



η/η' physics at BESIII

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Mini-workshop on Light Hadrons

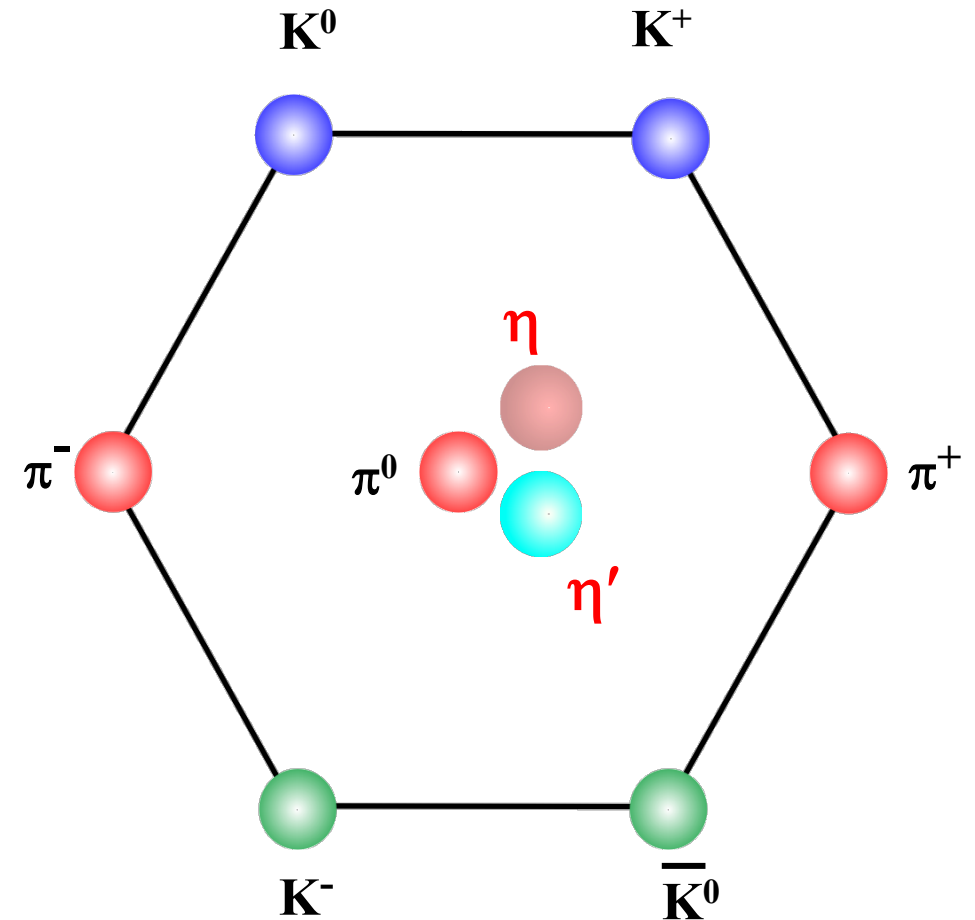
30th September, 2025, IHEP

OUTLINE

- Light meson physics
- BESIII: a light meson factory
- What is "NEW" at BESIII ?
- Summary

Light Meson Physics

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



Source of η/η' events



CLAS(12)



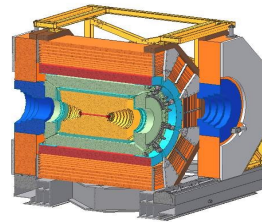
Crystal Ball



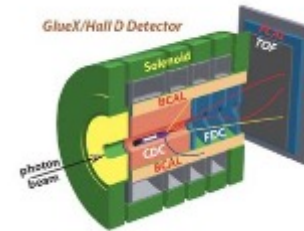
WASA-at-COSY



KLOE-2



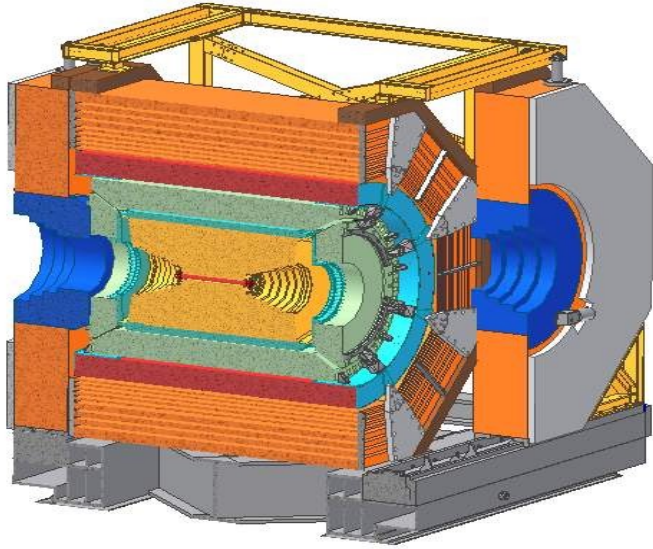
BESIII



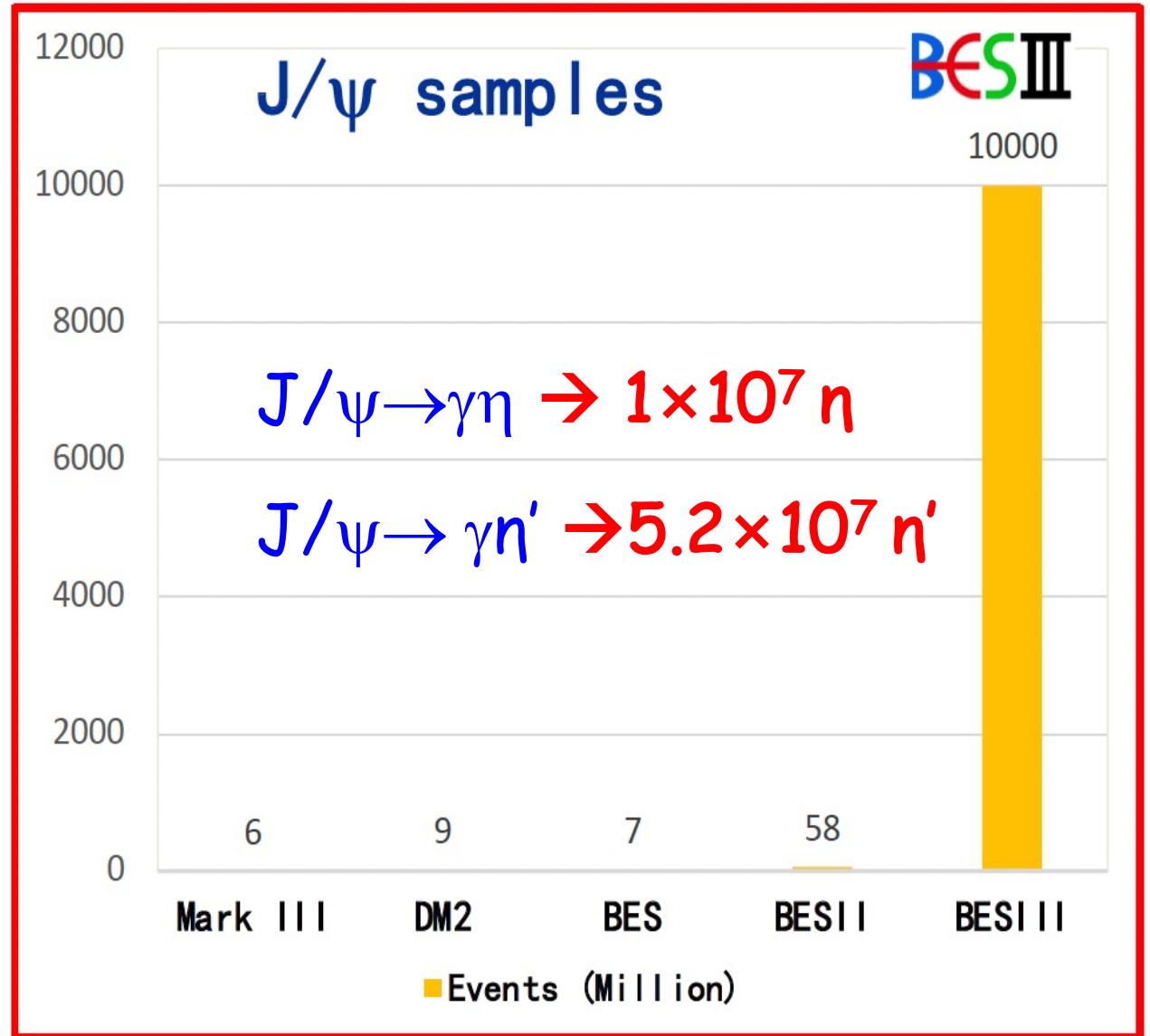
JEF @ GlueX

New proposals: REDTOP, η factory at HIAF.....

η/η' events at BESIII



A light meson factory !



BESIII: an important role in η/η' decays

η REFERENCES

ABLIKIM	23AN	PR D107 092007	M. Ablikim <i>et al.</i>	(BESIII Collab.)
HAYRAPETY...	23A	PRL 131 091903	A. Hayrapetyan <i>et al.</i>	(CMS Collab.)
ABLIKIM	21AM	PR D104 092004	M. Ablikim <i>et al.</i>	(BESIII Collab.)
BABUSCI	20A	JHEP 2010 047	D. Babusci <i>et al.</i>	(KLOE-2 Collab.)
ZHEVLAKOV	19	PR D99 031703	A.S. Zhevlakov <i>et al.</i>	(TMSK, MAINZ, TUBIN+)
ACHASOV	18B	PR D98 052007	M.N. Achasov <i>et al.</i>	(SND Collab.)
ADLARSON	18C	PL B784 378	P. Adlarson <i>et al.</i>	(WASA-at-COSY Collab.)
PRAKHOV	18	PR C97 065203	S. Prakhov <i>et al.</i>	(A2 Collab. at MAMI)
AAIJ	17D	PL B764 233	R. Aaij <i>et al.</i>	(LHCb Collab.)
ADLARSON	17B	PR C95 035208	P. Adlarson <i>et al.</i>	(A2 Collab. at MAMI)
ANASTASI	16A	JHEP 1605 019	A. Anastasi <i>et al.</i>	(KLOE-2 Collab.)
ARNALDI	16	PL B757 437	R. Arnaldi <i>et al.</i>	(NA60 Collab.)
ABLIKIM	15G	PR D92 012014	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ADLARSON	14A	PR C90 045207	P. Adlarson <i>et al.</i>	(WASA-at-COSY Collab.)
AGAKISHIEV	14	PL B731 265	G. Agakishiev <i>et al.</i>	(HADES Collab.)
NEFKENS	14	PR C90 025206	B.M.K. Nefkens <i>et al.</i>	(A2 Collab. at MAMI)
NIKOLAEV	14	EPJ A50 58	A. Nikolaev <i>et al.</i>	(MAMI-B, MAINZ, BONN)
ABLIKIM	13	PR D87 012009	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM	13G	PR D87 032006	M. Ablikim <i>et al.</i>	(BESIII Collab.)
BABUSCI	13	PL B718 910	D. Babusci <i>et al.</i>	(KLOE/KLOE-2 Collab.)
BABUSCI	13A	JHEP 1301 119	D. Babusci <i>et al.</i>	(KLOE-2 Collab.)
AGAKISHIEV	12A	EPJ A48 64	G. Agakishiev <i>et al.</i>	(HADES Collab.)
GOSLAWSKI	12	PR D85 112011	P. Goslawski <i>et al.</i>	(COSY-ANKE Collab.)
ABLIKIM	11G	PR D84 032006	M. Ablikim <i>et al.</i>	(BESIII Collab.)
AMBROSINO	11B	PL B702 324	F. Ambrosino <i>et al.</i>	(KLOE Collab.)
BERGHAUSER	11	PL B701 562	H. Berghauser <i>et al.</i>	(GIES, UCLA, GUTE)

PDG2024

$\eta'(958)$ REFERENCES

ABLIKIM	23AH	PRL 130 081901	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM	22E	PR D105 112010	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM	21I	PR D103 072006	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM	21J	PR D103 092005	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM	20E	PR D101 032001	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM	19AW	PR D100 052015	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM	19T	PRL 122 142002	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM	18	PR D97 012003	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM	18C	PRL 120 242003	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ADLARSON	18A	PR D98 012001	P. Adlarson <i>et al.</i>	(A2 Collab. at MAMI)
GONZALEZ-S...	18A	EPJ C78 758	S. Gonzalez-Solis, E. Passemar	(BEIJ, IND+)
AAIJ	17D	PL B764 233	R. Aaij <i>et al.</i>	(LHCb Collab.)
ABLIKIM	17	PRL 118 012001	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM	17T	PR D96 012005	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM	16M	PR D93 072008	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM	15AD	PR D92 051101	M. Ablikim <i>et al.</i>	(BESIII Collab.)
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ABLIKIM	15O	PR D92 012001	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM	15P	PR D92 012007	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ACHASOV	15	PR D91 092010	M.N. Achasov <i>et al.</i>	(SND Collab.)
AKHMETSHIN	15	PL B740 273	R.R. Akhmetshin <i>et al.</i>	(CMD-3 Collab.)
PDG	15	RPP 2015 at pdg.lbl.gov		(PDG Collab.)
ABLIKIM	14M	PRL 112 251801	M. Ablikim <i>et al.</i>	(BESIII Collab.)
DONSKOV	14	MPL A29 1450213	S. Donskov <i>et al.</i>	(GAMS-4 π Collab.)
PDG	14	CP C38 070001	K. Olive <i>et al.</i>	(PDG Collab.)
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ABLIKIM	13O	PR D87 092011	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM	13U	PR D88 091502	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM	12E	PRL 108 182001	M. Ablikim <i>et al.</i>	(BESIII Collab.)
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ABLIKIM	11G	PR D84 032006	M. Ablikim <i>et al.</i>	(BESIII Collab.)

More than 20 publications!

BESIII: an important role in η/η' decays

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ABLIKIM	15P	PR D92 012007	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ACHASOV	15	PR D91 092010	M.N. Achasov <i>et al.</i>	(SND Collab.)
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What is "NEW" at BESIII ?

- New decays
- New decay mechanisms
- New approaches
- New tests for fundamental symmetries

New decays

$$\eta' \rightarrow 2(\pi^+\pi^-), \pi^+\pi^-\pi^0\pi^0$$

PRL112, 251801(2014)

$$\eta' \rightarrow \gamma e^+e^-$$

PRD92, 012001(2015)

$$\eta' \rightarrow \omega e^+e^-$$

PRD92, 051101(2015)

$$\eta' \rightarrow \rho\pi$$

PRL118, 012001(2017)

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

PRD96, 012005(2017)

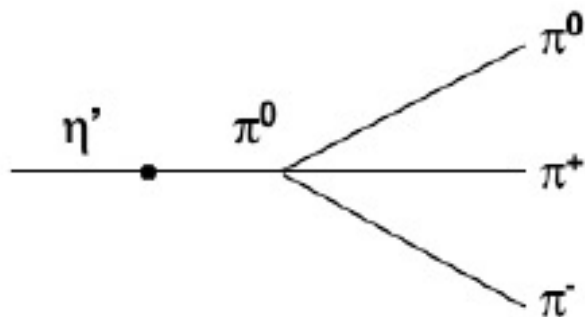
$$\eta' \rightarrow \pi^+\pi^-\pi^+\pi^-$$

PRD103, 072006(2021)

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

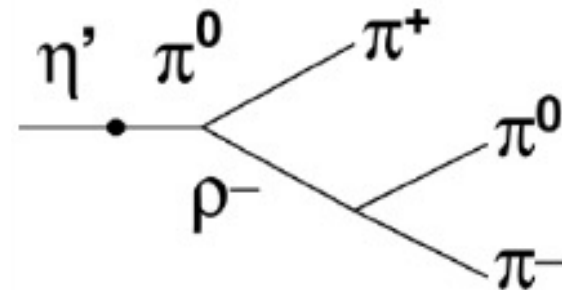
PRD105, 112010(2022)

Observation of $\eta' \rightarrow \rho^+ \pi^-$

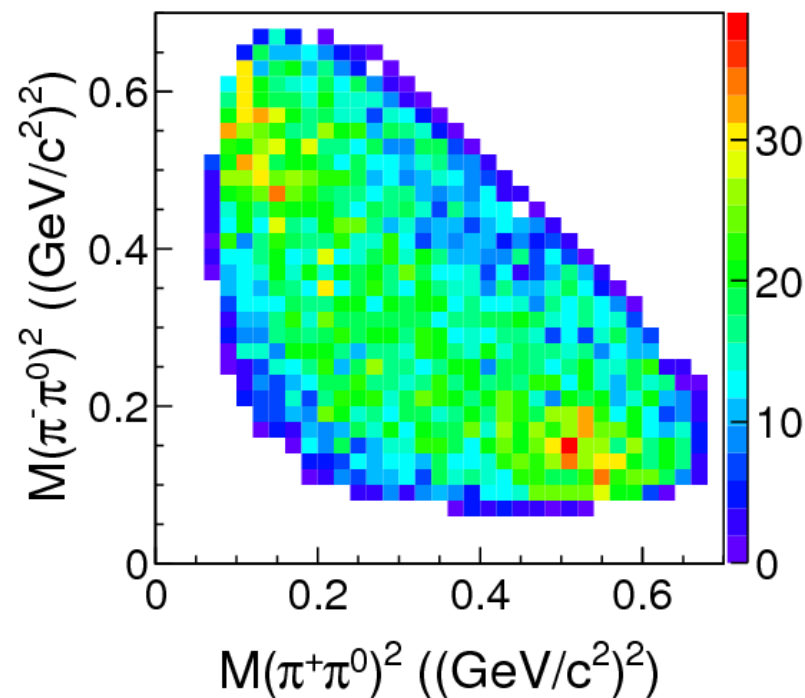
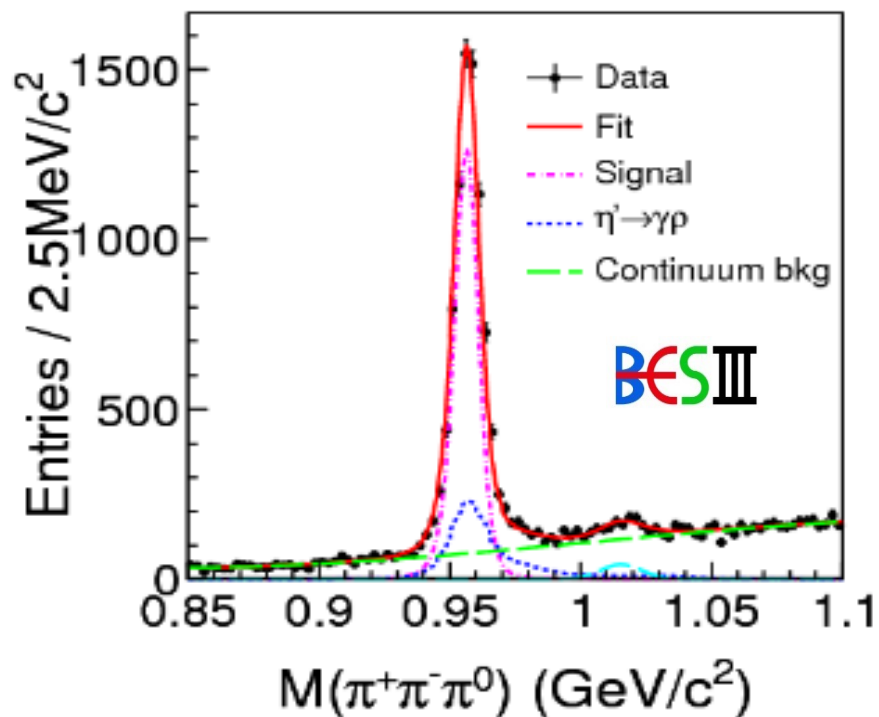


