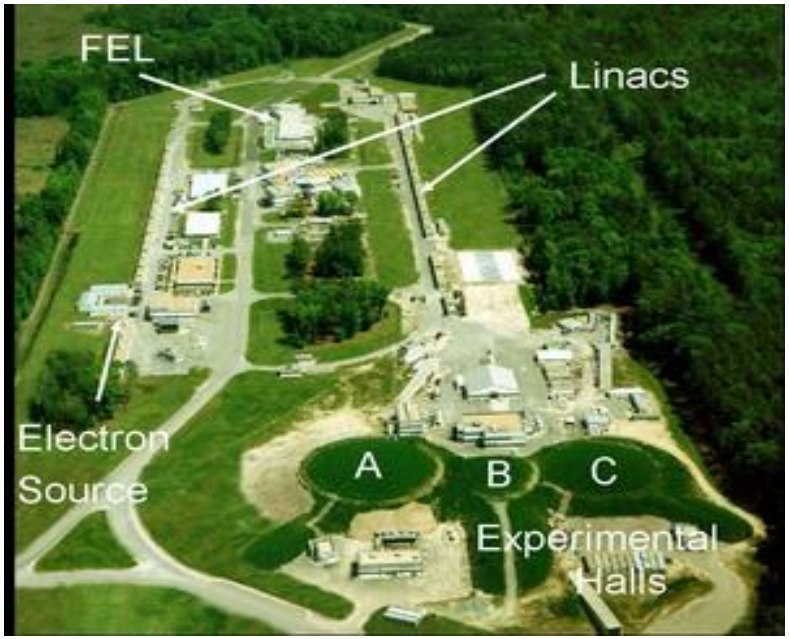
Photoproduction and Decay of Light Mesons in CLAS

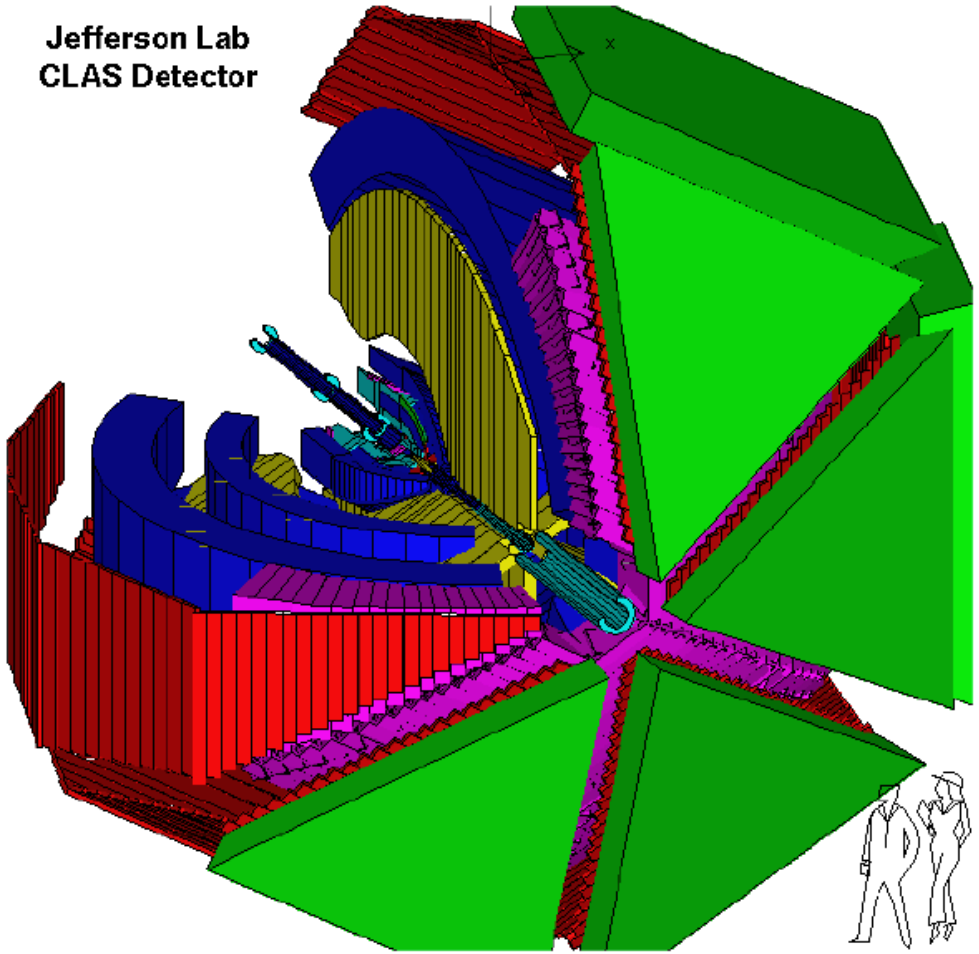
Diane Schott (GW)
On behalf of the CLAS Collaboration and
Light Meson Decay Group at JLab (LMD)

Light Meson Decay Group @ JLab

- Goal is to coordinate and promote analysis of existing CLAS light meson data
- CLAS had stored photoproduction data off of hydrogen for photon energies 1.1 to 5.45 GeV from experiments g11 and g12
- The focus of the group is
  - $\gamma\, p \rightarrow p\, (X)$
  - $X \rightarrow \eta, \eta', \pi^0, \omega, \phi$

