Poles in the SAID NN analysis

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13th International Workshop on Meson Production
Kraków, Poland

Why have an NN talk at the MESON conference?

PHYSICAL REVIEW C **88**, 055208 (2013)

Measurement of the $pn \to pp\pi^0\pi^-$ reaction in search for the recently observed resonance structure in $d\pi^0\pi^0$ and $d\pi^+\pi^-$ systems

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(WASA-at-COSY Collaboration)

After the experimental evidence found in the $d\pi^0\pi^0$ and $d\pi^+\pi^-$ channels, the $pp\pi^0\pi^-$ channel is now the third channel, which is consistent with the d^* hypothesis. If true, then this resonance should also been detected in the $pn \to pn\pi^0\pi^0$ reaction and—most importantly—in pn scattering, the *experimentum crucis*. Data for these reactions have been taken already by the WASA collaboration. Their analysis is in progress.

This d^*, assumed to be a $I(J^P)=0(3^+)$ state, is motivated by:

The "Inevitable" nonstrange dibaryon [T. Goldman *et al.,* PRC39, 1889 (1989)
which has these quantum numbers.

A number of very early and recent quark models predicting this state
[see M. Bashkanov, S.J. Brodsky, and H. Clement, PLB727, 438 (2013)]

Appearance in the 3-body calculation of A. Gal , H. Garcilazo, PRL 111, 172301 (2013)

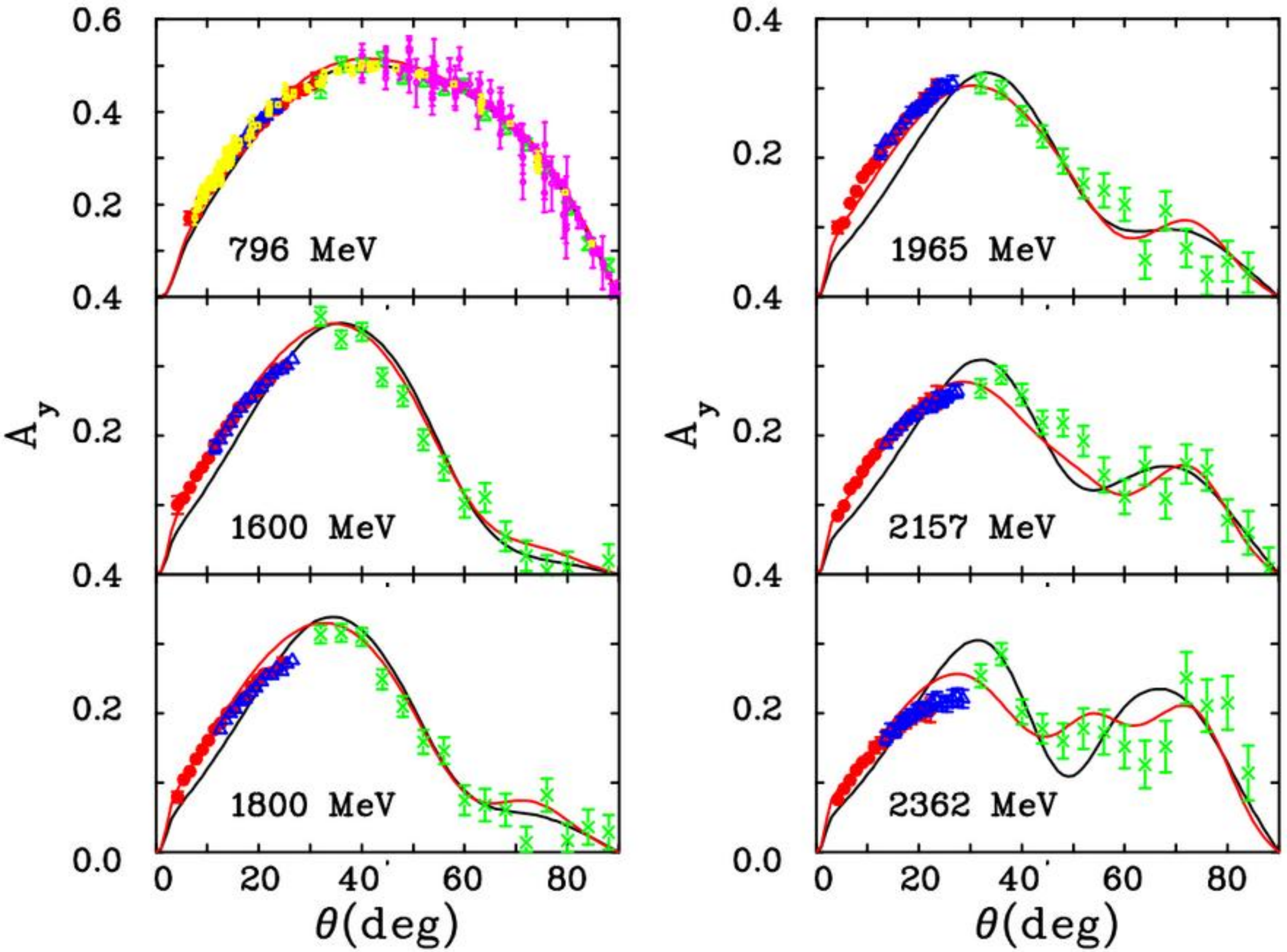
Does it appear in the analysis of np scattering data?

