Experimental Overview on η' Hadronic Decays

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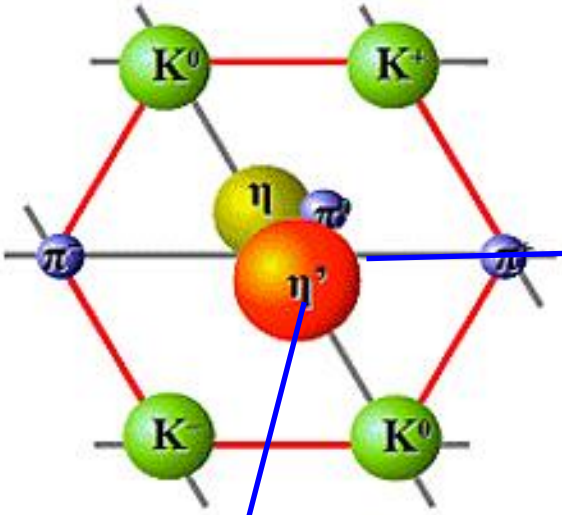
OUTLINE

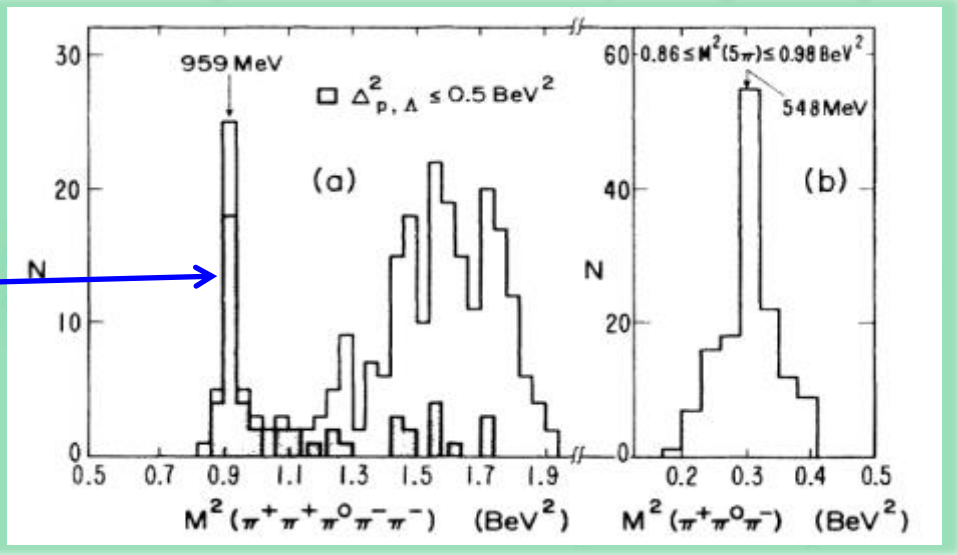
- Introduction
- η′ hadronic decays
- BESIII status on η′ decays
- Summary & Outlook

Discovery of η′

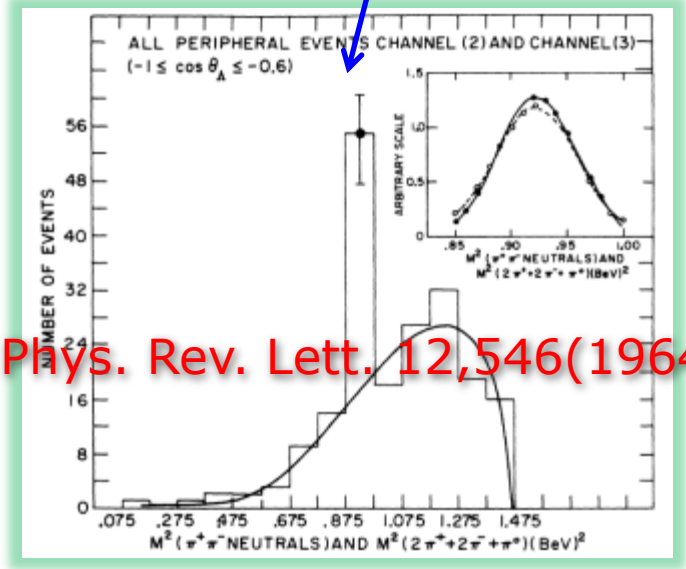
Lightest pseudoscalar nonet



Phys. Rev. Lett. 12,527(1964)



$K^-+p=\Lambda+$ multipions
in bubble chamber



Phys. Rev. Lett. 12,546(1964)

Dominant decays

$\eta' \rightarrow \pi+\pi-\eta$	44.6%
$\eta' \rightarrow \gamma\rho(\gamma\pi+\pi-)$	29.4%
$\eta' \rightarrow \pi^0\pi^0\eta$	20.7%
$\eta' \rightarrow 2\gamma$	3.02%
$\eta' \rightarrow \gamma\omega$	2.10%

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

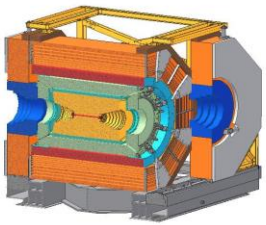
Source of η′ events

CLAS

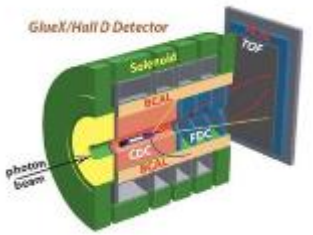
Crystal Ball

WASA-at-COSY

KLOE-2



BESIII



GlueX

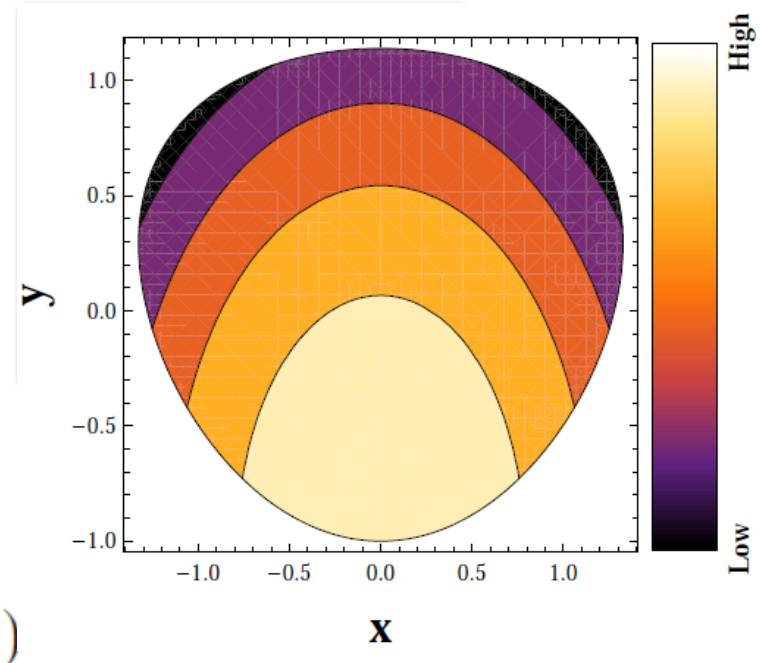
η' decays

- Hadronic decays
  - $\eta' \to \pi^+\pi^-\eta / \pi^0\pi^0\eta$
  - $\eta' \to 3\pi$
  - $\eta' \to 4\pi$
  - …
- Radiative decays
  - $\eta' \to \gamma\pi^+\pi^-$
  - $\eta' \to \gamma\gamma$
  - $\eta' \to \gamma\omega$
  - …
- Decays with leptonic pairs
  - $\eta' \to \gamma l^+l^-$
  - $\eta' \to \pi^+\pi^-l^+l^-$
  - …

