Dynamical coupled-channels approach to the $\pi^- p \longrightarrow \eta n$ process

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EBAC Project

Meson 2008 - June 9^{th} 2008

Plan

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2. Theoritical framework
3. Free parameters, Database
4. Results
5. Summary and concluding remarks

Introduction

- $\pi N \to \eta N$: though (almost) no recent measurments, intensive development of coupled-channels approaches $MB \to M'B'$
- Important amount of high quality data on electromagnetic meson production (CLAS, ELSA, GRAAL, LEPS, MAMI) : $\gamma N \to \eta N$

$$\pi N \to \eta N$$
$$\gamma N \to \eta N$$

$\Rightarrow$ better knowledge of PDG'resonances

$\Rightarrow$ discovery of new resonances ?

Introduction

coupled-channels $\gamma N \rightarrow \pi N ... \rightarrow \eta N$

$\downarrow$

$\pi N \rightarrow MB \equiv \pi N, \eta N, \pi \Delta, \sigma N, \rho N \rightarrow \eta N$

$\hookrightarrow$ intermediate state dynamic

$\Rightarrow \pi N \rightarrow \eta N$ process study

Present work : $\pi^- p \rightarrow \eta n$

Derivation of coupled equations

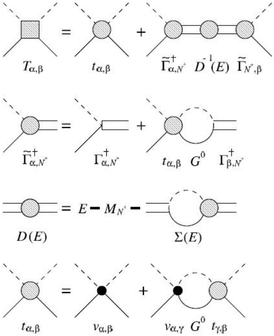
Lippman-Schwinger equation (potentials derived from a set of phenomenological Lagrangians) :

$$T(E) = V + V \frac{1}{E - H_0 + i\epsilon} T(E)$$

Standard projection operators technic in the $N^* \oplus \pi N \oplus \eta N \oplus \pi\Delta \oplus \sigma N \oplus \rho N$ space

$\longrightarrow$ the result can be written as (non-resonant term)+(resonant term)

$$T_{MB,M'B'}(E) = t_{MB,M'B'}(E) + t^R_{MB,M'B'}(E)$$



non-resonant + resonant

dressed resonant vertex

resonant self-energy

non-resonant T-matrix

Derivation of coupled equations (2)

non-resonant T-matrix

$$t_{MB,M'B'}(E) = v_{MB,M'B'} + \sum_{M''B''} v_{MB,M''B''} G_{M''B''}(E) t_{M''B'',M'B'}(E)$$

Resonant T-matrix

$$t^R_{MB,M'B'}(E) = \sum_{N_i^*,N_j^*} \bar{\Gamma}_{MB\to N_i^*}(E)[D(E)]^{-1}_{i,j}\bar{\Gamma}_{N_j^*\to M'B'}(E)$$

propagator :

$$[D(E)]^{-1}_{i,j} = \frac{1}{(E - M^0_{N_i^*})\delta_{i,j} - \bar{\Sigma}_{ij}(E)}$$

self-energy

$$\bar{\Sigma}_{ij}(E) = \sum_{MB} \Gamma_{N_i^*\to MB} G_{MB}(E) \bar{\Gamma}_{MB\to N_j^*}$$

vertex :

$$\bar{\Gamma}_{MB\to N*}(E) = \Gamma_{MB\to N*} + \sum_{M'B'} t_{MB,M'B'}(E) G_{M'B'}(E) \Gamma_{M'B'\to N*}$$

Process : $M(\vec{k}) + B(-\vec{k}) \longrightarrow M'(\vec{k'}) + B'(-\vec{k'})$

$$\frac{d\sigma}{d\Omega} = \frac{4\pi}{k^2}\rho_{M'B'}(k')\rho_{MB}(k)\frac{1}{(2j_M+1)(2j_B+1)} \sum_{m_{j_M},m_{j_B}} \sum_{m'_{j_M},m'_{j_B}} |< M'B'|T(E)|MB>|^2$$

Free parameters,Database

Study of the process $\pi N \longrightarrow \eta N$ with a coupled-channels formalism :

- 5 channels MB= $\pi N, \eta N, \pi\Delta, \sigma N, \rho N$
- 9 resonances : $S_{11}(1535)$, $S_{11}(1650)$, $P_{11}(1440)$, $P_{11}(1710)$, $P_{13}(1720)$, $D_{13}(1520)$, $D_{13}(1700)$, $D_{15}(1675)$, $F_{15}(1680)$

Free parameters :

- EBAC : $\pi N \longrightarrow \pi N$: 175 free parameters (10000 points)(Phys. Rev. C 76,065201 (2007))
- $\pi N \longrightarrow \eta N$: 29 most relevant parameters
  - non-resonant terms : 2 free parameters (with constraints)
    - $g_{\eta NN} \in [1; 5]$
    - $V_{\eta NN} \in [600; 1200]$ MeV
  - resonant terms : 3 free parameters per resonance (with constraints)
    - $M^0_{N*} \in [M^0 - 20MeV; M^0 + 20MeV]$
    - $g_{\eta NN*}$
    - Λ

Fitted database : 294 points (W$\leq 2GeV$). Most of the data are from the 80's $\rightarrow$ some inconsistencies. One set of data is from 2005.

