Proc. XIII Int. Seminar on High Energy Physics
Problems, Relativistic Nucl. Phys. & Quantum Chromodynamics
Dubna, RUSSIA
September 2-7, 1996
CONF-960977--1
BNL-64092

EXPLORING NEW FRONTIERS IN NUCLEAR AND PARTICLE PHYSICS WITH THE STAR DETECTOR AT RHIC

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MAR 25 1997
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1 Introduction

The Solenoidal Tracker At RHIC (STAR) is a large acceptance collider detector scheduled to begin operation at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory in the fall of 1999. In the sections which follow, details of the STAR detector and physics program, as well as the status of the RHIC construction project will be presented.

2 Status of the RHIC Construction Project

The project to construct the RHIC Collider is now approximately 70-80% complete, with all arc dipole magnets and correction quadrupole and sextapole (CQS) magnet assemblies successfully fabricated. The first sextant (5 o'clock to 4 o'clock) of the RHIC lattice is completely installed, and is presently being tested for full functionality with Au beams inserted from the Alternating Gradient Synchrotron (AGS) at BNL. Additionally, all of the arc dipole and insertion dipole magnets have been installed in the RHIC tunnel, with approximately 70% of the CQS magnet assemblies installed as well. A key aspect in being able to progress quickly was the excellent quality and uniformity of the magnets, all of which exceeded the designed quench current goal by a comfortable margin ($>$ 30% for dipole magnets, 50% for quadrupoles). Overall, the RHIC construction project including the detectors remains on schedule for completion in the spring of 1999. A section of the completed lattice is shown in Fig. 1.

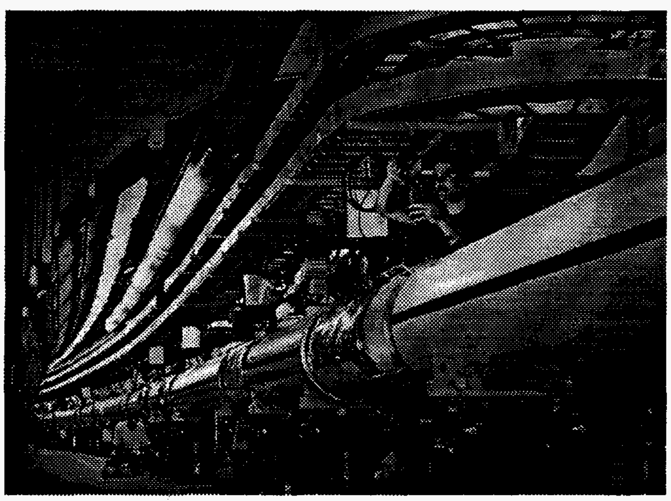

Figure 1: RHIC dipole, quadrapole and sextapole magnet assemblies installed in the RHIC ring.

[1]This research was supported by the U.S. Department of Energy under Contract Nos. DE-AC02-76CH00016.

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3 The STAR Detector

The baseline STAR detector (Fig. 2) utilizes a time projection chamber (TPC) in a solenoidal magnetic field of 0.5T covering approximately 4 units of the central rapidity. Additional elements of the detector include a silicon vertex tracker (SVT) to locate the position of the primary vertex to high accuracy, and to locate secondary vertices to an accuracy of 20 μm. A *Pb*-scintillator sampling electromagnetic calorimeter will be used to trigger on transverse energy and measure jets, direct photons and leading π^0 production. A portion of the acceptance will be instrumented with a highly segmented TOF array, extending the maximum momentum for π/K separation from 0.6 to 1.5 GeV/c and the corresponding limit for K/p separation from 1–2.4 GeV/c. Forward TPCs (FTPC) located in the region $2 \leq |\eta| < 4.5$ will be used to study the transfer of energy from projectile rapidity to midrapidity by following the fate of the incident baryons rescattered in the collision.

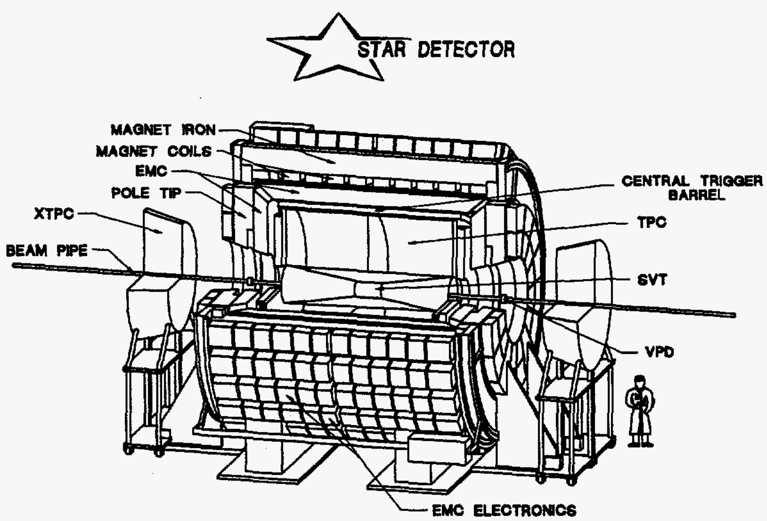

Figure 2: Schematic layout of the STAR detector.

An important measure of recent progress in the construction of STAR is the initiation of the first phase of the STAR "system test". In this effort, all of the key elements of the STAR data taking chain (TPC, front end electronics, DAQ, trigger, and slow controls) are interfaced and made to work together for the first time. Progress in this area is evident in Figure 3, in which the first cosmic ray data detected in a STAR TPC padplane are shown. Further work using both cosmic rays and lasers will test the channel to channel uniformity as well as the position resolution for a single track and the two-track resolution.

