CERN/ISRC/71-48
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INTERSECTING STORAGE RINGS COMMITTEE

PROPOSAL

MEASUREMENT OF NEUTRON PRODUCTION AT SMALL ANGLES

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Physics: In a recent PS experiment on np charge exchange scattering we have obtained as a by-product neutron production spectra. The result is shown in Fig. 1, together with comparable proton spectra. One notices that for 0^o production angle the neutron spectrum for $x < 0.8$ ($x \approx p/p_o$ in laboratory system) is similar but somewhat flatter than the proton spectrum. On the other hand near the kinematical limit $x \to 1$ the neutron spectrum drops whereas the proton spectrum stays up. This indicates that in the language of Chou and Yang [1] the neutron fragmentation is disfavoured whereas the proton fragmentation is favoured. A more detailed interpretation in terms of the Regge pole model can be given, e.g. relating[2] the inclusive reaction $p + p \to n + X$ to np charge exchange scattering, but we refrain from doing it here. The general interest in measuring neutron spectra was explained in ISRC/71-30.

Here we only want to make two additional remarks. A comparison of the neutron and proton spectrum at a production angle of 50mrad shows that the difference seen at 0^o degrees has disappeared. Hence production angles below 20mrad seem to be more interesting.

In terms of the quark model one expects [3] that the neutron spectrum of $p + p \to n + X$ and the K^o spectrum of $K^- + p \to K^o + X$ are similar since the same quark pair is involved in both reactions. In Fig. 1 the K^o spectrum is also shown [4] and indeed its shape agrees approximately with the n spectrum.

It would be very interesting to see if these features observed at PS energies also hold at the ISR, and in addition to find out if the neutron spectrum scales.

Experimental set-up

The essential part of the experimental apparatus is a total absorption neutron spectrometer. It consists of a sandwich of scintillator and iron plates (40 x 40cm^2) preceded by a smaller converter plate (20 x 20cm^2) and an anti-counter to suppress charged particles. We used such an instrument in various PS experiments and performed tests at the ISR at 15 and 22 GeV [5]. It was found that the spectrometer worked well without serious trouble from background.

The energy resolution of the total absorption spectrometer that could be obtained in previous experiments was about $\pm$ 13% around 20 GeV, and it was worse at lower neutron energies. Some resolution curves are shown in Fig. 2. During the last months we have performed extensive studies with the aim of improving the resolution. A mono-energetic proton beam was used for these tests. Among other things the influence of the thickness of the Fe plates on the resolution and losses at the end and on the sides of the counter were investigated. Based on these results an improved version of the spectrometer is under construction.

Unfortunately measurements at exactly 0^o are difficult, since the 0^o line passes through magnets. However it is easy to get down to angles $\lesssim$ 20mrad. The even intersections are more favourable since the distance to the first and second downstream F magnet is larger and it is these magnets which determine the smallest possible angle. Three set-ups are being considered :

1) Spectrometer in front of the first downstream F-magnet very close to the vacuum pipe (about 8m from the intersection)(see Fig. 3). It should be possible to measure at angles of about 25mrad. In this case charged particles are not swept aside by a magnet, but in our test measurements we found that the anticounter in front of the spectrometer suffices to suppress the charged particles.

2) Spectrometer between the ISR rings behind the second F magnet. In this case the smallest angle is determined by this F magnet, and it could be about 10mrad provided a step in the vacuum chamber after the first F-magnet is possible. The charged particles would be partly removed by the first F-magnet, but we do not consider this to be an essential advantage.

3) Spectrometer between D and F magnet (position 3 in Fig. 3).
In this position measurements at 0^{o} would be possible at the expense of the neutrons having to transverse approximately 1.5 interaction lengths.

In all cases a step in the vacuum chamber would be desirable since, as our test measurements have shown, an oblique passage of the neutron beam through the vacuum chamber produces too many low energy neutrons. However, we do not need a thin window, since a Pb filter will be put into the beam anyhow in order to reduce the γ flux.

Since the neutron spectrometer has no directional properties a beam - beam trigger is necessary to suppress beam - gas events. Any such trigger covering a large solid angle would be suitable. Such triggers exist for example in I6 and I8.

In the position 2) for medium production angles we would be able also to measure with a system of Fe-collimators pointing to the interaction region not needing the beam - beam trigger in coincidence. Background will be determined and subtracted by measuring with closed collimators.

