S_{11} resonances in meson baryon production

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FZ Jülich, University of Georgia

Narrow Nucleon Resonances 2009:
Predictions, Evidences, Perspectives

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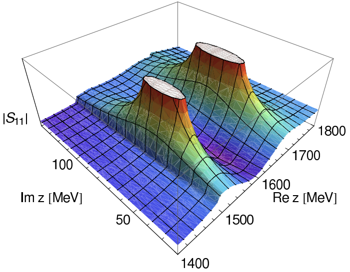
Resonances in πN scattering [M.D., C. Hanhart, F. Huang, S. Krewald, U.-G. Meißner, 0903.4337 [nucl-th]]

The Jülich model of meson exchange.



	Re z_0 [MeV]	-2 Im z_0 [MeV]	$\|R\|$ [MeV]	θ [deg] $[^0]$
$N^*(1440)\ P_{11}$	1387	147	48	-64
ARN	1359	162	38	-98
HOE	1385	164	40	
CUT	1375±30	180±40	52±5	-100±35
$N^*(1520)\ D_{13}$	1505	95	32	-18
ARN	1515	113	38	-5
HOE	1510	120	32	-8
CUT	1510±5	114±10	35±2	-12±5

	Re z_0 [MeV]	-2 Im z_0 [MeV]	$\|R\|$ [MeV]	θ [deg] $[^0]$
$N^*(1535)\ S_{11}$	1519	129	31	-3
ARN	1502	95	16	-16
HOE	1487			
CUT	1510±50	260±80	120±40	+15±45
$N^*(1650)\ S_{11}$	1669	136	54	-44
ARN	1648	80	14	-69
HOE	1670	163	39	-37
CUT	1640±20	150±30	60±10	-75±25
$N^*(1720)\ P_{13}$	1663	212	14	-82
ARN	1666	355	25	-94
HOE	1686	187	15	
CUT	1680±30	120±40	8±12	-160±30
$\Delta(1232)\ P_{33}$	1218	90	47	-37
ARN	1211	99	52	-47
HOE	1209	100	50	-48
CUT	1210±1	100±2	53±2	-47±1
$\Delta^*(1620)\ S_{31}$	1593	72	12	-108
ARN	1595	135	15	-92
HOE	1608	116	19	-95
CUT	1600±15	120±20	15±2	-110±20
$\Delta^*(1700)\ D_{33}$	1637	236	16	-38
ARN	1632	253	18	-40
HOE	1651	159	10	
CUT	1675±25	220±40	13±3	-20±25
$\Delta^*(1910)\ P_{31}$	1840	221	12	-153
ARN	1771	479	45	+172
HOE	1874	283	38	
CUT	1880±30	200±40	20±4	-90±30

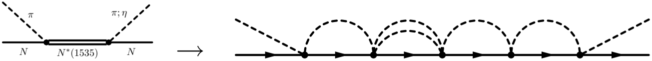
[ARN]: Arndt et al., PRC 74 (2006), [HOE]: Höhler, πN Newsl. 9 (1993), [CUT]: Cutkowski et al., PRD 20 (1979).

No pole term in the potential for the Roper; still a pole in the complex plane

The $N^*(1535)$ as a dynamically generated resonance

N. Kaiser et al., PLB **362** (1995) 23, NPA **612** (1997) 297,
T. Inoue *et al.*, PRC **65** (2002) 035204
Nieves, Ruiz Arriola, PRD 64 (2001)

- From the resonance picture to multiple rescattering:



- $(0^-)_M \otimes (1/2^+)_B$ in $SU(3)$: Coupled channels in $S = Q = 0$ are πN, ηN, $K\Sigma$, $K\Lambda$.
- Interaction from the LO chiral Lagrangian: (Isovector) Weinberg-Tomozawa interaction.
- Unitarization through the Bethe-Salpeter equation

$$T = (1 - VG)^{-1}\, V.$$

- $N^*(1535)$: Quasi-bound $K\Lambda$, $K\Sigma$ state

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Photon coupling to the $N^*(1535)$

[Talk K. Nakayama on the ECT* PWA meeting, Trento June 2009]

- Electromagnetic properties provide independent tests, because the couplings of the photon to the constituents of the resonances are well known. Parameter-free predictions are possible.

