# EXTRACTED AND SECONDARY BEAM TARGETRY

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## Abstract

Meson target manipulators are used to remotely plunge targets anywhere within a 32 in. x 60 in. x 3 in. targeting volume inside the circulating beam chamber of the Argonne Zero Gradient Synchrotron. The mesons produced are of different momentum and enter three separate beam tubes from a single crossover point. Two meson target manipulators normally position the targets for multitargeting of a single synchrotron beam pulse. The speed of targeting permits the rf to move the beam pulse to extract two meson beams of different momentum. Using a shaped two-step command function, a single target is moved swiftly into two distinct positions, again extracting two meson beams of different momentum. Targets, target angles, target positions, and the target manipulators are changed without losing beam chamber vacuum. Fixed point meson targeting mechanisms are used for extended experiments that require only single presurveyed positions. Unique electrical linear actuators drive energy loss targets vertically for fast or slow proton extraction. Such fast drive modules are easily removed without interruption of the beam chamber vacuum. Numerous economical drive units with presurveyed targets are held on standby for quick change into the accelerator. A periscope television apparatus permits remote observation of all targetry for accuracy of position under vacuum.

## Introduction

Most experiments in high energy physics utilize either an extracted proton beam or a beam of secondary particles from a high energy accelerator. At Argonne, the Zero Gradient Synchrotron (ZGS) proton beam is extracted by an energy loss beryllium target and suitable bending magnets. Secondary particles are produced from direct bombardment of suitable metal targets by the synchrotron's circulating beam. The unique systems for placing these targets in their crucial space and time coordinates will be reviewed in construction and operation.

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## General Targetry Area

The ZGS, very briefly, consists of a preaccelerator which injects protons into a linear accelerator and from there into a beam circulating ring. Energy of the circulating beam pulse is increased by synchronized rf impulses and is held in radial position by the increasing field of the ring magnets. Targeting of the beam occurs when proper beam structure and energy is reached. Figure 1 shows the general targetry complex where most targeting is done (L-3 chamber) to produce the proton and secondary beams for the various high energy experiments. The variable meson manipulators are shown in the chamber within the beam guide magnet. The fast beam extraction (beam bumper) target mechanism as well as the slow beam extraction (Piccioni target mechanism), are shown complete with structural supports entering through the top of the chamber. The periscope and television camera for remote control room target positional verification are also pictured.

Figure 2 shows the variable meson targets in more detail. The set point meson targetry also mounts in this area on the inner track.

## Variable Meson Targetry

The design of the ZGS provides for three distinct beam tubes through each of which an experimenter receives the particular meson momentum secondary beam for his experiment. Immediately prior to entering these tubes, all the beams have crossed through a common point termed the field-free point. Depending on the distinct placement of the meson targets and their angle with relation to the circulating beam, definite momentum beams of secondary particles with defined paths emerge from the targets, then curve through the field-free point to the required beam tube leading to the specific experiment. As can be readily envisioned, a great number of distinct target placements must be made to cover the great number of possible momentum particles. But even more demanding is the greater number of close proximity points used at the start of each long run to pinpoint the very optimum desired momentum beam of secondary particles. These operational demands, as well as a comprehensive beam survey at the startup of machine operation, established the need of a variable device to plunge meson targets remotely anywhere within a 32 in. x 3 in. x 60 in. targeting volume inside the circulating beam chamber of the Argonne ZGS.

Design requirements for this variable target manipulator are as follows:

1. Movement of the meson target as far out from the chamber wall as 21 in. within 1/10 second.

2. Provision for enough vertical adjustment to mount two vertically-operated targets on one manipulator arm allowing for targeting of either target without interference of the other.

3. Additional vertical adjustment of 1/2 in. for each target as it is shifted vertically to its beam position.

4. Angular adjustment in the horizontal plane of $9^{\circ}$.

5. Azimuthal adjustment along the beam direction of 60 in.

6. All controls of the motions done remotely from the Main Control Room of the ZGS.

7. Required accuracies of positioning are:
   a. $\pm$ 0.005 in. in the vertical direction.
   b. $\pm$ 0.050 in the azimuthal and radial directions.
   c. $\pm$ $0.1^{\circ}$ in the angular direction.

8. Environmental operating conditions are:
   a. Vacuum of $10^{-6}$ mm of Hg.
   b. Magnetic field of 24 kG.
   c. High radiation field created by the immediate bombardment of the intense high energy beam striking the target and causing particle and radiation scattering.

