Universität Münster

MENU 2023

LIGHT MESON DECAYS AT BESIII

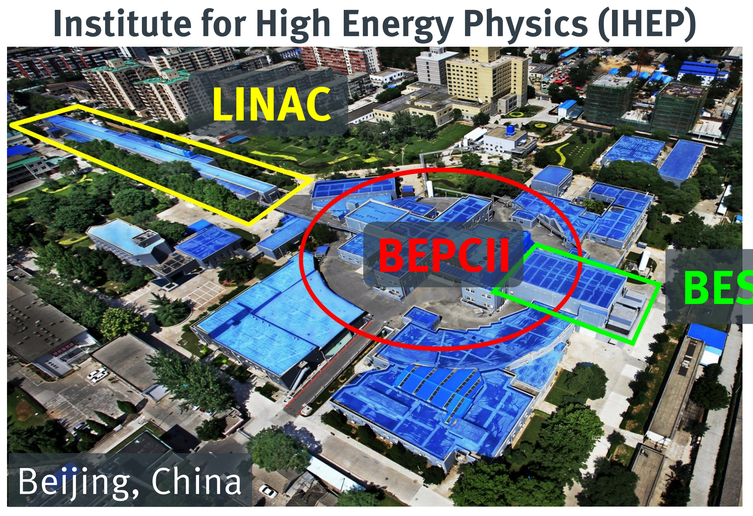
WHY STUDY LIGHT MESON DECAYS?

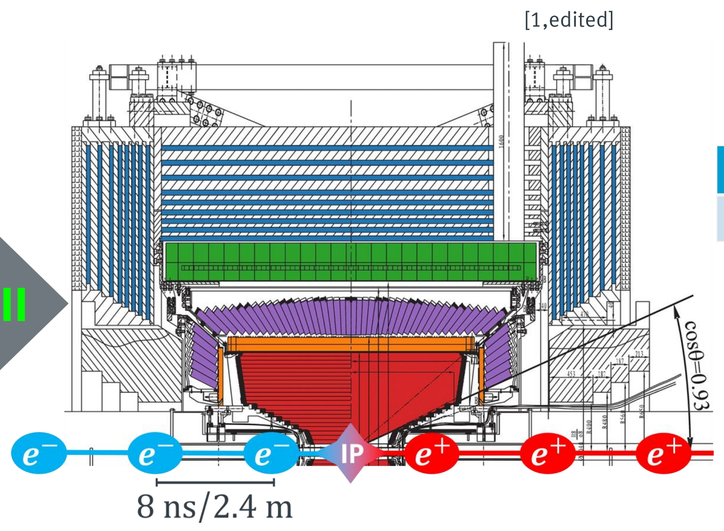
- **To perform precision tests of** → **effective field theories** describing the non-perturbative QCD regime; **fundamental symmetries** such as C, P, and CP symmetry; **common decay dynamics** like $\pi\pi$ S-wave scattering
- **To search for** → **rare/forbidden decays** sensible to symmetry breaking effects; **new particles** maybe even beyond the Standard Model
- **To determine** → **transition form factors** to probe the meson's substructure & investigate the hadronic light-by-light correction to the muon anomalous magnetic moment

HOW TO STUDY LIGHT MESONS AT BESIII

$e^+e^- \Downarrow J/\psi \Downarrow \gamma\eta^{(\prime)} \Downarrow$

Institute for High Energy Physics (IHEP)





BESIII provides the **worlds largest J/ψ data set with 10^{10} events** perfect for investigations of light mesons via radiative & hadronic decays

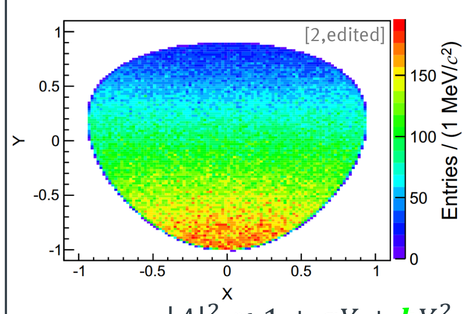
$J/\psi \to \gamma\eta^{(\prime)}$		$J/\psi \to \phi\eta^{(\prime)}$	
$1 \times 10^7 \eta$	$5.2 \times 10^7 \eta'$	$4 \times 10^6 \eta$	$2.5 \times 10^6 \eta'$

