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A 15 Foot Bubble Chamber Proposal for 485 GeV/c $\pi^- p$ Interactions Using a Track Sensitive Target

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We request 250,000 pictures of $\pi^- p$ interactions in the 15 foot bubble chamber at 485 GeV/c using the full magnetic field. The data will be processed with a unique 3-D automatic measuring device which provides:

1) good performance with high multiplicity and crowded topology,
2) automatic track matching by bubble-gap coincidence,
3) ultimate state-of-the-art measurement precision,
4) flexibility and operator intervention needed in handling complex events with multiple gamma conversions,
5) the ability to cope in an automatic way with non-linear optics in the 15 foot chamber and the obstructions, flares and multiple indices of refraction associated with the track sensitive target,
6) measurement speed that makes it possible to do a high statistics bubble chamber experiment even at high energy with a reasonable amount of time and expense.

Even with this device the task requires an investment of time and money that can be justified only when the highest magnetic field and the highest energy are available.

Physics Justification

It has become clear that an important change emerges in strong interactions above 50 GeV/c beam momentum and that this change becomes increasingly significant as the energy increases. We list some of these energy dependent changes below:

1) The average charged prong multiplicity for a produced mass M* changes from nearly linear in M* below 50 GeV/c to nearly ln M* above 50 GeV/c.[1] (See Fig. 1.)

2) The average number of π^0's produced with a fixed number of charged particles increases with the energy.[2] (See Fig. 2.)

3) The various integrated correlation functions, f_2, that can presently be measured indicate a near zero correlation around 50 or 100 GeV/c which increases very rapidly with energy beyond that point.[2] (See Fig. 3.)

4) Counter experiments at high energy observe particles with p_T an order of magnitude greater than the average p_T.[3-5] When these particles are π^0's (a convenient trigger), they are highly correlated in direction with other tracks.[3,5] (See Fig. 4.) This may only be the infrequent (but more easily distinguishable) tail of a distribution from some phenomena which is more common at lower p_T and readily studied in a TST bubble chamber experiment. That is, if correlated jets are produced, counters

can recognize them only for exceptionally large p_T and tightly defined clusters. Such clusters are rare. A bubble chamber could see the more numerous jets (if they exist) at smaller p_T that cover much larger solid angles with their clusters. Since much of the p_T will be carried by π°'s, it may be necessary to detect them in order to study the jets.

Understanding the behavior of the π°'s in the final state may be an important step in studying all of the changes listed above. Only the bubble chamber is capable of making a general 4π steradian study of correlations. Because of the poor γ-conversion efficiency bubble chambers have so far been able to look at differential correlation functions only for charged particle pairs: $\pi^+\pi^-$, $\pi^-\pi^-$ and $\pi^+\pi^+$. For π°'s one has at best been able to obtain integrated correlation functions and these at most contain one π° (e.g. $f_2^{+\circ}$ and $f_2^{-\circ}$). Since the role of the π° appears significant in items 2-4 listed above, it seems important to study differential correlations involving π°'s and charged particles as well as those involving $2\pi^\circ$'s. The $2\pi^\circ$ correlation is perhaps the most desirable to obtain since it is the only one clearly uncomplicated by charge conservation effects.[6]

On the other hand, $2\pi^\circ$ correlations are the most elusive experimentally. This problem is best illustrated by examining what is required to obtain the integrated correlation function $f_2^{\circ\circ}$, the simplest parameter one might hope to measure.

$$f_2^{\circ\circ} = \langle n_o(n_o - 1)\rangle - \langle n_o\rangle^2$$

where n_o is the number of π°'s in an event and $\langle n_o\rangle$ is the average number of π^o's in an event.

$$\langle n_o(n_o - 1)\rangle = \sum_c(\sum_{n_o} (n_o^c)(n_o^c - 1)F_o^c)\sigma_c/\sigma_{tot}$$

where σ_c = cross section for c charged prongs

c = number of charged prongs in an event

n_o^c = number of π^o's in an event with c charged prongs

$F_{n_o}^c$ = fraction of events with c charged prongs that have n_o^c π^o's.

