NAL PROPOSAL No. 143

Scientific Spokesman:
G. R. Kalbfleisch
Physics Department
Brookhaven National Laboratory
Upton, New York 11973

FTX/Commercial: 516-924-6262, x-7657

Proposal for a Rapid Systematic Study of All Interactions in a $\pi^- p$ Exposure of the Bare 30" Chamber at 120 GeV/c

P. L. Connolly, P. V. C. Hough, G. R. Kalbfleisch, R. C. Strand
Brookhaven National Laboratory

June 25, 1971

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Experimenters: P.L. Connolly, P.V.C. Hough, G.R. Kalbfleisch, R.C. Strand

Correspondent: G.R. Kalbfleisch, Physics Department, Brookhaven National Laboratory, Upton, N.Y. 11973
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I. Abstract

A request is made for 50,000 photographs in the bare ANL 30-inch hydrogen bubble chamber exposed to π^- mesons at 120 GeV/c* at NAL. A rapid, complete study of all interactions in these pictures with highest accuracy data extraction, including detailed bubble structure of all tracks, is proposed to obtain useful results quickly. The new results expected will be useful to prepare for future experimental programs at NAL and some will be able to rule out incorrect models and hypotheses proposed for hadron phenomenology.

*Alternate momenta are 200 and 400 GeV/c.

II. Rapid Complete Study of NAL Hadron Interactions in the Bare 30" HBC

To explore interactions of hadrons with the bare ANL 30-inch chamber (HBC) at NAL, a rapid analysis of 50,000 photographs will provide some useful physics results. Charged particle multiplicities, topological cross sections, total cross section (about 24 mb) and preliminary missing mass spectra with recoil protons can be determined to a few percent accuracy if there are two to ten tracks per picture and the muon contamination in the beam is known to a few percent. The data would be extracted with the BNL Mark II Hough-Powell Digitizer (HPD). These results can be ready six months after the pictures are taken. Within a year, all tracks (including beam tracks) can be measured.

Many high energy physicists believe that we must understand general features of hadron interactions at NAL energies before we can understand more details of hadron structure and behavior. We are in sympathy with this belief. Models and hypotheses have been proposed that describe known behavior of hadron interactions at cosmic ray energies and at pre-NAL laboratory energies. Results from the bare 30-inch HBC program will decide between some conflicting models.

Charged particle multiplicity increases with energy in the hypothesis of limiting fragmentation[1], the multiperipheral model[2] and the statistical model[3]. From the observed scaling of topological cross sections and other theoretical arguments, it approaches the limiting value of six[4]. From lower momenta accelerator data the multiperipheral model predicts about 6.4 and the statistical model predicts about 8.3 for charged particle multiplicities at 400 GeV/c laboratory momenta[5]. Present accelerator and cosmic ray data favor the multiperipheral model[5], but the bare 30-inch chamber program at NAL can provide a definitive answer from unbiased multiplicities known to better than two percent accuracy.

The existance of pionization (pions at rest in the C.M. system predicted by some hypotheses, excluded by others) can be detected in longitudinal momentum distributions for the first time at NAL energies. Diffraction dissociation[6] of beam and target hadrons can be studied. Topological cross sections qualitatively follow a Poisson distribution[7] in the number of prongs and they obey a

II. (Continued)

simple scaling law when pairs of particles share the same total energy[8]. These phenomena need checking at NAL energies. New data on neutral particle multiplicities can be obtained. About four per cent of the photons will make pairs in the HBC so the π^o multiplicity can be measured to about 10 percent accuracy. Cruder estimates for neutron, Y^o and K^o multiplicities would be obtained.

The search for unexpected results will focus on stable or long lived beam particles produced at the primary target and on new secondary particles produced in the HBC. The latter could be detected by their decay sequence if the lifetime, τ, is in the range ($10^{-10} < \tau < 10^{-12}$ sec) or by their characteristic interaction.

The dependence of experimental results upon energy and projectile constitute a substantial fraction of the useful data expected from the bare 30" HBC program at NAL. To minimize systematic bias variations in these data, we believe that these groups should keep in touch with each other. Maturity of the bubble chamber technique and the experience of previous successful large collaborations favor achievement of bias control with a minimal number of contacts. The groups could neet at NAL before the first exposures to discuss experiment priorities, picture quality tolerances and data extraction and processing procedures (including scanning rules and data summary tape formats). At about two month intervals after pictures are taken, meetings could be held at NAL to compare results and work out bias control problems. For some events, highest measurement resolution or advanced automation is required. In some instances special measuring resources of one group might be used for complex events from other groups.

Most of the useful results, such as total and elastic cross sections, particle dissociation, longitudinal momentum distributions, neutral particle multiplicities will be improved by electronic, or 15' bubble chamber, or hybrid programs at NAL. However a few results such as topological cross sections and

II. (Continued)

charged particle multiplicities should be definitive. More speculative is the exciting possibility that nature will reveal some new features that will significantly advance our understanding the laws governing hadrons.