D. Gross et al., PRD19,2188(1979)

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



N. Beisert et al., Nucl. Phys. A716,186(2003)

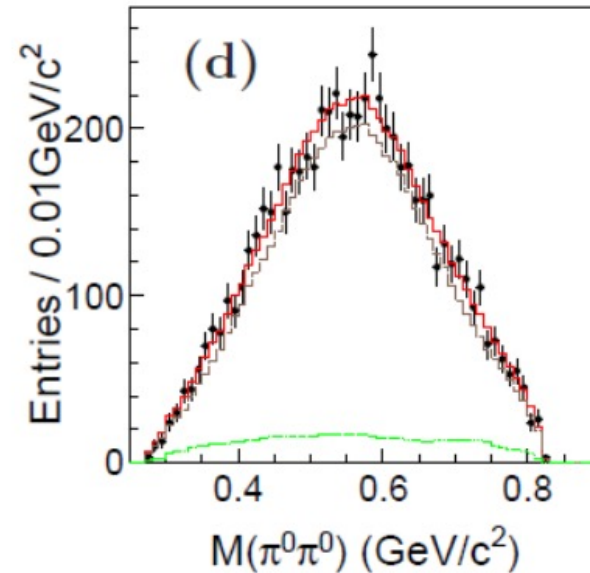
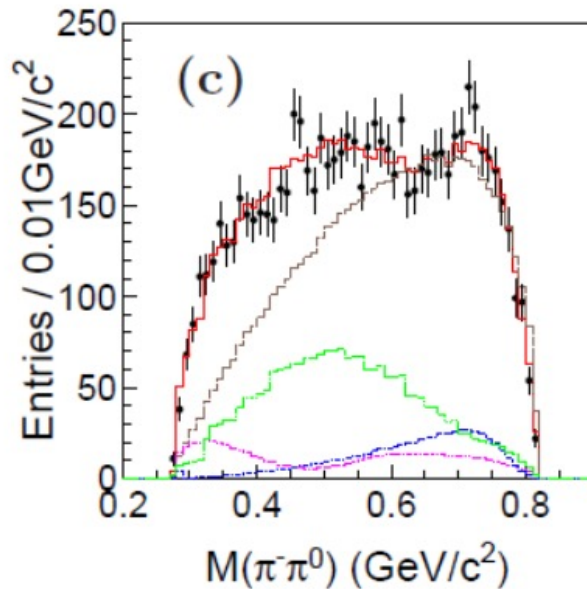
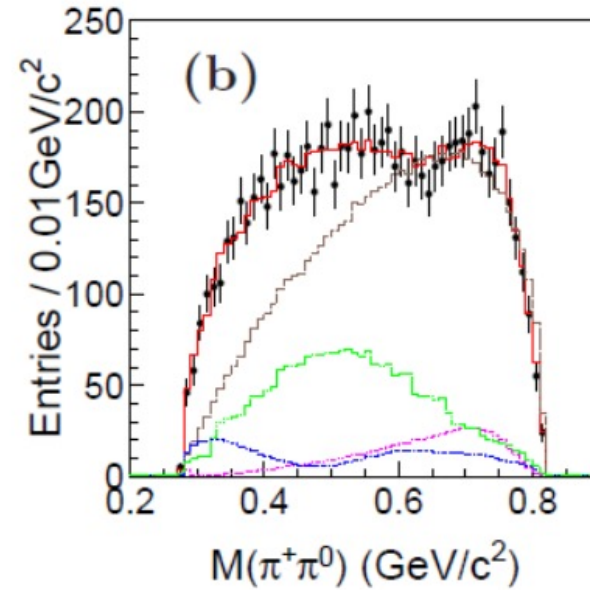
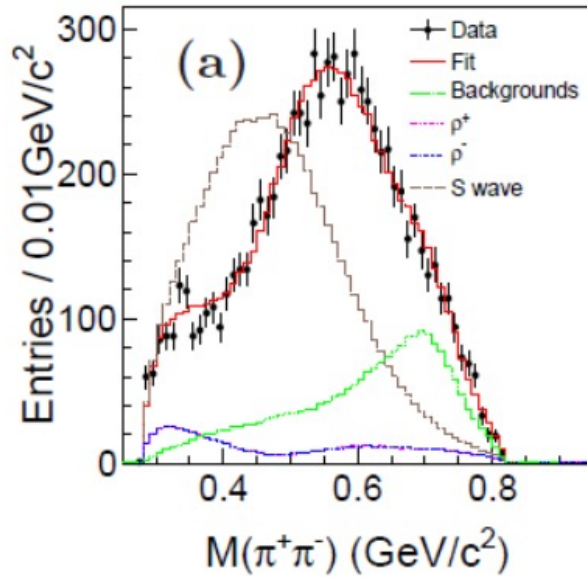


$\eta' \rightarrow \pi^+ \pi^- \pi^0$

PRL118, 012001(2017)

Amplitude analysis of $\eta' \rightarrow \rho^+ \pi^-$

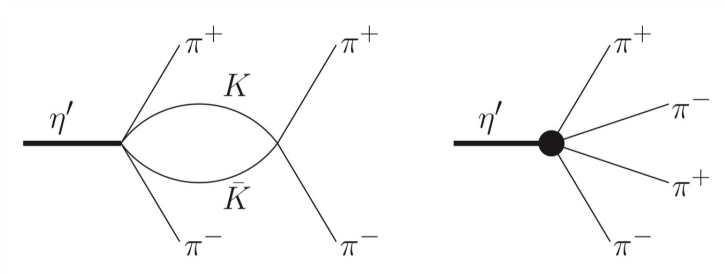
PRL118, 012001(2017)



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

Analysis with 10 billion J/ψ is in progress !

Observation of $\eta' \rightarrow \pi^+\pi^-\pi^+\pi^-$, $\pi^+\pi^-\pi^0\pi^0$

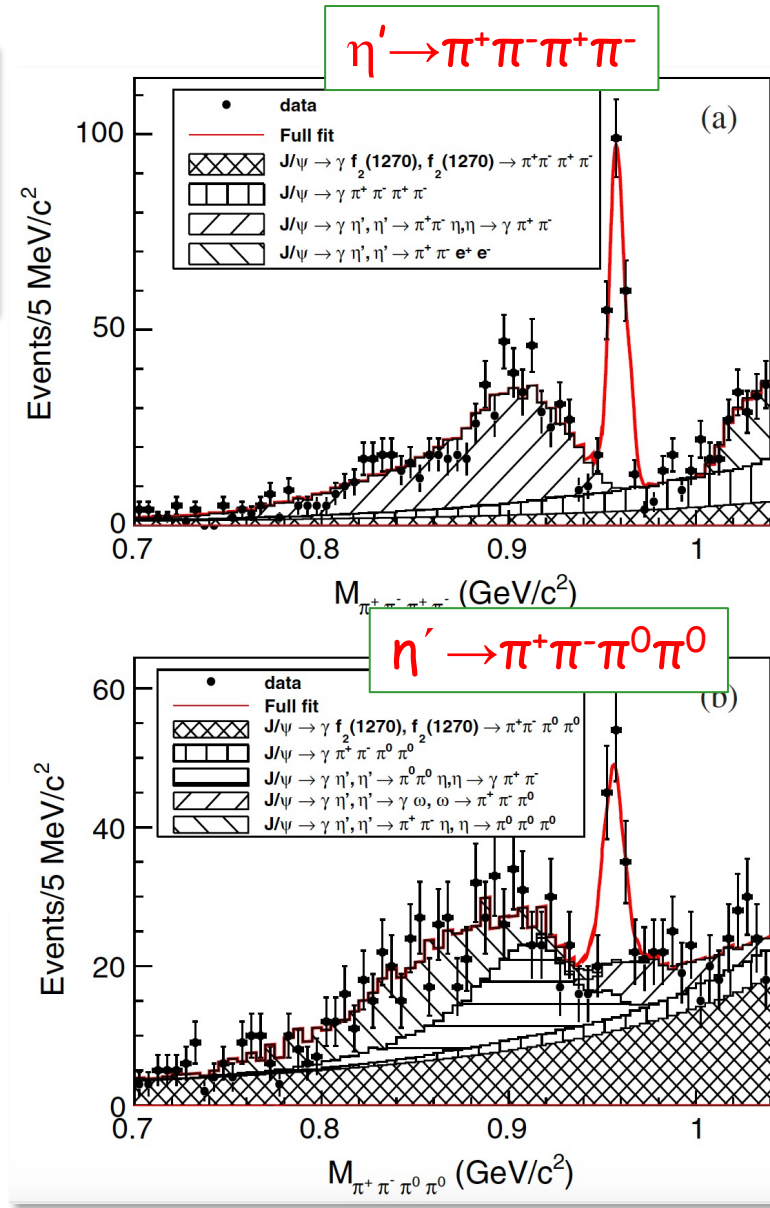


ChPT+VMD:
only occur at $O(p^6)$

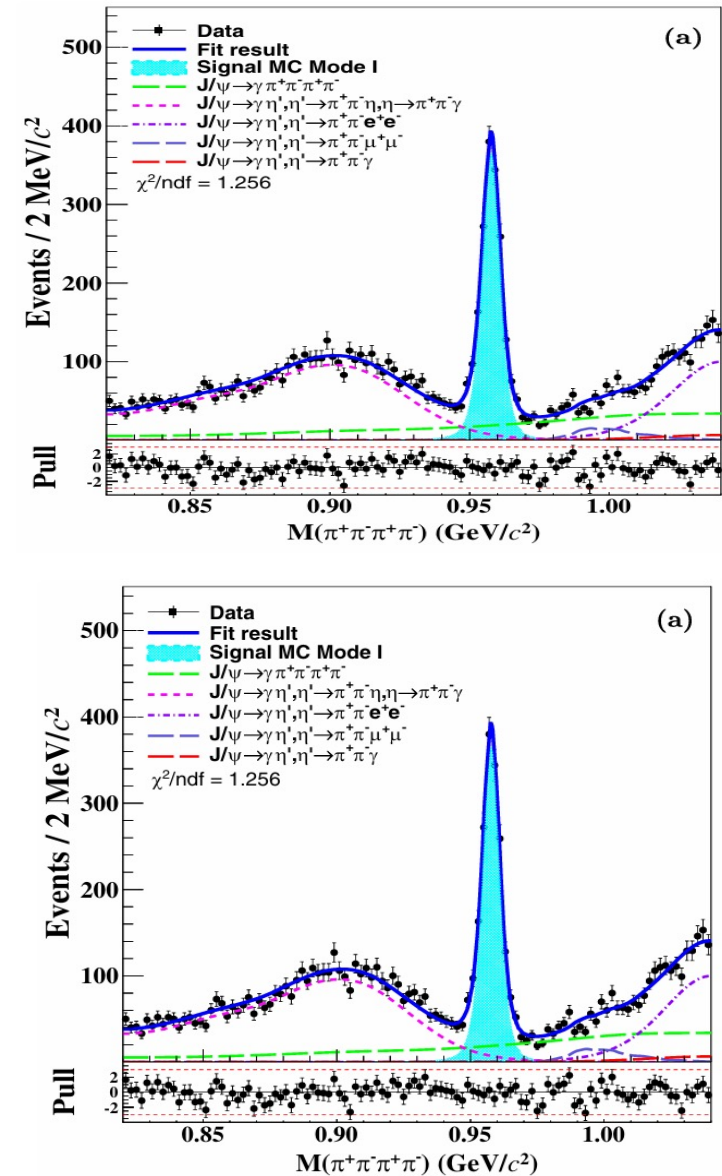
$$B(\eta' \rightarrow \pi^+\pi^-\pi^+\pi^-) = (1.0 \pm 0.3) \times 10^{-4}$$

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

F.K. Guo et al, PRD 85,014014 (2012)



PRL112,251801(2014)



PRD 109, 032006 (2024)

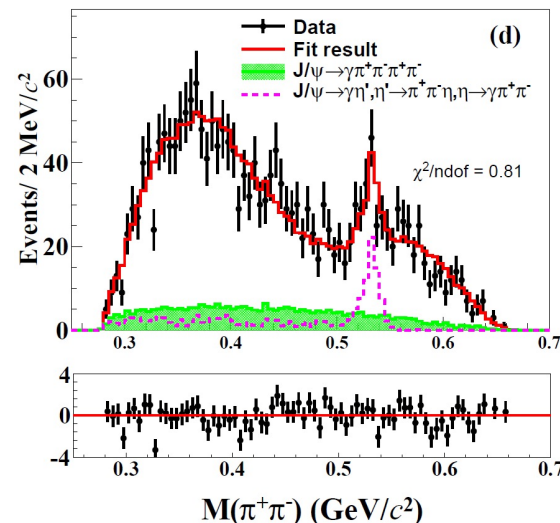
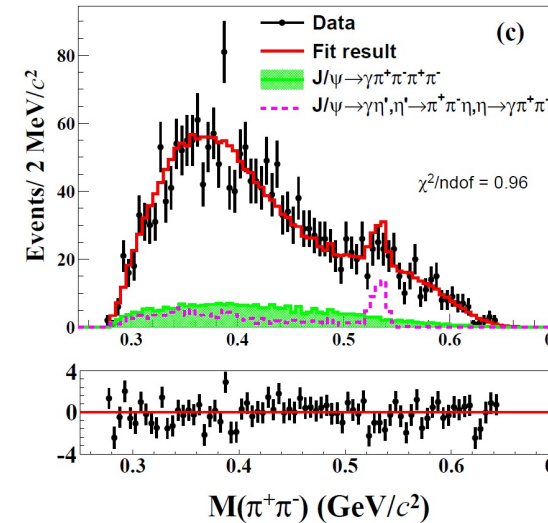
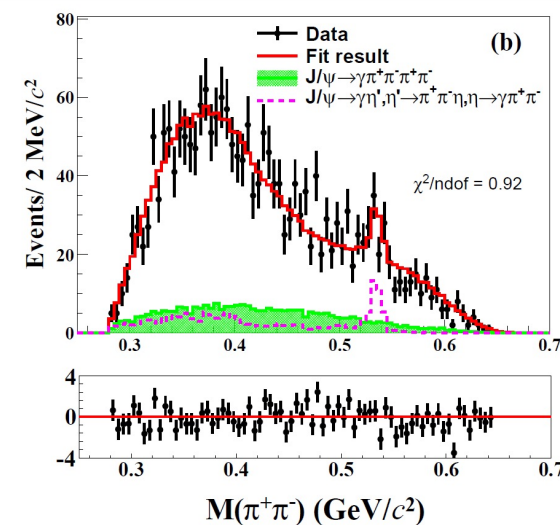
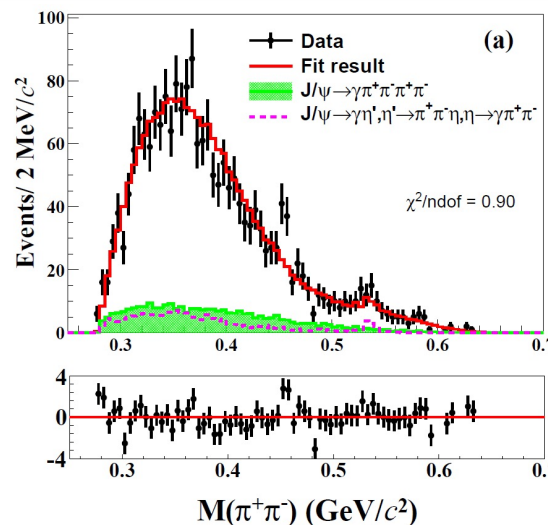
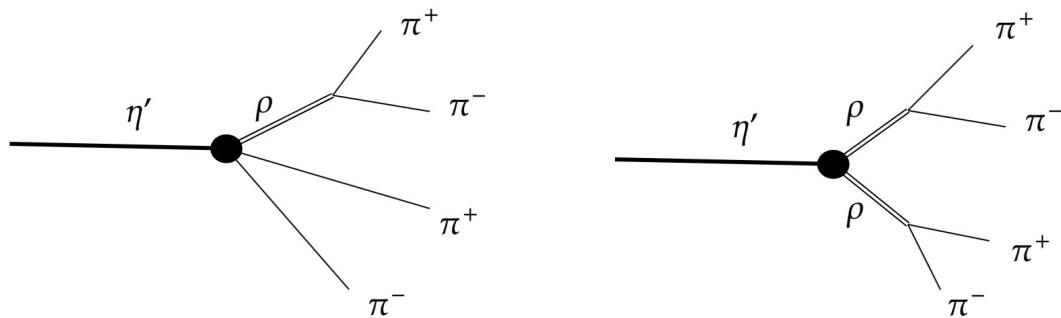
Amplitude analysis results

- The decay amplitude based on the ChPT and VMD model

$$\mathcal{A}(\eta' \rightarrow \pi^+ \pi^- \pi^+ \pi^-) = \epsilon_{\mu\nu\alpha\beta} p_1^\mu p_2^\nu p_3^\alpha p_4^\beta$$

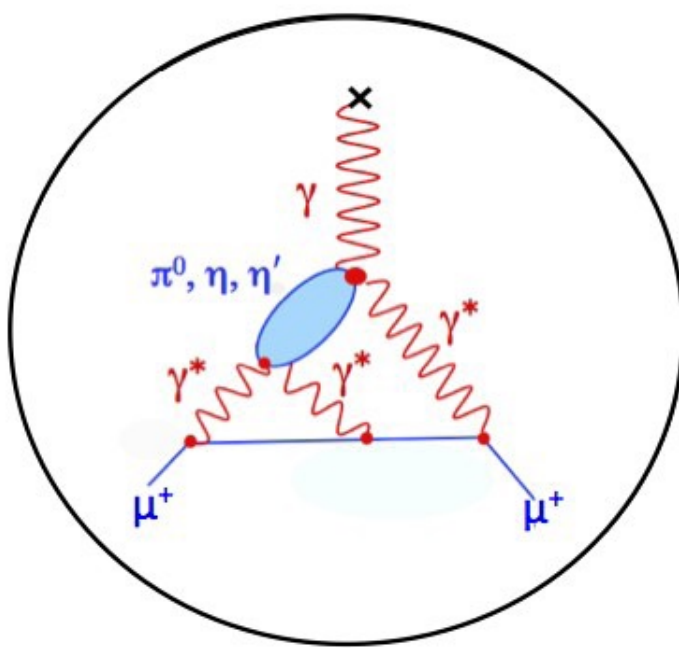
$$\times \left\{ \left[\frac{s_{12}}{D_\rho(s_{12})} + \frac{s_{34}}{D_\rho(s_{34})} - \frac{s_{14}}{D_\rho(s_{14})} - \frac{s_{23}}{D_\rho(s_{23})} \right] \right.$$

$$\left. + \alpha \left[\frac{M_\rho^2(s_{12} + s_{34})}{D_\rho(s_{12})D_\rho(s_{34})} - \frac{M_\rho^2(s_{14} + s_{23})}{D_\rho(s_{14})D_\rho(s_{23})} \right] \right\}$$



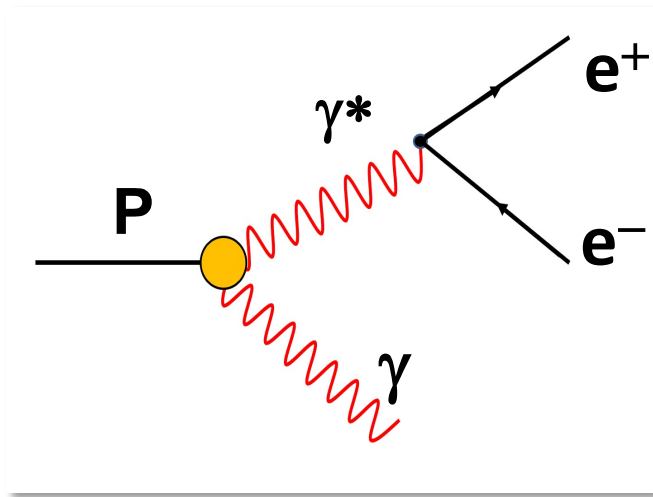
$\alpha = 1.22 \pm 0.33 \pm 0.04$, consistent with the theoretical expectation

TFFs as experimental input @ BESIII

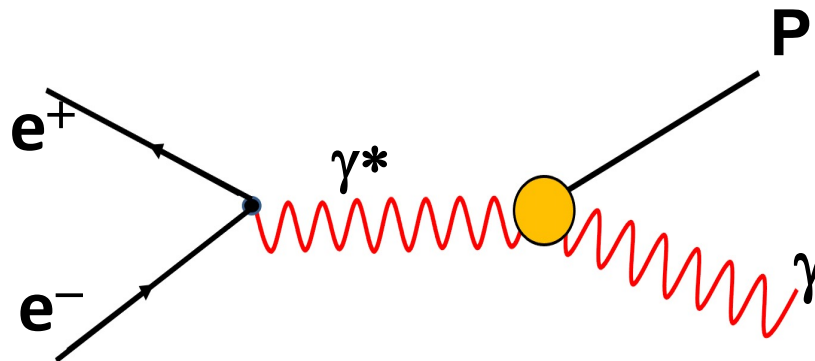


HLbL contributions

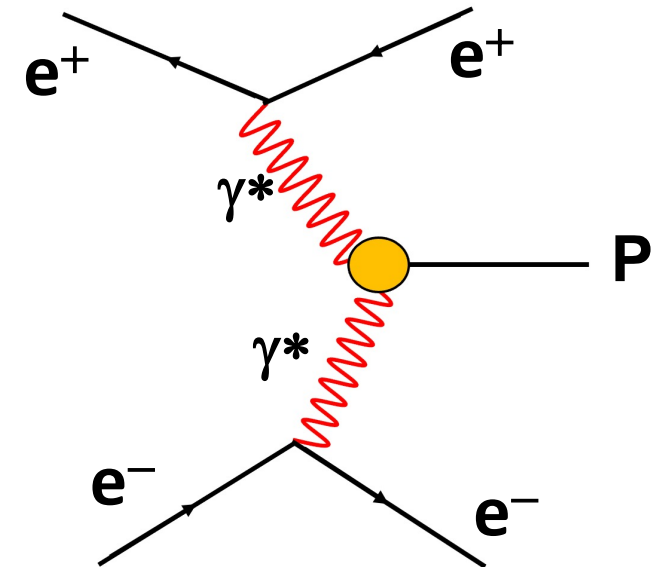
Pseudoscalar TFFs are experimentally accessible in three different processes



