BESIII 实验上轻介子衰变的研究

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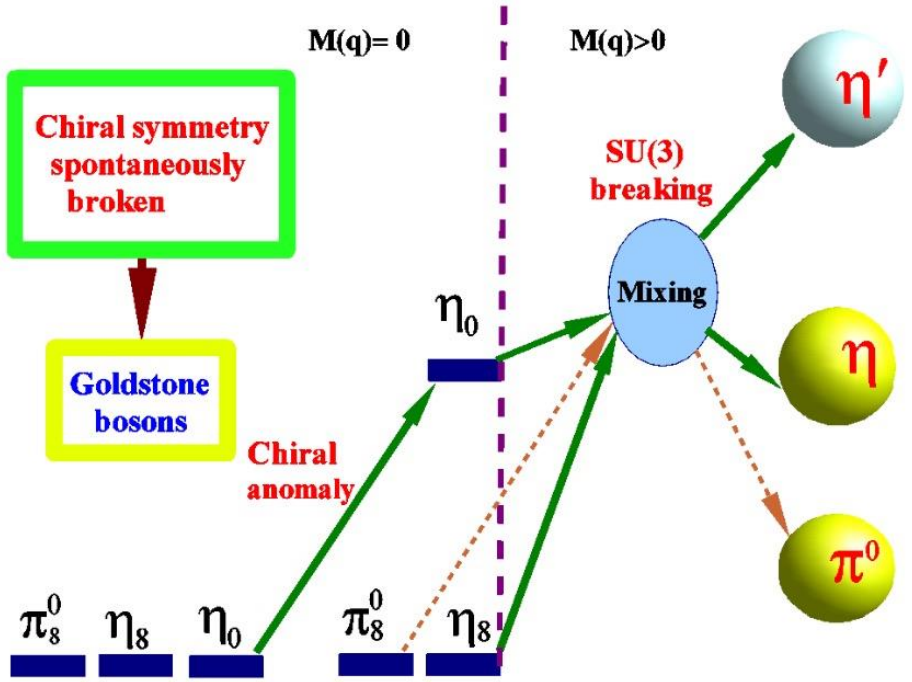
Outline

- Light meson Physics
- BESIII: a light meson factory
- Recent highlights
- Conclusion

Light meson Physics

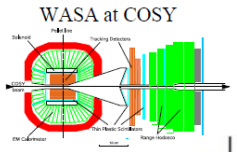
- Light mesons
  - ✓Important roles in particle physics
  - ✓Strong interactions, Quark Model, CP violation …
- Rich physics
  - ✓Test ChPT predictions
  - ✓EM Form factors
  - ✓Test fundamental symmetries
  - ✓Probe new physics beyond the SM

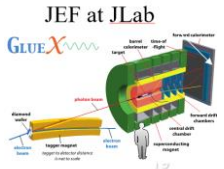


Experimental η/η' samples

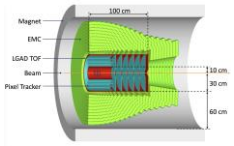
e^+e^- Collider

Fixed-target



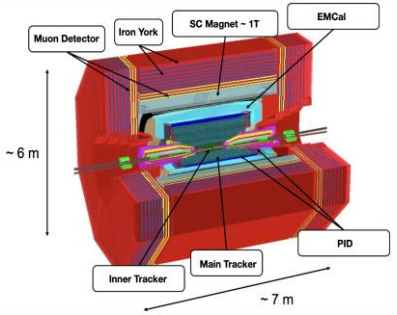


Proposed RedTop and HHaS@HIAF



Technique	η events	η' events
$J/\psi \to \gamma\eta/\eta'$	1.1×10^7	5.2×10^7
$J/\psi \to \gamma\eta'(\pi^+\pi^-\eta)$	2.2×10^7	
$J/\psi \to \phi/\omega\eta/\eta'$	2.5×10^7	6.5×10^6
$\phi \to \gamma\eta/\eta'$	3×10^8	1.5×10^6
$pp \to \eta X$	$\sim 3 \times 10^7$	
$\gamma p \to \eta X$	$\sim 3 \times 10^8$	
$pp \to \eta X$	$\sim 4.5 \times 10^8$	
$\gamma p \to \eta X$	$\sim 10^7$	
$pLi \to \eta X$	$\sim 10^{13}\ \eta/yr$	

Proposed STCF



340 times BESIII statistics

$\sim 10^{10}$ η/η'

BESIII: an important role in η/η′ decays

η REFERENCES

ABLIKIM	23AN	PR D107 092007	M. Ablikim *et al.*	(BESIII Collab.)
HAYRAPETY...	23A	PRL 131 091903	A. Hayrapetyan *et al.*	(CMS Collab.)
ABLIKIM	21AM	PR D104 092004	M. Ablikim *et al.*	(BESIII Collab.)
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PRAKHOV	18	PR C97 065203	S. Prakhov *et al.*	(A2 Collab. at MAMI)
AAIJ	17D	PL B764 233	R. Aaij *et al.*	(LHCb Collab.)
ADLARSON	17B	PR C95 035208	P. Adlarson *et al.*	(A2 Collab. at MAMI)
ANASTASI	16A	JHEP 1605 019	A. Anastasi *et al.*	(KLOE-2 Collab.)
ARNALDI	16	PL B757 437	R. Arnaldi *et al.*	(NA60 Collab.)
ABLIKIM	15G	PR D92 012014	M. Ablikim *et al.*	(BESIII Collab.)
ADLARSON	14A	PR C90 045207	P. Adlarson *et al.*	(WASA-at-COSY Collab.)
AGAKISHIEV	14	PL B731 265	G. Agakishiev *et al.*	(HADES Collab.)
NEFKENS	14	PR C90 025206	B.M.K. Nefkens *et al.*	(A2 Collab. at MAMI)
NIKOLAEV	14	EPJ A50 58	A. Nikolaev *et al.*	(MAMI-B, MAINZ, BONN)
ABLIKIM	13	PR D87 012009	M. Ablikim *et al.*	(BESIII Collab.)
ABLIKIM	13G	PR D87 032006	M. Ablikim *et al.*	(BESIII Collab.)
BABUSCI	13	PL B718 910	D. Babusci *et al.*	(KLOE/KLOE-2 Collab.)
BABUSCI	13A	JHEP 1301 119	D. Babusci *et al.*	(KLOE-2 Collab.)
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GOSLAWSKI	12	PR D85 112011	P. Goslawski *et al.*	(COSY-ANKE Collab.)
ABLIKIM	11G	PR D84 032006	M. Ablikim *et al.*	(BESIII Collab.)

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η′(958) REFERENCES

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ABLIKIM	22E	PR D105 112010	M. Ablikim *et al.*	(BESIII Collab.)
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ABLIKIM	21J	PR D103 092005	M. Ablikim *et al.*	(BESIII Collab.)
ABLIKIM	20E	PR D101 032001	M. Ablikim *et al.*	(BESIII Collab.)
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AAIJ	17D	PL B764 233	R. Aaij *et al.*	(LHCb Collab.)
ABLIKIM	17	PRL 118 012001	M. Ablikim *et al.*	(BESIII Collab.)
ABLIKIM	17T	PR D96 012005	M. Ablikim *et al.*	(BESIII Collab.)
ABLIKIM	16M	PR D93 072008	M. Ablikim *et al.*	(BESIII Collab.)
ABLIKIM	15AD	PR D92 051101	M. Ablikim *et al.*	(BESIII Collab.)
ABLIKIM	15G	PR D92 012014	M. Ablikim *et al.*	(BESIII Collab.)
ABLIKIM	15O	PR D92 012001	M. Ablikim *et al.*	(BESIII Collab.)
ABLIKIM	15P	PR D92 012007	M. Ablikim *et al.*	(BESIII Collab.)
ACHASOV	15	PR D91 092010	M.N. Achasov *et al.*	(SND Collab.)
AKHMETSHIN	15	PL B740 273	R.R. Akhmetshin *et al.*	(CMD-3 Collab.)
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ABLIKIM	13O	PR D87 092011	M. Ablikim *et al.*	(BESIII Collab.)
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PDG	12	PR D86 010001	J. Beringer *et al.*	(PDG Collab.)
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ABLIKIM	11G	PR D84 032006	M. Ablikim *et al.*	(BESIII Collab.)

New approach to investigate η decays with $\eta' \to \pi^+\pi^-\eta$

Xiao-lin Kang, Yuyao Ji et al, PRD 108, 014038 (2023)

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η REFERENCES

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- Production rate lower than η'
- Background from QED and J/ψ decays
- Help distinguish muons from pions

➢ $J/\psi \to \gamma\eta \implies 1 \times 10^7\ \eta$

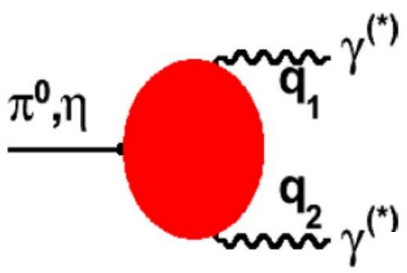
➢ $J/\psi \to \gamma\eta', \eta' \to \pi^+\pi^-\eta \implies 2.2 \times 10^7\ \eta$

One more η' constraint to suppress the background events !

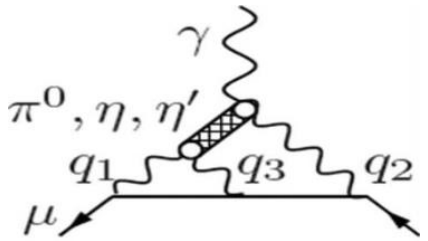
Allow us to access the rare η decays!

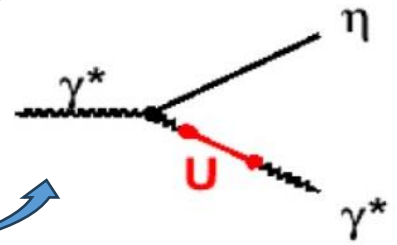
Recent highlights

Meson transition form factors

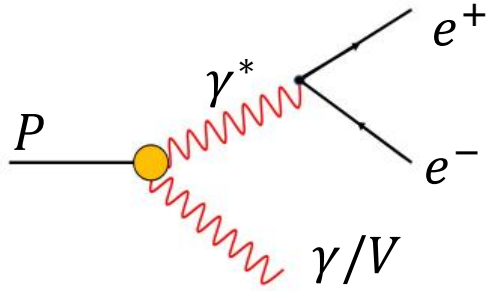


- Low energy QCD:
  - Enters in th. description of QCD processes
  - Evolution with Q^2 predicted by pQCD: models can be tested using data on Q^2 dependance
- Light-by-light contribution to a_μ
- Search for light dark force mediator

