BNL-104715-2014-TECH

AGS/AD/Tech Note No. 299;BNL-104715-2014-IR

A HIGH INTENSITY HADRON FACILITY, AGS II

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April 1988

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U.S. Department of Energy

USDOE Office of Science (SC)

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Accelerator Division
Technical Note

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April 25, 1988

There is a large and growing community of particle and nuclear physicists around the world who are actively lobbying for the construction of an accelerator that could provide 1-2 orders of magnitude increase in proton intensity above that of the present AGS. There have been a series of proposals from Canada, Europe, Japan, and the U.S.A. They can all be characterized as machines varying in energy from 12-60 GeV and intensities of 30-100 μA. The community of physicists using the AGS are in a unique position however. The AGS is the only machine available that can provide the beams to execute the physics program that this large international community is interested in. The BNL approach to the communities interests involves a stepwise intensity upgrade program. At present the AGS slow extracted beam current is 1 μA. With the completion of the Booster in 1990 and the associated AGS modifications, the current will rise to 4 μA. With the subsequent addition of the Stretcher the current will rise to 8 μA and approximately 100% duty factor. In this note we examine the possibility of a further enhancement to a current level of 40 μA CW.

Let us first examine the capabilities of each of the present AGS accelerators. The Linac is capable of running ten pulses a second of 30 mA H^- ions with a 500 μsec pulse length. The Linac output current exceeds the input capabilities of the Booster. The Booster is capable of pulsing ten cycles a second. Because of the large power swing both in real and reactive power, the Booster is limited presently to operate at 7.5 Hz and an energy to 1.5 GeV. If the Booster were operated beyond these limits, the electrical line voltage fluctuation due to its pulsing would severely affect other parts of the Laboratory. In certain resonant situations, the entire LILCO power grid and some generating stations would be adversely effected. One way to overcome this limitation would be to pulse, out-of-phase, an equivalent electrical device as an analog to a flywheel so as to smooth the power swing. Once the power swing problem is corrected one could cycle the Booster faster and to a higher energy.

At present the AGS is capable of cycling every 1.2 seconds. The pulse rate is limited mainly by two factors. One is the limitations of the main magnet power supply and the second is the peak voltage of the present radio frequency acceleration system. Both of these can be improved. An important consideration that minimizes the scope of the improvements is that with the Stretcher used for slow extraction one no longer needs to operate the AGS with a magnetic flattop. The highest current that can be achieved is when one matches all the accelerators to the repetition rate of the Linac. Our scheme assumes that one does not replace either the Linac or the AGS. We previously mentioned the problems with the Booster power swing, AGS main magnet power supply and radio frequency systems. There are other problem areas, such as, crossing AGS transition energy with no beam losses, space charge effects, etc.

We first propose to increase the Booster energy to 2.8 GeV and the repetition rate to 10 Hz. This is below the Booster transition energy and well within the capabilities of this machine. The Booster is already designed to operate at the increased dB/dt rate. The increased Booster energy is motivated by the energy swing solution described below.

We next propose to introduce a Post Booster accelerator (see Table I) after the Booster. This machine would operate at 10 Hz and accelerate protons to an energy above the AGS transition energy. This machine would be capable of accelerating the full Booster beam pulse to an energy above 9 GeV. The Post Booster power swing could be made to complement that of the Booster and thus overcome the Booster repetition rate limitations. The AGS main ring power supply cycling limitations would also be eased due to the reduced AGS beam energy swing. By adjusting the Post Booster magnet aperture, magnetic field range and radius, the Post Booster would be designed to have the same magnetic energy difference swing as the Booster. These two machines would operate at the same repetition rate but 180° out of phase with each other. To reduce the construction costs by minimizing the number of tunnels, it would be desirable to install the Post Booster in the same tunnel as the Collector ring. The Collector ring that is introduced below requires a minimum circumference of three times that of the Booster ring. The Post Booster would thus have a circumference three times that of the Booster, 75% of the AGS. The spacing of the Booster pulses would be preserved in the Post Booster. Table II shows the proposed parameters for the Booster, the Post Booster, Collector, and the AGS. We note that the space charge intensity limit for a given normalized emittance is proportional to $\beta\gamma^2$ of the proton. Thus once one is below the space charge tune shift limit in the Booster, the space charge problem is minimal for all subsequent accelerators in the chain.

