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Material issues for the super neutrino beam and high-intensity spallation source (measurements using the multi-particle correlation)

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Abstract

I discuss the technology related to producing the high-intensity spallation neutron source, and the super neutrino beam for neutrino oscillation studied at Brookhaven National Laboratory, especially material integrity. The pitting problem for solid walled liquid mercury target, has been remedied by the Kolsterized target in some what, further study for required neutron source is needed. For neutrino source study, the low mass nuclei target such as carbon–carbon composite target is promising results and the use of the tacky gluey target composed with entangled string material for high mass nuclei seems to be desirable to get high integrity stand for large energy deposition by short proton injection. Recent developments in nano-technology, such as CCD, might alleviate the high demands of maintaining the integrity of the target material. I also describe the advantages of operating the many facilities including the fast-pulsed prompt super-critical reactor in a deep underground site.

1. Introduction

Brookhaven National Laboratory (BNL) has been developing the technology for particle production of many kind, for not only scientific studies, but also engineering developments, such as nuclear energy. In this paper, I will discuss recent activities at the spallation neutron source, the technology related to neutrino oscillation [1,2], and also the outlook for extending this methodology in future using the rapidly advancing field of nano-technology which has great promise for improving detectors.

As discussed in Feyman's path integral formalism [3], physical quantities such as the cross-section are obtained from the square of the transition amplitude, which is defined as the integral of the transfer function between the initial state and final wave functions. These cross-section parameters, in turn, are determined by the source and measured after the transition process. Although the particle's source can be refined by using a shorter time and spatial function, so alleviating the complications of the measurements after the transfer process, the recent rapid progress in obtaining measurements using new devices such as CCD technology offer the opportunity to overcome the difficulties facing front-end source technology. Physical quantities, such as cross-section measurements in condensed matter physics, can be achieved by properly balanced technological developments as well as by reviving the technologies of fast pulsed reactor that were

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developed in the early days of the nuclear science technology but were abandoned prematurely in Western Europe and USA [4–6].

It has been emphasized that only environment friendly technology will be fully supported by the public. Accordingly, I have promoting the use of the deep underground for not only science but also energy production [7–11]. Therefore, in relation to my present study of neutron scattering and neutrino oscillation, I will discuss the use of a deep underground laboratory facility and industrial facility.

2. Recent activities for the neutrino factory

Recently, the interests of the high-energy physics community have focused on the high neutrino source, the target which produces the pions, and the low mass nuclei target has been studied. The neutrinos for oscillation experiments shown in Fig. 1 are produced from the decay of pions and muons produced in the spallation reaction. To get a well focused neutrino beam, the muon and pions must go through the Lithium magnet horn. Issues concerning material of the horn martial have come up. To reduce the overall energy to produce muon for muon–muon collider, the author proposed the use of the target compressed by laser or ion beam as the inertial fusion devices were proposed in Ref. [12].

Fig. 1 depict the configuration of the BNL neutrino oscillation experiment (BNLNWG: BNL Neutrino Working Group).

Fig. 2 depict the configuration of the target and magnetic horn.

From our former BNL-E951 [13] experiments, we learned a great deal about improving the chances of survival of solid targets using graphite, carbon–carbon composite, inconel, and super-Invar. These experiments

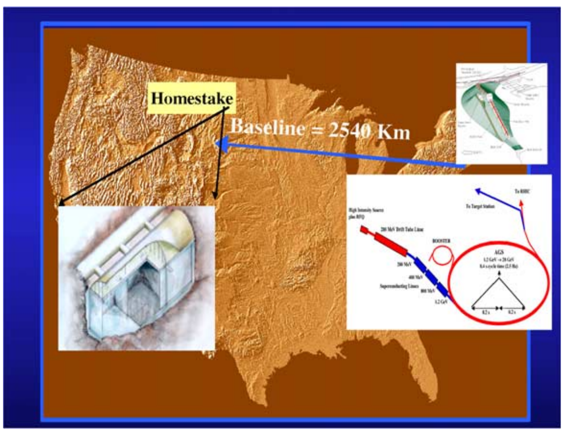

Fig. 1. The configuration of the BNL neutrino oscillation experiment.