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

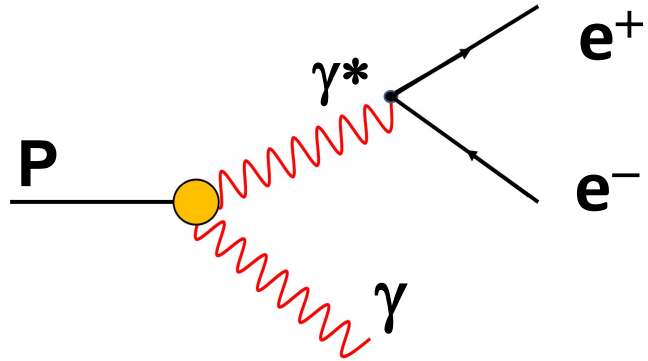


Annihilation process $q^2 = s > M^2$



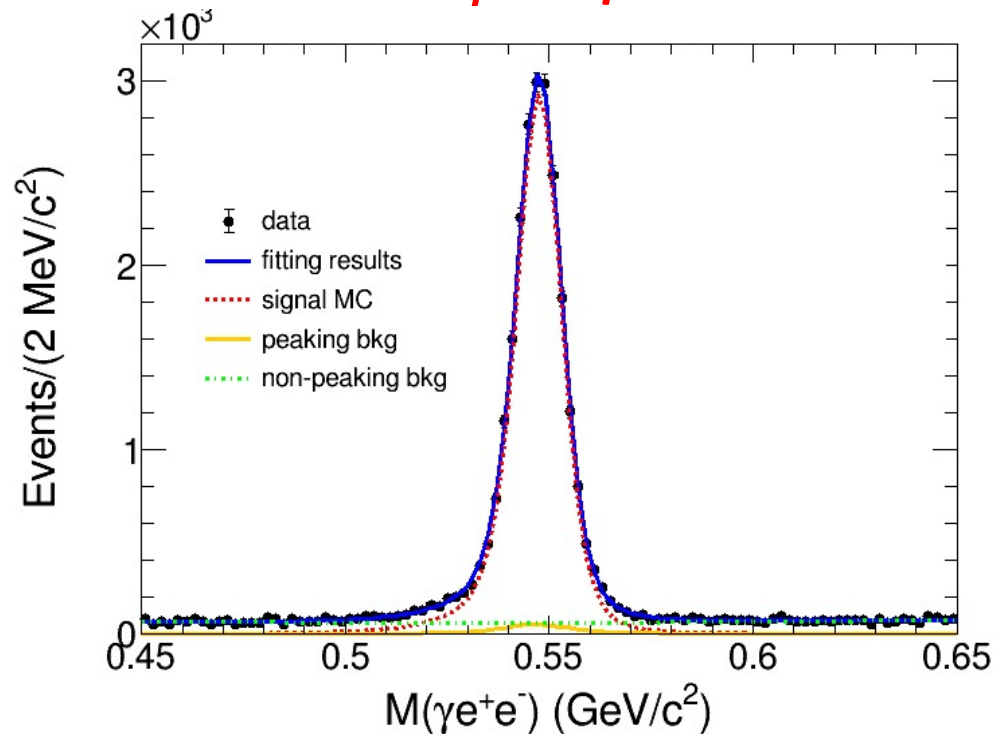
Two photon process

Transition Form Factors in $\eta/\eta' \rightarrow \gamma e^+ e^-$ PRD 109, 072001 (2024)

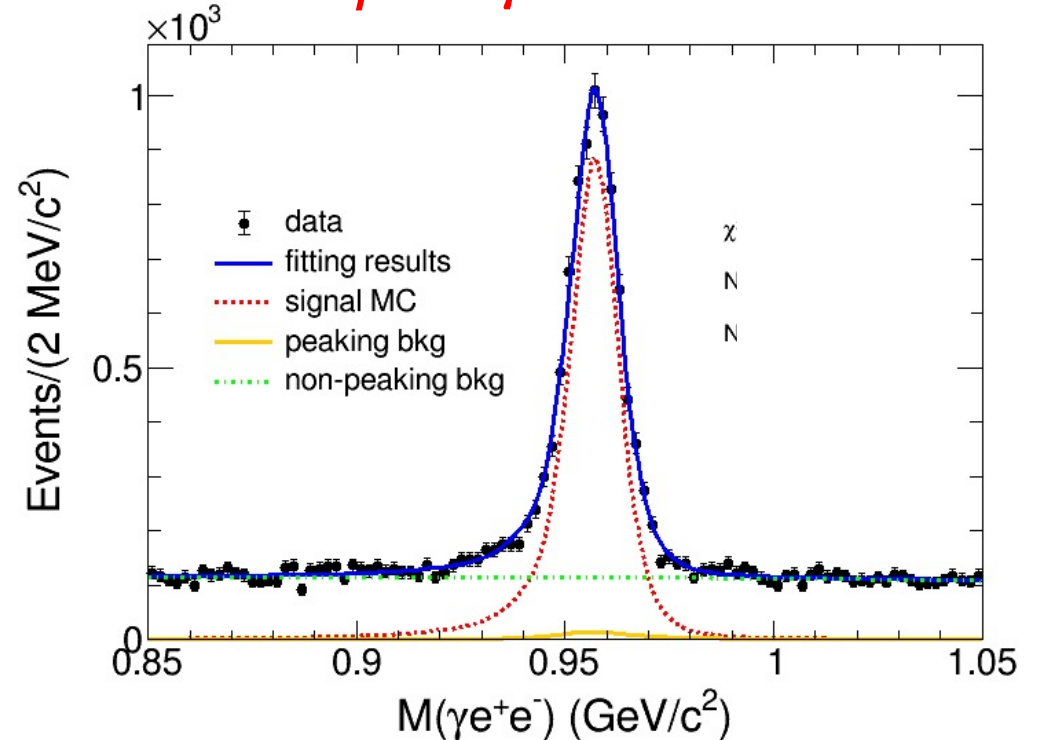


$$\frac{d\Gamma(P \rightarrow \ell^+ \ell^- \gamma)}{dq^2 \Gamma_{\gamma\gamma}} = \frac{2\alpha}{3\pi} \frac{1}{q^2} \sqrt{1 - \frac{4m_\ell^2}{q^2}} \left(1 + \frac{2m_\ell^2}{q^2}\right) \left(1 - \frac{q^2}{M_P^2}\right)^3 |F_P(q^2, 0)|^2$$

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



$\eta' \rightarrow \gamma e^+ e^-$

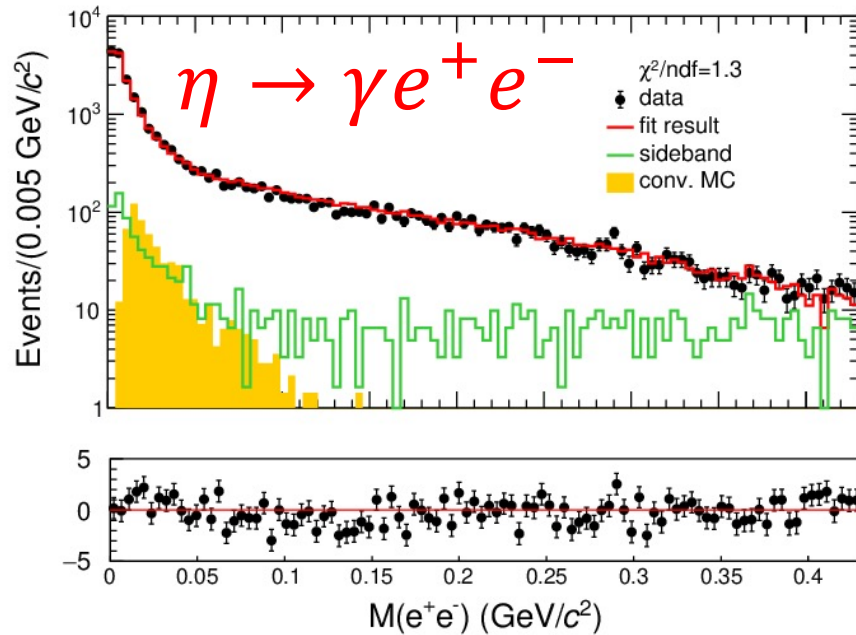


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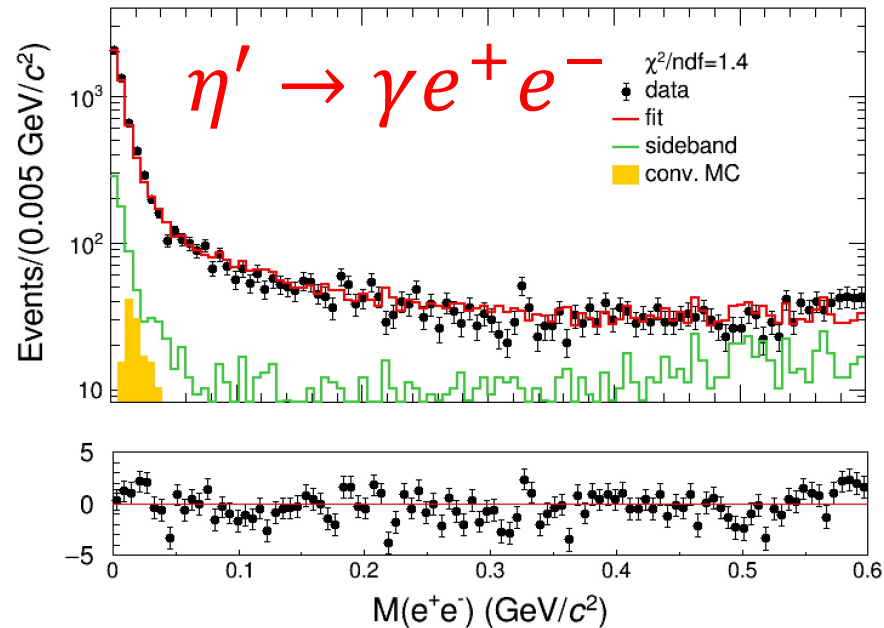
HEPdata: <https://www.hepdata.net/record/ins2747714>

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

$$b_P = \left. \frac{d \ln |F_P(q^2)|}{dq^2} \right|_{q^2=0}$$

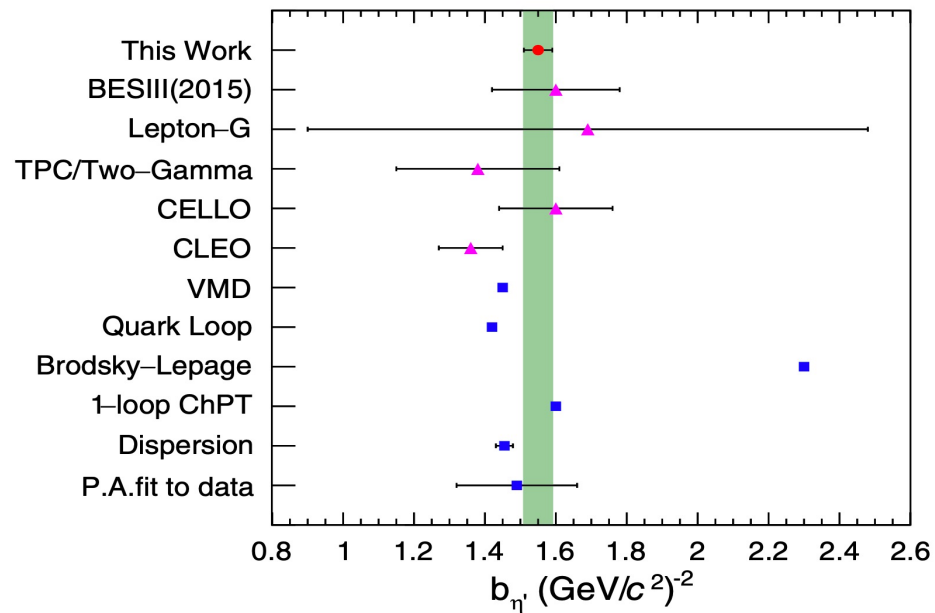
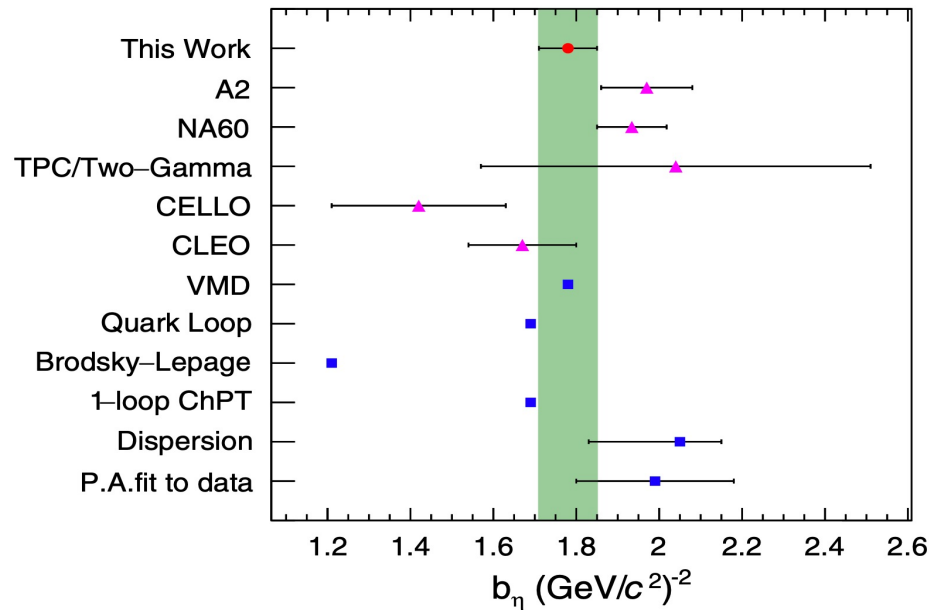


$$b_\eta = (1.78 \pm 0.12(\text{stat})) (\text{GeV}/c^2)^{-2}$$



$$b_{\eta'} = (1.57 \pm 0.05(\text{stat})) (\text{GeV}/c^2)^{-2}$$

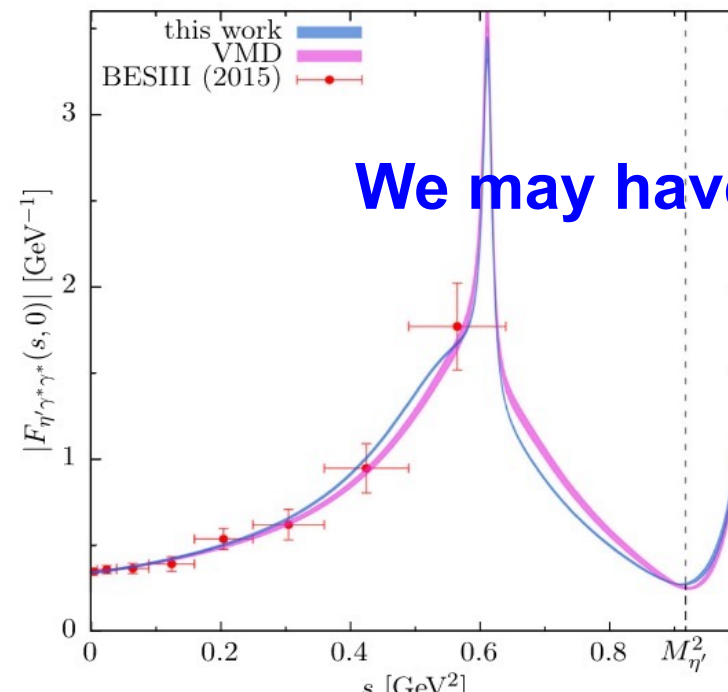
Comparisons



New parameterization ?

$$F_{P\gamma^*\gamma^*}(s, 0) = F_{P\gamma\gamma} + \left[1 + \frac{\epsilon_{\rho\omega} s}{M_\omega^2 - s - i M_\omega \Gamma_\omega} \right] \times \frac{s}{48\pi^2} \int_{4M_\pi^2}^\infty ds' \frac{\sigma_\pi^3(s') P(s') |F_\pi^V(s')|^2}{s' - s - i\epsilon} + \frac{F_{P\gamma\gamma} w_{P\omega\gamma} s}{M_\omega^2 - s - i M_\omega \Gamma_\omega} \left[1 + \frac{\epsilon_{\rho\omega} s}{48\pi^2 g_{\omega\gamma}^2} \times \int_{4M_\pi^2}^\infty ds' \frac{\sigma_\pi^3(s') |F_\pi^V(s')|^2}{s'(s' - s - i\epsilon)} \right] + \frac{F_{P\gamma\gamma} w_{P\phi\gamma} s}{M_\phi^2 - s - i M_\phi \Gamma_\phi},$$

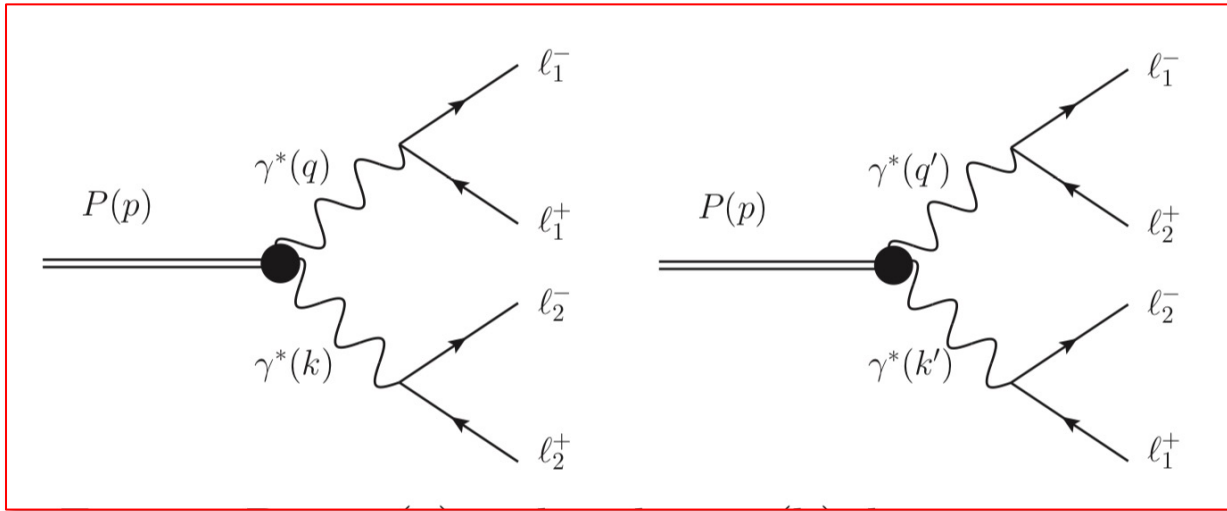
(EPJC 82,434(2022))



We may have a fit to data ?

