# 2023-2024 年度考核

答 辩 人:平荣刚

内容:

一、岗位职责

二、本年度工作情况

三、存在问题

四、下年度工作计划

# 一、岗位职责

- **BESIII数据物理分析工作**
- **BOSS事例产生子软件的维护和升级**

# 二、本年度工作情况

## 1. 研究任务完成情况

### ➢ BESIII事例产生子的软件工作

KKMC, BesEvtGen, Babayaga等10多个BESIII事例产生子软件的BOSS71x升级维护

I. **KKMC+BesEvtGen:** 解决了**gcc49**升级后**LundCharm**模型不工作的问题
II. **BesEvtGen:** 维护多道初态辐射产生子的截面数据
III. 升级**BabayagaNLO:** 解决了它在$\psi(2S), J/\psi$ 点参数事例太慢的问题
IV. 在邮件、**qq**群、微信群提供**BES**合作组成员对产生子使用的帮助

## ➢ 产生子研究工作对BESIII的文章的直接贡献

**Event generators at BESIII** #1

Rong-Gang Ping (Beijing, Inst. High Energy Phys.) (2008)

Published in: *Chin.Phys.C* 32 (2008) 599

新增99引用

DOI cite claim reference search 527 citations

**An exclusive event generator for $e^+e^-$ scan experiments** #1

Rong-Gang Ping (Beijing, Inst. High Energy Phys.) (Sep 16, 2013)

Published in: *Chin.Phys.C* 38 (2014) 083001 • e-Print: 1309.3932 [hep-ph]

新增17引用

pdf DOI cite claim reference search 107 citations

**Tuning and Validation of the Lundcharm Model with $J/\psi$ Decays** #1

Rui-Ling Yang (SWU, Chongqing), Rong-Gang Ping (Beijing, Inst. High Energy Phys.), Hong Chen (SWU, Chongqing) (2014)

Published in: *Chin.Phys.Lett.* 31 (2014) 061301

新增66引用

DOI cite claim reference search 262 citations

# ➢ BEPCII束流的横向极化测量

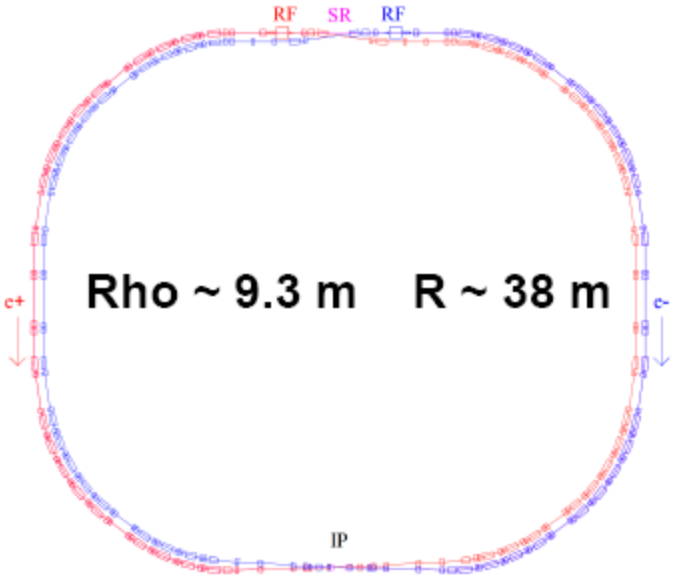
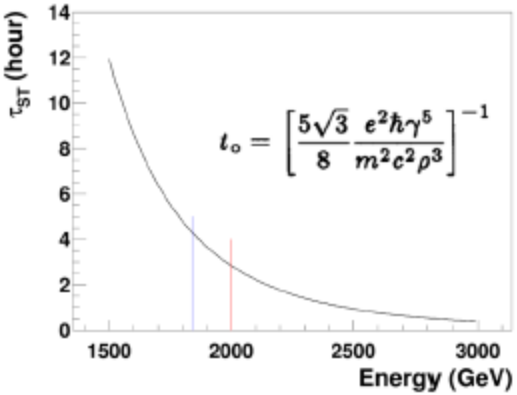
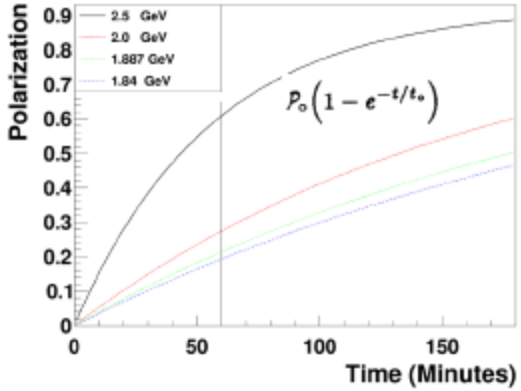
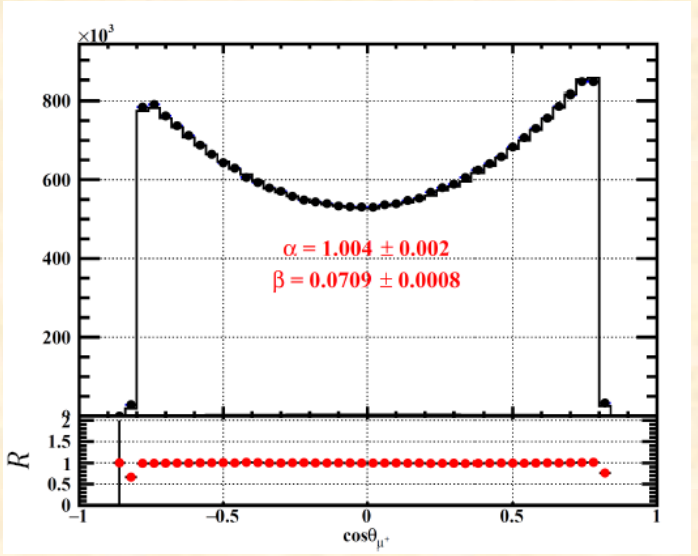
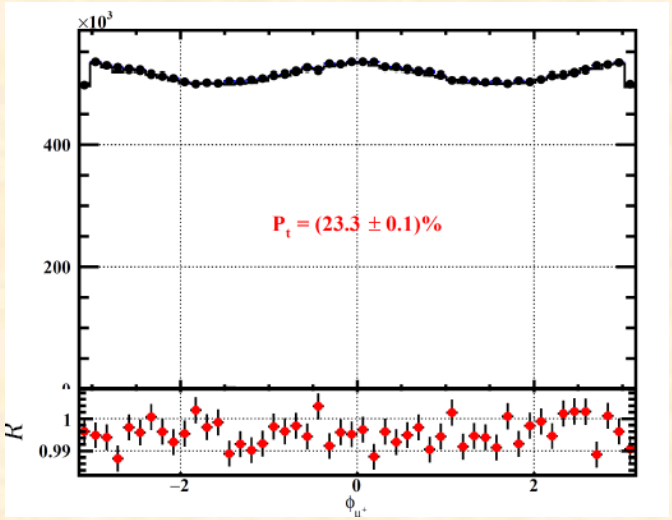



Figure 1: The BEPCII Complexity




J.S. Luo, **Beam polarization measurement of $e^+e^- \to \mu^+\mu^-$ at $\sqrt{s} = 3.686$** GeV, BEIII workshop at Shengyang,

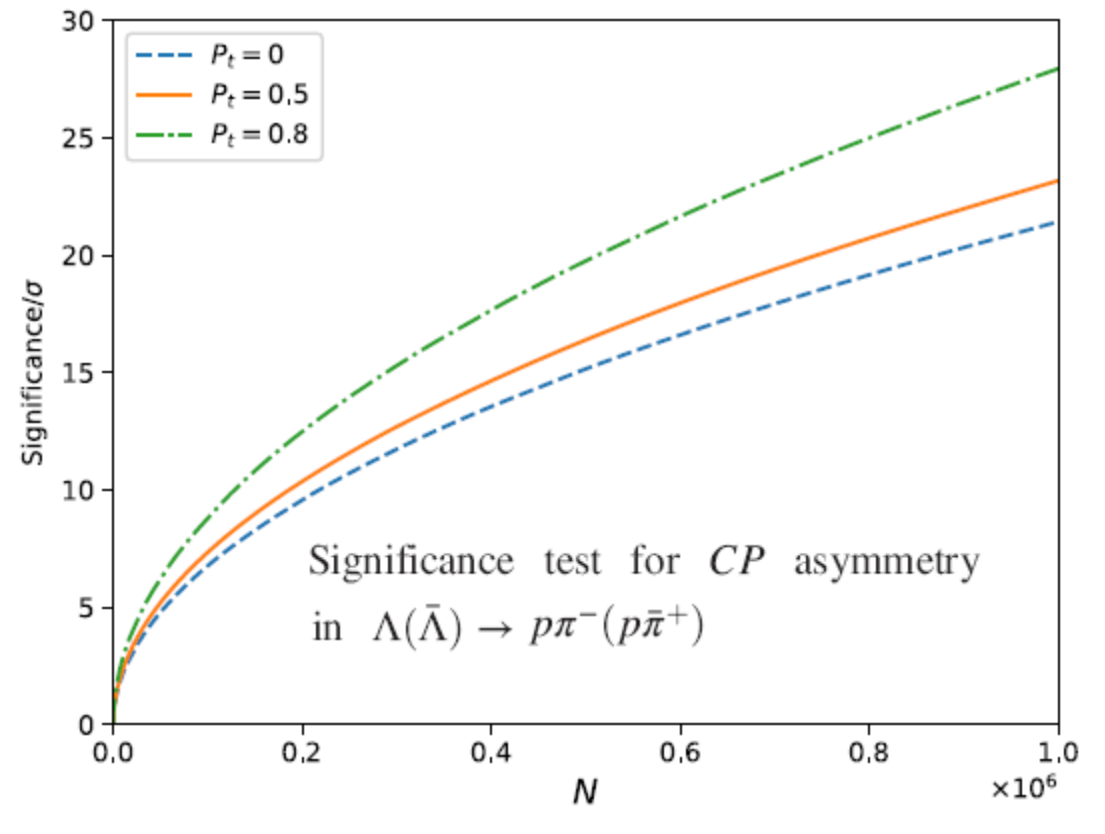
# ➢ BEPCII束流的横向极化的应用

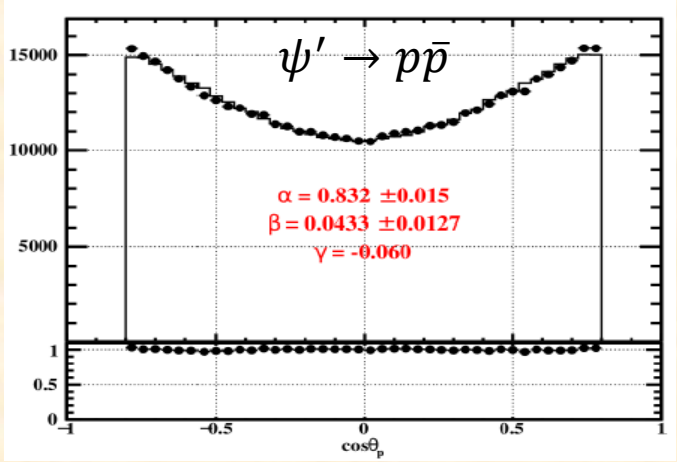
PHYSICAL REVIEW D **110,** 014035 (2024)