The d^* appears to have a mass of about 2.37 GeV and a width of about 70 MeV
not seen in the published SAID fit (2007).

New data are now becoming available

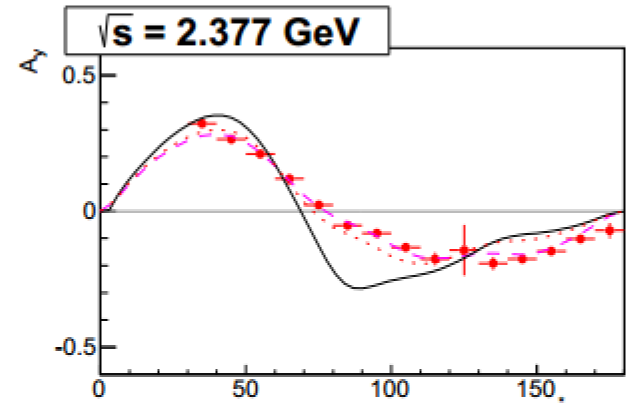
New pp A_y data from COSY suggest improvements to SAID NN PWA (SP07) may be necessary

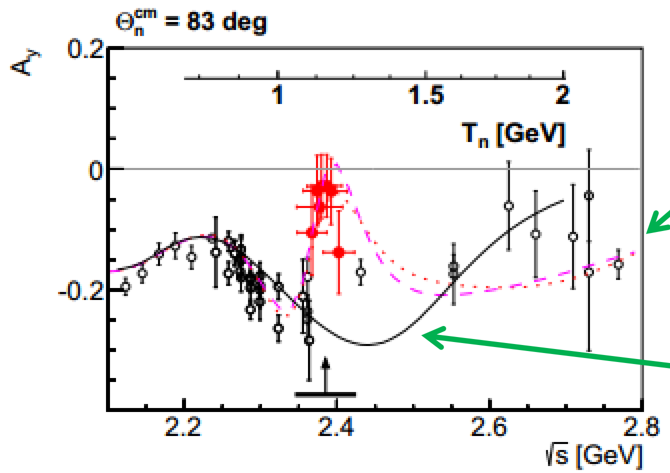
Preliminary COSY-ANKE data : red/blue + selected older data versus SP07 and a re-fit (red)



New np A_y data from COSY suggest improvements to SAID NN PWA (SP07) may be necessary

COSY-WASA
data : red
+ selected older
data versus
SP07 and a
re-fit (red)





Revised fit

SP07

SAID fit of new np A_y data from COSY-WASA

See Arndt et al., PRD35,128(1987)

$$S = S_x{}^{1/2} S_p S_x{}^{1/2} = 1 + 2iT \ ,$$

where

$$T = T_x + S_x{}^{1/2} T_p S_x{}^{1/2} \ .$$

(exchange) K-matrix elements have appropriate left-hand cuts, 1-π exchange.

$$T_p = \rho^{1/2} K_p (1 - C K_p)^{-1} \rho^{1/2} \ ,$$

where C is the 2×2 diagonal Chew-Mandelstam matrix

(production) K-matrix elements are polynomials – the Chew-Mandelstam function gives the right-hand cuts.

$$K_p = \begin{bmatrix} K_e & K_0 \\ K_0 & K_i \end{bmatrix}$$

Uncoupled ($^3F_3$)

$$K_p = \begin{bmatrix} K_e^- & K_e^0 & K_0^- \\ K_e^0 & K_e^+ & K_0^+ \\ K_0^- & K_0^+ & K_i \end{bmatrix}$$

Coupled ($^3D_3 - {}^3G_3$)