Table I
Post Booster Parameters

Injection energy	2.815 GeV (3.634 GeV/c)
Ejection energy	9.26 GeV (10.2 GeV/c)
Circumference	605.25 m
Superperiods	6
# cells	48
Cell length	12.61 m
ν_x/ν_y	12.75/11.75
Phase advance/cell	95.6/88.1 °
β_{max}/β_{min}	22/3.3
η_{max}	0.62
# long straight section/length	12/5.3 m
Dipoles	
No.	80
Length	3.8 m
Field injection/ejection	2.5 kG/7 kG
Aperture	17.96/5.84 cm
Quadrupoles	
No.	96
Length	1 m
Aperture	13 cm
Max. poletip field	5.2 kG

Table II

	Input Energy	Input $\beta\gamma^2$	Output Energy	# Bunches	# rf Buckets
Booster	200 MeV	0.833	2.8 GeV	3	3
Post Booster	2.8 GeV	14.87	9.3 GeV	3	9
Collector	9.3 GeV	117.6	9.3 GeV	12	12
AGS	9.3 GeV	117.6	30 GeV	12	12

The next accelerator in the chain is the Collector ring (see Table III). The AGS cycling limitations require the introduction of an intermediate storage ring so as not to lose the advantages of the 10 Hz capabilities of the preinjectors. The Collector would be a short term (0.4 sec) intermediate storage ring. This machine would reside in the Post Booster tunnel. The function of this ring is to temporarily store three Post Booster pulses prior to injection into the AGS (the Post Booster accelerates with only one-third of its rf buckets filled). The AGS would accept the three Poster Booster pulses (9 bunches) stored in the Collector and one additional pulse (3 bunches) directly from the Post Booster for a total of 12 bunches. The Post Booster and the Collector would inject into the AGS every 400 milliseconds. A proposed cycle for the Booster, Post Booster, Collector, AGS, and Stretcher is shown in Figure 1. Potential locations for the proposed Accelerators are shown in Figure 2. We show in Table IV the estimated proton currents at various implementation stages of the above-mentioned proposal. The delivered currents are for slow extracted beam operation.

Table III
Collector Ring Parameters

Energy	9.26 GeV (10.2 GeV/c)
Circumference	605.25 m
Superperiods	6
# cells	30
Cell length	20.175
ν_x/ν_y	7.25
Phase advance	87 °
β_{max}/β_{min}	34.1/6.3 m
η_{max}	3.3 m
straight section	12/9 m
Dipoles	
No.	96
Length	3.55
B	6.26 kG
Aperture	14/5 cm
Quadrupoles	
No.	60
Length	0.5 m
Aperture	11 cm
Poletip	5.1 kG

