粒子物理卓越创新中心

青年骨干成员考评

平荣刚

（高能物理研究所）

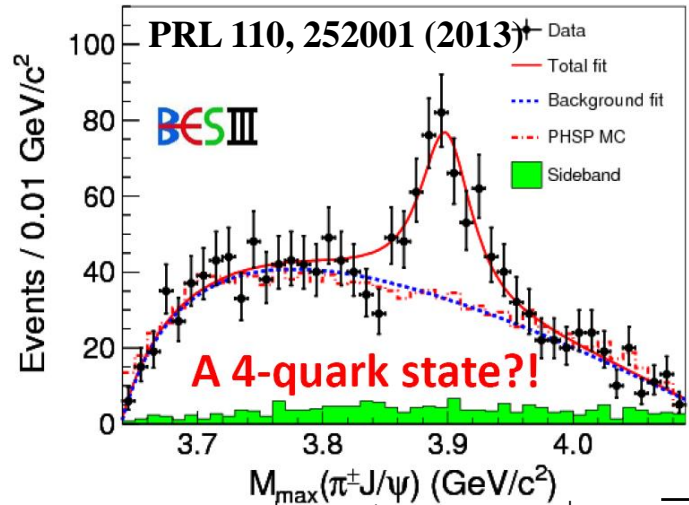**内容:**

1. 物理分析工作

2. 软件服务工作

3. 承担/参加的基金项目和研究生培养

4. 总结

(1) Z_c(3900), Z_c(3885), Zc(4020)自旋-宇称的测量
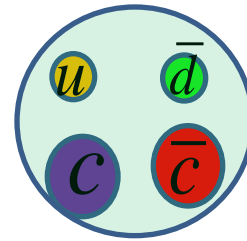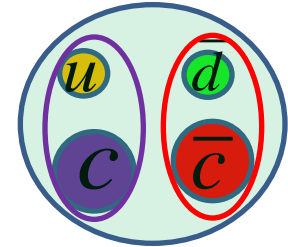
$$Z_c(3900)^{\pm} : e^+e^- \to \pi^+\pi^- J/\psi$$

PRL 110, 252001 (2013)

BESIII

A 4-quark state?!

$$Z_c(3885)^{\pm} : e^+e^- \to \pi^{\pm}(D\bar{D}^*)^{\mp}$$

Z_c(3885)$^{\pm}$

PRL 112, 022001 (2014)

J^P=1$^+$

$$J^P = ?$$

$Z_c(3900)^+$ u π^+ $\bar{d}$ c J/ψ $\bar{c}$
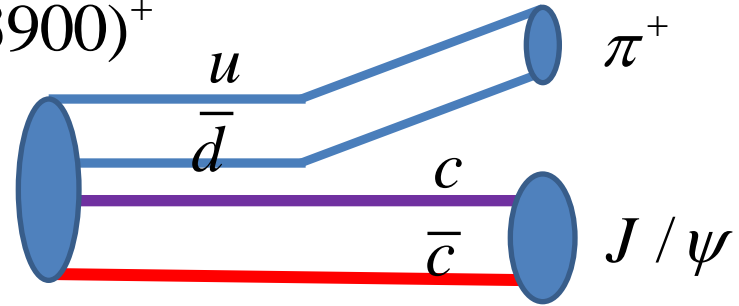
tetraquark

diquark-antidiquark
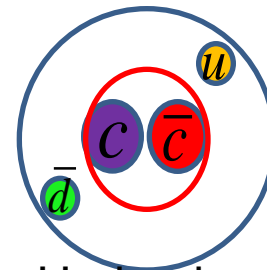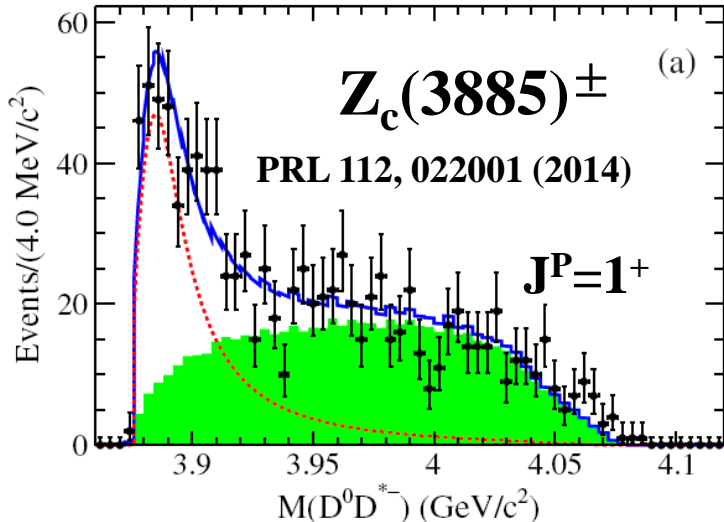
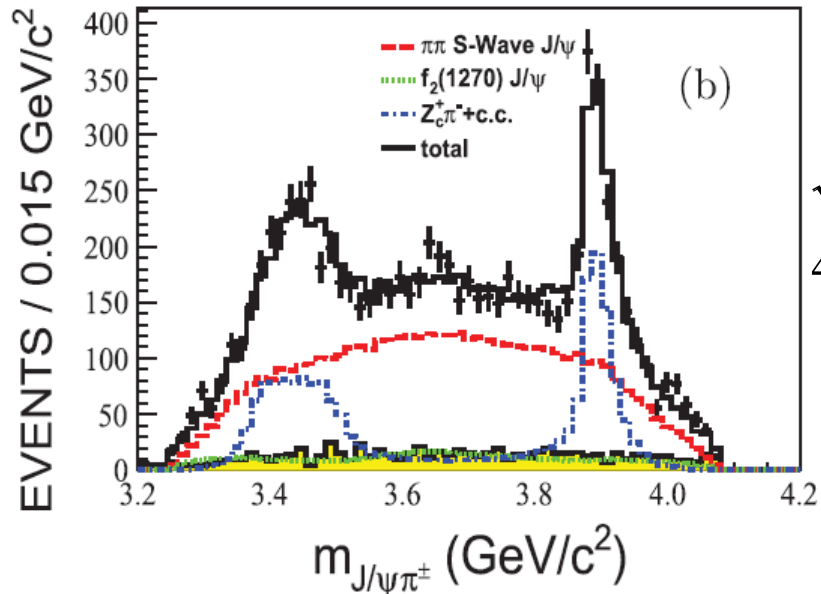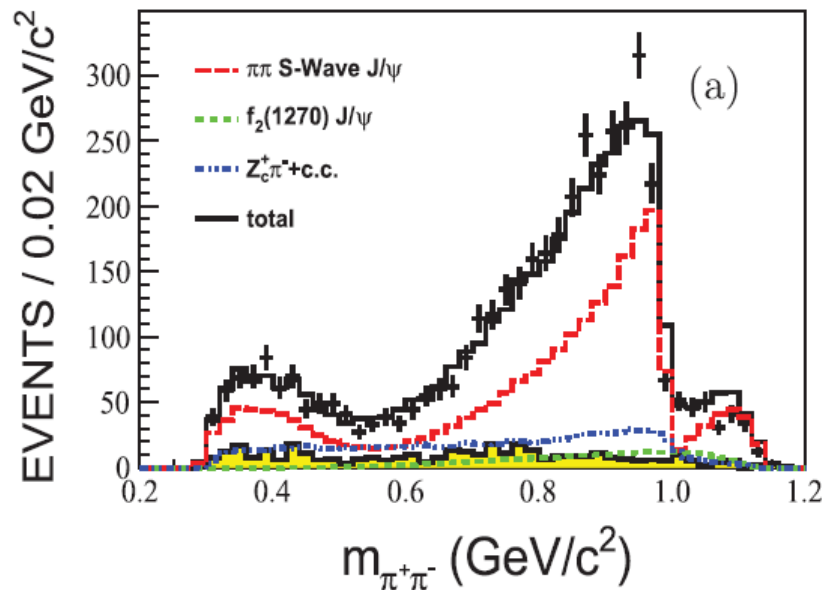Hadronic charmonium

