The recent results from Bonn-Gatchina group

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Bonn-Gatchina Partial Wave Analysis

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- SAID
- MAID
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- Publications
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Useful Links

- SPIRES
- PDG Homepage
- Durham Data Base
- Bonn Homepage

CB-ELSA Homepage

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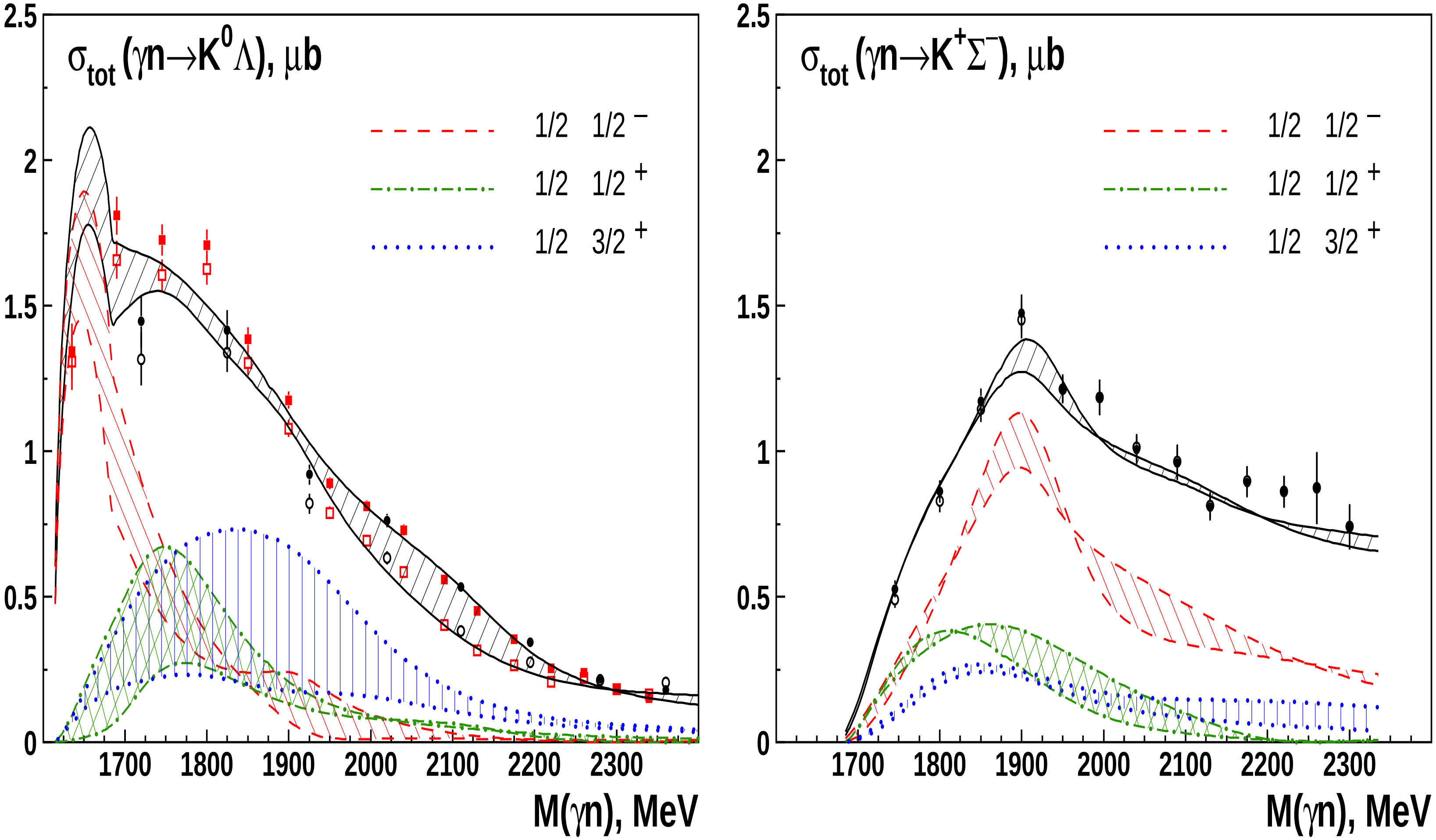
Last changes: January 26th, 2010.

Recently included data

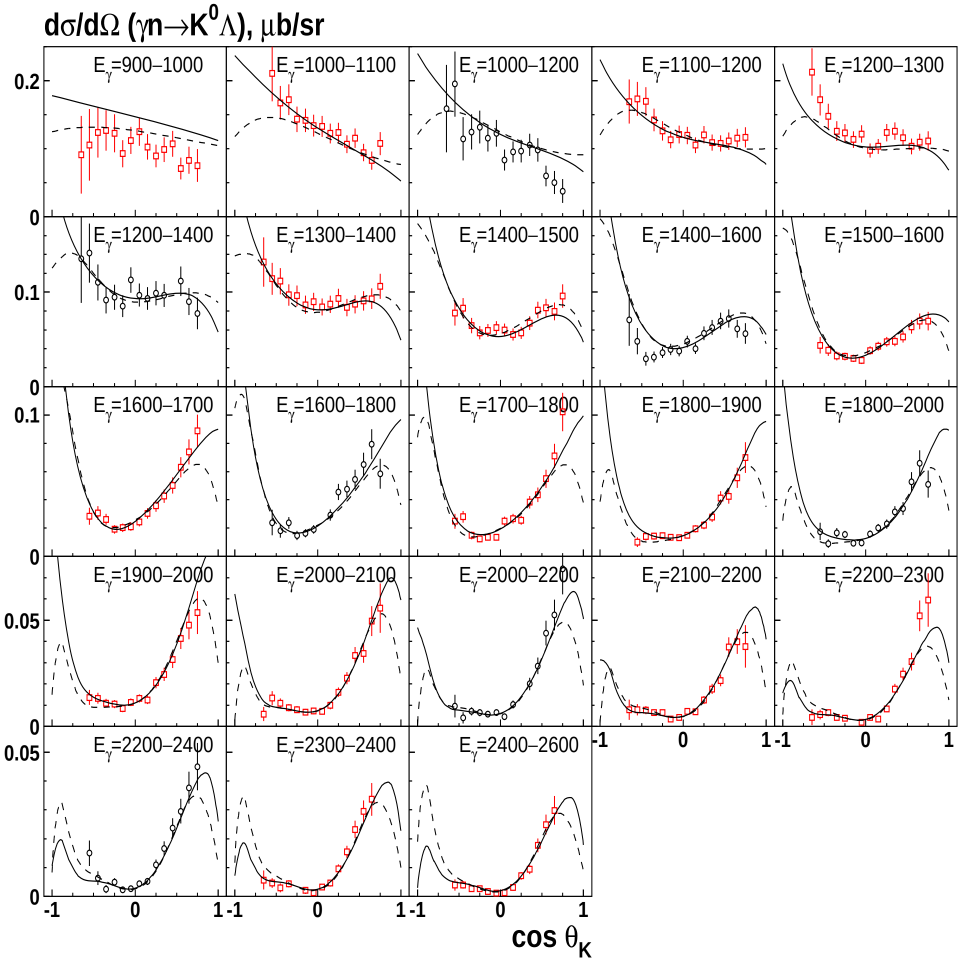
DATA	2011-2016	added in 2016-2018
$\gamma n \to \Lambda K, \Sigma^- K$		$\frac{d\sigma}{d\Omega}$ **(CLAS), E (CLAS)**
$\gamma n \to \pi^- p$	$\frac{d\sigma}{d\Omega}, \Sigma, P$	E, Σ **(CLAS)**
$\gamma n \to \eta n$	$\frac{d\sigma}{d\Omega}, \Sigma$	$\frac{d\sigma}{d\Omega}$ **(MAMI)** $\frac{d\sigma}{d\Omega}(h = \frac{1}{2})$ **(CB-ELSA)**
$\gamma p \to \eta p$	$\frac{d\sigma}{d\Omega}, \Sigma(GRAAL)$	$\frac{d\sigma}{d\Omega}, F, T$ **(MAMI)** T, P, H, G,**(CB-ELSA)** E, Σ **(CB-ELSA,CLAS)**
$\gamma p \to \eta' p$ $\gamma p \to K^+ \Lambda$ $\gamma p \to K^+ \Sigma^0$	 $\frac{d\sigma}{d\Omega}, \Sigma, P, T, C_x, C_z, O_{x'}, O_{z'}$ $\frac{d\sigma}{d\Omega}, \Sigma, P, C_x, C_z$	$\frac{d\sigma}{d\Omega}, \Sigma$ Σ, P, T, O_x, O_z **(CLAS)** Σ, P, T, O_x, O_z **(CLAS)**
$\pi^- p \to \pi^+ \pi^- n$ $\pi^- p \to \pi^- \pi^0 p$		$d\sigma/d\Omega$ **(HADES)** $d\sigma/d\Omega$ **(HADES)**
$\gamma p \to \pi^0 \pi^0 p$ $\gamma p \to \pi^+ \pi^- p$	$d\sigma/d\Omega, \Sigma, E, I_c, I_s$	T, P, H, F, P_x, P_y **(CB-ELSA)** $d\sigma/d\Omega, I_c, I_s$ **(CLAS)**
$\gamma p \to \omega p$	$d\sigma/d\Omega, \Sigma, \rho^k_{ij}, E, G$ **(CB-ELSA)**	Σ **(CLAS) P,T,F,H (CLAS)**
$\gamma p \to K^* \Lambda$		$d\sigma/d\Omega$**,** ρ_{ij}

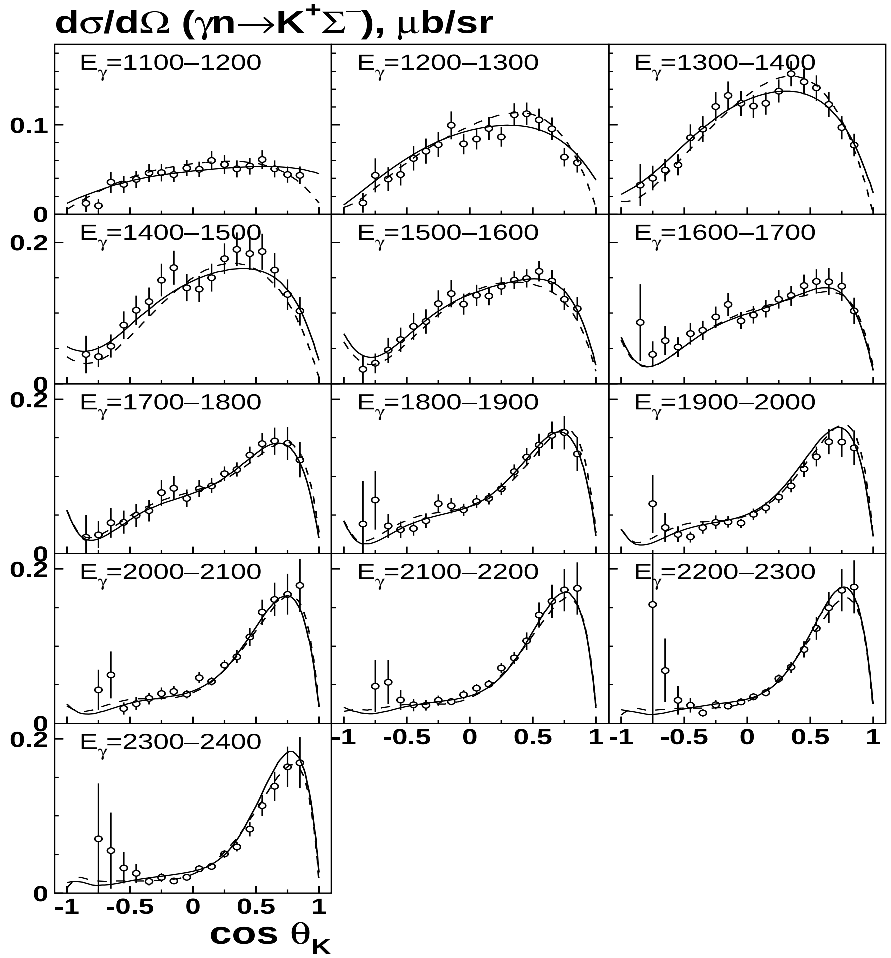
The analysis of the $\gamma n \to K\Lambda$ data and the $\gamma n \to K^+\Sigma^-$ data (Practically no free parameters)



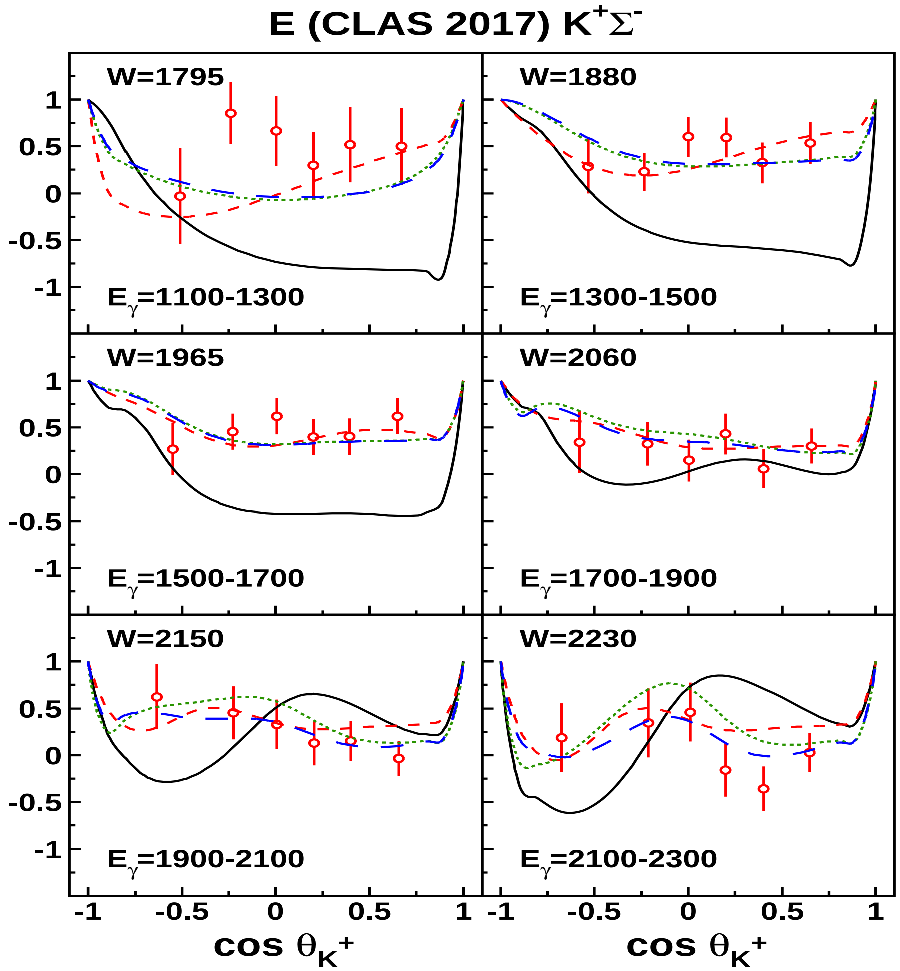
Clear contributions from the $S_{11}(1895)$ and $P_{13}(1900)$ states.

Description of the differential cross section





New CLAS data on the helicity asymmetry $\gamma n \to K^+\Sigma^-$



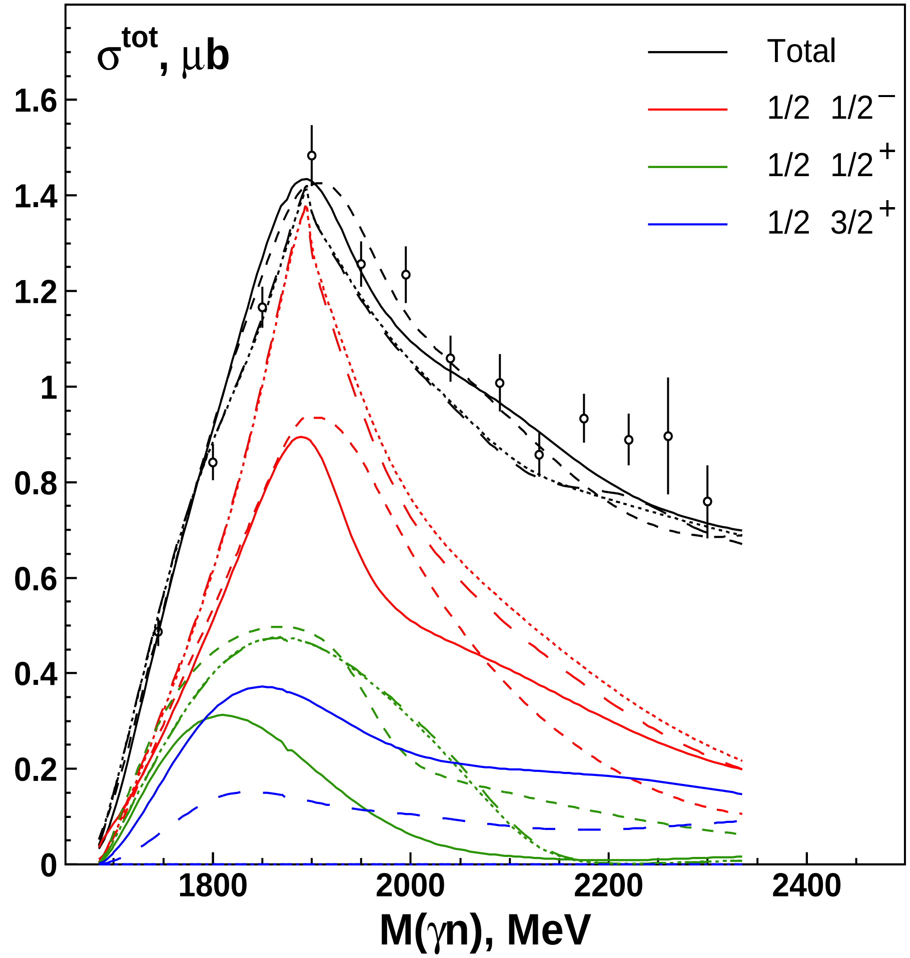
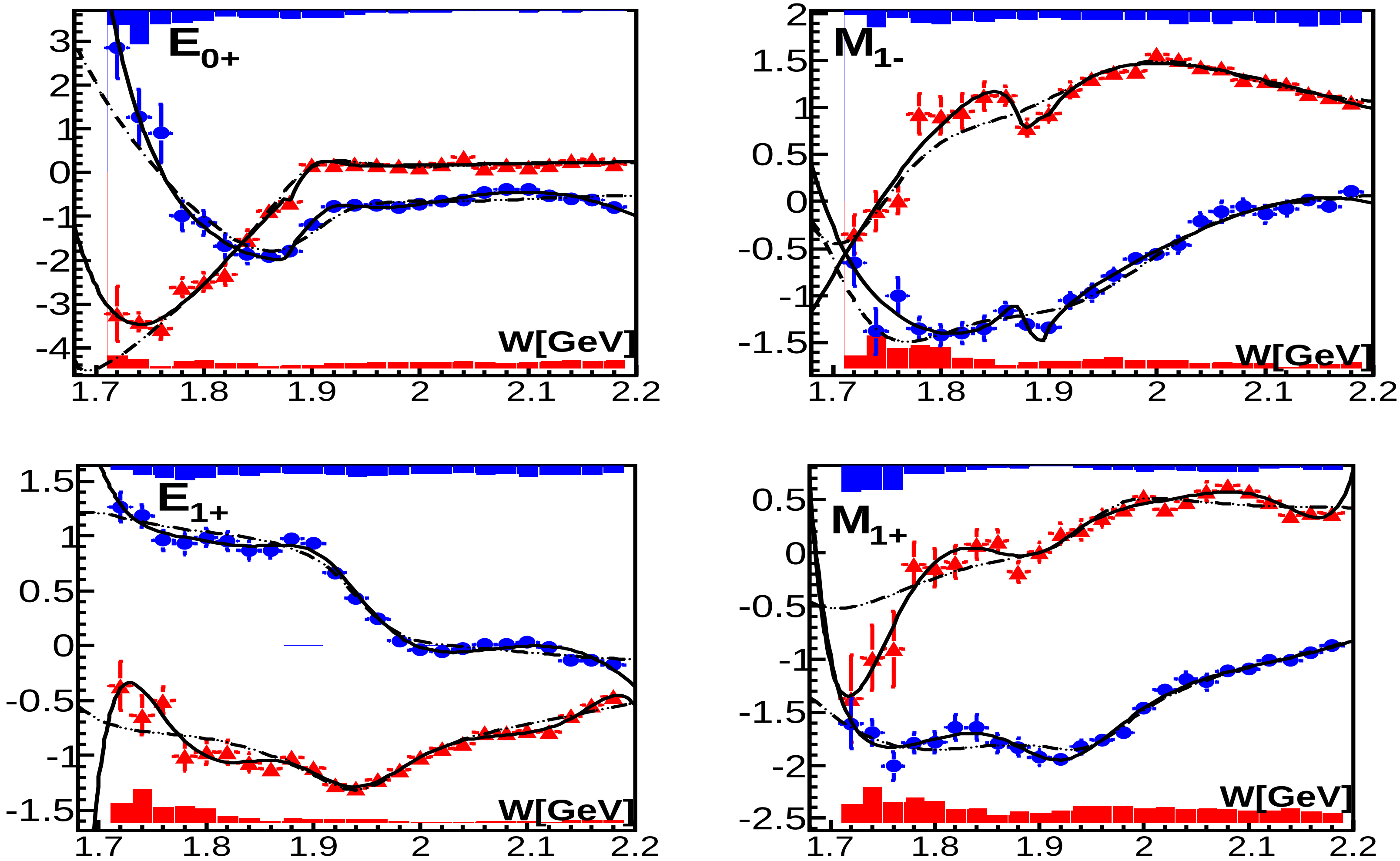


Table 1: The γN couplings (GeV$^{-1/2} 10^{-3}$) at the pole position

	$A_{1/2}$	Phase	$A_{3/2}$	Phase
$N(1535)1/2^-$	-88±4	5±4°		
$N(1650)1/2^-$	16±4	-28±10°		
$N(1895)1/2^-$	-15±10	60±25°		
$N(1440)1/2^+$	41±5	23±10°		
$N(1710)1/2^+$	29±7	80±20°		
$N(1880)1/2^+$	72±24	-30±30°		
$N(2100)1/2^+$	29±9	35±20°		
$N(1520)3/2^-$	-45±5	-5±4°	-119±5	5±4°
$N(1875)3/2^-$	4±3	-85±35°	-6±4	-85±45°
$N(2120)3/2^-$	80±30	15±25°	-33±20	-60±35°
$N(1720)3/2^+$	$-(25^{+40}_{-15})$	-75±35°	100±35	-80±35°
$N(1900)3/2^+$	-98±20	-13±20°	74±15	5±15°
$N(1975)3/2^+$	-26±13	8±25°	-77±15	5±20°
$N(1675)5/2^-$	-53±4	-3±5°	-73±5	-12±5°
$N(2060)5/2^-$	52±25	-5±20°	12±7	-40±35°
$N(1680)5/2^+$	32±3	-7±5°	-63±4	-10±5°
$N(2000)5/2^+$	19±10	-80±40°	11±5	82±30°
$N(1990)7/2^+$	-32±15	5±20°	-70±25	0±20°
$N(2190)7/2^-$	30±7	5±15°	-23±8	13±20°

Energy independent analysis of the $\gamma p \to K\Lambda$ reaction

Bonn-Gatchina-Tusla-Zagreb analysis

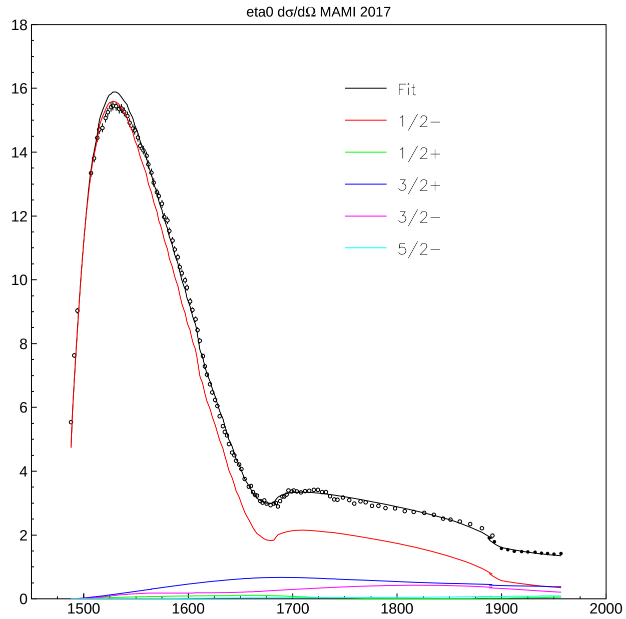


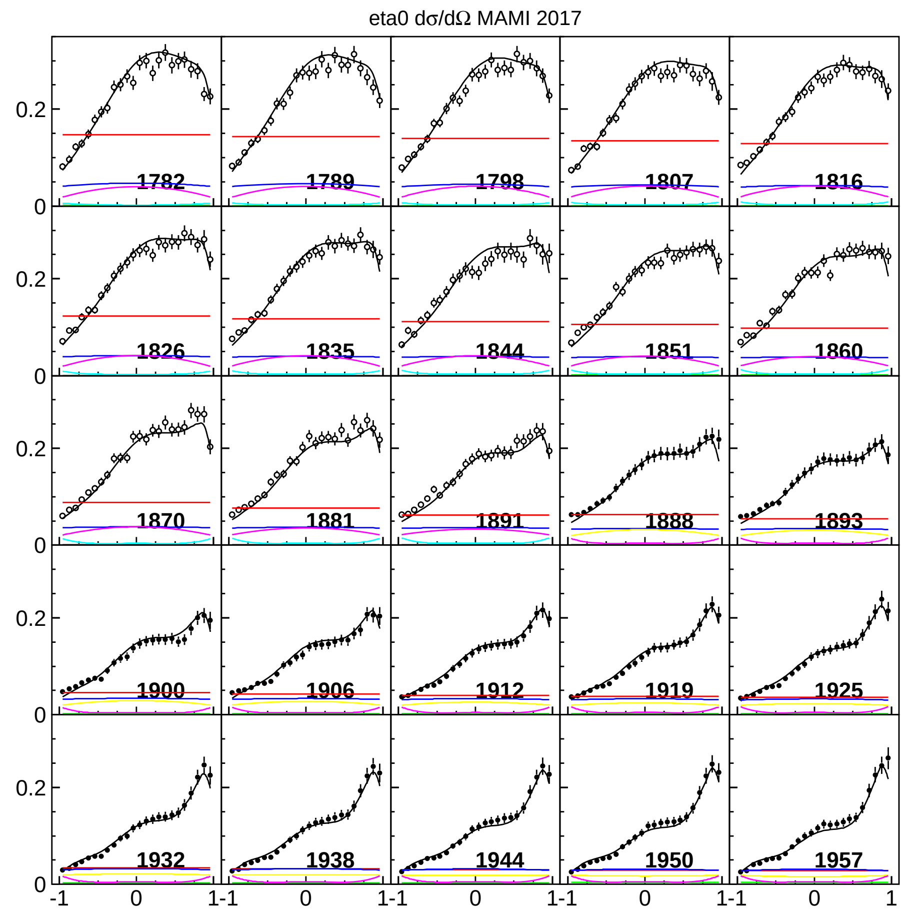
The resonance parameters from the Bonn-Gatchina solution and from the analysis of the energy-independent data

