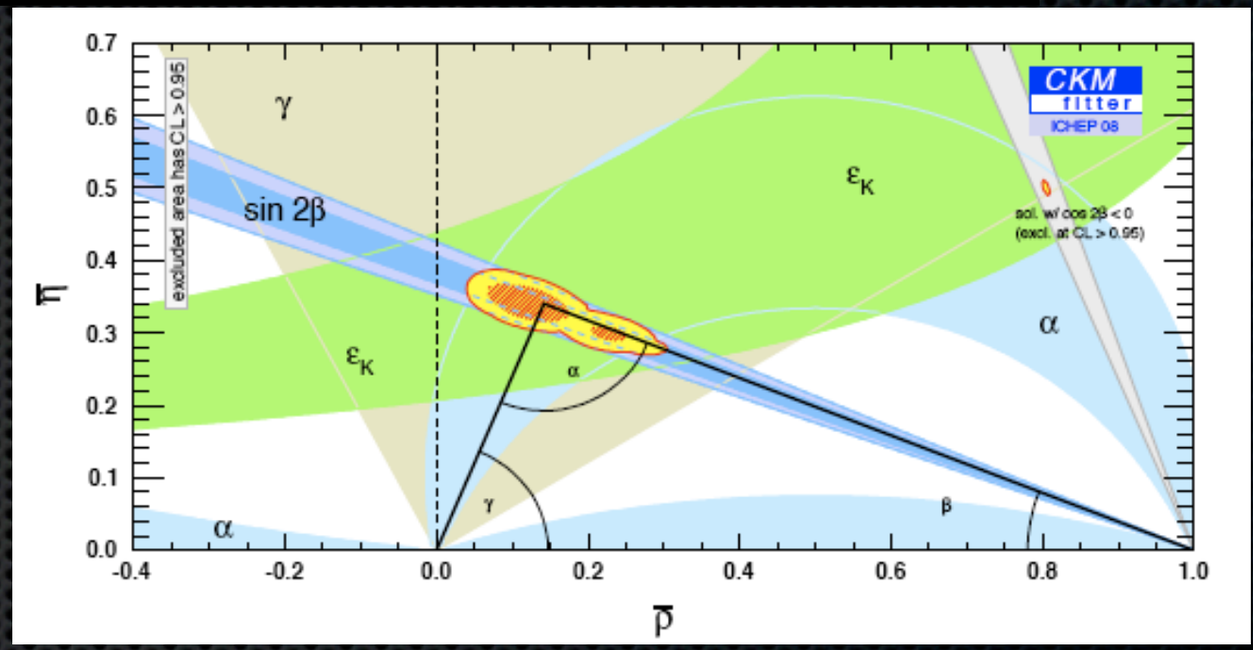
Kaon system - Δm_K, ε_K, ε'/ε

E. Scholz

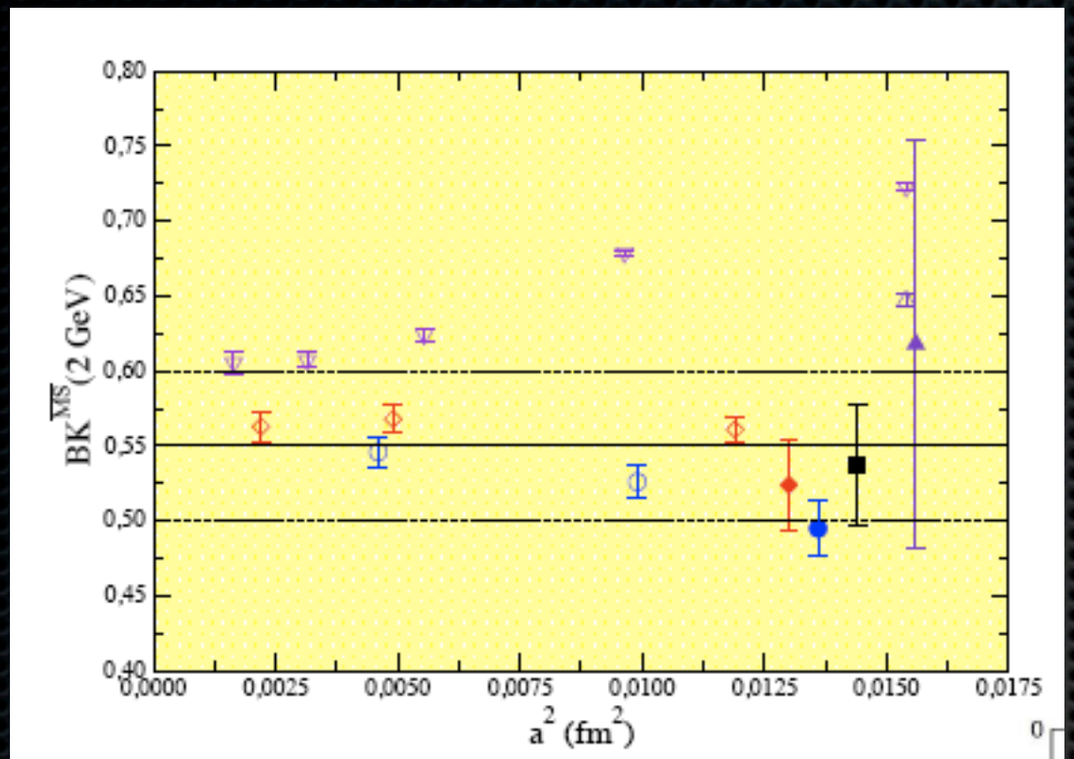
$$B_K(\mu) = \langle \bar{K}^0 | Q^{\Delta S=2} | K^0 \rangle \; / \; (\tfrac{8}{3} f_K^2 m_K^2)$$

$$|\epsilon_K| = C_\epsilon \hat{B}_K \lambda^2 \bar{\eta}^2 |V_{cb}|^2 \Big[|V_{cb}|^2 (1-\bar{\rho}) \eta_{tt} S_0(x_t) + \eta_{ct} S_0(x_c, x_t) - \eta_{cc} S_0(x_c) \Big]$$

- PDG'08 $\delta|V_{cb}|^4 \sim \delta B_k^{lat}$
- unquenched results for B_k
- $N_f = 2$
  - ETMC '08 twisted mass fermions (prelim.)
  - JLQCD '08 overlap fermions
- $N_f = 2 + 1$
  - HPQCD '06 staggered fermions
  - RBC/UKQCD '08 Domain Wall Fermions
- work in progress:
  - mixed action (DWF on stagg. sea) Aubin, Laiho, van de Water
  - staggered fermions: Lee et al

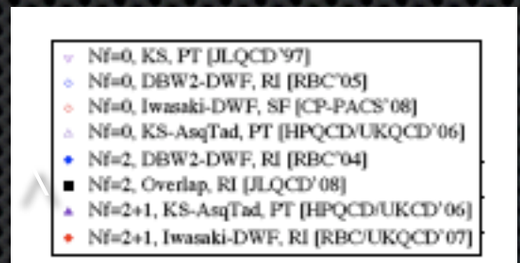


Kaon System - B_k Results



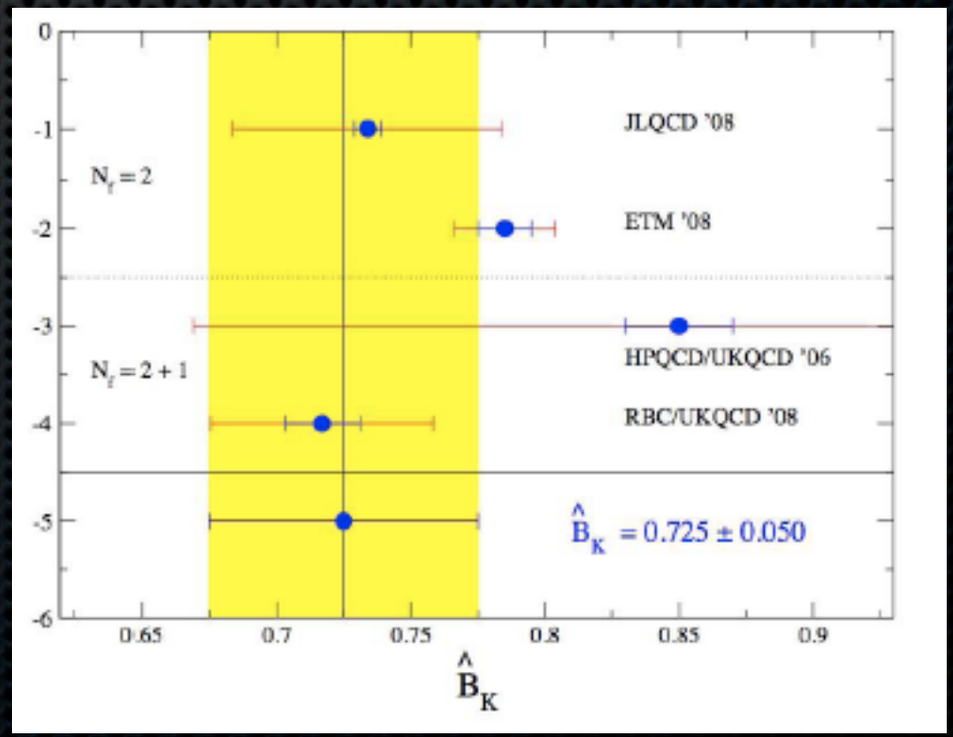
V. Lubicz, C. Tarantino, IFAE 2008

- scale dependence from quenched sim.
- $B_K^{\overline{MS}}$ (2 GeV) = 0.55(.05)
  $\hat{B}_K$ = 0.75(.07)



L. Lellouch, LATTICE 2008

- only dynamical N_f = 2+1 data used
- $\delta\hat{B}_K \approx 7\%$
- $\hat{B}_K$ = 0.725(.050)



