SLAC PEP-II/BaBar Status

Persis S. Drell
SLAC

B-Factory Physics Program

- Campaign of precision measurements to define the charged weak sector of the SM and CKM parameters
  - "Defining SM of weak interactions of quarks"
- Highly constrained and redundant set of precision tests of weak interactions in the Standard Model
  - legacy of fundamental constraints on future New Physics discoveries
  - Sensitivity to New Physics at LHC mass scales
  - "Testing SM of weak interactions of quarks"
- Discovery potential from large data sample across range of heavy quark and lepton flavor, two-photon and ISR physics

A brief history of major milestones in B physics

#B's

10^9-- **The 1/ab phase**: Precision tests of the CKM paradigm- Search for N.P. using loop dominated B decays, LFV tau decays, DD(bar) mixing …

10^8-- Precision sin2β; α & γ measured; CKM over-constrained and established as the primary source of observed CPV in nature. Data consistent with no NP effects in b→d and s→d.

10^7-- **2001**- CPV in B decays observed. Sin2β consistent with SM

1999- B Factories start operation.

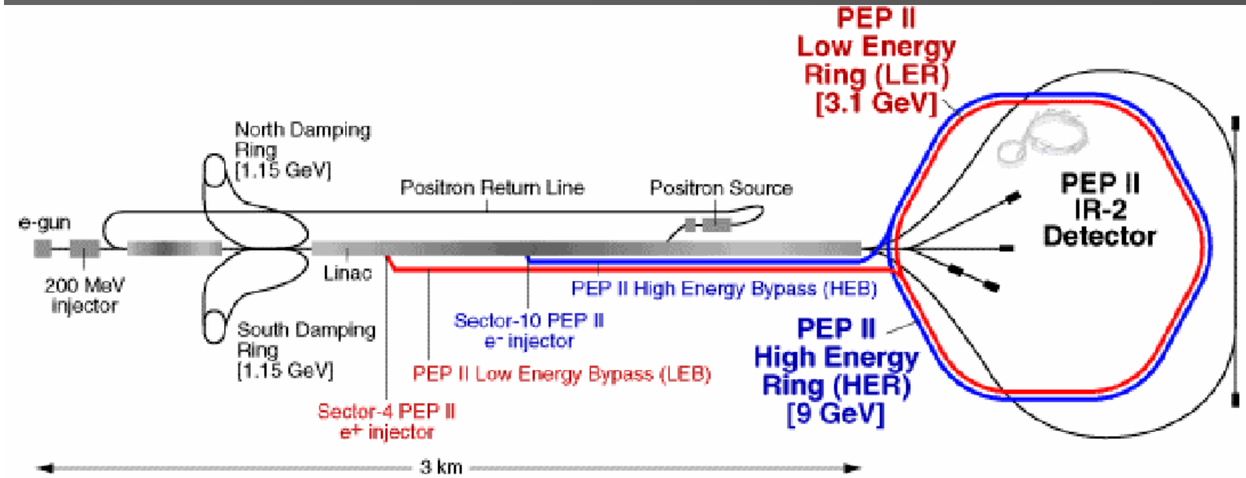
10^6-- **1993**-Radiative penguin b→sγ observed; Major constraint on models of New Physics;Rare decays B→Kπ and ππ obserevd; Role of gluonic penguins established;

B factory projects launched.

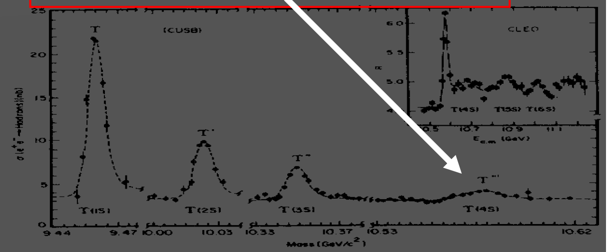
10^5-- **1987**-B^0 mixing & V_{ub} measured; Lower bound on m(top)>42 GeV; with non-zero V_{ub}, CKM in the game as a source of CPV

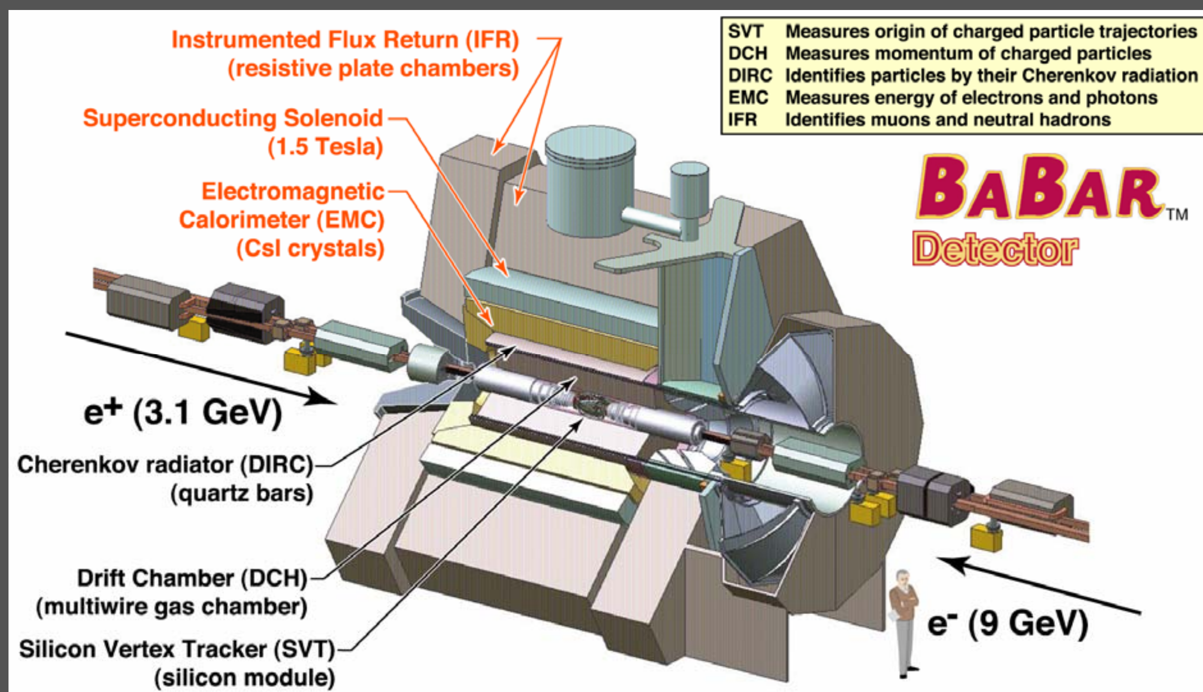
10^4-- **1981**-B meson observed

The B factory: PEP II Machine & BaBar Detector



Operating at the $\Upsilon(4s)$ resonance





The *BABAR* Collaboration

11 Countries

80 Institutions

623 Physicists

USA [38/311]

California Institute of Technology
UC, Irvine
UC, Los Angeles
UC, Riverside
UC, San Diego
UC, Santa Barbara
UC, Santa Cruz
U of Cincinnati
U of Colorado
Colorado State
Harvard U
U of Iowa
Iowa State U
LBNL
LLNL
U of Louisville
U of Maryland
U of Massachusetts, Amherst
MIT
U of Mississippi
Mount Holyoke College
SUNY, Albany
U of Notre Dame
Ohio State U
U of Oregon
U of Pennsylvania
Prairie View A&M U
Princeton U
SLAC
U of South Carolina
Stanford U
U of Tennessee
U of Texas at Austin
U of Texas at Dallas
Vanderbilt
U of Wisconsin
Yale

Canada [4/24]

U of British Columbia
McGill U
U de Montréal
U of Victoria

China [1/5]

Inst. of High Energy Physics, Beijing

France [5/53]

LAPP, Annecy
LAL Orsay
LPNHE des Universités Paris VI et VII
Ecole Polytechnique, Laboratoire Leprince-Ringuet
CEA, DAPNIA, CE-Saclay

Germany [5/24]

Ruhr U Bochum
U Dortmund
Technische U Dresden
U Heidelberg
U Rostock

Italy [12/99]