	$J^P = 1/2^-$		$J^P = 1/2^+$		$J^P = 3/2^+$	
	BnGa	**L+P**	**BnGa**	**L+P**	**BnGa**	**L+P**
M_1	1658 ± 10	1660 ± 5	1690 ± 15	1697 ± 23	-	-
Γ_1	102 ± 8	59 ± 16	155 ± 25	84 ± 34	-	-
$\|Res\|$	0.26 ± 0.10	0.10 ± 0.10	0.16 ± 0.05	$0.12^{+0.24}_{-0.12}$	-	-
Θ_1	$(110 \pm 20)^0$	$(95 \pm 33)^0$	$-(160 \pm 25)^0$	$-(119 \pm 83)^0$	-	-
M_2	1895 ± 15	1906 ± 17	1860 ± 40	1875 ± 11	1945 ± 35	1912 ± 30
Γ_2	132 ± 30	100 ± 10	230 ± 50	33 ± 9	235^{+70}_{-30}	166 ± 30
$\|Res\|$	0.09 ± 0.03	0.06 ± 0.02	0.05 ± 0.02	0.30 ± 0.10	0.03 ± 0.02	$-$
Θ_2	$(8 \pm 30)^0$	$(87 \pm 27)^0$	$(27 \pm 30)^0$	$(82 \pm 9)^0$	$(90 \pm 40)^0$	$-$

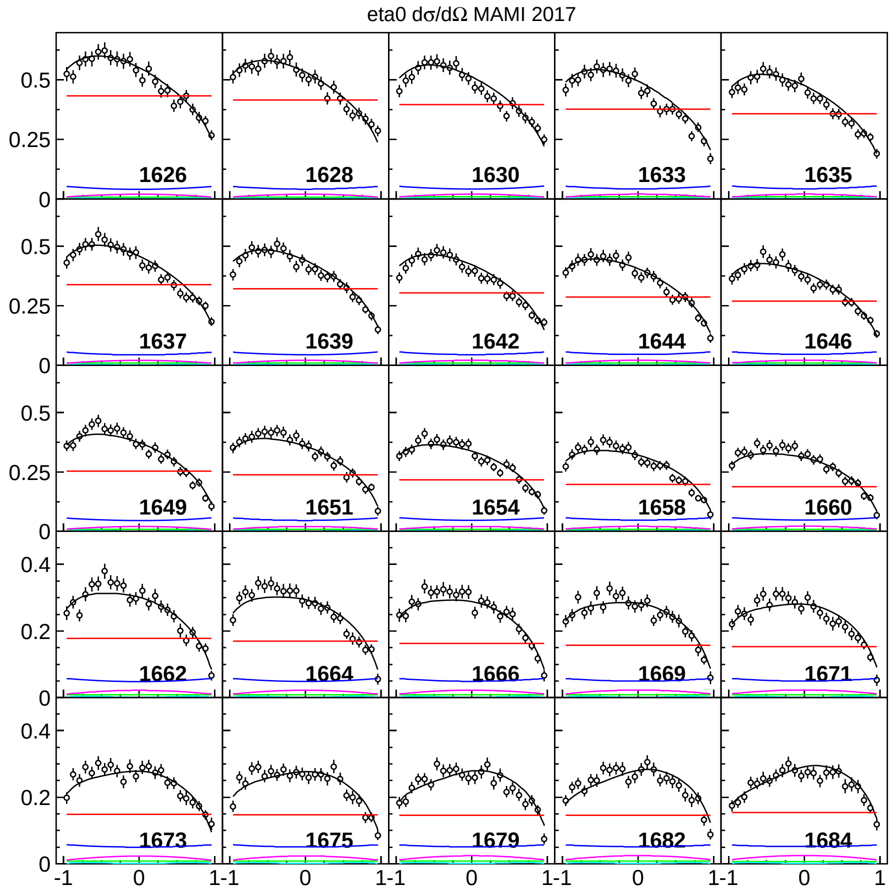
The analysis of the new $\gamma p \to \eta p$ data.

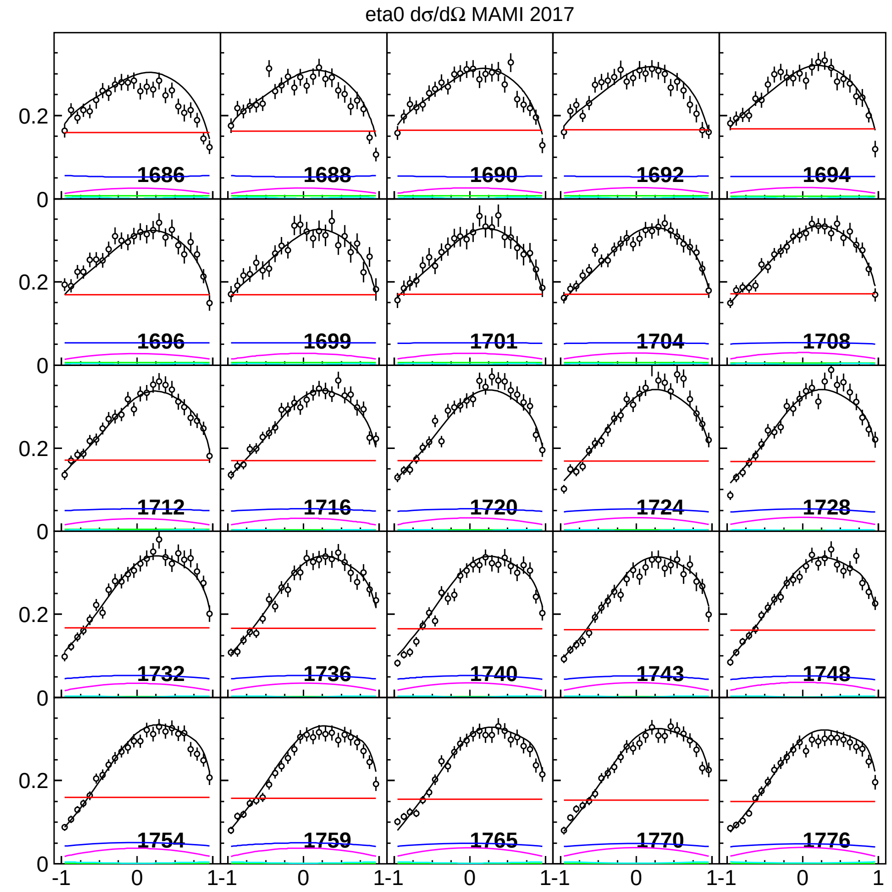
New MAMI data: a strong cusp effect from the $\eta' p$ channel



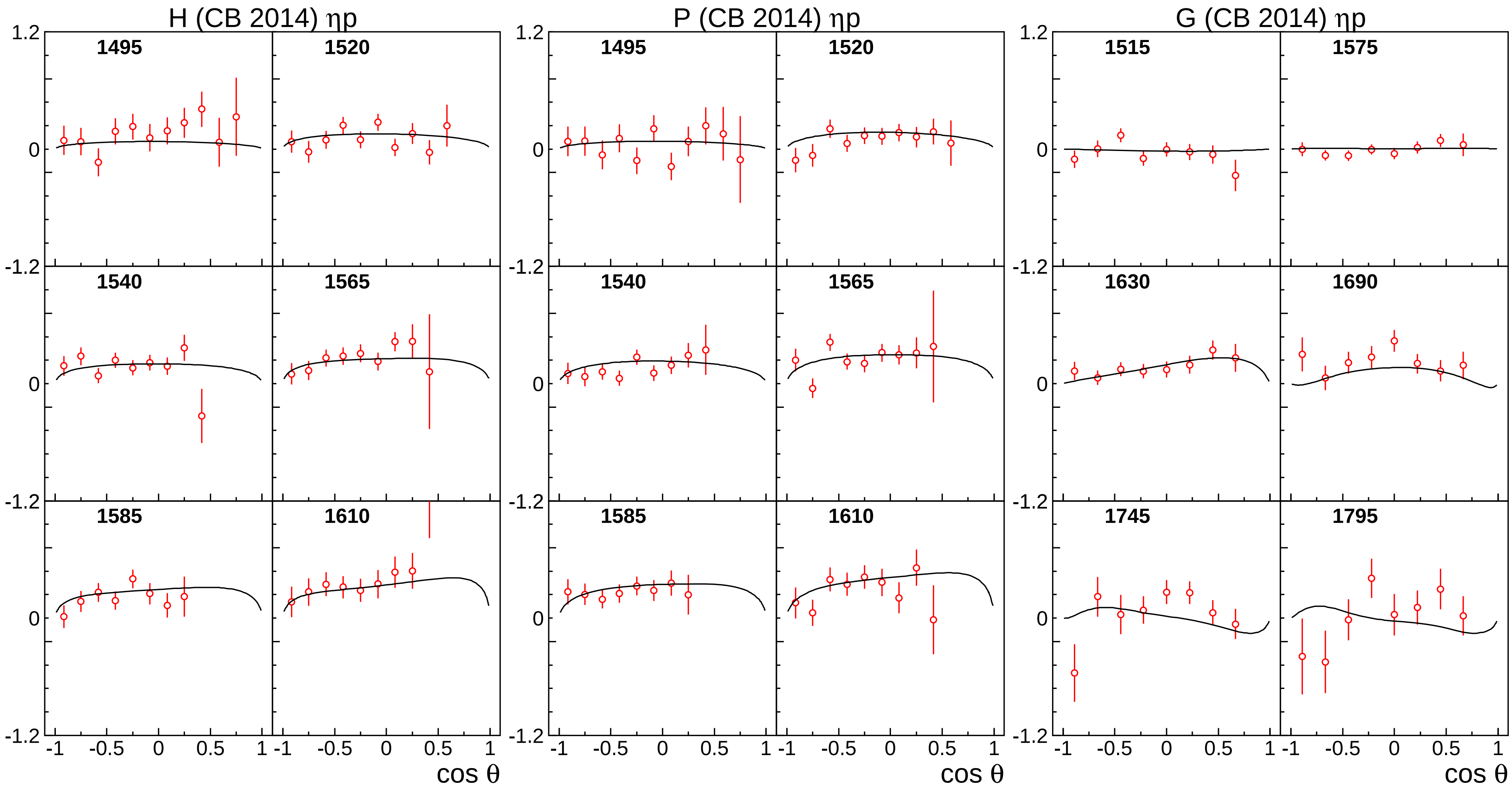


The analysis of the new $\gamma p \to \eta p$ data. $d\sigma/d\Omega$ (MAMI)

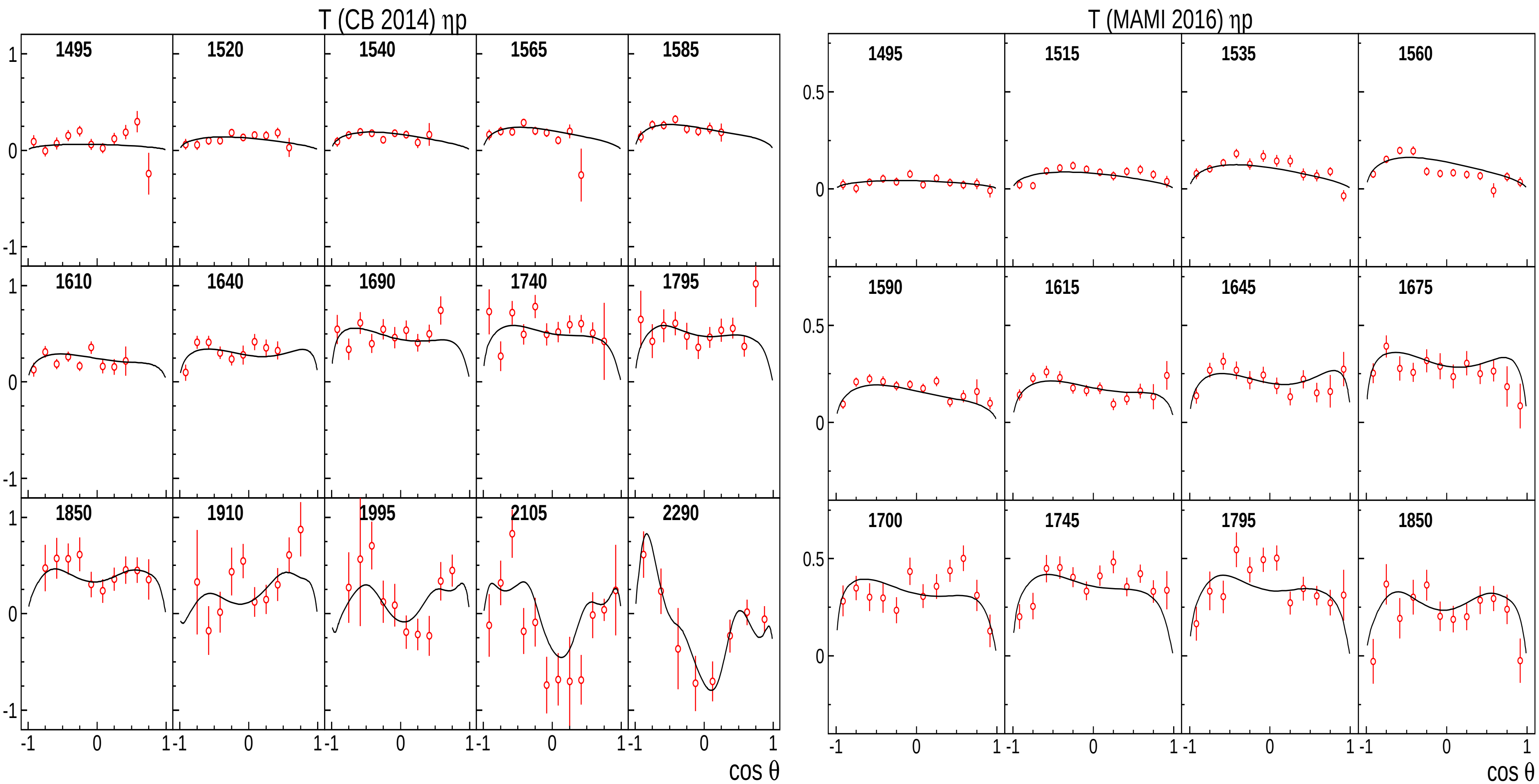




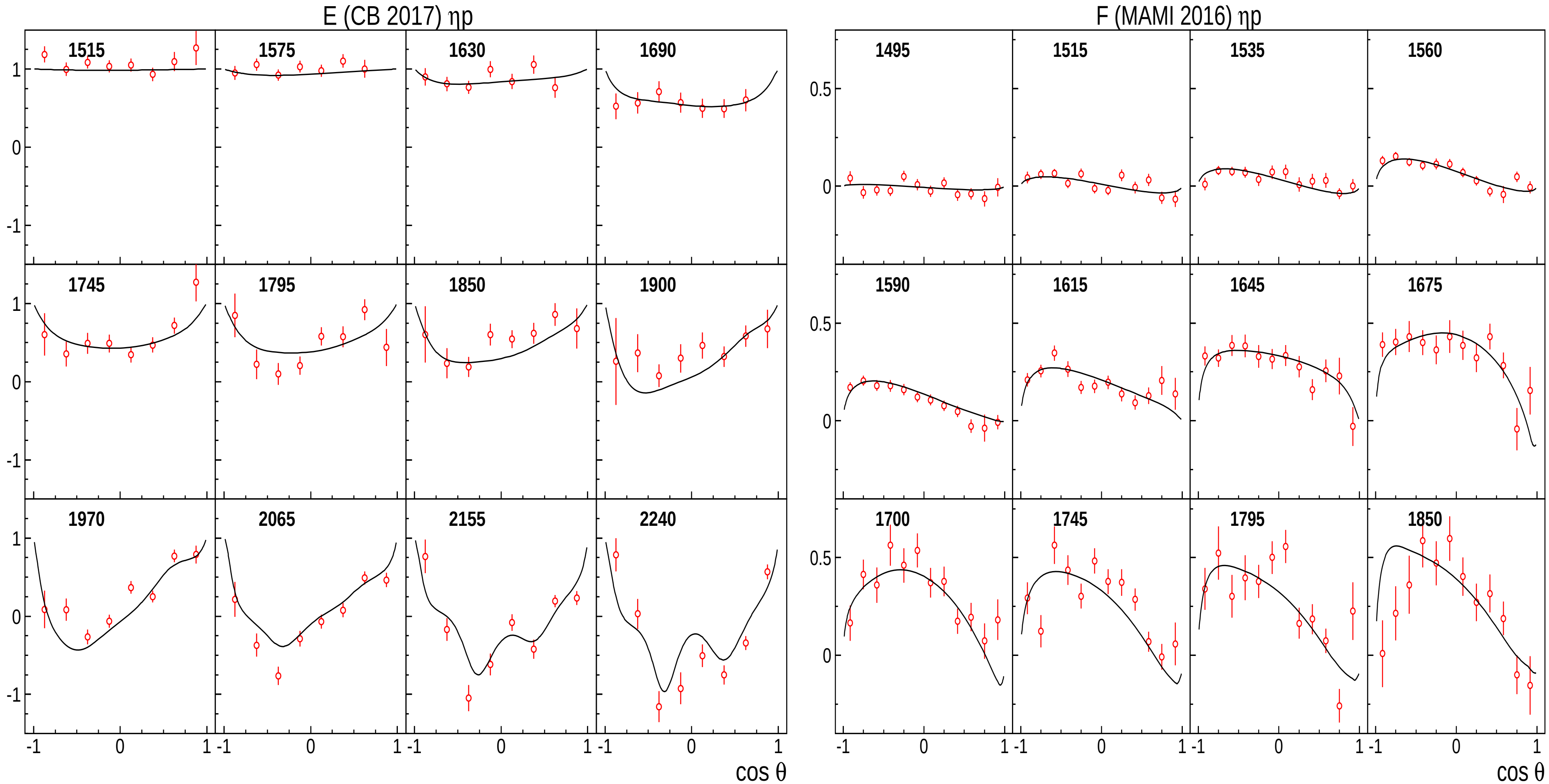
The analysis of the new $\gamma p \to \eta p$ data. H, P, T (CB-ELSA)



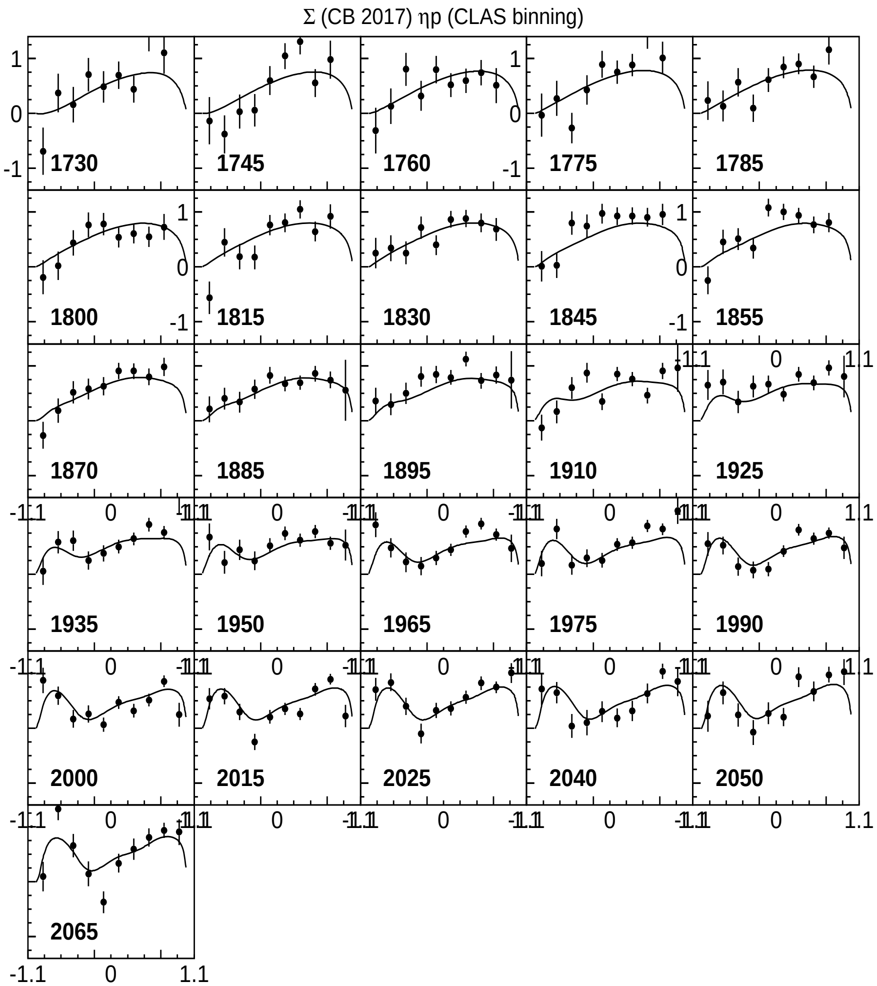
The analysis of the new $\gamma p \to \eta p$ data. T (CB-ELSA), (MAMI scale 1.4)

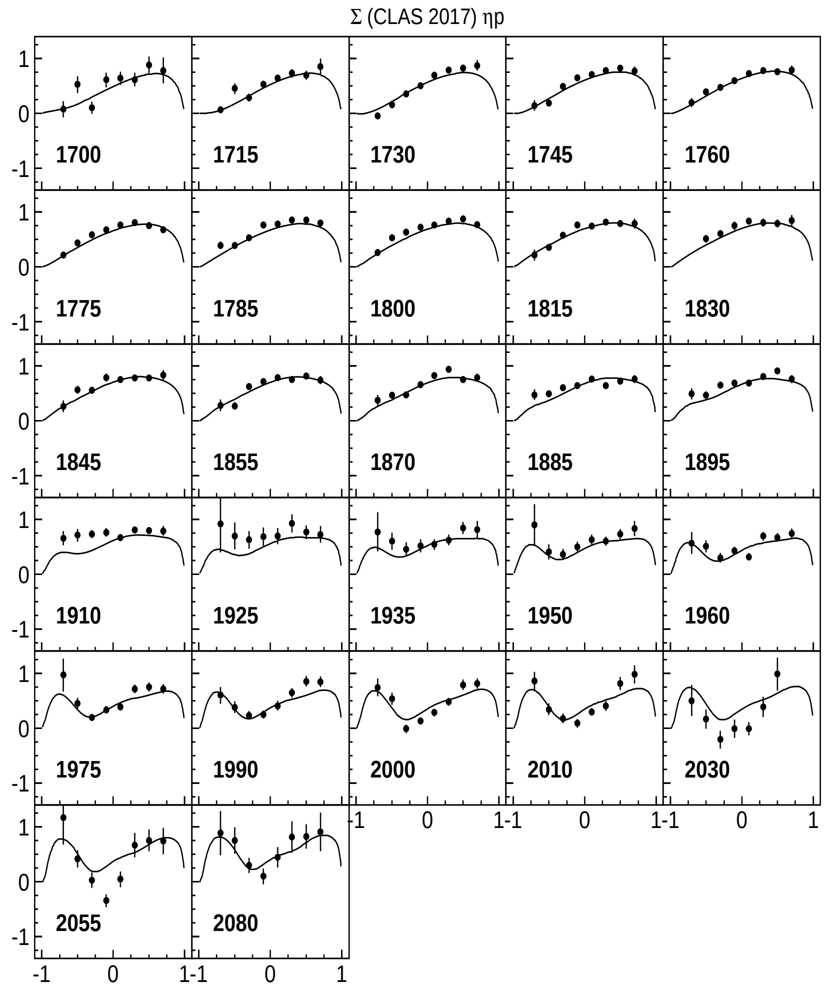


The analysis of the new $\gamma p \to \eta p$ data. E (CB-ELSA), F (MAMI) (scale 1.4)



The analysis of the new $\gamma p \to \eta p$ data. Σ (CB-ELSA and CLAS)

