

Coherent Vector -Meson Photoproduction off Deuterium: g_{10} Data

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CLAS COLLABORATION MEETING 2017

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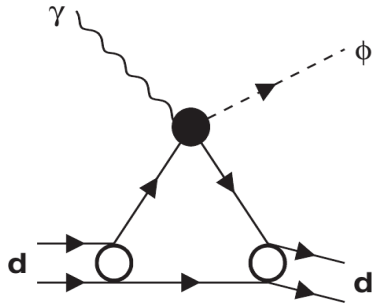
Outline

- $\gamma d \rightarrow \rho d$
 - PID
 - Yield Extraction
 - Results
- Updates on $\gamma d \rightarrow \omega d$
- Summary

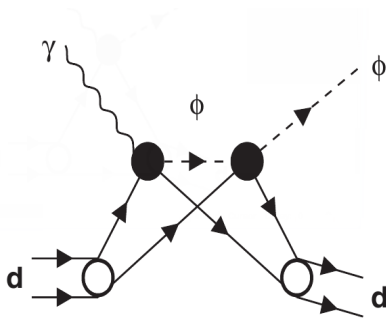
Motivation

$\gamma d \rightarrow \phi d$

Single scattering

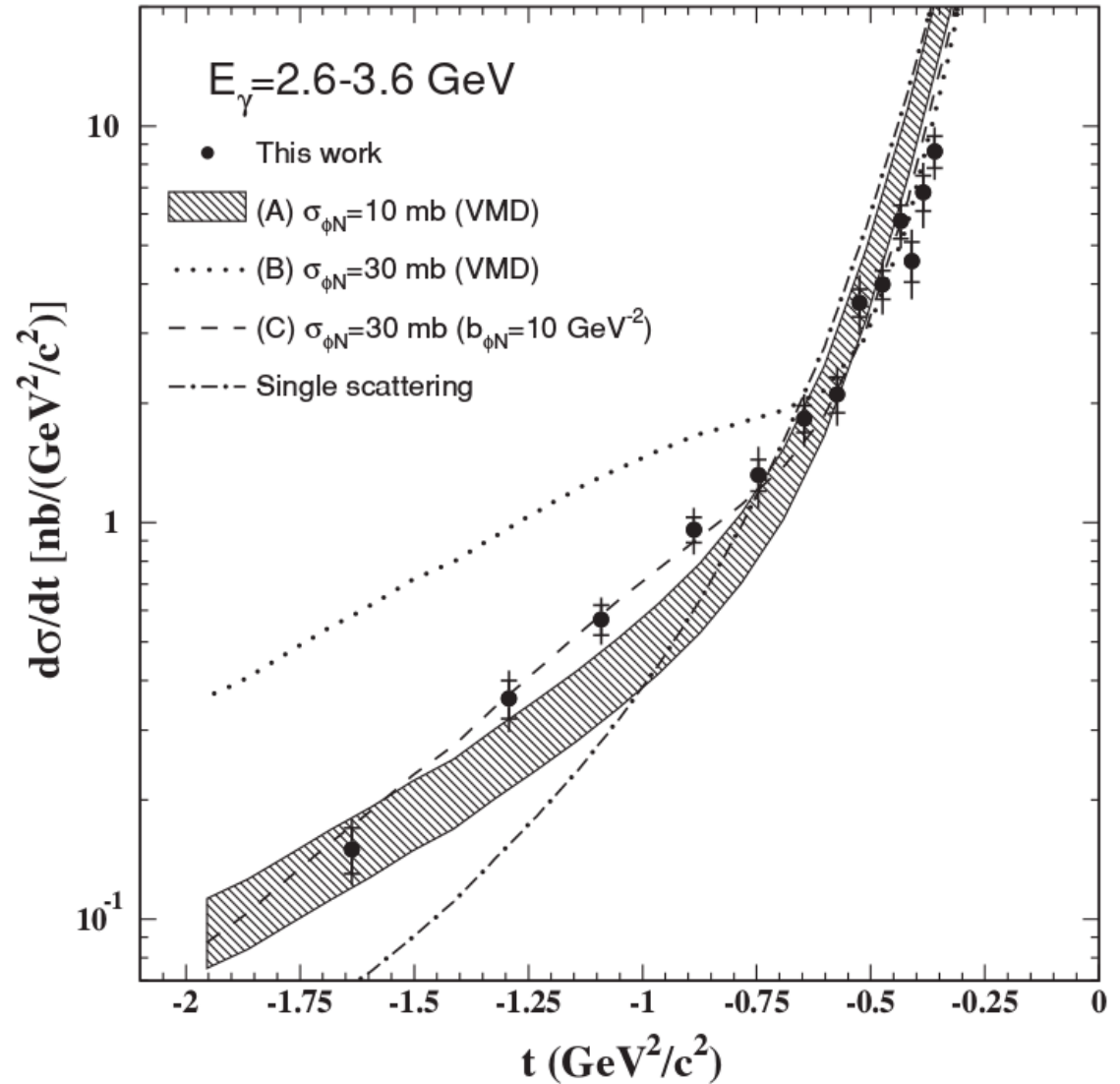


Double scattering



Mandelstam t :

$$t = (P_\gamma - P_\phi)^2 = (P_{d_i} - P_{d_o})^2$$

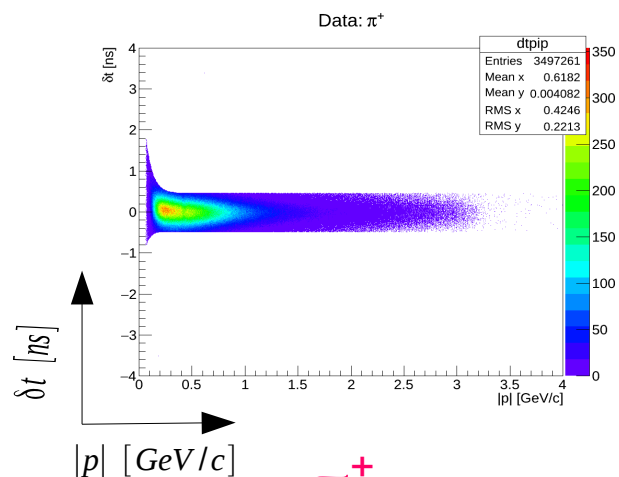
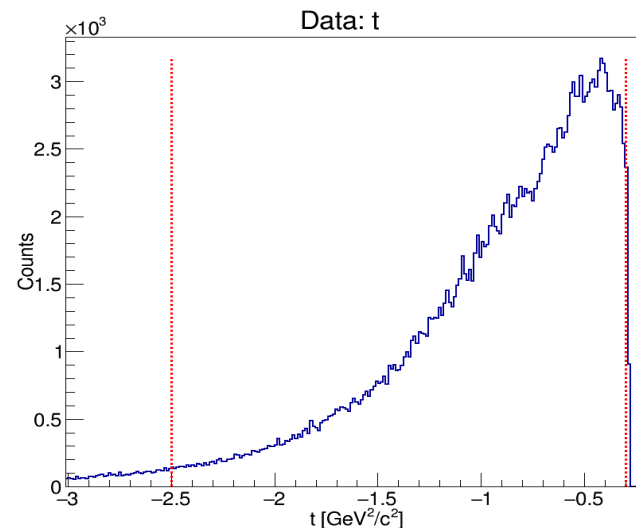
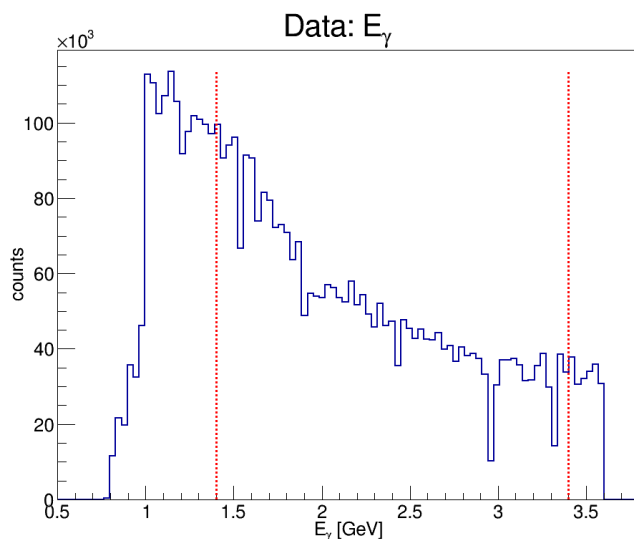


