NAL PROPOSAL NO.

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MEASUREMENT OF THE REAL PART OF THE p-n and p-p FORWARD SCATTERING AMPLITUDES; PRODUCTION OF LOW MASS ISOBARS IN THE VERY SMALL MOMENTUM TRANSFER REGION

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ABSTRACT

We propose an internal target experiment with the following goals:

1. A measurement of the real part of the p-d forward scattering amplitude from 8 GeV to ≥ 400 GeV. The p-n real part would be extracted form the data using Glauber theory and compared with measurements of the p-p real part. The highest energy p-n real part measurements to date are 70 GeV.

2. A remeasurement of the real part of the p-p forward scattering amplitude from 8 GeV to 400 GeV using the same apparatus as the p-d measurements to facilitate the p-p, p-n comparison. By using a long ion guide and position sensitive detectors the accuracy attainable will be significantly improved over previous measurements (E36).

3. Measurements of the production of low mass isobars $1.0 < M_x < 2.0$ GeV/c^2 in the very small momentum transfer region $.005 < |t| < .025$ (GeV/c)^2. The use of a 7.5 meter, long ion guide and position sensitive detectors will result in a mass resolution of 16 MeV, a big improvement over previous measurements (E186, E317).

No additional equipment is required beyond what is already proposed and partly under construction for E289, proton-Helium scattering. The performance of these proposed measurements with hydrogen and deuterium are a logical first step in commissioning the full E289 apparatus.

I. INTRODUCTION

We propose an internal target experiment to study the real part of the p-p and p-d forward scattering amplitudes. The motivation is to see to what extent the p-n amplitude behaves as the p-p amplitude. Previous measurements[1] have established that ρ, the ratio of the real to the imaginary parts of the forward scattering amplitude, for pp scattering rises smoothly and crosses zero at 280 GeV. Measurements of ρ_{pn} at Serpukhov and lower energies[2,3,4] shown in Fig. 1 have shown no large differences between the p-p and p-n forward amplitudes at energies below 70 GeV/c. It is important that these measurements be extended up to the highest energies available and the precision improved to make the $\rho_{pn} - \rho_{pp}$ comparison more meaningful.

Since the goal of the pd real part measurement is to determine ρ_{pn} and compare it with ρ_{pp} over as broad an energy range as possible, it seems desirable to perform the pd and pp runs with the same apparatus. This is easily done by switching gases in the jet target. At the same time it will be possible to effect a significant improvement in the precision of ρ_{pp}. The measurement of ρ_{pp} is of fundamental importance in understanding the dynamics of strong interactions and by means of dispersion relations is a way of obtaining a "sense" of the behavior of $\sigma_T(pp)$ at energies well beyond the ISR limit. It is a case of a measurement where additional precision does provide new physical information.

The discovery in E36 of the changing sign of the real part was independent evidence for the rise in the pp total cross section. The accuracy of ρ in E36 was $\Delta\rho = \pm .012$. In the course of running E36 data was taken using position sensitive detectors. This was done more as a test of a new type of recently available detector than as a serious physics run and unfortunately data with these detectors was taken only up to 300 GeV or only slightly above the point where ρ becomes positive. In the recently completed analysis of these data (not yet published) we obtain an accuracy of $\Delta\rho = \pm .004$. This proposed experiment should achieve at least this good accuracy since it combines the position sensitive detector technique with a longer target-detector distance.

Figure 2 shows the E36 results on an expanded scale together with a recent dispersion relation calculation[5] based on the Fermilab total cross section results. More precise data on ρ_{pp} not only constrain σ_{tot} (E) for energies above which precise measurements do not exist but also serve at high energies as a check on the validity of the dispersion relations themselves.

