Belle Results

(non-CPV measurements)

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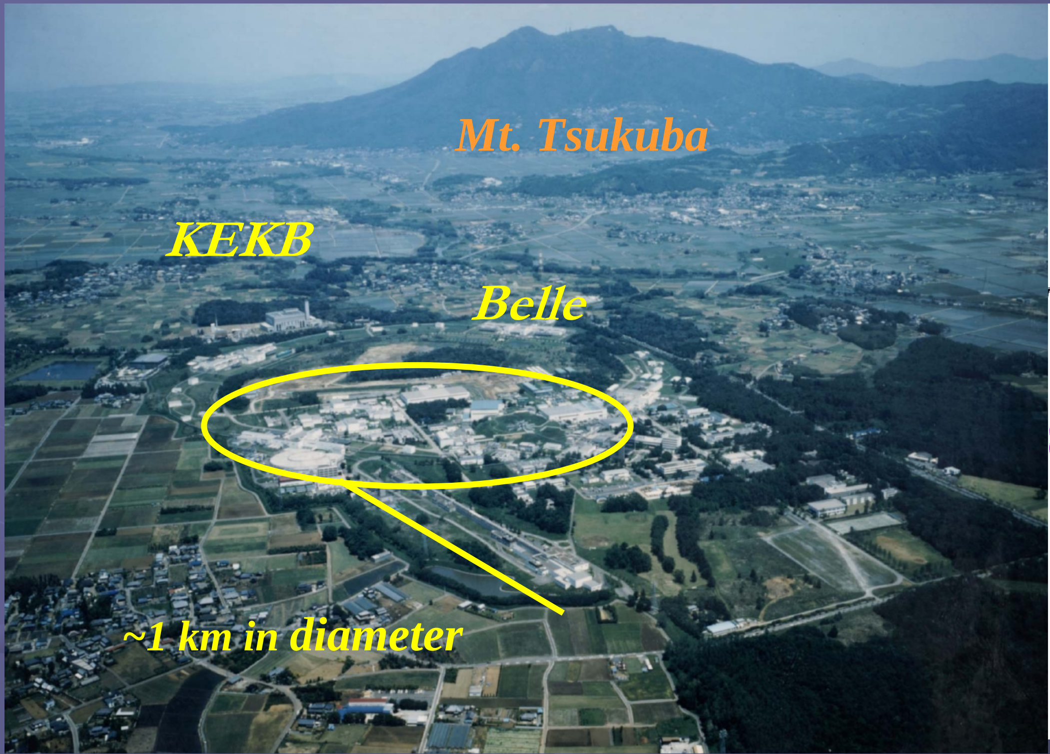
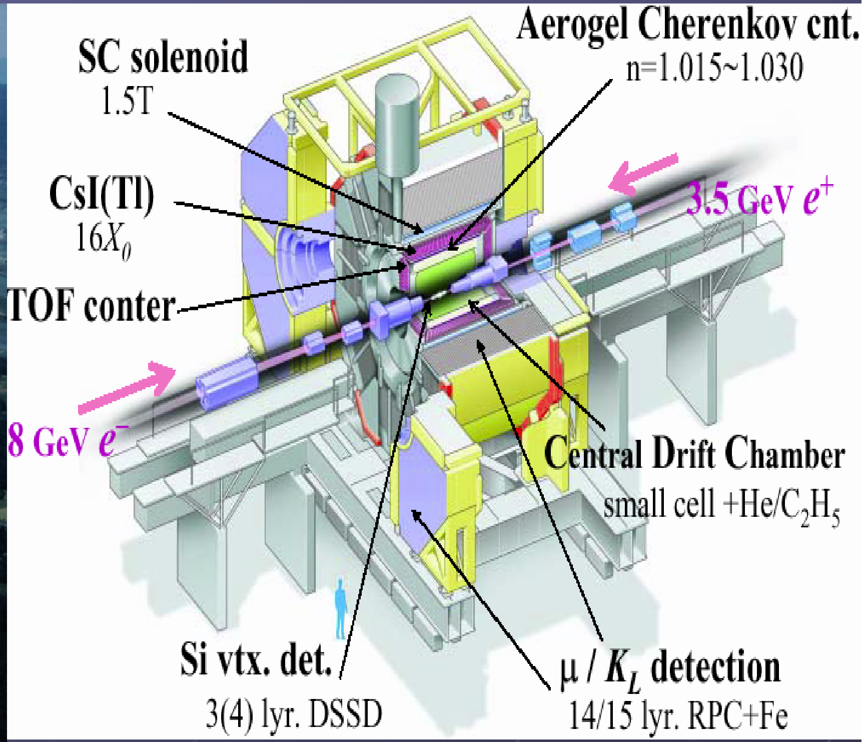
(for Belle)

Outline:

1. Physics stage
2. Spectroscopy case: X(3872)
3. Particle production: double $c\underline{c}$ production puzzle
4. Glimpse of τ physics: m_τ and $\pi\pi$ spectral function

