DIFFRACTION DISSOCIATION OF PHOTONS AT HIGH ENERGIES MEASURED WITH A HYDROGEN TPC PRELIMINARY RESULTS FROM EXPERIMENT 612

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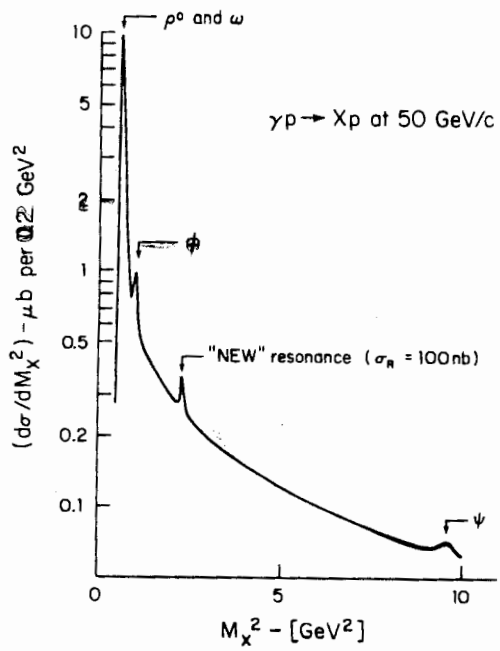
The diffraction dissociation of photons on protons

$$\gamma + p \rightarrow X + p$$

at high energies and low momentum transfer provides a unique window through which we can view the strong interaction properties of the photon. In this process the photon transforms coherently, with no exchange of quantum numbers, into high mass hadronic states while the recoil proton remains intact. These hadronic states can be rich in structure surprises. The figure below from our proposal shows the distribution in missing mass that might arise in such interactions. In addition to the



Expected mass distribution for diffractively excited photons.

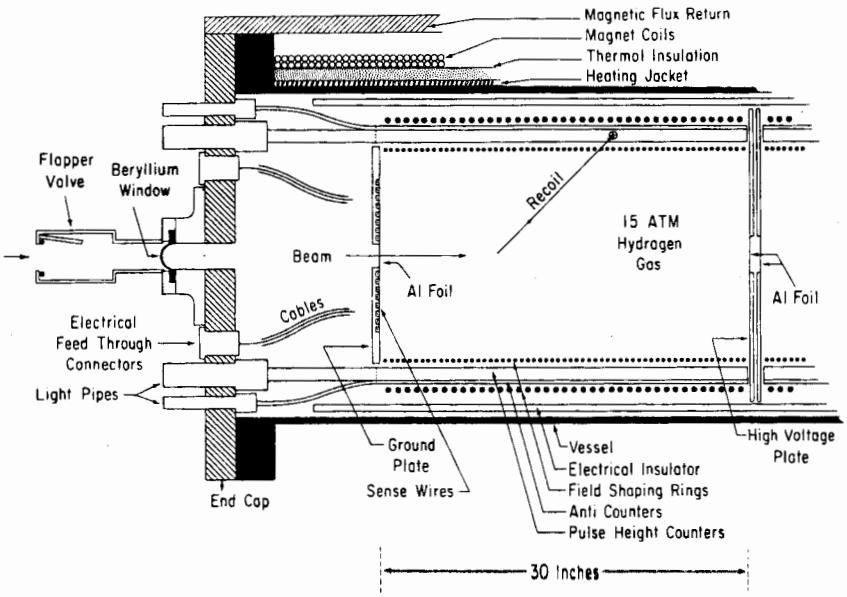
known and familiar resonances such as the ρ and the ψ, new resonances might be produced, along with a continuum of masses like that found in the diffraction of pions, kaons, and protons.

Our experiment was designed to measure the missing-mass distribution in photon dissociation with a resolution of $\Delta M_y/M_y \approx 1.5\%$ in order to search for these new resonances and to extract the shape and level of the continuum. Among other results, we wanted to compare whether the photon continuum has the same shape and scales to the total cross section in the same way as othr hadrons, a behavior dictated by what is known as the factorization of the diffractive vertex. In a previous experiment performed at Fermilab, E-396, we showed that factorization works well for many different hadrons.[1]

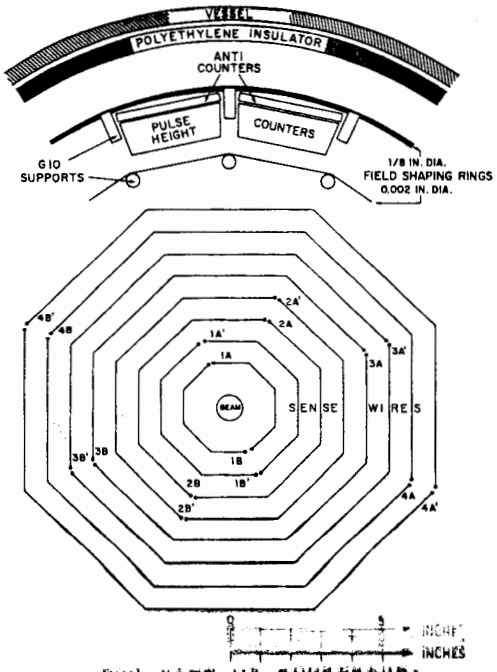
The experiment is located in the Tagged Photon Laboratory, which provides a flux of $1\text{-}2\times10^6$ photons with an energy resolution of $\pm2\%$. The photons interact in a high-pressure gas hydrogen target, transferring a small fraction of their momentum to the target protons, which recoil at large angles. By measuring the kinetic energy T and polar angle θ of the recoil we obtain the missing mass

