Light-quark baryon spectroscopy from ANL-Osaka dynamical coupled-channels analysis

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The 10th International Workshop on the Physics of Excited Nucleons (NSTAR2015)
Icho Kaikan, Osaka University, Osaka, Japan, May 25-28, 2015

Outline

1. **N* and Δ* spectroscopy via ANL-Osaka Dynamical Coupled-Channels (DCC) analysis of πN, γN, and eN reactions**

   ➔ **HK, Nakamura, Lee, Sato, PRC88(2013)035209**

   (See also talk by Toru Sato in NSTAR2013: http://ific.uv.es/nucth/nstar/talks/P1_Sato.pdf)

2. **Λ* and Σ* spectroscopy via ANL-Osaka DCC analysis of K^- p reactions**

   ➔ **HK, Nakamura, Lee, Sato, PRC90(2014)065204; in preparation.**

ANL-Osaka DCC approach to N* and Δ*

Dynamical coupled-channels model [Matsuyama, Sato, Lee, Phys. Rep. 439(2007)193]

$$T^{(LSJ)}_{a,b}(p_a,p_b;E) = V^{(LSJ)}_{a,b}(p_a,p_b;E) + \underbrace{\sum_c}_{\text{CC effect}} \underbrace{\int_0^\infty q^2 dq}_{\text{off-shell effect}} V^{(LSJ)}_{a,c}(p_a,q;E) G_c(q;E) T^{(LSJ)}_{c,b}(q,p_b;E)$$

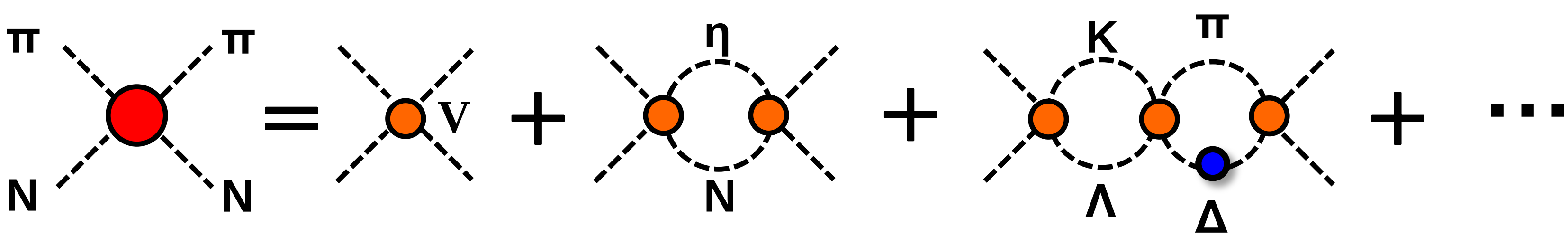
CC effect

off-shell effect

$$a,b,c = (\gamma^{(*)}N,\ \pi N,\ \eta N,\ \underbrace{\pi\Delta,\ \sigma N,\ \rho N}_{\pi\pi N},\ K\Lambda,\ K\Sigma,\cdots)$$

✓ **Summing up all possible transitions between reaction channels !!**
(➔ satisfies multichannel two- and *three*-body unitarity)

e.g.) πN scattering



✓ **Momentum integral takes into account off-shell rescattering effects in the intermediate processes.**

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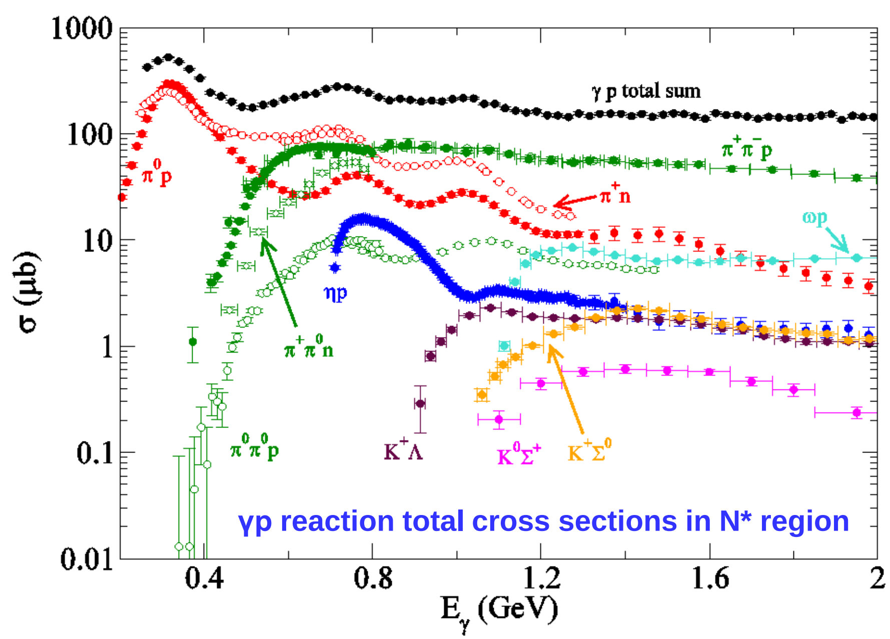
Latest published model:

HK, Nakamura, Lee, Sato, PRC88(2013)035209

Constructed by simultaneous analysis of

- **πN SAID PW amps. (W < 2.3 GeV)**
- **πp → ηN, KΛ, KΣ (W < 2.1 GeV)**
- **γp → πN, ηN, KΛ, KΣ (W < 2.1 GeV)**

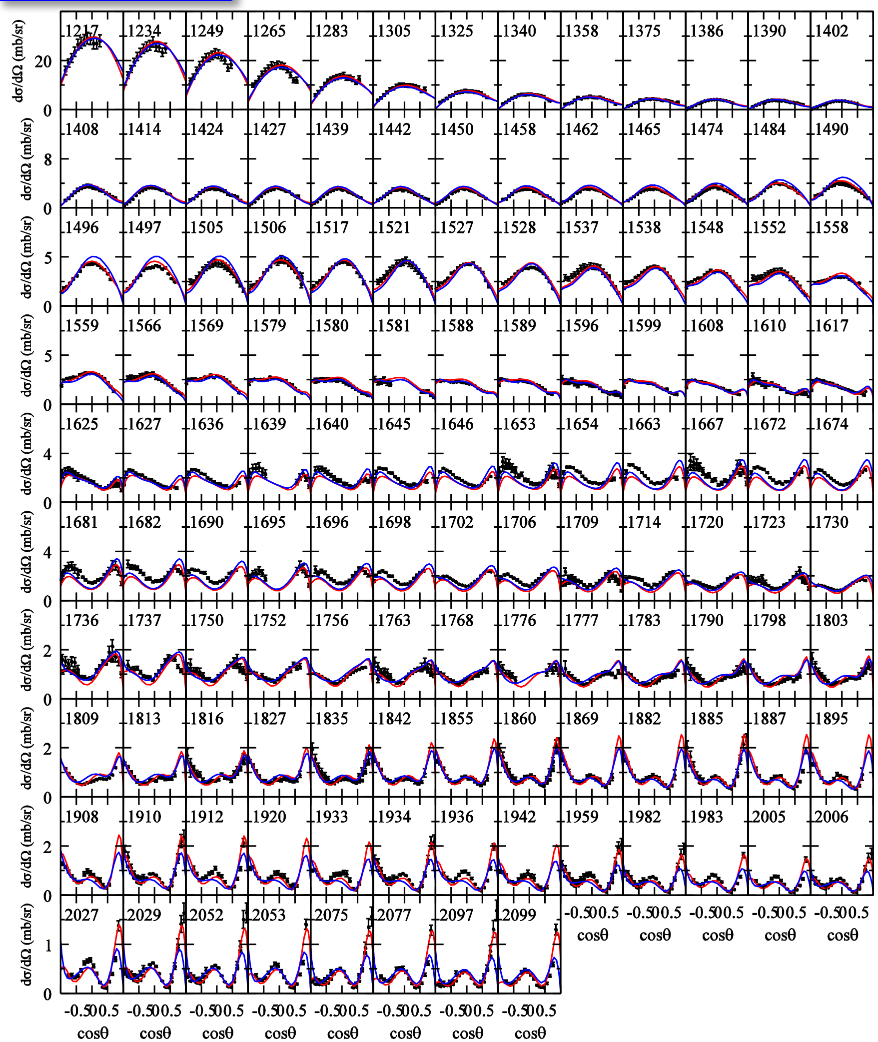
Region our model can cover



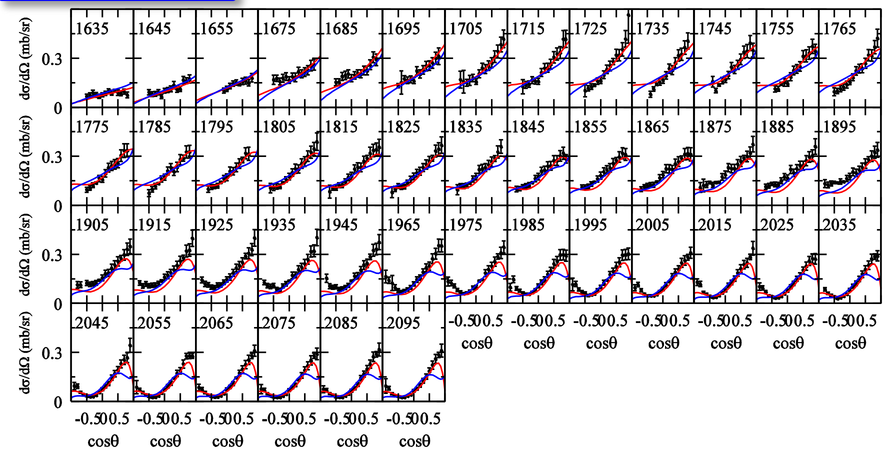
ANL-Osaka DCC approach to N* and Δ*

HK, Nakamura, Lee, Sato, PRC88(2013)035209 (with update)

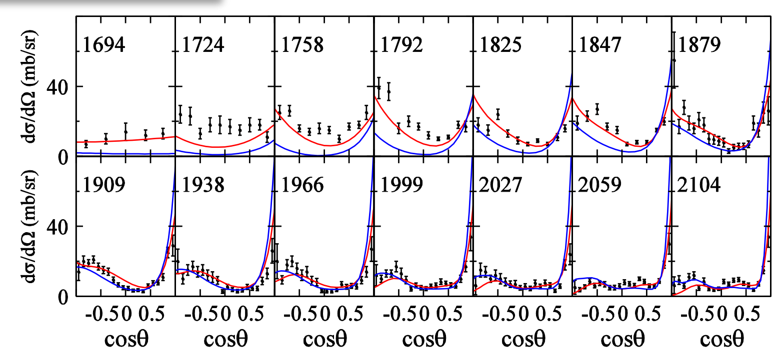
γp → π^0p   dσ/dΩ for W < 2.1 GeV



γp → $K^+\Lambda$ dσ/dΩ for W < 2.1 GeV



π^-p → $K^0\Sigma^0$ dσ/dΩ for W < 2.1 GeV



Red: minor updated ver.
Blue: PRC88(2013)035209

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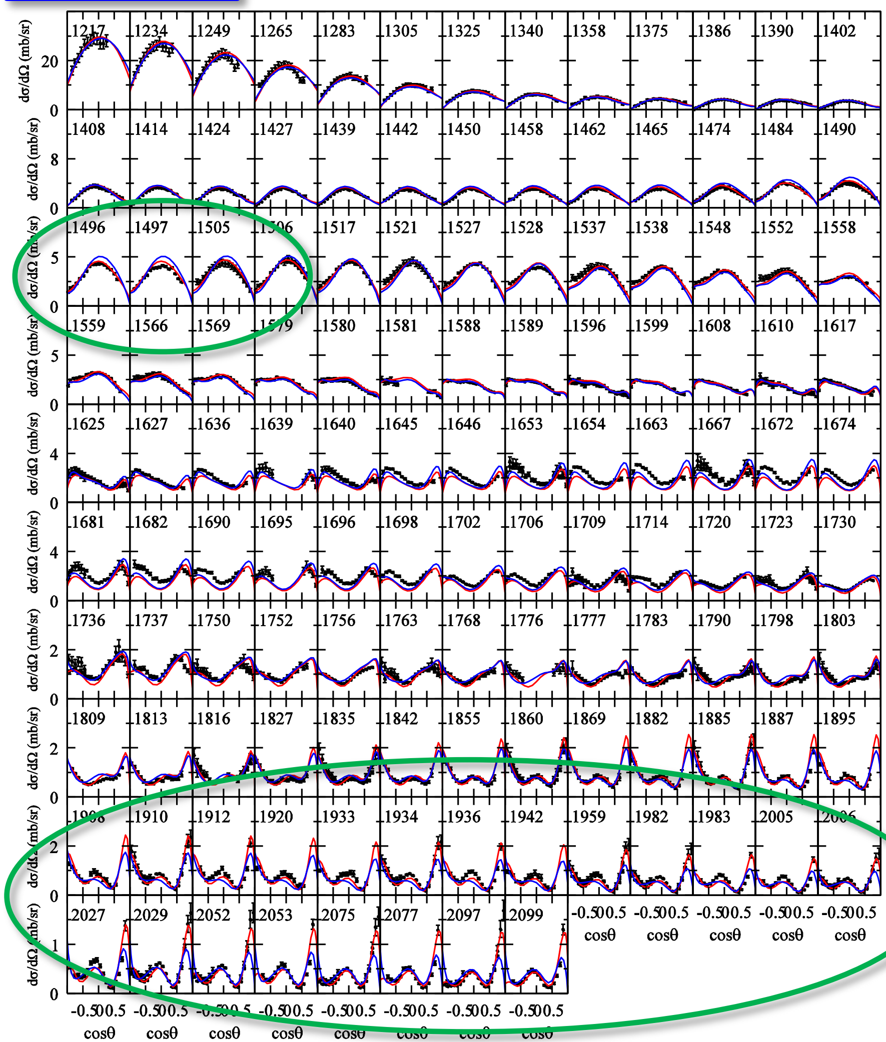

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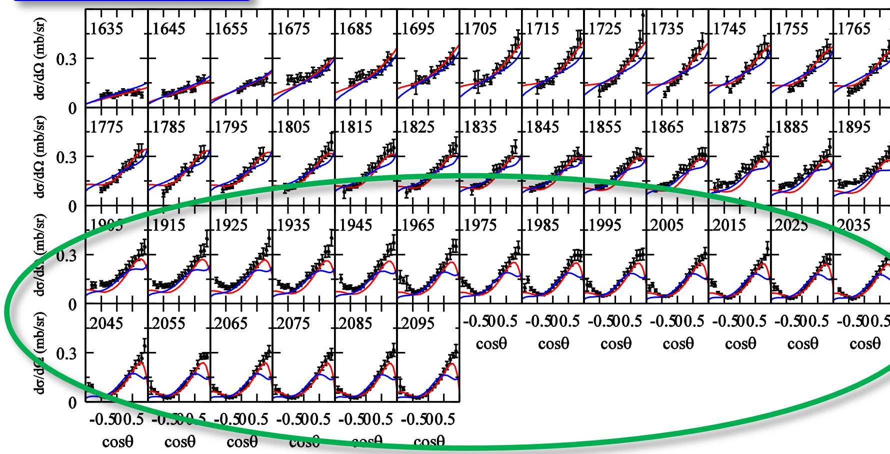

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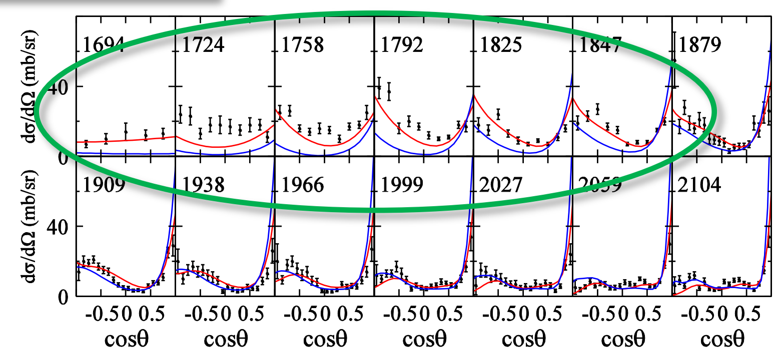

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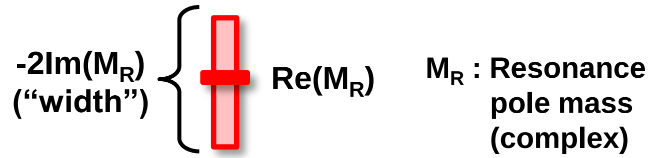
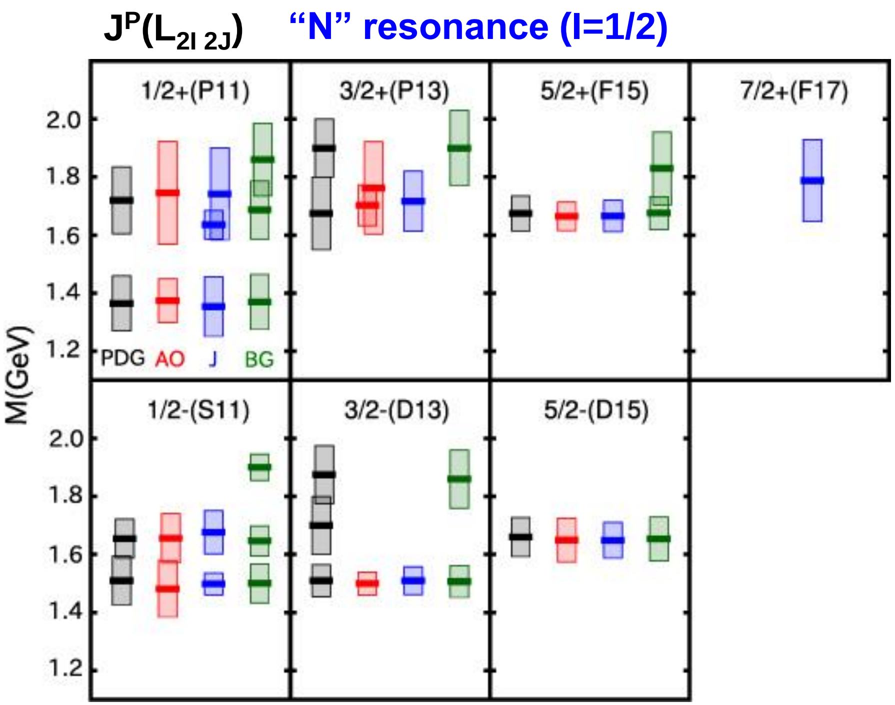
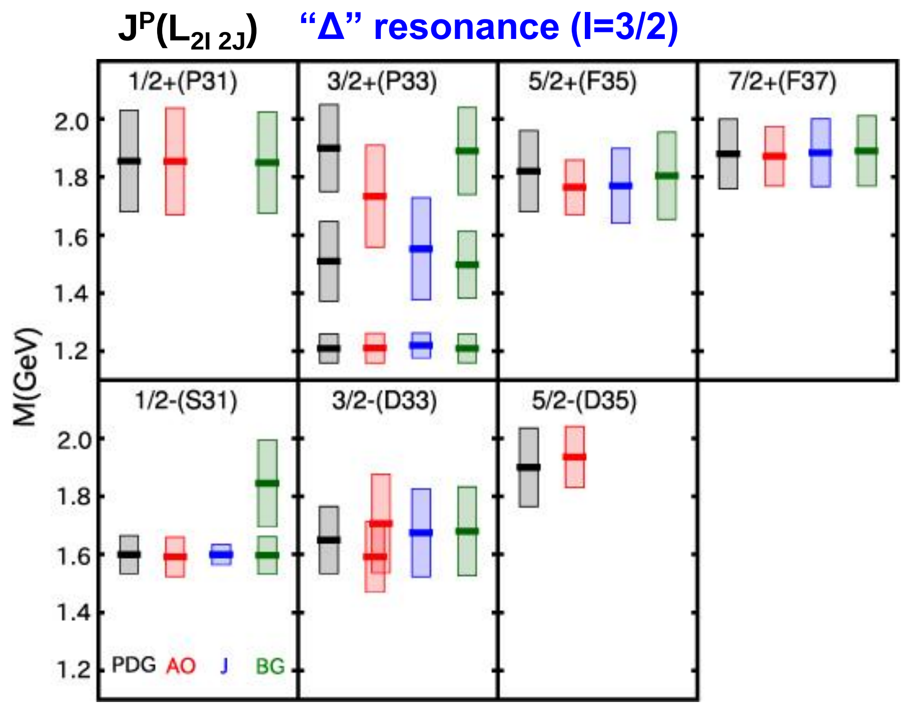
Comparison of N* & Δ* spectrum between multichannel analyses

HK, Nakamura, Lee, Sato, PRC88 (2013) 035209







PDG: 4* & 3* states assigned by PDG2012

AO : ANL-Osaka

J : Juelich [EPJA49(2013)44]

BG : Bonn-Gatchina [EPJA48(2012)5]

Comparison of N* & Δ* spectrum between multichannel analyses

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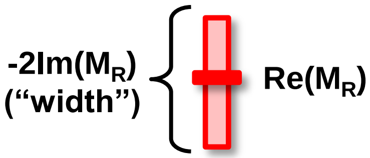
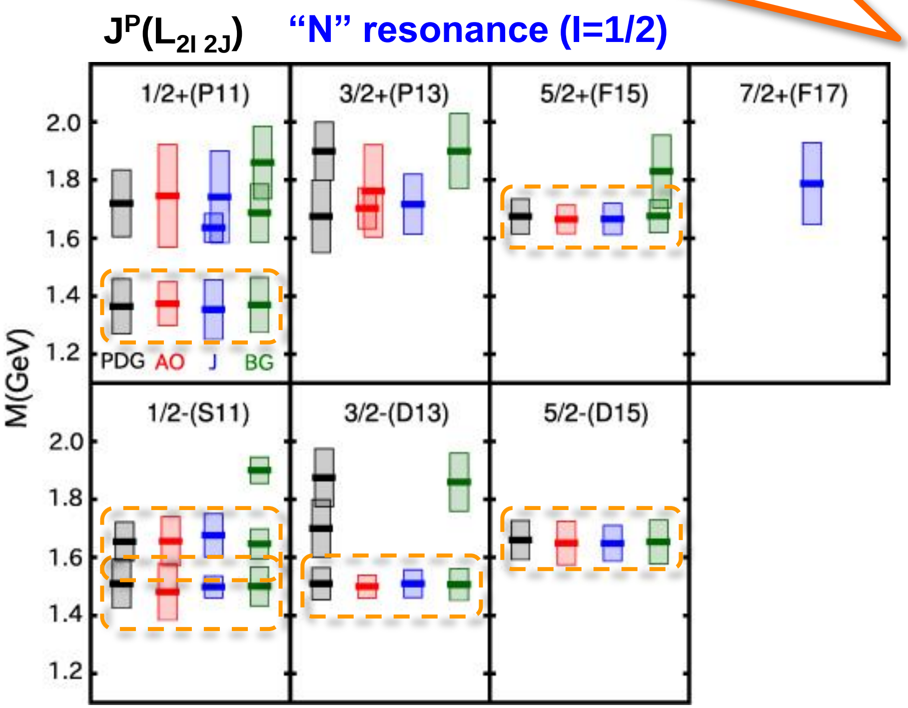
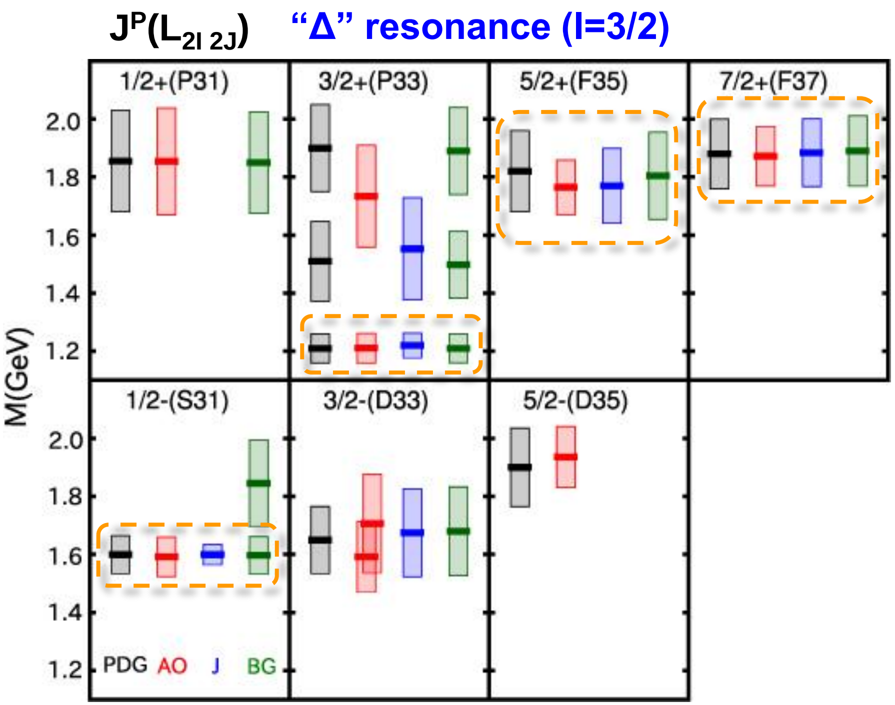
Existence and mass spectrum are now well established for most low-lying resonances !!
(➔ Next task: establish high-mass resonances)



M_R : Resonance pole mass (complex)





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Necessity of inelastic reaction data for establishing high-mass N* and Δ* spectrum