KEKB collider & Belle detector

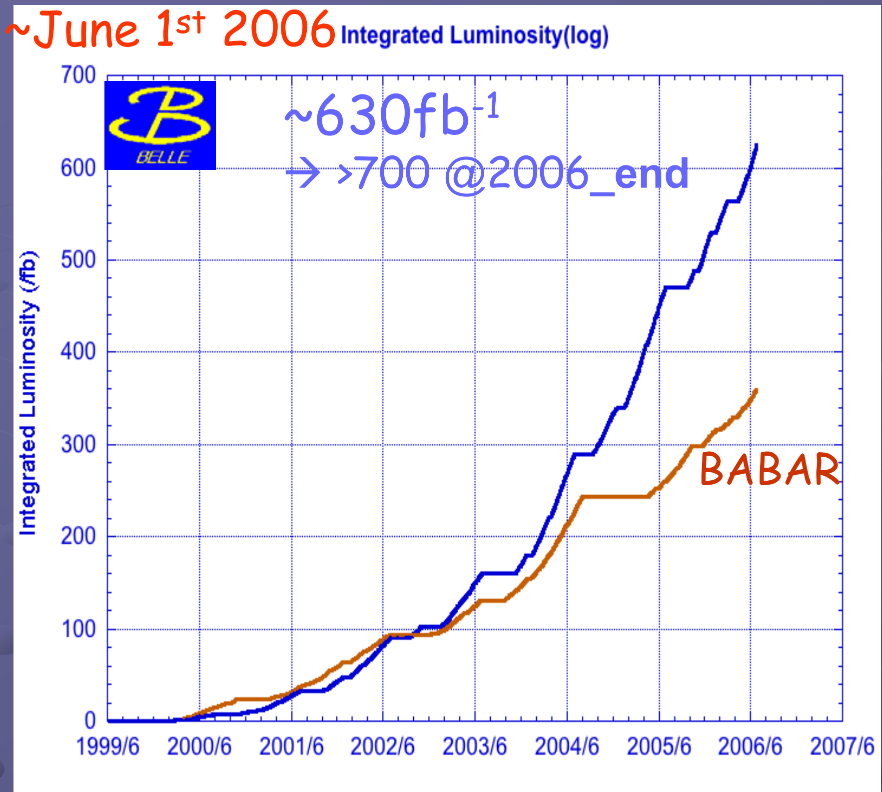


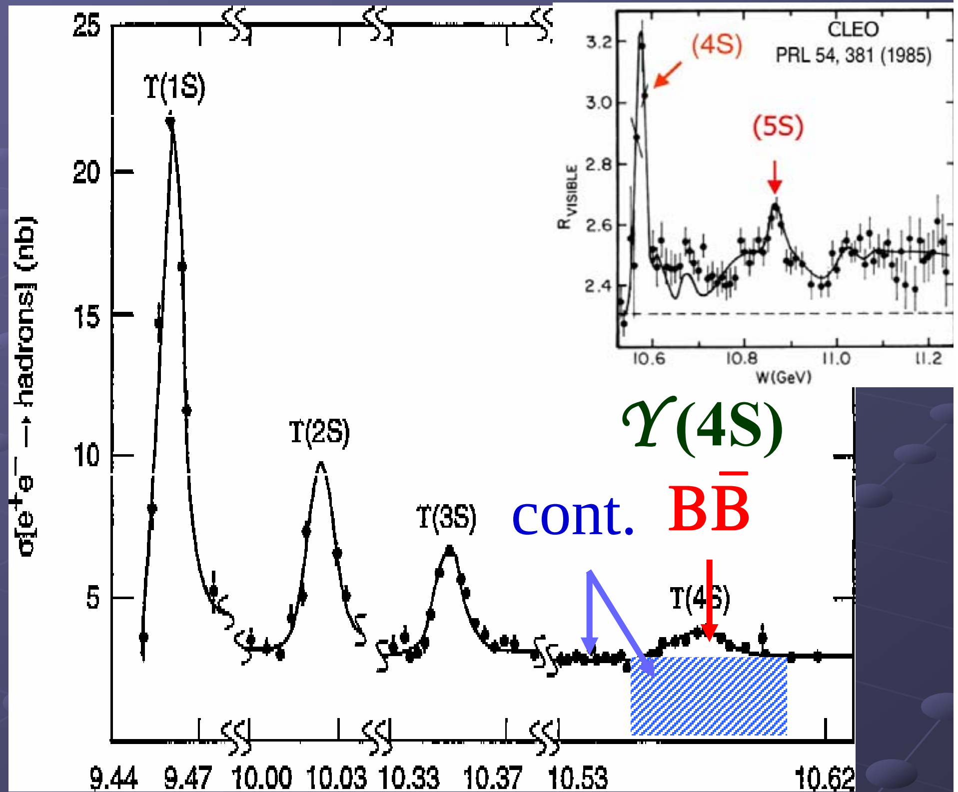


2 separate rings, 22 mrad beam crossing,
8(e^-)x 3.5(e+)GeV, $\sigma(E_b)$~1.5MeV
L_{max} > 1.6×10^{34} $cm^{-2}s^{-1}$(~continuous fill)
> 1M B$\underline{B}$/day; (crab cavities(07)→ x 3)
long range plans: see Yamauchi's talk

Many interim improvements to accommodate high lumi: shields against n backsplash (now), new SVD's 2 inermost layers + readout (2007)

Data samples





Υ(4S): ~570 fb^{-1}

qq cont.: ~ 60 fb^{-1}

Υ(3S): ~ 3 fb^{-1}(<5 days)

Υ(5S): ~24 fb^{-1} (~3weeks)

→

~600 M B$\bar{B}$

>2 G q$\bar{q}$ (~0.8 G c$\bar{c}$), >550 M $\tau^+\tau^-$

~10 M Υ(3S) [Γ_{inv}(Υ(1S))]

>7 M Υ(5S) (~15% are $B_s\bar{B}_s$)

(signal selection eff. large)

Wealth of non-CPV physics @ Belle

Spectroscopy:

available in many mechanisms:

B, D, τ decays

ee→had , J/Ψ X, γ X,

τ physics,

$\gamma\gamma$,

charm production, mixing, CPV

quark FF (polarized),

mesons decay constants,

QM non-locality tests…

Spectroscopy : >2 new states/year

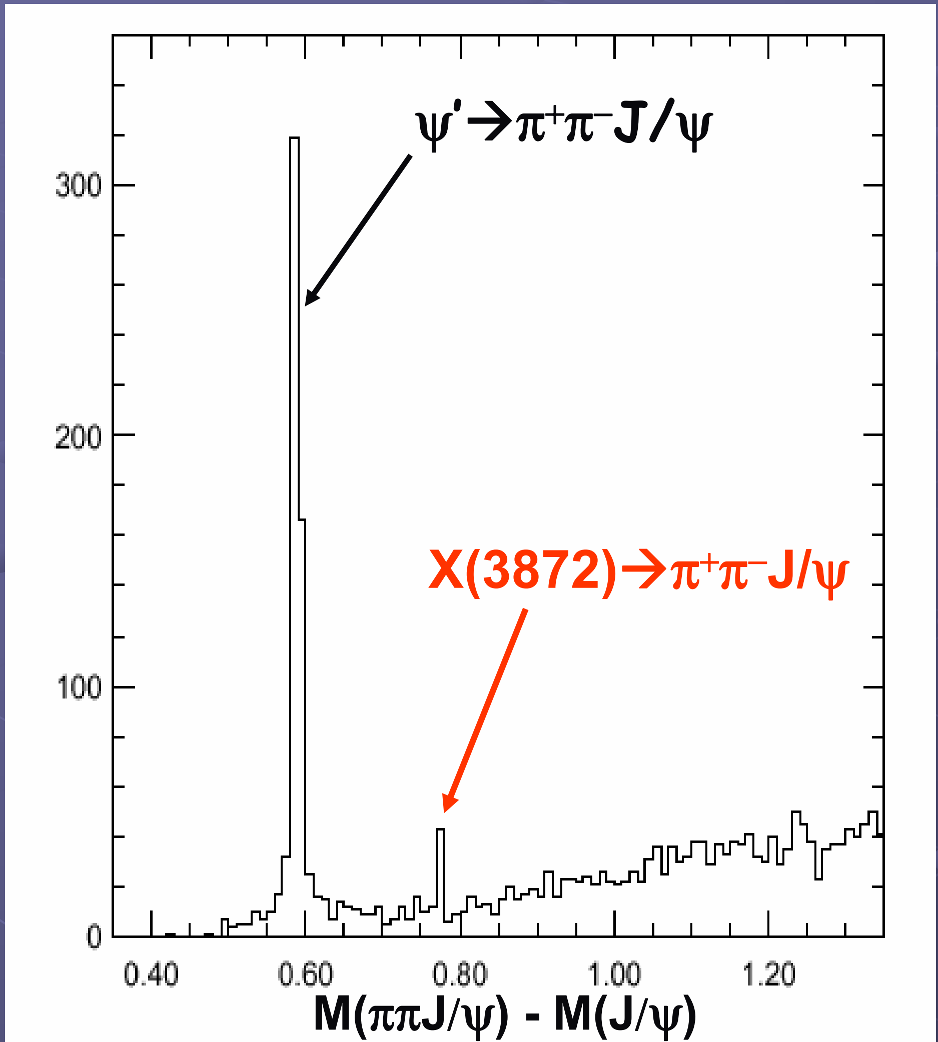
- X(3872) $B \to K \pi^+ \pi^- J/\psi$
- Z(3930) $\gamma\gamma \to DD$
- Y(3940) $B \to K \omega J/\psi$
- X(3940) $e^+e^- \to J/\psi X$, $J/\psi DD^*$
- Y(4260) $e^+e^- \to \gamma \pi^+ \pi^- J/\psi$ (c)
- $\eta_c(2S)$ $B \to (K_S K \pi)K$, $e^+e^- \to J/\psi X$
- $D_0(2308)$, $D_1'(2430)$, $D_{s0}(2316)$, $D_{s1}(2460)$ (c)

