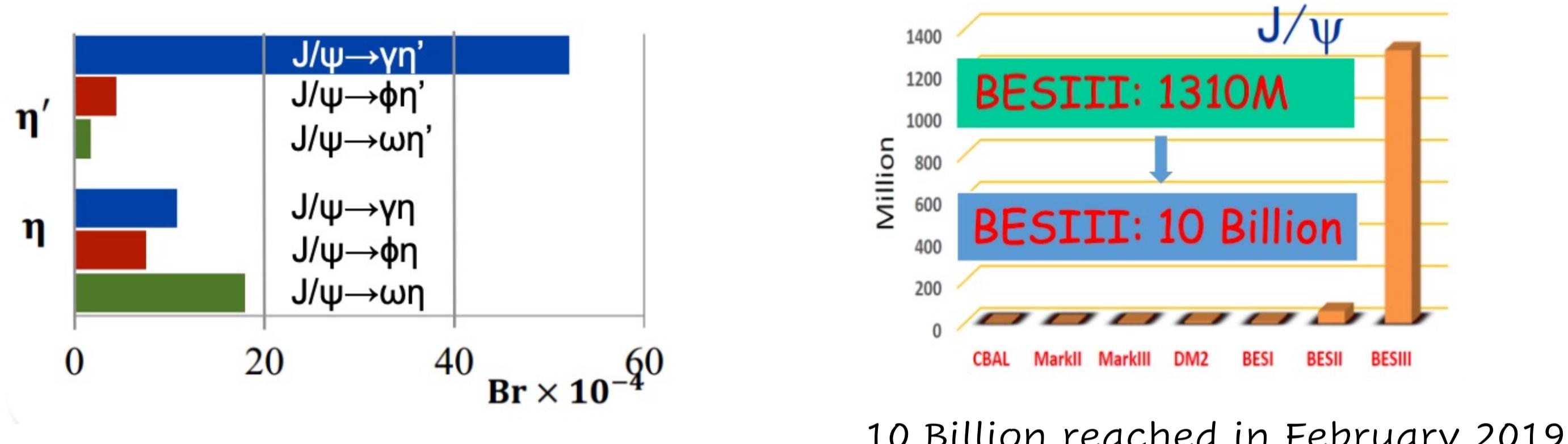


BES III

Introduction

- Both η and η' play an important role in understanding the low energy quantum chromodynamics (QCD).
- Decays of the η/η' probe a wide variety of physics issues, as $\pi - \eta$ mixing, light quark masses and pion-pion scattering.
- η' meson, much heavier than the Goldstone bosons of broken chiral symmetry, plays a special role as the predominant singlet state arising from the strong axial U(1) anomaly.
- The decays of both η and η' mesons are used to search for processes beyond the Standard Model (SM) and to test fundamental discrete symmetries.

Light meson physics @BESIII



Unique opportunity to investigate the decays of η/η' .

Recent analyses

- Based on 1.3 billion J/ψ events:
- $\eta' \rightarrow \pi^0 \pi^0 \pi^0 \pi^0$ (Phys. Rev. D 101, 032001 (2020))
 - $\eta' \rightarrow \gamma \eta \eta$ (Phys. Rev. D 101, 052015 (2019))
 - $\eta' \rightarrow \pi^+ \pi^- e^+ e^-$ (Phys. Rev. D 103, 092005 (2021))
 - $\eta' \rightarrow \pi^+ \pi^- \mu^+ \mu^-$ (Phys. Rev. D 103, 072006 (2021))
 - $\eta' \rightarrow e^+ e^- e^+ e^-$ (Phys. Rev. D 105, 112010 (2022))

- Based on 10 billion J/ψ events:

- Absolute branching fractions of η decay modes (Phys. Rev. D 104, 092004 (2021))