This last average can be very difficult to define experimentally. As c increases, σ_c does decrease rapidly as one might hope, but the sum of products in parenthesis grows with increasing c because the fraction of events with a large number of π^o's does not tend to decrease rapidly with increasing n_o. Events with large numbers of π^o's thus dominate the average. When gamma conversion efficiency is low, one can never convert enough gammas from these events to estimate what the fraction E_{n_o} is. For this reason a bubble chamber with high conversion efficiency is essential. There is no other technique for obtaining this correlation information.

A TST in the 14 foot chamber will make it possible to study π^o correlations in an inclusive way without constraining the entire event. This task is in no way as simple as the typical inclusive study of charged tracks. The converted pairs will also bremsstrahlung, and frequent secondary interactions will produce spurious sources of gammas which will also point to the primary vertex. Interactions in the entrance window of the bubble chamber can also produce gammas. A careful analysis will require severe cuts on fiducial volume, entering beam hodoscope, secondary interactions, and gamma pointing angles. These cuts can be expected to reduce the yield of useful <u>high multiplicity</u> events by as much as a factor of 10. Additional care will be required in measuring only the length of track needed for an optimum momentum measurement, since the heavy liquid introduces small nuclear scatters, undetected bremsstrahlung (for e^+e^-), and large multiple scattering. We hope to automate the feature which limits the track length measured.

It should be possible without constraining entire events to search for particular resonances with π° or electromagnetic decay modes. One possible explanation for the unusual dependence of $\langle n_{\pi^\circ} \rangle$ on charge multiplicity is that resonances are produced in an abundance which is comparable to single pion production. In particular, ρ, ω° and ε° production have been postulated. These resonances would make their presence felt in the correlation functions previously discussed, but the most direct evidence could come from the effective mass spectra. The effective 2π mass spectrum for charged pairs peaks well below the ρ mass, but it will be difficult to identify the ε° here without a $\pi^\circ\pi^\circ$ spectrum. Such a resonance which could also decay into $\mu^+\mu^-$ with a branching ratio of about 10^{-4} is also indicated by the large μ/π ratio found in strong interactions.[7]

We believe there is some possibility of obtaining 4-C kinematic fits with a limited sample of the data. The unreliability of such fits at high energy is well known to those who have tried them first without using information from converted gammas and then checked them against observed e^+e^- pairs. With the neon converter we hope to preselect a sample of events to which one can apply constraints more reliably. Events with no gamma conversions will be the most hopeful candidates. Those with converted gammas and a good transverse momentum balance may also be useful. Information on exclusive channels at NAL energies has been very limited. The TST may make it possible once more to have some of this information although the sample will be small and the effort enormous when compared to lower energies.

Analysis

Experimenters in this group have had considerable experience with gamma detection in bubble chambers. We have used Ta plates in the PPA rapid cycling chamber[8], MURA 30" chamber[9], and BNL 80" chamber.[10] In a 25 GeV/c π^-p experiment in the 80" chamber we initiated the technique now used for inclusive gamma studies in hydrogen chambers. By the time the TST is available in the 14 foot chamber we will have completed a 25 GeV/c π^-p run using a TST in the BNL 80" chamber and a neon run at NAL in the 30" chamber. We know that working with gammas is many times more difficult than a typical bubble chamber experiment. We are also aware that this difficulty will be compounded by the high multiplicity and high momentum. However, a TST in the 15 foot chamber offers a unique opportunity to obtain physics information that can be had no other way.

Our confidence that we can handle a large amount of such complex data in a more than cursory way is based almost entirely on the existence of a Semi-Automatic Track Reconstruction device (SATR) which exists at Wisconsin. This device digitizes all three views of the bubble chamber at once with a film plane HPD, giving the best available accuracy. A very high speed (150 ns multiply), specialized computer generates optical rays for each digitized bubble and demands a coincidence of these rays in space in order to follow tracks through the bubble chamber in 3-D. There is no need for a TVGP reconstruction program or assumptions of linear optics. Control of the device is given to an operator who can assist or intervene in the measuring process. A Fortran control program in a conventional supervisory computer makes it relatively simple for a physicist to alter the mode of operation of the device to meet special demands presented by the data. SATR is currently being used to measure 100 GeV/c π^+p data in the 30" HBC. It appears to be especially useful in measuring high multiplicity events where the track matching problems become formidable with conventional techniques.

Special Requirements

We have assumed a 33% atomic mixture of neon in hydrogen. It would be necessary to examine again our goals and analysis methods if the mixture is to be much greater or less than this. Another assumption is that the TST will be constructed in such a way as to give at least 4 feet of visible converter mixture downstream of the TST.

