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

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

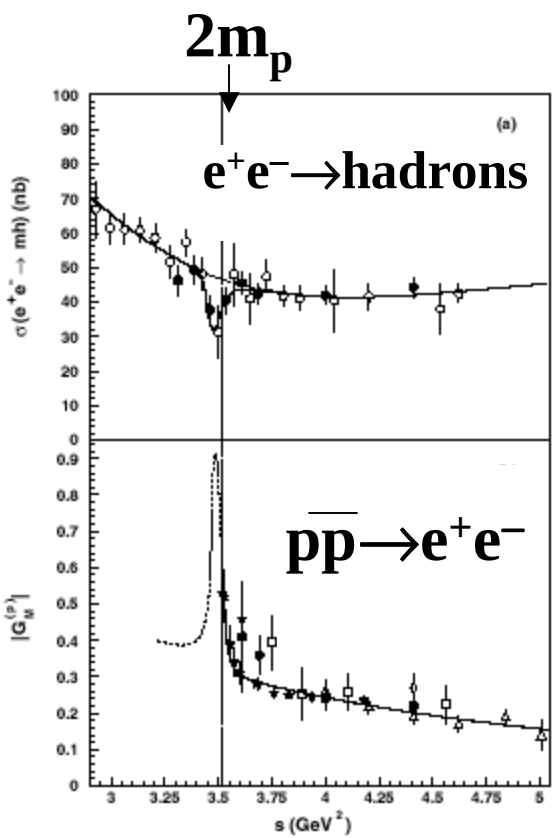


Figure 6: (a) Total multihadronic cross section (FENICE data and the average over previous experiments) with superimposed the result of the fit to a narrow resonance close to the $N\bar{N}$ threshold; (b) comparison of the proton FF data to the expected behaviour for the presence of such a resonance.

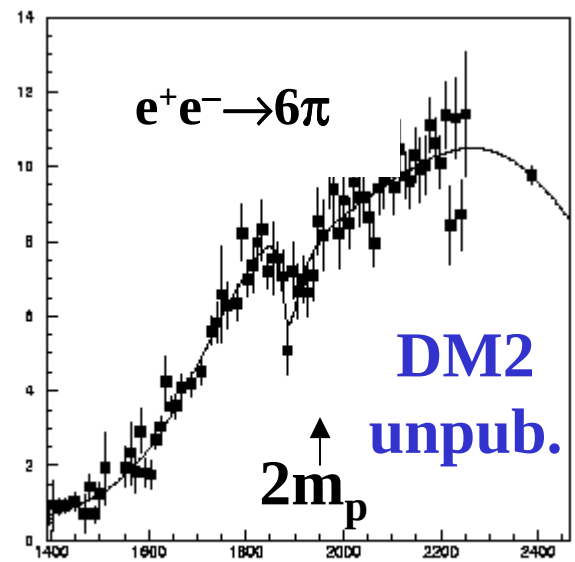


Figure 7: Cross section for the reaction $e^+e^- \to 6\pi$ measured by the DM2 experiment.

Fit: M = 1870 ± 10 MeV
Γ = 10 ± 5 MeV

R. Calabrese PEP-N work-shop proceedings

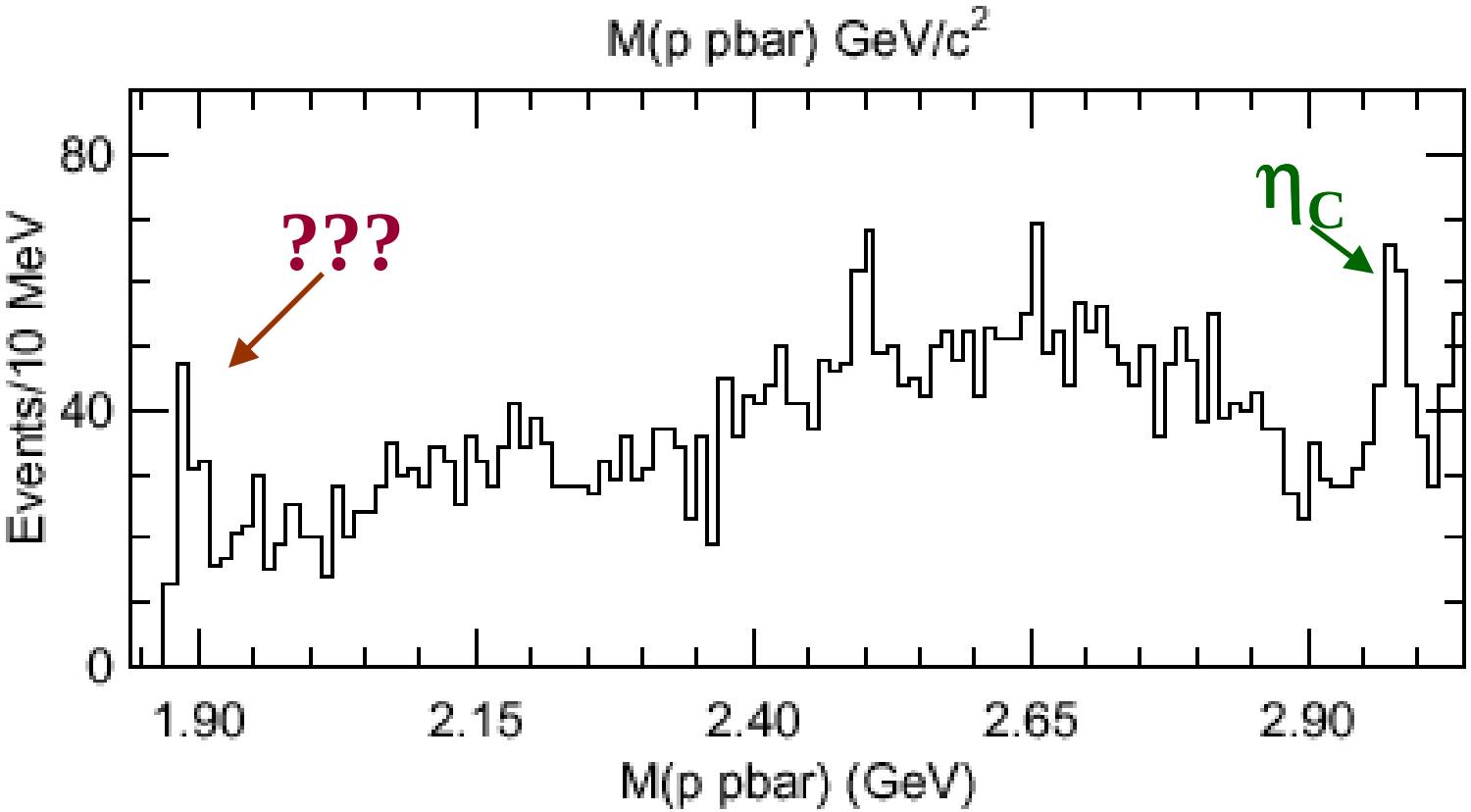
Look at $p\bar{p}$ from $J/\psi \rightarrow \gamma pp$

