Photoproduction of Excited η Resonances $\gamma p \longrightarrow p\pi^+\pi^-\eta$ at CLAS

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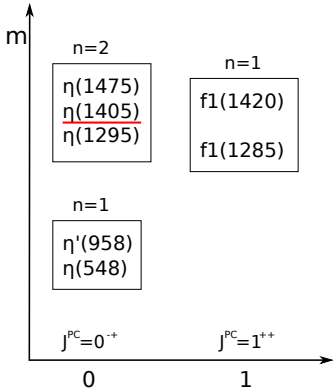
Motivation

- Supernumerous resonance with $J^{PC} = 0^{-+}$
- $\eta(1295)$
  - Seen in $\pi^- p$ scattering experiments
  - Seen by DM2 in $J/\psi \to \gamma\pi^-\pi^+\eta$
  - No further observation
  - Interference with $f_1(1285)$
  - Artifact of f_1?
- $\eta(1405)$
  - Only seen in gluon rich processes like $\overline{p}p$ annihilations and radiative J/ψ decays
  - Not seen in photoproduction or $\gamma\gamma$ fusion
  - Decays to $K\overline{K}\pi$ and $\pi\pi\eta$
  - Glueball candidate
- $\eta(1475)$
  - Strong coupling to $K\overline{K}\pi$
  - Not yet seen in $\pi\pi\eta \to$ weak coupling



Event Selection

$$\gamma p \longrightarrow p\pi^+\pi^-(\eta)$$

- g12 :
  ($\approx 60\%$)
- Photon energy 1.5 to 5.5 GeV
- Trigger Conditions: 3 charged tracks in 3 different sectors
  or 2 charged tracks in 2 different sectors and photon energy > 3.2 GeV
- Require:
  - 3 charged particles
    (2 positive, 1 negative)
  - PID: p, π^+, π^-
  - η reconstruction via missing mass method
- Applied E_γ-, momentum-correction

$\longrightarrow \approx 200 \cdot 10^6$ events

- Origin in target: $r < 2$ cm, $-110\,\text{cm} < z < -70\,\text{cm}$
- Timing: $\Delta t = t_{Tagger} - t_{StartCounter}$, $|\Delta t| < 0.5$ ns
- Minimal momentum: $p_p > 0.3$ GeV/c, $p_{\pi^+,\pi^-} > 0.1$ GeV/c
- Fiducial volume cut
- PID: $\beta_{calc} = \frac{p}{\sqrt{m^2_{PDG}+p^2}}$
  $\Rightarrow d = \beta_{calc} - \beta_{meas.} \Rightarrow |d| < 0.04$
- Cut on missing mass:
  $480\,\text{MeV/c}^2 < m_{miss} < 620\,\text{MeV/c}^2$
- Track Efficiency

$\longrightarrow \approx 18.6 \cdot 10^6$ events

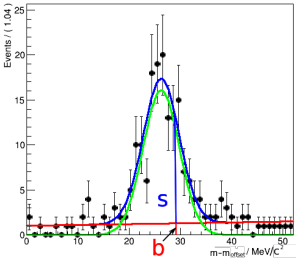
Event-based Background Suppression

Assumption: Distribution of background events in a small cell of the phasespace is different compared to signal events.

→ Event-by-event procedure:

- First step: find N nearest neighbours B of seed event A in phasespace
  - Define metric to calculate distances in phasespace
  - Choose N events with smallest distance to seed event
- Second step: fit invariant mass spectrum $m(\eta)$ of nearest neighbours with appropriate functions for signal and background

- Metric contains:
  - Production angle η'
  - E_γ

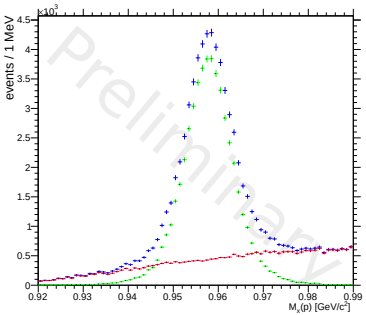


Event-based Background Suppression

- Third step: calculate signal to background ratio

$$Q = \frac{f_s s}{f_s s + (1 - f_s) b}$$
$$s = S(m_{\text{seed}})$$
$$b = B(m_{\text{seed}})$$

