

Pion-induced $\Lambda(1405)$ production



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0. Contents

1. Features of $\Lambda(1405)$
2. Photoproduction of $\Lambda(1405)$
3. Pion-induced $\Lambda(1405)$ production

1. Features of $\Lambda(1405)$

Isgur and Karl,PRD18, S.X.Nakamura and D.Jido,PTEP014

Simple uds state?: Quark model, Reaction analysis,..

Meson-Baryon molecular?: Chiral Unitary Model (ChUM),

Lattice,.. V.K.Magas,E.Oset and A.Ramos,PRL95, J.M.M.Hall et al,PRL114

Pentaquark?: Quark model, Lattice,..T.Inoue,NPA790, Y.Nemoto et al,PRD68

The structure is not governed by symmetries, it is difficult to make a unique way to determine it

H.Kawamura,S.Kumano & T.Sekihara,PRD88

Are there possibilities to pin down it via production reactions?: More N^* and Y^* and nontrivial BG!?!?

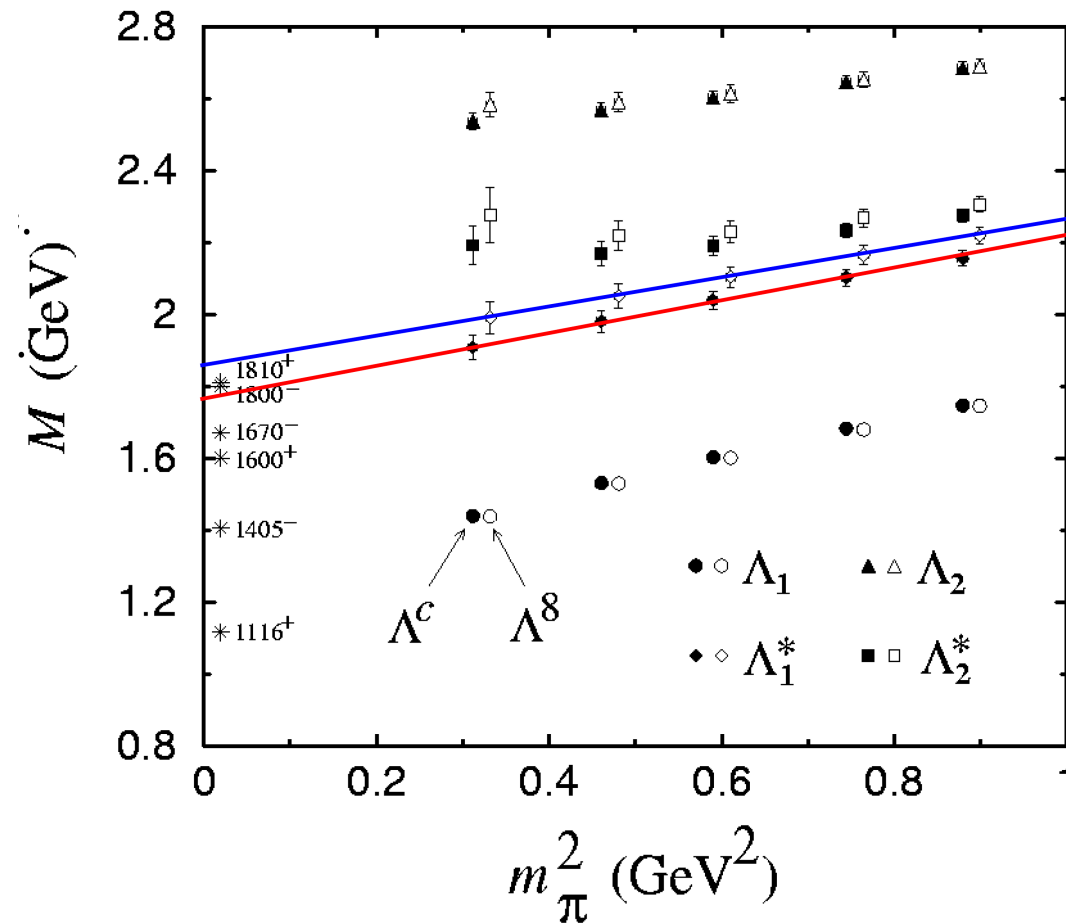
1. Features of $\Lambda(1405)$

Isgur and Karl, PRD18, S.X.Nakamura and D.Jido, PTEP014

Quark models gives larger mass for $\Lambda(1405)$

in general: Mass=(1.5~1.8) GeV

Isgur and Karl, PRD18

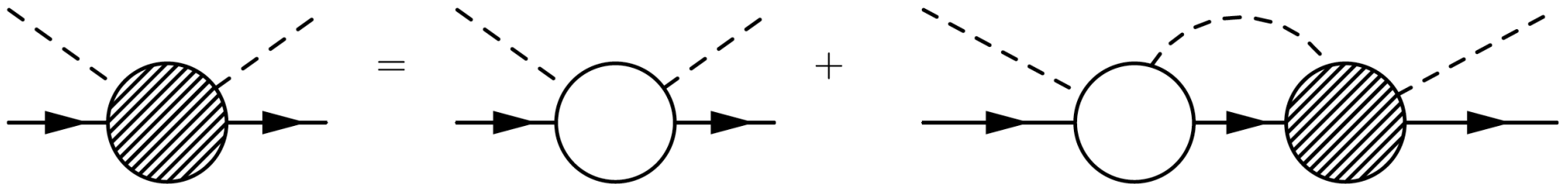


Lattice with
Quark flavor
operators gives
also larger mass
for $\Lambda(1405)$

J.M.Zanotti, J.B.Zhang PRD67

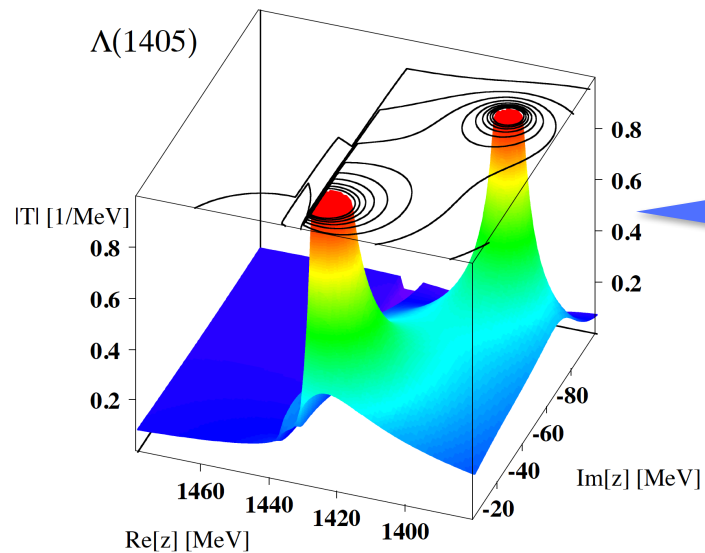
1. Features of $\Lambda(1405)$

Coupled channel models with meson-baryon chiral (WT) interaction: $\bar{K}N$ and $\pi\Sigma$ molecular structure

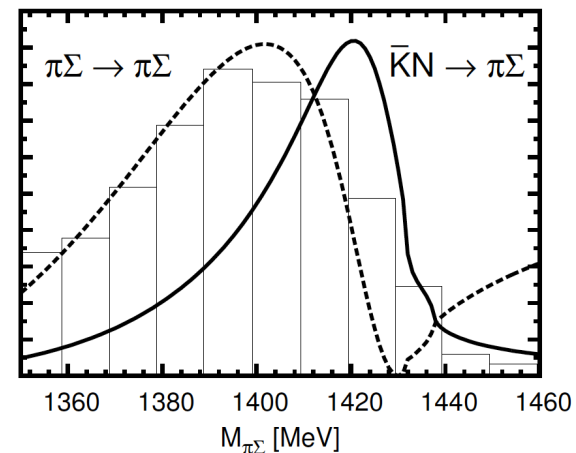


$$\mathcal{L}^{\text{WT}} = \frac{1}{4f^2} \text{Tr} (\bar{B} i \gamma^\mu [\Phi \partial_\mu \Phi - (\partial_\mu \Phi) \Phi], B).$$

