NAL Proposal No. 207

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PROPOSAL TO STUDY pp INTERACTIONS AT 500 GeV IN THE 30-INCH BUBBLE CHAMBER AT NAL

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We propose a 50,000 picture exposure of the 30-inch bubble chamber to 500 GeV protons. The total pp cross section will be measured to 1.7%. Charged secondary multiplicity parameters will be determined and $\langle n_{\pi^o} \rangle$ will be estimated. We will measure $\pi^-\pi^-$ correlations in the complete backward hemisphere, study the diffractive process $pp \rightarrow p_{slow} + MM$, Δ^{++} and neutral strange particle production.

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I. Exposure:

We propose to take 50,000 pictures with the 30-inch bubble chamber at NAL exposed to a 500 GeV proton beam. We intend to run with five beam tracks per picture. Using a 45 cm fiducial volume and expecting about 70%[1] good physics pictures, we will have 10,000 events, roughly 1/5 of them elastic.

We propose to insert a thin lucite plate into the downstream end of the chamber. This creates corresponding points on the fast forward-going tracks which improves the track matching considerably.[2]

II. Measurements and Their Physics Interest:

(1) σ_{tot} at 500 GeV:

Recent results from the ISR[3] show an increase of the total pp cross section of 10% from "low energy" accelerator energies at 60 GeV to ISR energies up to 1500 GeV stationary-target-equivalent lab momentum as shown in Fig. 1.

In the ISR experiment, the measurement of flux and target density, i.e., the luminosity in the storage ring, is complicated. Additionally, about one-half of the observed effect is contained in Monte Carlo corrections to the raw data.

Hence, it is important to measure the total cross section in an experiment where the determination of flux and target density and the

event detection is simple and straightforward! This - although statistics are low - is the case in a BC experiment at NAL! A measurement at 500 GeV provides enough "energy lever arm" to expect a 5% effect. With our proposed exposure of the 30-inch bubble chamber, a measurement with 1.5% accuracy can be made and gives a significant answer.

The various contributions to this error are:

(a) H-target density: The H density can be determined with 1% accuracy from energy-range measurements of μ^+ from π^+ stop $\rightarrow \mu^+$ stop $\rightarrow e^+$.

(b) Scan efficiency: The scan efficiency for events with 4 and more prongs is close to 100% and its error negligible. The scan efficiency for 2-prong events in the 200 GeV exposure,[4] where the aim was a fast determination of the multiplicity parameters, was (96 ± 1)%. One will do better than that in a more careful scan for 2-prongs.

(c) Correction for short p recoil losses in 2-prong events: From the results at 200 GeV,[4] it is estimated that this correction for the proposed exposure will have an error of 1% due to uncertainty in the extrapolation of the t-distribution to t = 0.

These errors combined with a 1% statistical error give a 1.7% error on σ_{tot}.

(2) $\sigma_{e\ell}$ at 500 GeV:

The slope of the elastic t-distribution at high energies (NAL and ISR) is well measured.

However, the various absolute values of the elastic cross section quoted from ISR experiments fluctuate considerably!

The best known value so far though low statistics - is the 200 GeV BC result at NAL![4]

Here the kinematical analysis uses only the "engineering values" for the beam parameters and the accurately measured slow recoil proton. The background in the elastic sample is estimated by analyzing 4-prong events in the same manner.

We estimate from these data that the error on $\sigma_{e\ell}$ at 500 GeV will be 8%.

(3) Moments of the Multiplicity Distribution:

Comparisons of the measured multiplicity parameters,

$\langle n \rangle$

$\langle n(n-1) \rangle$

.

.

.

etc. with n = number of charged secondaries ,

with model predictions, show that much more data are needed for a meaningful distinction between models. In particular in energy

dependence studies of the higher moments, accurate measurements at highest available NAL energies look promising.[5]

We will measure the moments at 500 GeV with about twice the accuracy of the reported results at 100,[6] 700,[7] and 300[8] GeV.

