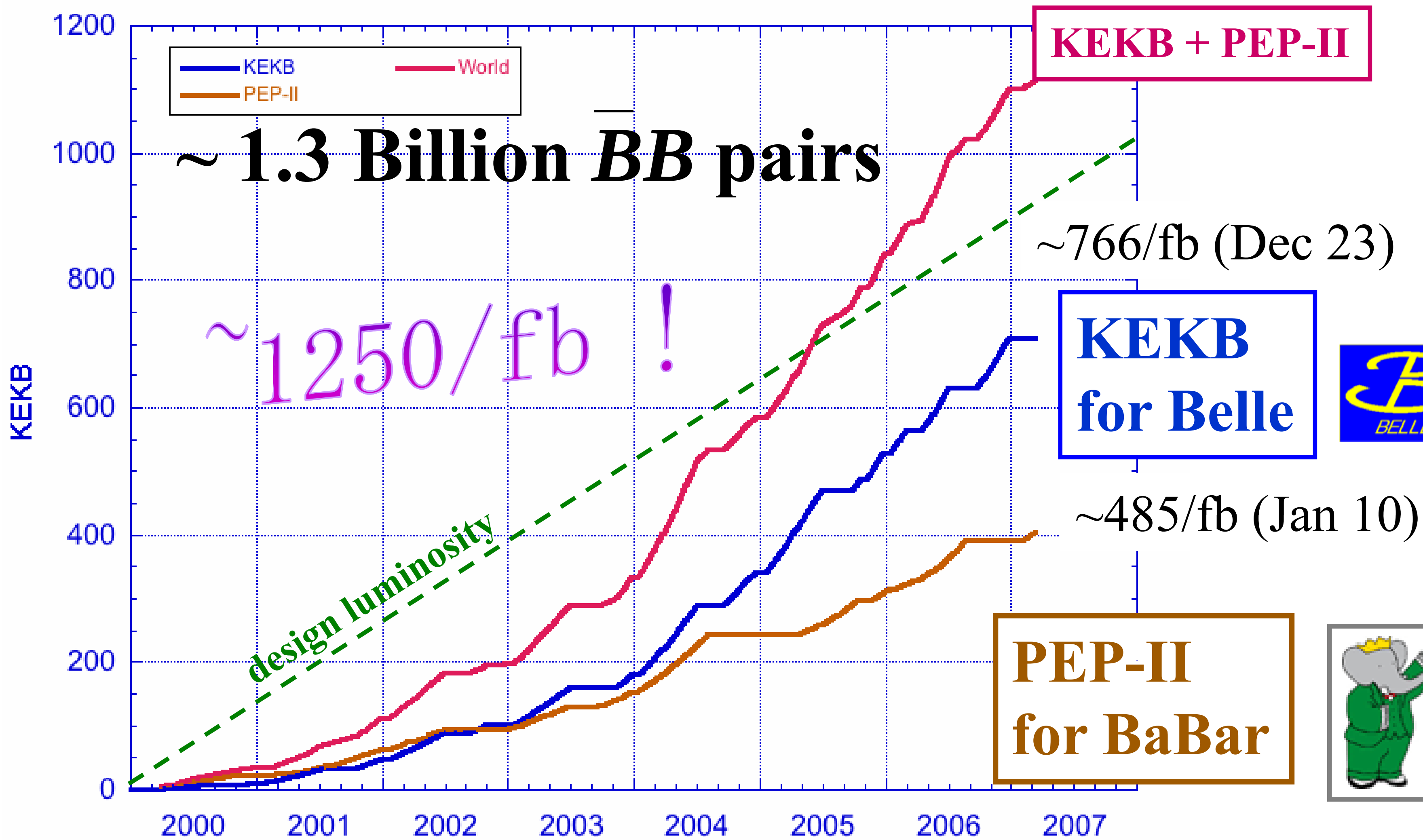
New Particles, New Physics, Super B

Tom Browder (University of Hawaii)

- *New Particles* (strong interaction)
- *New Physics* in the weak interaction (with some recent examples from BaBar and Belle)
- ***The Super B Factory upgrade at KEK***
  (including the latest news on crab cavities, schedule etc…)

Apologies: Will cover only a small subset of relevant B-factory results, many highlights but no details.

Integrated luminosity at B factories



May be time to switch units to ab^{-1}

One Example of the Surprises at the current B Factories

- Many narrow *unanticipated new particles*
- Although the *strong interaction* is "well-understood", these particles were not predicted in the Physics Reports, Yellow Books, review committees and workshops that preceded the B factory…..

[Could there be surprises in the weak interactions of quarks ?]

[Lesson for the LHC ?]

Particle Physics Textbooks

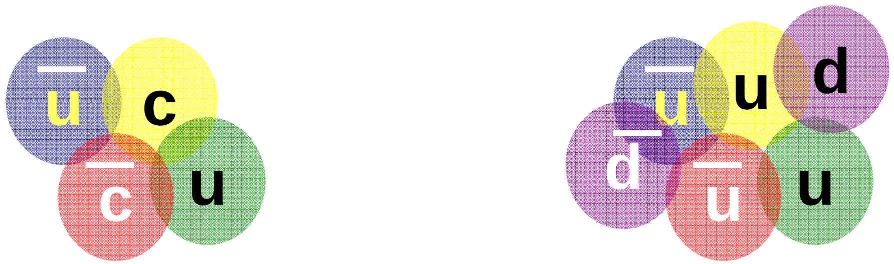
Textbook of Perkins, Introduction to High Energy Physics p.118

"The states observed in nature consist of three-quark combinations (the baryons) and quark-antiquark combinations (the mesons)."

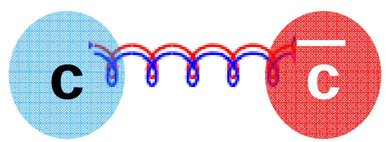
Yes, but other possibilities such as 4-quark or quark-antiquark-glue combinations are not forbidden by any conservation law.

One approach to going beyond the textbook: look for non-$q\bar{q}$ mesons

4 (& perhaps 6) quark states

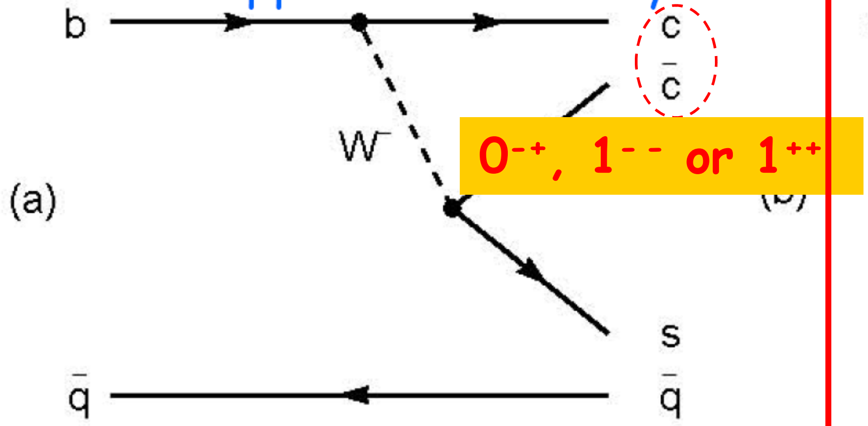


“hybrid” $q\bar{q}$-gluon states

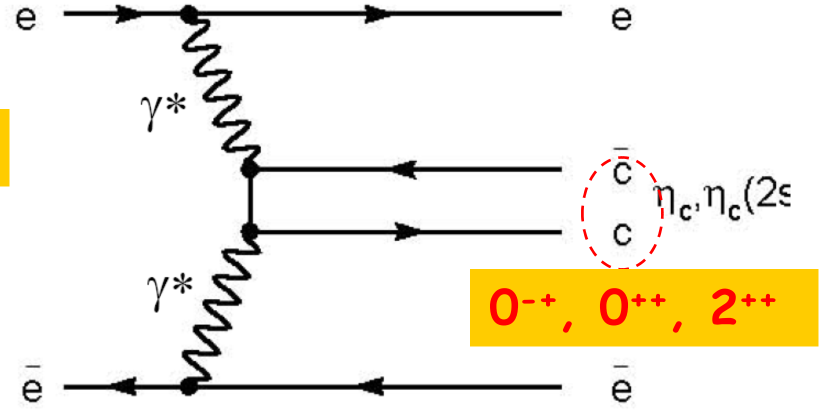


B-factories produce lots of $c\bar{c}$ pairs

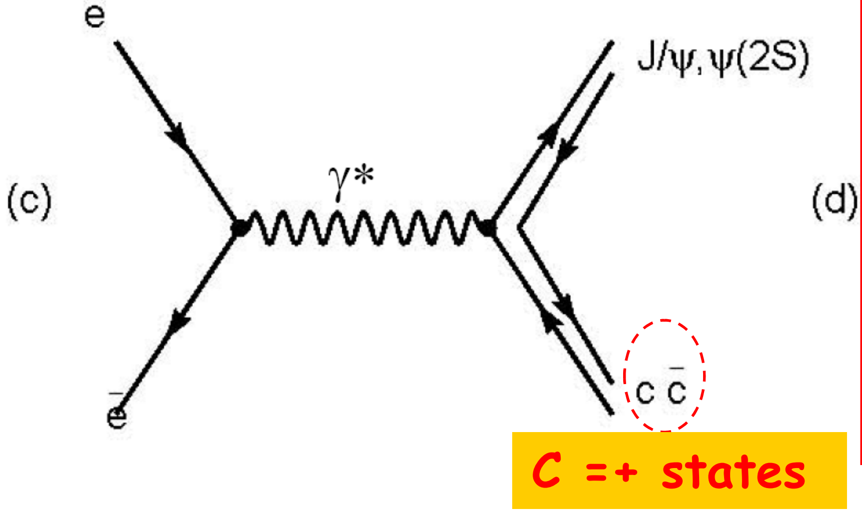
Color-suppressed B decays



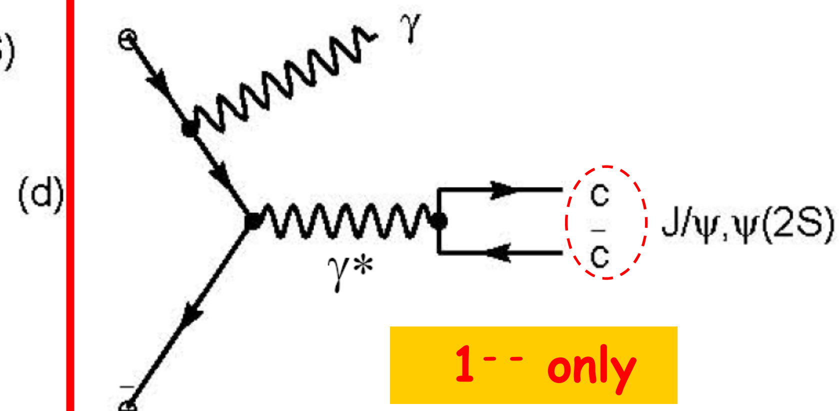
Two photon Production



Double Charmonium Production



Initial State Radiation



Selected News on the "X,Y,Z" particles

Status summer 2007:

- **X(3872)**
  - $\pi^+\pi^-$ J/ψ in B→K$\pi^+\pi^-$J/ψ
- **Z(3930)**
  - $D\bar{D}$ in γγ → $D\bar{D}$
- **Y(3940)**
  - ωJ/ψ in B→K ωJ/ψ
- **X(3940)**
  - e^+e^- →J/ψ X & e^+e^- → J/ψ $D\bar{D}^*$
- **Y(4260)**
  - $\pi^+\pi^-$J/ψ in e^+e^- →γ $\pi^+\pi^-$ J/ψ
- **Y(4325)**
  - $\pi^+\pi^-\psi'$ in e^+e^-→γ $\pi^+\pi^-\psi'$

New Belle/BaBar results:

X(3880)→$D\bar{D}$
- e^+e^- → J/ψ $D\bar{D}$

confirmed by BaBar (Y(3940))

updated by Belle (X(3940))

Y(4008)? (from Y(4260))

X(4160)→$D^*\bar{D}^*$
- e^+e^- → J/ψ $D^*\bar{D}^*$

Y(4250) (from Y(4260))

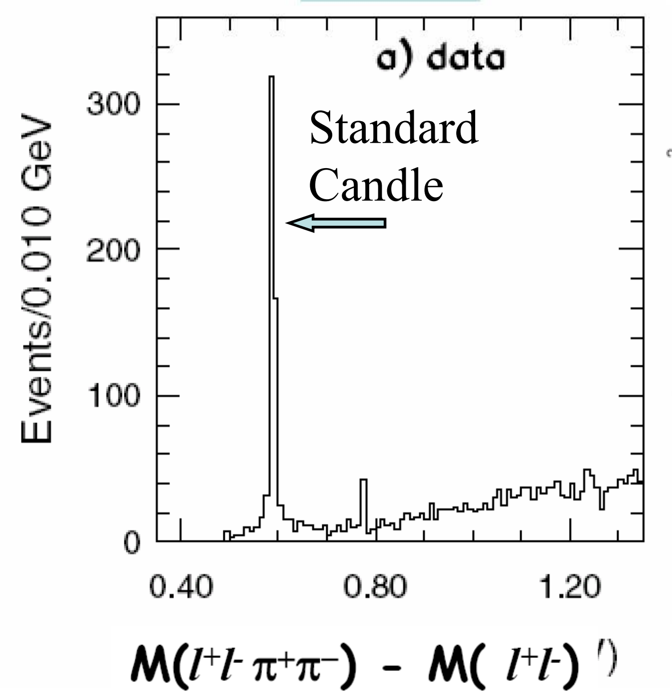
Y(4370) (from Y(4325))

Y(4660) (from Y(4325))

Z^+(4430)→$\pi^+\psi$
- B→K$\pi^+\psi'$

X(3872), the first one

BELLE

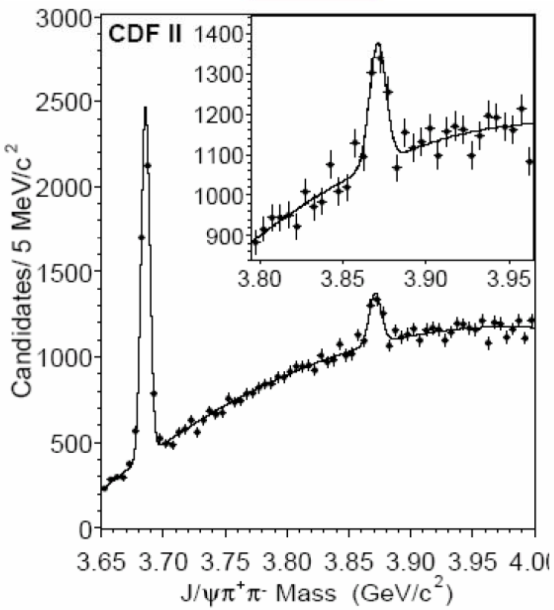


based on $152M\ B\overline{B}$ evts.

PRL 91,262001,2003

S-K Choi, S.L Olsen et al,

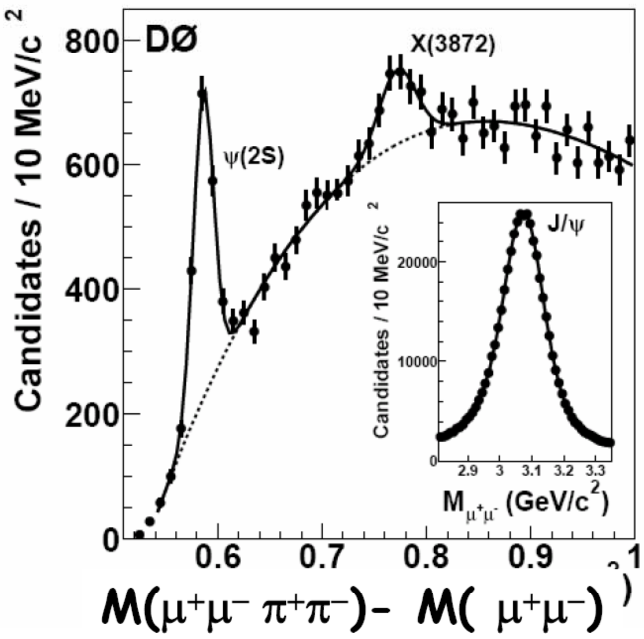
CDF



M(J/ψ $\pi^+\pi^-$)

PRL 93,072001,2004

D0



PRL 93,162002,2004

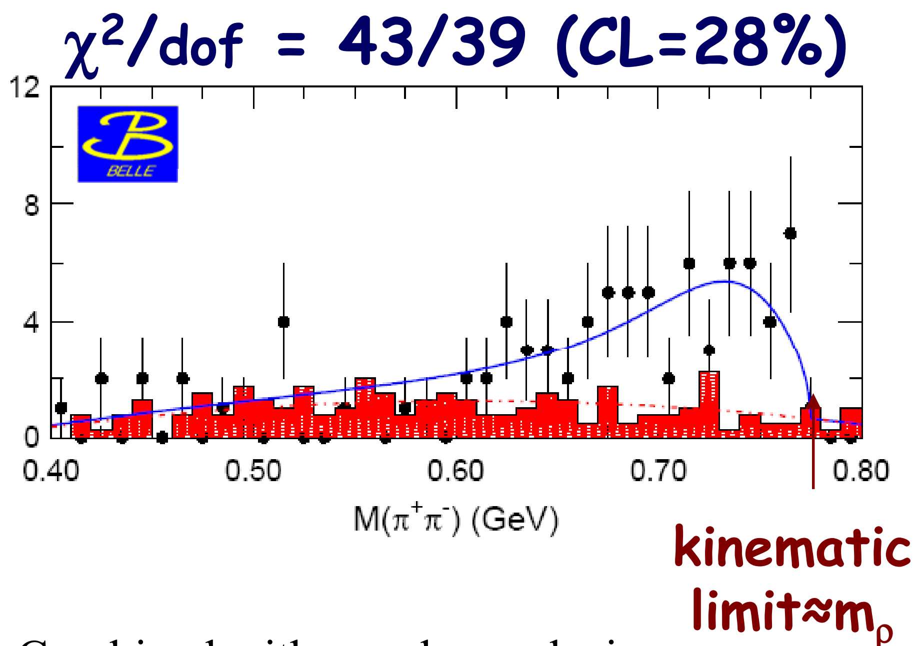
and by BaBar in PRD 71,071103,2004

WA Mass: 3871.4±0.6 MeV
(Clue to its nature)

$M_{D0} + M_{D^{*}0} = 3.871.8 \pm 0.4$

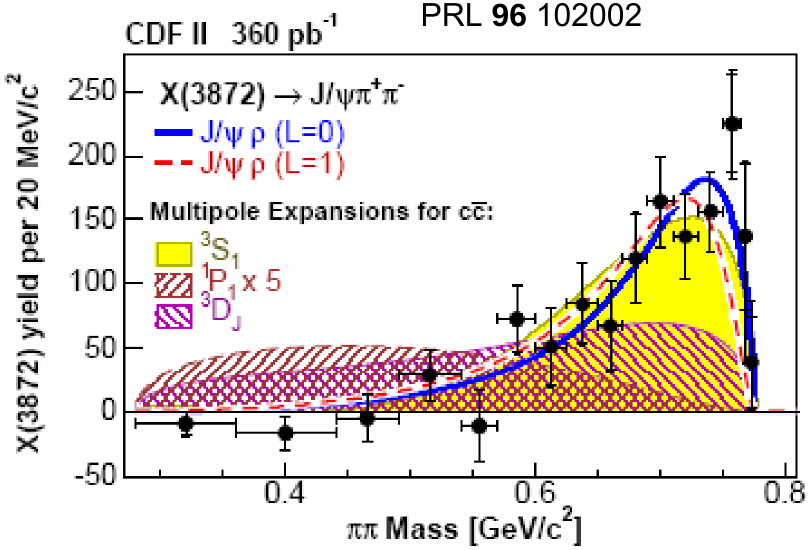
M(ππ) looks like ρ→ππ

Belle



CDF

PRL **96** 102002



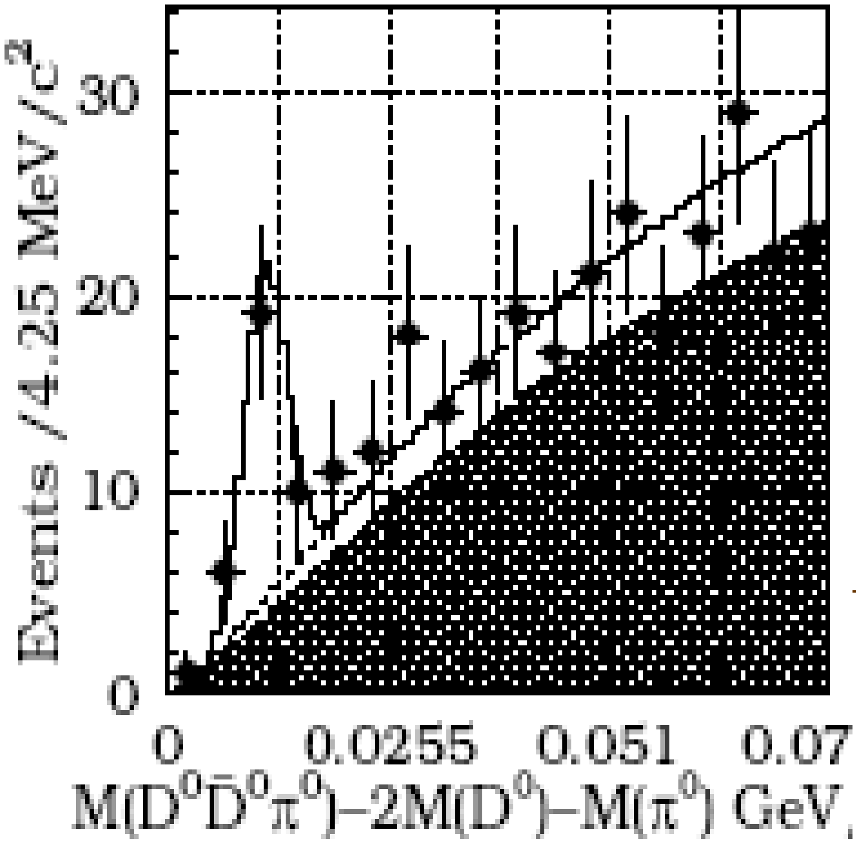
Combined with angular analysis,

- **Belle & CDF: $J^{PC} = 1^{++}$ ← most likely**

J=2 also allowed

What's new with the X(3872)?

BaBar confirms Belle's DDπ threshold enhancement



BaBar, submitted to PRD-RC based on 347fb^{-1}

Both groups see a high mass value

Belle Mass	BF(B^+ & B^0)
$3875.2 \pm 0.7^{+0.3}_{-1.6} \pm 0.8$	$\left(1.22 \pm 0.31^{+.23}_{-.30}\right)\times 10^{-4}$
BaBar Mass	**BF(B^+)**
$3875.1 \pm 1.1 \pm 0.5$	$(1.67 \pm 0.36 \pm 0.58)\times 10^{-4}$

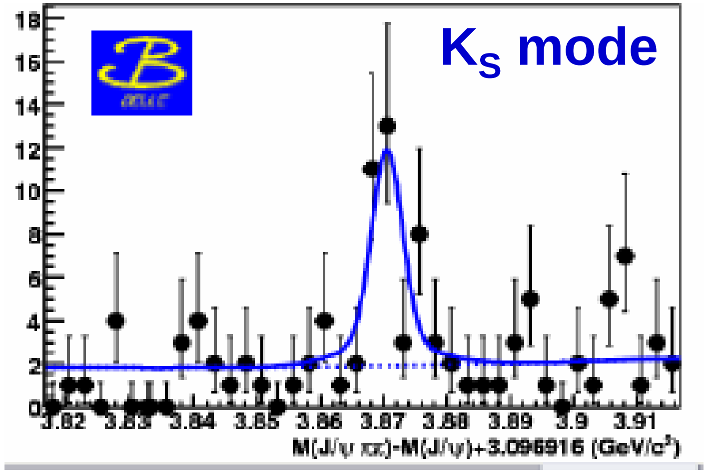
BaBar bug: Error +0.7_-0.5

Mass is 3.8±1.2 MeV above WAvg X(3872)→ππJ/ψ mass; (~3σ) is this significant?

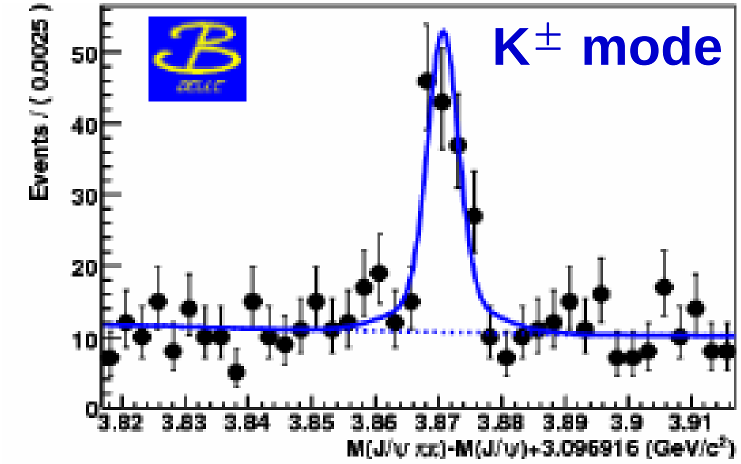
Belle's $B^0 \rightarrow K_S X$ & $B^{\pm} \rightarrow K^{\pm} X$ comparison

Consistent with an earlier BaBar result but much higher statistics

Clear signal in the neutral mode



29.6±6.7 events



125.2±14.5 events

$$\frac{B\left(B^0 \rightarrow K^0 X(3872)\right)}{B\left(B^+ \rightarrow K^+ X(3872)\right)} = 0.94 \pm 0.24(stat) \pm 0.10(syst)$$

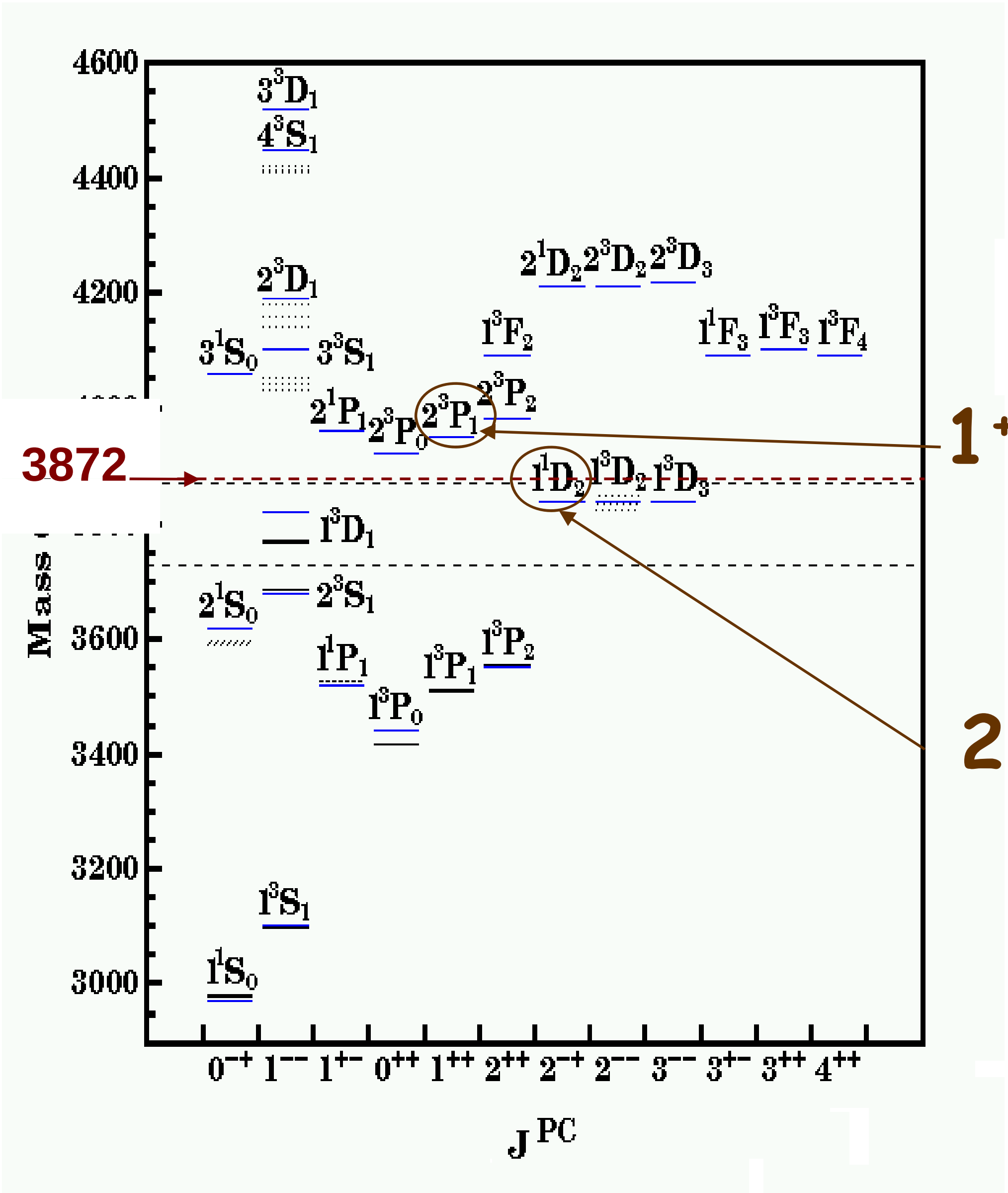
A "molecular" model predicted this to be <<1
(Braaten et al PRD 71 074005)

$\Delta M = 0.22 \pm 0.90 \pm 0.27$ MeV

Early "diquark-antidiquark" models predicted this to be 8 ± 3 MeV
(Maiani et al PRD 71 014028)

Belle-CONF-0711
Aug 2007
based on 605 fb^{-1}

Is there a $c\bar{c}$ slot for the X(3872)?



1^{++} (χ_{c1}')

- $Br(\gamma J/\psi)$ too small
- $Br(\rho J/\psi)$ too big

2^{-+}(η_{c2})

- $\eta_{c2} \to \rho J/\psi$ isospin forbidden
- $D^0\underline{D}^0\pi^0$ @ thresh.suppressed
- $B \to Kc\underline{c}(J=2)$ suppressed

What is the X(3872) ?

The mass, width and decay modes do not appear to correspond to those of any predicted charmonium state.

