ACCELERATOR COMPLEX FOR A RADIOACTIVE ION BEAM FACILITY AT ATLAS

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Since the superconducting heavy ion linac ATLAS is an ideal post-accelerator for radioactive beams, plans are being developed for expansion of the facility with the addition of a driver accelerator, a production target/ion source combination, and a low q/m pre-accelerator for radioactive ions. A working group including staff from the ANL Physics Division and current ATLAS users are preparing a radioactive beam facility proposal. The present paper reviews the specifications of the accelerators required for the facility.

I. INTRODUCTION

There is much enthusiasm in the nuclear physics research community for the opportunities for studies which would be enabled by an advanced, high intensity accelerated radioactive beam facility based on the isotope-separator on-line (ISOL) method. There are recent reports from both North American and European study groups [1,2]. A group including many ANL Physics Division staff and ATLAS outside users has discussed the research possibilities and prepared a working paper entiled “Concept for an Advanced Exotic Beam Facilitty Based on ATLAS.” This paper is available on the World Wide Web at the ANL Physics Division home page (http://www.phy.anl.gov). This paper summarizes the accelerator complex proposed in the working paper.

A schematic layout of the conceived facility is shown below in Fig. 1. The existing ATLAS accelerators and experimental facilities are in the lower part of the figure, and the proposed driver linac, production target area, mass separators, new low energy experimental areas, and post accelerator injector are in the upper part.

