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RECENT EXPERIENCE AT BNL WITH THE MK I DOUBLE VEE MAGNETIC SPECTROMETER AND FUTURE PLANS AND RECOMMENDATIONS FOR NAL

S. J. Lindenbaum
Brookhaven National Laboratory

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In response to requests by NAL Facilities Group staff members, I am pleased to summarize the status of the Double Vee Magnetic Spectrometer program at BNL and make recommendations for possible applications of these techniques at NAL. My purpose in making these recommendations is to attempt to assist the NAL Administration and the user community in formulating effective plans of action utilizing these exciting new techniques.

I recognize, of course, that there is an enormous possible variety of opinions on subjects as complex as these, and that future ideas can and should change rapidly with the times. In the last analysis, the NAL Administration will have to decide its own course of action, and an important consideration of which is the best course is the taste and experience of the individual or group in charge of the execution of the plans. A brilliant plan for A may be a horrible disaster for B, and vice versa.

The digital electronic detectors with on-line computer techniques are in a rapid state of advance. Exploitation of present techniques and exciting new developments, which will occur from time to time, make it imperative to recognize that flexibility of approach and the highest attainable technical quality and administrative ability of management are on the best assets in a growth technique of this nature.

In the recommendations that I do make, I fully reserve the right to constantly reevaluate, modify, and if necessary change my position as the advances of time dictate.

Recent Tests at BNL of the MK I Double Vee Spectrometer

The MK I Double Vee Spectrometer has been described in a number of publications.[1,2]

Figure 1 shows the version of it which will be utilized during the coming year. The forward leg of the spectrometer was set up with one 48D48 magnet, but without the Cerenkov hodoscope, and tested at the AGS in the last month before the present shutdown.

Within two weeks of the completion of the magnet setup, we were able to detect and reconstruct K^o events generated with ~ up to 10^5 π^- incident pions/pulse.

The first test version of the system used Be-Cu wires while aluminum wires were life-tested, and no attempt was made to minimize multiple scattering. In spite of this, we attained 0.8% momentum resolution at 10 and 15 BeV/c, and in a fraction of a day's run under poor test conditions, we were able to obtain the attached curve which is a typical result.*

*Our group consisted of D. Cheng, K. Foley, W. A. Love, S. J. Lindenbaum, S. Ozaki, E. Platner, A. Saulys, and E. Willen.

The momentum resolution attained with Be-Cu wires (~0.8%) is being improved to ~0.4% with one magnet and ~0.2% with two magnets by replacing the Be-Cu wires in the spark chambers with Al wires, and by reducing other sources of multiple scattering.

In the next few months, the wide-angle Vee detecting system, particle detecting chambers on the other side of the H_2 target, and a Cerenkov counter hodoscope downstream of the forward Vee detecting system, which will allow identification of the two particles involved, will all be added. π^-, K^-, and $\bar{p}$ in the negative beam, and p, π^+, and K^+ in the positive beam will be detected and can be tagged and triggered on during the same run. Surveys of the following classes of reactions will be pursued in the 10-25 GeV/c incident momentum range. Obviously, new reactions of a similar type will also be detectable. The examples generally refer to some of the presently known ones.

I. K_o Trigger--anticoincidence forward of target plus two particles detected beyond magnet.

A. $\pi^- + p \rightarrow K^o + Y^o(\Lambda, \Sigma^o, \text{etc.})$

$K^o \rightarrow \pi^+ + \pi^-$; $\Lambda \rightarrow p + \pi^-$; $\Sigma^o \rightarrow (p + \pi^- + \gamma)$; etc. $\rightarrow K + p$

