Super B factories.

Antimo Palano
INFN and University of Bari, Italy
Beauty 2005, Assisi, Italy
June 20 – 24, 2005

Current and future *B* Factories

- Two *B* Factories (PEP-II at SLAC, KEK-B at KEK) have been in operation since 1999
  - These high luminosity asymmetric energy e^+e^- colliders have made the first measurements of *CP*-violating asymmetries in *B* meson decays
- *CPV* measurements provide unique new tests of the quark sector of the Standard Model
  - The Standard Model seems to have passed the most straightforward of these tests, but there are hints of failure in more subtle areas tests
    - These seem to occur in places predicted by supersymmetric extensions of the Standard Model
- A Super *B* Factory with >50 times current luminosity is needed to provide definitive answers on New Physics beyond the Standard Model effects in the heavy flavor sector

Success of B Factories

- About 300 papers in the last 5 years from BABAR & Belle on:
- B Physics;
- Charm Physics;
- Charmonium Physics;
- $\gamma\gamma$ and τ Physics.

- Many new analyses and ideas in progress.

Success of B Factories

First precise test of CKM picture for CPV.

- $\sin 2\beta = +0.726 \pm 0.037$ is now a precise measurement (~5%).
- The other angles are becoming interesting.
  - α from $S\rho\rho$ and $\rho\pi$ Dalitz
  - $2\beta+\gamma$ from $B \to D^{(*)}\pi$
  - γ from $B \to DK$ (w/ D Dalitz)

  + side measurements too.

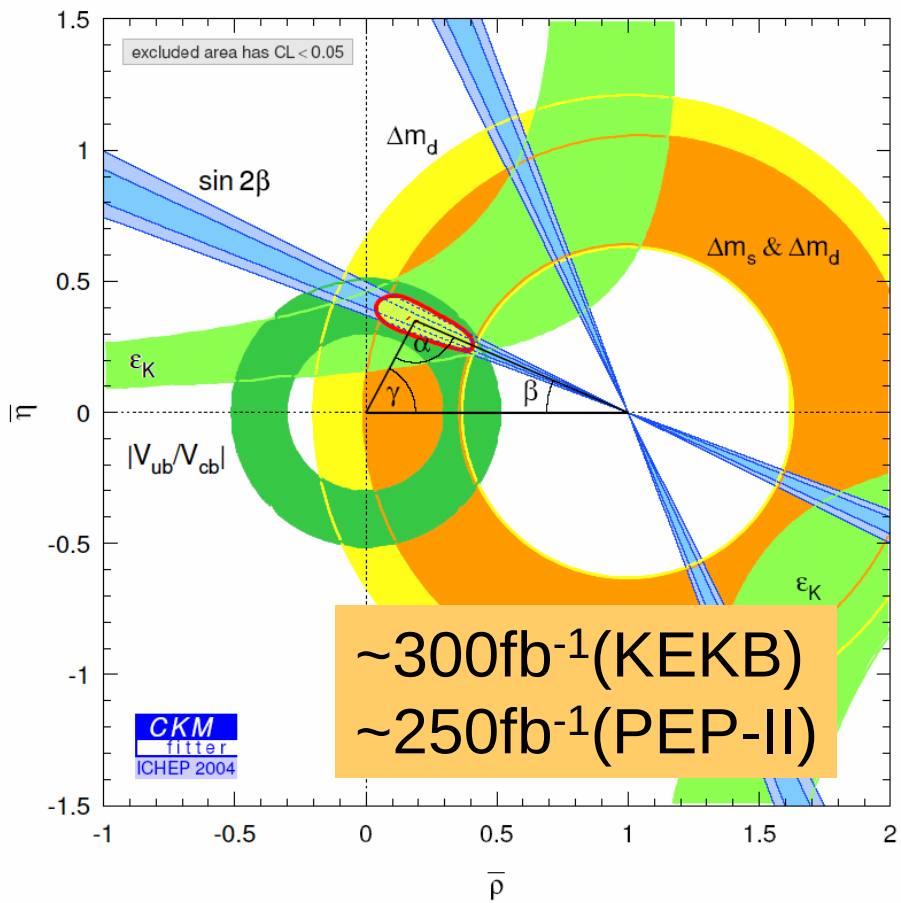
    $|V_{cb}|$, $|V_{ub}|$. Δm_d

Paradigm change: look for Alternatives to CKM

⇩

Corrections by NP

Need far precise tests



sin2β from charmonium modes (b → ccs)

HFAG

sin2β(WA) = +0.726 ±0.037
|λ|(WA) = +0.969 ±0.028

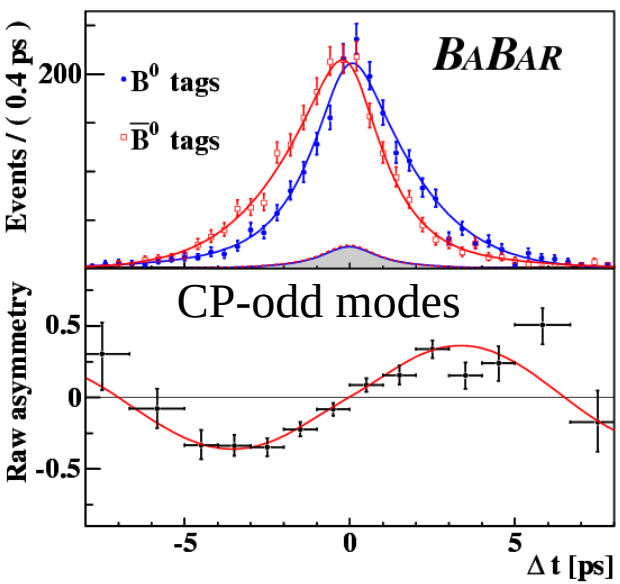
227M $B\overline{B}$

sin2β = +0.722 ±0.040 ±0.023
|λ| = +0.950 ±0.031 ±0.013

BELLE

152M $B\overline{B}$

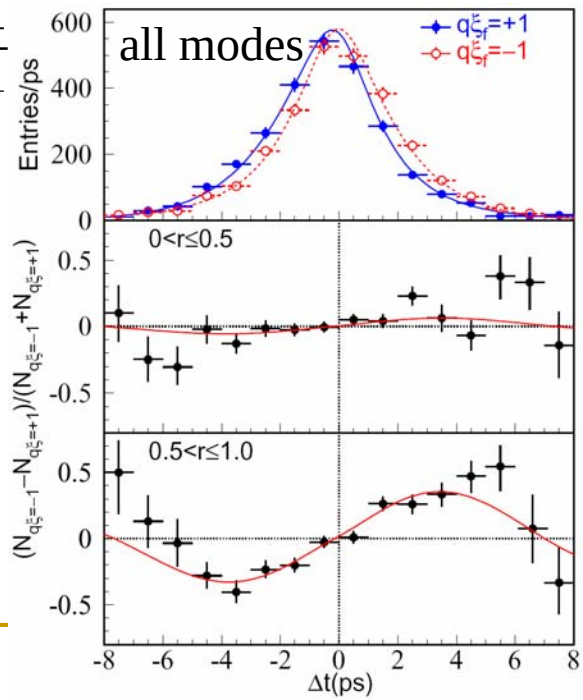
sin2β = +0.728 ±0.056 ±0.023
|λ| = +1.007 ±0.041 ±0.033