(a) Comparison of two spectra

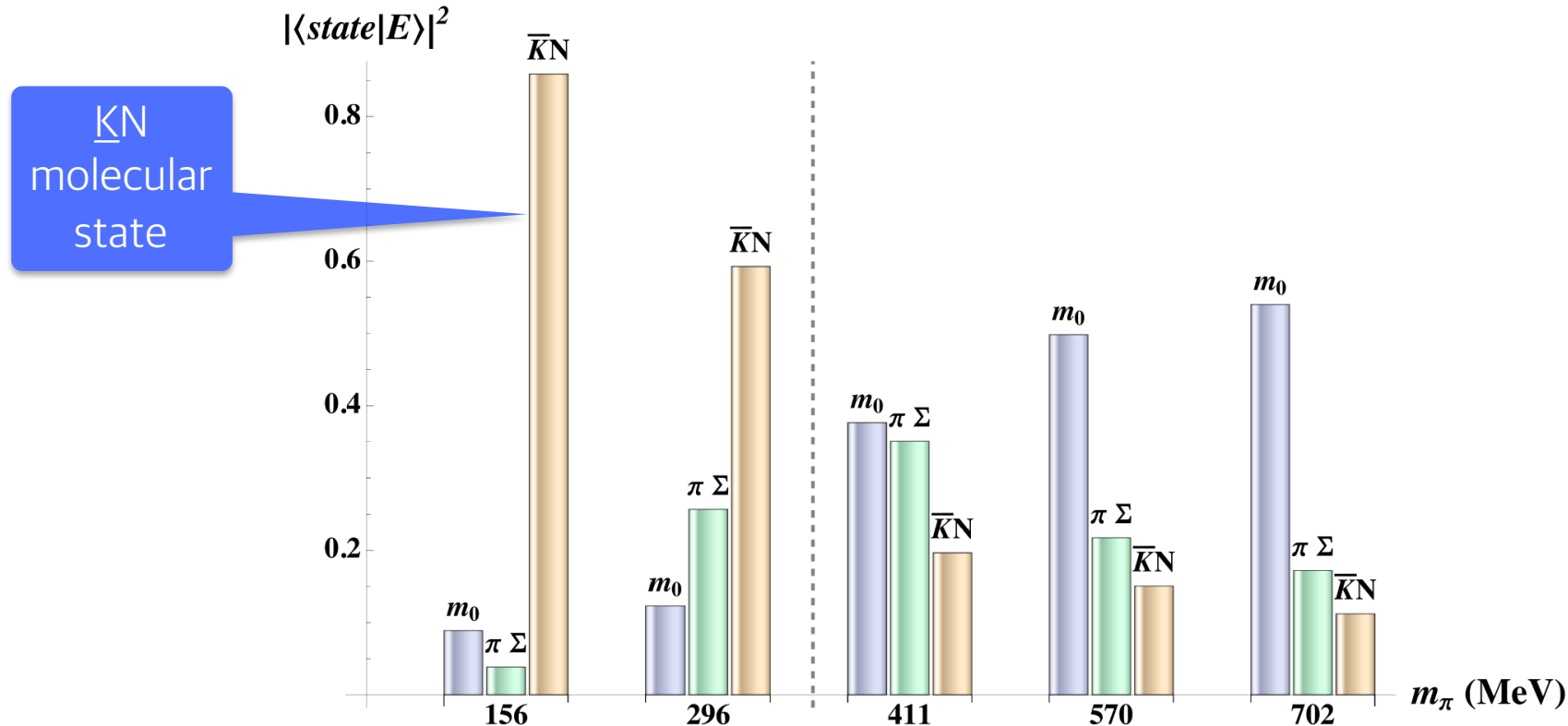


Two-pole structure



T.Hyodo and D.Jido, PPNP67

1. Features of $\Lambda(1405)$



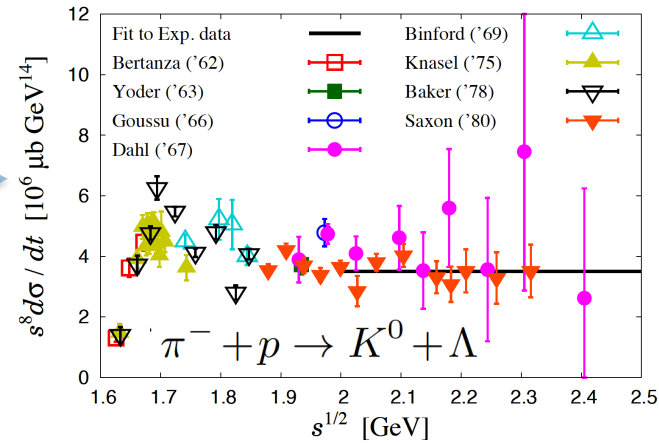
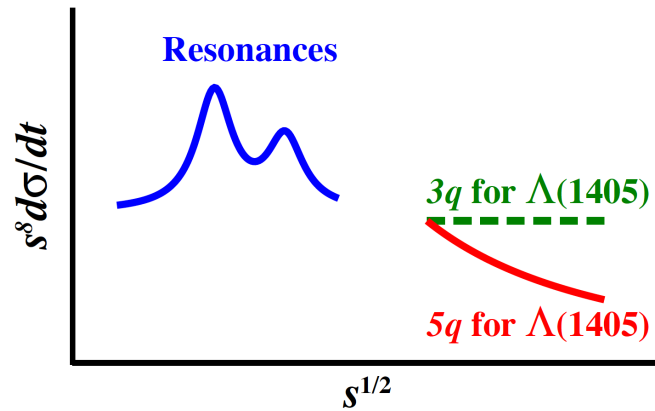
Lattice shows a possible configuration for $\Lambda(1405)$ w.r.t. pion mass: KN composite via strange magnetic form factor ~ 0

1. Features of $\Lambda(1405)$

G. P. Lepage and S. J. Brodsky, PRD22

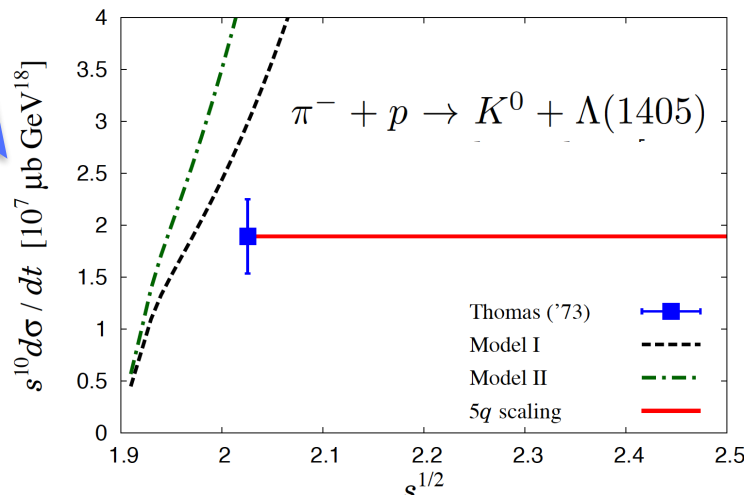
H.Kawamura, S.Kumano & T.Sekihara, PRD88

Constituent-counting rule (CCR) at high-E
from dimensional analysis of scattering amplitude



H.Kawamura, S.Kumano & T.Sekihara, PRD88

Low-E model

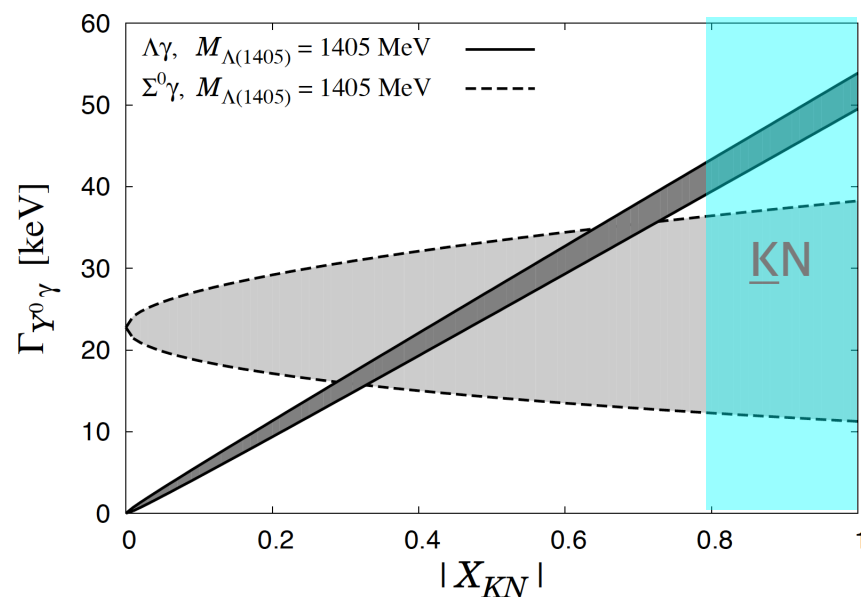


Indicating 5-quark,
including KN?

