Transition form factors of π^0 and η mesons (experiments)

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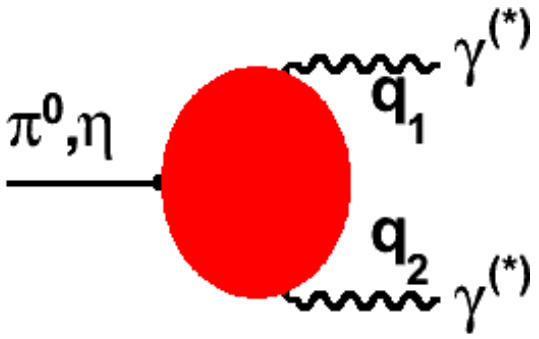
Pseudoscalar Transition Form Factors (TFF)

Structure of light mesons

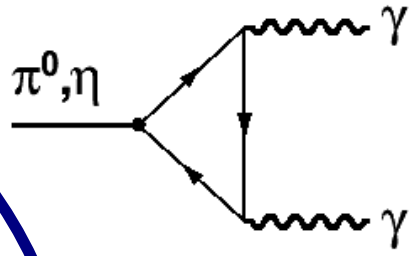
L/H energy QDC LAB

l^+l^- spectra in HIon

$\Gamma(P \to \gamma\gamma)$



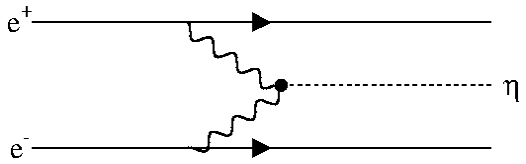
$F_P(q_1^2, q_2^2)$

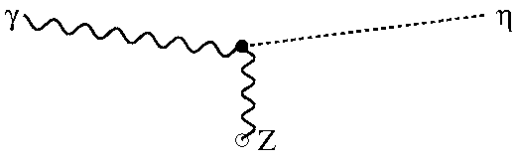


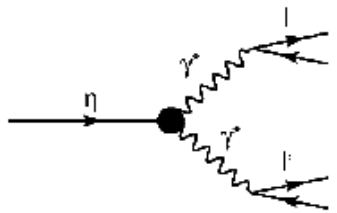
η: Γγγ

m_u/m_d

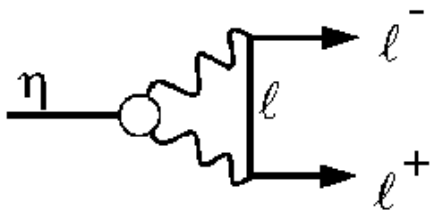
$F\pi^0$ $q^2 \to \infty$ puzzle

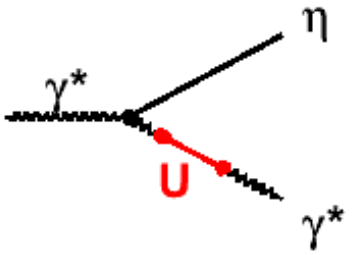




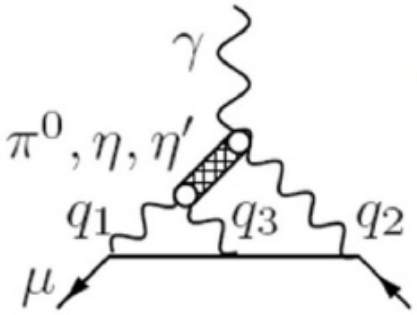


$P \to l^+l^-$





Dark photon



g-2 HLbL

Radiative widths of η, π^0

η, π^0 : narrow and short lived

=> $\Gamma_{tot}=\Gamma_{\gamma\gamma}/BR_{\gamma\gamma}$

η: 5×10^{-19} s; Γ=1.3 keV $\quad \eta \to \gamma\gamma$

π^0: 8×10^{-17} s; $c\tau$=25 nm $\quad \pi^0 \to \gamma\gamma$

Two exp. techniques:

$\gamma Z \to \eta, \pi^0$ Primakoff

$\delta\Gamma(\pi^0\to\gamma\gamma)$ ~2.8%

PrimEx PRL 106,162303(2011)

$\delta\Gamma(\eta\to\gamma\gamma)$ ~5%

VALUE (keV)	EVTS	DOCUMENT ID		TECN	COMMENT
0.510 ± 0.026	**OUR FIT**				
0.510 ± 0.026	**OUR AVERAGE**				
0.51 ± 0.12 ± 0.05	36	BARU	90	MD1	$e^+e^-\to e^+e^-\eta$
0.490 ± 0.010 ± 0.048	2287	ROE	90	ASP	$e^+e^-\to e^+e^-\eta$
0.514 ± 0.017 ± 0.035	1295	WILLIAMS	88	CBAL	$e^+e^-\to e^+e^-\eta$
0.53 ± 0.04 ± 0.04		BARTEL	85E	JADE	$e^+e^-\to e^+e^-\eta$
* * * We do not use the following data for averages, fits, limits, *etc.* * * *					
0.476 ± 0.062	[1]	RODRIGUES	08	CNTR	Reanalysis
0.64 ± 0.14 ± 0.13		AIHARA	86	TPC	$e^+e^-\to e^+e^-\eta$
0.56 ± 0.16	56	WEINSTEIN	83	CBAL	$e^+e^-\to e^+e^-\eta$
0.324 ± 0.046		BROWMAN	74B	CNTR	Primakoff effect
1.00 ± 0.22	[2]	BEMPORAD	67	CNTR	Primakoff effect

e^+e^-: $\gamma\gamma \to \eta, \pi^0$

KLOE-2 Taggers

$5fb^{-1}$ => $\delta\Gamma(\pi^0\to\gamma\gamma)$ ~1%

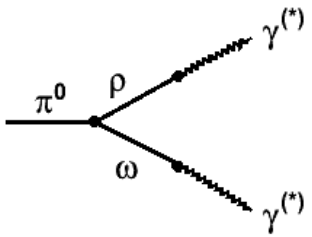
Details: [EPJC 72, 1917 (2012)]

$\sigma(e^+e^- \to e^+e^-\eta, \sqrt{s}=1GeV)$

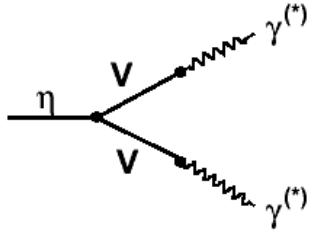
$\Gamma_{\gamma\gamma}=520\pm20_{stat}\pm13_{syst}$ eV

[KLOE JHEP1301 (2013) 119]