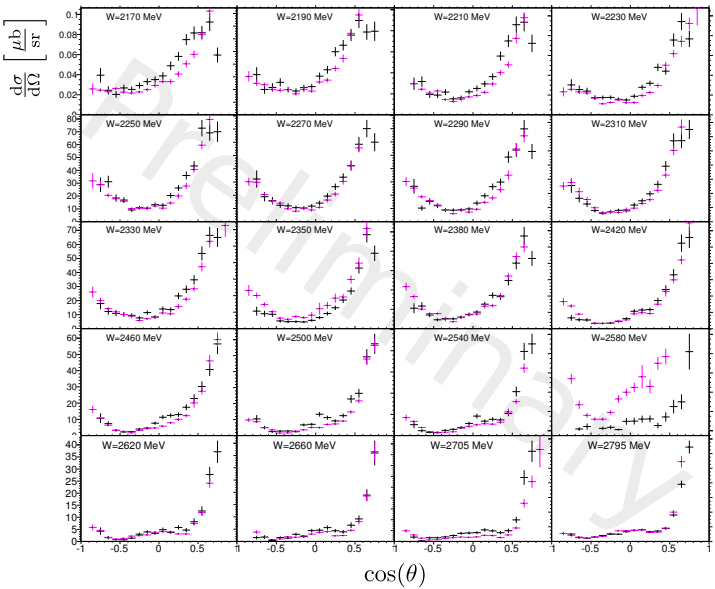
- Fourth step: normalize S/B and assign it as probabilistic weight for each event



Unweighted 1-Q weighted Q weighted

- Benefit: No knowledge on the origin of background is needed!

Differential Cross Section of $\gamma p \rightarrow p\eta'$

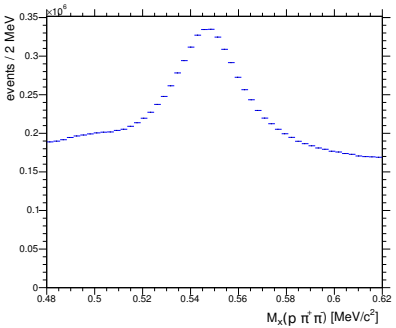


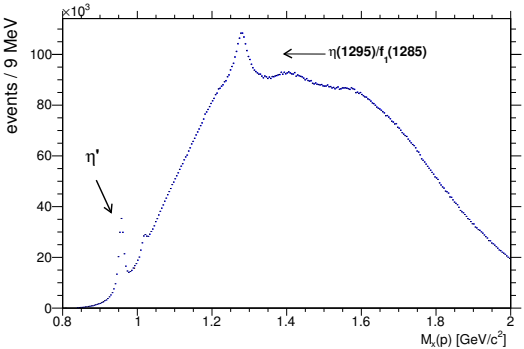
Differential cross section of $\gamma p \rightarrow p\eta'$:

CLAS g11 run
(CLAS ,Phys.Rev. C80 (2009) 045213)

This work (g12 run)

Excited η states in $\gamma p \rightarrow p\pi^+\pi^-(\eta)$





- Broad η peak
- Neutral kaon contribution
- Kinematic fit takes background events in as well as "real" η events

$\rightarrow$ Q-factor method on missing mass in η region

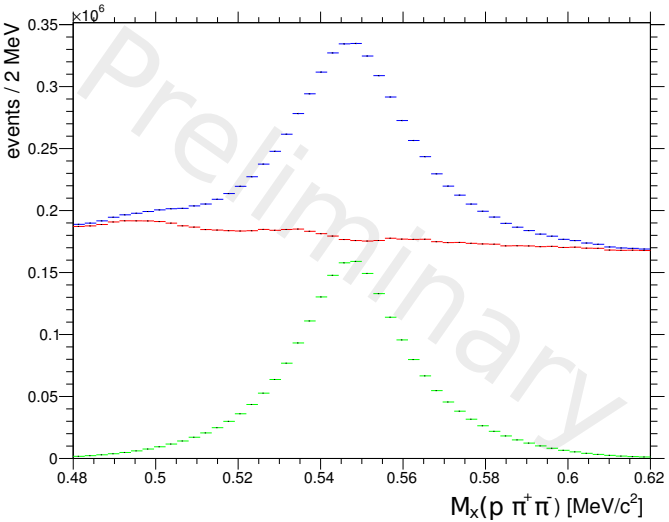
Huge background contribution.

