Gluonic Mesons: Experimental Status and Prospects

Jim Napolitano, Rensselaer Polytechnic Institute

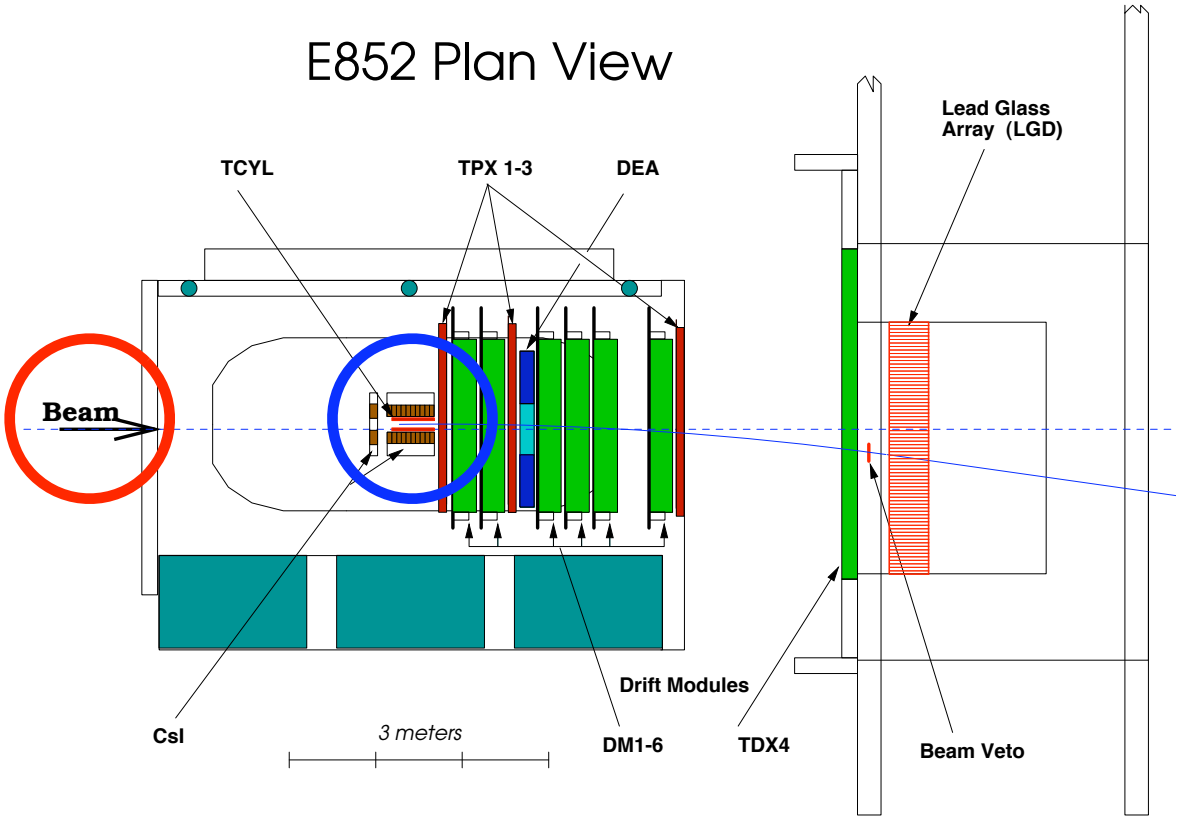
Workshop on Future PRC-US Cooperation in High Energy Physics
Beijing, China, 11-18 June 2006

Main Point of this Talk

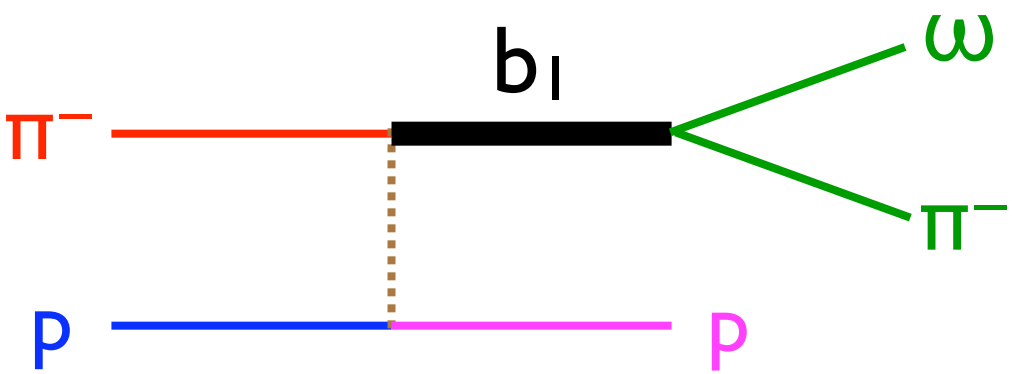
Experimental investigations of gluonic mesons need to move beyond "bump hunting." Amplitudes must be extracted and poles identified.

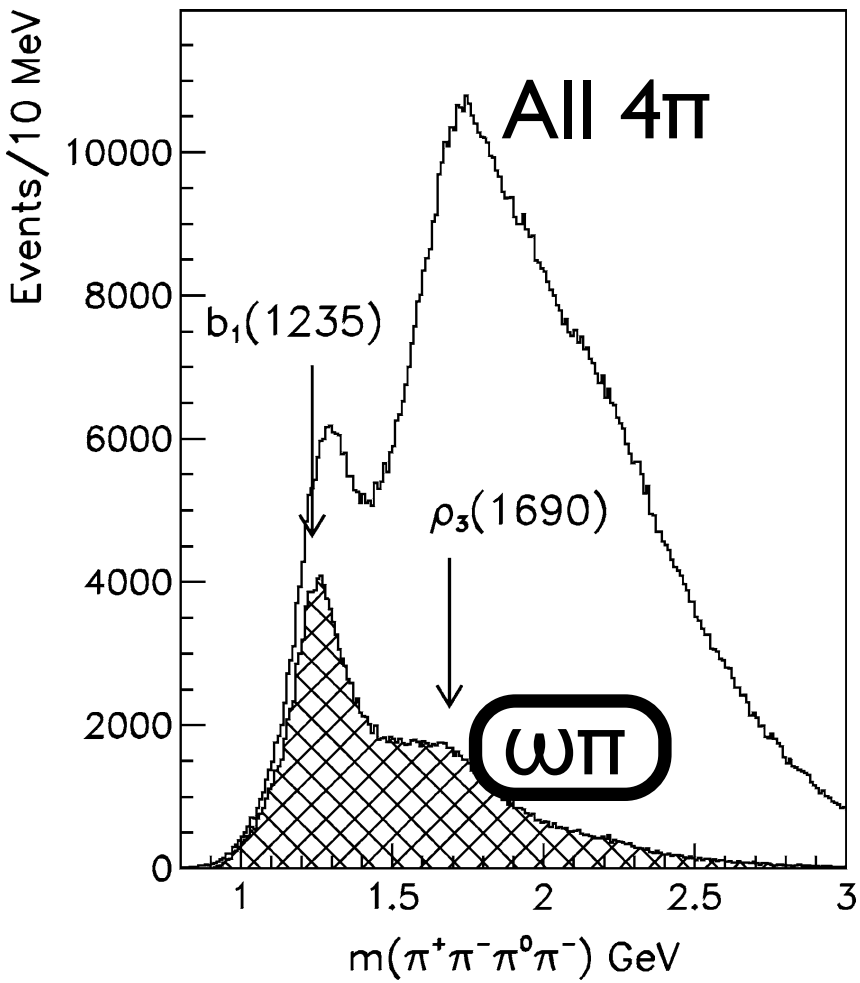
Careful "amplitude analyses" are difficult and it is necessary to keep a close eye on systematic effects.

