Meson-baryon dynamics as a tool for baryon resonance analysis

M. Döring, H. Haberzettl[2], C. Hanhart, F. Huang[1],

S. Krewald, K. Nakayama[1], U.-G. Meißner, A. Sibirtsev

Forschungszentrum Jülich, Uni Bonn, Germany

[1]University of Athens, Georgia, USA

[2]GWU, Washington, DC, USA

Contents

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EBAC = Excited Baryon Analysis Center
Thanks, Tony!

- The Juelich coupled reaction channels approach
- Photoproduction of mesons
- Meeting the lattice

Analyticity and Unitarity

Pole and Non-Pole T-Matrix

$$T = T^P + T^{NP}$$

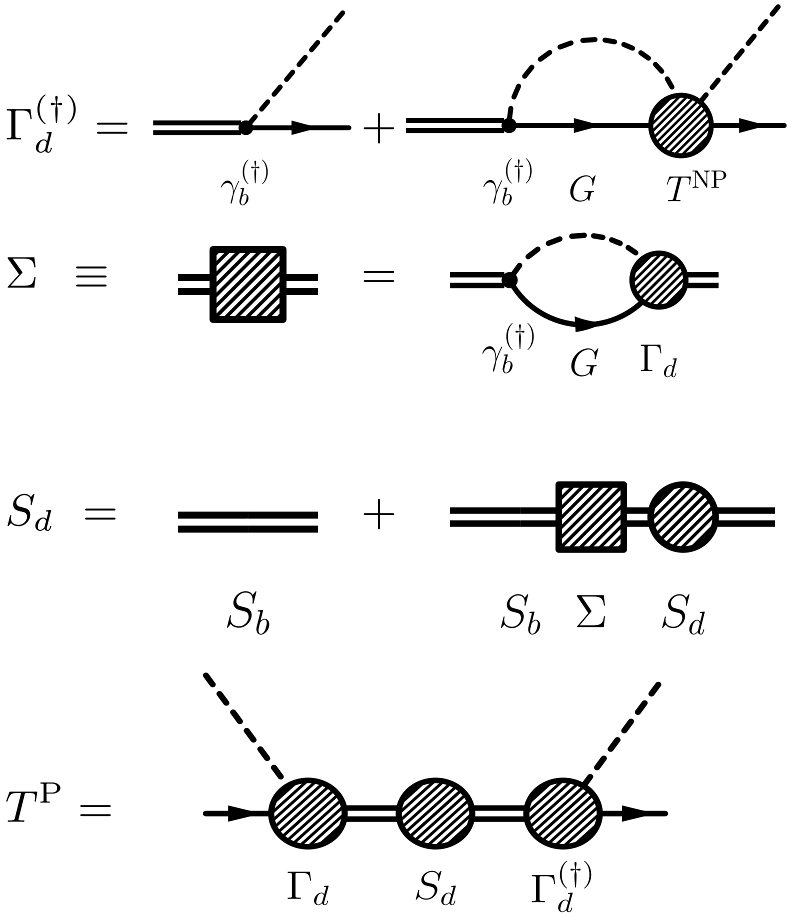
$$T = \frac{a_{-1}}{Z-Z_0} + a_0 + O(Z-Z_0)$$

$$a_{-1} = \frac{\Gamma_d \Gamma_d^{(\dagger)}}{1-\frac{\partial}{\partial Z}\Sigma}$$

$$a_0 = T^{NP} + a_0^P$$

$$a_0^P = \frac{a_{-1}}{\Gamma_d \Gamma_d^{(\dagger)}} *$$

$$* \left(\frac{\partial}{\partial Z}(\Gamma_d \Gamma_d^{(\dagger)}) + \frac{a_{-1}}{2} \frac{\partial^2}{\partial Z^2} \Sigma \right)$$



Partial wave amplitudes: $\pi N \to \pi N$

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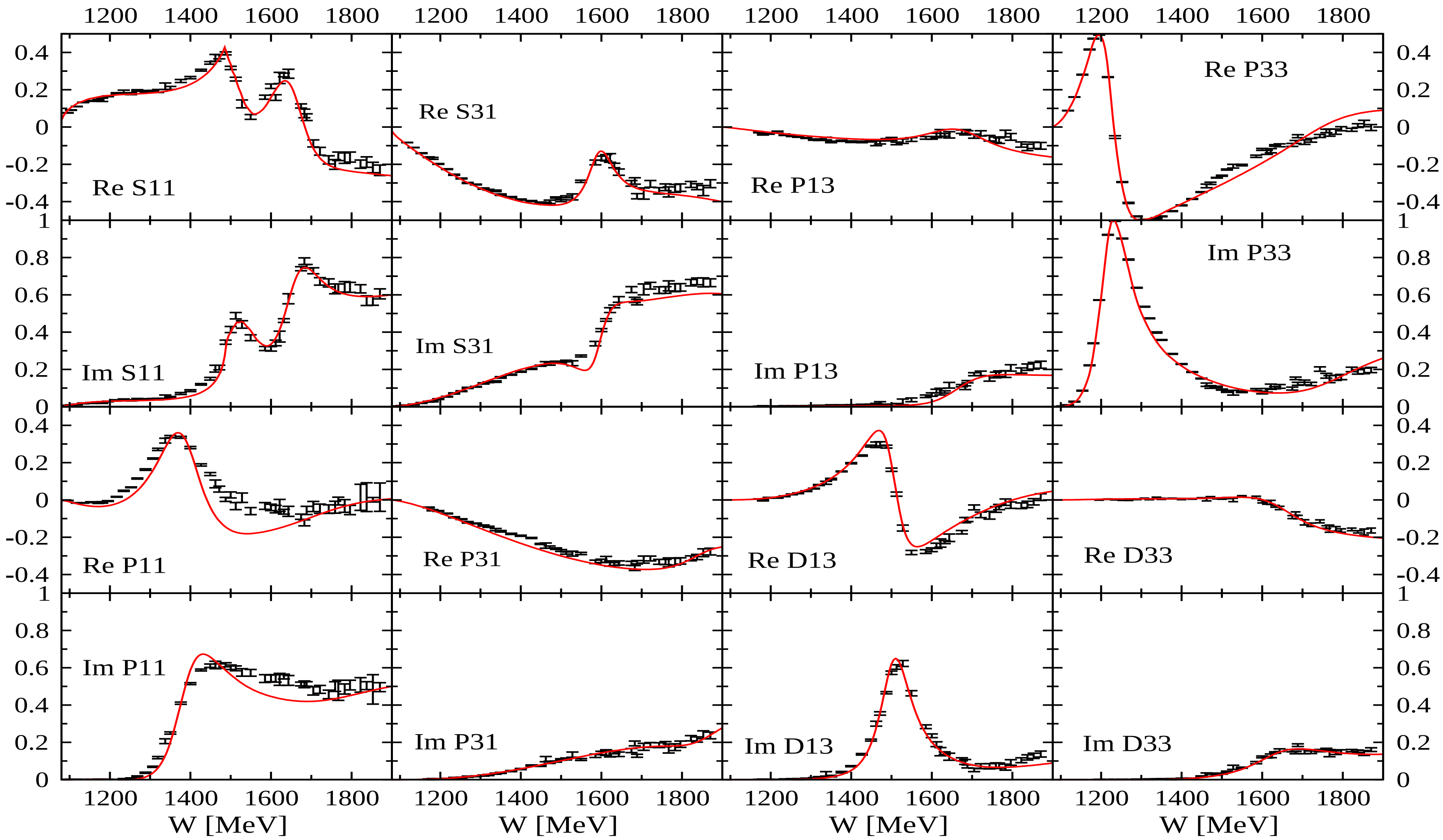
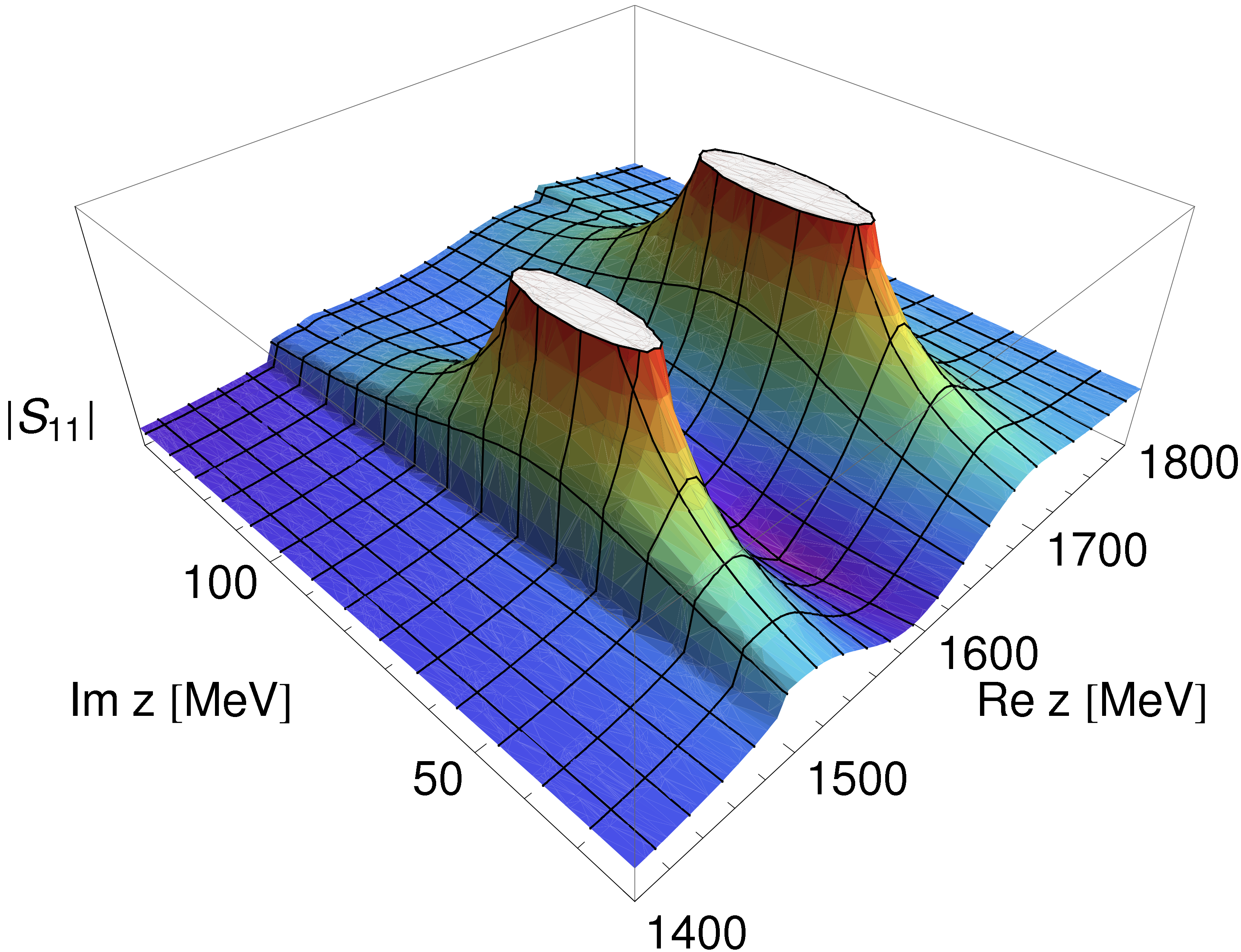
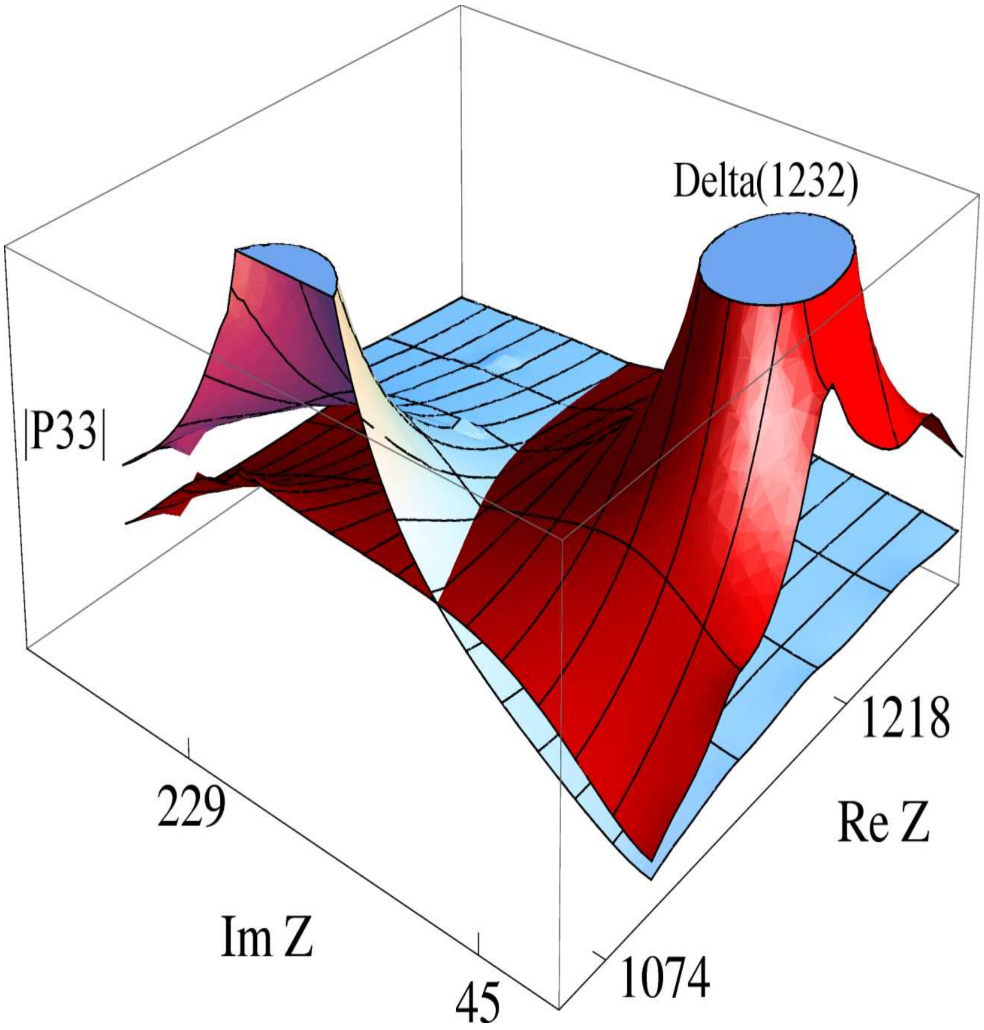