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

Selection

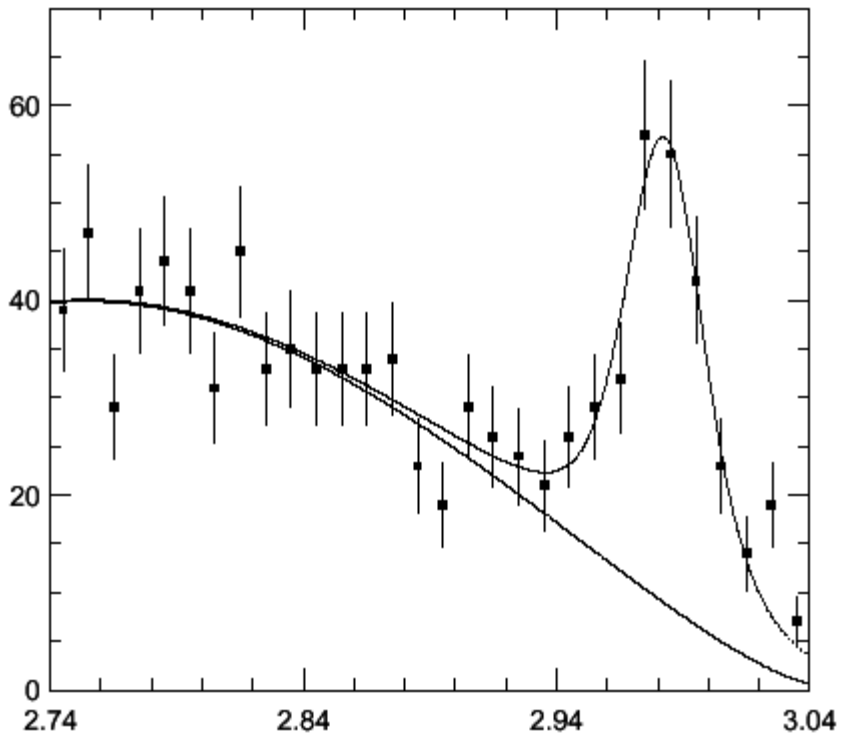
- ≥ 2 chrgd trks; $\geq 1\gamma$ veto e^+e^- & $\mu^+\mu^-$
- 4C-fits
  - **CL(γppbar)> 0.05; CL(γppbar)>CL(γK^+K^-)**
  - **CL(π^0ppbar)<0.001**
- PID(p) ≥ 0.02; PID(pbar) ≥ 0.02
- for γ: $BSC_{max}<0.8$
- no explicit TOF requirements
  - **used by pid if available (Anal memo wrong!)**
- …

$p\bar{p}$ masses for selected events



use entire (50M) J/ψ data sample

Fit gives "reasonable" results for the η_C

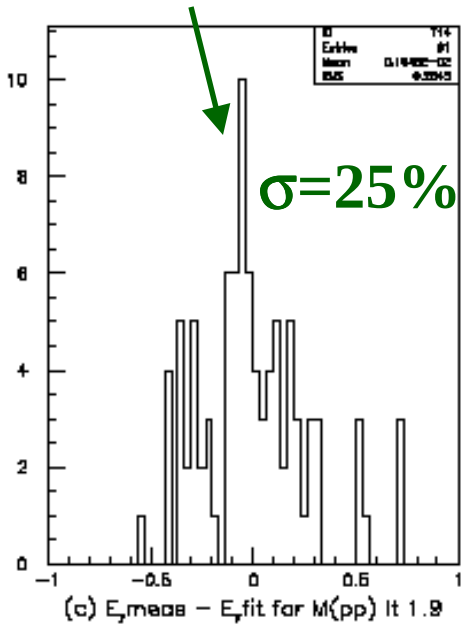


- **M=2983 ± 2 MeV**
  - **PDG: 2980 ±2 MeV**
- **Γ= 23 ± 6 MeV**
  - **PDG: 13 ± 4 MeV (& rising?)**
- **$B(J/\psi \rightarrow \gamma\eta_C \rightarrow \gamma p\bar{p})$ = (1.8 ± 0.4) x 10^{-5}**
  - **PDG: (1.6 ± 0.7) x 10^{-5}**

Are the pulls reasonable ??

