Study of the $\gamma p \to f_1(1285)p$ reaction using the effective Lagrangian approach

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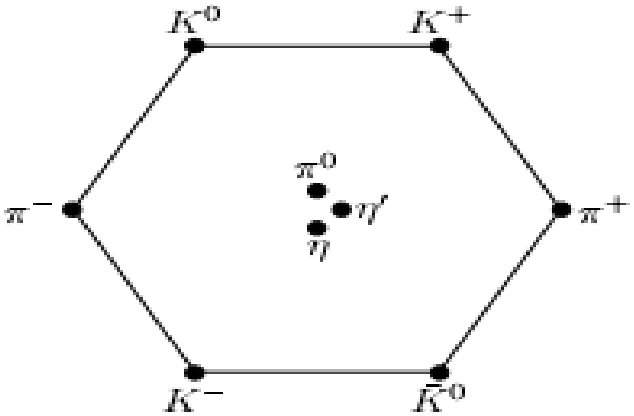
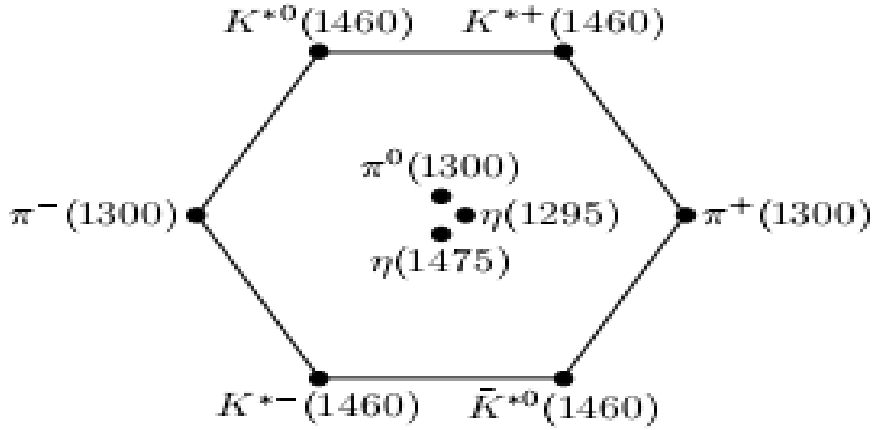
Outline

Motivation

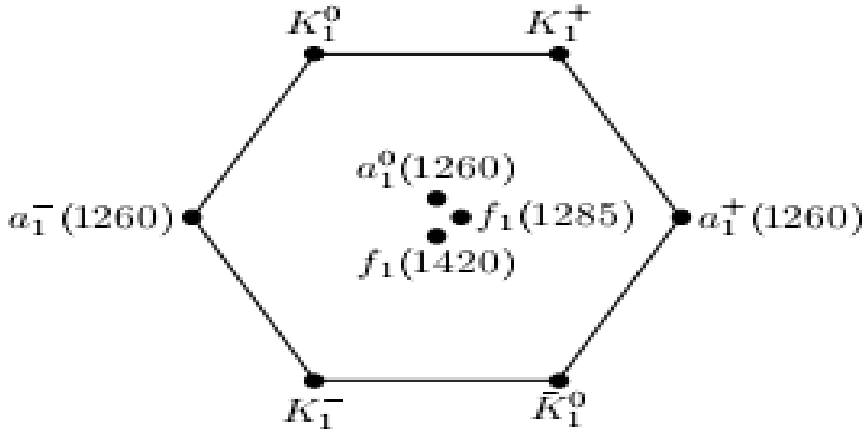
Axial Vector Mesons



(a) Pseudoscalar Mesons



(b) Radial-Excited Pseudoscalar Mesons



(c) Axial Vector Mesons

Motivation

The properties of the $f_1(1285)$ based on PDG [1]

Properties of the $f_1(1285)$

Citation: J. Beringer *et al.* (Particle Data Group), PR **D86**, 010001 (2012) and 2013 partial update for the 2014 edition (URL: http://pdg.lbl.gov)

$f_1(1285)$ $\quad I^G(J^{PC}) = 0^+(1^{++})$

$f_1(1285)$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1281.9 ± 0.5 OUR AVERAGE		Error includes scale factor of 1.8. See the ideogram below.			
1281.16 ± 0.39 ± 0.45		[1] LEES	12X	BABR	$\tau^- \to \pi^- f_1(1285)\nu_\tau$
1285.1 ± 1.0 $^{+1.6}_{-0.3}$		[2] ABLIKIM	11J	BES3	$J/\psi \to \omega(\eta\pi^+\pi^-)$
1281 ± 2 ± 1		AUBERT	07AU	BABR	10.6 $e^+e^- \to f_1(1285)\pi^+\pi^-\gamma$
1276.1 ± 8.1 ± 8.0	203	BAI	04J	BES2	$J/\psi \to \gamma\gamma\pi^+\pi^-$
1274 ± 6	237	ABDALLAH	03H	DLPH	91.2 $e^+e^- \to K^0_S K^\pm\pi^\mp + X$

[1] J. Beringer *et al.*, Phys. Rev. D. **86**, 010001 (2012)

Motivation

The decay width of the $f_1(1285)$ based on PDG [2]

The decay width $\Gamma_{f_1(1285)}$

$f_1(1285)$ mass (MeV)

$f_1(1285)$ WIDTH

Only experiments giving width error less than 20 MeV are kept for averaging.

