THE SURA/CEBAF PROJECT

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INTRODUCTION

A multi-GeV electron accelerator with high current and high duty cycle is needed for a broad range of nuclear and particle physics investigations. To fulfill this need in the U. S., the scientific community has chosen the Southeastern Universities Research Association's (SURA's) Continuous Electron Beam Accelerator Facility (CEBAF). This new accelerator will be built in Newport News, Virginia. A detailed perspective on many of the physics and accelerator aspects of CEBAF can be obtained from surveying four conference proceedings: Refs. 1-4.

Some organizational and operational information will be useful to some readers. SURA has thirty three member institutions from the southeastern region of the U. S. While CEBAF was its first project, SURA now supports a variety of projects. Funding for the proposals for CEBAF came mostly from the SURA member institutions and the Commonwealth of Virginia. The project itself will be mostly funded by federal grants via the Department of Energy (DOE). The Commonwealth of Virginia will also be providing ongoing funding.

The status of the present funding and staffing of CEBAF is that as of July 1, 1984 the Commonwealth of Virginia began funding CEBAF at a rate of approximately $1.3 M per year. These funds include seventeen and one half support staff positions of personnel who are already at CEBAF. Most of the funds are for senior personnel and a group of junior accelerator physicists. On August 3, 1984 SURA signed its first contract with DOE to start the federal funding. The total of the FY 1984 and FY 1985 federal funding for CEBAF is $4.8 M. These funds are for staffing, R&D, A&E and related startup expenditures. In addition to the seventeen support positions, there are at present approximately a dozen senior CEBAF staff positions filled. By January 1985 this number will be approximately twenty to twenty-two.

It is the intent of SURA and CEBAF to have CEBAF in the President's FY 1986 budget for construction funds. This budget will be submitted to Congress in late January or early February of 1985. With the successful passage of this budget, CEBAF would begin expenditure of construction funds sometime shortly after October of 1985 and the accelerator would become operational in 1990. A strong voice of support of these events was recently given by the Nuclear Science Advisory Committee when it reaffirmed that the construction of CEBAF is the number one priority of the nuclear science community for new facilities.

ACCELERATOR

The CEBAF accelerator design is a linac-pulse stretcher.[5-7] The overall layout is shown in Figure 1. The linac accelerates high current pulses of electrons up to 2 GeV. The electrons can then be deflected along the recirculation path to pass through the linac again, thereby achieving an energy of up to 4 GeV. The pulses from the linac are injected into the pulse stretcher ring, PSR. The method of slow extraction used in synchrotrons is used to extract the electrons from the PSR. Electrostatic septa and magnets are used to place the beams in the three beam lines.