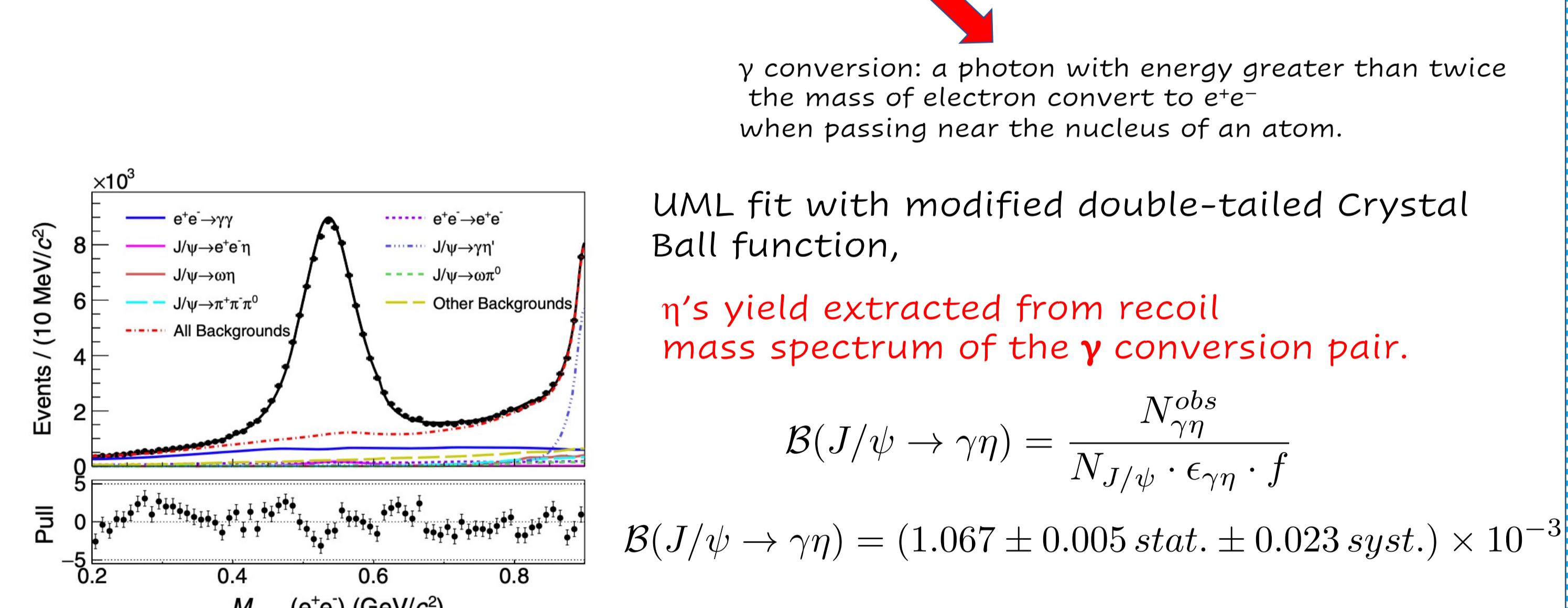
Absolute Branching Fractions of η Decay Modes

No absolute branching fractions(BFs) of η decays since now.
Difficulty in tagging its inclusive decays.

η tagging method developed by γ conversion:

Phys. Rev. D 104, 092004 (2021)

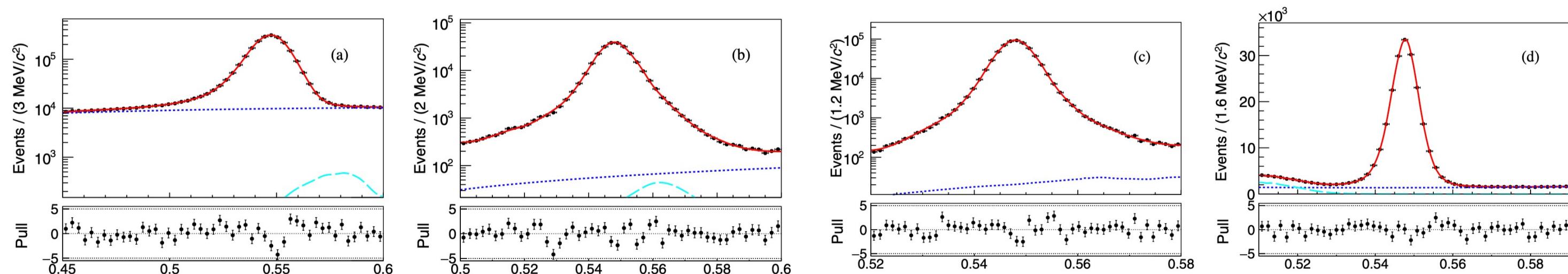
$J/\psi \rightarrow \gamma\eta$, $\eta \rightarrow$ anything, $\gamma \rightarrow e^+e^-$ (γ conversion process)