4 The STAR Scientific Program

Simply stated, the physics goals of STAR are,

- to study strongly interacting matter at high energy density
- to search for signatures of a deconfined phase of matter, and

- to study the importance of spin as a fundamental QCD variable and measure the spin-dependent parton distributions (gluon, valence quark, sea quark) of the proton.

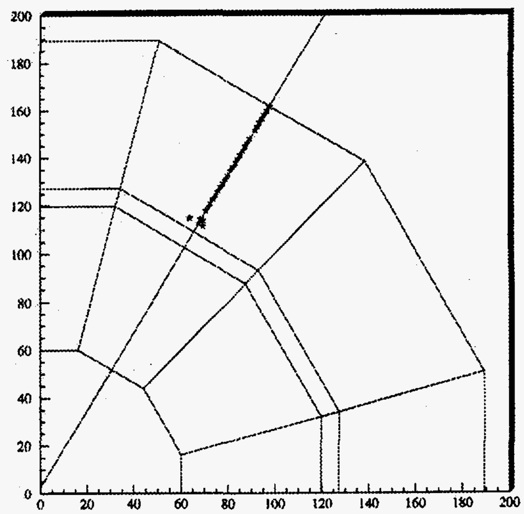

Figure 3: The first cosmic ray data recorded in a STAR TPC pad plane as part of the STAR system test.

The primary goal of RHIC is to produce nuclear matter under extremes of temperature and density sufficient to excite the primordial QCD vacuum, resulting in the creation of a deconfined plasma of quarks and gluons. The transition to deconfinement should be accompanied by restoration of one of the fundamental symmetries of nature–chiral symmetry. A hint that such processes may occur in nature is afforded by evidence from cosmic ray data in which the isospin ratio $(\pi^0/\pi^+ + \pi^-)$ in high energy proton induced interactions appears to show significant non-statistical fluctuations (Fig. 4).[1] Such a fluctuation might result if local excitation of the QCD vacuum within the collision volume resulted, prior to hadronization, in two degenerate vacua (the "normal" QCD vacuum and the degenerate vacuum produced in the collision) being in proximity with different spontaneously broken symmetry states. Thus far, the search for such Disoriented Chiral Condensates (DCC) in accelerator induced reactions has not provided any evidence for this phenomena. However, the search for DCC behavior continues to be of particular interest, since observation of this effect would provide strong evidence that a chiral transition had taken place.

With regard to the search for a deconfined, chirally symmetric phase of matter, STAR[2] is designed to search for signatures of QGP formation through the measurement and correlation of global observables on an event-by-event basis and the use of hard scattering of partons to probe the properties of high density matter. A second program of fundamental measurements, including the search for physics beyond the standard model, will be possible using beams of longitudinally and transversely polarized protons. In particular STAR will measure the spin dependent gluon, valence quark and sea quark distributions of the proton using the QCD Compton process and vector boson production as probes. It will also be possible to search for new physics beyond the standard model by measuring parity violation in high p_t jet production.

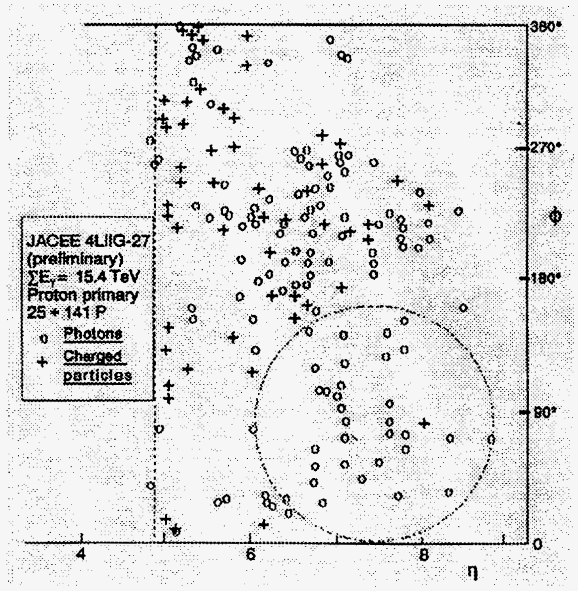

Figure 4: JACEE event showing the leading particle region $\eta > 6.5$ At lower rapidities the photon detection efficiency becomes small. The leading cluster, indicated by the circle, consists of about 32 γ's with only one accompanying charged particle.

5 Searching for the Deconfinement Transition with STAR

One important aspect of the STAR program will be to search for special events in which the measurement and correlation of event-by-event observables (e.g. dn_π/dy, T_π, K/π, $p_{t\pi}$, dn/dy) indicates the transition to a deconfined phase may have occurred. An event in this category might be characterized, for example, by an unusually high inverse slope parameter for the pion spectrum or large non-statistical fluctuations in the dn/dy spectra. A second goal will be to measure the thermodynamic observables (T, μ_B, μ_s) for an ensemble of events to establish whether a state of thermal and chemical equilibrium has been reached. This state of matter is predicted to occur in the evolution of the system from deconfinement to hadronization, and its observation would provide supporting evidence that a phase transition to a QGP had taken place. The design of the detector allows for the precise measurement, for example, of particle ratios ($p/\bar{p}$, $\bar{\Lambda}/\Lambda$, K/π) to determine the strange chemical and baryo-chemical potentials, inverse slope parameters and p_t to determine the energy density (temperature), and dn/dy distributions to investigate entropy production. These observables will be measured and correlated to determine if a state in which chemical and thermal equilibrium has been reached can be identified.

