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U. S. NUCLEAR PHYSICS RESEARCH ACCELERATORS (1-1000 Mev)

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INTRODUCTION:

The present listing is intended to include all U. S. particle accelerators used primarily for nuclear research in the energy range of 1 MeV to 1 BeV per nucleon. The listing includes accelerators authorized, under construction, and in use. Accelerators in the planning stages which have not yet been funded have been excluded. Facilities which are known to have been shutdown or dismantled have been excluded. The information has been assembled for the most part without contacting persons associated with the specific accelerators. Sources include the references listed below, documents supplied to the AEC by its contractor, and private communications with numerous individuals. The listing is undoubtably neither complete nor accurate. Constructive criticism will be welcomed.

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Possible Fast Neutron Facilities in the U. S., B. C. Diven, October 15, 1962 (private communication).

Isochronous Cyclotrons, Specifications, F. T. Howard, ORNL (List prepared May 15, 1963).

Survey of Particle Accelerators, D. J. Hamman and W. H. Veazie, Jr., REIC Report No. 31 (Part II), September 15, 1963; also, First Revision, September 15, 1964.

1a. SYNCHROCYCLOTRONS (F. M. Cyclotrons)

Location	Pole Diameter (inches)	Particle Energies (Mev)	Nominal Average Current (Internal) (μa)	Nominal Average Current (External (μa)	Federal Support	Research Program, Remarks
Carnegie Inst. of Technology	144"	440 p	2		AEC-R	Mu-Mesic Capture & X-Rays, Proton-Induced Reaction Studies, Etc.
Chicago, Univ. of	170"	460 p	1.5	?	ONR	Meson and Nuclear Physics
Columbia Univ.	168"	385 p	1		ONR	Meson and Nuclear Physics
Harvard University	95"	168 p	10	0.08	ONR	Nucleon-Nucleon Scattering, Nucleon-Nucleon Bremsstrahlung, etc.
LRL, Berkeley	184"	740 p also d, He^3, α	1-2	0.06	AEC-R	Pion-Proton Scattering, Nucleon-Nucleon Scattering, Rare Decay Modes of Pions and Muons, Pi-Mesic X-Ray Studies, Pion Production Studies, etc.
Princeton Univ.	33"	18 p	17	0.4	AEC-R	Proton-Induced Reaction Studies, Short-lived Production
Rochester, Univ. of	130"	240 p	5		AEC-R	Pion-Proton Scattering, Nucleon-Nucleon Scattering, Nucleon-Nucleon Bremsstrahlung, Pion-Nucleus Scattering, Few-Nucleon Problems
Space Radiation Effects Lab, Newport News, Virginia	197"	600 p	1	0.05	NASA	50% NASA-Oriented, 50% Physics Research. Operation 1965 (?)

1b. SECTOR-FOCUSED CYCLOTRONS

Location	Pole Diameter (inches)	Particle Energies (Mev)	Nominal Average Current (Internal) (μa)	Nominal Average Current (External) (μa)	Federal Support	Research Program, Remarks
Calif, Univ. (Davis)	76"	75 p	---	---	AEC-R	Operational 1965; proton inelastic scattering, few-nucleon studies, neutron scattering, polarization studies, radio-isotope production.
Calif, Univ. (Davis)	22"	10 p 11.5α	10 50	5 25	AEC-R	Charged Particle Scattering
Calif, Univ(Los Ang.)	49"	52*p, H^-			ONR	Elastic and Inelastic Scattering of Polarized and unpolarized protons, negative hydrogen ion beam development. *limited energy variation
Colorado, Univ. of	52"	30p, H^- 15d 30α 30He^3	1000	>1 0.1 0.1 0.1	AEC-R	Charged Particle Reaction studies, proton elastic and inelastic scattering, radio-isotope production, negative hydrogen in acceleration studies.
Illinois, Univ of	44"	15p 14.5d 28α 36He^3	1000 1000 1000	100 100 50	ONR	Nuclear Physics Research.
LRL (Berkeley)	88"	55p 65d 130α HI	100 100 100	20 20 20	AEC-R	Nuclear Physics and Chemsitry
Maryland, Univ. of	88"	100p 65d 130α	--	--	AEC-R	Nuclear Physics Operational 1969
Michigan, Univ. of	83"	35p 40d 80α	200 7200	15 15	AEC-R	Charged-particle spectroscopy