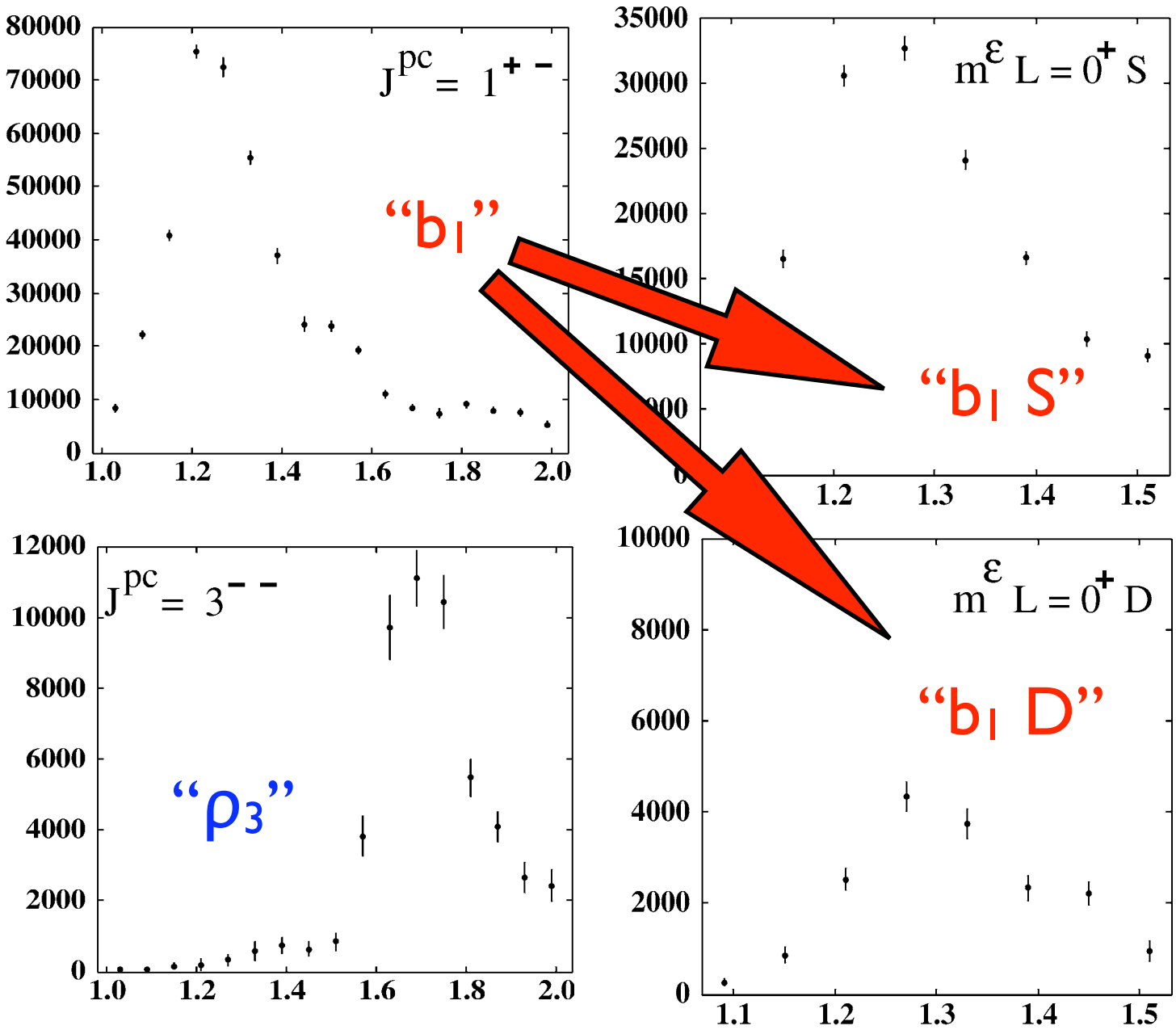
Resonant poles may have large widths. Various manifestations of the strong interaction will have to be considered and, possibly, used to interpret results.



