Photoproduction of the $f_2(1270)$ meson using the CLAS g12 data

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Motivation: what is the nature of the $f_2(1270)$?

- Three possible scenarios:
  1. Pure quark-model (q-qbar) state with $J^{PC}=2^{++}$: PDG and LQCD
  2. Dynamically generated (ρ–ρ molecule): Theory model by Oset et al. (2009)
  3. Mixture with tensor glueball (2^{++}): Theory by Shen and Yu (1989)

- Calculations available for photoproduction:
  1. Xie and Oset : Eur. Phys. J (2015) compared to g11 data ($\pi^+\pi^-$) from 2009
  2. JPAC: Regge-exchange model, developed for $a_2(1320)$ photoproduction

Quark model description of the $f_2(1270)$

Table of Quark Model states (C. Meyer lecture notes)

State	S	L	J	P	C	J^{PC}	*Mesons*				*Name*
$^1S_0$	0	0	0	$-$	$+$	0^{-+}	π	η	η'	K	pseudoscalar
$^3S_1$	1	0	0	$-$	$-$	1^{--}	ρ	ω	ϕ	K^*	vector
$^1P_1$	0	1	1	$+$	$-$	1^{+-}	b_1	h_1	h_1'	K_1	pseudo–vector
$^3P_0$	1	1	0	$+$	$+$	0^{++}	a_0	f_0	f_0'	K_0^*	scalar
$^3P_1$	1	1	1	$+$	$+$	1^{++}	a_1	f_1	f_1'	K_1	axial vector
$^3P_2$	1	1	2	$+$	$+$	2^{++}	a_2	f_2	f_2'	K_2^*	tensor

Tensor meson nonet: $J^{PC} = 2^{++}$ includes: $a_2(1320)$, $f_2(1270)$ and $f_2'(1525)$.

Crystal Barrel Collab. (Phys. Lett. B, 1999)

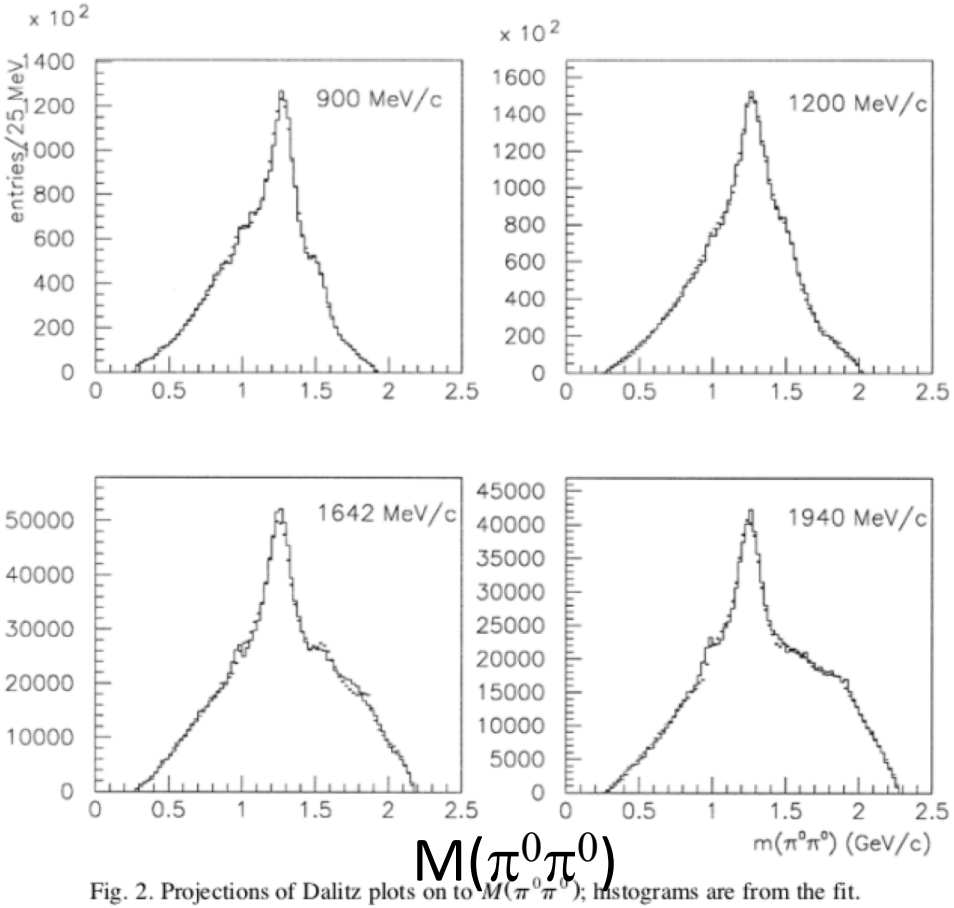
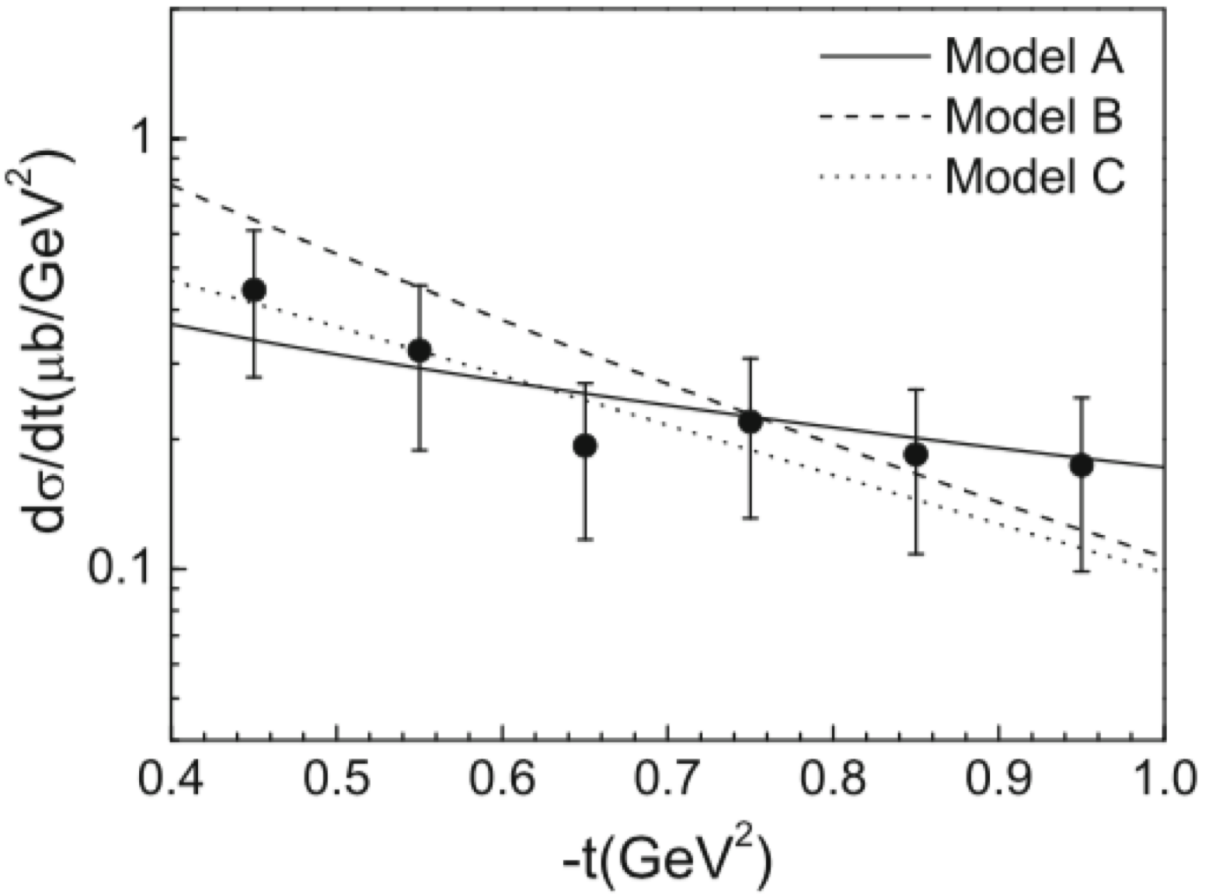


