

# $\eta'$ and $\eta$ decays at BESIII

BESIII



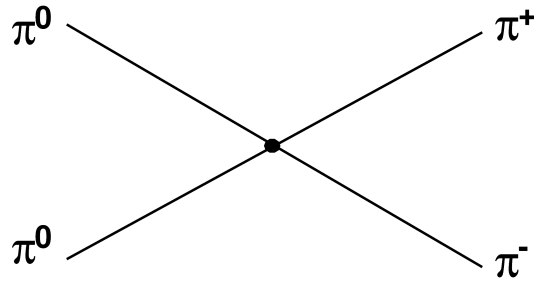
UPPSALA  
UNIVERSITET

A. Kupść

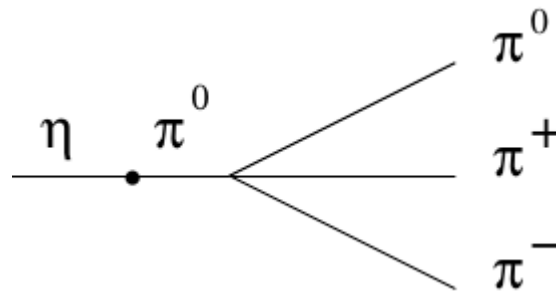
Mainz, Feb 11th, 2014

# Low Energy QCD processes

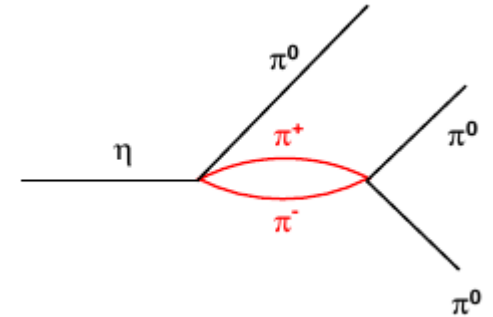
## Even # pseudoscalars PPPP



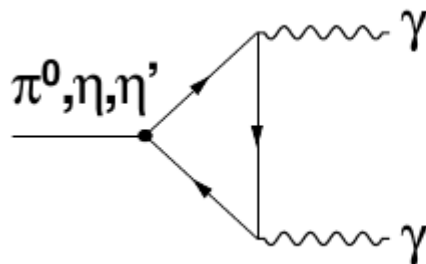
u-d quark masses



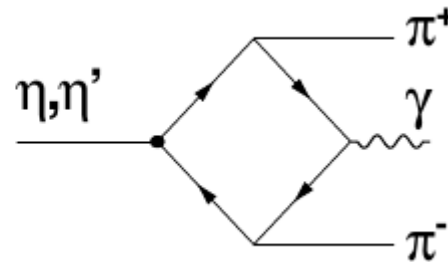
$\pi$ - $\pi$ ,  $\pi$ - $\eta$  scattering



## Anomalous: odd # pseudoscalars: PVV( $P\gamma\gamma$ ), PPPV



$V \rightarrow PV$



Vector Meson Dominance:  
 $V^0 \leftrightarrow \gamma$

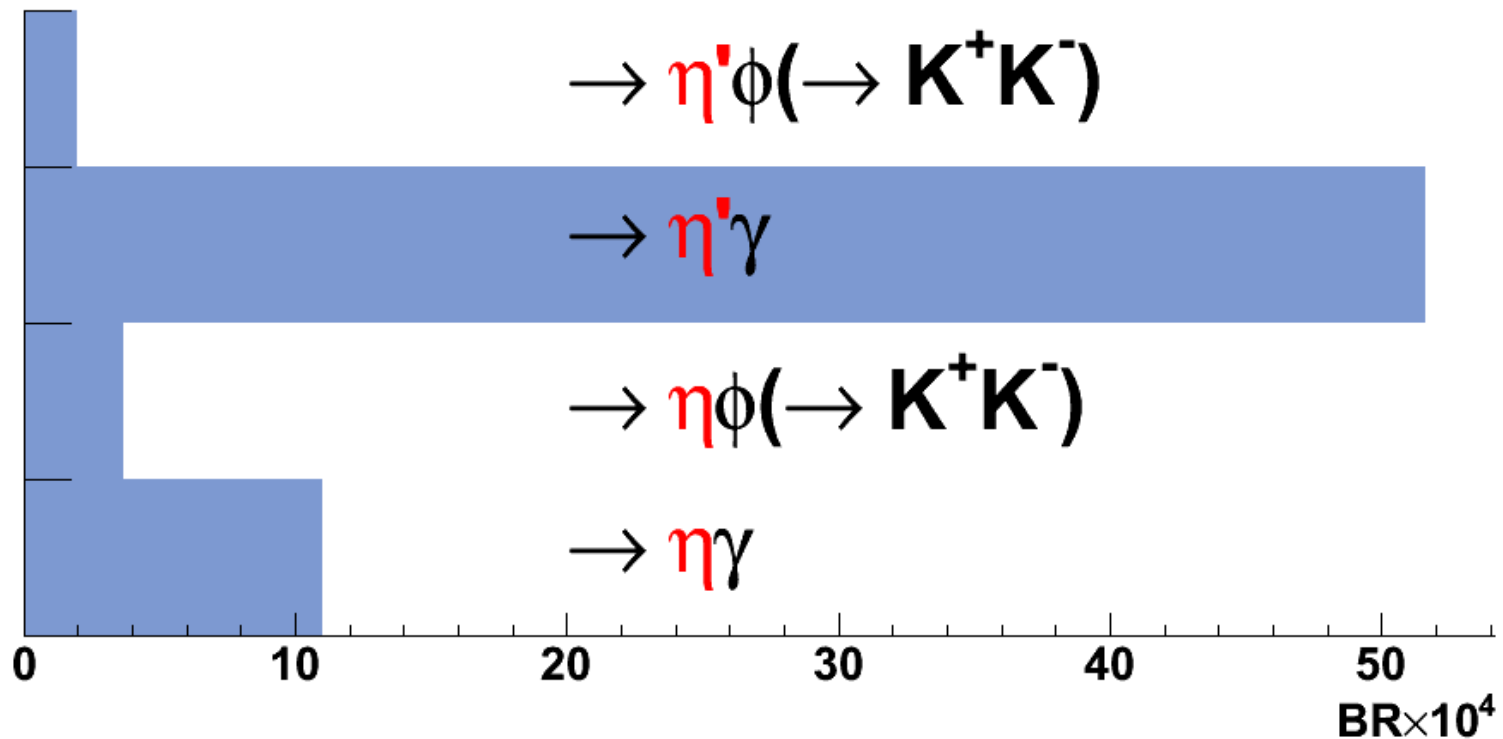


# $\eta$ and $\eta'$ events at BESIII

$225 \times 10^6$   $J/\psi$  events (2009)

$\sim 10^9$   $J/\psi$  events (2012)

