Recent results from BESIII

王大勇
北京大学物理学院

全国第十六届重味物理和CP破坏研讨会

郑州, 2018年10月26日

105
大事记
EVENTS

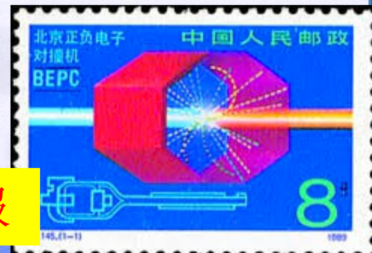
我国高科技领域又取得重大突破

北京正负电子对撞机对撞成功

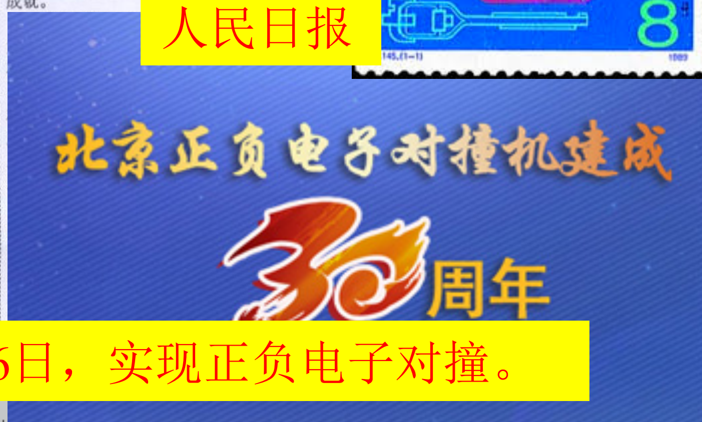
为粒子物理和同步辐射应用研究开辟广阔前景

据新华社北京10月19日电 （记者施宝华、陈金武）10月16日凌晨5点56分，位于北京西郊的中国科学院高能物理研究所传出令人振奋的喜讯：我国第一座高能加速器——北京正负电子对撞机首次对撞成功。

这是我国继原子弹、氢弹爆炸成功、人造卫星上天之后，在高科技领域又一重大突破性成就。



人民日报



1972年8月 周恩来
回开展
建议信
1973年2月 在原了
物理研
1983年4月 国务院
准设计
1983年12月 中央书
重点工
1984年10月 北京正
平同志
1985年8月 35MeV
1988年10月 北京正
导人来
领域占
1989年7月 北京谱仪

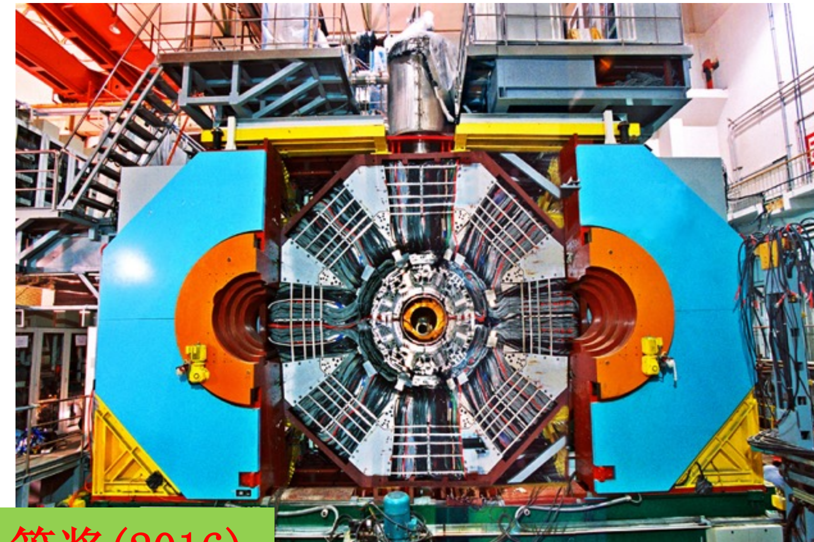
1988年10月16日，实现正负电子对撞。

国家科技进步特等奖(1990)

的空气簇射阵列
的簇射事例。

http://www.ihep.cas.cn/zt/bepc30/

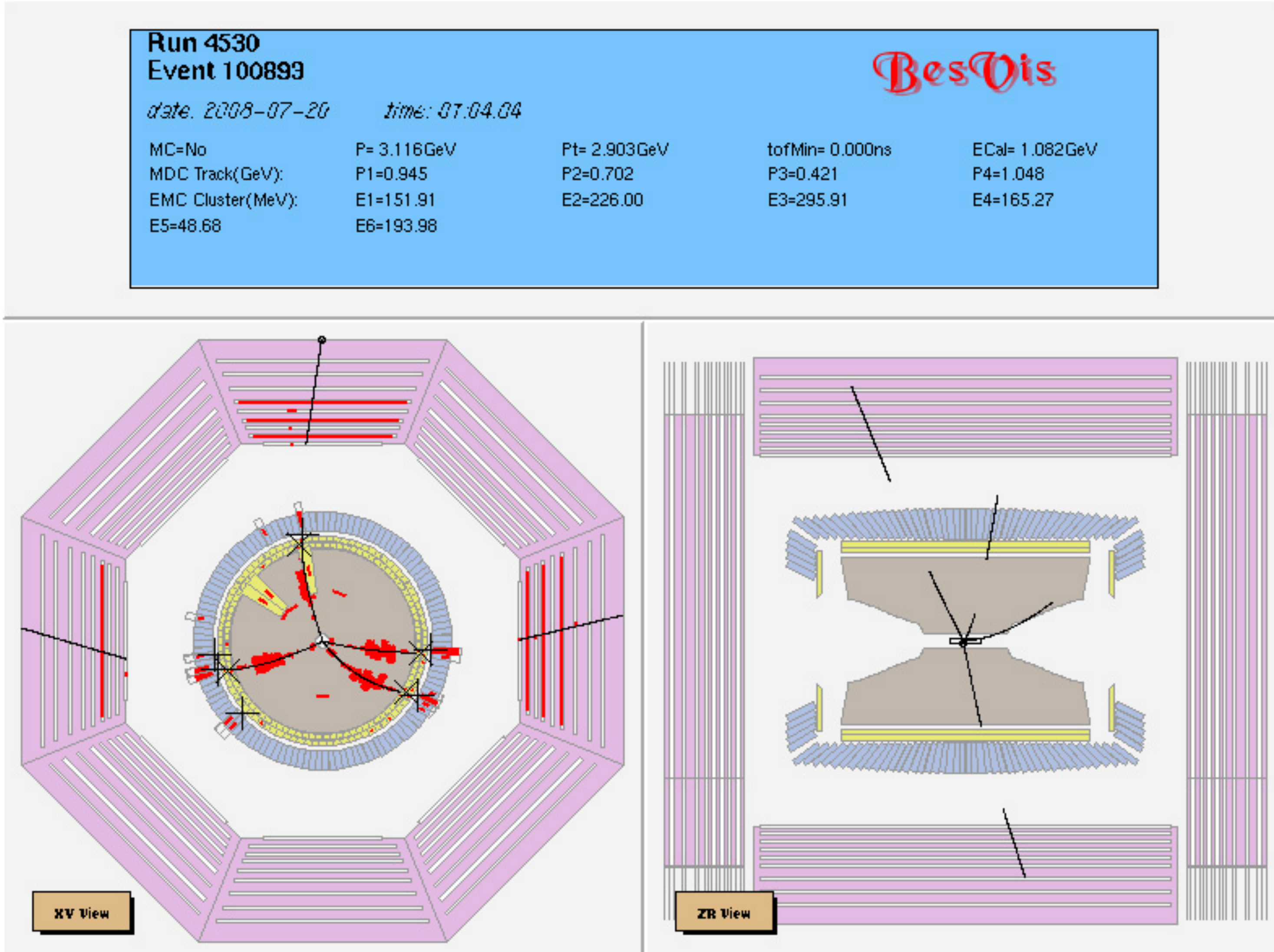
BEPCII: a τ-c Factory



国家科技进步一等奖(2016)

- First collision in 2008, physics run started in 2009
- Operation c.m. energy: 2.0-4.6GeV
- **BEPCII reached peak lumi of $1\times10^{33}\ cm^{-2}s^{-1}$@1.89GeV in April 2016**
- BESIII collaboration includes 66 institutes: 38 Chinese institutes，16 European ones，5 US ones and 7 from other Asian countries
- Secured the running for another 6-7 years, with small(but critical) energy increase and lumi upgrade

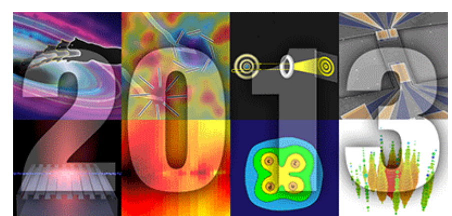
BESIII: First collision event on July 19, 2008



10-year anniversary of BEPCII/BESIII !

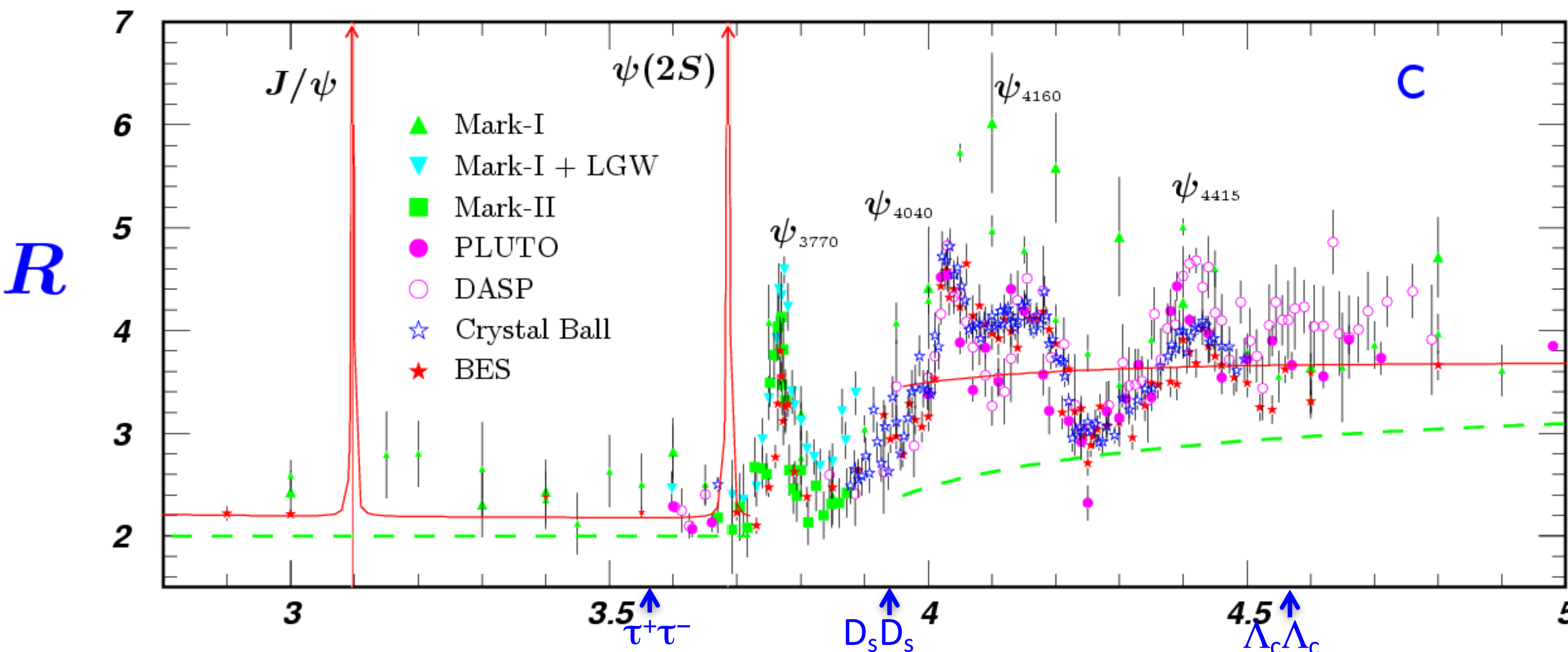
Physics accomplishments

- τ mass measurement (BES+BESIII)
  - 1995年国家自然科学二等奖
- R value measurement (BESII)
  - 2004年国家自然科学二等奖
- Charmonium physics
  - 2001年国家自然科学二等奖
- Charm physics (BESII+BESIII)
  - 2010年国家自然科学二等奖
- Exotic hadrons (BESII+BESIII)
  - 2013年国家自然科学二等奖



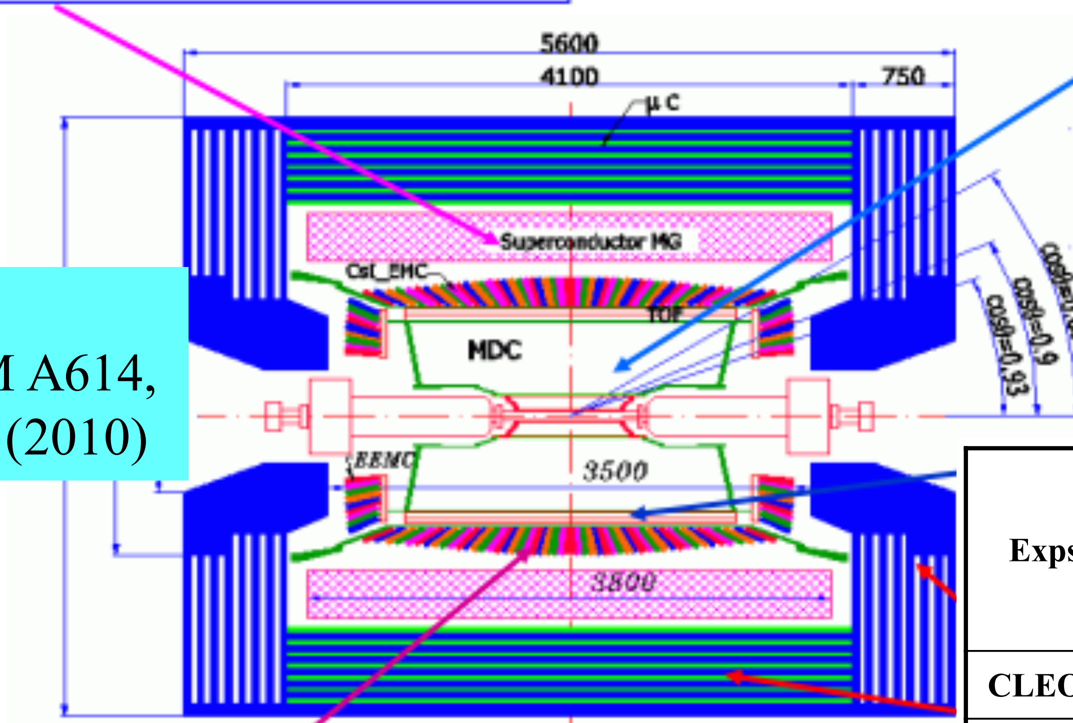
BEPCII: a τ-c Factory

- Rich of **resonances**, charmonia and charmed mesons.
- **Threshold** characteristics (pairs of τ, D, D_s, charmed baryons…).
- **Transition** between perturbative and non-perturbative **QCD**.
- New **hadrons**: glueballs, hybrids, multi-quark states
- **New Physics:** large datasets, hermetic detector, good performance



BESIII@BEPCII

Magnet: 1 T Super conducting



2015 ETOF upgrade: 60ps

2019/20: Inner upgrade?

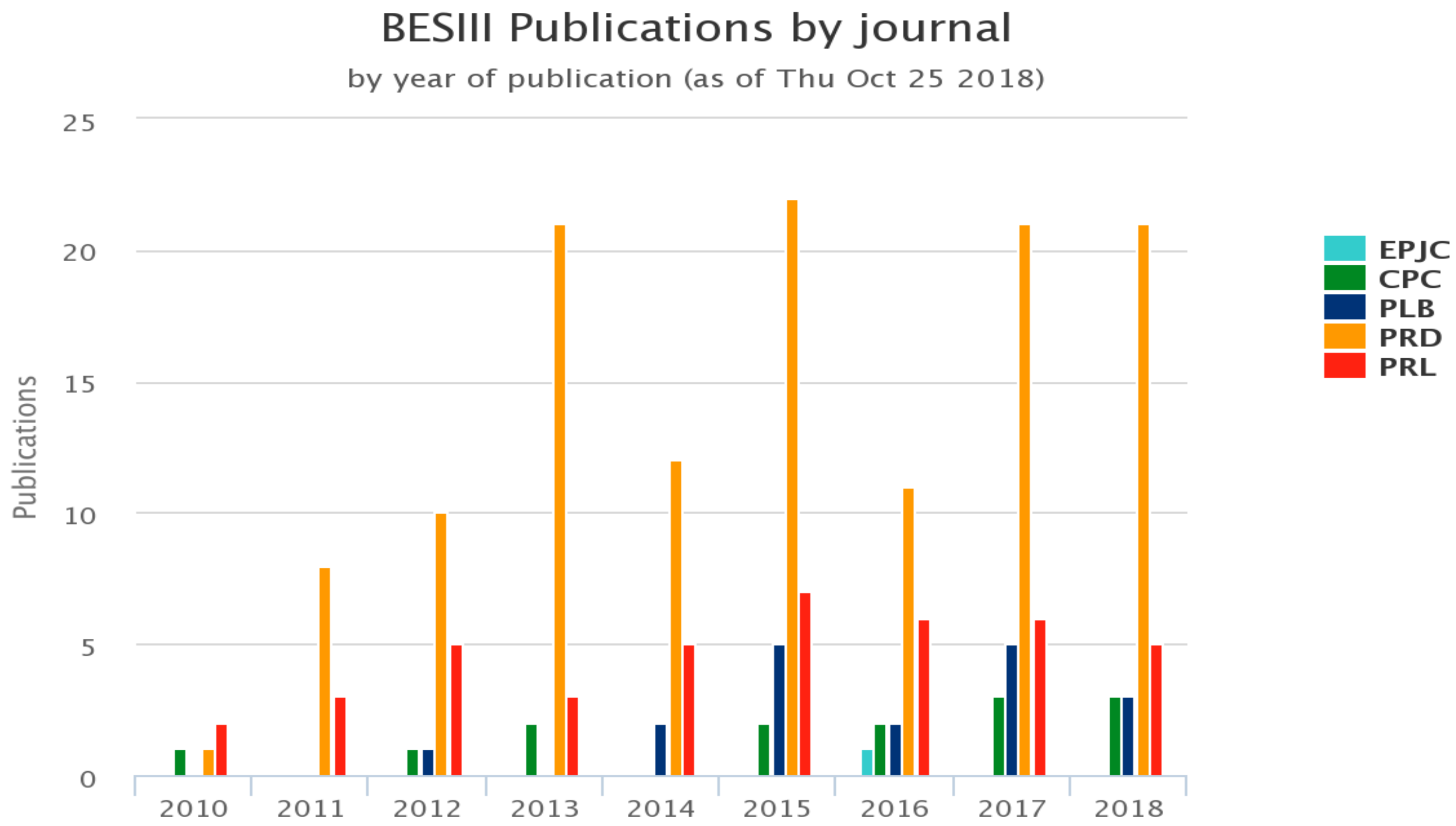
Ref:
NIM A614, 345 (2010)