1. Features of $\Lambda(1405)$

Considering theoretical observation, it seems KN composite state is plausible

However, we have not have concrete experimental evidences: Radiative decay of $\Lambda(1405)$ helpful?

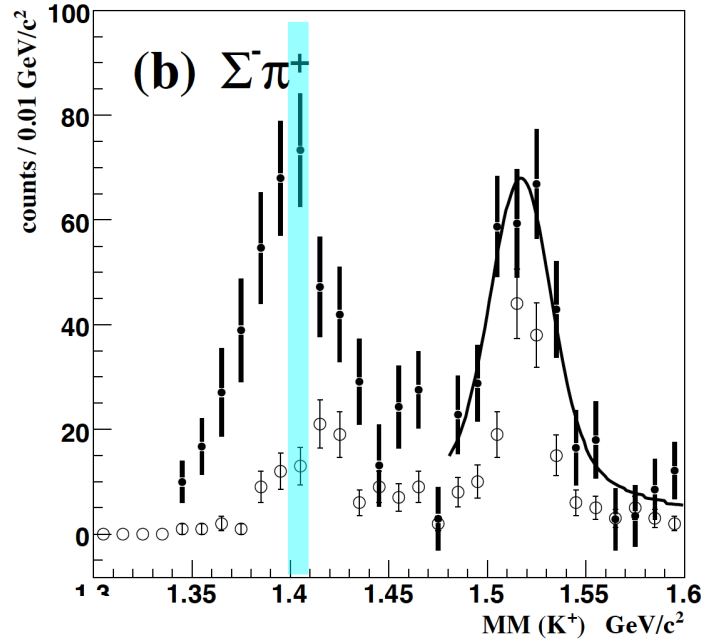
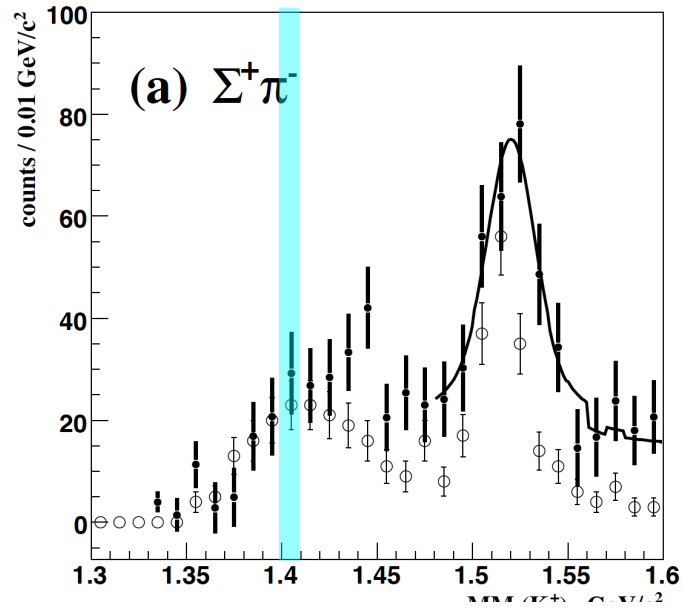


$$\Lambda(1405) \rightarrow \Lambda\gamma \text{ and } \Sigma^0\gamma$$

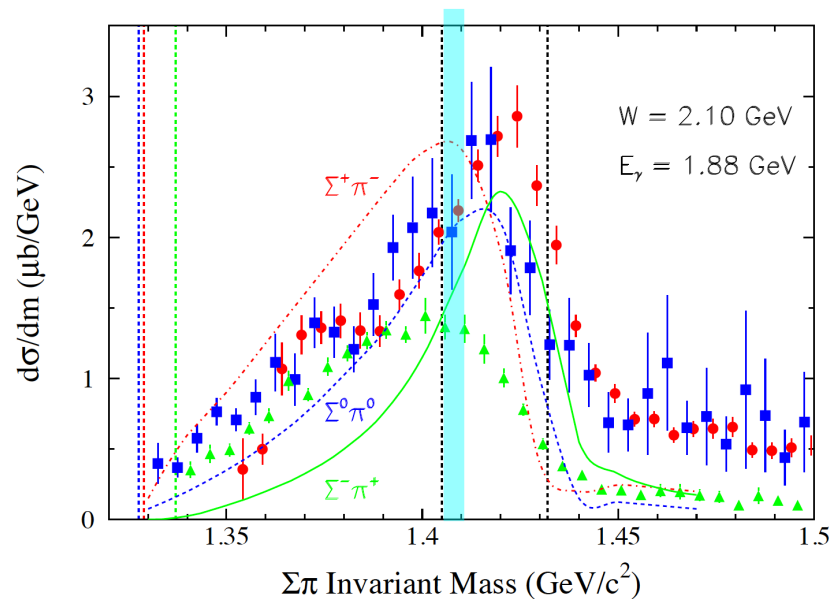
$$X_{\bar{K}N} = -g_{\bar{K}N}^2 \left[\frac{dG_{K^-p}}{d\sqrt{s}} + \frac{dG_{\bar{K}^0n}}{d\sqrt{s}} \right]_{\sqrt{s}=Z_{\text{pole}}}$$

T.Sekihara and S.Kumano, PRC89

1. Features of $\Lambda(1405)$

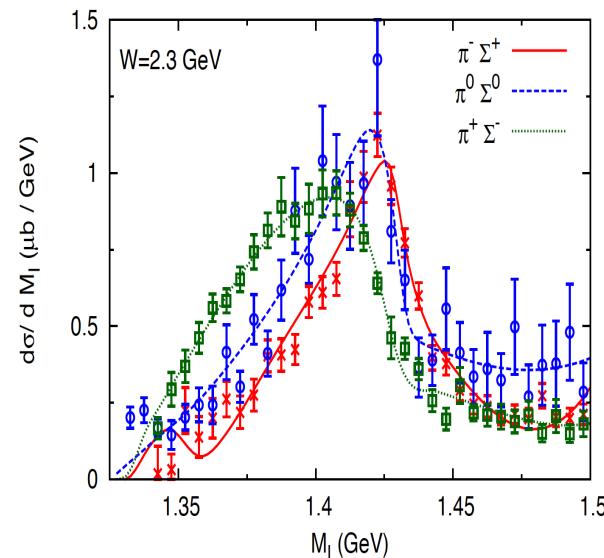
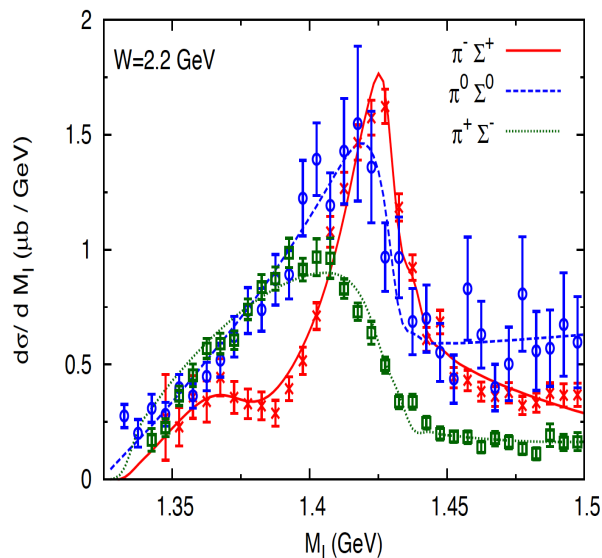
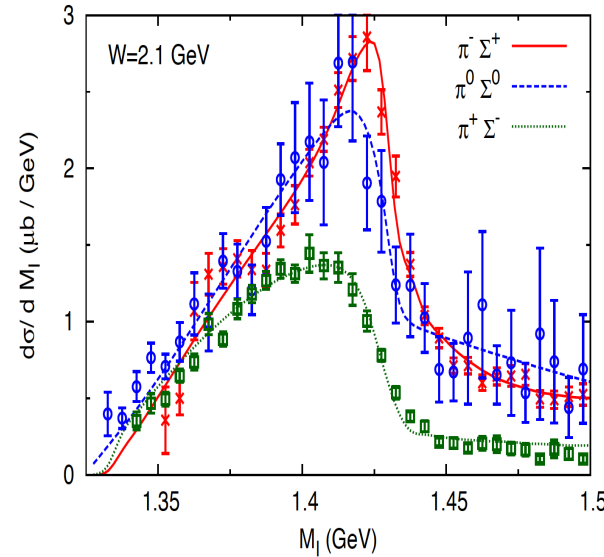
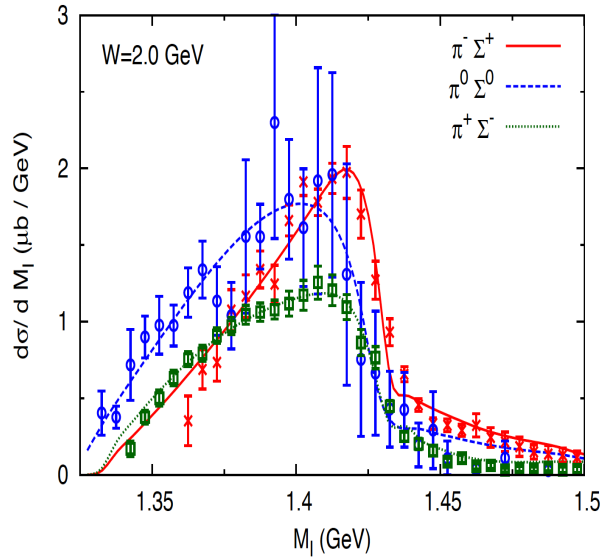