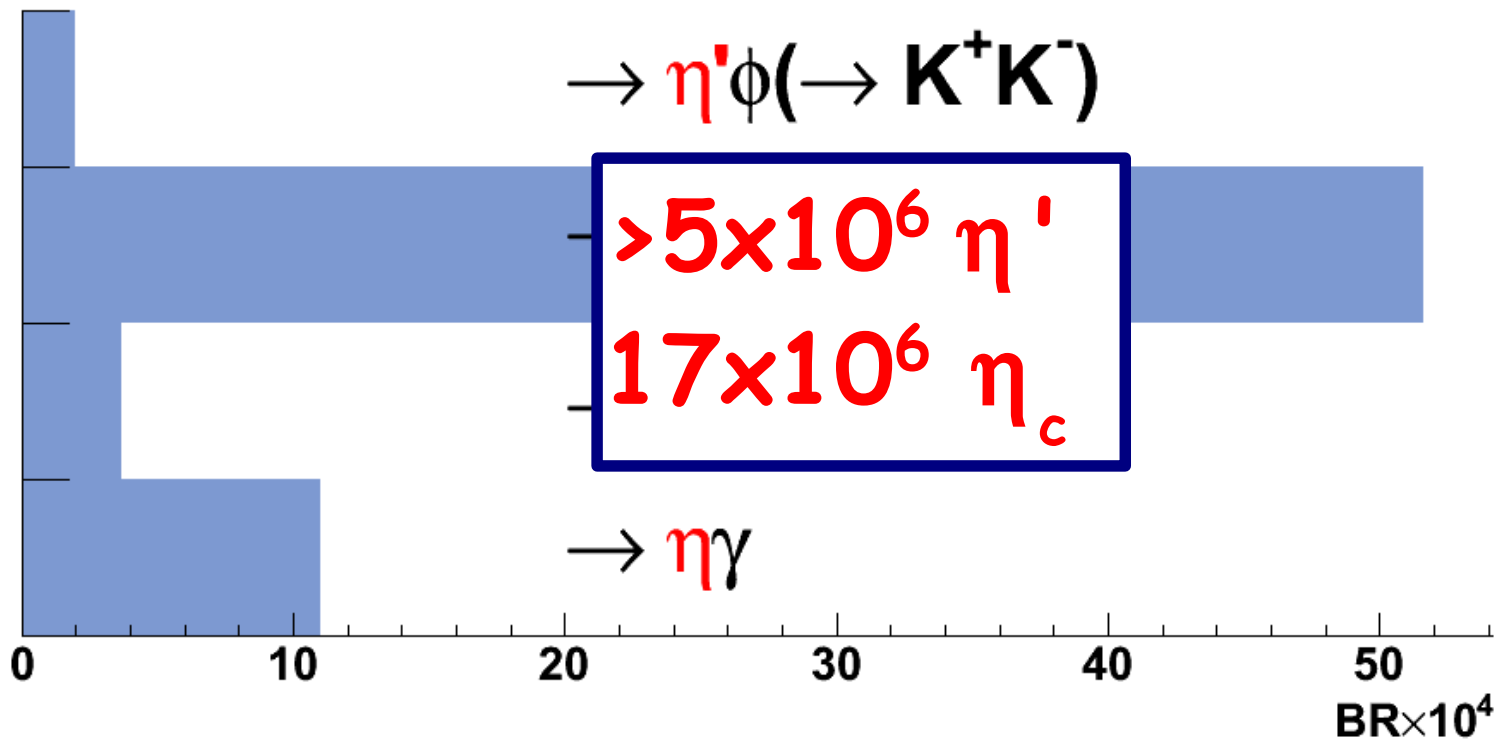
## $\eta$ and $\eta'$ production in $J/\psi$ decays



# $\eta$ and $\eta'$ events at BESIII

$225 \times 10^6$   $J/\psi$  events (2009)  
 $\sim 10^9$   $J/\psi$  events (2012)

## $\eta$ and $\eta'$ production in $J/\psi$ decays



## $\eta/\eta'$ results from BESIII:

- $\eta' \rightarrow \pi^+\pi^-\eta$  DP PRD83, 012003('11)
- $\eta/\eta' \rightarrow \pi^+\pi^-, \pi^0\pi^0$  CPV UL PRD84, 032006('11)
- $\eta' \rightarrow \pi^+\pi^-\pi^0, \pi^0\pi^0\pi^0$  BR PRL108, 182001('12)
- $\eta' \rightarrow \pi^+\pi^-l^+l^-$  BR PRD87, 092001('13)
- invisible decays UL PRD87, 012009('13)
- weak decays UL PRD87, 032006('13)

These results are based on 2009 data only

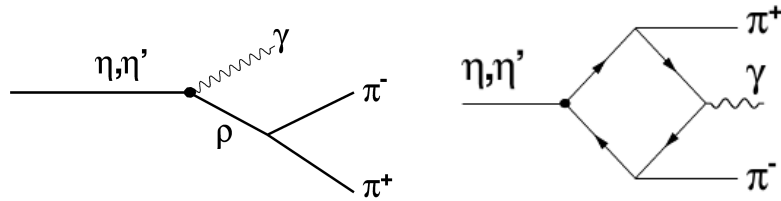


## More BESIII analyses on $\eta/\eta'$ decays:

- DP  $\eta' \rightarrow \pi^+\pi^-\eta$
- DP of  $\eta/\eta' \rightarrow \pi^+\pi^-\pi^0, \pi^0\pi^0\pi^0$
- $M_{\pi\pi}$  of  $\eta/\eta' \rightarrow \gamma\pi^+\pi^-$
- Search for new  $\eta'$  decays ( $4\pi, \gamma\gamma\pi^0, \dots$ )
- $\eta/\eta' \rightarrow e^+e^-\gamma$  BR/TFF
- Tests of C,P or CP violation



# $\eta \rightarrow \pi^+ \pi^- \gamma$

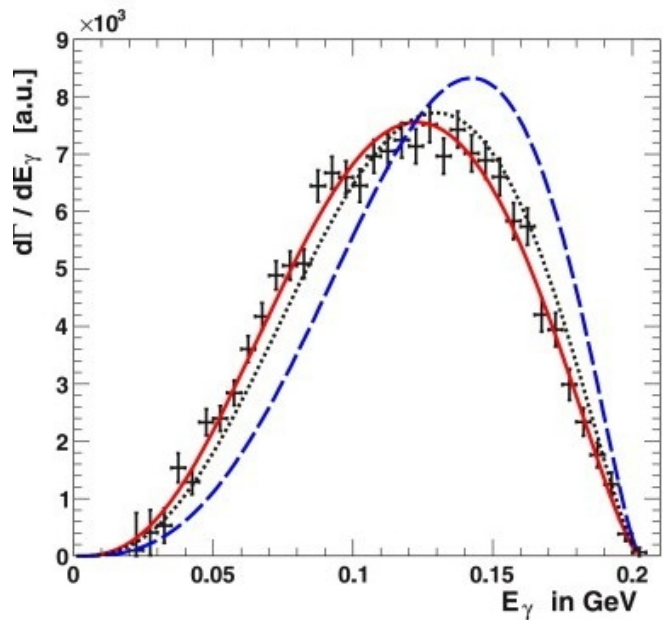


$$\frac{d\Gamma_{\eta(\eta')}}{ds_{\pi\pi}} \propto \left| C + \frac{1}{s_{\pi\pi} - m_\rho^2 - im_\rho \Gamma_\rho} \right|^2$$