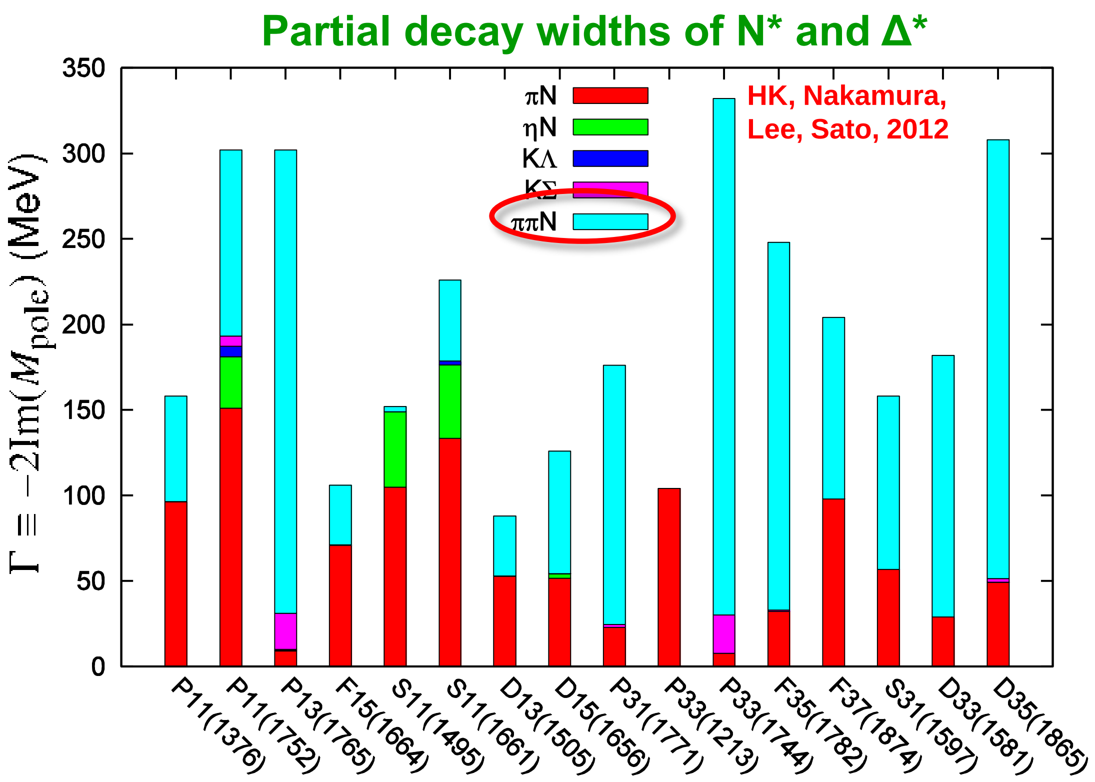
To establish the spectrum of high-mass resonances, inelastic reaction (particularly double pion production) data are highly desirable:

πN, γN → ππN, KΛ, KΣ, ηN, η'N, ωN, ΦN,…

Measurements of
πN → ππN, … :

HADES
[➔ Talk by W. Przygoda 27th(Wed.) Plenary 27-2]

J-PARC E45
[➔ Talk by K. Hosomi 27th(Wed.) ParallelA 27-2]



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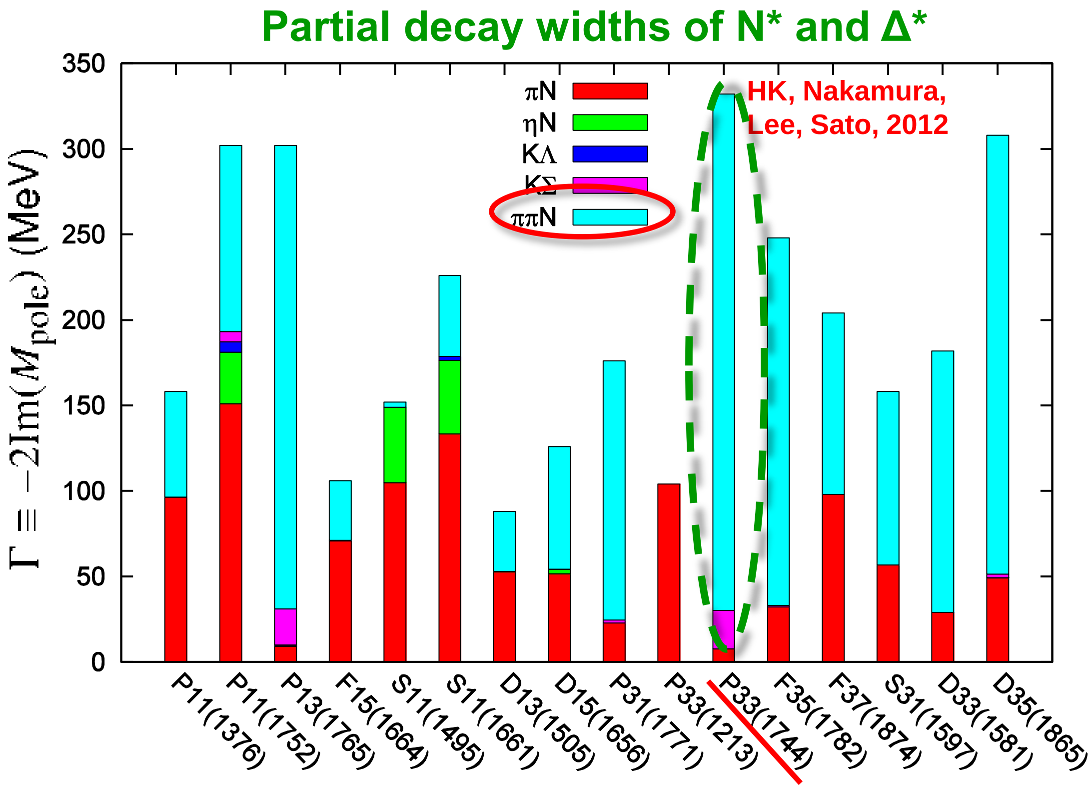
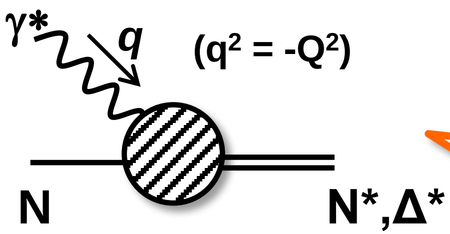
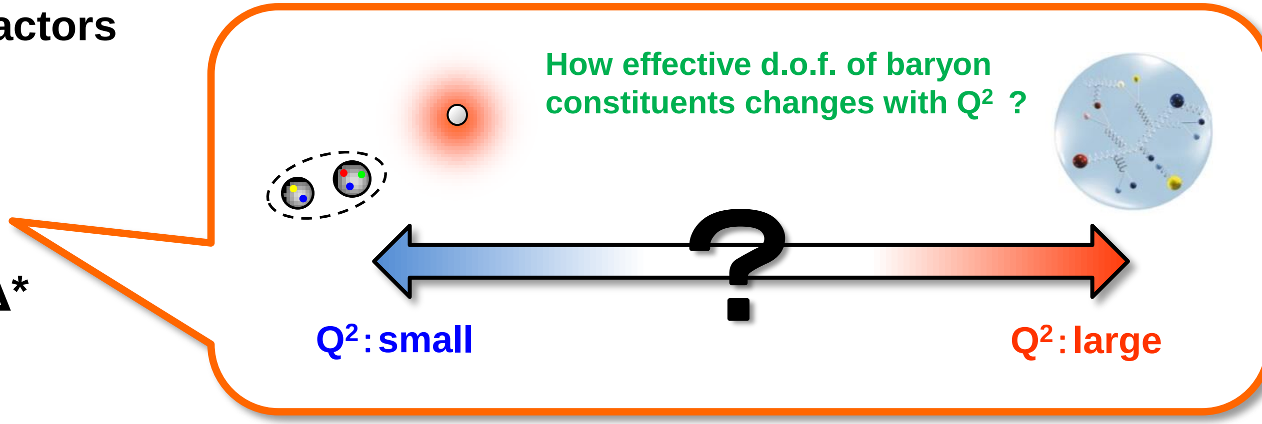


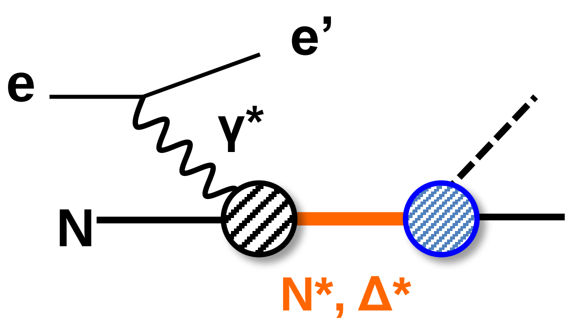
Analysis of electroproduction reactions: Determining N-N* e.m. transition form factors

N-N* e.m. transition form factors

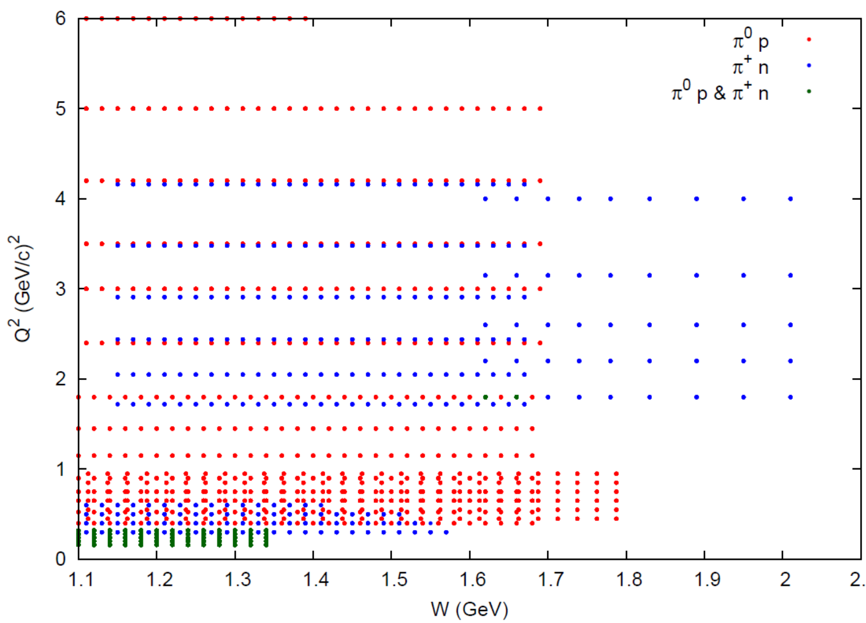




Meson electro-productions:



CLAS database for 1π electroproductions ($Q^2 < 6$ GeV²)



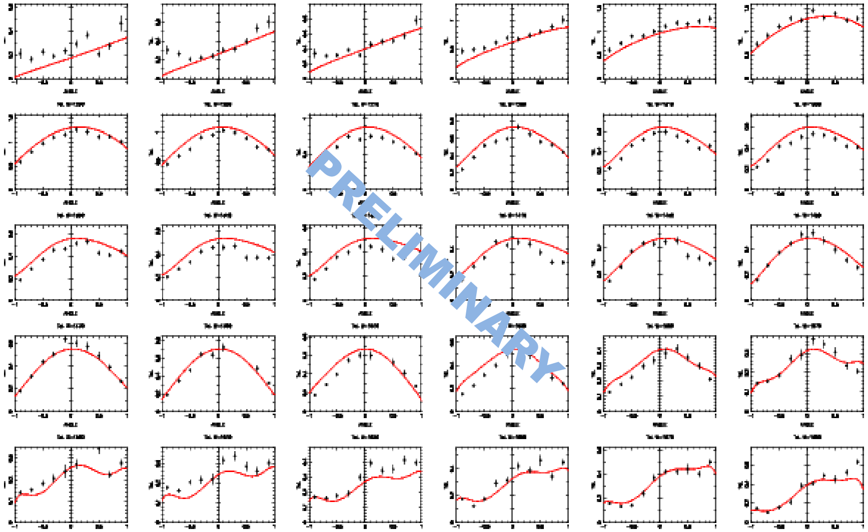
+ $K^+\Lambda$, $K^+ \Sigma^0$ electro-production data

Analysis of electroproduction reactions: Determining N-N* e.m. transition form factors

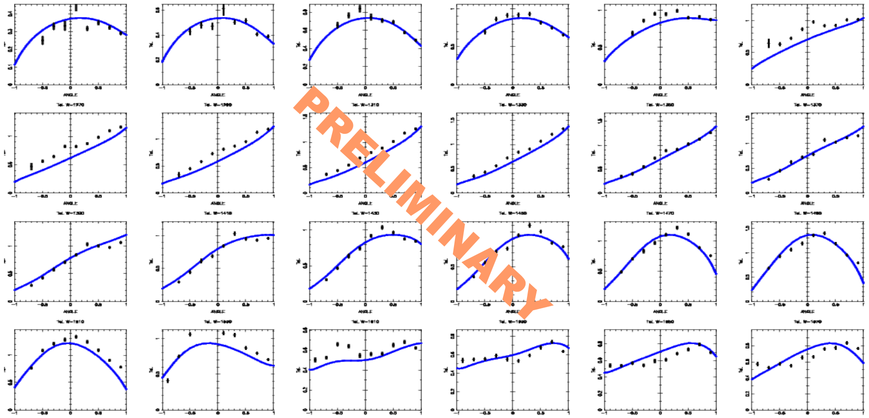
$\sigma_T+\varepsilon\sigma_L$ @ Q^2 = 2.42 $(GeV/c)^2$

Structure functions are provided by K. Joo and C. Smith.

ep → $e\pi^0 p$ (1.11 < W < 1.69 GeV)



ep → $e\pi^+ n$ (1.15 < W < 1.67 GeV)



cosθ

Analysis of electroproduction reactions: Determining N-N* e.m. transition form factors

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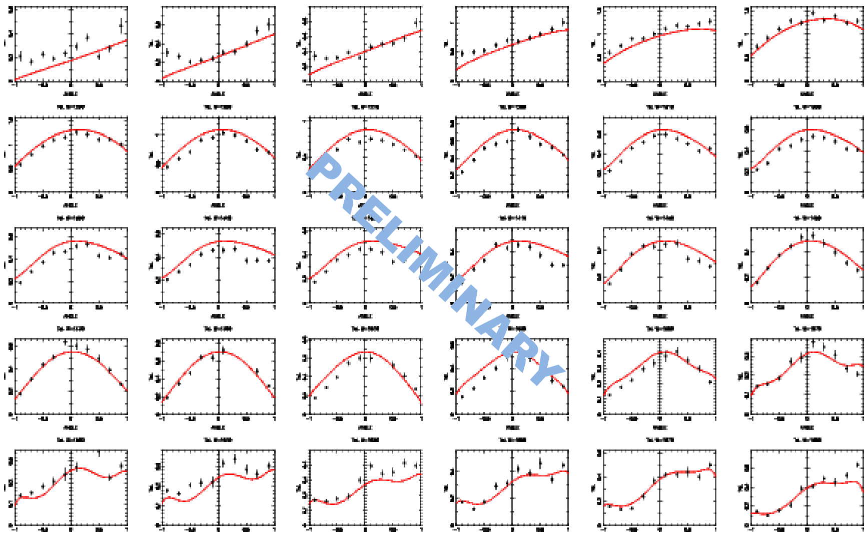

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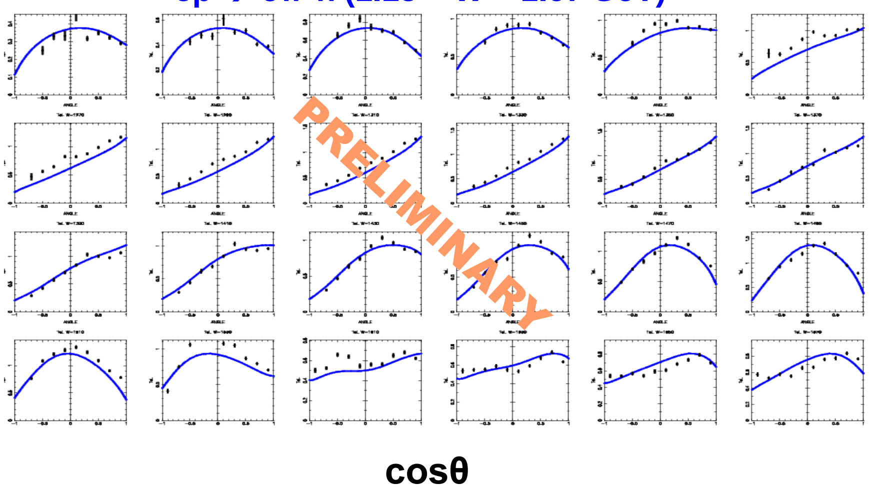
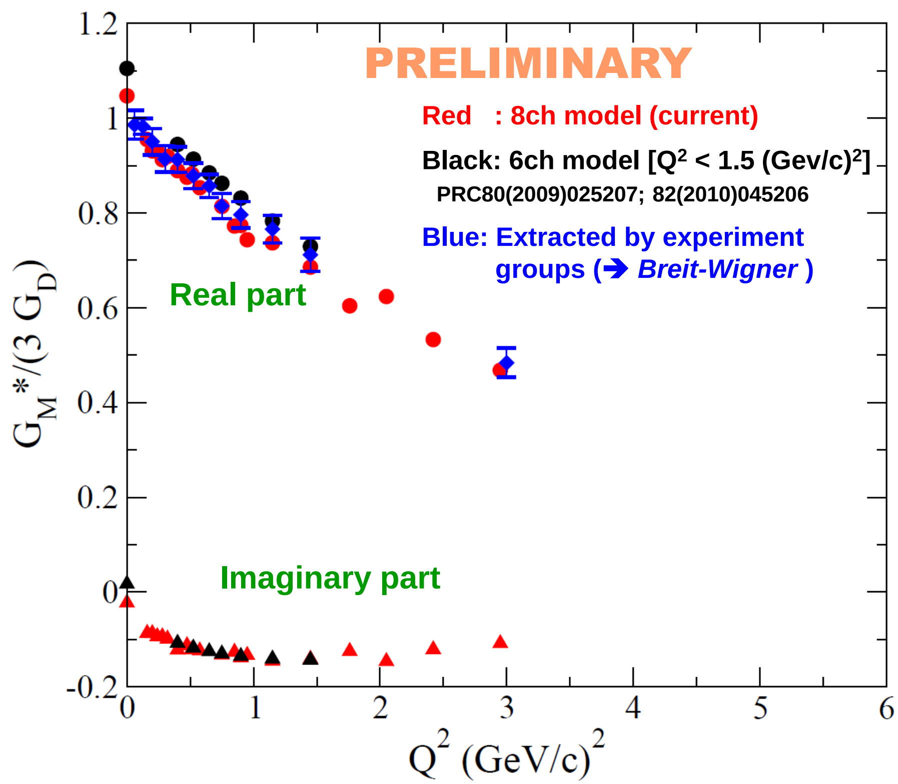


$G_M(Q^2)$ for γ*N → Δ(1st P33) evaluated *at pole*



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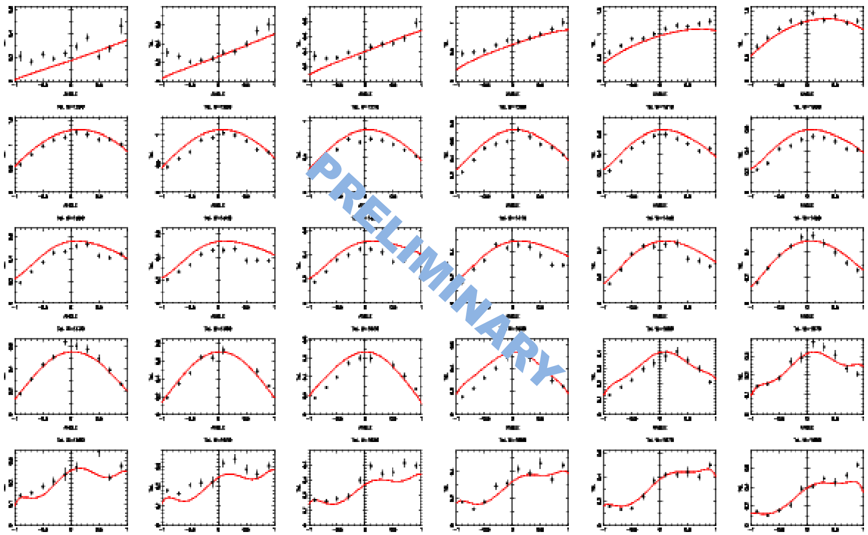

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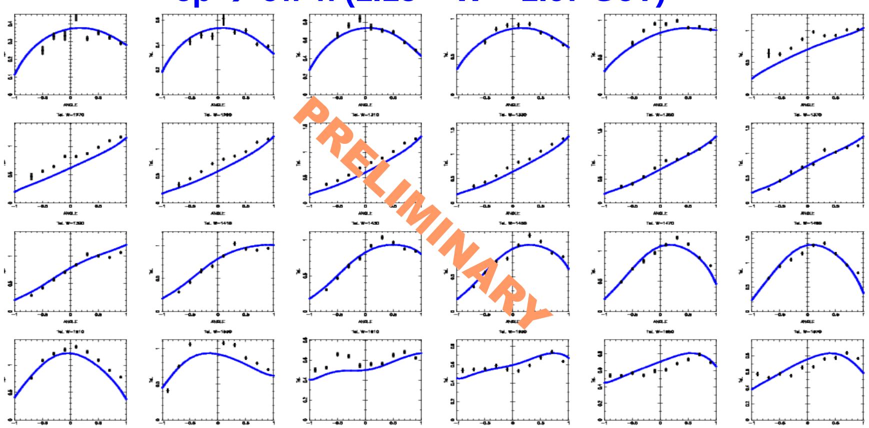

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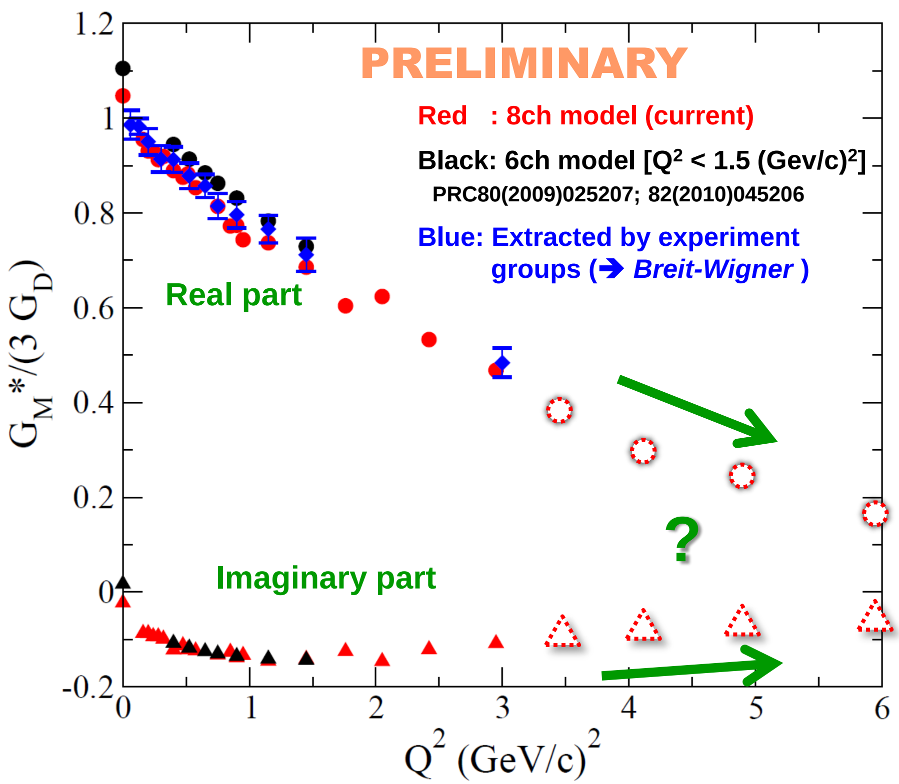


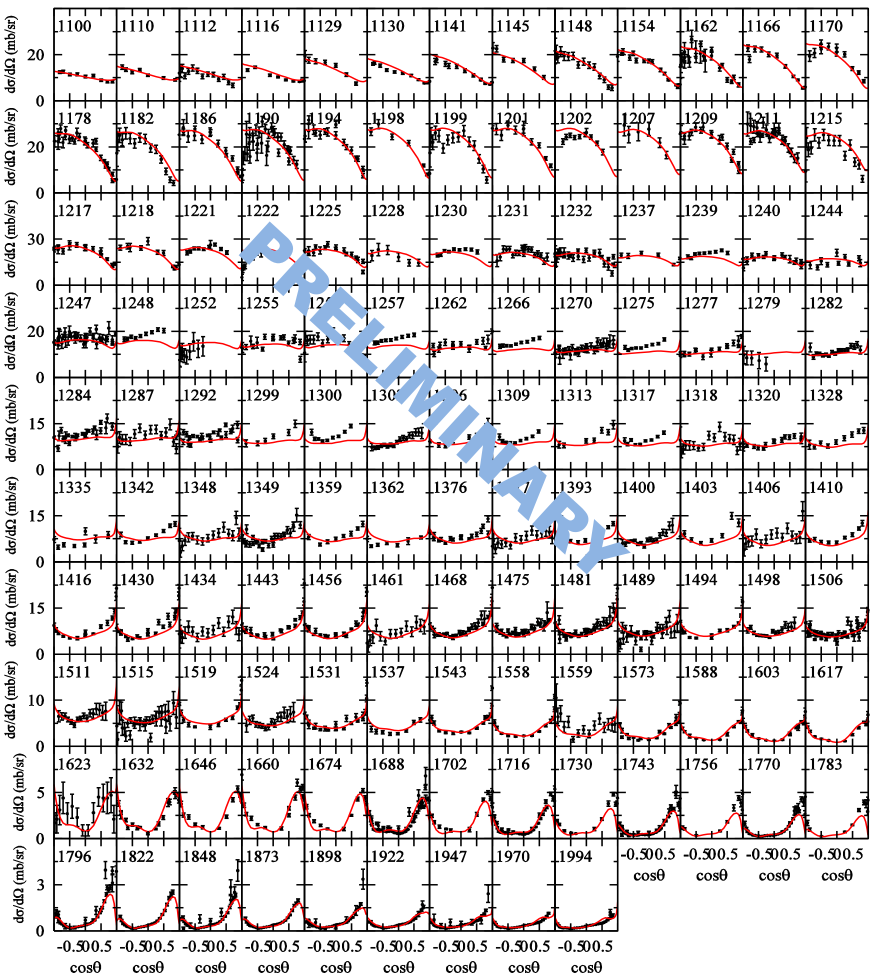
Meson photoproductions off “neutron”

✓ Need for **isospin decomposition** of electromagnetic currents.

