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POLARIZATION PRESERVATION IN THE AGS*

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Introduction

The successful operation of a high energy polarized beam at the Argonne Zero Gradient Synchrotron (ZGS)[1] with the concommitant development of depolarizing resonance correction techniques has led to the present project of commissioning such a beam at the Brookhaven Alternating Gradient Synchrotron (AGS). A description of the project was presented at the 1981 National Accelerator Conference.[2] I would like to now present a more detailed description of how we plan to preserve the polarization during acceleration, and to present our "game plan" for tuning through some 50 resonances and reaching our goal of a 26 GeV polarized proton beam with greater than 60% polarization.

Resonances

Although higher order depolarizing resonances have been observed at the ZGS and at SATURNE, we are primarily correcting for the "intrinsic" and "imperfection" resonances and we feel that we will have sufficient redundance in our correction hardware to apply to any exotic resonances that may appear.

The so-called "intrinsic resonance" is due to the natural periodicty of the accelerator and the "imperfection resonance" is due to misalignments which lead to closed vertical orbit distortions. These are characterized by

	$G\gamma$	=	$kP \pm \nu_y$ intrinsic
and	$G\gamma$	=	k imperfection
where	G	=	$g/2 - 1$ anamolous magnetic moment
	k	=	integer
	P	=	periodicity of the accelerator (= 12 in AGS)
	ν_y	=	vertical machine tune (number of betatron oscillations per revolution)
	γ	=	relativistic energy factor

Discussion and derivation have appeared many times before[3] so we won't say anymore here other than that the intrinsic resonance can be corrected for by a fast vertical tune shift (ν_y) and the imperfection resonance by a radial magnetic field at the proper harmonic. If the resonances are very strong, it is also possible to pass through the resonances naturally with an 180° spin flip. For the AGS, we are planning to pass through the resonences using fast pulsed quadrupoles for tune shifts and 96 dipoles to correct for vertical orbit distortions.

The magnitude of this job can be seen in Figure 1, which shows the AGS resonances.[4] The x's are the intrinsic resonances and the lines represent the imperfection resonances. Despite the fact that there are over 50 resonances, correction for 25 of them should give a reasonable polarization. Eight others contribute a total of 5% and the remaining 21 only 2% depolarization. There were about the same number of resonances that were corrected in the ZGS, so that this appears to be a reasonable situation.

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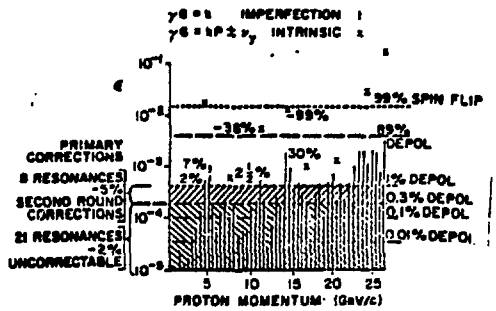

Figure 1 - AGS resonances.

Resonance Correction Techniques

Intrinsic Resonances

We plan to cross resonances by fast passage and not rely on "spin-flip". For this purpose, 12 ferrite quadrupoles (one for each AGS superperiod) were constructed by the University of Michigan. These have been described previously[2] so that we will only mention that they produce a 2 μsec 2500 ampere pulse with a 3 msec decay time. These have all been electrically tested and 4 of them with their aluminized ceramic vacuum chambers are now installed in the AGS ring. The aluminum coating will have about 96% transmission for the quadrupole pulse ($f = 125$ KHz) and a 99% attenuation for accelerated beam ($f = 4$ MHz) interaction with the ferrite.

Figure 2 shows some typical corrections in tune-energy space. The resonance line is crossed in less than 1 turn (~ 2 μsec) and the tune remains a fixed distance from the resonance as the correction pulse decays at a rate comparable to the change of energy during the normal acceleration cycle (~ 3 msec). For the strongest resonances we would like to make tune changes of the order of 0.25 to 0.30. With the AGS nominal tune of 8.75, we would normally hit integer or half-integer resonances at $\nu = 9.0$ and 8.5. In order to avoid this, we plan to use the slow AGS tune shifting quadrupoles to give us more "headroom". An example of this manipulation of betatron tune space is shown in Figure 3 where we turn on a slow quad pulse so that the basic AGS tune is shifted by about 0.1 in the opposite direction to the fast tune shift. The slow quad can be turned off fast and is approximately off by the time the fast pulse is off and the AGS tune is back to its nominal value. We also plan to pulse the ring sextupoles during this time in order to flatten the vertical tune profile and keep the total tune shift constant as a function of radius. We are also prepared to use a compensating horizontal (ν_x) shift during the correction time should this prove necessary.