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Additional degrees of freedom

Phase problem as explained in K. Nakayamas talk on the ECT* PWA Workshop Trento 06/2009.

- The $N^*(1650)$: Closeby resonance with the $N^*(1535)$'s quantum numbers $\rightarrow$ interfering resonances
- Could the $N^*(1535)$ be genuine? $\rightarrow$ put it as a resonance!
- $\rightarrow$ Include two genuine pole terms $\delta V_{ij} \sim \frac{g_i\, g_j}{(\sqrt{s}-M)}$ in the potential.
- Consider all available data on pion- and photon-induced reactions.
- Adjust the parameters: subtraction constants, couplings of the genuine resonances.
- With the following results:

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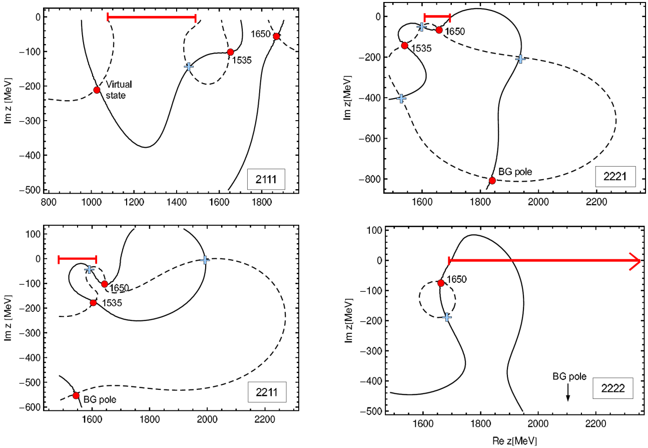
Pole structure

Schematic picture; explained in greater detail in K. Nakayama's talk, ECT*/Trento/06/2009.



Implications for fits using subthreshold resonances:

The $N^*(1535)$ may be gone!

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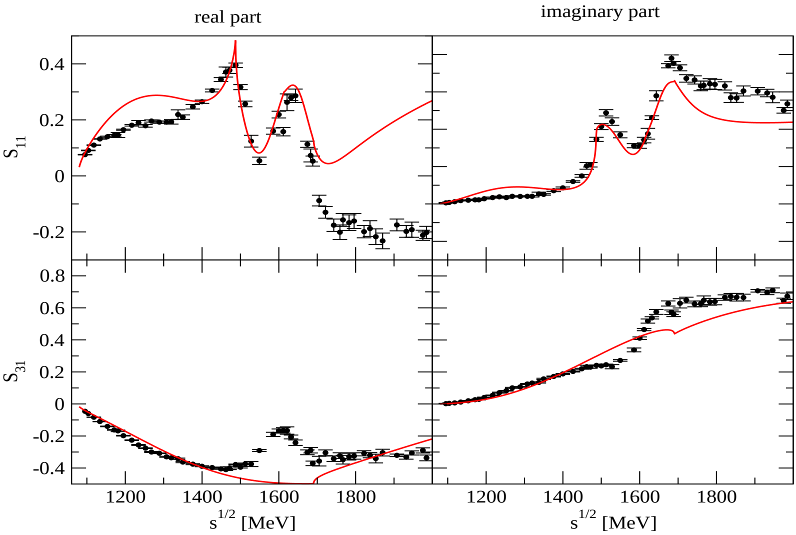
$\pi N \to \pi N$



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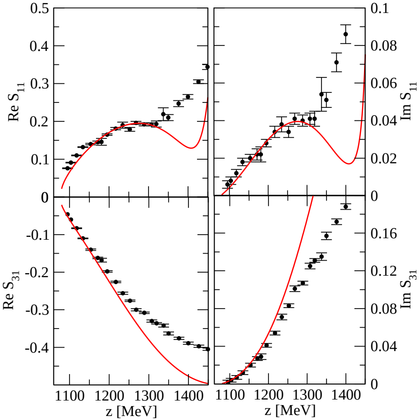
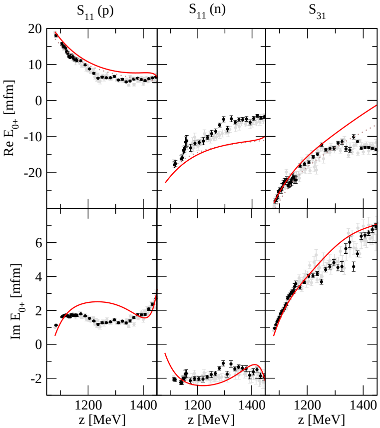
$\pi N \rightarrow \pi N$ at low energies

Refit; no genuine resonance terms.





