

$K_L^0$  SECONDARY BEAM CHARACTERISTICS

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The mean decay distance of a 100-GeV  $K_S^0$  meson is 5.4 meters. Any experiment involving the direct production of  $K_S^0$  mesons at a primary target will necessarily have to be performed well within the meson shield and in the vicinity of the first optical elements of the charged beams. To provide such facilities at the first target station seems unwise. Tertiary beam intensities of  $K_S^0$  produced outside the meson shield will be sufficient for many experiments.

The amplitude for ordinary  $K_S^0$  decay becomes comparable to the CP-violating two-pion decay of the  $K_L^0$  in about 12  $K_S^0$  mean lives--or a distance of 212 feet. Therefore, at a distance of 400 feet or so where the first experiments become possible, the beams may be considered as pure, or nearly pure,  $K_L^0$  beams.

 $K_L^0$  Intensity

Hagedorn and Ranft<sup>1</sup> give intensities for  $K^+$  and  $K^-$  production by 200-GeV protons. The intensity of  $K_L^0$  production has been taken to be the average of the  $K^+$  and  $K^-$  intensities. Figure 1 shows the  $K_L^0$  production intensities as a function of angle for 100 GeV to 20 GeV  $K_L^0$ 's.

The units are particles produced per GeV of secondary particle momentum, per steradian of solid angle, for each interacting primary proton.

A  $K_L^0$  beam can contain a solid angle of the order of  $10^{-6}$  steradians, but is more likely to contain about  $4 \times 10^{-8}$  steradians, which is about a 1-in. square collimator 400 feet from the target. Thus a  $4 \times 10^{-8}$  steradian beam at 5 milliradians production angle from  $10^{13}$  protons interacting in the primary target contains  $0.88 \times 10^5$  100-GeV  $K_L^0$  per GeV of  $K^0$  energy, and about ten times as many 20-GeV  $K_L^0$ . This is quite an intense beam. Table I contains other typical beam intensity calculations.

### Neutron Background

The principal barrier to the use of intense  $K_L^0$  beams is frequently the neutron background, and the energy of the background neutrons is not of interest in many experiments. The curves of Hagedorn and Ranft for proton production by protons have been taken to be characteristic for neutron production also. These curves have been roughly integrated graphically over energy to give Fig. 2, the number of neutrons (i. e. protons) produced per steradian for each interacting primary proton given as a function of production angle.

Incidentally the curve of Fig. 2 has been roughly integrated over angle. This integration gives 0.45 neutrons (i. e. protons) produced per incident proton in the forward 15 milliradians and a rather indeterminate number, not far from 0.5, at somewhat larger angles. This is reasonable--at least to factors of 2 or so.

The neutron background in our example of a  $4 \times 10^{-8}$  steradian beam at 5 milliradians from  $10^{13}$  interacting protons is  $5.2 \times 10^8$  neutrons. Such a beam creates an experimental problem for the equipment and a serious health hazard that must be shielded very carefully.

In an experiment run primarily for 100-GeV  $K_L^0$ , one might be concerned with  $K_L^0$  in a region of  $100 \pm 20$  GeV. This "useful"  $K_L^0$  flux is  $3.5 \times 10^6$  per  $10^{13}$  protons and the total neutron background is the  $5.2 \times 10^8$  calculated above. One can think very roughly, then, of 100 : 1 ratios of neutrons to useful  $K_L^0$ . This is not very different from beams that are now used at the AGS and ZGS.

In the high energy regeneration experiment, the neutrons with energies above 100 GeV are serious background; a discussion of this background problem is given by Smith and Wattenberg, NAL Summer Study Report B. 4-68-27.

#### Desirable Angles for $K_L^0$ Beams

Absolute intensity seems quite adequate for most  $K_L^0$  beam experiments so that the quality of the beam is determined primarily by the  $K_L^0$  to neutron ratio.

Figure 3 gives the ratio of  $K_L^0$  to total neutron intensity for several  $K_L^0$  energies as well as for an integrated  $K_L^0$  spectrum. The best angle to use for 100-GeV  $K_L^0$  is about 7.5 milliradians and for 20-GeV  $K_L^0$  is about 27.5 milliradians. There is no single best angle, but if one had a free choice it would probably be about 12.5 milliradians.