Observation of $\eta' \rightarrow e^+e^-e^+e^-$

Chinese Physics C42 (2018) 023109

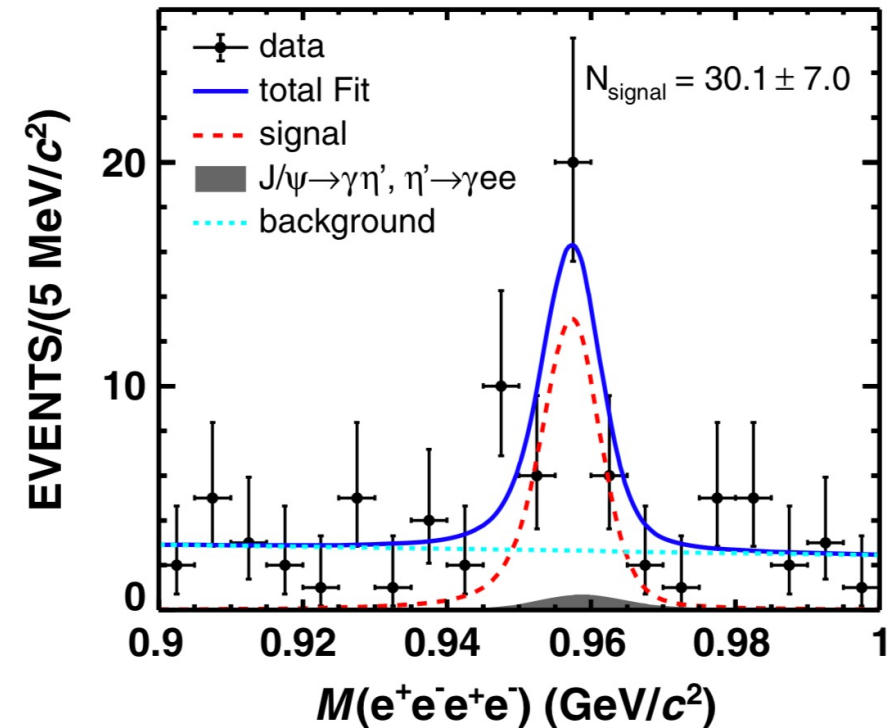


$$\begin{aligned}\eta' &\rightarrow e^+e^-e^+e^- & 2.10(45) \times 10^{-6} \\ \eta' &\rightarrow \mu^+\mu^-\mu^+\mu^- & 1.69(36) \times 10^{-8} \\ \eta' &\rightarrow e^+e^-\mu^+\mu^- & 6.39(91) \times 10^{-7}\end{aligned}$$

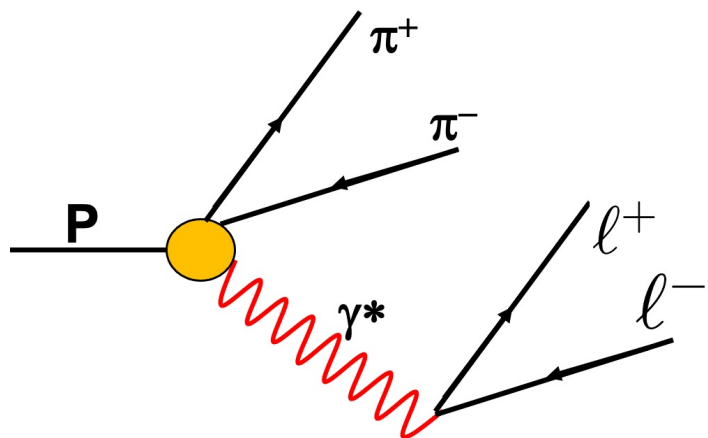
- Test the theoretical models
- Form factors $\rightarrow (g-2)_\mu$
- No experimental evidence yet!

$$B(\eta' \rightarrow e^+e^-e^+e^-) = (4.5 \pm 1.0 \pm 0.5) \times 10^{-6}$$

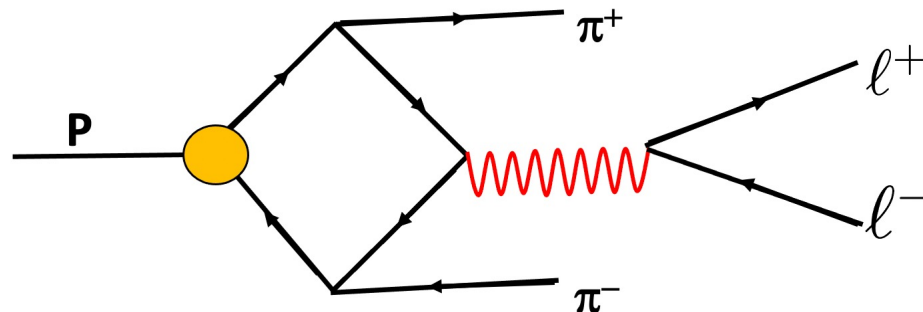
PRD 105, 112010 (2022)



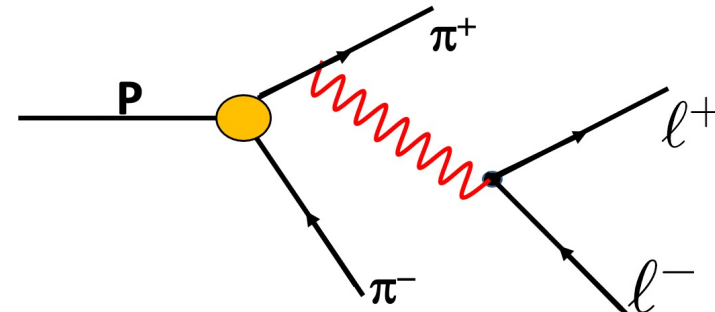
Updated results on $\eta' \rightarrow \pi^+ \pi^- l^+ l^-$ JHEP07 (2024) 135



VMD

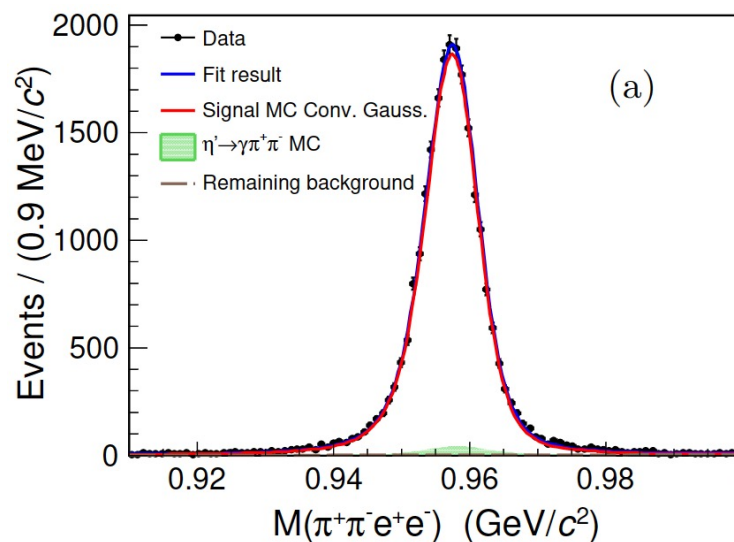


Box-anomaly

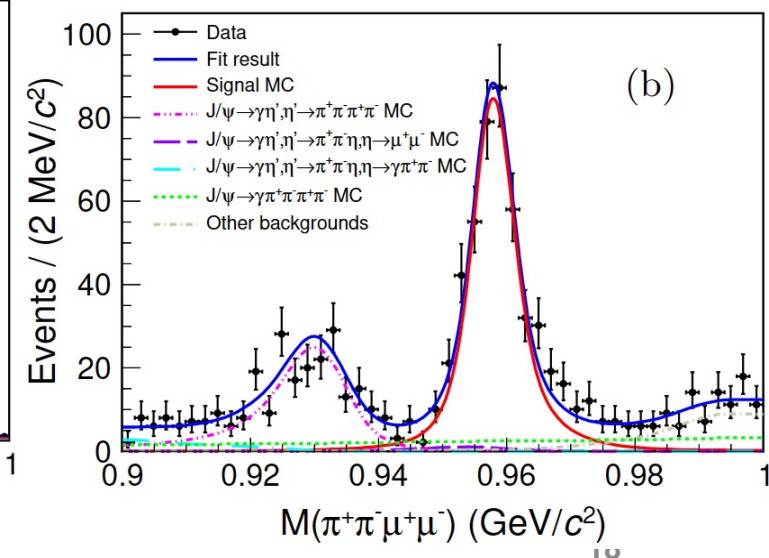


CP violation

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



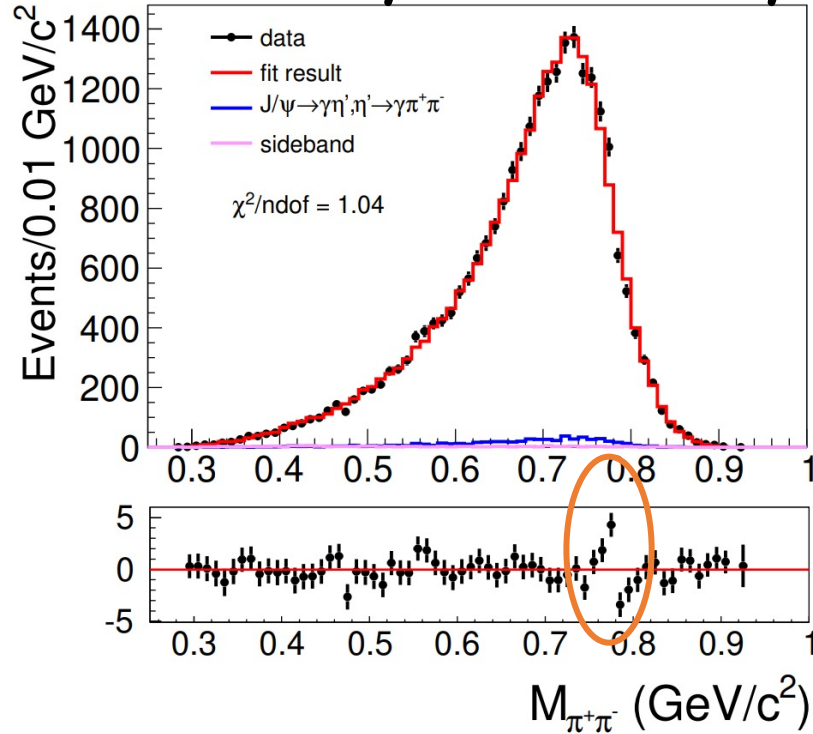
$\eta' \rightarrow \pi^+ \pi^- \mu^+ \mu^-$



	$\mathcal{B}(\eta' \rightarrow \pi^+ \pi^- e^+ e^-)$ (10^{-3})	$\mathcal{B}(\eta' \rightarrow \pi^+ \pi^- \mu^+ \mu^-)$ (10^{-5})
Hidden gauge*	2.17 ± 0.21	2.20 ± 0.30
Unitary χ PT*	$2.13^{+0.17}_{-0.31}$	$1.57^{+0.96}_{-0.75}$
VMD*	2.27 ± 0.13	2.41 ± 0.25
BESIII (2013) $^\diamond$	$2.11 \pm 0.12 \pm 0.15$	< 2.9
BESIII (2021) $^\diamond$	$2.42 \pm 0.05 \pm 0.08$	$1.97 \pm 0.33 \pm 0.19$
CLEO $^\diamond$	$2.50^{+1.2}_{-0.9} \pm 0.5$	< 24

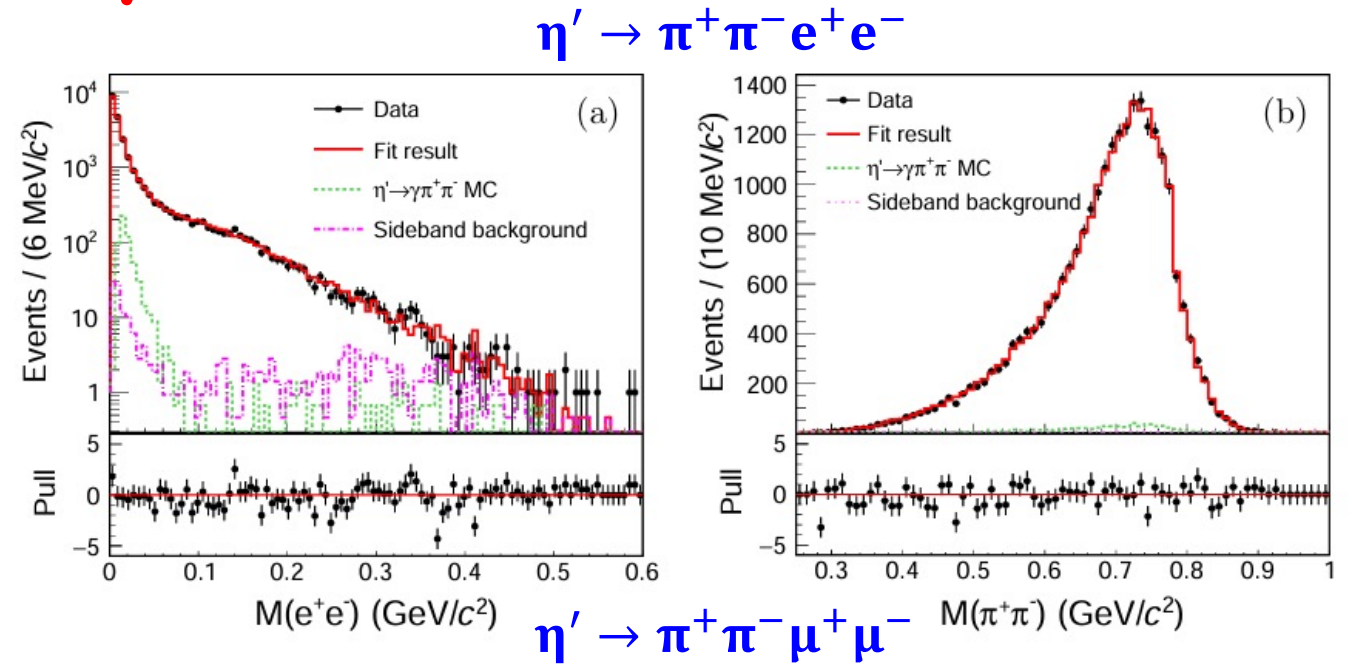
Amplitude analysis results

- ✓ ρ^0 only can not describe data
- ✓ $\omega \rightarrow \pi^+ \pi^-$ decay is necessary!



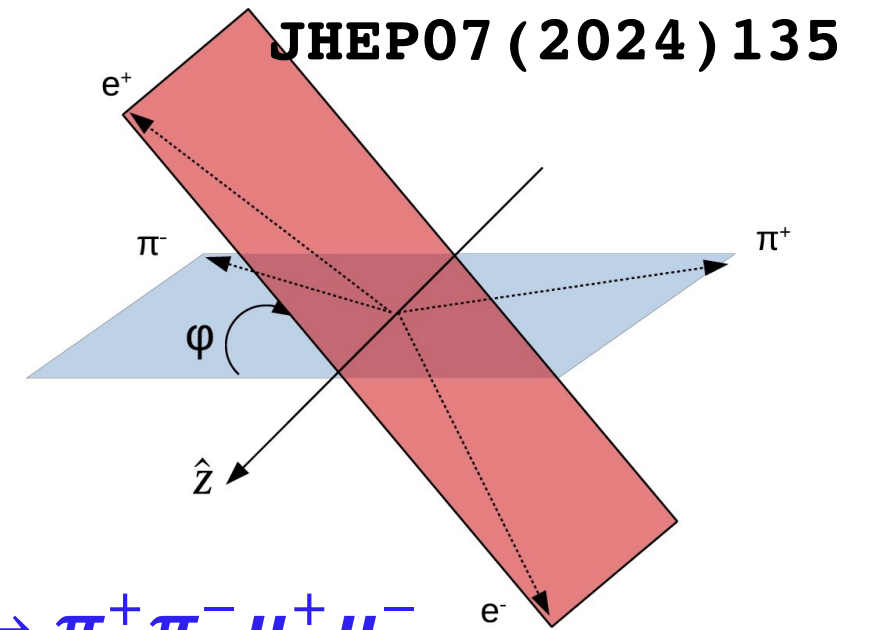
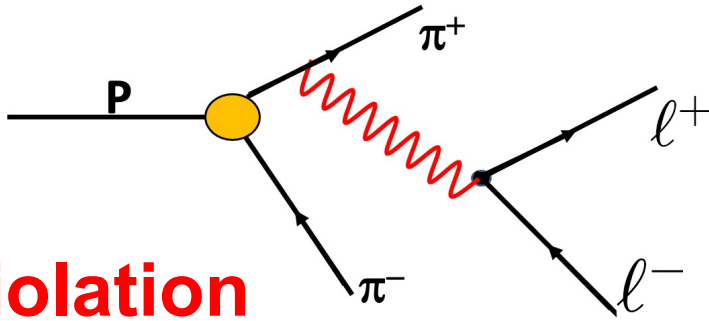
- First time to measure form factors with $\eta' \rightarrow \pi^+ \pi^- l^+ l^-$

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

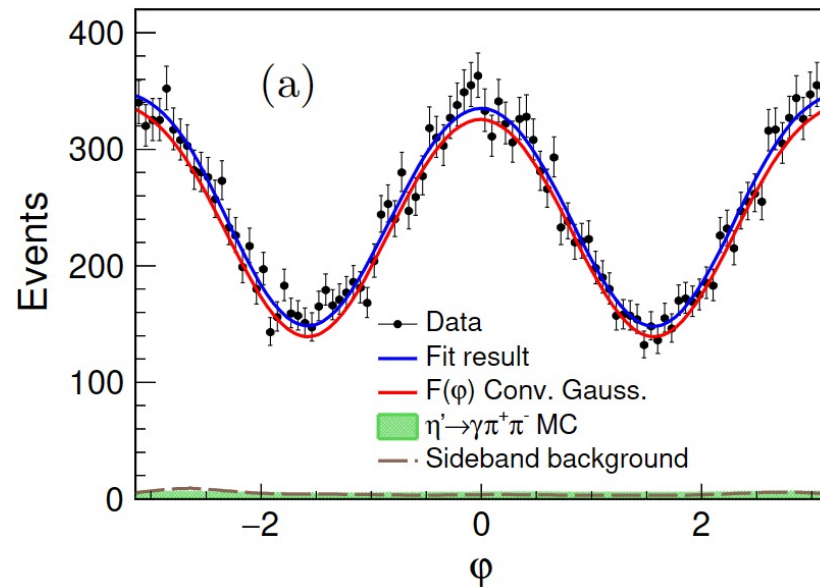


Search for CP Asymmetry

CP violation

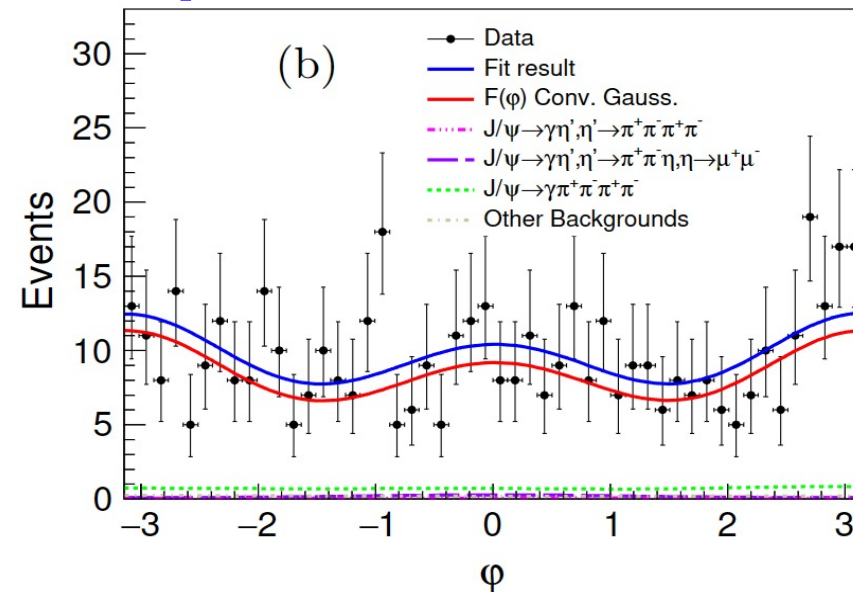


$$\eta' \rightarrow \pi^+ \pi^- e^+ e^-$$



$$\mathcal{A}_{CP} = (-0.21 \pm 0.73(stat))\%.$$

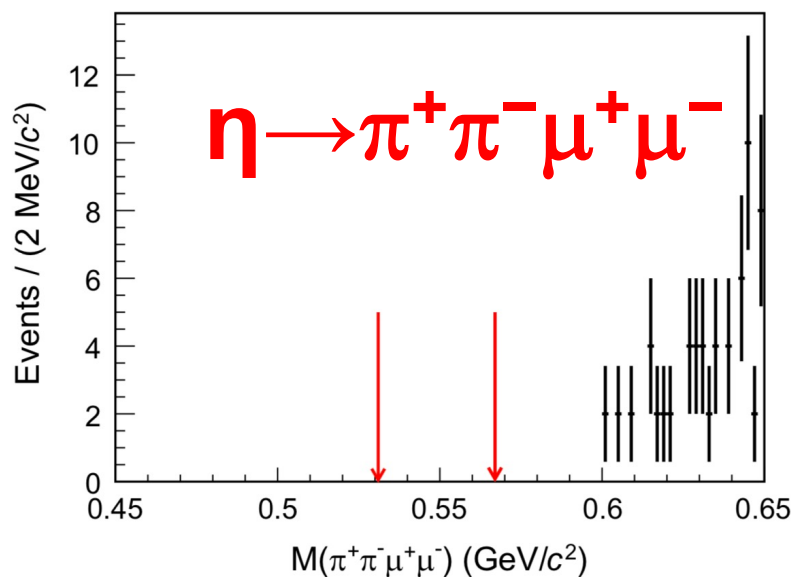
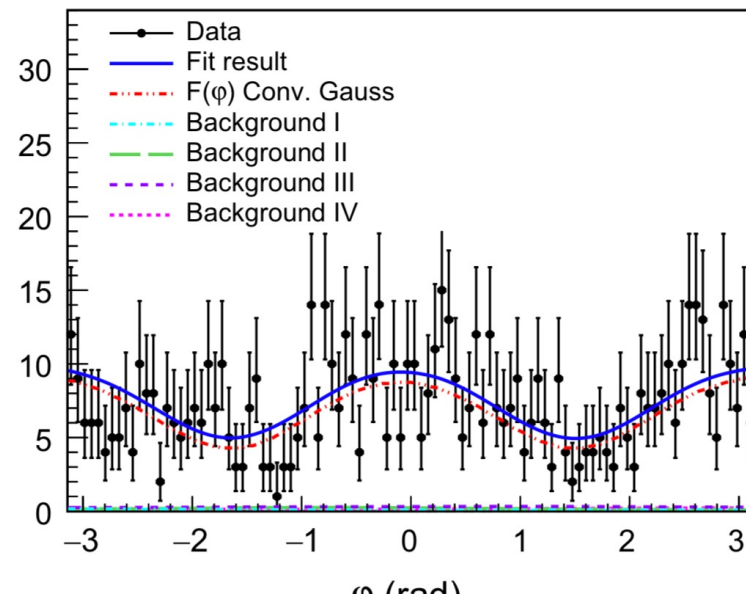
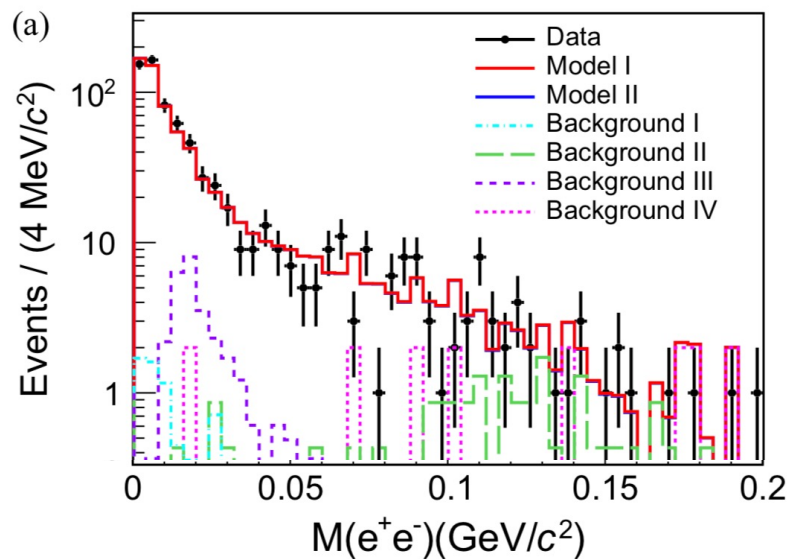
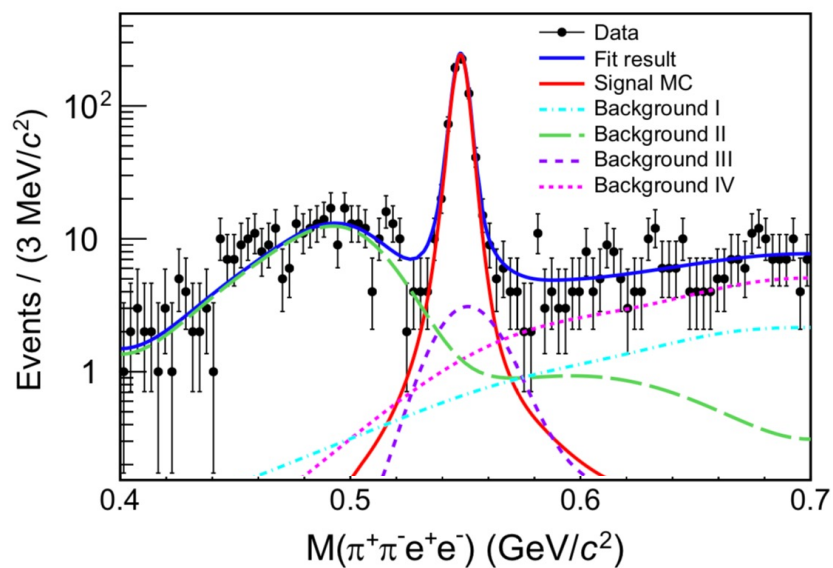
$$\eta' \rightarrow \pi^+ \pi^- \mu^+ \mu^-$$