$$M_x^2 = 2p_\gamma \sqrt{2M_pT}\ \cos(\sigma) - \sqrt{\frac{T}{2M_p}}\ .$$

The apparatus, pictured on the next page, is of novel design. It is described in Ref. 2. High-pressure hydrogen gas is used both as a target for the photons and as a track detector for the recoil protons. The hydrogen is contained in a vessel that may be pressurized up to 20 atmospheres. The photon beam enters through a 2-in. diam. × 0.03-in. thick window, made of beryllium in order to minimize photon-window interactions. The recoiling protons are stopped in scintillation counters whose light output determines the kinetic energy. These counters are placed inside the pressure vessel 9 in. from the axis. The ionization electrons generated by the recoil proton drift along axial electric field lines toward a ground plate where they are detected by a set of concentric octagonal sense wires. The electric field is established by an aluminum high-voltage plate in the center of the vessel and two ground plates near the ends and is shaped to the required uniformity by two concentric wire cages that carry a graded potential from the high voltage to the ground. The central plate divides the vessel into two equivalent detectors, each 75 cm long. The sense wires and associated electronics record the arrival time and the amount of ionization, from which we calculate the polar angle θ and the energy loss dE/dX. From dE/dX and T we can verify that the mass of the recoil particle is that of the proton. Typically, as seen in the graph on page 10, the drift velocity is 0.5 cm/μsec at our normal running conditions of 15 atmospheres and 130 kV. Our detector, known as TREAD, The Recoil Energy and Angle Detector, is similar in concept to the Time Projection Chamber (TPC) now operating at Stanford.

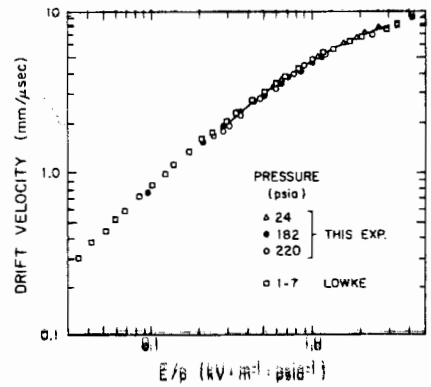


Side view of apparatus.



[redacted]

Many technical problems had to be overcome to realize this apparatus. As one can imagine, a high-pressure hydrogen vessel with thin windows presents formidable safety problems. With the help of a special Fermilab safety committee, chaired by George Biallas, and the Proton Department engineering staff, headed by Ron Currier, these were overcome largely by sealing the endcaps in a nitrogen atmosphere that would vent out safely any small amounts of leaking hydrogen, and by mounting on the beryllium window a special valve, the "flapper valve," designed to shut quickly if the window burst. Impurities in the hydrogen gas can seriously degrade the ionization drifting toward the sense wires. Materials placed inside the vessel were selected for low outgassing rates and the chamber gas is continuously circulated through a purifier that removes oxygen, the worst contaminant, to a level of 10 ppb. Another concern was that hydrogen is a poor proportional gas. It does not reach very high gain. Tests we performed proved that it would work adequately provided the appropriate sense-wire material, such as stainless steel, is used. Finally, in order to obtain the required angular resolution, we had to maintain the drift velocity constant to 0.1%, requiring careful monitoring and good control of the pressure, temperature, and electric field. Sensitive transducers placed inside and outside TREAD measure these parameters and radioactive α-particle sources positioned over the sense wires are used to keep track of the drift time, the wire gain, and the impurity level.



Drift velocity of electrons in H_2 gas.

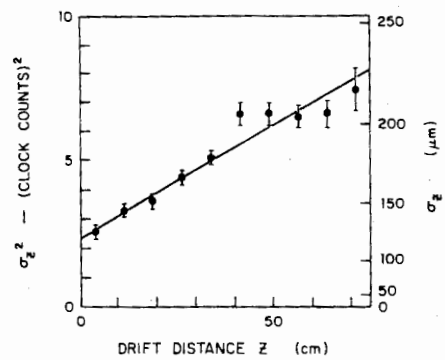
Before being placed in the beam, TREAD was tested with cosmic rays. The figure at the top of page 11 shows the rms deviation of one wire from a fit to cosmic-ray tracks. Also shown is a straight line fit to the form

$$\sigma_z^2 = \sigma_1^2 + \sigma_0^2 z$$

with z in cm. This functional form is expected from electron diffusion, where σ_0 depends on the electronic thresholds and σ_1 on known transport coefficients. The fit gives σ_0 = 123±5 μm and σ_1 + 22±1 μm, whereas the calculated value for σ_1 is 21 μm. With an average resolution over the length of the chamber better than 200 μm, TREAD worked as designed.

