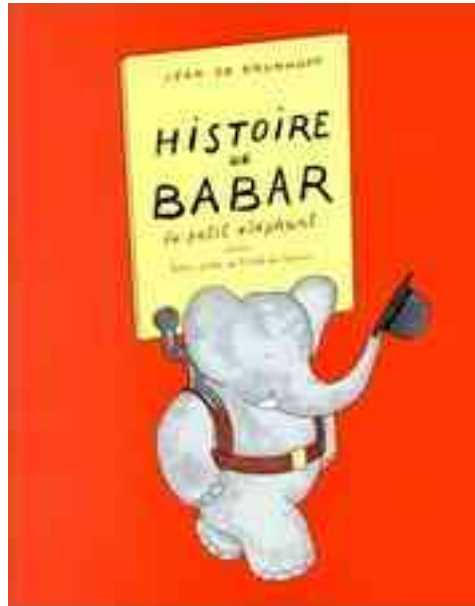


The Nature of the X(3872)



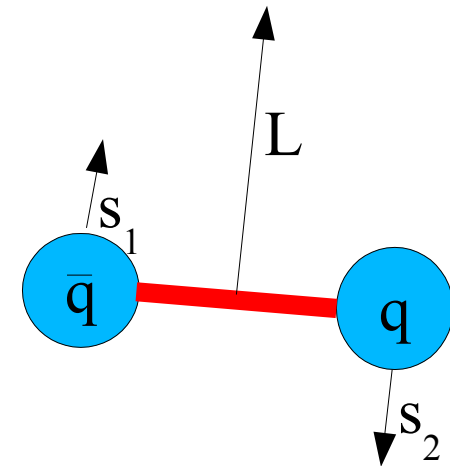
Brad Wogsland
DOE Presentation
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New States Discovered by B-Factories

- New states: X(3940), Y(3940), X(3872), Y(4260)
- Need to establish nature (conventional, exotic)
 - Use several different production modes:
B-decay, ISR, $\gamma\gamma$
 - Angular analysis (complicated)
 - Compare different decay modes (rate measurements)

QCD

- QCD predicts $q\bar{q}$ and qqq (which are observed), but also $qq\bar{q}\bar{q}$, $q\bar{q}g$, gg , etc.
- $\alpha_s = .22$ at the mass of J/ψ
- Conserved quantities in QCD:
 - Parity $P = (-1)^{L+1}$
 - C-Parity $C = (-1)^{L+S}$
 - Isospin I