One possibility suggested by a number of authors is a loosely bound S-wave molecule of charm mesons. $1/\sqrt{2}(D^0\ D^{*0}bar + D^0bar\ D^{*0})$

F. Close, P.R. Page, Phys. Lett. B 578, 119 (2003)

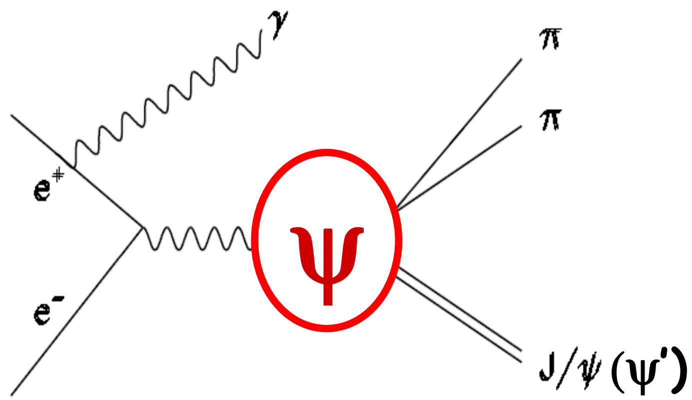
N.. A. Tornqvist, Phys Lett. B 590, 209(2004)

E. Braaten, M. Kusunoki, S. Nussinov, Phy. Rev. Lett. 93, 162001 (2004)

Another intriguing idea: X(3872)= c cbar u ubar state. In such a 4-quark picture there should be charged and neutral states

L. Maiani, F. Piccinini, A. D. Polosa, V. Riquer, Phys Rev. D71: 014028 (2005)

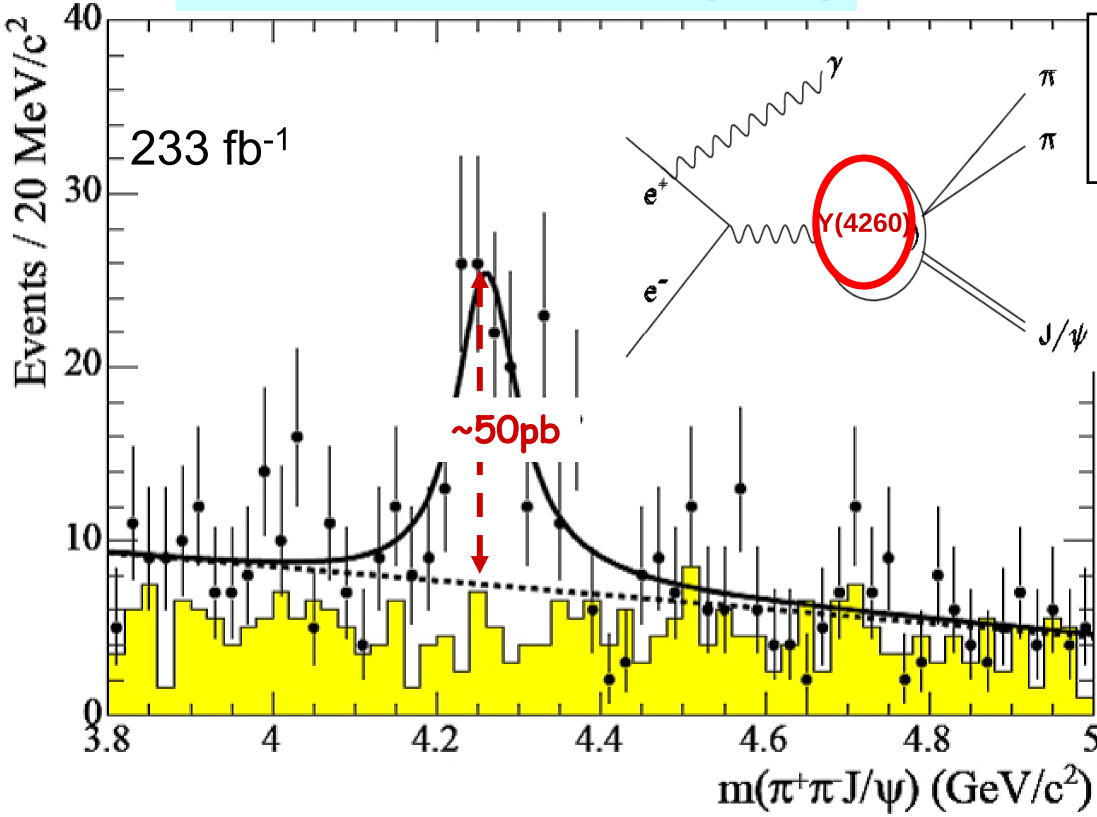
The 1^{--} states seen in ISR



(Until recently this was not a very fashionable reaction)

$e^+e^- \rightarrow \gamma_{ISR}$ Y(4260) at BaBar

BaBar PRL95, 142001 (2005)



fitted values:

$M = 4259 \pm 8\ ^{+2}_{-6}$ MeV

$\Gamma = 88 \pm 23\ ^{+6}_{-9}$ MeV

"Y(4260)" at Belle (New)

$M = 4247 \pm 12\ ^{+17}_{-32}$ MeV

$\Gamma = 108 \pm 19 \pm 10$ MeV

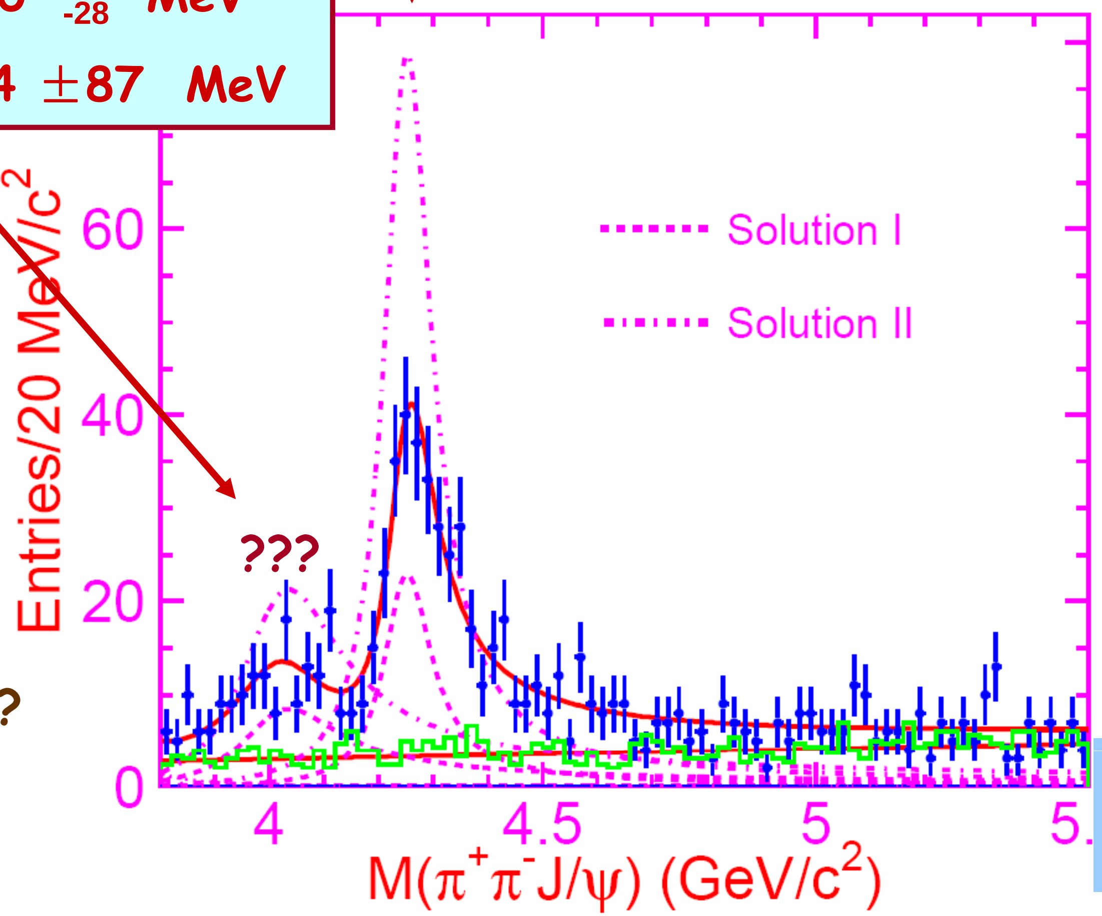
BaBar values:

$M = 4259 \pm 8\ ^{+2}_{-6}$ MeV

$\Gamma = 88 \pm 23\ ^{+6}_{-9}$ MeV

$M = 4008 \pm 40\ ^{+114}_{-28}$ MeV

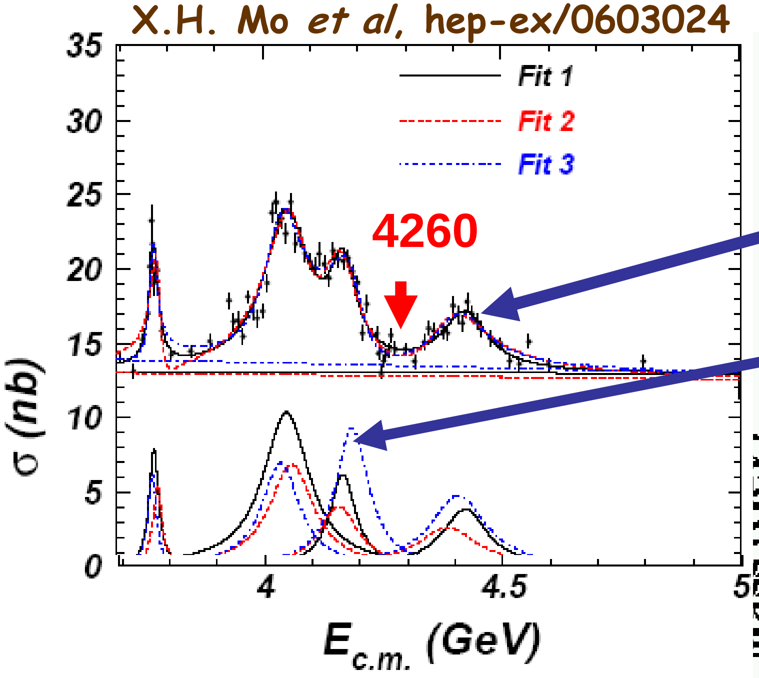
$\Gamma = 226 \pm 44 \pm 87$ MeV



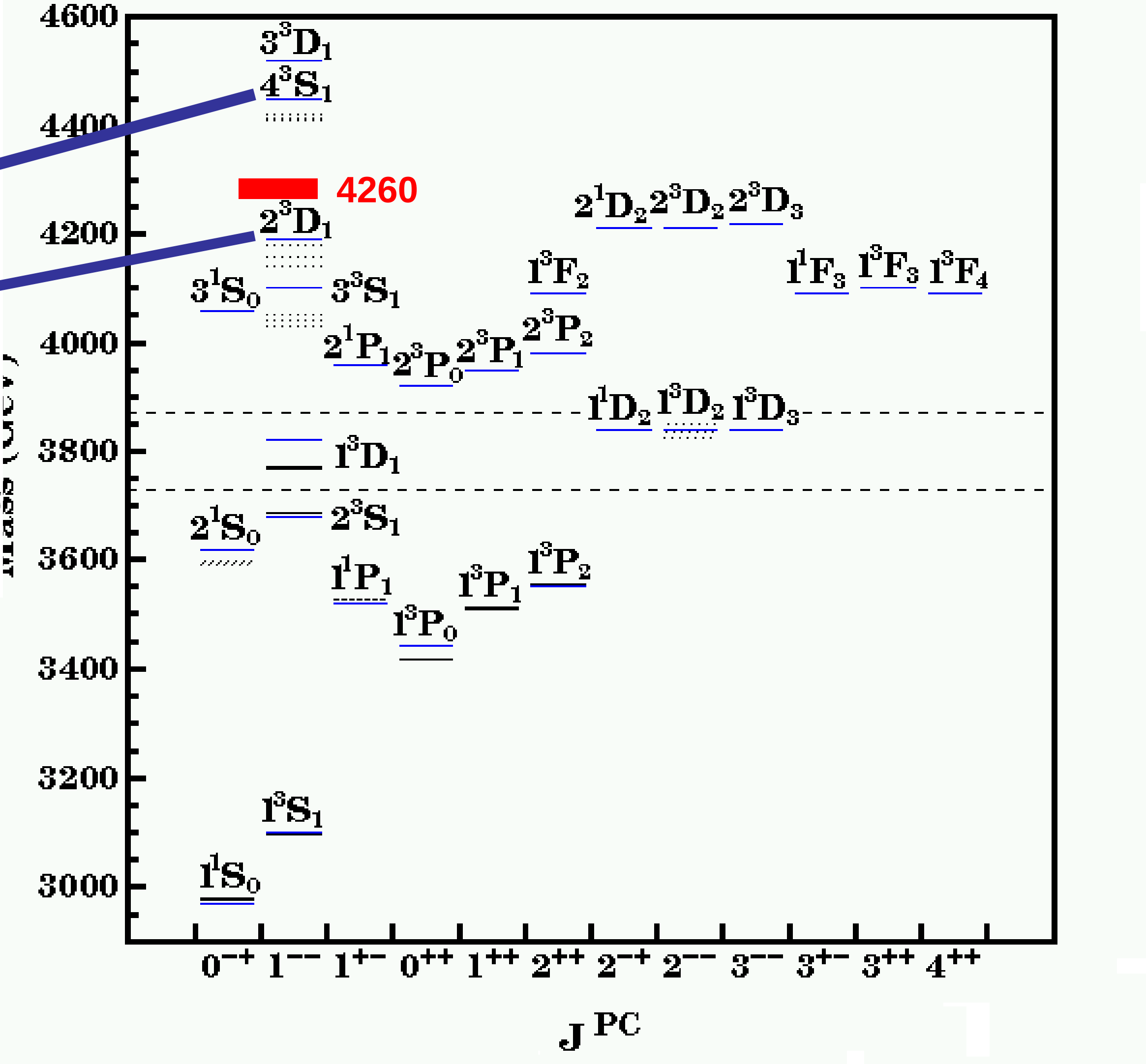
Resonance?
Thresh effect?
…?

C.Z Yuan et al (Belle)
arXiv:0707.2541
To appear in PRL

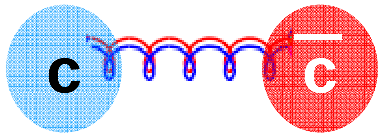
No 1^{--} $c\bar{c}$ slot for the Y(4260)



Hadronic cross section



Is the Y(4260) a $c\bar{c}$-gluon hybrid?

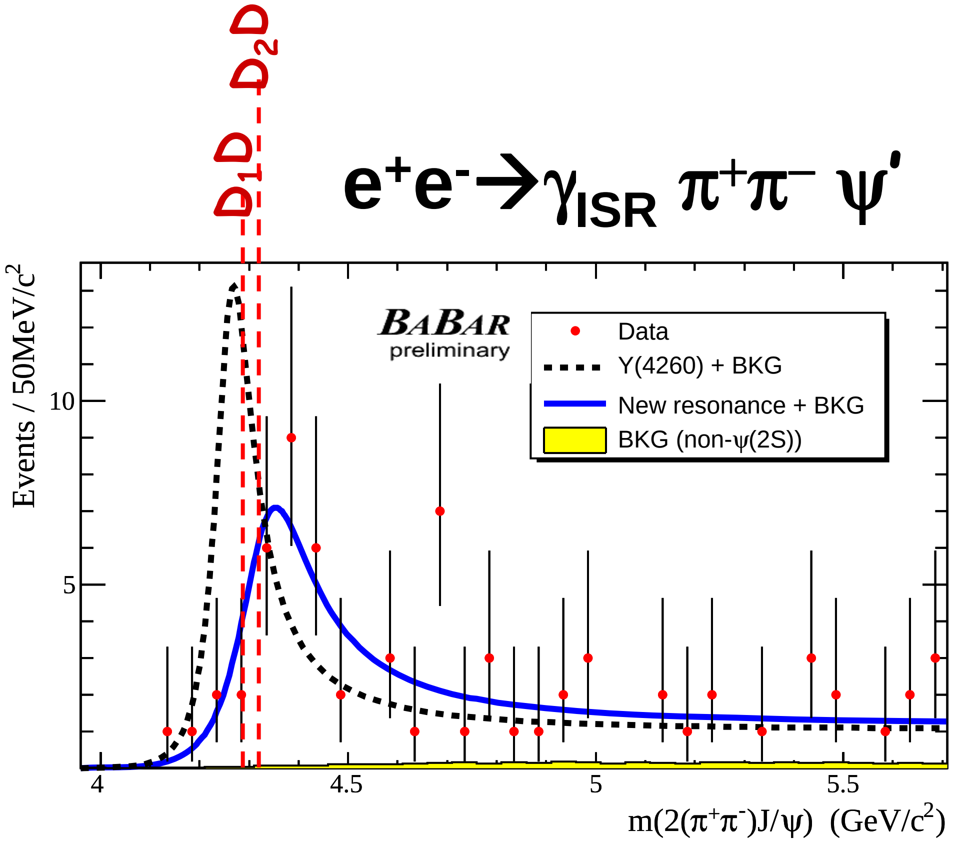


- $q\bar{q}$-gluon excitations predicted 30 yrs ago
  Horn & Mandula PRD 17, 898 (1977)
- lowest 1^{--} $c\bar{c}$-gluon mass expected at ~4.3 GeV
  Banner et al, PRD 56, 7039 (1997); Mei & Luo, IJMPA 18, 5713 (2003)
- relevant open charm threshold is D**D (~4.28 GeV)
  Isgur, Koloski & Paton PRL 54, 869 (1985)
- $\Gamma(\pi\pi J/\psi)$ larger than that for normal charmonium
  McNeile, Michael & Pennanen PRD 65, 094505 (2002)
- $\Gamma(e^+e^-)$ smaller than that for ordinary charmonium
  Close & Page NP B443, 233 (1995)

Y(4260) seems to match these expectations

BaBar's $\pi^+ \pi^- \psi'$ peak at 4325 MeV

$e^+e^- \rightarrow \gamma_{ISR}\, \pi^+\pi^-\, \psi'$



Not Compatible with the Y(4260)

BaBar PRL 98 252001 (2007)

298 fb^{-1} (BaBar) hep-ex/0610057

Nevt = 68 (<5.7 GeV/c^2)

Nbkg = 3.1 ±1.0

M=4324 ± 24 MeV

Γ = 172 ± 33 MeV

above all D**D thresholds

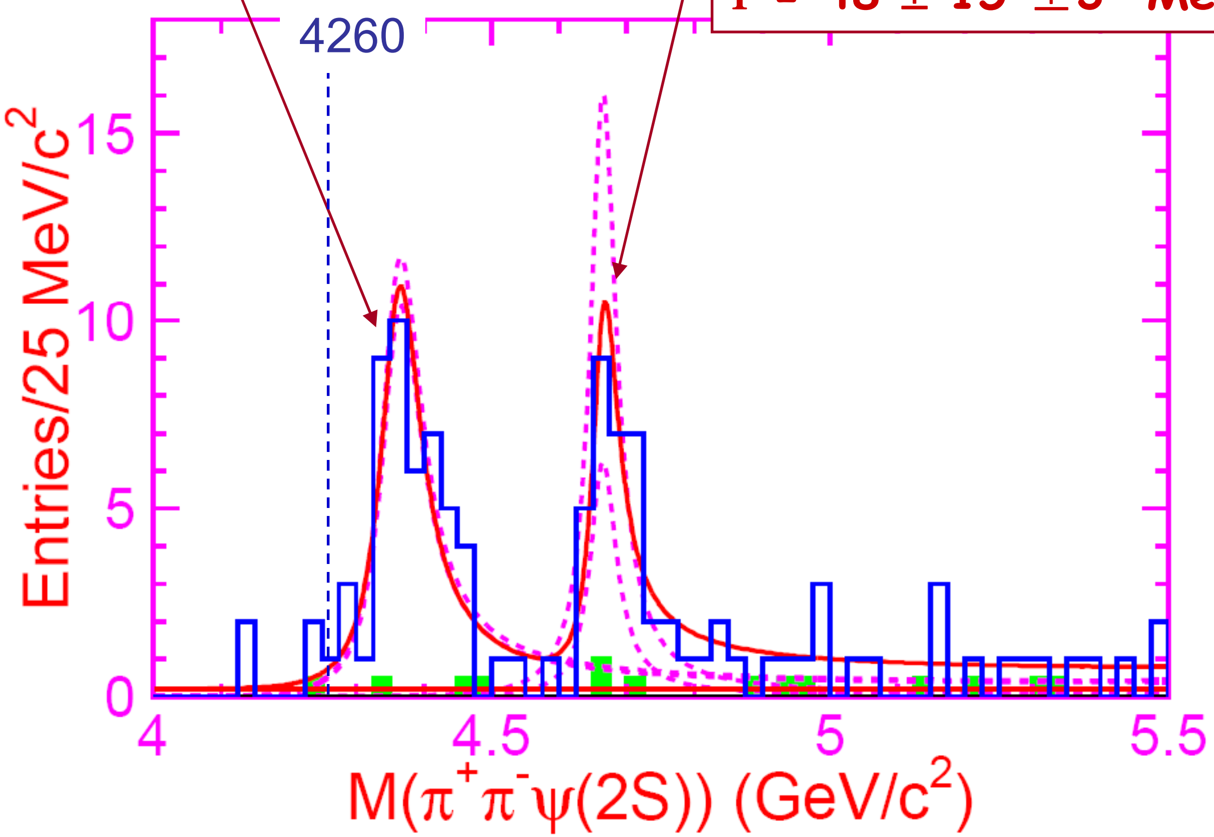
χ^2-prob	< 5.7 GeV/c^2
Y(4260)	**6.5 ×10^{-3}**
ψ(4415)	**1.2 ×10^{-13}**
Y(4320)	**29%**

4325 MeV $\pi^+\pi^-\psi'$ peak in Belle (new)

Two peaks! (both relatively narrow)
(& both above D**D thresh)
(& neither consistent with 4260)

M=4361 ± 9 ±9 MeV
Γ = 74 ± 15 ±10 MeV

M=4664 ± 11 ±5 MeV
Γ = 48 ± 15 ±3 MeV



BaBar values

M=4324 ± 24 MeV
Γ = 172 ± 33 MeV

X.L. Wang et al (Belle)
arXiv:0707.3699

From the major Japanese newspapers on Nov 10

朝　日　新　聞

33 社会 S 13版 2007年（平成19年）11月10日 土曜日

電荷持つ中間子発見
素粒子4個で構成

素粒子物理学では珍しい、4個の素粒子（クォーク）から成る電荷を持つ新しい中間子を発見したと、国際研究チームの高エネルギー加速器研究機構（KEK）が9日、発表した。

これまで見つかっていた中間子は基本的に、物質の最小単位とされるクォーク1個と反クォーク1個が強い力で結びつき、電荷がゼロだった。

KEKの加速器「Bファクトリー」で作った約6億6千万個のB中間子が崩壊する様子を詳しく調べたところ、知られていない中間子が約120個見つかった。「Z(4430)」と名付けられた新中間子は、クォーク2個と反クォーク2個の計4個から成り、しかも電荷を持っている。

日　本　経　済　新　聞

2007年（平成19年）11月10日（土曜日） ★13版 社会 42

「クォーク」4個の新粒子

高エネ研発見

高エネルギー加速器研究機構（茨城県つくば市）は九日、物質を構成する素粒子「クォーク」が四個結びついてできた新タイプの粒子を発見したと発表した。中性子や陽子など普通の粒子はクォークが二個か三個でできている。クォークの性質を知る新たな手がかりとなる研究成果で、宇宙誕生の謎解明などにつながりそうだ。

新粒子の質量は陽子の約四・七倍で、中間子とは性質が異なり、電荷を持っているのが特徴。つくば市にある大型実験装置「Bファクトリー」で、電子と陽電子を光速近くまで加速して衝突させる実験を繰り返した。約六億六千万回分のデータから新粒子ができたと考えられる事例約百二十件を見つけた。

実験を進めている高エネ研の山内正則教授は「今後も（クォーク四個からなる）同様の新粒子が見つかるのではないか。素粒子物理学の新たなページになる」と話している。

日　刊　工　業　新　聞

13☆ 2007年（平成19年）11月10日 土曜日

電荷持つ新粒子発見

クォークの謎解明に道

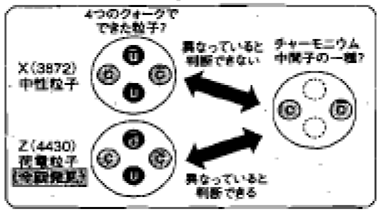
高エネ機構など国際共同チーム

大型加速器Bファクトリーを用いて実験を進める高エネルギー加速器研究機構などの国際共同チームは9日、電荷を持つ新粒子を発見したと発表した。物質を形づくる基本粒子クォークが4個結びついた複合粒子である可能性があり、クォークがなぜ単独で存在できないかという謎を解く手がかりが得られると期待される。

同チームはBファクトリーでB中間子と反B中間子のペアを大量につくり、その崩壊過程を詳しく調べている。06年12月までにつくった約6億6000万ペアの中から今回、B中間子がK中間子と新粒子に壊れ、新粒子がさらに2種類の中間子に崩壊する例を約120個見つけた。解析の結果、質量が44億3000万電子ボルトと陽子の約4・7倍あり、電荷を持つことがわかった。「Z（4430）」と名づけた。

クォークは単独で存在できず、複数個が結びついて陽子や中間子などの中に閉じ込められる。クォーク同士を結びつける力については量子色力学（QCD）という基礎理論で説明されている。今回の発見により、なぜこのような現象が起こるのか、理解が進む可能性があるという。

同チームがこれまで発見した「X（3872）」「Y（4260）」などの新粒子は電荷がゼロの中性粒子で、質量は陽子の約4～4・5倍だった。

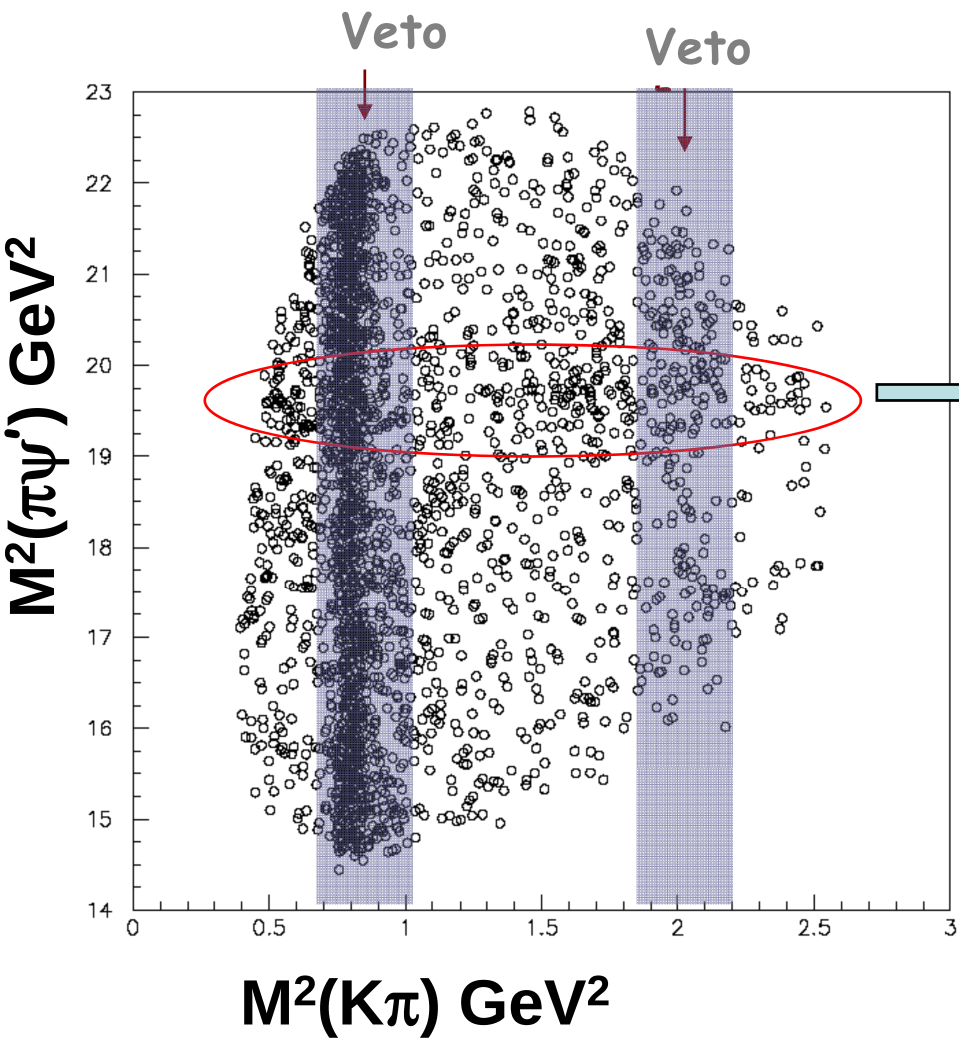


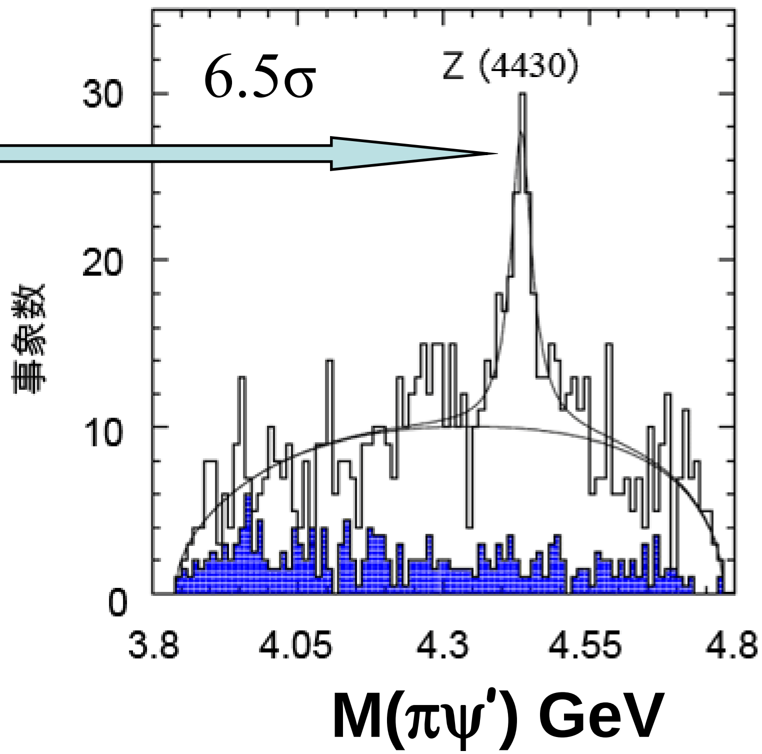
$M(\pi^{\pm}\psi')$ from $B \rightarrow K\, \pi^{\pm}\, \psi'$

$M = 4433 \pm 4 \pm 1$ MeV

$\Gamma_{tot} = 45\, ^{+17}_{-13}\, ^{+30}_{-11}$ MeV

Nsig $= 124 \pm 31$ evts





K. Abe et al (Belle
arXiv:0708.1790, submitted to PRL

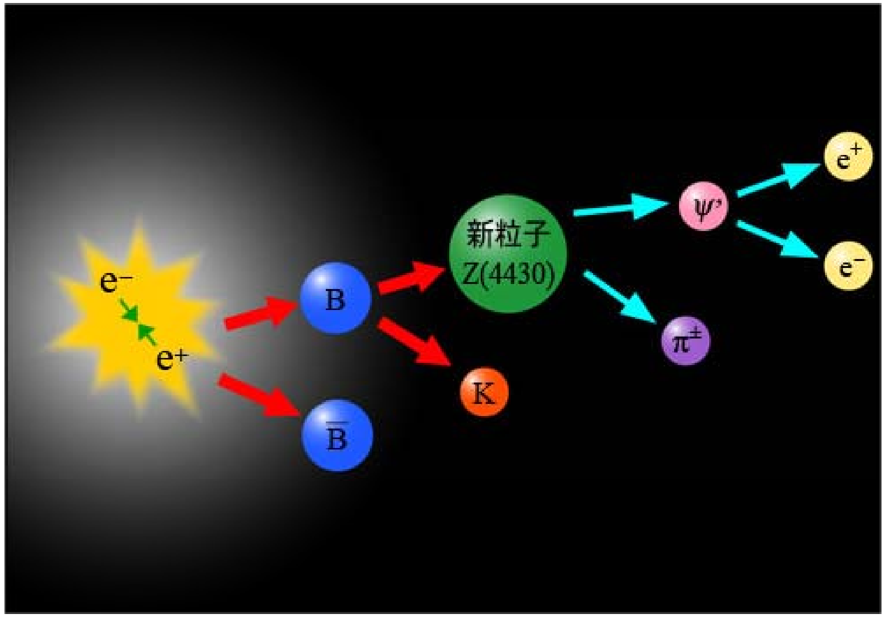
Comments on the $Z^+(4430)$

Not a reflection from the $K\pi$ system

No significant signal in $B \rightarrow K\pi J/\psi$

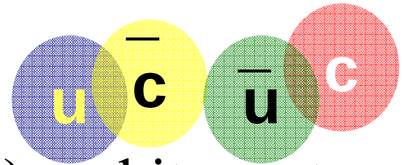
It has non-zero electric charge → not $c\bar{c}$ or hybrid

Mass, width & decay pattern similar to Y(4360) & Y(4660)

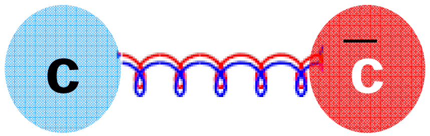


Tentative conclusions for the new states

There are two ***four-quark or molecular candidates***: the X(3872) and Z(4430). *The Z(4430) is charged and so cannot be conventional charmonium (c cbar bound state).*



The Y(4260) and its partner Y(4320), first seen by BaBar, are ***good hybrid candidates***. Belle found that there appear to be extra states nearby in each case.



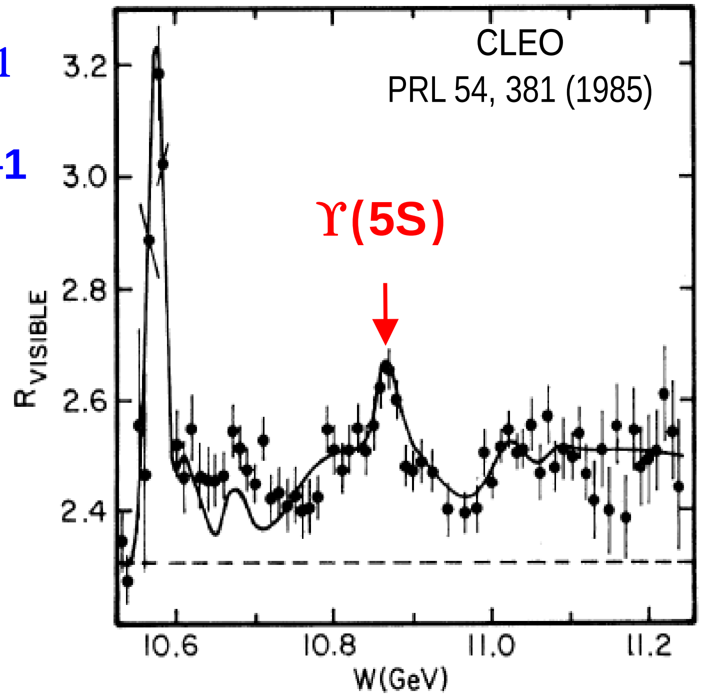
The effects of thresholds and mixing between states can easily complicate these simple interpretations

None of this was anticipated

Surprising Results from the ϒ(5S)

1985: CLEO,CUSB @ CESR ~ 116 pb^{-1}

2003: CLEO III @ CESR **~ 0.42 fb^{-1}**



Motivated by interest in studying B_s decays

2005: Belle @ KEKB **~ 1.86 fb^{-1}**
engineering run

2006, June 9-31: Belle @ KEKB
≅ 21.9 fb^{-1}

KEKB is flexible: Belle has ~ 23.8 fb^{-1} of ϒ(5S) data

Expectations for non-B Bar decays of Upsilon(5S)

(OZI Suppressed)

$\Upsilon(4S)$

$\Gamma \simeq$ 20.5 MeV

$\Gamma_{ee} \simeq$ 0.27 keV

$\Upsilon(5S)$

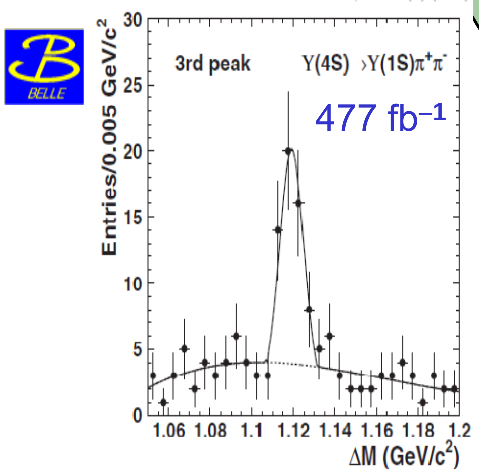
$\Gamma \simeq$ 110 MeV

$\Gamma_{ee} \simeq$ 0.13 keV

$$\Upsilon(4S) \to \Upsilon(1S)\pi^+\pi^- = (9.0 \pm 1.5) \times 10^{-5}$$

$$\Upsilon(4S) \to \Upsilon(2S)\pi^+\pi^- = (8.8 \pm 1.9) \times 10^{-5}$$

PHYSICAL REVIEW D 75, 071103(R) (2007)

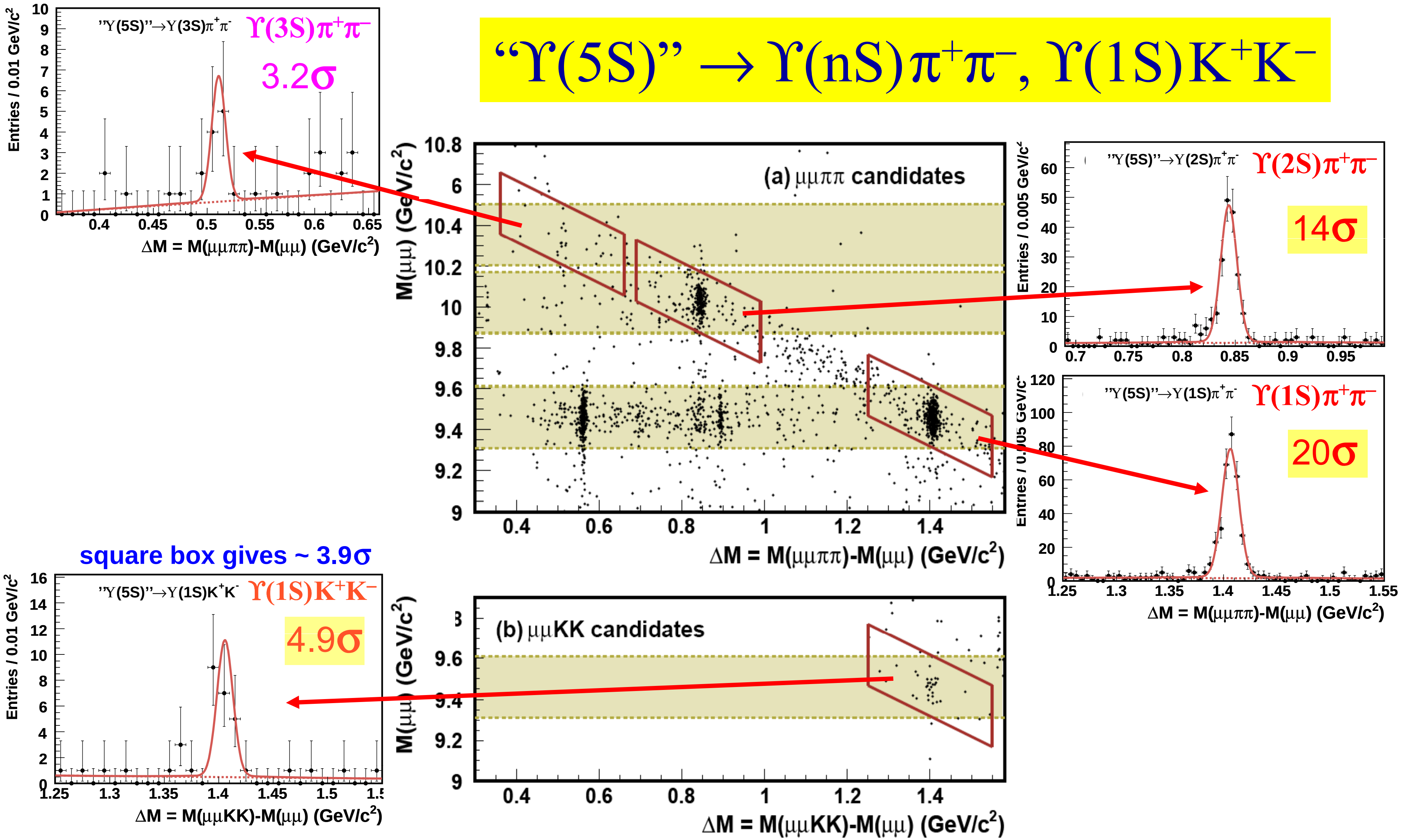


$$\frac{20.5}{110}$$

$\sim 1.7 \times 10^{-5}$

expect only limits ...