Determination of the strangeness density in relativistic heavy ion collisions has long been recognized[3] as an important probe of plasma production primarily because a rapid increase in $s\bar{s}$ production through gluon-gluon interactions in a QGP would allow saturation of the strangeness degrees of freedom much more quickly than could be achieved in multiple hadronic interactions. The measurement of strange baryons at RHIC however is complicated due to the short lifetime and low mean p_t which characterize the production. As a consequence, combinatorics pose a significant background, and an inner tracking system capable of accurate determination of secondary vertices is essential.

In STAR, this is accomplished with a new type of detector developed at Brookhaven National Laboratory (BNL) through RHIC R&D – the silicon drift detector (SDD). With careful shaping of the electrostatic potentials, the ionization deposited by a charged particle traversing a fully depleted silicon wafer can be made to drift at a constant velocity the entire length of the wafer. Knowing the time of the drift and determining the position in the anode direction by charge sharing, the position of the charged particle can be determined with great precision. Extensive bench tests at BNL and elsewhere have shown that space point resolutions on the order of a few tens of microns are achievable. The STAR silicon vertex tracker (SVT) is constructed of ladders of SDDs arranged in three concentric cylinders at mean radii of 6, 10, and 15 cm.

The utility of the STAR SVT, is demonstrated in Figure 5. Using the characteristic resolutions demonstrated through R&D for this device, the Ξ^- yield and signal to noise ratio expected for approximately 2-3 days of *AuAu* running are shown to be quite good. This detector is nearing the beginning of its construction phase, and completion is projected for the end of calendar year 1999.

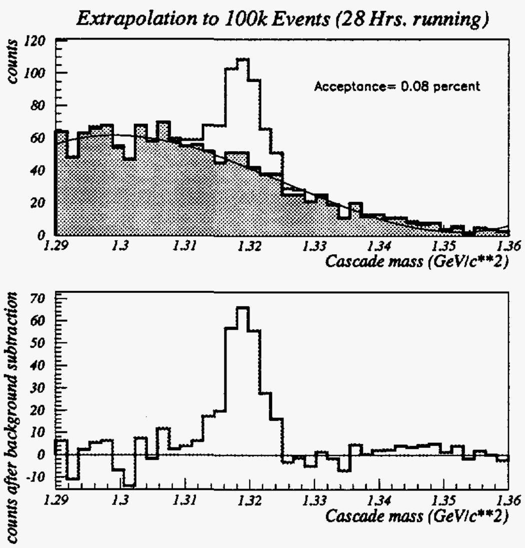

Figure 5: Simulated invariant mass distribution for the Ξ^- using the STAR SVT.

Two specific aspects of the STAR program relating to the detection of the deconfinement transition merit a somewhat more detailed discussion; measurement of the gluon distribution in the nucleus, and the detection and interpretation of multiple non-statistical correlations possibly indicative of new physics.

An important element in the ion studies at RHIC and LHC will be the determination of the initial conditions – the parton distributions in the nucleus. RHIC will be the first heavy ion accelerator in which a large part (50%) of the energy transferred into particle production comes directly from partonic processes which are calculable in pQCD. Theoretical guidance as to the evolution of the early stages of the collision is therefore possible if the initial distribution of partons in the nucleus is known. Presently it is expected that gluon-gluon scattering will dominate at early times with chemical and kinetic equilibration of the quark degrees of freedom proceeding more slowly. Determination of the gluon distribution in the nucleus in pA interactions, which is not provided by deep inelastic scattering studies, is therefore of particular interest. One would like to know the distribution down to the smallest values of x_{BJ} of relevance for particle production in the ion studies. At RHIC this value is $x_{BJ} \sim .01$. At LHC it is an order of magnitude lower, and this study may be more difficult since the two-in-one magnet design at LHC does not allow the acceleration of particles of unequal rigidity.

The fact that the quark (valence plus sea) structure function of a nucleon in a nucleus is modified with respect to that for a free nucleon is well known from deep inelastic scattering(DIS). It has also been pointed out for some time[4] that one also expects a similar modification of the gluon structure function. Inspecting the middle panel of Fig. 6, for example, the ratio of single particle inclusive production in AA to that in pp varies by a factor of approximately two depending on whether or not such a modification – "gluon shadowing" – is assumed. To reduce this uncertainty in the interpretation of the measured spectra, it would be of great value to have independent knowledge of the gluon structure function in the nucleus.

