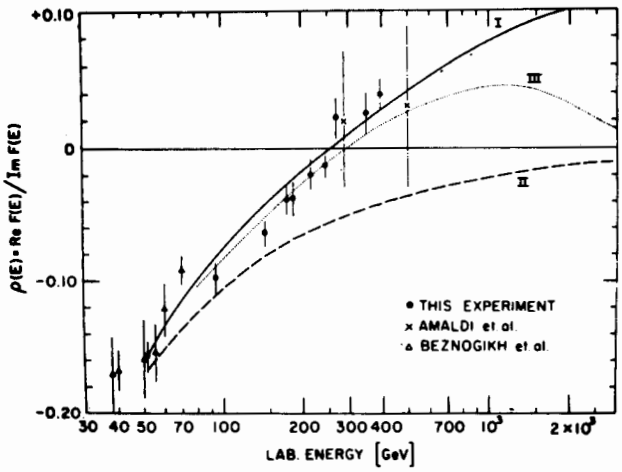
INTERNAL TARGET AREA EXPANDED

With the completion of additional experimental floor area, the Internal Target Area is entering a new era of operation. In the past two and one-half years, experiments have been conducted within the confines of the main-ring tunnel enclosure at C-Zero. This tunnel section, which measures 155 by 12 feet, offers very little "maneuvering space." The problems of doing experiments are compounded by the Accelerator Division requirement that passage be instantly provided for the magnet moving vehicle, thus limiting space for experimental apparatus even further.

Despite these severe limitations, a number of successful experiments have been conducted in the C-Zero straight section, using targets consisting of jets of hydrogen gas or carbon-CH_2 fibers mounted on a rotating disc. Several fundamental experiments have been made by collaborations of United States and Soviet Union scientists: Proton-Proton Scattering # 36, Proton-Deuteron Scattering # 186, and Proton-Nucleon Inelastic # 317 to name a few. As one example of an outstanding contribution, one may cite the measurement of ρ parameter for proton-proton scattering as shown in the curve on page 2:

$$\rho(E) = \mathrm{Re}\, f(E)/\mathrm{Im}\, f(E).$$

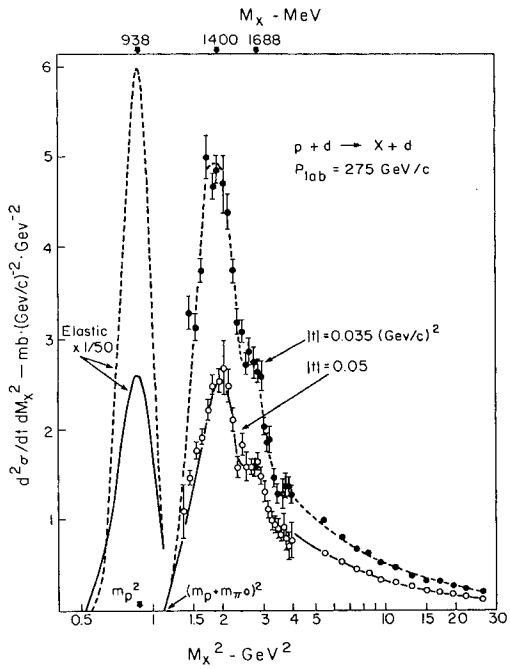
The $\rho(E)$ was measured up to 400 GeV, the highest laboratory energy available, with the value crossing zero in the vicinity of 250 GeV. The experimental errors are significantly smaller than the corresponding results from the CERN ISR. Using a rotating fiber target, the Proton-Proton Inelastic # 221 group undertook to measure inelastic inclusive cross sections at small momentum transfer--a domain not accessible at the ISR. The # 317 group is currently doing similar work using the hydrogen jet target.



The measured values of the ρ (E) parameter; ratio of the real to imaginary part of the forward scattering amplitude, versus laboratory energy. The circles represent Fermilab Proton-Proton Scattering # 36 values, while crosses are ISR results and triangles represent some earlier values from Serpukhov. The three lines are theoretical model predictions.

Several particle search experiments have been carried out in the C-Zero tunnel section also. The Particle Search # 184 group looked for direct muon production as a function of laboratory energy, and Particle Search # 363 looked for charm particles by measuring the K/π ratio with varying incident momenta. As a further example of timely results, one can mention the inclusive π^0 production spectra measured by the Photon Search # 63 group. The excellent resolution capability of the Internal Target Area is evident in the curves provided by the # 186 group, shown on page 3.

The inaccessibility of the experimental apparatus placed severe demands upon the experimenters' ingenuity in designing reliable apparatus. The difficulties of limited access were overcome, however, and the operation of the Internal Target Area has not caused more than one or two hours of accelerator down time during the past two years.



Missing mass spectrum obtained by measuring the angle and energy of recoiled deuterons in the reactions $p + d \rightarrow X + d$. The largest peak, demagnified by a factor of 50, is the elastic peak; the dashed curve represents the observed production of low-mass resonances (isobars) at the 275-GeV incident energy. Two such curves are drawn, each for a different recoil angle corresponding to the momentum transfers of 0.035 and 0.050 $(GeV/c)^2$, respectively. The curves exhibit a clear minimum at a mass value just before a single pion production sets in: $M_X = M_p + M$. (Courtesy of #186 group)

The gas jet target operated on demand for almost two years without significant troubles. Late in 1974 the original hydrogen jet target developed small helium leaks, presumably caused by the cycles of cooling and mechanical motion to which it was subjected during its long operating period. Some 2000 to 3000 thermal cycles from room temperature to 4°K have been recorded. Although in no way catastrophic, these leaks were a nuisance to accelerator maintenance personnel, creating a significant helium background during leak testing with helium mass detectors. For this reason, the jet target was removed in late 1974, and a tedious repair begun. The

collaboration between the USSR group from Dubna and the Fermilab experimenters worked well. In fact, besides repairing the old target, a whole new spare jet target has been brought in pieces from the USSR, and with significant improvements completed, is being readied for tests.

