Search for missing Sigma-hyperon states

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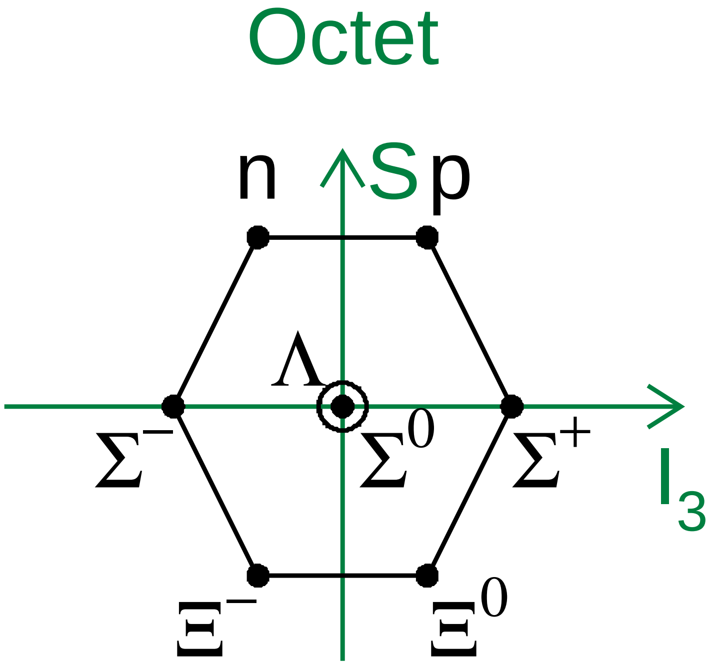
$$3 \otimes 3 \otimes 3 = 10_S \oplus 8_M \oplus 8_M \oplus 1_A$$



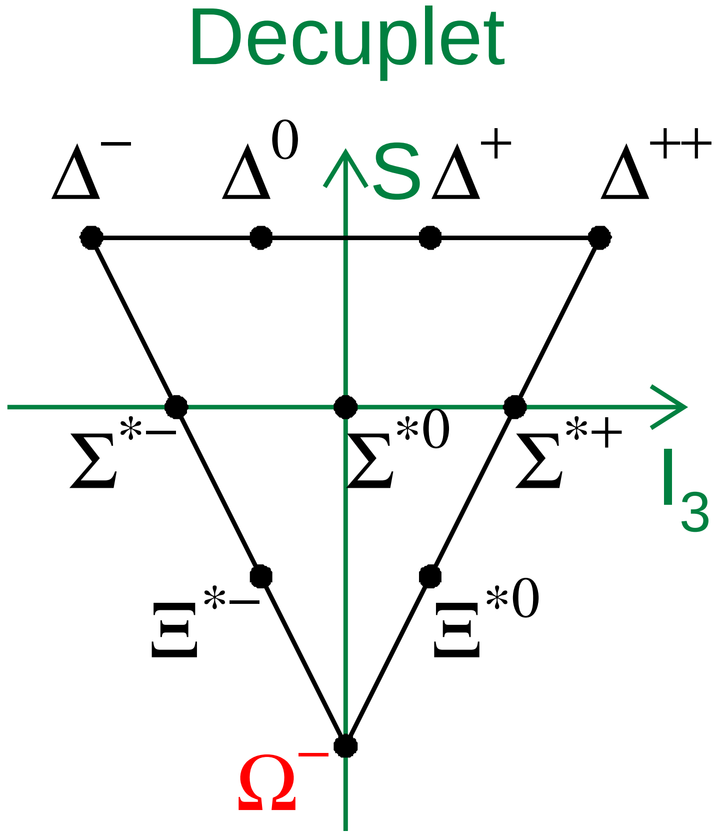


Table 1: Λ-hyperons used in the first fit of the data.

		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
$N(1520)$	$\Lambda(1690)$	$3/2^-$	****	$1685 - 1695$	$50 - 70$
$N(1675)$	$\Lambda(1830)$	$5/2^-$	****	$1810 - 1830$	$60 - 110$
$N(2190)$	$\Lambda(2100)$	$7/2^-$	****	$2090 - 2110$	$100 - 250$
$N(1440)$	$\Lambda(1600)$	$1/2^+$	***	$1560 - 1700$	$50 - 250$
$N(1710)$	$\Lambda(1810)$	$1/2^+$	***	$1750 - 1850$	$50 - 250$
$N(1700)$	$\Lambda(1890)$	$3/2^+$	****	$1850 - 1910$	$60 - 200$
$N(1680)$	$\Lambda(1820)$	$5/2^+$	****	$1815 - 1825$	$70 - 90$
$N(2060)$	$\Lambda(2110)$	$5/2^+$	***	$2090 - 2140$	$150 - 250$

Table 2: Σ-Hyperons used in the first fit of the data.

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

Many Σ states are missing.