Complex plane: S_{11}



Second Riemann sheet: P_{33}



T^{NP}

$T^{P} + T^{NP}$

Tool: X-ray plot (Gauss)

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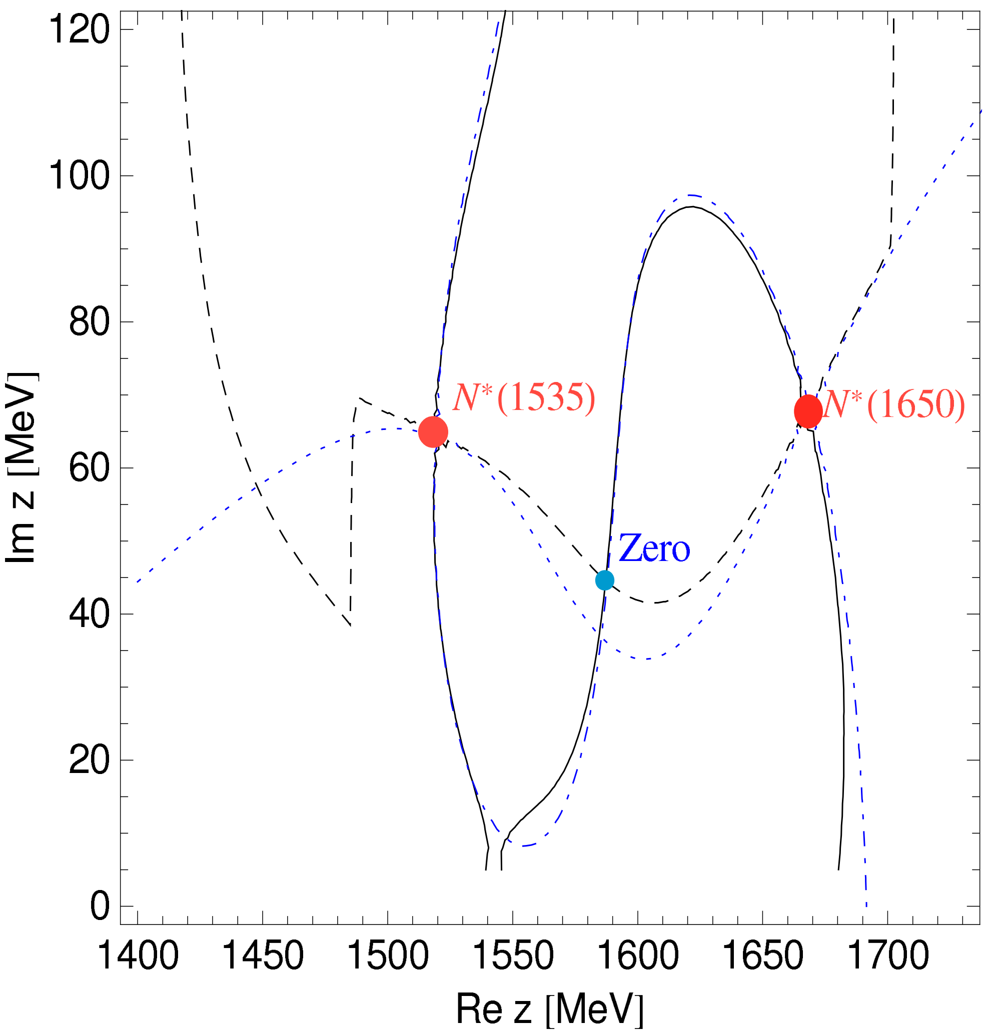

Re[T(z)]=0

Im[T(z)]=0

$$\frac{1}{x-iy} = \frac{x+iy}{x^2+y^2}$$

$$T^{[2]}(Z) = \frac{a_{-1}(1535)}{Z-Z_0(1535)} + \frac{a_{-1}(1650)}{Z-Z_0(1650)}$$