T. Mibe *et al.* PHYSICAL REVIEW C 76, 052202(R) (2007)

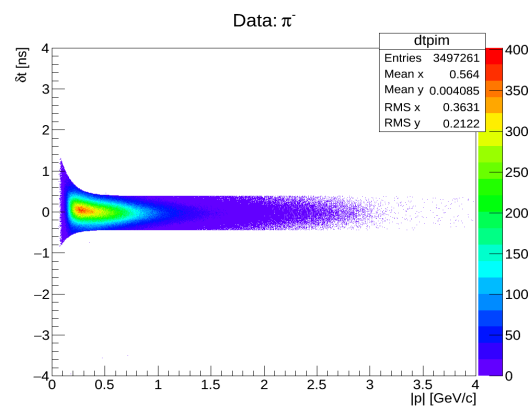
Particle Identification

$$\gamma d \rightarrow \rho d$$

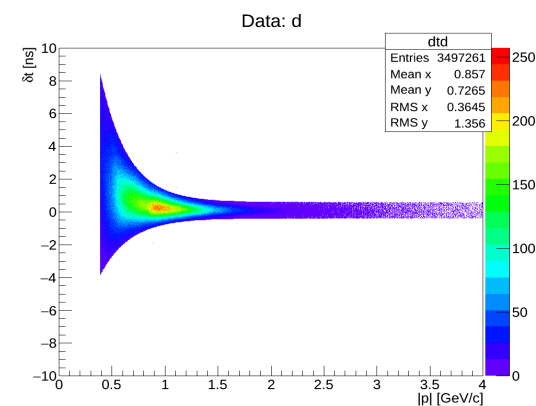
$$t = (p_\gamma - p_\rho)^2$$



π^+



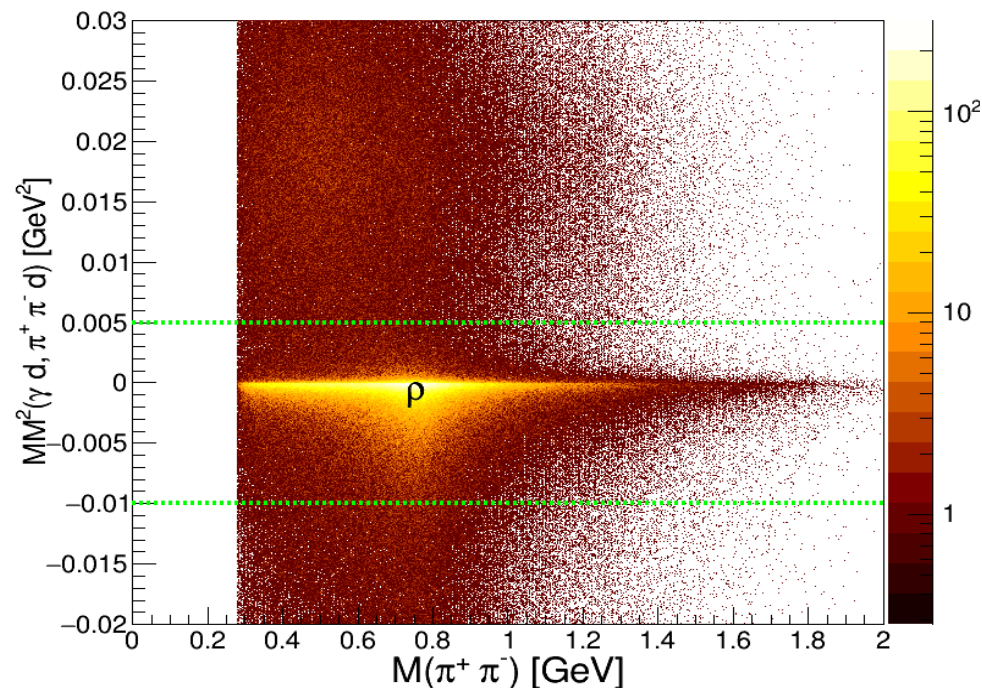
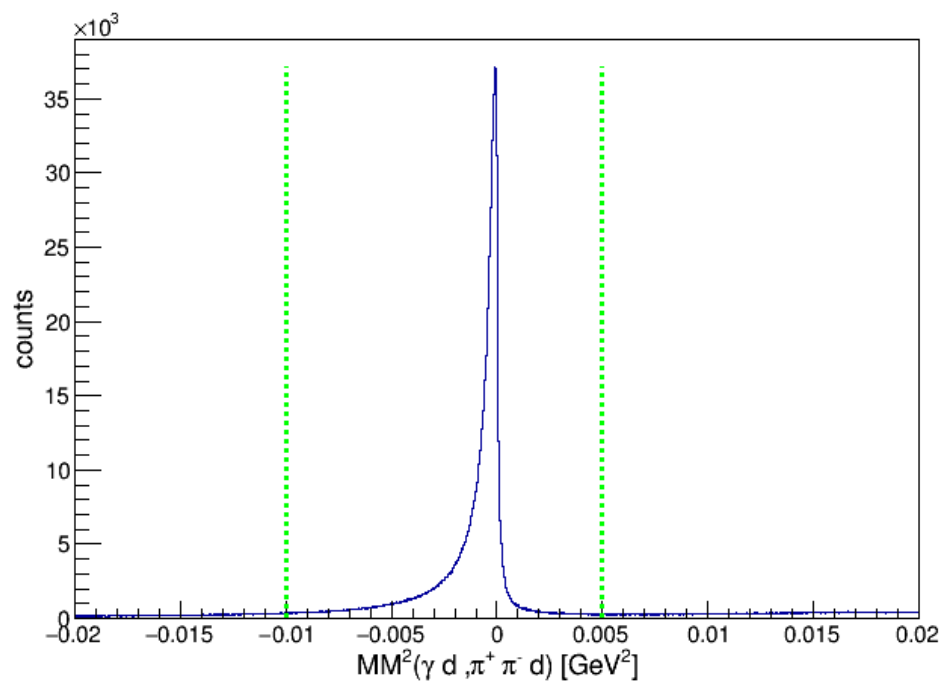
π^-



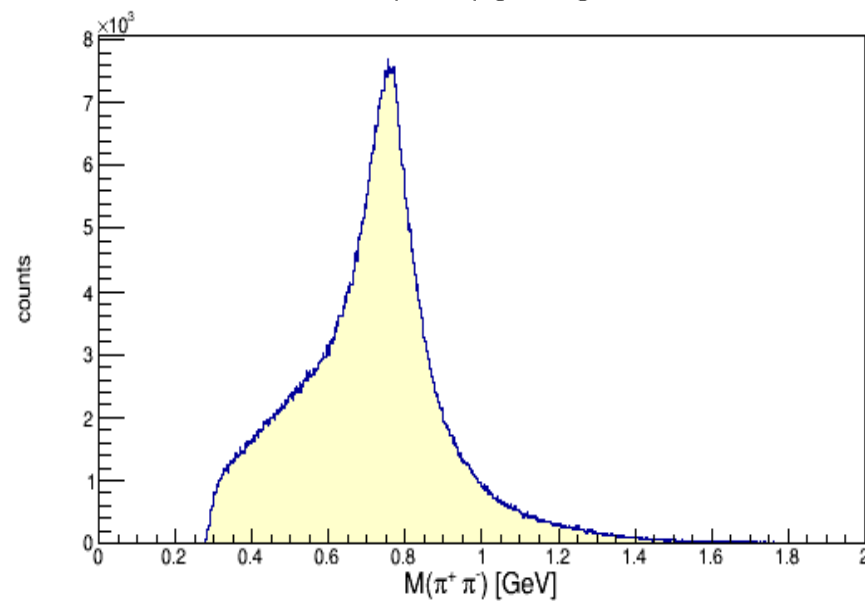
d

Global Spectrum

$$\gamma d \rightarrow \rho d$$



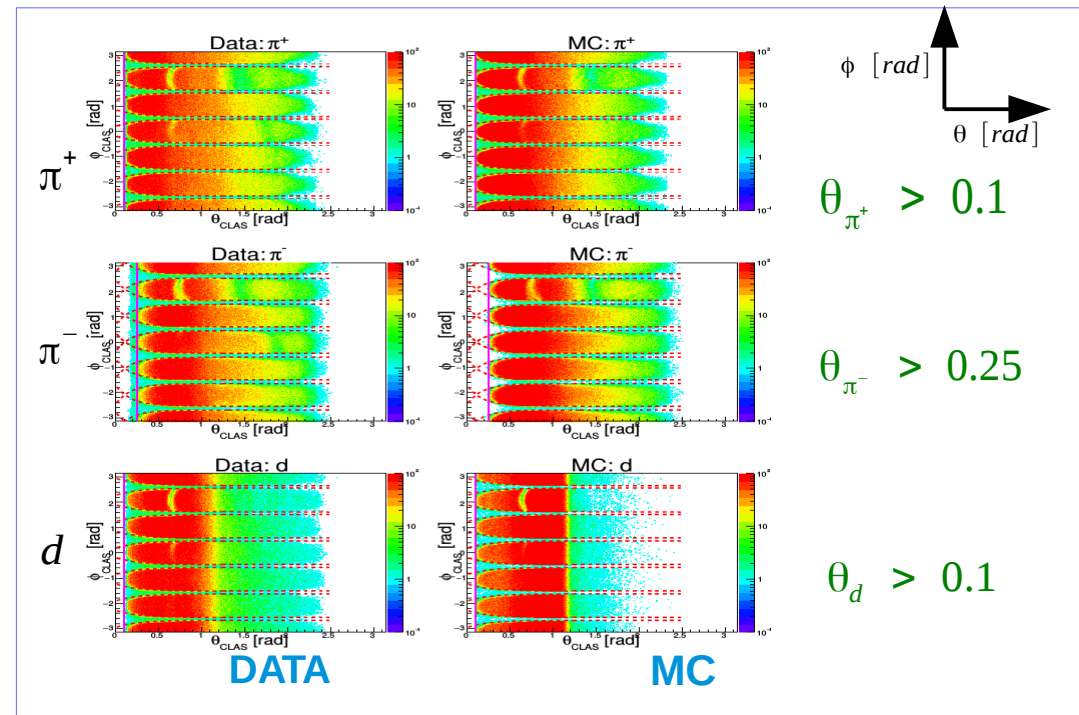
- $-0.01 < MM^2(\gamma d, \pi^+ \pi^- d) < 0.005$ $[\text{GeV}^2]$
- Signal over smooth background.
- Cuts applied to reduce background.