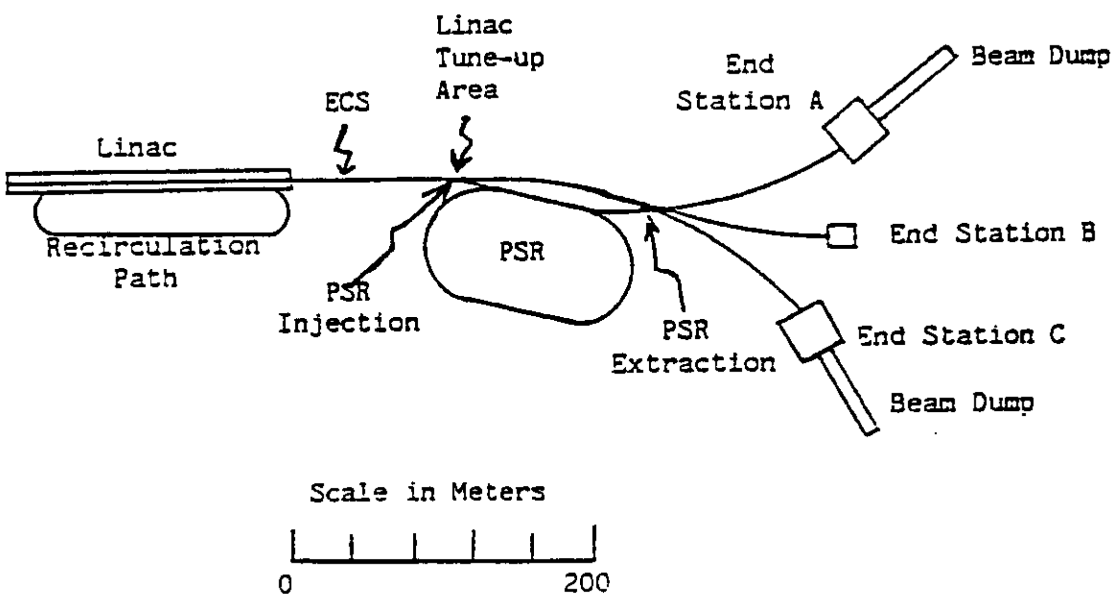

Figure 1. Accelerator Layout

Figure 2 shows the progress of the beam in detail. The electron beam fills the linac and part of the recirculator in Fig. 2a. As seen in Fig. 2b, the timing and lengths of the linac and recirculator have been chosen so that