III. Experimental Arrangements

Fifty thousand $\pi^- p$ photographs at 120 GeV/c in the bare Argonne 30" HBC are requested. An alternate momentum of 200 or 400 GeV/c is acceptable. The beam momentum resolution is less critical for topological and total cross sections than for missing mass determination and unique identification of four constraint fits.

A few of the first high energy pictures would be needed to tune our data extraction and processing resources in order to accelerate the schedule for final results. Up to about ten tracks per picture seem optimal, but this number should be adjusted after early rolls have been scanned.

Bubble size should be optimized for scanning contrast, with smaller bubbles favored for better resolution of fast forward secondaries. Lacunarities* near 0.5 are optimal for bubble density and point data[9]. Six times minimum density tracks, 30 cm long, would still exhibit about 15 misses in 1000 HPD hits for about thirty micron bubble images. Then the number of overlayed forward secondaries could be measured up to five by their effective bubble density. At least three and if possible five or more glass "X" fiducial marks for HPD detection are required. Either the 35mm or the 70mm film is suitable, with 70mm film favored for resolution of fast forward tracks.

*Average fractions of tracks consisting of gap.

IV. Apparatus

At least two physicists per picture-taking shift to monitor film quality will be provided. A continuous film developer is desirable so final developed film can be related qualitatively to test strip developed film. A scan table for immediate scanning would be desirable.

The contamination of undesired particles in the beam needs to be measured to an accuracy of about two percent of all tracks for correction of the total cross section data. Particularly important is the number of muons in the beam. We are able to provide counters behind the HBC to measure this contamination if necessary.

To measure charge of beam particles produced at the target using bubble density, the age of the tracks must be uniform to a few microseconds. We are able to provide counters to drive one or two bits in the HBC data box for the purpose of marking pictures with early and/or late beam tracks.

V. Data Extraction and Processing

A physicist will be assigned to each scan shift to maintain contact with film and scanners. To find every event, including related neutral vertices, film would be double scanned in random roll order. Discrepancies between the two scans would be resolved and corrected, making use of vertex coordinates measured (±25 μ) on each single scan. All events (primary and secondary vertices) would be measured. Precision coordinates and bubble density of all tracks would be extracted from HPD digitizations by track recognition programs, supplemented as required by a very high resolution manual-recognition station[10]. The full range of magnifications here will greatly aid the understanding of complex jets of particles. A three view geometry diagnostic program is on-line to check predigitization, computer track recognition and manual track recognition to guarantee accuracy of the extracted data.

If fast forward secondaries are separated by only a few track widths, they would be matched by correlations of their linear bubble distribution. If they are overlayed, their number would be determined by the apparent bubble density.

Sixty scan table shifts per week and fifteen Mark II HPD shifts per week are available for this experiment. A few thousand events per week should be completed.

VI. Data Analysis Priorities and Problems

After scanning is completed, topological and preliminary total cross sections will be obtained. An approximately two percent correction must be made for undetectable forward elastic events. This result will be finalized after elastic events have been measured. Charged particle multiplicities would be completed except for addition of events where the number of forward secondaries is found by effective bubble density measurement.

After the first measurement pass, all low energy tracks from less complex verticies would be available. One could begin to look at missing mass to the final proton and other inclusive reaction behavior.

Four constraint events would be identified, including the elastic scattering sample. Since the coplanarity constraint is frequently lost by HBC angle resolution at NAL energies , π^0 production will contaminate the elastics. A longitudinal phase space plot of all candidates interpreted as π^0 production will permit their separation to the extent allowed by beam momentum resolution.

After the remeasurement pass all tracks from all verticies would have been measured. Fast forward tracks will give most difficulty. For single and superposed tracks with sagittae less than one-tenth bubble-width, the direction will be known but the sign of charge must be determined from charge conservation at the primary and/or secondary verticies. For superposed tracks, the effective bubble density will indicate the number of tracks if they have unit charge.

Neutral particle multiplicities need to be corrected for neutral verticies lost in the confusion of forward tracks. Here longitudinal distribution of bubbles in jets may indicate the presence of hidden neutral verticies. The range of magnifications available at our manual track recognition station will allow the operator to probe transverse structure in the jet for signs of missing verticies. A final appeal to microscope examination of the jet

VI. (Continued)

would be made when necessary. When secondary track data had been extracted from all verticies the charged particle, π^0, neutral hyperon and neutron multiplicities could be obtained and final data display figures would be plotted.

A systematic study of beam tracks would be performed. They would be digitized and reconstructed to obtain their bubble density and distribution of small angle kinks. The bubble density distribution for tracks of the same age is related to charge of particles in the beam. Kinks down to about ten milliradians should be found with useable efficiency[11]. All candidates would be displayed at high lateral magnification (an electronic anamorphic lens) for inspection. Elastic events would have visible recoil protons, so kinks are evidence for decays of particles produced at the target. Since the decay geometry reduction is 10^{-4} for an optimal mass-lifetime combination, detection of kinks above this level would upset our understanding of known particle decays.

VII. References

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