Kaon system - Experiment

C.Bloise

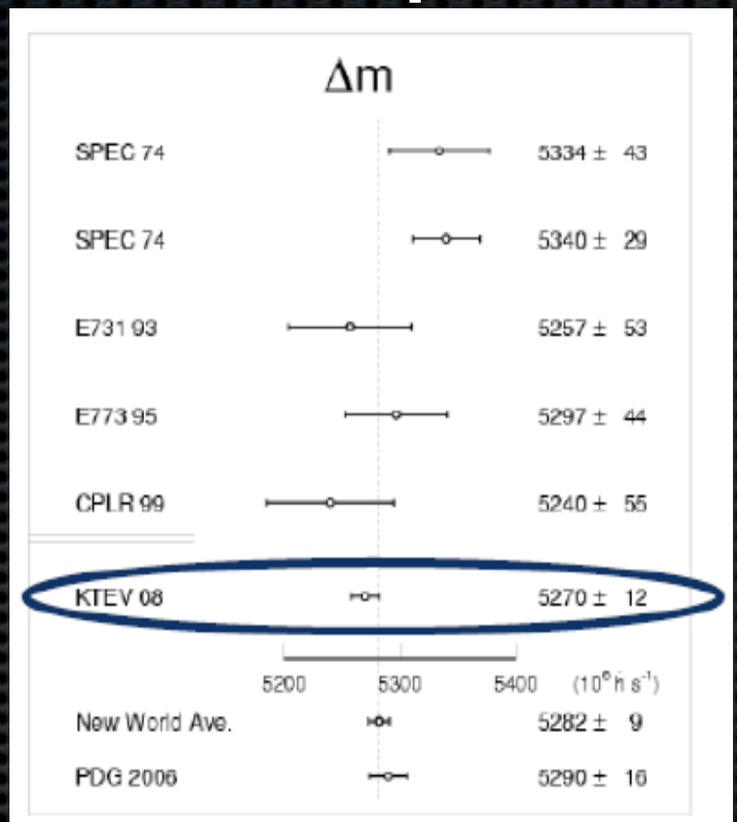
- In recent years, the knowledge of CP-violation parameters in the Kaon sector has been improved by precision experiments
- Data are consistent with CPT symmetry and unitarity
- Present generation of experiments, KTeV, NA48 and KLOE have obtained precision results in disagreement with older data
- Present results are limited to the mixing and the direct-decay phenomena
- To investigate CP-violation in the interference between mixing and direct-decay transition with Kaons, a challenging experimental program on the very rare $K \rightarrow \pi\nu\nu$ channel (and 2 generations of experiments) has to be pursued