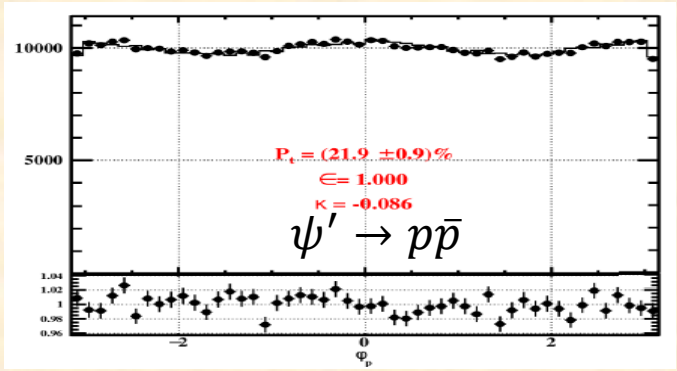
**Production and decay of hyperons in a transversely polarized electron-positron collider**

Xu Cao,[1,2,3,*] Yu-Tie Liang,[1,2,†] and Rong-Gang Ping[4,2,‡]

Zhi Gao, **Improved measurement of $\psi' \to p\bar{p}$**, talk at BESIII workshop, September 24th, 2024

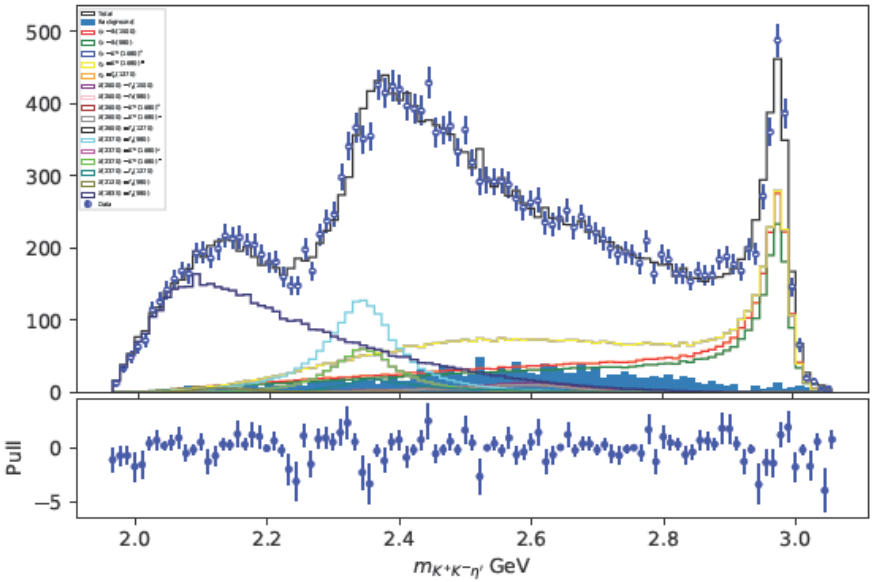


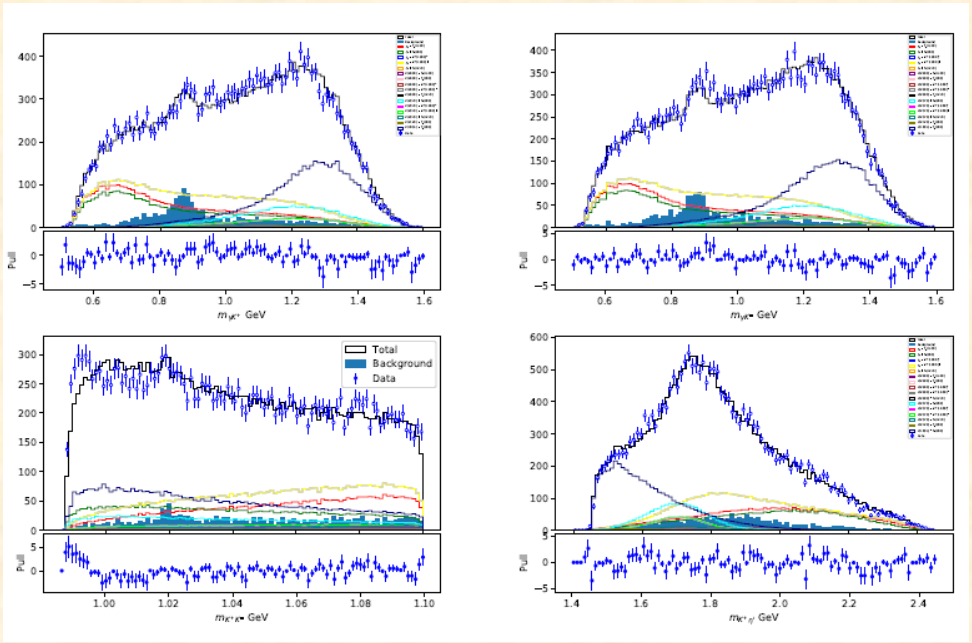



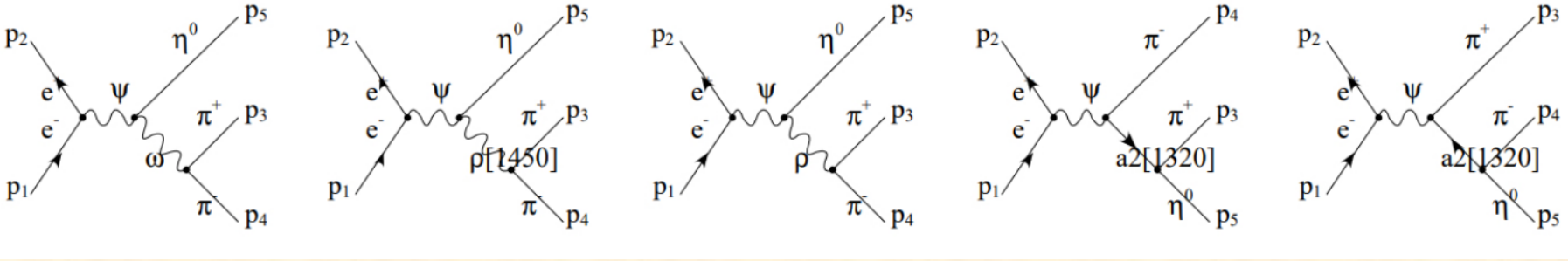
# ➢ $X(2370)$: $J/\psi \to \gamma K^+K^-\eta$

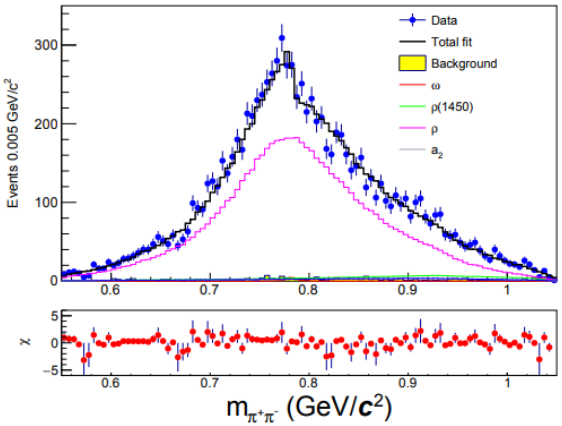
- Lattice QCD predicts the existence of a pseudoscalar glueball in mass range $2.3 - 2.6\ GeV/c^2$, and the **X(2370)** is a potential candidate.
- The **X(2370)** is observed in $J/\psi \to \gamma\pi^+\pi^-\eta'$ (2009 $J/\psi$ data) and confirmed in $J/\psi \to \gamma K\bar{K}\eta'$ (2009, 2012 $J/\psi$ data) with $8.3\sigma$.
- After performing PWA analysis on $J/\psi$ data collected in 2009, 2012, 2018 and 2019, the quantum number and mass-width of X(2370) can be determined in a higher significance.

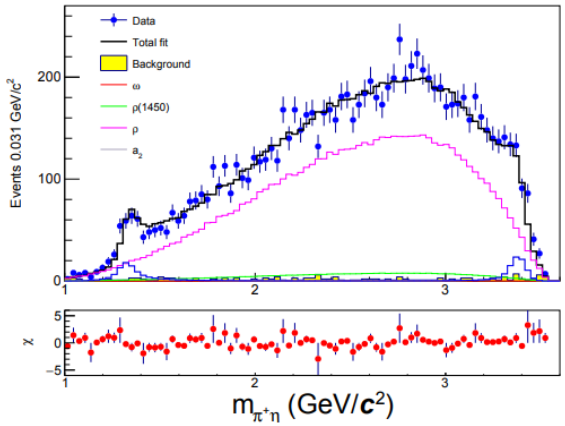


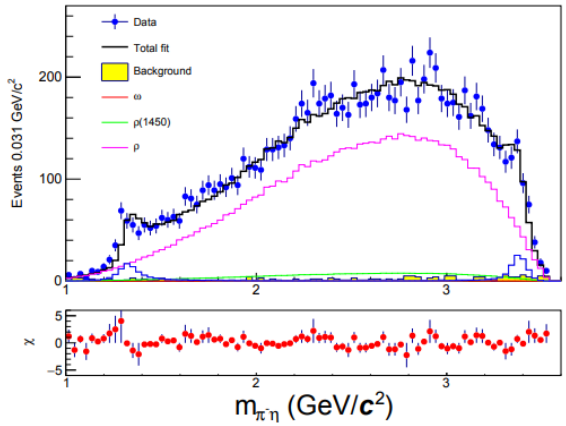



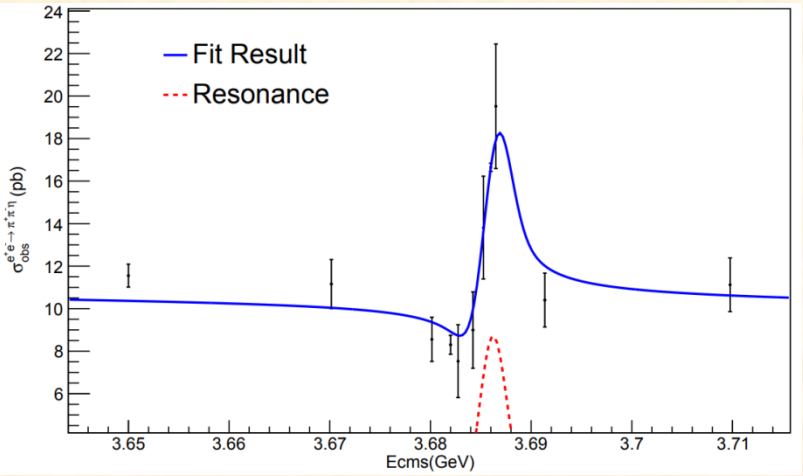
# ➢ BAM-00889: PWA for $\psi(2S) \to \pi^+\pi^-\eta$



