BEACH 2006

EXPERIMENTAL SUMMARY TALK

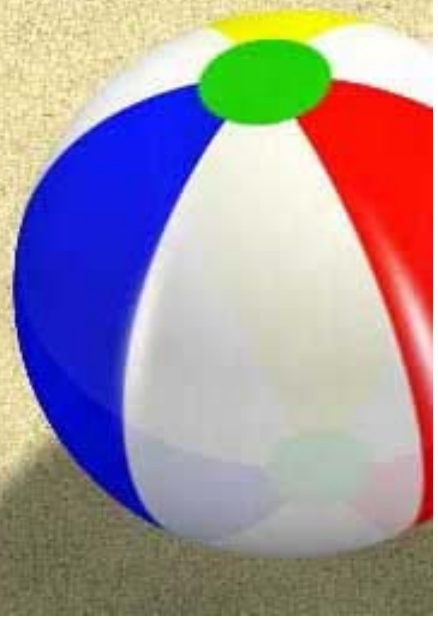
JULY 8TH 2006, LANCASTER

STEVE PLAYFER

UNIVERSITY OF EDINBURGH

“to see a universe in a grain of sand” (William Blake)

- At this conference there were a lot of talks ...and I only have 50 minutes
  - My apologies if your bit of BEACH 2006 has not been used
- All the talks were very interesting
- Flavour physics is clearly a very active field!
- The discussion on future directions shows we are not finished



A plea for the English language

- "***There is a Tension between*** …"
  - Vub and sin2β
  - Vub and Vcb inclusive & exclusive
  - Sin 2β from b–>ccs and b–>sss
- Means difference >1σ and <3σ?
  - Statistical fluctuation is likely
  - Experimental systematics
  - Theory uncertainties (in some cases)
- There might be New Physics!
  - … but only if we understand uncertainties
- My translation into English :

"***There is attention (that should be given to differences) between*** …"

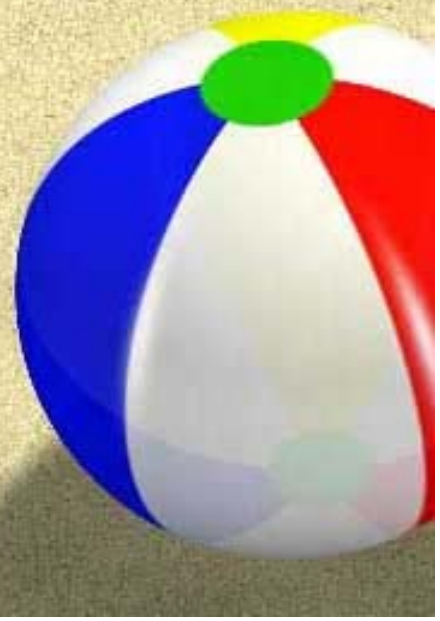
Tension -

A stretching of

a string or spring

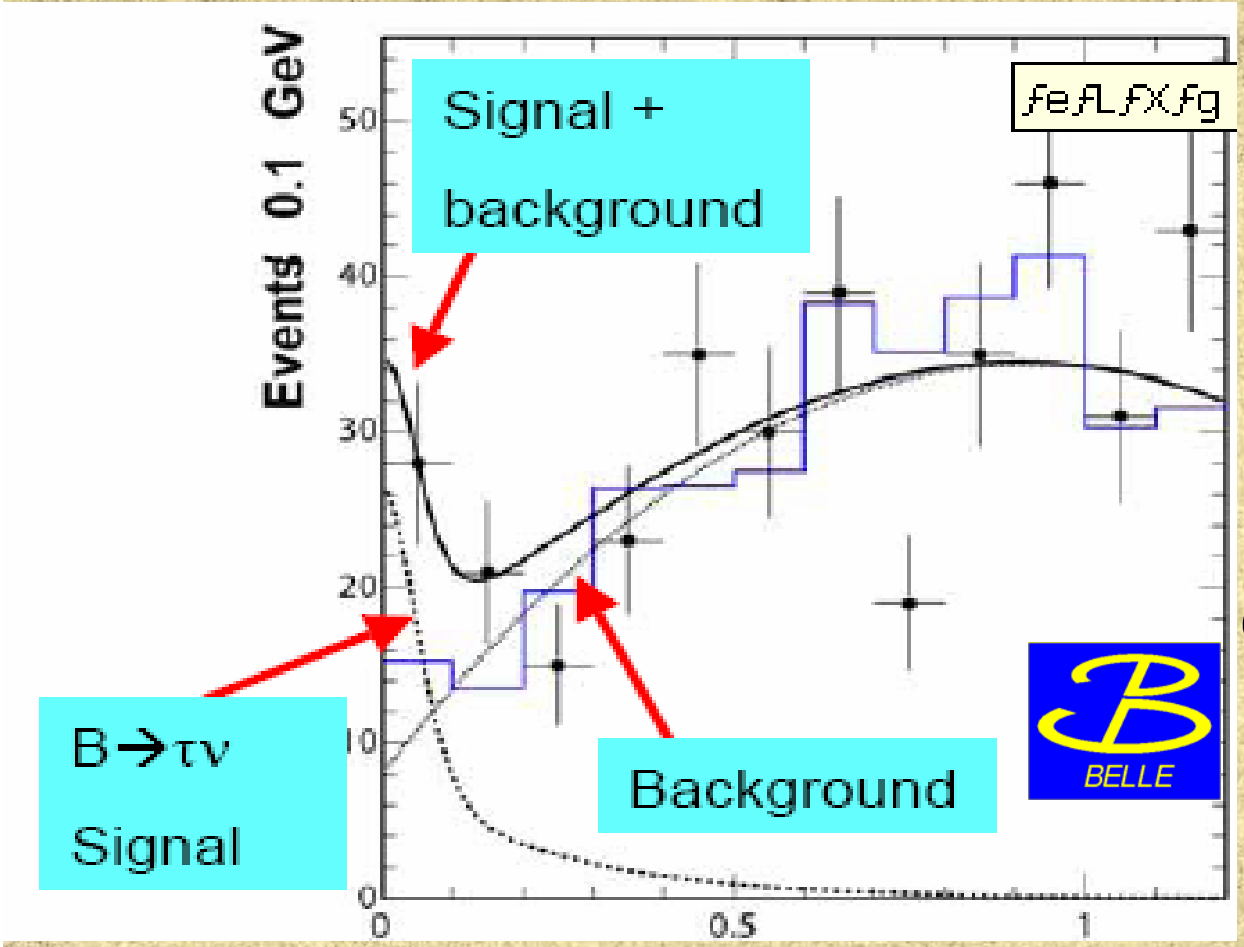
OED/Golowich

!



B–> τν was thought to be impossible not so long ago ...

Mancinelli



New result from Belle this spring

Uses hermeticity to identify signal

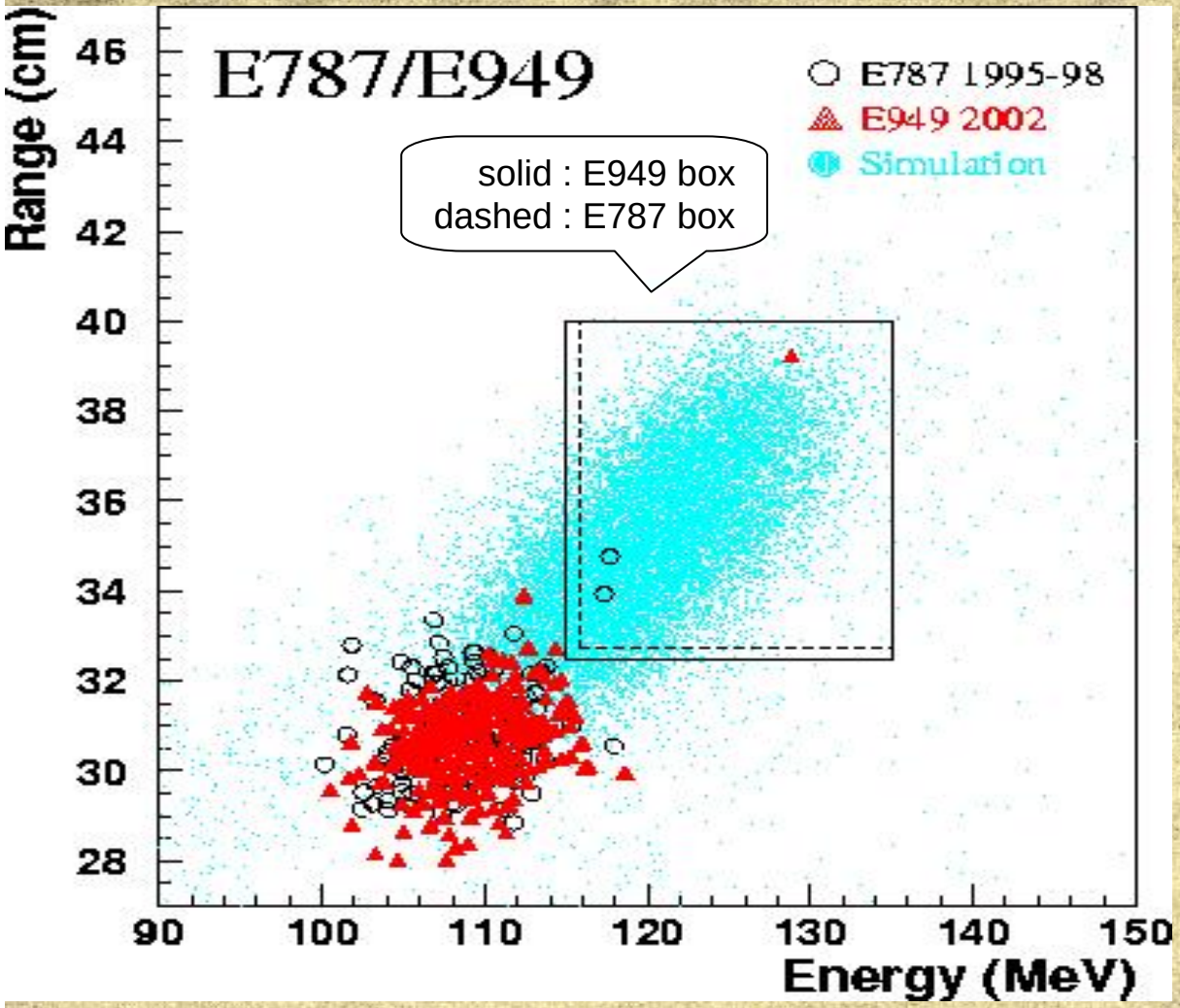
Measures $f_B^2|V_{ub}|^2$
Constrains H^+

$$BF(B^+ \to \tau^+ \nu_\tau) = 1.06^{+0.34+0.18}_{-0.28-0.16} \times 10^{-4}$$

significance 4.2σ, $SM \sim 10^{-4}$

There are a few $K^+ \to \pi^+\nu\nu$ events…

Nomura



Three candidates observed at Brookhaven after several years of running

Uses hermeticity Range and $E\pi$

Measures $|Vtd|^2$

$$B(K^+ \to \pi^+\nu\nu) = (1.5^{+1.3}_{-0.9}) \times 10^{-10}$$

And lots of rare K decays

Nguyen

Gatti

Fantechi

Duk

Raggi

From the NA48 (K_L,K_S,K+), KTeV (K_L),

KLOE (K_L,K_S,K+) and ISTRA (K+) experiments

K_L –> π+π–γ, π+eνγ, ππee, eeγ, π0γγ, π+π–π0γ

K+ –> π+π0γ, π0eνγ, π0μνγ, μνγ

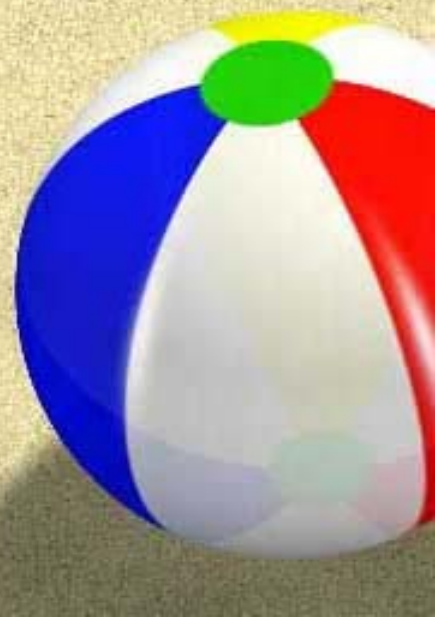
K_S –> π+π–π0, π0π0π0, γγ, πeν, πμν

Large statistics 10-100K in some modes

Branching fractions 10-3 to 10-7

Some first observations

Many interesting precision measurements



CP Violation in K decays

Gatti

Collozuol

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

KLOE

Fit to many inputs

to be compared with CPLEAR:

$Re(\varepsilon) = (164.9+-2.5)x10^{-5}$

$Im(\delta) = (2.4+-5.0)x10^{-5}$

Dalitz plot asymmetry in $K^+ \to \pi^+\pi^-\pi^+$ (NA48)

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

An order of magnitude better than previous results

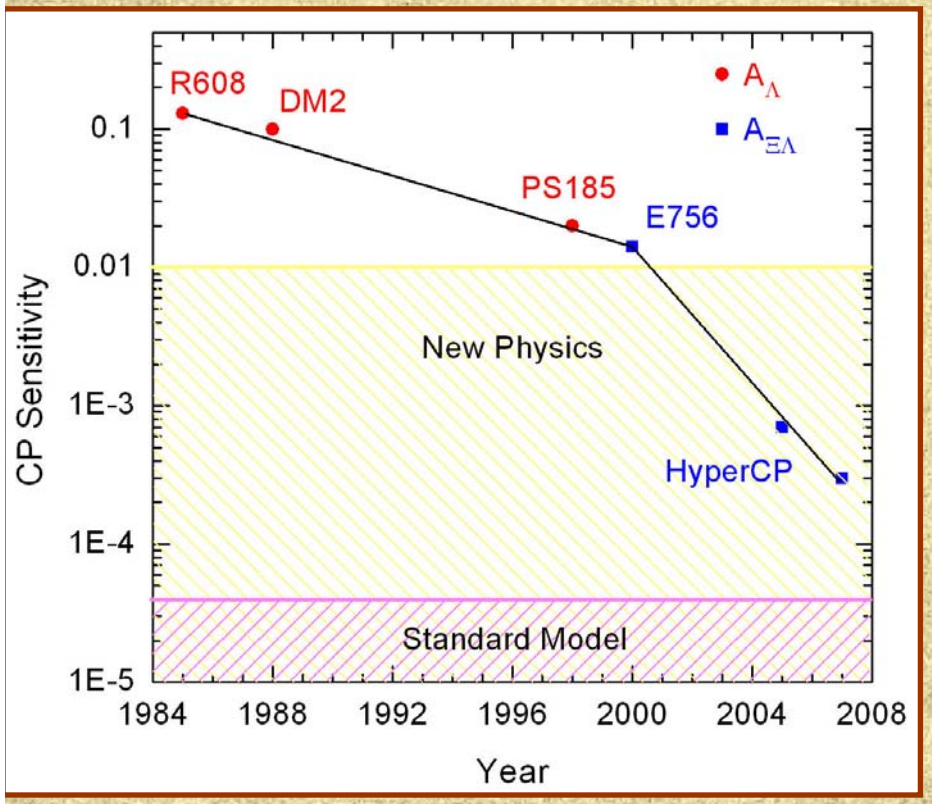
CP Violation in Hyperons

Dukes

Direct CP violation in ΔS=1 (between S and P waves)