B. $\pi^- + n$ (using deuterium-hydrogen difference) $\rightarrow K^o + \Sigma^-$

$$K^- + p \rightarrow K^o + n \rightarrow (\pi^+ + \pi^-) + n$$

$$\phi + \Lambda \rightarrow (K^+ + K^-) + (p + \pi^-)$$

C. $\pi^{+} + p \rightarrow K^{o} + Y^{*++}$

$$\overline{K}^{o} + Z^{*++} \rightarrow (\pi^{+} + \pi^{-}) + (p + K^{+})$$

D. $\pi^{+} + n \rightarrow K^{o} + Y^{*++}$

II. ρ-like forward trigger (and other specific requirements for various reactions).

A. $\pi^{-} + p \rightarrow \rho^{o} + n \rightarrow (\pi^{+} + \pi^{-}) + n$

$$\phi + n \rightarrow (K^{+} + K^{-}) + n$$

$$K^{o*} + Y^{o}(Y^{o*}) \rightarrow (K^{+} + \pi^{-}) +$$

$$\{[(p + \pi^{-}) \text{ or } (p + \pi^{-} + \gamma) \text{ or } (K^{-} + p)]\}$$

B. $K^{-} + p \rightarrow K^{o*} + n \rightarrow (K^{-} + \pi^{+}) + n$

$$\phi + \Lambda \rightarrow (K^{+} + K^{-}) + n$$

C. $\pi^{+} + p \rightarrow \phi^{o} + N^{*++} \rightarrow (K^{+} + K^{-}) + (p + \pi^{+})$

$$\rho^{o} + N^{*++} \rightarrow (\pi^{+} + \pi^{-}) + (p + \pi^{+})$$

D. $K^{+} + p \rightarrow K^{o*} + N^{*++} \rightarrow (K^{+} + \pi^{-}) + (p + \pi^{+})$

E. $p + p \rightarrow N^{*++} + N^{o*} \rightarrow (p + \pi) + (p + \pi^{-})$

The following are typical estimates of the rates obtained per 100 hour run (production running time only which may have to be doubled for actual operational running time). We are using unseparated

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* Many other types of two-body intermediate state reactions which can be detected have not been mentioned.

beams with a measured tolerance of 10^5 incident particles/pulse for our apparatus, etc. If separated beams were available, all rates would approach the π^- incident rate.

Forward Vee Detection:

π^- initiated reactions $\sim \frac{10^3 - 10^4 \text{ events}}{\mu b}$

p initiated interactions have similar rates.

π^+ initiated reactions $\sim \frac{10^2 - 10^3 \text{ events}}{\mu b}$

K^+ and K^- initiated reactions $\sim \frac{50 \text{ events}}{\mu b}$

In addition, we can obtain some information in $\bar{p}$-p interactions such as, for example:

$$\bar{p} + p \rightarrow \bar{\Lambda} + \Lambda$$
$$\bar{K}^o + K^o$$

with rates ~6-8 events/μb. In ~10% of the cases both decay products of the recoil particle are detected. In ~3% of the cases both decay products will be detected, and one will go through the wide-angle magnet. At medium $|t|$ values, ~1% of these cases will have both recoil particles passing through the magnet.

The estimated forward Vee mass resolution based on our test measurements is ± 2 MeV for 10 BeV K^o events. The estimated missing mass (Y_o) resolution in the reaction $\pi^- + p \rightarrow K^o + Y^o$ is estimated

~20 MeV at 10 BeV. Detection of recoil particles should reduce this by more than a factor of two.

We plan to run this program in two phases as already outlined, and hope to turn the MK I (Fig. 1) into a general-user facility after completing Phase II, as soon as Laboratory actions involving addition of personnel and budget permit this.

Our first choice for our next program will involve the MK I (b) using a 15 feet long by 8 feet wide by 4 feet gap magnet based on the MURA magnet. Alternately, we have a plan called MK I (a) using the existing 120D36 and the two 48D48 magnets. MK I (b) will handle complete detection of many complex multiparticle interactions with rates ~ 10^4 events/μb per 100 hours. The MK I (b) would also make a very universal user facility, and a diagram of one of its proposed arrangements is attached (Fig. 3). The magnet would be operated at 10 kG, and the resolution attained will be comparable to that stated for the MK I. There are other proposed versions, including a helmholtz coil field along the beam line preceeding the magnet.

It is clearly of great scientific interest to exploit these new research capabilities which for many very interesting reactions allow increased rates of several orders of magnitude, much higher accuracy than the usual previous studies in this field via bubble chambers, and complete automatic computer analysis. Of course, for many reactions the bubble-chamber technique will still be very appropriate and complementary.