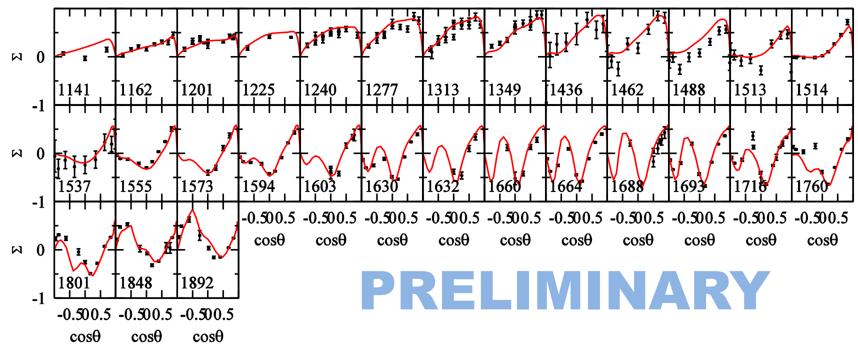
➔ Necessary for applications to ***NEUTRINO*** reactions: S. Nakamura, 27th (Wed) ParallelA 27-1

γ ‘n’ ➔ π^- p

dσ/dΩ for W < 2 GeV



Σ for 1.14 < W < 1.9 GeV



PRELIMINARY

Meson photoproductions off “neutron”

- ✓ **Need for isospin decomposition of electromagnetic currents.**
  - ➔ **Necessary for applications to *NEUTRINO* reactions: S. Nakamura, 27th (Wed) ParallelA 27-1**

γ ‘n’ → π⁻ p

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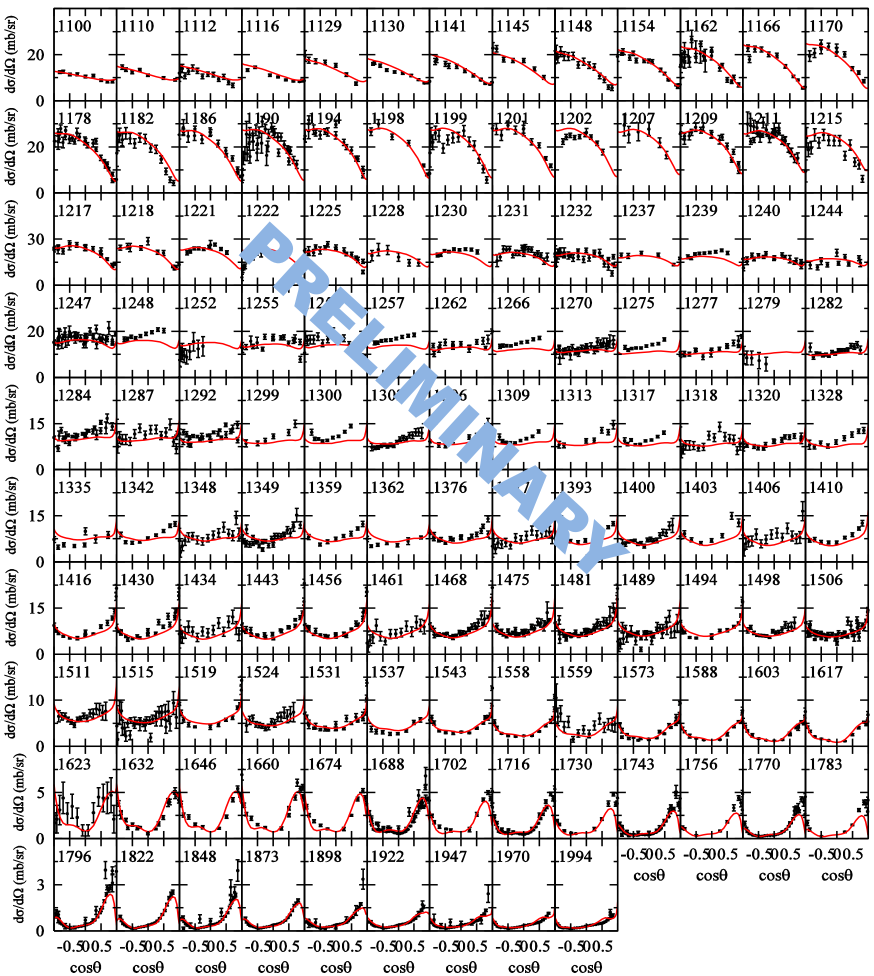

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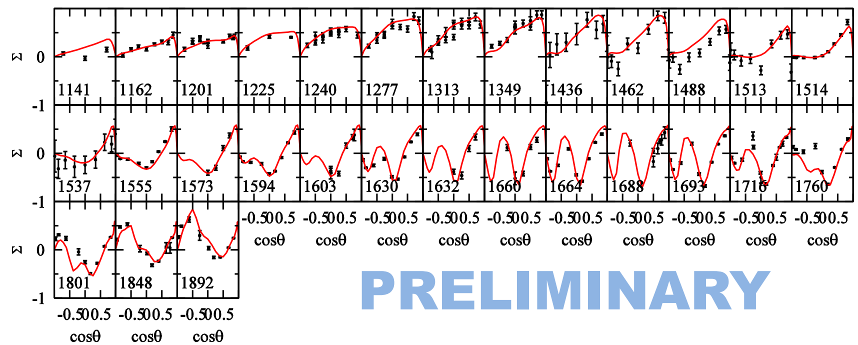
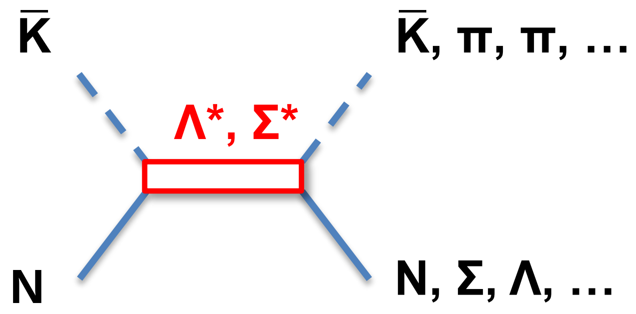


Future work:
Analyze deuteron reaction data directly to extract single- & double-polarization observables for “neutron-target” reactions in a fully consistent way in our approach.

Current situation for Y* spectroscopy

- ✓ Y* (= Λ*, Σ*) resonances are much less understood than N* and Δ*.
- ✓ Comprehensive & systematic PWA to extract Y* *defined by poles of scattering amplitudes* has ***only recently*** been made:
  - ➢ Kent State University (KSU) group (2013, "KSU parametrization" of S-matrix)
  - ➢ Our group (2014- , dynamical approach)



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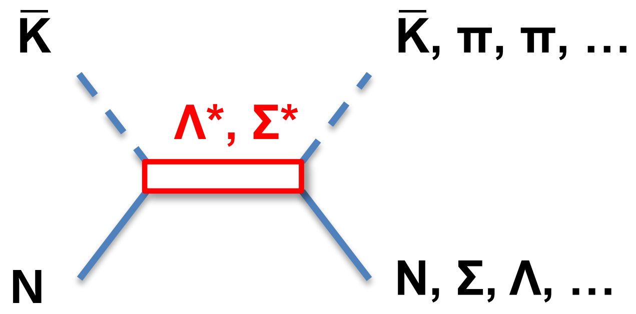


What we have done so far

- ✓ Formulation of DCC approach for S = -1 sector
  ➔ contains $\bar{K}N$, πΣ, πΛ, ηΛ, KΞ, ππΛ(πΣ*), π$\bar{K}$N($\bar{K}$*N) channels

- ✓ Comprehensive analysis of *all* available data of $K^- p$ → $\bar{K}N$, πΣ, πΛ, ηΛ, KΞ up to W = 2.1 GeV.
  [HK, Nakamura, Lee, Sato, PRC90(2014)065204]
  - ➢ Successfully determined the partial-wave amplitudes for S, P, D, and F waves !!

- ✓ Extraction of Λ* and Σ* resonance parameters defined by poles of scattering amplitudes.
  [HK, Nakamura, Lee, Sato, in preparation]

Database of our analysis (W < 2.1GeV)

HK, Nakamura, Lee, Sato, PRC90(2014)065204

Issues in the availability of data:

- ✓ Most data are from 60-70's.
- ✓ Kinematical coverage is rather scarce for most reactions.
- ✓ No data for spin rotations (β, R, A).
- ✓ No data near the threshold for K- p → $\bar{K}$N, πΣ, πΛ.

The K^- p reaction data are far from "complete"!!

➔ Need help of hadron beam facilities !!

Reactions	Observables	Number of data
$K^-p \to K^-p$	$d\sigma/d\Omega$	3962
	P	510
	σ	253
$K^-p \to \bar{K}^0 n$	$d\sigma/d\Omega$	2950
	σ	260
$K^-p \to \pi^-\Sigma^+$	$d\sigma/d\Omega$	1792
	P	418
	$P \times d\sigma/d\Omega$	177
	σ	173
$K^-p \to \pi^0\Sigma^0$	$d\sigma/d\Omega$	580
	P	196
	$P \times d\sigma/d\Omega$	189
	σ	125
$K^-p \to \pi^+\Sigma^-$	$d\sigma/d\Omega$	1786
	σ	181
$K^-p \to \pi^0\Lambda$	$d\sigma/d\Omega$	2178
	P	693
	$P \times d\sigma/d\Omega$	176
	σ	207
$K^-p \to \eta\Lambda$	$d\sigma/d\Omega$	160
	P	18
	σ	78
$K^-p \to K^0\Xi^0$	$d\sigma/d\Omega$	33
	σ	15
$K^-p \to K^+\Xi^-$	$d\sigma/d\Omega$	92
	σ	27
Total		17229

$K^-p \to K^-p$:
- $d\sigma/d\Omega$: 1465 MeV < W
- P : 1730 MeV < W
- β, R, A: No data

$K^-p \to \bar{K}^0 n$:
- $d\sigma/d\Omega$: 1465 MeV < W
- P : No data
- β, R, A: No data

$K^-p \to \pi^-\Sigma^+$:
- $d\sigma/d\Omega$: 1535 MeV < W
- P : 1535 MeV < W < 1967 MeV
- β, R, A: No data

$K^-p \to \pi^0\Sigma^0$:
- $d\sigma/d\Omega$: 1535 MeV < W < 1763 MeV
- P : 1535 MeV < W < 1696 MeV
- β, R, A: No data

$K^-p \to \pi^+\Sigma^-$:
- $d\sigma/d\Omega$: 1536 MeV < W
- P : No data
- β, R, A: No data

$K^-p \to \pi^0\Lambda$:
- $d\sigma/d\Omega$: 1535 MeV < W
- P : 1535 MeV < W
- β, R, A: No data

$K^-p \to \eta\Lambda$:
- $d\sigma/d\Omega$: 1664 MeV < W < 1696 MeV
- P : 1669 MeV < W < 1681 MeV
- β, R, A: No data

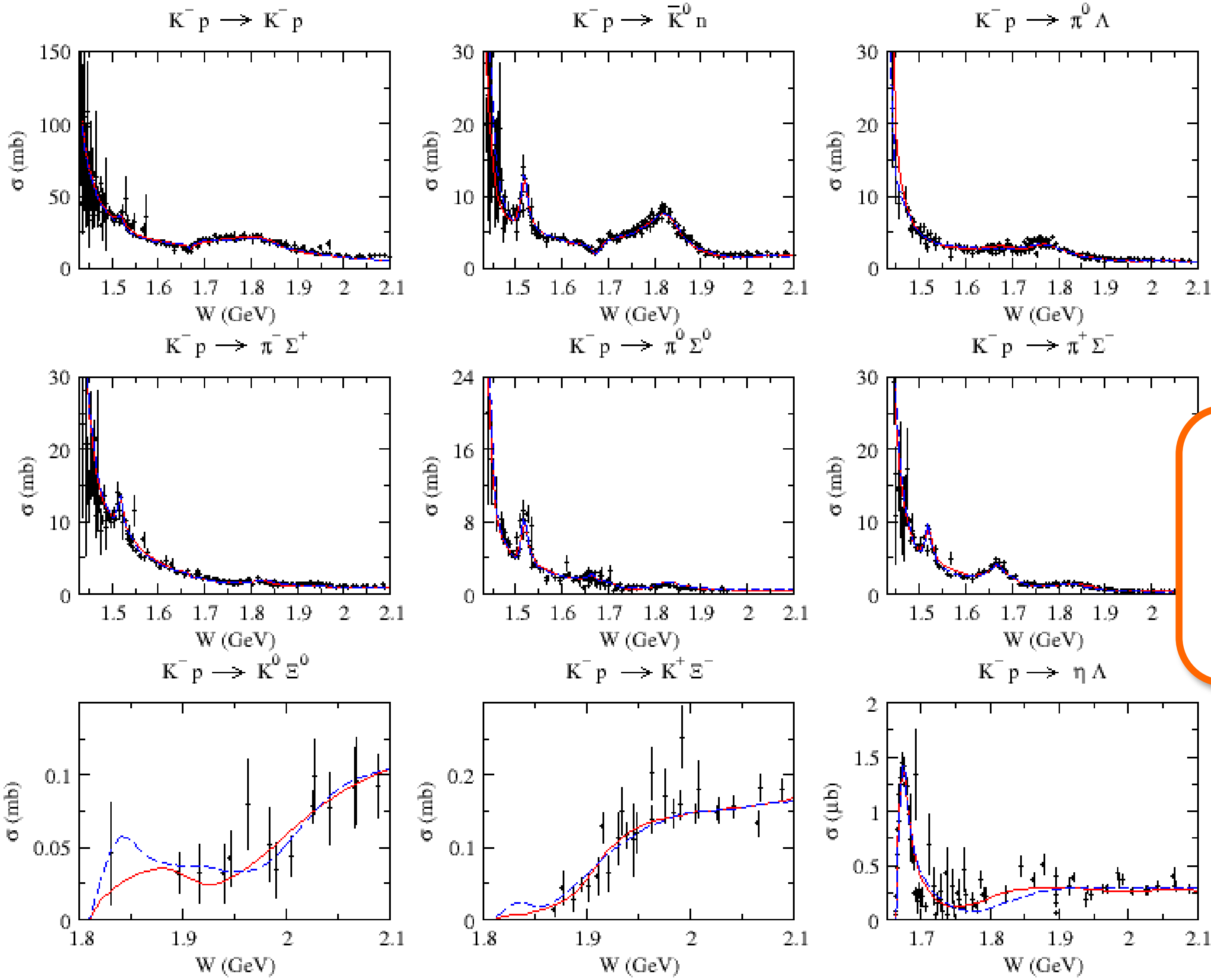
$K^-p \to K^0\Xi^0$:
- $d\sigma/d\Omega$: 1970 MeV < W < 2070 MeV
- P : No data
- β, R, A: No data

$K^-p \to K^+\Xi^-$:
- $d\sigma/d\Omega$: 1950 MeV < W < 2070 MeV
- P : No data
- β, R, A: No data

Results of the fits

K⁻ p → MB total cross sections

HK, Nakamura, Lee, Sato, PRC90(2014)065204



Red: Model A

Blue: Model B

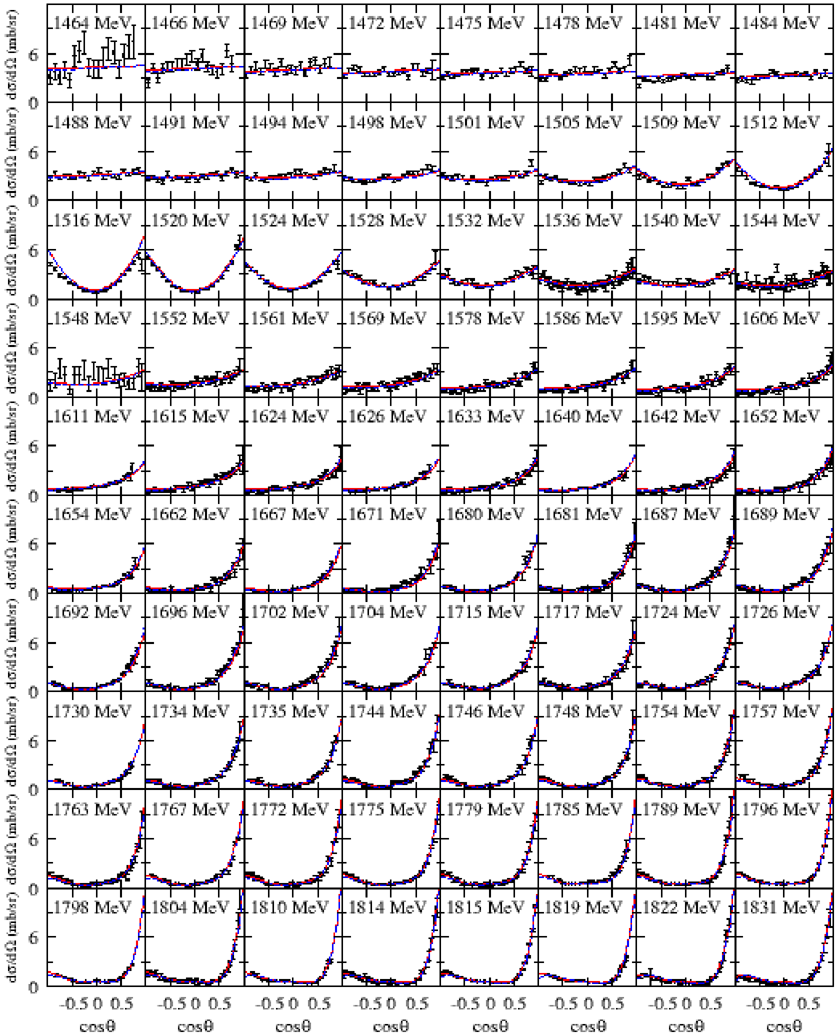
"Incompleteness" of the current database allows us to have two parameter sets that give similar quality of the fit.

Results of the fits

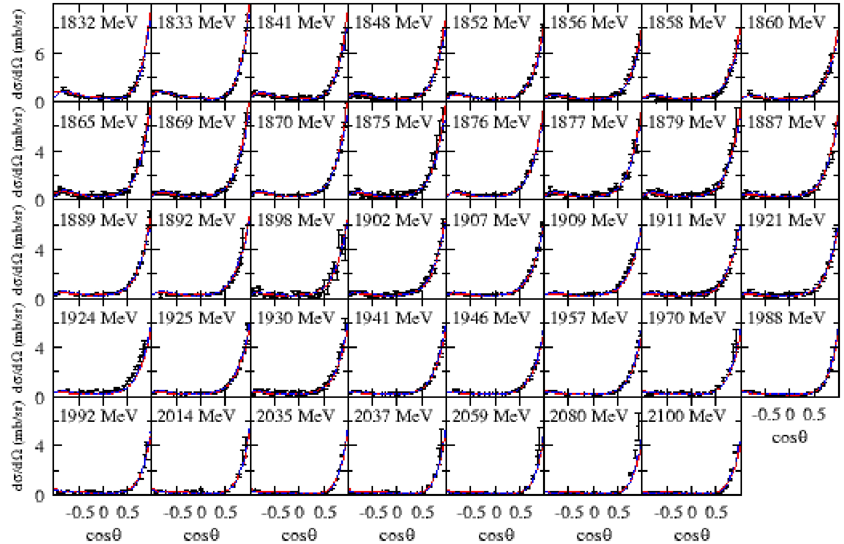
K$^-$ p → K$^-$ p scattering

HK, Nakamura, Lee, Sato, PRC90(2014)065204

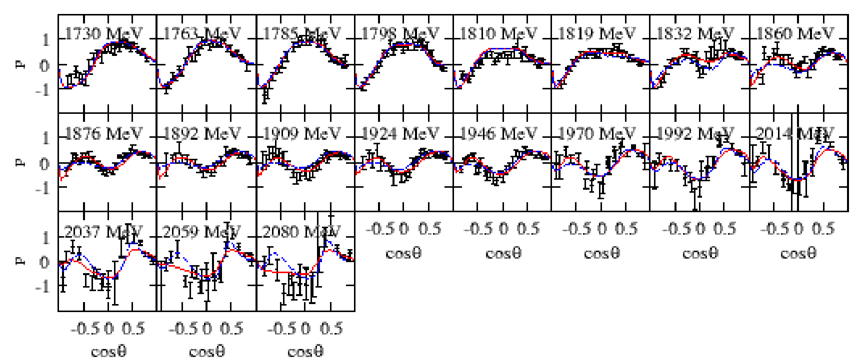
dσ/dΩ (1464 < W < 1831 MeV)



dσ/dΩ (1832 < W < 2100 MeV)



P



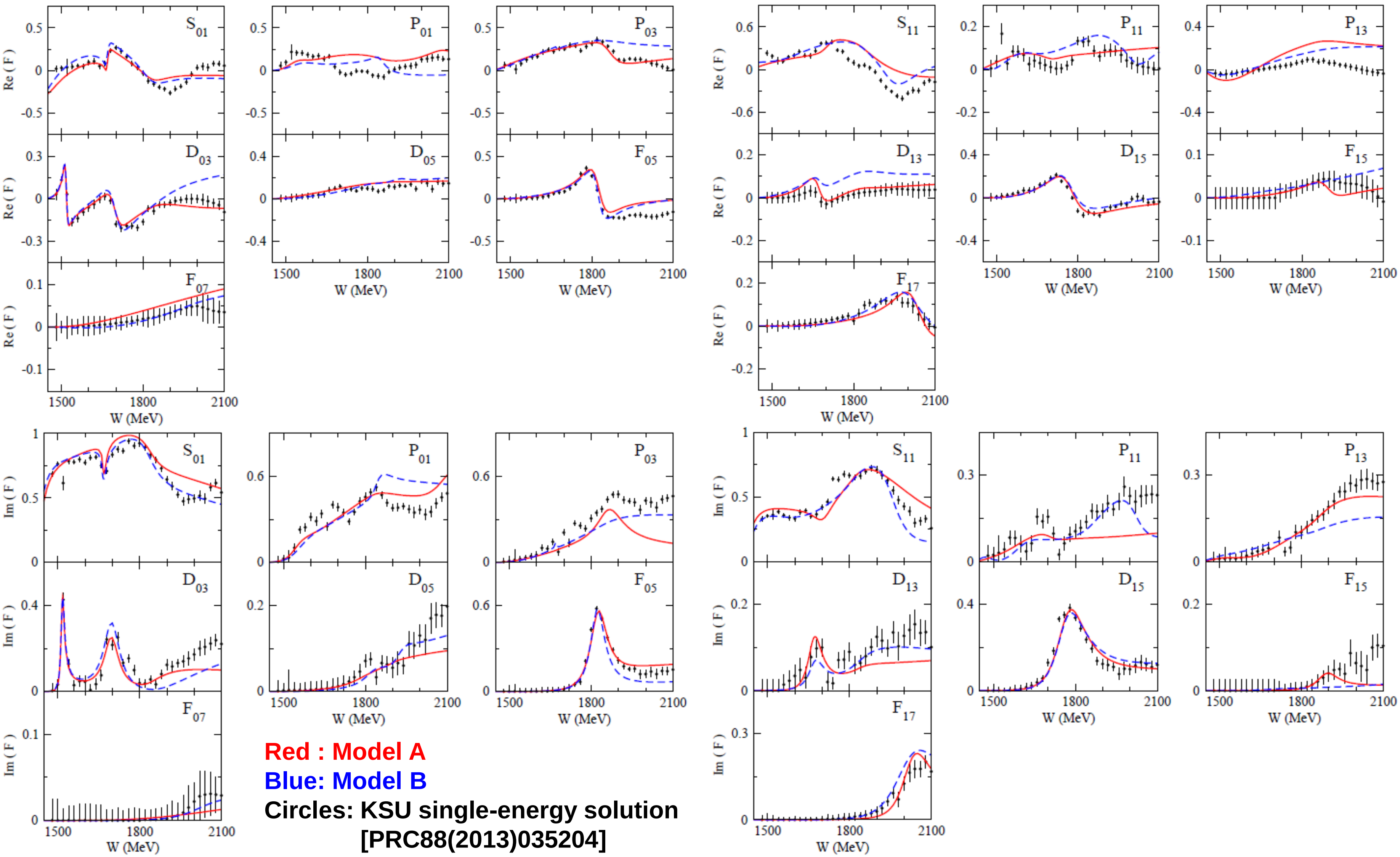
Red: Model A Blue: Model B

Comparison of extracted partial-wave amplitudes

Extracted $\bar{K}N$ scattering amplitudes

HK, Nakamura, Lee, Sato, PRC90(2014)065204

$L_{I\,2J}$: L = S,P,.. ; I = isospin; J = Total angular mom.