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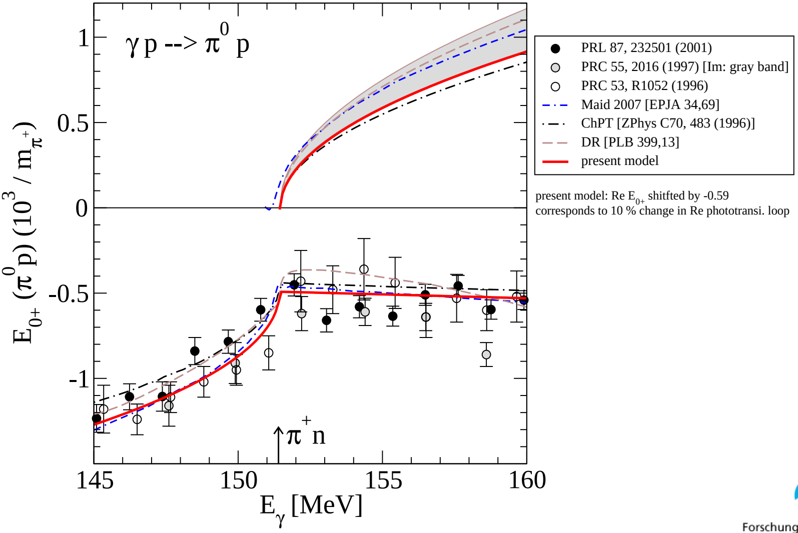
$\gamma p \to \pi^0 p$ at threshold



present model: Re E_{0+} shitfted by -0.59
corresponds to 10 % change in Re phototransi. loop

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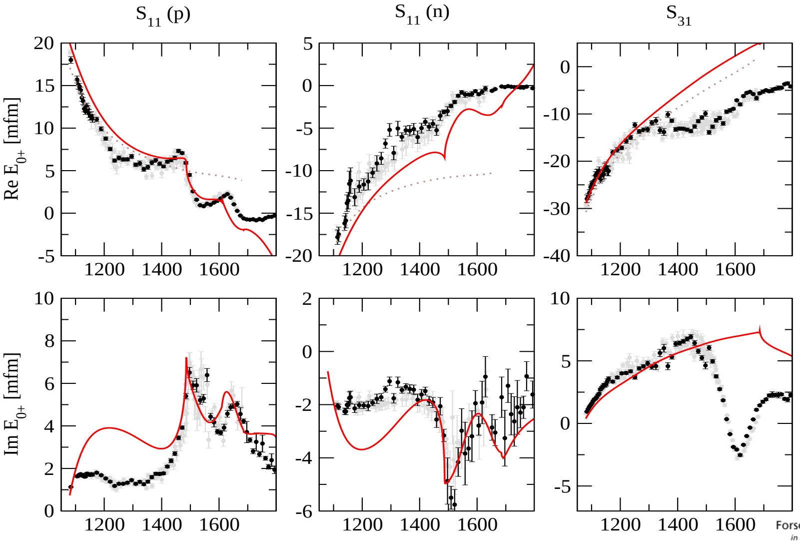
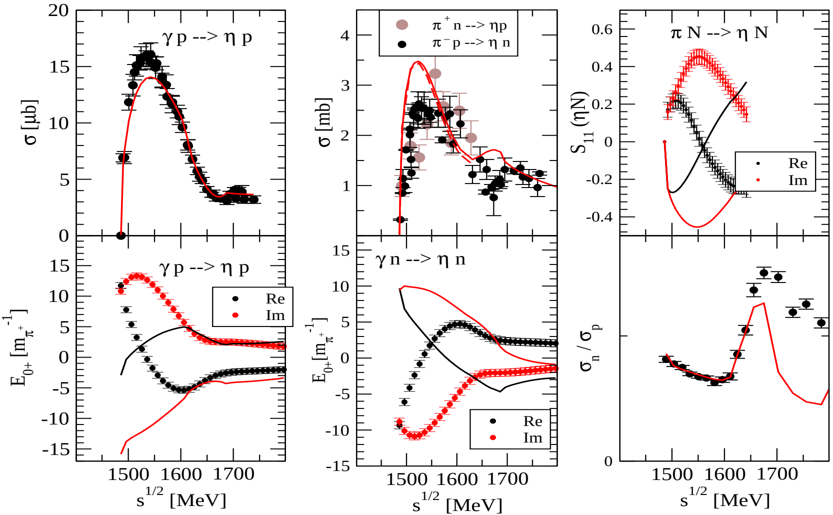
$\gamma N \to \pi N$