The CLAS Detector





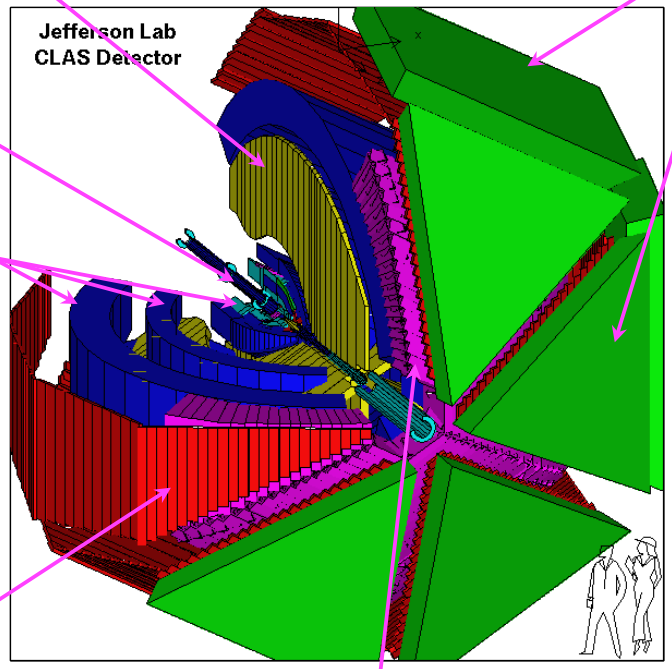
The CLAS Detector

Torus magnet
6 superconducting coils

Electromagnetic calorimeters
Lead/scintillator, 1296 photomultipliers

target +
start counter

Drift chambers
argon/CO_2 gas, 35,000 cells



Time-of-flight counters
plastic scintillators, 684 photomultipliers

Gas Cherenkov counters
e/π separation, 256 PMTs

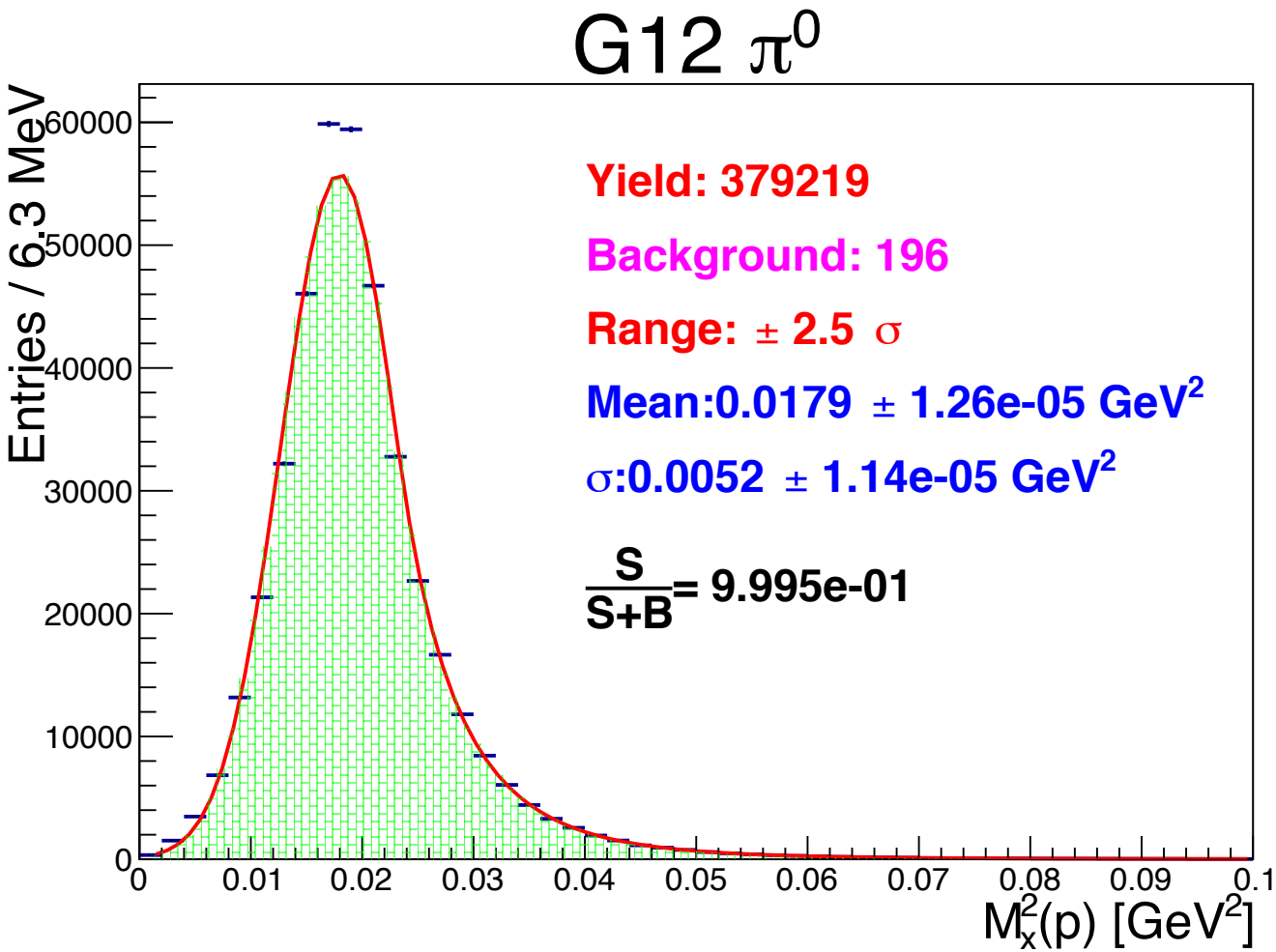
Analysis

- Dalitz Decays
  - $\pi^0, \eta, \eta' \rightarrow e^+ e^- \gamma$
  - $\omega \rightarrow e^+ e^- \pi^0$
- Radiative Decays
  - $\eta, \eta' \rightarrow \pi^+ \pi^- \gamma$
- Hadonic Decays
  - $\eta, \eta', \omega \rightarrow \pi^+ \pi^- \pi^0, \pi^+ \pi^- \eta$

High Energy Cross Section of π^0

- The following work is done the ODU group at CLAS:
  - M. C. Kunkel and M. Amaryan
- Used g12 data with lepton trigger and calculated cross-section for below 3.6 GeV and open trigger for above 3.6 GeV (maximum 5.45 GeV).
  - Extends the SAID Database to include higher photon energies to allow the addition of Regge analysis to the standard PWA.