Red : Model A

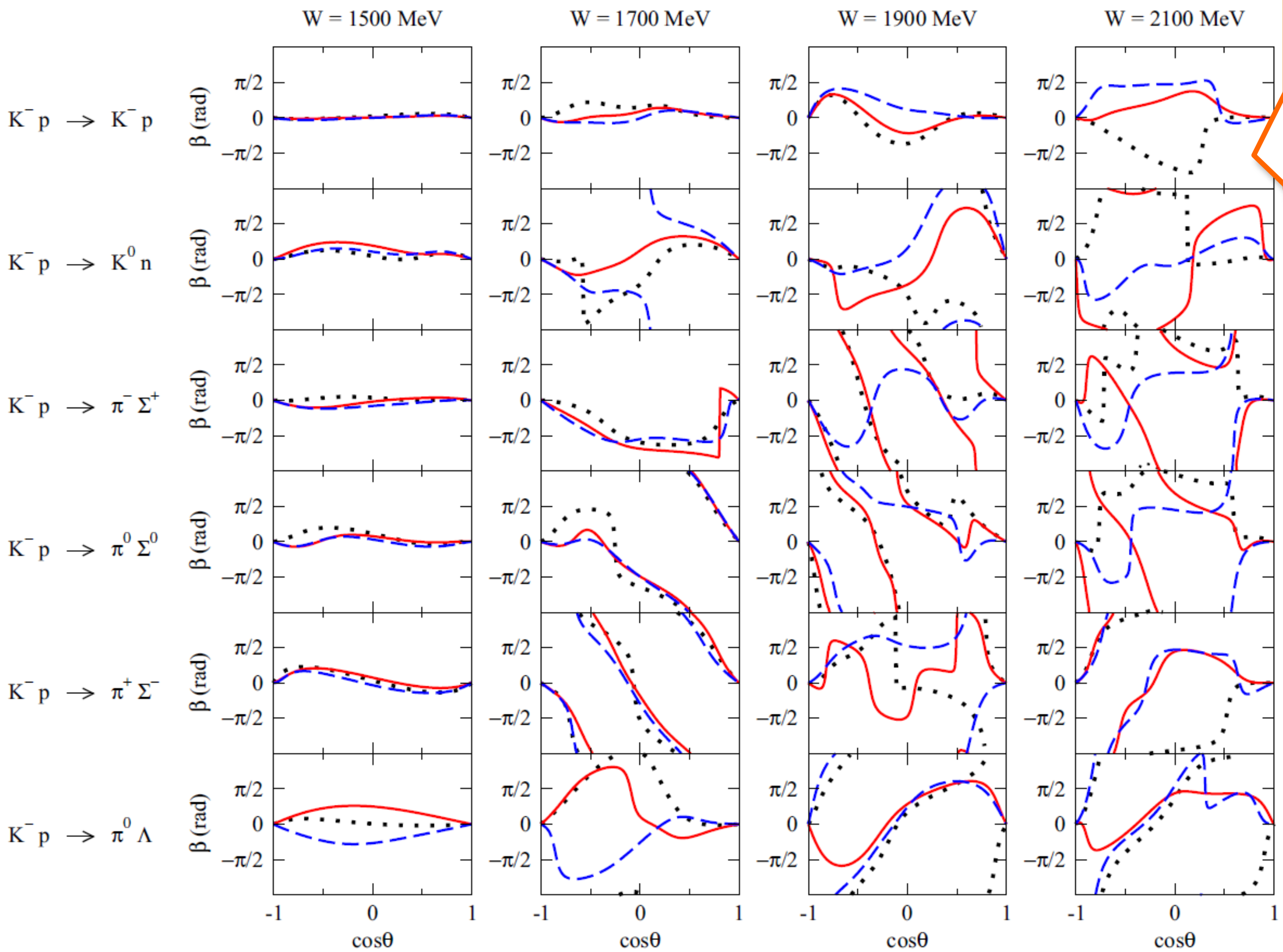
Blue: Model B

Circles: KSU single-energy solution [PRC88(2013)035204]

Predicted spin-rotation angle β

HK, Nakamura, Lee, Sato, PRC90(2014)065204

Currently no data for spin-rotation angle β



Analysis dependence is clearly seen !!

Measurement of β will give strong constraints on Y* spectrum !!

Red: Model A

Blue: Model B

Black: KSU

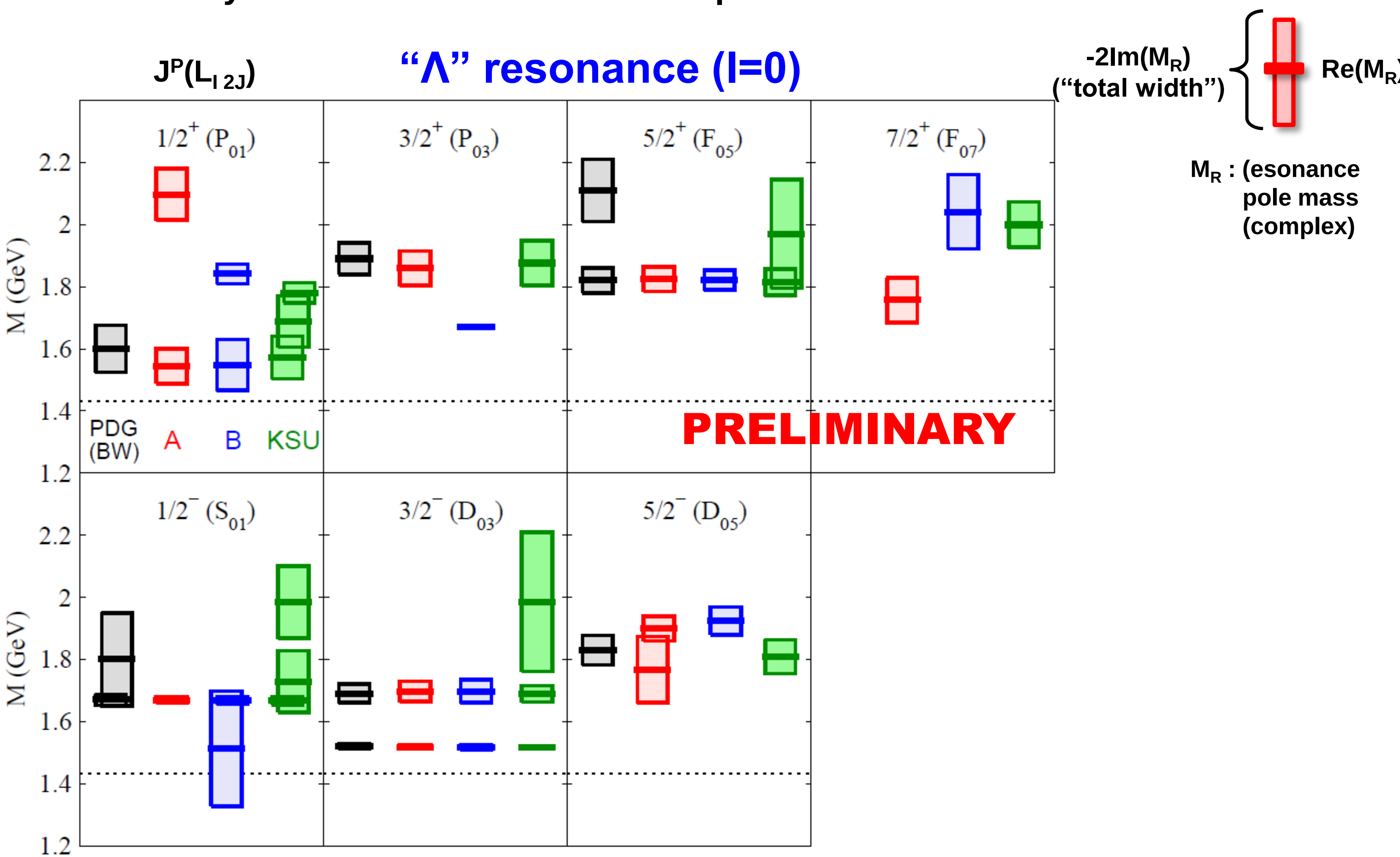
The KSU results are computed by us using their amplitudes in PRC88(2013)035204.

NOTE:
β is modulo 2π

Comparison of Λ* spectrum between multichannel analyses

HK, Nakamura, Lee, Sato, in preparation

Here only Y*s above $\bar{K}N$ threshold are presented.



Red: Model A, Blue: Model B, Green: KSU[on-shell K-matrix,PRC88(2013)035205], Black: PDG(Breit-Wigner)

Comparison of Λ* spectrum between multichannel analyses

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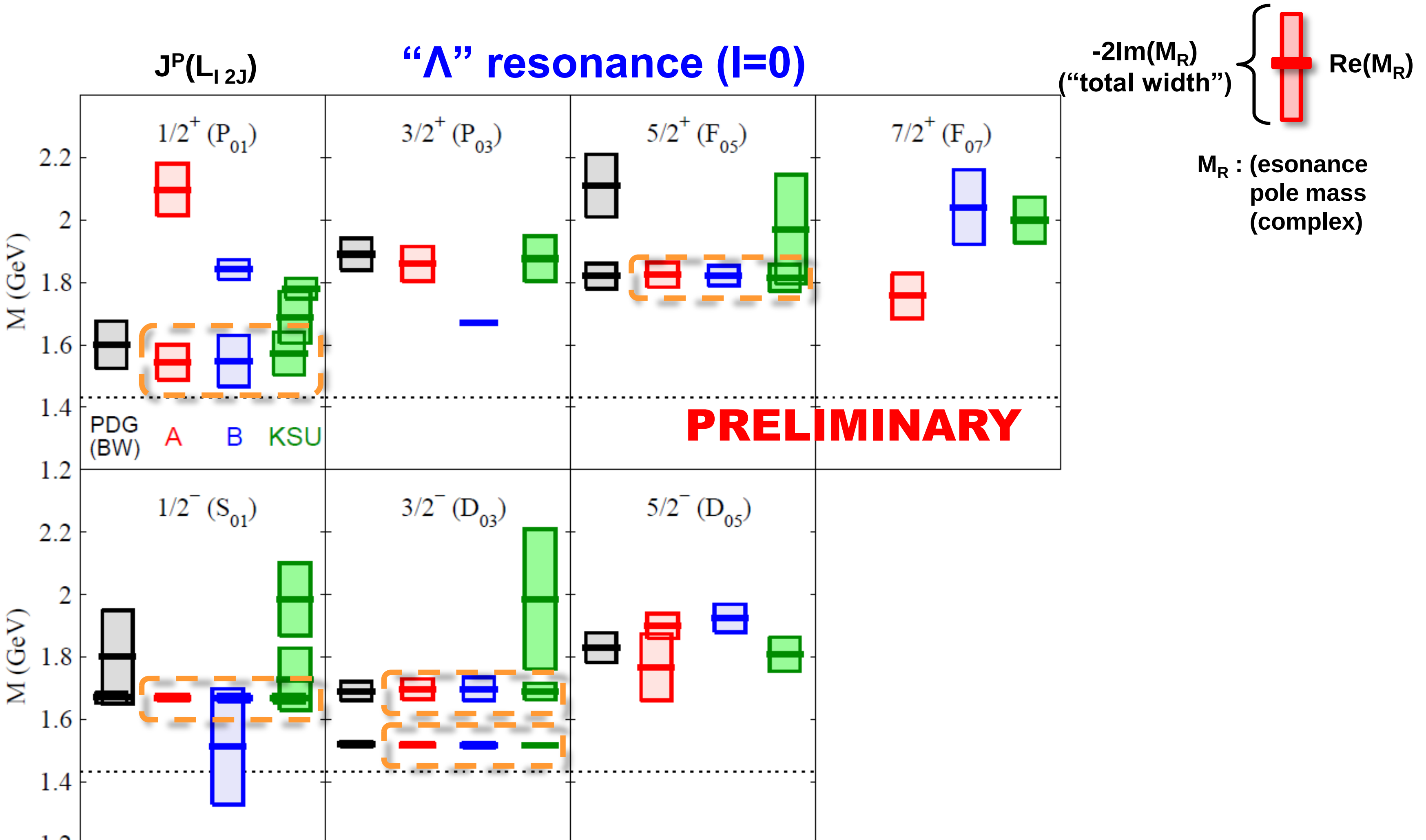

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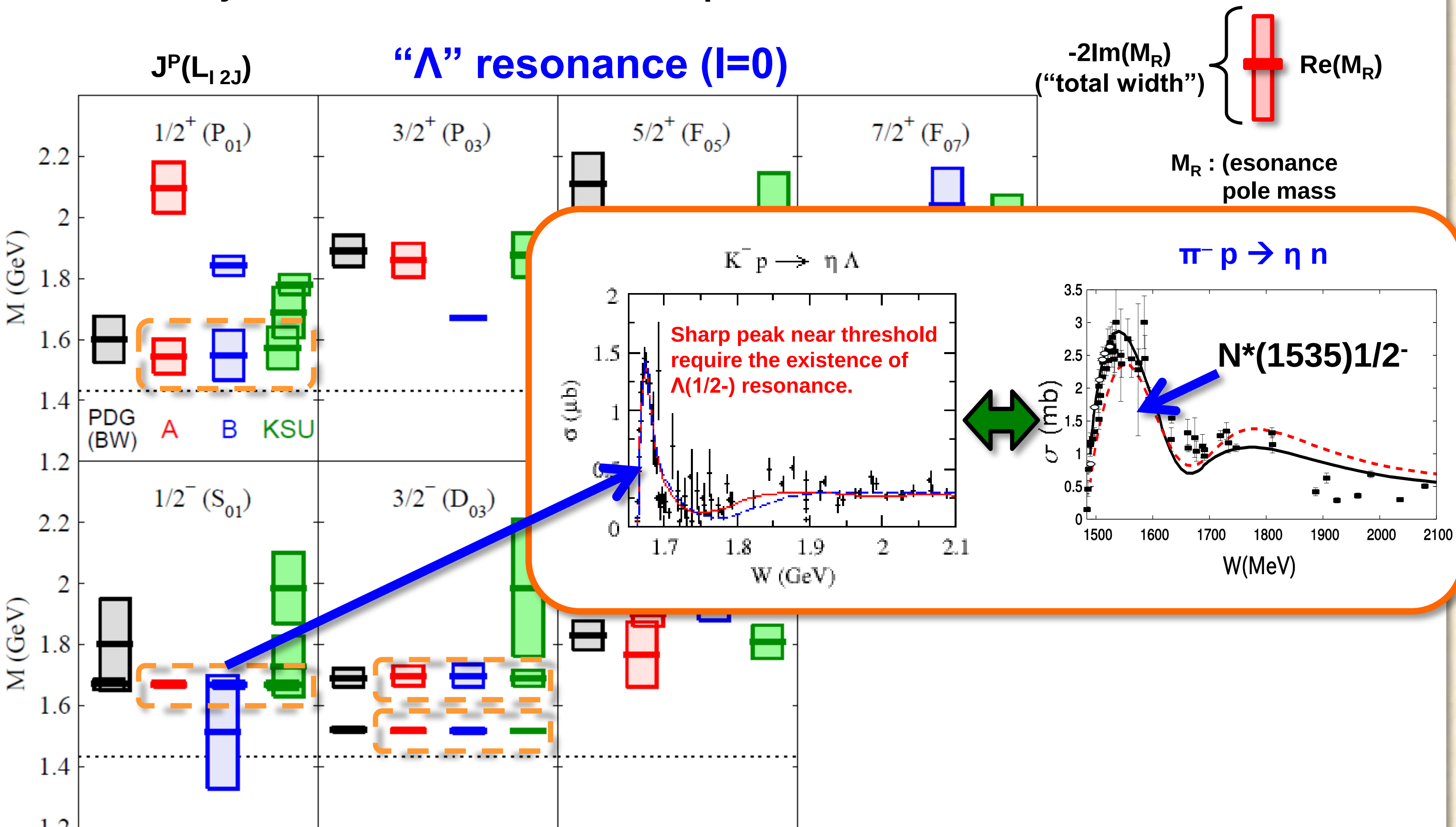

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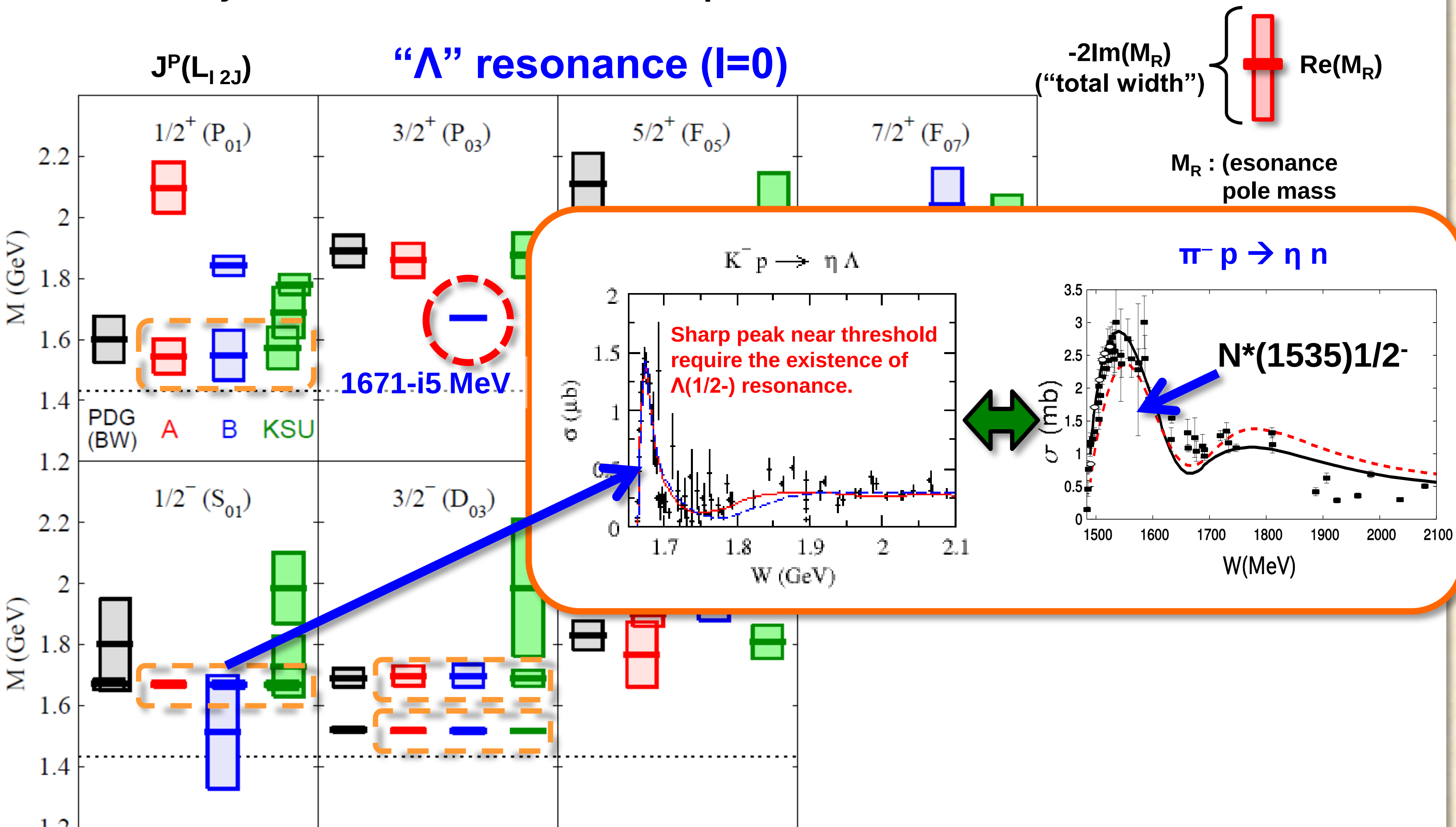

Red: Model A, Blue: Model B, Green: KSU[on-shell K-matrix,PRC88(2013)035205], Black: PDG(Breit-Wigner)

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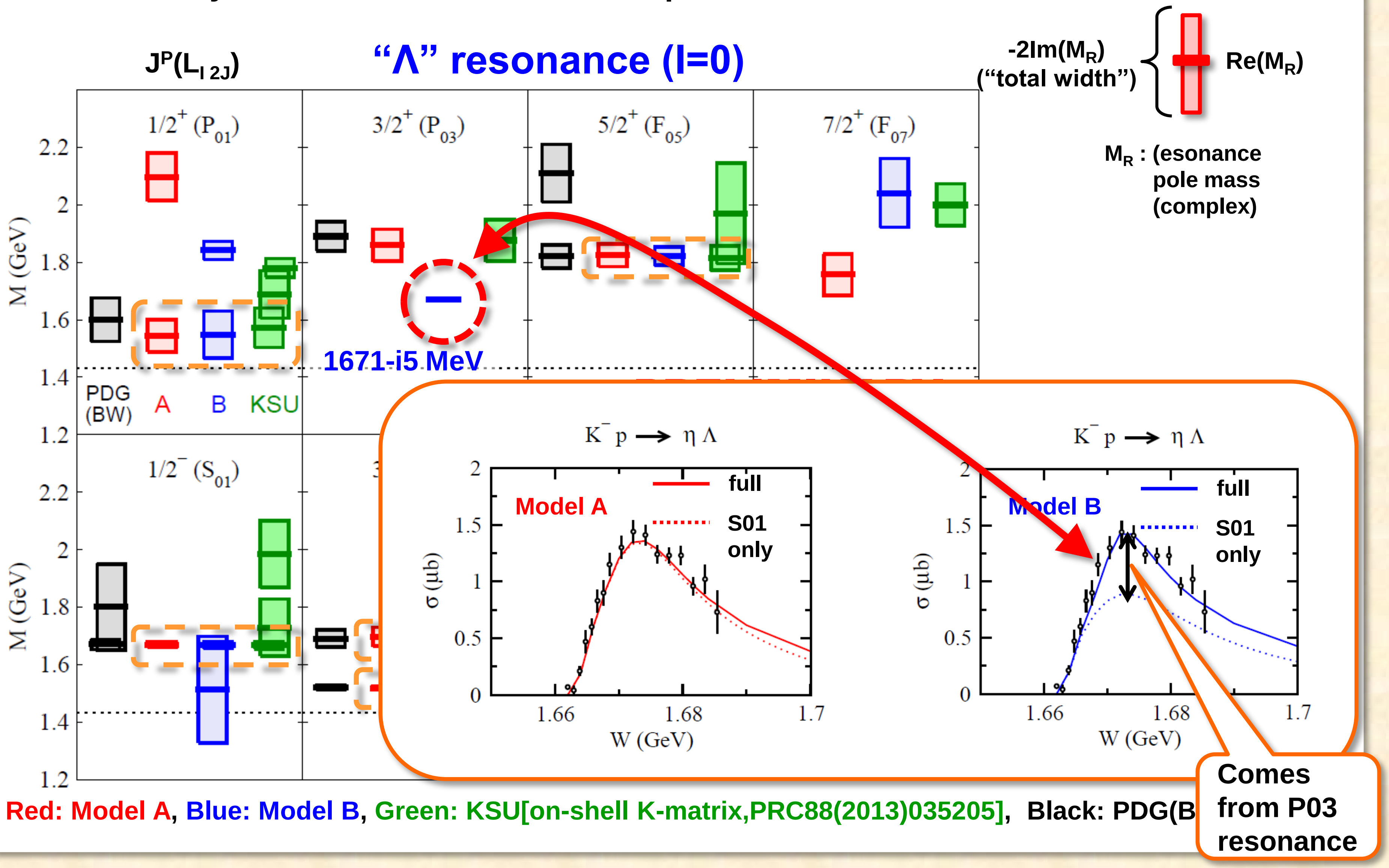


Red: Model A, Blue: Model B, Green: KSU[on-shell K-matrix,PRC88(2013)035205], Black: PDG(B

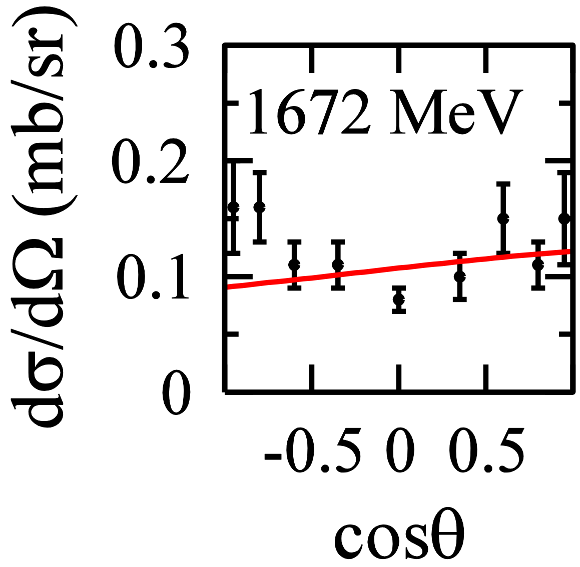
P03 resonance just above the ηΛ threshold

HK, Nakamura, Sato, in preparation

dσ/dΩ of K- p → ηΛ @ W=1672 MeV (just 8 MeV above the threshold)

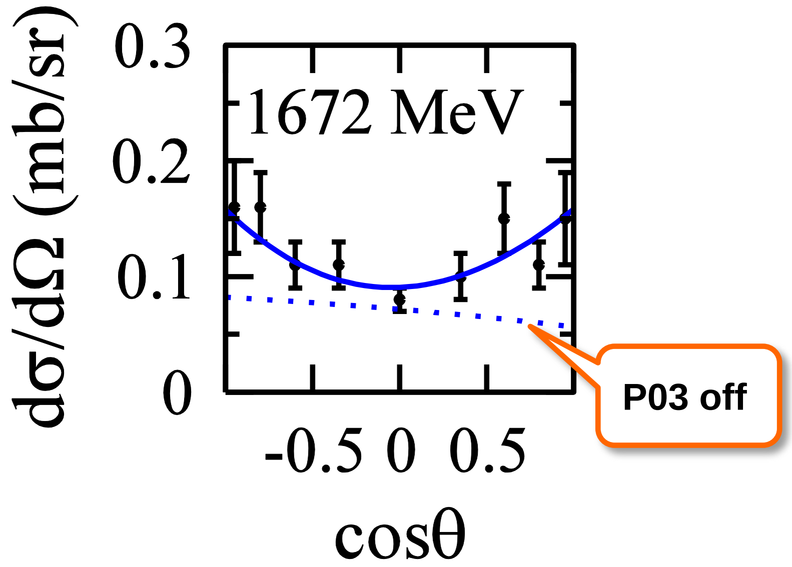
- Even close to the threshold, the data show **a clear angular dependence.**

Model A
(S01 wave ~99%)



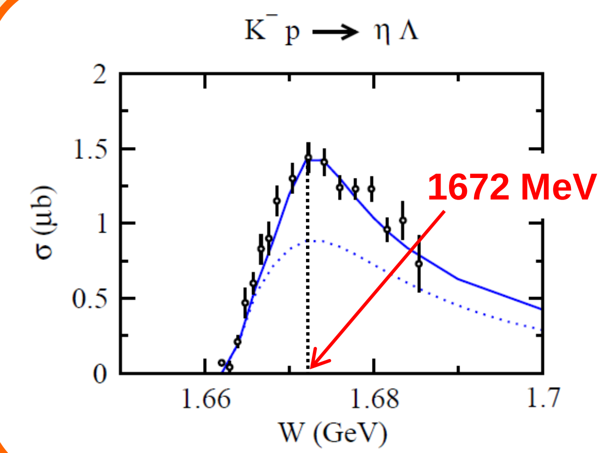
✓ Concave-up behavior not reproduced.

Model B
(S01 wave ~60%, P03 wave ~40%)



✓ **Narrow P03 resonance** responsible for the angular dependence !!