Results

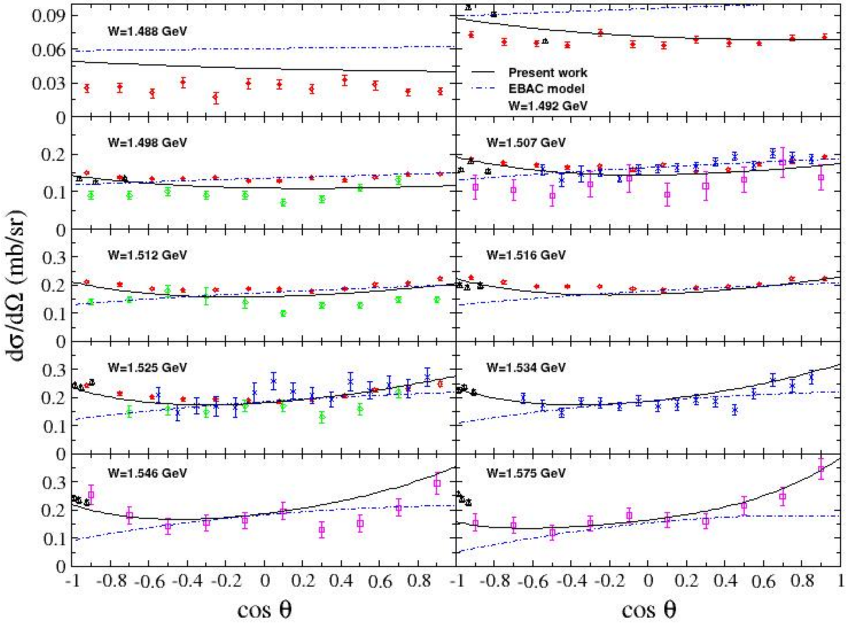
Two curves

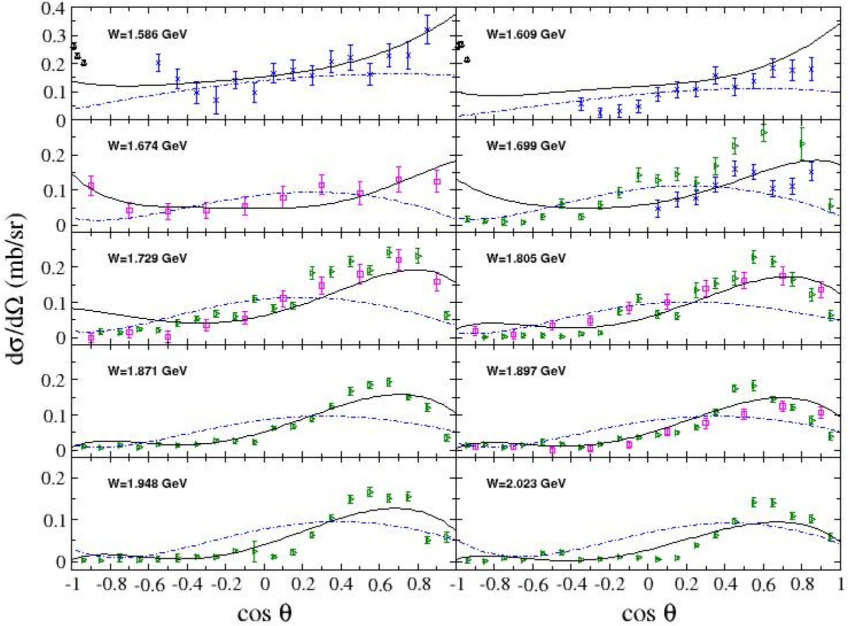
- Present work
- EBAC model (Phys. Rev. C 76,065201 (2007))