π^0 Yield

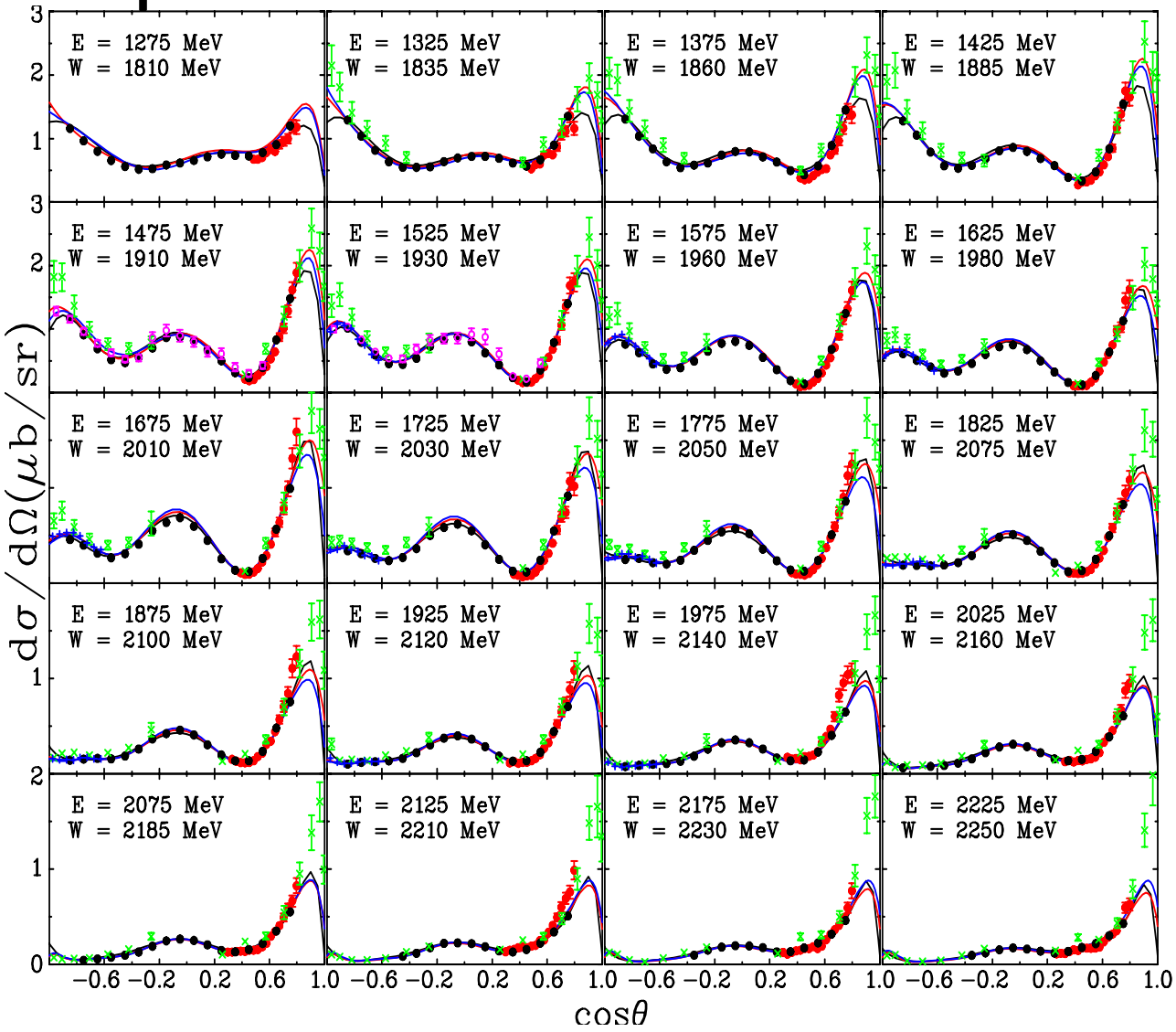


By M. C. Kunkel

Lower Energy Range Compared to SAID

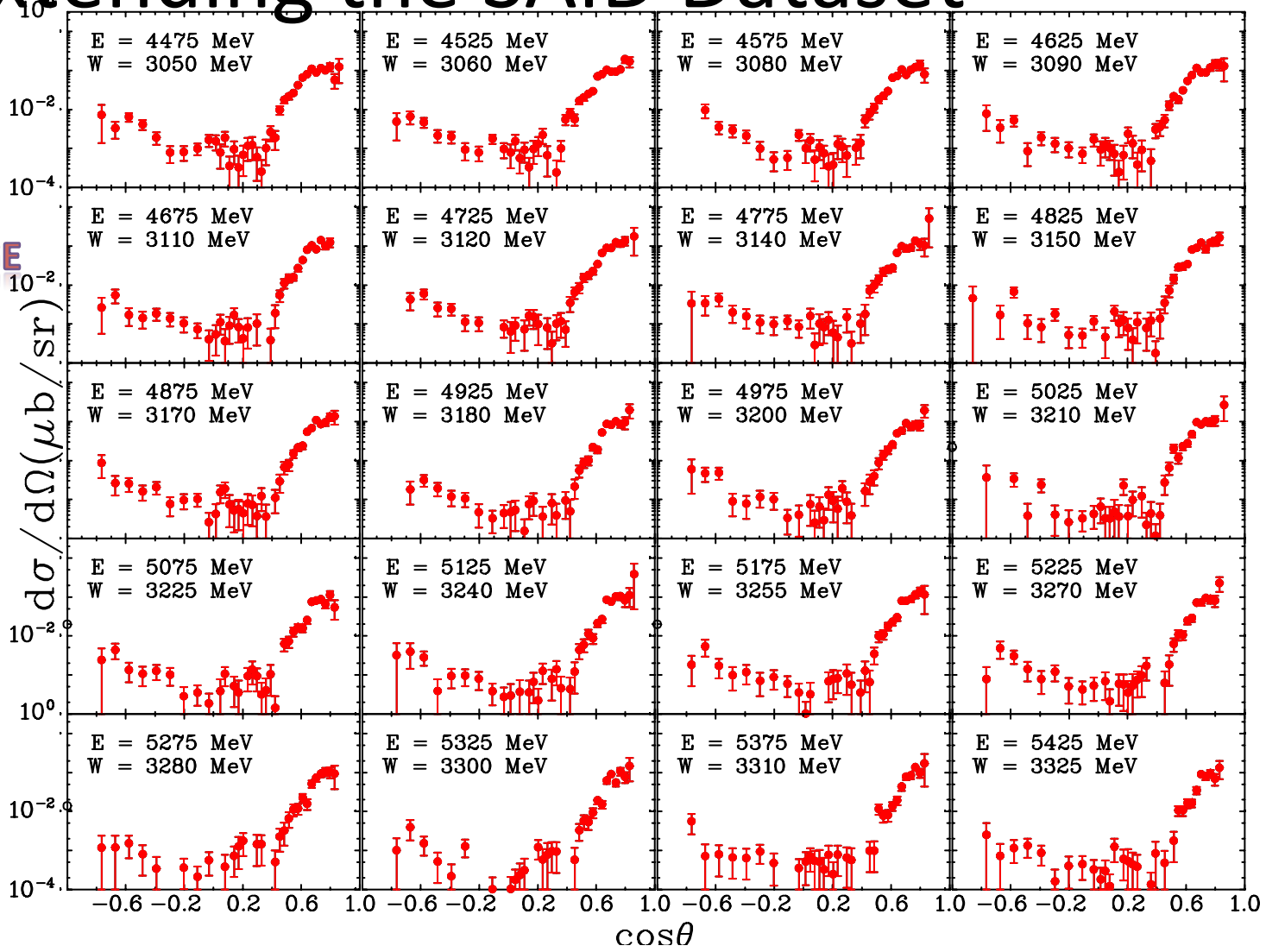
- Red solid (blue solid) lines SAID KU14 (DU13)
- Black solid lines BG2011-02 BnGa predictions.
- Experimental data
  - current (red filled circles),
  - CLAS (black filled circles),
  - GRAAL (magenta open circles),
  - LEPS (blue plus),
  - CB-ELSA (green crosses).

