LA-UR- 93-1388

Title: ETA PRODUCTION AT THE LAMPF P3 CHANNEL

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Submitted to: Workshop on the Future Directions in Particle & Nuclear Physics at Multi-GeV,
Upton, NY (BNL)
March 1993

η Production at the LAMPF P^3 Channel

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Abstract

We discuss the pion flux that would be available at the P^3 channel at LAMPF with modifications to east leg of the channel. Modifications involve tayloring the optics of the channel to match the pion beam into a section of superconducting linac in both transverse dimensions and also longitudinally. The performance of this channel with these modification is discussed. The possible η flux with this channel is also discussed.

1 Introduction

The LAMPF linac provides a micropulse of protons every ~5 ns that has a width on the order of 20 ps. This particular time structure allows the possiblity of manipulating the longitudinal properties (time spread or momentum spread) of a secondary beam of pions produced by these micropulses. The possibility of using this feature to accelerate secondary beams of particles was first suggested by Nagle in the early '70s. While the possibility of accelerating secondary pion has long been recognized, the practicality of such an accelerator has only been realized with the advent of high gradient superconducting (SC) cavity technology.

The first use of a SC cavity at LAMPF to manipulate the longitudinal properties of a secondary pion beam was the SCRUNCHER cavity at Low Energy Pion (LEP) channel. This device, a 402.5 MHz SC cavity, has been used to increased the LEP pion flux[1] in a small momentum bite ($\Delta p/p$ 10.4%) by over a factor of 4. This increased flux is obtained by transporting a large momentum speard beam and then using the correlation between longitudinal position and particle energy that the beam line introduces to the beam. This correlation is removed by the RF field of the SCRUNCHER cavity if the field is appropriately timed and adjusted in magnitude i.e. the energy of high energy particles is decrease and the energy of low energy particles increase to minimizing the energy spread in the beam.

2 Application of SC cavities to higher energy pion beams

The highest energy pion beam at LAMPF is obtained at the P^3 channel Fig. 1 show the P^3 pion flux as given in the LAMPF handbook. While a Pion Linear ACcelerator (PILAC) has discussed[2, 3] as a means of obtaining 1 GeV π^+ beam with a flux of ~1×10^9/sec, the work discussed here is a modest means of enhancing the P^3 channel performance. This design should not be confused with PILAC which uses a zero degree extraction system to transport the secondary beam to the accelerator. While work described here uses the same type SC cavities as PILAC, it should be considered as a parallel effort using the same cavity technology.

The optics of the east leg of the P^3 channel have been studied[4] and a first-order beam optics solution found that matches the secondary pion beam into the 13-cm diameter aperture of a 805-MHz SC cavity in the transverse coordinates. This optics solution also minimizes the contribution to the pion bucket size in time due to the geometric terms (i.e. $(l|x)=(l|\theta)=0$) and due to the momentum spread in the pion beam (i.e. $(l|\delta)=0$) at the entrance to the cavity. Since this work was first reported[4] the tunes, originally studied with the code TRANSPORT[5], have been verified using the code COSY INFINITY[6], and higher-order studies are in progress.

Fig. 2 shows the floor layout of the P^3 channel with the location of the new beam line indicated. This new beam line would add a 4^{th} dipole to the P^3-East line. This dipole is a 50° bend and is located just downstream of Q16 in the existing beam line. The new dipole is followed by a quadrupole doublet that had the same dimensions as the doublet that sits on the floor in the East cave experimental area. After the doublet is the linac structure. Note that this arrangement points the beam at LAMPF Staging Area – an existing building.

Fig. 3 shows the first-order envelopes for this beam line for 500-Mev pions for three different effective lengths, all three solution have the same transverse matching conditions. The effective length is the length of a drift that would give the same longitudunal correlation in the beam as the beam line does.

The superconducting, 805-MHz linac has been studied in detail for one case – the acceleration of 500 MeV pions to 624 MeV. The accelerator structure in this particular case used 10 7-cell 805 MHz cavities and had a total length of just over 23 meters. The specific cell geometry of the linac structure is shown in Fig. 4. With this accelerator the survival fraction when starting with 500 MeV pions is ~56%, and the initial momentum spread ($\Delta p/p$ 5%) is compressed by a factor of two at the linac output. With this information we can determine the 624 MeV flux that is available, this is shown in Fig. 5.

