

years of construction, is between 500 and 550 MDM.

There is a preliminary estimate that about 400 people will be involved in the project. DESY would like to recruit some 70 additional staff, since this is the number which would be needed to operate the additional facilities long-term, and could move almost 250 people of the existing staff onto HERA if it is authorized.

The remaining effort of about 100 people it is hoped can be found amongst potential users of the machine from outside the Laboratory, half within the Federal Republic of Germany and half elsewhere in Europe. Specific components, such as the linac, ion pump system, etc... could be farmed out to other Laboratories, so that there is no need for people to move in large numbers to DESY.

It is hoped that approval of the

project will be forthcoming by mid-1981, following further discussions both inside and outside Germany, more prototype work and the preparation of a formal proposal. If this authorization date were met it would be possible to bring the electron ring into action in 1986 and the proton ring (installed above the electron ring) two years later.

It is obvious that some electron-positron physics in the electron ring could be possible during the two years prior to completion of the proton ring. However, there would be a great deal of machine physics to be done with the electrons (perfecting feedback systems, mastering the polarization techniques). Also there may not be much to be gained from electron-positron physics at energies up to 30 to 35 GeV when, for this, LEP will be able to exceed the HERA parameters. The exceptions may be the finding of the top quark

and a study of the electromagnetic-weak interference region. Nevertheless, the HERA emphasis is definitely on electron-proton physics.

An ECFA meeting following the exposition of the HERA project on 28 March took a preliminary look at the project and expressed its great interest in the physics and the machine design. ECFA has always stated that two significant projects are desirable in Europe to sustain the high energy physics community with front-line research facilities. The ECFA Working Group Report (described in the March issue, page 11) showed that fruitful programmes could be mounted on both LEP and HERA with the present levels of finance and manpower. HERA is now being discussed in the European high energy physics community prior to formulating an ECFA recommendation at its meeting scheduled for 9 May.

Protons in a spin

Scattering experiments using polarized beams are a potentially rich source of detailed information on particle interactions. The swan-song of the Argonne Zero Gradient Synchrotron before it shut down last year was the acceleration of polarized proton beams to GeV energies. Experiments with these beams yielded a series of unexpected results (see for example October issue 1978, page 347 and November issue 1979, page 351) and this success has prompted Brookhaven and Fermilab to launch polarized proton beam programmes for the near future.

After some three years of study, design and evaluation, Brookhaven and the USA Department of Energy

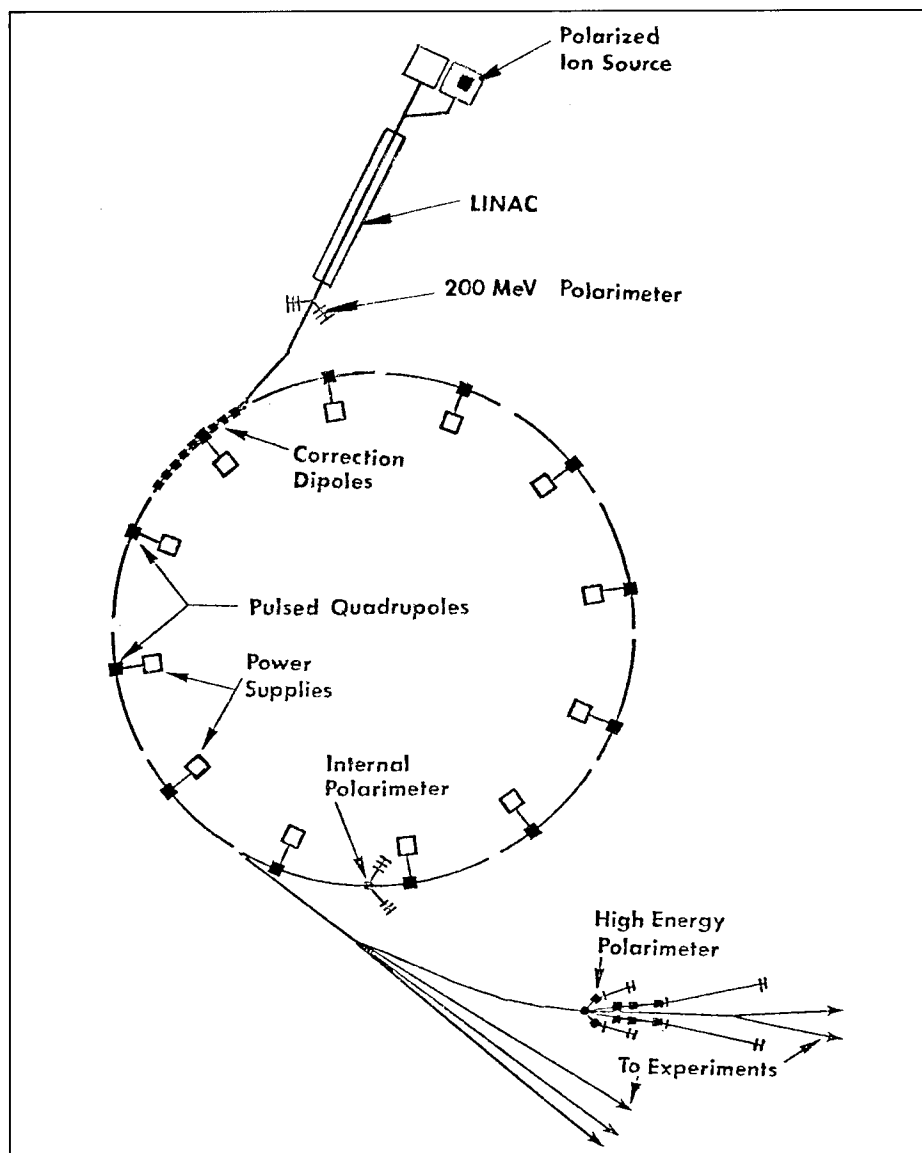
have agreed on a plan to modify the 33 GeV Alternating Gradient Synchrotron to allow the acceleration of polarized protons. Because of ISABELLE's heavy manpower demands, physicists from Argonne, Brookhaven, Michigan, Rice and Yale will collaborate in order to make these modifications.