By M. C. Kunkel,
I. Strakovsky

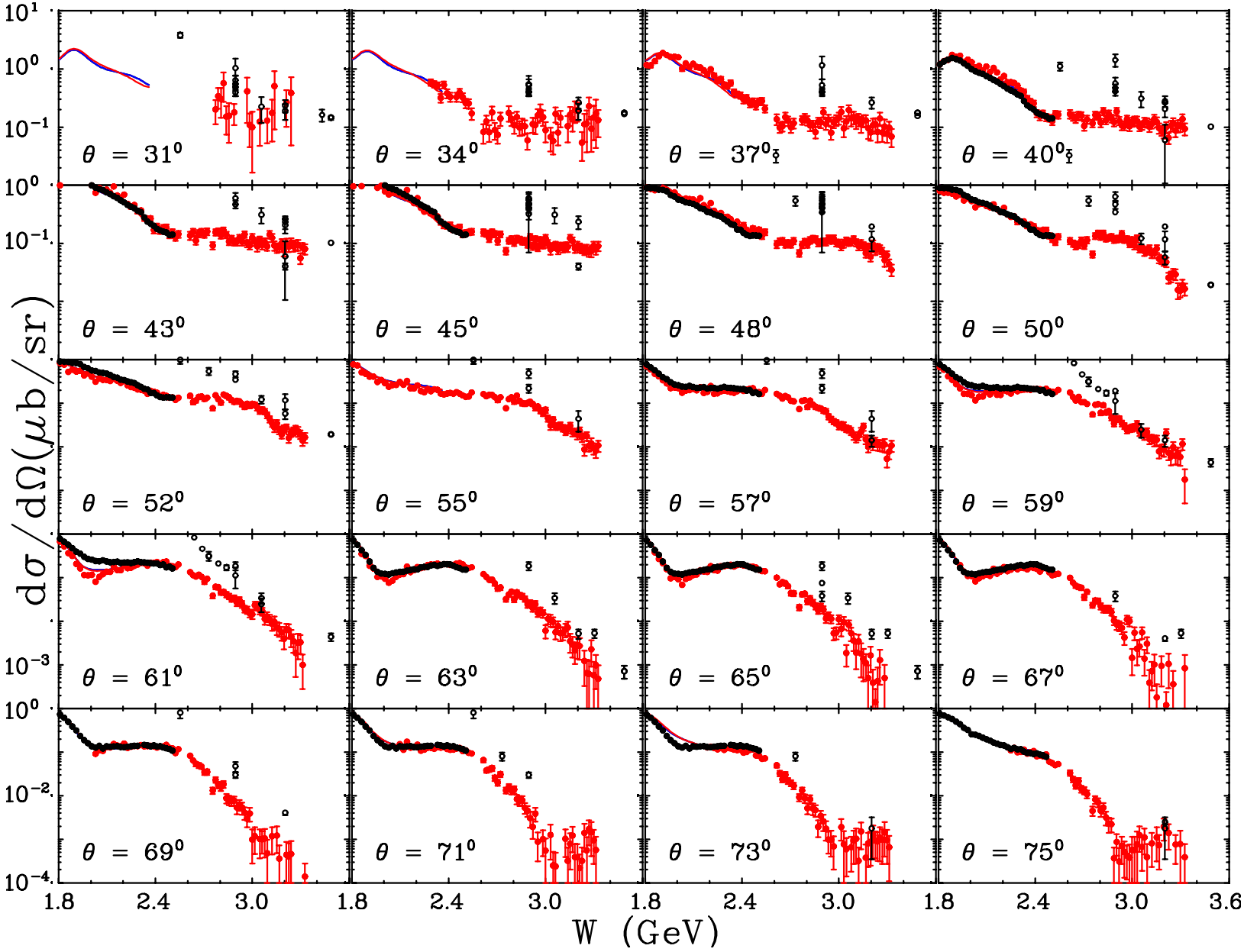


Higher Energy Range Extending the SAID Dataset

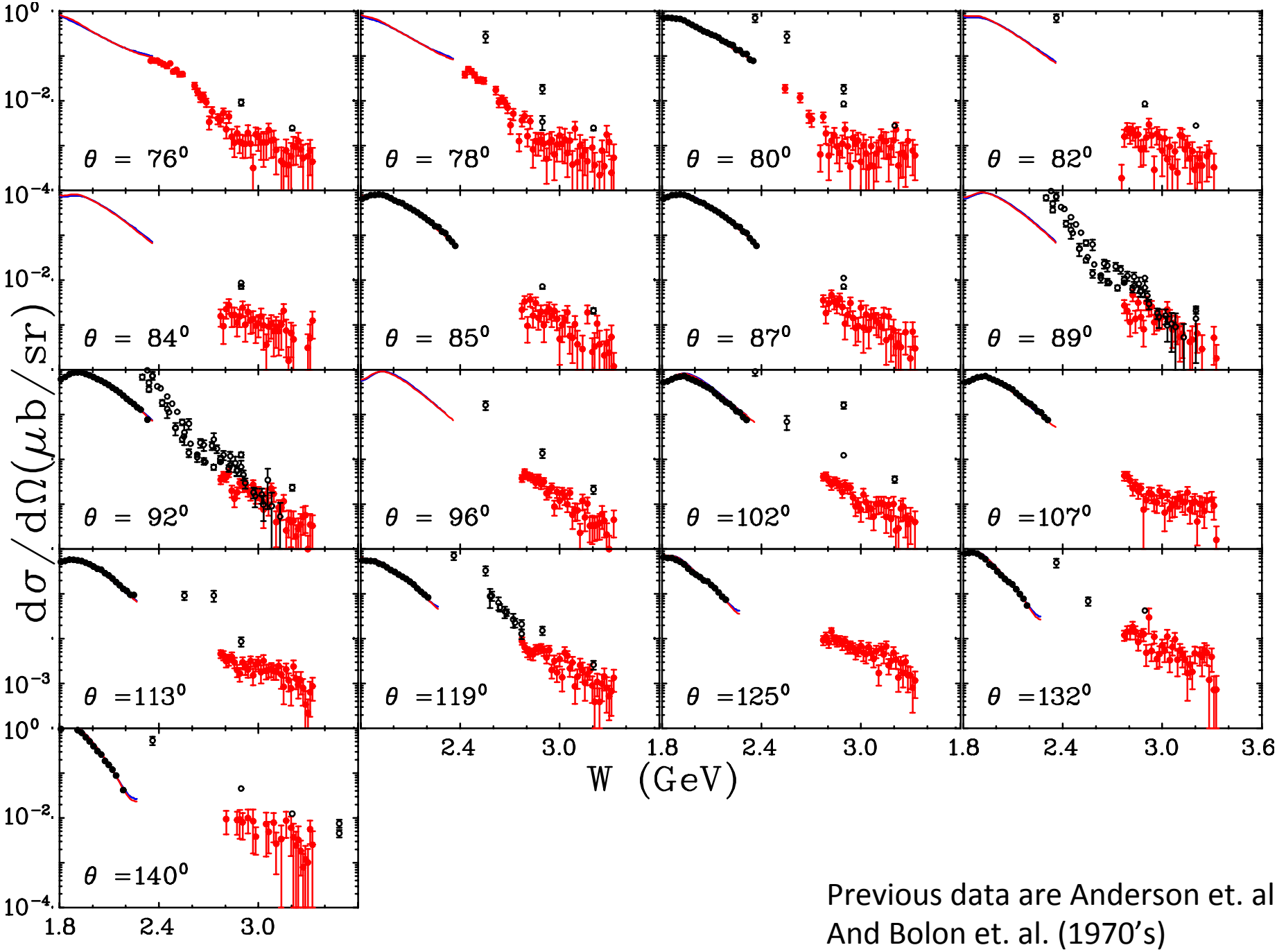
DATA EXTENDS BEYOND SAID DATABASE RANGE



By M. C. Kunkel



Previous data are Anderson et. al.,
And Bolon et. al. (1970's)



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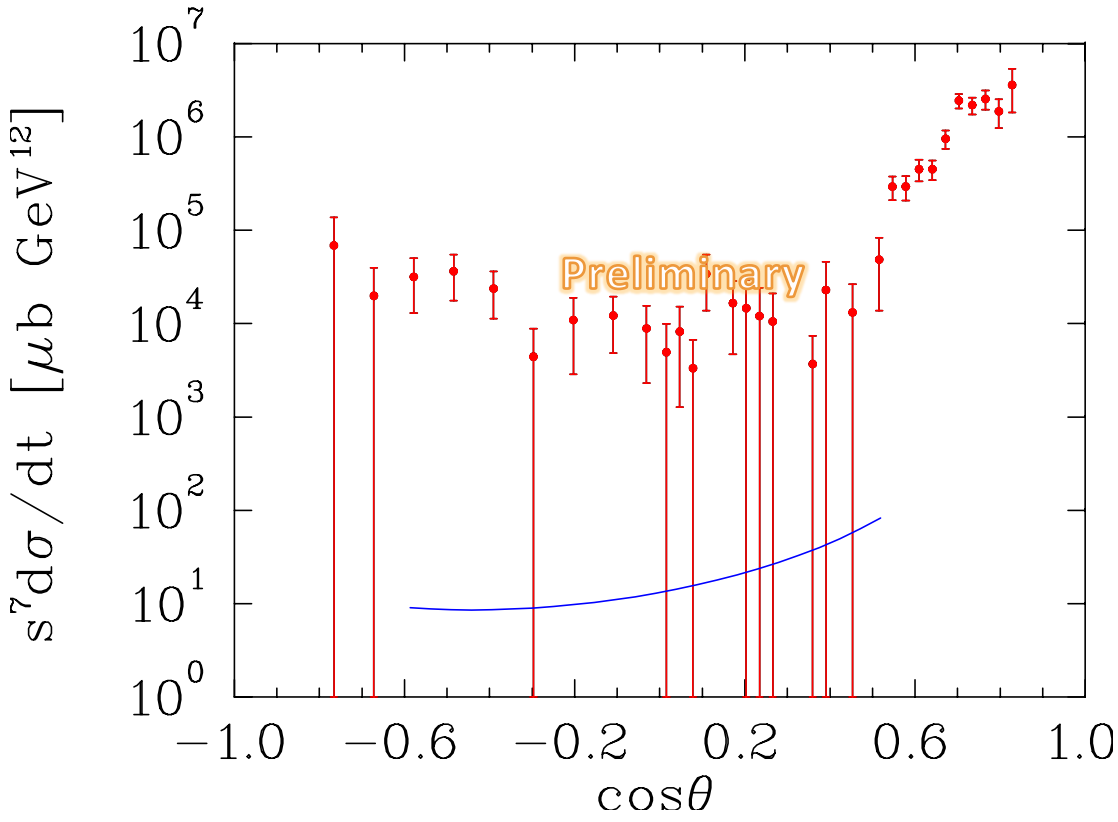
High Energy Theory

- s^7 scaling
  - A tool used to generalized the cross-sections of hadrons above resonance production regions
- Experimental data at $s = 11.08\ GeV^2$ are from the current (red filled circles).
- The theoretical prediction at $s = 10\ GeV^2$ by Kroll et al. within the Handbag model.

