RHIC Run V Beam Use Request
The STAR Collaboration

August 14, 2004

Executive Summary

The first four RHIC runs have resulted in compelling evidence that a qualitatively new form of matter is produced in central AuAu collisions. To further probe the nature of this matter and understand its properties, STAR proposes to acquire > 50M minimum-bias events and to sample ~10 nb^{-1} for rare triggers (1-2 nb^{-1} recorded) at $\sqrt{s_{NN}}$ = 200 GeV with an A+A system in the mass range A ~ 60. These data will provide important additional experimental controls, illuminating the nature of high p_t particle suppression, elliptic flow, and heavy flavor production by testing the dependence of the gluon density and pressure in the early stage of the collision on system size. Combined with data acquired in Run IV, they will allow investigation of the centrality dependence of global observables and afford important tests key to our understanding of the dependence of observables such as jet quenching, resonance production, elliptic flow, radial flow and meson/baryon scaling on energy density and system size (N_{part}).

The time requested for this measurement is 4+10 weeks. Depending on machine performance, if the $\sqrt{s_{NN}}$ = 200 GeV goals are substantially met before the end of the ten week period proposed for heavy ion data taking, a run of 1-2 weeks is proposed with the same species at reduced energy ($\sqrt{s_{NN}}$ = 62.4 GeV). This will allow robust comparison with the Au+Au data acquired in Run IV with respect to both energy and system size.

During Run V STAR will continue measurements related to its ultra-peripheral collisions program.

At the end of the proposed heavy ion run STAR requests 3+11 weeks of polarized proton running. STAR's goal is to sample > 7 pb^{-1} with beams of longitudinally polarized protons (P > 40%) to obtain a significant measurement of the gluon helicity preference in the proton through studies of $A_{LL}(\pi°)$ and A_{LL}(jet) out to p_t > 8 and 20 GeV/c respectively. These are beginning measurements which will be followed by a detailed mapping of $\Delta G(x)$ as a function of Bjorken x_{gluon} using direct γ + jet coincidences once further improvements in luminosity and polarization have been achieved. Once the goal with longitudinal polarization is substantially met, STAR proposes to sample > 4 pb^{-1} with beams of transversely polarized protons (P > 40%) to measure the transverse spin dependence of di-jet back-to-back correlations related to the Sivers function and to further study the transverse spin asymmetry observed earlier for forward $\pi°$ production. Concurrent with these measurements, most probably at the beginning of the polarized proton running period, STAR's goal is to acquire > 20M minimum bias pp events for comparison with Au+Au heavy ion data from Run IV.

In the longer term STAR believes the following beam configurations to be compelling up to 2008-2009:

- an extended d+Au run to study the parton distribution functions and specifically gluon saturation effects in heavy nuclei
- a high statistics Au+Au run at full energy with upgraded detector capability to begin to fully characterize the nature of the new matter produced at RHIC and search for evidence of broken/restored fundamental symmetries
- extended running with longitudinally polarized protons to map the gluon helicity preference in the proton

Shorter, focused polarized proton runs with transverse polarization and initial commissioning of the RHIC machine for $\sqrt{s}$ = 500 GeV polarized proton running are important additional goals during this period.

1. Report on Progress from Run IV (2003 - 2004)

For the heavy ion program the first priority for beam use by STAR in the 2003-2004 run (Run IV) was the accumulation of approximately 50 million minimum bias and 30 million central Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. An additional goal was to sample > 70 μb^{-1} for high p_t particle suppression studies. A performance based goal of running for approximately 1 week at reduced energy in the range where ISR pp data exist for comparison was also proposed if machine performance allowed the full energy goals to be met sufficiently early. For the spin program, a commissioning run of 5 weeks duration to demonstrate the machine capability required for a significant measurement of the helicity preference of gluons in the proton as well as other important transverse spin measurements was proposed. Depending on performance, it was envisioned that a request would be made to extend the run by 1-2 weeks for possible spin physics data taking. These goals were all substantially met. Table I shows the data acquired by STAR during this running period.