$$\frac{d\Gamma}{ds} = |A(1 + \alpha s + \dots) F_V(s)|^2 K_P(s)$$

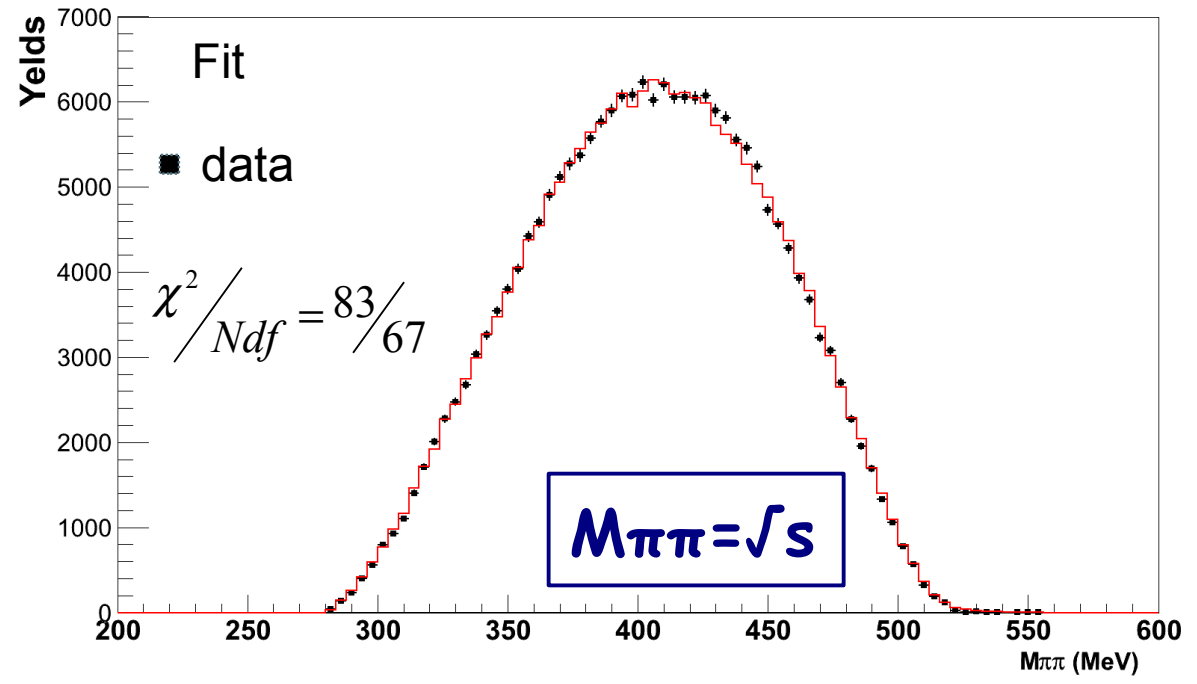
PLB707 (2012) 184

$e^+ e^- \rightarrow \pi^+ \pi^-$



$$\alpha = 1.89 \pm 0.25_{\text{stat}} \pm 0.59_{\text{syst}} \text{ GeV}^{-2}$$

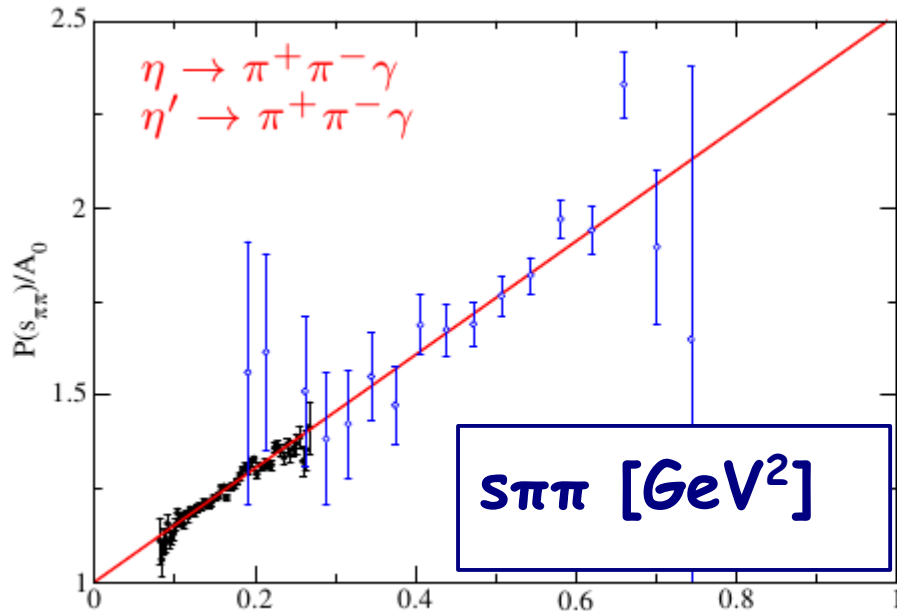
[WASA PLB707 (2012) 243]



$$\alpha = 1.31 \pm 0.08_{\text{stat}} \pm 0.40_{\text{syst}} \text{ GeV}^{-2}$$

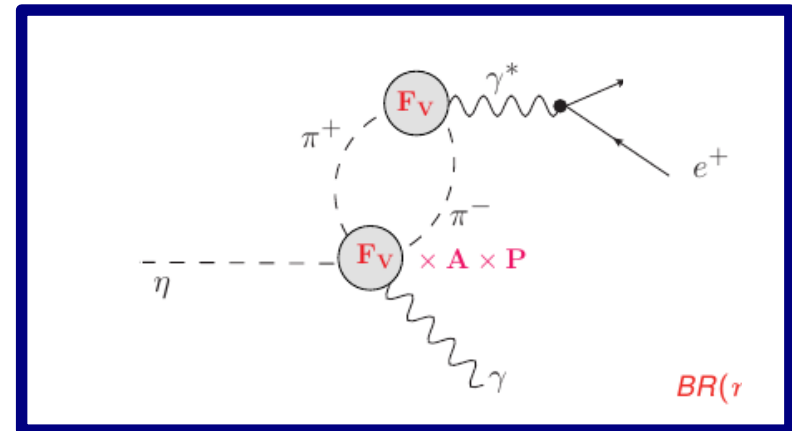
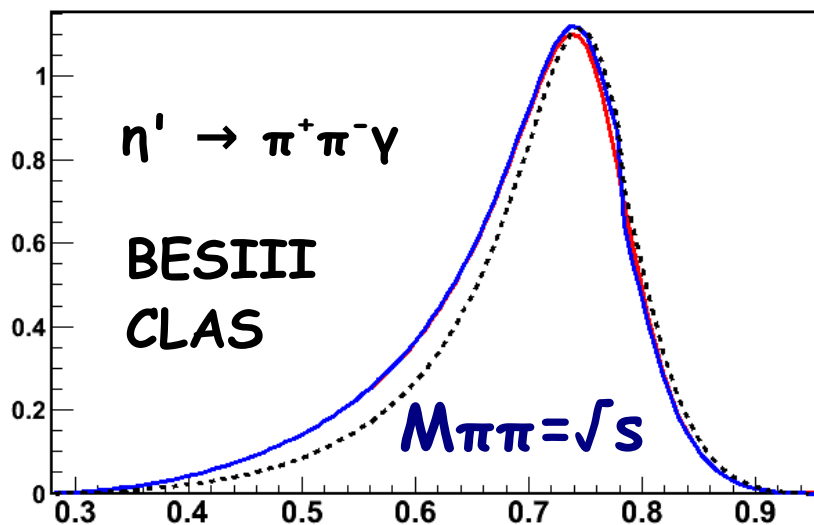
[KLOE PLB718 (2013) 910]

# From $\eta \rightarrow \pi^+\pi^-\gamma$ to $\eta \rightarrow e^+e^-\gamma$



$$P(s_{\pi\pi}) = A_0(1 + \alpha s_{\pi\pi})$$

- $\alpha$  reaction specific
- $\alpha[\eta] = \alpha[\eta']$  understood  
1-loop ChPT + large  $N_c$