Fig. 2. Projections of Dalitz plots on to $M(\pi^0\pi^0)$; histograms are from the fit.

What we measured at CLAS

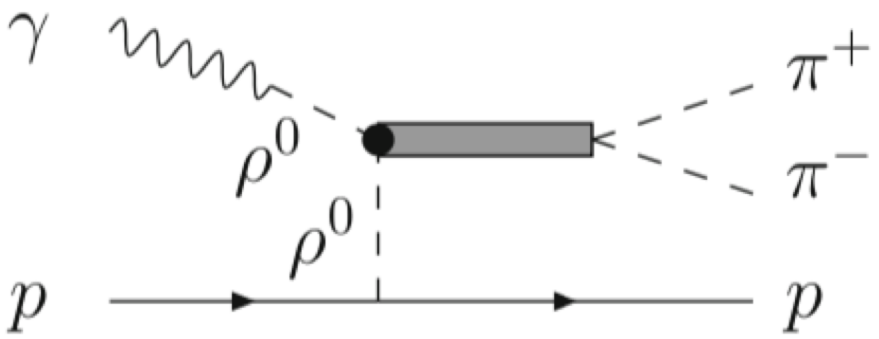
- Reaction: γ p → f_2 p → π^0 π^0 p → 4γ p
  - $2\pi^0$ decay restricted to $J^{PC} = 0^{++}$ and 2^{++} (due to identical particles)
- Data set: g12, proton target with E_g = 3.6-5.4 GeV
- Analysis procedures: same as for η π^0 → 4γ (approved analysis)
- Previous photoproduction measurements:
  - 1976 Daresbury: backward-angle ρ and f_2 photoproduction (2.8-4.8 GeV)
  - 1992 OMEGA (CERN): $f_2(1270)$ and $f_0(980)$, various beams (65-175 GeV)
  - 2009 CLAS: Battaglieri et al., g11 data, $\pi^+\pi^-$p final state, PWA extraction
    - Large uncertainty for $f_2(1270)$ due to background from ρ →$\pi^+\pi^-$ (large width)

CLAS g11 data compared with theory model



Models A,B,C: ρNN vertex vector or vector+tensor; propagator: ρ-only or Regge trajectory.

Xie and Oset, Eur. Phys. J. **51**, 111 (2015).



Model: vector meson - vector meson interaction based on local hidden gauge Lagrangians, which shows poles in the scattering plane. The large ρ–ρ interaction creates strong binding for J=2.

