A Study of the Contribution from Non-Perturbative Effects to Di-jet Yields at Forward Rapidity

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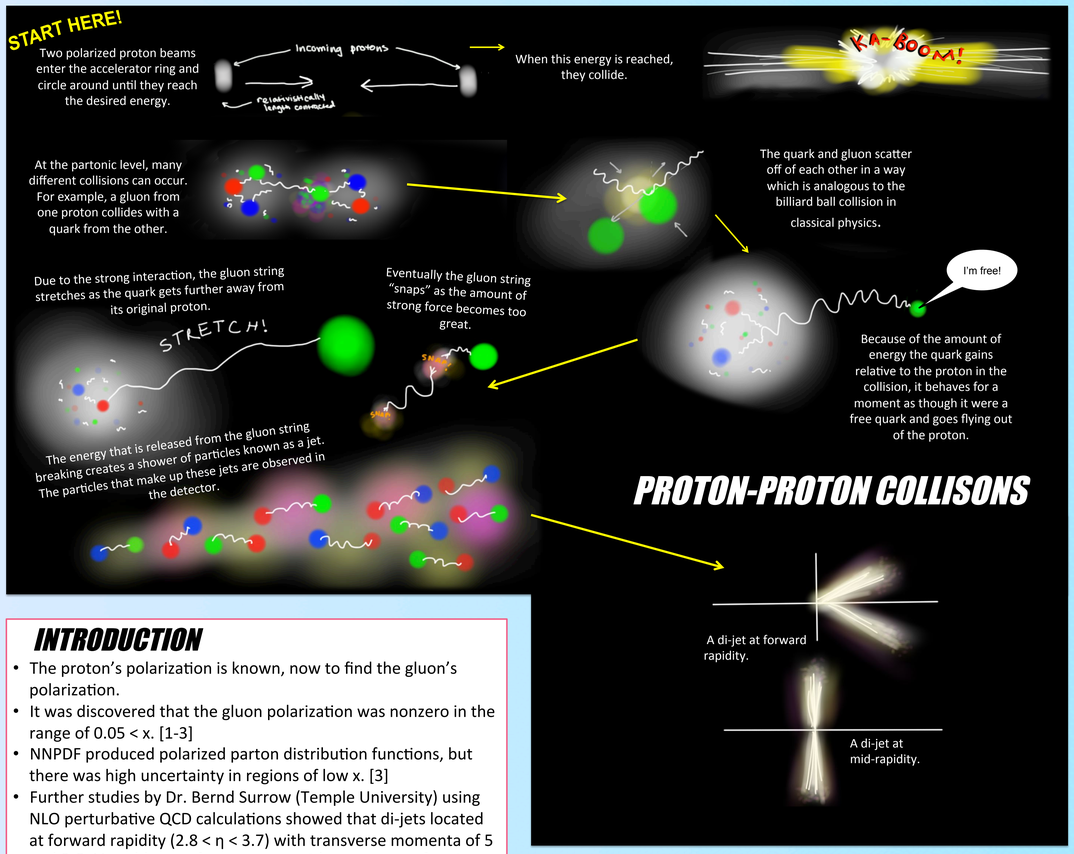
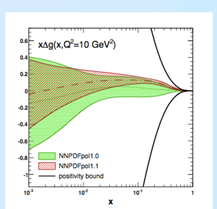
ABSTRACT

It is well known that the spin of the proton is equal to ħ/2, but the internal structure of the proton and the spin contributions made by its parton constituents, especially gluons, remains enigmatic. By studying asymmetric pairs of jets produced in polarized proton-proton collisions at forward rapidity, more information about the spin contribution of the gluon can be attained. Next to leading order perturbative quantum chromodynamics calculations indicate that measurements of a pair of jets at forward rapidity with transverse momenta (p_T) of 5 and 8 GeV/c can provide valuable additional information regarding the polarization of the gluons. However, these calculations do not include background contributions from initial-state radiation, underlying events, and beam remnants that can create additional particles, which appear in a detector as jets. In this study, PYTHIA simulations were used to analyze jets of stable final-state hadrons. A simple procedure is found to reject the background contributions. Most of the di-jets that remain can be matched to initial hard scattered partons with momentum fractions x_2 of the order 10^{-3}, and x_1 of 0.4 or greater. These kinematics indicate that the remaining jet pairs will provide relevant information about the gluon's contribution to the proton spin. The information provided by this simulation will help prepare the way for future experiments at RHIC that will provide us with a better understanding of the proton's structure at the partonic level.