P03 resonance just above the ηΛ threshold

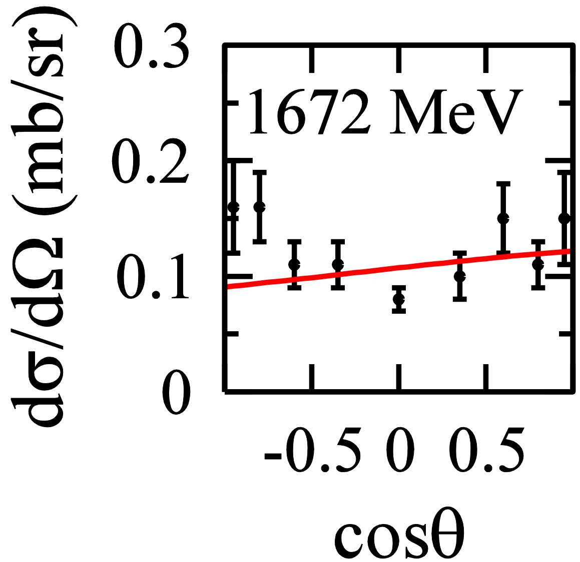


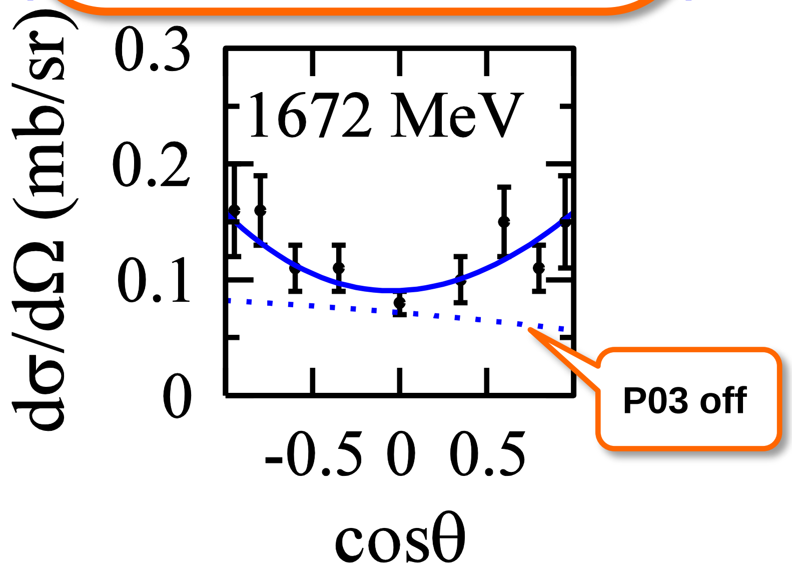
aration

dσ/dΩ of K- p → ηΛ @ W=1672 MeV (jus d)

- Even close to the threshold, the data sho e.

Model A
(S01 wave ~99%)





✓ **Concave-up behavior not reproduced.**

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P03 resonance just above the ηΛ threshold

HK, Nakamura, Sato, in preparation

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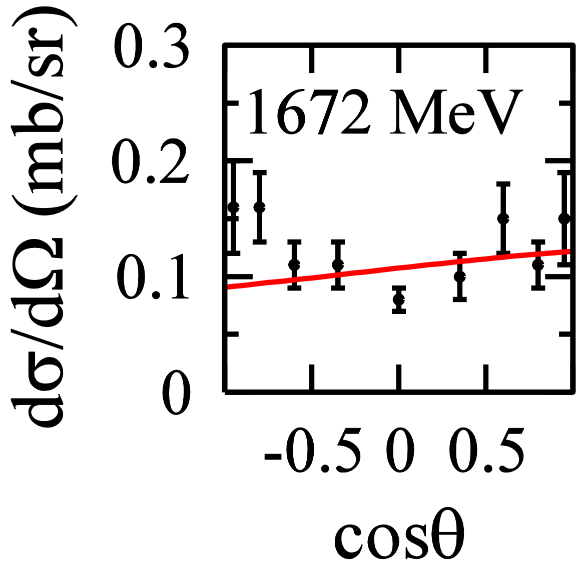

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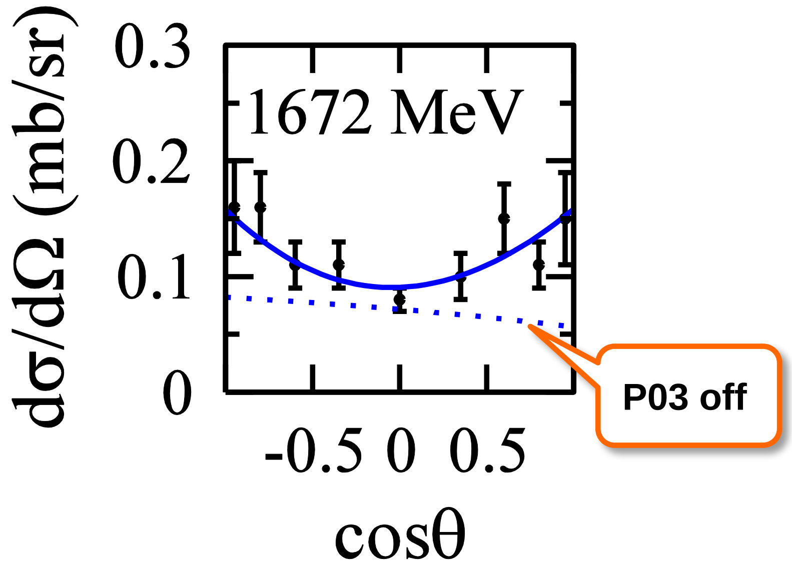
Model B
(S01 wave ~60%, P03 wave ~40%)



✓ Narrow P03 resonance responsible for the angular dependence !!

Summary & ongoing/future works

Summary

- ✓ **Comprehensive PWA to extract properties of light-quark baryons (N*, Δ*, Λ*, Σ*) within Dynamical Coupled-Channels (DCC) approach.**
- ✓ **Visible analysis dependence in extracted resonance spectrum.**
  - needs more extensive meson production data (including polarization observables) from electron, photon, and hadron beam facilities.

Ongoing/future works

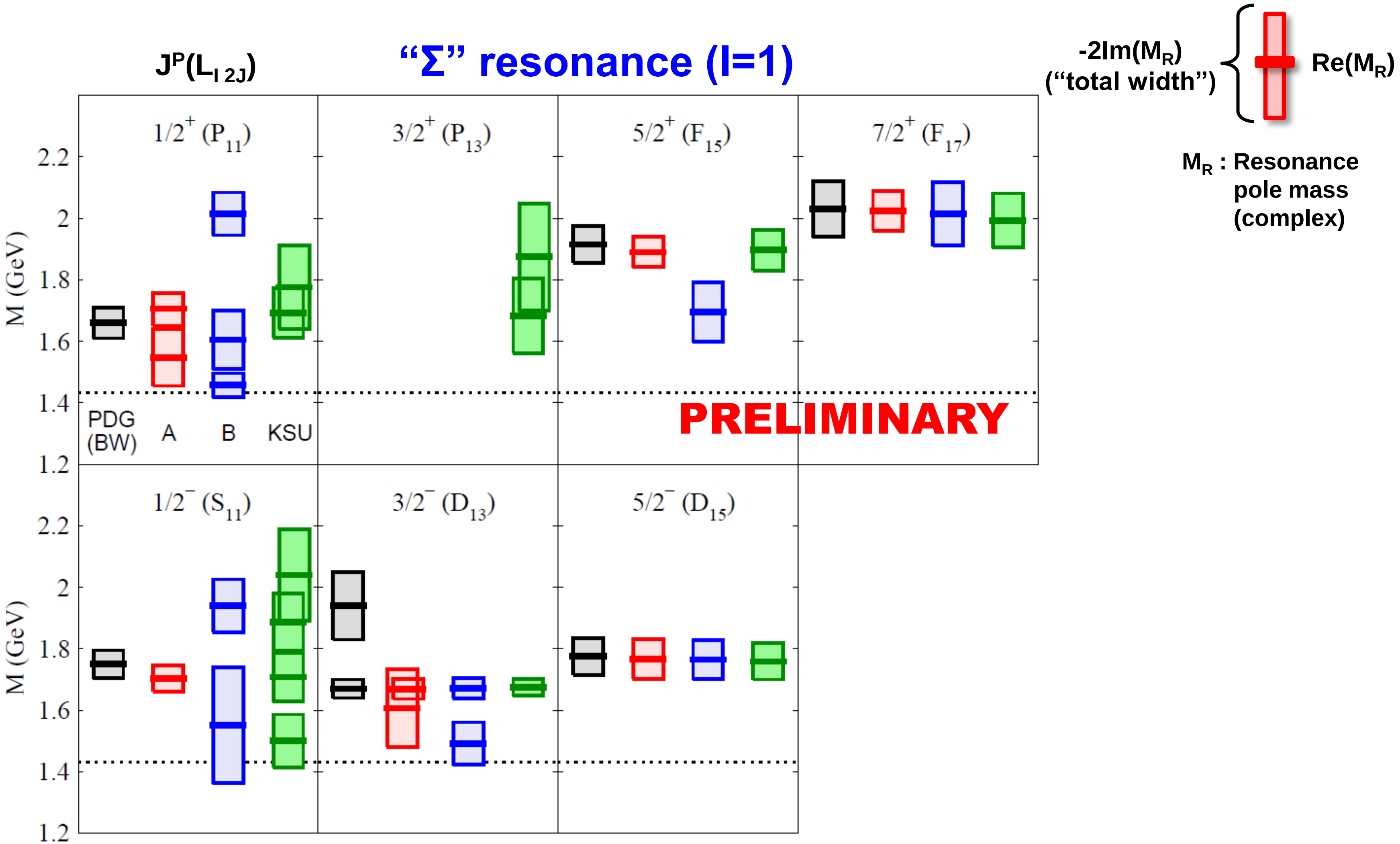
- ✓ **N-N* e.m. transition form factors to high Q2**
- ✓ **High-mass N* and Δ* spectroscopy (extends channel space, inclusion of ππN data)**
- ✓ **DCC approach to deuteron target reactions**
  - Helicity amplitudes for γ-neutron → N* (need for isospin separation)
  - Y* spectroscopy below $\bar{K}N$ threshold with K^- d reactions (J-PARC E31)
- ✓ **Applications to neutrino-induced reactions (input for neutrino-oscillation experiments)**
  - ➔ Collaboration@J-PARC Branch of KEK Theory Center
    (http://j-parc-th.kek.jp/html/English/e-index.html)
- ✓ **Applications to hypernuclei & kaonic nuclei productions**

Back up

Comparison of Σ* spectrum between multichannel analyses

HK, Nakamura, Lee, Sato, in preparation

Here only Y*s above $\bar{K}N$ threshold are presented.

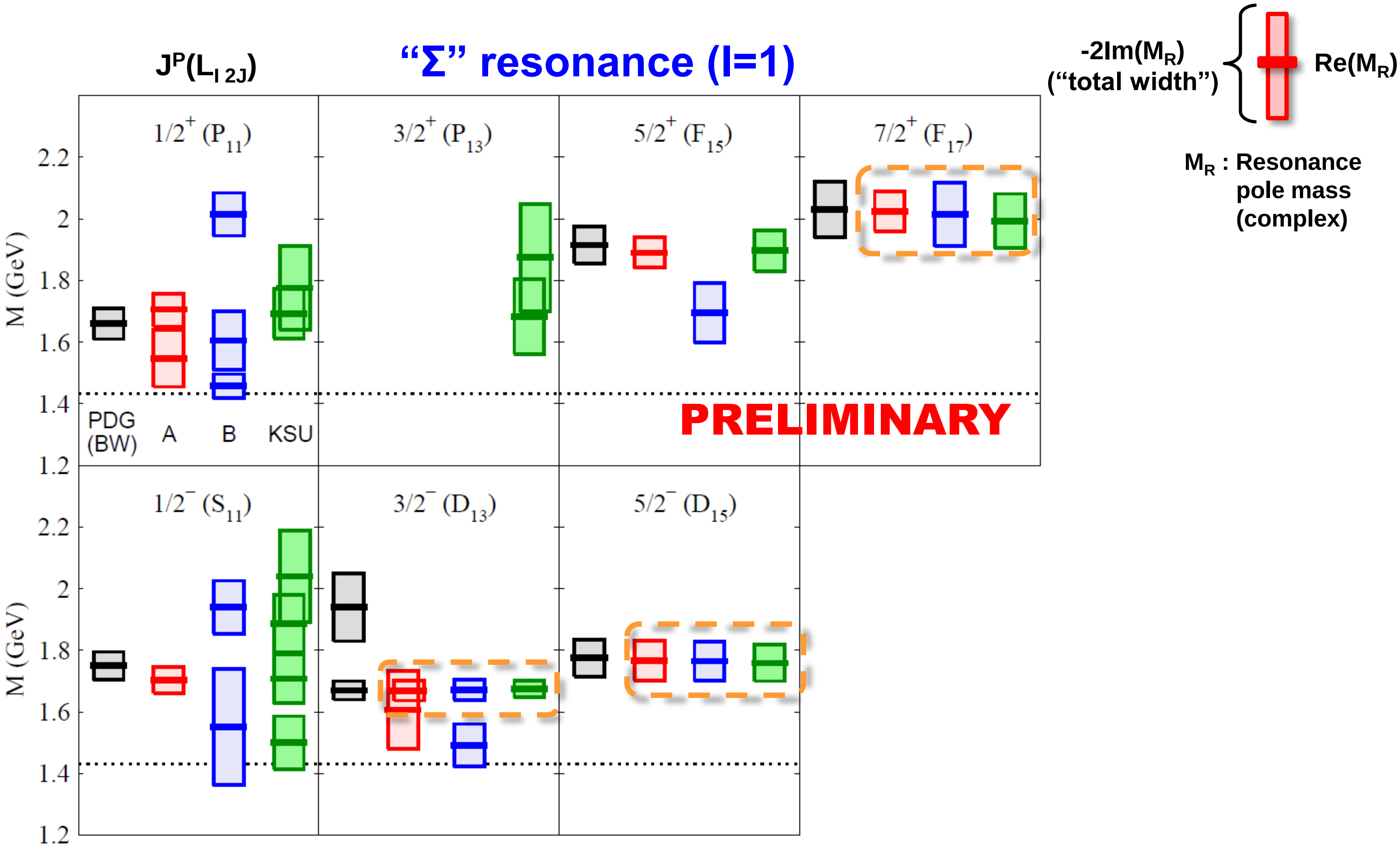


Red: Model A, Blue: Model B, Green: KSU[on-shell K-matrix,PRC88(2013)035205], Black: PDG(Breit-Wigner)

Comparison of Σ* spectrum between multichannel analyses

HK, Nakamura, Lee, Sato, in preparation

Here only Y*s above $\bar{K}N$ threshold are presented.



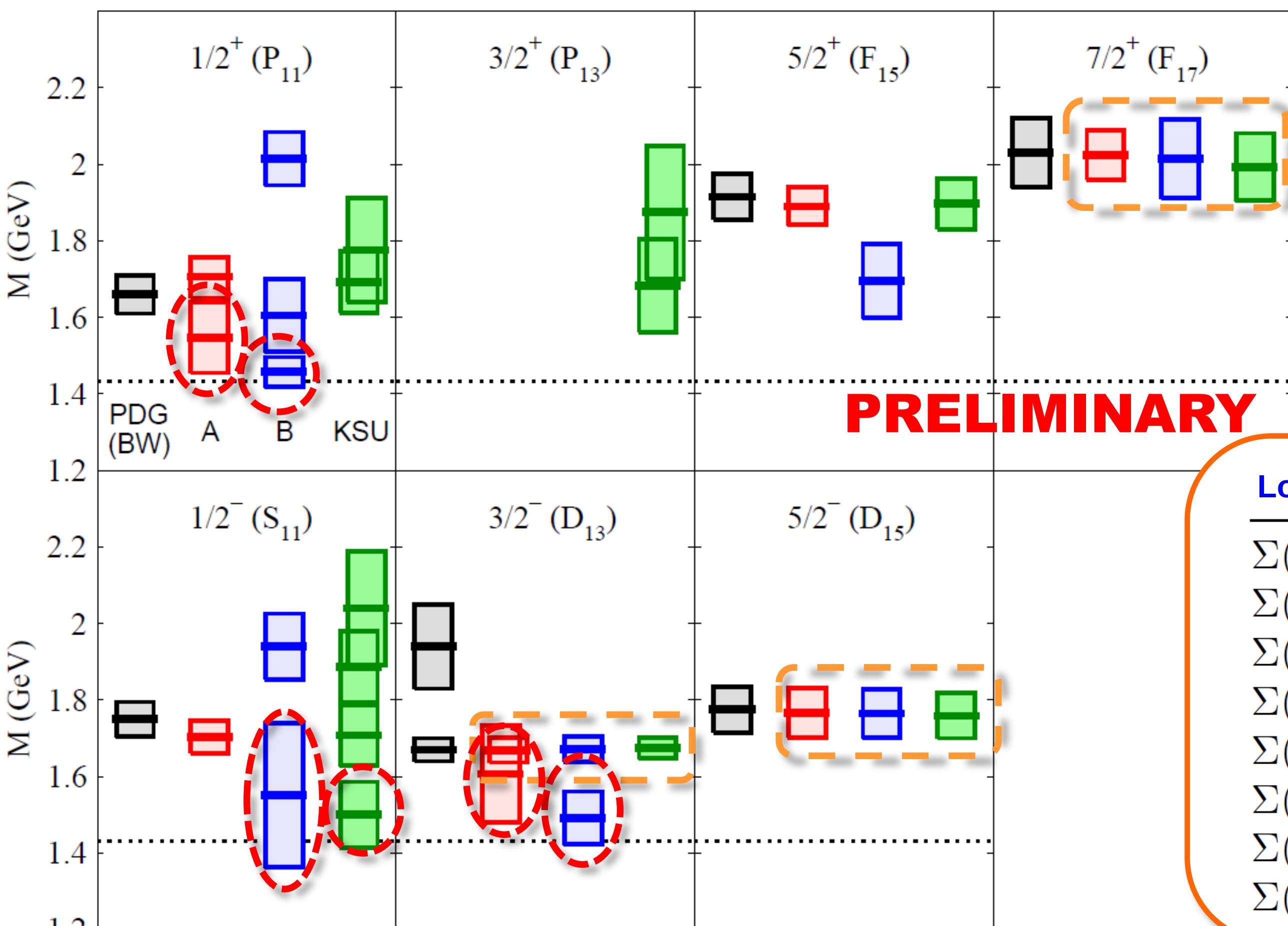
Red: Model A, Blue: Model B, Green: KSU[on-shell K-matrix,PRC88(2013)035205], Black: PDG(Breit-Wigner)

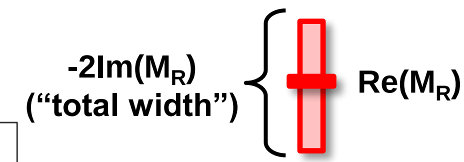
Comparison of Σ* spectrum between multichannel analyses

HK, Nakamura, Lee, Sato, in preparation

Here only Y*s above $\bar{K}N$ threshold are presented.

"Σ" resonance (I=1)





M_R : Resonance pole mass (complex)

Low-lying Σ* resonances(PDG)

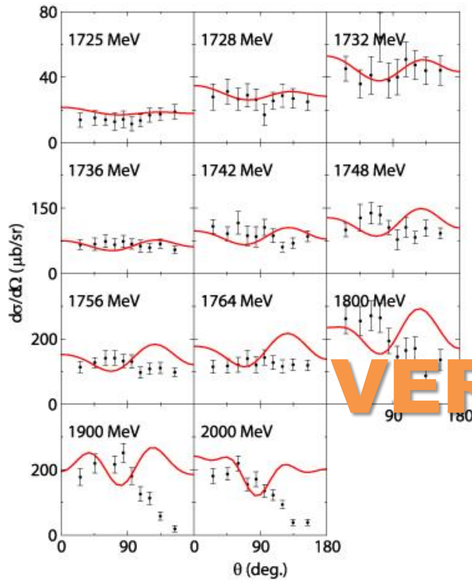
Σ(1193)	1/2+	****
Σ(1385)	3/2+	****
Σ(1480)		*
Σ(1560)		**
Σ(1580)	3/2−	*
Σ(1620)	1/2−	**
Σ(1660)	1/2+	***
Σ(1670)	3/2−	****

? (Σ(1480), Σ(1560), Σ(1580), Σ(1620))

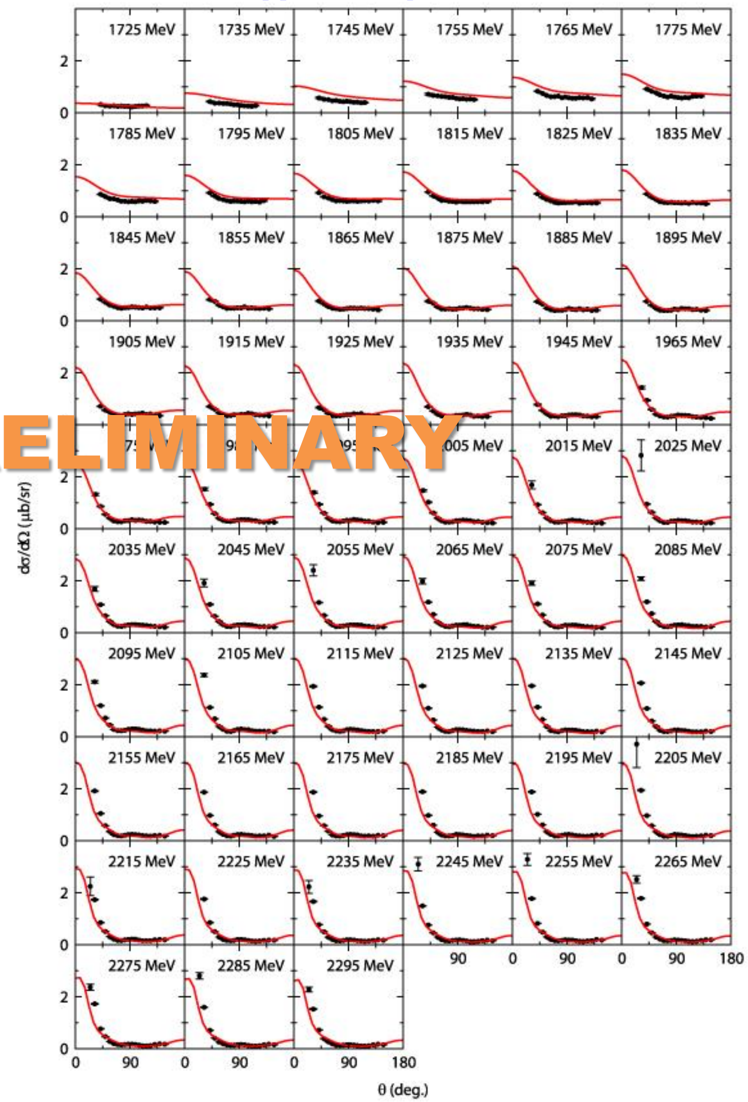
Red: Model A, Blue: Model B, Green: KSU[on-shell K-matrix,PRC88(2013)035205], Black: PDG(Breit-Wigner)

Extending analysis of N* production within ANL-Osaka DCC approach

$\pi^- p \rightarrow \omega n$ DCS



$\gamma p \rightarrow \omega p$ DCS



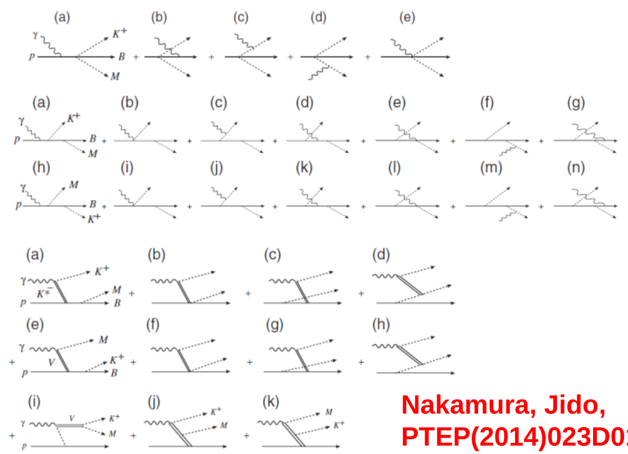
VERY PRELIMINARY

Combined analysis including ωN data is *in progress* !!

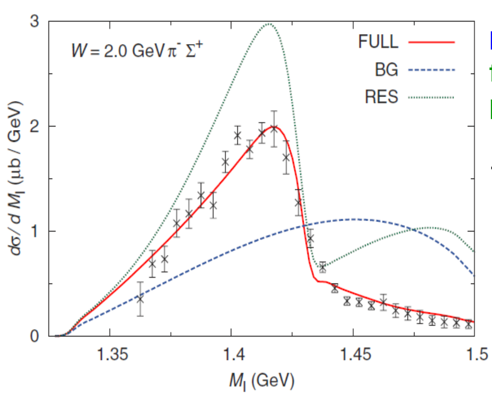
How we study the region below the $\bar{K}N$ threshold ?

E.g.) γp → $K^+\pi\Sigma$ @CLAS

At the CLAS energy, **many production processes contribute** and sizably affect mass distributions as **backgrounds**.



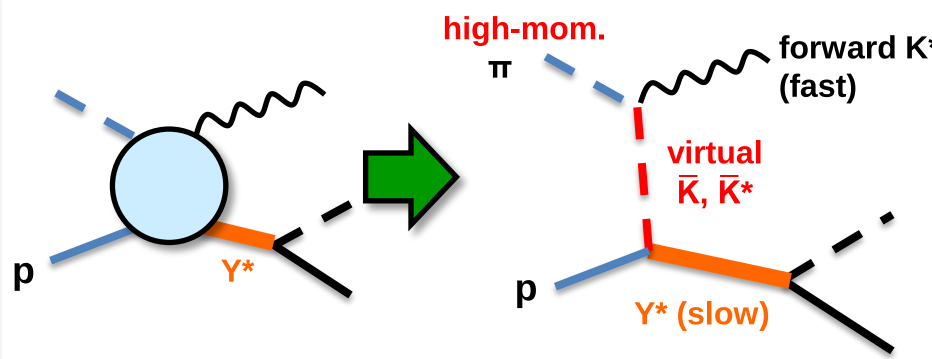
Nakamura, Jido, PTEP(2014)023D01



Large model dependence from complicated production processes.

→ Makes unambiguous determination of Λ(1405) difficult.

