LA-UR-00-4920

99520

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Title:

Enabling R&D for Future Proton Applications.

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Submitted to: DOE Office of Scientific and Technical Information (OSTI)

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Abstract

This is the full final report of an LDRD project at Los Alamos National Laboratory. The project was expected to be a three-year-effort, but because of an LDRD funding reduction, it was terminated in early FY 2000. This project proposed a coordinated research effort to establish a stronger basis of understanding and capability for future defense and non-defense science applications of proton radiography. The research was done to explore scientific and technological principles that extend significantly beyond any programmatic research in this field. We made a reference design for a synchrotron and beam transport system that would deliver beams on eight beam lines simultaneousl; we pursued concepts for nearly windowless containment and tested materials for low-z windows; we initiated a study of and set up experiments for super-conducting quadrupoles to improve proton beam imaging; we developed transport-system concepts to the point that a pre-conceptual design report could be initiated; and we built a portion of experimental capability to perform measurements on magnetic fields to ensure synchotron performance. A draft pre-Conceptual design report was completed (but not published) before project termination.

Background and Research Objectives

A key part of this project was a study of an option for staging a proton-radiography-based advanced hydrotest facility at low initial cost. However, we also planned to look at options for combining a proton radiography facility with an advanced neutron spallation source. In addition to exploration of the overall technology path options to a realizable system, the project also included research necessary to explore and establish high-risk, high-payoff approaches to proton radiography. These approaches included low-Z containment, and an exploration to identify and resolve issues in the feasibility of multi-GeV proton beam transport over distances up to several miles from accelerator to radiographic experiment firing point.

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Importance to LANL's Science and Technology Base and National R&D Needs

Radiographic evaluation of explosive-driven experiments has become even more essential in the absence of a nuclear test program. LDRD researchers developed a new technique for radiography that produces radiographs of an object's interior using high-energy protons, rather than the more traditional x-rays. Proton radiography has several advantages over the x-rays. Unlike x-rays, protons are not simply attenuated as they pass through a material, they can be highly scattered because of their charge. In proton radiography, a beam of protons impinges directly on the object to be radiographed. There is no need for a bremsstrahlung converter (the device used to produce x-rays from electrons) or its equivalent, since the proton beam directly illuminates the radiographed object. Unlike most x-ray radiographic machines, a proton accelerator fires multiple bursts of protons in an almost steady stream. Special cameras can catch and separate the image made by each burst in the sequence, producing a "motion picture." This approach creates "radiographic movies" of fast events such as detonations. For example, up to 14 radiographs—each with sub-100 nanosecond resolution—have been taken in rapid succession using 800 megaelectron-volt protons. In addition, the technique can measure very small density changes, identify the elemental composition of an object, and provide magnified views of an object. These measurements cannot be accomplished with x-rays. Finally, proton radiography provides a significantly better signal to noise over x-rays in the final image. This kind of tool will give great insight into benchmarking computer codes that are being developed in the weapons program as part of the Accelerated Strategic Computing Initiative. The increasing capabilities of proton radiography will present new insight into the important questions of hydrodynamics. It will be possible, for the first time, to relate fundamental materials properties to hydrodynamic behavior.

Using this technology, the Laboratories are poised to measure physical processes critical to weapons behavior and understand that behavior in ways that previous generations of weapons designers have only dreamed of. Fundamental research and development into the basic application principles of this valuable new evaluation tool through this project were designed to ensure he maximum applied effectiveness of the tool for our stockpile stewardship mission.

Scientific Approach and Accomplishments

Efforts in this project focused on four distinct technical areas – 1) advanced containment concepts; 2) Large-aperture superconducting quadrupoles; 3) accelerator and beam-delivery system concepts; and 4) magnetic-field measurements.

In containment, we have developed concepts for nearly windowless containment and confinement that maximize resolution by putting window material only at the end of long beam tubes and have tested some materials for low-Z windows.

A study of large-aperture (75 cm diameter) quadrupole design was initiated in collaboration with the MIT High-Field Magnet Laboratory. In a contract with General Atomics, cost estimates for a 75 cm diameter and 30 cm diameter superconducting quadrupoles were produced. An experiment to measure the heat input to a superconducting coil was set up at Brookhaven National Laboratory. Several accelerator and beam transport system concepts were investigated, work was completed, and these concepts were the starting point for a draft pre-Conceptual Design Report that was prepared. In order to make any synchrotron perform as desired, it is necessary to understand the imperfections of the magnetic field. To this end, we have obtained and installed the necessary AC power supplies, have refurbished the LANSCE magnet measuring laboratory, and began preparing measuring coils

The reduction in funding for the FY-2000 LDRD program resulted in a decision to terminate this project. The unfortunate consequence is that much of the innovative technology that could have come out of this effort was significantly delayed in development while alternate funding was sought. Essentially all of the tasks were left incomplete except for the draft pre-Conceptual Design report, which is being used internal to the laboratory but was not published.