Coherent ω-Meson Photoproduction off Deuterium from CLAS

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CLAS COLLABORATION MEETING 2017

30 March, 2017

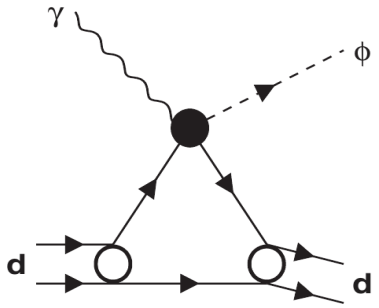
Outline

- **Motivation**
- **Particle Identification**
- **Yield Extraction**
- **Results**
- **Summary**

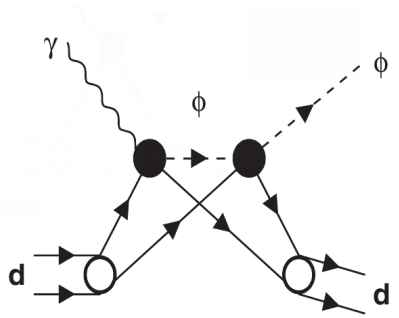
Motivation

$\gamma d \rightarrow \varphi d$

Single scattering

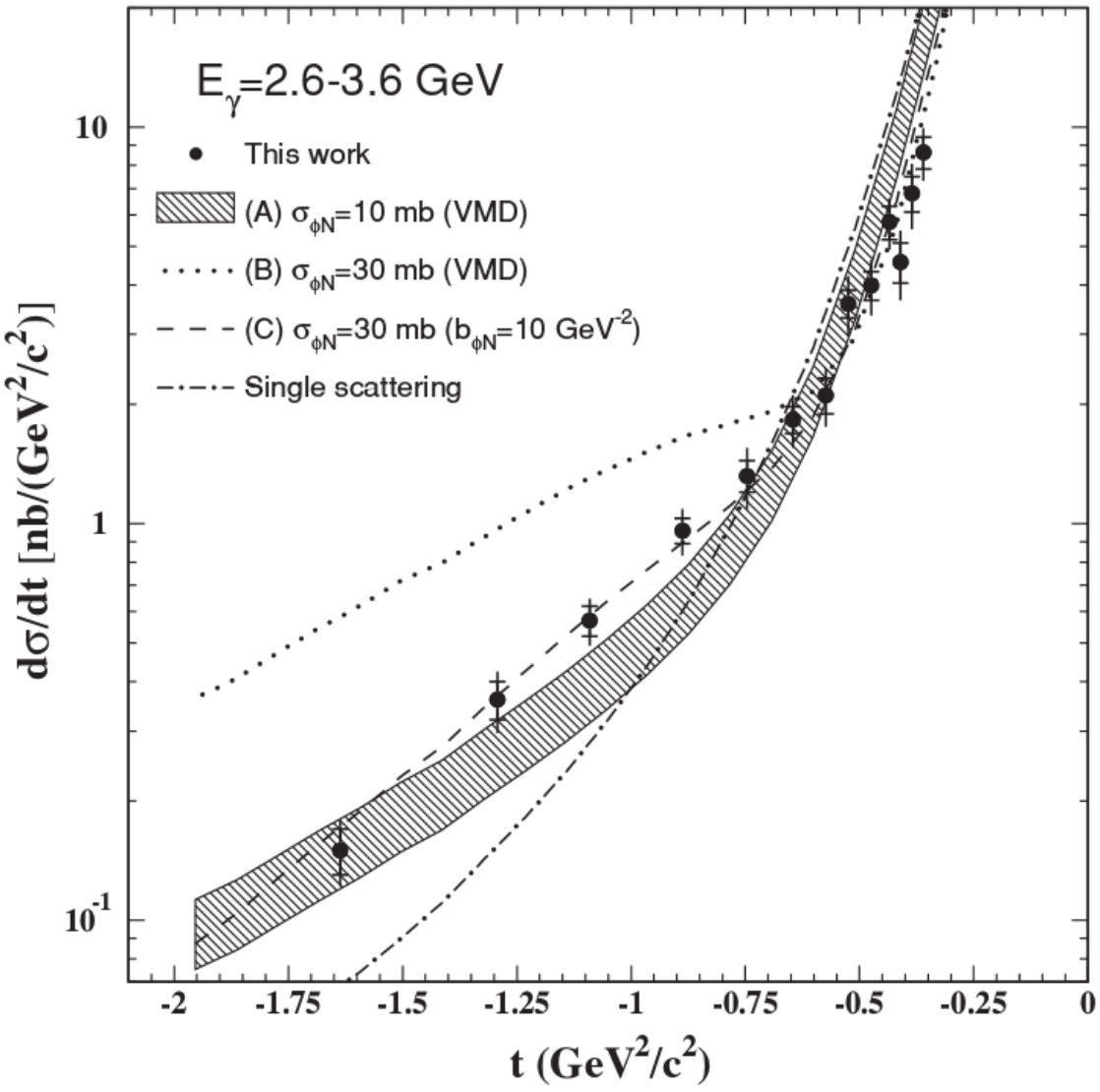


Double scattering



Mandelstam *t* :

$$t=\left(P_{\gamma}-P_{\varphi}\right)^2=\left(P_{d_i}-P_{d_o}\right)^2$$



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

Motivation

Reaction of interest

- $\gamma d \rightarrow \omega d \rightarrow \pi^+\pi^- d(\pi^0)$
- ω-meson beam cannot be produced in a lab.

Group	E_γ [GeV]	t [GeV/c^2]	Comments
Gupta *et. al.* [SLAC] Phys. Rev. D 14, 42 (1976)	5.5	-	Low statistics. No mass fit was possible
Morris *et. al.* [NINA] Nuclear Physics B119 (1977)	3.9	-	*Total Cross-section measured: 1.4 ± 0.5 μb *Coupling constant ratio (rho/omega) measured

Limited World Data

- Photoproduction of omega mesons off Deuteron: limited studies → limited world data.

Photon Coupling ratio of the vector mesons:

$$\gamma_\rho : \gamma_\omega : \gamma_\varphi = 1 : 3 : -3/\sqrt{2}$$

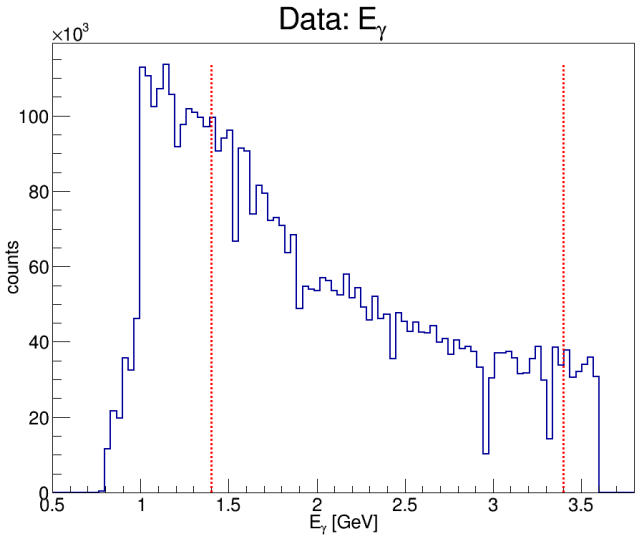
- Assuming SU(3) and SU(6) symmetry.
- The coupling constants provide understanding for EM form factors of pseudo-scalar mesons and nucleons, EM meson decays, etc.

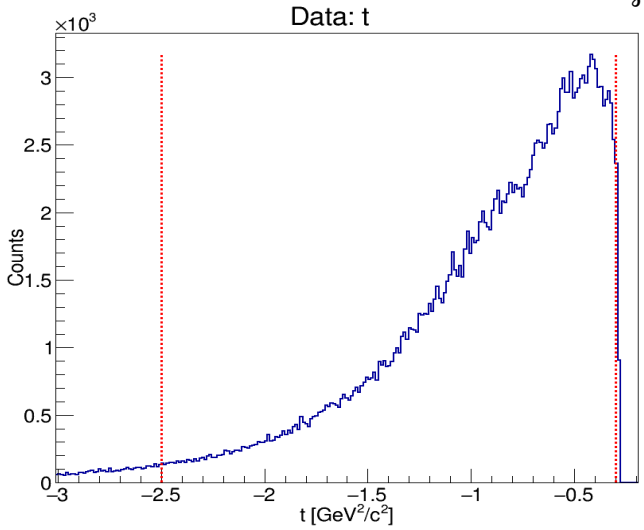
Understanding in the Perturbative Regime:

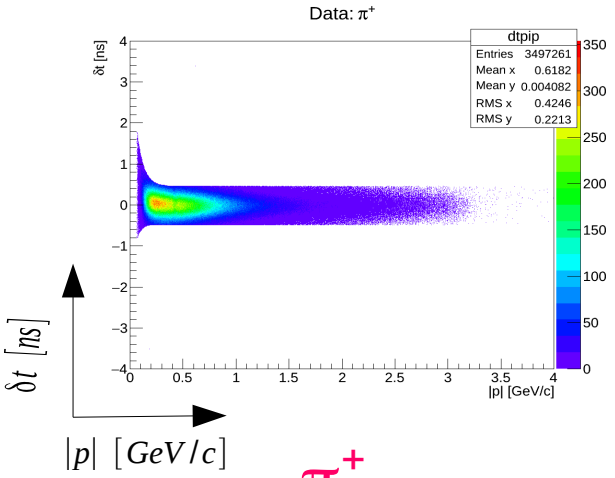
- Gluon exchange between hadrons at higher energies dominates hadron-hadron total cross-sections.
- Jlab energy regime: Double scattering contributions are enhanced.