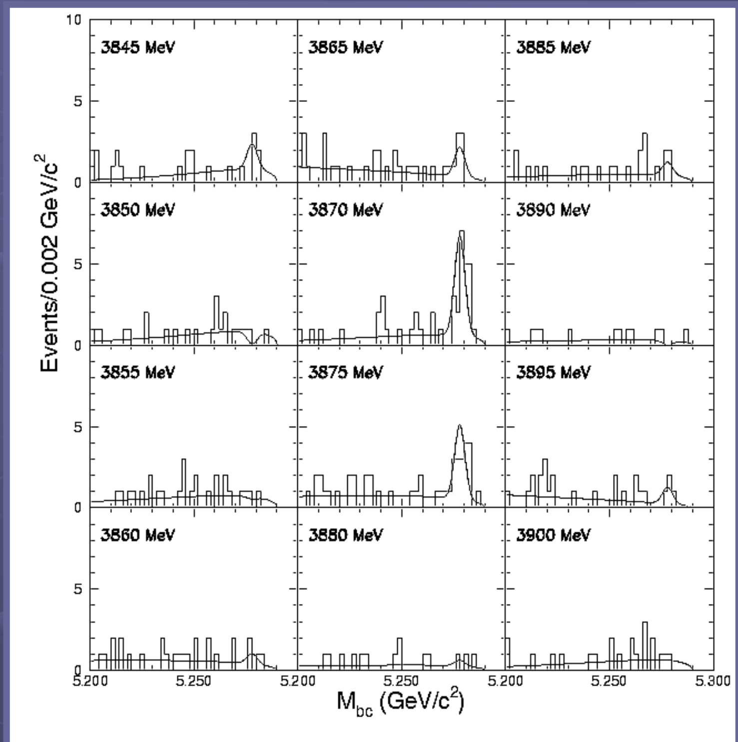
new charmed baryons in $e^+e^- \to c\underline{c}$:

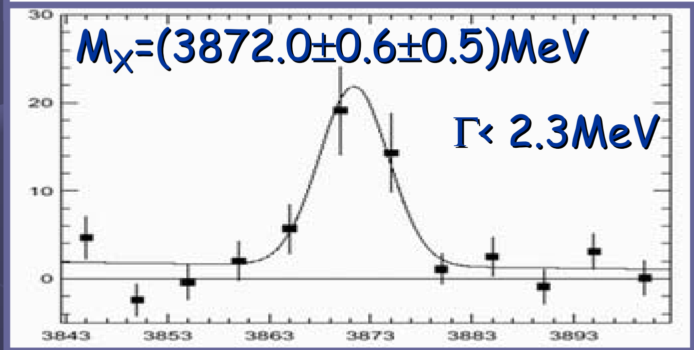
- $\Sigma_c(2800)^{0,+,++} \to \Lambda_c^+ \pi$
- $\Xi_{cx}(2980)^+ \to \Lambda_c^+ K^- \pi^+$
- $\Xi_{cx}(3077)^+ \to \Lambda_c^+ K^- \pi^+$
  $\Xi_{cx}(3077)^0 \to \Lambda_c^+ K_S^0 \pi^-$

X(3872)

Found in $B \to K\pi^+\pi^- J/\psi$ 140fb^{-1} PRL 91, 262001







$M_X \approx M_D + M_{D^*}$

accidental?

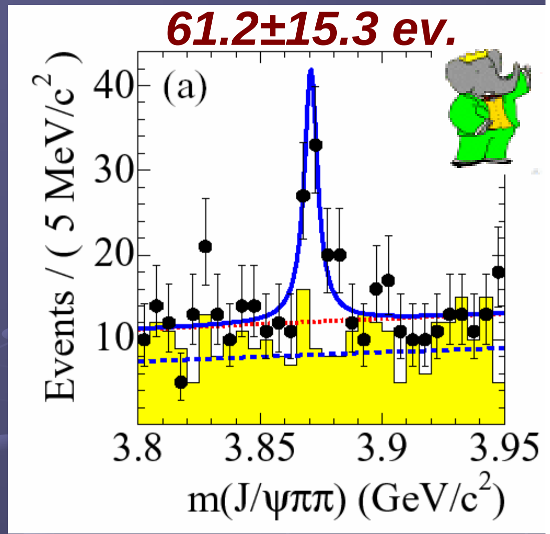
X(3872) properties

Branching ratio:

$$\frac{\mathcal{B}(B^+ \to K^+ X(3872)) \times \mathcal{B}(X(3872) \to \pi^+\pi^- J/\psi)}{\mathcal{B}(B^+ \to K^+ \psi') \times \mathcal{B}(\psi' \to \pi^+\pi^- J/\psi)} =$$

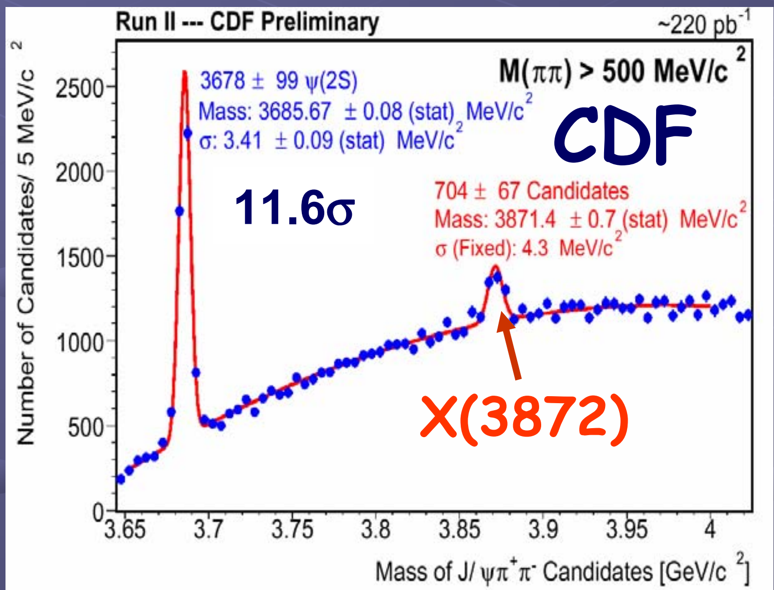
$$0.063 \pm 0.012(\text{stat}) \pm 0.007(\text{syst})$$

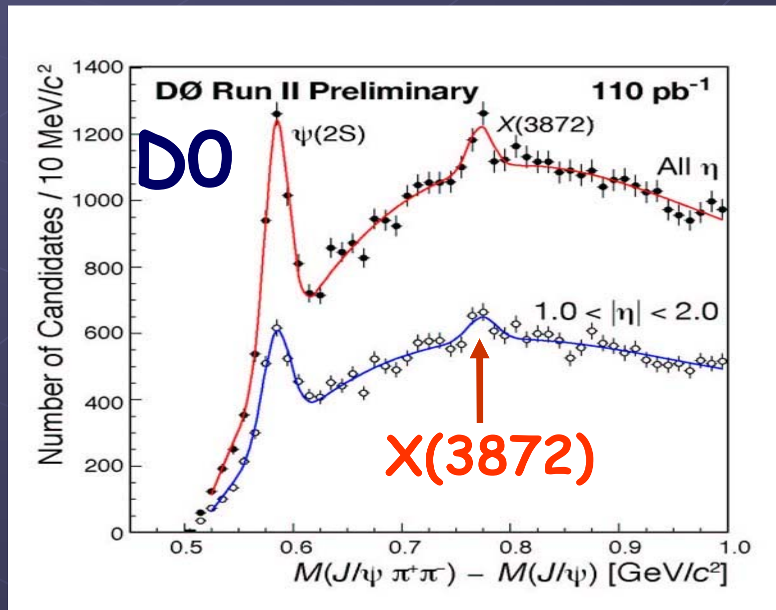
typically: $B(B \to K\ (c\underline{c})(J=0,1)) \sim 10^{-3}$



confirmed by BABAR

Seen also in p$\underline{\text{p}}$
(production properties like ψ')