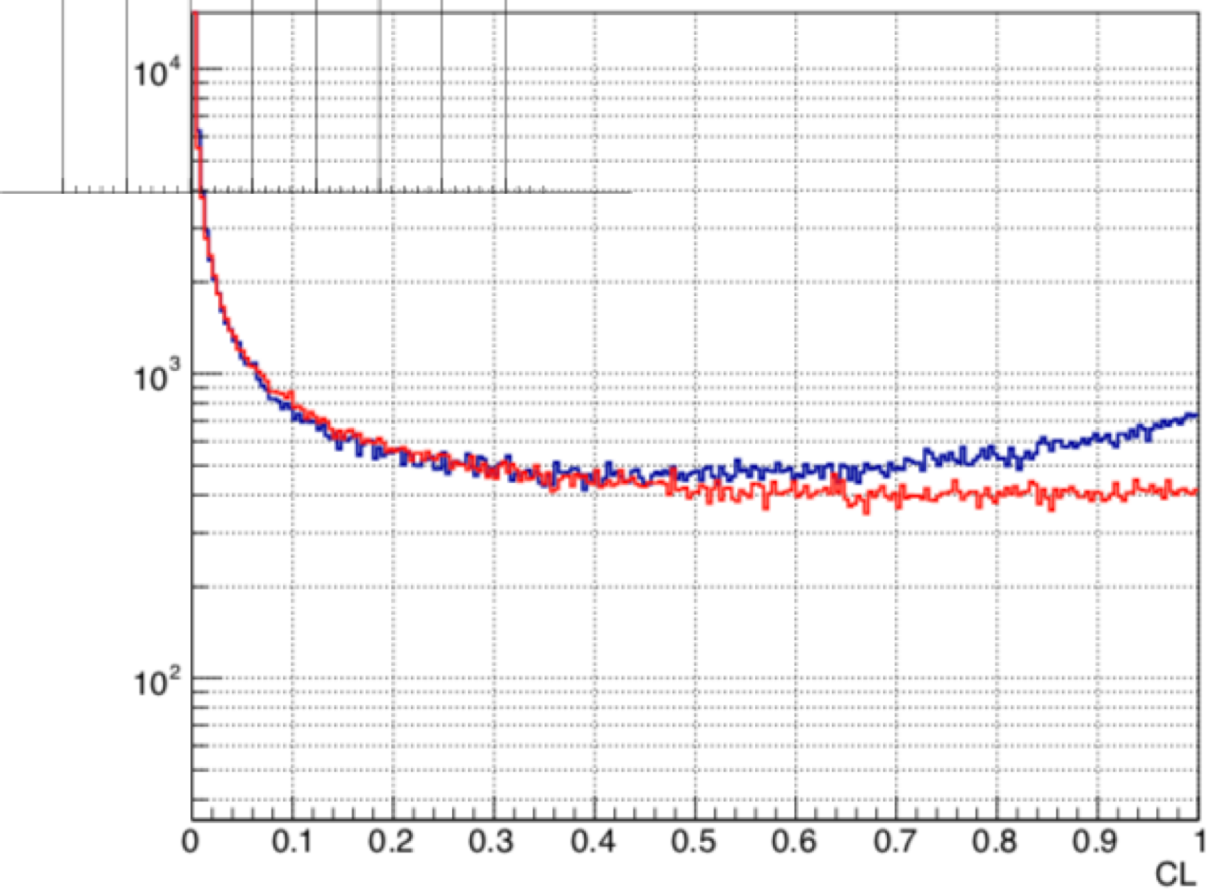
Basic idea: $f_2(1270)$ is a ρ–ρ "molecule".

g12 analysis: overlap with $\eta\pi^0$ analysis

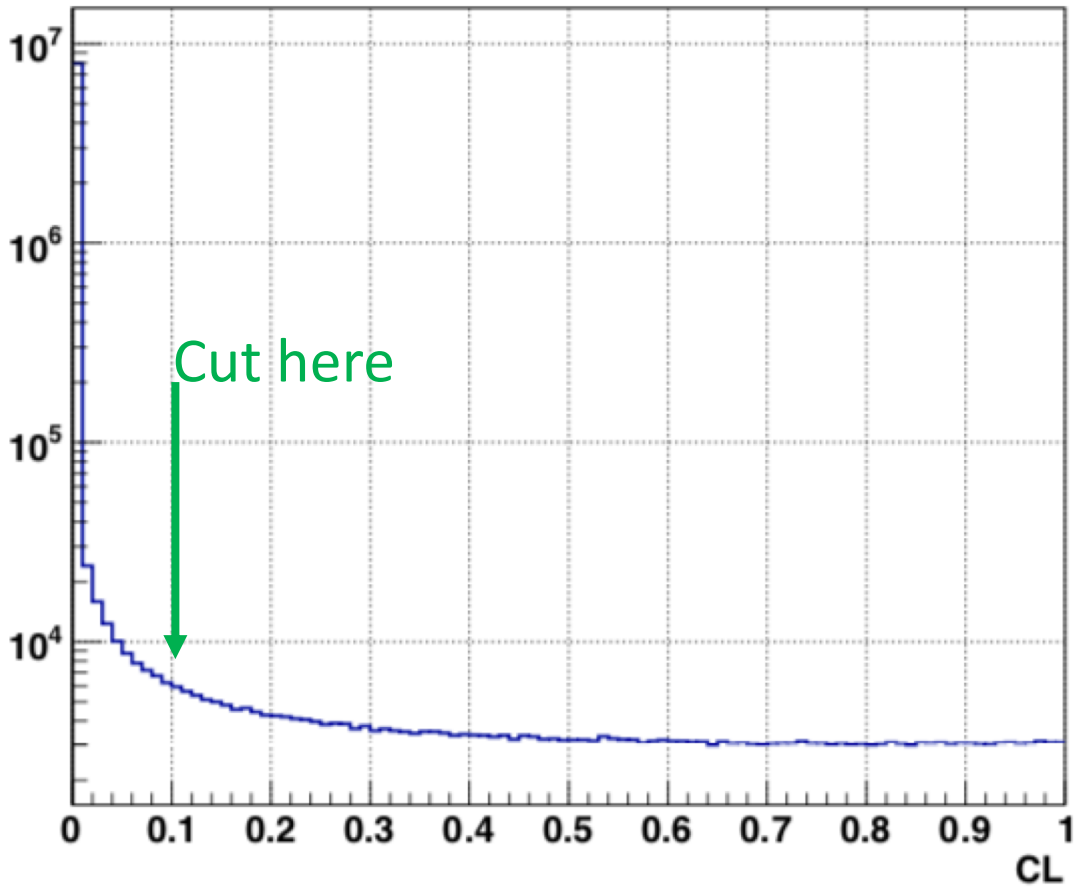
- Same run selection, same event skim (exclusive: 4γ + proton)
- Same 4-C kinematic fit
- Same trigger efficiency corrections
- Same Monte Carlo procedure (but now $\pi^0\pi^0$ event generator)
- All approved g12 procedures (momentum, E_γ corr., etc.) are followed