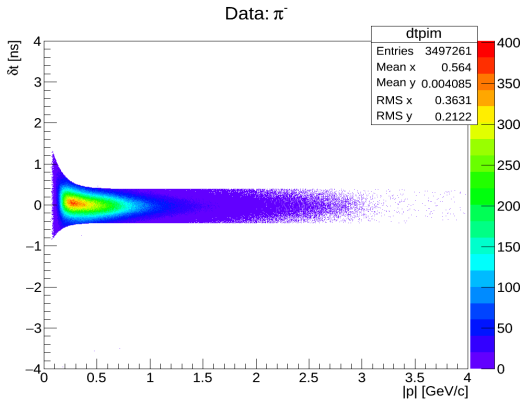
Particle Identification

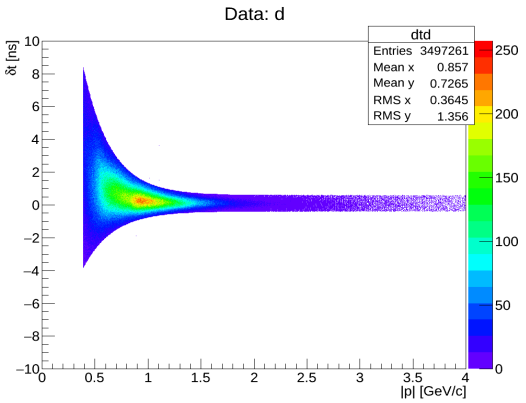
$t = (p_\gamma - p_\omega)^2$





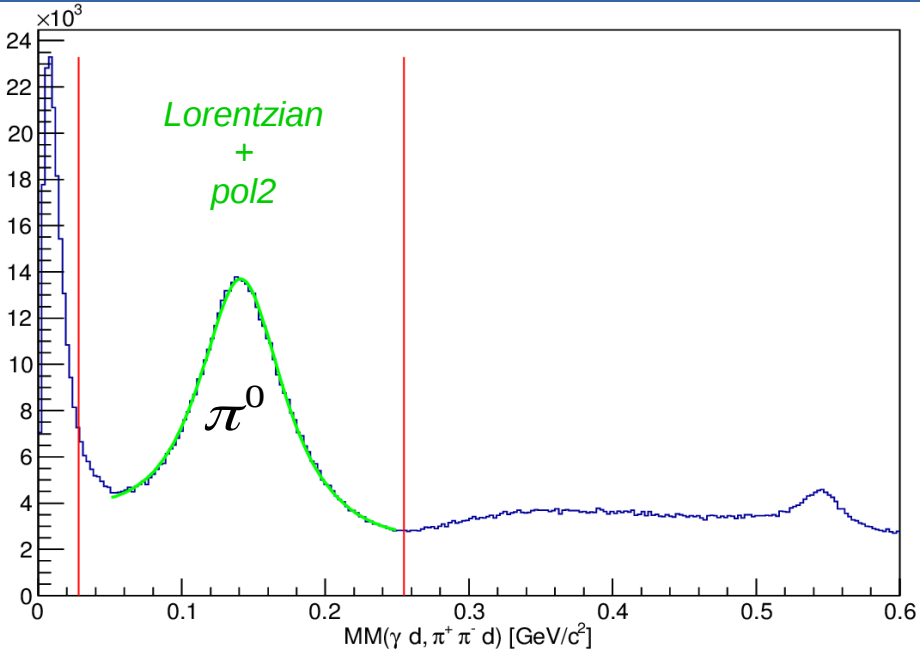


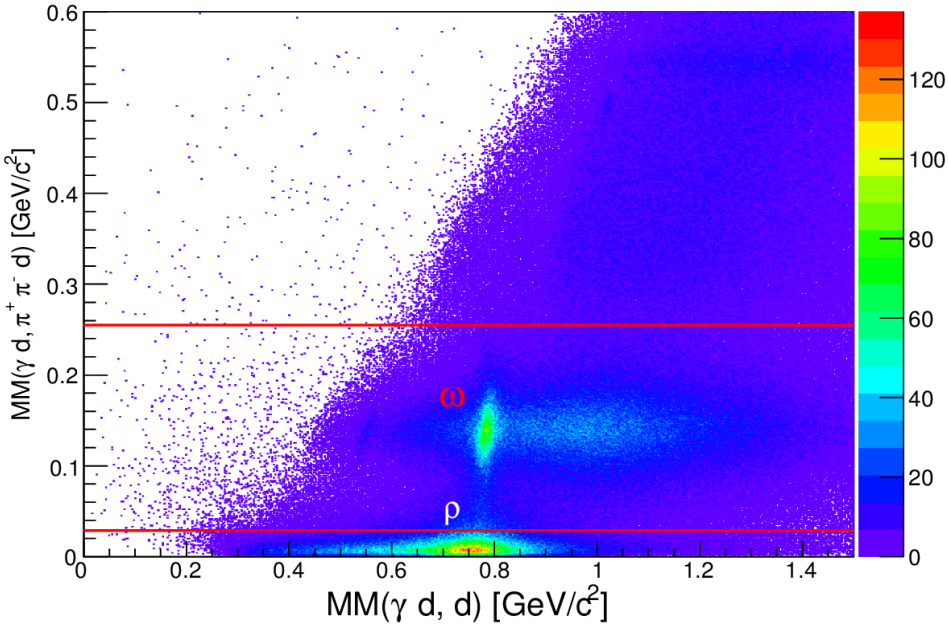




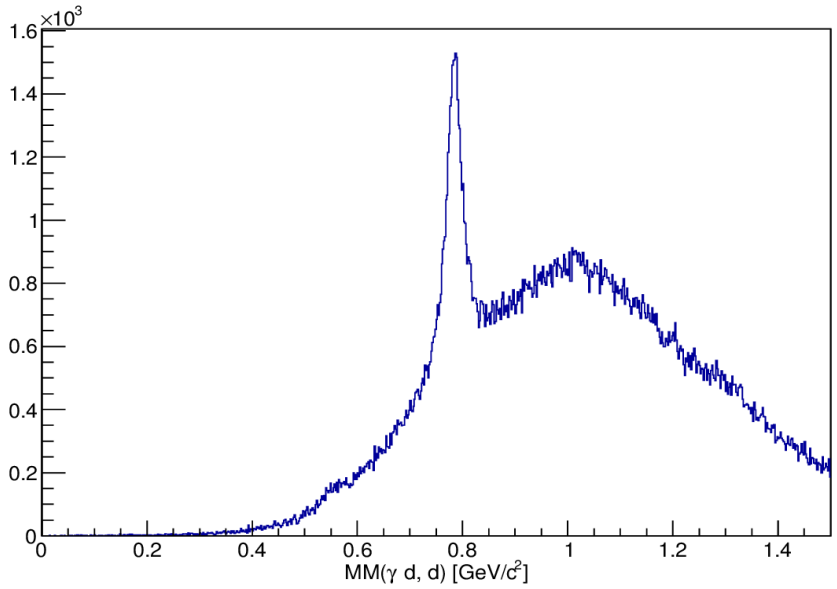
π^+ π^- d

Global Spectrum



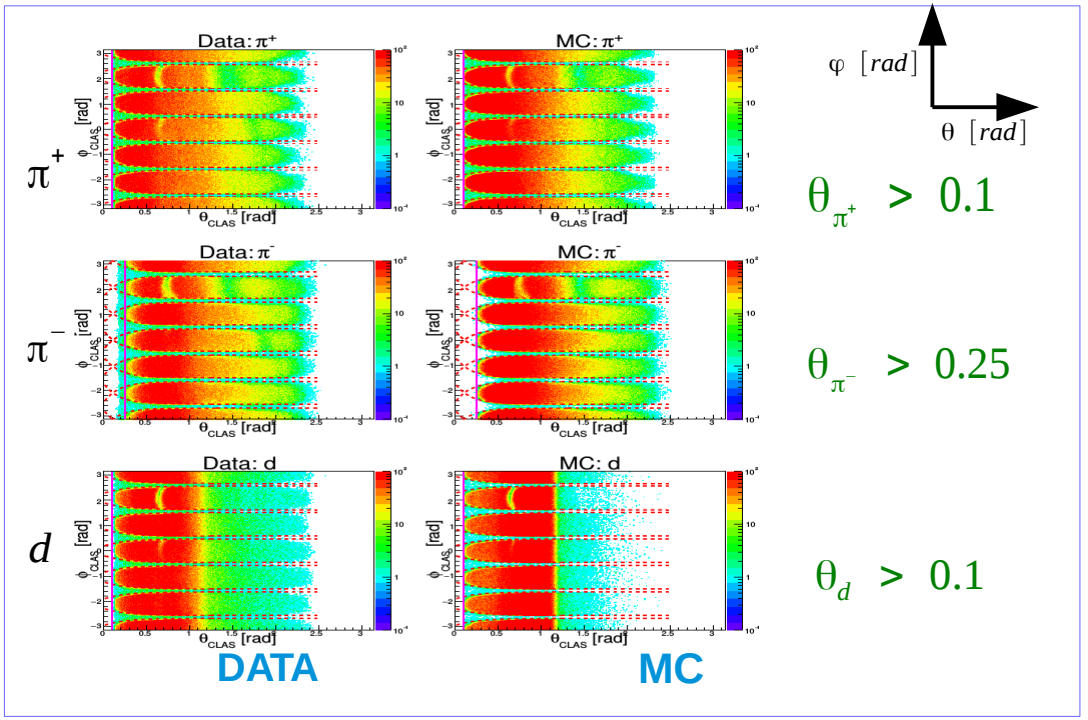


- 0.028 < MM(γd,π⁺π⁻d) < 0.255 [GeV]
- Signal over smooth background.
- Basic cuts to reduce background.