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

$$X = \frac{\sqrt{3}}{Q}(T_{\pi^+} - T_{\pi^-})$$

$$Y = \frac{m_\eta + 2m_\pi}{m_\pi}\frac{T_\eta}{Q} - 1$$



Decay amplitudes:

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

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

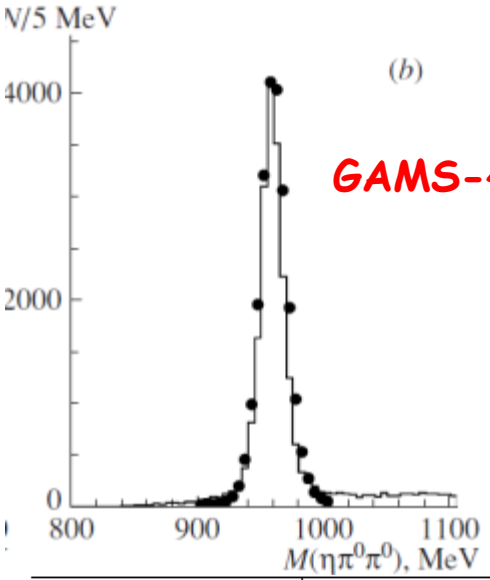
B. Borasoy et al, Eur.Phys.J.A26,383(2005)

R. Escribano et al, JHEP 1105,094(2011)

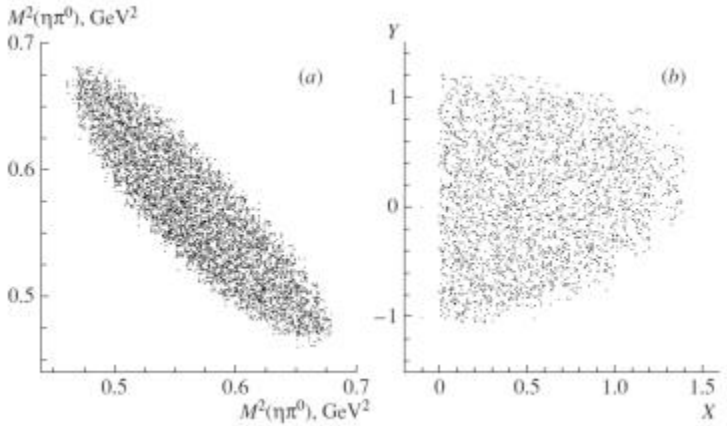
……..

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

Phys. Ato. N. 72,236(2009)



GAMS-4π



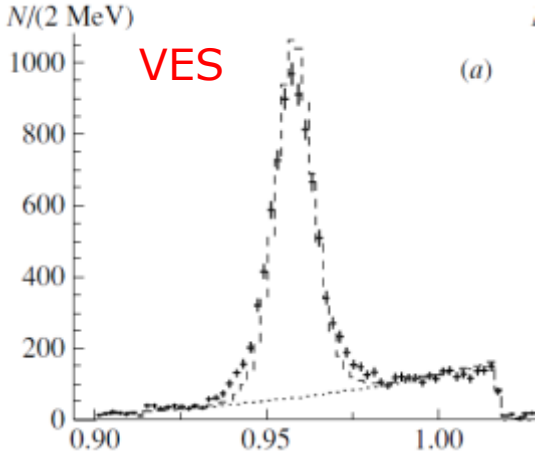
Parameter	GAMS	GAMS-4π	[1]	[2]
a		$-0.066 \pm 0.016 \pm 0.003$		
b		$-0.063 \pm 0.028 \pm 0.004$		
c		$-0.107 \pm 0.096 \pm 0.003$		
d		$0.018 \pm 0.078 \pm 0.006$		
$a(c=0)$		$-0.067 \pm 0.016 \pm 0.004$	-0.127 ± 0.009	-0.105
$b(c=0)$		$-0.064 \pm 0.029 \pm 0.005$	-0.049 ± 0.036	-0.065
$d(c=0)$		$-0.067 \pm 0.020 \pm 0.003$	0.011 ± 0.021	-0.004
$\mathrm{Re}(\alpha)$	-0.058 ± 0.013	-0.042 ± 0.008		
$\mathrm{Im}(\alpha)$	0.00 ± 0.13	0.00 ± 0.07		
d	0.00 ± 0.03	-0.054 ± 0.019		

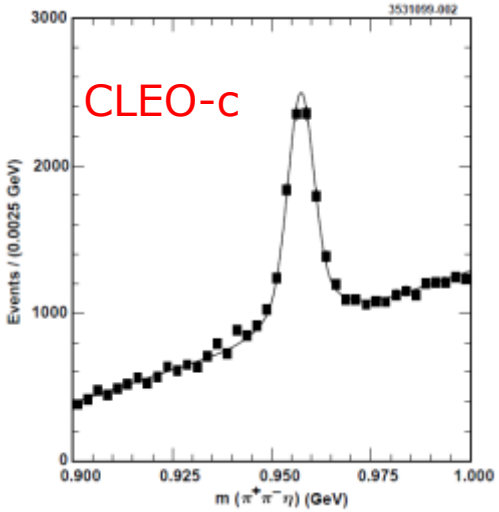
[1] Eur.Phys.J.A26,383(2005)

[2] Nucl.Phys. A716 ,186(2003)

η′ → π+π−η

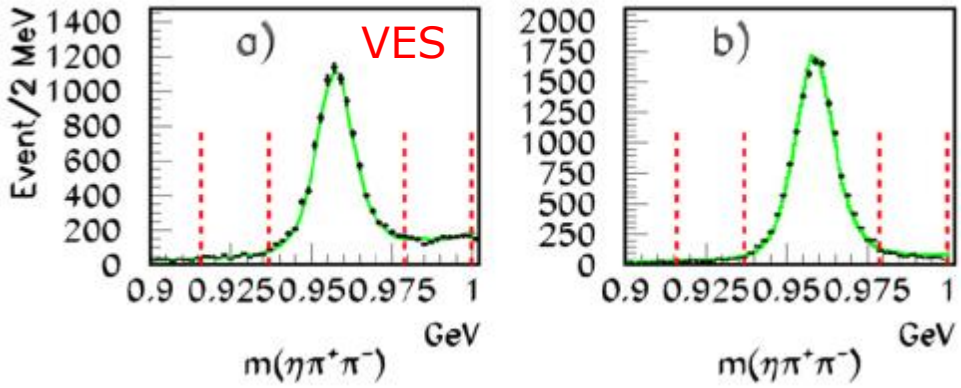
Phys. At. Nucl. 68,372(2005)