3 η production rates

There are three η production processes of interest: $\pi^- p \to \eta n$, $\pi^+ d \to \eta pp$, and $\pi^+ {}^3He \to \eta\, {}^3H$; further discussions of these η production processes can by found in Ref. [2], and elsewhere in these proceedings. For the purpose of this discussion consider the $\pi^- p \to \eta n$. Fig. 6 (due to J. A. McGill) shows the η production rate that is obtained when the total cross section for this reaction is folded with the P^3 π flux. Also shown in Fig. 6 is the production rate that would be possible with 50 MeV of acceleration and with 100 MeV of acceleration. One sees that with a modest acceleration (50 MeV) that the η production flux is increased by over an order of magnitude.

4 Conclusion

A secondary pion beamline that this is a simple modification of the LAMPF P^3 bealine is described. This beamline allows the time structure of the proton beam incident on the pion production target to be preserved in the secondary beam while matching the transverse dimensions of the pion beam to the aperture of a superconducting cavity. The initial temporal structure in the proton beam is that of a 805 MHz proton linac that is fed by a 201.25 MHz drift tube linac, i.e. the LAMPF accelerator.

With the initial time spread preserved in the pion beam appropprietely phased RF cavities can be used to immediately accelerate the secondary beam, i.e. no compression of the longitudinal phase space of the beam is required. High gradient[7] superconducting RF cavities are well suited for this task. With a modest increase in the energy (50 MeV) of the pion beams from the P^3 channel at LAMPF the η production flux is increased by over an order of magnitude.

The superconducting cavities would also act as an RF seperator, eliminating any prtons which might remain in a π^+ beam. This would be of great benifit to many of the LAMPF experiments[8] that use 500-MeV π^+ beam that is currently available. The π^+ flux would be increased and the beam purity would be inproved.

Further studies on the beamline and cavities are continuing. Layout of magnets and target matching system downstream of the cavities is yet to be studied. Details of the cryogenic system are also being studied.

References

[1] J. M. O'Donnell et al., NIM **A317**, 445 (1992).

[2] PILAC Users Group Report on the Physics with PILAC, Los Alamos Report LA-UR 92 150 (1991).

[3] See H. A. Thiessen and J. D. Zumbro in these proceedings.

[4] J. D. Zumbro, H. A. Thiessen, G. R. Swain, C. L. Morris, and J. B. McClelland, BAPS **37**, 1307 (1992).

[5] K. L. Brown, "The ion optical program TRANSPORT," Technical Report 91, SLAC, 1979; the Los Alamos version of the code with variable 5 being the particle bunch length instead of the path length has been used for these studies.

[6] M. Berz, "COSY INFINITY Version 6 User's Guide and Reference Manual," Michigan State University, Jan. 1993.

[7] Accelerating gradients in excess of 22 MV/m have been obtained for single cell 805 MHz super conducting cavities by the Los Alamos (AT 1) group. The group is in the process of procuring a multi cell 805 MHz cavity. B. Rusnak and J. N. Dimarco, private communication.

[8] LAMPF Exp. 1285 "Search for Δ components in nuclear ground states" and Exp. 1299 "Pion Scattering to the Continuum and Pion Transparency in Nuclei," C. L. Morris and J. D. Zumbro Spokesmen are just two examples of experiments that would be greatly enhanced by the increased 500 MeV π^+ that would be available with a few superconducting cavities after the modified p^3 beamline described here.