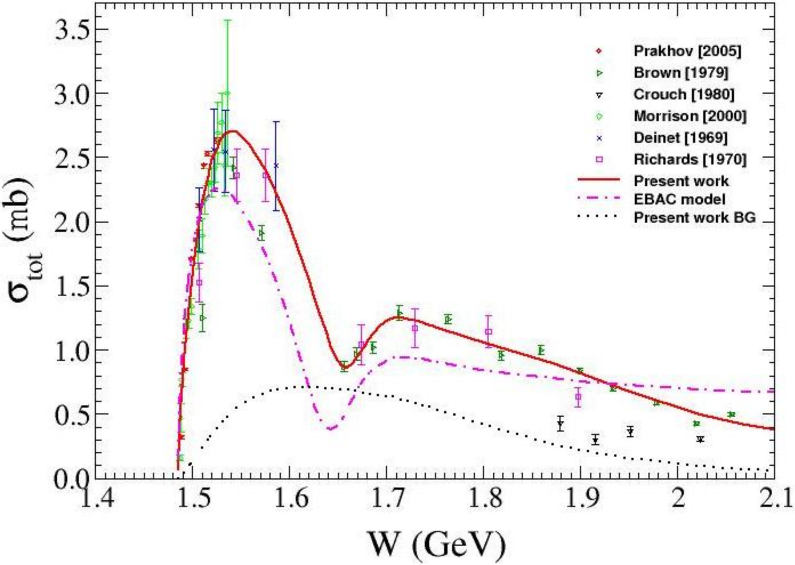
$\frac{d\sigma}{d\Omega}$ in the range $1.4GeV \leq W \leq 2GeV \Leftrightarrow 0.7GeV \leq p_{\pi lab} \leq 1.5GeV$

More details in the manuscript :

arXiv :0804.3476v1 [nucl-th] 22 Apr 2008
J.Durand, B. Julià-Diaz, T.-S.H.Lee, B.Saghai and T. Sato


W=1.488 GeV
Present work
EBAC model
W=1.492 GeV
W=1.498 GeV
W=1.507 GeV
W=1.512 GeV
W=1.516 GeV
W=1.525 GeV
W=1.534 GeV
W=1.546 GeV
W=1.575 GeV
dσ/dΩ (mb/sr)
cos θ
cos θ


W=1.586 GeV
W=1.609 GeV
W=1.674 GeV
W=1.699 GeV
W=1.729 GeV
W=1.805 GeV
W=1.871 GeV
W=1.897 GeV
W=1.948 GeV
W=2.023 GeV
dσ/dΩ (mb/sr)
cos θ
cos θ



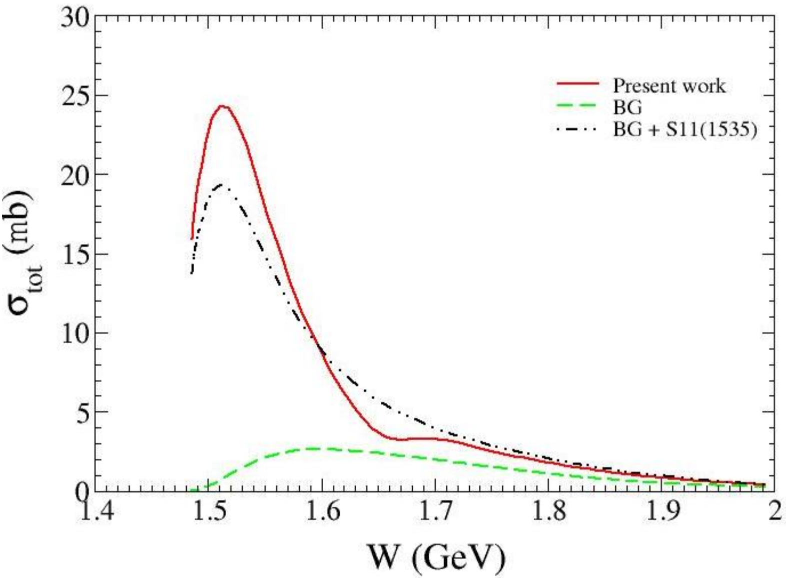
Prakhov [2005]
Brown [1979]
Crouch [1980]
Morrison [2000]
Deinet [1969]
Richards [1970]
Present work
EBAC model
Present work BG
σ_{tot} (mb)
W (GeV)

Prediction of the scattering length for the process $\eta N \longrightarrow \eta N$:

$$a_{\eta N} = (0.301 + i0.182) \text{ fm}$$

$$Re(a_{\eta N}) \in [0; 1] \text{ fm et } Im(a_{\eta N}) \in [0; 0.5] \text{ fm}$$

Phy. Rev C 72,045202 (2005)



Present work
BG
BG + S11(1535)
σ_tot (mb)
W (GeV)
30
25
20
15
10
5
0
1.4
1.5
1.6
1.7
1.8
1.9
2

