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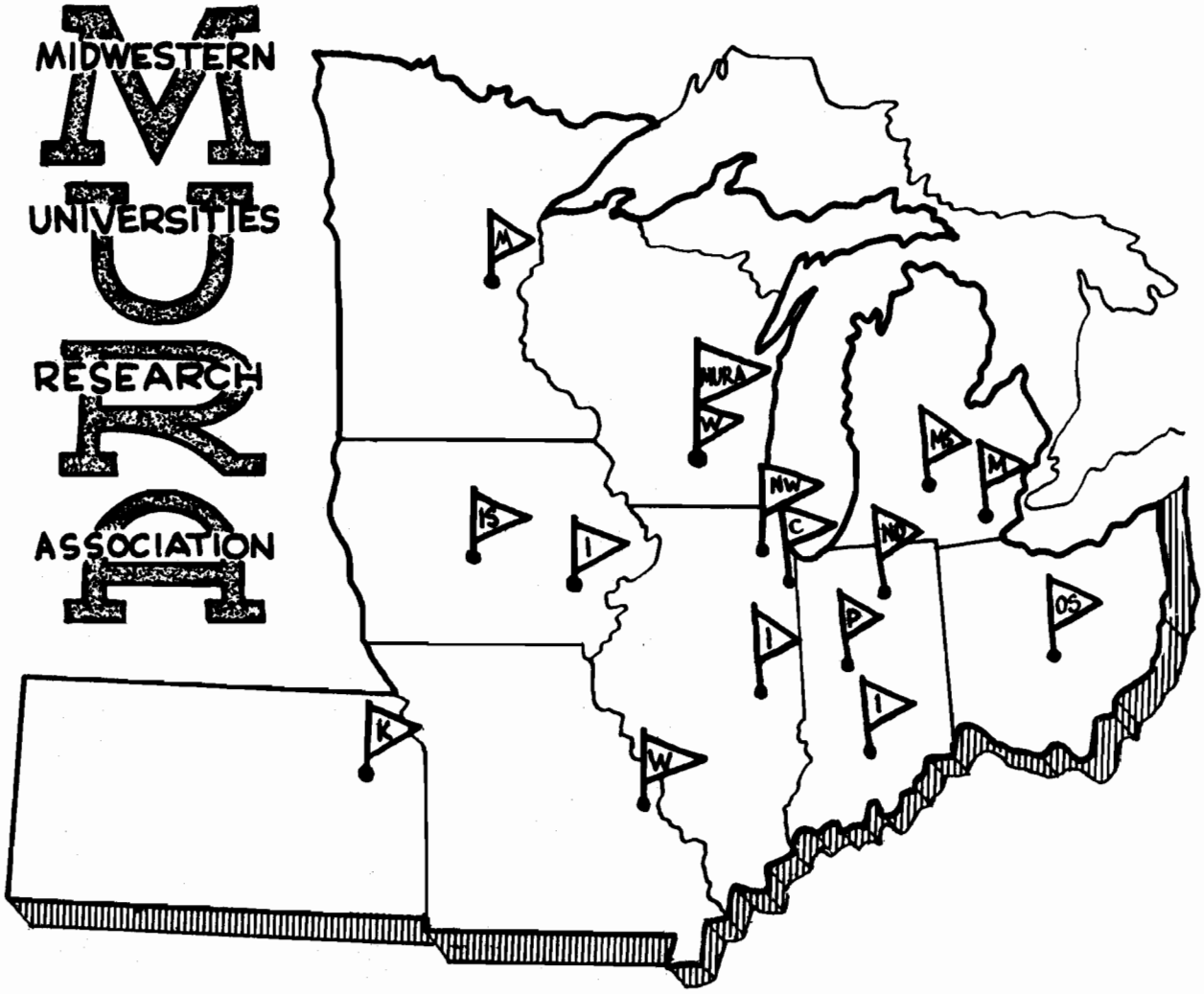