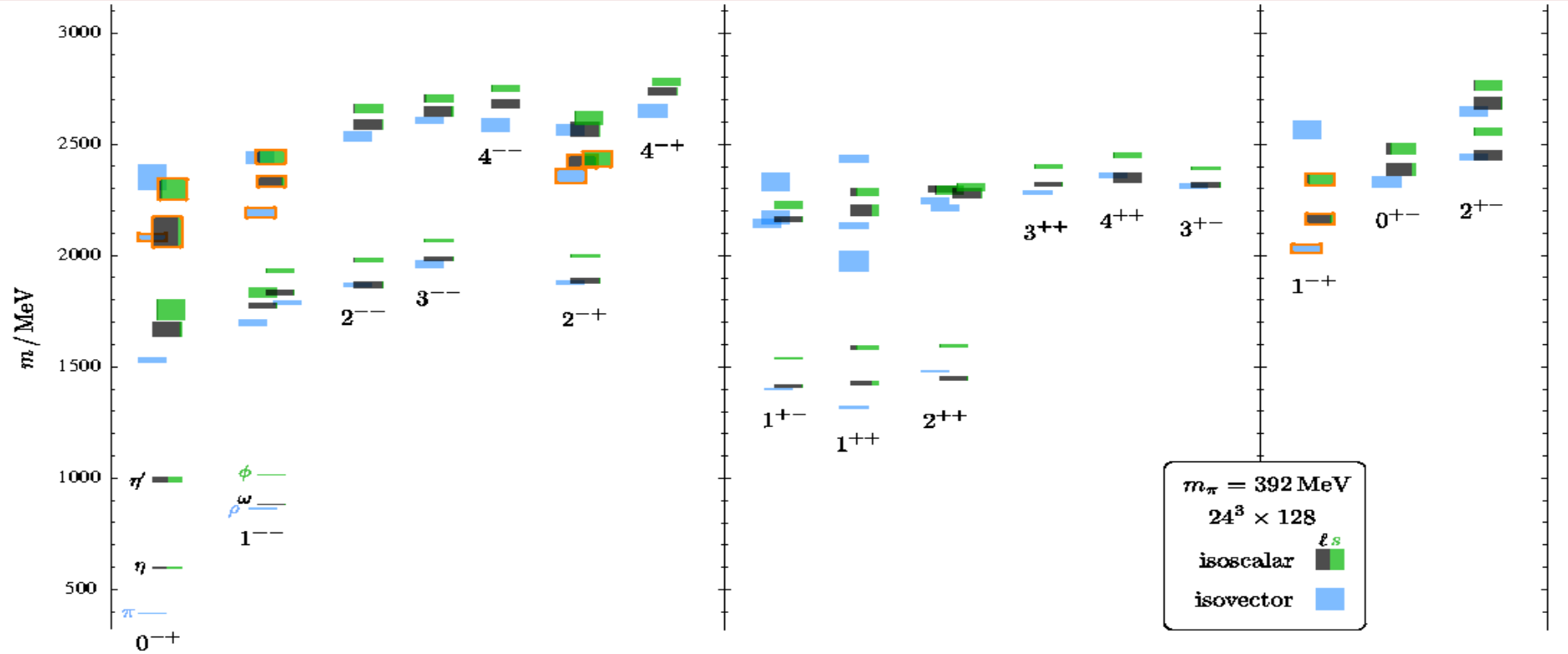
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
24.2± 1.1 OUR AVERAGE		Error includes scale factor of 1.3. See the ideogram below.			
$22.0 \pm 3.1^{+2.0}_{-1.5}$		[9] ABLIKIM	11J	BES3	$J/\psi \to \omega(\eta\pi^+\pi^-)$
35 ± 6 ± 4		AUBERT	07AU	BABR	10.6 $e^+e^- \to f_1(1285)\pi^+\pi^-\gamma$
40.0± 8.6± 9.3	203	BAI	04J	BES2	$J/\psi \to \gamma\gamma\pi^+\pi^-$
29 ±12	237	ABDALLAH	03H	DLPH	91.2 $e^+e^- \to K^0_S K^\pm \pi^\mp + X$
45 ± 9 ± 7	20k	ADAMS	01B	B852	18 GeV $\pi^- p \to K^+K^-\pi^0 n$

[2] J. Beringer *et al.*, Phys. Rev. D. **86**, 010001 (2012)

Motivation

A spectrum of isoscalar Meson from Lattice QCD results [3]

Meson isoscalar spectrum



NOTE : Isoscalar: Green and Black and isovector: Cyan

[3] J. Dudek *et al.*, Phys. Rev. D **88**, 094505 (2013)

Motivation

New data and lack of theoretical model for this channel

Driving by the current experimental status and the lack of the theoretical (our understanding) of $f_1(1285$ and $\eta(1295)$, hence we have two underlying motivation for studying this reaction. However we briefly remind that we concentrate on $f_1(1285)$ with properties $J^{PC} = (1^{++})$, mass $= 1281 \pm 0.6\ \mathrm{MeV}$ and the Full width, $\Gamma = 24.3 \pm 1.1\ \mathrm{MeV}$ in this talk [4]

1. Theoretical Model Prediction status

Kochelev Model

$\rightarrow$ Exchange of ρ and ω trajectories in the Regge framework for $|t| = -Q^2 \leq 1\mathrm{GeV}^2$. They predicted that the total cross section of $f_1(1285)$ is about four times that of $\eta(1295)$, where the value of the total cross section respectivvely, $\sigma_{f_1(1285)} = 68\mathrm{nb}$ and $\sigma_{\eta(1295)} = 18\mathrm{nb}$ [5]