Exps.	MDC Spatial resolution	MDC dE/dx resolution	EMC Energy resolution
CLEO-c	110 μm	5%	2.2-2.4 %
BaBar	125 μm	7%	2.67 %
Belle	130 μm	5.6%	2.2 %
BESIII	115 μm	<5% (Bhabha)	2.4%

high lumi, large datasets, hermetic detector with good performance and clean environment

competitive in channels with low energy electron/photons, neutrons, pi0's

BESIII publications



BESIII charm data samples

~ 0.5 B $\psi(3686)$ events ~ 24×CLEO-c

~ 1.3 B J/ψ events ~ 21×BESII

~ 2.9/fb $\psi(3770)$ ~ 3.5×CLEO-c yellow book: 90M DDbar

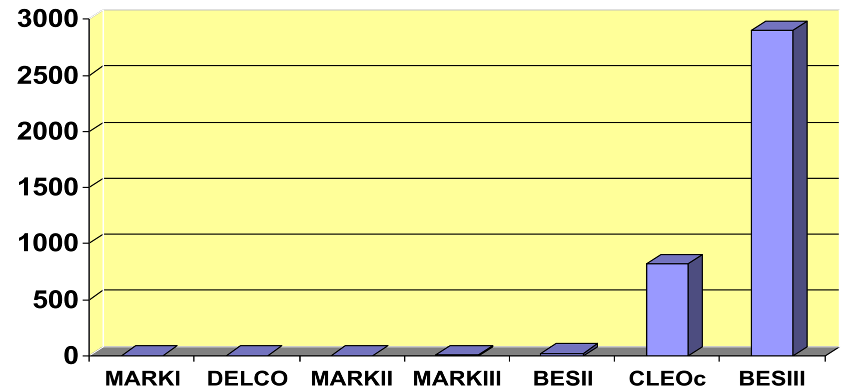
~ 0.482/fb 4.009 Ds study

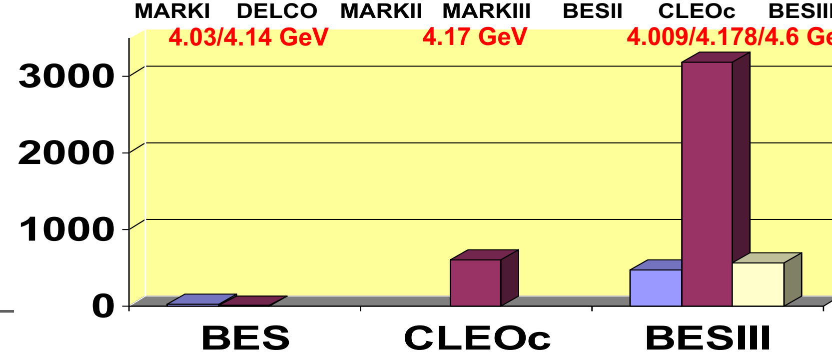
~ 0.6/fb Λ_c pairs at threshold Unique

~ 9/fb **XYZ** above 4 GeV

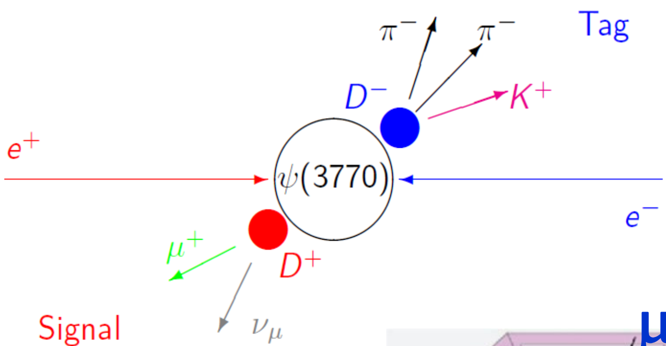
- 20 points for R &QCD Scan: 500/pb finished in May 2015
- Y(2175) resonance: 100 /pb
- 2016: 3/fb Ds data at 4170 MeV
  ~ 5×CLEO-c
- 2017: Y(4260), X(3872)
- 2018: 4.6B J/ψ (NEW)

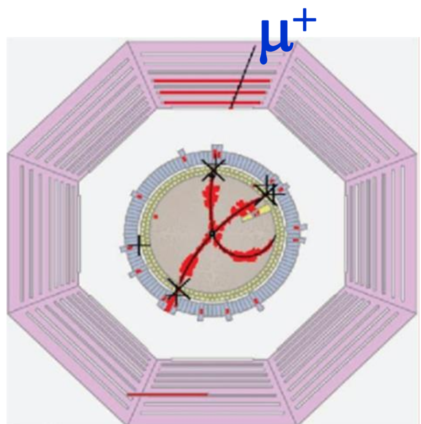
~ other data sets: tau, resonance scan and continuum, etc.





Tagging technique at threshold





$D^- \to K^+\pi^-\pi^-$ vs. $D^+ \to \mu^+\nu$

- $e^+e^- \to D\bar{D}$ ($\Lambda_c^+\Lambda_c^-$), near Thrs.
- Double tag analysis
  - ✓ Tagging D^- ($\bar{D}^0$), Λ_c^- from hadronic decay modes

$$M_{\mathrm{BC}} = \sqrt{E_{\mathrm{beam}}^2 - p_{\bar{D}_{\mathrm{tag}}}^2}$$

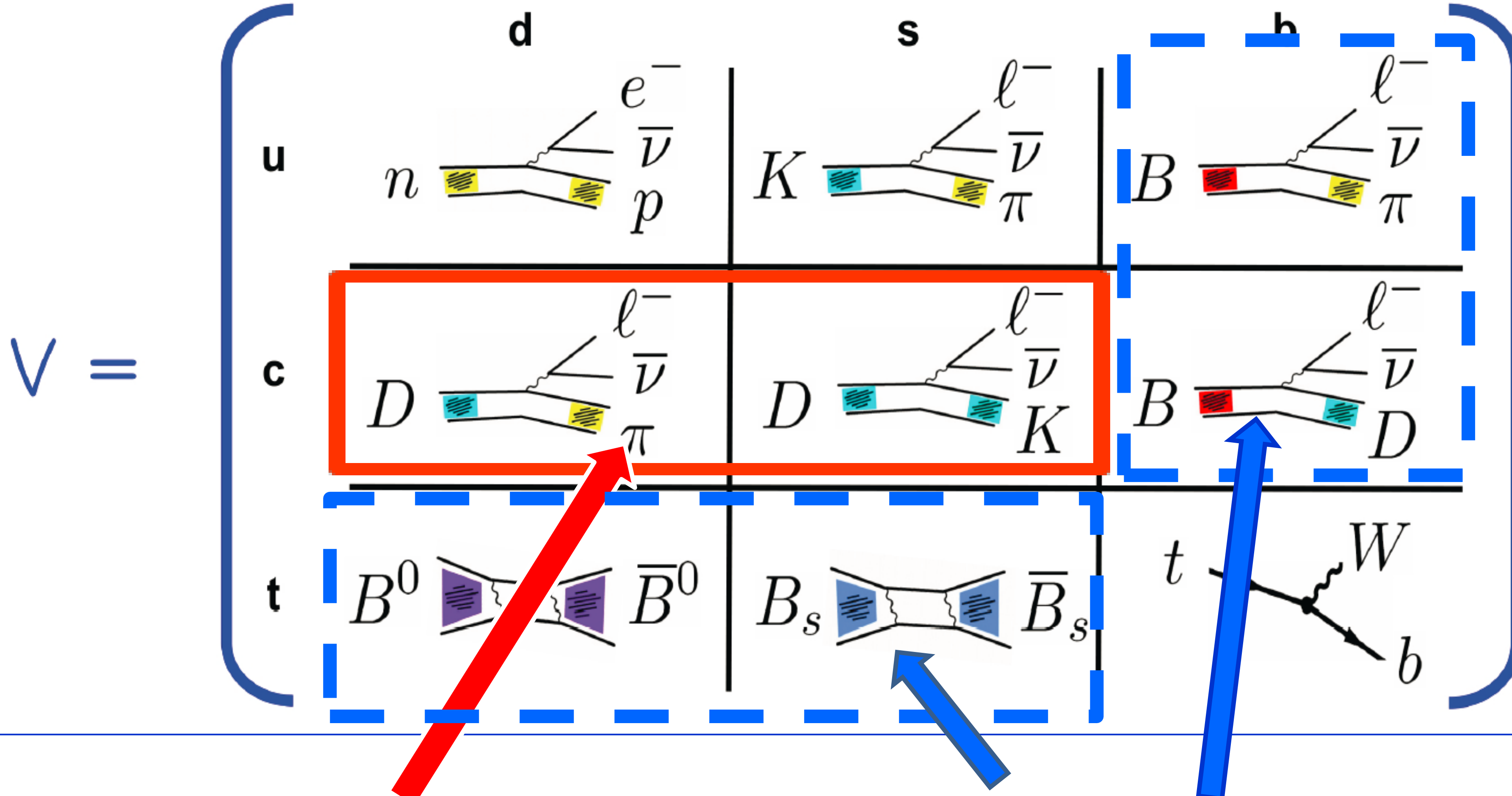
  - ✓ (semi-)leptonic decay event can be well reconstructed in the recoil side of the tagged $\bar{D}$ (Λ_c^-)

$$M^2_{\mathrm{missing}} = E^2_{\mathrm{miss}} - p^2_{\mathrm{miss}} \sim 0$$

$$U_{\mathrm{miss}} \equiv E_{\mathrm{miss}} - |\vec{p}_{\mathrm{miss}}| \sim 0$$

- ☐ Event is very clean
- ☐ High tagging efficiency
- ☐ Most systematic uncertainties can be cancelled
- ☐ Could measure absolute BFs

Measuring CKM matrix
--- test SM EW theory



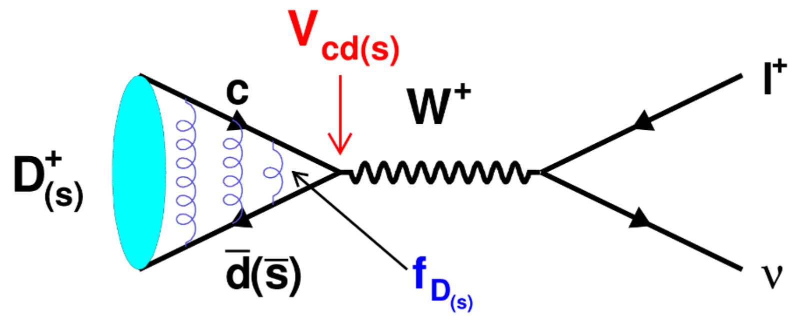
Charm decays + LQCD

Expected precision < 2% at BESIII

Charm decays + B decays + LQCD

$D_{(s)}$ Leptonic decays

- **Extract decay constant $f_{D(s)}$ incorporates the strong interaction effects (wave function at the origin)**
- **To validate Lattice QCD calculation of $f_{B(s)}$ and provide constrain of CKM- unitarity**



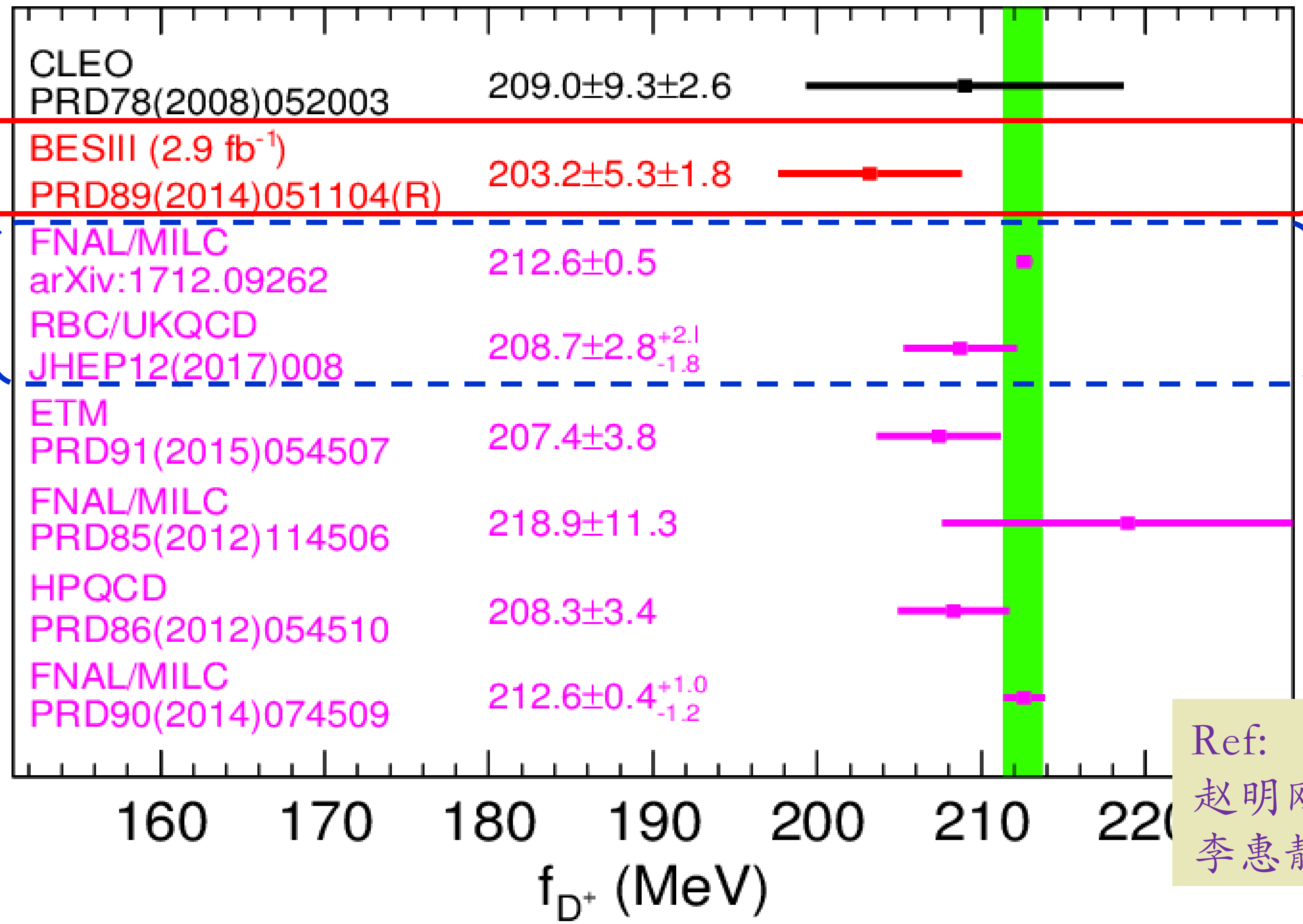
Decay rate (Exp.)

Decay constant (LQCD)

$$\Gamma(D_{(s)} \to \ell\nu) = |V_{cd(s)}|^2 \times f^2_{D_{(s)}} \times \frac{G_F^2}{8\pi} m_\ell^2 m_{D_{(s)}} (1 - m_\ell^2/m^2_{D_{(s)}})^2$$

CKM matrix element

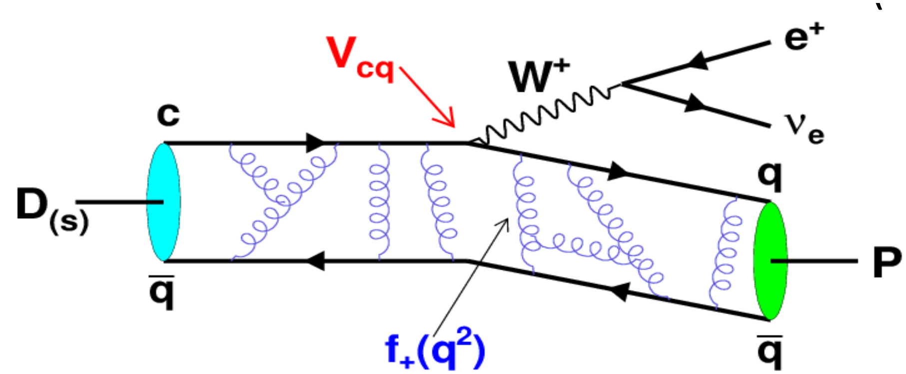
f_{D+} Comparison



Ref:
赵明刚（南　开）
李惠静（复　旦）

- **Most recent LQCD calculation, very precise**
- **BESIII: f_{D+}=(203.2±5.3±1.8) MeV ($\mu^+\nu$ mode), most precise measurement**

$D_{(s)}$ Semi-leptonic decays



- form factor (FF)
  - Measure |Vcx| x FF
  - CKM-unitarity => |Vcx|, extract FF, test LQCD
  - Input LQCD FF to test CKM-unitarity

At zero positron mass limit:

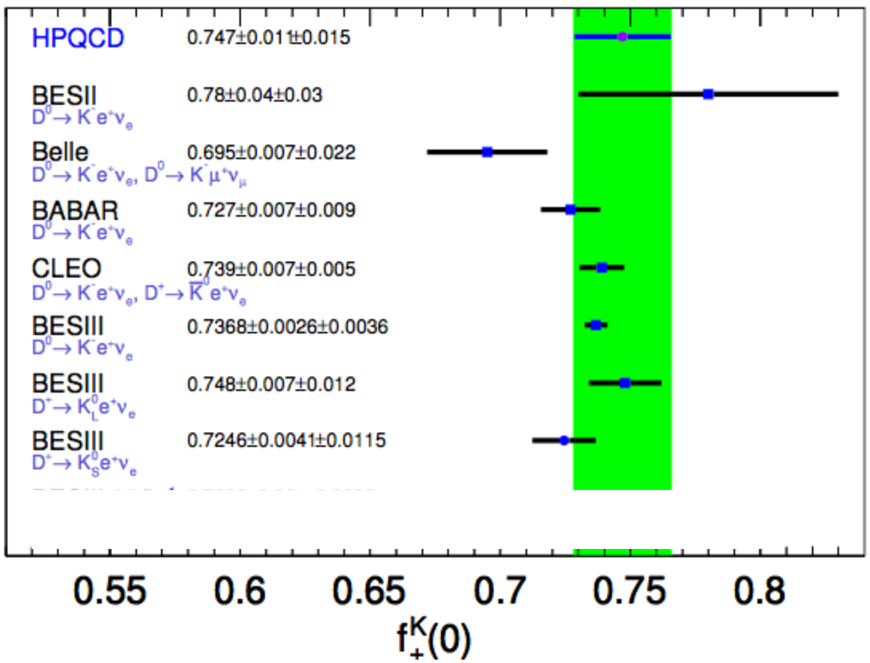
$$\frac{d\Gamma\left(D_{(s)} \to K(\pi)\ l\nu\right)}{dq^2} = \frac{G_F^2 \left|V_{cs(d)}\right|^2 P_{K(\pi)}^3}{24\pi^3} \left|f_+\left(q^2\right)\right|^2$$

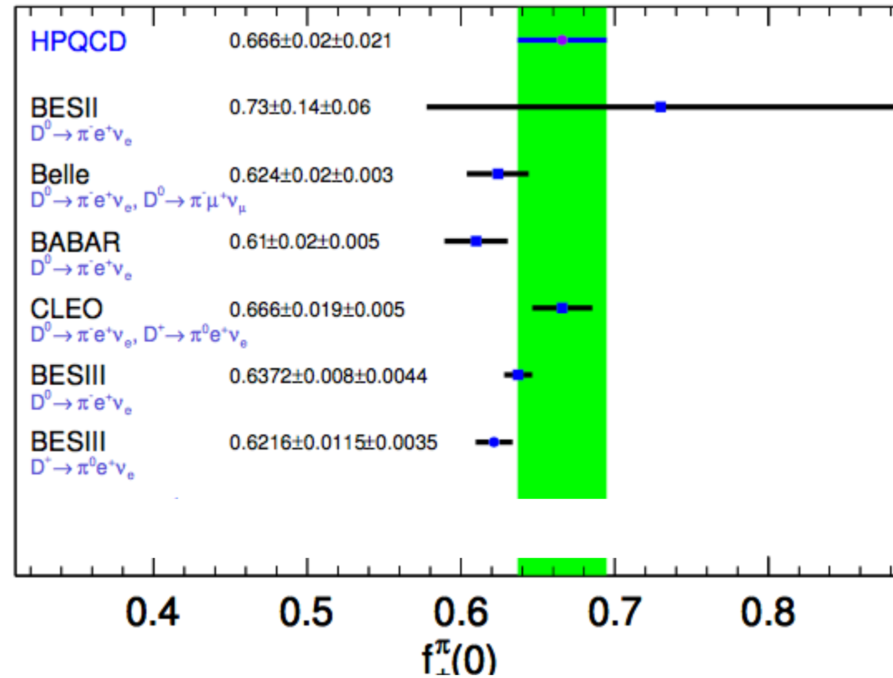
Differential rate (Exp.)