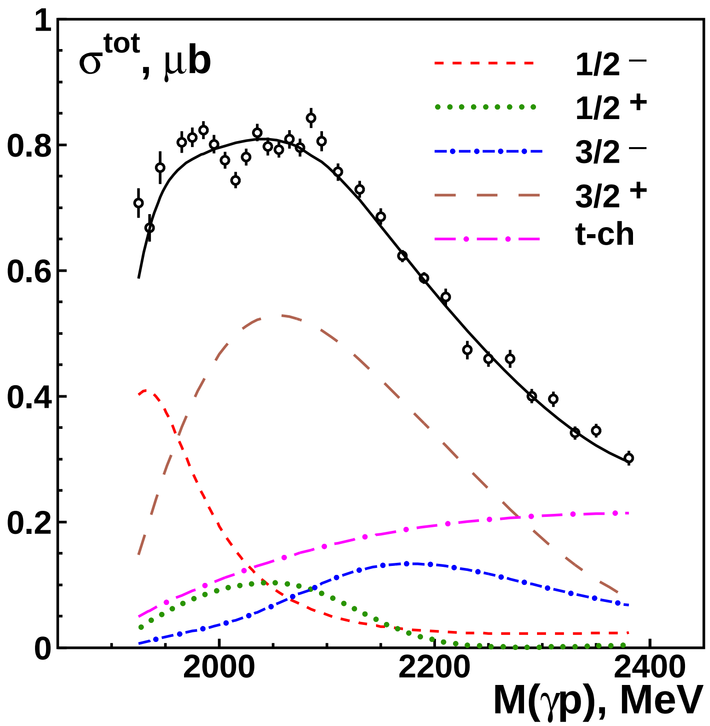


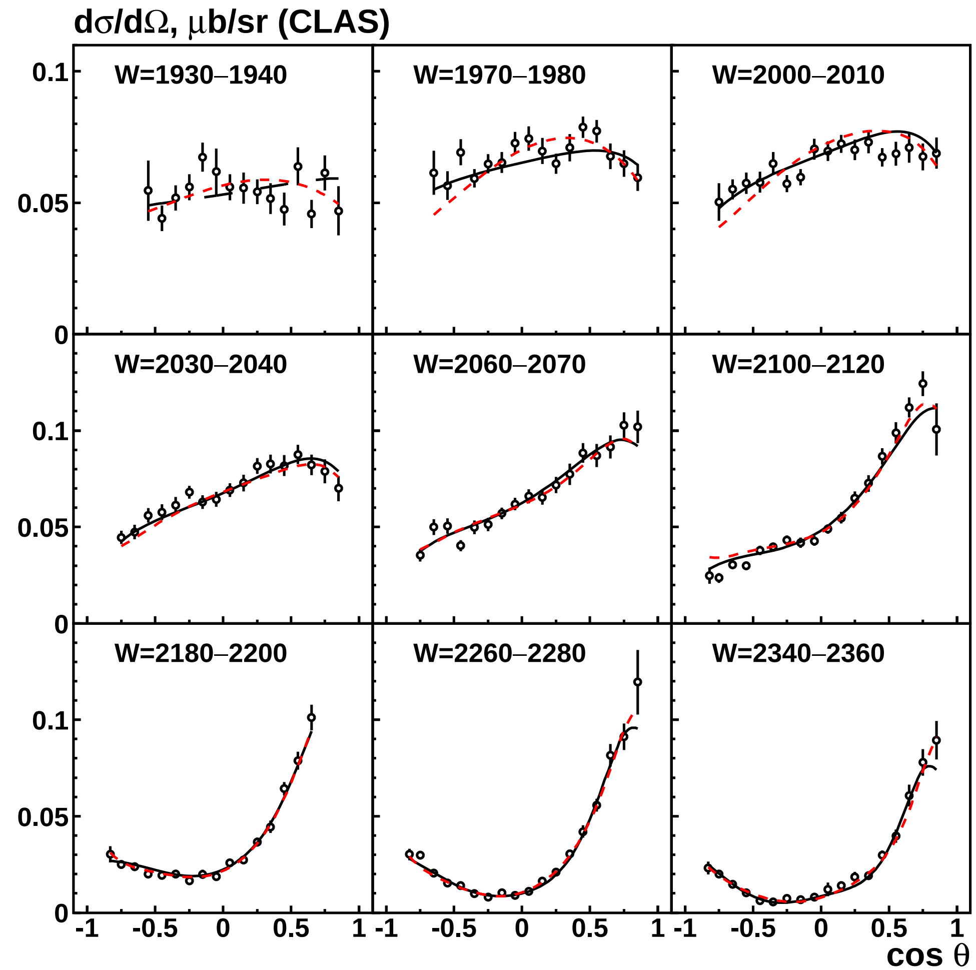


Resonance branchings to the ηN channel

Res.	BR	Res.	BR	Res.	BR
$N(1535)$ $1/2^-$	**0.42±0.04** **0.42±0.10**	$N(1650)$ $1/2^-$	**0.32±0.04** **0.05 - 0.15**	$N(1895)$ $1/2^-$	**0.10±0.05** **(0.21±0.06)**
$N(1710)$ $1/2^+$	**0.25±0.09** **0.10 - 0.30**	$N(1880)$ $1/2^+$	**0.19±0.07** $(0.25^{+0.30}_{-0.20})$	$N(2100)$ $1/2^+$	**0.25±0.10** **0.61±0.61**
$N(1520)$ $3/2^-$	< 0.001 **0.0023±0.0004**	$N(1700)$ $3/2^-$	**0.01±0.01** **0±0.01**	$N(1875)$ $3/2^-$	**0.02±0.01** **0.012±0.018**
$N(1720)$ $3/2^+$	**0.03±0.02** **0.021±0.014**	$N(1900)$ $3/2^+$	**0.03±0.01** **∼0.12**	$N(2120)$ $3/2^-$	**≤0.01** **-**
$N(1675)$ $5/2^-$	**0.005±0.005** **0±0.007**	$N(2060)$ $5/2^-$	**0.04±0.01** **0.04±0.02**	$N(2190)$ $7/2^-$	**0.025±0.005** **0±0.01**
$N(1680)$ $5/2^+$	**0.002±0.001** **0±0.007**	$N(2000)$ $5/2^+$	**0.002±0.001** **0.002±0.002**	$N(1990)$ $7/2^+$	**≤0.01** **-**

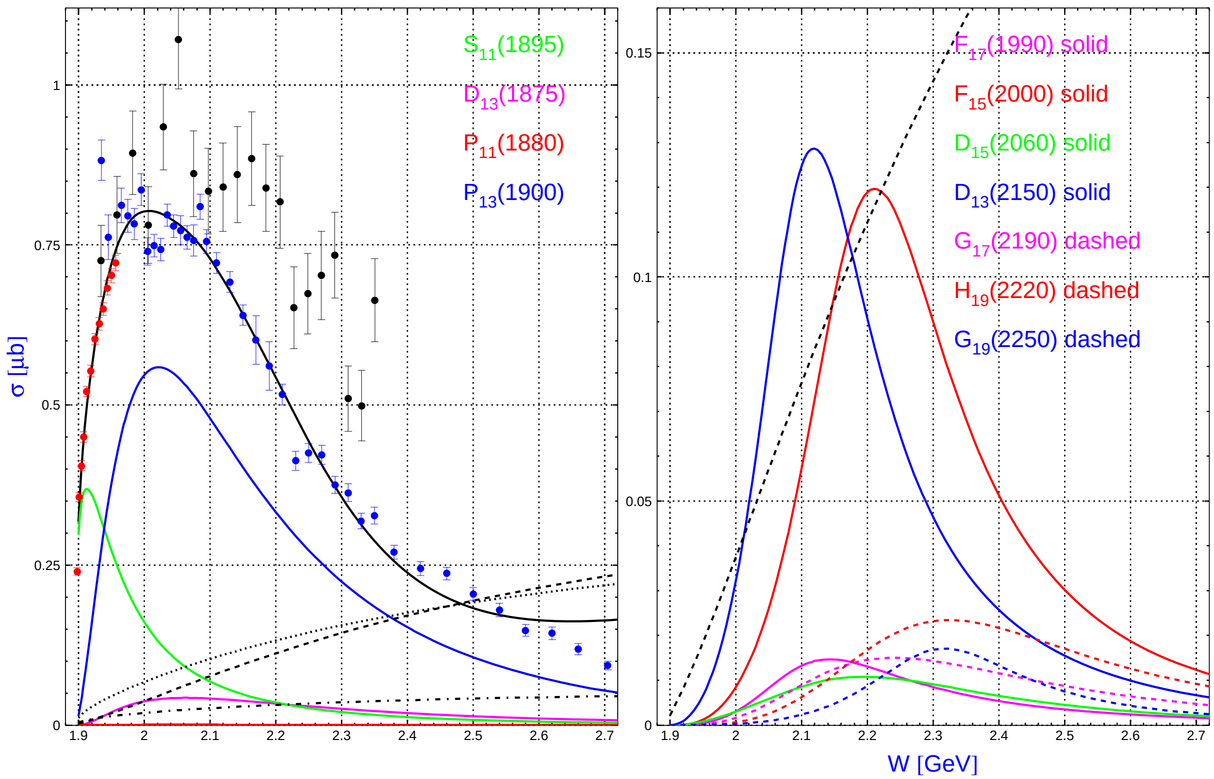
The analysis of the $\gamma p \to \eta' p$ data.





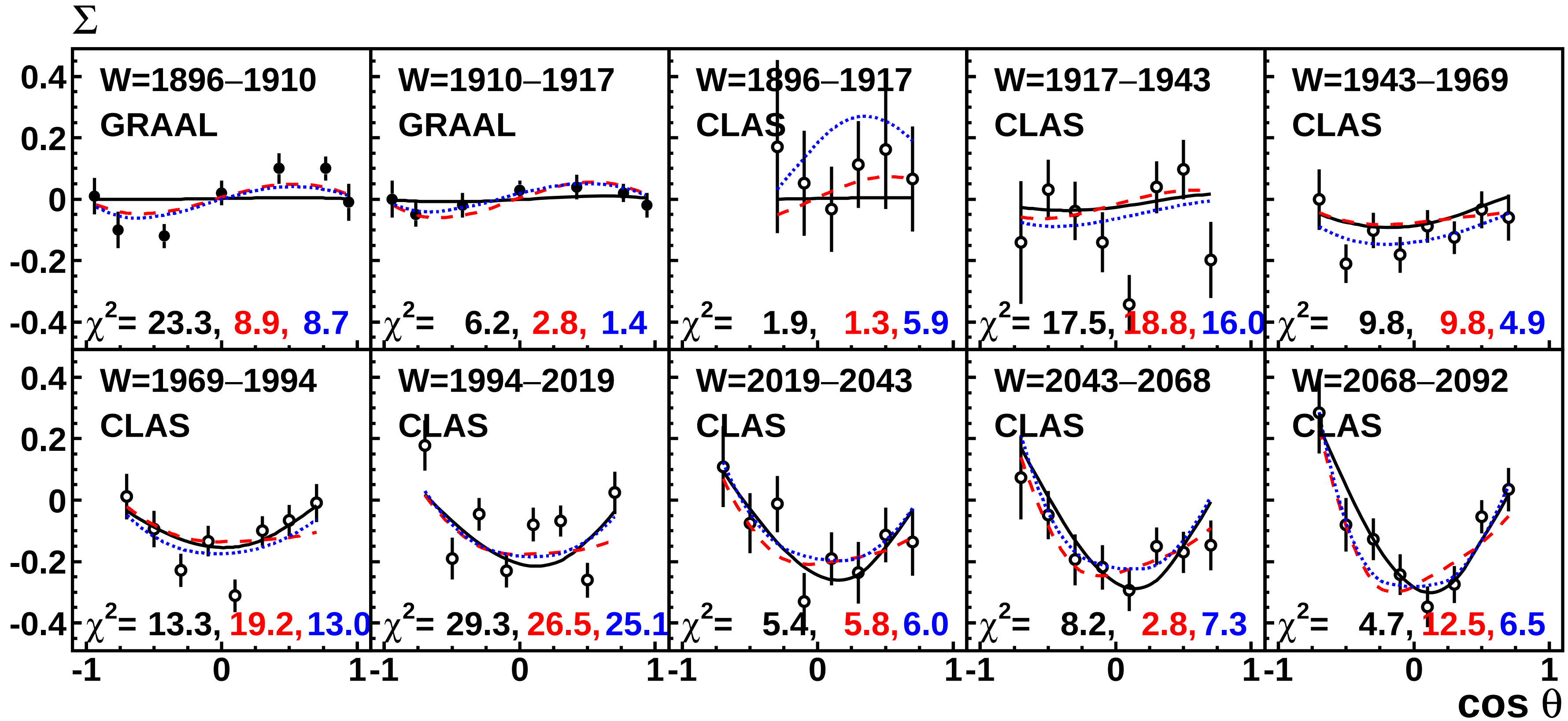
Strong contribution from the $S_{11}(1895)$, $P_{13}(1900)$, $P_{11}(2100)$ and $D_{13}(2120)$ states.

MAID analysis of the new $\gamma p \to \eta' p$ data



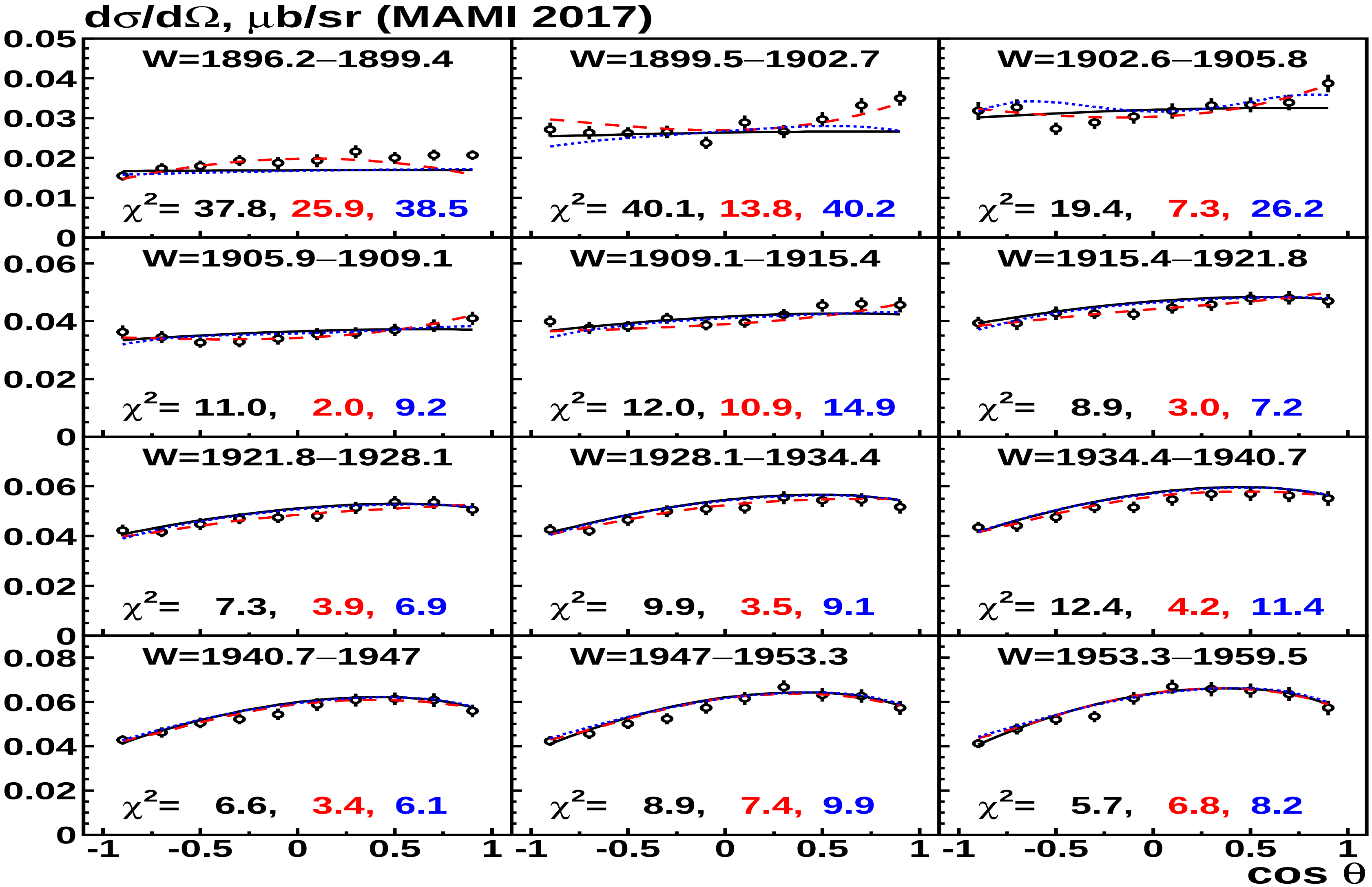
	Bonn-Gatchina	MAID
Mass (MeV)	1895 ± 15	1896 ± 1
Width (MeV)	90^{+30}_{-15}	93 ± 13

The beam asymmetry on $\gamma p \to \eta' p$



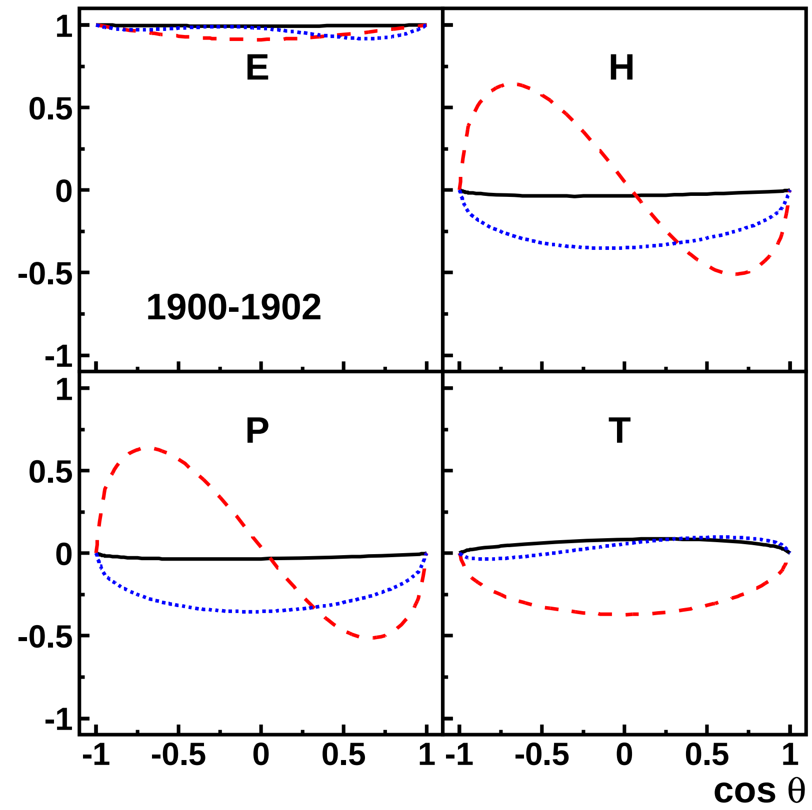
No narrow states $D_{15}(1903)$ $D_{13}(1900)$

The differential cross section from MAMI on $\gamma p \to \eta' p$

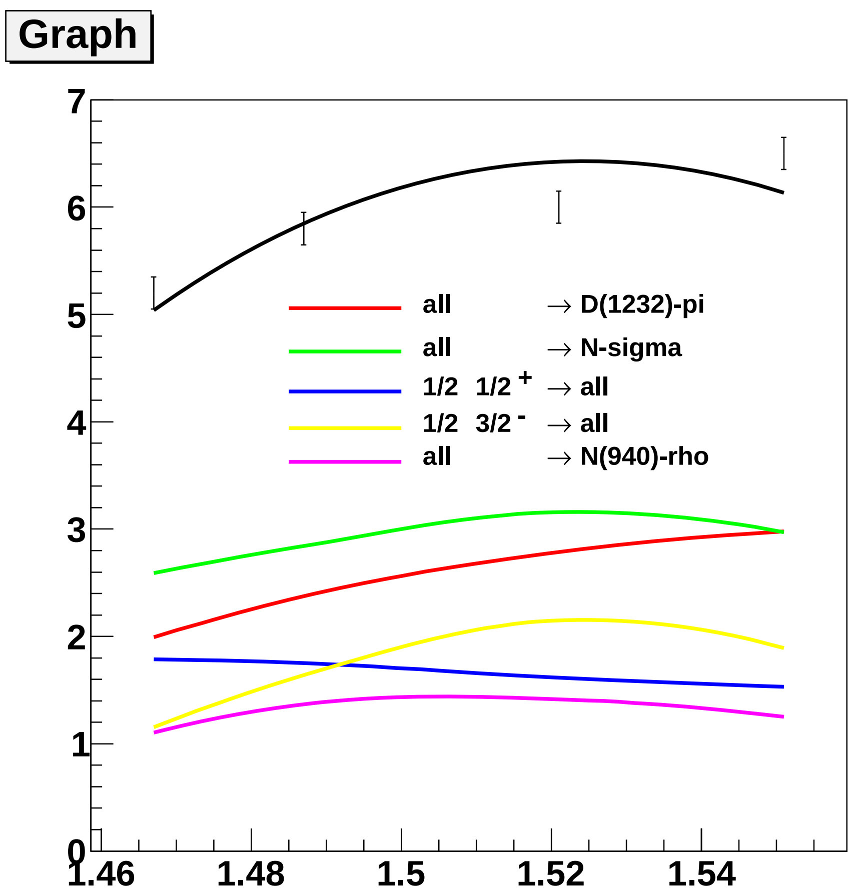


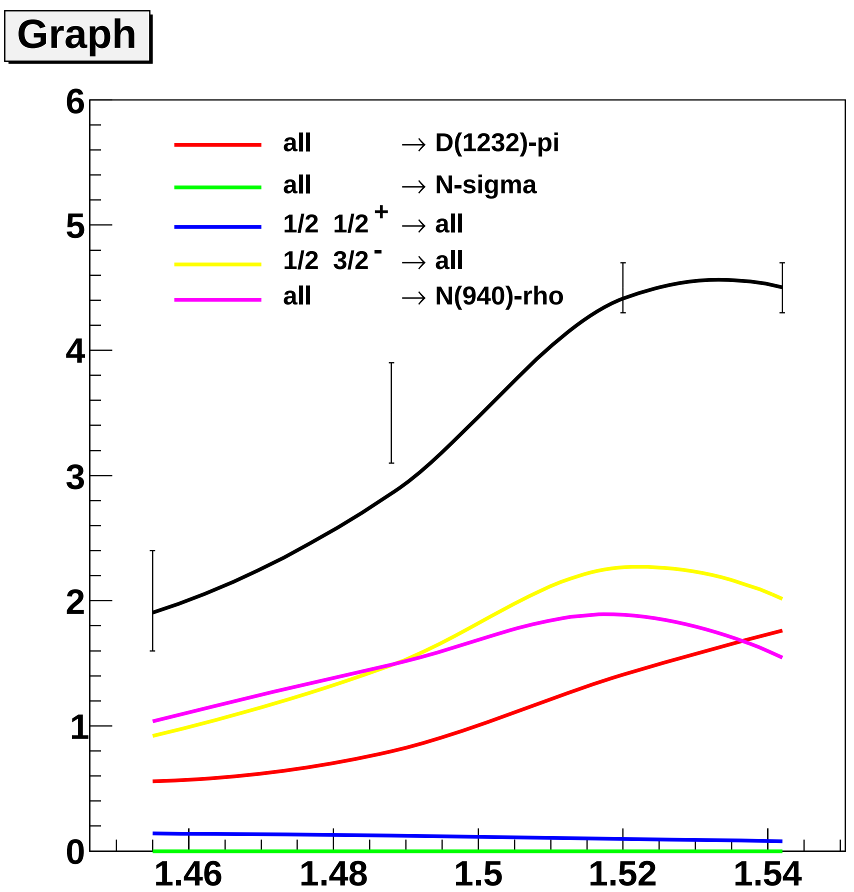
The description of the data below W=1917 MeV and the prediction of other observables

Resonance	N	Basic	D_{13}	D_{15}
M (MeV)			1900	1903
Γ (MeV)			1	1
χ^2 (Σ)	13	29.5	11.7	10.1
χ^2 $(\frac{d\sigma}{d\Omega})$	50	120.3	59.9	129.0

