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ALTERNATING GRADIENT SYNCHROTRON FACILITY AND PHYSICS* PROGRAM

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ABSTRACT

We present a description of the present and future plans for the BNL Alternating Gradient Synchrotron accelerator complex and its concomitant physics program.

The Alternating Gradient Synchrotron (AGS) has been in operation 30 years providing proton and polarized protons for the high energy physics program and in addition for the past 5 years providing heavy ions for the nuclear physics program. With the enviable record of three Nobel Prize experiments: J/ψ discovery (1976), CP violation (1980), 2 neutrinos discovery (1989), the AGS has embarked on an ambitious physics program to look for physics beyond the Standard Model. The major emphasis has been on rare kaon decay experiments of which the first round will be completed at the end of the present running cycle and the second phase preparations are well underway. As an example, the present experiments have reached branching ratio sensitivities of 5×10^{-11} for the decay $K^0 \rightarrow \mu e$ and have measured a branching ratio of $\sim 7 \times 10^{-9}$ (750 events) for the decay $K^0 \rightarrow \mu\mu$. Figure 1 summarizes the present status of both the completed and to be run kaon decay experiments. The experiment that is measuring the Standard Model allowed decay $K^+ \rightarrow \pi\nu\bar{\nu}$ is expected to reach the range of model predictions during their next phase and the experiment

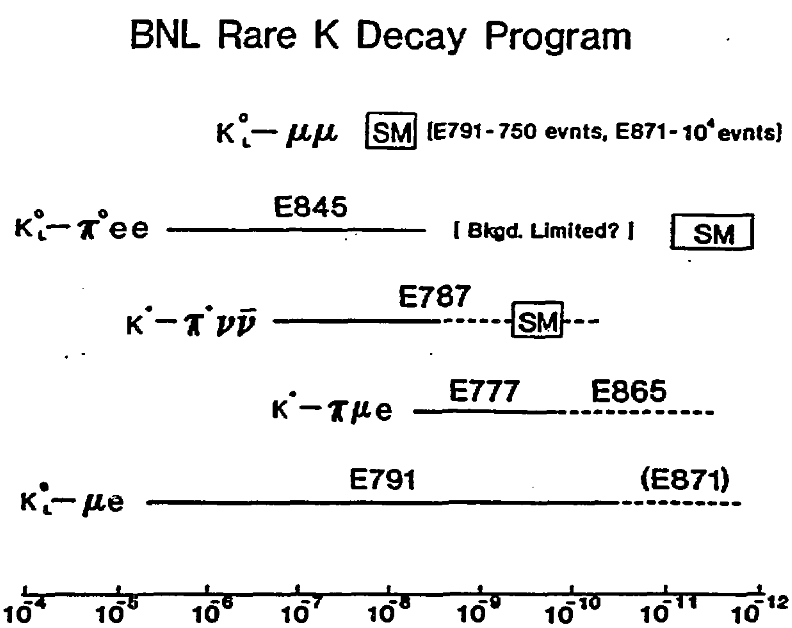

Fig. 1. Branching ratio sensitivities for AGS rare kaon decay experiments. Solid lines are reported results, dashed lines are expected results.

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that has measured the decay $K^0 \rightarrow \pi ee$ indicates that an irreducible background from the internal bremsstrahlung in K^0 Dalitz decays, $K^0 \rightarrow \gamma\gamma ee$, will limit the search to sensitivities to the order of 10^{-10}. This is one to two orders of magnitude greater than theoretical predictions.

The high energy physics program is not just limited to the study of kaons however. A significant effort is being expended to measure the muon anomalous magnetic moment to an accuracy of 0.35 ppm. This is a factor of 20 greater sensitivity than the previous CERN measurement and will place serious limitations on theoretical constructs within and beyond the Standard Model. The major construction effort is a 3 GeV/c storage ring. This storage ring consists of a single 15 meter diameter superferric dipole magnet. Figure 2 is a photograph of one of 4 superconducting coils that will make up this magnet/storage ring, the largest continuously wound superconducting magnet ever fabricated.

