Plans for a New Pulsed Spallation Source at Los Alamos

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ABSTRACT

Los Alamos National Laboratory has proposed to change the emphasis of research at its Meson Physics Facility (LAMPF) by building a new pulsed spallation source for neutron scattering research. The new source would have a beam power of about one megawatt shared between two neutron production targets, one operating at 20 Hz and the other at 40 Hz. It would make use of much of the existing proton linac and would be designed to accommodate a later upgrade to a beam power of 5 MW or so. A study of technical feasibility is underway and will be published later this year.

Introduction

The US, which took a leading role in establishing the field of neutron scattering, has fallen seriously behind Europe in the provision of modern facilities for this type of research. At a time when there is increasing recognition of the important contributions that neutrons can and will make to national initiatives in materials science and engineering as well as biotechnology, correction of this problem is increasingly urgent. A recent panel, convened by the US Department of Energy and chaired by Professor Walter Kohn concluded that "the nation has a critical need for a complementary pair of sources: a new reactor, the Advanced Neutron Source (ANS)...; and a 1-MW pulsed spallation source (PSS)" to meet this challenge. In response to the Kohn panel, Los Alamos National Laboratory has proposed that a high-power spallation source be constructed, using much of the existing infrastructure of the Los Alamos Meson Physics Facility (LAMPF).

Specifications for the New Source

The design parameters of the proposed new facility are summarised below:

- 800 MeV linac plus compressor ring
- 1.25 mA average current (1 mA demonstrated*)
- Ion Source — 40 mA peak
- Linac — 20 mA peak (17 mA demonstrated*)
- Macropulse length — 1.8 msec
- Duty Factor — 10.8% (10% demonstrated*)
- Chopping — 400 nsec on, 200 nsec off
- 60 Hz operation — two targets @ 20 Hz and 40 Hz
- Nine months operation per year
- Greater than 90% availability
- 24 hours maintenance period every two weeks

* refers to production mode for the present H^+ operation

As planned, the new facility will make use of a number of existing LAMPF assets that would be expensive to reproduce elsewhere and are very appropriate as part of a modern accelerator complex. The 800-metre long, shielded tunnel that contains the present linac will remain as will buildings, cooling towers, 30 MW of site electrical power, and the 600-metre existing coupled-cavity linac (cf Figure 1). The cost saving that would result from the use of LAMPF as an injector for a new spallation source is at least $100M. Our current (rather rough) estimate of the cost of the new facility—which includes $100M for new neutron spectrometers and $100M in contingency—is $575M.

