Title
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Publication Date
1969-07-01

Contribution to the Lund International Conference on Elementary Particles, June 25-July 1, 1969 Lund, Sweden

UCRL-19231
Preprint

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July 1969

AEC Contract No. W-7405-eng-48

LAWRENCE RADIATION LABORATORY
UNIVERSITY of CALIFORNIA BERKELEY

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PARTIAL-WAVE ANALYSIS OF K^+p ELASTIC SCATTERING*

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K^+p elastic scattering is known to exhibit the following general features: below 800 MeV/c a large negative S wave dominates,[1,2] and above 1400 MeV/c the scattering is diffractive,[3,4] with a smooth transition taking place between 800 and 1400 MeV/c.[5,6] At about 800 MeV/c inelastic final states start to become important, and until recently the lack of proton polarization data has precluded a model-independent phase shift analysis. Using a (model-dependent) analysis of the inelastic final states to determine the inelasticity parameters, we found partial-wave solutions at 864 and 969 MeV/c,[7] showing small P and D waves in addition to the large negative S wave. Lea, Martin and Oades[8] have obtained partial-wave solutions up to 1500 MeV/c, assuming an energy-dependent parametrization of the partial-wave amplitudes and allowing only two or three waves to be inelastic; because of these assumptions their solutions are only qualitative. They found three families of solutions, two of them including a $P_{1/2}$ resonance near 1500 MeV/c.

The proton polarization in K^+p elastic scattering at 1220 MeV/c was measured recently by Andersson et al.[9] Their data immediately ruled out all but the nonresonant solutions of Lea et al., the best-fitting one of which resembles ours at 864 and 969 MeV/c. In this paper we give revised results at 864 and 969 MeV/c based on final data, and several solutions at 1207 MeV/c which we have obtained using the new polarization data. One 1200-MeV/c solution corresponds to a smooth continuation of our lower-energy solutions, with a large, negative S wave, and agrees reasonably well with the nonresonant solution of Lea et al.; the others have positive S-wave phase shifts, requiring rapid variation of the S-wave amplitude between 969 and 1207 MeV/c. Presently-existing data cannot decide between these two possibilities.

As input to our phase-shift program we have used the differential cross section data of Bland et al. at 864, 969, and 1207 MeV/c, and the polarization data of Andersson et al. at 1220 MeV/c. In addition we have used the K^+p inelastic cross section[10] and the real part of the forward scattering amplitude calculated by Carter using dispersion relations.[11] Rough measurements of the polarization at 785 and 864 MeV/c require it to be positive, as it is at 1220 MeV/c.[12,13] In the absence of additional polarization data at 864 and 969 MeV/c we do not have enough information to determine both the phase shifts and the absorption parameters η. Therefore we have made use of an analysis of the inelastic channels to obtain the inelastic cross section in each partial wave and hence the absorption parameters.[14] These values and their errors have been used as input data at the two lower momenta.

At 864 and 969 MeV/c D waves were required to fit the data, as they were in a published phase shift analysis at 785 MeV/c; the inclusion of F waves did not improve the fits. At 1207 MeV/c we included F waves, with an improvement in χ^2 of about 5 (28 degrees of freedom) over the SPD fits. Using a variety of starting values for the phase shifts and absorption parameters, we have found the solutions given in Tables I and II. At 864 and 969 MeV/c we find two solutions, which we call A^- and B^-. At 1207 MeV/c there are four solutions, one A^- and three of the B^- type. All of these give statistically acceptable fits to the data.

In Fig. 1 we show the angular distribution and polarization data and the curves corresponding to the A^- and B^-(ii) solutions. Both solutions adequately reproduce the data. An interesting, though not independent, piece of information is the backward differential cross section, shown in Fig. 2 as a function of momentum. The sharp peak at 860 MeV/c comes from the backward asymmetry seen in Fig. 1, which gives way at once to a forward-asymmetric diffractive shape. The asymmetry at 864 and 969 MeV/c is due to S-P interference, and is reproduced equally well by the A^- and B^- solutions. We prefer the A^- solution at the two lower momenta, since the B^- solutions do not join smoothly with the low energy solutions. At 1207 MeV/c we can no longer pick a preferred solution, particularly as at 969 MeV/c the negative $P_{1/2}$ phase shift is getting larger and the negative $S_{1/2}$ phase shift may be decreasing. In the Argand plot of Fig. 3 we show the A^- solution at all three momenta and the B^-(ii) solution at 1207 MeV/c.