Poles have appeared in previous NN analyses

PHYSICAL REVIEW D VOLUME 35, NUMBER 1 1 JANUARY 1987

Nucleon-nucleon partial-wave analysis to 1100 MeV

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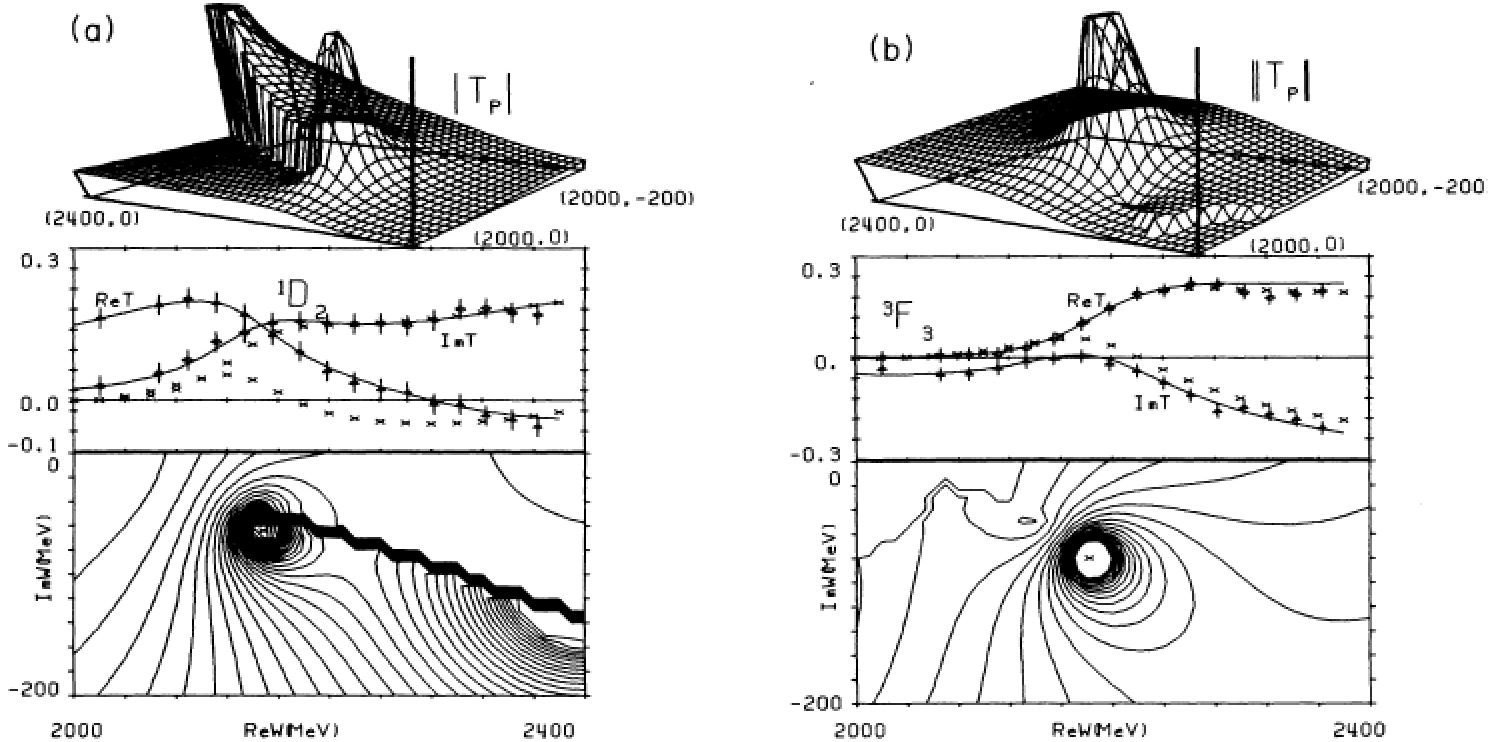
(Received 11 September 1986)

TABLE III. Pole parameters for ${}^1D_2$, ${}^3F_3$, ${}^3P_2$-${}^3F_2$, and ${}^3F_4$-${}^3H_4$ states. W_p is the pole position in MeV. G (modulus phase) is the function $(W_p-W)T_p$ evaluated at the pole; it is the residue of T_p at the pole. $G_r=\mathrm{Re}G$ and $G_i=\mathrm{Im}G$.

State	W_p (MeV)	$\lvert G \rvert$ (MeV)	$\arctan(G_i/G_r)$ (deg)
${}^1D_2$	$2148-i63$	10	−15
${}^3F_3$	$2183-i79$	14	−78
${}^3P_2$	$2163-i75$	7.7	52
${}^3F_2$	$2163-i75$	0.28	86
${}^3F_4$	$2210-i78$	1.2	87
${}^3H_4$	$2210-i78$	0.04	−41



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$^1D_2$ large residue, very near NΔ branch point (2148 – i 50) MeV

`On Pseudoresonances: Nonresonant Argand Loops',
B.L.G.Bakker *et al*., Nuovo Cimento 19, 265 (1977)

of the $\pi\mathcal{N}$ resonances over several partial waves in the πd system. Although we propose here a different cause for such loops, we agree that they are not resonant and therefore we use the same terminology as Hoenig and Rinat.