Poles and residues: Delta

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	Re z_0 [MeV]	-2 Im z_0 [MeV]	$\|R\|$ [MeV]	θ [deg] [^{0}]
$\Delta(1232)\, P_{33}$	1218	90	47	-37
ARN	1211	99	52	-47
HOE	1209	100	50	-48
CUT	1210± 1	100± 2	53± 2	-47$\pm$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$\pm$20
$\Delta^*(1910)\, P_{31}$	1840	221	12	-153
ARN	1771	479	45	+172
HOE	1874	283	38	
CUT	1880± 30	200± 40	20± 4	-90$\pm$30

$\gamma N \to \pi N$ Gauge invariance

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Hadronic scattering:

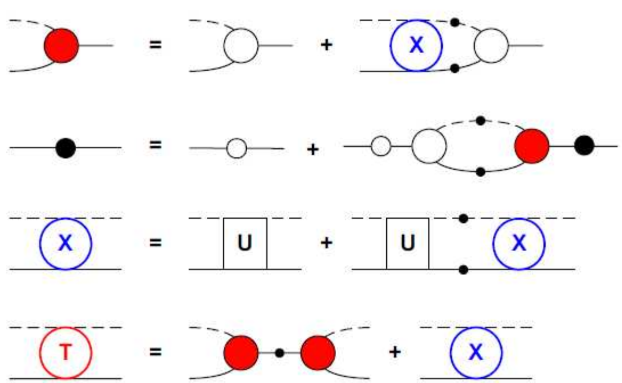
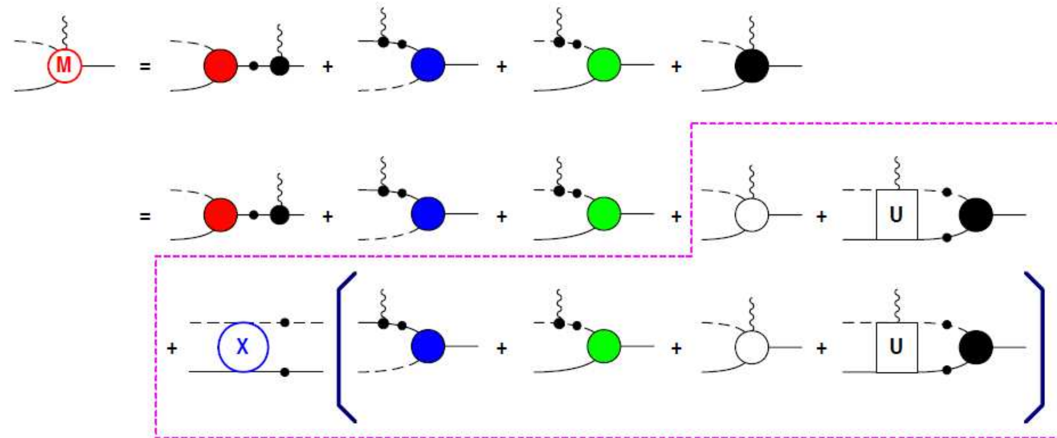


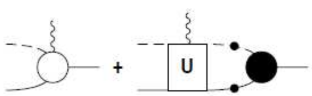
Photo-production:



Gauge invariance: Generalized Ward-Takahashi identity (WTI)

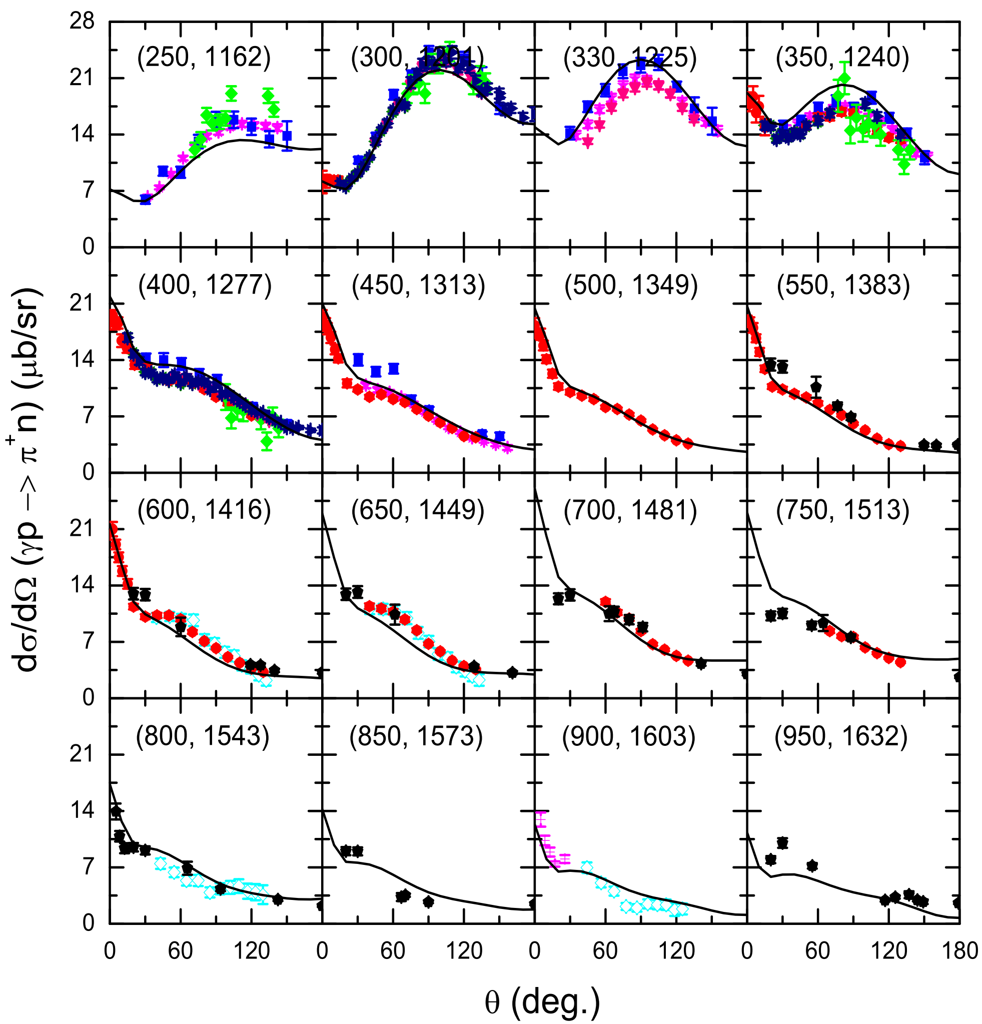
(Note the condition of current conservation $k_\mu M^\mu = 0$ is necessary but not sufficient!)

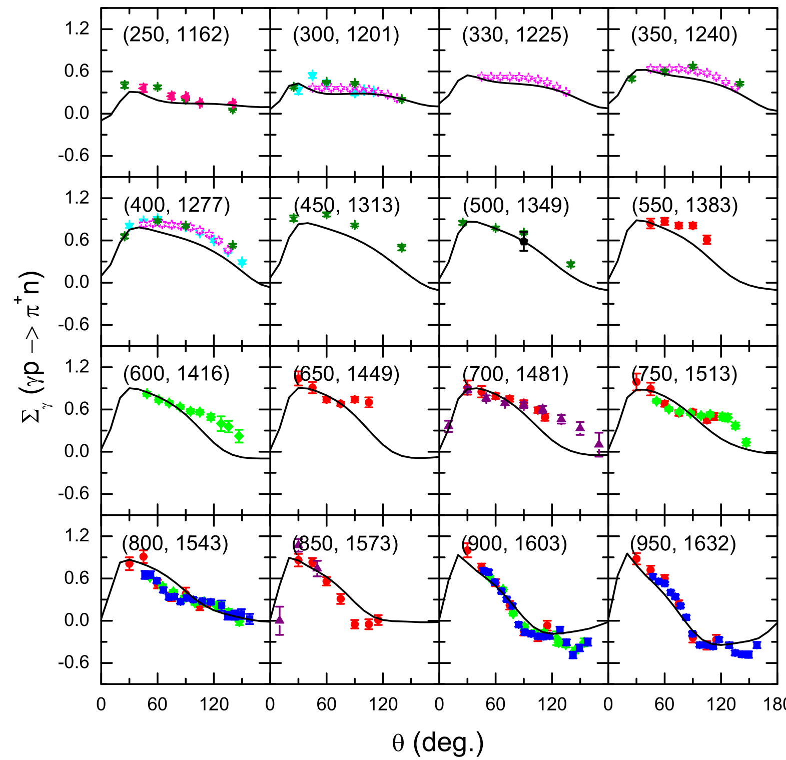
$$k_\mu M^\mu = -|F_s\tau\rangle S_{p+k} Q_i S_p^{-1} + S_{p'}^{-1} Q_f S_{p'-k} |F_u\tau\rangle + \Delta^{-1}_{p-p'+k} Q_\pi \Delta_{p-p'} |F_t\tau\rangle$$

Strategy: Replace  by phenomenological contact term such that the generalized WTI is satisfied

Haberzettl, PRC56 (1997), Haberzettl, Nakayama, Krewald, PRC74 (2006)