η related quantities



E_{0+} amplitudes: ETA MAID, S_{11} (ηN): Arndt

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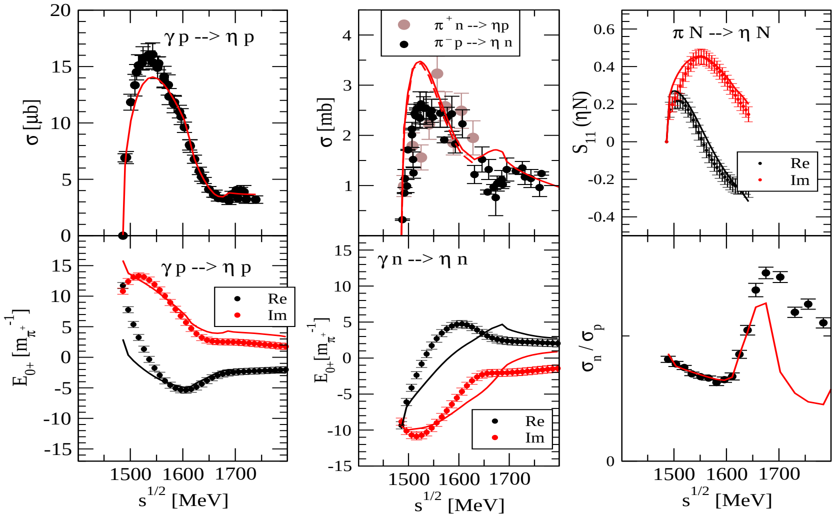
η related quantities



E_{0+} amplitudes: ETA MAID, S_{11} (ηN): Arndt

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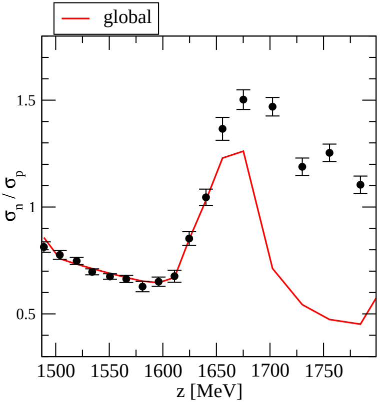
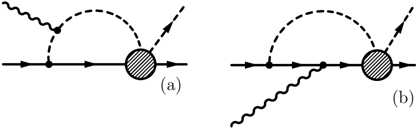
The ratio $\frac{\sigma(\gamma n \to \eta n)}{\sigma(\gamma p \to \eta p)}$ Fermi motion not yet included.



- Intermediate states in photon loops, $Q = 0,\ 1$:
- $\pi^- p$, $\pi^0 n$, ηn, $K^0\Lambda$, $K^+\Sigma^-$, $K^0\Sigma^0$
- $\pi^0 p$, $\pi^+ n$, ηp, $K^+\Lambda$, $K^+\Sigma^0$, $K^0\Sigma^+$



$$a^{\gamma}_{-1} = g_\gamma\, g_j, \quad g_\gamma = \sum_{i=1}^{6} \tilde{\Gamma}^i g_i,$$

$$i\,\tilde{M}^{\rm PA} = \frac{a^{\gamma}_{-1}}{z - z_0}.$$

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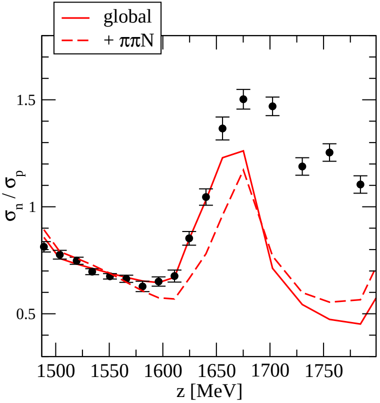