Measurements of Secondary Momenta:

Due to the sharp fall-off in the transverse momentum ($P_\perp$) distributions of secondaries, one can neglect events with $P_\perp > 1$ GeV/c. One captures then the complete backward hemisphere (b. w. h.) at 500 GeV incident energy if one measures the following lab momenta for the different secondaries

$$p^{\pi} < 15 \text{ GeV/c}$$
$$p^{K} < 17 \text{ GeV/c}$$
$$p^{P} < 20 \text{ GeV/c}$$
$$p^{\Lambda^o} < 23 \text{ GeV/c} \quad .$$

Charged Secondaries:

One selects reliably secondary lab momenta up to 15 GeV/c with a sagitta criterion on the scan table. Hence, we will measure π^- reliably in the complete b. w. h. , p/π^+ only in part of it. Protons are identified by ionization up to 1. 4 GeV/c lab momentum, which includes still a large fraction of the b. w. h. in the target fragmentation region.

Neutral Secondaries:

The V^o topology events

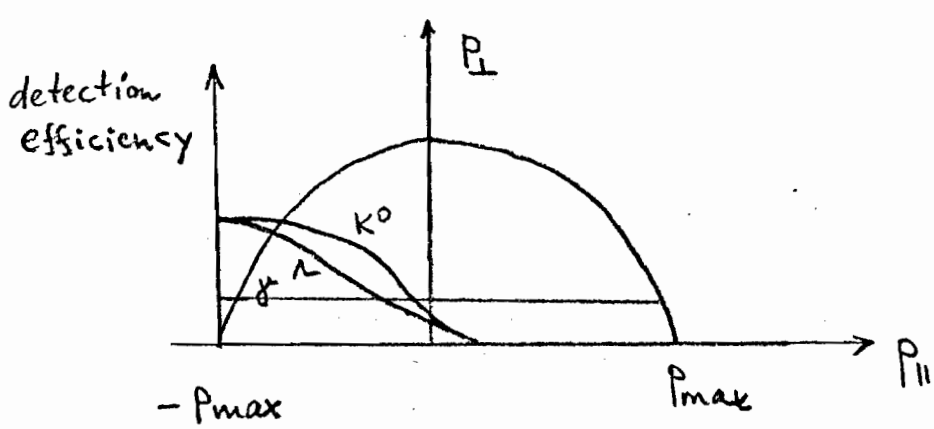
$$\Lambda^o \rightarrow p\pi^-$$

$$K^o \rightarrow \pi^+\pi^-$$

$$\gamma(p) \rightarrow e^+e^-(p) \, .$$

can be separated up to about 17 GeV/c V^o momentum as demonstrated in the 200 GeV[9, 10] and 300 GeV[11] 30-inch bubble chamber experiments. We expect, therefore, to detect K^o in the complete b. w. h. and Λ^o in part of it.

The conversion probability for γ is constant across the Peyrou plot whereas the detection efficiency for neutral strange particle decays drops sharply as the CM symmetry line $p_{\parallel} = 0$ is approached, ($p_{\parallel}$ is longitudinal momentum of the secondary in the CM). The fast Λ and K^o are thrown out of the BC before they decay.



We expect, therefore, to detect γ in both hemispheres.

(4) π^o Multiplicity:

The results from the 200 GeV[9] and 300 GeV[11] bubble chamber experiments on π^o production indicate that at high energies, the number of π^o "tracks" the number of π^-. This has been interpreted as support for multiperipheral models.[12]

We will study the reaction

$$pp \rightarrow \gamma(\pi^o) + \text{anything}$$

in the same manner at 500 GeV with about 500 γ conversions.

(5) $\pi^-\pi^-$ Correlations:

The results on two particle correlations from the Pisa-Stony Brook experiment at the ISR give strong support to the Short Range Correlation models.[13] Specific predictions using a very simple Mueller approach[13] for the two particle correlation function are:

$$C_2(Y_1, Y_2) = 0.7\, e^{-|Y_1 - Y_2|/2} \quad \text{for } \pi^+\pi^-$$

$$= 0 \quad \text{for } \begin{cases} \pi^+\pi^+ \\ \pi^-\pi^- \end{cases} .$$

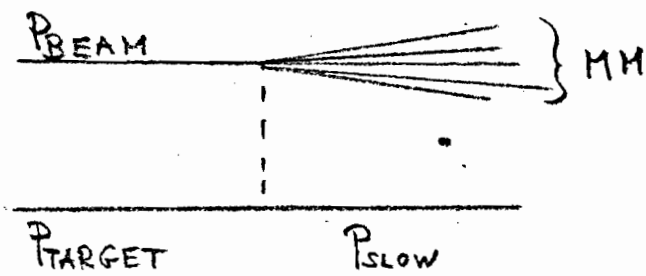
We will measure C_2 with about 22,000 π^-, and study C_2 as a function of prong number.