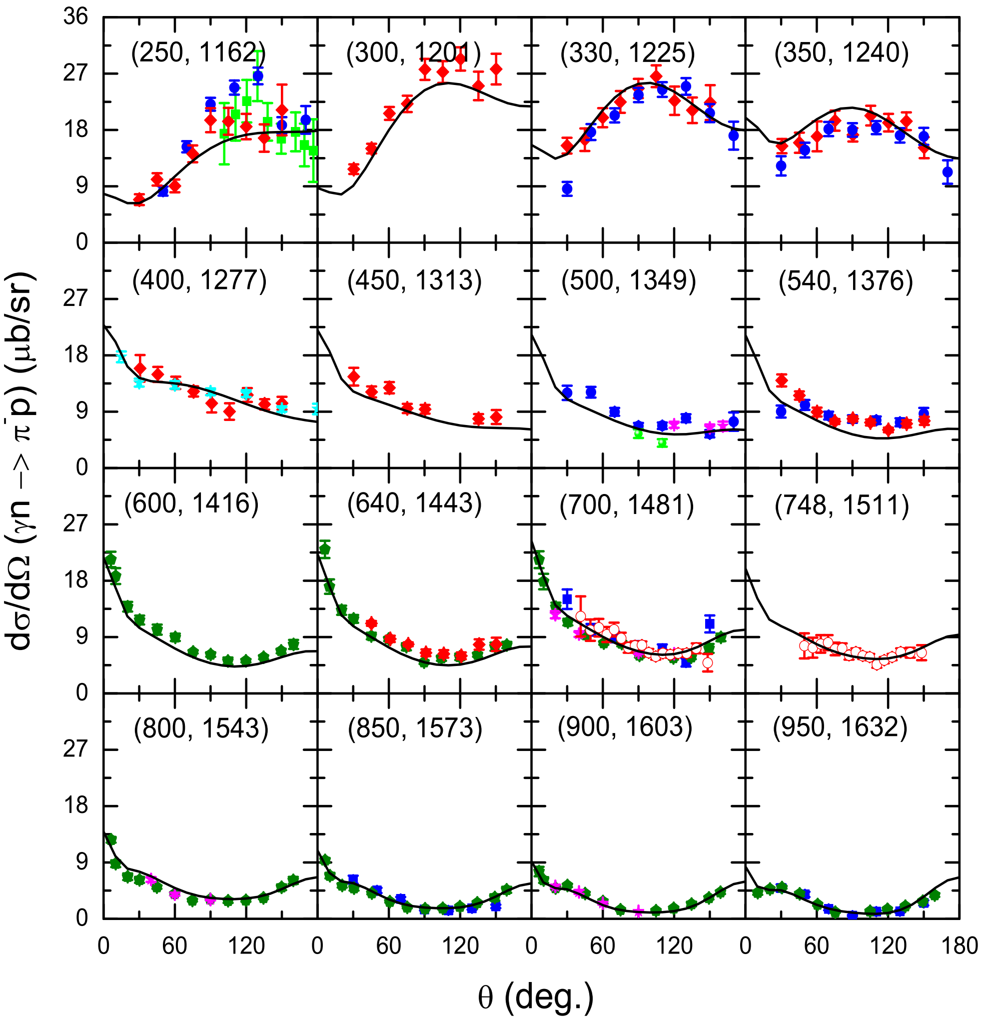
$d\sigma/d\Omega$ and Σ_γ for $\gamma p \to \pi^+ n$

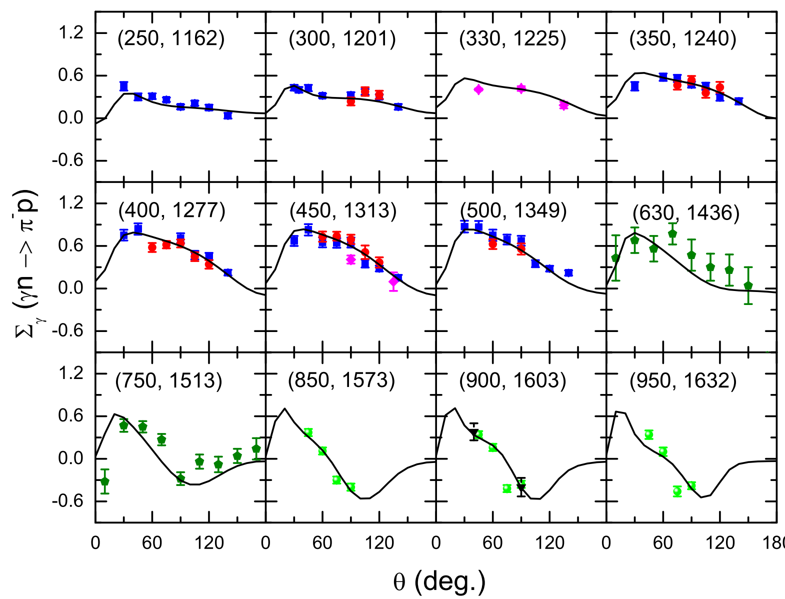




preliminary (Fei Huang, Kanzo Nakayama)

$d\sigma/d\Omega$ **and** Σ_γ **for** $\gamma n \to \pi^- p$





preliminary (Fei Huang, Kanzo Nakayama)

$d\sigma/d\Omega$ and Σ_γ for $\gamma p \to \pi^0 p$

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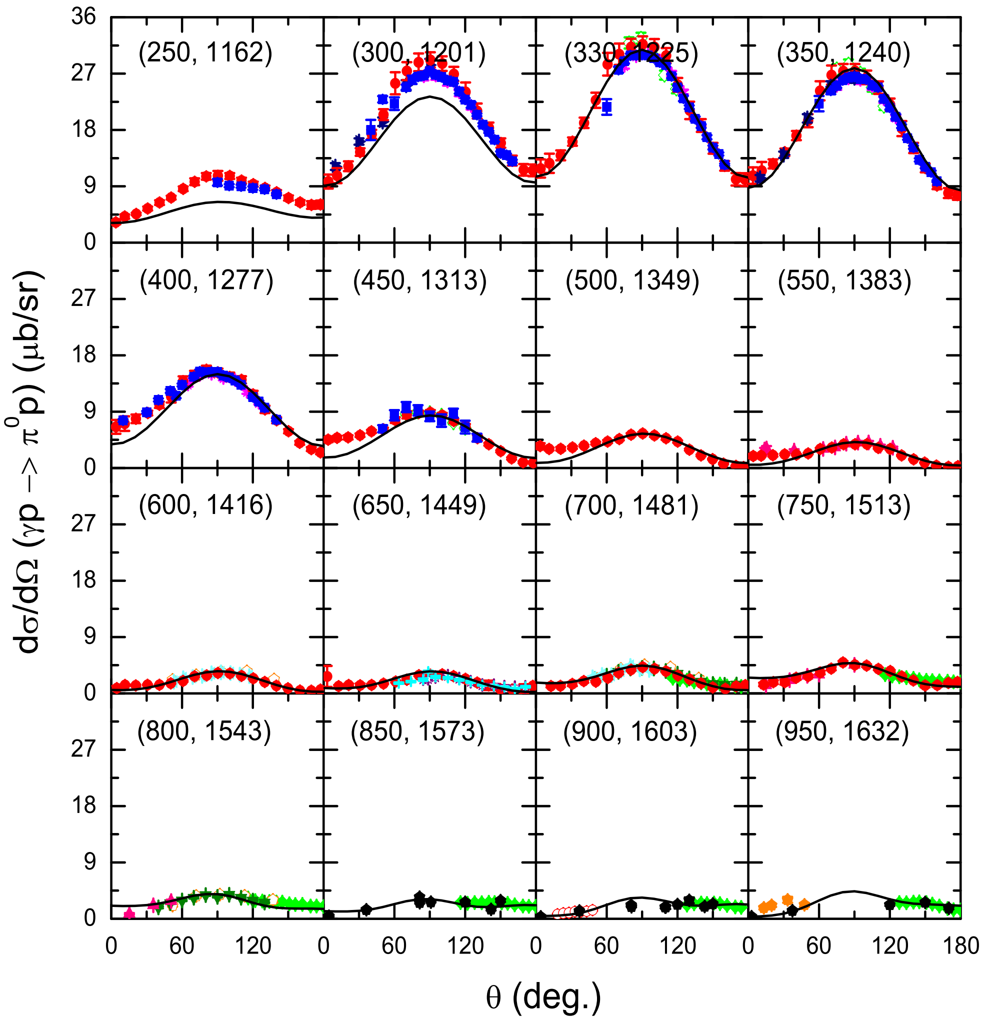

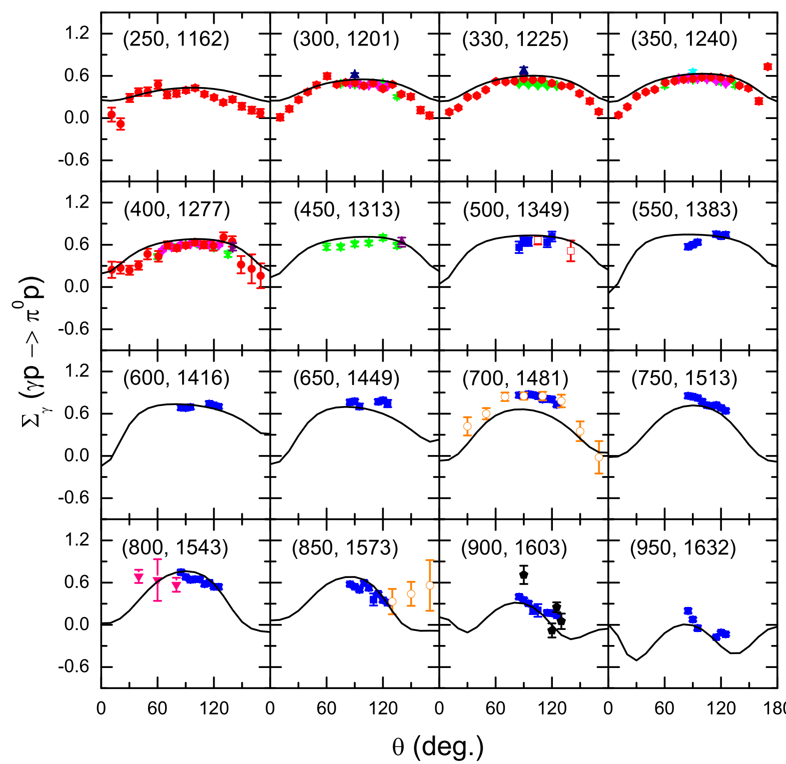

preliminary (Fei Huang, Kanzo Nakayama)