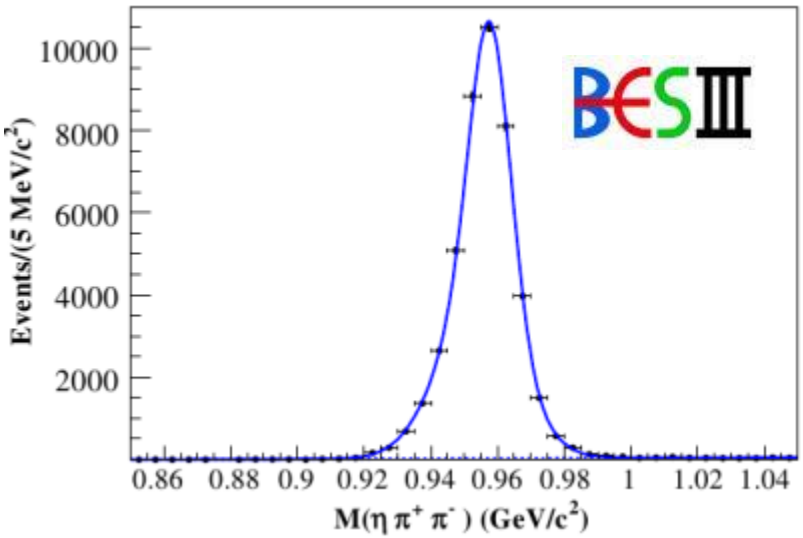




Phys. Rev,Lett.84,26(2000)

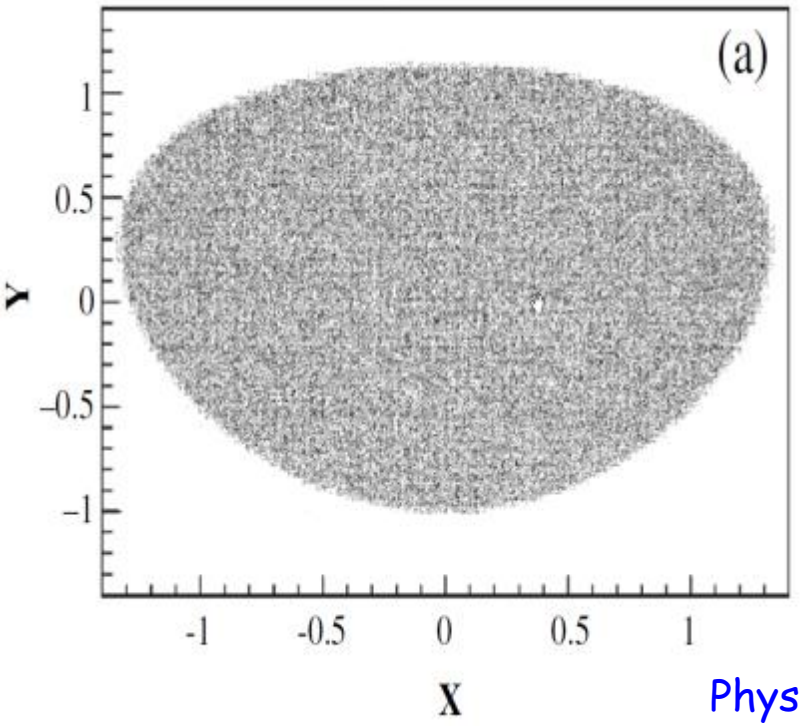
Phys. Lett.B651,22(2007)

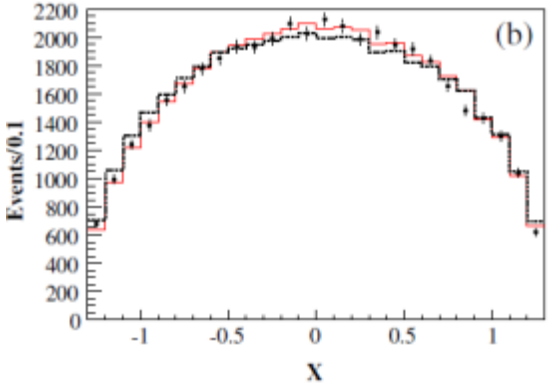


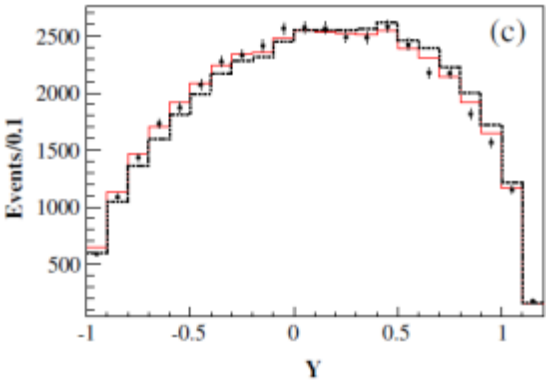


Phys. Rev. D83,012003(2011)

seems no dynamics is involved







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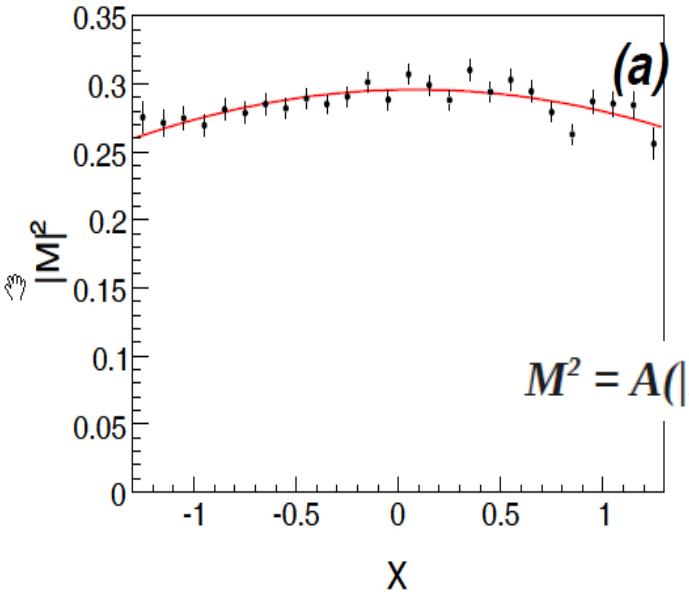
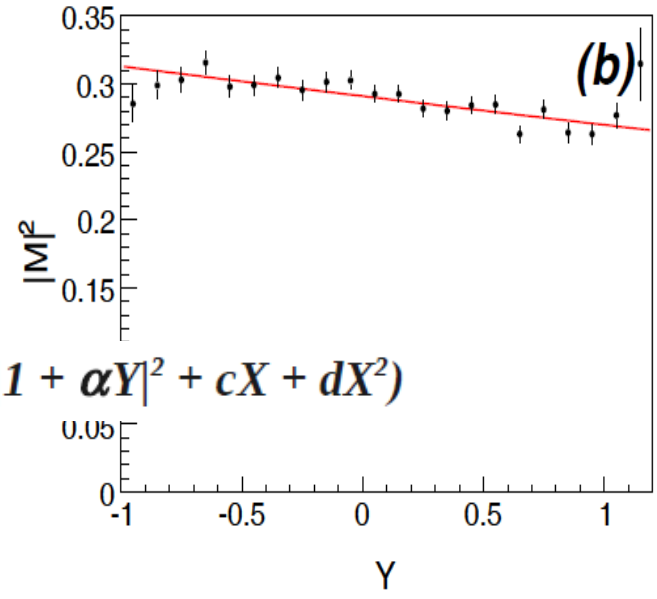