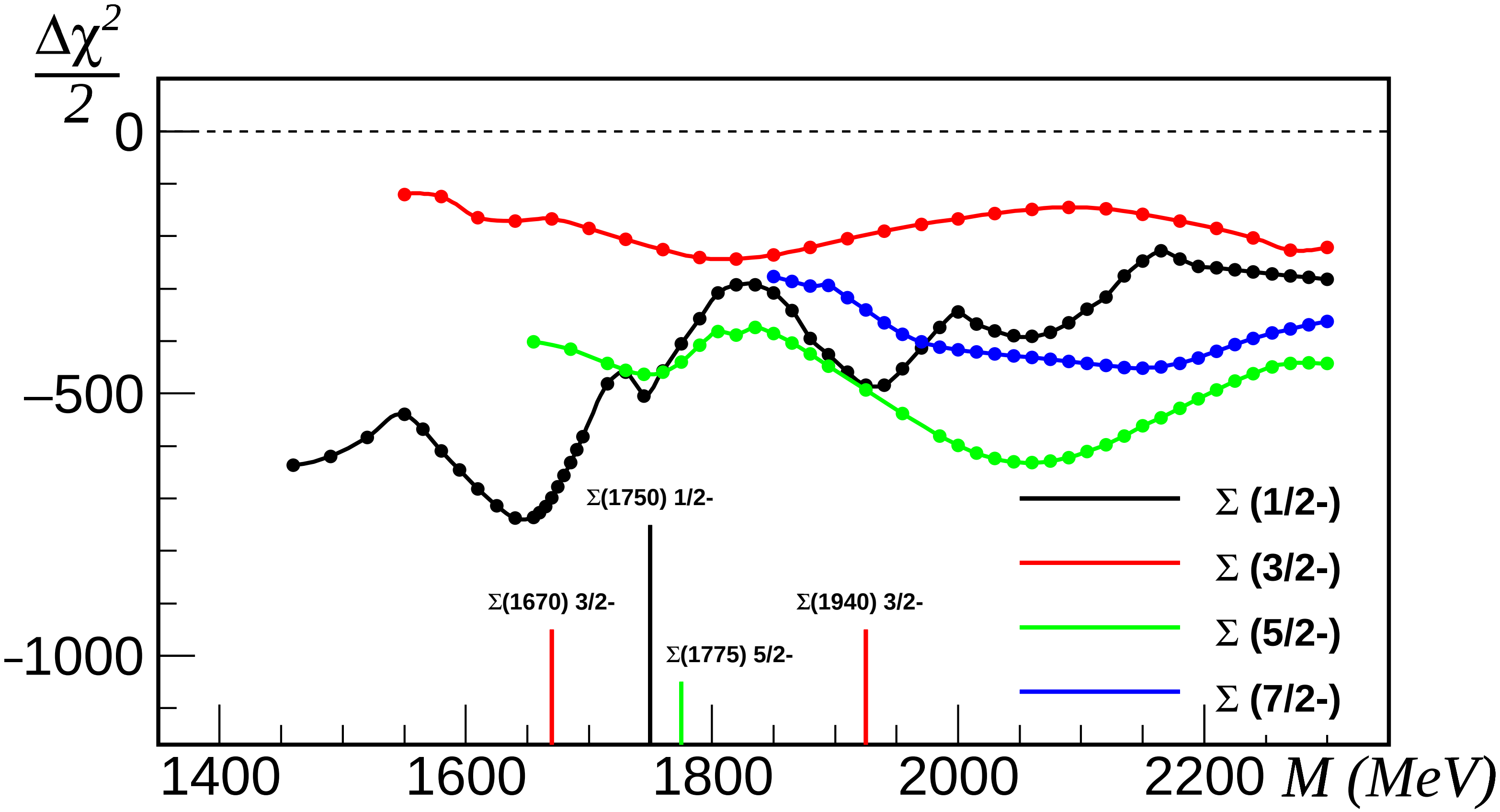
Kaon beam motivation

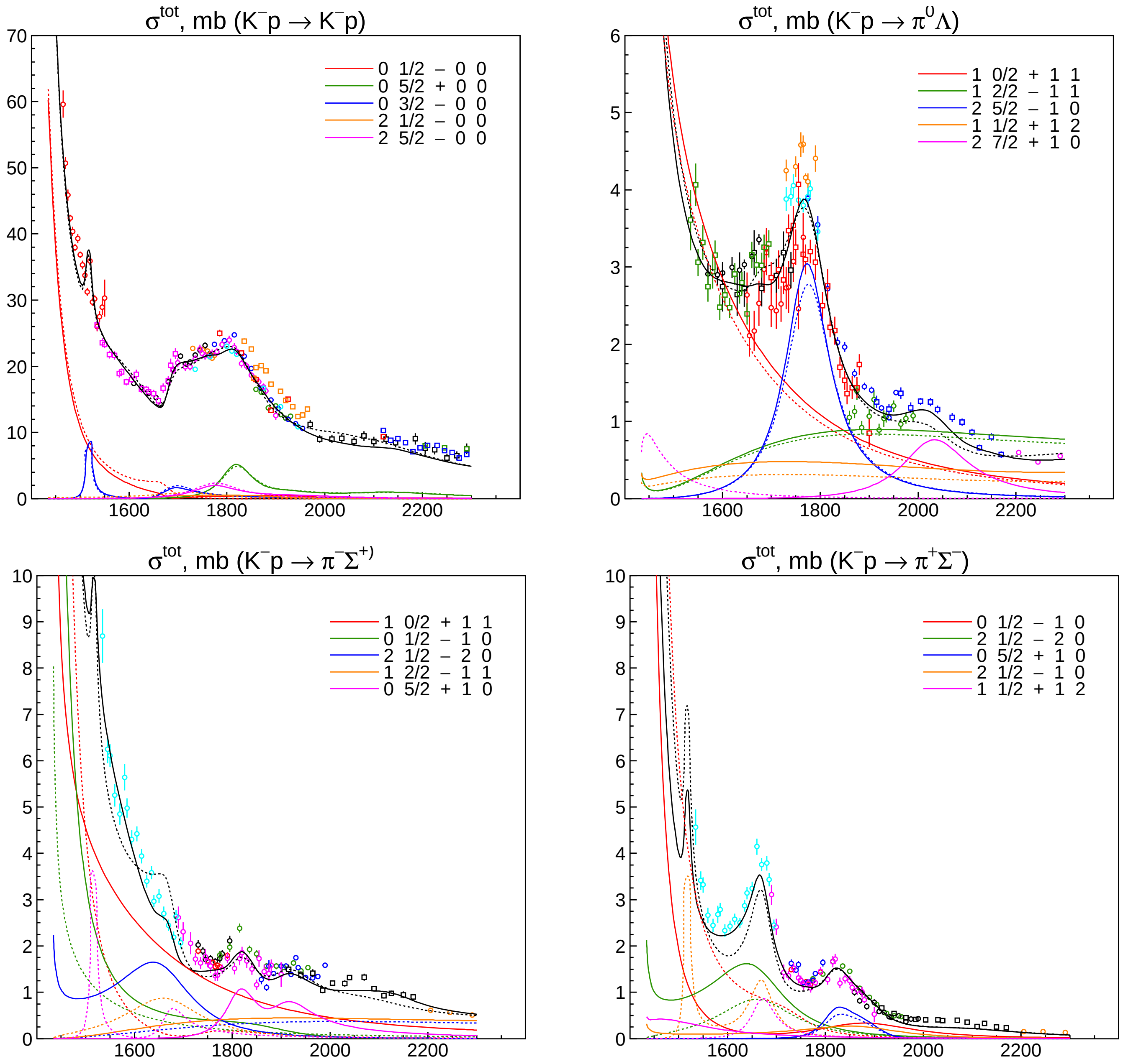
There is a hope to observe the baryon multiplets and therefore to confirm the states observed in the Nucleon and Delta sector.

Table 3: List of reactions used in the partial wave analysis.

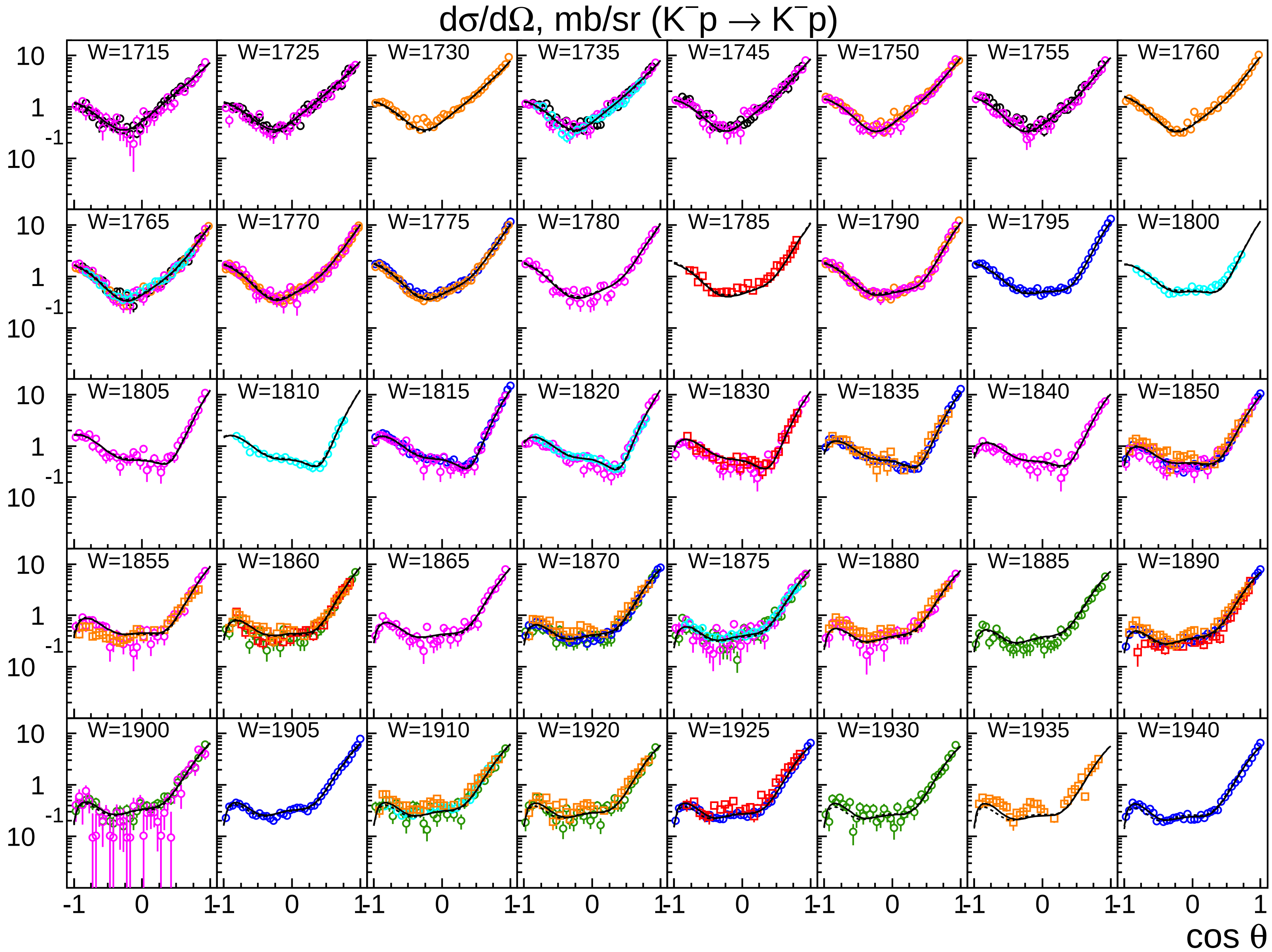
$K^- p \to K^0 n$	$K^- p \to K^- p$	$K^- p \to \omega \Lambda$
$K^- p \to \pi^0 \Lambda$	$K^- p \to \eta \Lambda$	$K^- p \to \pi^+ \Sigma^-$
$K^- p \to \pi^0 \Sigma^0$	$K^- p \to \pi^- \Sigma^+$	$K^- p \to \pi^0 \pi^0 \Lambda$
$K^- p \to K^+ \Xi^-$	$K^- p \to K^0 \Xi^0$	$K^- p \to \pi^0 \pi^0 \Sigma^0$

