BOOK OF 2009 SBIR-STTR PHASE I PROPOSAL SUMMARIES

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FIRM NAME:	RESEARCH INSTITUTION:
Muons, Inc.	**Oak Ridge National Laboratory** **Dr. Yoon Kang, subgrant PI**
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NAME of PRINCIPAL INVESTIGATOR: **Michael Neubauer** PHONE NUMBER: **(xxx) xxx-xxxx**

PROJECT TITLE: **02b Robust Vector Modulator System for Klystron Power Distribution**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Many user facilities require a reliable technique to distribute power from a single klystron to several RF cavities to reduce both capital and operating expenses. However, neither robust vector modulators nor sophisticated control systems to use them for integrated phase and amplitude control at the individual cavity level are commercially available.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

A complete system for klystron power distribution will be developed that includes improved vector modulators as well as low and high level control systems for their use in a practical application. An innovation to be developed is a reliable fast feedback algorithm that will allow the phase and amplitude of all RF cavities to be quickly adjusted to compensate for local and global variations in operating parameters.

What will be done in Phase I – typically, two to three sentences.

Here we must describe a plan that is reasonable and significant. The outcome of the Phase I work should make it clear that Phase II will yield something good.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

This part will expand on all the uses of distributed klystron power and what additional markets would be served, such as the project-x proton driver, FELs, etc.

Key Words:

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

A system to control one klystron power source to feed several RF cavities is being developed to save both operating and capital expenses for many scientific and commercial applications.

2. RADIO FREQUENCY (RF) DEVICES AND COMPONENTS FOR ACCELERATOR FACILITIES

The Office of Basic Energy Sciences, within the DOE's Office of Science, is responsible for current and future synchrotron radiation light source, free electron lasers, and spallation neutron source user facilities. This topic seeks the development of radio frequency devices and components to support these user facilities. Grant applications are sought only in the following subtopics.

b. Modulators for High Level Radio Frequency (RF) Accelerator Systems—Grant applications are sought to develop a high-level amplitude and phase modulator (in either waveguide or coaxial topology) that can demonstrate modulation ability out to 20 kHz. Significant cost savings could be achieved if one klystron were used to drive multiple accelerating cavities, while retaining phase and amplitude control at the individual cavity level. Grant applications also are sought to develop (1) a 1KHz. 300 kV, 300A solid state modulator for production of picosecond X-ray pulses using RF deflecting cavities; and (2) a robust, high-average-power (200kW) 1kHz modulator system that operates at about 300 kV, 300 A with ultimate rep rate at 1kHz or higher. Questions - contact Roger Klaffky (roger.klaffky@science.doe.gov

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NAME of PRINCIPAL INVESTIGATOR: **Dr. Rolland Johnson** PHONE NUMBER: **(757) 870-6943**

PROJECT TITLE: **01b BPMs for FELs and Light Sources**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Advanced electron-beam diagnostic instruments are needed to support the development of X-ray Free Electron Lasers (FEL), as well as the operation and upgrade of 3rd generation light sources. Transverse wakefields in a linac may produce beam-breakup instabilities that create "banana shaped" beam bunches that are difficult to characterize with existing devices.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

A novel approach based on some clever idea (the innovation requirement has to be addressed!! Any ideas?) will use bench tests and computer modeling to develop detectors capable of measuring these bunch distortions with spatial resolution on the order of 1 micron, and with temporal resolution (along the bunch) of 10-100 fs, in bunches of peak current 10 to 500 A.

What will be done in Phase I – typically, two to three sentences.

Here we must describe a plan that is reasonable and significant. The outcome of the Phase I work should make it clear that Phase II will yield something good.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

The part will expand on all the other uses of such detectors and what additional markets would be served and/or how the operation of existing or future machines will benefit the users of the BES community.

Key Words:

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

Extremely sensitive devices to measure the distortions of beams caused by instabilities are being developed in order to improve the operation of light sources that are widely used in the study of basic energy sciences.

1. TECHNOLOGY TO SUPPORT BES USER FACILITIES

The Office of Basic Energy Sciences (BES), within the DOE's Office of Science, is responsible for current and future user facilities including synchrotron radiation, free electron lasers, and the Spallation Neutron Source (SNS). This topic seeks the development of technology to support these user facilities. **Grant applications are sought only in the following subtopics:**

b. Beam Diagnostic Instrumentation for Free Electron Lasers and 3rd Generation Light Sources—Advanced electron-beam diagnostic instruments are needed to support the development of X-ray Free Electron Lasers (FEL), as well as the operation and upgrade of 3rd generation light sources. Grant applications are sought to develop monitors for beam position and electron bunch length. The beam position monitor should have

nanometer resolution and associated electronics for both linac and storage ring applications. The electron beam bunch length monitor should perform non-destructive measurements, be capable of single-bunch resolution better than 100 fs, and possess a system design that is relevant for the bunch parameters of the future X-ray FEL and 3rd generation light sources.

Grant applications also are sought to develop diagnostic devices for the non-destructive measurement of electron beam emittance and for the energy spread within electron bunches. For FEL applications, measurements of electron bunch properties require resolution on the order of 10 _m, so that the so-called "slice" properties can be determined with sufficient accuracy. Both the beam emittance and the energy spread of the beam are critical parameters in FELs, and the measurement techniques must allow for rapid and noninvasive tuning, as well as for the implementation of feedback systems for systems optimization. Approaches of interest include optical techniques that employ transition radiation or synchrotron radiation. The diagnostics should be small (< 1 m length scale) and suitable for integration into an operational light source.

Grant applications also are sought to develop diagnostics for the measurement of charge modulation within an electron bunch at optical wavelengths in the regime 50-1000 nm. Seeded FELs utilize an inverse FEL scheme to first introduce an energy modulation into an electron bunch; then a dispersive transport region converts the energy modulation into a charge density modulation along the electron bunch. The charge density is modulated with the same period as the laser, i.e., in the wavelength regime 50-1000 nm.

Finally, grant applications are sought to develop a diagnostic technique for the dynamic measurement of the transverse position of the centroid of an electron bunch, as a function of position along that bunch. The transverse wakefields in a linac may introduce the socalled "banana shape" beam as a result of the beam-breakup instability, in which deflecting wakefields introduce a transverse spatial offset in the electron distribution along a bunch. Proposed diagnostics must be able to measure this effect with spatial resolution on the order of 1 _m, and with temporal resolution (along the bunch) of 10-100 fs, in bunches of peak current 10-500 A.

Questions – contact Roger Klaffky (Roger.Klaffky@science.doe.gov)

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FIRM NAME:	RESEARCH INSTITUTION:
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NAME of PRINCIPAL INVESTIGATOR: **Michael Neubauer** PHONE NUMBER: **XXX-XXX-XXXX**

PROJECT TITLE: **JLab 01b High Power Co-Axial SRF Coupler**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

There are over 35 coupler designs for SRF cavities ranging in frequency from 325 to 1500 MHz. Two-thirds of these designs are coaxial couplers using disk or cylindrical ceramics in various combinations and configurations. While it is well known that dielectric losses go down by several orders of magnitude at cryogenic temperatures, it not well known that the thermal conductivity also goes down, and it is the ratio of thermal conductivity to loss tangent (SRF ceramic Quality Factor) and ceramic volume which will determine the heat load of any given design.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

We propose a novel, robust co-axial SRF coupler design which maximizes the SRF ceramic Quality Factor, and minimizes the heat load for a broadband coaxial coupler design which can be used in several different applications. The high power RF design will incorporate window materials investigated in a previous SBIR Phase I and have a moveable center conductor for adjustable couplings.

What will be done in Phase I – typically, two to three sentences.

The RF and mechanical design for the coupler will be done in Phase I. A critical design feature which will be prototyped, will be a thin compressed coaxial window with minimum ceramic volume to minimize the heat load.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

A novel broad-band high power co-axial SRF coupler can be used in many accelerator applications where there are currently over 35 different coupler designs.

Key Words: broad-band, coaxial coupler, SRF, heat load

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

A universal SRF coupler will be designed for many accelerator applications to reduce overall accelerator costs and improve reliability.

