High-t Exclusive π^0 Photoproduction

Moskov Amaryan

Old Dominion University

On behalf of the CLAS Collaboration

Exclusive Meson Production and Short-Range
Hadron Structure Workshop
Jefferson Lab, Newport News
January 23, 2015

Outline

-Introduction

-Dalitz decay and Photon Conversion

-CLAS Data analysis

-Exclusive photoproduction cross section of neutral pions on hydrogen target in CLAS

-Conclusions

Introduction

In general pion photoproduction cross section in terms of amplitudes could be presented as:

$$\frac{d\sigma}{d\Omega} = \frac{q}{k} | < 2|\mathcal{F}|1 > |^2$$

For given isospin configuration there are four amplitudes:

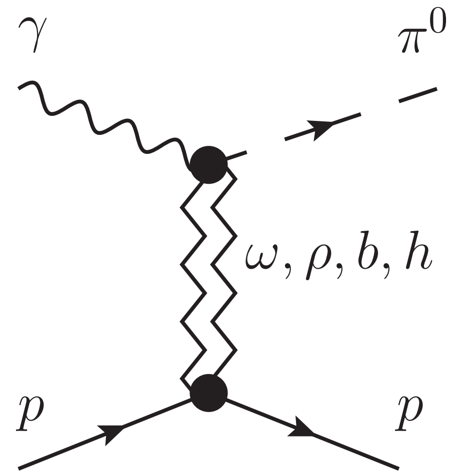
$$\mathcal{F} = i\sigma \cdot \epsilon \mathcal{F}_{\mathbf{1}} + \frac{\sigma \cdot \mathbf{q} \sigma \cdot (\mathbf{k} \times \epsilon)}{\mathbf{qk}} \mathcal{F}_{\mathbf{2}} + \frac{\mathbf{i}\sigma \cdot \mathbf{kq} \cdot \epsilon}{\mathbf{qk}} \mathcal{F}_{\mathbf{3}} + \frac{\mathbf{i}\sigma \cdot \mathbf{qq} \cdot \epsilon}{\mathbf{q^2}} \mathcal{F}_{\mathbf{4}}$$

G.F. Chew, M.L. Goldberger, F.E. Low, and Y. Nambu, Phys.Rev. 106, 1345 (1957)
called CGNL amplitudes

At low energies these amplitudes could be expanded in terms of linear combinations of associated Legendre polynomials and partial waves.

At higher energies number of relevant waves increases and it becomes very difficult to perform expansion of amplitudes.

In this case one can use crossed-channel Regge expansion.



Regge trajectories contribute only to a particular combinations of invariant amplitudes A_i.

The combination of CGNL amplitudes with good quantum numbers for neutral pion production are:

$$F_1 = A_1 - 2mA_4, \qquad F_2 = A_1 + tA_2,$$
$$F_3 = 2mA_1 - tA_4, \qquad F_4 = A_3.$$

The vector (ω, ρ) trajectories contribute to F_1, F_3.

The axial-vector (b, h) trajectories contribute to F_2, F_4.

In the leading Reggeon exchange approximation

$$F_i(s,t) = \beta_i(t) \frac{\pi}{\Gamma(\alpha)} \frac{1 - e^{-i\pi\alpha}}{2 \sin \pi\alpha} s^{\alpha - 1}$$

α is Regge trajectory.

The vector and axial-vector trajectories are:

$$\alpha_V(t) = 0.9(t - m_\rho^2) + 1, \qquad \alpha_A(t) = 0.7(t - m_{b_1}^2) + 1.$$

In these terms the differential cross section is represented as:

$$\frac{d\sigma}{dt}(s,t) = \frac{1}{32\pi}\left[\frac{|F_3|^2 - t|F_1|^2}{4m^2 - t} + |F_2|^2 - t|F_4|^2\right]$$

This model was applied by V. Mathieu and A. Szczepaniak to describe neutral pion photoproduction cross section at high energies (to be published).

Regge exchange model was used by M. Guidal, J.-M. Laget and M. Vanderhaeghen in PLB 400, 6 (1997) to describe pion photoproduction.

Later Regge model of GLV was modified in J.M. Laget, PLB 695, 199 (2011) and includes pion rescattering as well as u-channel exchange.

Experiment

Photoproduction cross section in the reaction

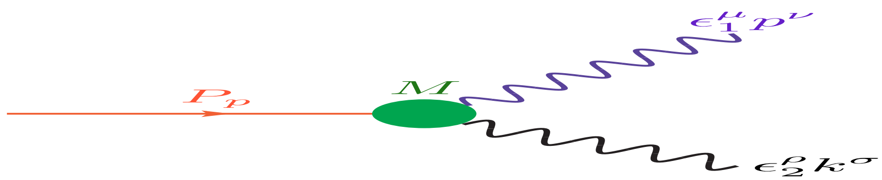
$$\gamma + p \rightarrow p\pi^0 \rightarrow pe^+e^-\gamma$$

was measured in CLAS using data from g12 run period. It is reported in M.Kunkel's Ph.D. Thesis.