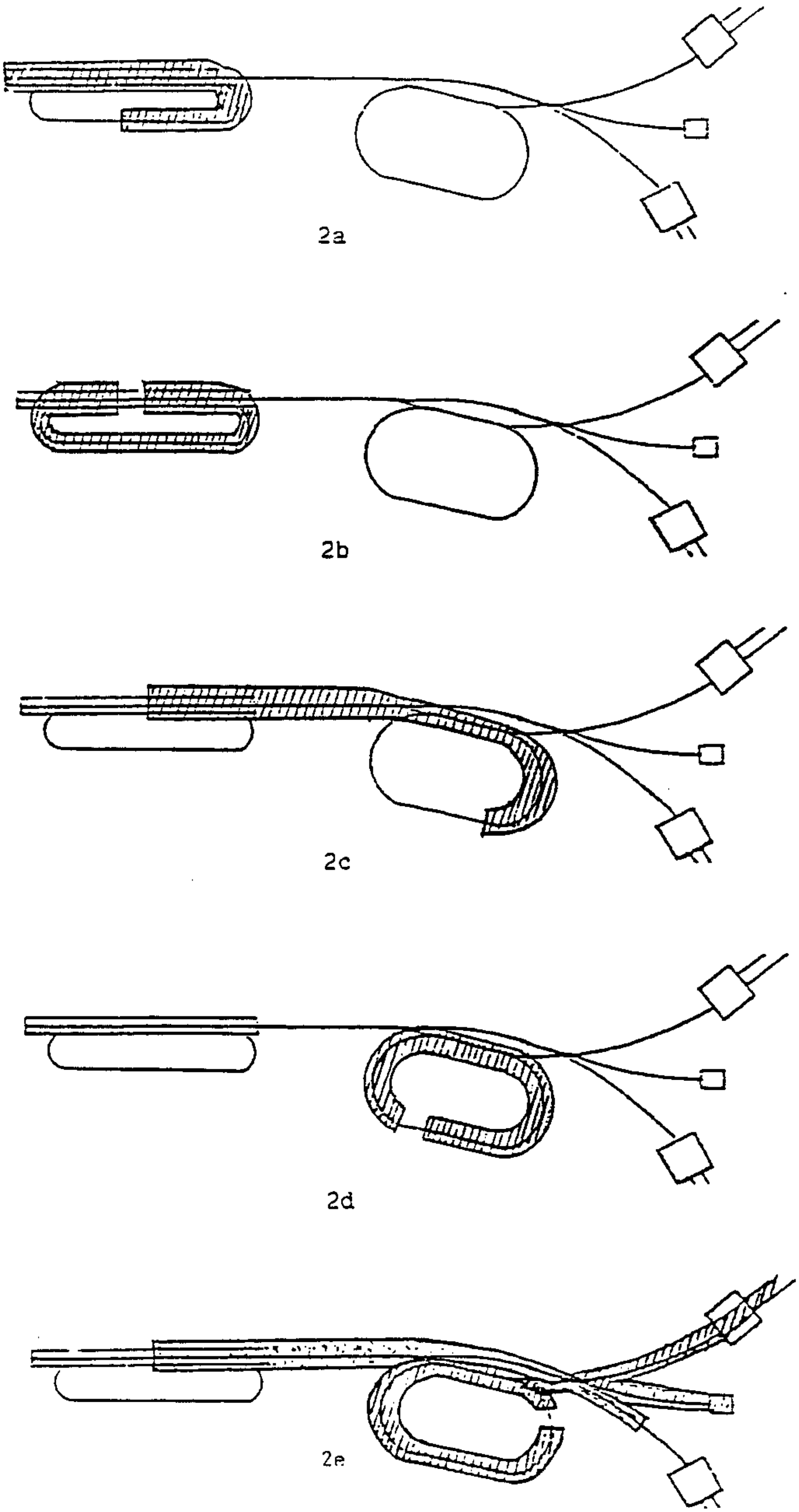

Figure 2.

the head of the recirculated beam is just at the tail of the unrecirculated beam. Fig. 2c shows the injection into the PSR. Fig. 2d shows the beam in the PSR just after injection and just before extraction. The length of the PSR is chosen to match the 1.2 µs pulse length of the linac to give the single turn injection. Fig. 2e shows the beam being extracted from the PSR and sent to the upper two experimental areas. There is also a second beam shown in Fig. 2e.