46. NUCLEAR PHYSICS ACCELERATOR TECHNOLOGY

The Nuclear Physics program supports a broad range of activities aimed at research and development related to the science, engineering, and technology of heavy-ion, electron, and proton accelerators and associated systems. Research and development is desired that will advance fundamental accelerator technology and its applications to nuclear physics scientific research. Areas of interest include the basic technologies of the Brookhaven National Laboratory's Relativistic Heavy Ion Collider (RHIC), with heavy ion beam energies up to 100 GeV/amu and polarized proton beam energies up to 250 GeV; technologies associated with RHIC luminosity upgrades; the development of an electron-ion collider (EIC); linear accelerators such as the Continuous Electron Beam

Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF); and development of devices and/or methods that would be useful in the generation of intense rare isotope beams for the next generation rare isotope beam accelerator facility (FRIB). A major focus in all of the above areas is superconducting radio frequency (RF) acceleration and its related technologies. Relevance of applications to nuclear physics must be explicitly described. Grant applications that propose using the resources of a third party (such as a DOE laboratory) must include, in the application, a letter of certification from an authorized official of that organization. **Grant applications are sought only in the following subtopics**.

a. Materials and Components for Radio Frequency Devices—Grant applications are sought to improve or advance superconducting and room-temperature materials or components for RF devices used in particle accelerators. Areas of interest include: (1) peripheral components, for both room temperature and superconducting structures, such as ultra high vacuum seals, terminations, high reliability radio frequency windows using alternative materials (e.g., sapphire), RF power couplers, and magnetostrictive or piezoelectric cavity tuning mechanisms; (2) fast ferroelectric microwave components that control reactive power for fast tuning of cavities or fast control of input power coupling; (3) materials that efficiently absorb microwaves from 2 to 90 GHz and are compatible with ultra-high vacuum, particulate-free environments at 2 to 4 K; (4) innovative designs for hermetically sealed helium refrigerators and other cryogenic equipment, which simplify procedures and reduce costs associated with repair and modification; (5) more cost effective, kW-to-multiple-kW level, liquid helium refrigerators; (6) simple, low-cost mechanical techniques for damping length oscillations in accelerating structures, effective in the 10-300 Hz range at 2 and/or 4.5 K; and (7) alternative cavity fabrication techniques, such as hydroforming or spinning of seamless SRF cavities. Potential applicants interested in items (1) through (7) above should contact Dr. Robert Rimmer at Thomas Jefferson Laboratory (rarimmer@jlab.org).

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NAME of PRINCIPAL INVESTIGATOR: **Dr. Rolland Johnson** PHONE NUMBER: **(757) 870-6943**

PROJECT TITLE: **03b H^- Ion Sources for High Intensity Proton Drivers**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Spallation neutron source user facilities require reliable, intense beams of protons. The technique of H^- charge exchange injection into a storage ring or synchrotron has the potential to provide the needed beam currents, but it is limited by the ion sources that have currents and reliability that are too low for user demands and emittances that are too large for efficient acceleration.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

A novel approach based on some clever idea (the innovation requirement has to be addressed!! Any ideas?) will use bench tests and computer modeling to develop an H^- source with sufficient current, emittance, and reliability to satisfy the next generation of proton drivers for diverse purposes.

What will be done in Phase I – typically, two to three sentences.

Here we must describe a plan that is reasonable and significant. The outcome of the Phase I work should make it clear that Phase II will yield something good.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

The part will expand on all the other uses of H- sources and what additional markets would be served, such as the project-x proton driver, etc.

Key Words:

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

A device to produce H^- ions, which are each made of a proton and two electrons, is being developed to enable higher intensity beams with better reliability and improved efficiency for many powerful particle accelerators used in science and industry.

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FIRM NAME:	RESEARCH INSTITUTION:
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NAME of PRINCIPAL INVESTIGATOR: **Michael Neubauer** PHONE NUMBER: **XXX-XXX-XXXX**

PROJECT TITLE: **03a Improved DC Gun Insulator**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Many user facilities such as synchrotron radiation light sources and free electron lasers require accelerating structures that support electric fields of 10-100 MV/m, especially at the start of the accelerator chain where ceramic insulators are used for very high gradient DC guns. These insulators are difficult to manufacture, require long commissioning times, and have poor reliability, in part because energetic electrons bury themselves in the ceramic causing a buildup of charge and eventual puncture.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

A novel ceramic manufacturing process will be developed to incorporate bulk resistivity in the region where it is needed to bleed off accumulated charge due to highly energetic electrons. The process will be optimized to provide an appropriate gradient in bulk resistivity from the vacuum side to the air side of the HV standoff ceramic cylinder. The ceramics will be metalized and brazed to support flanges designed for maximum flexibility and strength.

What will be done in Phase I – typically, two to three sentences.

A computer model will be used to determine the optimum cylinder dimensions and required resistivity gradient for an example RF gun application. A ceramic material example with resistivity gradient appropriate for use as a DC gun insulator will be fabricated by glazing using doping compounds and tested.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

Ceramics with gradients in bulk resistivity will have a wide range of application in high voltage standoffs. (There must be a lot of practical standoff examples!!!)

Key Words: RF Guns, Ceramic insulators, Bulk resistivity, HV standoff

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

Ceramics with specific changes in resistivity throughout their volume will be developed and manufactured to improve very high voltage gradients in DC guns used for accelerator research and industrial applications.

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NAME of PRINCIPAL INVESTIGATOR: **Rolland Johnson** PHONE NUMBER: **(xxx) xxx-xxxx**

PROJECT TITLE: **04d Laser Stripping for H^- Injection**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Spallation neutron source user facilities require reliable, intense beams of protons. The technique of H^- charge exchange injection into a storage ring or synchrotron has the potential to provide the needed beam currents, but it is limited by materials used to strip the electrons from the ion beam.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

A powerful laser will be employed in combination with magnetic stripping to develop systems for efficient injection for SNS upgrades. A novel use of technology for RF windows under development for new power coupler designs will be adapted for the mirrors that control the laser power in the accelerator vacuum chamber where the ions will be stripped. (need to refer to paper on next page on proof of principle experiment).

What will be done in Phase I – typically, two to three sentences.

Here we must describe a plan that is reasonable and significant. The outcome of the Phase I work should make it clear that Phase II will yield something good.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

This part will expand on all the uses of H^- charge-exchange injection and what additional markets would be served beyond the SNS, such as the project-x proton driver.

Key Words:

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

New systems are being developed to create intense proton beams based on the use of powerful lasers to strip electrons from H^- ions for the Spallation Neutron Source and other scientific and commercial accelerators.

4. ANCILLARY TECHNOLOGIES FOR ACCELERATOR FACILITIES
The Office of Basic Energy Sciences, within the DOE's Office of Science, is responsible for current and future synchrotron radiation light source, free electron laser, and spallation neutron source user facilities. This topic seeks the development of computational, control, and superconducting technologies to support these user facilities. Grant applications are sought only in the following subtopics.

d. Advanced Laser Systems for Accelerator Applications—Advanced laser systems are needed for photoinjectors, for Free-Electron Laser Seeding or for current-enhanced self-amplified spontaneous emission (ESASE), for laser-ion stripping of hydrogen beams, and for laser wire beam profile measurements in proton particle accelerators. Grant applications are sought for the development of:

(6) Lasers for laser-ion stripping of hydrogen beams with the following features: high repetition rate (~400 MHz), high peak power (~1MW), picosecond 355 nm pulses to match the SNS linac in-beam structure (50 ps long micropulses separated by 2.5 ns and gated into minpulses of 650 ns repeating at 1.058 MHz and bunched into 1 ms macropulses).

Proof-of-principle demonstration of high efficiency laser-assisted H^- beam conversion to protons

V. Danilov, A. Aleksandrov, S. Assadi, J. Barhen,W. Blokland, Y. Braiman, D. Brown, C. Deibele,W. Grice, S. Henderson, J. Holmes, Y. Liu, A. Shishlo, and A. Webster
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(Received 17 November 2006; published 2 May 2007)
Thin carbon foils are used as strippers for charge exchange injection into high intensity proton rings. However, the stripping foils become radioactive and produce uncontrolled beam loss, which is one of the main factors limiting beam power in high intensity proton rings. Recently, we presented a scheme for laser stripping an H^- beam for the Spallation Neutron Source (SNS) ring. First, H_ atoms are converted to H0 by a magnetic field, then H0 atoms are excited from the ground state to the upper levels by a laser, and the excited states are converted to protons by a magnetic field. In this paper we report on the proof-of principle demonstration of this scheme to give high efficiency (around 90%) conversion of H_ beam into protons at SNS in Oak Ridge. The experimental setup is described, and comparison of the experimental data with simulations is presented.