DD* molecule

2
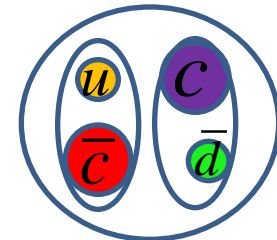
$Z_c(3900)^{\pm}$ in $e+e-\to\pi^+\pi^-J/\psi$

$\sqrt{s} =$ 4.23 GeV

4.26 GeV

3

(a) $|\cos(\theta_{Z_c^\pm})|$

(b) $|\cos(\theta_{J/\psi})|$
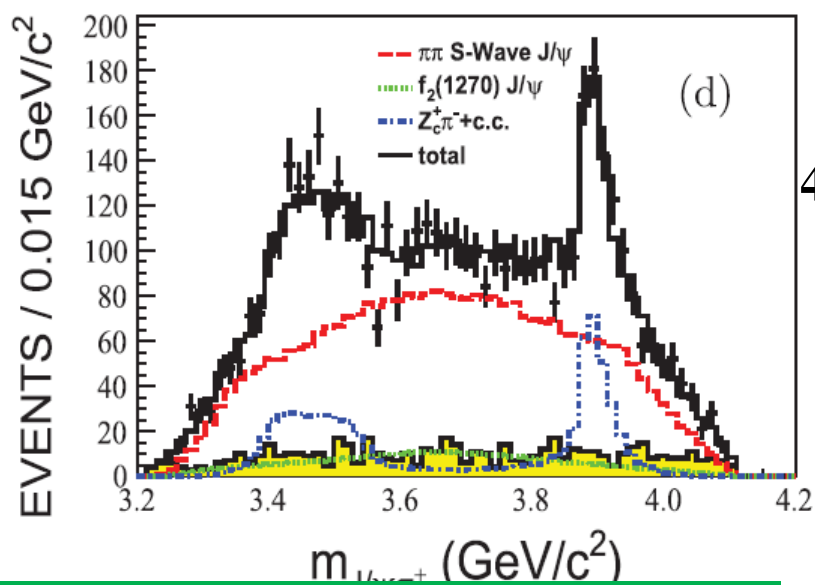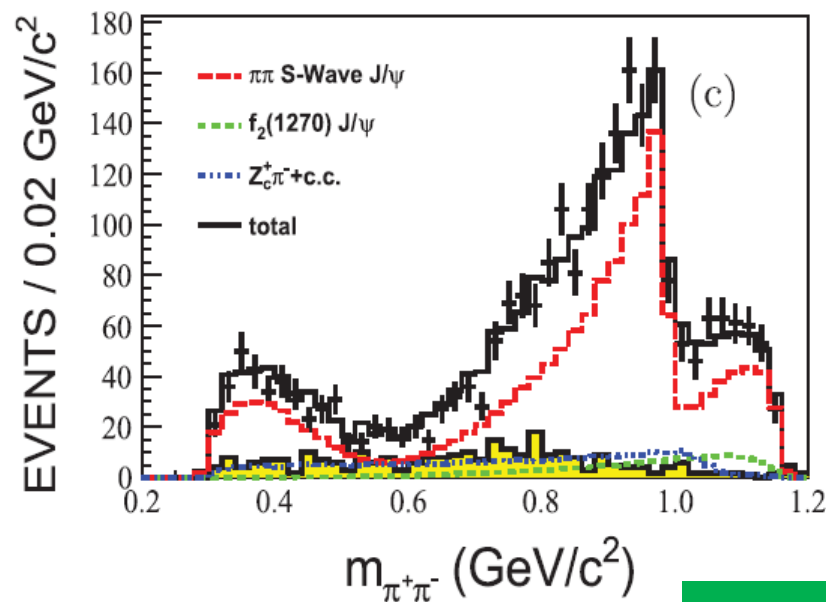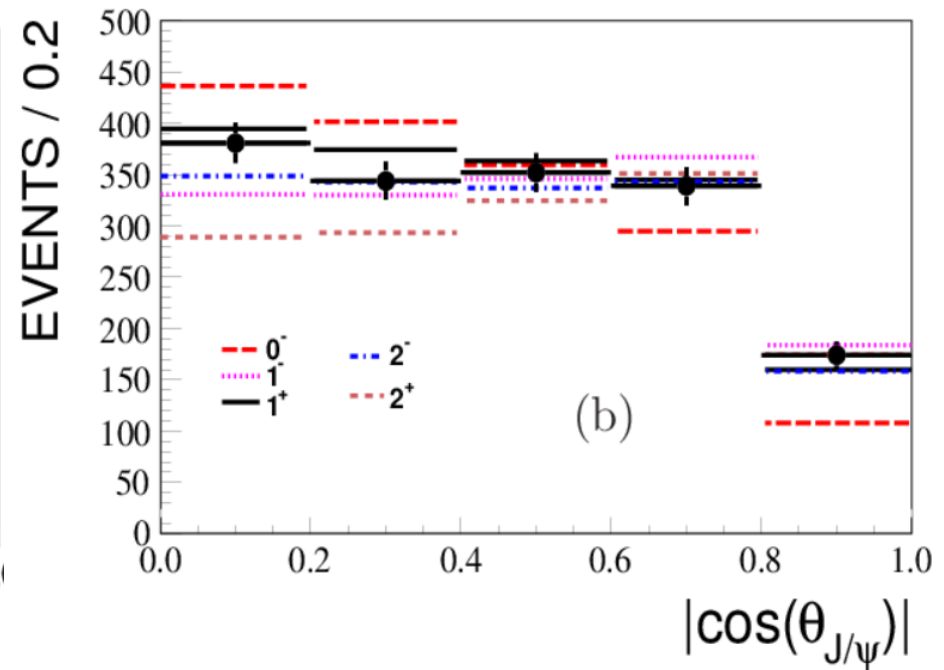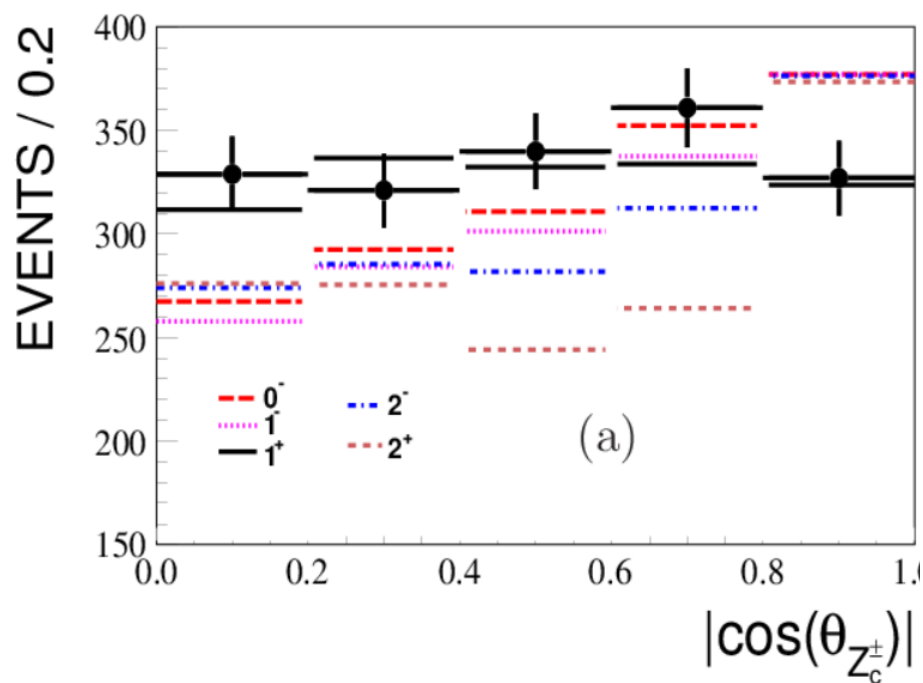
Significance to distinguish the quantum number 1^+ over other quantum numbers.