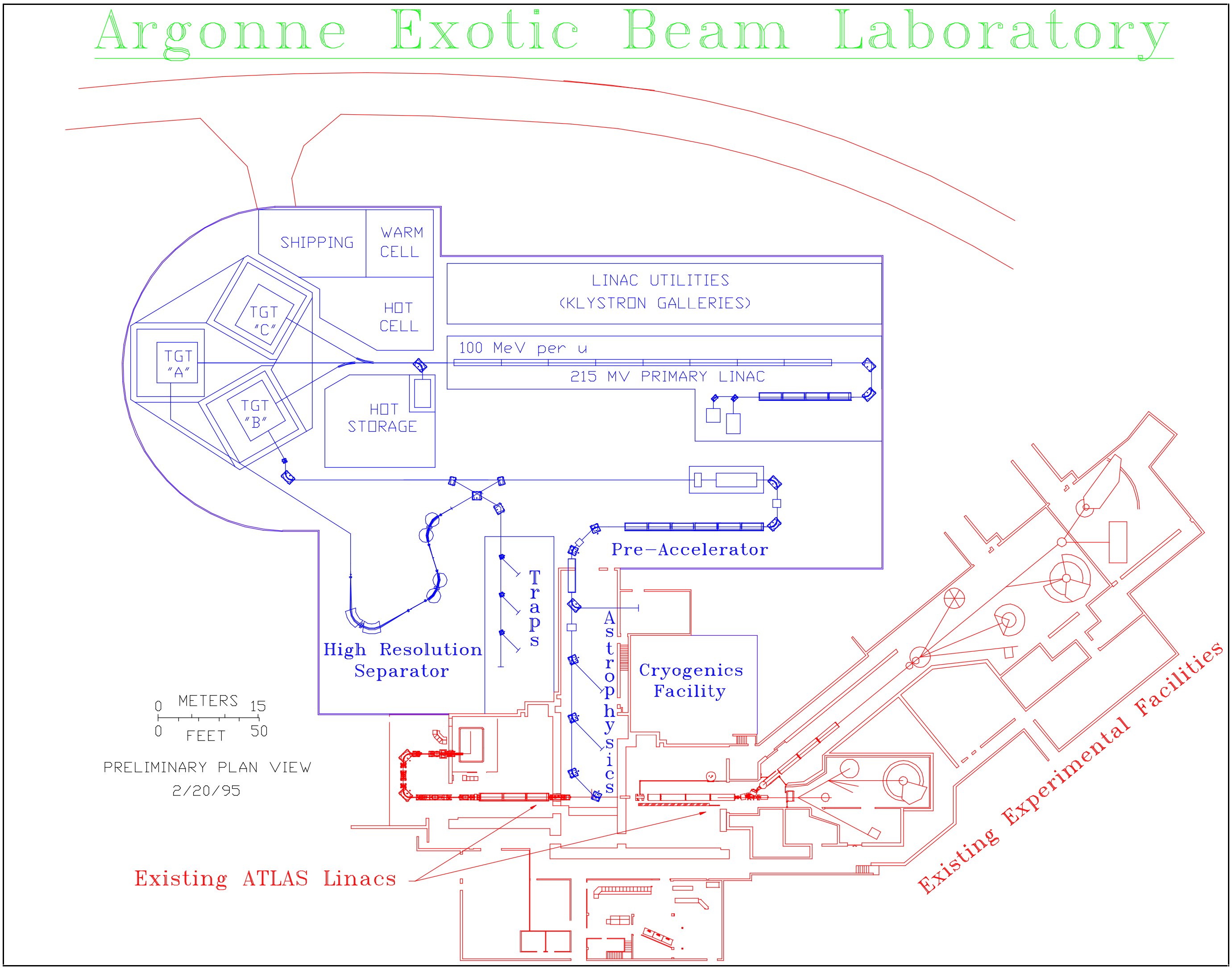

Figure 1. Schematic layout of the present ATLAS accelerators and experimental facilities (lower part of the figure) and the proposed additions to the facility (upper part).

Table I. Beam parameters of the Production Linac

Max Output Beam Energy:	100 MeV per nucleon^{sss}
Max Output Beam Power:	100 kW
Typical Light Ions (multicusp ion source):	^{1}H, ^{2}H, ^{4}He
Typical Heavy Ions (pulsed ECR ion source):	^{12}C$^{2+,6+}$; ^{16,18}O$^{3+,8+}$; ^{20,22}Ne$^{4+,10+}$; ^{36}Ar$^{6+,16+}$
Typical Max. Light Ion Currents @100 kW:	^{1}H, 1000 pμA; ^{2}H, 500 pμA; ^{4}He, 250 pμA
Typical Max. Heavy Ion Currents @100 kW:	^{18}O^{8+}, 55 pμA; ^{36}Ar^{16+}, 28 pμA
Typical Heavy Ion Source/Stripping Limits:	^{18}O^{8+}, 20 pμA; ^{36}Ar^{16+}, 3 pμA

As indicated in Fig. 1 the new components for the radioactive beam laboratory will be constructed in a new building just north of the present ATLAS facility. Radionuclides are produced by irradiating targets in well-shielded areas with light ion beams from a modern drift tube linac. The present plan is for the primary linac and production targets to be located below grade level to assist with shielding prompt neutron radiation. Using standard ISOL (Isotope Separator On-Line) target/ion source techniques the radionuclides are extracted and ionized, mass separated, and then sent either directly to an experimental area for research with ion or atom traps, or on to the secondary-beam accelerator. All secondary beamlines will be at the elevation of those in the existing ATLAS facility. Acceleration of these very low q/m ions requires a sequence of three new subsystems: a short, low-frequency RFQ and two new sections of superconducting linac optimized for these low charge-state ions. After initial acceleration to the 0.5-1.0 MeV per nucleon energy range the secondary beams can be delivered to a new experimental area for astrophysics experiments (labeled “Astrophysics”, in Fig. 1). This area is in the existing ATLAS building, in the room presently occupied by the tandem injector for ATLAS. For further acceleration to the 1 to 15 MeV per nucleon range, the beam merges into the present ATLAS beamline at the south end of this room. The capability of ATLAS to accelerate stable beams will remain independent of the added radioactive beam capability, both during construction and afterwards.

Table II. Driver Linac Specifications

Injector RFQ/Linac:	5 MeV/u output @ q/m ≥ 1/6, (30 MV)
Main Linac:	100 MeV/u output @ q/m ≥ 8/18, (215 MV)
Duty Cycle:	2% @ 120 Hz
Input Power:	1 MW
Output Energy Variability:	15% increments
Controls:	Pulse-pulse ion source and energy variation possible

II. PRODUCTION METHODS

The basic concept is to use a conventional drift-tube linac with 100 kW beam power available for a variety of light ions as indicated in Table I. The essential specifications of the driver linac are given in Table II.

Secondary beam intensities have been calculated using a variety of production mechanisms, proven target/ion source methods where known [3], and the efficiencies of bunching, stripping, etc. in the post acceleration. A table of specific beam intensity predictions for this facility is given in the working paper discussed above. A common problem for many second-generation radioactive beam facilities is learning to deal with very high power densities in the production targets. A large collaboration is currently preparing to test a new geometry target system with a 100 kW, 800 MeV proton beam at the ISIS accelerator at the Rutherford Laboratory[4]. Continued R&D on high power targets and associated ion sources is important for advanced radioactive beam facilities worldwide.