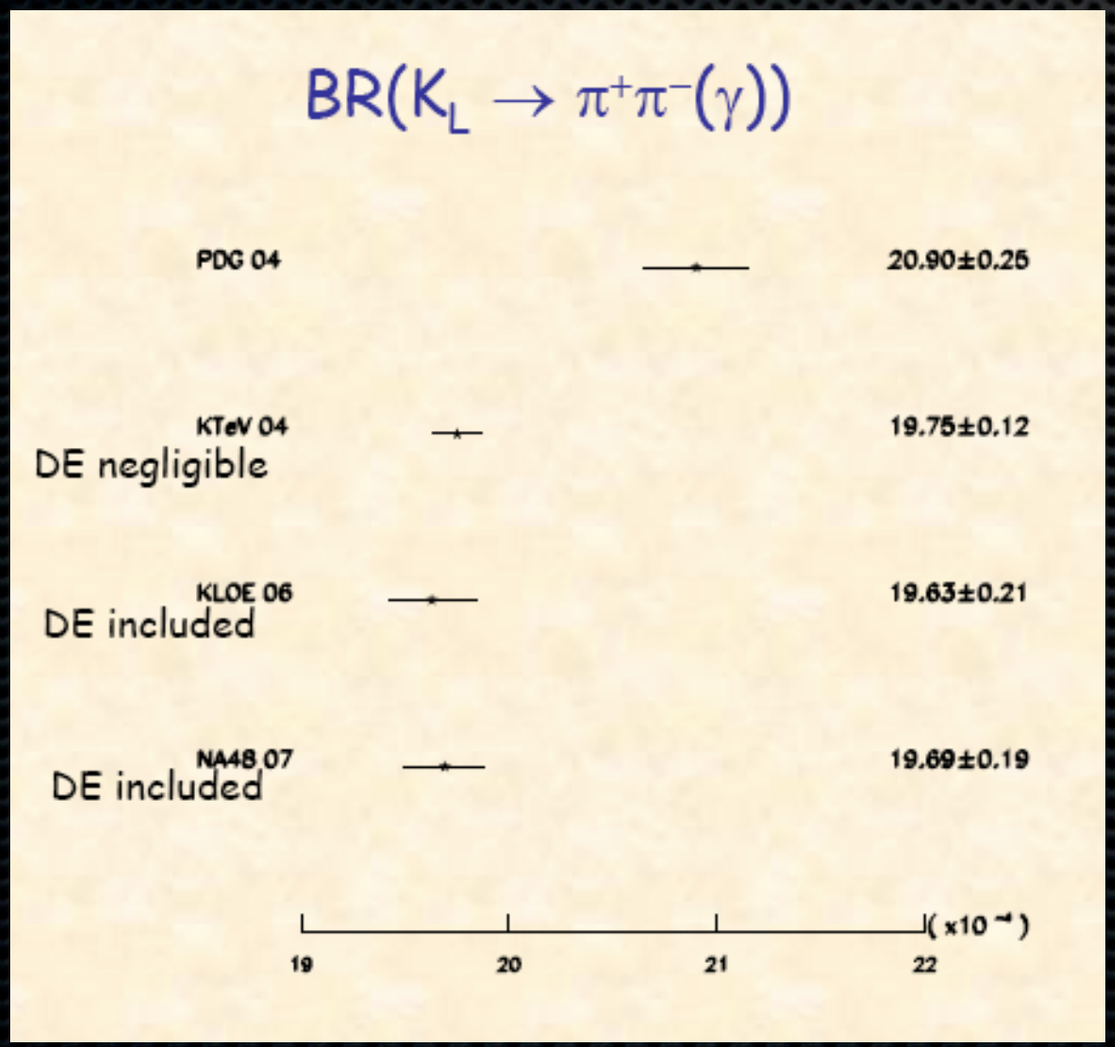
Kaon system - Experiment

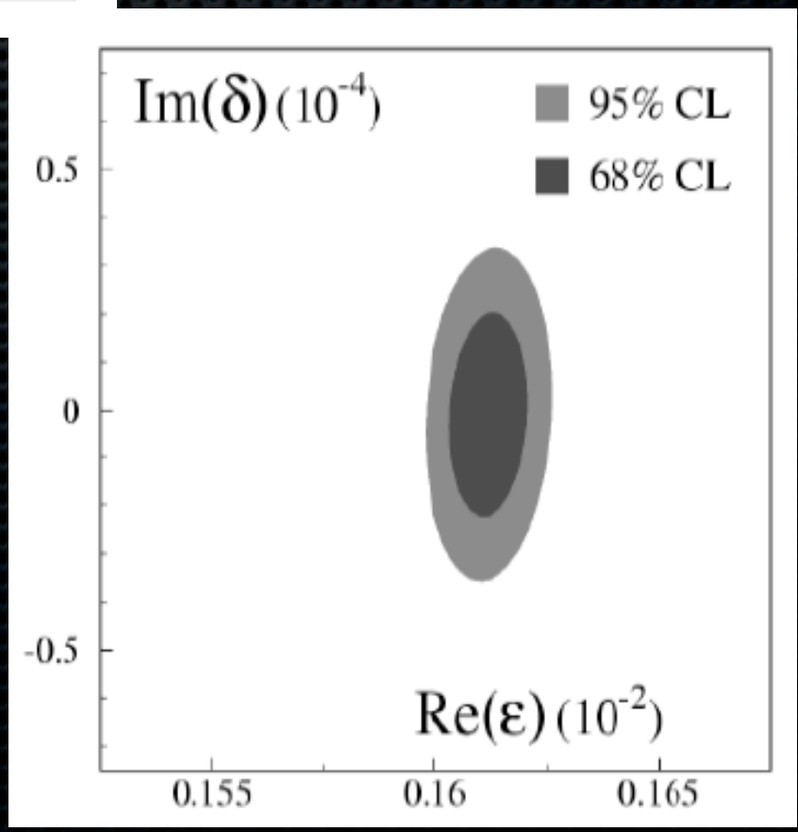
C.Bloise

HQL08, Melbourne, June 08

M. Palutan - Flavianet, Capri Workshop, June '08







The Charm System

D^0 Mixing, CP violation

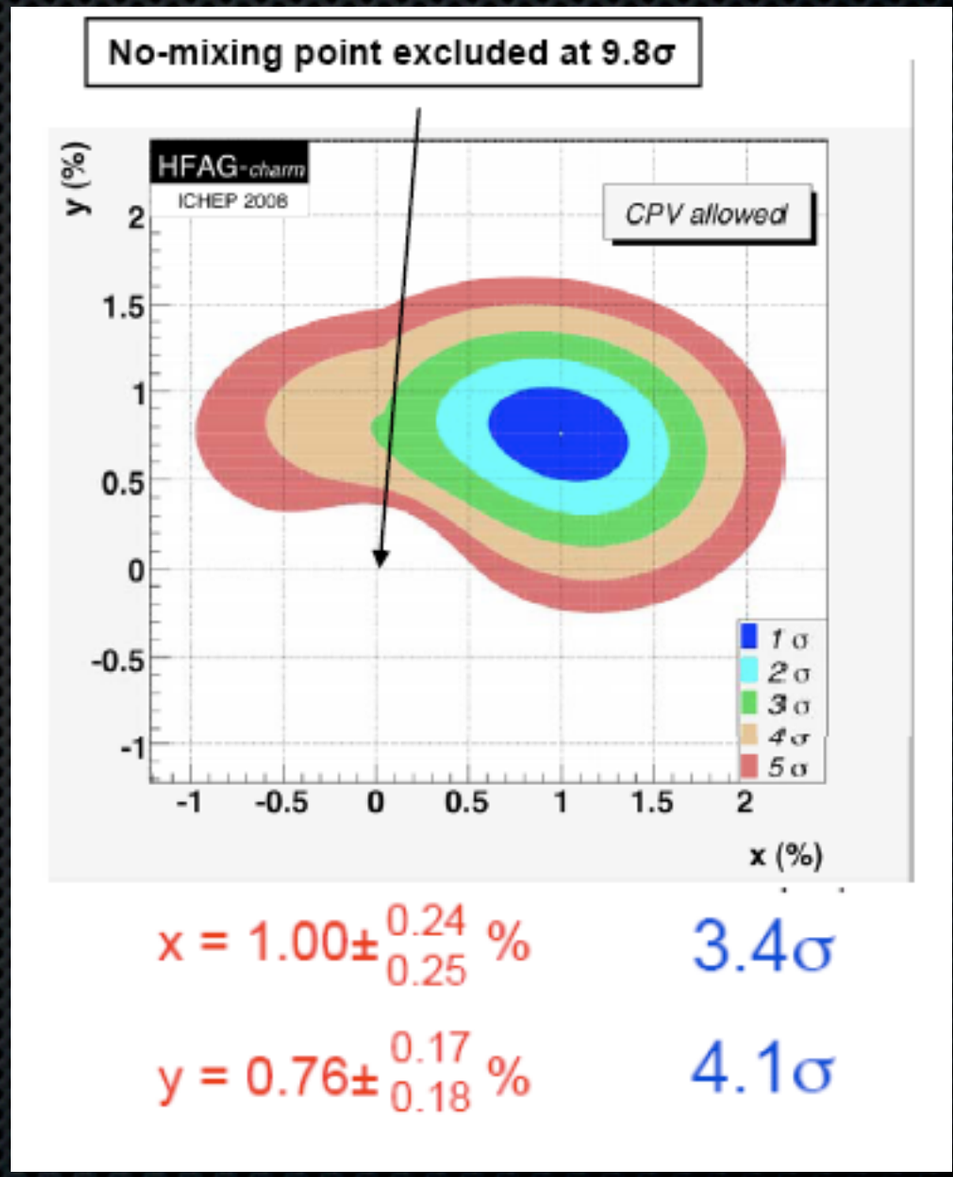
E. Golowich

- **SM Theory** (Hadron Analysis)
  - Estimate $y_D \sim 10^{-2}$ but hadronic physics messy; x_D problematic (wrong sign!).
- **NP Theory**:
  - Many NP models can yield sizable x_D but a few cannot. Charm mixing data yield useful constraints. Could x_D have a NP component?
- **Theory -Things to Do**:
  - Sign of SM prediction for x_D.
  - Relate charm mixing to charm rare decays.
  - Keep working on CPV in charm.
  - Respond to LHC findings!

D^0 Mixing - Experiment

J. Coleman

- After 30 years, evidence for D^0 mixing is now compelling
- – World averages of the mixing parameters exclude "No D^0 Mixing" at ~10**σ**
- Evidence of D^0 Mixing from several independent experiments
- Measured values of the mixing parameters |x| ≈ |y| ≈ 1% are compatible with Standard Model expectations

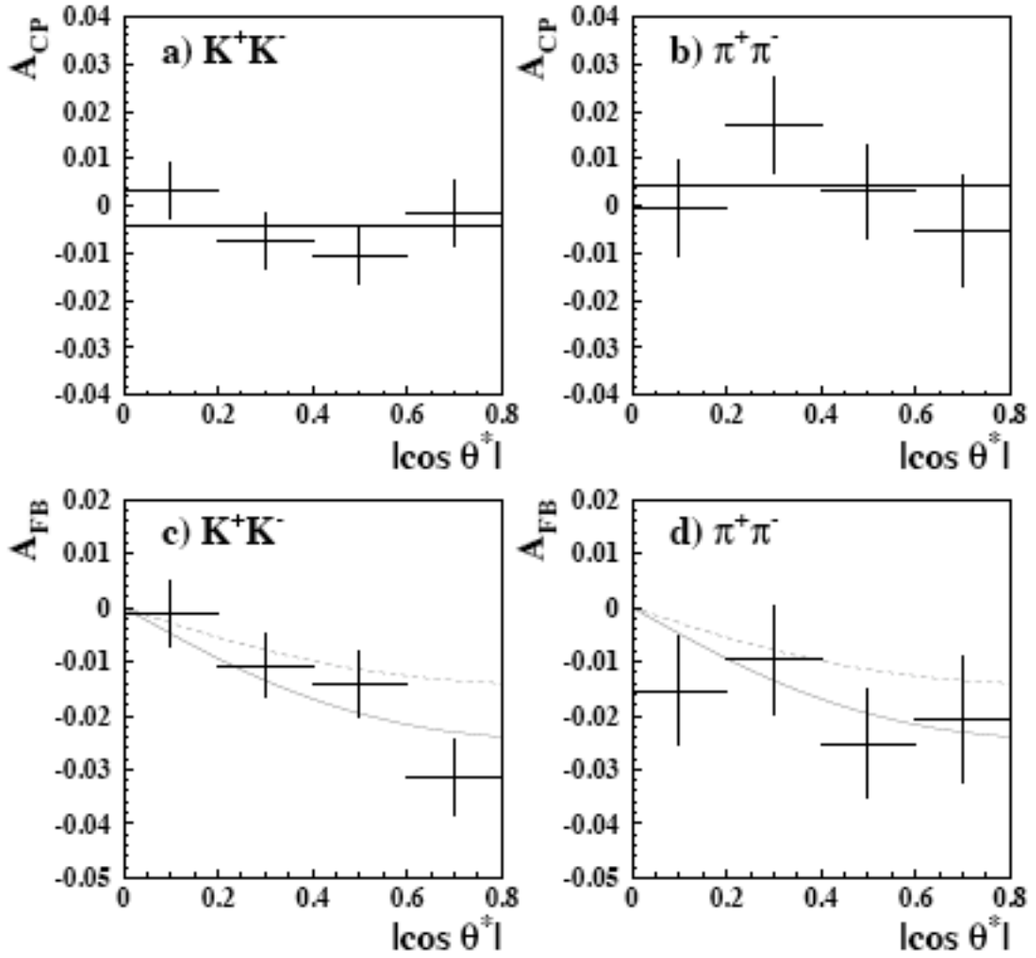


D^0 CP violation - Experiment

M. Starič

- Many D^0 decay modes searched at B-factories (Belle, BaBar) for CP violation.
- No evidence has been found.
- Most stringent constrains obtained from decays to CP eigenstates (K^+K^-, $\pi^+\pi^-$) and, using Dalitz analysis, from decays to charge conjugate states ($K^0_S\pi^+\pi^-$, $\pi^+\pi^-\pi^0$).
- Several CP asymmetries measured to ±0.25%
- Average of CPV parameters |q/p| and φ consistent with no CPV to ±15%

Belle, arXiv:0807.0148 (2008), 540 fb^{-1}



$$A_{CP}^{KK} = (-0.43 \pm 0.30 \pm 0.11)\%$$

$$A_{CP}^{\pi\pi} = (+0.43 \pm 0.52 \pm 0.12)\%$$

consistent with no CPV

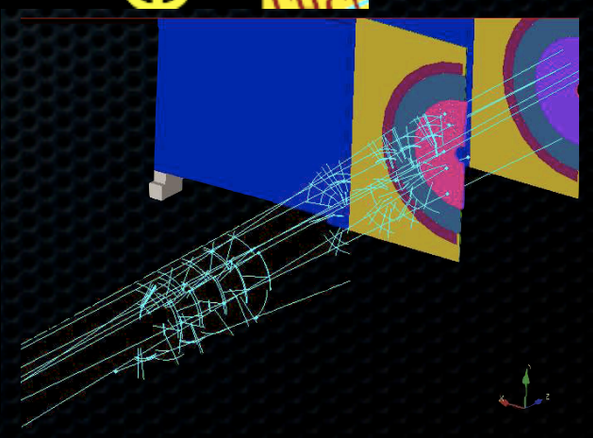
D^0 Mixing, CP: Future Outlook

- B Factories plan to update + improve results
- CDF mixing - partial dataset (x2 on tape, x4 next year)
- CDF CP violation: x40 data on tape
- manpower (not data) is becoming a problem
- LHCb: impressive potential

P. Spradlin

	Data set	N_{WS}	$x'^2(\times 10^{-3})$	$y'(\times 10^{-3})$
BaBar	$384\,\text{fb}^{-1}$	4030	$-0.22 \pm 0.30 \pm 0.21$	$9.7 \pm 4.4 \pm 3.1$
Belle	$400\,\text{fb}^{-1}$	4024	$0.18^{+0.21}_{-0.23}$	$0.6^{+4.0}_{-3.9}$
CDF	$1.5\,\text{fb}^{-1}$	12700	-0.12 ± 0.35	8.5 ± 7.6
LHCb	**$10\,\text{fb}^{-1}$**	**232500**	**$x'^2 \pm 0.064$ (stat)**	**$y' \pm 0.87$ (stat)**

	Data set	$N(K^-K^+\pi_s^\pm)$	$y_{CP}(\%)$
Belle	$540\,\text{fb}^{-1}$	111000	$1.31 \pm 0.32 \pm 0.25$
BaBar	$384\,\text{fb}^{-1}$	70000	$1.03 \pm 0.33 \pm 0.19$
LHCb	**$10\,\text{fb}^{-1}$**	**8×10^6**	**$y_{CP} \pm 0.05$ (stat)**