[4] K. Nakamura *et al.*, J. Phys. G **37**, 075021 (2010)

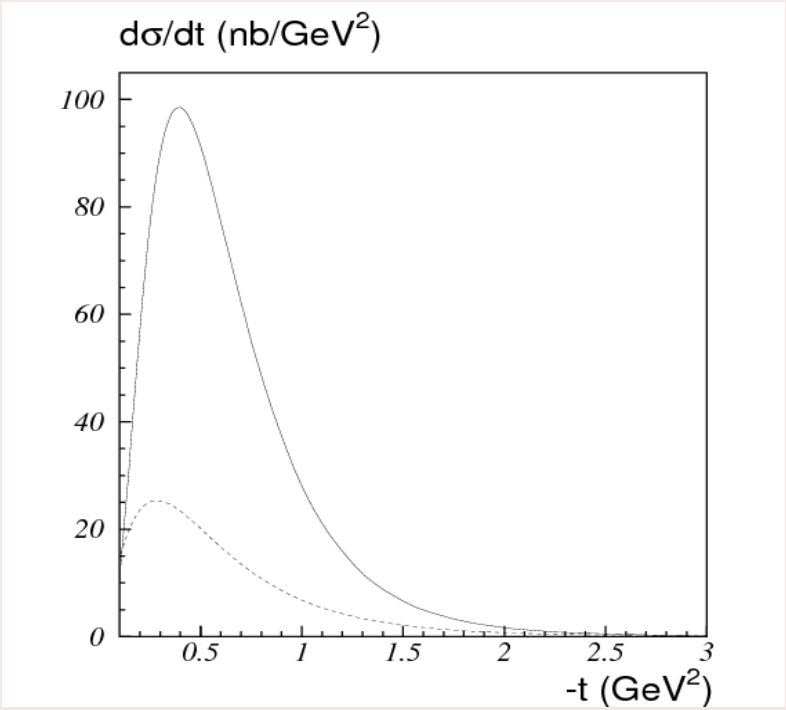
[5] N. I. Kochelev *et al.*, Phys. Rev. D **80**, 025201 (2009)

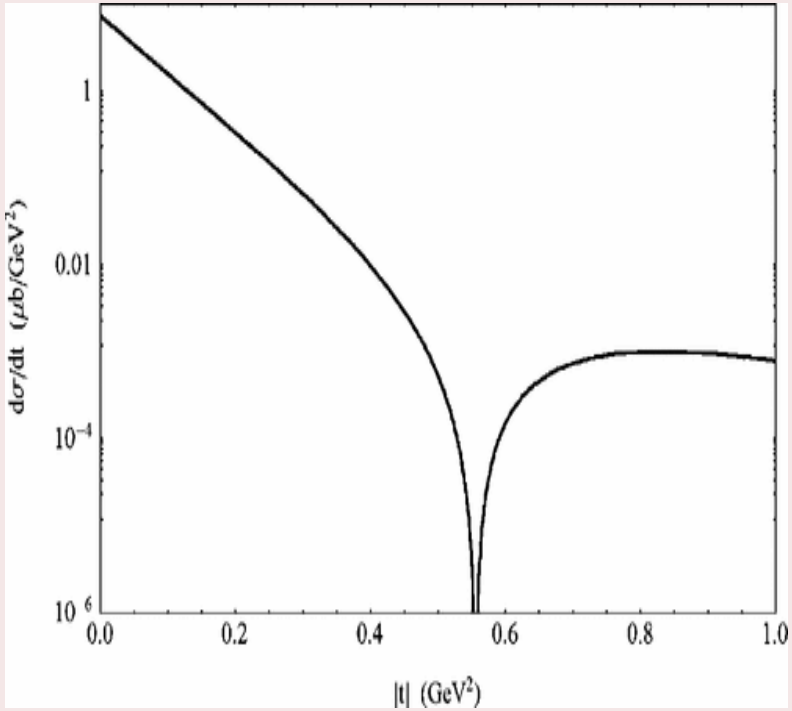
Motivation

Domokos Model

$\rightarrow$ Using the Chern-Simons term induced interation in holographic QCD. Their result is quite different prediction to the Kochelev Model [6]

Kochelev (Left) and Domokos (Right) Model Predictions





[6] S. K. Domokos, *et al.*, Phys. Rev. D **80**, 115018 (2009)

Motivation

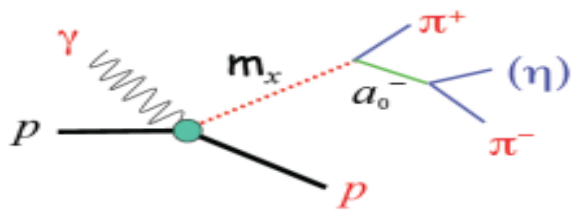
A CLAS collaboration at JLAB program. The status of the $f_1(1285)$ [7]