Surprise: There are huge signals



$\Upsilon(5S)$ *: Two orders of magnitude too large* !

Assume "ϒ(5S)" = ϒ(5S)

PDG value taken for ϒ(nS) properties

Process	N_s	Σ	Eff.(%)	σ(pb)	$\mathcal{B}$(%)	Γ(MeV)
$\Upsilon(1S)\pi^+\pi^-$	325^{+20}_{-19}	20σ	37.4	$1.60 \pm 0.10 \pm 0.12$	$0.53 \pm 0.03 \pm 0.05$	$0.58 \pm 0.04 \pm 0.09$
$\Upsilon(2S)\pi^+\pi^-$	186 ± 15	14σ	18.9	$2.33 \pm 0.19 \pm 0.31$	$0.77 \pm 0.06 \pm 0.11$	$0.85 \pm 0.07 \pm 0.16$
$\Upsilon(3S)\pi^+\pi^-$	$10.5^{+4.0}_{-3.3}$	3.2σ	1.5	$1.43^{+0.55}_{-0.45} \pm 0.19$	$0.47^{+0.18}_{-0.15} \pm 0.07$	$0.52^{+0.20}_{-0.16} \pm 0.10$
$\Upsilon(1S)K^+K^-$	$20.2^{+5.2}_{-4.5}$	4.9σ	20.3	$0.184^{+0.047}_{-0.041} \pm 0.028$	$0.061^{+0.016}_{-0.014} \pm 0.010$	$0.067^{+0.017}_{-0.015} \pm 0.013$

N.B. Resonance cross section 0.302 ± 0.015 nb at E_{CM} = 10.87 GeV

PRD **98,** 052001 (2007) [Belle]

$\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^+\pi^-$ ~ 6 keV
ϒ(3S) 0.9 keV
ϒ(4S) 1.8 keV
ϒ(5S) 580 keV

- *Is this really the ϒ(5S), or is there something else e.g. a Y_b state that overlaps with it? (like the Y(4260)).*

⟹ Need CM Scan to tell

Last week of December run for 10 days

BELLE-CONF-0774, hep-ex/0710.2577

New Physics

(in the Weak Interaction)

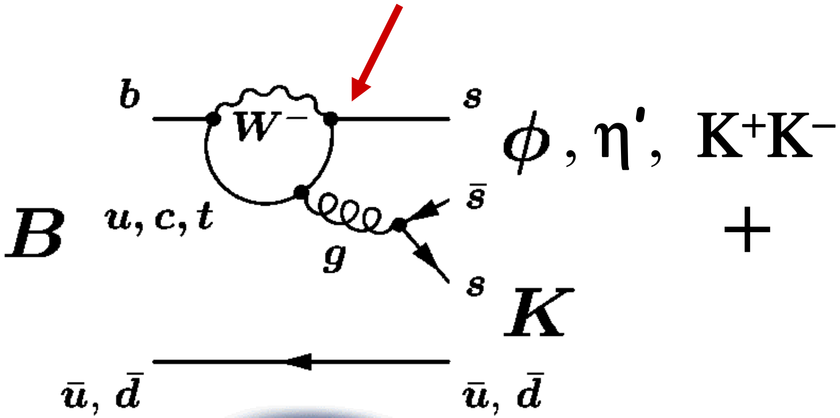
Are there new particles beyond those in the SM, which have different couplings (either in magnitude or in phase) ?

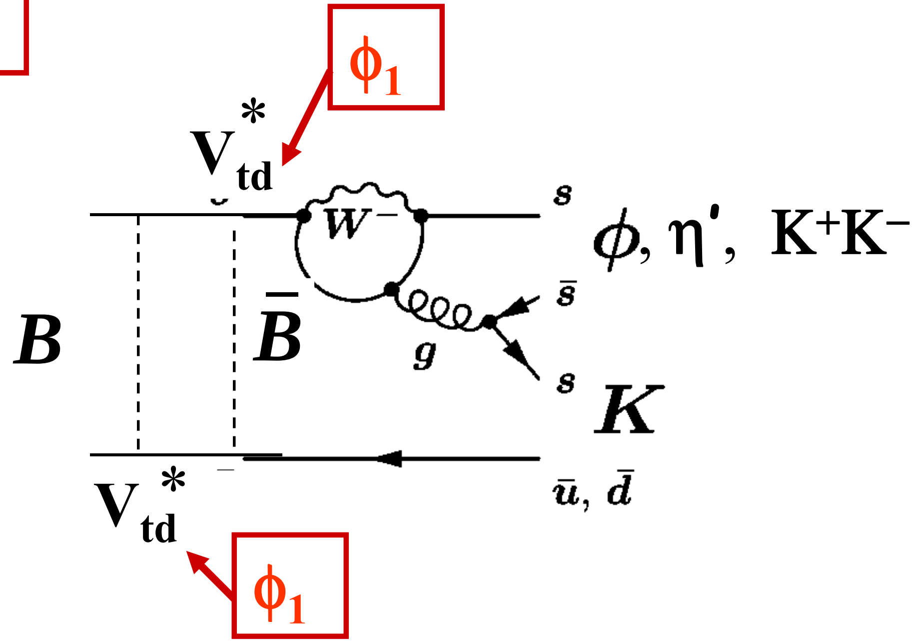
Supersymmety is an example (~40 new phases)

One method to find New Physics Phases

Example:

V_{ts}: no KM phase

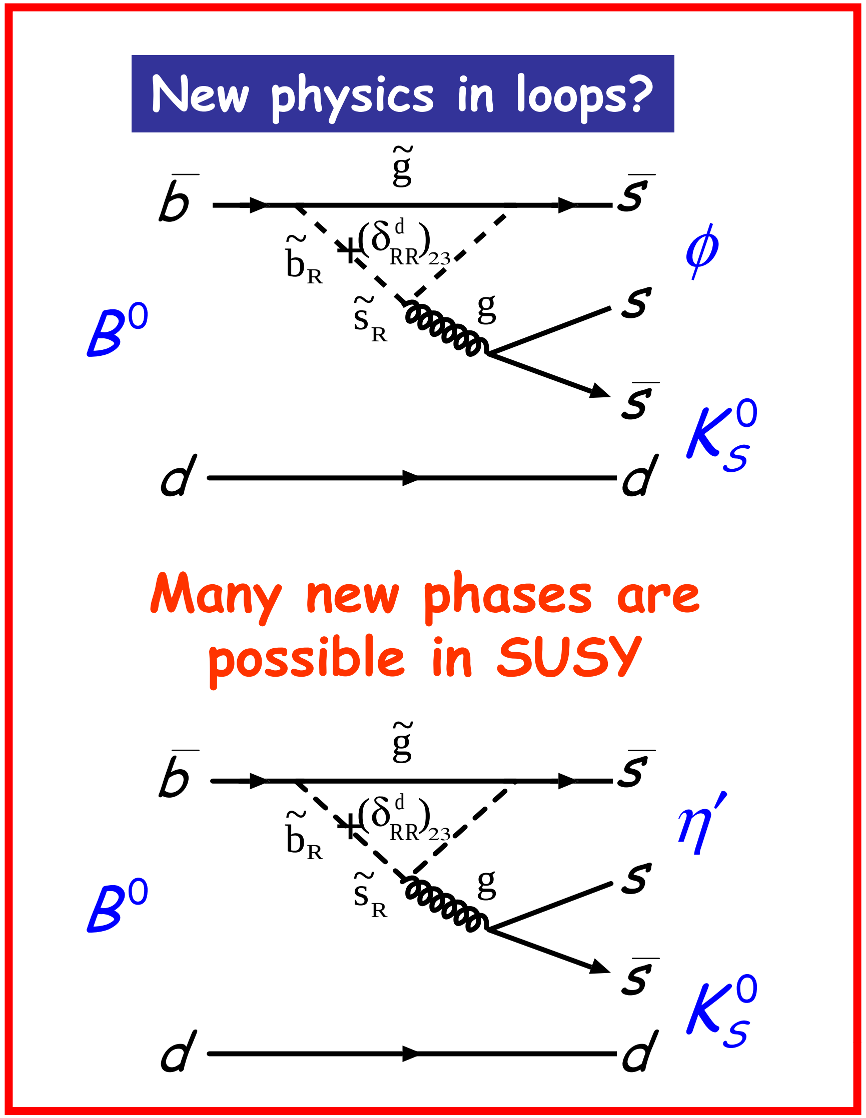




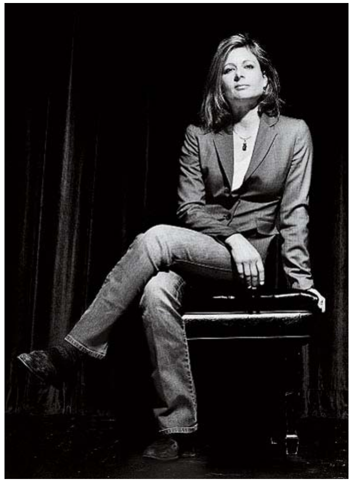
SM: $\sin 2\phi_1^{eff} = \sin 2\phi_1$ ***from*** $B \to J/\psi K^0$ ($b \to c\,\bar{c}\,s$)

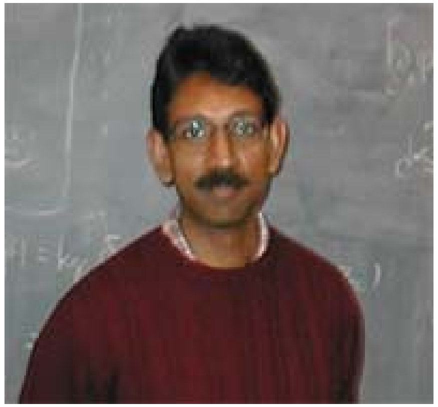
unless there are other, non-SM particles in the loop

How New Physics may enter in b→s



O(1) effect allowed even if SUSY scale is above 2TeV.





Extra dimensions (by Randall + Sundrum)

New Kaluza-Klein (K.K) particles are associated with the extra dimension.

("Tower of states")

Some may induce new phases and flavor-changing neutral currents.

Two Aspen talks: G. Perez, C.Csaki

e.g. K.Agashe, G. Perez, A. Soni, PRD 71, 016002 (2005)

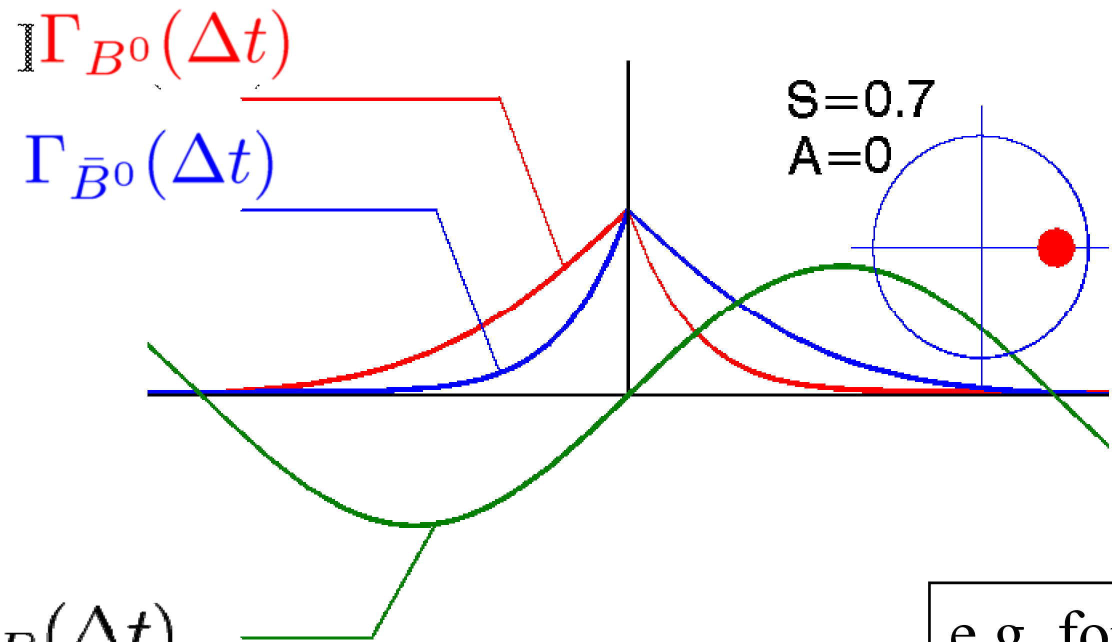
	$S_{B_s\to\psi\phi}$	$S_{B_d\to\phi K_s}$	$Br[b\to sl^+l^-]$	$S_{B_{d,s}\to K^*,\phi\gamma}$	$S_{B_{d,s}\to\rho,K^*\gamma}$
RS1	$O(1)$	$\sin 2\beta \pm O(.2)$	$Br^{\rm SM}[1+O(1)]$	$O(1)$	$O(1)$
SM	λ_c^2	$\sin 2\beta$	$Br^{\rm SM}$	$\frac{m_s}{m_b}\left(\sin 2\beta, \lambda_c^2\right)$	$\frac{m_d}{m_b}\left(\lambda_c^2, \sin 2\beta\right)$

++CPV in D decay

Model: K.K. Gluon near 3 TeV

Const. ε_K ?

Time Dependent CPV in B^0 decays



$$A_{CP}(\Delta t)$$

$$\equiv \frac{\Gamma_{\bar{B}^0}(\Delta t) - \Gamma_{B^0}(\Delta t)}{\Gamma_{\bar{B}^0}(\Delta t) + \Gamma_{B^0}(\Delta t)}$$

$$= \mathcal{S} \sin \Delta m \Delta t + \mathcal{A} \cos \Delta m \Delta t$$

Mixing-induced CPV

Direct CPV

e.g. for $B \rightarrow J/\psi Ks$

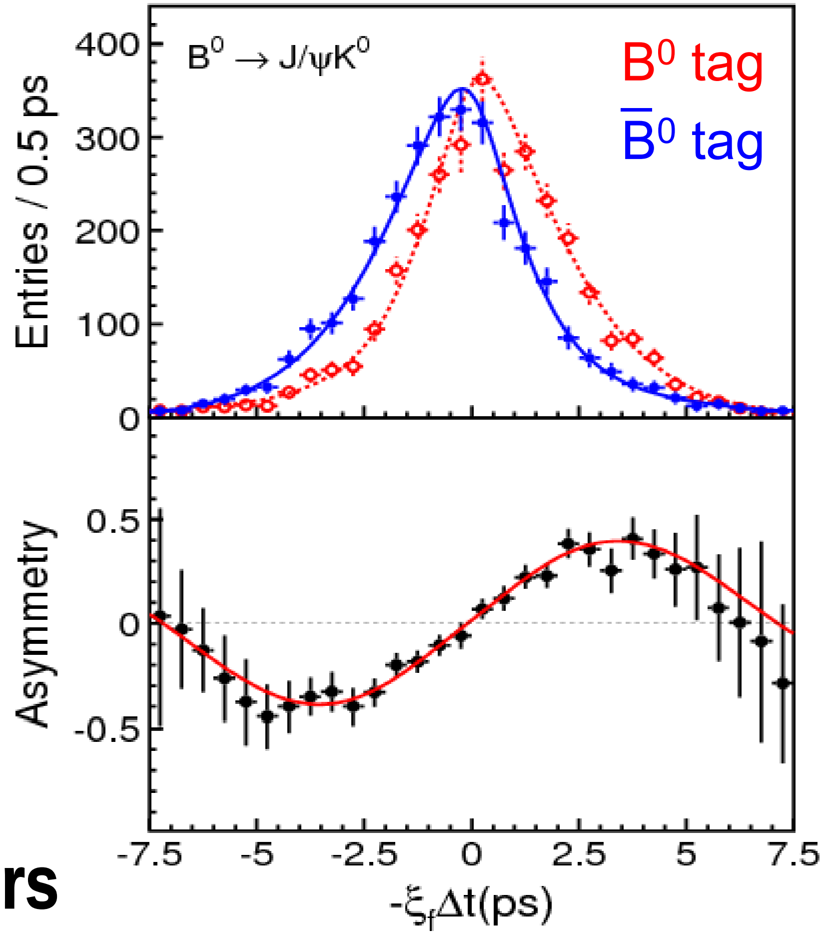
$\mathcal{S} = -\xi_{CP} \sin 2\phi_1 = +\sin 2\phi_1$

$\mathcal{A} \sim 0$

(ξ_{CP} : CP eigenvalue ± 1)

N.B. Time integrated mixing-induced asymmetries vanish

$B^0 \rightarrow J/\psi K^0$



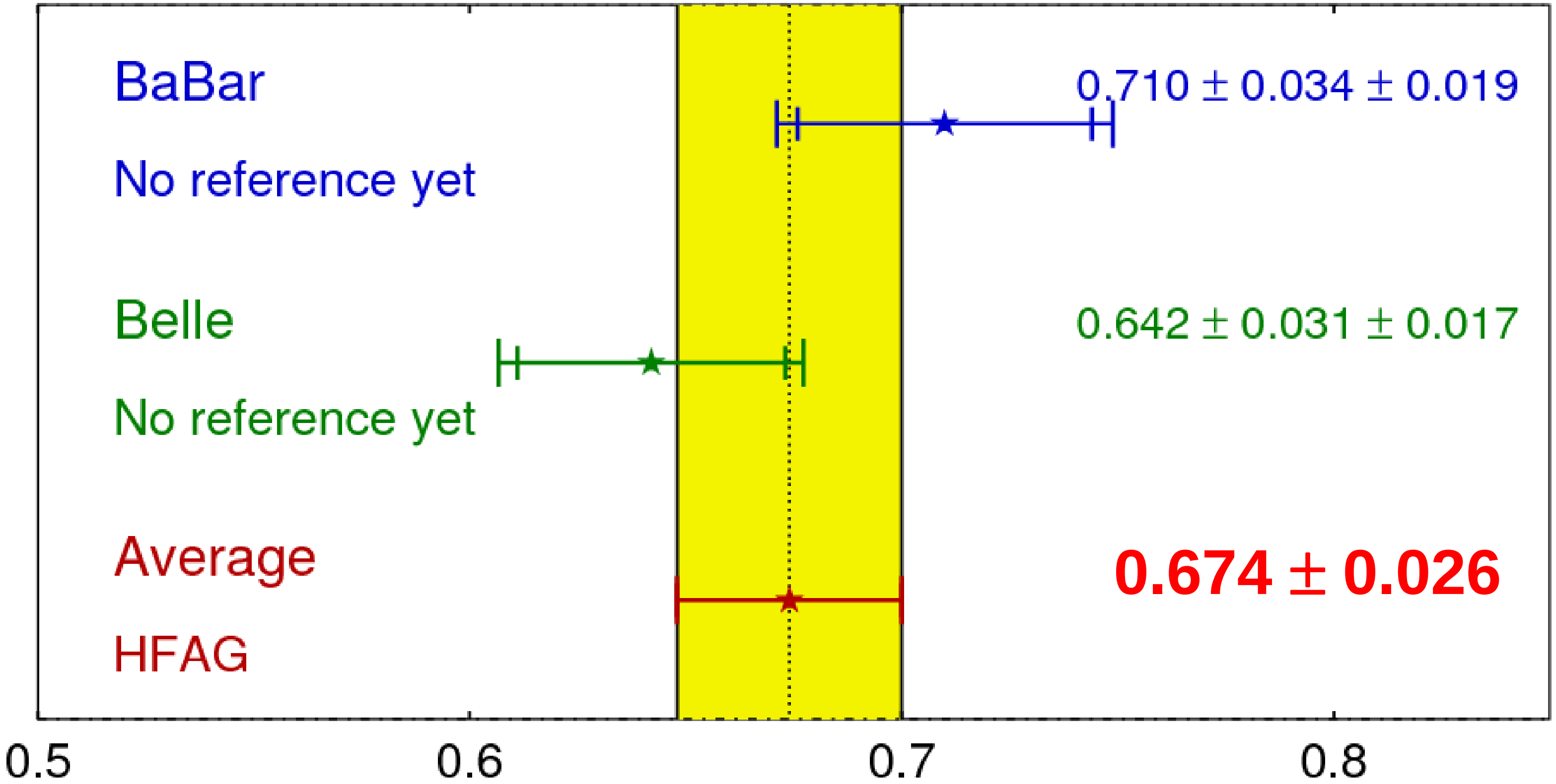
535 M $B\bar{B}$ pairs

previous measurement
$\sin 2\phi_1 = 0.652 \pm 0.044$
(388 M $B\bar{B}$ pairs)

$\sin 2\phi_1 = 0.642 \pm 0.031$ (stat) ± 0.017 (syst)
$A = 0.018 \pm 0.021$ (stat) ± 0.014 (syst)

hep-ex/0608039, PRL

$\sin 2\phi_1$: *BaBar + Belle*



A precise measurement of the phase of B_d mixing (< 4 % error)

"Yesterday's sensation is today's calibration and tommorow's background." - Val Telegdi

Reference Point for NP search

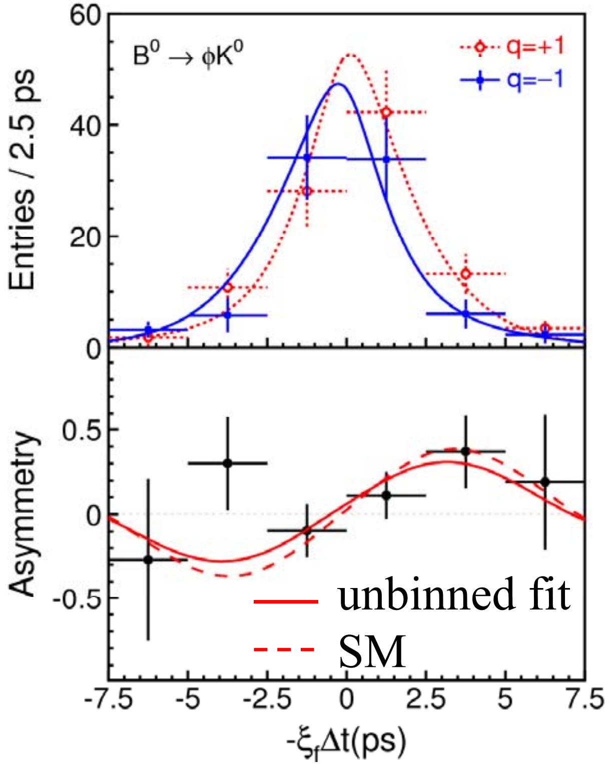
Belle: t*CP*V in $B^0 \to \phi K^0$

535M $B\bar{B}$

“$\sin 2\phi_1$” = +0.50 ± 0.21(stat) ± 0.06(syst)

a.k.a sin(2 β)

Δt distributions and asymmetry



- Consistent with the SM (~1σ lower)
- Consistent with Belle 2005

(Belle2005: “$\sin 2\phi_1$” = +0.44±0.27±0.05)

- ϕK_S and ϕK_L combined
- background subtracted
- good tags
- Δt → –Δt for ϕK_L

hep-ex/0608039, PRL 98, 031802(2007)

BaBar: ϕK^0 using $B^0 \rightarrow K^+K^-K^0$

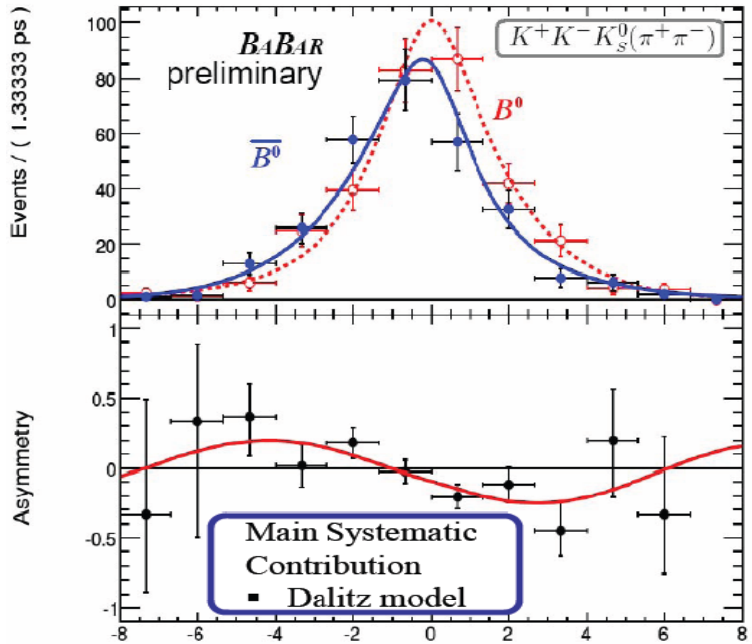
347M $B\bar{B}$

[hep-ex/0607112]

Fit to low mass K^+K^- region (<1.1 GeV) to extract ϕK^0 and $f_0(980)K^0$ CPV parameters

$\mathcal{A}_{CP}(\phi K^0)$	$-0.18 \pm 0.20 \pm 0.10$
$\beta_{eff}(\phi K^0)$	$0.06 \pm 0.16 \pm 0.05$

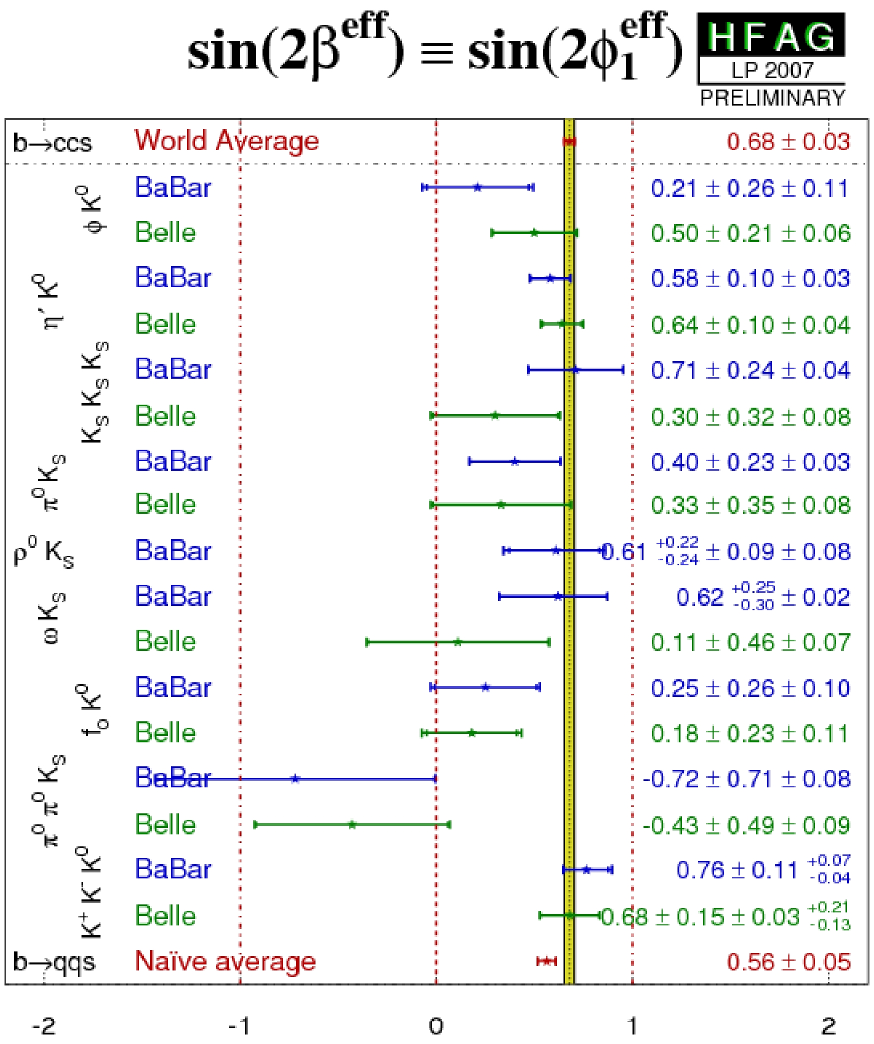
β measurement (not sin2β)



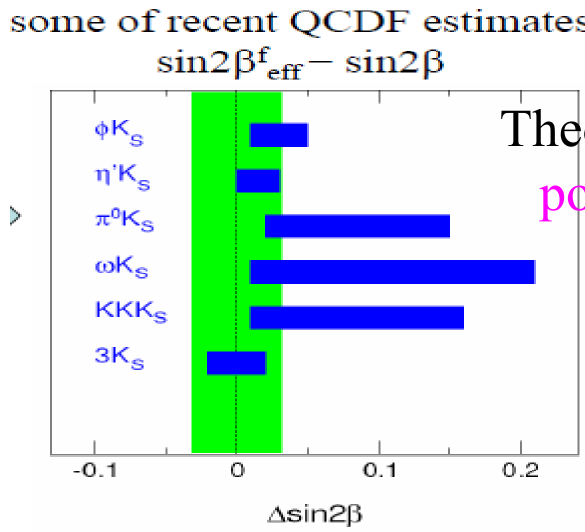
ϕK^0: $\sin 2\beta_{eff} = +0.12 \pm 0.31(stat) \pm 0.10\ (syst)$

a.k.a. $\sin(2\ \varphi_1)$

2007: Hints of NP in *b* → *s* Penguins ?