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NAME of PRINCIPAL INVESTIGATOR: **Neubauer et. al.** PHONE NUMBER: **XXX-XXX-XXXX**

PROJECT TITLE: **4b High Power SRF Coupler**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

High Power SRF Couplers depend on ceramic windows to transfer the microwave energy from the source to the SRF Cavity. Various window materials were investigated in an SBIR Phase I proposal, and the best material found with highest thermal conductivity and lowest loss tangent, and fabricated with a compression ring for thermal and mechanical efficiencies; however, the heat load, the total number of watts generated was not minimized, and the lower the heat load of an SRF coupler, the lower the costs of cryogenics. (This needs work! Should be related to the rejected 2008 proposal that was similar.)

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

In order to minimize heat load, the fewest number of watts generated by the window will be investigated by producing the thinnest compression window possible of the best window material available. The goal would be to reduce the heat load by a factor of 2 or more; to build, test and measure the losses of such a high power SRF coupler.

What will be done in Phase I – typically, two to three sentences.

An RF and mechanical design will be generated with the thinnest window possible using the material determined in a previous SBIR grant. A window will be built and tested for its thermal and mechanical characteristics.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

Thin windows in SRF applications reduce the heat load and cryogenic costs. In SRF applications, the thinner the better.

Key Words: Thin robust windows

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

An improved method for feeding power to superconducting RF accelerating structures is being developed to reduce costs and provide additional capability for old and new particle accelerators.

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FIRM NAME:	RESEARCH INSTITUTION:
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NAME of PRINCIPAL INVESTIGATOR: **Dr. Richard Sah** PHONE NUMBER: **XXX-XXX-XXXX**

PROJECT TITLE: **Cornell 04b Beam Pipe HOM Absorber for 750 MHz RF Cavity Systems**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Superconducting RF (SRF) systems typically contain unwanted frequencies or higher order modes (HOM) that must be absorbed by ferrite and other lossy ceramic-like materials that are brazed to substrates that are strategically located and mechanically attached, often to the drift tube adjacent to the SRF cavity. These HOM loads need to be robust both thermally and mechanically with broadband microwave loss characteristics, but the ferrites and their attachments are weak under tensile and thermal stresses and tend to crack.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

A high gradient 750 MHz superconducting cavity system for linac-driven synchrotron radiation sources will be developed by improving HOM absorber materials and designs based on novel construction techniques which were developed for the SLAC B-factory.

What will be done in Phase I – typically, two to three sentences.

750 MHz RF system designs will be numerically modeled to determine the optimum ferrite load required to meet broadband loss specifications. The shape of the ferrites will be determined by the manufacturing process requirements of the supplier; attachment techniques to the metal substrates will include variations from full compression rings, to stress-free ferrite assemblies designed to yield in the buffer layer of posts or vanes. Prototype structures will be fabricated and tested for mechanical strength.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

Better attachment techniques for dissimilar materials such as ferrite bonding to a metal substrate are needed for many microwave applications, where thermal heat transfer is critical and there is a great difference between assembly temperature and operating temperatures.

Key Words: Superconducting RF, Higher order modes, Ferrite loads

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

Superconducting RF cavity systems will be improved by developing better designs and materials for the absorption of unwanted higher order mode (HOM) frequencies that lead to beam instabilities in synchrotron light sources.

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NAME of PRINCIPAL INVESTIGATOR: **Mary Anne Cummings** PHONE NUMBER:

PROJECT TITLE: **35a Low Beta Region Muon Collider Detector Design**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

The physics reach of energy-frontier muon colliders can be significantly enhanced by increasing the active area in the forward region by instrumentation of material, which was previously designed as shielding. Earlier muon collider detector designs need to be revised in order to take advantage of advances in detector technology, particularly for resistance to high radiation and lower occupancy due to increased granularity.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

Challenges for detectors in the low beta region are high precision and fast readout in a high radiation environment. New technology that is compact, insensitive to high magnetic fields, with good timing resolution is emerging, but pose challenges for readout uniformity and noise reduction.

What will be done in Phase I – typically, two to three sentences.

Recent work in MPPCs at NIU will be the basis for simulations of large-scale, high-granularity instrumentation of interaction regions considered suitable only for shielding material in previous muon collider detector studies. Integration into more complete muon collider simulations will be carried out in Phase II.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

This new detector design in the forward region will take advantage of the higher luminosity of recent muon colliders with more aggressive designs of beam focusing systems for the interaction regions of particle colliders.

Key Words: muon collider, low beta, detector design, high intensity.

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

In order to maximize the discovery potential of elementary particle colliders at the energy frontier, the active area, sensitivity, and radiation resistance of particle detectors will be improved by using recent advances in detector technology.

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FIRM NAME:	RESEARCH INSTITUTION:
Muons, Inc.	**University of Chicago** **Prof. Henry J. Frisch, subgrant PI**
ADDRESS: **552 N. Batavia Ave.** **Batavia, IL 60510**	ADDRESS: **Chicago, …**

NAME of PRINCIPAL INVESTIGATOR: **Dr. Thomas J. Roberts** PHONE NUMBER: **(630) 840-2424**

PROJECT TITLE: **35a Picosecond Timing Counters**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Many measurements in particle and accelerator physics are limited by the time resolution with which individual particles can be detected. This includes particle identification via time-of-flight in major experiments like CDF at Fermilab and CMS at the LHC, as well as the measurement of longitudinal variables in accelerator physics experiments. While new concepts based on micro-channel plates hold great promise for improved time resolution, optimizing their design is a challenge.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

Several groups are working on counters with timing resolutions of a few picoseconds, and we will work in collaboration with them. The specific expertise Muons, Inc. brings to the problem is our experience in developing and performing particle simulations, which we will apply to the modeling and optimization of the inner workings of these counters.

What will be done in Phase I – typically, two to three sentences.

The existing Geant4 physics processes will be added in to G4beamline, and their accuracy validated. If necessary, additional physics processes will be developed, in conjunction with the Geant4 collaboration. Simulations of the counters will begin.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

We are specifically interested in counters with sufficient timing resolution to measure the longitudinal phase space variables for the MANX experiment. Many other experiments will benefit from increased timing resolution, including potential upgrades for the LHC experiments.

Key Words: particle simulation, detector modeling

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

New particle detectors are being developed with significantly improved timing resolution, for use in several state-of-the-art scientific experiments and instruments.

Phase I-SBIR/STTR Fiscal Year 2009

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FIRM NAME: **Muons, Inc.**	RESEARCH INSTITUTION: **Northern Illinois University Prof. David Hedin**
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NAME of PRINCIPAL INVESTIGATOR: **Dr. Robert J. Abrams** PHONE NUMBER: **(630) 840-6317**

PROJECT TITLE: **35a Advances in Multi-Pixel Photon Counter Technology**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences:

Multi-Pixel Photon Counters (MPPC), also called Silicon Photomultipliers (SiPM), which have recently become commercially available, have the potential to be low-cost photon sensors for high-energy physics detectors and medical imaging. However, noise rates and after-pulsing must be reduced and high density arrays of MPPCs and associated electronic instrumentation for signal processing must be developed in order to realize the potential of these devices.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects.

Operational characteristics will be studied at various temperatures with MPPCs coupled to scintillating fibers and other light sources. Arrays of MPPCs will be assembled and interfaced to integrated electronics to digitize the signals, while mitigating effects of noise and after-pulsing. These studies will lead to development of large-scale systems based on MPPCs that can be used in high energy physics experiments and medical applications.

What will be done in Phase I – typically, two to three sentences.

Samples of available MPPCs will be measured to verify and extend manufacturer's specifications, such as bias voltage for optimal operation and signal strength and noise rates at various temperatures from room temperature down to liquid helium temperatures. The most promising MPPCs will be assembled into arrays interfaced to prototype electronics. Studies of these prototypes will be used to design an electronics platform for arrays of MPPCs in Phase II.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

MPPCs have potential for use in high energy physics, nuclear physics, and medical imaging applications for detecting light that is emitted from scintillation counters and Cherenkov counters. They may also be used for other commercial applications that require detection of very low light levels.

