Plans for Work at the National Accelerator Laboratory

Fifth Lecture by Owen Chamberlain
at the
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As you know, the National Accelerator Laboratory is the new, very high energy laboratory in the United States located at Batavia, Illinois, near Chicago. The large accelerator has been under construction for several years. In March, 1972, the energy of 200 GeV was reached, for the first time.

In this written version of my talk, I shall not try to include the numerous pictures of the NAL site that I showed at Tsukuba. Instead, I refer the reader to the various monthly reports of activities at NAL, which are probably to be found in various libraries in Japan. Those monthly reports include a great variety of pictures of the accelerator site.

The accelerator has four main segments, just as your new accelerator has four main segments. They are: a) a Cockroft-Walton, b) a linear accelerator, c) a booster ring, and d) the main ring. The Cockroft-Walton is very similar to that which is already constructed at your new laboratory. The linear accelerator brings the beam energy to 500 MeV. The booster ring delivers protons of 8 GeV. The main ring, which is two kilometers in diameter, should produce protons of up to 450 GeV. The design intensity is 5×10^{13} protons per pulse. The intensity at the present is 5×10^{10} protons per pulse. Because of the high energy and high intensity of the anticipated final beam, there are expected to be great problems in handling the large amounts of radioactivity produced. Therefore, it is not anticipated that many experiments will be done with internal targets. Rather, it is expected that most experiments will be done in external beams, where the radioactivity can be more easily handled. In fact, the machine has been designed on the assumption that very little radioactivity will be induced in the components of the main ring.

In accordance with these restrictions, only very small amounts of experimental space are located close to the main ring. Nevertheless, a few experiments will be done in the main ring. One of these is Exp. 36, a Rockefeller University-USSR collaboration. The spokesman for the experiment is Rod Cool of Rockefeller University. It is a measurement of proton-proton elastic scattering. Some test runs have already been done using a foil target, but the eventual target is to be a gas jet. The gas jet target is to be installed very soon. Another experiment to be done based upon the same gas jet target is Exp. 67 involving Bogdan Maglic. This is a proton-proton inelastic scattering experiment. It is a missing-mass measurement, using the reaction $p + p \rightarrow p + x$, where x stands for anything. The method of the Jacobian peak is used, where the experimenters need an accurate measure of the angle of scattering but not a very accurate measure of the energy of the scattered proton.

Another experiment that is expected to be done in the vicinity of the main ring, even though space is very limited, is Exp. 120 of Kline and Rubbia and collaborators. This is a study of gamma rays emitted downstream from the gas jet target. It should give information on the yield of π^0 mesons. It is expected that Exp. 120 will include also some search for W bosons, and possibly some estimates of the production of short-lived neutral kaons.

As the proton beam emerges from the main ring it heads directly toward the neutrino laboratory. At the present time the beam handling magnets in the neutrino laboratory are completely in place, and their power supplies are complete. Some tests have been done on the beam in the neutrino area, but very little running has been accomplished up to the present time. Planned for the neutrino laboratory are two experiments on muon scattering, two neutrino experiments based on counter techniques, and the 30-in. hydrogen bubble chamber as well as the 15-ft. hydrogen bubble chamber. At the present time 200 GeV protons are being sent to the 30-in. hydrogen bubble chamber for the first time.

Where the beam emerges from the main ring and heads towards the neutrino laboratory there are magnets which can deflect the beam slightly to the left (to the west) toward the meson laboratory. At the meson laboratory the magnets for handling the external proton beam are in place, but there are at present no power supplies fully installed. There is hope that the proton beam may reach the target in the meson laboratory in late July, 1972.

The particles emerging from the target in the meson laboratory will be used to form five secondary beams. The first of these M1, is a high-intensity beam formed at 3.5 milliradians from the beam direction. M2, the second of these secondary beams, is designed to be a diffracted proton beam. M3 and M4 are neutral beams designed primarily for neutron and neutral kaon experiments. Beam M6, formed at 3 milliradians, is a beam capable of high momentum resolution.

I will mention a number of experiments for the meson laboratory.

Experiment 75, for which Dr. Yamanuchi is the spokesman, is a quark search. It is often called Quark I. The search will be conducted by tuning the secondary beam forming magnets to a momentum higher than the momentum of the incident protons. Thus, the only particles that could come through the magnetic spectrometer would be particles of fractional electric charge. It is thought that this should be a very effective way to search for quarks.

