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# AN EXPERIMENT TO LOOK AT BACKWARD PEAKS IN $\pi$-p SCATTERING

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The experiment is a straightforward extension of experiments that are already complete and is designed to measure the energy dependence of the cross section and to detect energy dependence in the shape of the cross section (shrinkage). Just to get oriented, we are proposing an experiment which measures between 20-100 GeV/c, and with $\pi^-$ only, at least at this time. Recall that the center-of-mass energy squared is

$$s = 2m_p\, p_{LAB} + m_\pi^2 + m_p^2$$

$$\approx 2m_p\, p_{LAB} \text{ for high energy .}$$

The relevant invariant momentum transfer is u and a high energy expression is

$$-u = \left(\frac{s}{2} - m_p^2\right)\left(1 + \cos\theta_{c.m.}\right) - \frac{m_p^2}{2s} \text{ .}$$

The available u in elastic scattering is limited at 180° and is approximately + 0.003 (GeV/c) at 100 GeV/c. We suggest then that to go very close to 180° is experimentally difficult and in particular we limit the u range to - 0.05 and out to - 1.0 $(\text{GeV/c})^2$.

The momentum of the backward scattered pion is close to $m_p/2$ and there seems to be a theorem that says that all other particles at the same angle of emission have a lower momentum than this. The magnet spectrometer need not have a very high $\int Bdl$, 36 in. of 10 kG should be excellent.

Rates

We are in a position to estimate the variation of the integrated cross section through the backward peak rather well. At 10 GeV/c the Cornell-BNL group had an integrated cross section of $0.3 \times 10^{-30} cm^2$. The energy dependence we shall assume to be $s^{-2}$ or using the approximate expression $\propto p_{LAB}^{-2}$.

Then the rate is given by

$$R = \left( \frac{10}{p_{LAB}} \right)^2 \times 0.3 \times 10^{-30} \times 60 \times 0.07 \times 6 \times 10^{23} ,$$

for a 60 cm long target

$$= 7.5 \times 10^{-5} \frac{1}{p_{LAB}^2} \Bigg| \text{incident pion} .$$

Let us assume a 10% collection efficiency remembering that this is probably optimistic.

Then

$$R_{ev} = 7.5 \times 10^{-6} \frac{1}{p_{LAB}^2} .$$

We shall put in the further constraint that we wish to have 100 hours to run a single energy and at 4 sec repetition rate, then 900 pulses/hour and $9 \times 10^4$ pulses for an experimental measurement; 1000 events is a realistic measurement so if the number of pions/burst is $N_\pi$

$$R_{ev} = 7.5 \times 10^{-6} \times \frac{1}{p_{LAB}^2} \times 9 \times 10_4 \times N_\pi ,$$

$$N_\pi = 1.5 \times 10^3 \times p_{LAB}^2 ,$$

this number is plotted as a function of $p_{LAB}$ in Fig. 1.

Yield from the 2.5 mrad Beam

It is proposed that the 2.5 mrad beam designed by Read and Garren be used in this feasibility study. The beam is described in the report (B. 7-68-16) on the layout of target station number 1 in this summer study. They chose to use it at 100 MeV/c momentum bite (0.1% at 100 GeV/c) with the advertised solid angle acceptance of 2μster and $3 \times 10^{12}$ interacting protons/sec. The yield is plotted also in Fig. 1, derived from Hagedorn and Ranft. The beam is 600 ft long so that the intensity loss from decay is negligible.

$$\begin{array}{lccccc} & \text{rep. rate} & \text{No. of protons} & \Delta\Omega & \Delta p & \\ \text{Yield/burst} = & 4 \times & 3 \times 10^{12} \times & 2 \times 10^{-6} \times & 0.1 \times & F_{HR} \\ = & 2.4 \times & 10^{6} \times & F_{HR} & & \end{array}$$

You can see from this plot that experiments on reactions with this kind of cross section are feasible with this beam up to about 75 GeV/c with factors of two or so that one can pick up from momentum bite, solid angle of the beam, etc. The beam is described in more detail in the paper on the layout of target station 1 of this study.