Counting rates and background

In our test measurements we found for the total number of neutrons with energies larger than 5 GeV at a production angle of 84mrad the following numbers:

at 15 GeV	1.3	neutrons/sr. interaction
at 22 GeV	2.0	" "

In the forward direction these figures are expected to be about a factor 10 higher. With a conversion efficiency for the neutron detection of 20%, a solid angle of about 10^{-4} and 24 stacked in each ring one obtains counting rates of about 1/sec.

The background consists of γ and K^{o}. The photons are removed by a Pb absorber about two radiation lengths thick which does not affect the neutrons seriously. A distinction between K^{o} and n, however, does not seem possible. Also the decay of K^{o} does not give more than a factor of 10 lower than the proton flux (see Fig. 1). The K^0 contamination should therefore be only a few percent.

Running time

With the estimated counting rates only a few runs are needed for each energy. In order to test scaling we should like to take data at three different energies. Hence the whole experiment would take about two months.

Since most of the equipment exists we could start in 1972 after the shut-down.

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References

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2) Peccei and Pignotti, Phys. Rev. Lett. 26, 1076 (1971)

3) D. Horn, private communication

4) Beaupré et al., CERN/D.Ph.II/70-52/Rev.

5) Sens and Potter, CERN NP Internal Report 71-6 (1971)
Engler et al., CERN NP Internal Report 71-4 (1971)

6) Allaby et al., CERN 70-12 (Yellow Report)

7) Engler et al., Phys. Lett. 31B, 669 (1970)
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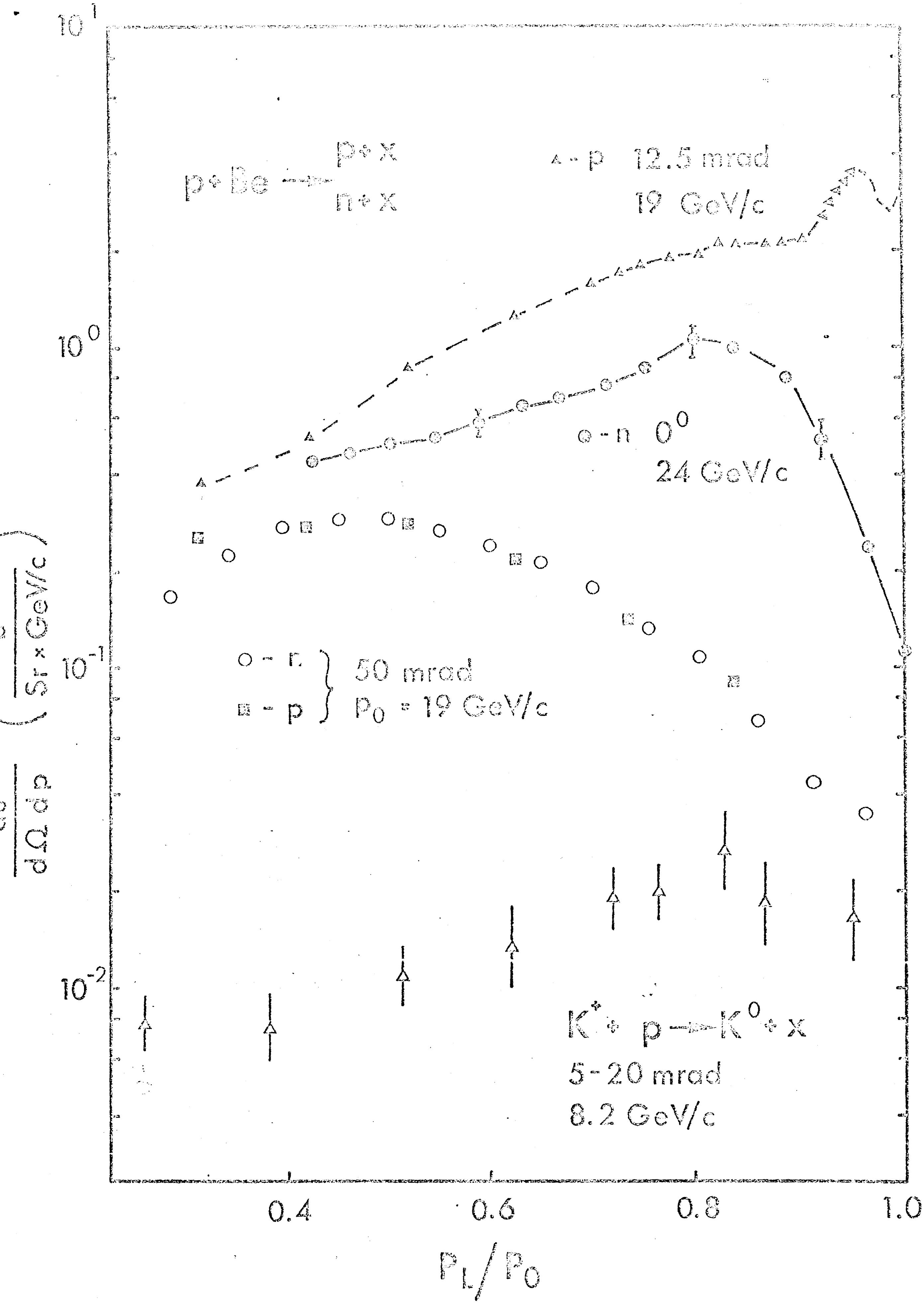
Figure captions