Key Words: MPPC, SiPM, photon detector

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

A new light sensor with the potential to revolutionize detection low light level signals is being developed for scientific instruments and medical imaging.

Phase I-SBIR/STTR Fiscal Year 2009

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FIRM NAME: **Muons, Inc.**	RESEARCH INSTITUTION: **National High Field Magnet Laboratory Justin Schwartz, subgrant PI**
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NAME of PRINCIPAL INVESTIGATOR: **Stephen Kahn** PHONE NUMBER: **(631) 344-2282**

PROJECT TITLE: **36d HTS development for 30-50 T final muon cooling solenoids**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

High temperature superconductors (HTS) have been shown to carry significant current density in the presence of extremely high magnetic fields when operated at low temperature. The successful design of magnets needed for high energy physics applications using such high field superconductor (HFS) depends critically on the detailed wire or tape parameters which are still under development and not yet well-defined.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

HFS will be developed for accelerator use by concentrating on the design of an innovative magnet that will have a useful role in muon beam cooling. The essential properties of available HFS at low temperature and high field will be measured as input to high-field solenoid designs. HTS manufacturers will be engaged to improve their materials, designs, and techniques for HFS operation based on these measurements and limitations discovered in detailed magnet designs.

What will be done in Phase I – typically, two to three sentences.

In Phase I, a conceptual design of a high field solenoid using YBCO HFS conductor will be analyzed. Mechanical properties of HFS conductors will be measured along with the maximum engineering current density (J_e) as a function of temperature and strain to extend the HFS specifications to conditions needed for low temperature applications. HFS quench properties will be measured and quench protection schemes developed for the solenoid.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

The high field magnet designed will have an immediate use as an essential part of the cooling chain for a muon collider. The expertise gained from this project will enable very high field solenoids, dipoles and quadrupoles using HFS at low temperature for applications in future particle accelerators. High-field solenoid magnets are also essential for NMR research in physics, biology, chemistry, and material science.

Key Words: high temperature superconductor, high field magnets, muon collider

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

High-temperature superconducting wire is being developed to operate at low temperature for extremely high field magnets for particle accelerators and NMR.

The Department of Energy High Energy Physics program supports a broad research and development (R&D) effort in the science, engineering, and technology of charged particle accelerators, storage rings, and associated apparatus. Advanced R&D is needed in support of this research in high-field superconductor and superconducting magnet technologies. This topic addresses only those superconductor and superconducting magnet development technologies that support dipoles, quadrupoles, and higher order multipole corrector magnets for use in accelerators, storage rings, and charged particle beam transport systems. **Grant applications are sought only in the following subtopics:**

d. Ancillary Technologies for Superconductors—Grant applications also are sought to develop innovative wire and cable design and processing technologies. Approaches of interest include methods to utilize stranded conductors with high aspect ratio, such as Rutherford cables, or low-loss tape geometries in particle accelerator applications; and technologies to improve wire piece length and increase billet mass.
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Grant applications also are sought for innovative insulating materials that are compatible with the use of inter-metallic superconductors in practical devices. Approaches of interest should enable the use of inter-metallic superconductors (such as the A-15, HTS, or MgB2 types) in practical devices. Insulating systems must be compatible with high temperature reactions in the 750-900 ºC range, be capable of supporting high mechanical loads at both room and cryogenic temperatures, have a high coefficient of thermal conductivity, be resistant to radiation damage, and exhibit low creep and low out-gassing rates when irradiated.

Lastly, grant applications are sought to develop HTS conductors suitable for the very high-field 30-50 T solenoids needed for final ionization cooling stages of a Muon Collider.

Questions - contact Bruce Strauss (bruce.strauss@science.doe.gov)

Phase I-SBIR/STTR Fiscal Year 2009

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FIRM NAME: **Muons, Inc.**	RESEARCH INSTITUTION: **Jefferson Lab** **Dr. Yaroslav Derbenev, subgrant PI**
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NAME of PRINCIPAL INVESTIGATOR: **Dr. Rolland P. Johnson** PHONE NUMBER: **(757) 870-6943**

PROJECT TITLE: **38b Epicyclic Helical Channels for Parametric Resonance Ionization Cooling**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Muon beam ionization cooling is a key element in the design of next-generation low-emittance and high-luminosity muon colliders. Present designs, however, have limitations that need to be addressed with new approaches.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

To obtain low-emittance muon beams, a new concept is being developed that combines ionization cooling in a Helical Cooling Channel (HCC) with parametric resonances. The novelty consists of creating an alternating orbit dispersion in the HCC by imposing an additional helical field of opposite helicity.

What will be done in Phase I – typically, two to three sentences.

In this project we will develop a theoretical description of a muon transport line that includes a solenoid with superimposed transverse dipole fields that vary with *two* characteristic periods. An analytical theory for parametric resonance ionization cooling in such a transport line the will be developed. Initial numerical analysis will prepare grounds for full-scale simulations to be performed in Phase II, including analysis of non-linear effects.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

This new approach will allow more aggressive designs of cooling channels for muon colliders that will result in significant increase of luminosity. The resulting greater feasibility and discovery potential of muon colliders such as Higgs factories and energy-frontier machines will make their construction more likely. Formation of highly focused neutrino beams can also benefit from the technology that will be developed in this project.

Key Words: muon collider, parametric ionization cooling, emittance exchange

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

In order to maximize the discovery potential of elementary particle colliders at the energy frontier, or to create low-divergence neutrino beams, the momentum spread of particles in the beams must be reduced via `cooling'. A new approach to the design of the required beam cooling systems is being developed.

Phase I-SBIR/STTR Fiscal Year 2008

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NAME of PRINCIPAL INVESTIGATOR: **Dr. Rolland P. Johnson** PHONE NUMBER: **(757) 870-6943**

PROJECT TITLE: **38b Achromatic Low Beta for Colliders**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Designers of high luminosity energy-frontier muon colliders must provide strong beam focusing in the interaction regions, where compensation of the resulting aberrations is difficult because the beams have large momentum spread. Successful interaction point designs have relied on the intuition of talented scientists rather than a comprehensive mathematical formalism such that extrapolations to new machines and different operating conditions are difficult.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

A new concept for achromatic low beta designs is being developed, in which optical correction elements are installed before the final focusing magnets in order to avoid the extension of beam area at the collision point. The essential idea is formulated analytically by use of the Hamiltonian method, where symmetry considerations drastically reduce the "dimensionality" of the problem. Numerical simulations will be used to verify the designs and to investigate sensitivities to errors.

What will be done in Phase I – typically, two to three sentences.

An analytical theory for the low beta insertion enhanced by a symmetric compensating block will be developed into a publishable paper. Initial simulations will demonstrate the benefits of the approach and dynamic aperture explorations will be initiated. A preview of topics to be explored in Phase II, including analysis beyond second order and numerical simulations will be carried out.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

This new approach will allow more aggressive designs of beam focusing systems for the interaction regions of particle colliders. The resulting greater feasibility and discovery potential of muon colliders such as Higgs factories and energy-frontier machines will make their construction more likely. Other colliders can also benefit from the technology that will be developed in this project.

Key Words: muon collider, low beta, interaction region, lattice design, aberration compensation

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

In order to maximize the discovery potential of elementary particle colliders at the energy frontier, the particle beams must be focused to a very small size when they collide. A new approach to the design of the required beam focusing systems is being developed.

Phase I-SBIR/STTR Fiscal Year 2009

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NAME of PRINCIPAL INVESTIGATOR: **Dr. Chuck Ankenbrandt** PHONE NUMBER: **(757) 870-6943**

PROJECT TITLE: **38b Novel Muon Collection Scheme**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Intense muon beams have many potential commercial and scientific applications, ranging from low-energy investigations of the basic properties of matter using spin resonance to large energy-frontier muon colliders. However, muons originate from a tertiary process that produces a diffuse swarm. To make useful beams, the swarm must be rapidly cooled before the muons decay.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects.

A promising new concept for the collection and cooling of muon beams to increase their intensity and reduce their emittances will be investigated, namely, the use of a nearly isochronous helical cooling channel (HCC) to facilitate capture of the muons into several RF bunches. Such a distribution can be cooled quickly and then coalesced efficiently into a single bunch to optimize the luminosity of a muon collider. Optimal ways to integrate such a subsystem into the rest of a muon collection and cooling system will be developed by analysis and simulation.