TABLE 5: Running conditions for *g12*

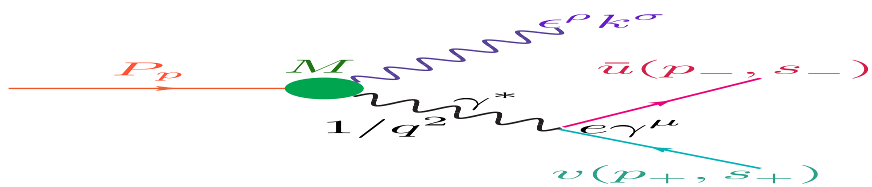
Electron Beam Energy	5.714 GeV
Electron Beam Current	60-65 nA (production) & 24 nA(single-prong)
Electron Beam Polarization	Circular
Radiator Material/Density	Au / $646\mu g/cm^2$
Radiator Thickness	$10^{-4}\chi_0$
Radius of Photon collimator	6.4 mm
Photon Beam Energy Range	1.142-5.425 GeV
Target Shell Material	Kapton
Target Length/Diameter	40 cm/4 cm
Target Inside Material	ℓH_2
Target Position	-90 cm from CLAS center
Target Polarization	None
Torus Magnetic Current	$\frac{1}{2}B_{max} = 1930$ A

π^0 Decay Modes



(a)

$$\pi^0 \to \gamma\gamma(Br = 98.8\%)$$



(b)

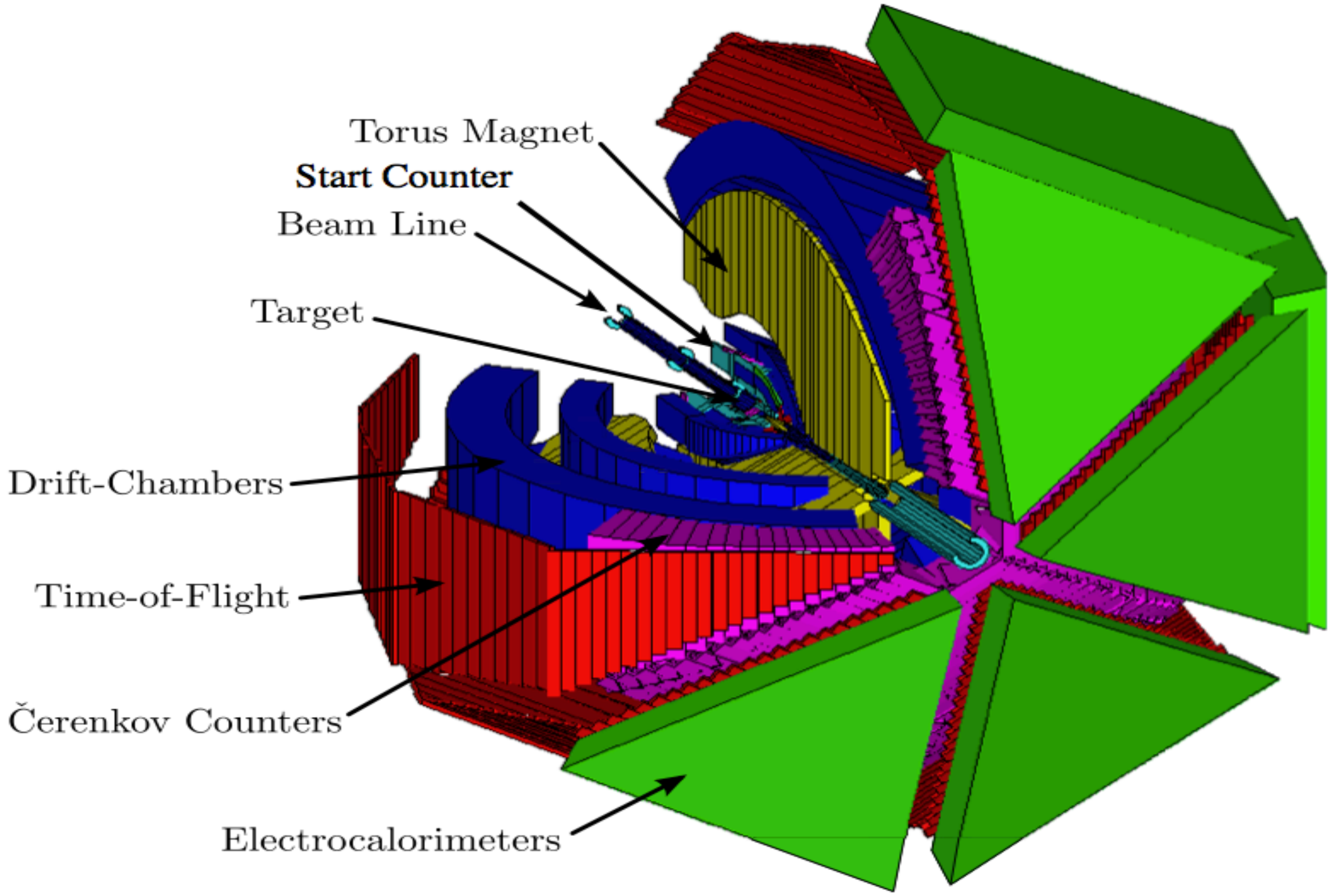
$$\pi^0 \to e^+e^-\gamma(Br = 1.2\%)$$

Dalitz decay

From the trigger point of view we choose Dalitz decay mode.

The lepton pairs could be produced from the conversion in LH target as well. From MC simulation the final sample contains roughly equal number of events coming from Dalitz decay and pair production in LH target.