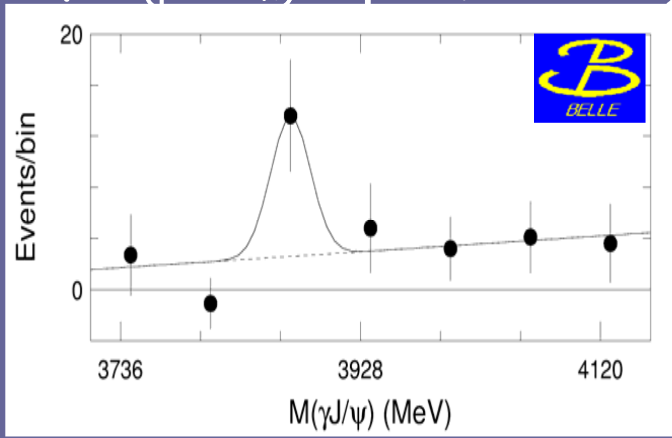


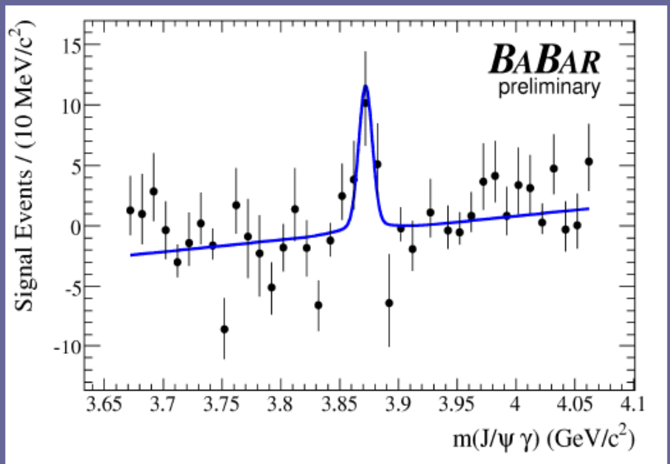


X(3872) properties:

X(3872)→ γ J/Ψ seen

(256fb^{-1}(prelim) **hep-ex/0505037**)

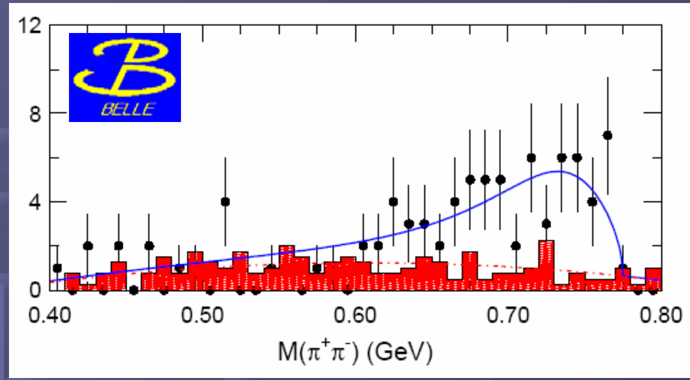


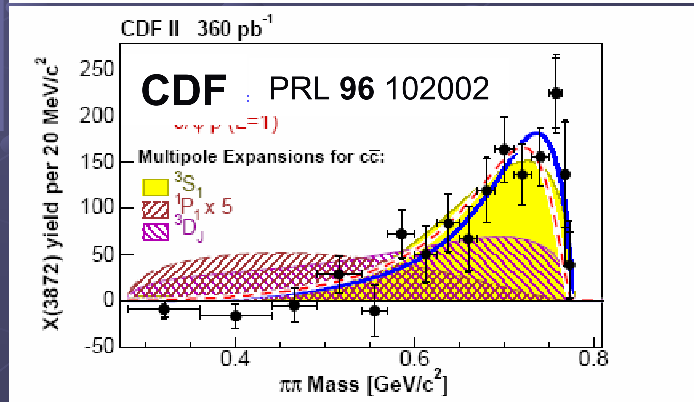


→ C(X)=+1

$$\frac{B(X \to J/\psi\gamma)}{B(X \to J/\psi\pi^+\pi^-)} = 0.14 \pm 0.05$$

ρ(770) –like M(ππ) distribution
(no I=1 found → isospin viol. ?)





Seen also in:
X(3872)→J/ψ ω*
ω* = ω peak low mass tail

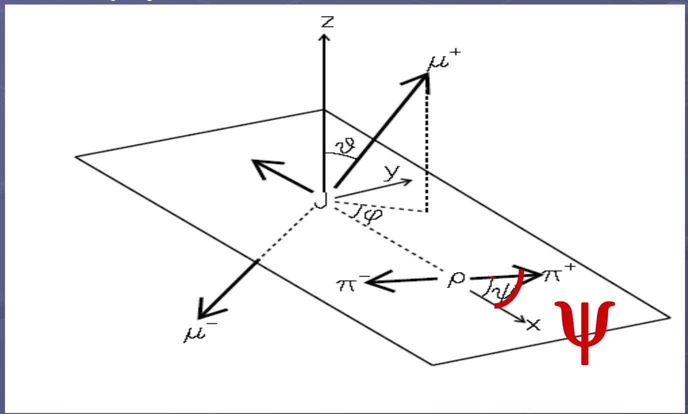
$$\frac{B(X \to J/\psi\pi^+\pi^-\pi^0)}{B(X \to J/\psi\pi^+\pi^-)} = 1.0 \pm 0.4 \pm 0.3$$

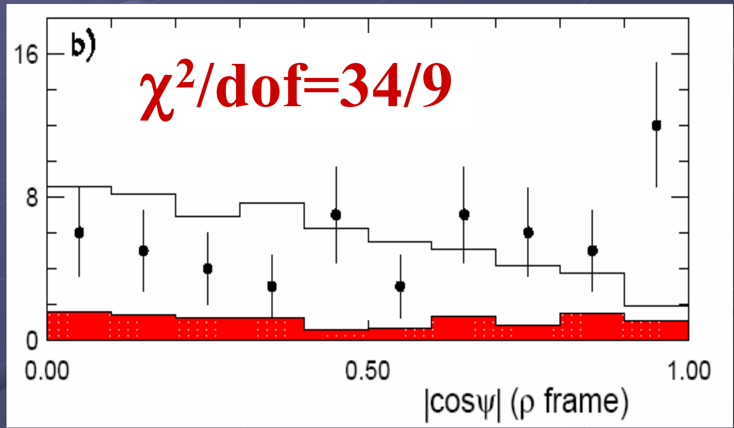
X(3872) properties:

Angular distributions study (Belle 256fb^{-1} hep-ex/0505038)

$B \to K\pi^+\pi^- J/\psi(\to ll)$: 4 independent angles, the most discriminative one chosen for each J^{PC} hypothesis

e.g. hyp. **$J^{PC} = 0^{-+}$** :





