NN, BB and MB Potentials in One-Hadron-Exchange Model

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Meson-Exchange Model of Nuclear Force
One-Hadron-Exchange Model of Pion-Nucleon Interaction
Baryon-Baryon(BB) Potentials
Meson-Baryon(MB) Potentials
One-Hadron-Exchange Model of Hadron-Hadron Interaction

(Feb. 27, 2009 @ Atami)

Meson-Exchange Model of Nuclear Force

Pion Theory of Nuclear Force

OPEP(by ***H. Yukawa***)

Resion I, II and III (by ***M. Taketani***)

Static Approximation and Dynamical Effect

Fourth-Order Potential(TPEP) ***TMO potential***

Strong Tensor Force in OPEP

Strong LS Force in Region II

One-Boson-Exchange Potential

Composite Model of Hadrons(by ***S. Sakata***)

Scalar and Vector Mesons

OPEP+TPEP+OBEP or OPEP+OBEP

Yukawa Interaction as a Model Hamiltonian

Difference from the Bootstrap Model

π, σ, ρ, ω

Hamada-Johnston

Reid

OPEG(***R. Tamagaki***)

OPEP+Phen.

Paris

OPEP+TPEP+Phen.SR

One-Hadron-Exchange Model of Pion-Nucleon Interaction

Description of πN interaction

Chew-Low Theory based on Yukawa interaction
p-wave interaction: **Relativistic Δ-isobar model**(***Oset, Toki and Weise***)
s-wave interaction: **ρ-meson exchange**

… we have seen that the πN interactions can be successfully described in terms of the pion, the nucleon, the Δ-isobar, and the ρ-meson considered as 'elementary' constituents. … (*Ericson and Weise*)

Pearce and Jennings, NPA528(1991)655.
Gross and Surya, PRC47(1993)703.
C. Schutz et al, PRC49(1994)2671, 51(1995)1374, 54(1996)2660, 57(1998)1464.
Sato and Lee,PRC54(1996)2660.
Pascalutsa and Tjon, PRC61(2000)054003.
O. Krehl, A.M. Gasparyan et al, PRC62(2000)025207

Baryon-Baryon(BB) Potentials

Extension to YN, YY and to BB

Phenomenological ΛN Potentials

Dalitz Herndon Tang

Range, Form

Spin-dependence

Meson-theoretical YN Potentials

Brown Downs Iddings

Nijmegen Potentials

Julich

OBEP for BB interaction

NSC, ESC

GSOBEP

Experimental Knowledge

ΛN scattering and Light Λ–Hypernuclei

'Overbinding Problem in $_{\Lambda}^{5}$He'

'Excitation Energy of $_{\Lambda}^{4}$He, $_{\Lambda}^{4}$H'

S-wave Interaction

NN and YN scattering data

Λ–Hypernuclei

Σ–Hypernuclei and Their widths

S- and P-wave Interaction

+ Double Λ Hypernuclei, Ξ-Hypernuclei

ΛΛ and ΞN Interaction

Meson-Baryon(MB) Potentials

One-Hadron-exchange Potentials for KN interaction
(with Fourth-order diagrams)

R. Buttgen, K. Holinde, et al, NPA506(1990)586.
H. Polinder and Th. A. Rijken, PRC72(2005)065210&065211.

One-Hadron-exchange Model for K^bN interaction
(with Fourth-order diagrams)

P.B. Siegel and W. Weise, PRC38(1988)2221.
A.Muller-Groeling, K. Holinde, et al., NPA513(1990)557.