What will be done in Phase I – typically, two to three sentences.

The application of quasi-isochronous helical cooling channels for rf capture of muon beams will be developed analytically. Simulations will be performed to optimize an HCC for muon capture. A preliminary examination of the integration of this subsystem into the rest of a muon collider facility will be carried out.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

Bright muon beams are needed for many commercial and scientific reasons. Potential commercial applications include the use of muon beams to screen cargo containers for homeland security, low-dose radiography, and muon catalyzed fusion. Scientific uses include low energy beams for rare process searches, muon spin resonance applications, muon beams for neutrino factories, and muon colliders as Higgs factories or energy-frontier discovery machines.

Key Words: muon beams, muon collection, muon cooling, neutrino factory, muon collider

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

Beams of muons would have many commercial and scientific advantages if the disadvantage of their short lifetime can be overcome. New ways to collect large numbers of muons and to form them into bright beams are being developed for many applications, including a muon collider at the energy frontier.

2009 Phase I-SBIR/STTR

FIRM NAME: **Muons, Inc.**	RESEARCH INSTITUTION: **Brookhaven National Laboratory** **Dr. Richard Fernow, subgrant PI**
ADDRESS: **552 N. Batavia Ave.** **Batavia, IL 60510**	ADDRESS: **P. O. Box 5000** **Upton, NY 11973**

NAME of PRINCIPAL INVESTIGATOR: **Dr. Thomas J. Roberts** PHONE NUMBER: **(630) 840-2424**

PROJECT TITLE: **38g Simulation Tools for the Muon Collider Feasibility Study**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

The U.S. muon collider community is mobilizing itself to produce a "Feasibility Study Report" (FSR) for a muon collider. This is happening on an aggressive schedule and must include the best possible simulations to support the technical design. The FSR for a muon collider will require innovative new approaches to many aspects of accelerator design, and the simulations to support it will require tools with features and capabilities that have not yet been determined.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

Two computer programs have emerged as the most commonly used simulation tools within the muon collider community: ICOOL (primary author: Dr. Fernow), and G4beamline (primary author: Dr. Roberts). This project will support the ongoing development and testing of both tools for the FSR, including a common suite of tests to ensure that both tools give accurate and realistic results as well as innovative user-friendly interfaces, with emphasis on graphical user interfaces and windows.

What will be done in Phase I – typically, two to three sentences.

The schedule of this Phase I project meshes well with the startup of the simulation effort leading to the FSR. We will participate in the initial organizational effort, assist in defining the tools for use by the different groups comprising the FSR team, and develop a longer-range plan to ensure that the G4beamline and ICOOL programs will be supported and thrive into the future.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

G4beamline and ICOOL, which are freely available to all users, have many applications outside of the muon collider community, and are especially useful for designs of beam lines and accelerator components that involve the passage of particles through matter. For example, at last count, G4beamline was being used to support the DOE mission for over 30 applications ranging from designs of photocathodes and studies of beam halos, to muon cooling systems and the muon collider FSR.

Key Words: particle simulation, accelerator modeling, muon collider

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

A major effort is starting that will result in a feasibility study of a new type of accelerator facility: a muon collider. This project will support the primary simulation tools that will be used in that effort.

g. Computational Tools and Simulation of Accelerator Systems—Grant applications are sought to develop new or improved computational tools for the design, study, or operation of charged-particle-beam optical systems, accelerator systems, or accelerator components. These tools should incorporate innovative user-friendly interfaces, with emphasis on graphical user interfaces and windows. Grant applications also are sought for the conversion of existing codes for the incorporation of these interfaces (provided

that existing copyrights are protected and

Phase I-SBIR/STTR Fiscal Year 2009

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FIRM NAME:	RESEARCH INSTITUTION:
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ADDRESS: **552 N. Batavia Ave.** **Batavia, IL 60510**	ADDRESS: **12000 Jefferson Av.** **Newport News, VA 23606**

NAME of PRINCIPAL INVESTIGATOR: **Dr. Charles Ankenbrandt** PHONE NUMBER: **(757) 870-6943**

PROJECT TITLE: **38b RF-Induced Emittance Exchange**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

The ionization cooling schemes that have been devised for muon beams intended for an energy-frontier muon collider produce beams with transverse emittances that are too large and longitudinal emittances that are unnecessarily small. To make adequate luminosity with those beams, the muon intensities would have to be very large, leading to various problems.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects.

The luminosity can be enhanced by exchanging the transverse emittances into the longitudinal phase space, reducing transverse beam sizes with a tolerable growth in the bunch length. Previous schemes to accomplish this goal involve passing the beams through matter, leading to various difficulties. The objective of this project will be to establish a method to exchange transverse emittances into the longitudinal phase space via the use of gradient RF cavities. The beam manipulations will be designed and simulated, and the required rf cavity will be designed and prototyped.

What will be done in Phase I – typically, two to three sentences.

Analytical and computational tools will be employed to elaborate on the design of the series of beam manipulations to accomplish the emittance exchange. Likewise, the required rf cavity will be designed using well-established tools.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

The success of this SBIR/STTR project would enhance the feasibility and affordability of an energy-frontier muon collider by allowing the muon production and detector performance requirements to be relaxed. That in turn would allow future muon collider facilities to be planned with more aggressive schedules at reduced costs.

Key Words: muon beams, muon collection, muon cooling, emittance exchange, muon collider

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

A new way to reshape bunches of muons for a collider is being developed to achieve higher collision rates with fewer muons, leading to a more affordable energy-frontier collider.

Phase I-SBIR/STTR Fiscal Year 2009

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FIRM NAME: **Muons, Inc.**	RESEARCH INSTITUTION: **Illinois Institute of Technology Prof. Daniel Kaplan, subgrant PI**
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NAME of PRINCIPAL INVESTIGATOR: **Dr. Rolland Johnson** PHONE NUMBER: **(757) 870-6943**

PROJECT TITLE: **IIT 39a Gridded-Wire Windows for High Pressure RF Cavities**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

RF cavity windows that have been proposed for muon cooling and acceleration are circular foils that close the cavity ends to reduce the power requirement and increase the on-axis electric field. Gridded-tube windows, which are grid-like structures composed of tubes that carry coolant, have been proposed and studied for vacuum cavities but not yet tested. RF windows for high-pressure cavities for muon cooling and acceleration, however, have yet to be developed.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

A novel concept first discussed in an earlier SBIR proposal is to use the excellent thermal properties of hydrogen gas to externally cool grids of wires that would act as RF windows with negligible distortion and detuning from heating. Gridded RF windows for high-pressure cavities will be designed, built, and tested at high RF power for muon-cooling and acceleration applications.

What will be done in Phase I – typically, two to three sentences.

Several possible geometrical designs of gridded-wire RF windows will be compared for high pressure RF cavities. The designs will include electromagnetic, thermal, and structural simulations in addition to analyses of fabrication and surface-coating requirements. Based on these studies a design will be chosen for construction and high-power testing it at high RF power in Phase II.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

The gridded-wire windows to be developed will improve muon cooling efficiency for neutrino factories and muon colliders.

Key Words: gridded windows, RF windows, high-pressure RF cavities.

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

Low-mass RF windows are being developed to improve the efficiency for accelerating muons for neutrino factories and muon colliders, new tools for physics research.

Phase I-SBIR/STTR Fiscal Year 2009
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FIRM NAME:	RESEARCH INSTITUTION:
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NAME of PRINCIPAL INVESTIGATOR: **Michael Neubauer** PHONE NUMBER: **XXX-XXX-XXXX**

PROJECT TITLE: **FNAL 46a Dielectric Loaded RF Cavities**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Muon beams need to be cooled and accelerated for neutrino factories and muon colliders. RF cavities below 800 MHz are required for muon beams for several stages of beam cooling, not only for the initial capture of the very diffuse beam, but also later in the cooling process when longitudinal and transverse emittance manipulations are required. The sizes of RF cavity structures are so large that mechanical size constraints become significant cost and technical drivers especially when high magnetic fields are required for controlling beam dynamics.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

RF cavities will be developed that use ceramic dielectric inserts to reduce the size of low frequency cavities so they will fit inside magnetic coils required for muon beam cooling.

