Light Meson Decays at BESIII

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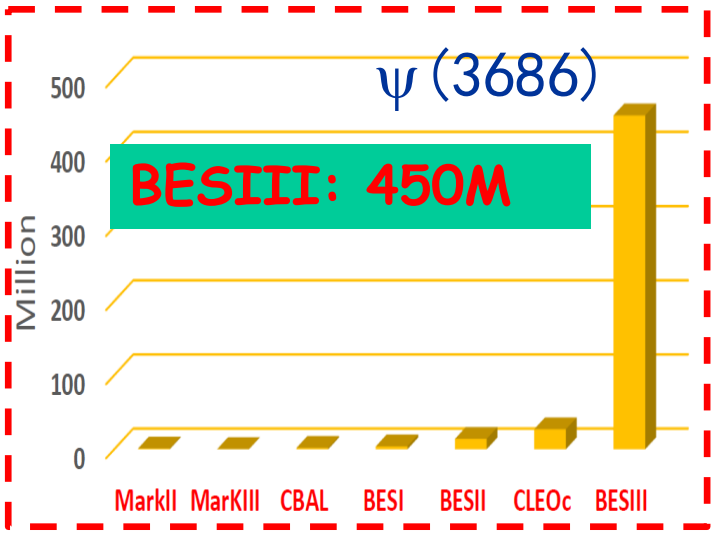
OUTLINE

- Introduction
- Recent results on light meson decays
  - η' decays
  - a_0-f_0 mixing
- Summary

J/ψ and ψ (3686) events （2009+2012）



- BESIII: τ –charm factory
- High production rate of light mesons in J/ψ decays
- Also a factory for light mesons (η/η' /ω.....)
- η/η' from J/ψ radiative decays

  → 1.4×10^6 η

  → 6.8×10^6 η'

η/η' : a rich physics field

- plays an important role in ChPT
- test ChPT predictions
- form factors
- test fundamental symmetries
- probe physics beyond the SM

$\eta' \to 2\gamma$	chiral anomaly
$\eta' \to \pi^+\pi^-\pi^0$	quark masses, $\pi^+\pi^-$ scattering
$\eta' \to \gamma\pi^+\pi^-$	box anomaly
$\eta' \to \gamma\pi^+\pi^-$	form factor
$\eta' \to \pi\pi$	CP violation
$\eta' \to \mu^+\mu^-\pi^0$, $e^+e^-\pi^0$	C violation
$\eta' \to \mu\, e$	LF violation

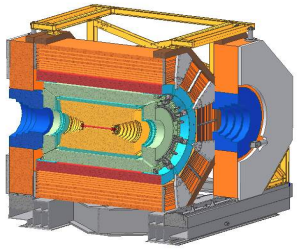
Source of η/η' events

CLAS

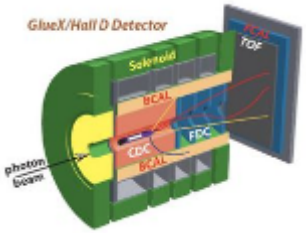
Crystal Ball

WASA-at-COSY

KLOE-2



BESIII

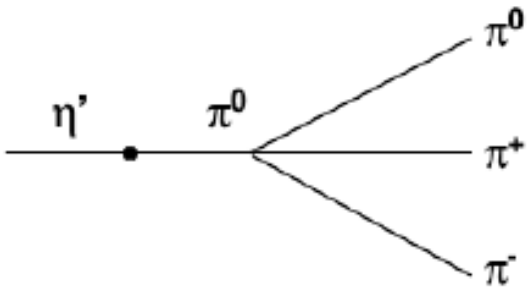


GlueX

Recent results on η′ decays

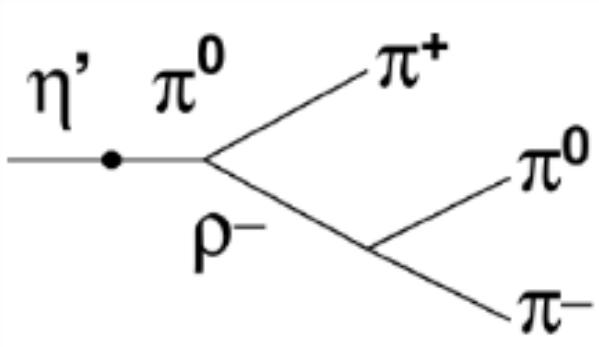
- Hadronic decays
  - Observation of $\eta' \to \rho\pi$
  - Dalitz plot of $\eta' \to \pi^+\pi^-\eta$, $\pi^0\pi^0\eta$
- Radiative decays
  - Observation of $\eta' \to \gamma\gamma\pi^0$
  - Study $\eta' \to \gamma\pi^+\pi^-$ decay dynamics

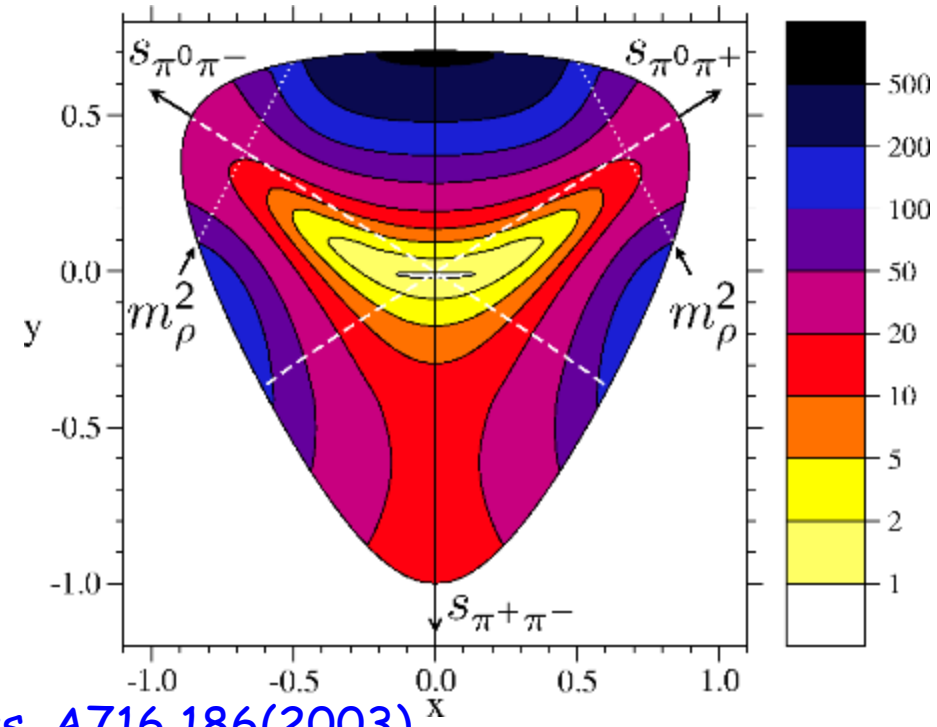
Observation of $\eta' \to \rho^+\pi^- + c.c.$



D. Gross et al., PRD19,2188(1979)

$$r = \frac{\Gamma_{\eta' \to \pi^+\pi^-\pi^0}}{\Gamma_{\eta' \to \eta\pi^+\pi^-}} \approx (16.8)\frac{3}{16}\left(\frac{m_d - m_u}{m_s}\right)^2$$