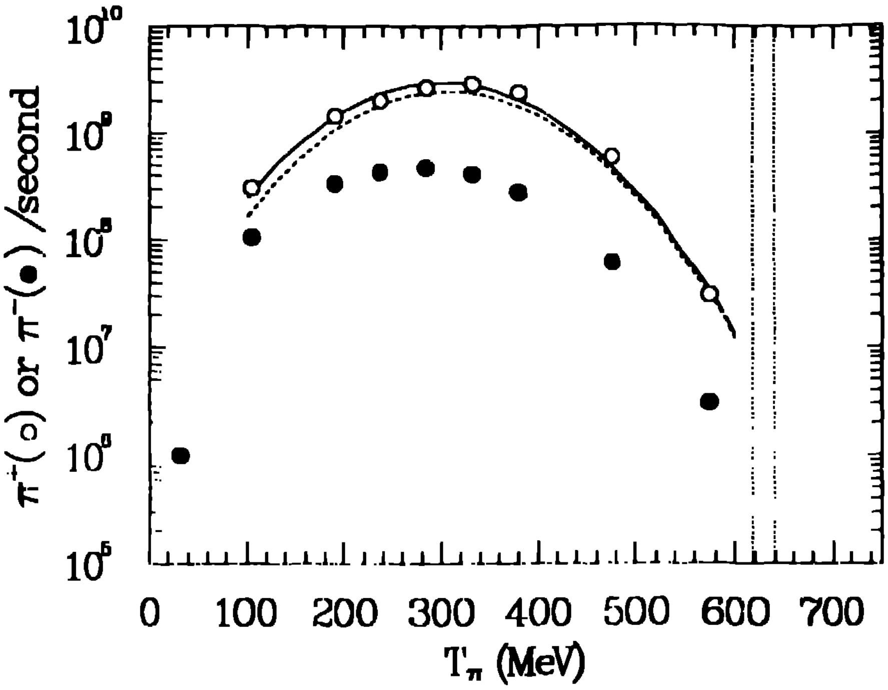

Fig. 1 LAMPF Handbook vaules for the P^3 pion flux with a momentum bite of ±2.5% assuming a 1 mA primary proton beam current and a 6 cm thick A2 production target. The vertical dotted lines at about 620 and 640 MeV, represent the maximum π^- and π^+ energies, respectively, that are kinematically possible. The solid and dashed lines are fits to the π^+ fluxes for two different length beamlines, 19.63 m (data points) and 24.66 m, respectively.

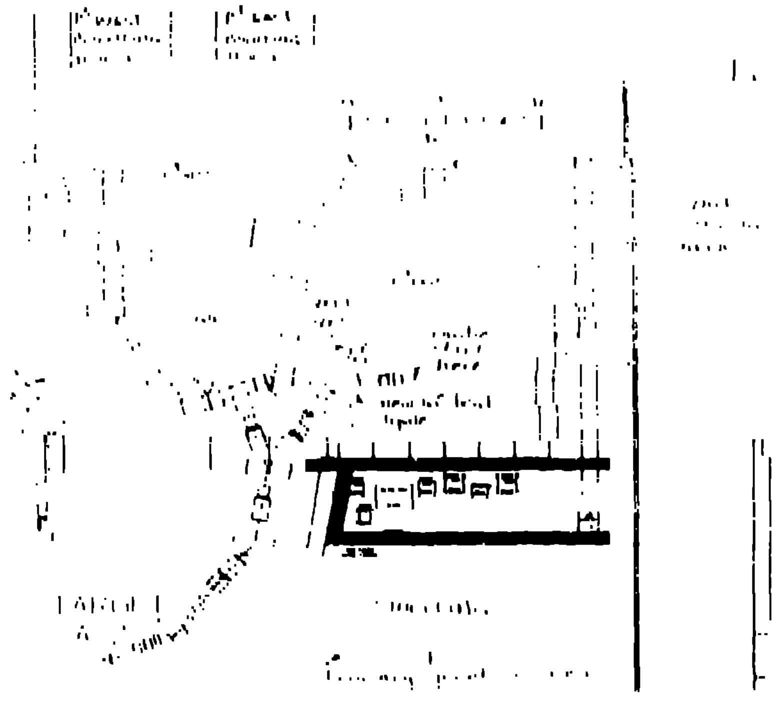

Fig. 2 Floor layout of the P^3 secondary pion beam lines at LAMPF. The modifications to the east leg are indicated.