$$(0.62 \pm 4.71(stat))\%$$

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

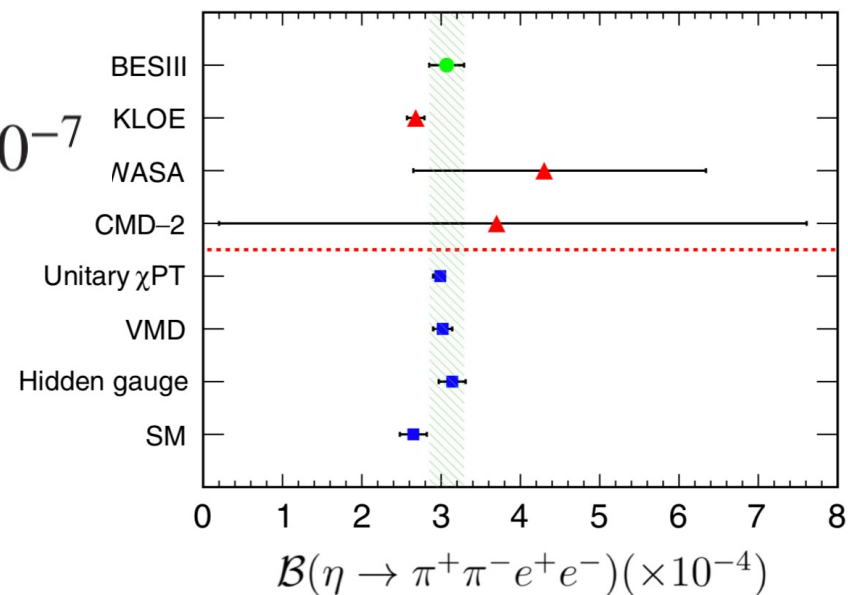
$$\mathcal{A}_{CP}(\eta \rightarrow \pi^+ \pi^- e^+ e^-) = (-4.04 \pm 4.69)\%$$



$$\mathcal{B}(\eta \rightarrow \pi^+ \pi^- \mu^+ \mu^-) < 4.0 \times 10^{-7}$$

PDG2024: 3.6×10^{-4}

PRD 111, 072008 (2025)



New decay mechanisms

Precision study of $\eta' \rightarrow \gamma \pi^+ \pi^-$

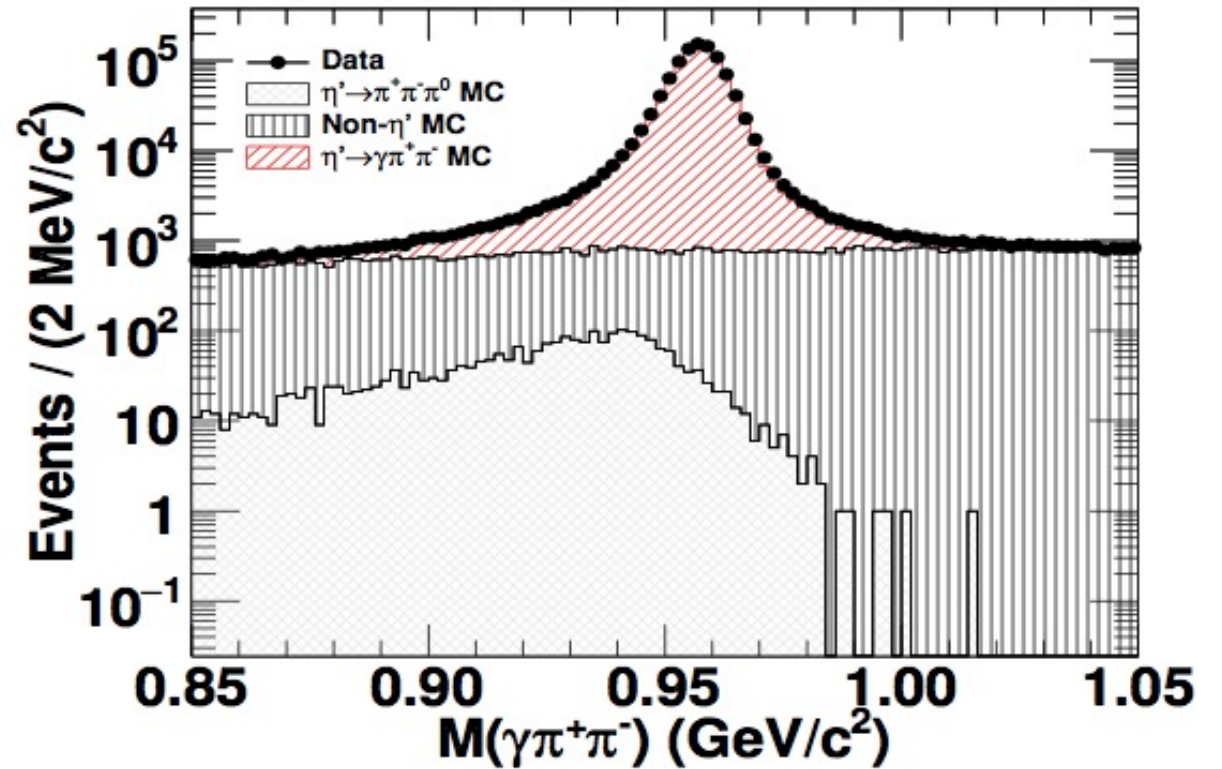
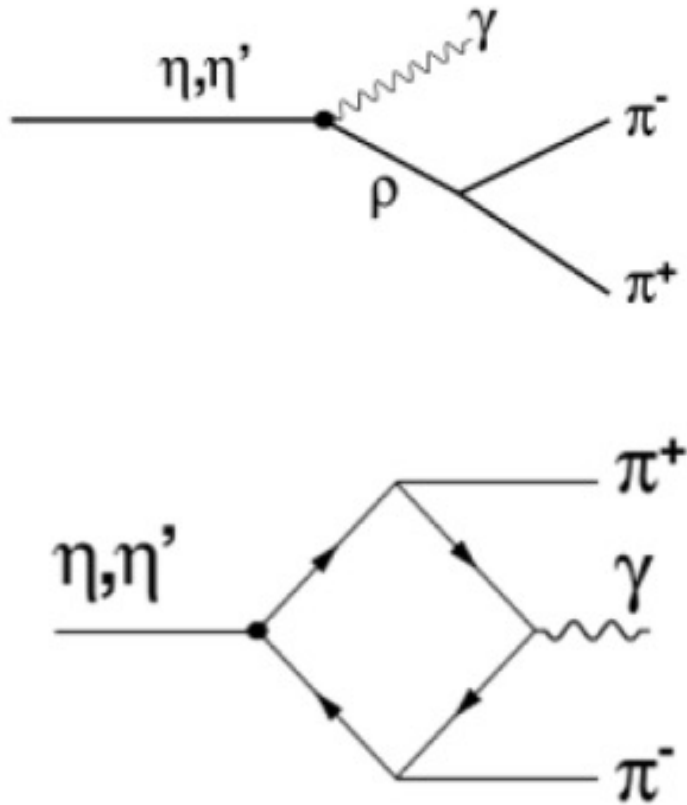
PRL120, 242003(2018)

Cusp effect in $\eta' \rightarrow \pi^0 \pi^0 \eta$

PRL130, 081901(2023)

$\eta' \rightarrow \gamma \pi^+ \pi^-$ decay dynamics

$\sim 0.9M$ events



high term of ChPT $\rightarrow$ box anomaly

PRL120,242003(2018)

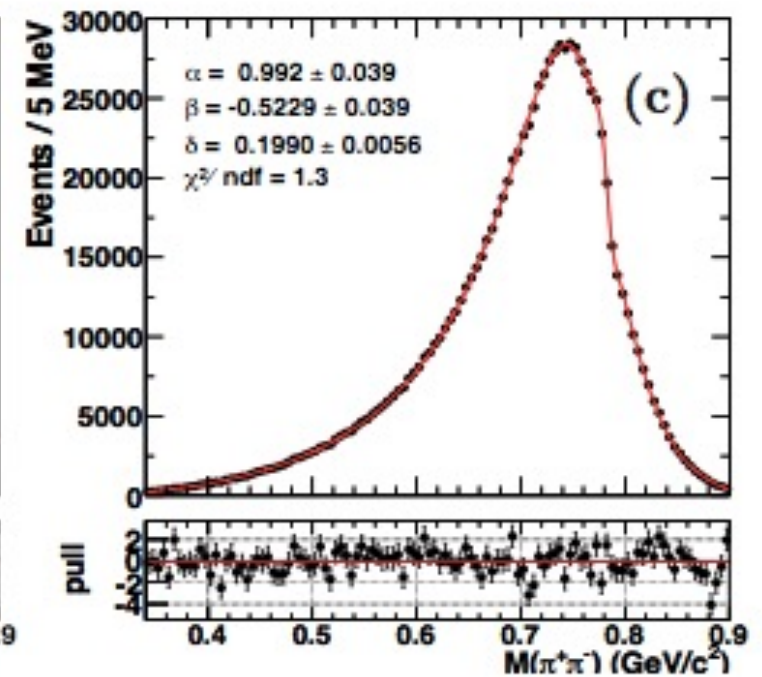
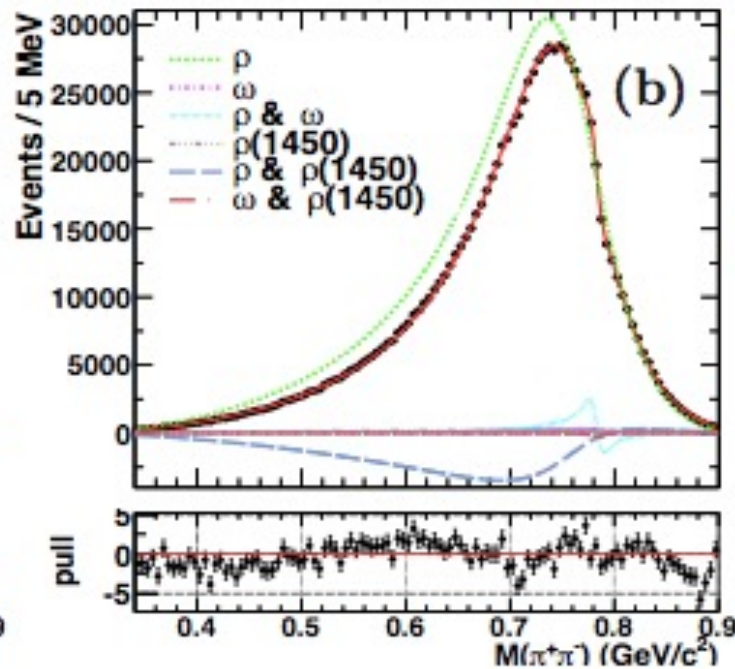
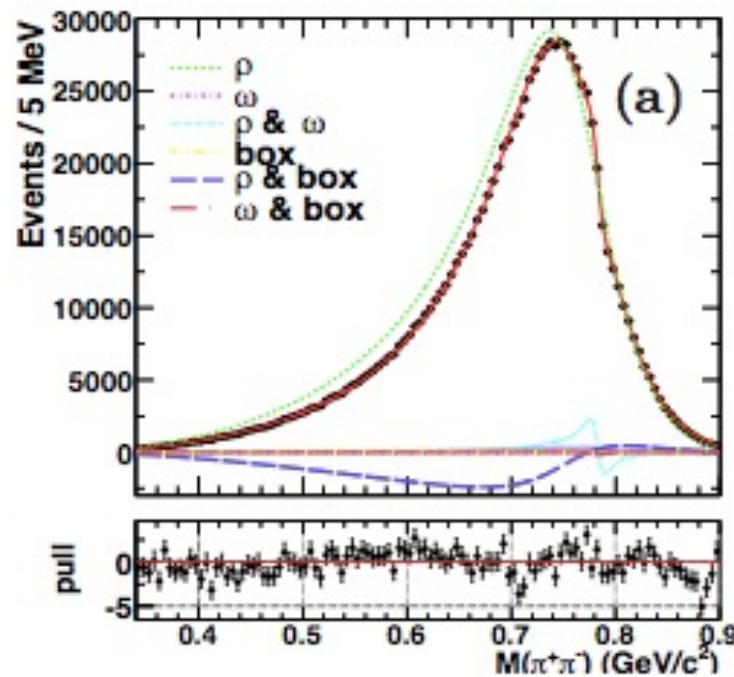
HEPData: <https://www.hepdata.net/record/ins1641075>

Model-(in)dependent fit

$\rho(770)$ - ω -box anomaly

$\rho(770)$ - ω - $\rho(1450)$

$$P(s_{\pi\pi}) = 1 + \alpha s_{\pi\pi} + \beta 0(s_{\pi\pi}^2) + \delta$$



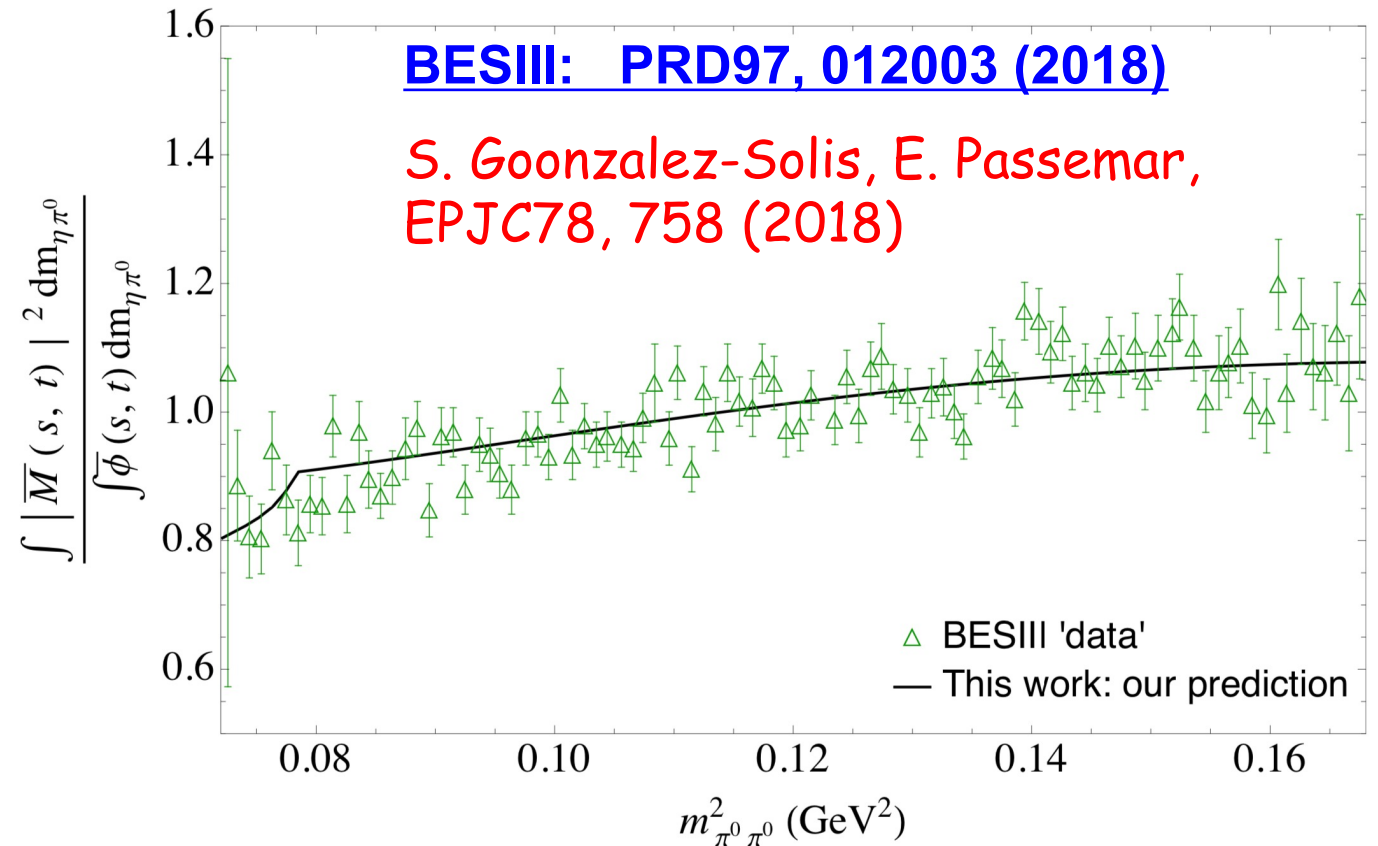
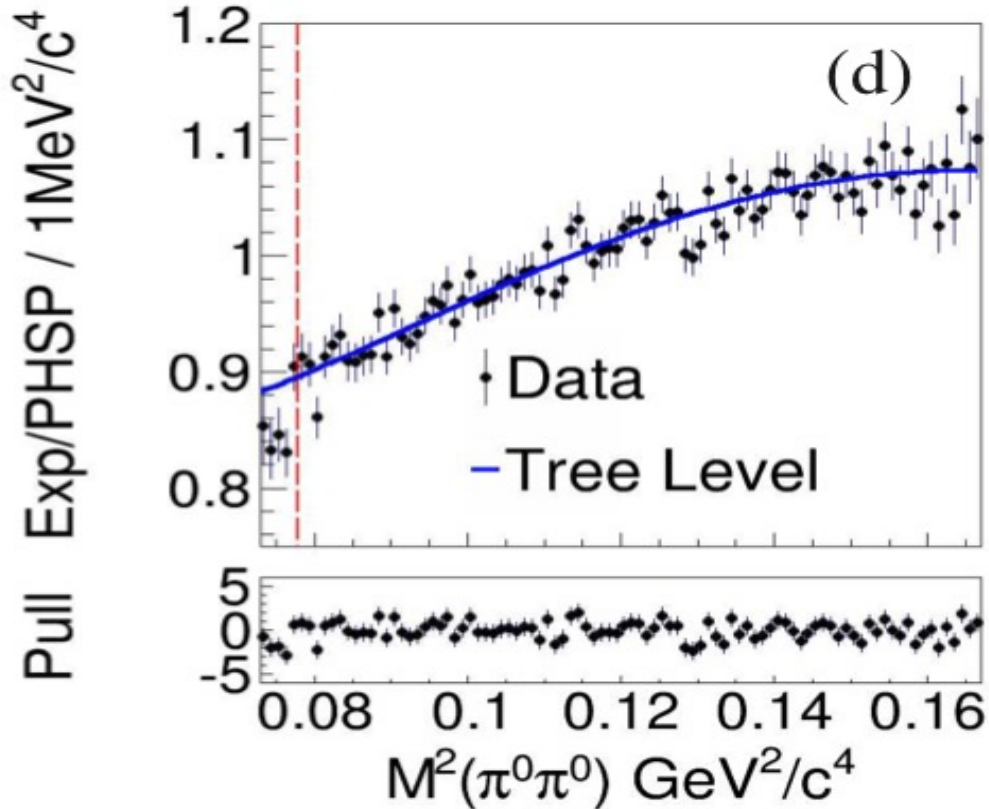
- ✓ $\rho(770)$ - ω cannot describe data well
- ✓ Extra contribution (maybe $\rho(1450)$ or box-anomaly) is also necessary