LEPS
M.Niiyama et al.
PRC78,035202



CLAS
K.Moriya et al. PRC.87.035206

1. Features of $\Lambda(1405)$



S.X.Nakamura and D.Jido, PTEP014

Line shape is a complicated mixture of various contributions:

N^* and Y^* ,
 Nonresonant BG,
 Meson exchange,
 Chiral interaction,
 etc.

Data from K.Moriya et al. PRC.87.035206

2. Photoproduction of $\Lambda(1405)$

Studied in theories and experiments

Gauged ChUM (E.Oset, L.Roca, S.X.Nakamura, D.Jido...)

Eff. Lagrangian (SiN, H.C.Kim, A.Hoska, H.K.Jo..)

Dalitz process (S.X.Nakamura, D.Jido, M.Soyeur, ...)

We consider the latest experiment as an input:

CLAS collaboration (K.Morita, R.Schumcher, ...)

2. Photoproduction of $\Lambda(1405)$

M.Niiyama (LEPS) shows strong enhancement of σ near the threshold: Threshold enhancement

M.Niiyama et al. PRC78,035202

Unfortunately, LEPS and CLAS line shapes of $\Lambda(1405)$ invariant mass look inconsistent

K.Moriya et al. PRC.87.035206

Also, it does not match with ChUM

We are still missing many unknown ingredients...

2. Photoproduction of $\Lambda(1405)$

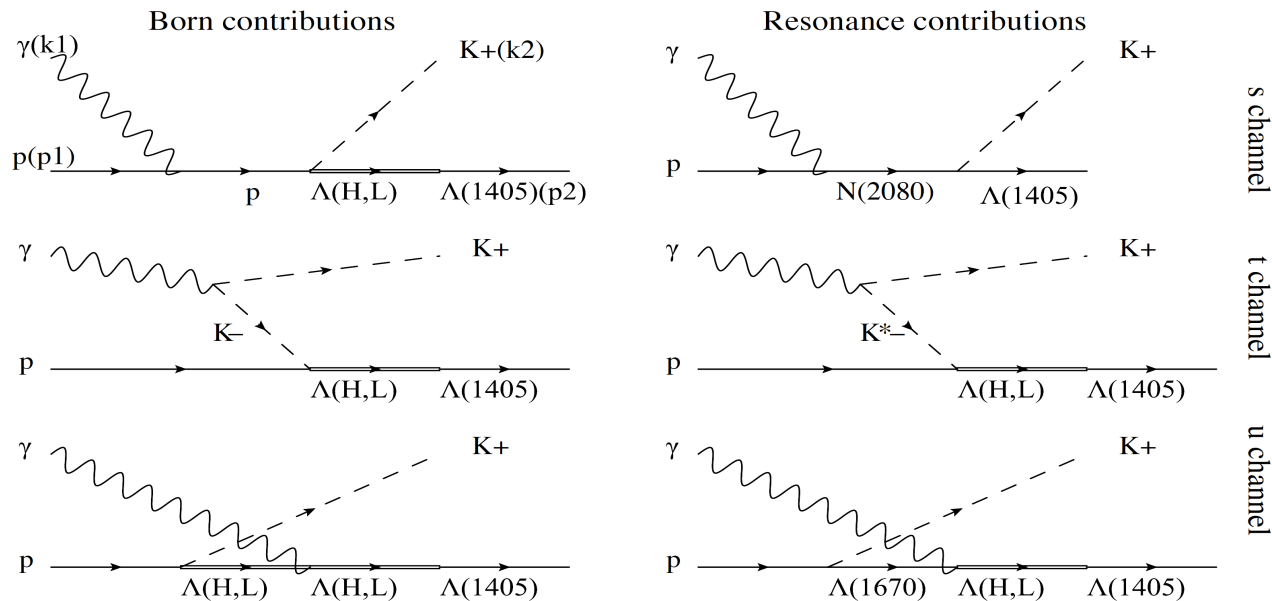
We are motivated by

SiN and H.K.Jo, arXiv:1503.00419

- 1) Threshold enhancement: N^* near threshold
- 2) Line shape deviated from Breit-Wigner shape:

Two-pole structure

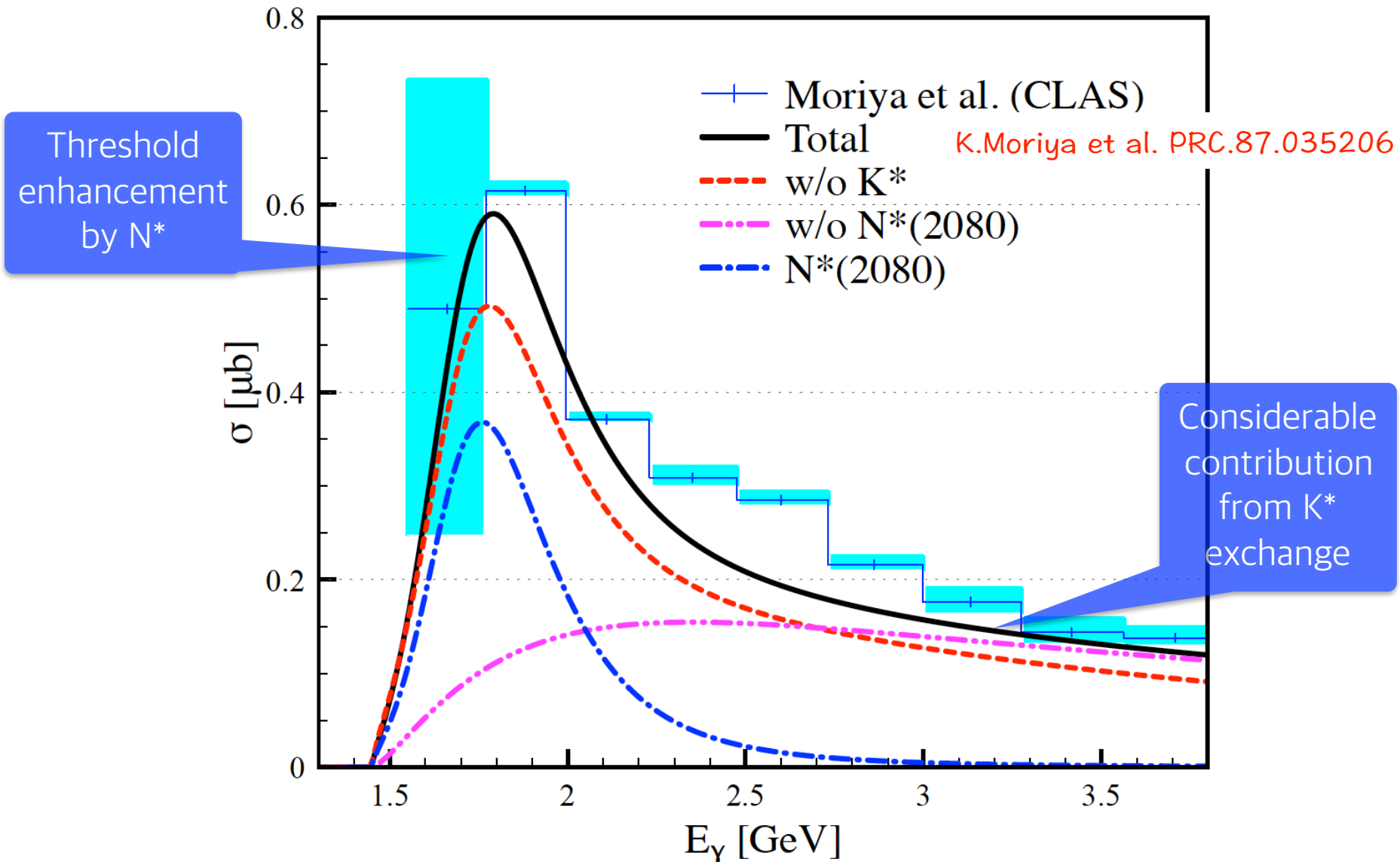
- 3) Well-established $2 \rightarrow 2$ eff. Lag. reaction calculation



