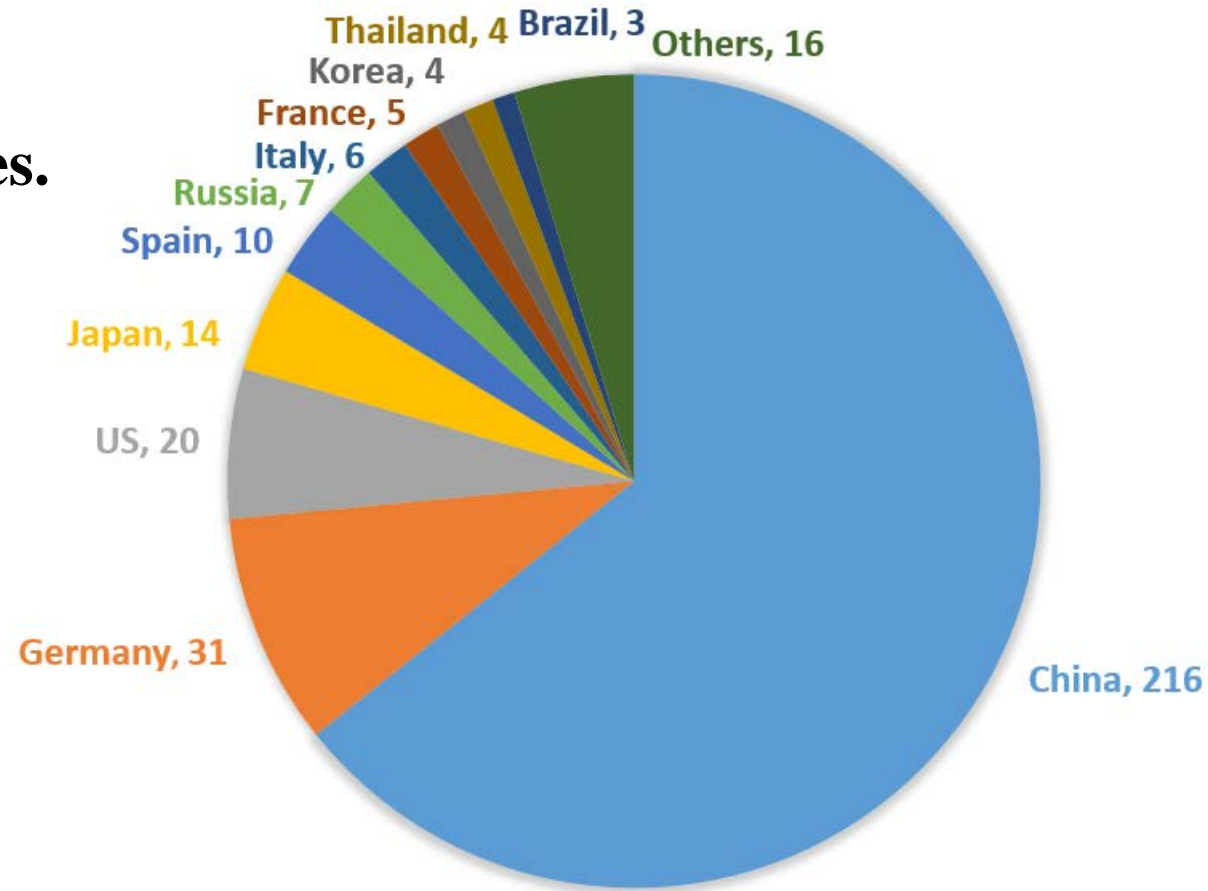


Distribution of participants

336 participants,
around 150 institutions,
from more than 20 countries.



2019

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Thank you all for your contributions



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Contributions: 229

22 plenary + 35 leading parallel + 145 parallel + 26 posters + 1 round-table discussion

Junior Poster Prizes Committee:

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Li-Sheng Geng,

Sebastian Neubert,

Cheng-Ping Shen

Junior Poster Prizes

Best Junior Poster Prize, second place

conferred to
Xiaolin KANG
for the poster

Studies of the ISR process $e^+e^- \rightarrow \pi^+\pi^-\pi^0\gamma$ at the ϕ mass with the KLOE detector

(From INFN-LNF)

2019
Guilin, China

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XVIII International Conference on Hadron Spectroscopy and Structure

Studies of ISR process $e^+e^- \rightarrow \pi^+\pi^-\pi^0\gamma$ at the ϕ mass with KLOE and KLOE-2

¹Xiaolin Kang and ²B. Cao on behalf of the KLOE-2 Collaboration

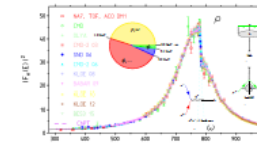
¹Western Institute of Nuclear Physics, Nanjing Normal University, Jiangsu, China
²Department of Physics and Astronomy, Uppsala University, Sweden, Uppsala, Sweden



g-2 & ISR Technique

The long-standing $\sim 3.6\sigma$ discrepancy between Standard Model (SM) prediction of the muon anomalous magnetic moment a_μ ($a_\mu - 2/2$) and experimental measurement is highly sensitive to new physics beyond the SM, where a_μ is the muon gyromagnetic factor. The evaluation of a_μ has hadronic contributions $a_\mu^{\text{had}} = a_\mu^{\text{had,LLO}} + a_\mu^{\text{had,LHO}} + a_\mu^{\text{had,HLO}}$, with the predominant lowest-order contribution $(0.011 \pm 3.4) \times 10^{-10}$ of the total and in the uncertainty that requires a complete and accurate experimental input of hadronic ratio $R_{\text{had}}^{\text{had}}$ using a dispersion relation

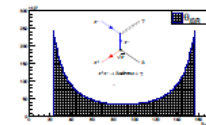
$$a_\mu^{\text{had,LLO}} = \frac{\alpha^2}{3\pi} \int_{m_\pi^2}^{\infty} \frac{ds}{s} K(s) R_{\text{had}}^{\text{had}}(s).$$



