Beam Use Proposal for 2001
The STAR Collaboration

November 2000

1 Executive Summary

With the successful completion of the first data-taking at RHIC in Summer 2000, the STAR Collaboration has established and understands the performance of its detector and trigger systems, and has embarked upon analysis of these data for physics. During the Summer 2000 run, STAR collected two million events at $\sqrt{s_{nn}} = 130$ GeV Au + Au. These data were accumulated using two different geometry triggers: a central trigger, which represents 15 % of the geometrical cross section, and a minimum bias trigger. This resulted in 844 K central events and 458 K minimum bias events for analysis. A paper on elliptic flow results from STAR has been accepted for publication in Physical Review Letters, and preliminary results of other physics analyses and detector performance were reported in 21 presentations at the Division of Nuclear Physics Meeting in early October.

For the RHIC 2001 run, STAR requests that a significant part of the RHIC running focus on collisions in the Au + Au system at $\sqrt{s_{nn}} = 200$ GeV for heavy ion studies and in the p + p system at $\sqrt{s_{nn}} = 200$ GeV for spin commissioning, transverse and longitudinal spin studies, and as reference data for the heavy ion program. However, STAR also requests changes to Au + Au at lower energies and to a lighter system Cu + Cu at $\sqrt{s_{nn}} = 200$ GeV in order to initiate a survey in the heavy ion physics program. In general, it is anticipated that measurements of various observables over a range of beams and energies are required for a thorough search and investigation of the deconfinement and chiral phase transitions. However, it is imperative to first accumulate sufficient statistics in STAR to thoroughly investigate Au + Au at the highest RHIC energy prior to measurements in other systems.

A comparison of the three different systems at $\sqrt{s_{nn}} = 200$ GeV will allow an initial investigation into hard scattering processes and parton propagation, new in relativistic heavy ion physics to RHIC. A comparison of the most central Cu + Cu collisions with a less central trigger in Au + Au collisions will provide a cross-check for determination of the participant number as a function of collision centrality, which is important for understanding the data accumulated with the heavy ion beams.

2 Time-Ordered Beam Request and Physics

This proposal is for 32 weeks of data-taking (as per guidance from the Lab), with data-to-tape rates estimated from the Summer 2000 run. This rate is 2 Hz (9 Hz) for central (minbias) trigger(s) for 200 GeV Au + Au. In addition, a combined STAR detector plus RHIC collider efficiency of 50% will be assumed (which reduces the above rates by a factor of 2 in order to estimate the average rates for the running over a period of time).

- $\sqrt{s_{nn}} = 200$ **GeV Au + Au**: 5 M minimum bias events (13 days) and 5 M central events (58 days); total request 12 weeks data-taking (with initial efficiency of 25% for new detector studies during the first 4 weeks, as described below).

- $\sqrt{s_{nn}} = 60$ **GeV Au + Au**: 5 M minimum bias (13 days) and 2 M central events (11.5 days), request 4 weeks (includes $\sim$ 3 - 4 days for trigger studies after changeover).

- $\sqrt{s_{nn}} = 200$ **GeV Cu + Cu**: 5 M minimum bias (13 days) and 2 M central events (8 days), request 4 weeks (includes one week for RHIC changeover).

- $\sqrt{s_{nn}} = 200$ **GeV p + p**: combined spin program and reference data request is for 9 weeks commissioning and data-taking; which consists of 1 week of p + p collision commissioning at RHIC, 2 weeks of polarized p + p collision commissioning, 3 weeks of measurements with transverse spin, 3 weeks with vertical spin, plus 50 M minimum bias events for heavy ion reference data (5 weeks of data-taking concurrent with spin running, plus 1 week of prior trigger testing).

- $\sqrt{s_{nn}} = 20$ **GeV Au + Au**: up to 5 M minimum bias (10 days) and 2 M central events (9 days), request 3 - 4 weeks (includes $\sim$ 3 - 4 days for trigger studies after beam changeover). It is useful to start on this, even if 1 - 2 weeks are available.

2.1 $\sqrt{s_{nn}} = 200$ GeV Au + Au (weeks 1 - 12)

The initial beam-energy requested is 12 weeks of operation with $\sqrt{s_{nn}} = 200$ GeV Au + Au. It is anticipated that one half of the data-taking time in STAR during the initial four weeks of RHIC operation for physics will be devoted to testing and understanding the operation and performance of the newly installed STAR detector systems - the Silicon Vertex Tracker, 20 modules of Barrel Electromagnetic Calorimeter, Forward Time Projection Chamber, Time-of-Flight patch, and additional triggering systems and algorithms.

Starting with the 5th week of the run using $\sqrt{s_{nn}} = 200$ GeV Au + Au, it will take 8 more weeks to accumulate 5 million events in each of the central trigger and minimum bias trigger. The luminosity only affects STAR's data rates using these triggers, when it drops below 5 percent of design luminosity.