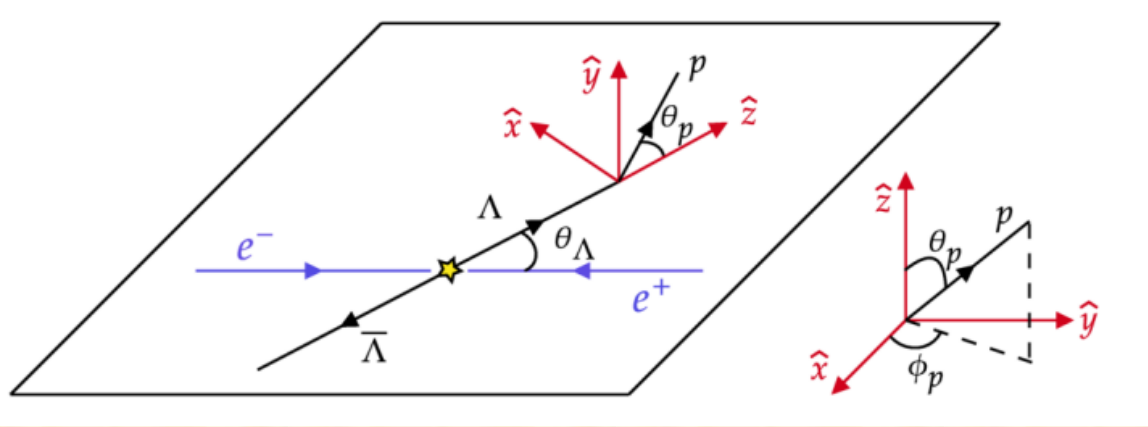

$$\mathcal{B}_{\psi(2S)\to\rho\eta} = (1.032 \pm 0.077_{(stat)} \pm 0.038_{(syst)}) \times 10^{-5}.$$

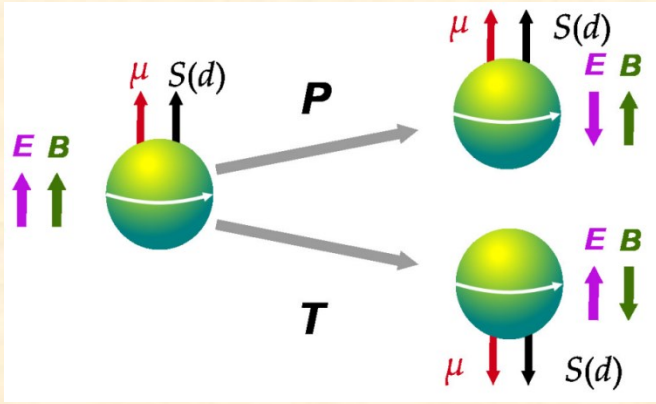
$$\mathcal{B}_{\psi(2S)\to a_2^{\pm}\pi^{\mp}} = (2.670 \pm 0.416_{(stat)} \pm 0.243_{(syst)}) \times 10^{-5}$$

$$\mathcal{B}_{\psi(2S)\to\omega\eta} = (1.182 \pm 0.473_{(stat)} \pm 0.103_{(syst)}) \times 10^{-7}$$

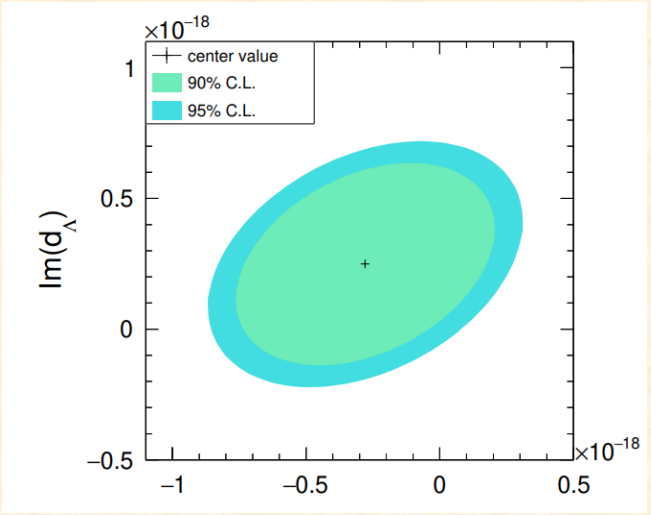
# ➢ 寻找CP破环源：Λ的电偶极矩

BAM-00779: Search for Lambda electric dipole moment in J/psi decay



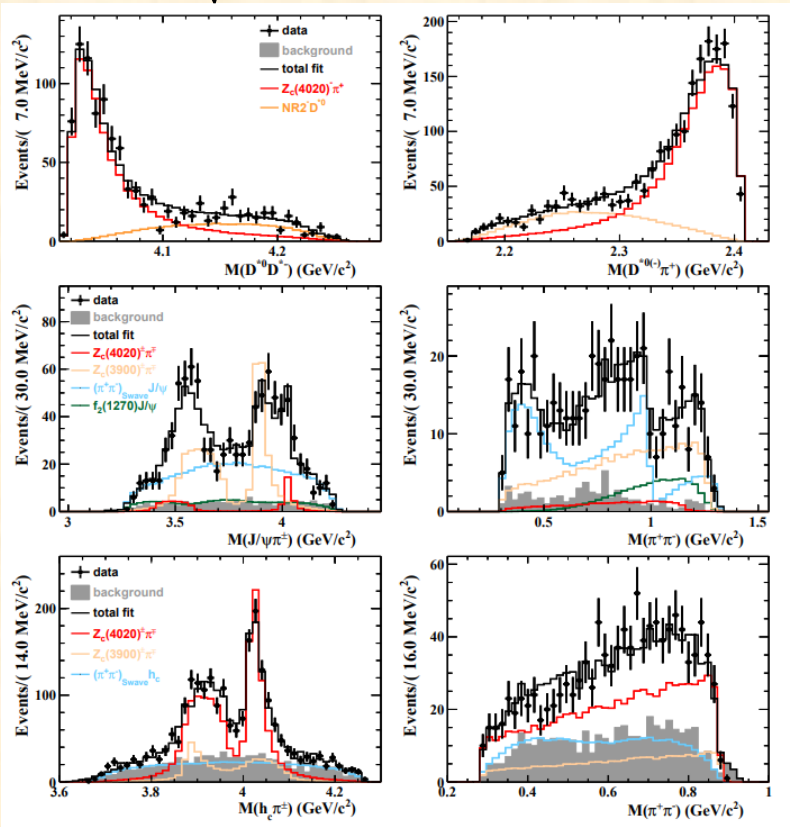

| Paras | Published results | Our fit |
|---|---|---|
| $\alpha_\Lambda$ | $(7.519 \pm 0.036 \pm 0.024) \times 10^{-1}$ [41] | $(7.524 \pm 0.036 \pm 0.008) \times 10^{-1}$ |
| $\alpha_{\bar{\Lambda}}$ | $(-7.559 \pm 0.036 \pm 0.030) \times 10^{-1}$ [41] | $(-7.571 \pm 0.036 \pm 0.008) \times 10^{-1}$ |
| $Re(G_2)$ | - | $(9.71 \pm 0.06 \pm 0.24) \times 10^{-4}$ |
| $Im(G_2)$ | - | $(9.14 \pm 0.04 \pm 0.23) \times 10^{-4}$ |
| $P_L$ | - | $(-1.8 \pm 1.2 \pm 0.8) \times 10^{-3}$ |
| $Re(F_A)$ | - | $(-2.4 \pm 1.6 \pm 3.1) \times 10^{-6}$ |
| $Im(F_A)$ | - | $(-7.9 \pm 3.7 \pm 2.5) \times 10^{-6}$ |
| $Re(H_T)$ | - | $(-1.4 \pm 1.4 \pm 0.2) \times 10^{-6}$ |
| $Im(H_T)$ | - | $(1.3 \pm 1.2 \pm 0.4) \times 10^{-6}$ |
| $\alpha_{J/\psi}$ | $(4.748 \pm 0.022 \pm 0.031) \times 10^{-1}$ [41] | $(4.748 \pm 0.022 \pm 0.017) \times 10^{-1}$ |
| $\Delta\phi$ | $(7.521 \pm 0.042 \pm 0.066) \times 10^{-1}$ [41] | $(7.552 \pm 0.042 \pm 0.013) \times 10^{-1}$ |
| $A_{CP}$ | $(-2.5 \pm 4.6 \pm 1.2) \times 10^{-3}$ [41] | $(-3.1 \pm 4.6 \pm 1.1) \times 10^{-3}$ |
| $sin^2\theta_W$ | - | $(-1.5 \pm 1.2 \pm 2.6) \times 10^{-1}$ |
| $Re(d_\Lambda)$ | $d_\Lambda < 1.5 \times 10^{-16} e$ cm [30] | $(-3.1 \pm 3.2 \pm 0.5) \times 10^{-19}$ |
| $Im(d_\Lambda)$ | | $(2.9 \pm 2.6 \pm 0.6) \times 10^{-19}$ |