CKM matrix element

Form factor (LQCD)

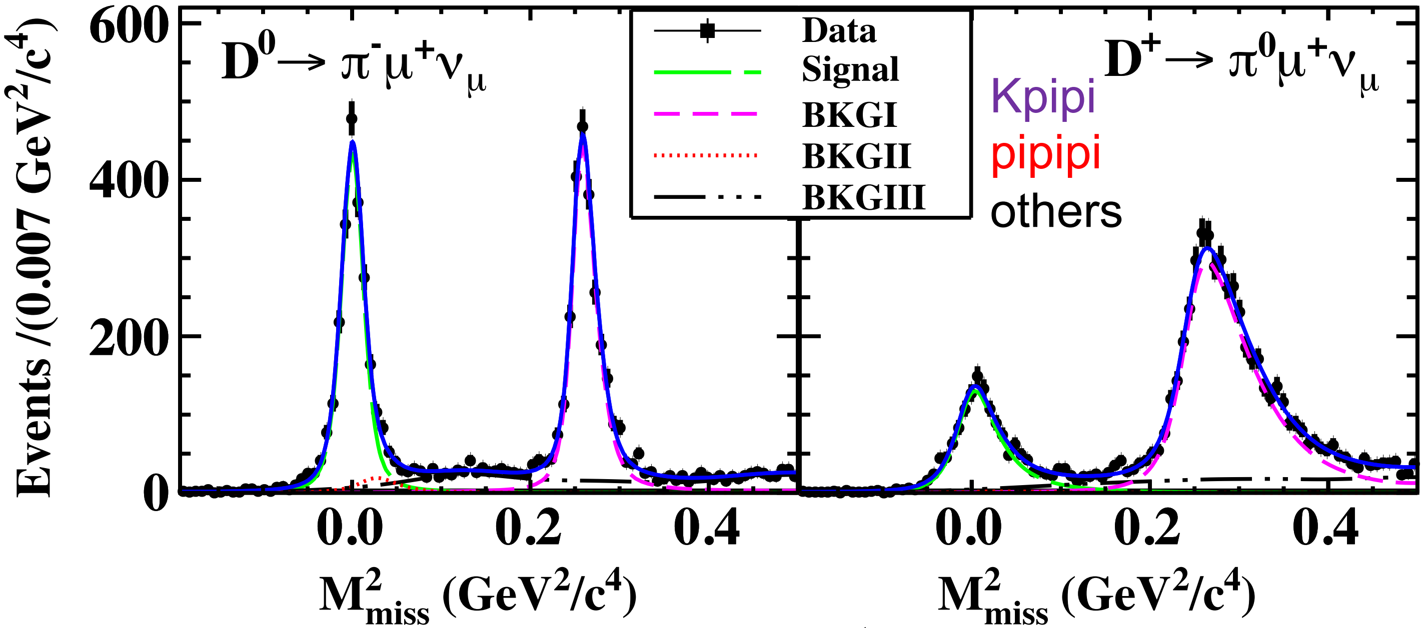
FF comparison





Ref:
赵明刚（南 开） Charmed meson leptonic and semi-leptonic decays at BESIII

Cabbibo-supressed $D^{0(+)} \to \pi^{-(0)}\mu^+\nu_\mu$



$(0.295 \pm 0.004_{\rm stat.} \pm 0.003_{\rm syst.})\%$

$(0.363 \pm 0.008_{\rm stat.} \pm 0.005_{\rm syst.})\%$,

Much improved precision

First measurement

$\mathcal{R}^0_{\rm LFU} = 0.922 \pm 0.030_{\rm stat.} \pm 0.022_{\rm syst.}$

$\mathcal{R}^+_{\rm LFU} = 0.964 \pm 0.037_{\rm stat.} \pm 0.026_{\rm syst.}$

Arxiv:1802.05492
Accepted by Phys. Rev. Lett.

Agree with SM expectations within 1.7σ(0.5σ)

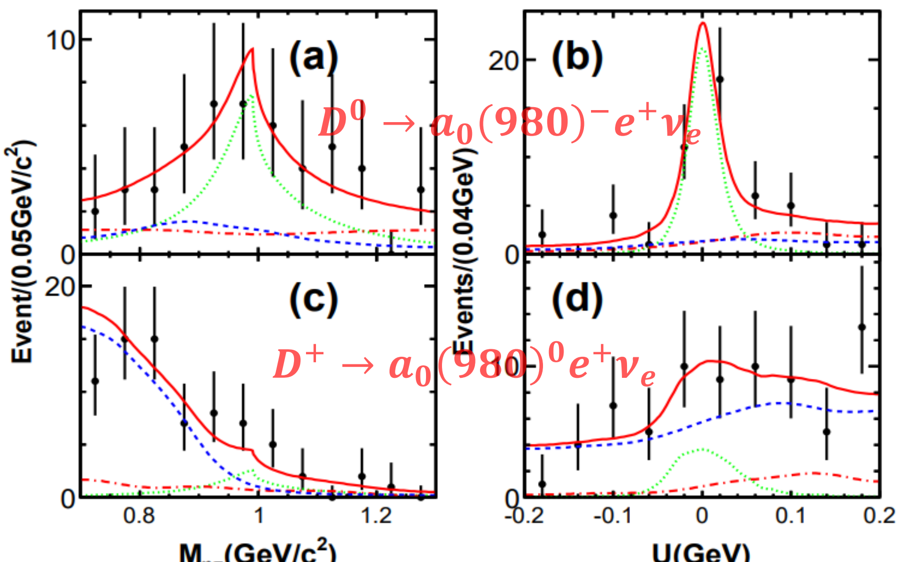
First observation: $D^{0(+)} \rightarrow a_0^{+(0)} e^+\nu$

To understand the internal structure of $a_0(980)$ -- two quark states or tetra quark system:

- **A prediction for the BF for $D^+ \to a_0(980)^0 e^+ \nu_e$ is : $5 \sim 5.4(6 \sim 8) \times 10^{-5}$ for two(tetra) quark description**
- **A model-independent way to distinguish two different descriptions: R=1(3) for two(tetra) quark. (PRD 82, 034016 (2010))**

$$R = \frac{\mathcal{B}(D^+ \to f_0(980) l^+ \nu) + \mathcal{B}(D^+ \to f_0(600) l^+ \nu)}{\mathcal{B}(D^+ \to a_0^0(980) l^+ \nu)}.$$

BESIII $2.93 fb^{-1}$@$\psi(3770)$



$$\mathcal{B}(D^0 \to a_0(980)^- e^+ \nu_e) \times \mathcal{B}(a_0(980)^- \to \eta\pi^-) = (1.33^{+0.33}_{-0.29} \pm 0.09) \times 10^{-4}$$ **6.4 σ**

$$\mathcal{B}(D^+ \to a_0(980)^0 e^+ \nu_e) \times \mathcal{B}(a_0(980)^0 \to \eta\pi^0) = (1.66^{+0.81}_{-0.66} \pm 0.11) \times 10^{-4},$$ **2.9 σ**

$$< 3.0 \times 10^{-4} \text{ at the } 90\% \text{ C.L.}$$

$$\frac{\Gamma(D^0 \to a_0(980)^- e^+ \nu_e)}{\Gamma(D^+ \to a_0(980)^0 e^+ \nu_e)} = 2.03 \pm 0.95 \pm 0.06,$$

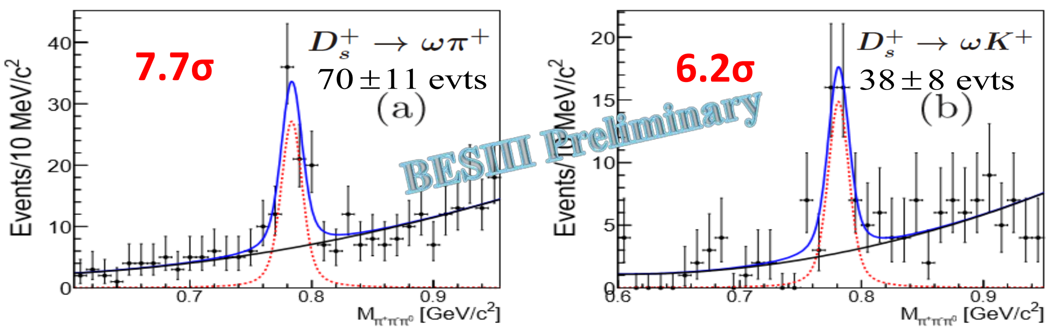
PRL 121, 081802(2018)

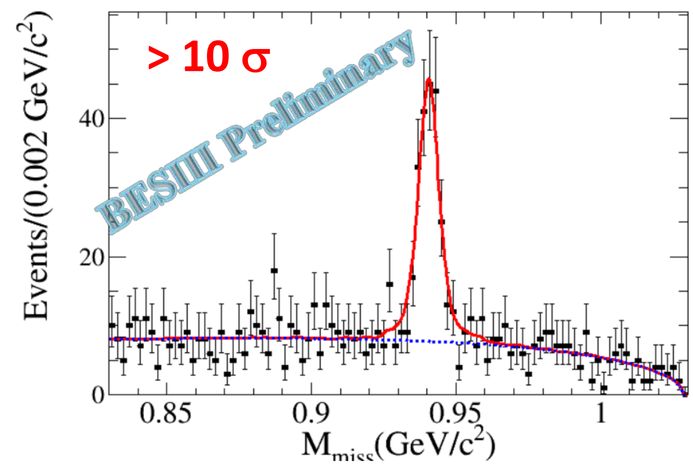
- **Isospin conservation holds**
- **BESIII results for $D^+ \to f_0 e^+ \nu_e$ ongoing.**

34

$D_{(s)}$ hadronic decays

- Strong phase measurement with quantum correlated $\psi'' \to D^0 D^0$ is crucial in the model-independent determinations of γ and charm mixing/direct CPV.
- Probe non-perturbative QCD
  - Help to understand hadron spectroscopy – Study SU(3) flavor symmetry
  - Study short and long distance effects





BESIII Preliminary results:

$\mathcal{B}(D_s^+ \to \omega\pi^+) = (1.85 \pm 0.30_{stat.} \pm 0.19_{syst.}) \times 10^{-3}$

$\mathcal{B}(D_s^+ \to \omega K^+) = (1.13 \pm 0.24_{stat.} \pm 0.14_{syst.}) \times 10^{-3}$

First observation
pure W-annihilation process

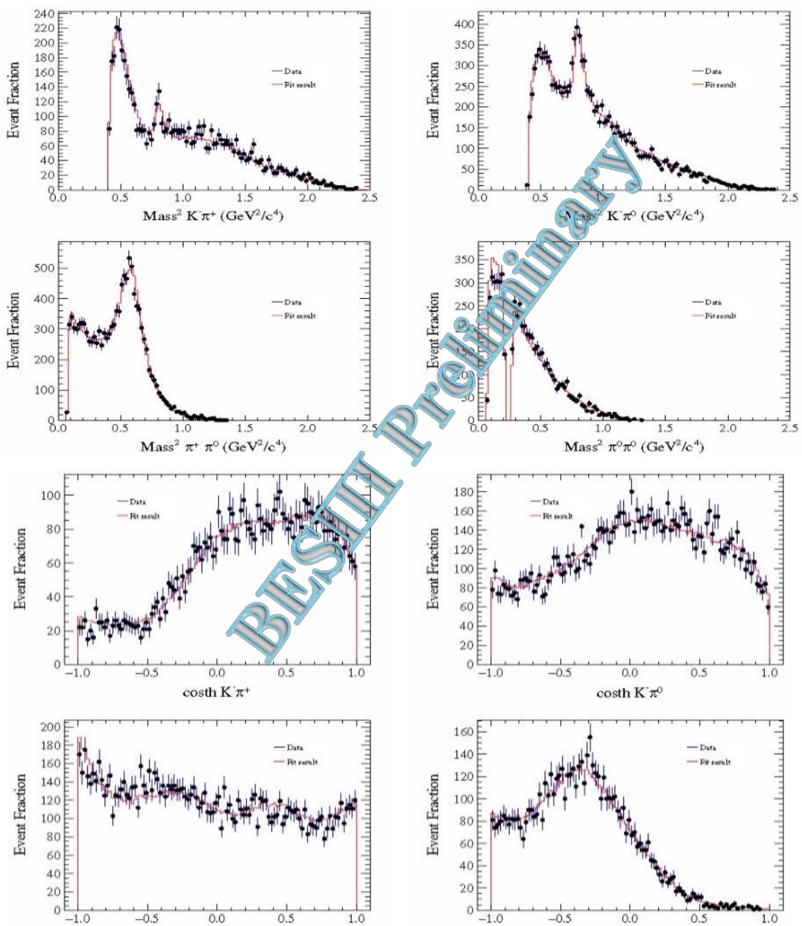
$\mathcal{B}_{D_s^+ \to p\bar{n}} = (1.22 \pm 0.10) \times 10^{-3}$

Amplitude analysis: $D^0 \to K^-\pi^+\pi^0\pi^0$

$$\mathcal{B}(D^0 \to K^-\pi^+\pi^0\pi^0) = (8.98 \pm 0.13(\text{stat}) \pm 0.40(\text{syst}))\%$$

BESIIIPreliminary

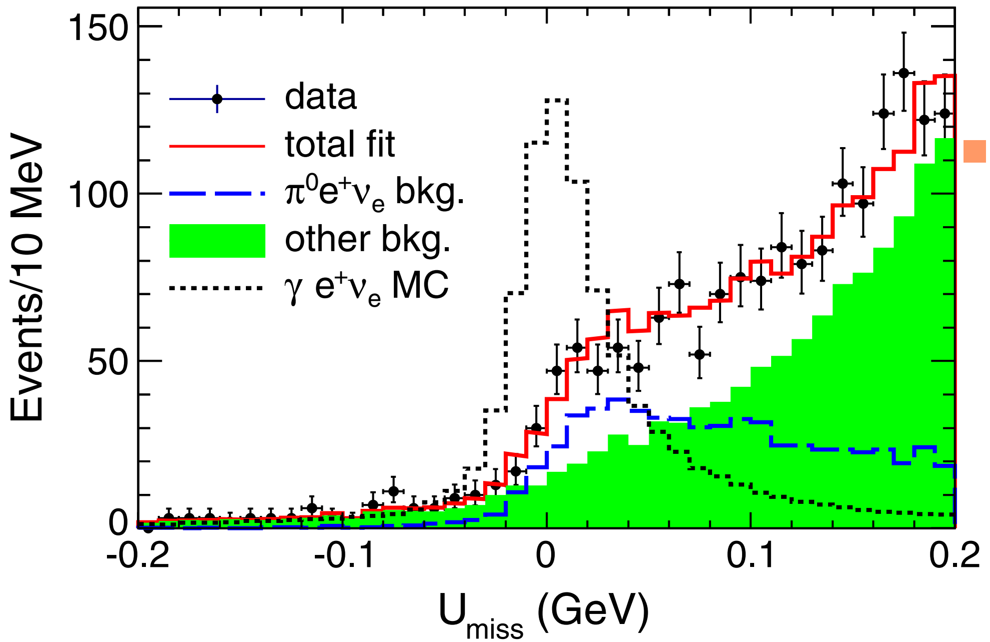
First measurement



Amplitude mode	FF(%)	Phase (ϕ)	Significance(σ)
$D \to SS$			
$D \to (K^-\pi^+)_{S\text{-wave}}(\pi^0\pi^0)_S$	$6.92 \pm 1.44 \pm 2.86$	$-0.75 \pm 0.15 \pm 0.47$	> 10
$D \to (K^-\pi^0)_{S\text{-wave}}(\pi^+\pi^0)_S$	$4.18 \pm 1.02 \pm 1.77$	$-2.90 \pm 0.19 \pm 0.47$	6.0
$D \to AP, A \to VP$			
$D \to K^-a_1(1260)^+, \rho^+\pi^0[S]$	$28.36 \pm 2.50 \pm 3.53$	0 (fixed)	> 10
$D \to K^-a_1(1260)^+, \rho^+\pi^0[D]$	$0.68 \pm 0.29 \pm 0.30$	$-2.05 \pm 0.17 \pm 0.25$	6.1
$D \to K_1(1270)^-\pi^+, K^{*-}\pi^0[S]$	$0.15 \pm 0.09 \pm 0.15$	$1.84 \pm 0.34 \pm 0.43$	4.9
$D \to K_1(1270)^0\pi^0, K^{*0}\pi^0[S]$	$0.39 \pm 0.18 \pm 0.30$	$-1.55 \pm 0.20 \pm 0.26$	4.8
$D \to K_1(1270)^0\pi^0, K^{*0}\pi^0[D]$	$0.11 \pm 0.11 \pm 0.11$	$-1.35 \pm 0.43 \pm 0.48$	4.0
$D \to K_1(1270)^0\pi^0, K^-\rho^+[S]$	$2.71 \pm 0.38 \pm 0.29$	$-2.07 \pm$ [illegible] ± 0.20	> 10
$D \to (K^{*-}\pi^0)_A\pi^+, K^{*-}\pi^0[S]$	$1.85 \pm 0.62 \pm 1.11$	1.9[illegible] $\pm 0.10 \pm 0.15$	7.8
$D \to (K^{*0}\pi^0)_A\pi^0, K^{*0}\pi^0[S]$	$3.13 \pm 0.45 \pm 0.58$	$0.44 \pm 0.12 \pm 0.21$	> 10
$D \to (K^{*0}\pi^0)_A\pi^0, K^{*0}\pi^0[D]$	$0.46 \pm 0.17 \pm 0.29$	$-1.84 \pm 0.26 \pm 0.42$	5.9
$D \to (\rho^+K^-)_A\pi^0, K^-\rho^+[D]$	$0.75 \pm 0.40 \pm 0.60$	$0.64 \pm 0.36 \pm 0.53$	5.1
$D \to AP, A \to SP$			
$D \to ((K^-\pi^+)_{S\text{-wave}}\pi^0)_A\pi^0$	$1.99 \pm 1.08 \pm 1.55$	$-0.02 \pm 0.25 \pm 0.53$	7.0
$D \to VS$			
$D \to (K^-\pi^0)_{S\text{-wave}}\rho^+$	$14.63 \pm 1.70 \pm 2.41$	$-2.39 \pm 0.11 \pm 0.35$	> 10
$D \to K^{*-}(\pi^+\pi^0)_S$	$0.80 \pm 0.38 \pm 0.26$	$1.59 \pm 0.19 \pm 0.24$	4.1
$D \to K^{*0}(\pi^0\pi^0)_S$	$0.12^{+0.27}_{-0.12} \pm 0.12$	$1.45 \pm 0.48 \pm 0.51$	4.1
$D \to VP, V \to VP$			
$D \to (K^{*-}\pi^+)_V\pi^0$	$2.25 \pm 0.43 \pm 0.45$	$0.52 \pm 0.12 \pm 0.17$	> 10
$D \to VV$			
$D[S] \to K^{*-}\rho^+$	$5.15 \pm 0.75 \pm 1.28$	$1.24 \pm 0.11 \pm 0.23$	> 10
$D[P] \to K^{*-}\rho^+$	$3.25 \pm 0.55 \pm 0.41$	$-2.89 \pm 0.10 \pm 0.18$	> 10
$D[D] \to K^{*-}\rho^+$	$10.90 \pm 1.53 \pm 2.36$	$2.41 \pm 0.08 \pm 0.16$	> 10
$D[P] \to (K^-\pi^0)_V\rho^+$	$0.36 \pm 0.19 \pm 0.27$	$-0.94 \pm 0.19 \pm 0.28$	5.7
$D[D] \to (K^-\pi^0)_V\rho^+$	$2.13 \pm 0.56 \pm 0.92$	$-1.93 \pm 0.22 \pm 0.25$	> 10
$D[D] \to K^{*-}(\pi^+\pi^0)_V$	$1.66 \pm 0.52 \pm 0.61$	$-1.17 \pm 0.20 \pm 0.39$	7.6
$D[S] \to (K^-\pi^0)_V(\pi^+\pi^0)_V$	$5.17 \pm 1.91 \pm 1.82$	$-1.74 \pm 0.20 \pm 0.31$	7.6
$D \to TS$			
$D \to (K^-\pi^+)_{S\text{-wave}}(\pi^0\pi^0)_T$	$0.30 \pm 0.21 \pm 0.30$	$-2.93 \pm 0.31 \pm 0.82$	5.8
$D \to (K^-\pi^0)_{S\text{-wave}}(\pi^+\pi^0)_T$	$0.14 \pm 0.12 \pm 0.10$	$2.23 \pm 0.38 \pm 0.65$	4.0

Ref:
柯百谦（高能所） Charmed meson hadronic decays at BESII

$D^+ \to \gamma e^+\nu_e$ search at BESIII



- **Double Tag analysis with $2.9\,fb^{-1}$ @3.773GeV**
- **pi° e v background normalization with dedicate DT analysis**

$$N^{\rm exp}_{\pi^0} = \frac{N^{\pi^0}_{\rm DT}}{\sum_i \frac{N^i_{\rm ST}}{\varepsilon^i_{\rm ST}} \varepsilon^i_{{\rm DT},\pi^0}} \sum_i \frac{N^i_{\rm ST}}{\varepsilon^i_{\rm ST}} \varepsilon^{i,\gamma}_{{\rm DT},\pi^0},$$