Mass scan of additional states

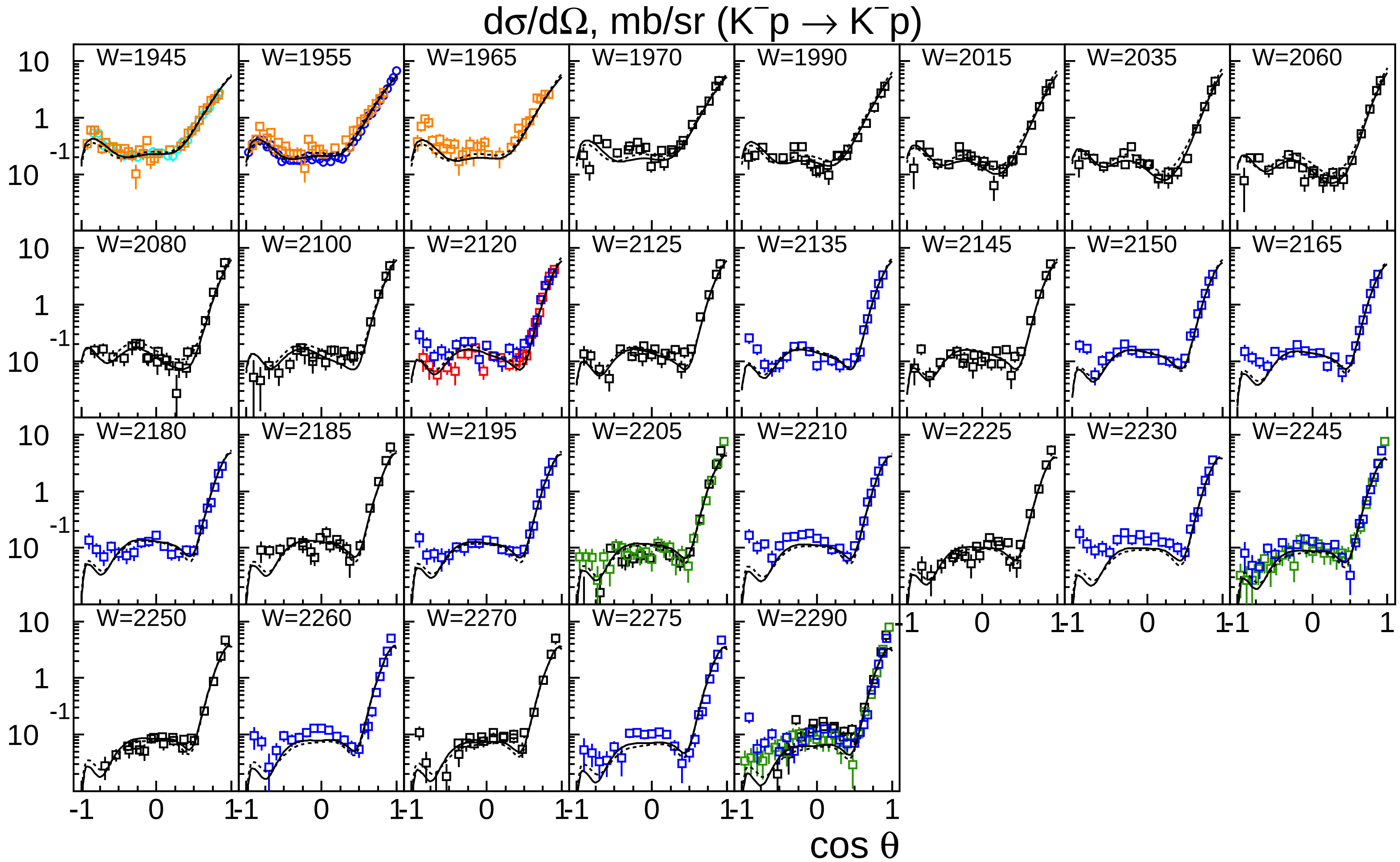


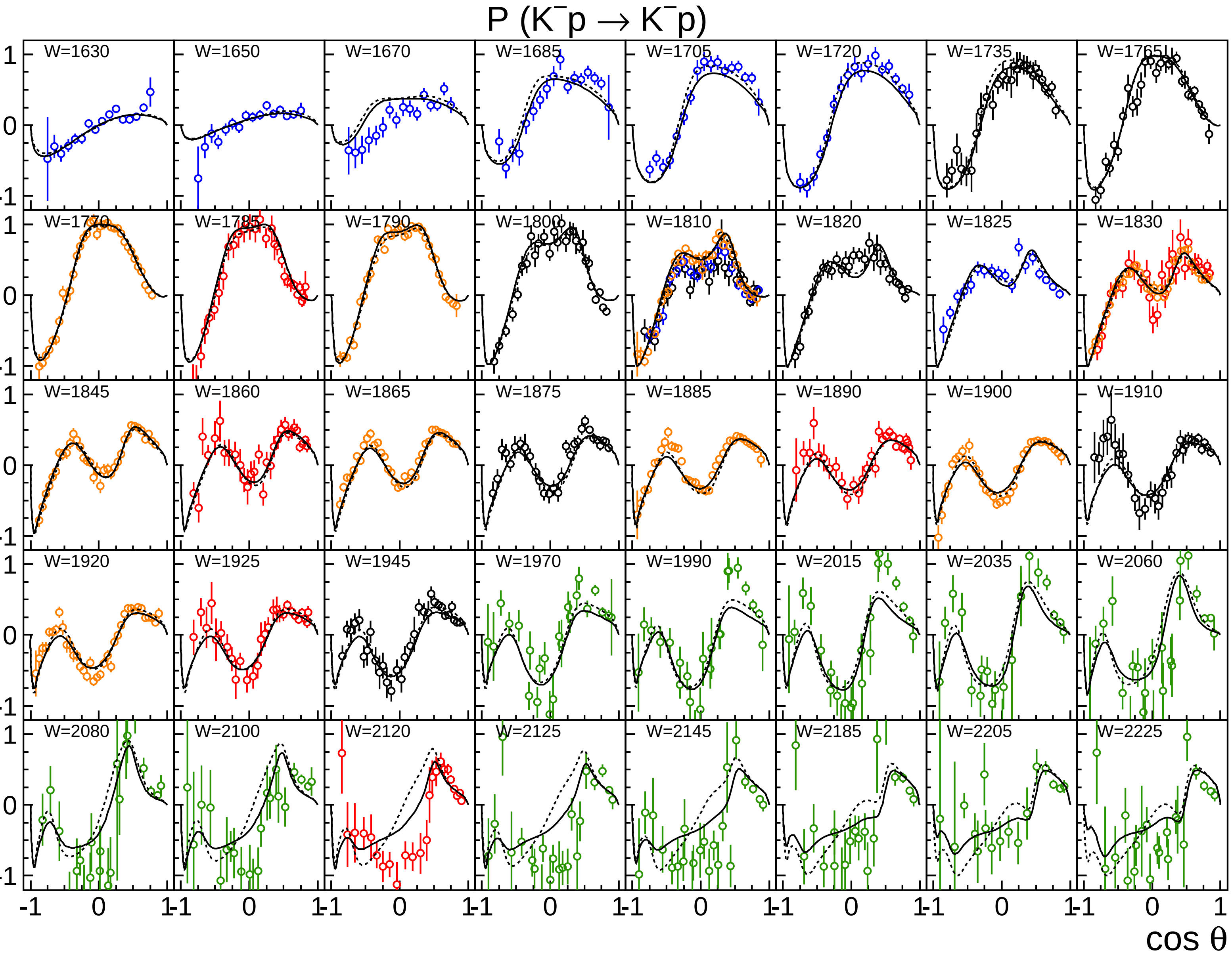


σ^tot, mb (K⁻p → K⁻p)
0 1/2 − 0 0
0 5/2 + 0 0
0 3/2 − 0 0
2 1/2 − 0 0
2 5/2 − 0 0
σ^tot, mb (K⁻p → π⁰Λ)
1 0/2 + 1 1
1 2/2 − 1 1
2 5/2 − 1 0
1 1/2 + 1 2
2 7/2 + 1 0
σ^tot, mb (K⁻p → π⁻Σ⁺)
1 0/2 + 1 1
0 1/2 − 1 0
2 1/2 − 2 0
1 2/2 − 1 1
0 5/2 + 1 0
σ^tot, mb (K⁻p → π⁺Σ⁻)
0 1/2 − 1 0
2 1/2 − 2 0
0 5/2 + 1 0
2 1/2 − 1 0
1 1/2 + 1 2