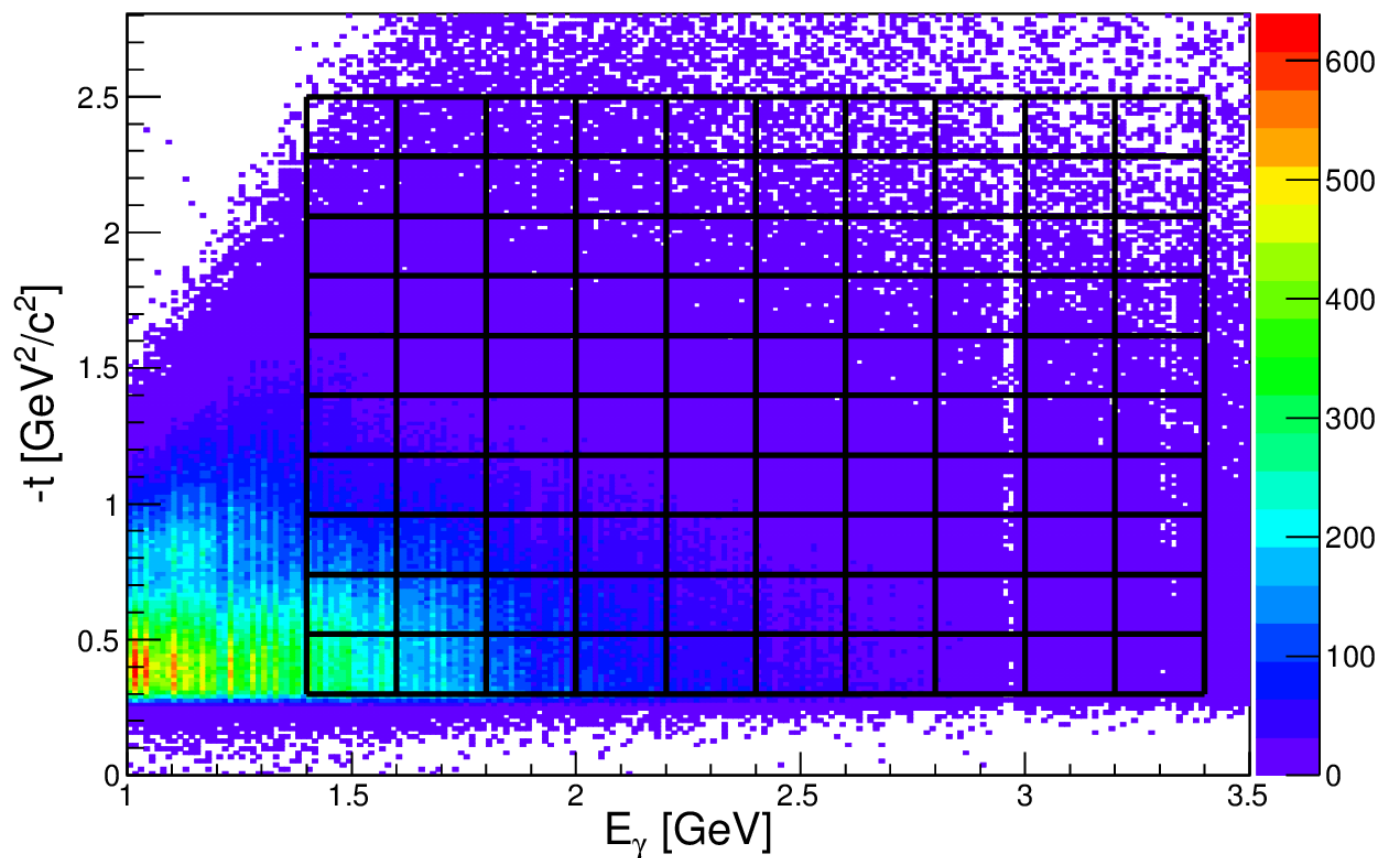
Cuts Applied

$$\gamma d \rightarrow \rho d$$

- Timing cuts made using momentum-dependent analysis
 - One “good photon”, $|\Delta t| < 1$ ns
- $-37 \text{ cm} < z_{\text{vertex}} < -13 \text{ cm}$
- Fiducial cuts applied $\phi = ae^{b\theta} + c$
 - Minimum Theta Cut
- Minimum Momentum Cuts
- Missing mass Squared Cut.
- Bad SC Paddles removed.



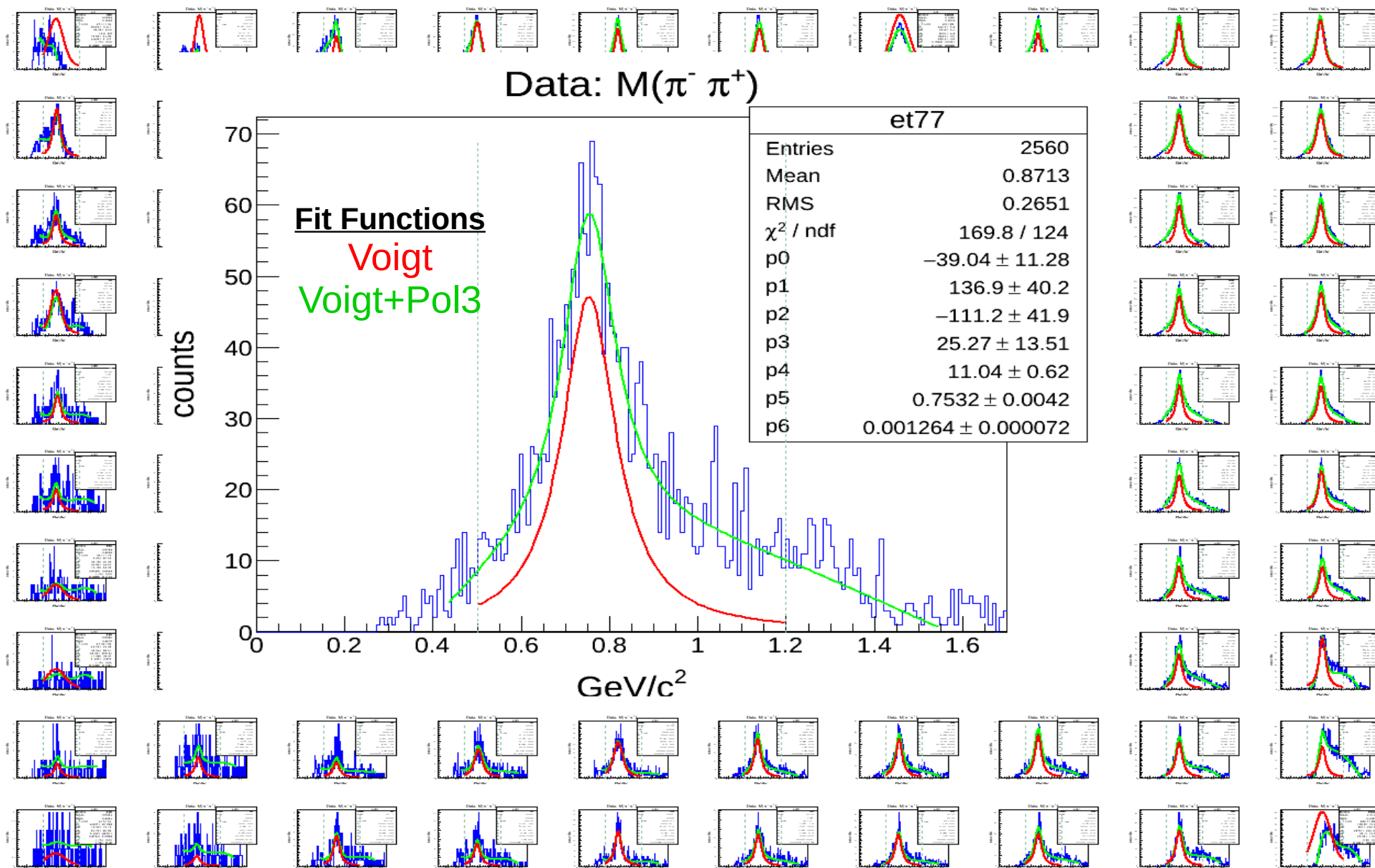
Particle	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5	Sector 6
π^+	23, 27 ≥ 43	≥ 45	11, 13, 23, 31 ≥ 40	23, 33, 35 ≥ 46	23, 29 ≥ 46	23 ≥ 45
π^-	23, 27 ≥ 41	≥ 41	11, 15, 16, 23, 31 34-36, ≥ 41	23, 27, 35 ≥ 43	20, 23, 29 ≥ 43	23 ≥ 42
d	23, 27 ≥ 35	23 ≥ 35	11, 22, 23, 31 ≥ 35	23 ≥ 35	23, 29 ≥ 35	23 ≥ 35



10 incident photon energy and 10 momentum transfer bins.