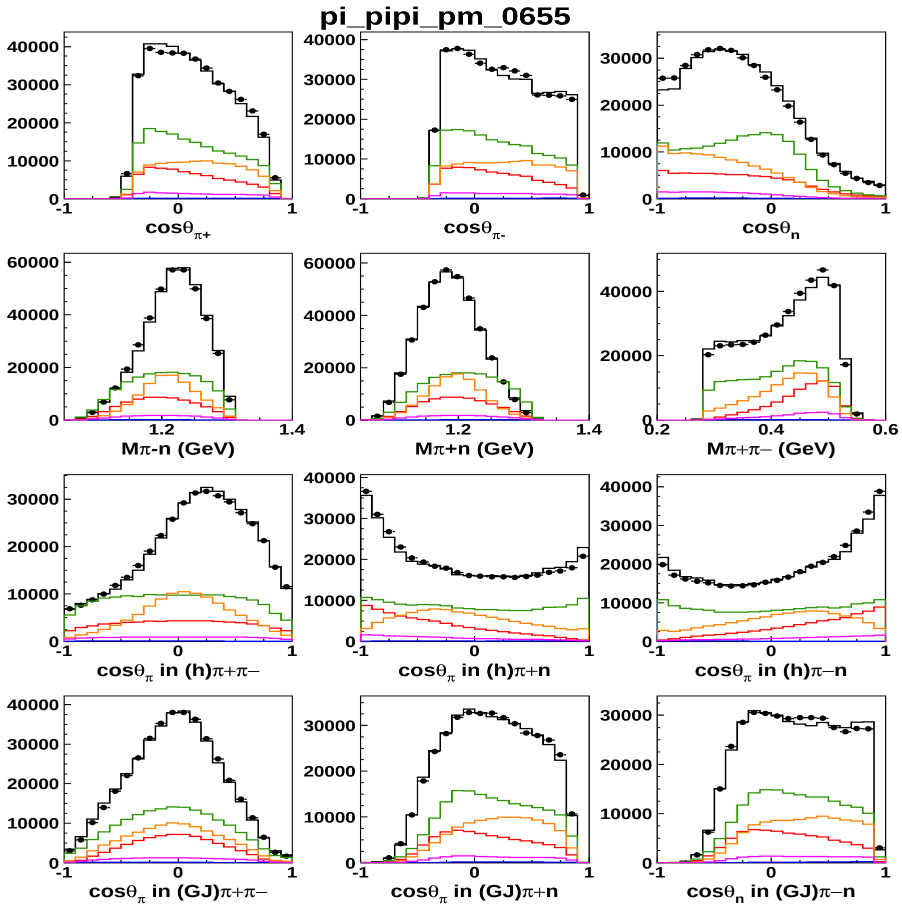


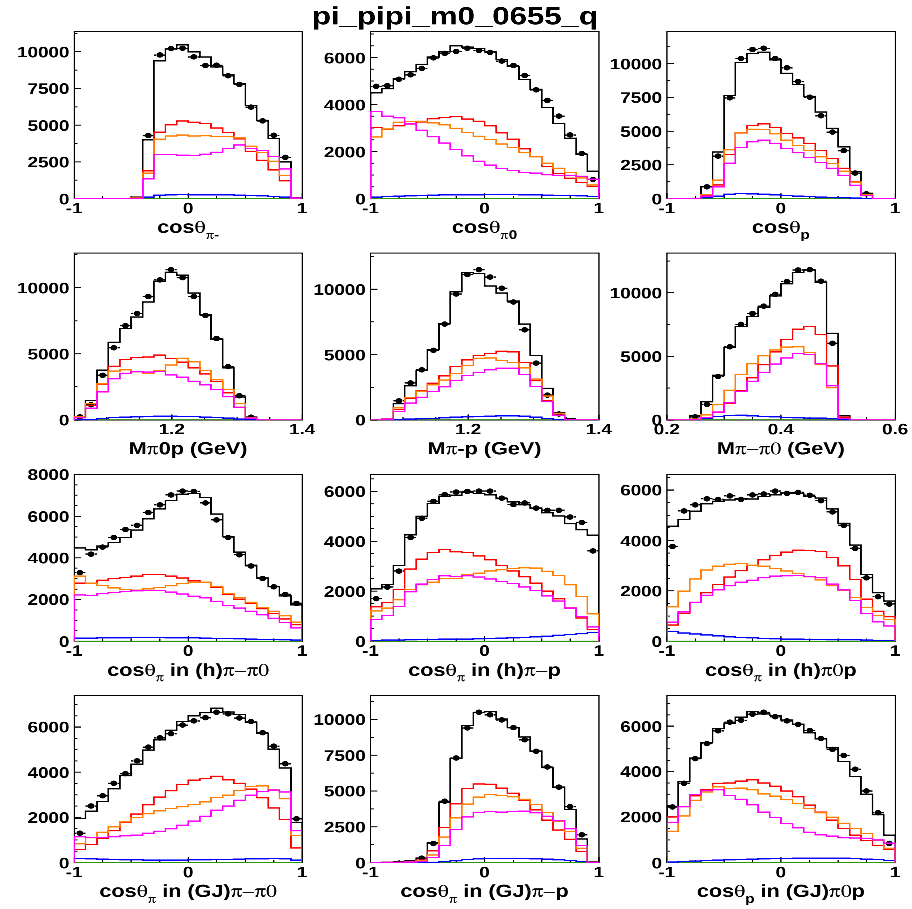
The total cross section from the HADES data $\pi^- p \to \pi^+ \pi^- n$ and $\pi^- p \to \pi^- \pi^0 p$ data (W.Przigoda)





HADES data on $\pi^- p \to \pi^+\pi^- n$ and $\pi^-\pi^0 p$ at P=656 MeV/c (W.Przigoda) (Preliminary)





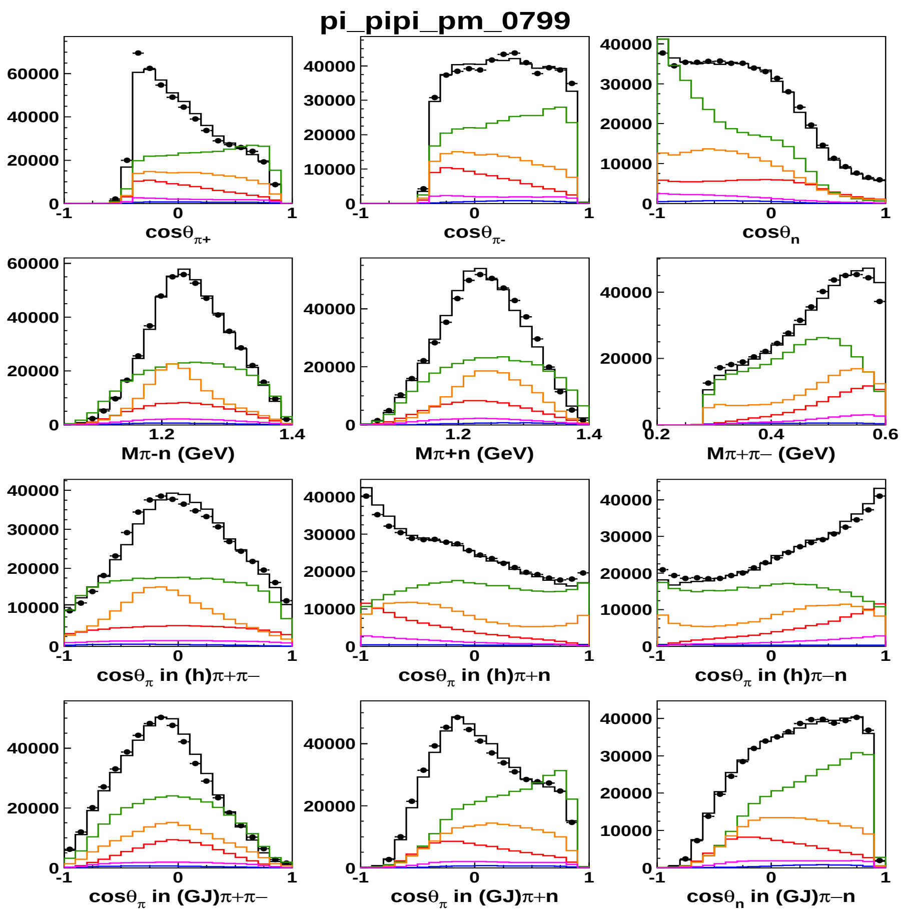
— $\Delta(1232)\pi$

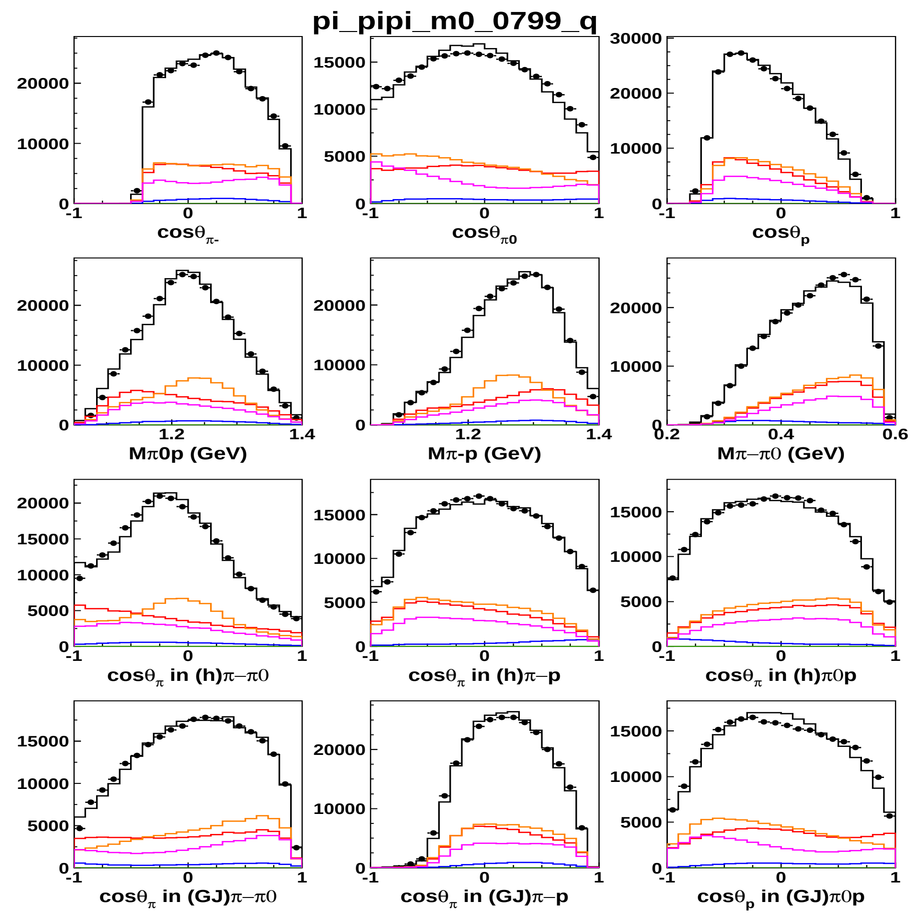
— $\rho N(940)$

— $N\sigma$

— $\frac{1}{2}\frac{3}{2}^-$

HADES data on $\pi^- p \to \pi^+\pi^- n$ and $\pi^-\pi^0 p$ at P=656 MeV/c (W.Przigoda) (Preliminary)





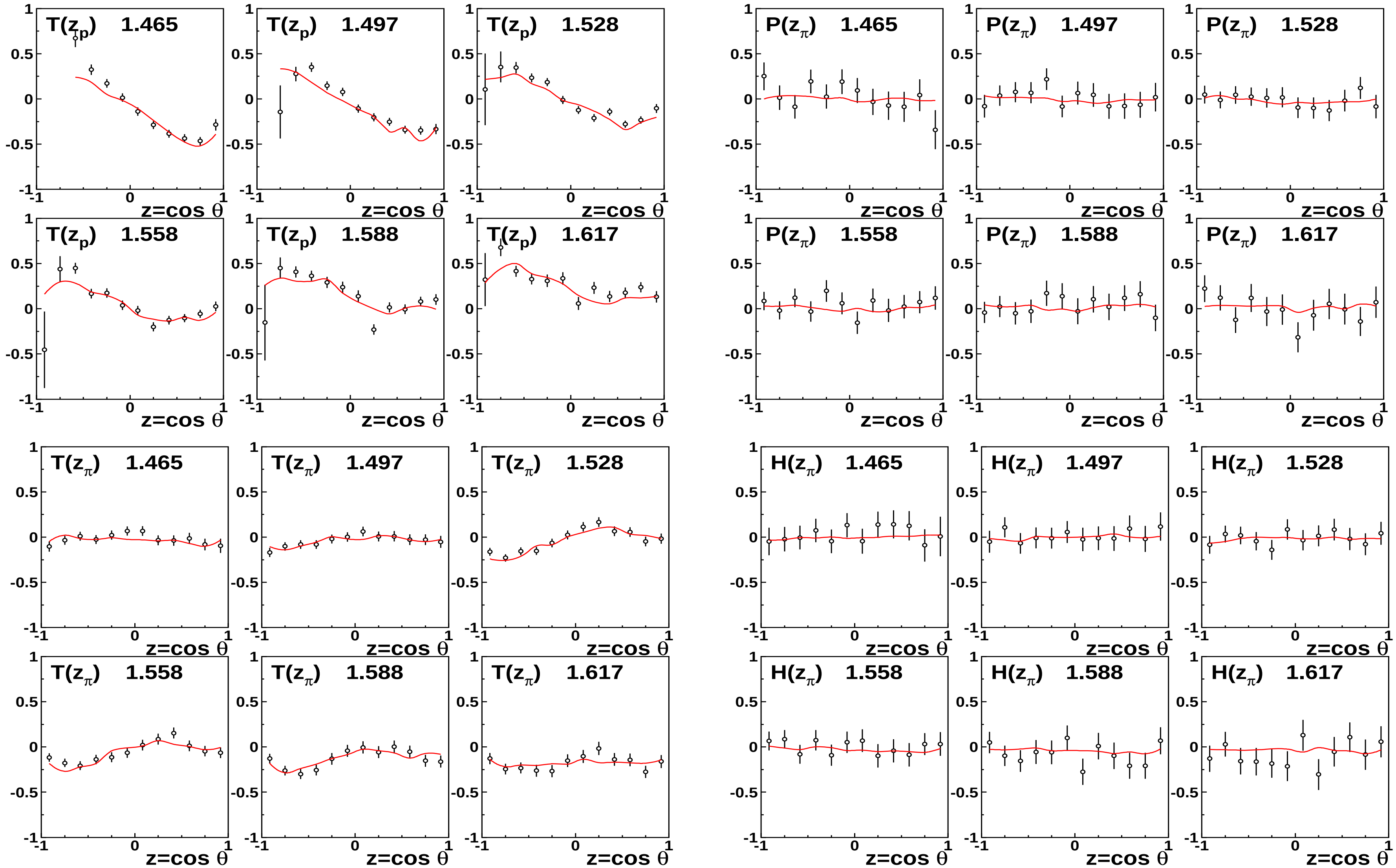
— $\Delta(1232)\pi$

— $N\sigma$

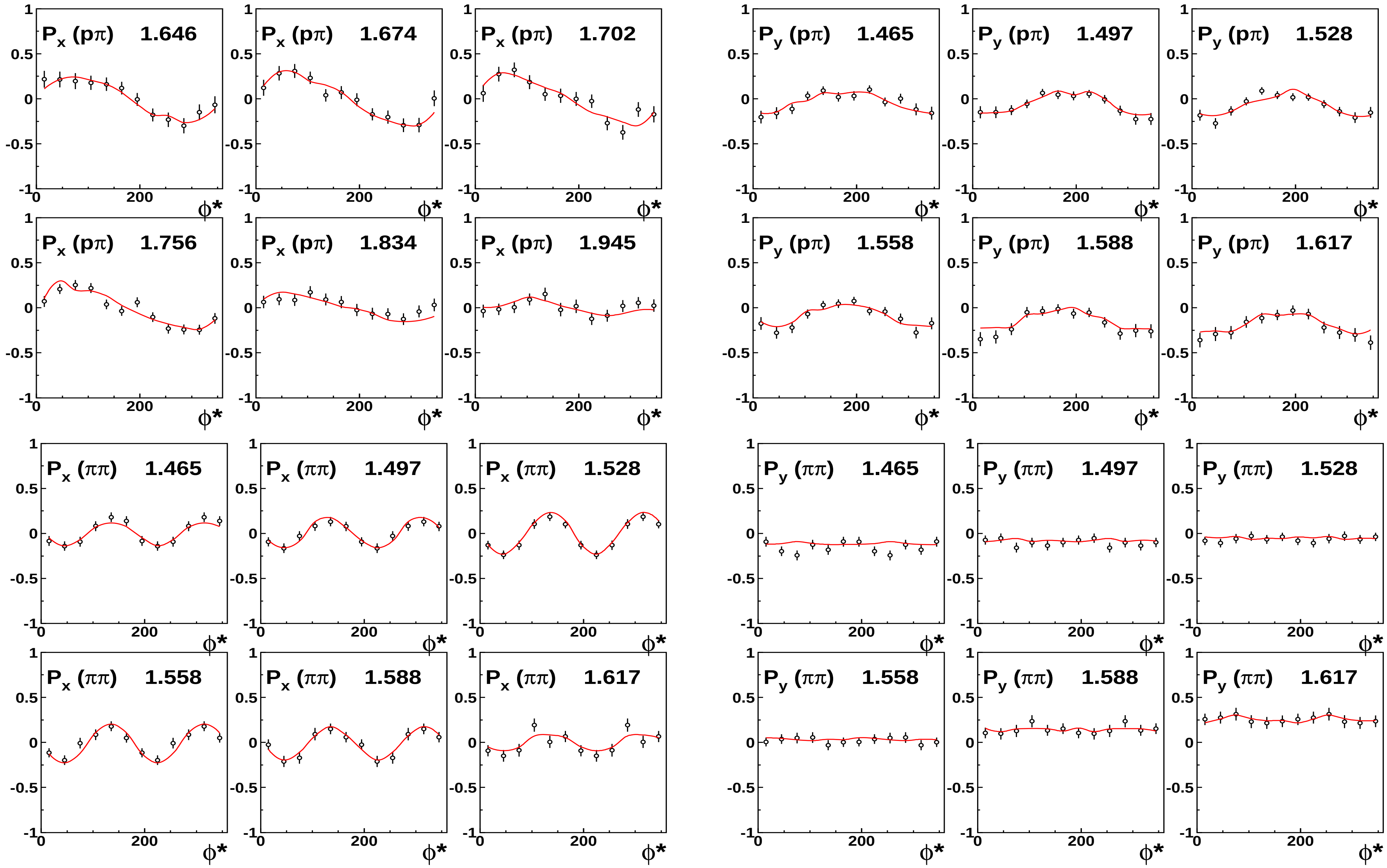
— $\rho N(940)$

— $\frac{1}{2}\frac{3}{2}^-$

Fit of the H, P, T ($\gamma p \to \pi^0\pi^0 p$) from CB-ELSA (T. Seifen, Preliminary)



Fit of the P_x, P_y, P_x^S, P_y^s observables ($\gamma p \to \pi^0 \pi^0 p$) from CB-ELSA (T. Seifen, Preliminary)



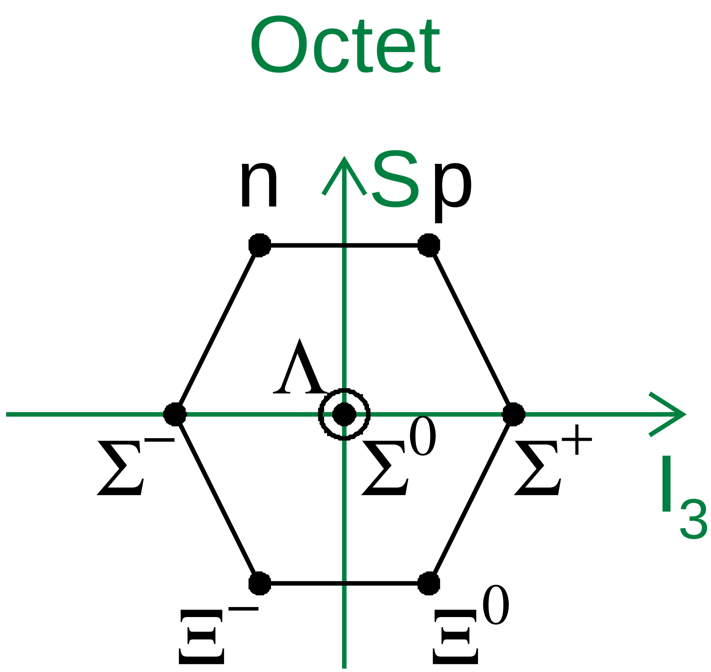
$N\rho(770)$ **branching ratio (Preliminary)**

$N(1440)1/2^+$	$<$**1%**	$N(1520)3/2^-$	**12$\pm$2%**	$N(1535)1/2^-$	**2$\pm$1%**
$N(1650)1/2^-$	**13$\pm$2%**	$N(1675)5/2^-$	$<$**1%**	$N(1685)5/2^+$	**12$\pm$2%**
$N(1710)1/2^+$	**9$\pm$3%**	$N(1720)3/2^+$	**60$\pm$18%**	$N(1880)1/2^+$	**30$\pm$8%**
$N(1895)1/2^-$	**55$\pm$10%**	$N(1875)3/2^-$	**60$\pm$14%**	$N(2060)5/2^-$	**12$\pm$8%**
$N(2120)3/2^-$	**50$\pm$17%**	$N(2000)5/2^+$	**20$\pm$12%**	$N(1900)3/2^+$	**25$\pm$10%**
$\Delta(1600)3/2^+$	**2$\pm$2%**	$\Delta(1620)1/2^-$	**40$\pm$5%**	$\Delta(1940)3/2^+$	**8$\pm$4%**
$\Delta(2200)3/2^+$	**20$\pm$8%**	$\Delta(1700)3/2^-$	**12$\pm$4%**	$\Delta(2100)3/2^-$	**11$\pm$5%**
$\Delta(1750)1/2^+$	**40$\pm$12%**	$\Delta(1900)1/2^-$	**30$\pm$8%**	$\Delta(1905)5/2^+$	**35$\pm$8%**

0.1 N^* and Δ spectrum

Resonance	Rating	N_{pp}	Resonance	Rating	N_{pp}	Resonance	Rating	N_{pp}
$N(1440)1/2^+$	****	13	$N(1520)3/2^-$	****	17	$N(1535)1/2^-$	****	15
$N(1650)1/2^-$	****	18	$N(1675)5/2^-$	****	14	$N(1680)5/2^+$	****	17
$N(1685)$	*		$N(1700)3/2^-$	***	15	$N(1710)1/2^+$	***	14
$N(1720)3/2^+$	****	17	$N(1860)5/2^+$	**	9	$N(1875)3/2^-$	***	16
$N(1880)1/2^+$	**	20	$N(1895)1/2^-$	**	17	$N(1900)3/2^+$	***	18
$N(1990)7/2^+$	**	9	$N(2000)5/2^+$	**	11	$N(2040)3/2^+$	*	
$N(2060)5/2^-$	**	13	$N(2100)1/2^+$	*		$N(2150)3/2^-$	**	11
$N(2190)7/2^-$	****	11	$N(2220)7/2^-$	****	7	$N(2250)9/2^-$	****	
$N(2600)11/2^-$	***		$N(2700)13/2^+$	**				
$\Delta(1232)$	****	8	$\Delta(1600)3/2^+$	***	12	$\Delta(1620)1/2^-$	****	10
$\Delta(1700)3/2^-$	****	11	$\Delta(1750)1/2^+$	*		$\Delta(1900)1/2^-$	**	13
$\Delta(1905)5/2^+$	****	11	$\Delta(1910)1/2^+$	****	13	$\Delta(1920)3/2^+$	***	21
$\Delta(1930)5/2^-$	***		$\Delta(1940)3/2^-$	*	5	$\Delta(1950)7/2^+$	****	13
$\Delta(2000)5/2^+$	**		$\Delta(2150)1/2^-$	*		$\Delta(2200)7/2^-$	*	
$\Delta(2300)9/2^+$	**		$\Delta(2350)3/2^-$	*		$\Delta(2390)7/2^+$	*	
$\Delta(2420)11/2^+$	****		$\Delta(2400)9/2^-$	****		$\Delta(2750)13/2^-$	**	
$\Delta(2950)15/2^+$	**							

$$3 \otimes 3 \otimes 3 = 10_S \oplus 8_M \oplus 8_M \oplus 1_A$$



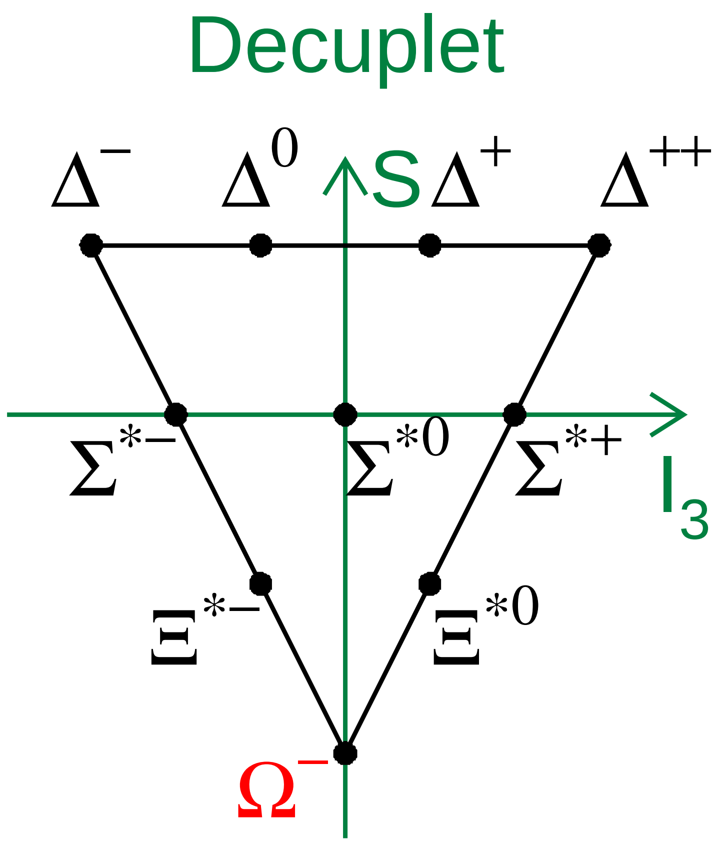


Table 2: Λ-hyperons used in the first fit of the data.

		J^P	**Status**	**Mass**	**Width**
singlet	$\Lambda(1405)$	$1/2^-$	****	$1405^{+1.3}_{-1.0}$	50.5 ± 2.0
$N(1535)$	$\Lambda(1670)$	$1/2^-$	****	$1660 - 1680$	$25 - 50$
$N(1650)$	$\Lambda(1800)$	$1/2^-$	***	$1720 - 1850$	$200 - 400$
singlet	$\Lambda(1520)$	$3/2^-$	****	1519.5 ± 1.0	15.6 ± 1.0
$N(1520)$	$\Lambda(1690)$	$3/2^-$	****	$1685 - 1695$	$50 - 70$
$N(1675)$	$\Lambda(1830)$	$5/2^-$	****	$1810 - 1830$	$60 - 110$
$N(2190)$	$\Lambda(2100)$	$7/2^-$	****	$2090 - 2110$	$100 - 250$
$N(1440)$	$\Lambda(1600)$	$1/2^+$	***	$1560 - 1700$	$50 - 250$
$N(1710)$	$\Lambda(1810)$	$1/2^+$	***	$1750 - 1850$	$50 - 250$
$N(1710)$	$\Lambda(1890)$	$3/2^+$	****	$1850 - 1910$	$60 - 200$
$N(1680)$	$\Lambda(1820)$	$5/2^+$	****	$1815 - 1825$	$70 - 90$
$N(2060)$	$\Lambda(2110)$	$5/2^+$	***	$2090 - 2140$	$150 - 250$

Table 3: Σ-Hyperons used in the first fit of the data.