Fig. 1 Comparison of n spectra with p and K^o spectra. The neutron spectra are arbitrarily normalized. The data are plotted as function of p_L/p_o with both quantities given in the lab system. With sufficient accuracy this ratio is equal to the Feynman scaling variable. The proton spectra from Be are from ref. 6 and the neutron from ref. 7. The K^o spectrum is from ref. 4.

Fig. 2 Resolution of the total absorption spectrometer for different energies. It shows the pulse height distribution for mono-energetic protons during test measurements at the ISR.

Fig. 3 Three possible locations of the n-spectrometer.

Insert: n- spectrometer : A anticounter
C converter, T trigger hodoscope
S Fe-scintillator sandwich



p + Be → p + x
n + x
▵ - p 12.5 mrad
19 GeV/c
⊙ - n 0°
24 GeV/c
○ - n
⊠ - p
50 mrad
P_0 = 19 GeV/c
$K^+ + p \rightarrow K^0 + x$
5-20 mrad
8.2 GeV/c
$\frac{d\sigma}{d\Omega\,dp}$ $\left(\frac{b}{Sr \times GeV/c}\right)$
10^1
10^0
10^{-1}
10^{-2}
0.4
0.6
0.8
1.0
P_L/P_0

Fig. 1

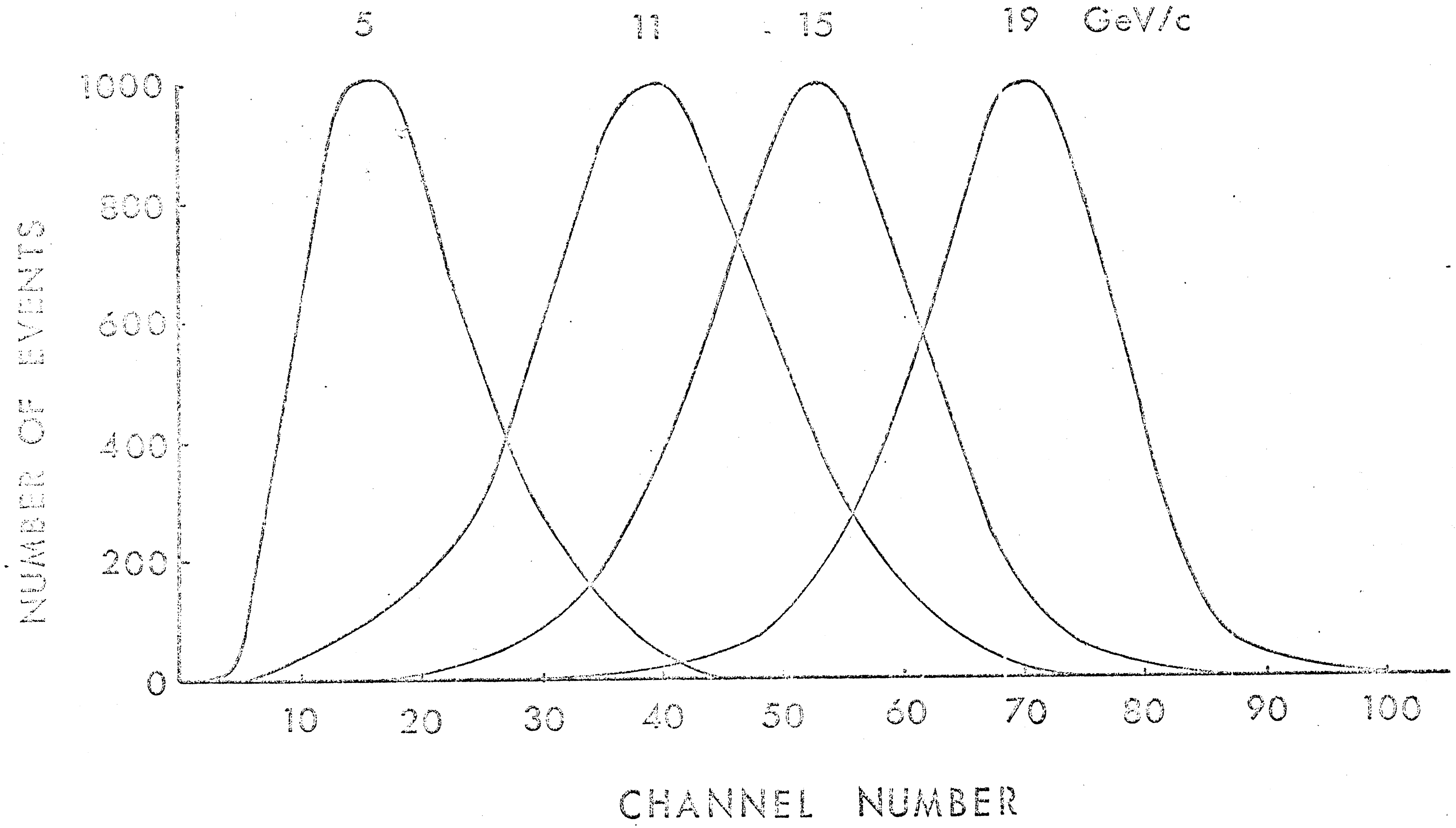

5
11
15
19 GeV/c
1000
800
600
400
200
0
10
20
30
40
50
60
70
80
90
100
NUMBER OF EVENTS
CHANNEL NUMBER

Fig. 2

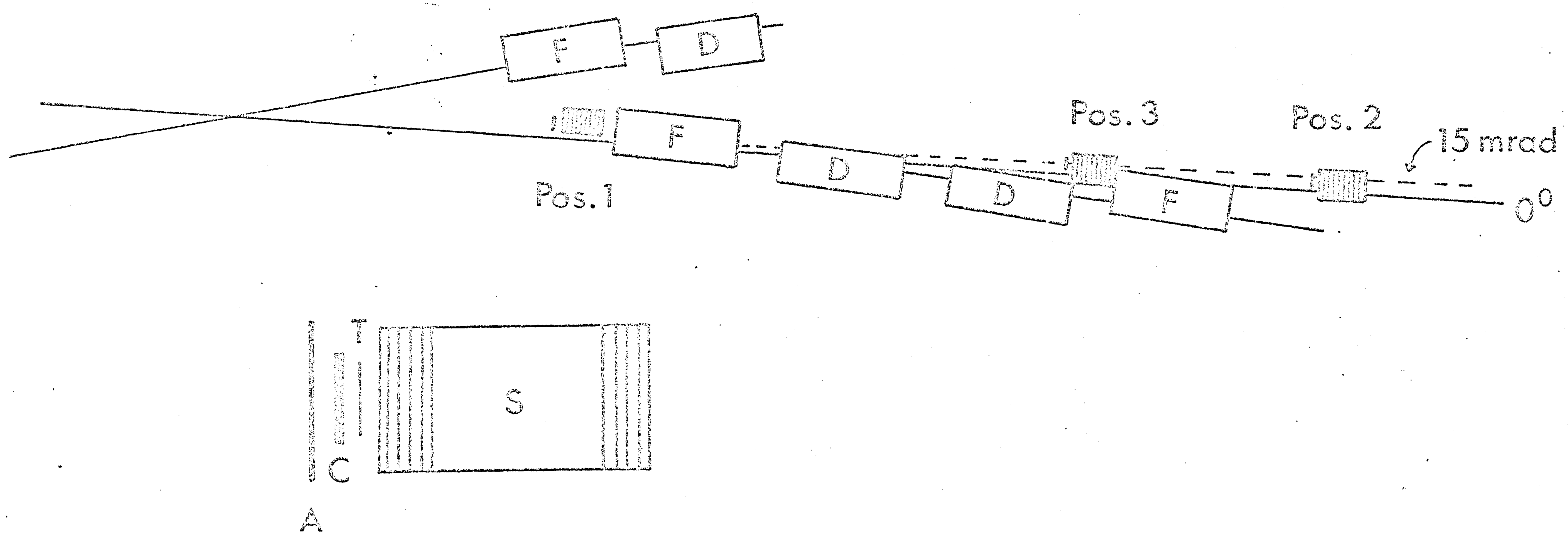


Fig. 3