One production mechanism which has been investigated for this facility is indicated schematically in Fig. 2. This method separates the issue of the primary target which must dissipate the 100 kW beam power from that of the isotope production target/ion source combination. Quantitative yields from such a geometry were measured recently by an ANL/MSU collaboration using a low intensity, 200 MeV deuteron beam at the NSCL. Yields of a variety of short-lived fission products, including ^{132}Sn, were determined. Scaling the measured yields to a 0.5 mA deuteron beam and a 100 g/cm^{2} secondary uranium target gives a ^{132}Sn production rate in the ion source/target system of 10^{13}/sec.

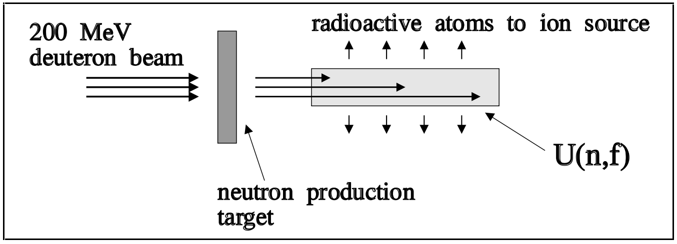

Figure 2. A conceptual layout showing the basic idea of using a 200 MeV deuteron beam to generate an intense secondary beam of neutrons for the production of fission fragments. This separates the problems of the high power in the primary beam from the secondary target/ion source system.

	Worksheet for the Secondary Beam Accelerator for the Argonne Exotic Beam Laboratory									
Driver Accelerator:				200 MV Linac, q/m=0.5, 100 kW beam power, 120 Hz						
Radioactive Beam Accelerator:					^{132}Sn Example		A=	132		
Voltage				Accel.						
gain	q	T/A	velocity	length	efficiency	efficiency	intensity	intensity	Device:	Comments:
(MV)		(MeV/A)	(v/c)	(m)	(this step)	(cumulat.)	(ions/sec)	(part. na)		
							1.0E+13		primary production rate	100 g/cm^2 UC target
0.1	1	0.0008	0.0013		0.03	0.030	3.0E+11	50.0	ion source & release	4π mm-mr
					0.80	0.024	2.4E+11	40.0	isobar separation	resolution ~30,000.
0.3	1	0.003	0.003	1.0	1.00	0.024	2.4E+11	40.0	onto HV platform	
					0.65	0.016	1.6E+11	26.0	prebunch/rebunch	
1.0	1	0.011	0.005	2.0	0.95	0.015	1.5E+11	24.7	RFQ on HV platform	12 MHz RFQ
-0.3	1	0.008	0.004	1.0	1.00	0.015	1.5E+11	24.7	leave HV platform	
0.0	2	0.008	0.004		0.40	0.006	5.9E+10	9.9	strip and rebunch	Gas stripper
2.0	2	0.039	0.009	2.0	0.95	0.006	5.6E+10	9.4	24 MHz linac	SC folded resonator
30.0	2	0.493	0.033	15.0	0.95	0.005	5.4E+10	8.9	48 MHz linac	PII-type, 4 gap
	20	0.493	0.033	1.0	0.20	0.0011	1.1E+10	1.8	strip to q/m=0.15	Foil stripper
	20	0.493	0.033	2.0	1.00	0.0011	1.1E+10	1.8	rebunch	
4.0	20	1.099	0.049	3.0	0.95	0.0010	1.0E+10	1.7	72 MHz matching linac	PII-type, 4-gap
40.0	20	7.160	0.123	25.0	0.90	0.0009	9.1E+09	1.5	out of ATLAS	existing accelerator

The spreadsheet shown above starts with these measured/scaled yields for ^{132}Sn in the production target and then lists the various ionization, bunching, acceleration, and stripping stages of the ISOL and secondary beam complex to illustrate, for a specific example, the predicted beam intensity for this facility. In this example the 3% efficiency for the combined release and ionization of the target/ion source is the established value for Sn isotopes given in reference [3]. Recently developed laser ionization techniques [5] have the potential to increase this number by more than an order of magnitude.

III. POST ACCELERATOR

An essential feature of the post accelerator is to preserve the excellent beam quality currently available at ATLAS for stable beams of any mass up to uranium in the energy range from 6-15 MeV per nucleon. Concepts for the injector stage of the post accelerator are presented in other contributions to this conference [6-8].

As indicated in the spread sheet above, a beam such as ^{132}Sn is first accelerated in the 1+ charge state through a voltage of about 1 MV and then stripped in a thin gas stripper to 2+. The advantage of stripping at this very low energy is that the efficiency is over 40%, whereas at higher energies the peak of the charge-state distribution is typically 20%. The second stripper is at the more typical energy of 500 keV/A where a q/m of 0.15 is reached for final acceleration through ATLAS.

Preliminary estimates of the cost and schedule for this project are given in the working paper discussed above.

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