Meeting the lattice: Pole path

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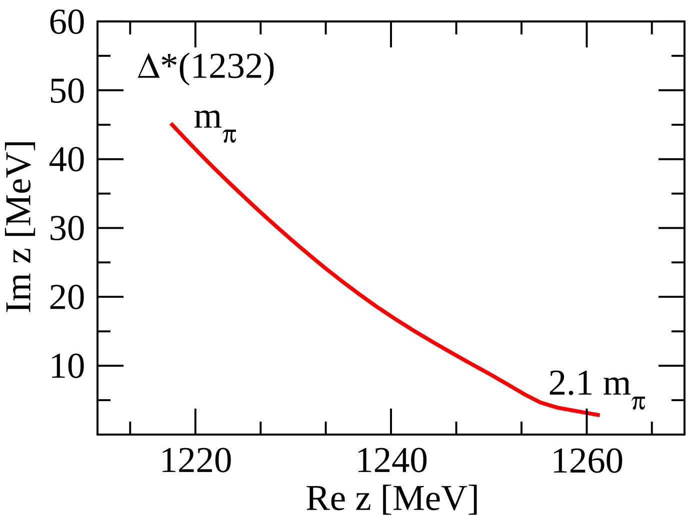

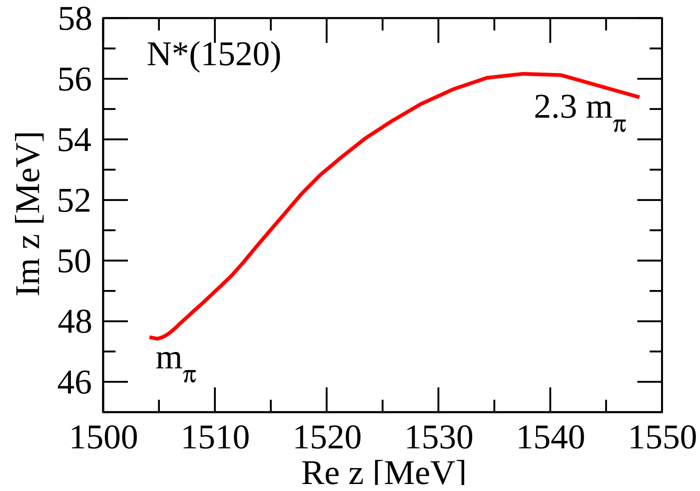

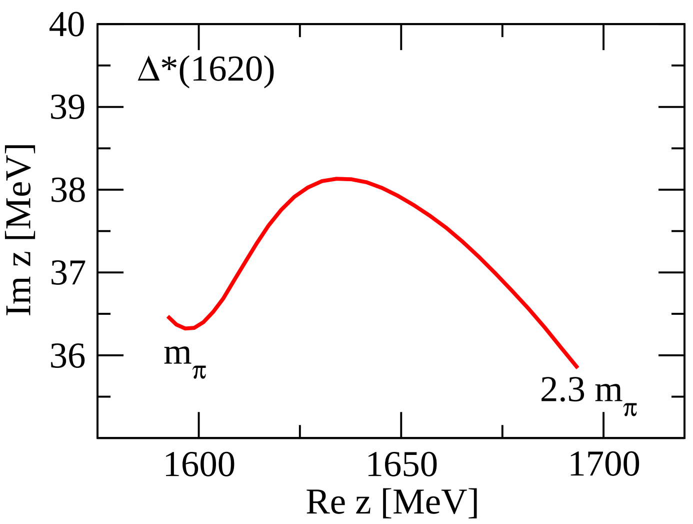

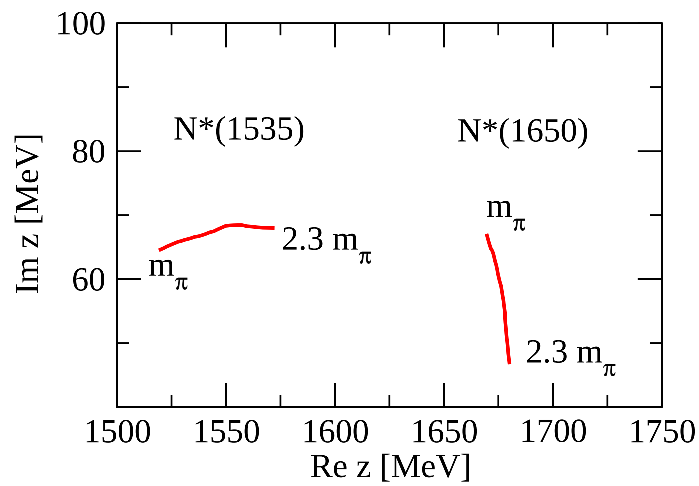

Pion mass dependence

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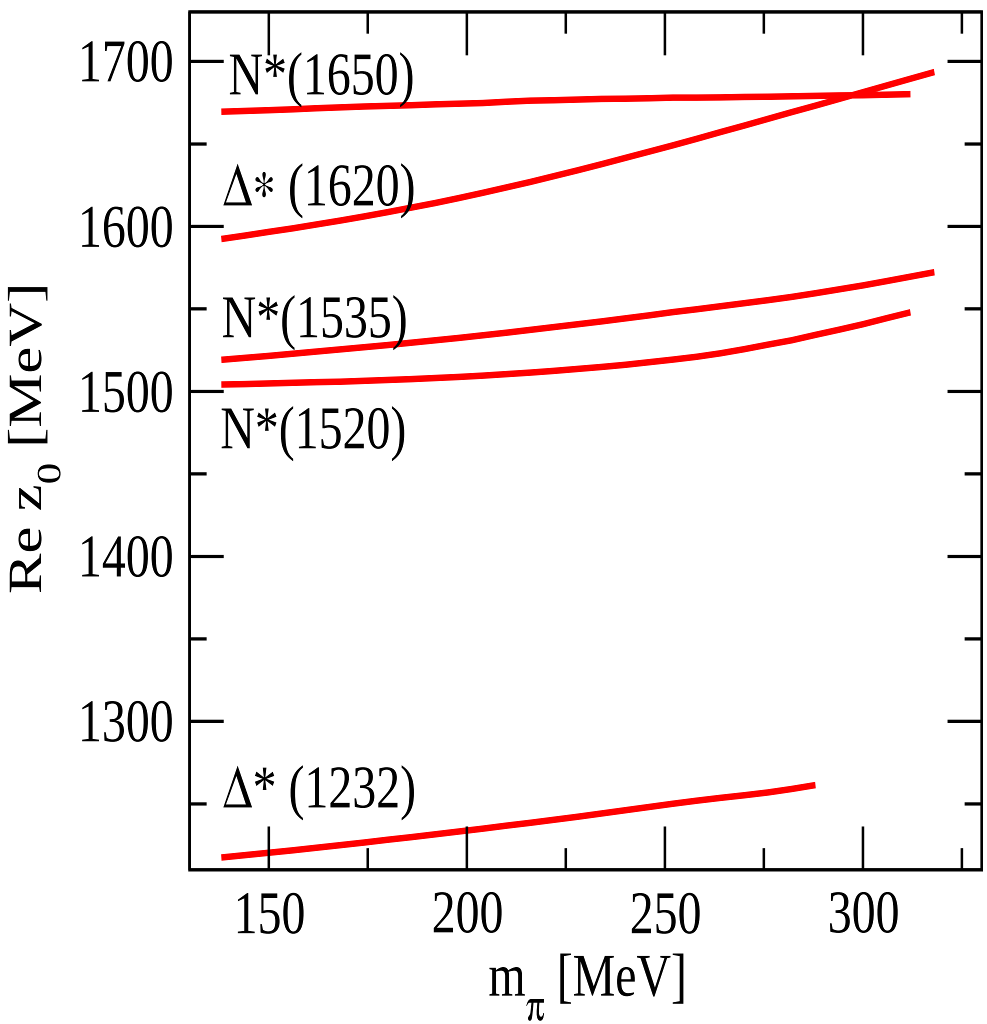