Yield Extraction

$$\gamma d \rightarrow \rho d$$



Yield is extracted by taking integral of the Voigt function

Differential Cross-section

Preliminary

Differential cross-section,

$$\frac{d\sigma}{dt} = \frac{Y_D}{\Delta t A \mathcal{L}}$$

A = Acceptance

Δt = Width of t -bin

Y_D = Signal Yield

Luminosity,

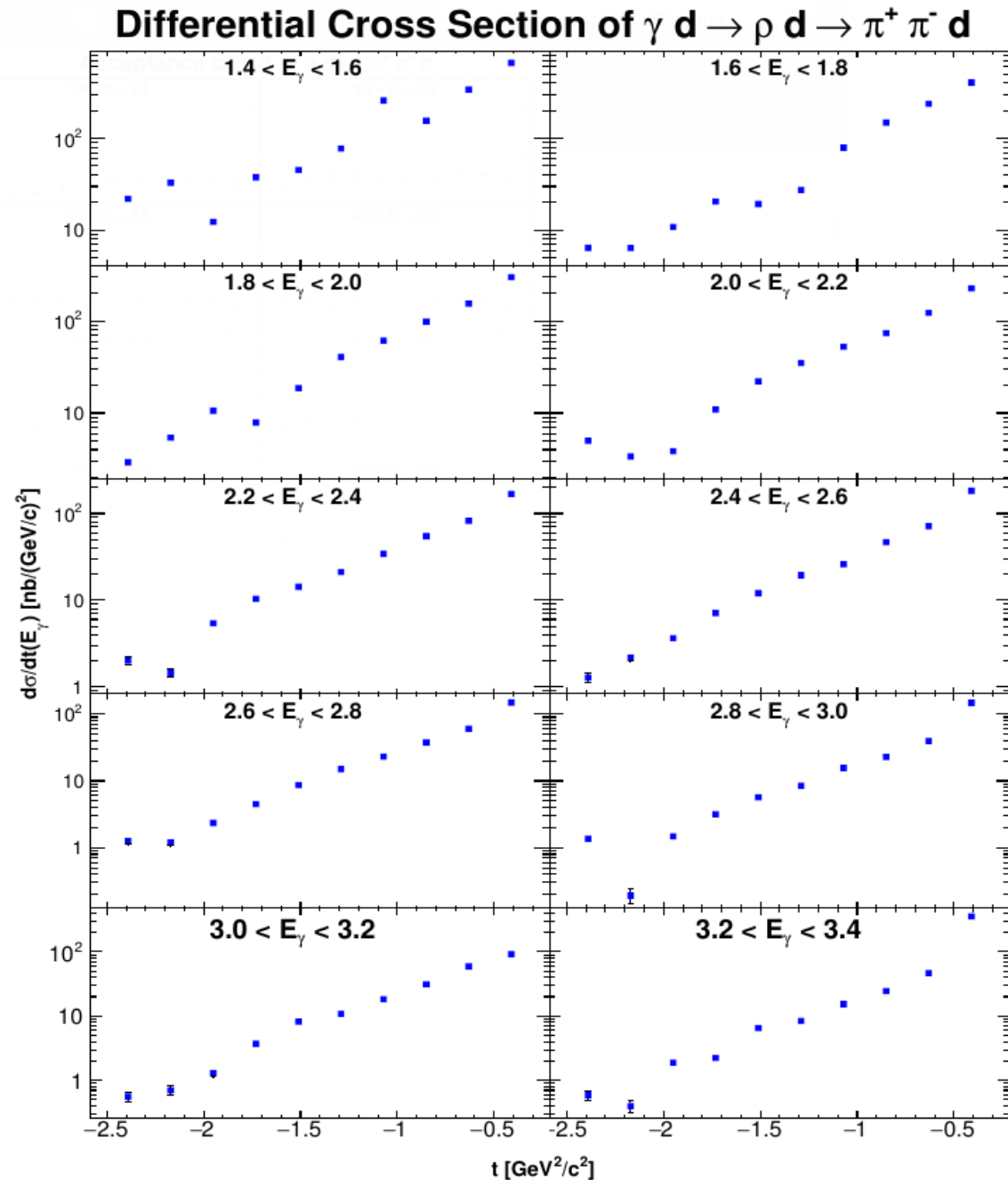
$$\mathcal{L}(E_\gamma) = \frac{\rho_T N_A l_T}{M_d} N_\gamma(E_\gamma)$$

$$\rho_d = 0.169 \text{ g cm}^{-3}$$

$$l_d = 24 \text{ cm}$$

$$M_d = 2.014 \text{ g mole}^{-1}$$

$$N_\gamma(E_\gamma) = \text{Photon Flux}$$



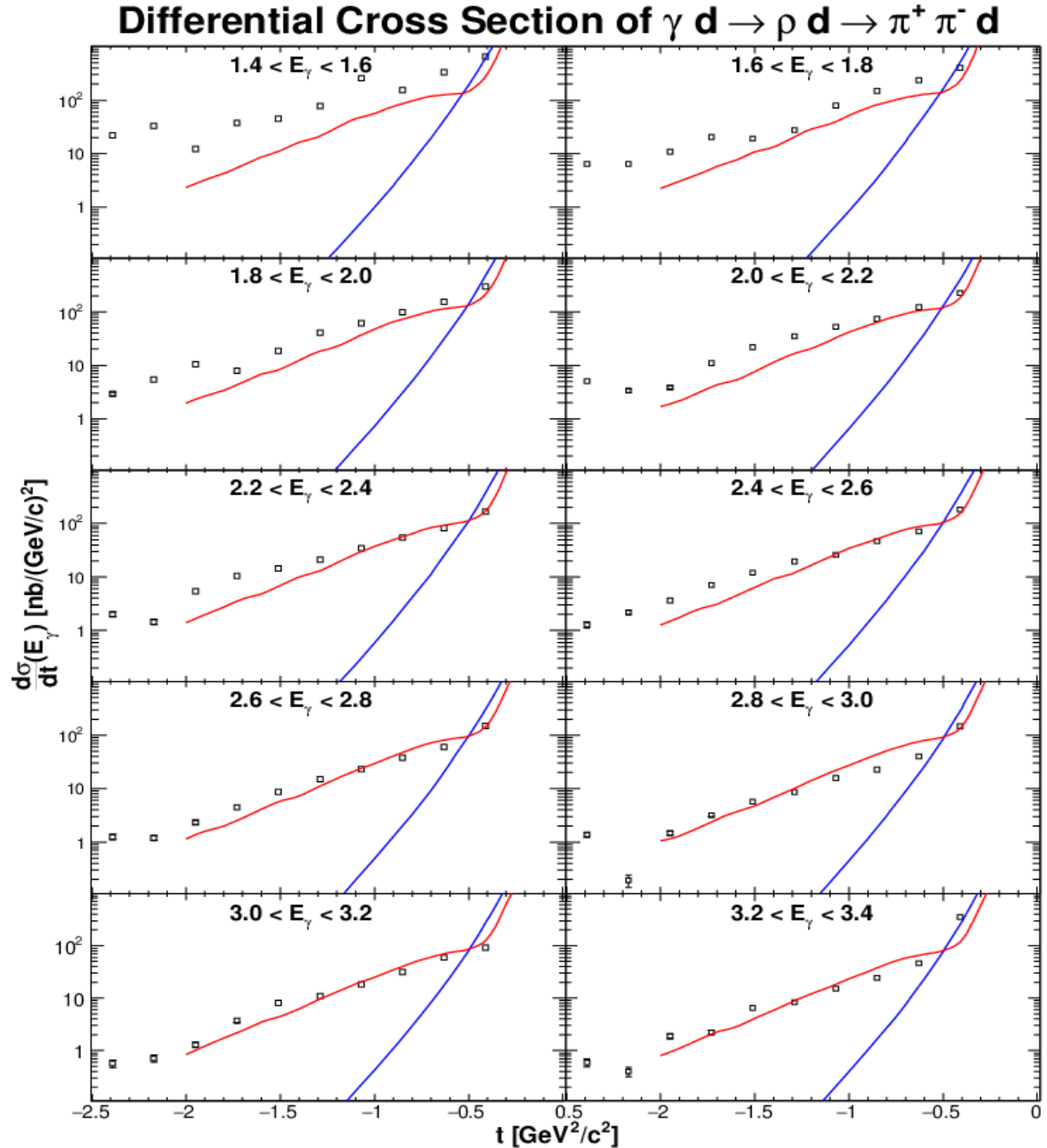
PRELIMINARY

Differential Cross-section

Preliminary

- Calculations are provided by Dr. Sargsian (FIU)*.
- Production of ρ is within the Vector Dominance Model.
- Born Term Contribution: single scattering
- Final State Interaction included

Work in Progress!



* Coherent Photo- and Leptoproduction of Vector Mesons from Deuterium, **Frankfurt et al**, Nucl.Phys. A622 (1997) 511-537

Differential Cross Section for $\gamma d \rightarrow \omega d$ using CLAS at Jefferson Lab

Taya Chetry* and Kenneth Hicks†
Ohio University, Athens, Ohio 45701
(CLAS Collaboration)
(Dated: September 26, 2017)

The cross section for the coherent ω -meson photoproduction off of deuteron have been measured for the first time as a function of the momentum transfer $t = (P_\gamma - P_\omega)^2$ and E_γ using the CLAS detector at the Thomas Jefferson National Accelerator Facility. The cross sections are calculated in the energy range $1.4 < E_\gamma < 3.4$ GeV. A rescattering model used for comparison is consistent with the data at low and intermediate momentum transfer regimes. For large $|t|$, discrepancy between data and the calculation suggests the need of the u -channel contribution to include the effects due to the large center of mass scattering angle. Due to limited world data on $\gamma d \rightarrow \omega d$, this measurement opens up the possibility to study ωN interaction at low energies and large $|t|$.

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The study of vector meson photoproduction off protons at high energies is well described theoretically using the phenomenological model of Vector Meson Dominance (VMD). At lower energies, closer to the production threshold, other diagrams become important which include either an intermediate nucleon or a Δ resonance, or exchange of mesons in the t -channel. At very low energies, the reaction dynamics off protons is dominated by the t -channel exchange of mesons. However, coherent ω -meson production from a deuteron avoids this additional complexity. Since both the deuteron as well as final ω state are isosinglets, they filter out contributions from non-isosinglet (i.e. ρ - ω meson) exchanges. Hence, natural parity exchange in the t -channel, usually described by Pomeron exchange (see Fig. 1a), is expected to dominate at low momentum transfer (low $|t|$) for vector meson photoproduction off deuteron, thus simplifying theoretical interpretations of the data.