KN Phase Shifts with Julich KN potential

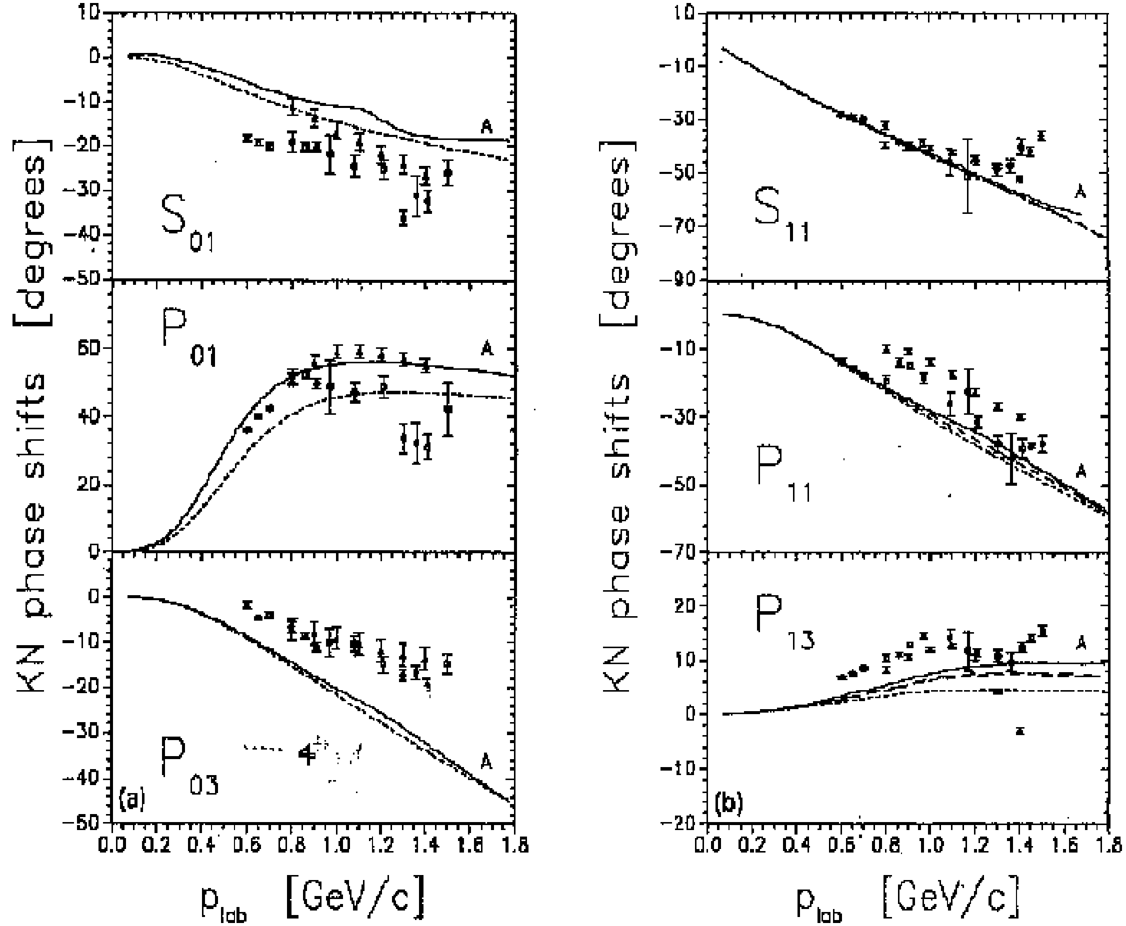


Fig. 4. K^+N scattering phase shifts as a function of the kaon laboratory momentum p_{lab} in various partial wave states $L_{I,2J}$. The solid lines denote the results predicted by model A. The dashed curves in isospin-zero states show the effect of omitting iterative processes with NK^* intermediate states in the potential of model A. For isospin-one states, the long-dashed curves originate from omitting ΔK^* contributions to model A. The medium-dashed curves are obtained if ΔK^* and NK^* contributions are omitted, whereas the short-dashed lines are obtained by omitting in addition the ΔK contributions. The empirical phase shifts are taken from Hashimoto [8]) (circles) and Watts *et al.* [10]) (triangles).