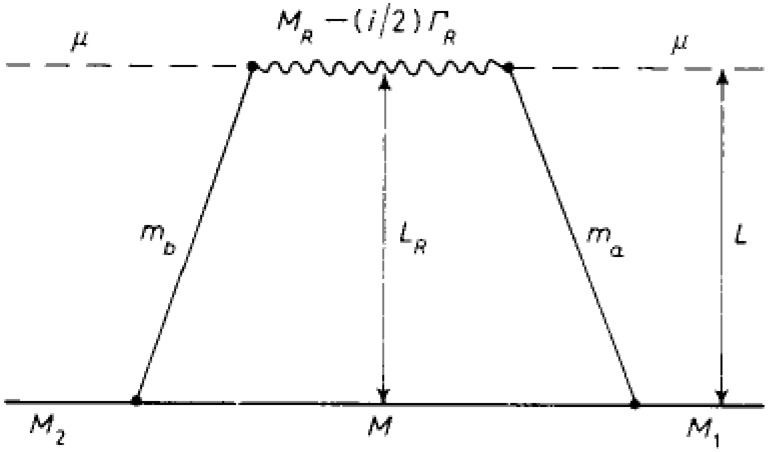


Fig. 1. – The box diagram with particle plus resonance in the intermediate state. L and L_R are the relative orbital angular momentum of the incoming particles and the particles in the intermediate state, respectively. The masses of the particles are also denoted.

Box diagram may produce \`resonance-like' behavior in NN , KN, or πN

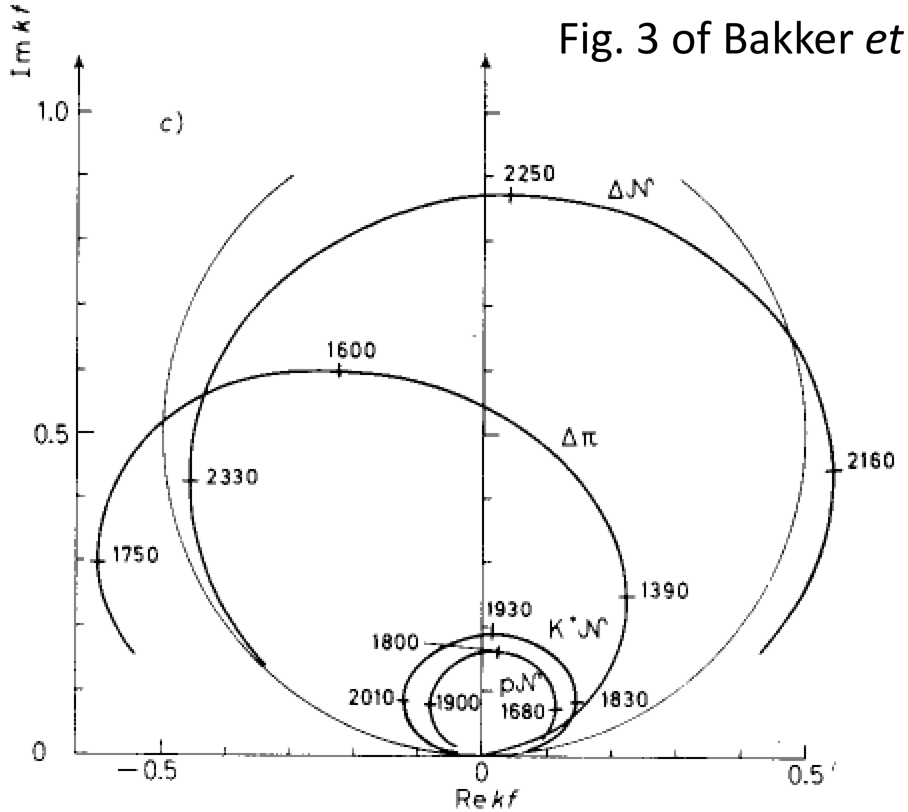
Compare

$^1D_2$
pole: (2148 – i 63) MeV
 NΔ : (2148 – i 50) MeV

to

N(1440)
pole: (1359 – i 81) MeV
 πΔ: (1349 – i 50) MeV

Fig. 3 of Bakker *et al*.