→ 0^{-+} ruled out

similarly: 0^{++} ruled out

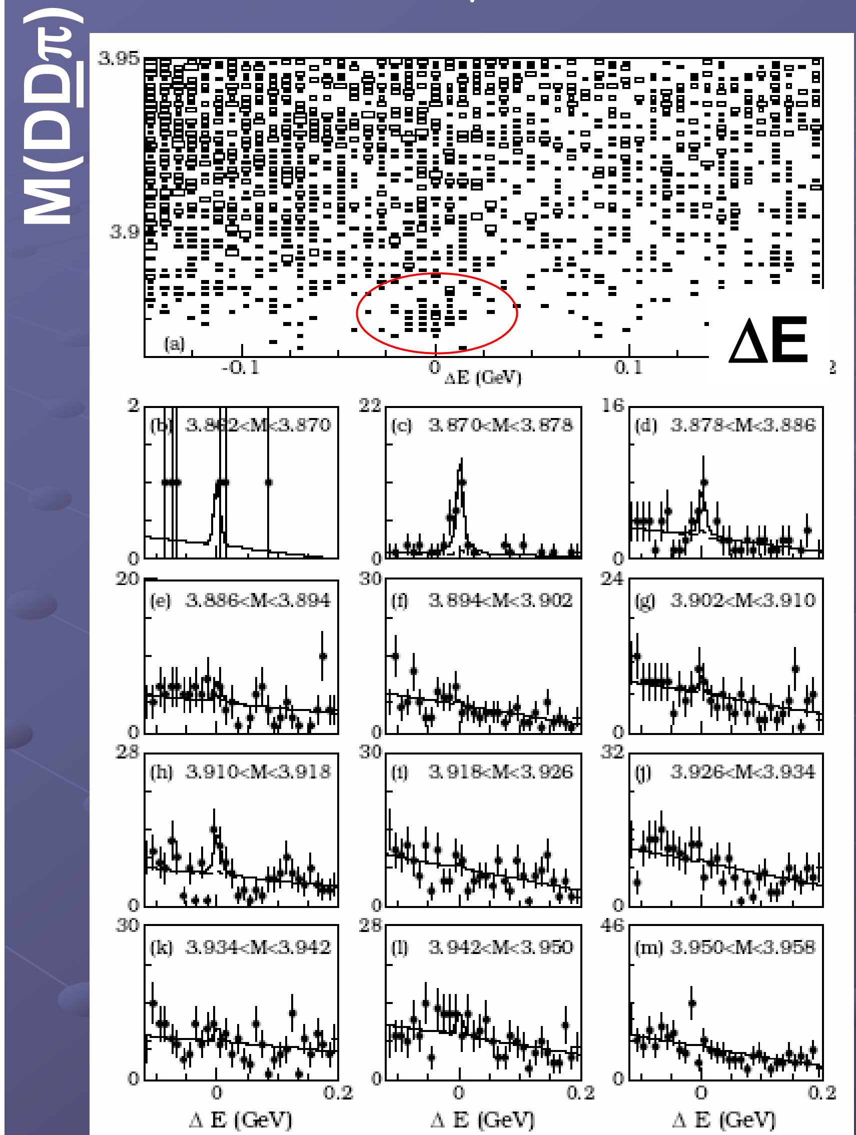
1^{-+}, 2^{-+} are disfavored by $M(\pi\pi)$ shape

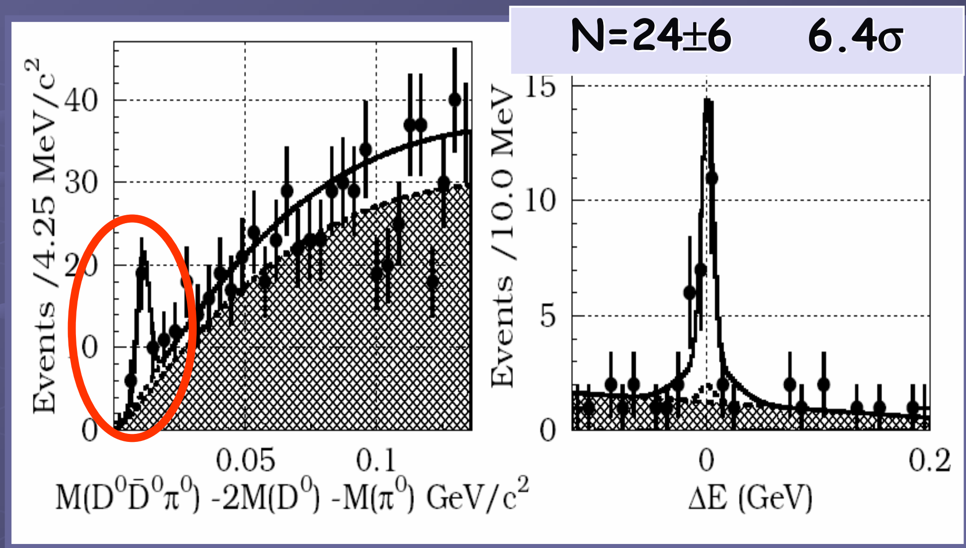
1^{++} (fav.), 2^{++} remain

does not fit well into charmonium levels

Threshold peak in $B \rightarrow K D^0\underline{D}^0\pi^0$

Belle 415fb^{-1} hep-ex/0606055 (submitted to PR L)





$$M = 3875.4 \pm 0.7 \,^{+0.7}_{-1.7} \pm 0.8 \text{ MeV}$$

$$B(B \rightarrow KX)B(X \rightarrow D^0\underline{D}^0\pi^0)$$

$$= (1.27 \pm 0.31 \,^{+0.22}_{-0.39}) \times 10^{-4}$$

$$\frac{Br(X \rightarrow D^0\underline{D}^0\pi^0)}{Br(X \rightarrow \pi^+\pi^- J/\psi)} \approx 9.3 \pm 5.0$$

Threshold peak in $B \to K D^0 \underline{D}^0 \pi^0$

Comments:

- $X \to D^0 \underline{D}^0 \pi^0$ and $X \to D^{*0} \underline{D}^0$ ($D^0 \underline{D}^{*0}$) indistinguishable in the data

- The peak position disagrees at 2.3σ with

  $\langle M(X(3872)) \rangle = 3871.2 \pm 0.5$ MeV (PDG)

- The peak position w.r.t to the $D^0 \underline{D}^{*0}$ threshold:

  $$M-(m_{D0}+m_{D^{*}0}) = 4.3 \pm 0.7 \, {}^{+0.7}_{-1.7} \text{ MeV}$$

  is also 2.3σ above the $D^0 \underline{D}^{*0}$ threshold

  (is it a resonance? why so narrow?)

- More studies needed to tell if the threshold peak and the X(3872) are the same objects;

  if it is the same $\to$ $J^{PC} = 2^{++}$ rejected

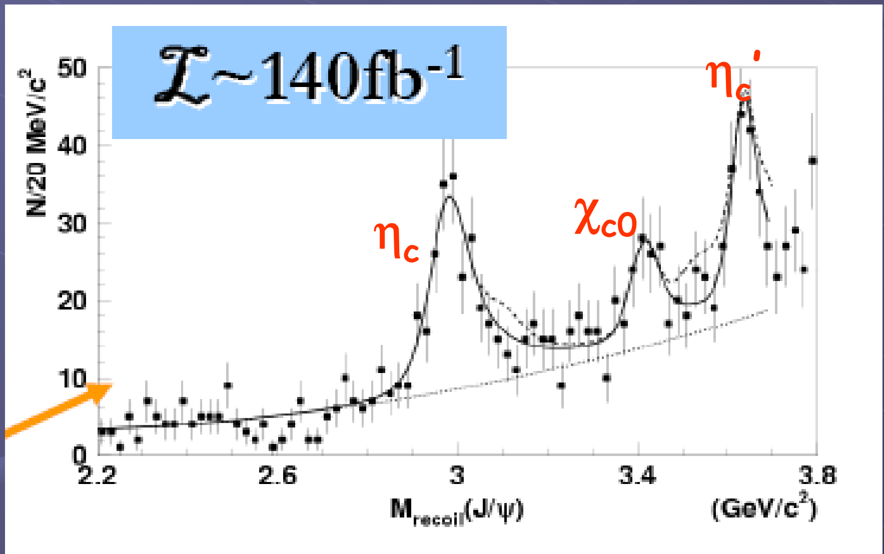
  $\to$ $D^{*0} \underline{D}^0$ molecule interpret. plausible