Hypothesis	$2\Delta(-\ln L)$	$\Delta(ndf)$	significance
1^+ over 0^-	94.0	$4\times2+5$	7.6σ
1^+ over 1^-	158.3	$4\times2+5$	10.8σ
1^+ over 2^-	151.9	$4\times2+5$	10.5σ
1^+ over 2^+	96.0	$4\times2+5$	7.7σ

4

■ **Comments from PRL referees**   arXiv:1706.04100

A: The BESIII collaboration has an excellent track record in the field of spectroscopy in the sector of charmonia and charmonium-like mesons…..

BESIII 合作组在粲偶素、类粲偶素谱学领域研究保持良好的记录 ….

Using partial-wave analyses, spin and parity of one of the charged states containing a pair of charm-anticharm and, thus, exhibiting a structure that cannot be reduced to simple quark-antiquark dynamics are addressed.

This is a very important contribution in view of the ongoing discussion of the nature of these puzz 这是一个非常重要的工作 ……

B: Besides mass, width, and production cross sections, open questions remained, and in particular spin and parity are crucial properties to know in order to understand the structure of this and make connections to other observations. The present paper unambiguously answers this question, by ruling out other than the 1+ spin-parity assignment with significances exceeding seven standard deviations.

The measurement will undoubtedly trigger a significant number of phenomenological publications.

- **Selected as Physics synopsis by the PRL Journal**

  Determination of the Spin and Parity of the Zc(3900), M. Ablikim *et al.* (BESIII Collaboration), Phys. Rev. Lett. **119**, 072001 – Published 16 August 2017
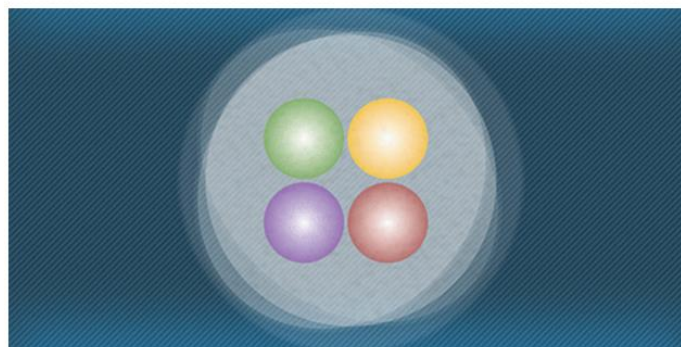
  Physics synopsis:

  https://physics.aps.org/synopsis-for/10.1103/PhysRevLett.119.072001

  ## Synopsis: Filling in a Tetraquark's Profile

  完善四夸克态档案

  August 16, 2017

  An analysis of electron-positron collision data has determined the spin and parity of a particle thought to consist of four quarks.
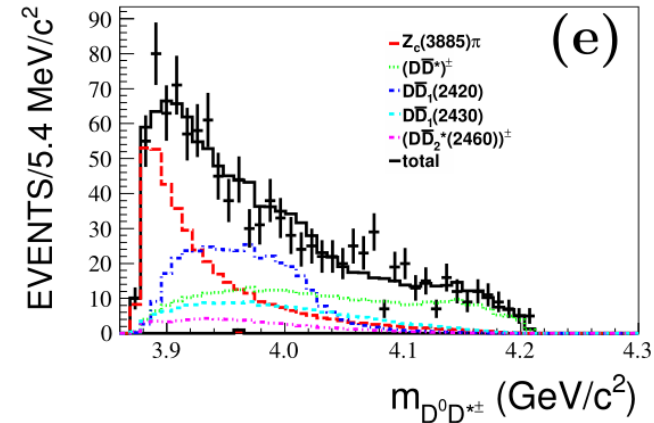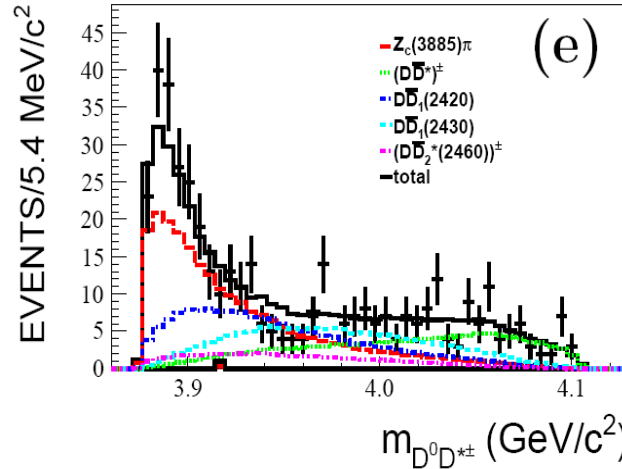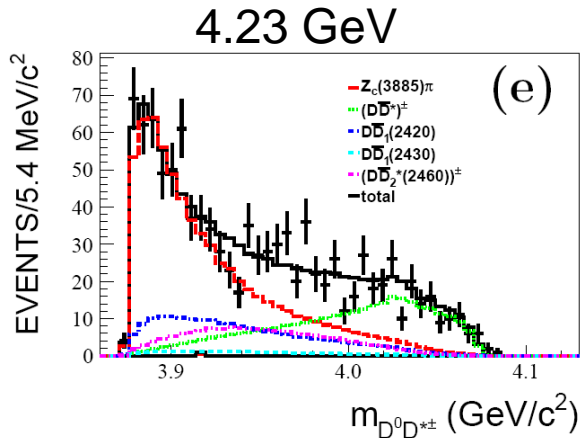
  Fermilab

- 高能物理研究所/ 2017高能新闻

  Zc(3900)的自旋和宇称量子数确立

$e^+e^- \to \pi^\pm (D\bar{D}^*)^\mp$ 中的 $Z_c(3885)^\pm$ 分波研究

4.23 GeV
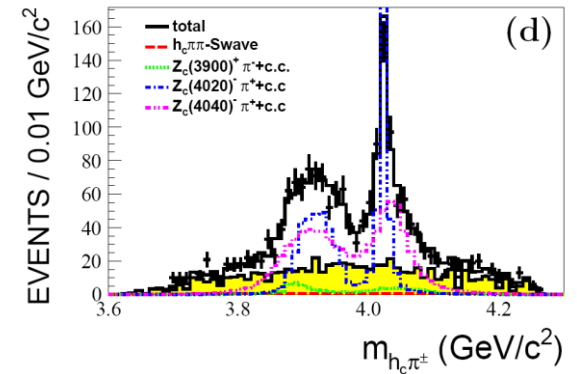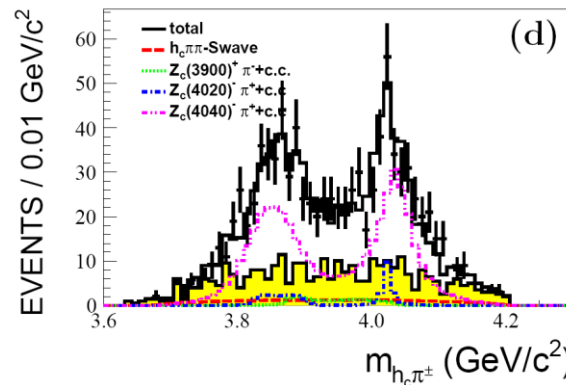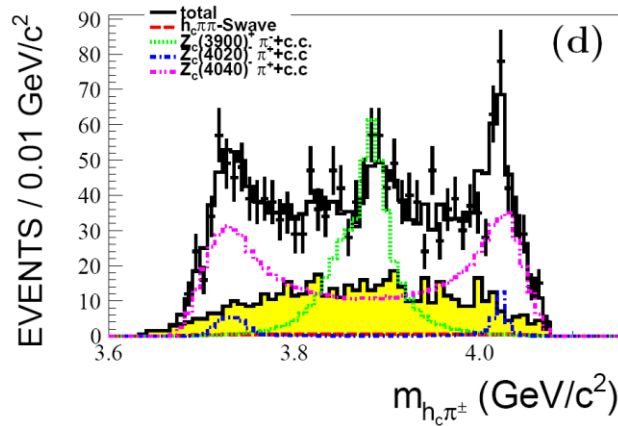### 4.26 GeV
4.36 GeV

$e^+e^- \to \pi^+\pi^- h_c$ 中的 $Z_c(4020)^\pm$ 分波研究
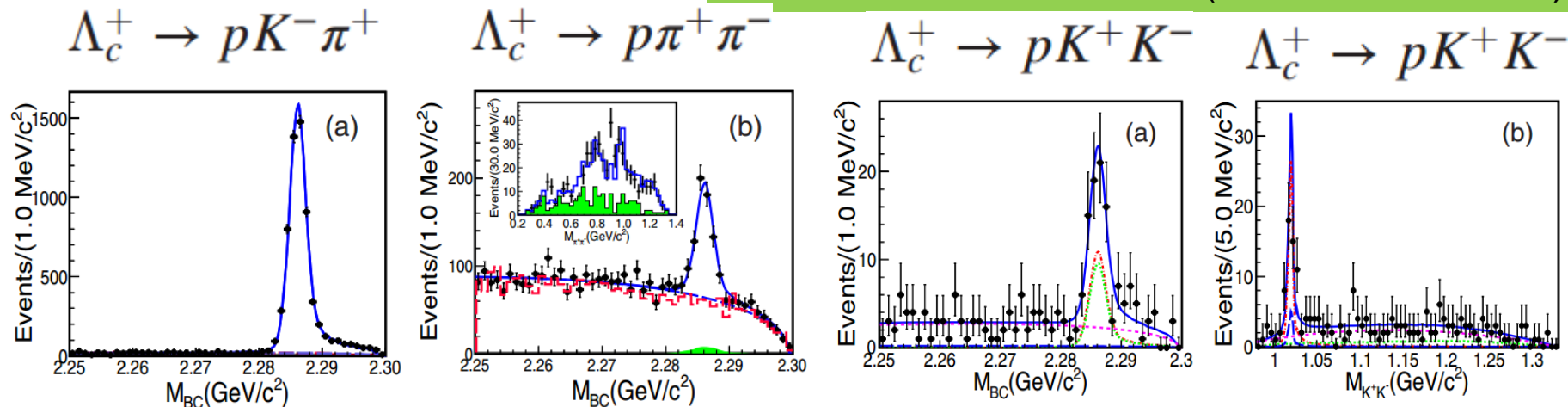
4.23 GeV
4.36 GeV
4.42 GeV