Forward p(π, K*)X reactions with high-momentum pion beam (→ J-PARC E50)



- **For forward K* (small t),** the processes are **dominated by diffractive t-channel exchange processes**.
- We DO have fully unitarized **$\bar{K}N$→ MB and $\bar{K}^*N$ → MB half off-shell amplitudes** !!
- 12 GeV JLab can do a similar measurement by replacing incident π by high-energy photon.
- Useful also for determining **low-lying Σ* resonances**

Low-lying Σ* resonances(PDG)

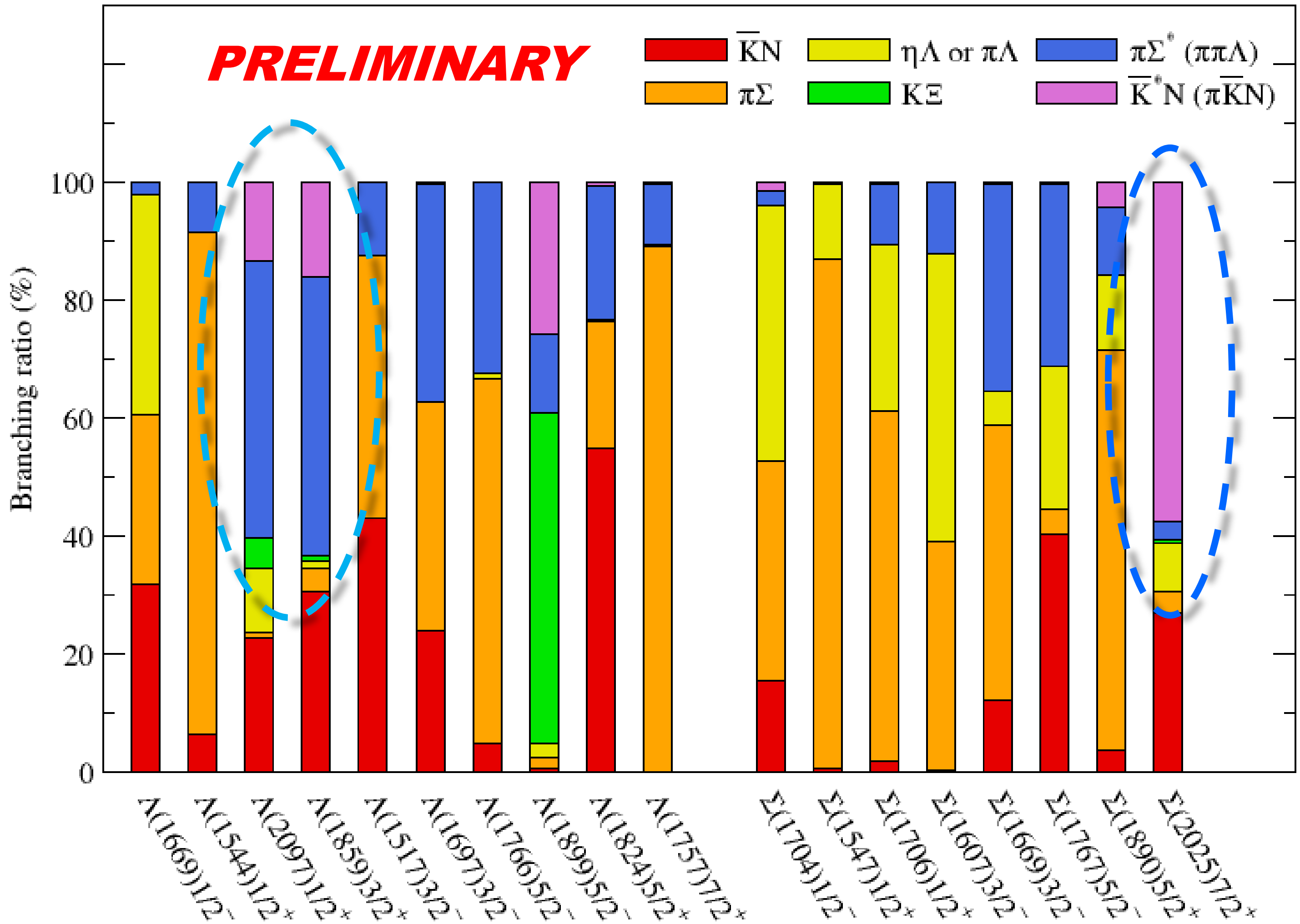
Σ(1193)	1/2+	****
Σ(1385)	3/2+	****
Σ(1480)		*
Σ(1560)		**
Σ(1580)	3/2−	*
Σ(1620)	1/2−	**
Σ(1660)	1/2+	***
Σ(1670)	3/2−	****

? (Σ(1480)–Σ(1620))

Branching ratios

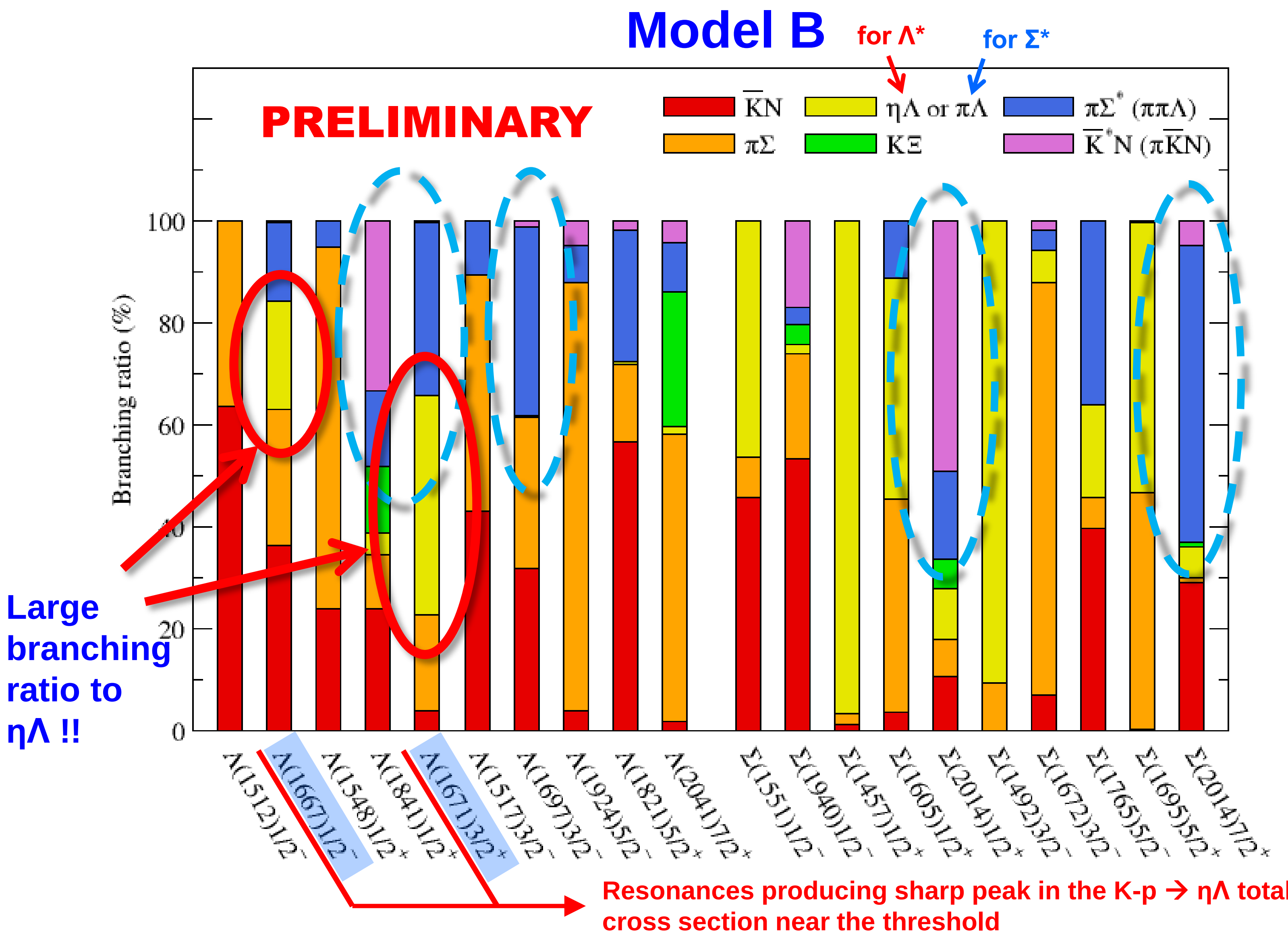
HK, Nakamura, Lee, Sato, in preparation

Model A



Branching ratios

HK, Nakamura, Lee, Sato, in preparation



Application to neutrino-induced reactions

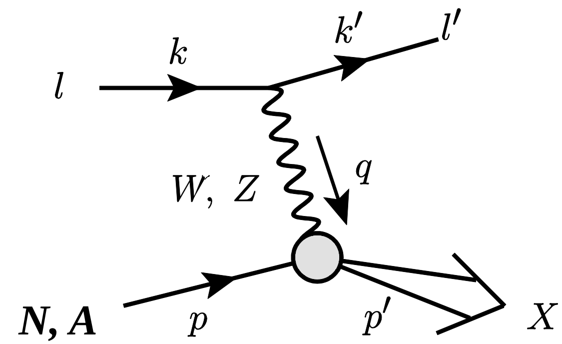
- ✓ **Reliable neutrino reaction model** is necessary for ***precise*** determination of neutrino parameters from **future neutrino-oscillation experiments** (leptonic CP phase, neutrino mass hierarchy…) .
- ✓ Relevant kinematical region extends over **Quasi elastic**, **Resonance**, and **DIS** regions.

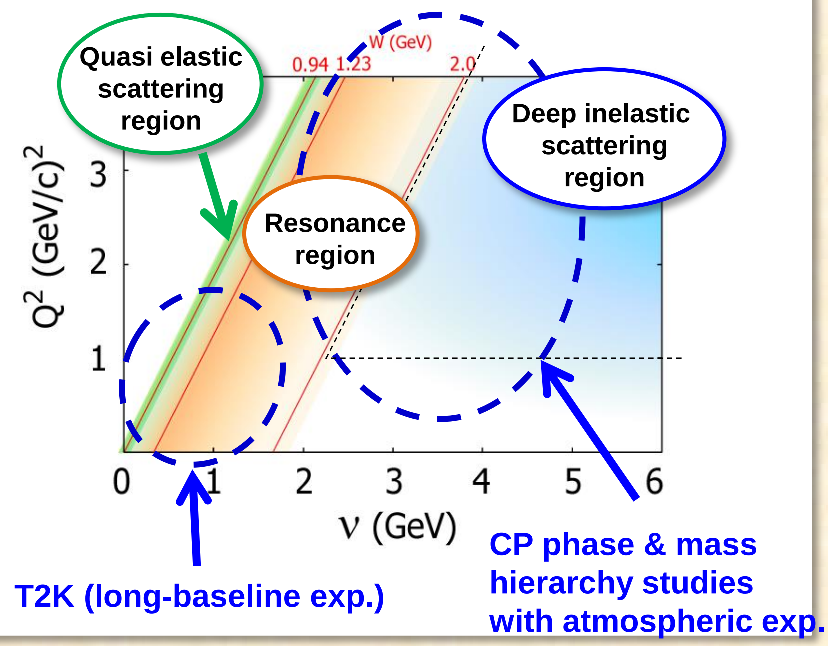
Collaboration@J-PARC Branch of KEK Theory Center
[http://j-parc-th.kek.jp/html/English/e-index.html]

Y. Hayato (ICRR, U. of Tokyo), M. Hirai (Nippon Inst. Tech.)
H. Kamano (RCNP, Osaka U.), S. Kumano (KEK)
S. Nakamura (Osaka U.), K. Saito (Tokyo U. of Sci.)
M. Sakuda (Okayama U.), T. Sato (Osaka U.)
[➔ arXiv:1303.6032]

➔ **Talk by S. Nakamura 27(Wed) Parallel-A:27-1**

Neutrino-nucleon/nucleus reactions



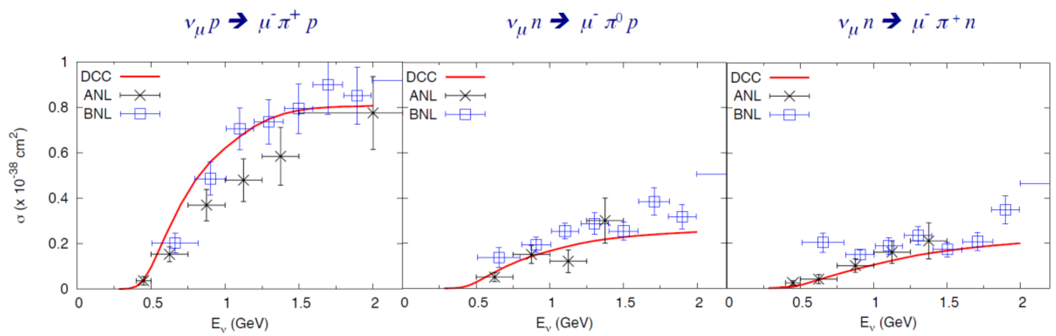


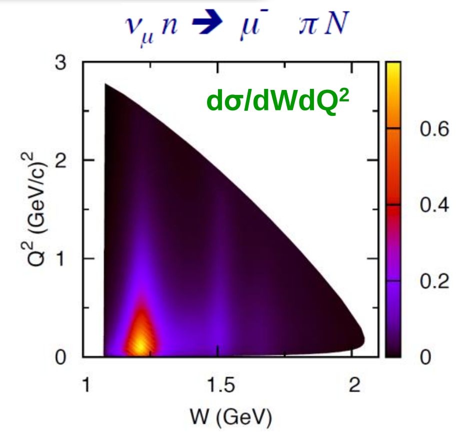
Application to neutrino-induced reactions

Nakamura, HK, Sato, in preparation

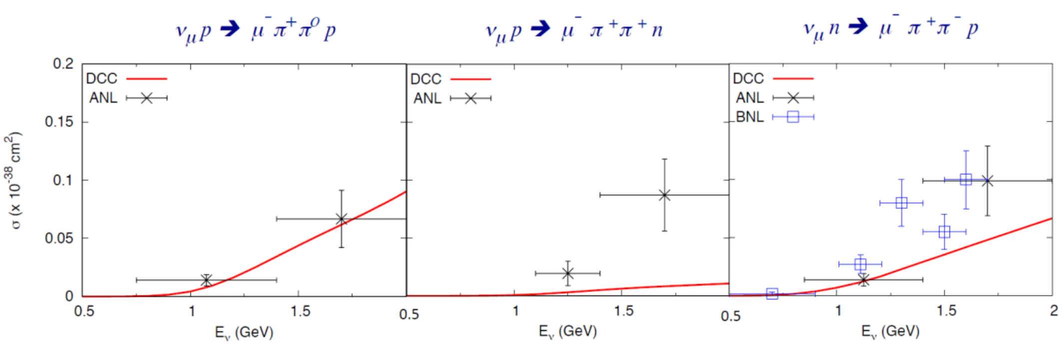
The first-time full coupled-channels calculation of ν-nucleon reactions beyond the Δ(1232) region !!

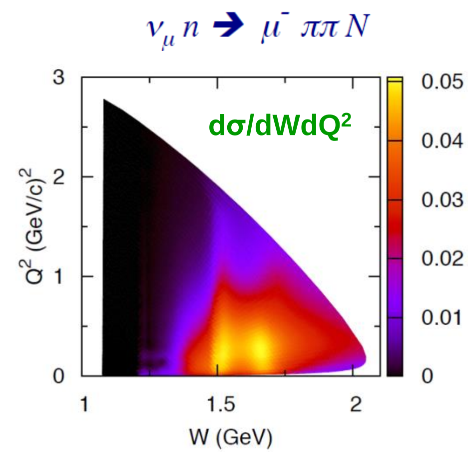
✓ **Single pion production:**





✓ **Double pion production:** **PRELIMINARY**

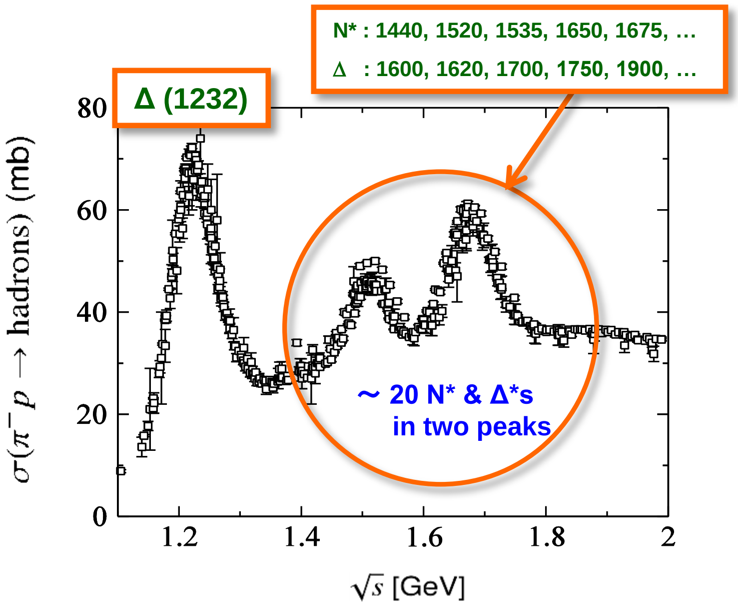


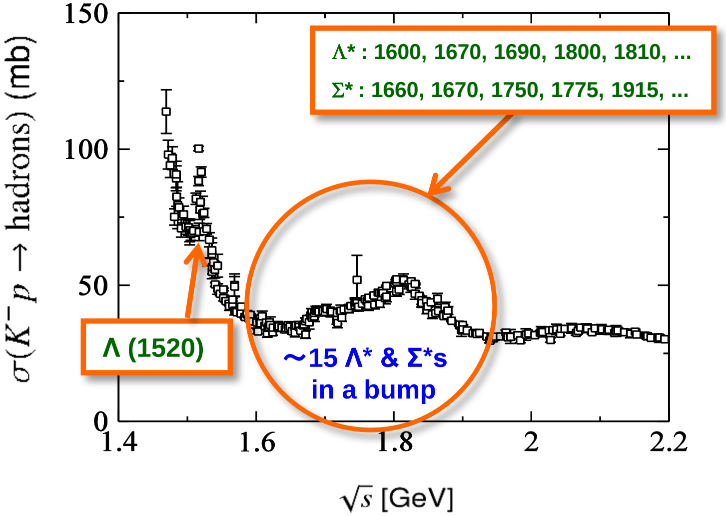


##NOTE: Q^2 dependence of all N-N* axial transition form factors are currently fixed with that of N-Δ(1232) transition.

ηN, KΛ, KΣ productions can also be calculated.

Light-quark baryon (N*, Δ*, Λ*, Σ*) spectroscopy : Physics of broad & overlapping resonances





- ✓ Width: *O*(10^1-10^2) MeV.
- ✓ Resonances are highly overlapping in energy except Δ(1232) and Λ(1520)

- ✓ To reliably extract baryon resonances, one must do comprehensive PWA of meson production reactions:
  - ➢ taking account of various final states simultaneously.
  - ➢ extending over the wide energy region.

- ✓ Analysis with a theoretical framework satisfying multichannel unitarity is essential.

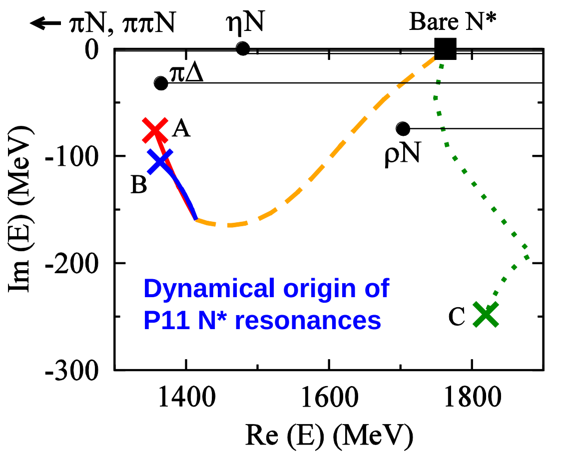
- ✓ Employ a Dynamical Coupled-Channels (DCC) approach for meson production reactions

➔ Matsuyama, Sato, Lee, Phys. Rep. 439(2007)193

Why DCC approach ??

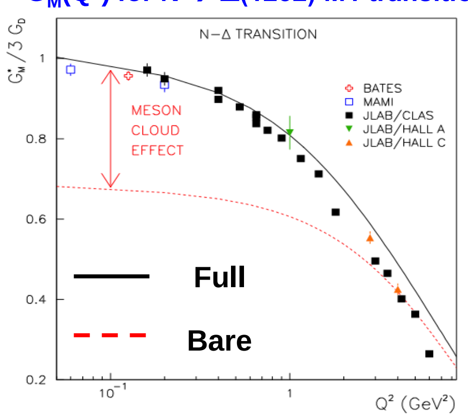
- Given the lack of "complete" data, theoretical guidance as taken within DCC approaches (introducing model Hamiltonian etc.) will be effective for reducing experimental uncertainties in determining partial wave amplitude and extracting resonance parameters.

- If one wants to explore and understand the *physics* behind hadron resonances (dynamical origin and internal structure, etc.), one needs a model that appropriately describes the dynamics of reaction processes.



Suzuki, Julia-Diaz, HK, Lee, Matsuyama, Sato PRL104 065203 (2010)

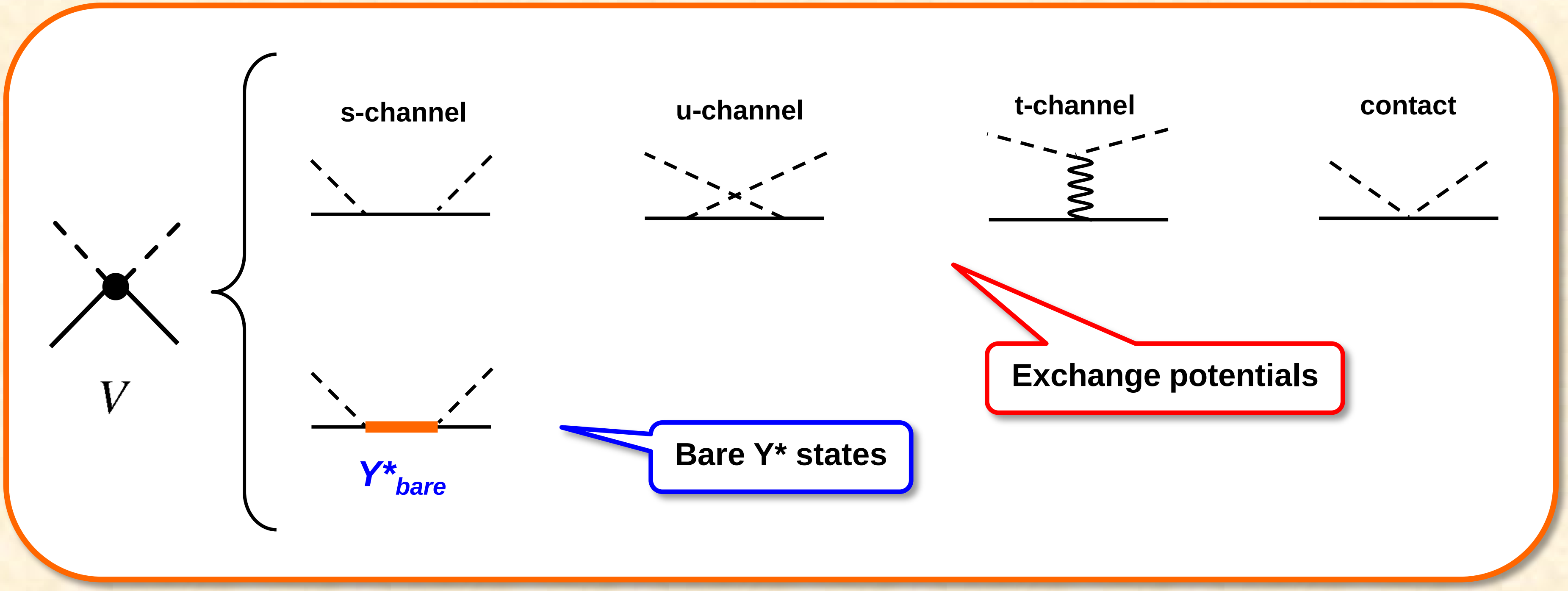
$G_M(Q^2)$ for N → Δ(1232) M1 transition



Julia-Diaz, Lee, Sato, Smith PRC75 015205 (2007)

Dynamical coupled-channels (DCC) model for Y* production reactions

HK, Nakamura, Lee, Sato, arXiv:1407.6839 (with updates)



$$V_{a,b} = v_{a,b} + \sum_{Y^*} \frac{\Gamma^\dagger_{Y^*,a}\Gamma_{Y^*,b}}{E - M_{Y^*}}$$