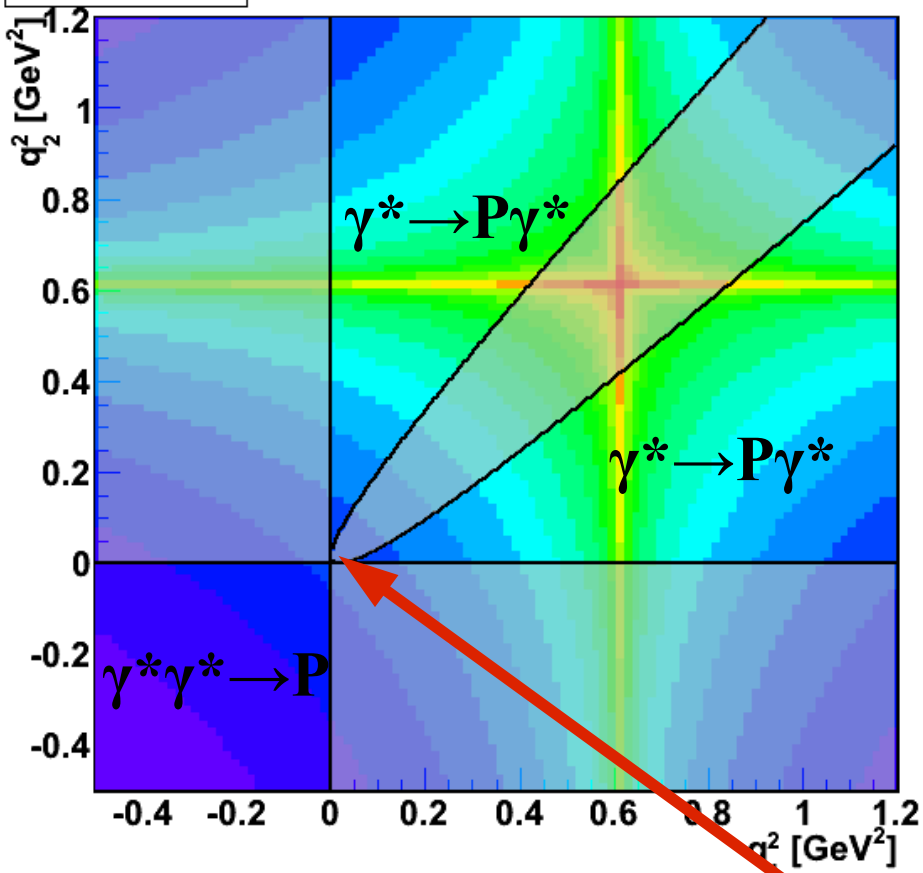
TFF kinematic regions: π^0,η



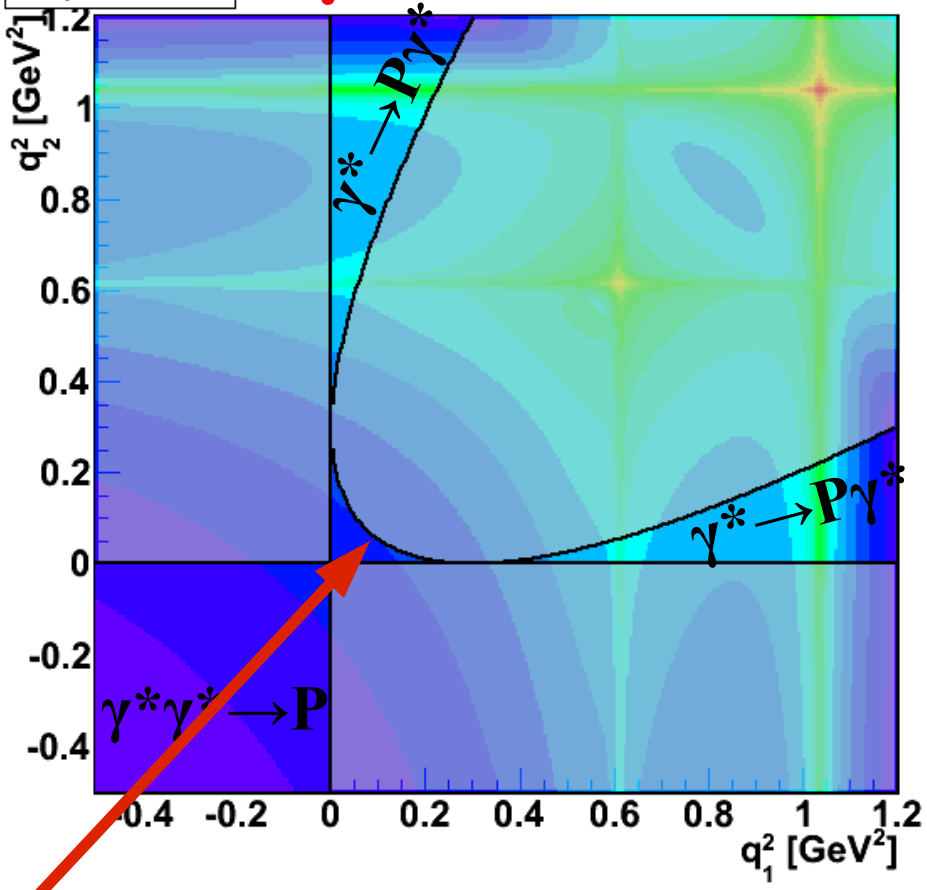
$$\sum_{V=\rho,\omega,\phi}$$



$|F_{\pi^0}(q_1^2,q_2^2)|^2$ **π^0**

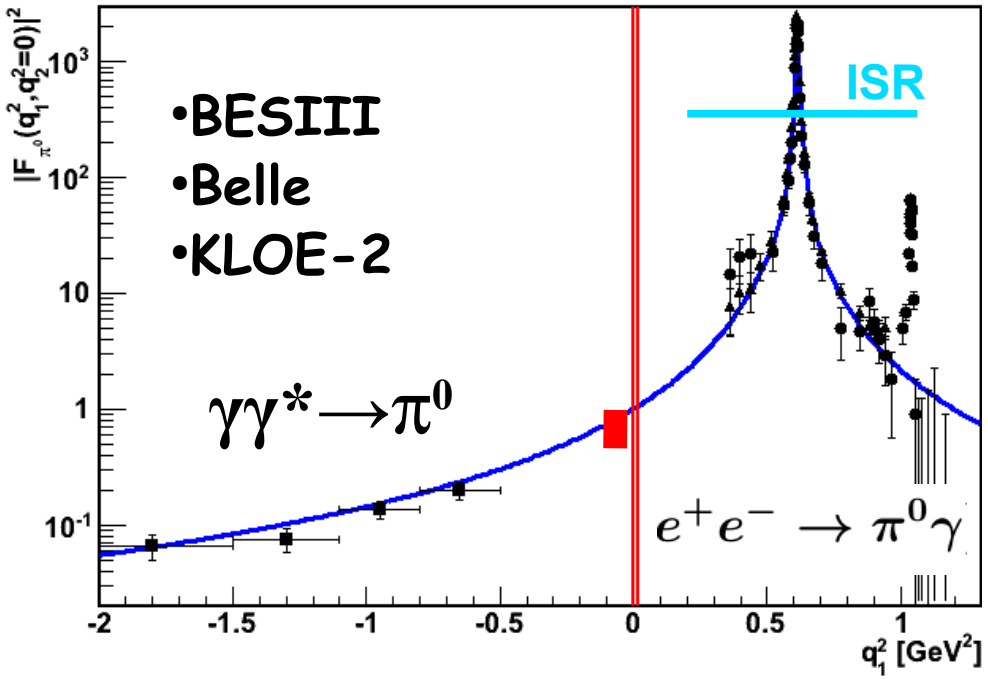


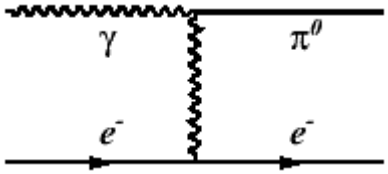
$|F_{\eta}(q_1^2,q_2^2)|^2$ **η**



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

η,π^0 single off shell TFF





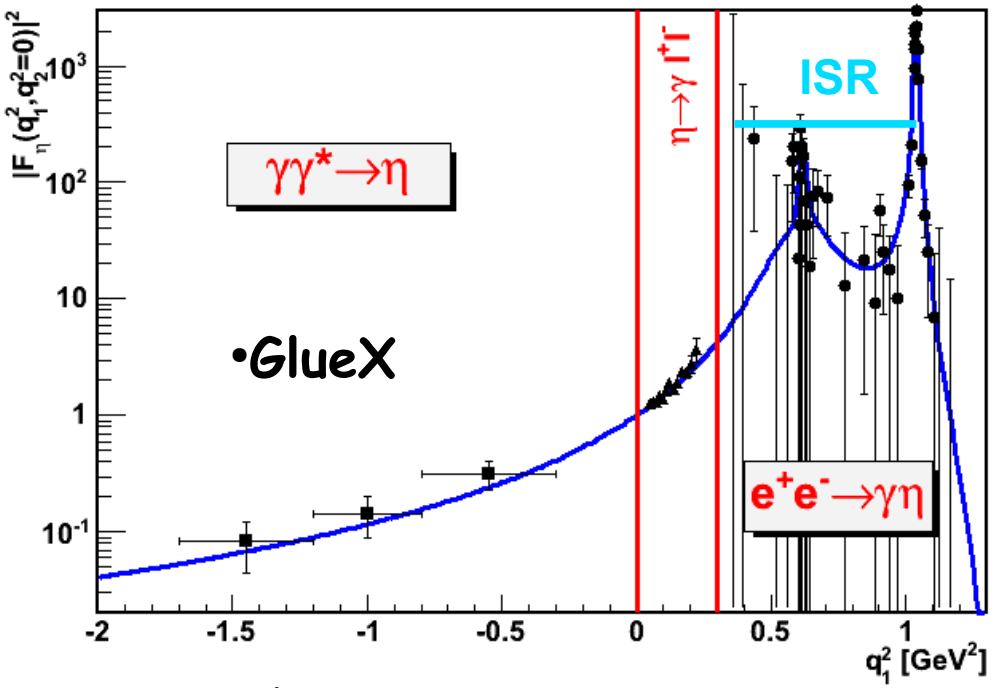
$$\frac{d\sigma}{dt}(e^-\gamma \to e^- P) = \frac{16}{3}\frac{\pi\alpha}{s m_P^3}\,\Gamma_{\gamma\gamma}|F_P(t,0)|^2\,\frac{s-m_P^2+t}{t}$$

P→γ*γ

Dalitz decays:

KLOE, WASA,CBall,BESIII

CLAS,NA48

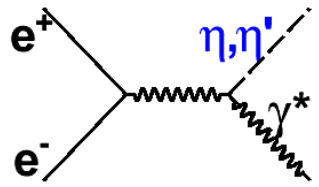


γ*→Pγ

VEPP 2000 0.3-2GeV

KLOE-2 ISR, BESIII

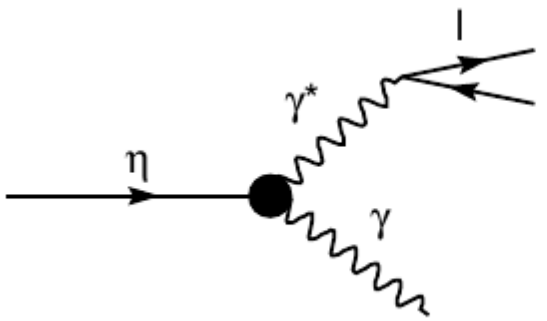
$$\sigma(e^+e^- \to P\gamma) = \frac{8}{3}\pi\alpha\,\Gamma_{\gamma\gamma}|F_P(s,0)|^2\left(\frac{s-m_P^2}{s m_P}\right)^3$$



Data:CELLO,NA60,CB-MAMI,CMD-2,SND

Dalitz decays

$$\frac{d\Gamma(P \to \ell^+\ell^-\gamma)}{dq^2\Gamma_{\gamma\gamma}} = \frac{2\alpha}{3\pi}\frac{1}{q^2}\sqrt{1-\frac{4m_\ell^2}{q^2}}\left(1+\frac{2m_\ell^2}{q^2}\right)\left(1-\frac{q^2}{M_P^2}\right)^3 |F_P(q^2,0)|^2$$



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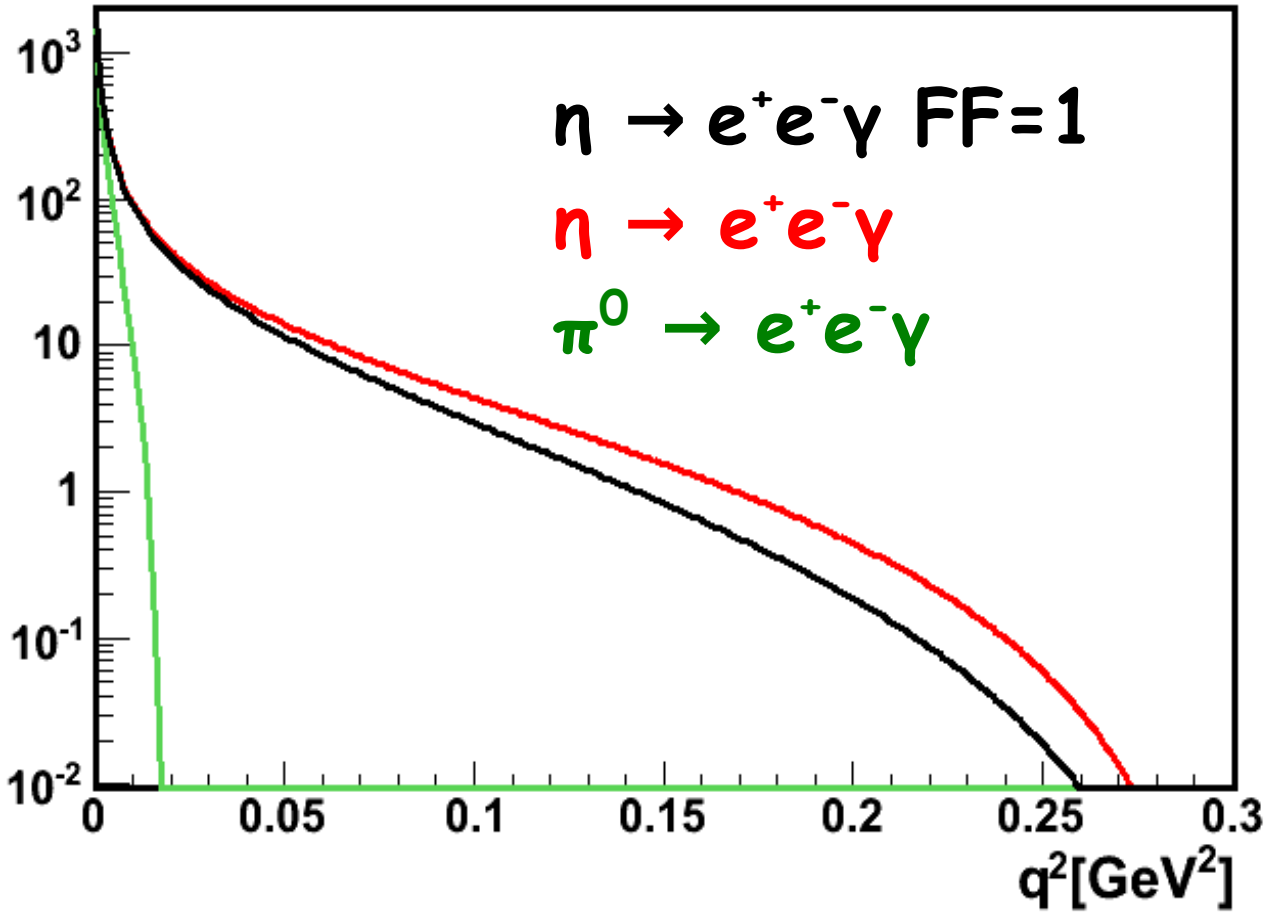