- **RPCs:** Muon identification
- **Solenoid:** 1 T magnetic field
- **EMC:** Detection and energy measurement of photons and electrons
- **TOF:** PID of charged tracks
- **MDC:** Momentum measurement, reconstruction and PID of charged tracks

- **LINAC + BEPCII** facilitate e^+e^- collisions at **energies between 2 GeV and 5 GeV** with a design **luminosity of 10^{33} cm^{-2}s^{-1}** at 3.78 GeV

EXCITING NEW BESIII RESULTS FROM THE STUDIES OF η AND η' DECAYS

Dalitz Plot Analysis of $\eta \to \pi^+\pi^-\pi^0$



$$X = \frac{\sqrt{3}}{Q_\eta}(T_{\pi^+} - T_{\pi^-})$$

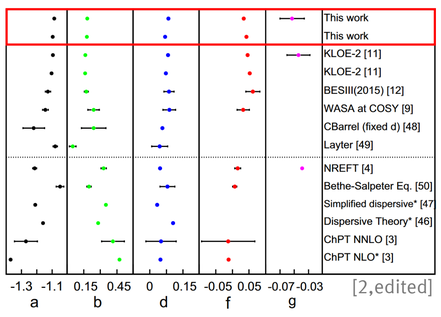
$$Y = \frac{3T_{\pi^0}}{Q_\eta} - 1$$

T: kinetic energy in η rest frame
Q_η: excess energy of $\eta \to 3\pi$

$$|A|^2 \propto 1 + aY + bY^2 + cX + dX^2 + eXY + fY^3 + gX^2Y + \text{H.O.T.}$$

c, e & H.O.T. are consistent with zero and Dalitz plot is symmetrical

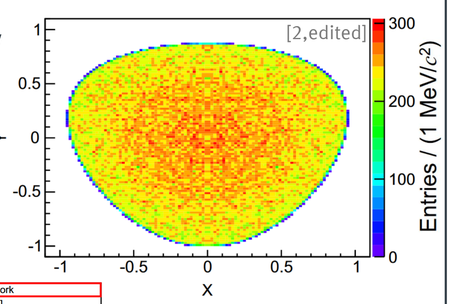
No evidence for C symmetry breaking

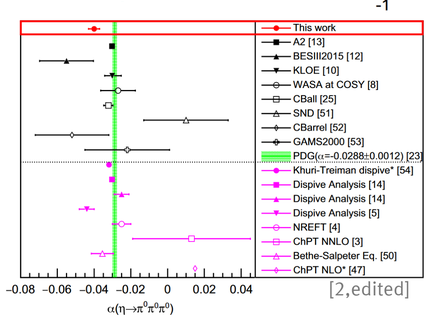


Dalitz Plot Analysis of $\eta \to \pi^0\pi^0\pi^0$

Threefold Symmetry
$Z = X^2 + Y^2$

$$|A|^2 \propto 1 + 2\alpha Z + 2\beta(3X^2Y - Y^3) + 2\gamma Z^2 + \text{H.O.T.}$$





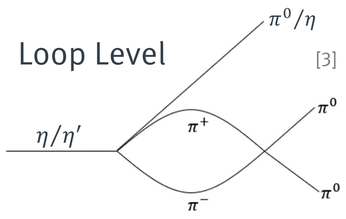
No significant contributions from β, γ and H.O.T.

Dominant $\pi^0\pi^0$ S-wave rescattering

Cusp Effect

Study light meson dynamics via **loop contributions** to the $\pi\pi$ scattering process