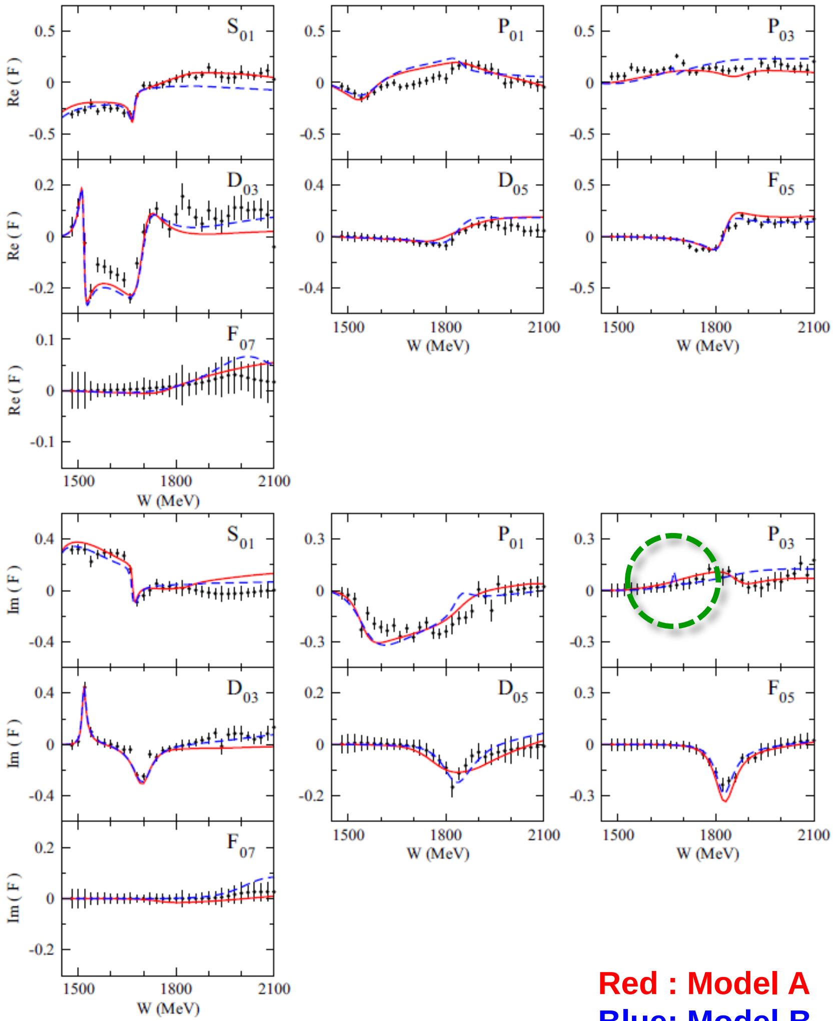
Exchange potentials

bare Y* states

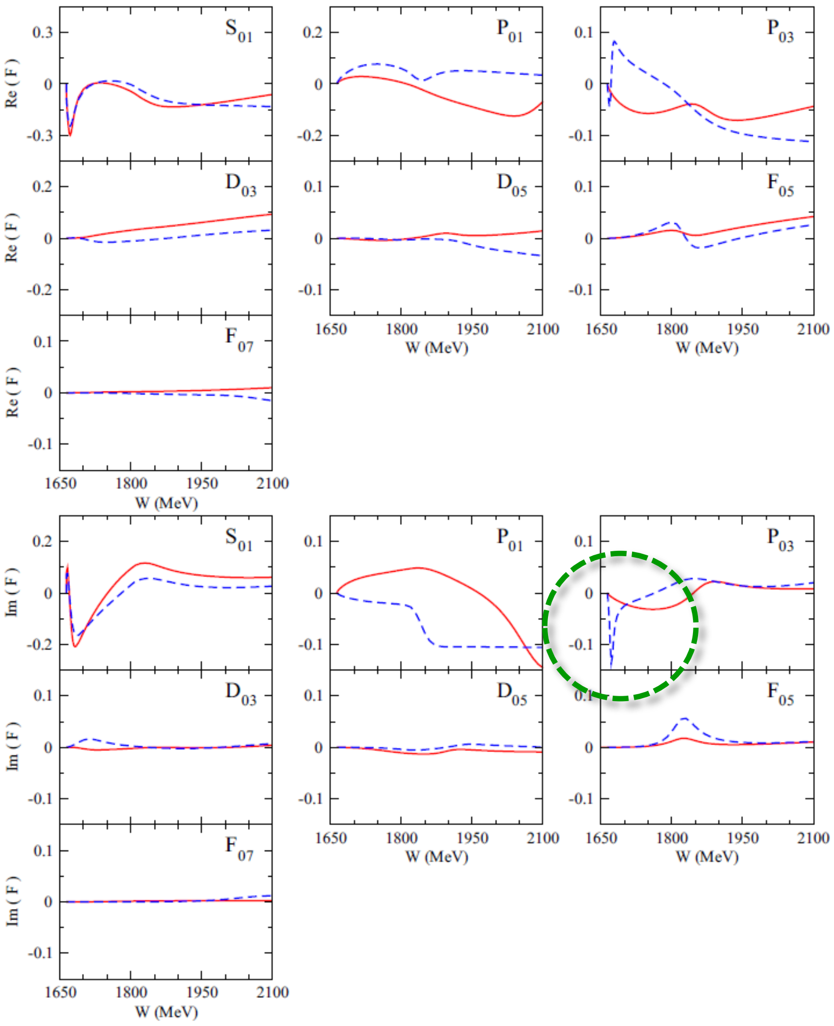
Contribution of narrow P03 resonance to amplitudes

HK, Nakamura, Lee, Sato, PRC90(2014)065204

Extracted $\bar{K}N \rightarrow \pi\Sigma$ amplitudes



Extracted $\bar{K}N \rightarrow \eta\Lambda$ amplitudes



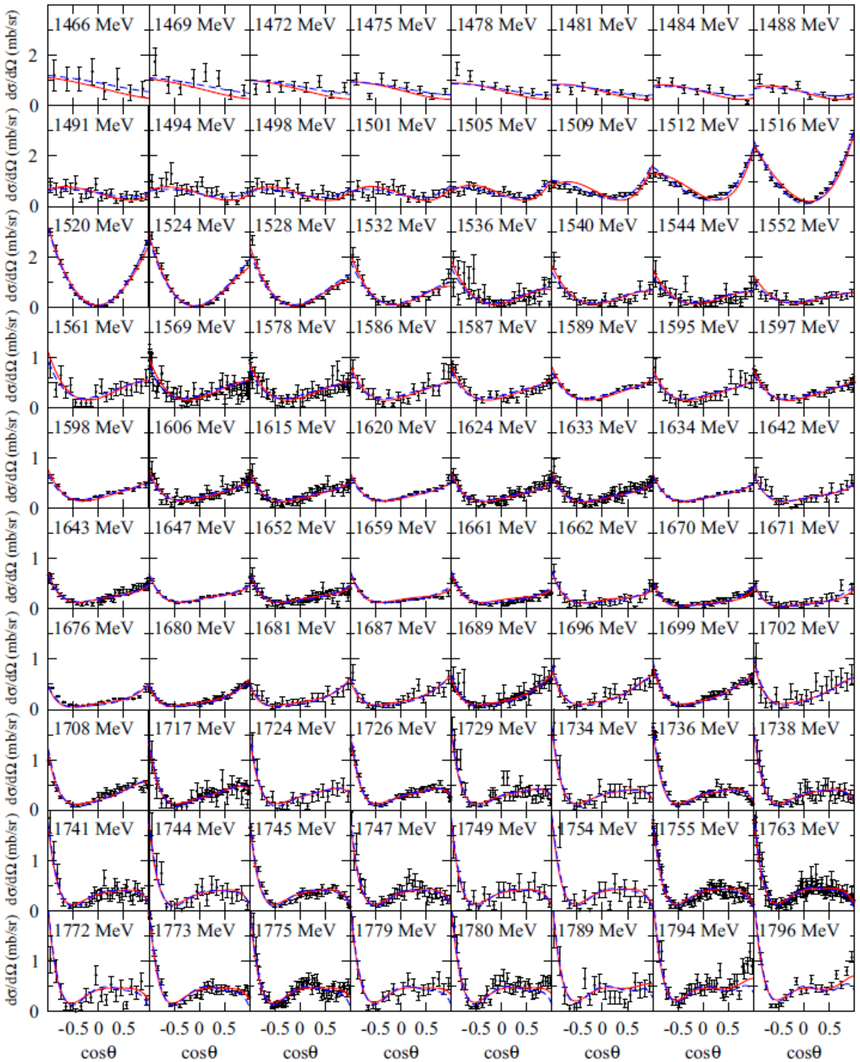
Red : Model A
Blue: Model B

Results of the fits

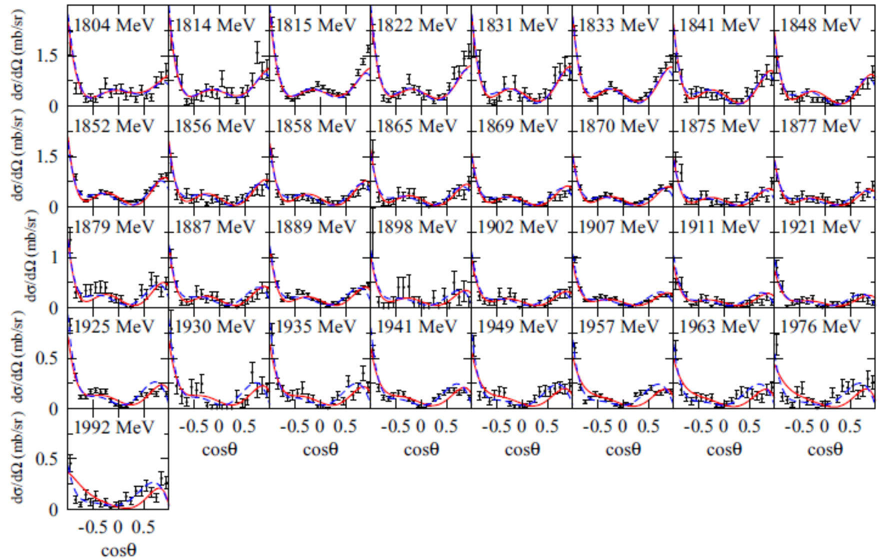
$K^- p \to K^0 n$ reaction

HK, Nakamura, Lee, Sato, PRC90(2014)065204

dσ/dΩ (1466 < W < 1796 MeV)



dσ/dΩ (1804 < W < 1992 MeV)



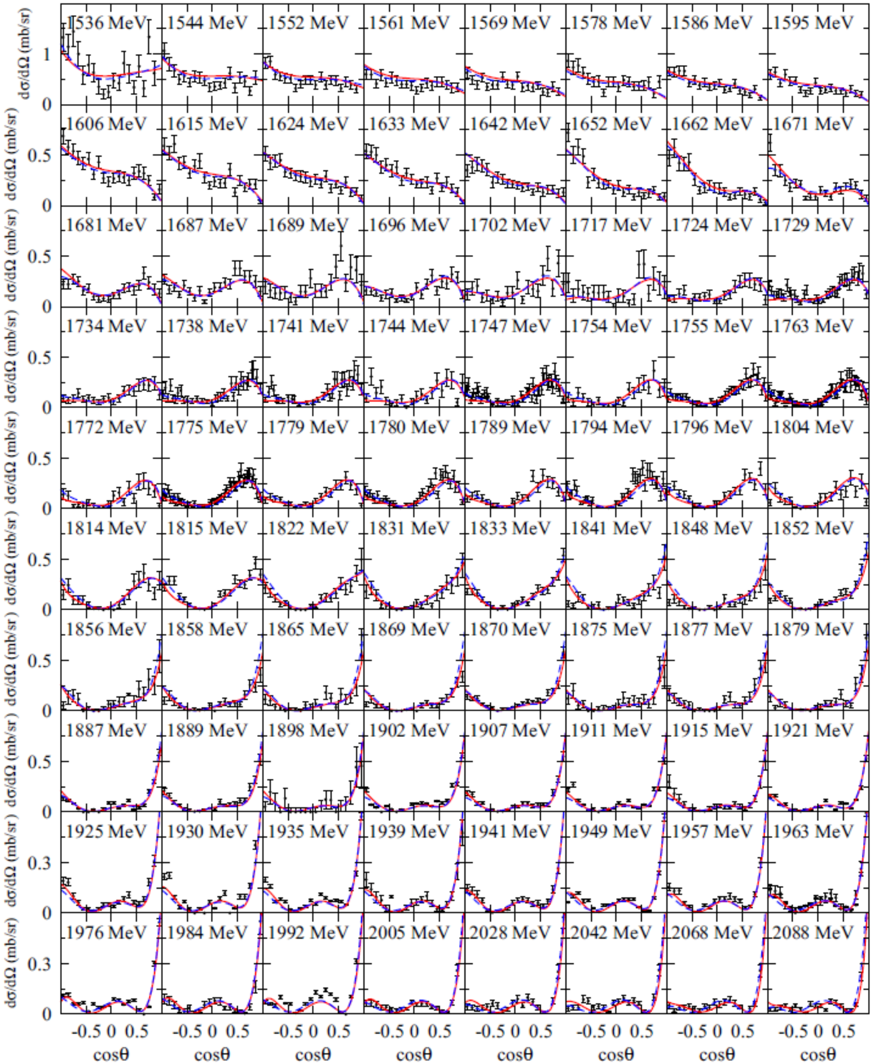
Red: Model A Blue: Model B

Results of the fits

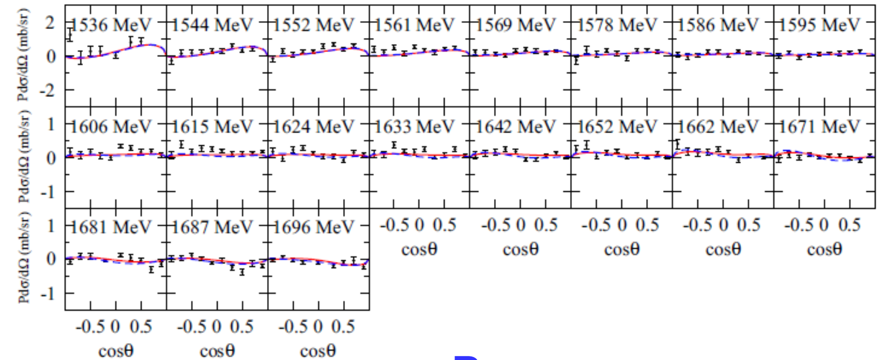
K⁻ p → π⁻ Σ⁺ reaction

HK, Nakamura, Lee, Sato, PRC90(2014)065204

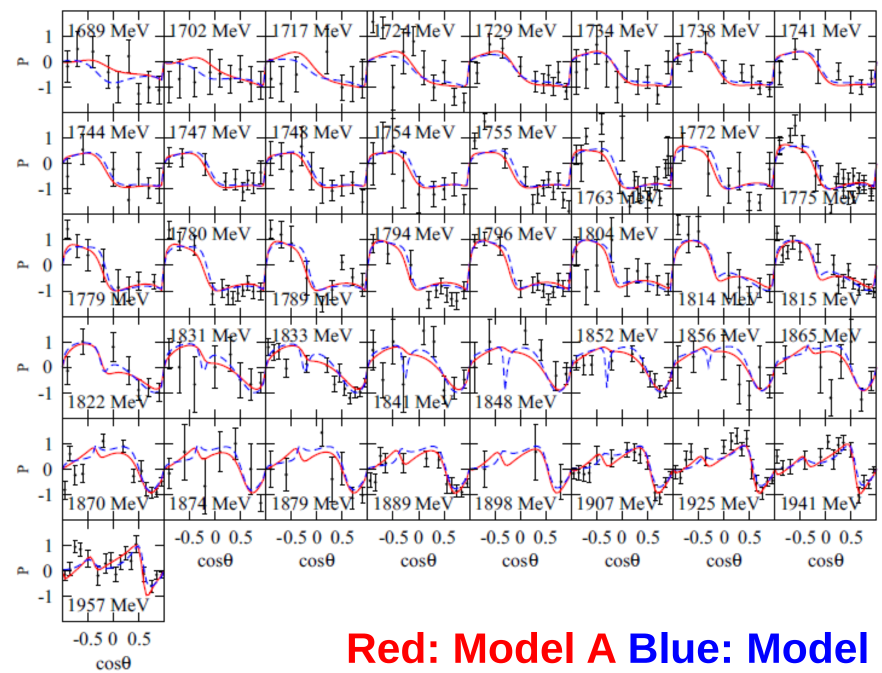
dσ/dΩ



P x dσ/dΩ



P



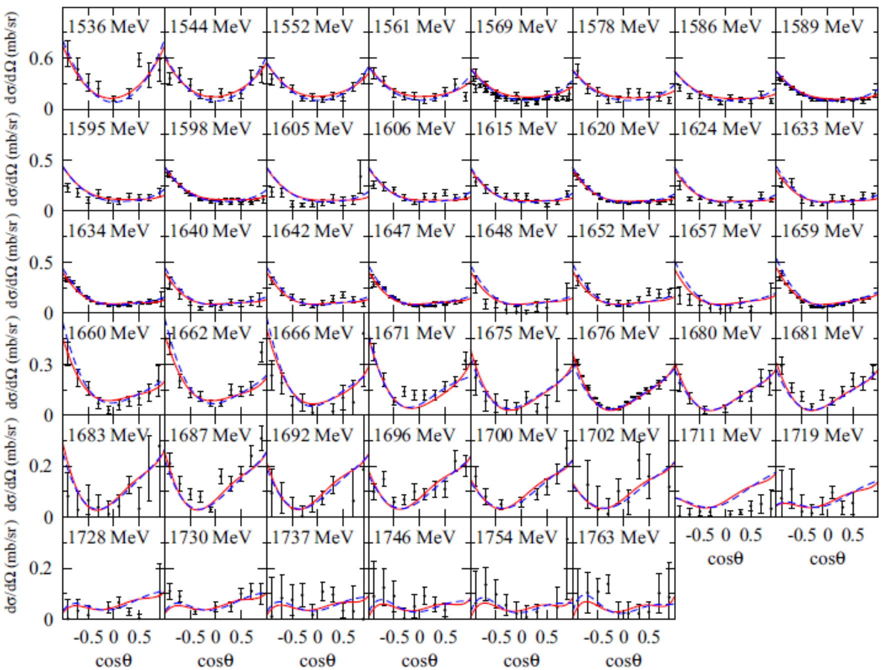
Red: Model A Blue: Model B

Results of the fits

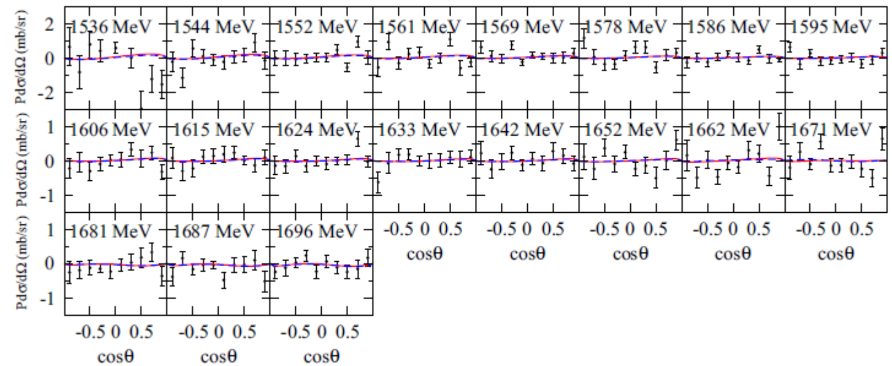
K⁻ p → π^0 Σ^0 reaction

HK, Nakamura, Lee, Sato, PRC90(2014)065204

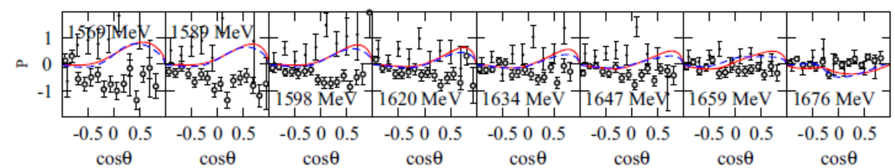
dσ/dΩ



P x dσ/dΩ



P



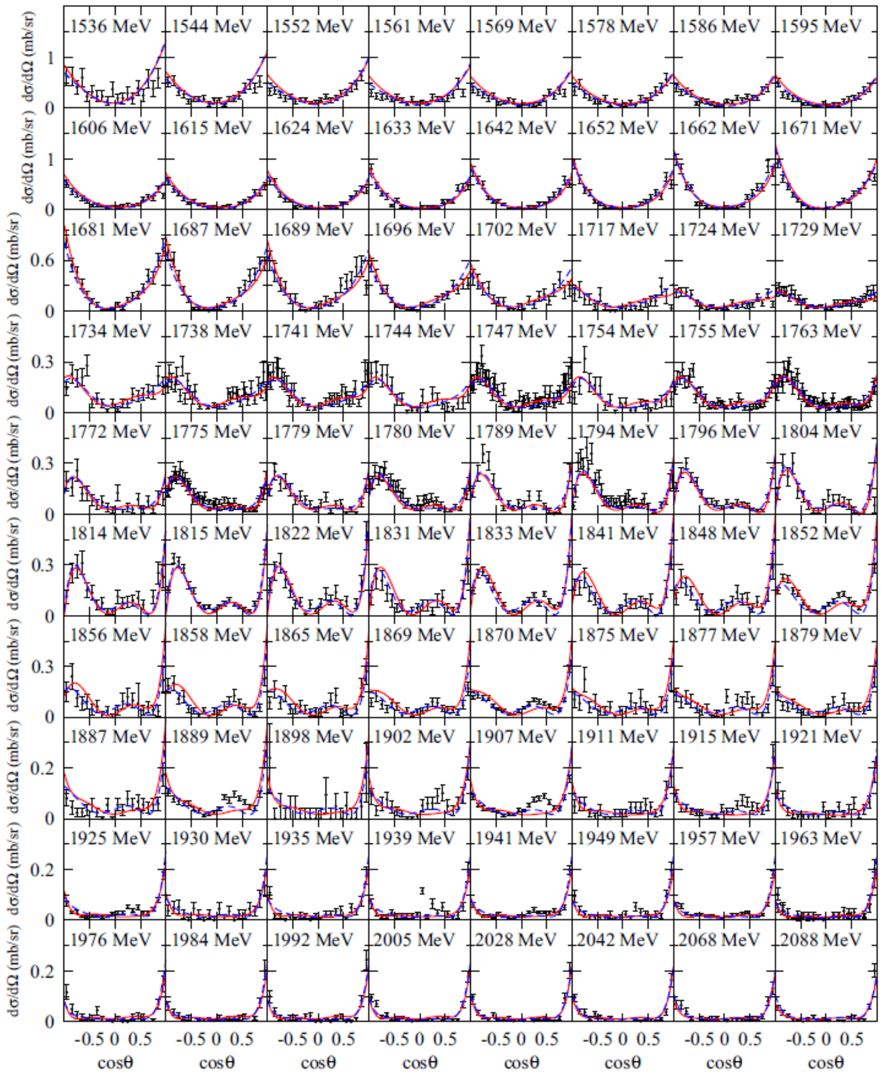
Red: Model A Blue: Model B

Results of the fits

$K^- p \rightarrow \pi^+ \Sigma^-$ reaction

HK, Nakamura, Lee, Sato, PRC90(2014)065204

dσ/dΩ



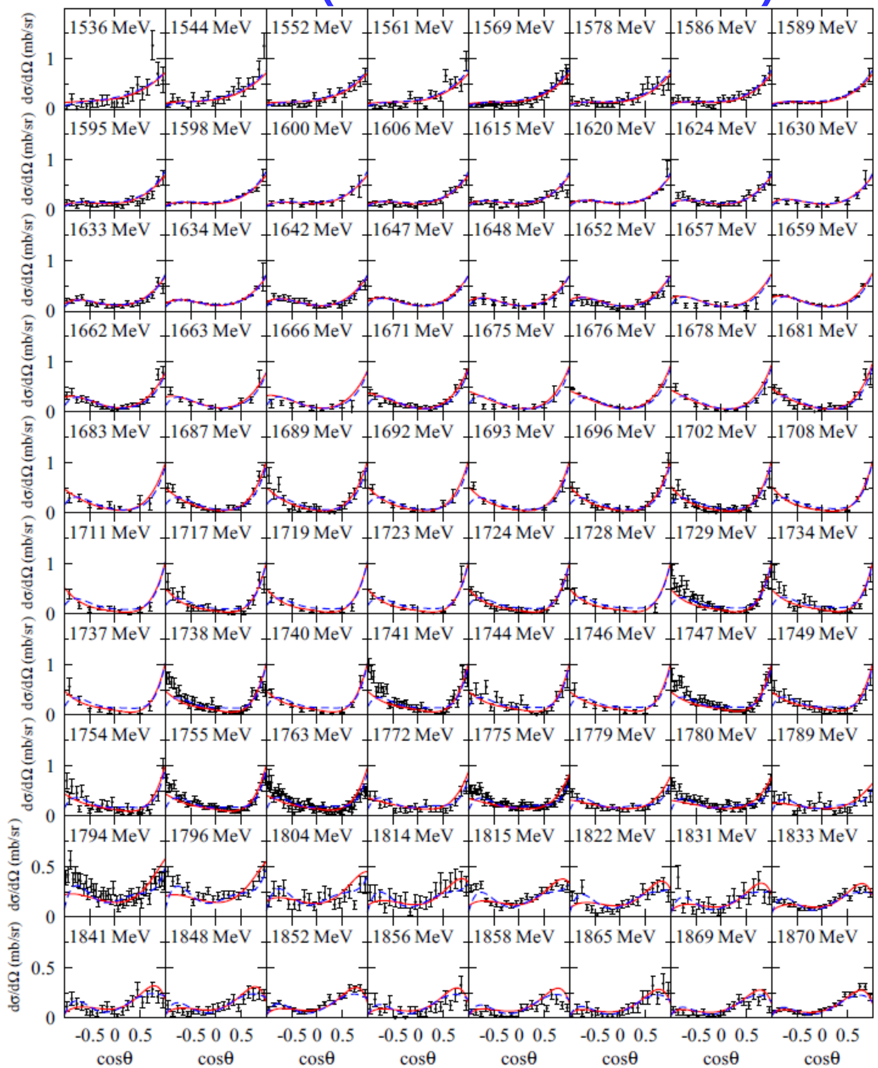
Red: Model A Blue: Model B

Results of the fits

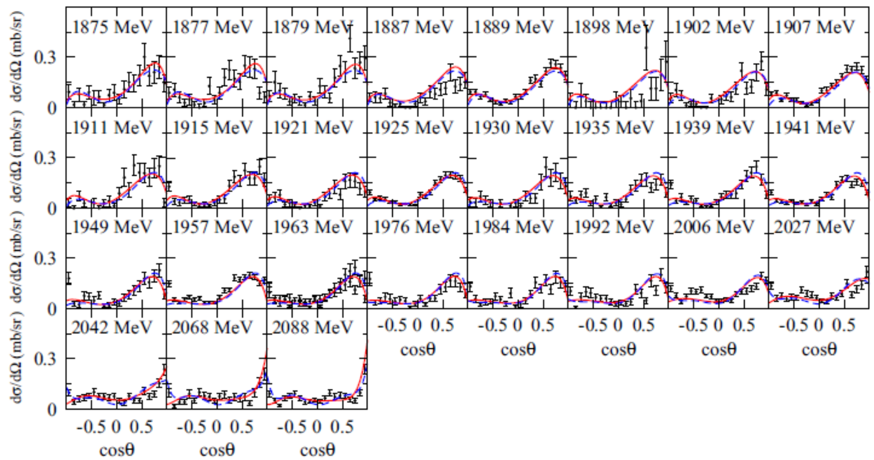
$K^- p \rightarrow \pi^0 \Lambda$ reaction

HK, Nakamura, Lee, Sato, PRC90(2014)065204

$d\sigma/d\Omega$ (1536 < W < 1870 MeV)



$d\sigma/d\Omega$ (1875 < W < 2088 MeV)