Example (*not* exotic): Peripheral Production of $b_1(1235)$ in E852

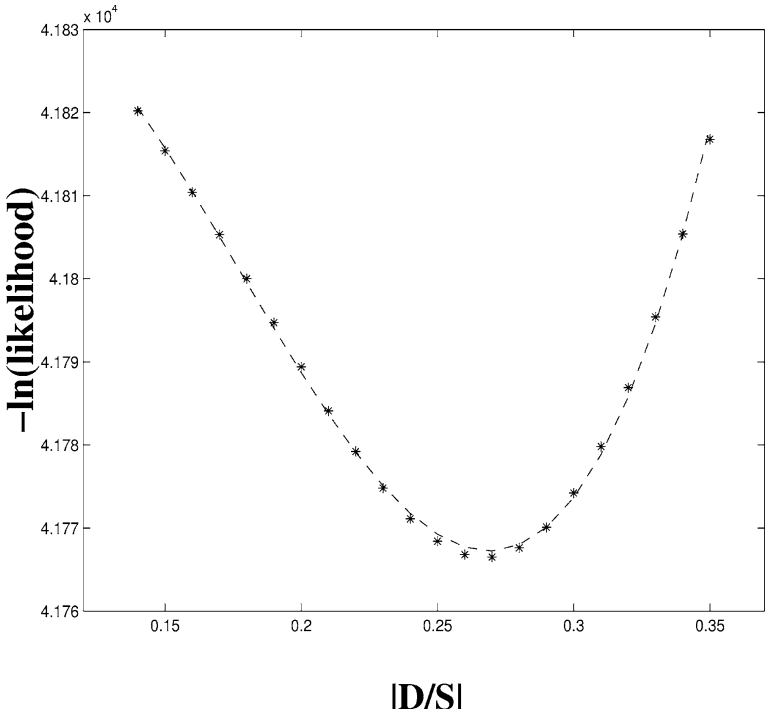


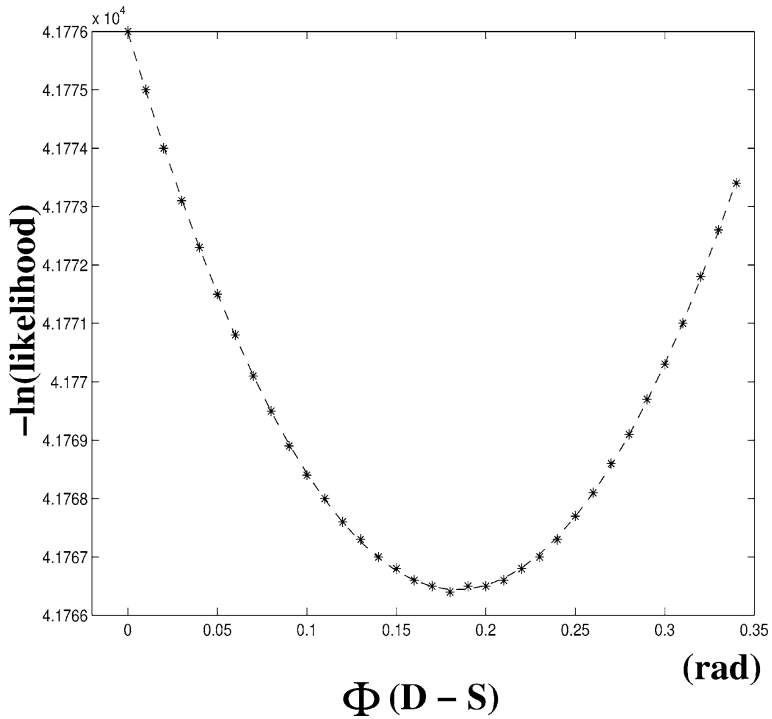




Amplitude analysis ("PWA")

M. Nozar, et al., Phys.Lett. B541 (2002)35

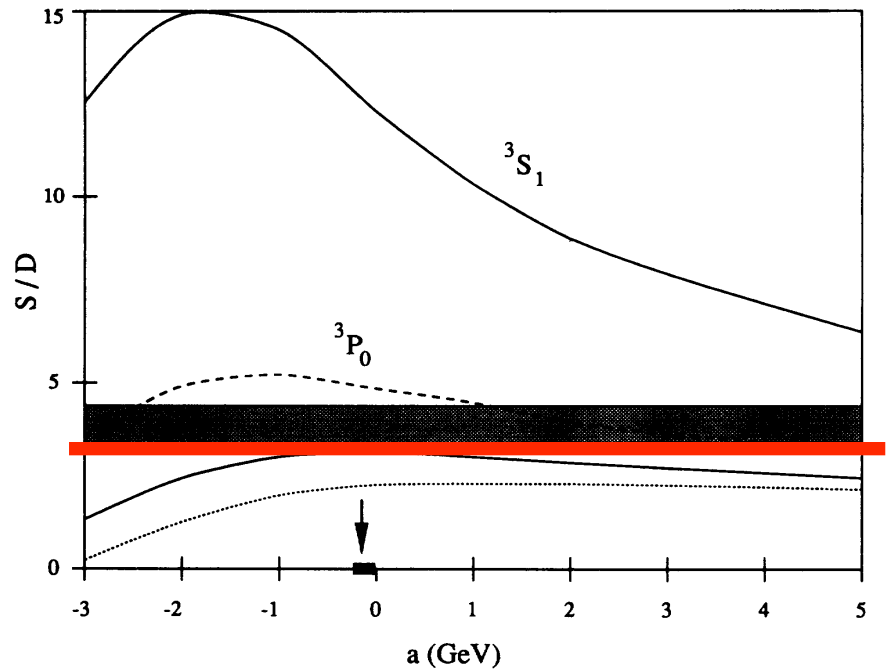




Precision Result

$|D/S| = 0.269 \pm 0.009 \pm 0.010$

$\Phi(D\text{-}S) = +0.184 \pm 0.042 \pm 0.07$



Note: Φ(D-S) agrees with Ackleh, Barnes, & Swanson Phys.Rev.D54(1996)6811

Two Important Classes of Gluonic Mesons

- Exotic Quantum Numbers

  "Manifestly exotic" states that cannot be formed by a quark plus antiquark

  Best bet for the future: GlueX

- Glueballs

  States with "pure glue" as the largest component of the wave function

  Best bet for the future: BES III

Exotic Quantum Numbers

- Some meson quantum numbers cannot be formed from a quark-antiquark pair

  e.g. $J^{PC}=0^{--}, 0^{+-}, 1^{-+}, 2^{+-}, \ldots$

- The identification of such a "resonance" is unequivocal evidence for an "exotic" meson

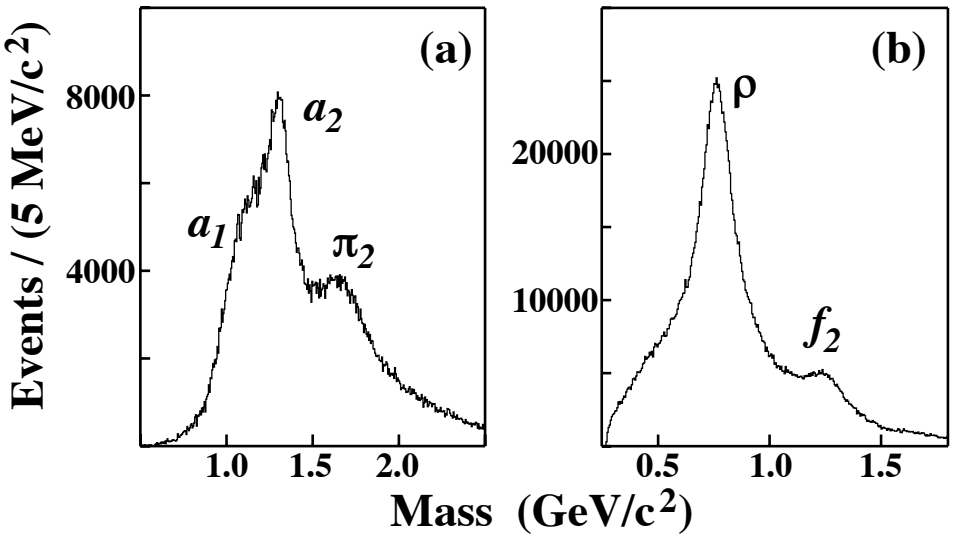
- *Is it a gluonic meson?* Do the spectroscopy and investigate the decay patterns.