What will be done in Phase I – typically, two to three sentences.

An internal dielectric sleeve will be designed for an 800 MHz cavity previously used in high-pressure breakdown experiments to lower the frequency to 500 MHz. The couplings for fundamental power input and pickup will be redesigned as necessary to maintain appropriate coupling factors. Low power tests will compare the Q of the cavity at room temperature to the Q at cryogenic temperatures evaluating the loss tangent of the ceramic and the impact of the difference in thermal expansion coefficient of the cavity metal and ceramic inserts. Two different ceramic inserts with significantly different dielectric constants and loss tangents will be tested at low power at cryogenic temperatures. High power tests at 500 MHz with a ceramic cylinder insert inside of a pill box cavity designed for 800 MHz and high pressure hydrogen gas will be compared to numerical models and measurements of a similar 500 MHz cavity designed to operate without a ceramic insert

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

Cavity designs in all applications will be simplified for frequency scaling by using specially designed ceramic inserts.

Key Words:

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

RF cavities will be designed with cylindrical ceramic inserts to reduce the size of cavities used in the 200-800 MHz range.

Phase I-SBIR/STTR Fiscal Year 2009

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FIRM NAME:	RESEARCH INSTITUTION:
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NAME of PRINCIPAL INVESTIGATOR: **Michael Neubauer** PHONE NUMBER: **XXX-XXX-XXXX**

PROJECT TITLE: **46a Phase and frequency locked magnetrons for SRF Sources**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Typically, high power sources for accelerator applications are many megawatt microwave tubes that may be combined together to form ultra high-power localized power stations. The RF energy is then distributed to multiple strings of cavities through high power waveguide systems. The cost of large systems for combining and/or distribution of RF energy is in efficiency, reliability, and manufacturing over and above the cost of the microwave source. Magnetrons are the lowest cost microwave source in $/kW with the highest efficiency, typically greater than 85%. But frequency and phase stability of magnetrons has been a problem when used as sources for accelerators.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

Muons, Inc has developed variable frequency cavity techniques which will be utilized to phase and frequency lock magnetrons, allowing their use for either individual cavities, or cavity strings. Economies of scale will further reduce magnetron costs, in addition to removing the dollar, efficiency, and reliability costs of combining and/or distributing power.

What will be done in Phase I – typically, two to three sentences.

Radial vaned, π–mode structures typically form the microwave structure for magnetron sources. Ferrite blocks will be brazed into the structure in the regions of high magnetic field. Orthogonal B-fields (which may be similar to sextupoles) will surround the magnetron to vary the permeability of the ferrites as already demonstrated in a Muons, Inc Phase I program. A feed-back loop will be designed and built to control the magnetic field which will control the phase and frequency difference between a reference signal, and the power reflected from a cavity load attached to the stabilized magnetron. A full system will be demonstrated in Phase II.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

Magnetron sources, with built in phase and frequency stabilizing structures, have broad applications from sputtering systems to phased array radars, as well as small to large accelerator systems.

Key Words:

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

Stabilized magnetrons are being developed to provide the lowest cost microwave sources for a number of diverse applications, such as: accelerators, phased array radars, and sputtering systems.

Phase II STTR FY 2008
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NAME of PRINCIPAL INVESTIGATOR: **Dr. Rolland Johnson** PHONE NUMBER: **(757) 870-6943**

PROJECT TITLE: **46a Compact, Tunable RF Cavities**

TECHNICAL ABSTRACT (Limit to space provided)
Statement of the problem or situation that is being addressed - typically, one to three sentences.
New developments in the design of fixed-field alternating gradient (FFAG) synchrotrons have sparked interest in their use as rapid-cycling, high intensity accelerators of ions, protons, muons, and electrons. Compact RF cavities that tune rapidly over various frequency ranges are needed to provide the acceleration in FFAG lattices.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects .
An innovative design of a compact RF cavity that uses orthogonally biased ferrite or garnet materials for fast frequency tuning and liquid dielectric to reduce the overall cavity size will be developed using computer models, prototyped, and tested. The chosen parameters will make this type of cavity useful in a variety of FFAG accelerators and other commercial applications.

What was done in Phase I – typically, two to three sentences.
RF cavity designs that employ liquid dielectric and orthogonally biased ferrite or garnet for use in FFAG accelerators and commercial applications were investigated via computer modeling. A test cavity was built and is being used to evaluate ferrite and garnet cores in strong transverse fields. A model RF cavity with an external biasing solenoid was designed and built to evaluate cavity designs with liquid dielectric and transversely biased cores; frequency measurements of the model show excellent agreement with computer simulations.

What is planned for the Phase II project - typically, two to three sentences.
The ferrite and garnet test cavity and the model cavity that were built in Phase I will be exploited to determine the range of possibilites for FFAG and other applications. A working prototype cavity will be designed and built to provide a second-harmonic RF cavity for the Fermilab Booster to improve the capture of protons from the Linac. The same cavity, using different magnetic and dielectric materials will also work for FFAG machines.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).
Rapid-cycling FFAG synchrotrons can provide high intensity beams for a variety of applications such as medical accelerators of protons and light ions for cancer therapy, proton drivers for neutron or muon production, rapid muon accelerators, and electron accelerators for synchrotron light sources. The successful development of compact, tunable accelerating RF cavities will establish or enhance the feasibility of these FFAG machines for medical, basic research, and other applications. Several upgrades of existing machines will also benefit from these cavities.

Key Words: RF Cavity, tunable, ferrite, transverse bias, liquid dielectric.

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)
Innovative accelerating structures are being developed for fixed-field alternating gradient synchrotrons and for older machines that require upgrades to provide high intensity beams of ions, protons, muons, and electrons for cancer therapy, medical and material diagnostics, and basic research.

Rf cavities below 800 MHz are required for the cases in which either low-kinetic energy capture or long drifts are required such as in muon phase rotation channels or helical cooling channels. Dielectric loaded RF cavities will allow smaller diameter cavities to be designed, and while the ceramic's loss characteristics have negative impacts on Q's at room temperature, their loss characteristics drop off by several orders of magnitude at cryogenic temperatures, making dielectric loaded RF cavities ideal for SRF applications. In addition, cavity designs will be simplified, because changing the frequency of a cavity design would be as simple as changing the dielectric cylinder insert inside the cavity.

especially when high magnetic fields are required for controlling beam dynamics.

The couplings for fundamental power input and pickup will be redesigned as necessary to maintain appropriate coupling factors. Low power tests will compare the Q of the cavity at room temperature to the Q at cryogenic temperatures evaluating the loss tangent of the ceramic and the impact of the difference in thermal expansion coefficient of the cavity metal and ceramic inserts.

46. NUCLEAR PHYSICS ACCELERATOR TECHNOLOGY

The Nuclear Physics program supports a broad range of activities aimed at research and development related to the science, engineering, and technology of heavy-ion, electron, and proton accelerators and associated systems. Research and development is desired that will advance fundamental accelerator technology and its applications to nuclear physics scientific research. Areas of interest include the basic technologies of the Brookhaven National Laboratory's Relativistic Heavy Ion Collider (RHIC), with heavy ion beam energies up to 100 GeV/amu and polarized proton beam energies up to 250 GeV; technologies associated with RHIC luminosity upgrades; the development of an electron-ion collider (EIC); linear accelerators such as the Continuous Electron Beam

Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF); and development of devices and/or methods that would be useful in the generation of intense rare isotope beams for the next generation rare isotope beam accelerator facility (FRIB). A major focus in all of the above areas is superconducting radio frequency (RF) acceleration and its related technologies. Relevance of applications to nuclear physics must be explicitly described. Grant applications that propose using the resources of a third party (such as a DOE laboratory) must include, in the application, a letter of certification from an authorized official of that organization. **Grant applications are sought only in the following subtopics**.