$$J = |L-S|, \dots, L+S$$

total angular momentum

Meson quantum numbers

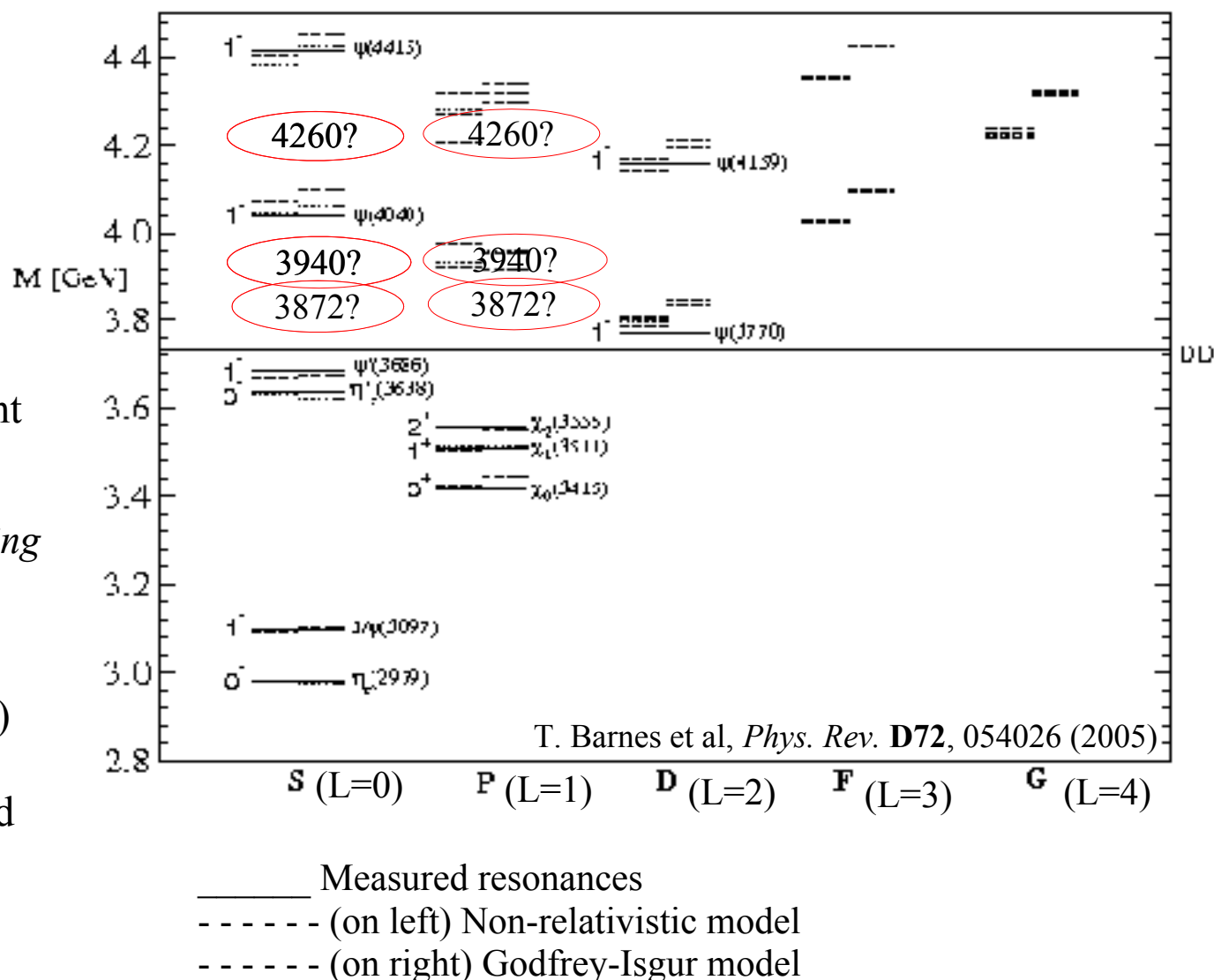
L can be any number, but S can only be 1 (spins aligned $\uparrow\uparrow$) or 0 (spins antialigned $\downarrow\uparrow$) for the two quarks in a meson:

L	J^{PC}
0	$0^{-+}, 1^{--}$
1	$1^{+-}, 0^{++}, 1^{++}, 2^{++}$
2	$2^{-+}, 1^{--}, 2^{--}, 3^{--}$

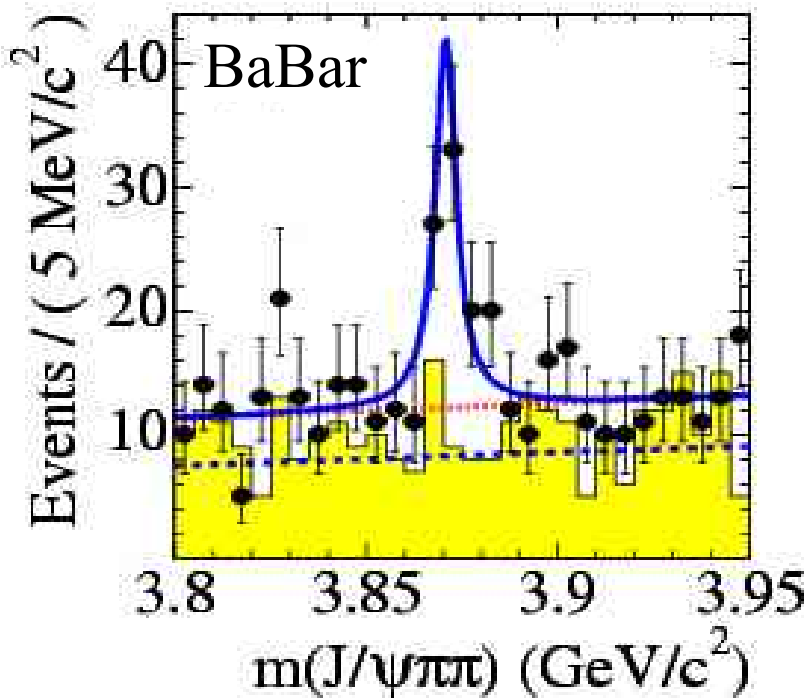
Resonances that otherwise look like mesons but don't have these quantum numbers are called exotics.