CLAS Detector



Event Selection

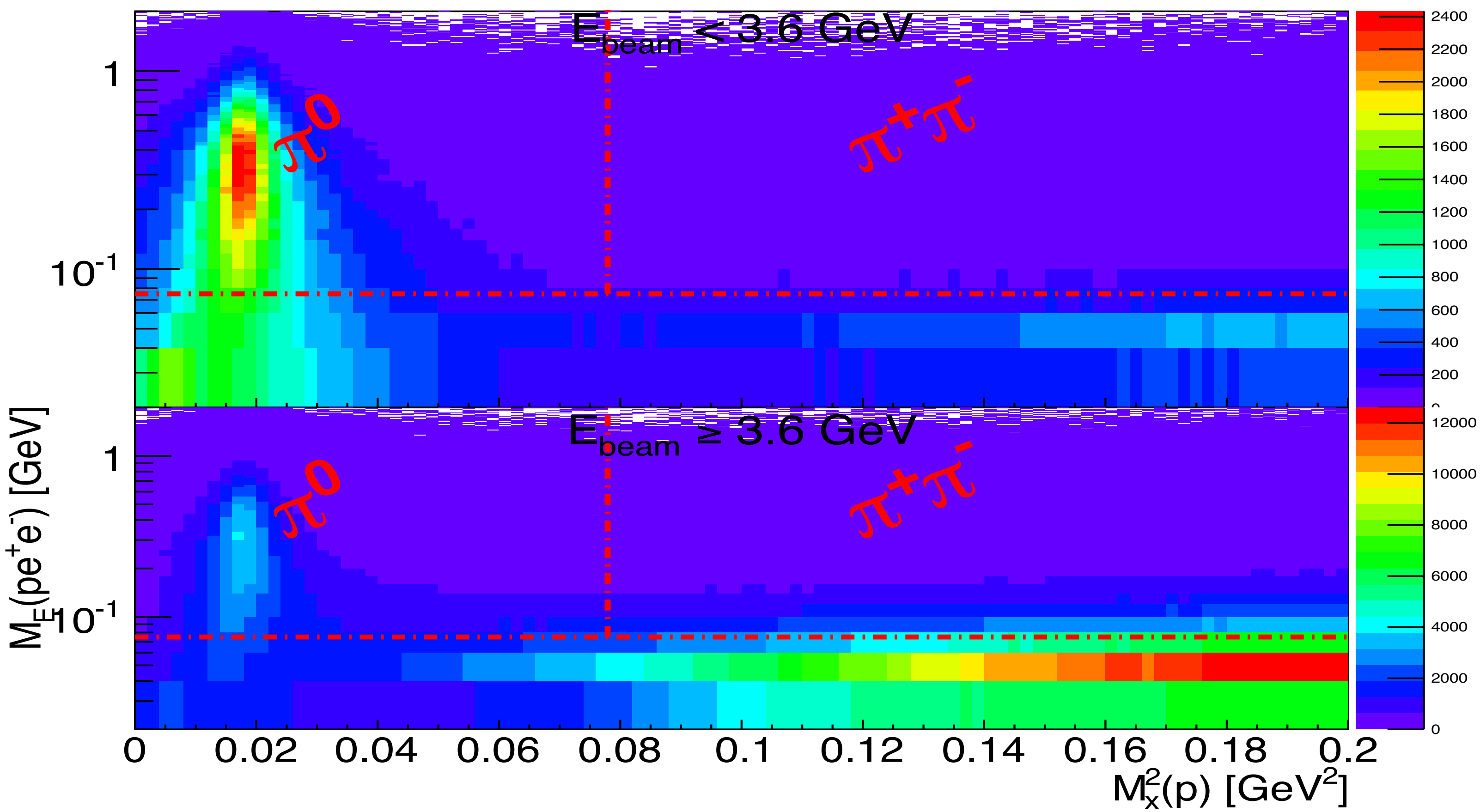
-Event are selected with $\gamma + p \rightarrow pq^+q^-(X)$ final state

-Identify $pe^+e^-(X)$ final state using CC and EC and TOF

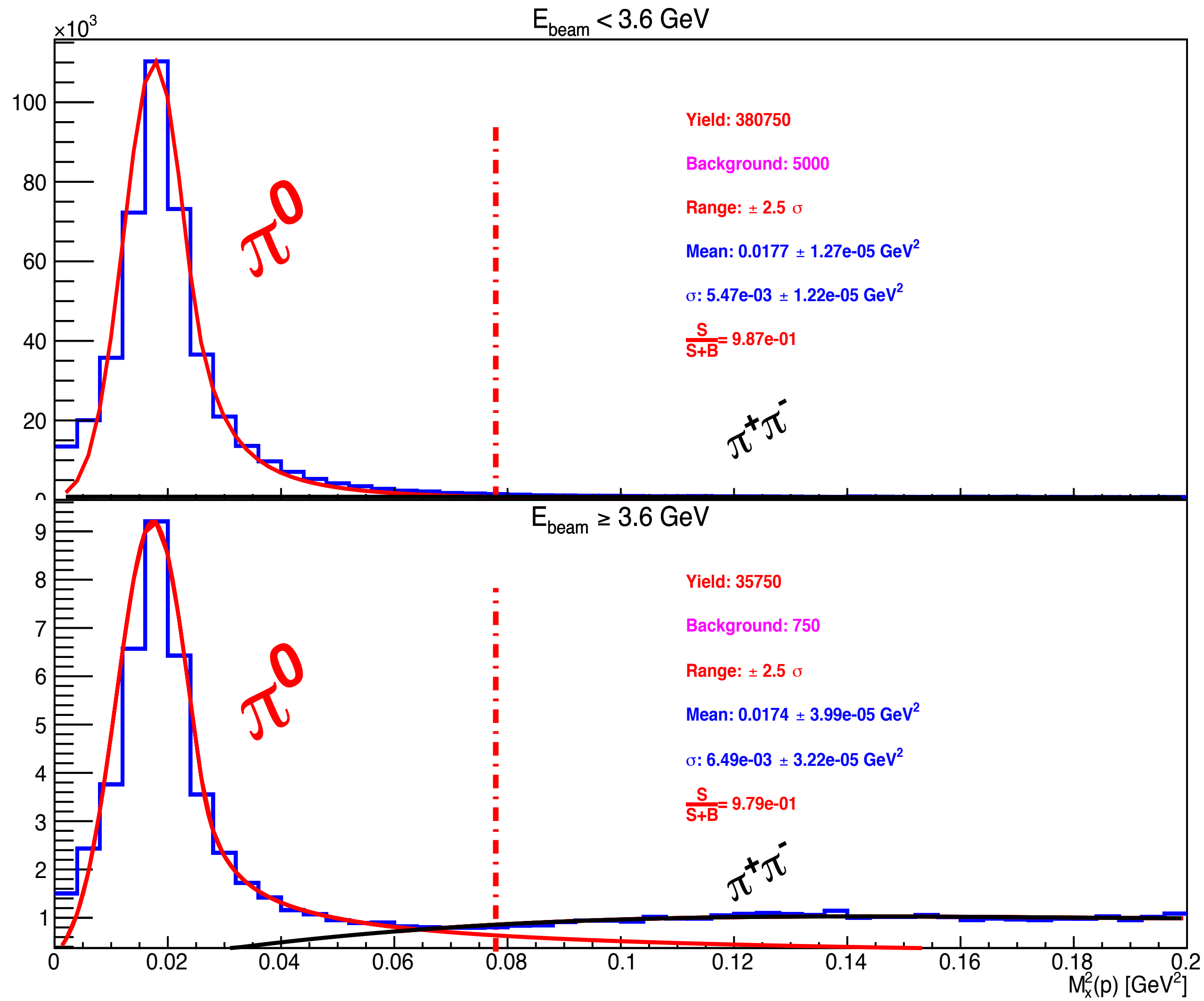
-Use kinematic fit to identify missing photon