Weighted Missing η Mass Spectrum

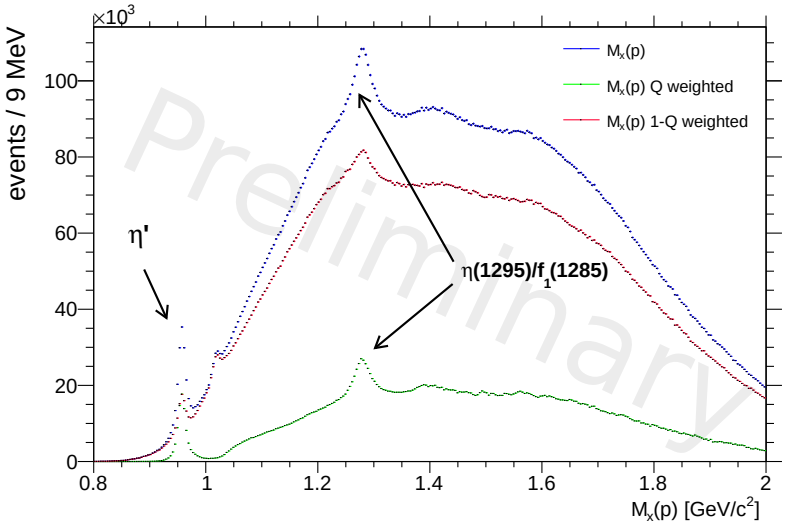
Metric:

- Angular Distributions
- E_γ
- $m^2(\pi^+\pi^-\eta)$

- Unweighted
- Q weighted
- 1-Q weighted

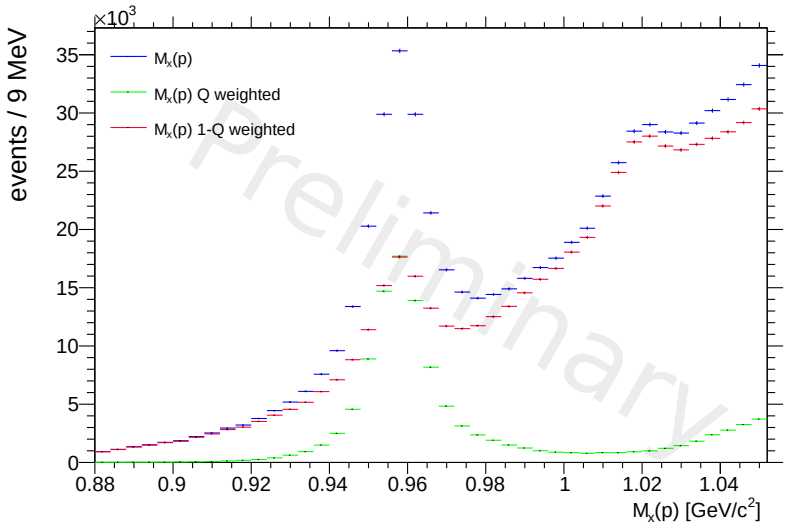


Weighted $\pi^+\pi^-\eta$ Invariant Mass Spectrum



Peaking background, e.g. $\eta' \to \pi^0\pi^0\eta(\pi^+\pi^-\pi^0)$

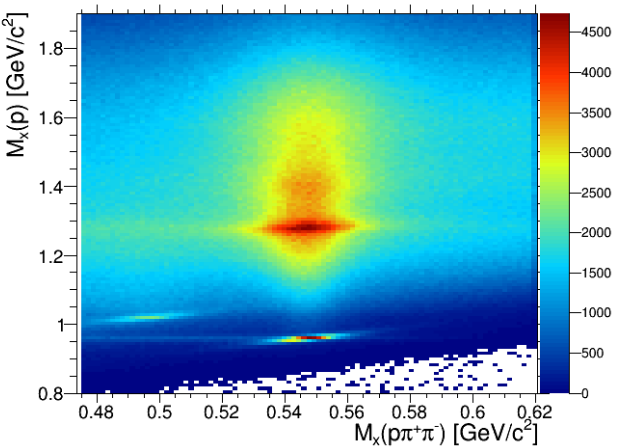
Weighted $\pi\pi\eta$ Invariant Mass Spectrum