Experimental status

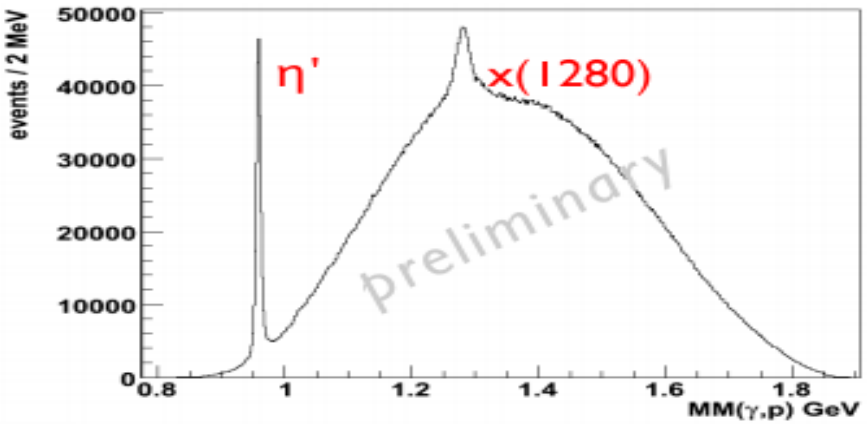
The $f_1(1285)$ at CLAS

$f_1(1285)$: $I^G(J^{PC}) = 0^+(1^{++})$

- Well-established axial-vector meson seen in several hadronic reactions;
  - ~7000 events reported world-wide
  - seen in PWA analyses
- Possible "dynamically generated" KK* – c.c. state
- Extraction of resonance parameters complicated by potential overlap with other states, e.g. η(1295)



(possible reaction topology)



Study of the $f_1(1285)$ in $\gamma p \to p\pi^+\pi^-(\eta)$ at CLAS:

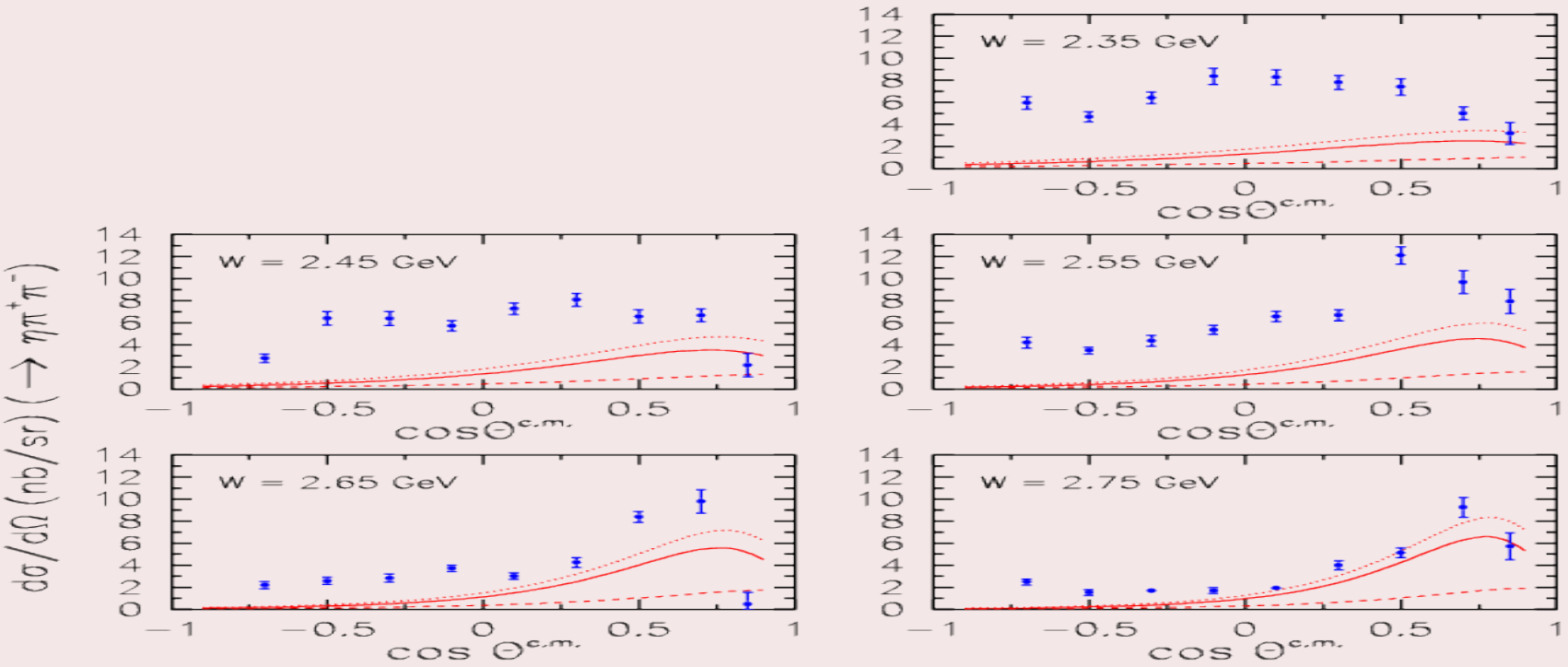
- Structure at m~1280 MeV observed in the γp missing mass spectrum
- great statistics: ~1.5 x 10^5 x(1280) events
- Which state is it? f1(1285), η(1295), or both?

Work by R. Schumacher and R. Dickson (CMU)

[7] De Vita slides, 2015

Motivation

Current Experimental data from JLAB



Note: The red solid line : Kochelev model prediction for the $f_1(1285)$ and the red dashed line for the $\eta(1295)$.