INFN, Bari
INFN, Ferrara
Lab. Nazionali di Frascati dell' INFN
INFN, Genova & Univ
INFN, Milano & Univ
INFN, Napoli & Univ
INFN, Padova & Univ
INFN, Pisa & Univ & Scuola Normale Superiore
INFN, Perugia & Univ
INFN, Roma & Univ "La Sapienza"
INFN, Torino & Univ
INFN, Trieste & Univ

The Netherlands [1/4]

NIKHEF, Amsterdam

Norway [1/3]

U of Bergen

Russia [1/13]

Budker Institute, Novosibirsk

Spain [2/3]

IFAE-Barcelona
IFIC-Valencia

United Kingdom [11/75]

U of Birmingham
U of Bristol
Brunel U
U of Edinburgh
U of Liverpool
Imperial College
Queen Mary , U of London
U of London, Royal Holloway
U of Manchester
Rutherford Appleton Laboratory
U of Warwick

Physics Harvest of Summer 2006
Runs 1-5

Submitted 114 papers to the ICHEP 2006 in Moscow

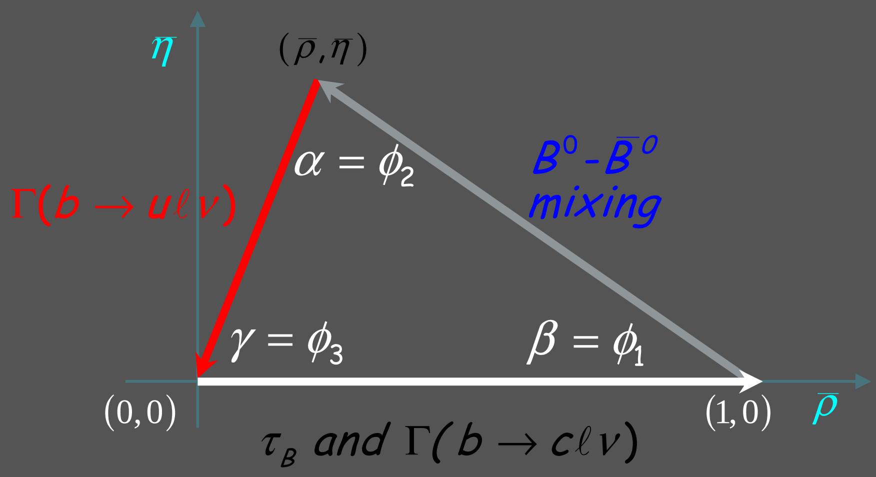
http://www-public.slac.stanford.edu/babar/ICHEP06_papers_temp.htm

Date taken to June1, 2006 presented in July/August conferences

Measurements related to alpha (5)
Measurements related to beta (14)
Measurements related to gamma (8)
Charmless B Decays (18)
B decays to open Charm (12)
Semileptonic B decays (10)
Radiative Penguin and Leptonic B decays (10)
Charmonium and Charm Spectroscopy (16)
Production and decay of Charm and Charmonium states (13)
Tau and low energy physics (8)
&
26 Invited Talks

Defining* CKM Quark Mixing

- Highly constrained and redundant set of precision measurements

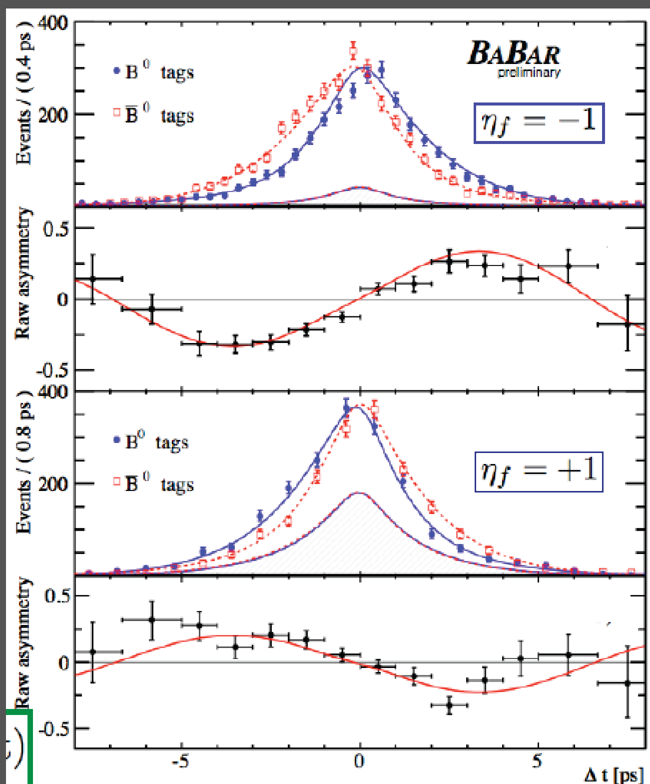


	World Average 2006
$\sigma(\alpha)$	~11^o
$\sigma(\sin(2\beta))$	~0.04
$\sigma(\gamma)$	~19^o
$\sigma(V_{ub})$	~7%

* $\sigma(V_{td}/V_{ts})$ from Tevatron

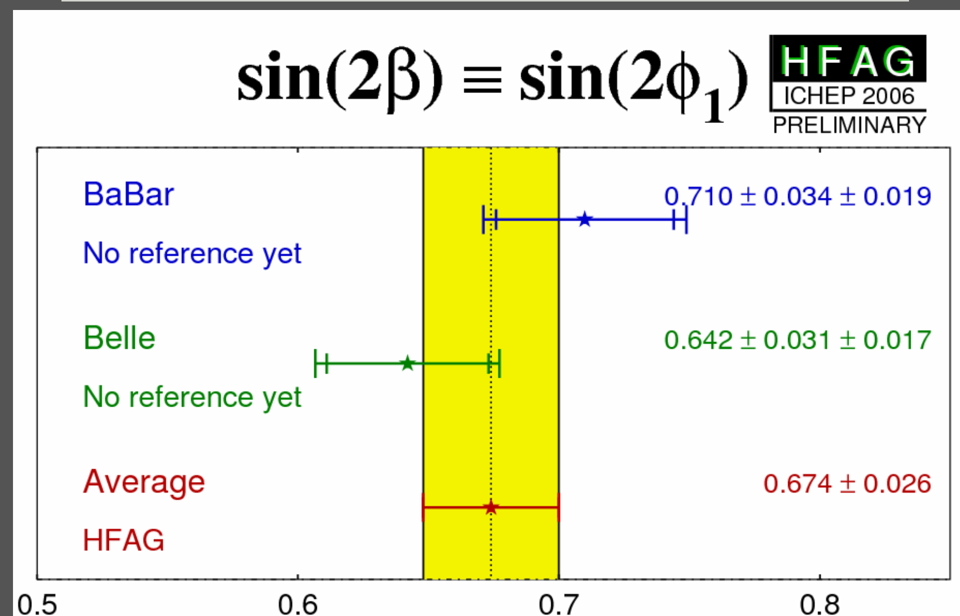
Measured by 'HEP Long Term Metric' -- 1

- Definition of "Successful"- part 1: ✔
  - Measure the matter-antimatter asymmetry in the primary (B-> J/psi K) modes to an overall relative precision of 4%



