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Using the curvilinear coordinate system, the spin transfer matrix after passing through a snake is given by. where the snake axis. is located in the horizontal plane and ? is the spin rotation angle called the snake strength . For a 100% snake, we have ? = ?.

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Spin Dynamics And Snakes In Synchrotrons
Spin Dynamics and Snakes in Synchrotrons Spin dynamics simulations include : 1) crossing and neighboring of spin resonances ; 2) dynamics in presence of the two helical snakes ; 3) Q-jump. Spin Dynamics Simulations At AGS Thomas Page 3/11

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Spin Dynamics and Snakes in Synchrotrons Spin Dynamics and ...
spin dynamics and snakes in synchrotrons uploaded by john creasey the material covers the equation of motion for polarized beams in synchrotrons spin depolarizing resonances practical methods used in overcoming spin resonances effects of spin rotators called siberian snakes on the polarization vector snake resonances

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S. Y. Lee: Spin dynamics and Snakes in synchrotrons. World Scientific (1997) Google Scholar. 19. Bryan W. Montague: Polarized beams in high-energy storage rings. Physics Reports, 113(1):1–96 (1984) CrossRef ADS MathSciNet Google Scholar. 20.

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The success in the standard model and to the continuing research for a better understanding of the quantum chromodynamics has resulted in a great interest in spin physics among high energy and nuclear physics. Advances in accelerator technology have also spurred renewed interest in accelerating and storing highly aligned spin particles in synchrotrons and storage rings. The development of polarized ion sources and polarized electron sources have seen remarkable progress. With these advances in ion sources, there is a growing interest in the acceleration and maintenence of this polarization. This book

is intended to be used as a graduate/senior undergraduate textbook in accelerator physics and sciences. The subject deals with acceleration and storage of polarized beams in high energy synchrotrons. The material covers the equation of motion for polarized beams in synchrotrons, spin depolarizing resonances, practical methods used in overcoming spin resonances, effects of spin rotators — called Siberian snakes — on the polarization vector, snake resonances, Sokolov–Ternov radiative polarization of electrons, and design principles of spin rotators. Experimental results of many polarized beam experiments are compared with theoretical analyses. Each chapter is also followed by exercises, which are intended to reinforce the concepts discussed, to derive useful formulae for applications, and to provide an introduction to some published literatures related to the polarized beam dynamics.

The AGS provides a polarized proton beam to RHIC. The beam is accelerated in the AGS from G[gamma]= 4.5 to G[gamma] = 45.5 and the polarization transmission is critical to the RHIC spin program. In the recent years, various systems were implemented to improve the AGS polarization transmission. These upgrades include the double partial snakes configuration and the tune jumps system. However, 100% polarization transmission through the AGS acceleration cycle is not yet reached. The current efficiency of the polarization transmission is estimated to be around 85% in typical running conditions. Understanding the sources of depolarization in the AGS is critical to improve the AGS polarized proton performances. The complexity of beam and spin dynamics, which is in part due to the specialized Siberian snake magnets, drove a strong interest for original methods of simulations. For that, the Zgoubi code, capable of direct particle and spin tracking through field maps, was here used to model the AGS. A model of the AGS using the Zgoubi code was developed and interfaced with the current system through a simple command: the AgsFromSnapRampCmd. Interfacing with the machine control system allows for fast modelization using actual machine parameters. Those developments allowed the model to realistically reproduce the optics of the AGS along the acceleration ramp. Additional developments on the Zgoubi code, as well as on post-processing and pre-processing tools, granted long term multiturn beam tracking capabilities: the tracking of realistic beams along the complete AGS acceleration cycle. Beam multiturn tracking simulations in the AGS, using realistic beam and machine parameters, provided a unique insight into the mechanisms behind the evolution of the beam emittance and polarization during the acceleration cycle. Post-processing softwares were developed to allow the representation of the relevant quantities from the Zgoubi simulations data. The Zgoubi simulations proved particularly useful to better understand the polarization losses through horizontal intrinsic spin resonances The Zgoubi model as well as the tools developed were also used for some direct applications. For instance, some beam experiment simulations allowed an accurate estimation of the expected polarization gains from machine changes. In particular, the simulations that involved involved the tune jumps system provided an accurate estimation of polarization gains and the optimum settings that would improve the performance of the AGS.