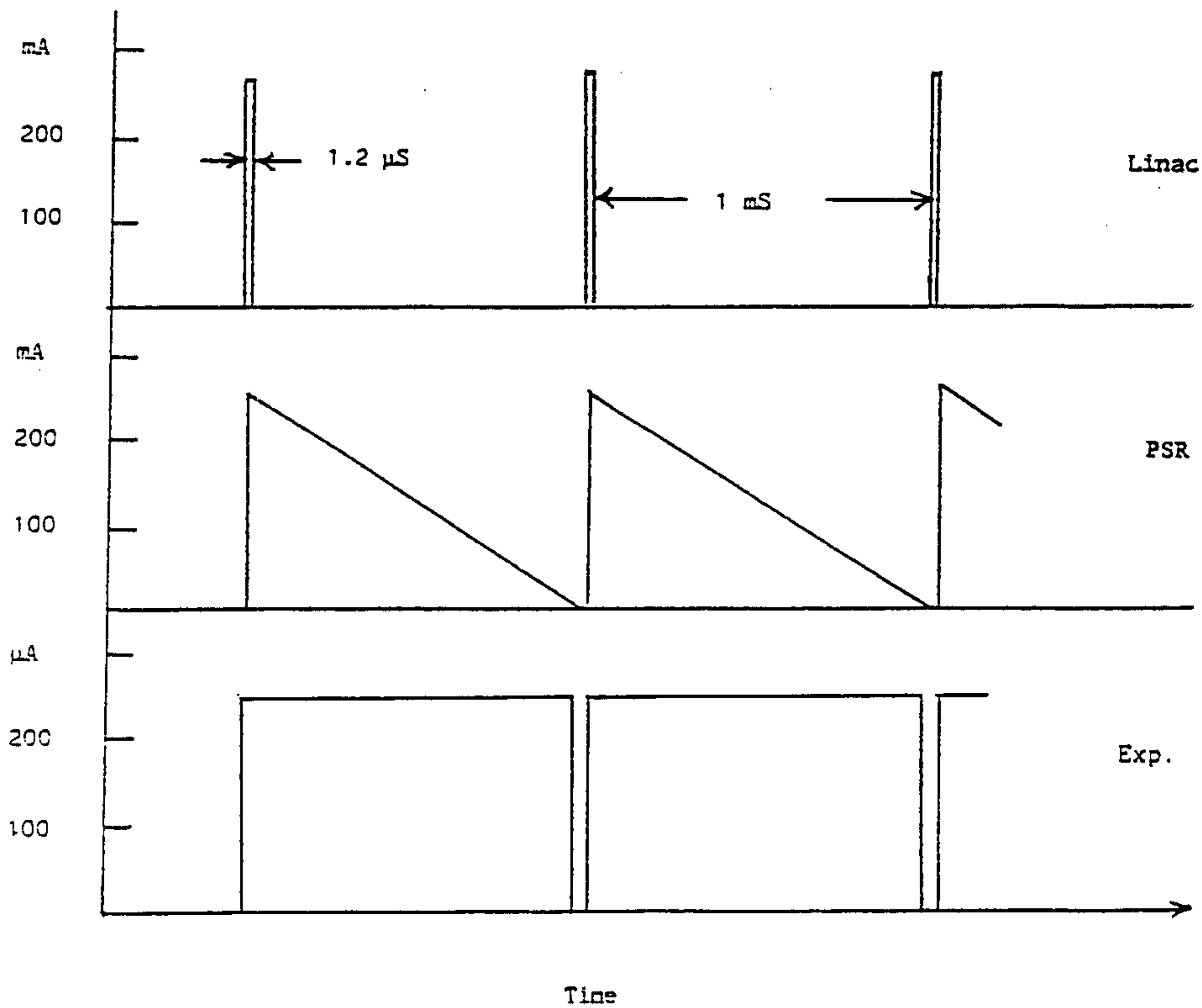

Figure 3. CEBAF Currents

The linac can send a pulsed beam to any experimental area that is not receiving beam from the PSR. This pulsed beam does not need to be at the same energy as the beam in the PSR. This is useful for experiments that do not require high duty cycle. Note that the beam from the PSR can be sent to any or all of the experimental halls at the same time.

With the assumption that the linac is operating at its maximum repetition rate of 1000 Hz and that all of the beam is going into the PSR, Fig. 3 shows the currents in the linac, PSR and leaving the PSR. The linac will carry in excess of 200 mA for 1.2 μs. With the single turn injection, the PSR starts with this value of current. During the millisecond following injection, the beam is extracted from the PSR at a constant rate bringing the PSR current to zero. The experimental areas receive in excess of 200 uA average current with a duty cycle in excess of ninety percent. If the linac is being used to send pulses to one of the experimental areas directly, then the extraction time can be extended beyond one millisecond. The variety of possibilities available is one of the nice features of the linac pulse stretcher combination. Tables I, II and III detail the parameters of the linac and PSR and accelerator design requirements.

Table I

Linac Parameters

Energy range	$0.5 < E_o < 4$ GeV
	$0.5 < E_o < 4.8$ GeV, Unloaded
Energy variability	Continuous from 0.5 GeV
Energy Spread	$\Delta E_o/E_o < 0.2\%$
Pulse Length	1.2 us
Pulse Repetition Rate	$\leq$ 1000 Hz (variable)
Klystron Frequency	2856 MHz
Bunching Frequency	714 MHz
Peak Current	> 200 mA
Transverse Emittance	20 (keV/c)-cm

Table II

Pulse Stretcher Ring Parameters

Circumference	362.773 m
Overall length	138.6 m
Overall width	76.2 m

Table II (Cont'd.)

Magnetic Radius	26.855 m
Packing Factor	46.5%
Harmonic Number	864
Momentum Compaction	0.022
Betatron Tunes	
Horizontal	8.5 (on resonance)
Vertical	8.8
Chromaticities	
Horizontal (Uncorrected/Corrected)	-10.4/0
Vertical (Uncorrected/Corrected)	-11.4/9
RF System	
Frequency	714 MHz
Peak Voltage (variable/continuous)	4.5/1.5 MV
Average Power (variable/continuous)	5/350 kW

Table III

Accelerator Design Requirements

Energy Range (@ 200 μA)	$0.5 \leq E_o \leq 4.0$ GeV
Energy Variability	Continuous from 0.5 GeV
Energy Spread	$\Delta E_o/E_o < 0.01\%$
Duty Factor	$\gtrsim$ 80%
Number of Beams	$\gtrsim$ 2 (1 to tagged γ facility)
Total Current	200 uA
Current per Beam	100 μA (standard end station)
	1 μA (tagged γ facility)
Transverse Emittance	0.2 π mm-mr in one plane
	0.4 π mm-mr in other