分析工作有**memo**，准备提交合作组评审

(2) Measurement of Singly Cabibbo Suppressed Decays $\Lambda_c^+ \to p\pi^+\pi^-$ and $\Lambda_c^+ \to pK^+K^-$

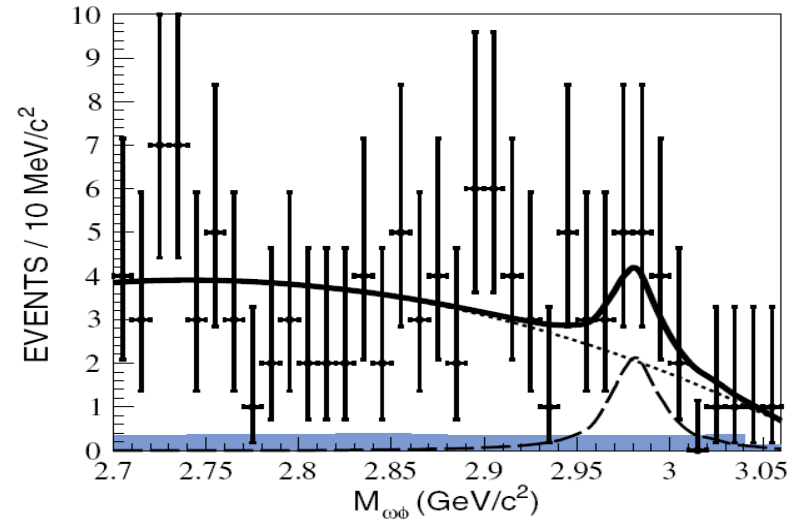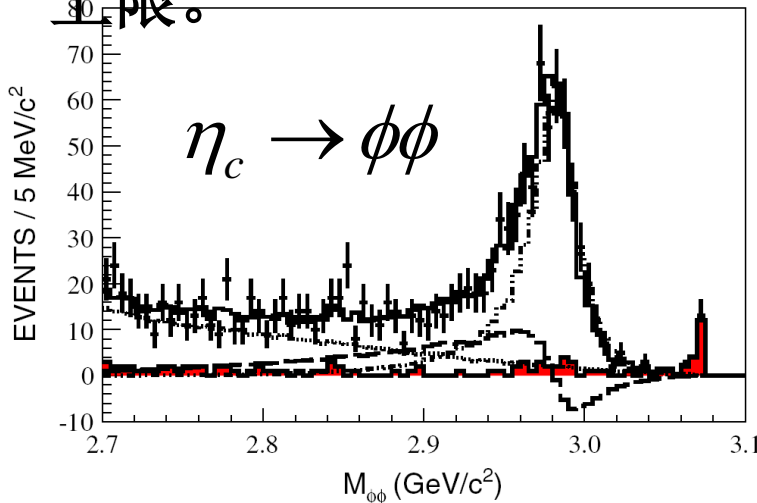| Decay modes	$\mathcal{B}_{mode}/\mathcal{B}_{ref}$ (This work)	$\mathcal{B}_{mode}/\mathcal{B}_{ref}$ (PDG average)
$\Lambda_c^+ \to p\pi^+\pi^-$	$(6.70 \pm 0.48 \pm 0.25) \times 10^{-2}$	$(6.9 \pm 3.6) \times 10^{-2}$
$\Lambda_c^+ \to p\phi$	$(1.81 \pm 0.33 \pm 0.13) \times 10^{-2}$	$(1.64 \pm 0.32) \times 10^{-2}$
$\Lambda_c^+ \to pK^+K^-$ (non-ϕ)	$(9.36 \pm 2.22 \pm 0.71) \times 10^{-3}$	$(7 \pm 2 \pm 2) \times 10^{-3}$
–	$\mathcal{B}_{mode}$ (This work)	$\mathcal{B}_{mode}$ (PDG average)
$\Lambda_c^+ \to p\pi^+\pi^-$	$(3.91 \pm 0.28 \pm 0.15 \pm 0.24) \times 10^{-3}$	$(3.5 \pm 2.0) \times 10^{-3}$
$\Lambda_c^+ \to p\phi$	$(1.06 \pm 0.19 \pm 0.08 \pm 0.06) \times 10^{-3}$	$(8.2 \pm 2.7) \times 10^{-4}$
$\Lambda_c^+ \to pK^+K^-$ (non-ϕ)	$(5.47 \pm 1.30 \pm 0.41 \pm 0.33) \times 10^{-4}$	$(3.5 \pm 1.7) \times 10^{-4}$