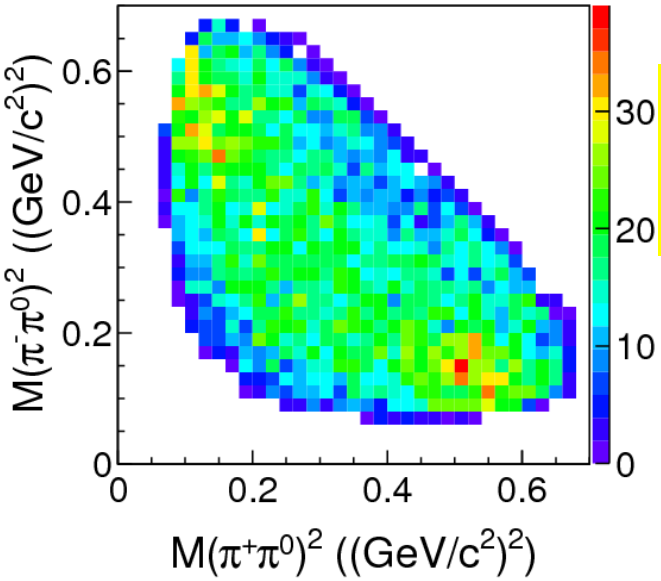




N. Beisert, B. Borasoy, Nucl. Phys. A716,186(2003)

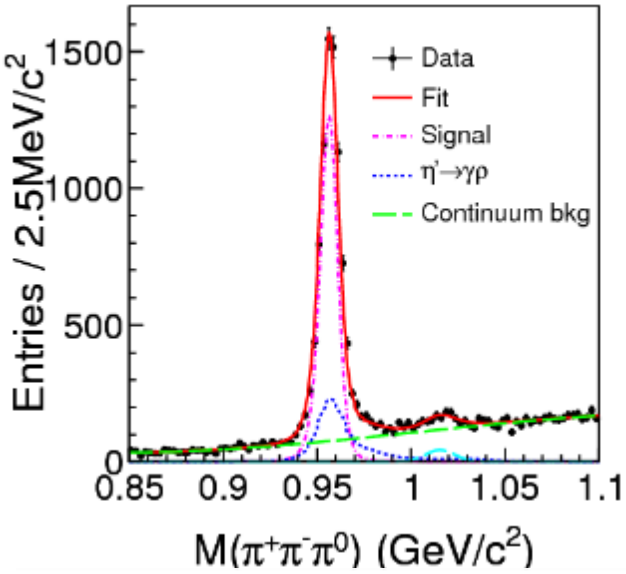
Observation of $\eta' \to \rho^+\pi^- + c.c.$

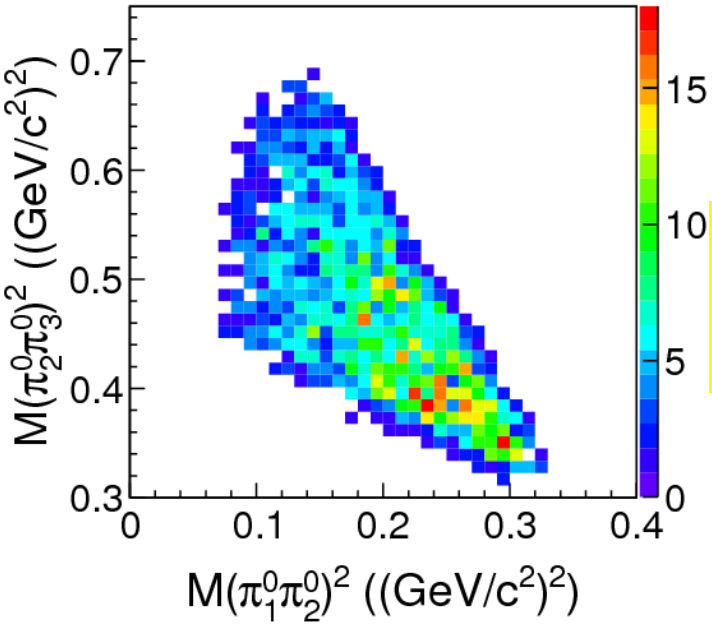
Phys. Rev. Lett. 118, 012001 (2017)



$\eta' \to \pi^+\pi^-\pi^0$

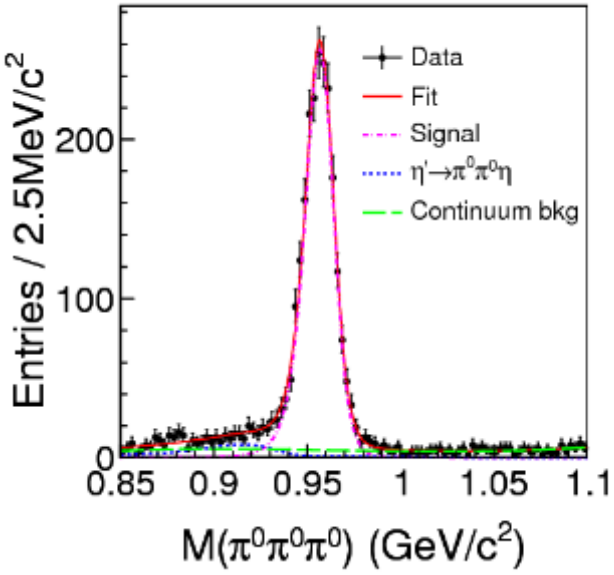
~8000 events



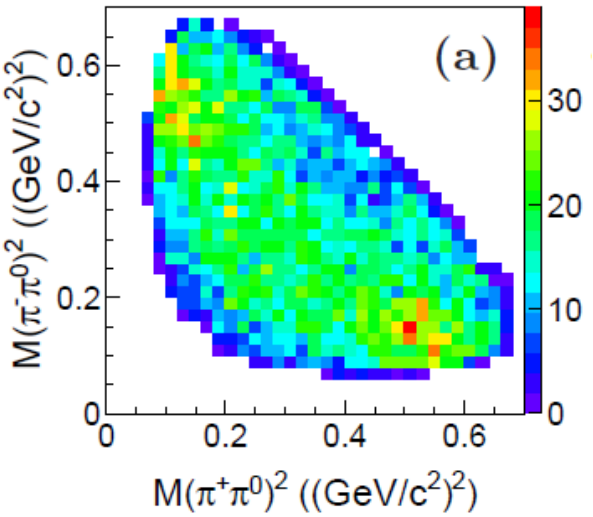


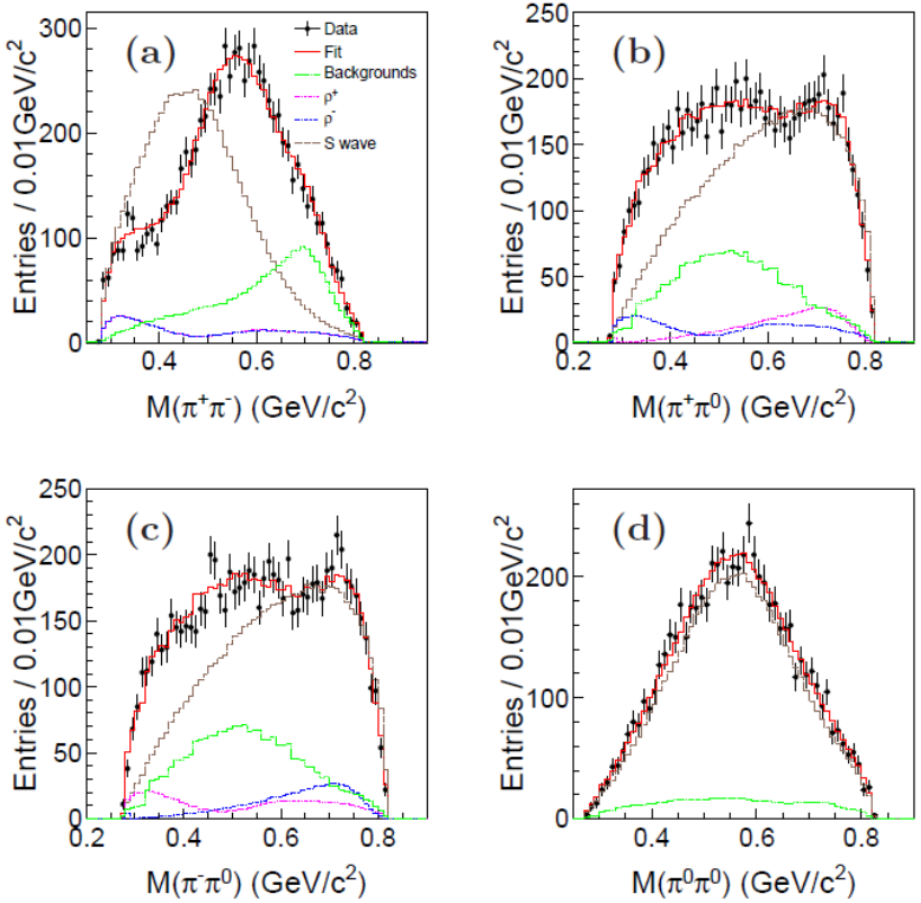
$\eta' \to \pi^0\pi^0\pi^0$

~2000 events



Observation of $\eta' \to \rho^+\pi^- + c.c.$





Decay Mode	$\mathcal{B}$ ($\times 10^{-4}$)
$\pi^+\pi^-\pi^0$	$35.91 \pm 0.54 \pm 1.74$
$\pi^0\pi^0\pi^0$	$35.22 \pm 0.82 \pm 2.60$
$\rho^+\pi^-$	$3.72 \pm 0.30 \pm 0.63 \pm 0.92$
$\rho^-\pi^+$	$3.72 \pm 0.30 \pm 0.63 \pm 0.92$
$(\pi^+\pi^-\pi^0)_S$	$37.63 \pm 0.77 \pm 2.22 \pm 4.48$