The physics measurements anticipated from this run are: identified charged particle spectra (yields, Pt slopes) at low Pt; charged hadron spectra at high Pt (to $\sim$ 10 GeV/c); identified particle spectra in the STAR RICH for π and K up to 3 GeV/c, for protons and anti-protons to 5 GeV/c; strange particle (π, K, p, Λ, Ξ, Ω and anti-particles) yields and slopes; particle correlations (various $\pi\pi$, KK, pp and anti-particles; also study feasibility of K^oK^o and Λp correlations); event-by-event physics (flow, correlations, fluctuations, dimensional analysis); and "photon/pomeron physics" collisions (which requires a special "photon/pomeron" trigger for events).

The request for this beam-energy combination is for 12 weeks of data-taking, divided among 5 M minimum bias events (13 days), 5 M central events (58 days), and 5 - 10 M "photon/pomeron" triggered events. The physics requirements which specify the numbers of central events to be accumulated for this beamtime (5 M) are the spectrum of the Ω, and the identified particle spectra in the RICH detector out to Pt = 5 GeV/c for protons and anti-protons. For the minimum bias trigger the physics which determines the number of events (5 M) are the spectrum of the Ξ, the particle correlations and the event-by-event physics. (Note that an initial efficiency of 25% for new detector studies is anticipated during the first 4 weeks of STAR operation as described above).

2.2 $\sqrt{s_{nn}} = 60$ GeV Au + Au (weeks 13 - 16)

This will be an initial survey run. The lower beam energy for the Au + Au system will allow a comparison with data accumulated at $\sqrt{s_{nn}} = 130$ GeV in the Summer 2000 run and at $\sqrt{s_{nn}} = 200$ GeV (requested above). Various quantities are expected to change as a function of energy and will be measured and compared. The measurements that will be made include: identified charged particle spectra (yields, Pt slopes) at low Pt and charged hadron spectra at high Pt (to $\sim$ 10 GeV/c); identified particle spectra in the STAR RICH for π and K up to 3 GeV/c, and for protons and anti-protons to 5 GeV/c (the latter only once a specialized level 3 high Pt trigger is developed for the RICH/TPC); strange particle (π, K, p, Λ, Ξ and anti-particles) yields and slopes; Ω yields; particle correlations (various $\pi\pi$, KK, pp and anti-particles); a first look as a function of energy for event-by-event physics (complete flow analysis, while investigations of correlations, fluctuations, and dimensional analysis may require more data in this beam-energy configuration).

The central trigger data rate is assumed to be twice that at full energy due to the lower average multiplicity (by $\sim 1/2$) at this energy relative to the full energy.

The request for this beam-energy combination is for 4 weeks of data-taking, divided between 5 M minimum bias events (13 days), and 2 M central events (11.5 days). This includes $\sim$ 3 - 4 days for trigger studies after changeover.

2.3 $\sqrt{s_{nn}} = 200$ GeV Cu + Cu (weeks 17 - 20)

This will be part of an initial survey run. Cu is chosen at $\sqrt{s_{nn}} = 200$ GeV in order to control the geometry (central) and to vary the pathlength through which hard-scattered partons must propagate to measure the parton energy loss. It is also a way to vary the volume of the interaction region in a controllable way while maintaining a fixed energy density (i.e. by comparing results from different beam-energy combinations at the same dn/dy). Comparisons will also be made between central events in Cu + Cu and events measured in peripheral collisions of Au + Au to cross-check the participant number determination. The physics results anticipated from this run are: identified charged particle spectra (yields, Pt slopes) at low Pt and charged hadron spectra at high Pt (to $\sim$ 10 GeV/c); identified particle spectra in the STAR RICH for π and K up to 3 GeV/c, and for protons and anti-protons to 5 GeV/c (once a specialized level 3 trigger is developed); strange particle (π, K, p, Λ and anti-particles) yields and slopes; Ξ yields and possibly slopes; Ω yields; particle correlations (survey $\pi\pi$, KK, pp and anti-particles); event-by-event physics (complete flow analysis, and survey correlations, fluctuations, dimensional analysis); first look at "photon/pomeron physics" collisions in this sytem (with specialized trigger).

The central trigger data rate is assumed to be $\sim$ three times that of the full energy Au + Au, from scaling the multiplicity by A.

The request for this beam-energy combination is for 4 weeks of data-taking, divided between 5 M minimum bias events (13 days), and 2 M central events (8 days). This includes $\sim$ 1 week for beam changeover.

2.4 $\sqrt{s} = 200$ GeV p + p (weeks 21 - 29)

The commissioning goals for this run are understood to be 50% polarization for each beam and a collision luminosity of 5×10^{30} cm^{-2}s^{-1}. This is expected to take $\sim$ 2 weeks for commissioning polarized beam in the AGS to improve the beam polarization prior to RHIC injection, then $\sim$ 1 week of proton collision commissioning in RHIC to accelerate and collide 100 GeV proton beams, and $\sim$ 2 weeks of polarized proton commissioning in RHIC to accelerate polarized proton beams to 100 GeV in each ring, while maintaining polarization with two operating Siberian snakes in each ring.