scalar meson(σ)
vector mesons(ρ,ω)
Λ,
Σ,
Y*
σ_0:Phenomenological
SR-Repulsion

Fourth-order diagrams

K^bN Phase Shifts with Julich KN potential

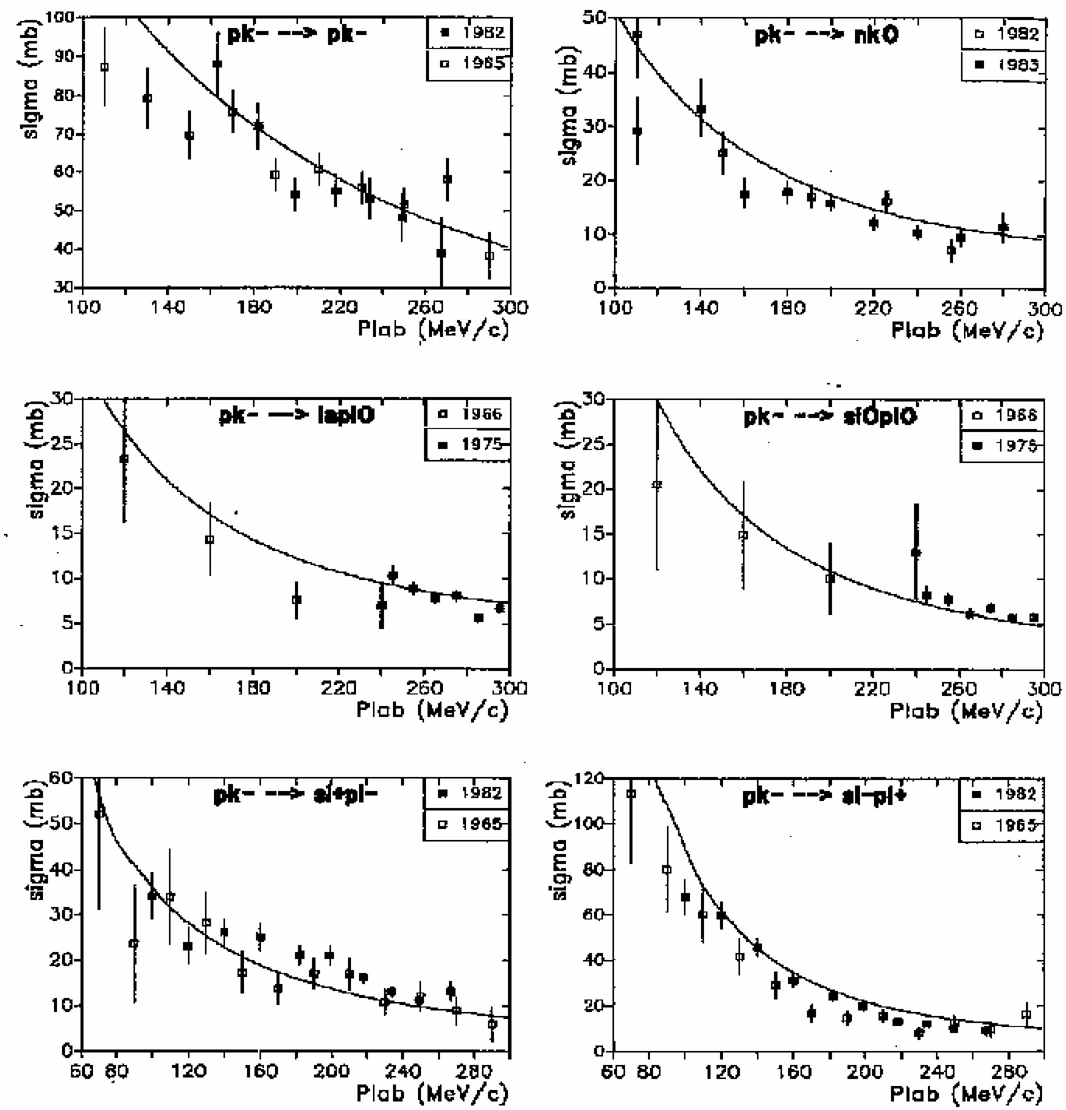


Fig. 5. Total cross sections in six different particle channels as predicted by model II which, in addition to model I, contains a pole graph motivated by $\Lambda(1670)$.

Not All Diagrams

scalar meson(σ)

vector mesons(ρ,ω,K^{b*})

Λ,

Σ,

σ_0:Phenomenological SR-Repulsion

Fourth Order Diagrams

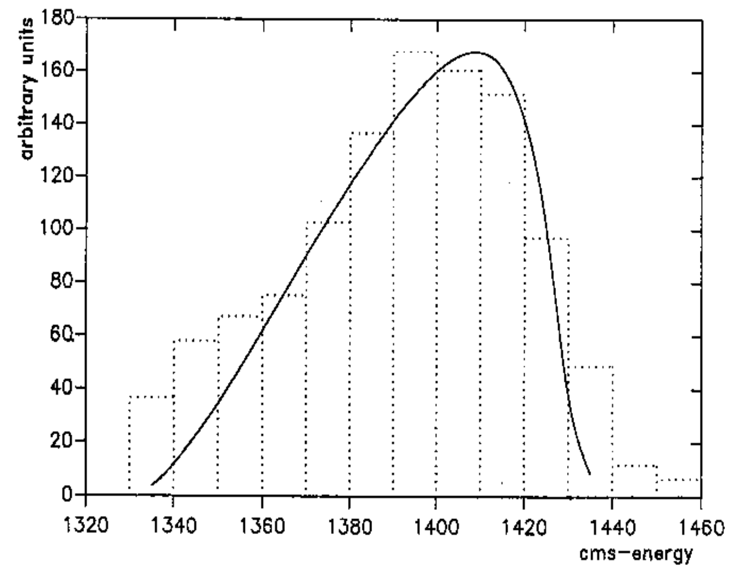


Fig. 6. The $\Lambda(1405)$ mass spectrum predicted by model II.