Table I

Energy (GeV)	Trigger	System	Events Acquired	Goal
$\sqrt{s_{NN}}$ = 200	Central	Au+Au	30.4M	30M
$\sqrt{s_{NN}}$ = 200	Hadronic Min Bias	Au+Au	47.5M	50M
$\sqrt{s_{NN}}$ = 200	Rare	Au+Au	6.0M (~ 100 μb^{-1})	> 70 μb^{-1}
$\sqrt{s_{NN}}$ = 200	UPC	Au+Au	4.1 M	5M
$\sqrt{s_{NN}}$ = 62.4	Hadronic Min Bias	Au+Au	13.3M	> 10M

The heavy ion data acquired in Run IV at $\sqrt{s_{NN}}$ = 200 will allow STAR to significantly extend its initial observations and to address the following Run IV core goals:

- 30 million central events useful for D meson spectra
- high pt triggered π° spectra out to 15 GeV/c
- > 50 million min bias events for omega v_2
- significant J/ψ sample and first measurement of the Upsilon in central collisions

Other goals this dataset is expected to address include:

- Sufficient statistics for detailed study of the centrality and p_t dependence of yields and spectra as well as elliptic flow of the Ω and Ξ; yields of strange resonances (Λ(1520), Σ*, and Ξ (1530))
- Extension of the p_t range for R_{cp} and v_2 studies of resonances as well as strange and rare particles.
- High statistics samples for event-by-event studies of fluctuations and correlations
- High statistics sample for non-identical particle correlations with respect to the reaction plane; π,K, baryon HBT with respect to the reaction plane; hyperon HBT

- High statistics sample for extending UPC measures

The $\sqrt{s_{NN}}$ = 200 GeV heavy ion data from Run IV are being produced. When complete, they are expected to yield important new results, particularly regarding the yields, spectra, and flow of multiply strange baryons and open charm, the yields of bound states of heavy quarks, and the suppression of high p_t particle production with respect to the reaction plane.

The analysis of the $\sqrt{s_{NN}}$ = 62.4 GeV data from Run IV is being finalized. The results are striking with respect to their qualitative and in some instances quantitative agreement with the results obtained for Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV in Run II. They provide an important additional experimental control for testing models of particle production and suppression at RHIC.

STAR's program of two-photon, photon-pomeron, and pomeron-pomeron studies to more fully explore the quantum chemistry underlying the structure of hadronic matter, and search for exotic states will also be continued using the results of the Run IV data analysis.

In parallel with the production and analysis of Run IV data, STAR has carried out, along with the other three RHIC Collaborations, a scholarly assessment of the experimental results and theoretical comparisons from Runs I-III, and a critical evaluation of the evidence they provide with respect to the search for Quark-Gluon Plasma formation. Future plans for analyses and measurements by the STAR Collaboration are informed by the results of this study, and its suggestions for additional needs to strengthen the case for QGP observation.

2. RHIC Run V (2004 - 2005)

2.1 Modifications to the STAR Detector Configuration for Run V

For Run V, several enhancements to the detector setup designed to extend the physics reach of STAR in the next data taking period are planned.

Additional Barrel Electromagnetic Calorimeter (BEMC) modules (perhaps the remainder if time permits) will be installed for this run with approximately ¾ of the full acceptance commissioned and read out for physics data taking. This instrumentation will provide measurement of electromagnetic energy as well as trigger capability for high pt photons, π°s, and jets. The Endcap Electromagnetic Calorimeter will be fully installed and commissioned for data taking in Run V.

The Photon Multiplicity Detector (PMD) installed on the east end of STAR at a distance of $\sim$ 550 cm from the interaction vertex will be completed and fully commissioned. This highly segmented detector uses gaseous detection of electron showers from photon conversions to count the multiplicity of photons in the pseudo-rapidity range $2.3 < \eta < 3.5$. These data will be used to examine the multiplicity and spatial distribution of photons on an event-by-event basis in this acceptance to set a baseline for non-statistical fluctuations and possible Disoriented Chiral Condensate behavior in future Au+Au studies, as well as to explore event shapes and flow.