- Unique to this analysis:
  - 2γ Mass cuts to isolate $\pi^0\pi^0$ final state
  - Peak fitting to get $f_2(1270)$ yield
  - Systematic studies

Kinematic fitting



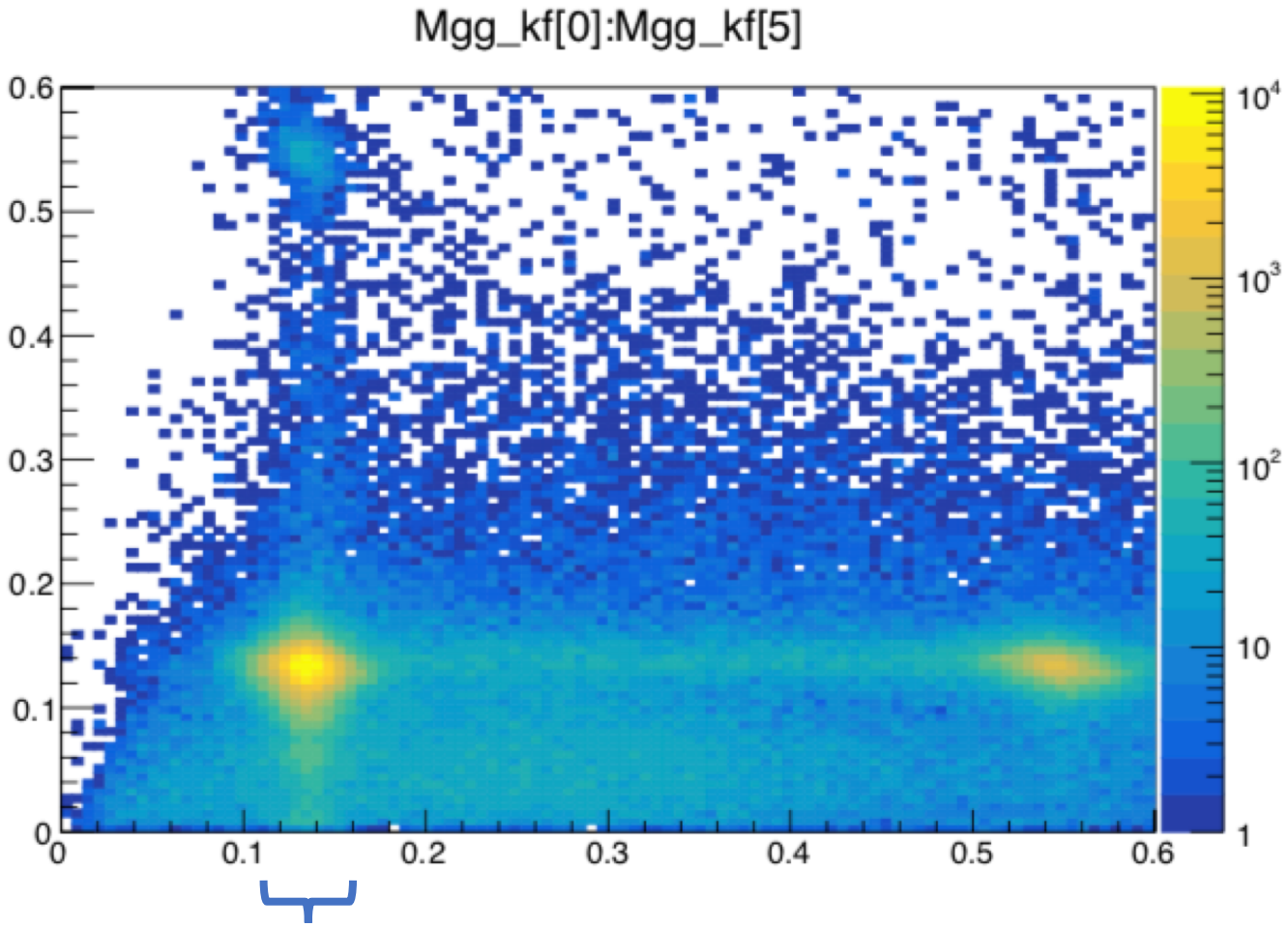
Tuning: Confidence Level for pγγ final state