-Use kinematic fit to cut out $\gamma + p \rightarrow p\pi^+\pi^-(X)$

Missing energy vs Missing Mass



Reconstructed peak of $\pi^0 \to e^+e^-\gamma$



New (preliminary) CLAS and World Data

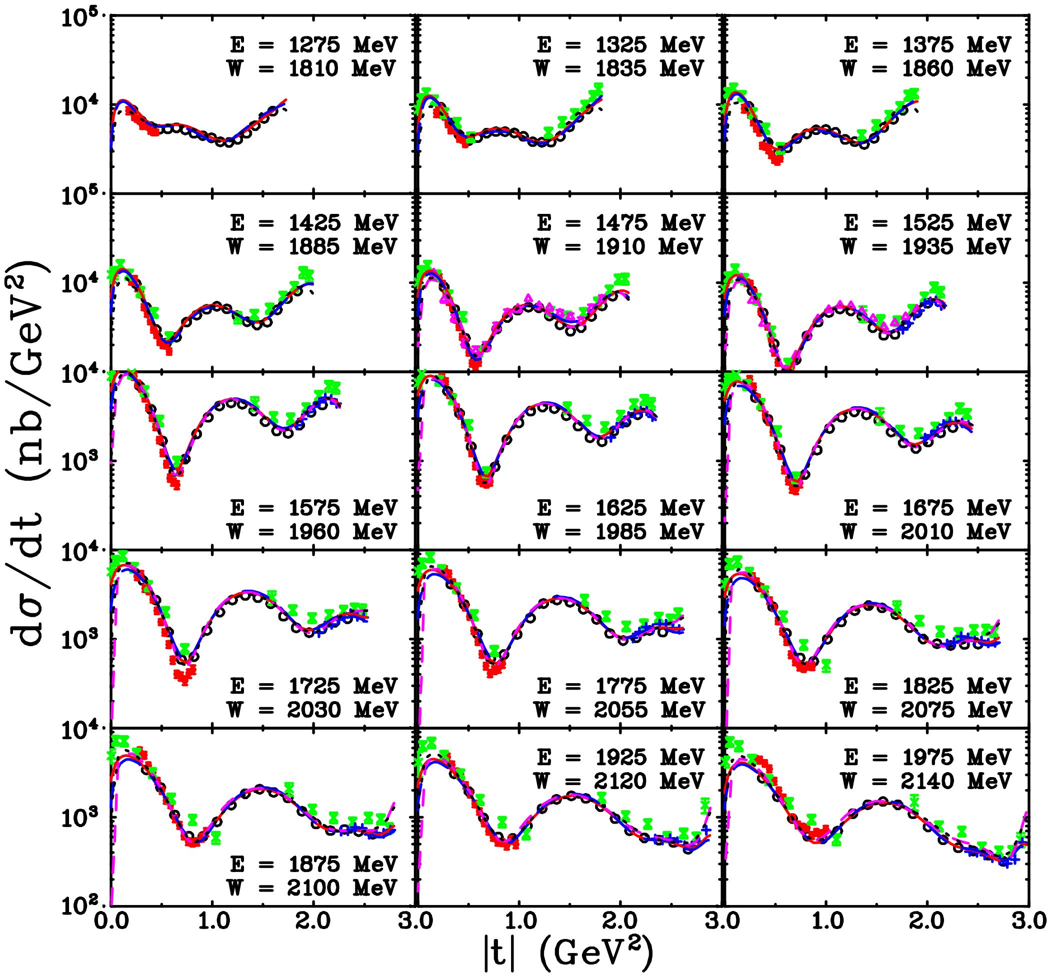
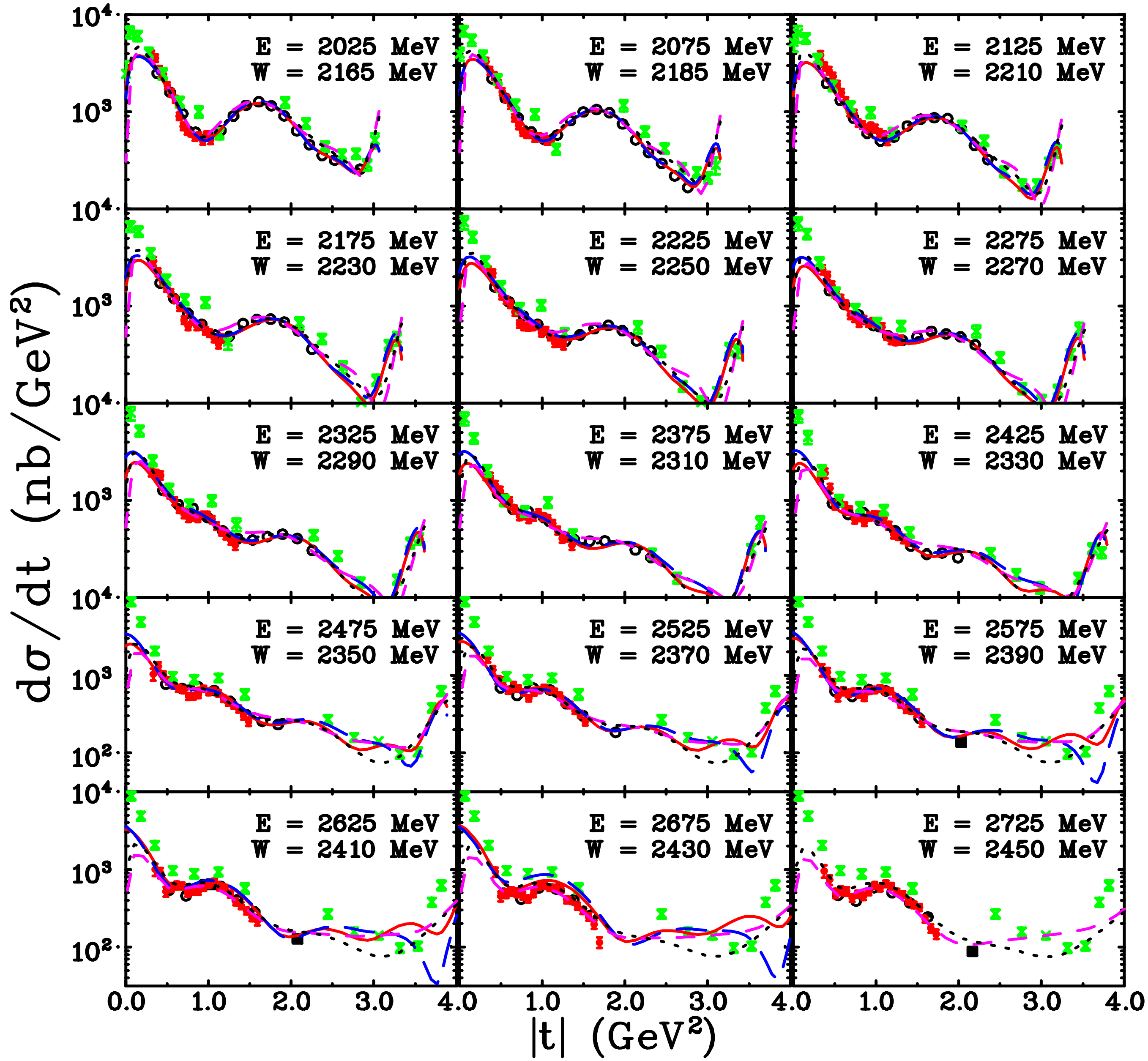
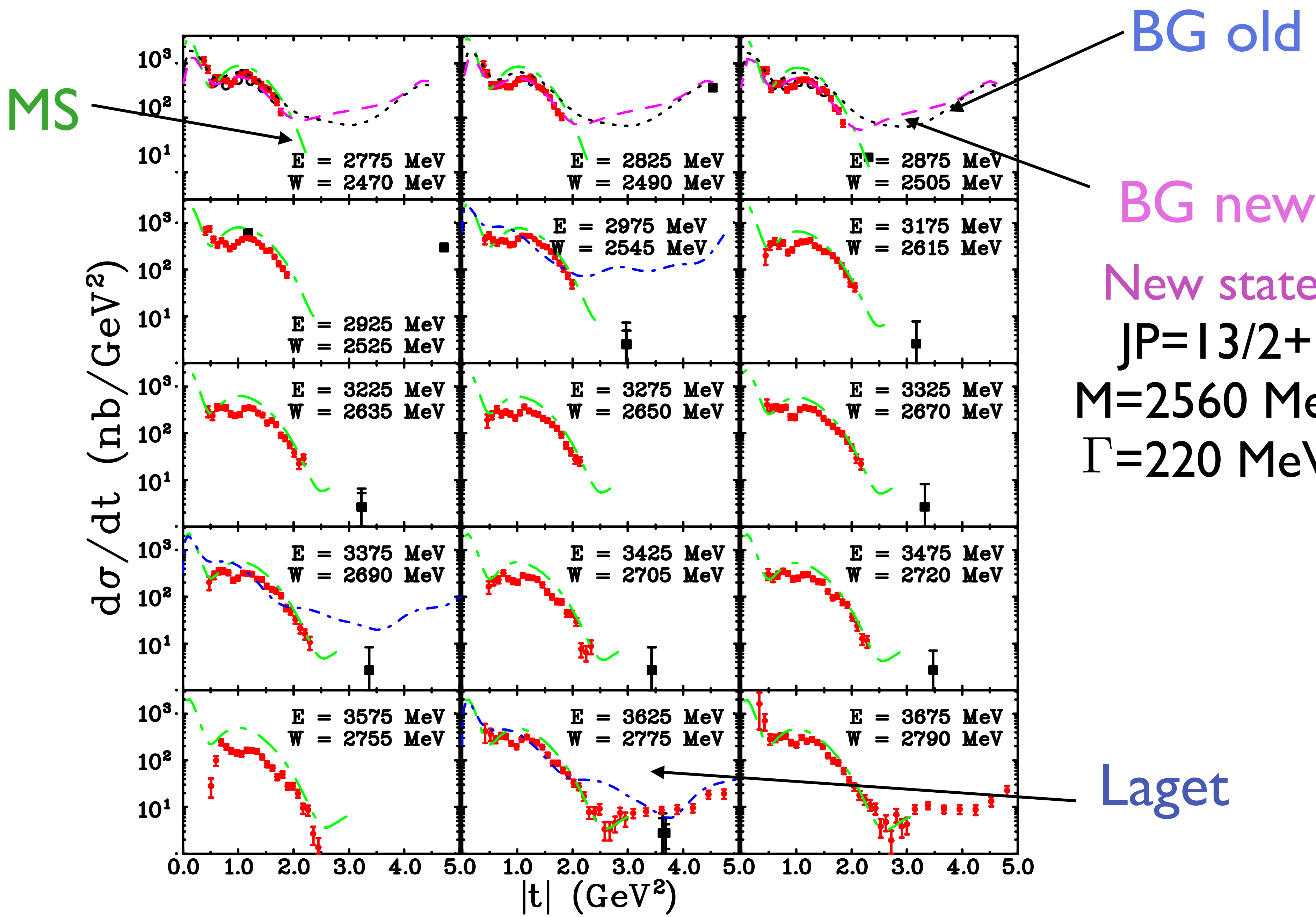