As we have so often proposed, these techniques can be utilized very well to provide the counter-spark chamber community with analogous facilities to the bubble-chamber facility operated so successfully at BNL, and which has made and will continue to make significant contributions to the user research community.

The detectors planned on at present for the MK I (b) and MK II include:

1. Digitized spark-chamber hodoscopes of the present generation wire chambers with magnetostrictive readouts outside of the field

2. Sparkostrictive when feasible

3. Electrostatic when feasible.

The first one is the brute force method we can count on. The top of the magnet will be striated (i.e., regular spaces allowed) to allow chamber wires for x and w planes to escape the magnetic field and be read out magnetostrictively.

The resolution of all of these is ~0.25 mm. There is always the possibility of new exotic detectors of much higher resolution, but surprisingly enough, even if these become available, we do not anticipate reducing the size of the magnetic field volume appreciably since the length of hydrogen targets, K^o decay spaces, and multiple scattering effects by themselves lead to a similar size field volume (assuming 20 kG magnets).

At present, we favor planning on MK II magnets at about the same size as MK I (b), but with the field upped to 20 kG by using superconducting coils.

In thinking about the NAL problem, I have come to the conclusion that a basic magnet of this size is a good module, namely, about 15 feet long, 8 feet wide (~6 feet between coils), and 4 feet gap with 20 kG field supplied by superconducting coils. Then one can use a number of these spaced along a beam line. The first contains the hydrogen target and can be quite fully packed with spark chambers to detect as much of 4π solid angle as possible. The remainder could contain a few spark chambers with a considerable number of spark chambers between magnets.

For example, if one wanted to maintain the AGS mass resolutions for a 150-BeV incident beam, one would need about five of these magnets. Of course, after the first of these magnets, which in some setups contains the hydrogen target, one could reduce the lateral and height dimensions in the latter ones if one wished to sacrifice solid angle and t range convergence.

Rough order of magnitude estimates are about 3/4 million per magnet which refrigeration and power supply. Obviously, provision should be allowed for a series of slots in the top of the yoke for reasons previously mentioned. These magnets could be used in combination or separately for various simultaneously scheduled other experiments depending on need.

In addition, it is desirable to provide detector production facilities for these and other user purposes.

There appears to be a logical connection between the developments we propose at BNL and their application at NAL. Therefore, it may be relevant to discuss collaborative efforts in the mutual interests of both laboratories.

REFERENCES

[1] S. J. Lindenbaum, Digitized Spark Chamber and On-Line Computer Systems for Double Vertex Events, Proceedings of the International Symposium on Nuclear Electronics, Versailles, September 10-13, 1968, Vol. III, pp. 50-1-25.

[2] S. J. Lindenbaum, Large Digitized Spark Chamber Spectrometer and On-Line Computer Systems, Proceedings of the International Conference on Advanced Data Processing for Bubble and Spark Chambers, October 28-30, 1968, pp. 202-225.

FIGURE CAPTIONS

Fig. 1. The MK I setup as visualized in 1970. The forward Vee detecting leg with one 48D48 magnet and without Cerenkov hodoscope and a simpler triggering arrangement was tested very successfully in the month prior to the AGS shutdown. The anti-counters forward of the target are for K^o triggering. There are other anti's shown surrounding the target for use in, for example, $\pi^- + p \rightarrow \rho^o + n$. The two magnet setup will be used in our running part of the time. The remainder will be with one magnet. We already requested urgent need of the second magnet for a few months in the post shutdown period.

Fig. 2. One of the proposed setups for the MK I (b) using the MURA magnet, which has a field volume of about 15 feet in length, six feet of usable field width (8 feet physical width), and four feet of vertical height between the poles. The particles emerge in the forward direction and are detected by spark chambers, triggering scintillation hodoscopes, and Cerenkov counter hodoscopes.

Fig. 3. $d\sigma/dt$ vs $-t$ for $\pi^- + p \rightarrow K^o + \binom{\Lambda}{\Sigma}^o$. 15 BeV/c incident π^- were run for ~ 10 hours.