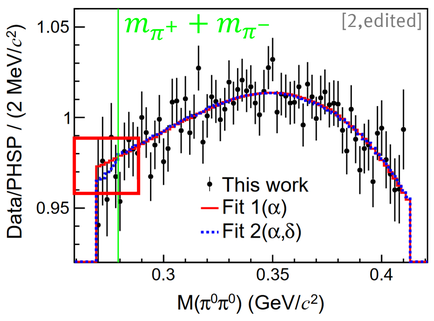
Loop Level



S-wave charge-exchange rescattering $\pi^+\pi^- \to \pi^0\pi^0$ at loop level in the **NREFT** amplitude:

$$C_x = \frac{16\pi}{3}\underbrace{(a_2 - a_0)}_{\pi\pi \text{ scattering length combination}}\left(1 + \frac{m_{\pi^\pm}^2 - m_{\pi^0}^2}{3m_{\pi^\pm}^2}\right)$$

cusp term



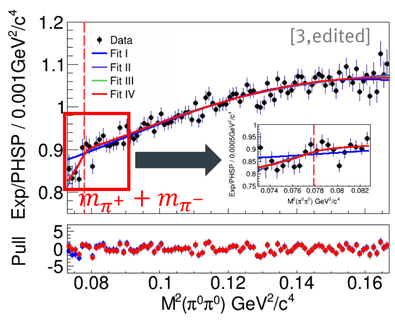
$\eta \to \pi^0\pi^0\pi^0$

Fit 1: Tree Level
Fit 2: NREFT Loop Level

No significant cusp effect (0.8σ)

$\eta' \to \eta\pi^0\pi^0$

Fit I: Tree Level
Fit II-IV: NREFT Loop Level

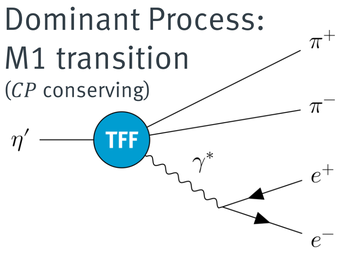


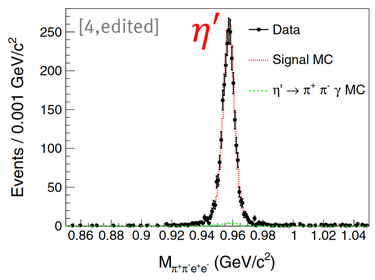
Evidence for cusp effect (3.5σ)

$\pi\pi$ scattering length combination
$a_0 - a_2 = 0.226 \pm 0.060_{\text{stat}} \pm 0.013_{\text{syst}}$
consistent with NREFT predictions

Precision Measurement of $\eta' \to \pi^+\pi^-e^+e^-$

Dominant Process:
M1 transition
(CP conserving)



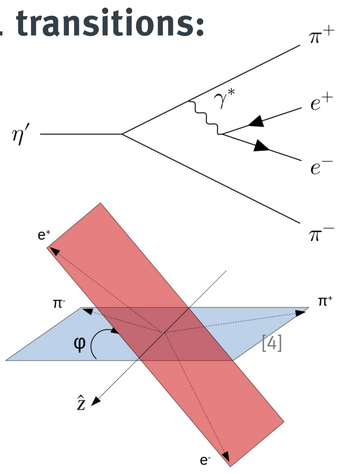


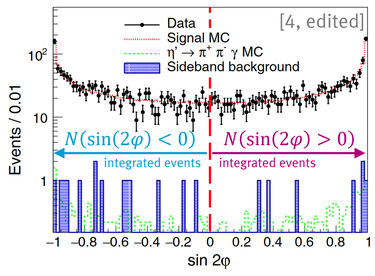
$$\text{BR}(\eta' \to \pi^+\pi^-e^+e^-) = (2.42 \pm 0.05_{\text{stat}} \pm 0.08_{\text{syst}}) \times 10^{-3}$$

Branching ratio is consistent with hidden gauge model, modified VMD and unitary ChPT

Test for CP-violating E1 transitions:

Interference term between M1 and E1 is proportional to $\sin 2\varphi$





$$\frac{N(\sin(2\varphi) > 0) - N(\sin(2\varphi) < 0)}{N(\sin(2\varphi) > 0) + N(\sin(2\varphi) < 0)} = (2.9 \pm 3.7_{\text{stat}} \pm 1.1_{\text{syst}})\%$$

No significant CP-violation

REFERENCES

[1] M. Ablikim *et al.*, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment **614**, 345 (2010).
[2] M. Ablikim *et al.*, Phys. Rev. D **107**, 92007 (2023).
[3] M. Ablikim *et al.*, Phys. Rev. Lett. **130**, 81901 (2023).
[4] M. Ablikim *et al.*, Phys. Rev. D **103**, 92005 (2021).

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BESIII

NRW-FAIR Netzwerk

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