赵忠尧博士后申请报告

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2018年3月28日

主要内容

- 个人简历
- 博士期间研究工作
- 发表学术成果
- 博士后工作计划
- 报告小结

个人简历

- 1988.2出生于河南省濮阳市
- 2006.9—2010.7:河南师范大学，本科，物理学
- 2010.9—2013.7:河南师范大学，硕士，理论物理
- 2013.9—2018.7:清华大学，博士，粒子物理实验
- 2011.7—2018.7:高能物理研究所联合培养，主要从事BESIII实验数据分析工作

博士期间研究工作

- Updated Measurement of Two-photon Width of χ_{cJ} States via $\psi' \to \gamma\chi_{cJ}$
  (PRD96, 092007, 2017)

- Observation of $\chi_{cJ} \to \phi\phi\eta$ via $\psi' \to \gamma\chi_{cJ}$
  (Memo under review)

- Measurement of $\sigma(e^+e^- \to D_2\bar{D} \to D^0D^-\pi^+ + c.c.)$
  (Memo under review)

Updated Measurement of Two-photon Width of χ_{cJ} States via $\psi' \to \gamma\chi_{cJ}$

$\psi' \to \gamma\chi_{cJ}, \chi_{cJ} \to \gamma\gamma$

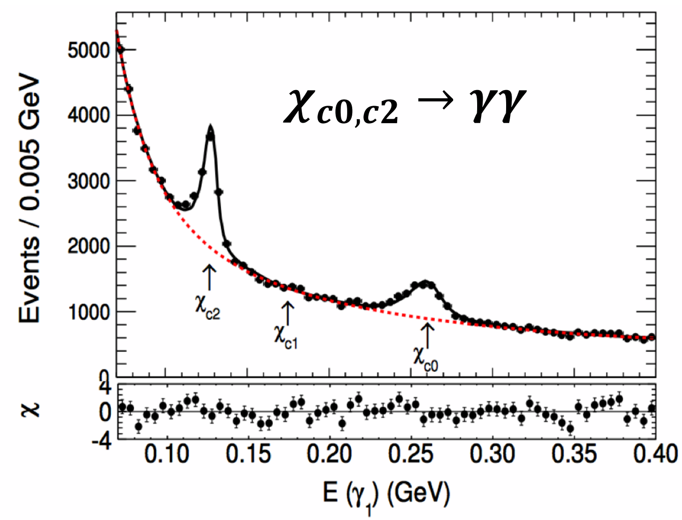
[(448.1±2.9)×10⁶ ψ']

选题动机

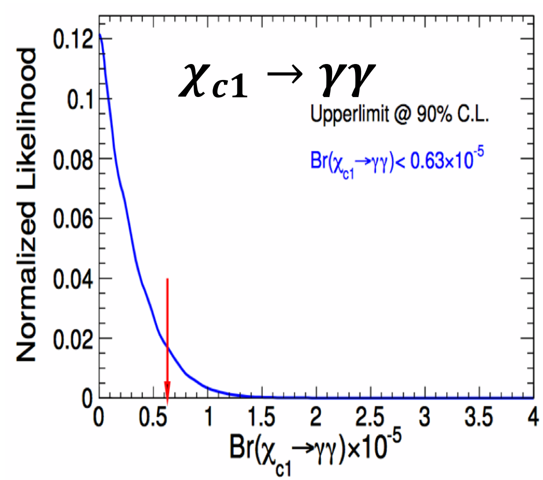
- ❑ 精确测量
- ❑ 研究χ_{cJ}的衰变性质
- ❑ 检验QCD理论模型的正确性

工作内容

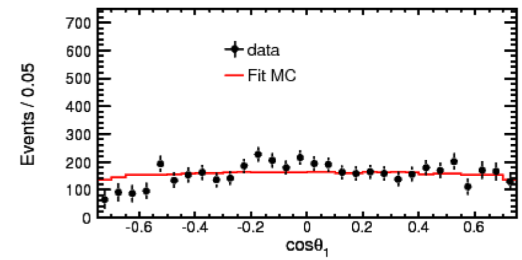
- ○ 分支比的测量($\chi_{cJ} \to \gamma\gamma$)
- ○ 角分布的拟合($\chi_{c2} \to \gamma\gamma$)

