CP violation and related issues

Part 12: advances in hadron spectroscopy

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X(3872)

D_{sJ} mesons

Pentaquark searches

Introduction

quark and anti-quark are bound by the strong force → mesons

bound states c$\bar{c}$

At small E → α_s large,
Perturb. calculation does not work →models

Ijana

Introduction

bound states c$\bar{c}$

Checking the properties of predicted states =>
Understanding of strong force

meson spin: ½ ⊕ ½ → J = 0,1; L=1 → J = 0,1,1,2

parity (P): (-1) (-1)^L = (-1)$^{L+1}$

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Hadron spectroscopy – X(3872)

Belle observed a new state decaying into J/ψ π+π−

$B^+ \rightarrow K^+ X(3872)$

35±7 events
M=3872.0±0.8 MeV
Γ<2.3MeV (90%)

ψ π+π−
→ l+l−
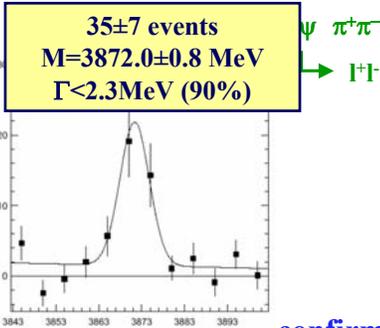
Belle, PRL 91 (2003) 262001
Mass 3872.0 ± 0.6 ± 0.5 MeV

X(3872)
~35 candidates
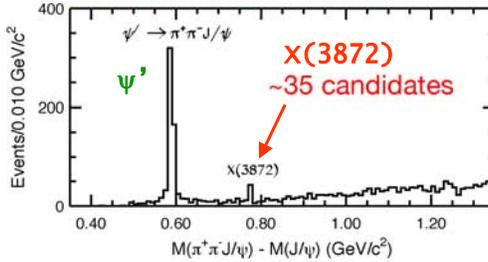
$M(J/\psi\ \pi^+\pi^-)- M(J/\psi)$ [GeV]

confirmed by CDF,D0,BaBar
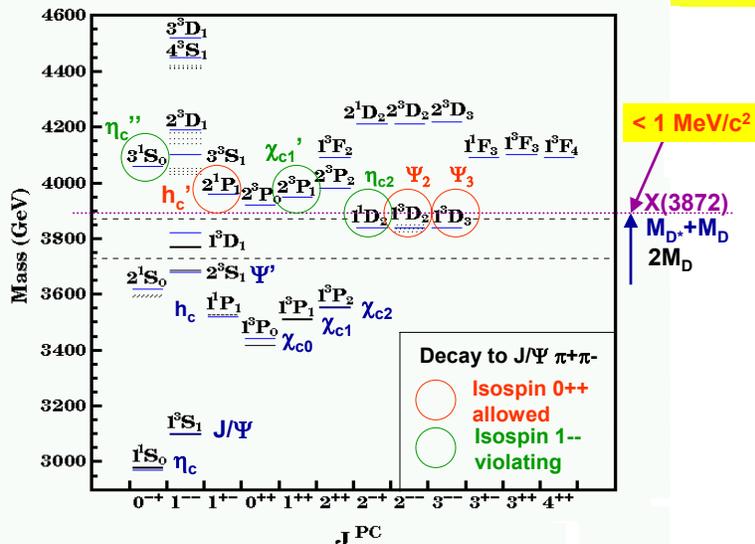
Hadron spectroscopy – X(3872)

Hadron spectroscopy – X(3872)

Search for other decay modes of X(3872):

90% C.L. upper limits (most from Belle):

$$\Gamma(X \to \gamma\chi_{c1})/\Gamma(X \to \pi\pi J/\psi) < 0.89$$

$$\Gamma(X \to \gamma\chi_{c2})/\Gamma(X \to \pi\pi J/\psi) < 1.1$$

$$\Gamma(X \to \gamma J/\psi)/\Gamma(X \to \pi\pi J/\psi) < 0.40$$

$$\Gamma(X \to \eta J/\psi)/\Gamma(X \to \pi\pi J/\psi) < 0.6$$

$$\Gamma(X \to D\bar{D})/\Gamma(X \to \pi\pi J/\psi) < 7$$

$$\Gamma(X \to D^0\bar{D}^0\pi^0)/\Gamma(X \to \pi\pi J/\psi) < 6$$

Non-observation of DD modes: $J^P = 0^+, 1^-, 2^+, \ldots$, is ruled out.