Smaller than $b \to c\bar{c}s$ in 7 of 9 modes



Theory predicts positive shifts

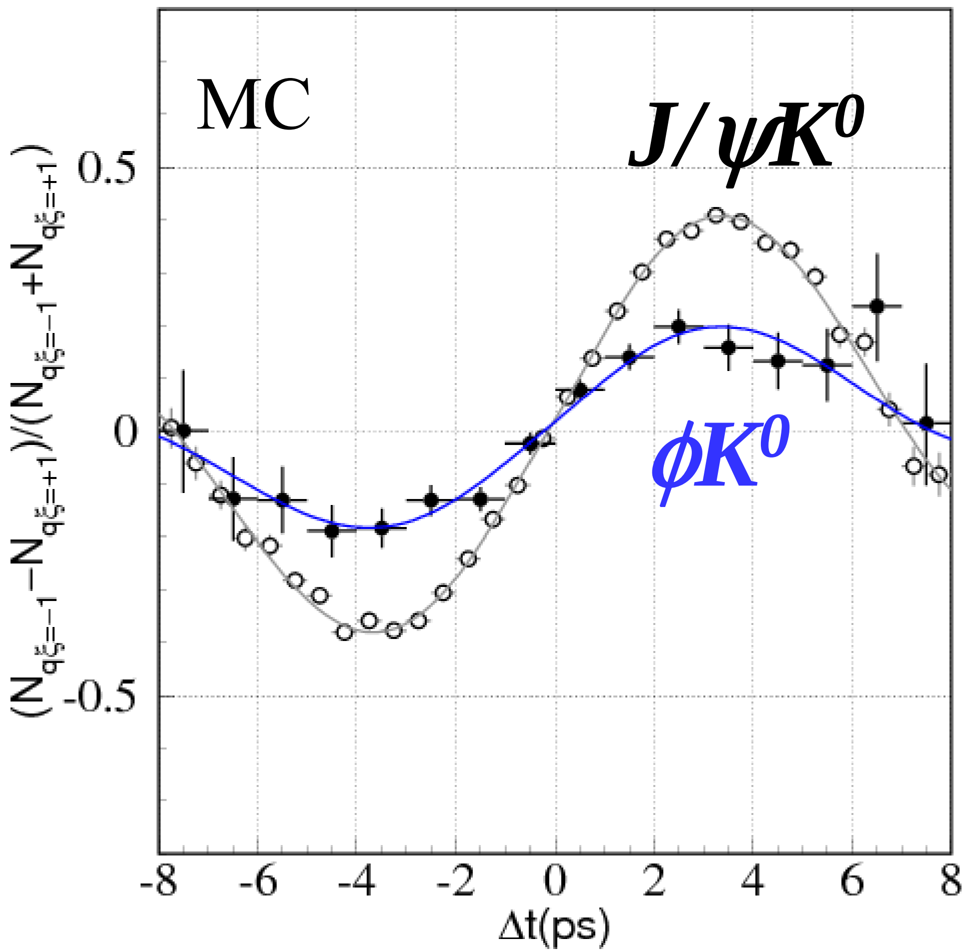
Naïve average of all b → s modes

$\sin 2\beta^{\mathrm{eff}} = 0.56 \pm 0.05$

2.2 σ deviation from SM

(CL=3%)

Extrapolation: $B \rightarrow \phi K^0$ at 50/ab with present WA values



This would establish the existence of a NP phase

Compelling measurement in a clean mode

2007 was the year of D^0 mixing

高エネ研

D中間子の混合現象を発見

新理論の可能性に期待

高エネルギー加速器研究機構（KEK、つくば市大穂、KEK）は13日、電子陽電子衝突型加速器（KEKBファクトリー）を使った実験で、D中間子の粒子・反粒子混合現象を世界で初めてとらえることに成功したと発表して観測した。

中間子はクォークと反クォークの束縛状態。粒子が反粒子に変わる混合現象は、電気的に中性の中間子に特有の現象で、これまで中性のK中間子とB中間子で確認されていた。中間子で唯一残っていたD中間子は、1976年に発見されて以来、電子・陽電子や陽子・反陽子加速器による衝突実験などで検出が試みられてきたが、発見されていなかった。

中間子に混合現象があると、崩壊の終状態によって寿命がわずか……のK中間子または2個のπ中間子に崩壊する場合の寿命を精密に比較し、統計的に有意な差があることを確認した。

標準理論に基づく混合の頻度は小さく、理論上は10万分の1から100分の1と予想されている。今回の測定では100分の1程度、寿命の違いが測定され、予想される範囲の上限近くにある。今……密に測定すると、未知の新粒子の存在を探ることができる。これまでも、K中間子の混合率の測定的からチャームクォークの存在や質量、B中間子の混合率の測定からトップクォークの存在や質量が予言されていた。今回の測定結果は、そうした新しい理論につながる可能性が期待されている。

この実験結果は13日

反粒子に高確率で「変身」

D中間子 標準理論に変更も

高エネ研確認

D中間子の"混合現象"

高エネ機構加速器で観測

国際研究グループ

反粒子経て崩壊

「D中間子」観測

国際研究チーム

高エネルギー加速器研究機構などの国際共同研究チームは十三日、韓国で開かれている国際会議で、「D中間子」という粒子の特殊な現象を世界で初めて観測したと発表した。素粒子物理学の新しい理論を構築する手掛かりになるという。

世界十四の国・地域から約四百人の研究者が参加している国際共同による加速器実験の成果。

D中間子は電子と、その反粒子（質量は同じだが、電気的性質などが反対の粒子）である陽電子が衝突したときに生じる微小な粒子。発生しても一兆分の一秒で壊れて別の粒子になるが、まれに反粒子にいったんなってから崩壊することがあり、この現象を観測することに成功した。

国際チームは一九九九年からD中間子の観測を重ね、約百回に一回の割合で、反粒子を経て崩壊することが分かった。

「現在の理論では、D中間子が反粒子を経て崩壊する割合に幅がある。実験で割合が確定したことで、新理論を作る道筋が与えられた」と山内正則高エネルギー加速器研究機構教授は話している。

反粒子の「混合」

D中間子で発見

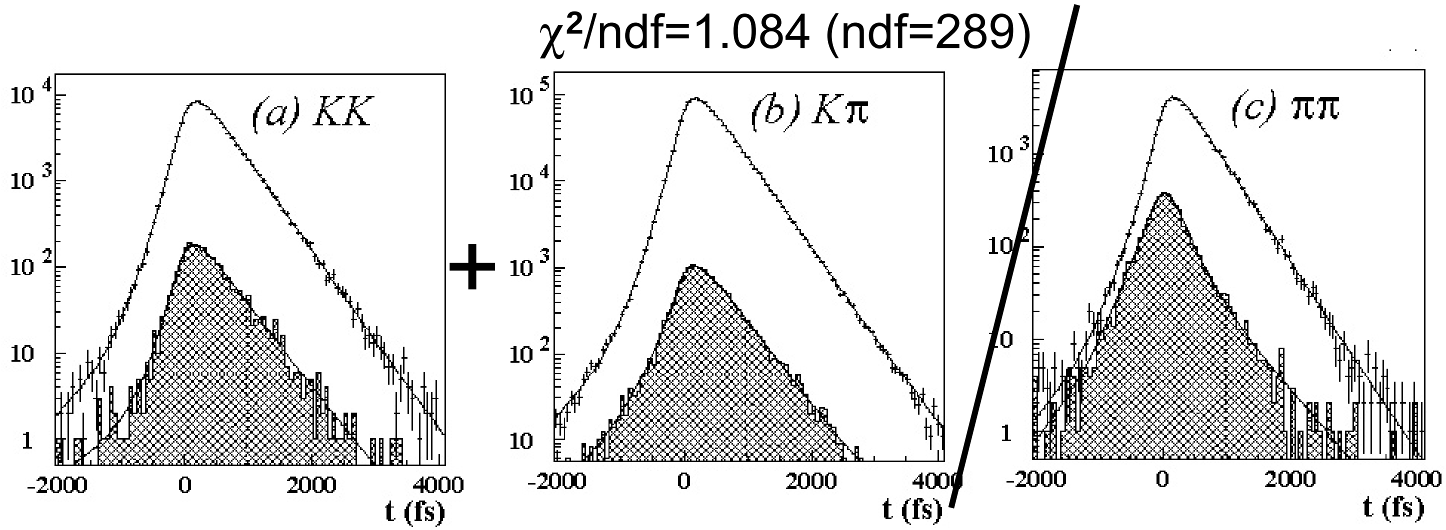
高エネ研チーム

宇宙に現在存在する粒子と、電気的な性質などが反対の反粒子が移り変わる「混合現象」が、D中間子で初めて見つかった。高エネルギー加速器研究機構（茨城県つくば市）の大型加速器「Bファクトリー」の国際実験チームが十三日、韓国で開かれた国際会議で発表した。米スタンフォード線形加速器センターの国際実験チームも別の測定方法で発見し、同会議で発表した。Bファクトリー実験の共同代表、山内正則高エネ研教授は「現在の素粒子物理学の標準理論を超える新理論や未知の新粒子を探る手掛かりになる」と話している。

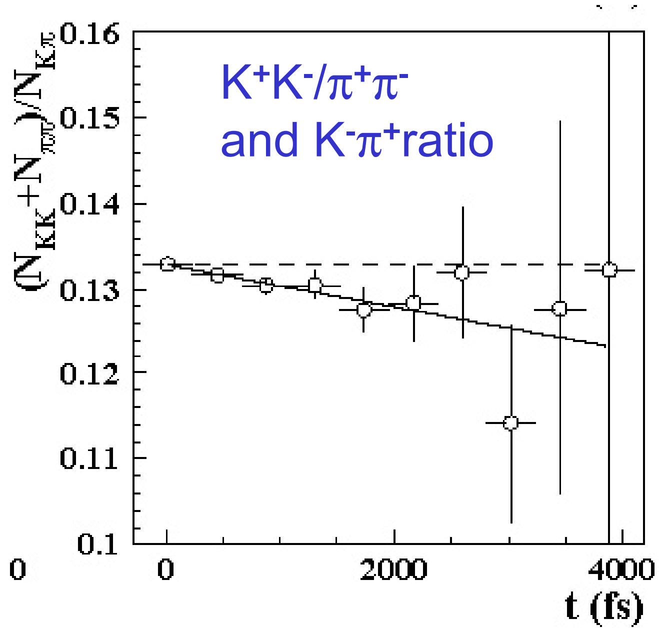
混合現象は、電気的に中性で、素粒子のクォーク二個で構成される中間子に特有の現象。K中間子ではほぼ100%、B中間子では約70%の確率で起こることが知られるが、残るD中間子では未発見だった。

Belle $D^0 \rightarrow K^+K^- / \pi^+\pi^-$

PRL 98, 211803 (2007), 540fb[-1]



Difference of lifetimes visually observable



$y=\Delta\Gamma/(2\Gamma)$

3.2 σ from zero
(4.1 σ stat. only)

Evidence for D^0 mixing
(regardless of possible CPV)

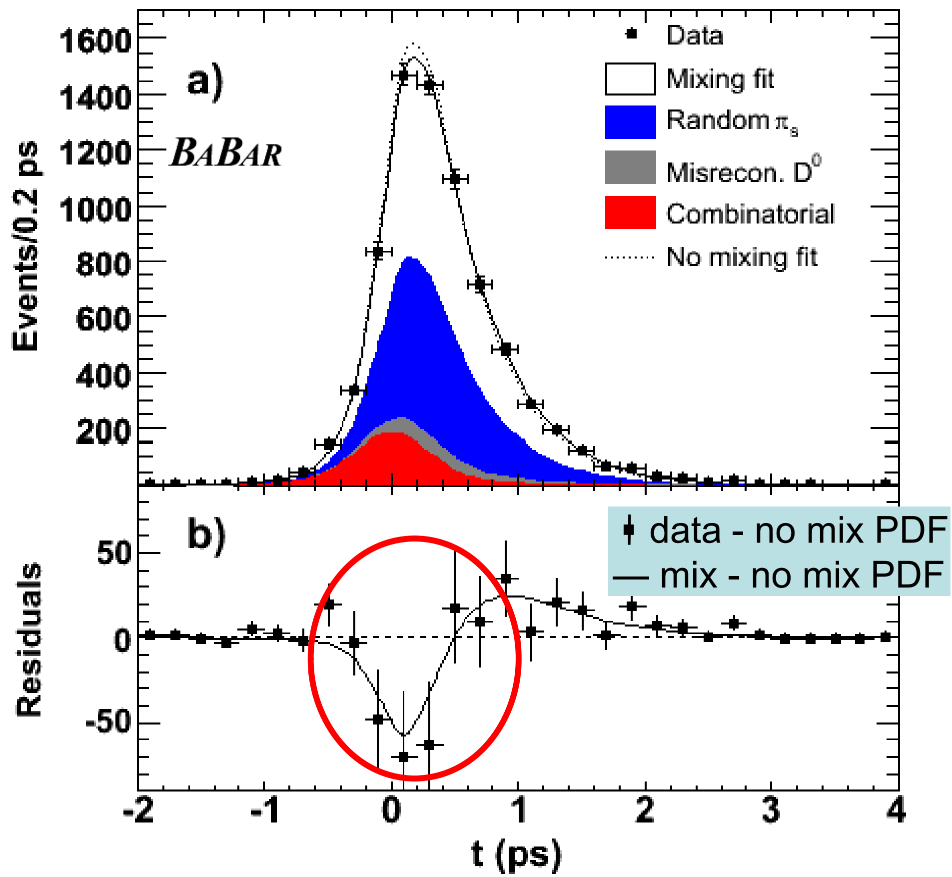
$y_{CP} = (1.31 \pm 0.32 \pm 0.25)\%$

negligible CPV, $y_{CP}=y$

BaBar D-mixing Signal in $D^0 \to K^+\pi$

- Fit results:

R_D: $(3.03\pm0.16\pm0.10)\times10^{-3}$
x'^2: $(-0.22\pm0.30\pm0.21)\times10^{-3}$
y': $(9.7\pm4.4\pm3.1)\times10^{-3}$



WS *mixing* fit projection in signal region
1.843 GeV/c^2 < m < 1.883 GeV/c^2
0.1445 GeV/c^2 < Δm < 0.1465 GeV/c^2

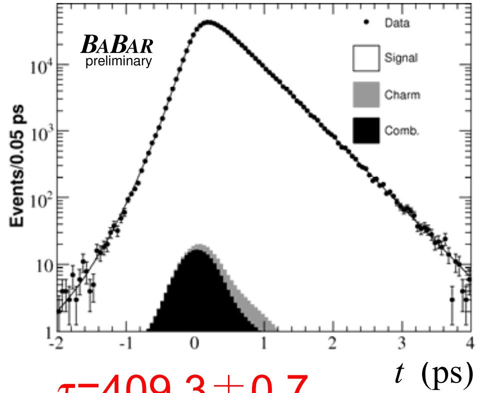
$x=\Delta m/\Gamma$ **$y=\Delta\Gamma/(2\Gamma)$**

The quantities x', y' are rotated versions of x, y
The rotation angle is an unknown strong phase

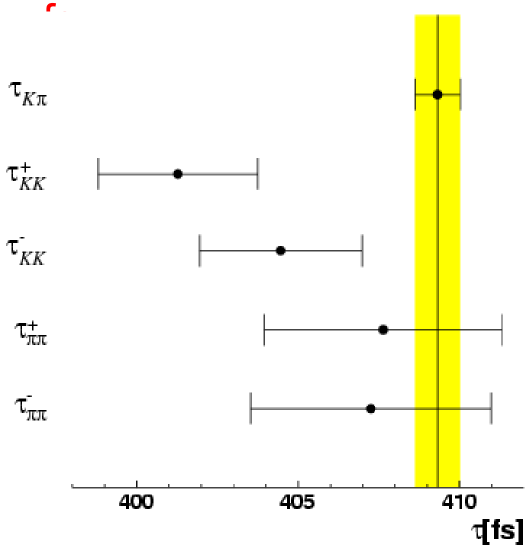
CDF confirmation
discussed on Monday

BaBar Decay time distributions

$D^0 \to K^-\pi^+$ +c.c.

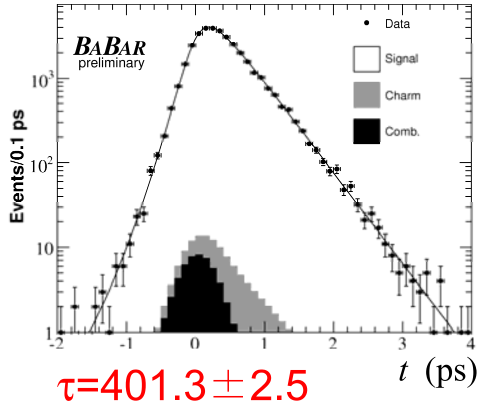


τ=409.3±0.7



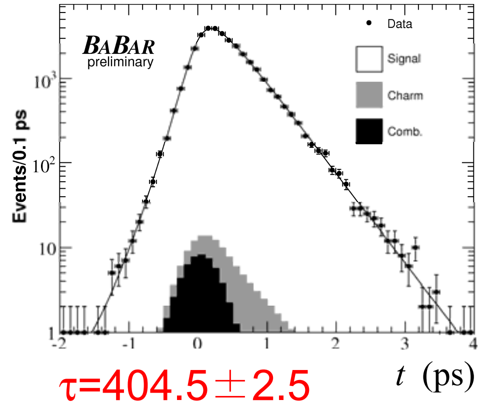
***Kπ* and *KK* lifetimes differ!**

$D^0 \to K^+K^-$



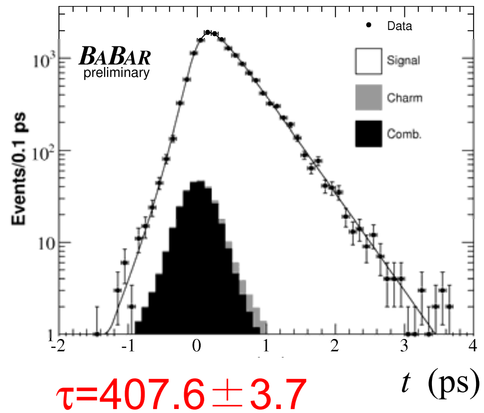
τ=401.3±2.5 fs

$\overline{D}^0 \to K^+K^-$



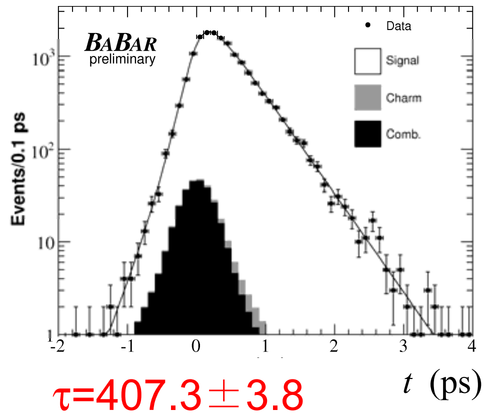
τ=404.5±2.5 fs

$D^0 \to \pi^+\pi^-$



τ=407.6±3.7 fs

$\overline{D}^0 \to \pi^+\pi^-$



τ=407.3±3.8 fs

Confirms Belle result

Measurements $K_S\,\pi^+\pi^-$

arXiv: 0704.1000, 540 fb^{-1}, to appear in PRL

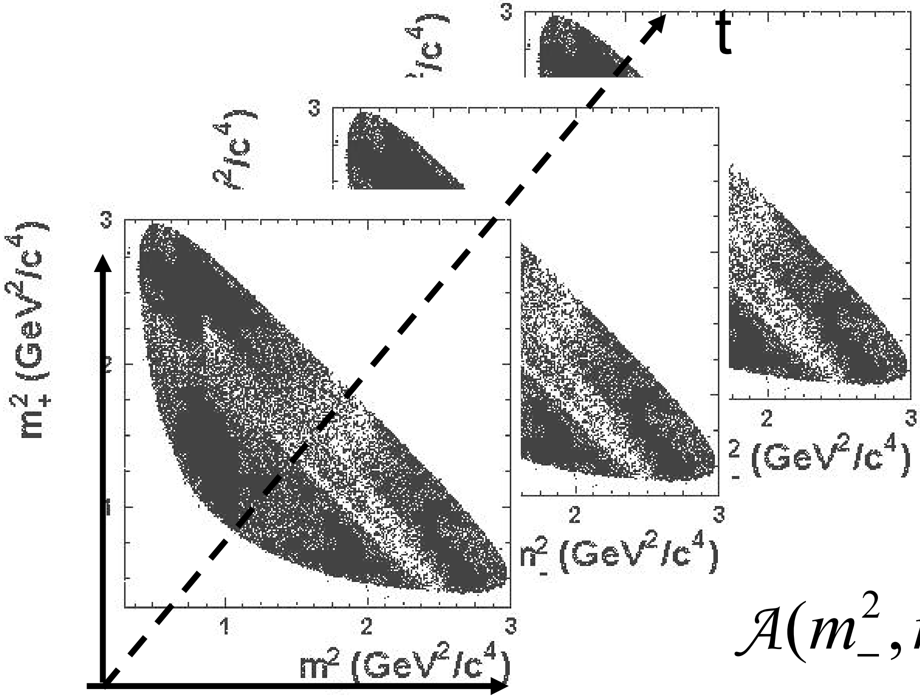
Decay-t projection of fit

$$x = (0.80 \pm 0.29 \pm {}^{0.13}_{0.16})\%$$
$$y = (0.33 \pm 0.24 \pm {}^{0.10}_{0.14})\%$$

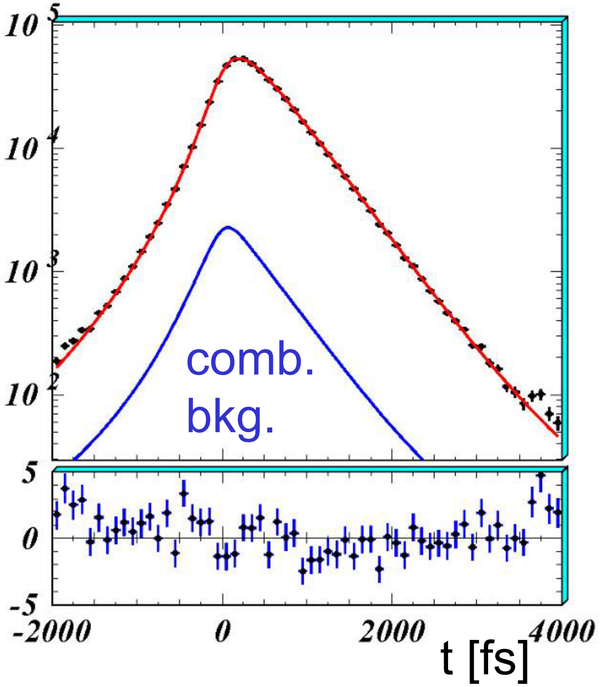
most sensitive meas. of x;

x = 1.8 ± 3.4 ± 0.6%
y = -1.4 ± 2.5 ± 0.9 %

Cleo, PRD72, 012001 (2005)



~534,000 signal events



τ = 409.9±0.9 fs

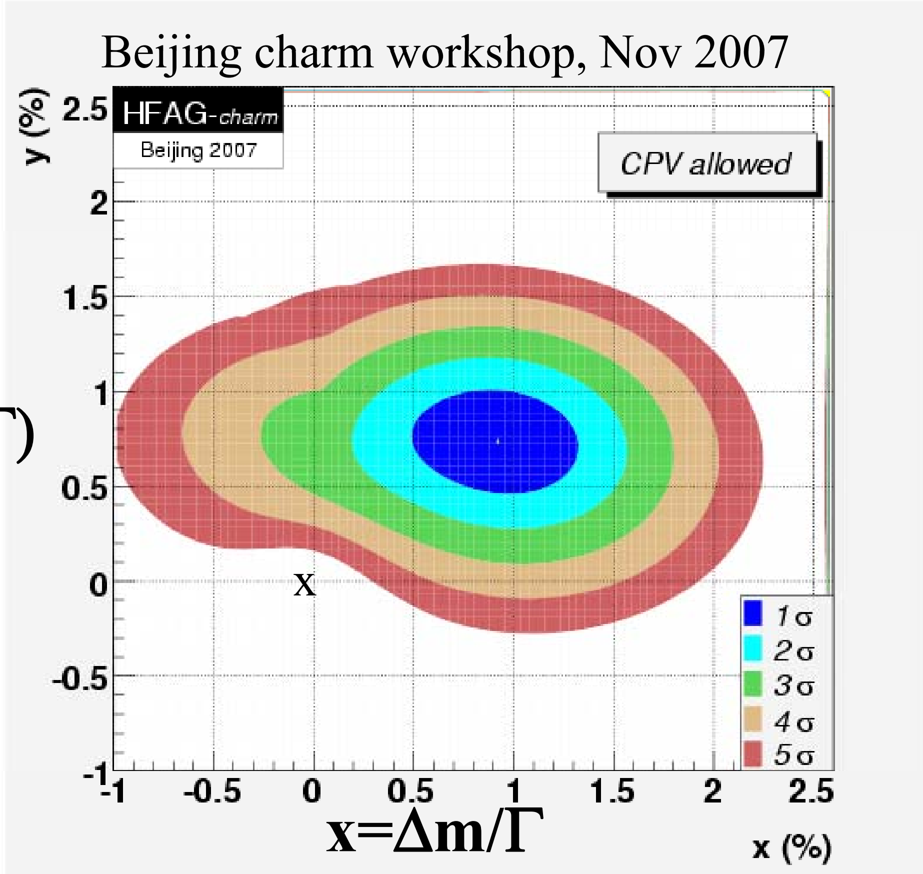
τ_{PDG}=410.1±1.5 fs

$$\mathcal{A}(m_-^2, m_+^2) = \sum a_r\ e^{i\Phi_r} B(m_-^2, m_+^2) + a_{NR}\ e^{i\Phi_{NR}}$$

Summary of D^0 mixing

semileptonic, $K^+\pi^-$, $K_s\pi\pi$, y_{CP}, $K^+\pi^-\pi^0$, $K^+\pi^-\pi^+\pi^-$, $\psi(3770)$

$y=\Delta\Gamma/(2\Gamma)$



$x=\Delta m/\Gamma$

Belle,BaBar,CLEO combined

Large mixing is established. (may be compatible with high end of SM predictions)

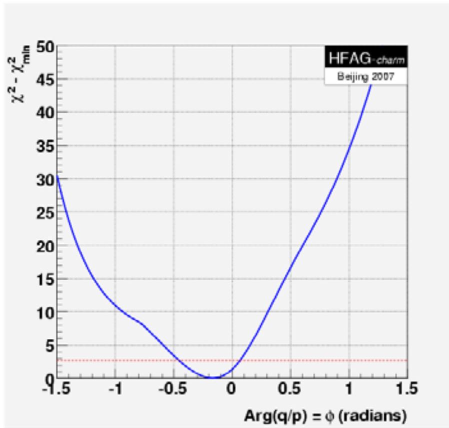
Why is D^0 mixing important for Super B Factories ?

Another new physics CPV phase !

$$\varphi \sim \frac{2\eta A^2 \lambda^5}{\lambda} \sim O(10^{-3})$$ CPV in D system negligible in SM

CPV in interf. mix./decay: $$\mathrm{Im}\frac{q}{p}\frac{\overline{A}_f}{A_f} \equiv (1+\frac{A_M}{2})e^{i\varphi} \neq 0; \varphi \neq 0$$

The existence of D mixing (if x is non-zero) allows us to look for another unconstrained NP phase but this time from up-type quarks. (c.f. CPV in B_s mixing)



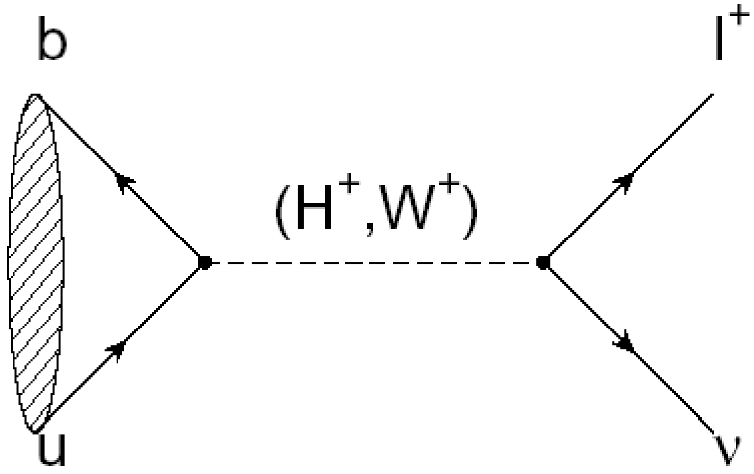
Current sensitivity $\sim\pm 20^0$, 50 ab^{-1} go below 2^0

Rare Decays with Large "Missing Energy"

(New physics couplings in trees)

Motivation for $\boldsymbol{B}^{+} \rightarrow \tau^{+} \nu$

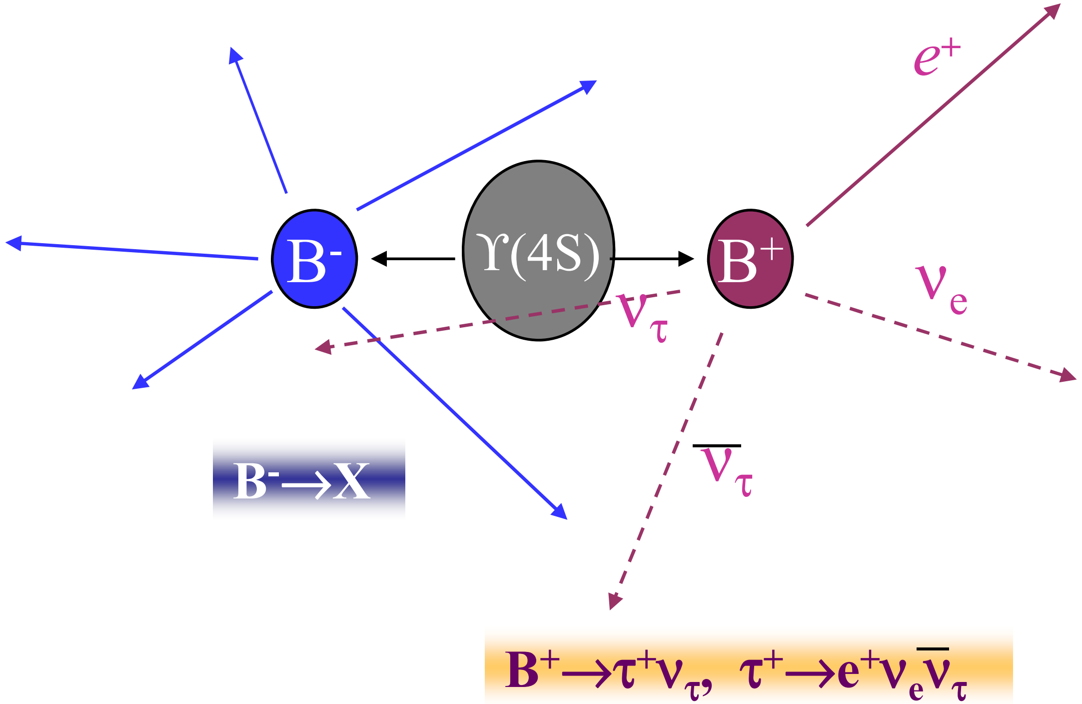
Sensitivity to new physics from charged Higgs if the B decay constant is known



$$\mathcal{B}(B^{+} \rightarrow \tau^{+}\nu_{\tau}) = \frac{G_F^2 m_B}{8\pi} m_\tau^2 \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

The B meson decay constant, determined by the B wavefunction at the origin

Why measuring $B \to \tau\nu$ *is non-trivial*

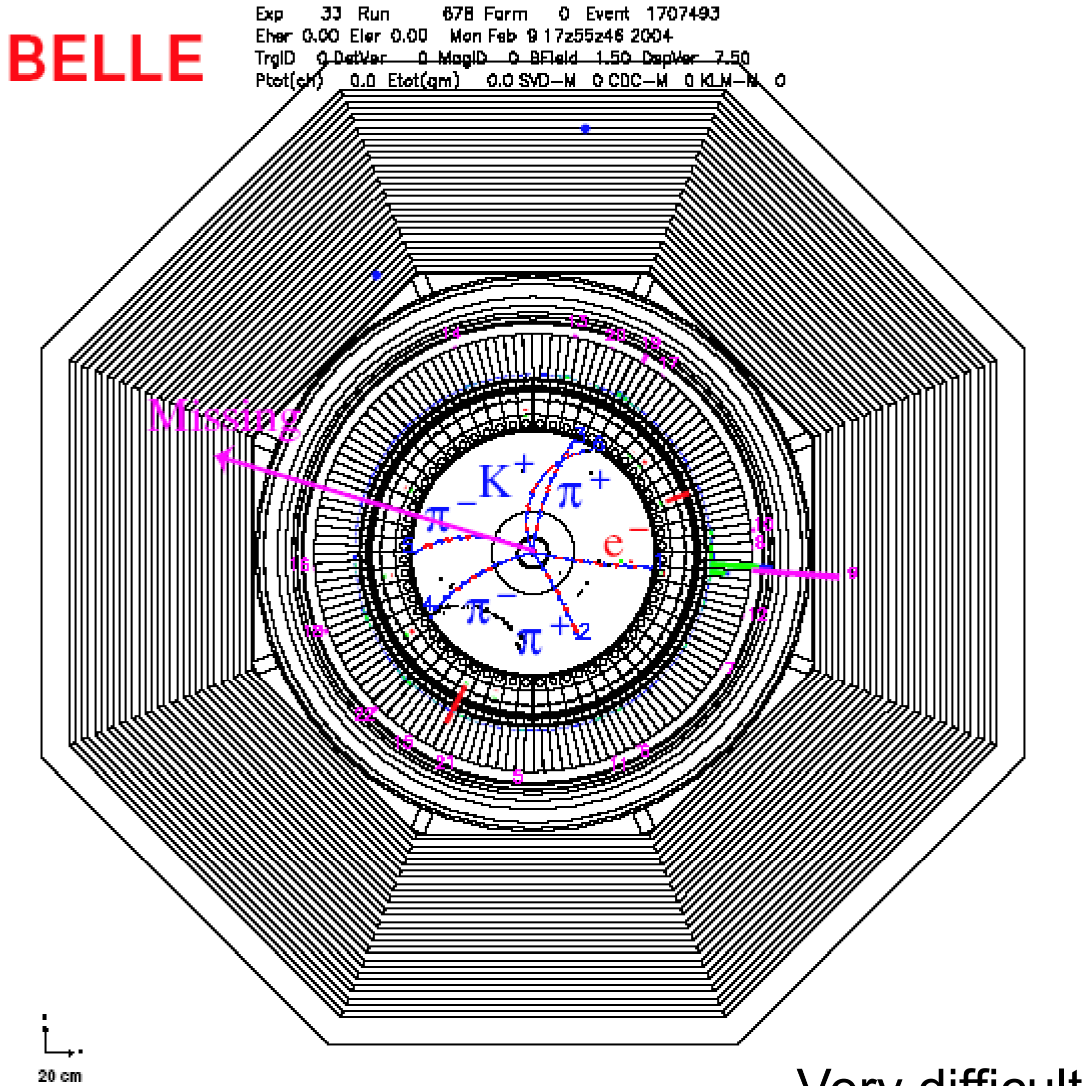


Most of the sensitivity is from tau modes with 1-prong

The experimental signature is rather difficult:

B decays to a single charged track + nothing

Example of a B→τ ν candidate



Tag: $B \to D^0\,\pi$,

$D^0 \to K\pi\pi\pi$

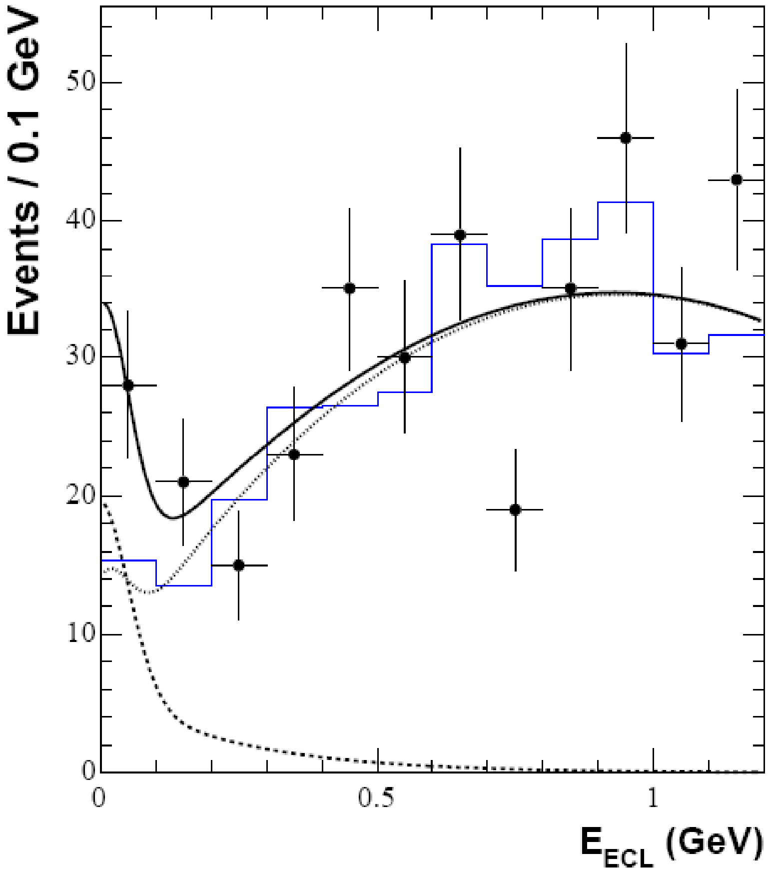
Very difficult or impossible at a hadron collider

Evidence for $B^+ \rightarrow \tau\nu$ (Belle)

449 ×10[6] B pairs

$B_{tag} \rightarrow D^{(*)}[\pi,\rho,a_1,D_s^{(*)}]$ 680k tags, 55% pure.