[Phys. Rev. Lett. 118, 012001 (2017)]

$\eta' \to \pi^+\pi^-\eta, \pi^0\pi^0\eta$

- Comparison to the theoretical calculations with the effective ChPT

- Previous measurements on the Dalitz plot of $\eta' \to \pi\pi\eta$ are from VES,GAMS and CLEO

$$X = \frac{\sqrt{3}(T_{\pi^+} - T_{\pi^-})}{Q}, \qquad Y = \frac{m_\eta + 2m_\pi}{m_\pi}\frac{T_\eta}{Q} - 1$$

$T_{\pi,\eta}$ denote the kinetic energies of mesons in the η' rest frame

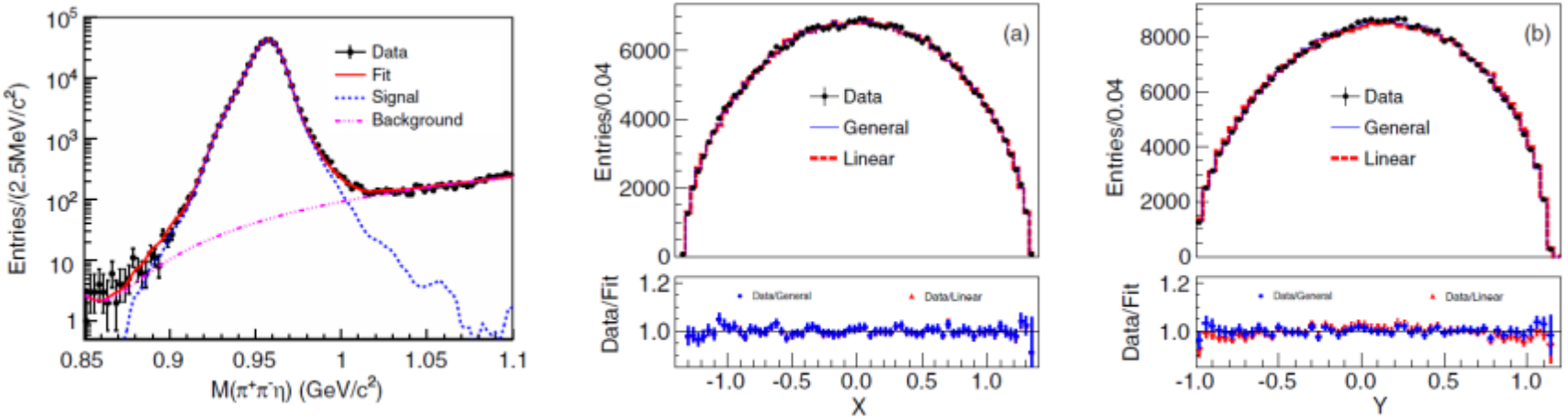
$$Q = T_\eta + T_{\pi^+} + T_{\pi^-} = m_{\eta'} - m_\eta - 2m_\pi$$

Two representations used:

$$M^2 = A(1 + aY + bY^2 + cX + dX^2)$$

$$M^2 = A(|1 + \alpha Y|^2 + cX + dX^2)$$

$\eta' \to \pi^+\pi^-\eta$



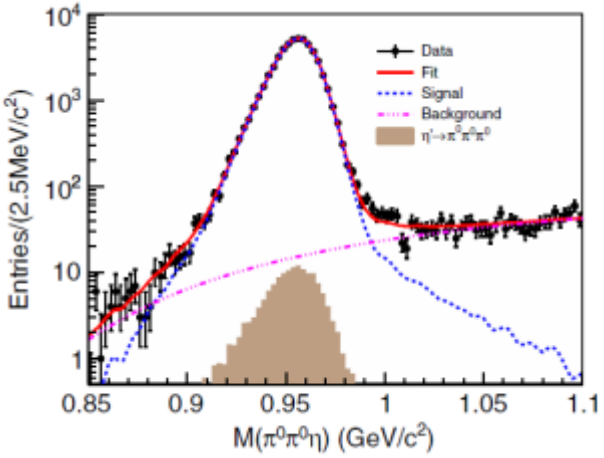
Parameter	$\eta' \to \eta\pi^+\pi^-$				
	EFT [5]	Large N_C [7]	RChT [7]	VES [10]	This work
a	−0.116(11)	−0.098(48)	(fixed)	−0.127(18)	−0.056(4)(2)
b	−0.042(34)	−0.050(1)	−0.033(1)	−0.106(32)	−0.049(6)(6)
c	···	···	···	+0.015(18)	0.0027(24)(18)
d	+0.010(19)	−0.092(8)	−0.072(1)	−0.082(19)	−0.063(4)(3)
$\Re(\alpha)$	···	···	···	−0.072(14)	−0.034(2)(2)
$\Im(\alpha)$	···	···	···	0.000(100)	0.000(19)(1)
c	···	···	···	+0.020(19)	0.0027(24)(15)
d	···	···	···	−0.066(34)	−0.053(4)(4)

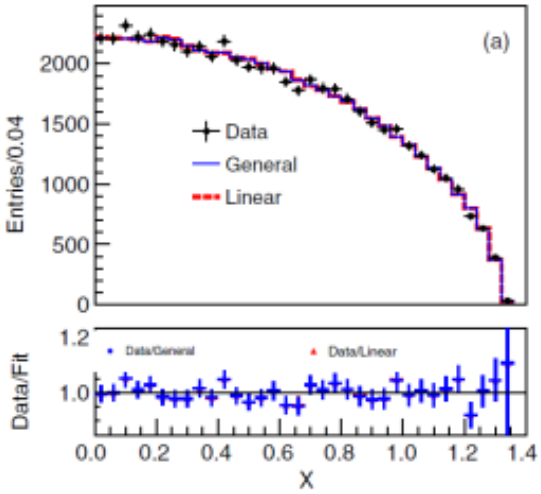
B. Borasoy and N. Nissler EPJA26,383(2005)

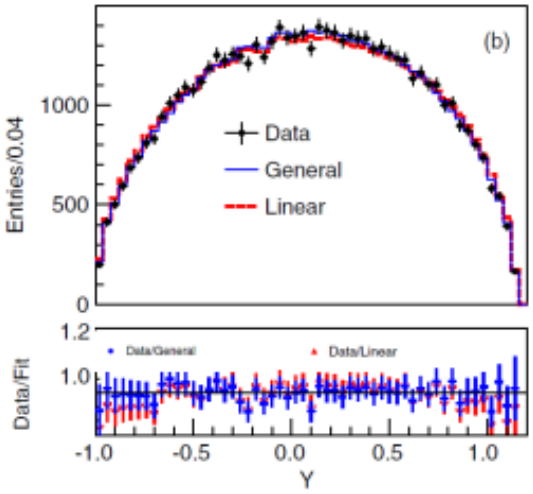
R. Escribanno et al., JHEP, 05, 094(2011)