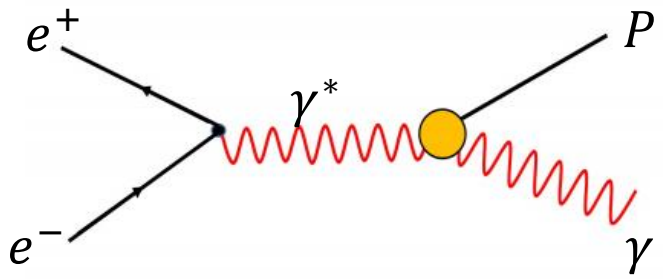




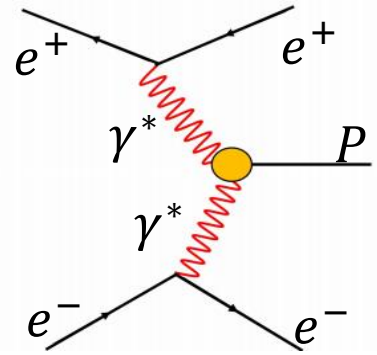
Experimentally



Dalitz decays $0<q^2<M^2$



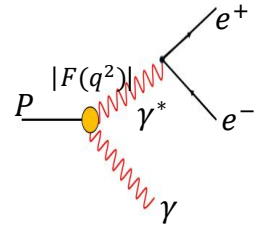
Annihilation process $q^2>M^2$



Two photon process $q^2<0$

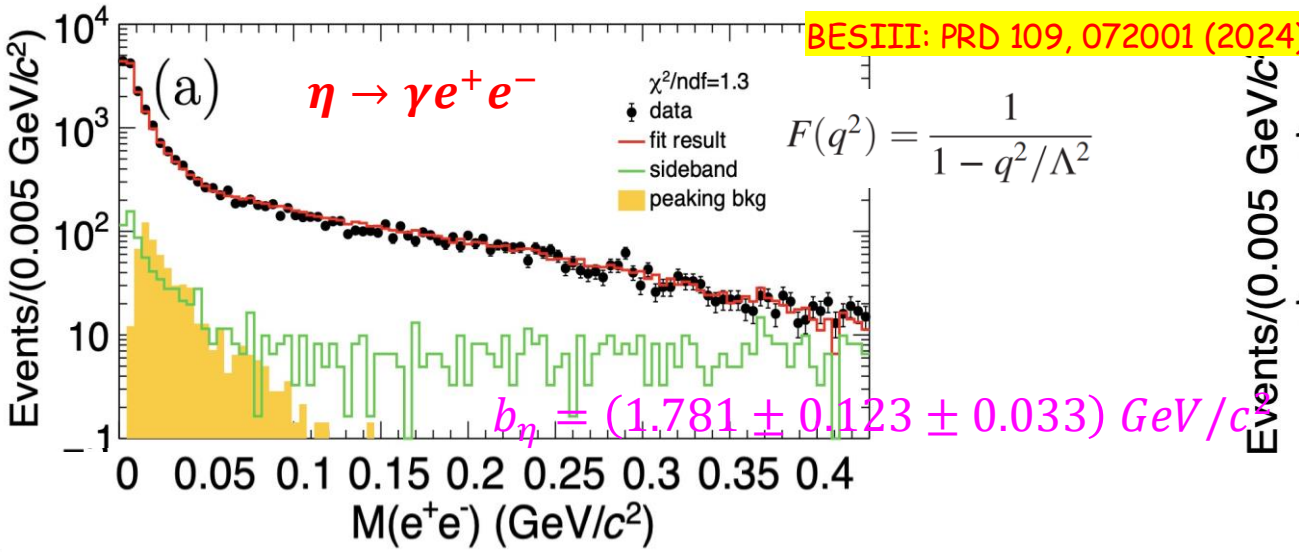
TFF of $\eta/\eta' \to \gamma e^+e^-$

$$\frac{d\Gamma(P \to \gamma l^+ l^-)}{dq^2 \Gamma_{\gamma\gamma}} = QED(q^2) \times |F_P(q^2,0)|^2$$



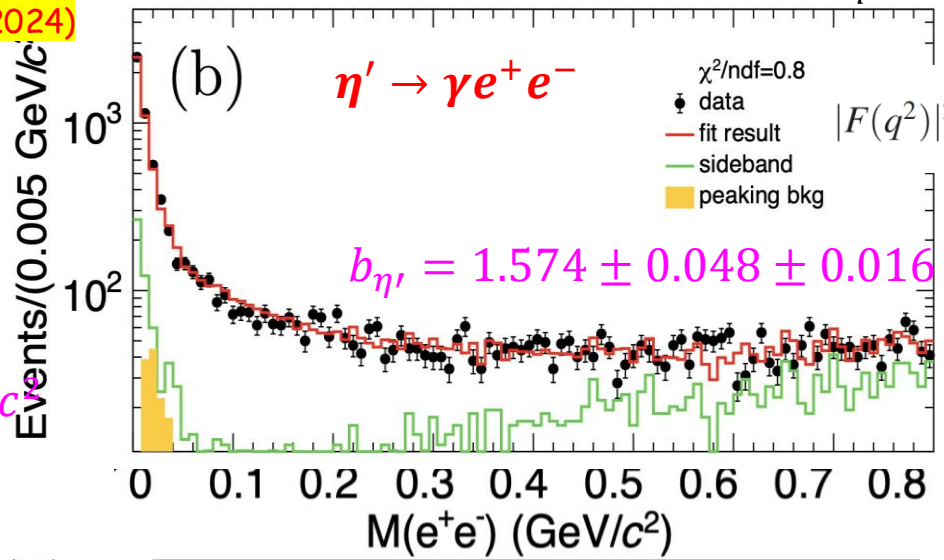
Slope par.: $b_{\eta/\eta'} = \frac{d|F(q^2)|}{dq^2}|_{q^2=0}$

BESIII: PRD 109, 072001 (2024)



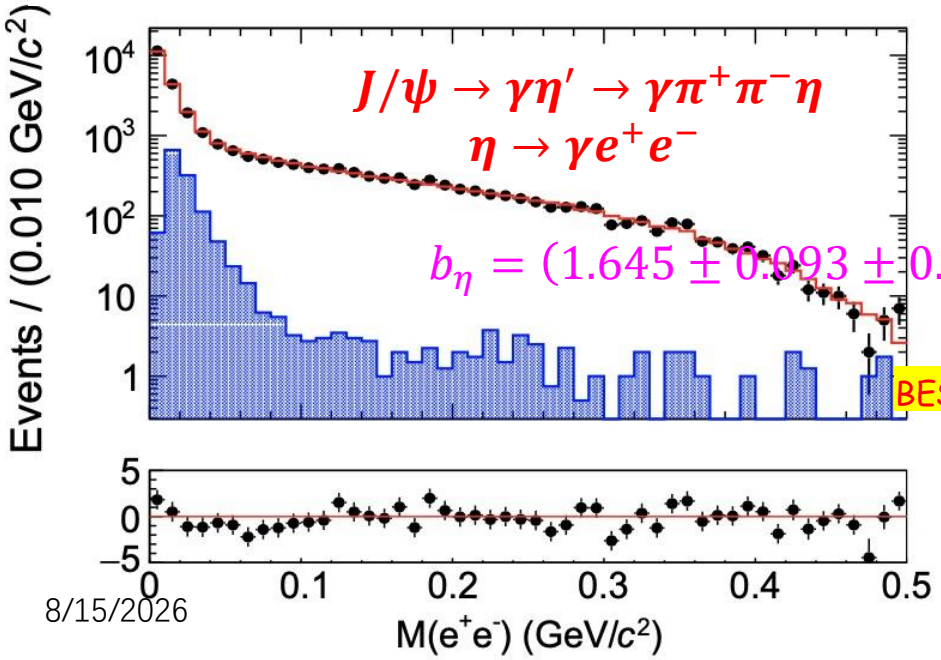
$$F(q^2) = \frac{1}{1 - q^2/\Lambda^2}$$

$b_\eta = (1.781 \pm 0.123 \pm 0.033)\ GeV/c^2$



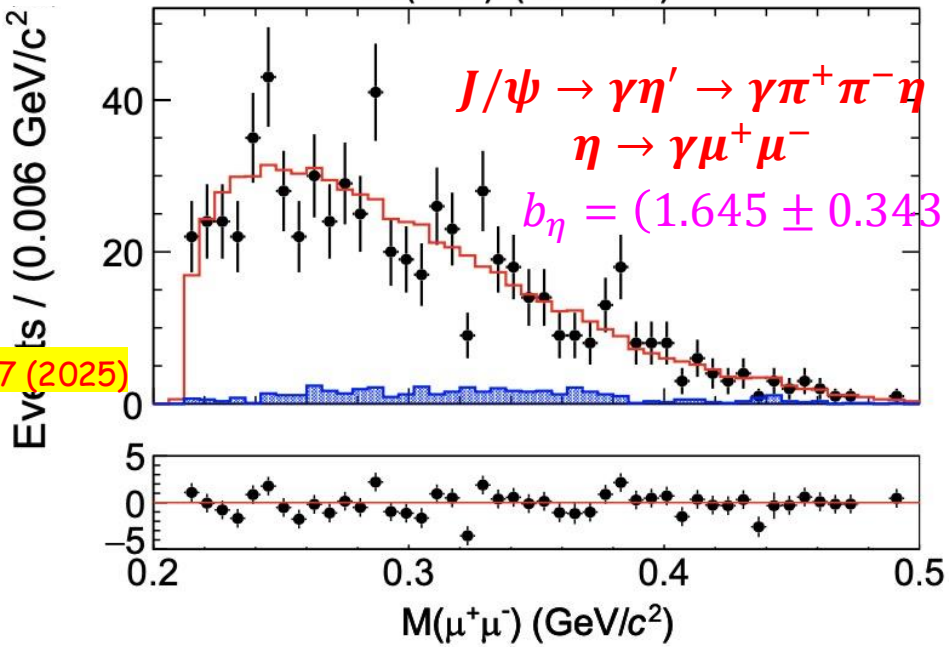
$$|F(q^2)|^2 = \frac{\Lambda^2(\Lambda^2+\gamma^2)}{(\Lambda^2-q^2)^2+\Lambda^2\gamma^2}$$

$b_{\eta'} = 1.574 \pm 0.048 \pm 0.016\ (\mathrm{GeV/c^2})^{-2}$



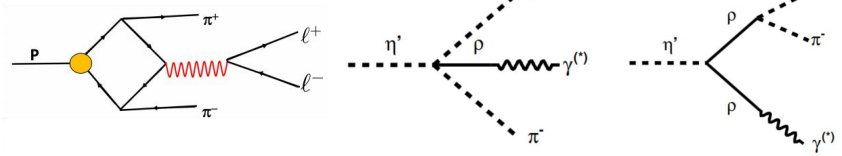
$b_\eta = (1.645 \pm 0.093 \pm 0.024)\ GeV/c^2$

BESIII: PRD112, 052007 (2025)

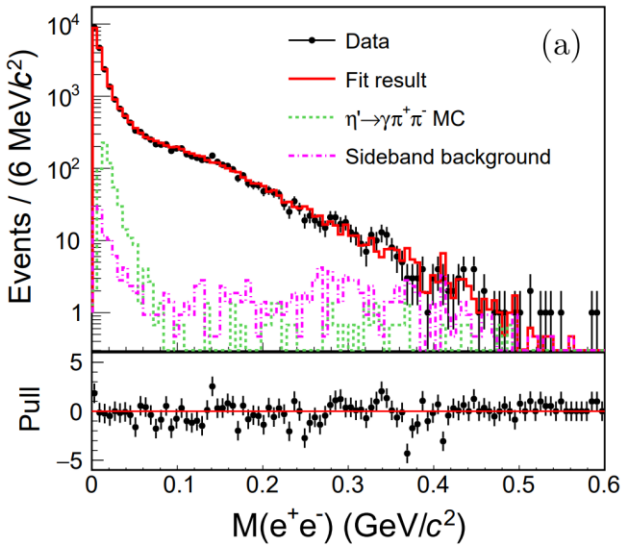


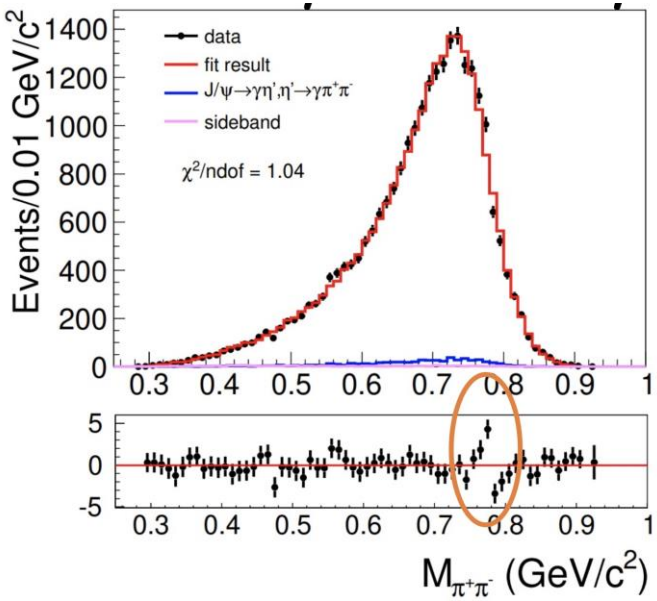
$b_\eta = (1.645 \pm 0.343 \pm 0.017)\ GeV/c^2$