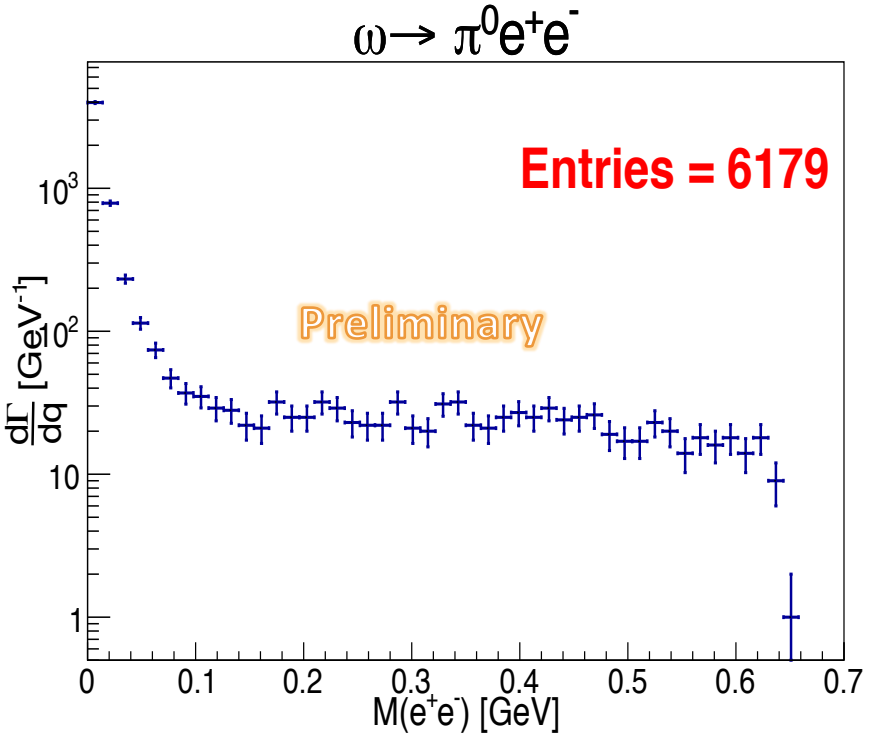


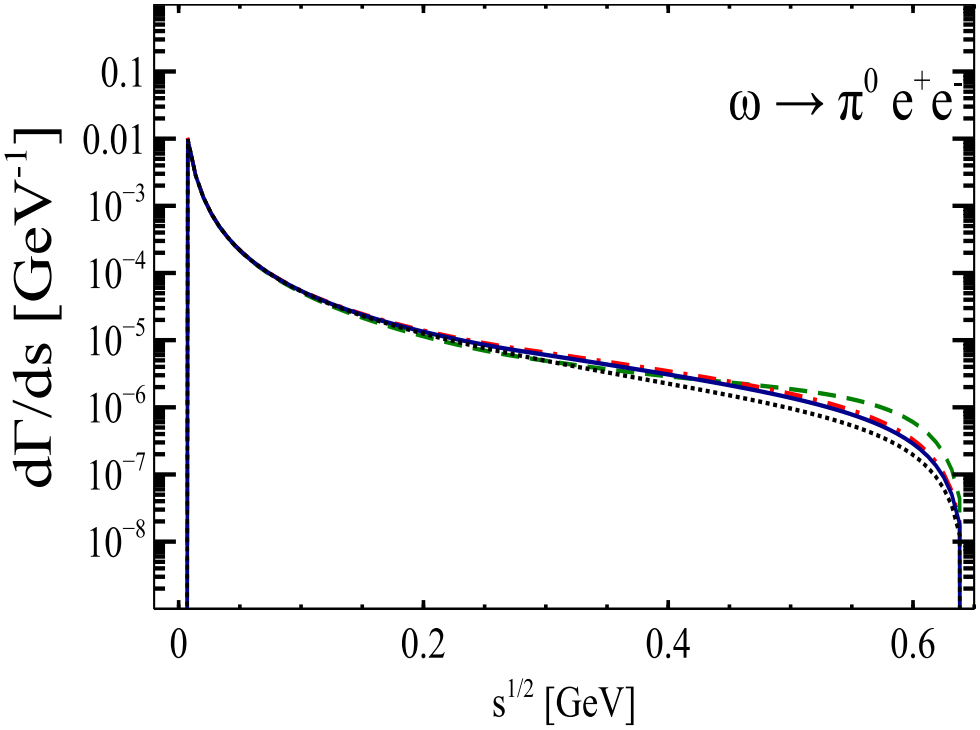
By M. C. Kunkel

Dalitz Decays

- $\omega \rightarrow e^+ e^- \pi^0$
  - Transition form factor

Transition Form Factor





Plot by M. C. Kunkel

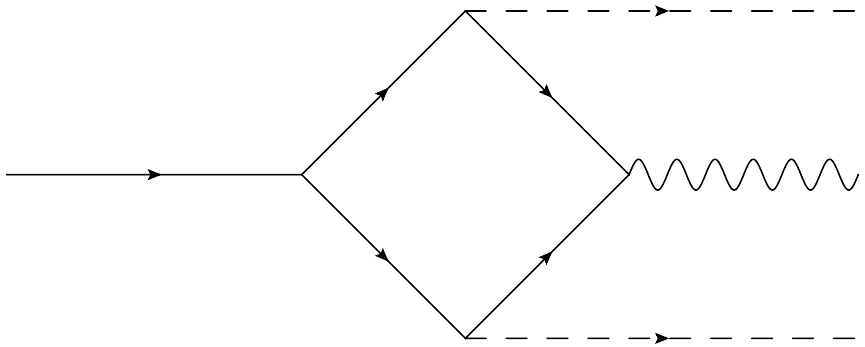
Theory by I. Danilkin,
Dispersive Analysis of ω/ϕ → 3π, πγ*

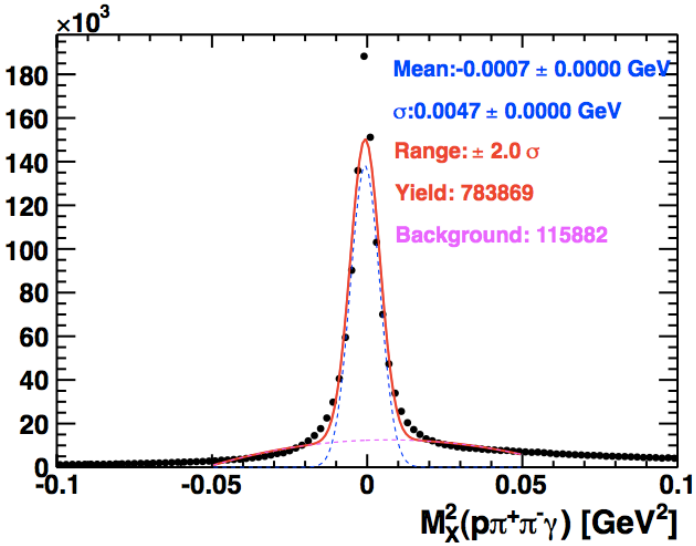
Analysis

- Dalitz Decays
  - $\pi^0, \eta, \eta' \rightarrow e^+ e^- \gamma$
  - $\omega \rightarrow e^+ e^- \pi^0$
- Radiative Decays
  - $\eta, \eta' \rightarrow \pi^+ \pi^- \gamma$
- Hadonic Decays
  - $\eta, \eta', \omega \rightarrow \pi^+ \pi^- \pi^0, \pi^+ \pi^- \eta$