$$\sin 2\beta = 0.710 \pm 0.034(stat) \pm 0.019(syst)$$

Relative error of: 5.4% - BaBar alone

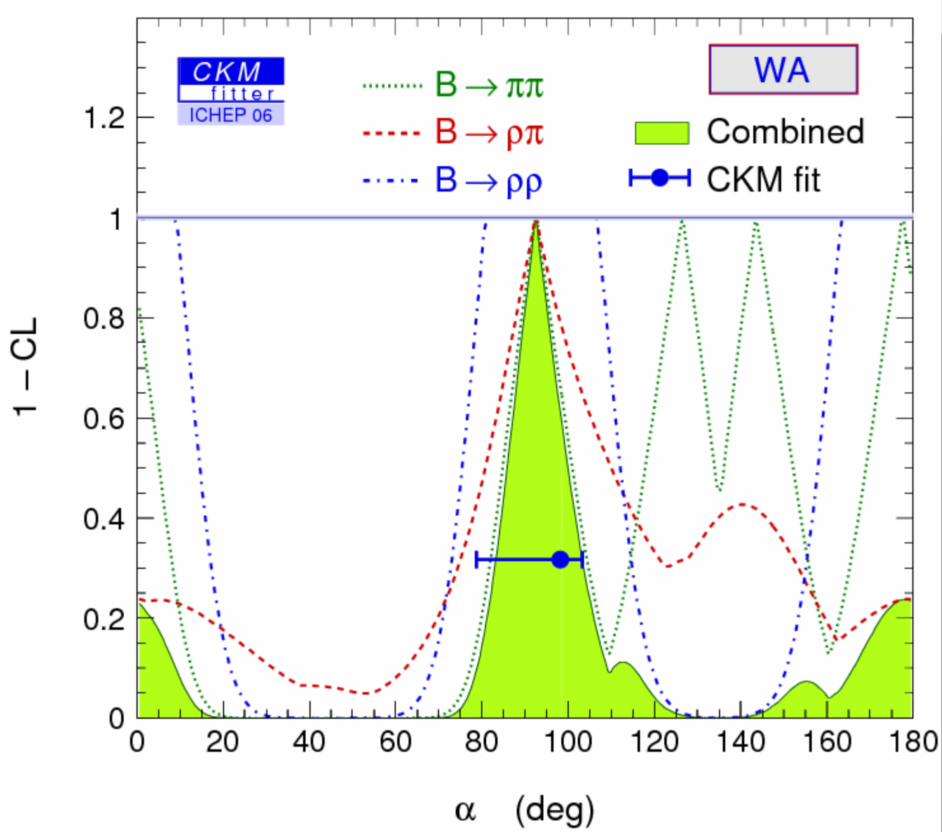


WA: A 3.8% measurement

Measuring α

BaBar: $\alpha \in [86,114]$ at 68% c.l.

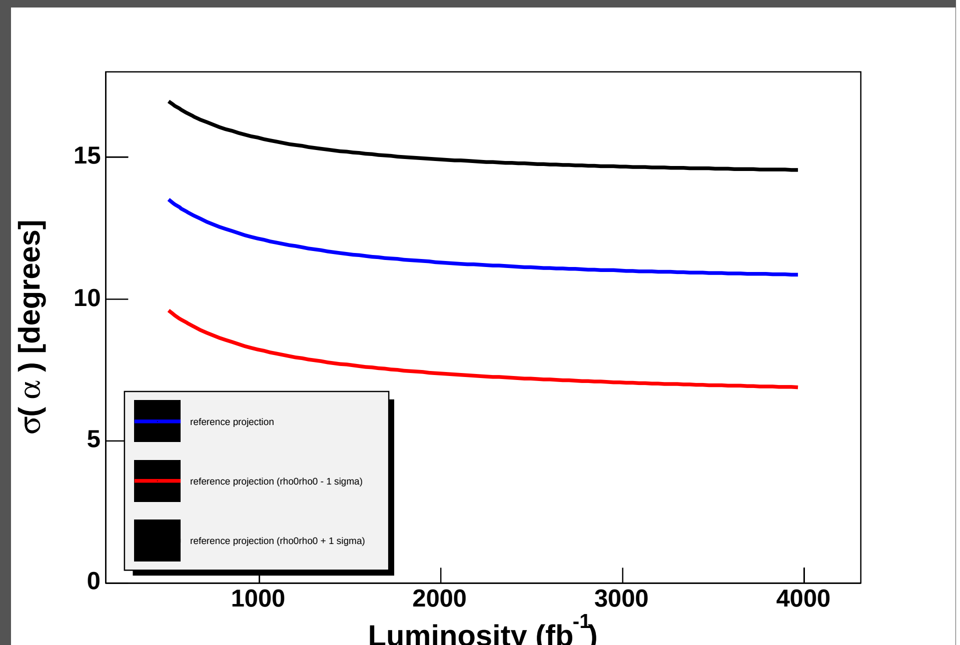
$\alpha = 93^{+11}_{-9}$ (B→ρρ, ππ, ρπ) (WA)



Already the error is systematic (theory) dominated.

At ~2/ab, expect σ(α) ~ 7° – 10° depending on the size of B->$\rho^0\rho^0$.

Measuring B->$\rho^0\rho^0$ & its Time-dependent CP asymmetry will shrink errors further.



Measuring γ: $V_{ub} = |V_{ub}|e^{-i\gamma}$

The method highly sensitive to r_B: ratio of (b→u) / (b→c) amplitudes
fits favor r_B ~ 0.1 (BaBar) ; r_B >0.2 (Belle).
Main cause of the difference in errors

From the Dalitz Analysis alone:

γ=(92+/- 41 ± 11 +/- 12)° (BaBar)

$\varphi 3$=(53° $^{+15}_{-18}$ ± 3° ±9°) Belle

Combined (UTfit): γ = (78 +/- 18)°

All methods

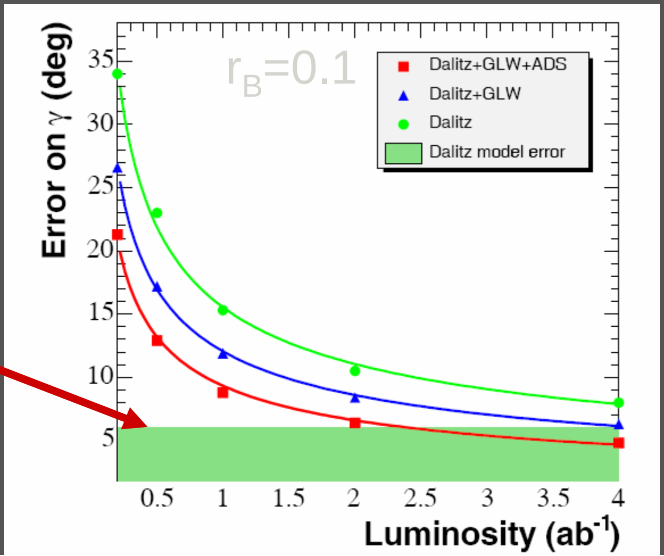
Error due to uncertainties in treatment of the D→$K_s\pi\pi$-Dalitz plot (amplitudes and phases)

-CLEO-c data can help. Projected error 3-5 deg (@1/ab

Future of γ

2008: 5-10°

Requires improvement in D-Dalitz model – BaBar and CLEO-c data will help achieve this.



Looking to the Future

- Increasing precision in CKM Quark Mixing Parameters

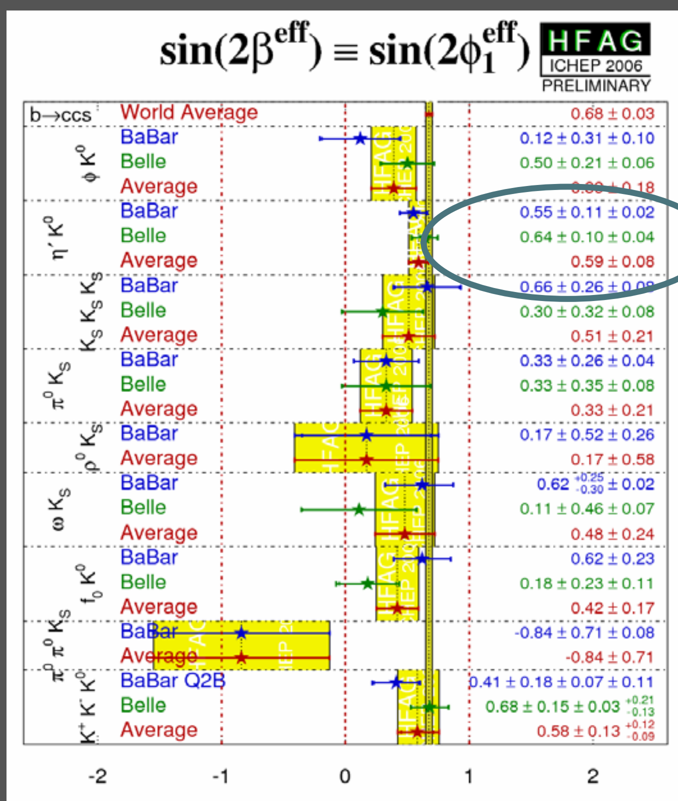
	World Average 2006	World Average 2008
$\sigma(\alpha)$	$\sim 11^0$	$\sim 8^0$
$\sigma(\sin(2\beta))$	~0.04	~0.02
$\sigma(\gamma)$	$\sim 19^0$	$\sim 5\text{-}10^0$
$\sigma(V_{ub})$	~7%	~5%