9. Desired endurance life of 1,000,000 cycles since 15 pulses of particles every minute on around-the-clock operation rapidly totals many target manipulator cycles.

10. Removal and change of the target manipulators without the loss of the beam chamber vacuum within a time of 1-1/2 hours.

The targetry placement occurs within the Zero Gradient Beam Magnet itself. Due to the desired close proximity of the magnet coils to the chamber wall, only a 2 in. wide space on each side of the beam chamber is available to house the variable meson target manipulators. Their ability to plunge in pencil-sized targets to as far as 21 in. from this narrow silhouette is partly due to their mechanical design. Basically, the targets are mounted on a sliding lever or scissors which is thrown out and controlled by a cambered tape. The tape resembles the conventional roll-up flexible tape rule except it is nonmagnetic. Its curved cross-section supports a column load as it pushes through the first half stroke and supports the tension load as the target is pulled to a stop at its desired target placement. Tape loading is largest on the inner manipulator since its maximum travel of 21 in. is farther than the outer manipulator's travel. It has a spring to facilitate the opening of its scissor links. The spring also increases the tape tension when drawing the arm and target to a positional stop. The approximate 35g deceleration load plus the spring load on the tape then are maximum at about 140 lb. tension for a target of 90 grams. On closing, the same forces repeat. Figures 3 and 4 show the inner manipulator in the open and closed positions, respectively. Two targets are shown mounted. The same cables that will pull the bottom target up to beam center and the top target out of targeting position maintain the target angle at all arm positions by a parallelogram motion.

The outer variable manipulators are positioned azimuthally in their outer track by a 1/16 in. thick tape while the inner variable manipulator is positioned azimuthally in its inner track by a lead screw. All of the above slow drive motions are produced by stepping motors. Attached digital encoders provide the necessary position feedback for both position indication and error bridge nulling.

The fast drive for the cambered tape that opens and closes the target arms is an electrohydraulic servo system. Figure 5 shows a block diagram. The top portion of the figure details the manner in which the electrical function is generated. The command function is entered into the summing junction of an operational amplifier. Also summed are signals from the target position feedback potentiometer, the balance or reference potentiometer and the derivative feedback amplifier. The balance potentiometer sets the initial target starting position. The target feedback potentiometer is mounted on the manipulator and its linear stroke is determined by the movement of the cambered tape. Thus, the command signal brings about servo valve change which, in turn, causes a hydraulic cylinder to ultimately move the cambered tape, the potentiometer and target. Feedback voltage from the potentiometer nulls the command signal, bringing the target to rest on position. The derivative feedback provides for transient stabilization and permits system stabilization with minor variations in mechanical constants.[1,2,3]

Changes of operating position are entered on a plot board as experiments require. A manipulator template is moved onto this point along a mock track. The correct encoder digital number is read off the track to place the actual manipulator azimuthally along its rail for the desired target position. The correct voltage signal amplitude is read off the template to open the manipulator arm to correct target position.

With the design speeds and versatility of positioning of these variable manipulators, differing types of multiple targeting can be performed on a single beam pulse.

The present mode of operation is the placement of one target just before the guide magnets reach their flat-top of magnetic flux. Subsequent withdrawal allows the placement of a second target in its proper point a few milliseconds after flat-top is obtained. The rf controls the beam to the first target for a short spill and then to the second target for a longer spill. All available meson and proton extraction targets can be used in multiple combinations. Individual variable manipulators can be moved in discrete steps to achieve two targeting positions in one beam pulse. A special function generator develops the required two-level control signal. Thus, two experimental groups receive their respective momentum secondary particles from the same target with the same circulating beam pulse.

The variable target manipulators are remotely withdrawable into an outer vacuum chamber separable from the main beam chamber by an isolation valve. Therefore, when necessary, the targets, target angles, and target manipulators can be changed without losing beam chamber vacuum.

## Fixed Point Target Mechanism

An extremely simple secondary particle targeting device is utilized when an experimentalist group is to occupy a particular targeting point for long duration. It is limited to the one point, although targeting periods have existed where it was used on other points when they conveniently laid on a line parallel to the manipulator track. (This simple device is remotely movable only along its support track.) Target angle and distance out from the track are adjusted on initial installation. Figure 6 pictures this device.

