FEASIBILITY STUDY OF A π MESON LINEAR ACCELERATOR

R. L. Gluckstern
Yale University

The feasibility of a linear accelerator for a secondary beam of π mesons has been studied. This is to be used in conjunction with a proton linear accelerator in the range of 600 to 800 Mev. Most of what follows is based on the unpublished report, written in 1959, by S. Devons entitled "The Production of High Quality Beams of Secondary Particles".

That acceleration of unstable particles may be feasible can be seen from the relativistic time dilation as the particles are accelerated. The fraction of particles which survive acceleration at the uniform rate W'(Mev/meter) from an initial γ_i to a final γ_f can be easily shown to be

$$f = \left(\frac{\gamma_i + \sqrt{\gamma_i^2 - 1}}{\gamma_f + \sqrt{\gamma_f^2 - 1}} \right)^{\zeta} \quad \text{where, } \zeta = \frac{m_o c^2}{c\tau W'}$$

and τ is the mean life of the unstable particle. As an example, for π mesons, being accelerated from 300 Mev to 1300 Mev, with $W' = 9$ Mev/meter, one has

$$c\tau = 7.8 \text{ meters}, \quad \zeta = 2, \quad \gamma_i \cong 3, \quad \gamma_f \cong 10;$$

$$f \cong 0.1.$$

Thus 10% of the π mesons injected into the linac will not have decayed by the time they have been accelerated from 300 to 1300 Mev.

An estimate of the beam intensity and optical qualities can be made along the following lines:

1) According to S. Devons (for the Harwell Proton Linear Accelerator) and W. A. Blanpied (for the proposed Yale Proton Linear Accelerator), one can produce good quality beams of π mesons at 300 Mev from either of the reactions

$$p + p \longrightarrow \pi^+ + d,$$

$$p + Cu \longrightarrow \pi^+ + \ldots..$$

Estimates of the secondary intensities expected at 300 Mev on the bases of 6×10^{15} protons/sec in the incident beam (1 ma time average) cover the range listed below.

Beam Intensity (particles/sec)	Energy Spread	Emittance (cm-mrad)
10^7	± 1%	2π
10^8	± 1%	10π
6×10^8	± 1%	25π

2) Crude estimates of the longitudinal acceptance of the π meson linac indicate that an energy spread of ± 2% can be tolerated at 300 Mev for a 1200 Mc/s linac.

3) Crude estimates of the transverse acceptance of the π meson linac based on doublets between tanks of 3 meters length with a transverse wave-length of 12 meters indicate that with an opening of 2 cm radius, the acceptance will be about 20π cm-mrad.

4) With the damping of the longitudinal and transverse phase areas expected, one estimates a 1300 Mev π beam of the following characteristics:

Beam Intensity	Energy Spread	Emittance
10^7/sec	± 1%	6π

This is assuming the intensity of 6 x 10^8/sec with 20π cm-mrad at the beginning. A factor 0.1 has been included for decay of the π mesons, and a factor 0.2 has been included for imperfect matching of the transverse phase areas and other beam transport losses.

5) This beam can be compared with existing Cosmotron and Bevatron 1.0-1.5 Bev beams of the following characteristics.

Beam Intensity (π^+)	Energy Spread	Emittance
10^4/sec	± 1%	20π
10^5 - 10^6/sec	± 7%	160π

The following additional points seem worth mentioning:

1) The estimated cost of such a secondary accelerator will be comparable with that of the primary accelerator. In particular, the necessary high gradient and long duty cycle needed imply high rf costs. However, problems of beam loading should be absent.

2) Secondary μ meson beams should be obtainable as well, although these will be produced with a larger angular spread.

3) It may be that such a secondary beam accelerator would be a reasonable application of the continuing development of superconducting linacs. Both seem to be somewhat in the future.

4) According to F. Mills and D. Young of MURA, π meson yields for the proposed MURA facility are of the order of 10^9/sec with comparable quality to the present linac estimates.

Discussion

H. B. Knowles (Yale): It may be possible by adjusting the gradient inside the accelerator to produce a reasonably pure beam of either π's or μ's because the rest mass varies by roughly 2 or 3 at the most.

R. L. Gluckstern (Yale): I think that what happens is that the angular spread of the μ's would be larger than can be accepted by the focusing system.

V. W. Hughes (Yale): Is it possible to obtain a variable energy with this machine?

R. L. Gluckstern (Yale): Yes, by turning off tanks.

E. D. Courant (BNL): As I see it, this does not compare too favorably with the kind of beam one could get from a proton accelerator energetic enough to make 1.3 Bev π's and this also could be high intensity. In other words, this would not be any better than the π beams that could be obtained from the MURA FFAG and Stanford machines.

R. L. Gluckstern (Yale): Well, I am not sure how the intensities would work out, but you would have to build a longer proton linac to get 1.3 Bev π's. The peak of the π meson production does not come to 1 Bev until you get up to several Bev protons. I do not know how it would compare. I expect the two ways would compete.