$$M^2 = A(|1 + \alpha Y|^2 + cX + dX^2)$$

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

Phys. Lett.B651,22(2007) Eur. Phys.J.A26,383(2005)

Parameter	VES [9]	Theory [26]	BESIII
a	-0.127 ± 0.018	-0.116 ± 0.011	-0.047 ± 0.012
b	-0.106 ± 0.032	-0.042 ± 0.034	-0.069 ± 0.021
c	$+0.015 \pm 0.018$	$\cdots$	$+0.019 \pm 0.012$
d	-0.082 ± 0.019	$+0.010 \pm 0.019$	-0.073 ± 0.013

Phys. Rev,Lett.84,26(2000) Phys.At.Nucl.68,372(2005) Phys. Rev. D83,012003(2011)

Parameter	CLEO [11]	VES [27]	BESIII
$\mathrm{Re}(\alpha)$	-0.021 ± 0.025	-0.072 ± 0.014	-0.033 ± 0.006
$\mathrm{Im}(\alpha)$	0.000 (fixed)	0.000 ± 0.100	0.000 ± 0.050
c	0.000 (fixed)	$+0.020 \pm 0.019$	$+0.018 \pm 0.010$
d	0.000 (fixed)	-0.066 ± 0.034	-0.059 ± 0.013

- "c" is consistent with zero
- Part of parameters are not consistent with each other ! ?

correlation between parameters ?

$$\begin{array}{l} a = -0.047 \pm 0.011 \\ b = -0.069 \pm 0.019 \\ c = +0.019 \pm 0.011 \\ d = -0.073 \pm 0.012 \end{array} \begin{pmatrix} 1.000 & -0.442 & -0.010 & -0.239 \\ & 1.000 & 0.025 & 0.282 \\ & & 1.000 & 0.030 \\ & & & 1.000 \end{pmatrix}.$$

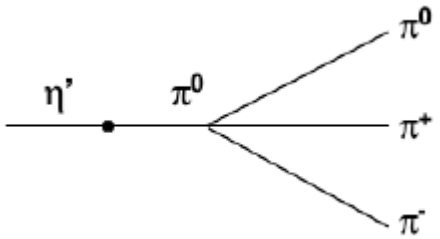
BESIII

$$\begin{array}{l} a = -0.066 \pm 0.016 \\ b = -0.063 \pm 0.028 \\ c = -0.107 \pm 0.096 \\ d = 0.018 \pm 0.078 \end{array} \begin{pmatrix} 1.000 & -0.395 & 0.191 & -0.210 \\ & 1.000 & -0.600 & 0.512 \\ & & 1.000 & -0.968 \\ & & & 1.000 \end{pmatrix}$$

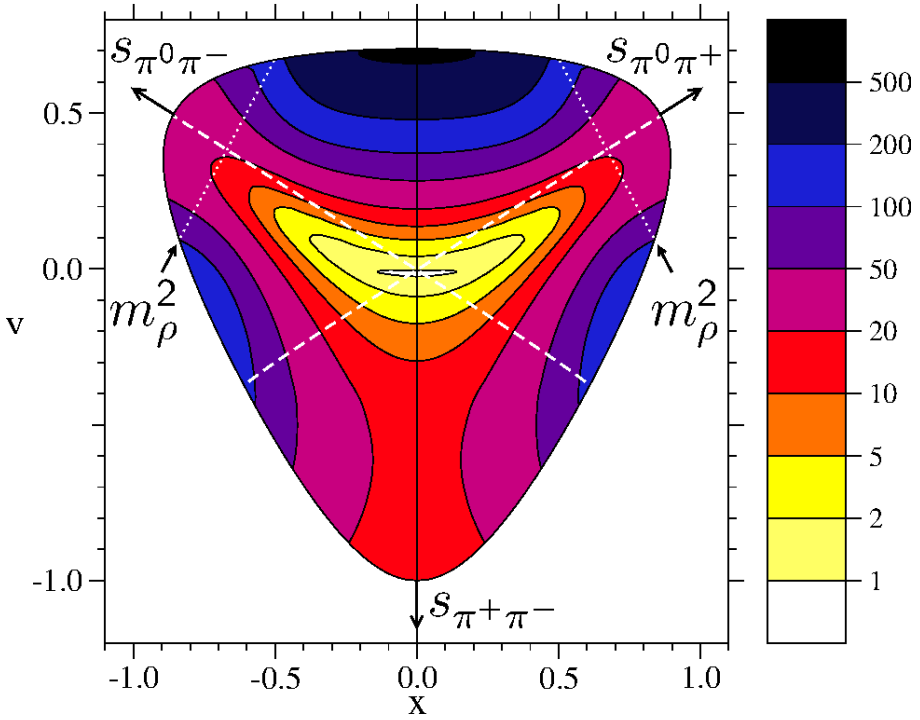
GAMS-4π

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

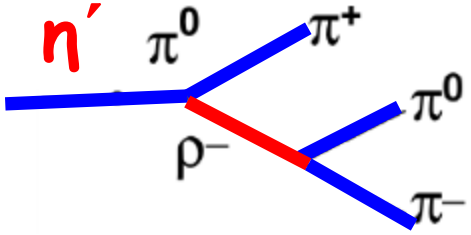
D. Gross et al, Phys. Rev.D19,2188(1979)



- Proceeds via $\eta' \to \pi^+\pi^-\eta$ followed by π^0-η mixing
- Decay amplitudes are "essentially constant"



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



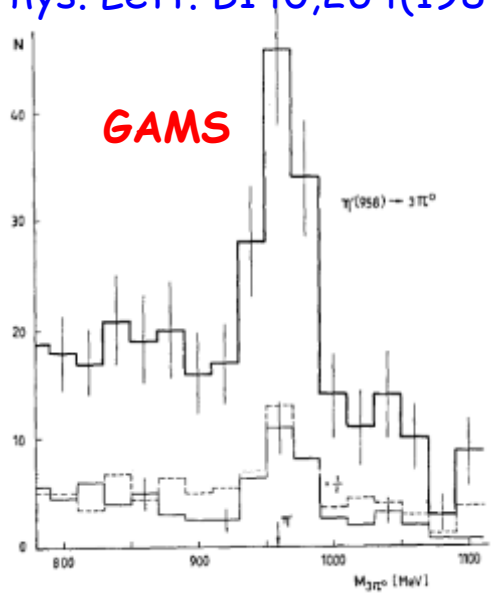
B. Borasoy et al, Phys. Lett.B643,41(2006)