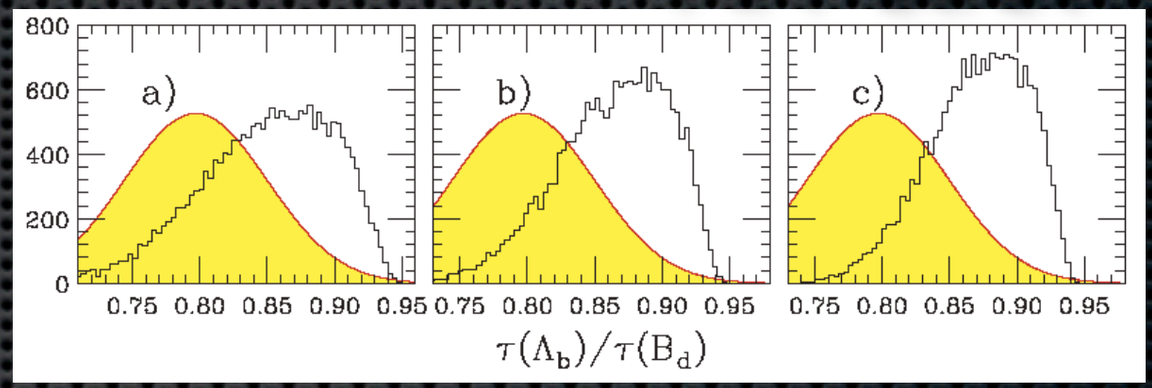
The Beauty System

B Meson Lifetimes

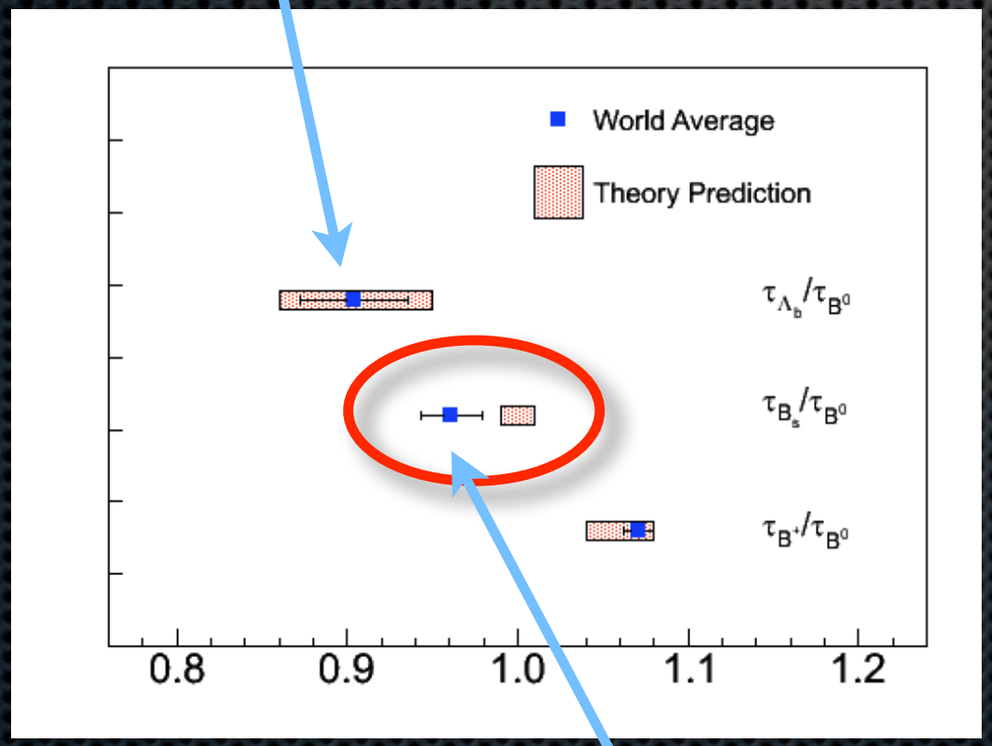
OPE appears well convergent for b-quark

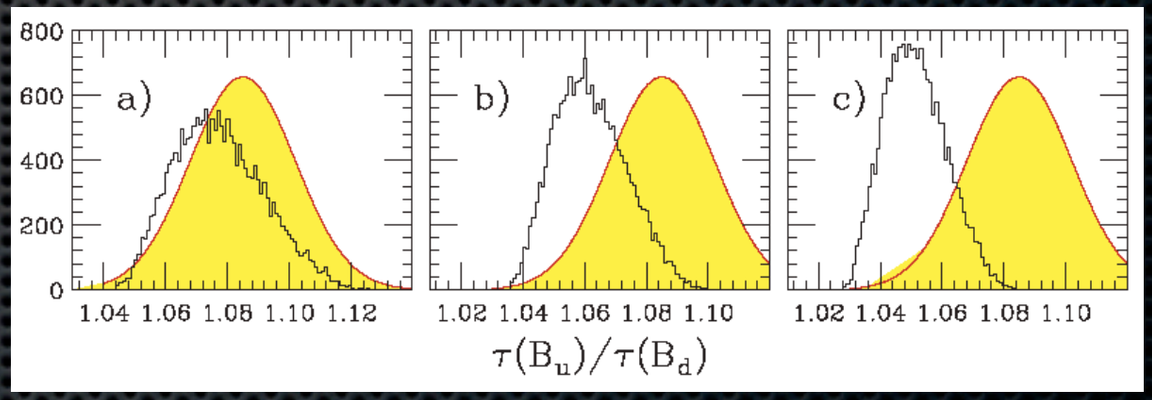
Lifetime ratio	Measured value	Predicted range
$\tau(B^+)/\tau(B^0)$	1.076 ± 0.008	1.04 – 1.08
$\overline{\tau}(B_s^0)/\tau(B^0)^a$	0.950 ± 0.019	0.99 – 1.01
$\tau(\Lambda_b^0)/\tau(B^0)$	0.912 ± 0.032	0.86 – 0.95

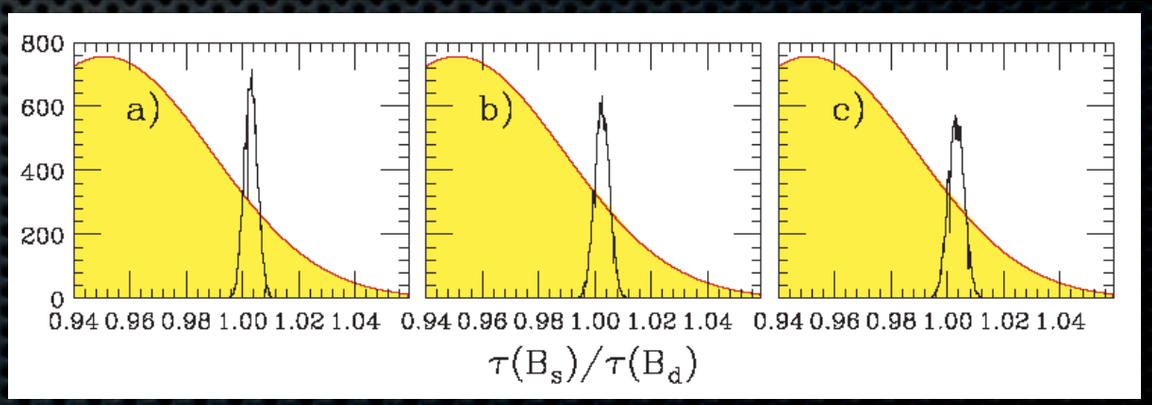
A. Petrov



"Λ_b problem" not a problem..







.. but what's with the B_s lifetime?

F. Gabbiani, A. Onishchenko, A.A.P.
Phys. Rev. D70, 094031 (2004)

$\Delta\Gamma_s/\Gamma_s$

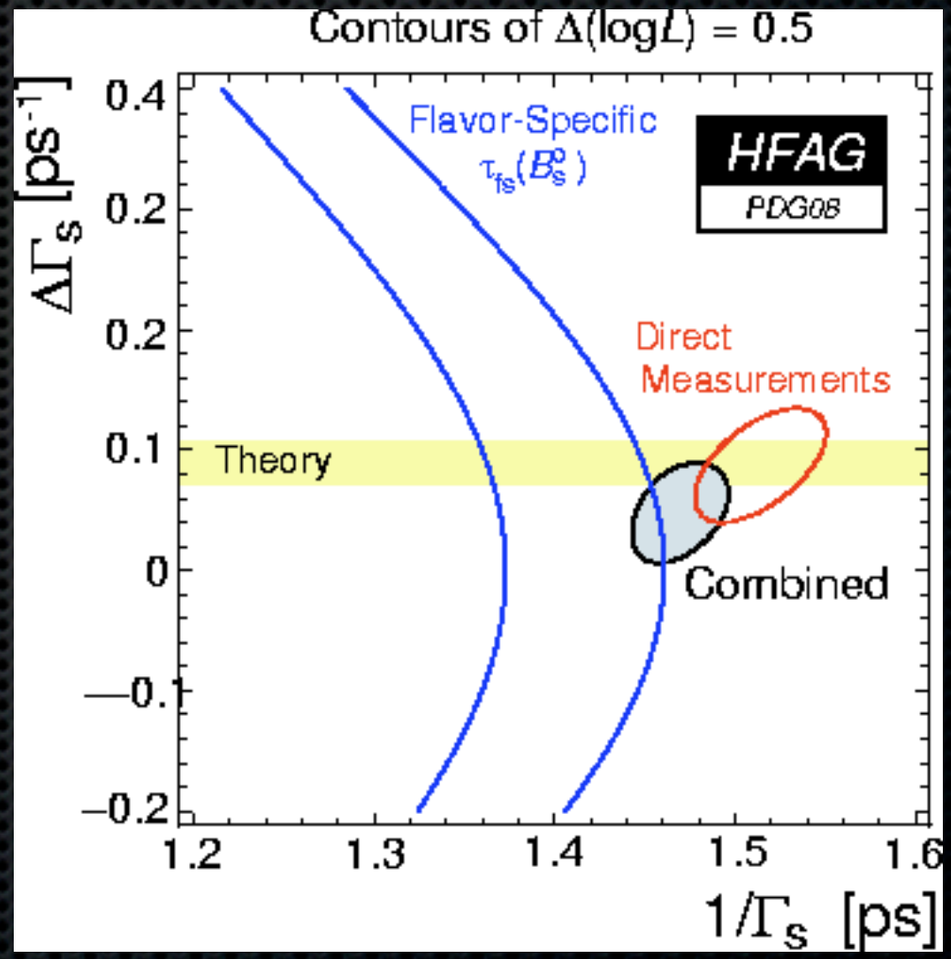
Assuming no NP contributions to ΔM_s

A. Petrov

$$\Delta\Gamma_s = \left(\frac{\Delta\Gamma_s}{\Delta M_s}\right)^{\text{Theory}} \cdot \Delta M_s^{\text{Exp.}} = 0.088 \pm 0.017\,\text{ps}^{-1}$$

$$\Rightarrow \quad \frac{\Delta\Gamma_s}{\Gamma_s} = \Delta\Gamma_s \cdot \tau_{B_d} = 0.127 \pm 0.024\,.$$