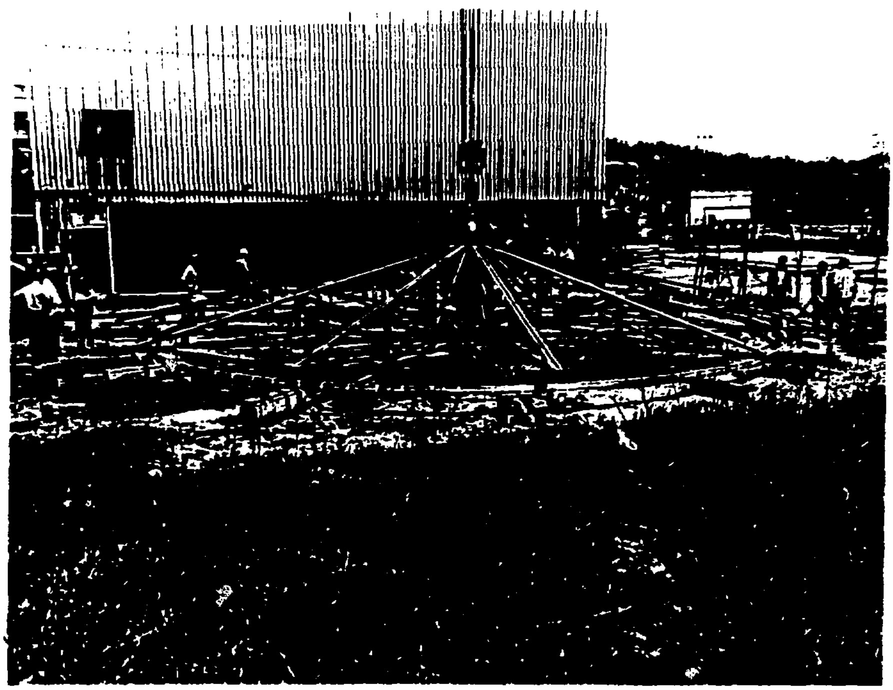

Fig. 2. Photograph of one of four 15 m diameter g-2 storage ring superferric coils.

In addition, the program includes experiments to search for glueballs and other exotica in both charged and neutral final states, hypernuclear spectroscopy, color transparency measurements, H dibaryon search, kaon scattering, spin physics with polarized protons, antiproton-nucleus reactions, muonium to antimuonium conversion, antiproton imaging for medical applications and muon spin rotation for condensed matter physics.

In the area of nuclear physics the heavy ion physics program has entered a virgin physics domain and is in the process of characterizing the nature of the interactions and searching for evidence of the quark gluon plasma and the production of strangeness enriched matter (strangelets). This part of the experimental program is the natural lead-in to the next generation of experiments to be performed at the Relativistic Heavy Ion Collider (RHIC) starting in 1997.

The future AGS and RHIC programs are very dependent on the performance of the new AGS injector, the Booster synchrotron, which is presently being commissioned. During the extremely short running time available this year for accelerator operations, the Booster has been brought on in less than 7 days of beam time. In this short period the injection, beam capture, acceleration and extraction aspects have been brought to an operational state. During the next running cycle in 1992, we expect to complete the injection into the AGS, and to accelerate gold ions for the first time. All of the initial work was accomplished with protons. The Booster was designed to accomplish three major objectives. These are to increase the AGS proton intensity by a factor of 4 to a minimum of 6×10^{13} protons per second, to accelerate all ion species and to increase the polarized proton intensity by a factor of twenty to the order of 10^{12} per pulse. The Booster specifications are described in Figure 3. The Booster is the linchpin of the future development of the AGS and RHIC accelerator facility. See Figure 4 for an aerial overview of he accelerator complex.