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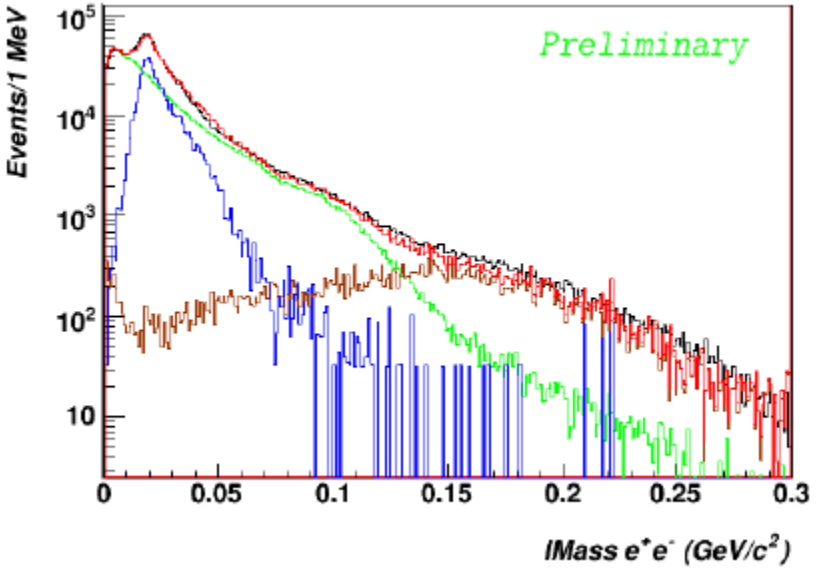
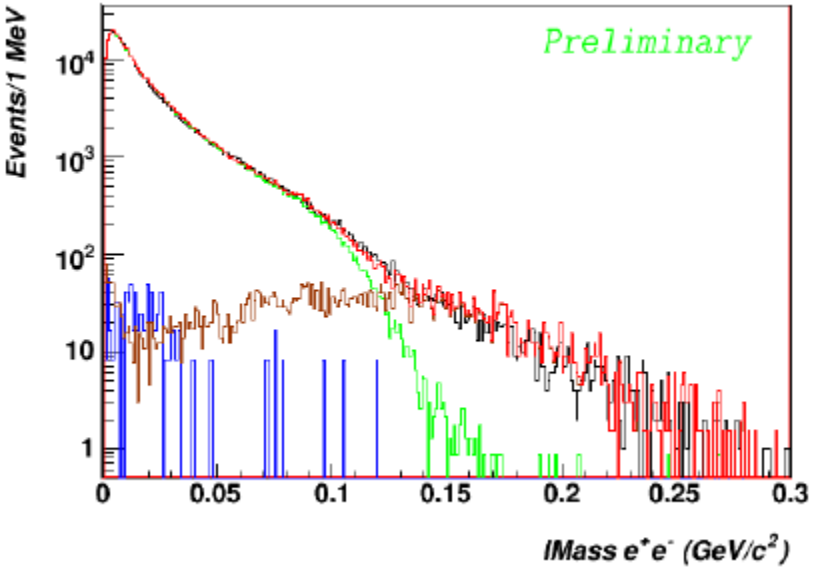
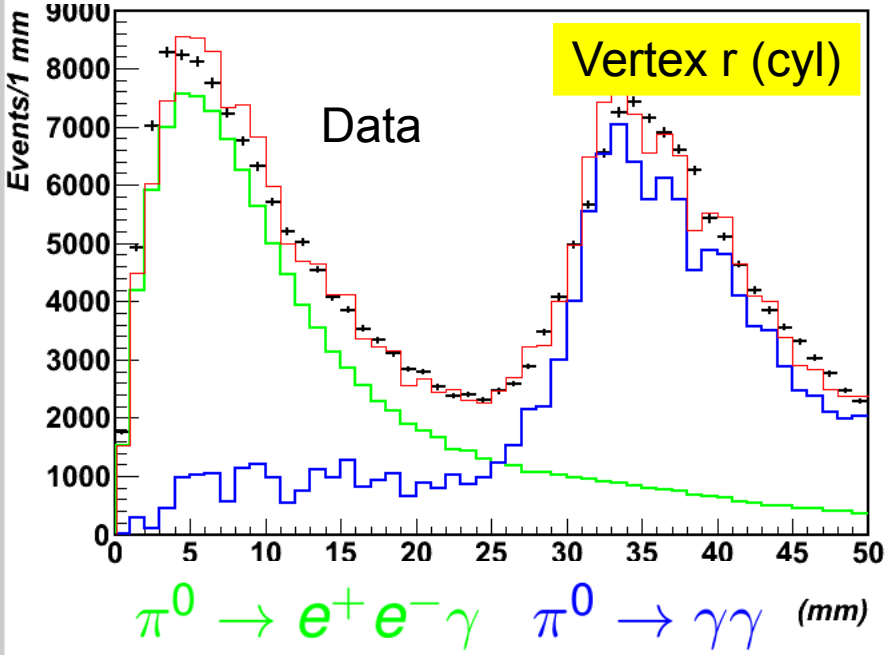
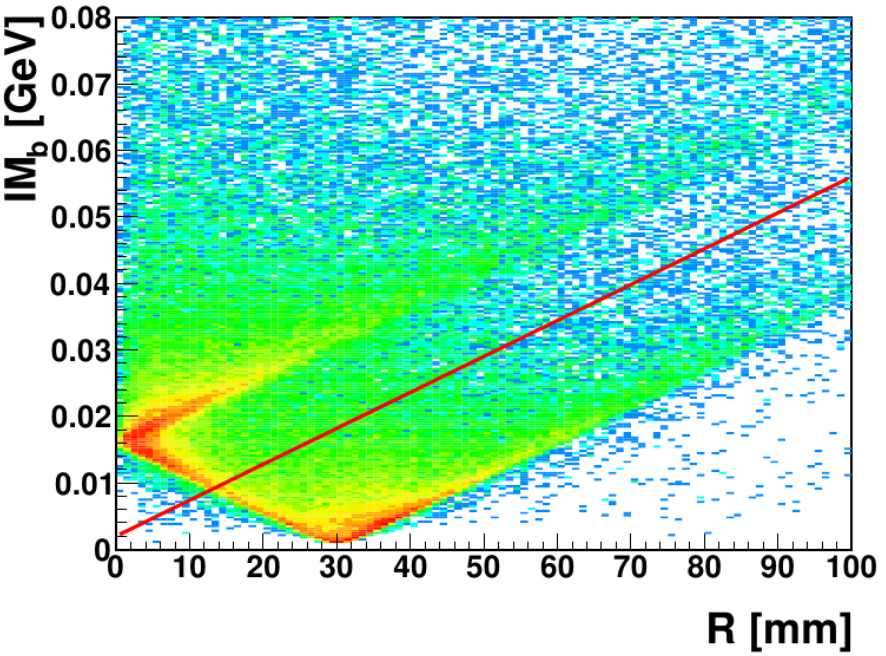
Analysis: $\pi^0 \rightarrow \gamma e^+ e^-$