Strong phase shifts are only a few deg. (Note - ε' is between I=0,2)

Measure transverse polarization of Λ in Ξ decays

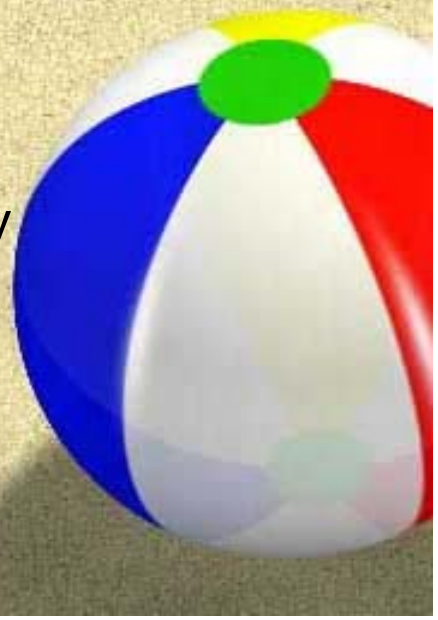


$A_{\Xi\Lambda} = (2.2 \pm 5.1) \times 10^{-4}$

SM: 5×10^{-5}

New Physics sensitivity

is interesting

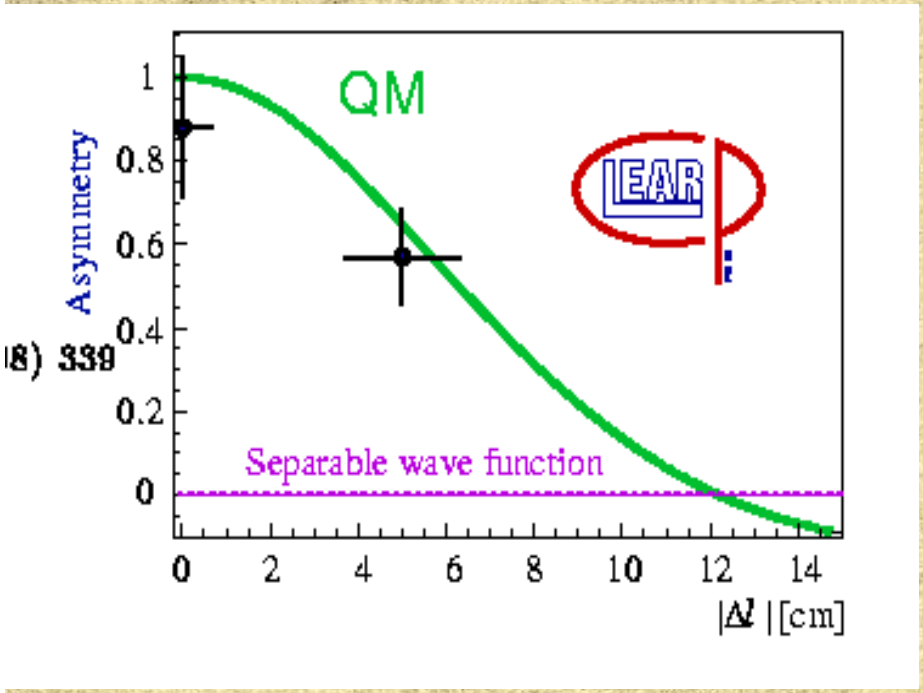


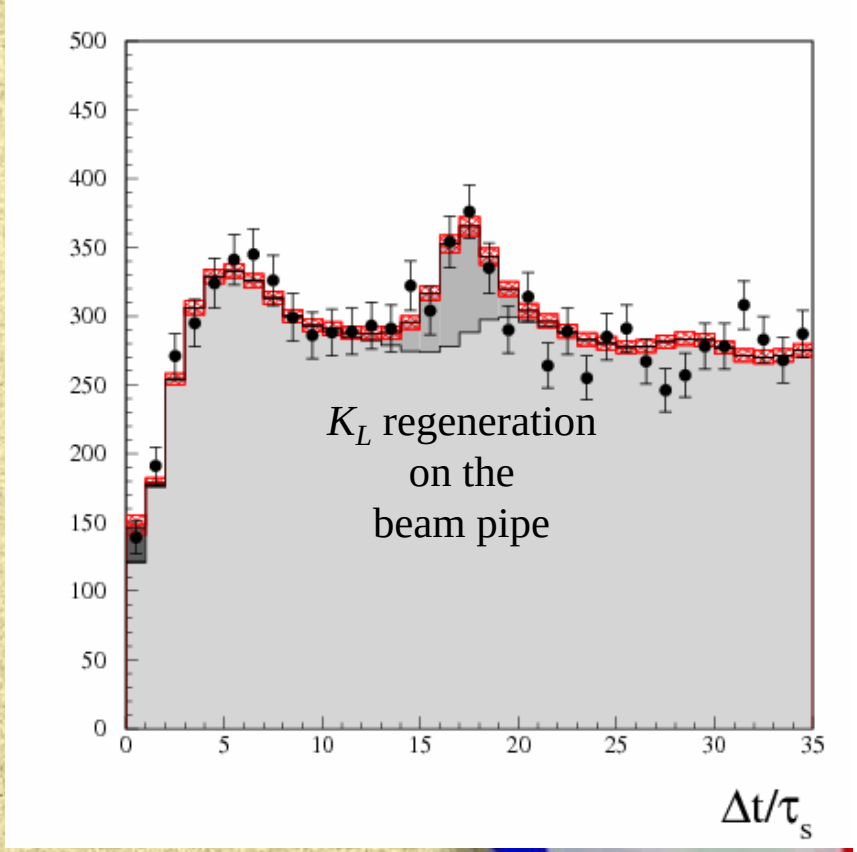
CPT Violation and QM

Gatti

Testa

Tests at CPLEAR (ppbar–>$K_S K_S$), KLOE (ϕ–>$K_S K_L$)
No evidence for either "well-defined" CPT violation
or "ill-defined" quantum decoherence



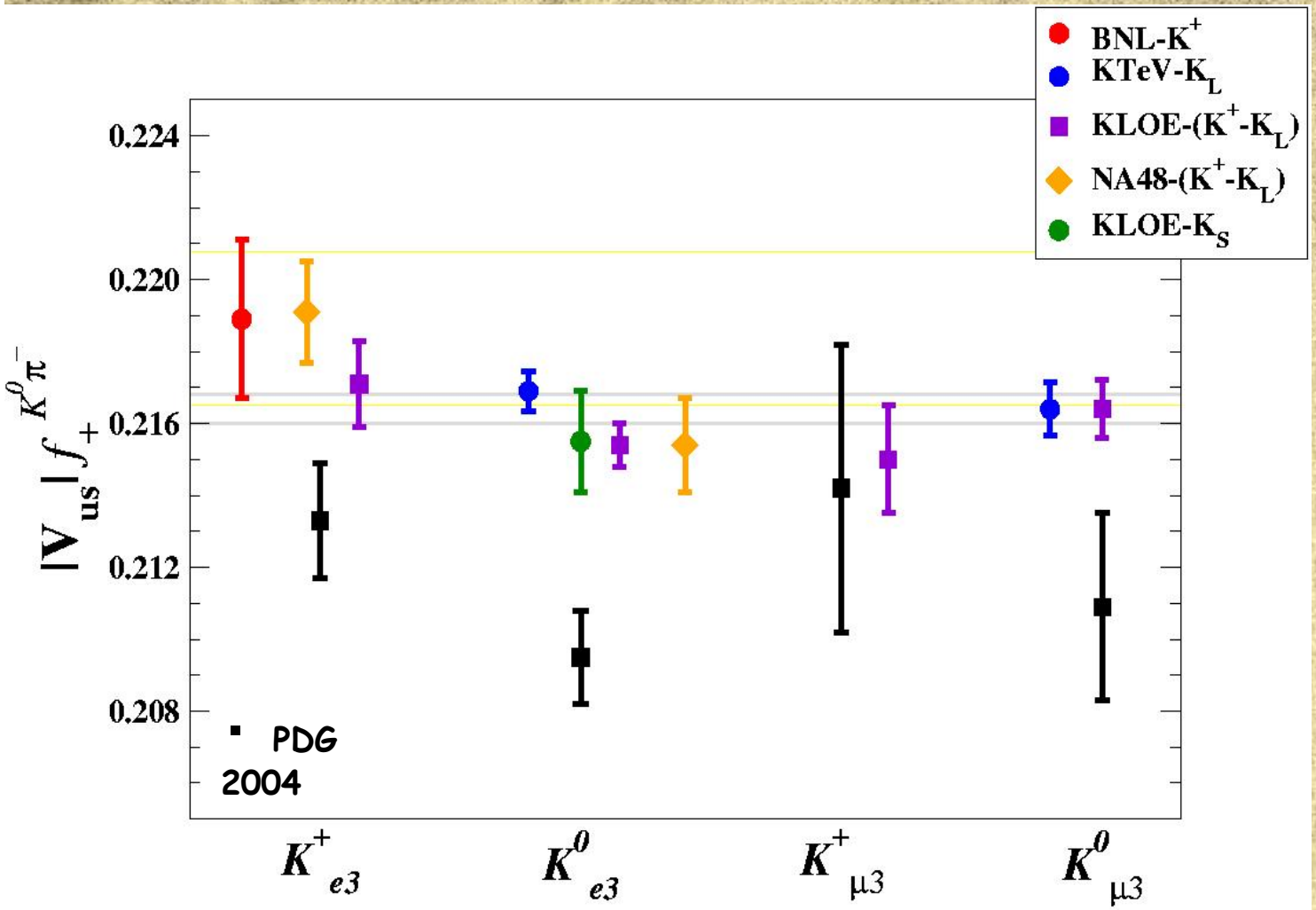


In the future ψ''–>DD and $\Upsilon(4S)$–>BB

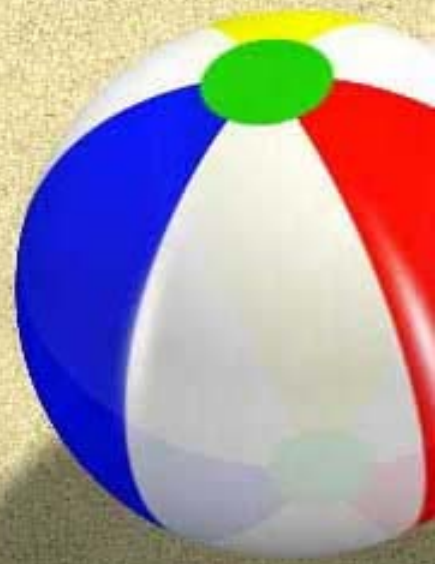
Results reaching interesting range
~10^{-21} GeV

Semileptonic K decays

Antonelli



Vus has increased significantly since PDG2004



The first row of the CKM matrix now satisfies unitarity to within 1σ (Vus known to 1%)

Semileptonic Hyperon decays

Lazzeroni

NA48: $\Xi^0 \rightarrow \Sigma^+ l \nu$

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Vus=0.208 +-0.006
+-0.030(theory)

Ratio of form factors
g1/f1 = 1.20+-0.05

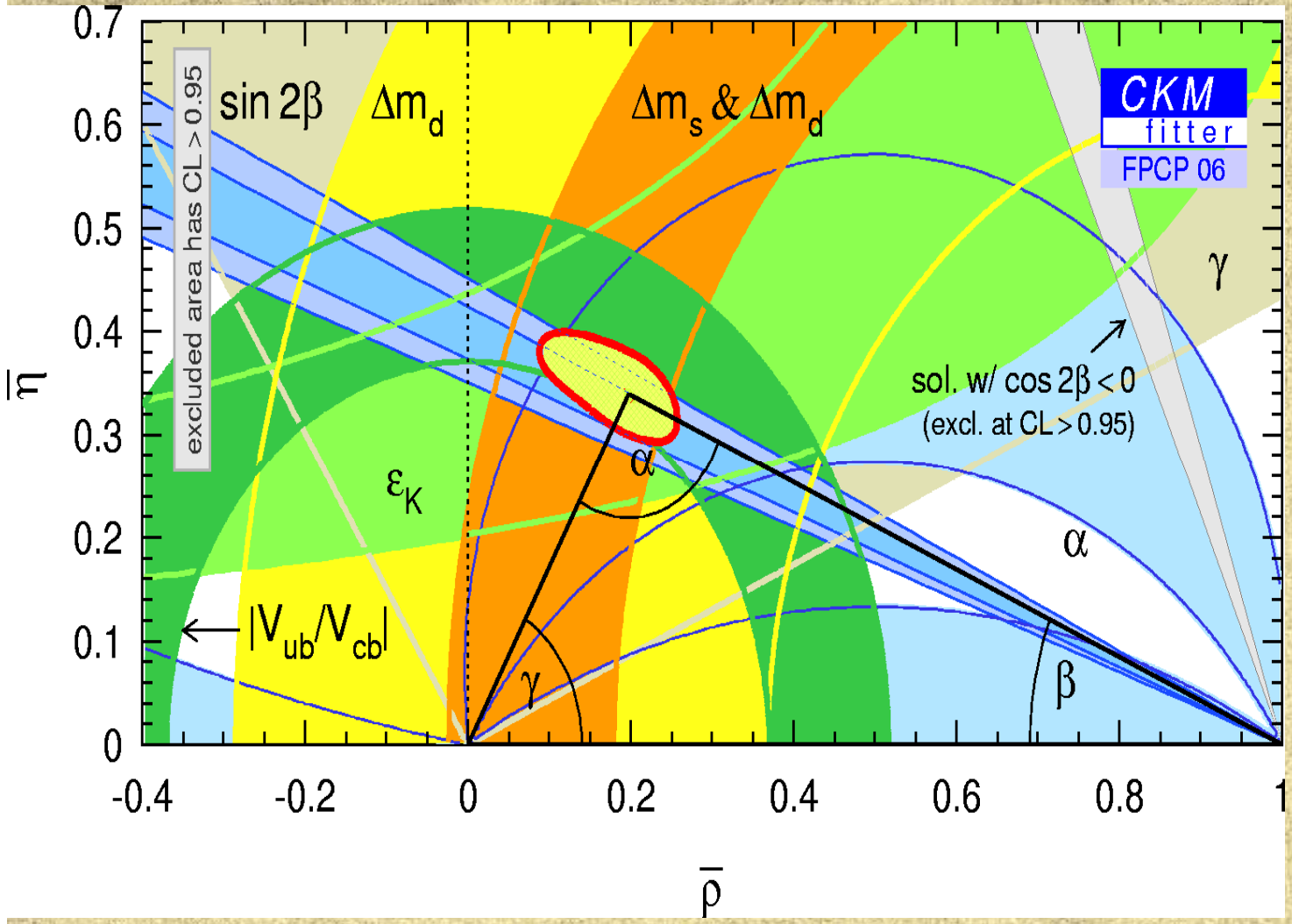
Only source of Σ^+ in neutral beam

$BF(\Xi^0 \rightarrow \Sigma^+ e\nu) = 2.51 \pm 0.03 \pm 0.11 \times 10^{-4}$

$BF(\Xi^0 \rightarrow \Sigma^+ \mu\nu) = 2.2 \pm 0.3 \pm 0.2 \times 10^{-6}$

Status of CKM

Mancinelli



Includes Bs mixing results from CDF/D0

There are several measurements for each UT angle and side

"Desperately consistent with the Standard Model"

