Towards the Electromagnetic Transition Form Factor of the η' meson with g12 and CLAS12

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Hadron Spectroscopy Working Group

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IKP-1

Transition Form Factors

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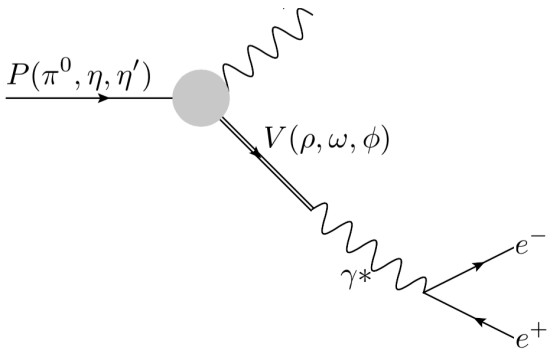
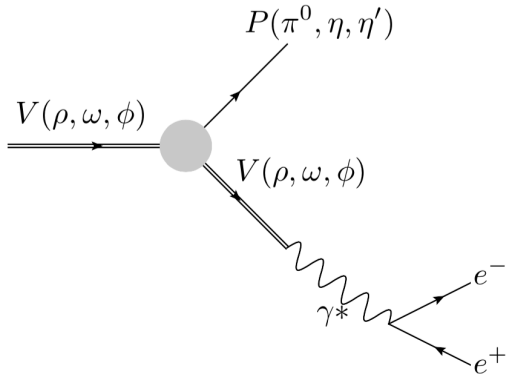
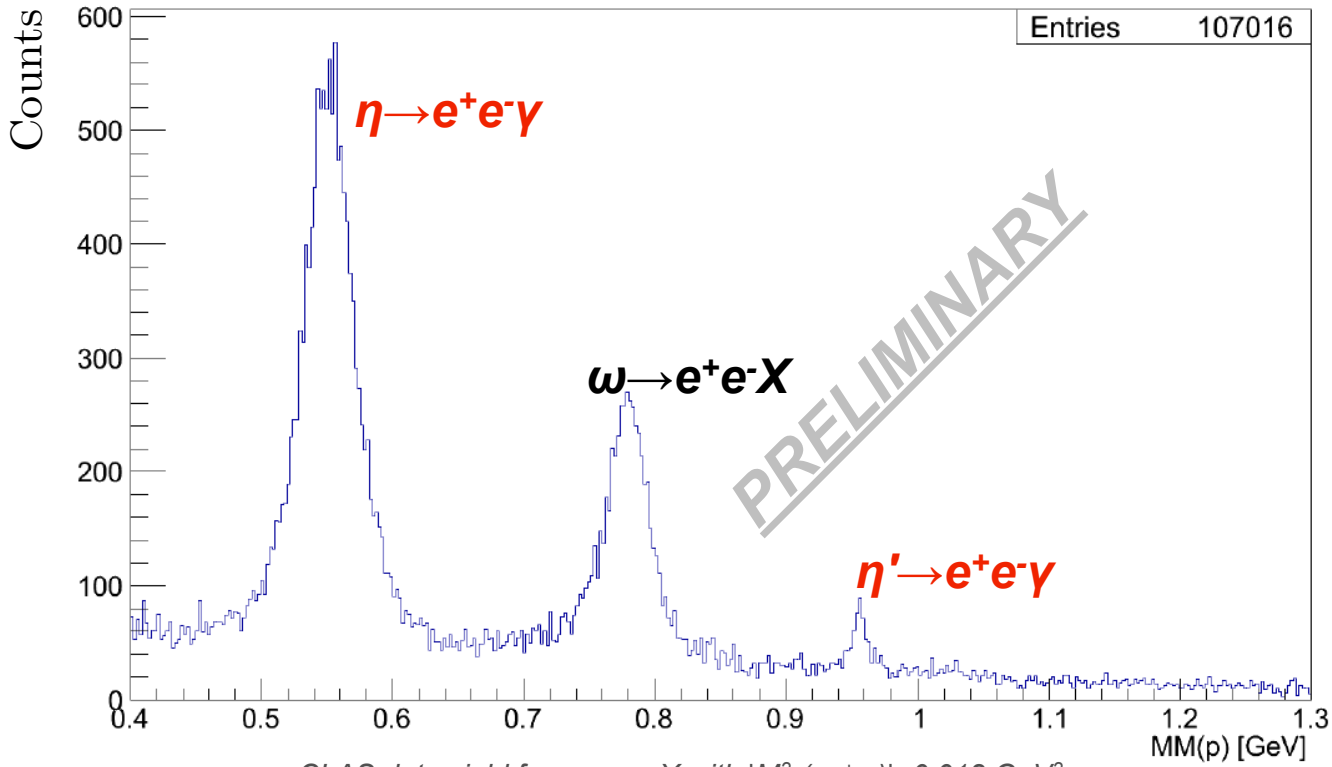