Each beam track entering the bubble chamber must be tagged with respect to position. This will help in eliminating frames with extraneous gamma sources in the upstream chamber walls and entrance windows. Failure to observe a tagged beam track in the bubble chamber will mean that it has interacted upstream. Use of this tagging system will make it possible to get some simple results from scanning and counting without extensive measuring and fitting. If NAL does not have a tagging facility at the time of this run, we will provide a scintillator tagging system.

References

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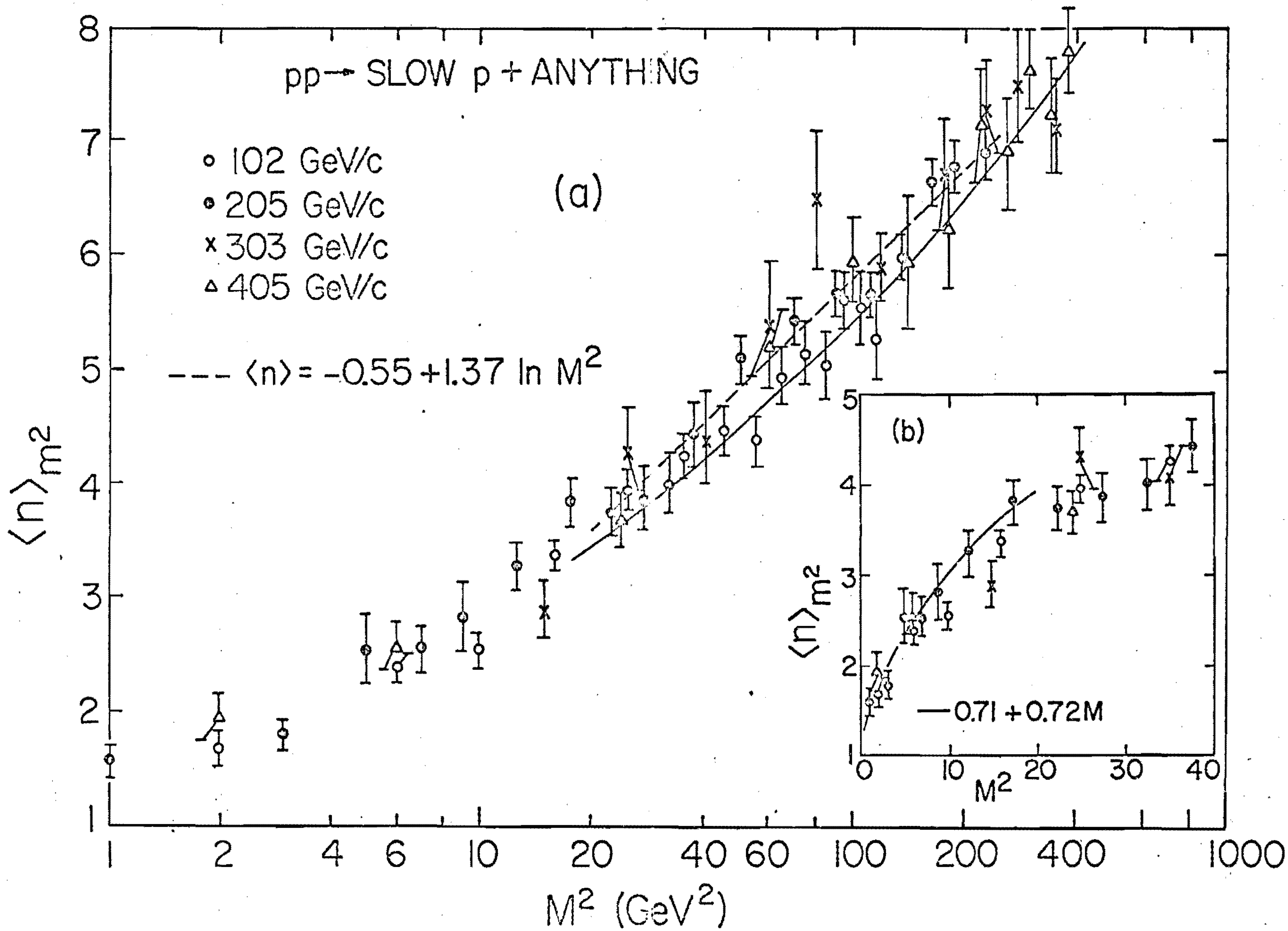

pp→ SLOW p + ANYTHING
○ 102 GeV/c
⊙ 205 GeV/c
× 303 GeV/c
△ 405 GeV/c
(a)
--- ⟨n⟩ = −0.55 + 1.37 ln M²
⟨n⟩m²
M² (GeV²)
(b)
—0.71 + 0.72M
⟨n⟩m²
M²