Musy

Sin 2β from Charmonium

Bracko

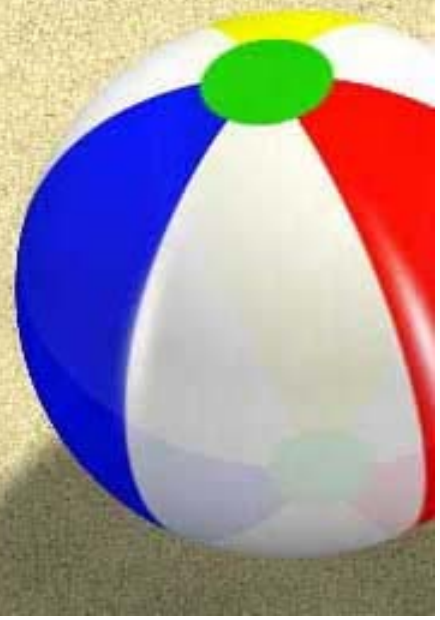
QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

BaBar:

227M BB pairs

Sin2β = 0.722
+-0.040+-0.023

C = -A = 0.051
+-0.026+-0.036



Sin 2β from Penguins

Bracko

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Theoretical differences:

+ a few % in "clean" modes

>10% otherwise

!

Replace "naïve" average with "informed" average of :

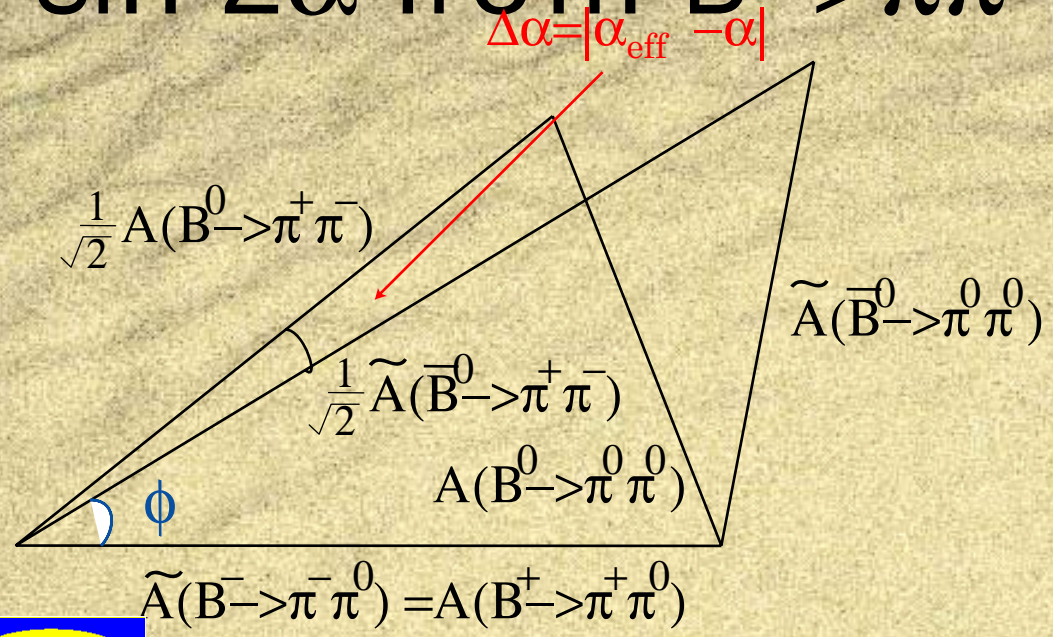
ϕK_S, $\eta' K_S$, $K_S K_S K_S$

0.52+-0.07

0.69+-0.03 (2σ)

Sin 2α from B–>ππ

Hutchcroft



Agreement between BaBar and Belle is still not very satisfactory !

Large $B(\pi^0\pi^0)$ limits isospin analysis to

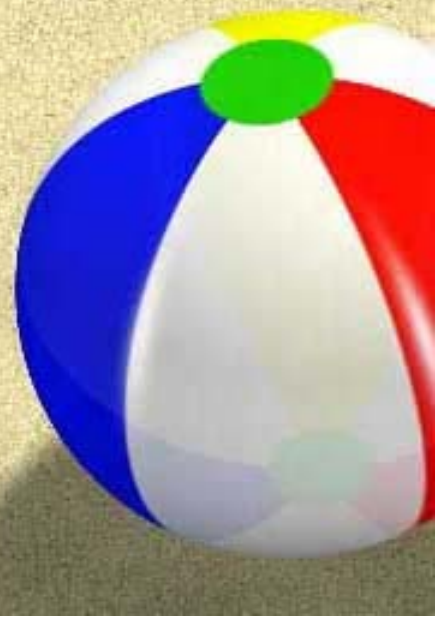
$\alpha-\alpha_{eff} < 35^o$

$A_{CP}(t)$ B–>$\pi^+\pi^-$

S = −0.67±0.16±0.06	S = −0.30±0.17±0.03
C = −0.56±0.12±0.06	C = −0.09±0.15±0.04

BF & A_{CP} B–>$\pi^0\pi^0$

B = 2.3±0.5±0.3 x 10^{-6}	B = 1.2±0.3±0.1 x 10^{-6}
C = −0.44±0.53±0.07	C = −0.12±0.56±0.06



Sin 2α from B–>ρρ & B–>ρπ

Hutchcroft

B–>ρρ

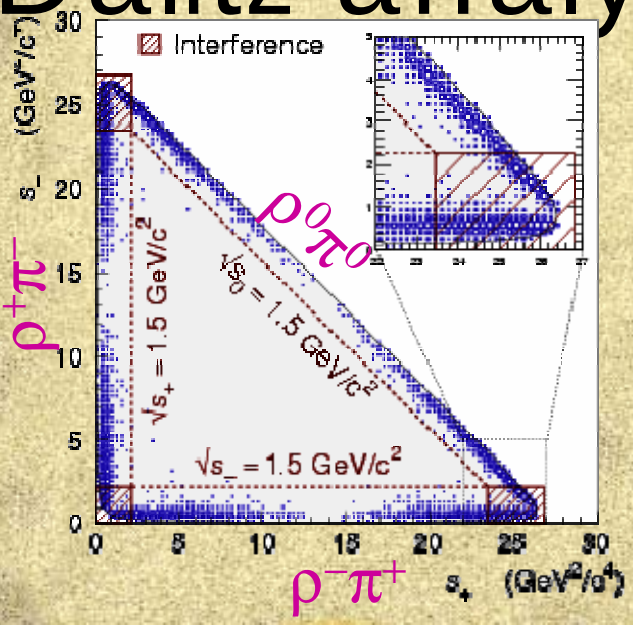
- Almost 100% longitudinally polarized
- $B(\rho^0\rho^0) < 1.1 \times 10^{-6}$ (90% C.L.)

ρρ not "lucky" - expected!

Small $B(\rho^0\rho^0)$ only limits isospin analysis to

$\alpha - \alpha_{eff} < 11^o$

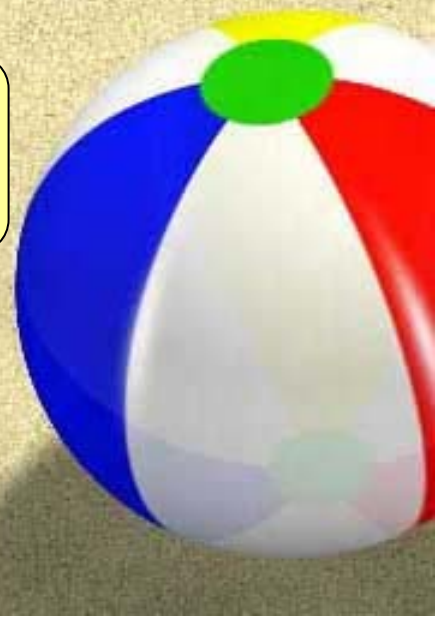
Dalitz analysis of B–>ρπ



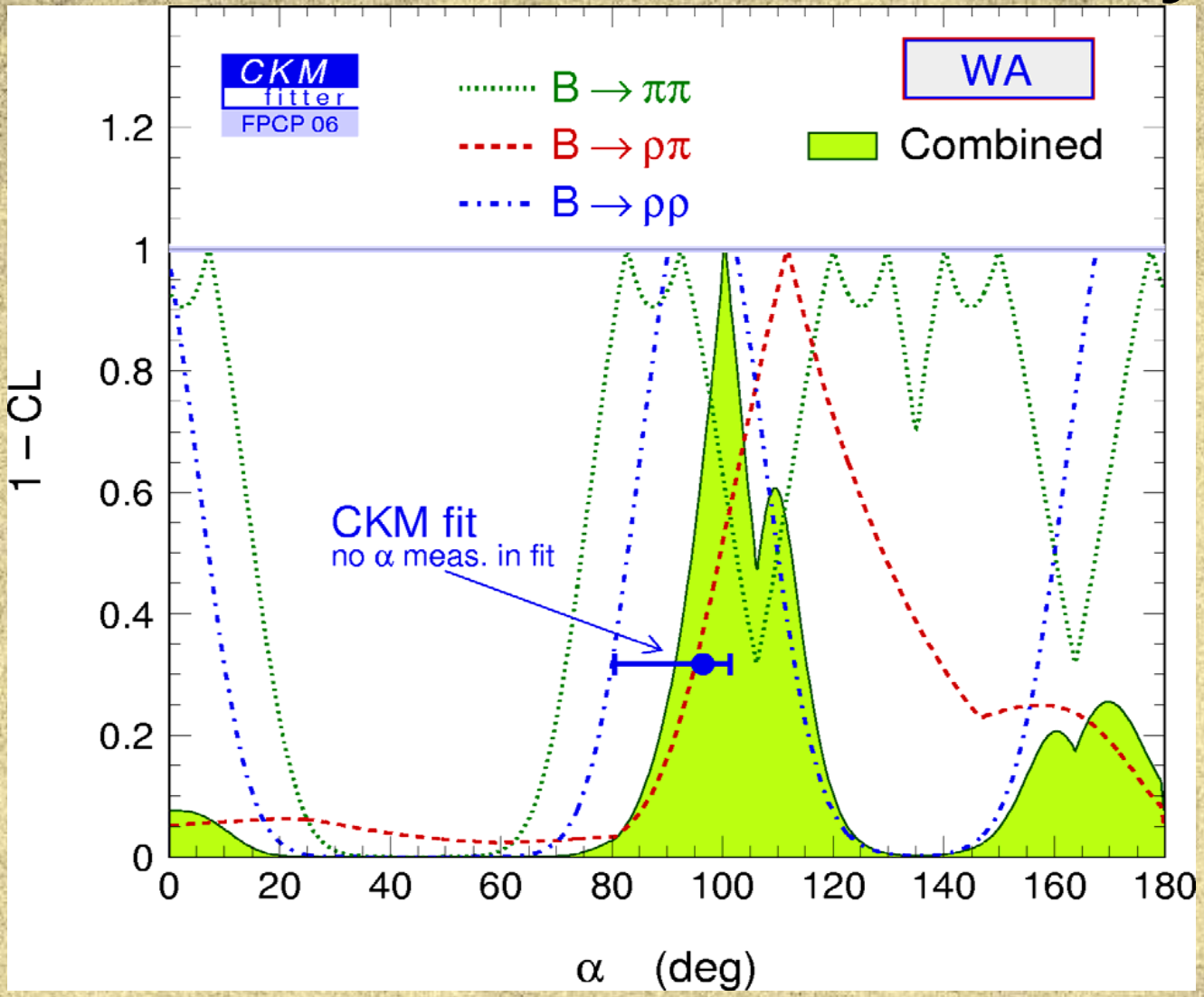
$$S = -0.10 \pm 0.14 \pm 0.04$$

$$C = 0.34 \pm 0.11 \pm 0.05$$

α from time-dependent analysis of interference regions



α combined summary



ρρ dominates the average

ρπ removes 2-fold ambiguity

$\alpha = 99^{+12}_{-9}$ (deg)

