Observation of a narrow, near threshold $p\bar{p}$ state produced via $J/\psi \rightarrow \gamma p\bar{p}$

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Something narrow in the $J^{PC}=1^{--}$ $p\bar{p}$ system near $M_{p\bar{p}} = 2m_p$??

Figure 6: (a) Total multihadronic cross section (FENICE data and the average over previous experiments) with superimposed the result of the fit to a narrow resonance close to the $NN$ threshold; (b) comparison of the proton FF data to the expected behaviour for the presence of such a resonance.

Figure 7: Cross section for the reaction $e^+e^- \rightarrow 6\pi$ measured by the DM2 experiment.

Fit: $M = 1870 \pm 10$ MeV
$\Gamma = 10 \pm 5$ MeV

R. Calabrese PEP-N work-shop proceedings
Look at $p\bar{p}$ from $J/\psi \rightarrow \gamma pp$

- C-parity = +
- Spin = 1 suppressed? (Yang rule)
- S-wave (for $M_{p\bar{p}} \approx 2m_p$)
- \(\therefore\) probes $J^{PC} = 0^{+-}$ states
  - complements $p\bar{p} \rightarrow e^+e^-\text{ and } e^+e^-\text{ annihilation}$
Selection

• \( \geq 2 \) chrgd trks; \( \geq 1 \gamma \) veto e\(^+\)e\(^-\) & \mu^+\mu^-

• 4C-fits
  – \( CL(\gamma pp\bar{p}) > 0.05; \) \( CL(\gamma pp\bar{p}) > CL(\gamma K^+K^-) \)
  – \( CL(\pi^0 pp\bar{p}) < 0.001 \)

• PID(p) \( \geq 0.02; \) PID(p\(\bar{p}\)) \( \geq 0.02 \)

• for \( \gamma \): \( BSC_{\text{max}} < 0.8 \)

• no explicit TOF requirements
  – used by pid if available (Anal memo wrong!)

• …
p¯p masses for selected events

use entire (50M) J/ψ data sample
Fit gives “reasonable” results for the $\eta_C$

- $M = 2983 \pm 2$ MeV
  - PDG: 2980 ±2 MeV
- $\Gamma = 23 \pm 6$ MeV
  - PDG: 13 ± 4 MeV (& rising?)
- $B(J/\psi \rightarrow \gamma \eta_C \rightarrow \gamma p\bar{p})$
  - $(1.8 \pm 0.4) \times 10^{-5}$
  - PDG: $(1.6 \pm 0.7) \times 10^{-5}$
Are the pulls reasonable??

γ's are okay

mean ≈ 0

σ = 25%

p & \( \bar{p} \) are a little off

peak shifts \( \rightarrow \Delta E \approx -10 \text{MeV} \)

(is dE/dx correction off?)

σ’s are ok

σ = 2.6%

σ = 2.8%

\( E_{\text{meas}} - E_{\text{fit}}(\gamma) \)

\( p_{\text{meas}} - p_{\text{fit}}(p) \)

\( p_{\text{meas}} - p_{\text{fit}}(\bar{p}) \)

\( M_{pp} < 1.9 \text{ GeV} \) “signal” events
Are these really p and \bar{p}'s? (yes!)

Tagged p & \bar{p} from J/\psi \rightarrow \Xi^- \Xi^+

Tagged K^+ & K from J/\psi \rightarrow K^{*+}K^-

signal
Main background: $J/\psi \rightarrow \pi^0 p\bar{p}$
(with 1 $\gamma$ missed)

$N_0(-4.8 \delta^{1/2} + 12.9 \delta^{3/2})$

$\delta = (M_{pp} - 2m_p)$
Mass-dependent acceptance

Jin Shan has noted that the acceptance is $M_{pp}$-dependent.

Fit results:

- $N_{\text{sig}} = 105 \pm 17 \text{ evts}$
- $M = 1884 \pm 4 \text{ MeV}$
- $\Gamma = 19 \pm 7 \text{ MeV}$

- Backgnd level agrees with MC-scaled $\pi^0 p\bar{p}$

Acceptance

Weight S-wave BW using bilinear fit

Use $\pi^0 p\bar{p}$ data for shape of the bkgd.
Fit to “known” resonance?

η(1760) gives best fit:

- \( M = 1760 \text{ MeV} \)
- \( \Gamma = 60 \text{ MeV} \)

Not so hot!!

- CL = 1.6%
- \( \sqrt{2 \ln \left( \frac{L_1}{L_2} \right)} = 4.6 \)
- Bkgd \( \approx 0.75 \text{ MC} \)
Charged & neutral multiplicities

\[ M_{pp} < 1.9 \text{ GeV} \] “signal” events

~20% of events have additional charged tracks

~50% of events have additional neutrals
Restrict charge & neutral multiplicities

\[ N_{\text{chg}} = 2 \quad N_{\text{neu}} = 1 \]
Compare with other fits

$M = 1884 \pm 4 \text{ MeV}$

$\Gamma = 19 \pm 7 \text{ MeV}$

$\Sigma = 6.8\sigma$
Is it from the J/ψ or radiative return?
(look in ψ(2S) data)

How many events are expected in the ψ(2S) data?

If it really is from the J/ψ:

\[
n_{ψ_{2S}} \approx \frac{N_{ψ_{2S}}}{N_{J/ψ}} \times 0.14 \times n_{J/ψ} \approx 0.01 \times n_{J/ψ} \approx 1 \text{evt}
\]

If it is a radiative return (ISR) process:

\[
n_{ψ_{2S}} = \frac{L(ψ_{2S})}{L(J/ψ)} \times \frac{f(k_{ψ_{2S}})}{f(k_{J/ψ})} \times \frac{M_{J/ψ}^2}{M_{ψ_{2S}}^2} \times n_{J/ψ} \approx 0.2 n_{J/ψ} \approx 20 \text{evts}
\]
There is $\leq 1$ event in the $\psi(2S)$ data

- $3.8 \times 10^6 \psi(2S)$ decays
- $L(\psi(2S)) = 6.0 \text{ pb}^{-1}$

Radiative return is strongly disfavored!!
Corrected $|\cos\theta_\gamma|$ distribution

$N(1 + \cos^2\theta_\gamma)$

(|$\cos\theta_\gamma$| < 0.8)

As expected for radiative decays to a $0^-$ state
What is it?

• pp molecular state?
  – too narrow for an S-wave?
• 0−+ glueball?
  – why so close to 2m_p? & the 1−− state?
• dynamical effect?
  – why not in γΛΛ? or γΞ−Ξ+?
• ???
Summary

• new and unexpected(?) narrow meson state
• significance is high 6.8σ
• definitely p and p’s
  – $CL_{\text{pid}}$ and $E_{\text{BSC}}$ distributions clearly show this
• pull distributions are reasonable??
  – are the low-p dE/dx corrections ok?
• background almost all from $\pi^0\bar{p}p$
  – well studied with data & MC
• radiative-return strongly disfavored
• no known meson resonance fits the data well
• angular distributions are consistent