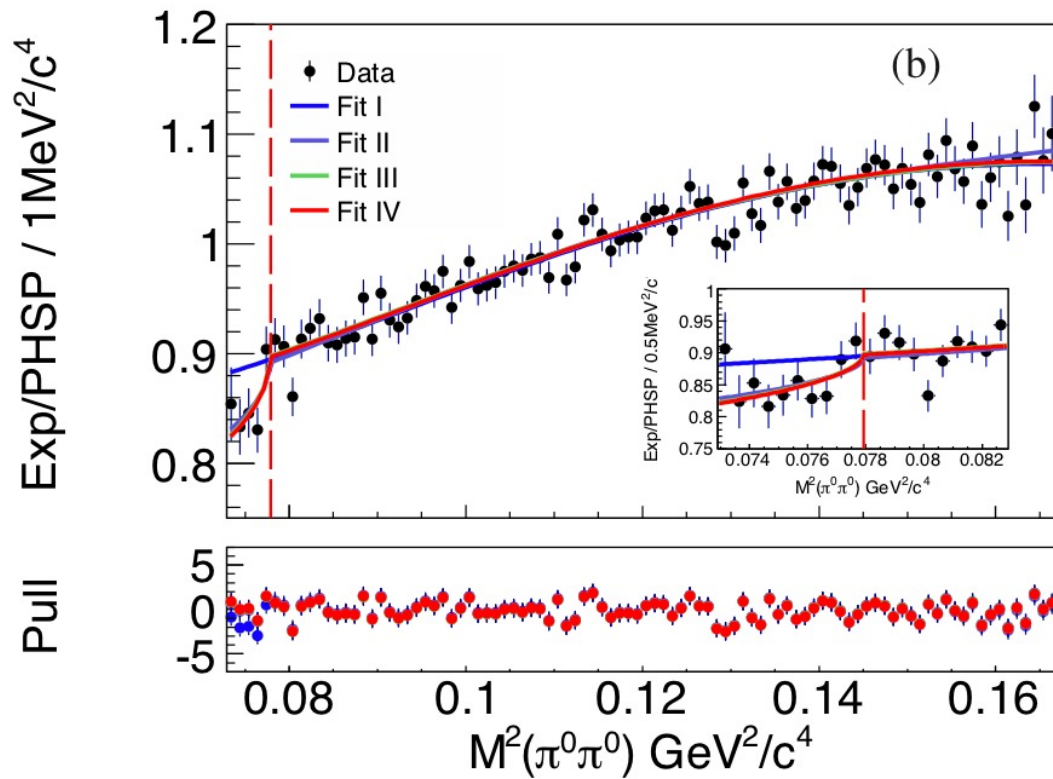
Analyses of $\eta/\eta' \rightarrow \gamma\pi^+\pi^-$ with 10 billion J/ψ are in progress !

Evidence of the cusp effect in $\eta' \rightarrow \pi^0 \pi^0 \eta$

PRL130,081901(2023)

- Investigation on $\pi\pi$ and $\pi\eta$ final interactions
- The cusp effect is sizeable in this decay





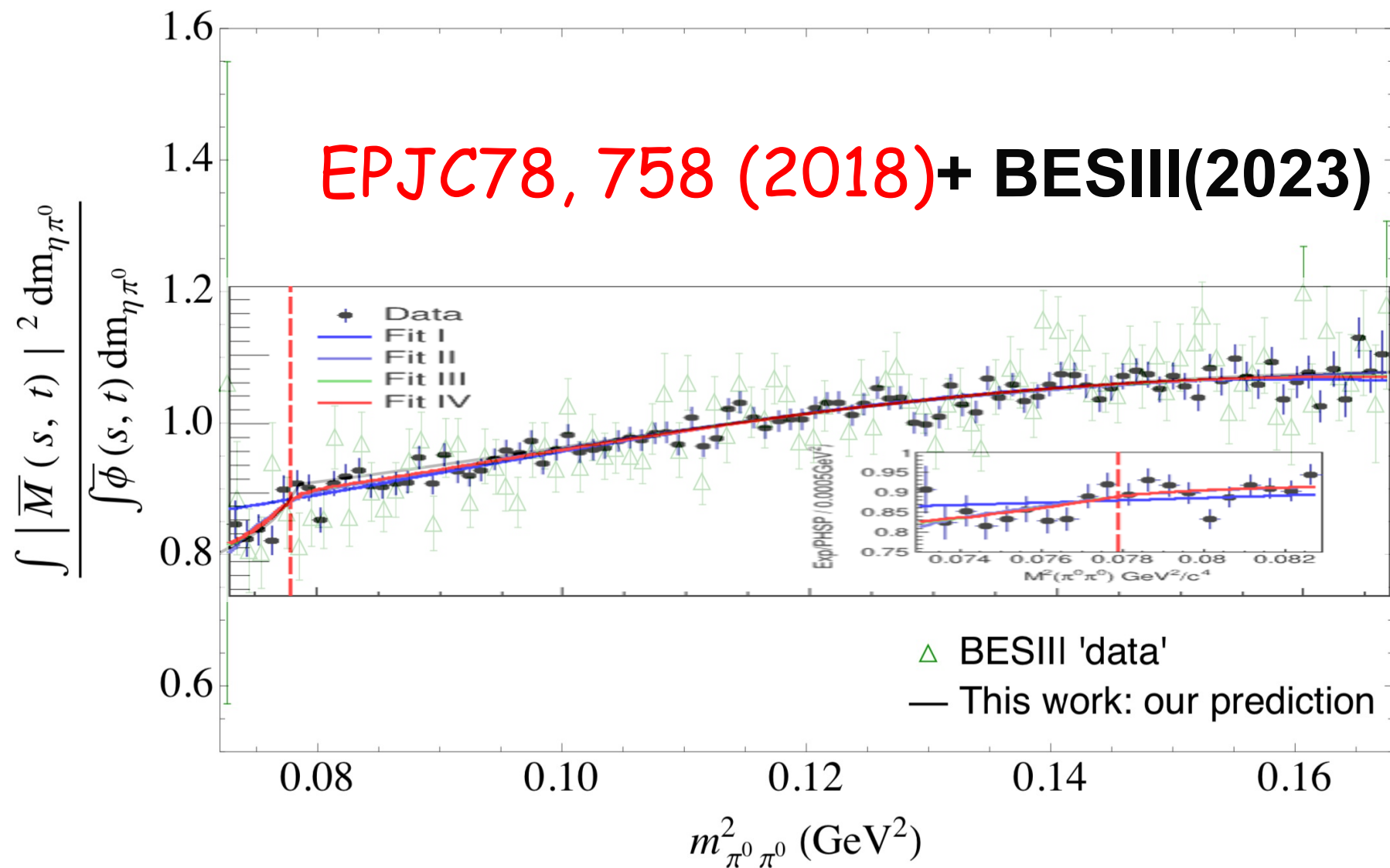
■ Non-relativistic effective field theory

B. Kubis and S. P. Schneider, EPJC 62, 511 (2009)

■ Fits at different cases

■ Evidence of the cusp effect @ 3.5σ !

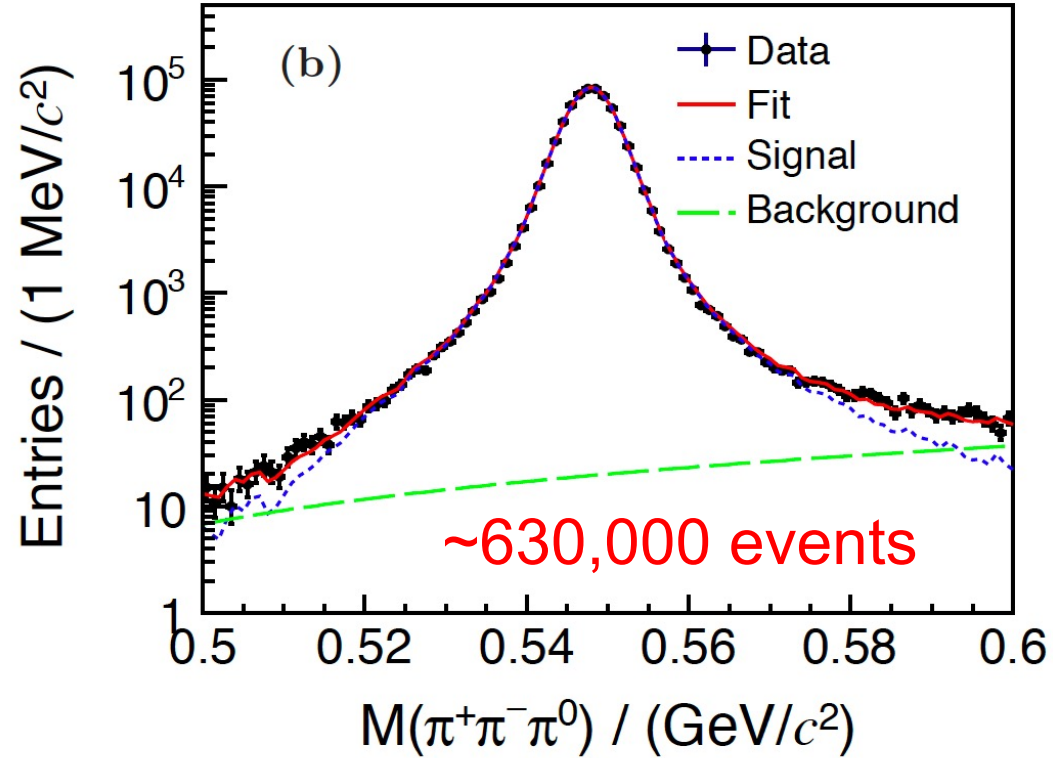
Parameters	Fit I	Fit II	Fit III	Fit IV
a	$-0.075 \pm 0.003 \pm 0.001$	-0.207 ± 0.013	-0.143 ± 0.010	$-0.077 \pm 0.003 \pm 0.001$
b	$-0.073 \pm 0.005 \pm 0.001$	-0.051 ± 0.014	-0.038 ± 0.006	$-0.066 \pm 0.006 \pm 0.001$
d	$-0.066 \pm 0.003 \pm 0.001$	-0.068 ± 0.004	-0.067 ± 0.003	$-0.068 \pm 0.004 \pm 0.001$
$a_0 - a_2$	-	0.174 ± 0.066	0.225 ± 0.062	$0.226 \pm 0.060 \pm 0.012$
a_0	-	0.497 ± 0.094	-	-
a_2	-	0.322 ± 0.129	-	-
Statistical Significance	-	3.4σ	3.7σ	3.6σ



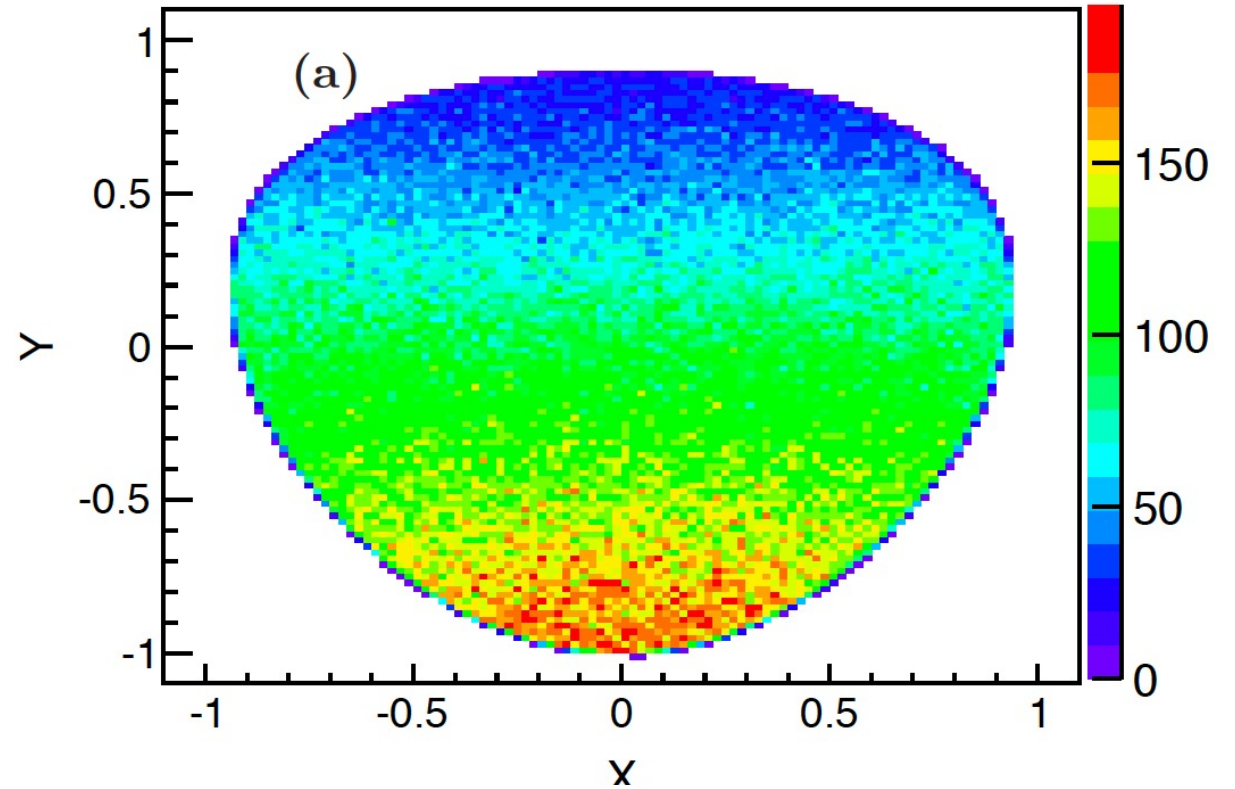
Determination of the **light quark mass ratio** using $\eta' \rightarrow \eta\pi\pi$ decays?

A. Guevara, FK Guo, HJ Jing arXiv: [2502.02837](https://arxiv.org/abs/2502.02837)

Updated results on $\eta \rightarrow \pi^+\pi^-\pi^0$, $\eta \rightarrow \pi^0\pi^0\pi^0$



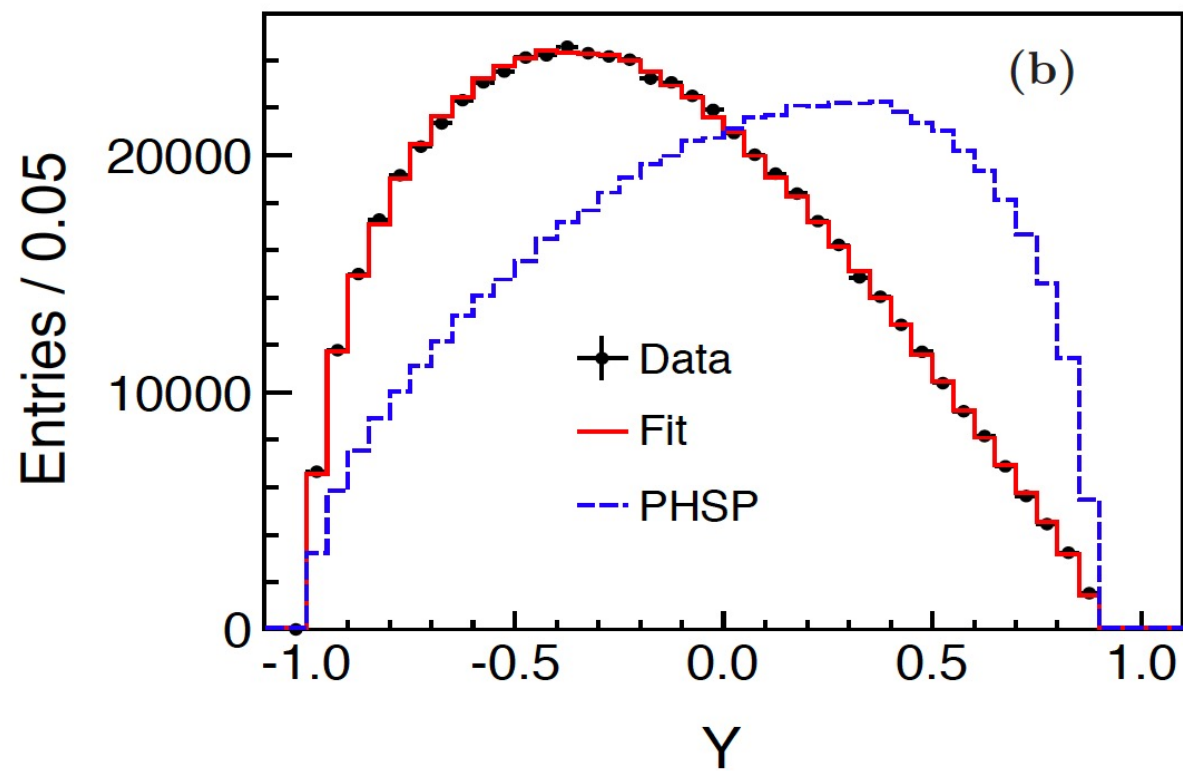
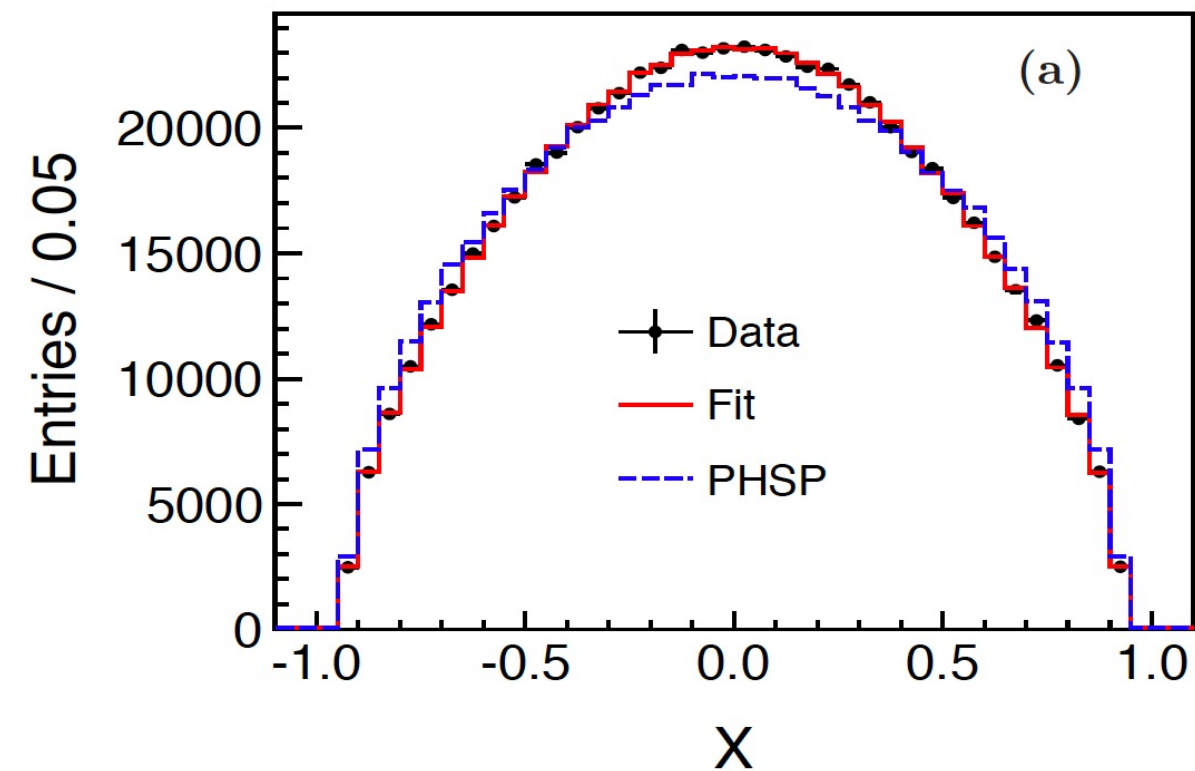
PRD107,092007(2023)



$$X = \frac{\sqrt{3}}{Q_\eta} (T_{\pi^+} - T_{\pi^-}), \quad Y = \frac{3T_{\pi^0}}{Q_\eta} - 1$$