The Search for Charmonia at B-Factories

- Charmonium is a 2 particle system like hydrogen.
- Therefore quantum mechanics “simple” like hydrogen, but QCD potential unknown.
- Many use modified Coulomb plus linear potential which gives good results with the right parameters.
- $V = -(4/3)(a_s/r) + kr + \text{something}$
- New resonances observed at B meson factories like X(3872), X(3940), Y(3940) and Y(4260) are possible candidates for the unobserved states **not** predicted by potential models for conventional mesons



X(3872)



- First discovered at Belle (the other B meson factory in Japan) in B decays
- First observed as a resonance in the channel $J/\psi \pi^+ \pi^-$

..... non-B background
..... + peaking background
— + X(3872) signal
■ m_{ES} sideband

61.2 ± 15.3 events
 6.1σ significance
mass $3871.3 \pm 0.6 \pm 0.1$ MeV

Finding the Isospin of the Dipion Subsystem in the Decay of X(3872)

- Since the isospin I of J/ψ is zero, the isospin of the dipion system is the same as that of the X ; $I(\pi^+\pi^-)=0,1$, $I(\pi^0\pi^0)=0$, $I(\pi^+\pi^0)=1$
- Define $R = \Gamma(X \rightarrow J/\psi \pi^0 \pi^0) / \Gamma(X \rightarrow J/\psi \pi^+ \pi^-)$
- This means that the quantum numbers of X(3872) are

R	C-Parity	Isospin
0	+	1
0.5	-	0

- Belle reports indirect $R(X) < 1.3R(\psi')$ where $R(\psi') \sim .6$ (@90% C.L.)
- $X \rightarrow J/\psi \pi^+ \pi^0$ not observed yet
- $X \rightarrow J/\psi \pi^0 \pi^0$ not measured --> my task

Search Strategy

- B meson decays
 - $B \rightarrow X K, X \rightarrow J/\psi \pi \pi$
 - B, K, pions can be charged or neutral
 - Only neutral X observed
 - Kinematics well defined
 - as compared to ISR and $\gamma\gamma$
- Two stage analysis
 - 1) Filter (wide open)
 - 2) Fine selection & likelihood fit

B-Decay Reconstruction

Kinematic variables:

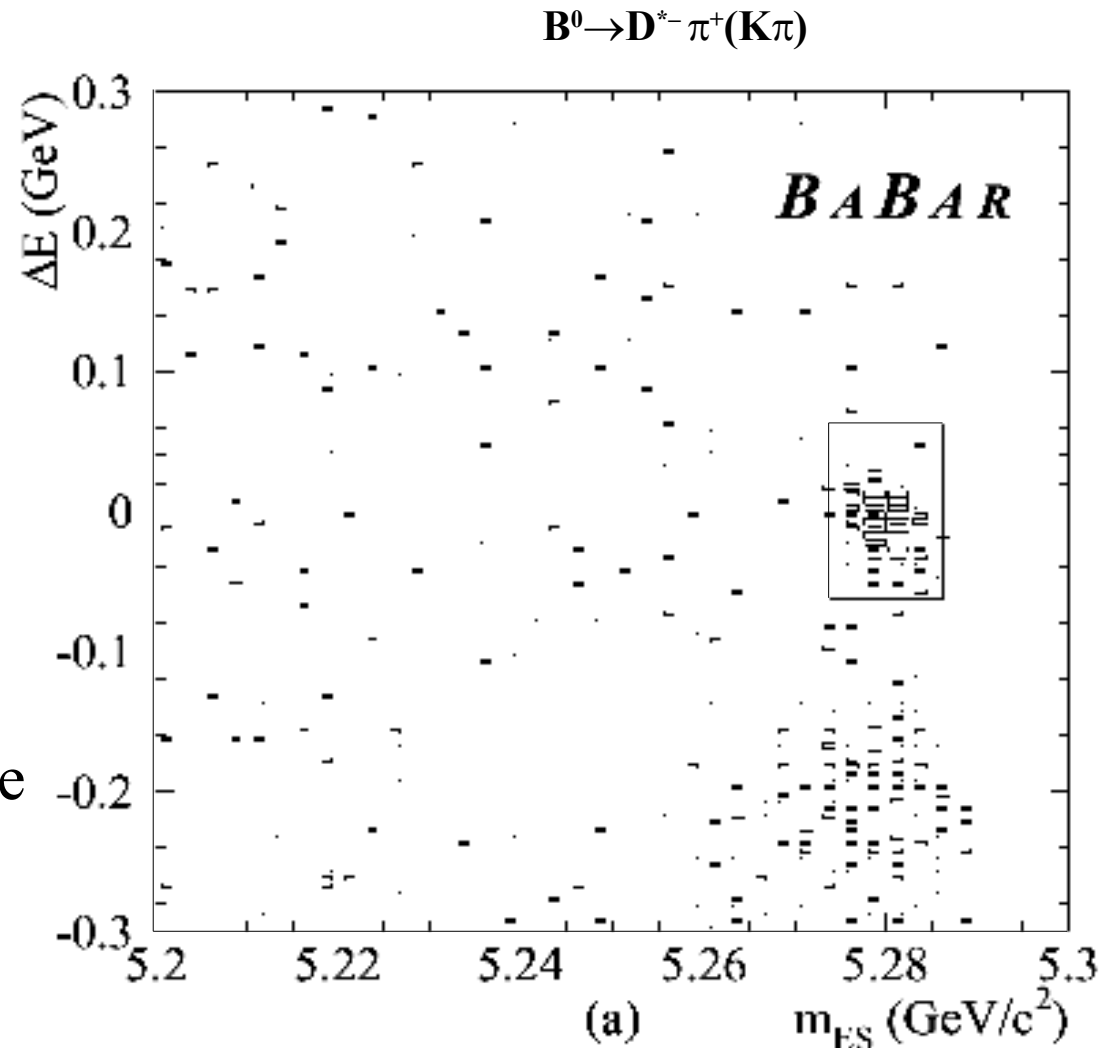
- Energy Substituted Mass

$$m_{ES} = (E_{bc}^2 - p_B^2)^{.5}$$

- Delta E

$$\Delta E = E_{bc} - E_B$$

- E_{bc} is the beam-constrained energy, E_B is the energy of the B meson, and p_B^2 is its momentum squared