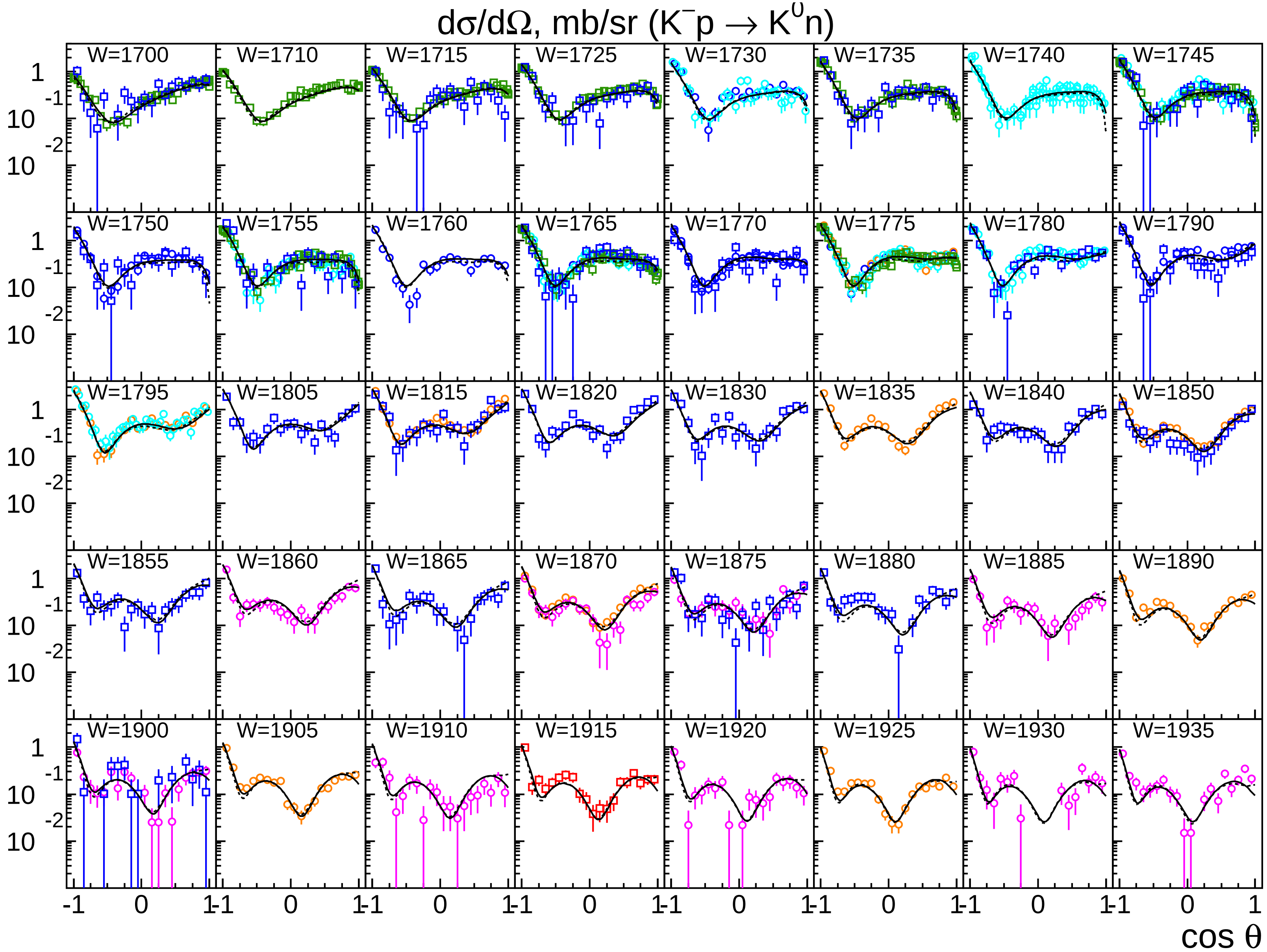


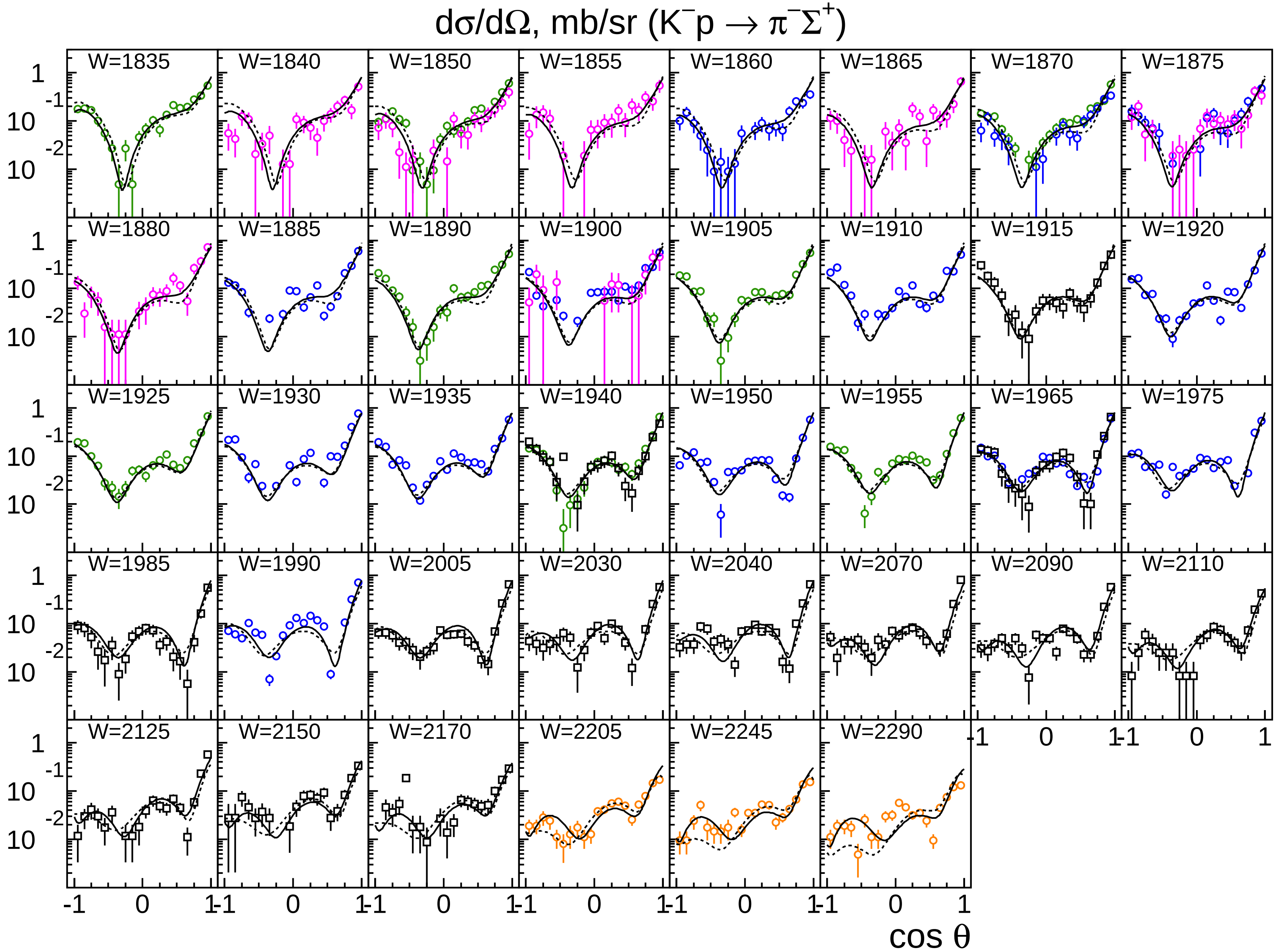
dσ/dΩ, mb/sr (K⁻p → K⁻p)
W=1715
W=1725
W=1730
W=1735
W=1745
W=1750
W=1755
W=1760
W=1765
W=1770
W=1775
W=1780
W=1785
W=1790
W=1795
W=1800
W=1805
W=1810
W=1815
W=1820
W=1830
W=1835
W=1840
W=1850
W=1855
W=1860
W=1865
W=1870
W=1875
W=1880
W=1885
W=1890
W=1900
W=1905
W=1910
W=1920
W=1925