Motivation:

- Transition form factors provides insight into the meson charge radius, $\langle r \rangle$.
- Ratio of η/η' form factors provides information on η/η' mixing angle.
- For ω there is a discrepancy between the measurement and the VMD model.
- The η form factor is needed to interpret the muon g-2 experiment.

η, ω, η' Yield

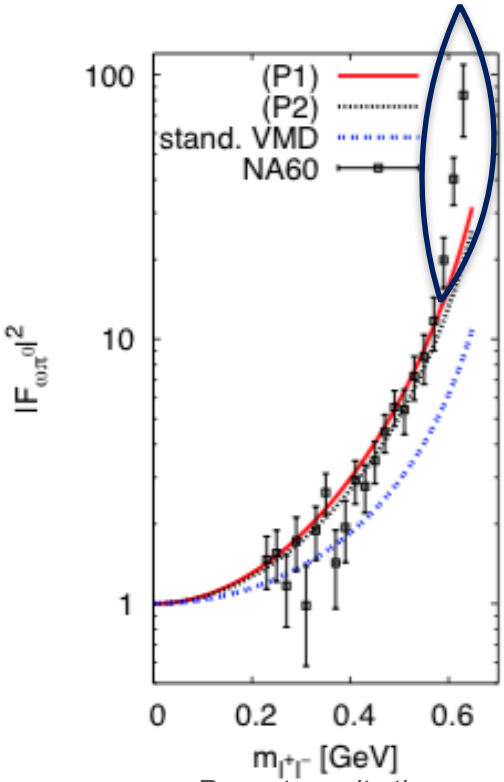


CLAS data yield from γp→pX with $|M^2_X(pe^+e^-)|<0.018$ GeV²
$M_E(pe^+e^-)>0.075$ GeV and electron/positron ID

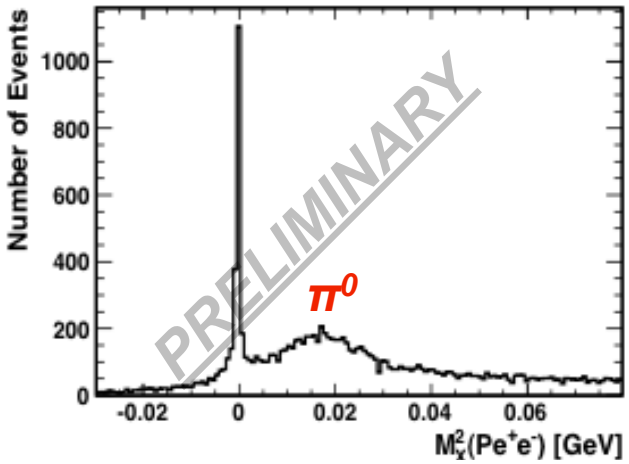
Goal: Measuring transition form factors

ω Transition Form Factor

$$\frac{d\Gamma_{\omega\to l^+l^-\pi^0}}{dq^2 d\Gamma_{\omega\to\pi^0\gamma}} = \frac{\alpha}{3\pi q^2}\left(\left(1+\frac{q^2}{m_\omega^2-m_{\pi^0}^2}\right)^2 - \frac{4m_\omega^2 q^2}{m_\omega^2-m_{\pi^0}^2}\right)^{\frac{3}{2}}\left(1-\frac{4m_l^2}{q^2}\right)^{1/2}\left(1+\frac{2m_l^2}{q^2}\right)|\text{Q.E.D}$$