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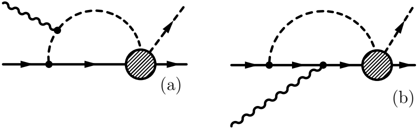

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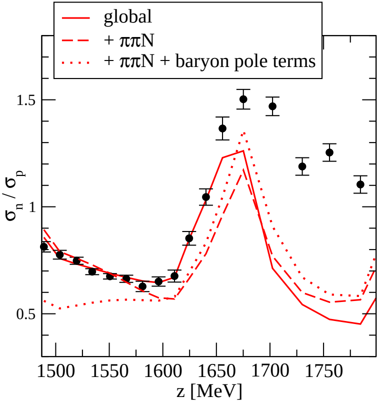

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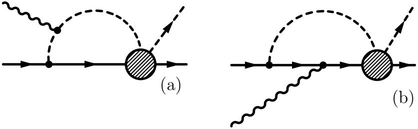

$$a_{-1}^{\gamma} = g_\gamma\, g_j, \quad g_\gamma = \sum_{i=1}^{6} \tilde{\Gamma}^i g_i,$$

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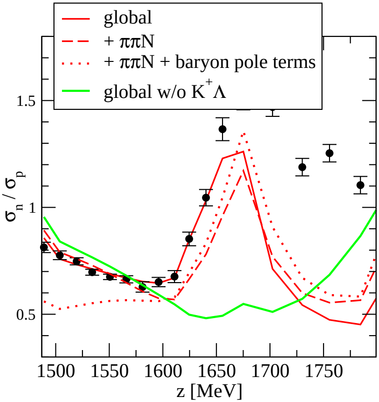

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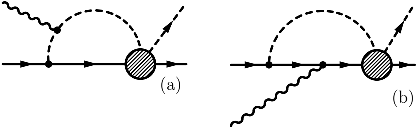

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- $SU(3)$ loop structure explains naturally the excess in σ_n.

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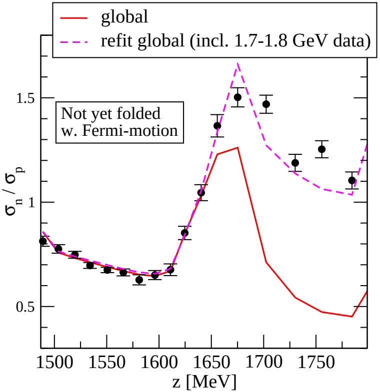

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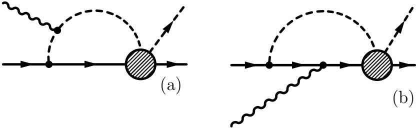

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Remarks on σ_n/σ_p

- Full $SU(3)$ structure appears in intermediate photon loops of the $U\chi PT$ model (not considered in many phenomenological models).
- Structure in σ_n/σ_p appears from coupling of the γ to the $K\Lambda$ intermediate state (in interference with all other SU(3) allowed states).
- This is connected to:
  - Strong coupling of the S_{11} partial wave to $K\Lambda$, $K\Sigma$, ηN...
  - One of the consequences being a dynamically generated $N^*(1535)$, but rather think of an energy dependent amplitude.
- The excess in $\sigma_n \equiv \sigma(\gamma n \to \eta n)$ appears as a pure interference effect in S_{11}, from 1535 and 1650, but – more important – intermediate photon loops with full $SU(3)$ structure. Signs of this have always been there.
- The excess in σ_n appears qualitatively in different coupled channel models that comprise SU(3) structure plus unitarization. It appears in fits where σ_n/σ_p is not included (the rest is fine tuning) $\pi\pi N$ in ηN production.
- Full rise and fall in σ_n/σ_p appears after including the $N^*(1650)$.
- Isospin limit, no genuine states, only πN photon loop: $\sigma_n/\sigma_p \equiv 1$