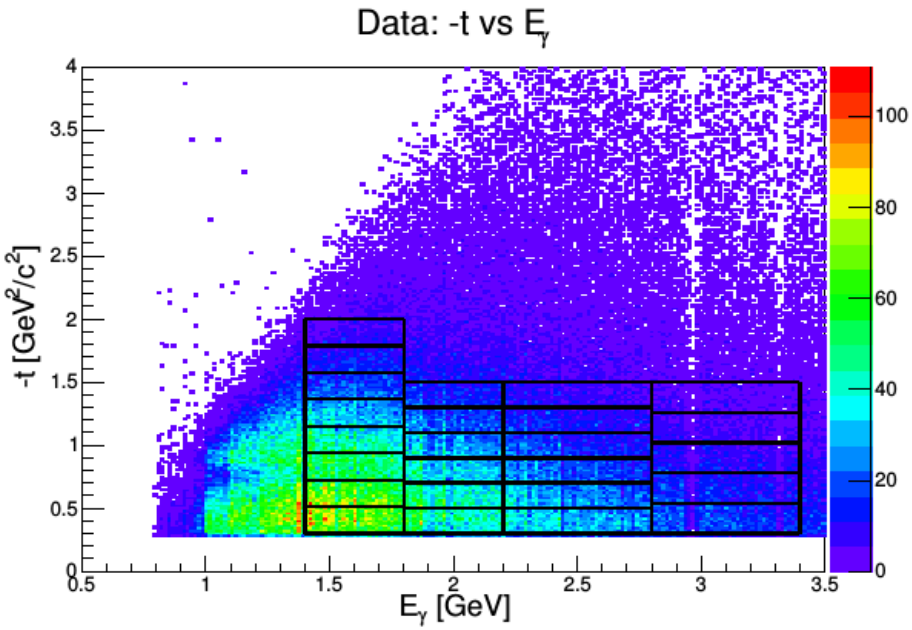
Cuts Applied

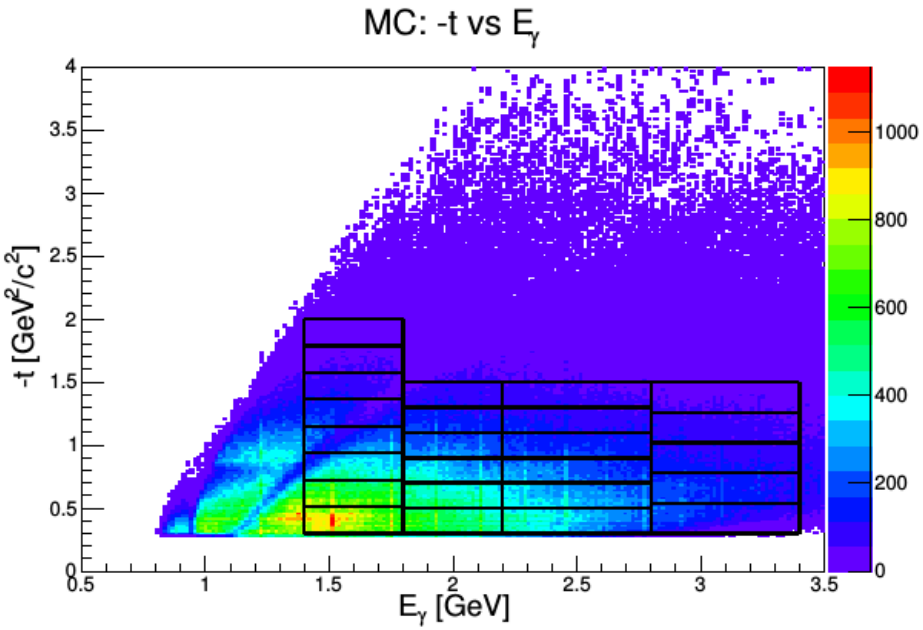
- Timing cuts made using momentum-dependent analysis
  - One “good photon”, |Δt|<1 ns
- -37 cm < z_{vertex} < -13 cm
- Fiducial cuts applied $\varphi = a e^{b\theta} + c$
  - Minimum Theta Cut
- Minimum Momentum Cuts
- Missing mass Cut.
- Bad SC Paddles removed.



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

Binning



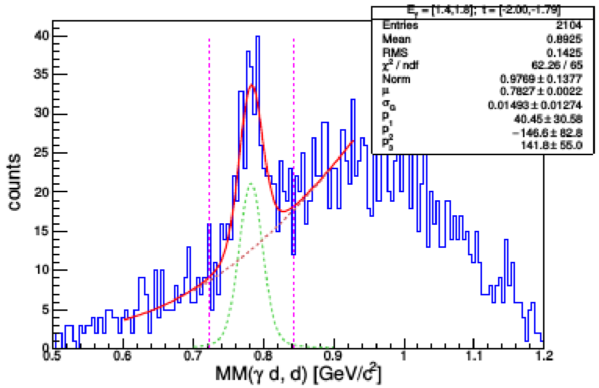


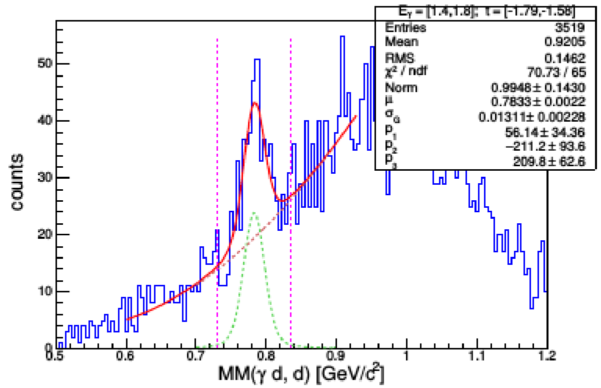
E_{photon} [GeV]	*t*-bins	$-t_{min}$ [GeV^2]	$-t_{max}$ [GeV^2]
1.4-1.8	8	2.0	0.3
1.8-2.2	6	1.5	0.3
2.2-2.8	6	1.5	0.3
2.8-3.4	5	1.5	0.3

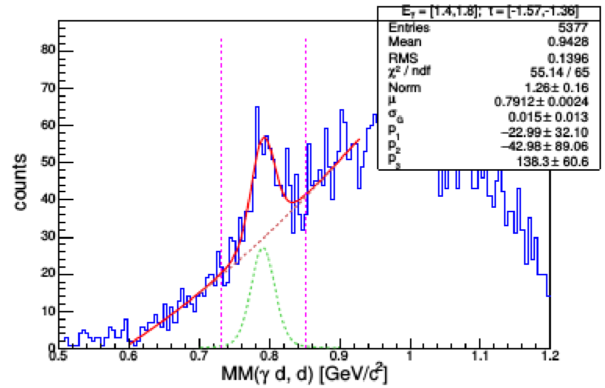
- 4 incident photon energy and variable 4-momentum transfer bins.