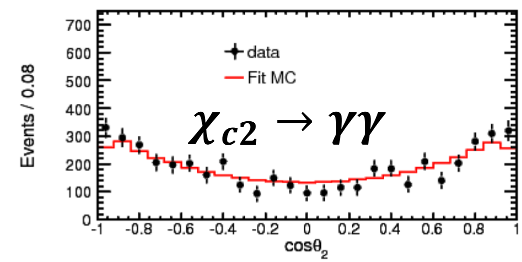


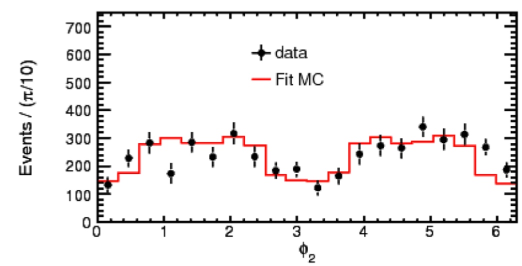
[辐射光子能量]



[已考虑系统误差]







[角分布]

Updated Measurement of Two-photon Width of χ_{cJ} States via $\psi' \to \gamma\chi_{cJ}$

➢精确的测量结果：

Quantity	PDG average values[a]	CLEO-c[b]	BESIII[b]	This measurement[b]
$\mathcal{B}_1 \times \mathcal{B}_2(10^{-5})(\chi_{c0})^{c}$	2.23 ± 0.14	$2.17 \pm 0.32 \pm 0.10$	$2.17 \pm 0.17 \pm 0.12$	$1.93 \pm 0.08 \pm 0.05$
$\mathcal{B}_1 \times \mathcal{B}_2(10^{-5})(\chi_{c2})^{c}$	2.50 ± 0.15	$2.68 \pm 0.28 \pm 0.15$	$2.81 \pm 0.17 \pm 0.15$	$2.83 \pm 0.08 \pm 0.06$
$\mathcal{B}_2(10^{-4})(\chi_{c0})^{c}$	2.23 ± 0.13	$2.31 \pm 0.34 \pm 0.15$	$2.24 \pm 0.19 \pm 0.15$	$1.93 \pm 0.08 \pm 0.07$
$\mathcal{B}_2(10^{-4})(\chi_{c2})^{c}$	2.74 ± 0.14	$3.23 \pm 0.34 \pm 0.24$	$3.21 \pm 0.18 \pm 0.22$	$3.10 \pm 0.09 \pm 0.13$
$\Gamma_{\gamma\gamma}(\chi_{c0})$ keV	2.24 ± 0.19	$2.36 \pm 0.35 \pm 0.22$	$2.33 \pm 0.20 \pm 0.22$	$2.03 \pm 0.08 \pm 0.14$
$\Gamma_{\gamma\gamma}(\chi_{c2})$ keV	0.53 ± 0.03	$0.66 \pm 0.07 \pm 0.06$	$0.63 \pm 0.04 \pm 0.06$	$0.60 \pm 0.02 \pm 0.04$
$\mathcal{R}$	0.23 ± 0.02	$0.28 \pm 0.05 \pm 0.04$	$0.27 \pm 0.03 \pm 0.03$	$0.30 \pm 0.02 \pm 0.03$
$f_{0/2}(10^{-2})$	...	...	$0 \pm 2 \pm 2$	$0.0 \pm 0.6 \pm 1.2$

➢上限估计：$\mathcal{B}(\chi_{c1} \to \gamma\gamma) < 6.3\times10^{-6}$ and $\Gamma(\chi_{c1} \to \gamma\gamma) < 5.3\mathrm{eV}$

➢0. 30 (Exp) >0. 267 (Th) :理论模型计算也许需要考虑更高阶效应

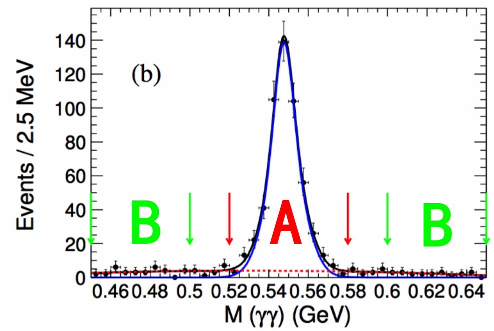
➢精确的结果表明：衰变过程 $\chi_{c2} \to \gamma\gamma$ 主要是通过螺旋度为2的过程发生的。