$D_s^+ \to \gamma e^+\nu_e$ is in progress

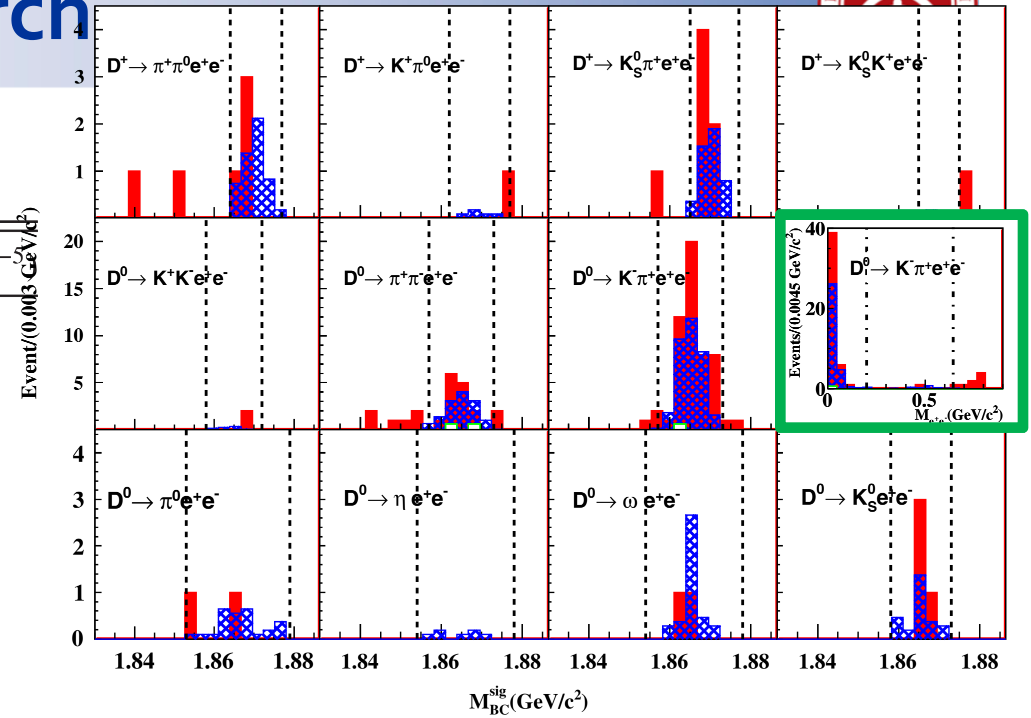
$$\mathcal{B}(D^+ \to \gamma e^+\nu_e) < 3.0 \times 10^{-5}.$$

With E_γ>10MeV

PHYSICAL REVIEW D 95, 071102(R) (2017)

Source	Relative uncertainty (%)
Signal MC model	3.5
e^+ tracking	0.5
e^+ PID	0.5
γ reconstruction	1.0
Lateral moment	4.4
$\pi^0 e^+\nu_e$ backgrounds	2.7[a]

D→h(h')ee search



Signal decays	$\mathcal{B}$ ($\times 10^{-5}$)	PDG [9] ($\times 10^{-5}$)
$D^+ \to \pi^+\pi^0 e^+e^-$	<1.4	$\cdots$
$D^+ \to K^+\pi^0 e^+e^-$	<1.5	$\cdots$
$D^+ \to K^0_S\pi^+ e^+e^-$	<2.6	$\cdots$
$D^+ \to K^0_S K^+ e^+e^-$	<1.1	$\cdots$
$D^0 \to K^-K^+ e^+e^-$	<1.1	<31.5
$D^0 \to \pi^+\pi^- e^+e^-$	<0.7	<37.3
$D^0 \to K^-\pi^+ e^+e^{-\dagger}$	<4.1	<38.5
$D^0 \to \pi^0 e^+e^-$	<0.4	<4.5
$D^0 \to \eta e^+e^-$	<0.3	<11
$D^0 \to \omega e^+e^-$	<0.6	<18
$D^0 \to K^0_S e^+e^-$	<1.2	<11
† in $M_{e^+e^-}$ regions:		
$[0.00, 0.20)$ GeV/c^2	<3.0 $(1.5^{+1.0}_{-0.9})$	$\cdots$
$[0.20, 0.65)$ GeV/c^2	<0.7	$\cdots$
$[0.65, 0.90)$ GeV/c^2	<1.9 $(1.0^{+0.5}_{-0.4})$	$\cdots$

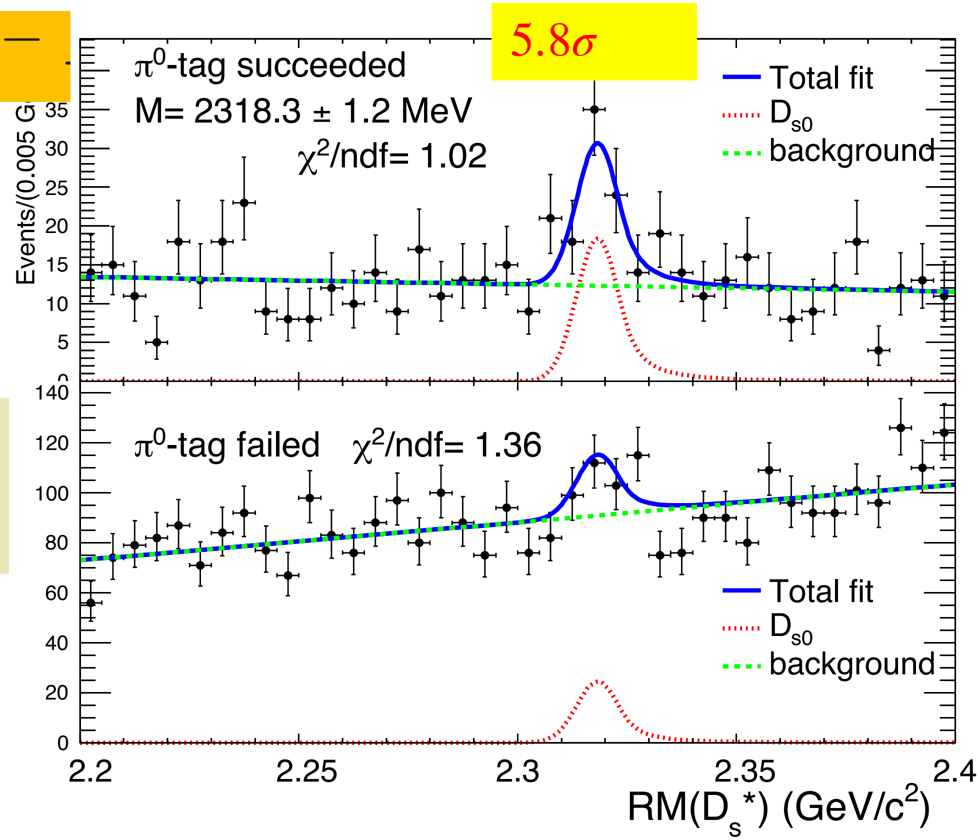
Phys. Rev. D 97, 072015 (2018)

- With double tag technique at threshold, both D⁰ and D⁺ FCNC are studied.
- UL for D⁺ 4-track events are provided for 1st time
- other FCNC upper limits are greatly improved
- divide the M(ee) distribution into 3 regions for Kpiee to help separate LD effect

absolute BF of $D_{s0}^*(2317)^{\pm} \rightarrow \pi^0 D_s^{\pm}$

$e^+e^- \rightarrow D_s^{*+} D_{s0}^*(2317)^-$

4.6GeV data 567pb^{-1}



M=(2318.3 ± 1.2 ± 1.2) MeV/c^2
BF=1.00+0.00 ± 0.14

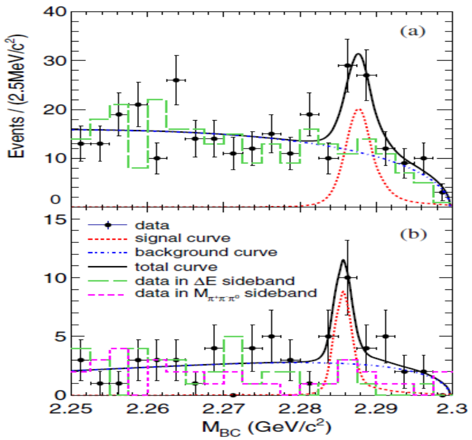
differs from the expectation of the conventional $c\bar{s}$ hypothesis of the $D_{s0}(2317)^-$ but agrees well with the calculation in the molecule picture

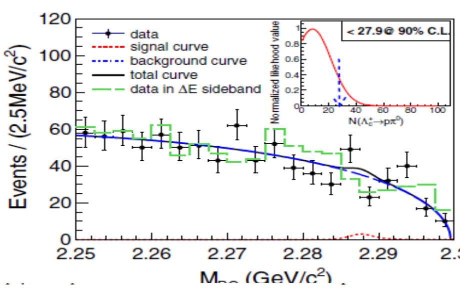
Phys. Rev. D 97, 051103 (2018)

Recent Λc decay results

- **Evidence of $\Lambda_c^+ \to p\eta$, and search for $\Lambda_c^+ \to p\pi^0$**

PRD95(2017)111102





$\Lambda_c \to \Xi^{(*)0} K^+$

PLB783, 200 (2018)

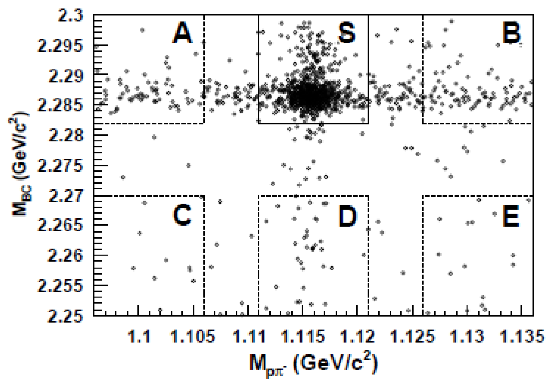
W-change only

[c]Calculated relying on different values of parameters b and α.

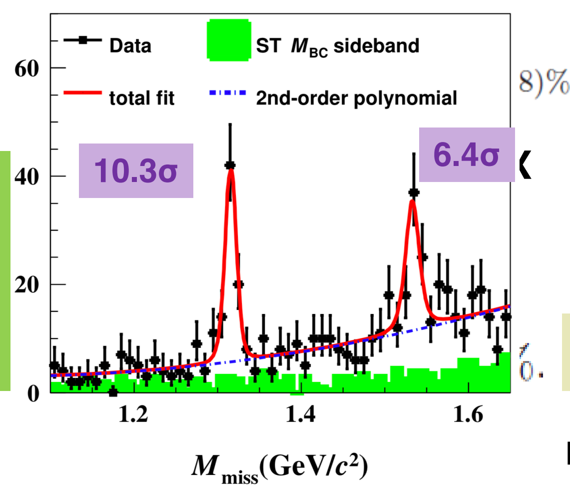
- **Measurement of $B[\Lambda_c^+ \to \Lambda X]$**

PRL121(2018)062003

PDG: $B[\Lambda_c^+ \to \Lambda X] = (35\pm11)\%$



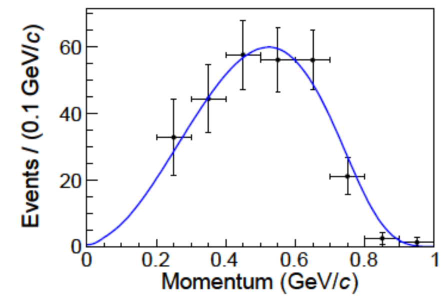
Important to calibrate the CF amplitude in charmed baryon sector, and guide



- **Measurement of $B[\Lambda_c^+ \to eX]$**

arXiv:1805.09060

PDG: $B[\Lambda_c^+ \to \Lambda X] = (4.5\pm1.7)\%$



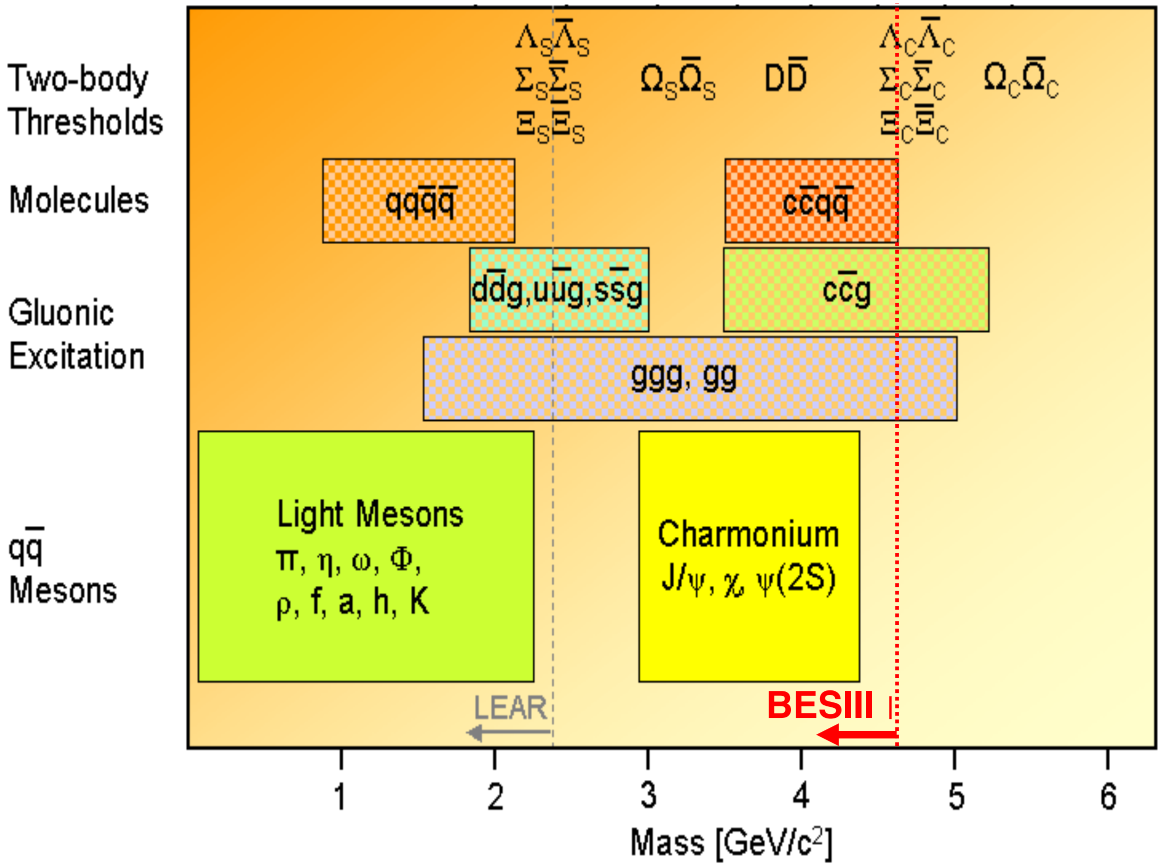
Test effective quark model calculation, and guide experimental searches.

$$\mathcal{B}(\Lambda_c^+ \to X e^+ \nu_e) = (3.95 \pm 0.34 \pm 0.09)\%$$

Result	$\Lambda_c^+ \to X e^+ \nu_e$	$\frac{\Gamma(\Lambda_c^+ \to X e^+ \nu_e)}{\Gamma(D \to X e^+ \nu_e)}$
BESIII	3.95 ± 0.35	1.26 ± 0.12
MARK II [7]	4.5 ± 1.7	1.44 ± 0.54
Effective-quark Method [9, 10]		1.67
Heavy-quark Expansion [11]		1.2

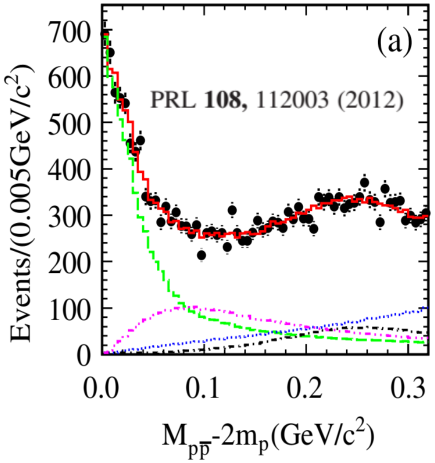
Ref: 潘　越（中科大）

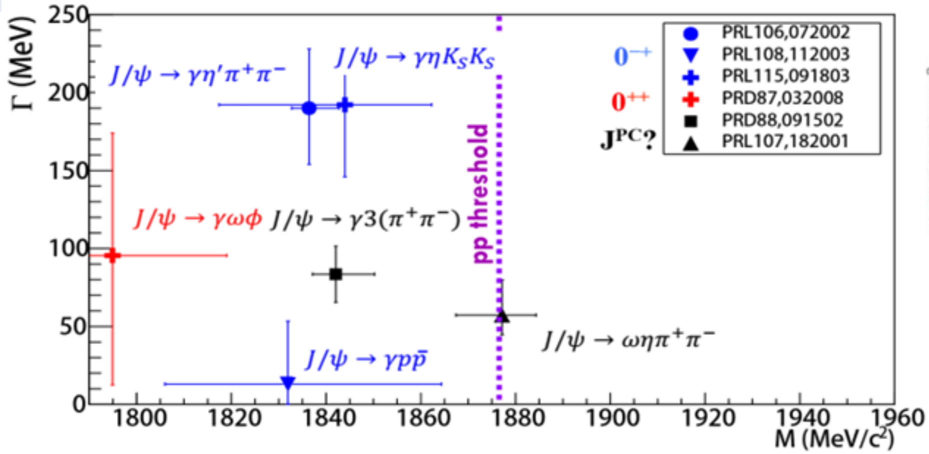
Hadron Landscape at BESIII

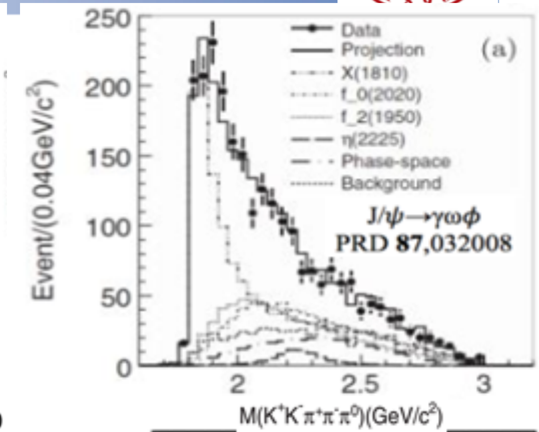


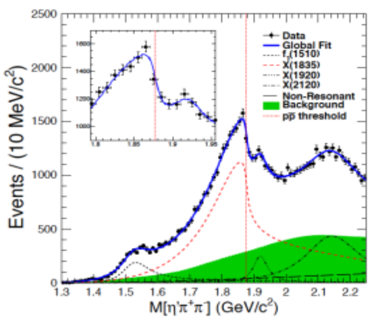
- Understanding of established states: precision spectroscopy
- Nature of exotic states: search and spectroscopy of unexpected states

$X(p\bar{p})$ and X(1835)







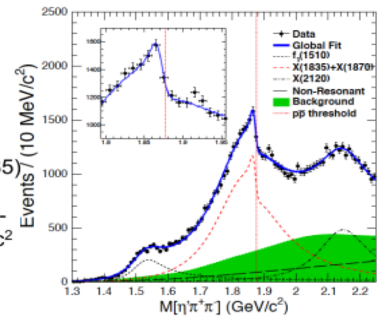


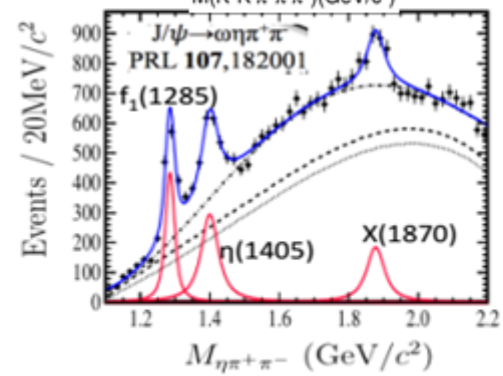
Connection is emerging

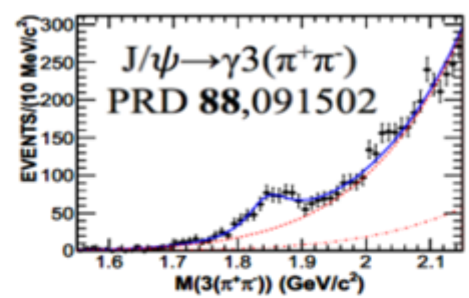
PRL 117, 042002 (2016)

Model 1:
Flatte lineshape with strong coupling to $p\bar{p}$ and one additional, narrow Breit-Wigner at ~1920 MeV/c²