RESEARCH PROGRAM

The CEBAF research program has evolved over a several year period. From 1980 to 1982 a group of over 40 physicists met six times to prepare the scientific justification that went into the proposal for CEBAF, then known as NEAL. After the proposal was accepted, there were several conferences[2-4] and three working groups were formed. At the present time there is a users group and five working groups; Magnetic Spectrometers, Large Acceptance Detectors, Internal Targets, Positrons, and Theory. Early in the summer of 1985 there will be a users group meeting, a workshop-conference and a summer program initiated to work on experimental equipment R&D. In the research division, two of the senior staff positions are currently filled and several more are in the process of being filled.

I will take the experimentalist point of view and outline the research program in terms of the beam lines and experimental equipment being considered. The upper and lower beam lines as seen in Fig. 1 will be capable of handling up to 200 μA of beam current each. The center beam line is for very low beam currents, < 1 μA, to be used in tagged photon or very low current electron experiments.

While there are a variety of experiments to consider that are single arm in character, the more demanding experimental requirements are the multi-arm experiments. The first class of these considered are the (e,e',k^+) experiments that are discussed in detail in the paper by T. W. Donnelly in this conference proceedings. These experiments study the hypernuclei because the production of a positive kaon leaves the nucleus with a strange baryon present. Incident electron energies in the 3 to 4 GeV region are ideal. The final electron and kaon need to have similar momenta in very forward directions, i.e., 5-15 degrees. To see the hypernuclei levels, spectrometer resolutions on the order of a few times 10^{-5} are required. The kaon spectrometer must have a fairly short flight path. Building spectrometers with the requisite properties is a challenge to spectrometer builders. The usefulness of these spectrometers for other areas of research will be evaluated.

(e,e',X) experiments forms the next class of experiments being discussed. X in this case is a pion, nucleon, deuteron, etc. and the target nucleus is usually low A for the majority of experiments discussed to date. The spectrometer resolution requirements are not as severe as in the kaon case but the spectrometer observing the X particle may need to observe it out of the plane of scattering. Such spectrometers would need to have large momentum bites and solid angles, and be able to effectively observe long targets.

The situation is similar with (e,e',X,Y) and $(e,e',2N)$ experiments. Except now, three spectrometers may be involved. Because of difficulties in moving magnetic spectrometers out of the plane, interest in detecting neutral particles in the final state, and experiments such as electro-production of vector mesons, experimental possibilities that do not exclusively involve magnetic spectrometers are being considered. When there are three or more particles to be detected in the final state, the counting rate is higher if large solid angle dedectors with possibly lower beam currents are utilized.[8] Designs combining a large acceptance - large momentum bite magnetic spectrometer to observe the electron with a fly eye 1-2 π nonmagnetic spectrometer are being investigated. Such a detector system would be able to view final states with large numbers of particles. The deep inelastic scattering region could be investigated in detail.

As the reader is now aware, three somewhat different experimental setups have been discussed so far and there are only two experimental halls initially being constructed to use high current electron beams. Additionally, there are other geometries designs and concepts for detectors to be considered beyond those mentioned above. Our approach at this point is to optimize each of the major design concepts. Push the designs to see if they are technically feasible. See if these designs will do the physics measurements of interest. Look for detector systems that can perform multiple functions. The physics will then be used to determine the experimental equipment to be initially installed.

