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HIGH-ENERGY PROTON-PROTON DIFFRACTION SCATTERING

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This Letter reports an experiment measuring the proton-proton elastic scattering cross section at laboratory angles of about 10, 20, 30, 40, and 50 mrad with initial momenta of 12.1, 15.5, 18.6, 21.4, and 26.2 Gev/c.

The beam, quasi-elastically scattered at 20 mrad from a Be target in the CERN proton synchrotron, was collimated to be $8 \times 1.5 \text{ cm}^2$ at the hydrogen target, and had a divergence of 0.6 mrad horizontally and 2 mrad vertically. The total intensity was $\sim 5 \times 10^5$ protons per pulse. Its momentum spectrum consisted of a peak at a momentum slightly below that for the circulating proton beam followed by a tail reaching about 1 Gev/c down. The peak contained typically 70% of the protons in a momentum interval smaller than 200 Mev/c.

A 18 cm long liquid hydrogen target was used. The scattered particles were momentum analyzed with 4 m of magnetic field and detected at each angle with a threefold scintillation counter telescope. The momentum resolution was typically 5% and the solid angle of acceptance of the order of 10^{-5} sr.

The beam was continuously monitored with two small scintillation counters in coincidence. In order to obtain the total flux, these counters were scanned across the beam and the resulting numbers integrated.

Figure 1 shows two typical momentum spectra after corrections for background and accidental coincidences. Curve A gives the geometrical resolution function with the input momentum spectrum folded in. Curve B shows the relative intensities of elastically and inelastically scattered protons used to obtain a fit to the experimental data (curve C). The relative intensities in B were consistent with the results obtained from an experiment with a momentum resolution of about 1%. The unfolding procedure was necessary only for the higher momentum transfers. The elastic differential cross sections obtained are listed in Table 1.

The results are plotted in Fig. 2 in terms of

$$\left[\left(\frac{4\pi}{\sigma_T k} \right)^2 \frac{d\sigma}{d\Omega} \right]_{c.m.}$$

as a function of $|t|$ (four-momentum transfer)². σ_T is the total proton-proton cross section and k is the wavenumber of the protons in the center-of-mass system (c.m.). Only relative errors between different angles within each momentum are shown. These errors are mainly due to statistics and uncertainties in the resolution functions. The absolute errors, listed in the table, are larger because of uncertainties in the determination of the flux and the momentum spectrum of the incoming beam.

According to the optical theorem for a purely imaginary forward scattering amplitude, for $t=0$

$$\left[\left(\frac{4\pi}{\sigma_T k} \right)^2 \frac{d\sigma}{d\Omega} \right]_{c.m.} = 1$$

A linear extrapolation to $t=0$ has been made using the data at the two smallest $|t|$ values at each momentum. An average value of 1.2 ± 0.2 was obtained. The initial slopes of the curves in Fig. 2 are all consistent with a t -dependence of $\exp(-11|t|)$.

The data are used in conjunction with other similar data in a Regge pole analysis presented in the following Letter.

The total elastic scattering cross sections shown in Table 2 have been obtained by integrating under the curves in Fig.2. The results are plotted in Fig.3 together with those of other measurements at momenta higher than $2 \text{ GeV}/c^{2-8}$.

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TABLE 1

Differential elastic proton-proton scattering cross sections

P_0 , θ , and $-t$ are momentum of incoming proton, scattering angle, and (four-momentum transfer)² respectively.