Model 2:
Coherent sum of X(1835) Breit-Wigner and one additional, narrow Breit-Wigner at ~1870 MeV/c²







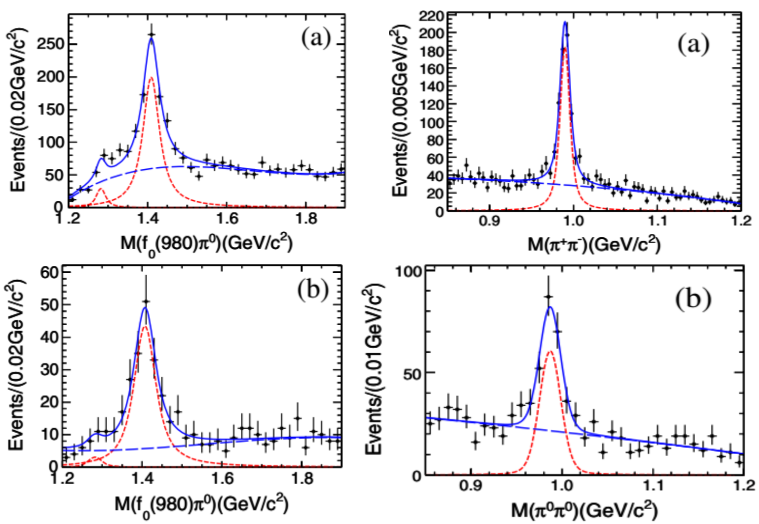
- **Suggest the existence of a state, either a broad one with strong couplings to $p\bar{p}$, or a narrow state just below the $p\bar{p}$ mass thresh.**
- **Support the existence of a $p\bar{p}$ molecule-like state or bound state**

- **Any relations?**
- **What is the role of the ppbar threshold (and other thresholds)?**
- **Patterns in the production and decay modes**

η(1405)/η(1475)

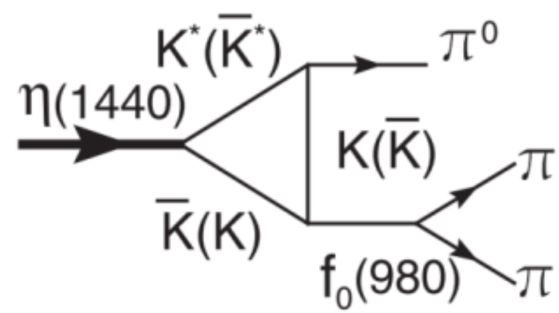
- η(1405)/η(1475) are two different states or one 0^{-+} state in different decay modes?
- MARK III reported two states mixture in the 1400 MeV/c² region for the first time in the PWA of $J/\psi \to \gamma K_S^0 K^{\pm}\pi^{\mp}$.
  - ✓ Described by $a_0(980)\pi$ and K^*K amplitudes [Phys. Rev. Lett. **65**, 2507 (1990)]
- Confirmed by Crystall Barrel and Obelix [Phys. Lett. B **545**, 261 (2002)]
- No observation by L3 on η(1405). Both states not found by CLEO

✓ First observation of $\eta(1405)\to f_0(980)\pi^0$ by BESIII in $J/\psi\to\gamma 3\pi$ decay with a narrow resonance $f_0(980)$ and isospin violation. [PRL **108**, 182001 (2012)]



According to triangle singularity, the shift of the peak positions in different channels occurs via the intermediate $K^*\bar{K} + c.c$ rescattering [PRL **108**, 081803 (2012)]

η(1405) and η(1475) could be one state appeared as different line shape in different channel

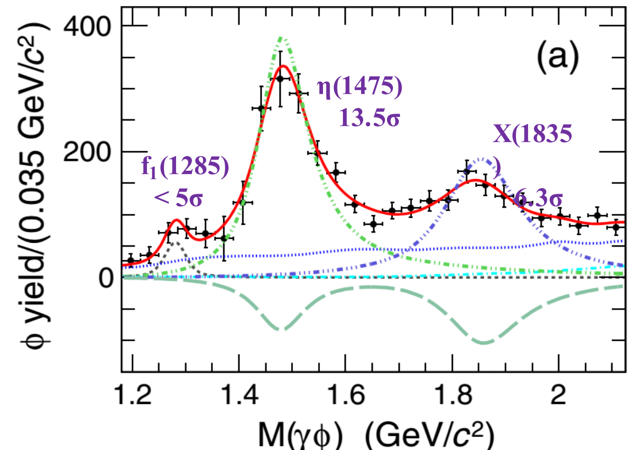


Observation of η(1475) and X(1835) in $J/\psi \to \gamma\gamma\phi$

- Two resonance structures corresponding to η(1475) and X(1835) mass positions are observed in the ϕ yield versus M(γϕ) data
  - ✓ Angular distributions are in favor of 0^{-+}
  - ✓ Measured M and Γ are consistent with η(1475) and X(1835)

Solution	Resonance	m_R (MeV/c^2)	Γ (MeV)	B (10^{-6})
I	$\eta(1475)$	$1477 \pm 7 \pm 13$	$118 \pm 22 \pm 17$	$7.03 \pm 0.92 \pm 0.91$
	$X(1835)$	$1839 \pm 26 \pm 26$	$175 \pm 57 \pm 25$	$1.77 \pm 0.35 \pm 0.25$
II	$\eta(1475)$	$1477 \pm 7 \pm 13$	$118 \pm 22 \pm 17$	$10.36 \pm 1.51 \pm 1.54$
	$X(1835)$	$1839 \pm 26 \pm 26$	$175 \pm 57 \pm 25$	$8.09 \pm 1.99 \pm 1.36$

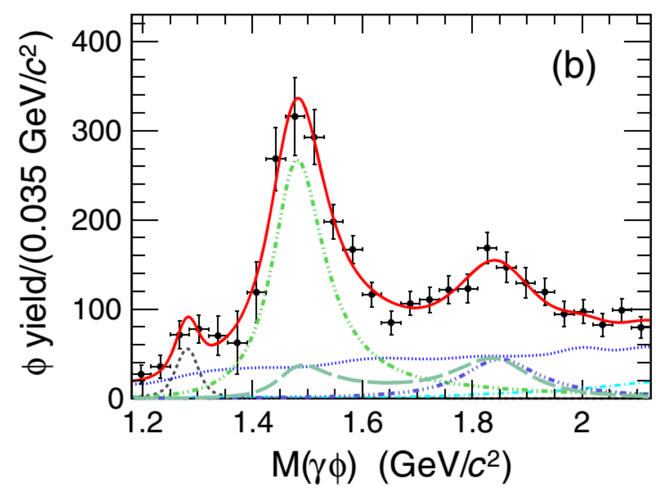
Solution1: constructive interference

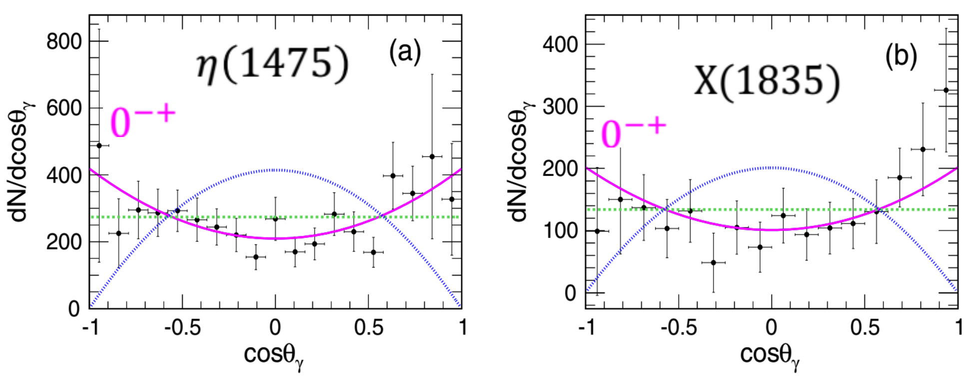


- $\Gamma(\eta(1405/1475)\to\gamma\rho):\Gamma(\eta(1405/1475)\to\gamma\phi)$ is slightly larger than the prediction of 3.8:1 in PRD 87, 014023 (2013) for the case of a single pseudoscalar state.
- Interpretation of $\eta(1475)/X(1835)\to\gamma\phi$
  - ✓ Sizable $s\bar{s}$ component
  - ✓ η(1475) could be a radial excitation of the η′, if η(1405) and η(1475) are different states [PRD 70, 114033 (2013)]

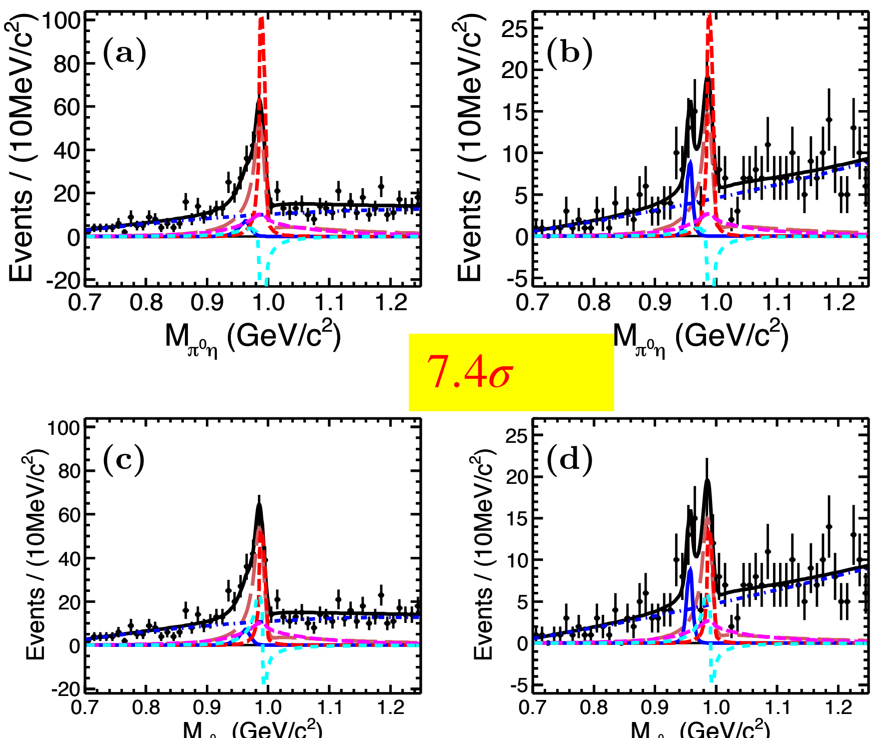
Phys. Rev. D 97, 051101(R) (2018)

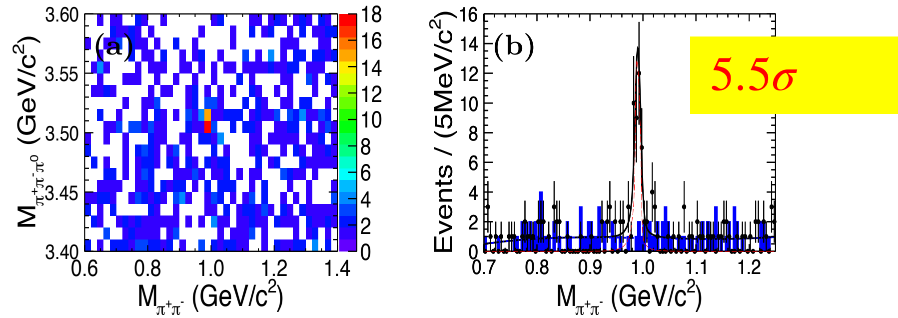
Solution II: destructive interference



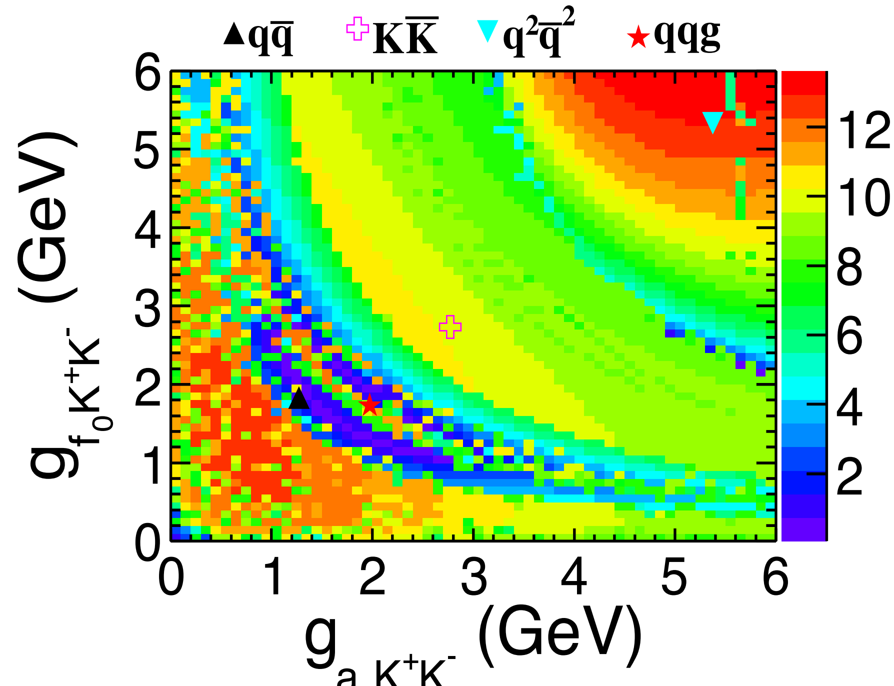


Observation of $a_0(980)$-$f_0(980)$ Mixing





$$\xi_{af} = \frac{\mathcal{B}(\chi_{c1} \to \pi^0 a_0^0(980) \to \pi^0 f_0(980) \to \pi^0\pi^+\pi^-)}{\mathcal{B}(\chi_{c1} \to \pi^0 a_0^0(980) \to \pi^0\pi^0\eta)}.$$

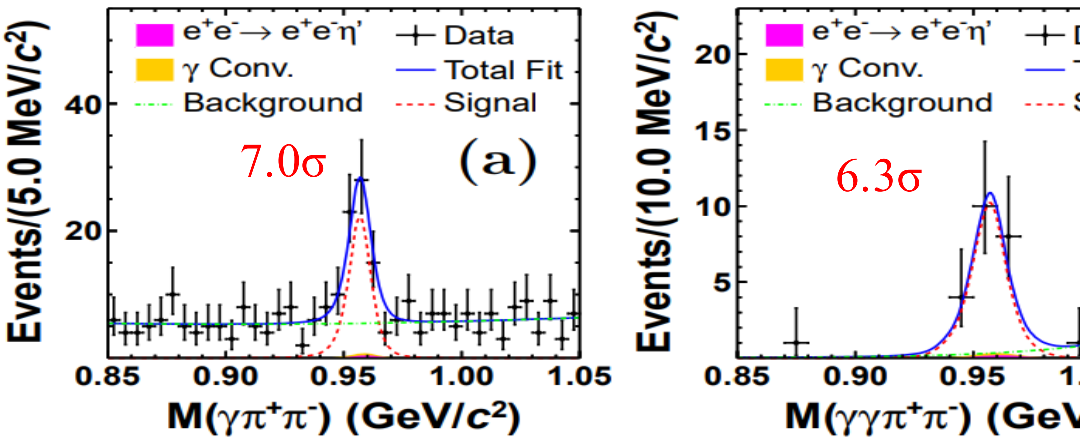


$$\xi_{fa} = \frac{\mathcal{B}(J/\psi \to \phi f_0(980) \to \phi a_0^0(980) \to \phi\eta\pi^0)}{\mathcal{B}(J/\psi \to \phi f_0(980) \to \phi\pi\pi)},$$

Phys.Rev.Lett. 121 (2018), 022001
Editor's suggestion

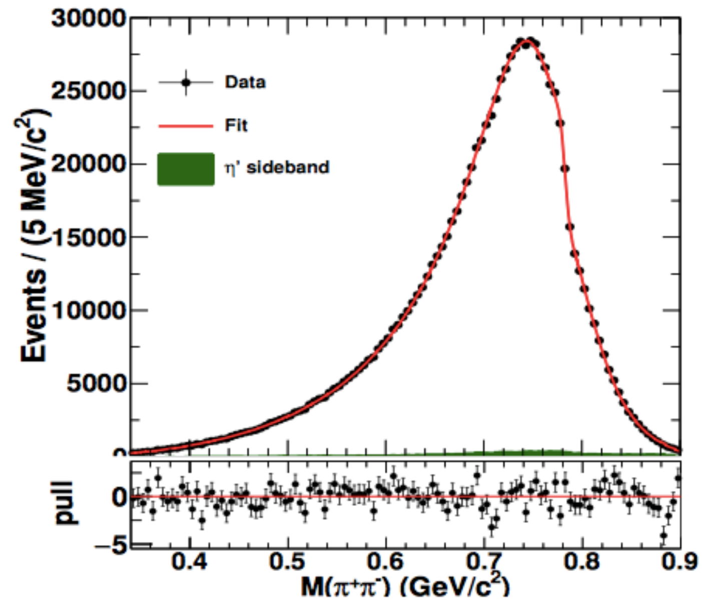
dynamics and meson structure

Observation of $\psi(3686) \to \eta' e^+ e^-$



arxiv:1803. 09714,
Phys. Lett. B 783 (2018) 452

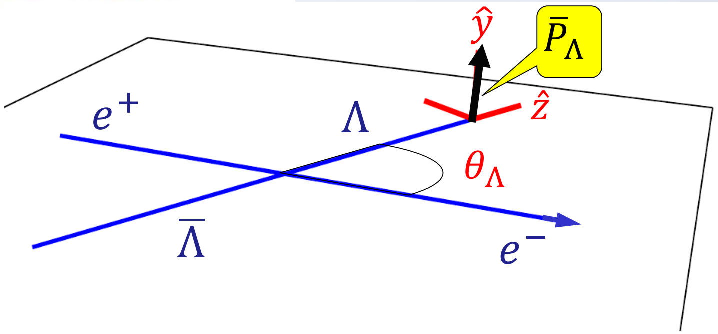
precision study of $\eta' \to \gamma\pi^+\pi^-$



Dalitz type decays to provide more info about meson structure, and plays important role in constraining the uncertainties to $(g\text{-}2)_\mu$

Phys.Rev.Lett. 120 (2018), 242003

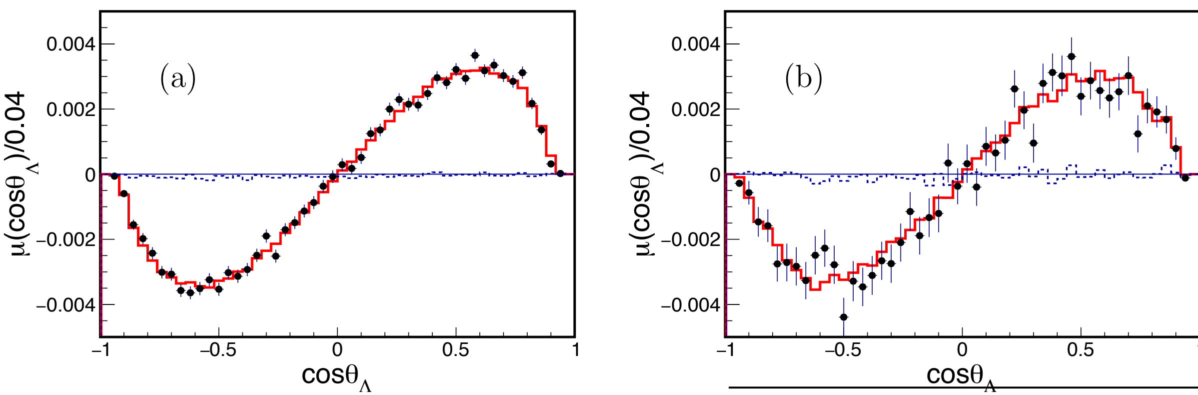
Observation of spin polarization



$$\bar{P}_\Lambda(\theta_\Lambda) = \frac{\sqrt{1-\alpha_\psi}\cos\theta_\Lambda \sin\theta_\Lambda}{1+\alpha_\psi \cos^2\theta_\Lambda}\sin(\Delta\Phi)\hat{y}$$

Moment: $\mu(\cos\theta_\Lambda) = \frac{1}{N}\sum_i (\sin\theta_1^i \sin\phi_1^i - \sin\theta_2^i \sin\phi_2^i$

ΔΦ=42.4±0.6±0.5 (degree)