We also propose to measure the high energy s and t dependence of the production of low mass isobars of the proton in the very small momentum transfer region. In particular, we would determine whether or not the differential cross sections for the 1400 enhancement, N*(1520), and N*(1690) production turn over and start to decrease at small t values ($|t| < .01$ GeV/c^2). Present experimental evidence[6] shows no turnover down to $|t| \approx .03$ $(\mathrm{GeV}/c)^2$. The production of these resonances will be measured continuously in beam energy over the t range $.005 < |t| < .025$ $(\mathrm{GeV/c})^2$. Most of the data required would be taken simultaneously with the real part measurements.

These proposed measurements complement E317, presently in progress, where the emphasis is on the large missing mass continuum and the mass resolution is poorer.

II. EXPERIMENTAL DETAILS

The experiment uses the E289 setup shown in Figure 3. The detectors are 7.5 m from the target (by adding a piece of 6" pipe). Rates are calculated assuming 10^{13} protons/pulse and a jet density $\rho = 10^{-7}$ gm/cm^2. If necessary the jet density can be increased or reduced a factor of 5.

To study elastic scattering position sensitive semiconductor detectors are used. Table I gives some pertinent experimental parameters.

TABLE I

pp elastic				pd elastic			
$-t$ $(\mathrm{GeV/c})^2$	θ_{recoil}	Range	$\Delta\theta_{resolution}$	$-t$ $(\mathrm{GeV/c})^2$	θ_{recoil}	Range	$\Delta\theta_{resoluti}$
.002	24 mr	18 μm	0.8 mr	.001	8 mr	3 μm	0.8 mr
.005	38	71	(Resolution is a factor of 4 better than in E36)	.0025	13	8	
.010	53	230		.005	19	20	
.020	75	780		.010	27	50	
.040	107	2500		.020	38	150	

The position sensitive detectors cover an area 7mm x 45 mm and have depletion depths of 100/500/1000 μm. A scintillation counter in anticoincidence will be placed in back of each semiconductor detector. Discrete semiconductor detectors of 10/25 μm thickness and of a small area, 10 mm^2, will be used for portions of the deuterium experiment.

Based upon the previous measurements from E36 where a single semiconductor detector was used background events are estimated at less than 1%. Counting rate is calculated to be ~ 20 (for pp) and 60 (for pd) counts/detector/20 ms gate. The calculated accidental rate is less than 1%. Normally 3 beam gates or 3 energies will be taken simultaneously. In order to obtain ± 0.5% statistical accuracy in the ρ measurement 1.4×10^6 events are necessary, so 3 energies may in principle be run during a period of 60 hours.

The p-p inelastic experiment utilizes the same 7.5 meter ion guide and the angular range, $60 < \theta < 130$ mr. The kinematic region is listed in Table II.

TABLE II

P_o	$M_x = 2.0$ GeV		$M_x = 1.4$ GeV	
GeV/c	$-t$ $(GeV/c)^2$	θ_{recoil}	$-t$ $(GeV/c)^2$	θ_{recoil}
200	.005 - .025	120 - 130 mr	.005 - .025	77 - 102 mr
300	.005 - .025	102 - 117	.005 - .025	63 - 96
400	.005 - .025	92 - 108	.005 - .025	60 - 93

The region $-.005 < -t < .025$ $(GeV/c)^2$ is to be covered with a 3 element sandwich consisting of: first a 100 μm totally depleted 7mm x 45mm transmission semiconductor detector, second a 1000 μm

7mm x 45mm position sensitive semiconductor detector, both functioning together in the $\Delta E/\Delta X$-E, identification mode, third a scintillation counter in anticoincidence. This technique permits elimination of background from non proton events. Estimated rates with $\Delta t = .020\ (\mathrm{GeV/c})^2$ and $1.0 < M_x < 2.0\ \mathrm{GeV/c^2}$ are

$$\frac{N_{\mathrm{inelastic}}}{N_{\mathrm{elastic}}} = \frac{\frac{d^2\sigma}{dt\,dm_x^2}\,\Delta t\,\Delta m_x^{\,2}}{\frac{d\sigma}{dt}\,\Delta t} = 0.75$$