Radiative Decays

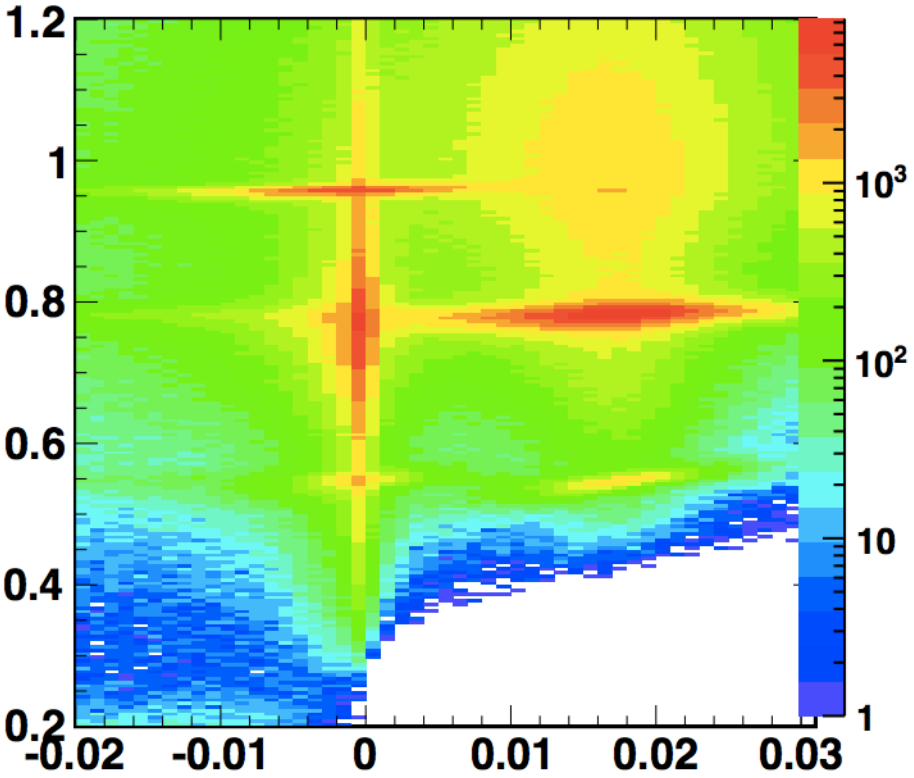
- $\eta, \eta' \rightarrow \pi^+ \pi^- \gamma$
  - These decays provide an important test of the box anomaly with the effects of η0 and η8 mixing.

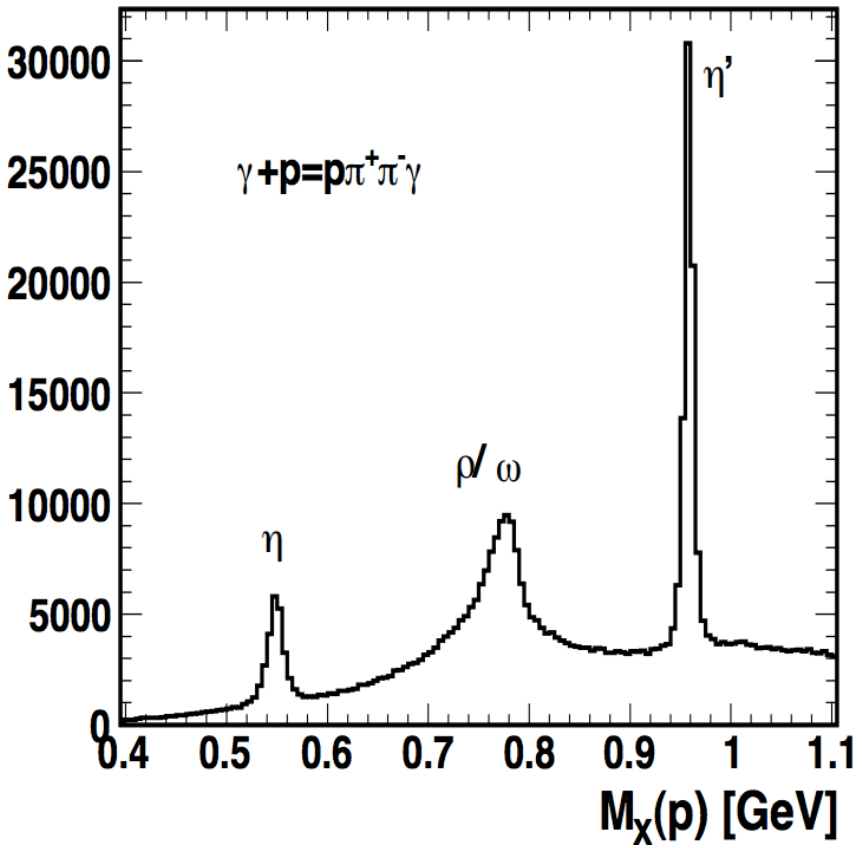




$\eta, \eta' \rightarrow \pi^+ \pi^- \gamma$

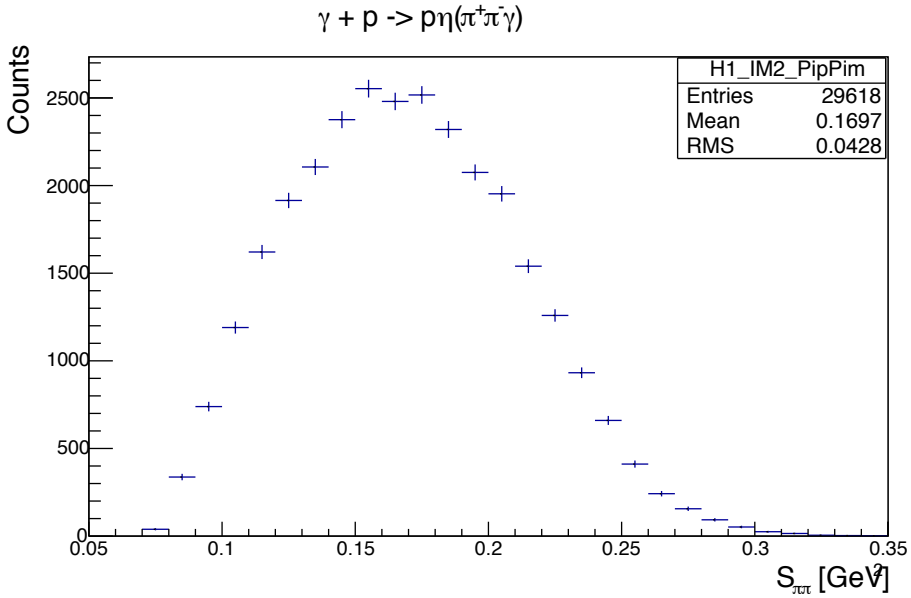
- ~800k p $\pi^+ \pi^-$ (γ) events





$\eta \rightarrow \pi^+ \pi^- \gamma$

- 30k η events
- Error in α expected to be close to published KLOE error.
- Next is η' with > 60k events



$$P(s_{\pi\pi}) = 1 + \alpha s_{\pi\pi} + O(s_{\pi\pi}^2)$$

By G. Mbianda Njencheu

Analysis

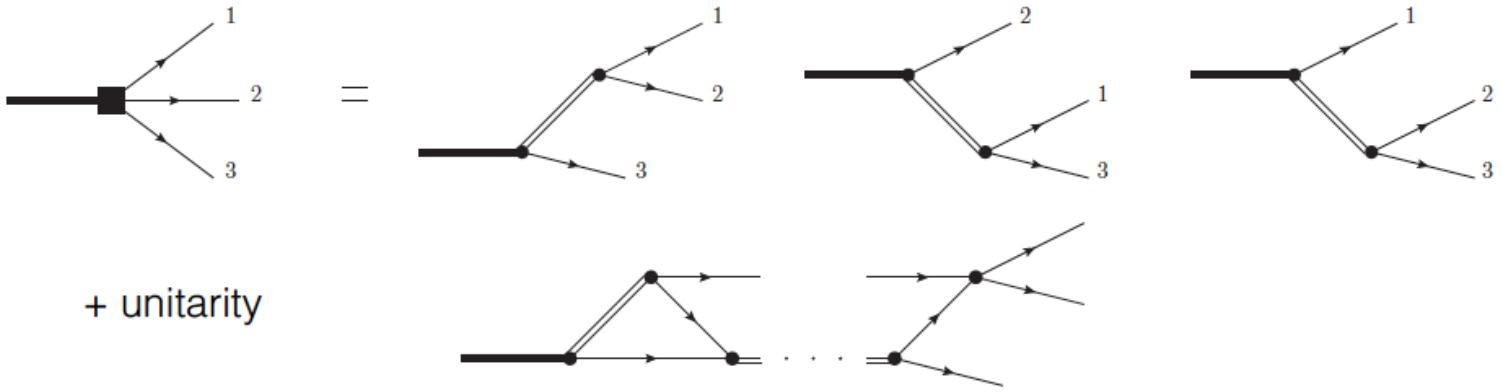
- Dalitz Decays
  - $\pi^0, \eta, \eta' \rightarrow e^+ e^- \gamma$
  - $\omega \rightarrow e^+ e^- \pi^0$
- Radiative Decays
  - $\eta, \eta' \rightarrow \pi^+ \pi^- \gamma$
- Hadonic Decays
  - $\eta, \eta', \omega \rightarrow \pi^+ \pi^- \pi^0, \pi^+ \pi^- \eta$