At higher momentum transfer ($|t| > 0.5$ GeV²), secondary scattering diagrams, where the ω is produced off one nucleon and scatters from the second, as shown

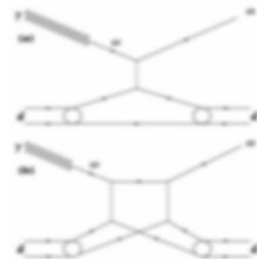


FIG. 1. Two ways of production of ω -meson during photoproduction: (a) Single and (b) Double scattering.

in Fig. 1b, enable both nucleons to remain bound as a deuteron in the final state [3]. These diagrams provide an opportunity to extract the ω - N total scattering cross section, $\sigma_{\omega N}$, from comparisons of data and calculations. Similar studies were done for coherent ρ -meson photoproduction off deuteron, resulting in the first-ever extraction of $\sigma_{\rho N}$ [4]. Of course, information from total cross sections is virtually impossible to extract cleanly via other methods, due to the short lifetimes of these mesons.

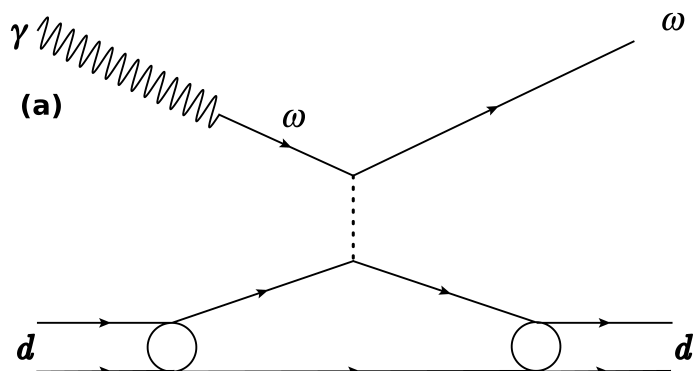
Experimental information on $\sigma_{\omega N}$ is of interest currently because of progress with lattice QCD. Lattice can now extract meson-meson scattering phase shifts directly based on QCD [5]. This same group is working on extracting meson-nucleon scattering phase shifts, which are directly related to the total cross sections. The ω meson is a particularly good choice for these studies, since isospin conservation requires the ω to decay into three pions, and hence the ω is a stable particle in lattice calculations where the pion mass is higher than its physical value. Hence, measurements of $\sigma_{\omega N}$ are timely and can be compared with predictions from lattice calculations when they become available.

Previous experimental data on coherent ω photoproduction are scarce. A summary of measurements is given in Bauer *et al.* [6], which are mostly data from bubble-chamber experiments, and have low statistical precision. The best data of this reaction are from a group at the Weizmann Institute [7], using a photon beam of energy 4.3 GeV and was limited to $|t| < 0.2$ GeV², which is too small to see the effect of double-scattering as shown in Fig. 1b. Data on coherent ρ photoproduction has been measured at higher $|t|$ in the SLAC experiment [8], which was used to extract $\sigma_{\rho N}$. No previous data exists that would allow an extraction of $\sigma_{\omega N}$.

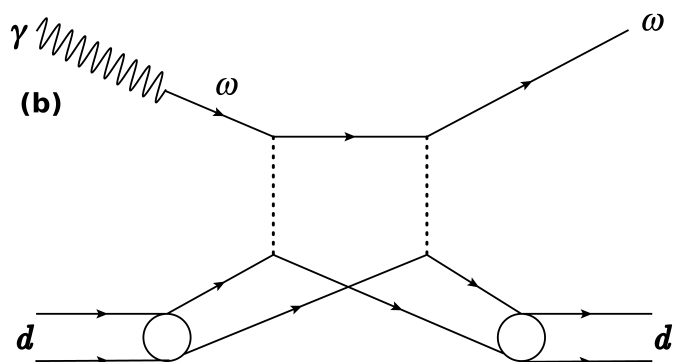
Here, we present data on coherent ω photoproduction off deuterons at photon energies ranging from 1.4–3.4 GeV over a wide range in the momentum transfer t . Due to the zero isospin of both particles in the final state, only isospin-0 exchange terms are allowed under the assumption of VMD. The t -dependence of the

Almost ready!