Testing CKM Quark Mixing

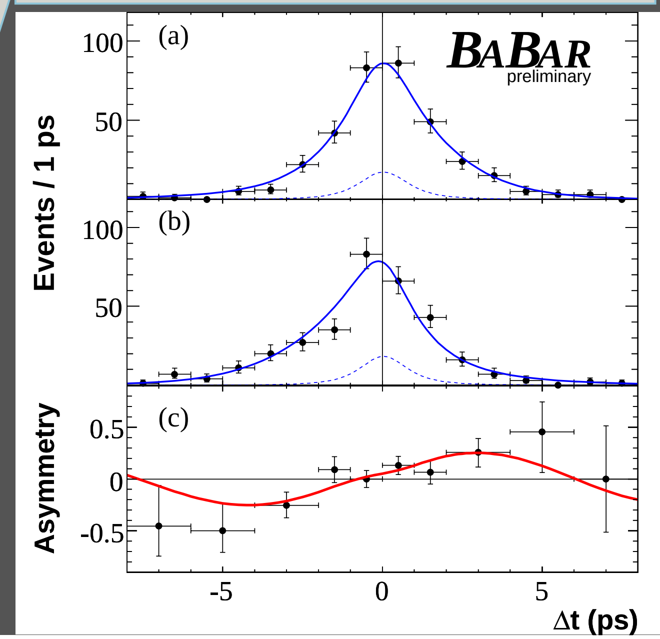
- Look for evidence of new physics and new phases that can enter in B decays via loop diagrams
  - $b \to s l^+ l^-$
  - $b \to s\gamma$
  - $B \to \tau\nu$
  - Tests with Direct CP violation
- Charm and Tau decays also provide powerful window for new physics searches
  - D mixing
  - LFV in τ decays

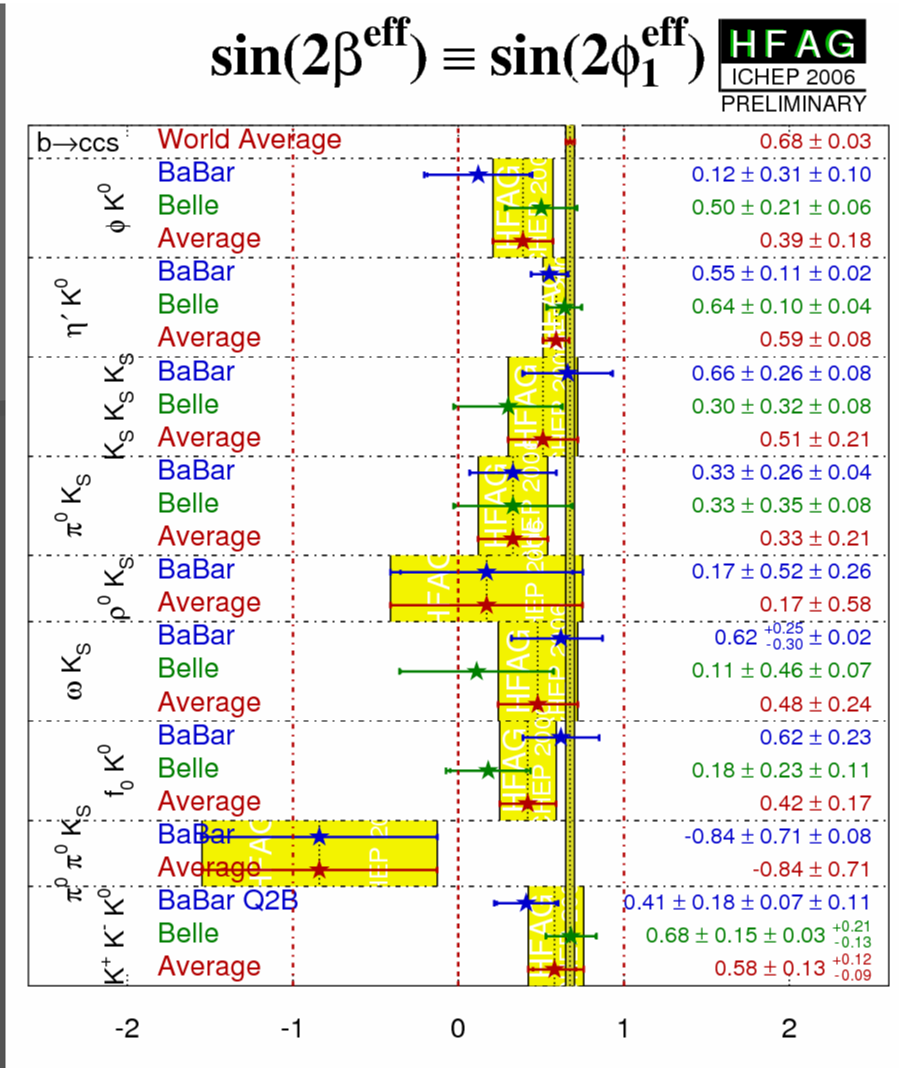
Measured by ‘HEP Long Term Metric’ -- 2

- <u>Definition of “Successful”- part 2:</u>
  - Measure the time-integrated asymmetry in at least 15 additional modes to an absolute precision of <10%. [We include all other CPV measurements]
    - Not there yet, but expect to reach there with the “1/ab” data
  - Some of the channels being measured:

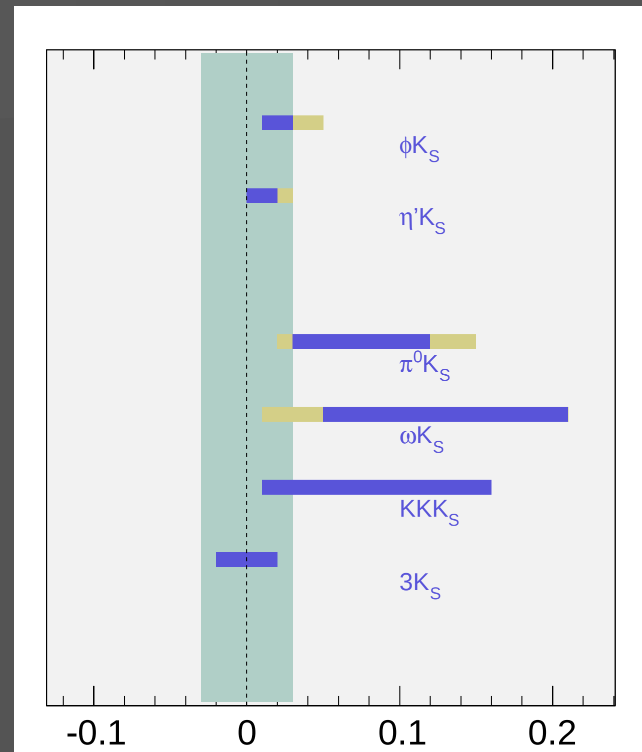


~5.5 σ observations by BaBar & Belle





Expected ΔS with SM



Simple average: $S_{penguins}$=0.52 +/- 0.05 vs reference point: sin2β=0.68+/-0.03

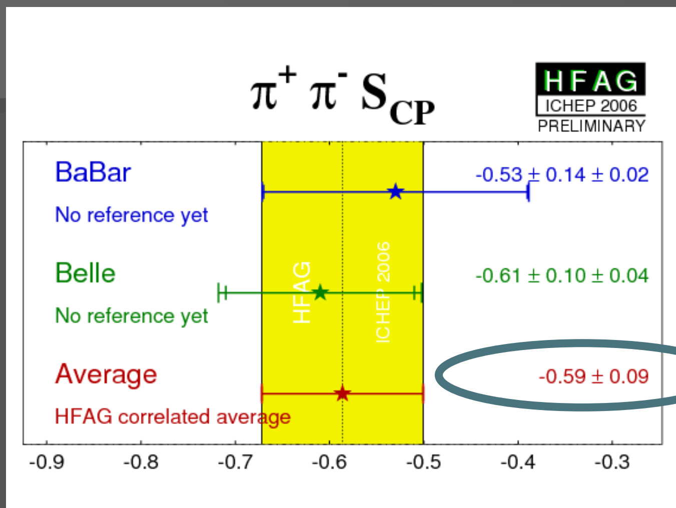
~ 2.5 σ deviation at this point.