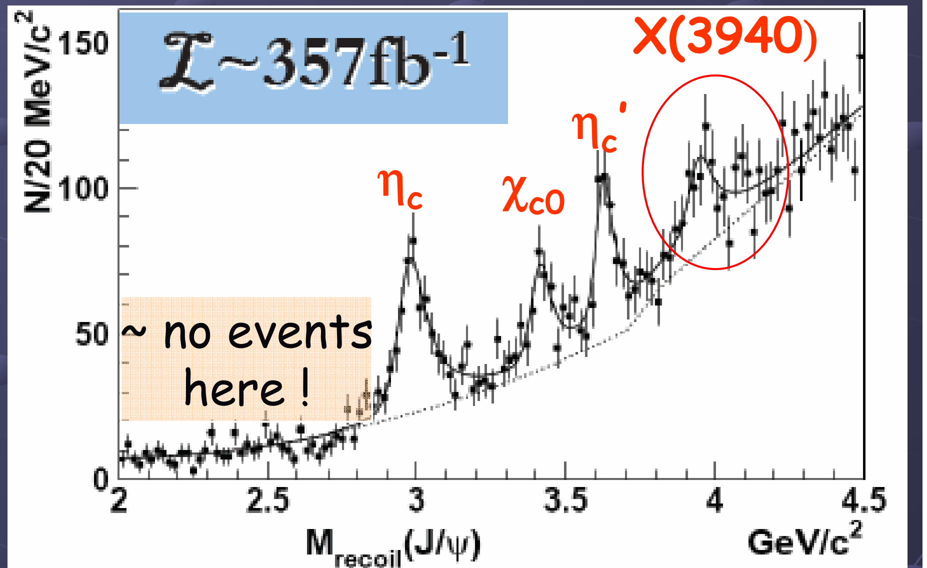
Charmonium production

$e^+e^- \rightarrow J/\Psi\, X$: already @ L~ 30 fb^{-1} (PRL 89 142001)
we have noticed rather copious (σ ~ 1.5pb) J/Ψ production,
however $p_{J/\psi} < p_{max}$ - ~300 MeV !!!

$$M_{recoil} = \sqrt{(E_{cms} - E_{J/\psi})^2 - P_{J/\psi}{}^2}$$

: the recoil mass (to the J/ψ) has proven to be a fruitful tool:





Double $c\underline{c}$ production

$J/\psi\, c\bar{c}$ [fb]	η_c	χ_{c0}	$\eta_c(2S)$
Belle [PRD**70**, 071102]	$25.6 \pm 2.8 \pm 3.4$	$6.4 \pm 1.7 \pm 1.0$	$16.5 \pm 3.0 \pm 2.4$
BABAR [hep-ex/0506062]	$17.6 \pm 2.8^{+1.5}_{-2.1}$	$10.3 \pm 2.5^{+1.4}_{-1.8}$	$16.4 \pm 3.7^{+2.4}_{-3.0}$
Braaten, Lee [PRD **67**, 054007]	2.31 ± 1.09	2.28 ± 1.03	0.96 ± 0.45
Liu, He, Chao [hep-ph/0408141]	5.5	6.9	3.7

Reconstruct $J/\Psi + D^0/D^+/D_s/\Lambda$:

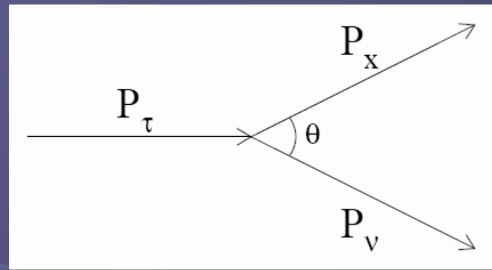
$$\frac{\sigma(e^+e^- \to J/\psi cc)}{\sigma(e^+e^- \to J/\psi X)} = 0.82 \pm 0.15 \pm 0.14$$

Preliminary !!

No satisfactory theory explanation exists up to now

τ physics: M_τ measurement

pseudo-mass method



$$M_\tau^2 = M_X^2 + M_\nu^2 + 2E_X E_\nu - 2P_X P_\nu \cos\theta$$
$$= M_X^2 + 2(E_\tau - E_X)(E_X - P_X \cos\theta)$$

$\cos\theta = 0 \rightarrow$ $$M_{\rm min} = \sqrt{M_X^2 + 2(E_{\rm beam} - E_X)(E_X - P_X)}$$

Preliminary ($250 fb^{-1}$ hep-ex/0511038)

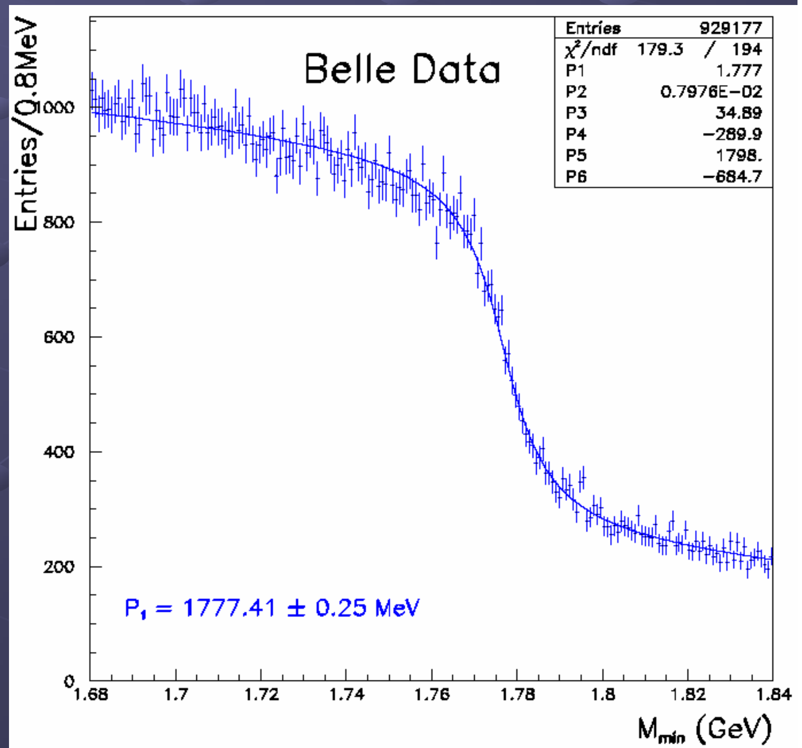
$M_\tau = 1776.77 \pm 0.25 \pm 0.62$ MeV/c2

CPT test:

$M_+ - M_- = -0.12 \pm 0.45 \pm 0.15$ MeV

$\Delta M/M < 5\ 10^{-4}$ @ 90% CL

factor of 10 improvement
w.r.t. previous results (Opal)



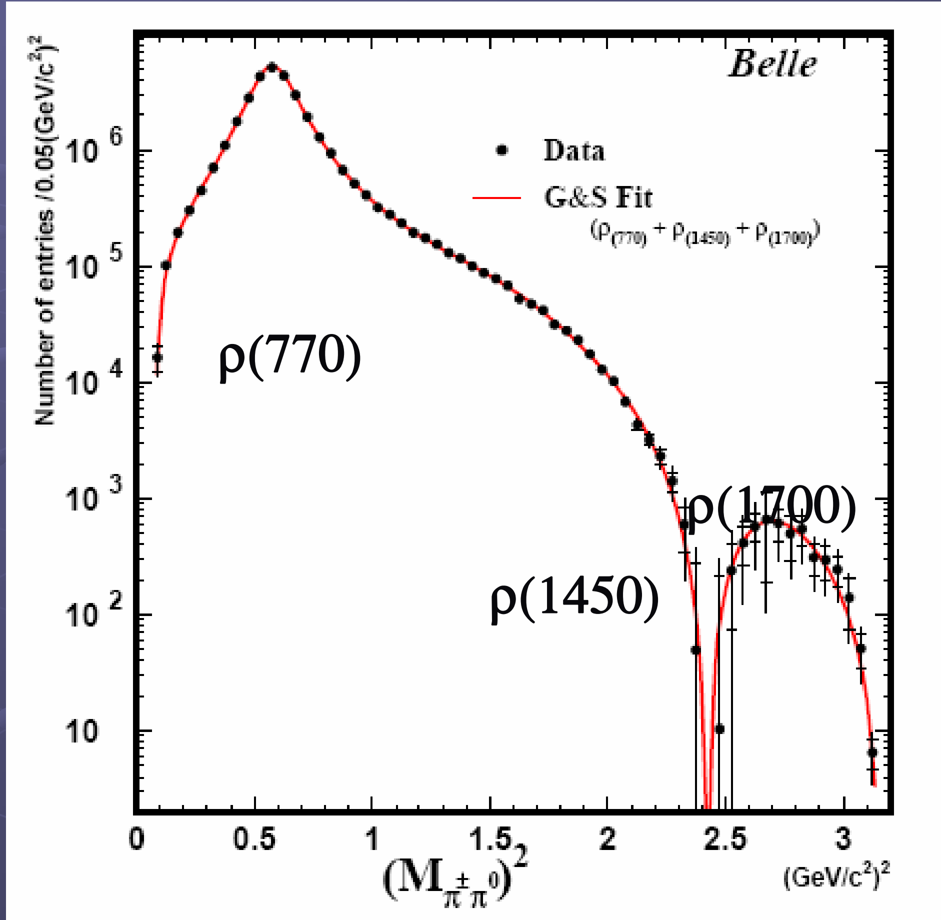
$\pi^-\pi^0$ spectral function from $\tau^- \to \pi^-\pi^0\nu$