Vertex r 20 mm + PID



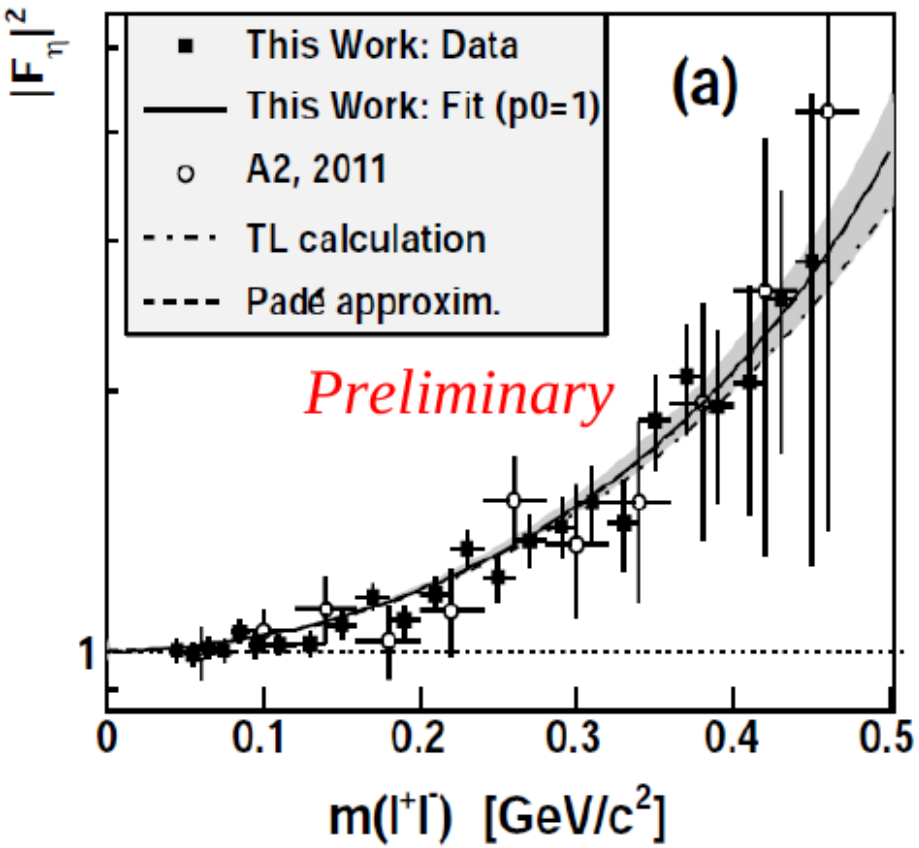


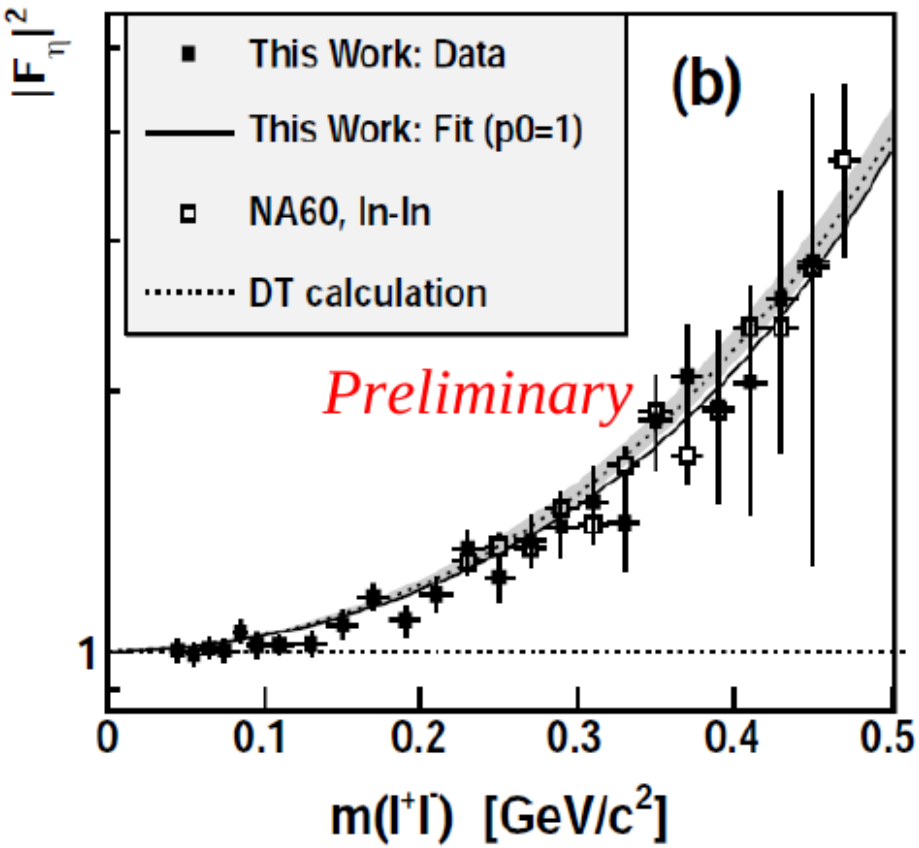




New A2 Result for η TFF

S. Prakhov, M. Unverzagt et al., accepted by Phys. Rev. C, arXiv: 1309.5648 [hep-ex]

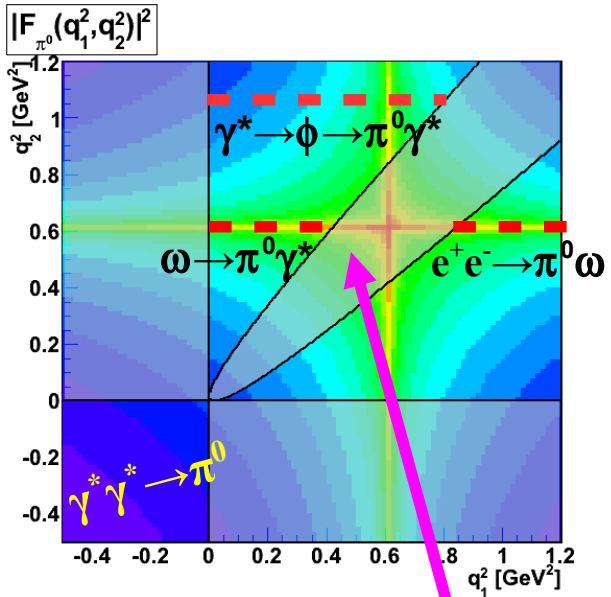


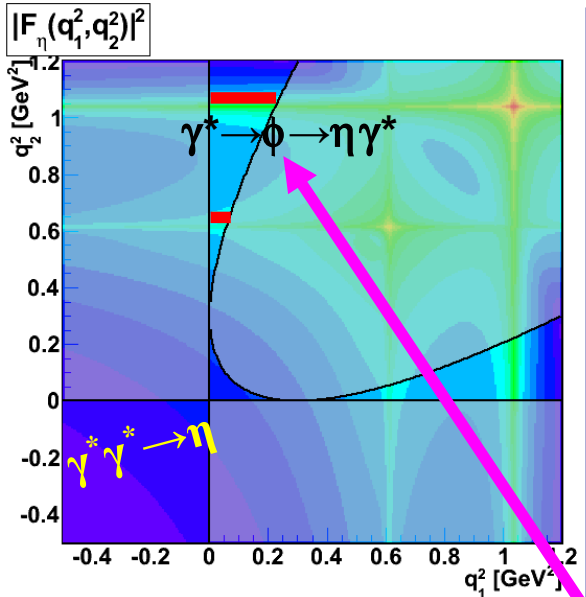


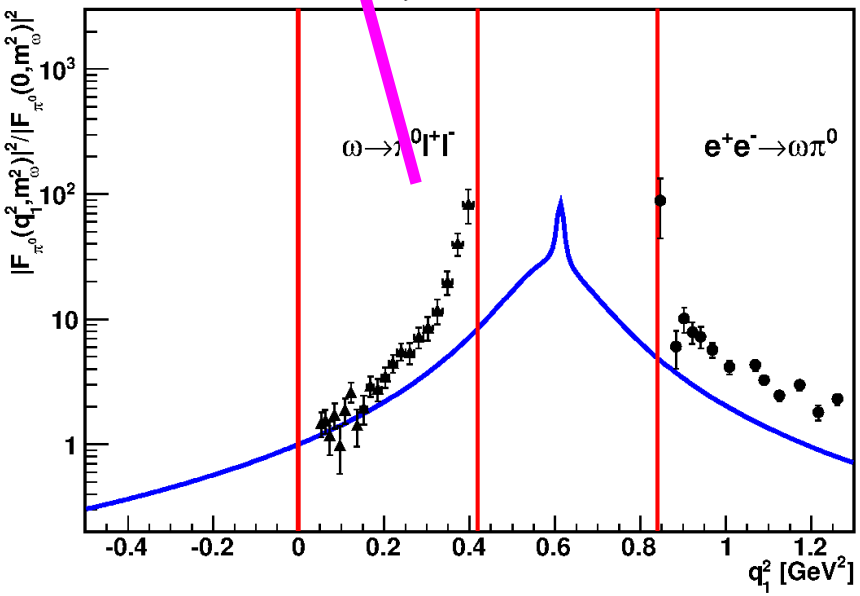
$$\Lambda^{-2} = (1.95 \pm 0.15_{\rm stat} \pm 0.10_{\rm syst})\ {\rm GeV}^{-2} \quad \textit{preliminary}$$

A2, 2011: H. Berghäuser et al., Phys. Rev. B **701** (2011) 562-567.
NA60, In-In: R. Arnaldi et al., Phys. Lett. B **677** (2009) 260.
TL calculation: C. Terschlüsen, Diploma thesis, University Gießen, 2010.
Padé-approximants: R. Escribano, P. Masjuan, P. Sanchez-Puertas, arXiv:1307.2061 [hep-ph].
DT calculation: C. Hahnhart, A. Kupść, U.-G. Meißner, F. Stollenwerk, A. Wirzba, Eur. Phys. J. C73 (2013) 2668.

V → Pγ* and e+e- → PV processes



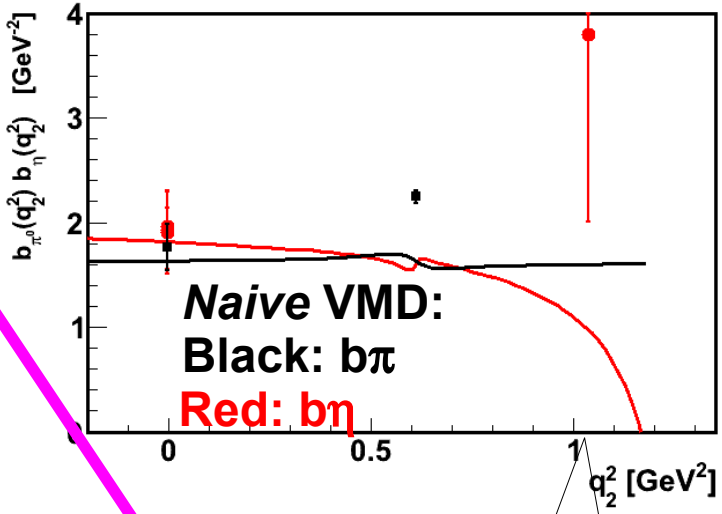




TH: → Bastian talk

slopes bπ, bη

$$b_P(q_2^2) = \left.\frac{\partial \ln |F(q_1^2, q_2^2)|}{\partial q_1^2}\right|_{q_1^2=0}$$