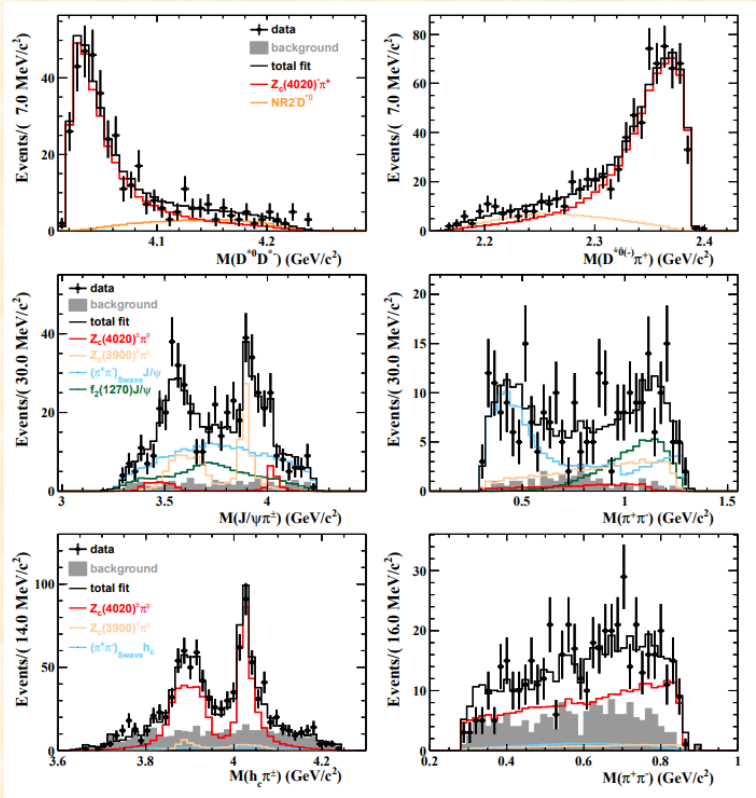
# $Z_c(4420)$ 自旋量子数的测量

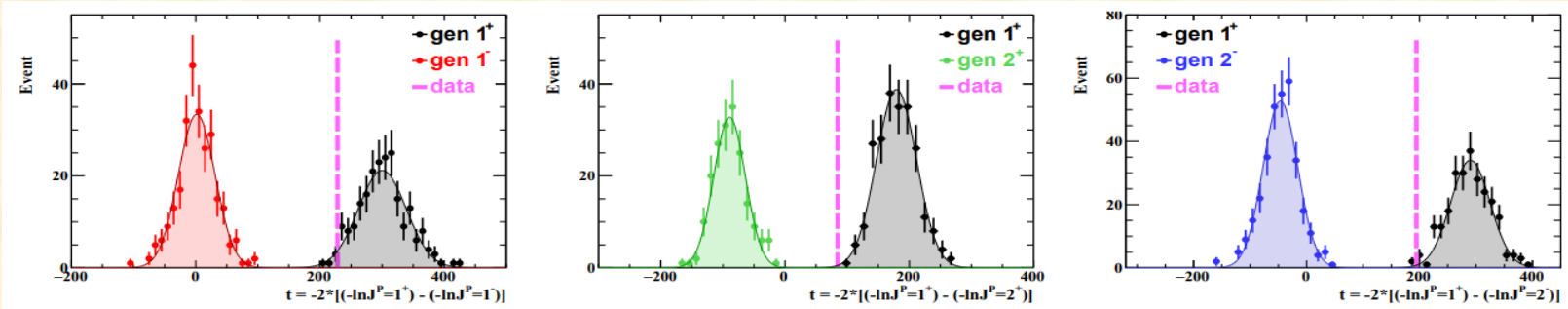
BAM-00752: Coupled channel analysis of Zc(4020/4025)+

$\sqrt{s}$ =4.416 GeV



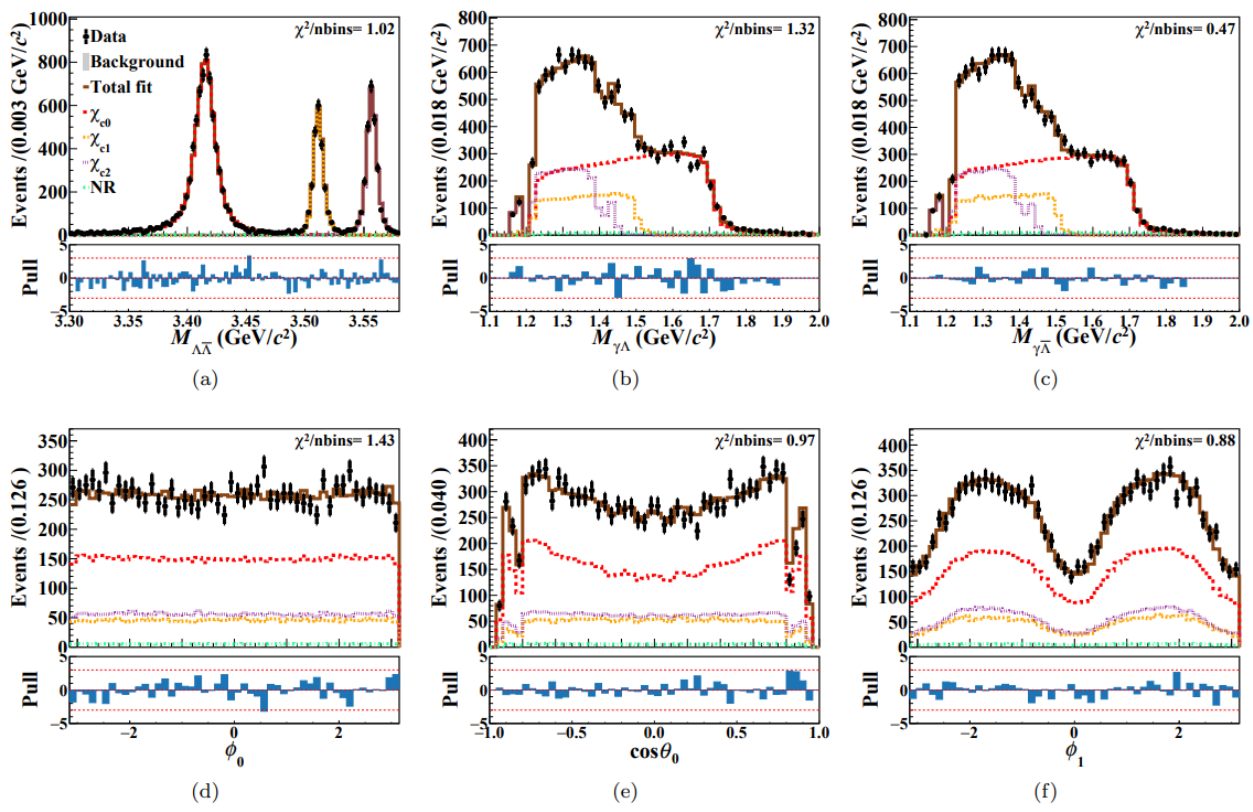

$\sqrt{s}$ =4.395 GeV



# $\chi_{cJ} \to \Lambda\bar{\Lambda}$衰变的螺旋度振幅分析

BAM-00825: Study of $\chi_{cJ} \to \Lambda\bar{\Lambda}$

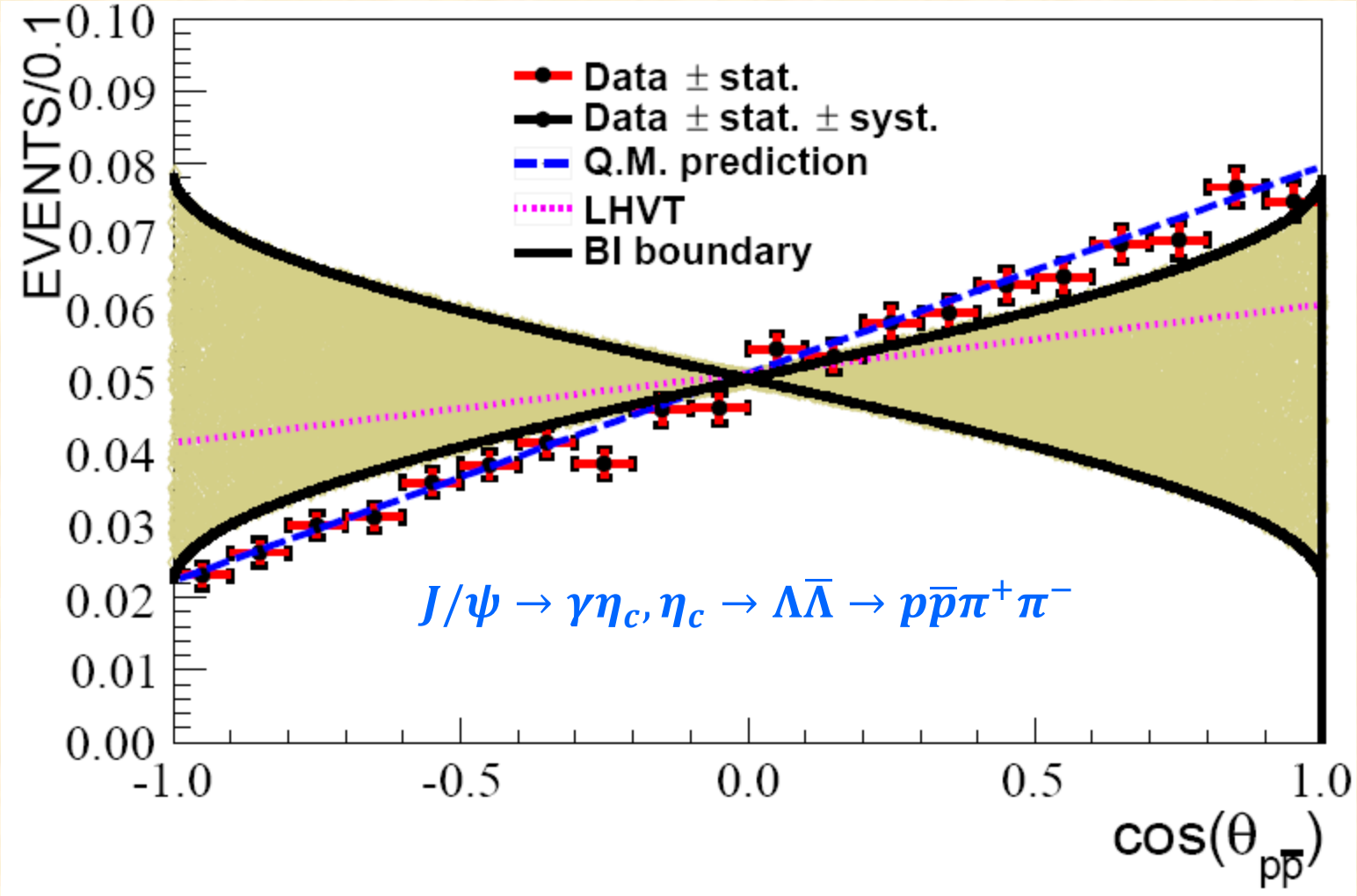



| Branching fraction | This work ($\times 10^{-4}$) | PDG ($\times 10^{-4}$) |
|---|---|---|
| $\mathcal{B}(\chi_{c0} \to \Lambda\bar{\Lambda})$ | $3.953 \pm 0.050 \pm 0.121$ | $3.59 \pm 0.15$ |
| $\mathcal{B}(\chi_{c1} \to \Lambda\bar{\Lambda})$ | $1.295 \pm 0.029 \pm 0.042$ | $1.27 \pm 0.08$ |
| $\mathcal{B}(\chi_{c2} \to \Lambda\bar{\Lambda})$ | $1.844 \pm 0.038 \pm 0.052$ | $1.83 \pm 0.16$ |