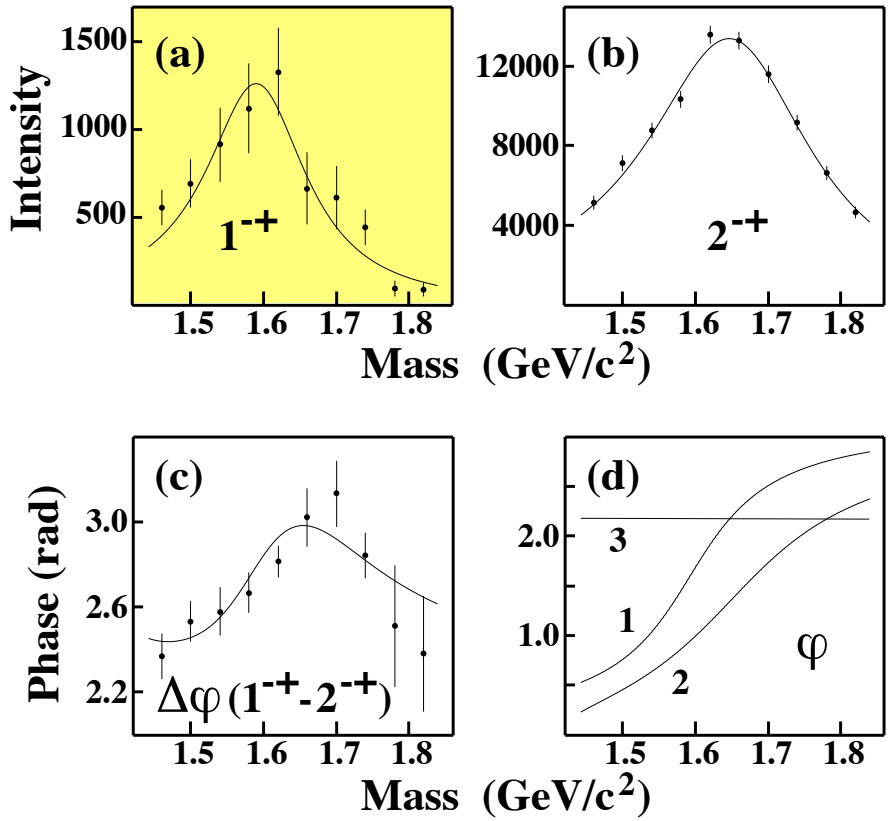
  In other words, the dynamics are the key

One Example: $J^{PC}=1^{-+}$ in 3π

Observation of a New $J^{PC} = 1^{-+}$ Exotic State in the Reaction $\pi^- p \to \pi^+\pi^-\pi^- p$ at 18 GeV/c

E852, Phys.Rev.Lett. 81(1998)5760

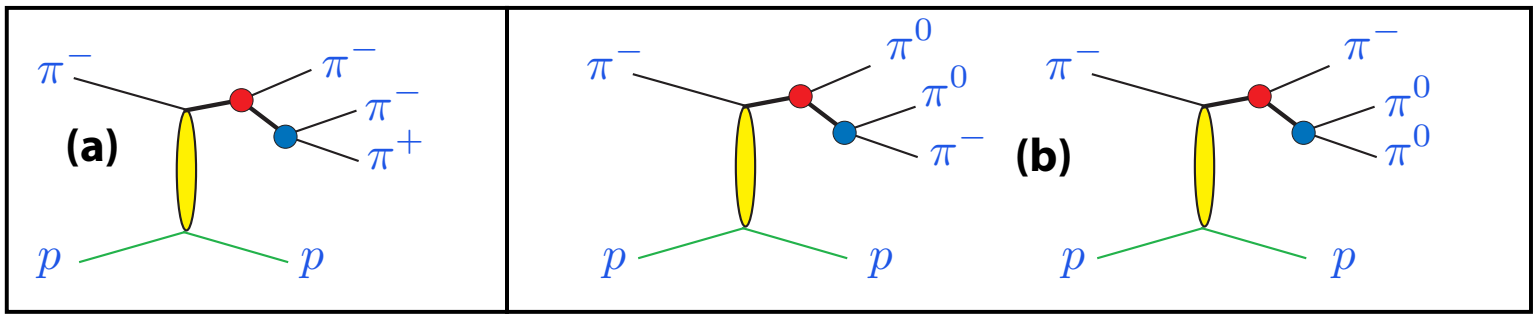




Same experiment, more data, another mode, and new analysis:

Phys Rev D73(2006)072001

The 1998 analysis based on 250K events of reaction (a). New analysis is based on 3M events each of reactions (a) and (b). The two modes provide important cross-checks.



PWA shows:

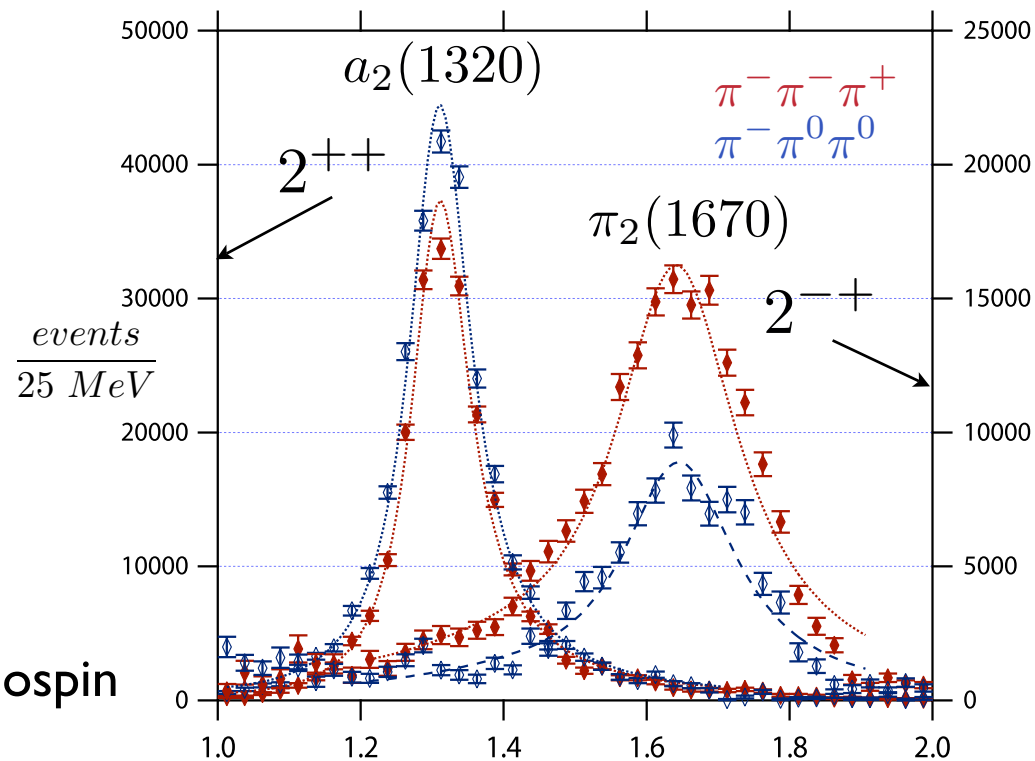
$a_2 \rightarrow \rho\pi$

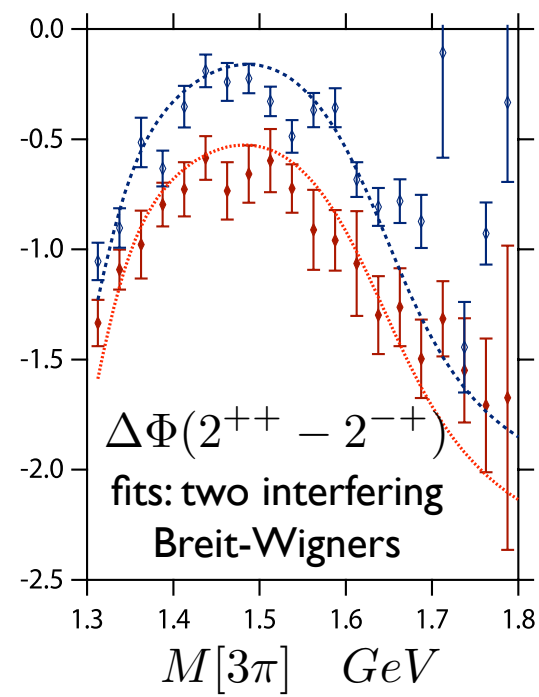
$$\frac{\pi^-\pi^-\pi^+}{\pi^-\pi^0\pi^0} \approx 1$$

$\pi_2 \rightarrow f_2\pi$

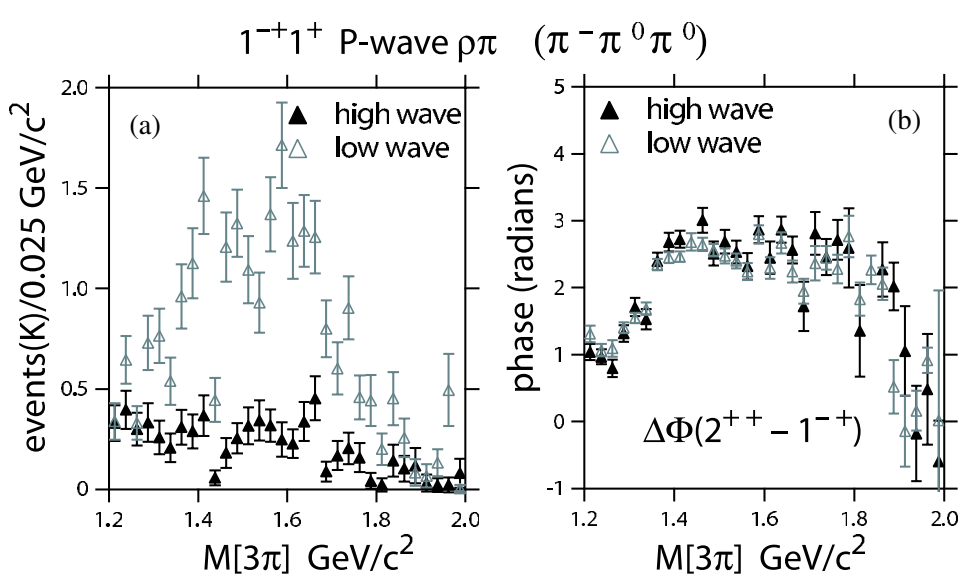
$$\frac{\pi^-\pi^-\pi^+}{\pi^-\pi^0\pi^0} \approx 2$$

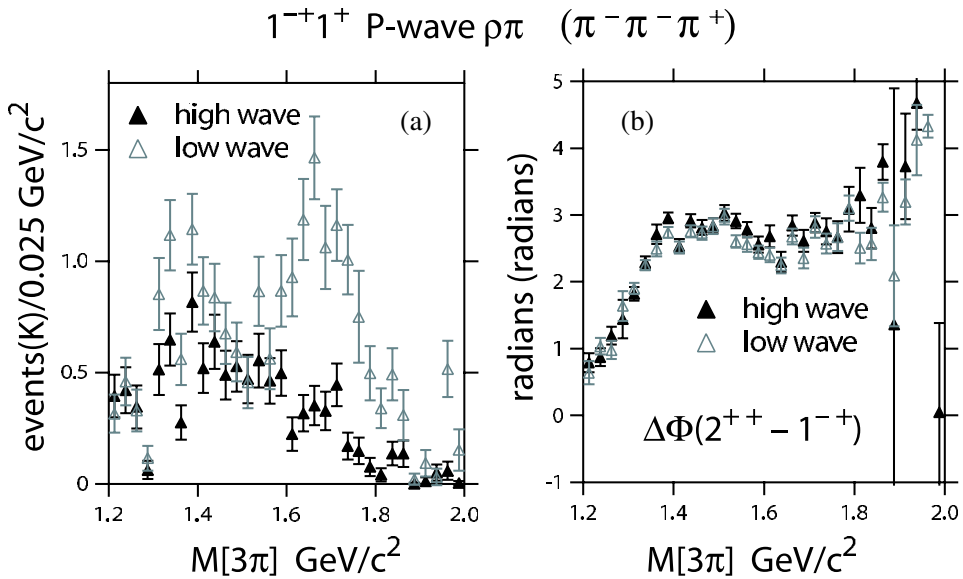
as expected from isospin





The effect of including the important waves...