P_0 (lab) (Gev/c)	θ (lab) mrad	θ (c.m.) degrees	$-t$ (Gev/c) ²	$\frac{d\sigma}{d\Omega}$ (lab) (barr/sr)	$\frac{d\sigma}{d\Omega}$ (c.m.) (mb/sr)	$\left[\frac{4\pi}{\sigma_T k} \right]^2 \frac{d\sigma}{d\Omega}$ (c.m.)	Relative errors with- in one mo- mentum (%)	Absolute errors (%)
12.1	8.8	2.66	0.011	4.03	146	1.10	11	19
	19.1	5.73	0.052	2.60	96	0.70	8	16
	29.1	8.72	0.121	1.20	45	0.33	5	16
	39.1	11.75	0.219	0.58	21.3	0.16	5	16
	49.1	14.7	0.342	0.20	5.9	0.057	6	16
15.5	8.9	3.02	0.019	5.79	165	0.96	12	18
	18.9	6.40	0.086	2.63	76	0.44	10	15
	28.9	9.71	0.195	0.92	27	0.16	6	15
	38.9	13.25	0.364	0.22	6.4	0.038	8	16
	48.9	16.50	0.563	0.036	1.1	0.0059	15	21
18.6	10.8	3.82	0.036	7.93	209	0.87	12	22
	20.8	7.30	0.134	2.46	66	0.28	6	20
	30.8	10.7	0.290	0.46	12.6	0.051	6	20
	40.8	14.4	0.520	0.059	1.6	0.0068	15	24
	50.8	17.8	0.794	0.009	0.25	0.0011	20	27
21.4	8.3	3.29	0.032	8.65	182	0.75	12	21
	18.6	7.30	0.155	1.95	43	0.175	8	18
	28.6	11.18	0.364	0.29	6.4	0.025	7	19
	38.6	15.30	0.680	0.024	0.52	0.0022	10	20
	48.6	19.0	1.055	0.0020	0.045	0.00018	30	34
26.2	9.5	4.21	0.064	11.3	189	0.65	13	22
	19.5	8.60	0.268	1.31	22.4	0.078	7	21
	29.5	12.88	0.596	0.072	1.24	0.0043	10	22
	39.5	17.03	1.042	0.0041	0.075	0.00025	20	28

TABLE 2

Total elastic proton-proton scattering cross section

P_0 (Gev/c)	12.1	15.5	18.6	21.4	26.2
Elastic σ_T mb	10.4 ± 1.7	9.2 ± 1.4	9.0 ± 1.8	8.0 ± 1.6	9.8 ± 2.2