FIG. 3: (Color online) π^0 photoproduction cross section, $d\sigma/dt$, off the proton at E = 1275 – 1975 MeV (W = 1810 – 2140 MeV) versus t, t is the squared four-momentum transfer between the incident photon and E, while the center-of-mass total energy is indicated by W. Red solid (blue dashed) lines correspond to the SAID KU14 (DU13 [7]) solution, which terminates at $W = 2.5$ GeV. Black dotted lines give the BG2014-02 BnGa [8] predictions. It terminates at $W = 2.75$ GeV. Magenta long dashed lines give BG2015 fit (included new CLAS data). Experimental data are from the current (red filled circles), CLAS [9] (black open circles), GRAAL [10] (magenta open triangles), LEPS [11] (blue plus), CB-ELSA [12] (green crosses). The plotted points from previously published experimental data above E = 2 GeV [13] (black filled squares) are those data points within $\Delta E = \pm 3$ MeV of photon energy in laboratory system indicated on each panel.

New (preliminary) CLAS and World Data (cont.)

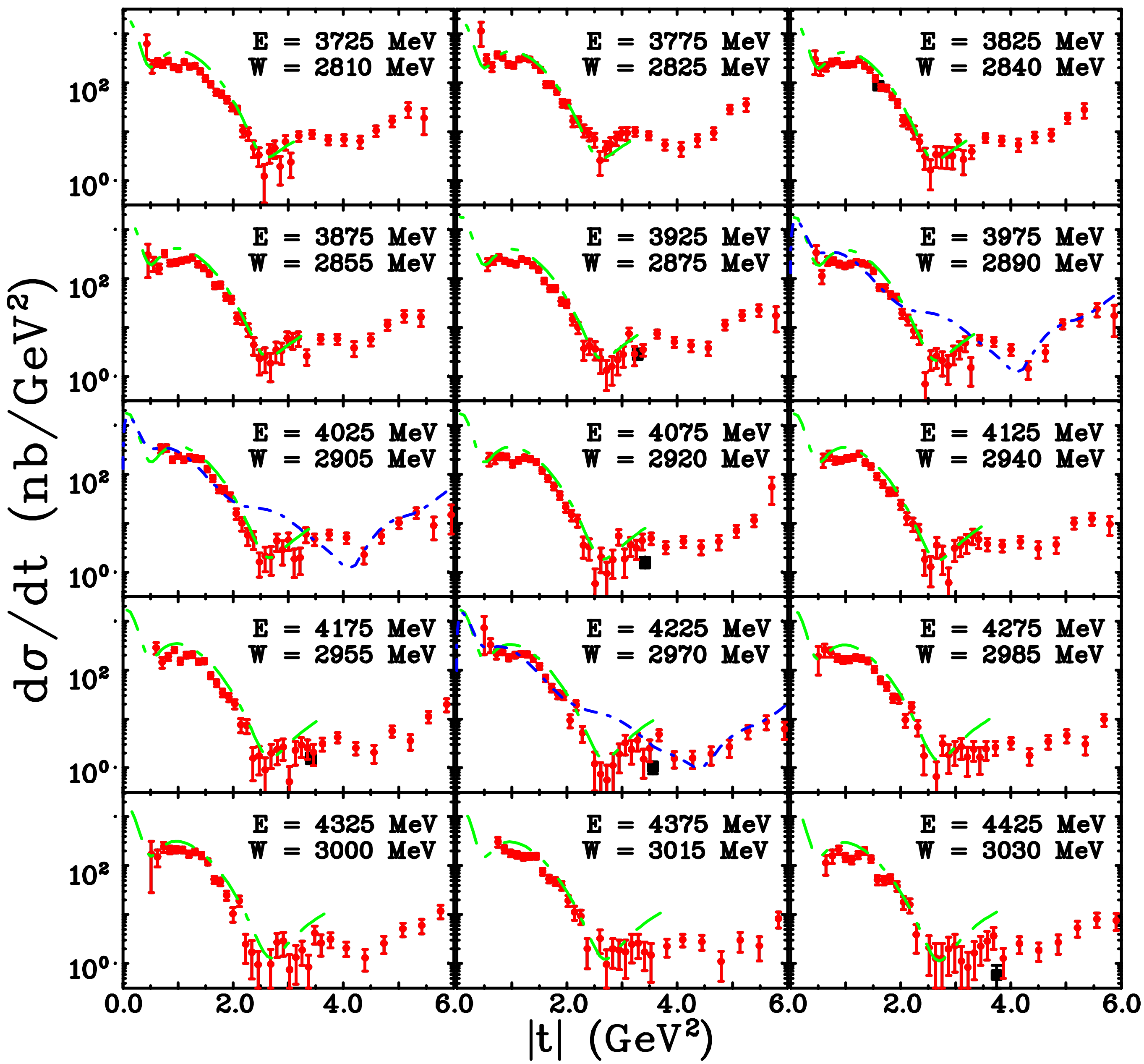


New (preliminary) CLAS and World Data (cont.)

