Systematic study of glueball at BESIII

Scalar : already " saturated "
- LQCD : ground state 0^+ glueball ~1.7 GeV, first excitation ~2.1 GeV

✓ **Strong production of $f_0(1710)/f_0(2100)$ in $J/\psi \to \gamma\, \eta\eta/KK/\pi\pi$**, the pattern consists with LQCD' s prediction

☐ $J/\psi \to \gamma\eta'\eta(')$ in crucial to the property of **$f_0(2100)$**. ← **High statistics**

Tensor : more complicated overpopulation
- LQCD : 2^{++}(2.3~2.4 GeV)

✓ **Strong production of $f_2(2340)$ in** $J/\psi \to \gamma\eta\eta/KK/\pi\pi/\phi\phi$; consists with LQCD' s prediction

Coupled channel analysis

Pseudoscalar : simple expected spectrum in quark model, **but very little known before**
- LQCD : 0^{-+}(2.3~2.6 GeV)

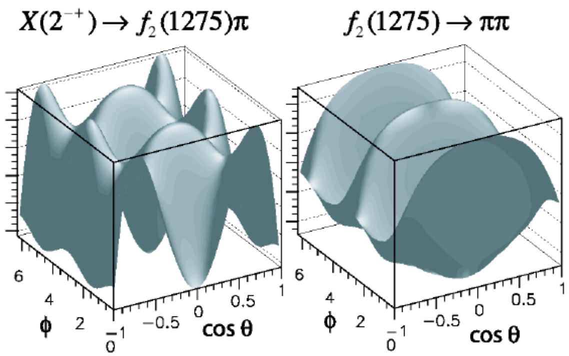
✓ **Trajectory** :
- **$f_1(1285)$? $\eta(1295)$?**
- **$\eta(1405)$? $\eta(1475)$?**
- **X(1835)/X(ppbar)**

- Flavor tags: $J/\psi \to \gamma\gamma V$, $J/\psi \to \phi/\omega X$

☐ **Above 2 GeV: X(2370)?** ← **High statistics**

Promising

Partial wave analysis at BESIII



Event-based ML fit to all observables simultaneously

dynamic ↓ angular ↓

$$\omega(\xi) \equiv \frac{d\sigma}{d\Phi} = \left|\sum_i c_i R_i B(p,q) Z(L)\right|^2$$

Event-wise efficiency correction

$$P(\xi) = \frac{\omega(\xi)\epsilon(\xi)}{\int \omega(\xi)\epsilon(\xi)}$$

Tasks: Map out the resonances

- **Systematic determination of resonance properties:**
  spin-parity,
  resonance parameters,
  production properties,
  decay properties, …
  - resonances tend to be broad and plentiful, leading to intricate interference patterns, or buried under a background in the same and in other waves.

Tools: PWA

- ✓ **Decompose to partial wave amplitudes**
- ✓ **Make full use of data**
- ✓ **Handle the interference**
- ✓ **Extract resonance properties with high sensitivity and accuracy**

Challenging issues in amplitude analysis

- Analysis techniques
  - High statistics data processing
    - A pioneer approach of GPU acceleration at BESIII -- GPUPWA
  - Background treatment
  - Detector resolution
  - Model selection
  - …

- Theoretical inputs
  - Coupled channel effects
  - Threshold effects
  - Non-resonant contribution
  - Extraction of pole properties
  - …


接下来我举个栗子

Isospin-violating decay of η(1405) → $f_0(980)\pi$

PRL 108, 182001

The long standing E-ι puzzle:

η(1405)→$a_0\pi$, η(1475)→$K^*\bar{K}$, overpopulation?

Anomalously large isospin violation:

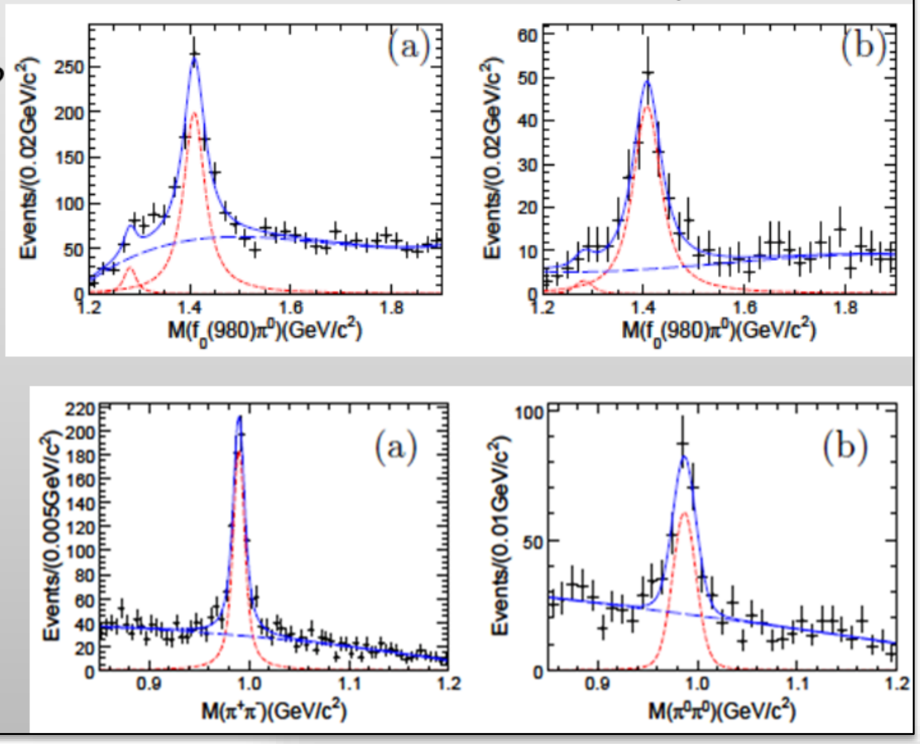
$$\frac{Br(\eta(1405)\to f_0(980)\pi^0\to\pi^+\pi^-\pi^0)}{Br(\eta(1405)\to a_0^0(980)\pi^0\to\eta\pi^0\pi^0)} \cong (17.9\pm4.2)\%$$

Much larger than a_0-f_0 mixing (PRD 83 032003)

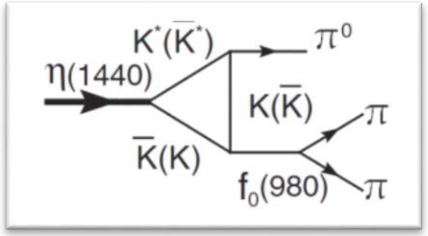
$$\xi_{af}=\frac{Br(\chi_{c1}\to f_0(980)\pi^0\to\pi^+\pi^-\pi^0)}{Br(\chi_{c1}\to a_0(980)\pi^0\to\eta\pi^0\pi^0)}<1\%(90\%\ C.L.)$$

$f_0(980)$ is extremely narrow: $\Gamma\cong$ 10 MeV.

PDG: Γ(f0(980)) ≅ 40~100 MeV.



Triangle singularity (PRL 108 081803)



Implementation in GPUPWA

Including the TSM in PWA

- The contribution of triangle are add in PWA as Loop Integral

Original Amplitude: $iM^{tre}_{\eta\to f_0\pi^0\to3\pi^0}=-g_{\eta f_0\pi^0}g_{f_0\pi^0\pi^0}(BW^{(1)}_{f_0}+BW^{(2)}_{f_0}+BW^{(3)}_{f_0})$

Triangle Loop Amplitude $iM^{tri}_{\eta\to f_0\pi^0\to3\pi^0}=-g'_{\eta f_0\pi^0}g_{f_0\pi^0\pi^0}(BW^{(1)}_{f_0}+BW^{(2)}_{f_0}+BW^{(3)}_{f_0})$

where $g'_{\eta f_0\pi^0}$ is modified term by triangle loop. $g'_{\eta f_0\pi^0}=\frac{g_{K^*K\pi}g_{f_0K\bar{K}}g_{f_0K\bar{K}}}{16\pi^2}I$

- Tensor formalism of amplitude

Original : $A_{total}=\epsilon_{\psi_\mu}\epsilon_{\gamma_\nu}\Lambda U^{\mu\nu}$

Including the TSM

$A_{total}=\epsilon_{\psi_\mu}\epsilon_{\gamma_\nu}(\Lambda U^{\mu\nu}+\Lambda' I\, U^{\mu\nu})$

coefficient to be fitted

I is a loop integral of couplings, which is obtained from theoretical calculations.
The calculation is time-consuming.
Theorists provide a Look-up-table for us.

Pin down the issues of $\eta(1405/1475)$ and $\eta(1295)/f_1(1285)$ in J/ψ→γ $\eta\pi\pi/KK\pi/\pi\ \pi\ \pi$