A. Lenz, U. Nierste, JHEP 06, 072 (2007)

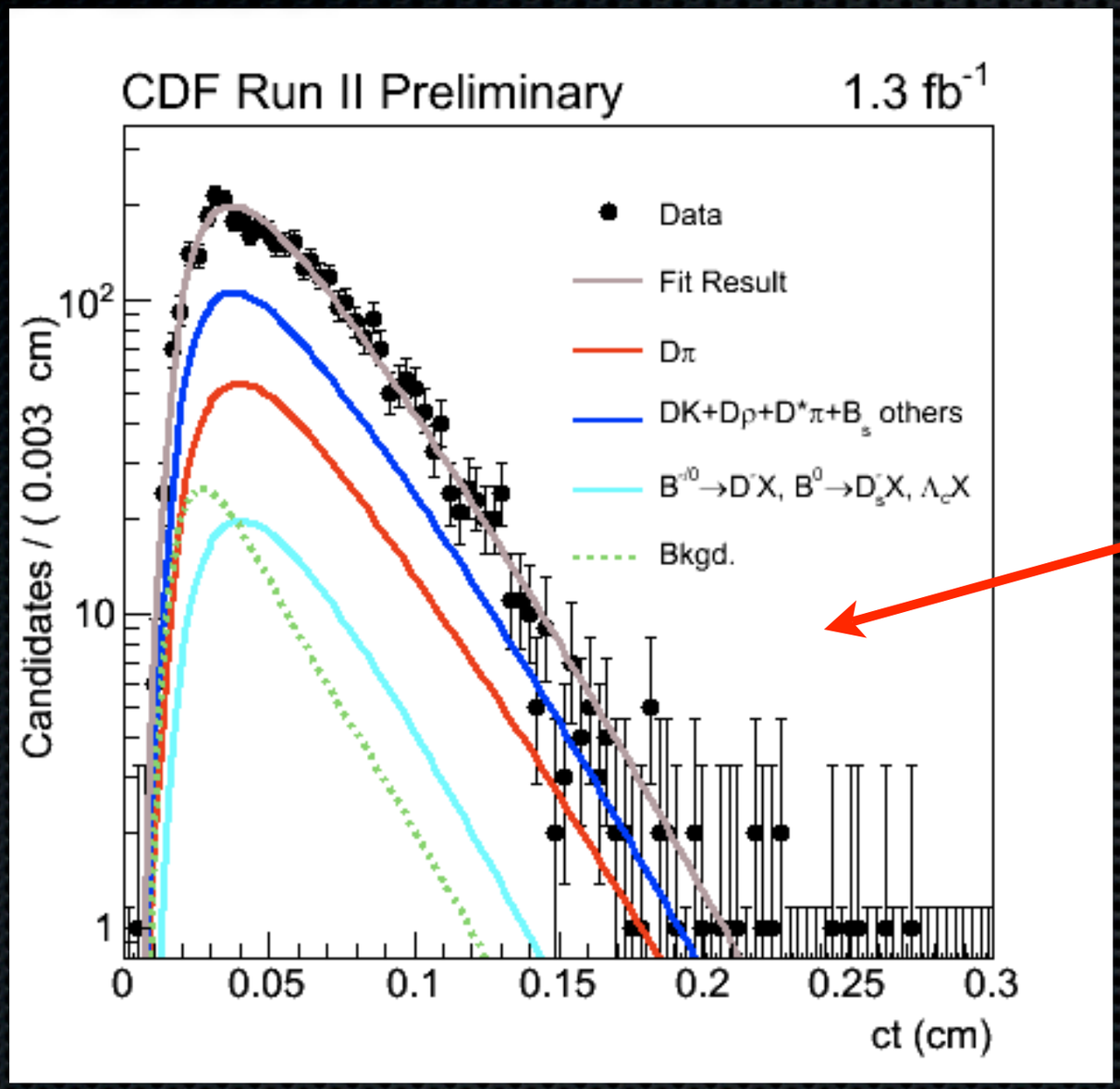


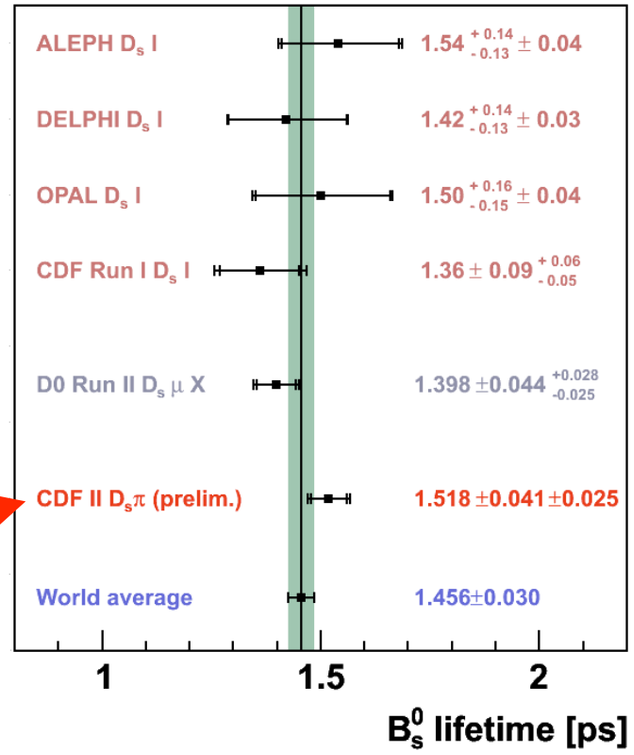
Theoretical accuracy:

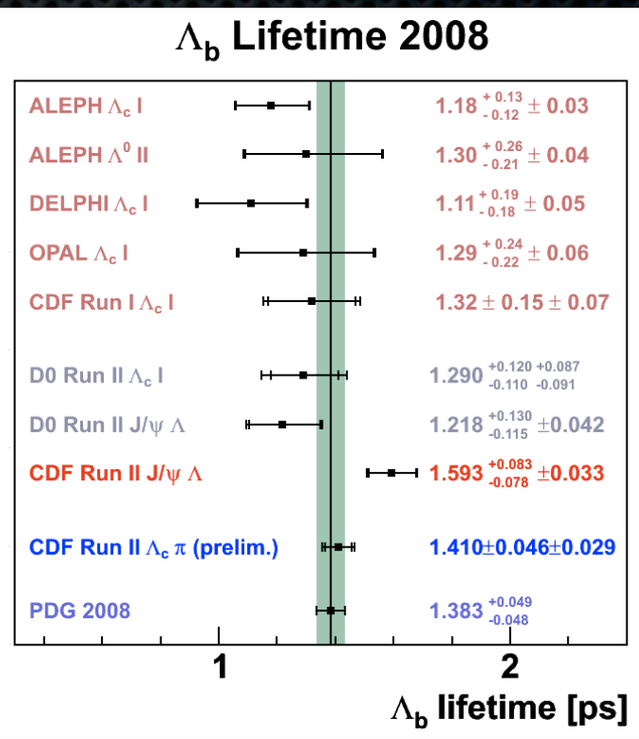
- corrections of $O(\alpha_s)$, $1/m_b$ and m_b^2 are known
- convenient change of operator basis avoids cancellations → better accuracy
- but it also shifts the central value (0.07 →0.127) → large unknown $O(\alpha_s/m_b)$ effects

Lifetimes and Δm - Tevatron

D. Bauer







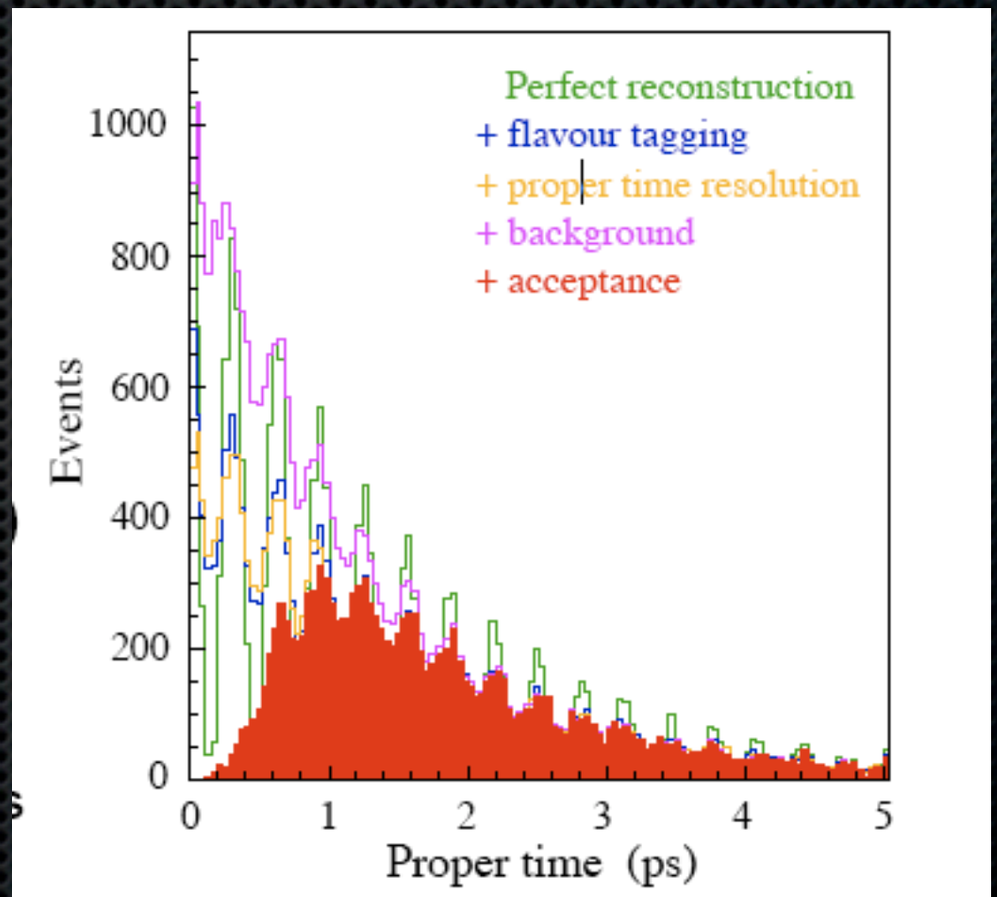
- CDF measures flavor specific lifetimes in trigger biased samples
- both detectors will update results

Lifetimes, Δm - in the Future

P. Robbe

- LHCb: in 2 fb^{-1}, 155 000 $B_s \rightarrow D_s \pi$ decays
- simultaneous measurement of τ_s, Δm_s, $\Delta\Gamma_s$:

- Sensitivities (stat only):
  - $\sigma(\tau_s)$=0.013 ps
  - $\sigma(\Delta m_s)$=0.008 ps^{-1}
  - $\sigma(\Delta\Gamma_s)$=0.03 ps^{-1} (Input=0.068 ps^{-1})