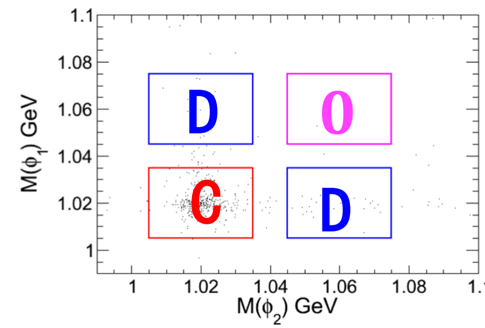
Observation of $\chi_{cJ} \to \phi\phi\eta, \phi \to K^+K^-$, $\eta \to \gamma\gamma$ via $\psi' \to \gamma\chi_{cJ}$

选题动机
- ❑ 首次测量
- ❑ 研究χ_{cJ}的强子衰变性质

工作内容
- ○ 分支比的测量
- ○ 中间共振态的寻找

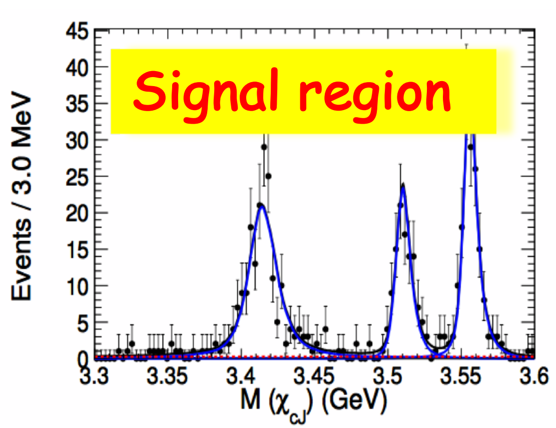
[(448.1±2.9)×10^6 ψ']