Step 2: Exclusive decays (four dominant ones) detected

$$\mathcal{B}(\eta \rightarrow X) = \frac{\mathcal{B}(J/\psi \rightarrow \boxed{\gamma\eta}, \eta \rightarrow X)}{\mathcal{B}(J/\psi \rightarrow \boxed{\gamma\eta})} = \frac{N_{\eta X}^{obs}}{\epsilon_{\eta \rightarrow X}} \cdot \frac{\epsilon f}{N_{J/\psi \rightarrow \gamma\eta}^{obs}}$$

y conversion



UML fit with MC-simulated shape convolved with a Gaussian function

X	$N_{\eta \rightarrow X}^{obs} \times 10^5$	$\epsilon_{\eta \rightarrow X} (\%)$	This work	CLEO	PDG
$\gamma\gamma$	20.78 ± 0.02	48.46 ± 0.01	$39.86 \pm 0.04 \pm 0.99$	$38.45 \pm 0.40 \pm 0.36$	39.41 ± 0.20
$\pi^0 \pi^0 \pi^0$	2.831 ± 0.006	8.230 ± 0.004	$31.96 \pm 0.07 \pm 0.84$	$34.03 \pm 0.56 \pm 0.49$	32.68 ± 0.23
$\pi^+ \pi^- \pi^0$	6.131 ± 0.008	24.73 ± 0.01	$23.04 \pm 0.03 \pm 0.54$	$22.60 \pm 0.35 \pm 0.29$	22.92 ± 0.28
$\pi^+ \pi^- \gamma$	2.018 ± 0.005	42.86 ± 0.01	$4.38 \pm 0.02 \pm 0.10$	$3.96 \pm 0.14 \pm 0.14$	4.22 ± 0.08

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on behalf of BESIII coll.
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Measurement of the branching fraction of and search for a CP-violating asymmetry in $\eta' \rightarrow \pi^+ \pi^- e^+ e^-$ [2]

Theoretical predictions for Branching fraction of rare decay $\eta' \rightarrow \pi^+ \pi^- e^+ e^-$
- Two different VMD models[3]: $(2.17 \pm 0.21) \times 10^{-3}$ and $(2.27 \pm 0.13) \times 10^{-3}$
- ChPT model[4]: $(2.13 \pm 0.17) \times 10^{-3}$

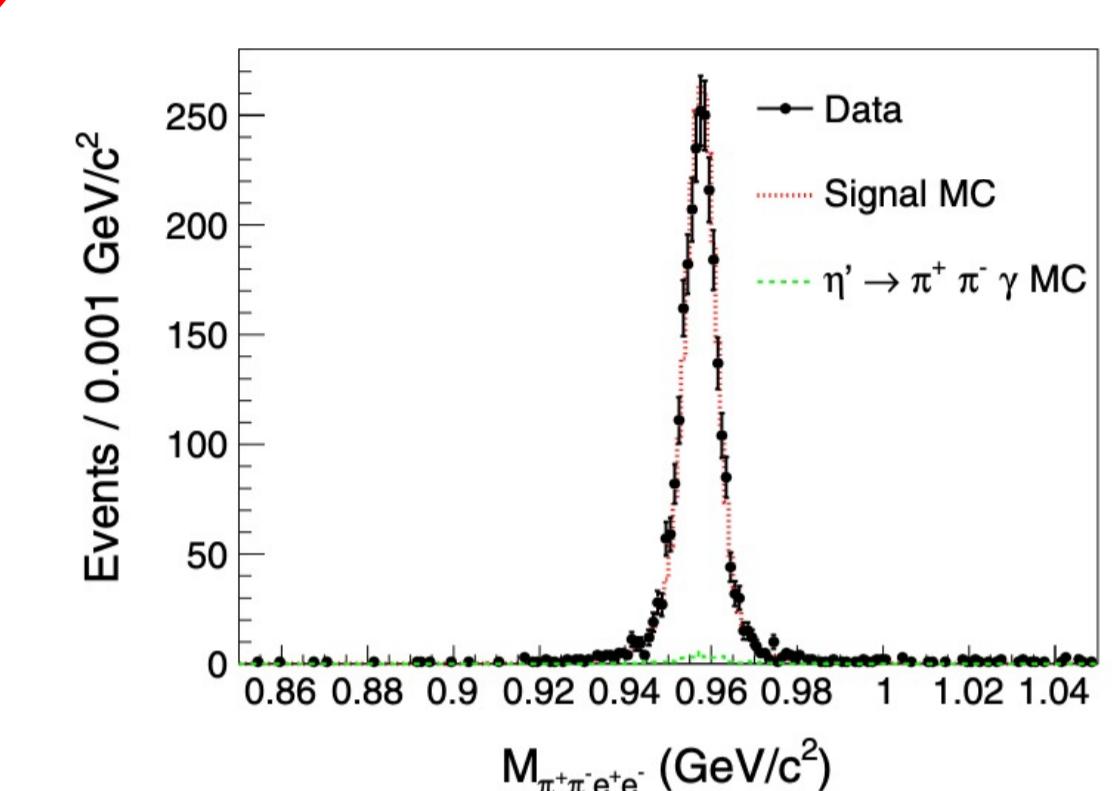
Previous best precision measurement [5]: $(2.11 \pm 0.12 \text{ stat.} \pm 0.15 \text{ syst.}) \times 10^{-3}$

