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SUMMARY OF THE ELECTRON ACCELERATORS SESSION*

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ABSTRACT

Since the last High Energy Physics Symposium, there has been considerable progress in the field of polarized electron accelerators. Projects well into construction include the SLC, HERA, and LEP. The status of polarized beams for these projects is discussed in this session. Semiclassical and quantum mechanical calculations of polarizing and depolarizing effects are discussed, for both linear colliders and for storage rings. Substantial progress is continuing in the understanding of depolarizing mechanisms for circular machines. Modelling of these machines is underway. Activities with polarized electron beams at Novosibirsk are described.

INTRODUCTION

The High Energy Spin Physics Symposium series has been extremely useful to the spin physics community of experimenters and machine physicists. It is one of the rare occasions to meet, talk, listen, and exchange ideas. The workshops associated with the symposium have been very helpful in facilitating these discussions. They are valuable to the community of physicists who design, build and use these facilities. In the parallel session on electron accelerators, we heard reports covering all aspects of activities, from projects under construction, to quantum mechanical calculations of polarizing and depolarizing mechanisms, to code development to implement the calculations for studies of machines. This report summarizes the highlights of the parallel session.

THE STATUS OF THE SLC, HERA, AND LEP PROJECTS

Ken Moffeit presented the plans and status of SLC. The SLC machine is an upgrade of a linear accelerator to provide a prototype linear collider. Polarization of one of the beams, the e^- beam, has been planned from the beginning, and the machine incorporates components for spin production, control, and monitoring with only minor modifications to its initial configuration. Polarized electrons are injected into the machine from a polarized electron source. The source, a laser-driven gallium arsenide photoemission cathode, produces longitudinally polarized electrons at full SLC currents. Spin manipulation before and after the SLC electron damping ring is required to preserve polarization

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Invited talk presented at the 8^{th} International Symposium on High Energy Spin Physics, Minneapolis, Minnesota, September 12-17, 1988 into and out of this small ring, and to provide control of spin orientation at the experiment. Monitoring of polarization occurs in three locations, at the end of the linac section, in the extraction line for electrons after the interaction region, and near the experiment. The first two of these uses polarized Moller scattering to measure beam polarization, while the latter uses polarized Compton scattering with a laser. Dr. Moffeit described the present status of the polarization project. The majority of the system components exist. The schedule for SLC polarization depends largely on the rate of progress toward physics with the SLC. Shutdowns in the SLC schedule are needed for opportunities to install the polarization components. Early tests of polarized beams in the SLC should be possible by late 1989.

The status report for HERA was given by Klaus Steffen. One rotator system will be installed initially in the East Hall, where no ep detector is currently planned. After tests and successful operations of the first rotator, adding rotators to the North Hall and the South Hall will be considered, where H1 and ZEUS respectively are located. The rotators consist each of 58 dipole magnets, 22 of which are for the rotator proper, and 36 are for modified machine magnets satisfying spin requirements. Thirty two moveable stands are required to locate vertically the magnets. Two different vertical configurations are required to provide the two different electron helicities at the interaction region. Vacuum systems in the magnets that move must be flexible enough to permit the motions. Flexible bellows joints, with current carrying needles which can bypass image currents past the bellows, are ready. These systems are under test at DESY, and installation of components will proceed as fast as schedules allow.

LEP, unlike HERA and SLC, is a machine whose initial configuration does not include polarization. Plans to polarize LEP beams exist, but require somewhat more revisions to the initial machine than in the other cases. Dr. Koutchouk presented the status of polarization planning for LEP. The strategy consists of first verifying that transverse polarization can exist. Compton polarimetry is being included at an early date for monitoring the transverse polarization. This facility will enable machine physics studies for polarization to occur, including studies of the polarizing time constants, depolarizing effects due to resonances and energy spread, and possible tuning of the machine to minimize the depolarization. Precision energy calibration of LEP using transverse polarization is an important capability, giving LEP the possibility for very precise Z° mass measurements.