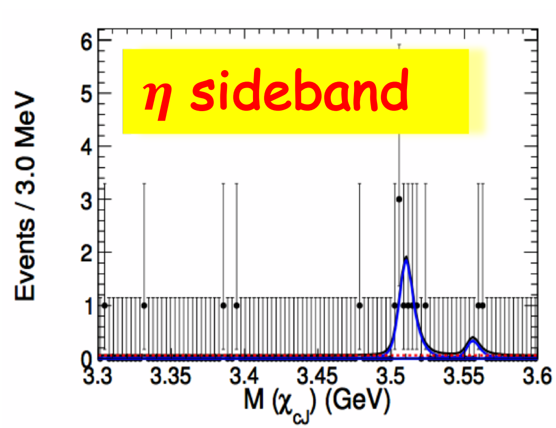


η一维信号区

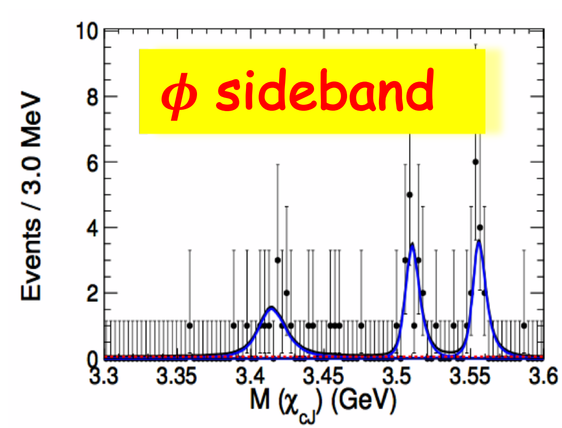
ϕ二维信号区



A+C



B+C



A+D

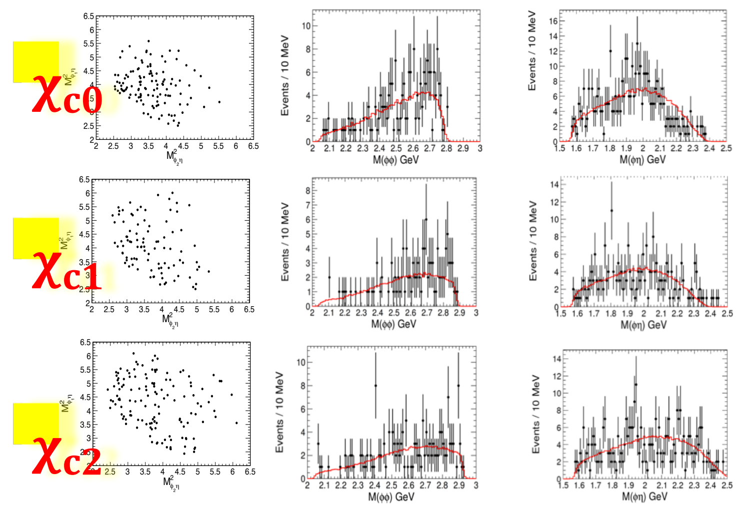
Observation of $\chi_{cJ} \to \phi\phi\eta$ via $\psi' \to \gamma\chi_{cJ}$

- 首次测量分支比：

$$\mathcal{B}(\chi_{cJ} \to \phi\phi\eta) = \frac{N_{sig}^{obs} - 1.0 \cdot N_{\eta}^{bkg} - 0.5 \cdot N_{\phi}^{bkg}}{N_{\psi'} \cdot \mathcal{B}r \cdot \epsilon}$$

Decay Modes	Branching fraction ($\times 10^{-4}$)	Significance (σ)
$\chi_{c0} \to \phi\phi\eta$	8.44 ± 0.69 ± 0.63	19.3
$\chi_{c1} \to \phi\phi\eta$	3.26 ± 0.41 ± 0.25	12.4
$\chi_{c2} \to \phi\phi\eta$	5.73 ± 0.51 ± 0.44	19.6

- 由于统计量的原因，
衰变过程并没有明显的中间共振态过程：

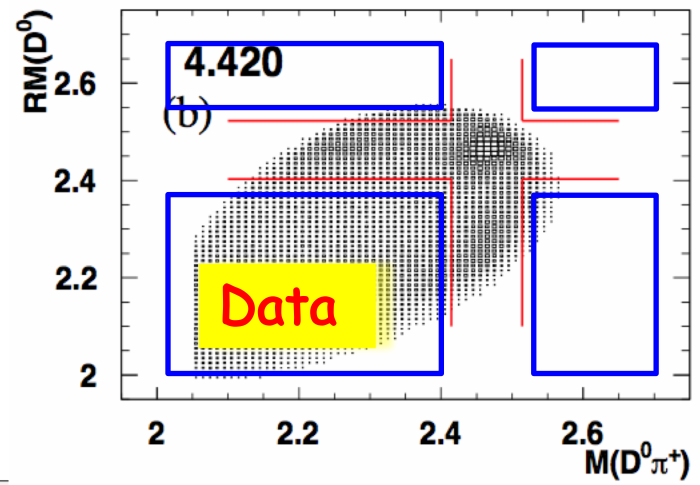


Cross Section Measurement of $e^+e^- \to D_2\bar{D} \to D^0D^-\pi^+ + c.c.$

选题动机

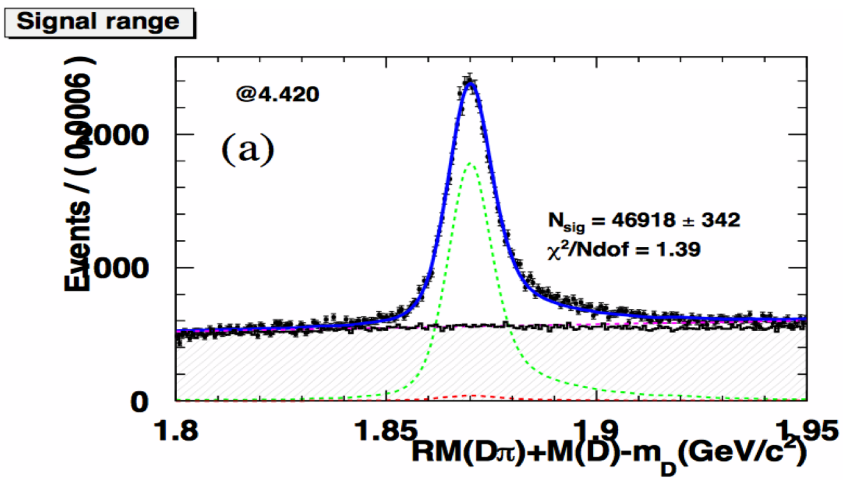
[@28 points: √s = 4.340~4.600GeV]