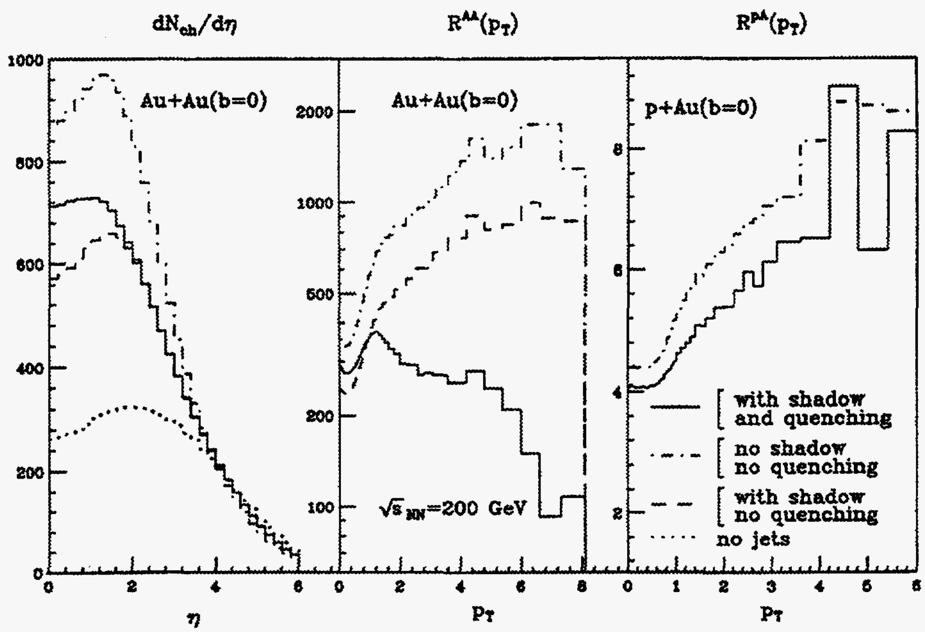

Figure 6: Results from HIJING calculations on the dependence of the inclusive charged hadron spectra in central $AuAu$ and pAu collisions on mini-jet production (dash-dotted), gluon shadowing (dashed) and jet quenching (solid) assuming that gluon shadowing is identical to that of quarks. $R^{AB}(p_t)$ is the ratio of the inclusive p_t spectrum of charged hadrons in $A + B$ collisions to that of pp[4].

Thus far, experimental effort has focused on measurement of the gluon distribution in the proton with the consequence that significant data on $xg(x)$ are now available at low x_{BJ} from H1 and Zeus, with complementary data closer to the valence region available from SMC and BCDMS. The data at low x_{BJ} come both from direct measurement of photon-gluon fusion processes, and from examining the scaling violation of the F_2 structure function at low x, the latter presumably resulting from the production of sea quark pairs in gluon-gluon interactions. A compilation of the available data on $xg(x)$ normalized at a q^2 of 20 GeV^2 is shown in Fig. 7.

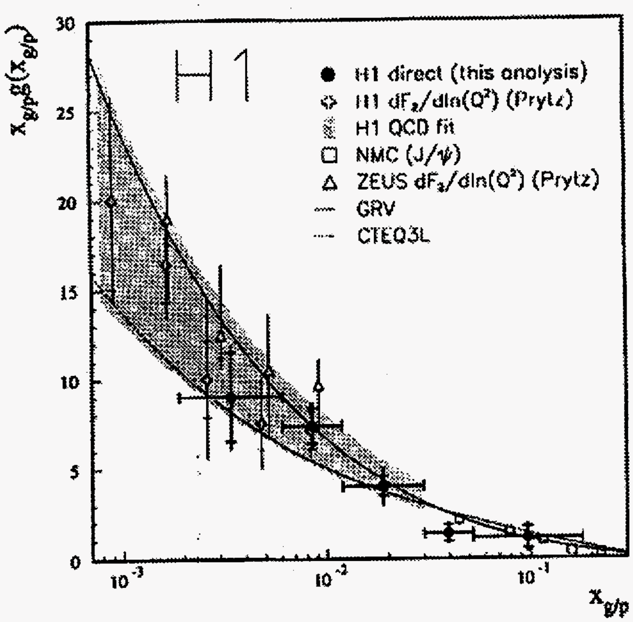

Figure 7: The measured gluon density at an average Q^2 of 30 GeV^2 as a function of the fractional gluon momentum compared with indirect determinations by $H1$ and ZEUS at $Q^2 = 20$ GeV^2 as well as with a determination from J/Ψ production by NMC evolved to $Q^2 = 30$ GeV^2 [5].

It is interesting to note that even at the lowest x_{BJ} measured, the value of $xg(x)$ is considerably less than the value one would naively expect if gluons completely filled the transverse size of the proton. In principle, saturation of the gluon density in the proton at low x_{BJ} could yield important information about the modification of the gluon distribution at higher x_{BJ} in the nucleus, since both effects result from the same basic gluon recombination processes. What is not obvious thus far in the data of Fig. 7 is the extent to which saturation of the parton distribution may already be present in the data, or indeed how to extract this information. A further technical difficulty is that it is precisely at the point where saturation of the parton density occurs that the assumption of factorization may break down.

In STAR, the intent is to measure the gluon distribution in the nucleus directly in order to determine the initial conditions before the collision. This will be probed using the QCD Compton diagram, detecting the final state jet and direct photon coincidences in the STAR TPC and electromagnetic calorimeter. The contribution to this channel from $q\bar{q}$ annihilation should be small (of order 10%) at these energies. The region of the STAR acceptance (in x_{BJ}) for this measurement as well as the projected sensitivity for a pAu run of 1 month at the design luminosity are indicated in Fig. 8. Work is on-going within STAR both to refine the design of the EMC to address the measurement of jets and direct photons in AA interactions (in pp and pAu this capability has already been demonstrated) as well as to perform realistic simulations focused on identifying and understanding potential sources of systematic error in this measurement.

A second effort that has recently become the focus of increased effort and interest[7] is to develop techniques from information theory on how, beyond simple two dimensional correlation techniques (e.g. scatter plots), to detect and measure non-statistical multi-dimensional correlations.