1b. (continued)

Location	Pole Diameter (inches)	Particle Energies (Mev)	Nominal Average Current (Internal) (μa)	Nominal Average Current (External) (μa)	Federal Support	Research Program, Remarks
Michigan, Univ. of	50"	7.5p* 15d 30α			AEC-R	*Modification to sector-focused machine nearly complete (1965). Specifications listed here are for cyclotron before modification.
Michigan St. Univ.	64"	50p 25d 50α			NSF	Nuclear Physics
Naval Radiological Defense Labs	70"	70p 35d			DOD	Neutron Irradiation
Naval Research Labs	76"	75p	---	---	DOD	Operational 1966
ORNL	76" [illegible] [illegible]	75p 40d 80α			AEC-R	Pick-up reaction studies, elastic and inelastic scattering of 40-MeV polarized protons, heavy ion studies of particle-transfer reactions.
Texas A&M Univ.	88"	55p	---	---	AEC-R	Operational 1968.
Washington Univ. (St. Louis)	54"	6-30p 12-30α 6-15d 40He^3			NSF	Operational 1965

1c. CONVENTIONAL CYCLOTRONS

Location	Pole Diameter (inches)	Particle Energies (Mev)	Nominal Average Current (Internal) (μa)	Nominal Average Current (External (μa)	Federal Support	Research Program, Remarks
ANL	60"	10.8p 21.6d 43α	350 700 350	100 200 100	AEC-R	Stripping & pickup reactions, alpha particle scattering.
BNL	60"	10.3p 20.5d 40α 30He^3	300 300 150 60	50 50 30 12	AEC-R	Particle-particle correlation scattering experiments, two-nucleon pickup studies, He^3 induced reactions.
Carnegie Institute Washington	60"	75p 15d 30α	120 130 40	10 12 0.6		
Indiana Univ.	45"	5.2p 11.4d 22.8α	 500 	30 150 100	NSF	Nuclear Physics Research.
LRL (Livermore)	90"	20p 15d 30α	300 500 100	50 50 10	AEC-DMA	Nuclear Physics Research.
Lewis Res. Center (Cleveland)	60"	10.5p 21.5d 43α	 300 100	80 120 50	NASA	
LASL	42"	9p 16d 30α 27He^3	2500 2000 1000 1000	50 50 50 50	AEC-DMA	Nuclear structure studies using charged particle reactions, elastic scattering of polarized protons, charged-particle induced fission.
MIT	43"	7.5p 15.1d 30α	 200 	50 60 	AEC-R	Inelastic alpha-particle studies, alpha-particle induced reactions, radioisotope production.

1c. (continued)

Location	Pole Diameter (inches)	Particle Energies (Mev)	Nominal Average Current (Internal) (μa)	Nominal Average Current (External) (μa)	Federal Support	Research Program, Remarks
Ohio St. Univ.	47"	6.2p 12.4d 24.0α 19.5He^3	150 150 100	50 50	NSF	Isotope Production, some nuclear physics (He^3 beam available)
ORNL	86"	22p	2000	40	AEC-R	Proton-induced reactions
Oregon St. Univ.	37"	7.5d		none	AEC-R	Radio-isotope production
Pittsburgh, Univ. of	47"	7.5d 15d 30α	200 300 40	10 30 5	NSF	Nuclear structure investigations emphasizing deuteron-induced reactions.
Purdue University	37"	9.6d	200	25	AEC-R	Deuteron, He^3 and alpha particle induced reaction studies.
Washington, Univ.	60"	10.5p 21d 42α	1000 500	300 150 90	AEC-R	Elastic & I[illegible]lastic scattering of protons and al[illegible] particles, angular correlations of gamma rays with inelastically scattered particles of alpha-particle induced fission, pick-up reaction studies.