# ➢ 超子极化

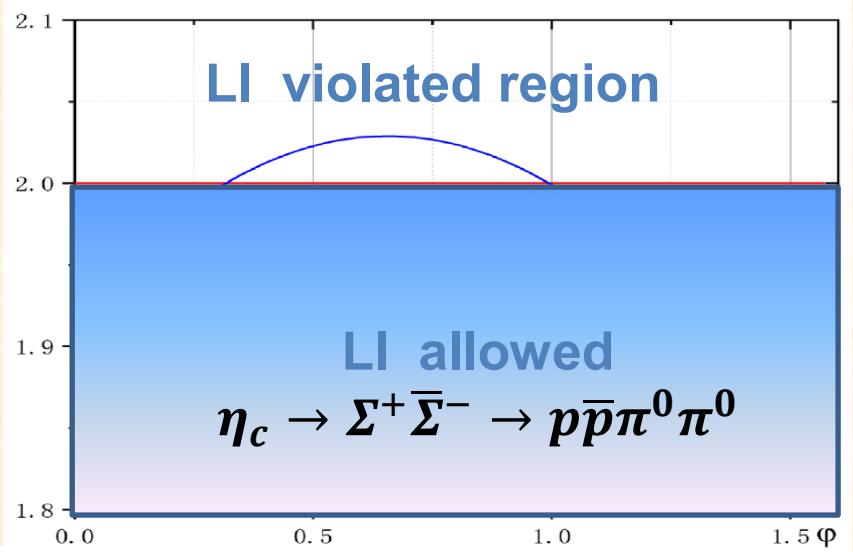
## ◘ 局域隐变量理论的检验(EPR佯谬检验)

BAM-00505: submitted to Nature Communications



# ➢ 超子极化

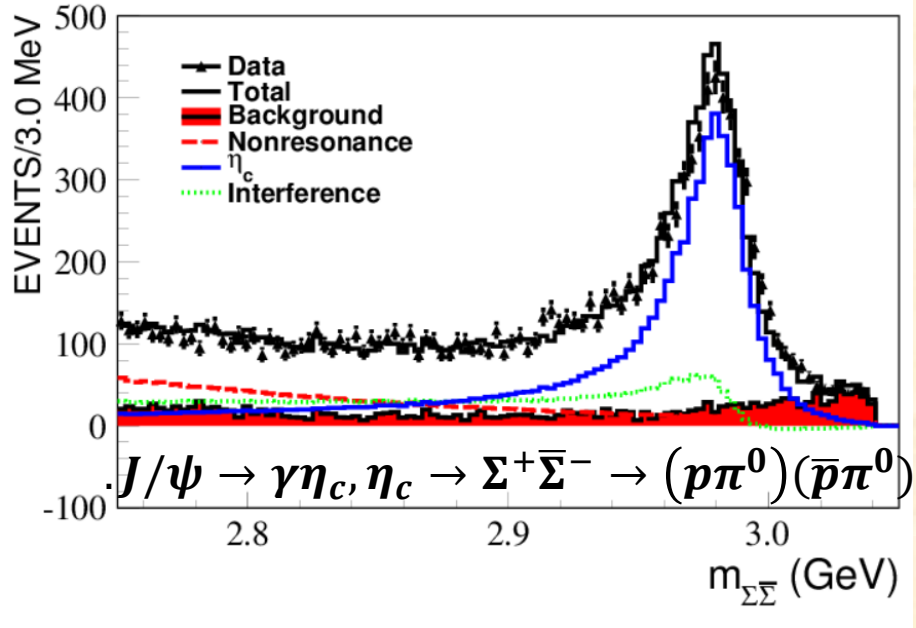
## ◘ 非局域隐变量理论的检验(Leggett不等式的检验)

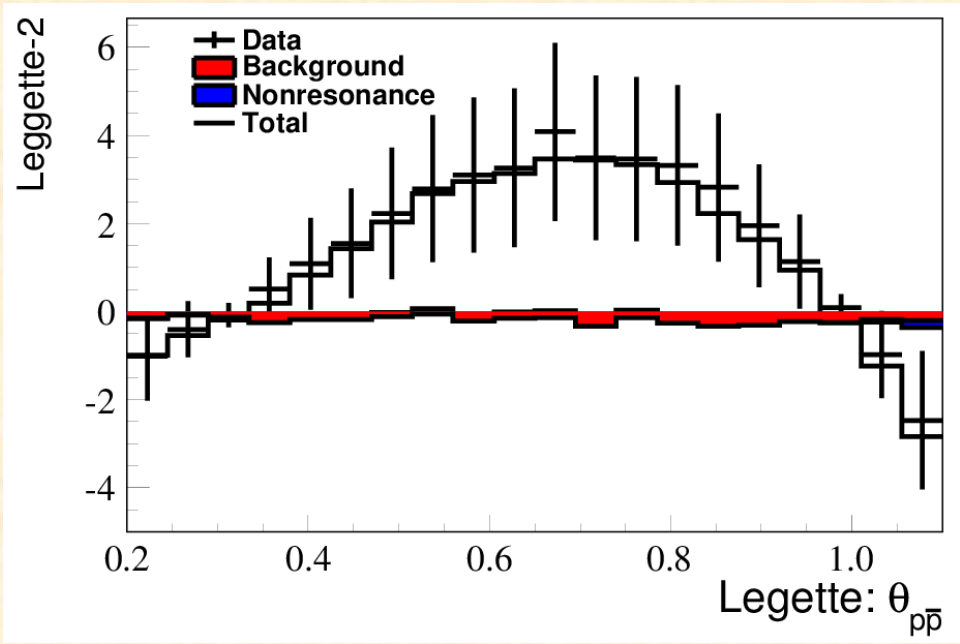



**Leggett 不等式：** Phys. Rev. D 101, 096016 (2020)

$$|\alpha_a\alpha_b||\vec{a}_i\cdot\vec{b}_i+\vec{a}_i\cdot\vec{b}'_i|+\frac{2|\alpha_b|}{3}\left|\sin\frac{\varphi}{2}\right|\le 2.$$

Report to Collaboration Meeting:



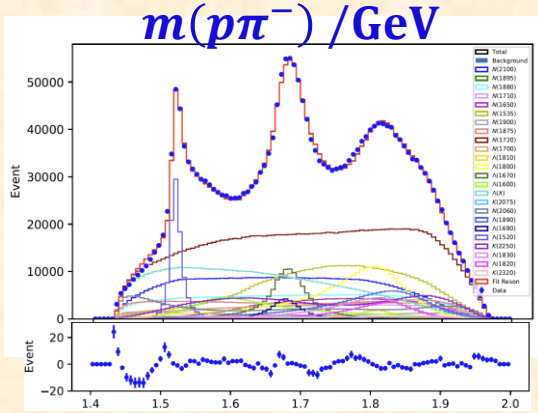
## GPU 设备上的分波分析软件开发

- ✓ 费曼图自动计算(FDC)系统的GPU实现：FDC + Tensorflow
- ✓ FDC-TF 的物理分析
  1. PWA $J/\psi \to \pi^+\pi^-\Sigma^+\bar{\Sigma}^-$
  2. PWA $J/\psi \to p\bar{p}K^+K^-$
  3. PWA $J/\psi \to \phi\eta\eta$
  4. PWA $J/\psi \to \phi\eta\eta'$
  5. PWA $\psi' \to \pi^0\Sigma^+\bar{\Sigma}^-$

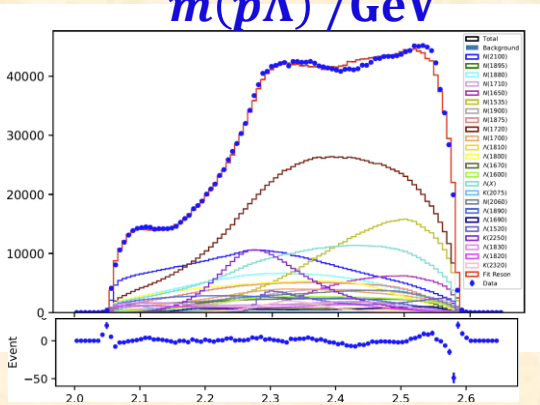
  ……
- ✓ FDC版本升级和两大功能扩展
  1. 超子的弱衰变
  2. 辐射衰变
- ✓ pyFDC组会：每周一晚

# $N^*$重子谱

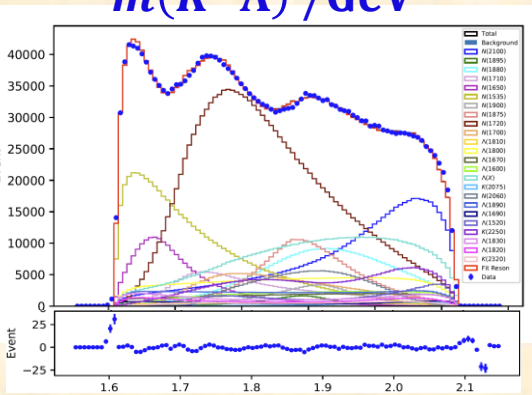
- $N(1535), N(1650)$ in $J/\psi \to pK^-\bar{\Lambda} + c.c.$ From Zhang Qiuyan




