TO: F.R. Huson
FROM: U.E. Kruse
University of Illinois, Urbana, Ill.
SUBJECT: Hadron Beam to the Chicago Cyclotron Magnet

I SUMMARY

Two feasible schemes to obtain hadron beams for the Chicago Cyclotron magnet are described in this note.

The first is a minor variation of the present \( \mu \) beam. The only changes involve the removal of the present hadron absorber, a possible change of the target position upstream of the present \( \mu \) triplet train, and retuning of the beam line. In this mode fluxes of \( 2 \cdot 10^6 \pi^- \) at 150 GeV/c are expected for \( 10^{12} \) 300 GeV/c protons on target. This mode is compatible with hadron beams to the bubble chambers but not with \( \nu \) running.

The second scheme uses the N7 bypass. The proton beam strikes a new target near the entrance of the decay tube. The target would be slightly above the present N7 beam. To provide hadron beams for the bubble chamber, the proton beam is shifted down by pingers onto the usual bubble chamber target in enclosure 100. We expect the new hadron beam will yield \( 10^5 \pi^- \) at 150 GeV/c for \( 10^{12} \) 300 GeV/c protons on the new target. This scheme allows simultaneous running with the \( \nu \) horns, hadron beams to the bubble chambers, and a hadron beam to the Chicago Cyclotron magnet. A test by Ray Stefanski indicates that there will be less than \( 10^{11} \) protons in the 100 enclosure for \( 10^{12} \) protons on the new target. A computer calculation of the new hadron beam indicates
that acceptable magnifications and momentum coalescence should be possible with angular acceptance of 2 mrad x 2 mrad and momentum bite of 2%.

We describe the two schemes in Sections II and III, in Section IV we comment briefly on some alternatives, and in an appendix we summarize the optical properties of the beam.

II USE OF THE TRIPLET TRAIN

The most straightforward hadron beam would use the target upstream of the triplet train, with the triplet train used to direct hadrons toward the N1 beam line. Since this scheme follows very closely the existing \( \mu \) beam it seems straightforward and we have estimated yields of \( 2 \cdot 10^6 \pi^- \) at 150 GeV/c for \( 10^{12} \) 300 GeV protons on target. We have not examined the optimum optics for this beam. Its principal advantage is minimum of change and high hadron yield, its obvious disadvantage is that it cannot run together with \( \mu \) or \( \nu \) beams.

III USE OF BYPASS N7 BEAM

It appears possible to insert "pingers" into the N7 beam to feed the usual target for the Bubble Chamber hadron beam. When the pingers are off the beam would strike a new target near the entrance of the decay tube. The scheme would be compatible with simultaneous running of the neutrino horn, hadron beams to the bubble chamber, as well as the proposed hadron beam to the Chicago cyclotron magnet.
The scheme would involve the long proton spill going down the N7 line; only the short burst of protons at the end of the spill being directed to the NO beam by the deflectors in enclosure G2. The long spill in N7 would then be split by new pingers or kicker magnets in Neuhall. The beam without pinger would go about .4 mrad above the existing N7 beam, while the new pingers kick the protons down onto the present N7 line for bursts to the bubble chamber. The target for the new beam would be just upstream of the decay pipe. The arrangement is shown schematically below:

The upper proton beam appears to pass cleanly through the magnets in the N7 line and through existing apertures in the horns.
A possible timing is indicated below during proton extraction:

The hadron beam from the new target would appear at a production angle of 1 or 2 mrad, depending on whether the center or left opening in the beam dump at the end of the decay tube is used. According to Grote, Hagedorn, and Ranft this would involve reductions from 0° corresponding to .85 (.70) for 1 (2)mrad. The hadrons produced would then go down the existing N1 beam line. We have calculated a possible optics for the beam which we estimate would yield $10^5 \pi^{-}$ at 150 GeV/c for $10^{12}$ protons on the new target. The new optical arrangement would use existing magnets in their present location but would require a new power supply for one of the quadrupoles in enclosure 100. Some of the details of the beam design are shown in appendix A.
We have examined briefly the possible effects of the new beam on the radioactivity in enclosure 100 and on early or late tracks in the Bubble Chamber. Ray Stefanski has made a direct measurement of the intensity in enclosure 100 using the NO beam to simulate the proposed new proton line. For these tests the NO focussing magnets in Neuhall were turned off. The beam was then deflected vertically by the magnet OUT. The results are summarized in Appendix B. He found that for .3 (.45)\( \text{mrad} \) deflection the intensity in 100 enclosure was down to .16 (.041) of the value obtained for no deflection. These ratios were not changed by the presence of a target in the NO line, we ascribe the enclosure 100 background to beam halo. Therefore we expect that if \( 10^{12} \) protons hit a new target .3 (.45)\( \text{mrad} \) above the N7 line there should be \( 1.6(.41) \times 10^{11} \) protons in enclosure 100. Thus with the present limit of \( 10^{11} \) protons per pulse a deflection of .4 mrad should be safe; in the future, as enclosure 100 is hardened there should be no difficulties with running more intense proton beams. As experience is gathered with the beam geometries, further improvements should be possible by reducing the size of the openings in the beam dump.