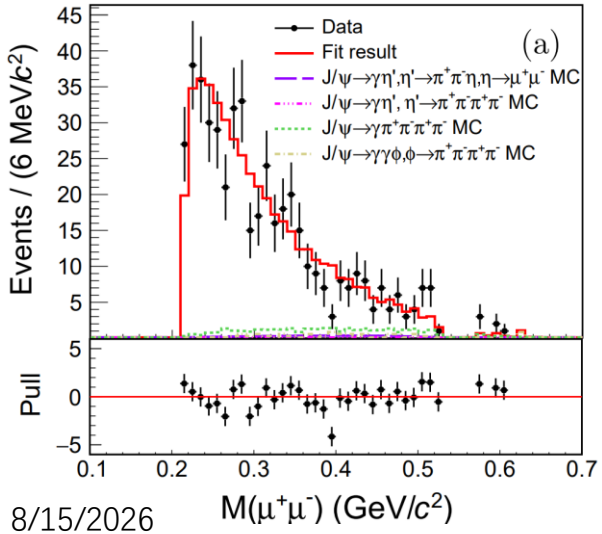
TFF of $\eta' \to \pi^+\pi^- l^+ l^-$

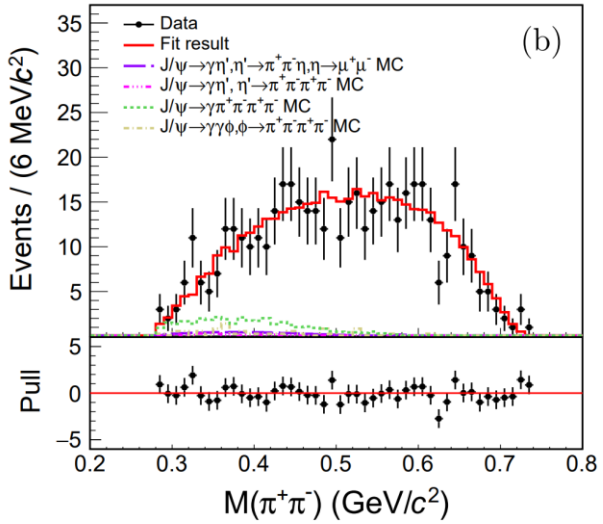


BESIII: JHEP 07, 135 (2024)



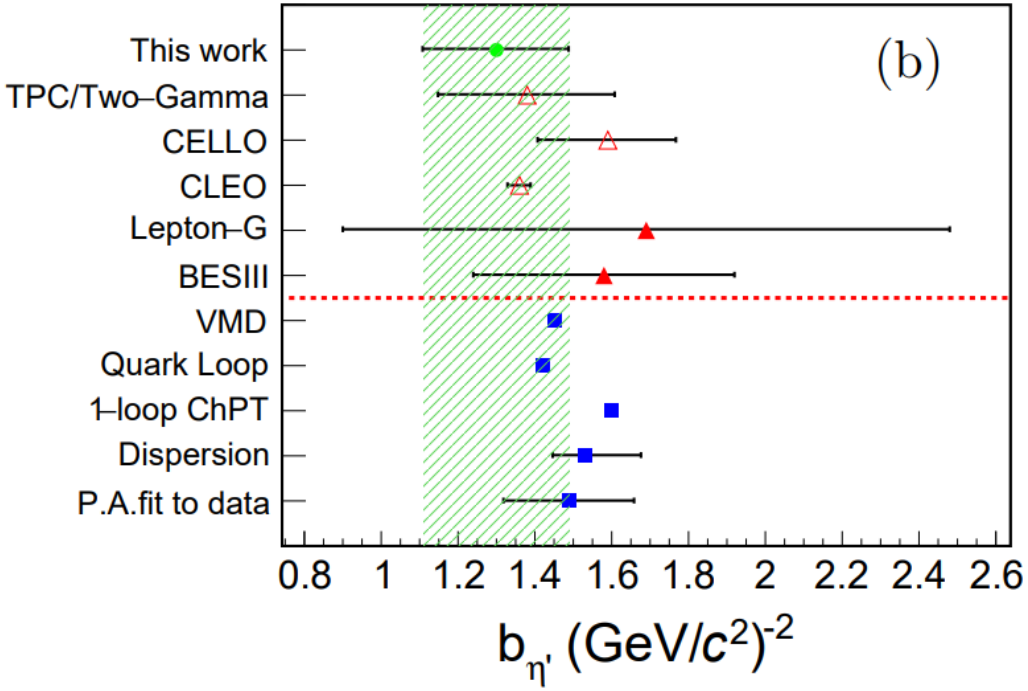




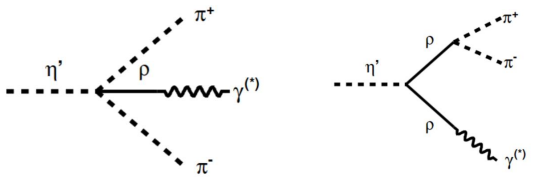


- 10 billion J/ψ allows to access the dynamic
- **Box-anomaly** is needed to describe data
- **$\omega \to \pi^+\pi^-$ is also necessary**
- First time to assess the form factors with $\eta' \to \pi^+\pi^- l^+ l^-$ within VMD

$$b_{\eta'} = 1.30 \pm 0.19\ (\mathrm{GeV}/c^2)^{-2}$$

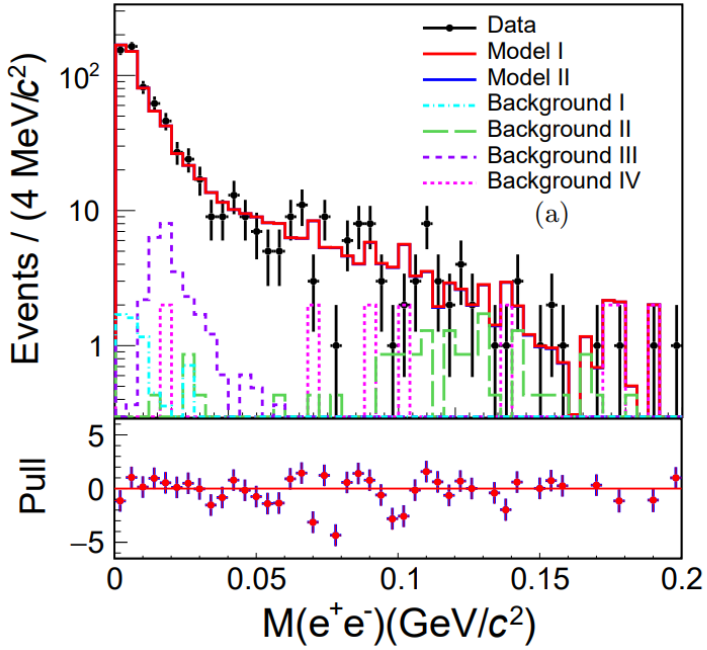


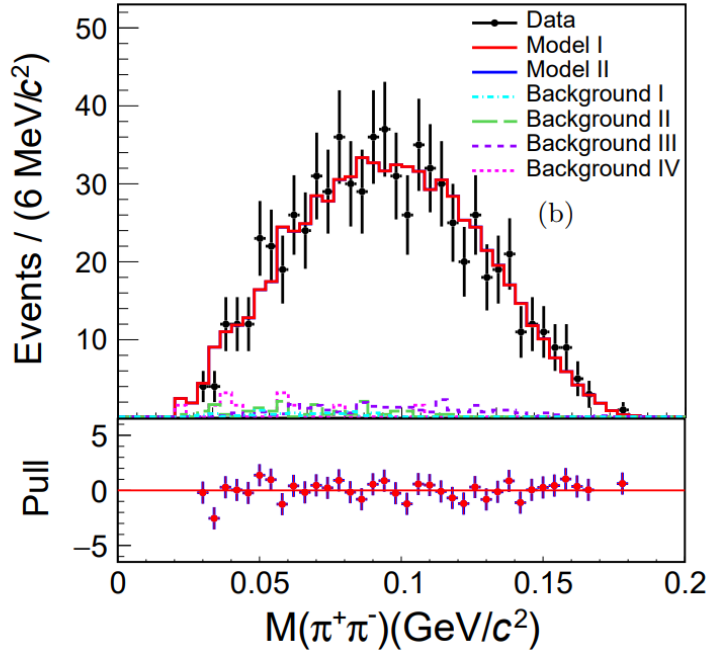
Study of $\eta \to \pi^+\pi^- l^+ l^-$



BESIII: PRD 111 (2025) 072008 (arXiv:2501.10130)

- BESIII: 10 billion J/ψ radiative decays $Br(\eta \to \pi^+\pi^- e^+ e^-) = (3.07 \pm 0.12 \pm 0.19) \times 10^{-4}$
- Allow to access dynamic but with limited statistics $m_V = (749 \pm 54 \pm 14)\ MeV/c$
- No event left for $\eta \to \pi^+\pi^-\mu^+\mu^-$ hypothesis $Br(\eta \to \pi^+\pi^-\mu^+\mu^-) < 4.0 \times 10^{-4}$ at 90% CL.





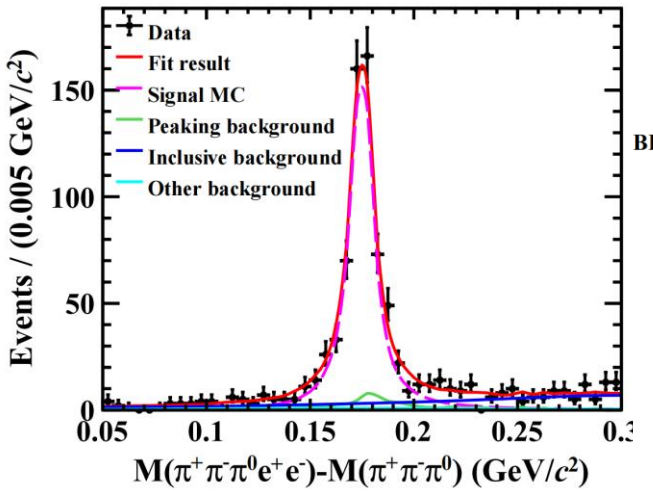
	$\mathcal{B}(\eta \to \pi^+\pi^- e^+ e^-)$ (10^{-4})	$\mathcal{B}(\eta \to \pi^+\pi^-\mu^+\mu^-)$ (10^{-9})
Unitary χPT [1]	$2.99^{+0.06}_{-0.09}$	$7.50^{+1.80}_{-0.70}$
Hidden gauge [2]	3.14 ± 0.17	8.65 ± 0.39
VMD [2]	3.02 ± 0.12	8.64 ± 0.25
CMD-2 [4]	$3.7^{+2.5}_{-1.8} \pm 3.0$	...
WASA [5]	$4.3^{+0.2}_{-1.6} \pm 0.4$	$< 3.6 \times 10^5$
KLOE [6]	$2.68 \pm 0.09 \pm 0.07$	...