V. Dorofeev et al., PLB651, 22(2007)

$\eta' \rightarrow \pi^0\pi^0\eta$





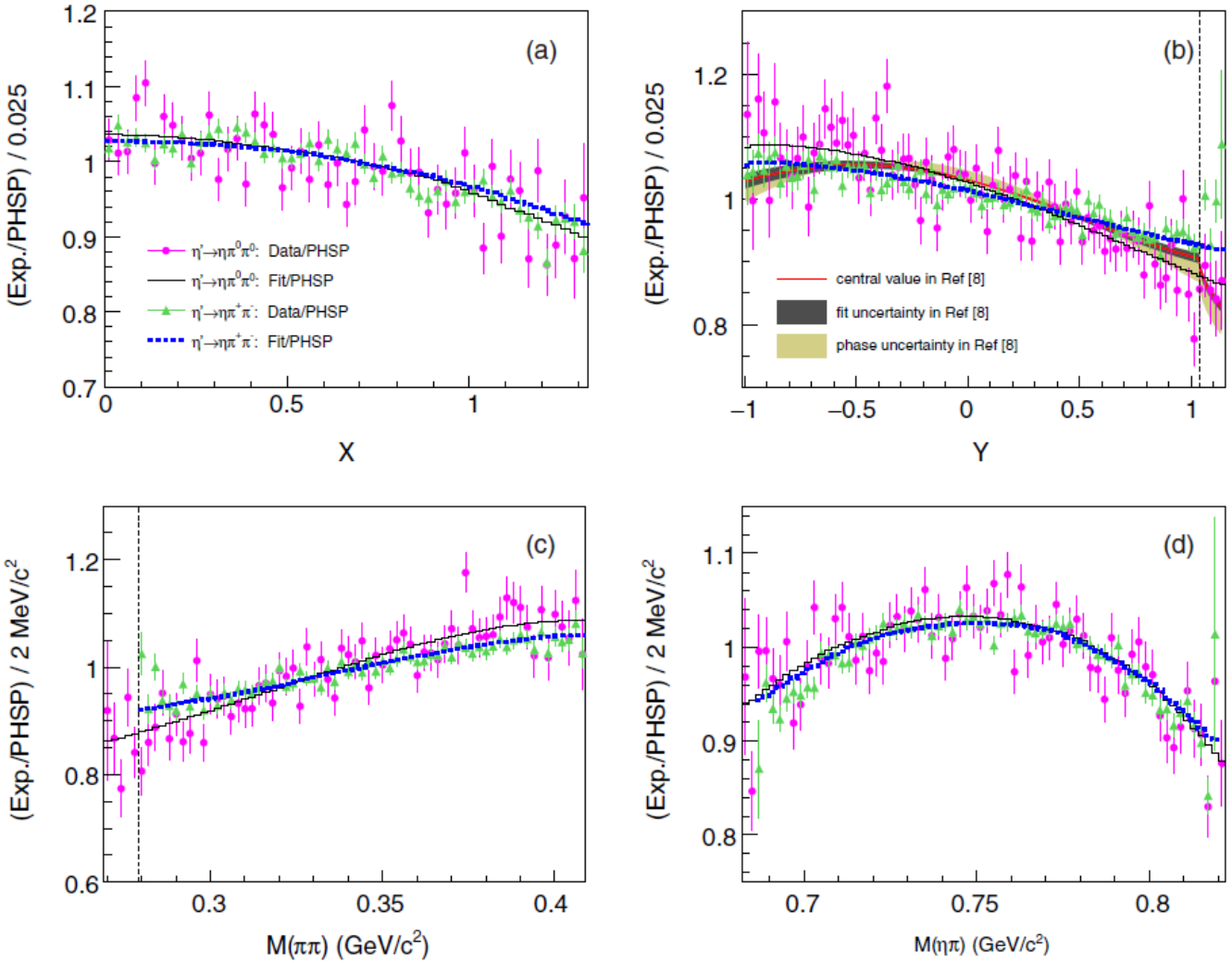


Parameter	$\eta' \to \eta\pi^0\pi^0$ EFT [5]	GAMS-4π [12]	This work
a	−0.127(9)	−0.067(16)	−0.087(9)(6)
b	−0.049(36)	−0.064(29)	−0.073(14)(5)
c	...	...	...
d	+0.011(21)	−0.067(20)	−0.074(9)(4)
$\Re(\alpha)$	...	−0.042(8)	−0.054(4)(1)
$\Im(\alpha)$	...	0.000(70)	0.000(38)(2)
c	...	...	...
d	...	−0.054(19)	−0.061(9)(5)

B. Borasoy and N. Nissler EPJA26,383(2005)

A. M. Blik et al, PAN 72,231(2009)

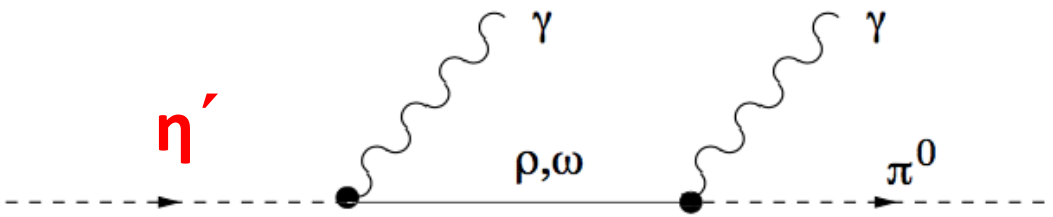
Search for cusp effect



Isken, B. Kubis, S. P. Schneider, and P. Stoffer,
EP JC 77, 489 (2017) ; EPJC62,511(2009)

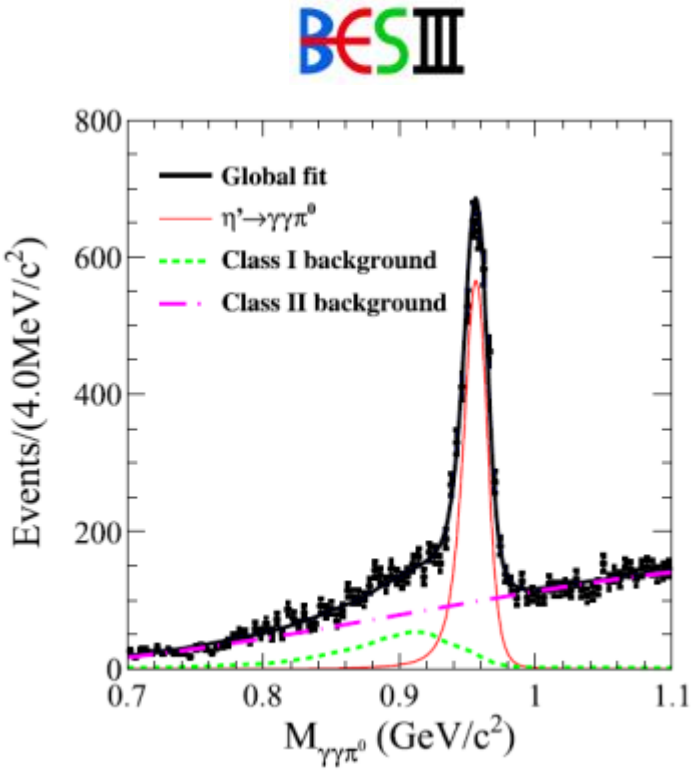
Observation of $\eta' \to \gamma\gamma\pi^0$

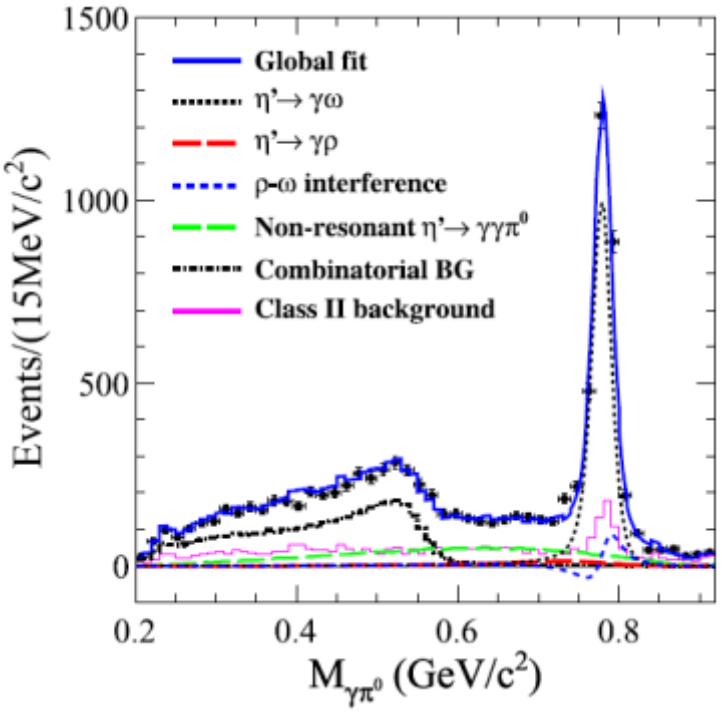
- test the high order of ChPT
- no experimental evidence yet