2a. ELECTRON LINACS

Location	Energy at Maximum Beam Power (Mev)	Peak Pulse Intensity (Amps)	Average Intenstiy at Maximum Beam Power (Microamps)	Federal Support	Research Program, Remarks
General Atomic	25*	2.0	540	Partial Support by AEC, ONR, DOD	*Now being upgraded to 54 KW average power at 50 Mev. Neutron spectra, neutron capture, radiation effects, photonuclear physics, positron and electron physics, radiation chemistry, isotope production, activation analysis.
LRL (Livermore)	100	5.0	500	AEC-DMA	Authorized 1965
LRL (Livermore)	25	0.25	100	AEC-DMA	Photonuclear cross sections measurements, radiation damage, fission cross-section measurements.
MIT	400	>1.0	150	AEC-R	Authorized 1965
MIT	10	0.1	5	AEC-R	Photoneutron energy spectra, gamma-induced reaction studies.
NBS	85	2.0	1000	NBS	Photonuclear reactions, electron scattering.
Naval Research Laboratory	40	1.0	200	ONR	Photonuclear Physics
Rensselaer Polytechnic Inst.	66	2	720	AEC-RDT	Neutron cross sections for reactor applications, reactor lattice spectra, neutron thermalization.
Yale University	40	1.6	160	AEC-R	Photonuclear reactions, electron scattering, positron scattering, captive gamma ray measurements.

2b. *PROTON LINACS*

Location	Proton Energy (Mev)	Nominal Current (Microamps)	Duty Cycle (Macroscopic)	Federal Support	Research Program, Remarks
Minnesota University	68 40 10	0.001 0.01 0.1	1.2%	AEC-R	Elastic & Inelastic scattering of polarized and unpolarized protons, proton-induced reaction studies.
South. Calif., Univ.	32	0.1	0.75%	AEC-R	Elastic and Inelastic scattering of protons, proton-induced reaction studies, proton energy loss studies.

2c. HEAVY ION LINACS

Location	Ion Energy (Mev/Nucleon)	Average Current (Microamps)	Federal Support	Research Program, Remarks
LRL (Berkeley)	10.	1.	AEC-R	Nuclear Chemistry
Yale University	10.	1.	AEC-R	Nuclear Physics and Chemistry

3a. MULTISTAGE ELECTROSTATIC ACCELERATORS

Location	Nominal Energy (Mev)	Particles Accelerated	Nominal Average Current (μa)	Federal Support	Research Program	Remarks
BNL	30	p,d,H1	0.5	AEC-R	nuclear physics	HVEC Double MP Tandem Operational about 1968 Terminal ion source
LASL	23	p,d,t,H1	2	AEC-DMA	charged particle, neutron physics	HVEC FN Tandem plus existing 8 Mev Van de Graaff Operational 1964
Pittsburgh, U. of	18	p,d	0.5	NSF	nuclear physics	HVEC Double EN Tandem Neutral-Negative Injection Operational 1966?
Rice Univ.	17.5	p,d,H1	2	AEC-R	studies of nuclear reaction mechanism, interaction of fast neutrons with nuclei, polarization effects, reactions in light elements, and other aspects of nuclear structure	HVEC EN Tandem plus HVEC CN Injector Coupling of Existing machines Estimated 1966
Texas, Univ. of	17.5	p,d,H1	2	AEC-R (operating)	Neutron-induced reactions, Coulomb excitation, charged particle reactions	HVEC EN Tandem plus HVEC CN Injector
Washington, U. of	22.5	p,d,H1	0.5	AEC-R (operating) NSF (bldg. and accelerator)	charged particle reactions fission studies	HVEC Double FN Tandem Neutral-Negative Injection Provision being made for beam bunching and pulsing Operational 1966?