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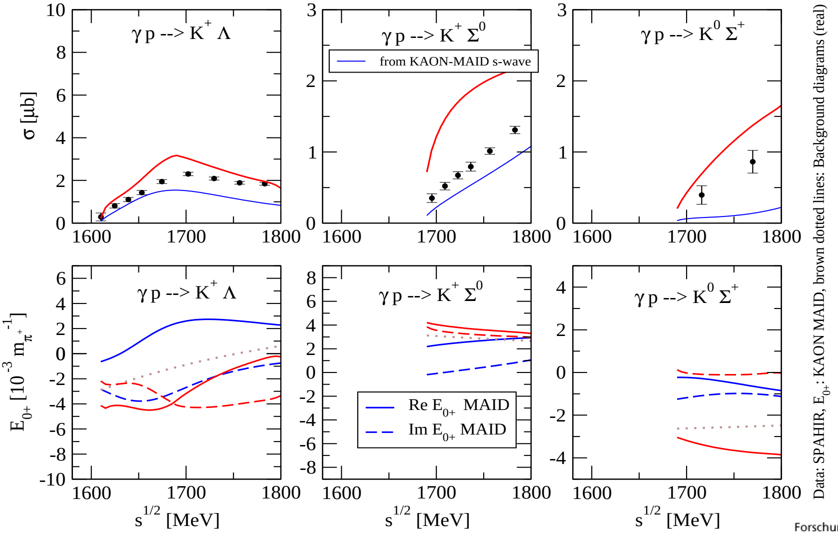
$\gamma N \longrightarrow KY$ [$\pi N \longrightarrow KY$ of similar quality $\pi N \longrightarrow KY$]



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Properties of the present solution

- Combined analysis of reactions in S_{11} and S_{31}, for
  - πN and γN initial state.
  - πN, ηN, $K\Lambda$, $K\Sigma$ final state.
- Features of the solution (decided by the fit):
  - Dynamically generated $N^*(1535)$.
  - Genuine pole term for the $N^*(1650)$ (resonance interferenc with $N^*(1535)$).
  - Second genuine pole far in complex plane produces small background instead of replacing the $N^*(1535)$. Mostly needed for missing t channel meson exchange with anomalous photon couplings.
  - Dynamical generation of virtual state close to threshold. May be genuine or "mock up" of subthreshold cuts.
  - Some need for higher chiral interactions at low energies is seen (too much strengths below the ηN threshold); $\pi\pi N$ channel could be included.
- Simultaneous description of different ηN cusps (forms, strengths) and $N^*(1535)$ phases in $S_{11}(\pi N \to \pi N)$, $E_{0+}(\gamma p)$, $E_{0+}(\gamma n)$.
- Photon coupling to intermediate πN, $K\Lambda$, $K\Sigma$ can explain σ_n/σ_p in $\gamma N \to \eta N$.

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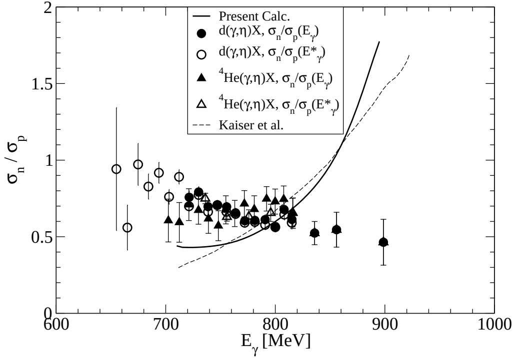
Previous results

back

The rise in σ_n/σ_p observed in different models.