## The Experiment

Forward Spectrometer. We are going to restrict measurement from $u = -0.05\ (\mathrm{GeV}/c)^2$ to $u = -1\ (\mathrm{GeV}/c)^2$ for reasons that will become clear in a moment. The loss of physics from the region near 180° seems minimal, and the backward peak has fallen below the detectable limit at $-u = (1\ \mathrm{GeV}/c)^2$. The "recoil" baryon then has a minimal angle of ~ 2 mrad and maximal angle of 12 mrad. We wish to have a spectrometer which will accept this range of angles in one slot. The spectrometer, we will argue, has to be a "C" magnet system and will start its active volume 6 in. from the main beam centroid. This gives the distance to the entrance of the spectrometer of 250 ft. We wish a precision in momentum of 0.1% in order to resolve elastic scattering from p production; for example, at 50 GeV/c this momentum discrepancy is ~ 0.2%. Since we propose to make the incident beam parallel we shall use a hodoscope to measure position only, say 20 elements each 0.1 in. wide. Then the angular precision at the entrance to the spectrometer is 0.04 mrad. To achieve a momentum resolution of

0.1% the bend must be 40 mrad; this comes with a single 25 ft magnet at 10 kG at 50 GeV/c easily.

The aperture of this magnet is then

$$(12 - 2) \times 10^{-3} \times (250 + 25) \text{ ft}$$

$$= 2.75 \text{ ft} .$$

This distance does not include aperture for the sagitta of the analyzed particles, the "throw" is 6 in. so that with careful design a 3 ft wide aperture is fine. If the azimuthal acceptance is to be 0.1 as advertised, then since the outside is to be 3.5 ft from beam axis then

$$0.1 \times 2\pi \times 3.5 \text{ ft} = 2 \text{ ft} .$$

This is the vertical aperture required although the acceptance will be much better than this at smaller u values.

Secondary Magnet. We shall calculate the size of the magnet necessary for elastic scattering; the $\rho^-$ decay can also be detected with comparable efficiency in it.

The range of u values corresponds to laboratory angles of the pion from 160° to about 75°. In Fig. 2 we have a plan view of the target and the plane immediately at the end of the large aperture magnet

(L. A. M. ). With the dimensions indicated the length of the magnet aperture is

$$= \ell + \frac{d}{\tan 20°} + \frac{d}{\tan 25°}$$

$$= \ell + 5d \ .$$

With the numbers given, this is 27 ft with this distance completely dominated by the 5 ft distance from the beam line to the output. To match the azimuthal acceptance to the forward spectrometer the height must be $2\pi \times 5 \times 0.1 = 3$ ft. The magnet has to be a 300 D 36 with a 3 ft aperture.

The other side of the magnet should have a lead plate detector for the $\pi^0$ from the $\rho$: it is indicated in Fig. 3.

Detectors

The trigger system is not very different from that of the Cornell-BNL group. We have no reason to expect that this concept is invalid at 50-100 GeV/c momenta; let us suppose that this can be done with 100 phototubes, not a large extrapolation of present technique. The chambers almost certainly must have digital output and be on line to a computer since the number of bits of information looks very large to store without some reduction. It should be remarked that the 0.1% momentum calibration (not resolution) might be effected by comparing the measured momentum of forward elastically scattered pions with the forward recoil particles on a pulse by pulse basis rather than relying on some absolute method. The backward scattered particle presents no problem of calibration.

## Apparatus Called For From the Laboratory

We use the following rules of thumb

50 cu ft of 15 kG field for 1 MW

5K$ of capital cost/1 cu ft

## Magnets

| | Capital Cost | Power MW |
|---|---|---|
| 300 D 36 | 1.1 M | 4.5 |
| 24 D 300 | 0.75 M | 3 MW |

## Detector Equipment

The main item of capital expenditure is probably the computer. Any estimate of cost will be nonsensical years from now, but we emphasize that the computer is imperative in maintaining the control over the momentum measurement we propose, together with the satisfactory control of the wire plane system.

## Liquid Hydrogen Target

60 cm long 3 in. diameter

## Beam Monitor

This experiment has the capacity to monitor with the entrance hodoscope at the intensities we expect to use. However, a supplementary system capable of intensity calibration up to $3\text{-}4 \times 10^7$/sec is probably necessary.

