2.7 JET PHOTOPRODUCTION AT THE TEVATRON

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The aim of this note is to emphasize the importance of future fixed-target photoproduction experiments at Fermilab.

Why?

The photon is a unique beam particle in that it is the only one which is its own antiparticle, i.e., it carries no prejudicial quantum numbers like baryon number, lepton number, strangeness, etc., and the photon couples directly as a point-like particle to the charge of the quarks. Consequently, photoproduction can study more directly the quark and gluon interactions[1-3] in high $p_\perp$ and jet production experiments. Hadron beams (π's, p's, K's) necessarily have a soft jet from the beam fragments, which in fixed-target experiments tends to overlap kinematically in the detector with the hard constituent scattering jets. The photon-beam experiments make available a class of simpler 3-jet interactions. This is illustrated in Fig. 1.

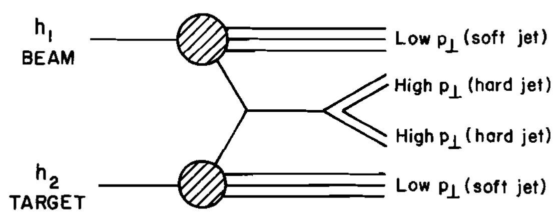

Fig. 1a Hadron-hadron type scattering (4 jet).

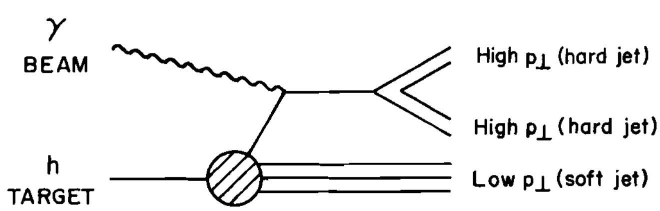

Fig. 1b Photon-hadron type scattering (3 jet).

Theoretically the reactions represented by Fig. 1b are of considerable interest. Experimentally they are easier to analyze than 1a. In addition, all the photon beam energy is available for the hard scattering process. For hadron-hadron scattering in

1a, the scattered quark or gluon in the beam carries a fraction of the beam energy. Thus, photoproduction experiments should have higher rates for measuring the high $p_\perp$ jet phenomena compared to similar energy and intensity hadroproduction experiments.

More thorough physics arguments for the advantages of photon beam experiments are presented by Jeff Owens. We now turn to the present and future photon beams.

Present γ Beams

To date there have been three different high energy photon beam lines used, two at Fermilab and one at CERN. Table I summarizes their experimental parameters. It is clear that the three beams have very different advantages and/or disadvantages for photoproduction physics.

Table I. Present Photon Beams.

	Fermilab Tagged Beam (E-25,152,516)	Fermilab Broad Band (E-87)	CERN Ω Beam (E-WA4)
Primary Protons	400 GeV 6×10^{12}	400 GeV 1×10^{12}	210 GeV 1×10^{13}
E_γ (GeV)	30-150	$50\text{-}250_{max}$ $50\text{-}150_{useful}$	20-70
N_γ/pulse	$\sim 5 \times 10^6$	$\sim 10^7$ (2 cm × 2 cm hole)	$\sim 2 \times 10^5$
Background $\mu/m^2/10^{12}p$	$\sim 10^4$	$\sim 2 \times 10^5$	?
hadrons/γ	$<10^{-6}$	≈few % (# hadron events from N, K_L^0 = # photon events)	?
E_γ	Known	Not Known	Known

(a) The Omega detector experiment was conducted at relatively low photon energy and luminosity. For both reasons, it is doubtful that it can do any significant jet analysis.

(b) The Fermilab broad band beam has completed a number of successful runs. Of the three beams, it has the highest energy and intensity, but it suffers from the inherently difficult background problems of K_L^0 and n component in the beam as well as the substantial background of muons from the proton target. It also lacks specific knowledge for the energy value of the interacting photon. This beam-line spectrometer has recently reported results on charmed hadron photoproduction (E-87A). With 30 million triggers on tape and a sensitivity of 1-2 picobarns per event, it sees about 150 inclusive D* events in the $K\pi\pi$ decay mode. This relatively low number must be a reflection of the above-mentioned background problems, as well as the low acceptance of the spectrometer for complex final states and the lack of a trigger for charmed final states.

(c) The Fermilab tagged photon beam has completed E-25 (the total photon cross section and ρ, ω, ϕ measurement) and E-152 (the Santa Cruz Compton experiment). At present the recently completed E-516 spectrometer in the tagged-photon beam is awaiting its first data run in the fall. While this spectrometer has a designed high acceptance for multi-particle final states, its ability to detect and reconstruct complex jet states has yet to be demonstrated. Clearly, the initial priority of E-516 is the study of the simpler exclusive naked and hidden charm states. At present, no jet type of trigger is planned for the fall run. The upcoming 1000 hour run should have a target luminosity of about 10 events/picobarn and if 50 events are recorded each beam spill, a maximum of 1.5% of all the hadronic interactions in the target will be recorded. This sample will provide the data for a realistic study for future jet-physics possibilities with the tagged-photon spectrometer.

(d) CERN will soon have a new photon beam at higher energy and intensity. It seems likely that jet photoproduction studies will be the first priority.

Tevatron γ Beams

(a) For the Tagged Photon laboratory, 1-TeV protons on target will provide a high-intensity electron beam up to 300 GeV.[4] This is the maximum energy posible for the present beam line. In addition to doubling the maximum useful photon energy from the present 150 GeV, the Tevatron will provide a substantially higher beam intensity. For example, the increased beam intensity over the present will be approximately ×6 at E_e = 100 GeV and ×40 at E_e = 200 GeV. With 1-TeV protons and

E_{e^-} = 300 GeV, the e^- flux is ×5 greater than with the present 400-GeV protons at E_e = 150 GeV. Given that the beam-cycle time will probably increase from 10 s to 50 s, a 1000-hour experiment (with ~3×10^{12}p at 1 TeV and 1.5 m H_2 target) will still give about 10 events per picobarn at the target with photon bremsstrahlung energy spectrum (1/k) of 150 GeV to 300 GeV. This photon-energy range and luminosity would appear to be ample for measurements of high $p_\perp$ ($\gtrsim$ 4 GeV) scattering of quarks and gluons with photons. Numerous tests of QCD predictions are possible in this kinematic region.[1-3]

(b) To go to photon energies above 300 GeV and to higher intenstities, a new wide-band neutral beam has been proposed by the Proton Department.[5] This photon beam would have a luminosity of about 10 events per nanobarn hour for 600 GeV electrons, that is, the same luminosity at twice the present TPL energy capability for the same 1 TeV protons on target. Clearly, the new wide-band neutral beam is needed to realize the Tevatron potential.

Conclusions

1) Large $p_\perp$ photoproduction can provide new information on the fundamental quark and gluon scattering processes.[1,2] It can measure the gluon distribution in the proton[3] and a number of other interesting measurements are suggested in the literature.

2) To date, no completed photoproduction experiment has made a serious attempt to measure high $p_\perp$ jet phenomena.

3) The Tevatron will greatly enhance the photon jet-physics capability of the **existing** tagged-photon beam and its spectrometer, to a maximum E_γ = 300 GeV.

4) To fully realize the Tevatron potential for photon-beam physics, a new beam, such as the one proposed by the Proton Department, is necessary.

References

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