KLOE prel result $b\eta(m^2_\phi)$

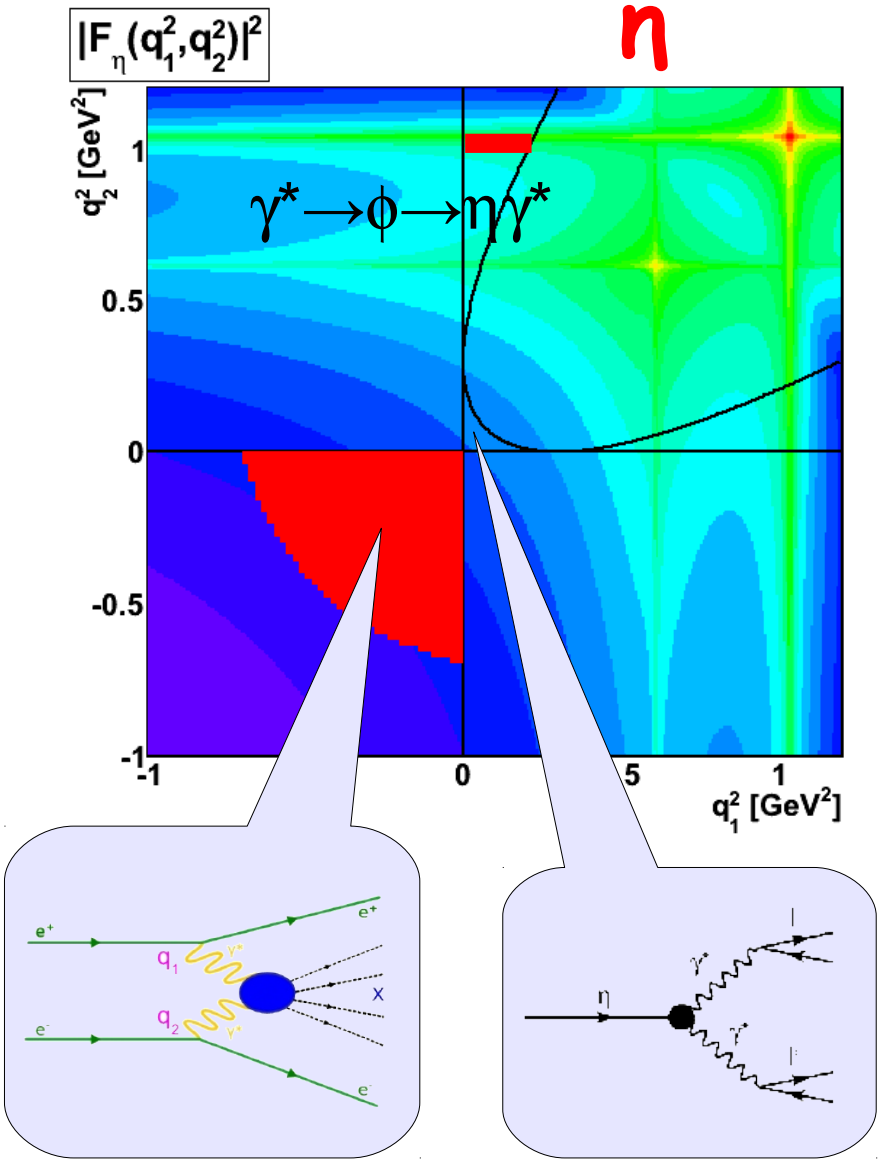
$\phi\to\eta\gamma^*$ BR 10^{-4}

$b\pi^0(m^2_\phi)$ $\phi\to\pi^0\gamma^*$ BR 10^{-5}

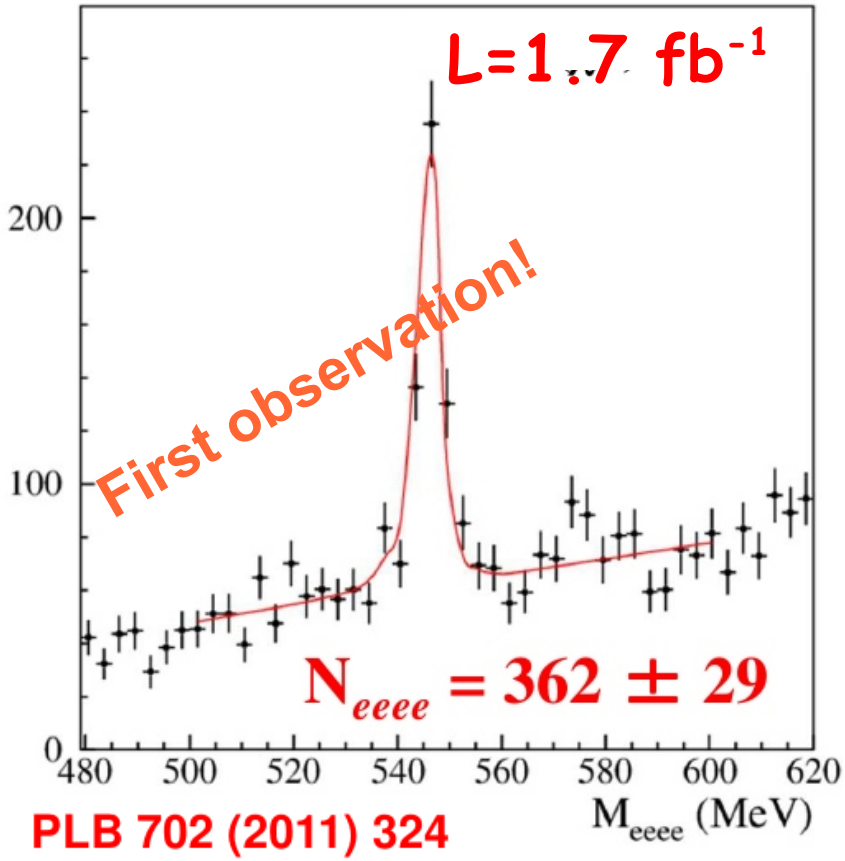
Relation to $\omega/\varphi\to\pi^+\pi^-\pi^0$

BESIIIJ/ψ→Pe+e- arXiv:1403.7042

Double off shell TFF



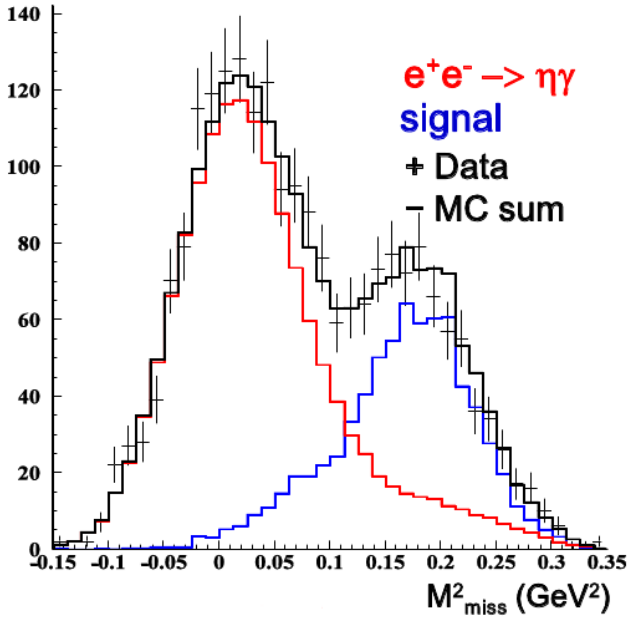
$$\eta \to e^+e^-e^+e^-$$



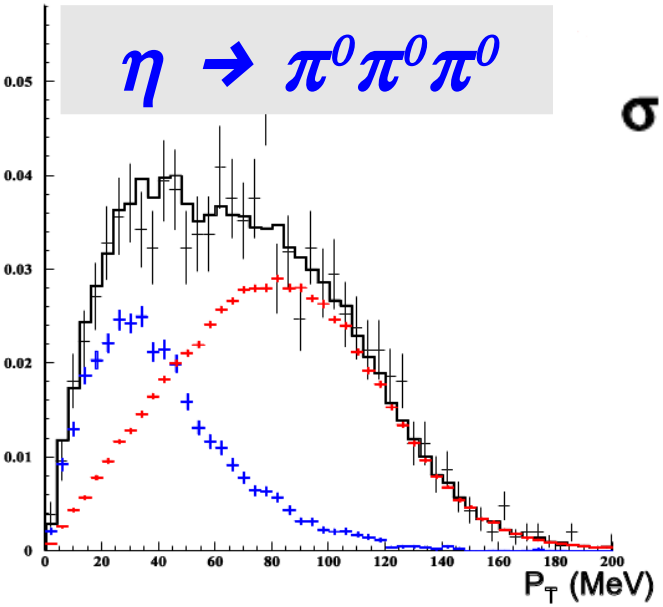
PLB 702 (2011) 324

$BR(\eta \to e^+e^-e^+e^-(\gamma)) = (\ 2.4 \pm 0.2_{stat} \pm 0.1_{syst}\ ) \times 10^{-5}$

η meson radiative decay width



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



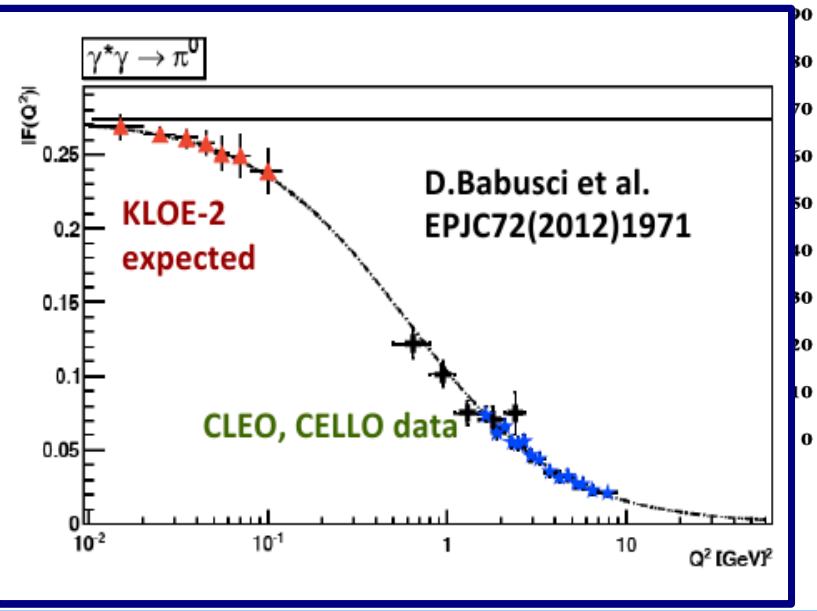
$\sigma(e^+e^- \rightarrow e^+e^-\eta, \sqrt{s}=1GeV)$