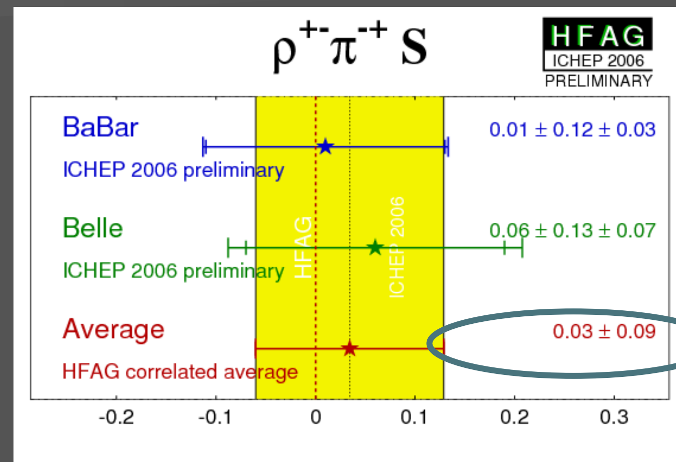
Eagerly waiting for more data

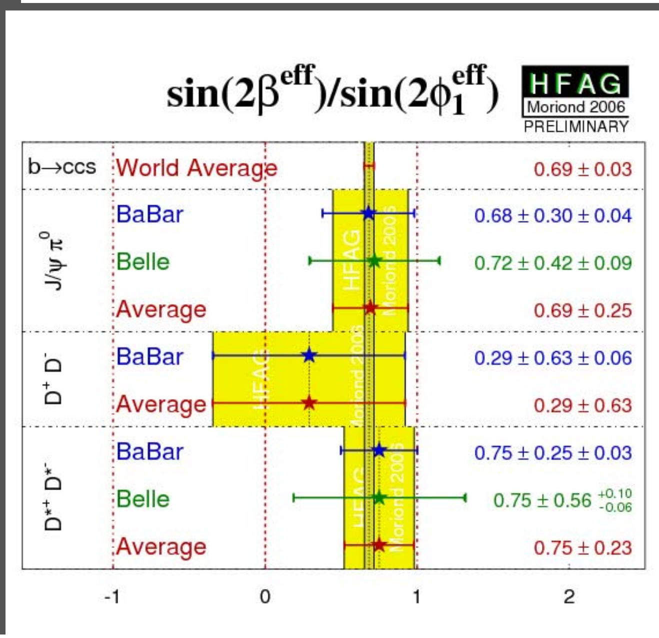
Measured by ‘HEP Long Term Metric’ -- 2

Definition of “Successful”- part 2:

➢More channels..



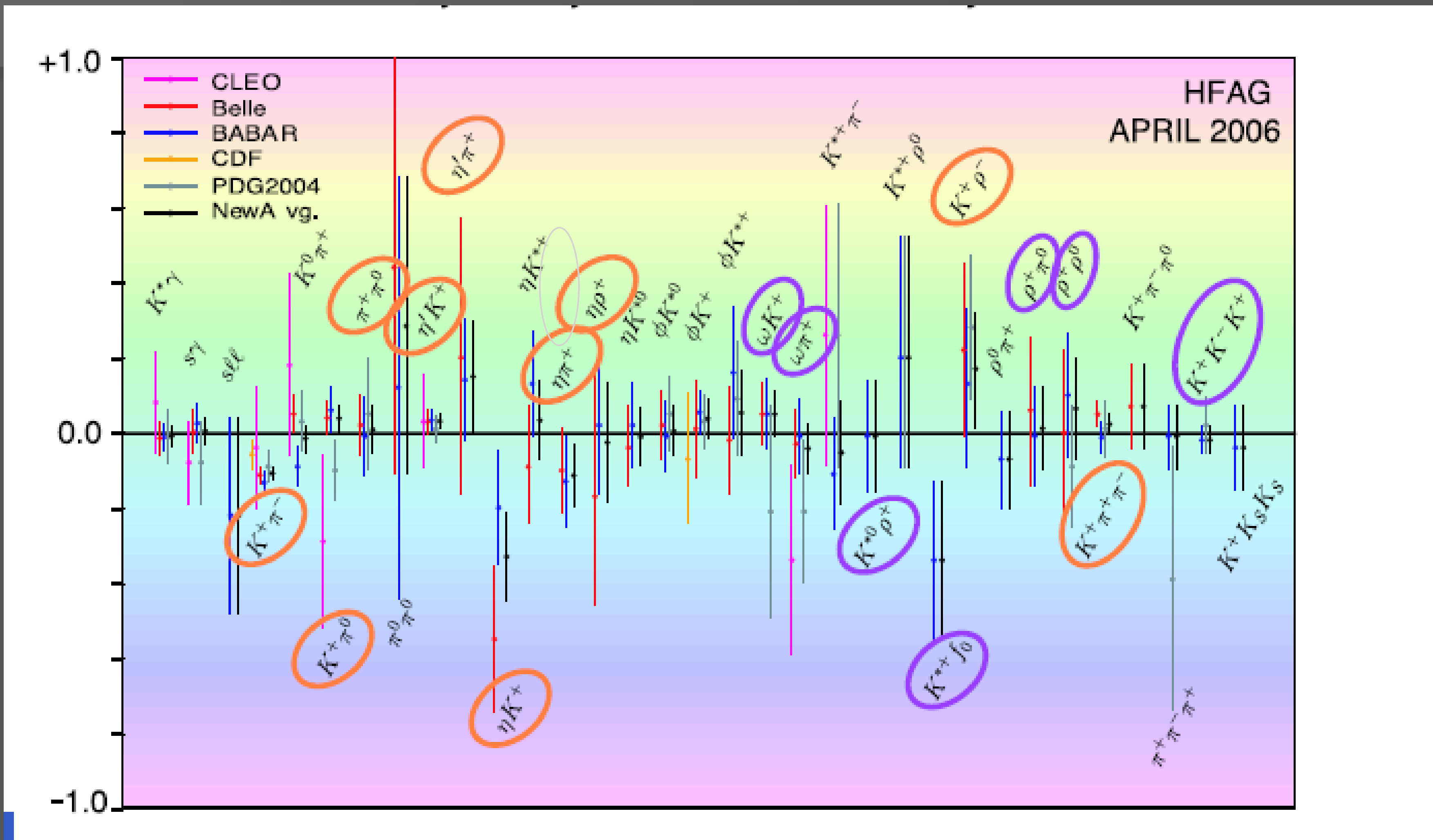




$$S(\rho^{+}\rho^{-}) = \text{-}0.19 \pm 0.21\ ^{+0.05}_{-0.07}$$

$$C(\rho^{+}\rho^{-}) = \text{-}0.07 \pm 0.15 \pm 0.06$$

Measured by the 'HEP Long Term Metric'—3 Direct CP Violation



The Message from New Physics Fits to CKM observables*

- New sources of CP violation in b→d & s→d are strongly constrained
- New Physics contributions to the b→s transitions are much less constrained & are in fact well motivated by models explaining large mixing angles in neutrino sector-

* L. Silvestrini UTFit LP2005

The physics reach of the BaBar Data:charm

Charm physics with $\sim 0.4 \times 10^9\ c\bar{c}$

- Search for D0 mixing – highly suppressed in SM- a powerful window for NP searches