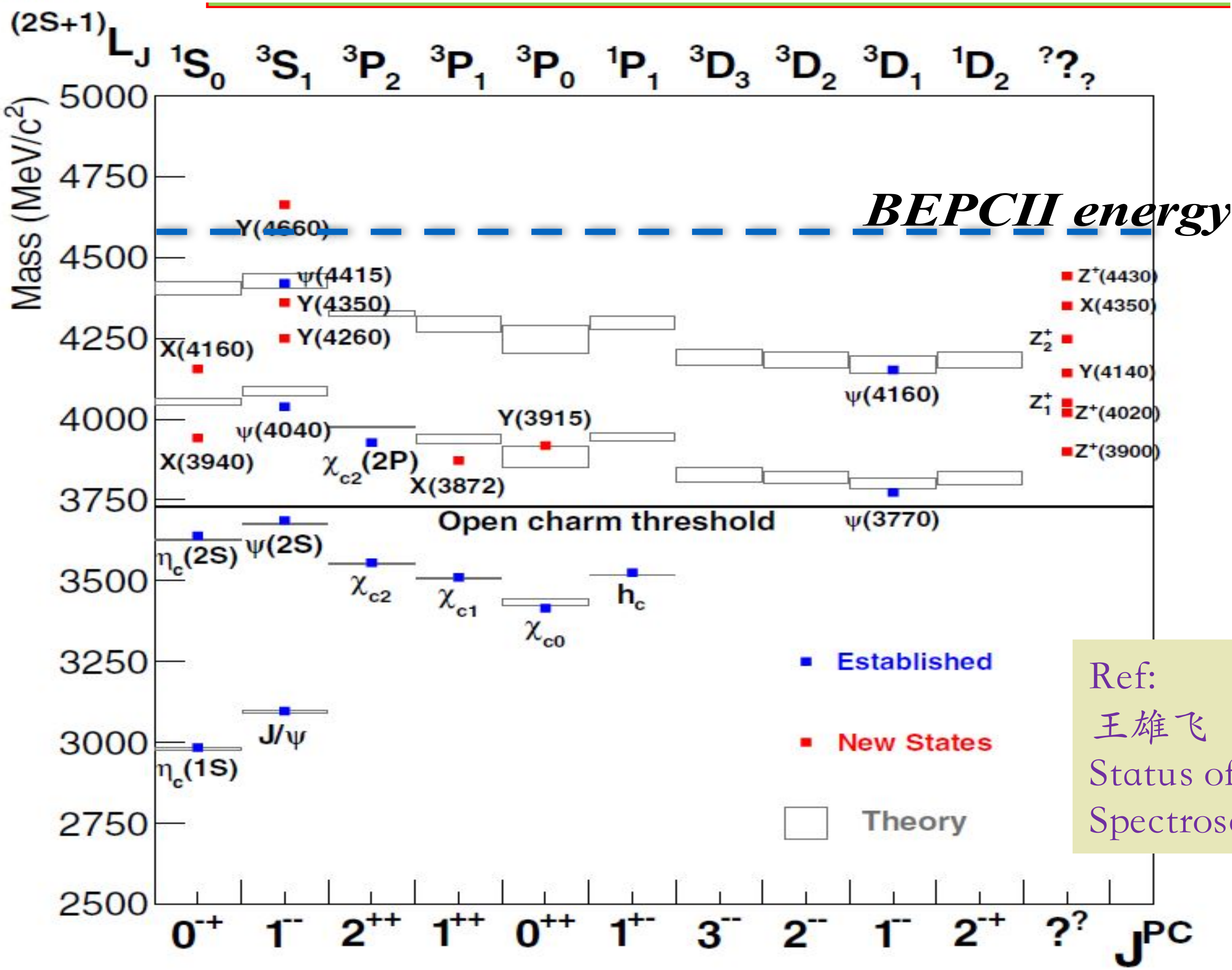


Ref:平荣刚（高能所）
BESIII上超子的横向极化
和CP破坏研究

arxiv:1808. 08917
In review of Nature Physics

Parameters	This work	Previous results
α_ψ	$0.461 \pm 0.006 \pm 0.007$	0.469 ± 0.027 [25]
$\Delta\Phi$	$(42.4 \pm 0.6 \pm 0.5)^\circ$	–
α_-	$0.750 \pm 0.009 \pm 0.004$	0.642 ± 0.013 [27]
α_+	$-0.758 \pm 0.010 \pm 0.007$	-0.71 ± 0.08 [27]
$\bar{\alpha}_0$	$-0.692 \pm 0.016 \pm 0.006$	–
A_{CP}	$-0.006 \pm 0.012 \pm 0.007$	0.006 ± 0.021 [27]
$\bar{\alpha}_0/\alpha_+$	$0.913 \pm 0.028 \pm 0.012$	–

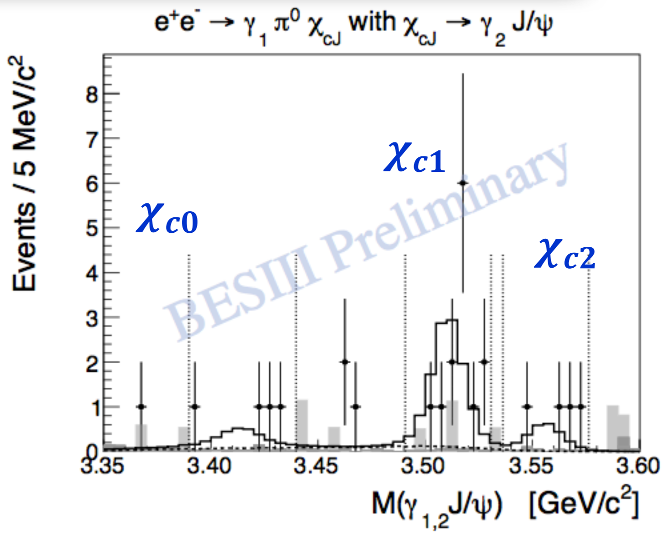
Charmonia and XYZ



Ref:
王雄飞（高能所）
Status of Charmonium Spectroscopy

Observation of for X(3872) to pi⁰ chic1

9.0 fb⁻¹ for $4.15 < E_{CM} < 4.30$ GeV



We measure branching ratios

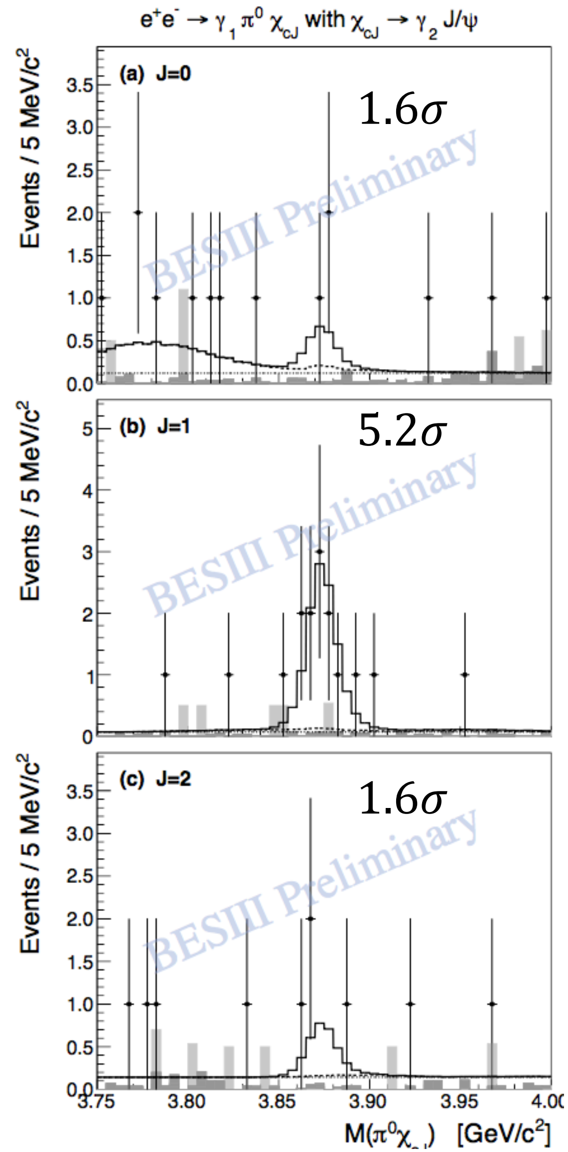
$R_J = B(X \to \pi^0 \chi_{cJ}) / B(X \to \pi^+\pi^- J/\psi)$:

$R_0 < 19$ (90% U.L.)

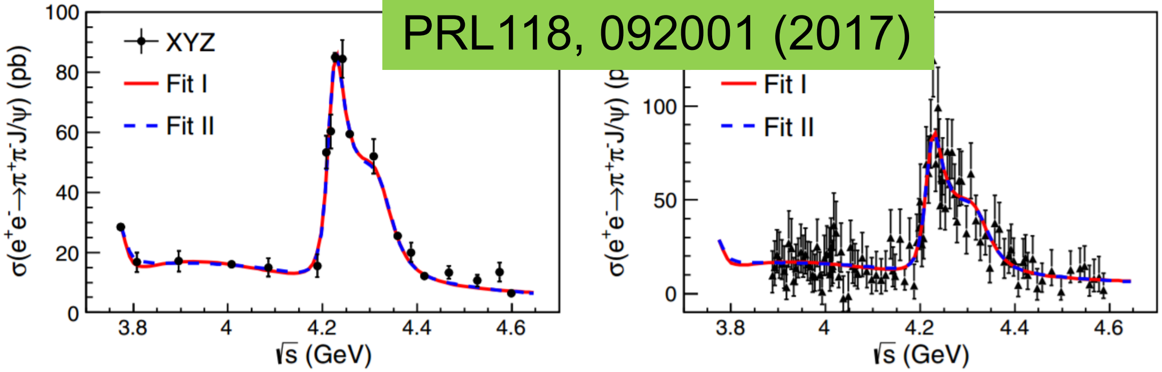
$R_1 = 0.88^{+0.31}_{-0.26} \pm 0.14$

$R_2 < 1.0$ (90% U.L.)

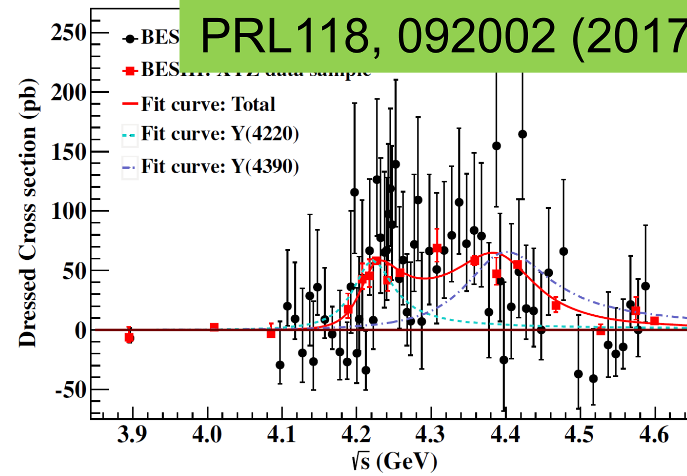
The large value for *R* disfavors the $\chi_{cJ}(2P)$ interpretation of the X(3872).



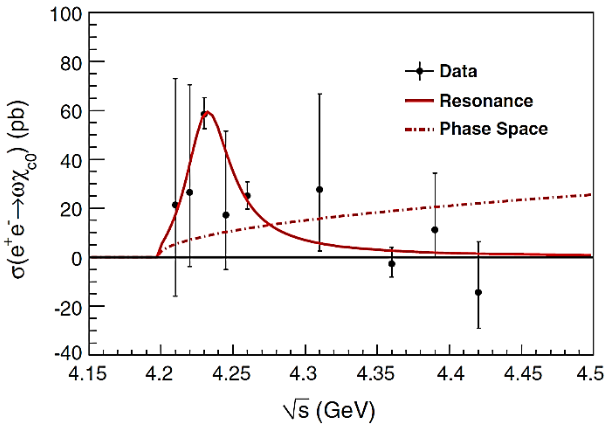
Y(4260)=>Y(4220)



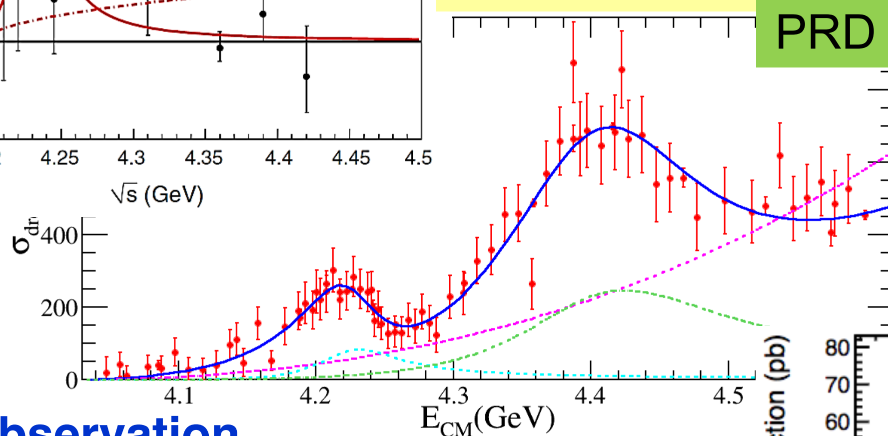
PRL118, 092001 (2017)

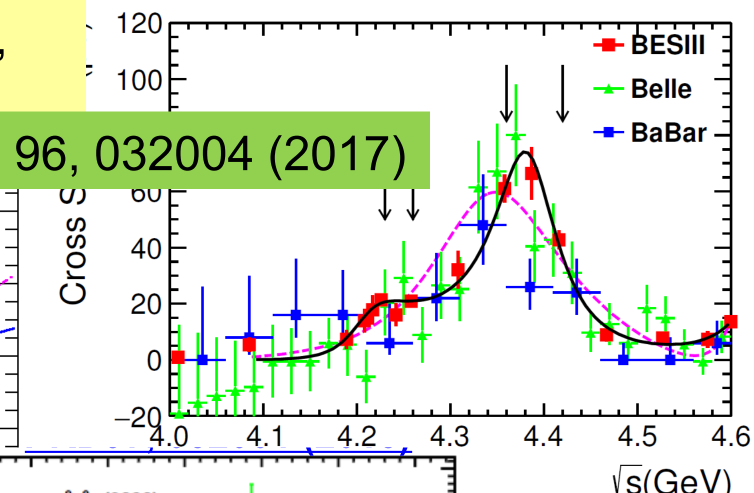


PRL118, 092002 (2017)

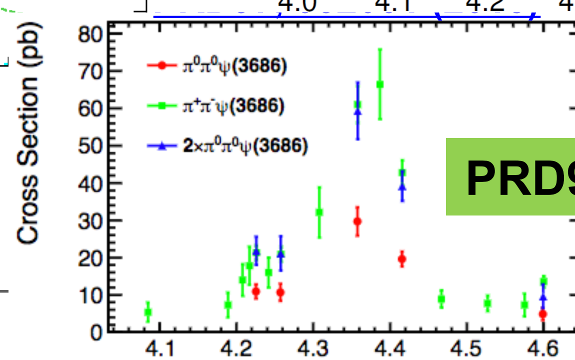


Consistent values of Mass~4220 MeV, Width~ 60 MeV!





PRD 96, 032004 (2017)

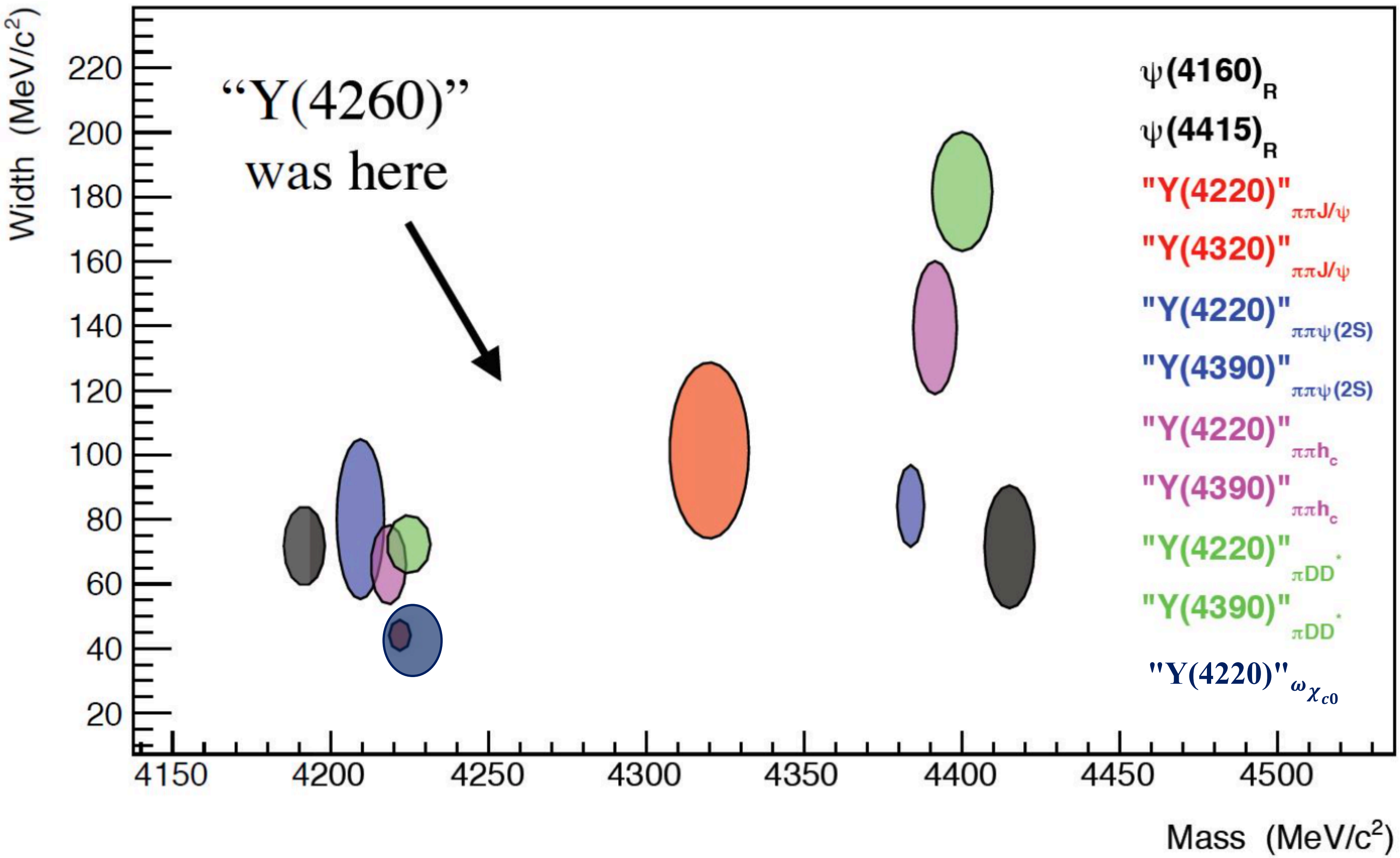


PRD97, 052001 (2018)

First observation of Y decays to open charm

arXiv:1808.02847

BESIII measurement



Search for Zc->$\rho\eta_c$

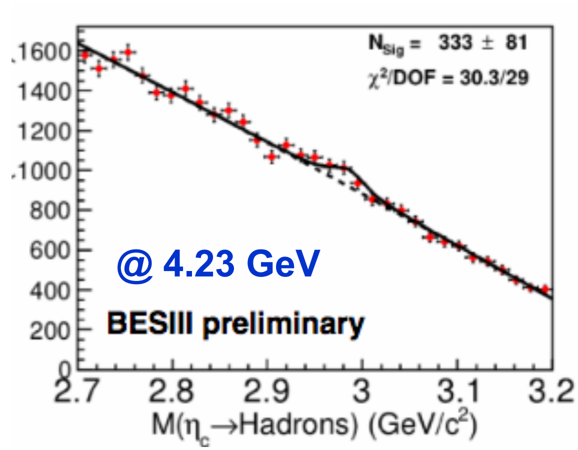
- Search for new decay mode of $Z_c(3900)$ and $Z_c(4020)$
- The ratios of $Z_c^{(\prime)} \rightarrow \rho\eta_c$ to $Z_c^{(\prime)} \rightarrow \pi J/\psi(\pi h_c)$ may discriminate **the tetra-quark** and **molecule** models.