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

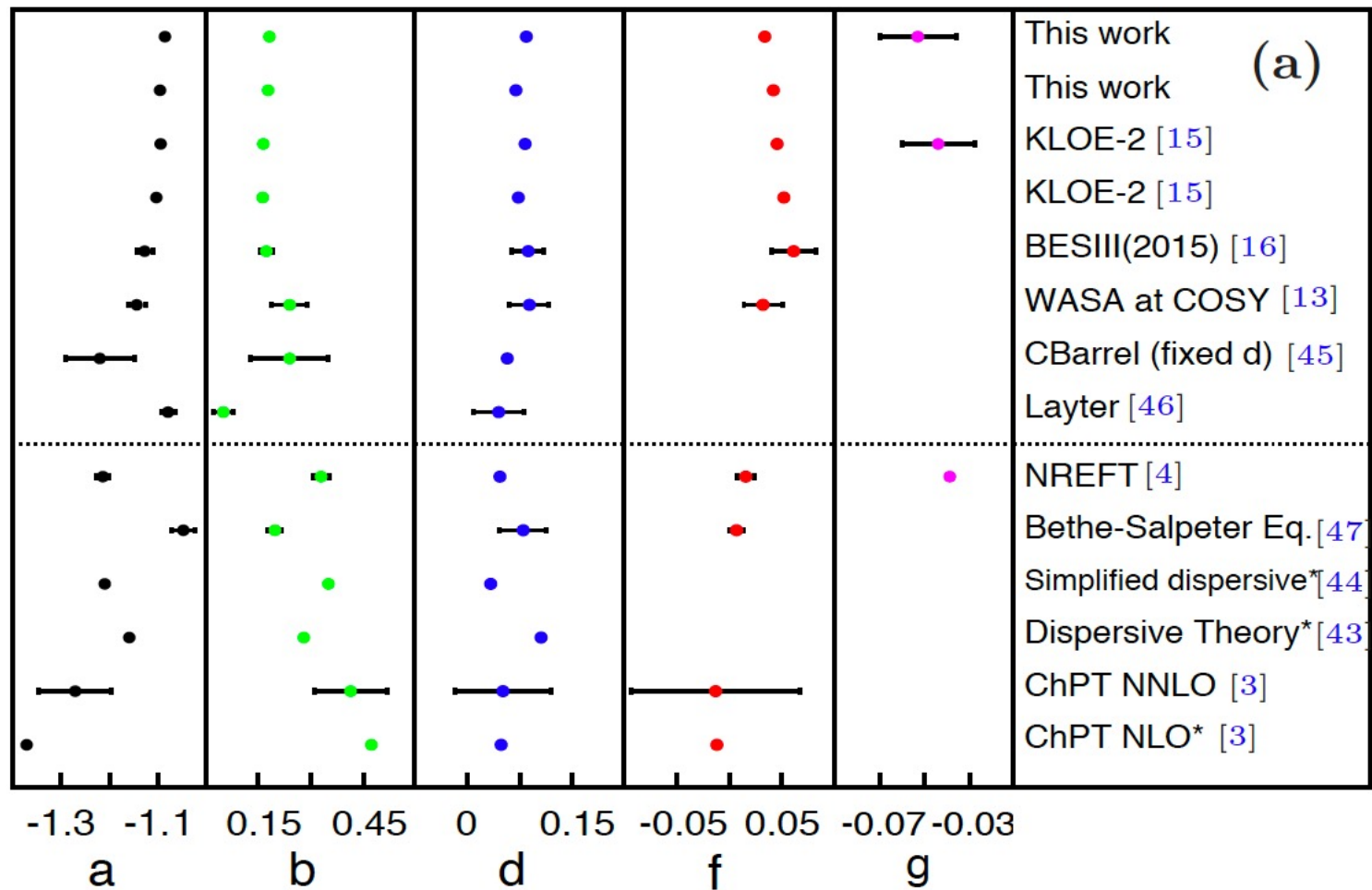
$$|A(X, Y)|^2 \propto 1 + aY + bY^2 + cX + dX^2 + eXY + fY^3 + gX^2Y + \dots$$



Comparison to experimental and theoretical results

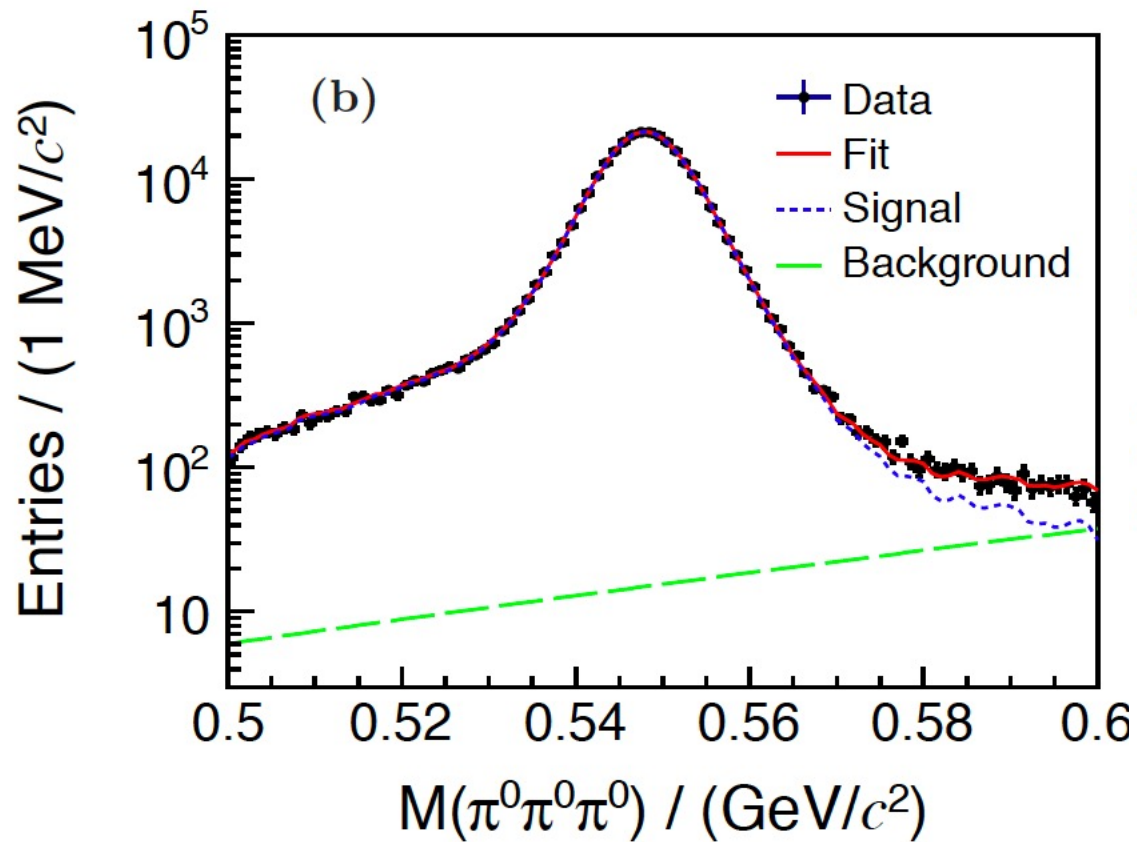
a	$=$	-1.097	$\pm$	0.005	$\pm$	0.001
b	$=$	0.158	$\pm$	0.006	$\pm$	0.003
d	$=$	0.070	$\pm$	0.006	$\pm$	0.001
f	$=$	0.134	$\pm$	0.010	$\pm$	0.003

$$\begin{aligned} a &= -1.086 \pm 0.006 \pm 0.001 \\ b &= 0.162 \pm 0.006 \pm 0.003 \\ d &= 0.083 \pm 0.007 \pm 0.001 \\ f &= 0.118 \pm 0.011 \pm 0.003 \\ g &= -0.053 \pm 0.017 \pm 0.003 \end{aligned}$$



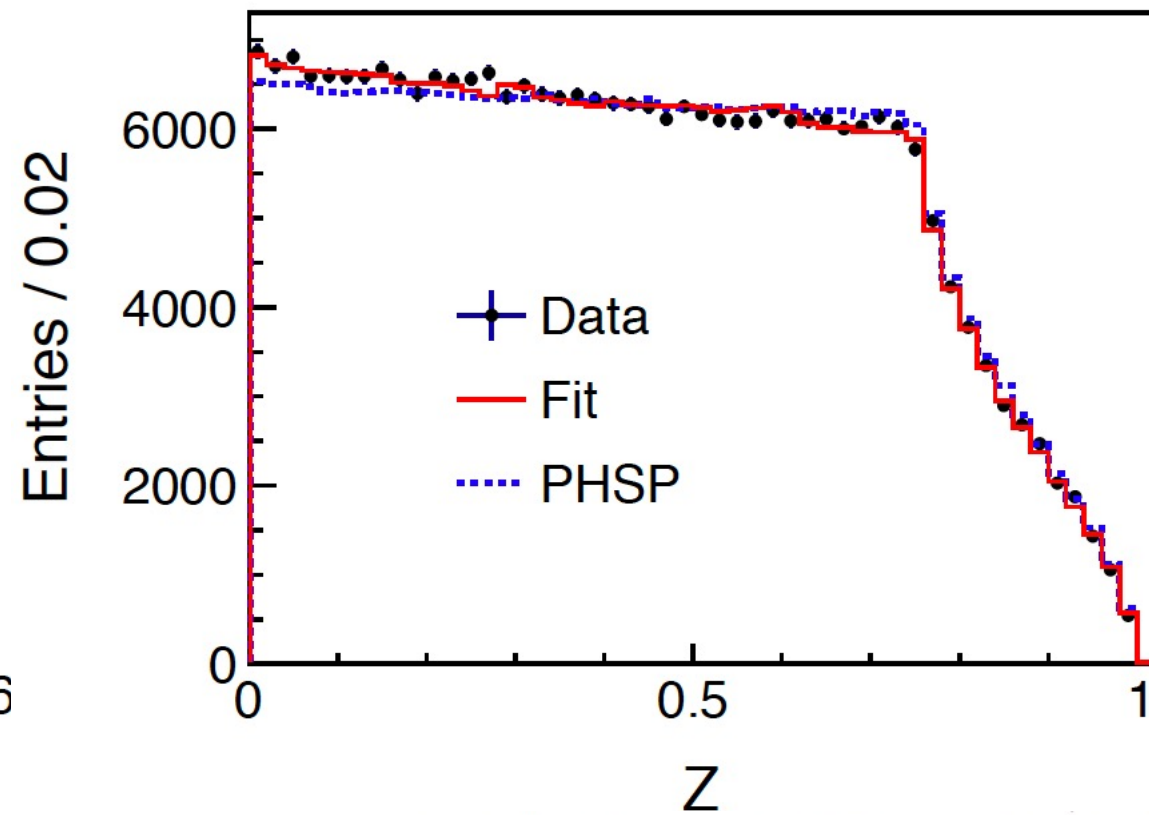
$$\eta \rightarrow \pi^0 \pi^0 \pi^0$$

~270,000 events



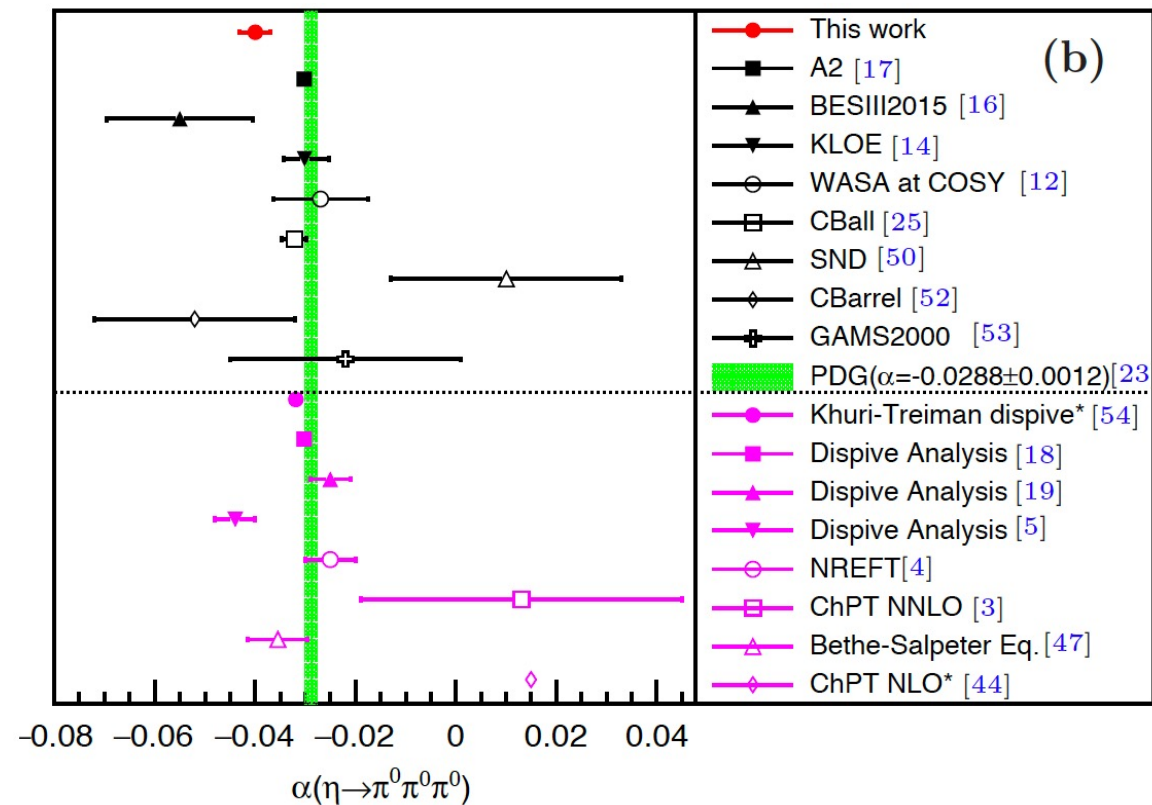
PRD107,092007(2023)

$$|A(X, Y)|^2 \propto 1 + 2\alpha Z$$

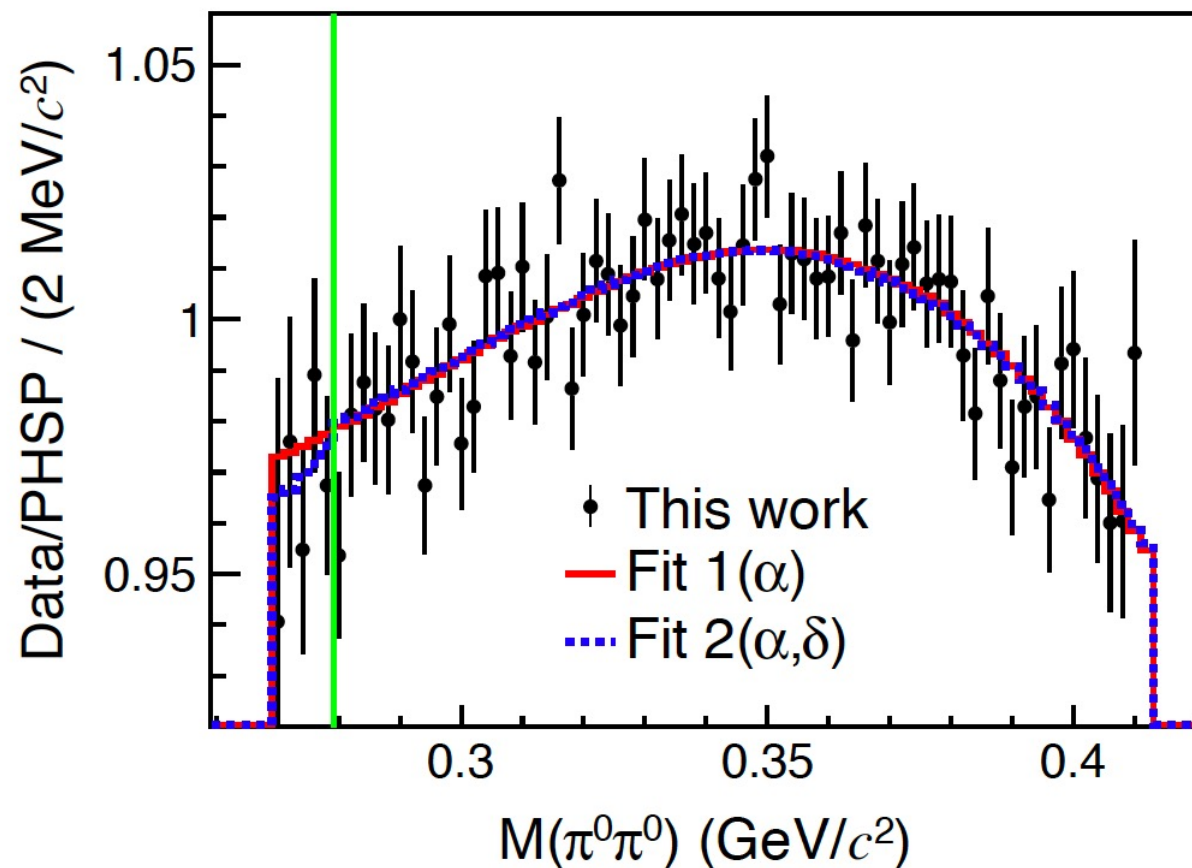


$$\alpha = -0.0406 \pm 0.0035 \pm 0.0008$$

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



Deviations from A2: 2.8σ



No evident cusp effect

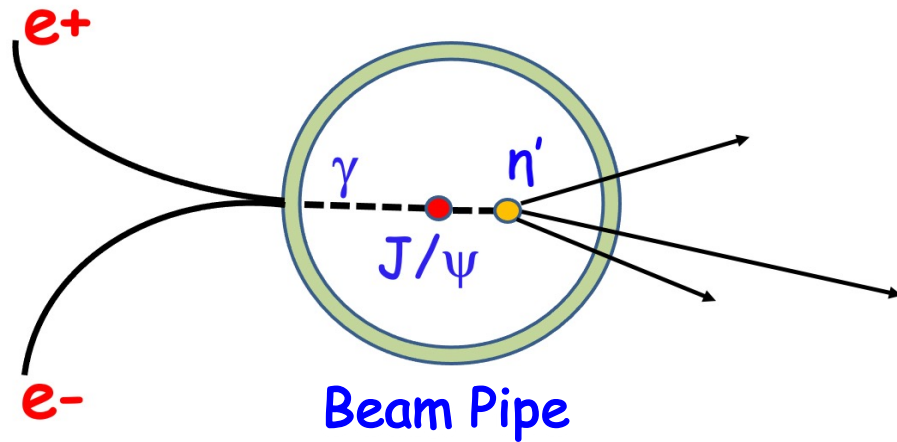
HEPData: <https://www.hepdata.net/record/ins2633025>

New approaches

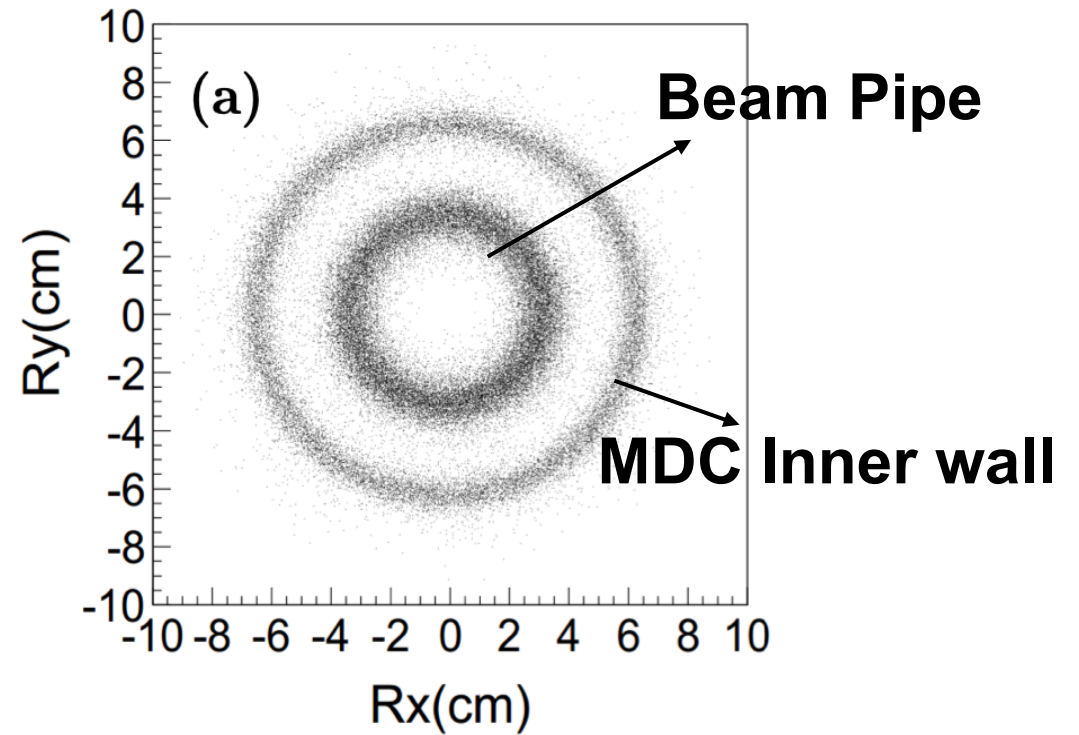
Absolute Measurement of BF's of η' decay modes	PRL122, 142002(2019)
Novel approach to investigate η decays	PRD108,014038(2023)

γ conversion: η/η' inclusive decays

- A novel way to measure the absolute BFs of η/η' decays
- Excellent momentum resolution for electrons @MDC