5 τ decay modes



Extra Calorimeter Energy

Find $17.2^{+5.3}_{-4.7}$ signal events from a fit to a sample of 54 events.

4.6σ stat. significance w/o systematics,

After including systematics (dominated by bkg), the significance decreases to 3.5σ

MC studies show there is a small peaking bkg in the $\tau \rightarrow \pi\pi^0\nu$ and $\tau \rightarrow \pi\pi\pi\nu$ modes.

Direct experimental determination of f_B

- Product of B meson decay constant f_B and CKM matrix element $|V_{ub}|$

$$f_B \times V_{ub} = (10.1^{+1.6+1.3}_{-1.4-1.4}) \times 10^{-4}\, GeV$$

- Using $|V_{ub}| = (4.39 \pm 0.33) \times 10^{-3}$ from HFAG

$$f_B = 229^{+36+34}_{-31-37}\, MeV$$

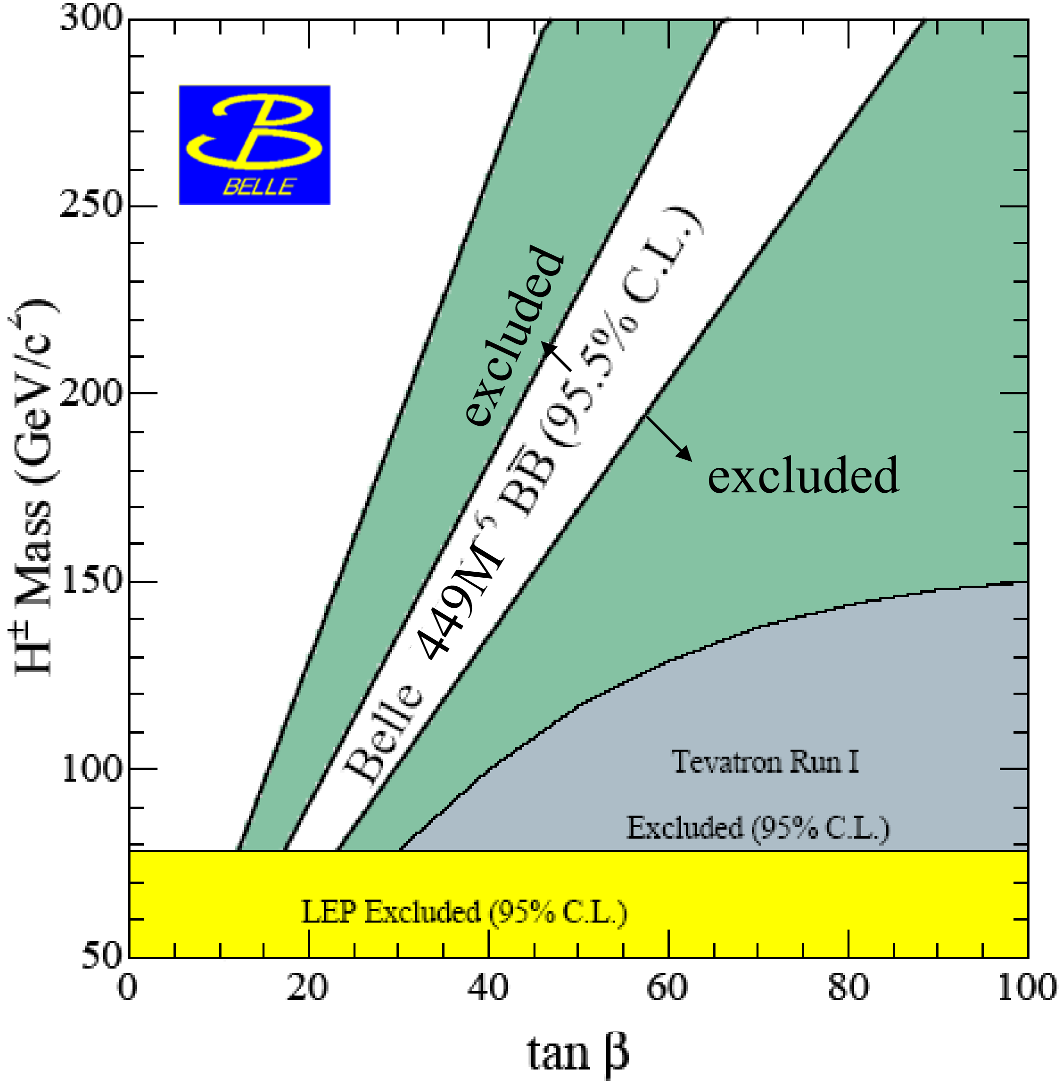
(Belle)

(PRL 97, 251802 (2006))

Theory: $f_B = 216 \pm 22$ MeV (an unquenched lattice calc.)

[HPQCD, Phys. Rev. Lett. 95, 212001 (2005)]

Constraints on charged Higgs mass



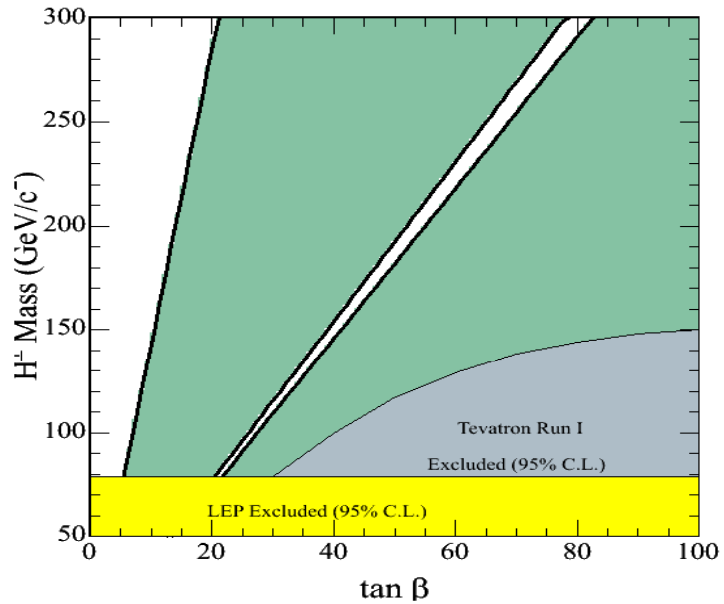
Compare to direct searches for H^+

Use known f_B and $|V_{ub}|$

Ratio to the SM BF.

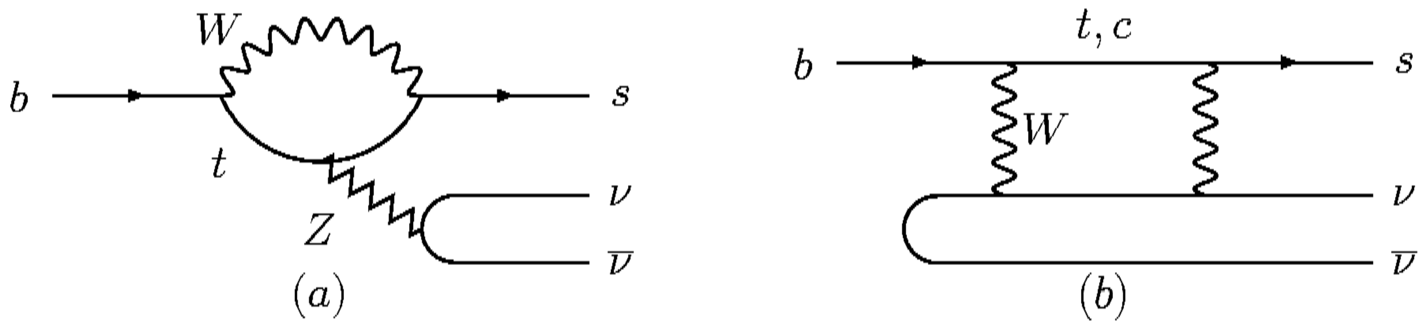
$$r_H = \left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$

$r_H = 1.13 \pm 0.51$



At 50 ab^{-1}

The next frontier: $B \rightarrow K^{(*)} \nu \bar{\nu}$



b → s with 2 neutrinos

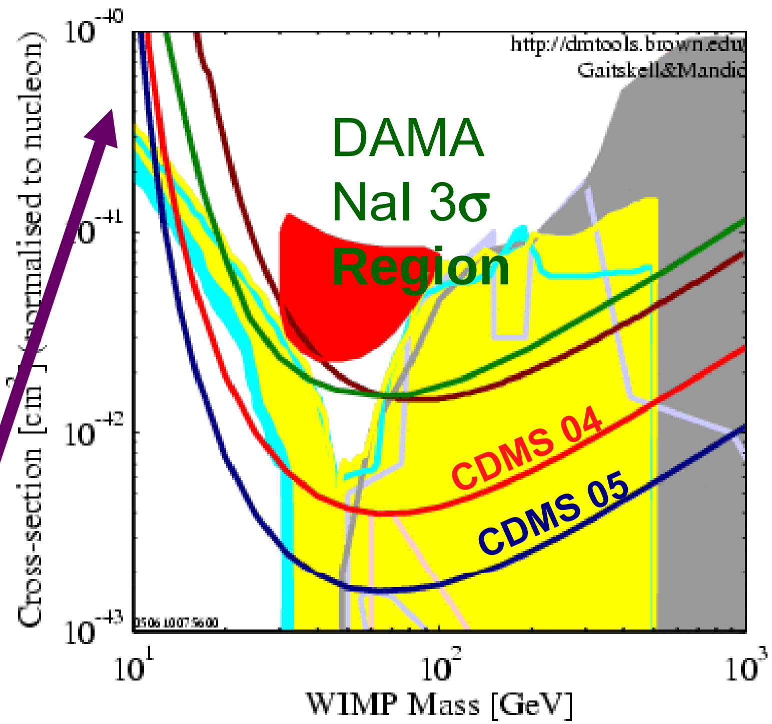
SM: $\mathcal{B}(B \rightarrow K^{*} \nu\bar{\nu}) \sim 1.3 \times 10^{-5}$

$\mathcal{B}(B \rightarrow K \nu\bar{\nu}) \sim 4 \times 10^{-6}$

(Buchalla, Hiller, Isidori)

PRD 63, 014015

- **New Physics in Loop**
- **Light Dark Matter (M~1GeV)**

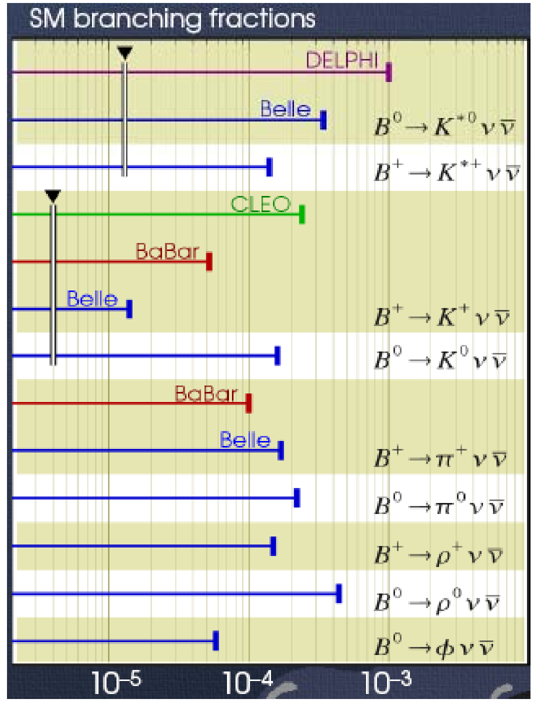


No sensitivity to M<10 GeV in direct searches

$B \to h^{(*)}\ \bar{\nu}\nu$ ($b \to s\ \bar{\nu}\nu$ penguins)

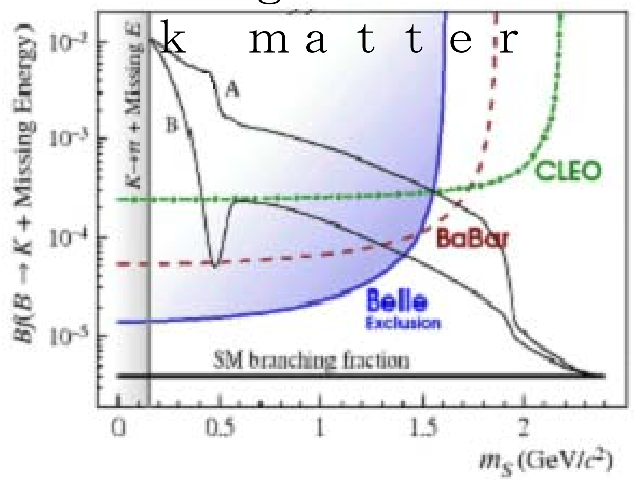
arXiv:0707.0138v1[hep-ex]; submitted to PRL

Mode	N_{obs}	N_b	U.L.
$K^{*0}\ \bar{\nu}\nu$	7	4.2±1.4	$<3.4 \times 10^{-4}$
$K^{*+}\ \bar{\nu}\nu$	4	5.6 ±1.8	$<1.4 \times 10^{-4}$
$K^{+}\ \bar{\nu}\nu$	10	20.0 ±4.0	$<1.4 \times 10^{-5}$
$K^{0}\ \bar{\nu}\nu$	2	2.0 ±0.9	1.6×10^{-4}
$\pi^{+}\ \bar{\nu}\nu$	33	25.9 ±3.9	$<1.7 \times 10^{-4}$
$\pi^{0}\ \bar{\nu}\nu$	11	3.8 ±1.3	$<2.2 \times 10^{-4}$
$\rho^{0}\ \bar{\nu}\nu$	21	11.5 ±2.3	$<4.4 \times 10^{-4}$
$\rho^{+}\ \bar{\nu}\nu$	15	17.8 ±3.2	$<1.5 \times 10^{-4}$
$\phi\ \bar{\nu}\nu$	1	1.9 ±0.9	$<5.8 \times 10^{-5}$



$K^{+}\ \bar{\nu}\nu$

Light dark matter



Need Super B statistics for discovery

More stringent U.Ls

$$Bf(B \to K^*\ \bar{\nu}\nu)_{SM} = 1.3 \times 10^{-5}$$
$$Bf(B \to K\ \bar{\nu}\nu)_{SM} = 4 \times 10^{-6}$$

Comments on Super B Factories

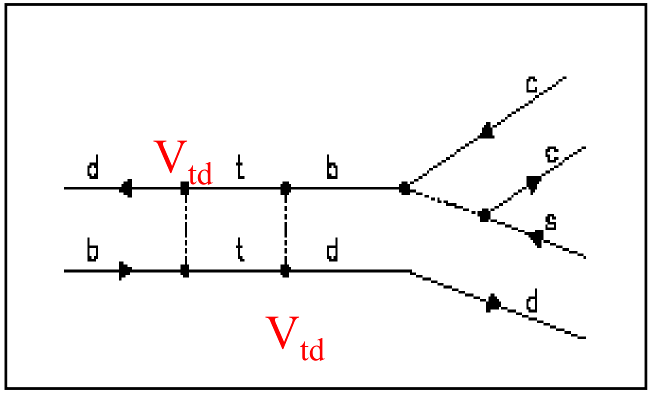
(recent developments and political, funding issues are included)

Lessons of History

New Physics is usually discovered first in loop processes, which involve high mass virtual particles. (Heisenberg Uncertainty Principle)

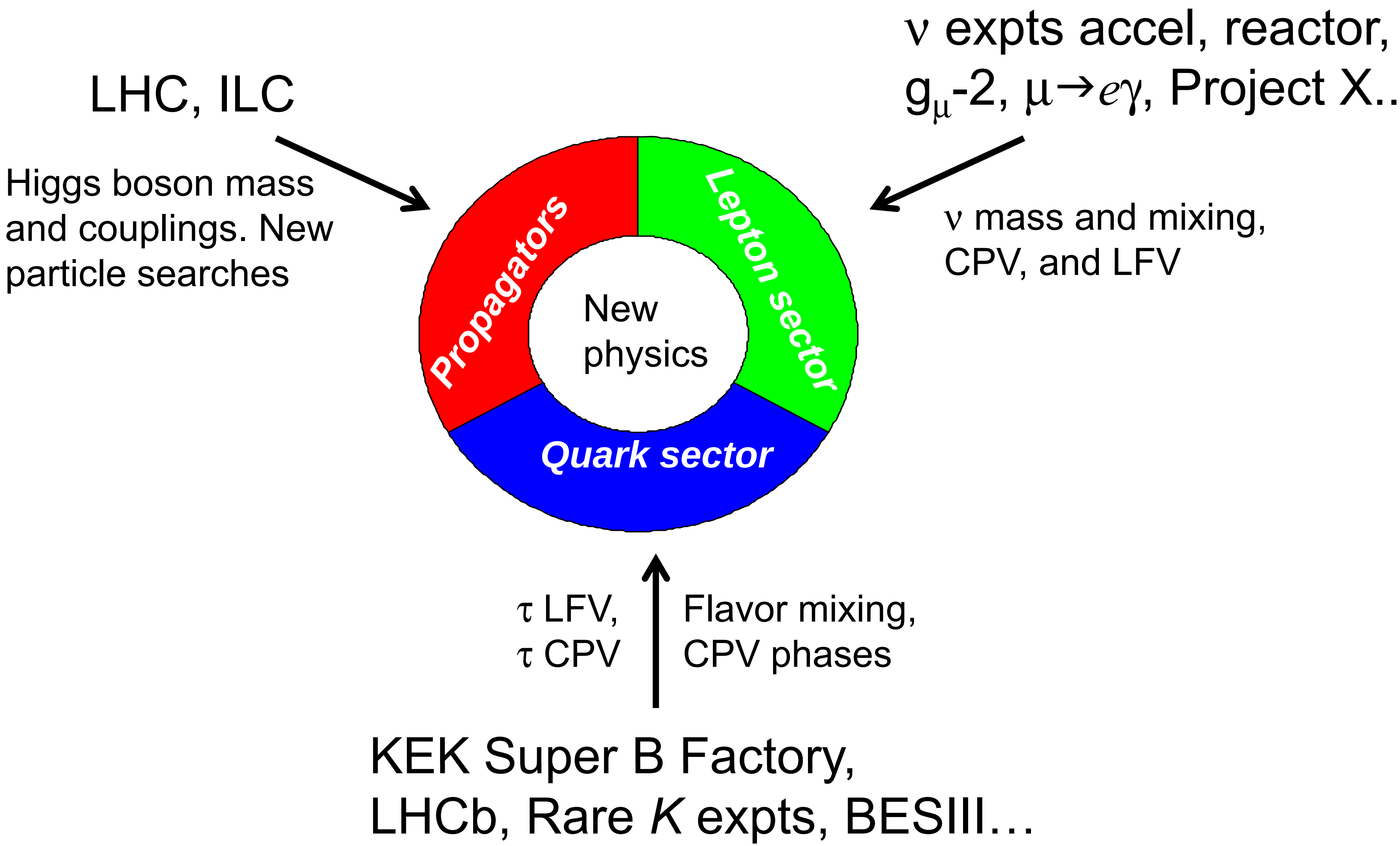
Example I: Absence of $K_L \rightarrow \mu\mu$ allowed theorists to deduce the existence of the charm quark. The rate of K mixing allowed a rough determination of the charm mass.

Example II: The absence of $b \rightarrow s$ decays and the long B lifetime ruled out topless models. Large B_d mixing showed the top was heavy contrary to theory prejudices of the time. Radiative corrections from Z measurements determined the rough range of the top mass.



Beautiful and precise measurements of the top quark mass at the Tevatron. However, the couplings $|V_{ts}|$, $|V_{td,}|$ and most importantly the phase of (V_{td}) cannot be measured in direct top production.

The Super B Factory is part of a Unified and Unbiased Attack on New Physics



Super B Factory vs current sensitivities

Hard to condense all the NP observables into one sound bite……

Observable	SFF sensitivity	Current sensitivity
$\sin(2\beta)$ $(J/\psi K^0)$	0.005-0.012	0.01
γ (DK)	1–2°	$\sim 31°$ (CKMFitter)
α $(\pi\pi, \rho\pi, \rho\rho)$	1–2°	$\sim 15°$ (CKMFitter)
$\lvert V_{ub}\rvert$(excl)	3-5%	$\sim$ 18% (PDG review)
$\lvert V_{ub}\rvert$(incl)	2-6%	$\sim 8(PDGreview)\%$
$\bar{\rho}$	1.7-3.4%	$^{+20\%}_{-12\%}$
$\bar{\eta}$	0.7-1.7%	$\pm 4.6\%$
$S(\phi K^0)$	0.02-0.03	0.17
$S(\eta' K^0$	0.01-0.02	0.07
$\mathcal{B}(B \to \tau\nu)$	$3-4\%$	30%
$\mathcal{B}(B \to \mu\nu)$	$5-6\%$	not measured
$\mathcal{B}(B \to D\tau\nu)$	$2-2.5\%$	31%
$\mathcal{B}(B \to \rho\gamma)/\mathcal{B}(B \to K^*\gamma)$	3-4%	16%
$A_{CP}(b \to s\gamma)$	0.004-0.005	0.037
$A_{CP}(b \to s\gamma + d\gamma)$	0.01	0.12
$S(K_S\pi^0\gamma)$	0.02-0.03	0.24
$S(\rho^0\gamma)$	0.08-0.12	0.67
$A^{FB}(B \to K^*\ell^+\ell^-)_{s0}$	4-6%	not measured
$\mathcal{B}(B \to K\nu\bar{\nu})$	16-20%	not measured
$\mathcal{B}(B \to s\ell^+\ell^-)_{s0}$		
$\mathcal{B}(B \to d\ell^+\ell^-)_{s0}$		not measured
ϕ_D (NP phase)	$\pm(1-2)°$	$\sim \pm 20°$
$\mathcal{B}(\tau \to \mu\gamma)$	$(2-8)\times 10^{-9}$	not seen, $< 5.0 \times 10^{-8}$
$\mathcal{B}(\tau \to \mu\mu\mu)$	$(0.2-1)\times 10^{-9}$	not seen, $< (2-4) \times 10^{-8}$
$\mathcal{B}(\tau \to \mu\eta)$	$(0.4-4)\times 10^{-9}$	not seen, $< 5.1 \times 10^{-8}$

(50-75 ab^{-1})

From TEB et al., hep-ph/0710.3799 and RMP in preparation

Recent Developments for the Super B Factory Accelerator

SuperKEKB final design luminosity is *8 x 10^{35}/cm^2/sec*

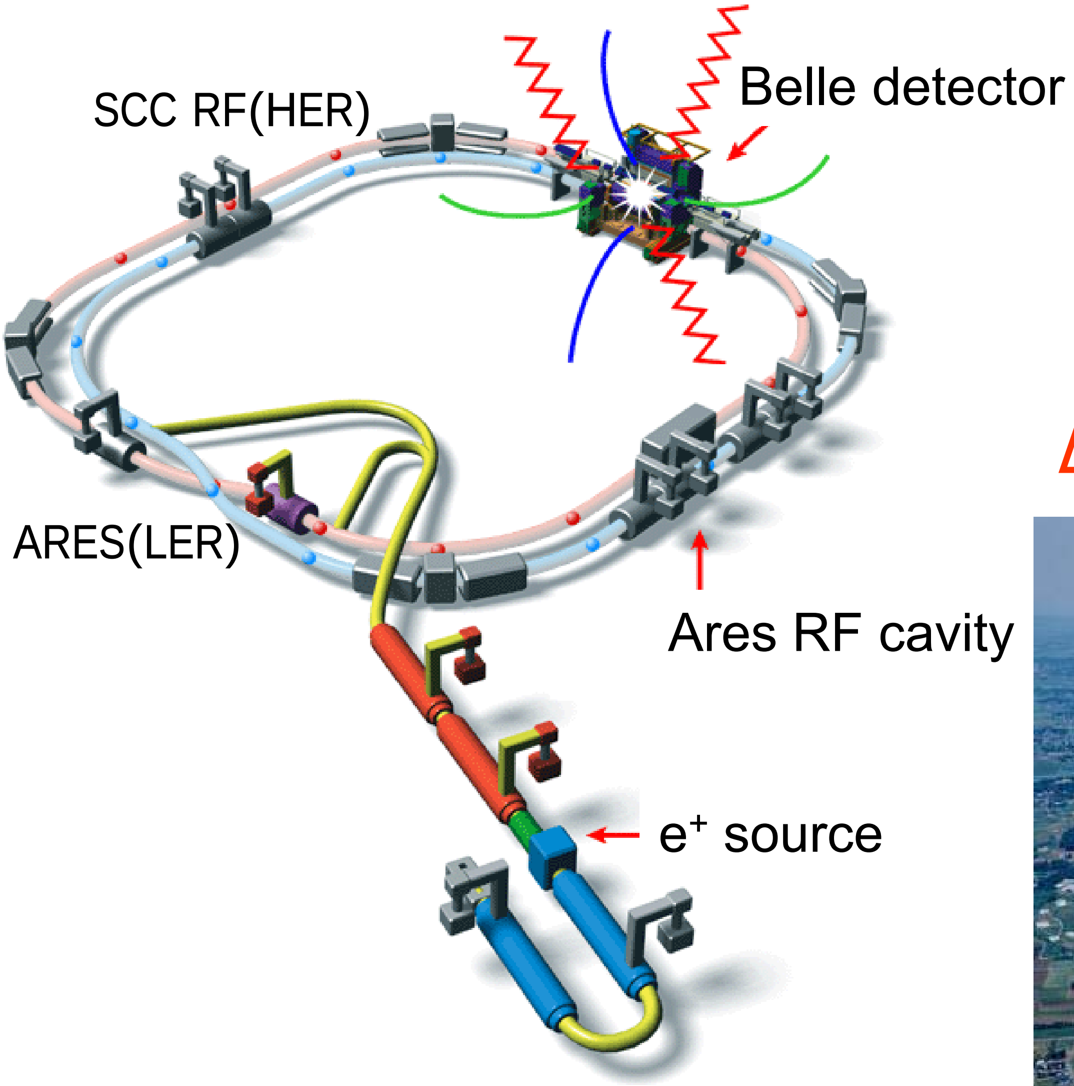
Low emittance/ILC inspired INFN design is ~10 x 10^{35}/cm^2/sec

c.f. Current KEKB luminosity is 1.7 x 10^{34}/cm^2 /sec

To address the full array of new physics searches, requires 10-50 ab^{-1} of integrated luminosity

c.f. Current KEKB integrated lumi 0.75 ab^{-1}

The KEKB Collider (Tsukuba, Japan)



8 x 3.5 GeV
22 mrad crossing angle

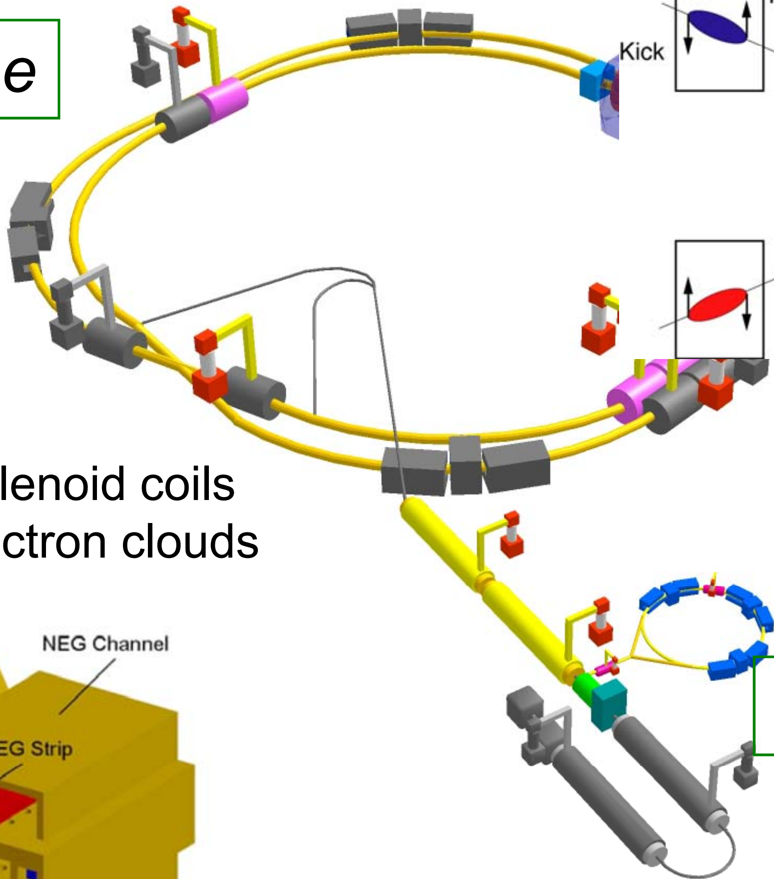
World record:

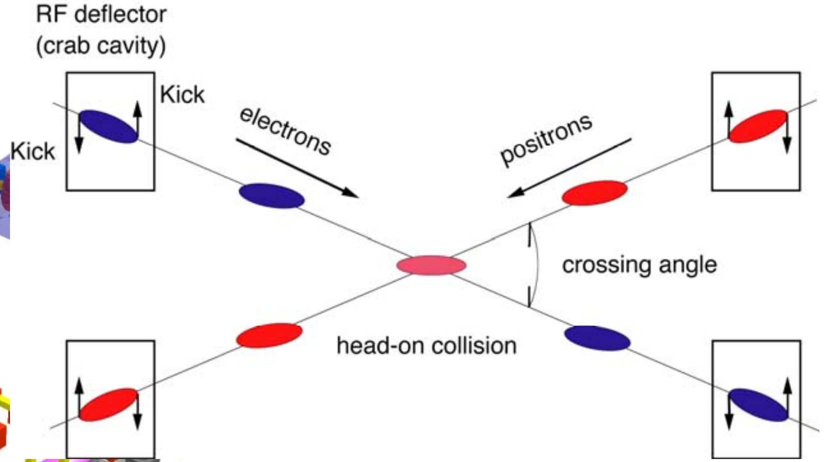
$L = 1.7 \times 10^{34}/cm^2/sec$

Corkheads Australian Bar

Super B Factory at KEK

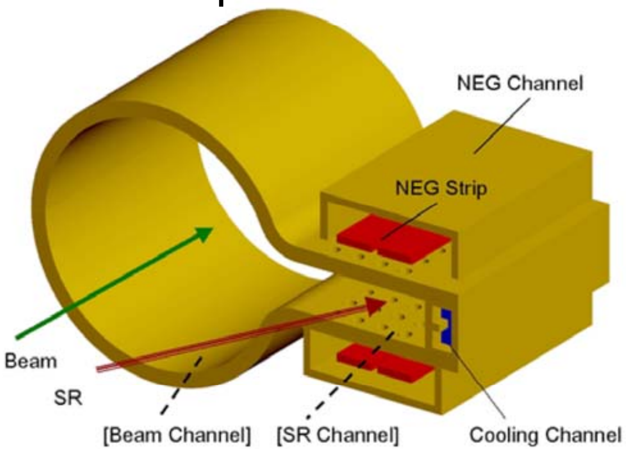
New Beam pipe





More RF power

Ante-chamber & solenoid coils
to reduce photo-electron clouds



Damping ring

Linac upgrade

$L_0 = 2\times10^{35}/cm^2\ /sec$ → $L_f = 8\times10^{35}/cm^2\ /sec$

New site next to Frascati

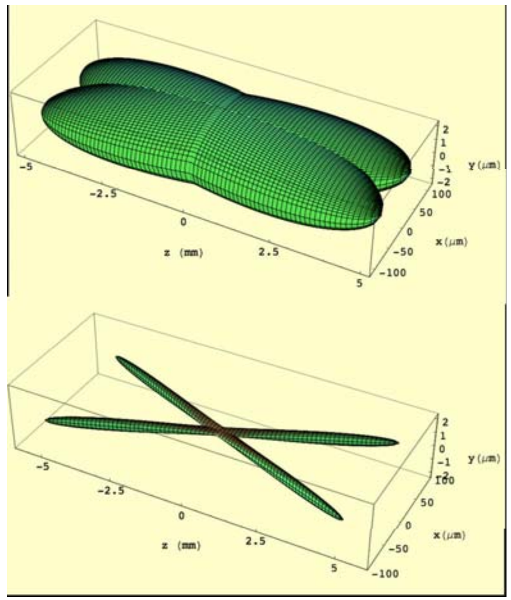
The Competition based in Italy

SuperB @ INFN

Conceptual Design Report has been finished. Review committee.

	PEP-II	SuperB
σ_z	1cm	1cm
$\theta_{1/2}$	0	25 mrad
σ_x	100 μm	2.7 μm
σ_z^{Eff}	1cm	40 μm
β_y	0.8 cm	80 μm
σ_y	4 μm	12 nm
ξ_y	0.07	< 0.07
$\mathcal{L}$	$\sim 10^{34}$	$\sim 10^{36}$

Beam size

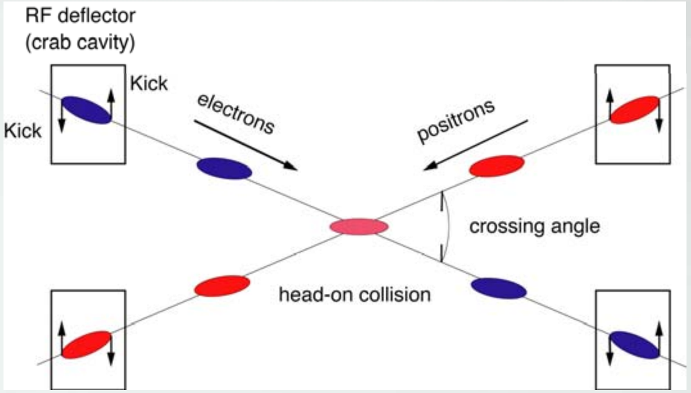


Question: 12 nanometer beam spot in y, 2.7 microns in x. Is this possible in a real 2-3 km circumference multi-orbit machine ?

