Discussions

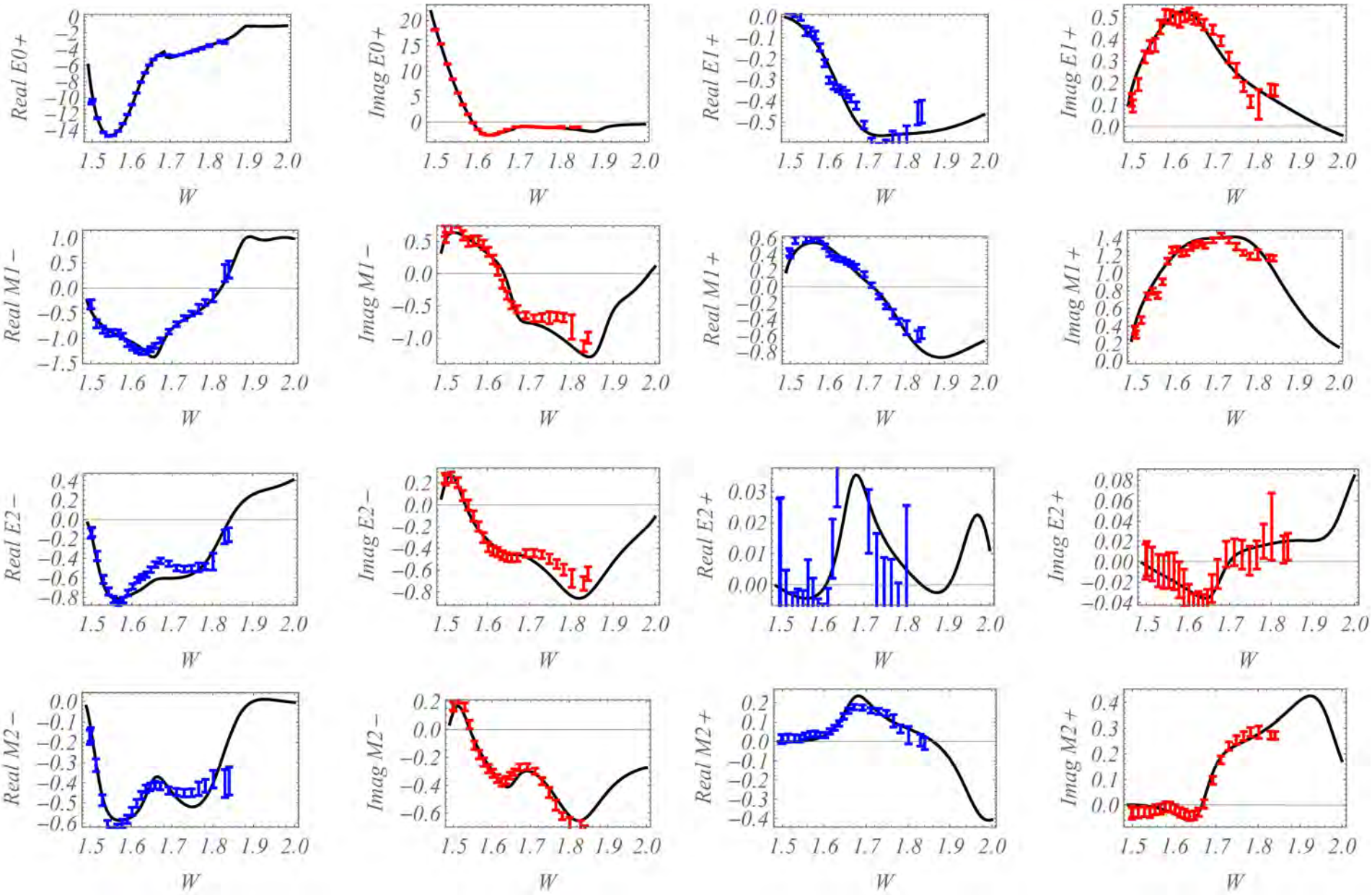
on

Single-Energy Solutions

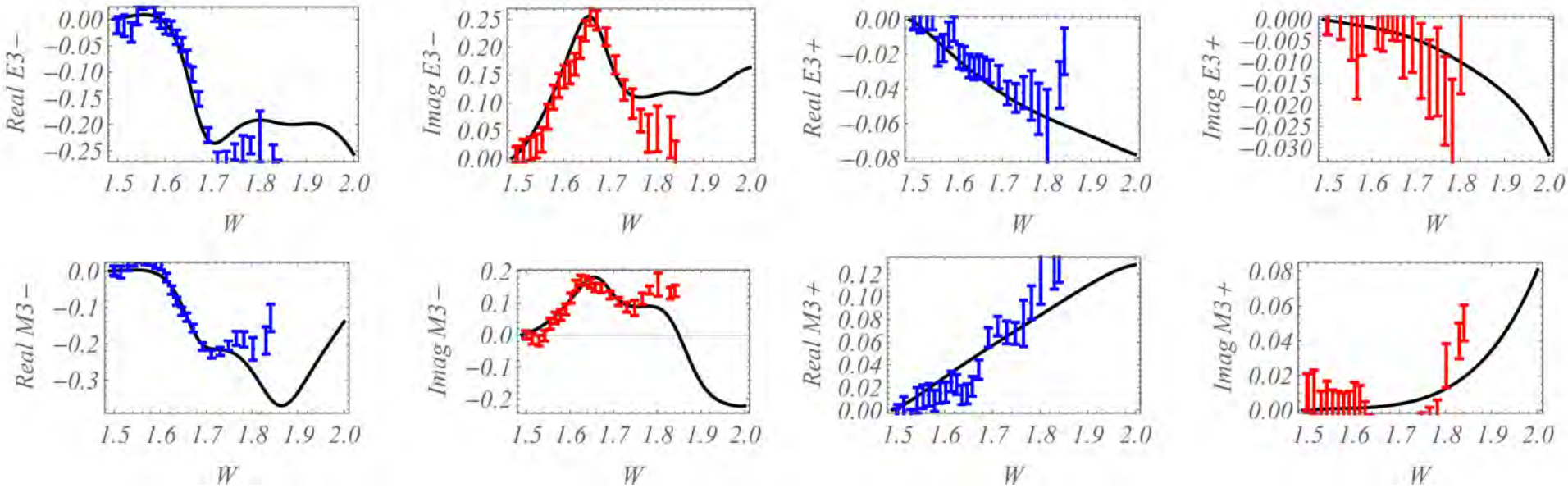
and

L + P

single-energy (SE-3) vs energy-dependent (ED) PWA for p(γ,η)p

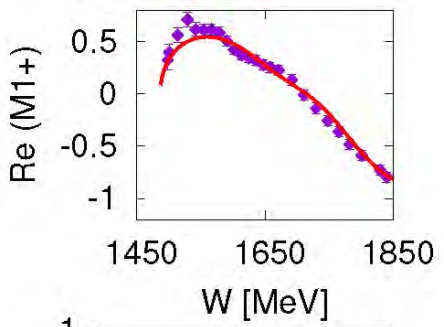


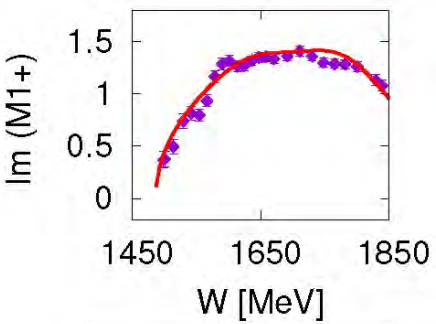
single-energy (SE-3) vs energy-dependent (ED) PWA for p(γ,η)p