Experiment 111 is a CalTech-Lawrence Berkeley Lab collaboration, with Prof. Alvin Tollestrup as the spokesman. It is designed to measure the differential cross sections for the processes $\pi^- p \to \pi^0 n$ and $\pi^- p \to \eta n$. In terms of Regge models, these reactions are particularly interesting, because they involve ρ exchange and A2 exchange. One purpose of the experiment is to see whether the higher energy behavior of these reactions is in accord with Regge theory.

Experiment 8 involves measuring the production of Λ, Ξ^0, K^0_{short}, and K^0_{long}, as well as a significant search for the process $K_s \to \mu^+\mu^-$, and the observation of Λ-p scattering.

Experiment 4, for which Prof. Longo is the spokesman, is a measurement of neutron total cross sections on hydrogen, deuterium, and various heavier elements. It involves a large total-absorption neutron spectrometer based on many steel plates.

Experiment 27A, for which Prof. Rosen is the spokesman, includes participants from the University of Rochester and from Northwestern University. It is a study of the coherent dissociation of the neutron, particularly as π^- and proton.

Experiment 12 is a study of neutron-proton charge-exchange scattering. It involves physicists from Ohio State and Michigan State Universities. Dr. Reay is the spokesman. Neutrons and protons in the final state will be counted in coincidence.

Experiment 72, with Dr. Leipuner as spokesman, involves physicists from Yale University and Brookhaven National Laboratory. It is often called Quark II. It involves observing the pulse height in many scintillation counters as charged particles pass through. They are looking for evidence of particles of charge 1/3 and charge 2/3.

Experiment 82, a University of Chicago-NAL collaboration, with Prof. Telegdi as spokesman, is to study the regeneration of K_S from K_L at high energy. This, of couse, is a very interesting reaction in terms of Regge theory.

Experiment 104, for which Dr. Kycia is the spokesman, involves Rockefeller University, NAL, and Brookhaven National Laboratory. It is expected to be the first experiment done in the beam line M1. It is a measurement of the total cross section on hydrogen and deuterium of the various particles produced at the meson laboratory target. Following the total cross section measurement should be Experiment 7 of the University of Michigan, with Prof. Don Meyer as spokesman. This is a set of measurements of differential cross sections for elastic scattering of π^-, π^+, and protons on protons.

Soon after Experiment 7, I hope to see set up in the same beam our own Experiment 61. It is a collaborative experiment involving physicists from Harvard and Yale Universities and from the Argonne National Laboratory, NAL and the Lawrence Berkeley Laboratory, and it is designed to measure the proton polarization in elastic scattering of π^-, π^+, and protons on protons, for incident momenta of 40, 80, and 160 GeV/c. The actual measurements will consist of asymmetry measurements for elastic scattering of the beam particles on polarized protons in a polarized proton target. As I mentioned in an earlier lecture, this measurement can be interpreted as measuring the polarization in scattering, provided one assumes time-reversal invariance (or, in some cases, parity conservation) in the strong interactions. Cherenkov counters in the incident beam and in the scattering arm for fast forward particles should give good particle identification. Magnetic analysis of both the forward scattered particle and the recoiling proton should allow good separation of elastic scattering events on free hydrogen from background events involving scattering on bound protons or inelastic scattering. The measurements are designed to cover the invariant squared momentum transfer range from -0.1 to -1.5 $(GeV/c)^2$. Even to cover this seemingly limited range of momentum transfer it will be necessary to use beams as high as 10^8 per pulse, so that we are not planning to have any scintillation counters in the incident beam during much of the experiment. The polarized target is to come partly from Berkeley, partly from the Argonne Laboratory. The Cherenkov counters are being made at Harvard. Much of the electronics is being designed at Yale. The counters will be made at Harvard and at Berkeley. Because of the several experiments that must precede this experiment, it is not expected to be actually started until the Summer of 1974.

Interesting new problems arise when one designs an experiment for these very high energies. For example, the scattered fast particles must be detected very close to the beam in the forward direction. In fact, in Experiment 61 the beam of unscattered particles will pass through some of the gas containers for the Cherenkov counters, there being an optical septum placed within the gas volume to separate the beam particles from the scattered particles. The septum also keeps Cherenkov light emitted from beam particles from being detected. Furthermore, elastic and inelastic processes can look very similar, as far as the kinematics of the forward particle is concerned, so that it is difficult to separate elastic from inelastic processes when observing only the fast forward particle. It is therefore important to get significant information about the recoiling proton for each event in Experiment 61.