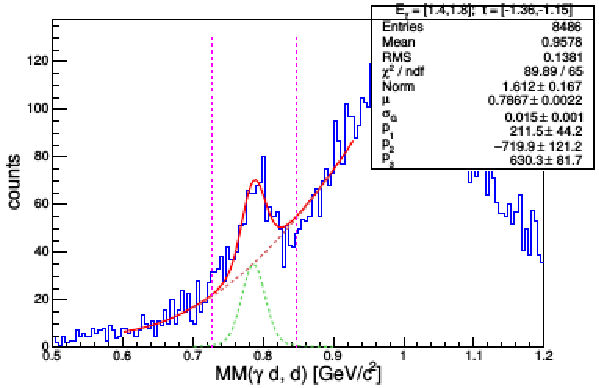
Yield Extraction

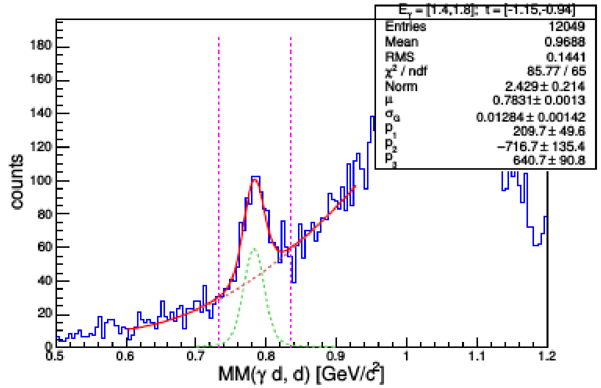
$E_\gamma = [1.4, 1.8]$

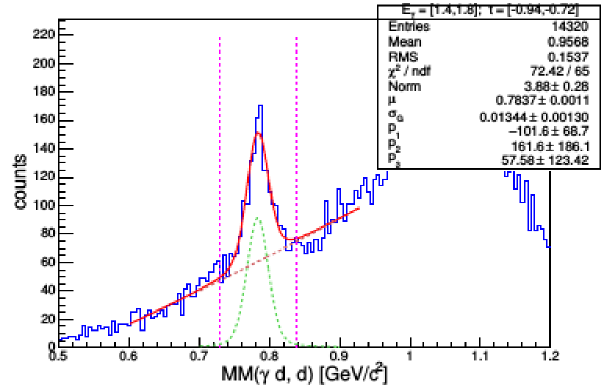




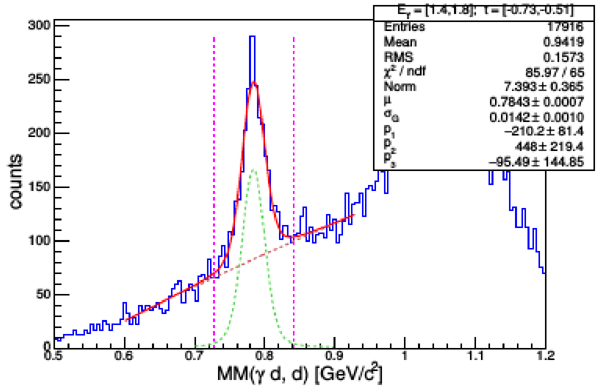


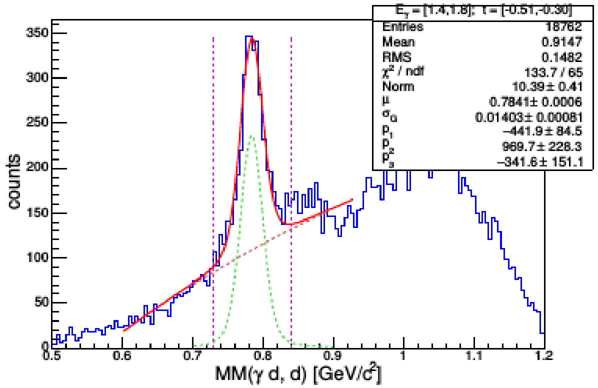






Yield is extracted by taking integral of the Voigt function





Fit Functions

Voigt

Pol2

Differential Cross-section

Preliminary

Differential cross-section,

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

A = Acceptance

Δt = Width of t-bin

Y_D = Signal Yield

γ_{corr} = Photon Multiplicity Correction factor

Luminosity,

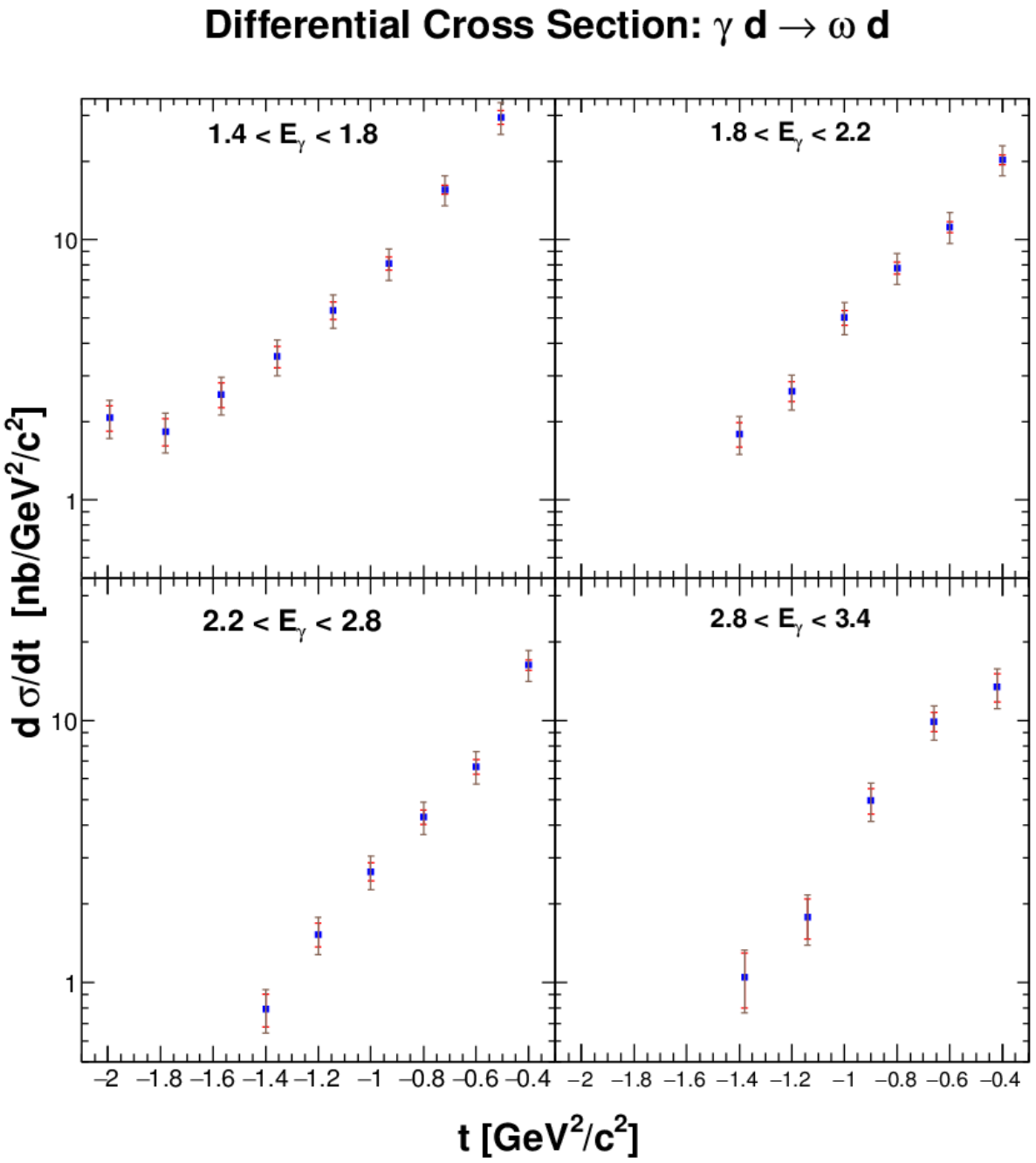
$$\mathscr{L}(E_\gamma) = \frac{\rho_T N_A l_T}{M_d} N_\gamma(E_\gamma)$$

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

$l_d = 24\, cm$

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

$N_\gamma(E_\gamma) =$ Photon Flux



Systematic Uncertainties

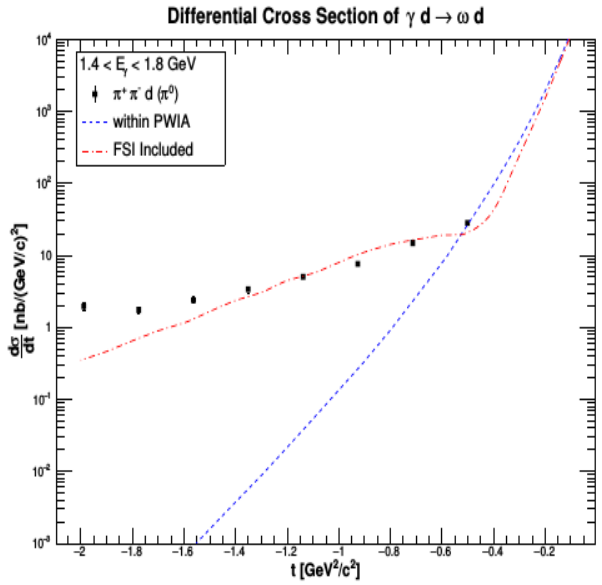
- Systematic errors are calculated based on the relative difference between the nominal and the variation.