What kind of state is X(3872)?

No good cc candidates for X(3872):

η_c'' ←——— M too low and Γ too small

h_c' ←——— angular distribution rules out 1^{+-}

χ_{c1}' ←——— $\Gamma(\gamma J/\psi)$ too small

ψ_2 ←——— $\Gamma(\gamma\chi_{c1})$ too small; (PRL 93, 2003)

η_{c2} ←——— $\pi\pi\,\eta_c$ should dominate over $\pi\pi J/\psi$

ψ_3 ←——— $\Gamma(\gamma\chi_{c2}$ & $D\bar{D})$ too small

◯ - Isospin violating decays to $J/\Psi\ \pi^+\pi^-$

X(3872) decay angular distribution

Check: for
$\psi'(1^-) \to J/\psi\,\pi^+\pi^-$
expect isotropic distribution in θ

$\chi^2/\text{dof}=36/9$

In the case of $h_c'(1^+)$ expect $\sin^2\theta$; Similar as for $\psi_2(2^-)$, $\eta_c''(0^-)$

$|\cos^2\theta|$

$\psi' \to J/\psi\,\pi^+\pi^-$

$|\cos^2\theta|$ 1

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Hadron spectroscopy – X(3872)

Search for
$B^+ \to K^+ X(3872)$
$\hookrightarrow J/\psi\ \pi^+\pi^-\pi^0$

c) ω mass region

$M(\pi^+\pi^-\pi^0)$ (GeV)

M_{bc} (GeV) ΔE (GeV)

N=10.0±3.6 S/N=5

M_{bc} (GeV) ΔE (GeV)