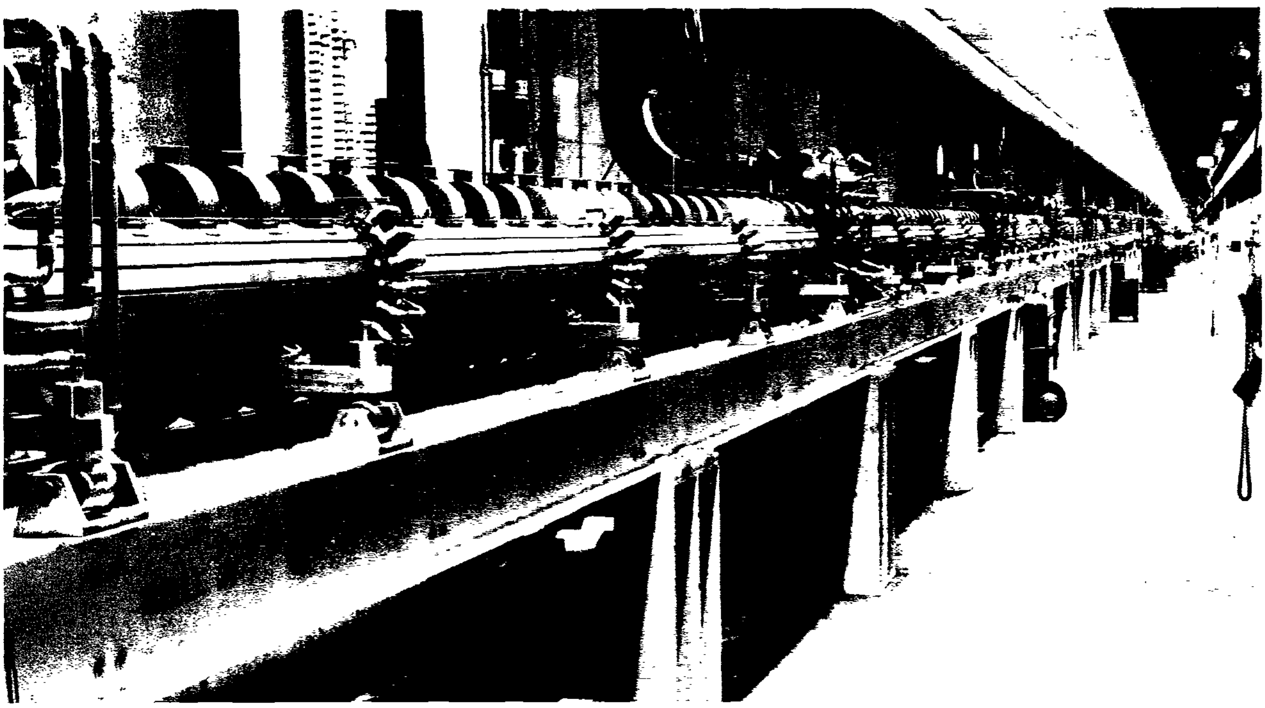

Figure 1: The 600-m-long coupled-cavity linac of the existing LAMPF accelerator will be retained for the new pulsed spallation source

Those parts of the linac that have given trouble in the past—the 201 MHz section, for example—or which could be improved by the application of modern methods will be replaced, taking full advantage of accelerator technology that Los Alamos and other laboratories have developed as part of the strategic defense initiative (SDI). There will be a new H^- ion source, a front end based on a radio-frequency quadrupole (cf Figure 2), a modern RF power system using klystrons instead of vacuum tubes, a new bridge-coupled linac, and a sophisticated RF control system. Our present reference design calls for injection of 800 MeV protons from the upgraded LAMPF linac into a compressor ring (cf Figure 3) that is similar in concept to the existing Proton Storage Ring. However, we are studying an option that would increase the proton energy and, perhaps, permit an easier upgrade to higher beam power in the future.

The new accelerator complex will produce 60 proton pulses per second, each of about 0.5 μsec duration, and distribute them between two neutron production targets operating at 40 Hz and 20 Hz. Power dissipation will be in the same ratio, with a total beam power of about 1 MW. Our reference design calls for vertical injection of the proton beam from below each target, a geometry that offers some neutronic advantages as well as the obvious 360° access for flight paths. There are disadvantages of this scheme, of course—cost and difficulty of maintaining underground proton transport lines, for example—which may eventually drive the design towards horizontal injection.

For both technical and environmental reasons, clad tungsten or a tantalum-tungsten alloy will be used as target material. Cooling and stress calculations have been carried out for several target designs and it appears that either a micro-channel target or a rod bundle with 15% to 20% coolant water fraction would work. A more serious issue may be the effect of spallation products on the mechanical properties of the target material as well as the propensity for such foreign atoms to migrate to the target surface and into the cooling water. Evidently, R&D will be needed to qualify materials for the target of a high-power source.

Figure 2: The radio-frequency quadrupole linac, designed and fabricated by Los Alamos National Laboratory for the Superconducting Supercollider, has now been commissioned.