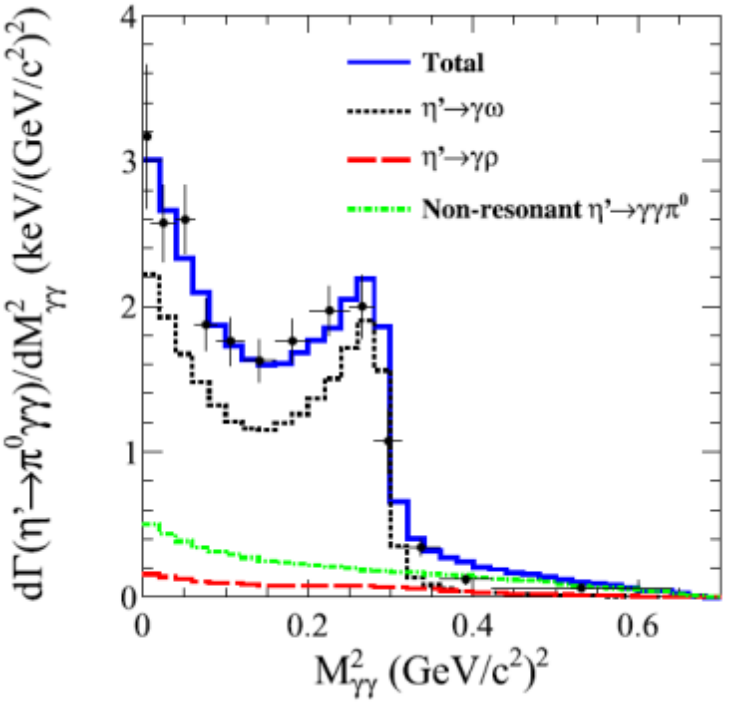


$B(\eta' \to \gamma\gamma\pi^0)$: ~$6 \times 10^{-3}$

P. Jora, Nucl. Phys. Proc. Suppl. 207-208, 224 (2010)
R. Escribano, PoS QNP 2012, 079 (2012)







B_{incl} $=[32.0\pm0.7\pm2.3]\times10^{-4}$

$B(\eta' \to \gamma\omega) = [23.7\pm1.4\pm1.8]\times10^{-4}$

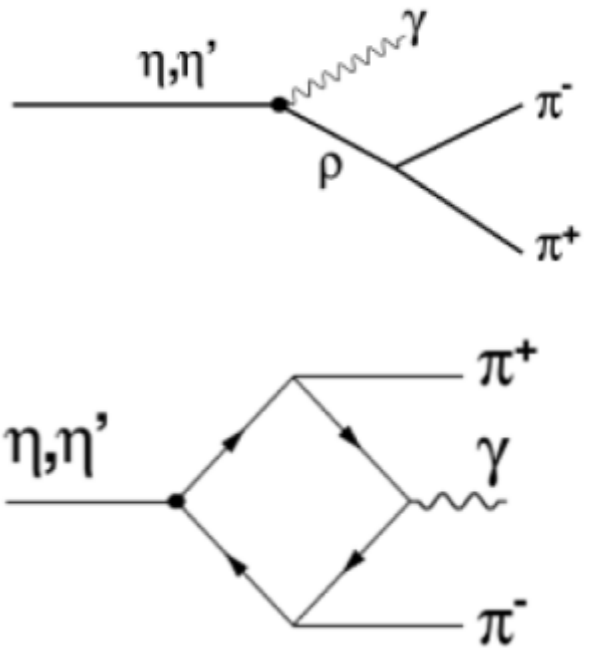
$B(\eta' \to \gamma\,\gamma\pi^0) = [6.16\pm0.64\pm0.67]\times10^{-4}$

$B(\eta' \to \gamma\gamma\pi^0)$: $\sim 6\times10^{-3}$ Linear σ model & VMD

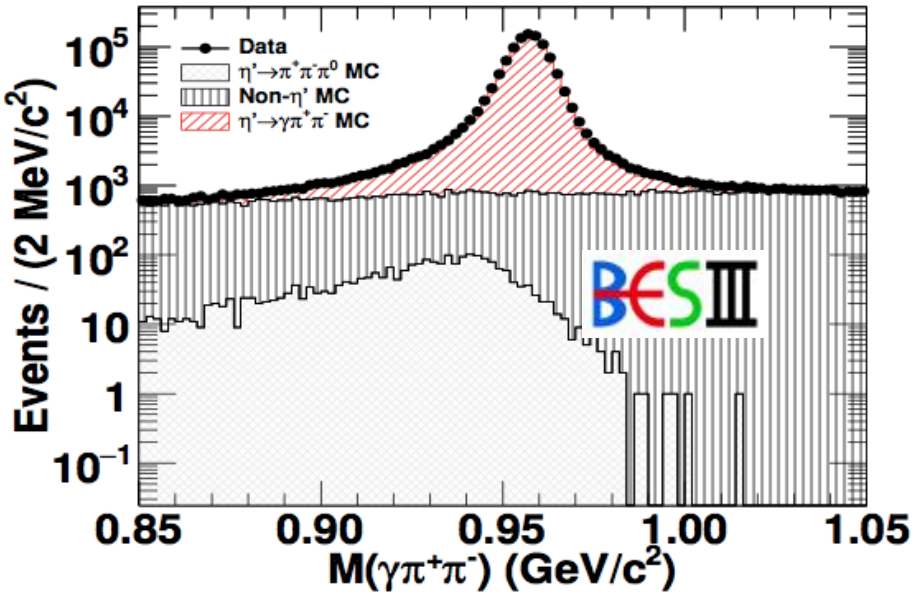
η′→γπ+π- decay dynamics

hep-ex/1712.01525, accepted by PRL

- high term of WZW ChPT→ box anomaly
- studied by many experiments (CB, L3 …)
- no consistent picture due to limited statistics
  - ρ mass shift or not ?
  - box anomaly or not ?