BOOSTER MAJOR DESIGN PARAMETER LIST

CIRCUMFERENCE	**201.78 m (1/4 AGS)**
AVG. RADIUS	**32.114 m**
MAGNETIC BEND RADIUS	**13.75099 m**
NO. OF PARTICLES/PULSE	**Protons, 1.5×10^{13} (AGS 6×10^{13}ppp)** **Polarized Protons, 10^{12}** **C S I Au** **54 15 6.6 3.2×10^{9} ions**
LATTICE TYPE	**Separated function, FODO**
NO. OF SUPERPERIODS	**6**
NO. OF CELLS	**24**
BETATRON TUNE, X, Y	**4.82, 4.83**
NUMBER OF MAGNETS	**36 Dipoles, 48 Quads**
MAGNET TYPE	**Iron-Dominated, Water-Cooled Cu Conductor**
DIPOLE LENGTH (Magnetic/Physical)	**2.4/2.34 m**
MAXIMUM DIPOLE FIELD	**5.46KG (for Protons)**
MAXIMUM DIPOLE FIELD	**12.74KG (for heavy ions)**
QUAD LENGTH (Magnetic/Physical)	**0.50375/0.472 m,**

VACUUM CHAMBER DIMEN.	70 X 152 mm, Dipoles 152 mm (Circular), Quads
ACCELERATION TIME	62 ms, Protons and Polarized Protons 500 ms Heavy Ions
REPETITION RATE	7.5Hz (4 Pulse/AGS Pulse), Protons 1Hz (1 Pulse/AGS Pulse),Polarized Proton 1Hz (1 Pulse/AGS Pulse), Heavy Ions
INJECTION KINETIC ENERGY	200 MeV (Proton) 4.688 MeV/Nuc (S) 1.066 MeV/Nuc (Au)
EJECTION KINETIC ENERGY	1.5 GeV (Proton) 0.967 GeV/Nuc (S) 0.350 GeV/Nuc (Au)

Fig. 3. Booster major design parameters.

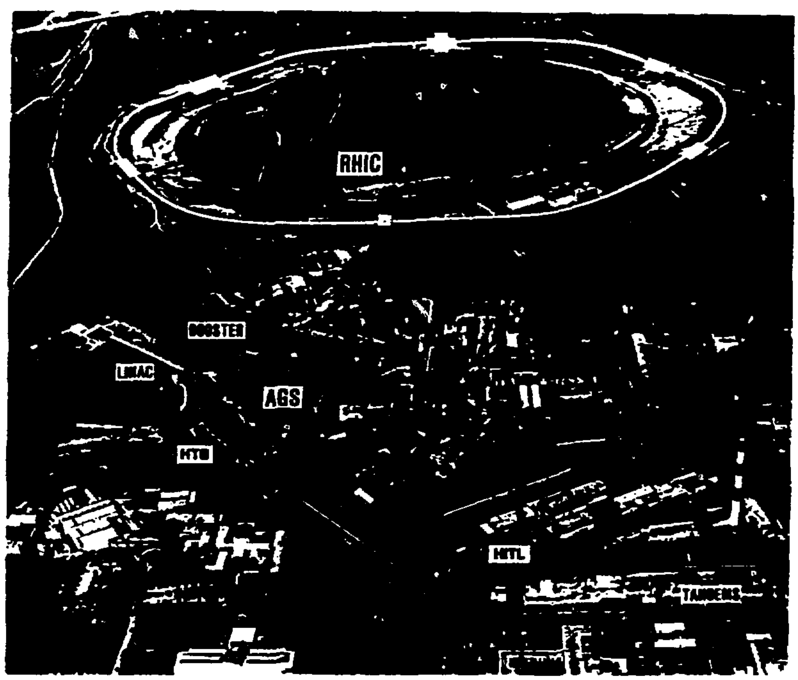

Fig. 4. AGS and RHIC accelerator facility aerial view.

With this marked increase in accelerator capabilities and a large and growing user demand, the experimental areas have been undergoing a major rebuild over the past several years. A new 2 GeV/c separated kaon beam and surface muon beam have recently been completed. A new low energy separated beam (< 1 GeV/c), a 6 GeV/c kaon beam, a new primary proton target station and 3 GeV/c pion beam, a new neutral kaon beam and a new heavy ion primary beam are under construction. In parallel with the beam transport are the new detectors such as for the rare kaon decays, muon g-2, color transparency, strangelet production, etc. The basic beam parameters are summarized in Figure 5.