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

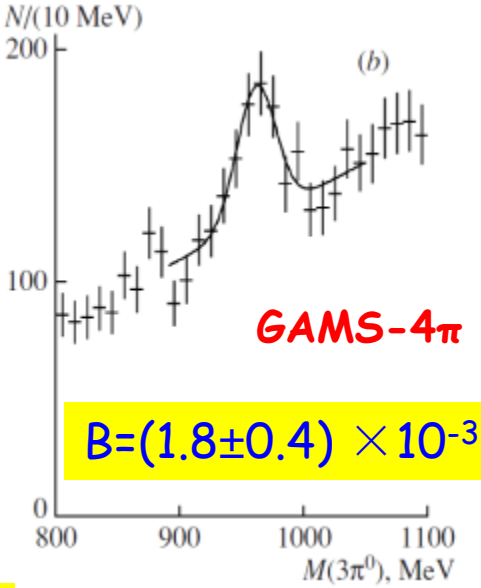
$\eta' \to \pi^0\pi^0\pi^0$

PRL 108, 182001 (2012)

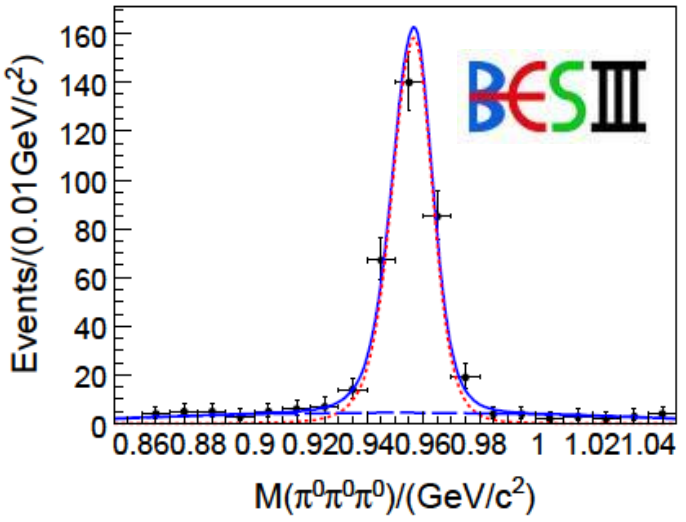
Phys. Lett. B140,264(1984)



Phys. At.Nucl.71,2124(2008)