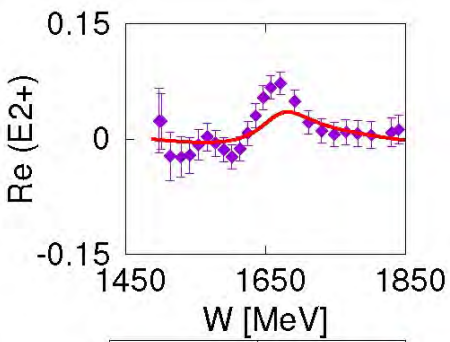


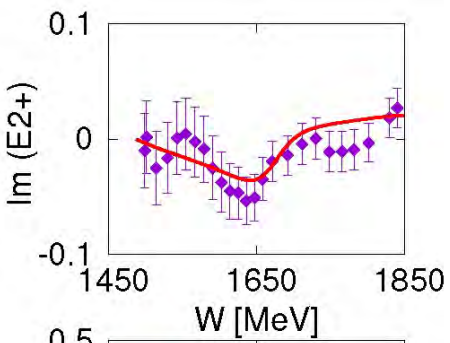
in SE-3 all multipoles up to L=5 have been freely fitted

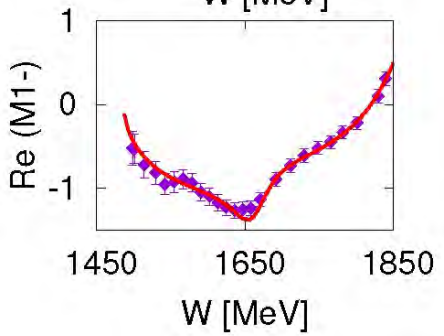
single-energy (SE-4) vs energy-dependent (ED) PWA for p(γ,η)p

