

ISR Experiments

A preliminary look at the types of experiment which could be mounted at the ISR when they come into operation in 1971.

The time is fast approaching when the thoughts about possible experiments at the ISR have to take definite shape so that experiments will be ready for the date when colliding beams become available. Two years may seem ample time to prepare an experiment but experimentation at the ISR is likely to take much longer in preparation than at a conventional accelerator. The experimental set-up will involve an integral part of the ISR and will not be something fed from afar with particles. Problems such as ensuring that the magnets used in the experiment do not disturb the delicate stability of the circulating beams, ensuring that the vacuum vessel in the interaction region is appropriate for the experiment, and so on, may well involve the installation of unique components which cannot be constructed overnight.

Since the beginning of this year a working party of experimental physicists and machine builders have met regularly to tackle some of these problems in detail. In June, participation in these discussions was extended to all interested European groups when an ISR Users Meeting was held at CERN. More than a hundred potential users took part and the interest that was generated has led to several European collaborations becoming busy developing proposals for experiments. A second Users Meeting is scheduled for 2, 3 December.

Experimental equipment

It is probable that in at least one of the two interaction regions, where experiments are initially planned to take place, a large general purpose magnet system will be installed. It would serve to analyse the high energy particles produced in the proton-proton collisions and its design would need to cover a rather narrow cone around the two downstream vacuum pipes. In this cone most of the high energy particles will emerge.

Several designs for such a magnet system are now under examination. Their main feature is that they must bend out the collision particles without, overall, disturbing the circulating beam. The system of magnetic fields must compensate for any effect on the beams.

Other devices will be needed to take measurements on the beam so that the experimenters know what sort of initial conditions have produced the particles they observe. Thus, for example, to make cross-section measurements information on the beam currents, the beam shapes and the volume within which the beams are interacting when they pass through one another is essential.

Methods of finding the beam shapes in the interaction regions such as by sweeping a thin wire at constant velocity across the beam have been proposed. A set of counter telescopes could be used to detect the forward emitted particles from collisions with the wire.

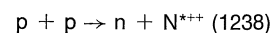
Some possible experiments

The range of energy beyond that available at present machines is often called the 'asymptotic region' since the energy extends to infinity. It is expected that particle phenomena will become much simpler at much higher energies and thus more easily understood. By reflecting backwards to present energies it is possible that much of the still confused behaviour that is now observed will become clearer.

The ISR is going to give a limited look into a very high energy region. Several 'expectations' can be put forward but most of the fascination in using the ISR lies in the fact that no-one knows what phenomena will be revealed — Nature has always proved richer than man's imagination.

Experiments at the energies available on existing accelerators have given evidence of two dominant mechanisms in particle interactions — particularly in the two-body or quasi two-body interactions (those involving two incident particles and two outgoing particles). These mechanisms are known as diffractive processes and exchange processes. With the diffractive process the outgoing particles have the same internal quantum numbers as the incident particles; with the exchange process the outgoing particles have different internal quantum numbers — and hence the name 'exchange' since something carrying quantum numbers must have passed between the incident particles in the interaction.

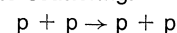
A striking difference in the behaviour of the two processes is seen in the limited energy range investigated so far, namely that they vary with energy in a very different way. If no quantum numbers are exchanged, the cross-section for the interaction varies little as the energy is increased but if quantum numbers are exchanged the cross-section falls off very rapidly as the energy is increased. (Also, there appears to be hierarchy in the quantum numbers — the rate of fall off depends upon what is exchanged.) To take a specific example — the cross-section of the two body process involving the N^* resonance of mass 1238, which has a different isospin quantum number



will be down by a factor of a thousand at full ISR energy, if it continues to fall at the rate observed so far.

Since the ability to trace phenomena over a very big energy range is one of the prominent experimental features of the ISR, it will be possible to extend the study of these differences in considerable detail.

One of the first experiments to be done will be the measurement of the proton-proton elastic scattering.



It is expected that, even at the very high energies available, the elastic scattering cross-section will be a significant fraction of the total cross-section — that protons will continue to bounce off one another very often rather than transforming into other particles. One of the first things the experiment will reveal is whether this expectation is true.

The way in which they 'bounce off' says something about the size and the structure of the particles. Does the proton effectively grow in size in higher energy interactions? What is the proton structure — does it have an irreducible, hard core with a diffuse sphere of influence around it? What is the mechanism of the scattering process? Measurements of the angular distribution of the scattered particles and the way this distribution varies with energy, together with some theoretical ideas, will give answers to this type of question.