The STAR Silicon Strip Detector (SSD) will be completed and commissioned providing significant improvement in the reconstruction efficiency for multiply strange baryons and low p_t particles. The SSD will complement and extend the capability already provided by the STAR Silicon Vertex Detector (SVT), recently optimized through a dedicated alignment effort prior to the Run IV data production.

A prototype tray of Time of Flight (TOF) detectors based on multi-gap resistive plate chamber technology will be installed for testing in Run V. This prototype will employ close-to-final-design readout electronics in anticipation of a possible construction start for a barrel TOF detector in FY2006.

Level II trigger developments will be completed and put into operation to enhance the measurement of bound states of heavy quarks.

The STAR data acquisition system will continue use of DAQ100, resulting in a projected DAQ rate (assuming a combined RHIC + STAR duty factor of 35-40%) of ~10M minimum bias Cu+Cu events per week while maintaining ~50% live time for rare triggers. These data (as well as the data from Run IV) will be analyzed using a new integrated tracking analysis framework, ITTF, which allows essential improvements in maintainability, operation, and efficiency of the data analysis code.

2.2. Run V (2004-2005): Comparison Data for Soft Physics Spectra; Charm and –Onium Yields; High p_t Yields for Lighter Species; Measurement of ΔG at $\sqrt{s}$ = 200 GeV; Transverse spin studies related to the Sivers Function

The STAR Beam Use Request for Run V is shown in Table II.

Table II

Beams	A ~ 60	$p_{\rightarrow} p_{\rightarrow}$; $p\uparrow p\uparrow$
Weeks	(4+10)	(3+11)
$\sqrt{s_{NN}}$	200*	200**

* Depending on performance a 1-2 week run at $\sqrt{s_{NN}}$ = 62.4 GeV is requested

** Goal is to sample > 7 pb^{-1} with longitudinal polarization (P > 40%), and to subsequently sample > 4pb^{-1} with transverse polarization (P > 40%); an additional goal is to acquire 20M minimum-bias pp events for comparison with the $\sqrt{s_{NN}}$ = 200 GeV Au+Au data set.

- Main Goals:
  - Soft physics comparison for lighter species
  - high p_t inclusive spectra and leading particle correlation studies for a lighter system
  - -Onium and open charm yield comparison for lighter species
  - Robust measurement of ΔG in $p_{\rightarrow} + p_{\rightarrow}$ at $\sqrt{s}$ = 200 GeV
  - Transverse spin studies related to the Sivers Function

Heavy Ion Goals:

In the first four RHIC runs, striking evidence has been obtained for the creation of a qualitatively new form of matter in central AuAu collisions.

Comparison of inclusive yields of high p_t charged particles and the correlation of back-to-back leading charged hadrons has shown[i,ii,iii,iv,v] (Figure 1) that inclusive high p_t particle production and "away side" leading hadrons are strongly suppressed (a factor of 5 for inclusive production) in central Au+Au collisions relative to the yields in p+p, peripheral Au+Au, and central d+Au collisions. These results suggest that the strong suppression of inclusive particle production and the disappearance of the back-to-back correlation in central Au+Au collisions are due to final state interactions of hard scattered partons or their fragmentation products in the dense medium created in central Au+Au collisions. High p_t hadrons that are seen (e.g. in the near side correlation peak) presumably arise preferentially from partons scattered outward from the surface region of the collision zone, while the away side partons must traverse significant lengths of dense matter. This picture is further supported by the fact that an asymmetry in the strength of the high p_t di-hadron correlation can be seen relative to the orientation of the high p_t trigger hadron with respect to the reaction plane, presumably reflecting the different amount of dense matter that must be traversed in and out-of-plane for a source with a significant eccentricity. Such a source is expected from geometrical considerations for non-central collisions and is strongly suggested by the results from elliptic flow studies.