(3) $\eta_c \to \phi\phi, \omega\phi$ 分支比测量

- 研究 η_c 衰变中螺旋度守恒规则的规避机制, 寻找双-**OZI** 衰变 $\omega\phi$ 模式。

- 在 η_c 区域做振幅分析，得到了 $\eta_c \to \phi\phi$ 分支比, 并设置了 $\omega\phi$ 的上限。

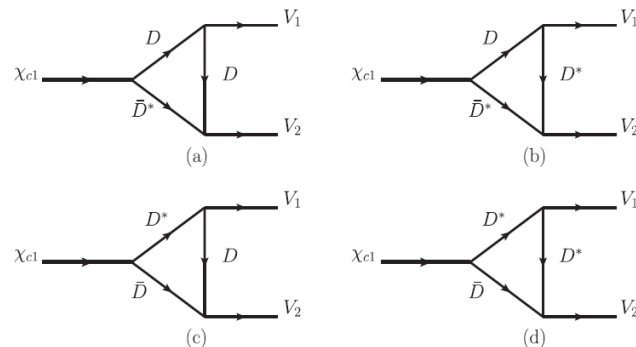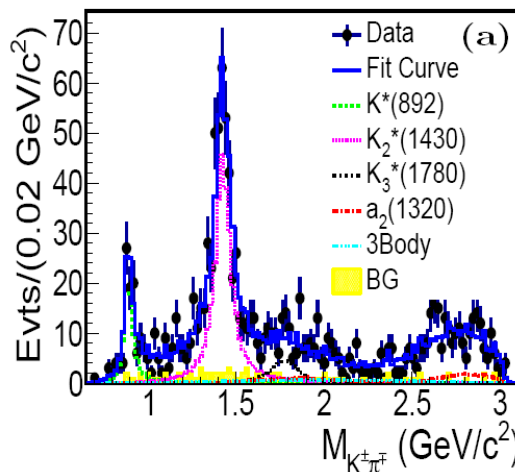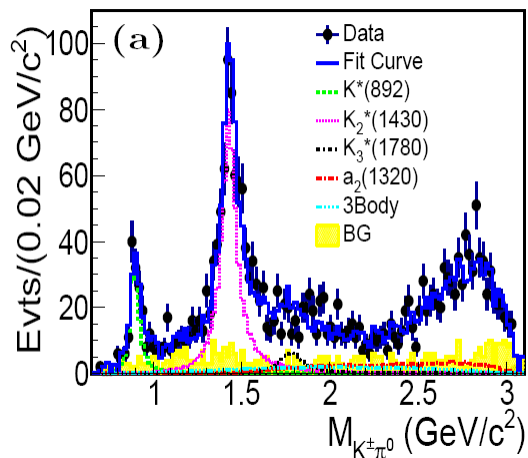| Experiment	Br$(J/\psi \to \gamma\eta_c)$ Br$(\eta_c \to \phi\phi)(\times 10^{-5})$	Br$(\eta_c \to \phi\phi)(\times 10^{-3})$
BESIII	$4.3 \pm 0.5^{+0.5}_{-1.2}$	$2.5 \pm 0.3^{+0.3}_{-0.7} \pm 0.6$
BESII [5]	3.3 ± 0.8	1.9 ± 0.6
DM2 [30]	3.9 ± 1.1	2.3 ± 0.8
Theoretical	Prediction	Br$(\eta_c \to \phi\phi)$ $(\times 10^{-3})$
	pQCD [10]	$(0.7–0.8)$
	$^3P_0$ quark model [13]	$(1.9–2.0)$
	Charm meson loop [14]	2.0

$$Br(\eta_c \to \omega\phi) < 2.5 \times 10^{-4}$$

at 90% confidence level

(4) Observation of the helicity-selection-rule suppressed decay of the χ_{c2} charmonium state

- 研究螺旋度守恒规则的规避机制: $\chi_{c2} \rightarrow$ **VP, TP**

- 检验非微扰**QCD**的长程效应

$$\chi_{c2} \rightarrow K^*(892)^{\pm} K^{\mp}$$

Br: $(1.5 \pm 0.1 \pm 0.2) \times 10^{-4}$

$$\chi_{c2} \rightarrow \rho(770)^{\pm} \pi^{\mp}$$

Br: (1.1×10^{-5})

Mode	$K^+K^-\pi^0$	$K_S K^{\pm}\pi^{\mp}$	Combined
$K^{*\pm}K^{\mp}$	$1.8 \pm 0.2 \pm 0.2$	$1.4 \pm 0.2 \pm 0.2$	$1.5 \pm 0.1 \pm 0.2$
$K^{*0}\overline{K}^0$	$-$	$1.3 \pm 0.2 \pm 0.2$	$-$
$K_2^{*\pm}K^{\mp}$	$18.2 \pm 0.8 \pm 1.6$	$13.6 \pm 0.8 \pm 1.4$	$15.5 \pm 0.6 \pm 1.2$
$K_2^{*0}\overline{K}^0$	$-$	$13.0 \pm 1.0 \pm 1.5$	$-$
$K_3^{*\pm}K^{\mp}$	$5.3 \pm 0.5 \pm 0.9$	$5.9 \pm 1.1 \pm 1.5$	$5.4 \pm 0.5 \pm 0.7$
$K_3^{*0}\overline{K}^0$	$-$	$5.9 \pm 1.6 \pm 1.5$	$-$
$a_2^0\pi^0$	$13.5 \pm 1.6 \pm 3.2$	$-$	$-$
$a_2^{\pm}\pi^{\mp}$	$-$	$18.4 \pm 3.3 \pm 5.5$	$-$

- **U-spin** 对称破缺效应

- 首次观测$\chi_{c2} \rightarrow K_2^* K$

(5) Precision measurement of the $e^+e^- \to \Lambda_c^+ \bar{\Lambda}_c^-$ cross section near threshold