Energy scan is often used to probe $R_{\text{had}}^{\text{had}}$. By using Initial State Radiation (ISR) technique at a fixed center-of-mass energy \sqrt{s} , measurements can be performed at a lower effective \sqrt{s} . High luminosity compensates for the small cross sections of radiative processes. This is an appealing method to investigate the Born cross section σ_B for the $e^+e^- \rightarrow \text{hadrons} + \gamma$ process

$$\frac{d\sigma(s, \pi, \theta)}{d\pi d\cos\theta} = W(s, \pi, \theta) \sigma_B(s'), \quad W(s, \pi, \theta) = \frac{\alpha}{\pi} \frac{(2 - 2\pi + \pi^2 - \pi'^2)}{\sin^2\theta}, \quad (1)$$

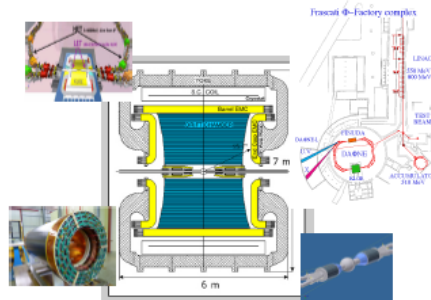
where $\pi = 2E_\gamma/\sqrt{s}$, E_γ and θ are the ISR photon energy and polar angle in the c.m. frame, and $\sqrt{s'} = \sqrt{s(1 - \pi)}$. The probability of ISR photon emission for $E_\gamma > m_e/\sqrt{s}$ is governed by the radiator function $W(s, \pi, \theta)$



KLOE/KLOE-2 & DAF@NE

KLOE 2000/2006: $2.5 \text{ fb}^{-1} @ \sqrt{s} = M_\phi$ & 250 pb^{-1} off-peak $@ \sqrt{s} = 1 \text{ GeV}$
• Drift Chamber: $\sigma_\eta = 150 \mu\text{m}$; $\sigma_\pi = 3 \text{ mm}$
• Electron Magnetic Calorimeter: $\frac{dE}{d\eta} = \frac{1.75}{\sqrt{R(\text{GeV})}} \sigma_1 = \frac{54 \text{ MeV}}{\sqrt{R(\text{GeV})}} @ 100 \text{ ps}$

KLOE-2 2014/2018: $5.5 \text{ fb}^{-1} @ \sqrt{s} = M_\phi$
• KLOE-KLOE-2 collected $\sim 8 \text{ fb}^{-1}$ gives a unique sample of $\sim 2.4 \cdot 10^{10}$ ϕ -meson's decays.



KLOE-2 detector upgrades
• Low/High Energy Tagger (top-left), $\gamma - \gamma$ physics.
• Inner Tracker (IT) with four layer C-GEM (bottom-left)
• QCALT and CCALT (bottom-right).

DAF@NE collider upgrades
• Crab waist collision scheme (top-right).
 $\theta_{\text{beam}} = 2 - 25 \text{ mrad}$,
 $C_{\text{peak}} = 2.0 \cdot 10^{12} \text{ cm}^{-2} \text{ s}^{-1}$,
 $\int \mathcal{L} dt > 10 \text{ fb}^{-1}$ Nov 2014/Jun 2015.

Analysis

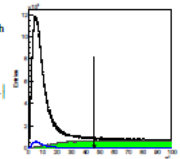
$\mathcal{L}_{\text{int}} \sim 1.02 \text{ fb}^{-1}$ collected in 2004-2005 ready to be included. $\sim 1/10$ of \mathcal{L}_{int} is used to shape the data analysis.

Event Selection

- Exact three prompt clusters
- $E \geq 15 \text{ MeV}$, $|\cos\theta| < 0.92$
- $t_{\text{cls}} - \frac{R_{\text{cls}}}{\sqrt{E_{\text{cls}}}} < \min(2, 5\sigma_2) \text{ ns}$,
 $\sigma_2 = \sqrt{R_{\text{cls}}^2 + \frac{R_{\text{cls}}^2}{E_{\text{cls}}^2}} @ 0.147 \text{ ns}$
- Two tracks with opposite charge
- $p_{\text{tr}} = \sqrt{p_x^2 + p_y^2} < 4 \text{ cm}$
- $|z_{\text{tr}}| < 10 \text{ cm}$

Background Rejection

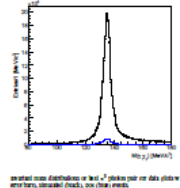
- Energy-momentum conservation kinematic fit with additional Time-of-Flight constraints on clusters, $\chi^2 < 46$ rejects $K_L K_S$ and $K^+ K^-$ background.
- Mass M associates to charged track momenta
 $\sqrt{s} - \sqrt{M^2 + p_{\text{tr}}^2} - \sqrt{M^2 + p_{\text{tr}}^2} - |p_{\text{tr}} - p_{\text{tr}} - p_{\text{tr}}|$
 $M > 300 \text{ [MeV/c}^2\text{]} \text{ rejects } \phi \rightarrow \rho\pi$.
- Alternative track-cluster association selection criteria allow one to reject processes in the continuum: Rhabha scattering.



π^0 photon pairing Pseudo chi-square function is used to select the best π^0 -photon pair as follows

$$\chi_{\pi\gamma}^2 = \frac{(m_{\pi\gamma} - m_{\pi\gamma}^{\text{MC}})^2}{\sigma_{\pi\gamma}^2} + \frac{1}{2} \left(\frac{m_{\pi\gamma}^2}{m_{\pi\gamma}^2} + \frac{p_{\pi\gamma}^2}{p_{\pi\gamma}^2} \right),$$

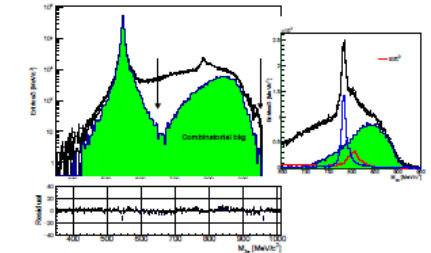
where $E_{\pi\gamma}$ and $\sigma_{\pi\gamma}$ are cluster energy and corresponding uncertainties, respectively. All three combinations are tested and photon pair with the lowest $\chi_{\pi\gamma}^2$ is chosen to be the best π^0 -photon pair