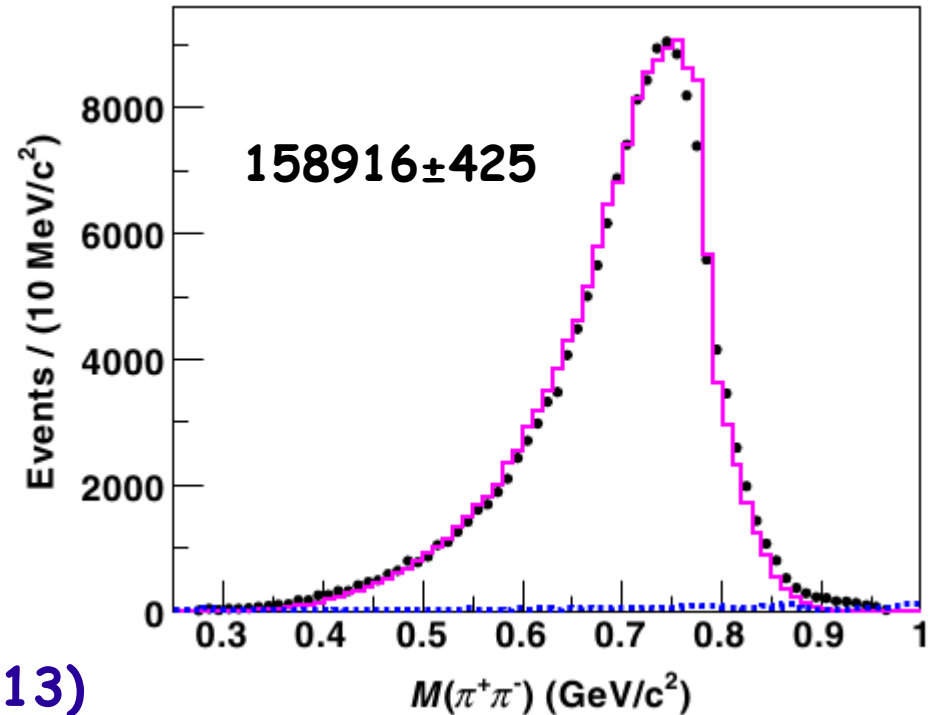
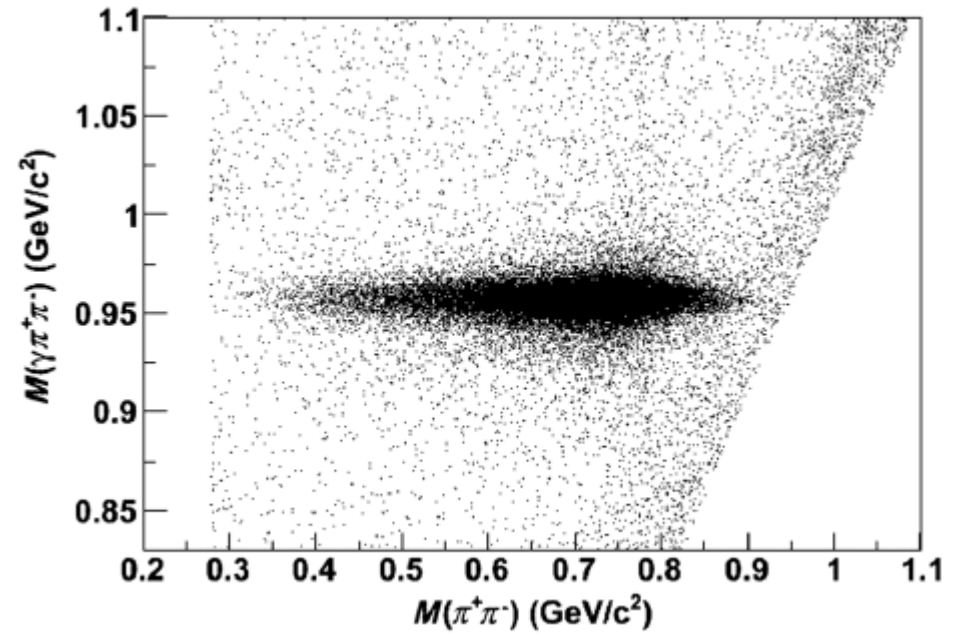
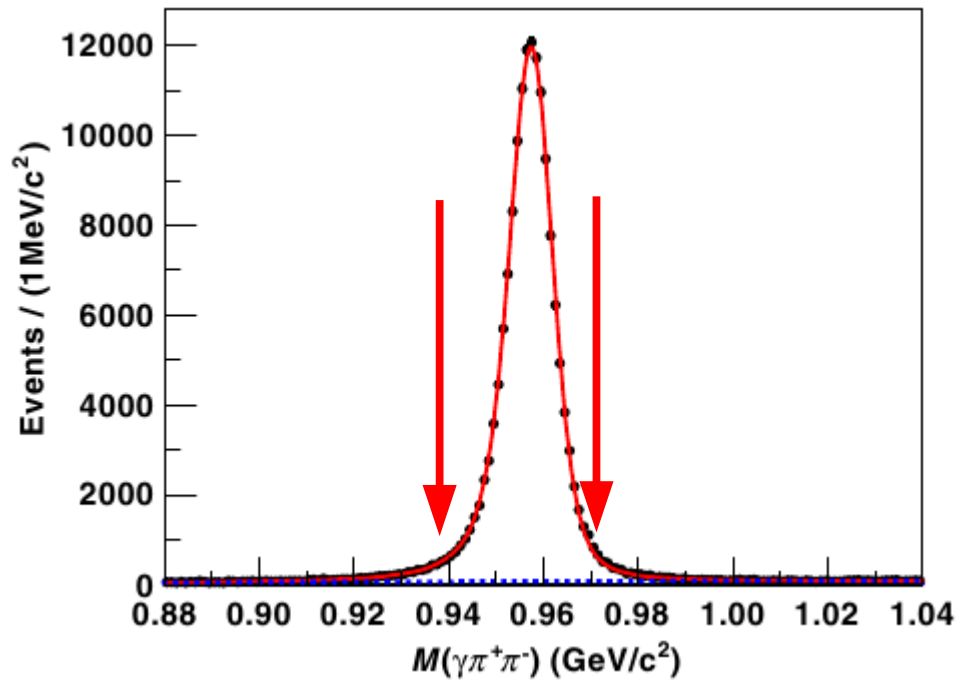


**KLOE:  $A + \alpha \Rightarrow b\eta(0) = 2.05^{+0.22}_{-0.10} \text{ GeV}^{-2}$**

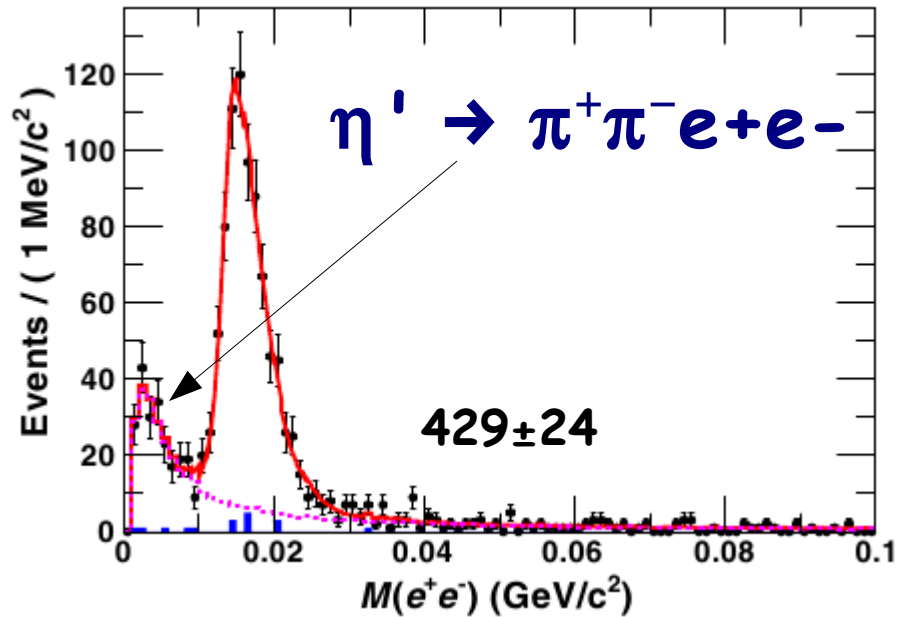
arXiv:1307.5654



# BESIII data sample on $\eta \rightarrow \pi^+\pi^-\gamma$



# $\eta' \rightarrow \pi^+\pi^-e^+e^- \dots$



BESIII PRD87, 092001('13)

$$\text{BR} = (2.11 \pm 0.12(\text{stat}) \pm 0.14(\text{syst})) \times 10^{-3}$$

