An Advanced Hadron Facility: A Combined Kaon Factory and Cold-Neutron Source

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Abstract: We present a concept for an advanced hadron facility consisting of a combined kaon factory and second generation spallation source. Our concept consists of a 1.2 GeV superconducting H^- afterburner to bring the LAMPF energy up to 2 GeV, a multi-ring 2 GeV compressor, a shared cold-neutron and stopped-pion neutrino source, a 60 GeV 25 μAmp 6 Hz proton synchrotron, and kaon and proton experimental areas. We discuss the considerations which led to this concept. We summarize recent results of r&d work on components for rapid-cycling synchrotrons. Finally, we mention briefly the possibilities for a pion linac at LAMPF.

1 Introduction

After recent discussions, we concluded that a combined kaon factory and spallation source is a better match to the needs of the nuclear physics and the materials science communities than the previous LAMPF II proposal [1]. The scope of this paper is limited to consideration of the specifications and cost of such a combined facility without detailed design.

2 Specifications

A next generation spallation source should provide a neutron flux comparable to a high flux reactor. Since there is a clear need for a world-class cold-neutron source, we decided to try to optimize the new source for cold- and ultracold-neutrons. We consider a plan for 1 megawatt of beam power with a target boost of a factor of three which gives a neutron flux approximately 1/2 that of the proposed SNQ facility [2]. A repetition rate of 12 Hz is essential to avoid frame overlap for the most interesting cold neutrons.

Neutrino physics discussions lead us to the conclusion that either a stopped pion neutrino source or a decay-in-flight source using the highest possible proton beam energy is needed. Since a stopped pion neutrino source is compatible with any neutron source, we decided to combine the two facilities to minimize cost and to gain an extra factor of two in flux by operating both facilities from the same target.

Our review of the physics of a kaon factory showed that for most experiments there is little dependence of the experimental program on proton energy above 30 GeV. However, for the highest priority nuclear physics objective, namely, the study of quark structure of nuclei, high energy is imperative. In particular, the experiment of measuring the strange quark and anti-quark structure functions of nuclei using the Drell-Yan process requires a kaon beam energy of 30 GeV. A proton beam energy of at least 60 GeV is required to produce 30 GeV kaons copiously. To keep costs at a manageable level, we reduced the beam current goal to 25 μAmp. This yields the same beam power as the previous LAMPF II design.

3 Accelerator Concept

The initial concept for an advanced hadron facility is shown in Fig. 1. In order to obtain a beam power of 1 MW with 500 μAmp of beam, it is essential to raise the beam energy to 2 GeV. A linac is the best accelerator for this current. Our study of linacs optimized for minimum lifetime cost showed that a superconducting linac is approximately a factor of two cheaper than a room temperature linac at the 5% duty factor required by the existing LAMPF linac. Such a linac would be made from 4-cell 402.5 MHz superconducting cavities similar to the CERN cavities [3] (See Section 6 below).

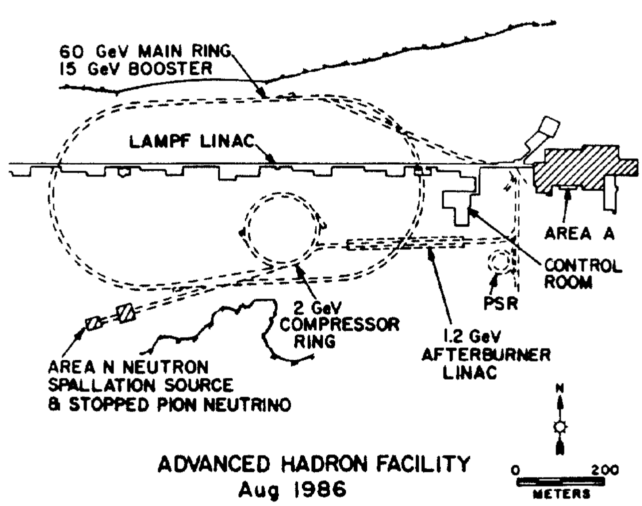

Figure 1: Possible site layout for an advanced hadron facility.