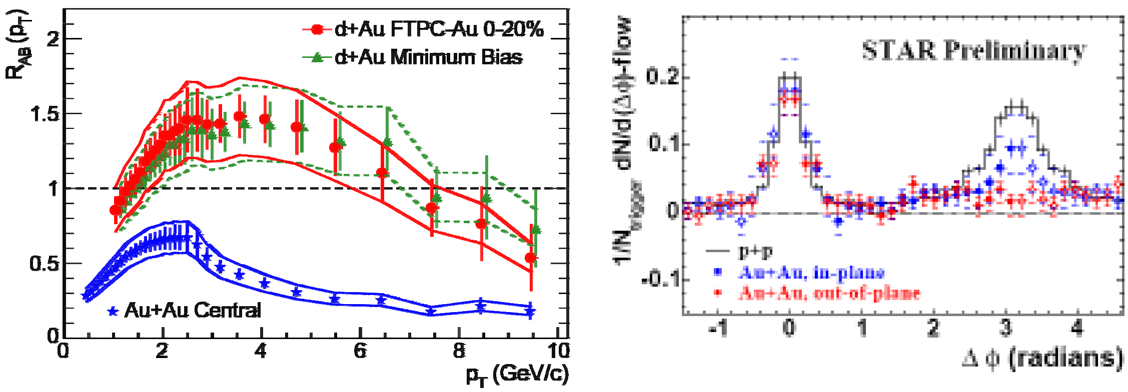

Figure 1. Left panel: Charged hadron nuclear modification factor for minimum bias and central d+Au collisions, and central Au+Au collisions. Minimum bias d+Au data are displaced 100 MeV/c to the right for clarity. There is a strong suppression (a factor or 5) of leading hadrons in central Au+Au collisions, relative to the yields in p+p, peripheral Au+Au, and central d+Au collisions. Right panel: Background-subtracted high p_t dihadron correlation as a function of relative azimuthal angle ($\Delta\phi$) for different orientations of the trigger hadron relative to the reaction plane

Measurement of the elliptic flow, v_2 (the second Fourier coefficient of the azimuthal anisotropy of the transverse momentum distribution), for a wide range of strange and non-strange mesons, baryons, and resonances[vi,vii,viii] has shown that the early stage of the collision is characterized by the buildup of large pressure gradients, and that the matter is strongly interacting and exhibits collective behavior during this stage. Elliptic flow measured for identified particles as a function of p_t has shown potential sensitivity to the underlying equation of state, with the distribution measured for protons being best described by a model dependent equation of state incorporating a phase transition from partonic to hadronic matter (Fig 2, right panel).

In Figure 3 d) all of STAR's particle-identified elliptic flow measurements for the 200 GeV Au+Au minimum bias sample are combined by taking both v_2 and p_t and scaling them by the number of constituent quarks in the hadron of interest. The apparent scaling behavior seen in this figure is intriguing, as the data seem to be pointing to constituent quarks as the most effective degree of freedom in determining hadron flow at intermediate p_t values.

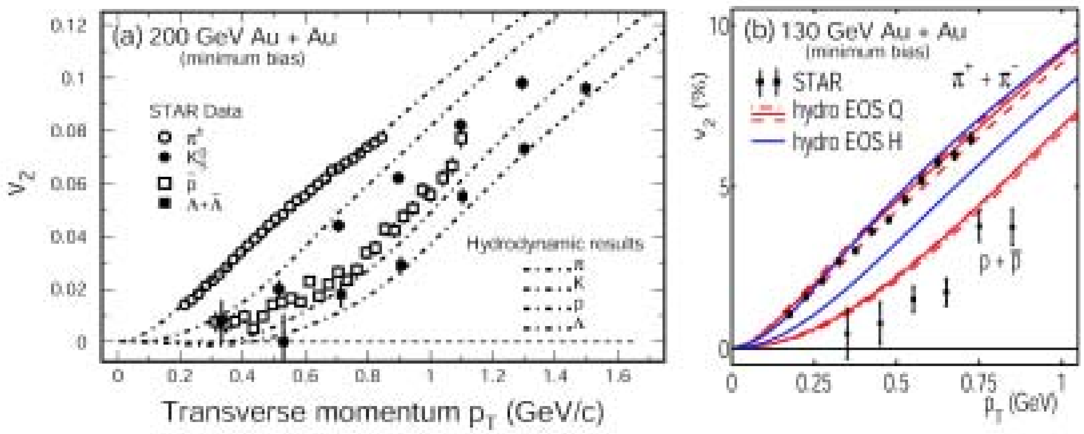

Figure 2. Comparison of particle-identified elliptic flow measurements in the soft sector, as a function of p_t, with hydrodynamics calculations from Refs. [ix]. The calculations in the left-hand frame and those represented by red curves in the right frame assume early thermalization, ideal fluid expansion, an Equation of State consistent with lattice QCD calculations including a phase transition from QGP to hadronic matter during the expansion, and a sharp kinetic freezeout at a temperature of 120 MeV. The blue curves on the right are similar calculations, but incorporating an EOS for a hadron gas, with no phase transition included.