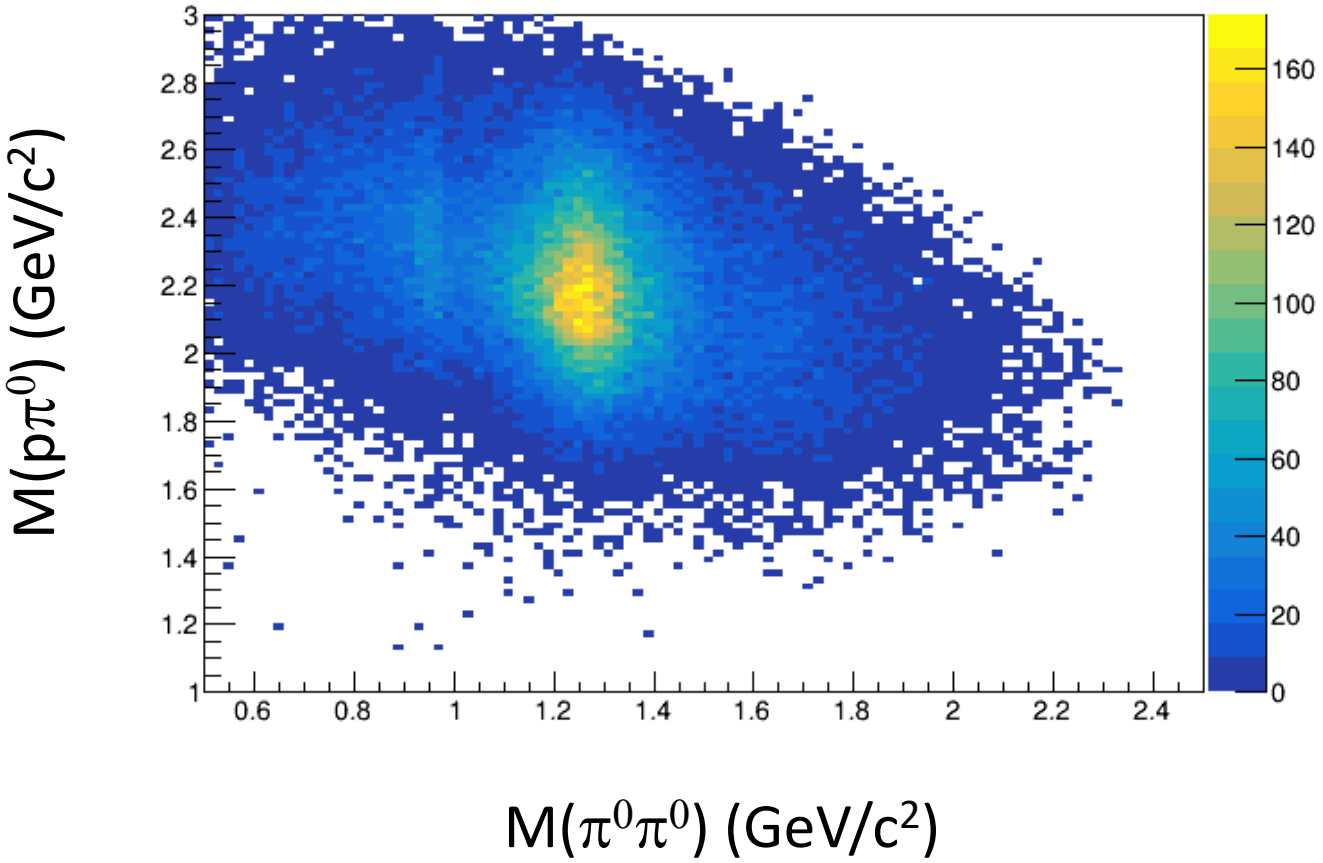
Applied: Confidence Level for pγγγγ final state

Ordered photon pairs: M(2γ) vs M(2γ')

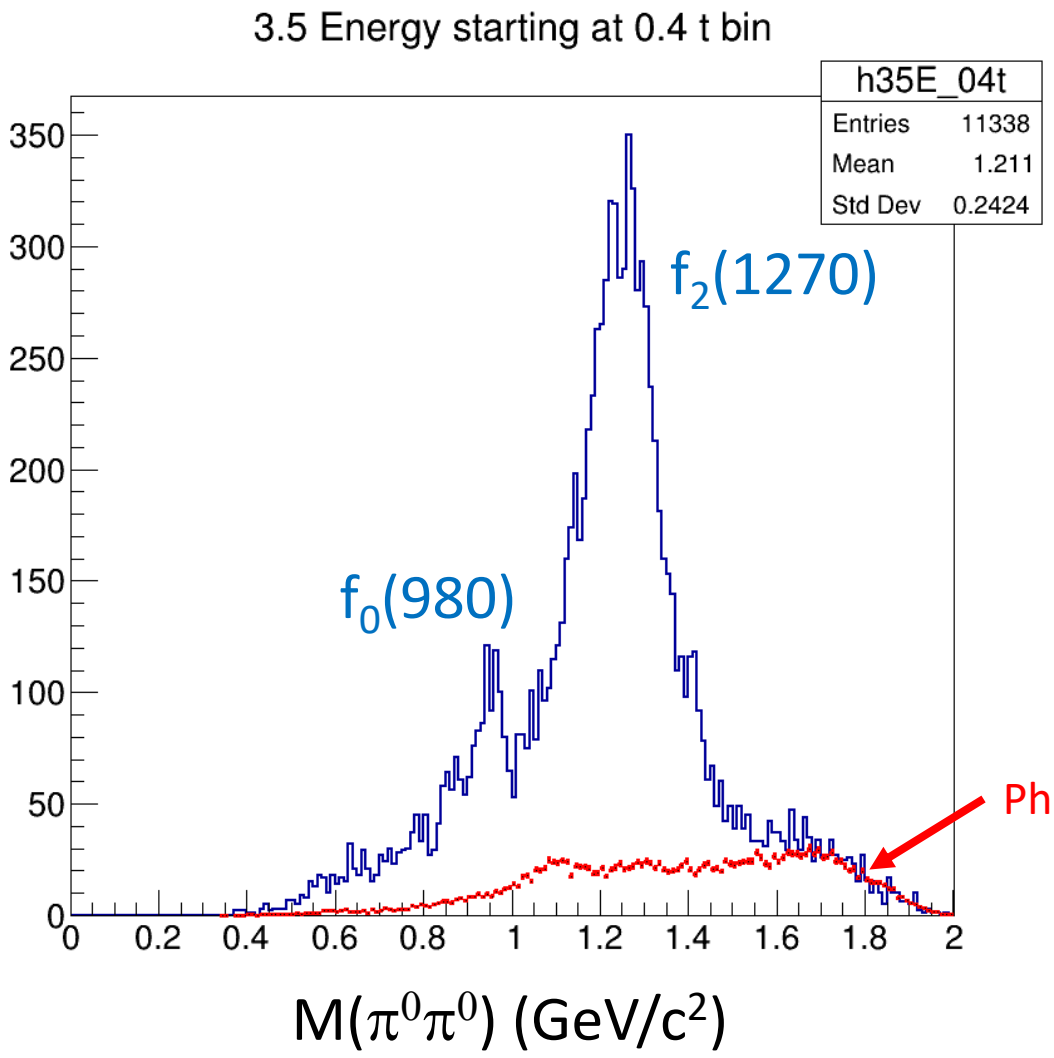
Cut on 3σ
(both axes)