$\chi^2$/ndf=1.655




$\chi^2$/ndf=1.949




$\chi^2$/ndf=1.786


**10 billion $J/\psi$:**

**data events: 2,537,989**

**MC events: 10 million**

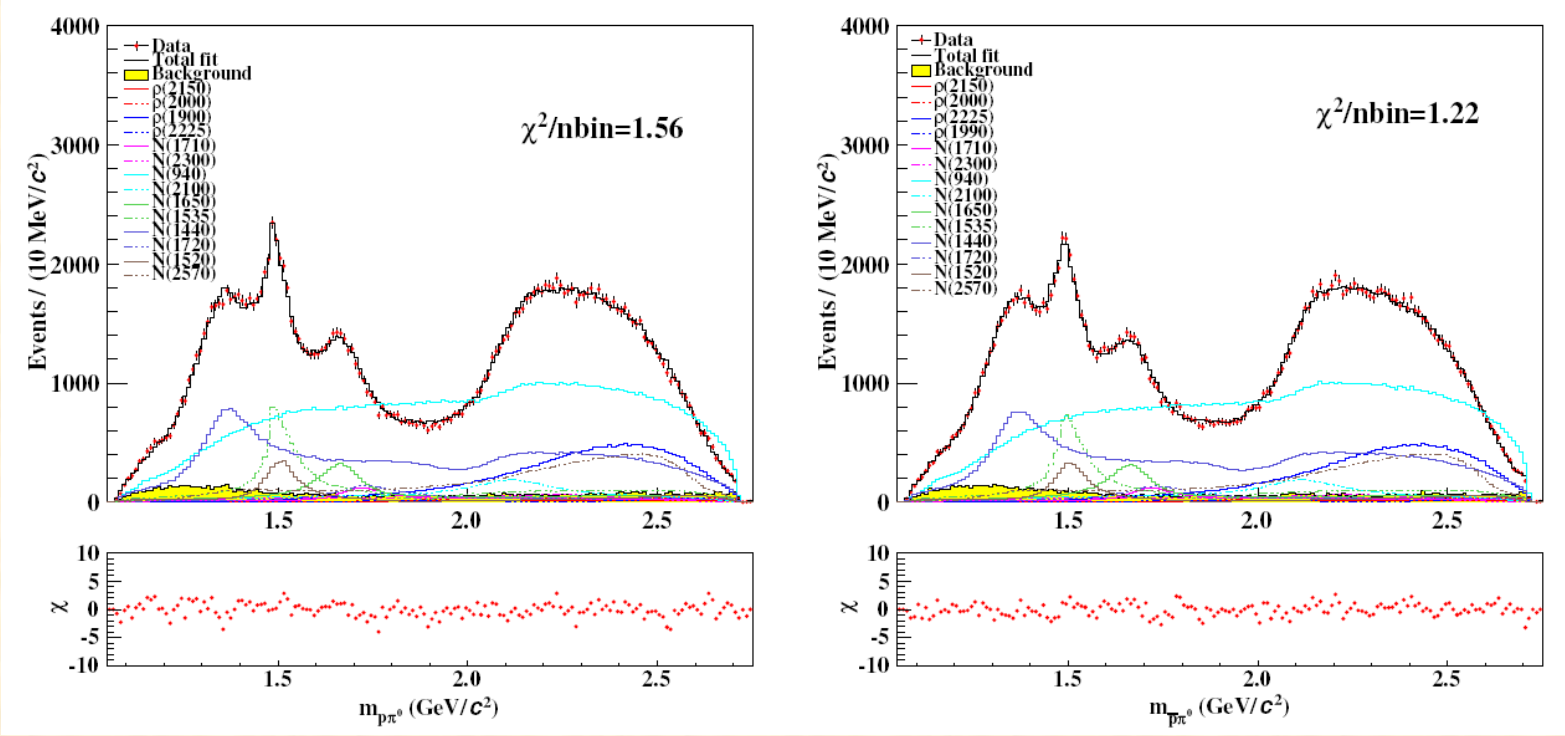
| Decay mode | ratio | $\mathcal{B}_i(\times 10^{-5})$ |
|---|---|---|
| $J/\psi \to N(1535)\bar{N} + c.c.$ | $0.2198 \pm 0.0088$ | $25.3869 \pm 1.0164$ |
| $J/\psi \to N(1650)\bar{N} + c.c.$ | $0.0835 \pm 0.0038$ | $9.6443 \pm 0.4389$ |
| $J/\psi \to K(2075)K^- + c.c.$ | $0.0077 \pm 0.0004$ | $0.8894 \pm 0.0462$ |

**可以确定$N(1535)$与$N(1650)$在$[70, {}^2 8]$，$[70, {}^4 8]$组态中的混合**

# $N^*$重子谱

- $N(1535) \to N\eta$ , exotic branching fraction

**BAMBAM-00616: 2.7 billion $\psi'$, $\psi' \to p\bar{p}\pi^0$**




**$N^*$ running width:**

$$\Gamma(\sqrt{s}) = \Gamma_0 \times \sum_i r_i \times \left(\frac{\rho_i(\sqrt{s})}{\rho_i(m_0)}\right),$$

**Br: $J/\psi \to N^*(1535)\bar{p} + cc. \to p\bar{p}\pi^0$**

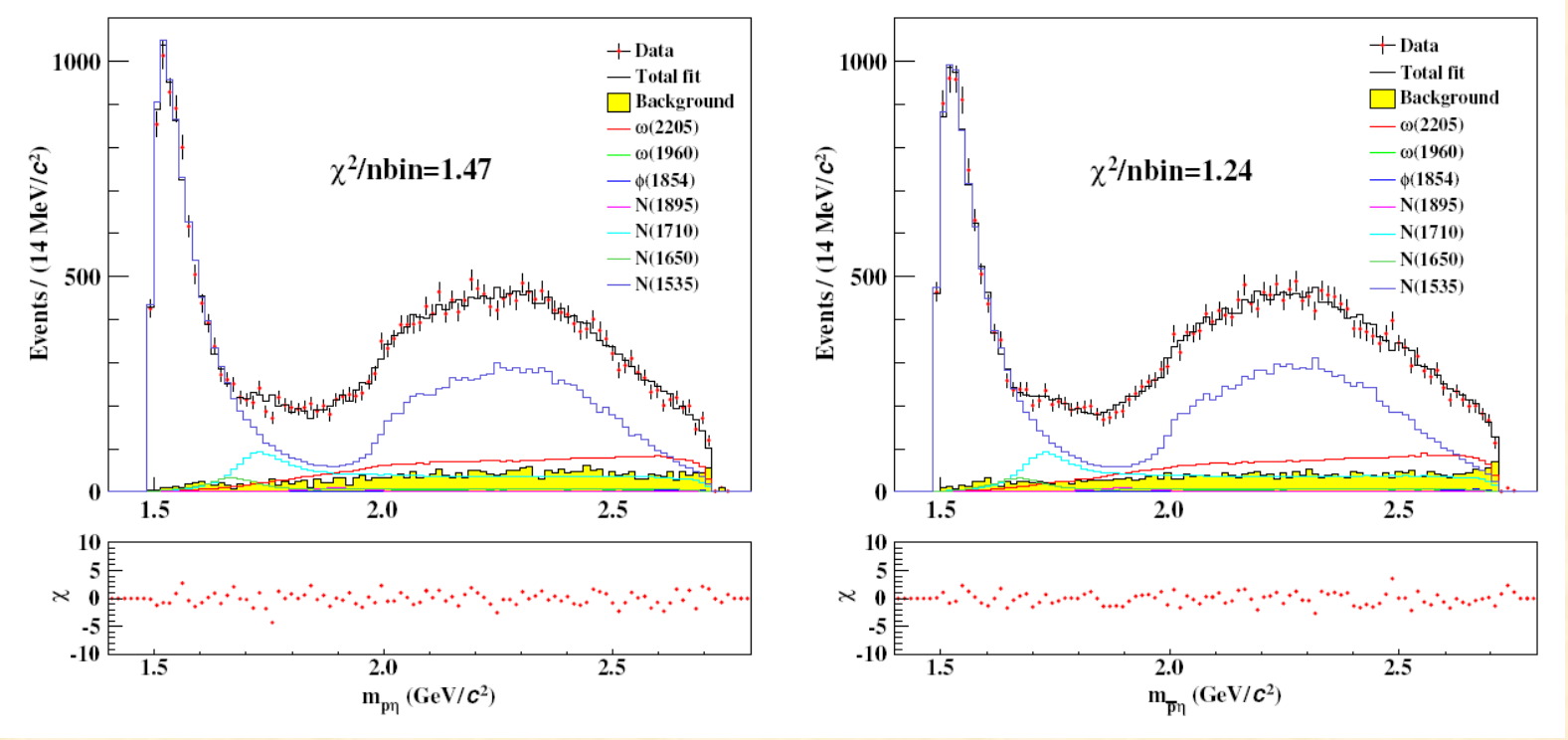
**This work:** $(17.53 \pm 0.74 \pm 3.64) \times 10^{-6}$

**Previous:** $(24.7 \pm 2.8^{+9.9}_{-9.7}) \times 10^{-6}$

# $N^*$重子谱

- $N(1535) \to N\eta$ , exotic branching fraction

**BAMBAM-00616: 2.7 billion $\psi'$, $\psi' \to p\bar{p}\pi^0$**




**Br: $J/\psi \to N^*(1535)\bar{p} + c.c. \to p\bar{p}\eta$**

**This work: $(50.69 \pm 1.29 \pm 7.24) \times 10^{-6}$**

**Previous: $(52 \pm 3^{+9.9}_{-12}) \times 10^{-6}$**

$$\frac{\Gamma_{N(1535)\to p\eta}}{\Gamma_{N(1535)\to p\pi^0}} = 0.99 \pm 0.05 \pm 0.19$$

# $\Lambda^*$超子谱

- $\Lambda(1380), \Lambda(1405)$

  在耦合道的手征么理论中，在$KN, \pi\Sigma$的阈值附近找到了dipole结构
  [Phys.Lett.B500,263]

- PDG条目

| | | |
|---|---|---|
| $\Lambda(1380)$ | $1/2^-$ | ** |
| $\Lambda(1405)$ | $1/2^-$ | **** |

[Eur. Phys. J. A 51, 3, 30]

| Solution | Pole 1 | Pole 2 |
|---|---|---|
| #2 | $1434^{+2}_{-2} - i\,10^{+2}_{-1}$ | $1330^{+4}_{-5} - i\,56^{+17}_{-11}$ |
| #4 | $1429^{+8}_{-7} - i\,12^{+2}_{-3}$ | $1325^{+15}_{-15} - i\,90^{+12}_{-18}$ |

- $J/\psi \to \Sigma^+\bar{\Sigma}^-\pi^+\pi^-$ (~10 billion $J/\psi$)