The principle of motivation is the utilization of the beam guide magnetic field by a small coil so pulsed as to react in a rotary motion. The coil is along the chamber wall in the track. Projecting out to the target location is a low outrigger resting on the chamber floor and occupying only 1/4 in. height. The outrigger houses a parallelogram device attached to the target to raise it about 2-1/2 in. up to beam elevation. A tubular shaft connects the motivating coil out to one arm of this parallelogram lift device. A torsion shaft return spring mounted to the other arm returns the target downward into the housing. A square pulse of dc current of specified amplitude and duration motivates the coil to raise and hold the target in position for proton bombardment. When the pulse terminates, the target springs back down. A small pulse retards the target at the end of its motion to cushion the return.

Such a simple device has operated for about seven months without need of repair or preventative maintenance. Small field perturbations are created by the coil as well as by the induced currents in the outrigger. However, calculations and experience demonstrate these to be negligible for normal operations. Also, apparently negligible for most runs is the 1/4 in. high beam obstruction of the outrigger and target nest.

## Energy Loss Target Mechanisms

The same type of targeting mechanism is used for both fast and slow proton extraction. Its construction is modular. That is, it can be removed completely from the accelerator without loss of beam chamber vacuum in one simple unit of drive motor, target mechanism, mount and target. The mechanism is mounted through the top of the L-3 chamber. The unit is inserted in a vacuum box and then remotely lowered through an isolation valve to its proper operating position. Upon operation, it vertically plunges its energy loss target into the circulating beam and holds for multiple passes during which time bending magnets extract the proton beam. Figure 7 shows the energy loss target mechanism with its shield cover removed.

The target motivation is by a special linear motor in which a current pulsed coil reacts to the field between the pole faces of ganged permanent magnets. This coil reaction drives the target down while loading a return tension spring. On approaching target position, a small holding coil is energized to magnetically latch the target into its exact targeting position. To return, the hold coil is de-energized and the target is drawn up by the tension spring, but also cushioned against abrupt impact by a small retard pulse. The permanent magnets are well above the beam and properly shielded so as not to affect the circulating beams intended path.[4]

Economical construction and modular design coupled with easy removal and replacement in an isolated vacuum box, enables quick complete changes of various types of targets with their drive units. It also provides backup for any certain unit. The technique of presurveyed unitized targets and drives is, in actuality, the first step in preparation of future targetry. Handling targets and drives in higher energy machines where radiation levels will not permit the normal manual operations will demand remote removal of modular type units.

## Periscope - Television Target Verification

As previously mentioned, target placements for variable meson manipulators are read out by digital encoders for the slow motions and by an accurate linear potentiometer mounted on the manipulator itself for the fast swing motion. The fast motion readout is on a digital voltmeter displayed in the Main Control Room. All of these readings are reviewed by optical survey at maintenance periods for new and old experimental target positions. Exact readouts are also then made on the target positions by a periscope. The sightings of the periscope are displayed via television, also in the Main Control Room.

In addition to an angular encoder periscope readout, a sighting is made on a survey scale below each target. The scale is attached to the magnet face immediately below the beam chamber. These scale readings are taken also at optical survey as well as off the periscope plot board during operational target change. Elevation checks are likewise taken by periscope sightings to optical targets on the L-3 box walls.

Therefore, during operation, target positional verification can be made by lowering the periscope while beam is off but with vacuum retained. A periscope plot board is also used to plot new target positions required during operations. From these plots, angular and scale readings are obtained which can be used to verify, by periscope sighting, the targets positioned through use of templates and plot board. The target placement for the energy loss target is also verified by this device.

## Acknowledgments

The foregoing paper outlines the efforts of many people. Space does not allow adequate individual credit to any of those involved. A. J. Gorka, Project Manager for targetry, gave excellent leadership and encouragement as well as many of the conceptual approaches embodied in the equipment. W. B. Hanson and J. F. Mech contributed greatly to the engineering of the variable meson targetry. T. Cassidy and L. Genens developed the slow meson positional drives and track systems. R. Batch devised the TV-periscope target verification systems. S. Zielinski rendered outstanding design effort. D. Giarrante and A. Creer competently led the excellent technician effort on testing, liaison, construction, and operation. The entire design and construction efforts of the Central Shops group was timely and effective.