E_γ > 3.5 GeV to remove N*'s (with M<2 GeV)



One kinematic bin: E_γ=3.5-4.5 and –t=0.4-0.7



Signal is very clean!

This is different from the $\pi^+\pi^-$ channel of g11

Fits to get the $f_2(1270)$ yield

E_γ = 3.6-4.0 GeV

E_γ = 4.0-4.4 GeV

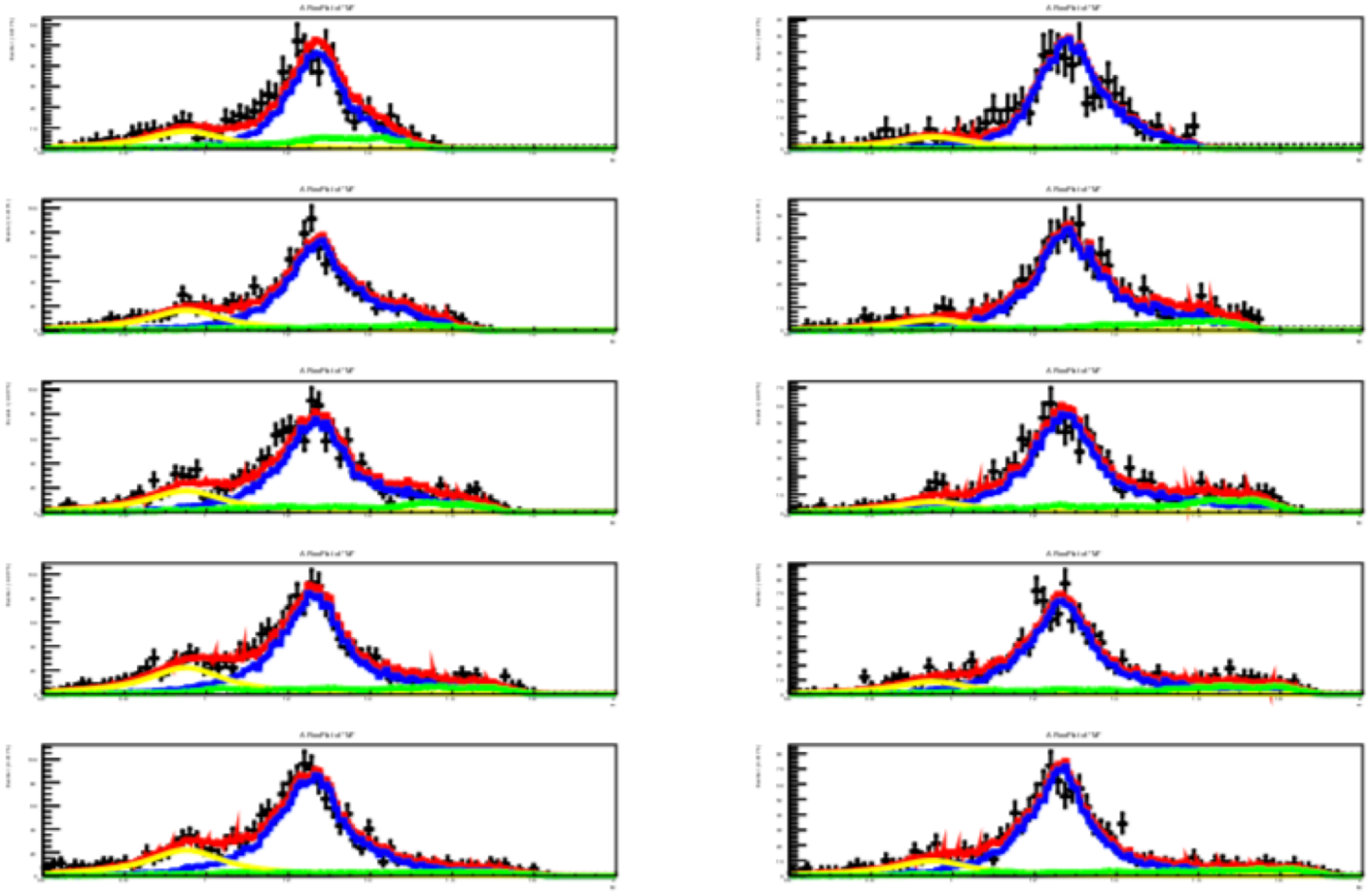
-t = 0.1-0.2

-t = 0.2-0.3

-t = 0.3-0.4

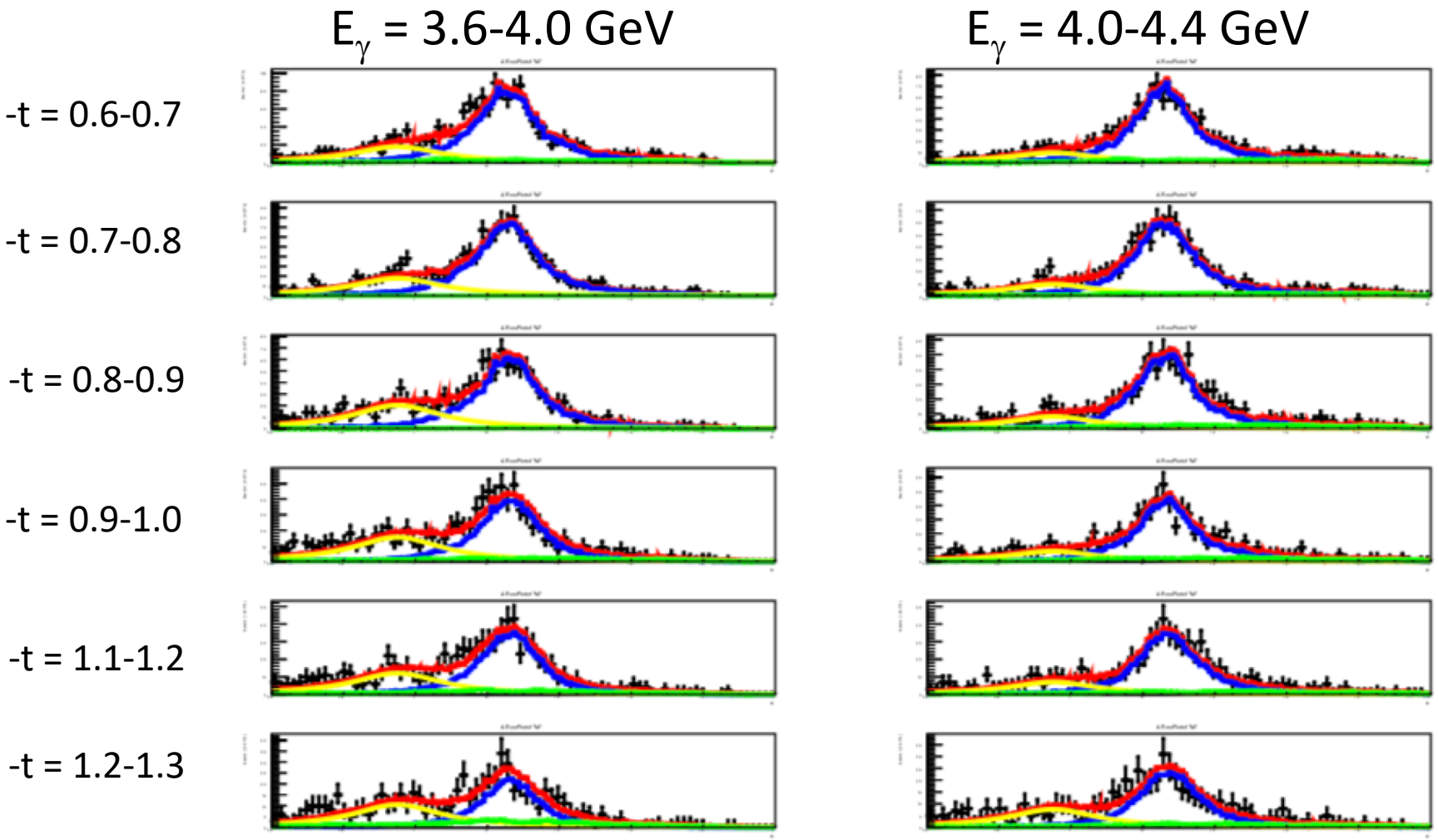
-t = 0.4-0.5

-t = 0.5-0.6

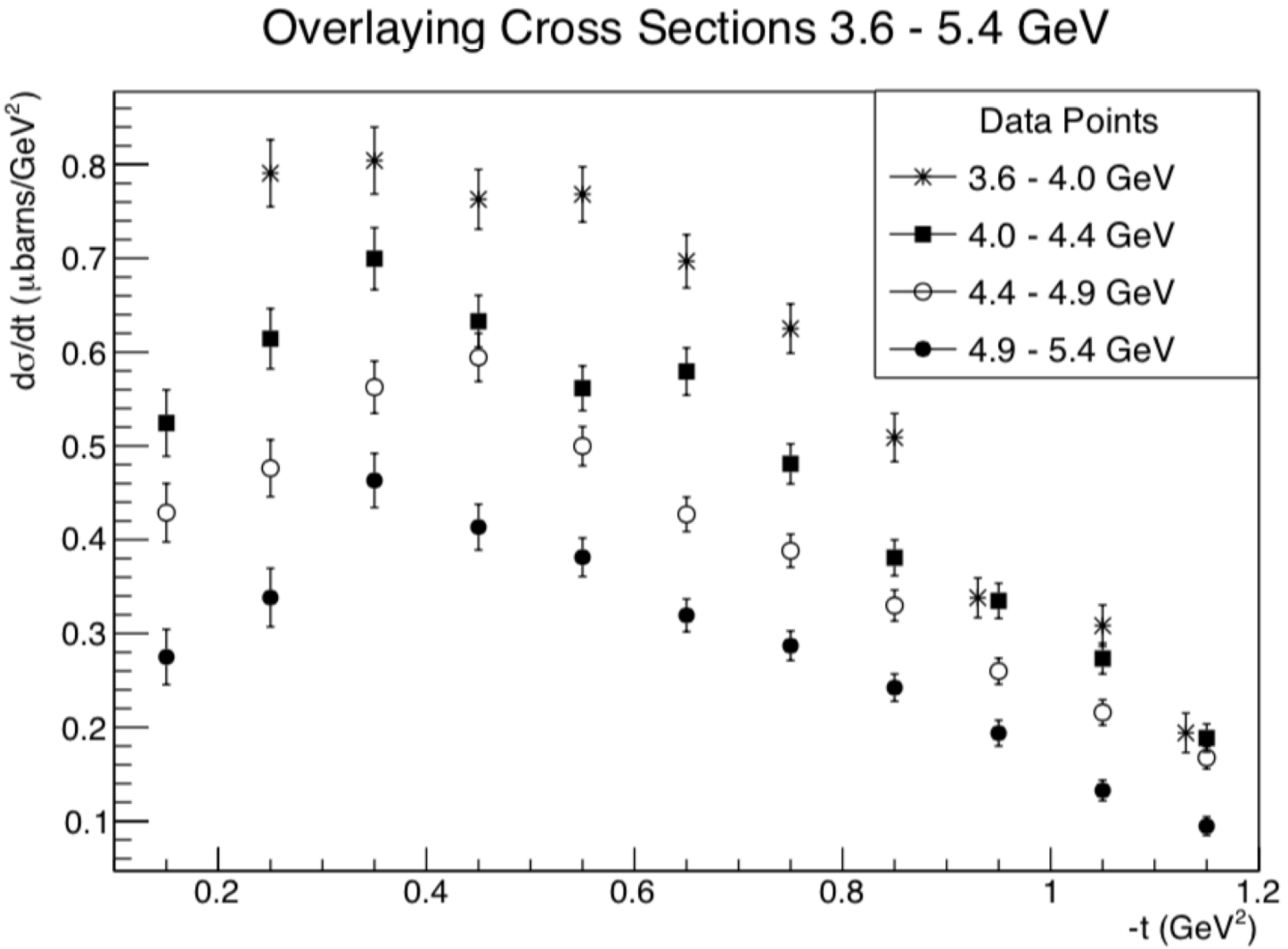


$M(\pi^0\pi^0)$ (GeV/c^2)

More fits


E_γ = 3.6-4.0 GeV
E_γ = 4.0-4.4 GeV
-t = 0.6-0.7
-t = 0.7-0.8
-t = 0.8-0.9
-t = 0.9-1.0
-t = 1.1-1.2
-t = 1.2-1.3

Cross sections from g12 analysis



Compared with g11, where PWA was needed, the error bars (statistical) are about 5 times smaller.

The turn-over at –t=0.35 indicates the presence of axial-vector exchange in the Regge calculation.

Systematic Uncertainties

Variation of Cut	Percent change (average)