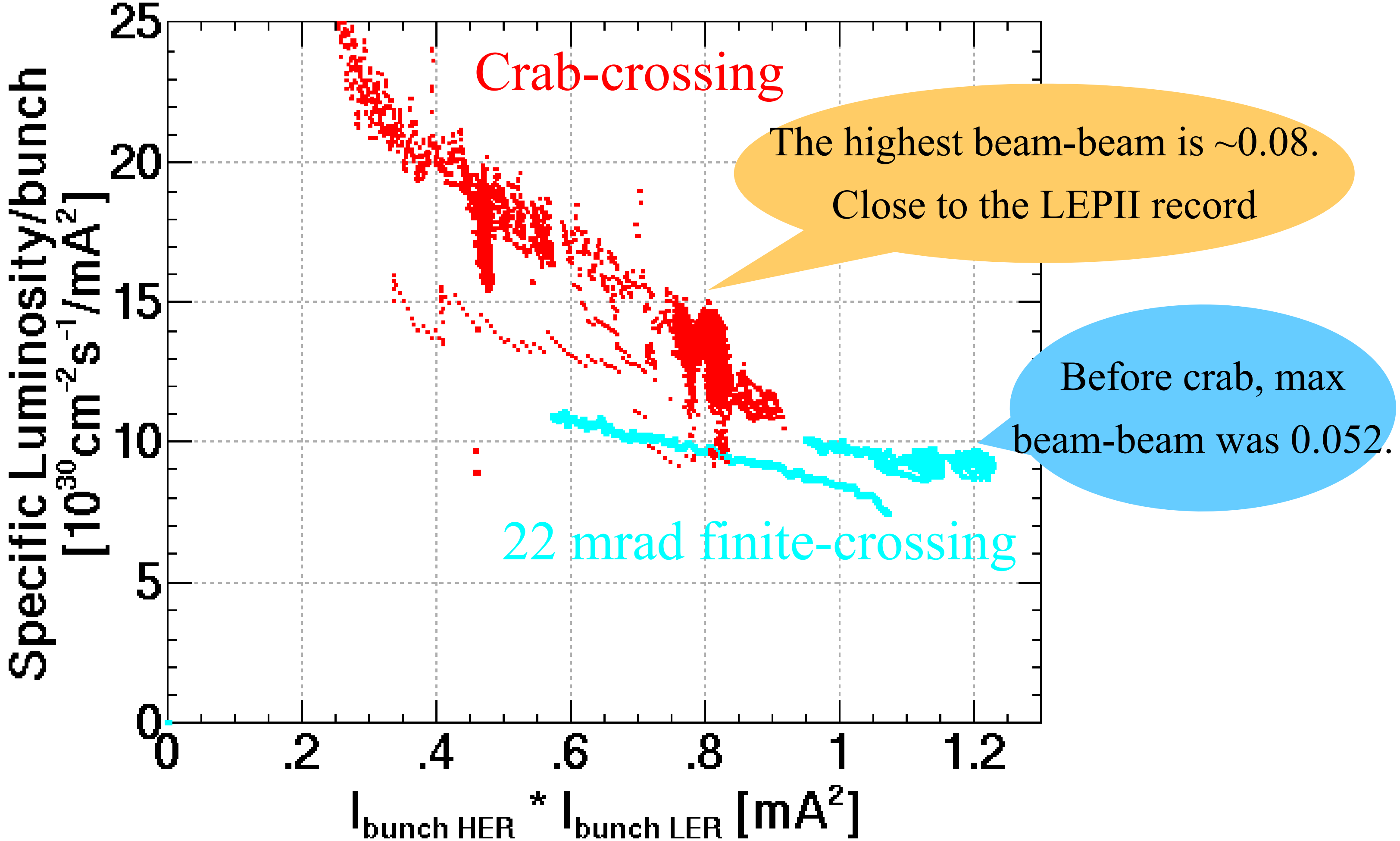
(Collaboration on beam dynamics with Ohnishi, Ohmi)

Super B Engineering: Crab crossing

- Superconducting crab cavities (1 LER and 1 HER) have been installed and now are being tested at KEKB.

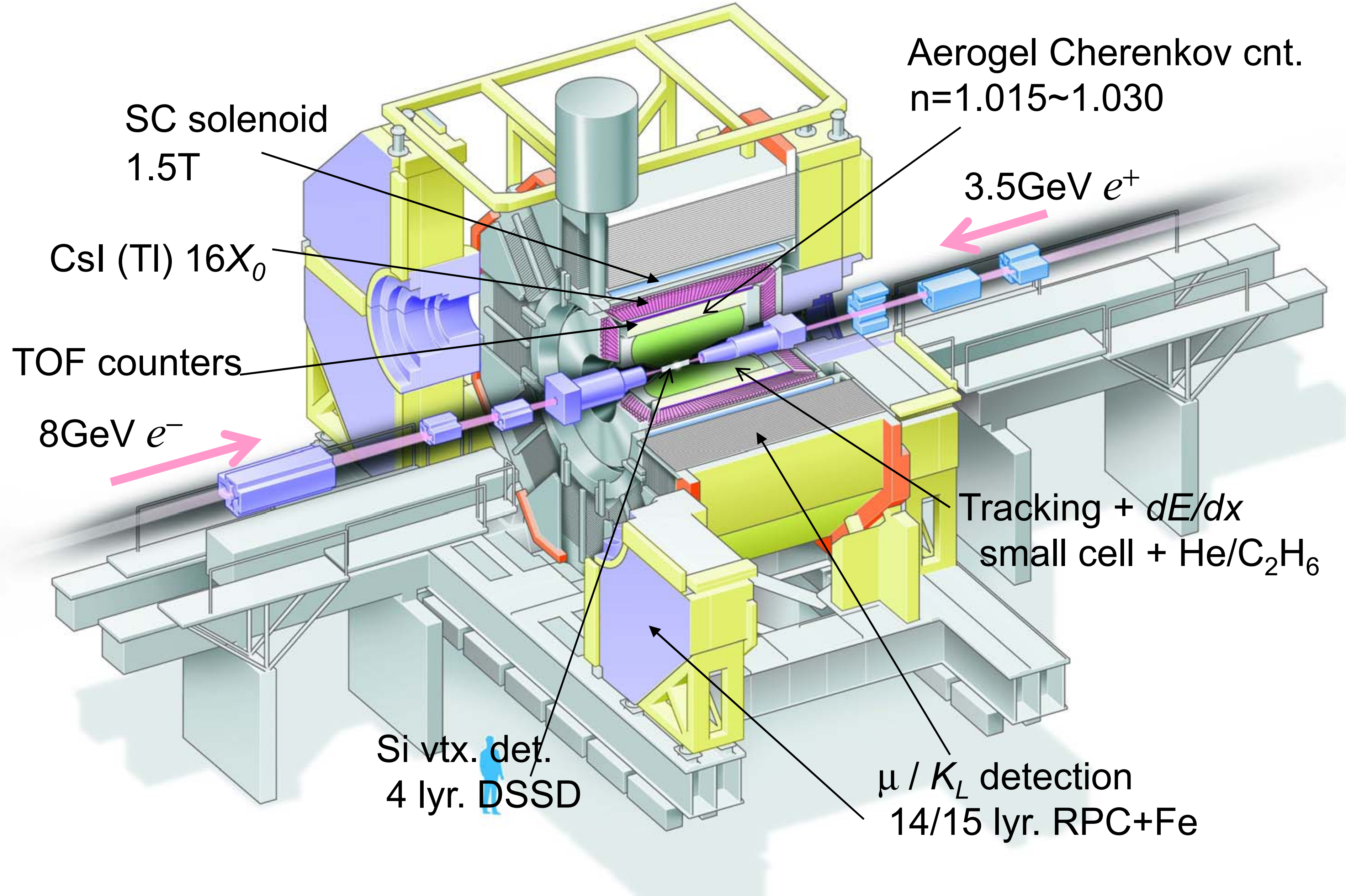


Crab Performance and Specific Luminosity at KEKB



So far (best with crab, I(e+)=1.6 A, I(e$^-$) =0.8 A)
L ~ 1.47 x 10^{34}cm^{-2}s^{-1}

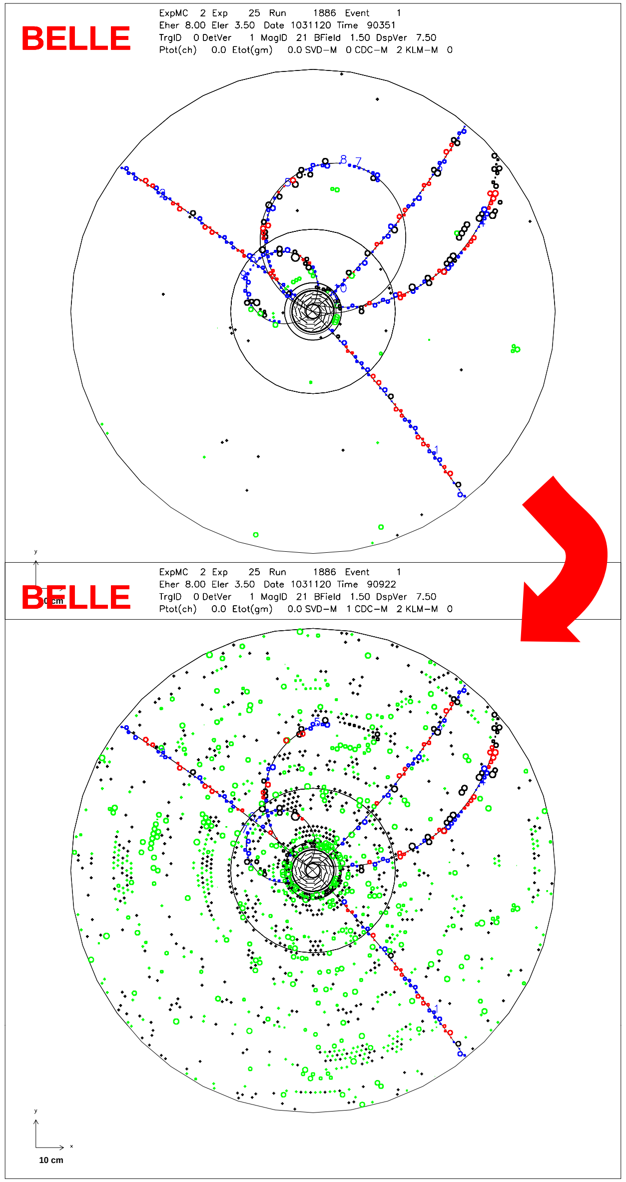
Belle Detector before the Super B upgrade



Requirements for the Super B detector

Issues:

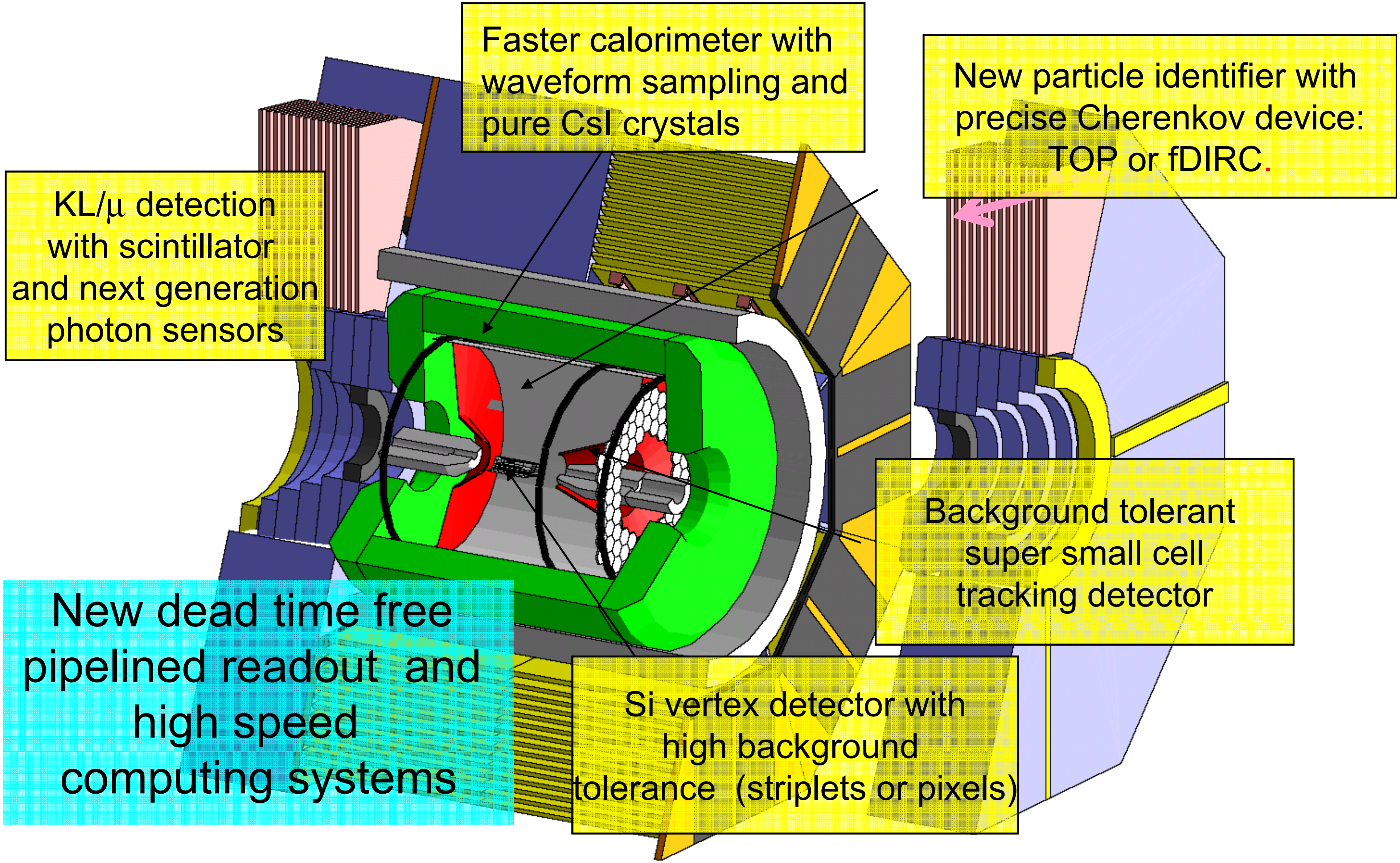
- **Higher background (×20)**
  - radiation damage and occupancy
  - fake hits and pile-up noise in the EM
- **Higher event rate (×50)**
  - higher rate trigger, DAQ and computing
- **Required special features**
  - low *p* μ identification ← sμμ recon. eff.
  - hermeticity ← ν “reconstruction”



Possible solution:

- Replace inner layers of the vertex detector with faster silicon readout or pixel detector
- Replace inner part of the central tracker with a silicon strip detector.
- Better particle identification device (TOP) focussing DIRC (fDIRC)
- Replace endcap calorimeter by pure CsI.
- Faster readout electronics and computing

Super Belle: A detector for SuperKEKB



Schedule and Plans at KEK

KEK's 5 year Roadmap

- Official 20 page report released on January 4, 2008 by director A. Suzuki and KEK management
- KEKB's upgrade to $2x10^{35}$ in 3+x years is the central element in particle physics. (Higher luminosity is not excluded.)
  - Will be finalized after recommendations by the Roadmap Review Committee (March 9-10).
    - Membership: Young Kee Kim, John Ellis, Rolf Heuer, Jon Rosner, Andrew Hutton and reviewers from material science and other fields.

Super-Belle (and Super KEKB) is an open international project.

Please join us for the next order of magnitude of exploration on the luminosity frontier

Backup Material

Preliminary schedule for Super Belle Detector Upgrade

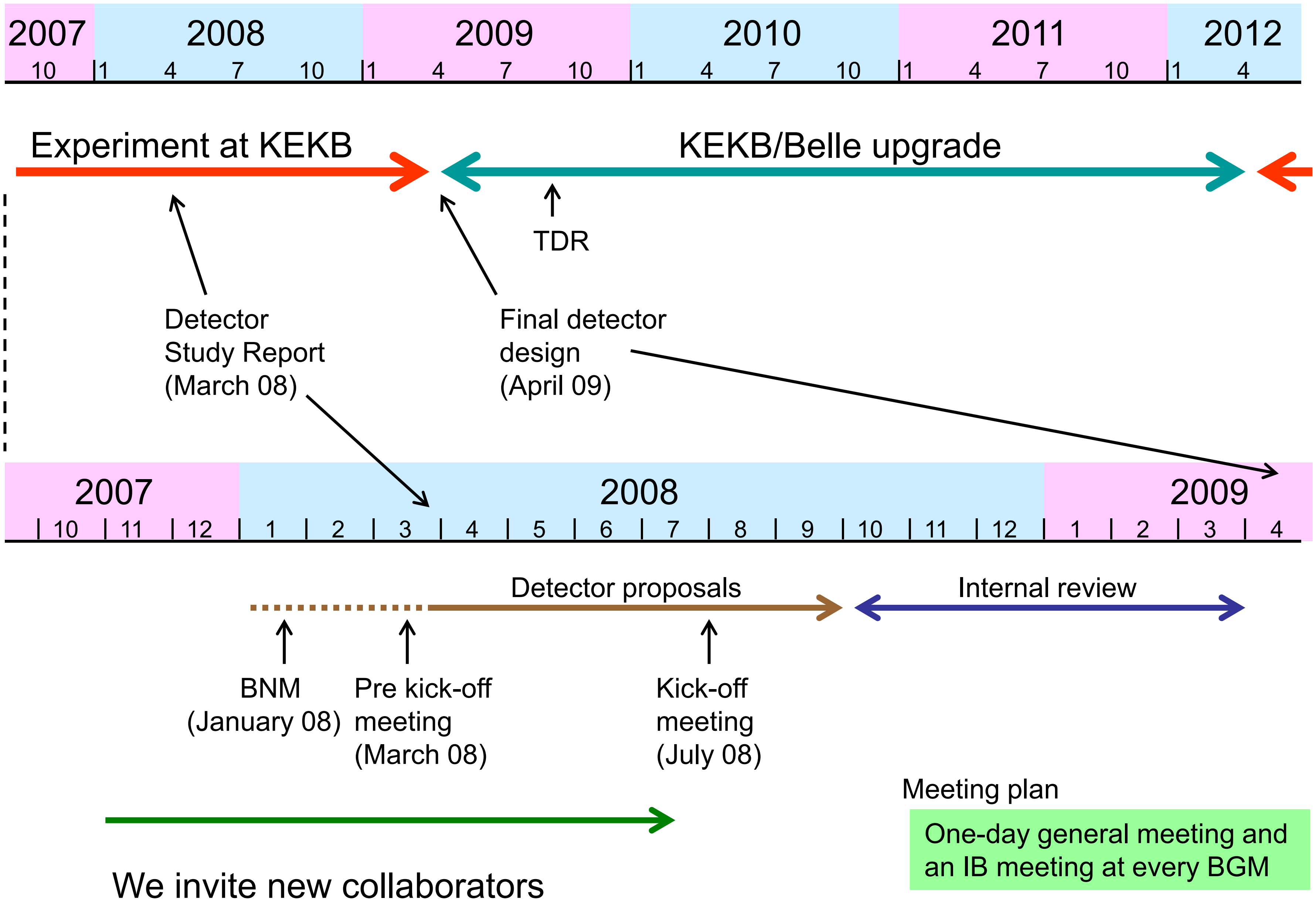


Table of Super B sensitivities at 50-75 ab^{-1}

Hard to condense all the NP observables into one sound bite……

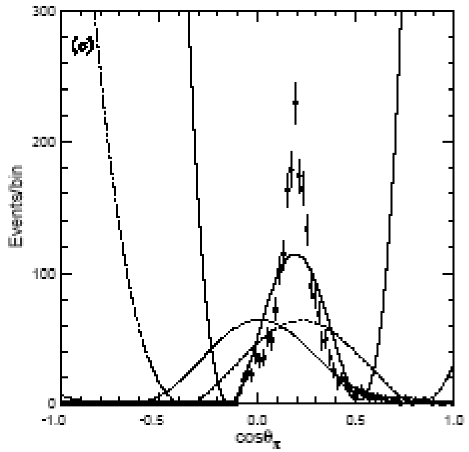
Observable	Super Flavour Factory sensitivity
$\sin(2\beta)$ $(J/\psi K^0)$	0.005–0.012
γ $(B \to D^{(*)}K^{(*)})$	1–2°
α $(B \to \pi\pi, \rho\rho, \rho\pi)$	1–2°
$\lvert V_{ub}\rvert$ (exclusive)	3–5%
$\lvert V_{ub}\rvert$ (inclusive)	2–6%
$\bar{\rho}$	1.7–3.4%
$\bar{\eta}$	0.7–1.7%
$S(\phi K^0)$	0.02–0.03 ⇐
$S(\eta' K^0)$	0.01–0.02
$S(K_S^0 K_S^0 K_S^0)$	0.02–0.04
$\mathcal{B}(B \to \tau\nu)$	3–4% ⇐
$\mathcal{B}(B \to \mu\nu)$	5–6%
$\mathcal{B}(B \to D\tau\nu)$	2–2.5%
$\mathcal{B}(B \to \rho\gamma)/\mathcal{B}(B \to K^*\gamma)$	3–4%
$A_{CP}(b \to s\gamma)$	0.004–0.005
$A_{CP}(b \to (s+d)\gamma)$	0.01
$S(K_S^0\pi^0\gamma)$	0.02–0.03
$S(\rho^0\gamma)$	0.08–0.12
$A^{FB}(B \to X_s\ell^+\ell^-)$ s_0	4–6%
$\mathcal{B}(B \to K\nu\bar{\nu})$	16–20% ⇐
$\mathcal{B}(\tau \to \mu\gamma)$	$2\text{–}8 \times 10^{-9}$
$\mathcal{B}(\tau \to \mu\mu\mu)$	$0.2\text{–}1 \times 10^{-9}$
$\mathcal{B}(\tau \to \mu\eta)$	$0.4\text{–}4 \times 10^{-9}$

From T. Browder et al., hep-ph/0710.3799

Backup slide for Z(4430) discussion

Table 3: $\cos\theta_\pi$-dependence for the κ, $K^*(890)$ and $K_2^*(1430)$ helicity states.

resonance	Longitudinal ψ'	Transverse ψ'
κ	constant	$--$
$K^*(890)$	$\cos\theta_\pi$	$\frac{1}{\sqrt{2}}\sin\theta_\pi$
$K_2^*(1430)$	$\frac{3}{2}\cos\theta_\pi^2 - \frac{1}{2}$	$\sqrt{\frac{3}{2}}\sin\theta_\pi\cos\theta_\pi$



Interference between K*'s cannot produce the signal (makes other structures)

$J^P = 1^+$ slightly favored but 0^- and 1^- also give acceptable chi^2

J^P	$\lvert dN/d\cos\theta_{\pi\ell^+}\rvert$ χ^2 (CL)	$\lvert dN/d\cos\theta_{K\ell^+}\rvert$ χ^2 (CL)
0^-	12.2 (1.6%)	3.5 (49%)
1^-	1.5 (83%)	8.5 (7.6%)
1^+ (S-wave)	3.2 (52%)	1.6 (81%)

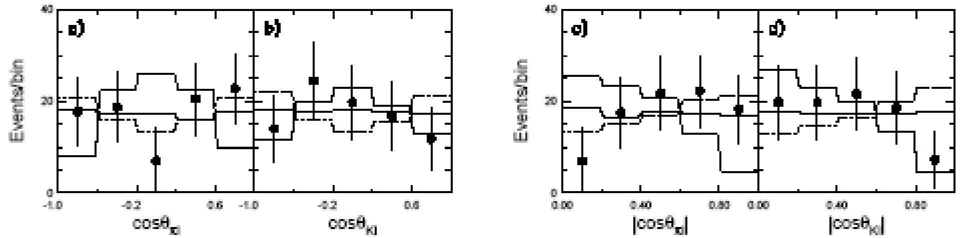


Figure 11: $M(\pi\psi')$-sideband-subtracted distributions for **(a)** $\cos\theta_{\pi\ell^+}$ and **(b)** $\cos\theta_{K\ell^+}$ distributions for events with $M(\pi\psi')$ within ± 30 MeV of the 4430 MeV peak. The histograms are MC results for the 0^- (dotted), 1^- (dashed) and 1^+ S-wave (solid) MC samples. The corresponding $|\cos\theta_{\pi\ell^+}|$ and $|\cos\theta_{K\ell^+}|$ distributions are shown in **(c)** and **(d)**,respectively.

Z(4430) discussion: backup slides

Examine large MC samples to look
for reflections

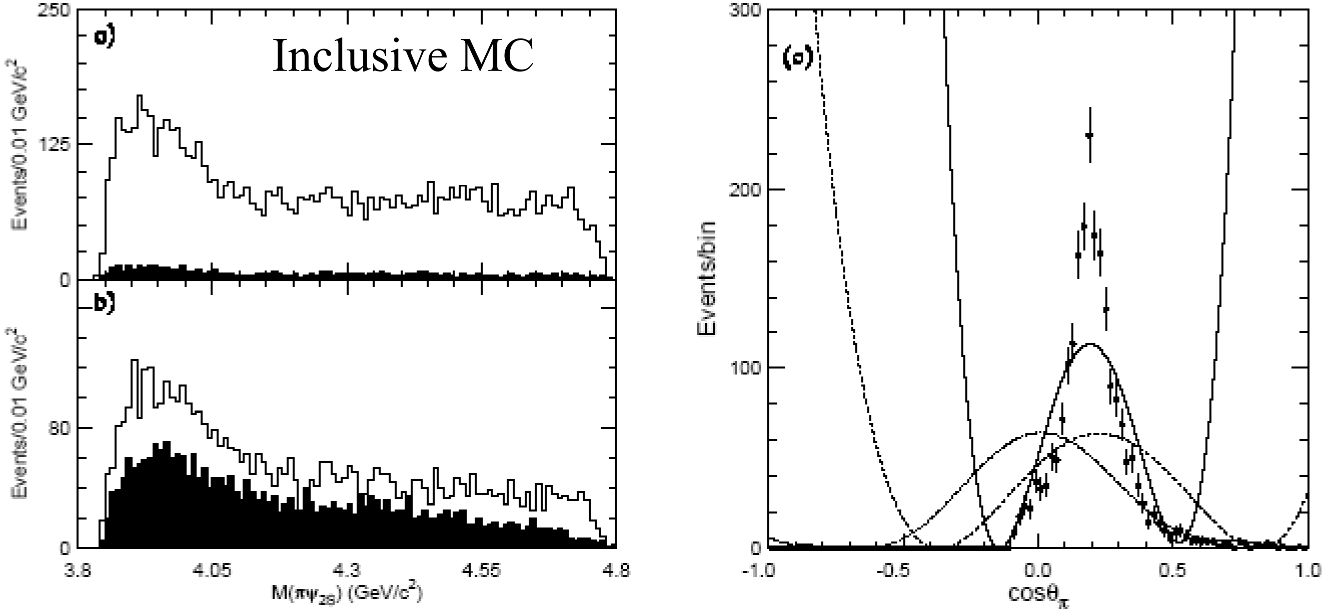


Figure 10: Right: $M(\pi\psi')$ distributions from very large inclusive Monte Carlo samples of inclusive **(a)** $\psi' \to \ell^+\ell^-$ and **(b)** $J/\psi \to \ell^+\ell^-$ events. The shaded histograms indicate background levels determined from ΔE sidebands. Left: **(c)** The $\cos\theta_\pi$ distribution for a MC-generated resonance with $M = 4.430$ GeV and $\Gamma = 0.05$ GeV. The curves show the results of fits described in the text.

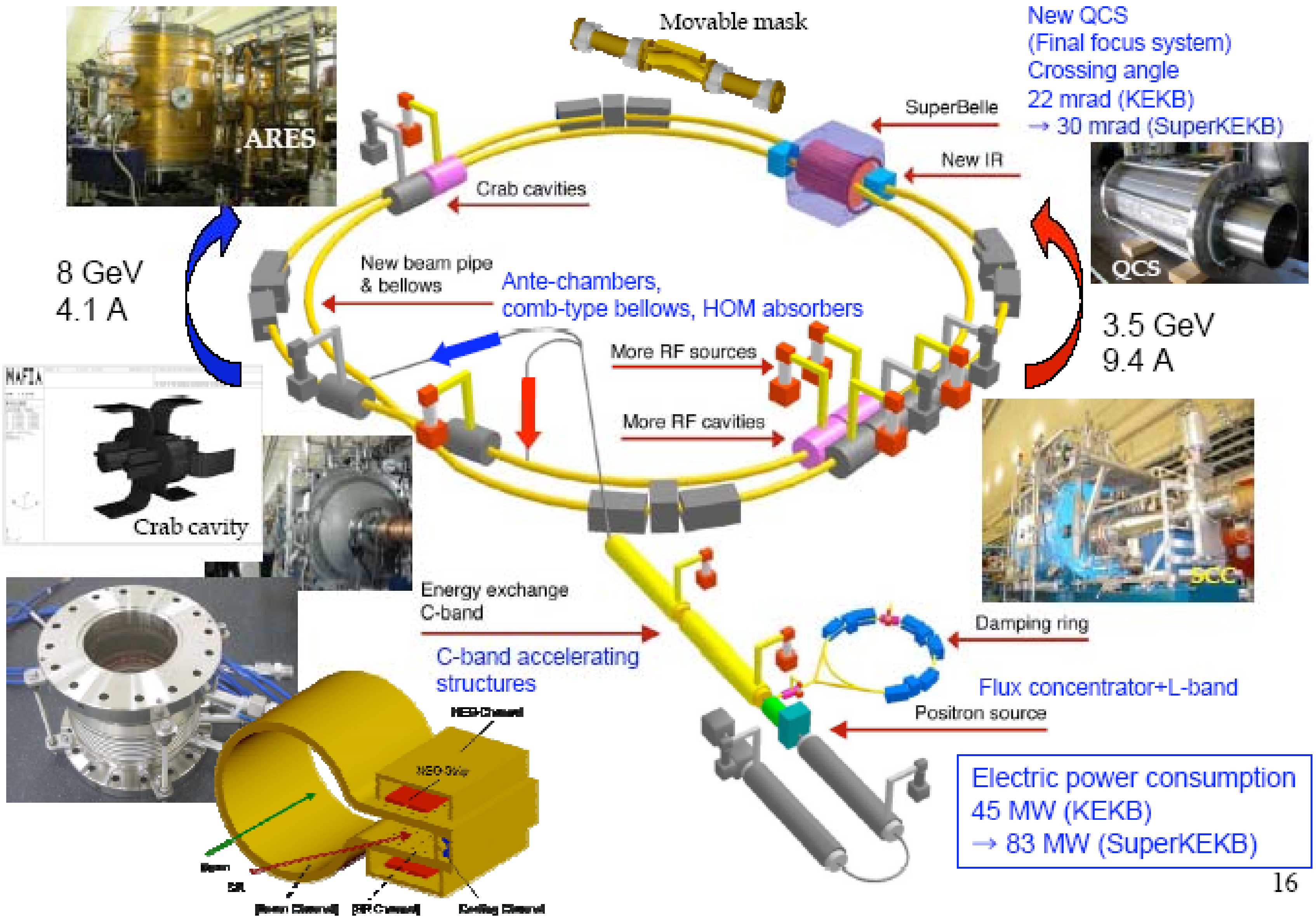
Comparison between SuperB and SuperKEKB

		SuperB (Nominal)	SuperKEKB (2006)	
Emittance	ε_x	1.6	9	nm
Horizontal beta	β_x^*	20	200	mm
Vertical beta	β_y^*	0.3	3	mm
Horizontal beam size	σ_x^*	5.7	42	μm
Vertical beam size	σ_y^*	35	367	nm
Bunch length	σ_z	6	3	mm
Half crossing angle	ϕ_x	17	15	mrad
Piwinski angle	φ	18	1	rad
Current(LER/HER)	I_b	2.28/1.30	9.4/4.1	A
Luminosity (x10[35])	L	10	8	$cm^{-2}s^{-1}$
AC Plug Power	P	34	83	MW

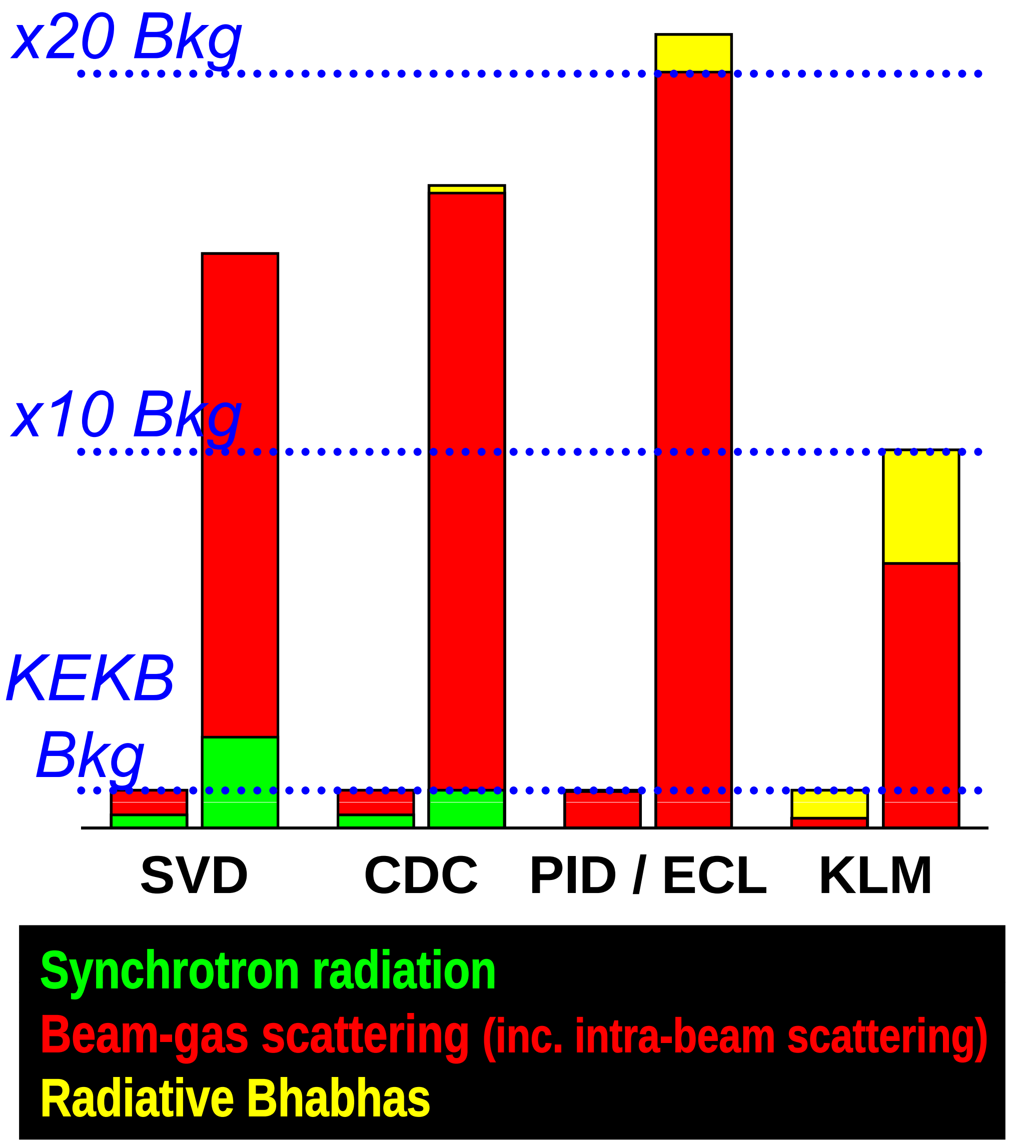
← One order magnitude smaller than SuperKEKB

AC power for KEKB is already 40 MW. Max site power is 100 MW at KEK.