This Note reports on the first, and successful, simulations of particle and spin dynamics in the AGS in presence of the two helical snakes and of the tune-jump quadrupoles, using the ray-tracing code Zgoubi. It includes DA tracking in the absence or in the presence of the two helical snakes, simulation of particle and spin motion in the snakes using their magnetic field maps, spin flipping at integer resonances in the 36+Qy depolarizing resonance region, with and without tune-jump quadrupole gymnastics. It also includes details on the setting-up of Zgoubi input data files and on the various numerical methods of concern in and available from Zgoubi.

To preserve proton polarization through acceleration, it is important to have a correct model of the process. It has been known that with the insertion of the two helical partial Siberian snakes in the Alternating Gradient Synchrotron (AGS), the MAD model of AGS can not deal with a field map with offset orbit. The stepwise ray-tracing code Zgoubi provides a tool to represent the real electromagnetic fields in the modeling of the optics and spin dynamics for the AGS. Numerical experiments of resonance crossing, including spin dynamics in presence of the snakes and Q-jump, have been performed in AGS lattice models, using Zgoubi. This contribution reports on various results so obtained.

In the two year funding period from August 15, 1992--August 14, 1994, the authors progresses can be summarized as follows: (1) the solenoidal partial snake was installed in the AGS synchrotron in May, 1993 and was subsequently successfully tested; (2) the internal polarimeter for the AGS was assembled, tested and installed in the AGS; (3) the 200 MeV polarimeter at the LINAC was tested; (4) the AGS polarized ion source was renovated; (5) the first phase of the polarized beam experiments was successfully accomplished in April 1--8, 1994, of polarized proton acceleration up to G{sub {gamma}} (almost equal to) 20; (6) they are currently renovating tune jump quadrupoles in order to accelerate polarized proton up to 25 GeV/c. The full test of these experiments will be in 1995. During this funding period, the principal investigator has spent about 20% of his research time on this project, which includes the design and manufacturing of the solenoid partial snake, beam dynamics issues of the AGS with the 5% solenoid partial snake and spin dynamics of synchrotrons with snakes in general. The graduate student, Mr. H. Huang has spent 100% of his research time working on spin dynamics. The graduate student is currently staying at BNL for the E880 experiment preparation.

This book examines the acceleration and storage of polarized proton beams in cyclic accelerators. Basic equations of spin motion are reviewed, the invariant spin field is introduced, and an adiabatic invariant of spin motion is derived. The text presents numerical methods for computing the invariant spin field, and displays the results in numerous illustrations. This book offers a more lucid view of spin dynamics at high energy than has hitherto been available.

A fundamental aspect of particle physics is the spin of the particles. With polarized beams, the

internal structure of the proton may be probed in ways that are unattainable with unpolarized beams. The Relativistic Heavy Ion Collider (RHIC) has the unique capability of colliding protons with both transverse and longitudinal polarization at center-of-mass energies up to 500 GeV. In this paper we examine the methods used to accelerate and manipulate polarized proton beams in RHIC and its injectors. Special techniques include the use of a partial Siberian snake and an ac dipole in the AGS. In RHIC we use four superconducting helical Siberian snakes (two per ring) for acceleration, and eight superconducting helical rotators for independent control of polarization directions at two interaction regions.