PHYSICAL REVIEW C VOLUME 50, NUMBER 4 OCTOBER 1994

Analysis of πd elastic scattering data to 500 MeV

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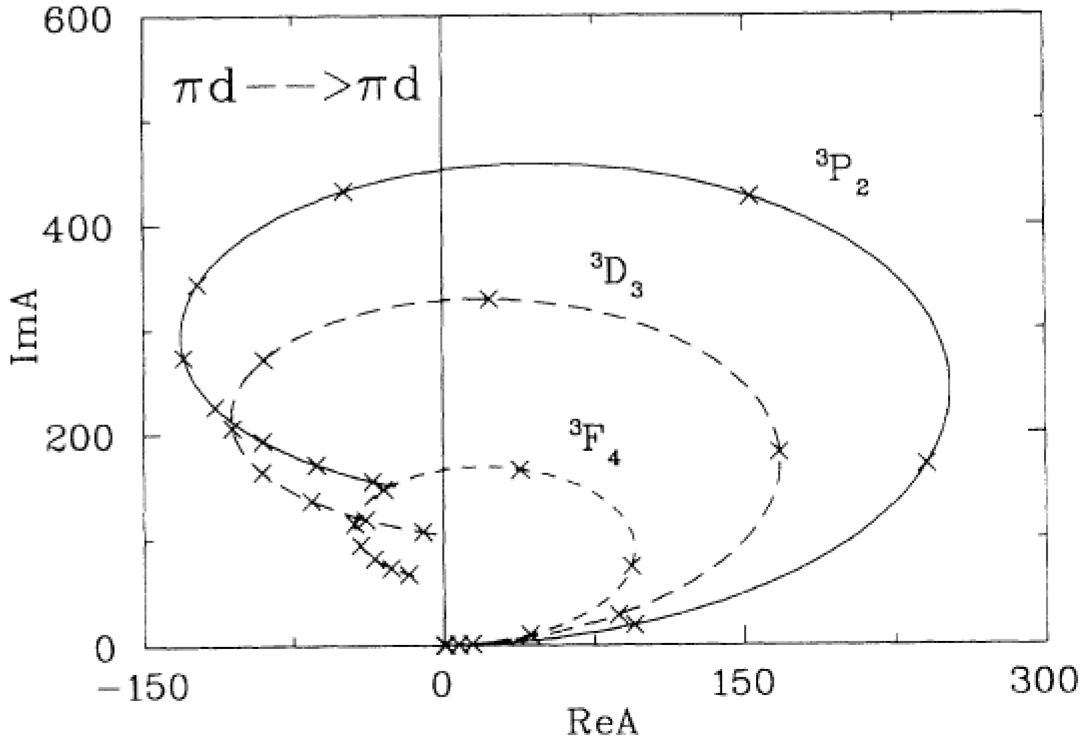

FIG. 7. Argand plot of the dominant πd partial-wave amplitudes $^3P_2$, $^3D_3$, and $^3F_4$ which correspond to the $^1D_2$, $^3F_3$, and $^1G_4$ pp states, respectively. (Compare Fig. 7 of Ref. [3]). The X points denote 50 MeV steps. All amplitudes have been multiplied by a factor of 10^3.

PHYSICAL REVIEW C VOLUME 48, NUMBER 4 OCTOBER 1993

Analysis of the reaction $\pi^+ d \to pp$ to 500 MeV

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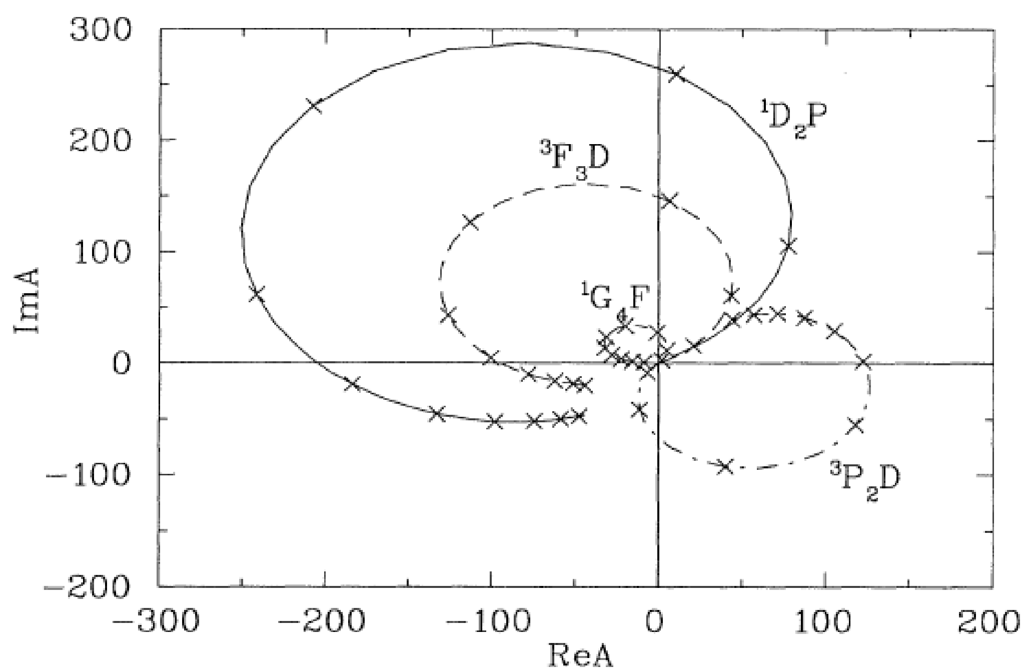


FIG. 7. Argand plot of dominant partial-wave amplitudes. The X points denote 50 MeV steps. All amplitudes have been multiplied by a factor of 10^3.