		J^P	**Status**	**Mass**	**Width**
$N(1440)$	$\Sigma(1660)$	$1/2^+$	***	$1630 - 1690$	36.0 ± 0.7
$\Delta(1230)$	$\Sigma(1385)$	$3/2^+$	****	1382.80 ± 0.35	$40 - 200$
$N(1680), \Delta(1905)$	$\Sigma(1915)$	$5/2^+$	****	$1900 - 1935$	$80 - 160$
$N(1990), \Delta(1950)$	$\Sigma(2030)$	$7/2^+$	****	$2025 - 2040$	$150 - 200$
$N(1520)$	$\Sigma(1670)$	$3/2^-$	****	$1665 - 1685$	$40 - 80$
$N(1535), \Delta(1620), N(1650)$	$\Sigma(1750)$	$1/2^-$	***	$1730 - 1800$	$60 - 160$
$N(1675)$	$\Sigma(1775)$	$5/2^-$	****	$1770 - 1780$	$105 - 135$
$N(1700), \Delta(1700)$	$\Sigma(1940)$	$3/2^-$	***	$1900 - 1950$	$150 - 300$

Many Σ states are missing.

Kaon beam motivation

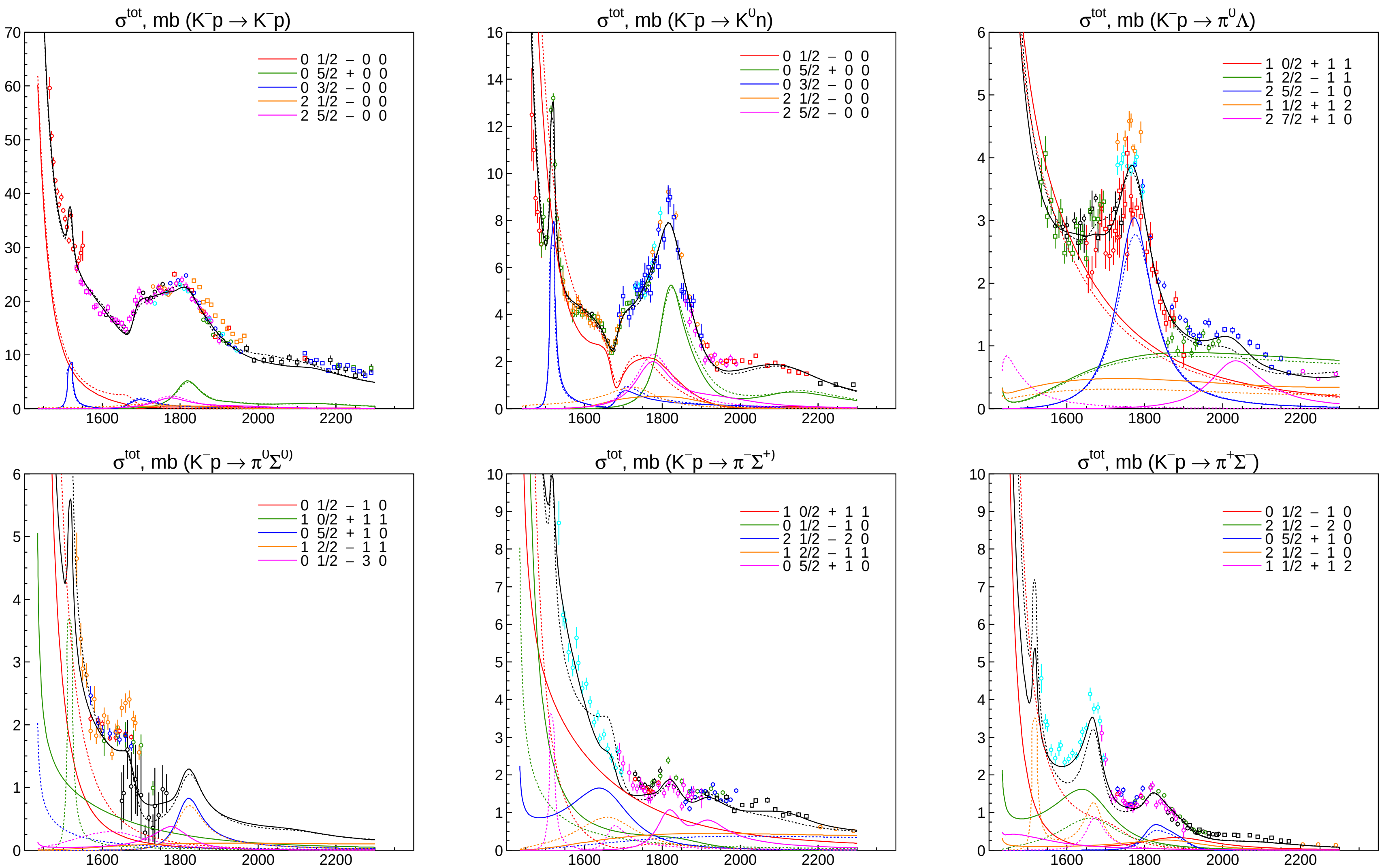
There is a hope to observe the baryon multiplets and therefore to confirm the states observed in the Nucleon and Delta sector.

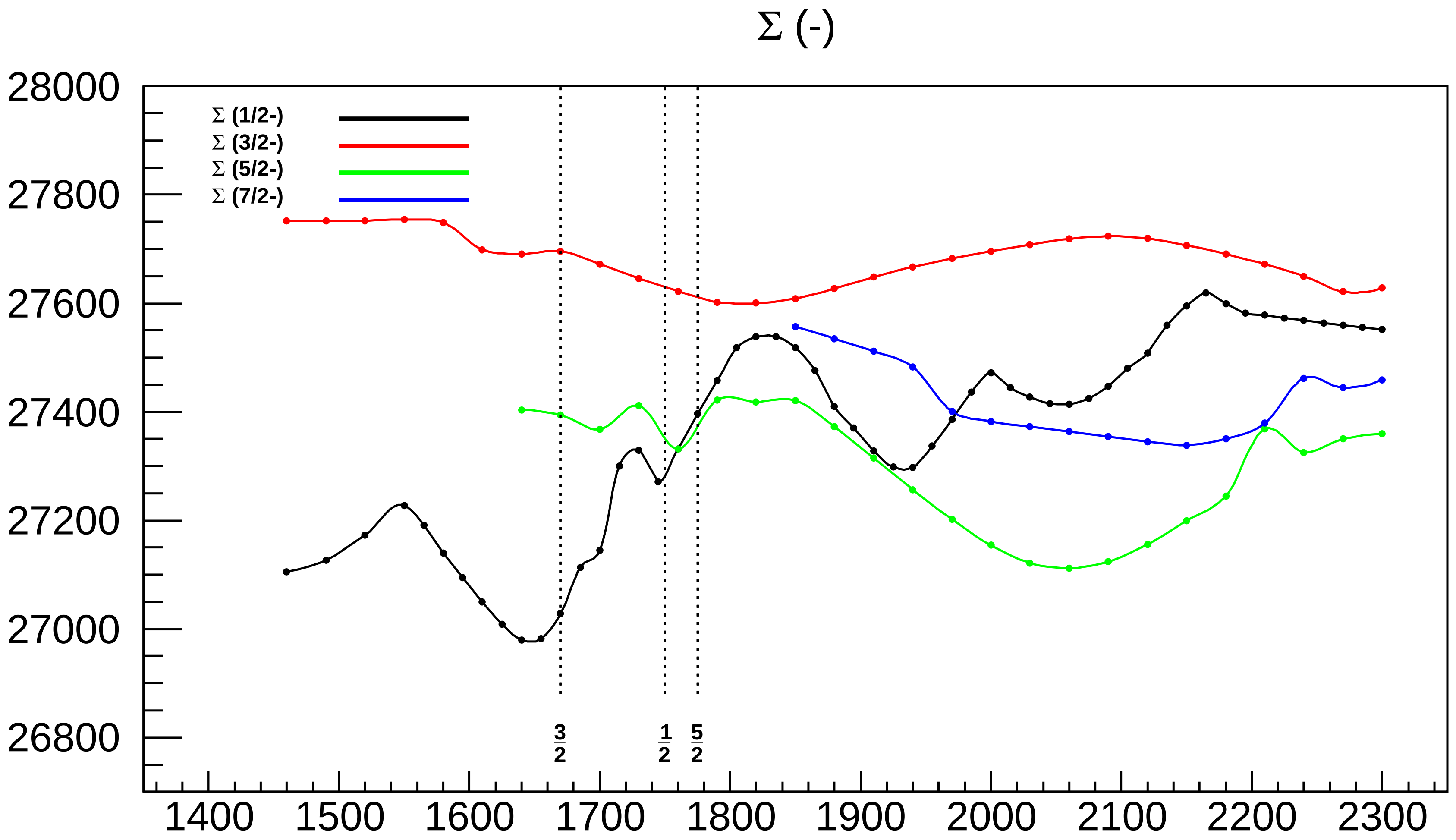
Table 4: List of reactions used in the partial wave analysis.

$K^- p \to K^0 n$	$K^- p \to K^- p$	$K^- p \to \omega \Lambda$
$K^- p \to \pi^0 \Lambda$	$K^- p \to \eta \Lambda$	$K^- p \to \pi^+ \Sigma^-$
$K^- p \to \pi^0 \Sigma^0$	$K^- p \to \pi^- \Sigma^+$	$K^- p \to \pi^0 \pi^0 \Lambda$
$K^- p \to K^+ \Xi^-$	$K^- p \to K^0 \Xi^0$	$K^- p \to \pi^0 \pi^0 \Sigma^0$

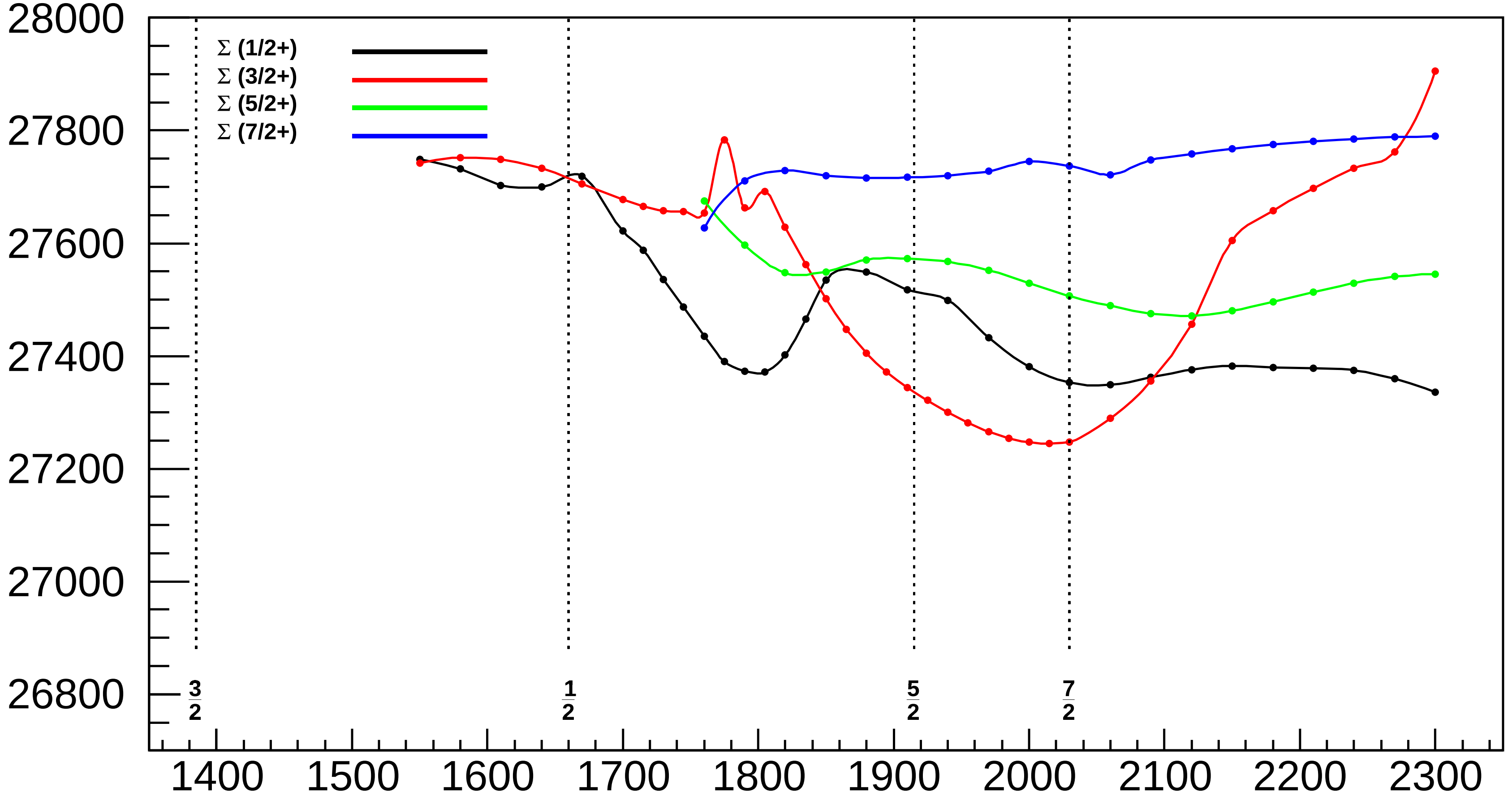
W **range is 1.57 – 1.68**

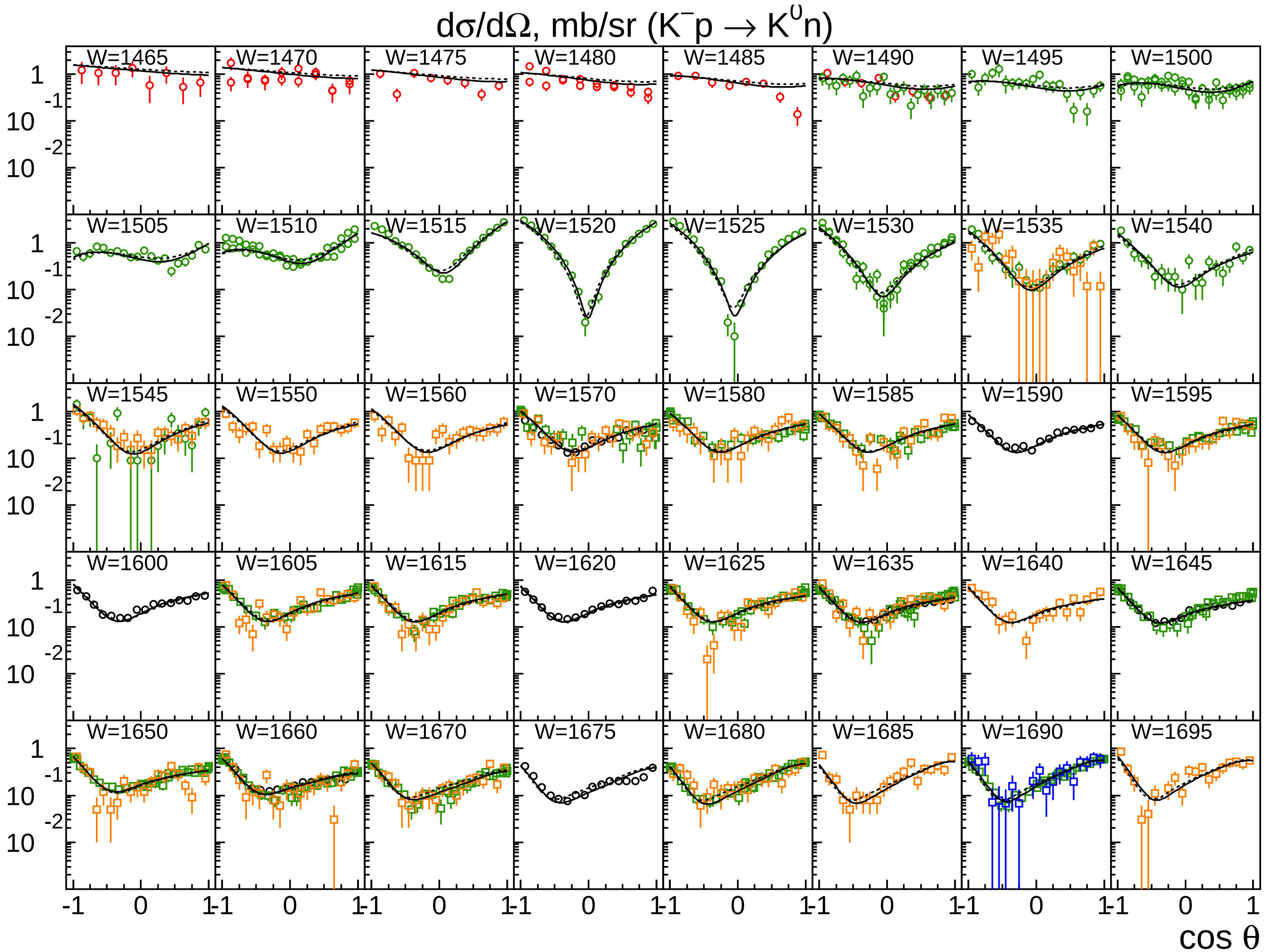
Analysis of the Kp collision reactions (Preliminary) (M.Matveev)

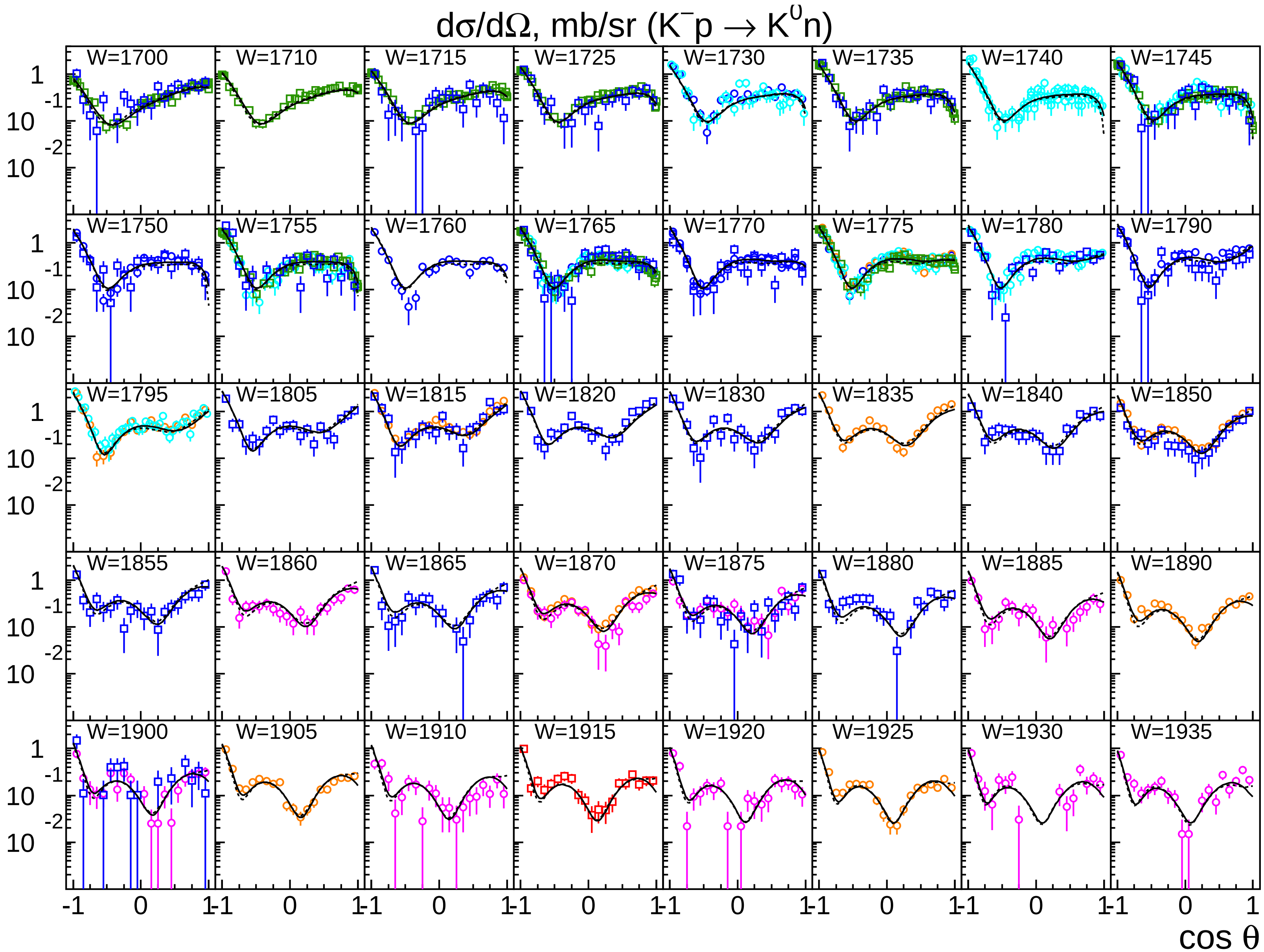



Σ (-)
Σ (1/2-)
Σ (3/2-)
Σ (5/2-)
Σ (7/2-)
28000
27800
27600
27400
27200
27000
26800
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
3/2
1/2
5/2

Σ (+)