Upgraded Components for SuperKEKB



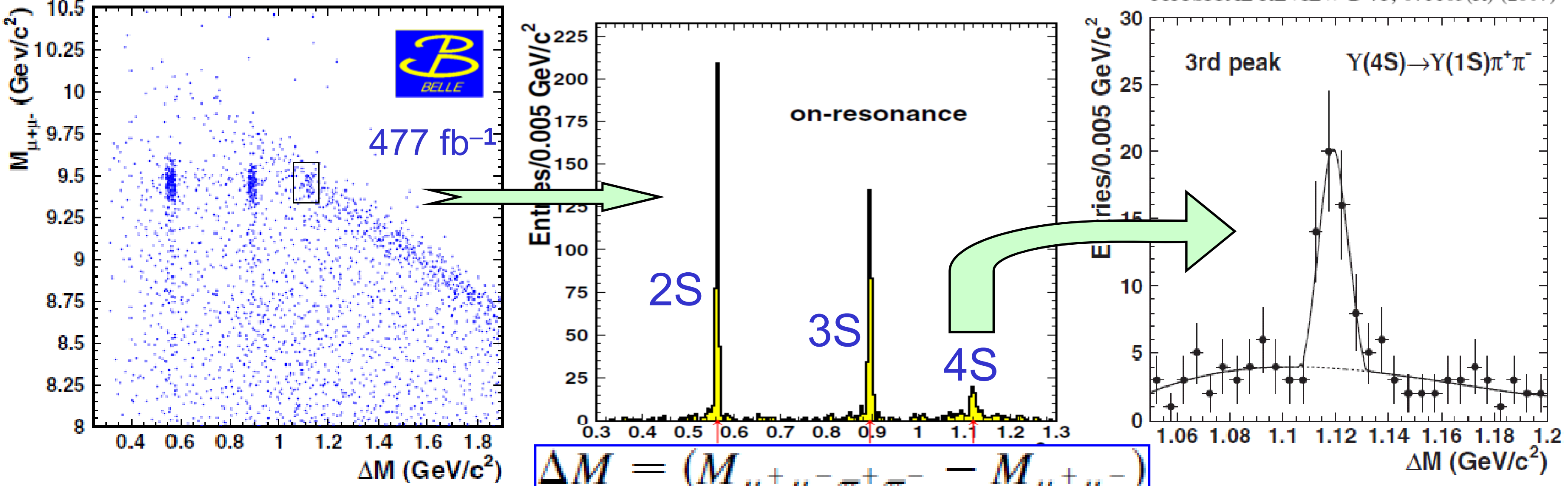
Detector issue: backgrounds



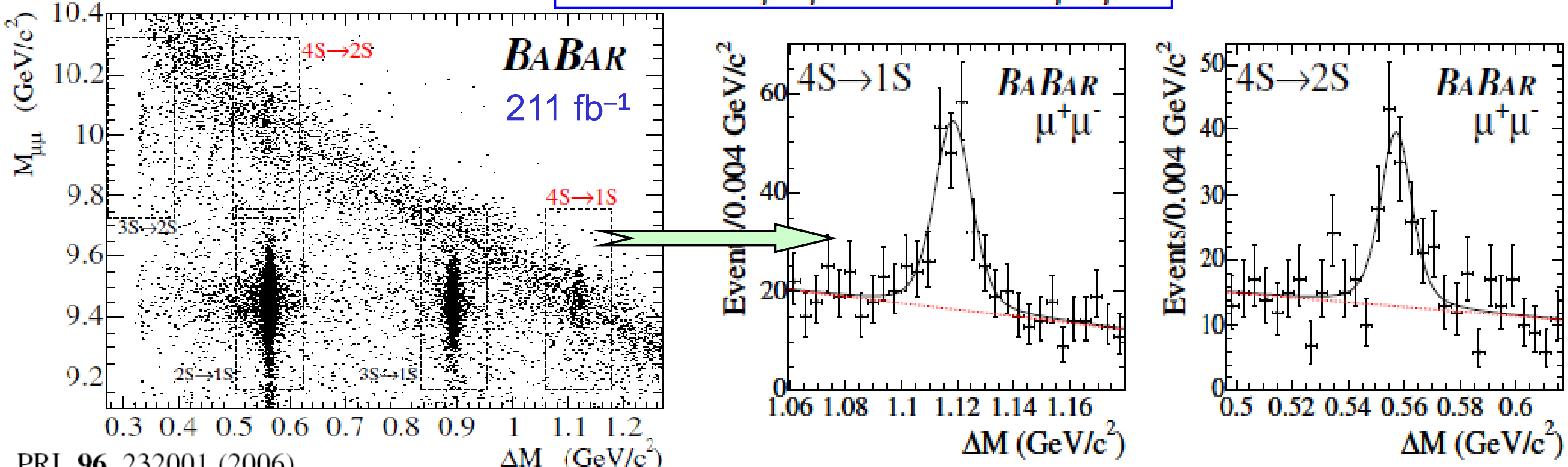
	KEKB	SuperB
Luminosity ($10^{34}cm^{-2}sec^{-1}$)	1.7	80
HER curr. (A)	1.2	4.1
LER curr. (A)	1.6	9.4
vacuum (10^{-7}Pa)	~1.5	5
Bkg increase	-	~ 20
TRG rate (kHz)	0.4	
phys. origin	0.2	
Bkg origin	0.2	

Non-B Bbar decays: $\Upsilon(4S) \rightarrow \Upsilon(1S)\,\pi^- \pi^+$ Template

PHYSICAL REVIEW D **75,** 071103(R) (2007)



$$\Delta M = (M_{\mu^+\mu^-\pi^+\pi^-} - M_{\mu^+\mu^-})$$



PRL **96,** 232001 (2006)

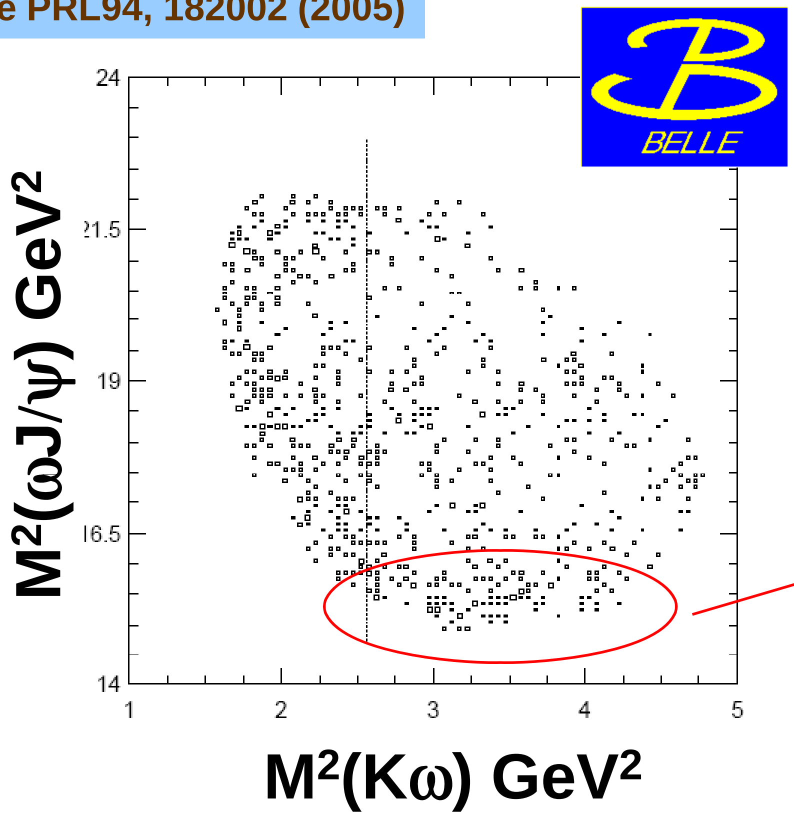
Next state: Y(3940) in B→K ωJ/ψ

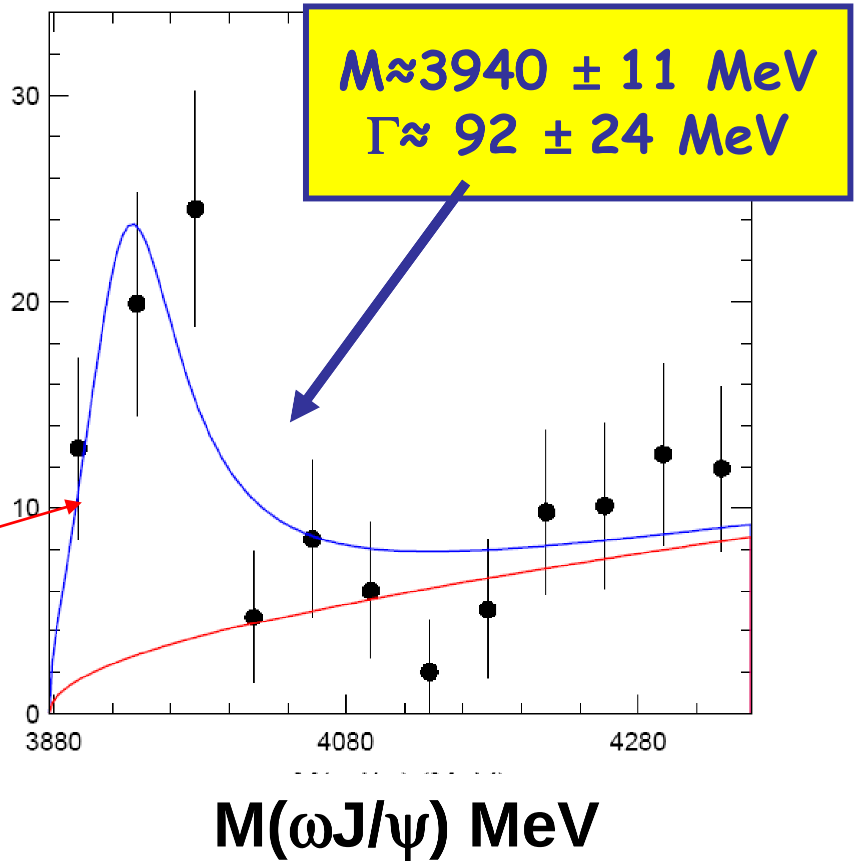
Reconstruct, B→K ω J/ψ.

Cut on K ω mass to remove contributions from K** resonances

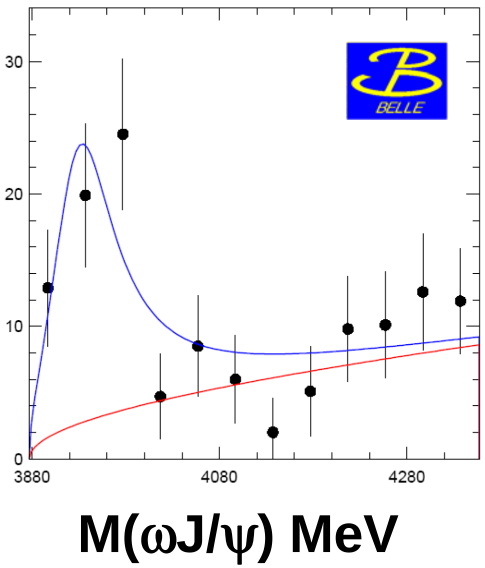
S-K Choi, SL Olsen et al,

Belle PRL94, 182002 (2005)





Y(3940) properties



Belle PRL94, 182002 (2005)

$\Gamma(Y_{3940} \rightarrow \omega J/\psi) \gtrsim 7$ MeV
(an $SU_F(3)$ violating decay)

this is $10^3 \times \Gamma(\psi' \rightarrow \eta J/\psi)$
(another $SU_F(3)$ violating decay)

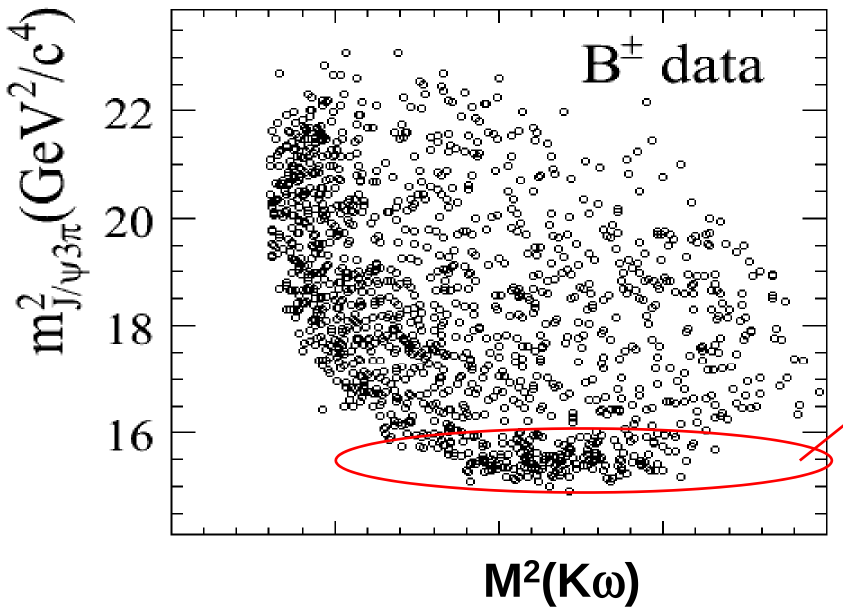
if the Z(3930) is the χ_{c2}' the Y(3940) mass is too high for it to be the χ_{c1}'

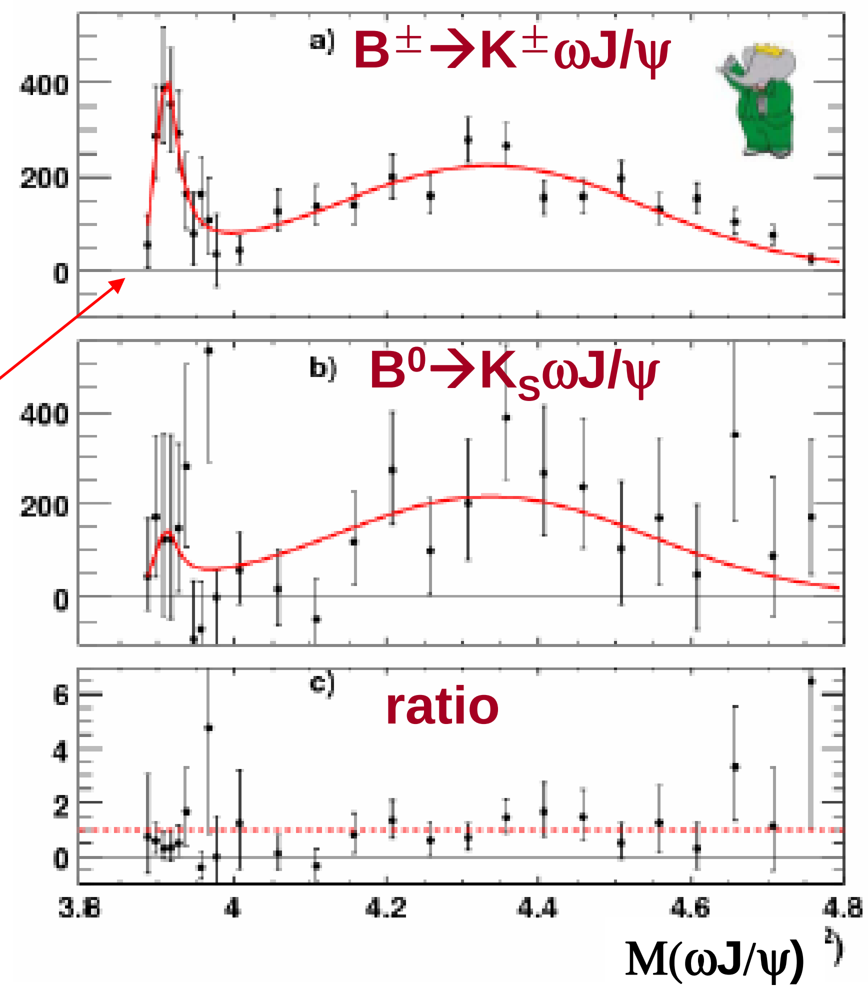
Jon Rosner: However, $\chi_b^{1,2}$ states are seen to decay to ω Y(1S)

Y(3940), confirmed by BaBar

G.Cibinetto
EPS-2007

$B^{\pm} \rightarrow K^{\pm}\omega J/\psi$

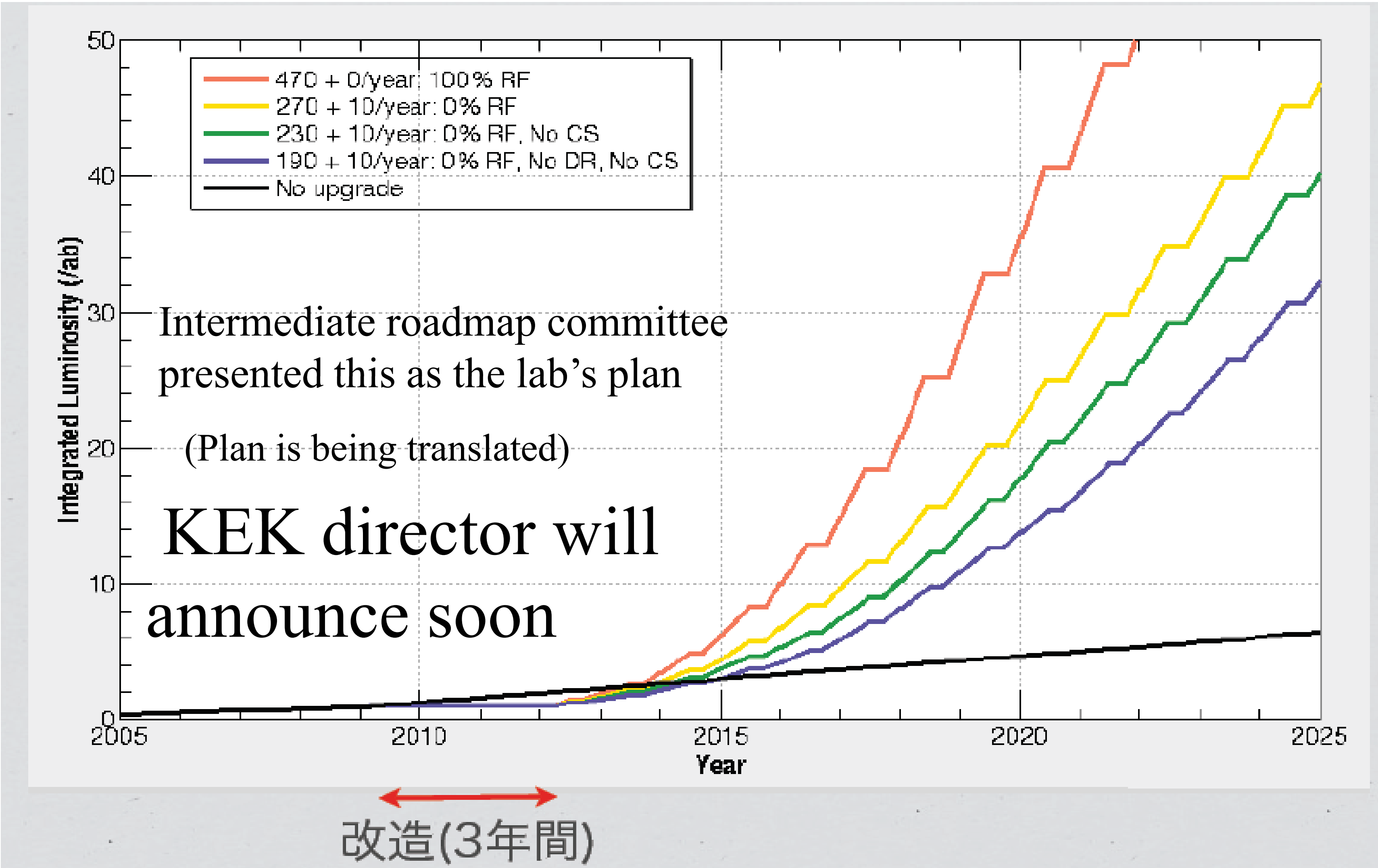




	Mass (MeV)	Γ (MeV)
Belle 253 fb^{-1}	$3943 \pm 11(stat) \pm 13(syst)$	$87 \pm 22(stat) \pm 26(syst)$
BaBar 350 fb^{-1}	$3914.3^{+3.8}_{-3.4}(stat)^{+1.6}_{-1.6}(syst)$	$33^{+12}_{-8}(stat)^{+0.6}_{-0.6}(syst)$

Some discrepancy in M & Γ; general features agree

"What can be accomplished for 200 oku-yen or ~ 200 x 10^6 dollars ?"



Intermediate roadmap committee presented this as the lab's plan

(Plan is being translated)

KEK director will announce soon

Intermediate conclusions/features of the new states

- **Some states are narrow even though they are far above decay thresholds**
  - **e.g. Y(4660)→$\pi\pi\psi'$ & Z^+(4430)→$\pi^+\psi'$ have large Q but Γ≈50 MeV**

- **characterized by large partial widths (BFs) to hadrons+J/ψ (or ψ')**
  - **BF(X(3872)→ρJ/ψ) > 4.3% (Isospin=1)**
  - **Γ(Y(3940)→ωJ/ψ) > 7 MeV (SU(3) octet)**
  - **Γ(Y(4260)→$\pi^+\pi^-$J/ψ) > 1.6 MeV**

- **States that decay to ψ' not seen decaying to J/ψ (and vice-versa)**
  - **BF(Y(4660)→$\pi\pi\psi'$) >> BF(y(4660)→$\pi\pi$J/ψ) ← same for Y(4360) & Z(4430→$\pi\psi'$**
  - **Y(4260) not seen in Y(4260)→$\pi\pi\psi'$**

- **The new 1^{--} states are not apparent in the e^+e^-→$D^{(*)}D^{(*)}$ cross sections**

- **There are no evident transitions at the D**D mass threshold**

None of this was anticipated

KEKB: 1st test of crab crossing

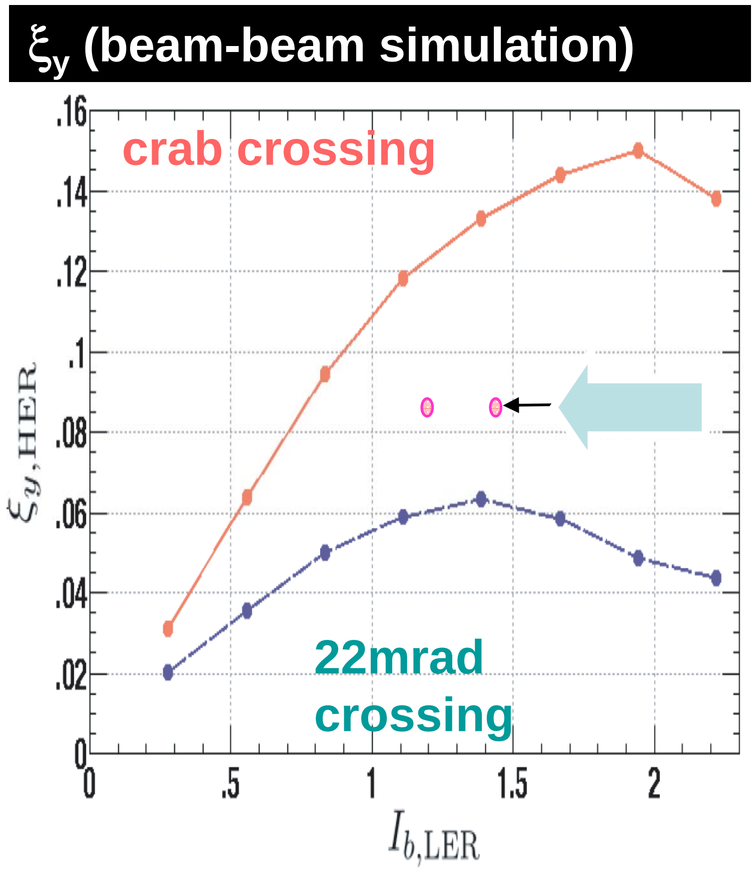
- Commissioning with beam
  - 4.5 months dedicated machine time (Mid Feb. -- end of June 2007)
- Performance with crab crossing
  - Encouraging but not easy
    - Machine error? Vertical? Narrow optimum in minimization ?
  - Specific luminosity ~ (30-40)% higher
  - Bunch current limitation in beam life time

Bottom line so far:

L ~ 1.47 x $10^{34}cm^{-2}s^{-1}$

[I(e+)=1.5 A, I(e^-) =0.8 A]

Data vs MC



http://www.jahep.org/hec/doc/jahep_tenbou_eng_final.pdf

Prospects for Elementary Particle Physics

The Japan Association of High Energy Physicists (JAHEP)

October 25, 2006

(An excerpt)

We, the Japanese HEP community, recognize that physics at the energy frontier is of primary importance. With this understanding, we give the highest priority to the realization of the ILC. Before the ILC experiment commences, we will also promote flavor physics that is complementary to physics at the energy frontier. We should pursue the above two goals as a single master plan.

....

Based on these achievements, we will endeavor to make neutrino and kaon experiments at J-PARC successful, and promote an upgrade of the B factory to achieve a significant breakthrough in luminosity in order to explore new physics that emerges in the phenomena of b, c and τ decays.

Recommendation by Belle-PAC

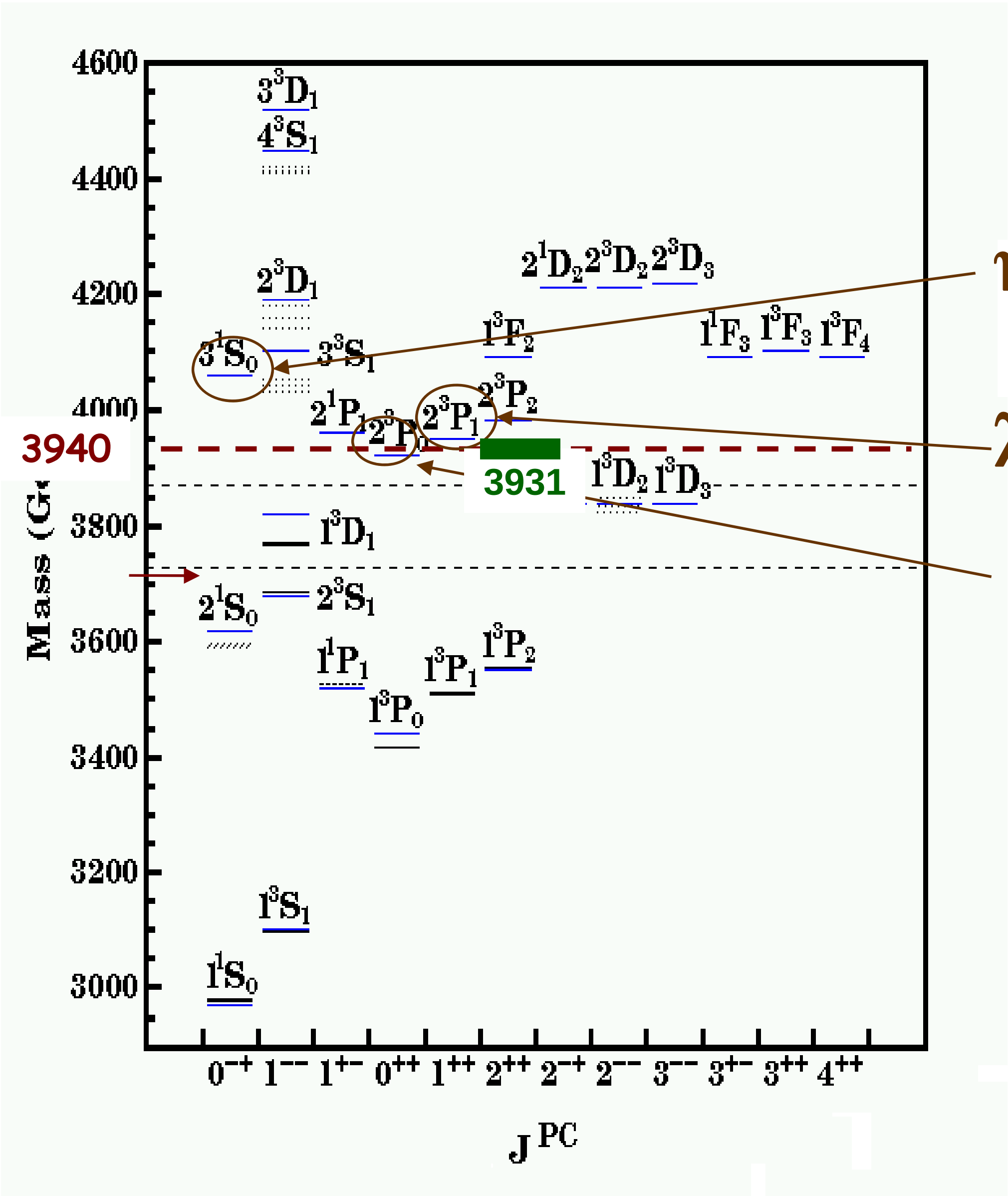
- The committee provided a strong endorsement for SuperKEKB at the review in April 2007.

In summary, the committee reached the following conclusions:

1) We endorse strongly the realization of a very high luminosity e^+e^- B meson factory for its potential to investigate physics beyond the Standard Model and improve our understanding of electroweak and strong dynamics.
2) We think that a timely realisation of such a facility is important so that several tens of ab^{-1} of $\Upsilon(4S)$ data can be collected by the middle of the next decade.
3) We think that KEK is an ideal laboratory to realise such a project by upgrading the existing KEK-B accelerator. It has a proven record in producing high performance e^+e^- machines and a successful and highly motivated experimental group, which could act as a catalyst for the new collaboration. Having the kaon and neutrino programme at JPARC, KEK would become a unique place in the world to explore flavour physics that is a complementary and, in some areas, more sensitive approach to investigate physics beyond the Standard Model than the experiments at the high energy frontier.

- This is important support from the int'l community.

Is there a $c\bar{c}$ slot for Y(3940) ?



η_c'' Mass is low

χ_{c1}' Can $M(\chi_{c1}')>M(\chi_{c2}')$?
(ok with BaBar mass value)

χ_{c0}' " " " "

For any charmonium assignment,
Γ[Y(3940)→ω J/ψ] is too large.

Braaten et al: Theoretical X→D D^{*0} mass spectrum

Theoretical prediction for a loosely bound D D^* state.

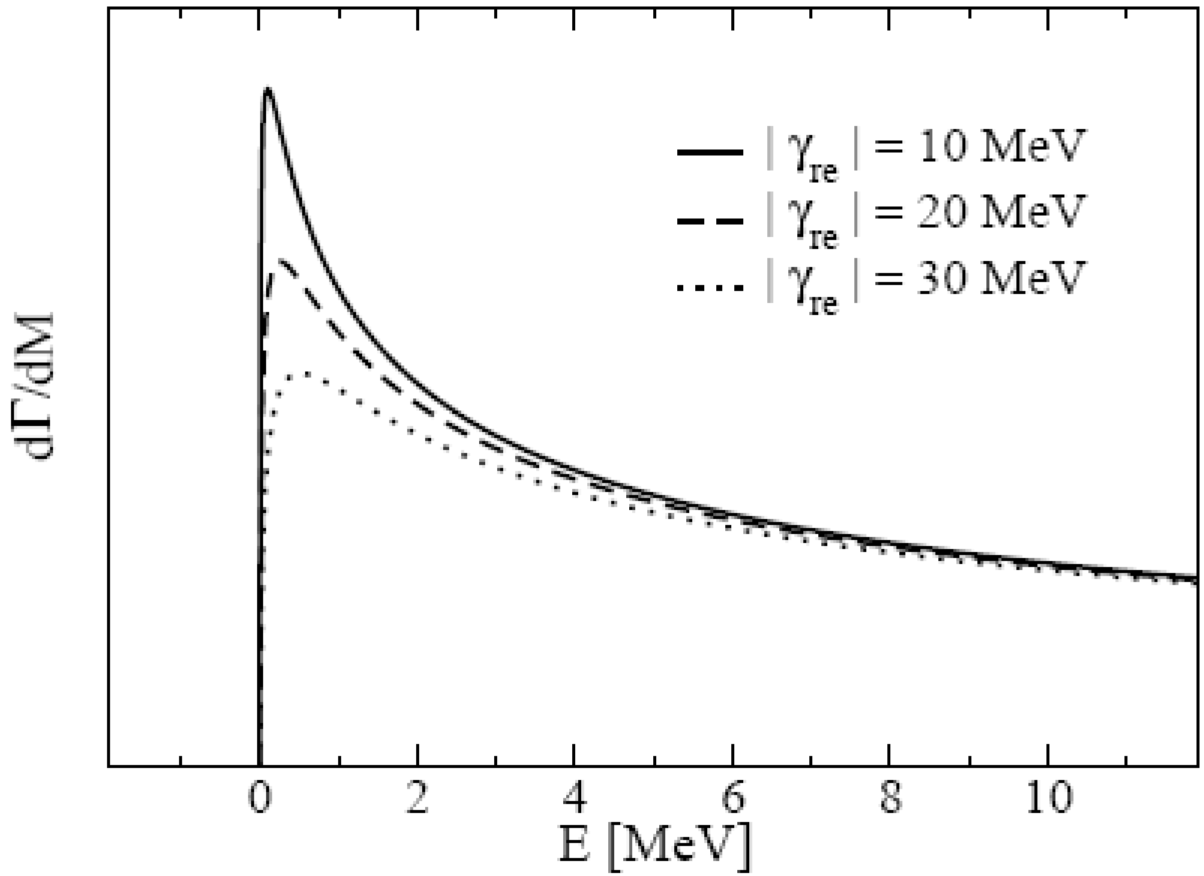


FIG. 6: The DD^* invariant mass distribution in $B \to D^0 \bar{D}^{*0} K$ for $\gamma_{\rm im} = 10$ MeV and various values of $|\gamma_{\rm re}|/\gamma_{\rm im}$. The horizontal axis is the difference $E = M - (m_{D^0} + m_{D^{*0}})$ between the invariant mass M and the $D^0 \bar{D}^{*0}$ threshold.

Recent News

electrically charged!!