$B=(1.8\pm0.4)\times10^{-3}$

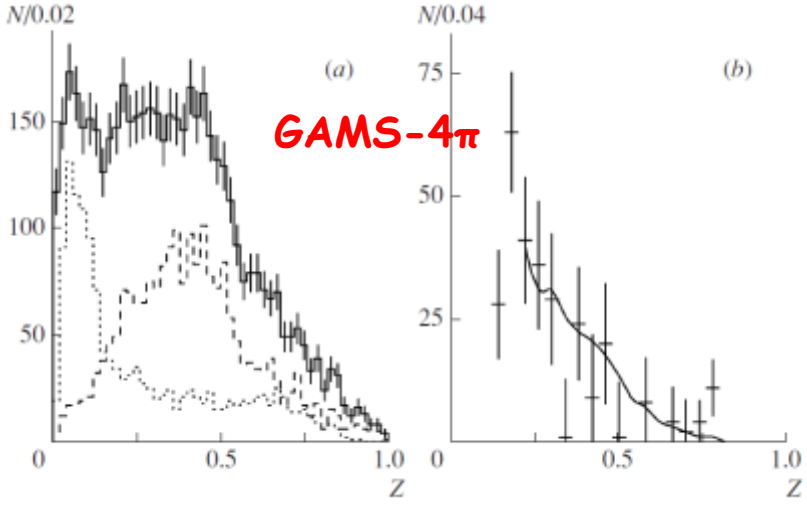


$B=(3.56\pm0.22\pm0.34)\times10^{-3}$

$B(\eta' \to 3\pi^0)=(1.6\pm0.4)\times10^{-3}$

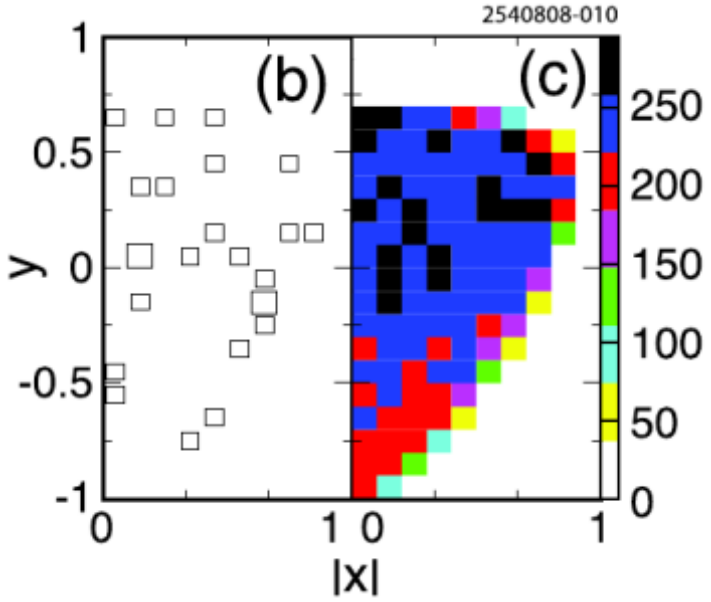
$$|M|^2 \propto 1 + 2\beta Z$$

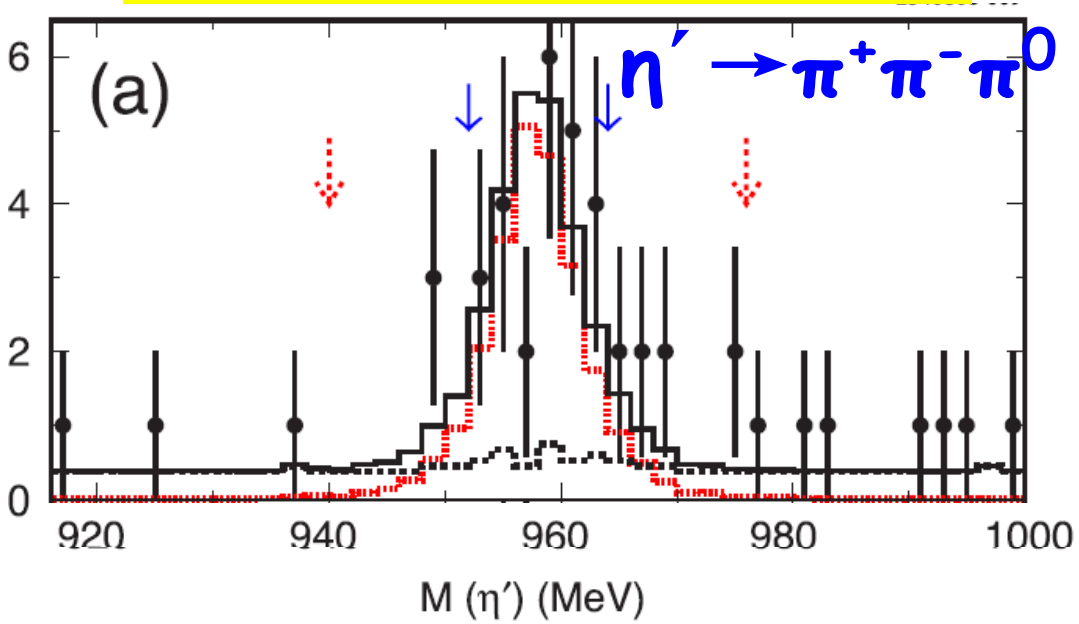
$$\beta = -0.59 \pm 0.18$$

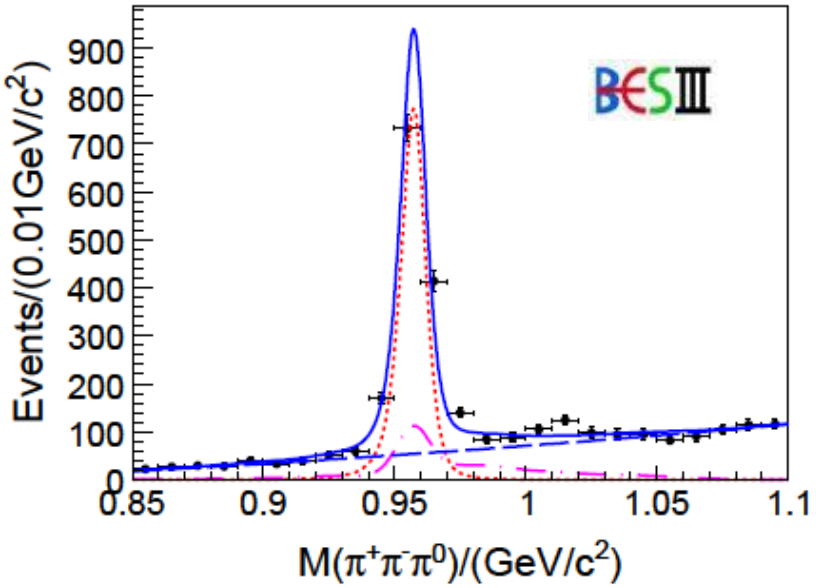


$\eta' \to \pi^+\pi^-\pi^0$

Phys. Rev.Lett.102,061801(2009)







$B(\eta' \to \pi^+\pi^-\pi^0) = (3.6^{+1.1}_{-0.9} \pm 0.4) \times 10^{-3}$

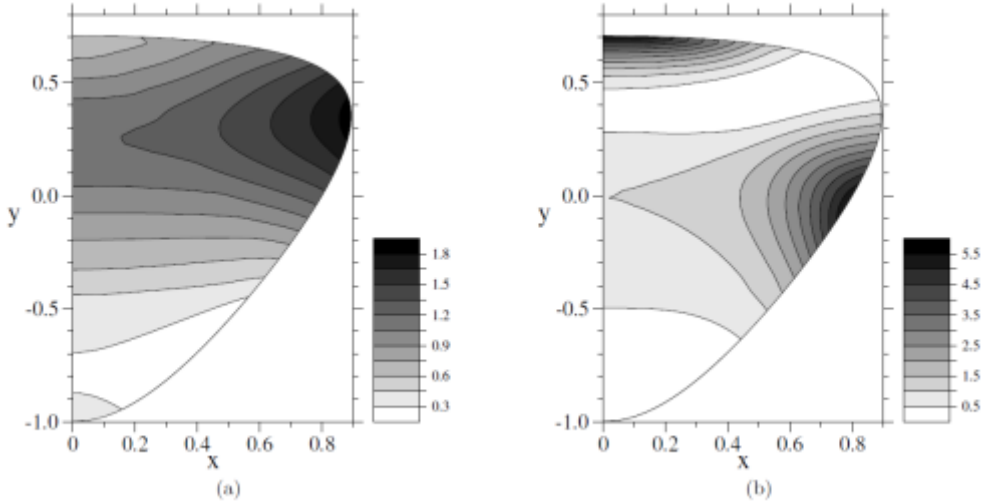
$B(\eta' \to \pi^+\pi^-\pi^0) = (3.83 \pm 0.15 \pm 0.39) \times 10^{-3}$

Phys.Rev.Lett. 108, 182001 (2012)

Dalitz Plot of $\eta' \to \pi^+\pi^-\pi^0$

$$|\mathcal{A}(x,y)|^2 = |N'|^2\left[1 + g(y^2 + x^2) + \cdots\right]$$

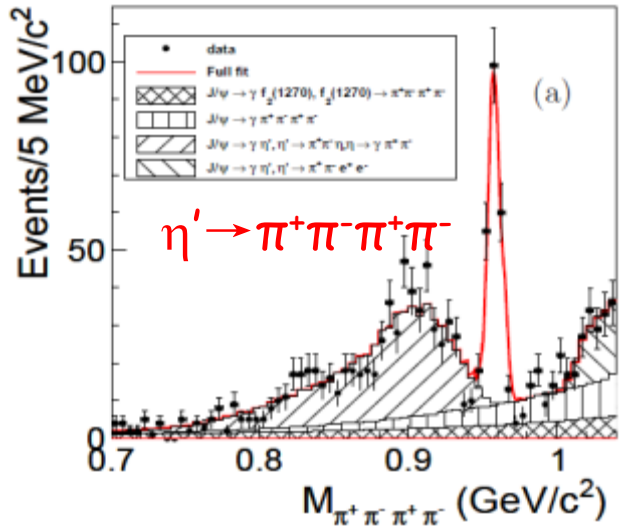
Eur. Phys. J. A **26**, 383–398 (2005)



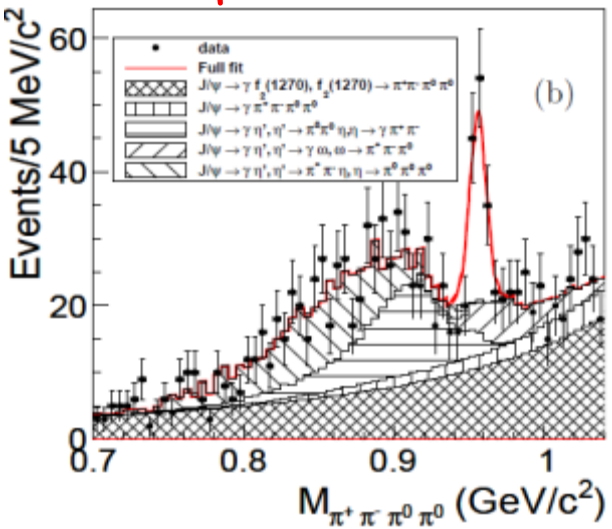
- Too many parameters
  - **strong correlated**
  - **unstable results (P-wave contributions)**
- How to describe the $\pi^+\pi^-$ S-wave (σ resonance?)
- Parameterization of ρ