For practical targeting considerations see the note in this report on Targeting for Neutral Beams (B. 4-68-106).

Table I. Fluxes of  $K_L^0$  of Various Energies as a Function of Angle From  $10^{13}$  Protons Interacting with a  $\Delta p = 1$  GeV/c and  $\Delta\Omega = 4 \times 10^{-8}$  Steradians.

Beam Angle mrad.	40 GeV	80 GeV	100 GeV
5	$5.8 \times 10^5$	$2.2 \times 10^5$	$0.9 \times 10^5$
7.5	$4.3 \times 10^5$	$1.1 \times 10^5$	$4.5 \times 10^4$
10.0	$2.9 \times 10^5$	$5.3 \times 10^4$	$1.3 \times 10^4$
12.5	$2 \times 10^5$	$2.2 \times 10^4$	$3 \times 10^3$

FIGURE CAPTIONS

Fig. 1.  $K_L^0$  intensity vs production angle for several different energies.

Fig. 2. Neutron production vs angle, integrated over all energies.

Fig. 3. Relative intensity of  $K_L^0$  to total neutron intensity, as a function of  $K^0$  energy and production angle.

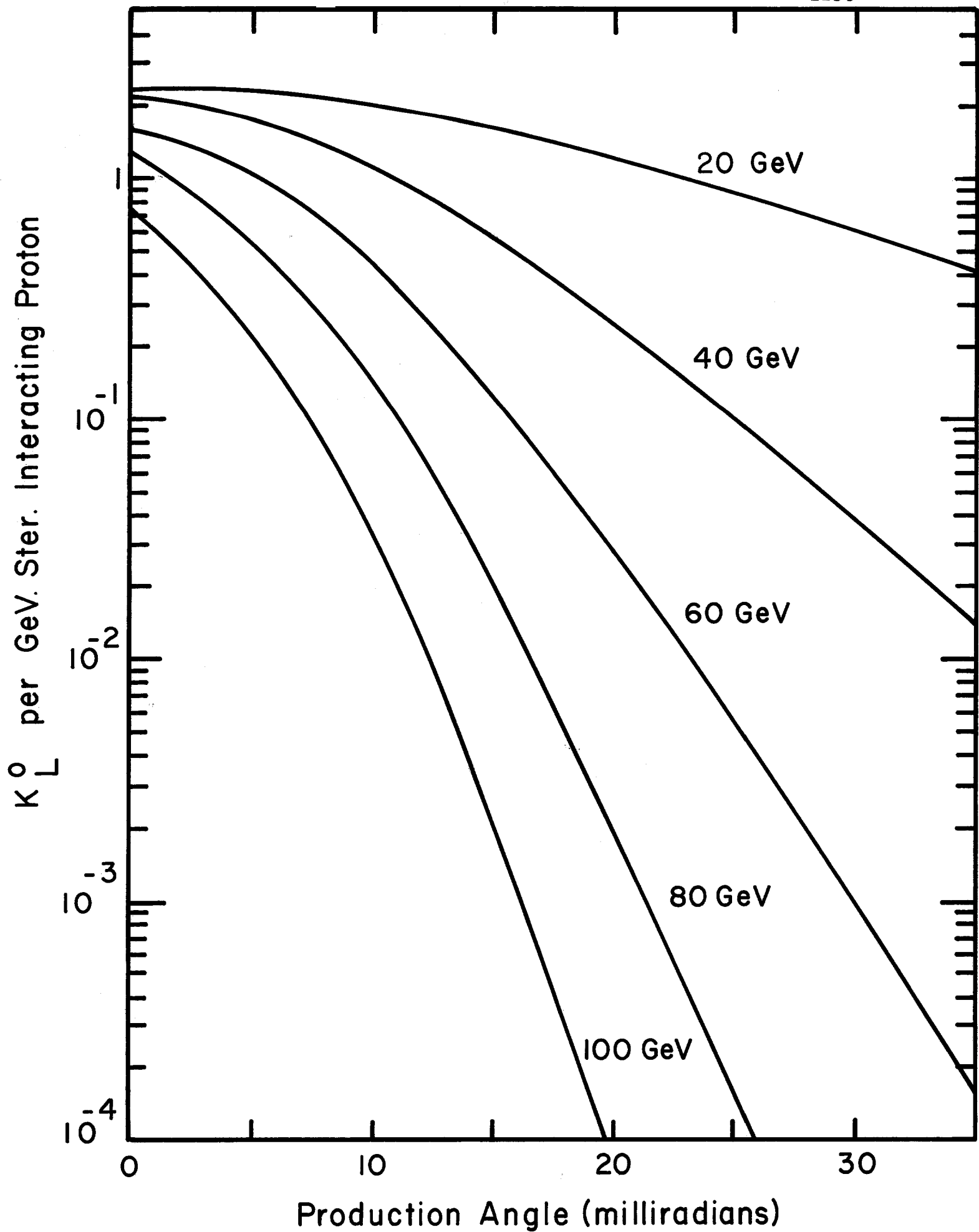


Fig. 1

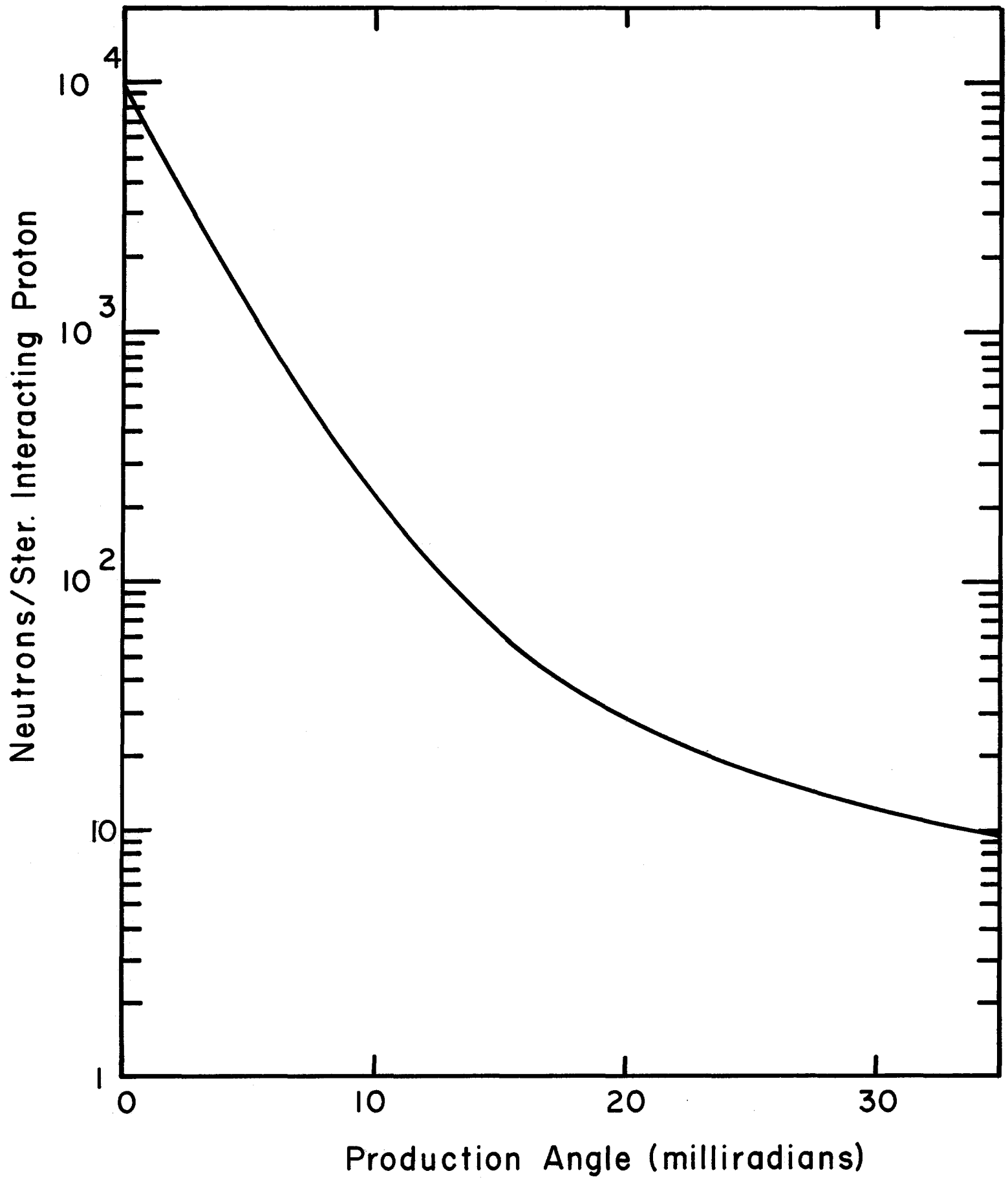


Fig. 2

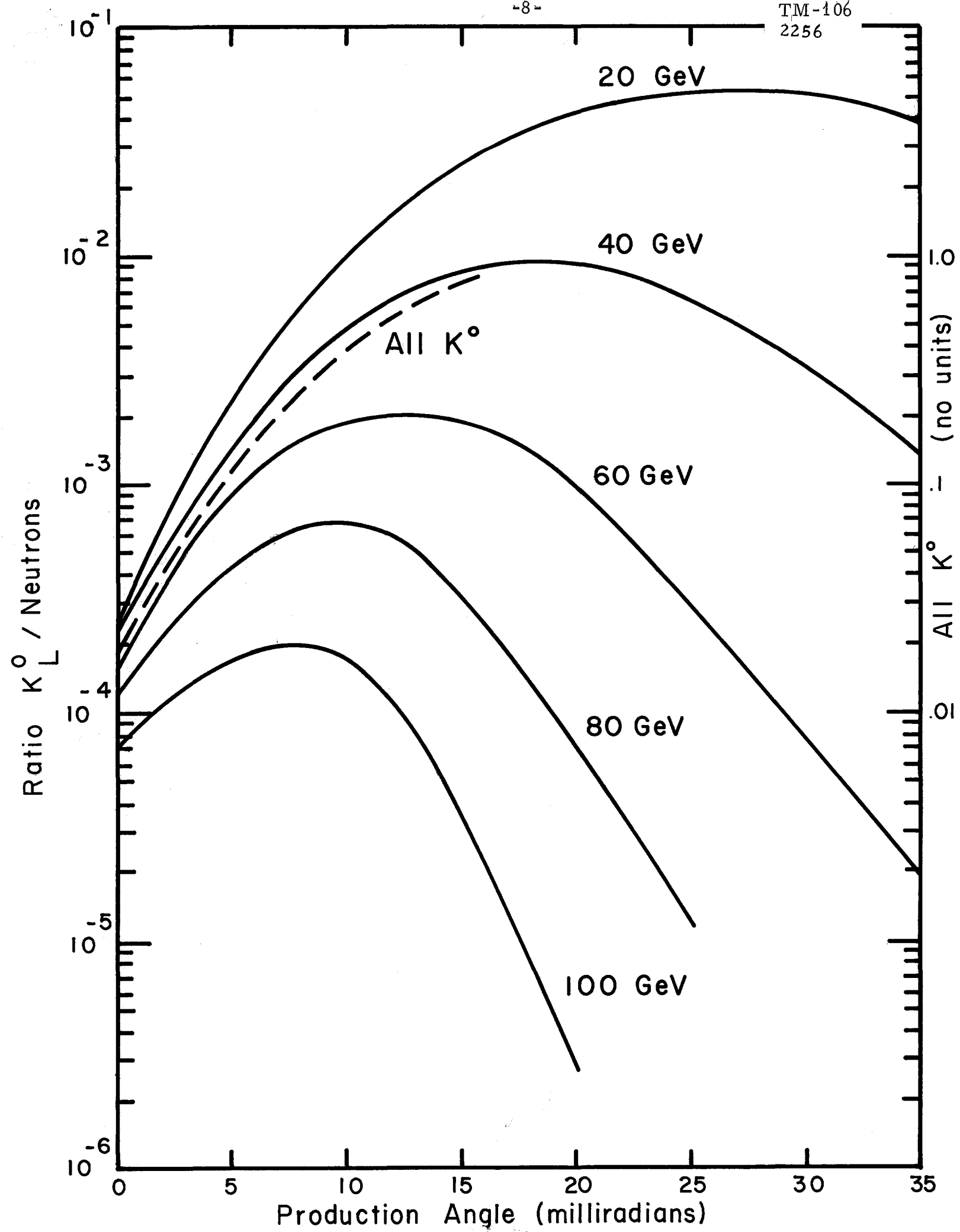


Fig. 3