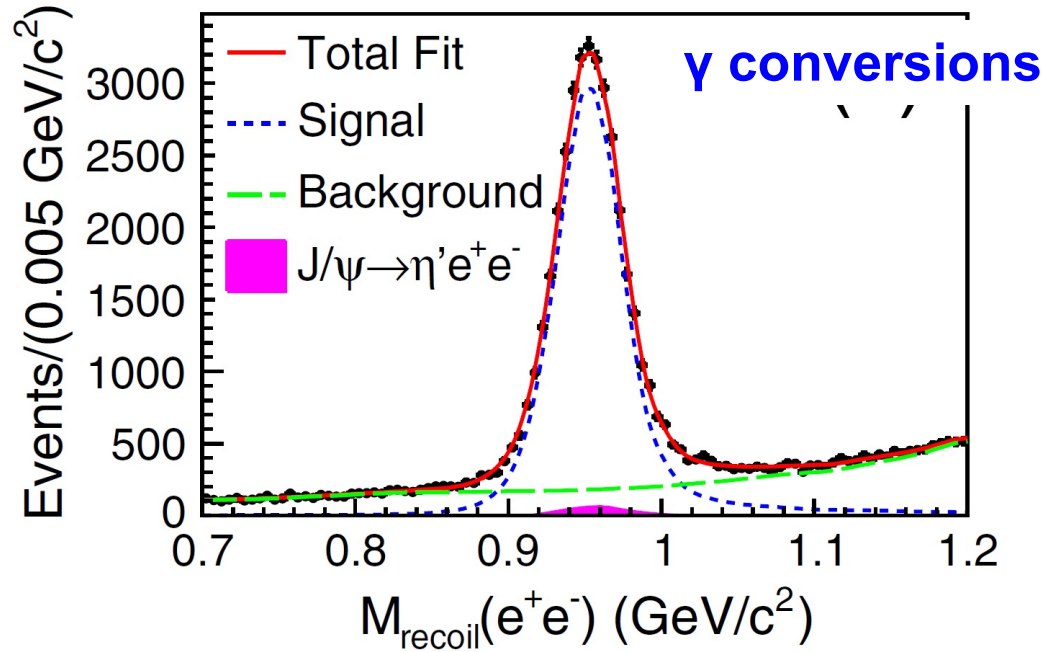


$$\mathcal{B}(\eta' \rightarrow X) = \frac{N_{\eta' \rightarrow X}^{\text{obs}}}{\epsilon_{\eta' \rightarrow X}} \frac{\epsilon}{N_{J/\psi \rightarrow \gamma \eta'}^{\text{obs}}}$$



First Measurement of Absolute BFs of η' / η decays

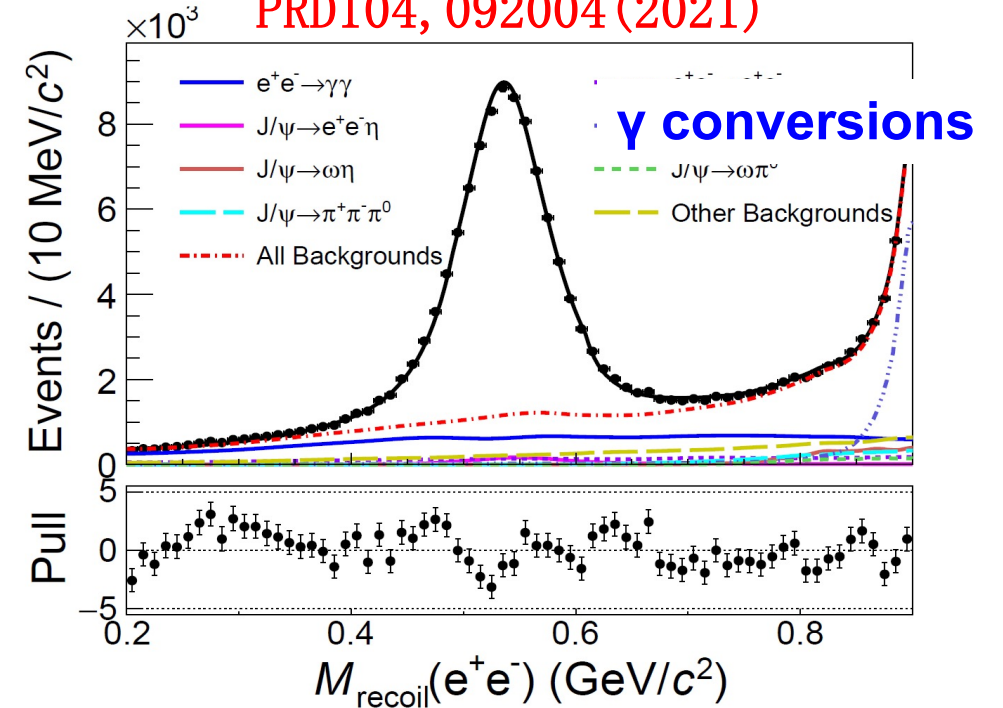
PRL122, 142002 (2019)



Decay mode	$\mathcal{B}(\eta' \rightarrow X)(\%)$	
	This measurement	PDG [7]
$\eta' \rightarrow \gamma\pi^+\pi^-$	$29.90 \pm 0.03 \pm 0.55$	28.9 ± 0.5
$\eta' \rightarrow \eta\pi^+\pi^-$	$41.24 \pm 0.08 \pm 1.24$	42.6 ± 0.7
$\eta' \rightarrow \eta\pi^0\pi^0$	$21.36 \pm 0.10 \pm 0.92$	22.8 ± 0.8
$\eta' \rightarrow \gamma\omega$	$2.489 \pm 0.018 \pm 0.074$	2.62 ± 0.13
$\eta' \rightarrow \gamma\gamma$	$2.331 \pm 0.012 \pm 0.035$	2.22 ± 0.08

$$\mathcal{B}(J/\psi \rightarrow \gamma\eta') = (5.27 \pm 0.03 \pm 0.05) \times 10^{-3}$$

PRD104, 092004 (2021)



X	This work	PDG
$\gamma\gamma$	$39.86 \pm 0.04 \pm 0.99$	39.41 ± 0.20
$\pi^0\pi^0\pi^0$	$31.96 \pm 0.07 \pm 0.84$	32.68 ± 0.23
$\pi^+\pi^-\pi^0$	$23.04 \pm 0.03 \pm 0.54$	22.92 ± 0.28
$\pi^+\pi^-\gamma$	$4.38 \pm 0.02 \pm 0.10$	4.22 ± 0.08

$$\mathcal{B}(J/\psi \rightarrow \gamma\eta) = (1.067 \pm 0.005 \pm 0.023) \times 10^{-3}$$

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

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

η REFERENCES

PDG2024

● Production rate lower than η'

● Background from QED and J/ψ decays

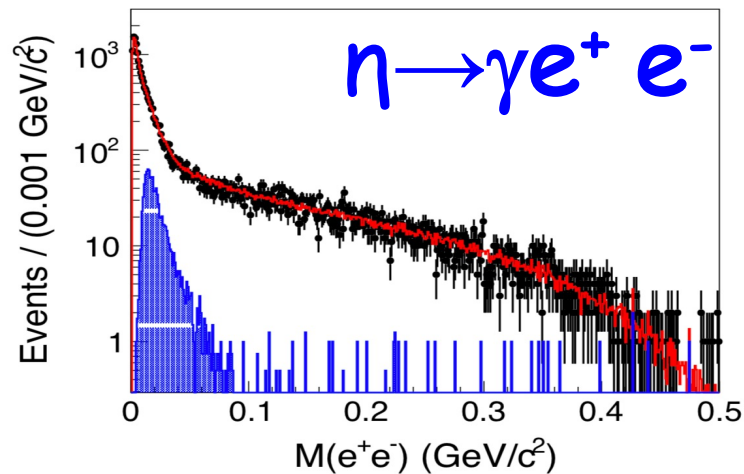
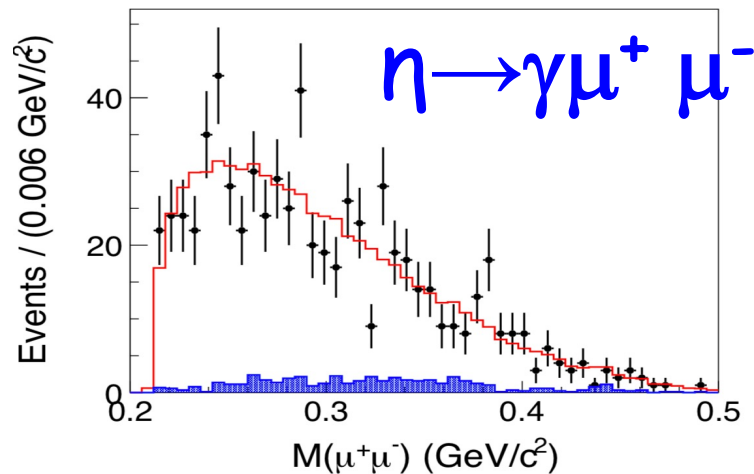
$$J/\psi \rightarrow \gamma \eta \rightarrow 1 \times 10^7 \eta$$

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

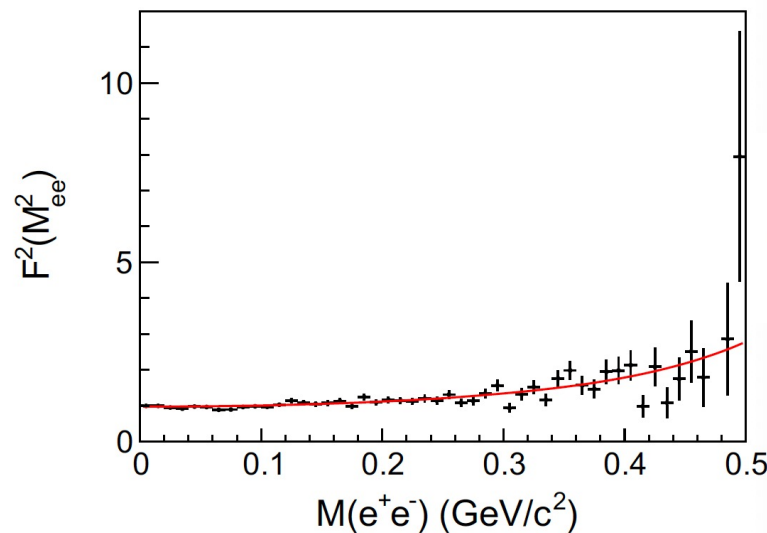
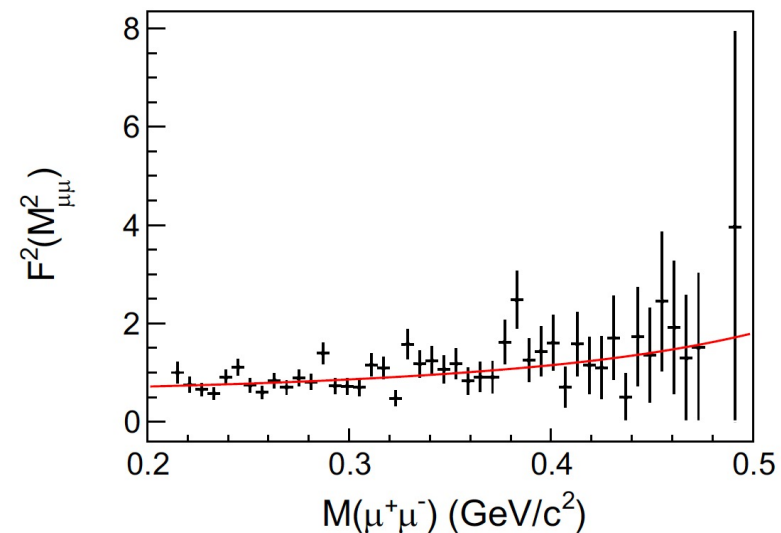
ABLIKIM	23AN	PR D107 092007	M. Ablikim <i>et al.</i>	(BESIII Collab.)
HAYRAPETYAN...	23A	PRL 131 091903	A. Hayrapetyan <i>et al.</i>	(CMS Collab.)
ABLIKIM	21AM	PR D104 092004	M. Ablikim <i>et al.</i>	(BESIII Collab.)
BABUSCI	20A	JHEP 2010 047	D. Babusci <i>et al.</i>	(KLOE-2 Collab.)
ZHEVLAKOV	19	PR D99 031703	A.S. Zhevlakov <i>et al.</i>	(TMSK, MAINZ, TUBIN+)
ACHASOV	18B	PR D98 052007	M.N. Achasov <i>et al.</i>	(SND Collab.)
ADLARSON	18C	PL B784 378	P. Adlarson <i>et al.</i>	(WASA-at-COSY Collab.)
PRAKHOV	18	PR C97 065203	S. Prakhov <i>et al.</i>	(A2 Collab. at MAMI)
AAIJ	17D	PL B764 233	R. Aaij <i>et al.</i>	(LHCb Collab.)
ADLARSON	17B	PR C95 035208	P. Adlarson <i>et al.</i>	(A2 Collab. at MAMI)
ANASTASI	16A	JHEP 1605 019	A. Anastasi <i>et al.</i>	(KLOE-2 Collab.)
ARNALDI	16	PL B757 437	R. Arnaldi <i>et al.</i>	(NA60 Collab.)
ABLIKIM	15G	PR D92 012014	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ADLARSON	14A	PR C90 045207	P. Adlarson <i>et al.</i>	(WASA-at-COSY Collab.)
AGAKISHIEV	14	PL B731 265	G. Agakishiev <i>et al.</i>	(HADES Collab.)
NEFKENS	14	PR C90 025206	B.M.K. Nefkens <i>et al.</i>	(A2 Collab. at MAMI)
NIKOLAEV	14	EPJ A50 58	A. Nikolaev <i>et al.</i>	(MAMI-B, MAINZ, BONN)
ABLIKIM	13	PR D87 012009	M. Ablikim <i>et al.</i>	(BESIII Collab.)
ABLIKIM	13G	PR D87 032006	M. Ablikim <i>et al.</i>	(BESIII Collab.)
BABUSCI	13	PL B718 910	D. Babusci <i>et al.</i>	(KLOE/KLOE-2 Collab.)
BABUSCI	13A	JHEP 1301 119	D. Babusci <i>et al.</i>	(KLOE-2 Collab.)
AGAKISHIEV	12A	EPJ A48 64	G. Agakishiev <i>et al.</i>	(HADES Collab.)
GOSLAWSKI	12	PR D85 112011	P. Goslawski <i>et al.</i>	(COSY-ANKE Collab.)
ABLIKIM	11G	PR D84 032006	M. Ablikim <i>et al.</i>	(BESIII Collab.)
AMBROSINO	11B	PL B702 324	F. Ambrosino <i>et al.</i>	(KLOE Collab.)
BERGHAUSER	11	PL B701 562	H. Berghäuser <i>et al.</i>	(GIES, UCLA, GUTE)

One more η' constraint to suppress the background events !

TFF with $J/\psi \rightarrow \gamma \eta'$, $\eta' \rightarrow \pi^+ \pi^- \eta$

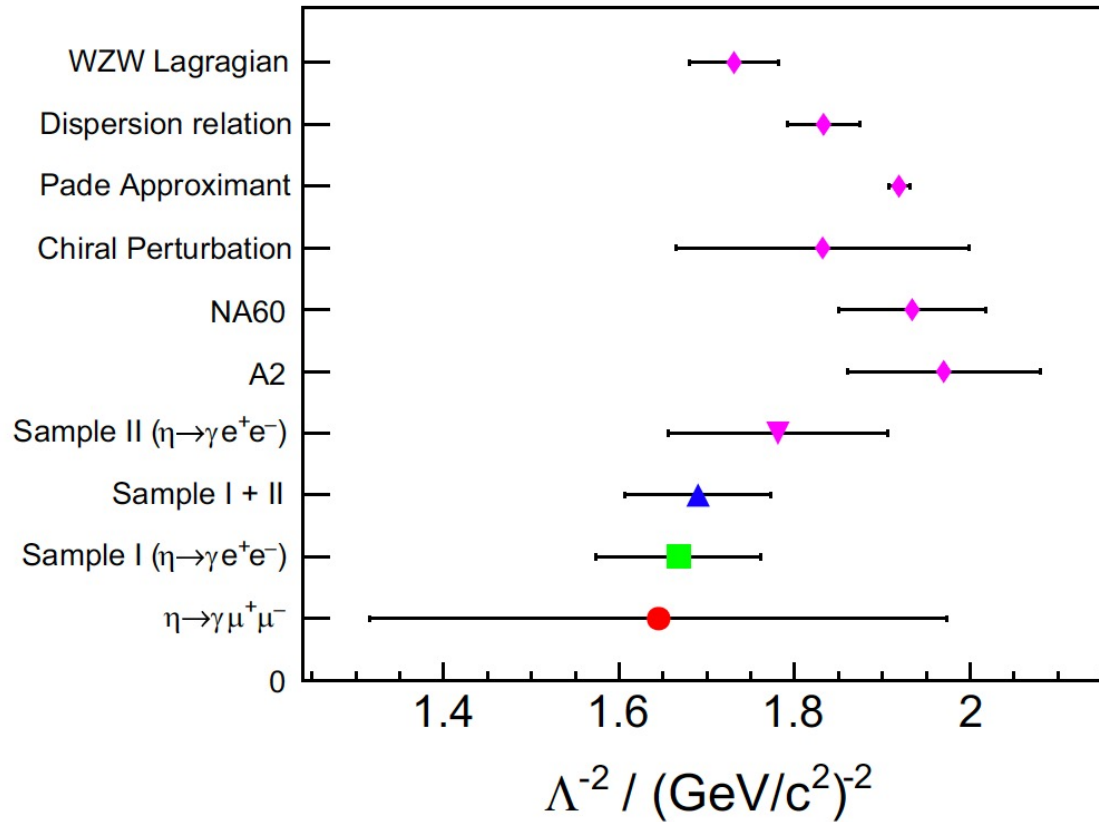


- Help distinguish muons from pions
- Background level is low



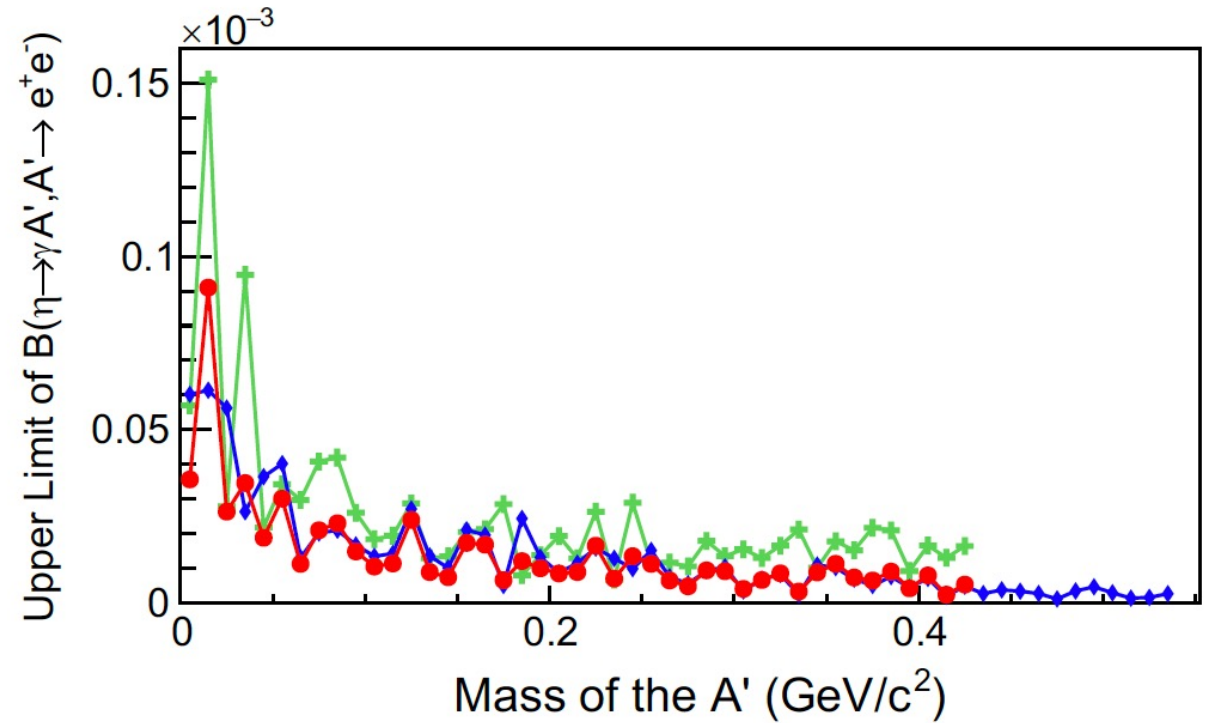
$$F(q^2) = N \sum_V \frac{g_{\eta\gamma V}}{2g_{V\gamma}} \frac{m_V^2}{m_V^2 - q^2 - i\Gamma_V m_V}$$

TFF comparisons



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

Dark photon searches



Summary

- BESIII: a light meson factory
 - a unique place for light mesons
 - Allow to study light meson decays with high precision
- Significant progresses achieved on η/η' decays
 - η/η' : hadronic, radiative and rare decays
- New proposals: STCF, HIAF, RETOP
- Together with other experiments, the light meson physics will be into a precision era

Many thanks !