PHOTOPRODUCTION EXPERIMENTS IN THE 25-FOOT HYDROGEN BUBBLE CHAMBER

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ABSTRACT

The possibility of an experiment in the twenty-five foot hydrogen bubble chamber with energies up to 125 BeV is explored.

I. INTRODUCTION

There is considerable interest in the production of hadrons by photons at higher energies. These experiments are usually best done on electron accelerators. However, the highest energy electron accelerator in sight is 20 to 40 BeV. Although there are plans to increase the energy of the SLAC electron accelerator to 100 BeV by superconductive means, these will not materialize before the completion of the NAL accelerator. Thus the region of photon energies from about 25 to 150 BeV will be unique to the 200-BeV proton accelerator at the National Accelerator Laboratory.

The proposed 25-ft liquid hydrogen bubble chamber is one of several possible detectors that can be used to study photoproduction processes. It should be feasible to build a tagged photon beam to the chamber giving a 1 to 2% photon energy resolution. In a 10^6 picture run, sensitivities of the order of 2000 events/microbarn can be obtained. The total hadron production cross section is expected to be about 120 μb, yielding a total of 270,000 events. Even though these events will be divided into many channels, detailed studies of many reactions should be possible.

The bubble chamber makes it possible to study reactions in which more than a few particles occur in the final state, which are difficult for other techniques. Even for simple processes like $\gamma p \to \rho^o p$, and $\gamma p \to \omega^o p$, the numbers of events produced above 100 BeV or so are comparable with those that can be obtained by other techniques. This is partly because of the large target mass of the 25-ft chamber and the

4π detection of secondaries, and in part because the photon yields at NAL drop off above 100 BeV and the bubble chamber can accept a non-trivial fraction of the total flux available to any technique.

II. THE TAGGED PHOTON BEAM FOR THE BUBBLE CHAMBER

The general method of producing photon beams at NAL has been discussed in the 1968 Summer Study by C. A. Heusch and others.[1] The basic idea is to use the protons from the accelerator to produce π^0's. A neutral beam is then selected, containing photons from π^0 decay as well as other neutral hadrons. To purify the beam, a thin radiator is used to produce an electron beam, which in turn is passed through a thin radiator to produce photons again. A very pure, although not terribly intense, photon beam should result from this two-step process.

The procedure for tagging the photons is a fairly standard one and is shown schematically in Fig. 1. The thin radiator (~0.02 radiation lengths) that produces the bremsstrahlung photons is followed by a bending magnet M2 which bends the recoil electrons into the tagging counters. The energy of the radiated photon then is taken to be the energy of the original electron beam minus the energy of the recoil electron.

There should be no problem in achieving a 1 to 2% precision in the photon energy by tagging. The electron beam should have a momentum spread of less than 1%. For a 150 BeV/c electron beam, a strength of 200 kG-meters for the tagging magnet M2, with the tagging counters about 10 meters from M2, would give the desired resolution with reasonably sized tagging counters.

In order to associate any particular event in the chamber with the proper electron tag, a bending magnet M1 is introduced just before the radiator. The field in this magnet is raised from near zero to some maximum value during the beam spill, which could be 500 μsec long. Since to a very high precision the photon keeps the direction of the original electron, and the electron beam before M1 is very tightly collimated, the position of the event in the chamber determines the time of arrival of the photon. At an electron beam momentum of 150 BeV/c, a 200 kG-meter field would sweep the photon beam through 40 mrad. If the electron beam spread can be made as small as 1/20 mrad, then a few hundred photons per pulse can be easily resolved from each other in time. With a 20-meter space between M1 and the chamber, the photons would be spread out 80 cm in the chamber. The position of an event should be easy to determine to a fraction of a mm, so again there should be no difficulty in resolving the photons in time from each other.

The optics of the electron beam need be nothing special. The requirements, as stated above, are to produce a 150 BeV/c beam with a momentum spread of less than 1% and a horizontal divergence of ~1/20 mrad (the vertical divergence can be larger).