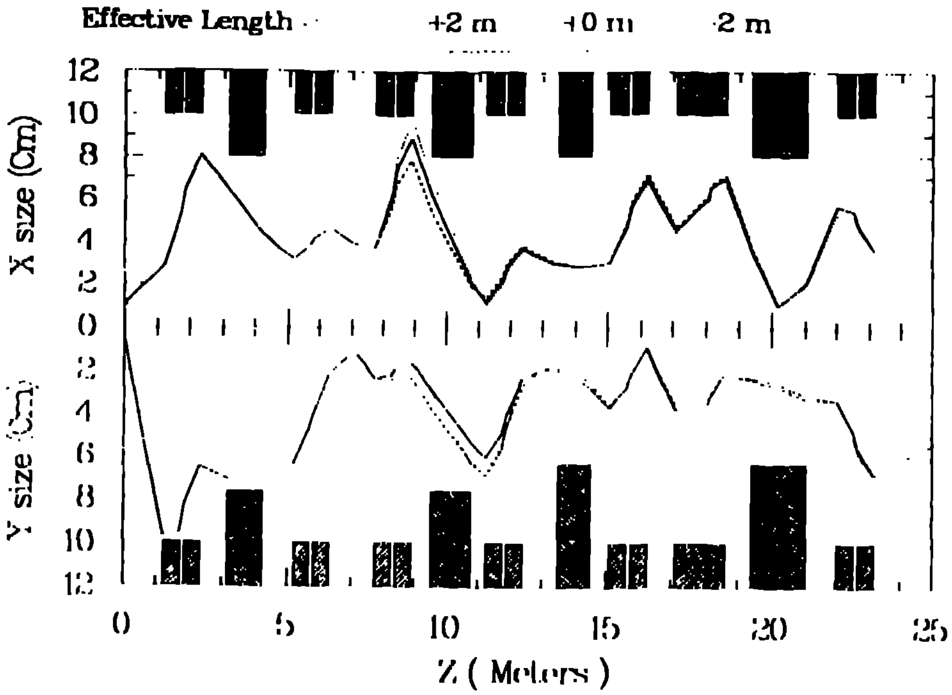

Fig. 3 First order envelopes for the modified P^3 East beam for three different effective drifts. All three solutions have the same transverse matching conditions at the beam exit/superconducting cavity entrance. The shaded areas indicate the lengths and apertures of the dipoles and quadrupoles in the beamline.

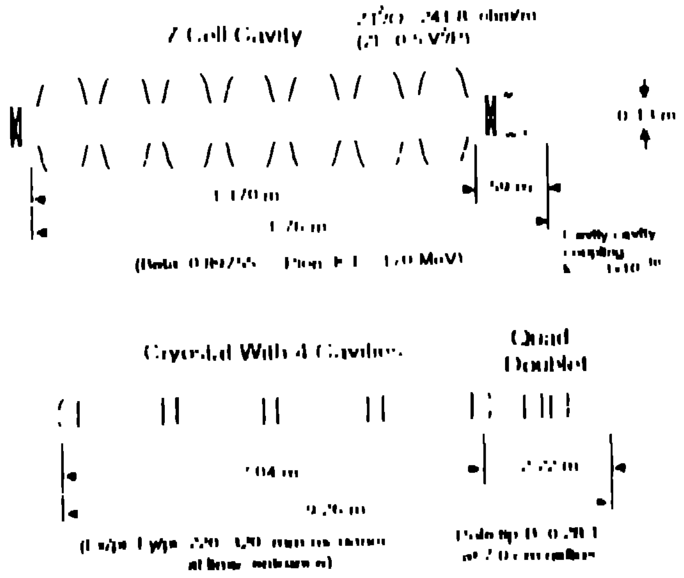

Fig. 4 Cell geometry of the superconducting 805 MHz linac for which the transverse matching was determined