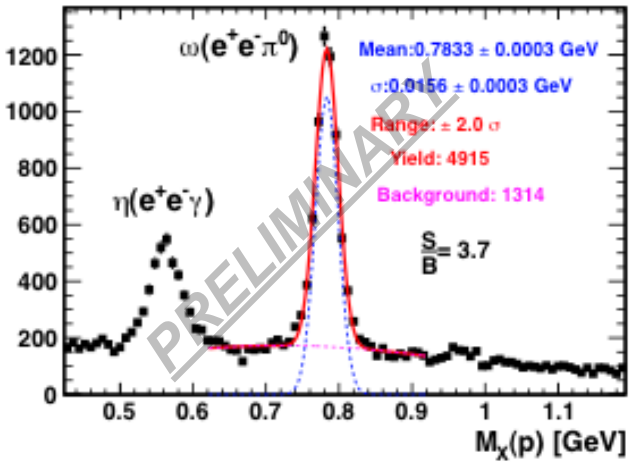


Recent results the ω transition form factor. Image Source: Conference Proceedings



CLAS data yield from $\gamma p \to p e^+ e^- X$ with $M_x(p) = M_\omega \pm 0.031$ GeV

CLAS data yield from $\gamma p \to p X$ with $M^2_x(pe^+e^-) = M^2_{\pi 0} \pm 0.01$ GeV^2



Status of η' charge radius

Current BESIII and CLAS data sets do not have enough statistics to determine which theoretical model fits the η′→ charge radius		
	$\langle r \rangle$	Number of events
BESIII (η′→γe+e−)	1.60 ± 0.17(stat) ± 0.08(sys) GeV^{-2} [1]	864
CELLO (η′→γμ+μ−)	1.7 ± 0.4 GeV^{-2} [2]	75
CLAS (η′→γe+e−)	TBD	89

Dispersion	$1.53^{+0.15}_{-0.08}$ GeV^{-2}	
ChPT	1.6 GeV^{-2}	
VMD	1.45 GeV^{-2}	

Current statistical error cannot discern the correct theoretical model

[1]M. Ablikim et al., Phys.Rev. D92 (2015) 012001
[2]R. I. Dzhelyadi et al., Phys. Lett. B 88, 379 (1979)

η′→γee : analysis

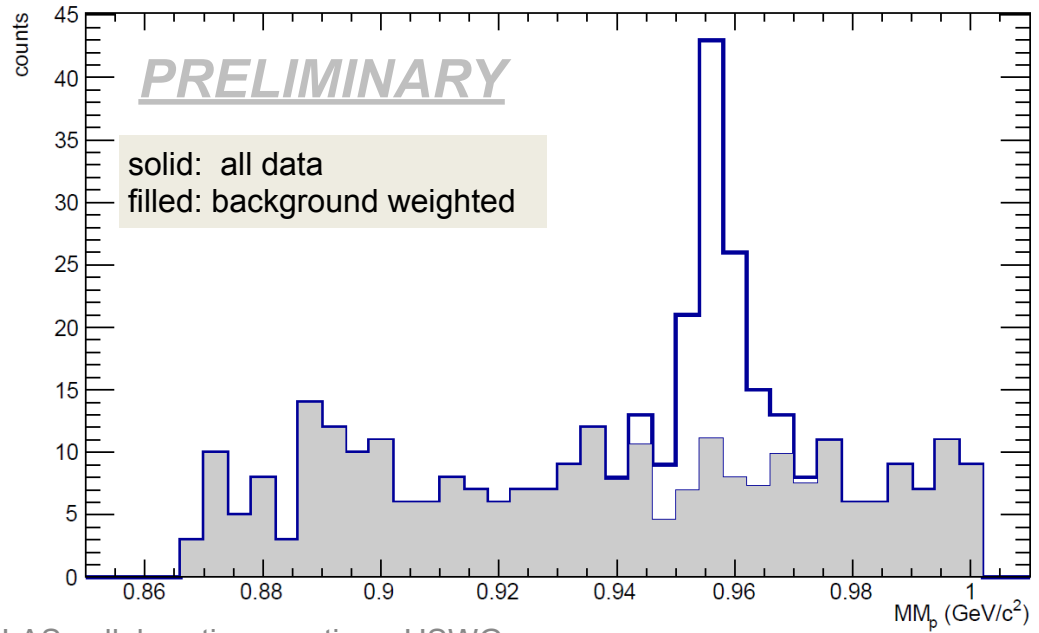
- lepton skim MK: IsLepG7_g12.root
- cuts:

(1)	pip_IsLepG7==1 && pim_IsLepG7==-1	g7 leptons (CC&EC cut)
(2)	NProt==1	final state proton
(3)	abs(pip_Beta -1.)<0.05 && abs(pim_Beta -1.)<0.05	ToF electron candidates
(4)	MM2P>=0.75 && MM2P<=1.	MMp : eta‘ mass window
(5)	MM2PEpEm<0.01 && MM2PEpEm>-0.01	MMpee : massless or no missing particle
(6)	MEPEpEm>0.2	MEpee : missing particle (has energy)
(7)	abs(pip_vx*pip_vx+pip_vy*pip_vy)<4.	vertex cut for positron
(8)	abs(pim_vx*pim_vx+pim_vy*pim_vy)<4.	vertex cut for electron

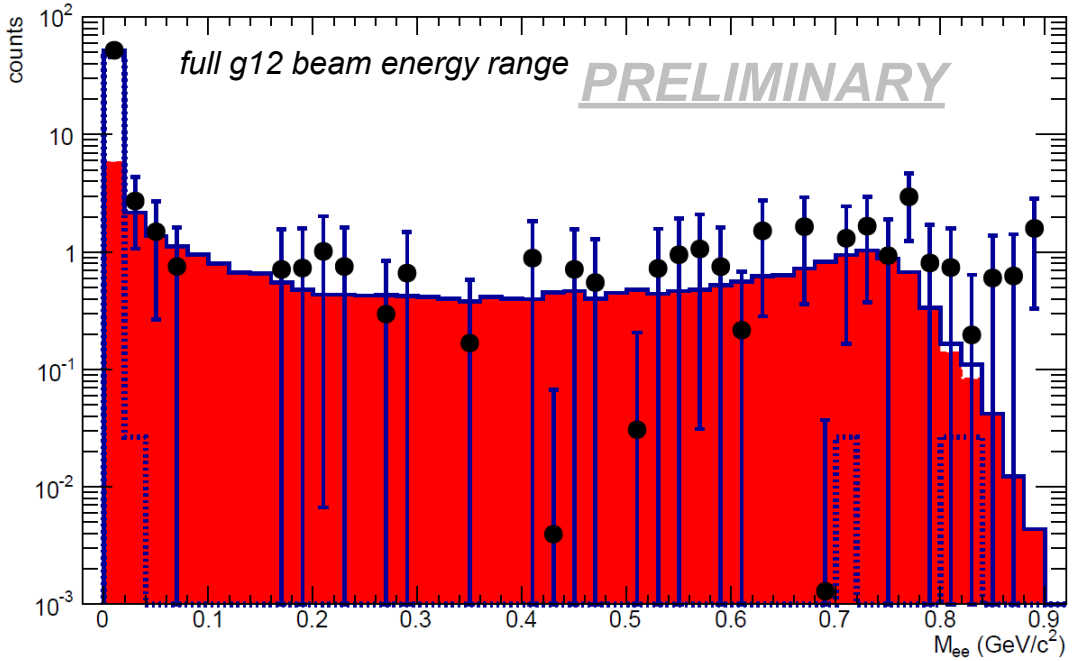
- g12 fiducial cuts
- event efficiency
- q-factor signal extraction

evaluate <u>smooth background</u>
event-by-event

➢ 359 event candidates
➢ 82 events (signal weight)
full g12 beam energy range



η′→γee : M_{ee} distribution



evaluate in-peak background via invariant mass distribution

sole background candidate: external conversion in the target

symbols:	data (signal weight)
filled:	η′→γee simulation
dotted:	η′→γγ simulation
solid:	summed simulations

fit to data, range (0.,0.1)
FCN=0.298654 FROM MIGRAD STATUS=CONVERGED 34 CALLS 35 TOTAL
EDM=3.39438e-020 STRATEGY= 1 ERROR MATRIX ACCURATE