W=1930
W=1935
W=1940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

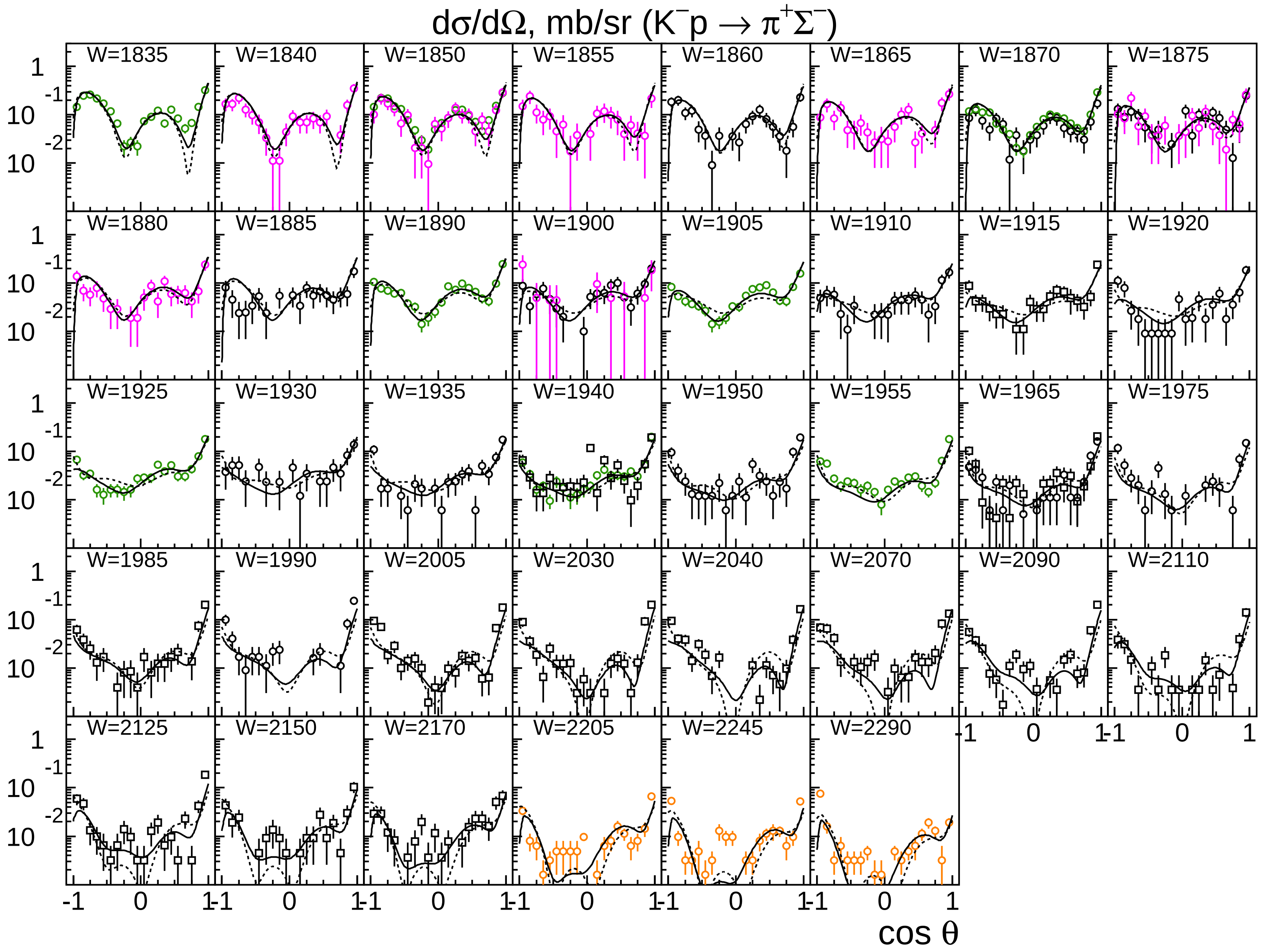

dσ/dΩ, mb/sr (K⁻p → K⁻p)
W=1945
W=1955
W=1965
W=1970
W=1990
W=2015
W=2035
W=2060
W=2080
W=2100
W=2120
W=2125
W=2135
W=2145
W=2150
W=2165
W=2180
W=2185
W=2195
W=2205
W=2210
W=2225
W=2230
W=2245
W=2250
W=2260
W=2270
W=2275
W=2290
10
1
10^-1
cos θ