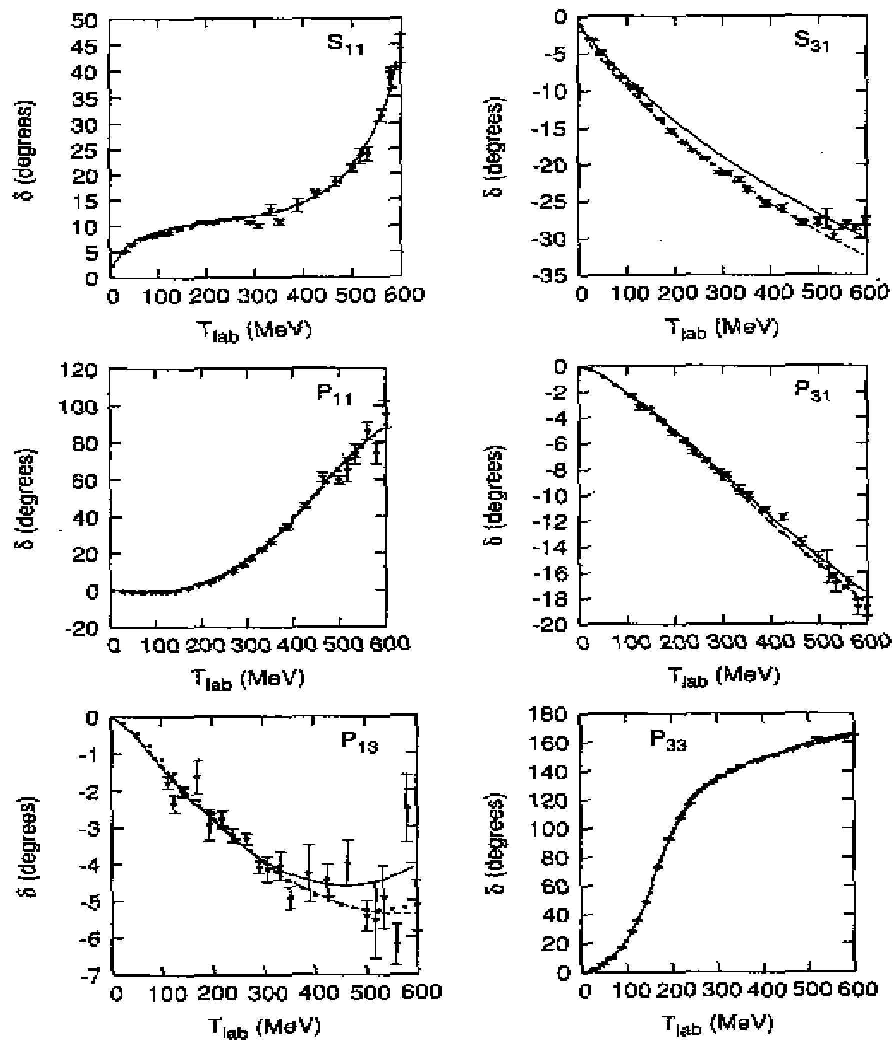


FIG. 8. S- and P-wave πN phase shifts δ as a function of T_{lab}. Empirical phases are from SM95 [21], dots are the multienergy phases, and triangles with error bars are the single-energy phases. NSC πN model is given by the solid lines; dashed line is the model without tensor mesons.

πN Phase Shift by NSC πN

by H. Polinder and Th. A. Rijken

scalar mesons(σ,f_0)

vector meson(ρ)

tensor mesons(f_2,f_2')

Pomeron

N

Δ

N*

S_{11}

KN Phase Shifts by NSC-KN

by H. Polinder and Th. A. Rijken

Not perfectly consistent with NSC πN
SU(3)-Breaking

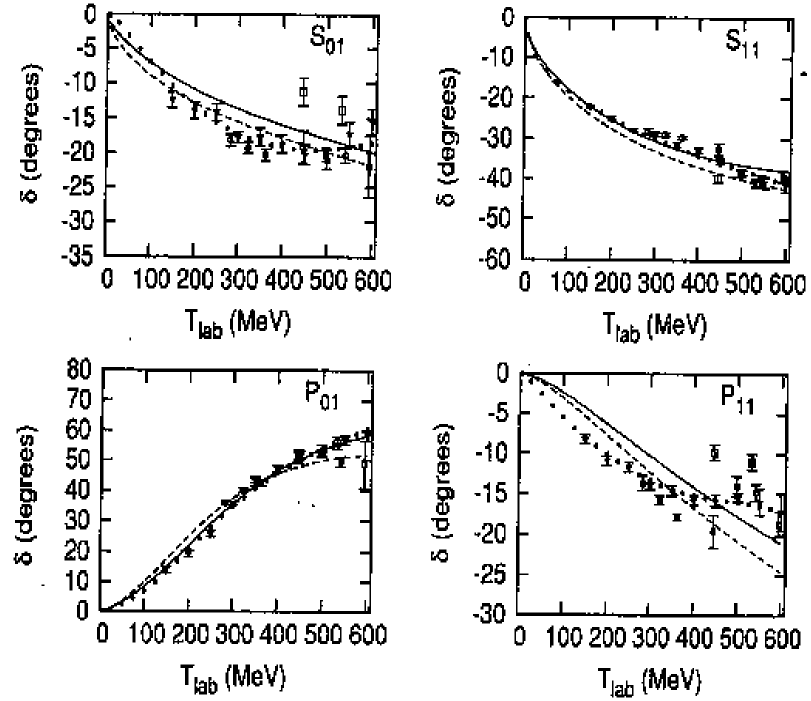


FIG. 13. S_{01}-, S_{11}-, P_{01}-, and P_{11}-wave K^+N phase shifts δ as a function of $T_{\rm lab}$. Empirical phases are from SP92 [44] multienergy phases (dots) and single-energy phases (filled triangles), [45] single-energy phases (open circles), and [46] single-energy phases (open squares). The NSC K^+N model is given by the solid line; the dashed line is the model without tensor mesons.