Σ (1/2+)
Σ (3/2+)
Σ (5/2+)
Σ (7/2+)
28000
27800
27600
27400
27200
27000
26800
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
3/2
1/2
5/2
7/2


dσ/dΩ, mb/sr (K⁻p → K⁰n)
W=1465
W=1470
W=1475
W=1480
W=1485
W=1490
W=1495
W=1500
W=1505
W=1510
W=1515
W=1520
W=1525
W=1530
W=1535
W=1540
W=1545
W=1550
W=1560
W=1570
W=1580
W=1585
W=1590
W=1595
W=1600
W=1605
W=1615
W=1620
W=1625
W=1635
W=1640
W=1645
W=1650
W=1660
W=1670
W=1675
W=1680
W=1685
W=1690
W=1695
cos θ


dσ/dΩ, mb/sr (K⁻p → K⁰n)
W=1700
W=1710
W=1715
W=1725
W=1730
W=1735
W=1740
W=1745
W=1750
W=1755
W=1760
W=1765
W=1770
W=1775
W=1780
W=1790
W=1795
W=1805
W=1815
W=1820
W=1830
W=1835
W=1840
W=1850
W=1855
W=1860
W=1865
W=1870
W=1875
W=1880
W=1885
W=1890
W=1900
W=1905
W=1910
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W=1935
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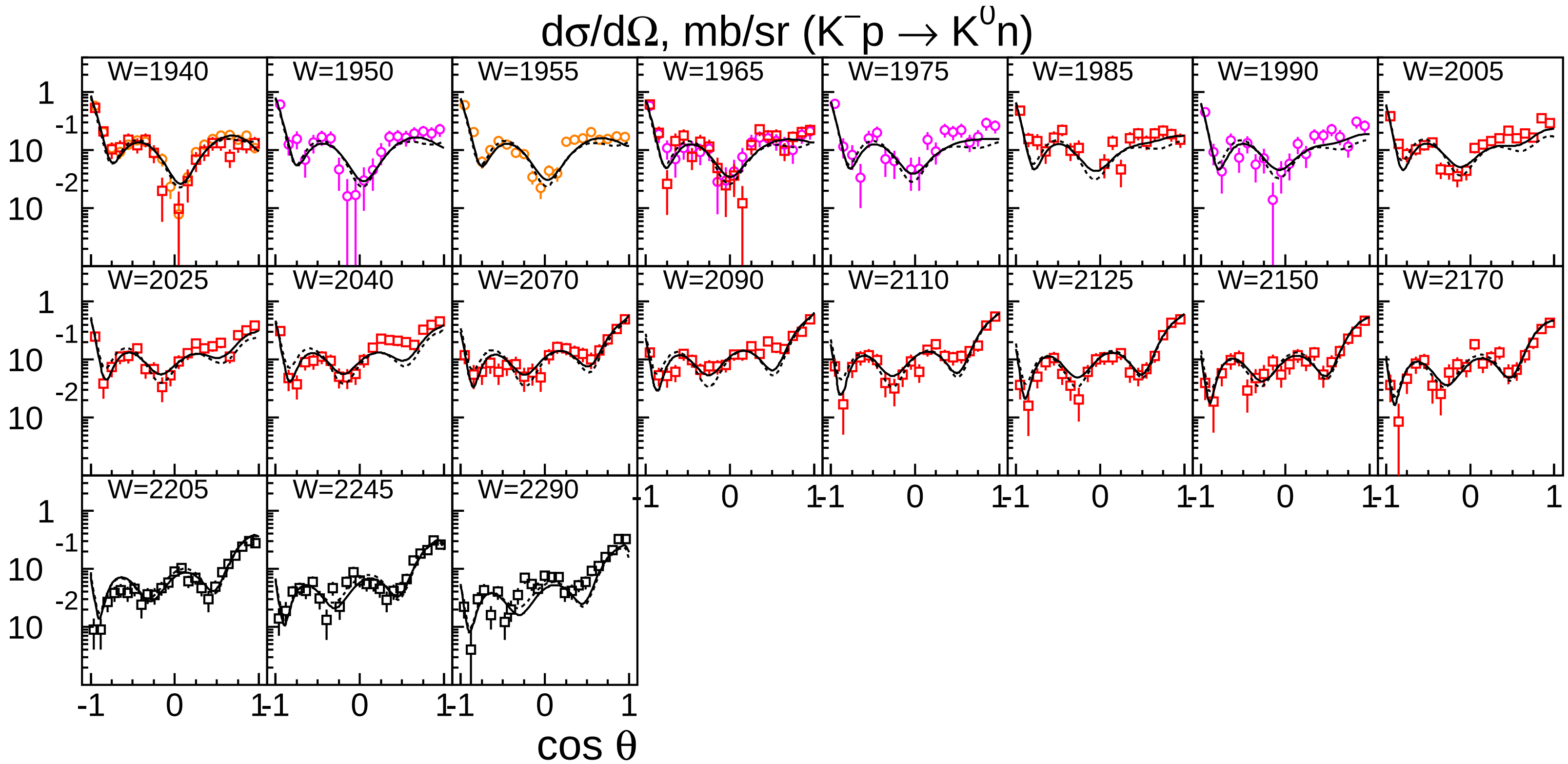
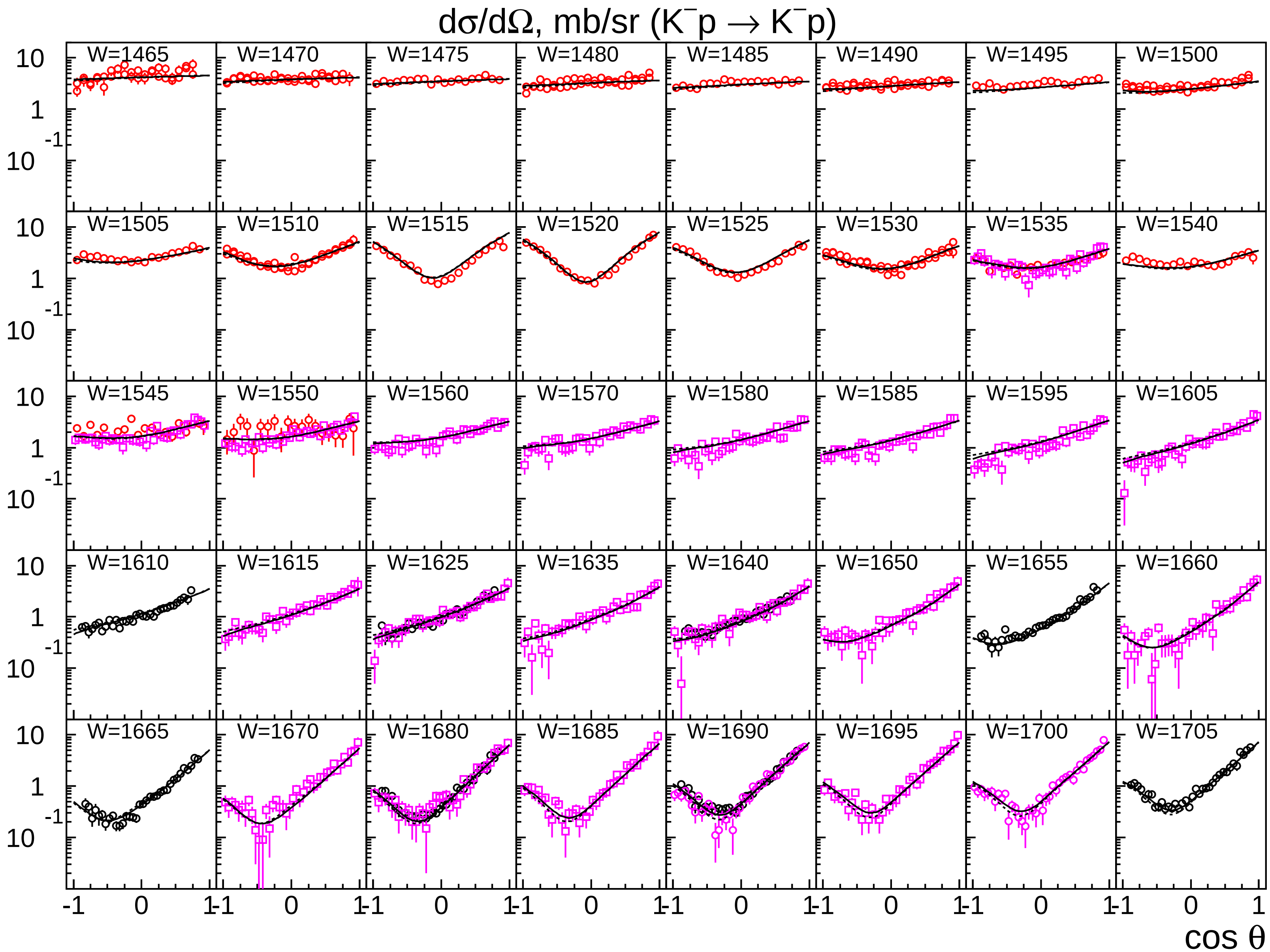
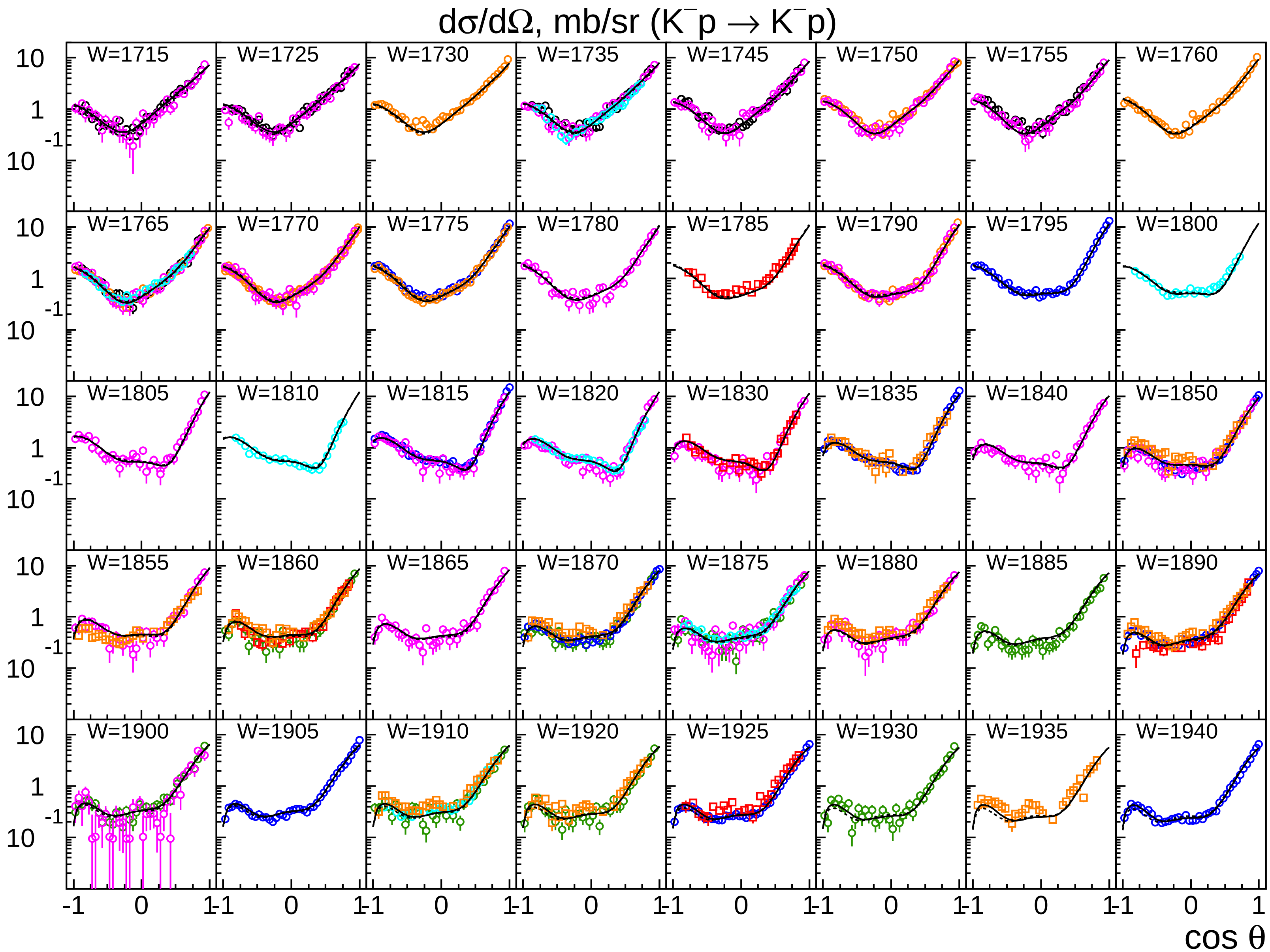
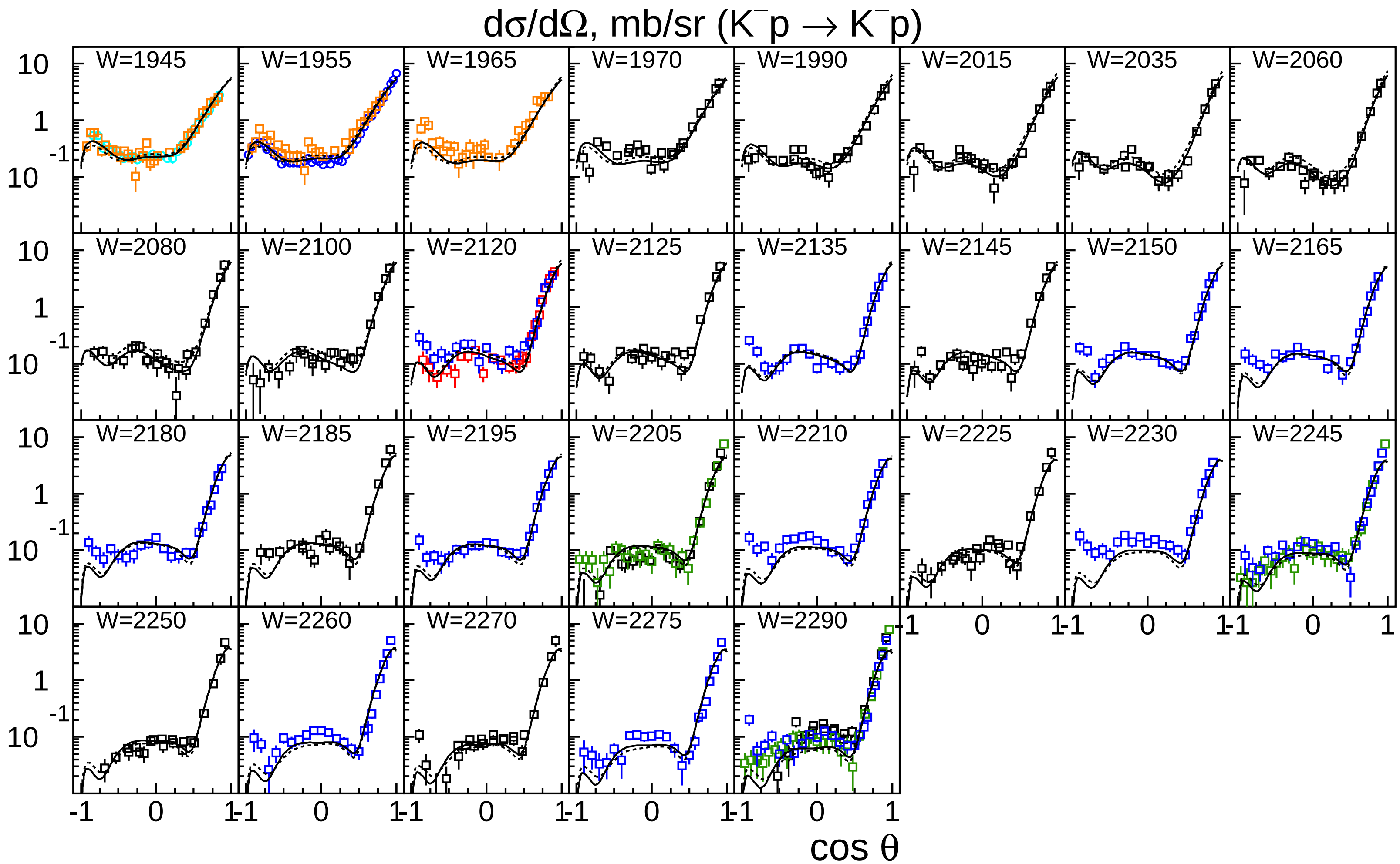
10^-2
-1
0
1
cos θ

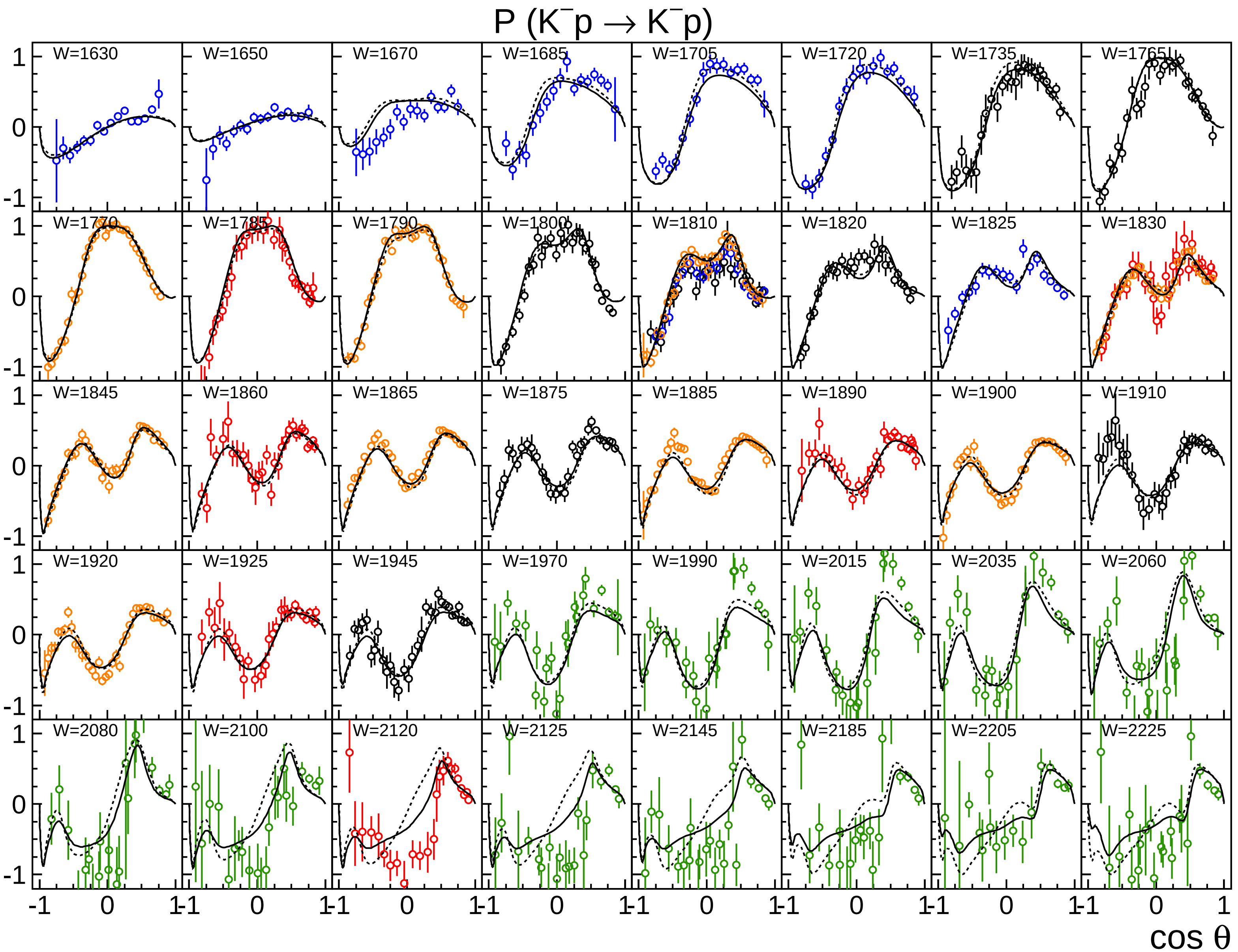

dσ/dΩ, mb/sr (K⁻p → K⁰n)
W=1940
W=1950
W=1955
W=1965
W=1975
W=1985
W=1990
W=2005
W=2025
W=2040
W=2070
W=2090
W=2110
W=2125
W=2150
W=2170
W=2205
W=2245
W=2290
cos θ

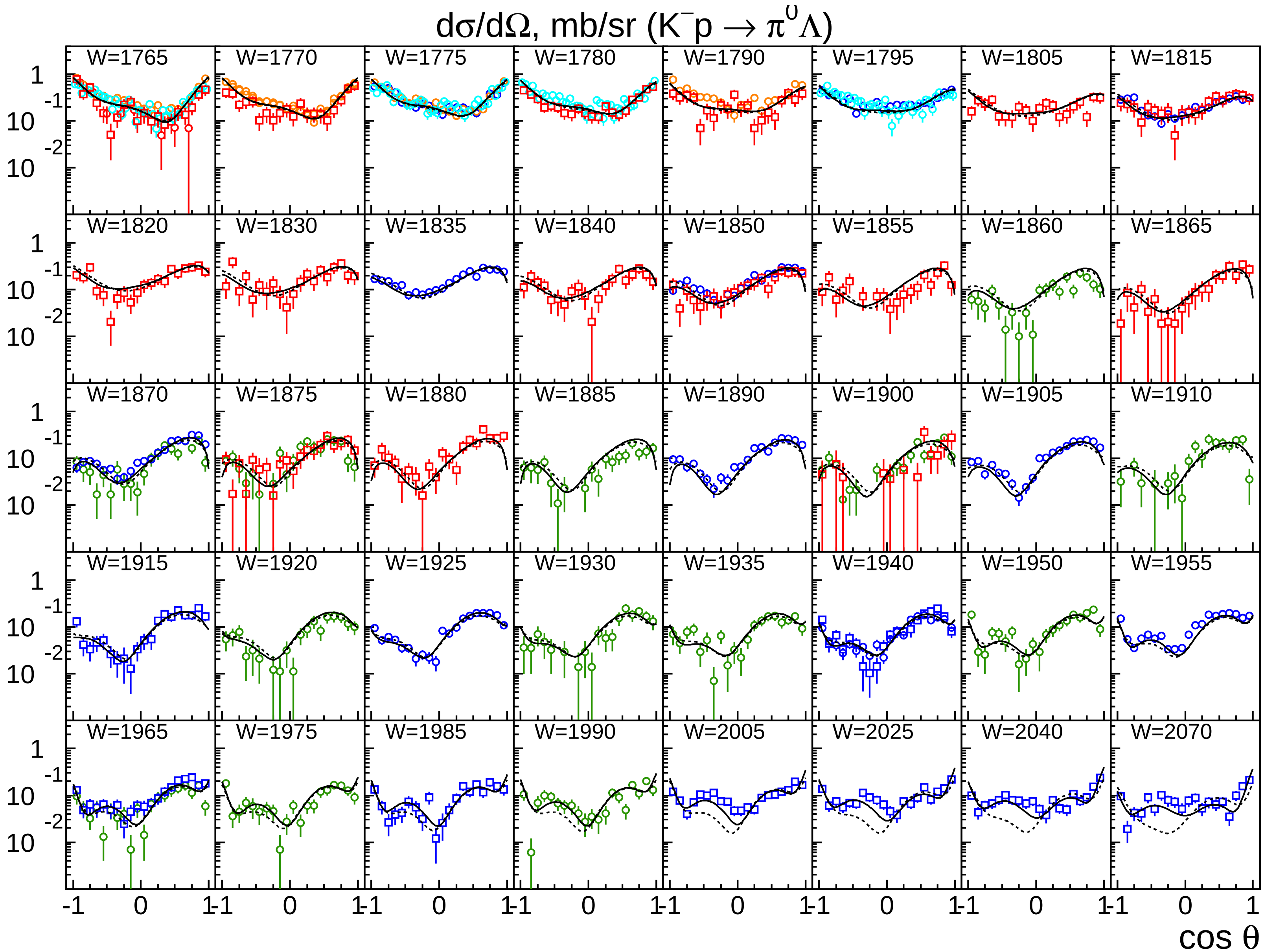

dσ/dΩ, mb/sr (K⁻p → K⁻p)
W=1465
W=1470
W=1475
W=1480
W=1485
W=1490
W=1495
W=1500
W=1505
W=1510
W=1515
W=1520
W=1525
W=1530
W=1535
W=1540
W=1545
W=1550
W=1560
W=1570
W=1580
W=1585
W=1595
W=1605
W=1610
W=1615
W=1625
W=1635
W=1640
W=1650
W=1655
W=1660
W=1665
W=1670
W=1680
W=1685
W=1690
W=1695
W=1700
W=1705
cos θ


dσ/dΩ, mb/sr (K⁻p → K⁻p)
W=1715
W=1725
W=1730
W=1735
W=1745
W=1750
W=1755
W=1760
W=1765
W=1770
W=1775
W=1780
W=1785
W=1790
W=1795
W=1800
W=1805
W=1810
W=1815
W=1820
W=1830
W=1835
W=1840
W=1850
W=1855
W=1860
W=1865
W=1870
W=1875
W=1880
W=1885
W=1890
W=1900
W=1905
W=1910
W=1920
W=1925
W=1930
W=1935
W=1940
10
1
10-1
-1
0
1
cos θ

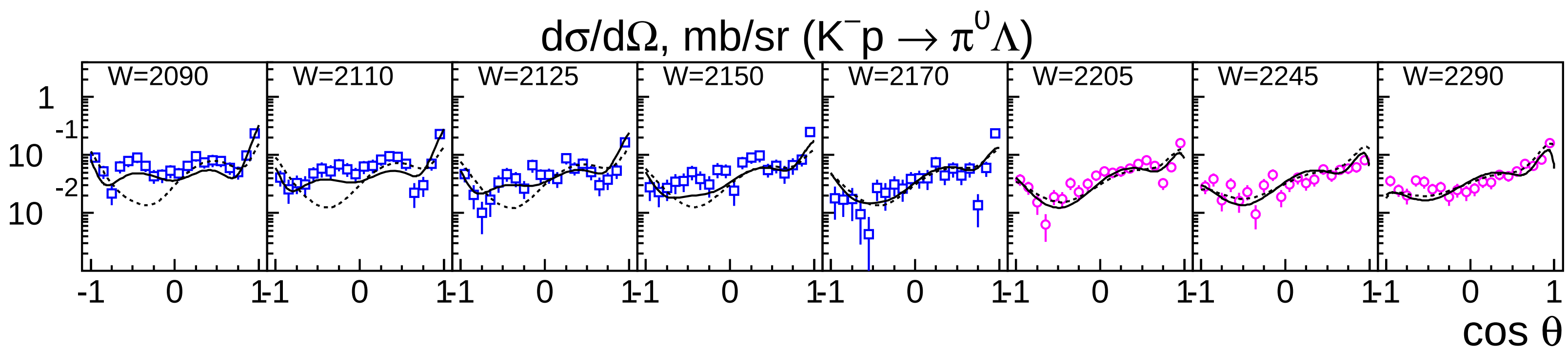


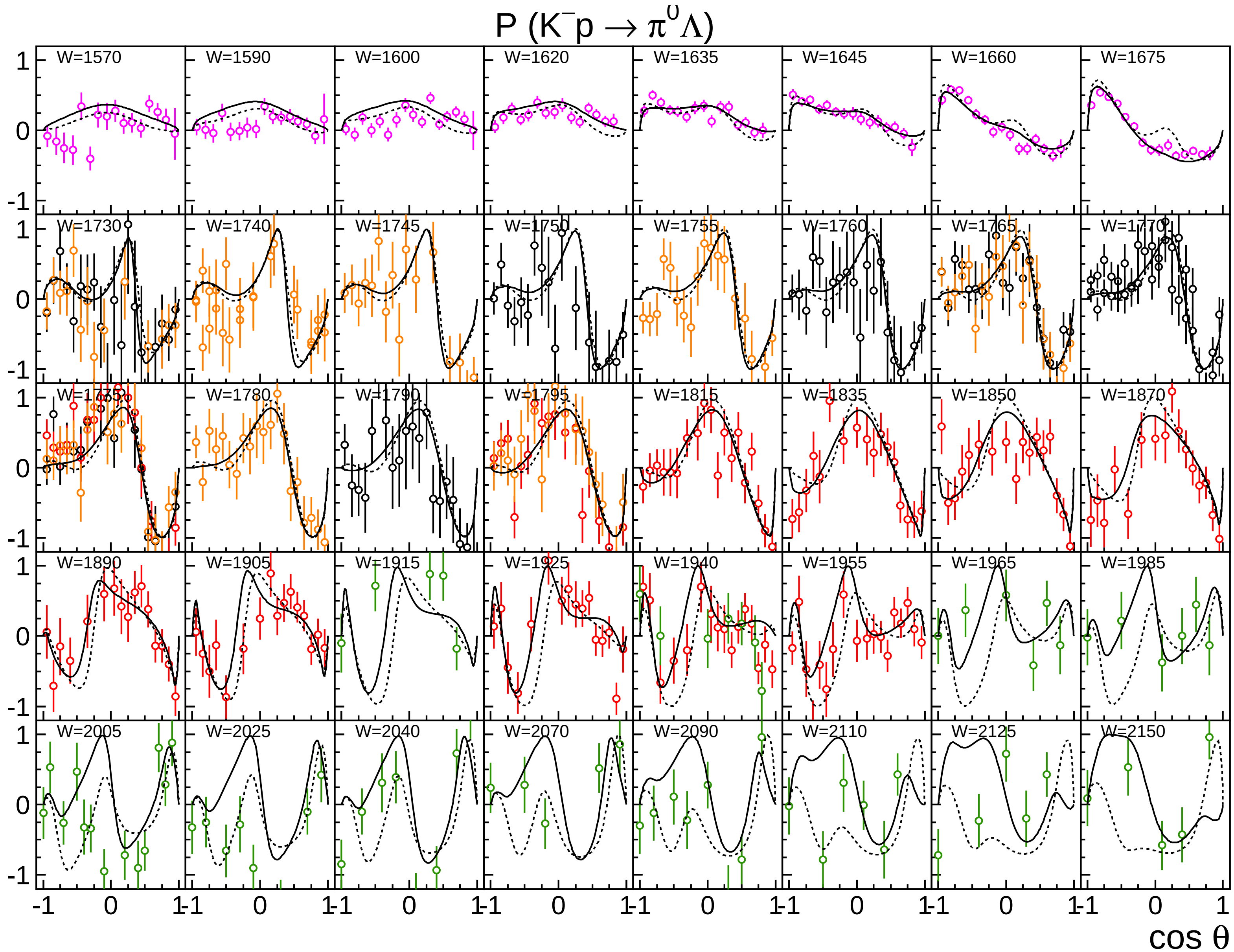
dσ/dΩ, mb/sr ($K^-p \to K^-p$)
W=1945
W=1955
W=1965
W=1970
W=1990
W=2015
W=2035
W=2060
W=2080
W=2100
W=2120
W=2125
W=2135
W=2145
W=2150
W=2165
W=2180
W=2185
W=2195
W=2205
W=2210
W=2225
W=2230
W=2245
W=2250
W=2260
W=2270
W=2275
W=2290
cos θ