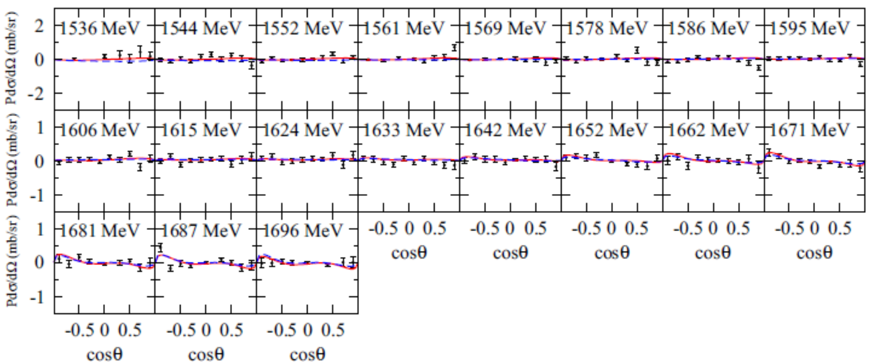
Red: Model A Blue: Model B

Results of the fits

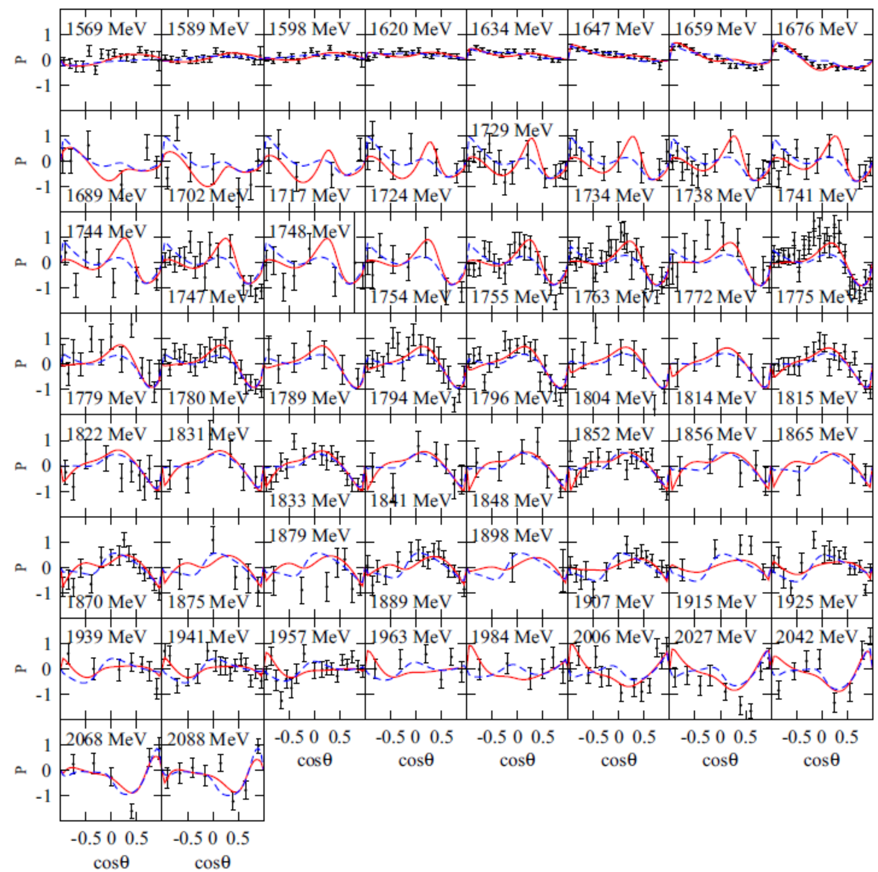
$K^- p \rightarrow \pi^0 \Lambda$ reaction (cont'd)

HK, Nakamura, Lee, Sato, PRC90(2014)065204

P x dσ/dΩ



P



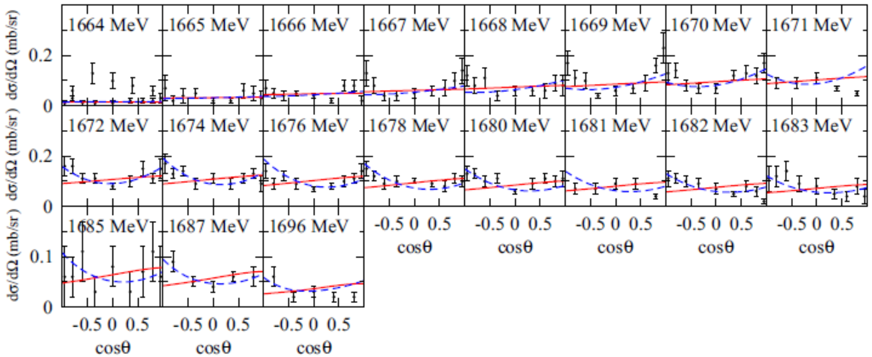
Red: Model A Blue: Model B

Results of the fits

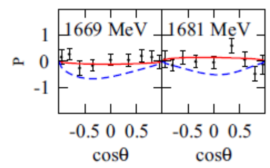
HK, Nakamura, Lee, Sato, PRC90(2014)065204

$K^- p \to \eta\Lambda$ reaction

dσ/dΩ

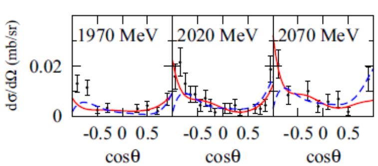


P



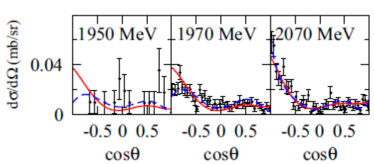
$K^- p \to K^0\Xi^0$ reaction

dσ/dΩ



$K^- p \to K^+\Xi^-$ reaction

dσ/dΩ



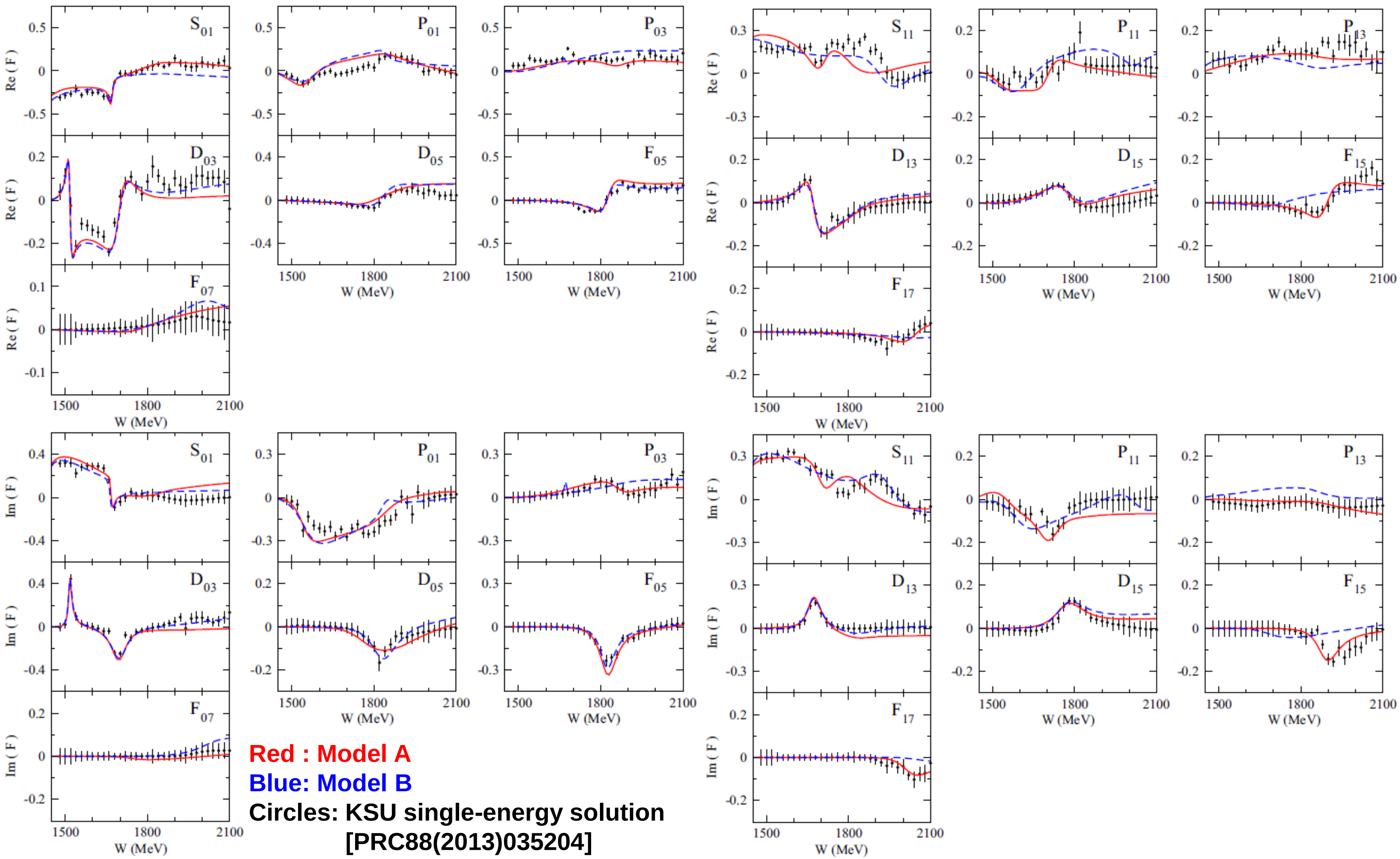
Red: Model A Blue: Model B

Comparison of extracted partial-wave amplitudes

Extracted $\bar{K}N \rightarrow \pi\Sigma$ amplitudes

HK, Nakamura, Lee, Sato, PRC90(2014)065204

$L_{I\,2J}$: L = S,P,.. ; I = isospin; J = Total angular mom.



Red : Model A

Blue: Model B

Circles: KSU single-energy solution [PRC88(2013)035204]

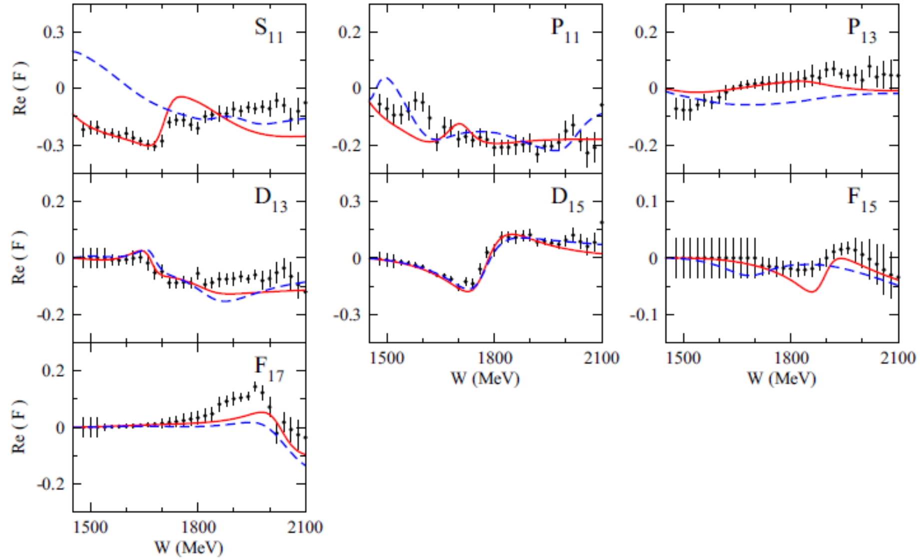
Comparison of extracted partial-wave amplitudes

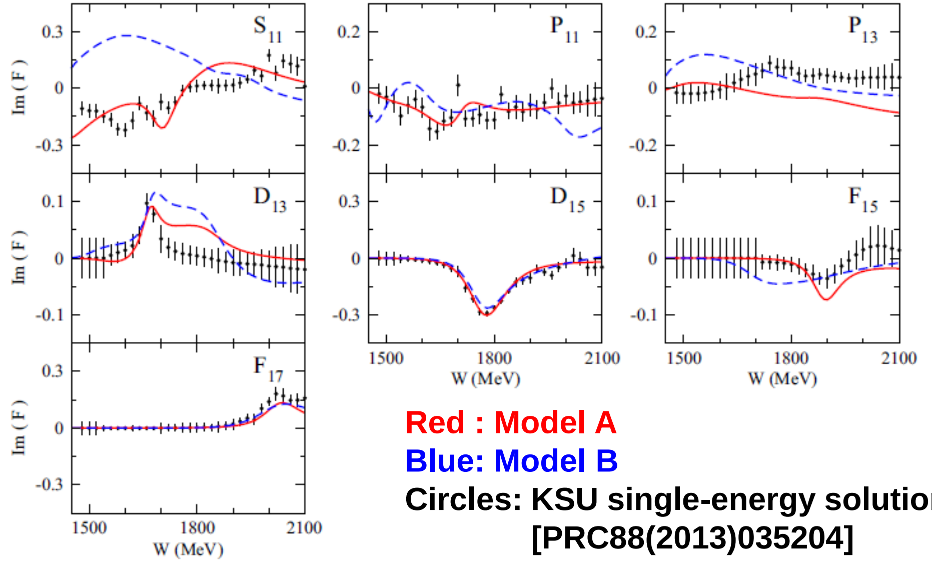
Extracted $\bar{K}N \rightarrow \pi\Lambda$ amplitudes

HK, Nakamura, Lee, Sato, PRC90(2014)065204

$L_{I\,2J}$: L = S,P,.. ; I = isospin; J = Total angular mom.

Sizable analysis dependence seen in S11 etc., even though the three analyses reproduce the available data equally well.





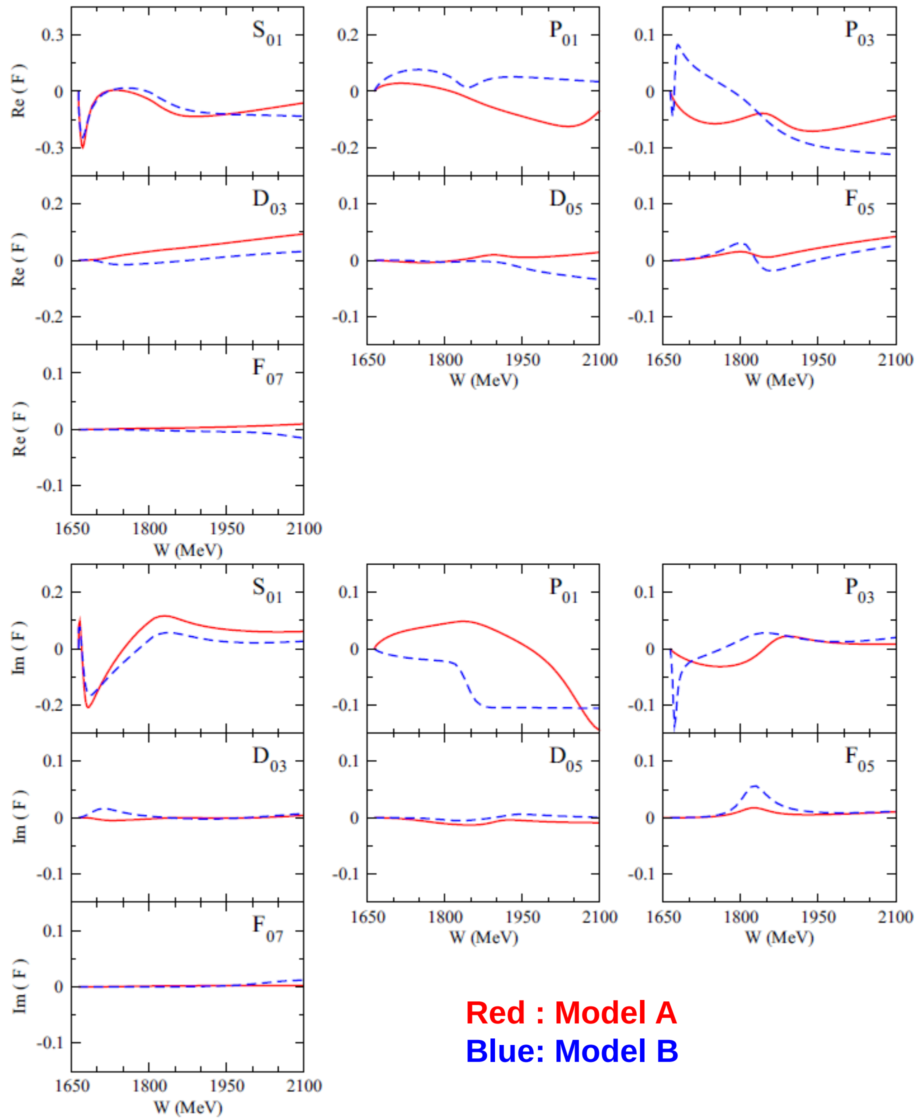
Red : Model A
Blue: Model B
Circles: KSU single-energy solution [PRC88(2013)035204]

Comparison of extracted partial-wave amplitudes

Extracted $\bar{K}N \rightarrow \eta\Lambda$ amplitudes

HK, Nakamura, Lee, Sato, PRC90(2014)065204

$L_{I\,2J}$: L = S,P,.. ; I = isospin; J = Total angular mom.



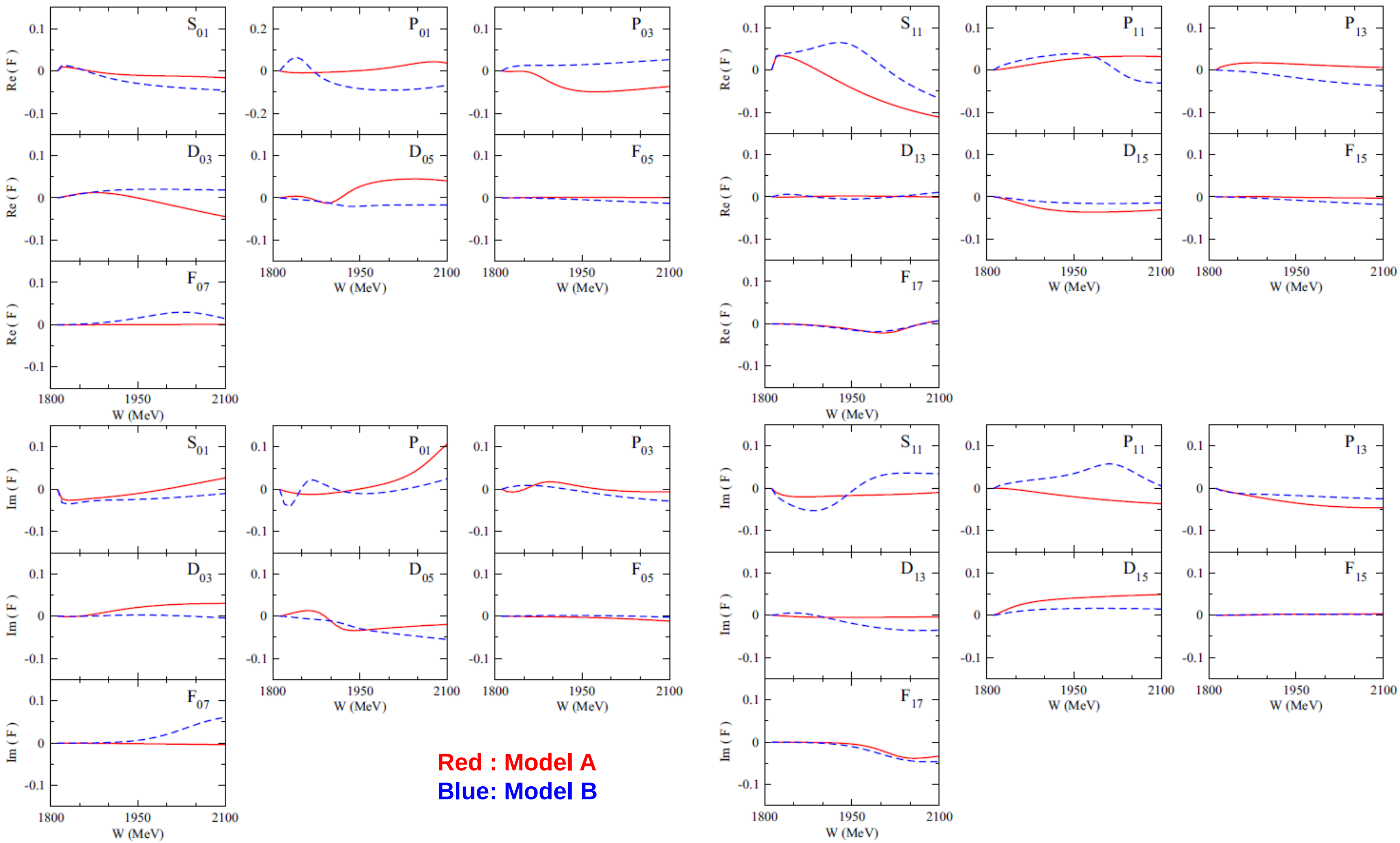
Red : Model A
Blue: Model B

Comparison of extracted partial-wave amplitudes

Extracted $\bar{K}N \rightarrow K\Xi$ amplitudes

HK, Nakamura, Lee, Sato, PRC90(2014)065204

$L_{I\,2J}$: L = S,P,.. ; I = isospin; J = Total angular mom.



Extracted scattering lengths and effective ranges

HK, Nakamura, Lee, Sato, PRC90(2014)065204

Scattering length and effective range

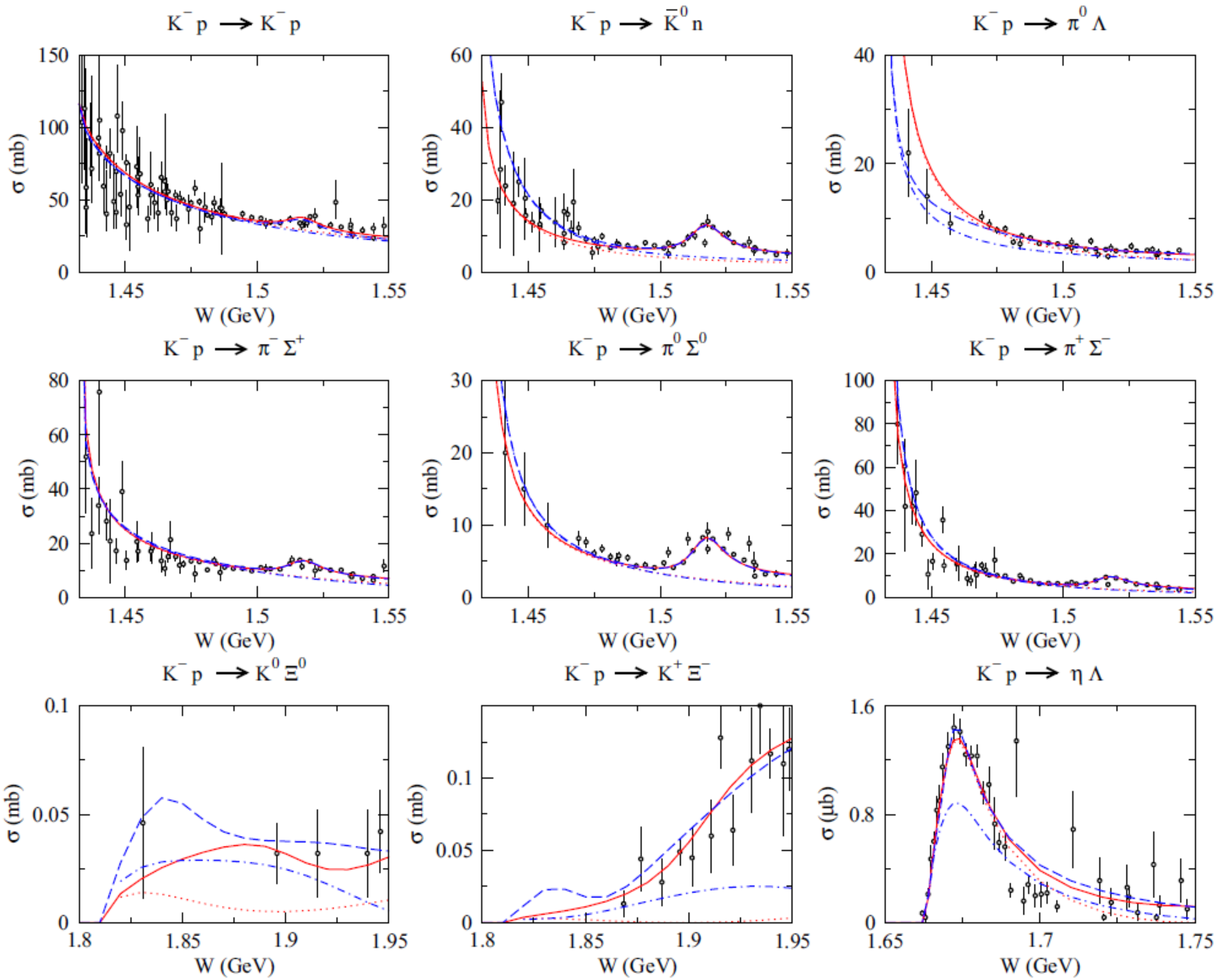
	Model A		Model B	
	$I=0$	$I=1$	$I=0$	$I=1$
$a_{\bar{K}N}$ (fm)	$-1.37+i0.67$	$0.07+i0.81$	$-1.62+i1.02$	$0.33+i0.49$
$a_{\eta\Lambda}$ (fm)	$1.35+i0.36$	-	$0.97+i0.51$	-
$a_{K\Xi}$ (fm)	$-0.81+i0.14$	$-0.68+i0.09$	$-0.89+i0.13$	$-0.83+i0.03$
$r_{\bar{K}N}$ (fm)	$0.67-i0.25$	$1.01-i0.20$	$0.74-i0.25$	$-1.03+i0.19$
$r_{\eta\Lambda}$ (fm)	$-5.67-i2.24$	-	$-5.82-i3.32$	-
$r_{K\Xi}$ (fm)	$-0.01-i0.33$	$-0.42-i0.49$	$0.13-i0.20$	$-0.22-i0.11$

$a_{K\text{-}p}$ = -0.65 + i0.74 fm (Model A)
$a_{K\text{-}p}$ = -0.65 + i0.76 fm (Model B)

S-wave contributions in the threshold region

$K^- p \rightarrow MB$ total cross sections

HK, Nakamura, Lee, Sato, PRC90(2014)065204



Red: Model A

Blue: Model B