Preliminary (72fb^{-1} hep-ex/0512071)

dN/ds (bkd subtr., unfolded):

→clear ρ(1700) – via interf. with ρ'
→accurate mass spectrum < 2 GeV²:
gives spectral function needed to interpret a_μ measurement

BNL E821 (2004):
$a_\mu^{exp} = (11\ 659\ 208.0 \pm 5.8)\ 10^{-10}$



hadronic vacuum pol. cor← exp.input

a_μ[exp] – a_μ[SM] = ~3σ (ee→ππ)
~1σ (τ→ππν)

which one is wrong?

spectral function:

$$v_- = \frac{m_\tau^2}{6\pi|V_{ud}|^2 S_{EW}} \left(\frac{\mathcal{B}_{\pi\pi}}{\mathcal{B}_e}\right) \left[\left(1-\frac{s}{m_\tau^2}\right)^2 \left(1+\frac{2s}{m_\tau^2}\right)\right]^{-1} \frac{1}{N}\frac{dN}{ds}$$

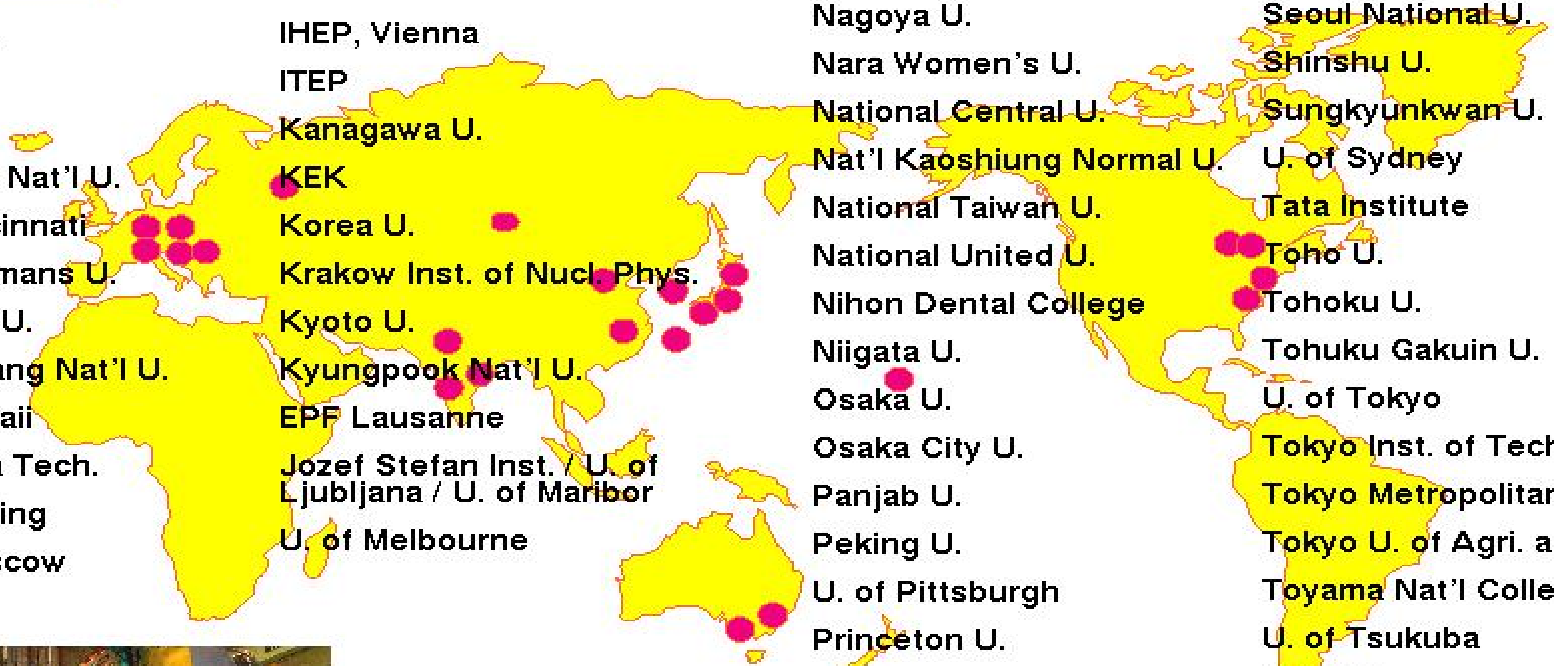
$$a_\mu^{\pi\pi} = \left(\frac{\alpha_0 m_\mu}{3\pi}\right)^2 \int_{4m_\pi^2}^{m_\tau^2} \frac{3\, v_-(s)}{s^2} \hat{K}(s)\, ds + \ldots$$

$$a_\mu^{\pi\pi}[0.50, 1.80] = (462.6 \pm 0.6\,(\text{stat.}) \pm 3.2\,(\text{sys.}) \pm 2.3\,(\text{isospin})) \times 10^{-10}$$

mostly external

All these results were possible thanks to:

International Collaboration: Belle



Aomori U.
BINP
Chiba U.
Chonnam Nat'l U.
U. of Cincinnati
Ewha Womans U.
Frankfurt U.
Gyeongsang Nat'l U.
U. of Hawaii
Hiroshima Tech.
IHEP, Beijing
IHEP, Moscow
IHEP, Vienna
ITEP
Kanagawa U.
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Krakow Inst. of Nucl. Phys.
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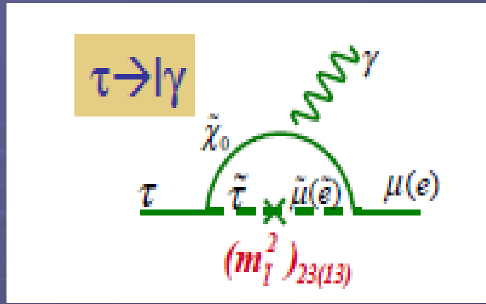
Tokyo Metropolitan U.
Tokyo U. of Agri. and Tech.
Toyama Nat'l College
U. of Tsukuba
Utkal U.
VPI
Yonsei U.