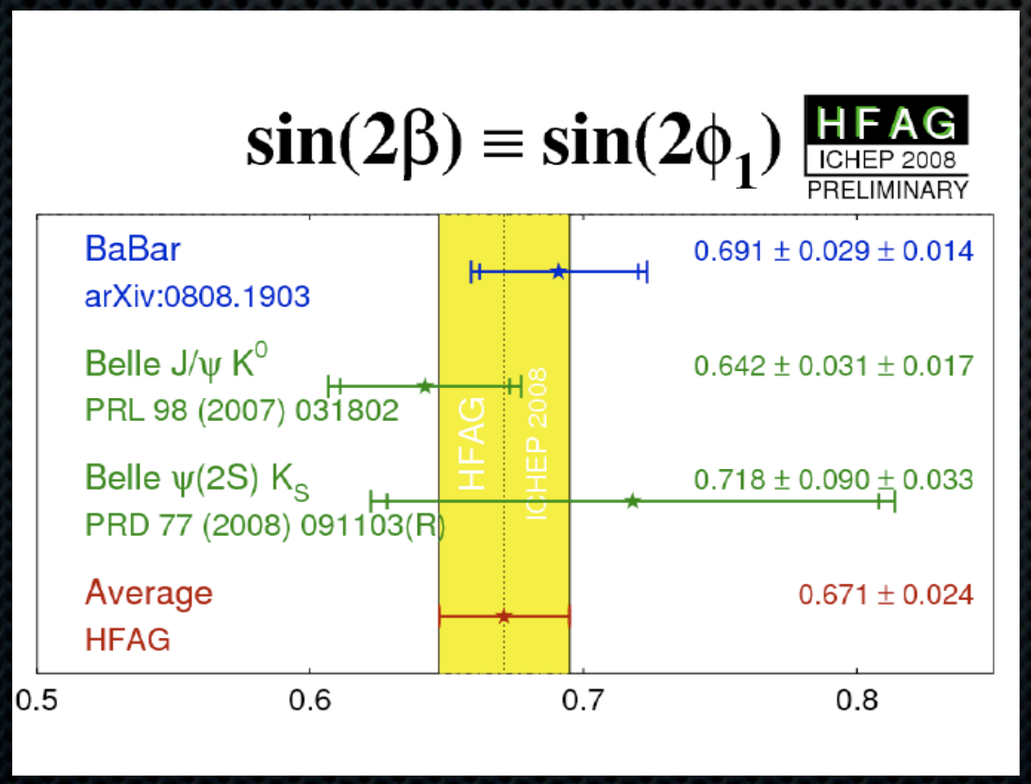
- $B_s \rightarrow J/\psi\phi$

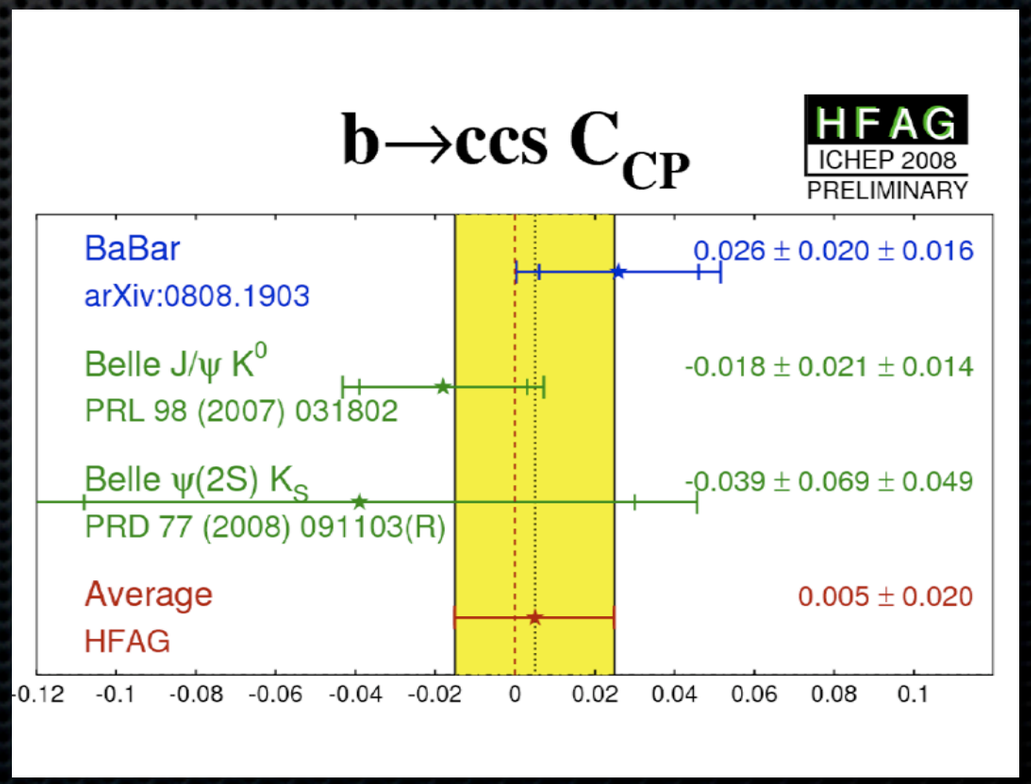
	ATLAS	CMS	LHCb
$\sigma(\Delta\Gamma_s)$	0.021 ps^{-1}	0.010 ps^{-1}	0.008 ps^{-1}
Input Value	0.1 ps^{-1}	0.142 ps^{-1}	0.1 ps^{-1}

CP violation in charmonium

E. Martin

- results presented correspond to 465-657 x 10^6 BB pairs
- $\sin(2\beta) \equiv \sin(2\Phi_1)$ has been measured in B → Charmonium decays with great accuracy.
- Excellent agreement with Standard Model.
- Looking forward to high precision measurements from at LHCb, SuperB and KEKb upgrade!