γ's are okay

mean ≈0



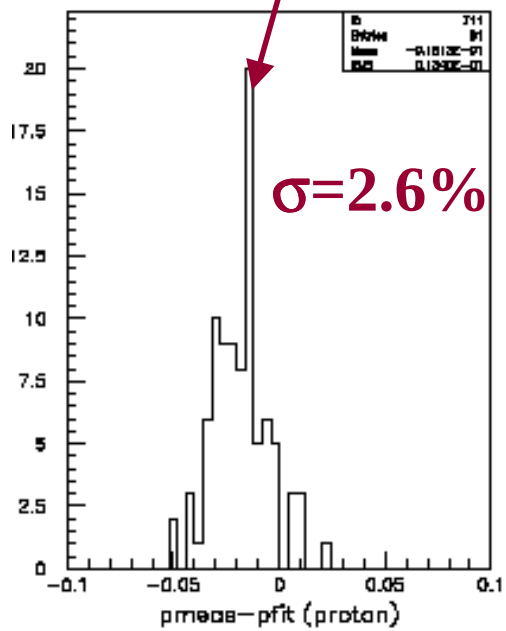
E_{meas}-$E_{fit}(\gamma)$

p & $\bar{p}$ are a little off

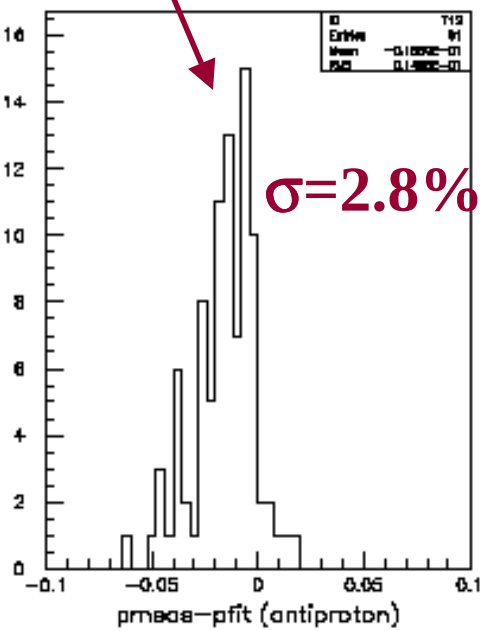
peak shifts➔ ΔE ≈ –10MeV

(is dE/dx correction off?)

σ's are ok



p_{meas}-$p_{fit}(p)$



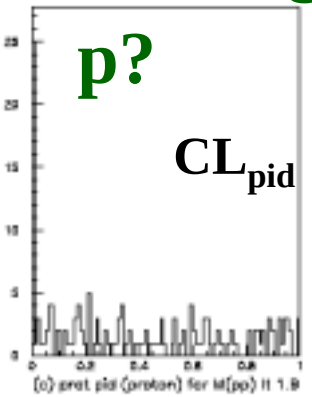
p_{meas}-$p_{fit}(\bar{p})$

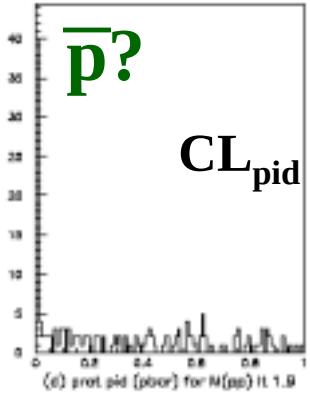
$M_{p\bar{p}}$ < 1.9 GeV "signal" events

Are these really p and $\bar{p}$'s? (yes!)

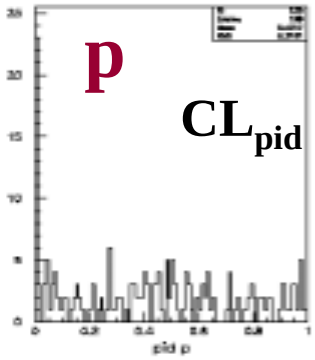
signal

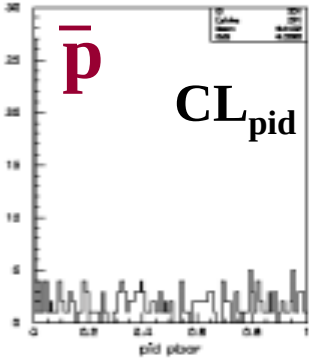
Tagged p & $\bar{p}$ from
$J/\psi \rightarrow \Xi^- \bar{\Xi}^+$

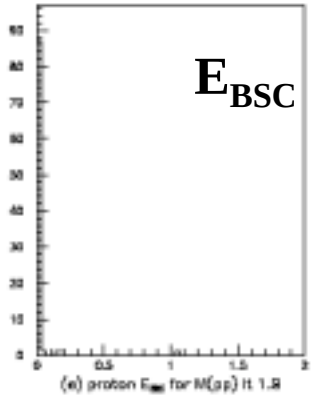


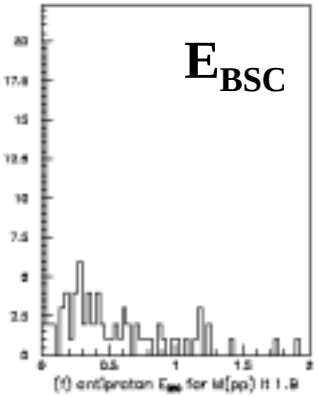


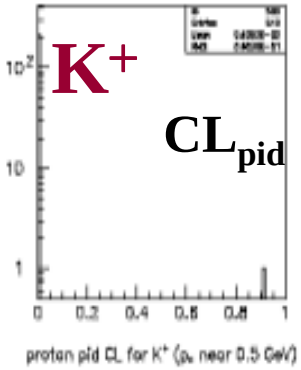
Tagged K^+ & K^- from
$J/\psi \rightarrow K^{*+}K^-$