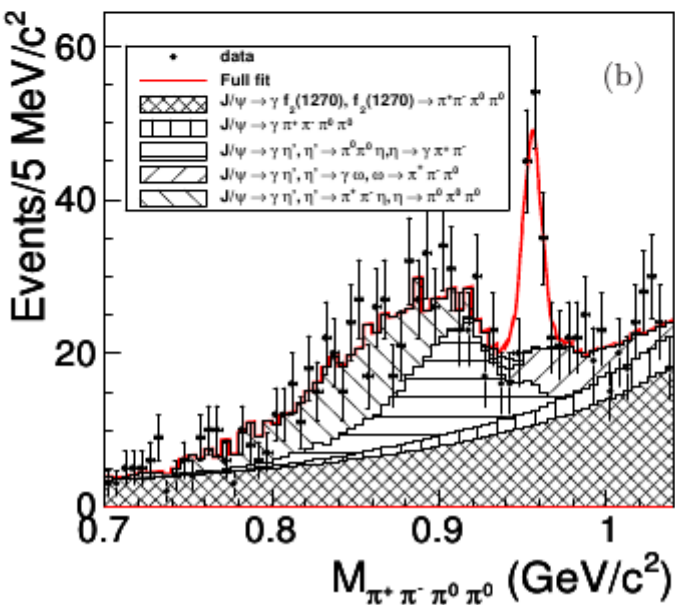
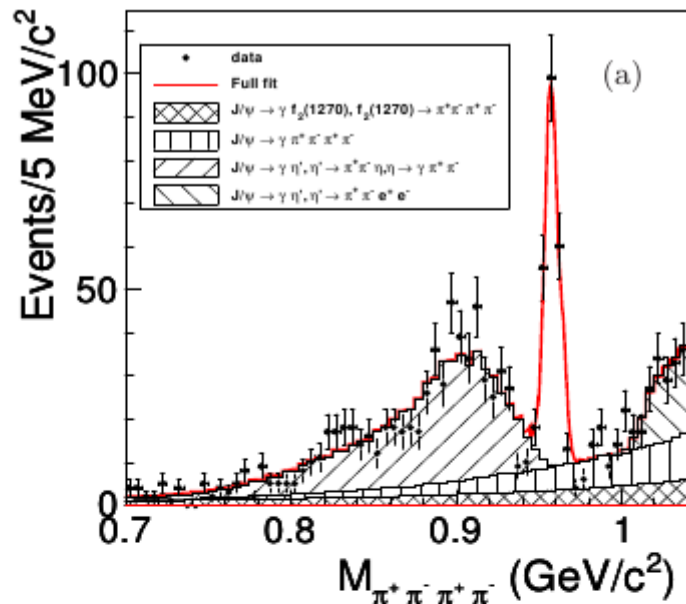
$$\text{VMD } 1.8 \times 10^{-3}$$

$$\text{BR}(\eta' \rightarrow \pi^+\pi^-\mu^+\mu^-) < 2.9 \times 10^{-5}$$

$$\text{VMD } 2 \times 10^{-5}$$

VMD: Faessler, Fuchs, Krivoruchenko PRC61 ('00) 035206





Mode	Yield
$\eta' \rightarrow \pi^+\pi^-\pi^+\pi^-$	$199 \pm 16$
$\eta' \rightarrow \pi^+\pi^-\pi^0\pi^0$	$84 \pm 16$

arXiv:1404.0096

$$\mathcal{B}(\eta' \rightarrow \pi^+\pi^-\pi^+\pi^-) = (8.41 \pm 0.68_{\text{stat}} \pm 0.63_{\text{syst}}) \times 10^{-5}$$

$$\mathcal{B}(\eta' \rightarrow \pi^+\pi^-\pi^0\pi^0) = (1.90 \pm 0.36_{\text{stat}} \pm 0.19_{\text{syst}}) \times 10^{-4}$$

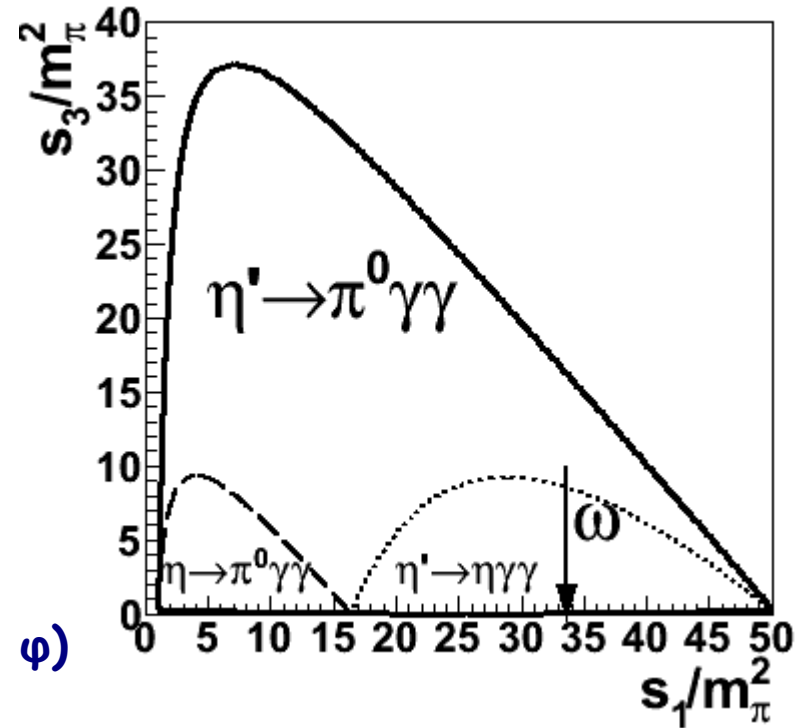
$$\mathcal{B}(\eta' \rightarrow 2(\pi^+\pi^-)) = (1.0 \pm 0.3) \times 10^{-4}$$

$$\mathcal{B}(\eta' \rightarrow \pi^+\pi^-\pi^0\pi^0) = (2.4 \pm 0.7) \times 10^{-4}$$

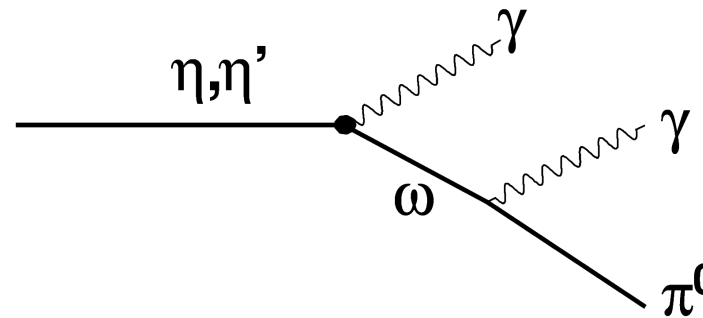
Guo, Kubis, Wirzba PRD85 (2012) 014014

# $\eta/\eta' \rightarrow \pi^0\gamma\gamma$

$BR \times 10^4$	VMD	Exp	
$\eta \rightarrow \pi^0\gamma\gamma$	2.1	$2.7 \pm 0.5$	PDG
$\eta' \rightarrow \omega[\pi^0\gamma]\gamma$	52		
$\eta' \rightarrow \pi^0\gamma\gamma$	3	$< 8$ (90% CL)	GAMS(87)
$\eta' \rightarrow \eta\gamma\gamma$	2.5	—	

