NAL PROPOSAL No. 130

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PROPOSAL TO STUDY pp INTERACTIONS UP TO 500 GeV/c WITH THE 30" BUBBLE CHAMBER

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WITH THE 30" BUBBLE CHAMBER

ABSTRACT

We propose to study pp interactions with the Argonne 30" bubble chamber. Taking advantage of the backward-forward center-of-mass symmetry in pp interactions, we intend to emphasize the aspects of the problem which can readily be done with a small chamber; namely, the measurements of the backward hemisphere pions which have relatively low momentum in the laboratory. We request 100K pictures at 120 GeV/c and 100K pictures at 500 GeV/c and, with our existing data at 30 GeV/c, we will study several kinds of correlations as well as the energy dependence of the distributions. Approximately 10K events with one event/μb, will be measured at each energy.

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PHYSICS JUSTIFICATION

1. Purpose of Experiment:

For the past few years we have been carrying out exploratory studies of particle production from pp and pd interaction with the primary momentum near 30 GeV/c with data from the BNL 80" bubble chamber.(1) A natural continuation of our work is to extend our analyses of pp interactions to the highest possible beam momenta. A year ago we submitted a proposal (2) to NAL (#58) for the purpose of pursuing these investigations with the 15 foot bubble chamber; however, since the decision was made to bring the Argonne 30 inch chamber to NAL, we are anxious to get data as soon as possible with the expectation we will be involved in making more thorough studies later with the 15 foot chamber. We discussed the physics justification in our previous proposal and, in addition, one of us (R.P.) was on the committee for strong interaction studies with bubble chambers at the 1970 NAL summer study where our report presented further details on physics justification.(3) However, since this is a specific new proposal, we outline briefly our justification and requirements for an experiment with the 30" bubble chamber.

2. Capability of the 30" Bubble Chamber for Very High Energy (up to 500 GeV/c) pp Studies:

Before going into details of experiments, it is necessary to point out what we expect can be accomplished with the 30 inch chamber. As discussed in the 1970 NAL summer study report, (3, 4) it should be relatively easy to measure accurately pions which are backward in the overall center-of-mass system. In pp interactions, because of the center-of-mass symmetry, it is sufficient to measure the distributions in only one hemisphere if we are not requiring that all produced particles in an event be correlated at once. To be more quantitative, we compute the value of the laboratory momentum of backward-hemisphere pions for 500 GeV/c incident protons in the most extreme case; i.e., where the center-of-mass longitudinal momentum is zero and for two values of transverse momentum; i.e. $p_t = 0$, and 1 GeV/c. For these cases, the laboratory longitudinal momentum, p_L, is given by

$$p_L = \gamma E_{cms} = \gamma \sqrt{p_t^2 + M_\pi^2}$$

where $\gamma = 16.4$ at 500 GeV/c and for $p_t = 0$, $p_L = (16.4)\ (.14) = 2.15$ GeV/c while for $p_t = 1$ GeV/c, $p_L = 16.5$ GeV/c. $\sqrt{1 + .02} = 16.5$ GeV/c.

This calculation shows that backward pions with p_t near zero will have very small laboratory momentum and will be easy to isolate in high multiplicity events because they will have a large curvature. The higher p_t pions will curve less but will subtend an appreciable angle at the interaction vertex with respect to the beam direction; e.g., for $p_t = 1$ GeV/c and $p_L = 16.4$ GeV/c, the laboratory angle is 3.5°.

It seems quite reasonable, therefore, to rely on useful momentum measurements for pions that come from the backward hemisphere while most multiplicities of the forward-hemisphere particles (forward jet) can be counted, if not measured.

3. Phenomenological Studies of Multiparticle Reactions:

The study of the correlations between particles and the contributions of specific channels in high energy collisions will obviously be important experimental input for a theoretical description of strong interactions. That is, besides the measurements of total cross sections, elastic cross sections, and single-particle spectra, we want to know more about the component channels and how they behave as a function of energy. Although measurements with a small bubble chamber are limited, it is clear that such measurements will represent a major improvement over the best results obtained in cosmic ray experiments in the same energy range. We follow with a summary of the measurements we expect to make with the 30" bubble chamber and the relevant physics questions.

3.1 Correlations in Longitudinal Momentum:

It is a well known feature of particle production in hadron-hadron interactions[1,5] that the transverse momentum distribution of particles cuts off very sharply; i.e., $\frac{d\sigma}{dp_t^2} \sim \exp(-b\, p_t^2)$ where $b \sim 10\ (\text{GeV}/c)^{-2}$.