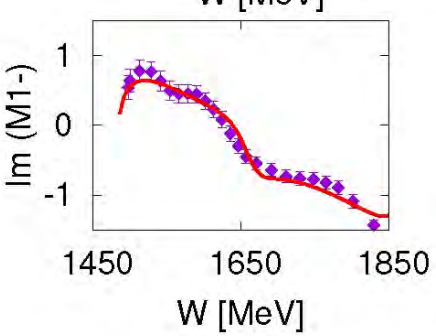


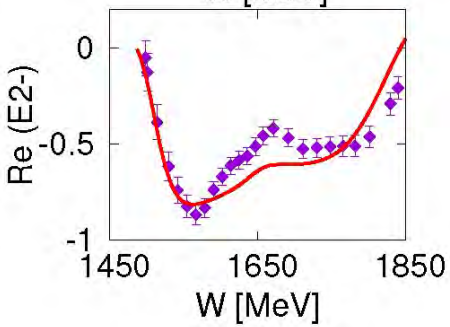


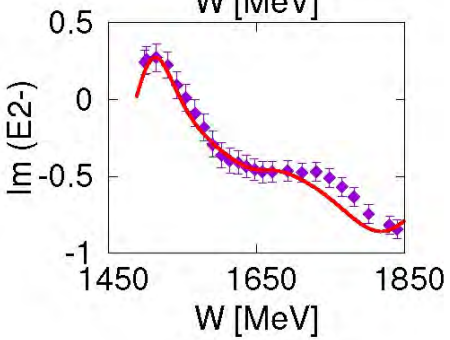


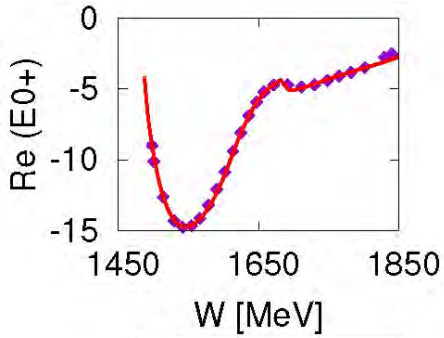


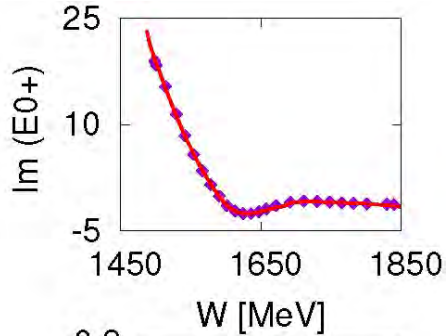


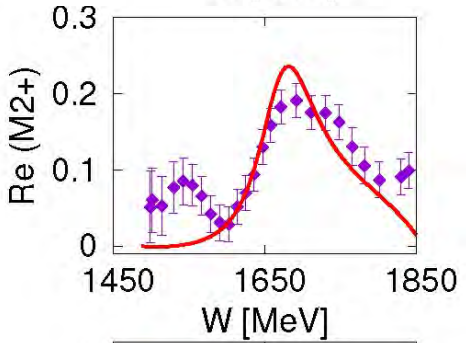


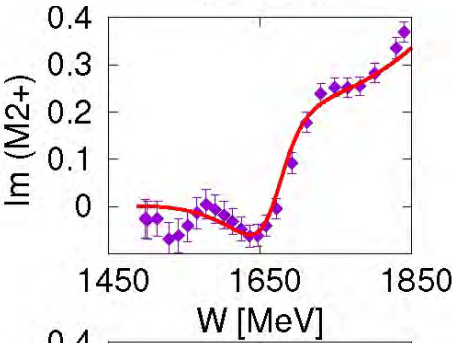


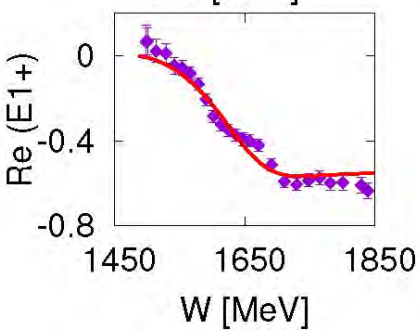


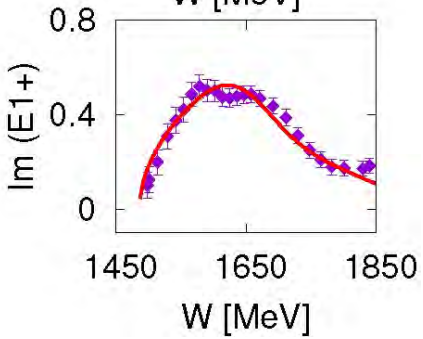


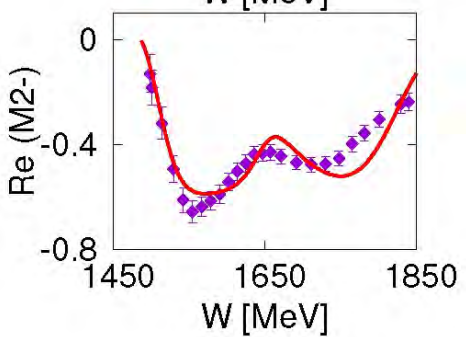


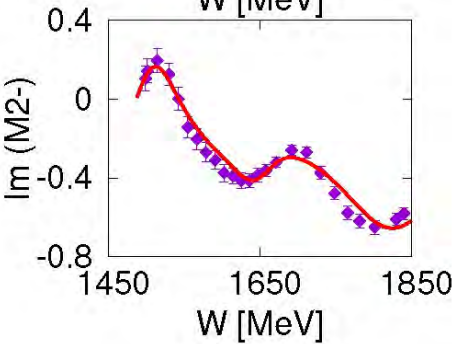




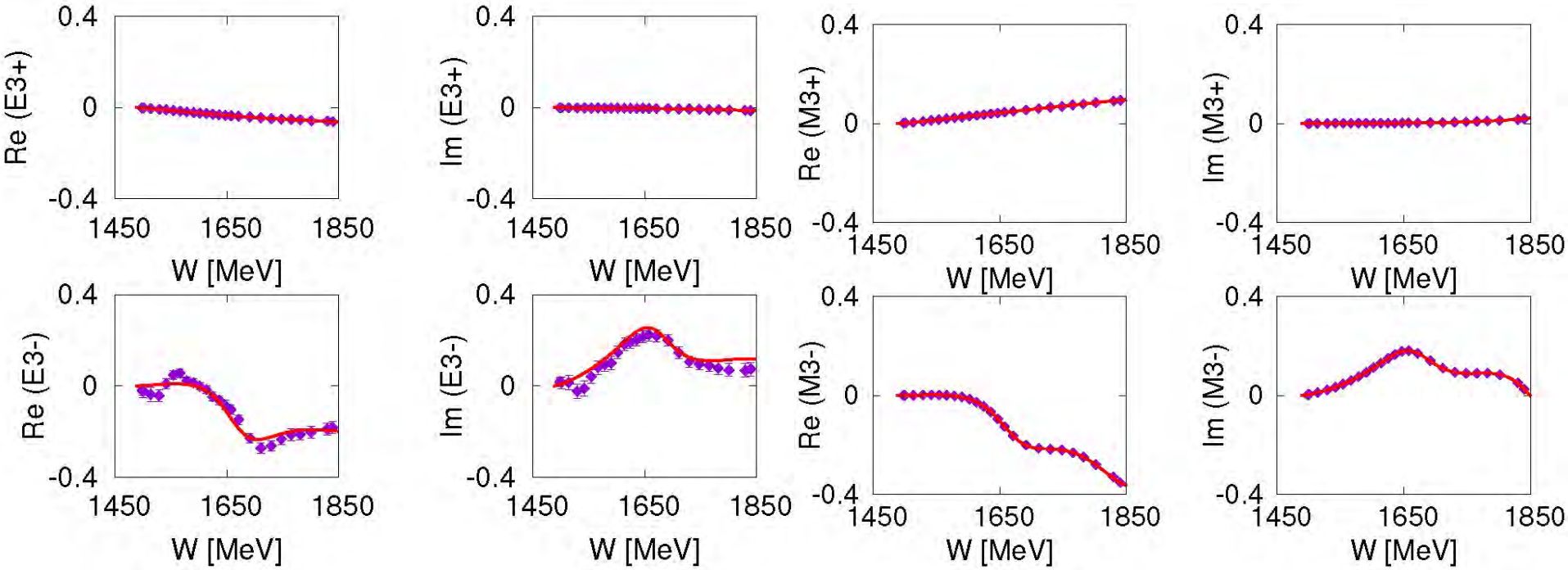








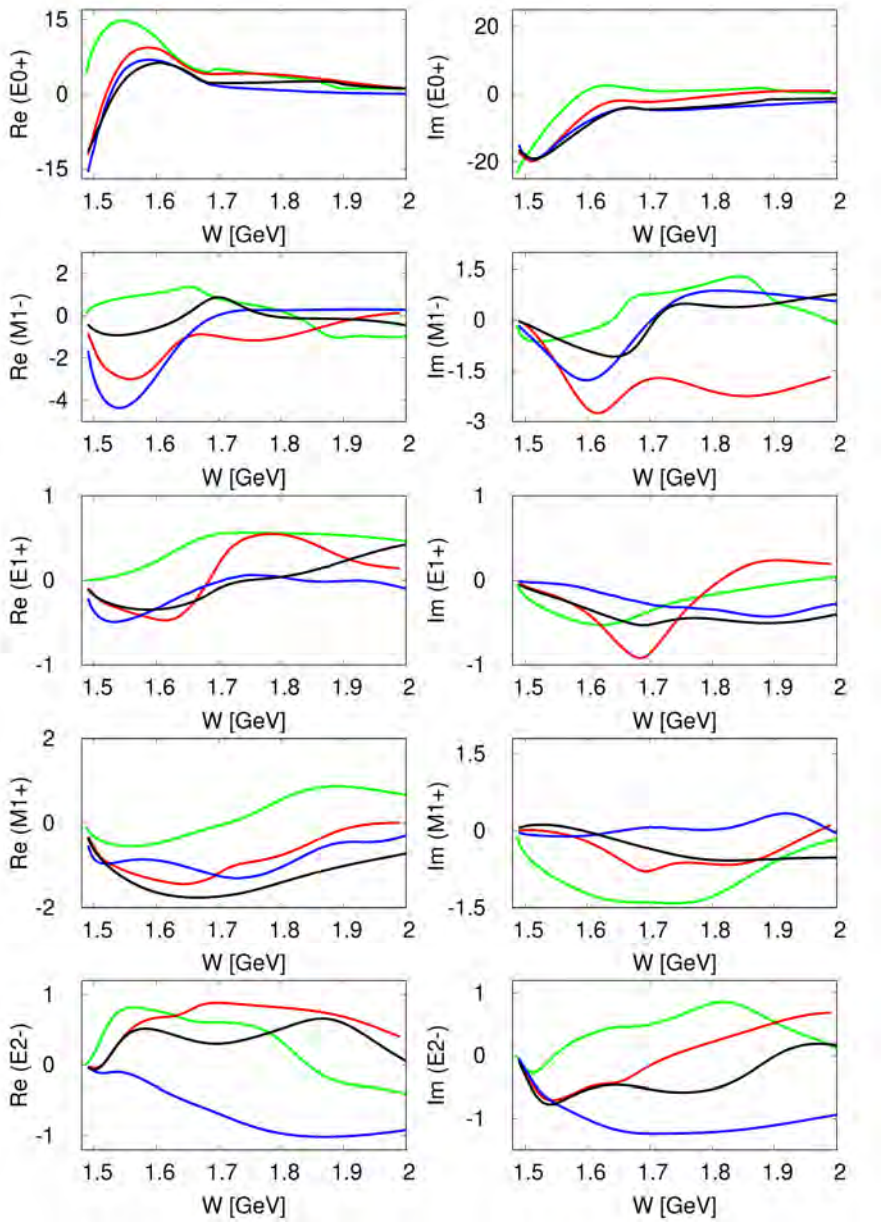
single-energy (SE-4) vs energy-dependent (ED) PWA for p(γ,η)p



in SE-4 only 9 multipoles have been freely fitted,

M3- was kept constant as all other higher multipoles

comparison of partial waves for $p(\gamma,\eta)p$



EtaMAID

BnGa

JüBo

KSU

comparison of S and P waves

between new (2018) PWA

from:

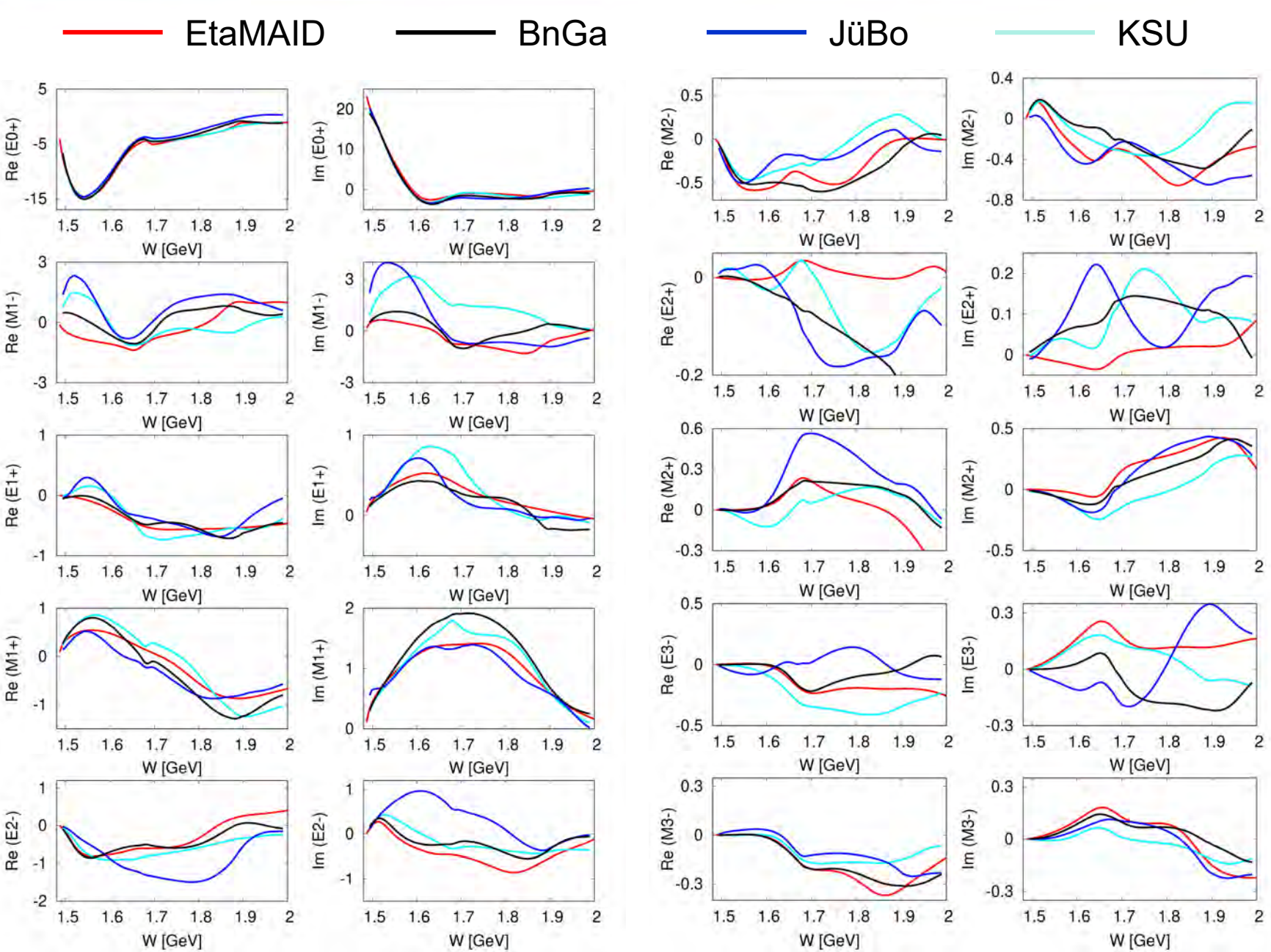
our MAID solution

Bonn-Gatchina

Jülich-Bonn

Kent-State

comparison of partial waves after phase rotation



comparison of partial waves after phase rotation for $p(\gamma,\eta)p$

comparison of S and P waves

between new (2018) PWA

from:

our MAID solution

Bonn-Gatchina

Jülich-Bonn

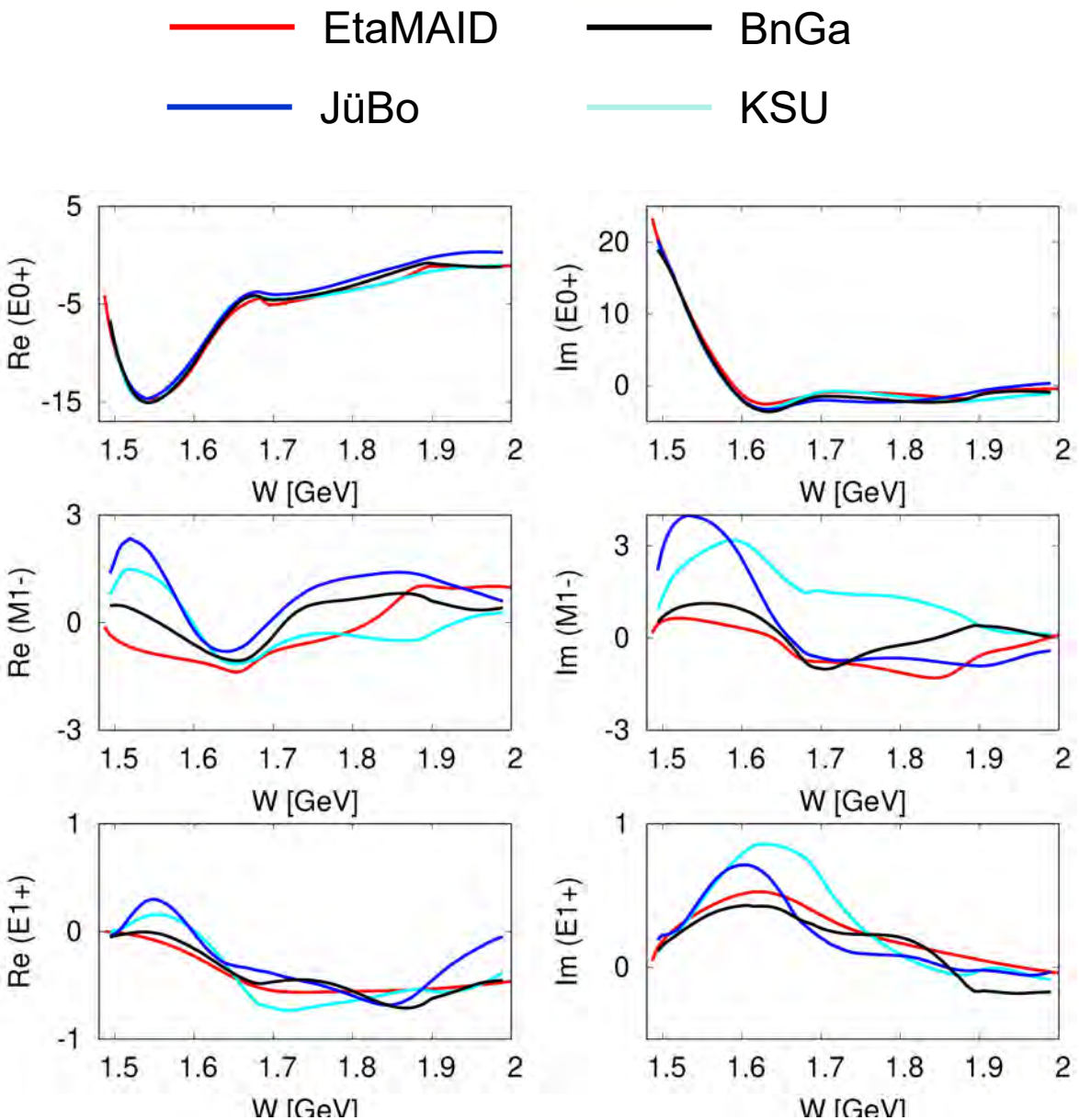
Kent-State

S waves are almost identical

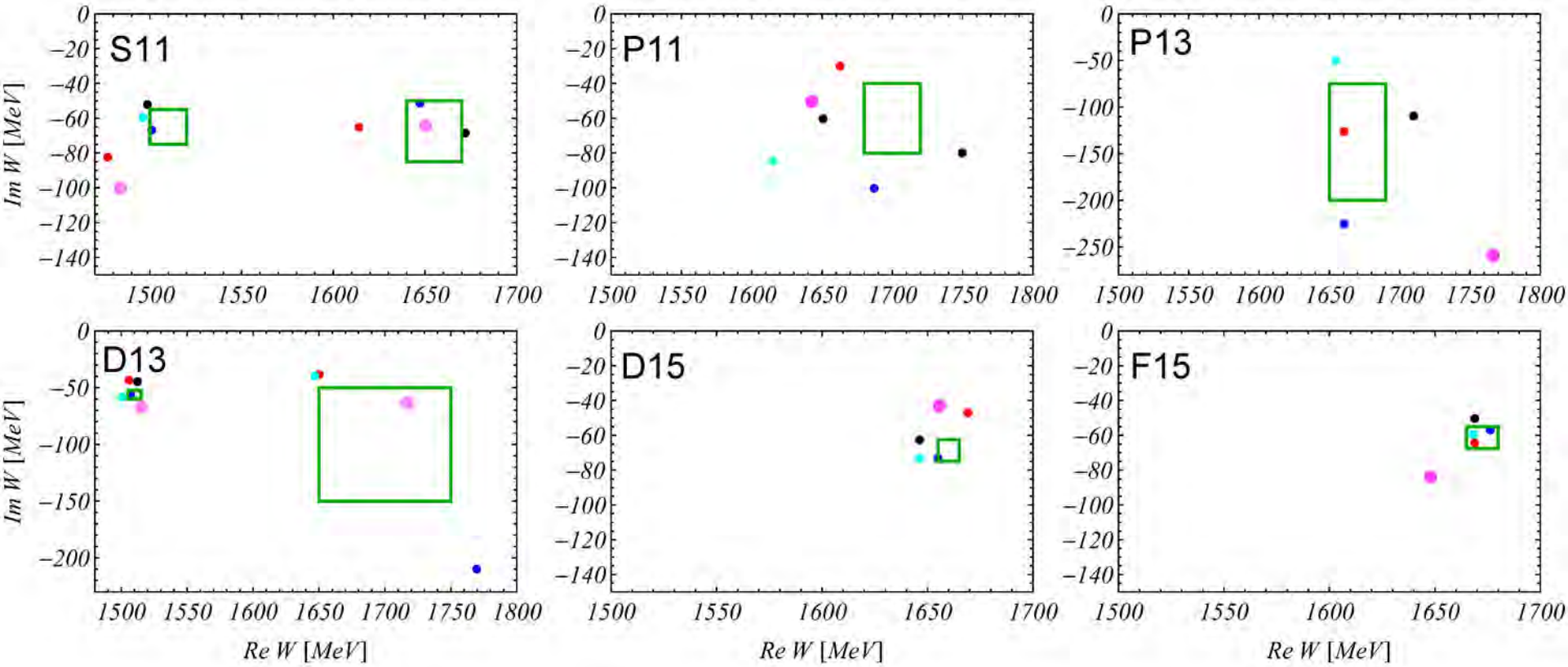
some higher pw are close

other pw differ a lot,

due to incomplete experiments!