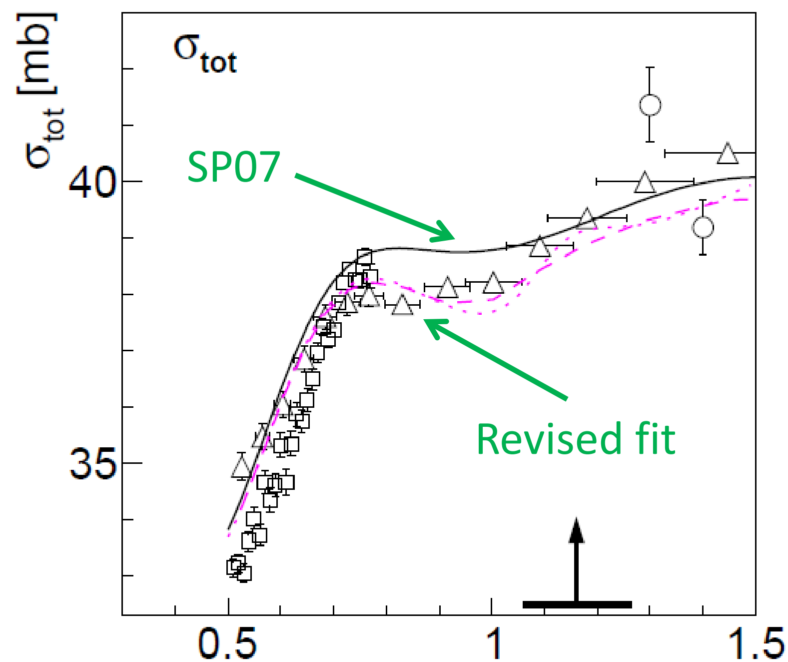
Notation:

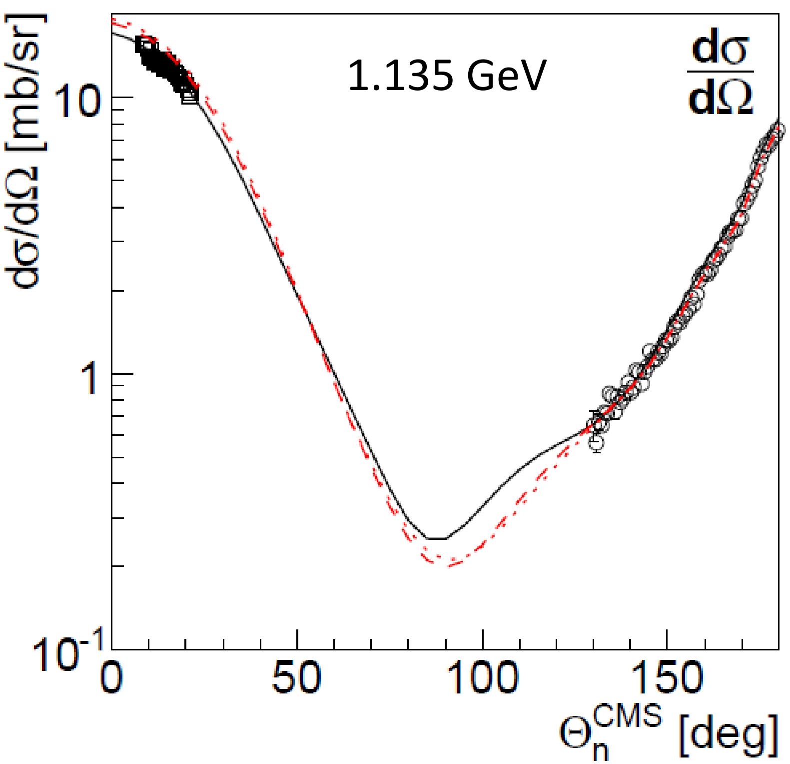
$({}^{2S_{pp}+1}L_J^{pp} L^{\pi})$

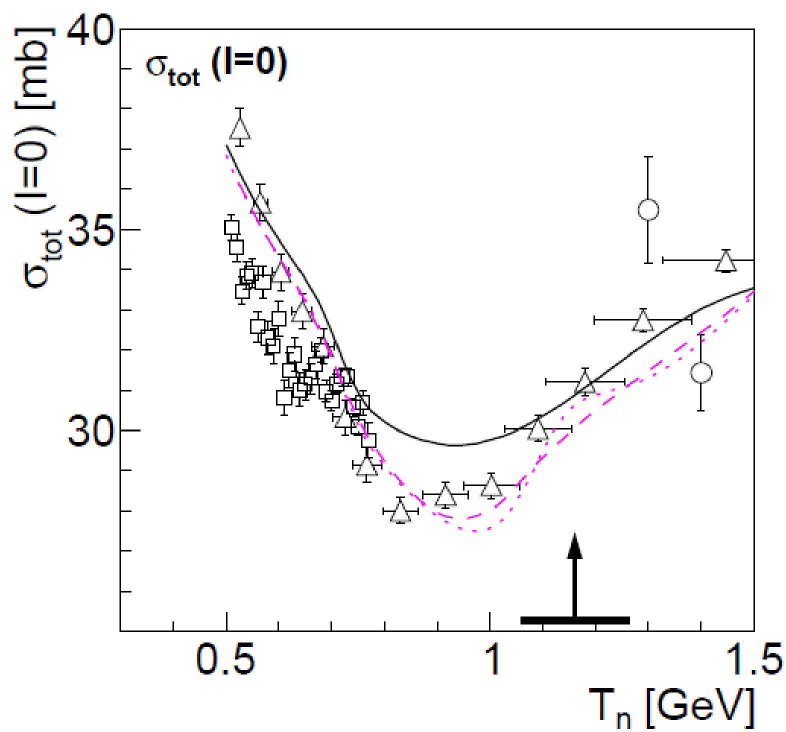
Revised NN fit including COSY-WASA data

- WASA data chi-squared (SP07) before fitting ~ 1300/68 data
- Included data: 1108, 1125, 1135, 1139, 1171, 1197 MeV
- Fit, start on SP07.
  Result: [1108, 1125, 1139, 1171, 1197 MeV] chi-square ~ 1.8/datum
  [1135 MeV] chi-square ~ 25/datum
- Forced fit [1135 MeV] cut errors/4 , add parameters coupling to the inelastic channel.
  Result: much better fit to 1135 MeV set - also better fit to other 'unforced' COSY-WASA sets, older data reproduced.
- Significant change to $^3D_3$ - $^3G_3$ waves, minor changes to others.
- Re-fit, new parameterization, no data weighting, gave qualitatively similar results

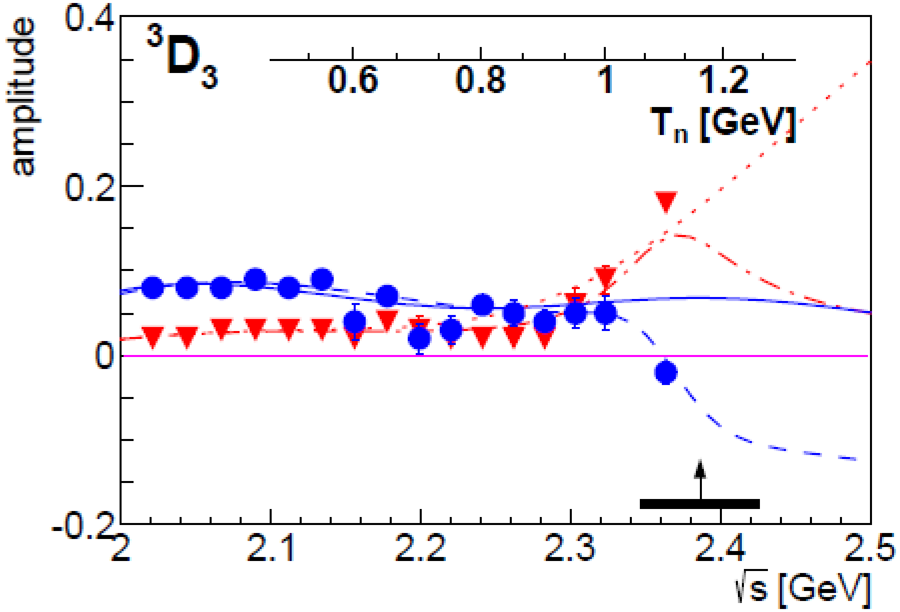
Fit to other quantities remains of similar quality - in some cases the revised fit is better

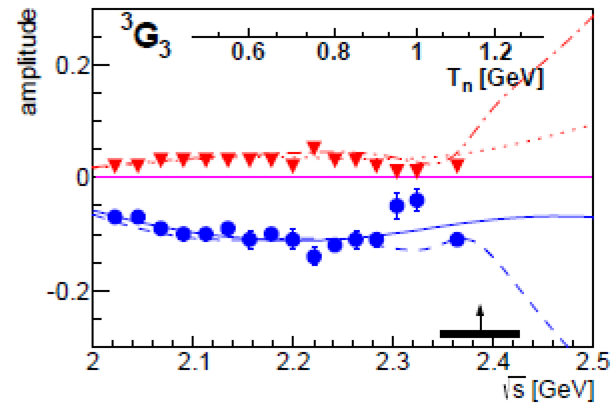


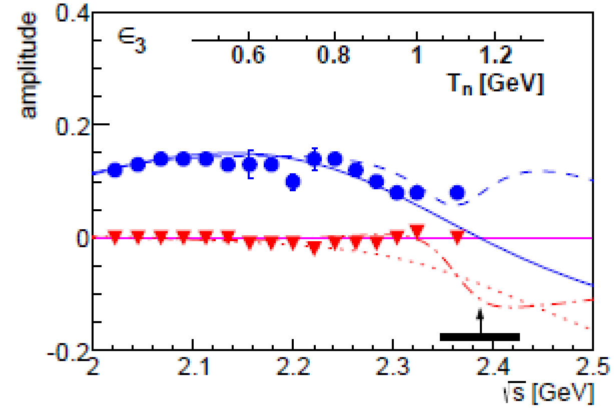




Few data beyond 1.3 GeV







$^3D_3$ develops resonant shape
(hints from SP07 SE fits)