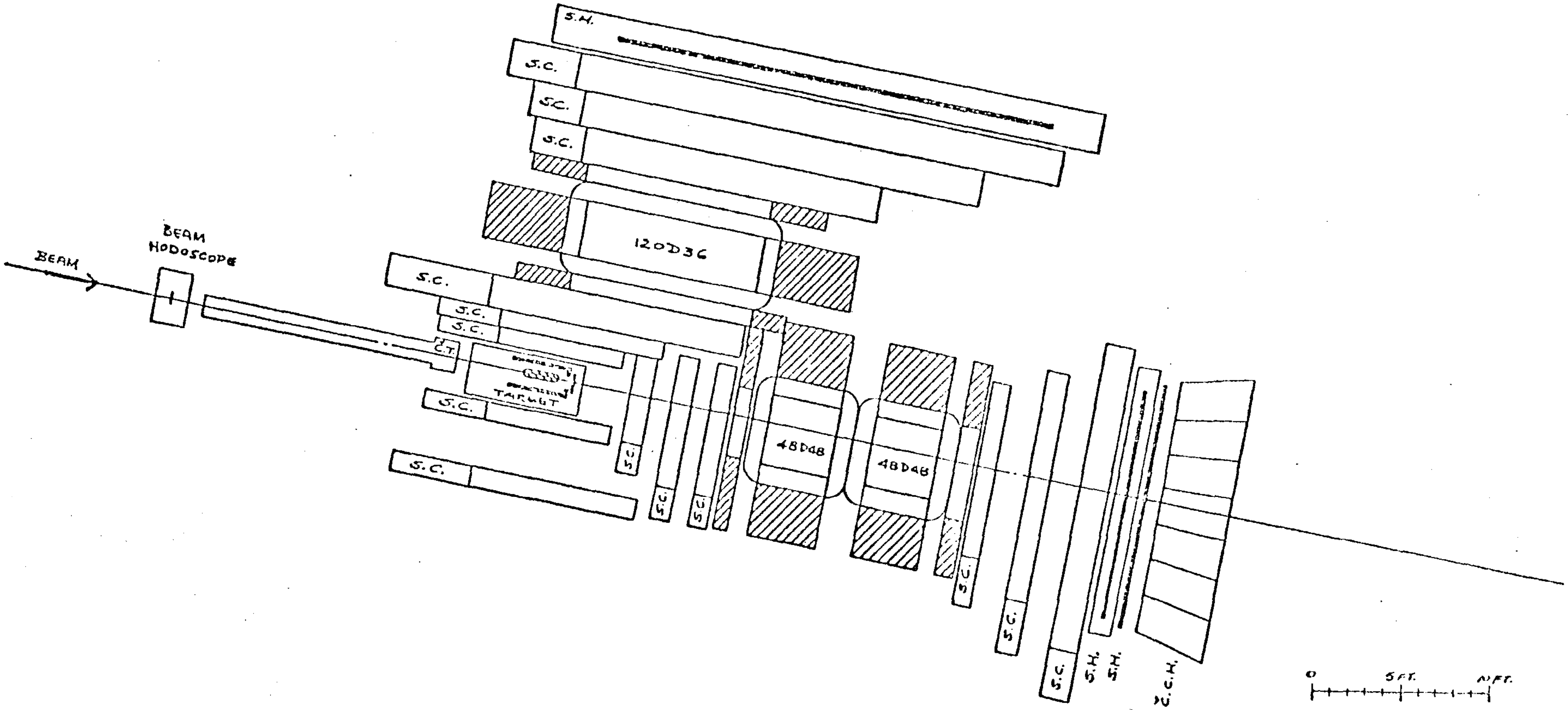
BEAM
BEAM HODOSCOPE
S.H.
S.C.
120D36
C.T.
TARGET
48D48
48D48
S.H.
S.H.
0
5 FT.

