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Letter of Intent

SEARCH FOR KAON PRODUCTION WITH THE $^{3}_{2}He$ BEAM AT THE CERN SYNCHRO-CYCLOTRON

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I. Introduction

We propose to perform an exploratory test on the possible production of K^+ from nuclear targets using the planned beam of $^{3}_{2}He$ ions of 910 MeV at the CERN Synchro-Cyclotron. The two-body reaction:

$$^{3}_{2}He + {}^{A}Z \rightarrow {}^{A+3}_{\Lambda}(Z+1) + K^+ \qquad (1)$$

induced by $^{3}_{2}He$ ions of 910 MeV (p = 2437 MeV/C) is energetically allowed if nuclear targets with A ⩾ 9 are used. Fig. 1 shows the Kinematics of reaction (1) for targets of $^{10}_{5}B$, $^{12}_{6}C$, $^{27}_{13}Al$ and $^{208}_{82}Pb$. One can observe that the maximum momentum of the produced K^+ varies from ~ 300 MeV/C to ~ 585 MeV/C increasing A from 10 to 208. The angular variation of the K^+ momentum is forward peaked for low mass targets and rather flat for heavy targets. Known or extrapolated values for B_Λ were used in the calculation of the Kinematics.

Various three or multi-body reactions can also be responsible for K^+ production, but we think that the two-body reaction is the most interesting and potentially useful for future physics experiments. It is clear that the Kaons cannot be produced in single nucleon-nucleon collisions. The threshold for the $p + \mathcal{N} \rightarrow K^+ + \Lambda + \mathcal{N}$ reaction is in fact about Tp = 1590 MeV, whereas the energy/nucleon for the incident ${}^3_2He$ beam is 303 MeV. A coherent Kaon production process could be the only process responsible for reaction (1). To our knowledge, there are no calculations or model for such a process. We could perhaps infer a possible value for the differential cross-section for reaction (1) from the observation that coherent production of π^0 from nuclei was observed with ${}^3_2He$ ions of 180 and 200 MeV[1)]. The relative cross-sections, at 90^o, were 2 and 7 pb/sr MeV for ${}^{12}C$ at 180 and 200 MeV, and 60 pb/sr MeV, at 90^o, for ${}^{208}Pb$ and 200 MeV. The ratio of the ${}^3_2He$ kinetic energy to the Q-value of the reactions is rather similar to that for Kaon production and we thus put 1 pb/sr MeV as a tentative value for the differential cross-section for reaction (1). A simple experimental layout capable of detecting such a production rate has been studied.

II. Experimental Arrangement

Fig. 2 shows the proposed experimental apparatus. The nuclear targets are placed inside a magnet with a field of order 15 Kgauss and length 50 cm. The direct ${}^3_2He$ beam suffers a deflection of ~ 10^o in passing through the magnet. Positive Kaons emitted from the target with momenta between 300 and 600 MeV/C and around $20^\circ \div 30^\circ$ can be transmitted through a large lead collimator constructed inside the magnet and detected by the counters placed immediately after it. Assuming an incident beam of 5.10^2 p.p.s, a target thickness of ~ 1 gr/cm^2, a solid angle for detection of ~ 5×10^{-2} sr and a momentum acceptance of ~ 30 MeV/c for the produced K^+, we expect ~ 0.1 events/sec for a differential cross-section of 1 pb/sr MeV. For the recognition of Kaons versus other particles we plan to use the following set-up of counters:

1) A Lucite Čerenkov counter (index of refraction ≃ 1.5), of a thickness of 2.5 cm.

2) Four scintillators, 1 cm thick each, measuring the dE/dx of the particles.

3) A Lead-glass Čerenkov counter (index of refraction ≃ 1.8), 15 cm long.