In some sense the AGS polarized beam project began at the 1977 Ann Arbor Workshop (see December 1977 issue, page 418) which concluded that it might be possible to jump depolarizing resonances at strong focusing synchrotrons. The 1978 Brookhaven Summer Study investigated in detail the possibility of polarized proton acceleration in the AGS and produced the 'Prelimi-

nary Design Study and Cost Estimate'.

For the past eighteen months the technical feasibility and overall impact of the project have been carefully evaluated by Brookhaven. Although the project has many technically challenging problems it appears that by 1983 the AGS should be able to accelerate about 10^{11} polarized protons/pulse to 26 GeV with a polarization of about 60 per cent.

Much of the physics enthusiasm for polarized protons came from the results at the Argonne ZGS. Large and unexpected spin-spin forces in high transverse momentum proton-proton elastic scattering were discovered by the Michigan / Argonne



Layout of the Alternating Gradient Synchrotron at Brookhaven showing the major modifications that must be made to allow acceleration of polarized protons. It is hoped that a programme of polarized beam experiments will be possible from 1983.

pulsed quadrupole magnets required to jump through the eight 'intrinsic' depolarization resonances. There will be twelve of these quadrupoles, each with a $1 \mu\text{s}$ rise time, compared to the two ZGS quadrupoles, with $10 \mu\text{s}$ rise times. The AGS quadrupoles will be constructed of ferrite by Michigan, while Brookhaven will construct the 25 kV, 3 kA power supplies and Argonne will aid in the system's design.

The other major problem is the polarized ion source. While the $100 \mu\text{A}$ ZGS polarized proton ion source could be used, it would give an intensity of only about 2×10^{10} polarized protons/pulse. A negative hydrogen ion polarized source is preferred since the AGS injection system will be changed to negative ions within the next year; Argonne is constructing such a source to give 10 to $100 \mu\text{A}$ with Yale aiding in its detailed design. This source should result in accelerated beam intensities of about 3×10^{10} to 3×10^{11} polarized protons/pulse. Argonne and Brookhaven will collaborate on the modification of the preaccelerator dome to house the polarized ion source.

The 'imperfection' depolarizing resonances will be avoided using 96 correction dipole magnets already in the AGS. These require new power supplies with computer control to produce the necessary harmonics to miss 47 different resonances. This system will be constructed by Brookhaven with software aid from Rice and Michigan.

Various polarimeters must be constructed to study depolarization effects and to measure the final beam polarization. These measurements require very close co-operation between accelerator physicists and experimenters. A 200 MeV polarimeter, which is being built at Rice, will measure the left-right

group and these forces may still be growing at the maximum transverse momentum values available at the

GS-5 GeV^2 . This is not understood in terms of the generally accepted version of quantum chromodynamics theory (though there are alternative ideas in line with the results, proposed by a few people such as G. Preparata and J. Soffer at CERN). Thus it seemed important to extend the study of spin effects to the AGS where values of 10 to 15 GeV^2 could be reached. Studying these spin-spin forces should help in understanding the direct quark-quark interaction.