The compressor ring is not yet designed. Our initial feeling is that a multiple ring version similar to the CERN PS Booster is the appropriate choice. A five-ring compressor will provide the desired beam current at 12 Hz. Each ring will store 5×10^{13} protons, the maximum available from LAMPF in one macropulse. In this design, no ring will store more than the present PSR, which is able to avoid instabilities without active dampers. We feel that this is a more conservative approach than a single ring, which would have to contend with a serious transverse coasting beam instability.

The kaon factory synchrotrons will be injected by H^- from the superconducting afterburner without using the compressor. Fig. 1 shows a full size booster. Such a booster is convenient since neither a main-ring flatbottom nor an accumulator ring is required. Compared with the European Hadron Facility design [4], the higher (2 GeV) injection energy allows a large bucket area at reasonable rf voltage. We may then consider a magnet power supply which transfers the magnetic energy between booster and the main ring. This reduces operating cost and eliminates all chokes and one condenser bank. To match the magnetic energy of the two rings, a booster energy on the order of 15 GeV is needed. We will also consider a half size booster and accumulator ring, as in the EHF design. A detailed cost optimization is needed to choose the injection energy and the booster energy. Such an optimization is beyond the scope of the present work.

Recent work at CERN [5] shows that the extraction efficiency of a kaon factory must be much higher than that of existing synchrotrons. In order to improve the extraction efficiency, the stretcher ring may be required. This will also provide a higher duty factor for the users than the previous LAMPF II design. It is likely that a stretcher ring will be a part of the AHF design, but it is not yet shown in the site layout of Fig. 1.

We have considered and rejected two adventurous alternatives. A 60 GeV proton linac scaled from the CEBAF design [6] would be more expensive than our concept by a factor of 12. A 60 GeV proton microtron would be somewhat cheaper, but still more expensive than the proposed synchrotrons. Such a microtron suffers from the problem that the injected beam should be highly relativistic before injection into the recirculation linac. Scaling from the CEBAF design we find that an injection energy of 100 GeV is required. We have thus demonstrated that the use of synchrotrons to reach 60 GeV is the only viable alternative at the present time.

4 Cost Considerations

The addition of an afterburner linac reduces the cost of the synchrotrons by nearly the price of the linac. Thus, relative to the LAMPF II design, our concept is more expensive by the price of a compressor and neutron source or approximately \$100 million. We believe that the cost of the total facility can be kept under \$500 million in 1986 dollars. A detailed design is needed to get an accurate cost estimate.

5 Progress on Generic Accelerator R&D

A perpendicular-biased ferrite-tuned cavity is being tested to determine its maximum average power handling capability. This cavity, which has a R/Q of 35 Ohms and a tuning range greater than 20%, achieved 140 kV on a single gap at 60% duty factor in a 15 minute test. Our cavity was designed for cold tests. We are adding cooling and a vacuum window between the ferrite and the gap. After these modifications are complete, we are confident that the design specification of 80 kV at 60% duty factor will easily be exceeded.

We have tested a dual-frequency resonant magnet power supply. Full control of the flattop and flatbottom current and slope was demonstrated. A ceramic vacuum chamber with internal conducting stripes was fabricated. A laboratory for measuring the coupling impedance of vacuum chambers and other devices was established at Los Alamos. These developments are reported in contributions to this conference [7].

6 PILAC: A Pion Linac At LAMPF

The LAMPF Users have emphasized the need for a high intensity pion beam in the 500 - 1000 MeV region. There are numerous physics objectives for such a beam including η mesons in nuclei, pion-nucleus physics at the second and third resonances, and hypernuclear physics. A pion linac may be an attractive method to generate the required beam. The brightness of such a beam at LAMPF may exceed that available at the Brookhaven AGS.

A superconducting linac for pions was first suggested by D. E. Nagle in 1968 [8]. Our study of superconducting cavities led us to the observation that the present state-of-the-art is sufficient to make an attractive pion linac.