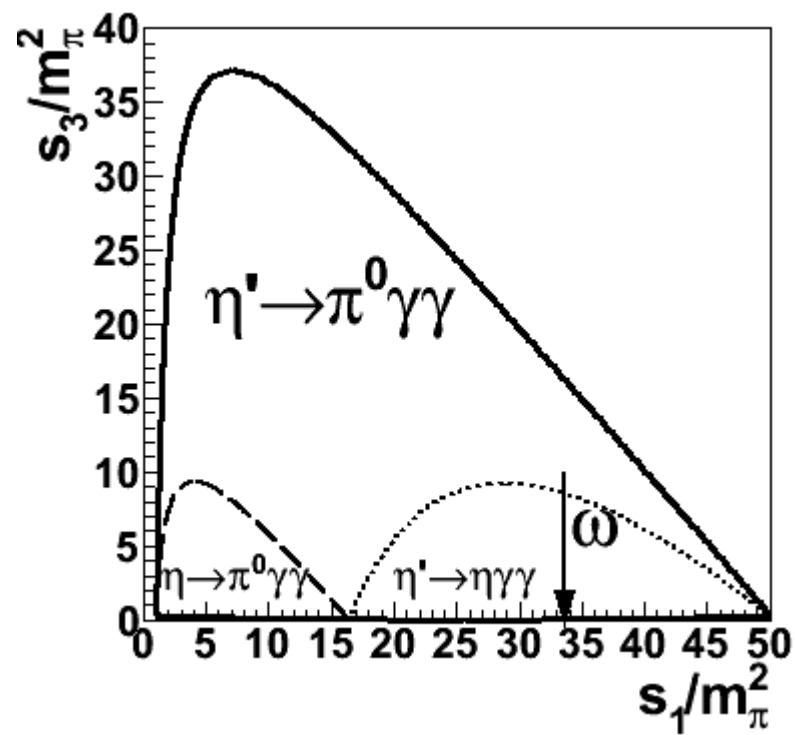
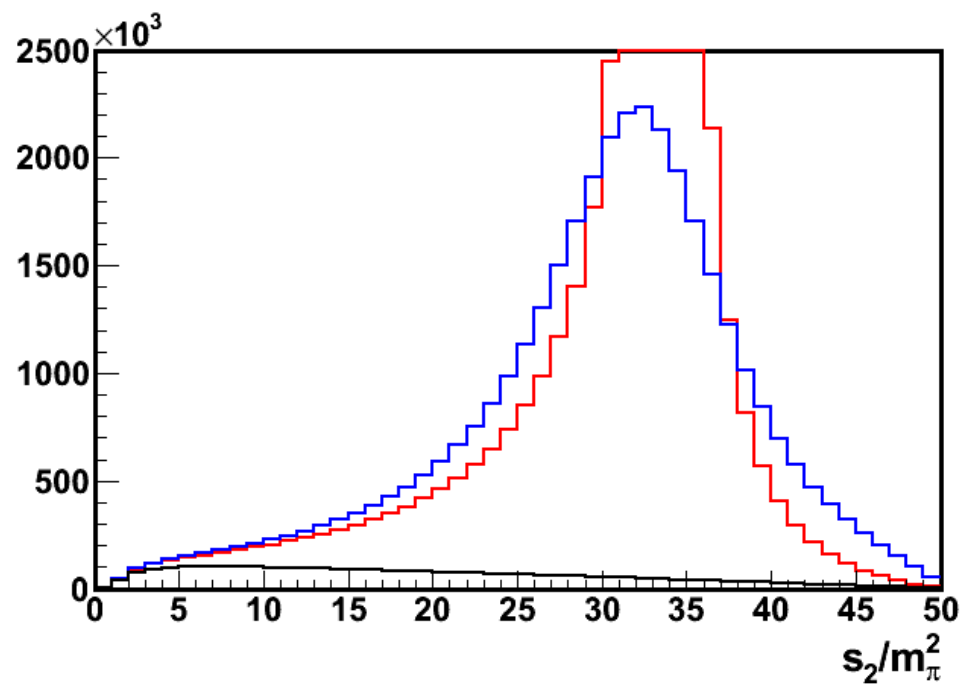
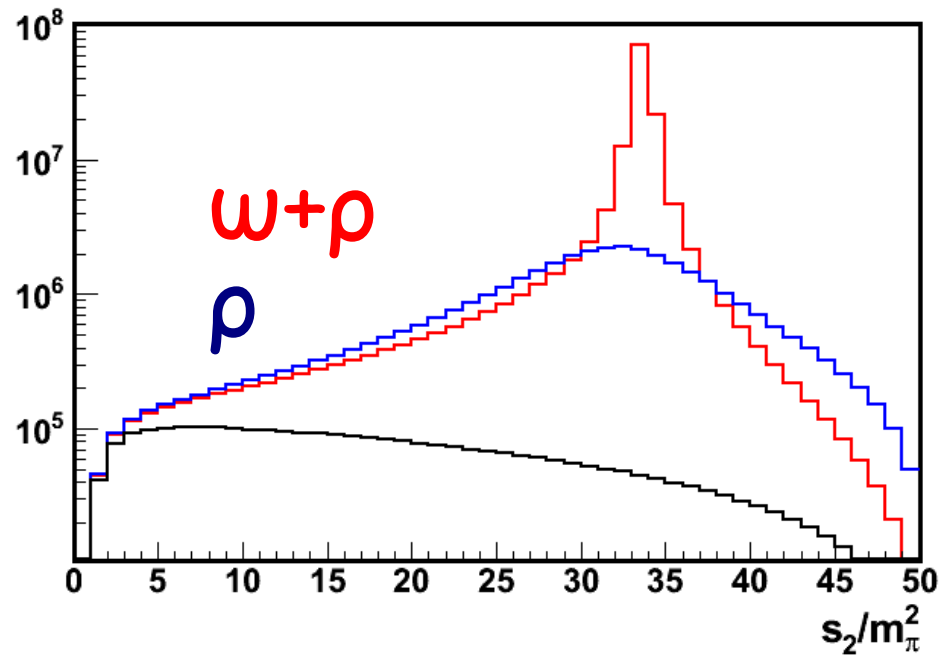


$\eta' \rightarrow \pi^0\gamma\gamma$  80%  $\omega$  4.6%  $\rho$  (+15%  $\rho\omega$  interf? and  $\varphi$ )  
 Rafel (arXiv:1207.5400)