[8] R. Dickson, *et al.*, Phys. Rev. C **93**, 065202 (2016)

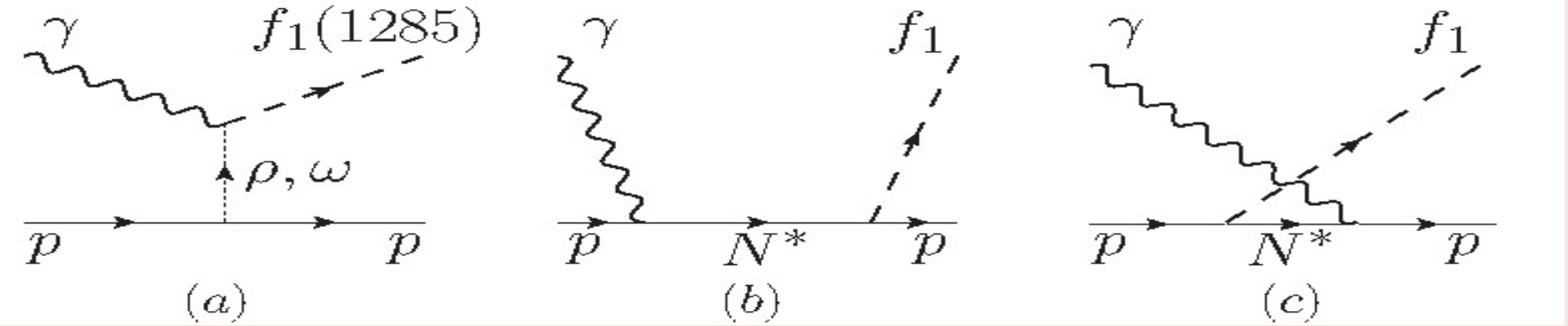
So now we need a model to describe the data??...

Outline

Effective Lagrangian Approach

General Formalism

The relevant tree diagrams for the reaction of $\gamma p \to f_1(1285)p$ are



Effective Lagrangian for t-channel

$$\begin{aligned} \mathcal{L}_{f_1 V\gamma} &= g_{f_1 V\gamma}\epsilon^{\mu\nu\alpha\beta} f_{1\mu}(\partial^\lambda \partial_\lambda V^0_\nu)\partial_\alpha A_\beta \\ \mathcal{L}_{VNN} &= -g_{VNN}\bar{N}[\gamma_\mu V^\mu - \frac{\kappa_{VNN}}{2M_N}\sigma_{\mu\nu}\partial^\nu V^\mu]N, \end{aligned} \tag{1}$$

where $V = \omega, \tau.\rho.$

Effective Lagrangian Approach

The scattering amplitude for the $\gamma p \to f_1(1285)p$ reaction is defined as

$$\mathcal{M} = \epsilon^*_\nu \bar{u}_{N'} \mathcal{M}^{\mu\nu} u_N \epsilon_\mu, \tag{2}$$

where u_N and $\bar{u}_{N'}$ stand for the Dirac spinors of the incoming and outgoing proton, respectively. The ϵ_μ and ϵ^*_ν denote the polarization vectors of the initial photon and the final $f_1(1285)$ meson.

$\mathcal{M}^{\mu\nu}$

$$\begin{aligned} \mathcal{M}^{\mu\nu}_V &= \mathcal{I}_V \frac{i g_{f_1 V\gamma} g_{VNN}}{(t - M_V^2)} \epsilon^{\mu\nu\alpha\beta} \left(\gamma^\rho - \frac{i\kappa_{VNN}}{2M_N} q_\lambda \sigma^{\rho\lambda} \right) P_{\alpha\rho} k_{1\beta} q^2, \\ P_{\alpha\rho} &= -g_{\alpha\rho} + \frac{q_\alpha q_\rho}{M_V^2}. \end{aligned} \tag{3}$$

Effective Lagrangian Approach

t-channel amplitude with the form factors taken into account

$$\mathcal{M}_t = \mathcal{M}_\rho F_{f_1\rho\gamma}(t) F_{\rho NN}(t) + \mathcal{M}_\omega F_{f_1\omega\gamma}(t) F_{\omega NN}(t) \quad (4)$$

where the form factors are defined as

Form Factors

$$F_{f_1 V\gamma} = \left(\frac{\Lambda^2_{f_1 V\gamma} - M_V^2}{\Lambda^2_{f_1 V\gamma} - t}\right)^2$$
$$F_{VNN} = \left(\frac{\Lambda^2_{VNN} - M_V^2}{\Lambda^2_{VNN} - t}\right). \quad (5)$$

where $\Lambda_{\rho NN} = 1.5\mathrm{GeV}$, $\Lambda_{\omega NN} = 1.5\mathrm{GeV}$ and $\Lambda_{\rho f_1\gamma} = 1.04\mathrm{GeV}$ and $\Lambda_{\omega f_1\gamma} = 1.04\mathrm{GeV}$.

Effective Lagrangian Approach

Form Factors

The ρ trajectory the rotating phase is defined as

$$\begin{aligned} \alpha_\omega &= 0.44 + 0.9t \\ \alpha_\rho &= 0.55 + 0.8t. \end{aligned} \tag{6}$$