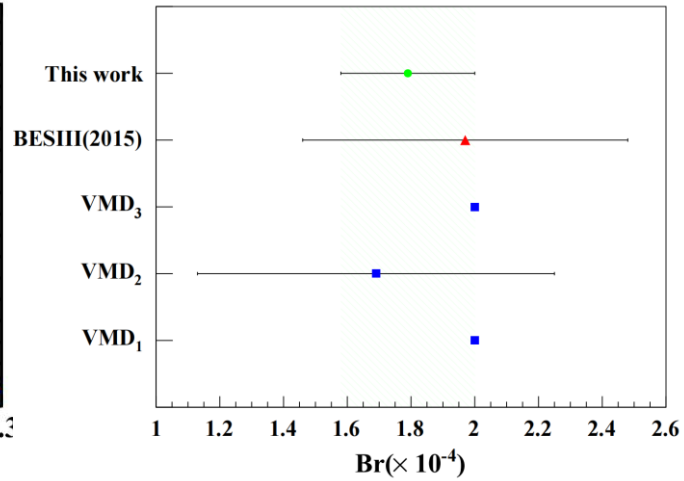
TFF of $\eta' \to \omega e^+e^-$

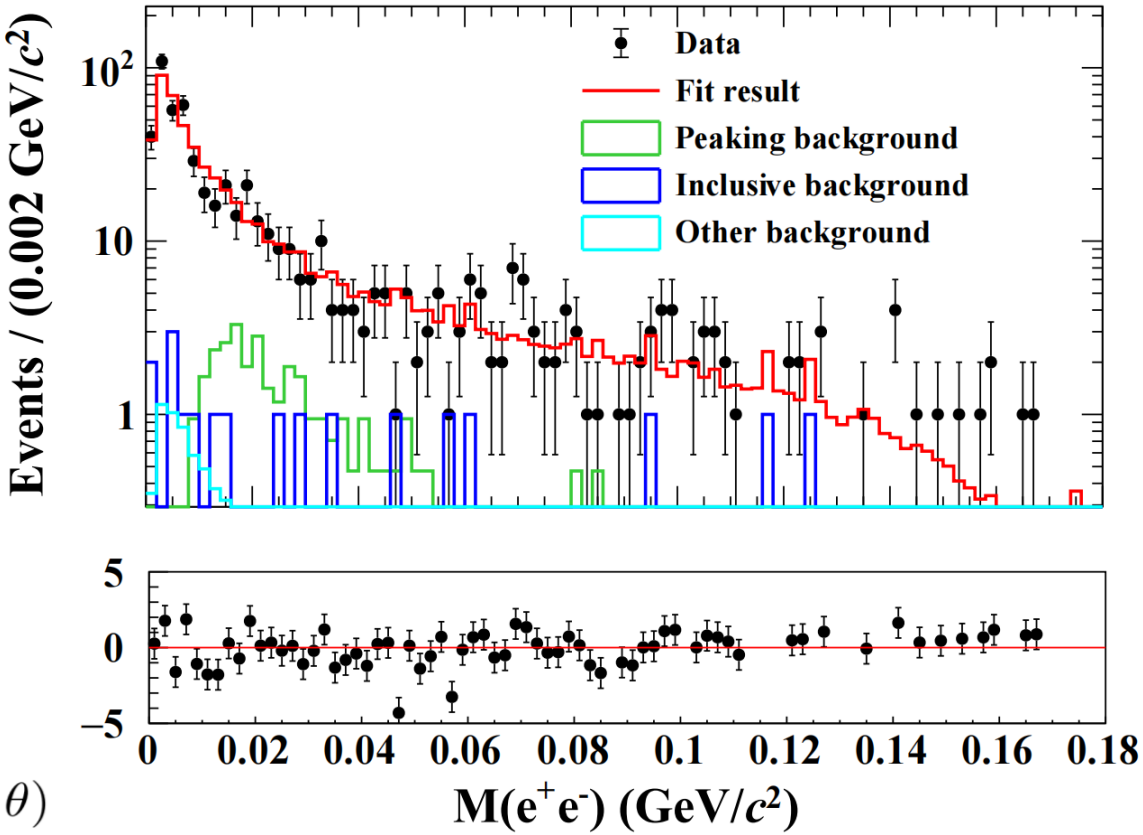
BESIII arXiv:2603.08120

- With 10 billion J/ψ events, 609.1 ± 27.7 $\eta' \to \omega e^+e^-$ signal events are observed

$$\mathrm{Br}(\eta' \to \omega e^+e^-) = (1.79 \pm 0.09 + 0.12) \times 10^{-4}$$





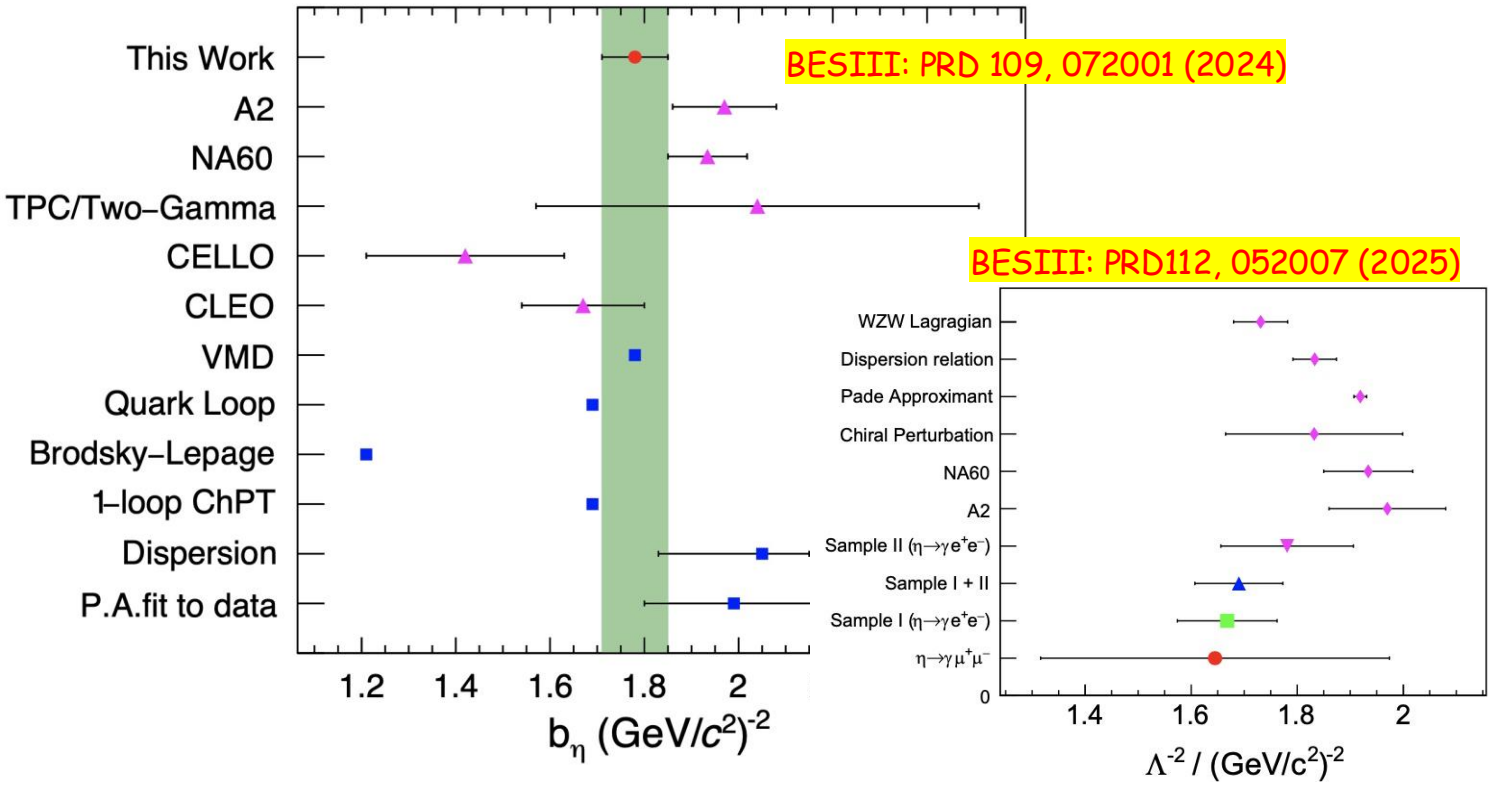


$$|\mathcal{A}_{\eta' \to e^+e^-\omega}|^2 = \frac{2^6\pi^2 M_{\eta'}^3 \alpha \Gamma_{\eta' \to \gamma\omega}}{(M_{\eta'}^2 - M_\omega^2)^3} |F(q^2)|^2 \cdot \frac{(M_{\eta'}^2 - q^2 - M_\omega^2)^2 - 4M_\omega^2 q^2}{q^2} (2 - \beta^2 \sin^2\theta)$$

$$\text{slope} \equiv \left.\frac{dF}{dq^2}\right|_{q^2=0} = \frac{1}{\Lambda^2}$$

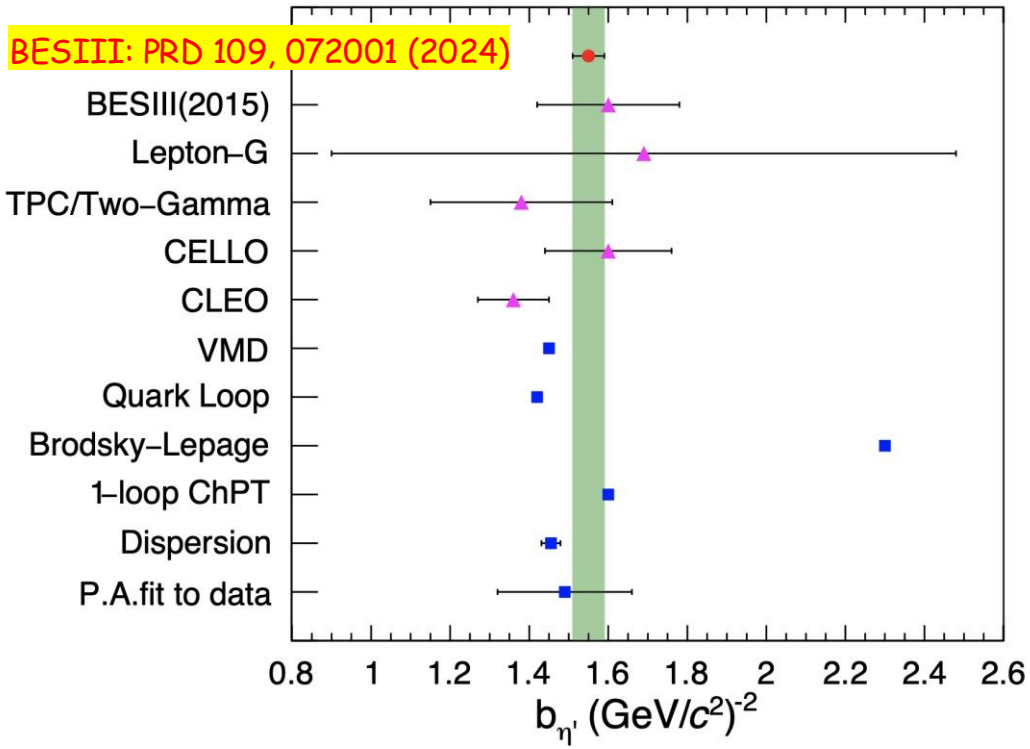
TFF is measured for the first time: $\Lambda^{-1} = (2.92 \pm 0.83 \pm 0.15)\ GeV^{-1}$

Summary of the TFF for η/η'



BESIII: PRD 109, 072001 (2024)

BESIII: PRD112, 052007 (2025)



Combined the two $\eta \to \gamma e^+e^-$ samples:

$$b_\eta = (1.707 \pm 0.076 \pm 0.029)\ GeV/c^2$$

$\boldsymbol{\eta \to \gamma\mu^+\mu^-}$: $b_\eta = (1.645 \pm 0.343 \pm 0.017)\ GeV/c^2$

$\eta' \to \gamma e^+e^-$: $b_{\eta'} = 1.574 \pm 0.048 \pm 0.016\ (\mathrm{GeV/c^2})^{-2}$

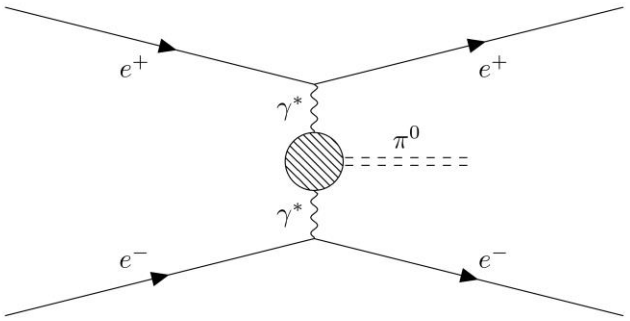
$\eta' \to \pi^+\pi^-e^+e^-$: $b_{\eta'} = 1.30 \pm 0.19\ (\mathrm{GeV/c^2})^{-2}$