Target length/density	0.5% (g12 procedures note)
Photon Flux	5.7% (g12 procedures note)
Trigger Efficiency	2.8% ($\eta\pi^0$ analysis note)
Acceptance (f_2 generated flat in phase space)	2-3%
Kinematic Fit (CL 10% or 15%)	2.0%
Mass cuts on p0 (2.5σ to 3.5σ)	2-4%
Fitting function (with/without $f_0(1370)$ included)	4.1%
$f_2(1270)$ B.R. uncertainty	2.2% (PDG)

Added in quadrature, the total systematic uncertainty is about 9-10%.

Theory calculations

- Calculations were done by Vincent Mathieu (JPAC/UCM)
  - Uses Regge-exchange formalism.
  - Predictions shown for CLAS $a_2(1320)$ paper (A. Celentano et al.)
  - Isospin relations can be used for the current $f_2(1270)$ cross sections.
  - We have preliminary curves, but can't show these yet.
- Published calculations by Xie and Oset
  - Linear in log($d\sigma/dt$) vs -t, without any turn-over
  - No predictions for relative B.R. to $\pi^+\pi^-$ compared with $\pi^0\pi^0$ decay of f_2.
  - The decay of $\rho \rightarrow \pi^0\pi^0$ is forbidden; not clear about decays of ρ–ρ molecule.

Summary

- We have completed an analysis note for $f_2(1270)$ photoproduction
  - Uses the g12 data, which has well-defined procedures.
    - Follows on to the already-approved exclusive 4γ final state of $\eta\pi^0$ analysis.
  - No background from ρ-decay allows clean extraction of $f_2(1270)$ yield.
  - Differential cross sections $d\sigma/dt$ are the primary result.
- What do we learn?
  - Regge exchange model does a good job describing the data (not yet shown)
    - Our data will constrain the parameters of this model
    - Can look at predictions for circular polarization observables
  - Because $\pi^0\pi^0$ and $\pi^+\pi^-$ give consistent cross sections, it seems unlikely that the $f_2(1270)$ has a ρ-ρ molecular structure.
- This analysis is based on a summer undergrad project by M. Carver