From the above test we can also estimate an upper limit for the background of early or late tracks introduced into the bubble chamber by the presence of the new target. Assuming a bubble chamber sensitive time of 10 msec, we have an upper limit of \( 10^9 \) protons diffracted onto the bubble chamber target during the sensitive time. In this we assumed the rate of \( 10^{11} \) protons per second applies during the sensitive time. This should be an
allowable background for many bubble chamber exposures. Larger deflection angles from the new pingers or reduction in the halo of the beam would give further reduction in this background.

SECTION IV

We have also considered the possibility of targeting on the usual neutrino target and obtaining a hadron beam through the neutrino horn. The hadron beam would then go through about 20" of Aluminum in the second horn if there is no beam stopper. With a beam stopper in place upstream of the second horn, any hadron beam from the neutrino target becomes impossible. Alternative targeting downstream from the second horn involves moving a heavy water cooled beam stopper with each pulse. These alternatives have not been explored further.

We want to thank E. Bleser, F.R. Huson, M.E. Johnson, P. Limon, F. Nezrick, S. Pruss, R. Stefanski, and D. Theriot for their advice and patient explanations.
APPENDIX A

Proposed Optics for the Hadron Beam

The proposed hadron beam uses the existing magnets in the N1 beam line. The basic design uses the quadrupoles in enclosure 100 and 101 to focus the production target horizontally and vertically onto enclosure 102. The quadrupoles in enclosure 103 then focus this spot onto the final target near the Chicago Cyclotron Magnet both horizontally and vertically. The two quadrupoles in enclosure 100 serve as the first two elements of a triplet with the quadrupoles in 101 serving as the third element of the triplet. The current is divided between these three elements to provide momentum coalescence at the hydrogen target. The horizontal and vertical acceptances are ~2 mrad and the momentum acceptance is 2%. The upper limit on momentum is at 170 GeV/c due to the current limit on quadrupoles in enclosure 103. The optics is outlined in the figure.
RAY TRACES IN PROPOSED BEAM

NEW TARGET -> ENCLOSE:  

100 101 102 103 104 CCM TARGET

X: HORIZ:

Y: VERT:

Z: OFF MOME:
# Appendix B

## SEM Readings in Enclosure 100 as Function of Beam Deflection

<table>
<thead>
<tr>
<th>OUT Deflection Magnet Setting (amps)</th>
<th>SEM Readings Neuhall</th>
<th>SEM Readings Enclosure 100</th>
<th>SEM Ratios Enclosure 100/Neuhall</th>
<th>Defl / 0 Defl</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3839</td>
<td>2153</td>
<td>.56</td>
<td>1</td>
</tr>
<tr>
<td>2.5</td>
<td>4246</td>
<td>2571</td>
<td>.62</td>
<td>1.05</td>
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<tr>
<td>5.0</td>
<td>3802</td>
<td>1910</td>
<td>.50</td>
<td>.89</td>
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<tr>
<td>7.5</td>
<td>3751</td>
<td>702</td>
<td>.19</td>
<td>.34</td>
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<tr>
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<tr>
<td>12.5</td>
<td>4194</td>
<td>152</td>
<td>.036</td>
<td>.07</td>
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<tr>
<td>15.0</td>
<td>4067</td>
<td>89</td>
<td>.022</td>
<td>.04</td>
</tr>
</tbody>
</table>

100 amperes corresponds to .3 mrad deflection.

![Graph showing the relationship between SEM Enclosure 100 deflected/0 deflection and deflection in mrad.](graph.png)