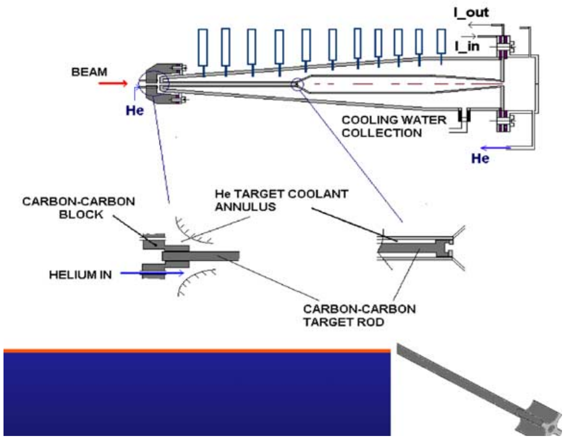

Fig. 2. The configuration of the target and magnetic horn.

provided data for identifying the best candidate materials through measured responses. The validation prediction models against measurements also gave us confidence in predicting material response and/or failure at extreme conditions. Further, these and recent PSI and Los Alamos experimental results can provide information on the benchmark energy depositions predicted by the various Monte Carlo codes.

In the optimization study of the target and horn, alternative materials, such as AlBe Met, and Toyota's Gum metal [2] have been considered, besides the Hg target.

To protect the magnetic horn-based metal, a nanostructural surface filling that enhances heat transfer through the use of nano-particles in the cooling medium was explored [2].

During the next stage assessments, the following items will be pursued, such as (A) an assessment of the long-term survival of the baseline target and horn materials (aluminum and carbon–carbon); (B) the effect of repeated irradiation/mechanical property changes on baseline materials; (C) experimental verification of the compatibility of cooling agents (corrosion, sublimation); (D) innovative schemes to enhance heat transfer and material protection using the nanostructure films, and nanofluids, and (E) new materials, such as AlBeMet, Toyota's Gum Metal, Titanium alloy, Vascomax, and Titanium (6A-6Va) [2].

The first problem facing in the material issue for target design is the integrity of the target for neutron and muon production. Due to the highly intense heat deposition in the target, its integrity is a major priority.

Neutrinos are produced from muon decay that is produced from the decay of pions whose mass is much smaller than the neutron mass; hence, the less massive nuclei can be used for the available for its production of pions. Instead of tungsten, the low mass of elements such as carbon can make the production of pions efficient. The use of the carbon has been considered as the target material; the carbon ring structure found in carbon nano-tubes can maintain the resistively and integrity of the target material by their entanglement within the tube's structure.

3. Spallation neutron source

For spallation neutron production, presently tungsten is considered as the target material for medium sized source, and mercury target for large sized source of SNS. Due to the 1 GeV mass of the neutron, high mass nuclei targets are preferable for highly efficient production of neutrons. Heavy mass nuclei have a larger cross-section than do low mass nuclei due to large radius of the target nuclei in nuclear spallation, unless some the resonance is observed in the spallation reaction.

For measuring the cross-section using the time-of-flight experiment, a short pulsed neutron is beneficial and also to get a high gain in the scattered neutron flux. One of the main purposes is to obtain a high neutron flux which has small phase space to make processing of the observed data much easier. However, recent advanced technology using the CCD can provide the opportunity get the correlation functions much easier than before; this reduces somewhat the stringent requirements imposed for the target design, although the development of CCD which resistant to radiation damage is needed.

The main issue for spallation neutron source in the SNS is now the cavitation erosion and pitting caused by the action of pulsed pressure wave in the liquid mercury target. To reducing the pitting, the integrity of a Kosterized target vessel has been studied by Farrell [14].

Even though this kind problem of pitting was not observed for tungsten material, radiation damage by high voltage electron beam on the tungsten was observed by the presence of string-like structures in the Kyoto University study [15]. One possibility for making the target material strongly resistant to rupture would be to use a rubber- like compound. Carbon nano-tubes are a good candidate. Tungsten has not usually this structure, but the observation of the coil-like structures observed in the Kyoto University. Experiments, suggest that it might be beneficial to pursue to this kind of structure to ensure high integrity against radiation damage.

Our study at BNL on crystallization of the material, revealed a process going through the string formation and the congregation of the these strings; later, large congregations of these strings became solidified [16]. Thus, there is the possibility of making the polymer-type configuration by refining the process in detail in similar to self assembled nano-structure. It is worthwhile to pursue the crystallization of tungsten through a thread-like structure to obtain a viscous material. Recent mathematical advances based on the differential geometrical or topological analysis might be used for these studies [17] Peter's note.

4. Use of multi-correlation function

Due to rapid development of nano-science technology, we can establish rather in the short-term detector technology useful for the multi-correlation functions that can be substituted for the high-intensity pulsed source.

The one reason for developing the high-intensity neutron source is to get the delta type functional form for the condensed matter physics experiments; the long-pulsed source has not been followed up due to the slow motion of the mechanical chopper; however, by introducing the CCD type fast reacting measuring device we can obtain the correlation function of time and spatial function so that the analysis can be similar to using the short-time pulsed source. The burden for the strong stress loading to the target can be alleviated, although data processing is required.