The decision to add spin rotators around the experiments has not yet been made. It is the subject of upcoming reviews. A version of the Schwitters-Richter rotator scheme has been studied, and appears feasible. RF stations near the LEP detectors are a constraint to rotator designs. Backgrounds from synchrotron radiation must be dealt with carefully in this rotator scheme. To shorten the natural polarizing times, wigglers can be used. LEP standard wigglers are part of the LEP design to allow control of emittance, bunch lengthening, and damping times. Standard wigglers at LEP reduce the 300 minute natural polarizing time to 90 minutes, but with a calculated reduction of polarization from 92.4% to 74%. The estimated energy spread increases from 37 MeV to 55 MeV. Dedicated polarization wigglers are under consideration. They would reduce polarization times to 36 minutes. Calculated equilibrium polarization with

dedicated wigglers is 88%, but the energy spread further increases to 83 MeV, and the uncertainties associated with energy spread are a concern. The shortened polarizing times are highly desired, because the storage ring fills may occur every few hours. Since luminosity decreases from initial values, the effective polarization, averaged over the fill, is enhanced by short polarizing times. Refined calculations of LEP polarization including recent developments on energy spread effects are underway. These studies are currently rather active.

SEMICLASSICAL AND QUANTUM MECHANICAL POLARIZATION AND DEPOLARIZATION

Dr. P. Chen of SLAC presented work by Chen and Yokoya on recent calculations of depolarization in linear colliders from beam-beam interactions. There are two sources of depolarization considered, classical spin rotation in the field of the opposite incoming beam, and quantum mechanical spin flip radiation. Chen and Yokoya relate the rotation of spin in a beam bunch to the number of synchrotron radiated photons. The relation $< \Delta P > \approx k\ n_\gamma^2$ is derived, with the constant of proportionality small, numerically approximately .006. The average polarization for physics events is different from the beam polarization after beams have passed. The luminosity weighted depolarization $[\Delta P]$ is estimated to be $0.27 < \Delta P >$. For the SLC the luminosity weighted depolarization is $[\Delta P] \approx .006$, coming entirely from classical precession. This depolarization is small and negligible relative to other known contributions. For TeV-scale linear colliders, these depolarization effects are not negligible, but remain small.

Semiclassical and quantum mechanical polarization and depolarization calculations in electron-positron storage ring beams occupied the main portion of the session. Electron-positron storage rings are quite different from proton rings due to the influence of quantum emission, a strong effect in all existing rings. The process leads to emittance damping, natural energy spread, and breeding of polarization. Sokolov and Ternov [1] first calculated quantum mechanical spin-flip transitions in uniform magnetic fields associated with synchrotron radiation. They showed that an asymptotic polarization of 92.4% results, with a time constant which depends strongly on the fields, usually in the range of tens of minutes to hours in existing machines. Depolarizing mechanisms exist which compete with this polarizing process, leading to an equilibrium polarization $P = 8/5\sqrt{3}\ [1 + \tau_{pol}/\tau_{dep}]^{-1}$, where τ_{pol} and τ_{dep} refer to polarizing and depolarizing time constants.

Derbenev and Kondratenko [2] calculated the rate of depolarization from energy loss due to quantum emission, and the influence it has on a steady state polarization vector. Their formula applies to general rings, and calculations require knowing the details of the ring lattice. At this conference Dr. Barber of DESY described work by Barber and Mane demonstrating the equivalence of calculations by Bell and Leinaas [3] to their own work. Bell and Leinaas, studying quantum mechanical calculations in accelerating frames, looked at spin motion in storage rings. They derived depolarizing formulae in the neighborhood of resonances which show an enhancement of polarization reaching 99% just above the resonance. This enhancement is not seen in the standard calculations.

Barber and Mane extend the formula of Derbenev and Kondratenko to include vertical deflections of orbiting electrons at the time of photon emission. They show that the extended version is equivalent to the Bell and Leinaas result.

Dr. S. Mane of Fermilab described calculations and a new computer code SMILE he wrote to handle higher order depolarizing resonances. The previously existing formulation of Chao [4] calculated only first order resonances, while data from SPEAR [5] clearly show higher order resonances which are strong. Yokoya [6] in 1983 and later Mane [7] in 1987 have developed formalisms which contain these higher order resonances. Mane showed that the data from SPEAR can be well fit by the new code SMILE.

