A High Energy Photon Beam Derived From Neutral Strange Particle Decay

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I. Summary

Conventional methods for generating photon beams include: tagged beams in which the photons are derived from electron bremsstrahlung in a radiator target; and broad band beams in which the photons are derived from π^0 decay - the hadronic component (n, K_s^0) accompanying such a beam is usually suppressed by passage of the beam through a low Z (D_2) filter.

Although one can generate high energy photons by these techniques, the major drawback to these beams is that the photon energy spectrum obtained is peaked at very low E_γ. (Recall that the bremsstrahlung spectrum falls as $1/k$). With very high energy proton beams (20 TeV/c), one can imagine other alternatives for photon beam design. We consider one such option here.

II. Photons from strange particle decay

Our goal was to generate a high energy photon beam of reasonable flux ($\gtrsim 10^5$ particles/sec) with negligible hadron contamination and with minimal low energy tail. A rather natural source of photons which could satisfy these requirements is neutral strange particles: Λ^0, K_s^0.[1] In the multi-TeV/c momentum range, mean decay lengths for these particles are several hundred meters, which is a convenient scale for beam design. Shown schematically in Fig. 1, a neutral beam is defined at 0° relative to a primary 20 TeV/c proton beam. The angular divergence of the neutral beam is controlled by a pin-hole collimator 100 meters from the production target. The next 1000 meters constitutes a decay volume. One would impose magnetic fields in this region to sweep out any charged particles. The stable component of the neutral beam (n, K_L^0) is absorbed in a magnetized dump located 1100 meters from the production target. The dump is in fact the central portion of an annular collimator, whose cylindrical aperture defines the transmitted beam. Some of the photons produced in the decays in the 1000 m long decay volume can be transmitted through the aperture ($10\,\mu$ rad $< \theta < 40\,\mu$ rad) to an experimental target 300 m beyond.

We have performed a Monte Carlo simulation of the beam characteristics assuming that Λ^0 and K_s^0 are produced with flat x and $(1-x)^5$ distributions respectively and that all particle decays are isotropic. In Figs. 2 and 3 are shown the resultant photon energy spectra obtained with the geometry defined in Fig. 1. Although there is some peaking at low E_γ, these peaks constitute a small fraction of the transmitted flux. Rather, the bulk of the photons have very high energy: $< E_\gamma > \sim 3$ TeV from the Λ_s^0 source, and $< E_\gamma > \sim 6$ TeV from the K_s^0 source. The spatial distribution of the photons at the experimental target (located 1500 m from the primary target) is shown in Fig. 4 for the two beam sources; they are quite similar. In essence, the composite profile represents a "ring" of illumination at the target. The characteristics of this beam are compared with those of tagged and broad-band beams in Table I.

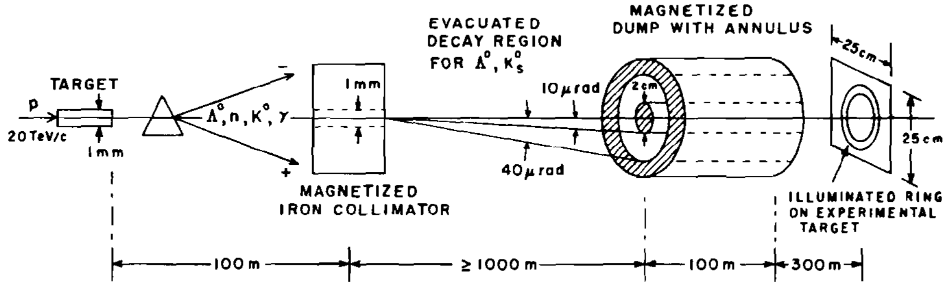

Fig. 1. Schematic of the beam line.