$\eta' \to \omega e^+e^-$: $\Lambda^{-1} = (2.92 \pm 0.83 \pm 0.15)\ GeV^{-1}$

Space-like TFF for π^0

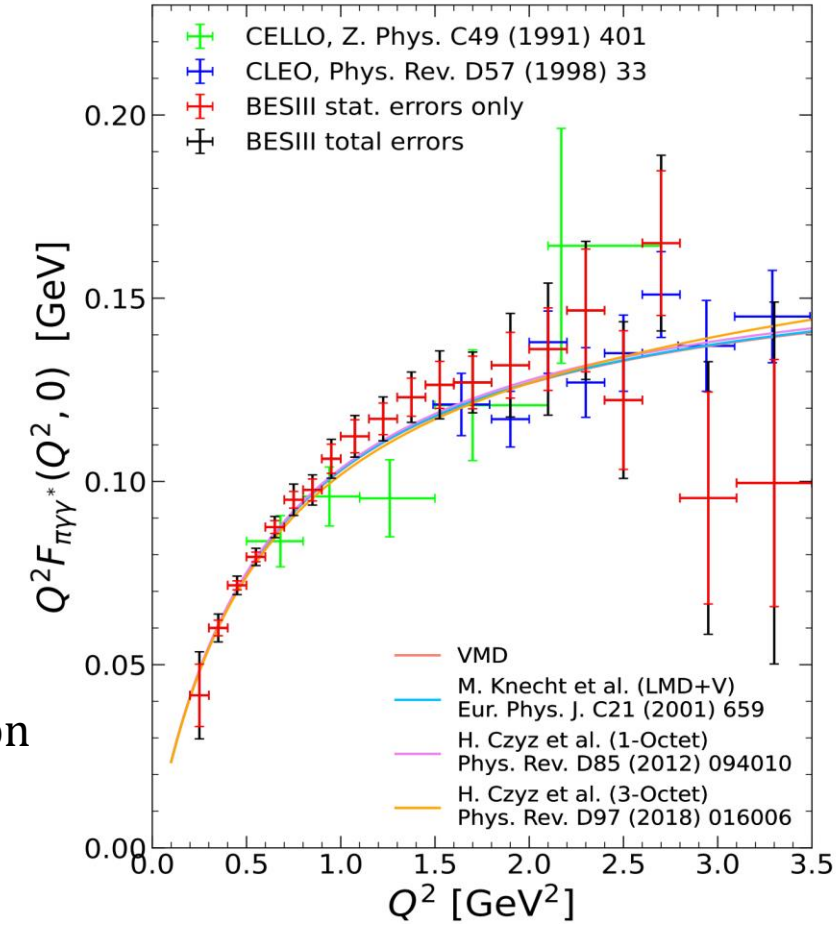
BESIII arXiv:2509.07685

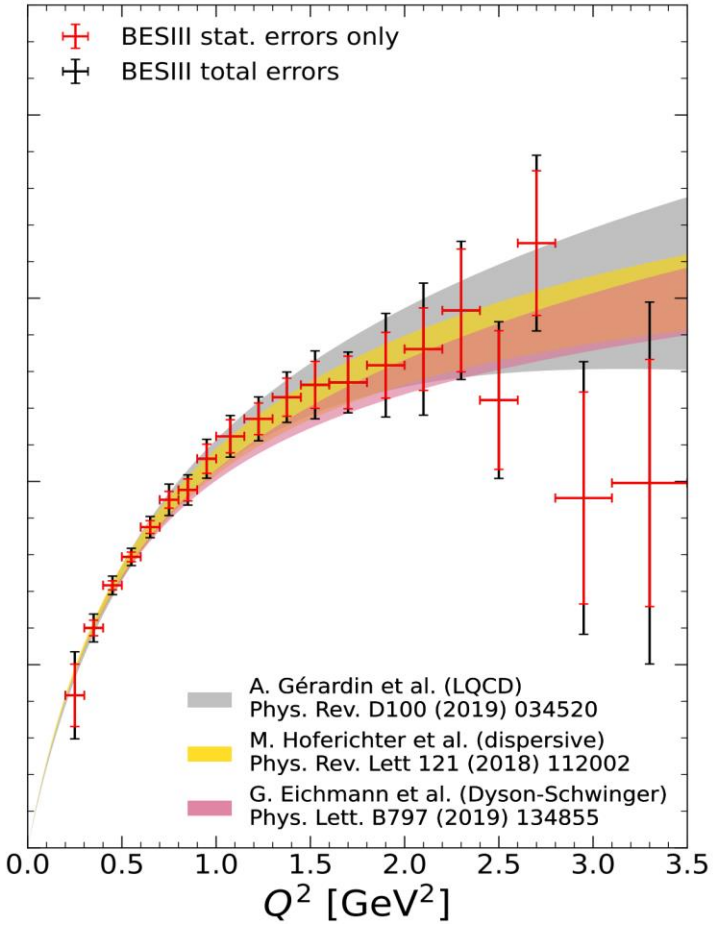
- 2.93 fb^{-1} e^+e^- collision data @ 3.773 GeV
- Signal tag method, measure TFF: $F(Q_1^2, Q_2^2 \approx 0)$ at $0.2 \leq Q^2 \leq 3.5$ GeV^2



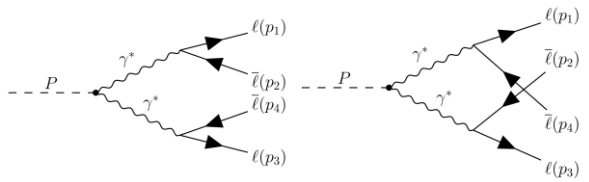
$$|F(Q^2)|^2 = \frac{\mathrm{d}\sigma_{\mathrm{Born}}}{\mathrm{d}Q^2}\left(\frac{\mathrm{d}\sigma_{\mathrm{WZW}}}{\mathrm{d}Q^2}\right)^{-1} = \frac{N_{\mathrm{sig}}}{\Delta Q^2\,\mathcal{L}\,\varepsilon\,(1+\delta)\,\mathcal{B}_{\gamma\gamma}}\left(\frac{\mathrm{d}\sigma_{\mathrm{WZW}}}{\mathrm{d}Q^2}\right)^{-1}$$

σ_{WZW} is the point-like Born cross section



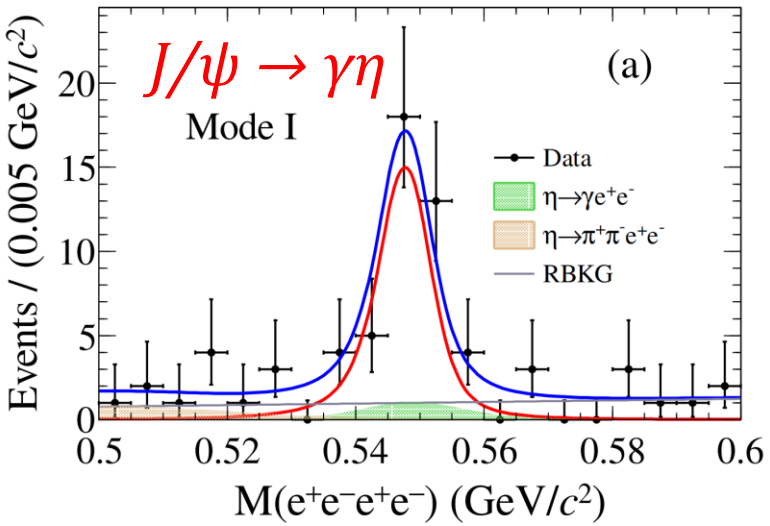


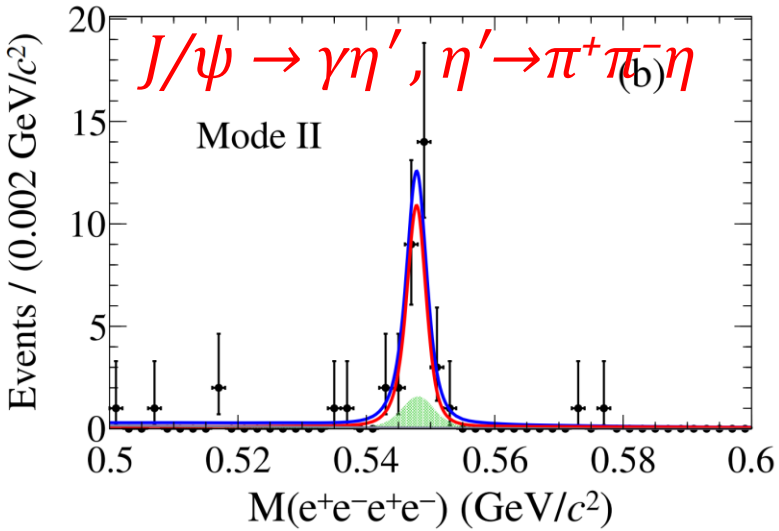
Double Dalitz decays $\eta \to e^+e^-e^+e^-$

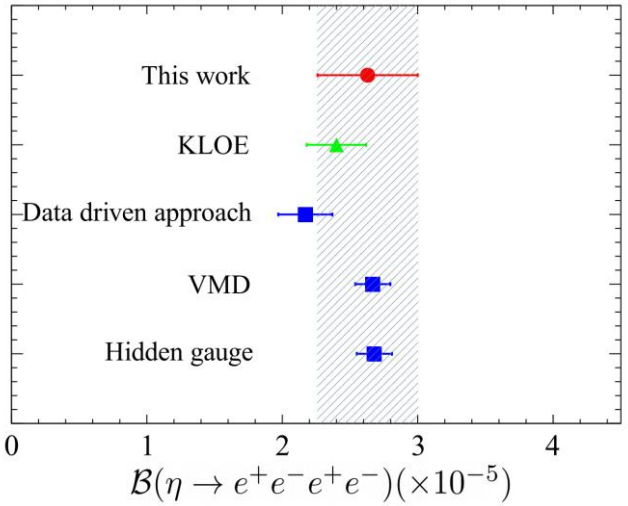


- Expected to proceed through two virtual photons, TFF

BESIII: arXiv:2605.04898v1







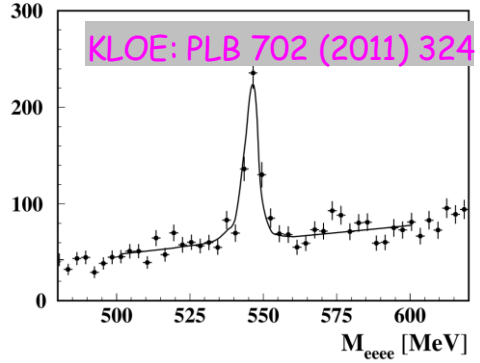
Mode	$N^{\rm obs}$	ϵ (%)	$\mathcal{B}$ ($\times 10^{-5}$)
I	35.9 ± 6.7	13.1	2.51 ± 0.47
II	29.5 ± 6.1	4.7	2.80 ± 0.58

The combined branching fraction is determined to be $(2.63\pm0.34\pm0.16)\times10^{-5}$

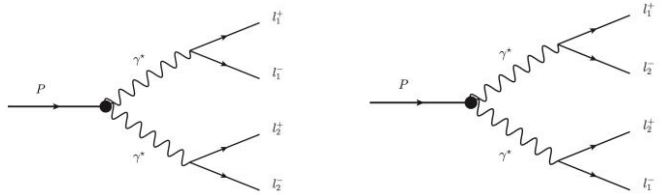
Source	$\eta \to e^+e^-e^+e^-$ ($\times 10^{-5}$)
Hidden gauge [11]	2.68 ± 0.13
Modified VMD [11]	2.67 ± 0.13
Data driven approach [12]	2.17 ± 0.20
KLOE [13]	2.40 ± 0.22
BESIII [14]	...