$L=240\ pb^{-1}$

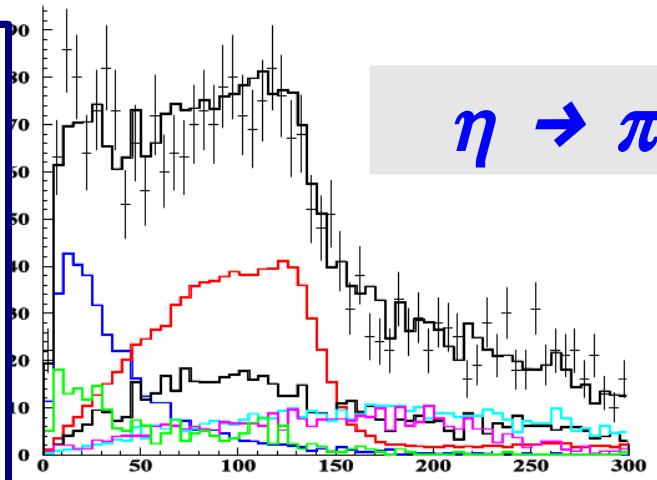
Insensitive to TFF

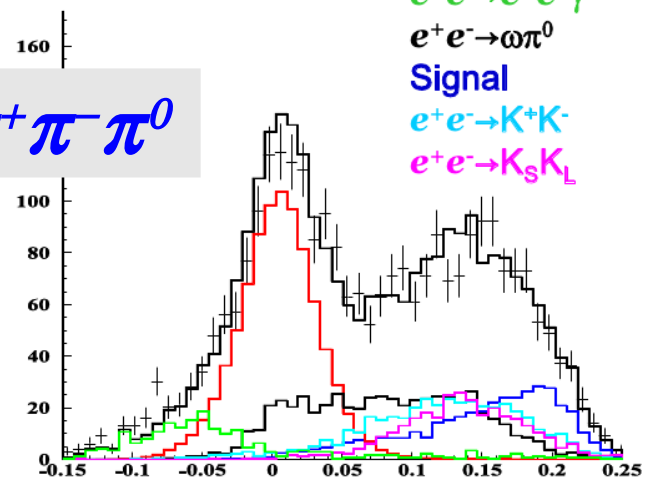
$\Gamma\gamma\gamma=520\pm20\pm13\ eV$

$32.0\pm1.5\pm0.9\ pb$



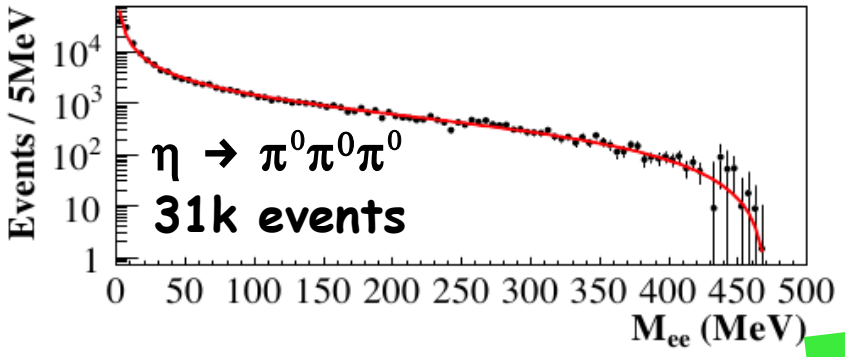
$\eta \rightarrow \pi^+\pi^-\pi^0$

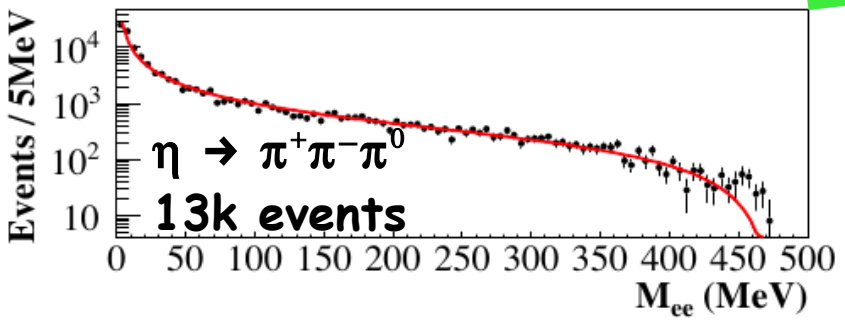


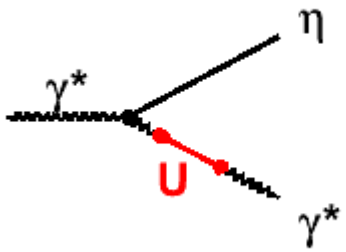


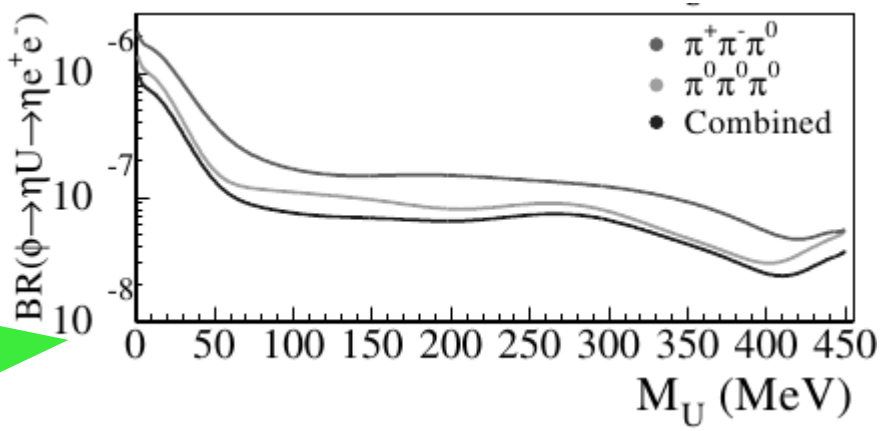
$34.5\pm2.5\pm1.0\ pb$

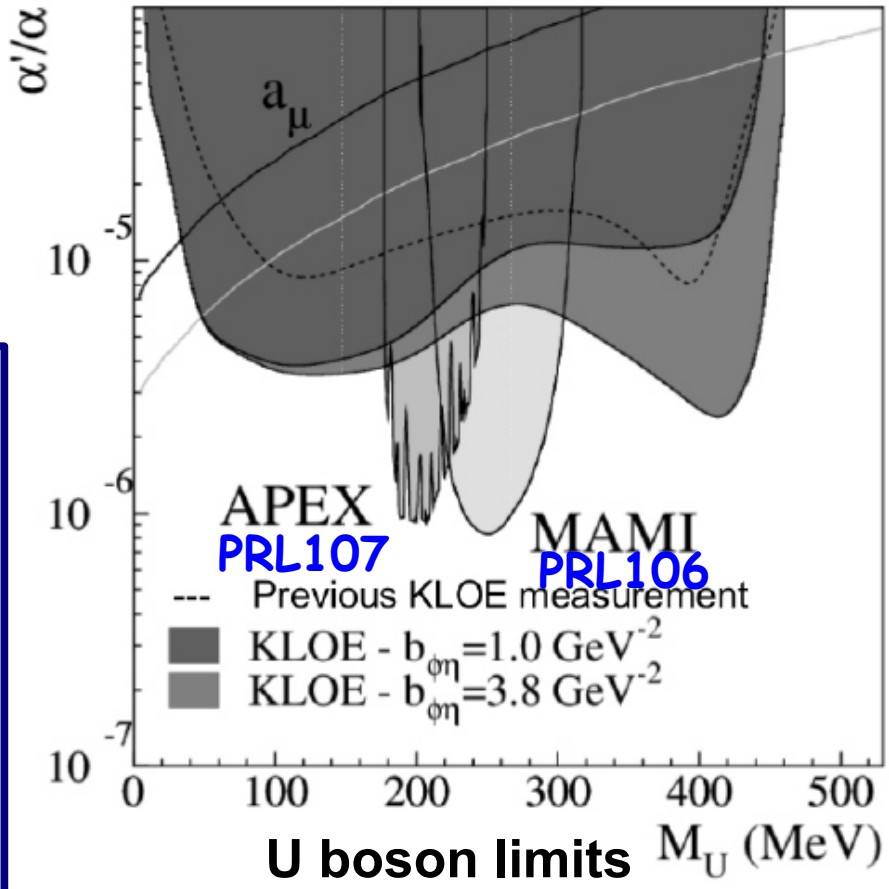
φ→e⁺e⁻η











U boson limits

Form factor/BR:

	SND/CMD-2 (2001)	KLOE – Preliminary Neutral Mode
$b_{\phi\eta}$ [GeV $^{-2}$]	3.8 ± 1.8/ --	$1.17 \pm 0.11^{+0.09}_{-0.08}$
BR (x10^4)	1.19 ± 0.31 / 1.14 ± 0.16	$1.131 \pm 0.031 \pm 0.007^{+0.011}_{-0.006}$

$$F_\eta(q^2, m_\phi^2) \propto \frac{1}{1 - b_\eta(m_\phi^2)q^2}$$

$\varphi \to e^+e^-\pi^0$

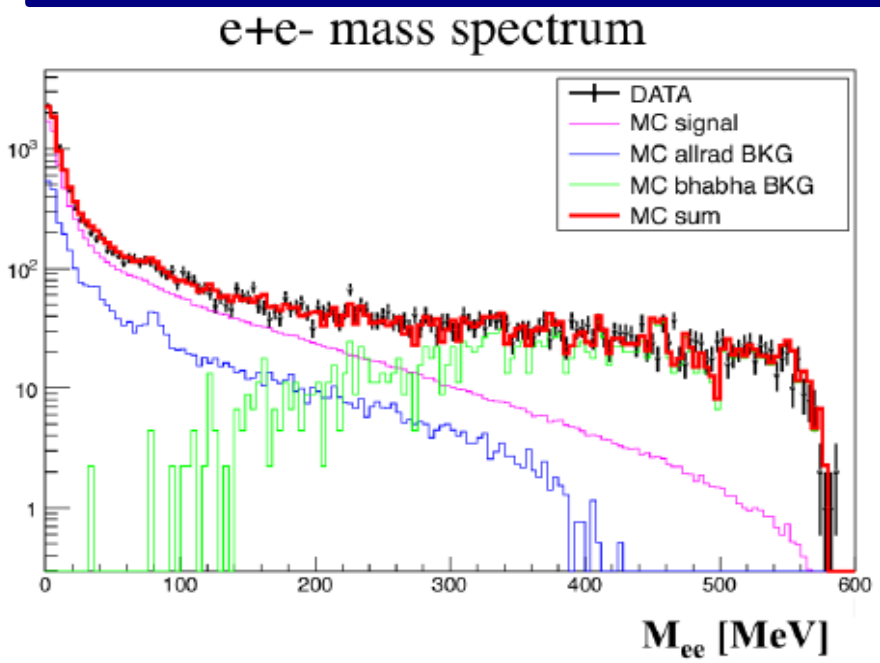
Value (10^{-5})	CL%	EVTS	Document ID		TECN
1.12 ± 0.28	OUR AVERAGE				
$1.01 \pm 0.28 \pm 0.29$		52	ACHASOV [1]	2002D	SND
$1.22 \pm 0.34 \pm 0.21$		46	AKHMETSHIN [2]	2001C	CMD2