Contribution of $\gamma p \rightarrow p\Phi \rightarrow pK_sK_L \rightarrow p\pi^+\pi^- m_{miss}$

$M_x(p)$ Vs. $M_X(p\pi^+\pi^-)$

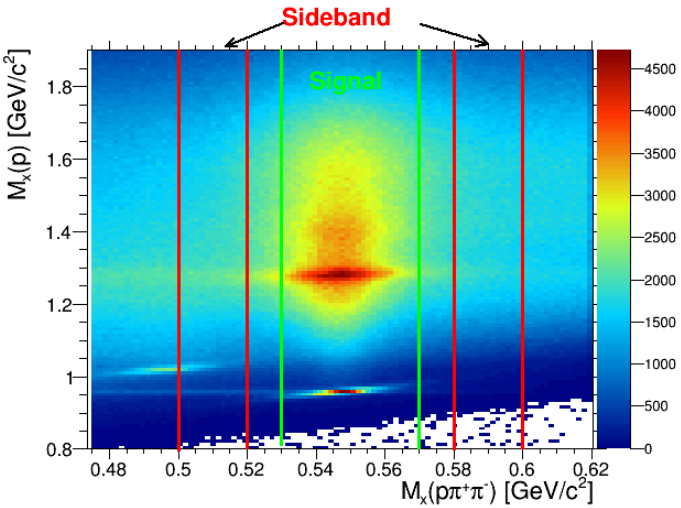
Horizontal Band crossing under η' and $\eta(1295)/f_1(1285)$



Possible background channels:

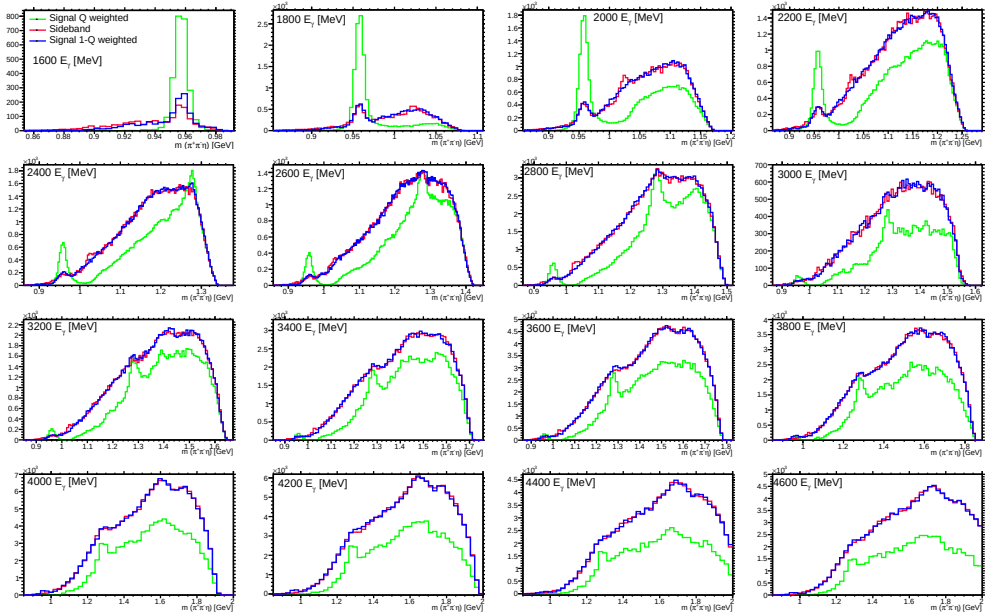
- $\Phi \rightarrow K_s(\pi^+\pi^-)K_L(m_{miss})$
- $\eta' \rightarrow \pi^0\pi^0\eta(\pi^+\pi^-\pi^0)$
- $f_1(1285) \rightarrow 4\pi$
- $\eta(1295) \rightarrow \pi^0\pi^0\eta(\pi^+\pi^-\pi^0)$
- ...