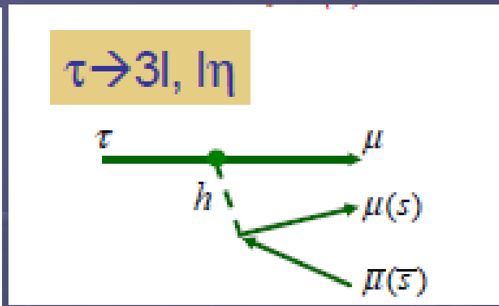
13 countries, 57 institutes, ~400 collaborators

Backups

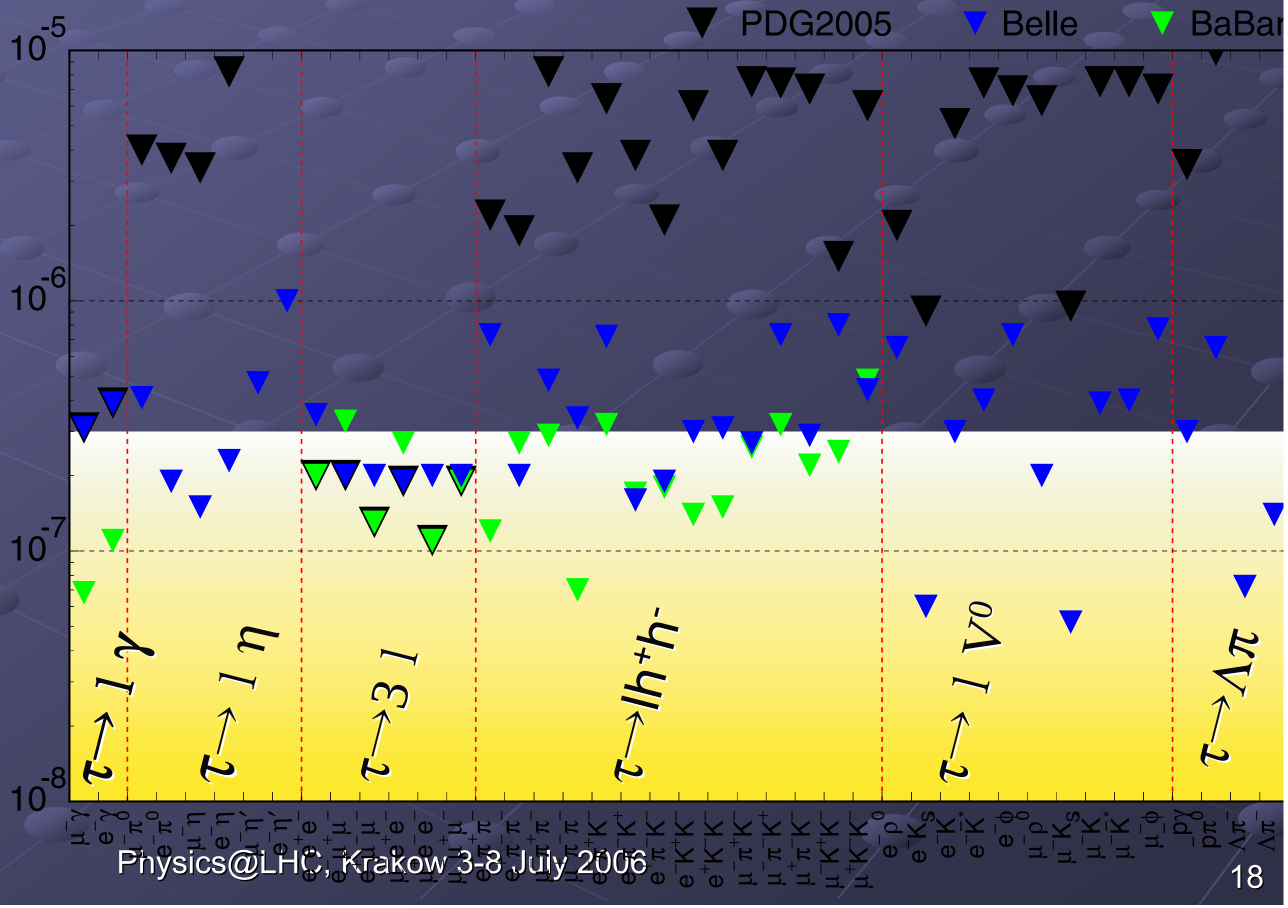
τ physics: LFV decays

- FV observed for leptons (ν)
- Many extensions of the SM predict LFV: they can occur e.g. in loops of new physics processes at the TeV scale such as SUSY, Extra-Dim etc.



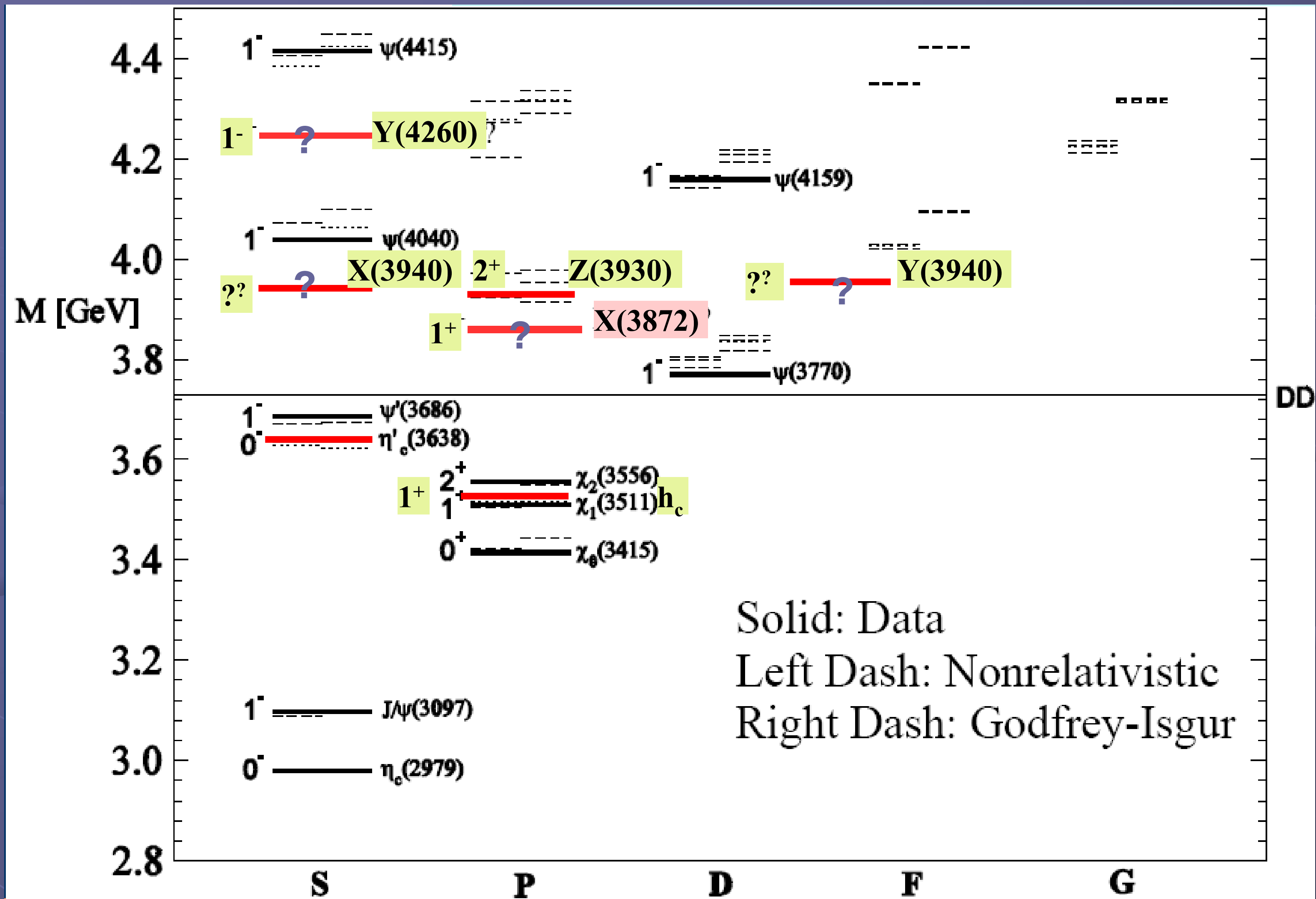


BF < O(10^{-7} – 10^{-8})
(improvements by 10-100)



Prospects:
- 1/L : clean modes
- 1/√L: bkd dominated

X(3872): charmonium assignment?



$\chi_{c1}{}'$?

$\Gamma(\gamma J/\psi)$ too small

& $\Gamma(\pi^+\pi^- J/\psi)$ too big