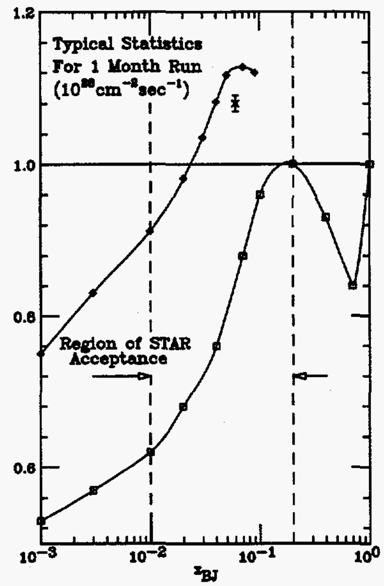

Figure 8: The range of x_{BJ} for which the gluon distribution in the nucleus will be investigated in STAR using direct photon + jet coincidences. The statistical accuracy expected for 1 month of running for pAu interactions at the design luminosity is indicated. The top curve shows a theoretical estimate of gluon shadowing in the nucleus[6]. The quark shadowing in the nucleus expected for pAu interactions is shown for reference (bottom curve).

The basic idea underlying this analysis is that there is a unique physical scale associated with correlations of a particular type. This is to some extent familiar from common experience. If viewed from many miles away, the correlation information contained within a city skyline might be hard to distinguish from the surrounding horizon by the naked eye. From several miles away, however, the "jet" of tall buildings forming the skyline of a city would be unmistakable and one would be able to make a fairly precise estimation, for example, of the size and outline of the city. If standing then between two tall skyscrapers within the city which subtended most of the field of view, it would be again hard to determine much about the overall dimensions or outline of the city, although it might be much easier to detect a different correlation, – for example, an unusually high probability of finding a delicatessen in the neighborhood. The essence of this technique then is to determine the correlation information content within a given central $AuAu$ interaction by examining the "topological or Renyi entropy" – the amount of information available–at a number of different physical scales which relate to the physical size of various elements of the STAR detector system. The goal is to select events based on the level of their information content, rather than on the extent to which they resemble or differ from criteria developed from event generators of unknown reality.

Practically, to make this determination, each event is first examined to determine the "Renyi entropy" at a given scale. In practice this can be as simple, for example, as counting the number of particles or the transverse energy (normalized for convenience) entering a set of bins (e.g. scintillator counters, calorimeter towers, etc.) of a given size and determining the logarithm of the moments of the distribution. This procedure is then repeated with a slightly different binning at the same scale, to insure the results are independent of the choice of binning. The results of several trials then determine the average "scaled entropy" for that event. The scaled entropy for a given event may then be compared to the scaled entropy for an ensemble of reference events generated either from an event generator, or some a priori notion concerning the nature of the fluctuations for a given type of distribution.

The difference between the average scaled entropy for an event of interest and the reference ensemble is termed the "scaled information" for that event. Having determined the scaled information at a given scale, the process is repeated to determine the scaled information for each event of interest for a range of different physical scales (usually 50-100). Finally the "dimension lowering" – the derivative of the scaled information with respect to scale size – is determined for example at 3 different scales, and the result plotted in a Cartesian space to determine if events which clearly belong to distinctly different populations in this space can be identified.

In principle one can generalize this technique to examine events in an n-dimensional space to search for unique non-statistical n-dimensional correlations. Further, this analysis technique may be used either at the trigger level, or in off-line analysis. The power of this technique is illustrated in Figs. 9 and 10, in which several event types which differ in the nature of the energy deposition in the interaction region have been used. What is noted is that essentially all event types exhibit very similar multiplicity distributions which do not distinguish one type of event from another. When the dimension lowering for each event at 3 different scales is plotted in a Cartersian space however, the event types are quite distinct and the events contained in one particular population can be separated out for further analysis with appropriate cuts.

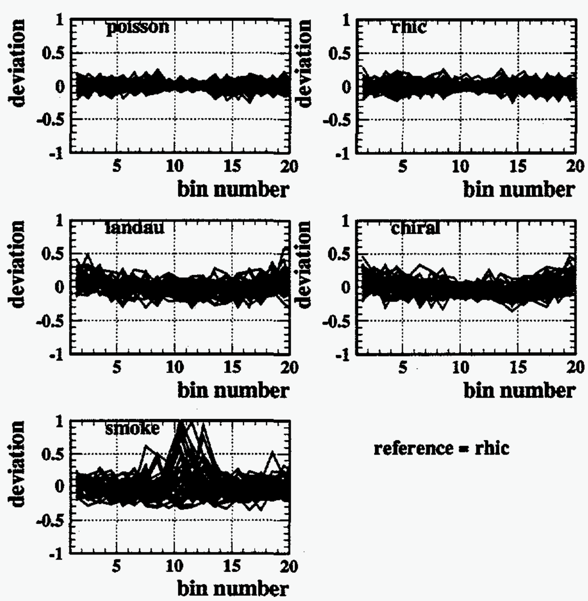

Figure 9: The relative deviation, as a function of pseudorapidity (bin number) of the charged-particle multiplicity for several hypothetical event samples from the event ensemble average of a standard RHIC event class (except for the POISSON events, which are shown relative to a uniform distribution).