REPORT ON BROOKHAVEN AGS USER'S MEETING

HELD IN WASHINGTON, D. C., April 29, 1959

Keith R. Symon

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MIDWESTERN UNIVERSITIES RESEARCH ASSOCIATION*

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REPORT ON BROOKHAVEN AGS USER'S MEETING HELD IN WASHINGTON, D. C., APRIL 29, 1959

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May 6, 1959

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G. K. Green gave a general outline of the status and plans for the Brookhaven AGS. The AGS will provide beams of 10 to 32 Bev protons. The upper limit is set by the maximum magnetic field, 13 kilogauss, which is anticipated. The lower limit of 10 Bev is set by the phase transition which occurs at 7 Bev. It will be possible to provide energies below 10 Bev for calibration purposes. The AGS will provide a pulse every three seconds at 32 Bev with higher repetition rates down to one pulse per second at 10 Bev. As the magnetic field rises, it will be possible to flat top the field at any desired energy for a period of 1/10 second in order to extract the beam or drive it onto a target.

The AGS has a full feedback rf system in which an rf signal from the beam is picked up, amplified and fed back to the accelerating cavities. This system will require at least 5×10^7 protons per pulse in order to operate. Feedback controls will make it possible to hold the radius of the beam within about one millimeter and to program the beam radius according to any desired function of time.

It is hoped that the linac will provide an injected beam of one milliampere which in one turn corresponds to 4×10^{10} protons. It is hoped that the AGS will be assembled by the beginning of 1960 and that some experimental work can begin in the late spring of 1960. Within about a year thereafter, it is hoped that the beam intensity will reach 10^{10} protons per pulse. The eventual beam intensity should be 10^{11} protons per pulse. Radical changes would be required in order to increase the ultimate beam intensity beyond 10^{11} protons per pulse.

The magnet structure provides long and short straight sections, the long straight sections being 10 feet. In order to allow special vacuum chamber sections to be inserted for extracting beams at angles less than two to three degrees from the equilibrium orbit, the vacuum chamber in the experimental areas will have gate valves and the ten foot straight sections of the vacuum tank will be removable.

Component bending and focusing magnets, beam separators, etc., for secondary beams from internal targets are now being designed. It is planned to order an assortment of such magnets and beam separators which can be combined in a variety of ways to provide various beam channels leading into and out of the experimental building. In a typical layout there might be, say five exit channels, including a channel leading out of the experimental building with focusing and bending magnets and beam separators providing a clean anti-proton beam of momentum 5 Bev/c, a 25 Bev/c momentum analyzed beam, a 5 Bev/c momentum analyzed beam inside the target area and just outside the shielding wall, a similar 10 Bev/c beam, and a neutral beam in the forward direction with clearing magnets to remove charged particles. There will not be room within the target building for more than a small amount of experimental equipment utilizing very short beam paths. Longer beam paths and the majority of the experimental equipment will be outside the experimental building. A large area outside the building has been provided with an asphalt surface strong enough to support heavy magnets and other equipment. Water, power and conduit will be provided in this external experimental area. Portable buildings will also be provided

which can be moved into position to house the various experimental setups as needed. This is intended to provide a flexible experimental area in which equipment for beam handling, magnets, separators, etc., can be moved about almost at will to provide a wide variety of beam arrangements. Green stated that with fiducial marks placed on magnets to facilitate alignment, six to eight magnets in a beam channel can be aligned within a period of two hours to an accuracy of six mils. Much of the beam handling equipment will simply be left outdoors.

Brookhaven is considering providing another experimental building at another azimuthal position around the machine in order to relieve crowding in the present building. It is also expected that loss targets will be provided at an azimuth opposite to the experimental area for the purpose of cleaning up stray beam which might otherwise strike unwanted targets in the experimental area.