On the other hand, the longitudinal components of momentum vary strongly with primary energy and are more interesting to study for the purpose of describing the characteristic features of the final states. A primary objective of our experiment is to examine the ordering of particles in longitudinal momentum and their correlations relative to each other as a function of charged-prong multiplicity and primary energy, at least for the backward pions. It will be interesting to see if particles are produced in clusters and if so we want to learn whatever we can about these clusters such as their net charge, invariant mass, and the dependence on primary energy. A specific example of the production of clusters is the diffraction dissociation of one or both protons whereby a proton "fragments" and results in a cluster of particles which, taken together, has the same internal quantum numbers as the parent proton.

3.2 Limiting Distributions:

Both Feynman [6] and Yang and his co-workers [7] have predicted that in the high energy limit, the spectra of produced particles approach finite limits. This is expected for single particle spectra as well as for correlations between particles and it will be interesting to put this hypothesis to a test. The 30" bubble chamber should provide good measurements of "target fragmentation" with the simultaneous determination, or at least an estimate of the number of fast tracks. The symmetry in pp should be useful for correlating fast particle with slow measured fragments. For example, for every event

$$p + p \rightarrow (p + \pi^+ + \pi^- + \cdots\cdots)_{slow} + p_{fast}$$

there will be a partner

$$p + p \rightarrow p_{slow} + (p + \pi^+ + \pi^- + \cdots\cdots)_{fast}$$

Another interesting question is whether or not there is "pionization" [7].

While it is not yet clear how best to define pionization, it is generally understood to mean a central component of pion production where the pions have small center-of-mass momenta and where these pions are understood to be distinct from the fragments of the incident particles. It is not clear that the pionization question can be meaningfully answered with 30" chamber data; however, it will be interesting if we can at least measure the energy dependence of the pion spectrum near zero center-of-mass momentum.

4. Unexpected Phenomena:

With the good spatial resolution and the visibility of the target vertex, it is possible that some unexpected events may be found. For example, very high energies may unleash from the target new particles with complex decay sequences.

5. It is important that the total and differential elastic cross sections be measured at the highest available energies as soon as possible. While we are aware of the limitations on such measurements in a bubble chamber, if the beam momentum to the 30" bubble chamber is significantly higher than those then available to NAL counter experiments, we shall measure these cross sections.

6. Data Requirements; Choice of Primary Energies:

From studies with our 28.5 GeV/c pp data, we estimate that it will be desirable to have one event per μb at each primary energy. Since studies of energy dependence are important, we will require more than one energy. We choose the following:

beam momenta:	120 GeV/c and the highest available, 500 GeV/c.
pictures:	100,000 at each energy with an average of 10 tracks per picture.
statistics:	one event/μb at each energy in 30cm fiducial length.

7. Competition with Other Experiments:

We are aware of the large number of groups that are interested in studies similar to what we propose and we are, of course, willing to work out some reasonable collaboration. This experiment is proposed for the 30" chamber without additional downstream detectors. It is our hope to obtain data as soon as possible in this manner with the expectation that we would carry out further studies later on with either a hybrid technique or the 15 foot chamber.

EXPERIMENTAL ARRANGEMENT:

APPARATUS

Chamber: 30" hydrogen bubble chamber without downstream detectors. We prefer the BNL type format, but we do not require it.

Beam: 120 and 500 GeV/c positive beam. The requirements on $\Delta p/p$ are not strict. A Cerenkov counter to tag the beam particles may be desirable for the lower momentum part of the exposure. (We will share the film with a group that wants $\pi+$ at this energy if we use a tagged beam.)

Data Processing: The measurements of the events discussed above can be done in about six months in the Vanderbilt measuring laboratory. We have found the Brookhaven geometry program suitable for our previous multiprong work and we will use it for this exposure.

References:

1. For a review of results, see R. Panvini, High Energy Collisions, Gordon & Breach 1970. (Stony Brook Conference Report).

2. NAL Proposal #58.

3. Burnstein et al., 1970 NAL Summer Study Report on Strong Interaction Studies with Bubble Chambers, SS-164.

4. C-Y Chien et al., 1970 NAL Summer Study Report on Inclusive Reactions, SS-182.

5. Koshiba, High Energy Collisions, Gordon & Breach, 1970. (Stony Brook Conference Report).

6. Feynman, High Energy Collisions, Gordon & Breach, 1970. (Stony Brook Conference Report).

7. Benecke et al., Phys. Rev. 188, 2159 (1969), C. N. Yang, High Energy Collisions, Gordon & Breach, 1970. (Stony Brook Conference Report).