Mass Spectrum

In the ω mass region, both the η peak and a hadronic structure are clearly visible on the 3σ mass spectrum with fully deterministic background simulations. After applying all analysis selection and acceptance cuts, the remaining background are $e^+e^- \gamma$, $K_L K_S$, $K^+ K^-$ etc. scaled according to luminosity scaling factors, it is notable that processes in the continuum: $\mu\mu$ and $\pi\pi$ scattering contributions are negligible. Above 650 MeV/c^2 , combinatorial background are coming from $\gamma\gamma$ or $K^+ K^-$ events with different decay topology. Due to the abundance of background, in order to determine their shapes respect to the ISR signal mass distribution, we have performed the Maximum Likelihood (ML) fit on the data sample with fractions of simulated physical channels as free parameters. Locally, in the ω mass region, a good agreement between the data and simulations has already been achieved after the ML fit with minimum degrees of freedom.

Ongoing and forthcoming analysis include background subtraction based evaluation of visible cross section σ_{vis} extraction of peak cross section using Vector Meson Dominance model and obtain upper limit on C-odd $\phi \rightarrow \omega\gamma$ decay with $e^+e^- \rightarrow 3\gamma$ as irreducible background.



Invariant mass distributions of $\pi^+\pi^-\pi^0\gamma$ for data (dots with error bars), $\gamma\gamma$ (dashed histogram), and ISR (blue) events.

References

- [1] M. Benayoun, S. I. Eidelman, V. N. Ivanchenko, and Z. K. Silagadze. Spectroscopy at B-Factories Using Hard Photon Emission. *Modern Physics Letters A*, 14(37):2605–2614, Jan 1999.
- [2] M. Davier, A. Hoecker, B. Malaescu, and Z. Zhang. Reevaluation of the hadronic contributions to the muon g-2 and to $\alpha(M_Z^2)$. *European Physical Journal C*, 71(1):1515, Jan 2011.

Junior Poster Prizes

Best Junior Poster Prize, second place

conferred to
Shuntaro SAKAI
for the poster

Decay of P_c into $J/\psi N$ and $\eta_c N$ with heavy quark spin symmetry

(From ITP, CAS)

2019
Guilin, China

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XVIII International Conference on Hadron Spectroscopy and Structure

Decays of P_c into $J/\psi N$ and $\eta_c N$ with heavy quark spin symmetry

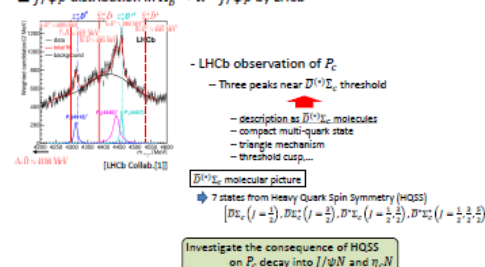
Shuntaro Sakai, Hao-Jie Jing, and Feng-Kun Guo
[Institute of Theoretical Physics, Chinese Academy of Sciences (Beijing, China)]

Abstract:

We investigate the consequences of heavy quark spin symmetry (HQSS) on hidden-charm pentaquark P_c states. As has been proposed before, assuming the $P_c(4440)$ and the $P_c(4457)$ as 5-wave $\bar{D}^* \Sigma_c$ molecules, seven hadronic molecular states composed of $\bar{D}^* \Sigma_c$, $\bar{D}^* \Sigma_c^*$, $\bar{D}^* \Sigma_c^*$, and $\bar{D}^* \Sigma_c^*$ can be obtained with the $\bar{D}^* \Sigma_c$ molecule corresponding to the $P_c(4312)$. These seven states can decay into $J/\psi N$ and $\eta_c N$, and we use HQSS to predict ratios of partial widths of the 5-wave decays. For the decay into $J/\psi N$, it is found that among all P_c molecules with spin $1/2$ or $3/2$, at least four states decay much more easily into the $J/\psi N$ than the $P_c(4312)$ and two of them couple dominantly to the $\bar{D}^* \Sigma_c$. While no significant peak around the $\bar{D}^* \Sigma_c$ threshold is found in the $J/\psi N$ distribution, these higher P_c states are either produced with lower rates, or some special production mechanism for the observed P_c states might play an important role, such as an intricate interplay between the production of pentaquarks and triangle singularities.

arXiv:1907.05414 [hep-ph]

■ $J/\psi p$ distribution in $\Delta_b \rightarrow K^- J/\psi p$ by LHCb



■ Description of P_c as $\bar{D}^{(*)} \Sigma_c^{(*)}$ molecule [2,3]

$(D^*, D^*), (\Sigma_c, \Sigma_c^*)$: doublet of HQSS $\left\{ \begin{array}{l} D^{(*)} \sim \bar{q} q \\ \Sigma_c^{(*)} \sim \bar{q} q q \end{array} \right\}_{[3]_{1/2, 1/2, 1/2}}$

- Recombination of quark spin with 9j symbol:

$$\left\{ \begin{array}{c} D^{(*)} \\ \Sigma_c^{(*)} \end{array} \right\} \rightarrow \left\{ \begin{array}{c} D^{(*)} \\ \Sigma_c^{(*)} \end{array} \right\} \rightarrow \left\{ \begin{array}{c} D^{(*)} \\ \Sigma_c^{(*)} \end{array} \right\}$$

- Spin of light sector and heavy quarks: conserved respectively [quark-gluon coupling $\sim \mathcal{O}((\text{mass of heavy quark})^{-1})$]

- heavy quarks: spectator

• Contact interaction $V_{\Sigma_c^{(*)} D^{(*)} \Sigma_c^{(*)} D^{(*)}} = \langle \Sigma_c^{(*)} D^{(*)} | V | \Sigma_c^{(*)} D^{(*)} \rangle$

