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THE AGS FIXED TARGET PROGRAM WITH NUCLEAR BEAMS *

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A. Introduction

The recent approval of the beam transfer line from the Tandem Van de Graaf to the AGS signals the advent of a new era of Nuclear and Particle Physics at BNL. High Energy nuclear beams are expected to be available for experiments in 1986.

A photograph of the BNL site is shown in Fig. 1.

Figure 1: A photograph of the BNL site. The Tandem accelerator and the AGS are in the foreground.

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I will discuss only the direct link between the Tandems and the AGS. Two other proposed projects, the Relativistic Heavy Ion Collider and the Synchrotron Booster, are discussed in another presentation to this conference.¹

B. The Accelerators²

The plan is to transport full stripped ions from the Tandem machines to the AGS at an energy of 8.A MeV. They will then be accelerated in the AGS to an energy of up to 15.A GeV before extraction for use in up to four simultaneous experiments.

Pulsed beams with the required characteristics have been produced at the Tandems for nuclei up to sulphur; for larger z , higher energy is required to produce sufficiently intense beams of fully stripped ions; a future booster for the AGS would produce such capability. The transporting of the beam from the Tandem to the AGS requires an 1800-foot-long tunnel, with eight quadrupole doublets to keep the beam focussed. The tunnel is of modest size (≈ 10 foot wide) with sufficient space for servicing the various magnet and vacuum systems. The AGS magnetic field required at injection is substantially lower than that currently used for proton beams, but is only 20% lower than that used with the original 50 MeV proton linac; no serious problem is anticipated in achieving the required field. Also, because of the lower injection energy, the present RF system does not have a large enough frequency swing, but the original AGS RF system is available and is being modified to accelerate from Tandem energies to the point where the usual RF can be used. The use of two RF systems is considered a safer route than an alternate scheme involving harmonic switching.

The maximum energy available in the AGS is 15.A GeV and fluxes will range from 4×10^{10} particles per pulse for oxygen to 6×10^8 particles per pulse for sulphur. The duty factor will be ≈ 0.4 (1 sec flat top every 2-1/2 seconds).

The existing external beam system delivers simultaneous beams in the A, B, C, and D lines. Each beam line has the capability of delivering primary beam particles to at least one experimental area and can therefore be used for experiments with nuclear beams. However, since the program with nuclear beams will supplement the existing High Energy Physics research, care will be required to mesh together the two programs.

C. Experiments

Extensive efforts are currently under way in the study of possible experiments with nucleus-nucleus collisions. It is expected

that during this summer several experiments will be proposed to the AGS Program Committee ("APC", formerly known as HEAC) requesting running time for first-round experiments in 1986. The people involved in these studies include scientists from Nuclear Physics, Particle Physics and Chemistry at BNL as well as many from outside institutions. I will not attempt a comprehensive review, but will mention a few of the potential experiments.

1. Single Arm Spectrometer³

The goal is to measure particle production cross sections in the central rapidity region, corresponding to angles in the lab of $5^\circ - 20^\circ$. A possible setup is shown schematically in Fig. 2. The

Figure 2: A possible arrangement of the single-arm spectrometer.

solid angle will be about 10 millisteradians. A set of Cerenkov counters and time-of-flight counters will be used to identify p , $\bar{p}$, $\pi^\pm$, $K^\pm$. Because of the high multiplicities expected in head-on collisions, up to 15 charged particles are expected at small angles even for a 10 ms solid angle, so sophisticated tracking detectors will be required. Additional detectors (probably streamer tubes) will be used to measure outgoing charged particles over a large solid angle (approaching 4π). This will permit the measurement of overall multiplicity and the distribution in pseudo-rapidity associated with particles detected in the spectrometer. The use of a 0° calorimeter is also envisioned.

2. Multiparticle Spectrometer

The Multiparticle Spectrometer (MPS), a user facility in the BNL High Energy Physics program, is a large solid-angle detector based on a C-magnet with a pole area 6 ft. x 15 ft. with a 4 ft. high gap. Typically it has been used for detailed study of events produced by pions and kaons in the momentum range 5 - 25 GeV/c. The detectors currently in use are narrow cell drift chambers⁴ designed for high beam rates (few $\times 10^6$ /sec) and multiplicities of ≤ 15 ; these criteria are well-satisfied by drift chambers using projective geometry rather than true "3D" detectors. Several large multi-cell Cerenkov counter hodoscopes are available and a large time-of-flight scintillation counter hodoscope is under construction.⁵ Various sophisticated triggering systems are also available.⁶

In order to assess the usefulness of the present MPS in the Heavy-ion Program, events produced by the Hijet⁷ Program have been superimposed on the MPS. A typical minimum-bias centrally-produced event, O^{16} on Au at 15.8 GeV, is shown in Fig. 3 (a plan view, looking along the magnetic field). The charged particle multiplicity is - 130.

Figure 3: A simulated event superimposed on the MPS.

We conclude that the existing system is not the correct approach for full reconstruction of events of such high multiplicity (although, as will be mentioned later, we can configure the present MPS for use as a very large aperture spectrometer for the negative particles in such events). Instead we propose to build a new detector system based on 3D point measurements to handle the high multiplicities, with a goal of angle measurements for virtually all charged particles, momentum measurement for charged particles emitted forward in the lab frame, and particle identification for charged particles exiting from the MPS magnet.