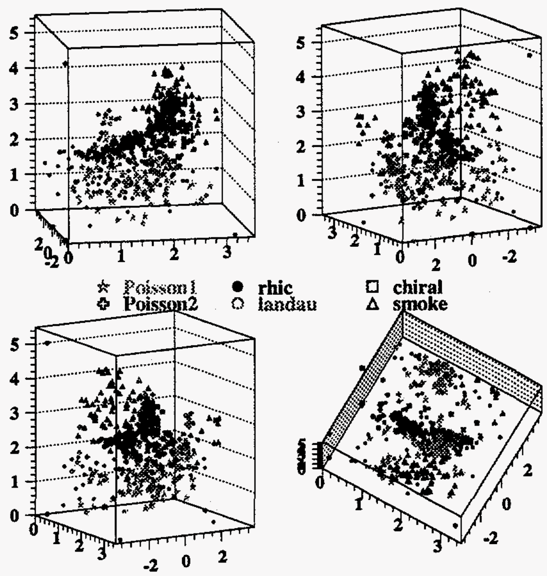

Figure 10: The distribution in a polar coordinate space, for the same event samples plotted in Fig. 9, of the dimension lowering at three different physical scales. (Each axis locates for a given event the dimension lowering at one physical scale). Close inspection (made easier by the use of color plots not shown here) indicates that, plotted in this manner, the event samples shown in Fig. 9 populate different regions in this space corresponding to differing assumptions regarding the deposition of energy and subsequent hadronization in the interaction.

This technique appears to be quite promising, and it would be of significant interest to perform such an analysis, for example, for events with and without mini-jets, the presence of which is in general difficult to isolate. One obvious consequence of this type of analysis technique is the somewhat urgent need for more realistic RHIC event and plasma event generators to assess the physical significance and interpretation of fluctuations and correlations which may be observed.

6 Spin Physics Measurements with STAR

A number of important questions concerning the fundamental structure of the proton will be addressed by studying parity conserving and parity violating spin asymmetries in polarized *pp* interactions in STAR. One topic of particular interest is the effective polarization of gluons in the proton. It is now well known from deep inelastic scattering (DIS) experiments that the net contribution to the proton spin from quarks ($\approx 30\%$) is smaller than expected relative to the momentum carried in this sector. In general, the spin of the proton may contain contributions not only from quarks, but also from gluons, and perhaps orbital angular momentum of the constituent partons as well. Once the degree of gluon polarization has been established using hadronic probes, it may also be possible to assess the significance of any possible contribution from orbital angular momentum.

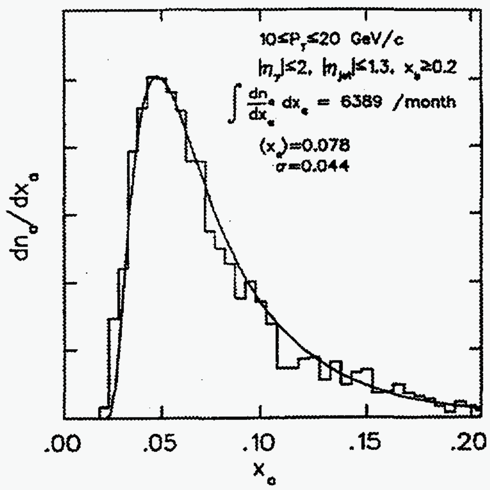

Figure 11: For jet + direct photon coincidences in the STAR; the acceptance and yield as a function of x for events in which at least one of the final state products has $x > 0.2$. The results indicate these are $\approx$ 6500 direct-γ + jet events per month in the kinematic region of interest for studying $\Delta G(x)$. Further details may be found in Ref. [8].

In STAR, measurement of the gluon polarization will be addressed with beams of longitudinally polarized protons using a number of hard QCD probes; inclusive direct photon production, di-jet production, and jet + direct photon coincidences. For measuring $\Delta G(x)$, the jet + jet and jet + direct photon final states are superior, since the kinematic information available on the initial state partons (quarks, gluons) is complete modulo the k_t of the partons. Figure 11 gives an estimate of the acceptance and yield of jet + direct photon coincidences in STAR in one month of running at the RHIC design luminosity at $\sqrt{s} = 200$ GeV. It is noted that for a jet p_t range of $10 < p_t < 20$ GeV/c, at this $\sqrt{s}$, the gluon distribution may be probed down to x Bjorken of approximately 0.02. (If the range for the measurement of jets is extended to lower p_t, the lower limit of the accessible x range is lowered as well). The results also show that for jet + direct photon events in which one of the final state products has $x_b \geq 0.2$, which statistically is most likely to correspond to a quark in the valence region in which the polarization transfer from the proton is rather well known from DIS, the yield of "gluon-like" events in which the other final state product has $x_a < 0.1$ is approximately 6500 per month. By measuring the parity conserving two-spin asymmetry

$$A_{LL} = (1/P^2)(N^{++} - N^{+-})/(N^{++} + N^{+-}) \tag{1}$$

for "gluon-like" events, where P is the beam polarization, it will be possible in a relatively short period of running (100 days with 50% efficiency yields an integrated luminosity of 320 pb^{-1} at the design luminosity for $\sqrt{s} = 200$ GeV) to make a significant measurement of both ΔG and $\Delta G(x)$. Table 1 shows the statistical uncertainty, δA_{LL}, in the jet + direct photon asymmetry for various combinations of the quark and gluon kinematics assuming an integrated luminosity of 320 pb^{-1}. Accounting for statistical errors only, this corresponds roughly to an uncertainty in the measurement of $\Delta G/G$ of a few percent.