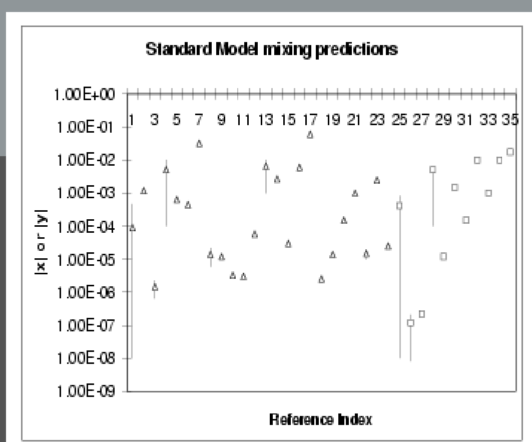
Observables:

CP even state: width Γ_1, mass m_1 ;

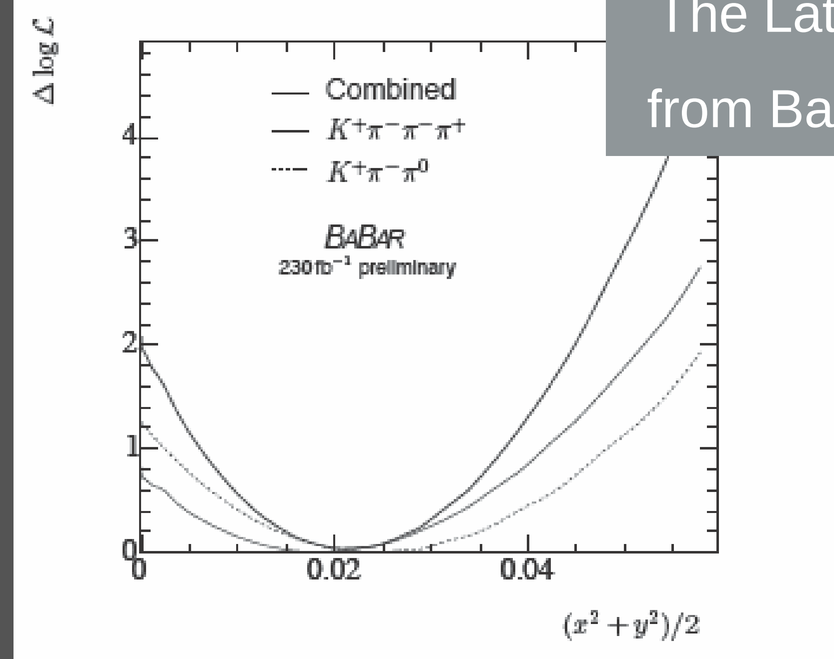
CP odd state: width Γ_2, mass m_2

$$y = (\Gamma_1 - \Gamma_2) / (\Gamma_1 + \Gamma_2) = \Delta\Gamma / 2\Gamma$$

$$x = (m_1 - m_2) / \Gamma = \Delta m / \Gamma$$



The Latest from BaBar



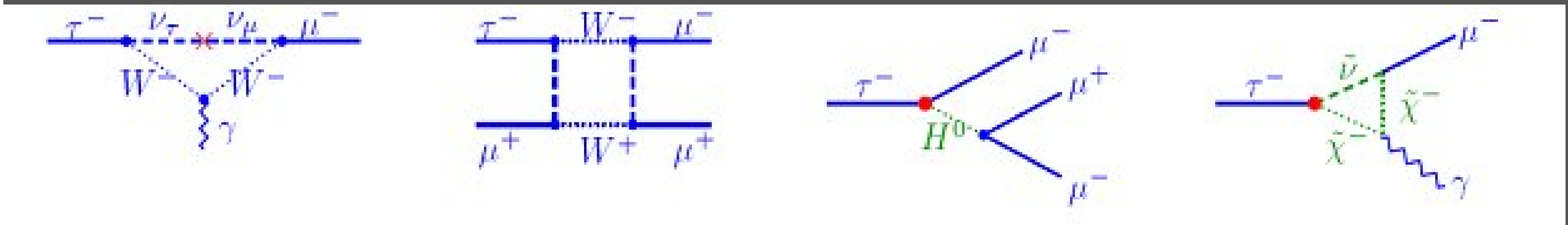
$$R_M = (0.020\ ^{+0.011}_{-0.010}\ (\text{stat.}))\%$$

D^0 Mixing Still consistent with zero. Limits approaching the SM expectation

The physics reach of the BaBar data: τ decays

B factory data the primary source for searches for Lepton Flavor Violation (LFV) in τ decays: Recent results on:

$\tau \rightarrow \mu\gamma$ & $\tau \rightarrow e\gamma$ – $\tau \rightarrow \mu\eta$ & (Lepton and Flavor Violating decays) $\tau \rightarrow \Lambda h$ highly suppressed in SM;



Limits on Branching ratios: @90% C.L

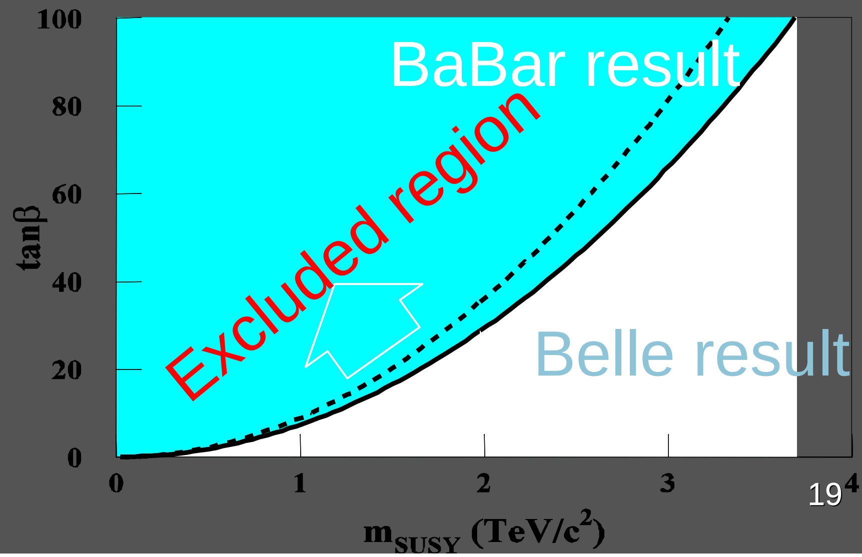
BaBar: $Br(\tau \rightarrow \mu\gamma) < 0.68 \times 10^{-7}$