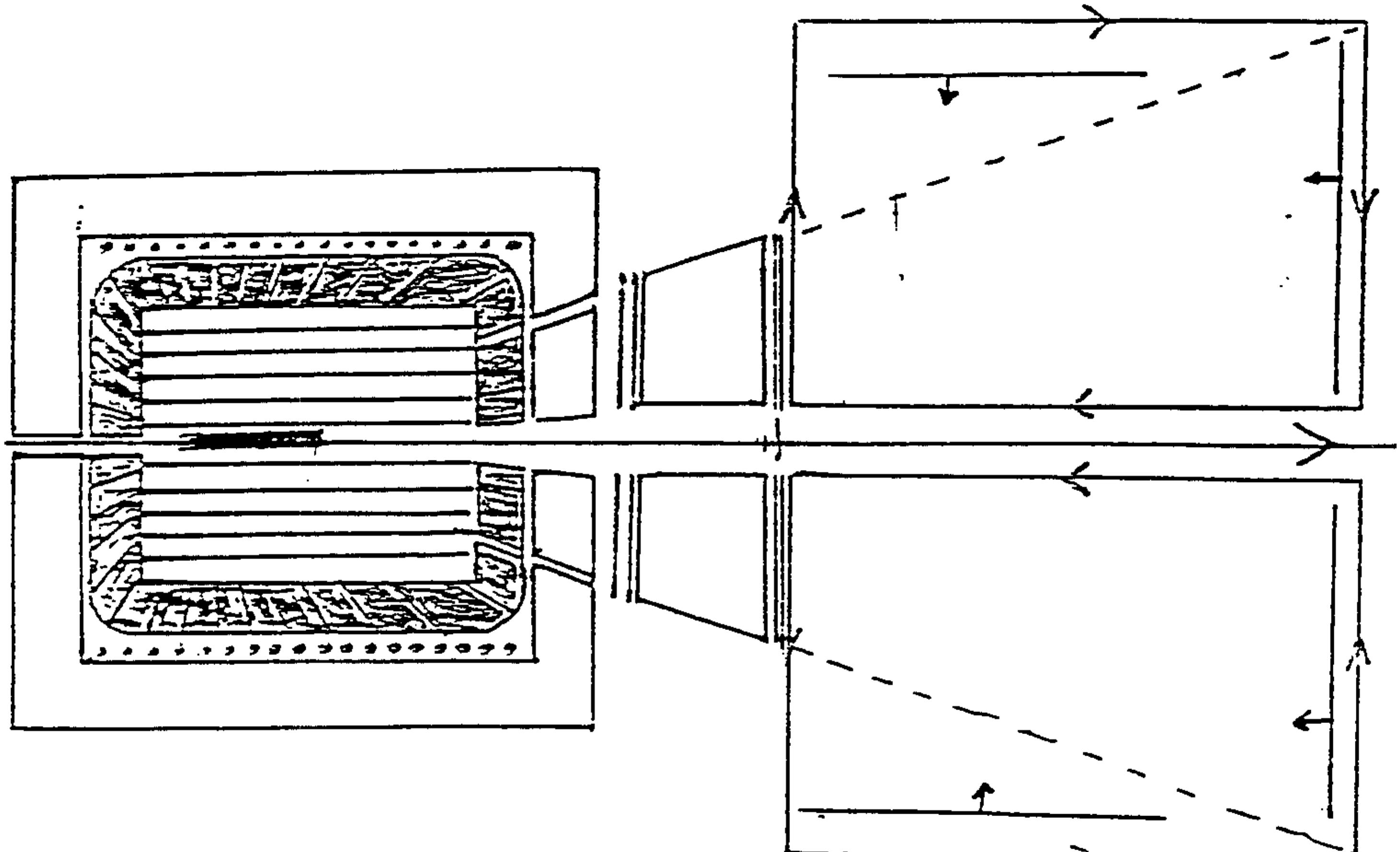

Figure 4. $B_\phi \propto \frac{1}{r}$

The tagged photon facility design has evolved in some detail.[9,10] A broad range photon tagger operating up to 4 GeV at a rate of 10^7 photons/second is envisioned. The tagging system could produce polarized photon beams.

The detector system for the photon beam line is conceptually shown in Figure 4. The first element is a superconducting solenoidal magnet with a magnetic volume three meters in length and one meter in radius. In terms of radius measurement, the first 50 cm of the magnetic volume will be filled with wire chambers which will determine the vertex of the event and moment of charged particles. The next 50 cm in radius and the 50 cm at each end will be filled with segments of CsI for detection of photons and total energy absorption measurements on the lower energy charged particles. CsI was chosen so that it could be used to see low energy nuclear decay photons as well as multi-GeV photons. For example, (γ,k) reactions can leave a hypernuclei in an excited state which decays via photon emission. The detectors as envisioned will also be ideal for investigation of nucleon resonances, and vector meson production.