From these results we conclude: (1) Up to 1200 MeV/c there are no large, inelastic resonances in the K^+p channel. Small, highly inelastic resonances such as many of the πN resonances at comparable c.m. momenta could be present but would not be resolved with the currently available data. (2) Our data are consistent with a smooth, slow variation of all partial-wave amplitudes from threshold to 1200 MeV/c with a consistently large, negative S-wave phase shift, resembling the best nonresonant solution of Lea, Martin, and Oades. It is equally plausible, however, that between 900 and 1200 MeV/c the dominant repulsive $S_{1/2}$ amplitude gives way to a large, repulsive $P_{1/2}$ amplitude. More data in this momentum region is required to distinguish these two possibilities.

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*Work supported by the U. S. Atomic Energy Commission.

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Table I. SPD phase shift solutions at 864 and 969 MeV/c.

Solution type		864 MeV/c A$^-$	864 MeV/c B$^-$	969 MeV/c A$^-$	969 MeV/c B$^-$
$S_{1/2}$	δ	-37.4±9.0	2.6±5.2	-23.0±8.2	-7.3±3.0
	η	$0.990^{+0.009}_{-0.018}$	$0.989^{+0.009}_{-0.018}$	$1.0^{+0.}_{-0.5}$	$1.0^{+0.}_{-0.3}$
$P_{1/2}$	δ	-15.2±9.0	-48.9±1.1	-35.9±7.1	-58.0±2.7
	η	0.910±0.012	0.910±0.012	0.798±0.017	0.799±0.022
$P_{3/2}$	δ	12.4±4.8	-4.2±0.5	17.0±0.6	-5.0±1.1
	η	0.975±0.004	0.975±0.004	0.914±0.007	0.914±0.007
$D_{3/2}$	δ	-3.5±0.6	-0.9±3.0	-4.6±1.6	2.8±4.1
	η	$0.998^{+0.001}_{-0.002}$	$0.998^{+0.001}_{-0.002}$	$0.989^{+0.004}_{-0.005}$	$0.989^{+0.004}_{-0.005}$
$D_{5/2}$	δ	-2.5±1.6	1.5±0.6	-3.9±0.7	0.8±1.1
	η	0.998±0.001	0.998±0.001	0.992±0.002	0.992±0.002
Re(kf) in c.m.		-0.55	-0.50	-0.59	-0.50
$\sigma_{inelastic}$(mb)		1.72	1.72	3.67	3.67
σ_{total}(mb)		13.60	13.60	15.35	15.35
χ^2		10.3	12.5	18.8	20.4
Degrees of freedom		18	18	15	15
Probability		0.92	0.82	0.22	0.16

Table II. SPDF phase shift solutions at 1207 MeV/c.

Solution type		A^-	B^-(i)	B^-(ii)	B^-(iii)
$S_{1/2}$	δ	-61.0±7.7	11.9±1.3	8.9±4.5	28.7±2.2
	η	0.70±0.15	0.71±0.04	$1.0^{+0.}_{-0.18}$	$1.0^{+0.}_{-0.13}$
$P_{1/2}$	δ	-20.6±5.7	-47.3±1.0	-69.4±10.2	-33.0±3.3
	η	$0.94^{+0.05}_{-0.26}$	$1.0^{+0.}_{-0.29}$	0.58±0.12	0.58±0.16
$P_{3/2}$	δ	5.6±4.6	2.1±1.0	3.3±1.6	-3.8±1.2
	η	$0.85^{+0.11}_{-0.16}$	0.57±0.01	0.91±0.08	$1.0^{+0.}_{-0.31}$
$D_{3/2}$	δ	-12.1±2.2	-13.7±0.9	-15.3±3.0	-23.4±1.9
	η	$1.0^{+0.}_{-0.05}$	$1.0^{+0.}_{-0.01}$	0.91±0.08	0.86±0.08
$D_{5/2}$	δ	0.3±1.0	0.2±0.4	2.6±0.8	4.1±1.2
	η	0.94±0.05	$1.0^{+0.}_{-0.01}$	$0.95^{+0.04}_{-0.07}$	0.94±0.03
$F_{5/2}$	δ	0.1±2.1	-0.3±0.5	-9.5±0.8	-7.3±1.4
	η	$0.99^{+0.01}_{-0.12}$	$1.0^{+0.}_{-0.05}$	0.95±0.03	0.91±0.02
$F_{7/2}$	δ	2.0±0.8	1.4±0.3	-0.3±0.6	-0.4±1.0
	η	0.92±0.03	0.96±0.01	$0.97^{+0.02}_{-0.04}$	$0.98^{+0.02}_{-0.04}$
Re(kf) in c.m.		-0.70	-0.68	-0.75	-0.77
$\sigma_{inelastic}$(mb)		7.41	7.42	7.42	7.41
σ_{total}(mb)		18.32	18.32	18.32	18.32
χ^2		24.7	25.4	24.4	24.6
Degrees of freedom		28	28	28	28
Probability		0.65	0.61	0.66	0.65