$^3G_3$ modified, but does not have resonance-like shape

Fit will be added to allow comparisons with existing data, other fits, as well as predictions for new measurements

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Partial-Wave Analyses at GW

[See Instructions]

- Pion-Nucleon
- Pi-Pi-N
- Kaon(+)-Nucleon
- Kaon(-)-Nucleon
- Nucleon-Nucleon
- Pion Photoproduction
- Pion Electroproduction
- Kaon Photoproduction
- Eta Photoproduction
- Eta-Prime Photoproduction
- Pion-Deuteron (elastic)
- Pion-Deuteron to Proton+Proton

Analyses From Other Sites

- Mainz (MAID – Analyses)
- Nijmegen (Nucleon-Nucleon OnLine)
- Bonn-Gatchina (PWA)

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CNS DAC Services [SAID Program]

- The SAID Partial-Wave Analysis Facility is based at GWU.
- New features are being added and will first appear at this site. Suggestions for improvements are always welcome.

Instructions for Using the Partial-Wave Analyses

The programs accessible with the left-hand side navigation bar allow the user to access a number of features available through the SAID program. Contact a member of our group if you are unfamiliar with the SSH version. If you enter choices which are unphysical, you may still get an answer (in accordance with the `garbage in, garbage out' rule). Please report unexpected garbage-out to the management.

Note: These programs use HTML forms to run the SAID code. If unfamiliar with the options, run the default setup first. The output is an (edited) echo of an interactive session which would have resulted had you used the SSH version. If the default example fails to clarify the specific task you have in mind, we can help (just send an e-mail message).

All programs expect energies in **MeV** units. All of the solutions and potentials have limited ranges of validity. Some are unstable beyond their upper energy limits. Extrapolated results may not make much sense.
Increments: The programs will not allow an arbitrary number of points to be generated. As a rule, stay below **100**.

ACKNOWLEDGMENTS

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Summary

- To accommodate a rapid change in np A_y data, over a narrow energy range, an SP07 re-fit generates a pole
- pole parameters [2380 ± 10] – i [40 ± 5] MeV are consistent with earlier estimates
- Structure is unfortunately near the limit of substantial coverage for np scattering data
- Narrow structures can also be interference effects [recall discussion of narrow structure in $\gamma d \rightarrow \eta n(p)$ and N(1685)] This should also be investigated.

Comparison to old SU(6) model

Dyson, Xuong 1964

VOLUME 13, NUMBER 26 PHYSICAL REVIEW LETTERS 28 DECEMBER 1964

Table I. $Y = 2$ states with zero strangeness predicted by the $\underline{490}$ multiplet.

Particle	T	J	SU(3) multiplet	Comment	Predicted mass
D_{01}	0	1	$\underline{10}^*$	Deuteron	A
D_{10}	1	0	$\underline{27}$	Deuteron singlet state	A
D_{12}	1	2	$\underline{27}$	S-wave N-N^* resonance	$A+6B$
D_{21}	2	1	$\underline{35}$	Charge-3 resonance	$A+6B$
D_{03}	0	3	$\underline{10}^*$	S-wave N^*-N^* resonance	$A+10B$
D_{30}	3	0	$\underline{28}$	Charge-4 resonance	$A+10B$

A = 1876 MeV
B = 50 MeV

	Predict	NN poles
D_{12}	2176 MeV	2148 MeV
D_{03}	2376 MeV	2380 MeV

TABLE II. Binding energy B and rms $\bar{R}$ of the deltaron $B=-(E_{\mathrm{deltaron}}-2M_\Delta)$, $\bar{R}=\sqrt{\langle r^2\rangle}$.

		$\Delta\Delta(L=0)$	$\Delta\Delta\binom{L=0}{+2}$	$\Delta\Delta$ CC $(L=0)$	$\Delta\Delta$ CC $\binom{L=0}{+2}$
OGE	B (MeV)	29.8	29.9	41.0	42.0
	$\bar{R}$ (fm)	0.92	0.92	0.87	0.87
OGE+π,σ	B (MeV)	50.2	62.6	68.6	79.7
	$\bar{R}$ (fm)	0.87	0.86	0.84	0.83
OGE+SU(3)	B (MeV)	18.4	22.5	31.7	37.3
	$\bar{R}$ (fm)	1.01	1.00	0.92	0.92