Although no proposals are yet being considered for the polarized beam, several experimental groups are already starting to plan polarized beam programmes. In fact a proposal by a Michigan / Argonne / Brookhaven / Copenhagen / Miami collaboration to study spin effects

with a conventional beam and a polarized target has been approved, while a Brookhaven / Minnesota group is proposing to measure large transverse momentum elastic scattering. The Yale and Massachusetts groups are each gearing up their polarized proton targets, and the Michigan and Rice polarized targets both seem to be moving eastward.

The biggest problem in accelerating polarized protons at the AGS will be to manoeuvre the proton beam through depolarizing resonances without losing all the polarization. Unfortunately, these resonances are about ten times worse at the strong focusing AGS than at the weak focusing ZGS. Nevertheless the same type of resonance jumping scheme will be used and should be successful, according to depolarization experts such as E.D. Courant.

One of the most challenging technical problems will be to develop the

asymmetry in proton-carbon scattering at the end of the linac. Michigan is building an internal polarimeter, to monitor the polarization during acceleration, and a high energy polarimeter, which will give an absolute measurement of the polarization by studying proton-proton elastic scattering from a hydrogen target.

While all the hardware work for the next few years will concentrate on polarized protons for research at the AGS, it is hard to forget that around 1986 the AGS will become the injector for ISABELLE. Ernie Courant has been studying the acceleration of polarized protons to 400 GeV in ISABELLE using the 'Siberian Snake' scheme. This novel idea for handling depolarization becomes easier as the energy increases and, if it really works, the late 1980s might see exciting studies of spin-spin effects at collision energies of up to 400 GeV per beam.

Fermilab: Polarized proton beam

In November 1979, approval was given to develop a polarized proton beam at the Fermilab 400 GeV synchrotron. Operation is expected around 1983 opening the way to this fruitful approach to physics at hundreds of GeV. Collaborators in this effort include Argonne, Fermilab, LAPP, Kyoto, Berkeley, Rice and the Italian INFN.

The polarized beam facility will be a joint project between Argonne and the Fermilab Meson Department. Argonne will have responsibility for most of the technical components and will construct sixteen new superconducting quadrupoles for the beamline. Conventional dipoles, formerly used at the ZGS, will be shimmed and reused. Fermilab will be responsible for the conventional construction and for a new experi-

mental area built as an extension of the Meson Area.

The parity-violating decay of lambdas or antilambdas will be used to produce the polarized protons or antiprotons. The beam will cover an energy range from about 50 to 350 GeV with either 400 or 1000 GeV primary protons. With some rearrangement it could work at 80 per cent of the highest primary momentum available from the Tevatron. The average transverse proton polarization at 250 GeV will be about 45 per cent for an intensity of over 10^7 polarized protons per spill (using 3×10^{12} primary protons at 400 GeV). The intensity per pulse will be higher when the Tevatron is in operation. The Tevatron will also make available fluxes of over 10^6 polarized antiprotons at energies up to 250 GeV.

There will be two basic modes of operation, one using the high momentum end point of the lambda production spectrum and the other using a correlation between polarization and position at a focus. The polarization can be reversed at short intervals and any direction of polarization can be obtained at the experiment by using a so-called magnetic spin precession snake.

The polarized beam facility can be used to carry out an intensive programme of experiments on spin effects in the proton-proton and proton-antiproton system, up to the limit of Fermilab energies. It will be a natural extension of the programme of high energy scattering carried on at the ZGS.

The first experiment, after the parameters of the beam have been established, may be a study of spin effects at high transverse momentum by detecting neutral pions produced using a transversely polarized beam scattering from a liquid hydrogen target.

These measurements could then be followed up using both a longitudinally polarized beam and a polarized target to look at interactions between the fundamental constituents of the proton. Later experiments might measure asymmetries in jet production at large transverse momentum. Another first-round experiment could be the study of the spin dependence of the rise of the proton-proton total cross-section at high energies. Experiments could also be done to help understand the enhanced particle production from nuclear targets. Experiments have also been discussed to study production of pions, di-muons and strange particles.

Meanwhile other experiments using polarized targets have provided important evidence for appreciable spin effects at high energy. Studies at both CERN and Fermilab show that the polarization parameter (which describes the spin effects in proton-proton scattering) changes sign twice with increasing momentum transfer, having an appreciable positive value in the region of the second maximum in the elastic differential cross-section (2 GeV^2 squared momentum transfer).