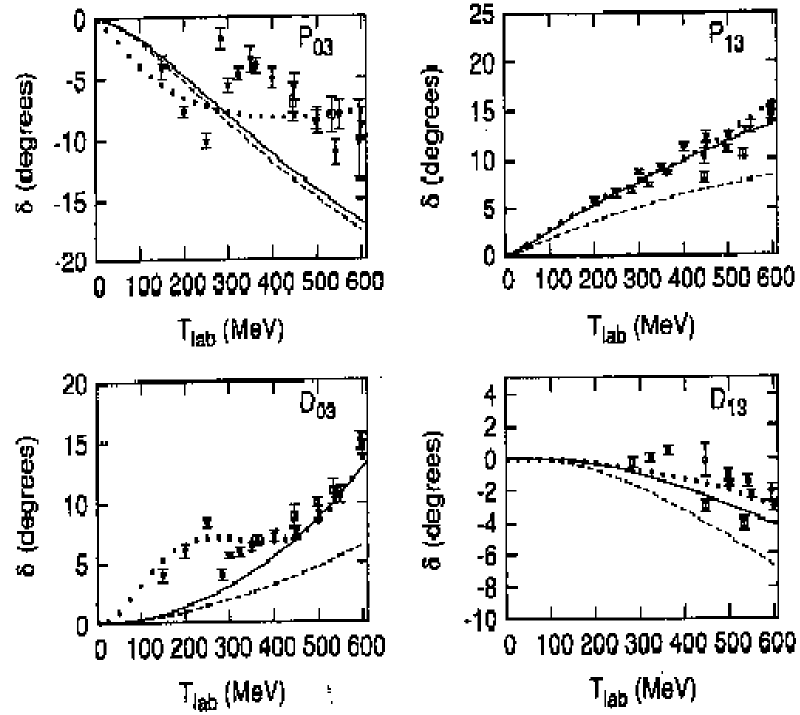


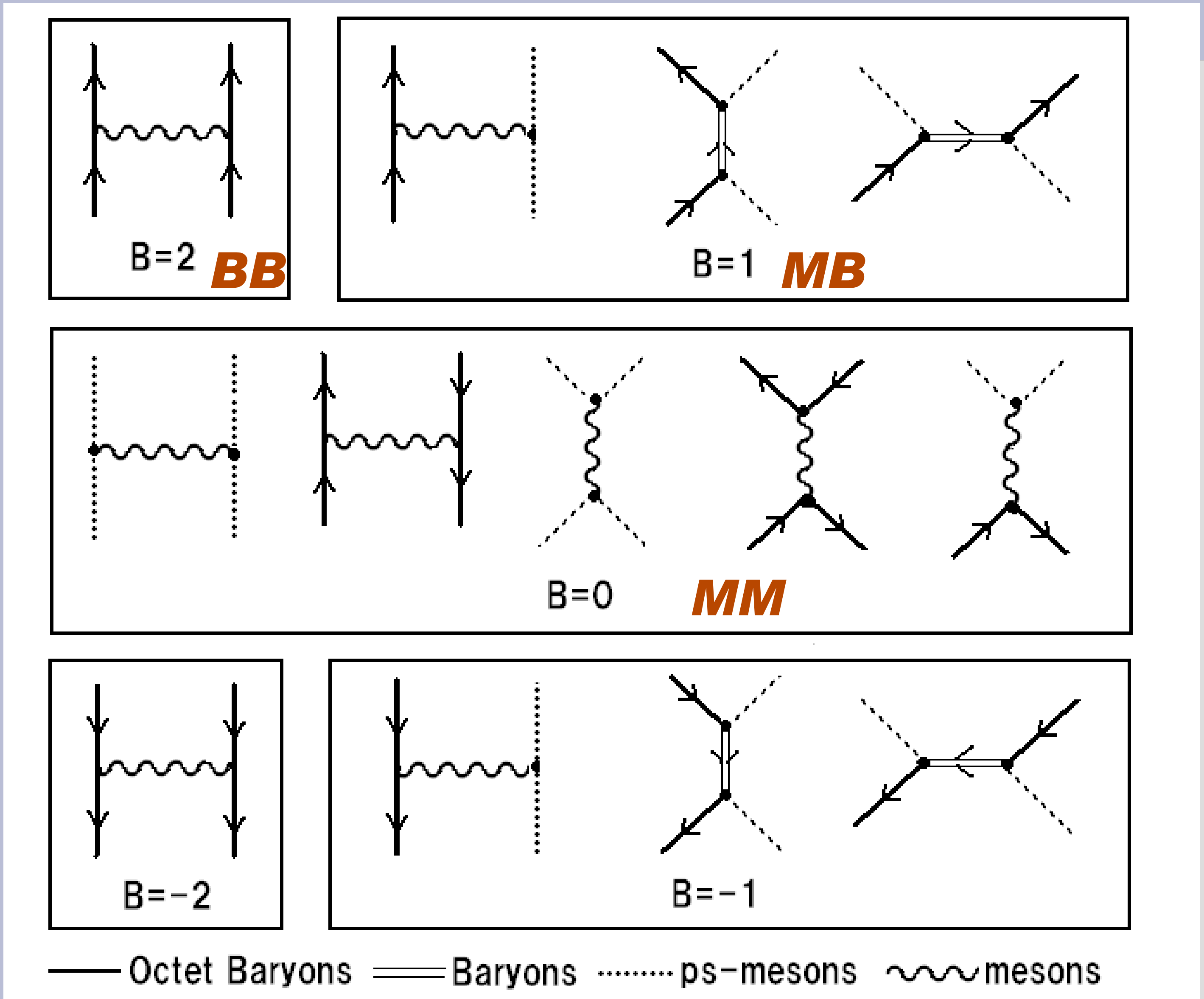
FIG. 14. As in Fig. 13, but for the P_{03}, P_{13}, D_{03}, and D_{13}-wave K^+N phase shifts.

One-Hadron-Exchange Model of Hadron-Hadron Interaction

One-Pion-Exchange Potential
One-Boson-Exchange Potentials for NN interaction
One-Hadron-Exchange Models of πN interaction
One-Boson-Exchange Potentials for YN and YY interactions
One-Hadron-Exchange Potentials for KN and K^bN interaction

* Exchanged hadrons
* The SU(3) symmetry
* Short Range Part
  (Phenomenological or Higher-Order Terms)

One-Hadron-Exchange Diagrams for Hadron-Hadron Interaction



Octet Baryons:

$p, n, \Lambda, \Sigma, \Xi$

pseudoscalar mesons:

$\pi, \eta, \eta', K, \bar{K}$

No hadronic loop !

Why?

model interaction between composite particles ?????

Meson-Baryon Potentials

Mesons:=Pseudoscalar Mesons
Baryons:=Octet Baryons

S= 1 sector: **KN**

S= 0 sector: **πN–ηN–KΛ KΣ**

S= -1 sector: **πΛ πΣ $\bar{K}$N ηΛ ηΣ KΞ ηΛ ηΣ**

S= -2 sector: **πΞ–ηΞ–$\bar{K}$Λ–$\bar{K}$Σ**

S= -3 sector: **$\bar{K}$Ξ**

p-space Meson-Baryon(MB) Potentials

$$V(p_f,p_i) = V_t(p_f,p_i) + V_u(p_f,p_i) + V_s(p_f,p_i)$$

$V_t(p_f,p_i)$ =meson−exchange diagrams

$V_u(p_f,p_i)$ =baryon−exchange diagrams

$V_s(p_f,p_i)$ =baryon−pole diagrams

$=\Gamma(p_f)\,\Gamma(p_i)\,/\,(s-M_B)$ for corresponding p.w.