Date sets:

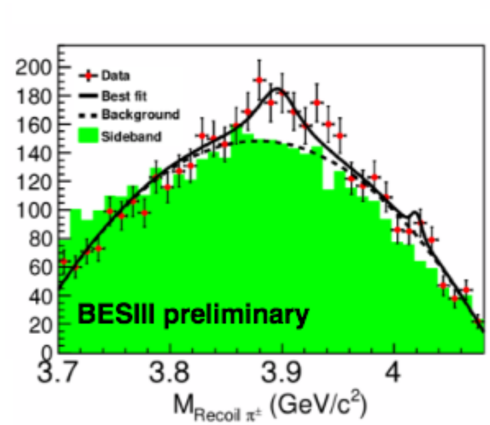
- ~4 fb^{-1} data set distributed at $\sqrt{s} =$ 4.23,4.26,4.36,4.40,4.60 GeV

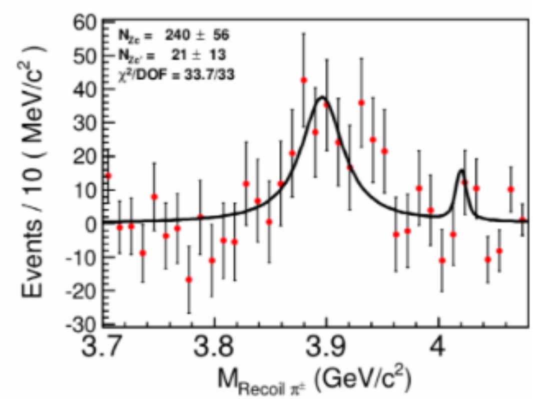
Strategy of this analysis:

- Start with looking for $e^+e^- \rightarrow \pi^+\pi^-\pi^0\eta_c, \eta_c \rightarrow 9$ hadronic decays



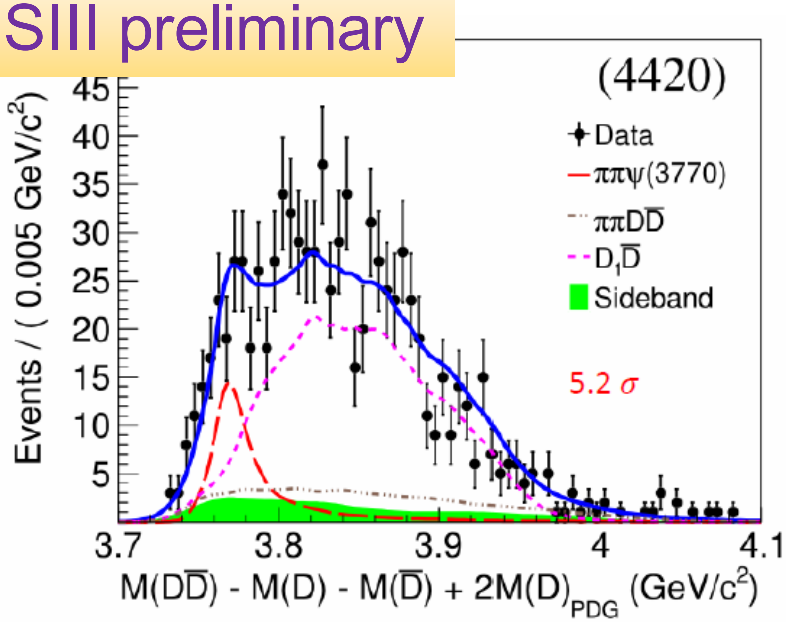
- Strong evidence of $e^+e^- \rightarrow \pi Z_c, Z_c \rightarrow \rho\,\eta_c$ is observed at $\sqrt{s} = 4.23$, statistical significance is 4.3σ. (3.9σ including systematics)
- $e^+e^- \rightarrow \pi Z_c', Z_c' \rightarrow \rho\,\eta_c$ is not seen in all data sets.

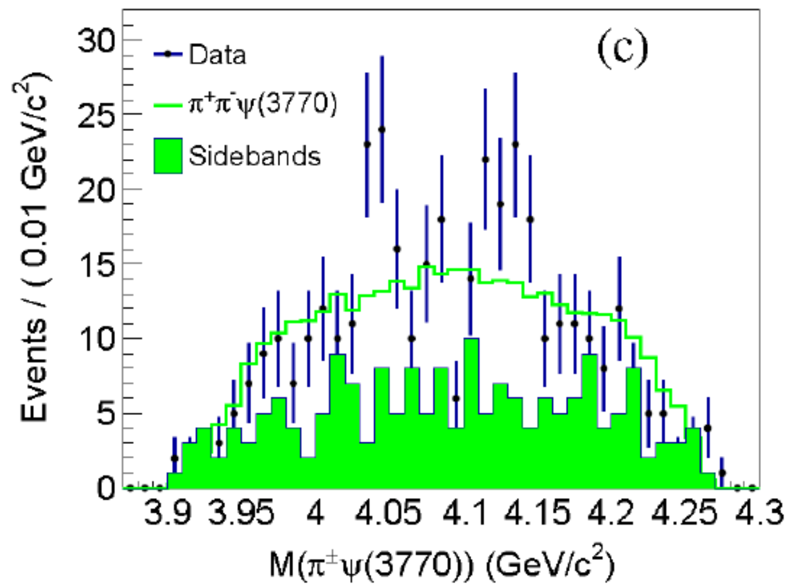




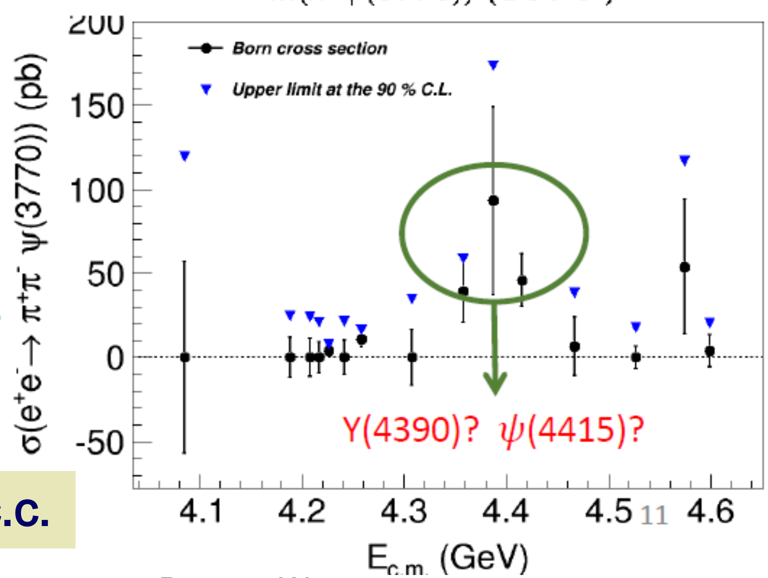
Observation of $e^+e^- \to \pi^+\pi^-\psi''$

BESIII preliminary



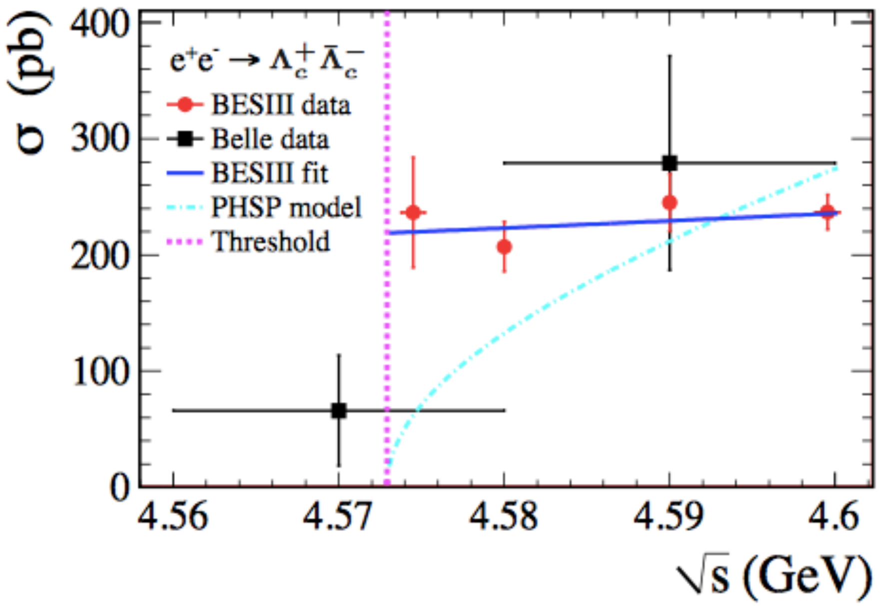


- Observed the process $e^+e^- \to \pi^+\pi^-\psi(3770)$.
- No $\psi(1^3D_3)$ signal and no significant signal of Z_c in the $\pi^{\pm}\psi(3770)$ system.
- Clear structure in the line-shape of $\pi^+\pi^-\psi(3770)$.



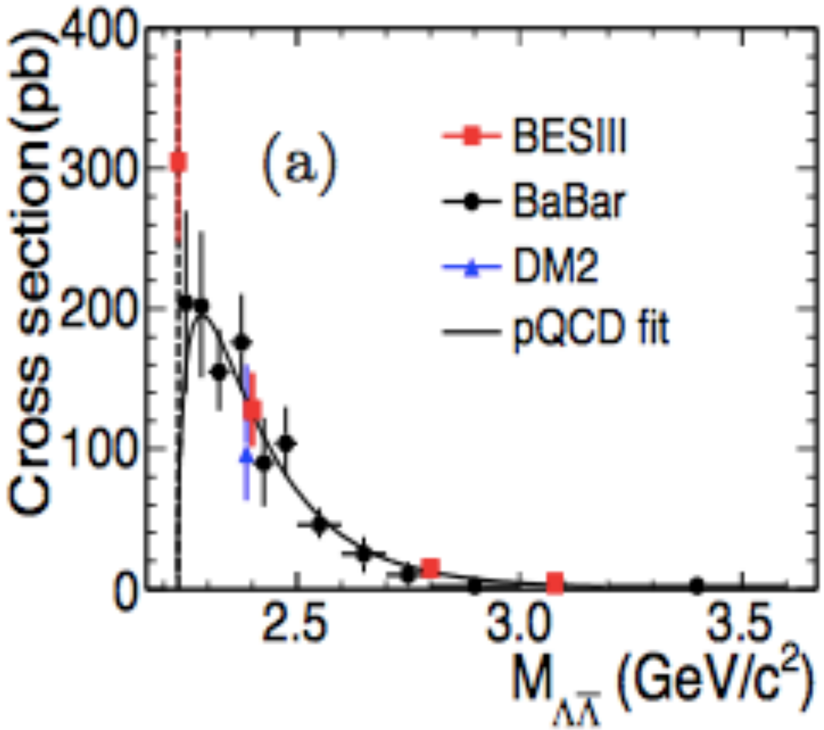
Also observed $e^+e^- \to \bar{D}D_1(2420)$+c.c.

Enhancement of hyperon pair production near threshold



Phys. Rev. Lett. 120, 132001 (2018)

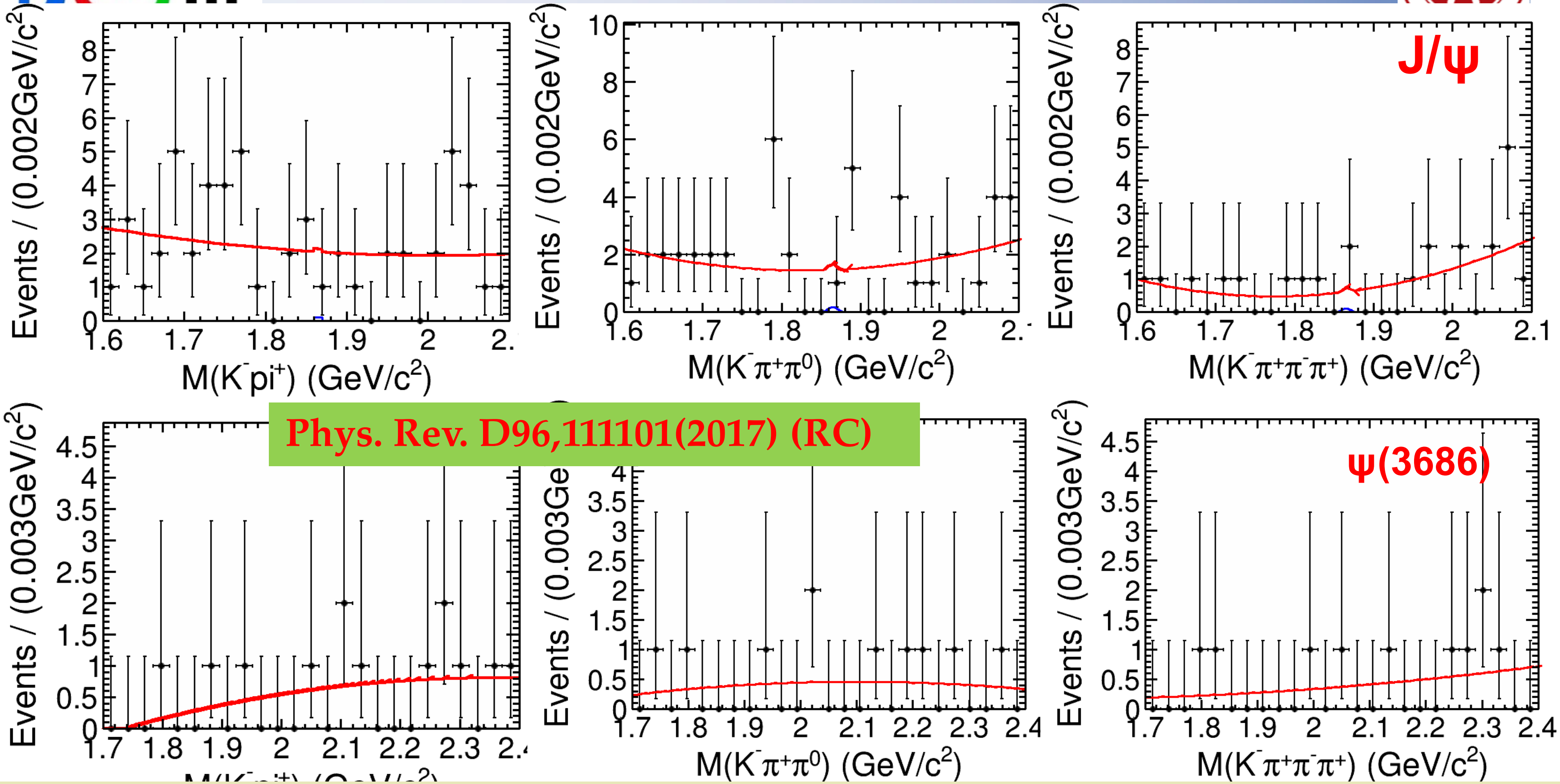
Phys. Rev. D 97, 032013 (2018)



Coulomb enhancement factor?

$$\sigma_{B\bar{B}}(q) = \frac{4\pi\alpha^2 C\beta}{3q^2}\left[|G_M(q)|^2 + \frac{1}{2\tau}|G_E(q)|^2\right]$$

Search for J/ψ[ψ(3686) → $D^0e^+e^-$.



Phys. Rev. D96,111101(2017) (RC)

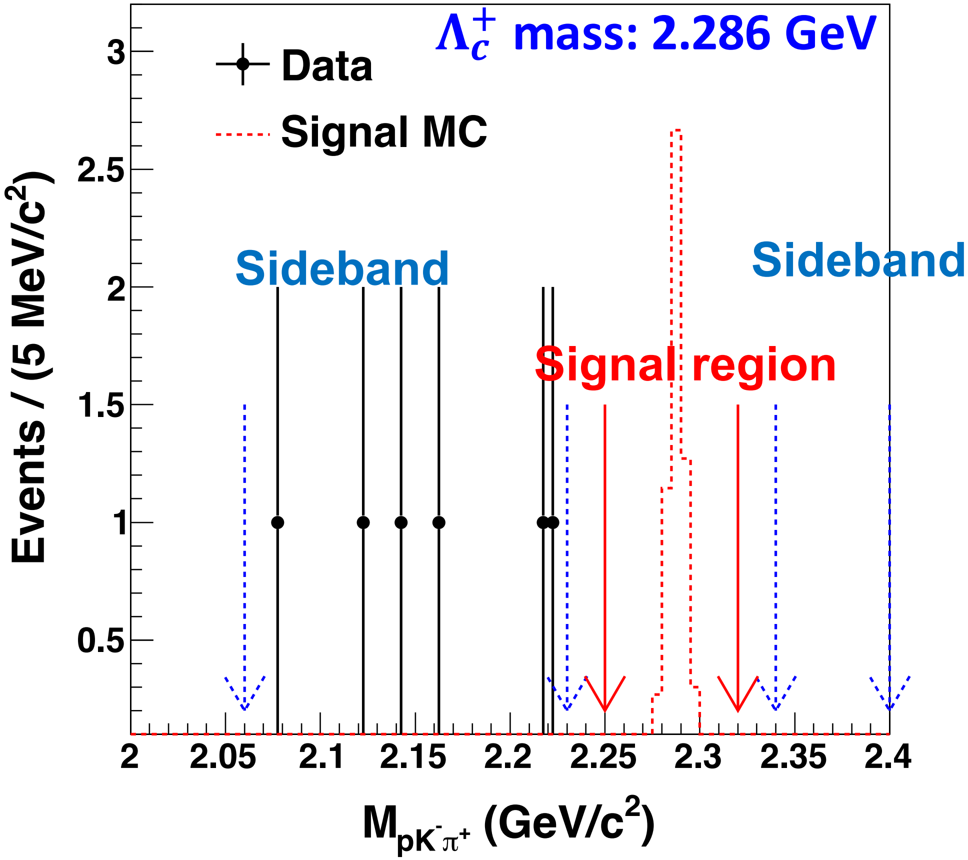
Considering the systematic uncertainty, at 90%C.L.

J/ψ→ $D^0e^+e^- + c.c. < 8.5\times10^{-8}$ 2 orders improvement over PLB 639, 418 (2006)

ψ(3686)→ $D^0e^+e^- + c.c.\ < 1.4\ \times\ 10^{-7}$ set for the first time

$\psi(3686) \to \Lambda_c^+ \bar{p} e^+ e^-$ search

Signal region:2.25-2.32 GeV.



Phys. Rev. D 97, 091102(RC)(2018)

- **No signal is found.**
- **the 90% C.L. upper limit (Nup=47.3) is obtained taking into account the efficiency and systematic uncertainties.**

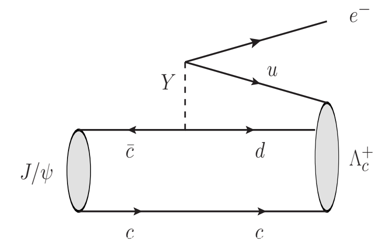
Nucl. Instrum. Methods A 551 (2005) 493– 503.