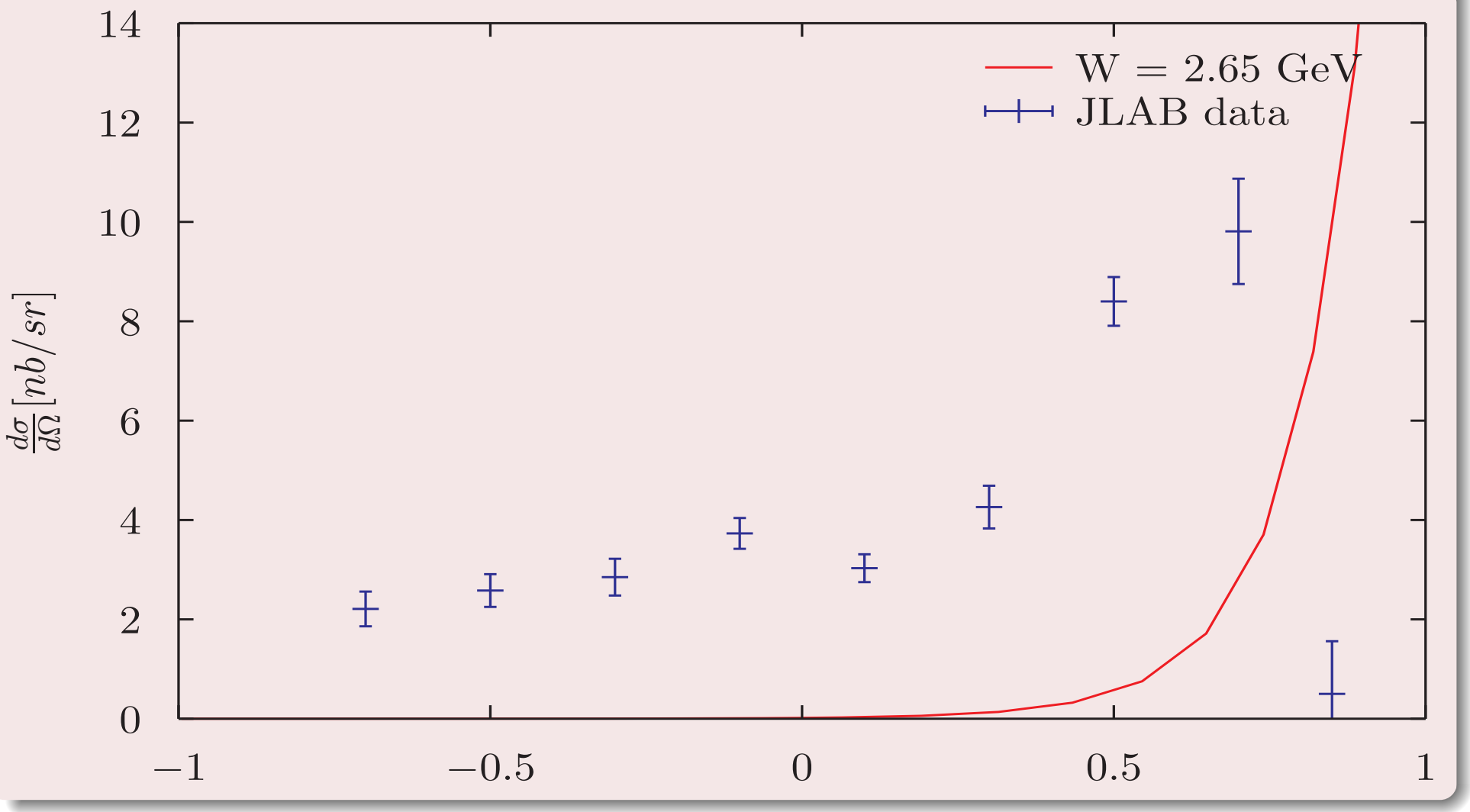
Coupling constants

Coupling constants	Kochelev	Domokos
$g_{\omega NN}$	10.6	9
$g_{\rho NN}$	3.9	2.4
g_ω^T	0.0	0.0
$\frac{g_\rho^T}{g_\rho}$	6.1	0.0
$g_{f_1\rho\gamma}$	0.97	-0.99
$g_{f_1\omega\gamma}$	$\frac{1}{3}g_{f_1\rho\gamma}$	-0.33