T. Petri, arXiv

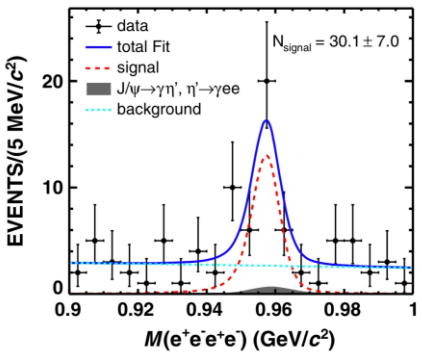
CPC 42 (201



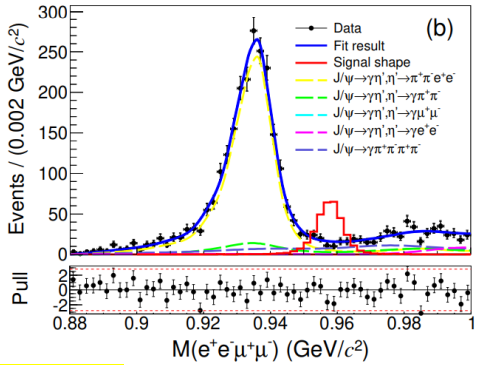
Double Dalitz decays $\eta/\eta' \to l^+l^-l^+l^-$



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

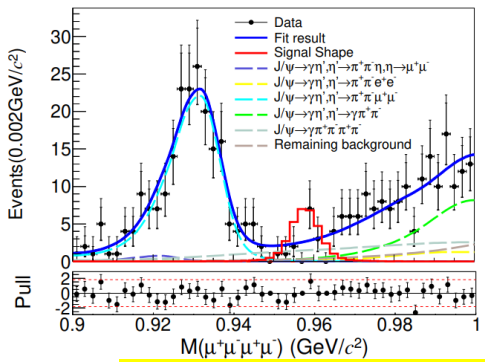


$\eta' \to e^+e^-\mu^+\mu^-$

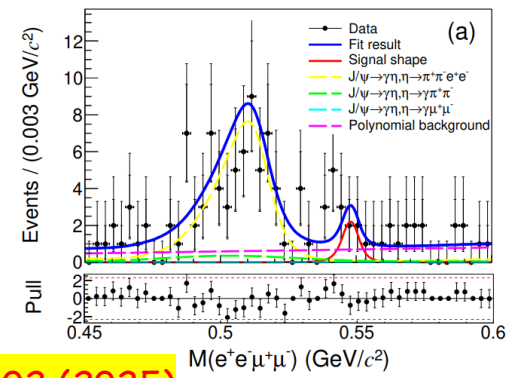


BESIII: PRD105,112010 (2022)

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

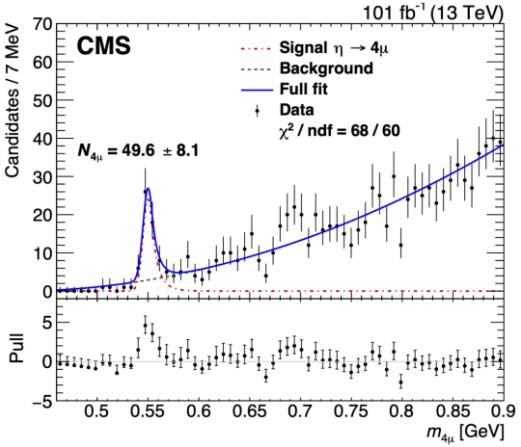


$\eta \to e^+e^-\mu^+\mu^-$



BESIII: PRD111,052002 (2025)

$\eta \to \mu^+\mu^-\mu^+\mu^-$



CMS: PRL 131 (2023) 091903

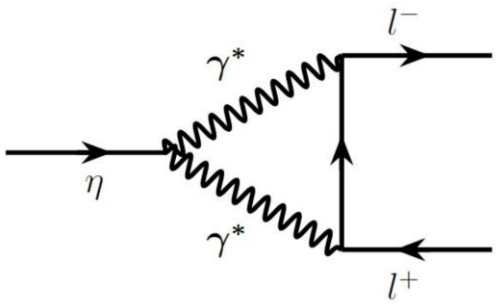
- Very limited Statistics!

Decay	Hidden gauge [9]	Modified VMD [9]	Data driven approach [10]	Experimental result
$\eta \to e^+e^-e^+e^-$	$2.680(13) \times 10^{-5}$	$2.668(13) \times 10^{-5}$	$2.17(2) \times 10^{-5}$	$2.40(22) \times 10^{-5}$ [11]
$\eta' \to e^+e^-e^+e^-$	$2.384(4) \times 10^{-6}$	$2.317(4) \times 10^{-6}$	$2.10(45) \times 10^{-6}$	$4.5(1) \times 10^{-6}$ [12]
$\eta \to \mu^+\mu^-\mu^+\mu^-$	$3.992(27) \times 10^{-9}$	$3.797(26) \times 10^{-9}$	$3.98(15) \times 10^{-9}$	$5.0(8) \times 10^{-9}$ [13]
$\eta' \to \mu^+\mu^-\mu^+\mu^-$	$2.360(12) \times 10^{-8}$	$2.185(10) \times 10^{-8}$	$1.69(36) \times 10^{-8}$	$< 5.28 \times 10^{-7}$
$\eta \to e^+e^-\mu^+\mu^-$	$2.213(26) \times 10^{-6}$	$2.154(22) \times 10^{-6}$	$2.39(7) \times 10^{-6}$	$< 6.88 \times 10^{-6}$
$\eta' \to e^+e^-\mu^+\mu^-$	$8.626(33) \times 10^{-7}$	$7.968(31) \times 10^{-7}$	$6.39(91) \times 10^{-7}$	$< 1.75 \times 10^{-6}$

Quite close to the SM predictions

Study of $\eta \to e^+e^-$ and $\mu^+\mu^-$

➢SM: $\eta \to l^+l^-$ proceeds via fourth-order electromagnetic transition, dominated by a two-photon intermediate state



➢**$\eta \to e^+e^-$**: Suppressed, helicity factor is proportional to m_e^2

$Br(\eta \to e^+e^-) = (5.31^{+0.14}_{-0.04}) \times 10^{-9}$
$Br(\eta \to \mu^+\mu^-) = \left(4.72^{+0.05}_{-0.21}\right) \times 10^{-6}$

P. Masjuan and P. Sanchez-Puertas, JHEP 2016 (8), 108.

➢Based on dispersive representation for the η transition form factors:

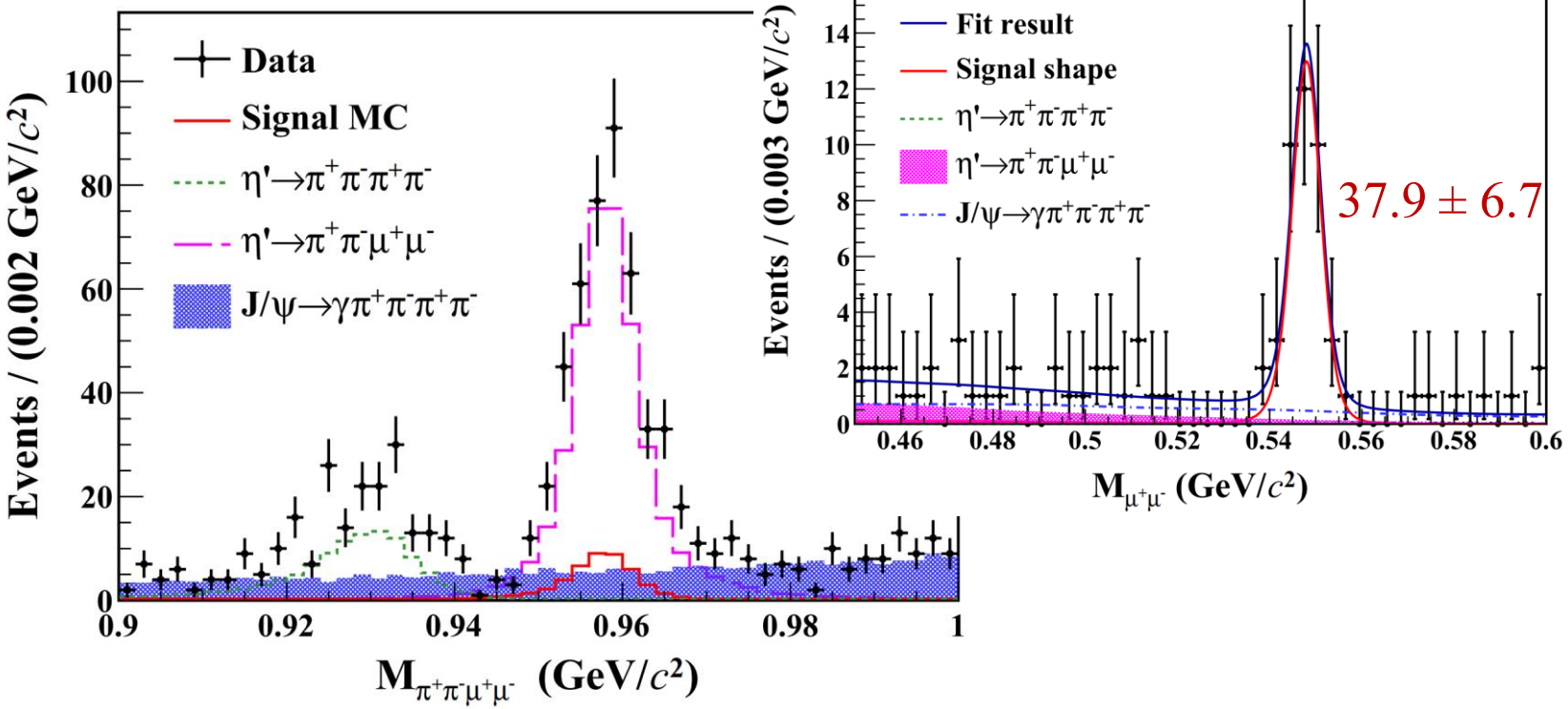
$Br(\eta \to e^+e^-) = (5.37 \pm 0.04 \pm 0.02) \times 10^{-9}$
$Br(\eta \to \mu^+\mu^-) = (4.54 \pm 0.04 \pm 0.02) \times 10^{-6}$

N. Messerli, M. Hoferichter, B.-L. Hoid, S. Holz, and B. Kubis, arXiv:2512.13776

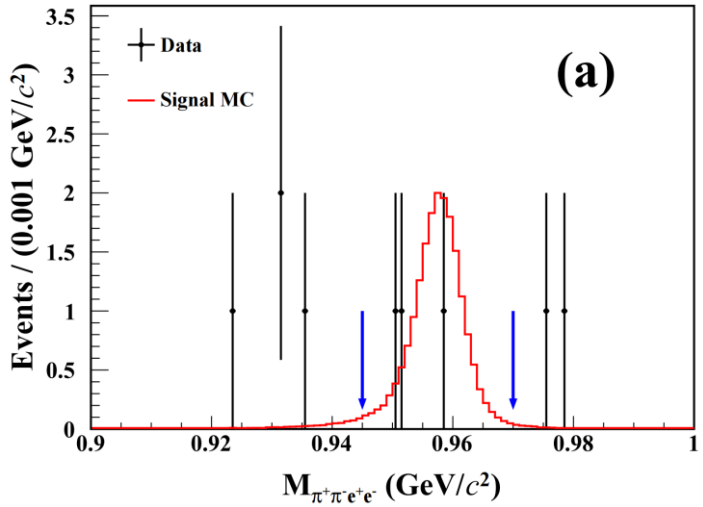
- A stringent UL of $Br(\eta \to e^+e^-) < 7 \times 10^{-7}$ at 90% CL obtained from $e^+e^- \to \eta$
- The world average of $Br(\eta \to \mu^+\mu^-) = (5.7 \pm 0.8) \times 10^{-6}$, combining the results from SATURNEII and Lepton-G more than thirty years ago

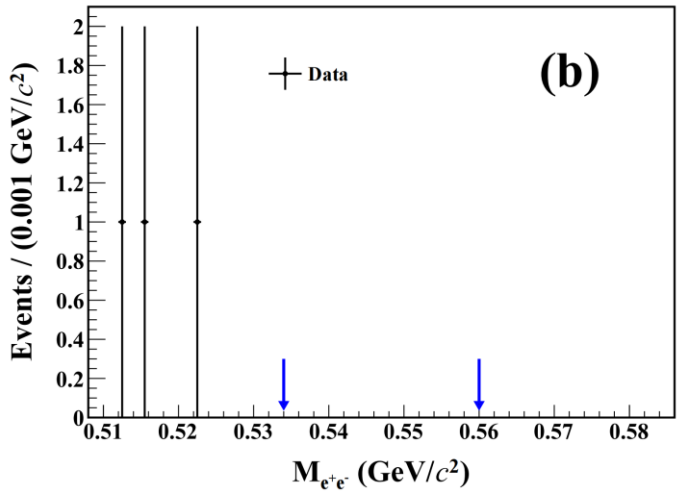
- With η sample from $J/\psi \to \gamma\eta', \eta' \to \pi^+\pi^-\eta, J/\psi \to \gamma l^+ l^-$ background is highly reduced compared with $J/\psi \to \gamma\eta$

BESIII: arXiv:2512.07144v2



$$Br(\eta \to \mu^+\mu^-) = (5.8 \pm 1.0 \pm 0.2) \times 10^{-6}$$

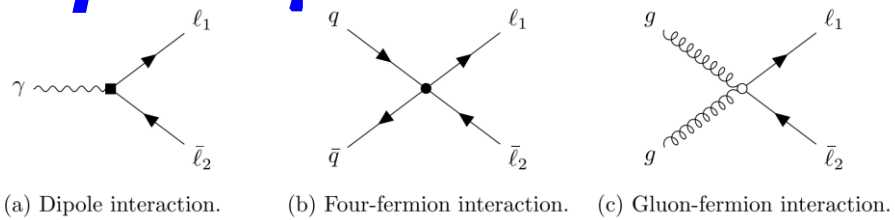




$$Br(\eta \to e^+e^-) < 2.2 \times 10^{-7}\ at\ 90\%\ CL$$

PDG: $Br(\eta \to \mu^+\mu^-) = (5.7 \pm 0.8) \times 10^{-6}$ and $Br(\eta \to e^+e^-) < 7 \times 10^{-7}$ at 90% CL