The particles produced after interaction of the ${}^3_2He$ beam on the target are protons (or heavier particles) and pions. The first ones will probably constitute the most serious source of background. Protons produced through stripping reactions will have an angular distribution strongly peaked in the forward direction. Since the lead collimator selects particles produced around $20^\circ \div 30^\circ$ with momenta higher than 200 MeV/C, we do not believe that the stripping reactions will produce a flux of particles greater than 10^4/sec[2)] (0.1 - 1 μb/sr for $d\sigma/d\Omega$). A similar flux of particles can be expected from ${}^3_2He$ ions elastically scattered from the target. Protons or heavier charged particles resulting from a fragmentation of the target are expected to have a considerably lower energy. The collimator inside the magnetic field will roughly select particles with momenta greater than ~ 200 MeV/C per unit charge. An absorber of variable thickness will be placed in front of the whole detection system in order to fix the minimum energy for each particle. All the particles heavier than Kaons will be detected only by the scintillators but not by the Čerenkov counters.

All the pions that will be produced with an estimated flux of $10^4 \div 10^5$/sec[2)] will be detected by both the Čerenkov counters. The measured efficiency for the first Čerenkov counters in a previous experiment[3)] was 99.6% and we could reasonably expect an efficiency of 99% for the second one.

From our previous experience[3)] on the use of scintillators in order to select charged particles with different energy losses, we could expect for a single scintillator a rejection factor of at least 99% for particles with dE/dx different by a factor 2, operating in a total flux of $10^6 \div 10^7$ particles/sec.

The Kaons that we are searching for will produce Čerenkov light in the first counter if $p_K \geq 440$ MeV/C and in the second one for $p_K \geq 330$ MeV/C. Thus a combination of the two counters allows the definition of a window of about 100 MeV/C.

The exploration of the spectrum of Kaons with momenta greater than 330 MeV/C and less than 440 MeV/C could be done with the trigger $\bar{\check{C}}.(S_1 \div S_4).\check{C}_G$. With some absorbers, different in thickness, placed before all the counters to degrade the energy of

Kaons at the values of the window, the region of the spectrum with high momenta can also be explored. From the numbers quoted before we could expect quite reasonably a rejection factor of 10^8, and hence the measurement of cross-sections in the order of 1 pb/sr MeV. From Fig. 1 we can see that Kaons of such momenta (> 330 MeV/C) are expected from two-body reactions with medium and high A targets.

For the light targets, the momenta of the Kaons are lower than 330 MeV/C and the Čerenkov counter will give only a rejection of pions. Discrimination between protons and Kaons must be given only with the scintillators, and is in the limit of the performance of the apparatus, with the foreseen fluxes of particles. If not sufficient, the discrimination of Kaons could be greatly increased by stopping the K^+ after the four scintillators and requiring the signature of the $K^+ \rightarrow \mu^+ + \nu$ decay. Such a procedure may in any case be necessary.

III. Conclusion

We think that the first part of the program (search for K^+ of high momenta) could be done in a limited number of shifts (10) with apparatus existing and tested. The second part (K^+ of low momenta) could require more care and machine time (15-20 shifts). Further details about the experiment will be specified. Should the search for K^+ be successful, a number of experiments become possible in the future.