Adding waves corresponding to allowed decays of the $\pi_2(1670)$ results in the disappearance of evidence for the exotic meson

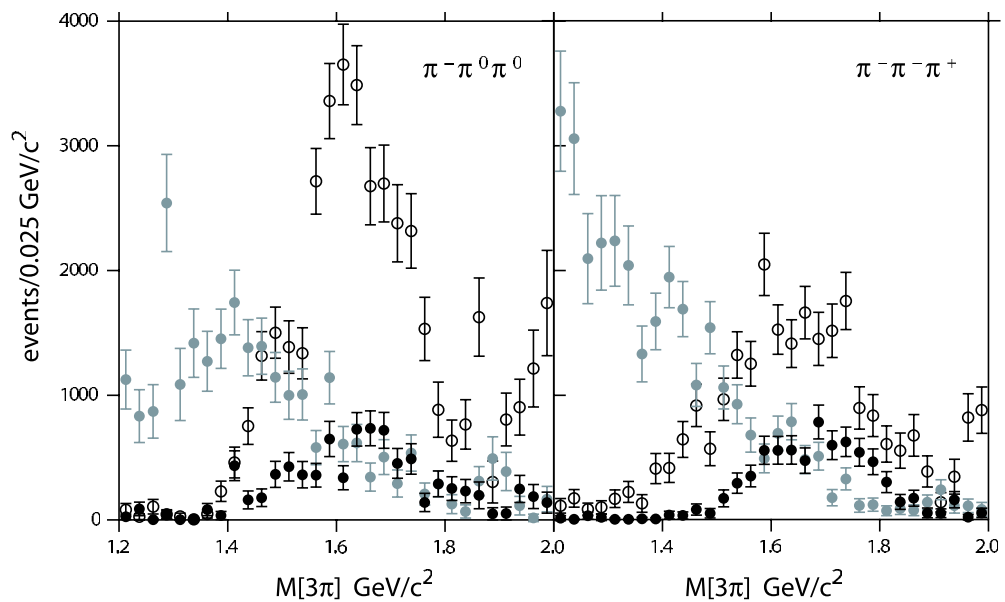
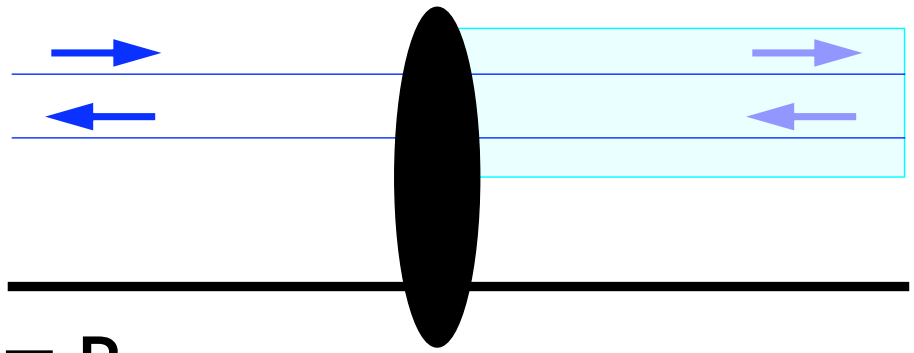
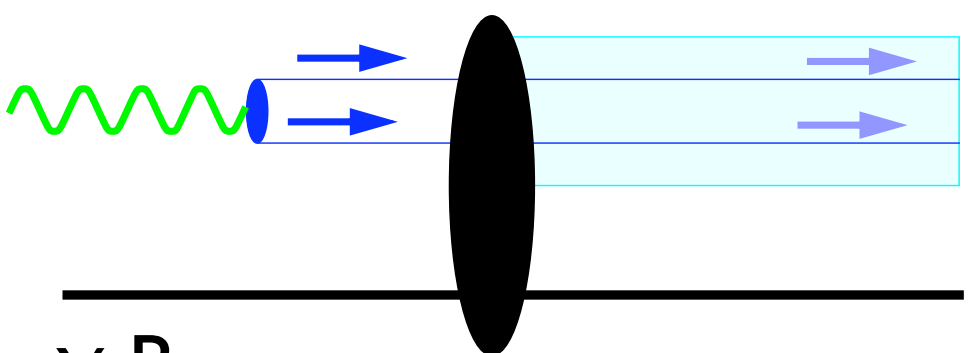


FIG. 26 (color online). The intensities for the $2^{-+}0^{+}$ F-wave $\rho\pi$ (open circles), $2^{-+}1^{+}$ F-wave $\rho\pi$ (filled black circles), and $2^{-+}1^{+}$ P-wave $\rho\pi$ (filled gray circles) waves for the neutral and charged modes. These waves were included in the high-wave set but not in the low-wave set.

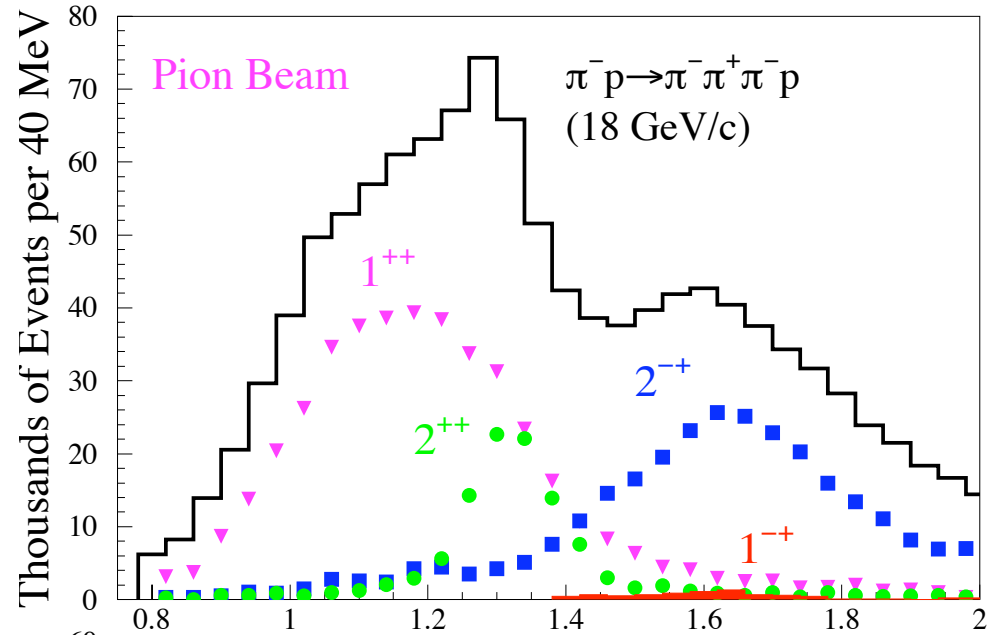
For the Future: The Production Mechanism Makes a Difference!