$$\sigma_{B\bar{B}}(s) = \frac{4\pi\alpha^2 C\beta}{3s} |G_M(s)|^2 \left[1 + \frac{2m_B^2 c^4}{s} \left|\frac{G_E(s)}{G_M(s)}\right|^2\right].$$
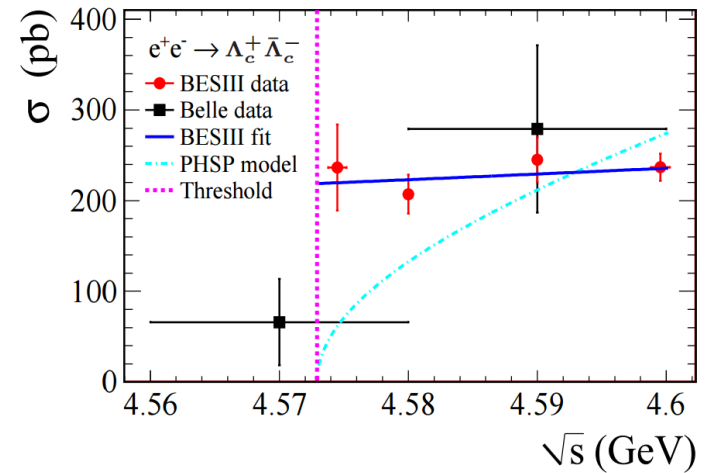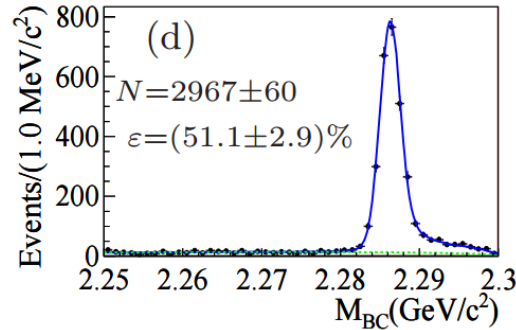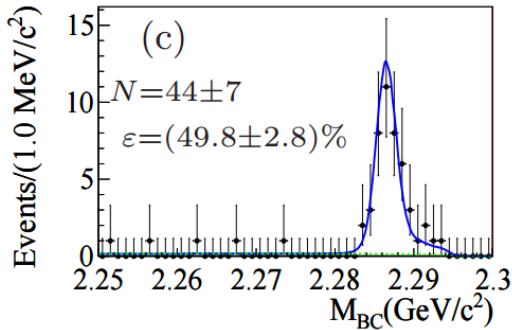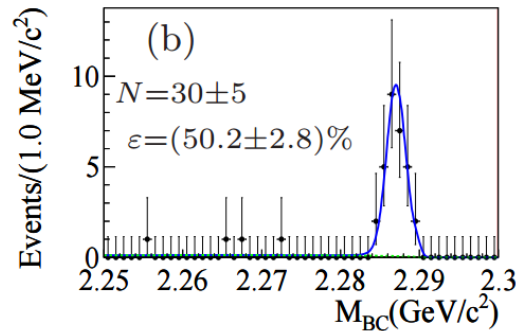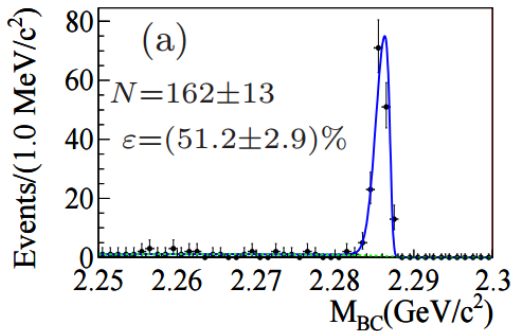
$\sqrt{s}$ (MeV)	α_{Λ_c}	$|G_E/G_M|$
4574.5	$-0.13 \pm 0.12 \pm 0.08$	$1.14 \pm 0.14 \pm 0.07$
4599.5	$-0.20 \pm 0.04 \pm 0.02$	$1.23 \pm 0.05 \pm 0.03$
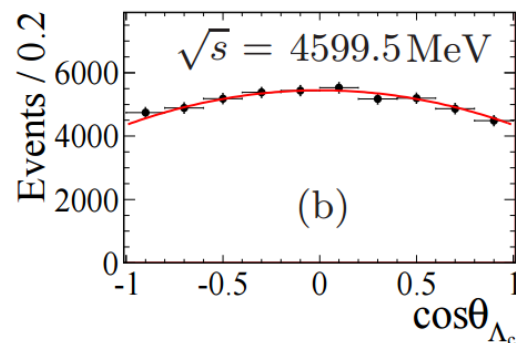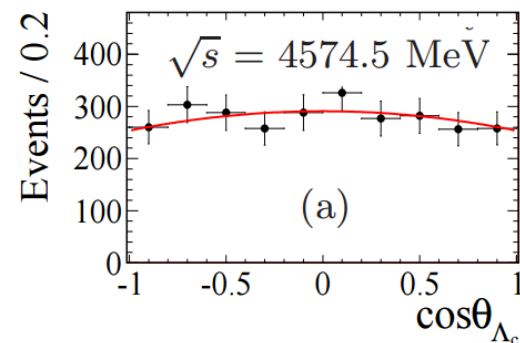
- 目前收到PRL的第一轮意见
- 阈附近截面的Sommerfeld效应
- 即使在阈附近，D-波也重要。

11

(6)Observation of the spin polarization of hyperons in the $J/\psi \to \Lambda\bar{\Lambda}$ decay

$$\mathcal{W}(\xi) = 1 + \alpha_\psi \cos^2\theta_\Lambda + \alpha_1\alpha_2 \left(\mathcal{T}_1(\xi) + \sqrt{1 - \alpha_\psi{}^2} \cos(\Delta\Phi)\mathcal{T}_2(\xi) + \alpha_\psi\mathcal{T}_6(\xi) \right)$$

$$+ \sqrt{1 - \alpha_\psi{}^2} \sin(\Delta\Phi)\sin\theta_\Lambda \cos\theta_\Lambda \left(\alpha_1 \sin\theta_1 \sin\phi_1 + \alpha_2 \sin\theta_2 \sin\phi_2\right),$$