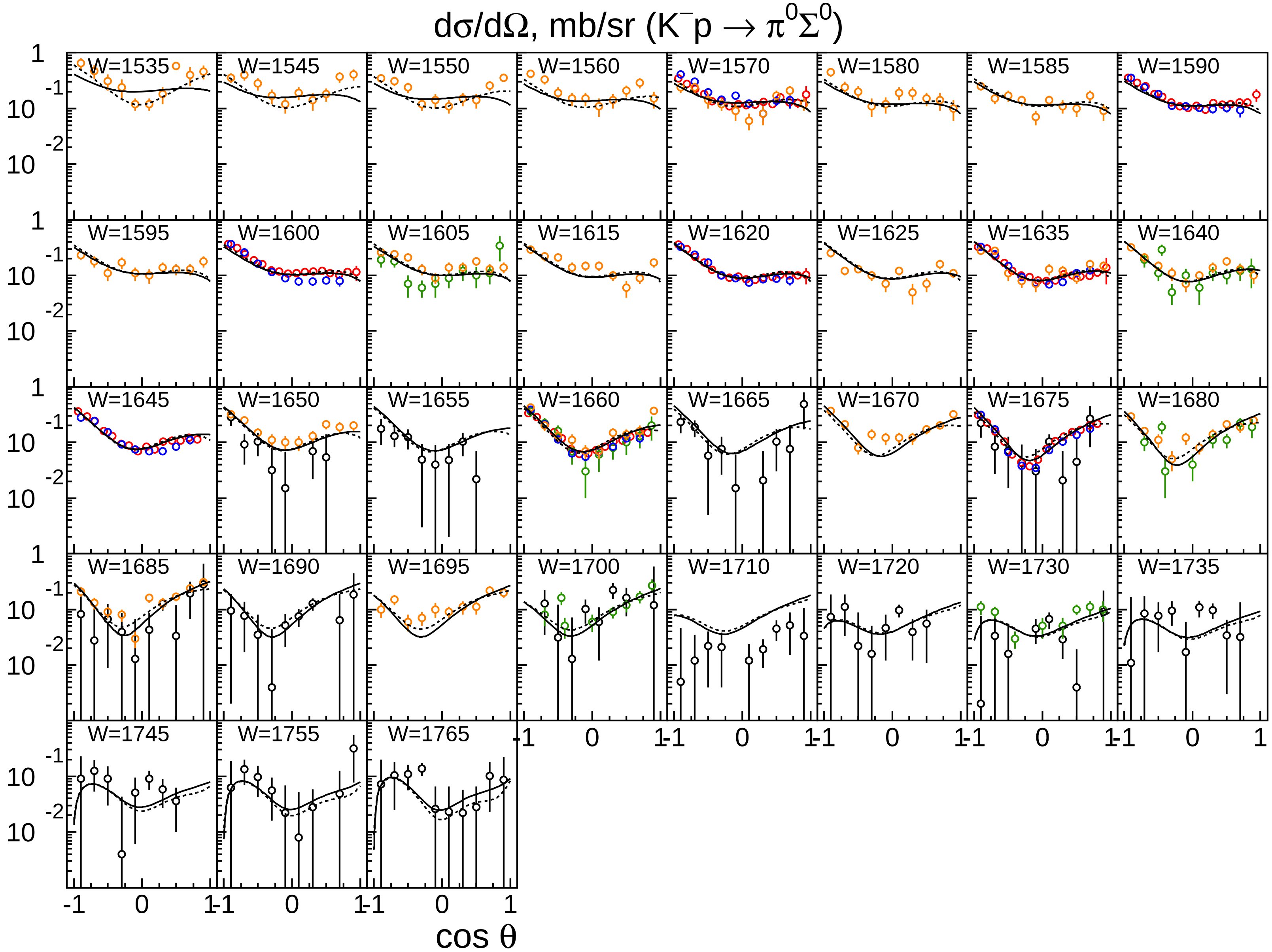


P (K⁻p → K⁻p)
W=1630
W=1650
W=1670
W=1685
W=1705
W=1720
W=1735
W=1765
W=1770
W=1785
W=1790
W=1800
W=1810
W=1820
W=1825
W=1830
W=1845
W=1860
W=1865
W=1875
W=1885
W=1890
W=1900
W=1910
W=1920
W=1925
W=1945
W=1970
W=1990
W=2015
W=2035
W=2060
W=2080
W=2100
W=2120
W=2125
W=2145
W=2185
W=2205
W=2225
cos θ


dσ/dΩ, mb/sr (K⁻p → 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
W=1915
W=1920
W=1925
W=1930
W=1935
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
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


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

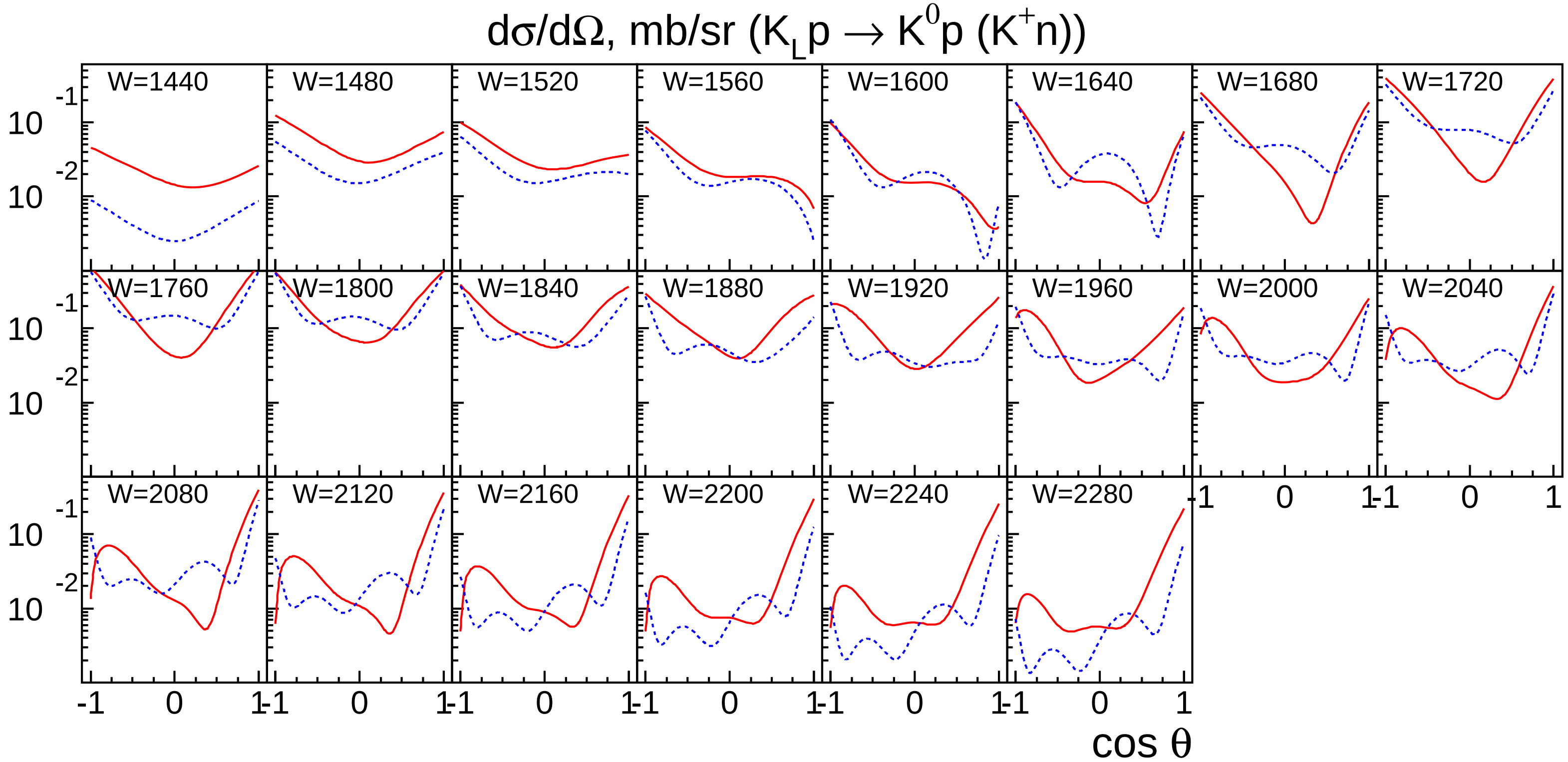


dσ/dΩ, mb/sr (K⁻p → π⁰Σ⁰)
W=1535
W=1545
W=1550
W=1560
W=1570
W=1580
W=1585
W=1590
W=1595
W=1600
W=1605
W=1615
W=1620
W=1625
W=1635
W=1640
W=1645
W=1650
W=1655
W=1660
W=1665
W=1670
W=1675
W=1680
W=1685
W=1690
W=1695
W=1700
W=1710
W=1720
W=1730
W=1735
W=1745
W=1755
W=1765
cos θ