The setup is shown schematically in Fig. 4. The angles (and hence pseudorapidity, η) of outgoing charged particles will be

Figure 4: A possible arrangement for experiments with nuclear beams at the MPS.

measured in an array of charge-coupled-devices (CCD's) surrounding the target. These detectors are admirably suited to the purpose. Recent measurements at CERN⁸ have demonstrated that CCD detectors can measure minimum ionizing particles with high efficiency ($98\% \pm 2\%$), extremely good resolution ($5\mu\text{m}$) and good two-particle separation ($40\mu\text{m}$). With a typical active size of 1 - 2 cm, one has an effective segmentation of $> 50,000$ elements per plane with true (x,y) point readout. A potential problem of errors due to particles traversing the detector during readout will be obviated by kicking the beam on to a beam-stop when a trigger is selected -- this is a relatively

simple task at the beam rates ($\sim 10^4/\text{sec}$) envisioned for this spectrometer.

The strongest candidate for the new detectors in the magnet are Time-Projection Chambers (TPC's). Such a detector would drift electrons along the magnetic field, measuring x by knowledge of the detector elements involved and y by the drift time. In order to make use of the full magnetic field length while keeping both the budget and construction problems manageable, we expect to build a set of relatively thin modules each with perhaps four measurements along the tracks. A possible geometry is shown in Fig. 5. Electrons produced

Figure 5: A schematic layout of a TPC for Heavy Ion experiments.

by charged particles in the gas drift up and down away from a negative high voltage electrode near the median plane and are measured by PWC (or multistep avalanche chambers) with short wires parallel to the beam direction at the top and the bottom of the TPC. These detectors are very similar in principle to those in use in the "RICH" counter at the Omega Spectrometer at CERN.⁹ One should note that a potential problem due to positive ion buildup from the very high dE/dx of non-interacting beam particles is eased by the proximity of the beam to the negative HV terminal. If we assume a two-particle separation of 1 cm, a somewhat pessimistic value, an effective segmentation of 20,000 elements is achieved in a 2 m x 1m chamber.

Particle identification can be achieved in the downstream region with two Cerenkov counters and a time-of-flight hodoscope. With the Cerenkov counters set at $\gamma_c = 10$ and 20 and a flight path of 10 m $\pi K p$ separation can be achieved from 1.4 to 10 GeV in one setup. Of course, at low momentum large corrections will have to be made for kaon decays.

As a first phase, to be run in 1986, we propose to use the existing MPS, augmented by a few TPC modules, to study the production of negative particles over a very large solid angle. We will bring in the incident beam alongside the MPS chambers, using the magnetic field to sweep positive particles away from the detectors. In addition to supplying information on the momentum spectra of π^- , K^- , $\bar{p}$ and the correlations therein, we can search for unusual energy flow patterns etc. We also plan to complete a CCD vertex detector in time for this run to give information on multiplicities and pseudorapidity. The knowledge and experience gained will be extremely valuable as we proceed with the full spectrometer.

3. π^0 Production

As is described in a paper¹⁰ presented to this conference, the production of π^0 's in $\alpha - \alpha$ collisions at the ISR continues to higher E_T than is predicted by models based on independent nucleon collisions. An experiment presently being considered¹¹ will use a lead-glass hodoscope to extend these measurements to heavy nuclei at the AGS in a very sensitive probe of collective effects in nuclear collisions. Studies are under way to see if this equipment can be set up in combination with the single arm spectrometer discussed above.

4. ϕ Meson Production

The use of a two-arm spectrometer to study ϕ meson production is being considered.¹² Since the ϕ is almost pure $s\bar{s}$ in quark content it should prove a sensitive probe of enhanced strange quark production - also, it's narrow width increases the probability of its detection in the K^+K^- decay mode. Possible experimental arrangements are being discussed.

5. Lepton Production

There is much discussion of the measurement of lepton pairs as a volume-sensitive probe in nuclear collisions. Because of the beam energy available at the AGS, muons from low mass produced near rest in the center-of-mass are in a region not easily accessible to detection; their low energy (and resultant short range) forces the use of relatively thin pion absorbers with a consequent worsening in

the identification of muons. Studies are also under way on measurement of electron-positron pairs; here one has to face a charged particle multiplicity of greater than 100 as well as spurious pairs produced by 50 or so π^0 's. Clearly, some good new ideas are needed!

D. Users Organization

A "Heavy Ion Users Group" has been established which is expected to function in a way very similar to the general AGS Users Group, HEDG, by being the contact surface between heavy ion users and the Brookhaven Laboratory management. An Executive Committee has been appointed by the Chairman of the BNL Physics Department, consisting of:

Peter Braun-Munzinger, (Chairman) SUNY-Stony Brook
 Eric R. Cosman, Massachusetts Institute of Technology
 Ole Hansen, Brookhaven National Laboratory
 Tom Ludlam, Brookhaven National Laboratory
 Leon Madansky, Johns Hopkins University
 Franz Plasil, Oak Ridge National Laboratory
 Julia A. Thompson, University of Pittsburgh (member of HEDG Executive Committee)
 James Symons, Lawrence Berkeley Laboratory

Among other things, the charge of this committee is to set up an infrastructure for the users organization and to arrange for the election by the users of the next Executive Committee.

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