Fig. 1

Dao & Whitmore

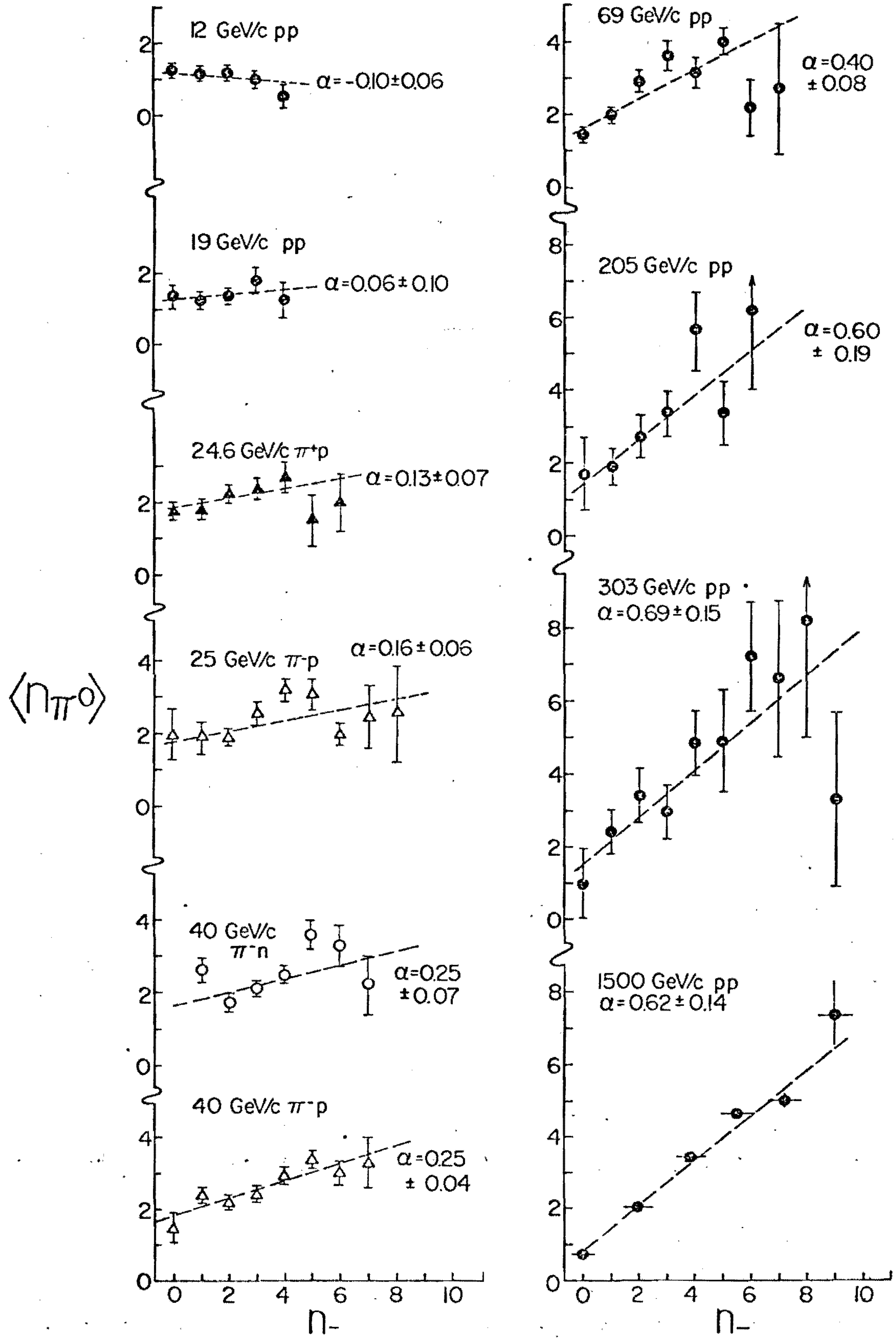
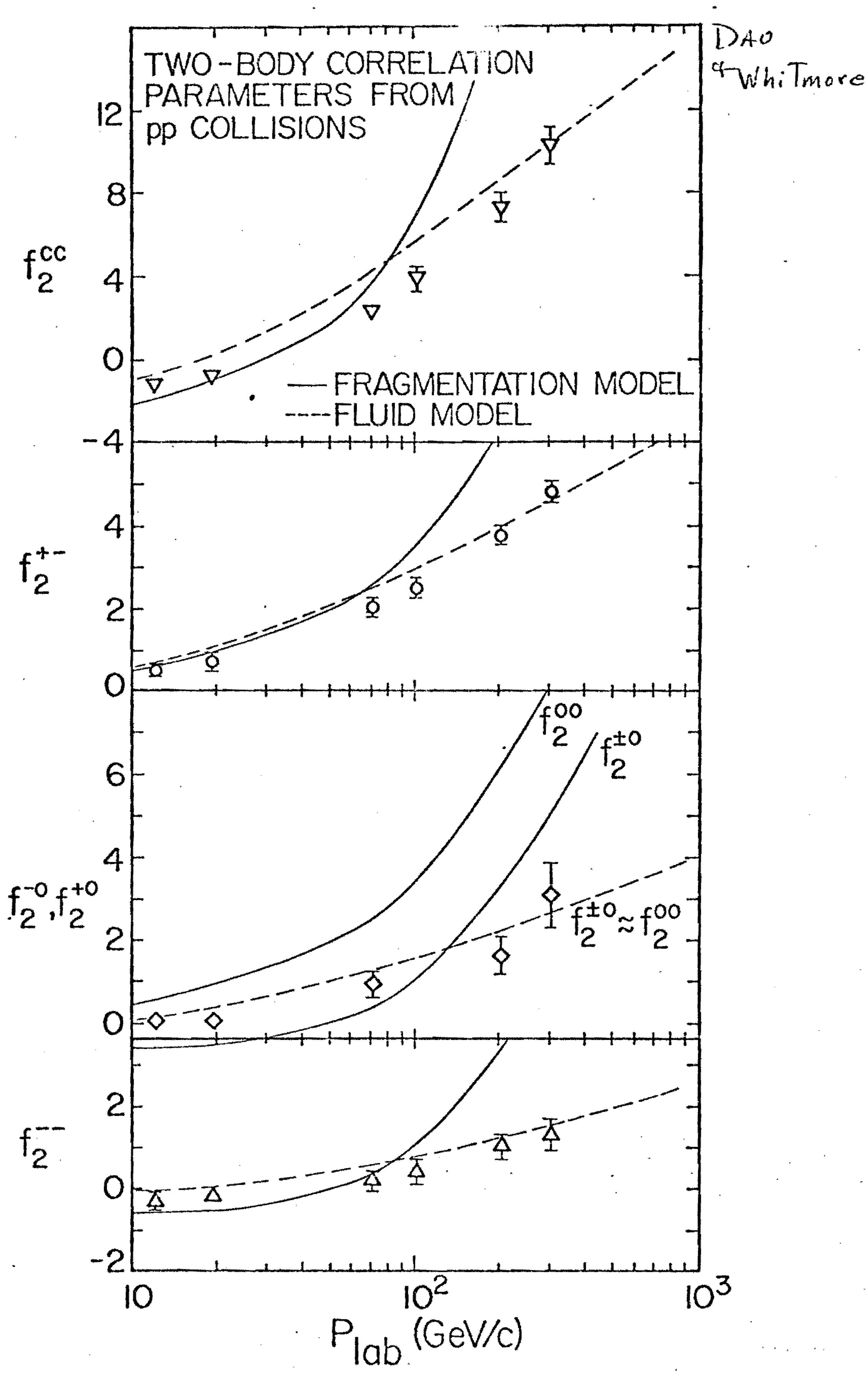


Figure 2



DAO & WhiTmore
TWO-BODY CORRELATION PARAMETERS FROM pp COLLISIONS
— FRAGMENTATION MODEL
---- FLUID MODEL
f_2^{cc}
12
8
4
0
-4
f_2^{+-}
4
2
0
f_2^{00}
$f_2^{\pm 0}$
f_2^{-0}, f_2^{+0}
$f_2^{\pm 0} \approx f_2^{00}$
6
4
2
0
f_2^{--}
2
0
-2
10
10^2
10^3
P_{lab} (GeV/c)