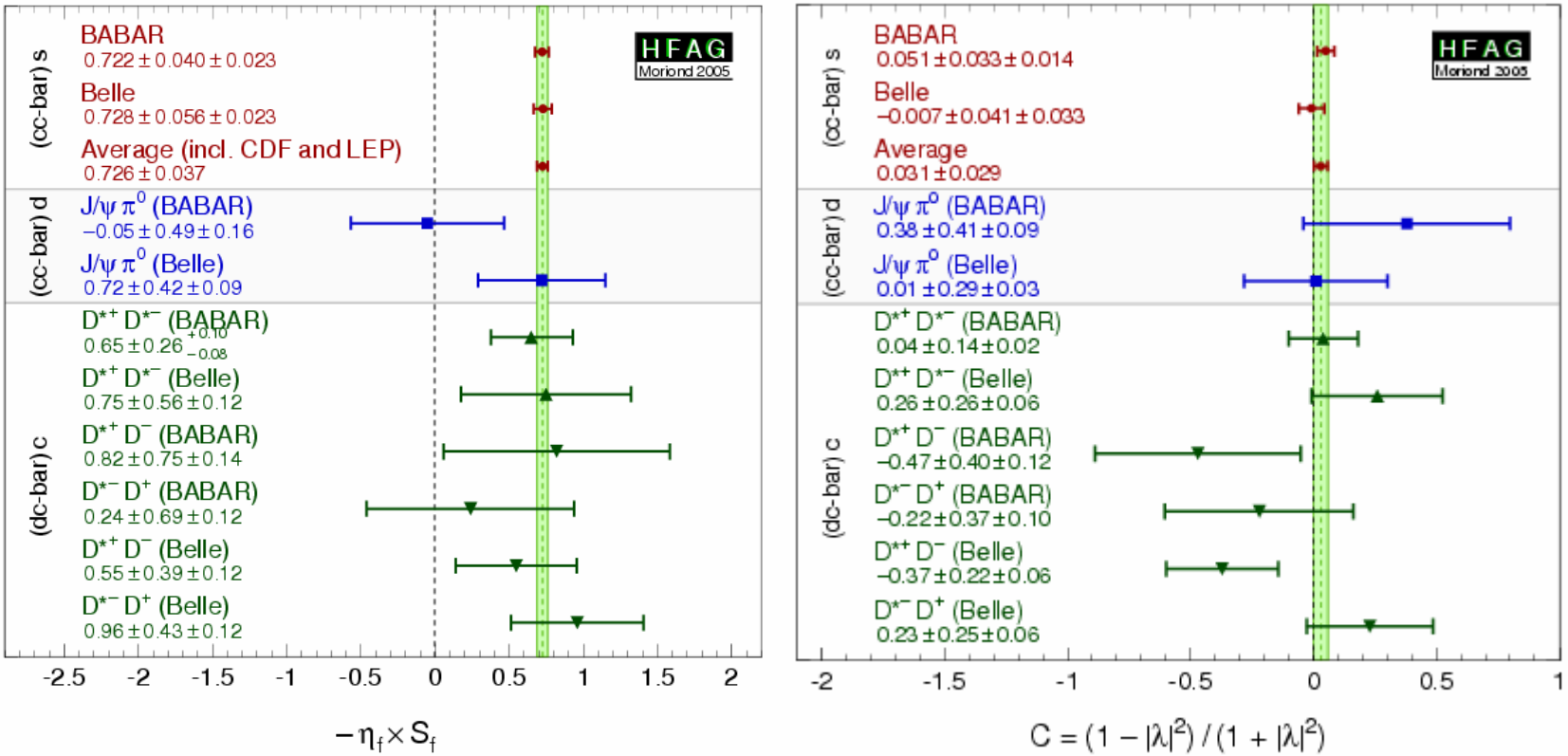
J/ψKs
J/ψK_L
ψ(2s)Ks
χ_{C1}Ks
ηcKs
J/ψK^{*0}(→ Ksπ⁰)

$$\mathcal{A} = \frac{|\lambda|^2 - 1}{|\lambda|^2 + 1}$$

cos2β:
BaBar: $+2.72\ ^{+0.50}_{-0.79}\ \pm 0.27$
Belle: $-0.56 \pm 0.86 \pm 0.11$
(convention not the same)
not yet very useful.



Summary of *CP* asymmetries in $b \to cc(s.d)$ decays



Measurements of both the S and C parameters are consistent with Unitarity Triangle constraints

Summary of constraints on α

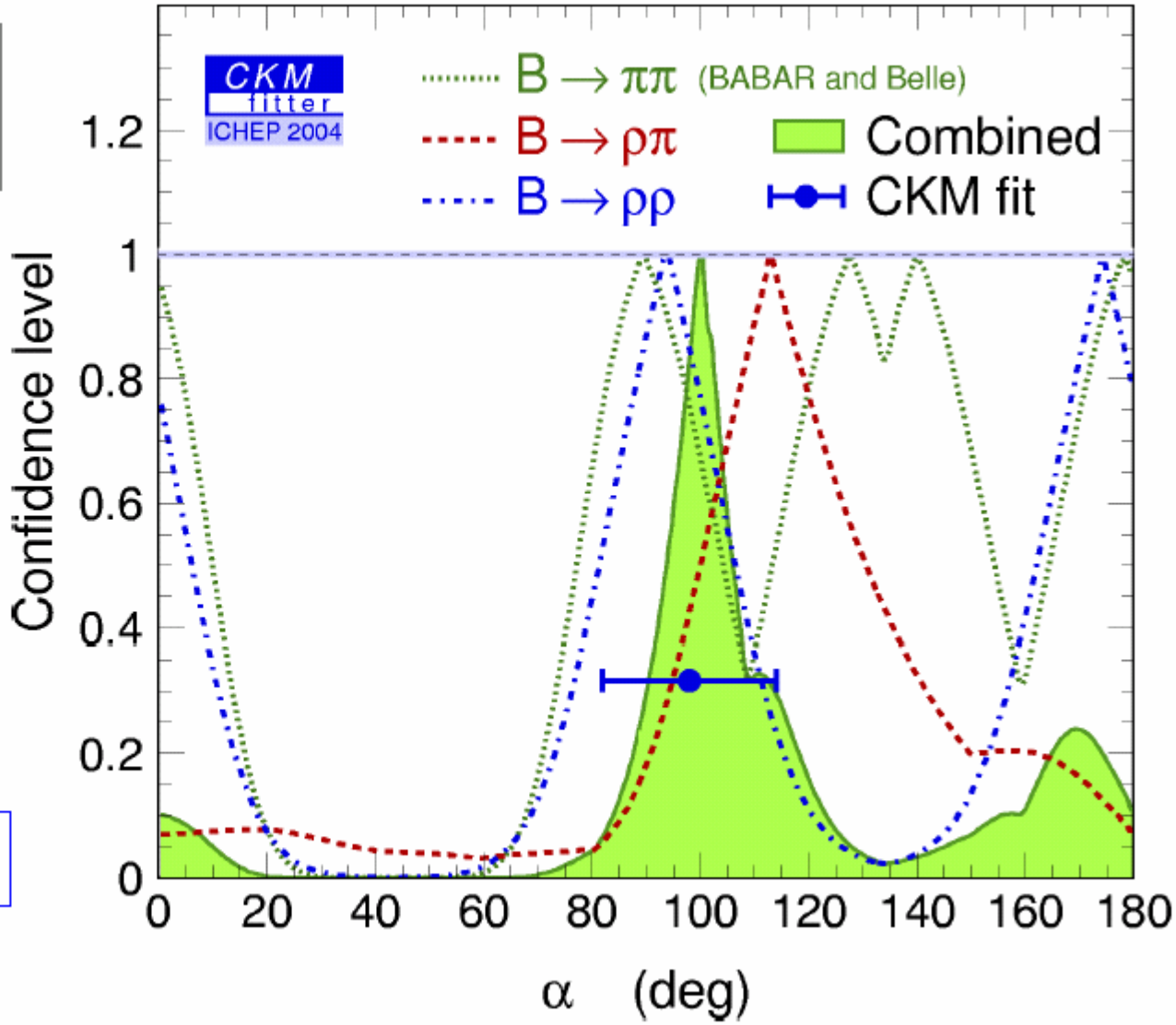
BABAR & Belle combined

Mirror solutions disfavored

From combined $\pi\pi, \rho\pi, \rho\rho$ results:

$$\alpha = \left[100^{+12}_{-11}\right]^{\circ}$$

CKM indirect constraint fit:
$\alpha = 98 \pm 16^{\circ}$



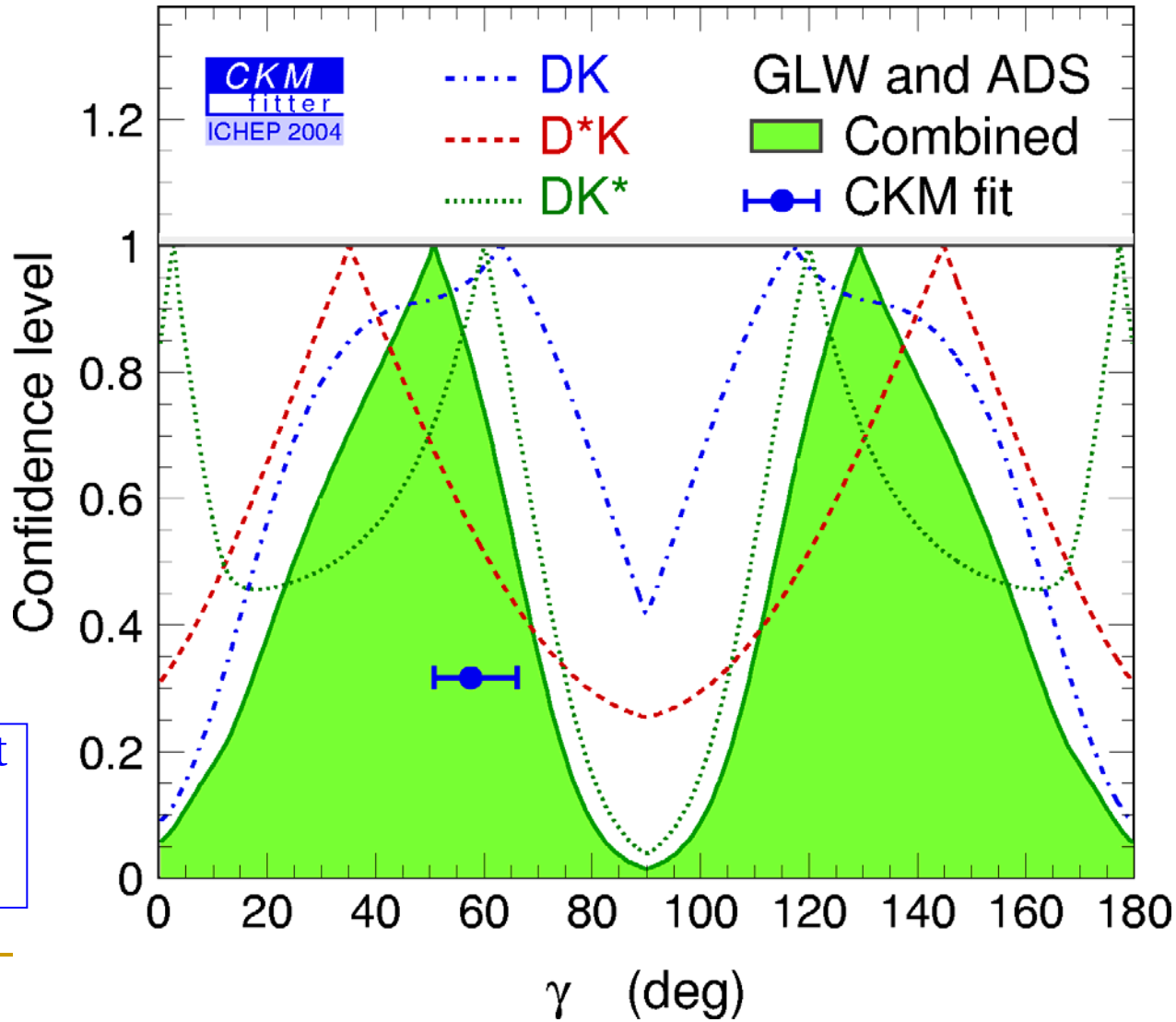
Combined GLW and ADS constraint on γ

BABAR & Belle combined

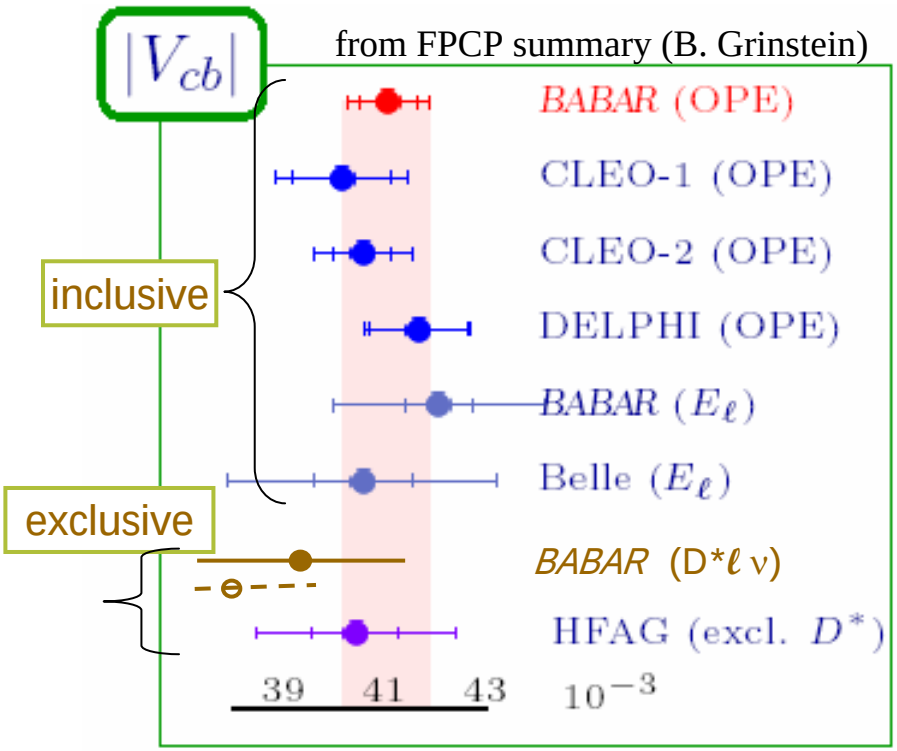
From combined GLW and ADS fit :

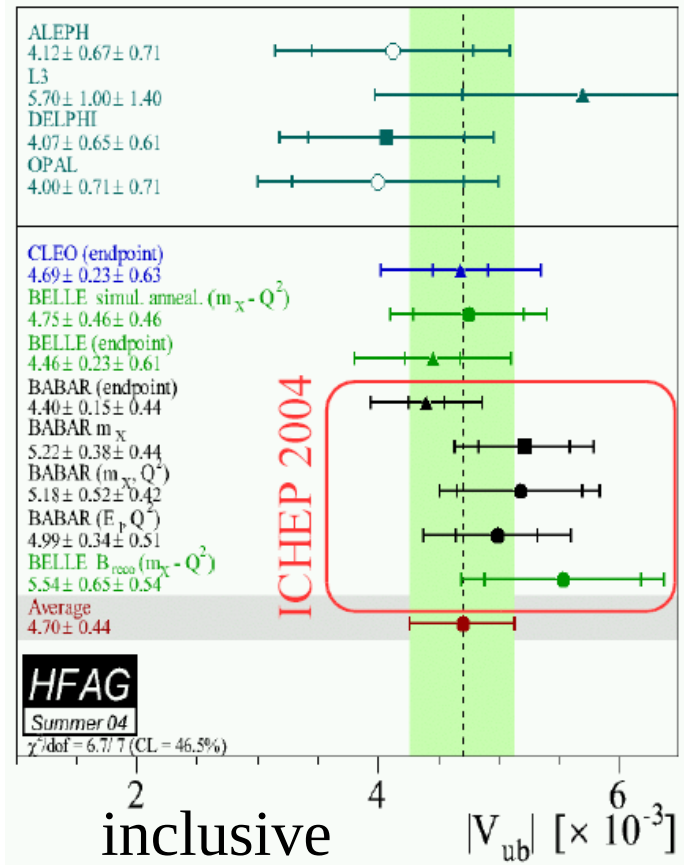
$$\gamma = \left[51 \,^{+20}_{-34} \right]^{\circ}$$

CKM indirect constraint fit : $\gamma = \left[58 \,^{+8}_{-7} \right]^{\circ}$



Sides of the UT: Vcb and Vub





HFAG

$|Vcb|_{excl} = (41.4 \pm 1.0_{exp} \pm 1.8_{theo}) \times 10^{-3}$

$|V_{ub}| = (4.70 \pm 0.44) \times 10^{-3}$

excl. |Vub| also in progress. |Vtd/Vts| from b → dγ in the near future ?

DCPV in $B^0 \to K^+\pi^-$

First observation from BaBar & Belle

HFAG

$\mathcal{A}$ (WA) = –0.109 ±0.019

227M $B\bar{B}$

BELLE

275M $B\bar{B}$

➢Evidence for DCPV (4.2σ)

➢Evidence for DCPV (3.9σ)