a. Materials and Components for Radio Frequency Devices—Grant applications are sought to improve or advance superconducting and room-temperature materials or components for RF devices used in particle accelerators. Areas of interest include: (1) peripheral components, for both room temperature and superconducting structures, such as ultra high vacuum seals, terminations, high reliability radio frequency windows using alternative materials (e.g., sapphire), RF power couplers, and magnetostrictive or piezoelectric cavity tuning mechanisms; (2) fast ferroelectric microwave components that control reactive power for fast tuning of cavities or fast control of input power coupling; (3) materials that efficiently absorb microwaves from 2 to 90 GHz and are compatible with ultra-high vacuum, particulate-free environments at 2 to 4 K; (4) innovative designs for hermetically sealed helium refrigerators and other cryogenic equipment, which simplify procedures and reduce costs associated with repair and modification; (5) more cost effective, kW-to-multiple-kW level, liquid helium refrigerators; (6) simple, low-cost mechanical techniques for damping length oscillations in accelerating structures, effective in the 10-300 Hz range at 2 and/or 4.5 K; and (7) alternative cavity fabrication techniques, such as hydroforming or spinning of seamless SRF cavities. Potential

applicants interested in items (1) through (7) above should contact Dr. Robert Rimmer at Thomas Jefferson Laboratory (rarimmer@jlab.org).
Grant applications also are sought to develop (8) methods for manufacturing superconducting radio-frequency (SRF) (>500 MHz) accelerating structures with $Q_0>10_{10}$ at 2.0 K, or with correspondingly higher Q's at higher temperatures such as 4.5 K; and (9) advanced fabrication methods for elliptical SRF cavities to reduce production costs (industrial metal forming techniques, especially with large grain or ingot material, have the potential for significant cost reductions by simplifying the sub-assemblies – e.g., dumbbells and beam tube – and reducing the number of electron beam welds).
Grant applications also are sought to develop (10) improved superconducting materials that have lower RF losses, operate at higher temperatures, and/or have higher RF critical fields than sheet niobium; and (11) techniques to create a layer of niobium on the interior of a copper elliptical cavity, such as by energetic ion deposition, so that the resulting 700-1500 MHz structures have $Q_0>8 \times 10_9$ at 2 K. Approaches of interest for items (10) and (11) should identify appropriate precursors and create high quality Nb, NbN, Nb_3Sn, or MgB_2 films with anti-diffusion dielectric overlayer via atomic layer deposition (ALD) synthesis.
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Finally, grant applications are sought to develop (12) advanced techniques for surface processing of superconducting resonators, including methods for electropolishing, high temperature treatments, and surface coatings that enhance or stabilize performance parameters. Surface conditioning processes of interest should yield microscopically smooth (R_q< 10 nm / 10μm$_2$), crystallographically clean bulk niobium surfaces; and/or reliably remove essentially all surface particulate contaminates > 0.1 μm from interior surfaces of typical RF accelerating structures. Also, grant applications are sought for laser surface glazing of niobium for surface purification and annealing in UHV.
Potential applicants interested in items (8) through (12) above should contact Dr. Charles Reece at Thomas Jefferson Laboratory (reece@jlab.org).
Questions - contact Manouchehr Farkhondeh (manouchehr.farkhondeh@science.doe.gov).

Phase I-SBIR/STTR Fiscal Year 2009

(All information provided on this page is subject to release to the public.)

FIRM NAME:	RESEARCH INSTITUTION:
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NAME of PRINCIPAL INVESTIGATOR: **Dr. Rolland Johnson** PHONE NUMBER: **(757) 870-6943**

PROJECT TITLE: **55c Fiber Optics for Fusion Applications**

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Fusion energy sources require the development of superconducting magnets beyond to today's capabilities in order to achieve safe and reliable operation. New electromagnetic noise-immune sensors are needed to provide rapid and redundant quench protection for operational systems as well as to measure temperature and strain for studies of magnet behavior for engineering development.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

Optical fibers with Bragg gratings will be imbedded within Nb3Sn and YBCO magnets to monitor strain, temperature, and irradiation, and to detect quenches. Protection methods for High-Temperature Superconducting magnets with their slow quench propagation velocities will be developed. Associated instrumentation will allow real-time measurements to aid the development of high-field magnets that are subject to large Lorentz forces and to allow the effective detection of quenches so that the stored energy of operating magnets can be extracted and/or dissipated without damaging the magnet.

What will be done in Phase I – typically, two to three sentences.

Fiber optic materials will be evaluated for compatibility with fusion system magnets. Coating materials to enhance their behavior within magnets will be evaluated and techniques for imbedding the fibers in coil packages, and their effectiveness for process monitoring and quench detection, will be investigated. Effects of irradiation on fiber and fiber Bragg gratings will be measured. Design of the sensor system to be built and implemented in phase II will begin.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

Fusion system magnets constructed from Nb3Sn or YBCO will benefit from sensitive fiber optic diagnostics to monitor strain and temperature for magnet development and also to provide redundant, electromagnetic noise-immune quench protection for day-to-day operation.

Key Words:

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

Optical fiber based sensors are being developed to monitor and protect the superconducting magnets used for fusion reactors, particle accelerators, and magnetic resonance imaging.

OFFICE OF FUSION ENERGY SCIENCES

55. ADVANCED TECHNOLOGIES AND MATERIALS FOR FUSION ENERGY SYSTEMS

An attractive fusion energy source will require the development of superconducting magnets and materials as well as technologies that can withstand the high levels of surface heat flux and neutron wall loads expected for the in-vessel components of future fusion energy systems. These technologies and materials will need to be substantially advanced relative to today's capabilities in order to achieve safe, reliable, economic, and environmentally-benign operation of fusion energy systems. Further information about research funded by the Office of Fusion Energy Sciences (OFES) can be found at the OFES Website (URL: www.ofes.fusion.doe.gov).

Grant applications are sought only in the following subtopics:c. Superconducting Magnets and Materials—New or advanced superconducting magnet concepts are needed for plasma fusion confinement systems. Of particular interest are magnet components, superconducting, structural and insulating materials, or diagnostic systems that lead to magnetic confinement devices which operate at higher magnetic fields (14T-20T), in higher nuclear irradiation environments, or allow for wider operating ranges in temperature or pulsed magnetic fields.

Grant applications are sought for:

(1) innovative and advanced superconducting materials and manufacturing processes that have a high potential for improved conductor performance and low fabrication costs. Of specific interest are materials such as MgB_2 with properties that allow for operation near 20K, or YBCO conductors that are easily adaptable to bundling into high current cables carrying 30 - 60 kA. Desirable characteristics include higher critical current at 20 K and high field, higher copper fractions, lower losses, low sensitivity to strain degradation effects, high radiation resistance, and better cabling methods for tape conductors

(2) novel methods for joining coil sections for manufacture of demountable magnets that allow for highly reliable, remakeable joints that exhibit excellent structural integrity, low electrical resistance, low ac losses and high stability in high field and pulsed applications. These include conventional lap and butt joints, as well as very high current plate-to-plate joints, as in a tokamak Toroidal Field system

(3) novel, advanced sensors and instrumentation for monitoring magnet and helium parameters (e.g., pressure, temperature, voltage, mass flow, quench, etc.); of specific interest are fiber optic based devices and systems that allow for electromagnetic noise-immune interrogation of these parameters as well as positional information of the measured parameter within the coil winding pack. A specific use of fiber sensors is for rapid and redundant quench detection. Novel fiber optic sensors may also be used for precision temperature or strain sensing for scientific studies of conductor behavior and code calibration.

(4) radiation-resistant electrical insulators,e.g., wrapable inorganic insulators and low viscosity organic insulators that exhibit low gas generation under irradiation, less expensive resins and higher pot life. Insulation systems with high bond and higher strength and flexibility in shear.

Questions - contact Barry Sullivan (barry.sullivan@science.doe.gov)

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(All information provided on this page is subject to release to the public.)

FIRM NAME:	RESEARCH INSTITUTION:
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NAME of PRINCIPAL INVESTIGATOR: **Dr. Richard Sah** PHONE NUMBER: **(510) 338-0181**

PROJECT TITLE: **DHS Be Film Deposition for HPRF Cavities for Mobile Muon Source**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

One of the most serious terrorist threats to the security of the United States is the smuggling of nuclear weapons or special nuclear materials (SNM) past the borders of the nation and into the homeland. In the case of smuggling within shipboard cargo containers, it is crucial to detect the SNM at a distance, and the most promising technology to accomplish this goal is to interrogate the target ship with a stopping mu-minus beam. The emission and detection of characteristic x rays from muonic atoms provide a clear detection signal.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

A crucial aspect of forming and accelerating a muon beam is to reduce the beam emittance (i.e., to "cool" the muon beam), so that the beam can be accelerated in small-aperture RF cavities. By far the most effective method to cool muon beams is ionization cooling. In this technique, muons lose energy in the direction of travel when they pass through high-pressure hydrogen gas, and only the longitudinal energy is replaced by RF cavities. A recent advance in this technology has led to the combining of these two functions in high-pressure gas-filled RF cavities (HPRF). High-efficiency, low-resistance cavities will be developed for use in a mobile muon source. They will operate at liquid nitrogen temperatures, and the aluminum cavity walls will be coated with a few microns of pure beryllium. Beryllium has an especially low resistivity, at a temperature of 80K.