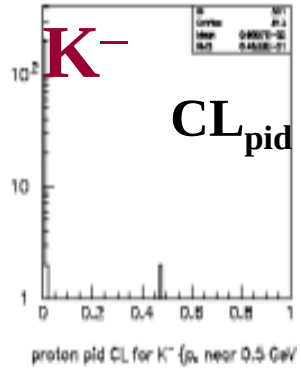


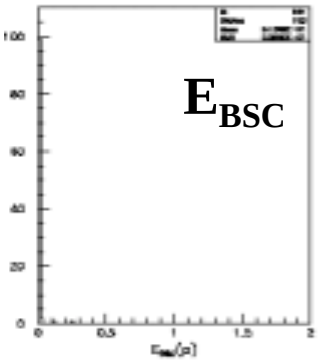


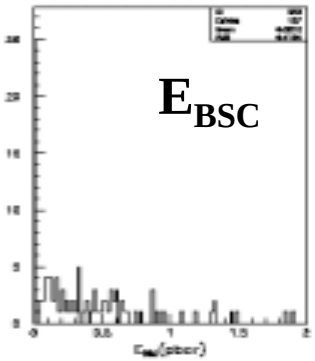


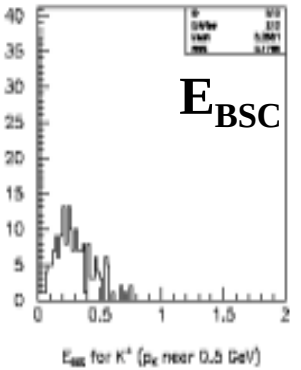


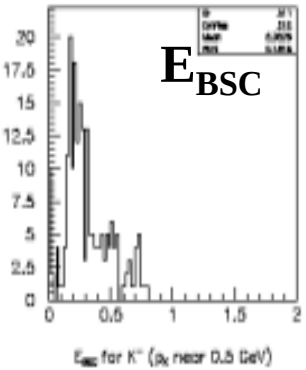




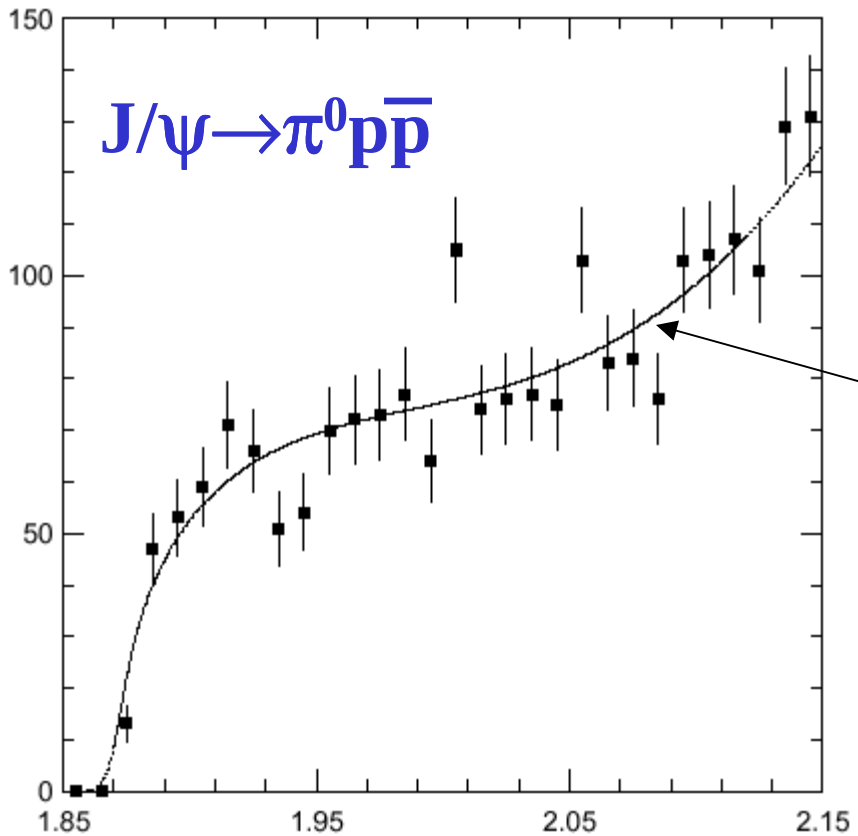








Main background: $J/\psi \rightarrow \pi^0 p\bar{p}$
(with 1 γ missed)