Figure 3

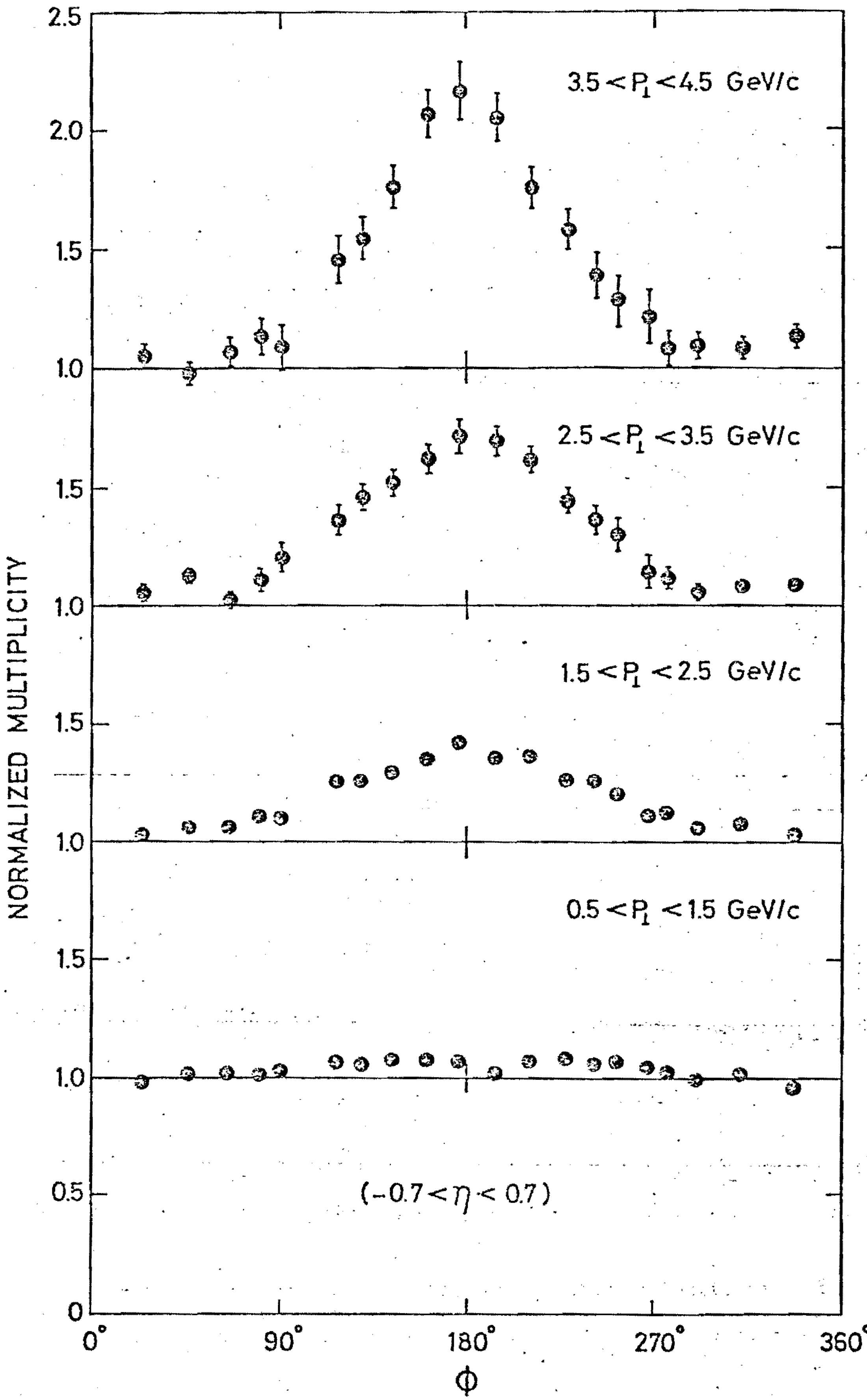


Fig. 4 Normalized partial multiplicities in the interval $-0.7 < \eta < 0.7$ as a function of the c.m. azimuthal angle. The photon detector is at $\phi = 0°$.