Cerenkov Counter

A veto counter for K mesons is not necessary, the kinematic constraints on the events are capable of this separation.

Electronic Logic

The experience with a central facility, e.g. BNL HEEP, leads us to hope for the approximately 200 K $ of logic would be loaned to the experimenter.

Conclusion

We have sketched an experiment that is certainly feasible and interesting. It involves magnets which, if they were only to be used for this experiment, would require a rather excessive expenditure. It is our thesis however that these magnets are of general use, in fact would form the nucleus of a "facility" for strong-interaction experiments. The 25 ft long magnet we suggest should be made in two sections, enhancing the usefulness as a spectrometer. It, or something like it, provides the necessary $\int Bdl$ to utilize the momentum resolution of the incident beam. The question of whether it should be a supermagnet or not is open, although the power consumption makes it attractive as a supermagnet. It is fairly likely that the field would not be changed very often although even this may be open to debate.

The large aperture magnet is very large by conventional standards and the supermagnet possibilities are again obvious. We comment that accessibility in this magnet is very necessary; it is used to improve the solid angle and the compactness of the entire system is important. The fringing field on smaller but comparable magnets has been burdensome. One may ask how it may be possible to get by with a smaller magnet. The vertical aperture loses rate to the experiment linearly. The horizontal aperture gains a large momentum transfer bite at once, and the loss of it essentially doubles the accelerator time for each experiment. It seems wise to make the investment.

The computer question is more difficult to evaluate mainly because computers are developing fast at this time in terms of the return of computing power on the dollar invested. However, the experiment we describe is a large one and although presently computers are used mainly as a sophisticated data log, some of the features of this experiment demand a more intelligent use. The watchdog facility of the computer on wire planes is clearly important. The number of planes that have been used in comparable experiments so far sometimes have been too small in a desire for economy. With five years to develop technology we should have emerged from this stage. The 0.1% momentum calibration is an escalation of present technique. The use of a computer to control this by comparision with the dominant elastic scattered particles allows this problem to be reduced to a different measurement in momentum with a general easing of the problem. In short, the computer is here to stay and unless we see a staggering change in cost, this investment will have to be borne by the laboratory.