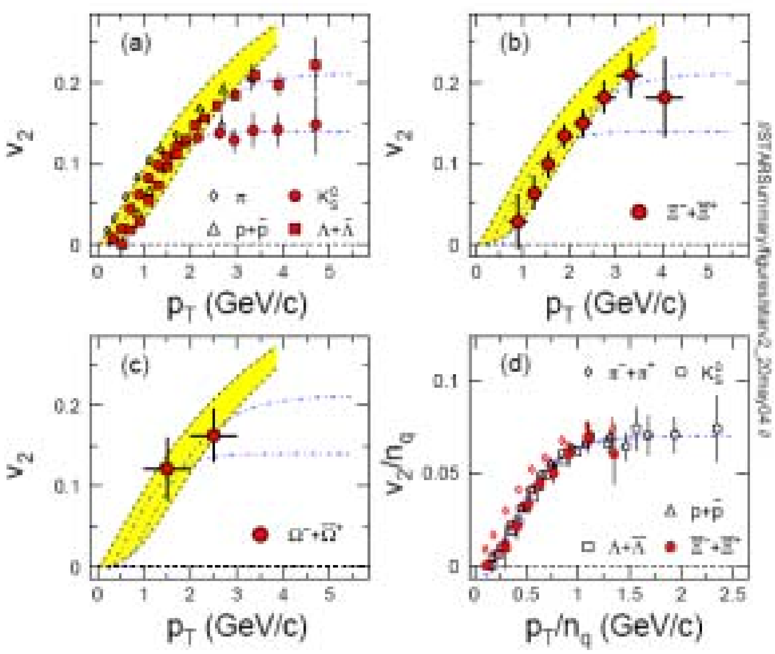

Fig 3 (a) STAR experimental results of the transverse momentum dependence of the event elliptic anisotropy parameter for π, K^0_s, p+pbar, Λ+ Λbar, all produced in minimum bias AuAu collisions at $\sqrt{s_{NN}}$ = 200 GeV. Dot-dashed lines are fits to the data using simple analytic functions. Hydrodynamics calculations are indicated by the shaded bands. Multi-strange baryon elliptic flow is shown in b) for Ξ and c) for Ω. d) Flow results for all of the above hadrons (except the statistically limited Ω) combined by scaling both v_2 and p_t by the number of constituent quarks in each hadron.

These data, as well as other measurements, are strongly suggestive of a new form of matter that is extremely dense and strongly dissipative, that behaves like an ideal fluid, and for which the relevant bulk matter degrees of freedom may be partonic. This tantalizing picture needs to be made compelling, not only with further results such as those expected to come from the Run IV data now in production on open charm yields, spectra, and elliptic flow, but also by crafting further tests with different experimental controls (beam energy, system size) to challenge the present interpretation of these observations, and confirm it is correct. An important beginning in this direction was the reduced energy ($\sqrt{s_{NN}}$ = 62.4 GeV) beam time at the end of Run IV. The results from analyzing this data set have already resulted in surprising indications that the degree of high p_t particle suppression, the strength of high p_t di-hadron correlations as a function of the orientation of the trigger hadron with respect to the reaction plane, and the amount of elliptic flow observed for various particle species are all strikingly similar to the results obtained for $\sqrt{s_{NN}}$ = 200 GeV Au+Au. An obvious and compelling question to ask next is what is the dependence of these key observables on the size of the colliding system (N_{part})? Measurements for lighter colliding nuclei are needed to complement studies already undertaken for Au+Au as a function of collision centrality and orientation with respect to the reaction plane, because the latter variations unavoidably also change parameters other than N_{part}, e.g., the initial spatial eccentricity in the case of centrality variations and the rate of matter expansion in the case of azimuthal orientation variations.