$= Q(p_f)\,Q(p_i)$ for other partial waves (background contribution)

Exchanged Hadrons in MB potentials

πN : $\sigma, f_0, \rho, N, \Delta, N^*(1440), S_{11}(1567)$

KN : $\sigma, f_0, a_0, \rho, \omega, \phi, \Lambda, \Sigma, \Sigma^*(1385), \Lambda^*(1405)$

$\bar{K}N$: $\sigma, f_0, a_0, \rho, \omega, \phi, N, \Lambda, \Sigma, \Sigma^*(1385), \Lambda^*(1405)$

scalar mesons(0^+), vector mesons(1^-),
$1/2^+$ baryons, $1/2^-$ baryons, $3/2^+$ baryons

Result for πN and KN scattering

πN scattering lengths

	calc	exp
S11	0.2461	0.2473±0.0043
S31	−0.1162	−0.1444±0.0057
P11	−0.2363	−0.2368±0.0058
P31	−0.1281	−0.1316±0.0058
P13	−0.1020	−0.0877±0.0058
P33	0.6260	0.6257±0.0058

g881 = 0.085

g888 = -0.035

(Very weak σ-ex, f_0-ex)

KN scattering lengths

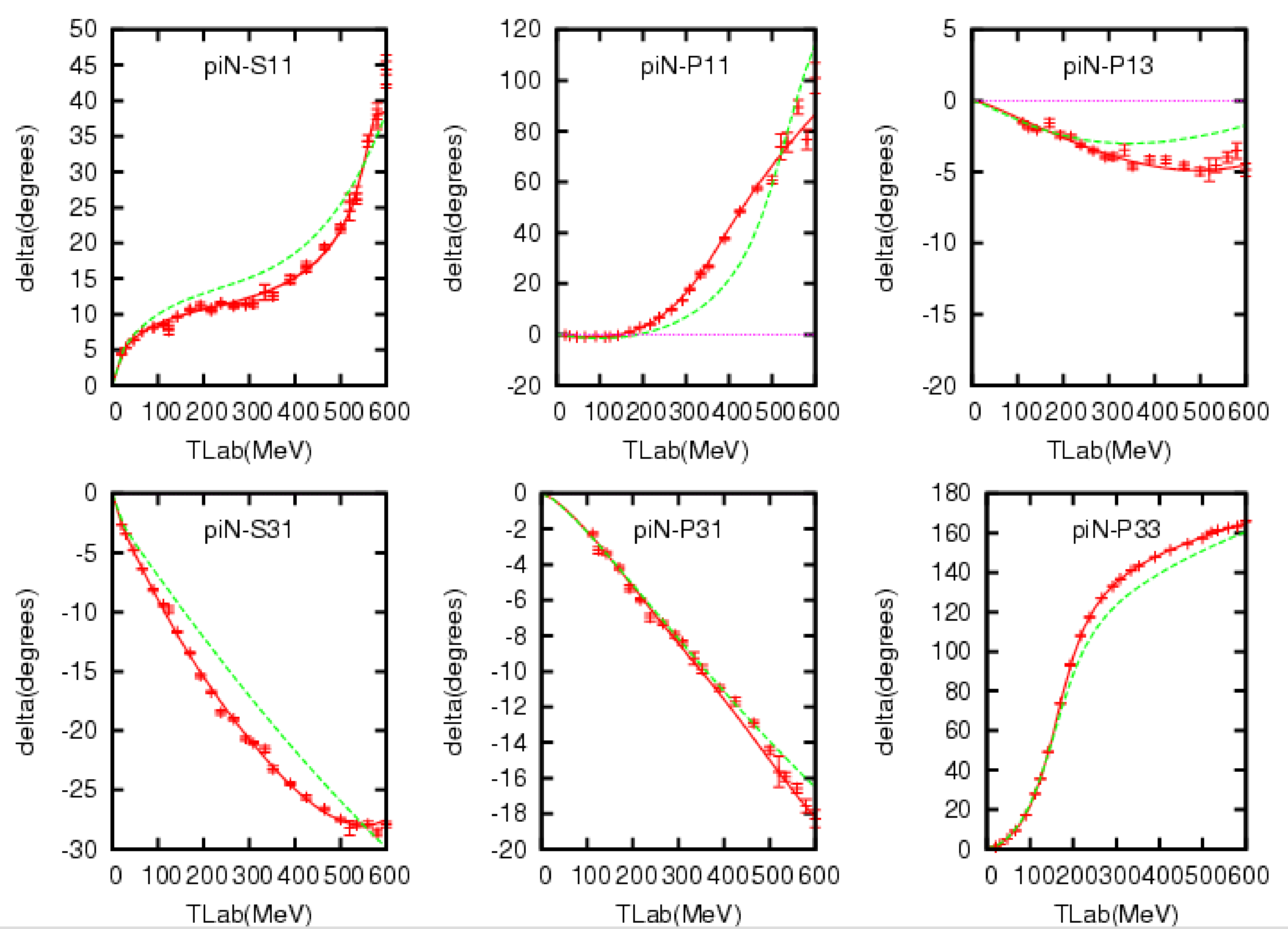
	calc	exp
S01	−0.016	+0.00±0.02
S11	−0.280	−0.33±0.02
P01	+0.059	+0.08±0.02
P11	−0.038	−0.16±0.02
P03	+0.039	−0.13±0.02
P13	0.008	+0.07±0.02

fm**(2L+1)