comparison of pole positions



PDG ranges

EtaMAID-SE4

EtaMAID

BnGa

JüBo

KSU

comparison of pole positions and residues

EtaMAID and JüBo: analytical continuation, SE-4: L+P

	EtaMAID 2018	SE-4	JüBo 2017
S11(1535)	1477 – 165/2 i	1484 – 201/2 i	1495 – 112/2 i
E0+	1971, 21°	3037, 26°	736, 149°
S11(1650)	1614 – 131/2 i	1650 – 129/2 i	1674 – 130/2 i
E0+	351, –176°	325, – 96°	102, 57°
D13(1520)	1506 – 88/2 i	1515 – 135/2 i	1509 – 98/2 i
E2 –	38.6, –13°	71.9, 12°	13.4, 123°
M2 –	25.4, –13°	70.7, 19°	10.4, 108°
D15(1675)	1669 – 94/2 i	1656 – 86/2 i	1647 – 135/2 i
E2+	38.6, –13°	3.3, – 121°	3.7, 59°
M2+	25.4, –13°	8.4, – 158°	22.6, –31°
F15(1680)	1669 – 128/2 i	1648 – 168/2 i	1666 – 80/2 i
E3 –	15.1, 36°	23.3, – 18°	2.9, 126°
M3 –	11.8, 36°	20.0, 14°	1.7, 125°

comparison of pole positions and residues

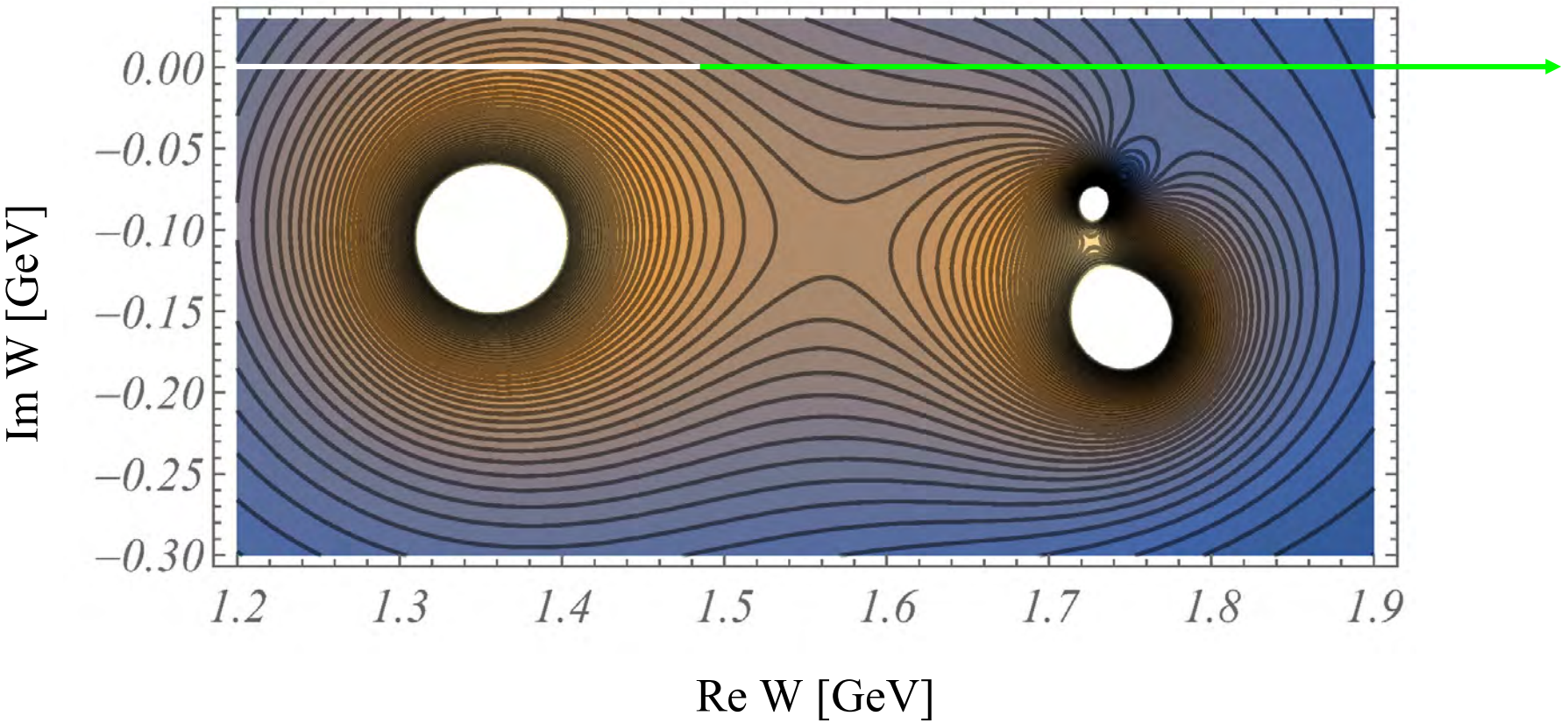
	EtaMAID 2018	SE-4	JüBo 2017
D13(1700)	1650 – 76/2 i	1717 – 128/2 i	
E2 –	3.3, –137°	20.4, 3°	
M2 –	8.6, –137°	23.3, 45°	
P11(1710)	1663 – 60/2 i	1643 – 101/2 i	1731 – 158/2 i
M1 –	16.9, 120°	30.9, 95°	30.9, 95°
P13(1720)	1660 – 251/2 i	1766 – 517/2 i	1689 – 190/2 i
E1+	68.4, 56°	428, 123°	3.7, – 165°
M1+	81.2, 56°	291, 82°	3.3, – 90°

JüBo has 2 poles in P11 partial wave in the region 1650 MeV < W < 1750 MeV, the pole masses are too close for a separation with data on the real axis

1750 – 316/2 i
57.0, 161°

simplified P11 map of JüBo model

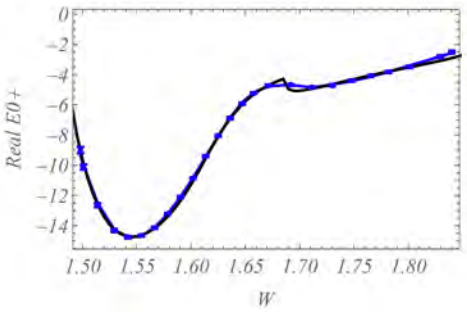
no bg is added

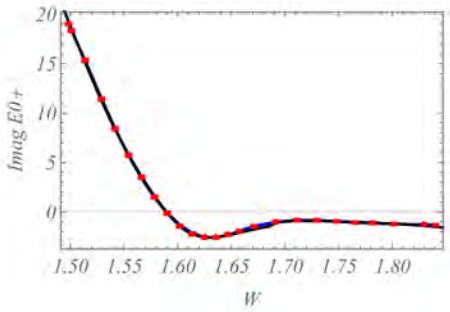


such a situation is too difficult for L+P

Details on L+P
with
Single-Energy Solution SE-4 (2019)