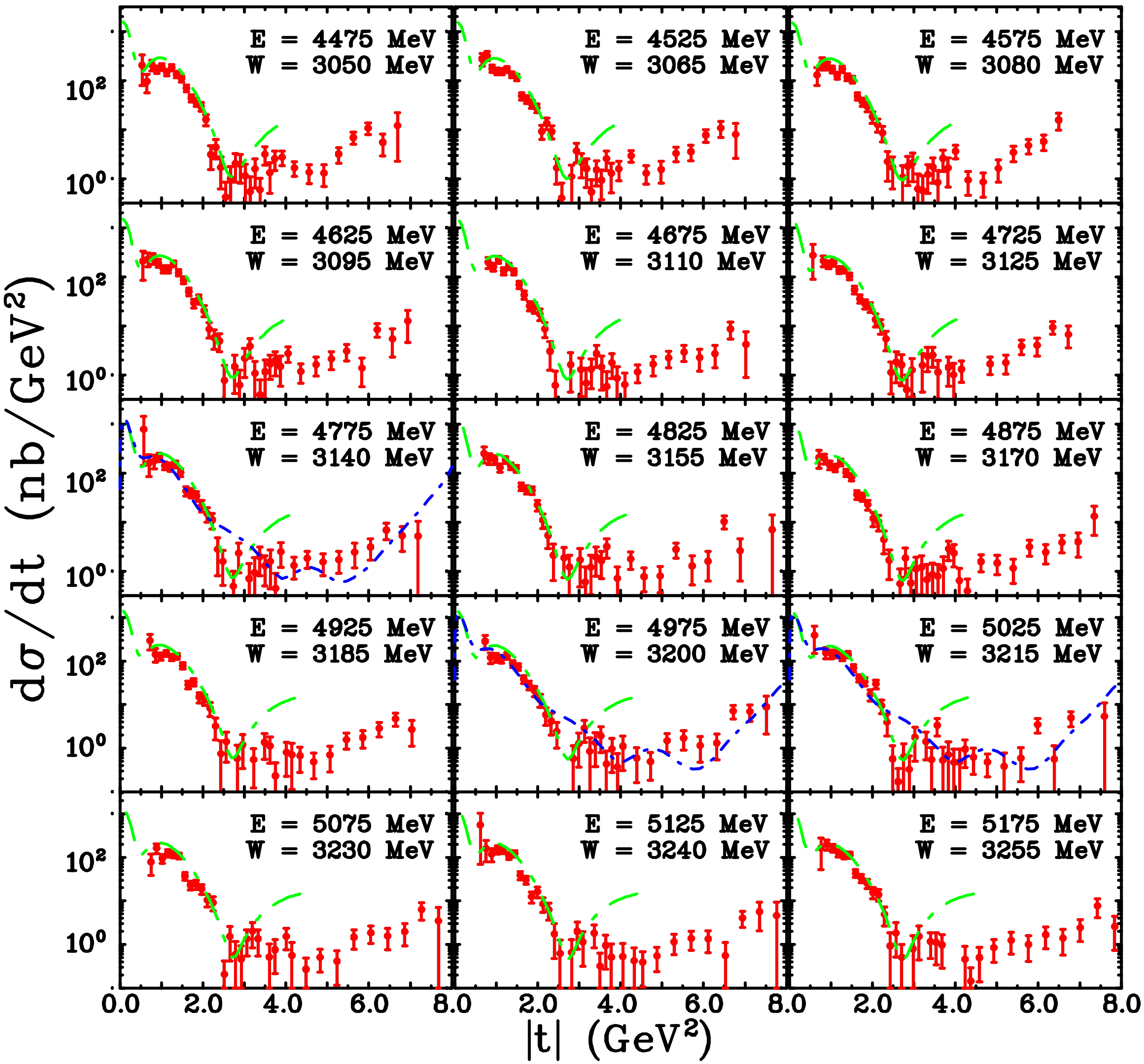


New state:
JP=13/2+
M=2560 MeV
Γ=220 MeV

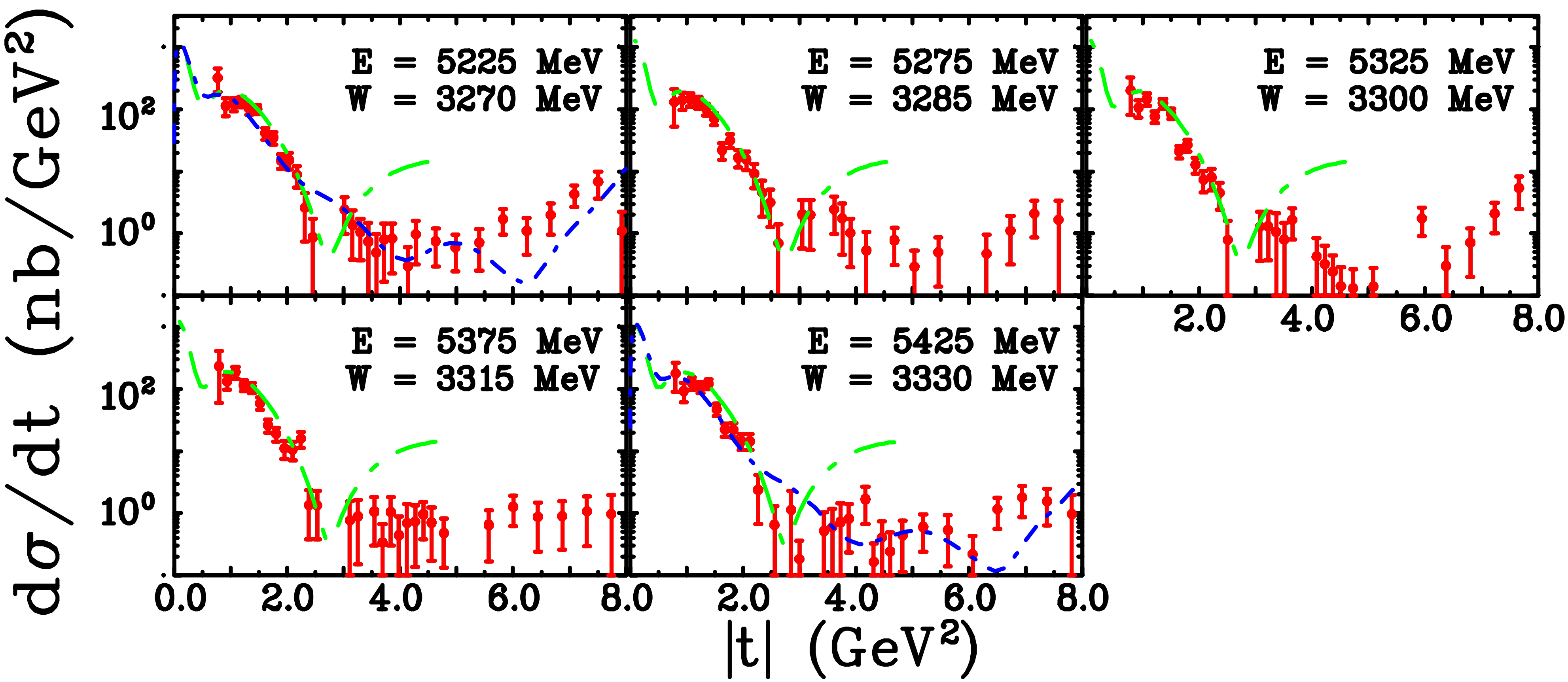
New CLAS and World Data (cont.)