We obtain also

a reasonable fit

πN scattering Phase Shifts in S- and P-waves



Five possibilities

to explain a small scalar-meson contribution in πN potential

(1) A Phenomenological repulsive contributions (σ_0) cancel the σ-meson (Julich model)

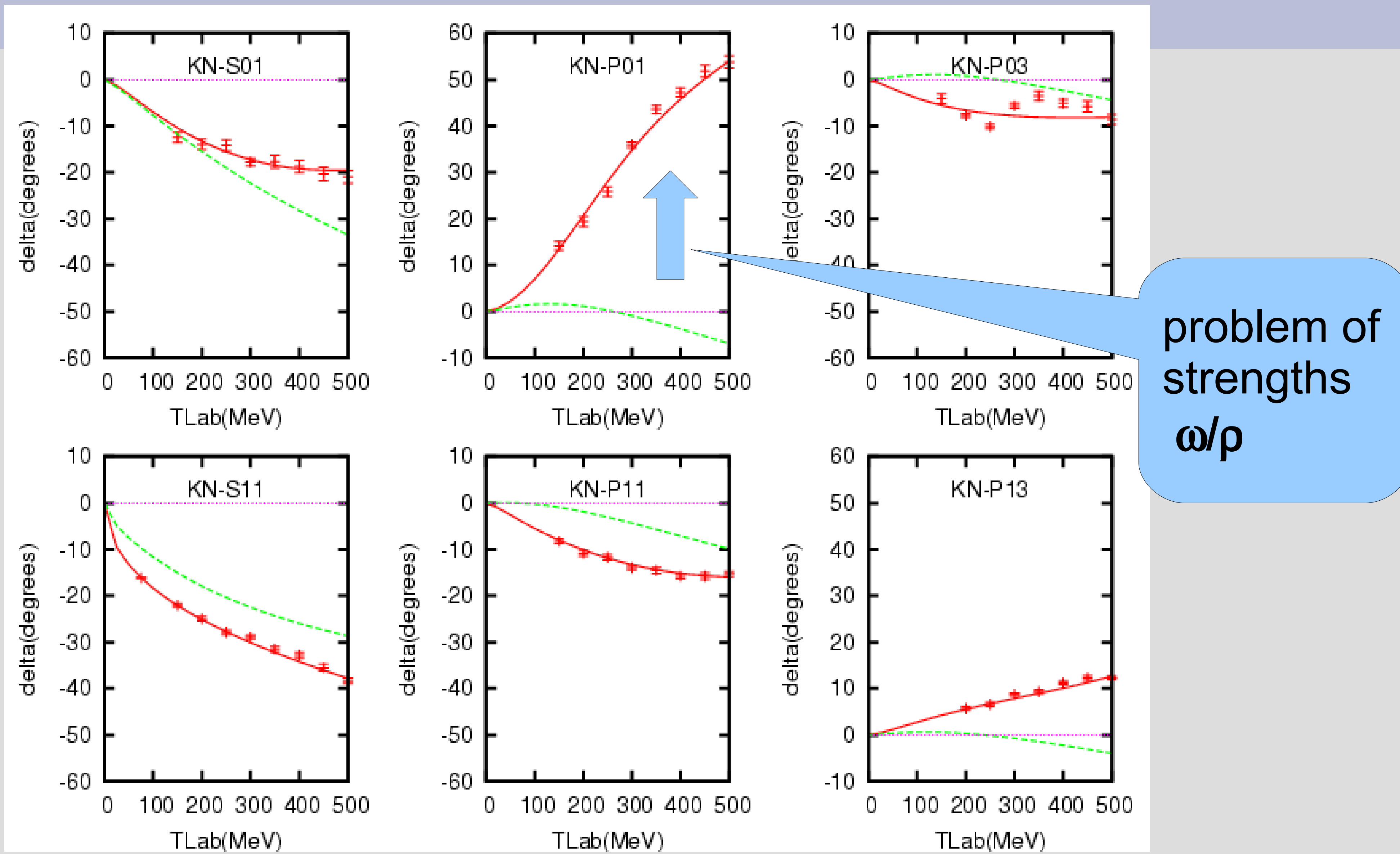
(2) **Pomeron** cancel the contributions from Scalar mesons (Nijmengen model)

(3) Direct and Derivative **$\pi\pi\sigma$-couplings** cancels each other (Pascalutsa and Tjon's model)