After the first 30 years the question is where does the AGS facility go from here? The initial answer is that the approved and anticipated high energy and nuclear physics program will continue to at least the initial operations of RHIC, whereupon the AGS will serve an additional role as the injector to the collider. The expectations by the Laboratory and funding agencies is that the fixed target program would continue beyond that time provided that the physics merits it. We expect to also enhance the spin physics efforts at the AGS with the introduction of a partial Siberian snake to eliminate the presently too costly and time consuming process of tuning out depolarizing resonances. This would then naturally lead to the introduction of Siberian snakes in RHIC to provide for colliding polarized proton beams at total energies of 500 GeV. Finally, should the Canadian KAON initiative not be realized, we expect to submit a proposal to construct a 30 GeV/c Stretcher ring to provide for 10 μA of proton current with 100% duty factor. This AGS kaon factory would be a cost effective alternative for the physics community.

AGS BEAMS (January 1991)

Separated Beams for General Use

Beam	GeV/c	p/p(%) (FWHM)	Prod. Angle	(mr)	Flux/10^{12} protons on target: K^+	K^-	p	$\bar{p}$	pi^+	pi^-	@ GeV/c	Purity	Remarks
B2,B4	1.5-6(K) 1.5-9($\bar{p}$)	5	3°	0.3	$2.7x10^5$	$1.2x10^5$	$2x10^7$	10^5	$4x10^7$	$3x10^7$	4	pi-/K-3 pi/pi- 3/4	To MPS
C2,C4	<1.1	4	10.5°	2.6	$9x10^4$	$3.2x10^4$	$2x10^7$	$2x10^3$	$8x10^7$	$8x10^7$	0.75	pi-/K-~10	L=15m.Remove after FY91 run
C2',C4'	<0.8	4	0	12	$3x10^5$	$1x10^5$	$1x10^8$	$1.4x10^4$	$6x10^8$	$8x10^8$	0.80	pi+/K < 1	L=18m.Construction FY91-92
C6,C8	<0.8	5	5°	10.0	$3x10^5$	$1.0x10^5$	$1.0x10^8$	$1.4x10^4$	$6x10^8$	$6x10^8$	0.7	pi-/K- -5	L=15m.
D6,D8	1.0-2.0	6	5°	1.6	$1.1x10^6$	$0.5x10^6$	$2x10^7$	$5x10^5$	$6x10^7$	$5x10^7$	1.8		L=31m.Commission in FY91
Unseparated Charged Beams													
A1	5-28	3	0°	0.2						10^6	22		To MPS:L=130m
A2	1-10	5	12°	0.3			$3x10^6$		$3x10^6$		2		Test Beam.
A3	1-28	4	0°	0.10			$6x10^7$		$1x10^7$	$4x10^6$	14		Test Beam,commission in FY91 Alternates with A1, can transport heavy ions
B1	5-28	3	0°	0.?5			$3X10^7$		$6X10^6$	$2X10^6$	14		Primarily heavy ions.
C1	1-20	5	0°	0.8	$6x10^6$	$7x10^5$	$2x10^8$	$1.4x10^5$	$7x10^7$	$5x10^7$	13		L=81m, or with C5
C5	1-28	2	0°	0.15			$1x10^7$			13			L=81m, Primarily heavy ions
Neutral Beams								K_L	n				
B5	2-15		1-4.5(V)	0.1				$5x10^7$	$3x10^8$		2-15		Based on E791 est:L=10m.
Muon Channel					mu^+								
D2,D4	.025- .15(mu)	9(pi±) 30(mu)	135° (pi±)	24(pi±)	$2x10^5$ 10^3 surface						0.20	e^-/mu^- = 8	Possible commissioning in FY91
Neutrino Beams					Neutrinos			Antineutrinos					
U line					$2x10^9/m^2$ $10^7/m^2$			$1.4x10^9/m^2$				$1.4x10^{13}$ ppp typical on target	Fast spill,flux avg over 1.5m radius Wide Band Horn,$<E_{nu}>$=1.4GeV/c Narrow Band Horn. $<E_{nu}>$=1.3GeV/c deltaE/E = ± 15%
					pi^+			mu^+					
V1 line 3.0		0.6	0°		$3.2x10^7$			$4x10^3$			3.0		Fast spill for injection into g-2 ring, available FY1993

Note that 0° beams can be used for polarized protons and/or heavy ion beams.

Fig. 5. AGS experimental area beamline specifications.