The rise has been observed in previouse models that comprise the full space of SU(3) allowed channels. No Fermi motion included

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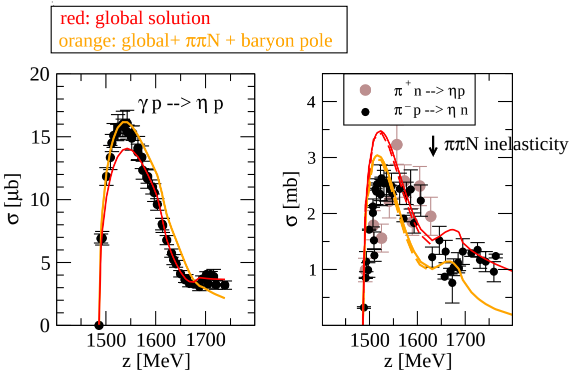
$\pi\pi N$ in ηN production

back



Necessary inelasticity from $\pi\pi N$ to bring the cross section in $\pi N \to \eta N$ down from $3.5\mu b$; consequence of unitarity and inelasticity [Argument by C. Hanhart].

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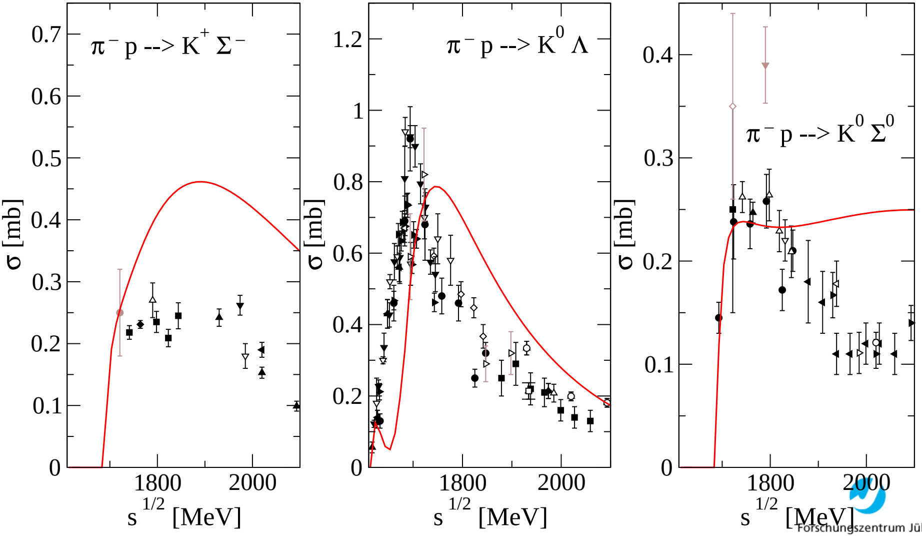
$\pi N \to KY$ back



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Pole positions and coupling strengths

◂ back

	previous	Fit 2	global
$N^*(1535)$			
z_0 [MeV]	$1537 - 37\,i$	$1537 - 139\,i$	$1508 - 108\,i$
$g_{K^+\Sigma^-}$	$2.20 - 0.17\,i$	$2.66 - 0.91\,i$	$2.33 - 0.72\,i$
$g_{K^0\Sigma^0}$	$-1.56 + 0.12\,i$	$-1.90 + 0.64\,i$	$-1.66 + 0.51\,i$
$g_{K^0\Lambda}$	$1.39 - 0.08\,i$	$0.94 - 0.55\,i$	$1.04 - 0.43\,i$
g_{π^-p}	$0.56 + 0.33\,i$	$1.42 + 0.46\,i$	$1.04 + 0.39\,i$
g_{π^0n}	$-0.39 - 0.24\,i$	$-1.00 - 0.33\,i$	$-0.73 - 0.28\,i$
$g_{\eta n}$	$-1.45 + 0.44\,i$	$-2.42 + 1.05\,i$	$-2.50 + 1.19\,i$
$N^*(1650)$			
z_0 [MeV]		$1655 - 59\,i$	$1662 - 59\,i$
$g_{K^+\Sigma^-}$		$0.79 + 0.65\,i$	$0.92 + 0.34\,i$
$g_{K^0\Sigma^0}$		$-0.56 - 0.47\,i$	$-0.65 - 0.24\,i$
$g_{K^0\Lambda}$		$-0.49 + 0.91\,i$	$-0.60 + 0.90\,i$
g_{π^-p}		$-0.89 + 0.48\,i$	$-0.75 + 0.21\,i$
g_{π^0n}		$0.63 - 0.34\,i$	$0.54 - 0.15\,i$
$g_{\eta n}$		$-0.08 + 0.32\,i$	$0.26 + 0.77\,i$

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