L+P result for S11 partial wave of SE−4 solution






```
------
Pole 1
------
ReRes=     2.7334( 0.02151)
ImRes=     1.3230( 0.02216)
Modul=     3.0367( 0.02163)
Phase=    25.8277( 0.00726)
 Mass=     1.4840( 0.00062) GeV
 -2Im=     0.2009( 0.00056) GeV
**************************************************************************
------
Pole 2
------
ReRes=    -0.0361( 0.00910)
ImRes=    -0.3227( 0.00844)
Modul=     0.3247( 0.00845)
Phase=   -96.3896( 0.02800)
 Mass=     1.6500( 0.00112) GeV
 -2Im=     0.1291( 0.00106) GeV
**************************************************************************
  TH1=    -9.4380-i0.0000
  TH2=     1.4860-i0.0000
  TH3=     1.7072-i0.0000
 del1=     1.8518
 del2=     0.6808
 del3=     0.5644
**************************************************************************
chi squared total + penalty =       16.74+       1.37=      18.11
  50  29  21
chi squared total (reduced) =        0.80         0.86
```

the fit is perfect

the 2 pole positions are close to PDG range

$M_{p1} = 1484$ MeV, $\Gamma_{p1} = 201$ MeV

$M_{p2} = 1650$ MeV, $\Gamma_{p2} = 129$ MeV

the first residue is a bit too large

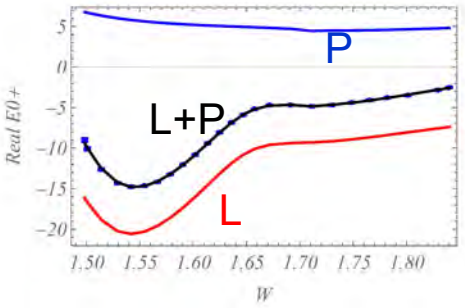
$r_{E0+,1} = 3\,037$ mfm MeV

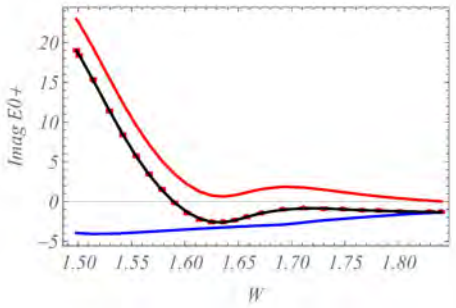
$r_{E0+,2} = 325$ mfm MeV

S11(1535) is difficult,

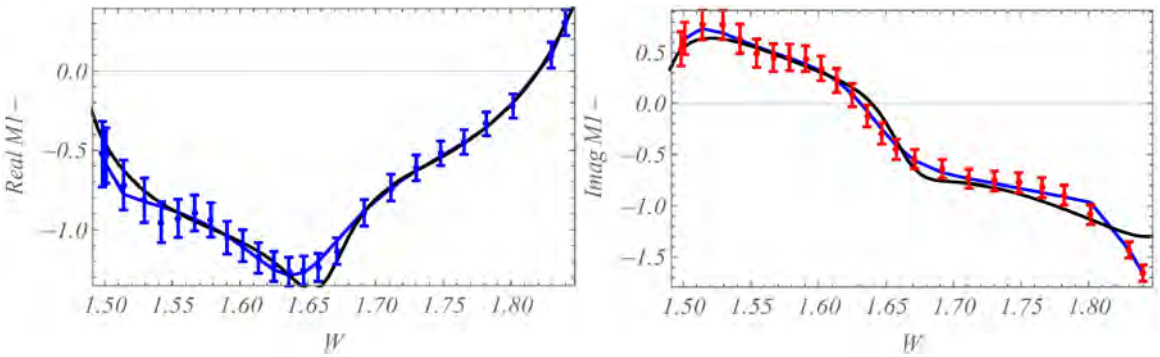
as it appears close or even below threshold

S11(1650) is easy





L+P result for P11 partial wave of SE−4 solution



the fit is perfect

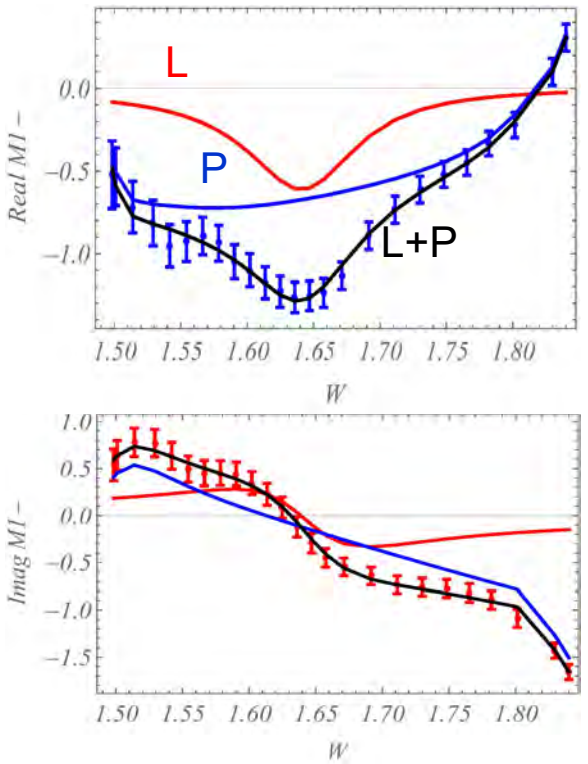
the pole position is near PDG range

$\mathbf{M_p = 1643\ MeV,\ \Gamma_p = 101\ MeV}$

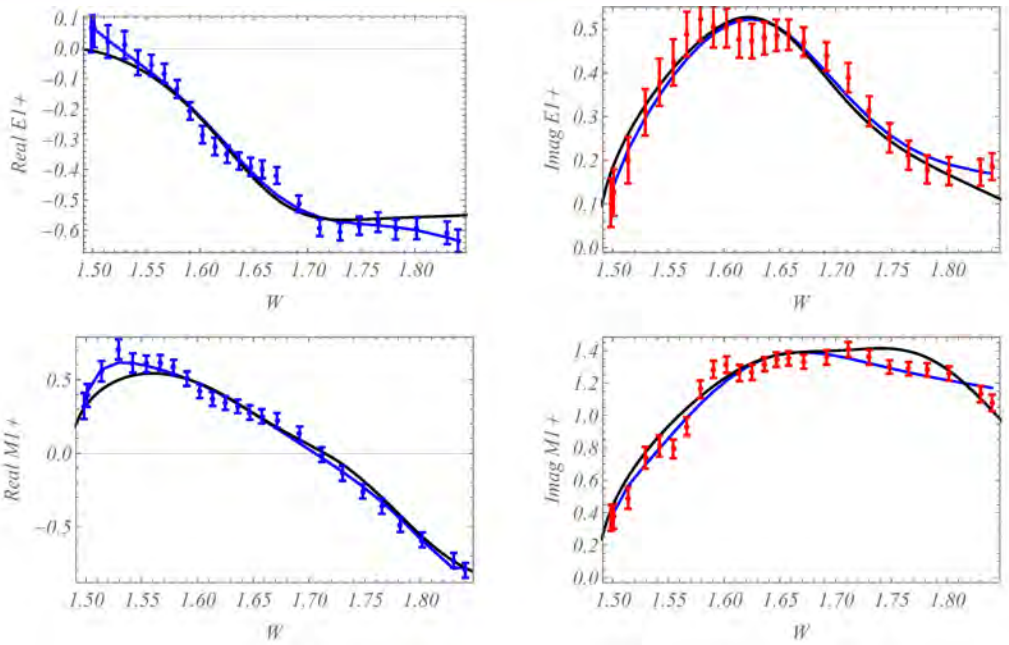
$\mathbf{r_{M1-} = 30.9\ mfm\ MeV}$

no need for a second pole

```
------
Pole 1
------
ReRes=    -0.0027( 0.00594)
ImRes=     0.0308( 0.00635)
Modul=     0.0309( 0.00635)
Phase=    95.0009( 0.19255)
 Mass=     1.6432( 0.00804) GeV
 -2Im=     0.1006( 0.00818) GeV
**************************************************************
  TH1=     1.3349-i0.0000
  TH2=     1.4860-i0.0000
  TH3=     1.8247-i0.0000
 del1=     0.7613
 del2=     0.4044
 del3=     0.3152
**************************************************************
chi squared total + penalty =        6.35+       2.24=       8.60
  50   25   25
chi squared total (reduced) =        0.25        0.34
```