$\mathcal{A}$ = –0.133 ±0.030 ±0.009

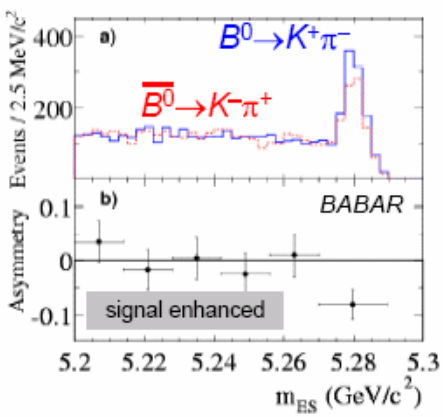
$\mathcal{A}$ = –0.101 ±0.025 ±0.005

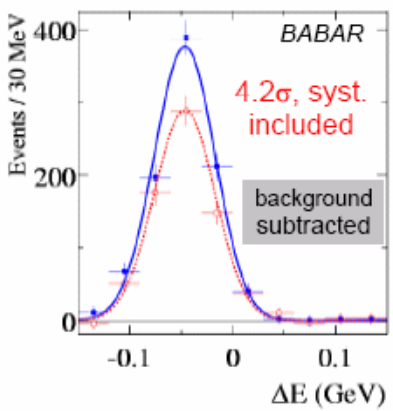
$n_{K\pi} = 1606 \pm 51$

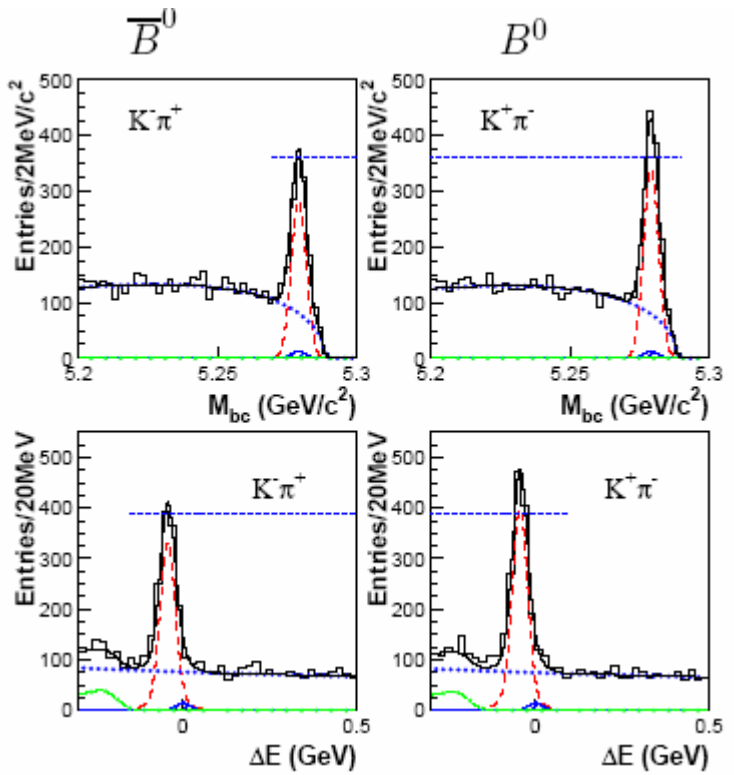
$A_{K\pi} = -0.133 \pm 0.030 \pm 0.009$

$n(B^0 \to K^+\pi^-) = 910$

$n(\bar{B}^0 \to K^-\pi^+) = 696$







$B^0 \to \phi K^0$ signals

227M $B\bar{B}$

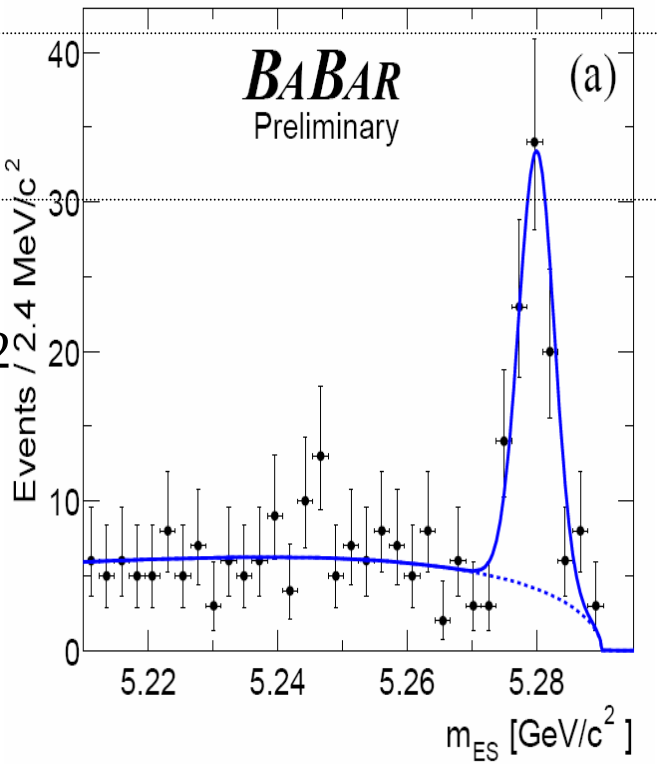
275M $B\bar{B}$

Nsig: the total number of signal events in the sample used for *TCPV* measurements

Plots for all signal events

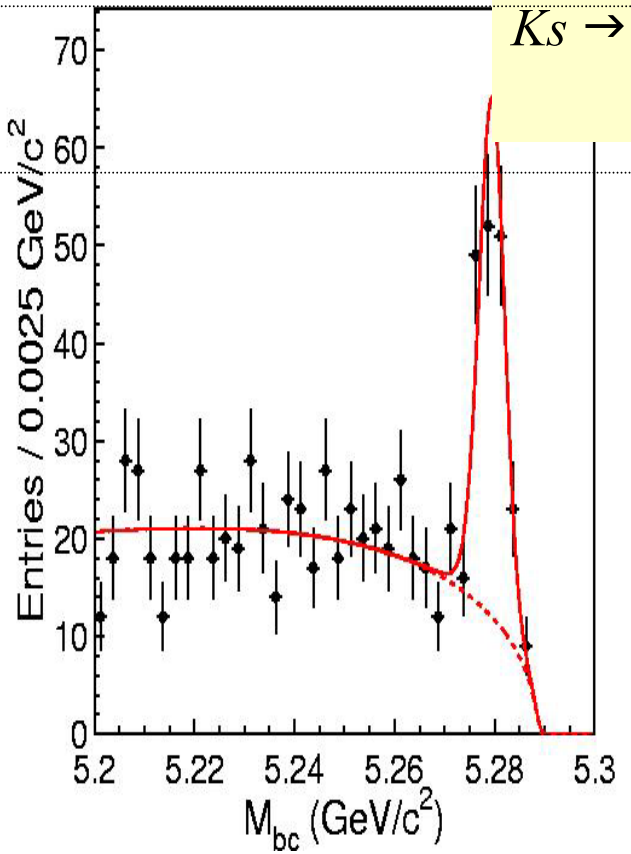
ϕKs:
$\phi \to K^+K^-$
$Ks \to \pi^+\pi^-$

Nsig = 114±12



Nsig = 139±14
purity = 0.63

ϕKs:
$\phi \to K^+K^-$
$Ks \to \pi^+\pi^-$,
$\pi^0\pi^0$



Search for New Physics.

- CP asymmetries in the decays of neutral B mesons into final CP eigenstates f exhibit a time dependent behavior:

$$A_f(t) = S_f \sin(\Delta m\, t) - C_f \cos(\Delta m\, t)$$

- The standard Model predicts that for most of the decays that proceed via $b \to q\bar{q}s$:

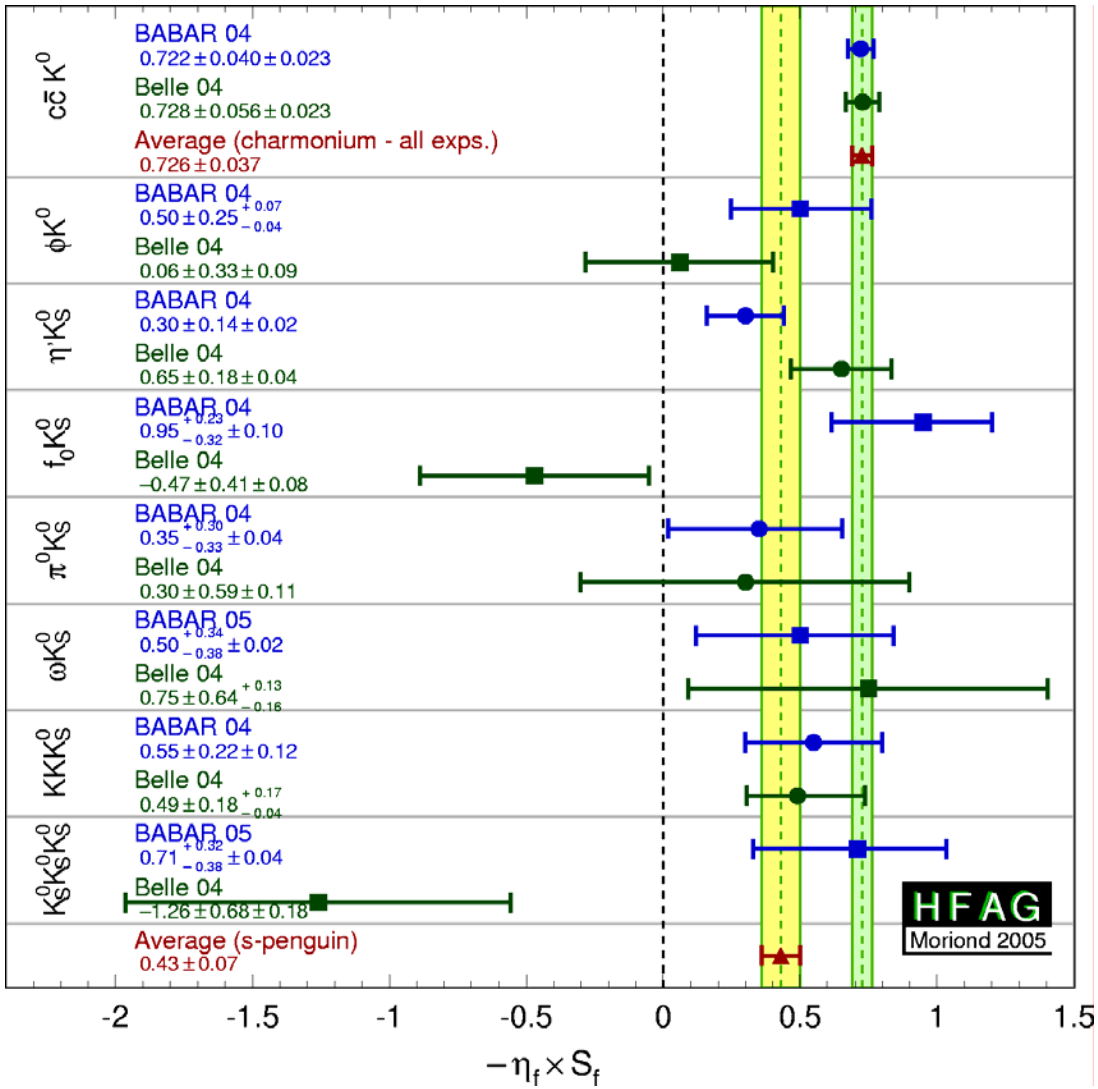
$$-\eta_f S_f = \sin 2\beta,\ C_f = 0$$

where $\eta_f = \pm 1$

New physics may appear through:

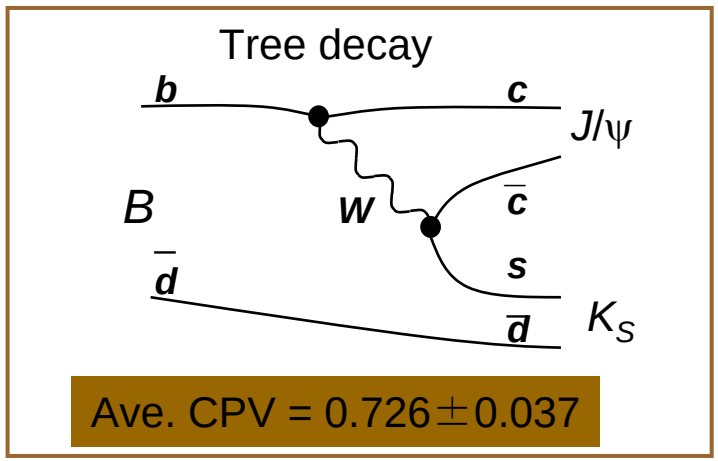
- S_f would be different from each other and from $S_{\psi K}$
- C_f would be different from each other and from zero

sin2β comparison – average of *BABAR* and Belle



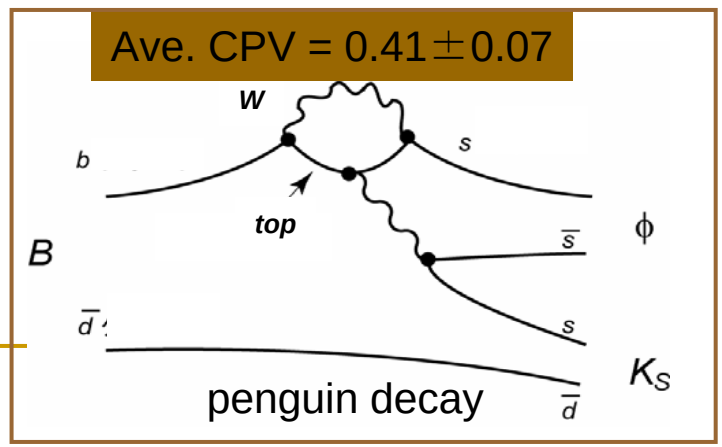
„sin 2β“

Anomalous CPV hints new physics?