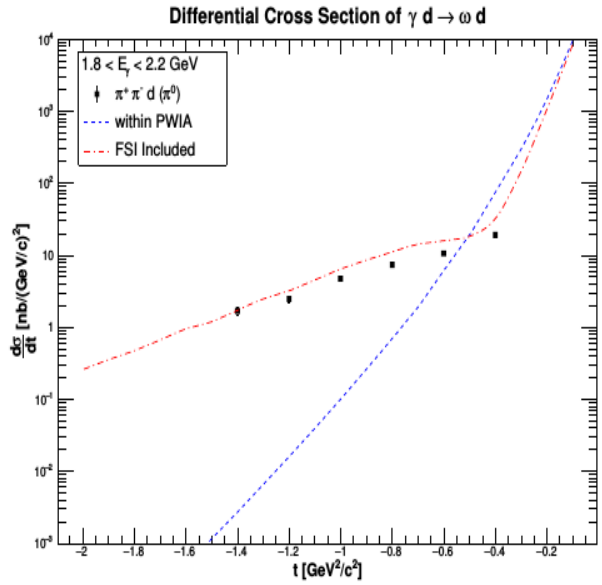
Source	Description	Uncertainty
Flux Consistency/Luminosity	Flux per run/sub run and previous $g10$ results	8.00%
t-slope dependence	Varied from $b = 2.5$ to $b = 0$	0.04%
Sector Dependence	Comparison of $(d\sigma/dt)_{sector}$ versus Nominal	2.00%
Timing Cut	Varied from a 3σ to 3.5σ cut	0.60%
Minimum $\lvert p\rvert$ Cut	Removed	0.52%
Missing Mass Cut	Varied from a 3σ to 2.5σ cut	3.46%
z-Vertex Cut	Varied from $\lvert z+25\rvert < 11$ to $\lvert z+25\rvert < 11.5$	0.73%
Fiducial Cut	Varied from a 50% to a 100% cut	1.34%
Signal Integral Range	Varied from 4σ to 5σ	0.10%
Choice of Background function	Pol1 versus Pol2	8.59%
Branching Ratio	PDG value	0.70%
Total Systematic Uncertainty (Added in quadrature)		**12.54%**

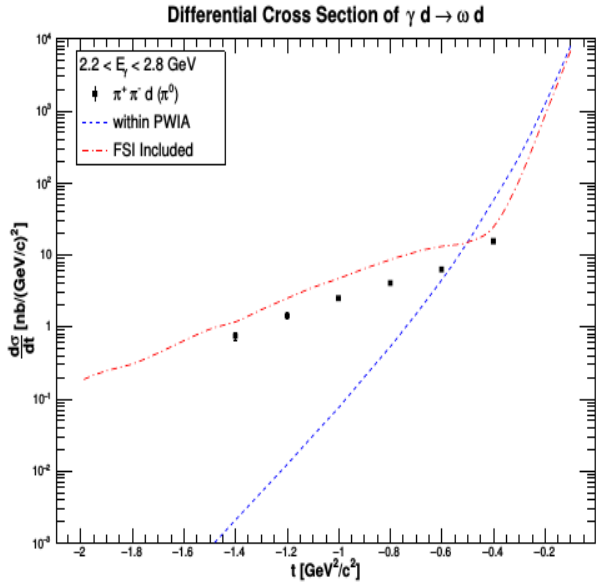
Differential Cross-section

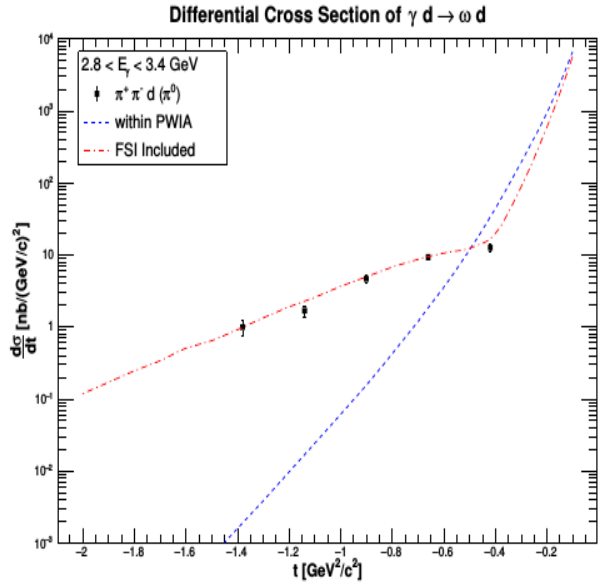
Preliminary

- Calculations are provided by Dr. Sargsian (FSU).
- Production of ω is within the Vector Dominance Model.
- Does not include:
  - Pion exchange contribution at low energy.
  - At large | t |, contibution of $\rho-\omega$ mixing.









PRELIMINARY

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

Summary

- The cross-section data provides sensitivity to the nucleon-scattering data in the energy and momentum transfer range mentioned.
- First high statistics world data for the reaction: $\gamma d \rightarrow \omega d$
- $\frac{d\sigma}{dt} \propto e^{-b|t|} \rightarrow$ as expected for a diffractive process.
- Analysis under Review.
- Next steps would include:
  - Collaboration with theorists focusing the kinematic regime under investigation.
  - Paper for publication
  - ρ meson photoproduction.
  - *d** interference.

Extras

Diffractive DCS

Preliminary

Differential cross-section,

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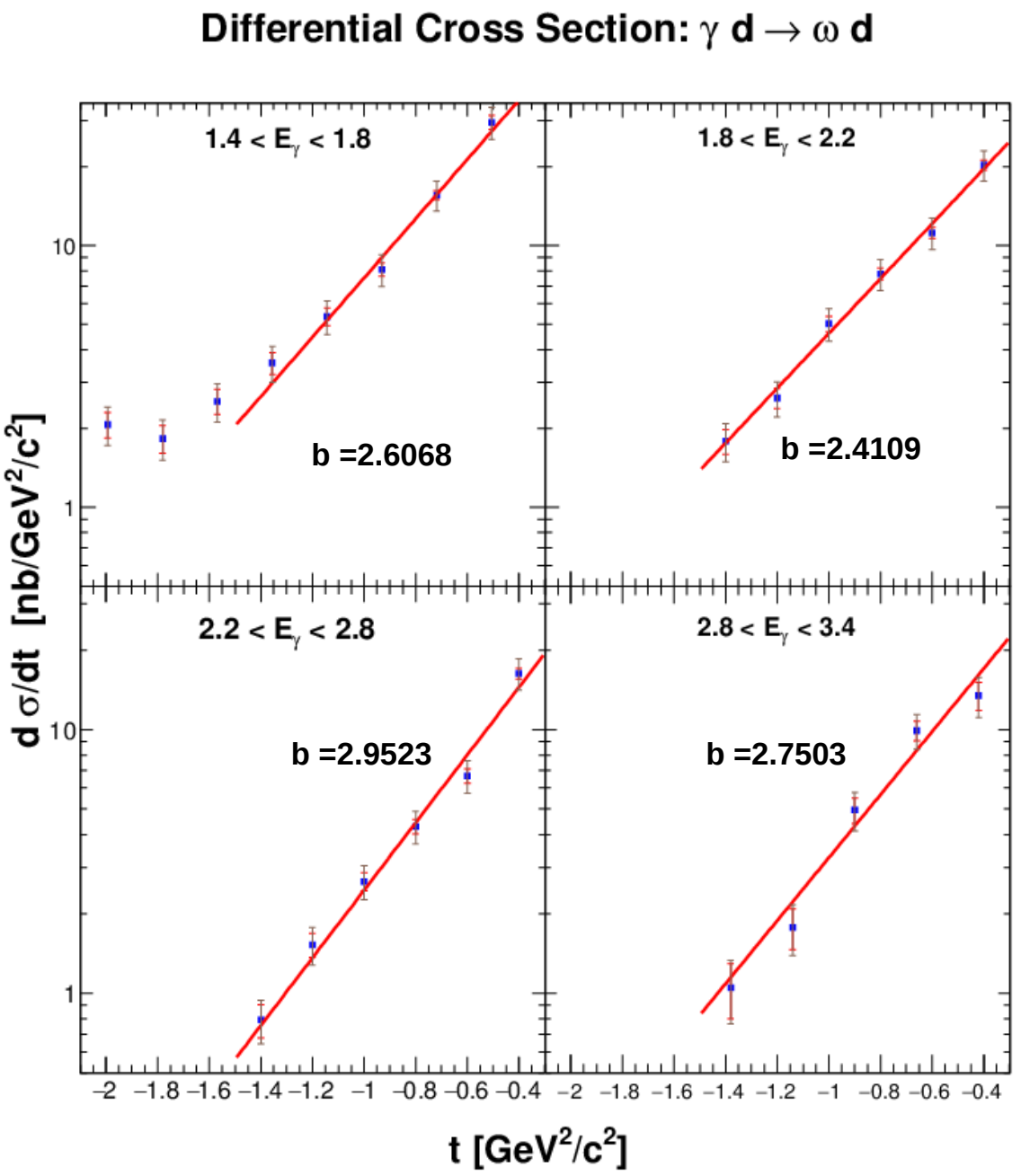
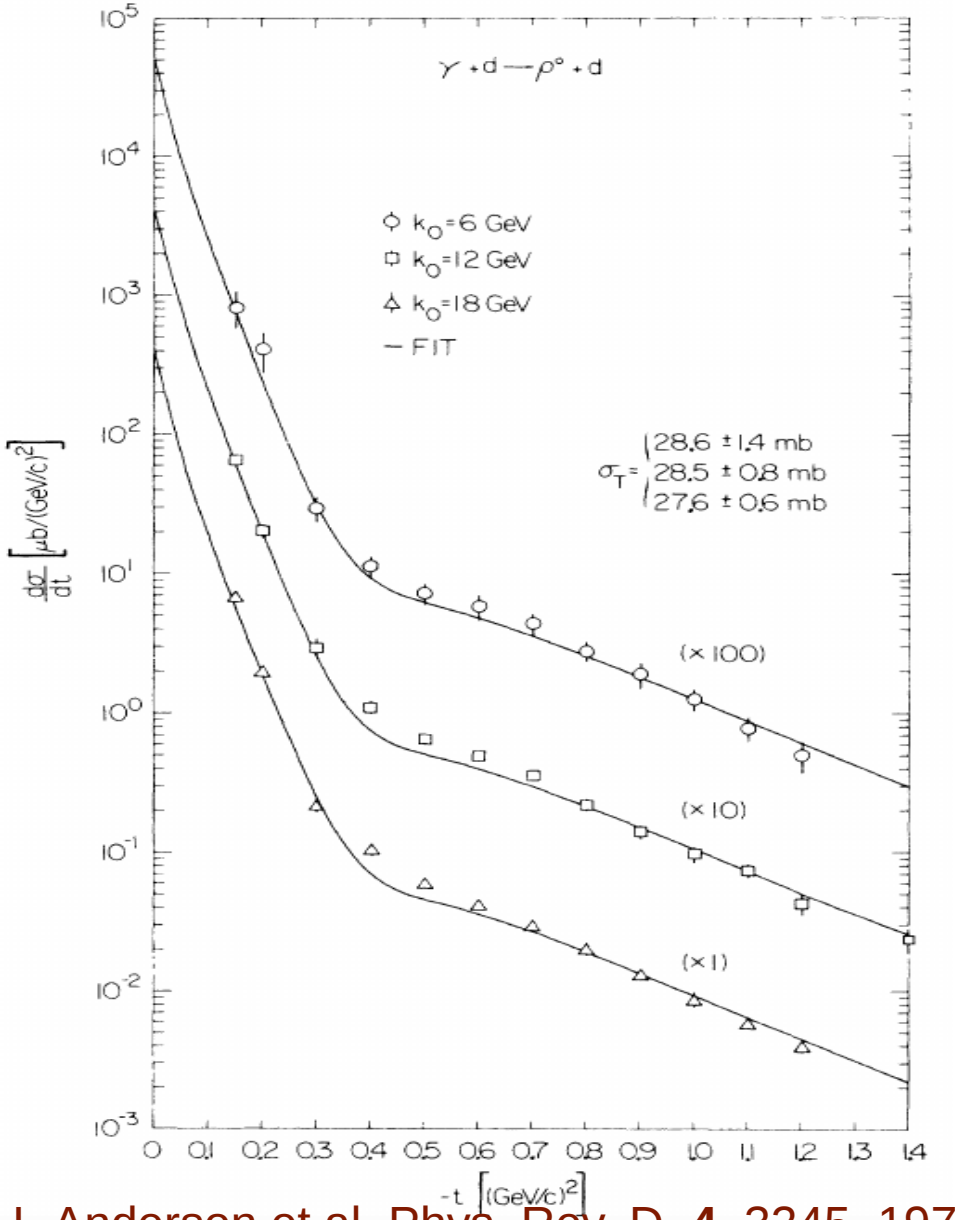
$N_\gamma(E_\gamma) =$ Photon Flux