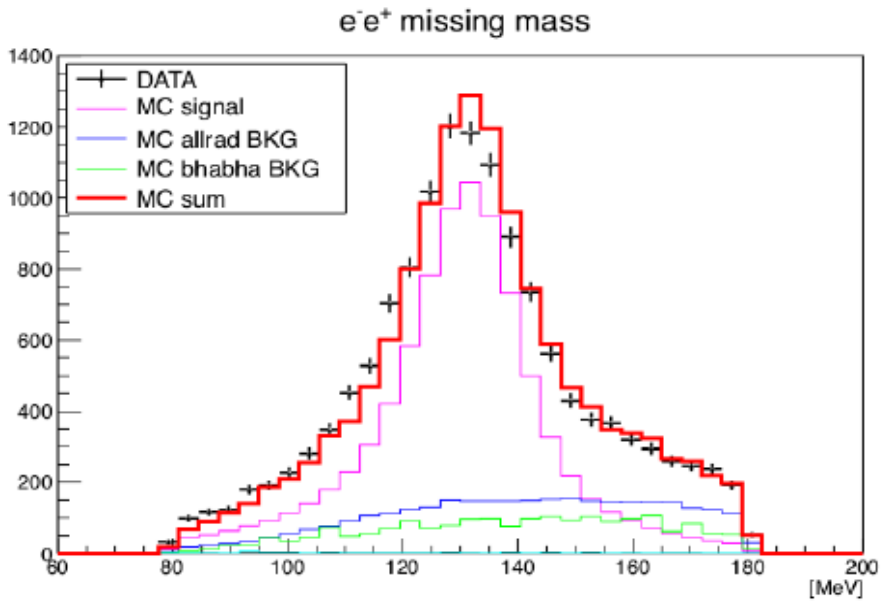
9k events

Background
radiative Bhabha
and $\varphi \to \pi^0\gamma$

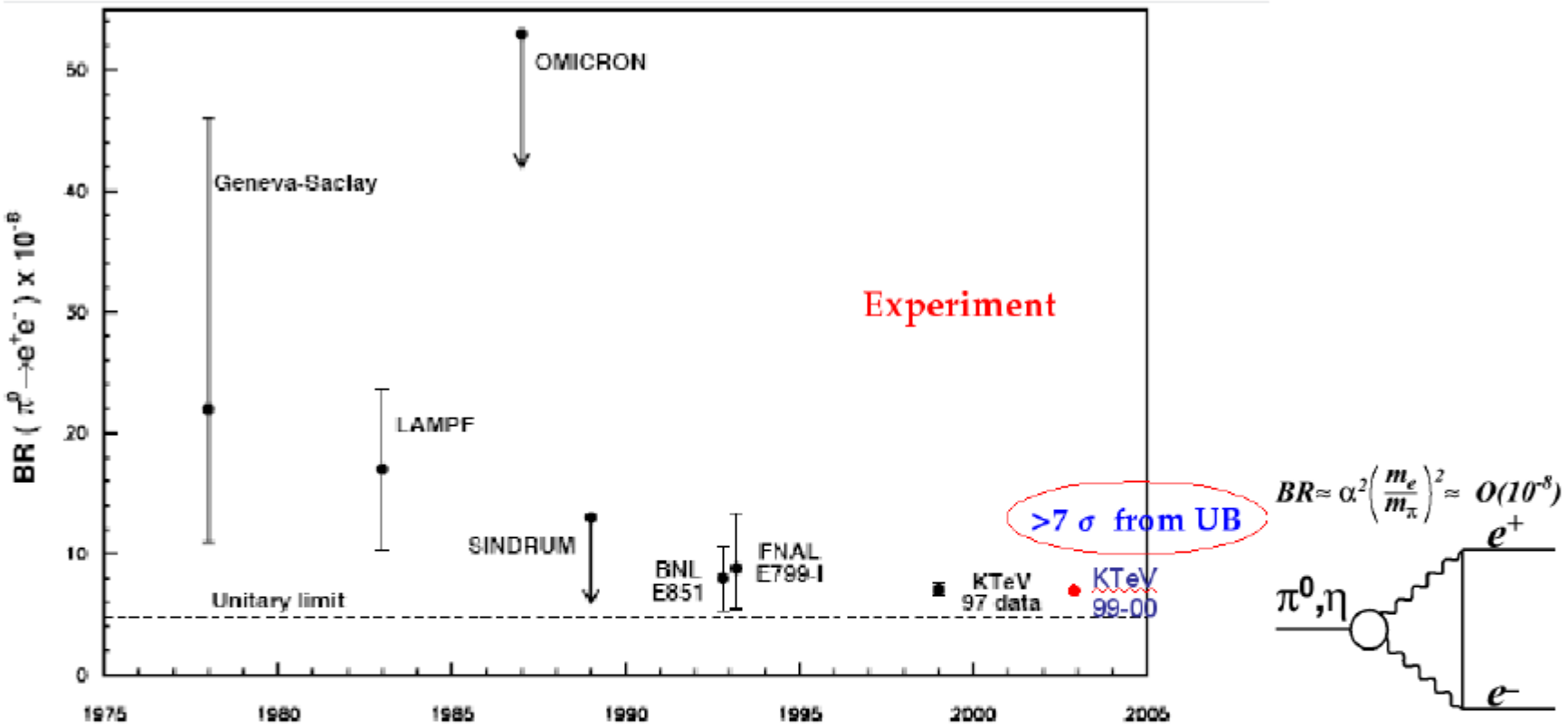
efficiency:
15% → 2%
low → high q

Analysis in progress:
background
subtraction +
global efficiency





History of $\pi^0 \to e^+e^-$ measurements

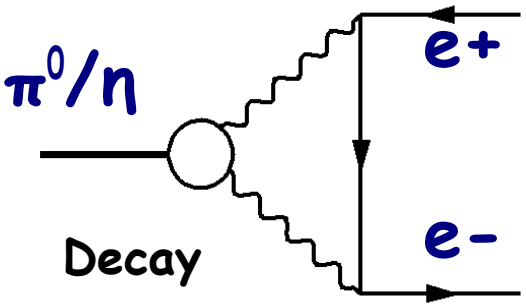


- Unitary bound (model independent) $BR \geq 4.75 \cdot 10^{-8}$
- Experiment: KTeV (794 events from $K_L \to 3\pi^0$):

  $BR(\pi^0 \to e^+e^-) = (6.44 \pm 0.25_{stat} \pm 0.22_{syst}) \times 10^{-8}$

  $BR_{\text{no-rad}}(\pi^0 \to e^+e^-) = (7.48 \pm 0.29_{stat} \pm 0.25_{syst}) \times 10^{-8}$

PRD75:012004(07)

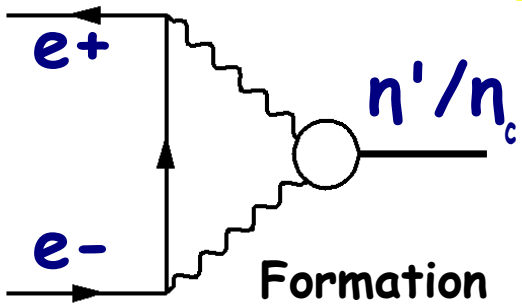


HADES
WASA
CBall
NA48/NA62

	UB	SM	EXP
$\mathcal{B}(\pi^0 \to e^+e^-) \times 10^8$	≥ 4.69	6.23 ± 0.12	7.49 ± 0.38 KTeV2007
$\mathcal{B}(\eta \to e^+e^-) \times 10^9$	≥ 1.78	5.2 ± 0.3	$\leq 5.6 \cdot 10^3$ HADES2012
$\mathcal{B}(\eta' \to e^+e^-) \times 10^{10}$	≥ 0.36	1.9 ± 0.3	$\leq 2.1 \cdot 10^3$ ND1988
$\mathcal{B}(\eta_c \to e^+e^-) \times 10^{14}$	≥ 4.2		

3σ diff

Dorokhov,PLB667,145



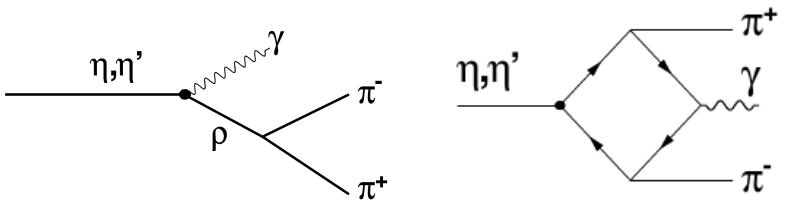
Searches using formation:

e+e- → η' , L=0.5pb^{-1}

=> B< $2.1 \cdot 10^{-7}$ 90% CL

Vorobev SJNP 48(1988)273

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

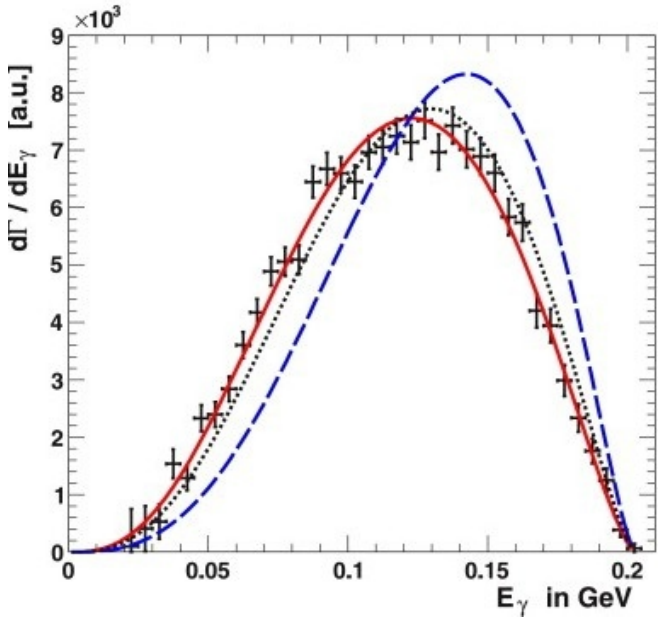


$$\frac{d\Gamma_{\eta(\eta')}}{ds_{\pi\pi}} \propto \left| C + \frac{1}{s_{\pi\pi} - m_\rho^2 - i m_\rho \Gamma_\rho} \right|^2$$

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

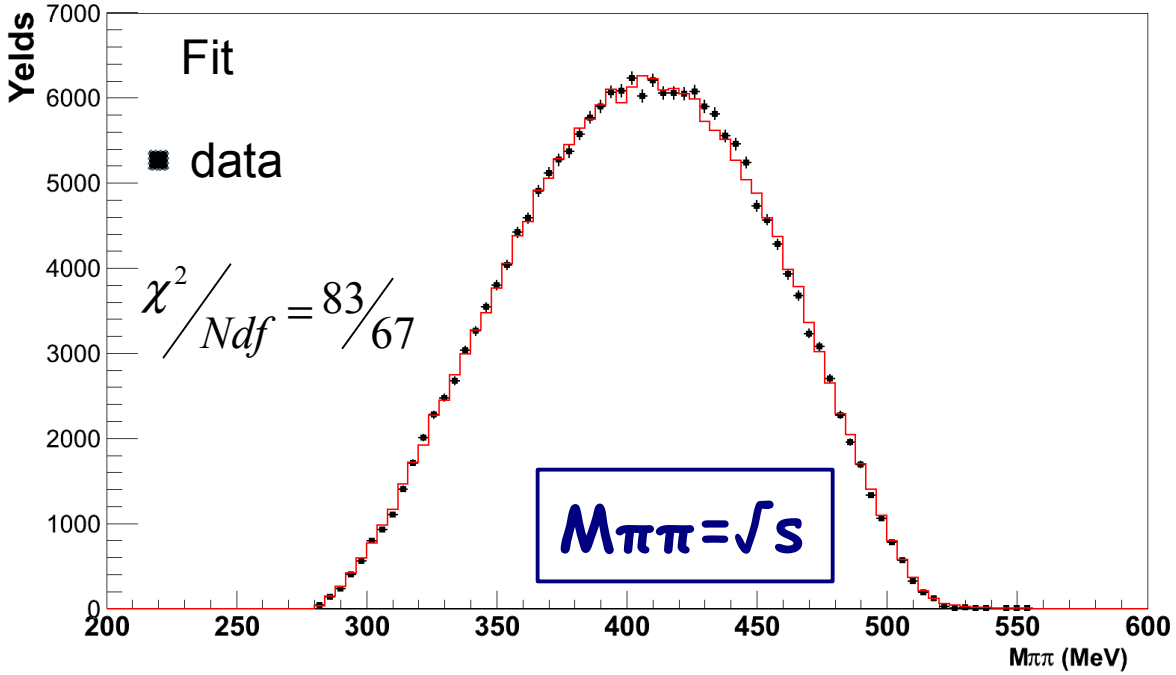
PLB707 (2012) 184

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



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

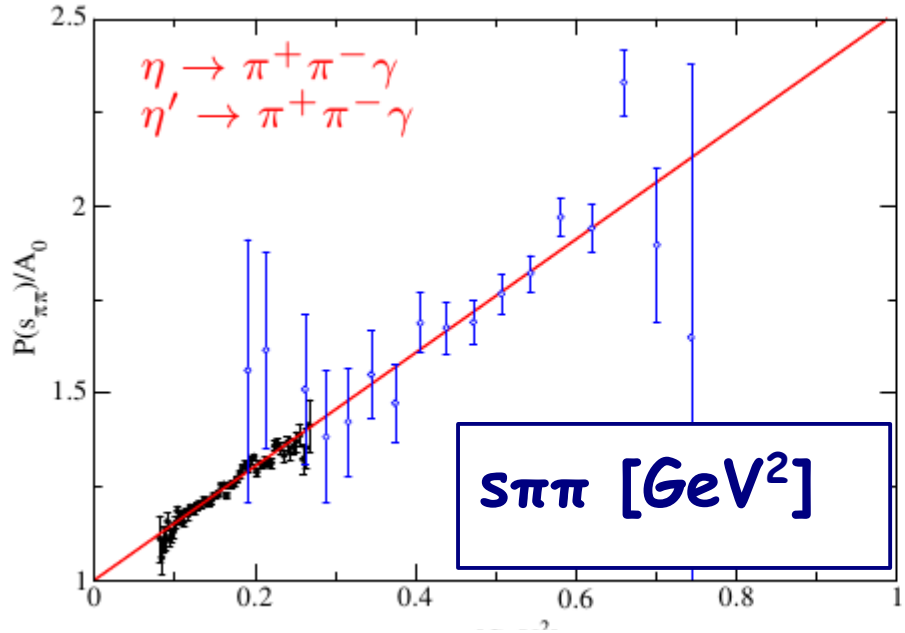
[WASA PLB707 (2012) 243]