2. Photoproduction of $\Lambda(1405)$

Total cross section

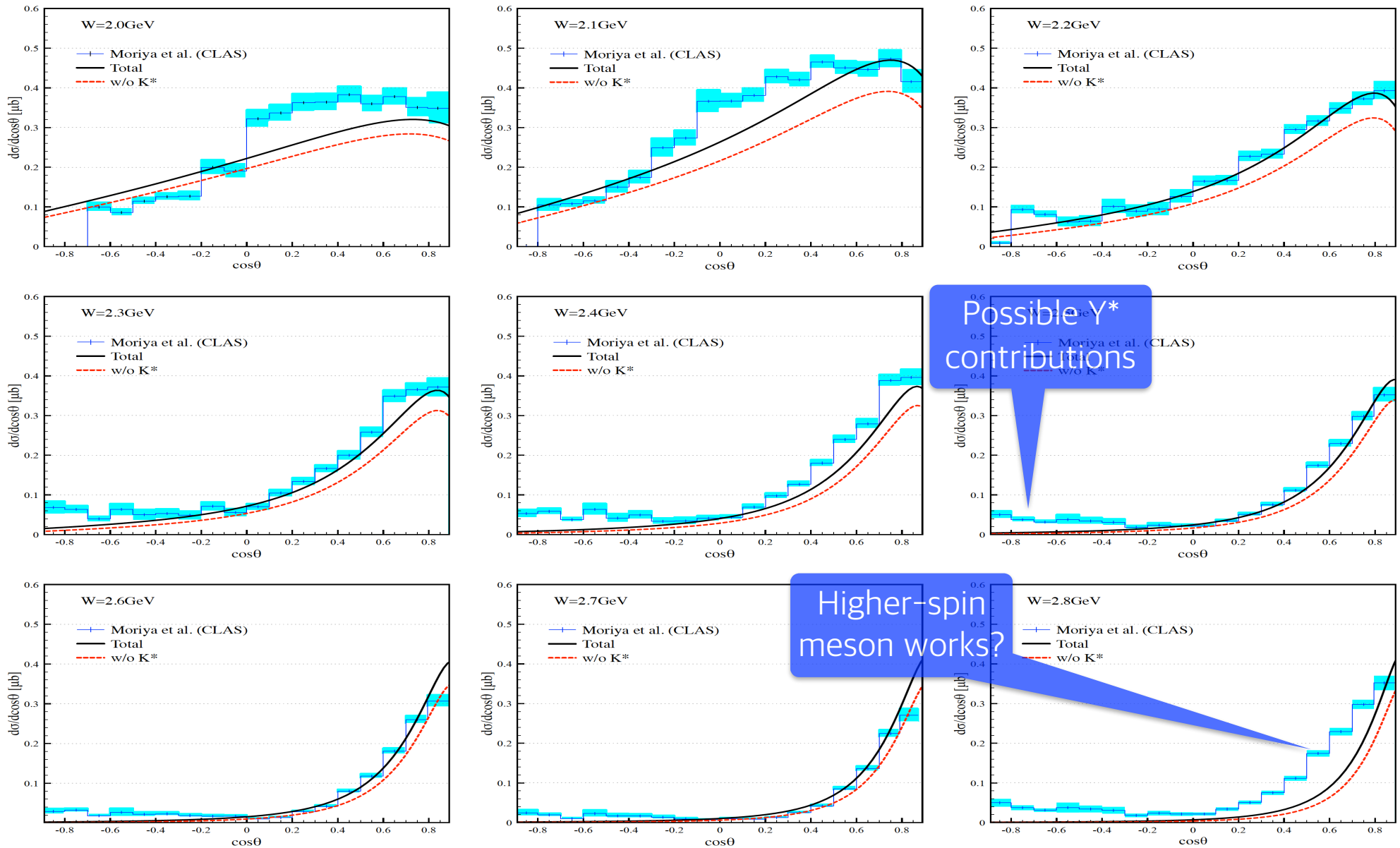
SiN and H.K.Jo, arXiv:1503.00419



2. Photoproduction of $\Lambda(1405)$

Angular dependence

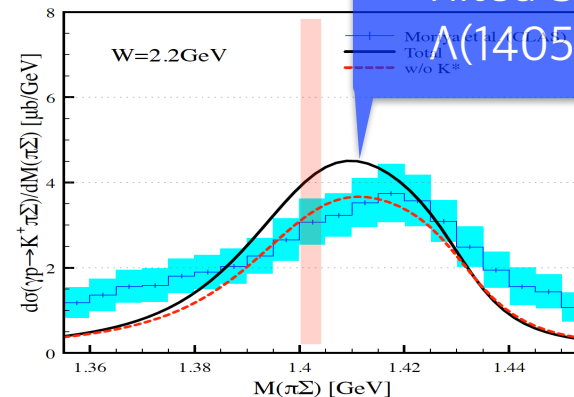
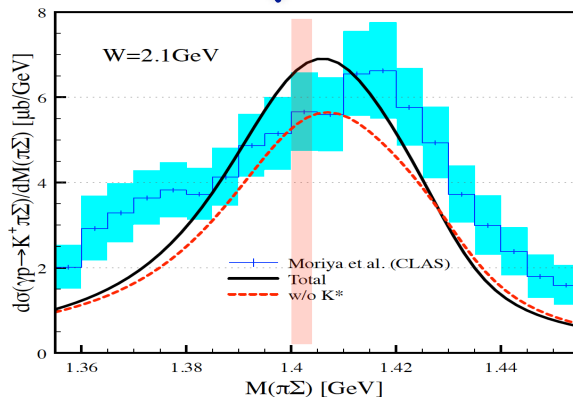
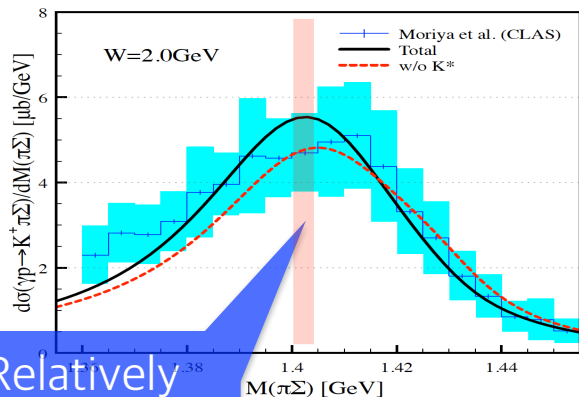
SiN and H.K.Jo, arXiv:1503.00419