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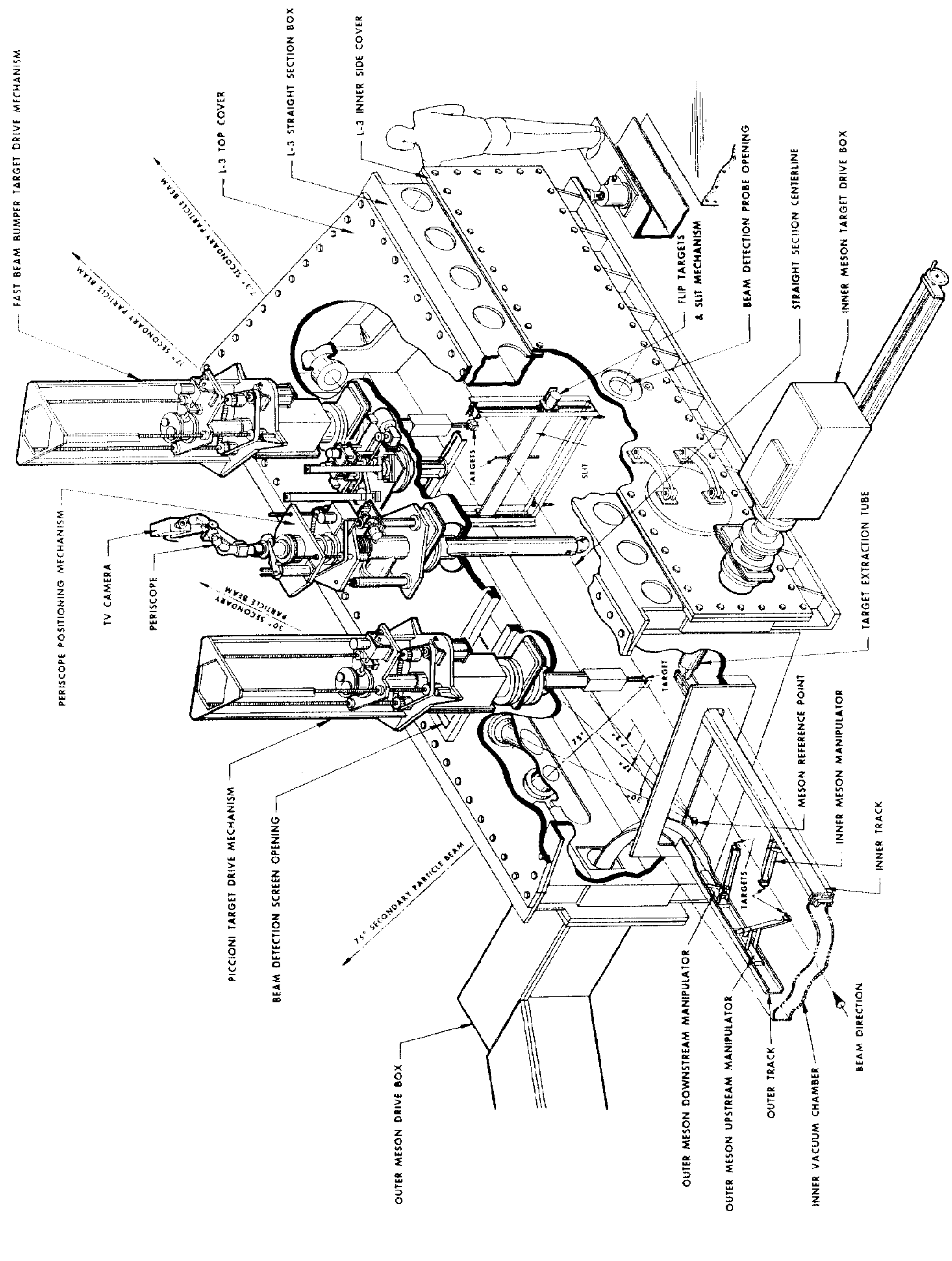


Fig. 1. Target arrangement.