It is estimated that eventually the total power requirement for experimental apparatus will run perhaps 20 million watts. The 80 inch bubble chamber alone for example requires 7 1/2 million watts. It has not yet been decided whether the beam handling magnets will be dc or pulsed. Pulsed magnets may be more difficult to design but will save magnet power.

R. Cool described some of the experimental plans for the AGS. He pointed out that the number of protons per pulse is about a factor of 10 lower than is available from the Cosmotron or Bevatron. A factor of three or so of this is made up by the faster repetition rate. Also the use of thin internal targets, which because of the momentum compaction can be traversed many

times by the beam, will provide an additional factor of two or three in intensity with internal targets. He pointed out furthermore that one can use an internal target smaller than the beam diameter since particles which miss the target on one turn can hit it the second turn if they arrive in a different phase of the betatron oscillation. This will provide a smaller and brighter source of secondary particles.

In order to get close to internal targets at small angles with the equilibrium orbit, special quadrupoles are being designed of small size and consequent larger power. They will be made rectangular in shape in order to match the shape of the beam, that is, they will be narrower in the defocusing dimension. Standard beam separators of varieties presently under design can separate anti-protons from particles of other masses up to momenta of about 5 Bev/c. Because of their short lifetime, beam separators for K particles are at present not practical above 3 Bev/c. It is planned to develop ultra-high field magnets which will provide up to 100,000 gauss in volumes of the order of 1/2 liter for times of the order .1 second. It is anticipated that an external proton beam from the AGS will be available late in 1960.

There will be at least four bubble chambers at Brookhaven available for use with the Cosmotron and the AGS. Adair has constructed a 15 inch hydrogen bubble chamber. Shutt has constructed a 20 inch bubble chamber. Both of these chambers will be available for general usage by physicists doing experiments at Brookhaven. A 30 inch propane bubble chamber which can also be used with hydrogen is being built by the Columbia group.

An 80 inch hydrogen bubble chamber is under design and will be finished in 1962.

E. D. Courant gave a discussion of the design considerations for beam separators and beam extraction. In the design of the electromagnetic beam separators, 50kilovolts per centimeter has been taken as a conservative figure for practical electric fields. If we wish to separate anti-protons from π^--mesons at a momentum of 6 Bev/c, the fractional difference in velocities is about 1.7%. If we use a crossed electric and magnetic field and adjusted to give zero deflection for the anti-proton, then the radius of curvature of the π^- beam will be about 6×10^6 centimeters. The deflection of the beam in a distance ℓ is given $\ell^2/2\rho$. For $\ell = 30$ meters we get about one centimeter separation of the two beams. However, it is necessary to provide focusing magnets into and out of the beam separator. If the focusing magnets are placed symmetrically so that the object and image are equally distant from the two ends of the beam separator, then the separation which can be achieved is given by $\ell f/\rho$, where f is the focal length of the lens. For a practical design this gives a beam separation of about 0.3 centimeter. Hence for effective separation, we need a target of not more than one millimeter high. Chromatic aberration introduces an additional spread in the image of the order of four millimeters for double quadrupole lenses. This spread can be reduced to two or three millimeters using lenses with three quadrupoles. Spherical aberration produces additional spread in image. The separator can most efficiently be designed by using two separating channels in succession with a defining slit between

them. The 5 Bev/c beam separators which have been designed will provide an anti-proton beam with a 1% momentum spread and an angular divergence of about 0.008 steradians.

Momentum analyzing channels have also been designed at 5, 10 and 25 Bev/c. The resulting beams will have angular divergences of 0.007, 0.001 and 0.005 steradians respectively coming from apertures of 12 inch by 24 inch, 8 inch by 24 inch and 12 inches square respectively.