• $\langle \chi_{1,1} \chi_{1,1} | J | \chi_{1,1} \chi_{1,1} \rangle = C_{2,1,1,1} \langle \chi_{1,1} \chi_{1,1} | \delta_{1,1} \delta_{1,1} \rangle$ (depend only on light-sector spin—two parameters to be fixed)

$\bar{D}^{(*)} \Sigma_c^{(*)}$ matrix: unitarized with scattering eq. using interaction $V_{\Sigma_c^{(*)} D^{(*)} \Sigma_c^{(*)} D^{(*)}}$

• $d = [1 - V G]^{-1} V$

with $G_{11}(W) = \frac{2M_1}{2\pi i} \int \frac{d^3 q}{(2\pi)^3} \frac{e^{-i q \cdot (W - m_1 - M_2 - i\epsilon)} q^2}{(W - m_1 - M_2 - i\epsilon)^2 + q^2}$ ($\bar{D}^{(*)} \Sigma_c^{(*)}$ two-body loop)

- $\bar{D}^{(*)} \Sigma_c^{(*)}$ molecules are dynamically generated (input: $P_c(4440, 4457)$ as $\bar{D}^* \Sigma_c^* (J = \frac{1}{2}, \frac{3}{2})$ molecule)

• Seven states related by heavy quark spin symmetry

Case 1: $P_c(4440, 4457)$ as $\bar{D}^* \Sigma_c^* (J = \frac{1}{2}, \frac{3}{2})$ molecule	Case 2: $P_c(4457, 4440)$ as $\bar{D}^* \Sigma_c^* (J = \frac{1}{2}, \frac{3}{2})$ molecule																														
<table><tr><th>Decomposed channel</th><th>$\Lambda = 8 \times 10^4$</th><th>$\Lambda = 1 \times 10^5$</th></tr><tr><td>$P_c(4440) \rightarrow J/\psi N$</td><td>0.011 (0.7)</td><td>0.011 (0.8)</td></tr><tr><td>$P_c(4457) \rightarrow J/\psi N$</td><td>0.011 (0.7)</td><td>0.011 (0.8)</td></tr><tr><td>$P_c(4440) \rightarrow \eta_c N$</td><td>0.011 (0.7)</td><td>0.011 (0.8)</td></tr><tr><td>$P_c(4457) \rightarrow \eta_c N$</td><td>0.011 (0.7)</td><td>0.011 (0.8)</td></tr></table>	Decomposed channel	$\Lambda = 8 \times 10^4$	$\Lambda = 1 \times 10^5$	$P_c(4440) \rightarrow J/\psi N$	0.011 (0.7)	0.011 (0.8)	$P_c(4457) \rightarrow J/\psi N$	0.011 (0.7)	0.011 (0.8)	$P_c(4440) \rightarrow \eta_c N$	0.011 (0.7)	0.011 (0.8)	$P_c(4457) \rightarrow \eta_c N$	0.011 (0.7)	0.011 (0.8)	<table><tr><th>Decomposed channel</th><th>$\Lambda = 8 \times 10^4$</th><th>$\Lambda = 1 \times 10^5$</th></tr><tr><td>$P_c(4457) \rightarrow J/\psi N$</td><td>0.011 (0.7)</td><td>0.011 (0.8)</td></tr><tr><td>$P_c(4440) \rightarrow J/\psi N$</td><td>0.011 (0.7)</td><td>0.011 (0.8)</td></tr><tr><td>$P_c(4457) \rightarrow \eta_c N$</td><td>0.011 (0.7)</td><td>0.011 (0.8)</td></tr><tr><td>$P_c(4440) \rightarrow \eta_c N$</td><td>0.011 (0.7)</td><td>0.011 (0.8)</td></tr></table>	Decomposed channel	$\Lambda = 8 \times 10^4$	$\Lambda = 1 \times 10^5$	$P_c(4457) \rightarrow J/\psi N$	0.011 (0.7)	0.011 (0.8)	$P_c(4440) \rightarrow J/\psi N$	0.011 (0.7)	0.011 (0.8)	$P_c(4457) \rightarrow \eta_c N$	0.011 (0.7)	0.011 (0.8)	$P_c(4440) \rightarrow \eta_c N$	0.011 (0.7)	0.011 (0.8)
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■ $\bar{D}^{(*)} \Sigma_c^{(*)} \rightarrow J/\psi N, \eta_c N$ transition in s wave

$J/\psi, \eta_c \sim \bar{c} c \rightarrow \left\{ \begin{array}{l} \eta_c N = [s_u = 0, s_l = 1/2]_{1/2, 1/2} \\ J/\psi N = [s_u = 1, s_l = 1/2]_{3/2, 1/2} \end{array} \right\}$

$V_{\Sigma_c^{(*)} D^{(*)} \Sigma_c^{(*)} D^{(*)}} = \langle \Sigma_c^{(*)} D^{(*)} | V | \Sigma_c^{(*)} D^{(*)} \rangle = b_0$

• $(\eta_c, J/\psi)$: form a heavy-quark spin doublet [4]

■ P_c decay into $J/\psi N$ and $\eta_c N$

Diagram showing P_c decaying into $J/\psi N$ and $\eta_c N$. The coupling $\mathcal{D} \Gamma_{P_c \rightarrow X} = \text{from residue of } \mathcal{D} \Gamma_{P_c \rightarrow X} \Sigma_c^{(*)} \Sigma_c^{(*)} \left[\mathcal{D} \Gamma_{P_c \rightarrow X} = \lim_{s \rightarrow s_0} (s - s_0) \mathcal{D} \Gamma_{P_c \rightarrow X}(s) \right]$

Decay amplitude of $P_c \rightarrow X \rightarrow J/\psi N$ or $\eta_c N$: $\mathcal{A}_{X(J)} = g_{P_c X} \bar{G}_{X N} h_{X(J)}$
 $[X = \bar{D} \Sigma_c, \bar{D}^* \Sigma_c, \bar{D}^* \Sigma_c^*, \bar{D}^* \Sigma_c^*]$
 $\bar{G}_X: \bar{D}^{(*)} \Sigma_c^{(*)}$ loop