Thus, it is worthwhile not only pursue the development of a strenuous source, but also that of a detector that can provide the spatially and timely fast response data.

These technologies have rapidly progressed in for the synchrotron light source, and the high-intensity X-ray and infrared light sources. They will play a substantial role for many researches in the fields of condensed matter, cell-biology, and medical image.

Neutron detector has not yet been as well developed as the X-ray detector, but the fast neutron detector using the p–n reaction is well established and the application of the low energy neutron detector might be realized in a short time. I hope this development occurs soon.

We designed and studied the pulsed fast reactor more than 30 years ago following the advent of the pioneering Dubna Fast pulsed reactor [4]. Ispra Euratom [5] and BNL [6] worked on this reactor, which is similar to Dubna reactor. Although the pulsed width is not short as the spallation neutron source, but when the multi-correlation functions are obtained using the nanotechnology, this kind of reactor could be very valuable tool for physics experiments, as discussed in my paper [8–11] on the deep-underground nuclear park concept. When installed deep underground, the safety issues for this supercritical reactor can be greatly relaxed and the security issues of non-proliferation resolved.

5. Environment Issue and deep underground facility

To protect the public is the one of most important issue for promoting the scientific activity. To operate the high power proton accelerator, the collimeter has been designed to localizing the beam loss.

By installing these collimates in the SNS facility, we can reduces the radiation level during accumulating the beam.

I have been promoting the deep underground nuclear park concept for energy production, there are many facilities in the world not only high energy physics field even for energy production as shown in the figures attached.

It has been considered to construct these facilities on the earth surface due to the fear of spend the extra money to built underground structure. But it has been demonstrated in the many underground facilities in the not only high energy facility such as Large Hadron Collider (LHC) program Figs. 3 and 4 respect show the overall view of LHC experiments, and LHC ring installed 50 m deep underground with 4.3 km radius site in CERN suburb of Geneva Switzerland. also the hydraulic power plant building at Tokyo Electric Power Company (TEPCO) power plant. And the deep underground science and engineering laboratory (DUSEL) are planning at Home Stake gold mine sites.

The deep underground facility has a great benefit for protecting the water level from the radiation, and for shielding the sky shine radiation.

Fig. 5 shows the Homestake gold mine pits and Fig. 6 shows the Home Stake gold mine shaft configuration where Dr R. Davis performed the Soar neutrino experiments.

As discussed in the above, the fast pulsed fast reactor which can be supercritical condition even though very short interval can be operated in the deep underground without fear of the nuclear fallout from the accident. By providing the accelerator near by we can get various types of particles of pion, muon and neutrino with many

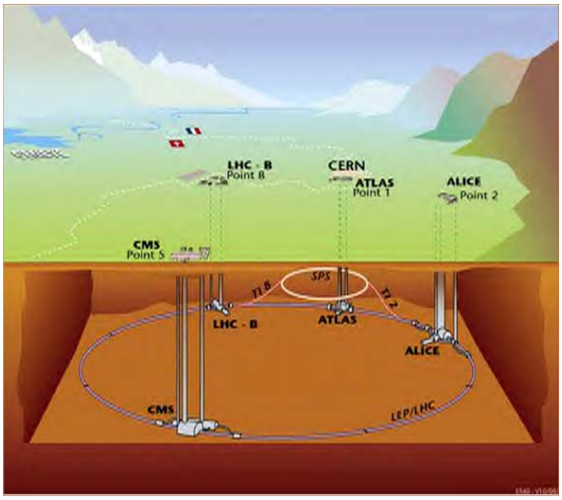

Fig. 3. Overall view of the LHC experiments.

Fig. 5. Homestake gold mine pits.

Fig. 4. LHC at CERN.

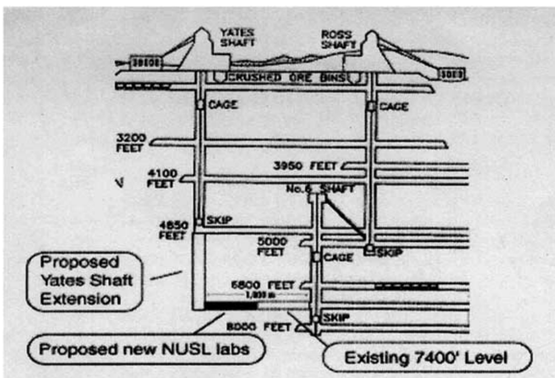

Fig. 6. Proposed new NUSL laboratory.

energies as well as the low energy neutrino from the pulsed reactor.

Which correlation functions are measured by newly developed detector, we can find the fundamental law of physics such as Parity, Charge,Time (P, C, T) violations, and we might get the Higgs mechanism controlled vacuum states.

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