FNAL Proposal No. 343

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PROPOSAL TO STUDY NEUTRAL PARTICLE PRODUCTION IN 250 GeV pp INTERACTIONS IN THE FERMILAB 15-FOOT BUBBLE CHAMBER

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SUMMARY

We propose a small exposure (25K pictures) of the hydrogen-filled FNAL 15-foot bubble chamber to a 250 GeV proton beam.

Our main physics objectives are:

1. To study the dependence of neutral particle production (π^o, K^o, Λ) on the charged multiplicity in diffractive and non-diffractive processes.
2. To measure integrated correlations ($f_2^{\pm 0}$ and f_2^{00}) for neutral pions in a "clean" experiment.

To make these measurements reliably requires neutral particle detection in both CM hemispheres and the CM symmetry of the pp system. For example, we will determine f_2^{00} to ± 0.2.

The event analysis of the neutral secondaries together with the measurement of the slow laboratory protons in $pp \rightarrow p_{slow} + X$ for the distinction between diffractive and non-diffractive events will be done in 1/2 year.

Further objectives are:

3. To measure differential neutral-charged correlations.
4. To measure multiplicities, spectra and correlations ("inclusive program") inside the mass M_X in $pp \rightarrow p_{slow} + X^{-}$.

OUTLINE OF THE PROPOSAL

I. Exposure and Event Rates

A. Choice of Beam Particle and Incident Momentum

The correlation measurements proposed must be done with known detection efficiency which can be checked by exploiting the CM symmetry of the pp system.

For convenience, the beam momentum should be close to the accelerator energy. Furthermore, 250 GeV allows comparison with the π^-p engineering run in the 15-ft bubble chamber.

B. Fiducial Volume and Beam Intensity

The upstream 2.5 m of the bubble chamber are chosen as fiducial volume which leaves at least 1 m for V^o and γ secondaries. With an average of three beam protons per picture, one out of 1.5 interactions per frame are in the fiducial region.

The scan, as well as $V^o(\gamma)$ association with primary interactions with this intensity, will be fast and reliable.

C. Event Rates

Event Type	No. of Observed Events	Comments
$pp \rightarrow X$	23,000	a)
$pp \rightarrow p_{\leq 1\ GeV} + X$	8,000	b)
$pp \rightarrow \gamma + X$	9,200	c) 5500 (1γ Events) 1350 (2γ Events) 270 (3γ Events) 40 (4γ Events) 5 (5γ Events)
$pp \rightarrow K^o_s + X$	2,500	d)
$pp \rightarrow K^o_s + K^o_s + X$	350	d)
$pp \rightarrow \Lambda + X$	1,000	d)
$pp \rightarrow \bar{\Lambda} + X$	100	d)

The following input data and/or assumptions were used in order to estimate these rates:

a) The topological cross sections from the 30-inch bubble chamber 205 GeV pp exposure[(1)] were used.

b) The slow protons will be identified by their ionization[(2)] and by trapping in the chamber with a field of at least 20 kG. The fraction of events with proton momenta of $P \leq 1$ GeV/c was estimated from the 205 GeV data.

c) The γ detection efficiency was estimated to be ~ 8[illegible] from the conversion length, the fiducial volume and minimum observable distance from the production point. This value is compatible with experience gained in an experiment in the ANL 12-ft bubble chamber.[3] The number of n-γ events was estimated assuming that

$$\sigma(\pi^o) = \frac{1}{2}\left[\sigma(\pi^+) + \sigma(\pi^-)\right]$$

and using the 205 GeV topological cross sections for $\sigma(\pi^{\pm})$.

d) The CM cross sections $d\sigma/dP_{CM}$ from the 205 GeV data were used in order to calculate the V^o detection efficiencies.

II. Physics Objectives and Measurements

We list our physics objectives starting with the measurements considered most important and feasible.