3b. TANDEM (Two-stage) ELECTROSTATIC ACCELERATORS

Location	Nominal Energy (Mev)	Particles Accelerated	Nominal Average Current (μa)	Federal Support	Research Program	Remarks
ANL	12	p,d,α	4	AEC-R	Gamma Rays from changed particle-induced nuclear reactions; Changed particle reactions; (d,n) reaction studies	HVEC EN Tandem Pulsed Beam <2ns
Cal. Inst. of Tech.	12	p,d	4	ONR	Nuclear Physics	HVEC EN Tandem
Florida St. Univ.	12	p,d,α,H1	4	AFOSR	Nuclear Physics	HVEC EN Tandem
Minnesota, Univ. of	20	p,d	10	AEC-R	Nuclear Physics	HVEC MP Tandem Operational 1966
ORNL	12	p,d,α,H1	4	AEC-R	Elastic & Inelastic of protons & deuterons; Coulomb excitation with oxygen ions; Heavy ion reaction and stopping power studies; Total neutron yield studies	HVEC EN Tandem
Penn., Univ. of	12	p,d,α	4	NSF	Nuclear Physics	HVEC EN Tandem
Rice University	12	p,d	4	AEC-R	(See description under Rice Univ. Section 3a)	HVEC EN Tandem
Rochester, Univ. of	20	p,d	10	NSF	Nuclear Physics	HVEC MP Tandem Operational 1966
Rutgers Universtiy	15	p,d	4	NSF	Nuclear Physics	HVEC FN Tandem
Stanford University	15	p,d	4	NSF	Nuclear Physics	HVEC FN Tandem
U.S. Air Force Wright Patterson Base Dayton, Ohio	8	p,d	?	DOD	?	HVEC 1ct Tandem Operational 1965 (?)

3b. (continued)

Location	Nominal Energy (Mev)	Particles Accelerated	Nominal Average Current (μa)	Federal Support	Research Program	Remarks
U.S. Army Edgewood Arsenal	15	p,d	4	DOD	?	HVEC FN Tande Operational 1966-67
Wisconsin, Univ. of	12	p,d	64	AEC-R	Charged particle-induced studies of nuclear energy levels, stripping reactions, polarization phenomena. Studies of neutron producing reactions and interaction of such neutrons. Emphasis on polarization effects.	HVEC EN Tande Polarized p,d ion source; Pre-acceleration bunching
Yale University	20	p,d	10	AEC-R	Nuclear Physics	HVEC MP Tande Operational 1965

3c. *SINGLE STAGE ELECTROSTATIC ACCELERATORS*

Location	Nominal Energy (Mev)	Particles Accelerated	Nominal Average Current (μa)	Federal Support	Research Program	Remarks
ANL	4.5	p,d,α	40	AEC-R	Gamma Rays from Charged-Particle-Induced Nuclear Reactions, Fast-Neutron-Induced Reactions, Lifetimes of Nuclear States	Pulsed Beam
ANL	3.0	p,d,α	200	AEC-RD	Neutron Cross-Section Measurements	Terminal Pulsing, Mobley Compression (1ns Pulse Width 2ma Peak Current)
Arizona, Univ. of	2.0	p,d,αHe^3	100	NASA/ AEC-R	Nuclear Physics, Optical Spectroscopy	HVEC
Arizona, Univ. of	5.5	p,d,HI		NSF	Nuclear Physics, Optical Spectroscopy	Operational 1966-67
Bartol Res. Found. Swarthmore, Pa.	1.75	p,d	50	?		
Bartol Res. Found. Swarthmore, Pa.	5.5	p,d,α	10	?	Charged Particle Reaction Studies	
Baylor University	2.0	p,d		---		
BNL	4.0	p,d,α,He^3	100	AEC-R	Charged Particle Induced Reactions	
Calif. Inst. Tech.	2.8	p,d,α,He^3	4	ONR		
Calif., Univ. Of,L.A.	2.0	p,d			Some Nuclear Research	
Carnegie Inst. Wash., D.C.	4.0	p,d	5		Nuclear Research	Polarized Ion Source