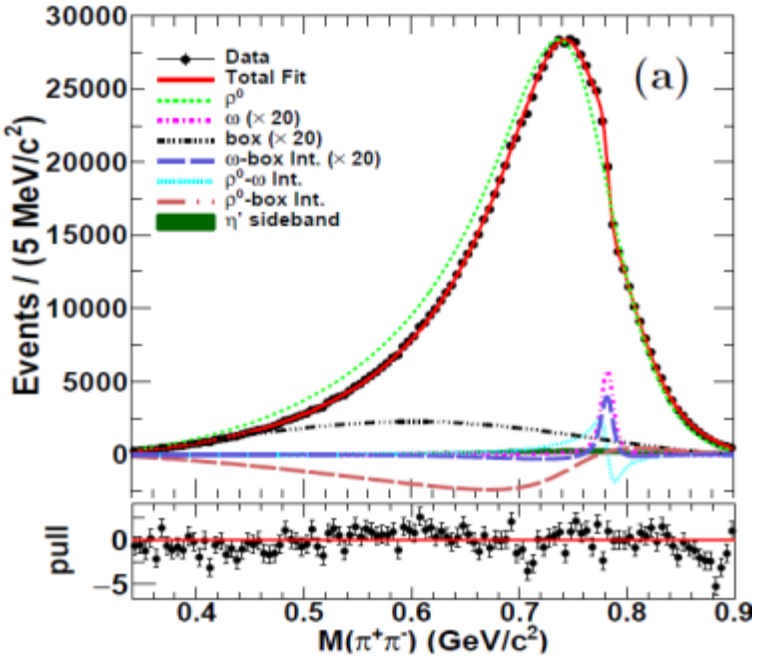
~0.9 million η′→γπ+π- events



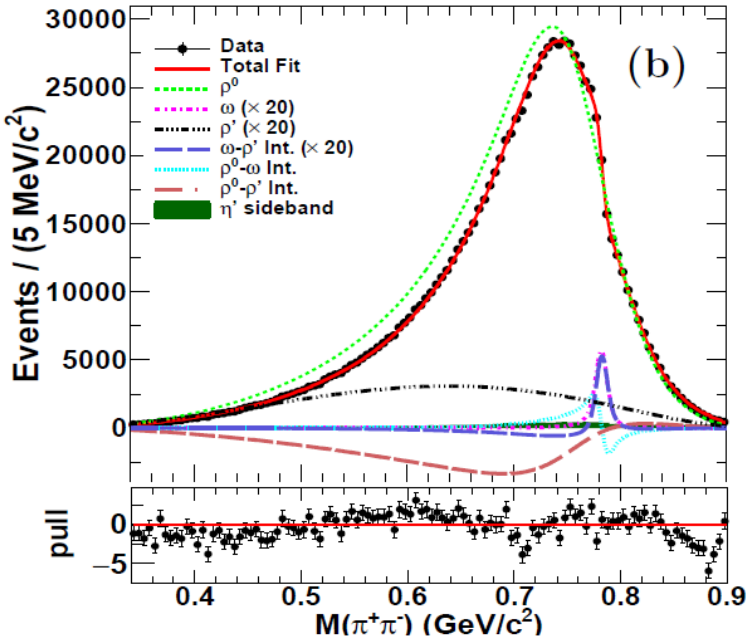
η′→γπ+π- decay dynamics

hep-ex/1712.01525, accepted by PRL

1). fit with ρ(770)-ω-box anomaly



2). fit with ρ(770)-ω-ρ(1450)



Model-dependent fit

- ✓ Besides ρ(770), the ω is needed
- ✓ ρ(770)-ω cannot describe data well
- ✓ Extra contribution (maybe ρ(1450) or box-anomaly, maybe both of them) is also necessary to provide a good description of data

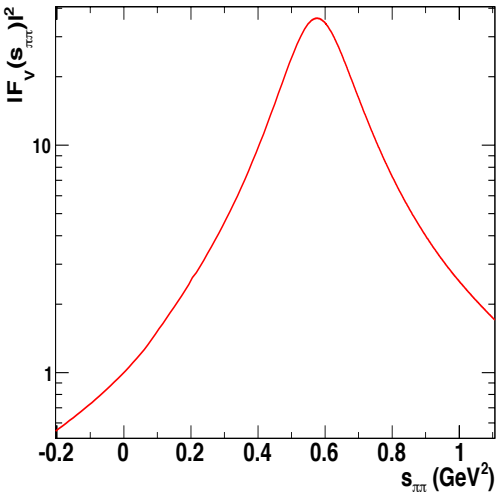
Model-independent fit

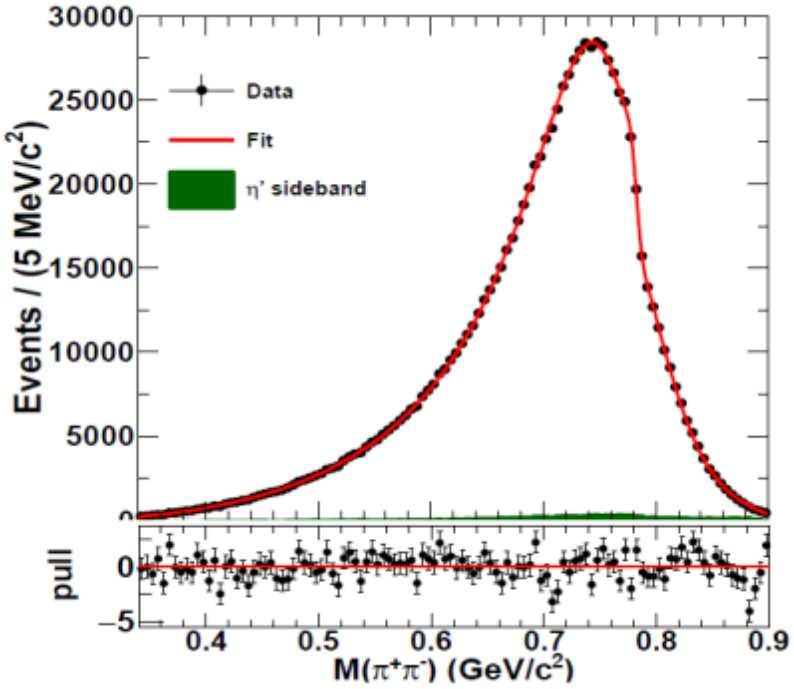
$$\frac{d\Gamma}{ds_{\pi\pi}} = \left|AP(s_{\pi\pi})F_V(s_{\pi\pi})\right|^2 \Gamma_0(s_{\pi\pi})$$

$P(s_{\pi\pi}) = 1 + \kappa\, s_{\pi\pi} + \lambda\, O(s^2_{\pi\pi}) + \delta\, BW_\omega$

F. Stollenwerk et al, PLB707,184(2012)

$|F_V(s_{\pi\pi})|^2$





$\kappa = (0.992 \pm 0.039 \pm 0.067 \pm 0.16)\text{GeV}^{-2}$

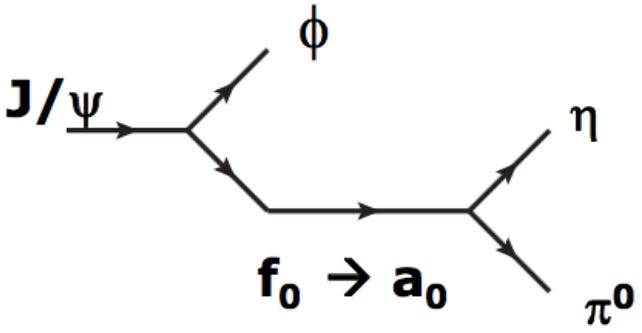
$\lambda = (-0.523 \pm 0.039 \pm 0.066 \pm 0.181)\text{GeV}^{-2}$

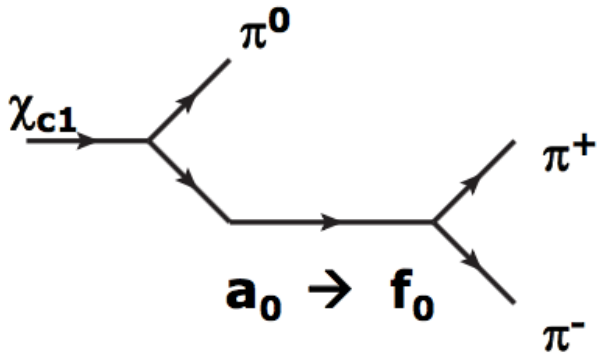
$\xi = (0.199 \pm 0.006 \pm 0.011 \pm 0.007)\text{GeV}^{-4}$

- ω is necessary
- Linear polynomial is insufficient

$a_0(980)$ and $f_0(980)$ mixing

- $a_0(980)$-$f_0(980)$ mixing was first proposed theoretically in 1979 N.N. Achasov, PLB88,367(1979)
- searched in various different reactions
- a search was performed by BESIII in 2011