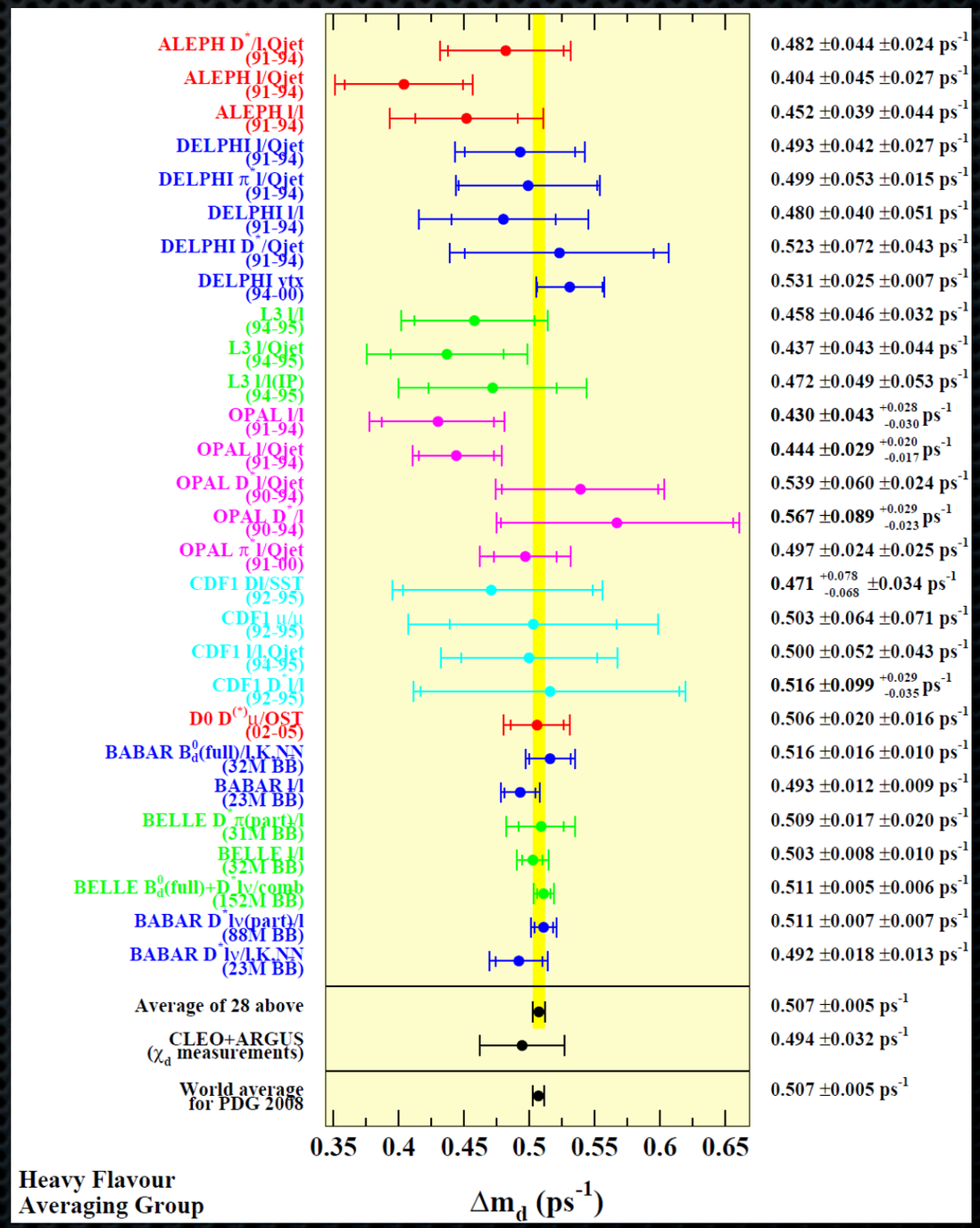


$\Delta m(B^0)$, CP, CPT

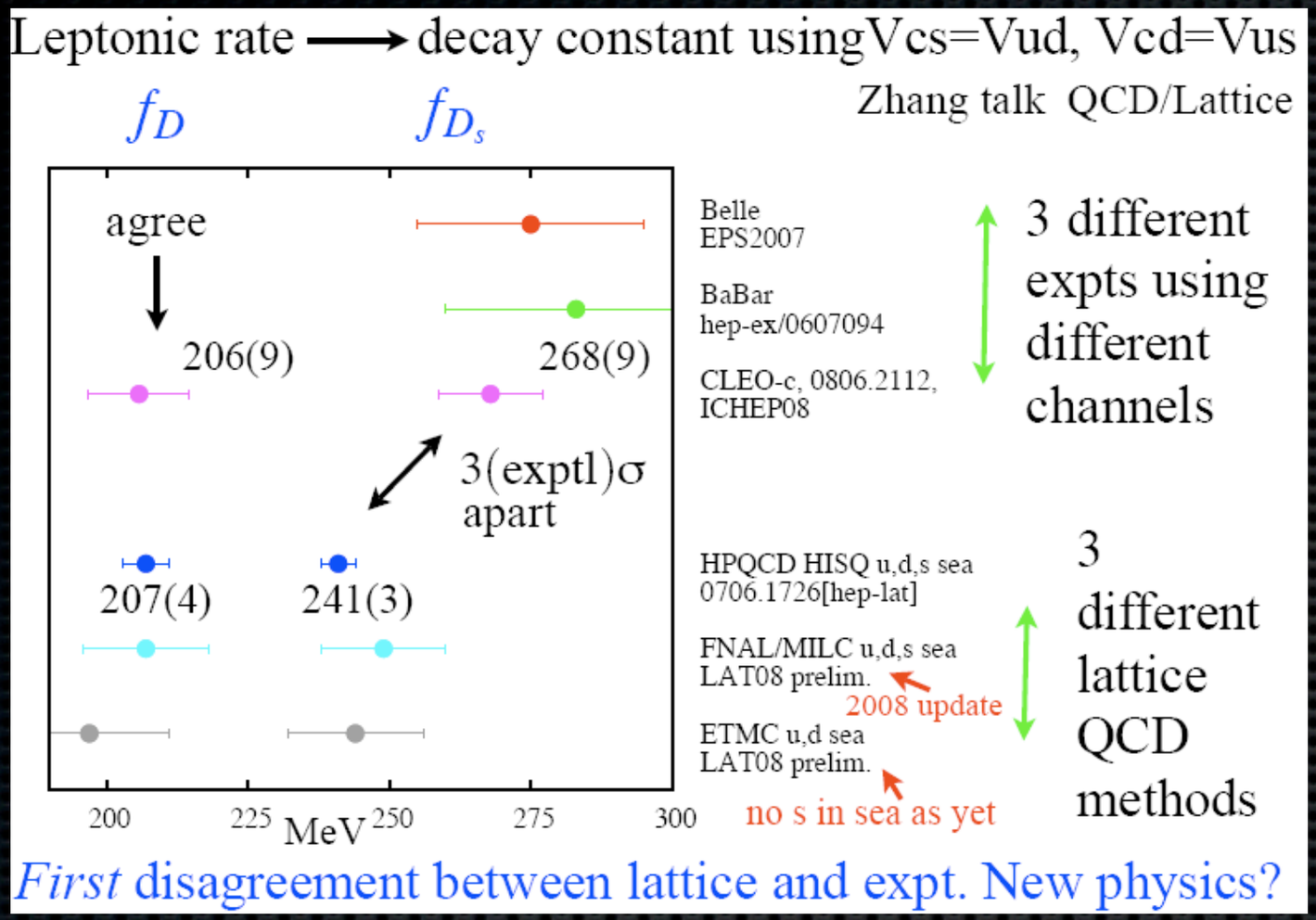
T. Higuchi

- statistical unc. on m comparable to systematic unc.
- Indirect CP violation measurements by Belle, BaBar, and DØ indicate the |q/p| is consistent to unity.
- CPT-violation with dilepton events by Belle and BaBar are reviewed. Belle will update the numbers with 535M BB pairs.

PDG2008 average
$\Delta md = 0.507 \pm 0.005\ ps^{-1}$



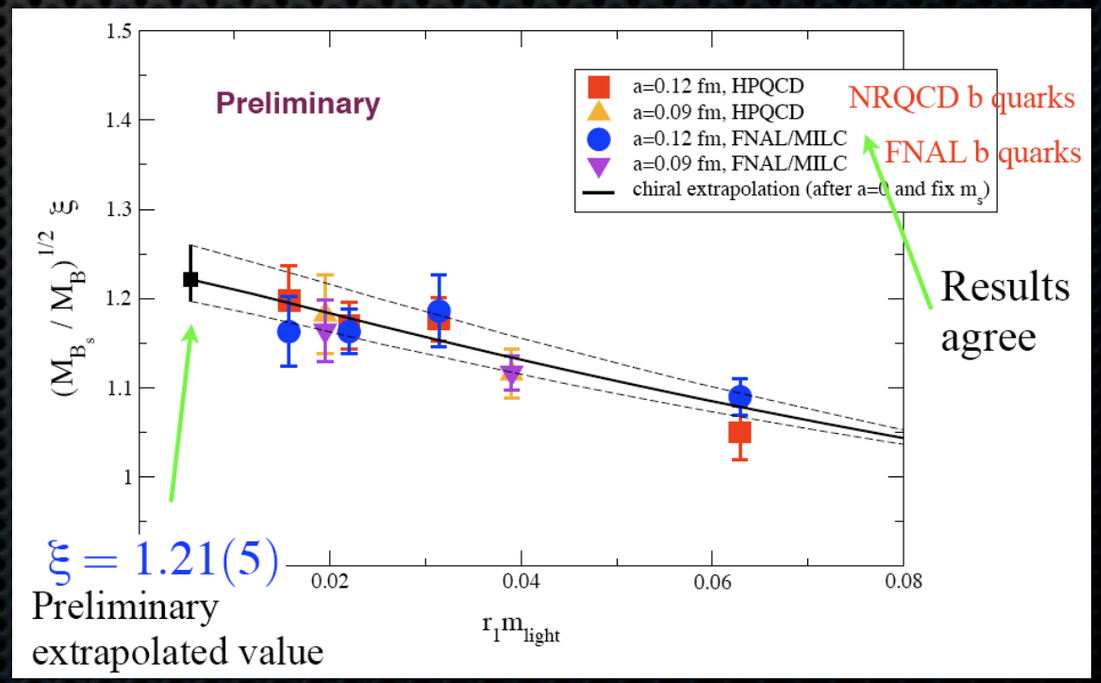
Leptonic D Decays



J. Libby, C. Davies

First full QCD results this year for

$$\xi = \frac{f_{B_s}\sqrt{B_{B_s}}}{f_B\sqrt{B_B}}$$

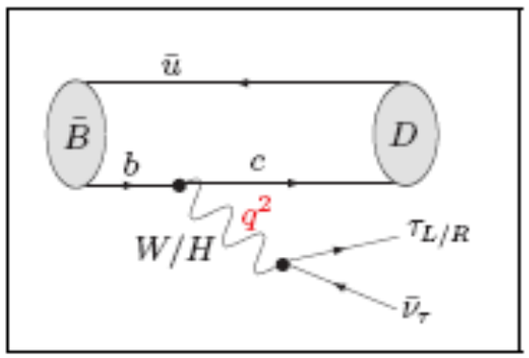


- D_s decay constant is the only result (of~ 15 quantities) that disagrees with experiment.
- Further tests this year confirm confidence in the lattice calculation → must take this seriously. Lattice tests continue.

$B \to D\tau\nu$: q^2 distribution

S.Westhoff

$$\frac{d\Gamma(B \to D\tau\nu)}{dw} \propto |V_{cb}|^2 \left\{ (w^2-1) F_V(w)^2 \rho_V(w) + F_S(w)^2 \left[1 - g_s \frac{q^2/m_B^2}{1 - m_c/m_b}\right]^2 \rho_S(w) \right\}$$



[Grzadkowski, Hou '92] [Kiers, Soni '97]

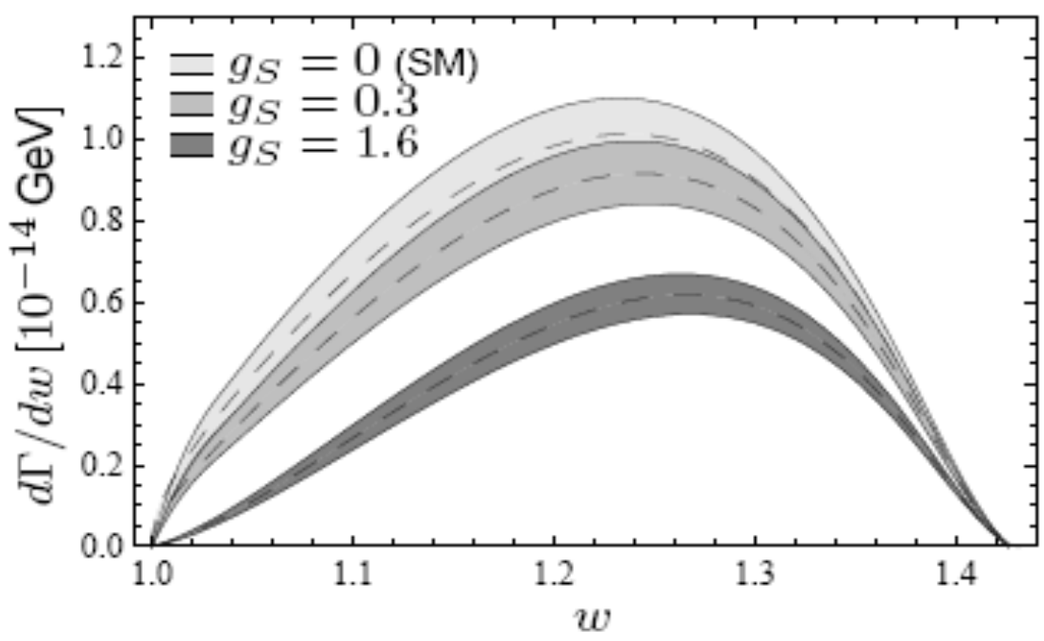
$$w = \frac{E_D}{m_D} = \frac{m_B^2 + m_D^2 - q^2}{2 m_B m_D}$$

$w = 1$:

transversal $W_\perp^+$ modes suppressed

relative $W_\parallel^+$ and H^+ contributions depend on q^2

$\to$ determine g_S from shape



Phase of the SM Bs mixing

M. Ciuchini

- The SM contribution to CP violation in Bs mixing is small and rather well determined:

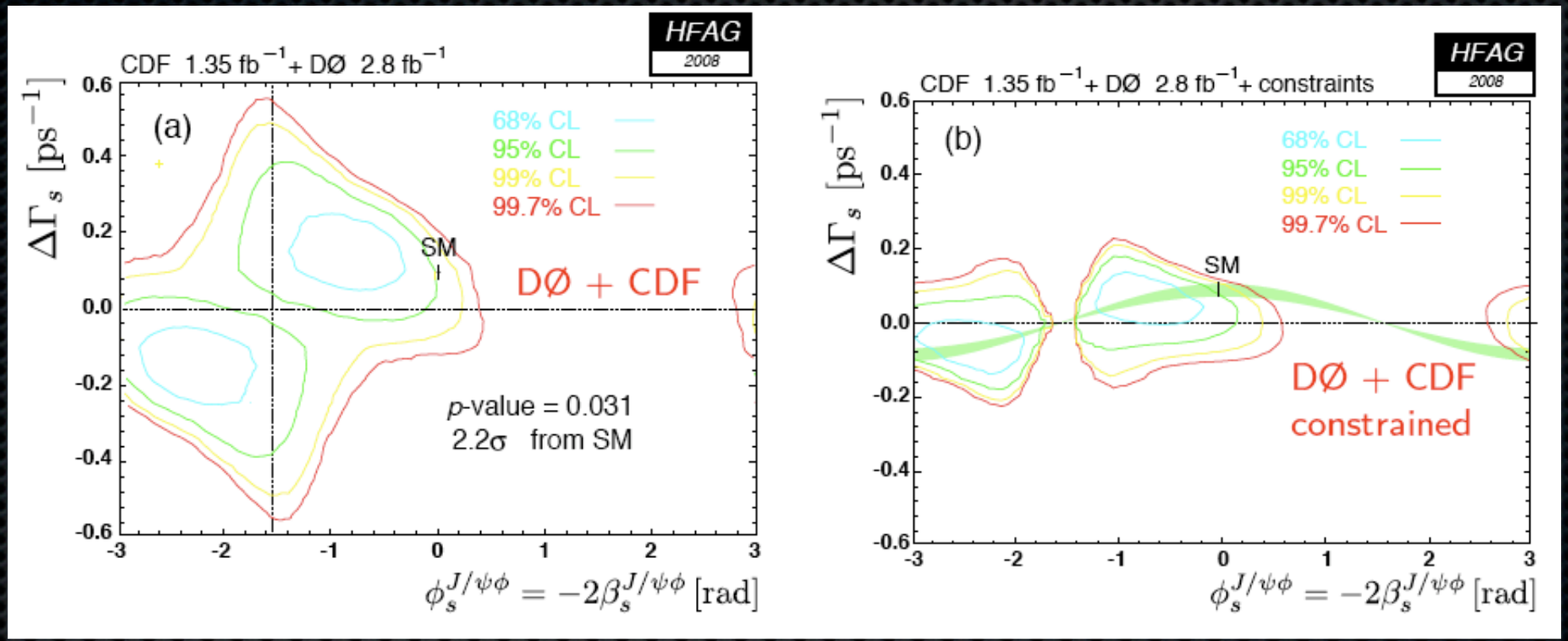
$$\sin 2\beta_s = 0.041 \pm 0.004 \text{ (arbitrary NP)}$$
$$= 0.037 \pm 0.002 \text{ (SM or MFV)}$$

- The phase of the B_s mixing amplitude can be extracted from $B_s \to J/\psi\phi$ with a small theoretical uncertainty
- Hence observing a mixing phase significantly larger than 0.041 would be a very clean signal of NP in B_s mixing

ϕ_s - Experimental Status

- D0 consistent with SM up to 8.5%
- CDF consistent with SM up to 15 %

L. Sonnenschein, D. Tonelli



- CDF partial update - new result consistent with SM at 7% - no combination available yet

ϕ_s - Global Fits

M. Ciuchini

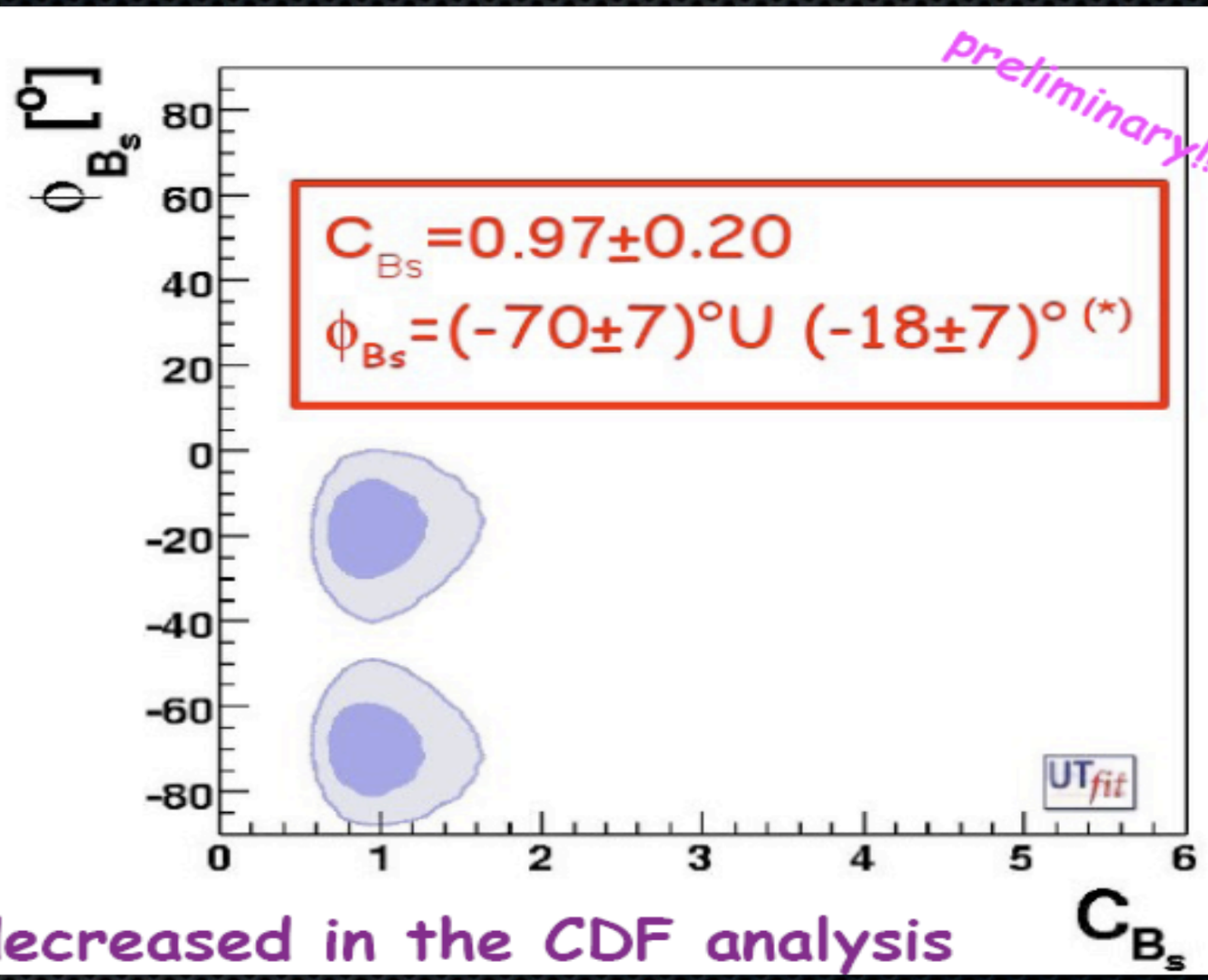
Including the reanalysis of the DØ data

(*) $\phi_{Bs} < 0$:

3σ -> 2.5σ

New CDF data not included:
new CDF likelihood "not ready yet"

SM compatibility decreased in the CDF analysis



If this evidence is confirmed...

* MFV models are ruled out, including the simplest realizations of the MSSM

ϕ_s - Discussion

cca 10 people

- Multifaceted issue of global fits vs published values
- Frequentist vs Bayesian approach
  - Experiments report frequentist CL regions
  - UTFit procedure reports Bayesian probability integral

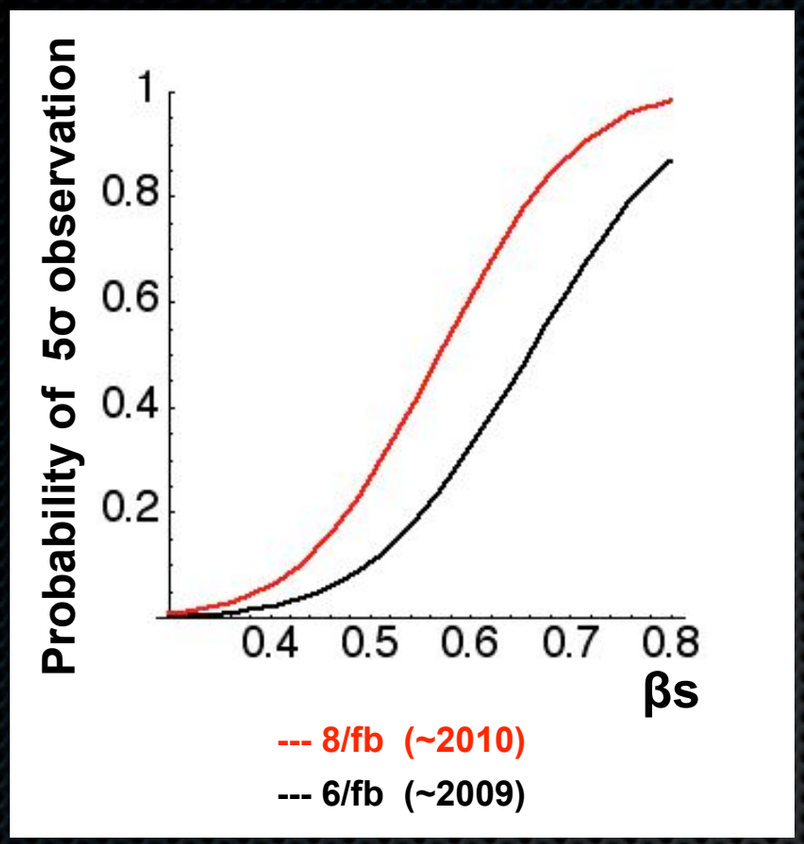
  a) these tend to disagree in tail situations

  b) the published likelihood can not be used to reproduce the published values - artificial performance boost

- suggestion: check for J/ψ f_0 contamination/interference
- suggestion: do not add strong phase constraints to fit

ϕ_s - Future Outlook

G. Lanfranchi



- CDF, D0 will keep taking data
- for large β_s, good chances of observation
- detector power is very close - will benefit from combination
- LHCb - unprecedented precision imminent with 2009 data

	ATLAS	CMS	LHCb	CDF *)	D0*)
L[fb^{-1}]	2.5	2.5	0.5	1.3	2.8
Yield [untagged]	~23k	~27k	~33k	~ 2k	~2k
2βs sensitivity	0.16+)	not yet done	0.06+)	[0.32,2.82]@68%CL	$0.57^{+0.24}_{-0.30}$
σ(ΔΓs/Γs)/(ΔΓs/Γs) [for ΔΓs/Γs~0.1]	0.45	0.28	0.17	0.75 *) published results	0.50 *) published results

+) assuming SM value

Writeup Status

- Writeup Authors' Meeting: Friday Lunch Break
- WGIV contribution distributed throughout book
- presenters had very little overlap in material
- we ask our presenters to write up 1-2 pages summarizing their talk ASAP
- already received 6 short contributions (6/19)
- information will be edited and incorporated into book writeup
- as needed, conveners will follow up with presenters
- once material is placed into book, review/discuss

Conclusions

- successful information exchange - suggestions, concerns
- speakers are hands-on experts on presented topics
- topics chosen to have little overlap
- nearly unit mapping speaker ↔ writeup author
- first work toward draft writeup started
- looking forward to contributing to book