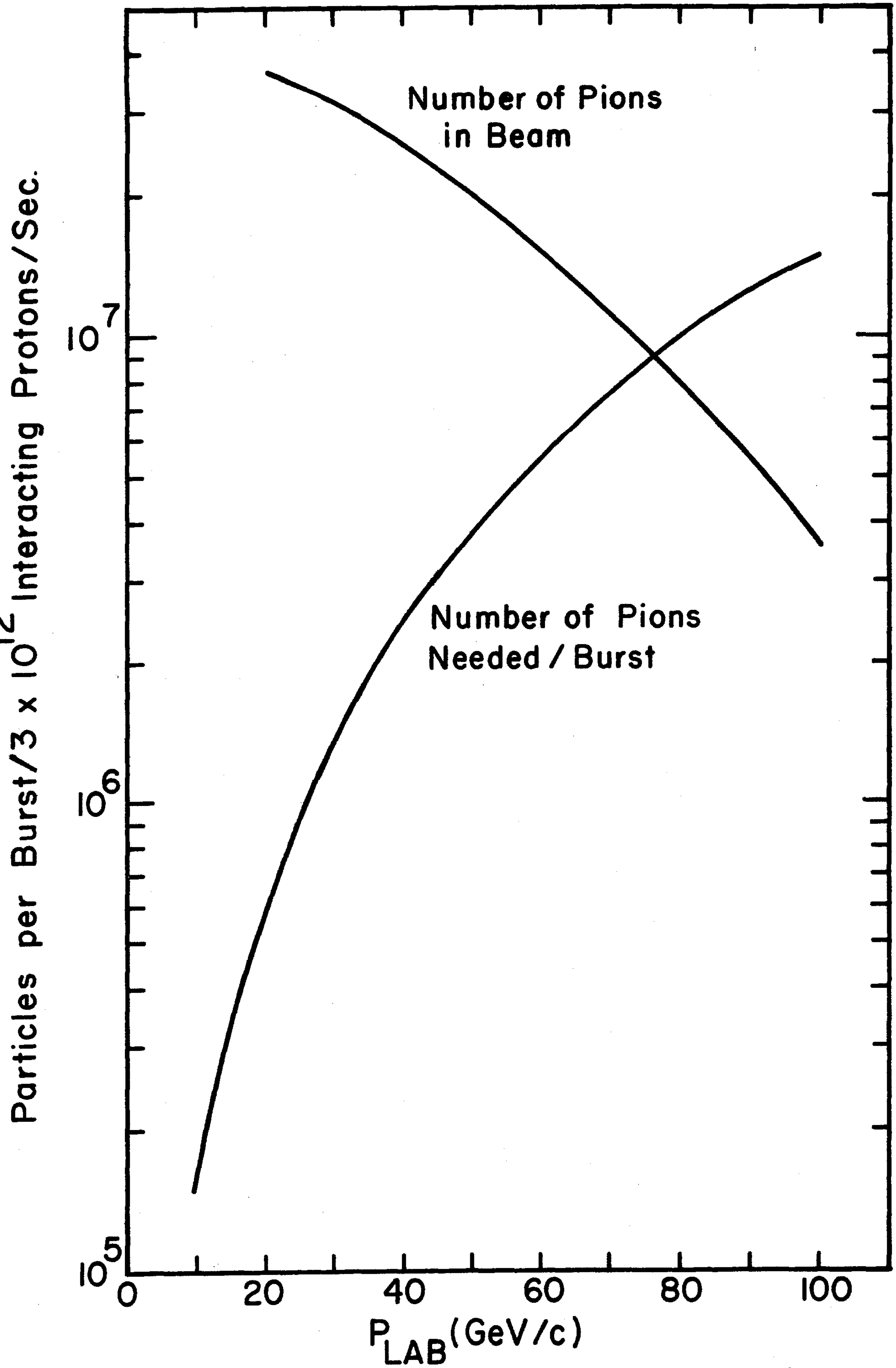


Fig. 1. Comparison of beam intensity with number of pions required.