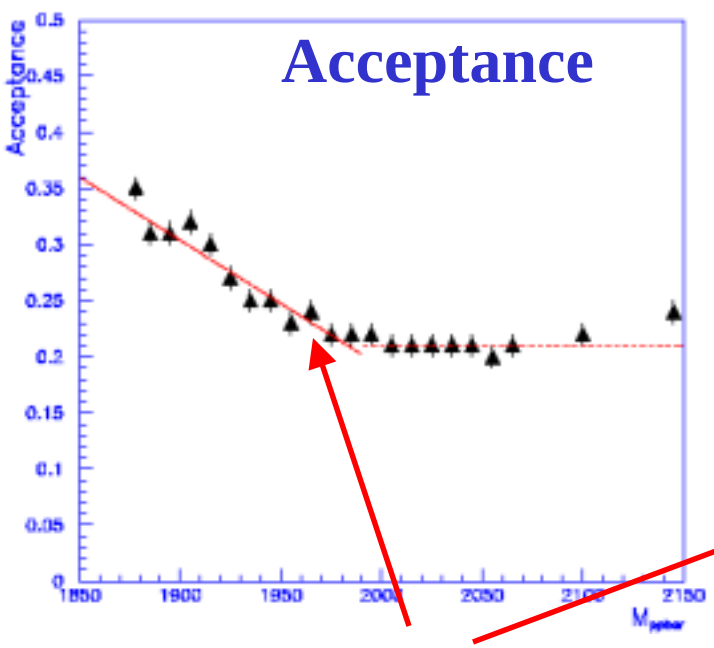


$$N_0(-4.8\,\delta^{1/2} + 12.9\,\delta^{3/2})$$

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

Mass-dependent acceptance

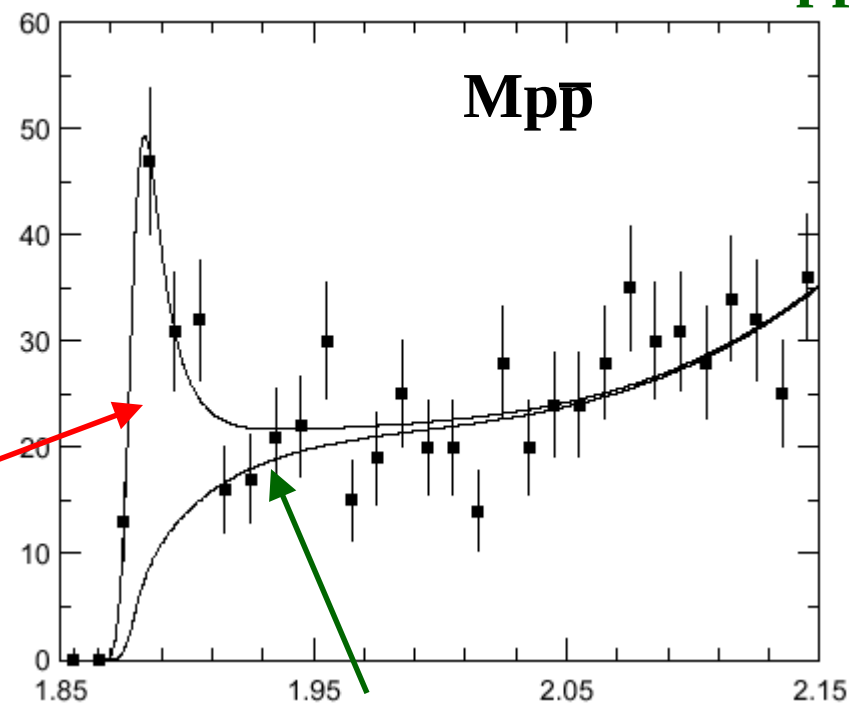
Jin Shan has noted that the acceptance is $M_{p\bar{p}}$-dependent



weight S-wave BW using bilinear fit

Fit results:

- Nsig=105 ± 17 evts
- M=1884±4 MeV
- Γ = 19 ± 7 MeV
- backgnd level agrees with MC-scaled $\pi^0 p\bar{p}$

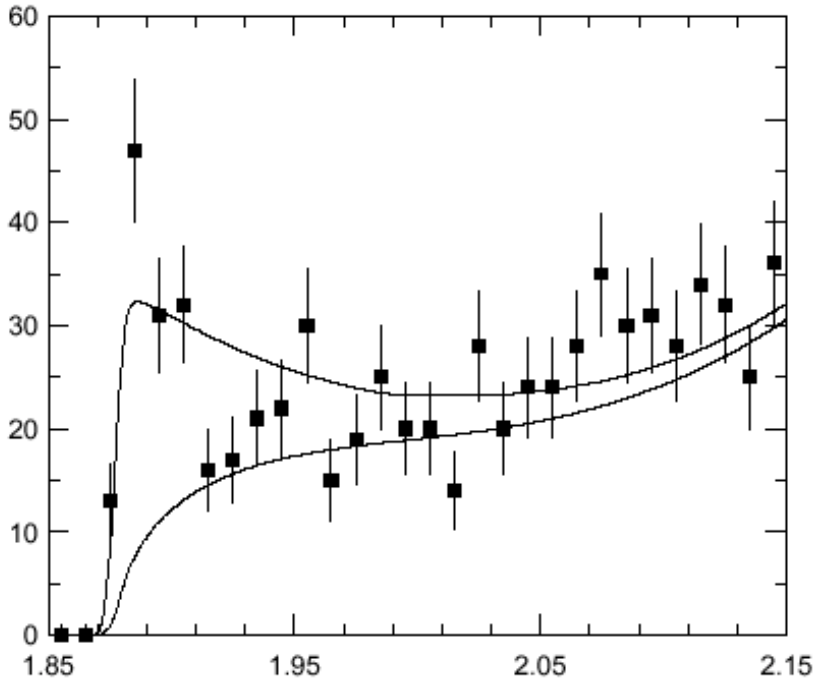


use $\pi^0 p\bar{p}$ data for shape of the bkgd

Fit to “known” resonance?

Likelihood = 45.0
χ^2= 43.8 for 28 - 2 d.o.f., C.L.= 1.6%
Func convoluted with Gaussian of width3.000E-03, intervals 50, sigma***

Errors		Parabolic	Minos	
Function 1: eta1760				
NORM	182.90	± 22.89	- 0.0000E+00	+ 0.0000E+00
* MASS	1.7600	± 0.0000E+00	- 0.0000E+00	+ 0.0000E+00
* WIDTH	6.00000E-02	± 0.0000E+00	- 0.0000E+00	+ 0.0000E+00
* 2MP	1.8770	± 0.0000E+00	- 0.0000E+00	+ 0.0000E+00
* MP	0.93830	± 0.0000E+00	- 0.0000E+00	+ 0.0000E+00
Function 2: bkgnd				
* THRESH	1.8770	± 0.0000E+00	- 0.0000E+00	+ 0.0000E+00
NORM	89.389	± 4.970	- 0.0000E+00	+ 0.0000E+00
* A1	-4.7800	± 0.0000E+00	- 0.0000E+00	+ 0.0000E+00
* A2	12.900	± 0.0000E+00	- 0.0000E+00	+ 0.0000E+00