$$N_{\mathrm{inelastic}} = 15 \text{ counts/20 ms gate}$$

In this type of measurement, where the recoil energy is determined to a precision of ~ 0.5%, the mass uncertainty is due almost entirely to the uncertainty in the recoil angle, according to the relation

$$\Delta M_x = \frac{p_o\sqrt{|t|}}{M_x}\ \Delta\theta \approx \frac{200\ \sqrt{.02}}{1.4}\cdot(0.80 \times 10^{-3}) = 16 \times 10^{-3}\ \mathrm{GeV/c^2}$$

This excellent mass resolution is attributable to a factor of 4 improvement over the angular resolution available in E36, an improvement due to main to the 7.5 meter distance available in the new C-0 Internal Target Spectrometer Room.

Normalization of the inelastic experiment will be made relative to the nearby elastic scatteing region. The elastic scattering itself is normalized using the optical point and published measurements of σ_{tot}. However, with sufficient accuracy in our alignment (absolute angle) it may be possible to normalize on the Coulomb cross section.

III. LOGISTICS, MANPOWER, AND TIME SCALE

This experiment makes use of the ion guide, detectors, electronics, computer all presently proposed for E289. The target would either be the present H_2 jet target, a proposed new spare for it to be built at Dubna, or the He jet target operated with hydrogen or deuterium. The target boxes and targets all have the same diameter bolt circle and are interchangeable.

These measurements will require approximately 300 hours of operation of the gas jet target with hydrogen and deuterium. We need to take data for one week with the accelerator running at 400 GeV and, of course, for the physics reasons given would very much like to take data at energies higher than 400 GeV.

The insertion of this proposed experiment between the end of E317 (summer 1975) and the beginning of E289 (fall or winter 1975) is reasonable to insure the continuity of the Dubna-Fermilab collaboration. The feasibility of the Helium jet for E289 is proven but there is still some uncertainty as to when engineering of it will be complete. Approval of this experiment now would provide a firm basis on which Dubna can organize a new team of physicists and all the equipment they intend to provide.

It has been our experience that several months are necessary each time a new ion guide is installed before final data taking can commence. Alignment procedures have to be perfected (more crucial now that higher precision is our goal), stray magnetic fields measured (important for very low energy recoils), and backgrounds understood (highly dependent on vacuum system and target-box, ion-guide geometry). In the course of getting E289 commissioned we would in any case be requesting hydrogen running at this checkout stage. But, as proposed, we would also be able to do interesting and important physics measurements at the same time.