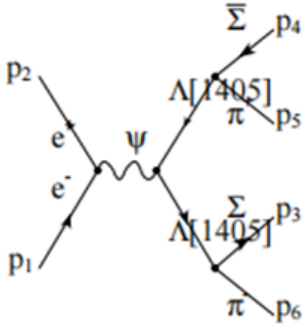


Fig. 2

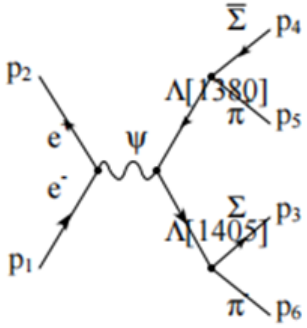


Fig. 3

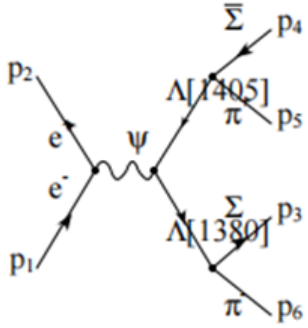


Fig. 4

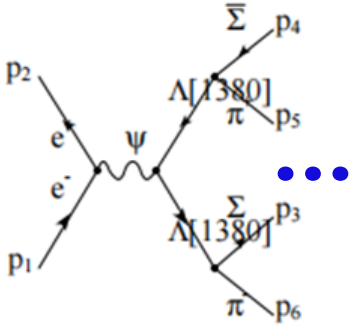


Fig. 5

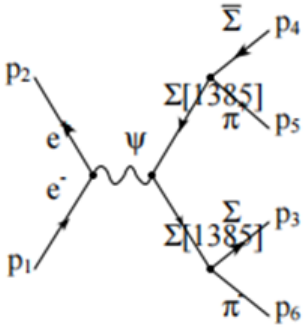


Fig. 14

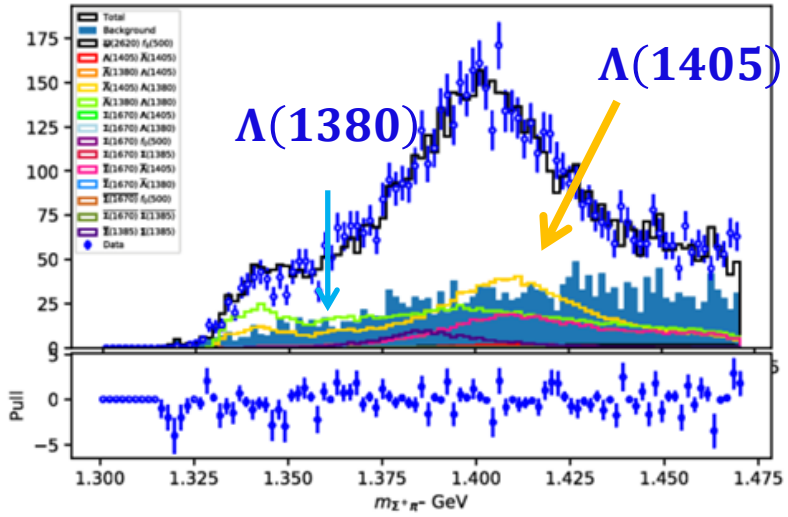
**Resonances:**

$f(500), \omega(2620), \Lambda(1380), \Lambda(1405), \Lambda(1670), \Sigma(1380)$

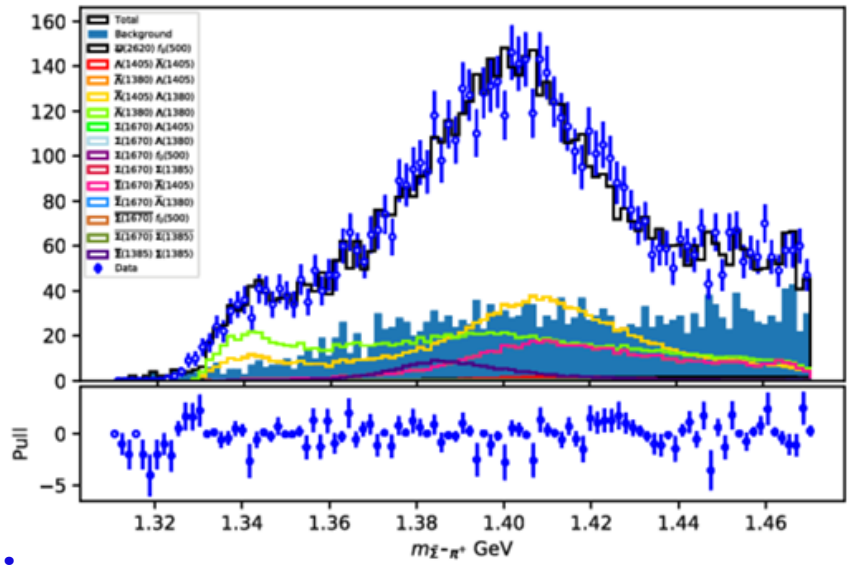
# $\Lambda^*$超子谱

- $\Lambda(1380), \Lambda(1405)$

$M(\Sigma^+\pi^-)$ GeV




$M(\bar{\Sigma}^-\pi^+)$ GeV



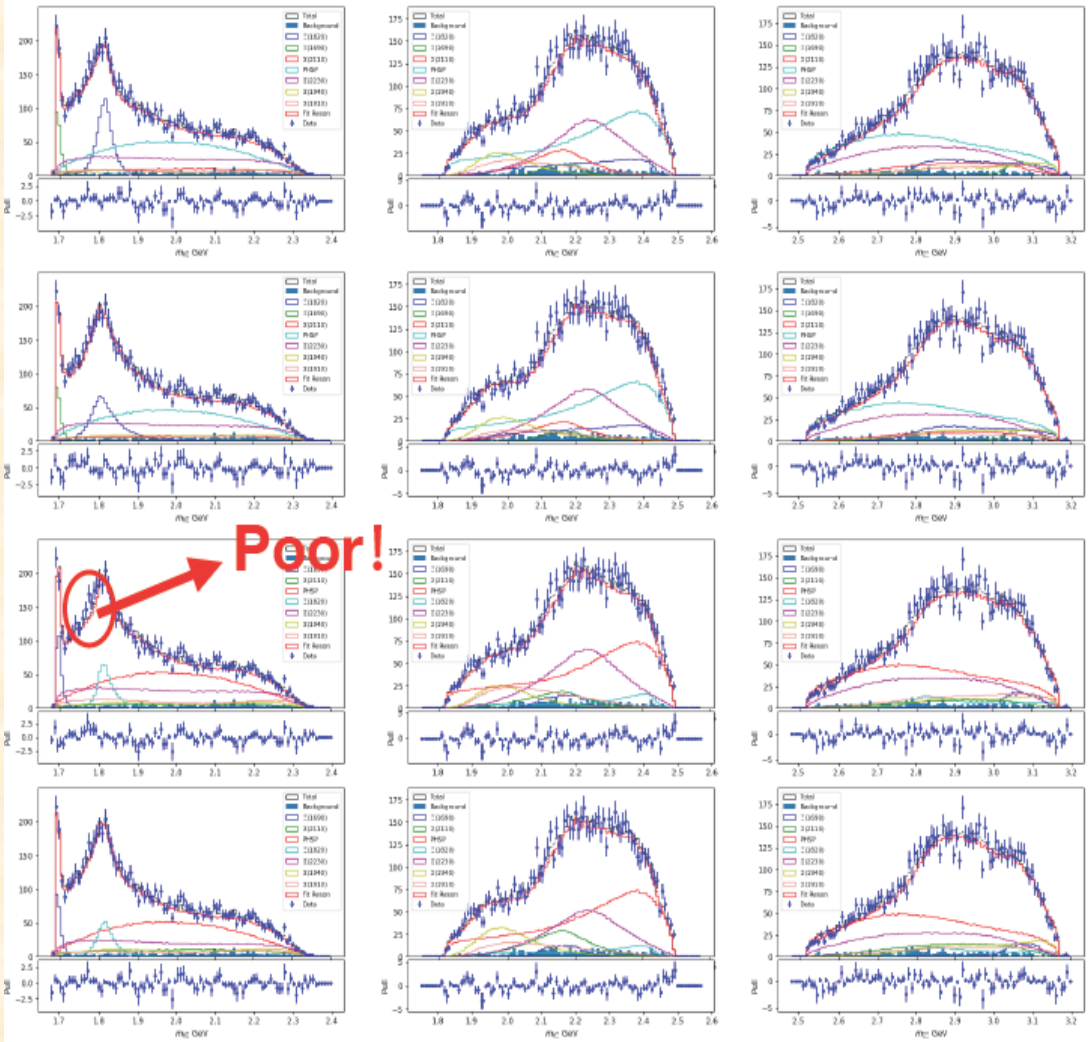

- $\Lambda(1380), \Lambda(1405)$ parametrization

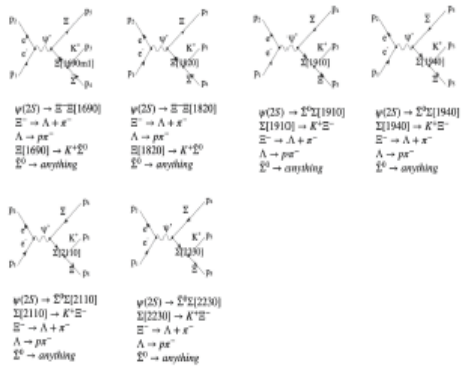
$$\Gamma(\sqrt{s}) = \Gamma_0 \frac{m_0}{\sqrt{s}} \sum_i \mathcal{B}_i \times \left(\frac{\rho_i(\sqrt{s})}{\rho_i(m_0)}\right)^{2L_i+1}$$

| | $m_0$ (GeV) | $\Gamma_0$ (MeV) | pole |
|---|---|---|---|
| Λ(1380) | 1.380±0.000 | 150.4±2.3 | 1.329-0.042j |
| Λ(1405) | 1.411±0.000 | 39.7±14.2 | 1.377-0.015j |

# $\Xi^*$超子谱

- **BAM-00882: $\Xi(1820)$ in $\psi' \to K^-\Sigma^0\bar{\Xi}^+ + c.c.$**



Ξ BARYONS
$(S=-2, I=1/2)$
$\Xi^0 = u\,s\,s, \Xi^- = d\,s\,s$

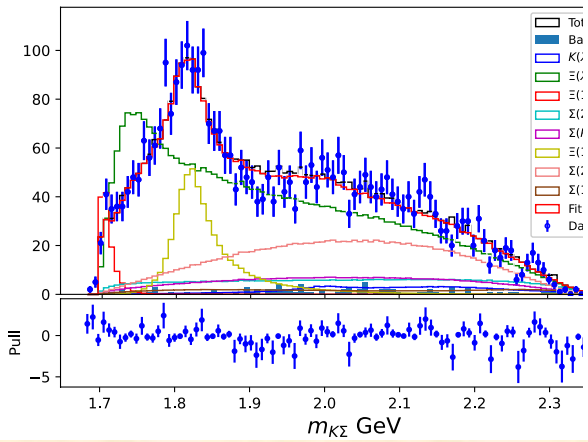
$\Xi(1820)$ $I(J^P) = 1/2\,3/2^-)$

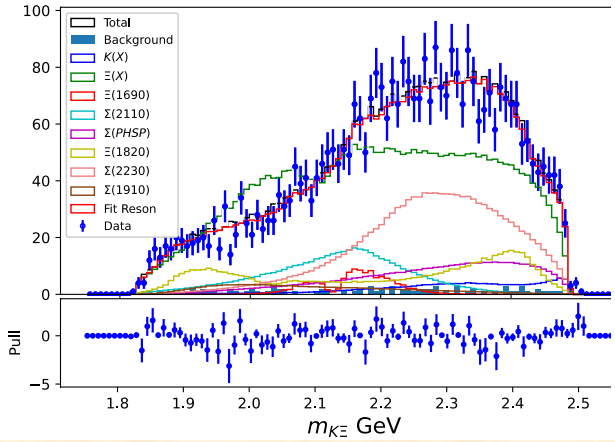
$\Xi(1820)$

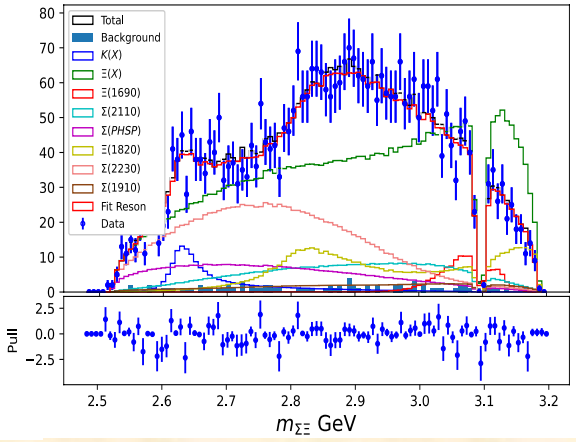
| J(P) | -lnL |
|---|---|
| 1/2- | -1868 |
| 1/2+ | -1892 |
| 3/2- | -1856 |
| 3/2+ | -1907 |