Hadronic Decays

- Working with the Joint Physics Analysis Center to include 2 and 3 body interactions
  - $\eta, \omega \rightarrow \pi^+ \pi^- \pi^0$
- Search for invisible decays
  - $\eta \rightarrow \pi^+ \pi^- \pi^0$

$\eta, \omega \to \pi^+ \pi^- \pi^0$

$$A(s,t) = \sum_J^{J_{max}} (2J+1)\, d^J_{1,0}(\theta_s)\, f_J(s) + \sum_J^{J_{max}} (2J+1)\, d^J_{1,0}(\theta_t)\, f_J(t) + \sum_J^{J_{max}} (2J+1)\, d^J_{1,0}(\theta_u)\, f_J(u)$$



Unitarity relation for the p-wave F(s):

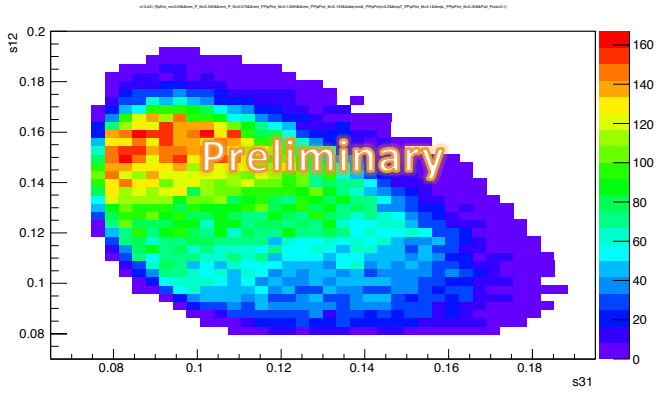
$$\text{Disc}\, F(s) = \rho(s)\, \overbrace{t^*(s)}^{\pi\pi \to \pi\pi} \left(F(s) + \hat{F}(s) \right)$$

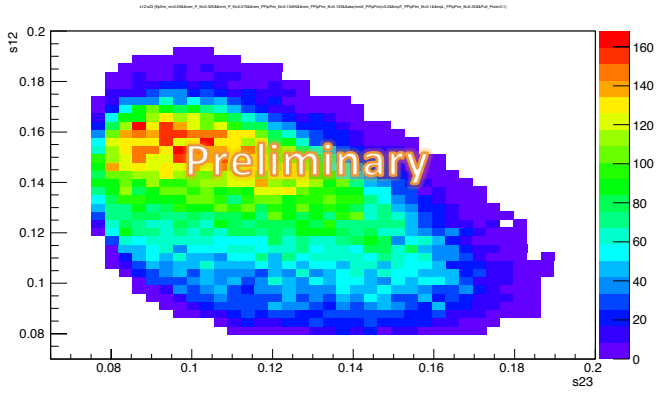
$$\hat{F}(s) = 3 \int_{-1}^{+1} \frac{dz_s}{2} \left(1 - z_s^2\right) F(t)$$

$\eta \rightarrow \pi^+\pi^-\pi^0$

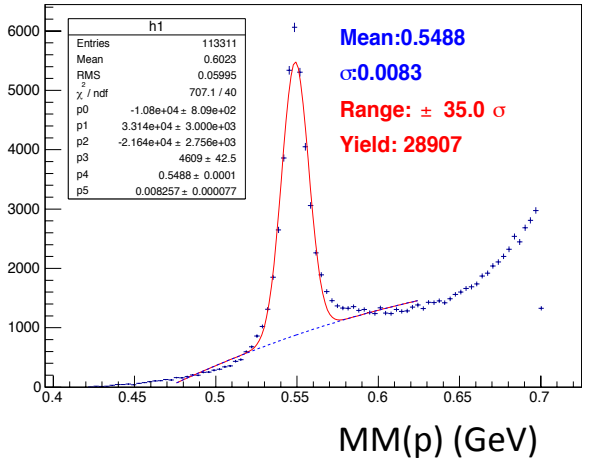
by D. Schott, M. C. Kunkel, P. Guo

- $\eta \rightarrow \pi^+ \pi^- \pi^0$ is of interest because it is sensitive to isospin breaking, which in QCD originates from the mass difference between the up and down quarks.
- ~29k events from g12
- Photon beam energy
  - [3.6, 5.45 GeV]
- Working with Joint Physics Analysis Center (JPAC) to fit 2 and 3 body decay contributions





Mass (η)



MM(p) (GeV)

Fit using:
2-body decay amplitudes

Amplitudes from G. Peng at IU

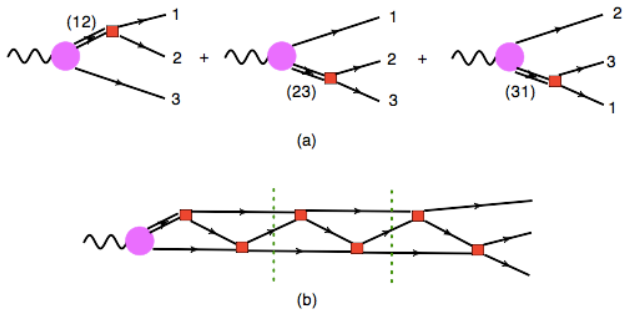
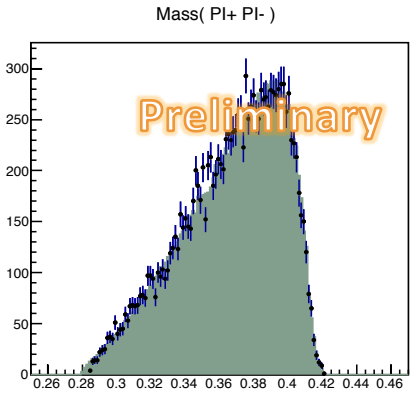
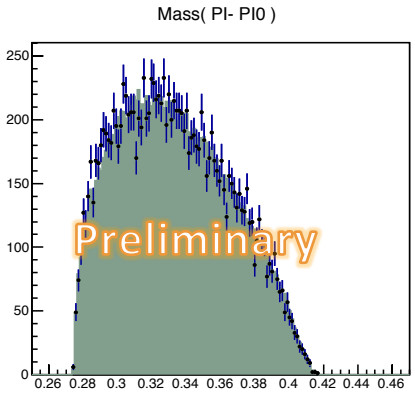
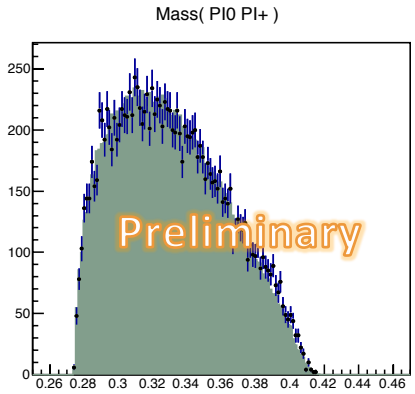
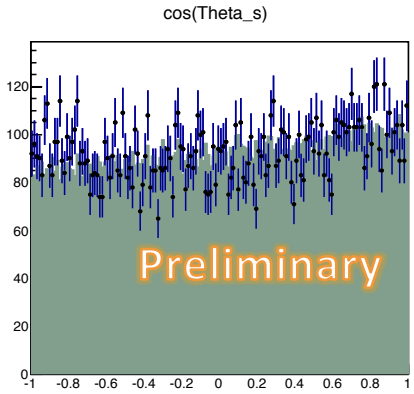


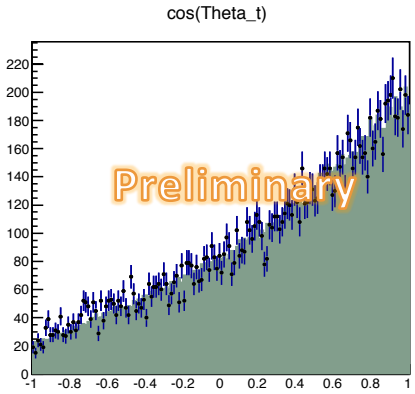
FIG. 2: (a) Naive Isobar model. (b) Three-body rescattering effect.

