Photoproduction of Hidden-Charm Pentaquark with CLAS12

Valery Kubarovsky Jlab October 22, 2015

LHCb: Background and Signal



- LHCb accidentelly found a signal in the J/ ψ p invariant mass spectrum
- PRL LHCb paper: In practice baryons decaying strongly into J/ψ p must have a minimal quark content of **CCUUC**, and thus are charmonium-pentaquarks.
- It is the consequence of the Okuba–Zweig–Iizuka rule.

Okubo Zweig lizuka (OZI) rule



The decay of ordinary baryons to J/ Ψ +p is highly suppressed by OZI rule

Claim of two pentaguark states $P_c(4380)$ and $P_c(4450)$ in J/ ψp decay mode $\Gamma(4380)=205 \text{ MeV}$ $\Gamma(4450)=40 \text{ MeV}$ with 9 and 12 standard deviations, respectively. $\rightarrow K^{-}J/\psi p$ 3000 Events/(20 MeV) Events/(15 MeV) LHCb (b) 2500 LHCb 800 (a) 2000 600 data 1500 phase space 400 1000 200 500 1.6 2.2 2.4 5.0 1.4 1.8 2.0 4.2 4.6 4.8 4.0 4.4 m_{Kp} [GeV] $m_{J/\psi p} \, [{ m GeV}]$

The fit includes **146** parameters. It was reduced in so called restricted model down to 64 keeping only low orbital Λ^* excitation in the Λ_b^o decay.

Baryocharmonium



 P_c is a composite of the charmonium state and the proton or exited nucleon states similar to the known resonances N(1440) or N(1520). We expect that the branching ratio Br(P_c ->J/ ψ +p) may lay in the range from 1% to 10%. This model predicts sizable branching ratios to J/ ψ p π and J/ ψ p $\pi\pi$.

Hadronic molecule



These molecules made from a charmed baryon and charmed meson with week coupling. Such pentaquarks will decay predominantly to the charmed baryon and charmed meson.

Bag with color objects:

tightly correlated diquarks, or colored baryon-like and meson-like constituents



Pentaquarks made of tightly correlated diquarks or colored baryon-like and mesonlike constituents.

Hidden-Charm Pentaquark Models

• It has been also suggested that at least one of the peaks is not a resonance at all, but rather a **kinematical singularity** due to rescattering in the decay $\Lambda_{\rm b}$ ->J/ ψ p K⁻.

Photoproduction

• It was shown^{*} that the vector dominance model describes well the s-channel photoproduction of hidden-charm pentaquark. $\sigma \sim Br^2(P_c \to J/\psi p)$

 $\sigma(W) \sim \frac{\Gamma^2/4 \cdot Br^2(P_c \to J/\psi + p)}{(W - M_c)^2 + \Gamma^2/4}$

V.Kubarovsky, M. B. Voloshin, Phys.Rev. D92 (2015) 3, 031502, arXiv:1508.00888.

hep-ph/0010343, Brodsky et al (2000)

J/ψ photoproduction cross section is around
 0.1 nb in the region of expected pentaquarks

V

р



Bounds for the formation cross section $\sigma(\gamma p \to P_c \to J/\psi p)$

 $BR(P_c \rightarrow J/\psi p) = 1\%$ | Unknown for a moment



Blue curves – maximum cross section (higher allowed partial wave only) Red cross section – minimum cross section (lower allowed partial wave only)

P_C 1450 Photoproduction cross section BR(P_c → J/ψp) = 1%



The S/B ratio is **extremely good** even for such small BR=1%

CLAS12 Statistics

- $\mathcal{L}(ep)=10^{35}$ events/cm²=100 events/nb/s
- Photon *L* (integrated over ∆W=20 MeV=2*10³¹ events/cm²=2*10⁻² events/nb/s
- $Br(J/\psi) -> e^+e^- = 6\%$
- Acceptance=10%
- <u>**10 events/day per 1 nb** γ p cross section for Δ W=20 MeV bin</u>
- The J/ ψ cross section in the pentaquark region is about 0.1 nb (1 event/day) for Δ W=20 MeV bin

CLAS12 statistics

$$BR(P_c \to J/\psi p) = 1\%$$

	P _c (4380)	P _c (4450)
σ , min-max (at pole)	0.15-4.7 nb	1.2-36 nb
Nevents/day, min-max	12-380 events	19-576 events

Conclusion

- Resolving between the models and clarifying the nature of the discovered hidden-charm pentaquark peaks requires further experimental studies.
- Photoproduction cross section depends on BR²(P_c->J/ψp) that may be in the range 1%-10%. If these estimations are correct CLAS12 has unique opportunity to detect pentaquark and measure this branching ratio. It will definitely help with the resolving between different models.
- Naturally, any observation of the P_c peaks in the γp cross section would strongly disfavor the interpretation in terms of 'accidental' singularities in the Λ_b decays.
- Charmonium molecule model predicts sizable BRs to $J/\psi p\pi$ and $J/\psi p\pi\pi$. CLAS can definitely detect these decay modes of pentaquark.

Recent experimental data