Table 4: Σ-Hyperons Observed states

J^P		Known state	New state	Mass
$1/2^+$	$N(1440)$	$\Sigma(1660)$		
$3/2^+$	$\Delta(1230)$	$\Sigma(1385)$		
$5/2^+$	$N(1680), \Delta(1905)$	$\Sigma(1915)$	**????**	
$7/2^+$	$N(1990), \Delta(1950)$	$\Sigma(2030)$	**????**	
$3/2^-$	$N(1520)$	$\Sigma(1670)$		
$1/2^-$	$N(1535), \Delta(1620), N(1650)$	$\Sigma(1750)$	$\Sigma(1620)$	1680 ± 8
			$\Sigma(1900)$	1936 ± 10
$5/2^-$	$N(1675)$	$\Sigma(1775)$		
$3/2^-$	$N(1700), \Delta(1700)$	$\Sigma(1940)$	$\Sigma(1860)$	1856 ± 10
$1/2^-$	$N(1895)$		$\Sigma(2120)$	2158 ± 25

Prediction for $\frac{d\sigma}{d\Omega}(K_L p \to K^0 p(K^+ n))$



Let us consider the decay of the isospin 0 and isospin 1 states into K^-p and K^0n

$$
\begin{aligned}
|A(K^-p)|^2 &= \left(A_1\frac{1}{\sqrt{2}} + A_0\frac{1}{\sqrt{2}}\right)^2 = \frac{1}{2}\left(|A_1|^2 + |A_0|^2 + 2Re(A_1A_0^*)\right) \\
|A(K^0n)|^2 &= \left(A_1\frac{1}{\sqrt{2}} - A_0\frac{1}{\sqrt{2}}\right)^2 = \frac{1}{2}\left(|A_1|^2 + |A_0|^2 - 2Re(A_1A_0^*)\right)
\end{aligned}
$$

$$
A_{KN} = \omega^*\left[G(s,t) + H(s,t)i(\vec{\sigma}\vec{n})\right]\omega' \qquad \vec{n}_j = \varepsilon_{\mu\nu j}\frac{q_\mu k_\nu}{|\vec{k}||\vec{q}|}\,.
$$

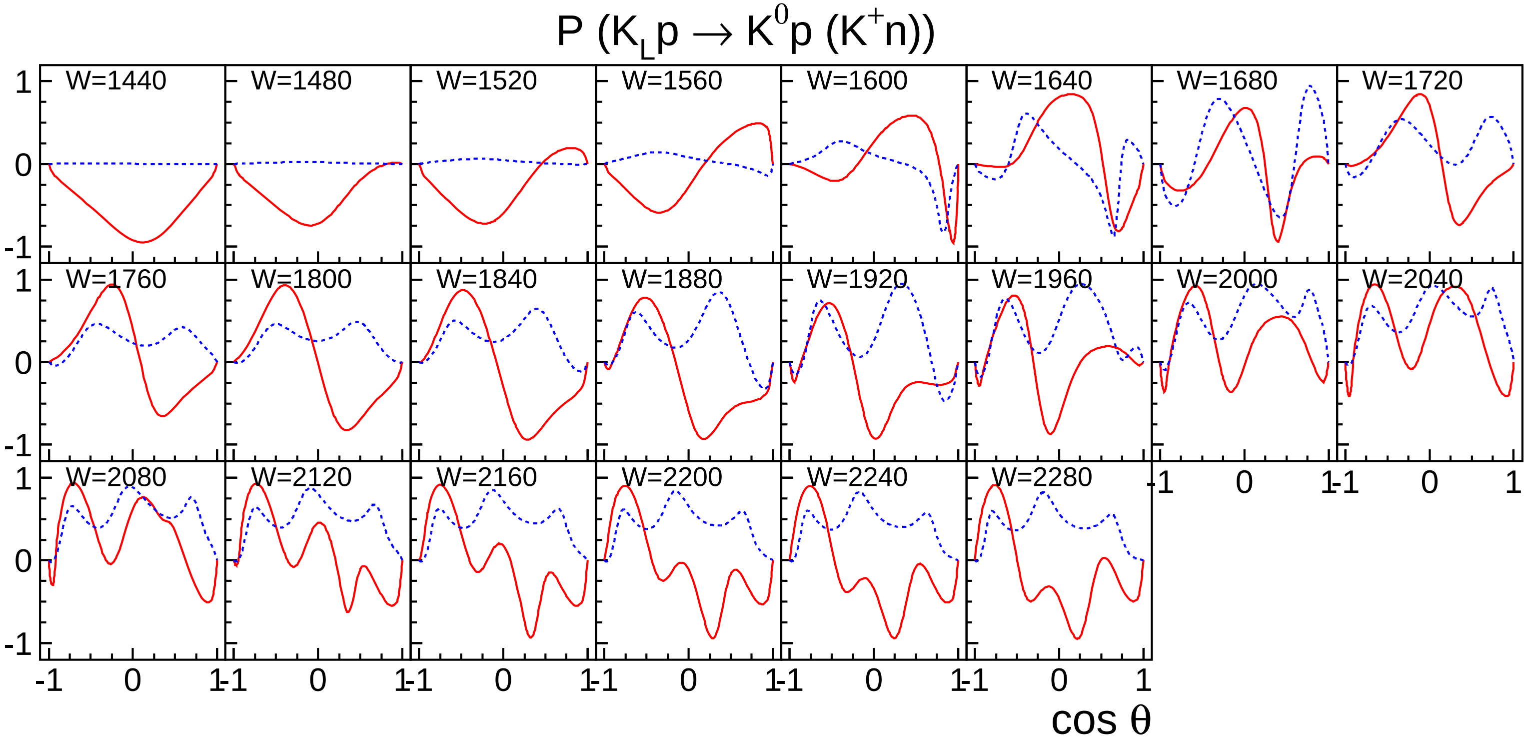
Differential cross section in c.m.s. of the reaction

$$
|A|^2 = \frac{1}{2}\mathrm{Tr}\left[A^*_{\pi N}A_{\pi N}\right] = |G(s,t)|^2 + |H(s,t)|^2(1-z^2)
$$