Most of the tagged photon experiments will have one or more high momentum particles moving in the forward direction. The solenoidal magnet will make provision for this. Immediately following the solenoidal magnet planes of wire chambers and Cherenkov detectors will be installed. Next a large aperture magnet will be placed. The one shown in Fig. 4 has a 1/r dependence. Other geometrics are also being considered.

FUTURE EXPANSION

Part of the design goals of the CEBAF project is that it will be amenable to future expansion. Clearly, all of the initial construction will be within the approved scope of the project. It is, however, interesting to consider the physics and the facility developments that are likely to be involved in the expansion of CEBAF.

Physics experiments using polarized electrons are likely to be the first CEBAF expansion. The beam switchyard has been carefully laid out so that longitudinally polarized electrons can be delivered to the experimental areas. The requisite polarized injector and polarization rotation magnets are not included in the initial project. Particle properties, such as measurement of the neutrons charge form factor, and details of the excitations of both nucleon and nuclear states can be investigated with polarized electrons. Further, examples of the physics of these measurements are in Ref. 11.

The polarization measurements are also relevant for internal targets where highly polarized targets are available. The possibility of putting internal targets in the PSR is being investigated.[12]

Beams of positrons are possible to develop at CEBAF with a flux of 1 - 4 μA at energies from about 0.75 - 3 GeV. The physics justification and technical details are being evolved.[13]

The powerful pulsed linear electron accelerator at CEBAF could be used to inject into more than one ring. At this time there are no proposals for more rings beyond the PSR, however land is available for possible future expansion. Space has also been left for increasing the energy of the CEBAF linac. As with additional rings, the potential for expansion in this direction is present. Other than leaving the door open for these and other as yet unthought of possibilities, the direction of the work at CEBAF is to bring the facility into operation as set forth in the present scope of the project so that the exploration of new areas of physics may begin.

REFERENCES

1. "Future Possibilities for Electron Accelerators", January 8-10, 1979, ed. J. S. McCarthy & R. R. Whitney, Dept. of Physics, University of Virginia, Charlottesville, VA 22901.

2. "New Horizons in Electromagnetic Physics", April 21-24, 1982, ed. J. V. Noble & R. R. Whitney, Dept. of Physics, University of Virginia, Charlottesville, VA 22901.

3. "Spectrometer Workshop", October 10-12, 1983, Physics Dept., College of William and Mary, Williamsburg, VA 23185.

4. "CEBAF 1984 Summer Workshop", June 25-29, 1984, ed. F. Gross & R. R. Whitney, CEBAF, 12070 Jefferson Ave., Newport News, VA 23606.

5. R. A. Beck et al, "ALIS, An Electron Linac Beam Stretcher", Proc. of the 7th International Conference on High Energy Accelerators, Erevan, 1969.

6. G. A. Loew, "Properties of a Linac-Storage Ring Stretcher System", in Ref. 1.

7. R. C. York et al, "Multi-GeV Electron Linac-Pulse Stretcher Design Options", IEEE Trans. Nucl. Sci. NS-30, No. 4, August 1983.

8. R. R. Whitney, "Very Large Acceptance Detectors", in Ref. 4.

9. B. Mecking, "Photo Nuclear Experiments Using Very Large Acceptance Detectors", in Ref. 4.

10. R. R. Whitney, "Workshop Report: Tagged Photons - Low Current Electron Beams and Large Acceptance - 4 π Detectors", in Ref. 4.

11. T. W. Donnelly "Coincidence and Polarization Measurements with High Energy Electrons", in Ref. 4.

12. R. J. Holt "Polarized Gas Targets in Electron Rings" and "Summary of Internal Target Working Group Meeting", in Ref. 4.

13. B. L. Berman, "Positron Beams at CEBAF", in Ref. 4.