Dr. Jean Buon of Orsay described recent work on higher order depolarizing resonances in electron-positron rings. He developed a semiclassical model using first principles of quantum emission, incorporating successive random photon emissions. The model calculates enhancement factors to depolarizing resonances arising from finite energy spreads. The spin vectors are perturbed by successive emissions of synchrotron photons. Depolarization in the vicinity of isolated resonances is enhanced by terms from synchrotron oscillation modulation of the spin precession rates. Buon shows that this fundamental approach achieves the same depolarizing formulae derived from other approaches by Yokoya, Mane, and others. Fits to SPEAR data, and estimates for HERA and LEP polarization were given. Energy spread in the LEP beams can suppress the polarization substantially, particularly for dedicated polarization wigglers intended to shorten polarizing times.

Dr. Skuja of Maryland presented a status report on a fully quantum mechanical calculation for storage rings. Recalling that Sokolov and Ternov calculated spin flip transition rates for electrons in a uniform magnetic field, Skuja and Hand have been working on the fully quantum mechanical calculation of transition rates in a non-uniform field given by the lattice of a real machine. The work in part has been published [8] where single photon emission is shown to give rise to first order depolarizing resonances. In this approach, equilibrium polarization goes to zero at resonances because the spin-flip transition rates become equal. To obtain higher order resonances, multiple emissions must be included. Progress in that direction was described. The work holds promise of an elegant approach to a quantum mechanical phenomenon that has been studied so far in a semi-classical approximation.

Modelling calculations of HERA and LEP were presented by Drs. Barber and Koutchouk, respectively. Barber is currently studying HERA with the code SMILE. This work is in progress. It is rather time consuming to calculate for the large machines HERA and LEP. Dr. Koutchouk showed calculations of LEP using two codes, SLIM and SITROS. The latter code is a ray tracing code. This code is also time consuming, so full studies are not complete. Both HERA and LEP modelling calculations are stated to be very preliminary.

ACTIVITIES AT NOVOSIBIRSK

Three reports from Novosibirsk on activities with polarized beams were presented. A design for spin transparent solenoid rotators for potential use at VEPP-4M was given by Dr. Zholentz. Relations between optical parameters which permit high polarization were derived.

Dr. Shatunov described a calculation and measurement of spin tune spread at VEPP-2M. The interest in minimizing the spin tune spread derives from the beautiful experimental work showing equality of $g-2$ for e^+ and e^- particles. Spin tune spread contributes to the systematic errors. Tuning the radial betatron chromaticity to zero is shown to minimize this quantity. The measurements were made at 600 MeV beam energy. At the minimum in spin tune spread, depolarizing time constants for spin in the plane of the machine is estimated to be 10^3 seconds.

Dr. Popov presented a proposal for electro-nuclear scattering studies on super-thin targets with polarized electrons. The proposal is based on a small storage ring operating at 220 MeV. In this proposal, polarized electrons are accelerated and injected into the machine, named NEP, at approximately 220 MeV, with the spin perpendicular to the plane. With an RF flipper, adiabatic approach to 220 MeV rotates the spin into the plane of the ring. Precession of spin at 220 MeV gives 2π every two turns, corresponding to a spin tune of 1/2. Alternate beam crossings at the experiment correspond to opposite helicity electrons. Injection into the ring can occur every few seconds, so high rate experiments can be achieved.

SUMMARY

I wish to thank the contributors of this session for their interesting presentations. We have seen considerable activity in practice and theory for both circular and linear accelerators. The SLC, HERA, LEP, and Novosibirsk facilities are actively preparing for polarized electron beams. LEP and HERA can polarize positrons, while the SLC cannot. In the analysis of depolarization, contributions include studies of linear colliders, where beam-beam effects are shown to be small. Depolarization in storage rings is well understood, with analysis from different points-of-view in agreement. Computer codes are available to facilitate calculations using the newer formulations. A fully quantum mechanical calculation for storage ring lattices may be available in the future. The future for polarized electons and positrons in accelerators looks very busy.

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