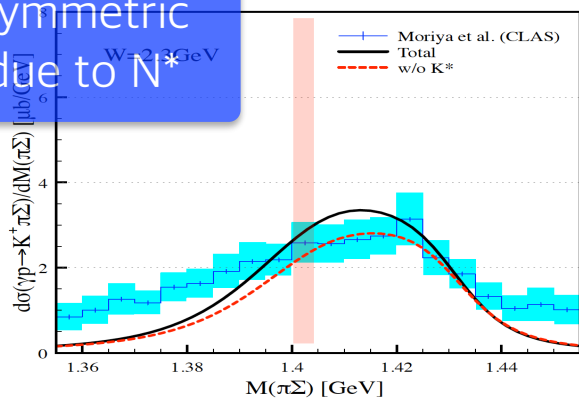
2. Photoproduction of $\Lambda(1405)$

$\pi\Sigma$ invariant mass line shape

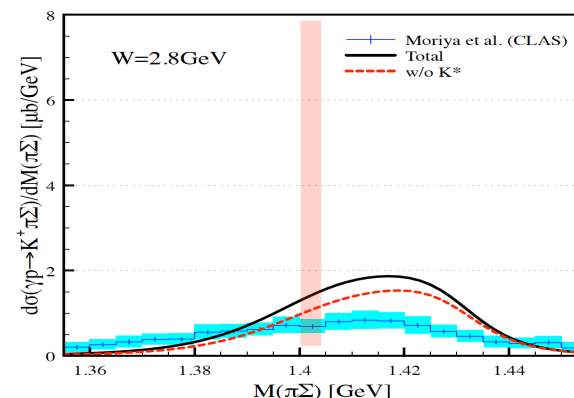
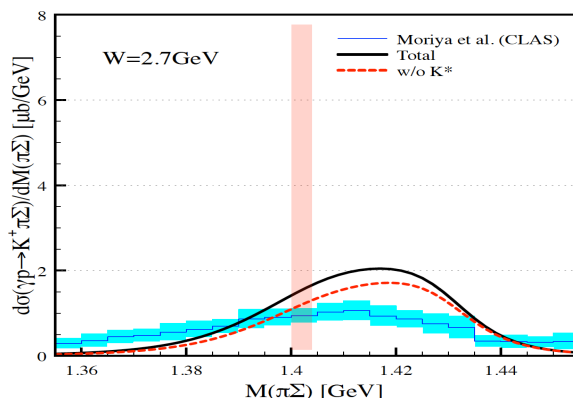
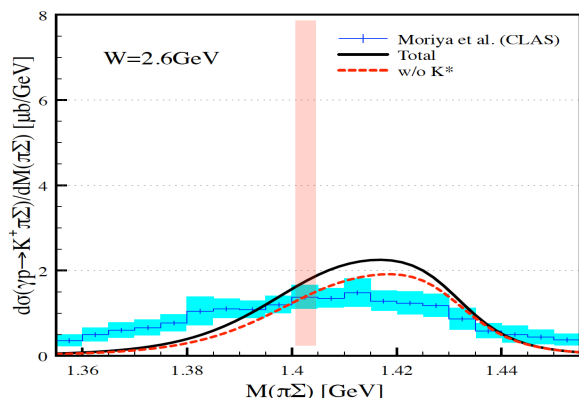
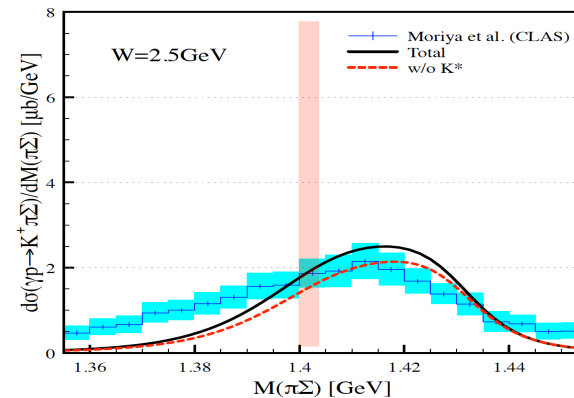
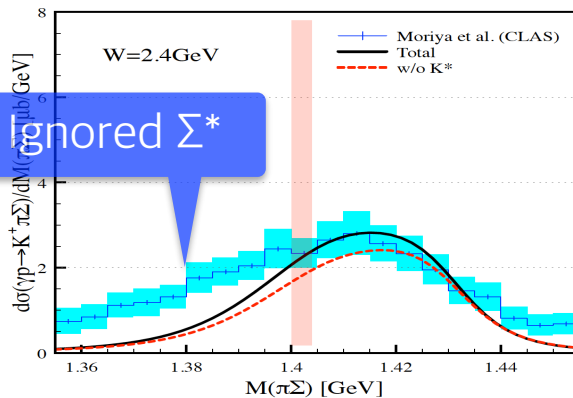
Tilted by $\Lambda(1405)$