Single scattering



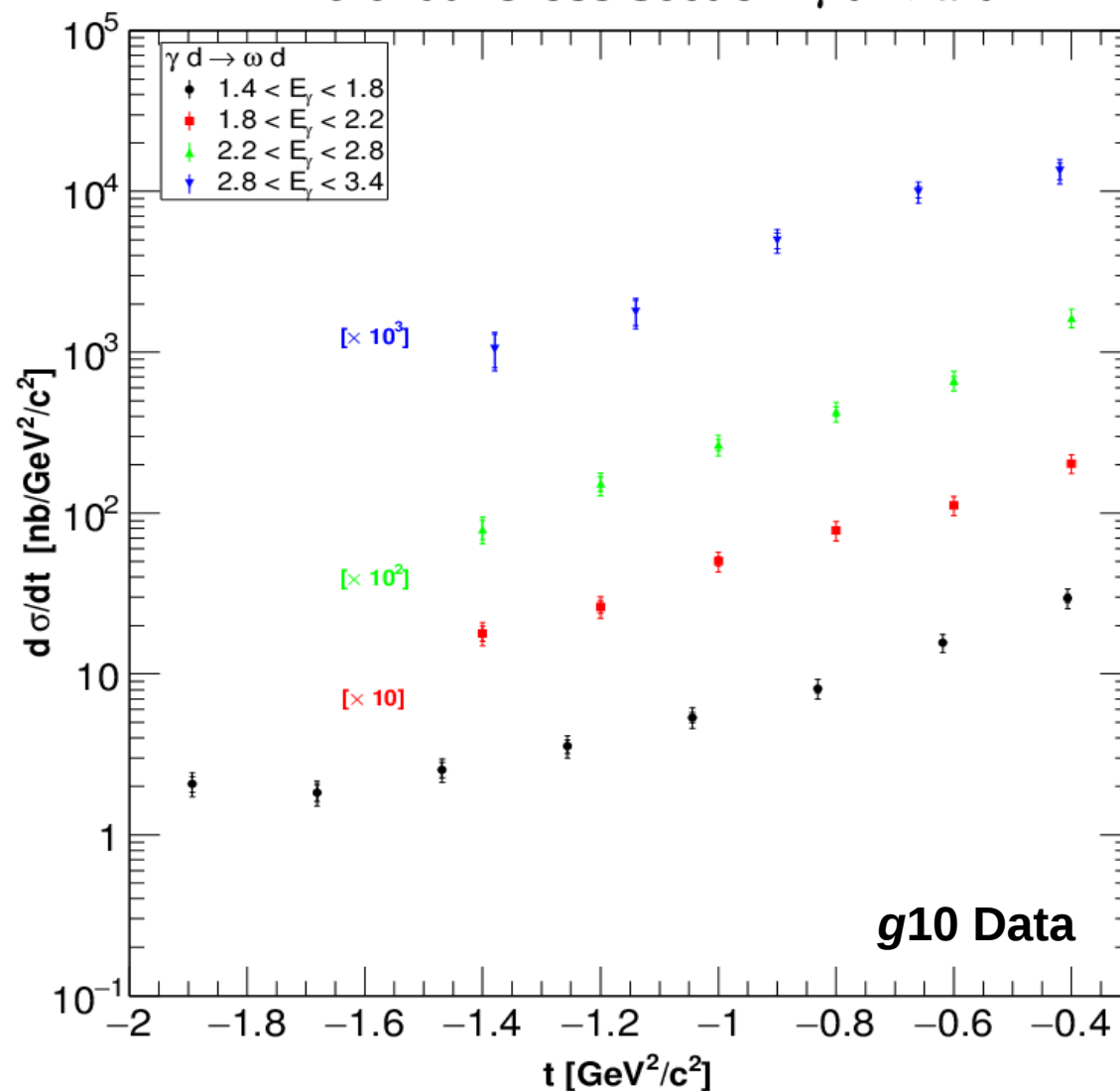
Double scattering

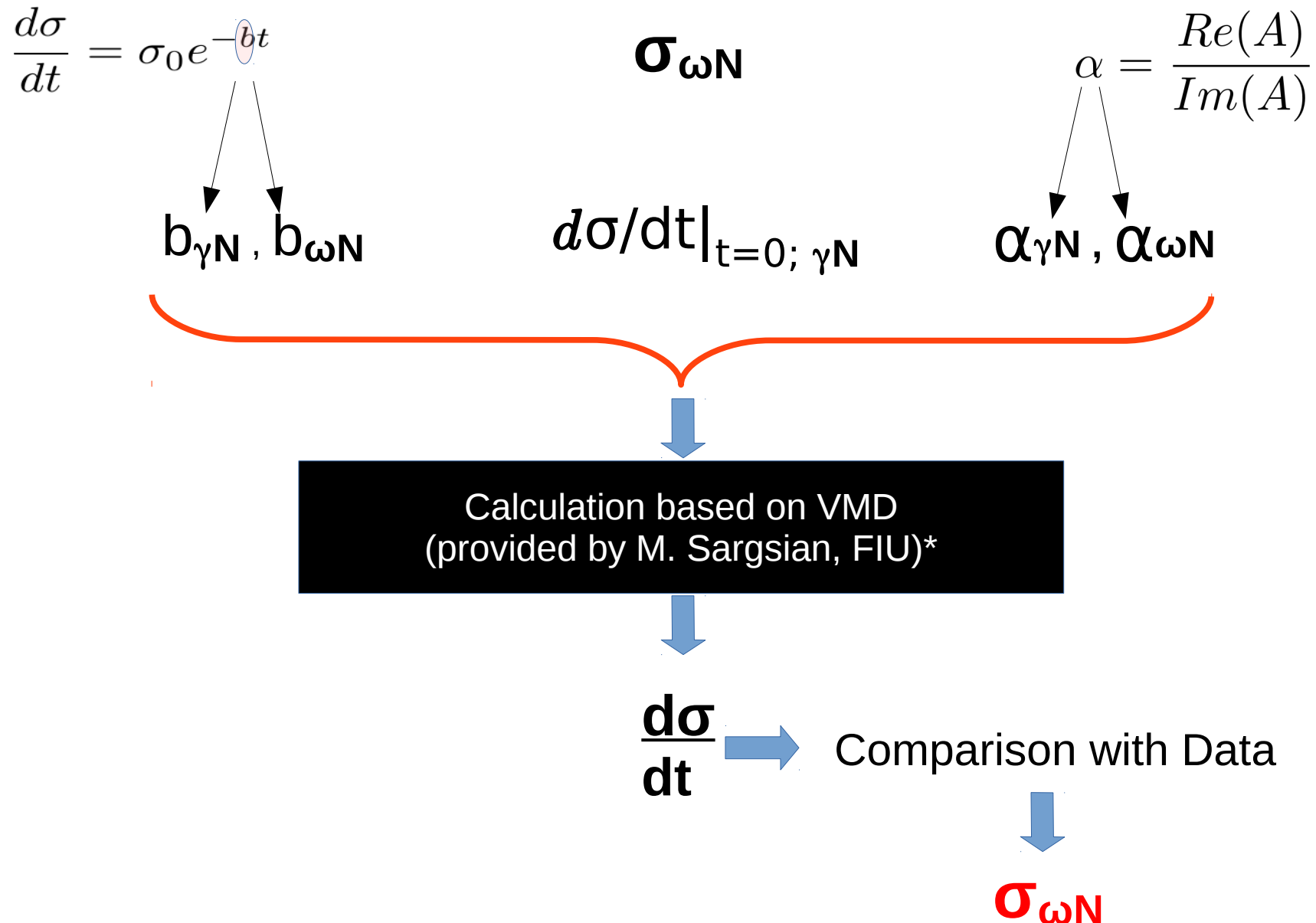


Mandelstam t :

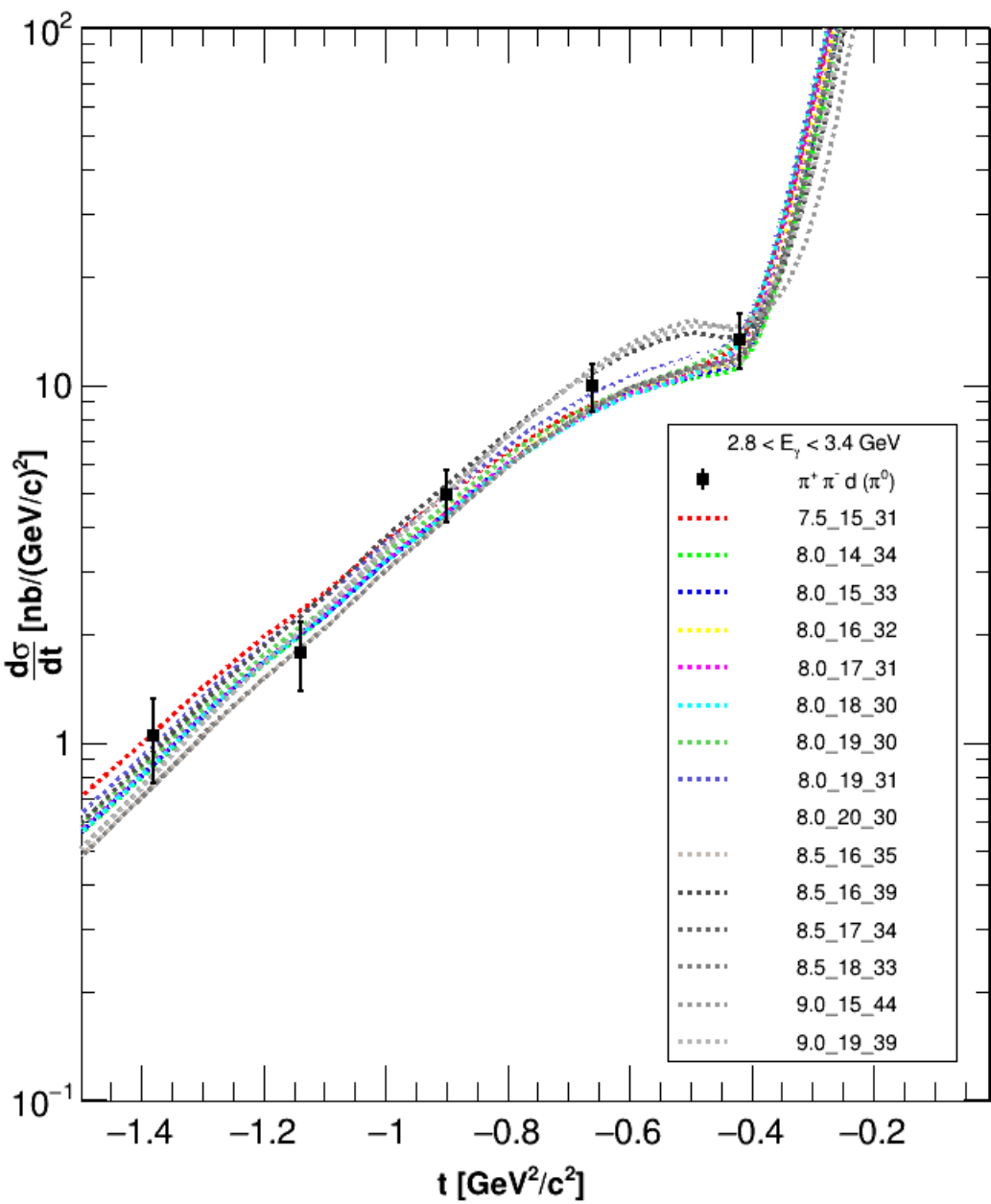
$$t = (P_\gamma - P_\omega)^2 = (P_{d_i} - P_{d_o})^2$$

Differential Cross Section: $\gamma d \rightarrow \omega d$





* Frankfurt et al, Nucl.Phys. A622 (1997) 511-537



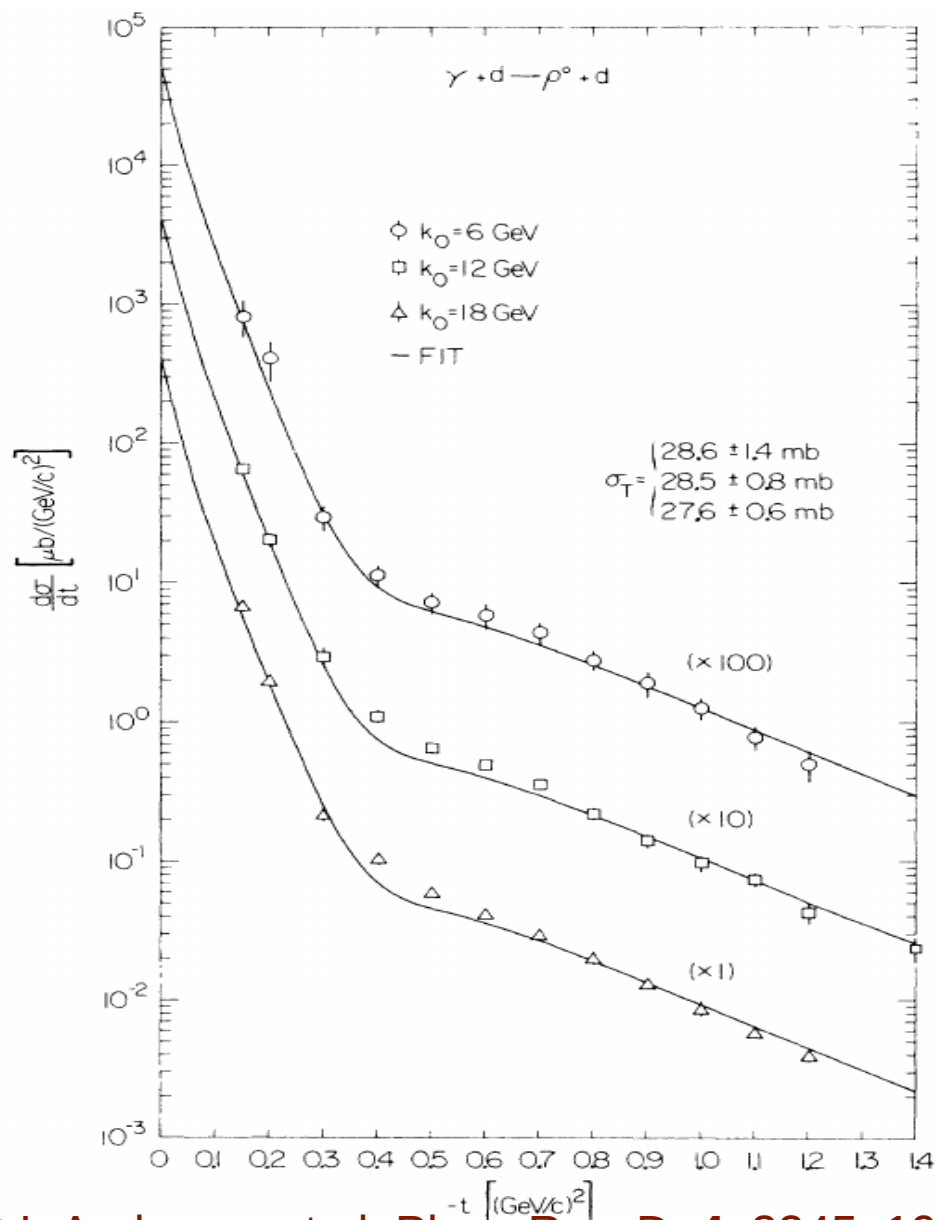
$$\alpha_{\gamma N} = \alpha_{\omega N} = -0.4$$