The AGS beam will be extracted by the Piccioni method. If an energy loss target provides a momentum loss Δp, then the radial amplitude of oscillation induced is given by $\Delta r/r = \alpha \Delta p/p$. In the Cosmotron, $\alpha = 4$ and a target providing 10 Mev energy loss will give a four inch separation of the beam to be extracted. In the AGS, $\alpha = 1/75$. In order to get even one centimeter amplitude of oscillation, the target must provide a 200 Mev energy loss. This requires about 100 grams per square centimeter of target which is greater than a mean free path for nuclear collisions. In the scheme being designed, the target will provide 20 Mev energy loss which gives an amplitude of oscillation of about two millimeters. A first magnet will be designed which will provide a magnetic field of about 2,000 gauss over a distance of eight feet with a septum between the 2,000 gauss and the zero field region two millimeters thick. This magnet will be one-half wavelength down from the energy loss target which will be on the inner side of the vacuum chamber. The beam will therefore have a maximum inward excursion of two millimeters from the equilibrium orbit when it passes through this first magnet which will give it sufficient momentum change to induce a betatron oscillation

of three inches in amplitude. Three quarters of a betatron wavelength further along, the beam will be at a maximum outward radial excursion of three inches from the equilibrium orbit, at which point a large permanently mounted magnet will be provided to extract the beam from the accelerator. During the early parts of the acceleration cycle, the beam will require the full aperture within the vacuum tank and the energy loss target and first magnet must therefore be pulled out of the region occupied by the beam. During the second half of the acceleration cycle, the rf program will move the beam out in radius and the target and kicker magnet weighing about 100 pounds will be pushed quickly toward the center of the vacuum tank. When it is desired to extract the beam, the beam can be moved inward in radius until it strikes the energy loss target. In order to reduce the betatron oscillation amplitude to less than two millimeters, a lip is provided on the target. That part of the beam oscillating with larger betatron oscillations will first strike the lip and the betatron amplitude will be damped until the entire beam oscillating at small amplitude passes through the entire thickness of the energy loss target and is moved into the kicker magnet. Calculations indicate that energy straggling in the target is not a serious problem. About one-sixth of the beam would be lost from nuclear interactions in the target. The addition of the lip provides an additional average energy loss of about 40 Mev and results in a loss of about half of the beam through nuclear interaction. It is therefore hoped that roughly half of the internal beam can be extracted in this way. The external beam is expected to have transverse dimensions of the order of five millimeters with an angular spread of the order of 0.5×10^{-3} radians.

Green stated that beam handling equipment is to be regarded as community property to be utilized by anyone doing experiments with the machine. Likewise, large bubble chambers and other large experimental apparatus constructed with Brookhaven funds will ordinarily be regarded as community property. About $3 million will be spent on experimental equipment next year. Haworth stated that it is anticipated that the eventual annual expenditure will be about $10 million per year or about 30 to 50 per cent of the original cost of the machine.

In answer to a question, Green stated that there would of course be no cranes available in the external experimental areas. However, the experimental building contains a 40 ton crane. Trucks will be provided which can be moved into the experimental building, loaded by means of the crane with heavy equipment, and taken out into the experimental area. Equipment will then be lifted up on jacks, and the trucks can be removed. There will also be a large preparation area in another building which can be utilized for the setup of experimental equipment. Green stated that plans for the first year's experimental and beam handling arrangements will be frozen this June.

Schwartz registered an objection to the placing of experimental equipment in an external area. In his opinion it would be much better to decide now where the experiments will be conducted and to construct suitable buildings to house beam handling and other experimental equipment.

Livingston urged the importance of settling on standard power supply voltages throughout the country in order that equipment could be moved from one installation to another.

H. Anderson questioned the relative apportionment of time and money to the various energy components in the secondary beams. He pointed out that a large fraction of time and money were being devoted to beams of 5 Bev/c or less which could be provided by smaller accelerators. He urged the importance of designing beam handling equipment to utilize beams of higher energies which are unique to the AGS. It was pointed out that the cost of beam separators is roughly proportional to the cube of the momentum.

It was announced that the Cosmotron should be ready again for experimentation this summer with an extracted beam of better than 10^{11} protons per pulse. Shielding has been designed for a level of 10^{12} protons per pulse.