Several other avenues of gas target development are now being explored by P. Mantsch and F. Turkot of Fermilab, and by P. Franzini and J. Lee- Franzini of Columbia University and Stony Brook, respectively. Tests are underway to see whether a "warm" jet target can be used for some specific measurements. In such a jet, the liquid helium cryo-pumping method is not employed; instead, the great evacuation ability of diffusion pumps is used to remove the hydrogen gas injected into the vacuum chamber. A massive effort to develop a successful helium gas jet target is in progress at Dubna, as well. When this target passes all of the required safety tests demanded by accelerator operation, it will be installed in the C-Zero straight section. Thus, three jets may be in operation in the main accelerator tunnel by the beginning of 1976. The operation of the jet target has been greatly improved by the addition of new controls and monitoring devices built by the C-Zero crew of technicians.

At the time of this writing, a new room addition has just been finished which will greatly facilitate doing experiments at the Internal Target Area. The addition, a room measuring 40 by 50 feet in area, is connected to the main-ring tunnel by a transition section 15 feet in length. Eventually the room will house a superconducting spectrometer. Besides the main penetration, another hole has been drilled into the tunnel section to accommodate "viewing" of the yet to be installed helium jet.

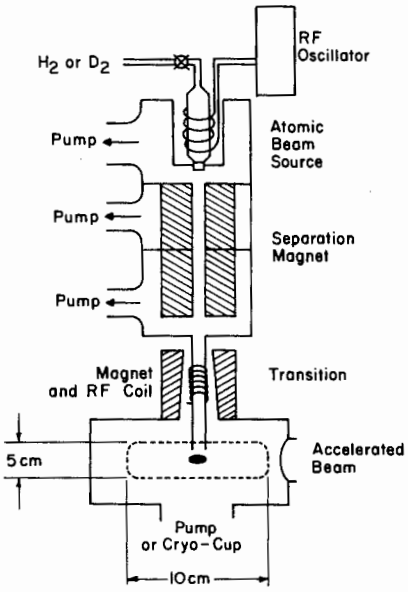
To construct an experimental area adjacent to an operating accelerator required finely planned engineering and arrangements between the Internal Target Group, the Architectural Services Department, and the outside contractors. No delays were experienced, and in a ten-day shutdown in April the remaining 7 feet of transition "hallway" was excavated, concrete poured, and a 7- by 7-foot hole opened into the tunnel wall.

This new recoil room will greatly augment the use of the jet targets for high energy physics research. The benefit is twofold. First, the room can house the spectrometer magnets, thus allowing the measurement of higher momenta for recoil particles than possible using solid state detectors alone. Secondly, by removing the detection apparatus from the main-ring tunnel, the background radiation can be more easily suppressed by adding shielding.

Remote operation of superconducting magnets, with only once-a-week access, together with improved jet cryogenics, will be a very complex undertaking. Just how well and how reliably the whole operation is going to proceed remains to be seen. Once the hurdle of construction and initial operation in the room is overcome and experiments are operating smoothly, one may begin to think of future developments such as a polarized gas jet target.

The increasing accelerator intensity, combined with multiple beam traversals, makes the use of polarized beam targets more than mere speculation. The present state of the art can produce atomic beams of 10^{12} hydrogen atoms/cm^3 with 70 to 95% polarization. A circulating beam of 2×10^{13} protons and 5×10^4 traversals/sec can result in a luminosity of:

$$\underset{\text{target}}{10^{12}} \times \underset{\text{beam}}{2 \times 10^{13}} \times \underset{\text{traversals.}}{5 \times 10^4} = 10^{29}\ \text{cm}^{-2}\ \text{sec}^{-1}$$



Schematic view of a polarized atomic beam target. At the top is a chamber where molecules are dissociated into atoms by an applied radio-frequency field. The atoms of thermal velocity then pass through a sextupole magnet and then through the transition field magnet and the rf spin-flip cavity. The sextupole field and rf field "separate" states of different spin orientation. Finally, highly polarized atoms emerge into a beam chamber and are caught at the bottom by a pumping orifice. The accelerating beam is normal to the diagram and in the center of the beam pipe indicated by the dashed contour.

This is actually an enviable luminosity when compared with the solid polarized targets of the butanol variety in which one achieves 70% polarization. However, solid polarized targets suffer from the contamination of the many non-polarized protons; in fact some 80% of the protons in the target are unpolarized, residing in carbon nuclei. The atomic beam target is free of such background. Therefore, one can contemplate the measuring of reactions in addition to elastic scattering. Since the spin can be flipped with ease a thousand times a second, polarization can be measured in a variety of inclusive processes by direct recoil counting. The cost of such atomic beams is also comparable with that of conventional polarized targets. It is hoped that when polarization

measurements in a variety of proton-proton reactions become important to make, such a target will be available and installed in Fermilab's Internal Target Area.

Reported by D. Jovanovic