Fig. 1

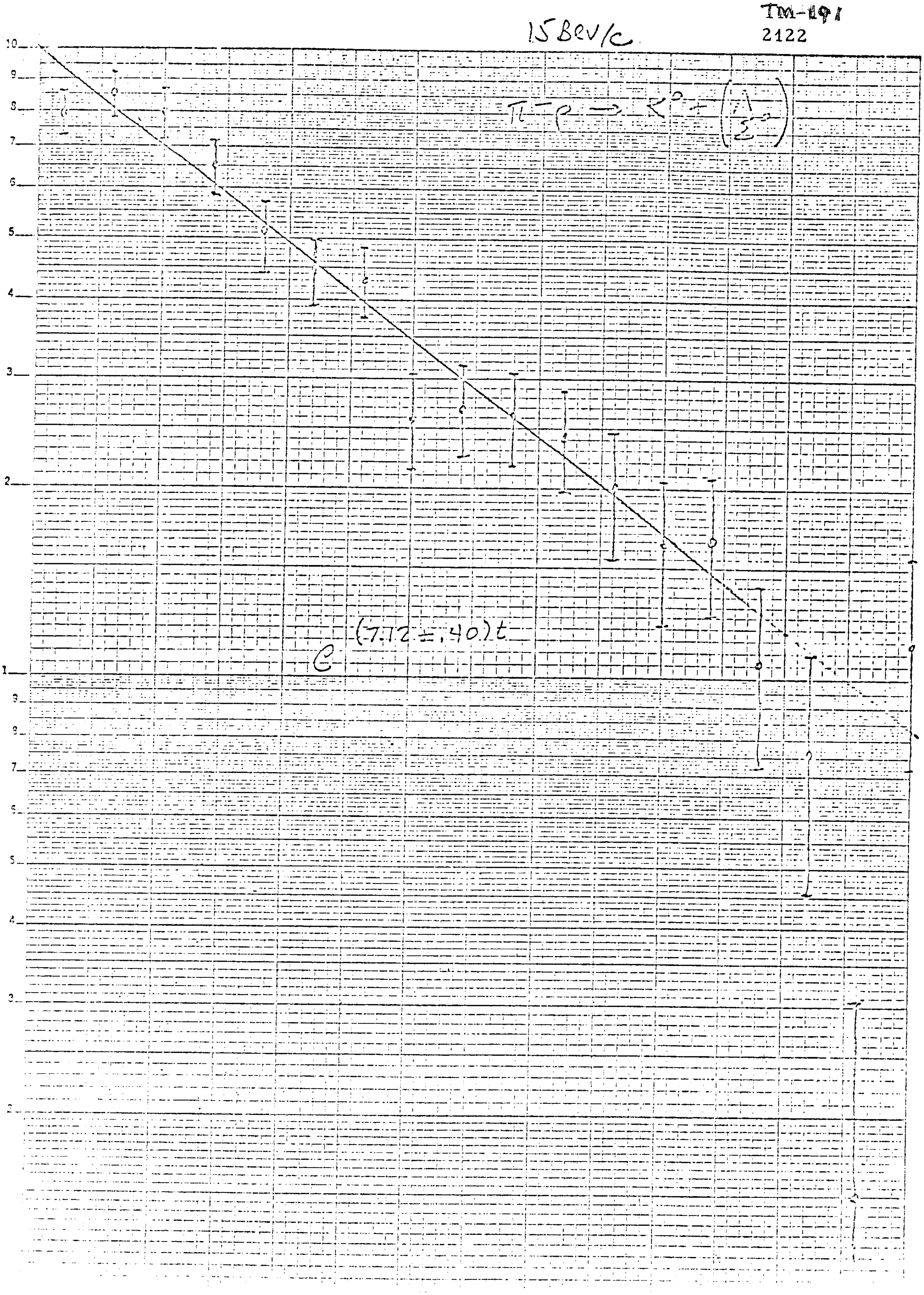
15 BeV/c
$\pi^- p \rightarrow K^0 + \binom{\Lambda}{\Sigma^0}$
$e^{(7.72 \pm .40)t}$
10
9
8
7
6
5
4
3
2
1
9
8
7
6
5
4
3
2