Summary and conclusions

$$\pi^- p \longrightarrow \eta n$$

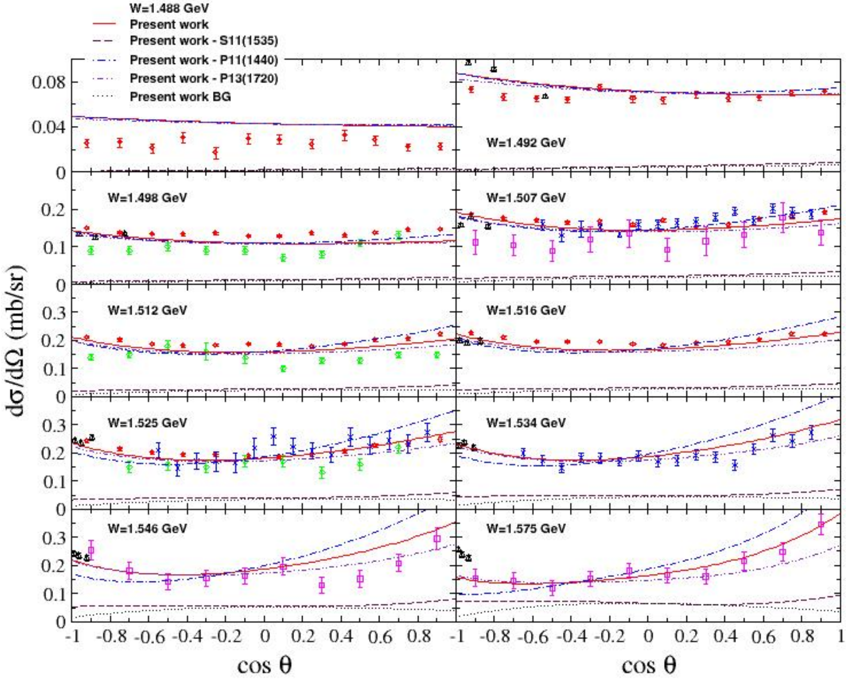
- Coupled-channels formalism : $MB = \pi N, \eta N, \pi\Delta, \sigma N, \rho N$

  $\frac{d\sigma}{d\Omega}$ in the range $1.4 GeV \leq W \leq 2 GeV$

- reaction mechanism : $S_{11}(1535), P_{11}(1440), P_{13}(1720), S_{11}(1650), F_{15}(1680), P_{11}(1710), D_{13}(1520), D_{15}(1675), D_{13}(1700)$

  $\Rightarrow$ model ready for the next step : $\gamma p \longrightarrow MB \longrightarrow \eta n$

  Moreover, ηN scattering length and total cross section prediction


W=1.488 GeV
Present work
Present work - S11(1535)
Present work - P11(1440)
Present work - P13(1720)
Present work BG
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dσ/dΩ (mb/sr)
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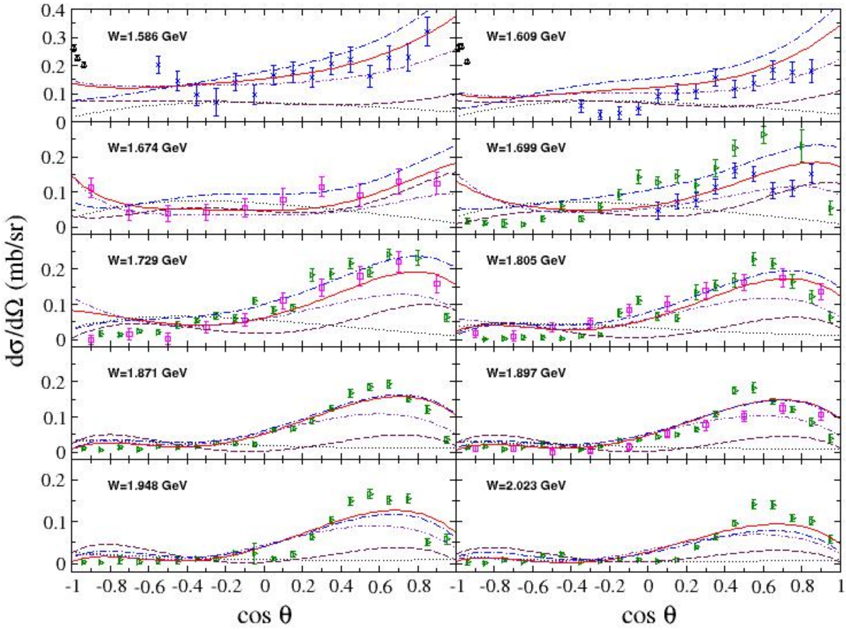
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