B-Decay Reconstruction

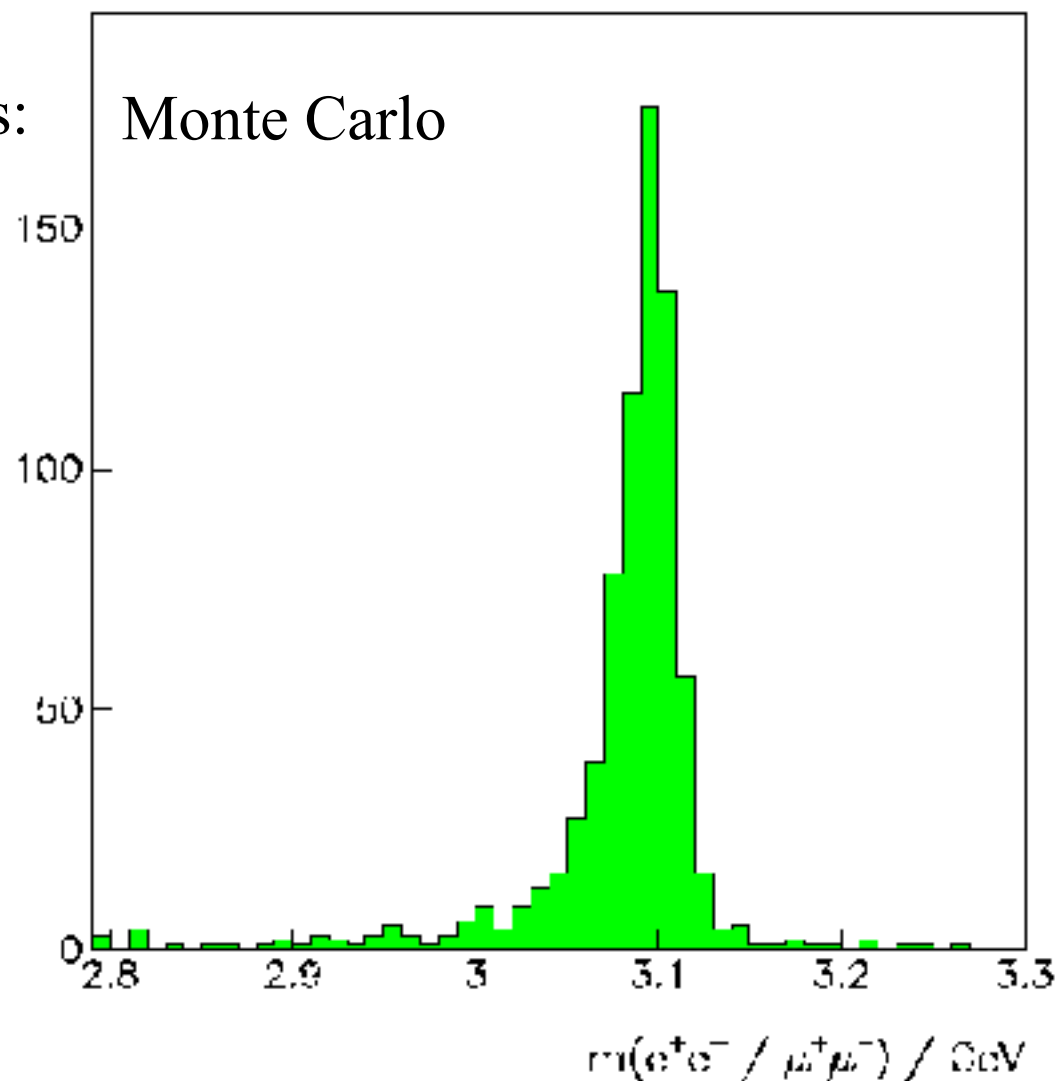
Stable + composite particles:

for example:

$J/\psi \rightarrow e^+e^- / \mu^+\mu^-$

invariant mass:

$$m^2 = (E_1 + E_2)^2 - (\mathbf{p}_1 + \mathbf{p}_2)^2$$



Filtering

- Data reduced in three stages:
 - 1) Raw Data Skim (processed)
 - 2) Selective Skim (ex. All events containing a J/ψ)
 - 3) Custom Skim (analysis-specific program prepared by me)
- Analysis started October 05
- BaBar software going through a period of rapid development
 - Filter written with two versions of the analysis software
 - Final version to be used in summer not yet known
 - Filtering started at SLAC on Monte Carlo
 - Skims moved to France (in2p3) during filtering
 - Filter program rewritten and tested to run at in2p3
- Filtering Runs 1-4 took ~ 1 week
 - Filter efficiency $\sim 60\%$ from MC testing
 - Completed late November 05
 - Root files to be moved to UT for microanalysis
 - Microanalysis takes ~ 1 day allowing for testing of final selection procedure

Filtering ... by the numbers

Run	All events ($\times 10^6$)	JpsitollTight skim ($\times 10^6$)	Filtered	% remaining
1 to 4	3317	19.9	743486	0.022

- Over 800 million Raw Data for Run 5 already processed
--> started tests of new release and data
- Run 5 will contain as much data as Runs 1-4 combined
- Expect to observe ~ 45 $X \rightarrow J/\psi \pi^0 \pi^0$ events in Runs 1-5 if $R=.5$
- Analysis projected for Summer'06