A. Integrated Correlations for Neutral Secondaries

1. Dependence of $\langle \pi^o, K^o, \Lambda \rangle$ on Charged Multiplicity for Diffractive and Non-Diffractive Processes

Recent studies[4] of the dependence of the average π^o multiplicity

$$\langle n_o \rangle = \alpha + \beta n_- \tag{i}$$

seem to indicate that the previously observed[5] correlation (i) between $\langle n_o \rangle$ and n charged disappears if "diffractive-type events" (see III, B) are removed from the event sample, i.e. the correlation does not hold for the major part of the inelastic cross section!

Since this correlation is one of the main motives for the generation of cluster models in the description of multiparticle production, it is extremely important to find out, beyond any doubt, whether or not the apparent correlation (i) is only a numerical accident caused by mixing diffractive and non-diffractive events. The measurements will be done for $n_o = \pi^o$ and will be expanded to $n_o = K^o, \Lambda$ as well (for further details, see III, A).

2. $f_2^{\pm 0}$, f_2^{00} for Pions

The next step in the investigation of multiparticle production will concentrate on the reliable measurement of the Mueller correlation parameter f_2^{00} for π^o production

$$f_2^{00} = \langle n_o (n_o - 1) \rangle - \langle n_o \rangle^2 \quad .$$

Under the assumption that almost all γ's originate from π^o decays,[3, 4, 7] we can rewrite the parameter as

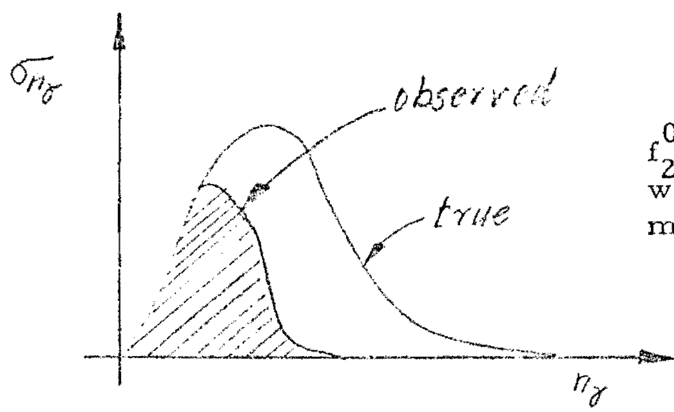
$$f_2^{00} = \frac{1}{4} \left[\langle n (n-1) \rangle - \langle n \rangle^2 \right] - \frac{1}{4} \langle n \rangle$$

with $\langle n \rangle$ being the average number of γ's.

We will determine f_2^{00} in this experiment to an accuracy of ± 0.2. Hence, a comparison of the energy dependence of this parameter is possible. Specifically, f_2^{00} has been determined accurately at 12 GeV/c[3] as 0.29 ± 0.33, a value compatible with zero. Another very inaccurate value of -2 ± 1 has been published for 70 GeV.[7]

[illegible] the energy dependence of f_2^{00} [illegible] $f_2^{\pm 0}$ and f_2^{--}, one can distinguish between different production mechanism models. In particular, the measurement of f_2^{00} at fixed n_{charged} is an excellent tool to distinguish between various cluster production models which are believed to describe the major part of the inelastic cross section for multiparticle production. (6)

The difficulty for measuring f_2^{00} is the accurate determination of the width of the γ-multiplicity distribution in the entire available phase space. This width is extremely sensitive to the observed number of high γ-multiplicity events. A small but unknown bias in the γ detection shifts f_2^{00} by large amounts.



f_2^{00} is sensitive to events with large observed γ-multiplicity ($n_\gamma \geq 3$).