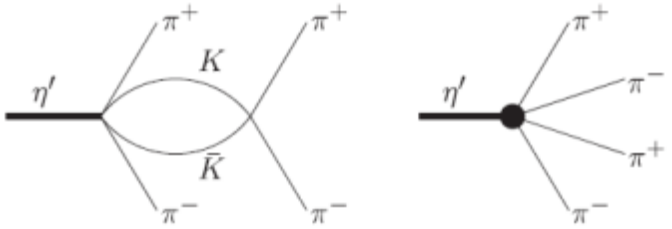
$\eta' \to \pi^+\pi^-\pi^+\pi^-, \pi^+\pi^-\pi^0\pi^0$

PRL112,251801(2014)



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



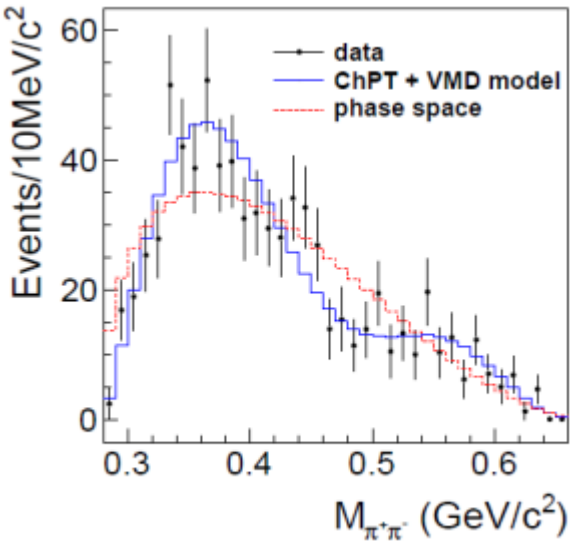


ChPT+VMD:
only occur at $O(p^6)$

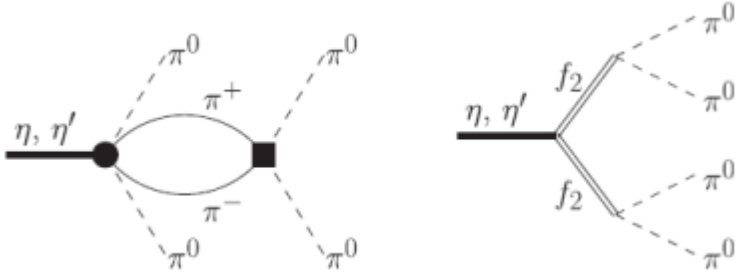
ChPT+VMD : $B(\eta' \to \pi^+\pi^-\pi^+\pi^-) = (1.0 \pm 0.3) \times 10^{-4}$
$B(\eta' \to \pi^+\pi^-\pi^0\pi^0) = (2.4 \pm 0.7) \times 10^{-4}$

F.K. Guo, B. Kubis, A. Wirzba,Phys. Rev. D 85,014014 (2012)

$B(\eta' \to \pi^+\pi^-\pi^+\pi^-) = (8.63 \pm 0.69 \pm 0.64) \times 10^{-5}$
$B(\eta' \to \pi^+\pi^-\pi^0\pi^0) = (1.82 \pm 0.35 \pm 0.18) \times 10^{-4}$

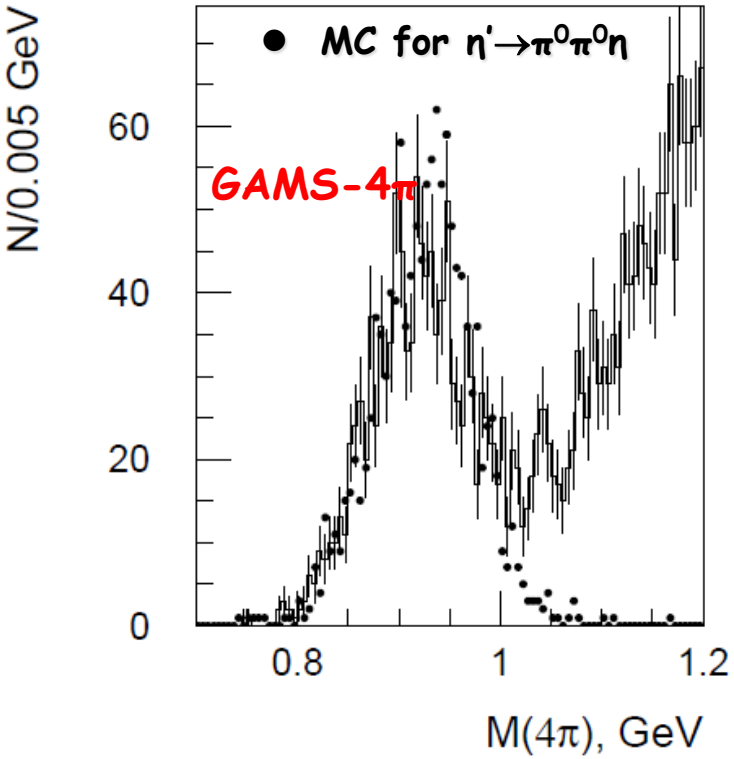


$\eta' \to \pi^0\pi^0\pi^0\pi^0$



ChPT+VMD

$B(\eta' \to \pi^0\pi^0\pi^0\pi^0) \sim 4 \times 10^{-8}$



F.K. Guo, B. Kubis, A. Wirzba,Phys. Rev. D 85,014014 (2012)