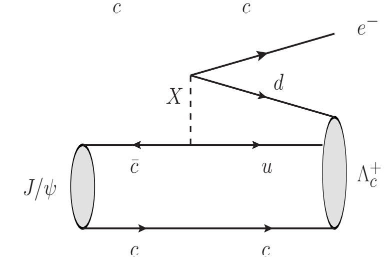
- **The BF upper limit @90% C.L. is determined to be 1.7×10^{-6} with systematic uncertainties taken into account.**

Search for BNV process $J/\psi \to \Lambda_c^+ e^-$

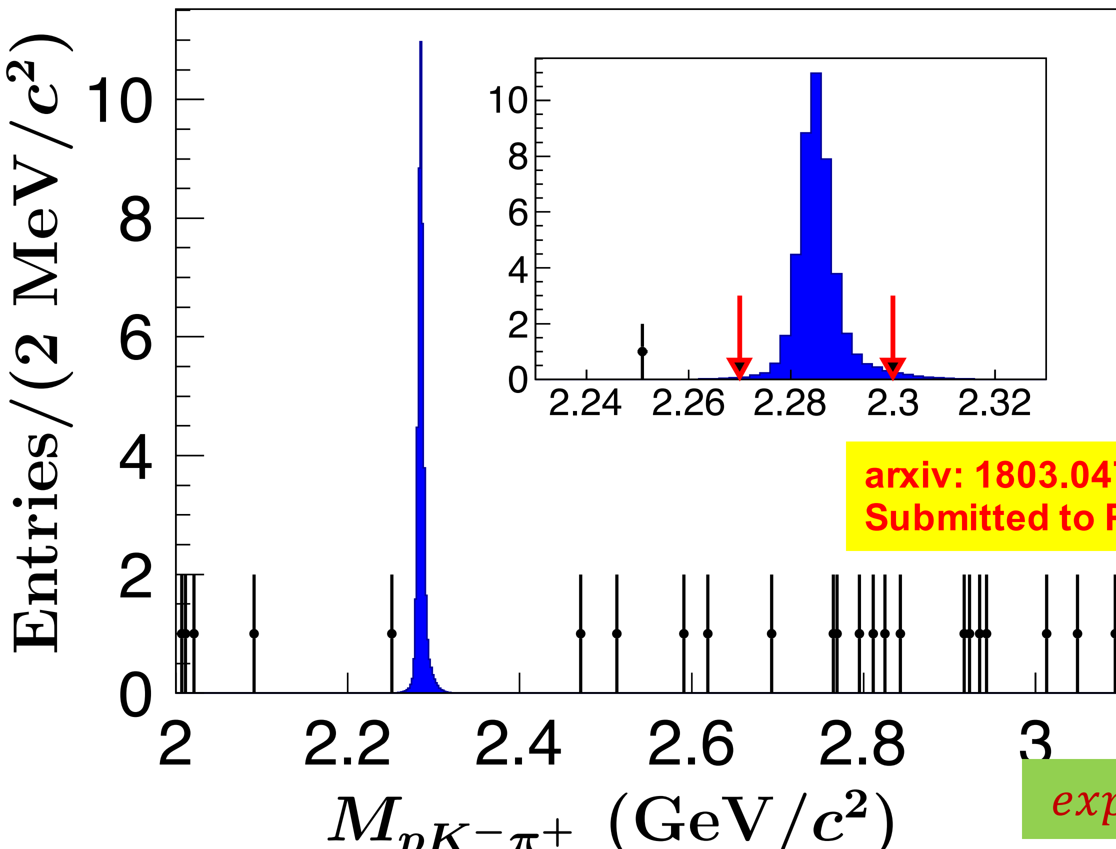
- The first of **"Sakharov conditions"**: "there must be BNV process"
- Many theory could have BNV, e.g. Georgi – Glashow GUT model, X and Y bosons with charges 4/3 and 1/3, BNV and LNV

Phys.Rev.Lett. 32 (1974) 438-441





$\Delta B=1$, $\Delta(B-L)=0$



$B(J/\psi \to \Lambda_c^+ e^-) < 6.9 \times 10^{-8}$

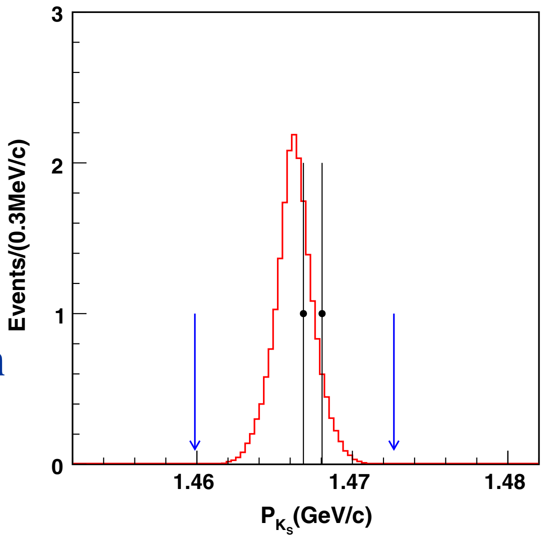
arxiv: 1803.04789
Submitted to PRL

expected UL with 10^{10} J/ψ: 10^{-9}

Measurement of $J/\psi \to K_S K_L$ and search for $J/\psi \to K_S K_S$

Search for $J/\psi \to K_S K_S$

- CP and Bose-Einstein statistics violating process
- EPR: $\sim 10^{-8}$ level
- K^0 oscillation model: 10^{-9}
- Compared MARKIII and BESII, the upper limit is improved by 10^2 and reaches the order of EPR expectation



$N_{\rm obs}$	2
$N_{\rm bkg}$	2.4
N^{UL}	4.7
$\epsilon_{\rm MC}$ (%)	25.7
$\mathcal{B}(J/\psi \to K_S K_S)$ (95% C.L.)	$< 1.4 \times 10^{-8}$

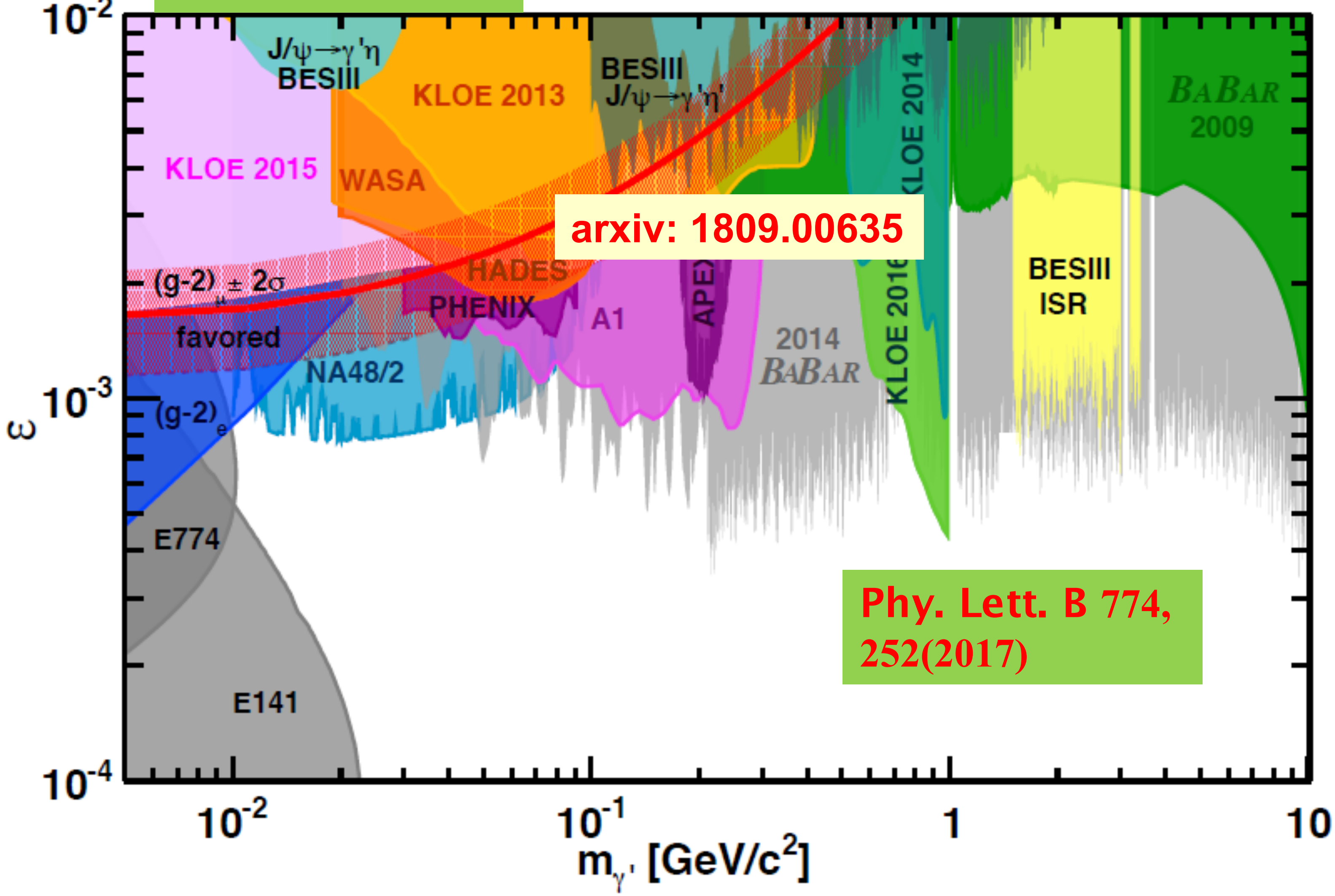
arXiv: 1710.05738
PRD 96, 112001 (2017)

Measurement of $\mathcal{B}(J/\psi \to K_S K_L)$

- $\mathcal{B}(J/\psi \to K_S K_L) = (1.91 \pm 0.01(stat.) \pm 0.05(syst.))\times 10^{-4}$.
- the precision is improved from 19%(PDG) to 2.6%, while the central value consistent.

Dark photon searches at BESIII

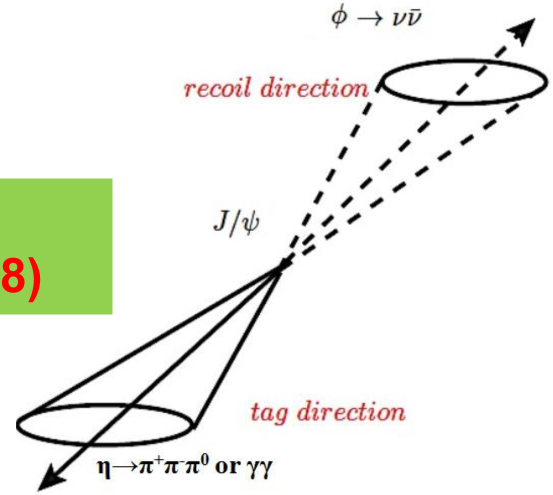
arxiv: 1810.03091

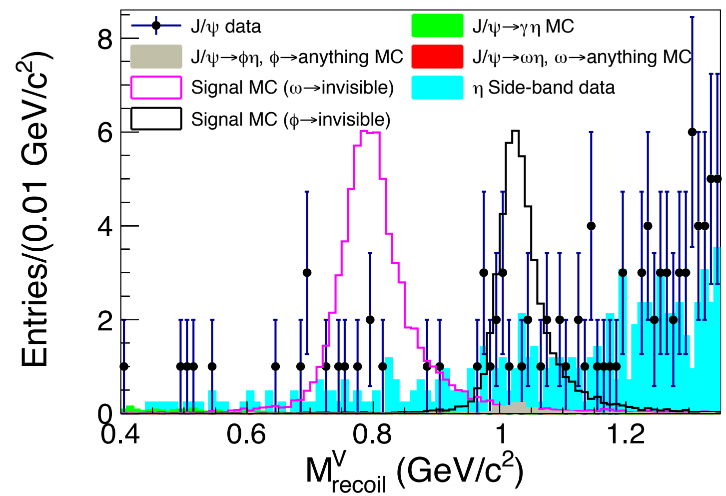


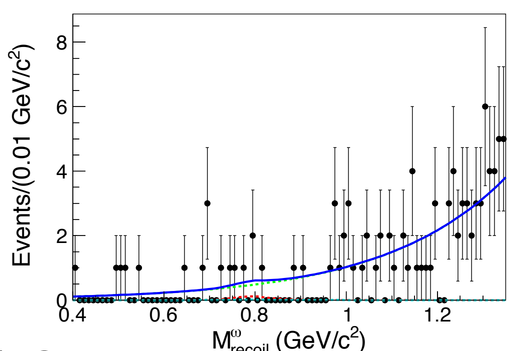
Omega and phi invisible decay

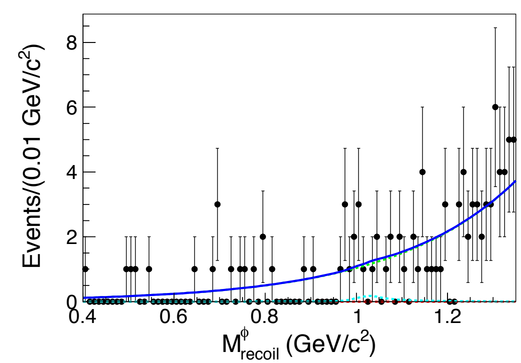
The first search of invisible decays of light vector mesons

arxiv:1805.05613
PRD 98, 032001(2018)









Upper limits set at 90% C.L.

$$\frac{\mathcal{B}(\omega\to\text{invisible})}{\mathcal{B}(\omega\to\pi^+\pi^-\pi^0)} < 8.1\times10^{-5} \qquad \frac{\mathcal{B}(\phi\to\text{invisible})}{\mathcal{B}(\phi\to K^+K^-)} < 3.4\times10^{-4}$$

$$\mathcal{B}(\omega \to \text{invisible}) < 7.3\times10^{-5} \qquad \mathcal{B}(\phi\to\text{invisible}) < 1.7\times10^{-4},$$

Summary

- It is 30 year anniversary of BEPC/BES, also 10 year anniversary of BESIII first collision event
- BESIII has performed wide range of physics studies
  - Light hadron spectroscopy and decays
  - Charmonia transitions and XYZ
  - R value and QCD studies
  - Charmed meson and charmed baryon
  - Rare decays and new physics search

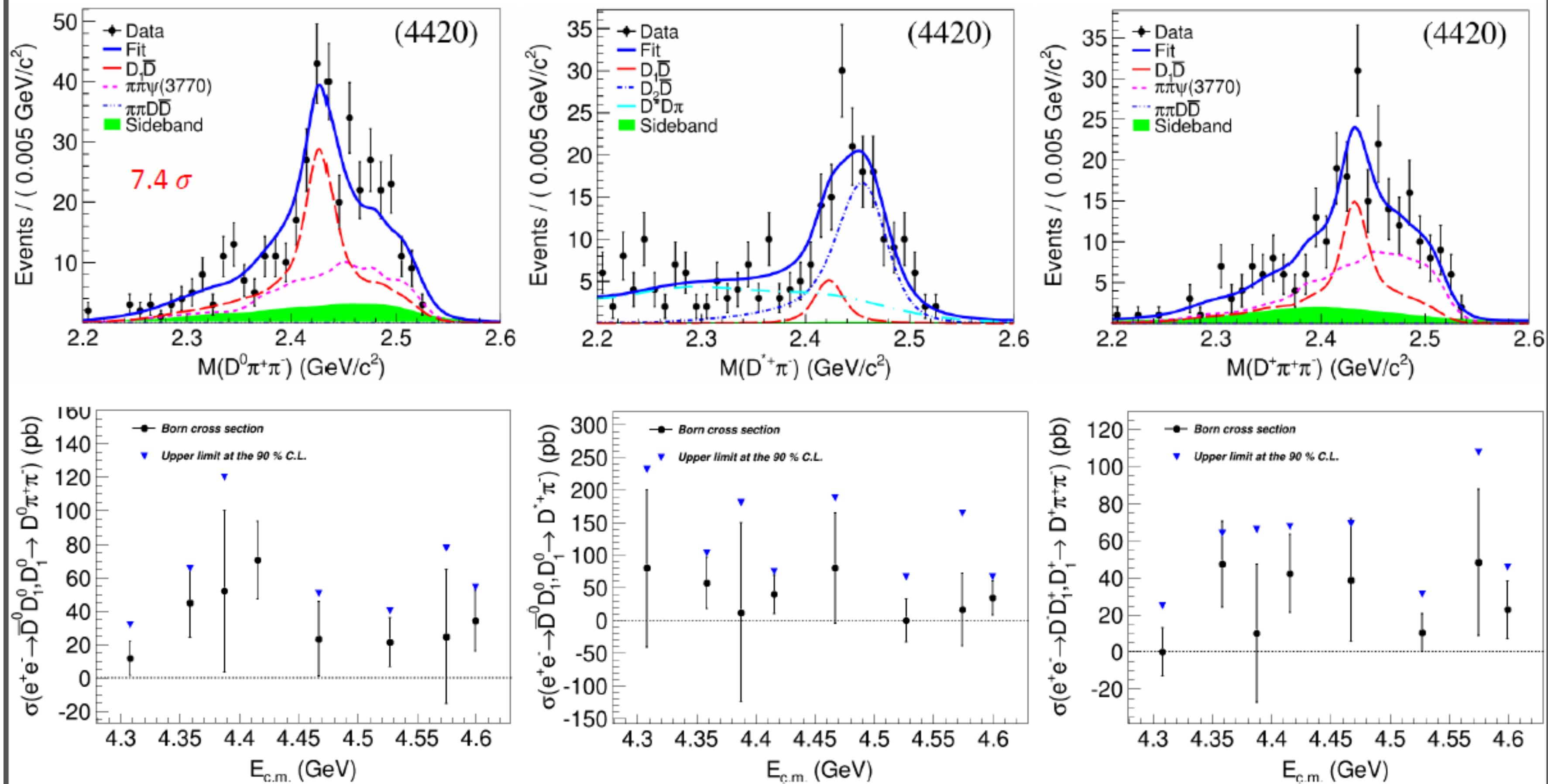
BESIII publication webpage:
http://english.ihep.cas.cn/chnl/245/index.html

- BESIII has great potential with unique datasets and analysis techniques. Operation for another 6-7 years forseen, with small(but critical) energy and lumi upgrade
  - …More to come!

Ref: 吕晓睿（国科大） BESIII prospect

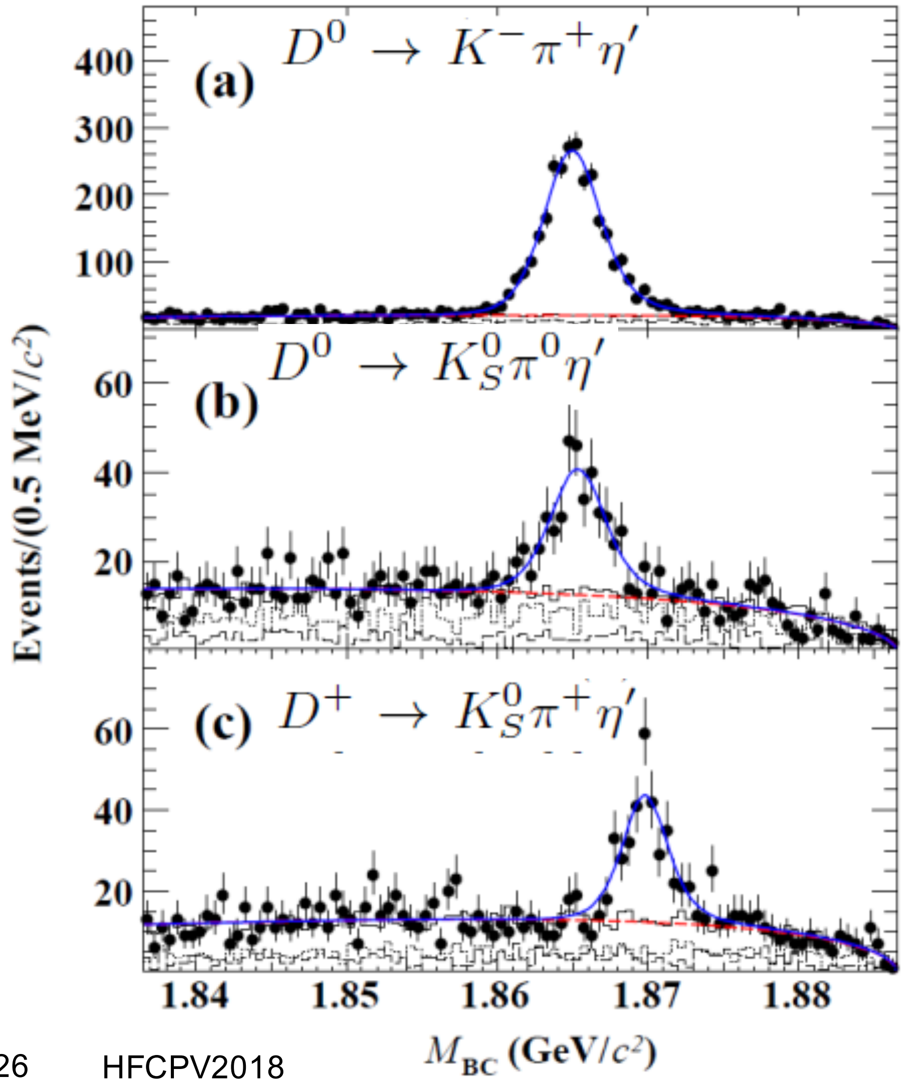
Observation of $e^+e^- \to \bar{D}D_1(2420)$+c.c.

BESIII preliminary



$D_1^0 \to D^0\pi^+\pi^-$ $D_1^0 \to D^{*+}\pi^-$ $D_1^+ \to D^+\pi^+\pi^-$

- Observed the process $e^+e^- \to \bar{D}D_1 + c.c.$.
- Clear structure in the line-shape of $e^+e^- \to \bar{D}D_1 + c.c.$.



(a) $D^0 \to K^-\pi^+\eta'$
(b) $D^0 \to K^0_S\pi^0\eta'$
(c) $D^+ \to K^0_S\pi^+\eta'$
400
300
200
100
60
40
20
60
40
20
Events/(0.5 MeV/c^2)
1.84
1.85
1.86
1.87
1.88
M_{BC} (GeV/c^2)