Attempts to measure f_2^{00} include the 30-inch hybrid system. (8) However, in that experiment, only γ's emitted in the forward CM hemisphere are detected. In order to extract f_2^{00} from the data, one assumes the shape of the differential distributions in order to predict the γ-multiplicity distribution in one hemisphere. Furthermore, the amount of background γ's from secondary interac-

[illegible]

Another attempt towards f_2^{00} will be made by the current 250 GeV π^- engineering experiment in the 15-ft bubble chamber. That experiment has 4π solid angle detection around the γ-source and, contrary to experiments with H_2-Ne mixtures, has a clean target. However, the γ-detection efficiency in the hydrogen-filled 15-ft bubble chamber is estimated at about 8%, and thus one observes only a small part of the true γ-multiplicity distribution as sketched above. Hence, it is extremely important to know the multi-γ-detection efficiency. This can be checked in a pp exposure using the pp CM symmetry as in this proposed experiment!

B. Neutral Secondary Spectra

The accuracy of determining the cross sections and spectra for π^o and V^o production depends crucially on a well-understood detection efficiency (for details on γ, K^o, Λ separation, see III, A) for fast γ's and V^o's around the 90^o CM boarder. In a pp system, one can measure across the 90^o line up to say $x = 2P_L^*/\sqrt{s} \leq +0.05$ and check the kinematics by folding about $x = 0$.

The measurements discussed so far are our main physics objectives and will be executed within one-half year (see III, C). The following measurements are considered a second stage of the experiment, not due to their "physics rating," but rather due to limited statistical and/or longer analysis time needed.

C. <u>Differential Correlations Between Neutral and Charged Secondaries</u>

The physics interest is evident from the section on integrated correlations. We will measure $(n_o \pi^{\pm})$ differential correlations in rapidity and transverse momentum for $n_o = \pi^o, K^o$, e. g.,

$$C(y_1, y_2) = \frac{1}{\sigma} \frac{d^2\sigma}{dy_1\, dy_2} - \frac{1}{\sigma^2} \frac{d\sigma}{dy_1} \frac{d\sigma}{dy_2} .$$

Of the one-third of the events in our exposure which have a V^o or γ associated with them, we will reconstruct all tracks. Track-matching can be done by computer matching: the produced fast tracks exit through the downstream Scotchlite and leave a clearly visible endpoint.[9] This matching can be done quickly with the special resolution of one-point-reconstruction. We emphasize that the downstream end of our fiducial volume is far enough upstream to allow for sufficient spreading of the fast tracks.

Other studies will include the ~350 $(K_s^o K_s^o)$ events. We will look [illegible]

production such as $f^* \rightarrow K\bar{K}$.

D. "Inclusive Program" for Charged Secondaries Inside the Mass M_X in $pp \to p_{slow} + X$

The multiplicity distribution inside the mass M_X in this reaction seems to be very similar[10] to the multiplicity distribution in $pp \to X$ at $\sqrt{s} \approx M_X$. Even the π^- rapidity distribution inside M_X shows such a simple regularity.[11] These points will be investigated with better statistics and extended to two-particle correlations.

III. Event Analysis

A. Separation of γ, K^o, Λ, $\bar{\Lambda}$ Events

The γ's and V^o's will be measured and identified by a kinematical 3C fit. The resolution in the 15-ft bubble chamber will be better by about a factor of 5. This value was arrived at from $\Delta P/P \propto \epsilon/L^2$ with ϵ being the setting error in space, which is given at $300\,\mu$ for the 15-ft bubble chamber,[12] a factor of five larger than the value for the 30-inch bubble chamber. However, the average track length in the large chamber is about five times as large as in the 30-inch bubble chamber.