$\Gamma(\omega\,J/\psi)/\Gamma(J/\psi\ \pi^+\pi^-)=0.8\pm0.3\pm0.1$

in accordance with $D\bar{D}^*$ molecule model
Swanson, PLB 588,189(2004)
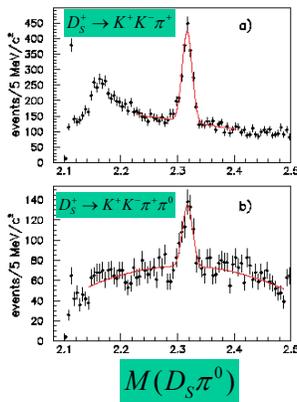
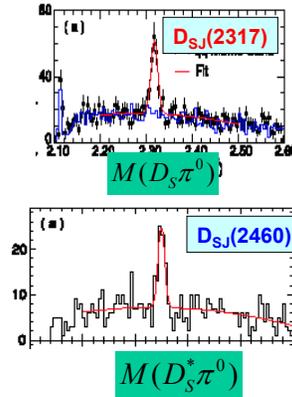May 17-25, 2005   Course at University of Barcelona   Peter Križan, Ljubljana
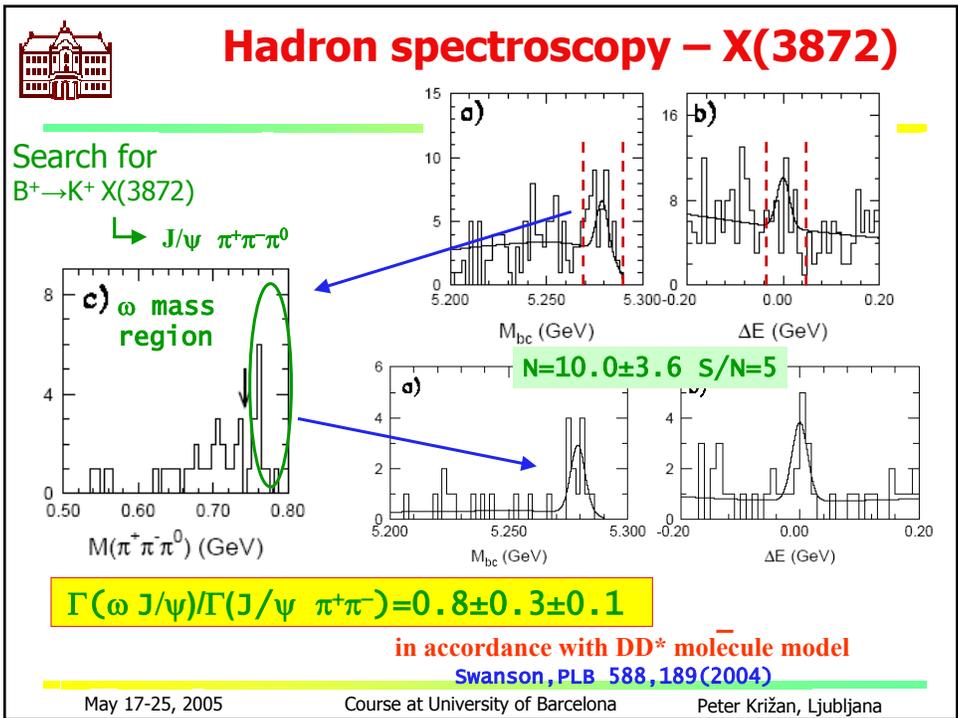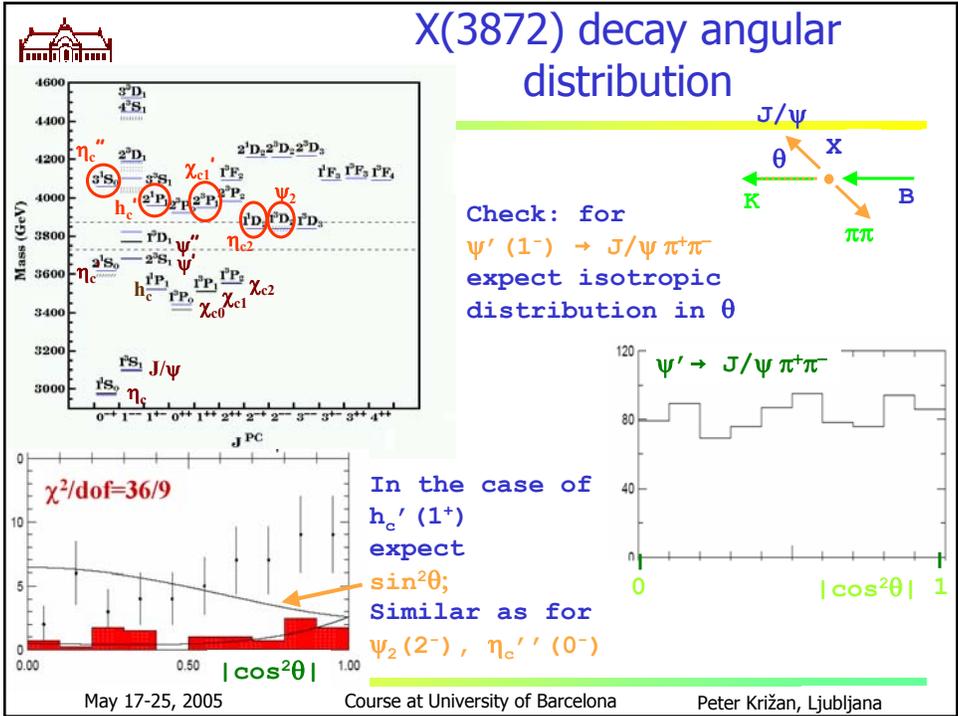
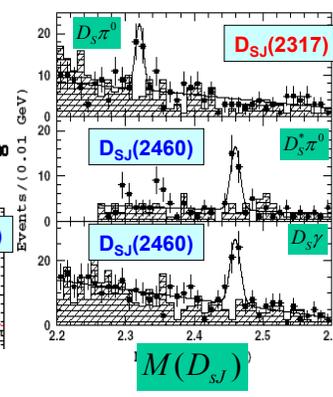**Hadron spectroscopy** – $D_{sJ}(2317)$ and $D_{sJ}(2460)$ mesons