Outline

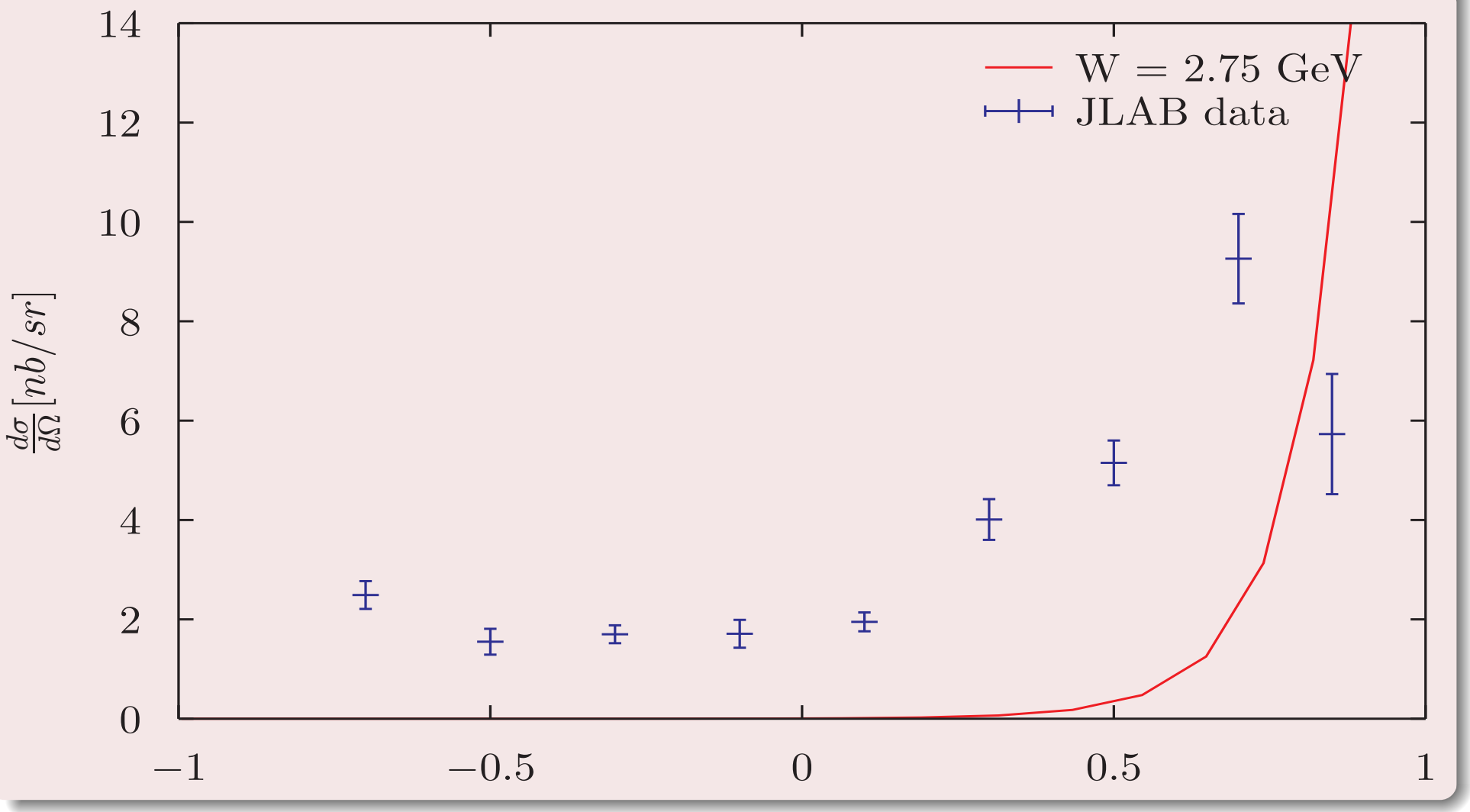
Our Model Prediction for differential Cross section

Our Model Prediction for differential Cross section of the axial vector meson $f_1(1285)$ vs Θ for $W = 2.65\ GeV$ (Preliminary)



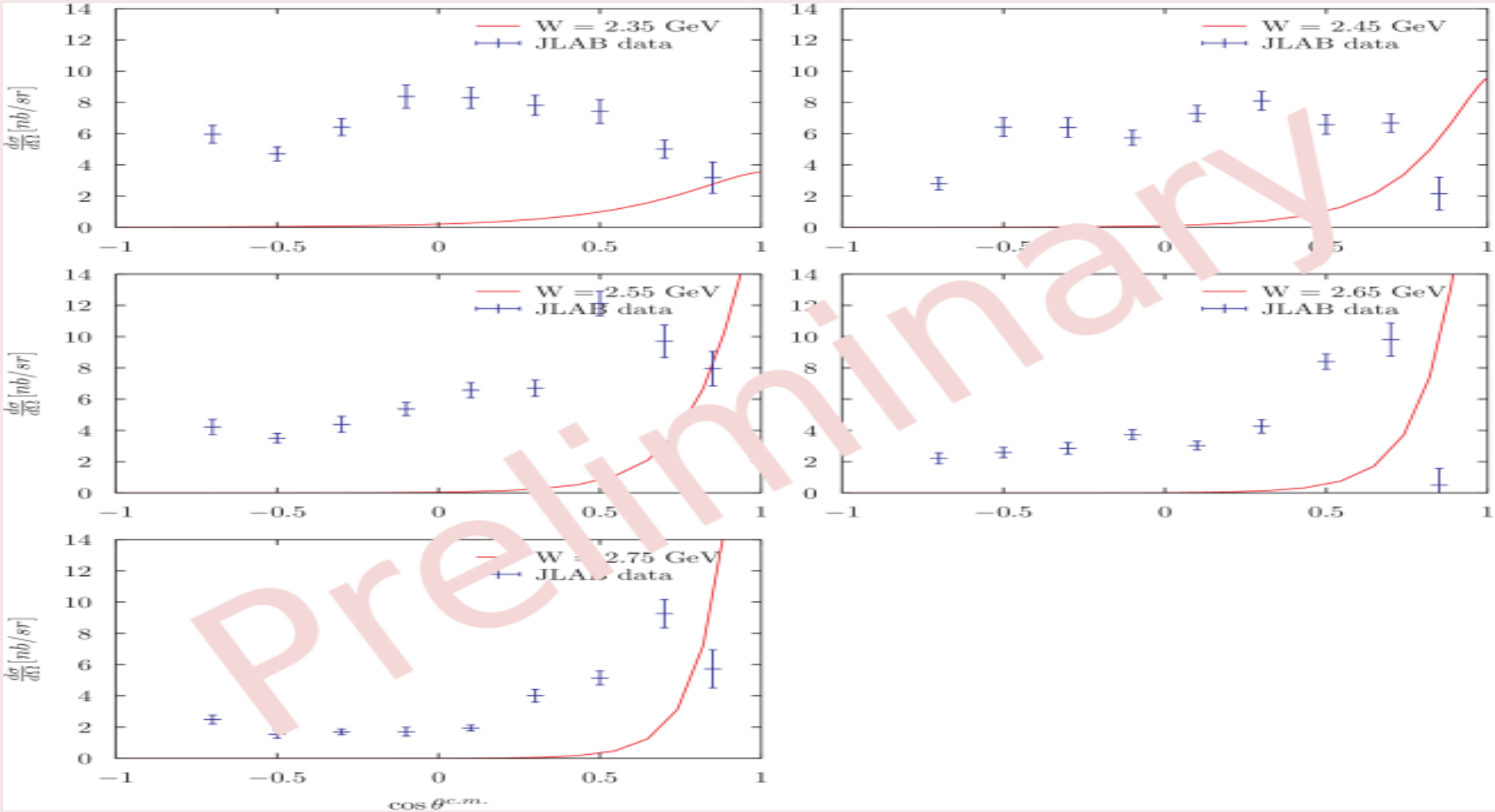
Our Model Prediction for differential Cross section