We assume in the backward hemisphere toward the target fragmentation region (here Coulomb errors become important), a resolution similar to the 30-inch bubble chamber, and in the central region and beam fragmentation region a much higher resolution. The kinematic ambiguities between γ, [illegible] cuts in the transverse momentum (P_T^-) distribution of the negative V^o

decay secondary in the V^o rest frame. This is plausible since for $\Lambda, \bar{\Lambda}$ and K^o events, the fraction of the total number of events expected between $P_\perp$ and $P_\perp + dP_\perp$ is

$$N(P_\perp^-)\, dP_\perp^- = \frac{P_\perp^-}{P^*} \frac{dP_\perp^-}{\sqrt{P^{*2} - P_\perp^{-2}}} \quad ,$$

where P^* is the CM decay momentum. Experience with the 205 GeV data shows that the γ- (K^o, Λ, Λ) ambiguities can be resolved to better than 1%. The K^o sample is clean after an appropriate cut in the $P_\perp^-$ distribution and the Λ sample has a possible 5% K^o background.

The separation becomes, however, exceedingly difficult in the forward hemisphere due to a sharp increase in V^o laboratory momentum as one moves across the x = 0 line into the forward hemisphere. Fig. 1 shows the expected observed x-distributions for forward γ's, K^o, Λ's. For example, about 20% of the forward γ's lie in the region $0.05 \leq x \leq 0.2$ with a K/γ ratio of ~ 0.6 and a Λ/γ ratio of ~ 0.15. The K(Λ) laboratory momenta are very high and vary from 15 (20) to 50 GeV in this region. The use of the pp CM symmetry in folding and checking the data becomes, therefore, extremely important. Recall that a very small bias in the detection of multi-γ events causes a large shift in f_2^{00}.

B. Separation of "Diffractive" from "Non-Diffractive" Events

We will adopt the following operational definition of "diffractive" events (present convention): Events of the type $pp \to p_{slow} + X$ in the low mass (M_X) peak with $M_X < 5$ GeV will be called "diffractive." In order to obtain these events, one only requires the measurement of the slow target proton.

C. Analysis Effort

We estimate scanning and measuring rates based on experience with 12 GeV pp interactions in the ANL 12-ft bubble chamber as well as the 205 GeV pp data from the 30-inch bubble chamber experiment. In addition, we already have scanned some 250 GeV π^-p film from the 15-foot bubble chamber engineering run.

Based on all this experience, we estimate a need of four man-years for one complete scan plus a partial rescan, as well as all measurements and remeasurements in order to finish the physics discussed in Section II(Parts A, B, C). With the planned effort of the collaboration, this part of the analysis will be done in about one-half year.

References and Footnotes

1. S. Barish et al., ANL/HEP 7361.

2. The ionization in the 15-ft bubble chamber is similar to the ANL 12-ft bubble chamber. Their experience shows that protons with $p_{lab} \leq 0.8$ GeV can be identified by ionization.

3. J. H. Campbell et al., Phys. Rev. D8, 8324 (1973); D. Swanson et al., Phys. Letters 48B, 479 (1974).

4. J. Whitmore, 205 GeV pp data, private communication.

5. F. T. Dao and J. Whitmore, Phys. Letters 46B, 254 (1973).

6. D. Horn, A. Schwimmers, Nucl. Phys. B52, 627 (1973); P. Grassberger, and H. I. Miettinen, CERN Preprint Ref. TH. 1870 (June 1974).

7. G. Blumenfeld et al., Phys. Letters 45B, 525 (1973).

8. ANL, Iowa State University, University of Maryland, Michigan State University and FNAL, Contribution to Session A2 of the Conference on High Energy Physics, London, June 1974. The quoted value for $f_2^{00} = -(0.5 \pm 0.6)$.

9. We found this to be the case when scanning some $\pi^- p$ "engineering" film.

10. S. Barish et al., Phys. Rev. Letters 31, 1080 (1973); J. Whitmore and M. Derrick, Phys. Letters 50B, 280 (1974).

11. J. Whitmore, [illegible]

Conference on High Energy Physics, London, June 1974.

12. Found in the $\pi^- p$ 250 GeV engineering run (private communication, R. Huson).

FIG. 1

EXPECTED OBSERVED $\gamma, K^{\circ}, \Lambda$
DIFFERENTIAL CROSS SECTIONS
IN THE FORWARD HEMISPHERE