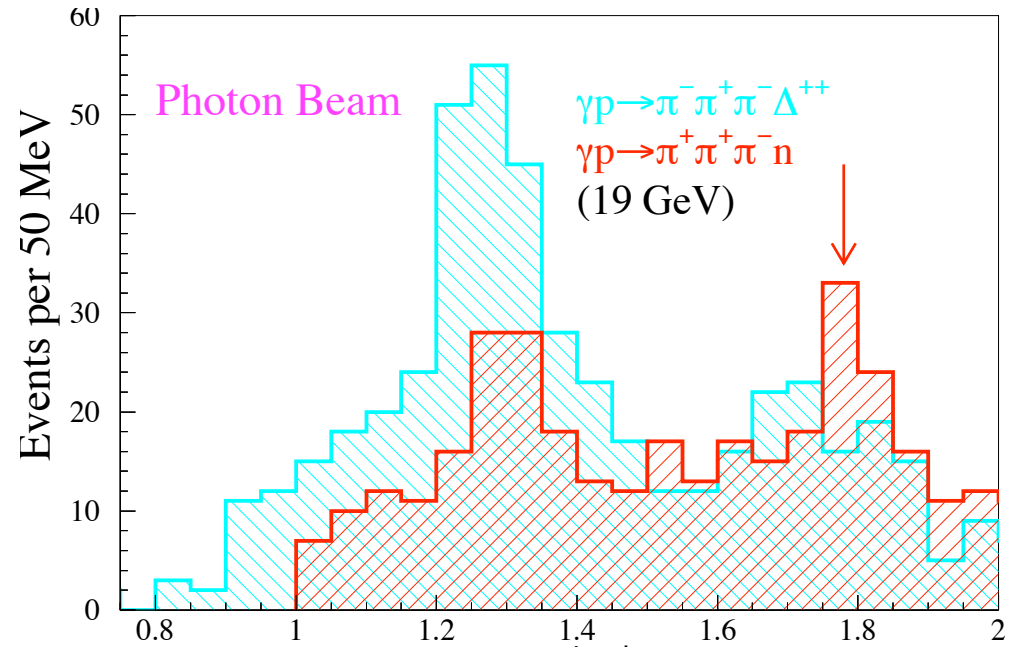


π Beam

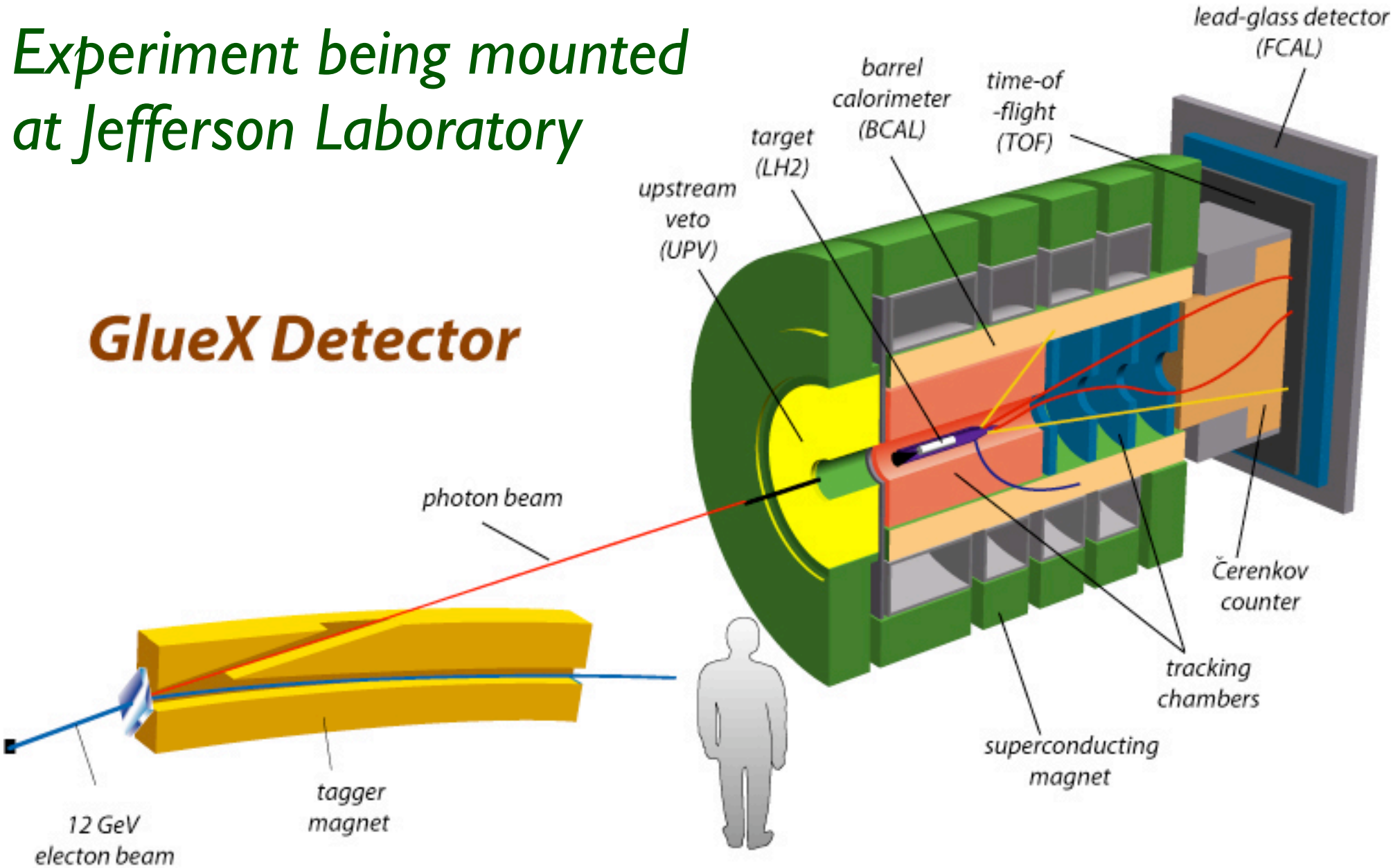


γ Beam





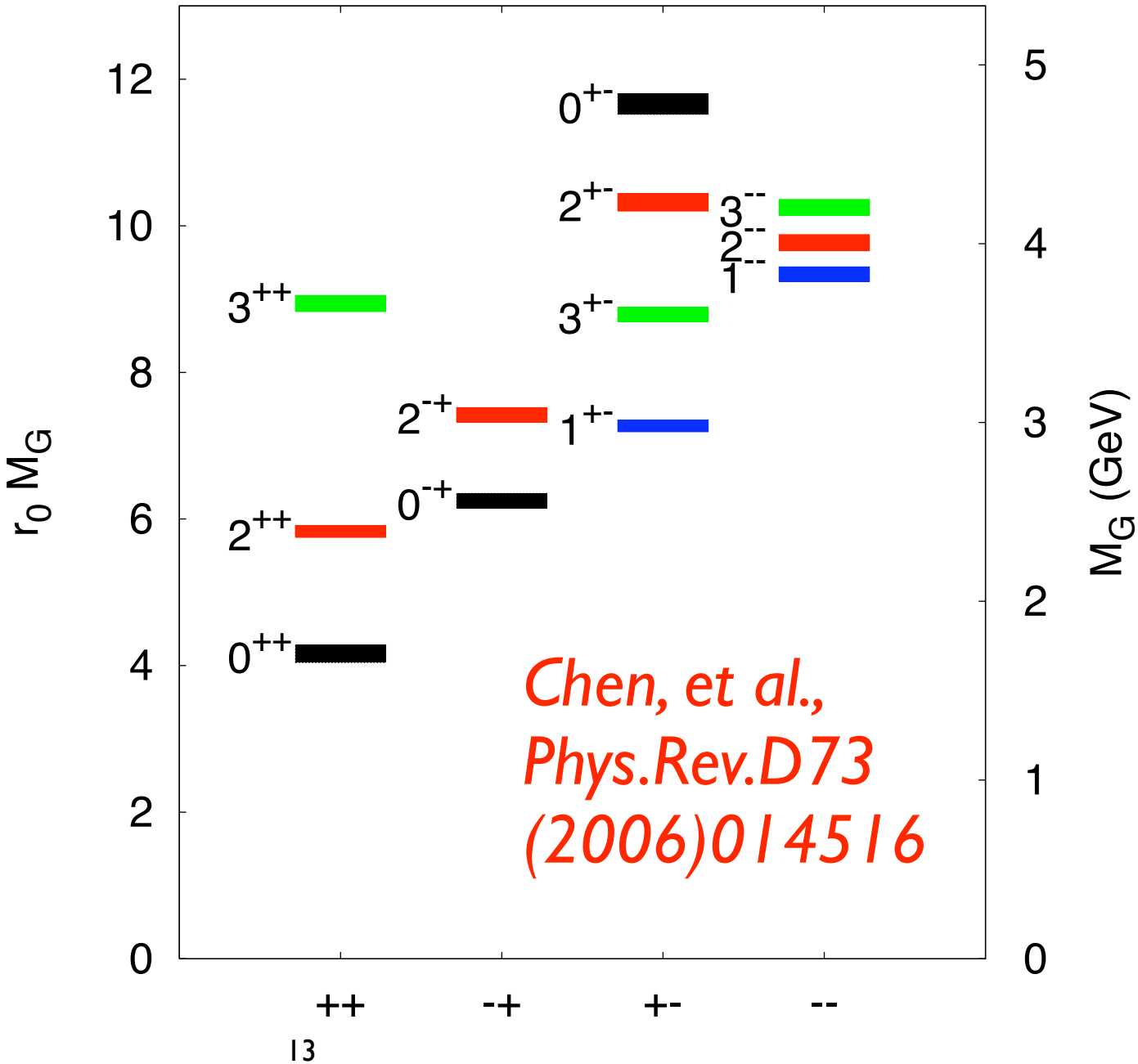
For the Future: Experiment being mounted at Jefferson Laboratory



Glueballs

Two big issues:

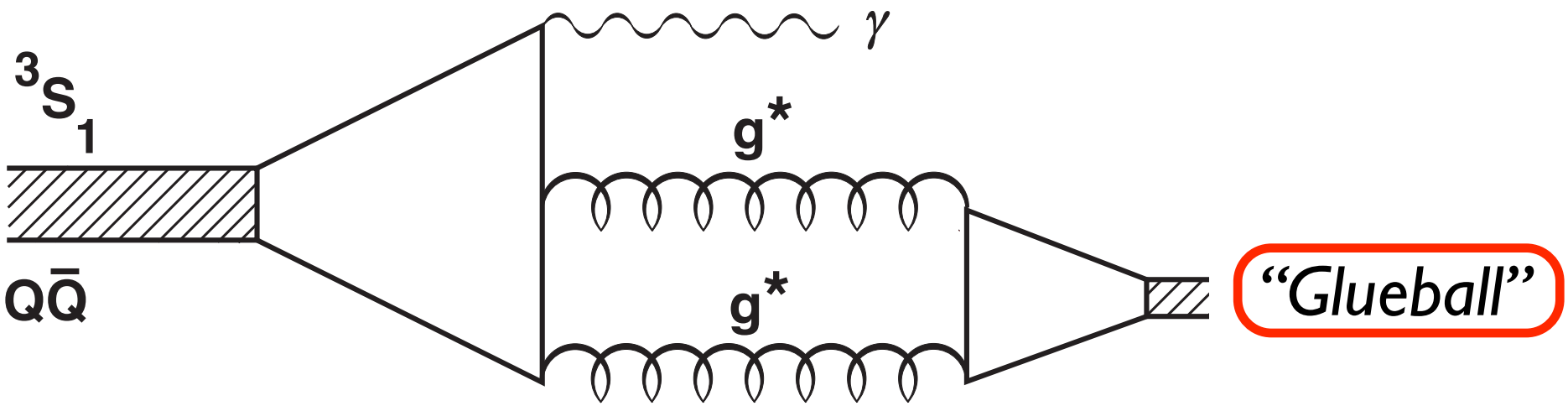
- What is the production mechanism to utilize?
- What is the mixing with quark model mesons?



The Golden Production Mechanism

(In my opinion)

"J/ψ Radiative Decay" i.e. J/ψ→γ+*Glueball*



Production rate should be calculable in pQCD *but* the manifestation of a "glueball" can be tricky!

See, e.g., Chanowitz, Phys.Rev.Lett. 95(2005)172001

How to Identify the Glueball(s)

(Again, in my opinion)

- Hermetic detector with excellent photon resolution and good background rejection
- Keep the final state as simple as possible

  e.g. $(\gamma)\pi\pi$, $(\gamma)KK$, $(\gamma)\eta\eta$ for 0^{++},2^{++}
- Model-independent amplitude analyses
- Fit final amplitudes to poles while forcing unitarity and allowing channels to couple

➥ Unravel the scalar (and tensor?) spectrum and look for "extra" states compared to the quark model

For the Future:
BES III is the Place to Be!

Expect very large J/ψ sample, taken with a detector having all the right characteristics.

The collaboration already has lots of experience!

Note: CLEO-c will not take data at the J/ψ

謝 *(Thank you)*