Partial width of $P_c \rightarrow J/\psi N$ or $\eta_c N$

$$\Gamma_1 \equiv \Gamma_{P_c \rightarrow J/\psi N} = \frac{m_N}{2\pi m_{P_c}} |\mathcal{A}_{J(J)}|^2$$
$$\Gamma_2 \equiv \Gamma_{P_c \rightarrow \eta_c N} = \frac{m_N}{2\pi m_{P_c}} |\mathcal{A}_{\eta_c(J)}|^2$$

■ Results

○ Ratio of partial width of $P_c \rightarrow J/\psi N$

Case 1: $r_1 = (4.4, 4.4)$, $r_2 = (3.3, 3.3)$, $r_3 = (1.2, 1.2)$, $r_4 = (2.7, 2.8)$, $r_5 = (5.1, 5.4)$, $r_6 = (1.1, 1.1)$

Case 2: $r_1 = (4.4, 4.7)$, $r_2 = (10.1, 10.5)$, $r_3 = (1.8, 1.9)$, $r_4 = (3.3, 3.5)$, $r_5 = (13.9, 14.4)$, $r_6 = (1.1, 1.1)$

$r_1 \approx 1 \rightarrow P_c$ are likely to be produced than $P_{c1} = P_c(4312)$ from $\bar{D}^{(*)} \Sigma_c^{(*)}$ molecule description of P_c with HQSS

○ Ratio of partial width of $P_c \rightarrow \eta_c N$

Case 1: $r_1 = (2.9, 2.9)$, $r_2 = (10.4, 10.4)$, $r_3 = (1.8, 1.8)$, $r_4 = (1.1, 1.1)$, $r_5 = (1.1, 1.1)$

Case 2: $r_1 = (4.6, 4.6)$, $r_2 = (2.4, 2.5)$, $r_3 = (10.2, 10.7)$, $r_4 = (1.1, 1.1)$, $r_5 = (1.1, 1.1)$

$r_{1,2,3} > 1 \rightarrow P_c$ in $\eta_c N$ is expected with HQSS [5]

Difference in $r_{1,2,3}$ with different assignment \rightarrow search for P_c in $\eta_c N$: important due to clarify the nature of P_c

○ Branching fraction of $\Delta_b \rightarrow K^- P_c$

$R = \frac{\mathcal{B}(\Delta_b \rightarrow K^- P_c) \mathcal{B}(P_c \rightarrow J/\psi N)}{\mathcal{B}(\Delta_b \rightarrow K^- P_c) \mathcal{B}(P_c \rightarrow \eta_c N)}$ measured by LHCb [1]

ratio of $R = \mathcal{B}(P_c(4440) \rightarrow J/\psi N) / \mathcal{B}(P_c(4457) \rightarrow J/\psi N)$

Case 1: 1.5 ± 0.4 , Case 2: 0.2 ± 1.9

Different ratio with different assignment

■ Summary

- Seven $\bar{D}^{(*)} \Sigma_c^{(*)}$ molecules with heavy quark spin symmetry
 - Input: $P_c(4440, 4457)$ as $\bar{D}^* \Sigma_c^*$ molecules
- With a formulation respecting HQSS,
 - $r_1 \approx 1 (P_c)$ would be more produced than $P_c(4312)$ in the $J/\psi N$ channel
 - $r_{1,2,3} > 1 (P_c)$ signal in $\eta_c N$ is expected
 - Different $r_{1,2,3}$ with different assignment of $P_c(4440/4457)$
- Branching fraction of $\Delta_b \rightarrow K^- P_c$
 - Different ratio with different assignment
- Other possible molecules (\bar{D} -wave molecule, $\bar{D}^{(*)} \Sigma_c^{(*)}$...)
- Coupling to compact exotic object (di-quark picture...)
- Kinematical effects (two-body threshold cusp, triangle singularities...)
- Production mechanism from Δ_b
- ...

References

- [1] B. Aul et al. [LHCb], Phys. Rev. Lett. 122, 222001 (2019)
- [2] M.-Z. Liu, Y.-M. Pan, F.-Z. Peng, M. Sanchez-Sanchez, L.-S. Geng, A. Hosaka, and M. Pavon Valdivia, Phys. Rev. Lett. 122, 242001 (2019)
- [3] C.M. Xie, J. He, and E. Oset, Phys. Rev. D 100, 054023 (2019)
- [4] E. Cleblanc, A. Gershtein, N. G. Beberbeque, S. Gabbiani, F. Peng, and G. Nardulli, Phys. Rev. Lett. 121, 141 (2018)
- [5] J.-J. Wu, R. Molina, E. Oset, and B.S. Zou, Phys. Rev. Lett. 105 (2010) 232001, Phys. Rev. C 84 (2011) 055202

Junior Poster Prizes

Best Junior Poster Prize, first place

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Hang ZHOU
for the poster

$e^+e^- \rightarrow \gamma X(3872)$ cross section measurement

(From Shandong University)

2019
Guilin, China

HABROO

2018 International Conference on Hadron Spectroscopy and Structure

Observation of $X(3872) \rightarrow \omega J/\psi$ decay

Hang Zhou (on behalf of BESIII Collaboration)

hzhou@mail.sdu.edu.cn

Research Center of Particle Physics & Technology
Shandong University

Phys. Rev. Lett. 122, 232002

BESIII

Introduction

- $X(3872)$ is first observed by Belle in 2003;
- The mass is very close to $\bar{D}^0 D^{*0}$ mass threshold ($M_{X(3872)} = 3871.69 \pm 0.17$ MeV);
- Very *narrow* width ($\Gamma_{X(3872)} < 1.2$ MeV);
- Isospin singlet ($I = 0$);
- $J^{PC} = 1^{++}$;

Theoretical interpretation: *loosely bound molecule, tetraquark state, ...*

What's inside of $X(3872)$?