The Relativistic Heavy Ion Collider (RHIC) operation as the polarized proton collider presents unique challenges since both luminosity(L) and spin polarization(P) are important. With longitudinally polarized beams at the experiments, the figure of merit is LP4. A lot of upgrades and modifications have been made since last polarized proton operation. A 9 MHz rf system is installed to improve longitudinal match at injection and to increase luminosity. The beam dump was upgraded to increase bunch intensity. A vertical survey of RHIC was performed before the run to get better magnet alignment. The orbit control is also improved this year. Additional efforts are put in to improve source polarization and AGS polarization transfer efficiency. To preserve polarization on the ramp, a new working point is chosen such that the vertical tune is near a third order resonance. The overview of the changes and the operation results are presented in this paper. Siberian snakes are essential tools to preserve polarization when accelerating polarized beams to higher energy. At the same time, the higher order resonances still can cause polarization loss. As seen in RHIC, the betatron tune has to be carefully set and maintained on the ramp and during the store to avoid polarization loss. In addition, the orbit control is also critical to preserve polarization. The higher polarization during this run comes from several improvements over last run. First we have a much better orbit on the ramp. The orbit feedback brings down the vertical rms orbit error to 0.1mm, much better than the 0.5mm last run. With correct BPM offset and vertical realignment, this rms orbit error is indeed small. Second, the jump quads in the AGS improved input polarization for RHIC. Third, the vertical tune was pushed further away from 7/10 snake resonance. The tune feedback maintained the tune at the desired value through the ramp. To calibrate the analyzing power of RHIC polarimeters at any energy above injection, the polarized hydrogen jet target runs for every fill with both beams. Based on the known analyzing power, there is very little polarization loss between injection and 100 GeV. An alternative way is to measure the asymmetry at 100 GeV followed by ramping up to 250 GeV and back down to 100 GeV and then to measure the asymmetry again at 100 GeV. If the asymmetry after the down ramp is similar to the measurement before the up ramp, polarization was also preserved during the ramp to 250 GeV. The analyzing power at storage energy can then be extracted from the asymmetries measured at 100 GeV and 250 GeV. The tune and orbit feedbacks are essential for the down ramp to be possible. The polarized proton operation is still going on. We will push bunch intensity higher until reaching the beam-beam limit. The even higher intensity will have to wait for the electron lenses to compensate the beam-beam effect. To understand the details of spin dynamics in RHIC with two snakes, spin simulation with the real magnet fields have been developed recently. The study will provide guidance for possible polarization loss schemes. Further polarization gain will requires a polarized source upgrade; more careful setup jump quads in the AGS to get full benefit; and control emittance in the whole accelerator chain.

This Note reports on the first simulations of and spin dynamics in the AGS using the ray-tracing code Zgoubi. It includes lattice analysis, comparisons with MAD, DA tracking, numerical calculation of depolarizing resonance strengths and comparisons with analytical models, etc. It also includes details on the setting-up of Zgoubi input data files and on the various numerical methods of concern in and available from Zgoubi. Simulations of crossing and neighboring of spin resonances in AGS ring, bare lattice, without snake, have been performed, in order to assess the capabilities of Zgoubi in that matter, and are reported here. This yields a rather long document. The two main reasons for that are, on the one hand the desire of an extended investigation of the energy span, and on the other hand a thorough comparison of Zgoubi results with analytical models as the 'thin lens' approximation, the weak resonance approximation, and the static case. Section 2 details the working hypothesis : AGS lattice data, formulae used for deriving various resonance related quantities from the ray-tracing based 'numerical experiments', etc. Section 3 gives inventories of the intrinsic and imperfection resonances together with, in a number of cases, the strengths derived from the ray-tracing. Section 4 gives the details of the numerical simulations of resonance crossing, including behavior of various quantities (closed orbit, synchrotron motion, etc.) aimed at controlling that the conditions of particle and spin motions are correct. In a similar manner Section 5 gives the details of the numerical simulations of spin motion in the static case: fixed energy in the neighboring of the resonance. In Section 6, weak resonances are explored, Zgoubi results are compared with the Fresnel integrals model. Section 7 shows the computation of the {rvec n} vector in the AGS lattice and tuning considered. Many details on the numerical conditions as data files etc. are given in the Appendix Section, pages A and sqs.

This book of proceedings is an up-to-date review of the advances made in the past two decades on the production, control and exploitation of bright electron and light beams for science — in particular, innovative manipulation and control, in linear and circular accelerators, of high brightness charged particle beams. In the conceptual, theoretical and experimental framework of nonlinear beam dynamics and collective cooperative effects, the book provides an update of the state-of-the-art theoretical formulations, techniques and technologies, innovative concepts and scientific results obtained at existing accelerator facilities. Challenges and solutions, proposed or implemented, for the operation of third and fourth generation storage rings as synchrotron radiation sources and circular colliders for high energy particle physics, as well as radiofrequency linear accelerators for Compton/Thomson

scattering-based light sources and free electron lasers, are reviewed and discussed. The complementarity between single-pass and recirculating light sources in energy, timing and spectral operational modes also emerges.