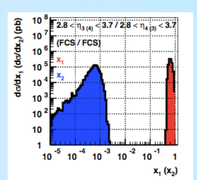


INTRODUCTION

- The proton's polarization is known, now to find the gluon's polarization.
- It was discovered that the gluon polarization was nonzero in the range of 0.05 < x. [1-3]
- NNPDF produced polarized parton distribution functions, but there was high uncertainty in regions of low x. [3]
- Further studies by Dr. Bernd Surrow (Temple University) using NLO perturbative QCD calculations showed that di-jets located at forward rapidity ($2.8 < \eta < 3.7$) with transverse momenta of 5 and 8 GeV could come from partons with momentum fractions in the region where the gluon polarization is uncertain. [4] His study did not consider non-perturbative effects that could produce background jets.



NNPDF gluon polarization distribution [3]



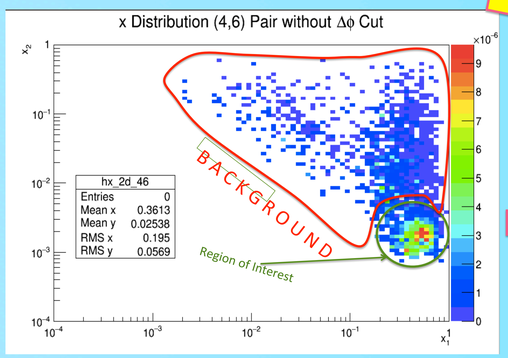
The x distributions for di-jets within $2.8 < \eta < 3.7$ probe the region where gluon polarization is uncertain. [4]

THE PROJECT

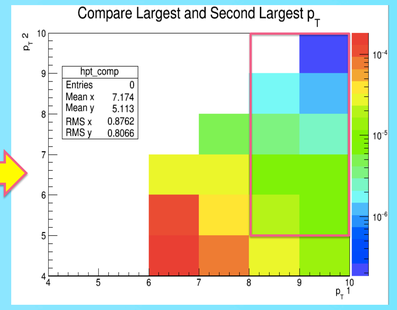
- Furthers Dr. Surrow's simulation by determining how many of the 5 and 8 GeV di-jets were produced by hard-scatter partons, isolating any background and determining its cause.
- Monte Carlo simulation of a proton-proton collision in PYTHIA, using CDF Tune A at 500 GeV center of mass energy to provide the parameters for the simulation.
- Jets were identified using the anti-k_T jet finding algorithm with a radius of 0.5.
- The analysis program was written in C++, using ROOT to make histograms to identify the jet pairs that fit all of the above conditions, and to handle the large amounts of event data from the proton-proton collision simulation.
- The program was run over six partonic p_T bins: 4-5GeV/c, 5-7GeV/c, 7-9GeV/c, 9-11Gev/c, 11-15GeV/c, and 15GeV/c - ∞.

ANALYSIS

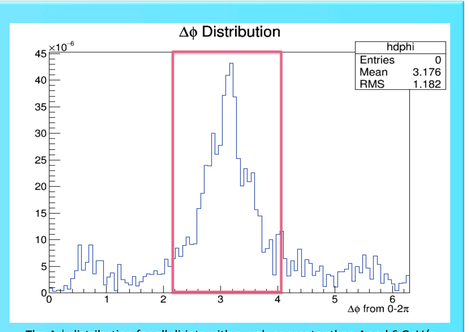
- The program goes through each event and through a process of elimination determines whether it has the desired kinematics.
- Analyze the jets that would be seen in the detector
  - η cut from 2.5-3.8
  - Selection of the largest and second largest p_T, and their corresponding p_T, η, and ϕ values
  - Calculate Δη and Δϕ
  - P_T cuts at 5 and 8 GeV/c
  - Δϕ cut from 2π/3 to 4π/3
- Match the jets to the hard scattered partons (PYTHIA analysis)
  - Get η and ϕ of the initial hard scattered partons (PYTHIA lines 7 and 8)
  - Get values of x_1 and x_2 from hard scattered partons and match to 5 and 8 GeV di-jets
  - x_1 and x_2 cuts



The distribution of x_1 vs. x_2 with no Δϕ cut, and a lower p_T cut. There is a large background and only a small number of significant events that lie within the region of interest. The process of reducing the amount of background begins with a higher p_T cut and then a detailed look at the Δϕ distribution.