(6) Diffractive Processes:

In the BC experiments at 100,[14] 200,[15] and 300[16] GeV, the reaction

$$pp \rightarrow p_{slow} + MM$$

has been studied in a missing mass (MM) experiment in the beam fragmentation region.

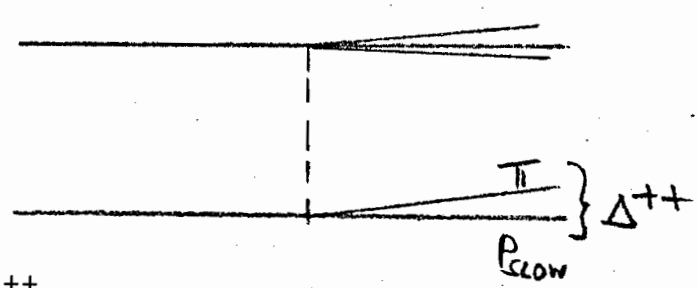


A low mass enhancement was found in the 2- and 4-prong events. The 6-prong events showed a flat MM distribution. This low mass enhancement was interpreted as diffractive production.

We will study the energy dependence of this process up to 500 GeV with about 4000 events.

(7) <u>Δ^{++} Production</u>

The 300 GeV experiment[17] detects in an effective mass experiment in the target fragmentation region



strong Δ^{++} production.

We will study the inclusive Δ^{++} production at 500 GeV.

(8) Neutral Strange Particle Production:

The cross section $\sigma(K^o)$ was found to rise strongly with energy but $\sigma(\Lambda^o)$ rises slowly at energies below 30 GeV.[18]

Up to 200-300 GeV, $\sigma(K^o)$ rises strongly and $\sigma(\Lambda^o)$ does too.[10, 11]

We will detect K^o in the complete b. w. h. and measure $\sigma(K^o)$ at 500 GeV. Λ^o will be detected in part of the b. w. h. where we will test the approximate scaling behaviour found at 200 and 300 GeV.[10, 11]

III. Equipment and Manpower:

Our equipment available for the analysis of the film includes four scan tables with image plane digitizers, three of them equipped with large magnification (60 times) for complicated events, three Vanguard measuring machines and one Vanguard with a TV zoom lens for large magnification.

The personnel consists of

10 full-time scanners

2 Ph. D. students

4 Ph. D. physicists .

We are currently analysing 200 GeV pp interactions on 30-inch BC film in collaboration with ANL. We have a running software chain for all measurements quoted above, and a scan crew trained to scan difficult multiparticle events on 30-inch film as NAL energy. We are confident that we can analyze the film fast and reliably.

References and Footnotes

1. This value is based on the experience gained in the recent runs with 200 and 300 GeV protons and 200 GeV π^-. It depends on the type of analysis to be performed. For a measurement of σ_{tot}, a conservative estimate is given.

2. J. Chapman, UMBC report and private communication.

3. Pisa-Stony Brook Collaboration, presented at the International Conference on Multiparticle Production, Nashville, March 1973.

4. G. Charlton et al., "Two and Four Prong pp Interactions at 205 GeV," Contribution No. 988, International Conference on High Energy Physics, Batavia, September 1972.

5. W. Weisberger, SUNY preprint.
   W. Frazer, NAL THY report

6. J. Chapman et al., Phys. Rev. Letters 29, 1686 (1972).

7. G. Charlton et al., Phys. Rev. Letters 29, 515 (1972).

8. F. T. Dao et al., Phys. Rev. Letters 29, 1627 (1972).

9. G. Charlton et al., Phys. Rev. Letters 29, 1759 (1972).

10. G. Charlton et al., Phys. Rev. Letters 30, 574 (1973).

11. F. T. Dao et al., presented at the APS Annual Meeting, January 1973.

12. E. L. Berger, D. Horn and G. H. Thomas, "Correlations Between

Neutral and Charged Pions in Multiparticle Production," ANL/HEP 7240, September 1972.

13. C. Quigg, Review of Two-Particle Correlation Data at the International Conference on Multiparticle Production, Nashville, March 1973.

14. Rochester-Michigan Collaboration, UMBC No. 72-14 and UR No. 416, January 1973.

15. ANL 200 GeV BC experiment; presented at the International Conference on Multiparticle Production, Nashville, March 1973.

16. J. Lach et al., "Study of the Reaction pp → p + Everything at 303 GeV/c," presented at the APS Annual Meeting, January 1973.