L+P result for P13 partial wave of SE-4 solution



the fit is good

the pole position is far outside PDG range

$\mathbf{M_p = 1766\ MeV,\ \Gamma_p = 517\ MeV}$

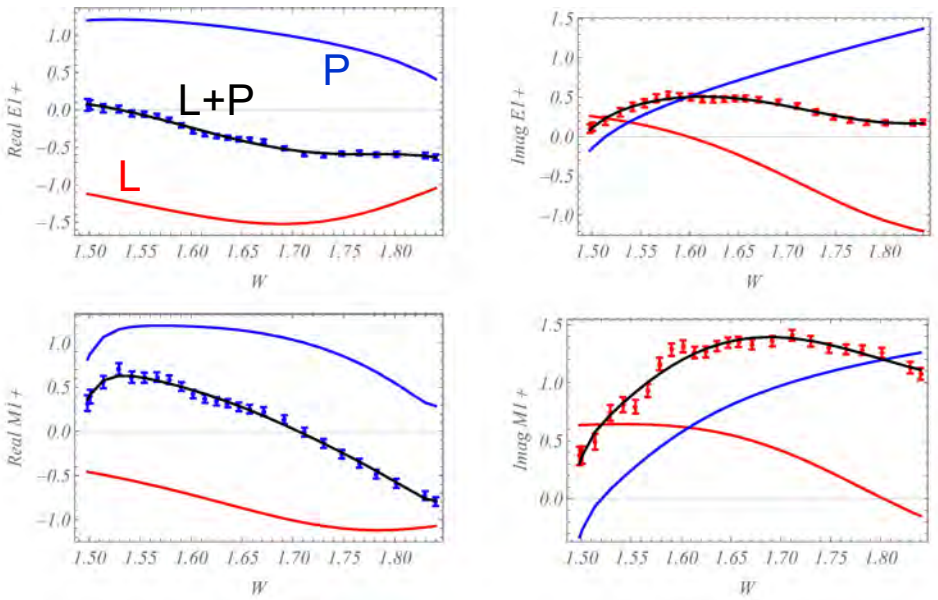
the residues are very much too large

$\mathbf{r_{E1+} = 428\ mfm\ MeV}$

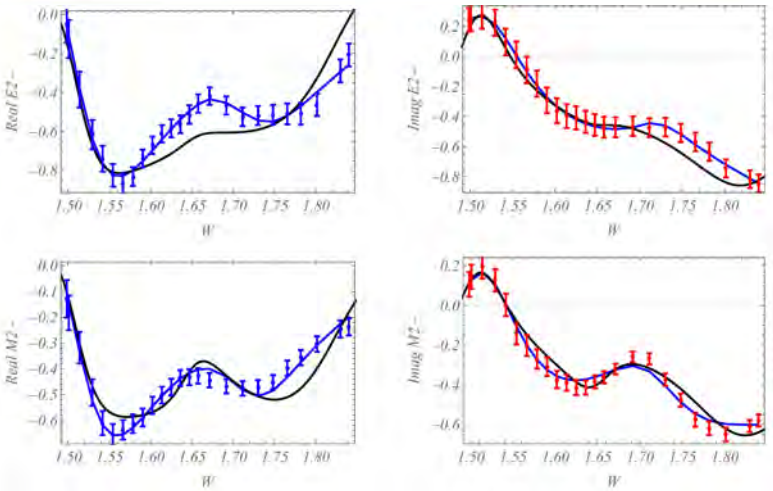
$\mathbf{r_{M1+} = 291\ mfm\ MeV}$

P13 is the most difficult partial wave

```
------
Pole 1
------
ReRes=    -0.2320( 0.00715)      0.0416( 0.00910)
ImRes=     0.3595( 0.00656)      0.2881( 0.01018)
Modul=     0.4279( 0.00674)      0.2911( 0.01015)
Phase=   122.8278( 0.01632)     81.7907( 0.03133)
 Mass=     1.7657( 0.00335) GeV
 -2Im=     0.5168( 0.00309) GeV
*********************************************************************
  TH1=     1.2003-i0.0000        1.3000-i0.0000
  TH2=     1.4860-i0.0000        1.4860-i0.0000
  TH3=     1.8876-i0.0000        1.8500-i0.0000
 del1=     1.0713                1.2679
 del2=     0.8917                0.5500
 del3=     0.6592                0.5805
*********************************************************************
chi squared total + penalty =       60.58+       4.75=      65.33
 100  48  52
chi squared total (reduced) =        1.16         1.26
```



L+P result for D13 partial wave of SE−4 solution




```
Pole 1
------
ReRes=     0.0703( 0.02872)      0.0669( 0.02360)
ImRes=     0.0148( 0.01836)      0.0228( 0.01717)
Modul=     0.0719( 0.02836)      0.0707( 0.02302)
Phase=    11.9186( 0.26331)     18.8335( 0.25381)
 Mass=     1.5147( 0.01020) GeV
 -2Im=     0.1346( 0.01076) GeV
**************************************************************
------
Pole 2
------
ReRes=     0.0204( 0.00710)      0.0163( 0.00745)
ImRes=     0.0010( 0.00647)      0.0166( 0.00679)
Modul=     0.0204( 0.00710)      0.0233( 0.00712)
Phase=     2.8681( 0.31777)     45.4624( 0.30664)
 Mass=     1.7173( 0.01089) GeV
 -2Im=     0.1283( 0.01072) GeV
**************************************************************
  TH1=     1.3419-i0.0000       -0.0147-i0.0000
  TH2=     1.4860-i0.0000        1.4860-i0.0000
  TH3=     1.6885-i0.0000        1.6800-i0.0000
 del1=     1.1439                1.5116
 del2=     0.4832                1.5708
 del3=     0.8091                1.0000
**************************************************************
chi squared total + penalty =       38.71+       0.95=      39.66
 100   54   46
chi squared total (reduced) =        0.84         0.86
```

the fit is good

the 2 pole positions are close to PDG ranges

$\mathbf{M_{p1} = 1515\ MeV,\ \Gamma_{p1} = 135\ MeV}$

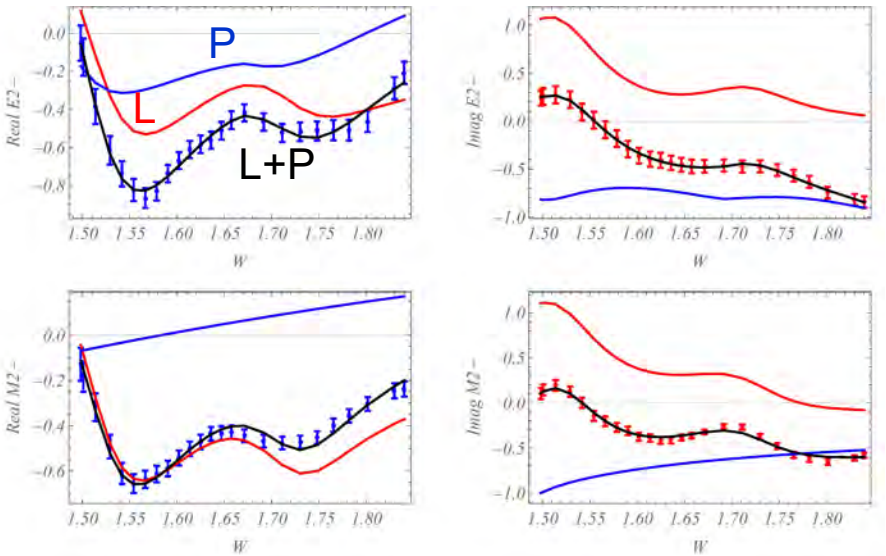
$\mathbf{M_{p2} = 1717\ MeV,\ \Gamma_{p2} = 128\ MeV}$