References

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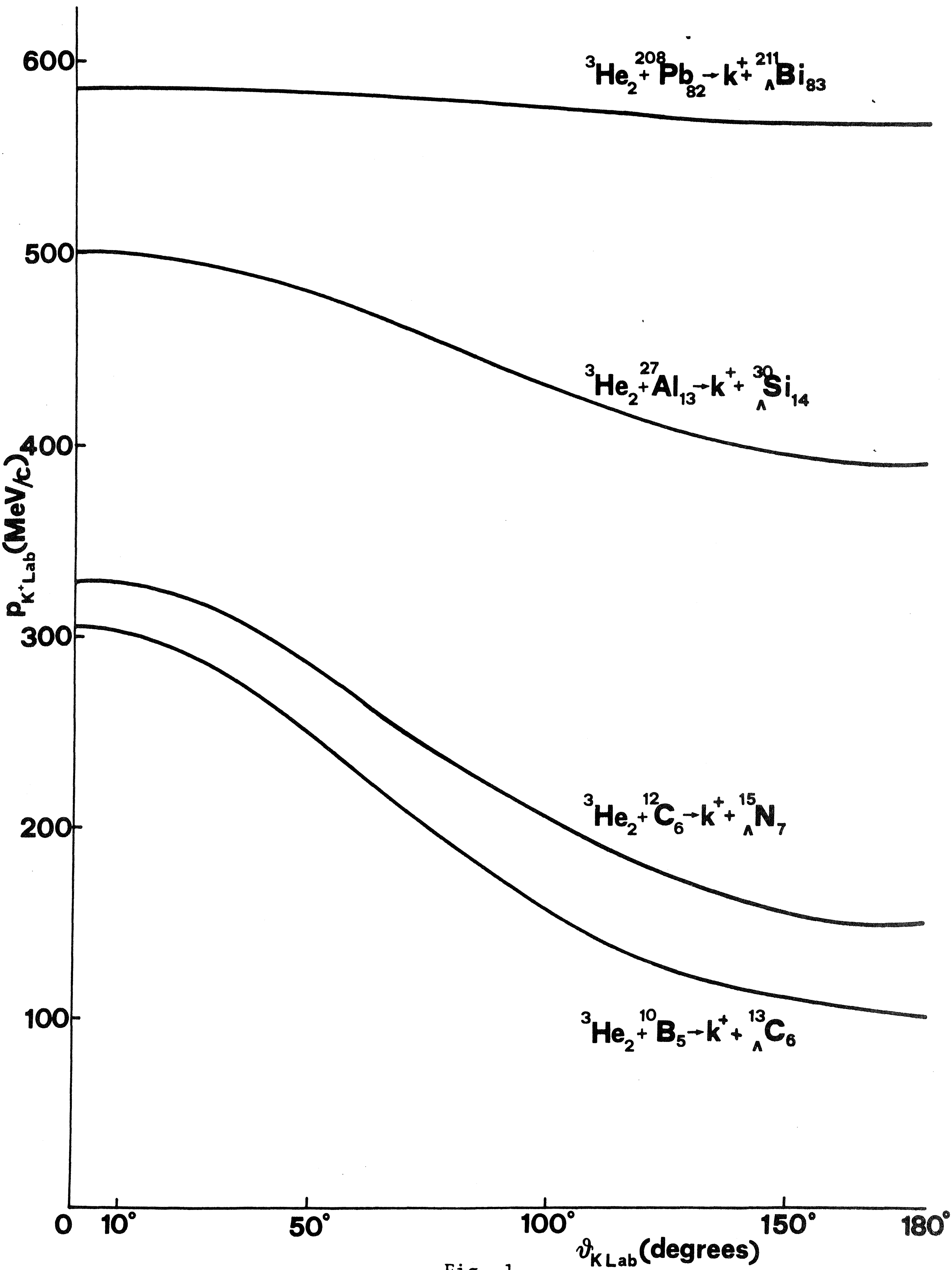
2) G. Igo, in Proc. VIth Int. Conf. on High-Energy Physics and Nuclear Structure, Santa Fe - Los Alamos 1975, p. 63.

3) G. C. Bonazzola, T. Bressani, R. Cester, E. Chiavassa, G. Dellacasa, A. Fainberg, M. Gallio, N. Mirfa-Khrai, A. Musso and G. Rinaudo, Nucl. Instr. and Meth. 123 1975, 269.



600
500
400
300
200
100
0
10°
50°
100°
150°
180°
p_{K^+Lab} (MeV/c)
$\vartheta_{K\,Lab}$ (degrees)
$^3He_2 + {}^{208}Pb_{82} \to k^+ + {}^{211}_{\Lambda}Bi_{83}$
$^3He_2 + {}^{27}Al_{13} \to k^+ + {}^{30}_{\Lambda}Si_{14}$
$^3He_2 + {}^{12}C_6 \to k^+ + {}^{15}_{\Lambda}N_7$
$^3He_2 + {}^{10}B_5 \to k^+ + {}^{13}_{\Lambda}C_6$