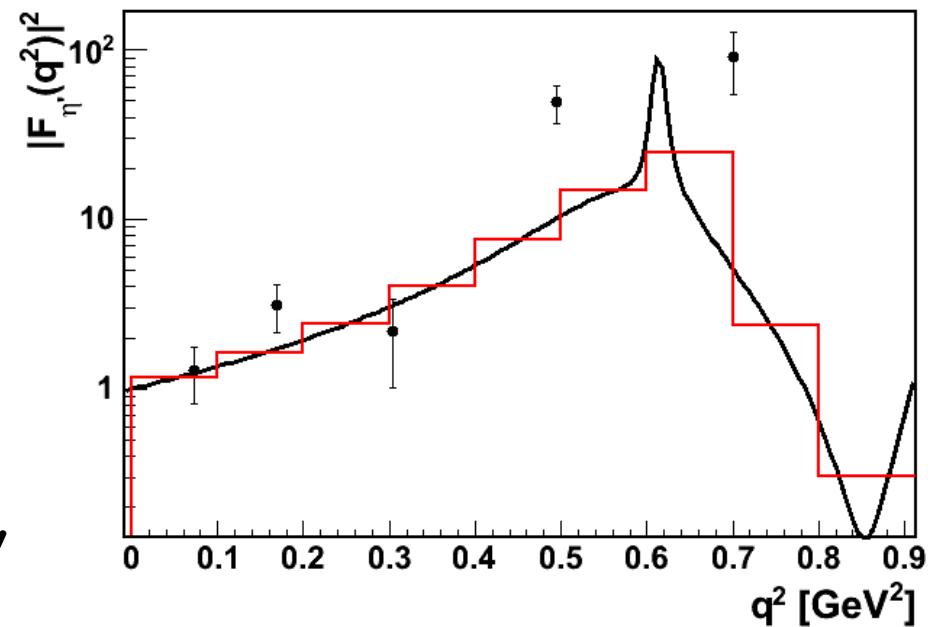
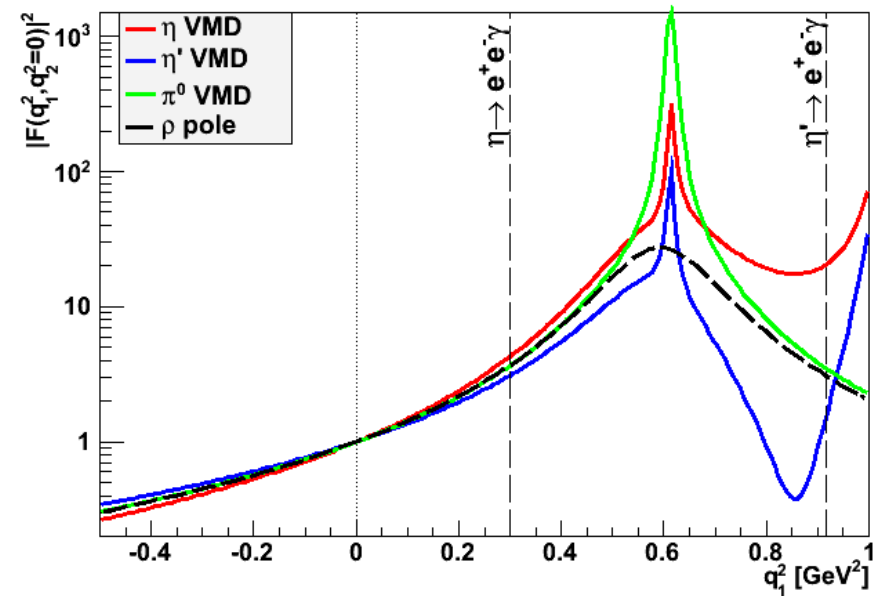
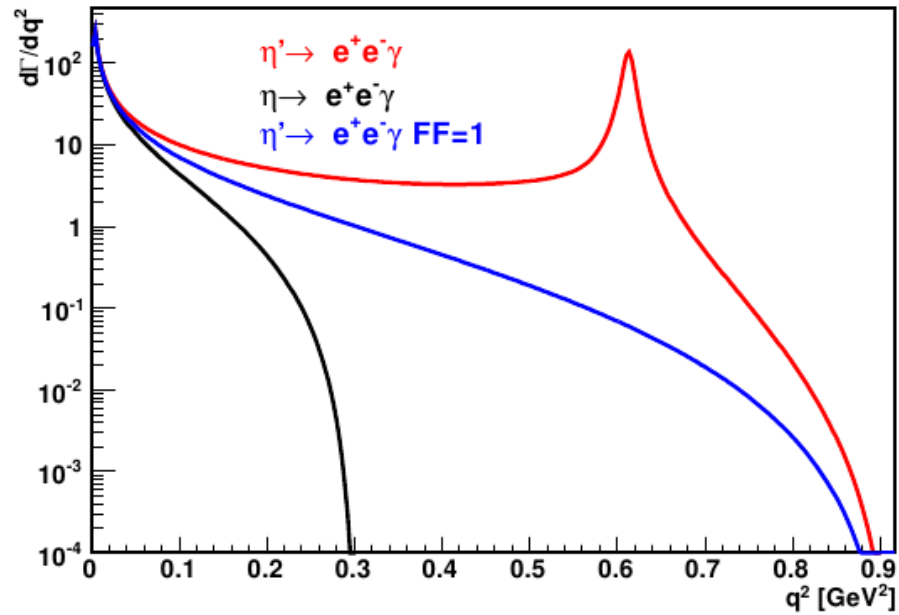


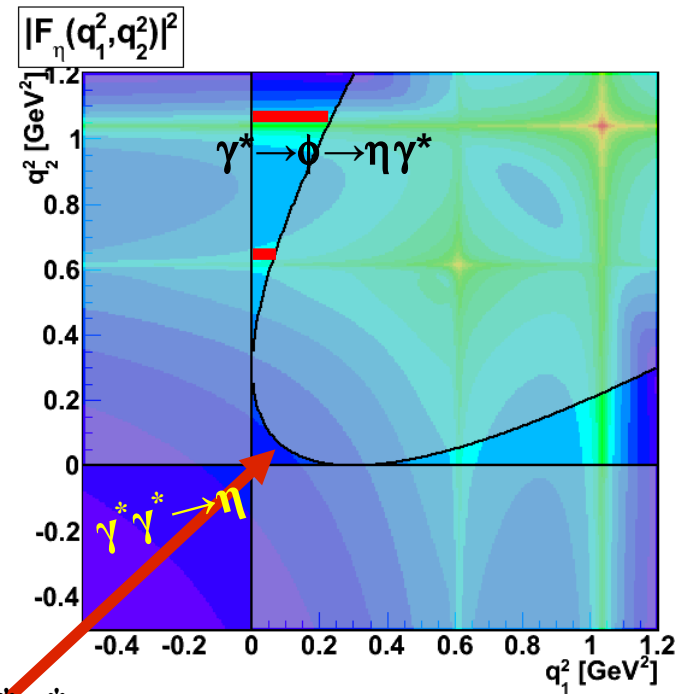
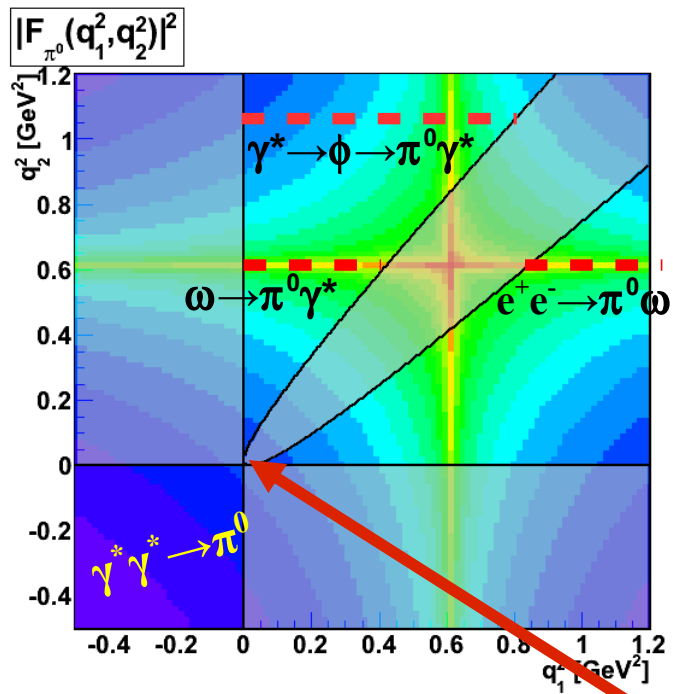
Dominant VMD contribution