Fig. 1

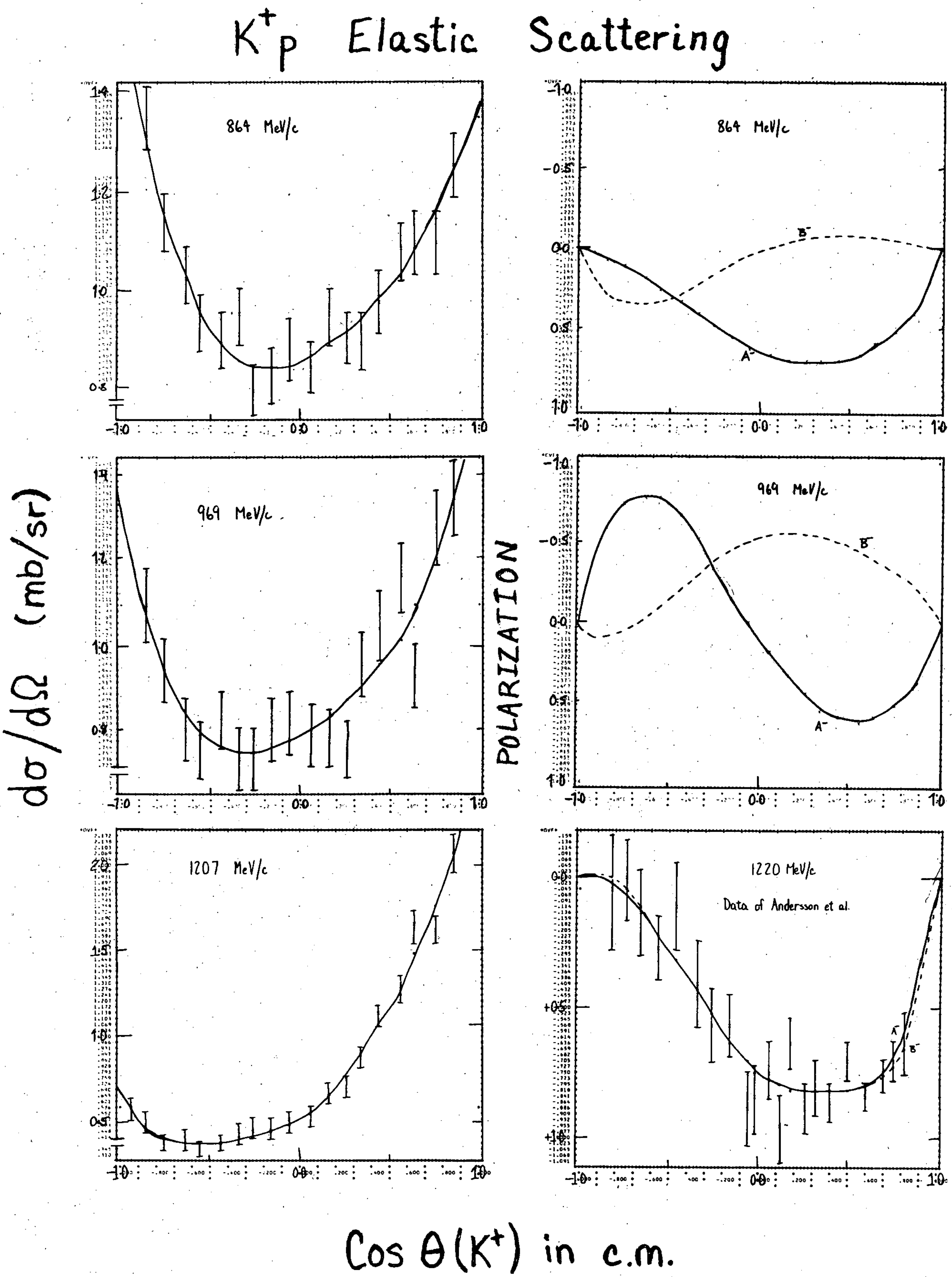

K⁺p Elastic Scattering
864 MeV/c
969 MeV/c
1207 MeV/c
1220 MeV/c
Data of Andersson et al.
A⁻
B⁻
dσ/dΩ (mb/sr)
POLARIZATION
Cos θ(K⁺) in c.m.