3c. (continued)

Location	Nominal Energy (Mev)	Particles Accelerated	Nominal Average Current (μa)	Federal Support	Research Program	Remarks
Case Inst. Tech.	3.0	p,d,α	50	AEC-R	Neutron Scattering and Reaction *Studies, g-Factor Measurements* of Excited States	Terminal Pulsing and Mobley Compression (1ns Pul Width, several μa average current)
Chance Vought Aircraft	3.0		200			
Chicago, Univ. of	3.75	p,α,Li^{++},He^{++}	10	AEC-R	Stopping Power Studies of Heluim and *Lithium ions, study of* Lithium-ion induced reactions.	
Columbia University	5.5	p,d,α,He^3,HI	75	AEC-R	Charged Particle Reaction Studies, Lifetimes of Excited Nuclear States, inelastic neutron scattering Cross-sections	Terminal Pulsing
Duke University	3.0	p,d	200	AEC-R	High Resolution Neutron Total Cross Sections	
Duke University	4.0	p,d,α	50	AEC-R	Elastic & Inelastic Neutron Scattering Cross Sections, Angular correlation Studies of various reactions	
General Dynamics Astronautics	3.0					
Georgetown University	2.0	p		---		
Georgia, Univ. of	2.0	p,d,α,He^3		---	Neutron Polarization Studies, Charged Particle Reaction Studies	
Iowa, St. College	4		1.5			
Iowa, St. Univ. of	5.5	p,d	5	NSF	Operational 1964. Li acceleration.	

3c. (continued)

Location	Nominal Energy (Mev)	Particles Accelerated	Nominal Average Current (μa)	Federal Support	Research Program	Remarks
Johns Hopkins Univ.	3	p,d	200	AEC-R	Neutron Spectroscopy, Proton Polarizarization Studies	
Kansas, Univ. of	3	p,d,He^3,α	200	AEC-R	Gamma-Rays from charged particle induced nuclear reactions, charged particle reaction studies	
Kentucky, Univ. of	6	p,d,He^{++}	35	NSF	Charged-Particle Induced Reactions Neutron Inelastic Scattering and Reaction Studies	Terminal Pulsing
LRL	2	d,p	150	AEC-DMA		Also a 1 Mev Accelerator in same area
Lockheed Missiles & Space Company	3.5	p,d,He^3α	25	---	Neutron Physics	Pulsed Beam
LASL	8	p,d,t,α,He^3	100	AEC-DMA	Neutron Elastic-Inelastic Scattering Neutron Polarization Studies, Charged Particle Reactions, Fission Studies	Terminal Pulsing, Mobley Compression Injector for HVEC Model FN Tandem
Maryland, Univ. of	3	p,d,He^3,He^4	200	AEC-R	Charged-Particle Induced Reaction Studies, Neutron Time of Flight Studies	Pulsed Beam
Mass. Inst. of Tech.	4	p,d	5	---	Nuclear Engineering	---
Mass. Inst. of Tech.	8.5	p,d,α	1	AEC-R	Energy Level Studies with Multi-Gap Spectrometer	
Mellon Inst., Pitts.	3	p,d	200			
Minnesota, Univ. of	3.5	Li^+	1			
NBS	3.0	p,d	100			

3c. (continued)