$b_{\gamma N} = b_{\omega N}$ [GeV ⁻²]	$\frac{d\sigma}{dt}\big _{t=0,\gamma N}$ [μb/GeV ²]	$\sigma_{\omega N}$ [mb]	χ^2/NDF
7.5	15	31	1.13
8.0	14	34	1.15
8.0	15	33	1.01
8.0	16	32	0.96
8.0	17	31	1.00
8.0	18	30	1.15
8.0	19	30	0.91
8.0	19	31	0.87
8.0	20	30	1.03
8.5	16	35	1.11
8.5	16	39	1.00
8.5	17	34	1.05
8.5	18	33	1.07
9.0	15	44	0.99
9.0	19	39	0.89
9.0	20	38	0.87

Summary

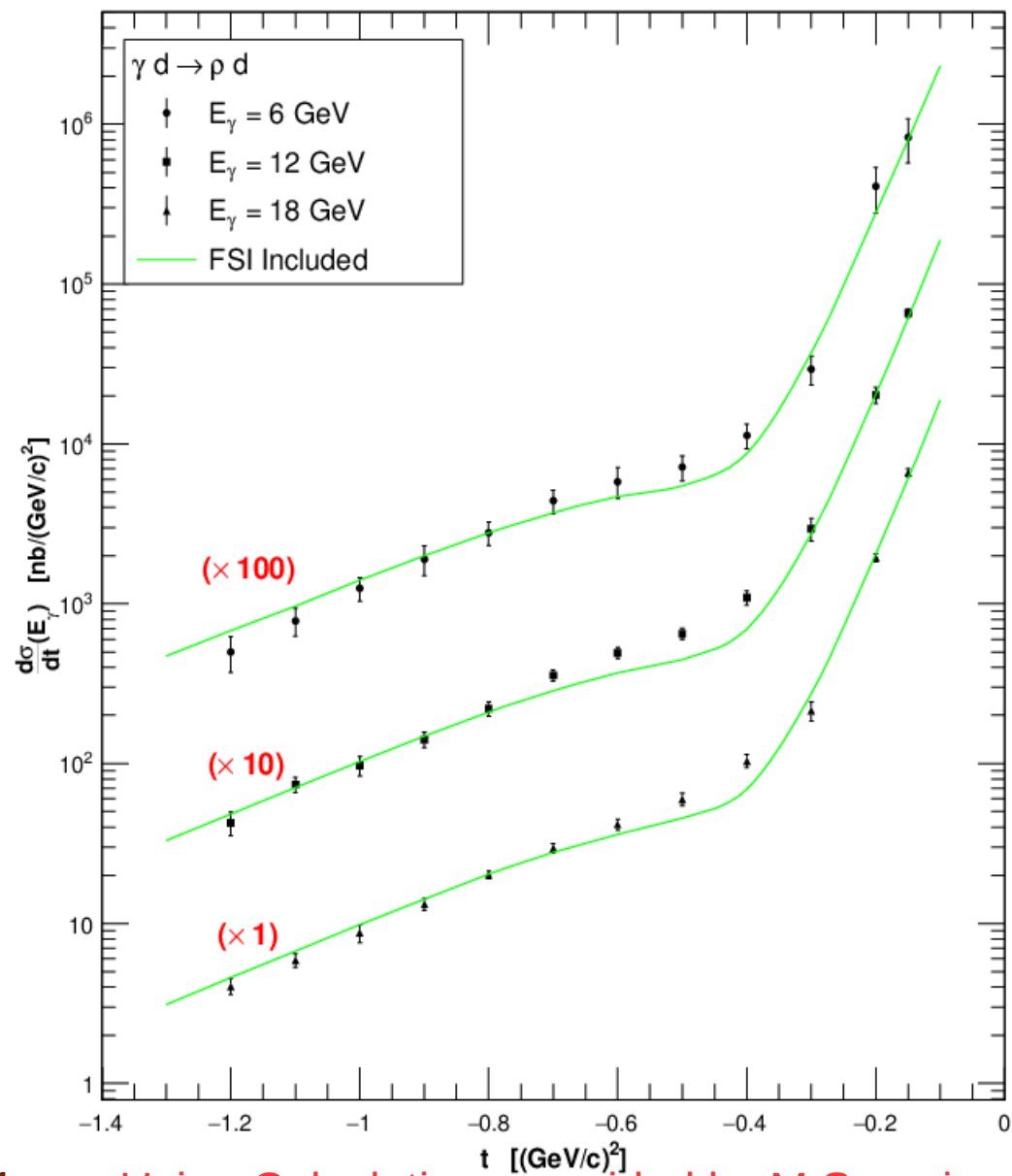
- The cross-section data provides sensitivity to the nucleon-scattering data in relatively low energy and high momentum transfer range mentioned.
- $\frac{d\sigma}{dt} \propto e^{-b|t|} \rightarrow$ as expected for a diffractive process.
- Rho analysis Note: soon to be submitted. With rho, the trio of vector meson will be complete!
- Omega paper almost done:
 - Tweaking with the theory parameters.
 - Quote $\sigma_{\omega N}$
 - Soon to be submitted to the *ad-hoc* committee.

Extras



R.L.Anderson et al, Phys. Rev. D. 4, 3245, 1971

Differential Cross Section of $\gamma d \rightarrow \rho d$ (SLAC)



Using Calculations provided by M.Sargsian

Differential cross-section,

$$\frac{d\sigma}{dt} = \frac{Y_D}{\Delta t A \mathcal{L}} \times \frac{\Gamma_\omega}{\Gamma_{\omega \rightarrow \pi^+ \pi^- \pi^0}} \times \gamma_{corr}$$

A = Acceptance

Δt = Width of t -bin

Y_D = Signal Yield

γ_{corr} = Photon Multiplicity
Correction factor

Luminosity,

$$\mathcal{L}(E_\gamma) = \frac{\rho_T N_A l_T}{M_d} N_\gamma(E_\gamma)$$

$$\rho_d = 0.169 \text{ g cm}^{-3}$$

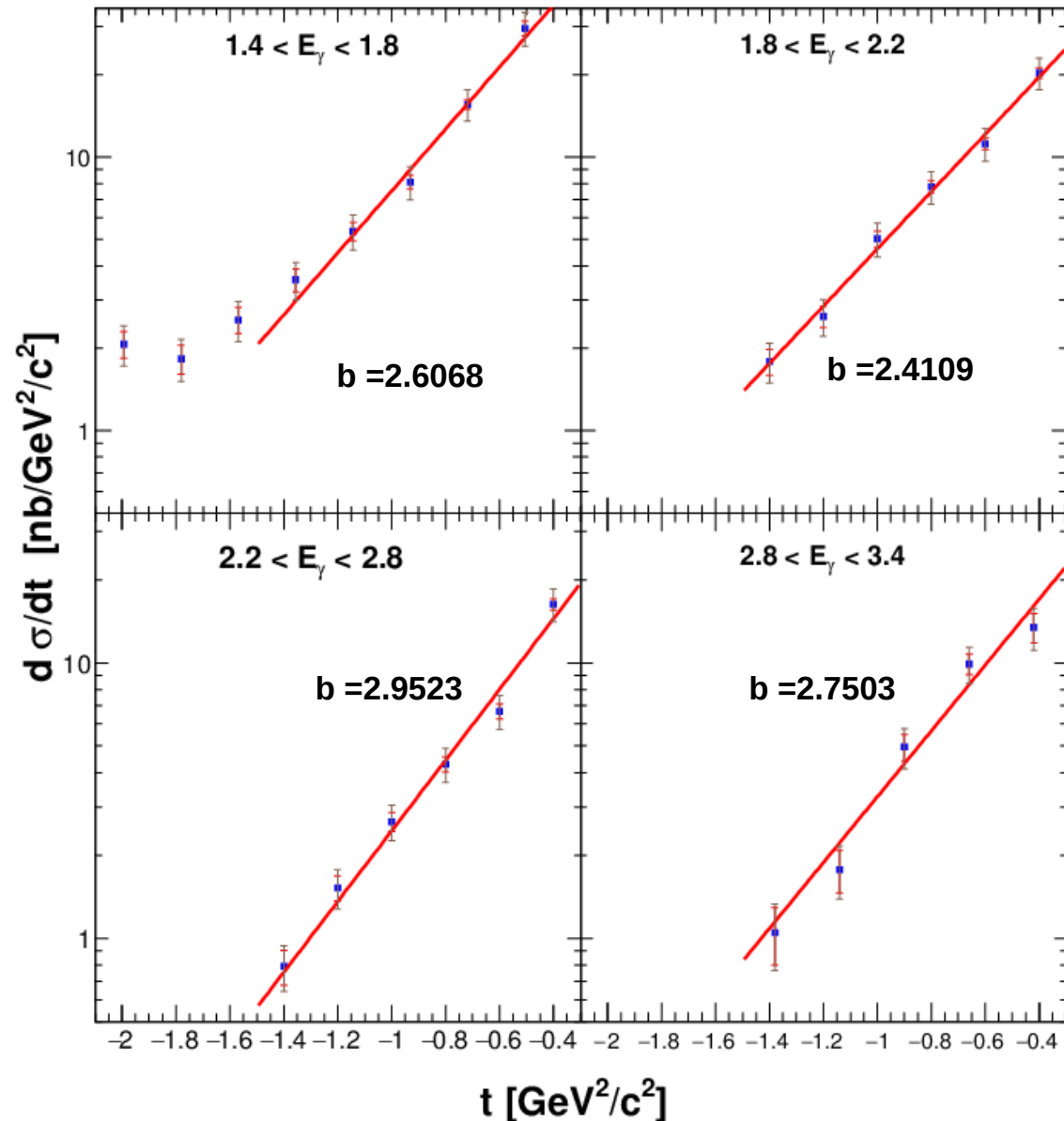
$$l_d = 24 \text{ cm}$$

$$M_d = 2.014 \text{ g mole}^{-1}$$

$$N_\gamma(E_\gamma) = \text{Photon Flux}$$

$$\frac{d\sigma}{dt} \propto e^{-b|t|}$$

Differential Cross Section: $\gamma d \rightarrow \omega d$



PRELIMINARY

Group	E_γ [GeV]	t [GeV/c ²]	Comments
Gupta <i>et. al.</i> [SLAC] Phys. Rev. D 14, 42 (1976)	5.5	-	Low statistics. No mass fit was possible
Morris <i>et. al.</i> [NINA] Nuclear Physics B119 (1977)	3.9	-	*Total Cross-section measured: $1.4 \pm 0.5 \mu\text{b}$ *Coupling constant ratio (ρ/ω) measured