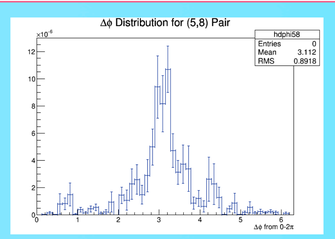
The largest values of p_T plotted versus the second largest values of p_T.



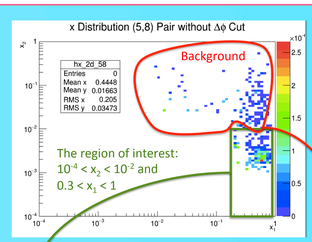
The Δ ϕ distribution for all di-jets with p_T values greater than 4 and 6 GeV/c

ANALYSIS

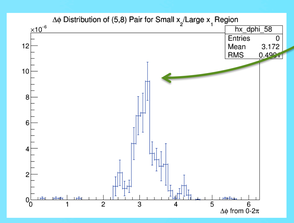
First, overall distributions of p_T and Δϕ are plotted in order to ensure that we have a good understanding of all of the events, including the background, before focusing only on those which are of interest. From looking at the p_T distribution, it can be seen that most of the events do not meet the 5 and 8 GeV p_T cuts. The Δϕ distribution shows a peak at π, background, and two smaller peaks near 0 and 2π that are indicative of a split jet event. Next begins the process of eliminating the background and narrowing down on the events which would be relevant in determining the gluon polarization.



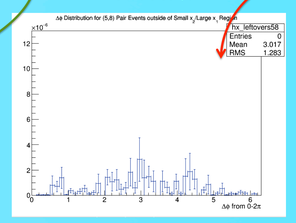
The distribution of Δϕ for all 5 and 8 GeV/c di-jets.



The distribution of x_1 vs. x_2 with no Δϕ cut, and a higher p_T cut at 5 and 8 GeV/c.



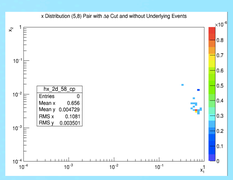
The distribution of Δϕ within the region of interest. It has a clear peak at π.



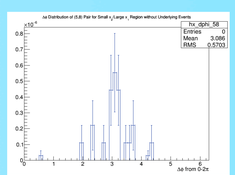
The distribution of Δϕ outside the region of interest. It shows a fairly flat background which could be subtracted.

BACKGROUND IDENTIFICATION

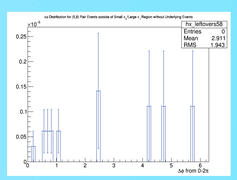
Additional runs were done over the 11-15 and 15-∞ GeV/c partonic p_T bins with initial state radiation and underlying events turned off. In both cases, a significant decrease in the amount of background is seen. However, neither process is solely responsible for all of the background, leading us to conclude that both processes are responsible.



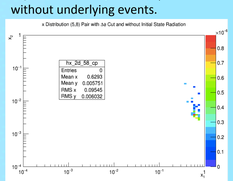
The distribution of x_1 vs. x_2 within the region of interest, with a Δϕ cut and without underlying events.



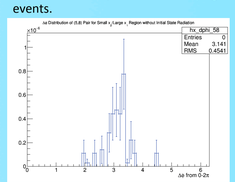
The distribution of Δϕ within the region of interest, without underlying events.



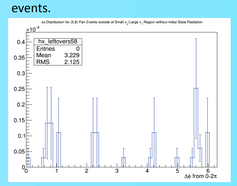
The distribution of Δϕ outside the region of interest without underlying events.



The distribution of x_1 vs. x_2 within the region of interest, with a Δϕ cut and without initial state radiation.



The distribution of Δϕ within the region of interest, without initial state radiation.



The distribution of Δϕ outside the region of interest without initial state radiation.

CONCLUSION

To summarize, this study expands on Dr. Surrow's study by showing that the 5 and 8 GeV di-jets are produced by the initial hard-scattered partons, and therefore would provide valuable information about the gluon polarization. It identifies the background as being produced by both initial state radiation and underlying events. The background is a mostly flat background which could be eliminated via a Δϕ subtraction as opposed to a Δϕ cut. This provides a basis for future experiments which could ultimately lead to a better understanding of the gluon polarization and the proton spin.

ACKNOWLEDGEMENTS

This material is based upon work supported by the National Science Foundation Graduate Research Fellowship under Grant No. 1263281.

REFRENCES

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[4] B. Surrow, [STAR Collaboration], arXiv:1407.4176.