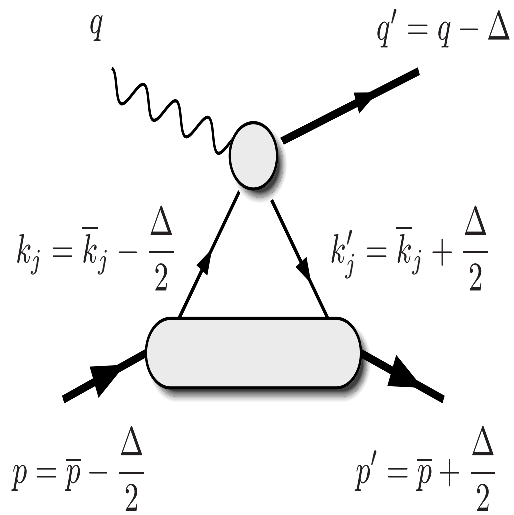
New CLAS and World Data (cont.)



New CLAS and World Data (cont.)



Handbag Model

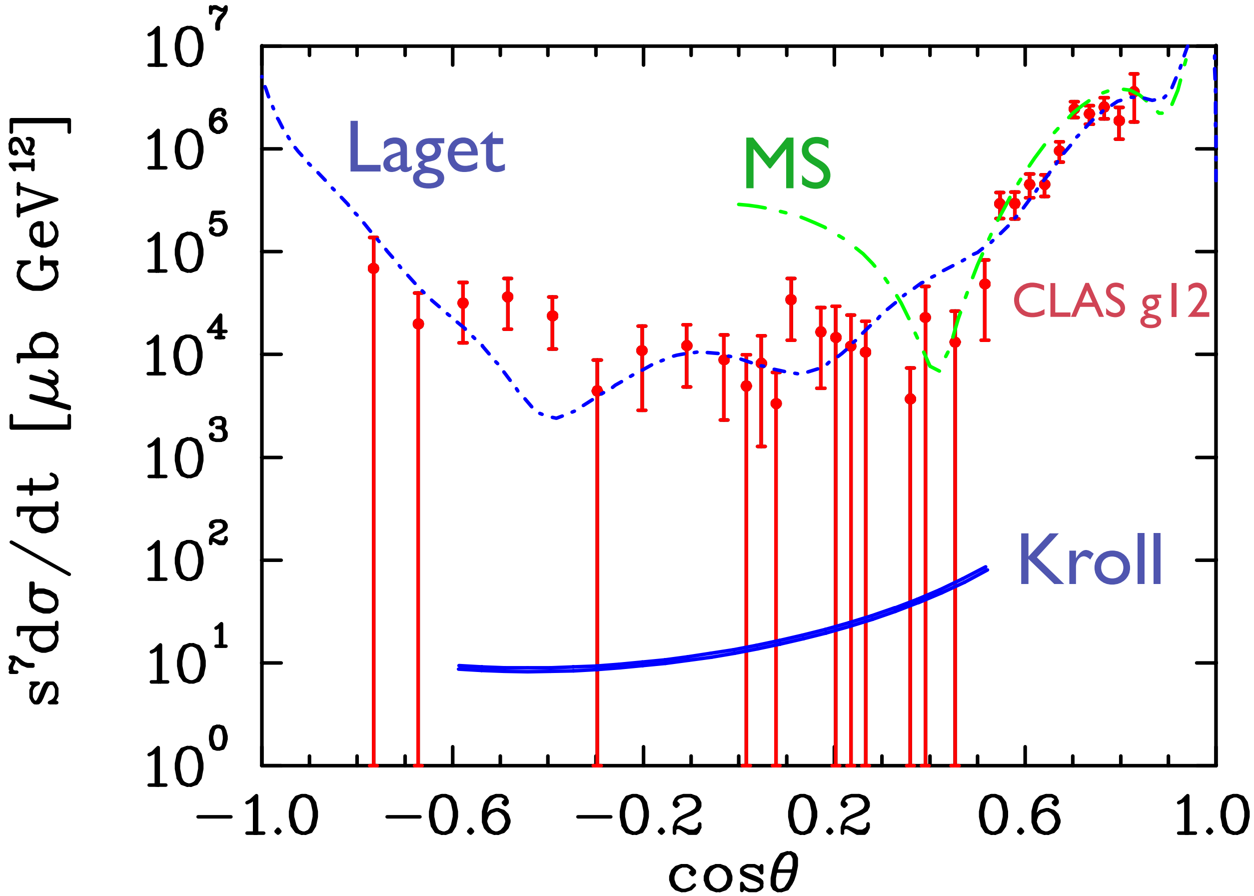


P. Kroll et al.

Applied to WACS is very successful

Underestimates neutral pion cross section significantly

s^7 Scaling in $\gamma + p \to p\pi^0$



Scaling: Future Prospects