We consider a 402.5 MHz linac based on the 352 MHz CERN LEP cavities [3]. Identical cavities can be used for an AHF afterburner linac and for a pion linac. The 350 π mm-mrad phase space of the existing LAMPF P^3 pion beam [9] can be contained within a 150 mm diameter beam tube if quadrupole doublets are placed at 11 meter intervals as shown in Fig. 2. The CERN cavities scaled to 402.5 MHz will have a bore diameter larger than 150 mm.

Pion decay is a serious problem for any pion linac. The survival fraction has been given by Nagle [8]. The results for a LAMPF version at an average gradient of 5 MeV/meter (including dead spaces) are shown in Fig. 3. From this figure, it is apparent that if a linac of 200 MeV is chosen, then the decay of pions will reduce the available flux by approximately a factor of 3. Even including decay, the brightness of the resulting pion beam is nearly 30 times higher than would be obtained at a conventional high energy machine such as the Brookhaven AGS. Part of the improvement comes because the longitudinal phase space of the pion beam can be rotated by the linac to a minimum energy orientation, thus effectively compressing the 5% dp/p fwhm output of P^3 into 1%. Further, the linac acts like an rf separator since protons of the same momentum as pions will have too low a velocity to be accelerated. More details of the beam dynamics of a pion linac will be reported in the near future.

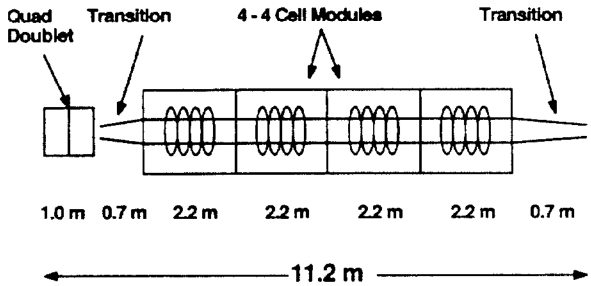

Figure 2: Unit cell for 402.5 MHz pion linac.

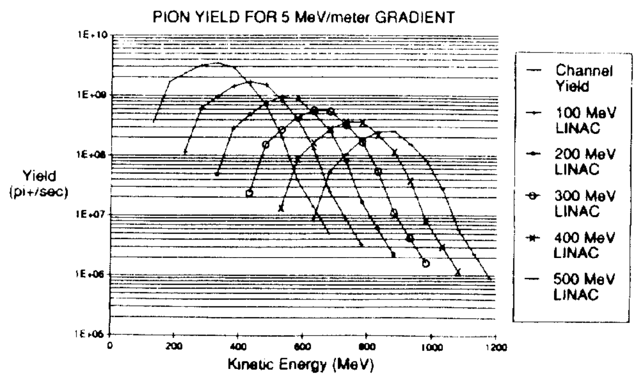

Figure 3: Yield of π^+ for Pion Linac at P^3 beam line of LAMPF.

The cost of a pion linac is reasonable. A 200 MeV linac would raise the maximum energy of pions useable at LAMPF to 700 MeV. Such a linac could be built for $15 million. This price includes a new beam line on the output of the linac. This facility would fit in the existing staging area of Area A at LAMPF.

The issue of whether a pion linac should be built at LAMPF depends on the schedule of a possible AHF. We will pay close attention to the schedule of competing facilities. The physics case for a pion linac will be discussed at a workshop on future directions in pion-nucleus physics to be held at Los Alamos August 17-21, 1987.

7 Conclusions

We have shown an initial plan for a combined kaon factory and cold-neutron source. Such a concept matches well the long-term goals of the physics community and of the materials science community. The program of generic accelerator r&d at Los Alamos has made substantial contributions to the state-of-the-art. One important area of r&d should be started, namely, superconducting rf. We have demonstrated that in addition to their possible use in an afterburner linac, superconducting rf cavities may be useful as a linac for unstable particles such as pions.

References

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