Fig. 2

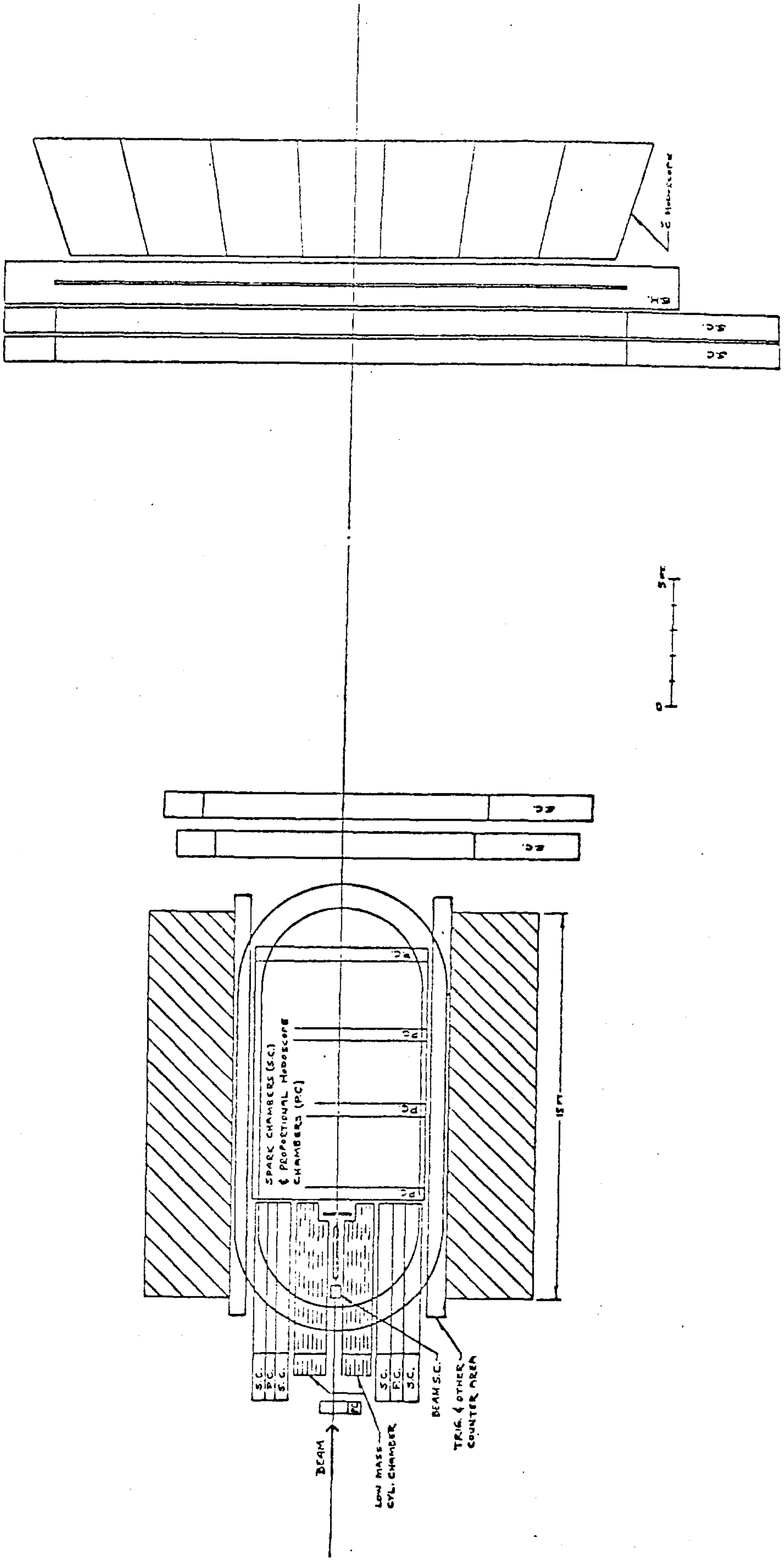
SPARK CHAMBERS (S.C.)
& PROPORTIONAL HODOSCOPE
CHAMBERS (P.C)
BEAM
LOW MASS
CYL. CHAMBER
BEAM S.C.
TRIG. & OTHER
COUNTER AREA
S.C.
P.C.
15 m
0
5 m

Fig. 3