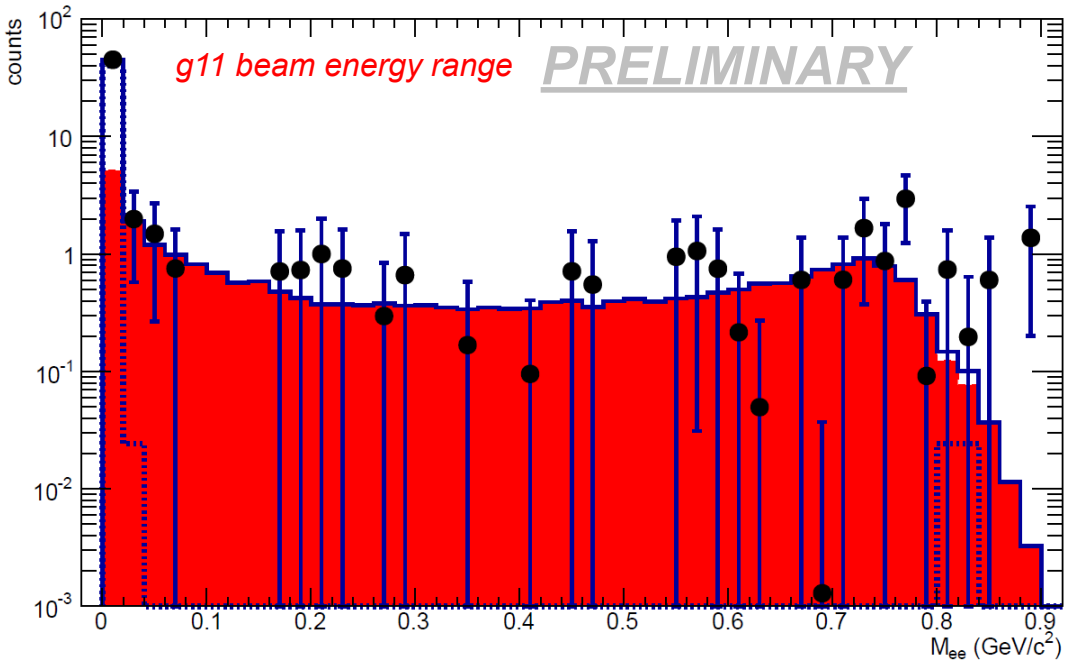
EXT PARAMETER NO.	NAME	VALUE	ERROR	STEP SIZE	FIRST DERIVATIVE
1	p0	9.90865e+003	4.62091e+003	1.92653e+000	4.30050e-014
2	p1	3.77484e+005	6.29736e+004	3.20771e+000	4.02354e-015

rel BR = p0/p1 = 0.0262492 +- 0.013001 (fit errors)

BESIII (2.13 +- 0.09(stat) +- 0.07(sys)) x 1e-2

next step: kinematic fit improved missing mass cuts will affect large-mass end

η′→γee : M_{ee} distribution



evaluate in-peak background via invariant mass distribution

sole background candidate: external conversion in the target

symbols:	data (signal weight)
filled:	η′→γee simulation
dotted:	η′→γγ simulation
solid:	summed simulations

fit to data, range (0.,0.1)
FCN=0.130833 FROM MIGRAD STATUS=CONVERGED 34 CALLS 35 TOTAL
EDM=7.68571e-019 STRATEGY= 1 ERROR MATRIX ACCURATE

EXT PARAMETER NO.	NAME	VALUE	ERROR	STEP SIZE	FIRST DERIVATIVE
1	p0	9.24417e+003	4.60182e+003	1.79231e+000	-2.07859e-013
2	p1	3.45819e+005	6.21834e+004	2.99290e+000	-1.93127e-014

rel BR = p0/p1 = 0.0267312 +- 0.0141485 (fit errors)

BESIII (2.13 +- 0.09(stat) +- 0.07(sys)) x 1e-2

next step: kinematic fit improved missing mass cuts will affect large-mass end

cross check: angular distribution

signal events -> cross section dsigma/dcosthcm
in limited beam energy range
compare to g11