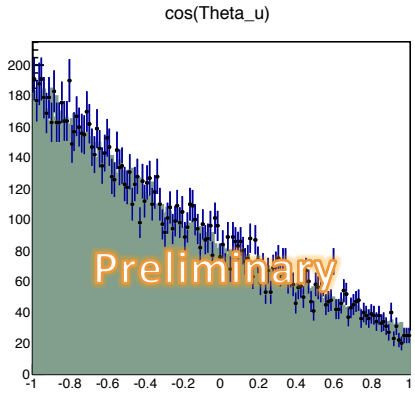




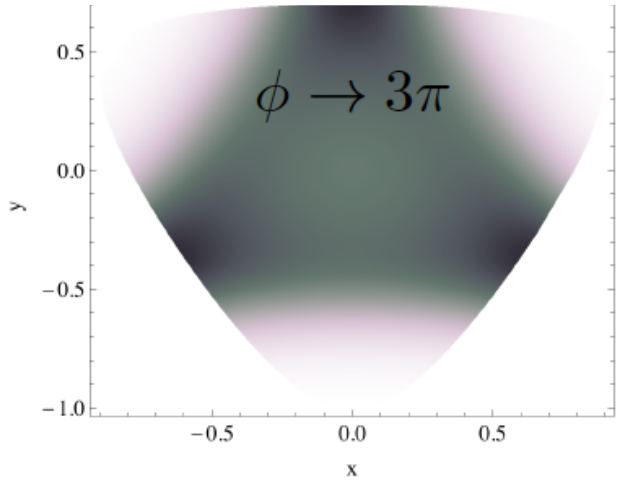


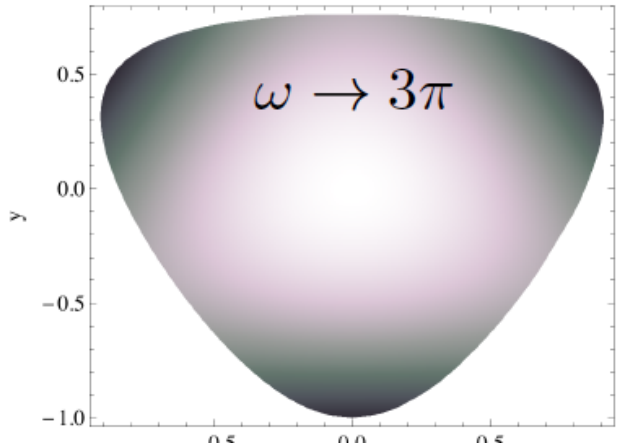


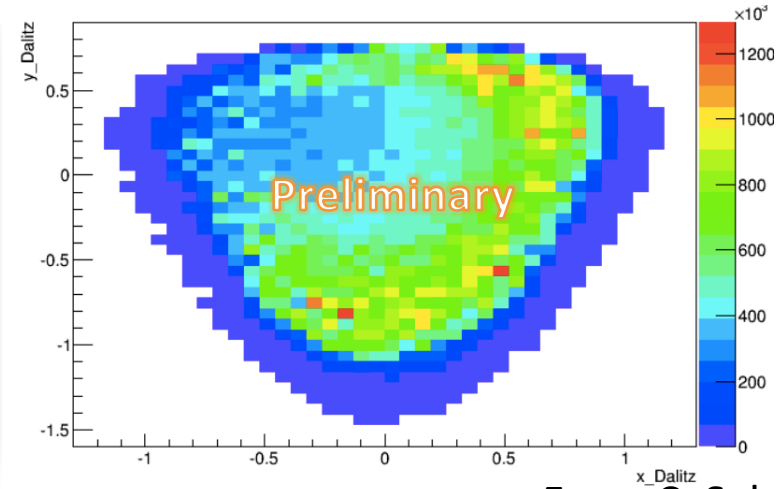




$\omega \to \pi^+ \pi^- \pi^0$







From C. Salgado
Not acceptance corrected

- $\omega \to \pi^+ \pi^- \pi^0$ is of interest because it sheds light on the vector mesons dominance and the interplay between the QCD dynamics.
- Theory work by Igor Danilkin and JPAC
- Data analysis by FSU, NSU, LMD

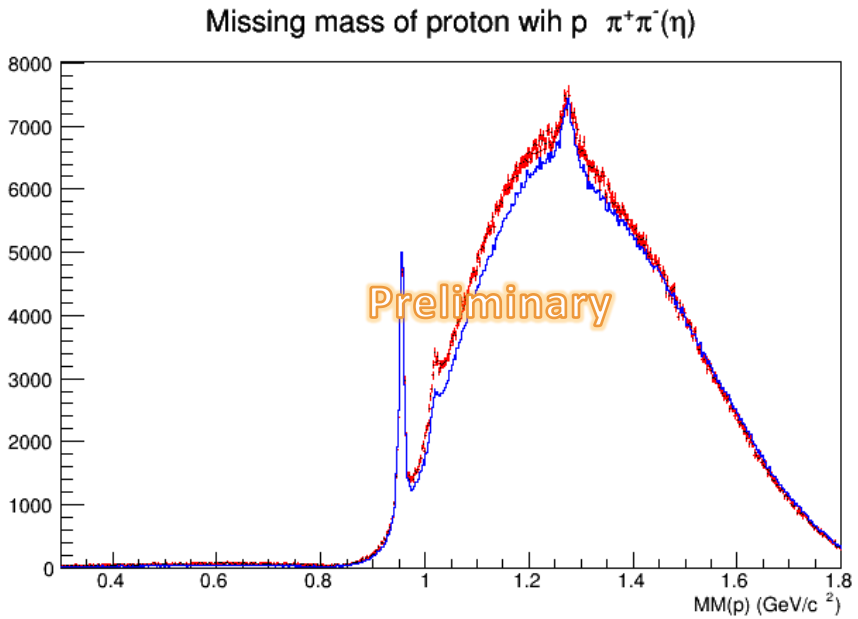
Invisible Decay

- Maybe used to search for new physics beyond Standard Model
  - Neutral states could be light dark matter
  - Channel being used is $\gamma\, p \rightarrow p\, \eta' \rightarrow p\, \pi^+ \pi^- (\eta)$
  - The invisible decays of η to $\chi\chi$ (where χ is like a U boson) could be a dark (or heavy) photon

Invisible Decay

- Method: Estimate the yield of η decaying into invisible particles.
  - The yield of η not being detected by the detector is subtracted from the yield of the η reconstructed for the missing mass but no decay components are detected.
  - The branching ratio of the invisible decay is the residue yield to the total yield of eta.

Expected upper limit ~10^{-4}



- Red is the yield of missing mass off of proton after selecting missing η with no decaying particles of η detected. The blue is the expected yield of η from neutral decay but no photon seen.

By H. Lu

Summary

- Analysis using CLAS data are underway to:
  - Measure Transition Form Factors
  - Box Anomaly Term
  - Measure Quark Mass Ratio
  - Test fundamental Symmetries C and CP
  - Search for Dark Photon
  - Search for Invisible Decay

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- B. Kopf, RuhrU-Bochum
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- C. Salgado, NSU
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- D. Schott, GWU
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- U. Wiedner, RuhrU-Bochum
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