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

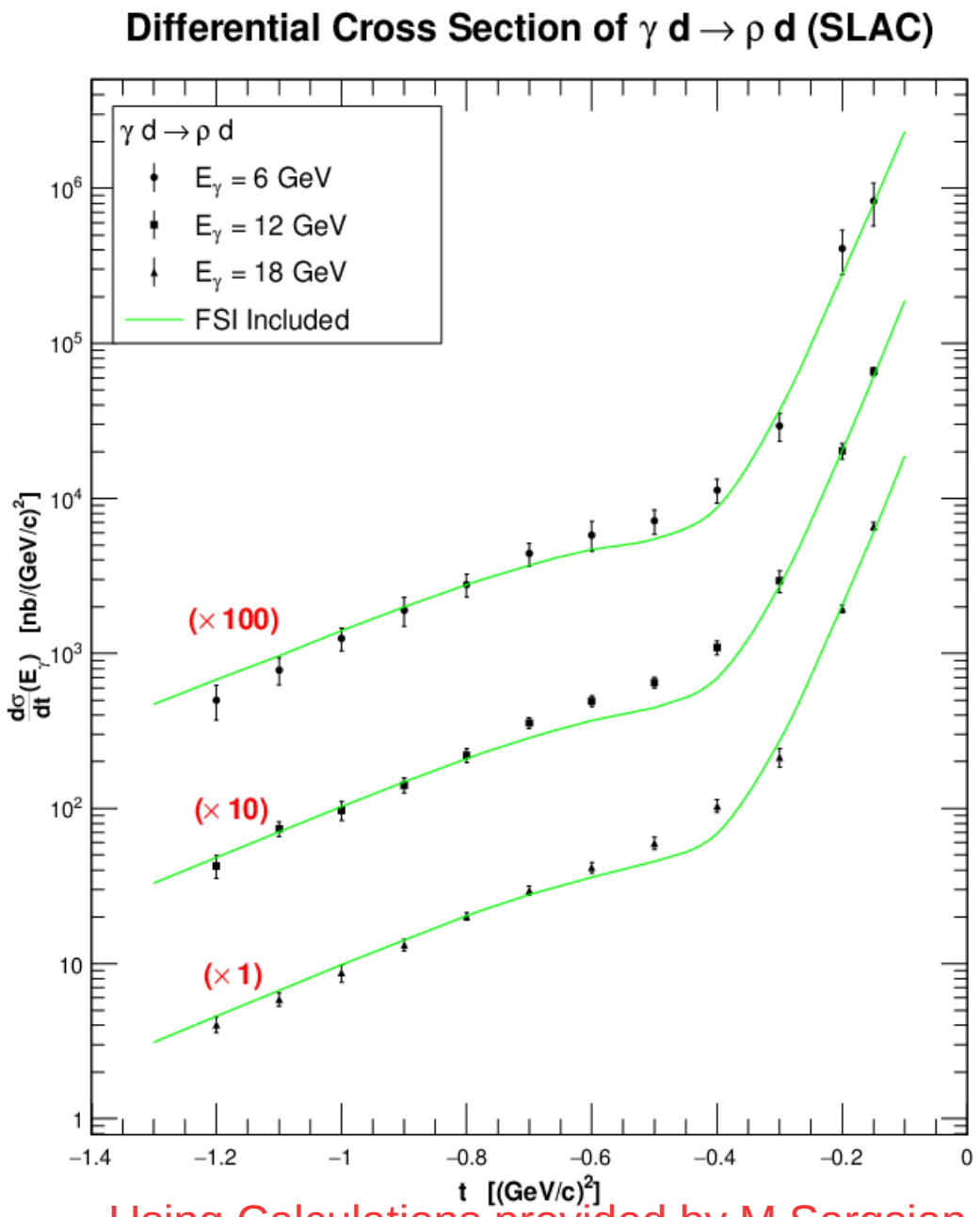


SLAC ρ Data

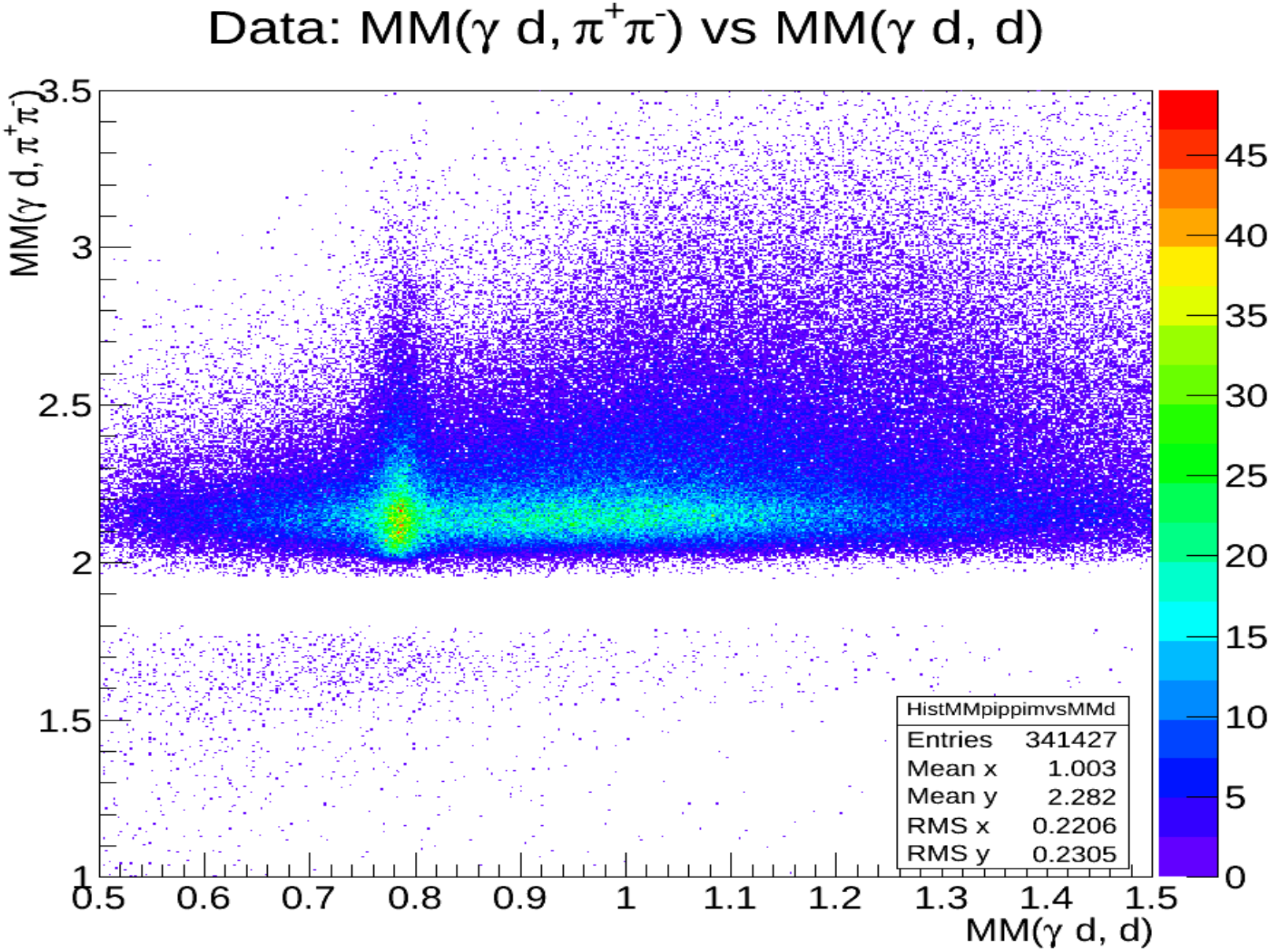
Back-up



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

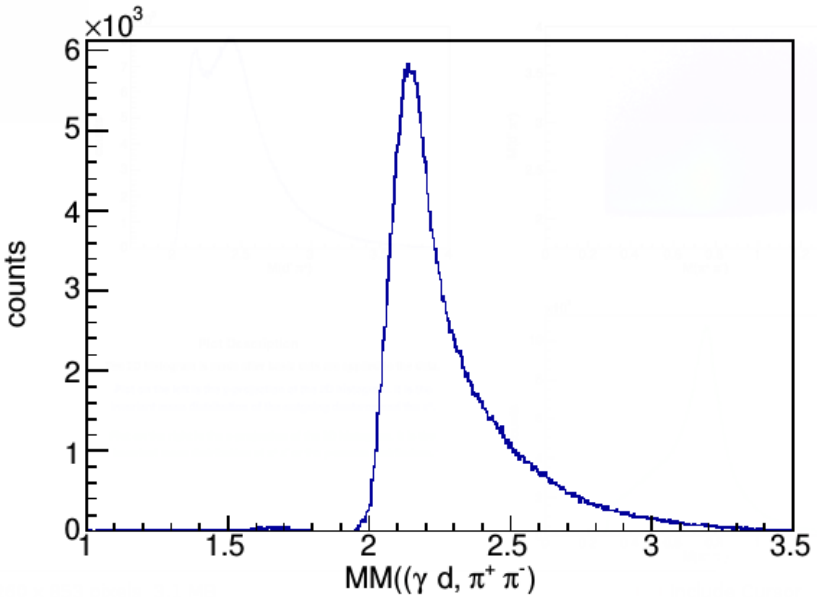


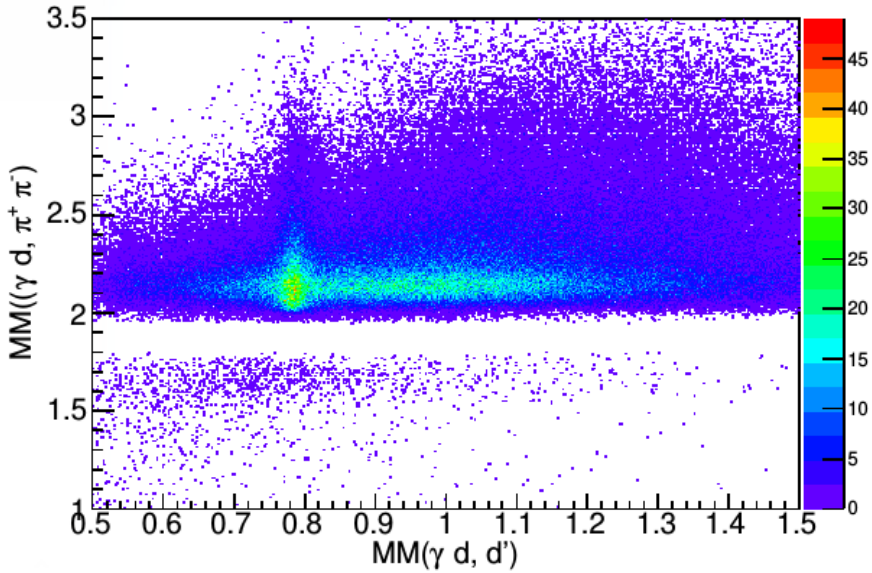
Using Calculations provided by M.Sargsian


Data: MM(γ d, π+π-) vs MM(γ d, d)
MM(γ d, π+π-)
MM(γ d, d)
HistMMpippimvsMMd
Entries 341427
Mean x 1.003
Mean y 2.282
RMS x 0.2206
RMS y 0.2305

Interference

Back-up



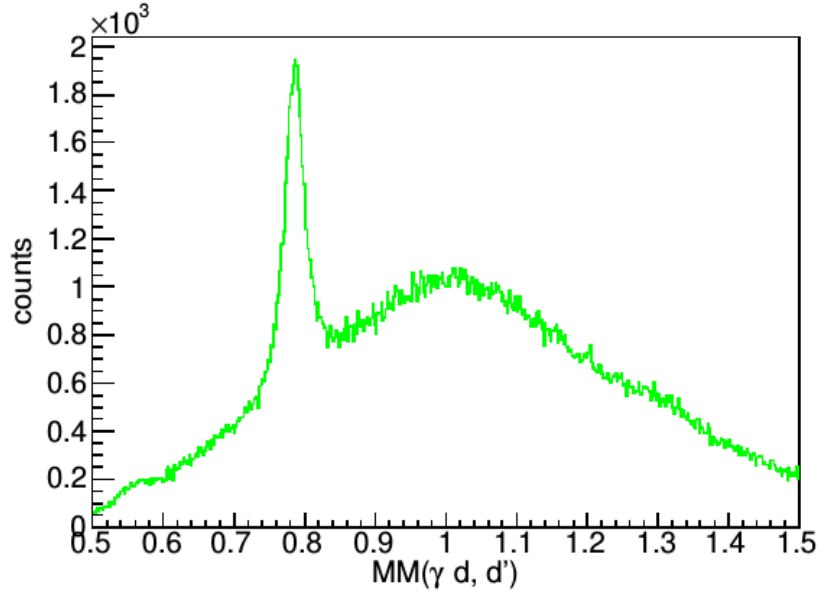


Plot Description