17. F. T. Dao et al., Phys. Rev. Letters 30, 34 (1973).

18. B. Y. Oh, G. A. Smith, Nucl. Phys. B49, 13 (1972).

Figure Captions

Fig. 1 Compilation of total cross section results for pp interactions including the recent ISR results.

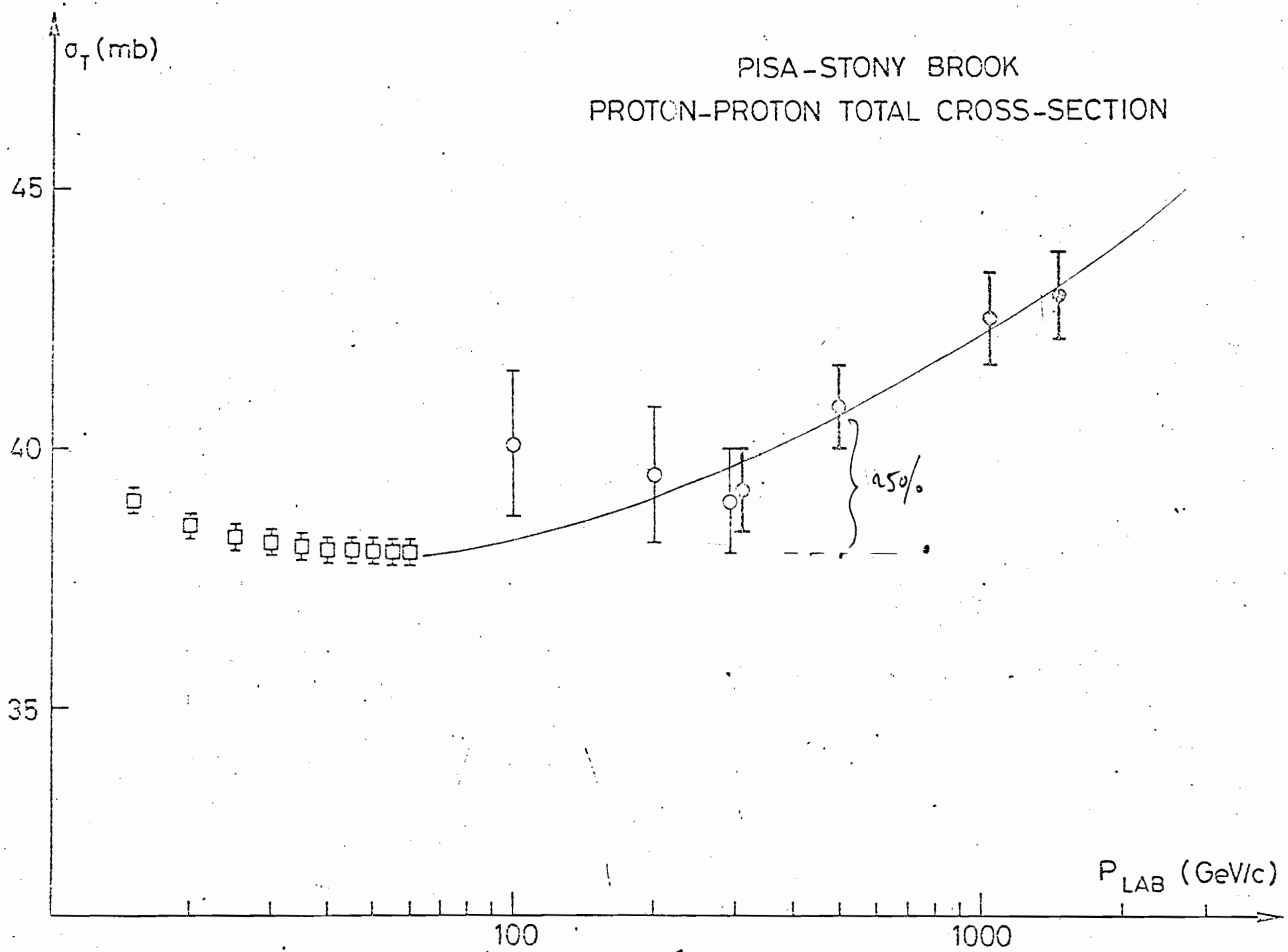

PISA-STONY BROOK
PROTON-PROTON TOTAL CROSS-SECTION
σT (mb)
45
40
35
25%
PLAB (GeV/c)
100
1000

FIG. 1