γ from $B \to D(K_S\pi\pi)K$ Dalitz

Garmash

Interference of b–>cus and b–>ucs tree diagrams

DK: $\gamma = 66^{+19}_{-20}{}^{o}$ $r_b = 0.16$

D*K: $\gamma = 86^{+37}_{-43}{}^{o}$ $r_b = 0.18$

DK*: $\gamma = 11^{+23}_{-57}{}^{o}$ $r_b = 0.56$

$\gamma = 53 \pm 18 \pm 9^{o}$

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Sensitivity

DK: $r_b = 0.12$

$\gamma = 67 \pm 28 \pm 17^{o}$

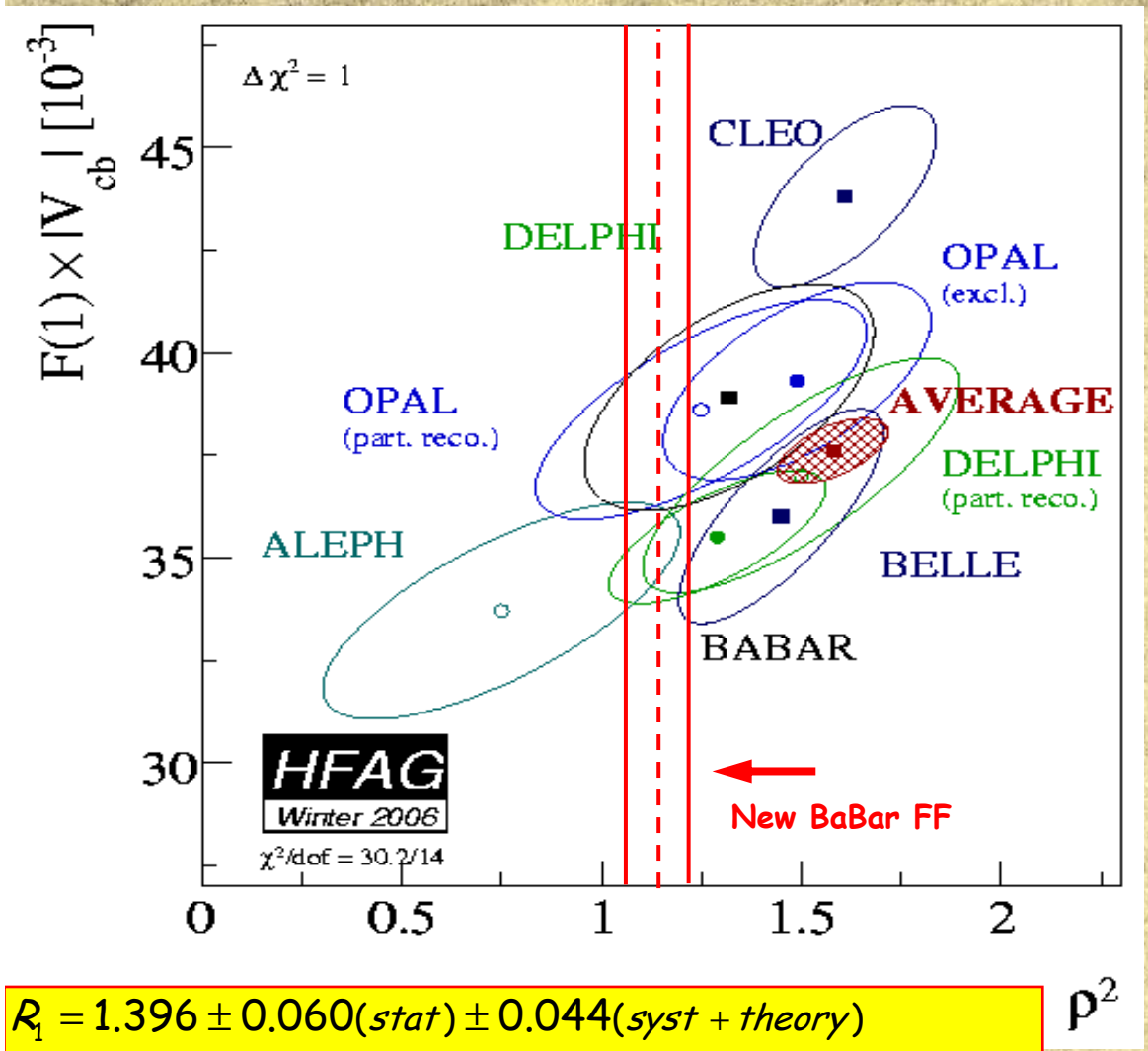
D*K: $r_b = 0.17$

Need to measure D Dalitz plot separately (Cleo-c/BaBar/Belle)

Vcb from B–>D*lv

Gambino

Mancinelli



$$R_1 = 1.396 \pm 0.060(stat) \pm 0.044(syst + theory)$$

$$R_2 = 0.885 \pm 0.040(stat) \pm 0.026(syst + theory)$$

$$\rho^2 = 1.145 \pm 0.059(stat) \pm 0.046(syst + theory)$$

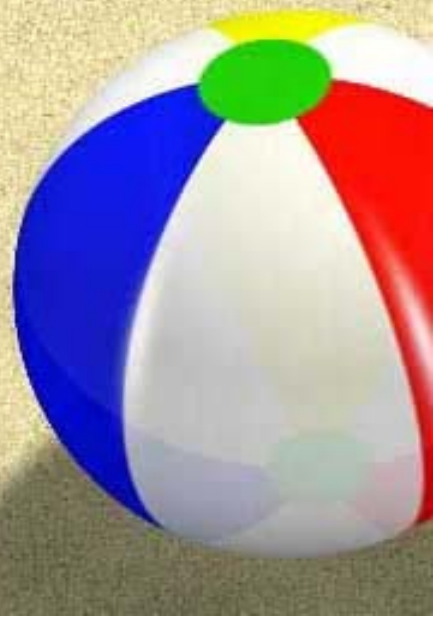
$$V_{cb} = 37.6 \pm 0.3(stat) \pm 1.3(syst)^{+1.5}_{-1.3}(theory) \times 10^{-3}$$

Inconsistent fits to data

Poor agreement

!

New BaBar Form Factors



Vcb from Inclusive b–>clv

Buchmuller

OPE fits to b–>clv hadronic mass and lepton energy moments and to b–>sg photon energy moments

… everything looks consistent

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Agreement between inclusive and exclusive Vcb depends on form factor F(1) in D*lv

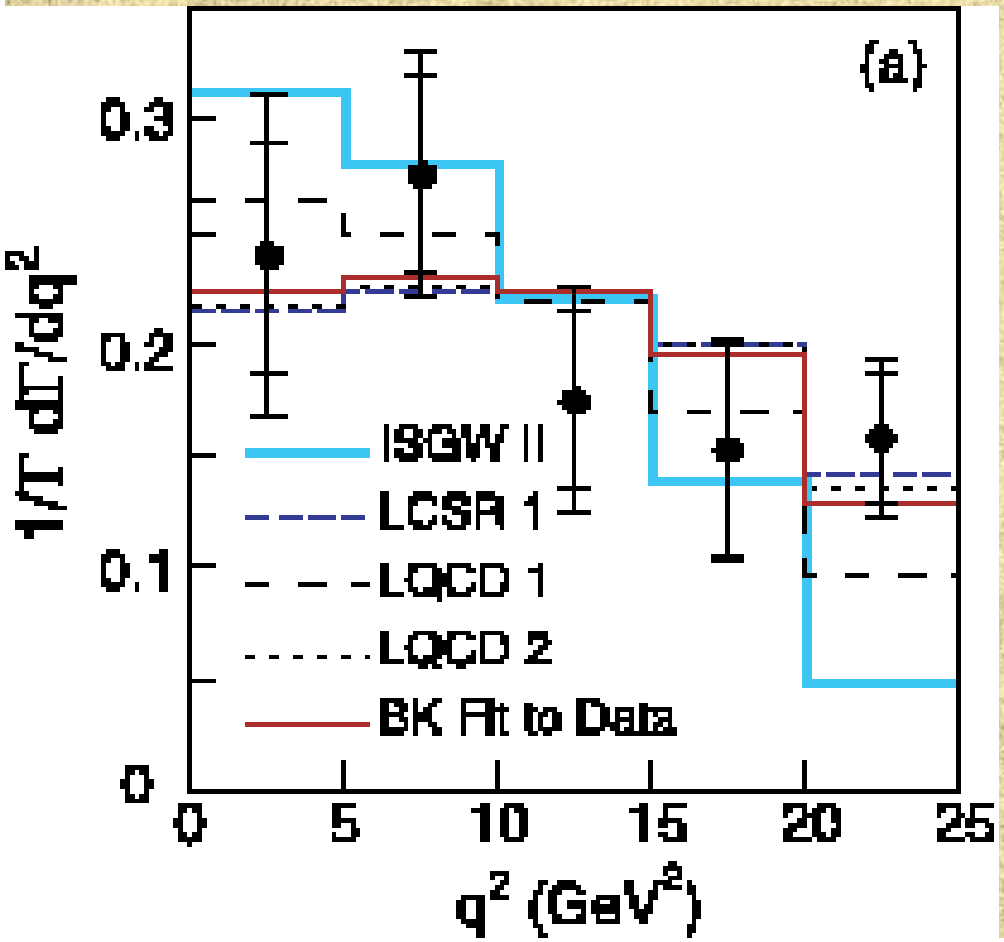
Vub from B–>πlν

Mancinelli

Three methods:
Untagged, B Semileptonic Tags
B Hadronic Tags

Untagged best now

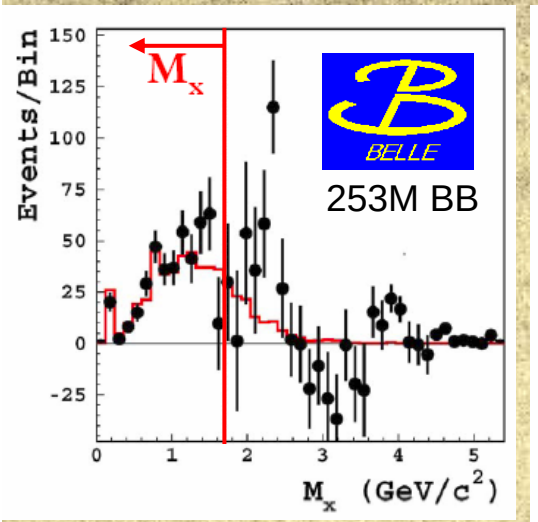
Hadronic tags will win with more statistics

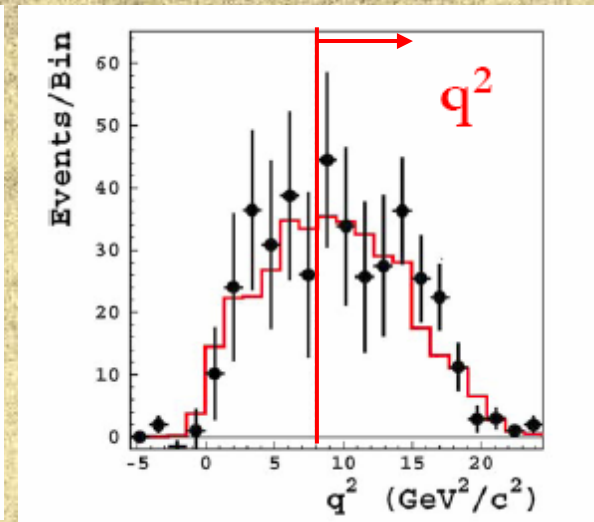


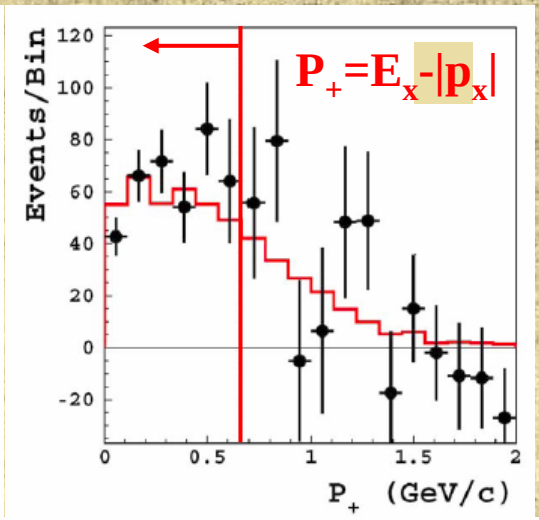
Form factor measurement is crucial to constrain theoretical calculations