Search for CLFV process $\eta' \to e\mu$ and $\eta \to e\mu$

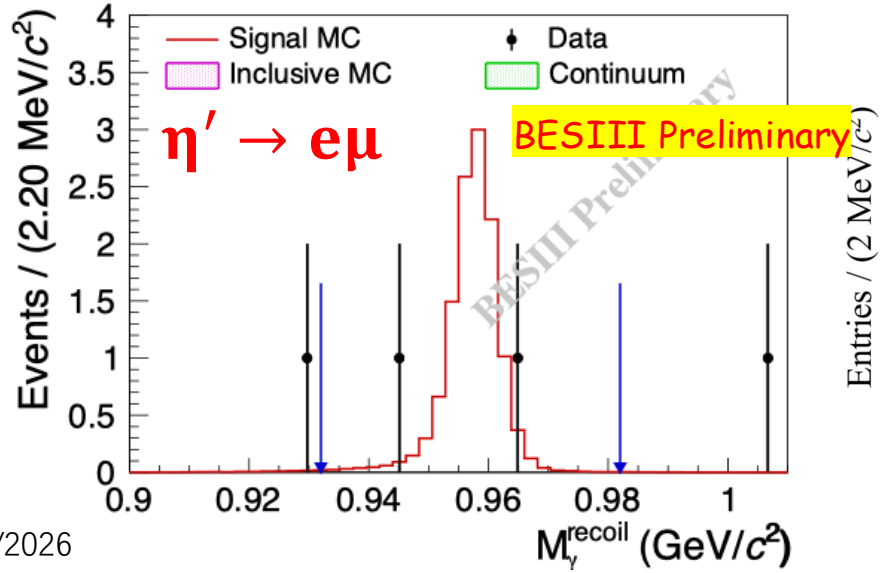


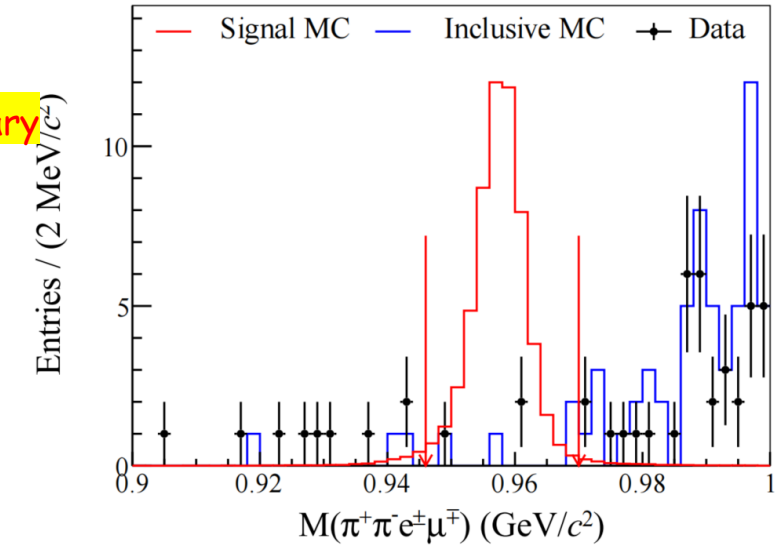
(a) Dipole interaction. (b) Four-fermion interaction. (c) Gluon-fermion interaction.

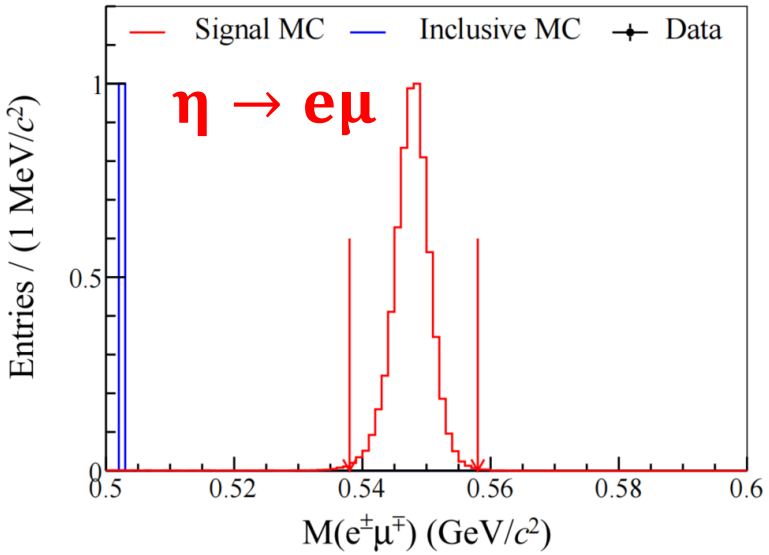
- Highly suppressed in SM $\propto \left(\Delta m_{ij}^2/M_W^2\right)^2 \sim 10^{-50}$
- Many New Physics models introduce Charge Lepton Flavor Violation (CLFV) processes
- Latest result $\mathcal{B}(\eta \to e\mu) < 6.0\times10^{-6}$ from CLEO in 2000 and $\mathcal{B}(\eta' \to e\mu) < 4.7 \times 10^{-4}$ from SPES2 in 1996

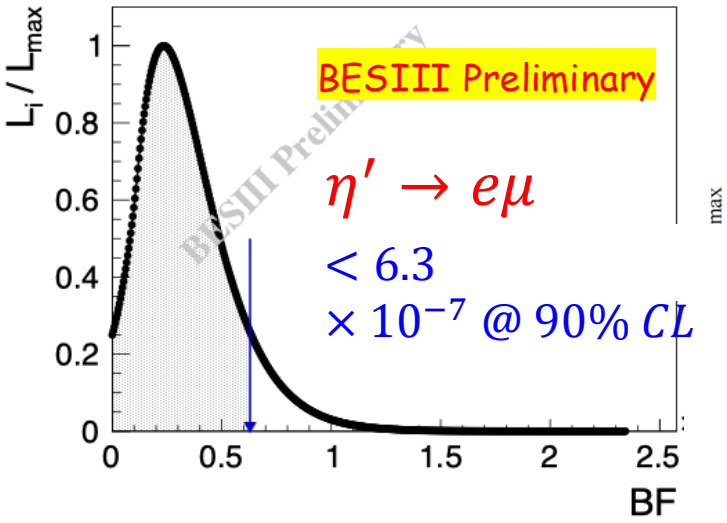
- For $\eta' \to e\mu$ with $J/\psi \to \gamma\eta'$ process is used.
- While for $\eta \to e\mu$, $J/\psi \to \gamma\eta' \to \gamma\pi^+\pi^-\eta$ is used to suppress continuum backgrounds

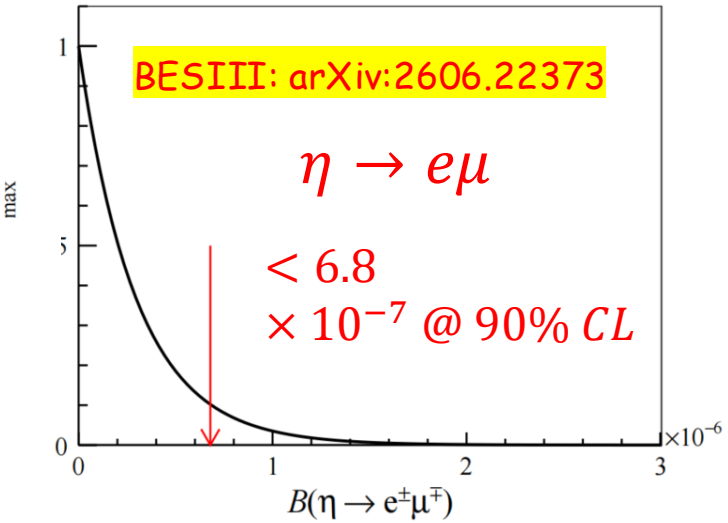
BESIII: arXiv:2606.22373











- $P \to \ell_1 \bar{\ell}_2$ are sensitive to different Wilson coefficients $C_i^{(D)}$ by $|C/\Lambda^2| \propto \sqrt{\mathcal{B}(P \to \ell_1 \bar{\ell}_2)}$
  - ✓ pseudoscalar coefficients in $\mathcal{L}_{\ell q}$: $C_{PL/PR}^{q\ell_1\ell_2}$
  - ✓ axial coefficients in $\mathcal{L}_{\ell q}$ $C_{AL/AR}^{q\ell_1\ell_2}$
  - ✓ gluonic coefficients in $\mathcal{L}_G$ $C_{\tilde{G}L/\tilde{G}R}^{q\ell_1\ell_2}$

L/R specify the chirality of the heavier lepton

$\|C/\Lambda^2\|$ (GeV^{-2})	$\ell_1\ell_2$	PDG $\mathcal{B}(\eta' \to e\mu) < 4.7 \times 10^{-4}$		This analysis $\mathcal{B}(\eta' \to e\mu) < 6.3 \times 10^{-7}$		PDG $\mathcal{B}(\eta \to e\mu) < 6.0 \times 10^{-6}$		This work $\mathcal{B}(\eta \to e\mu) < 6.8 \times 10^{-7}$	
		u,d	s	u,d	s	u,d	s	u,d	s
$\|C_{AL/AR}^{q\ell_1\ell_2}/\Lambda^2\|$	$e\mu$	2.1×10^{-1}	1.9×10^{-1}	7.4×10^{-3}	6.8×10^{-3}	3.0×10^{-3}	2.1×10^{-3}	1.0×10^{-3}	7.0×10^{-4}
$\|C_{PL/PR}^{q\ell_1\ell_2}/\Lambda^2\|$	$e\mu$	3.9×10^{4}	3.6×10^{4}	1.4×10^{3}	1.3×10^{3}	1.7×10^{3}	1.2×10^{3}	5.8×10^{2}	4.0×10^{2}
$\|C_{\tilde{G}L/\tilde{G}R}^{q\ell_1\ell_2}/\Lambda^2\|$	$e\mu$	5.0×10^{3}		1.8×10^{2}		1.6×10^{2}		5.4×10^{1}	

- Improvement of the ULs on the Wilson coefficients of effective operators describing LFV interactions at low energy scales

BESIII: PRD112, 112021 (2025)

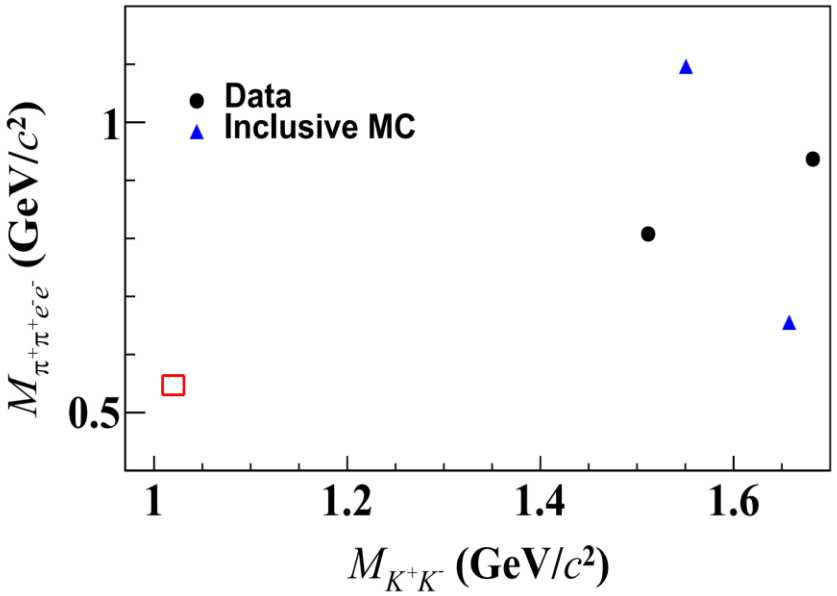
Search for LNV process $\eta \to \pi^+\pi^+e^-e^-$

- Rare and forbidden Lepton Number Violation (LNV) process
- According to the SU(2) ⊗ U(1) theory concerning left handed neutrino fields, massive neutrinos could induce spontaneous LNV processes