.... not yet

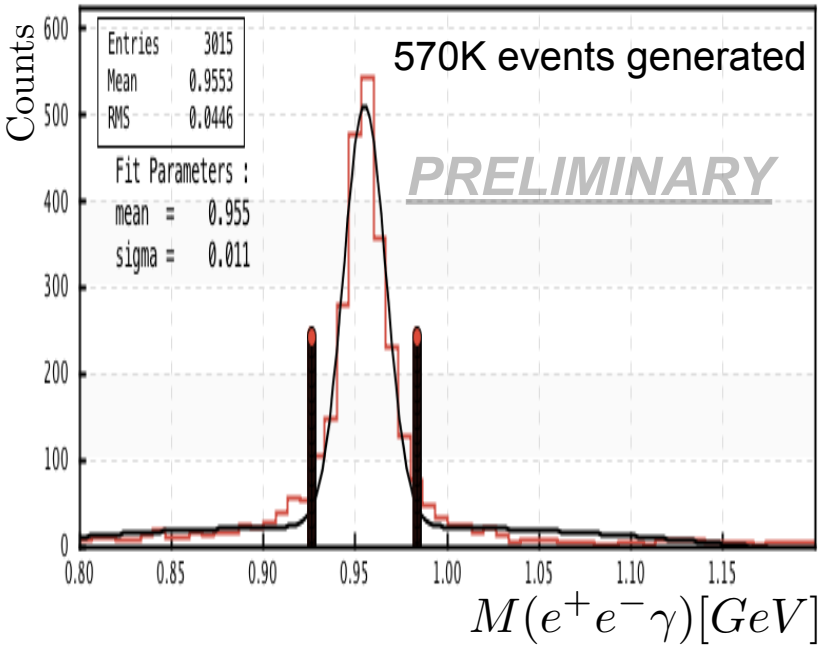
CLAS12 e^+e^- pair physics

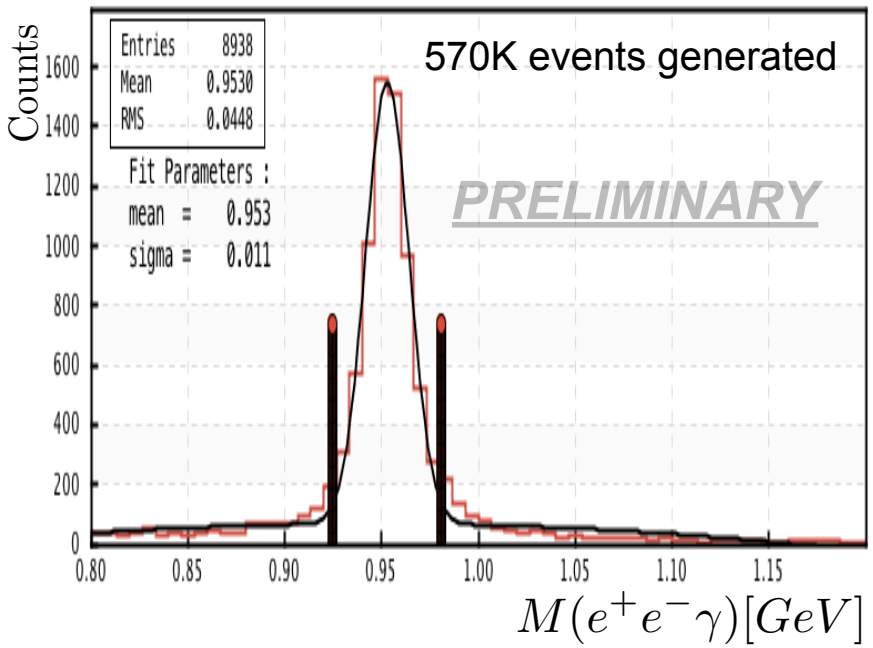
Electromagnetic structure of mesons and baryons. Currently we are benchmarking the $\eta' \rightarrow \gamma e^+e^-$ decay Here is a list of initial physics to be studied	
Meson	Baryon
$\eta' \rightarrow \gamma e^+e^-$	$(\Delta \rightarrow N e^+e^-)$
$\omega \rightarrow \pi^0 e^+e^-$	$\Lambda \rightarrow n e^+e^-$ $\Lambda(1520) \rightarrow \Lambda e^+e^-$
$J/\psi \rightarrow \pi^0 e^+e^-$	$\Sigma^0 \rightarrow \Lambda e^+e^-$ $\Sigma^+ \rightarrow p e^+e^-$