The branching fraction of $\eta' \rightarrow \pi^+ \pi^- e^+ e^-$ is determined relative to $\eta' \rightarrow \pi^+ \pi^- \gamma$ (well known) → to minimize systematics

$$\mathcal{B}(\eta' \rightarrow \pi^+ \pi^- e^+ e^-) =$$

$$\frac{N_{\eta' \rightarrow \pi^+ \pi^- e^+ e^-} \times \epsilon_{\eta' \rightarrow \pi^+ \pi^- \gamma} \times \mathcal{B}(\eta' \rightarrow \pi^+ \pi^- \gamma)}{N_{\eta' \rightarrow \pi^+ \pi^- \gamma} \times \epsilon_{\eta' \rightarrow \pi^+ \pi^- e^+ e^-}} = (2.42 \pm 0.05 \text{ stat.} \pm 0.08 \text{ syst.}) \times 10^{-3}$$

Consistent with predictions

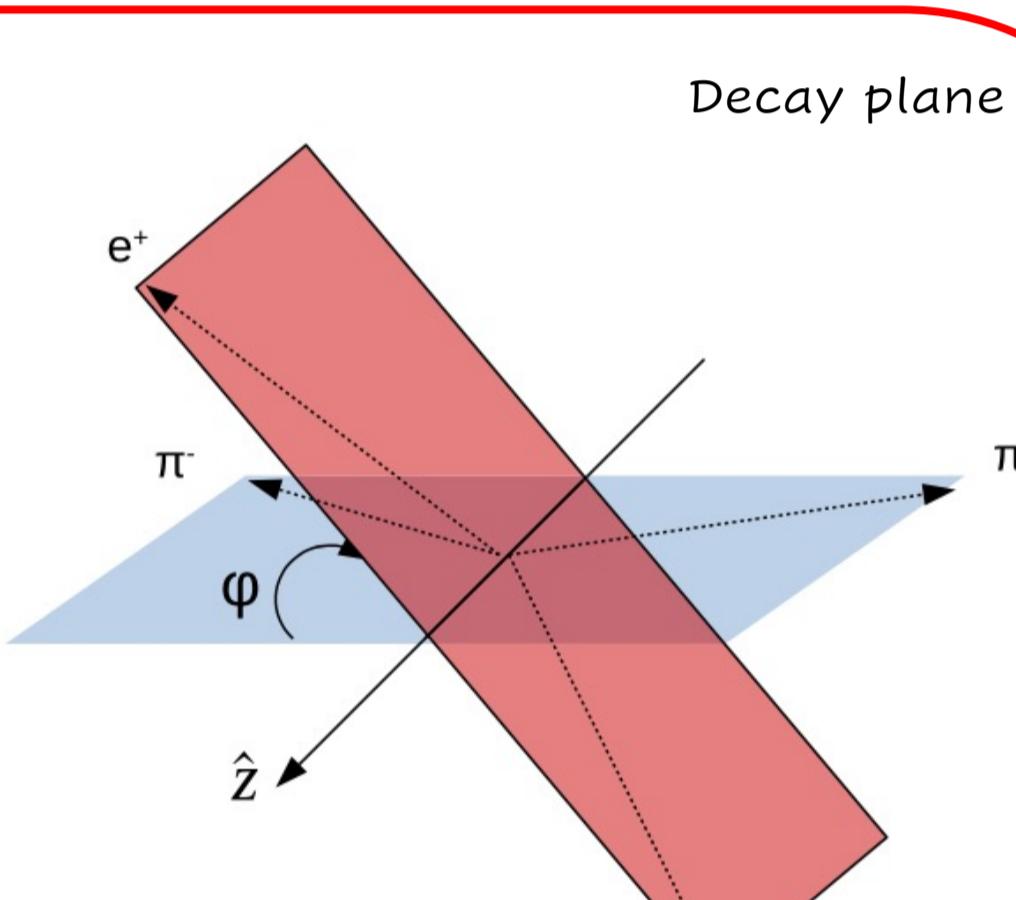


Signal region:
 $|M_{\pi^+\pi^-e^+e^-} - M_{\eta'}| < 0.02 \text{ GeV}/c^2$
Signal purity: 98%
based on MC simulations of $\eta' \rightarrow \pi^+ \pi^- \gamma$

Possible CP-violating contribution forseen:

- An electric dipole type transition
- Manifest itself as an asymmetry of $\sin 2\varphi$:

$$A_\varphi = \frac{N(\sin 2\varphi > 0) - N(\sin 2\varphi < 0)}{N(\sin 2\varphi > 0) + N(\sin 2\varphi < 0)}$$



Previous measurements consistent with 0 (WASA-at-COSY [6] and KLOE [7])

Due to the limited momentum resolution, some events with a true value $\sin 2\varphi < 0$ are reconstructed with a value $\sin 2\varphi > 0$. The fraction of such events, α is estimated with signal MC sample.