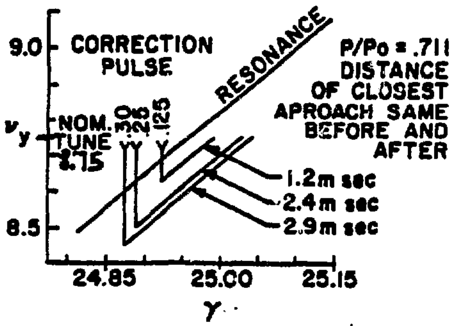

Figure 2 - correction pulse.

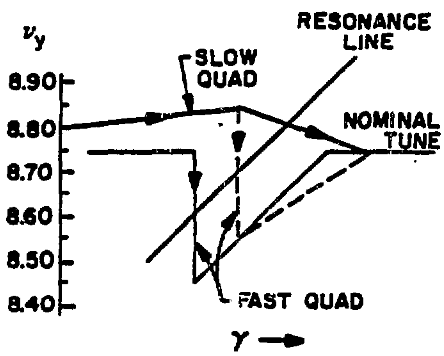

Figure 3 - slow quad effect.

Imperfection Resonances

For the imperfection resonances we will generate a harmonic correction at the appropriate energy using 96 existing dipole magnets. The strengths of these resonances were calculated assuming a RMS magnet misalignment of 0.1 mm which generates orbit distortions of a few mm (observed in the AGS). The dipole fields have been designed to correct up to 3.3 times this error at 25 GeV. This factor increases at lower energies. The alignment of the AGS to the order of 1 mm should then be adequate. Survey of the AGS was recently completed and the closure of the survey in going around the ring was of the order of 1/4 mm.

Tune-up Strategy

We are planning on a tune-up strategy that breaks up naturally into several regions. From the resonance map, the position of the strong resonances breaks up the space into five parts:

injection to 6 GeV/c
6 GeV/c to 12 GeV/c
12 GeV/c to 15 GeV/c
15 GeV/c to 22 GeV/c
22 GeV/c to 26 GeV/c

Both for ease of operation and to save power costs, we plan to operate the AGS only to the peak field necessary to correct each region. In each interval, we would insert an internal polarimeter target, measure the polarization, and correct the resonances. This scenario, of course, assumes that the calculations are close to reality. The procedure, and even what resonances we correct, may indeed change when we start taking measurements. In fact, with the very strong intrinsic resonances, the sort of expected "classic" picture of tuning through the resonance that we had at the ZGS[3] may not appear. We may have partial or total spin flip which will show us different patterns and may require some change in method. In any event, once we solve the problem at 6 GeV/c, we should have the pattern for the rest of the AGS cycle since resonances of all the expected types appear in this interval.

At some point in this procedure we will extract the beam and get an absolute measurement of the polarization in a high energy polarimeter in the D line. Whenever we extract on a long flat-top, we will have to vary the flat-top field to make sure that we do not sit on a high order resonance for an appreciable time. At the ZGS[5] we found that depolarizations as large as 30% per second occurred from higher order resonances such as $G\gamma = 4 - \nu_y + \nu_x$. Figure 4 shows two resonances occurring near the operating point on a 1 second FT.

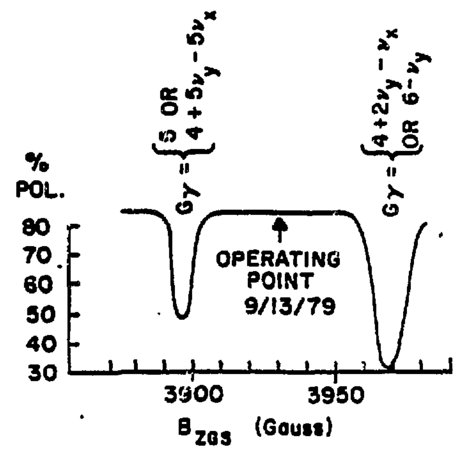

Figure 4 - higher order resonances.

Polarimeters

The absolutely essential ingredient for an efficient tune-up of the many resonances is good polarimetry. Several polarimeters will be used.

20 keV Polarimeter

The 20 keV polarimeter is being constructed by Yale University and testing should be completed this month.

200 MeV Polarimeter

This polarimeter was constructed by Rice University and will be used to continuously monitor the H- beam polarization before injection into the AGS. It uses a PC[12] reaction to provide a 1% absolute measurement of the beam polarization. The complete assembly was tested at the Indiana cyclotron last December and will be installed in the HEBT line as soon as possible. Figure 5 shows a plan view of the target box and spectrometer.