BaBar - $D_{sJ}(2317)$ CLEO   Belle

$D_s^+ \to K^+K^-\pi^+$

$D_s^+ \to K^+K^-\pi^+\pi^0$

$D_{sJ}(2317)$

$D_{sJ}(2460)$

$M(D_S\pi^0)$

$M(D_S^*\pi^0)$

$D_{sJ}(2317)$

$D_{sJ}(2460)$
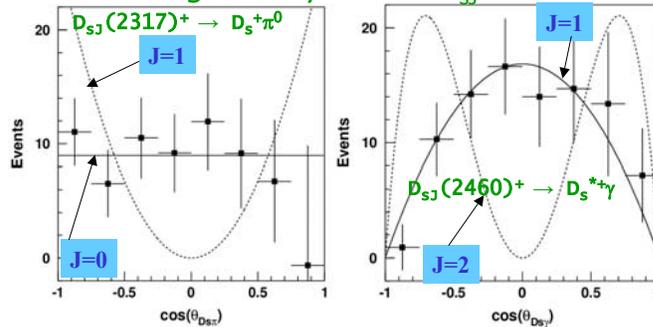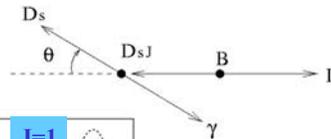
$D_{sJ}(2460)$

$M(D_{sJ})$

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Hadron spectroscopy – D_{sJ} mesons

Properties studied
e.g. helicity in B→DD$_{sJ}$

$D_{sJ}(2317)^+ \to D_s^+\pi^0$

J=1

J=0

$D_{sJ}(2460)^+ \to D_s^{*+}\gamma$

J=1

J=2

Properties in accordance with lowest level P states $J^P=0^+,1^+$
Masses lower than expected from models!
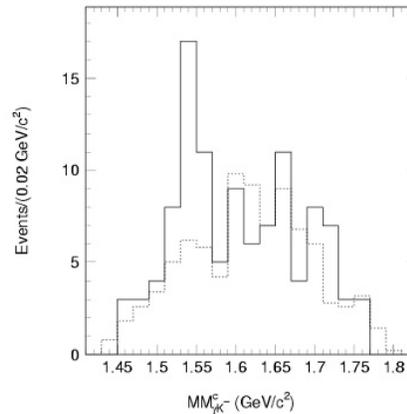
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Pentaquarks

Pentaquark discovery in 2003 of a state θ^+ at 1.520 GeV which decays into nK^+, uudds, was immediately confirmed by 10 experiments
(statistical significance of individual experiments is not high ~5-6 σ)

Discovery by LEPS ->

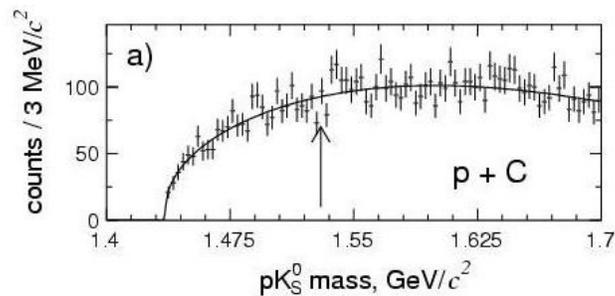# HERA-B: no evidence for θ^+

However many experiments DO NOT see pentaquarks

$\Rightarrow$ Situation IS NOT clear yet

$\Rightarrow$ Experiments which do not see θ^+ pentaquark are mainly at HIGH energy ->While pentaquarks are seen mainly at LOW energies

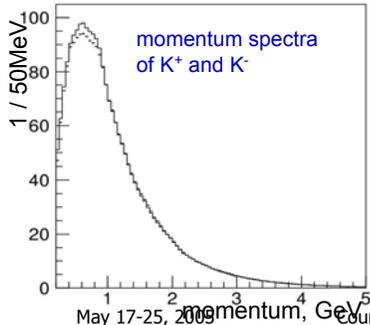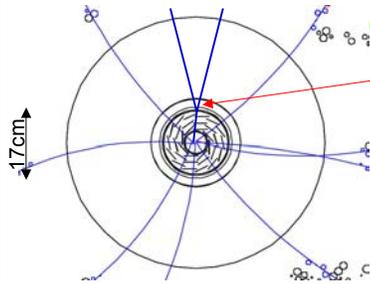$\Rightarrow$ Need for a high statistics experiment at LOW energy

Belle: Search for pentaquarks using kaon interactions in the detector material

17cm

1 / 50MeV

momentum spectra of K$^+$ and K$^-$

100
80
60
40
20
0

1   2   3   4   5
momentum, GeV

- Small fraction of kaons interacts in the detector material. Select secondary pK pairs to search for the pentaquarks.
- Momentum spectrum of the projectile is soft.
    $\Rightarrow$ low energy regime, similar to most experiments which observed pentaquark.
- Projectile is not reconstructed.
    $\Rightarrow$ K$_S$ flavor is not fixed.
    $\Rightarrow$ can not distinguish between elastic and inelastic scattering.