  ⇒ Related to the origin of neutrino mass
- $J/\psi \to \phi\eta$ is used to suppress continuum backgrounds

$$\mathcal{B}(\eta \to \pi^+\pi^+e^-e^-) < \mathcal{B}(\eta \to \gamma\gamma) \times \frac{N^{\rm up}_{\pi^+\pi^+e^-e^-}}{N^{\rm net}_{\gamma\gamma}/\epsilon_{\gamma\gamma}}$$

$$\mathcal{B}(\eta \to \pi^+\pi^+e^-e^-) < 4.6 \times 10^{-6}$$



The nature of η/η': Pseudoscalar mixing angle θ_P

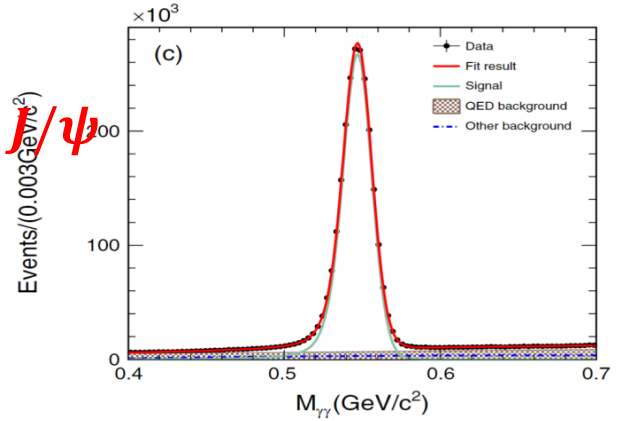
$$\eta = \eta_8 \cos\theta_P - \eta_1 \sin\theta_P$$
$$\eta' = \eta_8 \sin\theta_P + \eta_1 \cos\theta_P$$

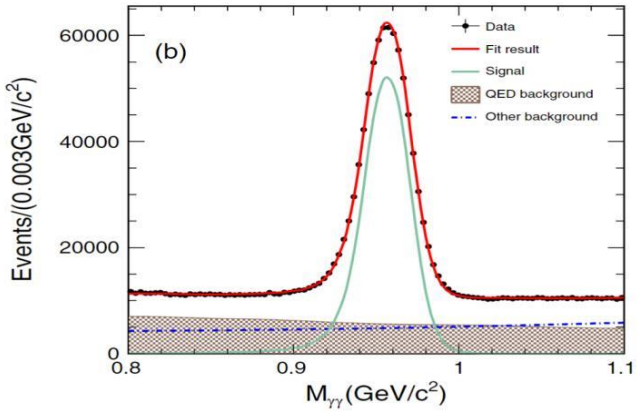
Pseudoscalar mixing angle θ_P
- ✓ QM basic parameter
- ✓ Input for Lattice QCD
- ✓ θ_P : $-14.1°$, $-17°$, $-18°$, $-24.5°$

N. H. Christ, et al., PRL 105 (2010)241601
T. Feldmann, IJMP A915 (2000) 159
C. Amsler and F. E. Close, PRD 53 (1996) 295
X. Y. Jiang, et al., PRL 130 (2023) 061901

- J/ψ radiative decay to η/η' can be used to measure θ_P

10 billion J/ψ





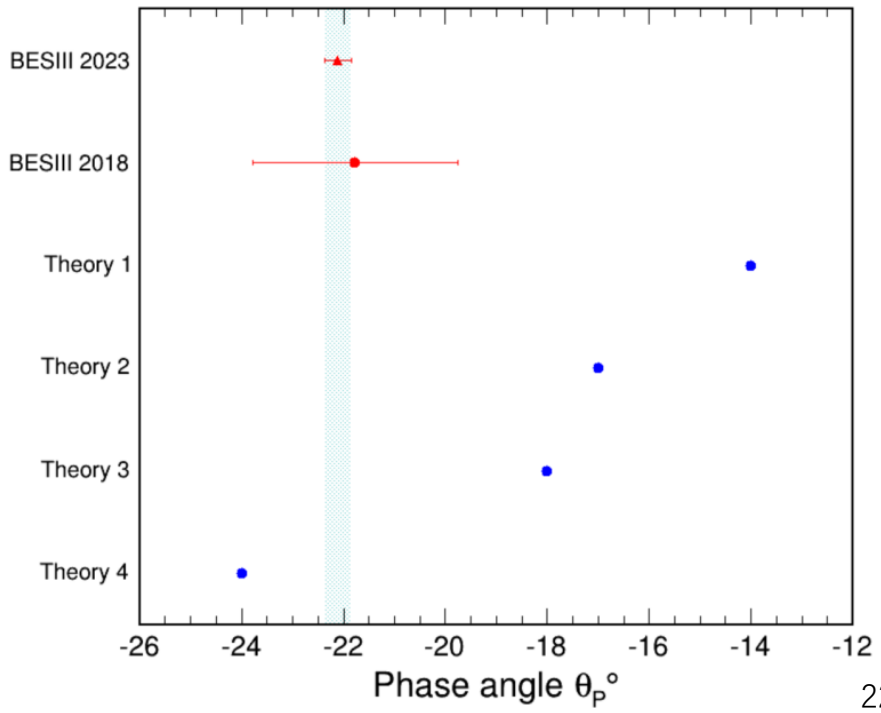
$$R = \frac{\Gamma(J/\psi \to \gamma\eta')}{\Gamma(J/\psi \to \gamma\eta)} = \left(\frac{p_{\eta'}}{p_\eta}\right)^3 cot^2\,\theta_P$$

$\theta_P = -(22.11 \pm 0.26)°$

Consider $J/\psi \to \gamma\pi^0$

$\theta_P = -(19.34 \pm 0.34)°$

BESIII: PRD108,092002 (2023)



Conclusions

- BESIII: a light meson factory
- Significant progresses achieved on η/η' decays
  - transition form factors, decay dynamics, rare/forbidden decays …
- $\eta' \to \pi^+\pi^-\eta$ significantly improves the ability to study rare η decays
- More results are expected to come soon !

Thanks for your attention!!!

Decay Amplitude of $\eta' \to \pi^+\pi^- l^+ l^-$

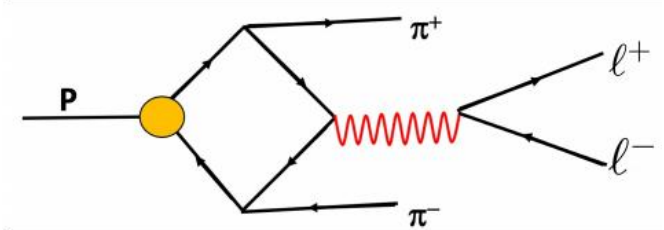
$$\overline{\left|\mathcal{A}_{\eta'\to\pi^+\pi^- l^+ l^-}\right|^2}(s_{\pi\pi}, s_{ll}, \theta_\pi, \theta_1, \phi) = \frac{e^2}{8k^2}|M(s_{\pi\pi}, s_{ll})|^2 \times \lambda\left(m_{\eta'}^2, s_{\pi\pi}, s_{ll}\right) \times \left[1 - \beta_1^2 \sin^2\theta_1 \sin^2\phi\right] s_{\pi\pi}\beta_\pi^2 \sin^2\theta_\pi$$

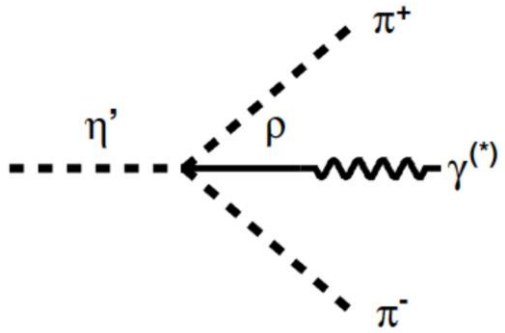
A. Faessler, C. Fuchs, M. I. Krivoruchenko, PRC 61, 035206 (2000)
B. Borasoy, R. Nissler, EPJA 33, 95 (2007)
T. Petri, arXiv:1010.2378

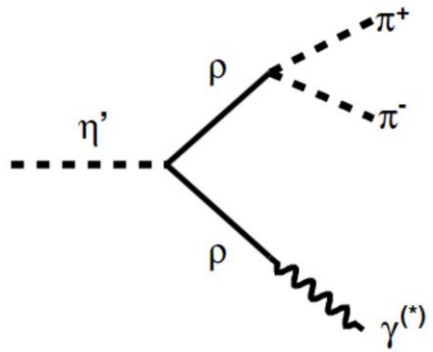
$$M(s_{\pi\pi}, s_{ll}) = M_{mix} \times VMD(s_{\pi\pi}, s_{ll})$$

contains the information of the decaying particle and the form factor

$$VMD(s_{\pi\pi}, s_{ll}) = \underbrace{1 - \frac{3}{4}(c_1 - c_2 + c_3)}_{\text{Box anomaly}} + \underbrace{\frac{3}{4}(c_1 - c_2 - c_3)\frac{m_V^2}{m_V^2 - s_{ll} - i m_V \Gamma(s_{ll})}}_{\text{VMD contribution}} + \underbrace{\frac{3}{2}c_3 \frac{m_V^2}{m_V^2 - s_{ll} - i m_V \Gamma(s_{ll})} \frac{m_{V,\pi}^2}{m_{V,\pi}^2 - s_{\pi\pi} - i m_{V,\pi}\Gamma(s_{\pi\pi})}}_{\text{VMD contribution}}$$







Various VMD models can be switch by adjusting the $c_{1,2,3}$ values

Amplitude analysis result of $\eta' \to \pi^+\pi^- l^+ l^-$

BESIII: JHEP 07, 135 (2024)

	Hidden gauge	Full VMD	Modified VMD
$\eta' \to \pi^+\pi^- e^+ e^-$	Model I	Model II	Model III
	$c_1 - c_2 = c_3 = 1$	$c_1 - c_2 = 1/3, c_3 = 1$	$c_1 - c_2 \neq c_3$
$m_V(\mathrm{MeV}/c^2)$	$954.3 \pm 87.8 \pm 36.4$	857.4 ± 76.5	787.5 ± 173.9
$m_{V,\pi}(\mathrm{MeV}/c^2)$	$765.3 \pm 1.2 \pm 20.2$	765.4 ± 1.2	764.8 ± 1.3
$m_\omega(\mathrm{MeV}/c^2)$	$778.7 \pm 1.3 \pm 17.3$	778.7 ± 1.3	778.7 ± 1.4
$\beta(10^{-3})$	$8.5 \pm 1.4 \pm 0.7$	8.5 ± 1.4	8.1 ± 1.5
θ	$1.4 \pm 0.3 \pm 0.1$	1.4 ± 0.3	1.4 ± 0.3
$c_1 - c_2$	1	1/3	-0.03 ± 1.09
c_3	1	1	1.03 ± 0.03
$\chi^2/ndof(e^+e^-, \pi^+\pi^-)$	77.9/82.0, 47.8/65.0	78.7/82.0, 47.6/65.0	79.4/82.0, 45.1/65.0
$b_{\eta'}(\mathrm{GeV}/c^2)^{-2}$	$1.10 \pm 0.20 \pm 0.07$	1.36 ± 0.24	1.61 ± 0.71

	Hidden gauge	Full VMD	Modified VMD
$\eta' \to \pi^+\pi^- \mu^+ \mu^-$	Model I	Model II	Model III
	$c_1 - c_2 = c_3 = 1$	$c_1 - c_2 = 1/3, c_3 = 1$	$c_1 - c_2 \neq c_3$
$m_V(\mathrm{MeV}/c^2)$	$649.4 \pm 55.9 \pm 35.6$	601.6 ± 25.7	589.6 ± 25.9
$m_{V,\pi}(\mathrm{MeV}/c^2)$	$757.3 \pm 24.1 \pm 18.0$	765.4 ± 18.8	774.4 ± 43.5
$c_1 - c_2$	1	1/3	0.01 ± 0.45
c_3	1	1	0.98 ± 0.40
$\chi^2/ndof(\mu^+\mu^-, \pi^+\pi^-)$	48.1/34.0, 32.9/46.0	48.3/34.0, 32.9/46.0	49.7/35.0, 32.4/46.0
$b_{\eta'}(\mathrm{GeV}/c^2)^{-2}$	$2.37 \pm 0.41 \pm 0.27$	2.76 ± 0.24	2.88 ± 0.25