Photoproduction of ω mesons off protons and neutrons

Eur. Phys. J. A (2015) 51: 6

Back-up

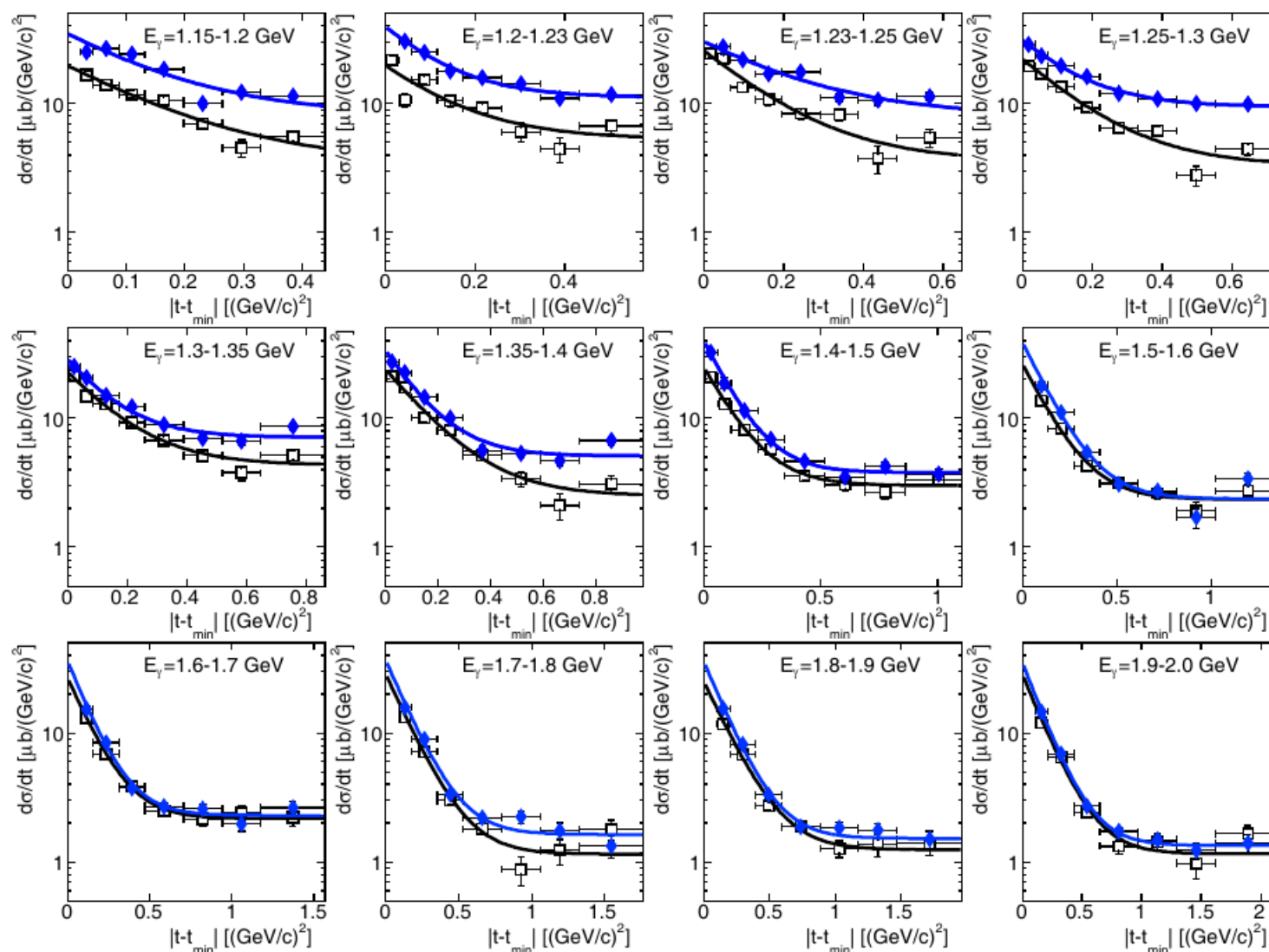


Fig. 11. (Color online) Differential cross-section *versus* the momentum transfer to the nucleon for ω mesons produced off the bound proton (open squares) and for ω mesons produced off the free proton (blue diamonds).

Photoproduction of ω mesons off protons and neutrons

Eur. Phys. J. A (2015) 51: 6

Back-up

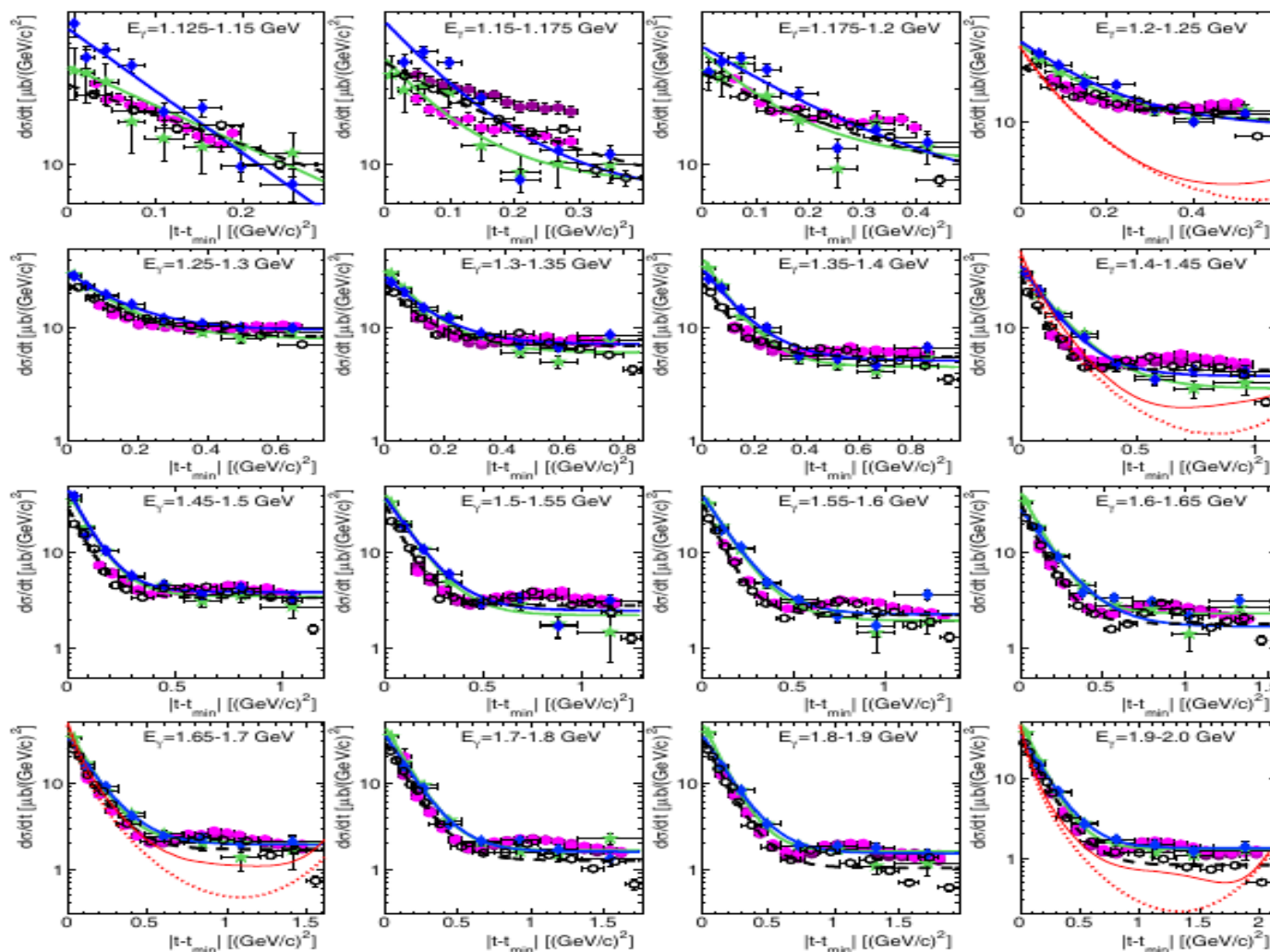


Fig. 9. (Color online) Differential cross-sections of ω mesons produced off the free proton versus the momentum transfer to the nucleon, t . The results of this work from the exclusive analysis (blue diamonds) and from the inclusive analysis (green stars) are compared to results from SAPHIR (open circles) [3] and CLAS (magenta circles) [4]. Since the incident energy binning of the present work does not coincide with that in [4] several CLAS data sets are shown for the incident energy intervals given in this figure. The lines are fits to the CBELSA/TAPS data (solid) and SAPHIR data (black dashed) according to eq. (6). For four incident beam energies theoretical curves are shown calculated with (red solid line) and without (red dotted line) N^* contributions [33].