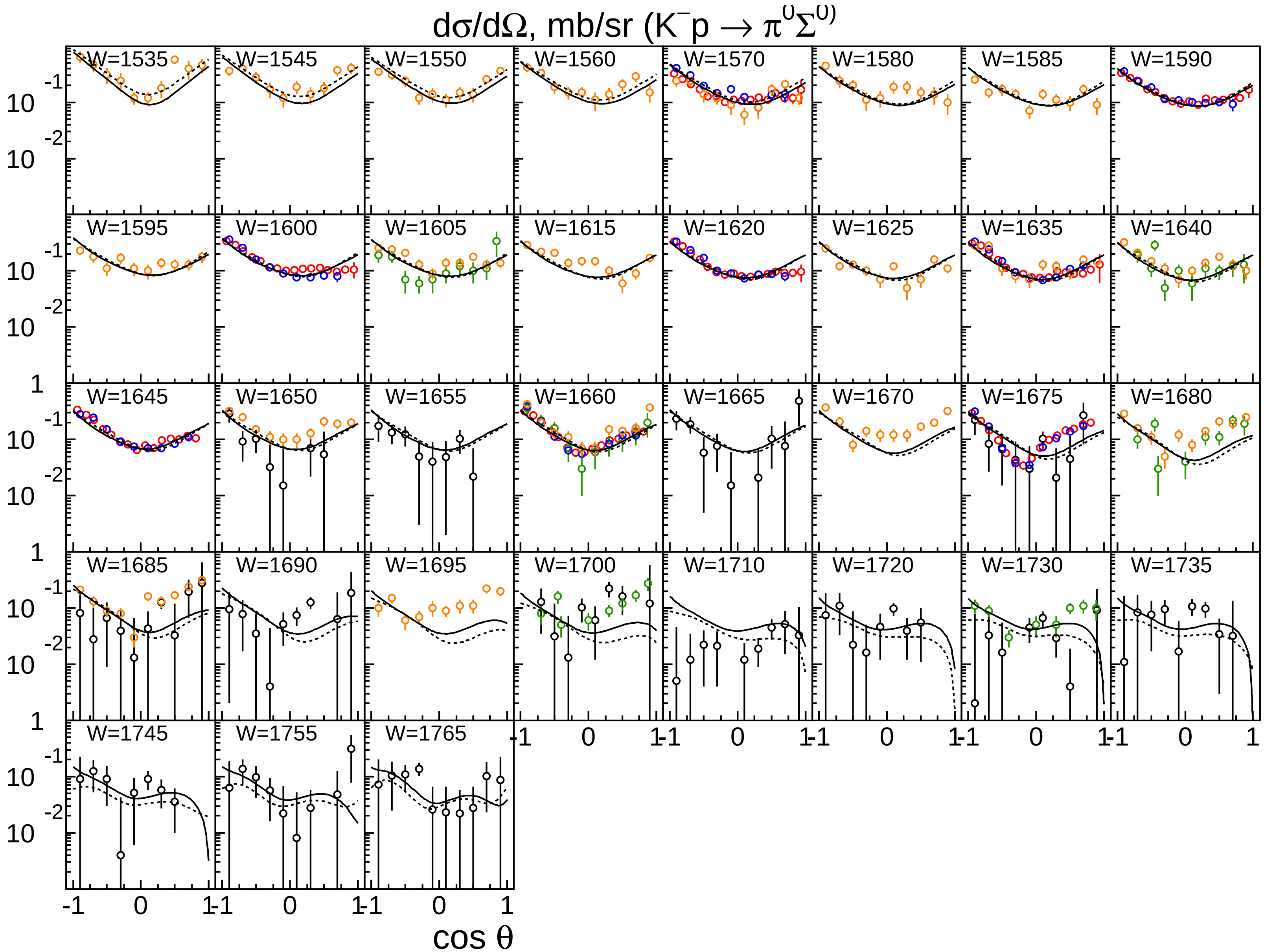

P (K⁻p → K⁻p)
W=1630
W=1650
W=1670
W=1685
W=1705
W=1720
W=1735
W=1765
W=1770
W=1785
W=1790
W=1800
W=1810
W=1820
W=1825
W=1830
W=1845
W=1860
W=1865
W=1875
W=1885
W=1890
W=1900
W=1910
W=1920
W=1925
W=1945
W=1970
W=1990
W=2015
W=2035
W=2060
W=2080
W=2100
W=2120
W=2125
W=2145
W=2185
W=2205
W=2225
cos θ

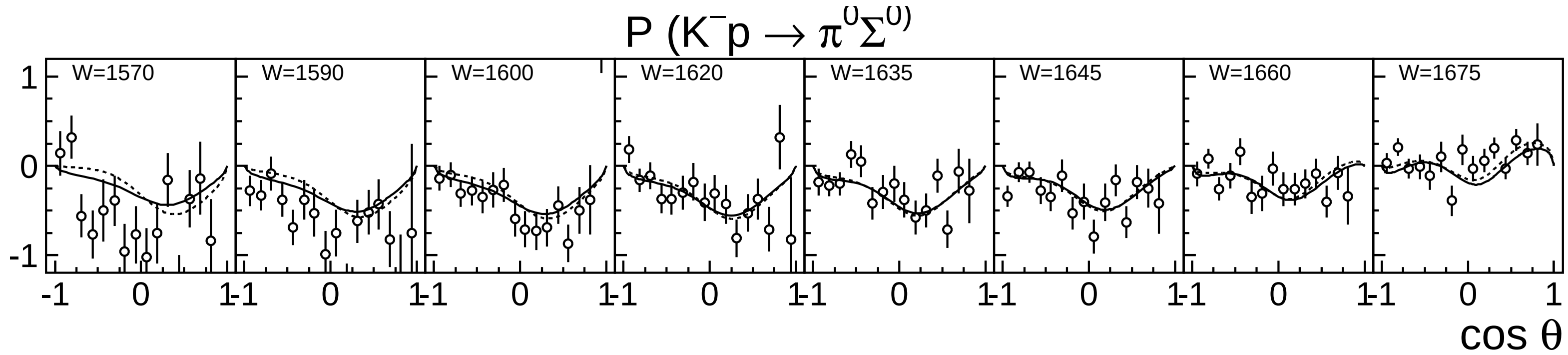


dσ/dΩ, mb/sr (K⁻p → π⁰Λ)
W=1765
W=1770
W=1775
W=1780
W=1790
W=1795
W=1805
W=1815
W=1820
W=1830
W=1835
W=1840
W=1850
W=1855
W=1860
W=1865
W=1870
W=1875
W=1880
W=1885
W=1890
W=1900
W=1905
W=1910
W=1915
W=1920
W=1925
W=1930
W=1935
W=1940
W=1950
W=1955
W=1965
W=1975
W=1985
W=1990
W=2005
W=2025
W=2040
W=2070
cos θ

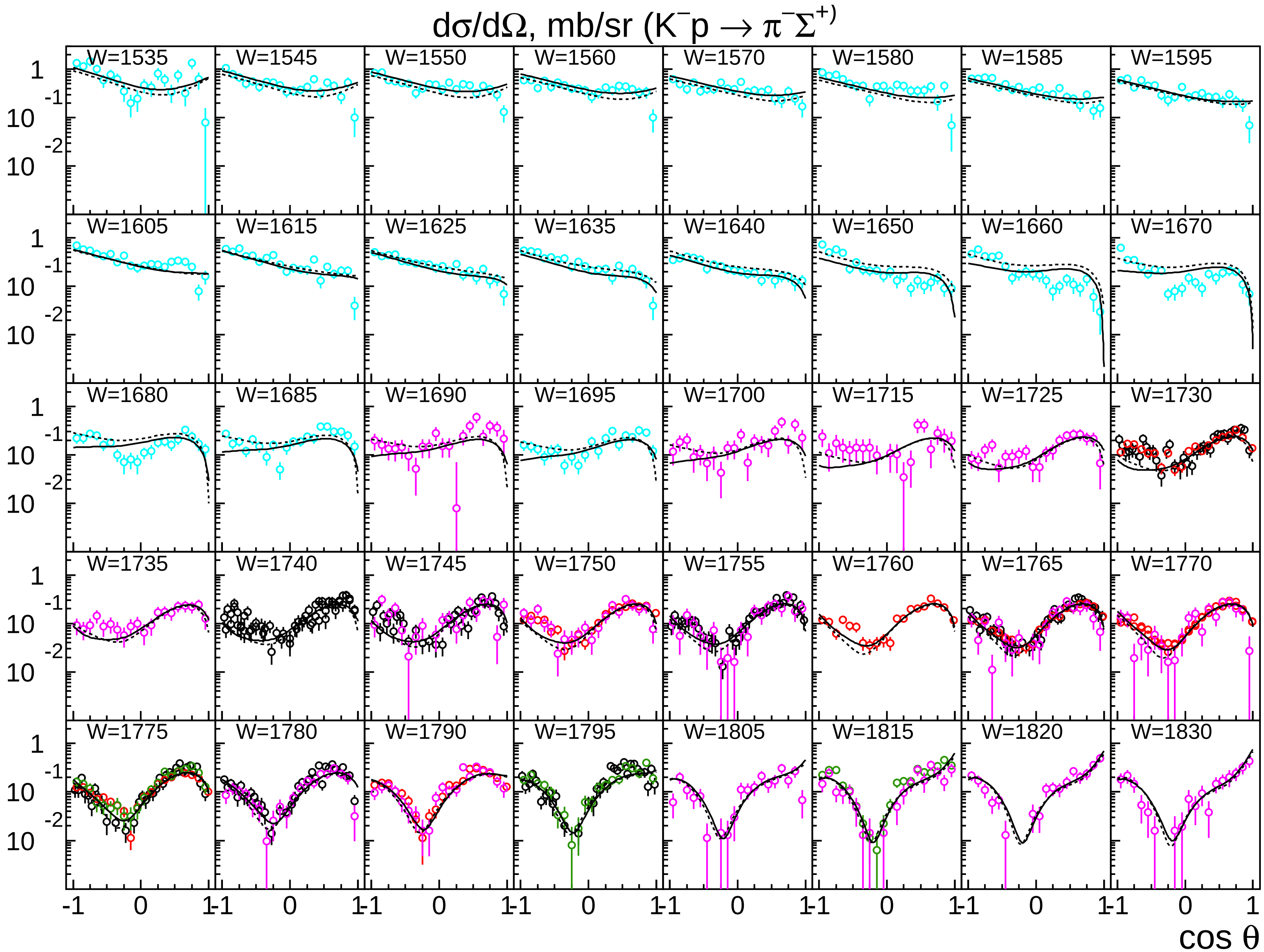

dσ/dΩ, mb/sr (K⁻p → π⁰Λ)
W=2090
W=2110
W=2125
W=2150
W=2170
W=2205
W=2245
W=2290
1
10^-1
10^-2
-1
0
1
cos θ


P (K⁻p → π⁰Λ)
W=1570
W=1590
W=1600
W=1620
W=1635
W=1645
W=1660
W=1675
W=1730
W=1740
W=1745
W=1750
W=1755
W=1760
W=1765
W=1770
W=1775
W=1780
W=1790
W=1795
W=1815
W=1835
W=1850
W=1870
W=1890
W=1905
W=1915
W=1925
W=1940
W=1955
W=1965
W=1985
W=2005
W=2025
W=2040
W=2070
W=2090
W=2110
W=2125
W=2150
cos θ


dσ/dΩ, mb/sr (K⁻p → π⁰Σ⁰)
W=1535
W=1545
W=1550
W=1560
W=1570
W=1580
W=1585
W=1590
W=1595
W=1600
W=1605
W=1615
W=1620
W=1625
W=1635
W=1640
W=1645
W=1650
W=1655
W=1660
W=1665
W=1670
W=1675
W=1680
W=1685
W=1690
W=1695
W=1700
W=1710
W=1720
W=1730
W=1735
W=1745
W=1755
W=1765
cos θ



P (K⁻p → π⁰Σ⁰)
W=1570
W=1590
W=1600
W=1620
W=1635
W=1645
W=1660
W=1675
1
0
-1
-1
0
1
cos θ



dσ/dΩ, mb/sr (K⁻p → π⁻Σ⁺)
W=1535
W=1545
W=1550
W=1560
W=1570
W=1580
W=1585
W=1595
W=1605
W=1615
W=1625
W=1635
W=1640
W=1650
W=1660
W=1670
W=1680
W=1685
W=1690
W=1695
W=1700
W=1715
W=1725
W=1730
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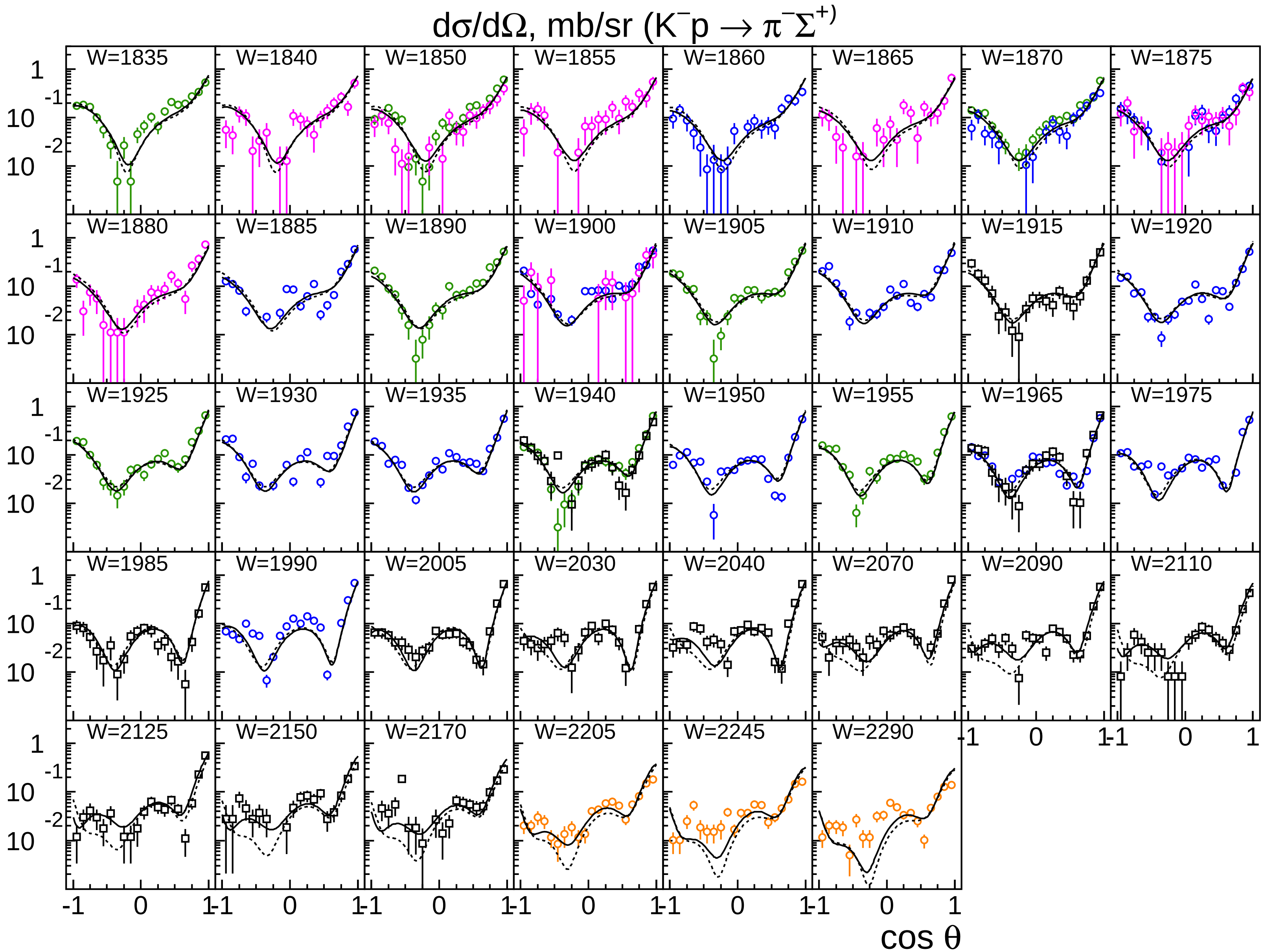
W=1755
W=1760
W=1765
W=1770
W=1775
W=1780
W=1790
W=1795
W=1805
W=1815
W=1820
W=1830
cos θ



dσ/dΩ, mb/sr (K⁻p → π⁻Σ⁺)
W=1835
W=1840
W=1850
W=1855
W=1860
W=1865
W=1870
W=1875
W=1880
W=1885
W=1890
W=1900
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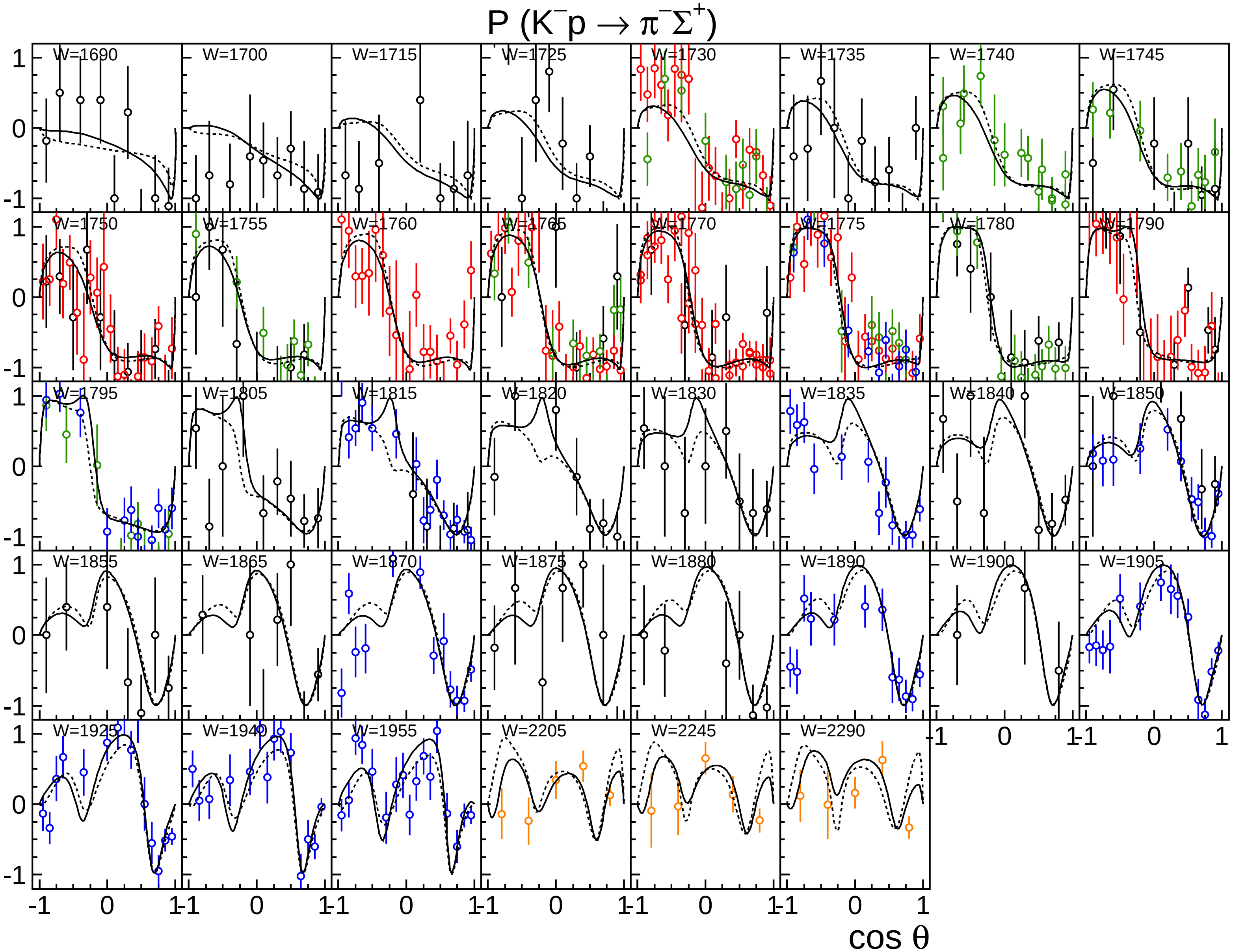
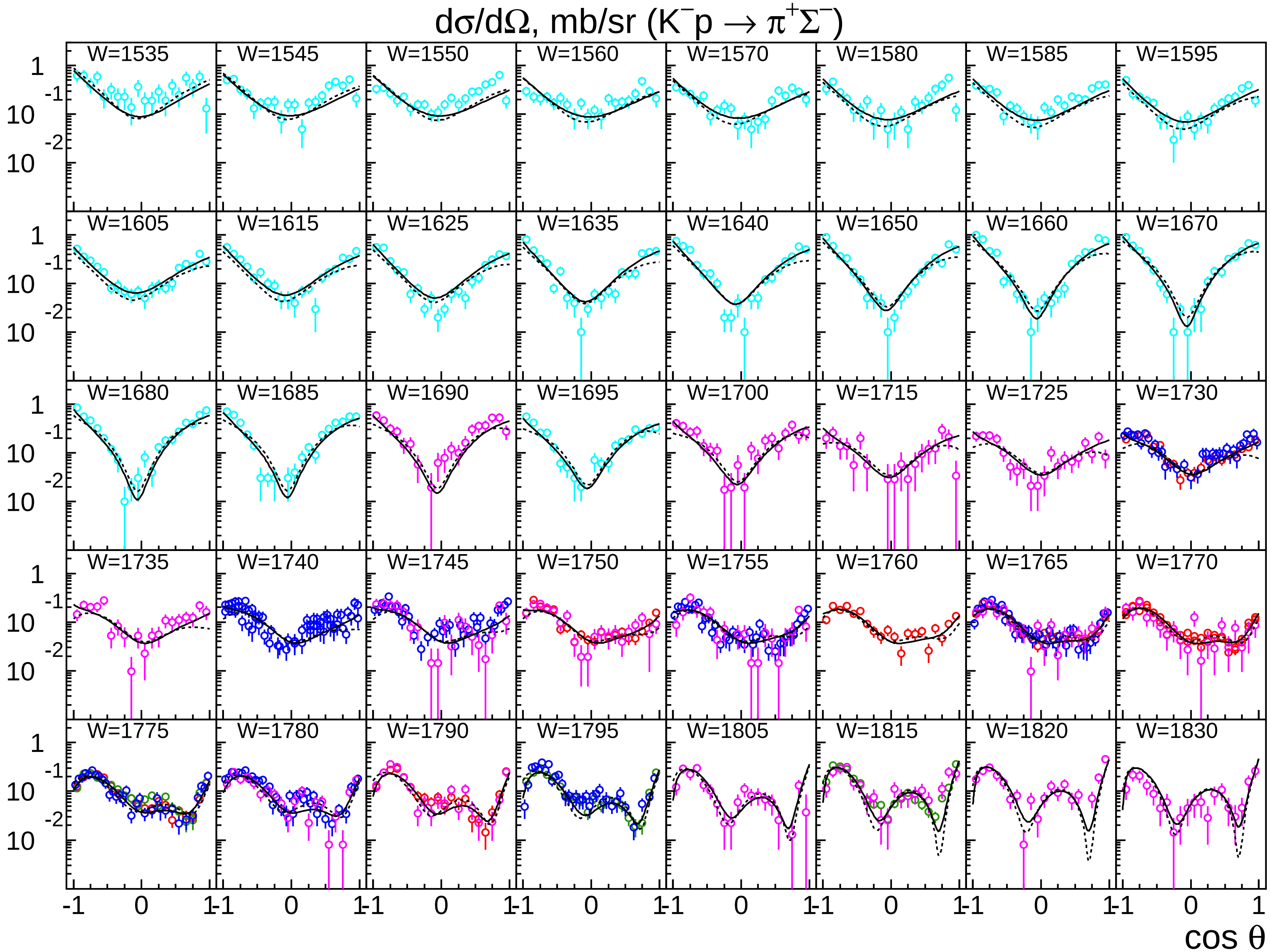
W=1925
W=1930
W=1935
W=1940
W=1950
W=1955
W=1965
W=1975
W=1985
W=1990
W=2005
W=2030
W=2040
W=2070
W=2090
W=2110
W=2125
W=2150
W=2170
W=2205
W=2245
W=2290
cos θ