$Br(\tau \rightarrow e\gamma) < 1.1 \times 10^{-7}$

Belle: $Br(\tau \rightarrow \mu\gamma) < 0.41 \times 10^{-7}$

$Br(\tau \rightarrow e\gamma) < 1.2 \times 10^{-7}$

Example of how it impacts

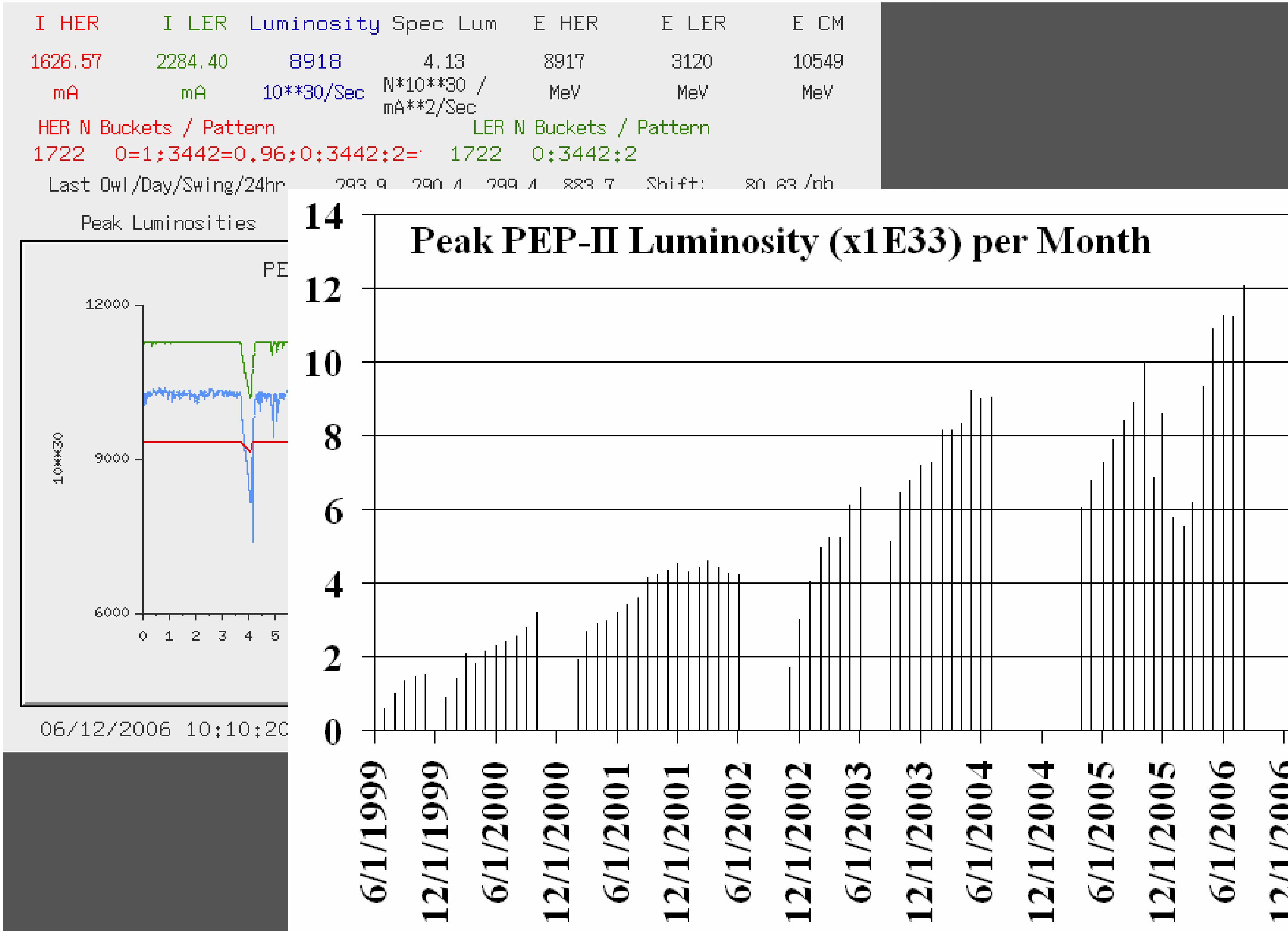


Looking Forward with PEP-II

- PEP-II Long Term Run Schedule
  - Run 5b: November 14, 2005-August 21, 2006
  - Down: September-December 2006
    - Safety checks
    - Major upgrades for PEP-II
    - Major upgrades for BaBar
    - LCLS installation
  - Run 6: January-August 2007
  - Down: September-November 2007
  - Run 7: December 2007-September 2008

Summary of Run 5

- Commissioned new RF allowing increased beam currents
- Dedicated work on optical magnet lattice for both rings paid off
  - Reduced beta errors around ring
  - Horizontal tunes closer to half integer
  - Higher beam-beam tune shifts
  - High specific luminosity
  - Better stability at high beam current
- New records in all performance milestones for PEP-II
  - L_{peak}=1.21 x 10^{34} cm^{-2} s^{-1} (4x design)
  - Int $L_{24\ hrs}$ = 911 pb^{-1} (7x design)


I HER
I LER
Luminosity
Spec Lum
E HER
E LER
E CM
1626.57
2284.40
8918
4.13
8917
3120
10549
mA
mA
10**30/Sec
N*10**30 / mA**2/Sec
MeV
MeV
MeV
HER N Buckets / Pattern
1722 0=1;3442=0,96;0:3442:2=
LER N Buckets / Pattern
1722 0:3442:2
Last Owl/Day/Swing/24hr
Shift:
Peak Luminosities
12000
9000
6000
10**30
0 1 2 3 4 5
06/12/2006 10:10:20
Peak PEP-II Luminosity (x1E33) per Month
14
12
10
8
6
4
2
0
6/1/1999
12/1/1999
6/1/2000
12/1/2000
6/1/2001
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12/1/2006

PEP-II Records

Last update:
August 18, 2006

Peak Luminosity

12.069×10^{33} cm^{-2}sec^{-1} August 16, 2006

1722 bunches 2900 mA LER 1875 mA HER

Integration records of delivered luminosity

Best shift (8 hrs, 0:00, 08:00, 16:00)	339.0 pb^{-1}	Aug 16, 2006
Best 3 shifts in a row	910.7 pb^{-1}	Jul 2-3, 2006
Best day	849.6 pb^{-1}	Aug 14, 2006
Best 7 days (0:00 to 24:00)	5.385 fb^{-1}	Jul 27-Aug 3, 2006
Best week (Sun 0:00 to Sat 24:00)	5.111 fb^{-1}	Jul 30-Aug 5, 2006
Peak HER current	1900 mA	Aug 15, 2006
Peak LER current	2995 mA	Oct 10, 2005
Best 30 days	19.315 fb^{-1}	Jul 19 – Aug 17, 2006
Best month	17.036 fb^{-1}	July 2004

Total delivered

410 fb^{-1}

Challenges of Run 5

- Two major vacuum problems developed in the month of December limiting the peak luminosity to about ~0.5 x $10^{34}/cm^2/s$:
  - Gap ring (RF seal) problem near LER RF cavity caused e^+ beam instability
  - Higher Order Mode absorbing bellows caused vacuum bursts in IR
- The first problem was quickly identified (~ 2 weeks) and solved in late January.
- The second problem was thoroughly investigated, replacement parts manufactured, and repaired in late March with elapsed time of about three months.

Conclusion of Run 5

- Run ended with a ‘bang’
  - – Series of very successful machine studies through out the run contributed to improvements in performance and stability of the machine
  - – Aug 18 during machine studies, using special bunch pattern, studied high bunch charge beam-beam effects
    - Demonstrated record per bunch luminosities
    - Consistent with achieving L_{peak}~ 2 x 10^{34} cm^{-2} s^{-1}
  - – Overheating in cable near transverse feedback kicker resulted in small cable fire
    - Cause of cable heating understood and being fixed

PEP-II Upgrades

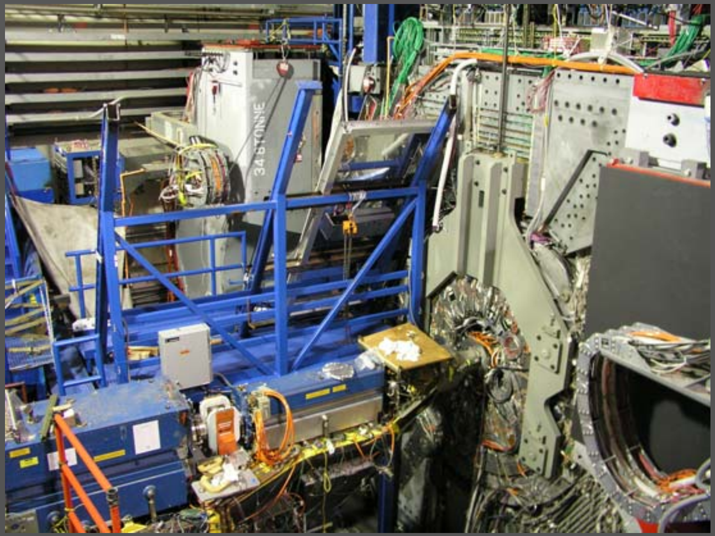
- Goal: Increase PEP-II luminosity by 60% by the end of run 6
- (1.2 → 2 $\times 10^{34}/cm^2/s$) will come from:
  - – Increasing each beam current by 40%.
  - – Lowering β_y^* from 11 to 8.5 mm giving 20%.
  - – Increasing the beam-beam parameters by 10%.
  - – Keeping detector backgrounds at the predicted levels.
  - – Maintaining (and improving) accelerator reliability.