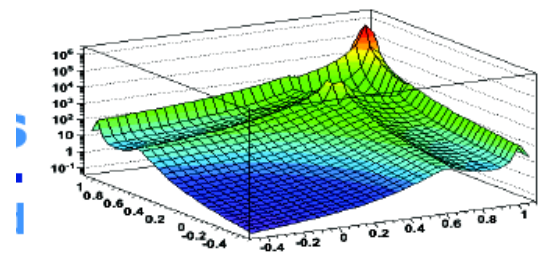


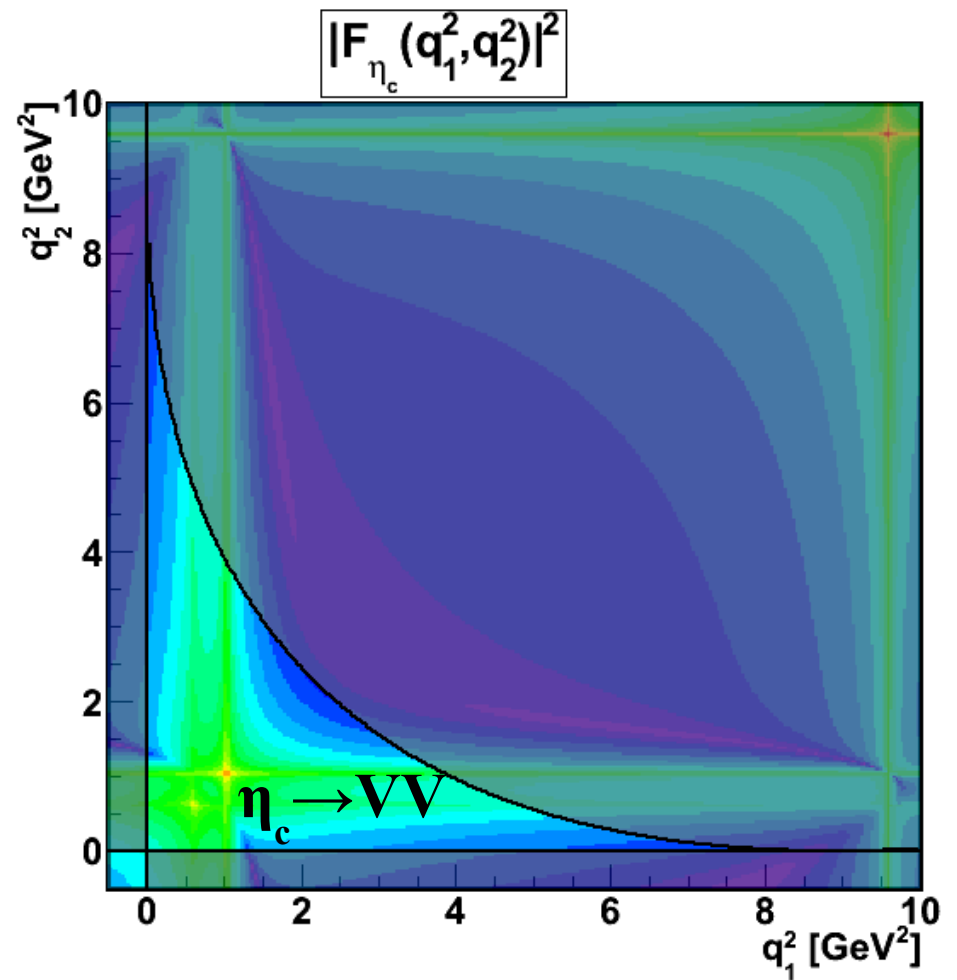
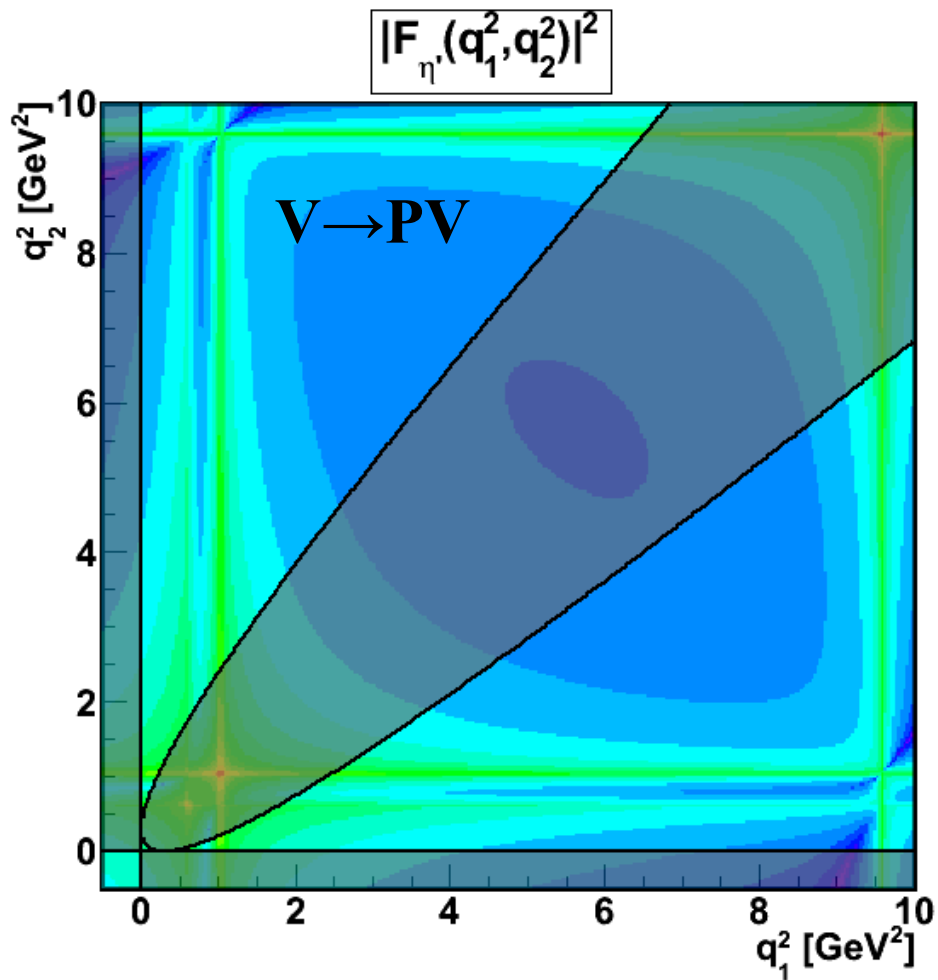
# Dalitz decays





$P \rightarrow \gamma^* \gamma^*$





$$\eta_c \rightarrow \rho\rho \quad 1.8\%$$

$$\eta_c \rightarrow K^*\bar{K}^* \quad 0.7\%$$

$$\eta_c \rightarrow \varphi\varphi \quad 0.2\%$$





BESIII (  $10^7\eta$ ,  $10^7\eta'$ ,  $10^7\eta_c$ ,  $10^9J/\psi\dots$  )

Expect many interesting results  $\eta'$ ...

Meson Transition Form Factors in  $P \rightarrow VV$ ,  
 $e^+e^- \rightarrow V \rightarrow V^*P$

Treatment of narrow  $V$  mesons in  $\eta'$  decays

Physics interest for  $\eta_c$  decays ?