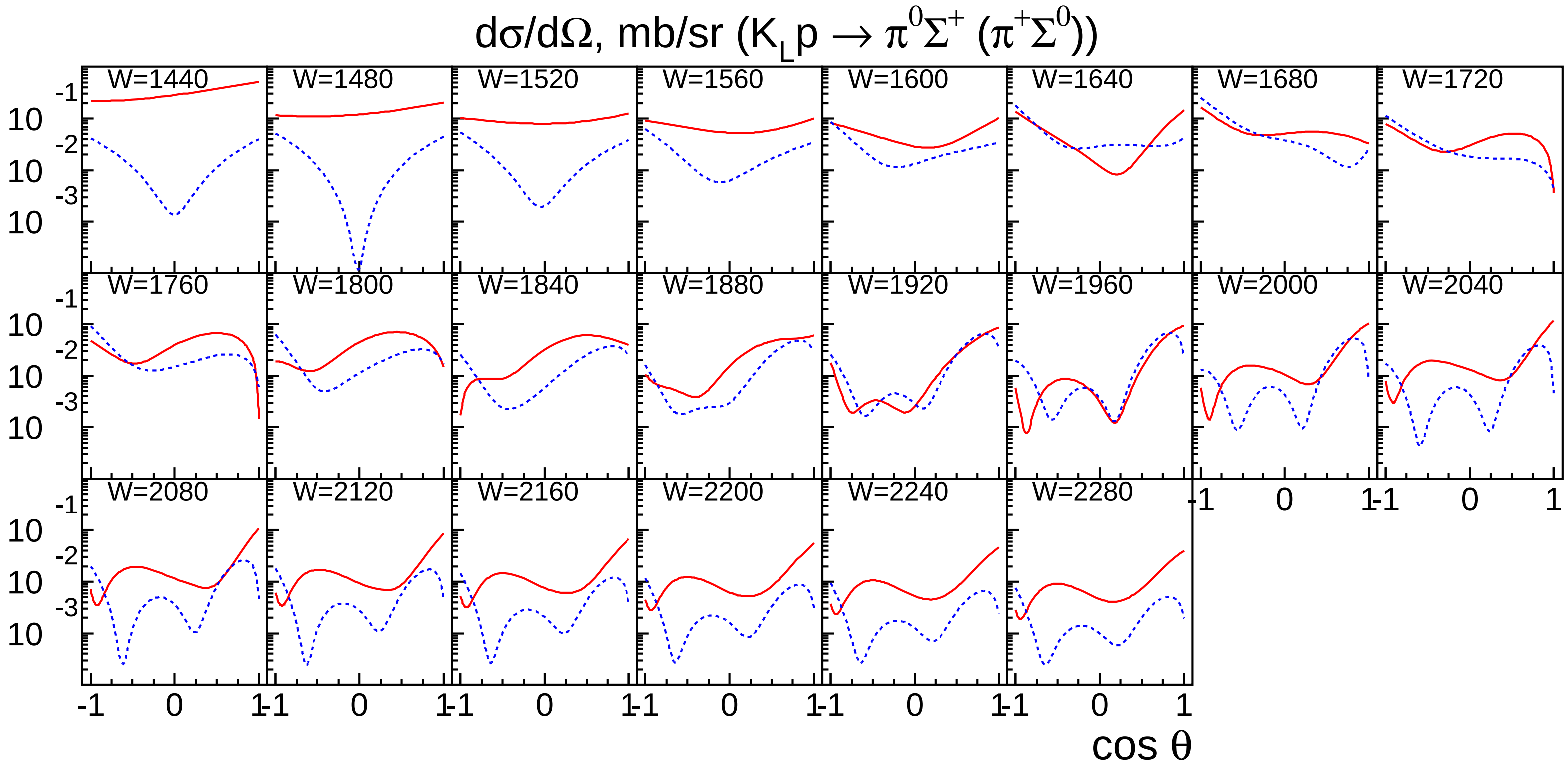
the recoil asymmetry:

$$
P = \frac{\mathrm{Tr}\left[A^*_{\pi N}\sigma_2 A_{\pi N}\right]}{2|A|^2\cos\phi} = \sin\Theta\,\frac{2Im\left(H^*(s,t)G(s,t)\right)}{|A|^2}\,.
$$

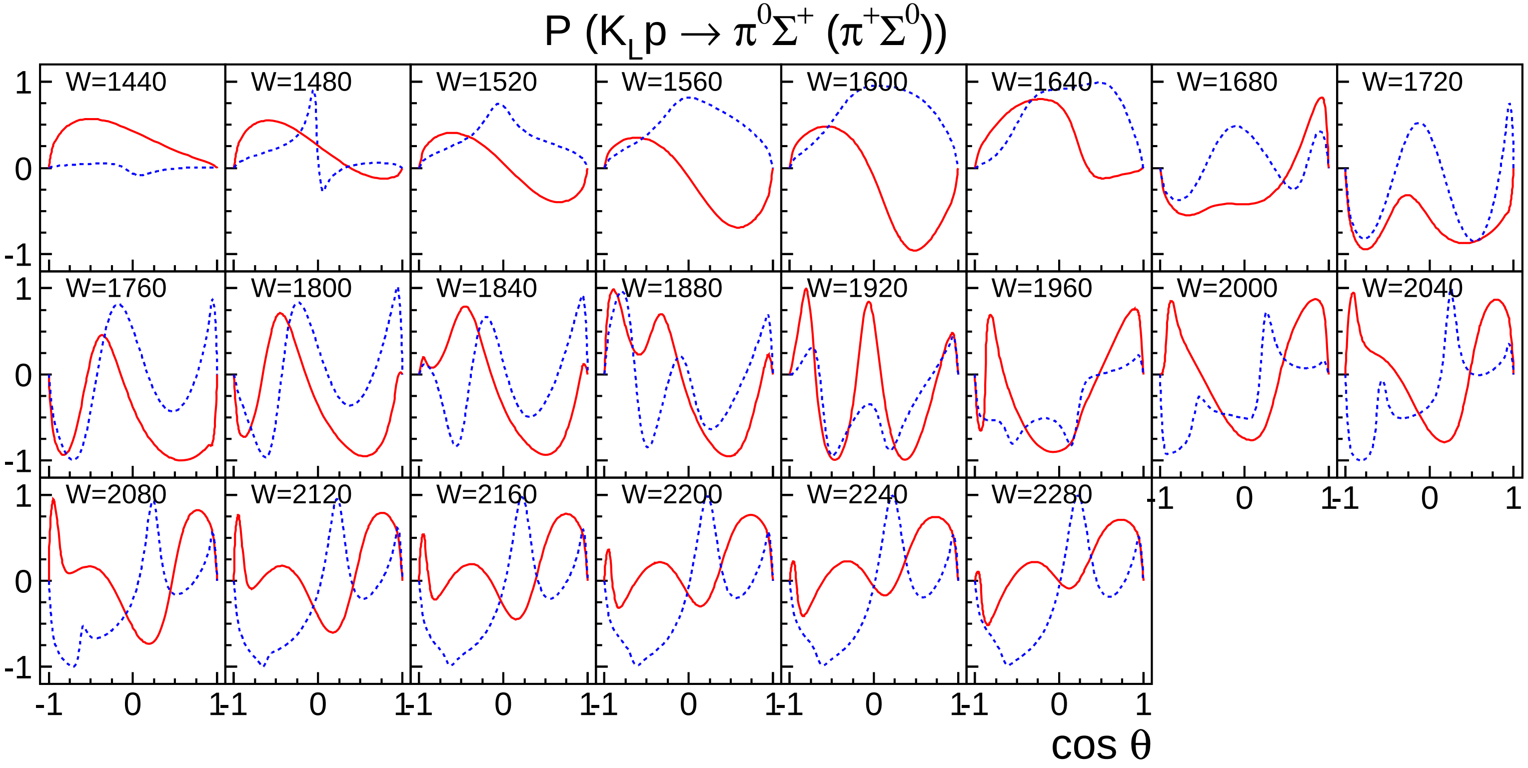
Prediction for the recoil asymmetry $K_L p \to K^0 p (K^+ n)$



Prediction for $\frac{d\sigma}{d\Omega}(K_L p \to \pi^0\Sigma^+(\pi^+\Sigma^0))$



Prediction for the recoil asymmetry $K_L p \to \pi^0\Sigma^+(\pi^+\Sigma^0)$



SUMMARY

- **The planned $K_L p$ experiment provides a unique possibility to study the spectrum and properties of Σ hyperons.**
- **The data on the $K_L p$ collision are necessary to perform the full amplitude decomposition of the observables measured in the $K^- p$ collision reactions: therefore the new data are important for the determination of the spectrum and properties of Λ hyperons.**