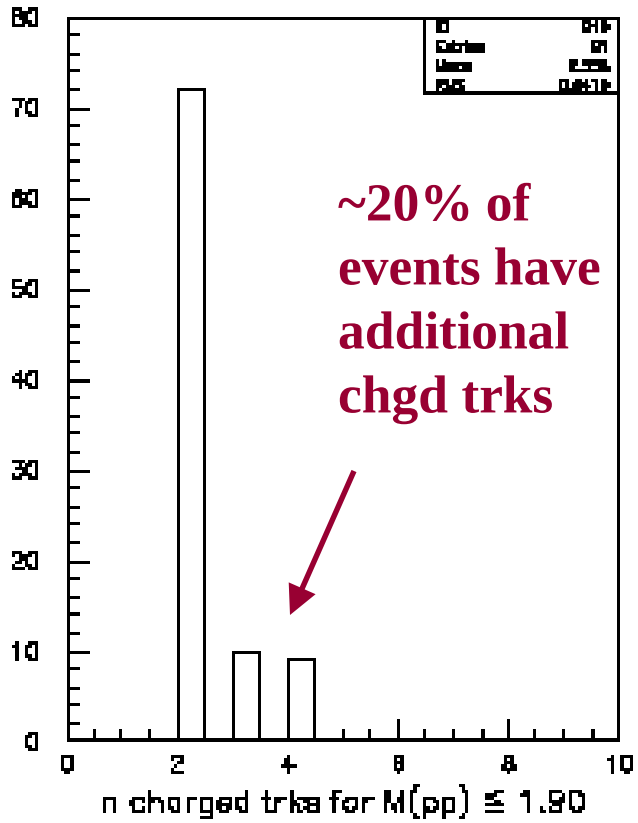
η(1760) gives best fit:

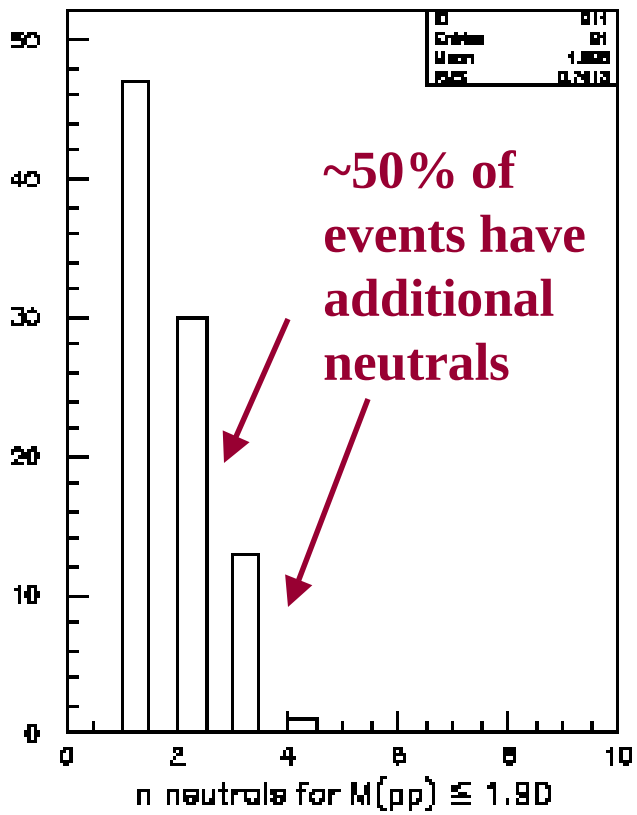
- **M=1760 MeV**
- **Γ = 60 MeV**

Not so hot!!