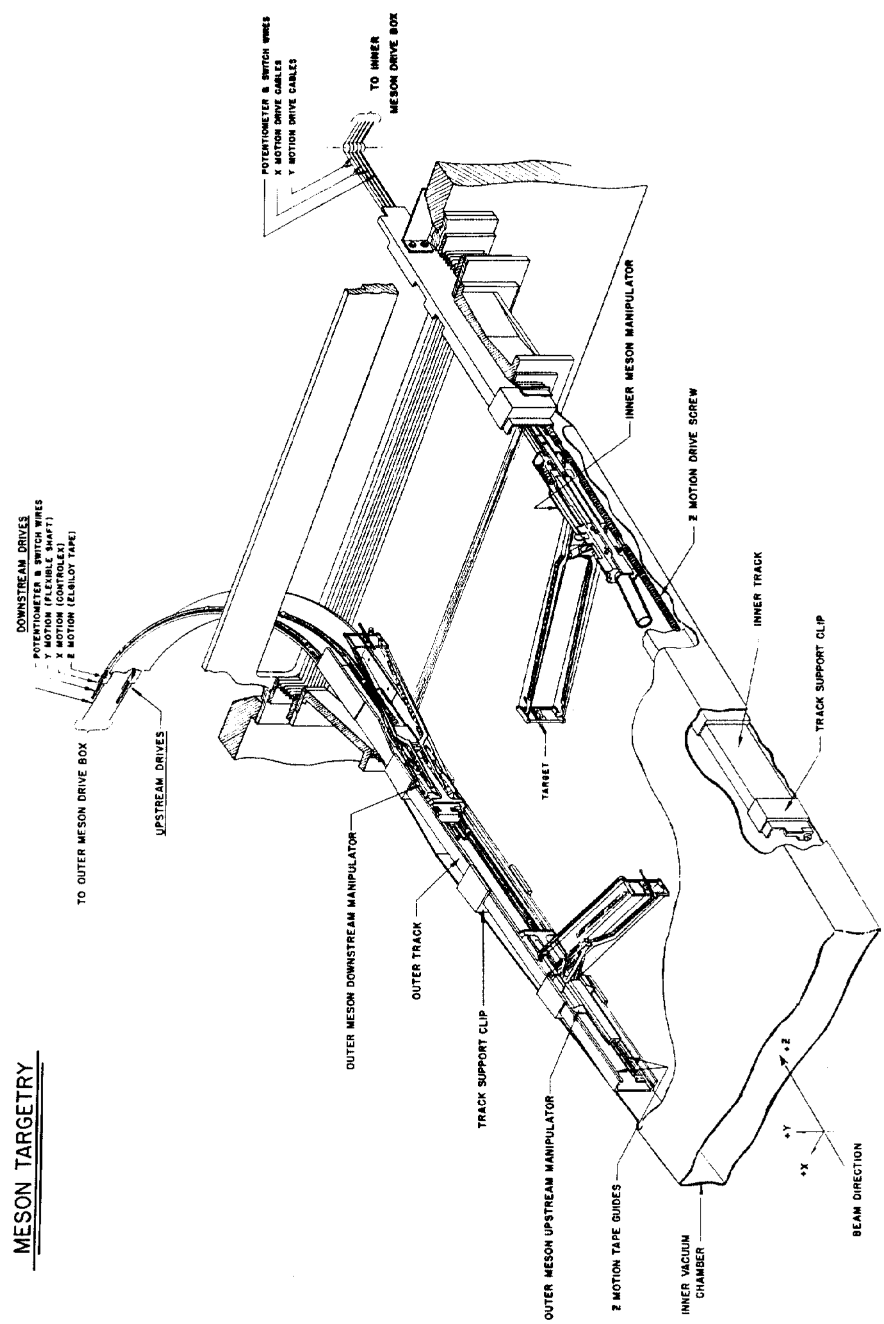


Fig. 2. Meson Target Manipulators.

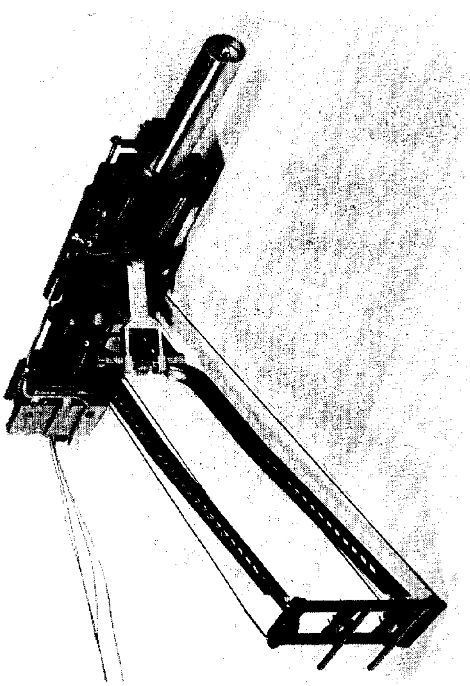

Fig. 3. Inner Meson Target Manipulator-Open Position.