Table 1					
		max(x_1, x_2)			
		≤ 0.2	0.2-0.3	0.3-0.4	> 0.4
	0.00-0.05		0.012	0.009	0.007
	0.05-0.10	0.006	0.006	0.010	0.012
min(x_1, x_2)	0.10-0.15	0.007	0.010	0.020	0.030
	0.15-0.20	0.021	0.019	0.038	0.060
	> 0.20		0.035	0.049	0.073

Table 1: The estimated statistical uncertainty δA_{LL} in the two-spin, parity conserving asymmetry of Eq. 1 in jet + direct photon events. Various ranges of the "quark" ($\max(x_1, x_2)$) and "gluon" ($\min(x_1, x_2)$) kinematics are indicated.

As noted in Table 2, it will also be possible to measure a significant yield of $W^{+/-}$ bosons using longitudinally polarized protons. The yield of $W^{+/-}$ is sensitive to the polarization of the valence quark and sea anti-quark distributions, and may be used to provide an independent measurement of both distributions. An example is shown in Fig. 12, in which the two spin parity violating asymmetry

$$A_{LL}^{PV} = \sigma^{--} - \sigma^{++} / \sigma^{--} + \sigma^{++} \tag{2}$$

as a function of rapidity is noted to be strikingly different depending on whether the $\bar{u}$ and $\bar{d}$ distributions of the proton are polarized or unpolarized[9]. Although the W yield can not be determined directly as a function of rapidity in STAR, an integral measurement across the STAR acceptance will provide a very sensitive measurement of the degree to which the sea anti-quark distributions in the proton are polarized. The background and trigger rates for the measurement of W production in STAR have been simulated, and the results indicate this study is feasible.

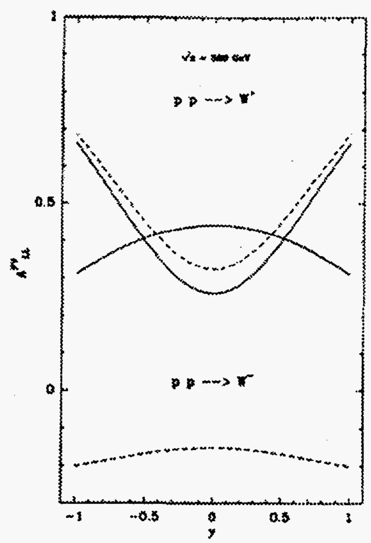

Figure 12: The parity violating asymmetry A_{LL}^{PV} versus y for W^+ and W^- production at center of mass energy of 500 GeV. The solid lines correspond to non-zero sea quark polarization whereas dashed lines correspond to $\Delta\bar{u} = \Delta\bar{d} = 0$. The estimated uncertainty

δA_{LL}^{PV} for an integral measurement in STAR for a running period corresponding to 800 Pb^{-1} (100 days at 50% efficiency) is approximately 1%.

Table 2		
Boson	STAR(Barrel)	STAR(Barrel+Endcaps)
$W^+ + W^-$	83,000	110,000
W^+	61,000	80,000
W^-	22,000	30,000
Z^0	3,840	7,200

Table 2: The $W^{+/-}, Z^0$ yield in the STAR acceptance for an integrated luminosity of 800 pb^{-1} (100 days at 50% efficiency) at a pp center of mass energy of 500 GeV.

Using Z production or jet-jet coincidences with one beam transversely polarized, STAR will also be able to address an entirely new aspect of the structure of the proton – the transversity distribution of quarks in the proton. Ostensibly, this study provides information on a new, as yet unmeasured, fundamental structure function of the proton, and will indicate the degree to which the quark spins are either aligned or anti-aligned with the spin of a proton which is polarized transverse to its direction of motion. In the non-relativistic limit, the results using longitudinally polarized protons should be recovered. The transversity distribution can not be probed using DIS measurements, and information from hadronic interactions is essential. The difference between the results for transversely and longitudinally polarized ultra-relativistic protons, will provide unique information on parton dynamics within the proton.

7 Searching for Physics Beyond the Standard Model with STAR

Another very interesting aspect of the STAR physics program is the ability to address the question of physics beyond the standard model by searching for parity violation in high p_t jet production. This measurement would be accomplished in pp interactions at $\sqrt{s} =$ 500 GeV, using longitudinally polarized protons. Specifically, by examining the two-spin parity violating asymmetry

$$A_{LL}^{pv} = \sigma^{--} - \sigma^{++}/\sigma^{--} + \sigma^{++} \tag{3}$$

as a function of p_t, it will be possible in one year of RHIC running to perform a sensitive test of the hypothesis that quarks may be composite objects up to a compositeness scale of $\Lambda \approx 3$ TeV. This is significantly higher than the limit presently available ($\Lambda \approx 1.4$ TeV) from unpolarized pp interactions at Fermilab (CDF) which is determined by comparing the cross section for inclusive high p_t jet production to the predictions of QCD in leading order. It is estimated that with approximately 20 times the integrated luminosity leading to the present CDF limit, the limit available from Tevatron data would increase to $\Lambda \approx$ 2 TeV. It is therefore possible that the information provided by measuring the degree of parity violation in inclusive high p_t ($60 < p_t < 120$ GeV) jet production at RHIC using longitudinally polarized protons may provide the best limit possible on the scale for possible quark substructure until the LHC begins operation sometime in the next decade.