Our Model Prediction for differential Cross section of the axial vector meson $f_1(1285)$ vs Θ for $W = 2.75\ GeV$ (Preliminary)



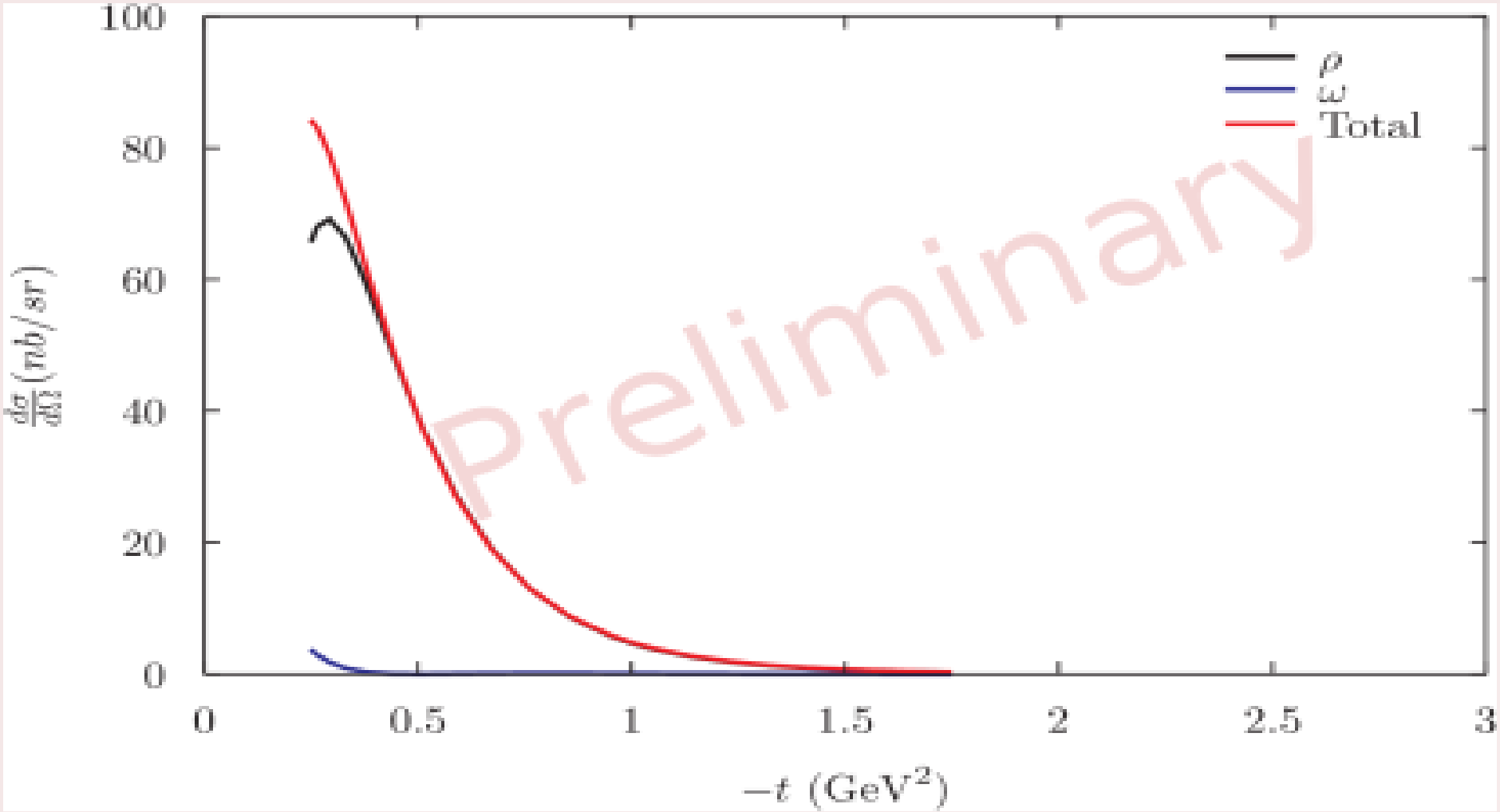
Our Model Prediction for differential Cross section

Our Model Prediction for differential Cross section of the axial vector meson $f_1(1285)$ vs Θ (Preliminary)



Our Model Prediction for differential Cross section

Our Model Prediction for differential Cross section of the axial vector meson $f_1(1285)$ vs t (Preliminary)



Our Model Prediction for differential Cross section

IN PROGRESS.....

Outline

Conclusion

1. The differential cross section of the $f_1(1285)$ have been studied in the effective Lagrangian approach
2. The only $t-$channel seems not enough to describe the recent differential cross section data from CLAS
3. Need advance study and analysis for this reaction by including the $s-$ and $u-$ exhanges

Thank You for Your Attention

감사합니다.

Thank you.