the residues are reasonable

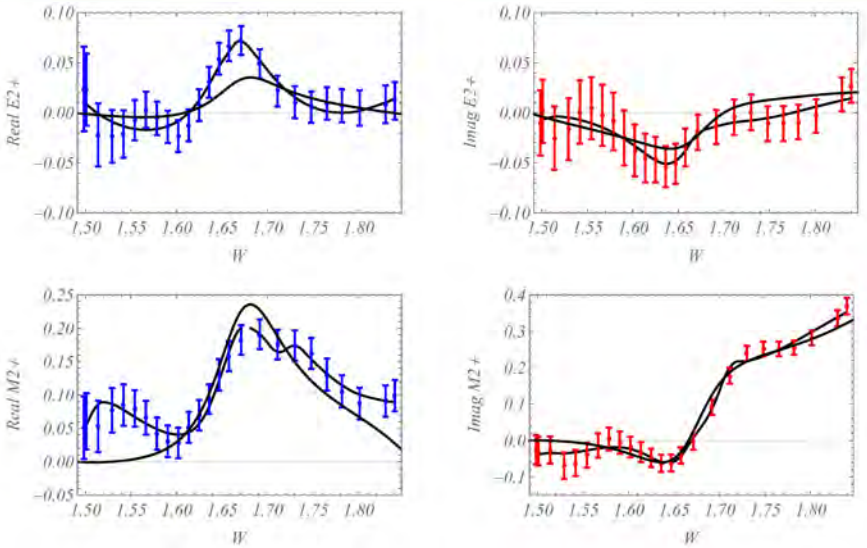
$\mathbf{r_{E2-} = 71.9}$ and $\mathbf{20.4\ mfm\ MeV}$

$\mathbf{r_{M2-} = 70.7}$ and $\mathbf{23.3\ mfm\ MeV}$

D13 is an easy partial wave



L+P result for D15 partial wave of SE−4 solution




```
------
Pole 1
------
ReRes=    -0.0017( 0.00051)     -0.0078( 0.00096)
ImRes=    -0.0028( 0.00056)     -0.0032( 0.00114)
Modul=     0.0033( 0.00054)      0.0084( 0.00099)
Phase= -121.3284( 0.16075)   -157.6509( 0.13285)
 Mass=     1.6562( 0.00490) GeV
 -2Im=     0.0863( 0.00444) GeV
*****************************************************************
  TH1=     1.2454-i0.0000        1.2860-i0.0000
  TH2=     1.4860-i0.0000        1.4860-i0.0000
  TH3=     1.6713-i0.0000        1.7016-i0.0000
 del1=     0.6510                0.9840
 del2=     0.9775                0.5500
 del3=     0.7570                0.5805
*****************************************************************
chi squared total + penalty =       21.99+       0.77=      22.76
 100   48   52
chi squared total (reduced) =        0.42         0.44
```

the fit is good

the pole position is far outside PDG range

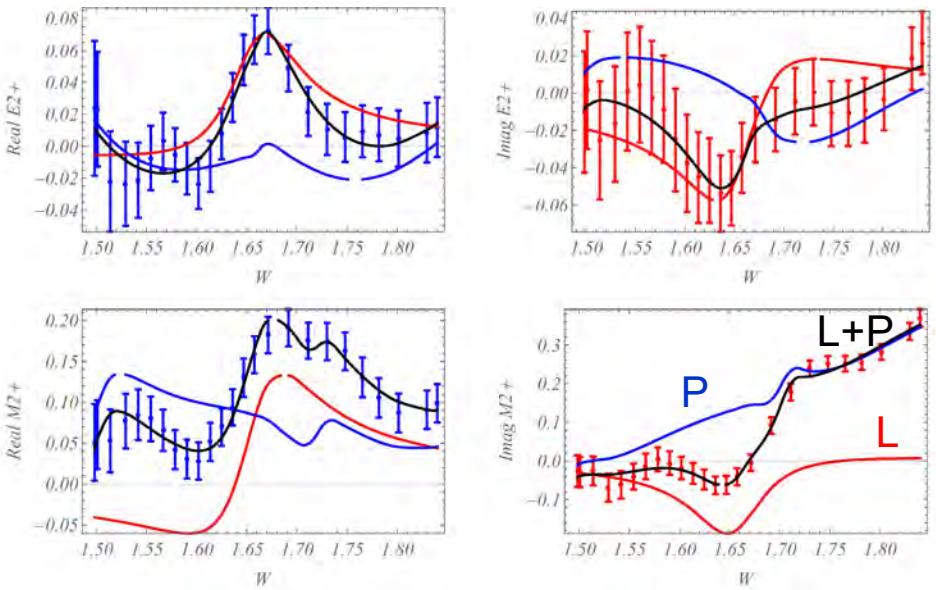
$\mathbf{M_p = 1656\ MeV,\ \Gamma_p = 86\ MeV}$

the residues look very reasonable

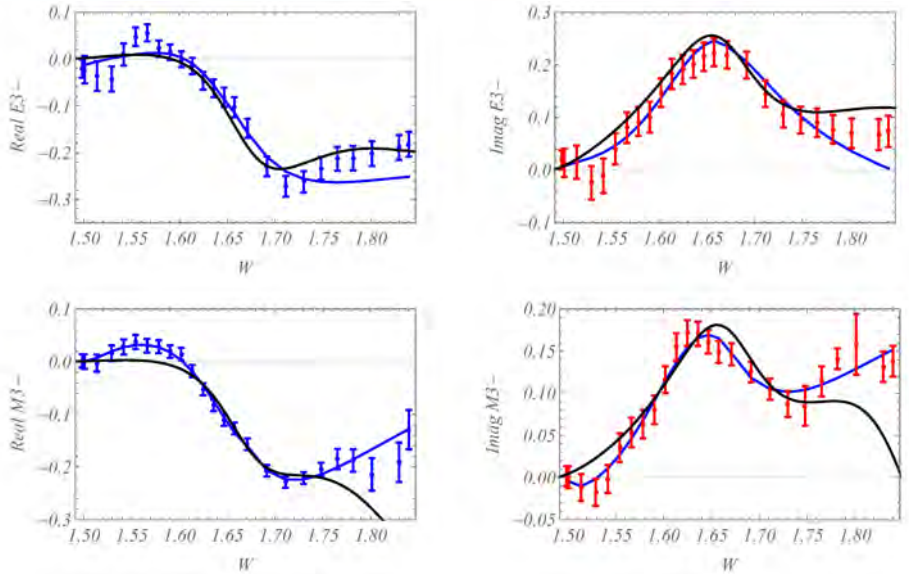
$\mathbf{r_{E2+} = 3.3\ mfm\ MeV}$

$\mathbf{r_{M2+} = 8.4\ mfm\ MeV}$

D15 is an easy partial wave



L+P result for F15 partial wave of SE−4 solution




```
------
Pole 1
------
ReRes=     0.0222( 0.00139)      0.0195( 0.00112)
ImRes=    -0.0073( 0.00168)      0.0047( 0.00134)
Modul=     0.0233( 0.00142)      0.0200( 0.00113)
Phase=   -18.2888( 0.07065)     13.6600( 0.06647)
 Mass=     1.6475( 0.00353) GeV
 -2Im=     0.1683( 0.00329) GeV
*********************************************************************
  TH1=     1.1127-i0.0000        1.3000-i0.0000
  TH2=     1.4860-i0.0000        1.4860-i0.0000
  TH3=     1.6576-i0.0000        1.6698-i0.0000
 del1=     0.6498                0.4685
 del2=     0.7155                0.5500
 del3=     1.1898                0.5805
*********************************************************************
chi squared total + penalty =       56.41+       0.83=       57.24
 100   48   52
chi squared total (reduced) =        1.08         1.10
```

the fit is good

the pole position is far outside PDG range

$\mathbf{M_p = 1648\ MeV,\ \Gamma_p = 168\ MeV}$

the residues look reasonable

$\mathbf{r_{E3-} = 23.3\ mfm\ MeV}$

$\mathbf{r_{M3-} = 20.0\ mfm\ MeV}$

SE solution is questionable for W>1.7 GeV