The question of the possibility of quark compositeness arises from the family structure of quarks and leptons within the standard model, the origin of which is not presently understood. In particular, if the family structure arises due to subconstituents (e.g. preons) which interact by means of a new contact interaction, there is no reason a priori to assume that the new interaction conserves parity. It is of some interest therefore to search for parity violation in strong processes which conserve parity to indicate the possible existence of new physics beyond what is presently known from the standard model. To accomplish this, all known "conventional" sources of parity violation in high p_t hadronic processes must first be taken into account – in particular, the parity violation expected in this regime due to interference effects between standard QCD (gluon)-electroweak (W, Z) exchange graphs in e.g. high p_t quark-quark elastic scattering.

Recently, a comprehensive study of the degree of parity violation expected from "known" processes in high p_t jet production has been performed by a number of authors[10, 11, 12]. In Fig. 13 the results from the work of Taxil and Virey[13] demonstrate the estimated sensitivity achievable in one year of RHIC running assuming a compositeness scale of $\Lambda = 2.0$ TeV. The middle curve of Fig. 13 is the asymmetry that would be observed if all of the parity violation resulted from standard QCD-electroweak interference effects presently understood within the standard model. The top and bottom curves result from assuming quarks are indeed composite objects whose subconstituents interact by means of a new parity violating contact interaction which interferes either constructively or destructively with known QDC and electroweak exchange graphs. These plots were developed using a particular choice[14, 15] of the parton structure functions presently thought to best represent the partonic structure of the proton. There is some sensitivity to the choice of structure functions, but the basic conclusion is unchanged regardless of which set is used. Figure 14 shows a realistic simulation within STAR, taking the acceptance and efficiency for jet detection into account, of the statistical uncertainty expected as a function of p_t in the measurement of A_{LL}^{PV} in one RHIC year of polarized proton running assuming all parity violation results from "conventional" sources within the context of the standard model. These results show that in one year of RHIC running, STAR will be able to provide significant new limits on the scale for possible quark substructure. An estimate from reference[13] of the limits which can be achieved in this study shown is in Table 3.

Table 3	
$\epsilon \cdot \eta = -1$	$\epsilon \cdot \eta = +1$
BS: 3050	3010
GS: 2710	2670

Table 3: The estimated limit (in GeV) on the scale (Λ) for quark compositeness achieved in one RHIC year of polarized proton running at a pp center of mass energy of 500 GeV assuming a new right handed ($\eta = -1$) or left handed ($\eta = +1$) parity violating contact interaction which interferes constructively ($\epsilon = -1$) or destructively ($\epsilon = +1$) with known QCD and electroweak exchange graphs. The limits shown are for the structure functions of reference 14 (BS) and 15 (GS).

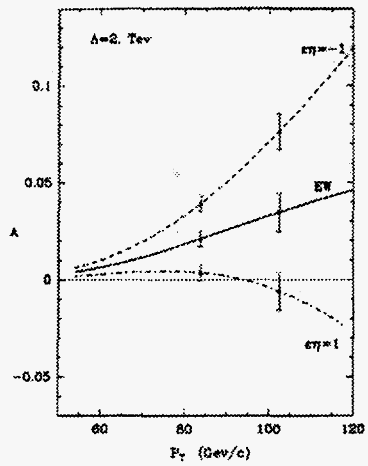

Figure 13: The two spin parity violating asymmetry of Eq. 3 (A_{LL}^{PV}) versus p_t at RHIC assuming a compositeness scale of $\Lambda \sim 2$ TeV. Calculations are shown for the structure functions of Ref. [14]. The middle curve results from standard QCD-electroweak interference terms. The top and bottom curves result if subconstituents of the proton interact by a new left handed ($\eta = -1$) or right handed ($\eta = +1$) contact interaction which interferes constructively ($\epsilon = -1$) or destructively ($\epsilon = 1$) with standard QCD-electroweak exchange graphs.

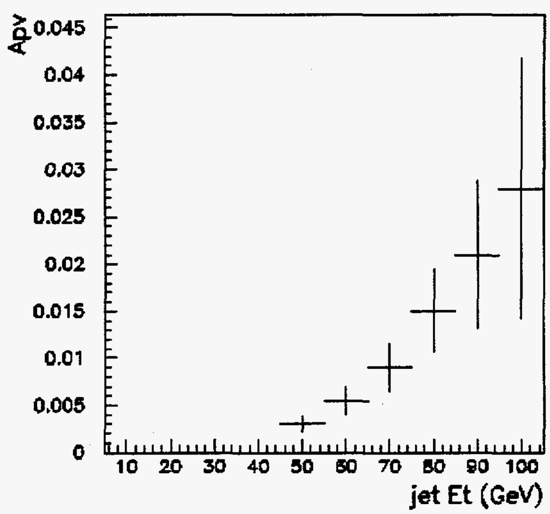

Figure 14: The estimated statistical uncertainty in the determination in STAR of the asymmetry A_{LL}^{PV} of Eq. 3 taking known sources of parity violation within the standard model into account. The data assumes one year of RHIC polarized proton running at a pp center of mass energy of 500 GeV.

8 Summary and Outlook

In conclusion, to search for evidence of a transition to a deconfined phase the STAR detector will measure and correlate a number of global observables on an event-by-event basis. STAR will also provide important information on the initial conditions, using jet-direct photon coincidences to probe the gluon distribution of a nucleon in the nucleus via the QCD Comtpon process. The study of parity violating asymmetries in high p_t jet production in STAR using polarized protons will afford a sensitive test of the possibility of new physics beyond the standard model. Work is continuing on refining the STAR capability to use hard-scattered partons as a penetrating probe to provide information on the medium in the early stages of relativistic $AuAu$ interactions.

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