AN ALTERNATIVE ACTIVITY TO STORAGE RINGS -- HIGH-INTENSITY AGS

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The title of this paper is to emphasize that the contents are more promotional than professional. Of course, raising the intensity of the AGS is a peachy idea and only makes storage rings technically more feasible. The hard facts, however, are that large technical problems are highly competitive for the finite amount of engineering manpower and even more finite number of accelerator scholars available. After observing the rather detailed study of the kinds of observations one can carry out with storage rings, made in this summer study, I have been led to consider what a comparable investment in money and invention can bring to the problems of high intensity. Let me assume that it is in fact possible, by means of a new high-energy injector, to raise the intensity of the AGS by a factor of 50 to 100. Since the quoted space-charge limit of the AGS is 2×10^{12} protons/pulse (CERN has reached 8 to 9×10^{11}), this required injection at an energy such that the space-charge limit will be 2×10^{14} protons/pulse. The simple $\beta^2\gamma^3$ dependence of the space-charge limit for a 940-Mev injector yields 1×10^{14} protons/pulse. It seems safe to assume that the increased injection energy can then lead to a beam of 2×10^{13} (safety factor of 5). It has also been mentioned that it would be relatively simple to increase the repetition rate by a factor of 2.

Let's be mildly optimistic and assume that in fact we can arrive at 2×10^{13} protons/pulse. The questions are: What will it cost? How long will it take? What physics can be done?

I. Cost

The basic assumption is that we can raise the intensity to 2×10^{13} p/sec via a 1-Bev linac similar to that under study at Yale. The Yale estimate for a 1-Bev injector is $29 million. If we compare with the estimated cost of a storage ring, this leaves approximately $30 million for shielding, remote-handling devices, AGS modernization and laboratory space and equipment to enable exploitation of the high intensity. Although these estimates are crude, they look good enough to warrant more serious study.

II. Feasibility and Schedule

There seems little question but that a 1-Bev proton linac can be built with properties suitable for an injector (peak current 50 ma, with energy spread $\lesssim .1\%$ and beam quality better than $4\pi \times 10^{-4}$ cm-radians). Since this is a very strong candidate for injection into the proposed super-high-energy machine, the sooner it is built, the more advanced we will be towards this end.

One can visualize a schedule which permits the construction of the linac behind a wall so as not to interfere with normal operation of the AGS. Concurrent developments of the AGS are spaced during the construction period, e.g., new magnet supply for faster repetition, higher power rf, new experimental areas with external-beam facilities, very intensive development of slow extraction, study (and construction) of remote-handling equipment, shielding and radiation damage problems. The main point is that these "natural developments of the AGS" are all supported by the construction budget for the new injector rather than piecemeal out of an inadequate operating budget.

The Yale construction schedule called for beam slightly more than four years after start. It may be interesting to estimate whether, with the more extensive facilities and experience at Brookhaven (plus the Yale cooperation), this could even be improved.

This time estimate is of great interest in that it will coincide with a need, at Brookhaven, for "something new". This, as opposed to storage rings, will serve to increase the flexibility of the machine and the number of experiments which can be handled. The increased beam can be used to provide four or five target areas with intense internal beams. Again, in contrast to the storage rings, such multiple-usage facilities are very much needed by university users with a mission in education as well as research. In fact, the philosophy of the storage-ring experiments is not in the spirit of the way Brookhaven operates, being very much a one-group problem. This makes it wise to consider the diversification of effort between CERN and Brookhaven, with CERN pursuing their interest in storage rings, the "window on the future", and Brookhaven exploring the (medium) high-intensity frontier.