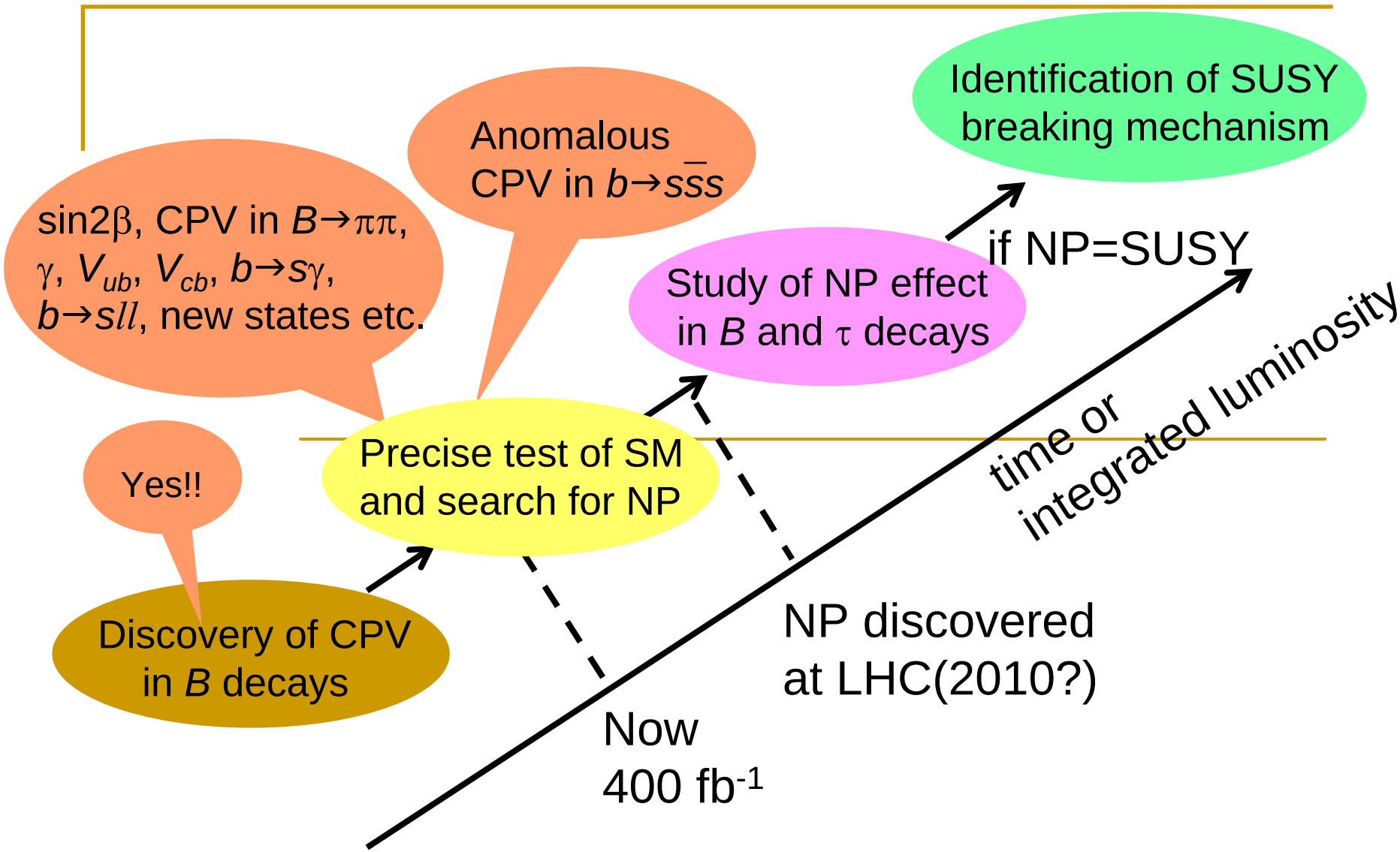


equal if only SM

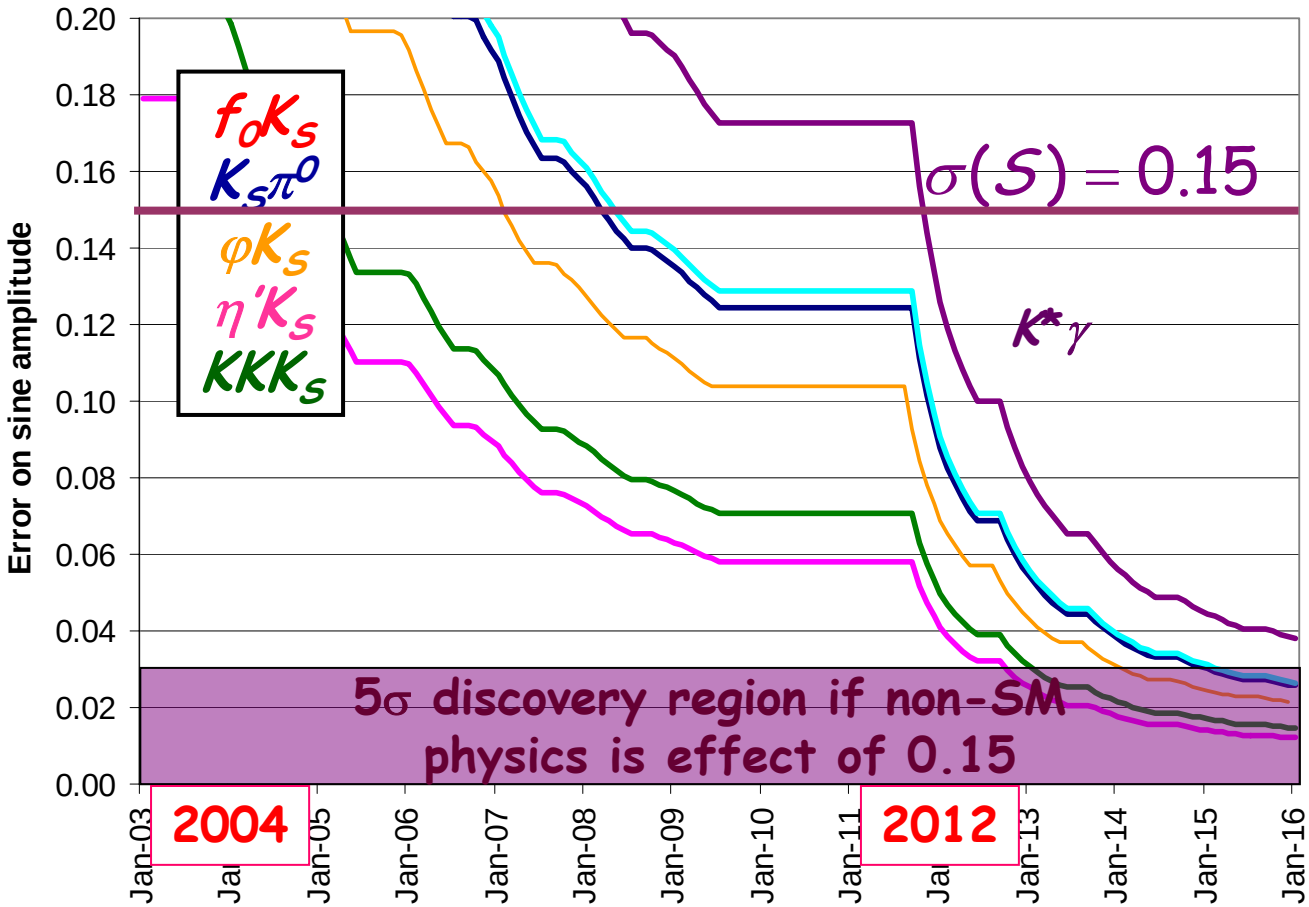
3.8σ deviation observed



Roadmap of B Physics



Projections for Super B Factory



Luminosity expectations :

Super *B* Factory
$5\text{-}7\times10^{35}$ cm^{-2}s^{-1}

Projections are statistical errors only;
but systematic errors at few percent level

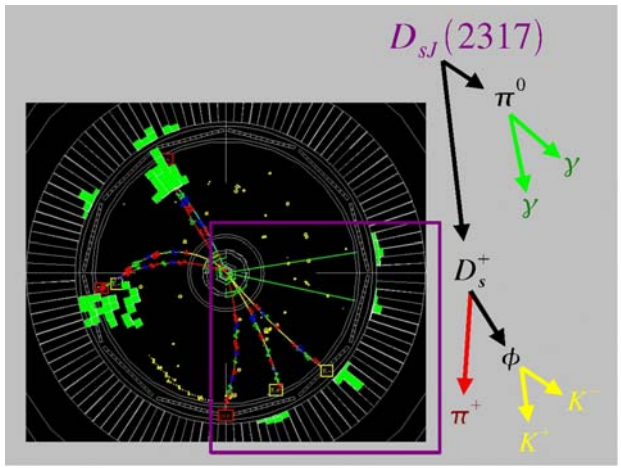
Charm physics at a Super B factory.

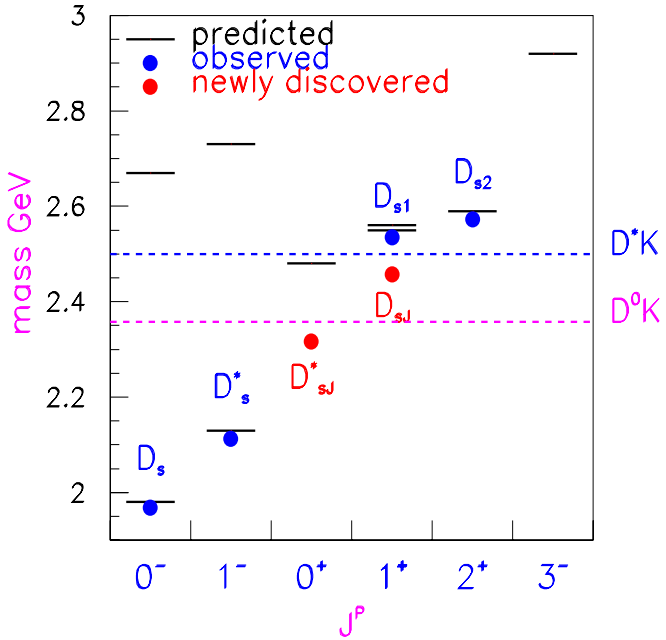
- A super B factory will produce copious amounts of charm particles.
- With 10 ab^{-1} a total of 13 billion $c\bar{c}$ pairs will be produced.
- This will allow to study many items related to charm physics:

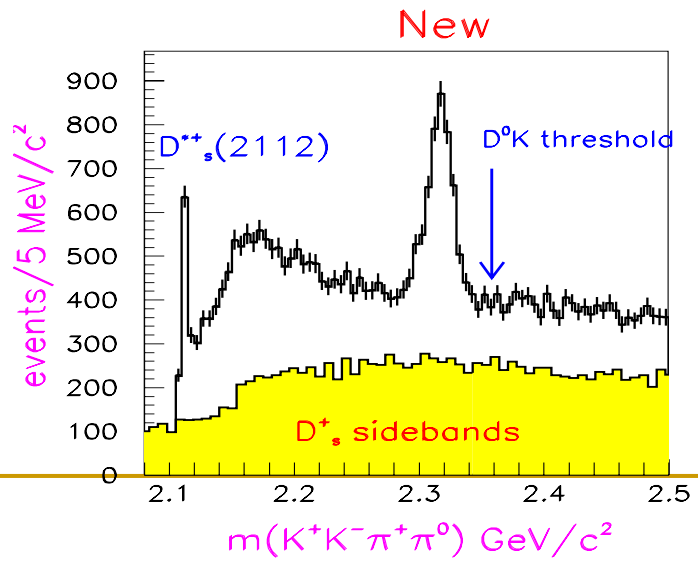
1. *D^0 D^0 mixing;*
2. *Search for Rare Decays;*
3. *Time-dependent Dalitz plot analyses*

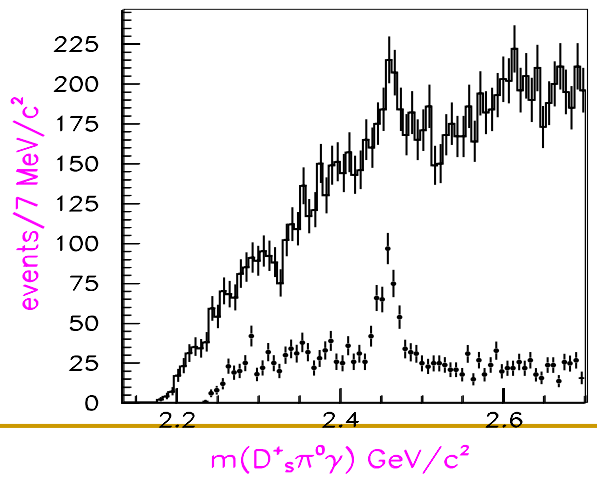
Charm Spectroscopy. **BaBar: discovery of new Ds states.**

- Potential models not always work!