Internal Polarimeter

This polarimeter[6] will be used to measure beam polarization during the acceleration cycle. A 0.003" nylon fiber target will be swung into the circulating beam at a rate of about 1 M/sec before and after resonances to allow us to correct the depolarization

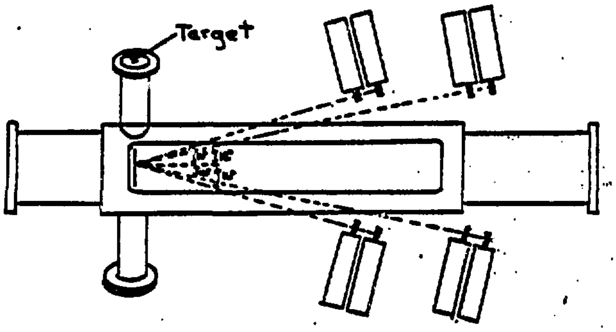

Figure 5 - 200 MeV polarimeter.

at each resonance. This will analyze P-P elastic scattering from the 10% H_2 in the nylon. The fiber on a spool containing about a KM of nylon will also move at a velocity of about 1 M/sec so that heating and radiation damage will be at reasonable levels. The sampling time will range from a few msec to 50 msec where the 50 msec will occur on a mini flat-top. This longer time may be necessary so that the instantaneous rates in our counters are manageable. We have produced such flat-tops and have run the rf at a few hundred volts during this time so that a good duty cycle spill is available. Figure 6 shows that beam debunching occurs at a low level rf voltage and yet we still can maintain beam control. This polarimeter is being constructed by the University of Michigan and is expected to be ready for test shortly. The target and vacuum box will be installed in the G10 straight section as soon as possible after testing. Measurements will then be made to determine emittance growth and to study systematic errors. Figure 7 shows an elevation view of the target.

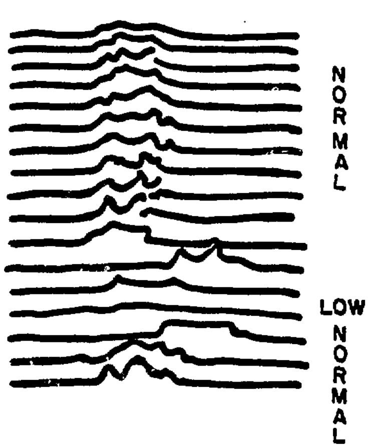

Figure 6 - rf debunching.

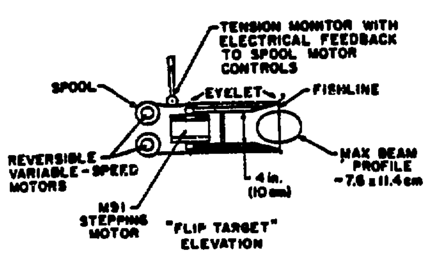

Figure 7 - internal polarimeter target.

High Energy Polarimeter

This polarimeter will measure the polarization in the AGS extracted beam in the D line and will provide an absolute calibration for the internal polarimeter. It measures P-P elastic scattering to the right and to the left from a liquid hydrogen target. It contains two identical forward arms and two identical recoil arms. Figure 8 shows 1/2 the spectrometer with the right scattering forward arm and the left scattering recoil arm. There is a small steering magnet and a vertical bending magnet in the recoil arm. This vertical bend gets rid of kinematic focusing effect and improves the measurement accuracy with a large solid angle. The ten magnets are installed now, and we plan to tune up and remove biases during the slow beam running of E-748 this spring.

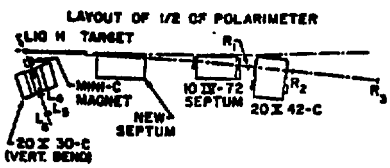

Figure 8 - high energy polarimeter.

Acknowledgements

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References

1. T.K. Khoe, et. al., Proc. of the 9th International Conference on High Energy Accelerators, 288 (1974).

2. K.M Terwilliger, et. al., IEEE Trans. on Nucl. Sci. NS-28, 2031 (1981).

3. T.K. Khoe, et. al., Particle Accelerators 6, 213 (1975).

4. E.D. Courant and R.D. Ruth, Brookhaven National Laboratory Report 51270, ISA 80-5 (unpub.).

5. L.G. Ratner, Argonne National Laboratory ARF Div. Internal Report AE19-2 (unpub.).

6. L.G. Ratner, Brookhaven National Laboratory Accelerator Dept. Polarized Proton Technical Note No. 9 and Addendum to No. 9 (unpub.).

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