Conclusions

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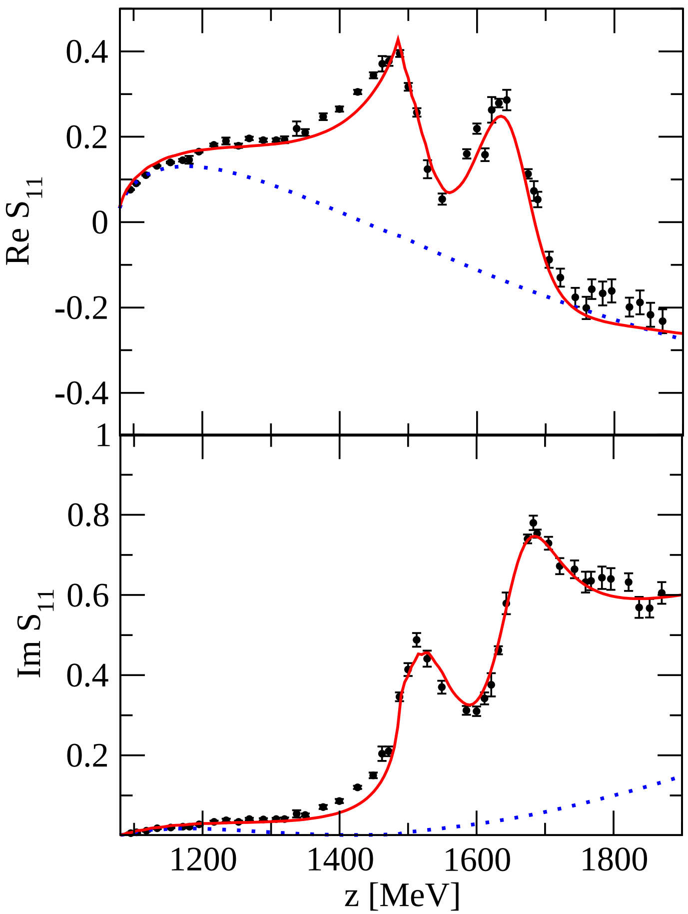
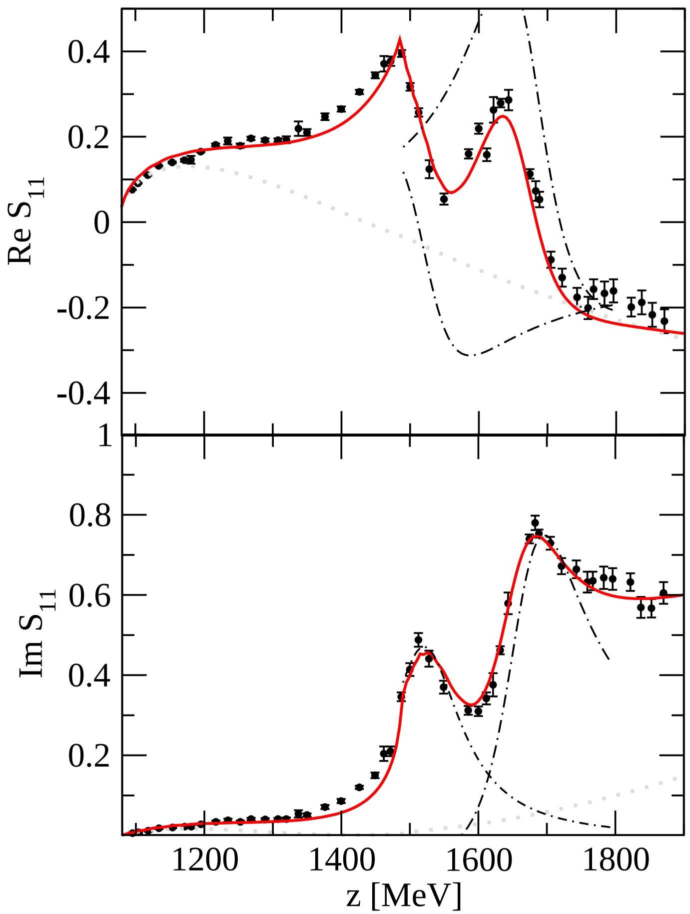
Resonances characterized by poles and residues of the S-matrix
M. Döring et al., NPA829,170(2009).

Separation of amplitude into contributions from bare resonances and background is model dependent.
Implication for constituent quark model and missing mass problem!
Outlook:
electroproduction
two pion production

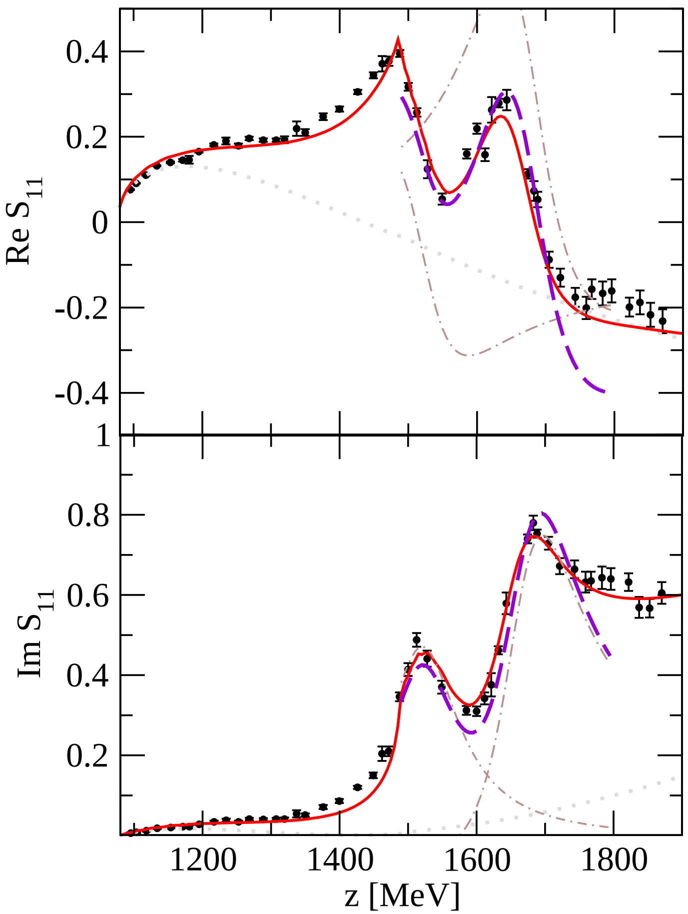
HAPPY BIRTHDAY, DEAR TONY!