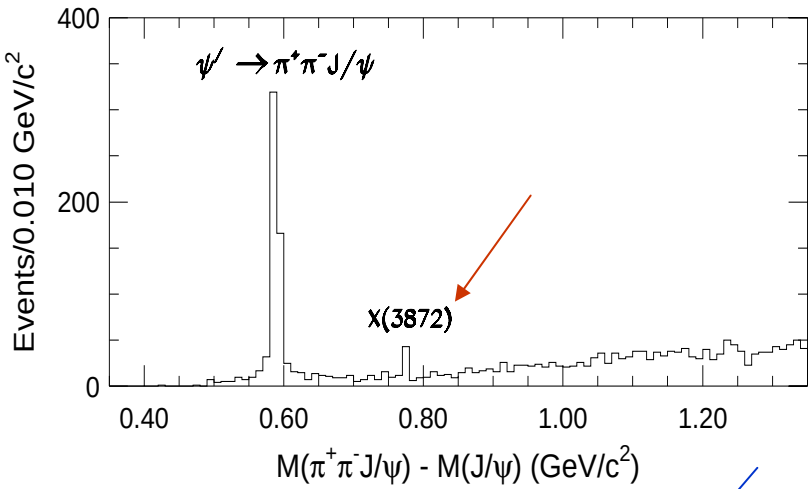


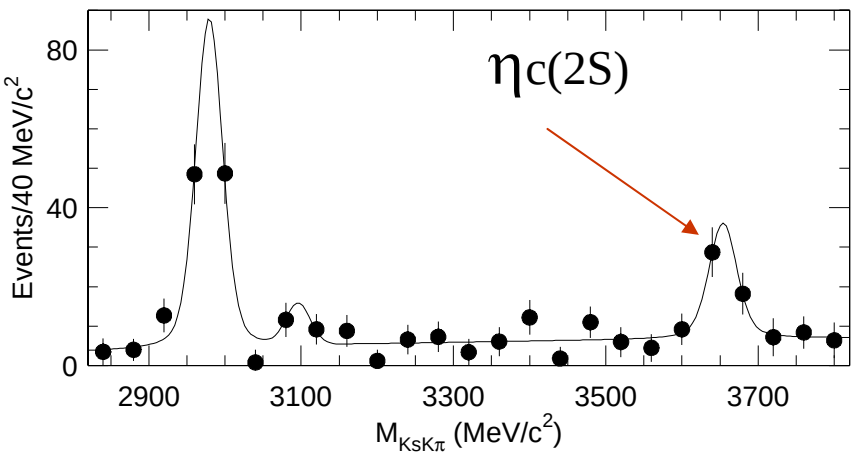
Spectroscopy: New Charmonium States.

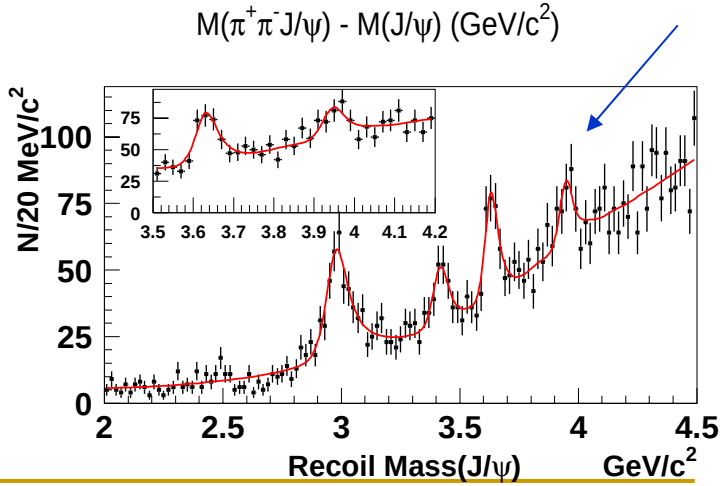
Belle: Discovery of new charmonium states: $\eta_c(2S)$, X(3872), Y(3920)

Not all of them have a clear place in the $c\bar{c}$ scheme.

Where are charmonium hybrids?







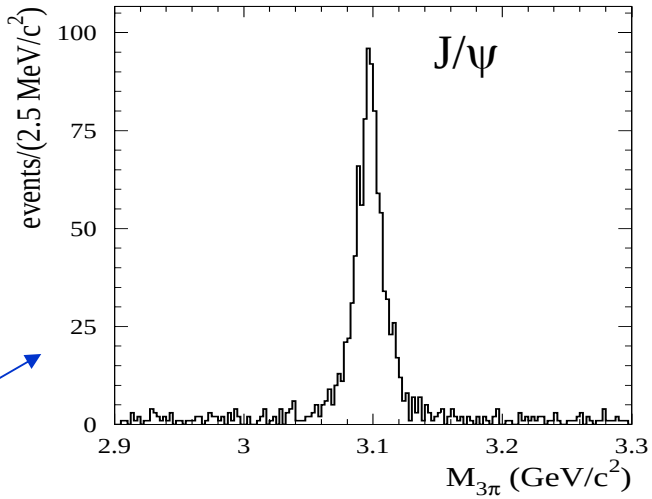
Spectroscopy at a super B-factory

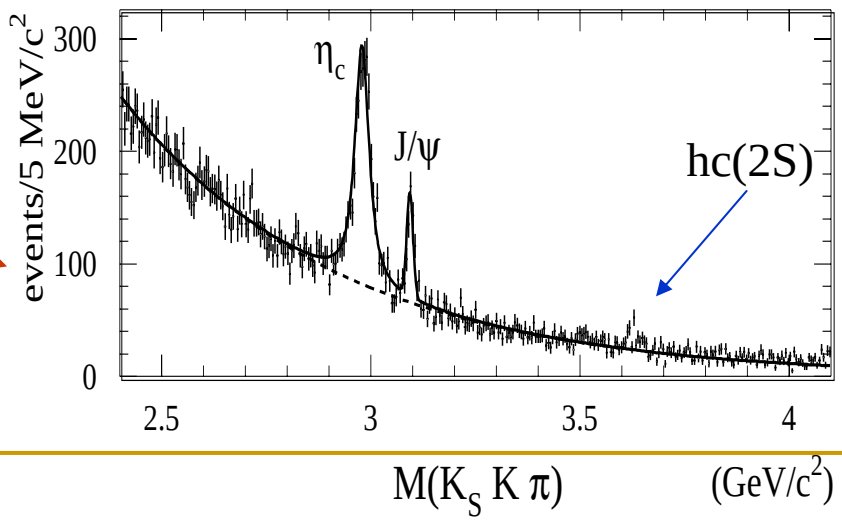
Key point for spectroscopy is:

Exclusive or quasi-exclusive reactions

- At a super B-factory, new charm and charmonium states can be discovered in:
- B decays,
- $e^+ e^-$ -> $(c\bar{c})$ $(c\bar{c})$
- $J^{PC}=1^{--}$ states can be studied using ISR $e^+e^- \rightarrow \gamma\, c\bar{c}$
- $J^{C}=even^{+}$ states can be studied in $\gamma\gamma$ collisions

A Super B factory is also a τ charm factory





Proposals for Super B-factories: SLAC Super B-factory

- Defining physics case for Super B Factory
  - Primarily New Physics sensitivity in *CP* violation & rare decays
  - Capability for precision SM measurements as benchmark for New Physics

SLAC Workshop, May 8-10, 2003

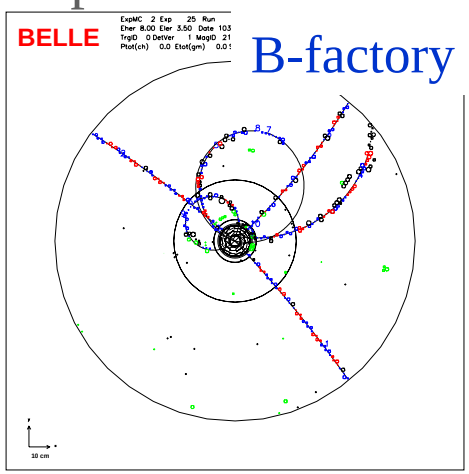
BABAR Roadmap Study: Jan – July 04

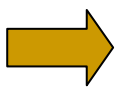
- Output:

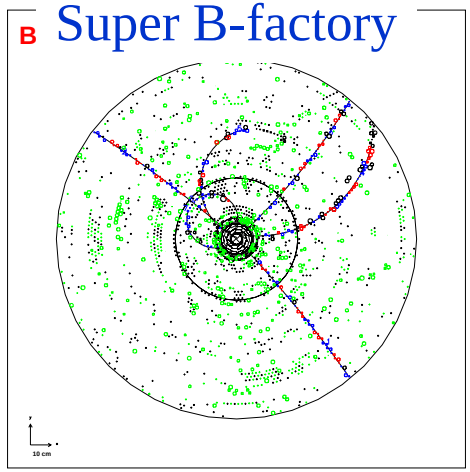
The Discovery Potential of a Super B Factory
(SLAC-R-709, December, 2004)

Detector Upgrades

- Replace inner layers of present SVT with segmented strips, should be viable to about 5 x 10^{35}
- Develop thin pixels and replace inner SVT at an appropriate time to go higher in luminosity
- Not at all clear that DRC will work at these luminosities, upgrades needed.
- Replace EMC with either radiation hard crystals or liquid xenon
- Replace IFR forward endcap