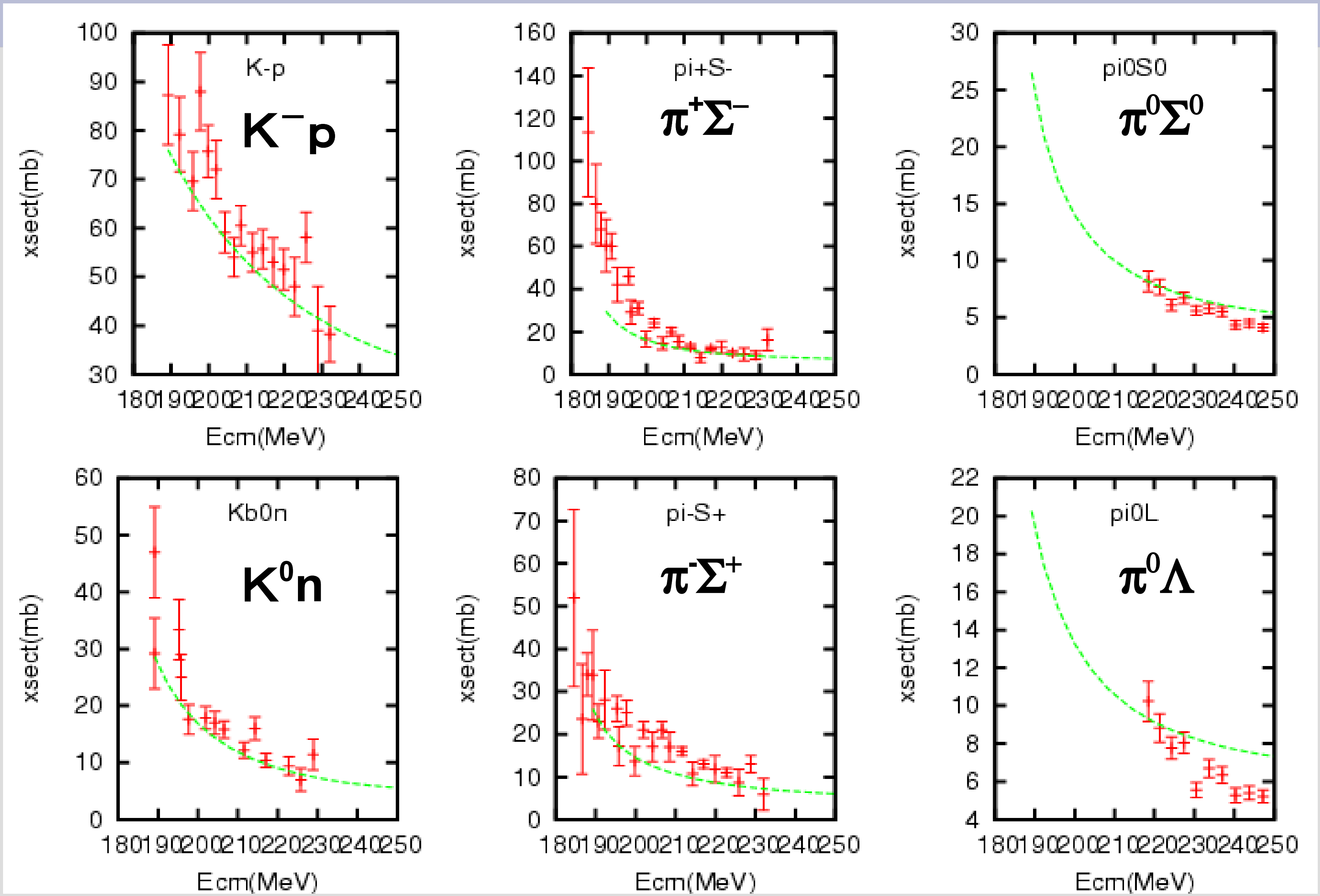
(4) Contributions from **σ and f_0** cancel each other out. Our model

(5) **σ-meson is discarded**(if derivative $\pi\pi$N coupling is used) Chiral symmetry model

KN scattering Phase Shifts in S- and P-waves



$K^{-}p$ sacttering Cross Sections



The Flavor-Singlet States

σ-meson = flavor-singlet state of M_8M_8 +···

= $\{\pi^+\pi^- + \pi^-\pi^+ + \pi^0\pi^0 + \eta_8\eta_8 + K^+K^- + K^-K^+ + K^0K^{b0} + K^{b0}K^0\}/\sqrt{8}$+···

D. Lohse et al., PLB234(1990)235

Λ*-baryon = flavor-singlet state of M_8B_8 +···

= $\{\pi^-\Sigma^+ + \pi^+\Sigma^- + \pi^0\Sigma^0 + \eta_8\Lambda + K^-p + K^{b0}n + K^0\Xi^0 + K^+\Xi^-\}/\sqrt{8}$+···

H-dibaryon = flavor-singlet state of B_8B_8 +···

= $\{\Sigma^+\Sigma^- + \Sigma^-\Sigma^+ + \Sigma^0\Sigma^0 + \Lambda\Lambda + p\Xi^- + n\Xi^0 + \Xi^-p + \Xi^0n\}/\sqrt{8}$+···

- Can we describe these states in a common picture?
- Lack of experimental Information

Summary

ハドロン間相互作用のハドロン交換モデルをつくる試み

One-Hadron-Exchnageの範囲内でどのような記述が可能か明らかにする。

ハドロンは広がりをもった「中間子（ハドロン）のソース」

ＳＵ（３）対称性、

ハドロンの物理的質量と幅

ＢＢ、ＭＢを結びつけた研究が必要

将来的には、Ｂ＝２（ＢＢ），１（ＭＢ），０（ＭＭ、ＢＢ）

ハドロン間の相互作用についての実験的知識

Flavor Singlet Statesについての実験的知識

ダブルハイパー核、

KbN、Kb-核散乱、Kb原子核の性質