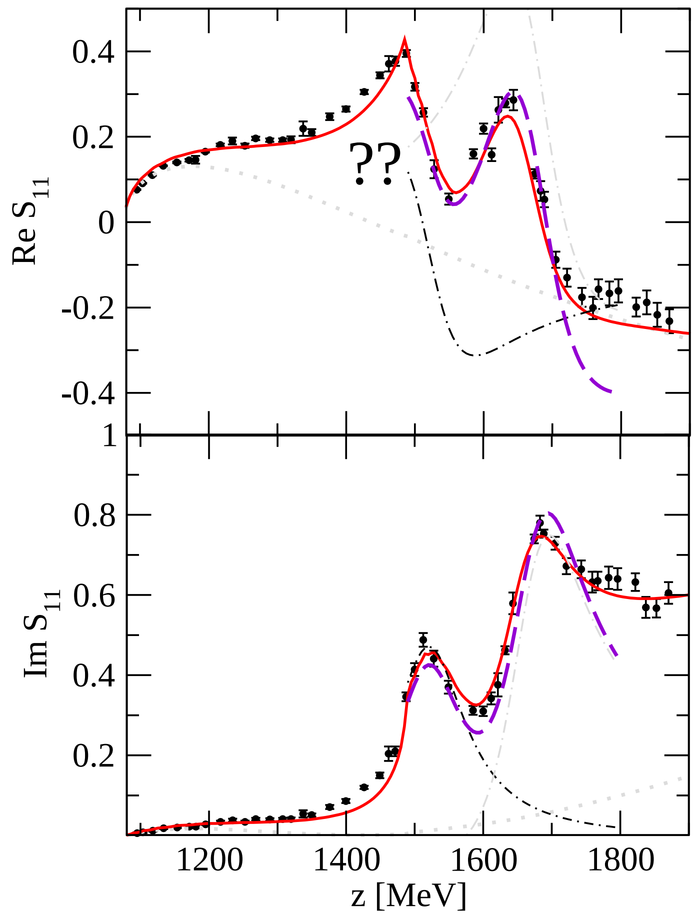
S11: background and poles



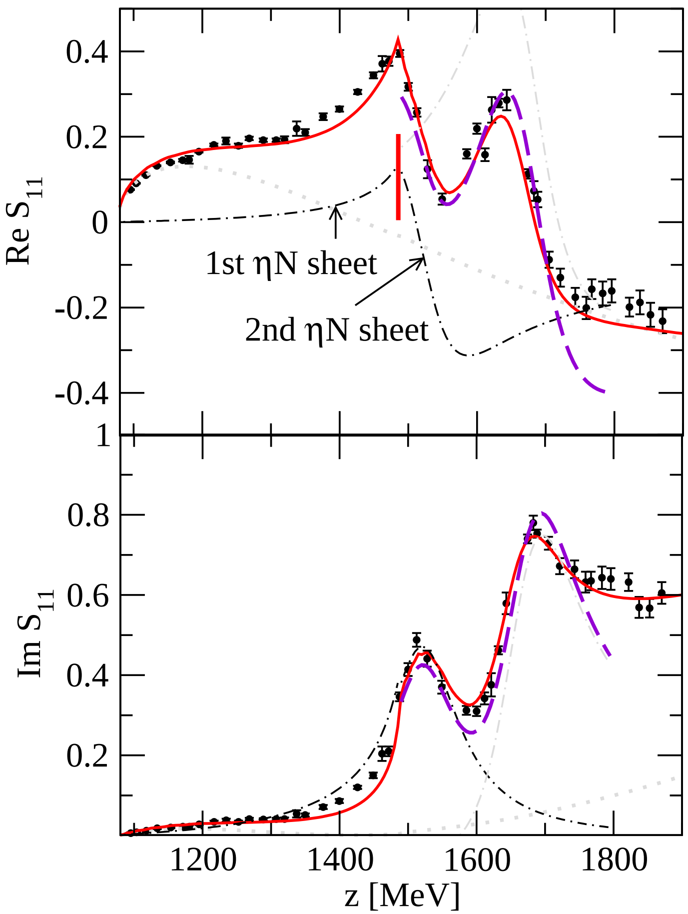


S11: background and poles

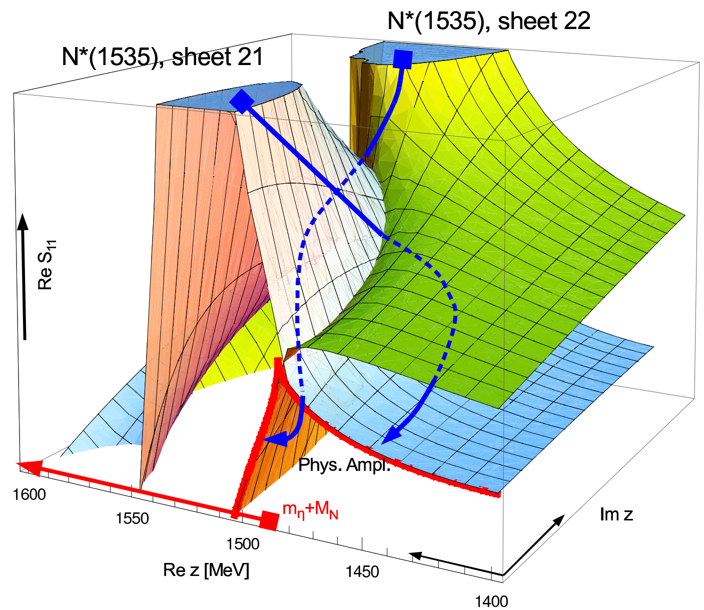




S11: cusp

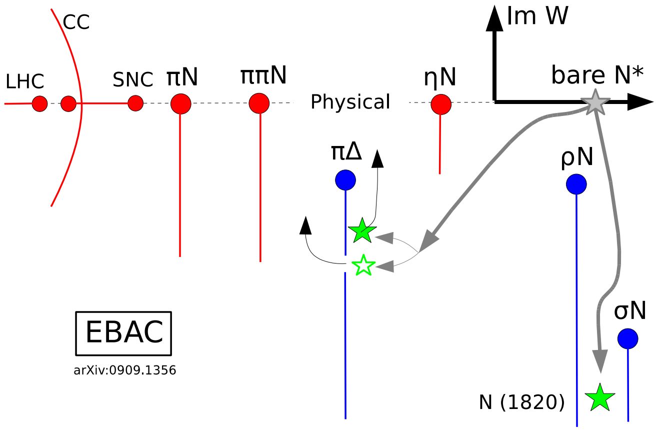


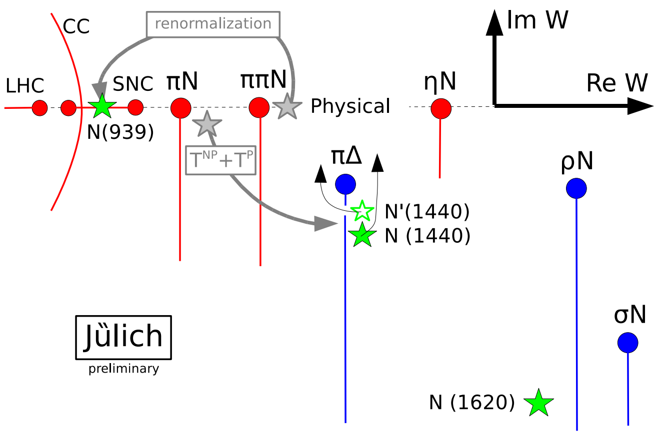
Re S_{11}
Im S_{11}
0.4
0.2
0
-0.2
-0.4
1
0.8
0.6
0.4
0.2
1st ηN sheet
2nd ηN sheet
1200
1400
1600
1800
z [MeV]



N*(1535), sheet 21
N*(1535), sheet 22
Re S_{11}
Phys. Ampl.
$m_\eta+M_N$
1600
1550
1500
1450
1400
Re z [MeV]
Im z

P11: analytical structure





Poles and residues I

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	Re Z_0 [MeV]	-2 Im Z_0 [MeV]	$\|R\|$ [MeV]	θ [deg] [^{0}]
$N^*(1520)\,D_{13}$	1505	95	32	-18
Arndt06	1515	113	38	-5
Hohler93	1510	120	32	-8
Cutkosky79	1510± 5	114± 10	35± 2	-12$\pm$5
$\Delta(1232)\,P_{33}$	1218	90	47	-37
Arndt06	1211	99	52	-47
Hohler93	1209	100	50	-48
Cutkosky79	1210± 1	100± 2	53± 2	-47$\pm$1
$\Delta^*(1700)\,D_{33}$	1637	236	16	-38
Arndt06	1632	253	18	-40
Hohler93	1651	159	10	
Cutkosky79	1675± 25	220± 40	13± 3	-20$\pm$25

Poles and residues II

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	Re Z_0 [MeV]	-2 Im Z_0 [MeV]	$\|R\|$ [MeV]	θ [deg] [^{0}]
$N^*(1535)\,S_{11}$	1519	129	31	-3
Arndt06	1502	95	16	-16
Hohler93	1487			
Cutkosky79	1510$\pm$50	260$\pm$80	120$\pm$40	+15$\pm$45
$N^*(1650)\,S_{11}$	1669	136	54	-44
Arndt06	1648	80	14	-69
Hohler93	1670	163	39	-37
Cutkosky79	1640$\pm$20	150$\pm$30	60$\pm$10	-75$\pm$25
$N^*(1440)\,P_{11}$	1387	147	48	-64
Arndt06	1359	162	38	-98
Hohler93	1385	164	40	
Cutkosky79	1375$\pm$30	180$\pm$40	52$\pm$5	-100$\pm$35

Poles and residues III

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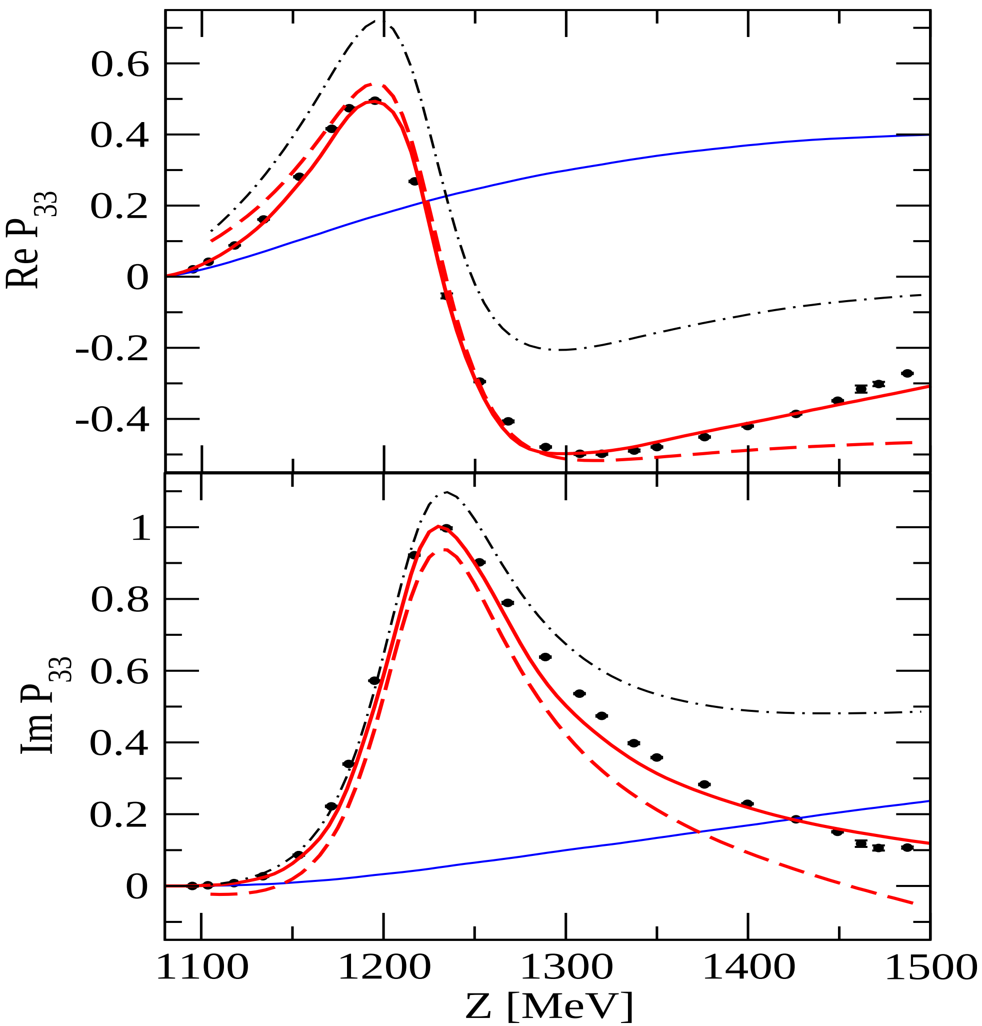
	Re Z_0 [MeV]	-2 Im Z_0 [MeV]	$\|R\|$ [MeV]	θ [deg] [^{0}]
$\Delta^*(1620)\,S_{31}$	1593	72	12	-108
Arndt06	1595	135	15	-92
Hohler93	1608	116	19	-95
Cutkosky79	1600±15	120±20	15±2	-110$\pm$20
$\Delta^*(1910)\,P_{31}$	1840	221	45	-153
Arndt06	1771	479	38	+172
Hohler93	1874	283	19	
Cutkosky79	1880±30	200±40	20±4	-90$\pm$30
$N^*(1720)\,P_{13}$	1663	212	14	-82
Arndt06	1666	355	25	-94
Hohler93	1686	187	15	
Cutkosky79	1680±30	120±40	8±12	-160$\pm$30