References

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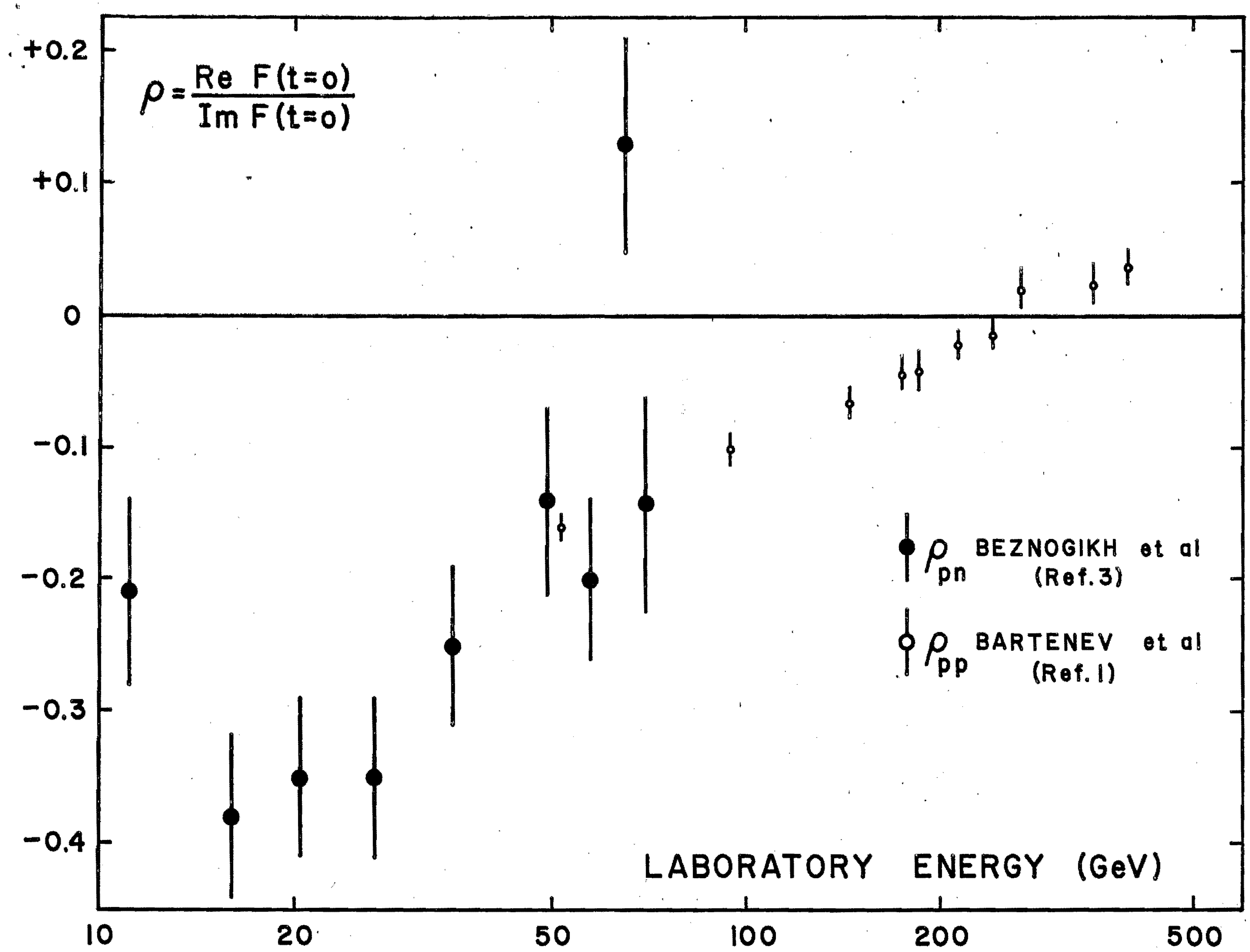
[4] G. G. Beznogikh et al., Nuclear Physics B54, 97 (1973).