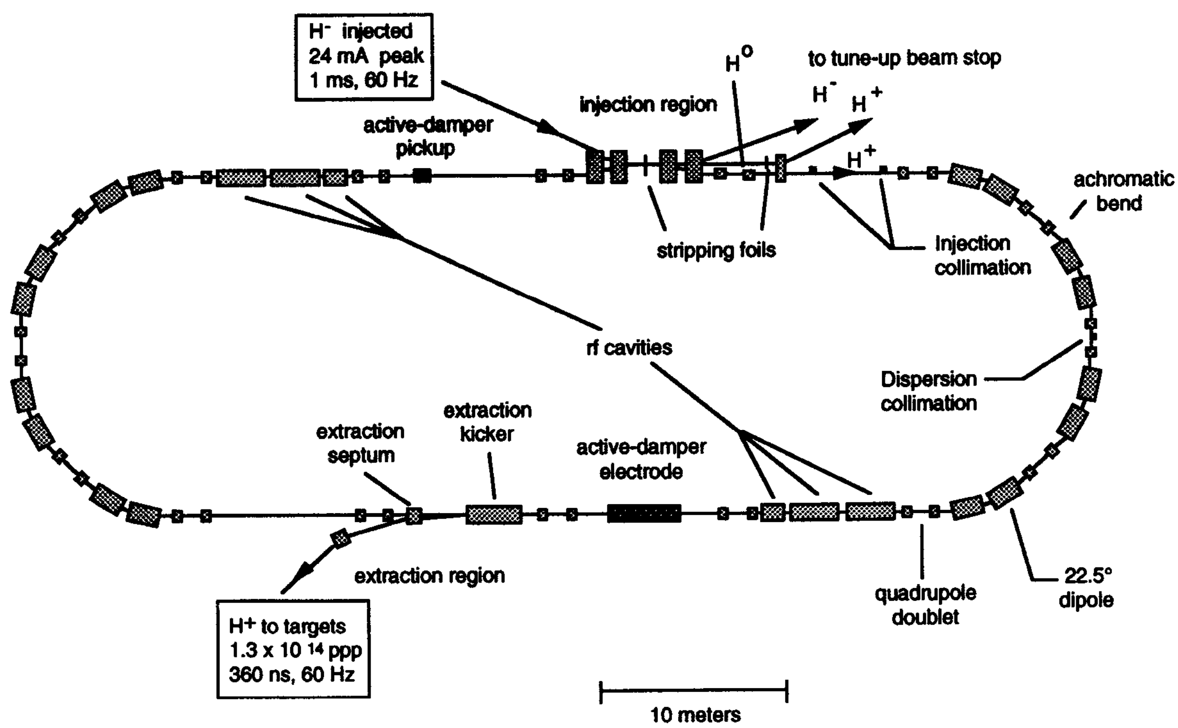

Figure 3: The new proton compressor ring draws on lessons learned from the existing PSR as well as computer-aided engineering tools developed at Los Alamos.

Flux trap moderators (first used at LANSCE), several of which will be in backscattering geometry, will provide the maximum possible flux of useful neutrons, and minimise those high-energy neutrons that contribute to background in scattering experiments. Gary Russell and his colleagues are working hard to design an optimised target/moderator system and have presented some of their thoughts in other sessions of this meeting. We expect the 40 Hz target to provide four to five times the average neutron flux generated by ISIS. Coupled cold moderators at the 20 Hz target will give twenty five times the flux of the present LANSCE. There will be room for 16 beam lines around each target. An arrangement for a possible instrument suite has been generated, principally to determine the number and nature of moderators as well as the dimensions of the single experimental hall that will house both targets.

A key design parameter for this source, which has to be considered in detail during the design stage, is reliability. In addition to engineering components so that breakdowns are minimised, Los Alamos designers have been giving serious thought to ease of maintenance and the time needed to recover from various failures. In the increasingly stringent regulatory environment in which a new source would be built, it is also important to think carefully about remote handling and the required safety systems. There is now widespread acceptance that most mitigation of radiation accidents should be based primarily on passive shielding rather than on active devices that shut down the accelerator when beam spill is detected. Since dose limits and other regulatory boundaries are likely to be a moving target during the coming decade, facility designers must adopt a conservative, proactive philosophy.

Capability of a "1 MW" Pulsed Spallation Source

At a recent workshop, held under the auspices of the Kohn panel, an international group of experts in neutron scattering instrumentation concluded that a pulsed spallation source with a beam power of about 1 MW could duplicate the capabilities of the ILL *and* provide facilities that exceed the ILL for some experiments. In other words, a 1 MW source would give the US the same capability as the ILL *plus* the obvious advantages over ISIS. An interesting concept that was introduced at the instrument workshop is that of a "matched pair" of complementary reactor and pulsed spallation sources. In such a pair, each source is used for what it does best, although there is a large area of overlap—science that can be done equally well at either source. The idea is that the ILL and ISIS form a matched pair, as would a 1 MW pulsed spallation source and the proposed Advanced Neutron Source (ANS) at Oak Ridge. A complementary pair of sources involving a 1 MW pulsed source and the ANS would clearly provide the best of all worlds for the US scientific community. However, if both sources could not be built, a 5 MW source would be required to duplicate and extend the neutron-scattering capabilities of the ANS.

Although the notion of complementarity of the ANS and a 1 MW PSS sounds intuitively appealing, it is a little difficult to quantify. The first thing one is tempted to examine is the region of Q-E space that can be probed at the two sources. As Figure 4 shows, this is largely governed by neutron kinematics so that there is no great difference between the sources in this respect. It is perhaps easier to achieve high resolution with neutron spin echo at the ANS (to achieve neV resolution would likely require a 10 Hz PSS) while the PSS has greater access to high energy transfers.. But broadly speaking the two sources access the same region of Q and E, both for elastic and inelastic scattering.