The 2D histogram is made after basic cuts are applied to the data.

Plot on the left is the y-projection of the 2D histogram. It is the mass distribution for the π^0 and the outgoing d.

Plot on the right is the x-projection of the 2D histogram. It is the mass distribution for $\pi^+ \pi^- \pi^0$ or the ω-meson distribution.



Previous Studies

Back-up

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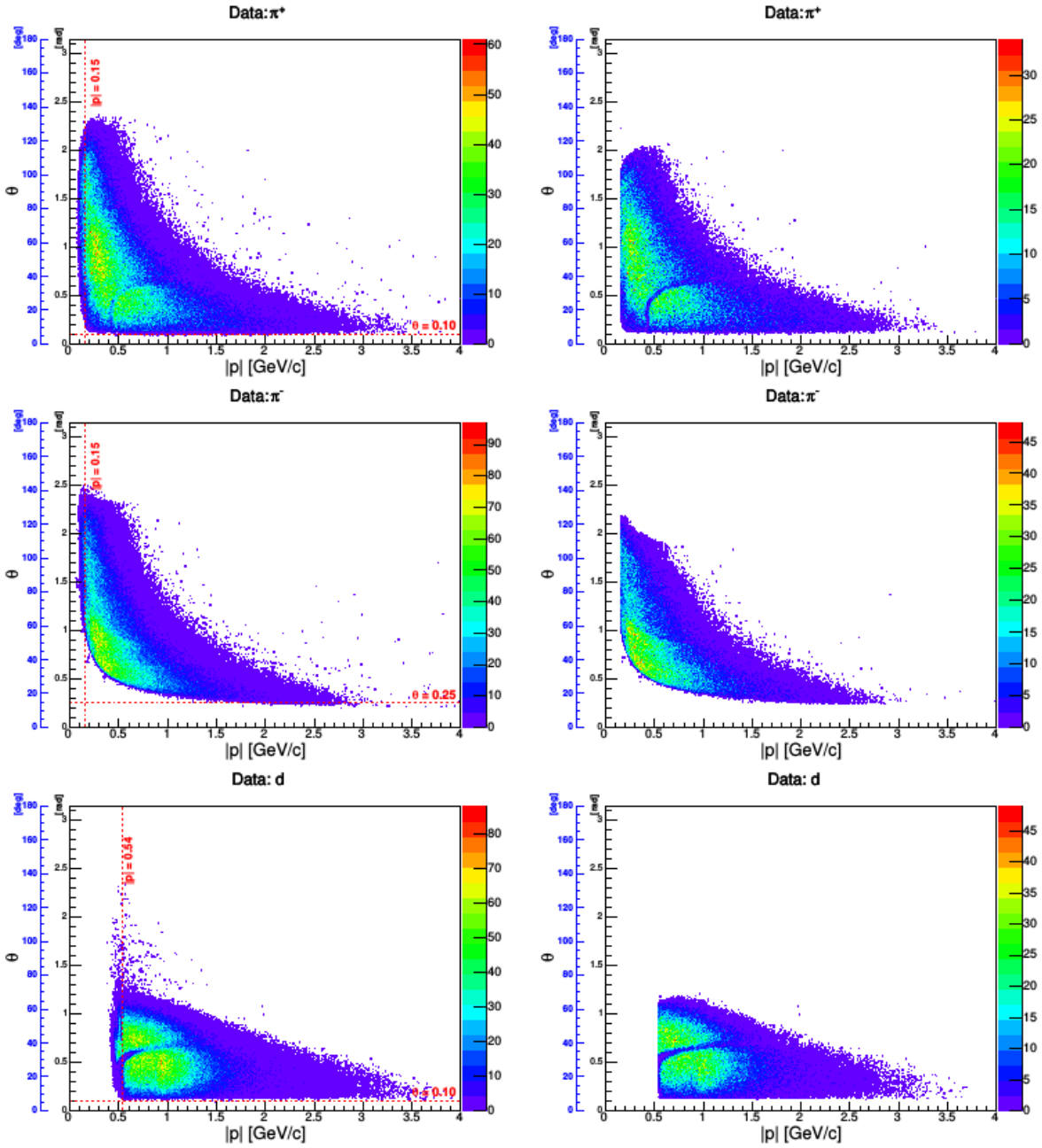
Morris *et. al.* [NINA] Nuclear Physics B119 (1977)	3.9	-	*Total Cross-section measured: 1.4 ± 0.5 μb *Coupling constant ratio (rho/omega) measured