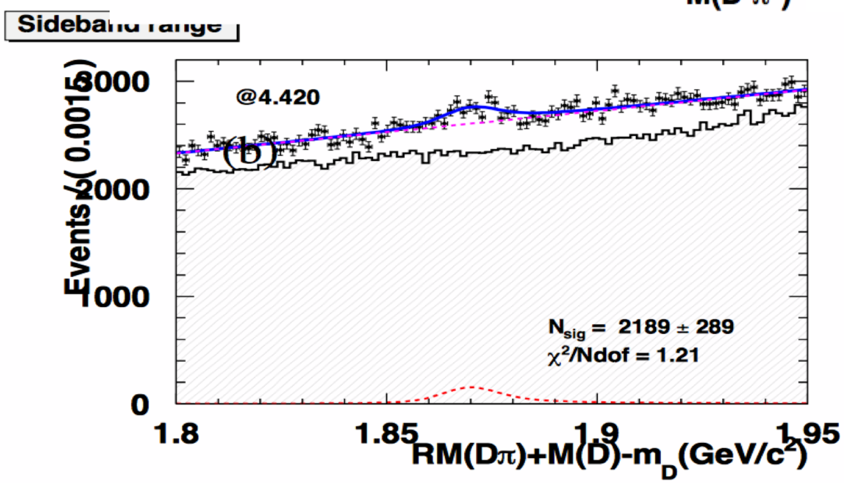
- ❑ 精确测量衰变过程的截面
- ❑ 研究$\psi(4415)$的性质及其衰变
- ❑ 检验夸克模型的正确性



工作内容

- ○ 波恩截面的测量（部分重建的方法）
- ○ 拟合测量得到的截面

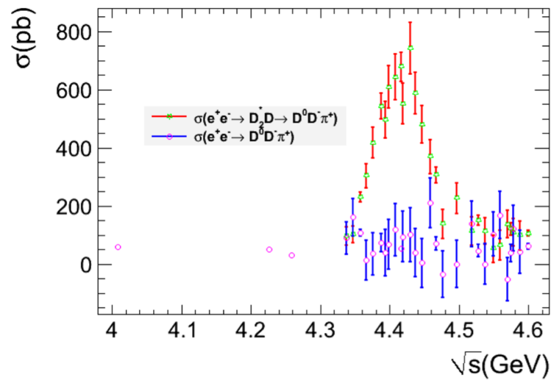


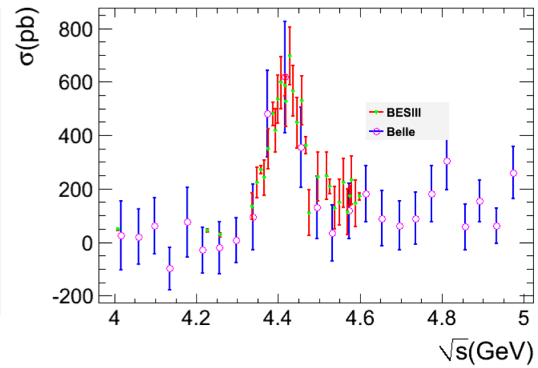


Cross Section Measurement of $e^+e^- \to D_2\bar{D} \to D^0D^-\pi^+ + c.c.$

➢ 波恩截面计算公式:

$$\sigma^B = \frac{\sum N_i^{obs} / \sum \epsilon_i \cdot Br_i}{\mathcal{L} \cdot (1+\delta^{ISR}) \cdot (1+\delta^{VP})}$$