III. FLUXES AND EVENT RATES

The photon flux that can be accepted in the bubble chamber is limited by production in the photon beam of e^+e^- pairs, which obscure the visibility in the chamber. Previous experience with photon beams in bubble chambers at SLAC indicates that 10 e^+e^- pairs per meter of beam path are quite tolerable. Assuming that this number can be permitted in the 25-ft chamber, we can allow a flux of 150 photons/pulse which will produce about 60 e^+e^- pairs in a 6-meter long fiducial volume. Early experience with the chamber should give some indication whether or not this assumption is too optimistic. A beam of about 10^4 150 BeV/c electrons per pulse would yield this photon flux with a 0.02 radiation length radiator. According to the calculation of Toner[2] and Diebold and Hand,[3] such electron fluxes at 150 BeV/c are easily obtainable with a small fraction of the accelerator intensity.

With the above photon flux, a 10^6 picture experiment will have a sensitivity of 2000 events per microbarn, using a 6 meter fiducial volume in the chamber. Using the $1/E_\gamma$ shape of the bremsstrahlung spectrum for the photon flux, the sensitivity as a function of γ energy can be calculated. These are shown in Table I.

To provide some feeling of what these sensitivities mean, the expected numbers of events for three photoproduction processes are listed in Table I. The cross sections for these reactions have been measured at lower energies; they seem to level off, as the photon energy is increased, to the values[4]

$\sigma(\gamma + p \rightarrow \text{hadrons}) \simeq 120\ \mu b$

$\sigma(\gamma + p \rightarrow \rho^0 + p) \simeq 15\ \mu b$

$\sigma(\gamma + p \rightarrow \omega^0 + p) \simeq 1.5\ \mu b$

We have assumed these cross sections to hold up to 150 BeV in calculating the entries to Table I.

REFERENCES

[1] See the section on Electron-Photon Facilities in the 1968 NAL Summer Study, Vol. II.

[2] W. T. Toner, Electron and Photon Beams at NAL, National Accelerator Laboratory 1968 Summer Study Report B.9-68-31, Vol. II, p. 125.

[3] R. Diebold and L. Hand, Electron-Photon Beam at NAL, National Accelerator Laboratory 1969 Summer Study Report SS-49, Vol. 1.

[4] For a summary see S. C. C. Ting, Proceedings of the 14th International Conference on High Energy Physics at Vienna, 1968, p. 43.

Table I. Numbers of Events Expected in a 10^6 Picture Exposure Of the 25-Ft Hydrogen Bubble Chamber to Photons at NAL.

E_γ (BeV)	Events/μb	$\gamma p \rightarrow$ hadrons	$\gamma p \rightarrow \rho p$	$\gamma p \rightarrow \omega p$
0.5-10	1250	150,000	18,750	1875
10 -50	625	75,000	9,400	940
50 -100	250	30,000	3,750	375
100-150	150	18,000	2,800	280
Total	2275	270,000	35,000	3500

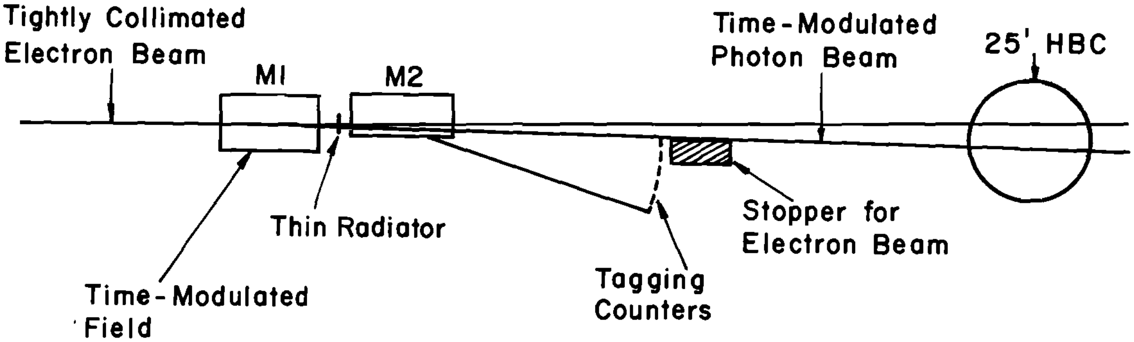

Fig. 1. Schematic layout of a tagged photon beam to the 25-ft bubble chamber (not to scale).