$e^+e^- \rightarrow \gamma \omega J/\psi$

Data sets: $\sqrt{s} = 4.008 - 4.600$ GeV, with a total integrate luminosity of 11.6 fb^{-1}

1. Fit with three Breit-Wigner resonances

	Mass (MeV/c ²)	Width (MeV)	Significance
$X(3872)$	3873.3 ± 1.1	1.2	5.7σ
$X(3915)$	3926.4 ± 2.2	3.8 ± 7.5	3.1σ
$X(3960)$	3963.7 ± 5.5	33.3 ± 34.2	3.4σ

2. Fit with two Breit-Wigner resonances

	Mass (MeV/c ²)	Width (MeV)	Significance
$X(3872)$	3872.8 ± 1.2	1.2	5.2σ
$X(3915)$	3932.6 ± 8.7	59.7 ± 15.5	6.9σ

Only 2.5σ difference between the two fit models

First observation with more than 5σ

BESIII detector

Beam energy:
• 1.0 – 2.3 GeV

Physical purpose:
• Charmonium (-like) physics
• Light hadron spectroscopy
• Charm physics
• τ physics

Cross section measurement

A simultaneous fit to the cross section for $X(3872) \rightarrow \omega J/\psi$ and $\pi^+ \pi^- J/\psi$ modes:

$$M_{Y(4200)} = 4200.6^{+7.9}_{-13.3} \pm 3.0 \text{ MeV}/c^2$$

$$\Gamma_{Y(4200)} = 115^{+38}_{-26} \pm 12 \text{ MeV}$$

The resonance $Y(4200)$ agrees with $\psi(4160)$ or $Y(4220)$ within errors.

Isospin violation effect

Isospin violation in $X(3872)$:
Previous BABAR measurement
 $\mathcal{B}(X(3872) \rightarrow \omega J/\psi) = 0.8 \pm 0.3$
 $\mathcal{B}(X(3872) \rightarrow \pi^+ \pi^- J/\psi) = 0.26^{+0.08}_{-0.05}$

Isospin violation in $\psi(2S)$:
 $r_{\psi(2S)} = g_{\pi^0 J/\psi} / g_{\eta J/\psi} \approx 0.03$

$R_{\text{This Work}} = \frac{\mathcal{B}(X(3872) \rightarrow \omega J/\psi)}{\mathcal{B}(X(3872) \rightarrow \pi^+ \pi^- J/\psi)} = 1.6^{+0.4}_{-0.3} \pm 0.2$

- LARGE isospin violation effect** in $X(3872)$ indicates it can NOT be a conventional hadron;
- This measurement is useful to determine the various components in $X(3872)$.

Junior Poster Prizes

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for the poster
The indirect production of semi-inclusive doubly heavy baryons via Higgs boson and top quark decay

(From Guangxi Normal University)

2019
Guilin, China

HABRON

XVIII International Conference on Hadron Spectroscopy and Structure

Production of doubly heavy baryons via Higgs boson decays

Juan-Juan Niu¹, Lei Guo^{1*}, Hong-Hao Ma², Xing-Gang Wu¹

¹ Department of Physics, Chongqing University, Chongqing 401331, People's Republic of China

² Faculdade de Engenharia de Guaratinguetá, Universidade Estadual Paulista, Guaratinguetá, SP 12516-410, Brazil

Abstract

We systematically analyzed the production of semi-inclusive doubly heavy baryons (Ξ_{cc} , Ξ_{bc} and Ξ_{bb}) for the process $H^0 \rightarrow \Xi_{QQ'} + \bar{Q}' + \bar{Q}$ through four main Higgs decay channels within the framework of non-relativistic QCD. The contributions from the intermediate diquark states, $(cc)[^3S_0]_0$, $(cc)[^1S_0]_0$, $(bc)[^3S_1]_{-1,0}$, $(bc)[^3S_1]_{1,0}$, $(bb)[^3S_1]_{-1,0}$ and $(bb)[^1S_0]_0$, have been taken into consideration. The differential distributions and three main sources of the theoretical uncertainties have been discussed. At the HL-LHC, there will be about 0.43×10^4 events of Ξ_{cc} , 6.32×10^4 events of Ξ_{bc} and 0.28×10^4 events of Ξ_{bb} produced per year. There are fewer events produced at the CEPC and the ILC, about 0.26×10^3 events of Ξ_{cc} , 3.83×10^3 events of Ξ_{bc} and 0.17×10^3 events of Ξ_{bb} in operation.

1. Introduction

Some future colliders that can be called "Higgs factories" would generate large amounts of Higgs particles. The HL-LHC running at center-of-mass collision energy $\sqrt{s} = 14$ TeV with the integrated luminosity of 361 fb^{-1} would produce about 1.65×10^6 Higgs boson events per year [1]. The CEPC would generate more than one million Higgs particles at the center-of-mass energy of 240 GeV with the integrated luminosity of 0.8 ab^{-1} in 7 years [2]; and the ILC would generate almost the same magnitude of Higgs bosons as the CEPC, about $10^6 - 10^7$ at each energy stage [3]. Therefore, the decay of Higgs boson will be a good platform for studying the indirect production mechanism of doubly heavy baryons. A careful study of the production of $\Xi_{QQ'}$ through Higgs boson decays shall be helpful for confirming whether enough baryon events could be produced and supporting forward guidance on the experiment research.

Attributed to the first observation of the doubly charm baryon Ξ_{cc}^{++} [4] by the LHCb collaboration in 2017, the quark model has proved to be a great success [5,6]. However, there is no explicit evidence of the other doubly heavy baryons Ξ_{bc} and Ξ_{bb} so far. To study all possible production mechanisms of doubly heavy baryons shall be helpful for better understanding their properties and shall be a verification of the quark model and NRQCD [7,8].

II. Calculation technology

Typical Feynman diagrams for the process $H^0(p_H) \rightarrow \Xi_{QQ'}(p_\Xi) + \bar{Q}'(p_{\bar{Q}'} + \bar{Q}(p_{\bar{Q}}))$ through four Higgs decay channels, $H^0 \rightarrow b\bar{b}/c\bar{c}/Z^0/Z^0/\gamma$, are presented in Fig. 1.