P (K⁻p → π⁻Σ⁺)
W=1690
W=1700
W=1715
W=1725
W=1730
W=1735
W=1740
W=1745
W=1750
W=1755
W=1760
W=1765
W=1770
W=1775
W=1780
W=1790
W=1795
W=1805
W=1815
W=1820
W=1830
W=1835
W=1840
W=1850
W=1855
W=1865
W=1870
W=1875
W=1880
W=1890
W=1900
W=1905
W=1925
W=1940
W=1955
W=2205
W=2245
W=2290
cos θ


dσ/dΩ, mb/sr (K⁻p → π⁺Σ⁻)
W=1535
W=1545
W=1550
W=1560
W=1570
W=1580
W=1585
W=1595
W=1605
W=1615
W=1625
W=1635
W=1640
W=1650
W=1660
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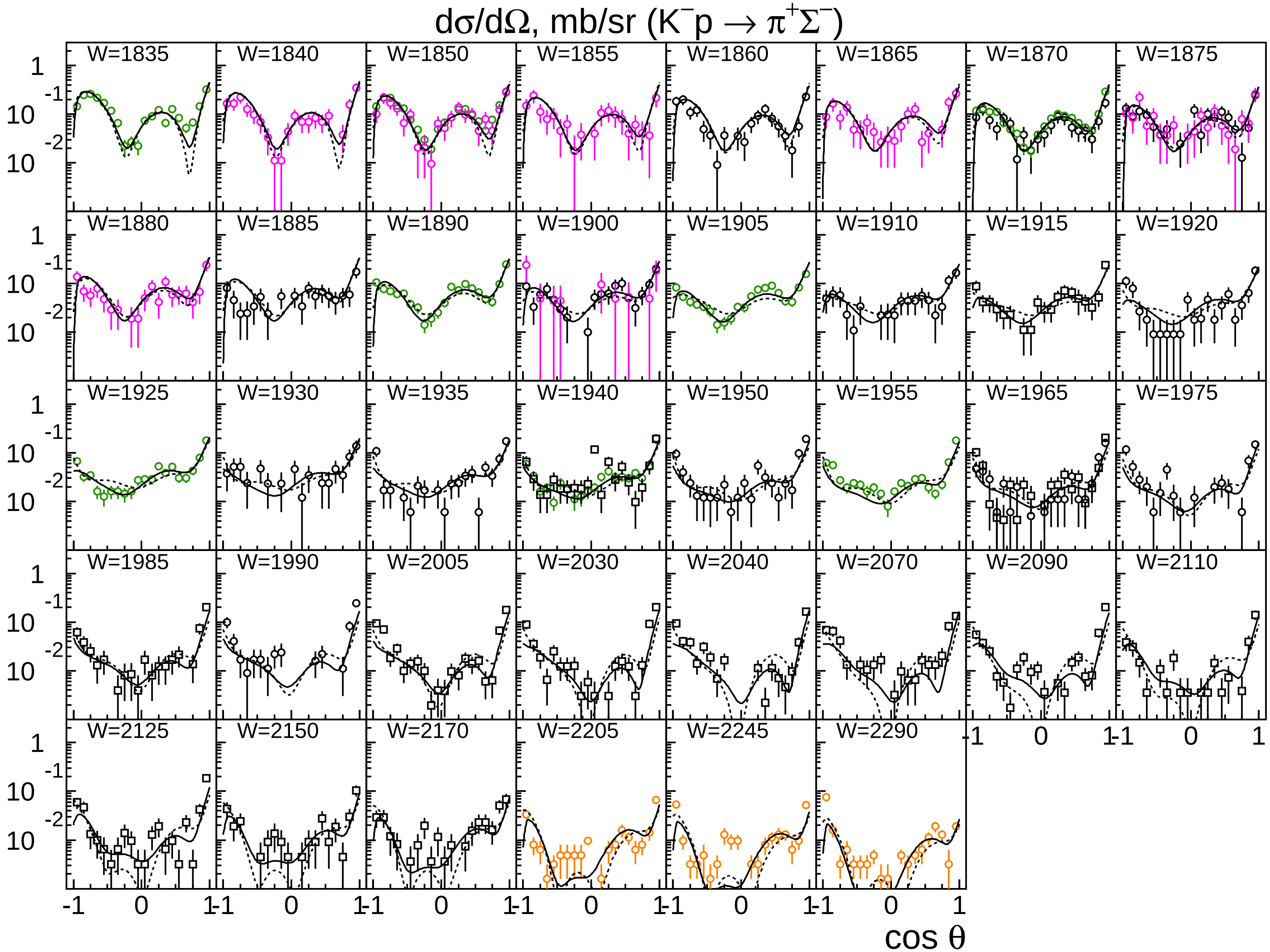
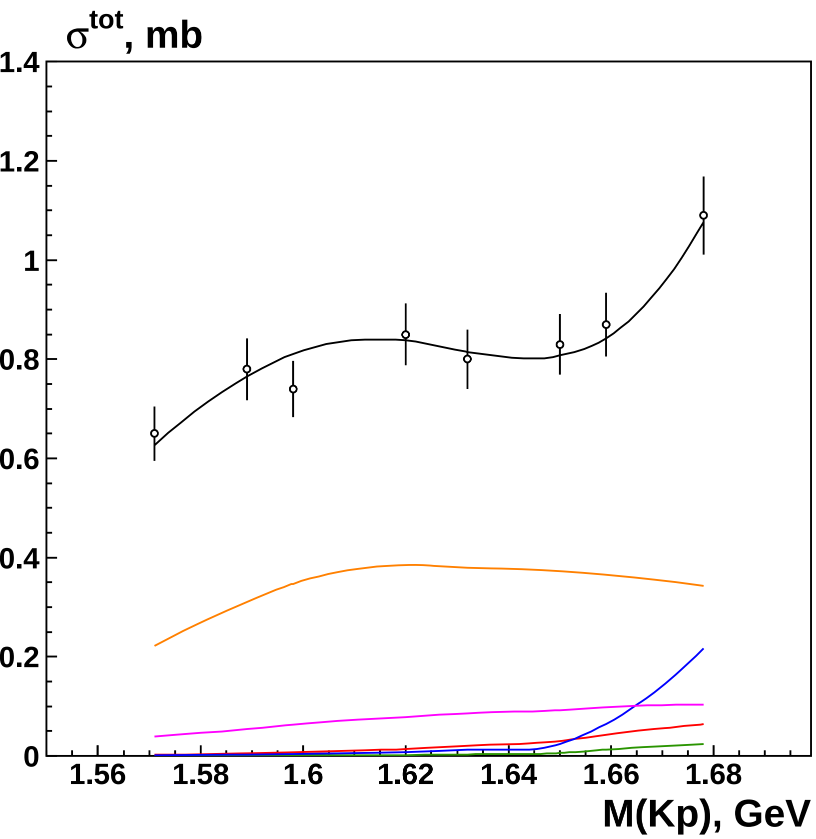
W=1735
W=1740
W=1745
W=1750
W=1755
W=1760
W=1765
W=1770
W=1775
W=1780
W=1790
W=1795
W=1805
W=1815
W=1820
W=1830
cos θ



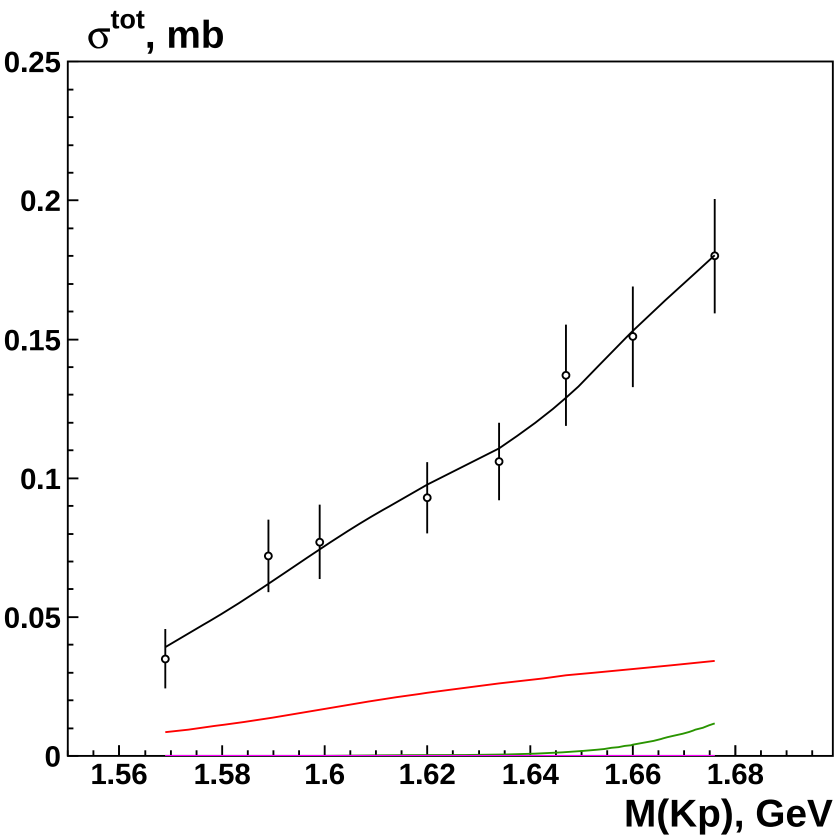
dσ/dΩ, mb/sr ($K^-p \to \pi^+\Sigma^-$)
W=1835
W=1840
W=1850
W=1855
W=1860
W=1865
W=1870
W=1875
W=1880
W=1885
W=1890
W=1900
W=1905
W=1910
W=1915
W=1920
W=1925
W=1930
W=1935
W=1940
W=1950
W=1955
W=1965
W=1975
W=1985
W=1990
W=2005
W=2030
W=2040
W=2070
W=2090
W=2110
W=2125
W=2150
W=2170
W=2205
W=2245
W=2290
cos θ

		ANL-Osaca	Bn-Ga	Model A	Model B	Bn-Ga
$K^- p \to K^- p$	$d\sigma/d\Omega$	3962	5495	3.07	2.98	2.28
	P	510	859	2.04	2.08	1.79
$K^- p \to \bar{K}^0 n$	$d\sigma/d\Omega$	2950	3445	2.67	2.75	1.62
$K^- p \to \pi^- \Sigma^+$	$d\sigma/d\Omega$	1792	2095	3.37	3.49	3.17
	P	418	578	1.30	1.28	2.06
$K^- p \to \pi^0 \Sigma^0$	$d\sigma/d\Omega$	580	581	3.68	3.50	3.57
	P	196	124	6.39	5.80	1.51
$K^- p \to \pi^+ \Sigma^-$	$d\sigma/d\Omega$	1786	2082	2.56	2.18	1.80
$K^- p \to \pi^0 \Lambda$	$d\sigma/d\Omega$	2178	2478	2.59	3.71	1.82
	P	693	732	1.41	1.73	1.73
$K^- p \to \eta \Lambda$	$d\sigma/d\Omega$	160	160	2.69	2.03	1.52
	P	18	—	0.94	3.83	—
$K^- p \to K^0 \Xi^0$	$d\sigma/d\Omega$	33	67	1.24	1.61	1.20
$K^- p \to K^+ \Xi^-$	$d\sigma/d\Omega$	92	193	2.05	1.74	1.38
$K^- p \to \Lambda \omega$	$d\sigma/d\Omega$	–	300	—	—	1.08

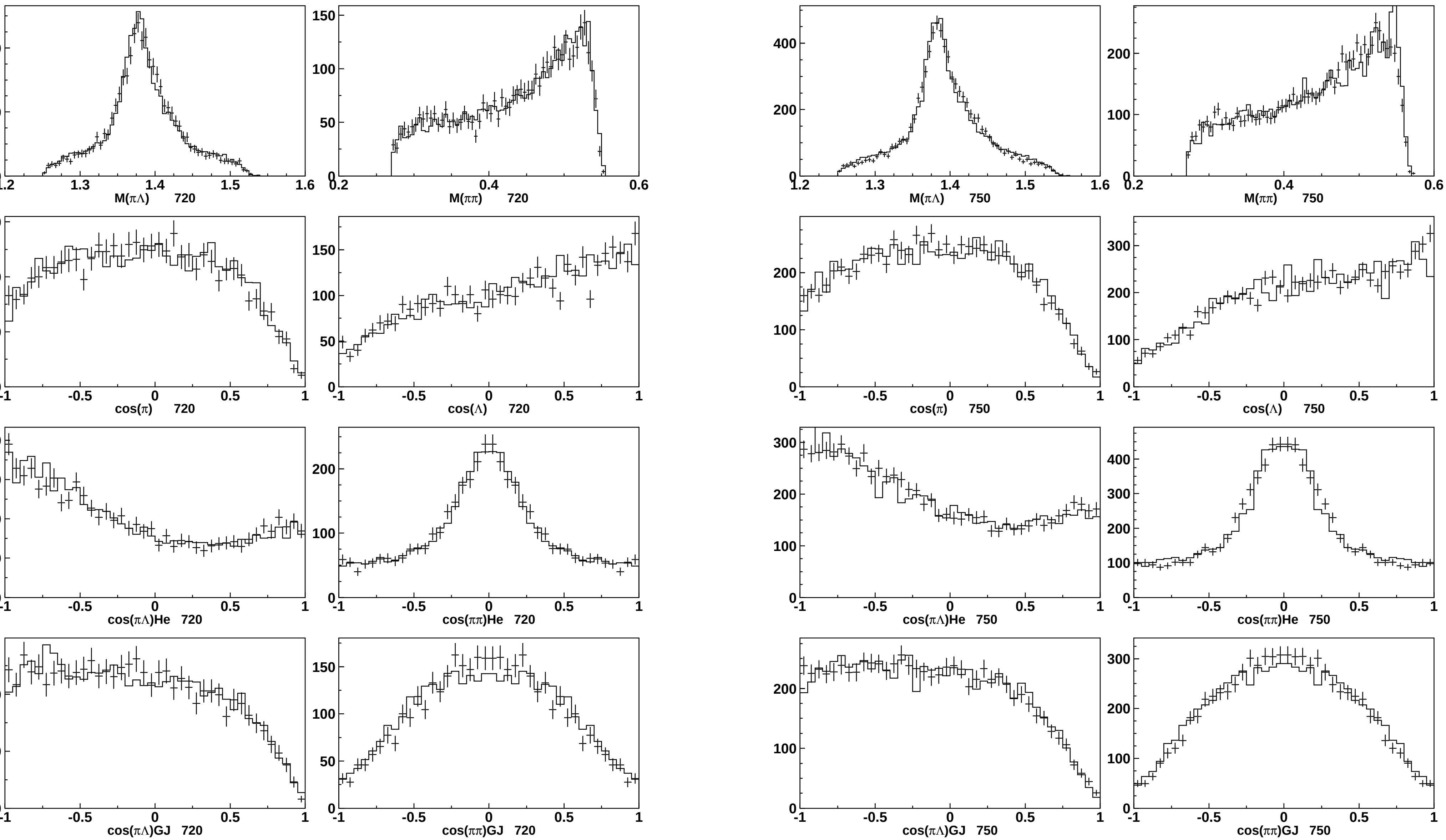
$K^- p \to \pi^0 \pi^0 \Lambda$



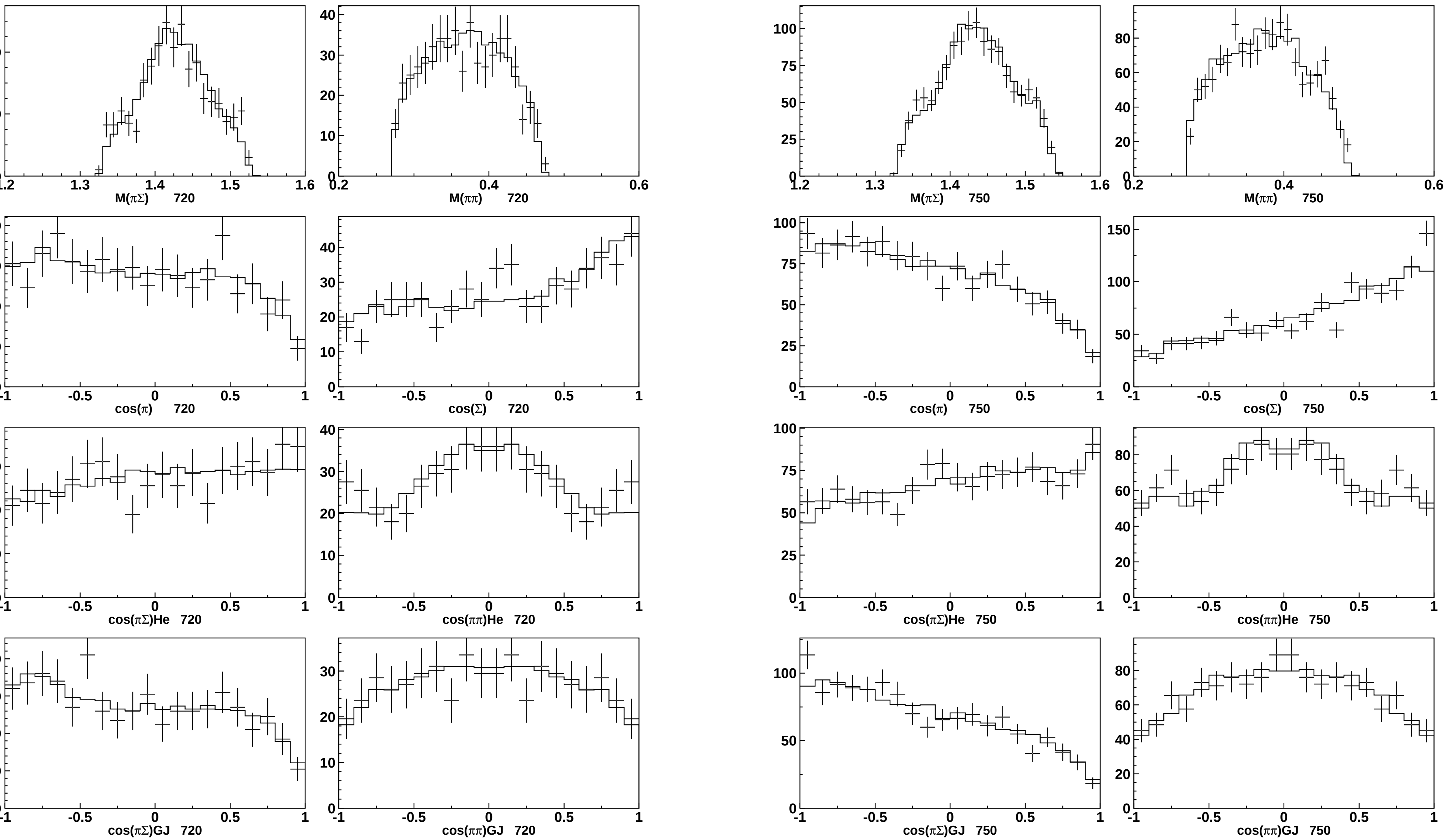
$K^- p \to \pi^0 \pi^0 \Sigma^0$



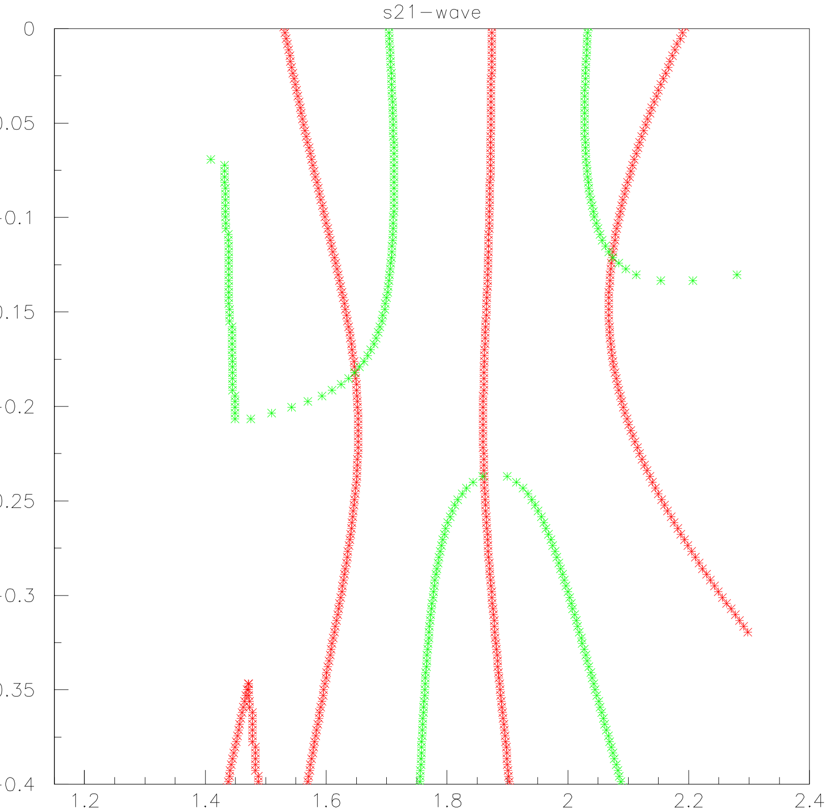
$K^-p \to \pi^0\pi^0\Lambda$ (beam momenta 720 and 750 MeV/c)



$K^- p \rightarrow \pi^0 \pi^0 \Sigma^0$ (beam momenta 720 and 750 MeV/c)



Pole position of the $\Sigma 1/2^-$ amplitude



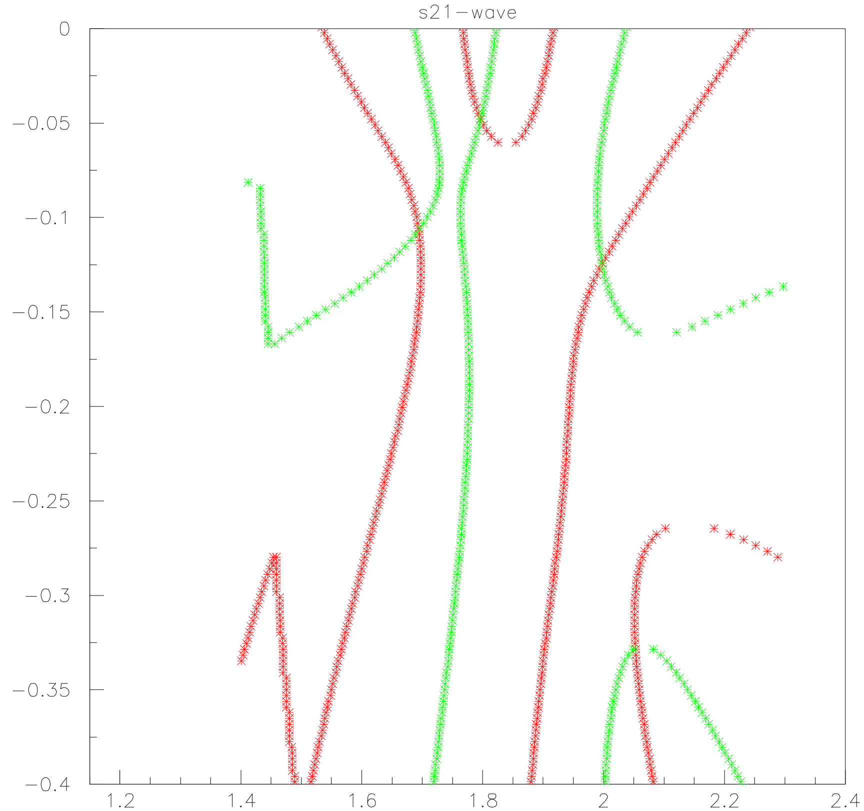


Table 5: Σ-Hyperons used in the first fit to the data.

	J^P	**Status**	**Mass**	**Width**
$\Sigma(1660)$	$1/2^+$	***	$1630 - 1690$	36.0 ± 0.7
$\Sigma(1385)$	$3/2^+$	****	1382.80 ± 0.35	$40 - 200$
$\Sigma(1915)$	$5/2^+$	****	$1900 - 1935$	$80 - 160$
$\Sigma(2030)$	$7/2^+$	****	$2025 - 2040$	$150 - 200$
$\Sigma(1670)$	$3/2^-$	****	$1665 - 1685$	$40 - 80$
$\Sigma(1750)$	$1/2^-$	***	$1730 - 1800$	$60 - 160$
$\Sigma(1775)$	$5/2^-$	****	$1770 - 1780$	$105 - 135$
$\Sigma(1940)$	$3/2^-$	***	$1900 - 1950$	$150 - 300$
$\Sigma(1665)$	$1/2^-$		1670 ± 15	210 ± 20
$\Sigma(2150)$	$1/2^-$		2160 ± 20	220 ± 25
$\Sigma(2250)$	$5/2^-$		2250 ± 30	330 ± 40

SUMMARY

- **The analysis of the $\gamma n \to K\Lambda$ and $\gamma n \to K\Sigma$ reactions confirms states in the mass region around 1900 MeV.**
- **The energy independent analysis of the $\gamma p \to K\Lambda$ data is consistent with the energy dependent analysis.**
- **The analysis of the new data on the η and η' photoproduction confirms the observed earlier $S_{11}(1895)$ state. There is puzzling behavior of the data near the $\eta' p$ threshold.**
- **The analysis of the reactions with two pion production provides an important information for the classification of the observed states and branching to the two meson final states.**
- **The analysis of the Kp collision data reveals the presence of the unknown Σ-hyperons. There is a hope to observe the baryon multiplets and therefore to confirm the states found in the Nucleon-Delta sector.**