For that reason, STAR proposes to measure comparison spectra for lighter species (A ~ 60) for soft physics observables and high p_t inclusive spectra and correlations, as well as -onium and open charm. Key goals will be to determine the dependence on the size and geometry of the colliding system for various physical properties such as the build-up of elliptic flow, the propagation and energy loss of hard scattered partons, the yield of strange particles, characteristics of the source(s) for particle emission, and the level of event-by-event fluctuations and correlations.

Specifically, to further probe the nature of this matter and understand its properties, STAR proposes to acquire > 50M minimum-bias events and to sample ~10 nb^{-1} for rare triggers (1 to 2 nb^{-1} recorded) at $\sqrt{s_{NN}}$ = 200 GeV with a system in the mass range A ~ 60. These data will provide important additional experimental controls illuminating the nature of high p_t particle suppression, elliptic flow, and heavy flavor production by testing the dependence of the gluon density and pressure in the early stage of the collision on system size. A particular goal with respect to high p_t particle production, which relates to STAR's request to run a symmetric system with A ~ 60, is to test the predicted approximate L^2-dependence of partonic energy loss where hadron suppression is still sufficiently large (based on projection from 30-40% Au+Au sample (Npart ~ 115)) to reliably observe it given the projected systematic error. For soft physics observables, data from Run V combined with those from Run IV will allow investigation of the dependence of observables such as elliptic and radial flow, resonance production, and meson/baryon scaling on energy density and system size (N_{part}).

The time requested for this measurement is 4+10 weeks. Depending on machine performance, if the $\sqrt{s_{NN}}$ = 200 GeV goals are substantially met before the end of the ten-week period proposed for heavy ion data taking, a run of 1-2 weeks is proposed with the same species at reduced energy ($\sqrt{s_{NN}}$ = 62.4 GeV). This will allow robust comparison with the Au+Au data acquired in Run IV with respect to both energy and system size. If these lower-energy data are not taken in conjunction with a full-energy run for lighter nuclei, the machine overhead needed for RHIC setup would become prohibitive for a run of such short duration.

Other important heavy ion physics goals

During this period STAR will also continue measurements related to its ultra-peripheral collisions program which has conclusively demonstrated the possibility for carrying out a unique study of coherent particle production (Figure 4).

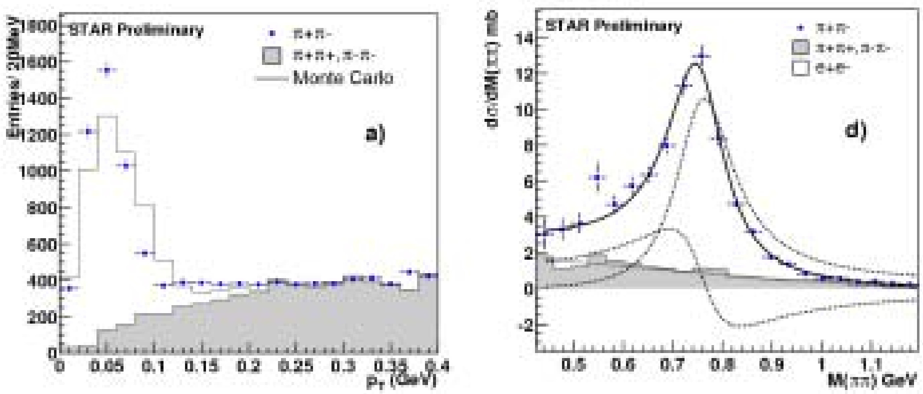

Figure 4. The p_T and π-π invariant mass spectrum of two-track events collected in 200 GeV Au-Au collisions with the minimum bias trigger, from coherent photoproduction of ρ^o and direct π-π pairs accompanied by mutual Coulomb excitation. The p_T spectrum is peaked below 100 MeV/c, as expected for a photon from the electromagnetic field of one nucleus scattering coherently from the other nucleus, emerging as a vector meson (from Ref [x]).

