Electro- and Photo-production of XYZ @EIC





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- Hadron Spectroscopy with a CEBAF energy upgrade
 - JLab June 2022



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Joint Physics Analysis Center



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Baryons and Mesons

Ordinary baryons:



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uud proton stable *udd* neutron $\tau \sim 10^3 s$ uds baryon Λ $\tau\sim 10^{-10}s$ ${\it uuu}\,\,{\rm baryon}\,\Delta\,\,\,\tau\sim 10^{-24}\,\,s$

Ordinary mesons



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Ordinary and Exotic Hadrons

Ordinary baryons:



proton stable $\tau \sim 10^3 s$ neutron

baryon $\Lambda~~\tau\sim 10^{-10}s$

Ordinary mesons

Exotic matter

U	
S	

 $\tau \sim 10^{-8} s$ pion

 $\tau \sim 10^{-8} s$ kaon





 J/ψ $\tau \sim 10^{-20}s$

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Pentaguarks candidates from LHCb



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unexplained excess of events in $J/\psi\,p$ spectrum

Cannot be qqq baryon



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What's a resonance?



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Bound state vs virtual state



 $e^{i2\delta(k)}$ $|k\rangle$ $|k\rangle$

Scattering length

Cross section

$$a = \lim_{k \to 0} \frac{1}{k} \tan \delta(k)$$
$$\sigma = 4\pi a^2$$

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$P_{c}(4312)^{+}$ analysis



Bootstrap: generate 10k data

When $J/\psi p$ decouples, pole moves to the real axis on the

Physical sheet - positive scattering length - bound state

Unphysical sheet - negative scattering length - virtual state

Fernández-Ramírez et al (JPAC), PRL123 (2019) 092001

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$P_c(4312)^+$ analysis

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Fernández-Ramírez et al (JPAC), PRL123 (2019) 092001

Virtual state in the $\Sigma_c^+ \bar{D}^0$ channel

- 0.7 %
- 99.3 %
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$P_c(4312)^+$ analysis

Deep neural network trained with 4 types of amplitudes

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Direct production of P_c^+ ?

Estimation of the couplings with VMD

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10⁻¹

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Data

2

(d),

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Exp. status of *XYZ*

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Discovered in e^+e^- interactions by BESIII

Quantum numbers 1^{+-} (more likely)

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Electro-production of XYZ will help understand them

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Exclusive $Z_{c,b}^+$ Production @EIC

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C++ code available online (D. Winney)

Implementation in simulation with El-Spectro (D. Glazier)

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X(3872)

Discovered in B decays by Belle $B \rightarrow KX(3872) \rightarrow K(J/\psi\pi\pi)$ Quantum numbers 1^{++} (more likely)

 $\frac{X(3872) \rightarrow J/\psi\omega}{X(3872) \rightarrow J/\psi\rho} = 0.8 \pm 0.3$ Strong isospin violation

Very close to DD^* threshold $M_X - M_{DD^*} = -3 \pm 192$ kev

Observations by independent collaborations $pp \rightarrow X(3872) + anything$ $X(3872) \rightarrow J/\psi \pi \pi$

Challenging interpretation

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XYZ Photoproduction 18

LHCb EPJC72 (2012) 1972

b)

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TPAC 10^{2} [ub] 10 E $\rightarrow X p$ $\sigma(\gamma p$ 10^{-1} $\chi_{cl}(1P)$ -X(3872) 10^{-2} 4.5 5.5 6.5 5 6 $W_{\gamma p}$ [GeV]

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Primakoff electro-production of X(3872)

Use Belle measurement of $\Gamma(X \to \gamma \gamma^*)$ to determine the normalization

Ion target enhance cross section as Z^2

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Exclusive Y(4260) Production @EIC

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Summary

Direct photoproduction of P_c :

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Exclusive and inclusive production of $Z_{c,b}^+$:

Primakoff producit of *X*(3872):

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