We request 3 weeks of polarized proton collisions at $\sqrt{s}$ = 200 GeV with transverse (vertical) beam polarization. The focus of these measurements is on left/right scattering asymmetries for bunch crossings with one beam vertically polarized, either up or down. Spin asymmetries can be measured in this configuration without relying on highly precise relative luminosity measurements for bunches with positive and negative vertical polarization. By comparing left/right scattering asymmetries with the two different beam polarization states, it will be possible to test the reliability of different monitors of the relative beam luminosity.

We request 3 weeks of polarized proton collisions at $\sqrt{s}$ = 200 GeV with longitudinal beam polarization. The beam time would be used to improve our understanding of systematic errors that will limit the measurement of the longitudinal spin correlation, A_{LL}, which is sensitive to the polarization of gluons within the proton. We will also perform studies on luminosity monitoring, beam polarization measurements, and measure a non-zero transverse single spin asymmetry. Resolving these issues is essential to allow a meaningful measurement of A_{LL} in the 2002 run.

During the polarized proton running, p + p reference data will be collected for understanding the Au + Au collision data. General characteristics of p + p collisions will be measured at $\sqrt{s}$ = 200 GeV and compared to results with $p+\overline{p}$ from the UA experiments at CERN. This will allow the collection of $\sim$ 50 M minimum bias events (possibly a combination of minimum bias and central collision events depending upon development of a central collision trigger in p + p) for heavy ion reference data in 5 weeks of data-taking concurrent with spin running (plus 1 additional week for p + p trigger studies). The combined spin program and reference data amounts to 9 weeks of RHIC commissioning and data-taking.

2.5 $\sqrt{s_{nn}} = 20$ GeV Au + Au (weeks 30 - 32)

This will be part of a survey, and will allow a comparison with data accumulated at $\sqrt{s_{nn}}$ = 60, 130, and 200 GeV. This will also allow a direct comparison with the measurements made at the top CERN Pb + Pb energy. Various quantities are expected to change as a function of energy and will be measured and compared.

The data rate is assumed to be 3/4 of that for $\sqrt{s_{nn}} = 60$ GeV Au + Au due to the lower average multiplicity expected at this energy. The request for this beam-energy combination is for 3 - 4 weeks of data-taking, divided between 5 M minimum bias events (10 days), and 2 M central events (9 days). This includes $\sim$ 3 - 4 days for trigger studies after changeover. It would be useful to start on this even if only 1 - 2 weeks are available.

3 Relative Priorities

The highest priority for STAR is to accumulate 5 million events in each of the two centrality trigger modes (minimum bias and central) with the beam-energy combination of $\sqrt{s_{nn}} = 200$ GeV Au + Au.

The second highest priority for STAR data-taking is to commission and collide polarized protons at $\sqrt{s} = 200$ GeV, and to spend 3 weeks utilizing collisions of transversely (vertical) polarized protons and 3 weeks with longitudinally polarized protons for spin measurements. This will also allow concurrent data-acquisition for heavy ion reference data with up to 50 million minimum bias events. This amounts to 9 weeks of RHIC running with protons at $\sqrt{s} = 200$ GeV.

The third highest priority for STAR data-taking is to accumulate approximately 5 million events in the central and 2 million events in the minimum-bias trigger modes with the beam-energy combination of $\sqrt{s_{nn}} = 60$ GeV Au + Au.

The fourth highest priority for STAR data-taking is to accumulate approximately 5 million events in the central and 2 million events in the minimum-bias trigger modes with the beam-energy combination of $\sqrt{s_{nn}} = 200$ GeV Cu + Cu.

If there is any additional running time during this period, our next priority would be to continue our physics measurements at lower energy with 3 - 4 weeks of data-taking at $\sqrt{s_{nn}} = 20$ GeV Au + Au for comparison with the CERN-SPS heavy ion data. This can be started and expected to yield results, even if only 1 - 2 weeks of data-taking is available.

We anticipate continuing the survey in 2002 utilizing Au + Au at the lower energies (mentioned in the previous paragraphs), Cu + Cu at 200 GeV (and possibly lower energies), 200 and 500 GeV polarized p + p, and possibly 200 GeV Au + Au again. All of this will depend upon the physics results from the 2001 run.

4 Collaboration Readiness

Additional detectors are being installed and new trigger algorithms are being developed. It is anticipated that the new detectors will be ready for operation and data-taking after the initial start-up period as specified above (4 weeks of RHIC operation). Specialized triggers will be tested during the beginning of the run and their implementation will be determined once tested. The STAR Collaboration is ready to carry out the proposed experimental program.