The two sources do not perform equivalently, however, even in the broad Q-E range which both can access. As Phil Seeger has demonstrated elsewhere at this meeting, some areas, such as very small Q diffraction, that were once considered impractical for a PSS can, in fact, be addressed. At a wavevector of 0.0005 $Å^{-1}$, however, an experiment at a 1 MW pulsed source would likely take thirty times as long as the same experiment at the ANS. On the other hand, measurements made on the same sample at ILL and LANSCE indicate that the PSS would be thirty times faster for many Reitveld analyses. Short of writing a long and detailed treatise, the best I have been able to do to express the complementarity of the two sources is contained in the following table. And one can easily find exceptions to most of the points listed.

Strengths of the ANS	Strength of a "1 MW" PSS
• Ability to make detailed measurements in a small Q-E window	• Large dynamic range, including an ability to make *in situ* measurements of elastic and inelastic scattering
• High integrated cold flux	• Copious hot neutrons
• Large signal strengths, especially for relaxed resolutions	• Intrinsically good signal-to-noise
• Ability to relax resolution and focus in Q-E space	• Intrinsically good resolution
• Polarisation analysis can be implemented on almost any spectrometer	• Very high pressures, pulsed high fields & single-pulse experiments are facilitated
• Flexibility of spectrometer hardware	• Flexibility to change experimental conditions in software during analysis
• UCN beams	• Bottled UCN

The natural competition between the two types of sources is likely to make their relative strengths a "movable feast", conditioned by the neutron technology of the day. In the final analysis, this competition may even be the best reason for building a balanced pair of sources because it will stimulate our field to progress towards overcoming the real problems of neutron scattering—that it is signal-limited at any source.

Next Steps

Within the next few months we expect to publish the results of our technical studies of a high-power spallation source, including a much better cost estimate for the proposed facility. An external committee has been established to advise the Laboratory Director on the needs of the scientific communities which could benefit from a new pulsed spallation source. We are hopeful that a site-independent study of the various technical options will be carried out in the near future by a team based at Lawrence Berkeley Laboratory. This study will provide ample opportunity for potential users of the new source to influence the design, particularly of the neutron spectrometers. To make proper use of a new facility of this type—or of the ANS for that matter—will require a dedicated program of R&D to

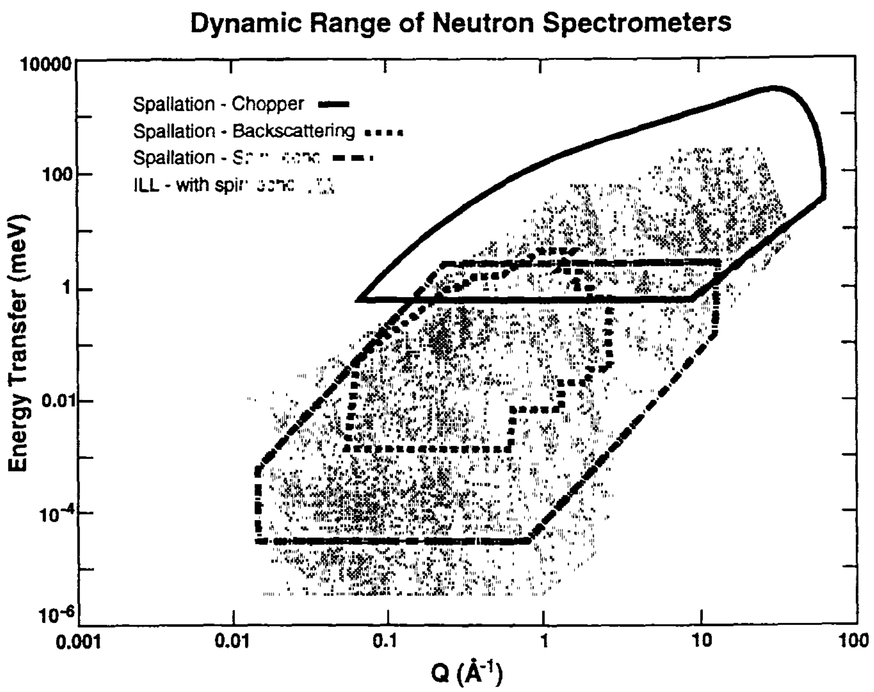

Figure 4: The Q-E space accessible to spectrometers at the ILL and at a "1 MW" PSS

develop better neutron detectors, better schemes for data visualisation and treatment, as well as improved neutron optical elements. We will work to obtain funds for this work, which should also lead to improvements at existing sources.