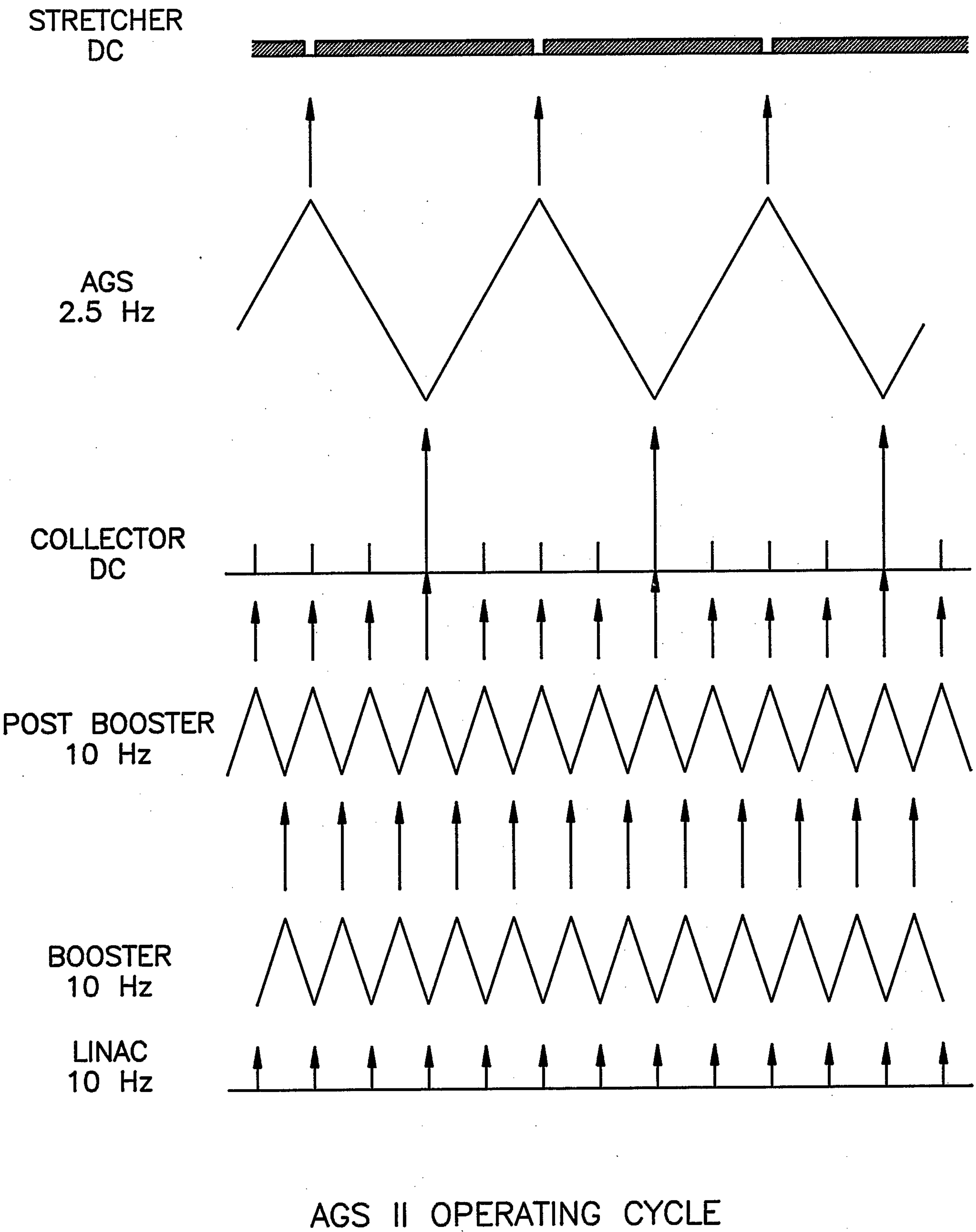

Figure 1. Accelerator Cycles

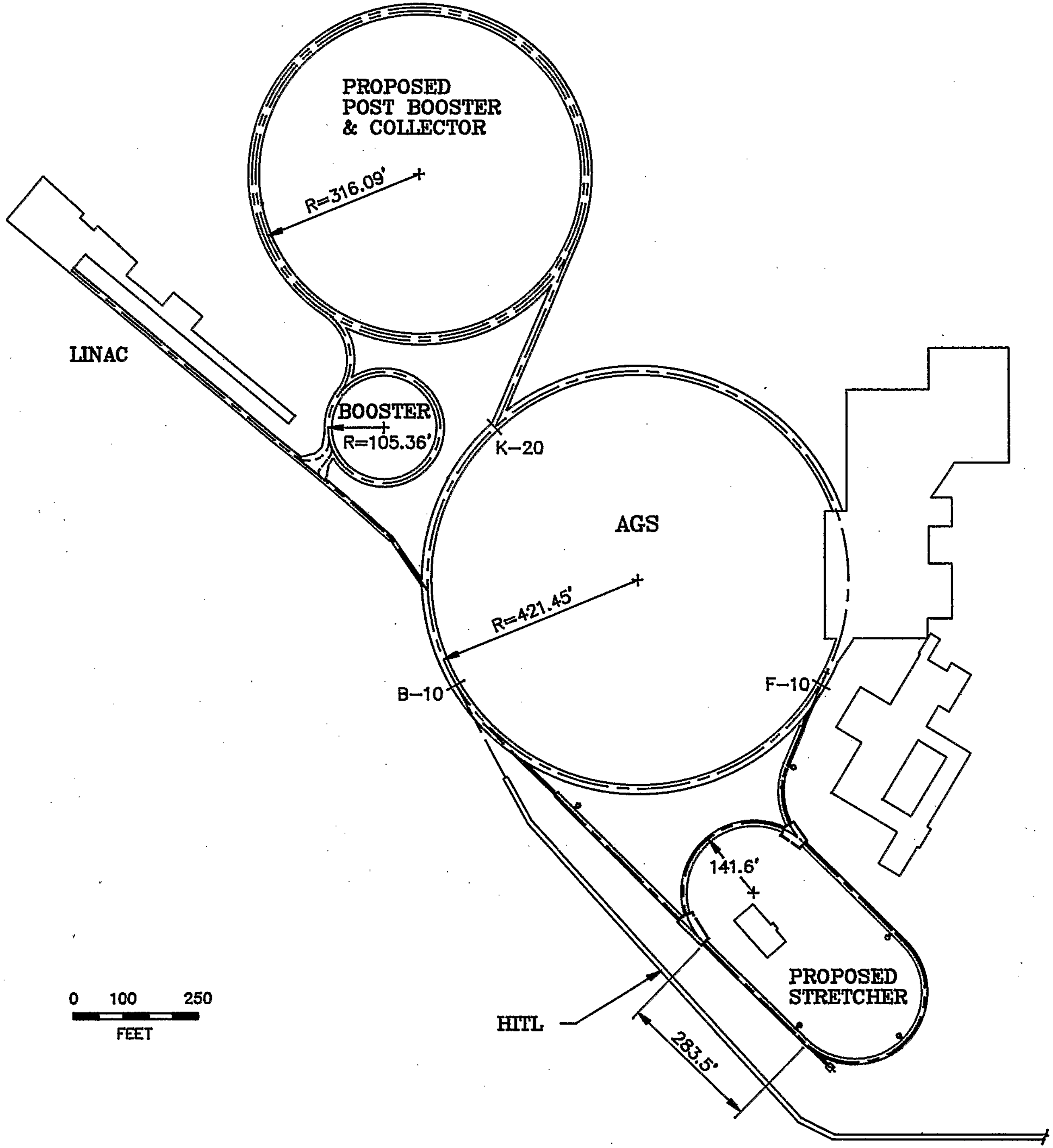

Figure 2. Accelerator Complex Layout

Table IV

Option	AGS Protons per pulse	AGS Cycle Time (sec)	Duty Factor (%)	Delivered Current (μA)
AGS	1.5×10^{13}	2.5	35	1.0
+ Booster	6×10^{13}	2.5	35	4.0
+ Stretcher	6×10^{13}	1.2	100	8.0
+ Post Booster and Collector	2.5×10^{14}	0.4	100	40.0

The proposed scheme utilizes every Linac pulse and thus there is no advantage to accumulate polarized protons in the Booster. The higher ejection energy however requires the crossing of one intrinsic depolarizing resonance at 1.57 GeV in the Booster. We have not calculated the depolarizing effect of this resonance nor yet considered a resonance crossing scheme. The Post Booster and the Collector, would be designed to avoid serious depolarizing resonances. For heavy ion operations we would consider moving the final electron stripping foil from the Booster to the Post Booster extraction line. For the heaviest ions the beam intensity would increase due to the larger stripping efficiencies at higher energy.

We have presented one of several possibilities for the evolution of the AGS complex into a high intensity hadron facility. One could consider other alternatives, such as using the AGS as the Collector and constructing a new 9-30 GeV machine. We believe the most responsible scenario must minimize the cost and downtime to the ongoing physics program. With a stepwise approach, starting with the Booster, the physics program can evolve without a single major commitment in funds. At each step an evaluation of the funds versus physics merit can be made. As a final aside, each upgrade at the AGS and Booster is presently being implemented to support an interleaved operation of both protons and ions.