Spin Physics Goals:

Longitudinal Polarization

A major goal of the STAR spin program is a comprehensive study of the proton's spin structure using polarized proton collisions. The centerpiece of this program is the delineation of gluon contributions to the proton spin. It is already known that gluons contribute at least half of a proton's momentum; do they also make a major contribution to the spin? Polarized deep inelastic lepton scattering (DIS) experiments have offered indirect hints of a possible sizable contribution from gluons, but it is impractical to make polarized DIS measurements over a suitably broad kinematic range, with sufficiently good statistical precision, to cleanly determine the gluon helicity preference as a function of Bjorken *x* [$\Delta G(x)$], as has been done from DIS for the unpolarized gluon distribution. Direct measurements of $\Delta G(x)$, and constraints on its integral ΔG (the net contribution to the proton's spin), from polarized proton collisions at RHIC are therefore widely anticipated to fill in the next crucial piece of the proton spin puzzle.

Run V will be the first run for which all of the components essential for a robust measurement of ΔG in $p_{\rightarrow} + p_{\rightarrow}$ at $\sqrt{s}$ = 200 GeV are substantially commissioned and ready. Specifically, it is anticipated that a fully commissioned jet target will be available to provide absolute calibration of the beam polarization to ~ ±5%. Additionally, the commissioning work on the machine accomplished in Run IV demonstrated that RHIC performance has advanced to the point that the main physics goals of the RHIC spin program can begin to be addressed. A strong cold-bore partial Snake should be installed in the AGS, and may be available late in the run to enhance beam polarization. Finally, most of STAR's electromagnetic calorimetry will be commissioned, optimizing efficiency for the triggering and reconstruction of jets and π°s.

As a consequence, STAR proposes to give high priority to a robust measurement of ΔG, a study which has been of world-wide interest for several decades, and which has the potential to elucidate the parton dynamics within the proton. Specifically, STAR's goal is to sample > 7 pb^{-1} with beams of longitudinally polarized protons (P > 40%) to obtain a significant measurement of the gluon helicity preference in the proton through studies of $A_{LL}(\pi°)$ and A_{LL}(jet) out to $p_t > 8$ and 20 GeV/c respectively. These are beginning measurements which will be followed by a study of $\Delta G(x)$ as a function of Bjorken x_{gluon} using direct γ + jet coincidences once further improvements in luminosity and polarization have been achieved.

Transverse Polarization

Once the goals with longitudinally polarized proton beams have been substantially met, STAR proposes to sample > 4 pb^{-1} with beams of transversely polarized protons (P > 40%).

Although the STAR spin physics program is still in its infancy, the first polarized proton runs have already yielded important new results. Specifically, the study of forward neutral pion production at large Feynman x and moderate p_t has indicated a large analyzing power for single spin asymmetries in collisions of transversely polarized protons (Figure 5). These results suggest a strong sensitivity to aspects of the parton distributions tied to the transverse spin orientation of a proton. That covers transversity and the so-called Sivers effect, which is a preference for quark transverse momentum in a proton to be directed to one side or the other of the plane formed by the spin direction and the proton's momentum direction. The proposed run with transverse polarization will allow STAR to measure the transverse spin dependence of mid-rapidity dijet back-to-back correlations as a function of the opening angle between the two jet axes. A deviation from 180° opening angle, for fully reconstructed jets, should be directly attributable to transverse parton momentum k_t in the initial protons. Consequently, as suggested by Boer and Vogelsang[xii], the single-spin transverse asymmetry for such not-quite-back-to-back dijets should provide a direct (i.e., leading twist) measurement of any Sivers function directional preference for $\mathbf{k_t}$ with respect to the proton's spin orientation. Combined with further measurements of the separated x_F and p_t-dependences of the forward $\pi°$ production asymmetry, these new data should significantly elucidate the origin of high-energy transverse spin asymmetries.