Observation of a resonance-like structure in the $\pi^{\pm}\psi'$ mass distribution in exclusive $B \to K\pi^{\pm}\psi'$ decays

(The Belle Collaboration)

arXiv:0708.1790v1 [hep-ex] 14 Aug 2007

S-K Choi, SL Olsen et al,

Belle, submitted to PRL

$$\mathcal{B}(\bar{B}^0 \to K^- Z^+(4430)) \times \mathcal{B}(Z^+(4430) \to \pi^+\psi') = (4.1 \pm 1.0 \pm 1.4) \times 10^{-5},$$

First Observation of $B^0 \to D^{*-} \tau^+ \nu_\tau$

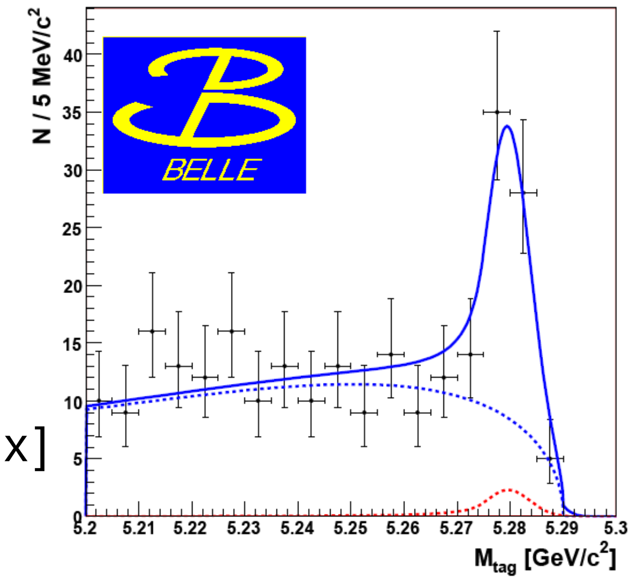
535 M $B\bar{B}$

$N_s = 60 \,^{+12}_{-11}$

6.7σ (5.2σ with syst.)

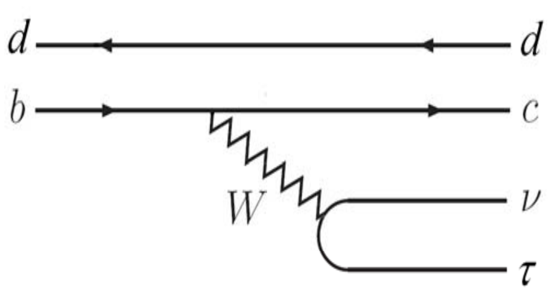
arXiv:0706.4429[hep-ex]

to appear in PRL

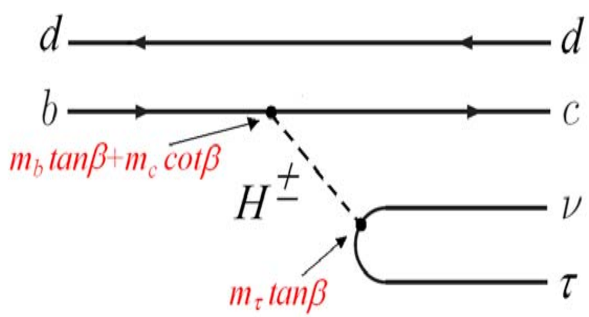


Use detector hermiticity and "inclusive B reconstruction" to isolate this 3-neutrino final state *(large missing energy)*

$$Bf(B^0 \to D^{*-} \tau^+ \nu) = (2.02 \,^{+0.40}_{-0.37} \pm 0.37)\ \%$$



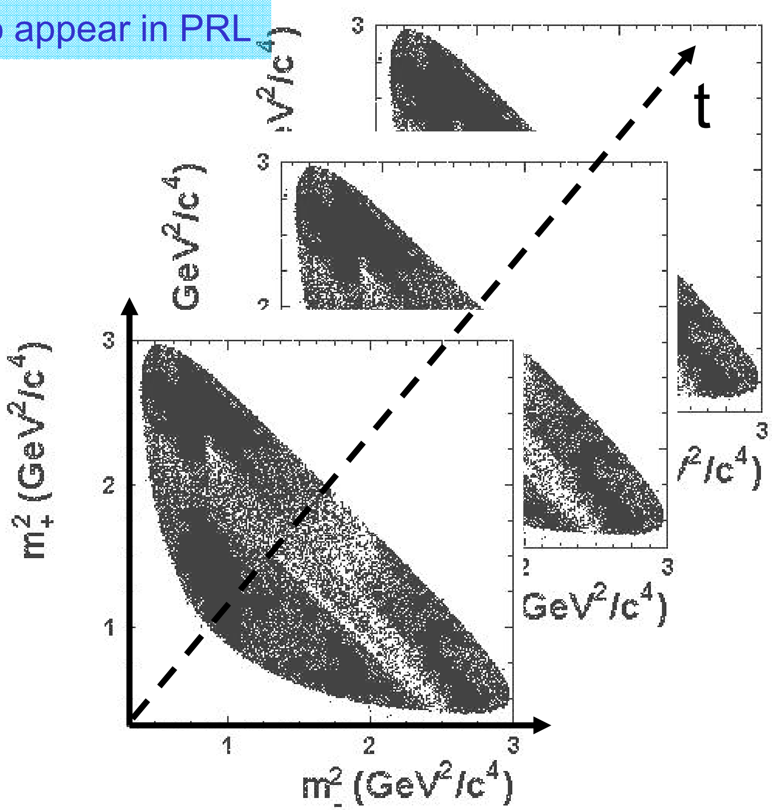
SM contribution



NP: Charged Higgs contribution

arXiv: 0704.1000, 540 fb^{-1}, to appear in PRL

Measurements $K_S \pi^+\pi^-$



Fit

no CPV: $\frac{q}{p} = 1, \ \mathcal{M}(m_-^2, m_+^2) = \overline{\mathcal{M}}(m_+^2, m_-^2)$

fit $\mathcal{M}(m_-^2, m_+^2, t)$ to data distribution ⇒ x, y

Signal

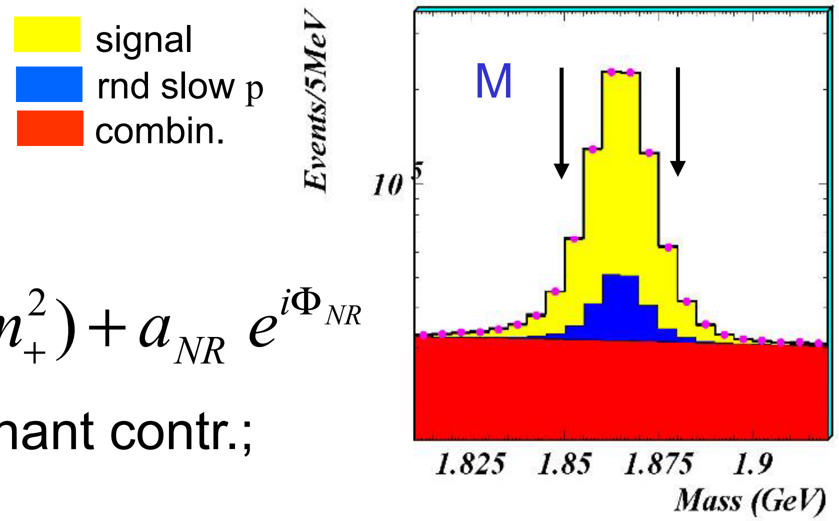
$M(K_S \pi^+\pi^-)$ and

$Q = M(K_S \pi^+\pi^-\pi_s) - M(K_S \pi^+\pi^-) - M(\pi)$;

3 σ signal region in M, Q

$N_{sig} = (534.4 \pm 0.8) \times 10^3$

$P \approx 95\%$

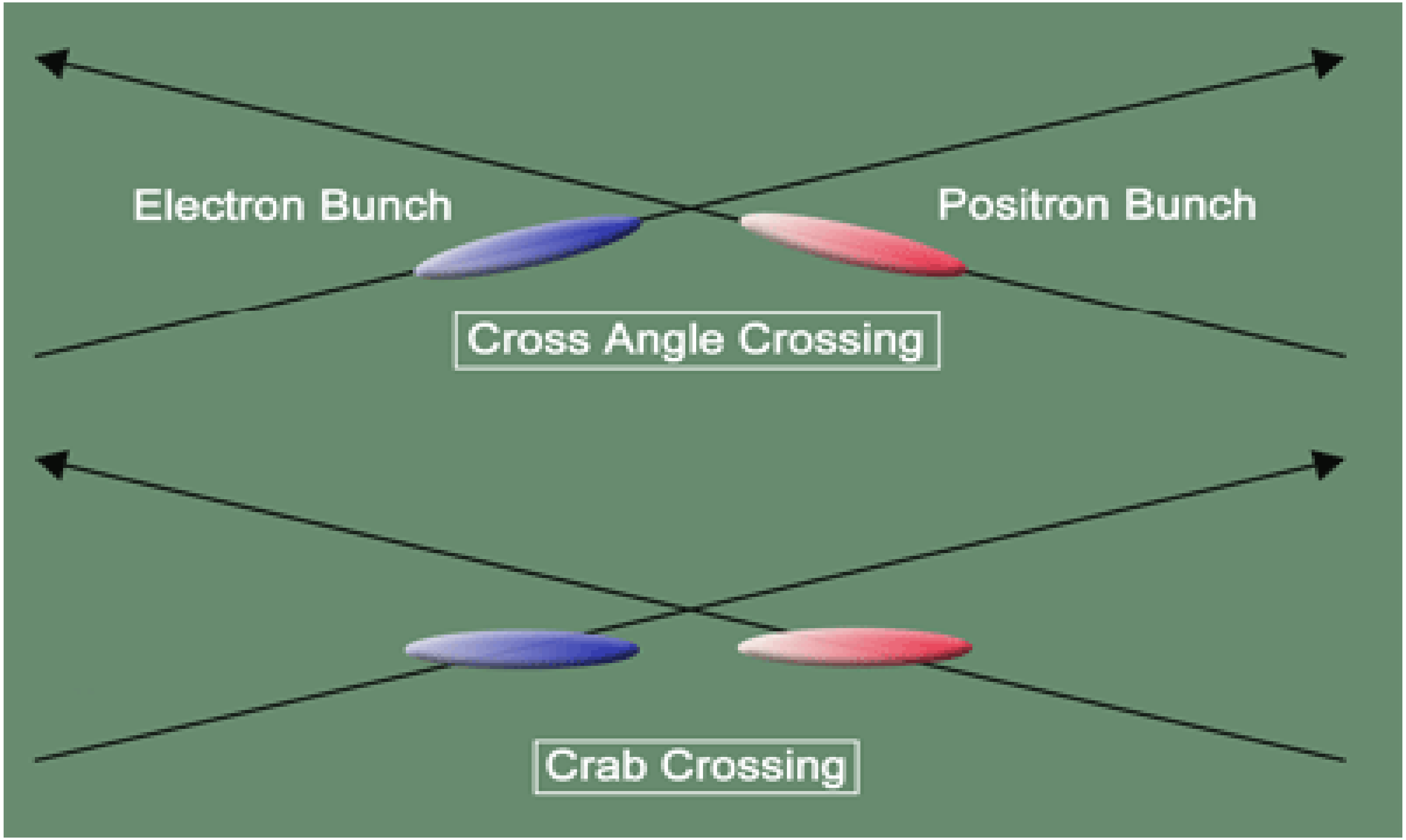


Dalitz model

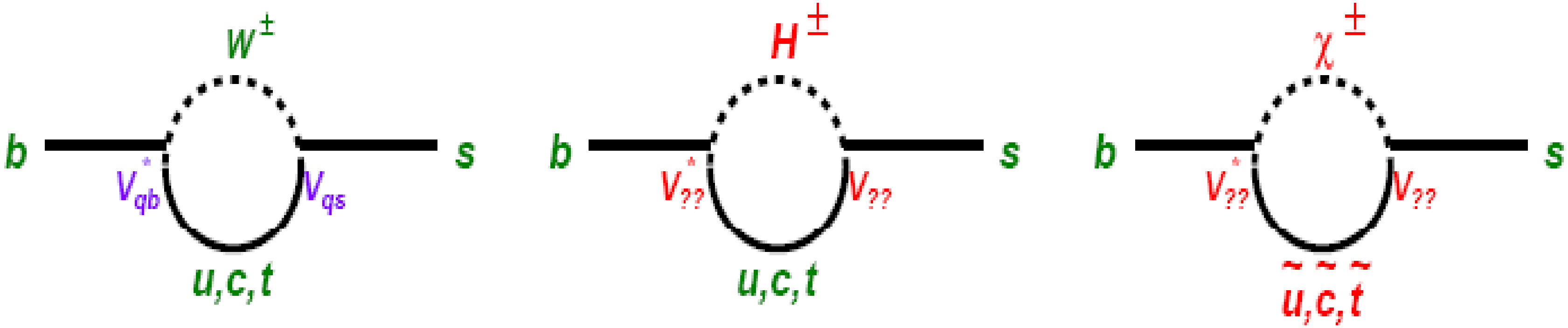
$$\mathcal{A}(m_-^2, m_+^2) = \sum a_r \, e^{i\Phi_r} B(m_-^2, m_+^2) + a_{NR} \, e^{i\Phi_{NR}}$$

13 BW resonances, non-resonant contr.;
comb. bkg.: from M sideband

Finite angle crossing and Crabbing



Results on Radiative and Electroweak Penguins

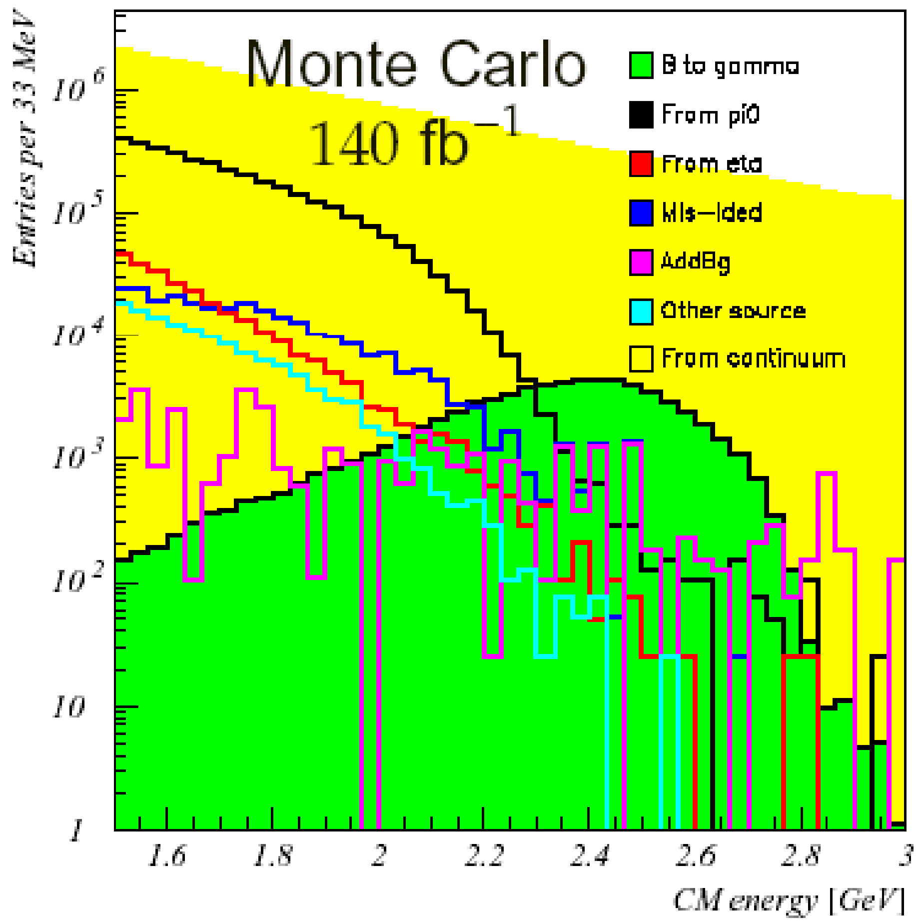


Example discussed here: modifications to the rate for b→s γ

Measurement of inclusive $b \to s\gamma$

$$\Gamma(b \to s\gamma) = \frac{G_F^2 \alpha_{\rm em} m_b^5}{32\pi^4} |V_{ts}^* V_{tb}|^2 \left(|C_7^{\rm eff}|^2 + 1/m_b,\ 1/m_c \text{ corrections} \right)$$

Measure primary γ only:
monochromatic Eγ spectrum



Huge Background (semi-log)

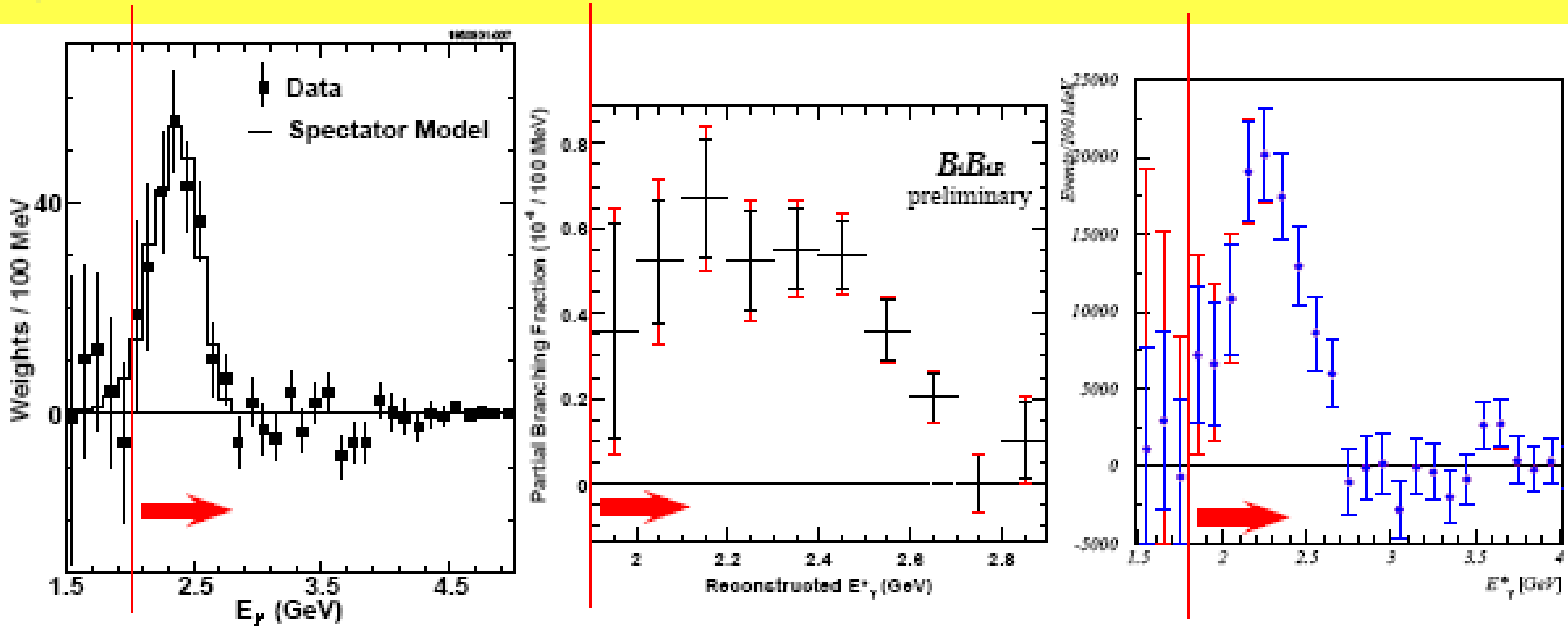
⇒ experimental challenge

Background suppression

- continuum: event shape
- π^0/η veto

Important to measure low Eγ
to reduce model dependence

E_γ spectrum (full-inclusive)



CLEO

9.1 fb^{-1} on $\Upsilon(4S)$

-4.4 fb^{-1} off-resonance

$E_\gamma > 2.0$ GeV

(PRL87,251807(2001))

BaBar

81.5 fb^{-1} on $\Upsilon(4S)$

-9.6 fb^{-1} off-resonance

$E_\gamma > 1.9$ GeV

(hep-ex/0507001)

Belle

140 fb^{-1} on $\Upsilon(4S)$

-15 fb^{-1} off-resonance

$E_\gamma > 1.8$ GeV

(PRL93,061803(2004))

More data, lower photon energy cut

Lower E_γ cut by 0.1 GeV with roughly twice more data

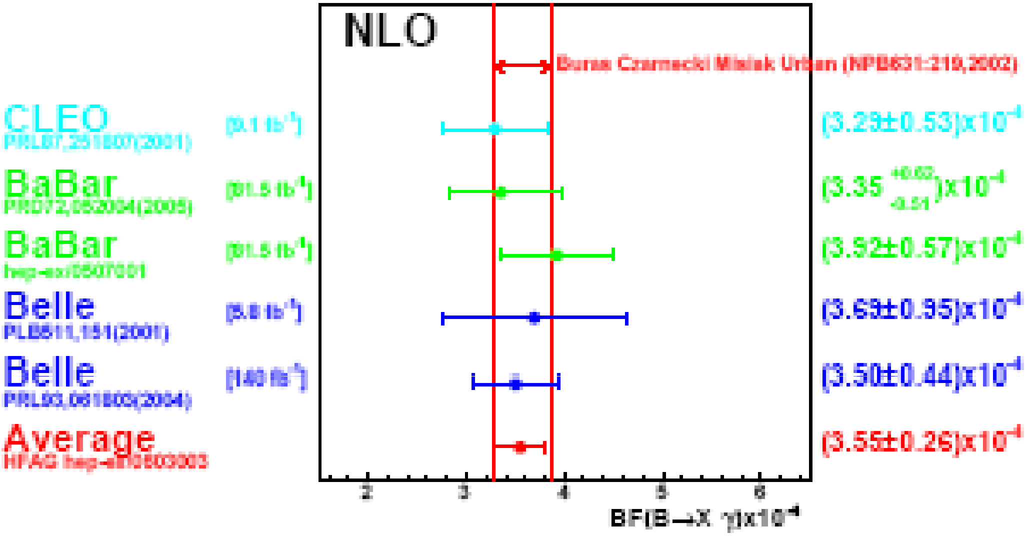
Nakao

$B \to X_s\gamma$ branching fraction

Average branching fraction for $E_\gamma > 1.6$ GeV

(Heavy Flavor Averaging Group (HFAG), hep-ex/0603003)

$$\mathcal{B}(B \to X_s\gamma;\, E_\gamma > 1.6\ \text{GeV}) = (355 \pm 24_{(\text{stat+sys})}\, {}^{+9}_{-10}(\text{shape}) \pm 3_{(d\gamma)}) \times 10^{-6}$$



PRL 98, 022003 (2007) PHYSICAL REVIEW LETTERS week ending 12 JANUARY 2007

Analysis of $\mathcal{B}(\bar{B} \to X_s\gamma)$ at Next-to-Next-to-Leading Order with a Cut on Photon Energy

Thomas Becher[1] and Matthias Neubert[2,3]

[1]*Fermi National Accelerator Laboratory, P.O. Box 500, Batavia, Illinois 60510, USA*

[2]*Institute for High-Energy Phenomenology, Laboratory for Elementary-Particle Physics, Cornell University, Ithaca, New York 14853, USA*

[3]*Institut für Physik (ThEP), Johannes Gutenberg-Universität, D-55099 Mainz, Germany*

(Received 9 October 2006; published 12 January 2007)

By combining a recent estimate of the total $\bar{B} \to X_s\gamma$ branching fraction at $O(\alpha_s^2)$ with a detailed analysis of the effects of a cut $E_\gamma \geq 1.6$ GeV on photon energy, a prediction for the partial $\bar{B} \to X_s\gamma$ branching fraction at next-to-next-to-leading order in renormalization-group improved perturbation theory is obtained, in which contributions from all relevant scales are factorized. The result $\mathcal{B}(\bar{B} \to X_s\gamma) = (2.98 \pm 0.26) \times 10^{-4}$ is about 1.4σ lower than the experimental world average. This opens a window for significant new physics contributions in rare radiative B decays.

Theory News

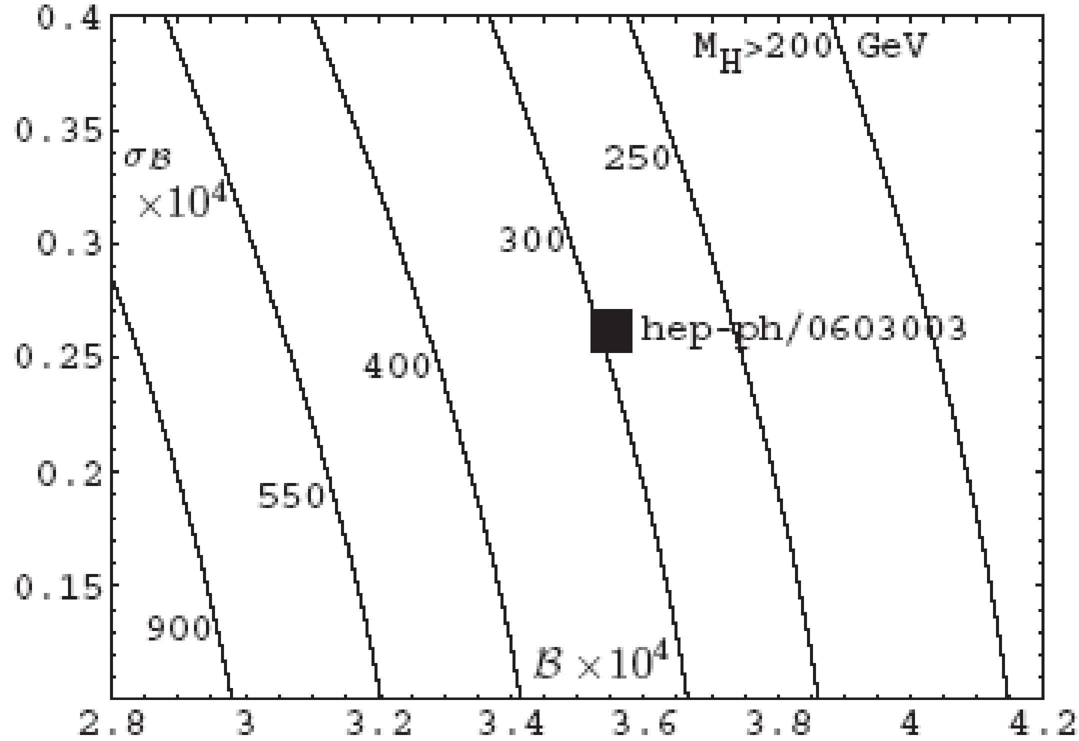
M. Misiak et al, hep-ph/0609232, PRL 98,022002(2007)

NNLO calculation➔

$(298 \pm 26) \times 10^{-6}$

95% CL lower limit on charged Higgs mass from exp and NNLO

Error on BF



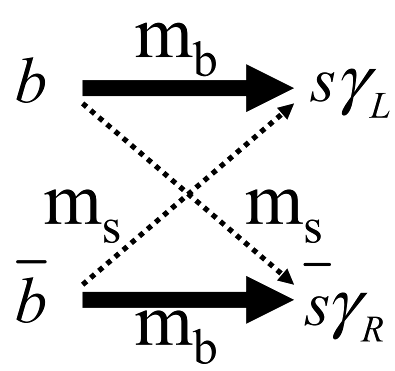
Central value of BF

FIG. 4. The 95% C.L. lower bound on M_{H^+} as a function of the experimental central value (horizontal axis) and error (vertical axis). The experimental result from Eq. (1) is indicated by the black square. The contour lines represent values that lead to the same bound.

M. Misiak et al, hep-ph/0609232, PRL 98,022002 (2007)

Right-handed currents in $b \to s\gamma$

D.Atwood, M.Gronau, A.Soni, PRL79, 185 (1997)
D.Atwood, T.Gershon, M.H, A.Soni, PRD71, 076003 (2005)



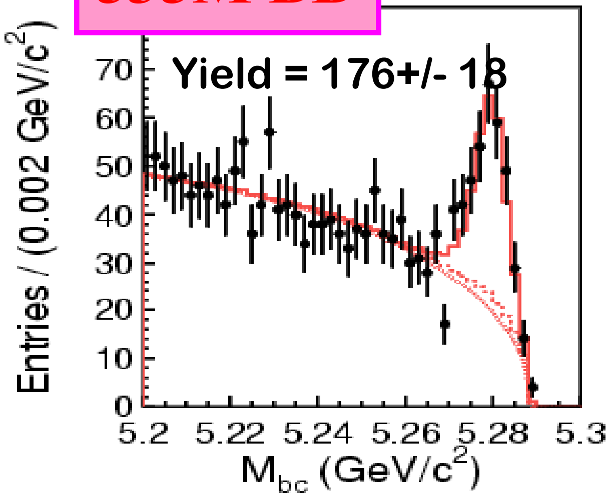
- tCPV in $B^0 \to (Ks\pi^0)_{K^*}\gamma$
  - SM: γ is polarized, the final state almost flavor-specific.
    $S(Ks\pi^0\gamma) \sim -2m_s/m_b \sin 2\phi_1$
  - m_{heavy}/m_b enhancement for right-handed currents in many new physics models

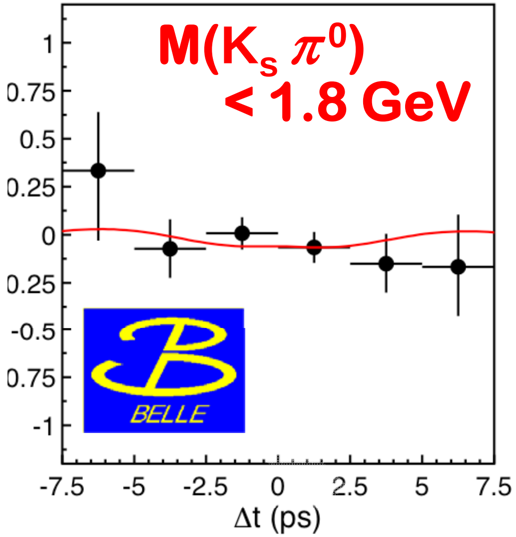
    e.g. LRSM, SUSY, Randall-Sundrum (warped extra dimension) model
  - LRSM: $SU(2)_L \times SU(2)_R \times U(1)$
    - Right-handed amplitude $\propto \zeta m_t/m_b$: ζ is W_L-W_R mixing parameter
    - for present exp. bounds ($\zeta < 0.003$, W_R mass > 1.4TeV)
      $|S(Ks\pi^0\gamma)| \sim 0.5$ is allowed.
  - **No need for a new CPV phas**

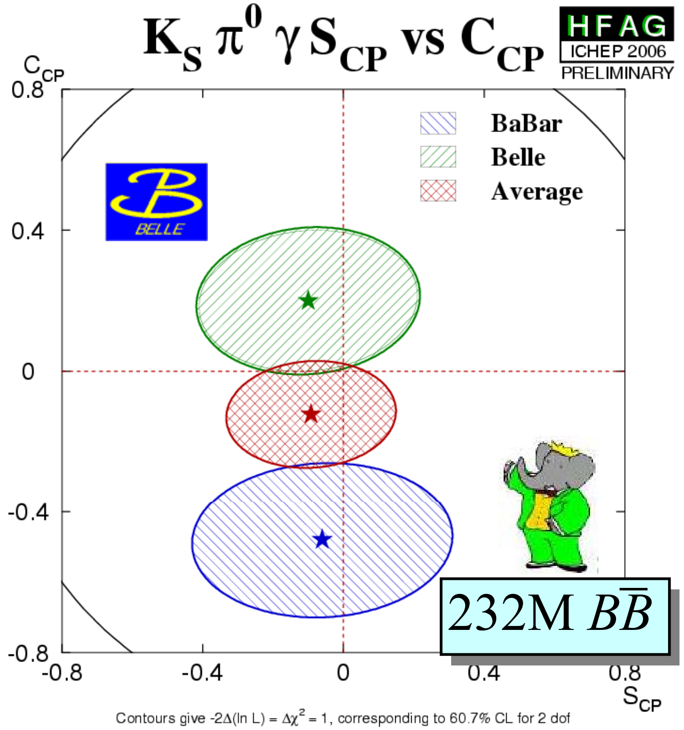
Photon polarization measurement via time dependent CPV !

Status of $B \to K_S \pi^0 \gamma$ tCPV

535M $B\bar{B}$







232M $B\bar{B}$

$$\mathcal{S} = -0.10 \pm 0.31 \pm 0.07$$

$$\mathcal{A} = -0.20 \pm 0.20 \pm 0.06$$

(–C)

hep-ex/0608017, PRD-RC 74, 111014(2006)

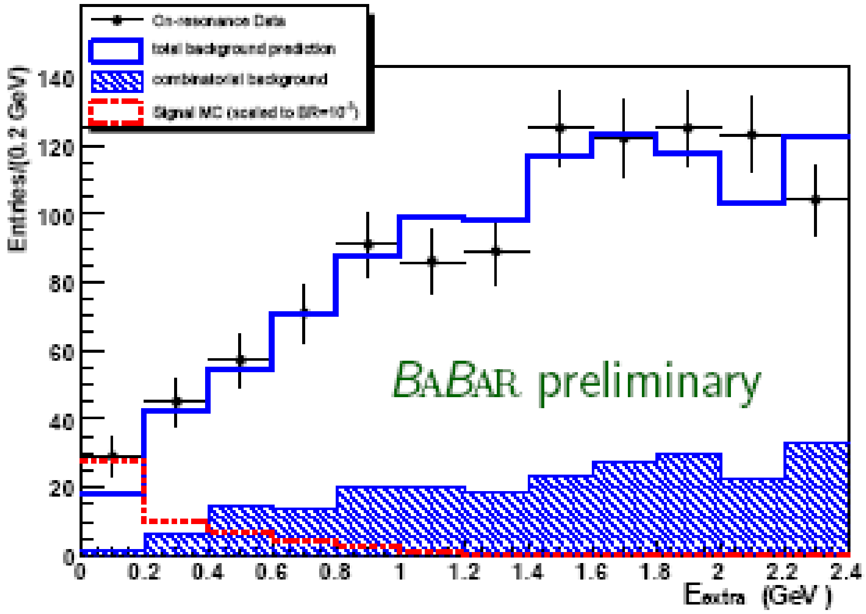
No new physics but *<u>errors on S are large</u>*

BaBar result announced at FPCP07 in Bled, Slovenia

BaBar preliminary

τ decay mode	$\langle b\text{ackground}\rangle$	observed
$\tau \to e\nu\nu$	1.47 ± 1.37	4
$\tau \to \mu\nu\nu$	1.78 ± 0.97	5
$\tau \to \pi\nu$	6.79 ± 2.11	10
$\tau \to \pi\pi^0\nu$	4.23 ± 1.39	5
all modes	14.27 ± 3.03	24

$$\mathcal{L}(s+b) \equiv \Pi_{i=1}^{4} \frac{e^{-(s_i+b_i)}(s_i+b_i)^{n_i}}{n_i!}$$



- Minimize $\quad Q(\mathcal{B}) = -2\ln(\mathcal{L}(s+b)/\mathcal{L}(b))$

$\mathcal{B} \neq 0 \;\Rightarrow 2.2\sigma$ (2.7 w/o bkg. error)

$$\mathcal{B}(B^\pm \to \tau^\pm \nu_\tau) = [1.8^{+1.0}_{-0.9}(\text{stat\&bkg}) \pm 0.3(\text{eff})] \times 10^{-4}$$

Seems to confirm the Belle result