# $\Xi^*$超子谱

- $\Xi(1820)$ in $\psi' \to K_S^0 \Sigma^- \bar{\Xi}^+ + c.c.$




| | $J^P$ | Goodness of fit (1D) | Goodness of fit (2D) | -lnL |
|---|---|---|---|---|
| Without $\Xi(X)$ | \ | 0.932 | 1.062 | -679.155 |
| With $\Xi(X)$ | $\frac{1}{2}^+$ | 0.930 | 1.036 | −770.415 |
| | $\frac{1}{2}^-$ | 0.929 | 1.055 | -733.545 |
| | $\frac{3}{2}^+$ | 0.929 | 1.044 | -735.784 |
| | $\frac{3}{2}^-$ | 0.930 | 1.043 | -715.102 |

$M_{\Xi(1820)} = 1809 \pm 1 \pm 4$ MeV/c$^2$ $\quad \Gamma_{\Xi(1820)} = 56.35 \pm 0.93 \pm 5.72$ MeV/c$^2$ $\quad J^P_{\Xi(1820)} = \frac{3}{2}^-$

$M_{\Xi(X)} = 1719 \pm 1 \pm 1$ MeV/c$^2$ $\quad \Gamma_{\Xi(X)} = 83.58 \pm 2.63 \pm 3.16$ MeV/c$^2$ $\quad J^P_{\Xi(X)} = \frac{1}{2}^+$

$M_{K(X)} = 2626 \pm 2 \pm 10$ MeV/c$^2$ $\quad \Gamma_{K(X)} = 43.68 \pm 3.27 \pm 20.29$ MeV/c$^2$ $\quad J^P_{\Xi(X)} = 2^-$

# 2. 本人研究成果与经费情况

1. BESIII Collaboration, Measurement of the $e^+ e^- \rightarrow p\bar{p}\pi^0$ cross section at $\sqrt{s} = 2.1000\text{-}3.0800$ GeV, Phys. Rev., D110, 052006 (2024)
2. BESIII Collaboration, Partial wave analysis of $\psi(3686) \rightarrow \bar{\Lambda}\Sigma^0\pi^0 + c.c.$, arXiv:2408.00495, submit to JHEP.

3. BESIII Collaboration, THE VERIFICATION OF QUANTUM NON-LOCAL CORRELATION IN $\Lambda\bar{\Lambda}$ SYSTEM, submit to Nature Communications.

4. BESIII Collaboration, Study of $e^+e^- \rightarrow \eta\phi$ at center-of-mass energies from 3.773 to 4.600 GeV, Phys.Rev. D108, 112011 (2023).

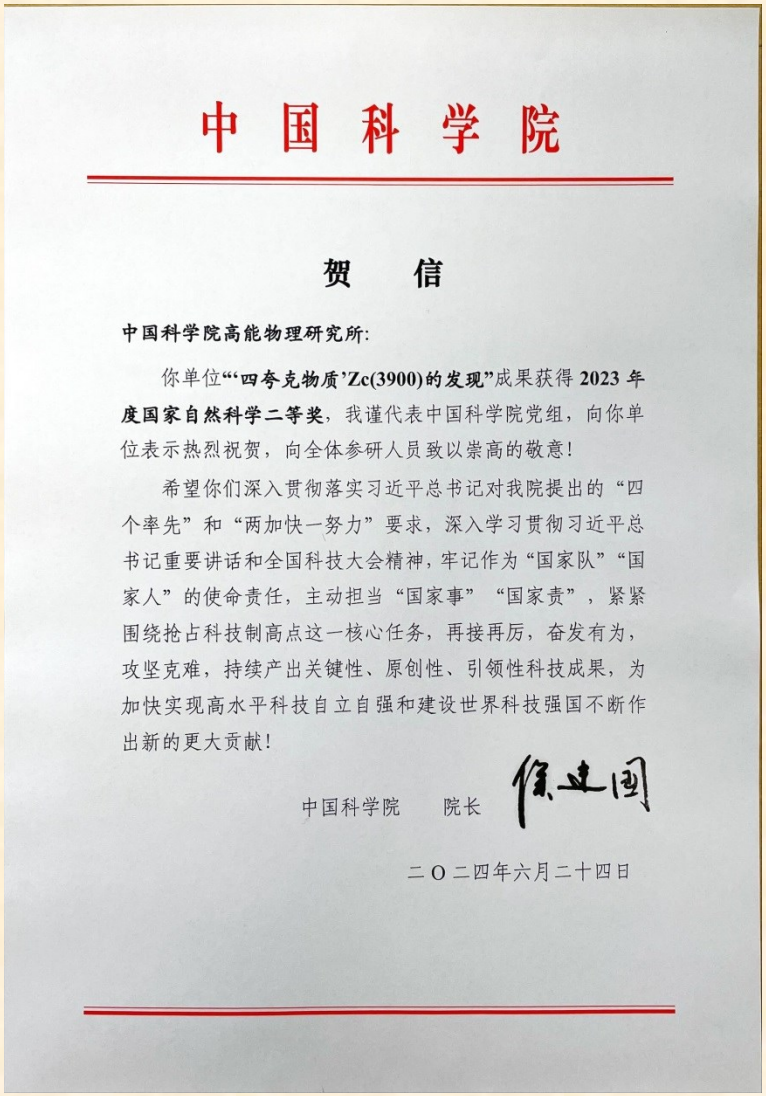
5. Xu Cao, Yu-Tie Liang, and Rong-Gang Ping, Production and decay of hyperons in a transversely polarized electron-positron collider, Physics Review D110, 014035(2024).

# 2. 本人研究成果与经费情况

6. Qi Huang, Zi-Xuan Ma, Jia-Jun Wu, Rong-Gang Ping, Jun He, and Hong-Xia Huang, Role of the triangle singularity in the isospin breaking process $J/\psi \to \Lambda\,\overline{\Lambda}\,\pi^0$ and the possible evidence of $\Sigma^*\left(\frac{1}{2}\right)$ states, Physics Review D110, 034018 (2024).

7. Zhe Zhang, Rong-Gang Ping, Tianbo Liu, Jiao Jiao Song, Weihua Yang,and Ya-jin Zhou, Polarization analysis of two baryons with various spin combinations produced in electron-positron annihilation, Physics Review D110, 0 034034 (2024).

# 3. 获奖情况



中 国 科 学 院

贺　　信

中国科学院高能物理研究所：

你单位**“‘四夸克物质’Zc(3900)的发现”**成果获得**2023年度国家自然科学二等奖**，我谨代表中国科学院党组，向你单位表示热烈祝贺，向全体参研人员致以崇高的敬意！

希望你们深入贯彻落实习近平总书记对我院提出的“四个率先”和“两加快一努力”要求，深入学习贯彻习近平总书记重要讲话和全国科技大会精神，牢记作为“国家队”“国家人”的使命责任，主动担当“国家事”“国家责”，紧紧围绕抢占科技制高点这一核心任务，再接再厉，奋发有为，攻坚克难，持续产出关键性、原创性、引领性科技成果，为加快实现高水平科技自立自强和建设世界科技强国不断作出新的更大贡献！

中国科学院　　院长

二〇二四年六月二十四日

国家自然科学奖

证　书

为表彰国家自然科学奖获得者，特颁发此证书。

项目名称：“四夸克物质”Zc(3900)的发现

奖励等级：二等

获 奖 者：平荣刚（中国科学院高能物理研究所）

中共中央　国务院

2024年6月

证书号：2023-Z-102-2-02-R05

# 2. 本人研究成果与经费情况

- 面上项目

1.主持《北京谱仪III上BELL不等式和隐变量理论的检验》执行期间： 2022年1月-2025年12月 ,批准号： 12175244

- 参加：

1.重点项目, 主持人：苑长征《BESIII实验类粲偶素的寻找和研究 》： 2019.01-2023.12

2.科技部重点专项,《类粲偶素》

# 3. 学术交流

## ➢ 国内会议报告

1. 平荣刚， 蒙特卡洛方法和事例产生器，北京谱仪十一科学研讨会, 2024年10月1-7，十堰
2. 平荣刚，粒子自旋和宇称量子数的测量，第二届强子物理新发展研讨会 暨 强子物理在线论坛100期特别活动, 2024年6月30-7月4日，合肥，中国科大
3. 平荣刚，FDC partial wave analysis software and excited-baryon study at BESIII，强子物理前沿研讨会, 2024年2月19-22日，惠州，近代物理研究所
4. 平荣刚，BEPC束流横向极化的测量，第八届R值与QCD强子结构研讨会, 2027年7月19-22日,哈尔滨
5. 平荣刚，BESIII上的重子激发态的研究， 第七届强子谱和强子结构研讨会，2024年4月26-4月30日，成都
6. 平荣刚，高能物理实验中粒子自旋和宇称量子数测量，南高师.沙龙，2024年5月7日，南京师范大学

# 4. 公共服务

- **BES referee /chair**

  目前，被分配评审**5**篇**BES**内部的分析工作。

- 谱仪运行负责人**(14**天**)**
- 国科大研究生课程教学：《实验模拟与分析》章节：蒙特卡洛方法，事例产生子

## ➢ 指导学生的工作

高能所研究生1名，

联合培养研究生：**9**名

联合指导毕业生论文： **3**人（ 洪鹏程，李明浩，王旨）

硕士升入博士生：**4**人（张秋岩，黄振秀, 洪鹏程，李明浩）

# 三、存在问题和下年度工作计划

- 现有的重子样本统计量，对我们的FDC-TF计算能力提出了挑战。
- 优化GPU分波软件的算法，进一步提高计算效率
- 推进物理分析工作的进展，争取多出成果，出好成果，完成获批项目中的工作
- 做好BOSS产生子软件的维护和升级工作，为物理分析提供支持

谢谢大家