Lab Angle vs Momentum

Back-up



Investigated Channels

Back-up

$\gamma d \rightarrow \rho d \rightarrow \pi^+ \pi^- d$

$\rho(770)$ [h] $I^G(J^{PC}) = 1^+(1^{--})$

Mass $m = 775.26 \pm 0.25$ MeV
Full width $\Gamma = 149.1 \pm 0.8$ MeV
$\Gamma_{ee} = 7.04 \pm 0.06$ keV

$\rho(770)$ DECAY MODES	Fraction (Γ_i/Γ)		Scale factor/ Confidence level	p (MeV/c)
$\pi\pi$	$\sim$ 100	%		363

$\gamma d \rightarrow \omega d \rightarrow \pi^+ \pi^- d \ (\pi^0)$

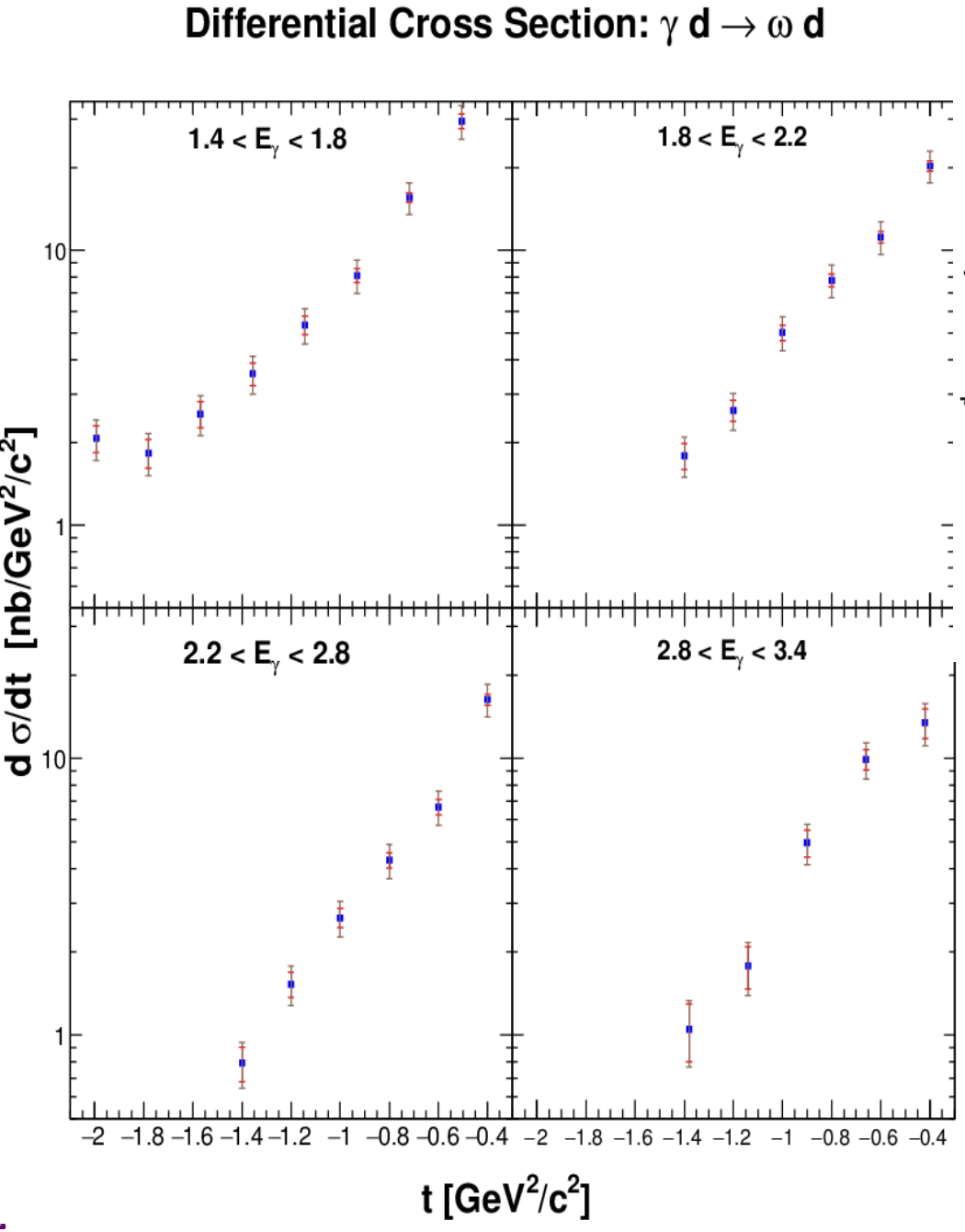
$\omega(782)$ $I^G(J^{PC}) = 0^-(1^{--})$

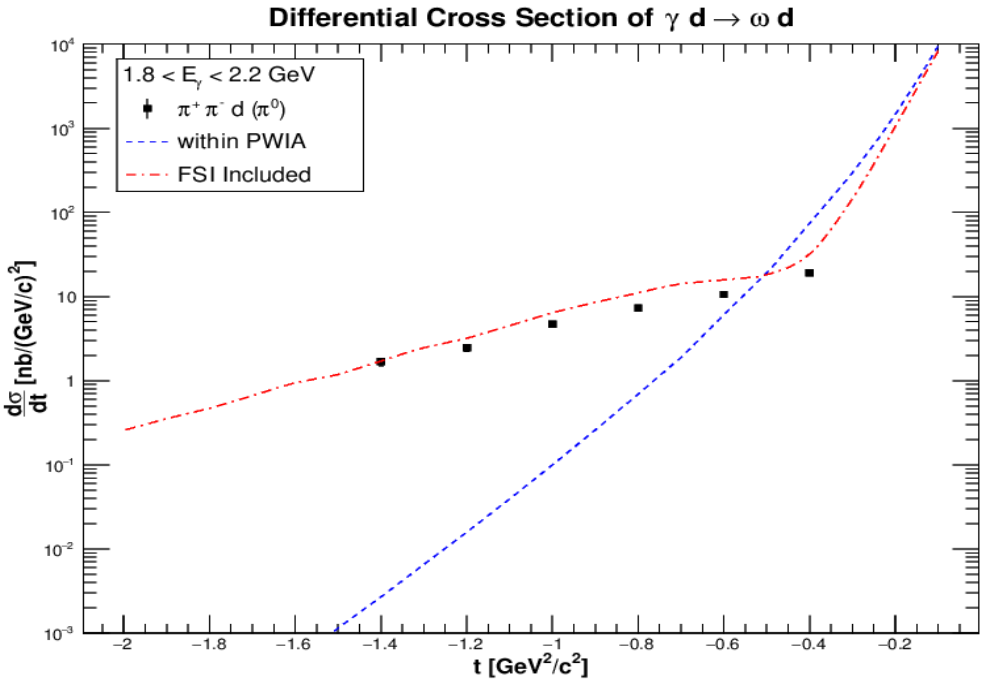
Mass $m = 782.65 \pm 0.12$ MeV (S = 1.9)
Full width $\Gamma = 8.49 \pm 0.08$ MeV
$\Gamma_{ee} = 0.60 \pm 0.02$ keV

$\omega(782)$ DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
$\pi^+\pi^-\pi^0$	(89.2 $\pm$0.7) %		327
$\pi^0\gamma$	(8.28$\pm$0.28) %	S=2.1	380
$\pi^+\pi^-$	($1.53^{+0.11}_{-0.13}$) %	S=1.2	366

Coherent ω -Meson Photoproduction off Deuterium (g12 Data)

Taya Chetry
Kenneth Hicks
Ohio University





- Differential Cross Section Results for $\gamma d \rightarrow \omega d$ are presented.
- Result shows diffractive nature as expected.
- Results are compared with (preliminary))theoretical calculations provided by M.Sargsian (FSU).
- Analysis note under REVIEW.
- First world data for $\gamma d \rightarrow \omega d$