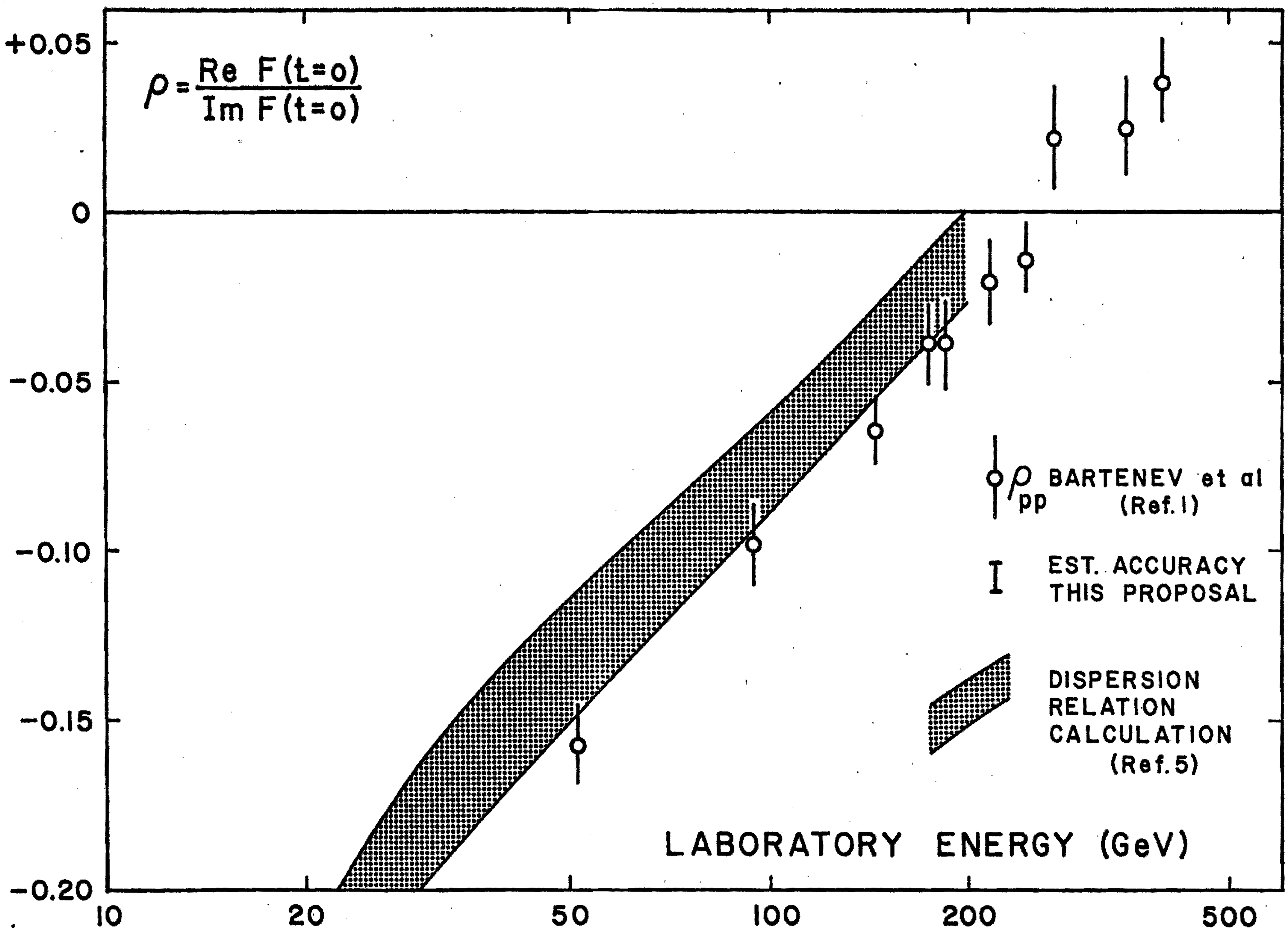
[5] R. E. Hendrick and B. Lautrup, to be published in Phys. Rev. D. Feb. 1, 1975.

[6] Yu. Akimov et al., "Excitation of High Energy Protons into Low Mass States in p-d Interactions." To be published.



$\rho = \frac{\text{Re } F(t=o)}{\text{Im } F(t=o)}$
+0.2
+0.1
0
-0.1
-0.2
-0.3
-0.4
10
20
50
100
200
500
LABORATORY ENERGY (GeV)
ρ_{pn} BEZNOGIKH et al (Ref.3)
ρ_{pp} BARTENEV et al (Ref. 1)

FIGURE 1



$\rho = \frac{\mathrm{Re}\ F(t=o)}{\mathrm{Im}\ F(t=o)}$
+0.05
0
−0.05
−0.10
−0.15
−0.20
10
20
50
100
200
500
ρ_{pp} BARTENEV et al (Ref. 1)
EST. ACCURACY THIS PROPOSAL
DISPERSION RELATION CALCULATION (Ref. 5)
LABORATORY ENERGY (GeV)