Relatively symmetric due to N^*



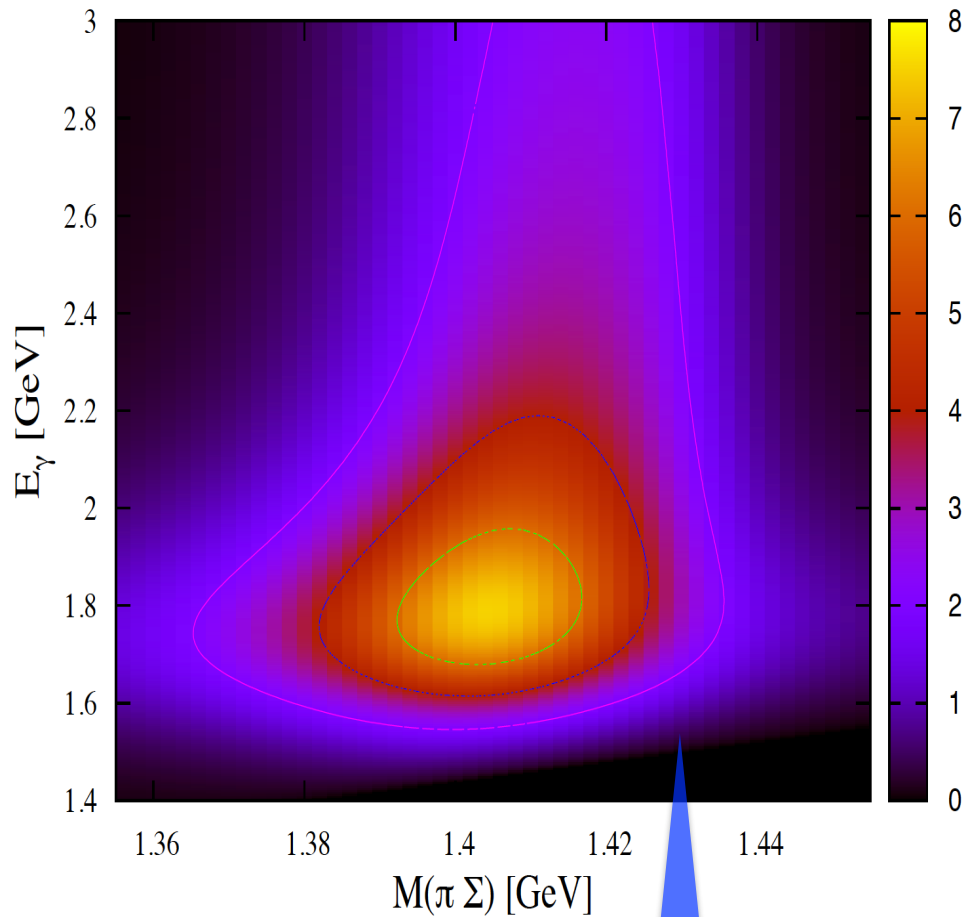
Ignored Σ^*



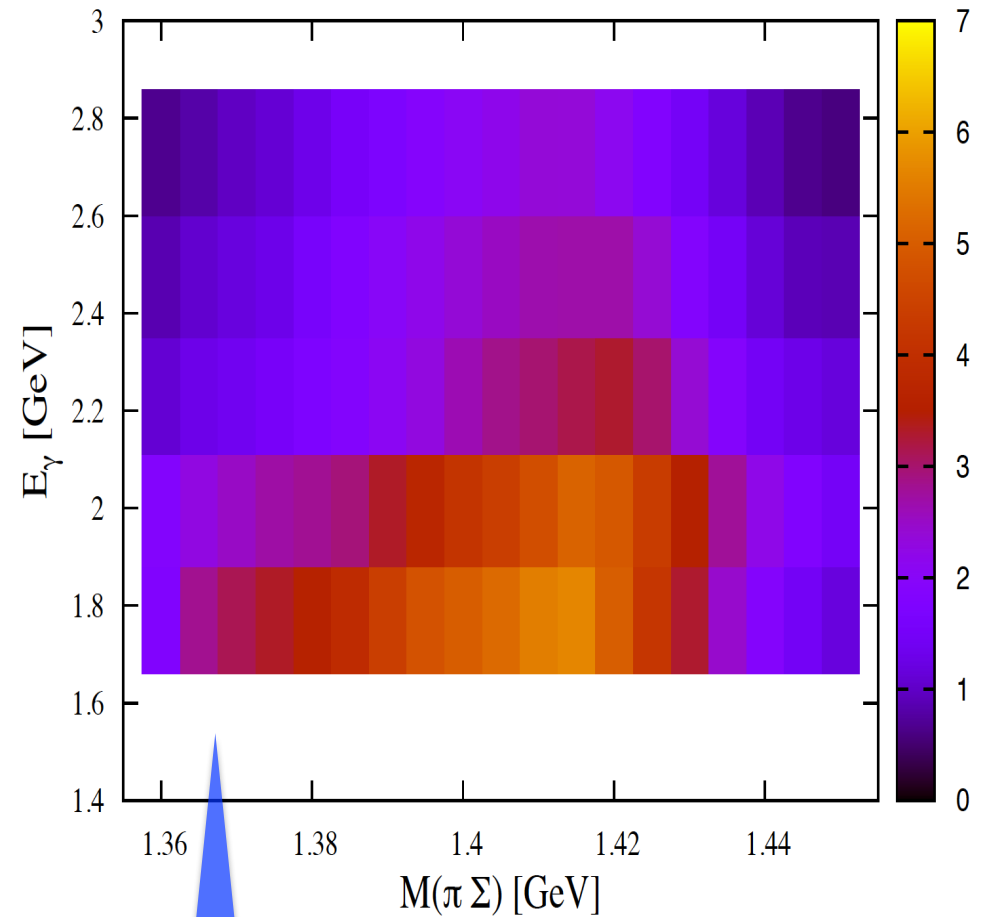
2. Photoproduction of $\Lambda(1405)$

$\pi\Sigma$ invariant mass ftn. of inv. Mass and E_γ

SiN and H.K.Jo, arXiv:1503.00419



Theory



Experiment

K.Moriya et al. PRC.87.035206

2. Photoproduction of $\Lambda(1405)$

Conclusion for $\Lambda(1405)$ photo production

- 1) Threshold enhancement explained by N^* s:
 $D_{13}(2080)$ plays the role: Peak shift w.r.t. energy
- 2) Two-pole scenario may explain the tilting, but not decisive...: Single-pole one also possible
- 3) Many unknown parameters: EM and strong

3. Pion-induced $\Lambda(1405)$ production

J-PARC is a good place for meson-beam hyperon production researches

Using meson (π, K) beam, one can construct more simple theoretical model: Less unknown parameters

A nice place to study $N^*-K-\Lambda(1405)$ information

Can we find a way to test the internal structure of $\Lambda(1405)$ in a pure-strong process?: CCR??

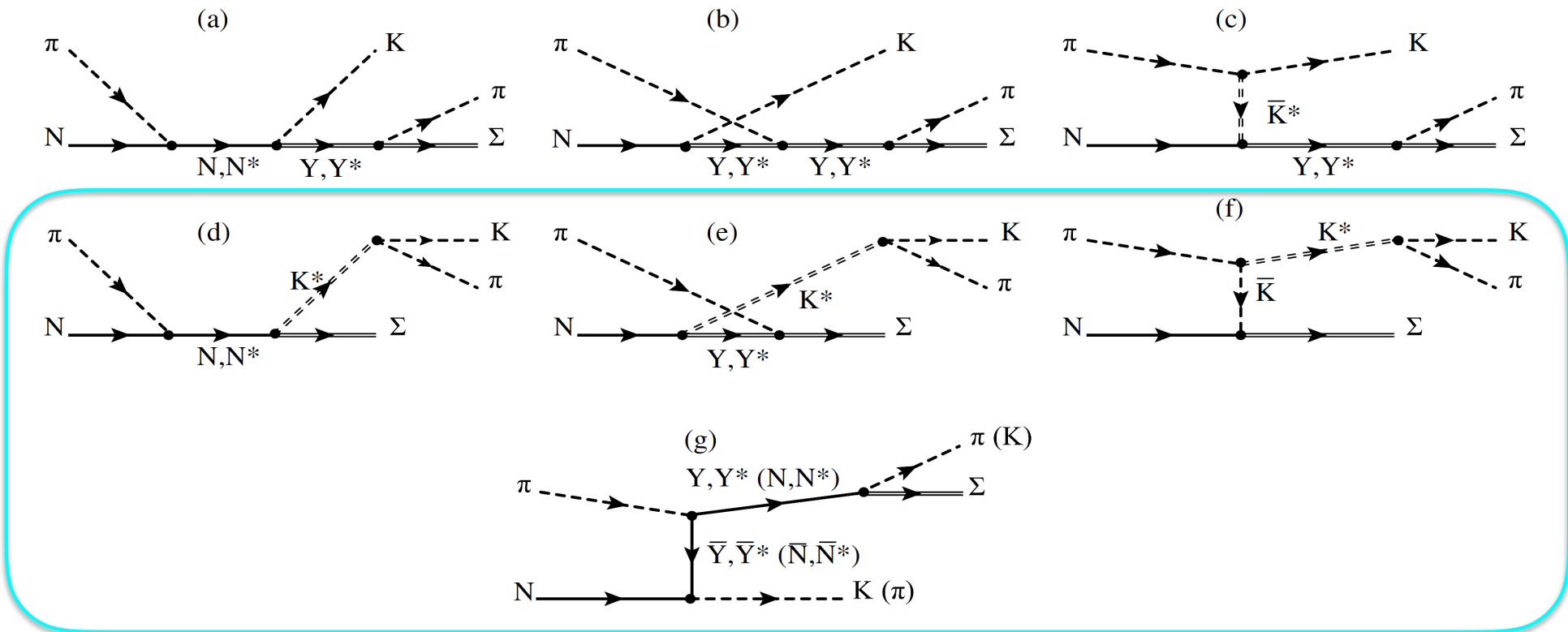
3. Pion-induced $\Lambda(1405)$ production

Under progress!!

Again, we employ eff. Lag. approach

For more adequate production analysis, we consider

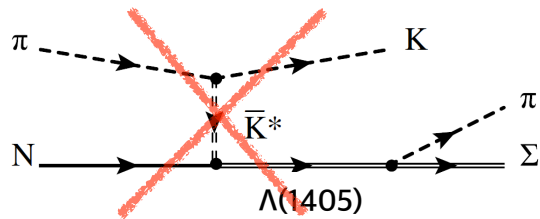
Dalitz process: $\pi^- p \rightarrow K^0 \pi \Sigma$



3. Pion-induced $\Lambda(1405)$ production

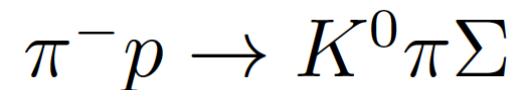
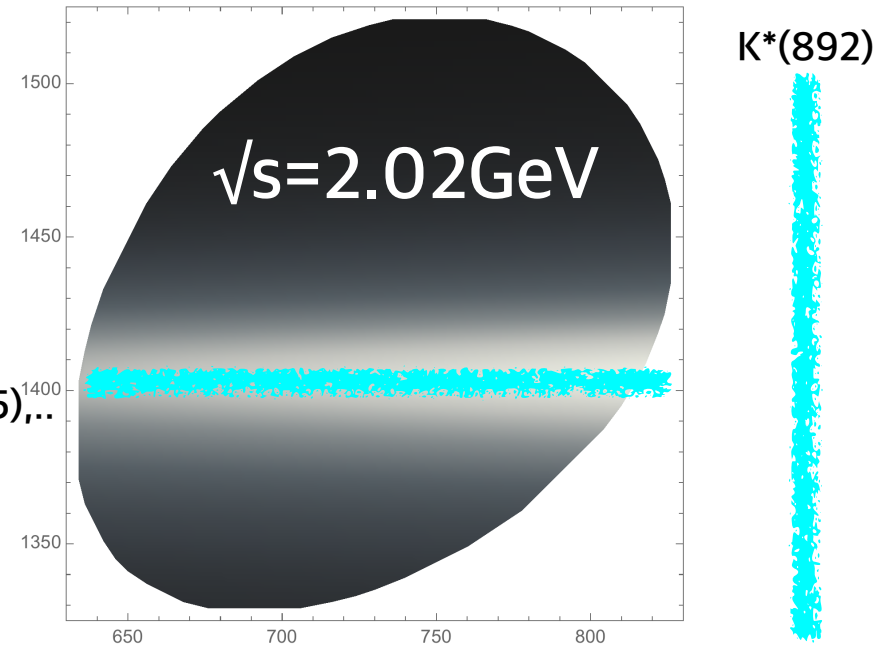
As a first step, we consider the contribution only with $\Lambda(1405)$ production: Ignoring $K^* \rightarrow \pi K$

Little known about $\underline{K}^* N \Lambda(1405)$ coupling:



Phenomenological form factor

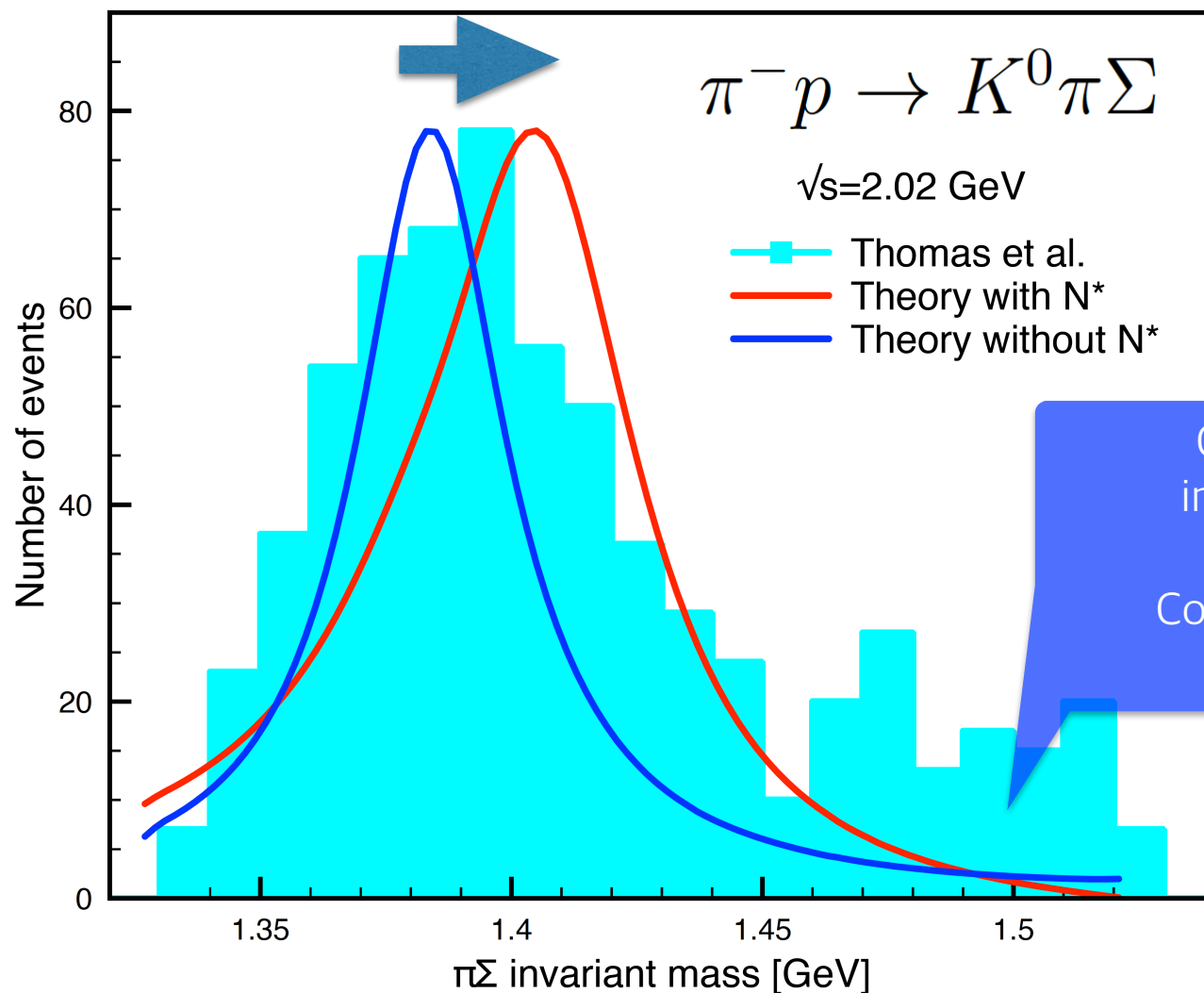
$$F_x = \frac{\Lambda_x^4}{\Lambda_x^4 + (x - M_x^2)^2}, \quad x = s, u, t.$$



3. Pion-induced $\Lambda(1405)$ production

Invariant mass

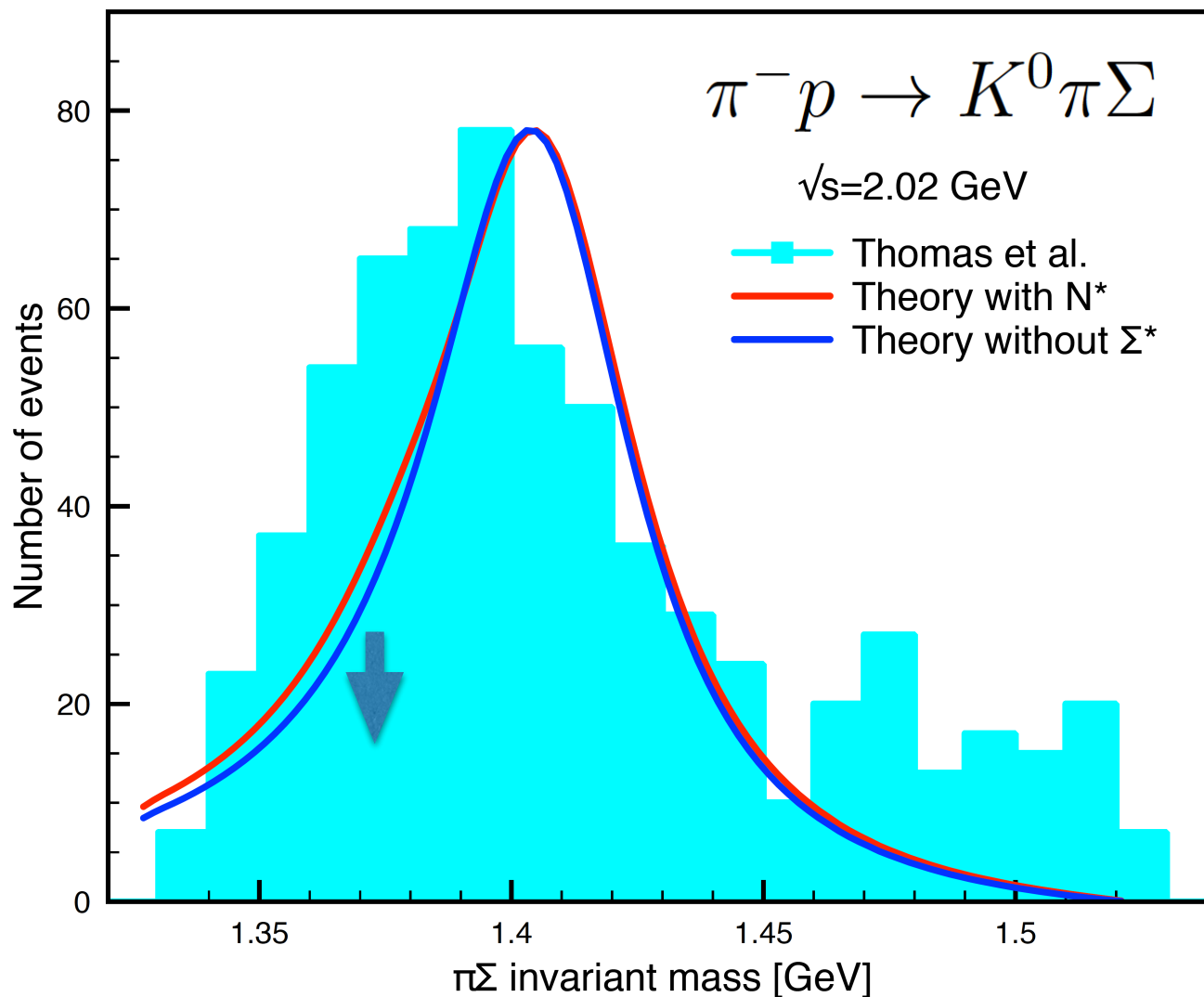
D.W.Thomas et al.,NPB56



3. Pion-induced $\Lambda(1405)$ production

Invariant mass

D.W.Thomas et al.,NPB56



3. Pion-induced $\Lambda(1405)$ production

Invariant-mass line shape effected much by N^* , while Σ^* gives small contribution

How to isolate $\Lambda(1405)$ from others?:

Polarization, angular separation, energy separation,
Gottfried-Jackson frame analysis

One suggest: $K^- p \rightarrow \pi^0 \Lambda(1405) \rightarrow \pi^0 \pi \Sigma$

More detailed works of $K^- p$ and $\pi^- p$ are under progress

Born approximation + Regge + more N^* s + KKN?

Thank you very much for your attention!!

Thanks to

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and Dr. Kei Moriya