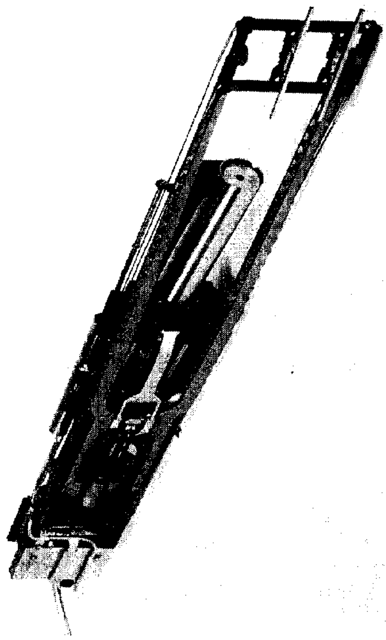

Fig. 4. Inner Meson Target Manipulator-Closed Position.

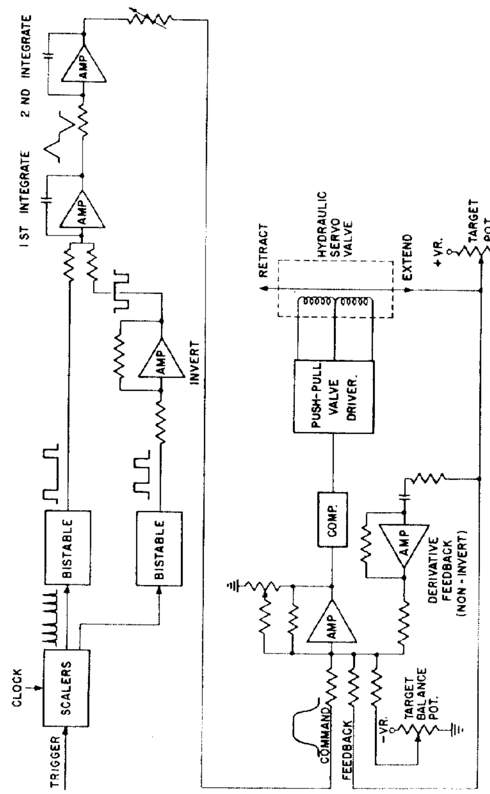


Fig. 5. Meson Target Servo Drive Block Diagram.

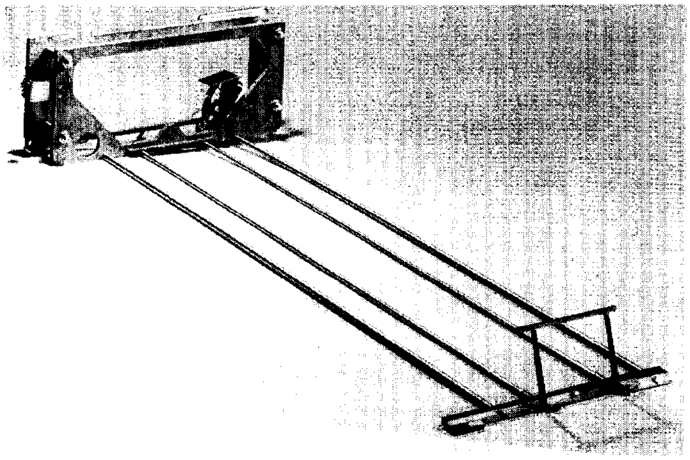

Fig. 6. Fixed Point Meson Target Manipulator.

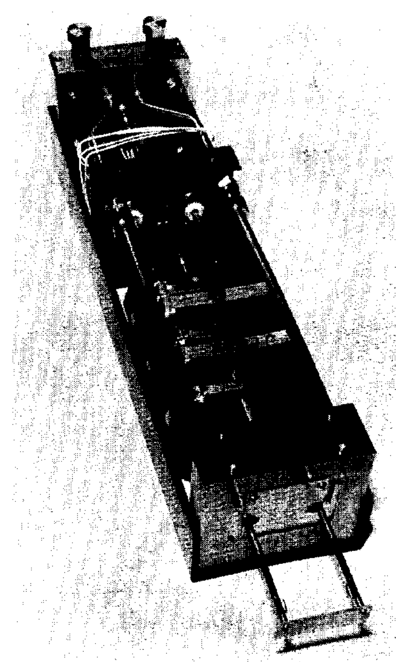

Fig. 7. Proton Extraction Target Drive Mechanism.