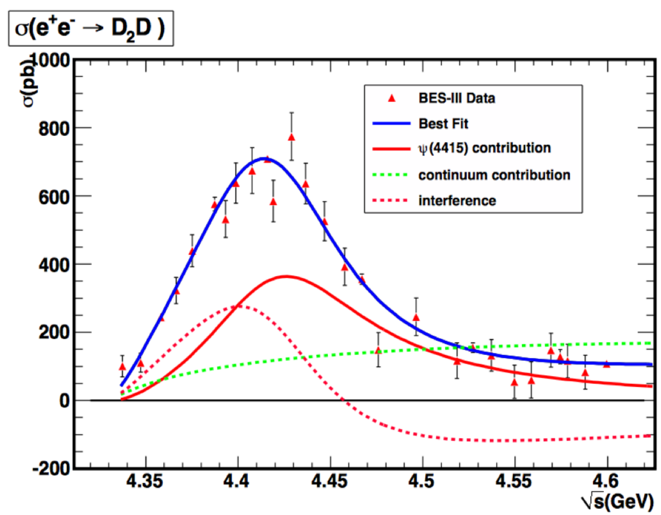


➢ 截面拟合公式:

$$\sigma^B \cdot (1+\delta^{VP}) = \frac{\pi\alpha^2}{3W^2} Z_{D_2^*\bar{D}} \beta_{\bar{D}}^{5} |F_D(W)|^2$$

$$F_D(W) = F_D^R(W)e^{i\phi} + F_D^{NR}(W):$$

parameters	M (MeV/c^2)	Γ (MeV)	$\Gamma_{ee} \cdot Br$ (eV)
Our Measurement	4415.7 ± 6.6 ± 6.3	109.7 ± 13.1 ± 4.5	49.3 ± 8.8 ± 17.1
PDG Value	4421 ± 4	60 ± 20	58 ± 24



发表学术成果

- **Updated Measurement of Two-photon Width of χ_{cJ} States via $\psi' \to \gamma\chi_{cJ}$**
  (PRD96, 092007, 2017)

Based on 448.1×10^6 $\psi(3686)$ events collected with the BESIII detector, the decays $\psi(3686) \to \gamma\chi_{cJ}$, $\chi_{cJ} \to \gamma\gamma (J = 0, 1, 2)$ are studied. The decay branching fractions of $\chi_{c0,2} \to \gamma\gamma$ are measured to be $\mathcal{B}(\chi_{c0} \to \gamma\gamma) = (1.93 \pm 0.08 \pm 0.05 \pm 0.05) \times 10^{-4}$ and $\mathcal{B}(\chi_{c2} \to \gamma\gamma) = (3.10 \pm 0.09 \pm 0.07 \pm 0.11) \times 10^{-4}$, which correspond to two-photon decay widths of $\Gamma_{\gamma\gamma}(\chi_{c0}) = 2.03 \pm 0.08 \pm 0.06 \pm 0.13$ keV and $\Gamma_{\gamma\gamma}(\chi_{c2}) = 0.60 \pm 0.02 \pm 0.01 \pm 0.04$ keV with a ratio of $\mathcal{R} = \Gamma_{\gamma\gamma}(\chi_{c2})/\Gamma_{\gamma\gamma}(\chi_{c0}) = 0.295 \pm 0.014 \pm 0.007 \pm 0.027$, where the uncertainties are statistical, systematic and associated with the uncertainties of $\mathcal{B}(\psi(3686) \to \gamma\chi_{c0,2})$ and the total widths $\Gamma(\chi_{c0,2})$, respectively. For the forbidden decay of $\chi_{c1} \to \gamma\gamma$, no signal is observed, and an upper limit on the two-photon width is obtained to be $\Gamma_{\gamma\gamma}(\chi_{c1}) < 5.3$ eV at the 90% confidence level. The ratio of the two-photon widths between helicity-zero and helicity-two components in the decay $\chi_{c2} \to \gamma\gamma$ is also measured to be $f_{0/2} = \Gamma^{\lambda=0}_{\gamma\gamma}(\chi_{c2})/\Gamma^{\lambda=2}_{\gamma\gamma}(\chi_{c2}) = (0.0 \pm 0.6 \pm 1.2) \times 10^{-2}$, where the uncertainties are statistical and systematic, respectively.