CLAS $\xi(e^+e^-)/\xi(\pi^+\pi^-)$ can be range 10^5 - 10^{11}
CLAS e^+e^- efficiency (ε) range 1 - 10^{-2}

CLAS12 η' Measurement

Using CLAS12 simulation and reconstruction software
(GEMC & coatjava-1.0)

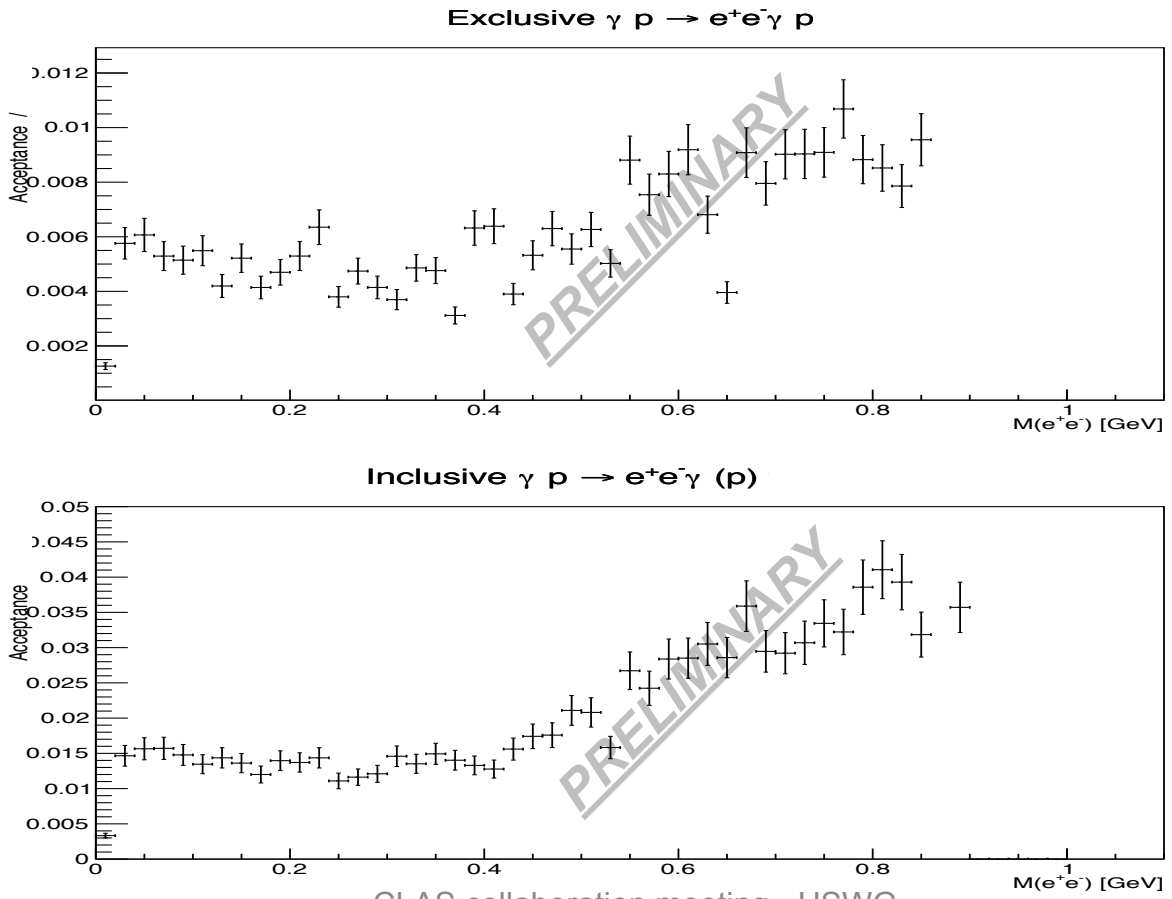




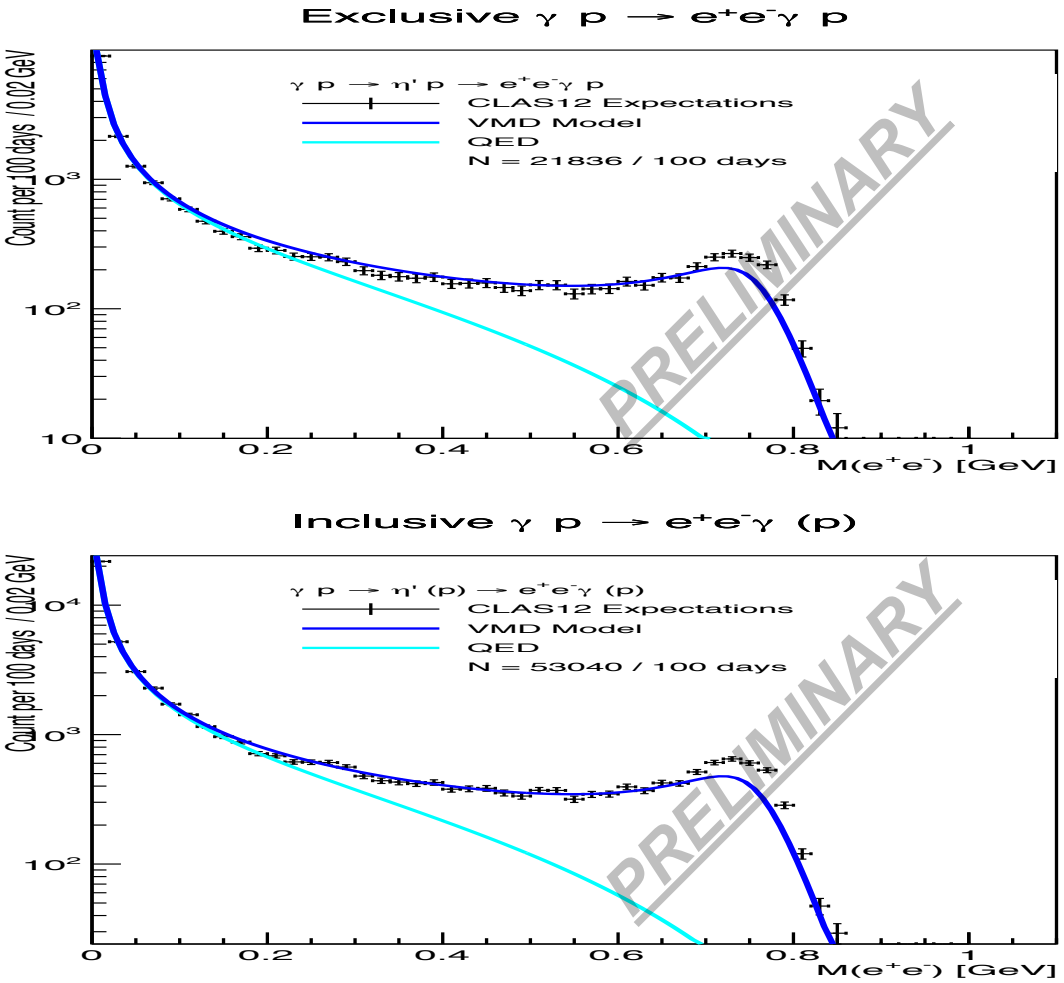
Fully Exclusive γp→η'p→ γe+e−p	Inclusive γp→η'(p)→ γe+e−(p)

CLAS12 η' Acceptance

e^+e^- Acceptance



CLAS12 η' Rates



Within 100 days of beam-time CLAS12 can measure the η' transition form factor with a statistical uncertainty ~1%

Summary

- Current statistics of CLAS data enables measurements of transition form factor for ω but not η'
- The η' branching ratio measurement is consistent with recent BESIII result
  - Cross check of angular distribution underway
- Future CLAS12 data:
  - Hadron transition form factors.
  - Branching ratios of meson conversion decays.
  - Fundamental properties of hadrons
- Currently seeking applicant for PhD for η transition form factor measurement

END

$\eta' \rightarrow \gamma ee$: MM_p distribution

solid line: data signal
filled histo: simu par(0)*gee+par(1)*gg