Fig. 2

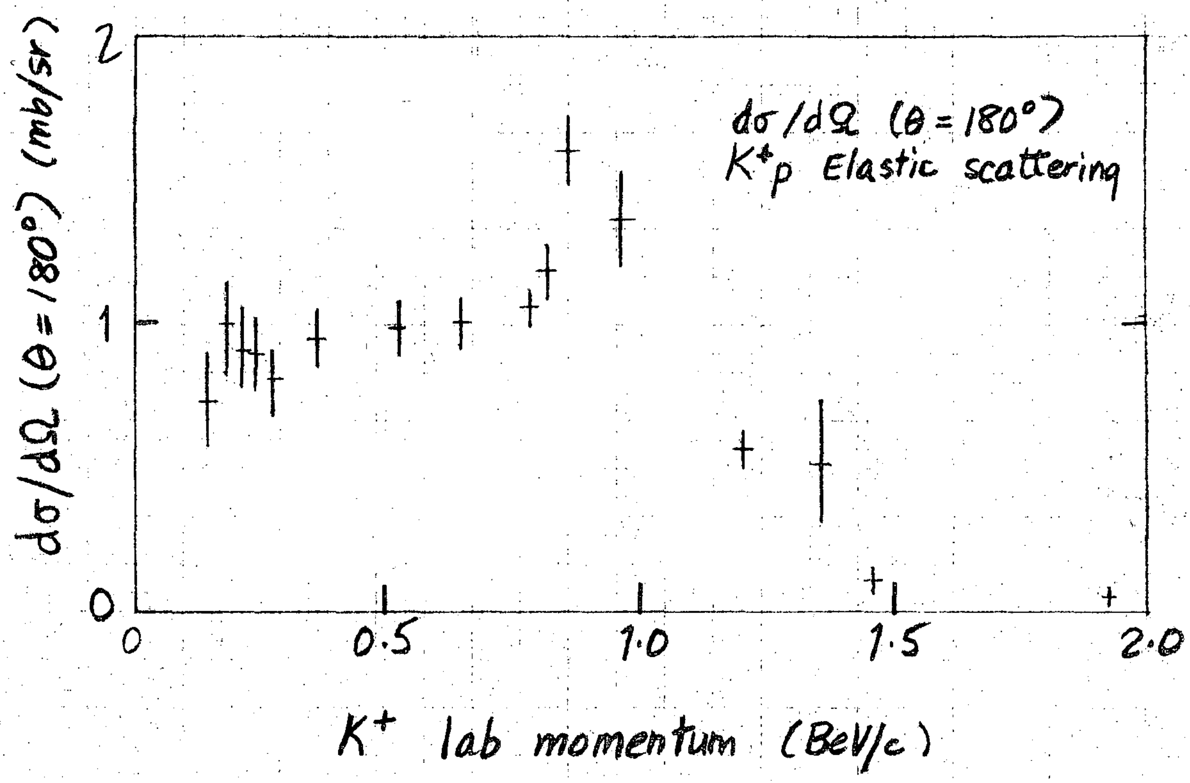
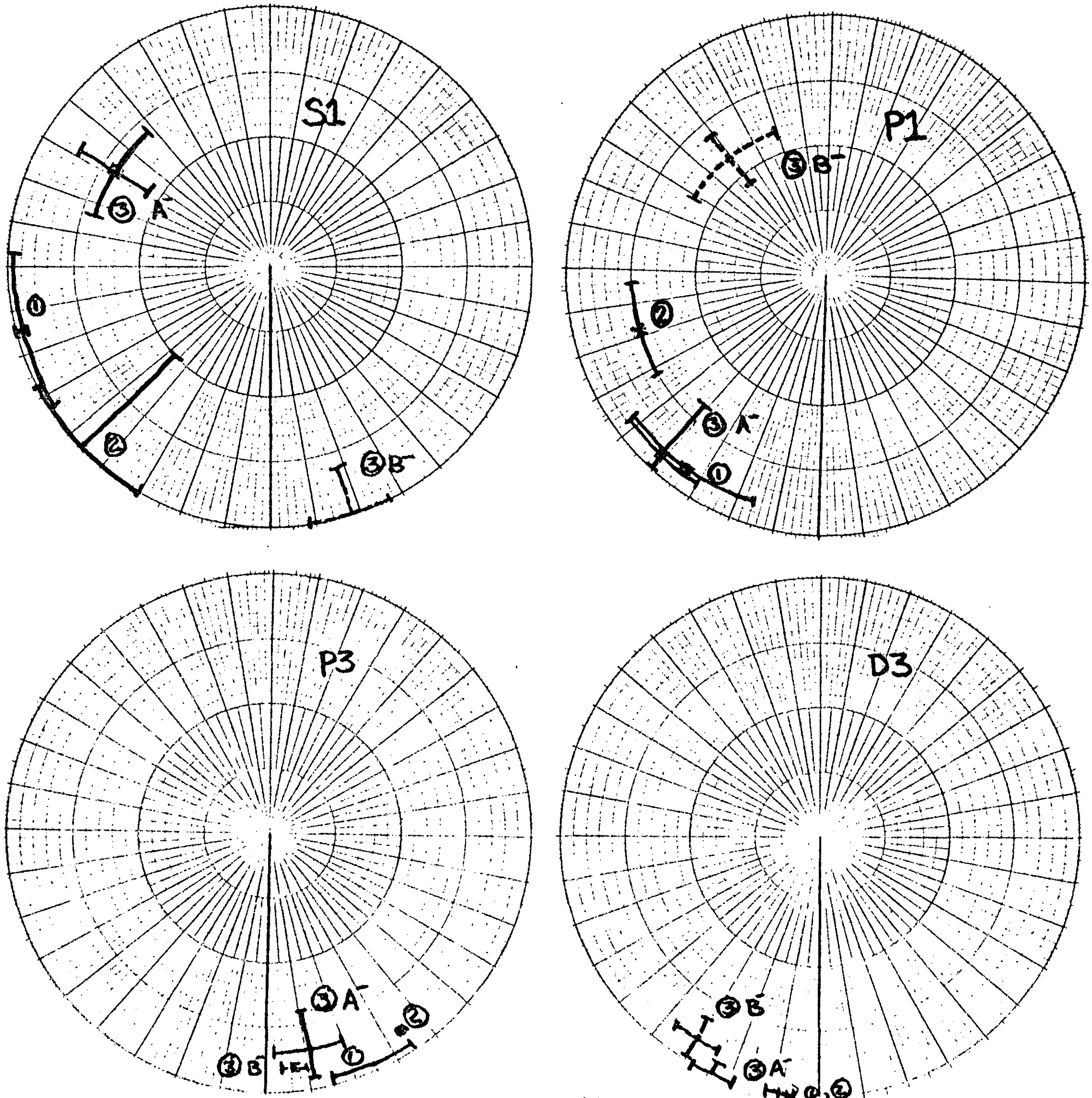

dσ/dΩ (θ = 180°)
K⁺p Elastic scattering
dσ/dΩ (θ = 180°) (mb/sr)
2
1
0
0
0.5
1.0
1.5
2.0
K⁺ lab momentum (BeV/c)

Fig. 3

K^+p



① 864 MeV/c
② 969 MeV/c
③ 1207 MeV/c

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