III. Physics

A. Pions

The secondary-beam intensities which will result from 2×10^{13} protons/pulse can be estimated by multiplying present beams by ~ 100. However, for external beams, recent experiments at the AGS (μ-p scattering[1] and π form factor[2]) are consistent with a pion flux:

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1. R.L. Cool, L.M. Lederman, A.W. Maschke, A.C. Melissinos, M. Tannenbaum, J.H. Tinlot and T. Yamanouchi, to be published.
2. M.Q. Barton, D.G. Cassell, V.L. Fitch and L.B. Leipuner, private communication.

$$\frac{d^2N_\pi}{dp\,d\Omega} = .77\, p^2 e^{-p/3.1}\, e^{-p\theta/.24} \quad \text{per interacting proton,}$$

valid for pion momenta between ~ 2 Bev/c and ~ 20 Bev/c.

Thus, <u>at 0°</u> and with 10^{-3} ster, 1% $\Delta p/p$, one can have pion beams as follows:

P_π =	2	3	5	10	20	Bev/c
N_π =	$.6 \times 10^9$	1.6×10^9	2.5×10^9	4×10^9	1.2×10^9	

A plasma lens can collect for short beam operation up to .03 ster, and the $\Delta p/p$ would be determined by a subsequent magnet. Thus, for example, a 10% momentum bite at 0° would yield a 5-Bev pion beam of

$$2\pi \left[\int_0^{0.1} \theta\, e^{-p\theta/.24}\, d\theta \right] 5^3(.1) \times 2 \times 10^{13}\, e^{-5/3.1} = 4.8 \times 10^{11} \text{ pions/pulse!}$$

(over ~ 300 cm^2).

B. <u>Muons</u>

A straightforward extrapolation of the observed muon flux at ~ 6 to 8 Bev yields

$$4 \times 10^9 \text{ muons/pulse}$$

over a 10 in. diameter.

This clearly is enough to define a very high quality, pure muon beam of enormous intensity.

C. <u>Neutrinos</u>

As a specific example of the range of this facility, let us discuss neutrino experiments. CERN is now recording ~ 10 events/day at 7×10^{11} protons/pulse in the 1600-lb freon bubble chamber. The Brookhaven

80-inch hydrogen chamber would, with the same flux, see $\frac{200}{1600} \times 2 = 1/4$ times the rate (all the weight of H_2 is in protons). Thus, the new injector would permit a rate of neutrino events of $\frac{30}{4} \times 10 = 75$ events per day. This is adequate for the initiation of quantitative neutrino-nuclear scattering experiments: $\bar{\nu} + p \rightarrow n + \mu^+$. Each event can be fully analyzed as to incident energy and momentum transfer. One thousand such events would provide an exceedingly sensitive test of the structure of weak-interaction currents involved. In D_2, one can similarly look at $\nu + n \rightarrow p + \mu^-$ with a spectator proton marking the event. Truly elastic reactions can be sought with great sensitivity. Inelastic processes can be analyzed with a resolution impossible to achieve with spark chambers.

Other Beams

K^+ beams of the order of .2 to .3 of the pion beams may be expected.

K^- beams somewhat under 0.1 of the π^- yield would result in fluxes of the order of 10^7 K^-/sec suitable for counter work or ~ somewhat higher for the production of tertiary hyperon beams suitable for bubble-chamber work.

Antiproton intensities would also permit differential $\bar{p}$-p and $\bar{p}$-n reactions with adequate statistics. Stopping beams of K^- and $\bar{p}$ are intense enough to do "mesic" X-ray work with K^--p and $\bar{p}$-p atoms. Dalitz[3] has also outlined an experimental program at this intensity.

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3. R.H. Dalitz, p. 39 of this volume.

Meson Factory

The Yale group has investigated the possibility of simultaneous operation of the 1-Bev linac as an injector and as a meson factory. The fruitfulness of the meson factory is detailed in the back of the many "blue book" proposals. There seems to be no reason why a separate laboratory cannot be built to use the linac between AGS pulses. This seems to be merely a question of money and certainly adds impressively to the desirability of the proposal.

In summary, the program has a wide range of flexibility, opens a new frontier in various fields -- certainly in weak interactions. If money is available later, the storage-ring problem becomes that much easier to do -- if, at that time the possibility of 60 Bev in the center of mass is still attractive.