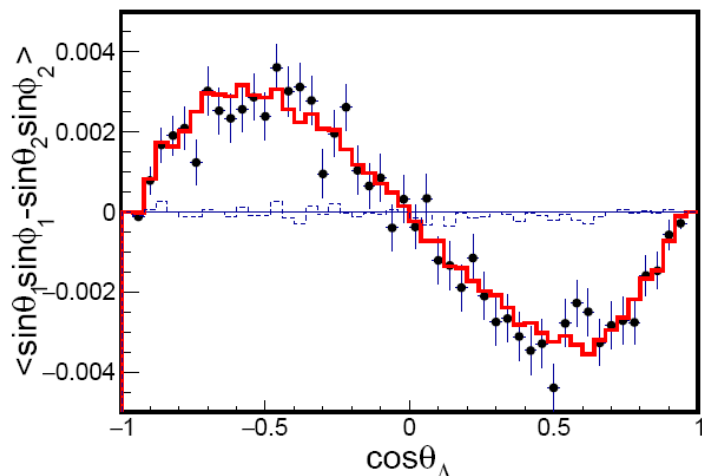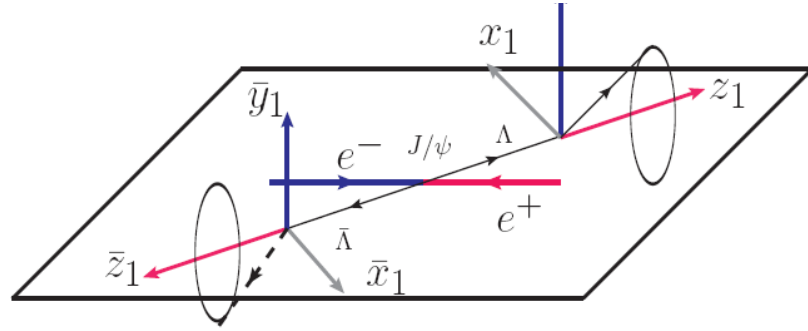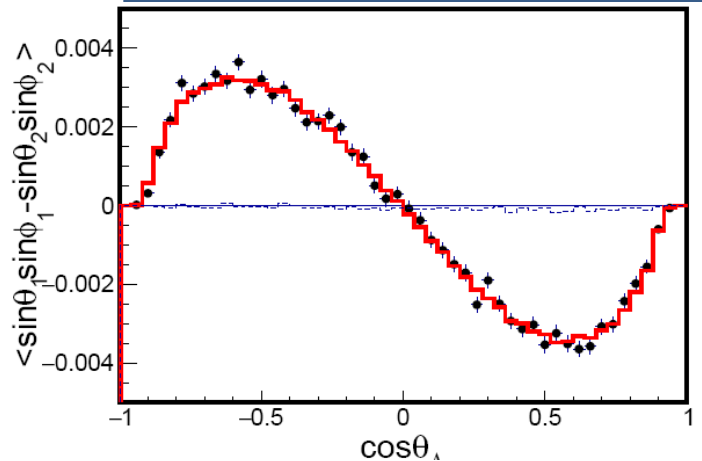| Parameters	This measurement	Previous
α_-	$0.750 \pm 0.009 \pm 0.004$	0.642 ± 0.013 [2]
α_+	$-0.758 \pm 0.010 \pm 0.007$	-0.71 ± 0.08 [2]
$\bar{\alpha}_0$	$-0.692 \pm 0.016 \pm 0.006$	$\alpha_0 : 0.65 \pm 0.04$ [2]
A_{CP}	$-0.006 \pm 0.012 \pm 0.007$	0.006 ± 0.021 [2]
$\bar{\alpha}_0/\alpha_+$	$0.913 \pm 0.028 \pm 0.012$	$\alpha_0/\alpha_- : 1.01 \pm 0.07$

- 首次在非激化束流实验中观测到超子的横向激化效应。
- 这种效应为**BES**研究**CP**破环，Λ_c的非对称参数提供了新的实验方案。

其他在合作组内评审的分析工作

1. **BAM-00142, Measurement of cross section for eta phi production above 4.0GeV**

2. **BAM-00200, Determination of Λ_c^+ spin**

3. **BAM-00251, Measurement of the Lambda_c weak decay asymmetry**

4. **BAM-00269, Measurement of e+e- $\rightarrow$ $\phi\eta$ cross sections**

5. **BAM-00309, Analysis of the semileptonic decay $D^0 \rightarrow \underline{K}^0 \pi^- e^+ \nu_e$**

6. **BAM-00311, Measurement of $\chi_{cJ} \rightarrow \phi\phi$ decays**

国际会议邀请报告：

1. PhiPsi2017, June 26-30, Mainz. , Event generators for Multi Hadronic Production in e⁺e⁻ collisions
2. QWG2017, Peking University, Beijing, 6-10, 2017, News on **Zc states**

2. 软件,服务工作

作为BESIII事例产生子召集人，负责组织BESIII事例产生子软件的移植/软件的设计和版本升级维护。目前，这些产生子在BES物理实验中的亮度测量，物理分析中得到了广泛的使用，基本满足了BES物理分析的要求。

➢ 事例产生子代码的升级和维护：
  BesEvtGen-00-02-57, Babayaga-00-00-26, KKMC-00-00-45 …

➢ 为XYZ新粒子课题组的研究提供新的产生子模型(ConExc)，包含了100个左右的衰变道，已经用于4GeV以上的能量点MC事例产生。

➢ R-值测量单举产生子参数的优化
  发展了一套新的方案，同时拟合数据的多个分布优化产生子参数的方法，克服了手动调节的很多弊端。这些优化的参数已经在R-值测量中应用.

➢ BESIII 谱仪运行负责人。

➢ BESIII分析评审5篇

-- 发表文章

1. BESIII Collaboration, Determination of the Spin and Parity of the Zc(3900), Phys. Rev. Lett. 119, 072001 (2017).
2. BESIII Collaboration, Measurement of Singly Cabibbo Suppressed Decays $\Lambda_c^+ \to p\pi^+\pi^-$ and $\Lambda_c^+ \to pK^+K^-$, Phys. Rev. Lett. 117, 232002 (2016)
3. BESIII Collaboration, Improved measurements of branching fractions for $\eta_c \to \phi\phi, \omega\phi$, Phys. Rev., D95, 092004 (2017).

4. BESIII Collaboration, Observation of the helicity-selection-rule suppressed decay of the χ_{c2} charmonium state, accepted by Phys.Rev. D in press

5. BESIII Collaboration, Precision measurement of the e+e-→ $\Lambda_c^+ \underline{\Lambda}_c^-$ cross section near threshold, arXiv: 1710.00150, submitted to PRL.

6. Hong chen and **Ping RongGang**, Coherent helicity amplitude for sequential decays, Phys. Rev. D95, 076010 (2017)

7. **Dan Wang, Ronggang Ping, et.al,** Charmed baryon decay asymmetry in e+e- annihilation, Chin. Phys. C41,023106 (2017)

3. 承担的基金项目和研究生培养

➢主持面上基金项目

《 eta_c 矢量介子衰变和Lambda-bar 衰变参数的实验研究》

执行期间： **2014年1月-2017年12月 ,批准号：11375205**

➢参加：

1.重点项目,主持人：苑长征《粲偶素与类粲偶素的实验研究》：

2014年-2017年

2.地区科学基金（与广西师大合作申请）

执行期间： **2016年1月-2019年12月**

➢ 指导两3名研究生

总结

- 发表**6篇(PRL:2, PRD:3, CPC:1)**文章,并提交 **PRL1**篇

- **6**项物理分析的**memo**在合作组内评审

- 承担产生子软件的维护和升级，优化产生子参数

- 主持**1**项科学基金面上项目，合作申请到**2**项基金项目

谢谢！