FIGURE 2

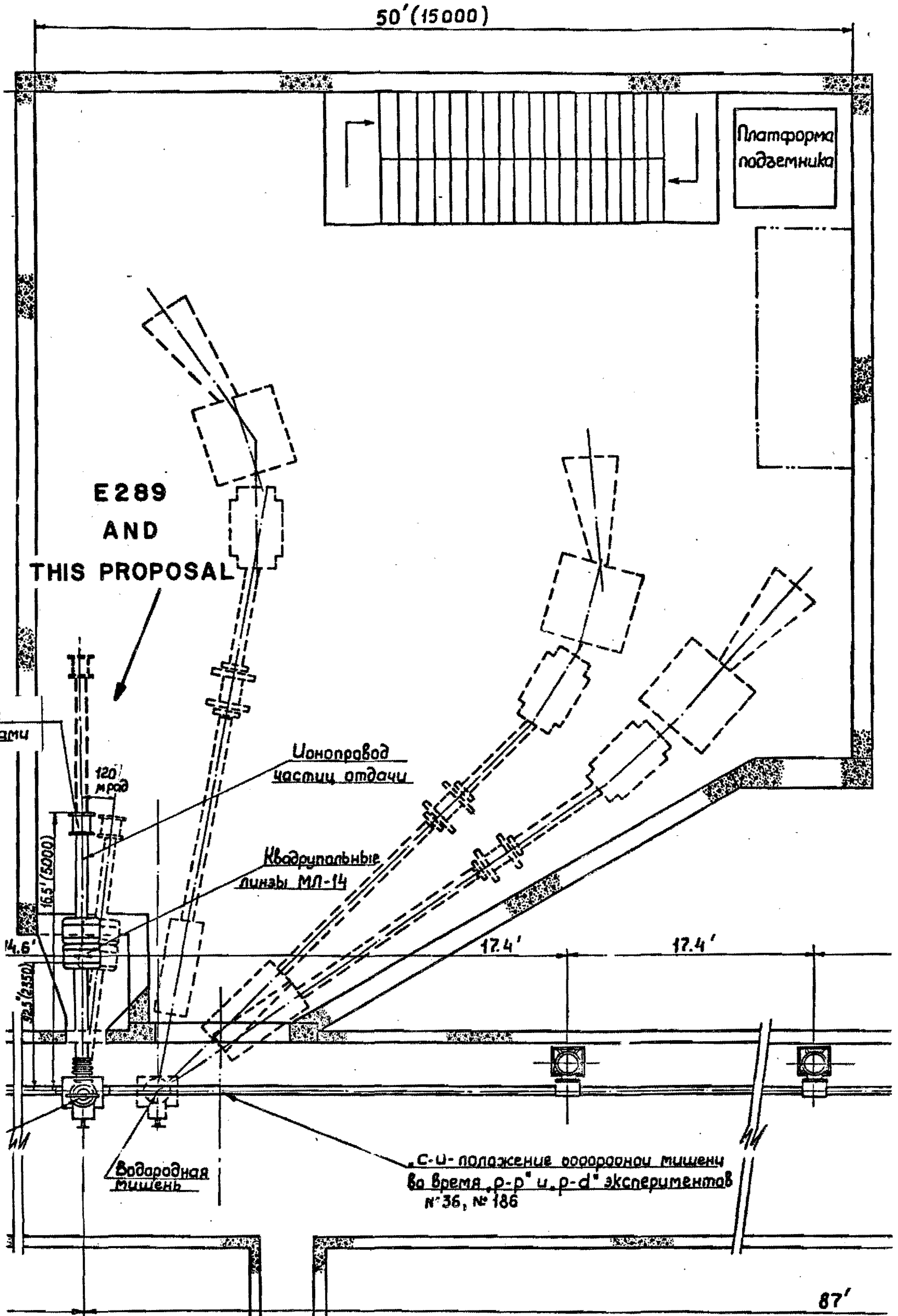


FIGURE 3
INTERNAL TARGET AREA