- **CL = 1.6%**
- $\sqrt{[2\ln(L_1/L_2)]}=4.6$
- **Bkgd ≈0.75 MC**

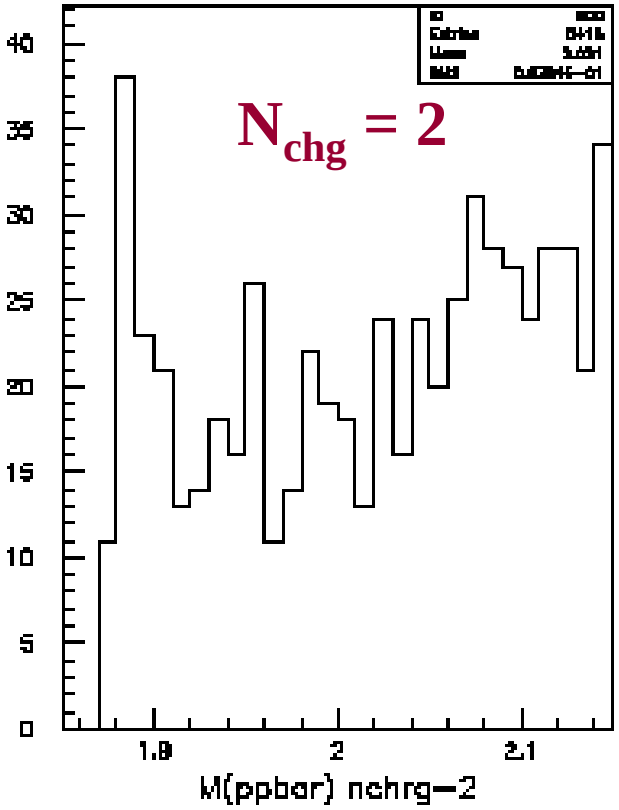
Charged & neutral multiplicities

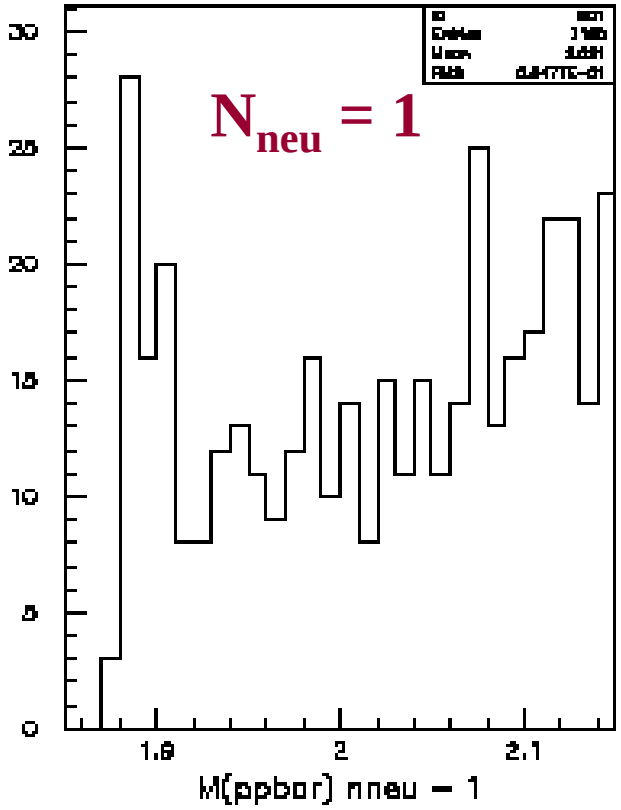




M_{pp} < 1.9 GeV "signal" events

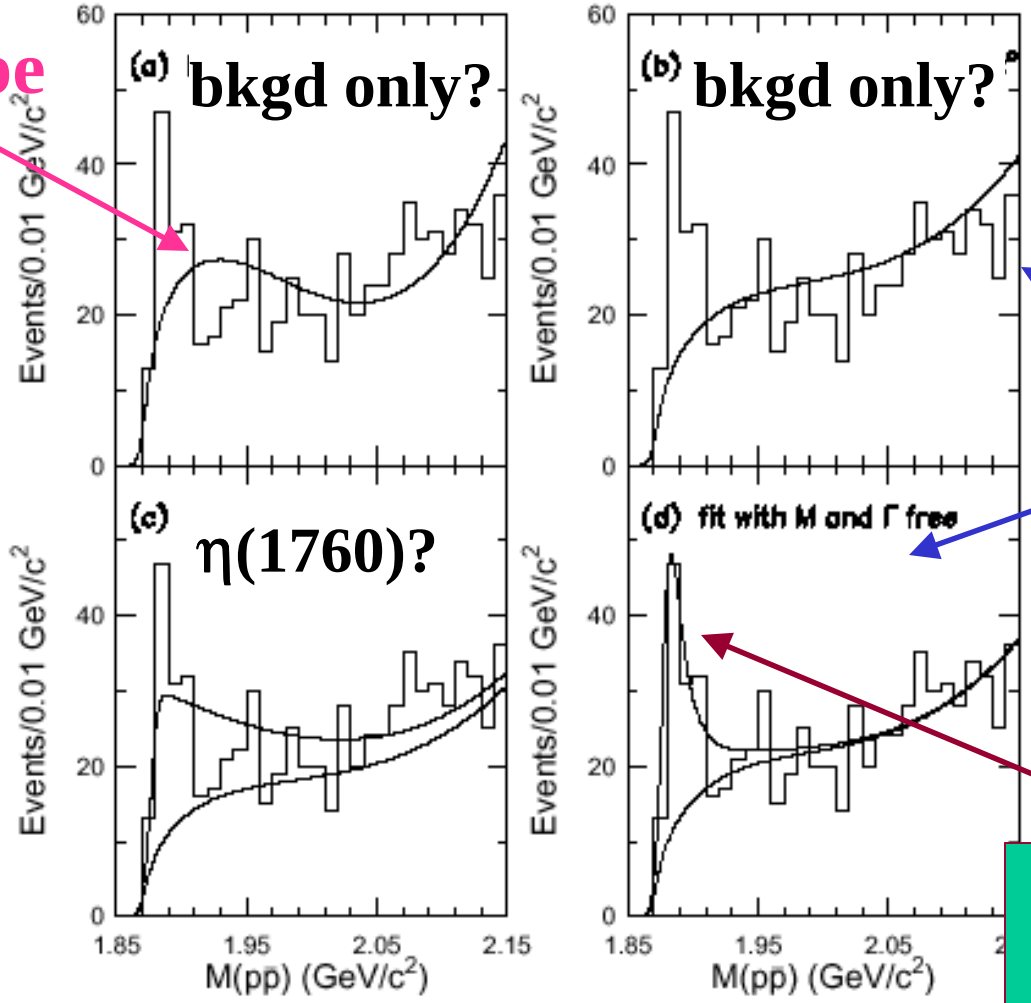
Restrict charge & neutral multiplicities





Compare with other fits

bkg shape free



bkg shape from $\pi^0 p\bar{p}$ fit

M=1884±4 MeV
Γ = 19 ± 7 MeV
Σ=6.8σ

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:

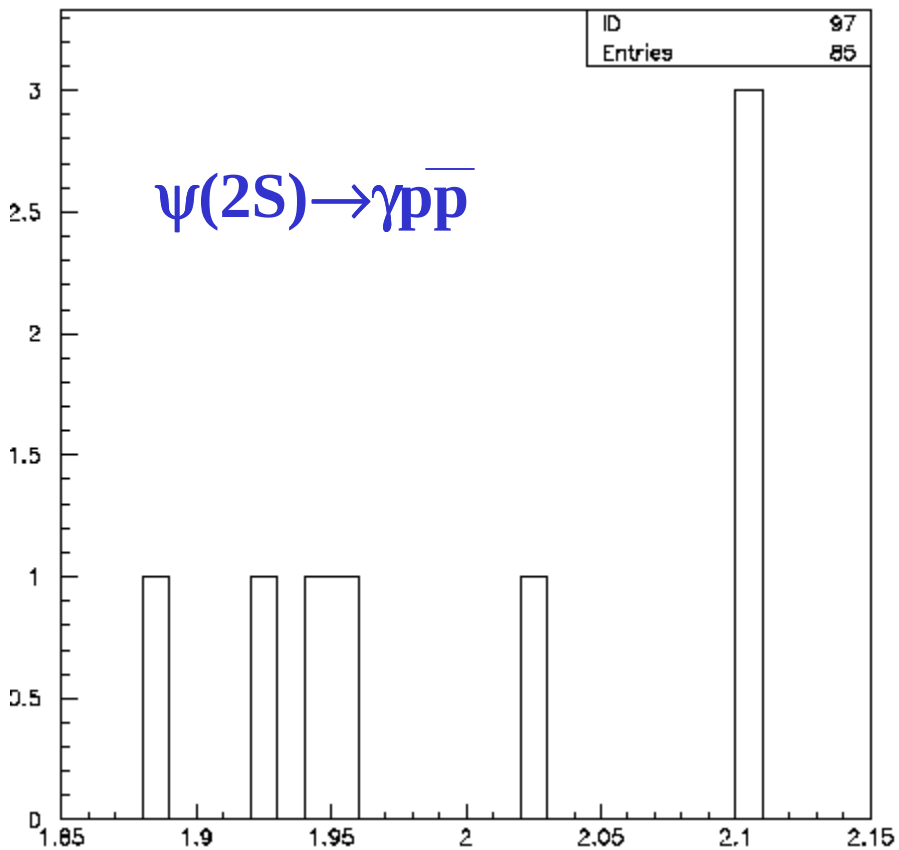
from the 14% rule

$$n_{\psi_{2S}} \approx \frac{N_{\psi 2S}}{N_{J/\psi}} \times 0.14 \times n_{J/\psi} \approx 0.01 \times n_{J/\psi} \approx 1 evt$$

If it is a radiative return (ISR) process:

$$n_{\psi 2s} = \frac{L(\psi 2s)}{L(J/\psi)} \times \frac{f(k_{\psi 2s})}{f(k_{J/\psi})} \times \frac{M_{J/\psi}^2}{M_{\psi 2s}^2} \times n_{J/\psi} \approx 0.2 n_{J/\psi} \approx 20 evts$$

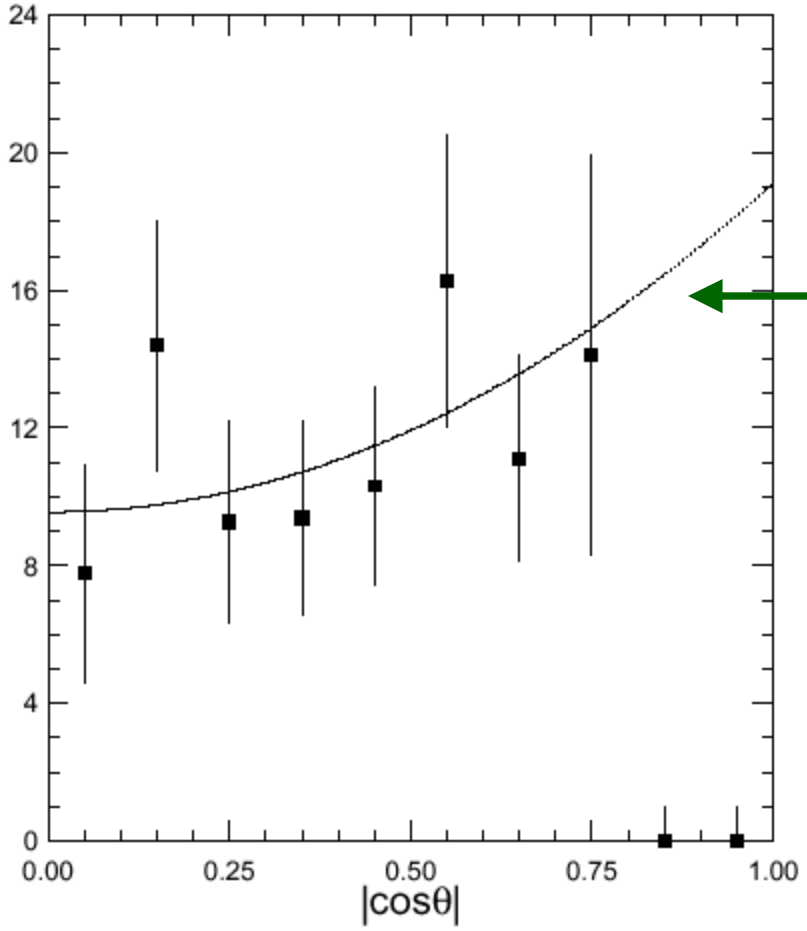
There is ≤1 event in the ψ(2S) data



- **3.8M ψ(2S) decays**
- ***L*(ψ(2S)) = 6.0 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?

- $p\bar{p}$ molecular state?
  - too narrow for an S-wave?
- 0^{-+} glueball?
  - why so close to $2m_p$? & the 1^{--}state?
- dynamical effect?
  - why not in $\gamma\Lambda\bar{\Lambda}$? or $\gamma\Xi^-\Xi^+$?
- ????

Summary

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