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COLOR TRANSPARENCY STUDY GROUP *

J. A. Appel[a], J. Botts[b], G. Bunce[c], G. Farrar[d], S. Pordes[a]
[a]FNAL; [b]Univ. of Washington; [c]Chair, BNL; [d]Rutgers Univ.

ABSTRACT

The group studied the relatively new notion of color transparency, discussed present experimental evidence for the effect, and explored several ideas for future experiments. This write-up summarizes these discussions.

I. INTRODUCTION

Color transparency was proposed by Mueller and Brodsky[1] as an intriguing test of dimensional scaling.[2] Scaling is observed for fixed angle exclusive scattering for many processes, such as ep, πp, and pp elastic scattering, for $Q^2 > 5$ GeV^2. Dimensional counting argues that the transverse distance scale of these interactions must be of order $1/Q$. If the otherwise extended objects–protons for example–scatter from a region small compared to their normal size, they may appear transparent to an appropriate sieve. Small colorless objects might pass through a nucleus without absorbtion–this is the color transparency proposal.

An analogous process to color transparency is seen with emulsion events. When high energy cosmic rays produce π^0s which Dalitz decay, emulsions register an anomalously low charge because the (e^+e^-) system is small compared to the atomic size for a period of time after collision, so the charge is shielded. This was explained by D. Perkins in the mid-1950s.

For color transparency, hadrons which are small at the time of interaction will be small for a period of time before and after the hard collision. While the hadrons are small, they will interact less with nuclear material which is used as a sieve to measure hadronic size. Estimates of the expansion length are roughly a few Fermi for a 10 GeV/c hadron.

There are many interesting questions which might be explored. Is there evidence for the effect in the scaling region for exclusive scattering? Is it seen in the A-dependence for inclusive resonance production, for example J/Ψ and Υ production? Will the nucleus filter out larger configurations, leaving smaller systems which obey pQCD expectations? Will observed departures from scaling disappear if the system is filtered by a nucleus? Will observed non-pQCD spin effects disappear if filtered? How do hadrons expand and contract; can we learn something about hadronic formation time?

II. EXPERIMENTAL EVIDENCE

Evidence for color transparency comes from an AGS experiment[3] on proton-proton elastic scattering for incident protons from 6-12 GeV/c, 90° CM. The experiment compared scattering from protons in nuclei to scattering from hydrogen, and transparency was defined as the ratio of the two observed cross sections. In Fig. 1 we see that the ratio of scattering from protons inside an aluminum nucleus to scattering from free protons is strongly energy dependent. The absorbtion cross section for protons incident on a nucleus is constant over this energy range. The observed variation with energy is not easily explained. It has been suggested that the increase in transparency from 6-10 GeV/c is due to the expected decrease in interaction size and dilated expansion time of the hadrons[4]; the mysterious decrease from 10-12 GeV/c may be due to the appearence of a larger "soft" contribution at that energy[5].

Proton-proton elastic scattering data near 90° CM show an intriguing oscillation in energy dependence about the s^{-10} scaling prediction. Ralston and Pire[5] have suggested that this could be due to the interference between a hard pQCD amplitude and a soft independent scattering contribution suggested by Landshoff. The transversally large Landshoff contribution would be filtered out of pN quasi-elastic scattering but not pp. This interference would then cause the oscillating color transparency. The phase of the oscillation derives from a final state interaction between the quarks forming the hadrons. Botts and Sterman have developed techniques to study this issue[6].

Color transparency should also affect J/Ψ production in a nucleus. FNAL E772[5] used incident protons at 800 GeV/c to produce heavy quark states in dileptons in different nuclei., and observed $A^{.92}$ for J/Ψ and Ψ', $A^{.97}$ for Υ, and A^1 for the continuum. The

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A-dependence of the continuum is consistent with production by a parton from the proton which is not absorbed by the nucleus.[7] At these energies one might expect total transparency, A^1, for the resonances also. However, the observed transparency is quite large and plausible.

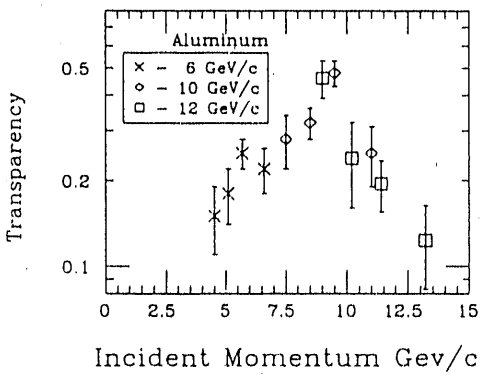

Fig. 1.Transparency for pp elastics at 90° CM, vs. effective incident beam momentum[3]

III.FUTURE PLANS

Two new experiments on color transparency are planned: an ep experiment at SLAC and a higher energy pp and πp experiment at the AGS (EVA). The ep experiment should reach $Q^2 = 7$ GeV^2 and they hope to confirm the color transparency effect for the struck proton. The EVA experiment will use the CLEO I solenoid, straw tubes and scintillating fiber to reach a much larger acceptance and interaction rate capability. They will first measure color transparency at higher energy–up to 22 GeV ($Q^2 = 20$ GeV^2). There is also a proposal to measure J/Ψ production by antiprotons off nuclear gas-jet targets in the anti-proton source at FNAL.

Beyond these confirmation experiments there are many striking phenomena that may be pursued using color transparency as a tool. The oscillating energy dependence of the pp 90° CM cross section, mentioned earlier, should disappear when pp scattering is filtered by a nucleus, leaving the pQCD scaling behavior[5]. Polarized proton-proton elastic scattering at large Q^2 shows an increasing asymmetry[9]. Little or no asymmetry is expected if quark masses are small, supressing spin flip at quark-gluon vertices[10]. If the reaction is filtered by a nucleus, only amplitudes participating in the hard scattering contribution should survive and the asymmetry should disappear. A similar test using color transparency could be done on the helicity violation observed for $\pi^- p \rightarrow \rho^- p$ scattering at large angle[11].

Color transparency can also be used to study the expansion from the small hadronic state and hadronic formation time. By matching effective CM energy for different combinations of beam energy and target proton Fermi momentum, one can isolate different contributions to the transparency.

The anticipated color transparency program is varied and exciting. Color transparency offers a remarkable window on the actual space-time configuration of scattering processes.

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