At energies so far investigated in the GeV range, the elastic scattering is largely

'diffraction scattering' where the distribution of the scattered protons is strongly influenced by the many possible 'inelastic' processes (where other particles are formed) which can occur. The angular distribution is strongly peaked in the forward direction, in other words, the scattered protons move predominantly in the direction of the incident particles. This diffraction peak has been shown to shrink (its width decreasing) with increasing energy. It is the detailed shape of this diffraction peak and its variation with energy which will be of interest at the new energies made available at the ISR.

To point to a few of the experimental complications. A special vacuum chamber with thin walls will be needed where the scattered protons emerge to avoid losing precision in the measurement of their true scattering angle due to the scattering introduced in the walls. Care will be needed to ensure that the measured protons come from a true beam-beam interaction and not from a collision with a proton in the residual gas in the vacuum vessel. (The fact that the two scattered protons would lie almost along the same line travelling in opposite direction will help to distinguish them correctly.) Also the momentum measurements on the scattered protons must ensure that no other particles have been produced in the collision (the event would then not be an elastic scattering event). Wire spark chamber and counter arrays could be used to detect and measure the trajectories of the protons.

A further development, which could take place if it proves possible to accelerate deuterons in the PS and store them in the ISR, would be to investigate the proton-neutron interaction. It should be possible to extract the proton-neutron scattering occurring in the deuteron, assuming that the proton-proton scattering is known.

Total cross-section measurements, by observing the loss of particles from the interaction region, is another important experiment taking in both elastic and inelastic scattering. The way in which the total cross-section of the proton-proton and the proton-neutron interaction varies with energy is of fundamental importance to check ideas about the asymptotic nature

of strong interactions. The expectation is that at sufficiently high energies the cross-section will no longer vary with energy and will become equal for both interactions.

One of the first experiments will be a survey type experiment which adds up the energy of two outgoing protons to see what they have lost in the interaction. It may emerge that particular amounts of energy are frequently 'lost' indicating that particles, equivalent in mass to these lost energies, are being produced.

The production of other particles when two high energy protons collide is an obvious source of interest. It is another way to look at the structure of the proton.

When two protons collide they may shake each other so violently that other particles are shaken off from them. If the proton is considered as a cloud in which there is some sort of structure, the production of new particles can be considered as the tearing away of part of the cloud. The most prolifically produced particle is the pion, which is a light particle easily knocked off from the proton — energies of around 140 MeV are sufficient. They can be considered as the constituents of the outer rim of the cloud. At higher energies, kaons and hyperons, or, at higher energies still, pairs of nucleons can be produced as if coming from deeper in the proton structure.

As energies at conventional accelerators have been pushed higher, the predominant observation in particle production has been that, as the proton is shaken more and more violently more and more pions are produced. (The predominant observation might have been that, instead of more and more pions, fewer heavier particles were produced). The colliding protons fly off with their clouds excited to high energy (these excited states are called isobars) and return to their normal state by emitting pions. In such a collision very little of the available energy goes into the production of new particles. The 'normal state' protons which result still keep say 60 % of the initial colliding proton energies. Occasionally, however, the protons share the full energy of the collision forming for an

instant something like a hot droplet from which heavy particles can boil off.

To examine these phenomena at ISR energies will be very intriguing. Again the experimental demands will be quite stringent and detection arrays will have to cope with the production of many particles per collision.

Two searches for heavy mass particles of vital interest in sub-nuclear physics become much more interesting with the energies available at the ISR.

The first of these is the quark, the particle postulated to explain the observed patterns in the list of strongly interacting particles. The experimental searches so far indicate that if the quark exists it has a mass probably in excess of 2.5 GeV. But the high energy of the ISR may be ample for production of the quark.

The second elusive particle is the intermediate vector boson, the postulated mediator of the weak interaction (just as the pion is the mediator of the strong interaction and the photon of the electromagnetic interaction.) Experiments at conventional accelerators have failed to reveal the W and suggest that if the particle exists its mass is in excess of 2 GeV. Here again the high energies available at the ISR could be ample to produce the intermediate boson.

These are some general thoughts about the experimental programme at the ISR. The detailed work on preparing proposals for specific experiments is now under way.