Fig. 1

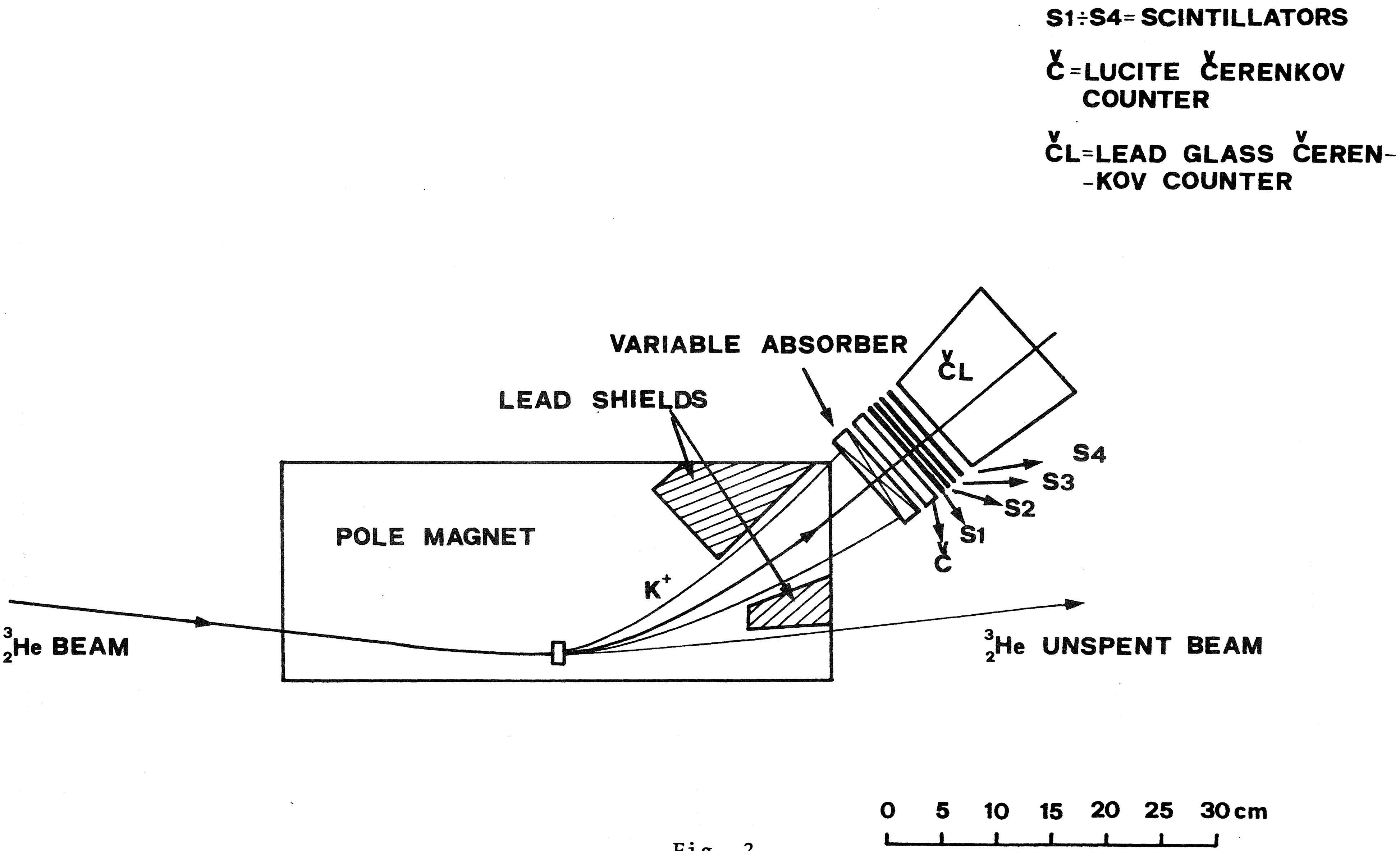

S1÷S4= SCINTILLATORS
Č =LUCITE ČERENKOV COUNTER
ČL=LEAD GLASS ČEREN--KOV COUNTER
VARIABLE ABSORBER
ČL
LEAD SHIELDS
S4
S3
S2
S1
Č
POLE MAGNET
K+
3 2 He BEAM
3 2 He UNSPENT BEAM
0 5 10 15 20 25 30 cm

Fig. 2