With the help of Peter Garbincius and the Proton Department staff, TREAD was installed in the photon beam in early 1981. Most of the running in the spring was devoted to shaking down the

hardware and software and to understanding the beam, but we did collect some data. Fortunately, since the photon beam can be converted to a pion beam, we could also compare the high mass continuum of photons and pions directly in our experiment, thus minimizing systematic uncertainties and obtaining reliable results even with limited statistics.

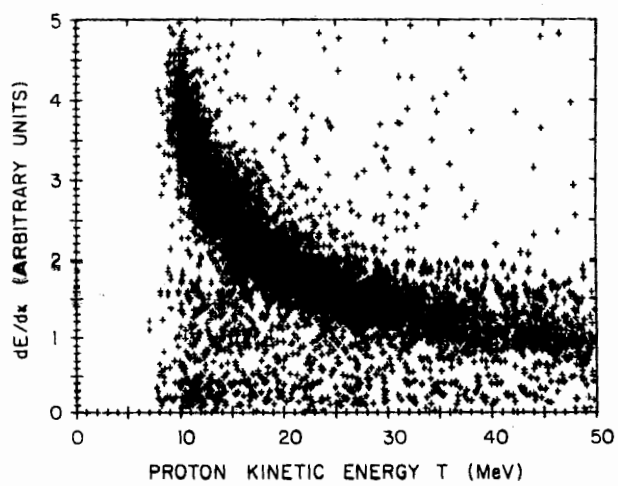


Spatial resolution of TREAD.

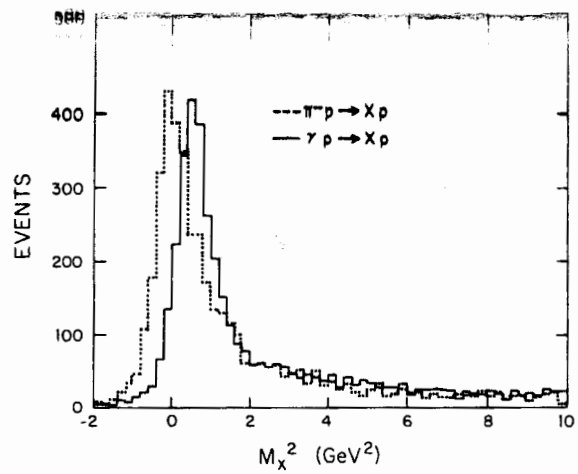
To extract the missing-mass distribution, recoil protons must be identified. The graph below, a scatter plot of dE/dX against T, shows how this is done. The dark band consists of protons. Keeping only events within this band, and making timing and fiducial cuts, leaves us with the missing mass distribution shown in the figure at the top of the next page. The prominent peak, the ρ, is followed by a continuum of events at higher masses. The photon and pion data look similar. We fit the high mass data to the form

$$\frac{d^2\sigma}{dxdt} = \left[\frac{A}{1-x} + B(1 - x)\right] e^{b(t+0.05)}$$

which describes well the pion, kaon, and proton data.[1] The



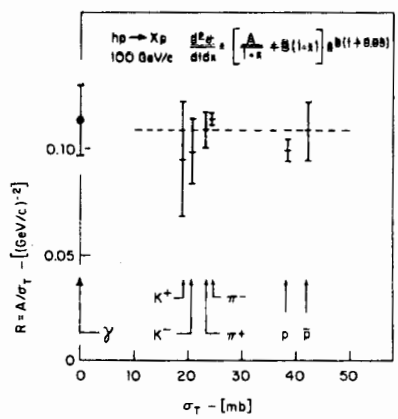
Energy loss of recoil particles in the H_2 gas vs. kinetic energy.



Missing mass distribution of pion and photon diffraction dissociation. The peak in the pion data is due to elastic scattering; the peak in the photon data is the p.

parameter A represents the true **diffractive component. The figure at the right shows that although** the total cross section, σ_T, for photons differs from hadrons by a factor of almost 100, the fraction A/σ_T remains about the same.

We must still collect more data before definitive comparisons between the photon and hadrons can be made, but we can already see in these results that the photon diffractive vertex indeed appears to factorize as it does for strongly interacting particles. We also look forward to a sensitive search for new resonances in our forthcoming run.



Test of factorization in hadron dissociation from E-396 and photon dissociation from E-612.

References

[1]R. L. Cool et al., Phys. Rev. Lett. **47**, 701 (1981).
[2]R. L. Cool et al., Phys. Rev. **D24**, 2821 (1981).
[3]T. J. Chapin et al., to be published in Nucl. Instrum. Methods.

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