CP violation decays

$B(\eta' \to \pi^0\pi^0\,\pi^0\pi^0) < 3.2 \times 10^{-4}$ @90%CL

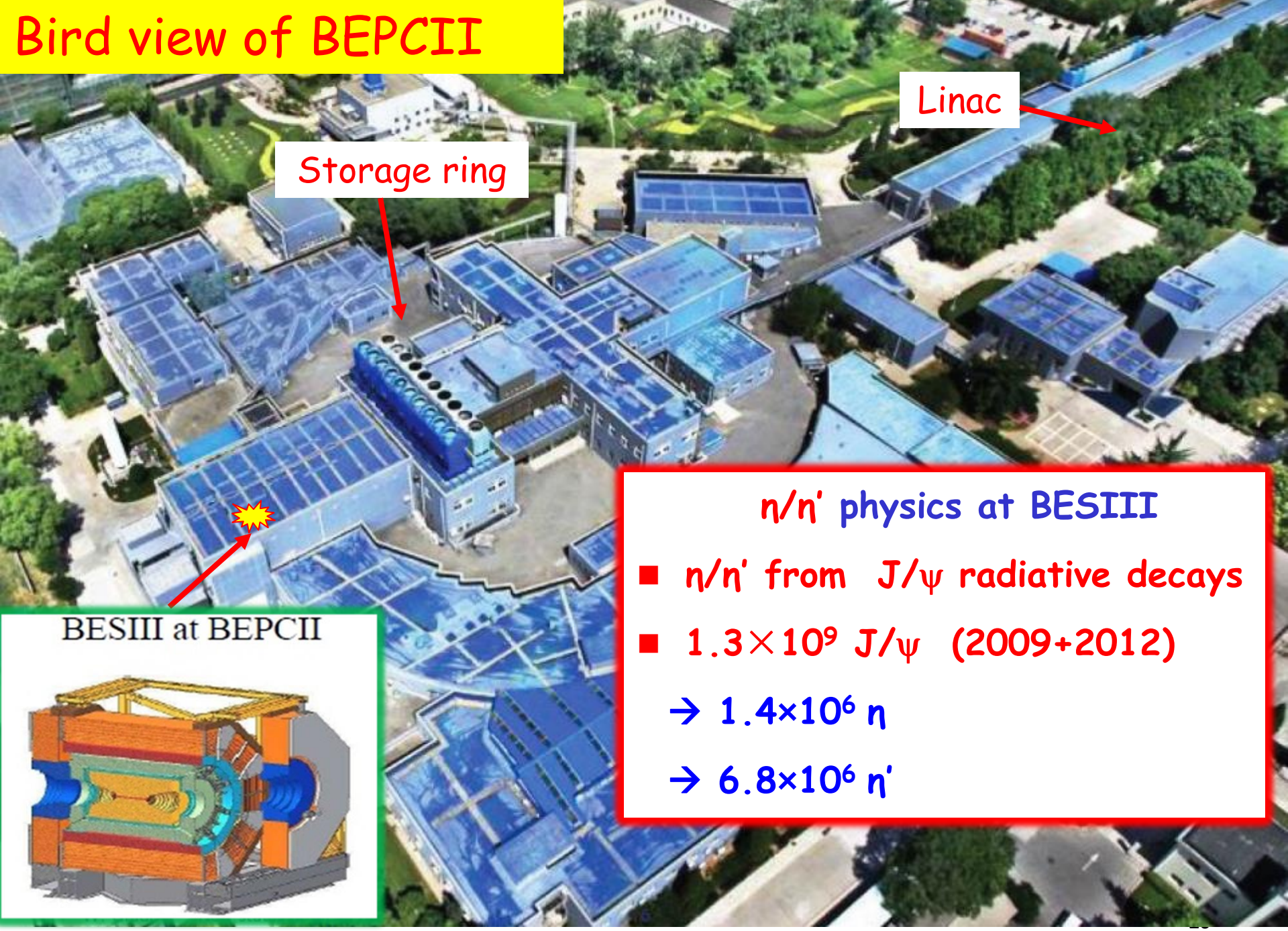
arXiv:1406.5057

Other hadronic η′ decays

$\eta' \to 2(\pi^+\pi^-)$nutrals	<1%@95%CL	HBC 1973 [1]
$\eta' \to 2(\pi^+\pi^-)\pi^0$	$<1.9\times10^{-3}$@90%CL	CLEO 2009 [2]
$\eta' \to 2(\pi^+\pi^-)2\pi^0$	<1%@95%CL	[3]HBC 1964[3]
$\eta' \to 3(\pi^+\pi^-)$	$<3.1\times10^{-5}$@90%CL	[4]BESIII 2013[4]

[1] J.S. Danburg et al., PRD8,3744(1973)
[2] P. Naik et al., PRL102,061801(2009)
[3] G.R. Kalbfleisch et al., PRL13,349(1964)
[4] M. Ablikim et al., PRD88,091502(2013)

Bird view of BEPCII



BESIII at BEPCII

η/η' physics at BESIII

- η/η' from J/ψ radiative decays
- 1.3×10^9 J/ψ (2009+2012)

→ 1.4×10^6 η

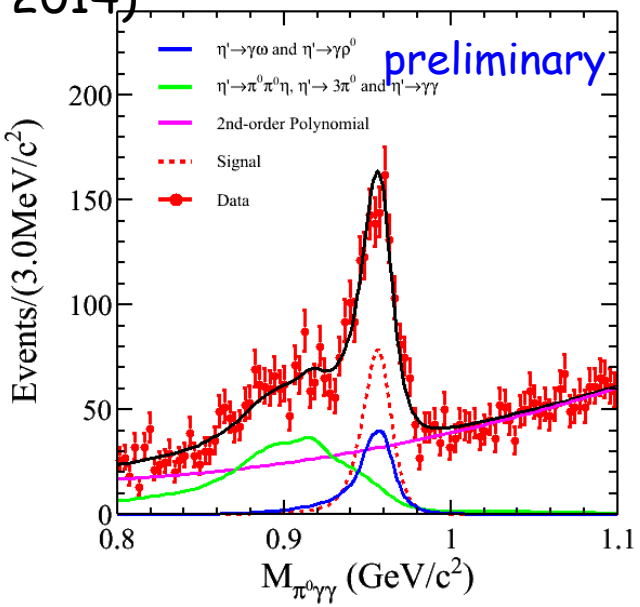
→ 6.8×10^6 η'

BESIII status on η/η' decays

Recent results from BESIII:

- $\eta' \to \pi^+\pi^-\eta$ PRD83, 012003(2011)
- $\eta/\eta' \to \pi^+\pi^-, \pi^0\pi^0$ PRD83, 032006(2011)
- $\eta/\eta' \to \pi^+\pi^- \pi^0, \pi^0\pi^0\pi^0$ 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)
- $\eta' \to \gamma\gamma\pi^0$ (preliminary)

$B=[6.91\pm0.51\pm0.54\pm0.20(PDG)] \times 10^{-4}$



BESIII status on η/η' decays

Based on the 1.3×10^9 J/ψ→ 1.4×10^6 η + 6.8×10^6 η'

MesonNet2013, Prague

- plan to update the study of η' decays
  - Study dynamics of $\eta/\eta' \to \gamma\pi^+\pi^-$ (in process)
  - Dalitz plot of $\eta' \to \pi^+\pi^-\eta/\pi^0\pi^0\eta$ (in process)
  - Dalitz plot of $\eta/\eta' \to \pi^+\pi^-\pi^0, \pi^0\pi^0\pi^0$ (in process)
  - Search for η' new decay modes (4π, $\gamma\gamma\pi^0$…)
  - Test of C,P or CP violations
  - form factor measurement

Summary&Outlook

- Current status of η' hadronic decays
- Still much room to improve the measurement
- High statistics η' in the future
  - KLOE-2: 40-50fb^{-1} $\phi \rightarrow$ ~10^7 η'
  - Crystal Ball: ~1500 η'/hour ?
  - BESIII: 10^{10} J/$\psi \rightarrow$~5$\times$ 10^7 η'
  - WASA-at-COSY: ?
  - GlueX: ?
- Allow to study η' with unprecedented precision

Thanks for you attention