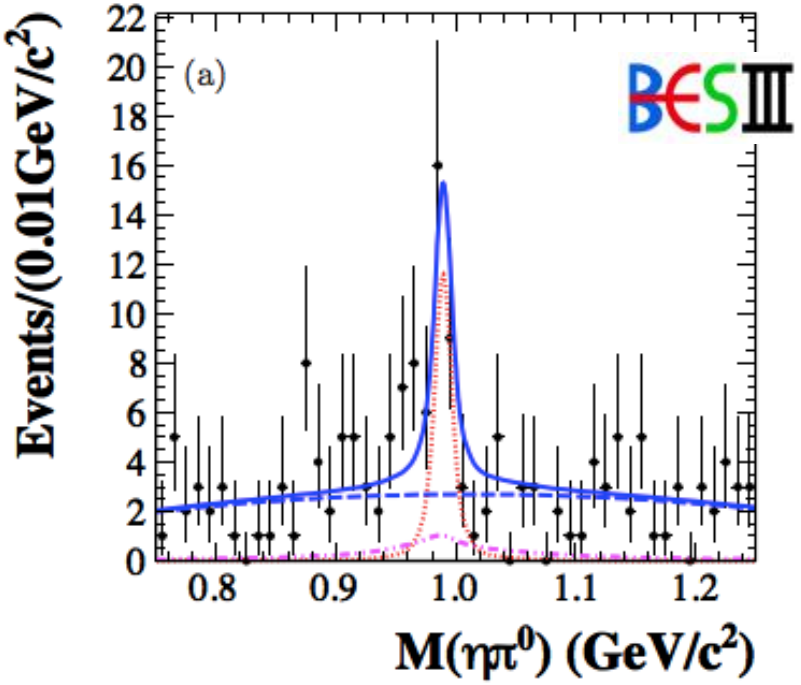


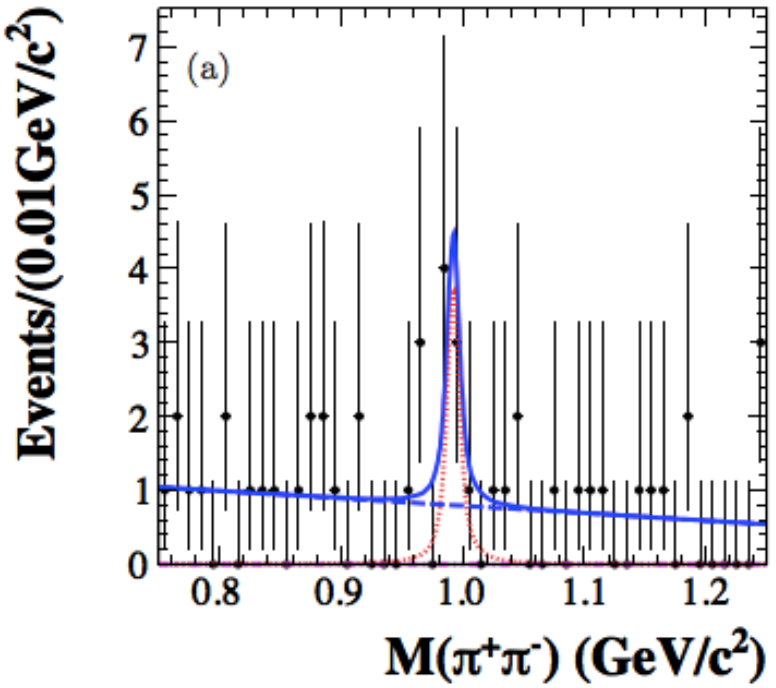
J.Wu, Q.Zhao, B.Zou PRD75,114012(2007)

J.Wu, Q.Zhao, B.Zou PRD78,074017(2008)

$a_0(980)$ and $f_0(980)$ mixing

225 M J/ψ and 1.06 M ψ(3686) in 2009





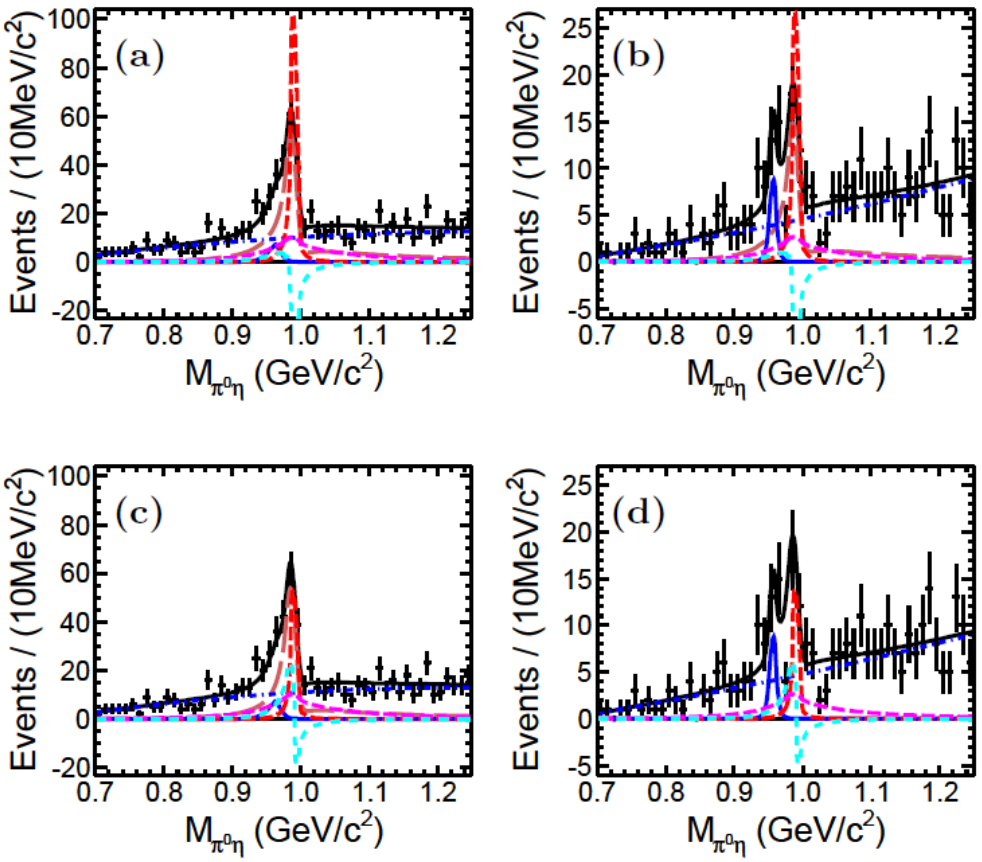
PRD 83, 032003 (2011)