Onward to the 1/ab phase 2006-2008

- Final Machine Upgrades
  - take the peak luminosity from 12×10^{33} /cm^2/s → 20 $\times10^{33}$ /cm^2/s
- Final Detector Upgrades
  - Complete the upgrade of the Instrumented Flux Return (IFR)
    - replace RPC's with LST's in the remaining 4 sectors (2 sectors were done in 2002).
    - Expect to fully recover (the slowly deteriorating) muon and K_L identification capabilities of the detector.
  - Prepare for the expected higher data rate (and possibly higher background)
    - stay at its usual very high efficiency of data collection (~96% historical average).
    - Now studying the trigger and data flow system for possible bottlenecks and preparing for solutions

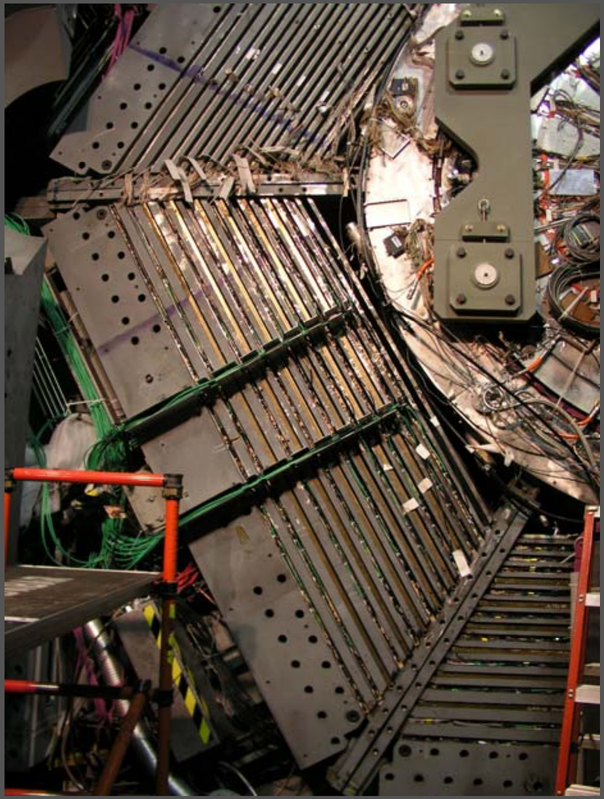
LST Installation

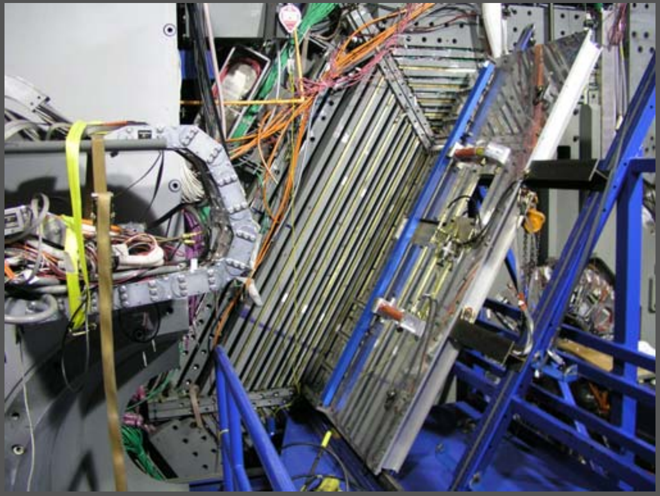
LST prep



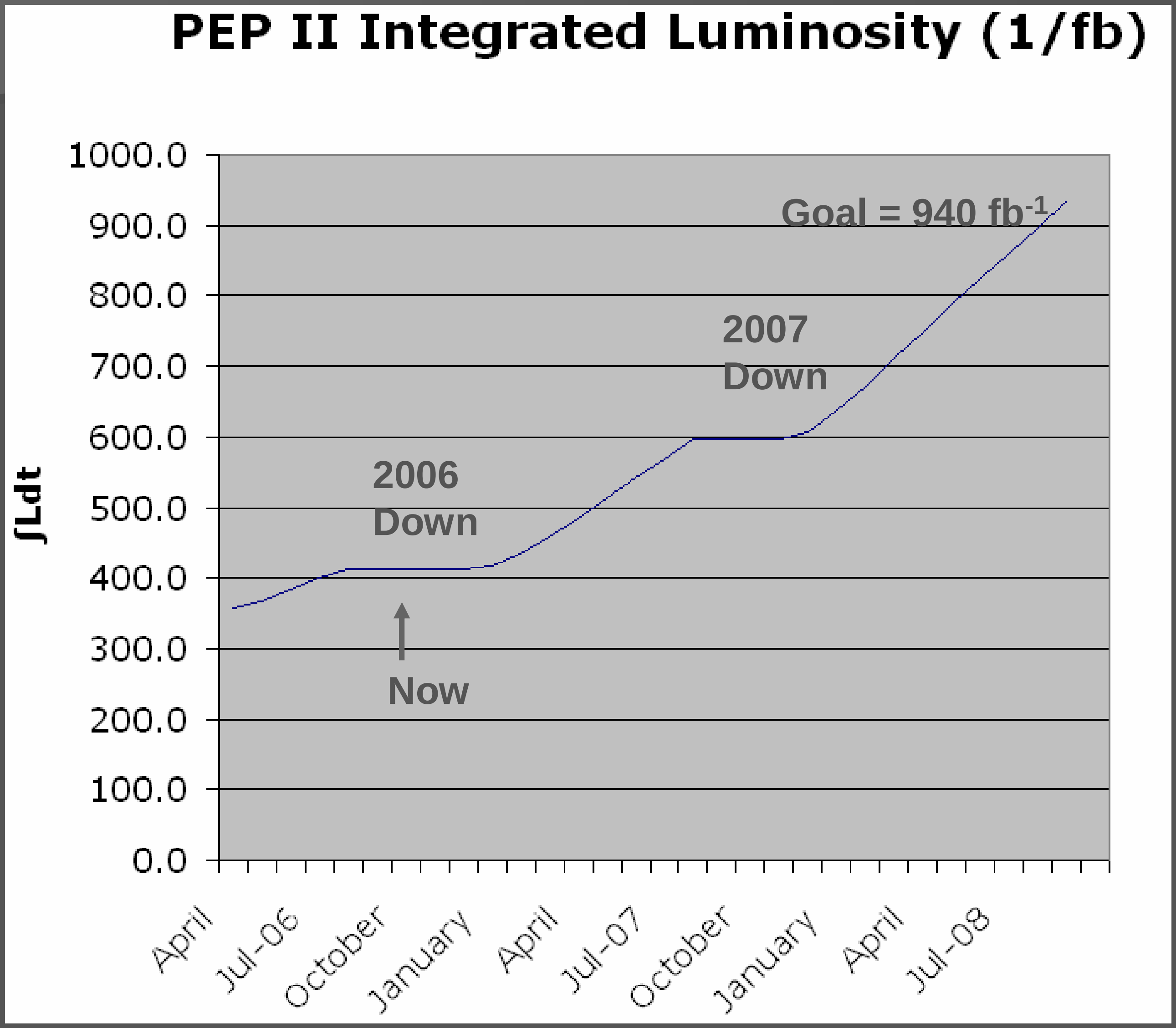
Upper West sextant tooling and brass installation

Lower West sextant installed





Onward to the 1/ab Phase of BaBar 2006-2008



Summary

- There is an enormous amount of flavor physics still to come from BaBar in its "1/ab" phase
  - Precision knowledge of the charge weak sector of the SM & CKM parameters
    - With the possibility of revealing deviation from the SM
  - Measurements of CP violation and decay properties in penguin dominated decay modes
    - with the possibility of revealing New Physics effects.
- If we continue to see no deviation at these precisions- the results will serve as major constraints on the flavor structure of New Physics- to be seen at LHC
- PEP II and BaBar are in preparation for the "1/ab" phase. Both upgrade efforts are proceeding well and on schedule.