$$A_{\varphi,corr} = \frac{A_{\varphi,rec}}{1 - 2\alpha}$$

$$A_\varphi = (2.9 \pm 3.7 \text{ stat.} \pm 1.1 \text{ syst.})\%$$

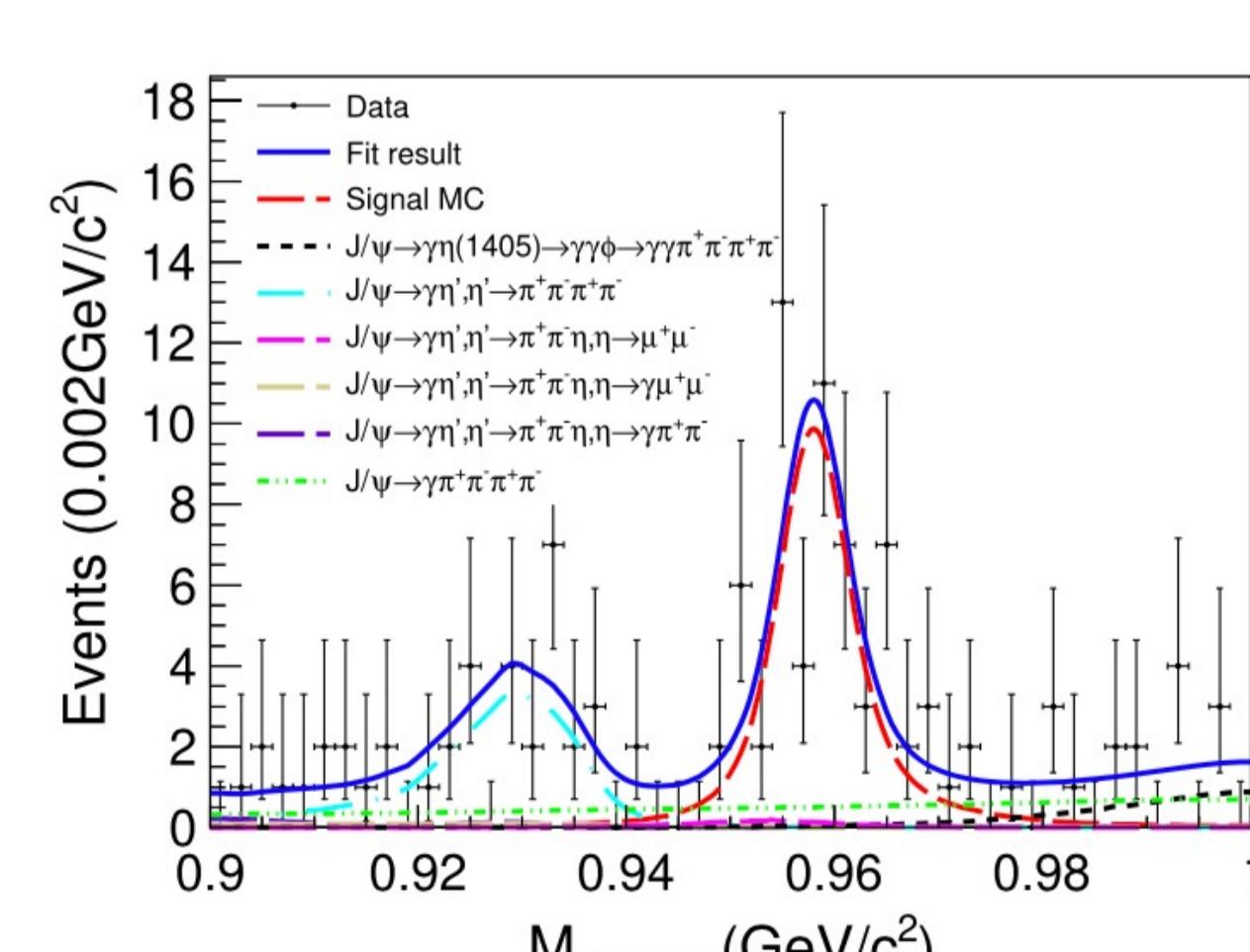
consistent with zero.

Observation of $\eta' \rightarrow \pi^+ \pi^- \mu^+ \mu^-$ [9]

Observed for the first time with a significance of 8σ via the process $J/\psi \rightarrow \gamma\eta$ thanks to 5 times the statistics in Ref[5].

Predictions on $\mathcal{B}(\eta' \rightarrow \pi^+ \pi^- \mu^+ \mu^-)$ - in the range of $(1.5 - 2.5) \times 10^{-5}$ [3,4,8]:

No significant signal in literature. Previous most stringent upper limit measured by BESIII: $\mathcal{B}(\eta' \rightarrow \pi^+ \pi^- \mu^+ \mu^-) < 2.9 \times 10^{-5}$ at the 90% C.L. by BESIII using 225 million J/ψ events collected in 2009 [5]



$$\mathcal{B}(\eta' \rightarrow \pi^+ \pi^- \mu^+ \mu^-) = (1.97 \pm 0.33 \text{ stat.} \pm 0.19 \text{ syst.}) \times 10^{-5}$$

In good agreement with theoretical predictions

- Large J/ψ decay sample at BESIII provides an excellent laboratory to study light meson decays.
- Thanks to the 10 billion J/ψ now available, more interesting results are expected as Standard Model precision tests, $(g-2)_\mu$; η/η' transition form factor, discrete symmetry tests; C and CP-violation, search for η/η' rare decays; searches for light BSM particles
- STAY TUNED!!!

[1] BESIII, Phys. Rev. D 104, 092004 (2021)

[2] BESIII, Phys. Rev. D 103, 092005 (2021)

[3] J. Sakurai, Ann. Phys. (N.Y.) 11, 1 (1960), Petri T. PHD Thesis arXiv:1010.2378

[4] Borasoy and Nissler Eur. Phys. J. A 33, 95 (2007).

[5] BESIII, Phys. Rev. D 87, 092011 (2013).

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[6] WASA-at-COSY, Phys. Rev. C 94, 065206 (2016).

[7] KLOE, Phys. Lett. B 675, 283 (2009).

[8] Faessler et al., Phys. Rev. C 61, 035206 (2000).

[9] BESIII, Phys. Rev. D 103, 072006 (2021)