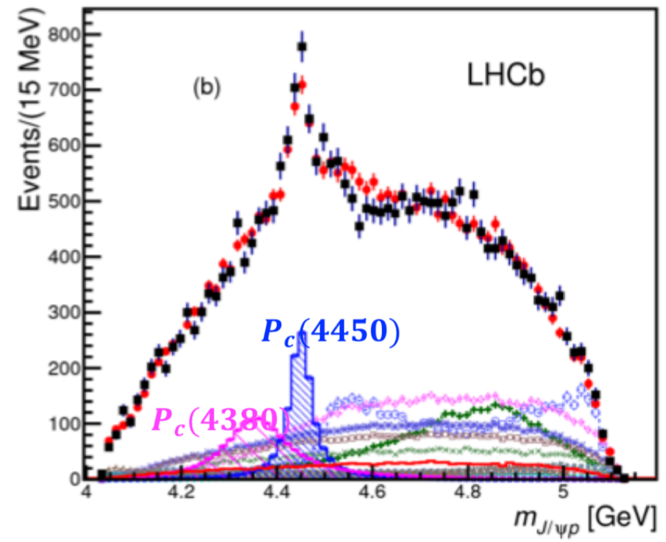
DOI: 10.1103/PhysRevD.96.092007

博士后期间的工作计划（LHCb）

- ❑ $\Lambda_b^0 \to J/\psi p K^-$ (PRL115, 072001, 2015)

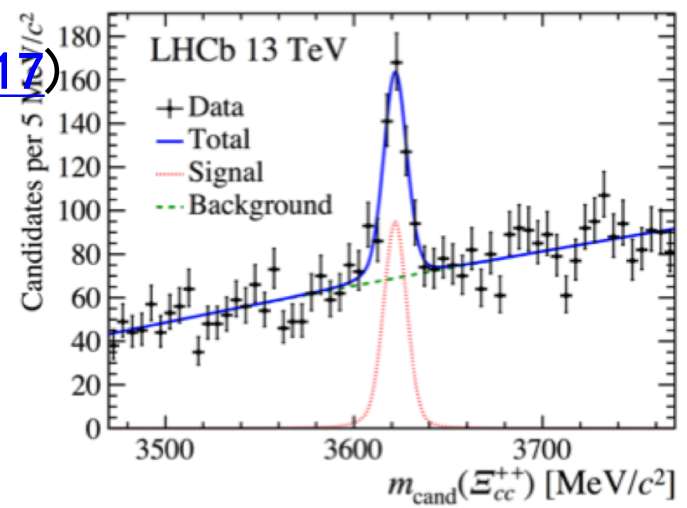
  利用dalitz分析的方法寻找类似过程中的共振态结构：

  $$\Lambda_b^0 \to \chi_{c1,c2} p K^-$$
  $$\Xi_b^0 \to J/\psi \Lambda K^-$$



- ❑ $\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^+$ (PRL119, 112001, 2017)

  寻找双粲重子的其它衰变过程，以及新的双粲重子



小结

❑ 博士期间研究工作（BESIII）

Updated Measurement of Two-photon Width of χ_{cJ} States via $\psi' \to \gamma\chi_{cJ}$
(PRD96, 092007, 2017)

Observation of $\chi_{cJ} \to \phi\phi\eta$ via $\psi' \to \gamma\chi_{cJ}$
(Memo under review)

Measurement of $\sigma(e^+e^- \to D_2\bar{D} \to D^0D^-\pi^+ + c.c.)$
(Memo under review)

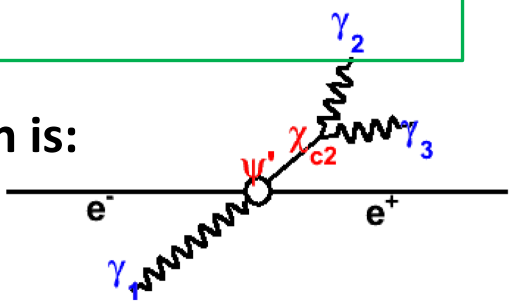
❑ 博士后期间工作计划（LHCb）

利用dalitz分析的方法寻找共振态结构
寻找双粲重子的其它衰变过程，以及新的双粲重子

谢谢各位老师的聆听！

Backup

Helicity Amplitude Analysis for $\chi_{c2} \to \gamma\gamma$



For $\psi' \to \gamma_1\chi_{c2} \to \gamma_1\gamma_2\gamma_3$, the joint angular distribution is:

$$\begin{aligned}
W_2(\theta_1,\theta_2,\phi_2) = f_{0/2}[&\frac{3}{2}y^2(1+\cos^2\theta_1)\sin^4\theta_2 + 3x^2\sin^2\theta_1\sin^2\theta_2 \\
&- \frac{3\sqrt{2}}{2}xy\sin 2\theta_1\sin^2\theta_2\sin 2\theta_2\cos\phi_2 + \sqrt{3}x\sin 2\theta_1\sin 2\theta_2(3\cos^2\theta_2 - 1)\cos\phi_2 \\
&+ \sqrt{6}y\sin^2\theta_1\sin^2\theta_2(3\cos^2\theta_2 - 1)\cos 2\phi_2 + (1+\cos^2\theta_1)(3\cos^2\theta_2 - 1)^2]|_{\lambda=0} \\
&+ [\frac{1}{4}y^2(1+\cos^2\theta_1)(1+6\cos^2\theta_2+\cos^4\theta_2) + 2x^2\sin^2\theta_1(1+\cos^2\theta_2)\sin^2\theta_2 \\
&+ \frac{\sqrt{2}}{4}xy\sin 2\theta_1\sin^2\theta_2(3+\cos^2\theta_2)\cos\phi_2 - \frac{\sqrt{3}}{2}x\sin 2\theta_1\sin 2\theta_2\sin^2\theta_2\cos\phi_2 \\
&+ \frac{\sqrt{6}}{2}y\sin^2\theta_1(1-\cos^4\theta_2)\cos 2\phi_2 + \frac{3}{2}(1+\cos^2\theta_1)\sin^4\theta_2]|_{\lambda=2}
\end{aligned}$$

- $\boldsymbol{\theta_1}$: **is the polar angle of** γ_1
- $\boldsymbol{\theta_2, \phi_2}$: **are the polar angle and azimuthal angle of** γ_2
- $\boldsymbol{\lambda}$: **is the difference of two photons' helicities.**
- $\boldsymbol{x = A_1/A_0,\ y = A_2/A_0,\ f_{0/2} = |F_0|^2/|F_2|^2}$
- **A is the** χ_{c2} **helicity component in** $\psi' \to \gamma\chi_{c2}$
- **F is the helicity amplitudes in** $\chi_{c2} \to \gamma\gamma$

Fit to the Dressed Cross Section

To determine the parameters of $\psi(4415)$, the dressed cross sections, $\sigma^B \cdot (1+\delta^{VP})$, are fitted using the following formula:

$$\sigma_{D_2^*\bar{D}}(W) = \frac{\pi\alpha^2}{3W^2} Z_{D_2^*\bar{D}} \beta_{\bar{D}}^5 |F_D(W)|^2$$

- $Z_{D_2^*\bar{D}}$: the Coulomb interaction between charged mesons;
- β: the velocity of $\bar{D}$ in the e^+e^- center-of-mass system;
- $F_D(W) = F_D^R(W)e^{i\phi} + F_D^{NR}(W)$: the form factor;
- ϕ: the phase of the resonance relative to the non-resonance;
- $F_D^R(W) = 6\sqrt{\frac{\Gamma_{D_2\bar{D}} \cdot \Gamma_{ee}}{\alpha^2 \cdot (Z_{D_2^*D} \cdot \beta_{\bar{D}}^5)}} \cdot \frac{M}{W^2 - M^2 + iM\Gamma}$, $\Gamma_{D_2\bar{D}} = \frac{(M/W) Z_{D_2^*\bar{D}}(M) d_{D_2^*\bar{D}} \cdot \Gamma \cdot Br}{Z_{D_2^{*0}\bar{D}^0}(M) d_{D_2^{*0}\bar{D}^0} + Z_{D_2^{*+}D^-}(M) d_{D_2^{*+}D^-}}$
- $F_D^{NR}(W) = \frac{b}{W^2 - c}$
- Γ, M: the full width and mass of $\psi(4415)$;
- $d_{D_2^*\bar{D}}$: the Blatt-Weisskopt damping factor;
- $\Gamma_{ee} \cdot Br$: a whole parameter to be determined. Γ_{ee} is the leptonic decay width, Br is the branching fraction of $\psi(4415) \to D_2^* D \to D^0 D^- \pi^+ + c.c.$

- ❑ $\Lambda_b^0 \to \chi_{c1,c2} p K^-$ (453+−25/285+−23)
- ❑ $\Xi_b^0 \to J/\psi \Lambda K^-$ (300)