Vub from Inclusive b–>ulv

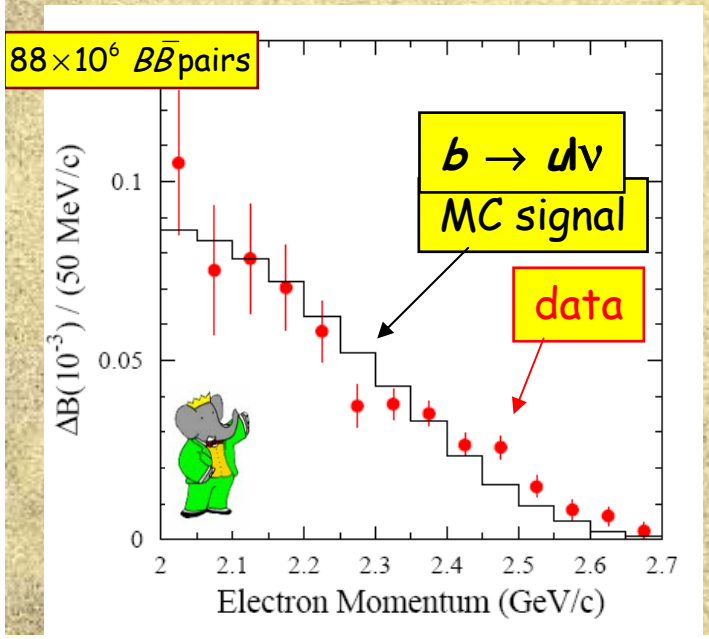
Mancinelli



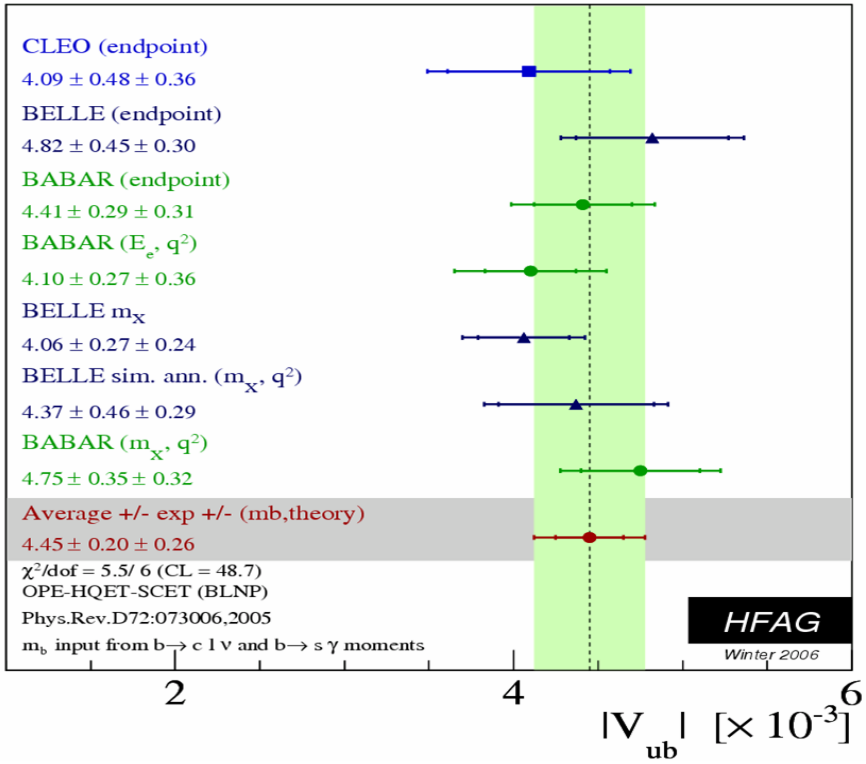




Hadronic Tags



Lepton Endpoint



Vub without Shape Function

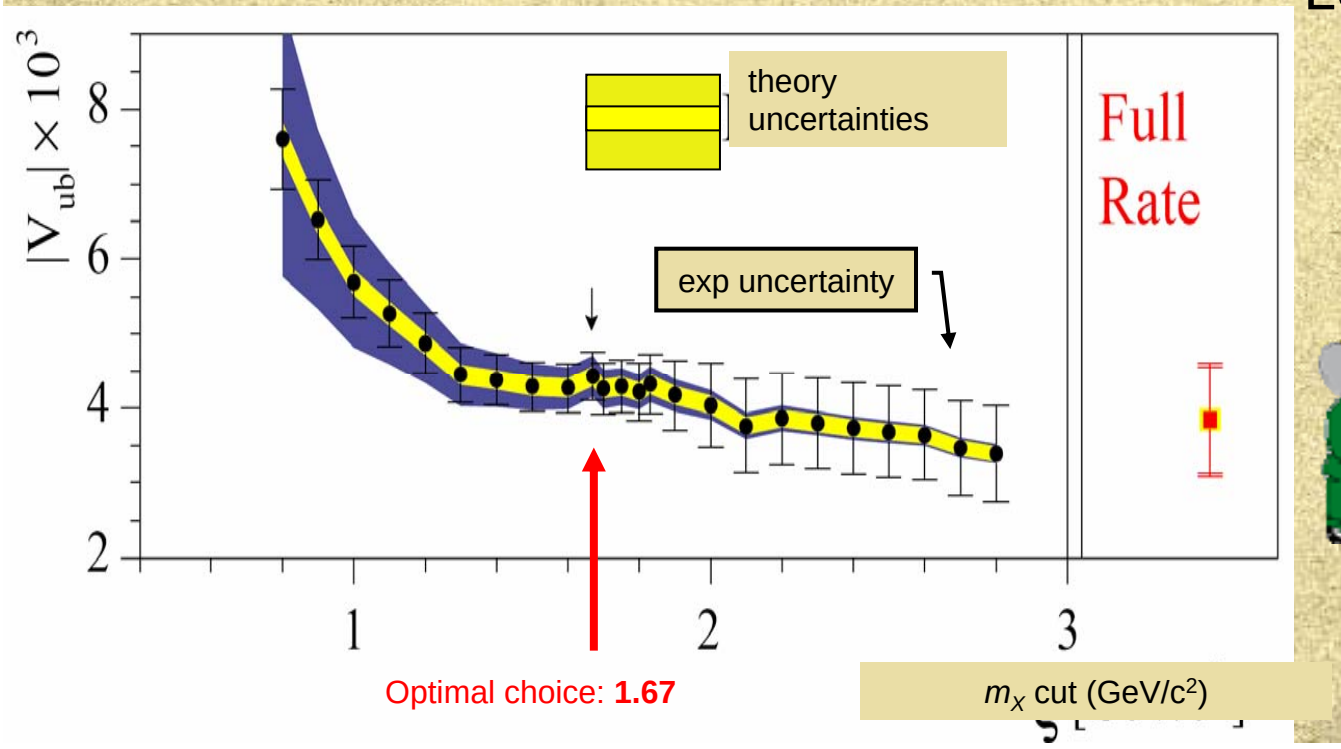
Mancinelli

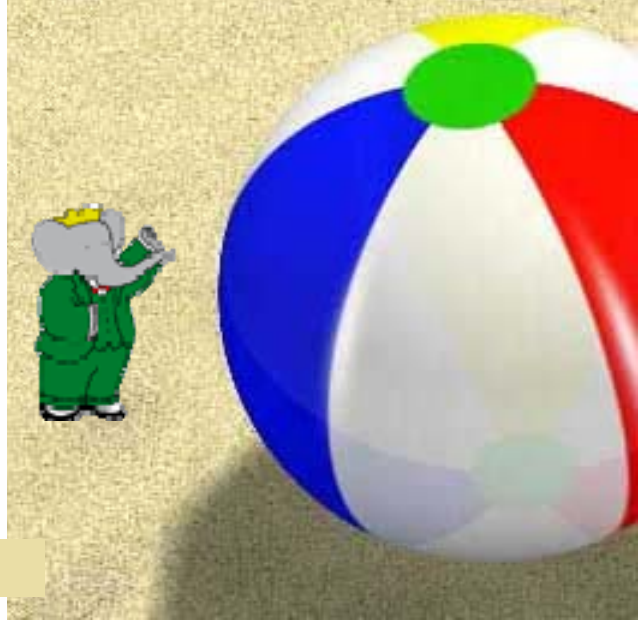
Relate b–>ulv spectrum directly to b–>sγ spectrum

$$\Gamma(B \to X_u \ell \nu) = \frac{|V_{ub}|^2}{|V_{ts}|^2} \int W(E_\gamma) \frac{d\Gamma(B \to X_s \gamma)}{dE_\gamma} dE_\gamma$$

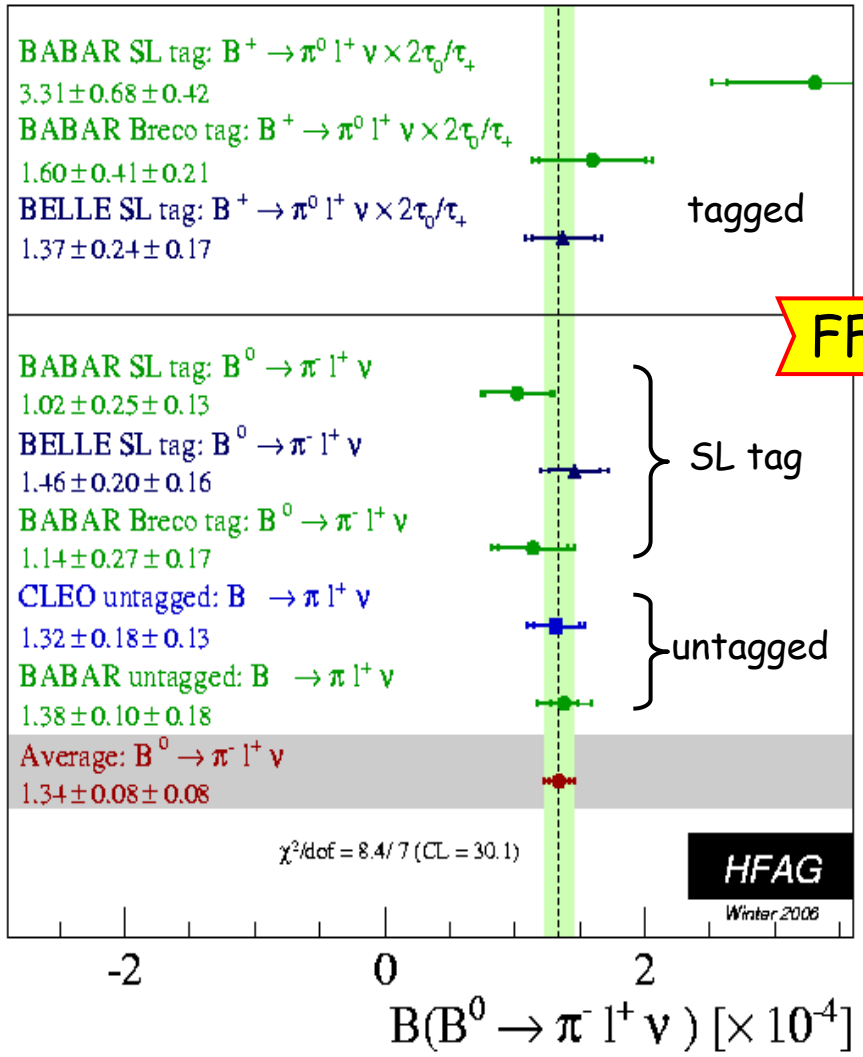
Two schemes: BLNP and DGE

Looks promising!

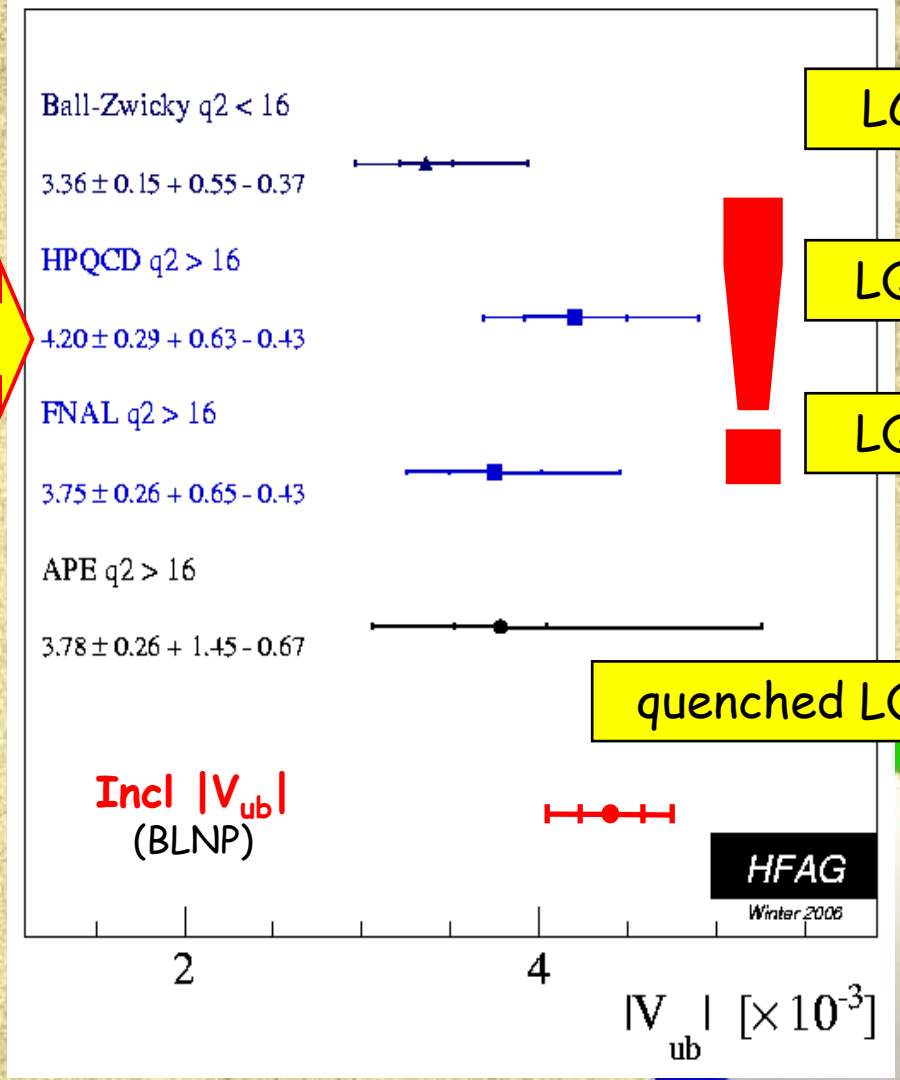




Vub Exclusive vs Inclusive



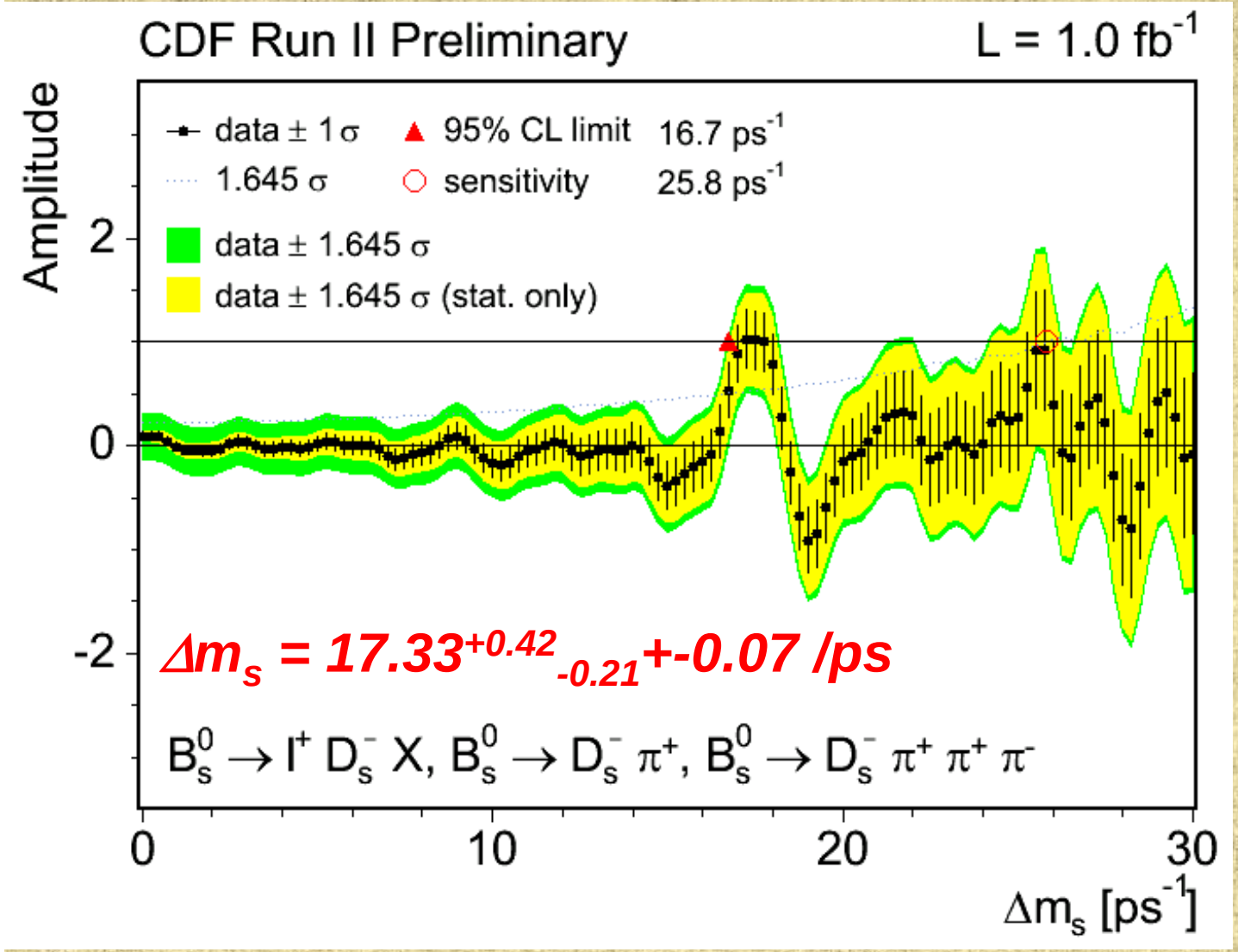
FF



Not sure this is really a problem. Wait for more data!