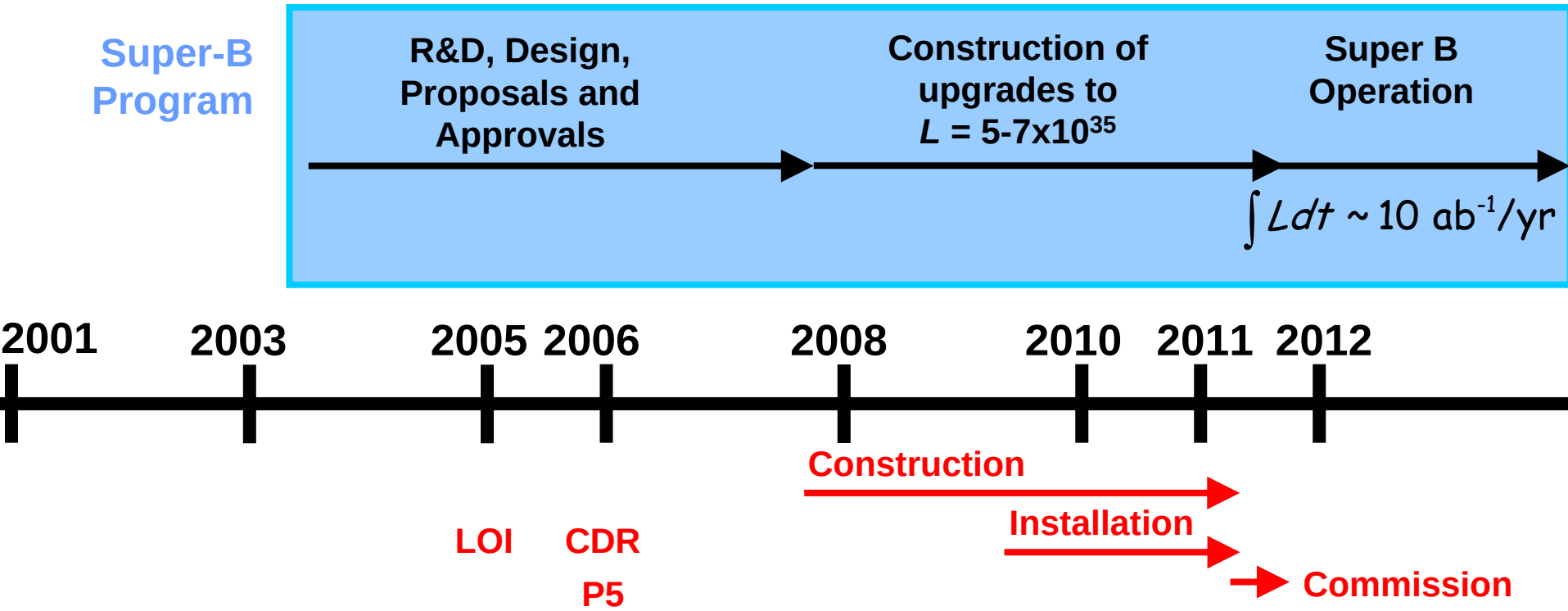






- **Replace DCH with all silicon tracker**

Possible Timeline for Super B Program



Planned PEP-II Program

$\int Ldt = 140$ fb^{-1} (June 30, 2003)

$\int Ldt = 500$ fb^{-1} (End 2006)

$\int Ldt \sim 1-2$ ab^{-1} (PEP-II ultimate)

Changes in US High Energy Physics Plans.

Budgetary backdrop in US.

• US domestic discretionary budget is under enormous pressure for the next few years.

Priorities for US program.

• Focus is on accelerator and non-accelerator based neutrino, dark matter, & dark energy experiments.

• After an initial interest, Ideas for Super PEP-II/BABAR do not fit in SLAC plans at present.

• Reflects changes underway to SLAC's scientific mission, which is broadening in a big way into light science: sad for a Nobel factory.

•Still some possibility?

• The US National Academy of Sciences (Board on Physics and Astronomy) study on Elementary Particle Physics in the 21st Century is underway, with a report expected in late 2005 or early 2006.

• Charge: "Identify, articulate, and prioritize the scientific questions and opportunities that define elementary-particle physics.

• Recommend a 15-year implementation plan with realistic, ordered priorities to realize these opportunities"

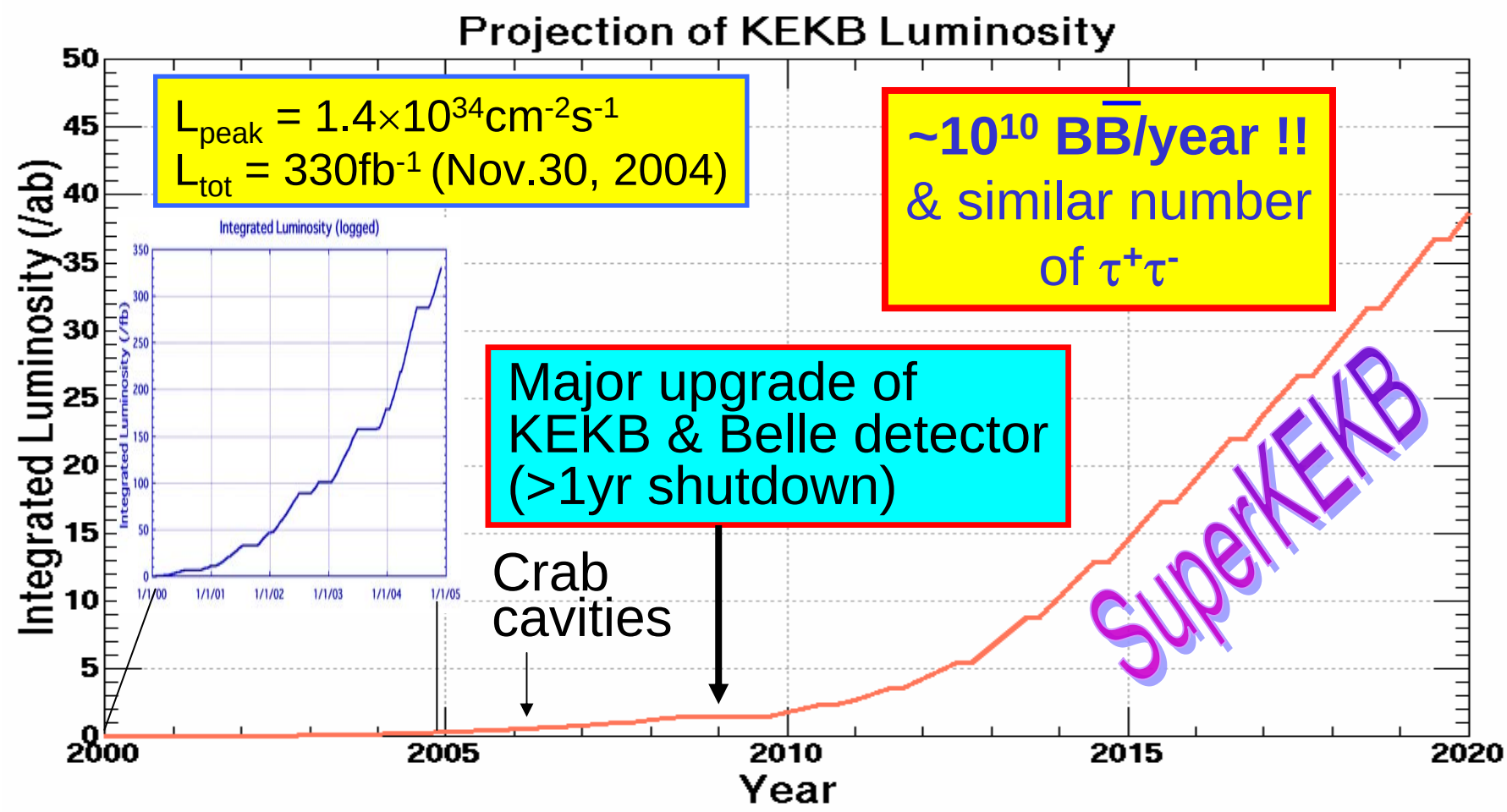
KEK Super B-Facory

- 6 workshops to discuss physics, detector and accelerator issues.
  - 2001, Aug: 1st workshop at KEK
  - 2002, Jan (KEK)
  - 2002, Aug (Shonan)
  - 2003, Feb (KEK)
  - 2003, Sep (Shuzenji)
  - 2004, Nov (KEK)

- Letter of Intent for KEK Super B Factory (KEK Report 2004-4)

- Belle/BaBar joint workshops:
  - February 14-16, 2002, TRIUMF
  - 2004, Jan (Hawaii)
  - 2005, April (Hawaii)

KEKB Upgrade Scenario



L_{peak} (cm^{-2}s^{-1})	1.4x10^{34}	5x10^{34}	5x10^{35}
L_{int}	330 fb^{-1}	~1 ab^{-1}	~10 ab^{-1}

Future.

- Members of PEP-II & BABAR communities are starting to discuss future options.
- Super KEKB is a possibility for a core part of PEP-II/BABAR, depending on the strength of the physics case & competitiveness with other physics opportunities.
- New participants could lead to expansion of scope for the Super B project and/or a more aggressive timescale

or

A Super B Factory in Europe?