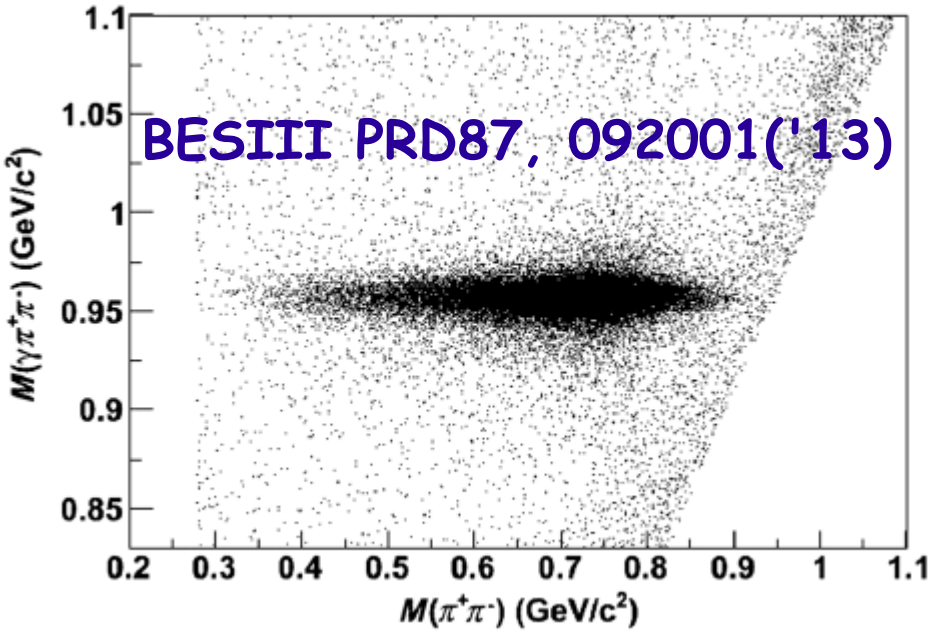


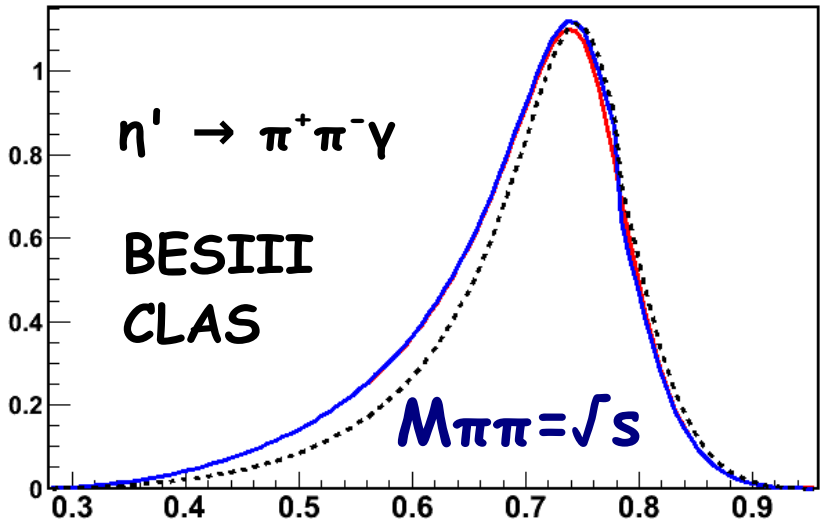
$\alpha = 1.31 \pm 0.08_{stat} \pm 0.40_{systv}$ GeV^{-2}

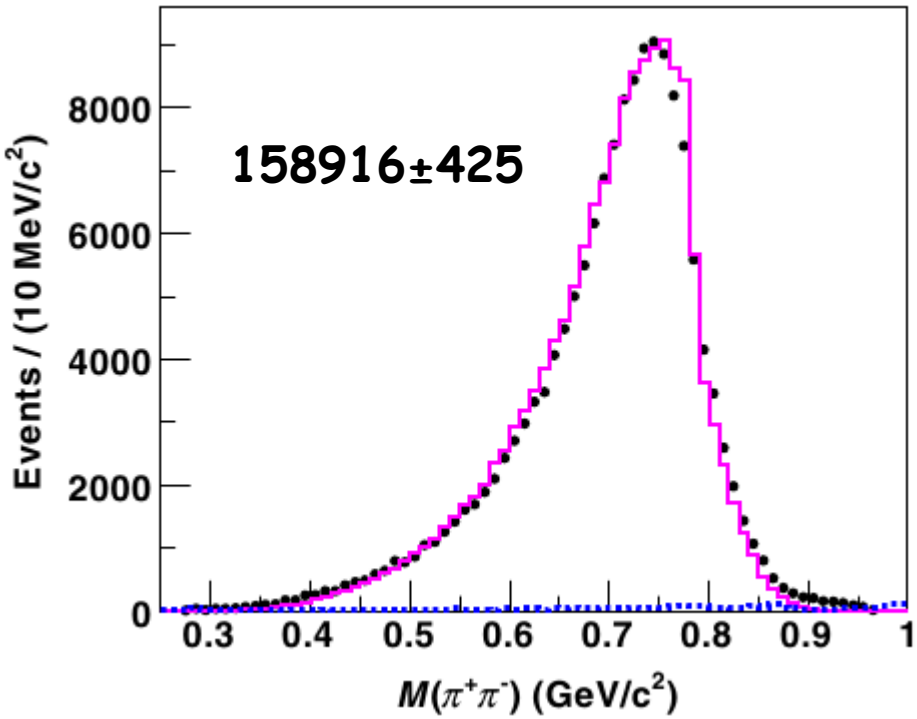
[KLOE PLB718 (2013) 910]

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



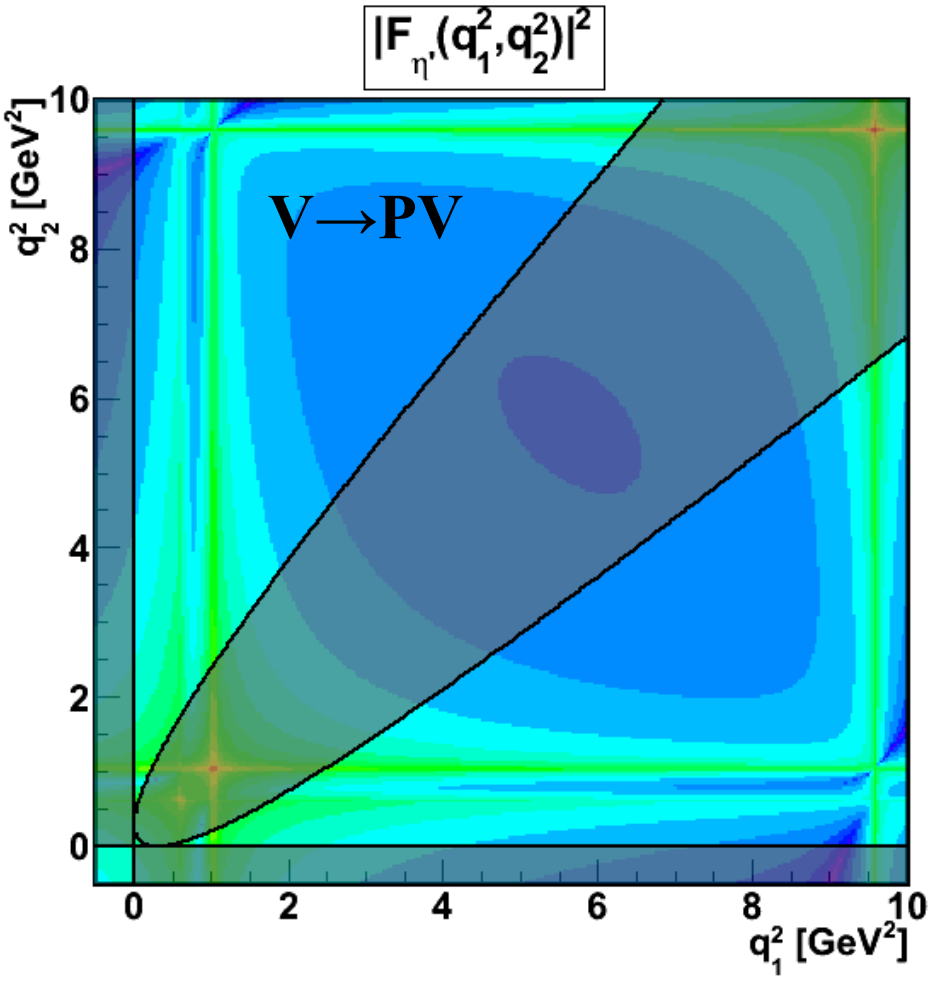


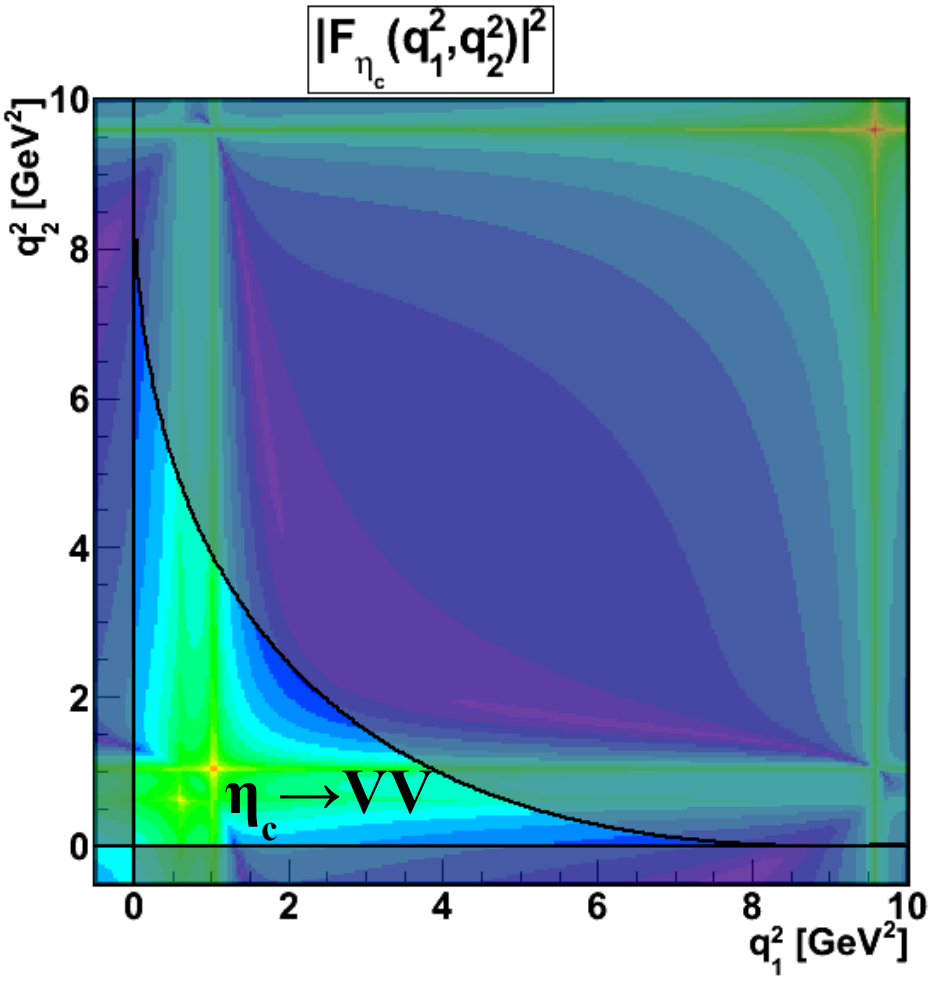




DATA: C Barrel PLB 402,195 ('97); KLOE PL B718, 910 ('13)

Outlook η', ηc





η′→π+π−π+π−
η′→π+π−π0π0

arXiv:1404.0096

BESIII:

>5x10^6 η'
17x10^6 η_c

ηc → ρρ 1.8%

ηc → $K^*\overline{K^*}$ 0.7%

ηc → φφ 0.2%