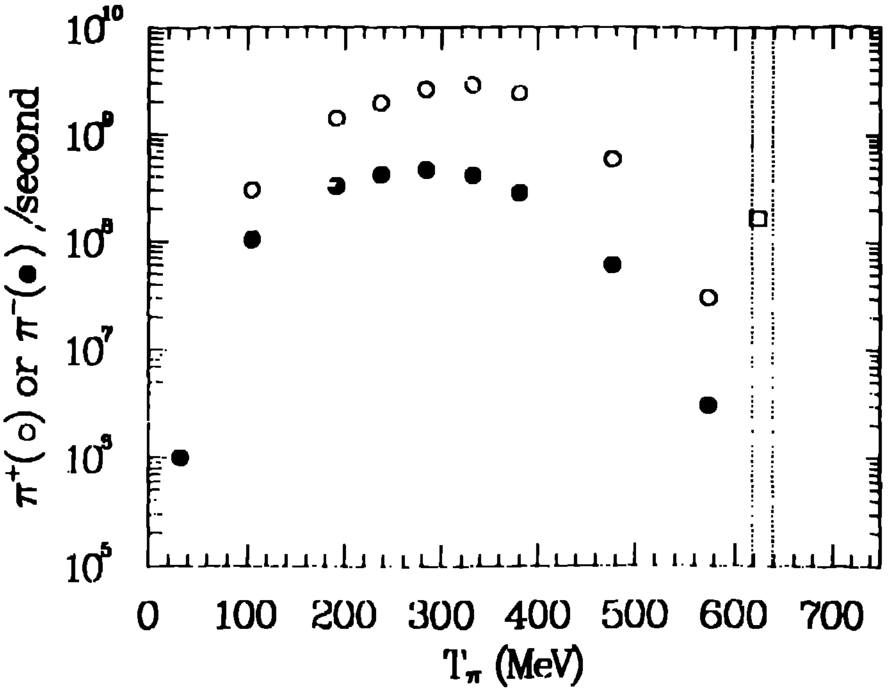

Fig. 5 This figure is the same as Fig. 1 with the calculated π^+ flux at 624 MeV (open square) obtained by accelerating 500 MeV pions.

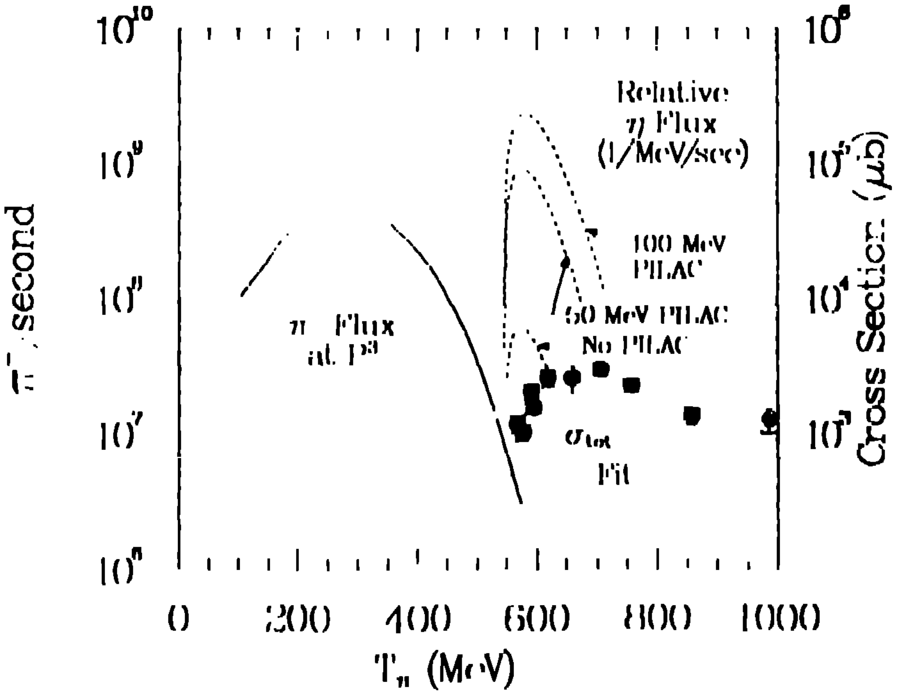

Fig. 6 The total cross for the $\pi^- p \rightarrow \eta n$ reaction is folded with the P³ π^- flux to determine the available η production fluxes. Also shown is the η flux that would be available with 50 MeV of additional acceleration, and the flux with 100 MeV of additional acceleration.