Bs Mixing Measurement

Salamanna



Same side Kaon and opposite side tags

D=4.0+-0.6%

Very nice measurement! Significance 3.7σ

Bs Mixing Measurement

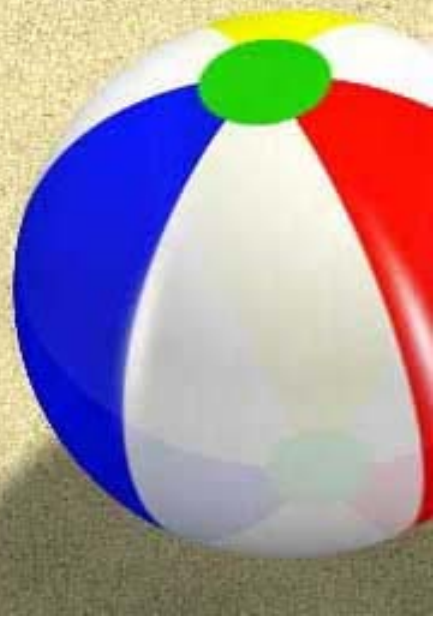
Walder

D0 only uses Semileptonic Bs decays

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

and only opposite side tags

D=2.5+-0.2%

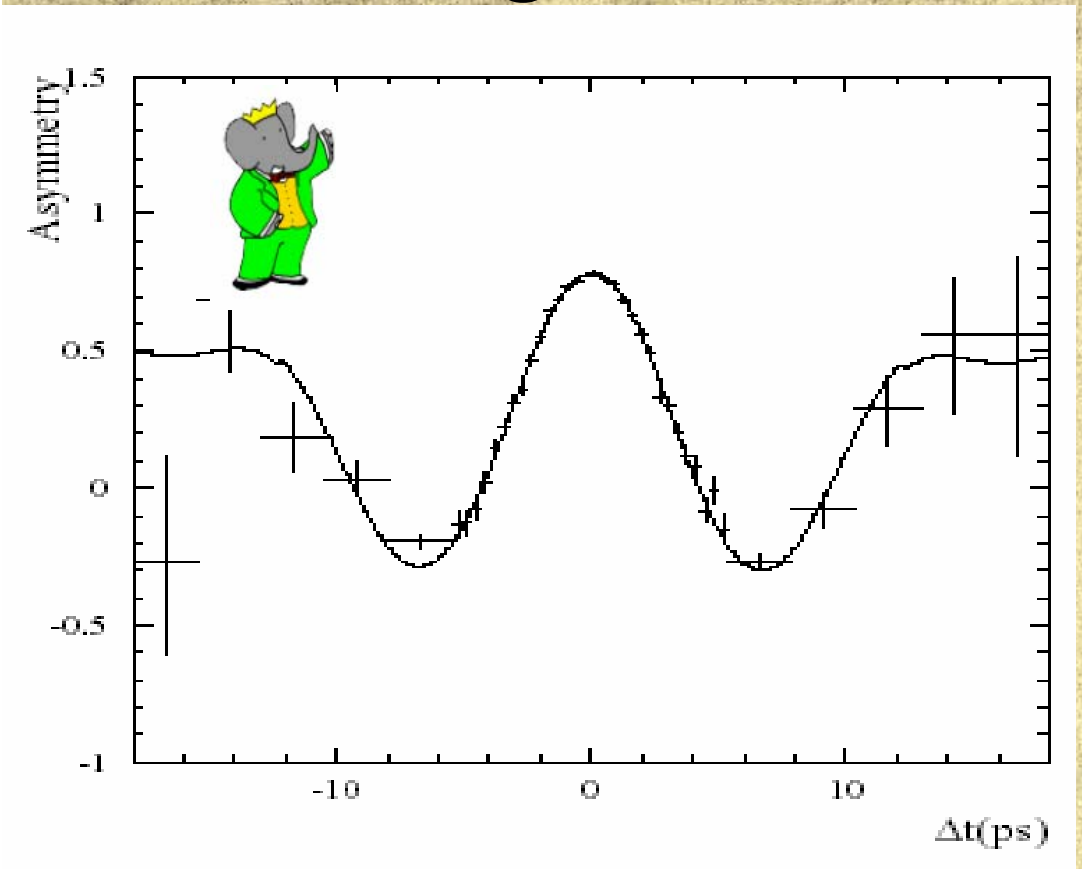


$17 < \Delta m_s < 21$ ***/ps (90% C.L.)***

D0 were first! Significance only 2.5σ, A=3 at 19/ps?

Bd Mixing and Vtd/Vts

Mancinelli



Extraction of Vtd/Vts is limited by knowledge of SU(3) breaking factor ξ

Lattice calculations!

More data on mixing doesn't help

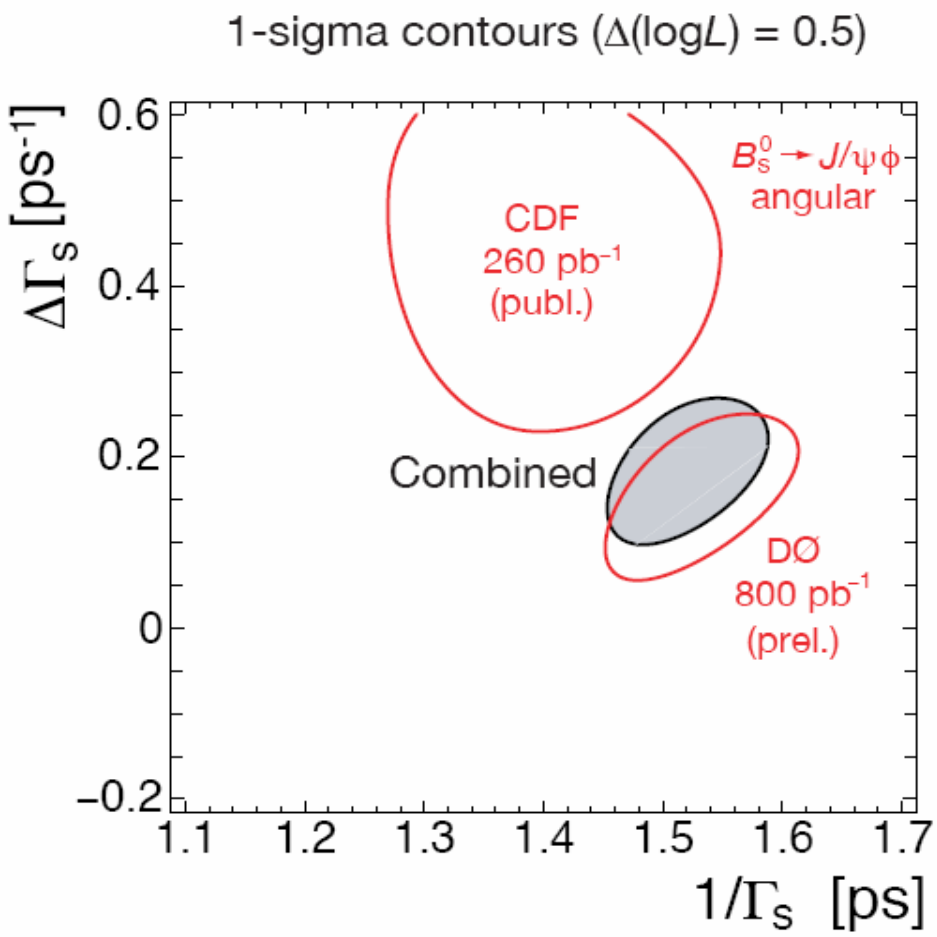
Δm_d =0.507+-0.004 /ps
(dominated by BaBar and Belle)

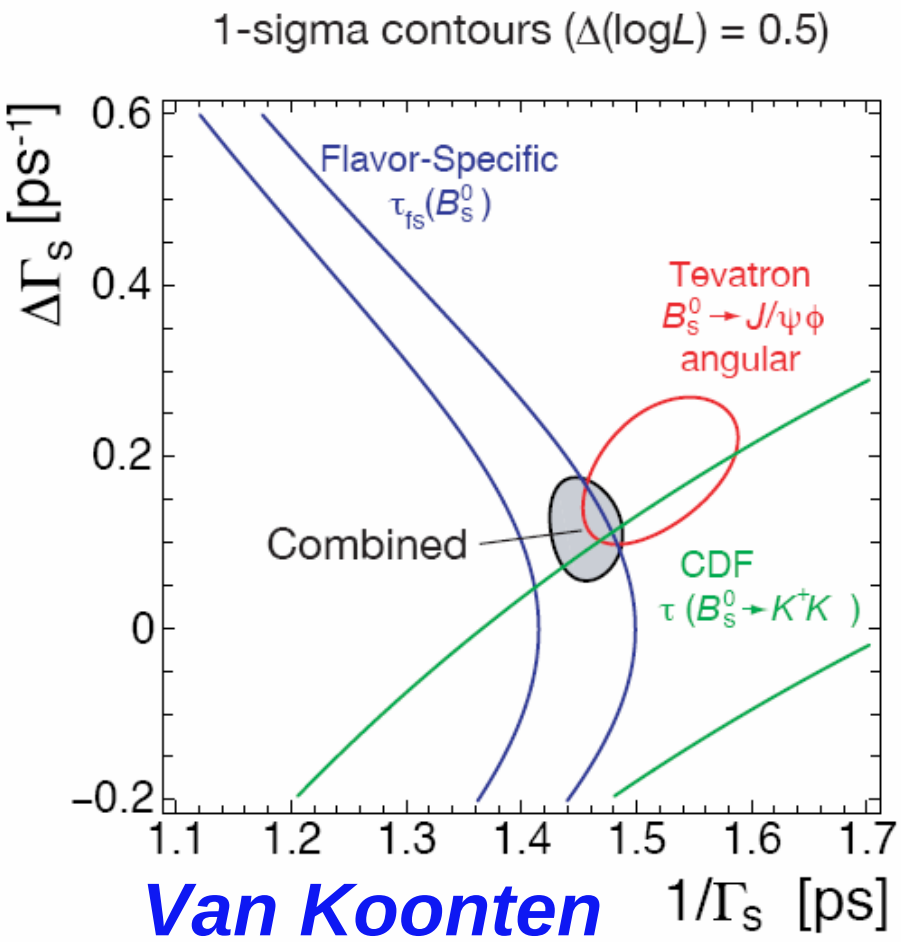
$$\frac{\Delta m_s}{\Delta m_d} = \frac{m_{B_s}}{m_{B_d}} \xi^2 \frac{|V_{ts}|^2}{|V_{td}|^2} \quad \triangleright \quad \frac{|V_{td}|}{|V_{ts}|} = 0.208 \; {}^{+0.008}_{-0.007}$$

Bs Lifetime Difference

Kin Yip

De la Cruz Burelo





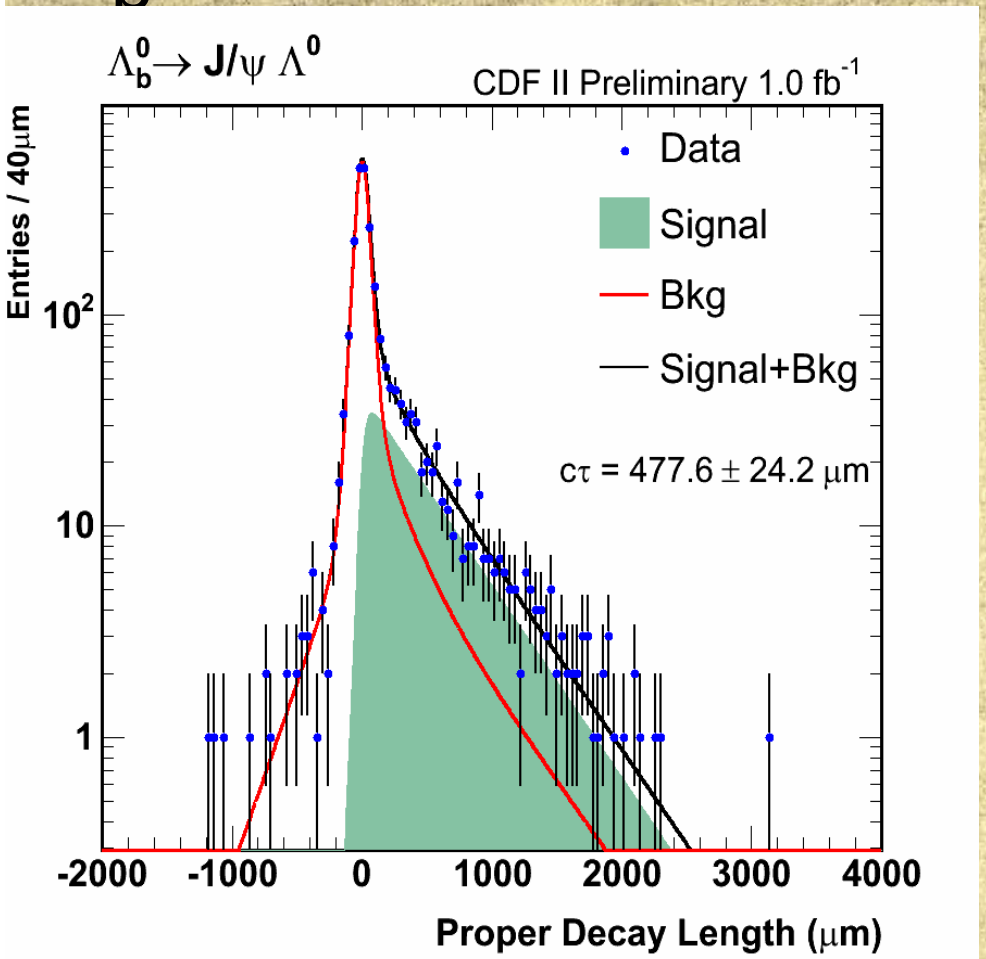
Van Koonten

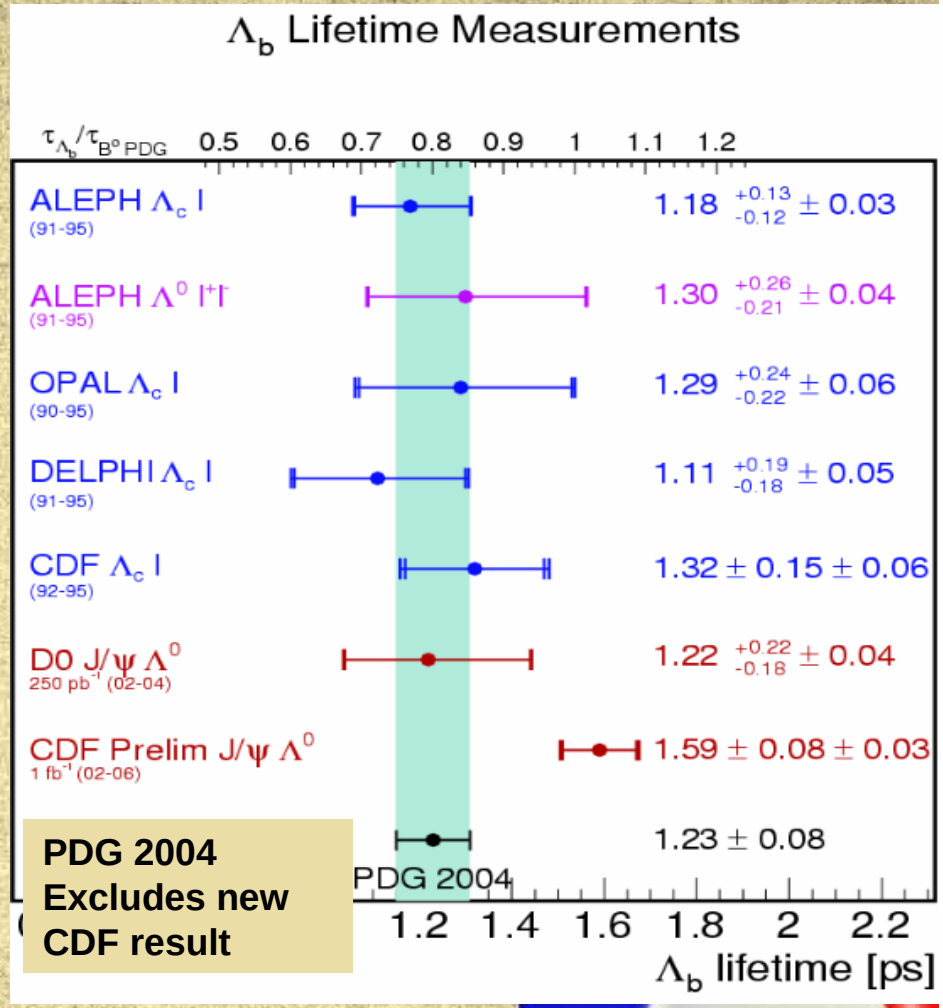
$\Delta\Gamma_s$ =0.18+-0.09 /ps
Mean τ_s = 1.52+-0.07 ps