Location	Nominal Energy (Mev)	Particles Accelerated	Nominal Average Current (μa)	Federal Support	Research Program	Remarks
Northwestern Univ.	5.0	p,d,α		DOD	Nuclear Physics	
Notre Dame, U. of	4.5	p,d,α,He^3	5	ONR		
ORNL	3	p,d	5	AEC-R	Neutron Reactions in 10-100 kev Region	Pulsed Source, Terminal Klystron Bunching (10ma Peak Current, 1ns Width)
ORNL	5.5	p,d,α	25	AEC-R	High Resolution Neutron Elastic Scattering, Charged Particle Spectros Copy, Neutron Yield Measurements	Terminal Pulsing
Ohio St. Univ.	5.5	p,d,He^3,α	30	NSF	Nuclear Physics	
Oregon, Univ. of	4.0	p,d		AEC-R	Neutron Time-of-Flight Spectrometry, Capture Gamma Ray Studies, Beta-and Gamma-Ray Spectroscopy.	HVEC Model KN Pulsed Source
Pacific Northwest Laboratory	2.0	p,d,He^{++}	5	AEC	Neutron Total Cross Sections	Post-Acceleration Chopping.
Penn-State Univ.	5.5	p,d	50	---	Nuclear Physics	
Penn., Univ. of	3	p	5		Nuclear Physics	
Rice University	5.5	p,d,He^3,α	4	AEC-R	(See description under Rice in Section 3a)	HVEC CN;also used as Injector for Rice Tandem
Stanford University	3	p,d	200	NSF	Nuclear Physics	
Texas Nuclear Corp.	3	p,d,α	5	AEC-R	Studies of Gamma Rays from Fast Neutron Interactions	Pulsed Beam

3c. (continued)

Location	Nominal Energy (Mev)	Particles Accelerated	Nominal Average Current (μa)	Federal Support	Research Program	Remarks
Texas, University of	4	p,d,t,α	250	AEC-R	Neutron Time-of-Flight, charged particle Reaction Studies	Pulsed Beam being Developed
U.S. Air Force Cambridge Research Center	3.0		200	DOD	?	
U.S. Army Ballistic Research Labs, Aberdeen, Md.	3.0	p,d,α	25	DOD	?	
U.S. Army Missile Command Redstone Arsenal, Alabama	2.0	p,d	25	DOD	Neutron Physics	
U.S. Naval Post-Graduate School Monterey, Calif.	2	p	10	DOD	?	
U.S. Naval Radio-logical Defense Lab, San Francisco	2	p,d,α	50	DOD	Some Neutron Physics	
U.S. Naval Research Lab, Washington, D.C.	5.5	p,d,He^3,α	5	DOD	Neutron Physics	
Virginia, Univ. of	5.5	p,d,α		NSF	Neutron Time-of-Flight Studies Operational 1966	Pulsed Beam
Westinghouse Electric Corp. (Bettis)	3.0			AEC-?	Neutron Physics	Pulsed Beam
West Virginia Univ.	2	p,d	120	---	Nuclear Physics	
Wisconsin, Univ. of	2	p		AEC-R	Precision measurement of P-P Scattering Resonance Parameters, etc.	

3r. (continued)

Location	Nominal Energy (Mev)	Particles Accelerated	Nominal Average Current (μa)	Federal Support	Research Program	Remarks
Worcester Polytechnic Institute	2	p,d	50			

4a. BETATRONS

Location	Energy (Mev)	Average Current (μa)	Federal Support	Research Program, Remarks
Illinois, Univ. of	340	0.001	NSF	Nuclear Physics Research

4b. ELECTRON SYNCHROTRONS

Location	Energy (Mev)	Average Current (μa)	Federal Support	Research Program, Remarks
Ames Laboratory	70	0.1	AEC-R	Photonuclear cross-section measurements, electron scattering.
Ames Laboratory	60	0.1	AEC-R	See Above.
NBS	180	0.001	NBS	Photonuclear Research
Virginia, Univ. of	75		NSF	Photonuclear Research

Note: HI indicates heavy ions.