Background

	T^{NP}	a_0^{P}	Ratio
$N^*(1440)\,P_{11}$	$15.3 - 7.60i$	$-10.9 + 7.92i$	0.26
$\Delta^*(1620)\,S_{31}$	$9.01 - 6.37i$	$-1.21 + 0.24i$	0.9
$\Delta^*(1910)\,P_{31}$	$4.58 - 2.76i$	$-0.78 + 0.24$	0.9
$N^*(1720)\,P_{13}$	$1.76 - 0.10i$	$0.45 - 0.56i$	1.3
$N^*(1520)\,D_{13}$	$-4.62 - 0.56i$	$3.03 + 1.23i$	0.4
$\Delta(1232)\,P_{33}$	$-16.7 - 3.57i$	$17.1 + 10.6i$	0.4
$\Delta^*(1700)\,D_{33}$	$0.80 - 0.52i$	$0.40 + 0.11i$	1.3

Poles and background P_{33}

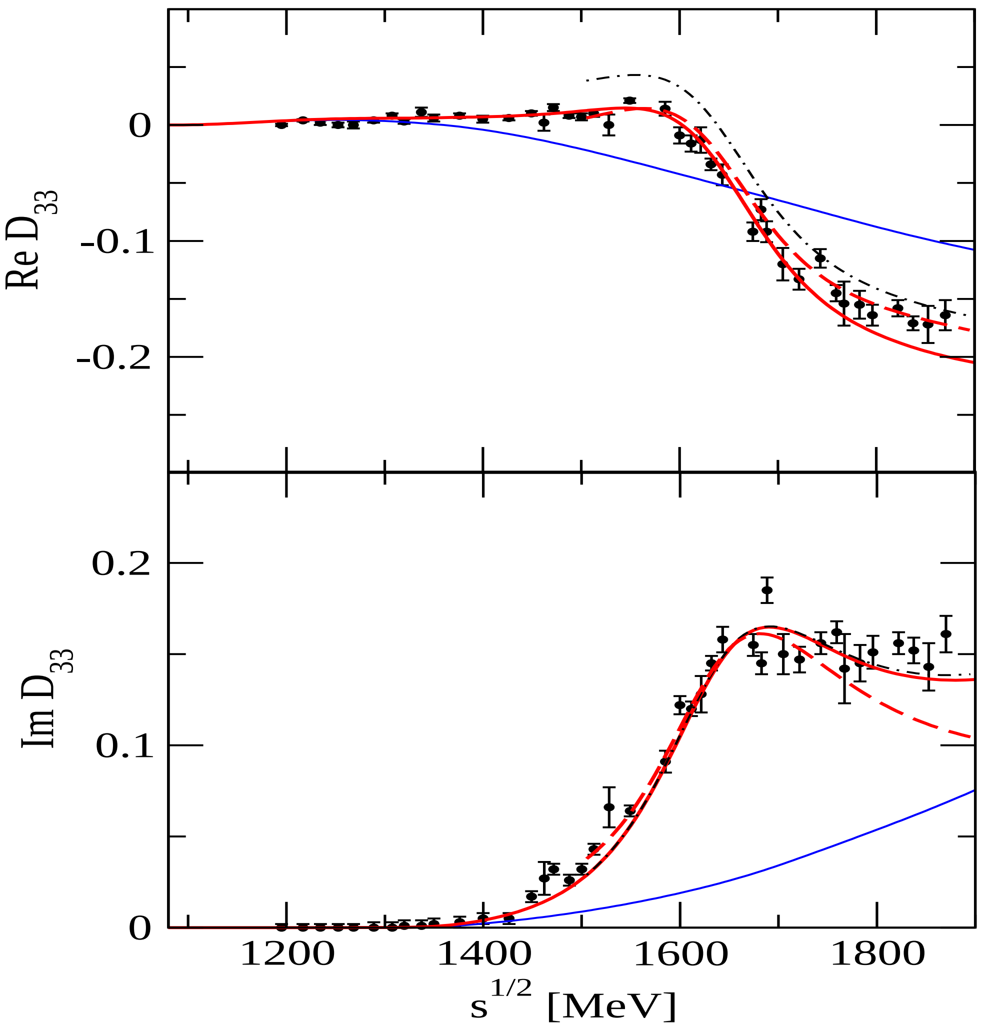


Vicinity of Pole:

$$T(Z) \sim \frac{a_{-1}}{Z - Z_0} + T^{NP}(Z)$$

$$T(Z) \sim \frac{a_{-1}}{Z - Z_0} + a_0$$

Poles and background D_{33}

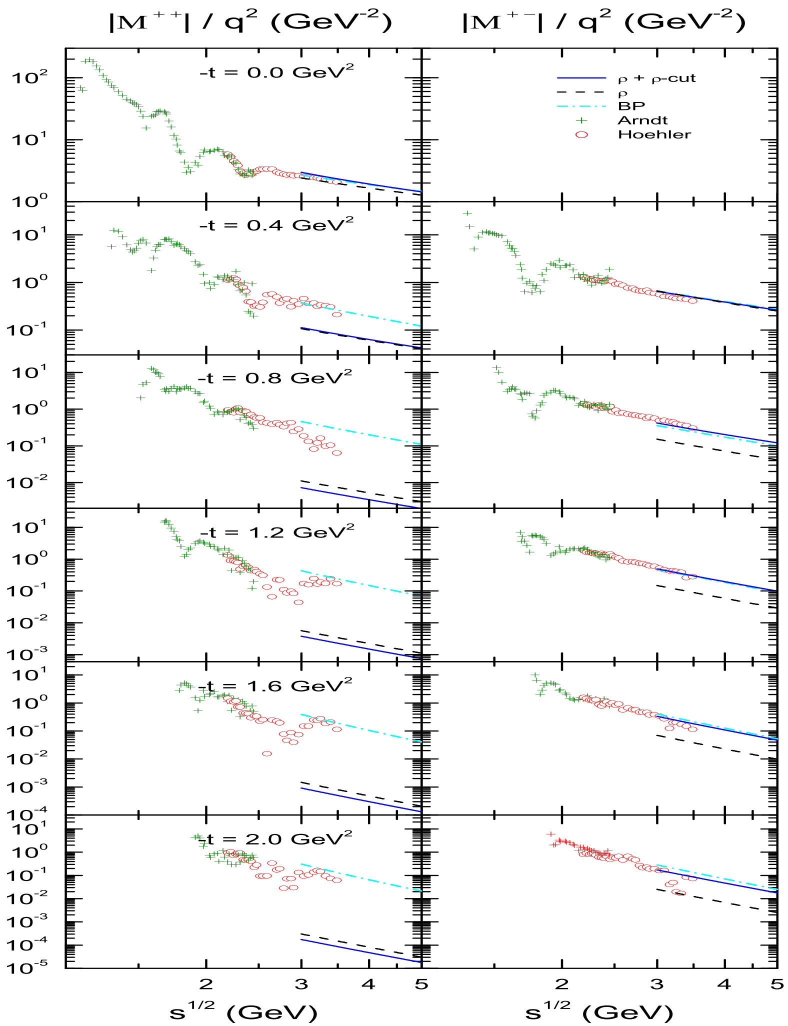


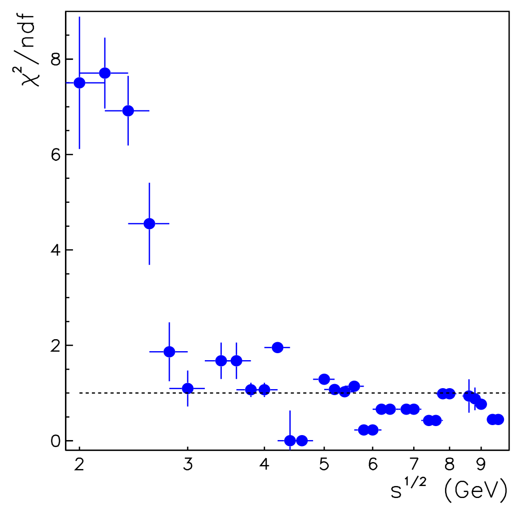
Vicinity of Pole:

$$T(Z) \sim \frac{a_{-1}}{Z - Z_0} + T^{NP}(Z)$$

$$T(Z) \sim \frac{a_{-1}}{Z - Z_0} + a_0$$

Amplitudes for charge exchange





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