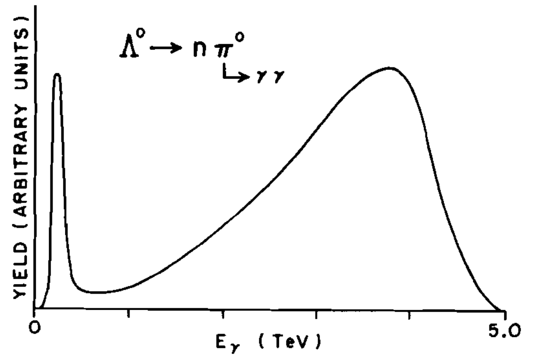

Fig. 2. Photon energy spectrum derived from Λ^0 decay in the geometry of Fig. 1.

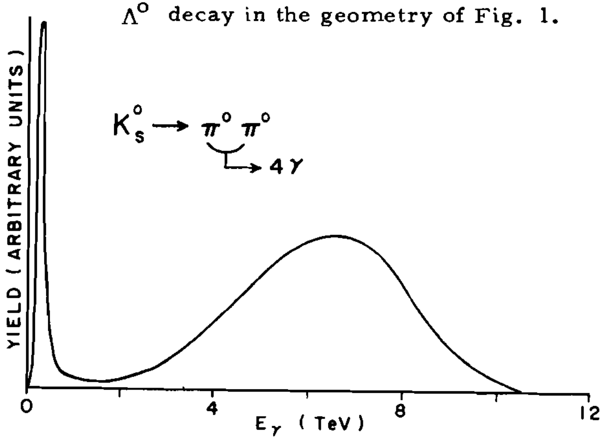

Fig. 3. Photon energy spectrum derived from K^0_s in the geometry of Fig. 1.

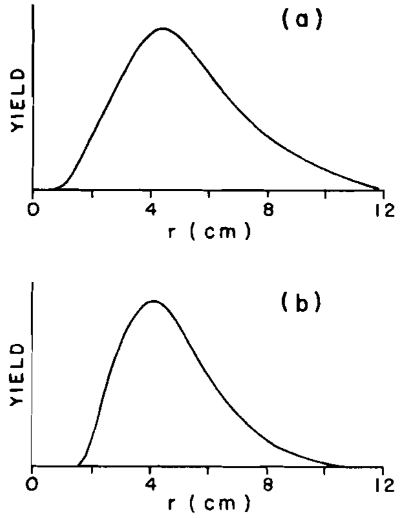

Fig. 4. Radial profiles of the photons reaching the experimental target at 1500 m =
(a) from the Λ^0 source; and,
(b) from the K^0_s source.

Table I

Photon Beams

	Broad Band[2]	Tagged[2]	Λ^0, K^0_s Decay[3]
Protons	20 TeV/c 5×10^{11}/sec	20 TeV/c 5×10^{11}/sec	20 TeV/c 5×10^{11}/sec
E	< 12 TeV	< 7.5 TeV	0.5 - 10 TeV
Average N_γ/sec (25% duty factor)	2.5×10^8	1.2×10^7	1.2×10^5
Comments	Hadrons in beam. Energy spectrum peaks at low E_γ.	No hadrons in beam. Energy spectrum peaks at low E_γ. E_γ known from tagging.	No hadrons in beam. Energy spectrum favors high energy photons. Λ^0, K^0_s contribute roughly equally to the flux.

Although the photon flux is definitely lower for the Λ^0, K^0_s decay beam, the absence of the low energy E_γ tail suggests that targets of short radiation length, which are impractical in conventional beams, might be now used effectively. Emulsion targets immediately come to mind. In fact one can well imagine a search for $t\bar{t}$ production and decay with such an arrangement.

References

1. The original suggestion that a photon beam with flat energy spectrum could be obtained from K^+ decays at Fermilab energies is due to R. Lipton, J. Rosen, and T. Yamanouchi.
2. Yields for Broad Band and Tagged Beams have been scaled from G. Luste, "Jet Photoproduction at the Tevatron," in Physics Opportunities for the Fixed Target Tevatron, Fermilab (1980) G. L. Kane and N. M. Gelfand, eds., p. 201-205, and J. Butler, private communication.
3. Λ^0, K^0_s yields have been derived from P. Skubic et al., Phys. Rev. D18, 3115 (1978).