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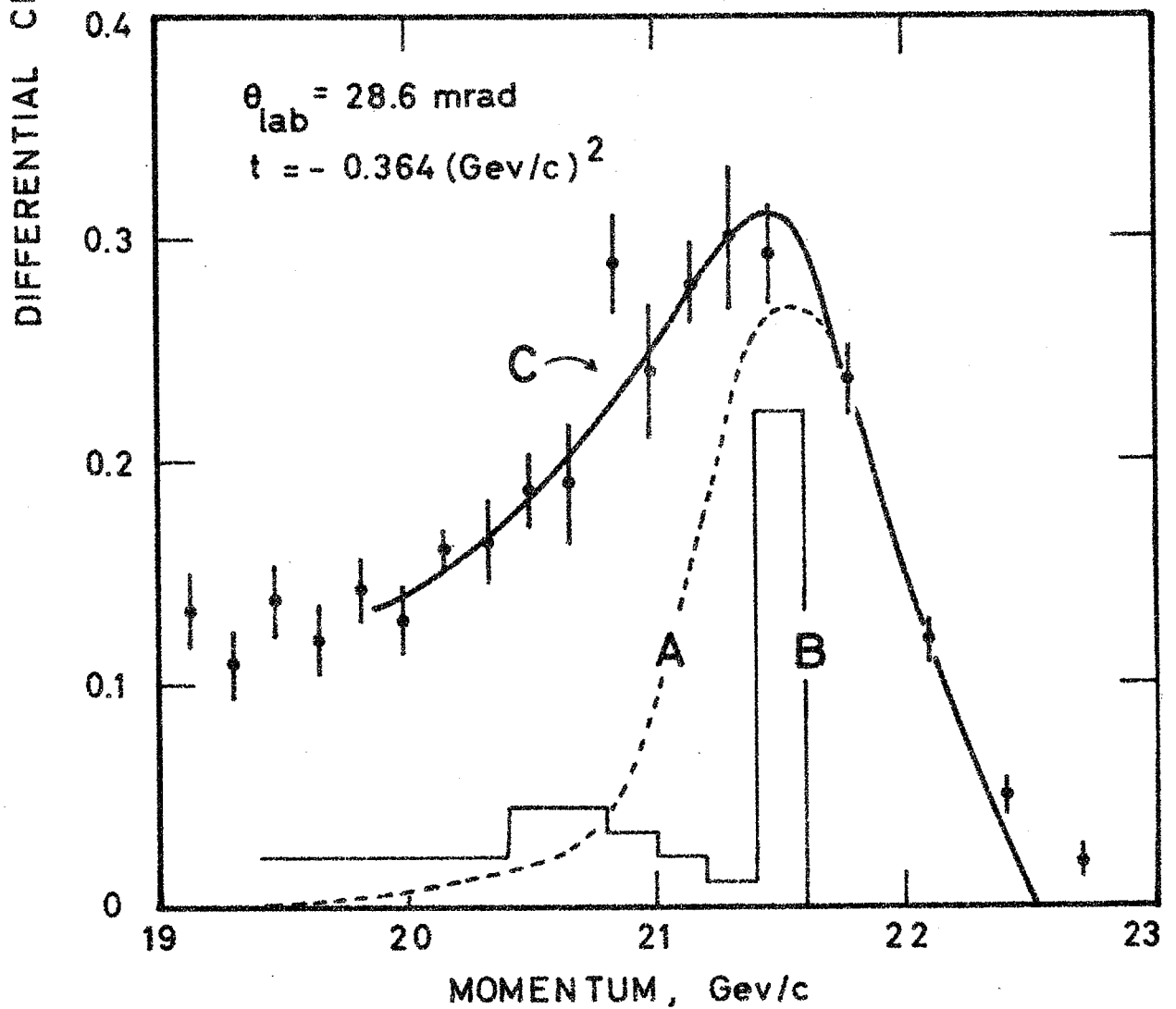
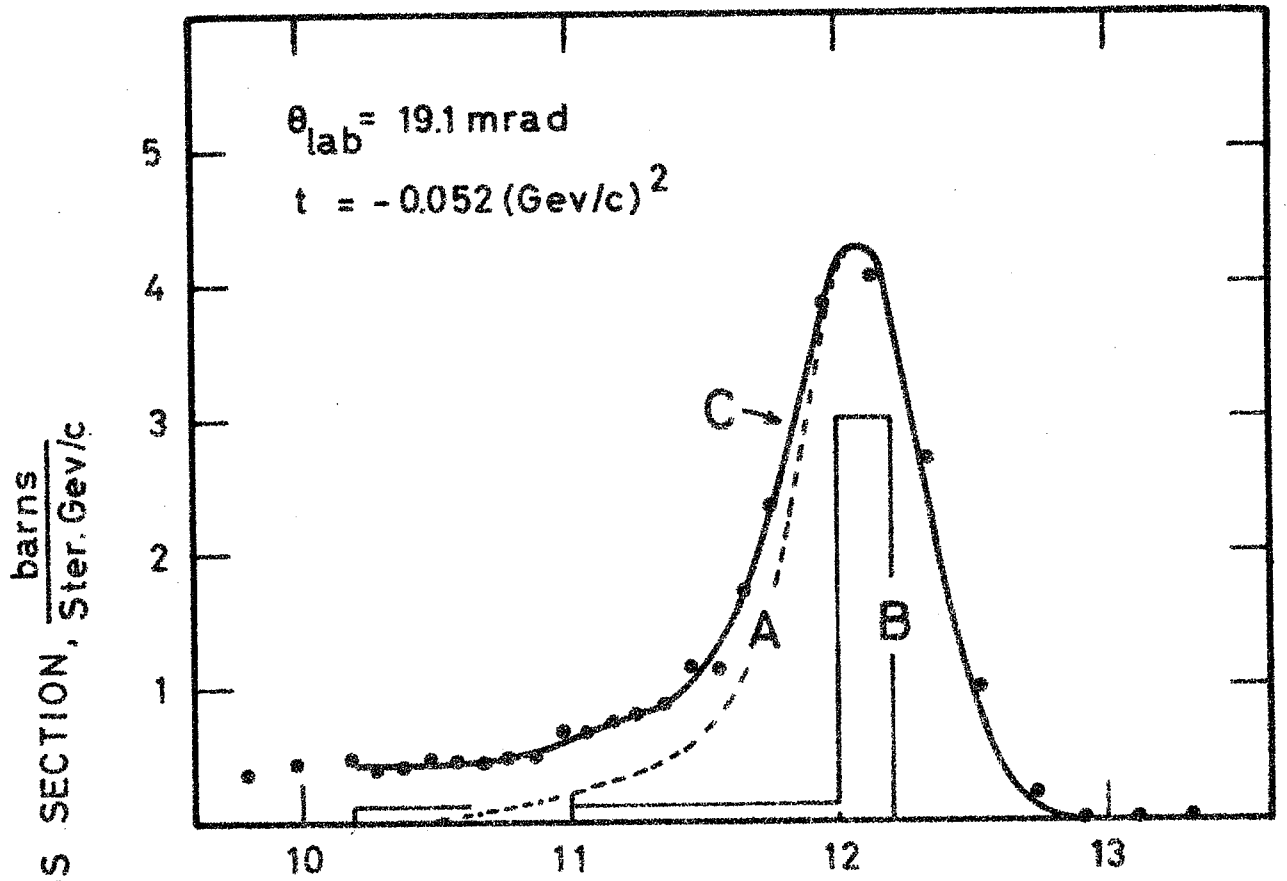
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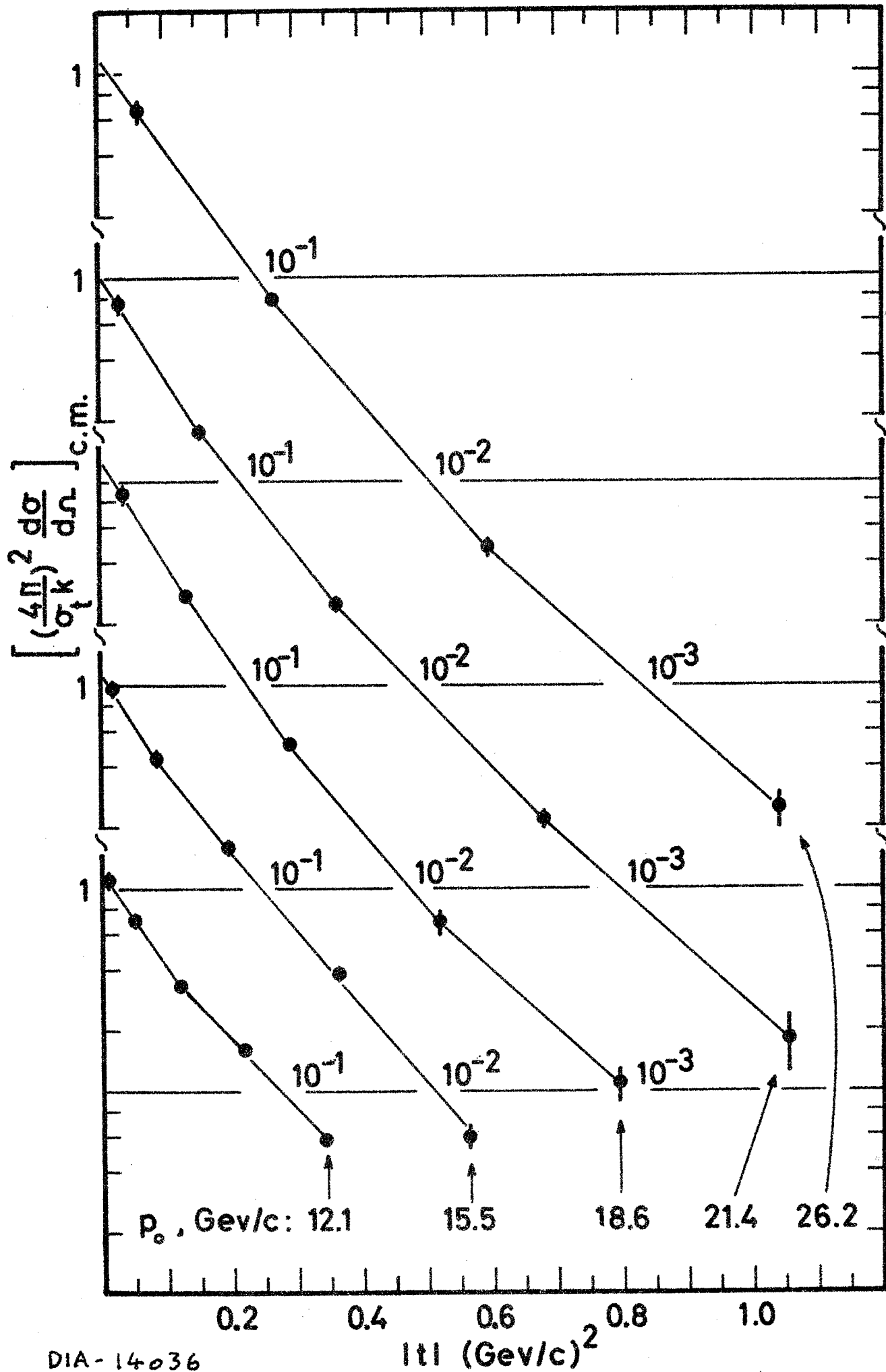
FIGURE CAPTIONS

Figure 1 - Typical momentum spectra from proton-proton scattering at initial momenta of 12.1 and 21.4 Gev/c at laboratory scattering angles of 19.1 and 28.6 mrad. Curves A, B, and C are explained in the text.

Figure 2 - Normalized differential elastic cross sections. Each distribution is displaced by one decade. Only relative errors are shown.

Figure 3 - Total elastic proton-proton cross sections. a-g, see refs. 2-8 respectively.





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TOTAL ELASTIC CROSS SECTION, MB.