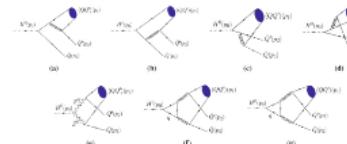


Fig. 1. Typical Feynman diagrams for the process $H^0(p_H) \rightarrow \Xi_{QQ'}(p_\Xi) + \bar{Q}'(p_{\bar{Q}'} + \bar{Q}(p_{\bar{Q}}))$ via four Higgs decay channels, $H^0 \rightarrow b\bar{b}/c\bar{c}/Z^0/Z^0/\gamma$.

Within the framework of NRQCD [17,18], the decay width for the production of $\Xi_{QQ'}$ can be factorized as the following form:

$$\Gamma(H^0(p_H) \rightarrow \Xi_{QQ'}(p_\Xi) + \bar{Q}'(p_{\bar{Q}'} + \bar{Q}(p_{\bar{Q}}))) = \hat{\Gamma}(H^0 \rightarrow \{Q\bar{Q}'\}[n] + \bar{Q}' + \bar{Q}) = \sum_n \hat{\Gamma}(H^0(p_H) \rightarrow \{Q\bar{Q}'\}[n](p_1) + \bar{Q}'(p_2) + \bar{Q}(p_3)) = \int \frac{1}{2m_H} \sum_n |\mathcal{M}[n]|^2 d\Phi_3,$$

where the non-perturbative long-distance matrix element $\langle O^H[n] \rangle$ is proportional to the transition probability from the perturbative quark pair $Q\bar{Q}'[n]$ to the heavy baryons. We shall use h_2 and h_3 to describe the transition probability of the color-singlet diquark state and the color-octet diquark state, respectively. In addition, the transition probability h_3 can be approximately related to the Schrödinger wave function at the origin $|\Psi_{S_0}(0)|$ for the S-wave states, while there is a relatively larger uncertainty for the transition probability h_3 , which has been analyzed detailedly in Ref. [9]. For convenience, we set $h_2 \approx h_3 = |\Psi_{S_0}(0)|^2$ [8,10] as an approximate estimate.

Conclusions

Within the framework of NRQCD, the decay widths for the production of baryons Ξ_{cc} , Ξ_{bc} and Ξ_{bb} have been analyzed through four main Higgs decay channels, $H^0 \rightarrow b\bar{b}/c\bar{c}/Z^0/Z^0/\gamma$. By summing up all the contributions from the intermediate diquark states, $(cc)[^3S_0]_0$, $(cc)[^1S_0]_0$, $(bc)[^3S_1]_{-1,0}$, $(bc)[^3S_1]_{1,0}$, $(bb)[^3S_1]_{-1,0}$ and $(bb)[^1S_0]_0$, the total decay width for the process $H^0 \rightarrow \Xi_{QQ'} + \bar{Q}' + \bar{Q}$ can be obtained, i.e., $\Gamma_{H^0 \rightarrow \Xi_{cc}} = 1.10^{+0.24}_{-0.17} \times 10^{-7} \text{ GeV}$, $\Gamma_{H^0 \rightarrow \Xi_{bc}} = 0.72^{+0.07}_{-0.06} \times 10^{-7} \text{ GeV}$, $\Gamma_{H^0 \rightarrow \Xi_{bb}} = 16.09^{+12.55}_{-6.15} \times 10^{-7} \text{ GeV}$.

where the uncertainty is caused by varying the quark mass $m_c = 1.8 \pm 0.3 \text{ GeV}$ and $m_b = 5.1 \pm 0.4 \text{ GeV}$. To be helpful as regards experimental detection, the invariant mass and the angular differential distributions have also been presented. The corresponding produced events of the doubly heavy baryons $\Xi_{QQ'}$ are both estimated at the HL-LHC and the CEPC/ILC. There are about $(0.27-0.43) \times 10^4$ events of Ξ_{cc} , $(4.21-6.32) \times 10^4$ events of Ξ_{bc} and $(0.17-0.28) \times 10^4$ events of Ξ_{bb} produced per year at the HL-LHC. There are fewer events produced at the CEPC/ILC, only about $(0.16-0.26) \times 10^3$ events of Ξ_{cc} , $(2.55-3.83) \times 10^3$ events of Ξ_{bc} and $(0.10-0.17) \times 10^3$ events of Ξ_{bb} , where the uncertainties are from the transition probability. Due to the high luminosity and high collision energy, there are sizable events of doubly heavy baryons $\Xi_{QQ'}$ produced per year at the HL-LHC via Higgs boson decays, which will be accessible by experiment research.

III. Numerical results

Basic results

Table 1: The decay widths for baryons Ξ_{cc} , Ξ_{bc} and Ξ_{bb} via Higgs boson decays by summing up the contributions from each intermediate diquark state.

$\Gamma(\text{GeV})$	Ξ_{cc}	Ξ_{bc}	Ξ_{bb}	Ξ_{cc}	Ξ_{bc}	Ξ_{bb}	Ξ_{cc}	Ξ_{bc}	Ξ_{bb}
$H^0 \rightarrow b\bar{b} (\times 10^{-7})$	0.65	0.29	0.05	0.65	0.29	0.05	0.65	0.29	0.05
$H^0 \rightarrow c\bar{c} (\times 10^{-7})$	0.02	1.02	4.25	0.02	1.02	4.25	0.02	1.02	4.25
$H^0 \rightarrow Z^0 (\times 10^{-7})$	0.01	0.07	2.86	0.01	0.07	2.86	0.01	0.07	2.86
$H^0 \rightarrow \gamma (\times 10^{-7})$	0.10	-0.57	2.45	0.10	-0.57	2.45	0.10	-0.57	2.45
$\text{Cross sum } (\times 10^{-7})$	0.68	0.84	2.86	0.68	0.84	2.86	0.68	0.84	2.86

Table 2: The invariant mass distributions of the doubly heavy baryons Ξ_{cc} by summing up the contributions from each intermediate diquark state.