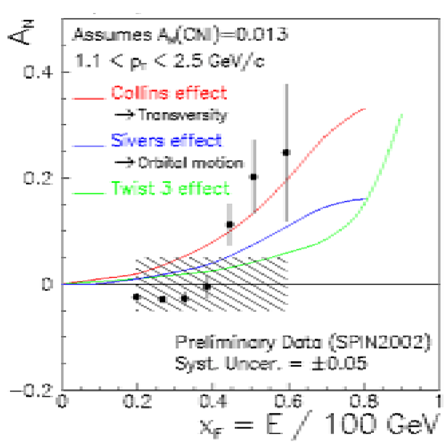

Figure 5. STAR results for the analyzing power for forward π^0 production at large pseudorapidity ($3.3 \le \eta \le 4.1$). The data are compared to several calculations including ones based on the Collins effect, corresponding to a spin dependent fragmentation (red curve), on a twist-3 quark-gluon correlation responsible for the spin effect evaluated at p_T =1.5 GeV/c (green curve), and on the Sivers effect, where the spin effects arise from a correlation between the proton spin and the colliding parton's transverse momentum in the distribution function (blue curve) (from ref. [[xi]]).

Concurrent with these measurements, most probably at the beginning of the polarized proton running period, when the luminosity build-up is just beginning, STAR's goal is to acquire > 20M minimum bias pp events for comparison with Au+Au heavy ion data from Run IV at $\sqrt{s_{NN}}$ = 200 GeV.

3. General Summary and Outlook on Beam Use

The first four RHIC heavy ion runs have yielded strong evidence suggesting the creation of a new form of matter. The near term plan to extend and strengthen the results which support this conclusion is timely production of the data from Run IV and the acquisition of further data which affords additional experimental controls (beam energy and system size) in order to change the experimental conditions (e.g. the energy density, number of participants, etc.) in ways that are thought to be understood, in order to gain insight into the nature of important observed effects such as high p_t particle production/suppression, the build-up of elliptic flow, and meson/baryon scaling.

In the longer term, for runs VII and VIII respectively, STAR believes the following to be compelling:

- an extended d+Au run to study the parton distribution functions and specifically gluon saturation effects in heavy nuclei related to a possible Colored Glass Condensate

- a high statistics Au+Au run at full energy with upgraded detector capability to begin to fully characterize the nature of the new matter produced at RHIC and search for evidence of broken/restored fundamental symmetries

With respect to the spin program, a major step forward was accomplished in Run IV with the demonstration of reproducible luminosity and polarization performance sufficient to begin to address high priority goals of the RHIC spin program. This program requires optimization of the running time up to 2008-2009 to also allow for:

- extended runs with longitudinally polarized protons to map the gluon helicity preference in a polarized proton as a function of Bjorken x of the gluons

Shorter, focused polarized protons runs with transverse polarization and initial commissioning of the RHIC machine for $\sqrt{s}$ = 500 GeV polarized proton running are important additional goals during this period.

4. Collaboration Readiness

The STAR Operations Group, as well as the STAR Collaboration membership have been participating in an extensive program of shut-down activities in preparation for Run V. STAR will be fully prepared to begin the program outlined for Run V.

[i] J. Adams et al., Phys. Rev. Lett. **91**, 072304 (2003)
[ii] J. Adams et al., Phys. Rev. Lett. **91** (2003) 172302
[iii] C. Adler et al., Phys. Rev. Lett. **90**, 082302 (2003).
[iv] C. Adler et al., Phys. Rev. Lett. **90**, 032301 (2003).

[v] C. Adler et al., Phys. Rev. Lett. **89**, 202301 (2002).
[vi] J. Adams et al, Phys. Rev. Lett. **92** (2004) 052302
[vii] C. Adler et al, Phys. Rev. Lett. **89**, 092301 (2002).
[viii] C. Adler et al, Phys. Rev. Lett. **87**, 182301 (2001).
[ix] P. Huovinen, et al., Phys. Lett. **B503**, 58 (2001); P. Huovinen, private communication (2003).
[x] C. Adler et al., Phys. Rev. Lett. **89** (2002) 272302
[xi] J. Adams et al., Phys. Rev. Lett. **92** (2004) 171801
[xii] D. Boer and W. Vogelsang, Phys. Rev. D**69**, 094025 (2004).