$\Delta\Gamma_s$ =0.10+-0.04 /ps
Mean τ_s = 1.46+-0.03 ps

Λ_b Lifetime

De la Cruz Burelo





PDG 2004 Excludes new CDF result

$$\tau(\Lambda_b) = 1.593\,^{+0.083}_{-0.078}(\text{stat}) \pm 0.033\,(\text{syst})\ \text{ps}$$

World average: $\tau\,(\Lambda_b)$=1.23 ± 0.08 ps

!

B_c Mass and Lifetime

Rahaman

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

QuickTime™ and a
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$B_c \rightarrow J/\psi\, \mu\nu$
95 +-16 events
$\tau(B_c) = 0.45^{+0.12}_{-0.10} +- 0.12$ ps

$B_c \rightarrow J/\psi\, \pi$
49 +-10 events
$M(B_c) = 6277 +- 5$ MeV

Other Tevatron B results

Ben Haim

Direct CP in $B^0 \to K\pi$

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TIFF (LZW) decompressor
are needed to see this picture.

Belle : $A_{CP} = -0.113 +- 0.022 + 0.008$
BaBar: $A_{CP} = -0.133 +- 0.030 + 0.009$

Still the only clear signal for Direct CP violation in B decays!

A_{CP} in Mixing with Dimuons

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QuickTime™ and a
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are needed to see this picture.

Charm and Hyperon Lifetimes

Sun

Akgun

Lazzeroni

$\tau(D_s)$ = 507.4+-5.5+-5.1 fs (FOCUS)

PDG: 490+-9 fs

$\tau(\Xi_c^+)$ = 430 +-22 +- 9 fs (SELEX)

$\tau(\Xi^0)$ = 3.082+-0.013+-0.012 x10^{-10} s (NA48)

Impressive accuracy

Some shifts from PDG

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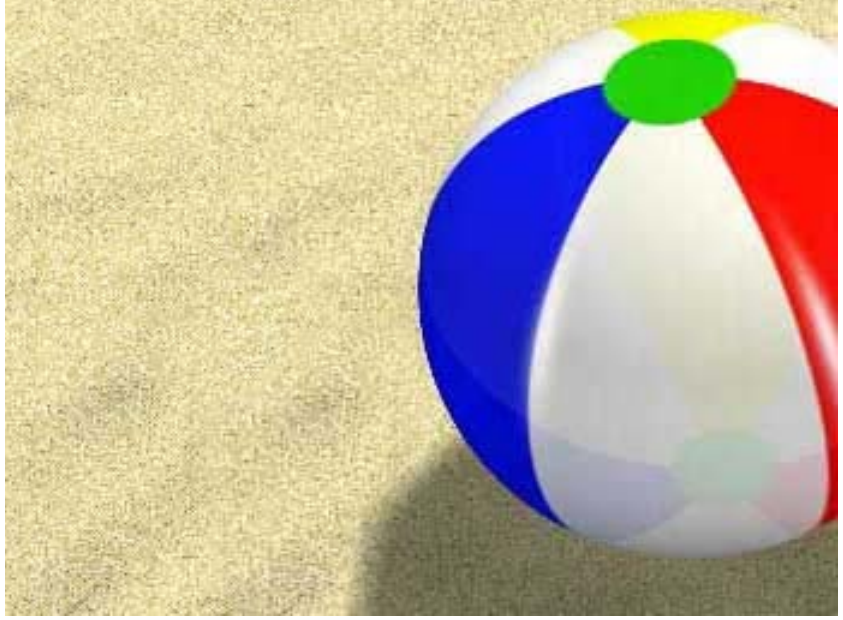


Charm Hadronic Decays

Sun

Bozek

Miller

CLEO-c double-tag/single-tag at DD and $D_s^*D_s^*$ thresholds

Reference Branching Fractions:

$B(D^0 \to K\pi)$ = 3.91+-0.08+-0.09 %

$B(D^+ \to K\pi\pi)$ = 9.5+-0.2+-0.3 %

$D_s \to \phi\pi$ is still a problem

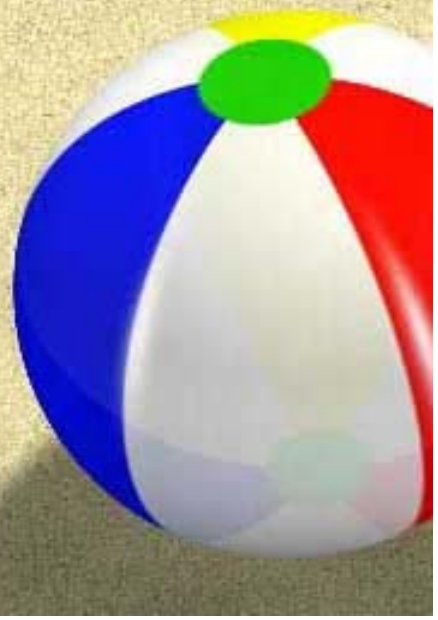
$B(D_s \to KK\pi)$ = 4.54+-0.08+-0.09 %

$B(D_s \to \phi\pi)$ = 3.49+-0.39 % ***Stone***

BaBar by Partial Reconstruction of $B \to D_s^*D^*$

$B(D_s \to \phi\pi)$ = 4.81+-0.52+-0.38 %

!



Charm Leptonic Decays

Miller

CLEO-c reconstruct one D and look for a single muon recoiling

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TIFF (LZW) decompressor
are needed to see this picture.

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TIFF (LZW) decompressor
are needed to see this picture.

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Lattice prediction consistent with experiment

$D_s \to \mu\nu$ from BaBar

Miller

Tag charm jets with D and reconstruct
$D_s^* \to D_s(\to \mu\nu)\gamma$ in other jet

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Reminder of $B(D_s \to \phi\pi)$ discr epancy

Expect results from Cleo-c soon

$B(D_s \to \mu\nu) = (6.5 \pm 0.9 \pm 0.9) \times 10^{-3}$

$f_{Ds} = 279 \pm 17 \pm 6 \pm 19)$ MeV

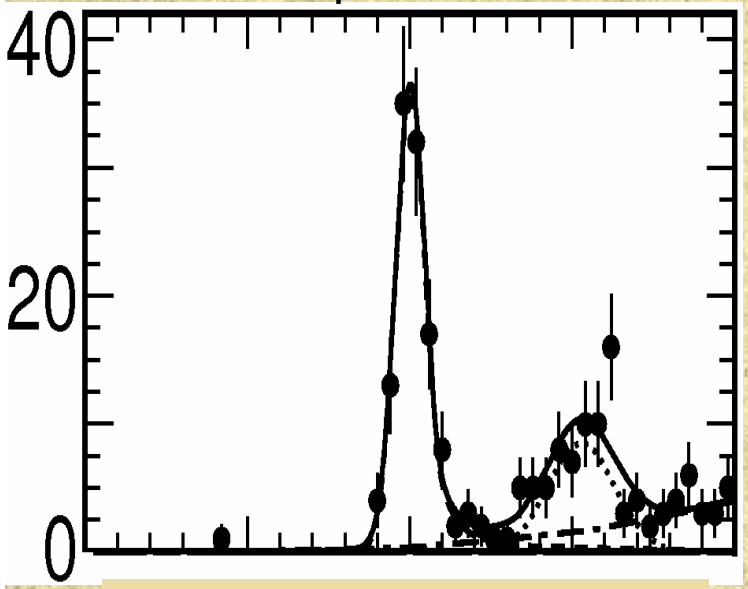
using $B(D_s \to \phi\pi) = 4.81 \pm 0.52 \pm 0.38$ %

Charm Semileptonic Decays

Kim

CLEO-c reconstruct one D hadronic decay and other D semileptonic decay

Example: $D^0 \rightarrow \pi^- e^+ \nu$



U (= Emiss – |Pmiss|)

Useful for comparison to theory

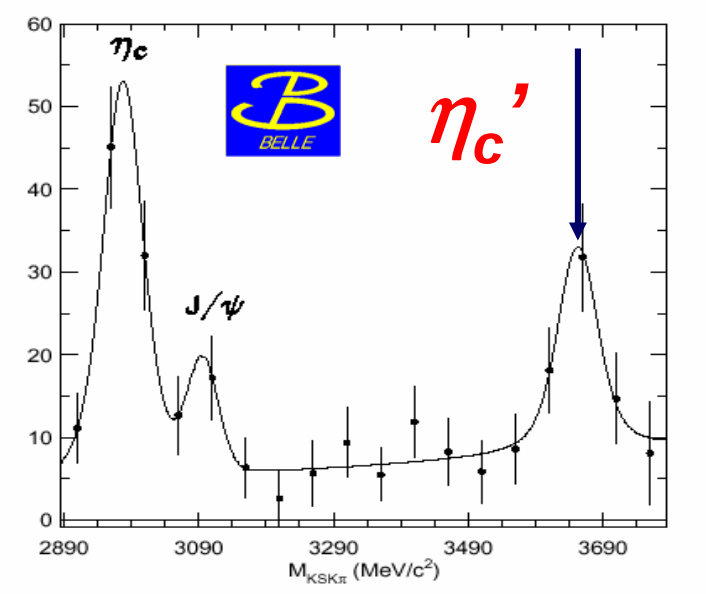
Eventually extract Vcd and Vcs

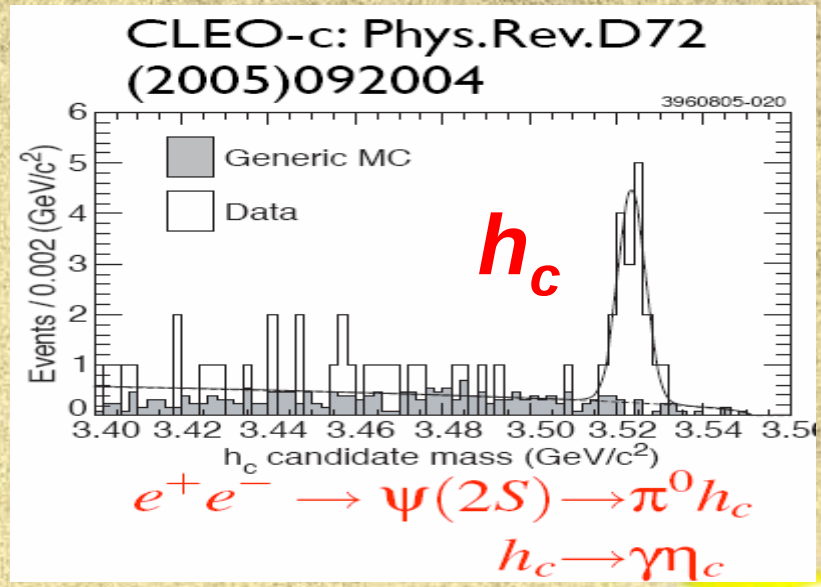
Many results on Inclusive and Exclusive Branching Fractions and on Form Factors

Charmonium States

Harris
"may you live in exciting times"
Petersen

2000-2005 Seven new charmonium states!
(Belle, BaBar, Cleo-c, CDF, D0)





Y(4260)

and X(3870)
first seen by Belle

Nature of X and Y states under study

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New Charm States

Petersen

2000-2006 Five new charm mesons and eight new charm baryons:

D_{sJ}(2317) - BaBar

D_{sJ}(2460) - CLEO

… identified as 0++ and 1++

P-wave cs states

D_{sJ}

QuickTime™ and a
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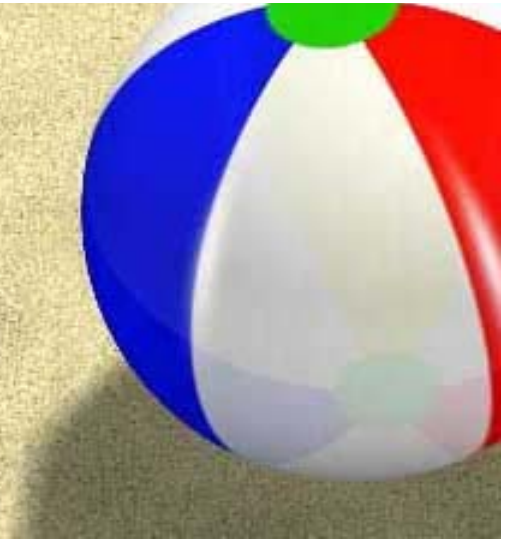
are needed to see this picture.

D_{sJ}(2630) - SELEX (not confirmed!)