- Secondary pK pairs selection:
    - p, K$^\pm$ do not originate from e$^+$e$^-$ interaction point, identified using dE/dx, TOF and Cherenkov info
    - K$_S \rightarrow \pi^+\pi^-$ detached vertex, momentum is not pointing to e$^+$e$^-$ interaction point
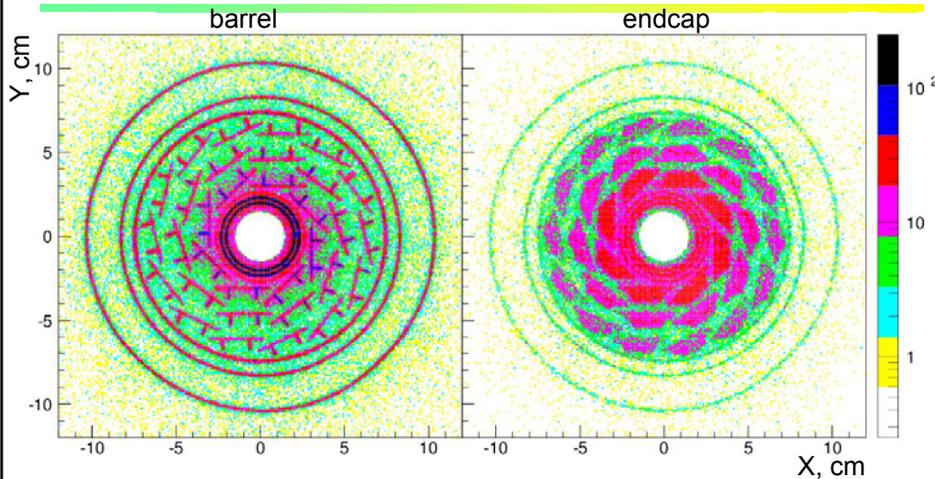   - detached common pK vertex

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XY Distribution of Secondary pK$^-$ Vertices in Data

barrel   endcap

Y, cm

10

5

0

-5

-10

-10   -5   0   5   10   -10   -5   0   5   10
                                                    X, cm

10^2

10

1

"Strange particle tomography" of the detector.
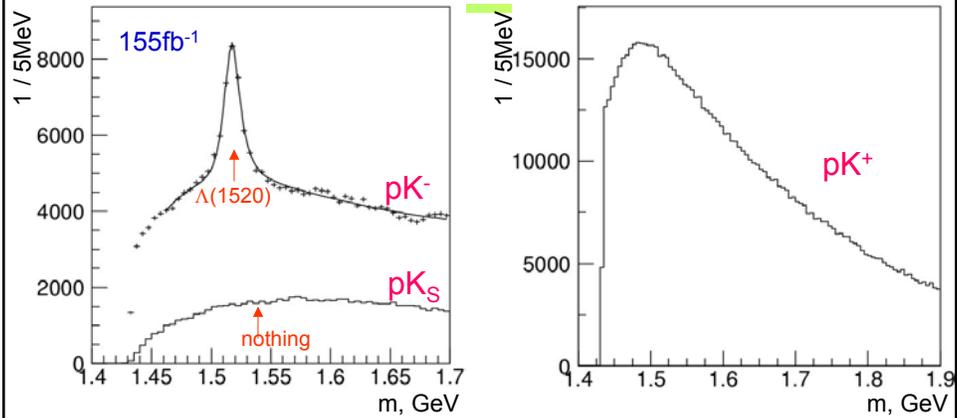$\Rightarrow$ Selected pK vertices originate from nuclear interactions.

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Mass Spectra of Secondary pK Pairs

Fit M(pK⁻) to D-wave BW ⊕ resolution function + threshold function.
⇒ Λ(1520) yield is 15519±412 events
M=1518.5±.2MeV in agreement with PDG'02 value 1519.5±1.0MeV