Observation of $a_0(980)$ and $f_0(980)$ mixing

hep-ex/1802.00583

$$J/\psi \to \phi f_0(980) \to \phi a_0^0(980) \to \phi\eta\pi^0$$

$\eta\to\gamma\gamma$ $\eta\to\pi^+\pi^-\pi^0$



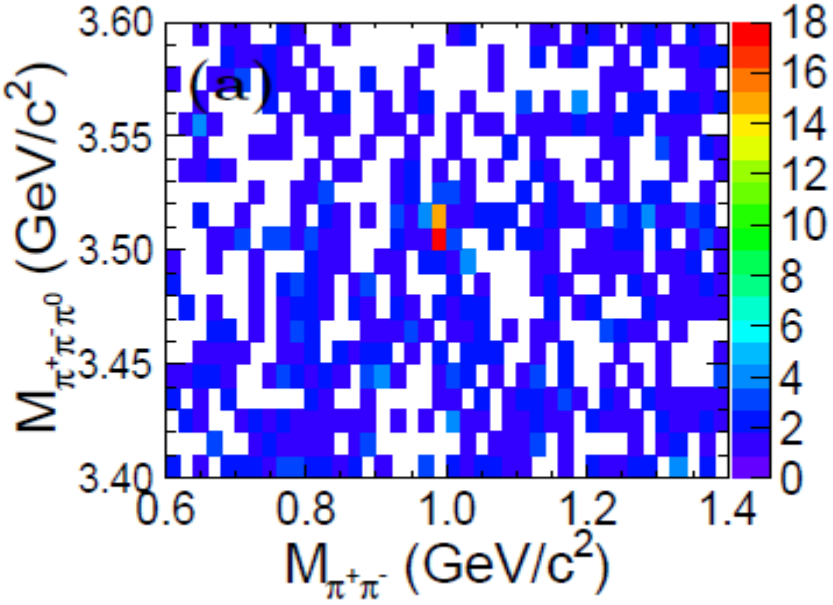
1.3 bliion J/ψ events in 2009+2012

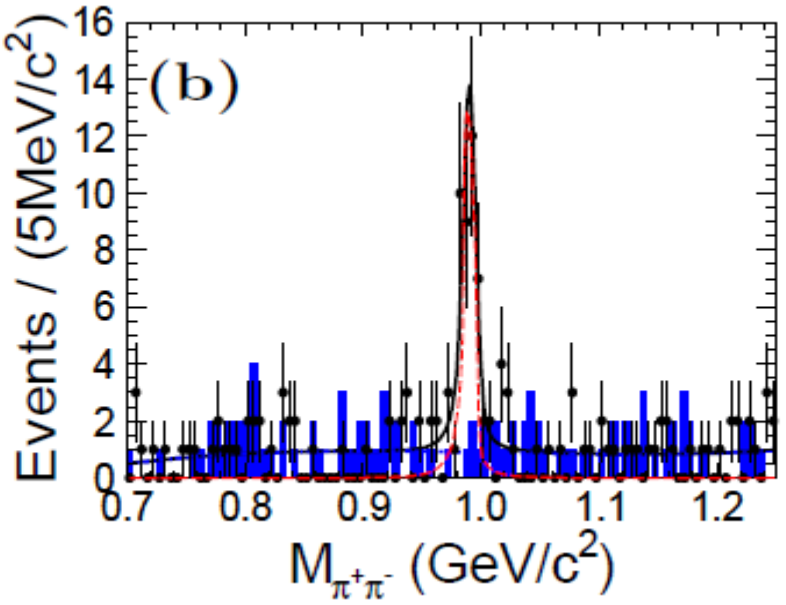
Observation of $a_0(980)$ and $f_0(980)$ mixing

hep-ex/1802.00583

$$\chi_{c1} \to \pi^0 a_0^0(980) \to \pi^0 f_0(980) \to \pi^0\pi^+\pi^-$$

448M $\psi(3686)$ events





Channel	$f_0(980) \to a_0^0(980)$ Solution I	$f_0(980) \to a_0^0(980)$ Solution II	$a_0^0(980) \to f_0(980)$
$\mathcal{B}$(mixing) (10^{-6})	$3.18 \pm 0.51 \pm 0.38 \pm 0.28$	$1.31 \pm 0.41 \pm 0.39 \pm 0.43$	$0.35 \pm 0.06 \pm 0.03 \pm 0.06$
$\mathcal{B}$(EM) (10^{-6})	$3.25 \pm 1.08 \pm 1.08 \pm 1.12$	$2.62 \pm 1.02 \pm 1.13 \pm 0.48$	—
$\mathcal{B}$(total) (10^{-6})	$4.93 \pm 1.01 \pm 0.96 \pm 1.09$	$4.37 \pm 0.97 \pm 0.94 \pm 0.06$	—
ξ (%)	$0.99 \pm 0.16 \pm 0.30 \pm 0.09$	$0.41 \pm 0.13 \pm 0.17 \pm 0.13$	$0.40 \pm 0.07 \pm 0.14 \pm 0.07$

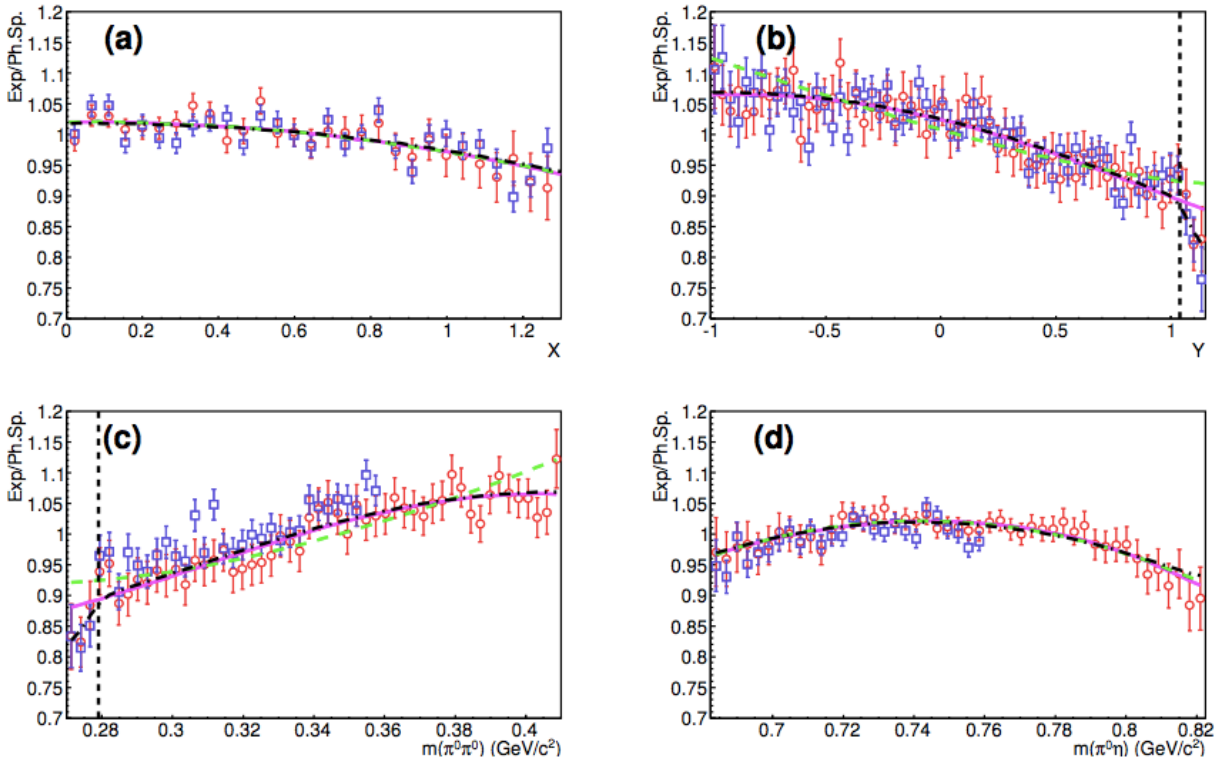
Summary

- **A unique place to study light meson decays**
  - Observation of $\eta' \to \rho\pi$
  - Dalitz plot of $\eta' \to \pi^+\pi^-\eta$, $\pi^0\pi^0\eta$
  - Observation of $\eta' \to \gamma\gamma\pi^0$
  - Study $\eta' \to \gamma\pi^+\pi^-$ decay dynamics
  - First observation of a_0-f_0 mixing
- **BESIII: 1.3 billion + 3.7 billion J/ψ events**
  - A sample of 3.7 billion J/ψ events was taken in 2017-2018
  - Allows to study light mesons with unprecedented statistics

Many thanks for your attention !

BESIII publications on η/η' decays

- $\eta' \to \pi^+\pi^-\eta$ PRD83, 012003(2011)
- $\eta/\eta' \to \pi^+\pi^-, \pi^0\pi^0$ PRD83, 032006(2011)
- $\eta' \to \pi^+\pi^- \pi^0, \pi^0\pi^0\pi^0$ PRL108, 182001(2012)
- $\eta/\eta' \to$ invisible PRD87,012009(2013)
- $\eta/\eta' \to \pi^+ e\nu$ PRD87,032006(2013)
- $\eta' \to 3(\pi^+\pi^-)$ PRD88,091502(2013)
- $\eta' \to 2(\pi^+\pi^-), \pi^+\pi^-\pi^0\pi^0$ PRL112,251801(2014)
- $\eta' \to \gamma e^+e^-$ PRD92,012001(2015)
- $\eta \to \pi^+\pi^- \pi^0, \eta/\eta' \to \pi^0\pi^0\pi^0$ PRD92,012014(2015)
- $\eta' \to \omega e^+e^-$ PRD92,051101(2015)
- $\eta' \to K\pi$ PRD93, 072008 (2016)
- $\eta' \to \rho\pi$ PRL118,012001(2017)
- $\eta' \to \gamma\gamma\pi^0$ PRD96,012005(2017)
- $\eta' \to \gamma\pi^+\pi^-$ arXiv:1712.01525, accepted by PRL
- $\eta' \to \pi^+\pi^-\eta, \eta' \to \pi^0\pi^0\eta$ PRD97, 012003 (2018)



hep-ex/1709.0423