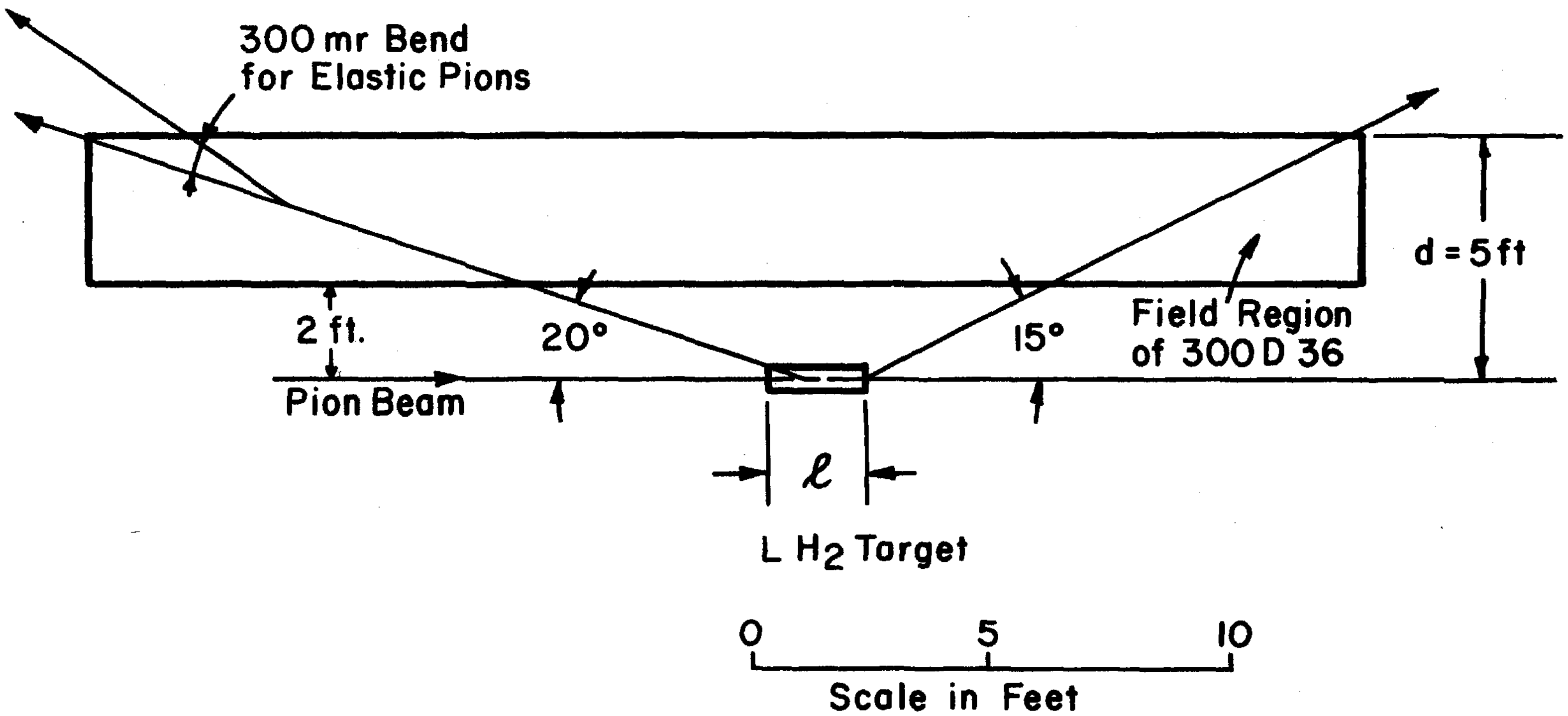


Fig. 2. Relative disposition of target and magnet for backward-scattered particles.

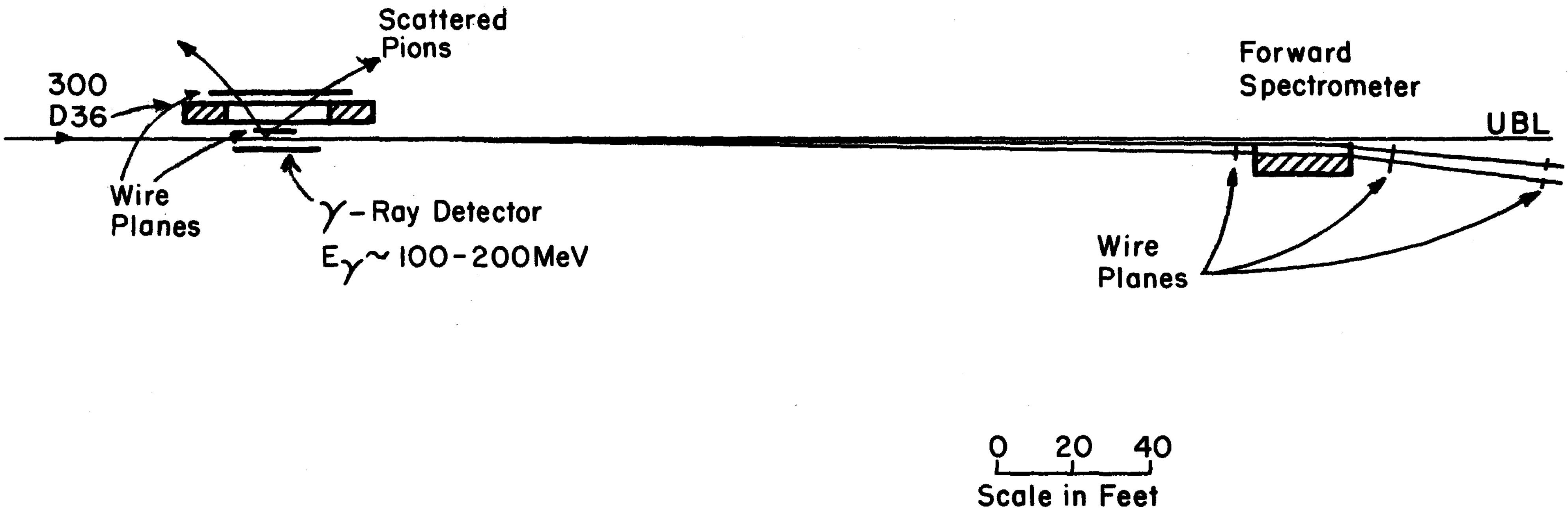


Fig. 3. Layout of experiment showing detectors for both forward and backward particles.