$\sqrt{s} (\text{TeV})$	Ξ_{cc}	Ξ_{bc}	Ξ_{bb}	Ξ_{cc}	Ξ_{bc}	Ξ_{bb}
$H^0 \rightarrow b\bar{b}$	1.00	0.01	0.01	0.01	0.01	0.01
$H^0 \rightarrow c\bar{c}$	16.09	2.83	6.32	6.32	16.09	2.83
$H^0 \rightarrow Z^0$	0.72	0.07	0.07	0.07	0.07	0.07

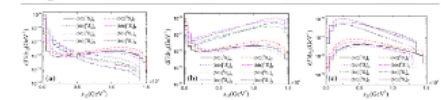


Fig. 2. The invariant mass distributions of the doubly heavy baryons Ξ_{cc} , Ξ_{bc} and Ξ_{bb} by summing up the contributions from each intermediate diquark state.

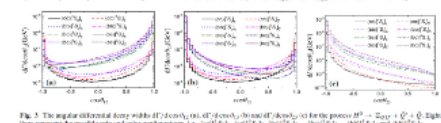


Fig. 3. The angular differential decay widths $d^2\Gamma/d \cos \theta d \cos \phi$ for the process $H^0 \rightarrow \Xi_{QQ'} + \bar{Q}' + \bar{Q}$. Right: then represent the possible spin and color configurations, i.e., $(cc)[^3S_0]_0$, $(cc)[^1S_0]_0$, $(bc)[^3S_1]_{-1,0}$, $(bc)[^3S_1]_{1,0}$, $(bb)[^3S_1]_{-1,0}$ and $(bb)[^1S_0]_0$.

Theoretical uncertainties

Table 3: The theoretical uncertainties for the production of baryons Ξ_{cc} via Higgs boson decays by varying $m_c = 1.8 \pm 0.3 \text{ GeV}$.

$\Gamma(\times 10^{-7} \text{ GeV})$	Ξ_{cc}	Ξ_{bc}	Ξ_{bb}	Ξ_{cc}	Ξ_{bc}	Ξ_{bb}	Ξ_{cc}	Ξ_{bc}	Ξ_{bb}
$m_c = 1.5 \text{ GeV}$	0.60	0.80	2.86	0.67	0.81	2.86	0.60	0.80	2.86
$m_c = 1.8 \text{ GeV}$	0.60	0.80	2.86	0.67	0.81	2.86	0.60	0.80	2.86
$m_c = 2.1 \text{ GeV}$	0.50	0.75	2.86	0.72	0.87	2.86	0.50	0.75	2.86

Table 4: The theoretical uncertainties for the production of baryons Ξ_{bc} via Higgs boson decays by varying $m_b = 5.1 \pm 0.4 \text{ GeV}$.

$\Gamma(\times 10^{-7} \text{ GeV})$	Ξ_{bc}	Ξ_{cc}	Ξ_{bb}	Ξ_{bc}	Ξ_{cc}	Ξ_{bb}	Ξ_{bc}	Ξ_{cc}	Ξ_{bb}
$m_b = 4.7 \text{ GeV}$	0.60	0.80	2.86	0.67	0.81	2.86	0.60	0.80	2.86
$m_b = 5.1 \text{ GeV}$	0.60	0.80	2.86	0.67	0.81	2.86	0.60	0.80	2.86
$m_b = 5.5 \text{ GeV}$	0.50	0.75	2.86	0.72	0.87	2.86	0.50	0.75	2.86

Table 5: The theoretical uncertainties for the production of baryons Ξ_{bb} via Higgs boson decays by varying $m_b = 5.1 \pm 0.4 \text{ GeV}$.

Caused by:	Ξ_{cc}	Ξ_{bc}	Ξ_{bb}	Ξ_{cc}	Ξ_{bc}	Ξ_{bb}
Heavy quark mass	0.60	0.80	2.86	0.67	0.81	2.86
Renormalization scale	0.60	0.80	2.86	0.67	0.81	2.86

References

1. LHC Higgs Cross Section Working Group, Higgs production cross-sections AN2 (2016).
2. CEPC Conceptual Design Report (2018). arXiv:1809.00285 [physics.hep-th]
3. T. Simon, PVS ICHEP 2012, 966 (2013).
4. LHC Collaboration, Phys. Rev. Lett. 119, 112001 (2017).
5. M. Gell-Mann, Phys. Lett. 8, 214 (1964).
6. G. Zweig, CERN-TH.4001 (1964).
7. T. Bodwin, et al. Phys. Rev. D 51, 1122 (1995).
8. A. Petrelli, et al. Nucl. Phys. B 514, 245 (1998).
9. J.J. Niu, et al. Phys. Rev. D 98, 044001 (2018).
10. E. Eichten, et al. Z. Phys. C 64, 57 (1994).

Proceedings

Proceedings will be published in **Int. J. Mod. Phys. A**. Please submit before **Nov. 30, 2019**.

Number of pages: Minutes/5 + 1

- plenary: 8 pages
- round-table: 15 pages
- leading parallel: 6 pages
- parallel: 5 pages
- poster: 4 pages

The template will be provided later.

Please join me in thanking

Colleagues in GXNU: Ms. MO Qiaoli,

Prof. Yang Yongxu, Wang Ning, Sun Xiaojun, Wei Daihui,

Dr. Liao Guangrui, Qin Liqing, Niu Juanjuan

Students in GXNU: Jiang Shengjuan, Li Haiping, Wang Shuai, Liang Yan, Wei Siyu, Li Mei, Lin Jiaxin, Li Jiating, Yu Xizhao, Zhong Jingli, Chen Zheng, Chen Chunchan, Peng Haiyuan, Wang Ting, Pei Junhui, Zhou Ting.

Students in ITP: TANG Mengna, ZHANG Xiaoyu, YAN Maojun, WANG Zhengli, LIN Yonghui

We wish you a safe trip back

And see you in the next HADRON conference,
to be held in Mexico in Aug./Sep. 2021, with exact
location and dates pending decision.