D_{sJ}(2860) - BaBar (preliminary)

Λ_c(2940) - BaBar (preliminary)

Ξ_c(2980), Ξ_c(3077) - Belle



Structure Functions from HERA

Grab

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QuickTime™ and a
TIFF (LZW) decompressor
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b Production at HERA

Grab

QuickTime™ and a
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Similar effects seen at Tevatron

Improvements in MC codes in progress

Trend is for Theory to underestimate cross-sections at low Q2

B Triggers at Hadron Colliders

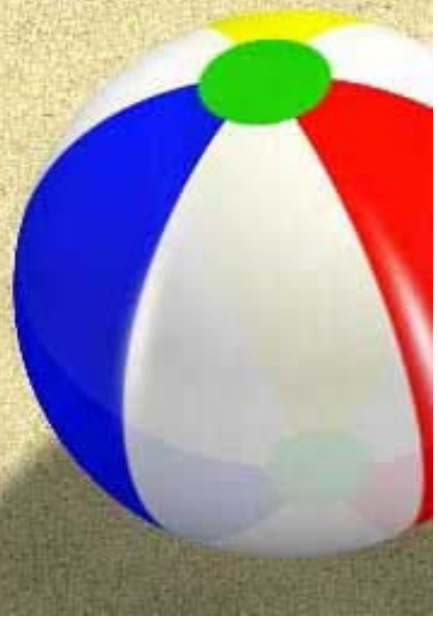
Donati

Welty

Speer

Metlica

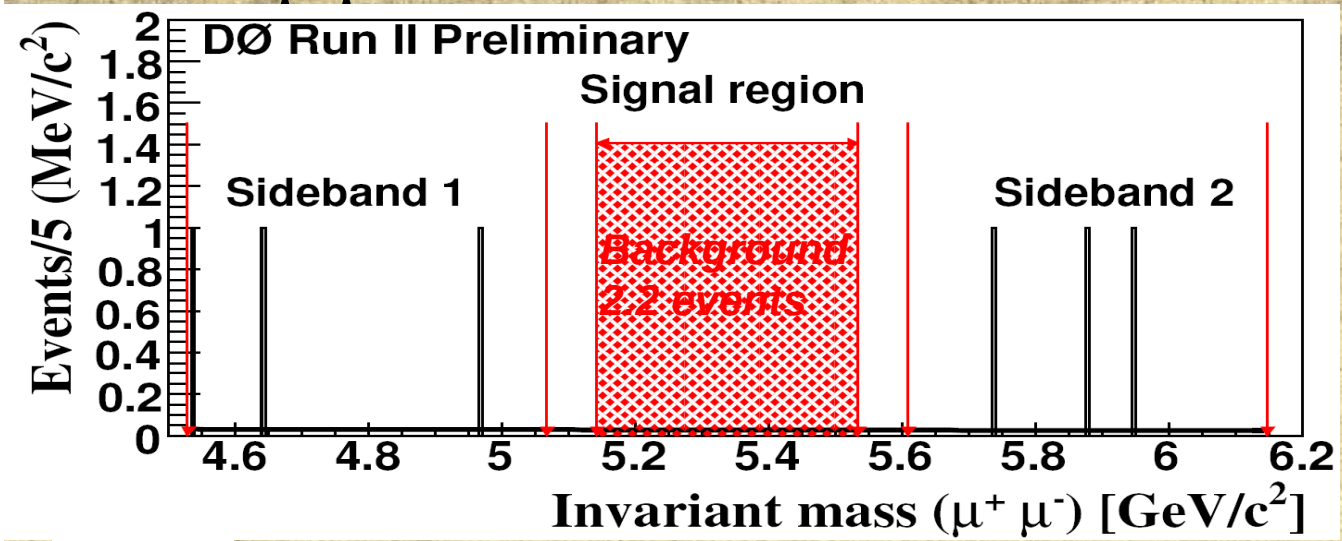
- D0/CMS/ATLAS rely (primarily) on (di)muons
  - D0 Level 0 uses p_t > (1.5)3.0 GeV
  - ATLAS Level 0 uses p_t > 6 GeV with single muon triggers only at low luminosity
  - CMS uses p_t > (3)14 GeV
- CDF have muon, calorimeter and two-track detached vertex triggers
  - Use dE/dx+TOF to study hadronic decays with K and π separation
- LHCb triggers on minimum p_t of μ, e, γ, h
  - Use RICH detectors to separate K and π
- All detectors use Higher Level triggers decided in PC farms
  - Big question is how to allocate bandwidth as a function of luminosity
- Example from LHCb:
  - 200Hz "core", 300Hz D(*), 600Hz $\mu\mu$, 900Hz μ



B–>μμ at Hadron Colliders

Rieger

Reznicek



SM:

B_s–>μμ 3×10^{-9}

B_d–>μμ $\sim 10^{-10}$

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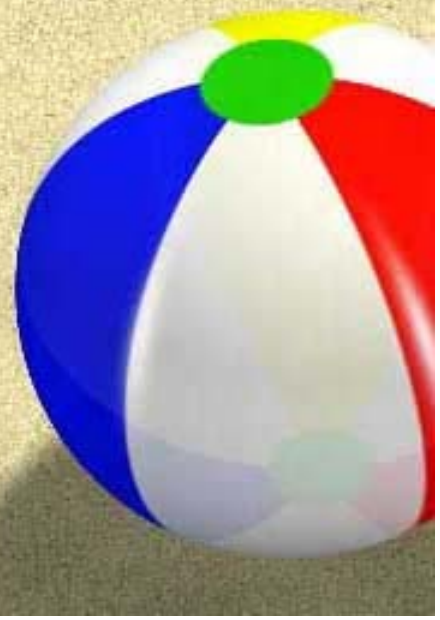
$BF(B_s \rightarrow \mu^+\mu^-) < 1\times10^{-7}$ @ 95% CL

The SM prediction for B_s–>μμ should be reached by ATLAS/CMS with 30/fb



B–>μμ remains the best probe for SUSY effects in B physics … at D0, ATLAS and CMS

B–>K(*)ll FB asymmetry

Koppenburg

Katayama

Simi

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Belle and BaBar already rule out wrong sign C9*C10 and C7

Consistency with SM?

!

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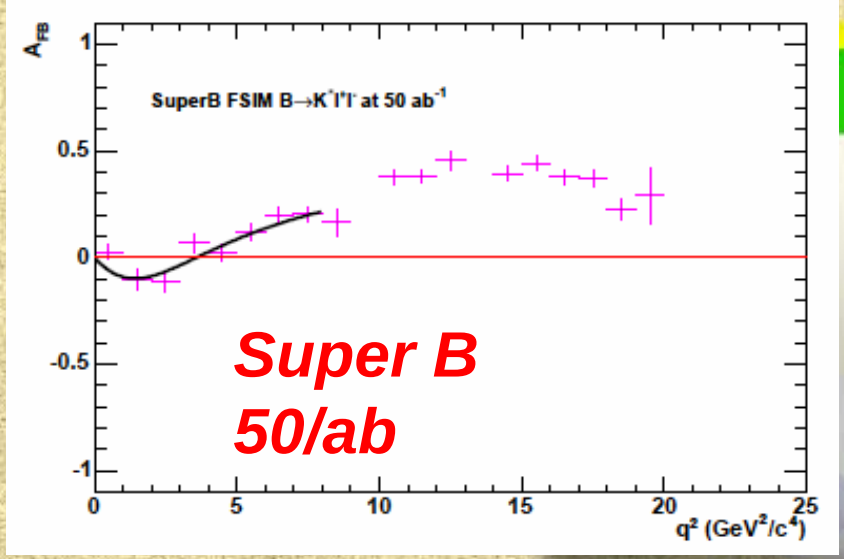
are needed to see this picture.

LHCb
2/fb



ϕ_s from $A_{CP}(t)$ of $B_s \to J/\psi\,\phi$

Musy

Catmore

With SM inputs: $\Delta m_s = 17.5/\text{ps}$, $\phi_S = -0.04$, $\Delta\Gamma_s/\Gamma_s = 0.15$
$R_T = 0.2$ and 2/fb stat:

LHCb

Channels	$\sigma(\phi_s)$ [rad]	Weight $(\sigma/\sigma_i)^2$ [%]
$B_s \to J/\psi\ \eta(\pi^+\ \pi^-\ \pi^0)$	0.142	2.3
$B_s \to D_s D_s$	0.133	2.6
$B_s \to J/\psi\ \eta(\gamma\ \gamma)$	0.109	3.9
$B_s \to \eta_c \phi$	0.108	3.9
Combined (pure CP eigenstates)	**0.060**	**12.7**
$B_s \to J/\psi\phi$	0.023	87.3
Combined (all CP eigenstates)	**0.022**	**100.0**

Atlas

will reach $\sigma(\phi_s) \sim 0.05$ (30/fb, $\Delta m_s = 20/\text{ps}$, 270k $J/\psi\phi$ evts)

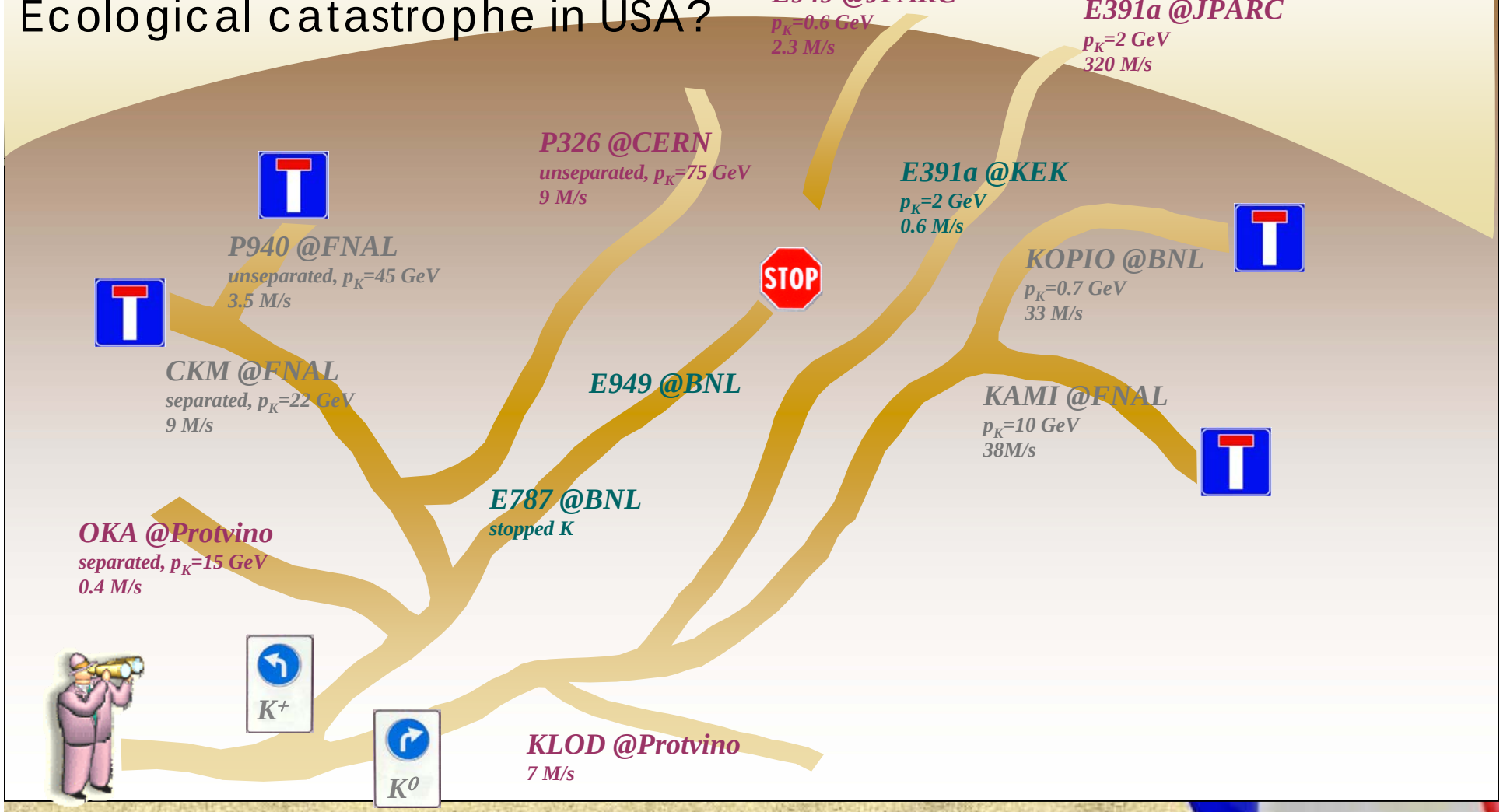
CMS

will reach $\sigma(\phi_s) \sim 0.07$ (10/fb, on $J/\psi\phi$ evts, no tagging)

Rare K decays panorama

Example of Darwinian evolution?
Ecological catastrophe in USA?

Valente
Nomura



Future Projects: P326 (CERN) $K^+ \to \pi^+ \nu\nu$

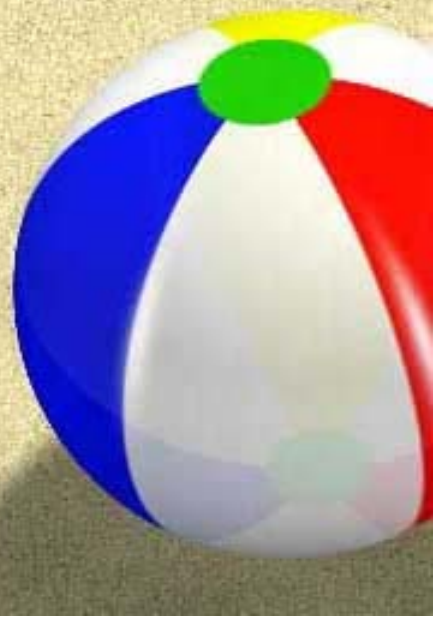
E949(JPARC) $K^+ \to \pi^+ \nu\nu$ E391a (JPARC) $K^0 \to \pi^0 \nu\nu$

Future of Charm and Tau

Harris
Obraztsev
Katayama
Rosner

- BES-III will be commissioned in Summer 2007 (Lumi = 10^{33})
- LHCb has plans to study D0 mixing and FCNC decays
- A Super B factory is the ideal place to study lepton-flavour violating Tau decays ($\tau \rightarrow \mu\gamma$...)
- FAIR will produce charmonium with antiprotons

The SM predictions are so low that there is plenty of room for New Physics…



Future of B Physics

Katayama
Obraztsov
Reznicek

Yesterday HEPAP confirmed continued running of BaBar/PEP-II through 2008

It is anticipated that Belle/KEK will continue with minor upgrades until ~2010 (depending when a Super B factory is approved)

- KEK and Frascati/SLAC are developing plans for a Super B factory with Lumi ~10^{36}
  - $B \to \tau\nu$, $b \to s\nu\nu$, $b \to s\gamma$, $b \to u l \nu$
- LHCb have upgrade plans to use ~10^{33} of the LHC luminosity
  - Aim at definitive measurement of ϕ_s
  - Best place to measure $b \to s l l$
- ATLAS/CMS will push limits on $B \to \mu\mu$