Figure 1 shows a plane view of the counting arrangement for counting the fast forward particles as the apparatus is planned for 40 GeV/c particles. Notice the figure is intentionally distorted to make parts more visible. The notation WS1 is to indicate Wire proportional chamber (for the fast Scattered particles) number 1.

Figure 2 shows the corresponding figure for 160 MeV/c.

Figure 3 is a beam's eye view of the forward proportional wire chambers, showing a desensitized region for the beam and showing the region where the scattered particles should pass through the wire chambers.

Figure 4 shows a plan view of the counting arrangement for the recoil protons as they emerge from the polarized-target magnet and are further analyzed in a bending magnet.

We are quite excited by the prospect of pursuing these experiments to the highest available energies. A great deal of work is involved, but it will be an interesting challenge to push our techniques into this new high-energy range. Above all, we hope that simplifications will become evident in the high-energy region that may complement the simplifications that we already know about in the low-energy regions. If so, the effort will be well worthwhile.

It has been a great pleasure to take part in this Summer School. I appreciate your kind hospitality. I hope these lectures have been helpful to some of you.

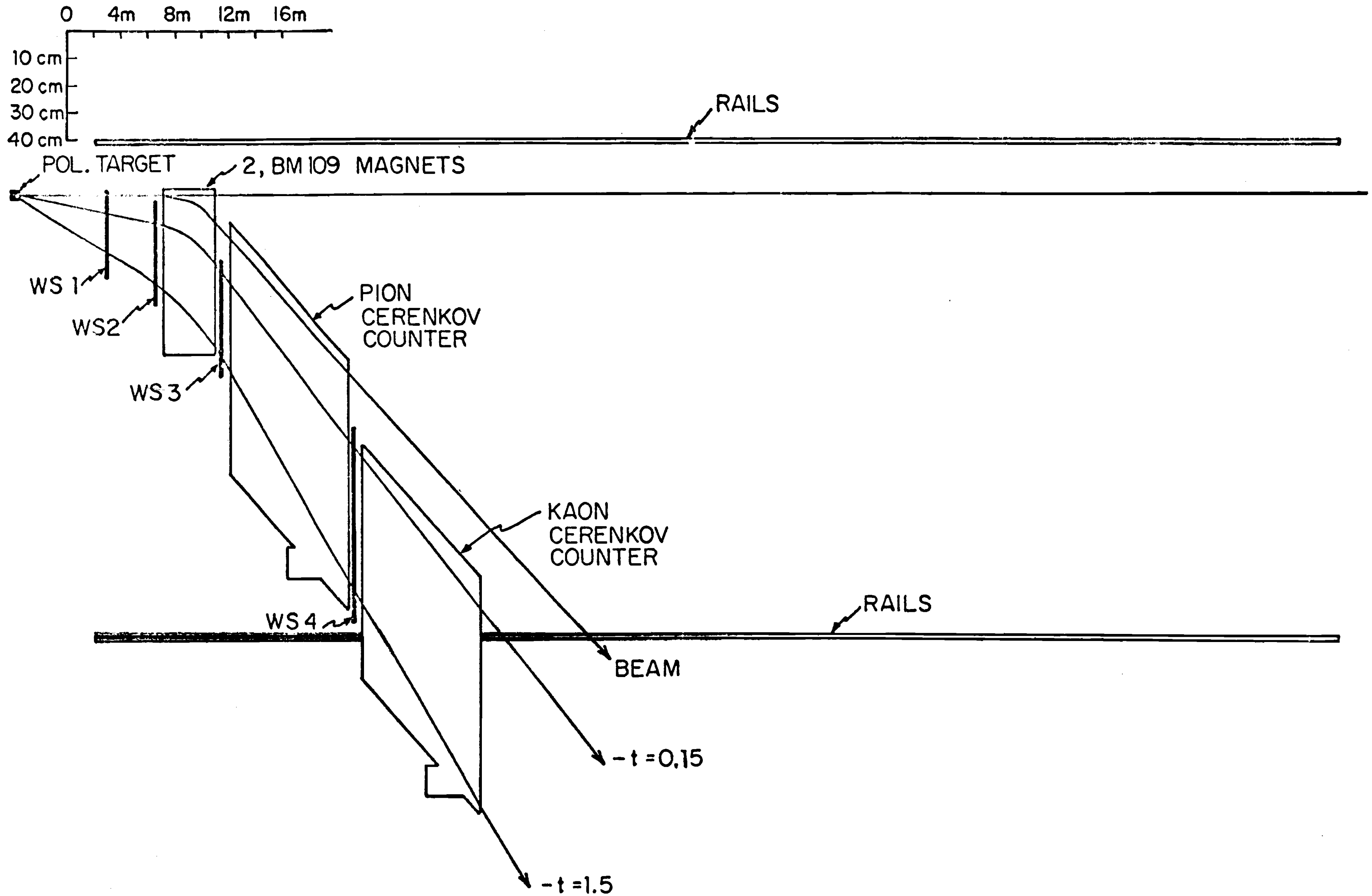

FIG. 1 SCATTERED PARTICLE DETECTOR AT 40 GeV/c

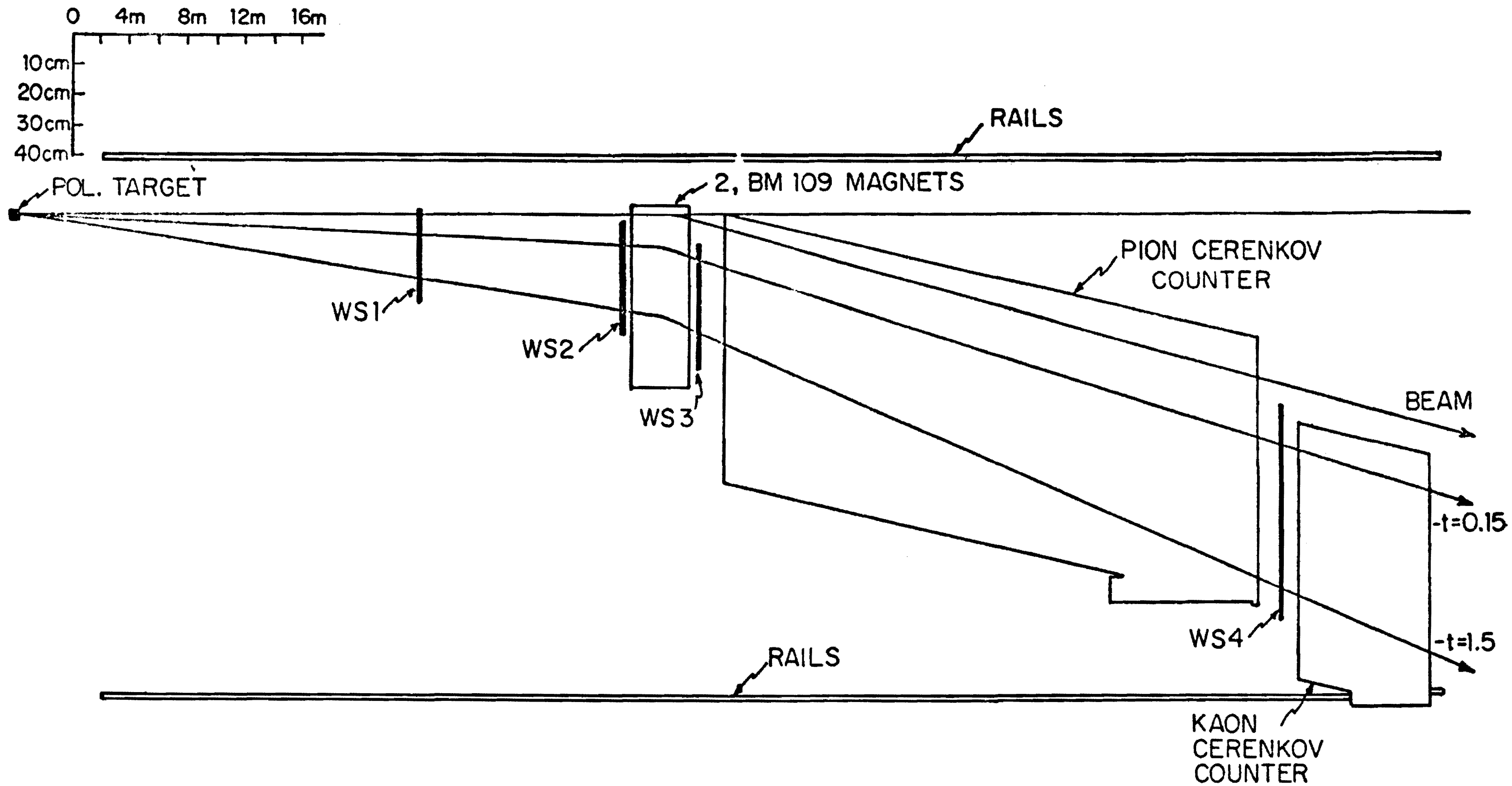

FIG. 2 SCATTERED PARTICLE DETECTOR AT 160 GeV/c

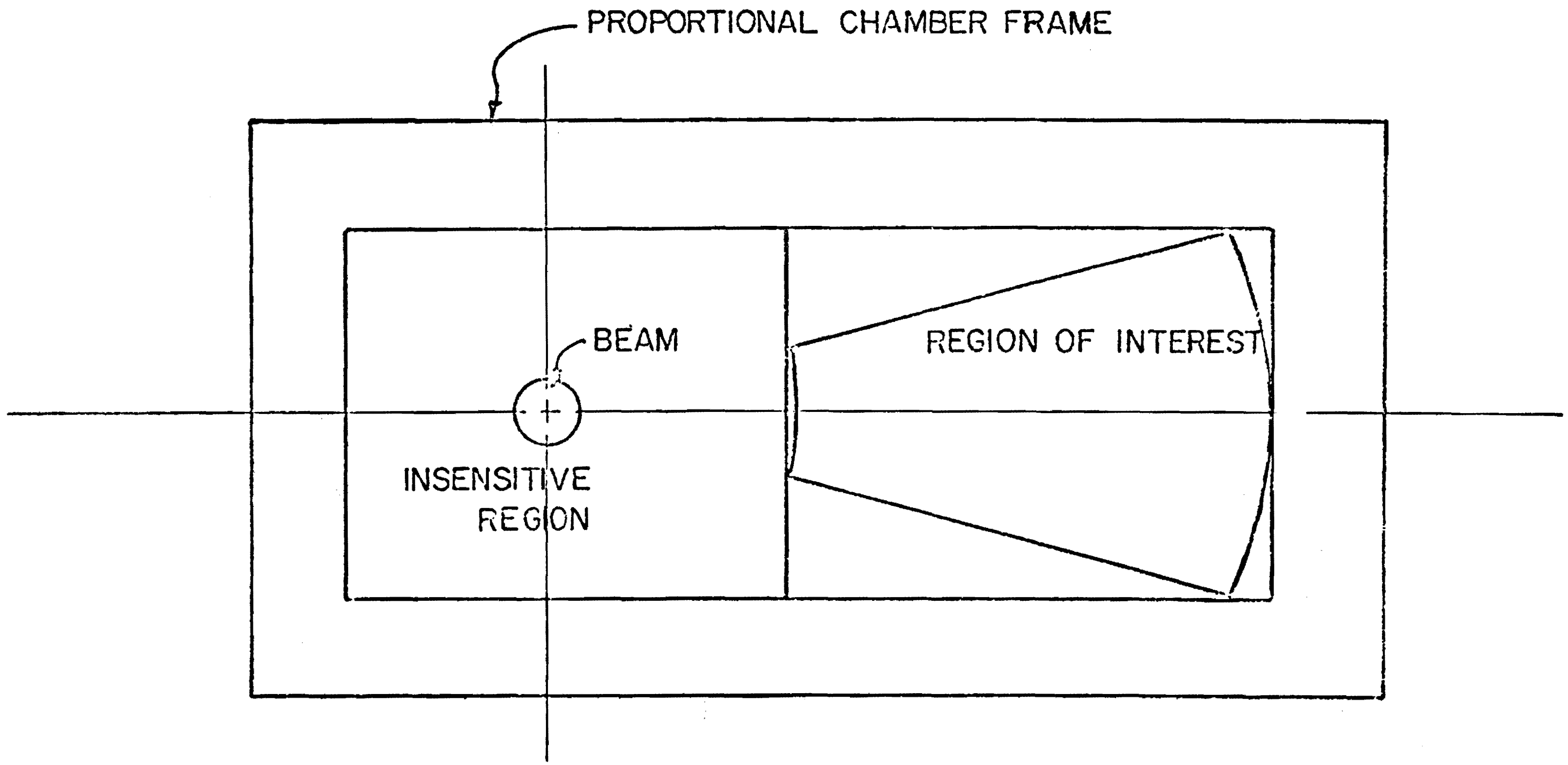

FIGURE 3

SCATTERED PARTICLE DETECTOR CONFIGURATION

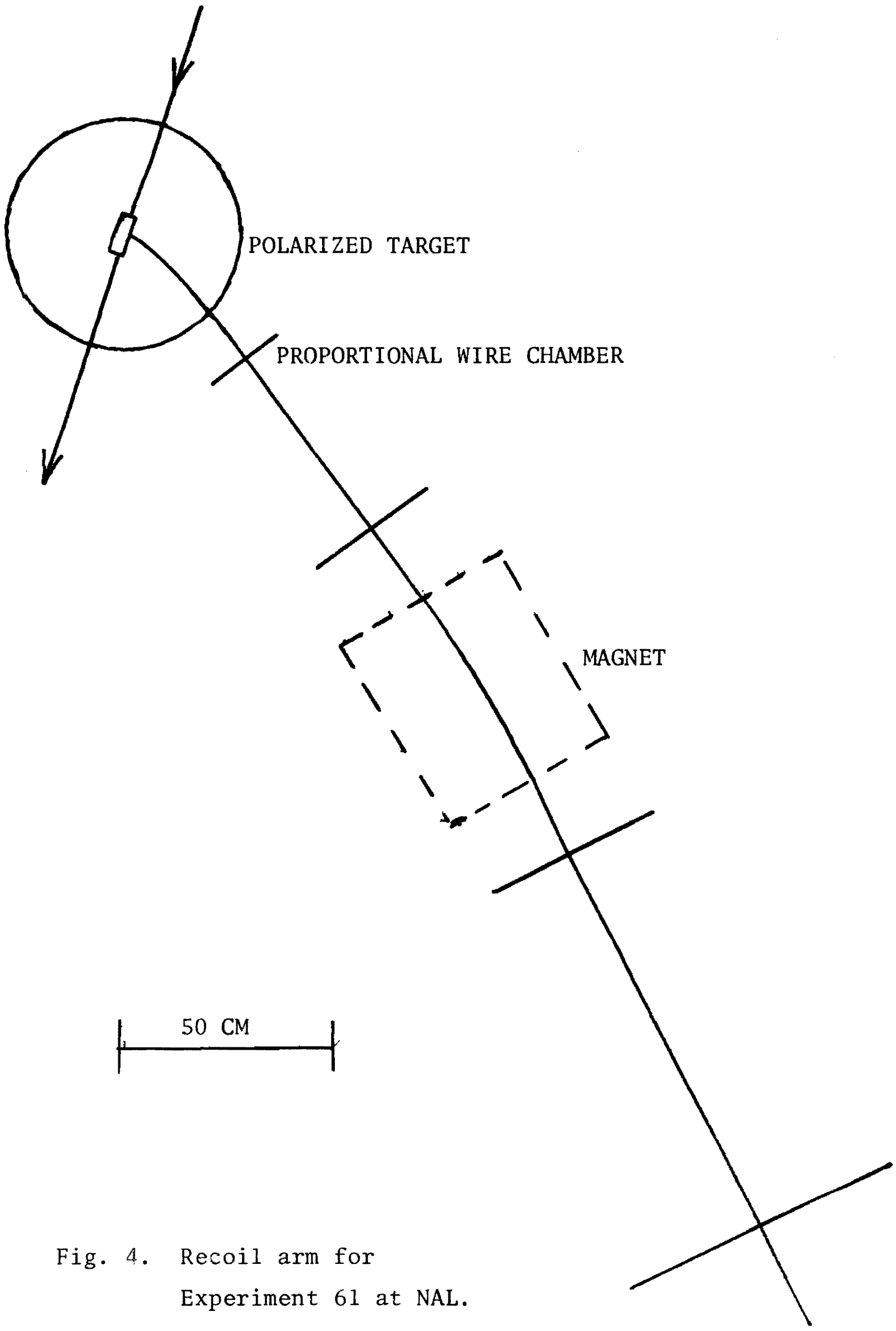

Fig. 4. Recoil arm for
Experiment 61 at NAL.