$M_x(p)$ Vs. $M_X(p\pi^+\pi^-)$

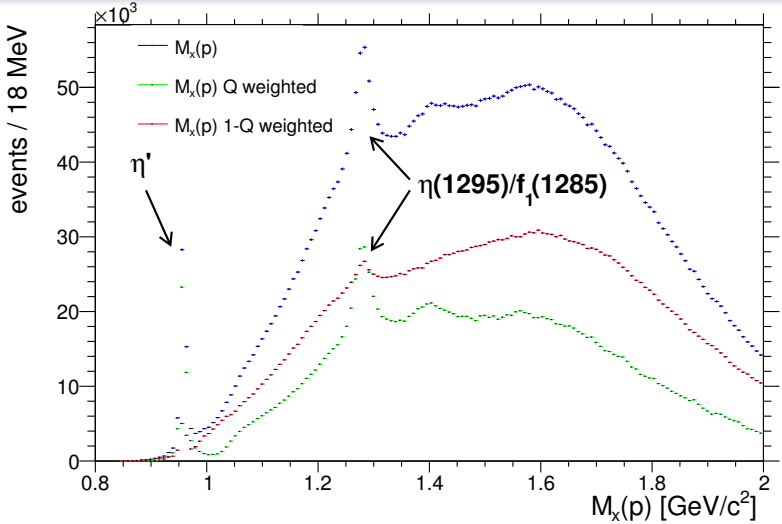


Selecting a band with signal events and two bands for sideband each half the width of the signalband

$M_X(p)$ for Signalband and Sidebands in bins of E_γ



Weighted $\pi\pi\eta$ Invariant Mass Spectrum



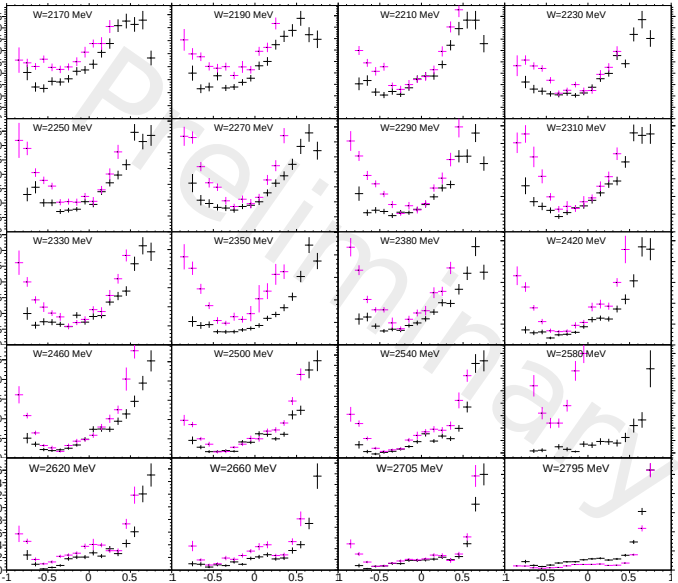
1-C kinematic fit with η mass constraint

$prob > 0.01$

Summary

- Study of excited η mesons in $\gamma p \longrightarrow p\pi^+\pi^-\eta$
  - Sample of $18.6 \cdot 10^6$ reconstructed events
  - Successfully applied event-based background suppression to η' and missing η
  - Observed an enhancement at $\approx 1295\,\mathrm{MeV/c^2}$ and at $\approx 1417\,\mathrm{MeV/c^2}$
- Extracted $\gamma p \longrightarrow p\eta'$ differential cross section from g12 data
  - Good agreement with previous study, for Q-factor method on η'
  - Small discrepancies for Q-factor method on $M_x(p\pi^+\pi^-)$ (under investigation)
- Next steps:
  - Further investigation of the nature of the enhancement at 1290 $\mathrm{MeV/c^2}$
  - Extract (upper limit) of $\eta(1405)$ production cross section

Differential Cross Section of $\gamma p \rightarrow p\eta'$



Differential cross section of $\gamma p \rightarrow p\eta'$:

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Q-factor mehtod for η