What will be done in Phase I – typically, two to three sentences.

A metal film deposition system, most likely a sputtering system, will be selected and designed. An R&D program to study the deposition of high-quality beryllium films will be planned in detail. Special emphasis will be placed in achieving film purity, thickness uniformity, crystal structure, crystal orientation, and film adhesion, so that the film will have the desired low resistivity.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

Muon cooling channels are also needed for energy-frontier muon colliders for high-energy physics research. High-efficiency HPRF cavities will be an attractive design option for these colliders.

Key Words: muons, gas-filled RF cavities

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

High-efficiency gas-filled RF cavities will be developed for mobile muon sources to be used for the detection at a distance of special nuclear materials.

Phase I-SBIR/STTR Fiscal Year 2009

(All information provided on this page is subject to release to the public.)

FIRM NAME:	RESEARCH INSTITUTION:
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PROJECT TITLE: **Proton Computed Tomography**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Cancer therapy using proton beams is developing rapidly in the US and worldwide. However, the domain of its applicability is limited by issues of affordability and complexity.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects.

The ability to produce medical images in situ via computed tomography using protons from the same accelerator that provides the treatment beams will be developed. Using that technology, simpler and more efficacious treatment methodologies will be devised. System integration issues will be addressed. That will allow more patients, particularly children, to be treated worldwide.

What will be done in Phase I – typically, two to three sentences.

The most promising particle detection technology and strategy for proton CT will be chosen. G4beamline will be used to simulate the passage of protons through patients in order to design the system and evaluate the required accuracy. System integration issues will be addressed for the new NIU cancer therapy facility.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

The success of this SBIR/STTR project would simplify the delivery of proton therapy treatments. That in turn would reduce the costs and extend the domain of applicability of proton therapy, allowing more patients to be treated at proton therapy centers worldwide.

Key Words: proton therapy, cancer, computed tomography

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

The ability to produce medical images using the same beam that is used for treatment at proton therapy facilities is being developed. That will allow simpler and less expensive procedures, allowing more patients to be treated.

Phase I-SBIR/STTR Fiscal Year 2009

(All information provided on this page is subject to release to the public.)

FIRM NAME:	RESEARCH INSTITUTION:
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NAME of PRINCIPAL INVESTIGATOR: **Dr. Richard Sah** PHONE NUMBER: **(510) 338-0181**

PROJECT TITLE: **Superconducting Dipole Magnet for Proton Gantry**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Photon radiotherapy is a standard mode of cancer treatment. In recent years, the improved dose localization possible for proton radiotherapy has been exploited to provide improved treatment outcomes for patients. Unfortunately, the full application of this new technology has been hindered by the enormous size and cost of proton radiotherapy centers. In particular, the isocentric beam-delivery gantries at proton facilities are very large and expensive.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

In a proton gantry, the largest component is the final 90-degree dipole magnet that bends the proton beam and directs it towards the patient located at the isocenter. A specially-designed superconducting magnet will be developed for use in an advanced proton gantry with a greatly reduced size and cost.

What will be done in Phase I – typically, two to three sentences.

An engineering design will be developed for a superconducting dipole magnet for a proton gantry. This high-field magnet will be much more compact than the current normal-conducting magnets. A conceptual design of the entire gantry will also be completed. This gantry will be designed solely for beam-scanning delivery of protons, and this feature will permit additional size reductions as compared with beam-scattering delivery of protons.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

MD Anderson Cancer Center will be a subcontractor to this project, and the center will commercialize this technology. The improvements to the proton gantry design will encourage the greater utilization of proton radiotherapy for cancer treatment.

Key Words:

Superconducting, magnet, gantry, protons, radiotherapy

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

A superconducting, high-field dipole magnet will be developed for use in a very compact beam-delivery gantry for proton radiotherapy.

2008 Phase I-SBIR/STTR

(All information provided on this page is subject to release to the public.)

FIRM NAME:	RESEARCH INSTITUTION:
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NAME of PRINCIPAL INVESTIGATOR: **Stephen Kahn** PHONE NUMBER: **(631) 344-2282**

PROJECT TITLE: **38b Plasma Lenses for Pion Collection**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Magnetic horns are normally used to capture and focus pions from a target to produce muon and neutrino beams. The horns are challenging to engineer for robust operation and the focusing power of a horn is limited by the maximum current that can be carried on the horn's inner surface.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

A plasma lens will be developed as an alternative to a focusing horn for a muon or neutrino beam facility. The lens is made by creating a high-current plasma downstream of the production target to provide an azimuthal magnetic field for focusing pions. The plasma lens can be configured to produce a larger neutrino flux than a standard neutrino horn.

What will be done in Phase I – typically, two to three sentences.

In Phase I, a simulation study of a plasma lens system will be used to optimize the design to maximize the neutrino flux for a typical experiment. An experimental plasma lens demonstration model will be designed to be built in Phase II to test design principles and operating characteristics such as pulse-to-pulse stability.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

A plasma lens system will provide increased pion flux for neutrino beams used for physics experiments. Intense muon beams will also benefit from the increased capture rates that a plasma lens will deliver for many commercial and scientific applications. These include muon beams for homeland security to scan cargo containers, studies of materials using spin resonance techniques, muon catalyzed fusion, neutrino factories based on muon storage rings, and muon colliders.

Key Words: magnetic horn, plasma lens, neutrino beam, muon beam, muon-collider, neutrino factory

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

A high-current plasma discharge is being developed as a lens to focus and collect pions into an intense beam. The intense pion beam will be used to make beams of neutrinos and muons for physics experiments and commercial applications.

2009 Phase I-SBIR/STTR

(All information provided on this page is subject to release to the public.)

FIRM NAME:	RESEARCH INSTITUTION:
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NAME of PRINCIPAL INVESTIGATOR: **Stephen Kahn** PHONE NUMBER: **(631) 344-2282**

PROJECT TITLE: **38b Low Kappa Helical Channel for Muon Cooling**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Helical cooling channels filled with gaseous absorbers have been proposed to reduce muon phase space. These channels are sufficiently compact that introducing rf cavities to replace energy lost in the absorber becomes difficult.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

Reducing the helical pitch (kappa) in the channel allows a larger coil radius for facilitating easier incorporation of rf cavities into the channel. This permits the use of lower frequency rf which will increase the acceptance into the channel. The channel will use LiH wedges to restore the path length momentum correlation that was lost by reducing the helical pitch.

What will be done in Phase I – typically, two to three sentences.

In Phase I, a simulation study of the low kappa helical cooling system will be used to optimize the channel design to maximize the cooling of muon phase space. The study will address achieving the greatest reduction of phase space under the constraints of using low frequency rf to increase the channel acceptance.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

The application of this technique should alleviate the difficulty of including large rf cavities into the tight spatial constraints imposed by helical cooling channels. This should make helical cooling channels both less expensive and more efficient. An optimal muon cooling channel should provide very bright muon beams for fundamental research for muon colliders, neutrino factories, and intense muon beam sources.

Key Words: helical cooling, ionization cooling, muon beam, muon-collider, neutrino factory

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

A beam lattice is being developed to produce intense muon beams by reducing beam phase space by many orders of magnitude. In this project we are proposing to use a helical cooling channel with modest pitch to achieve this phase space reduction.

2008 Phase I-SBIR/STTR

(All information provided on this page is subject to release to the public.)

FIRM NAME:	RESEARCH INSTITUTION:
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NAME of PRINCIPAL INVESTIGATOR: PHONE NUMBER: **( )**

PROJECT TITLE: **38b Traveling Wave RF system**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

The great advantage in the helical muon beam ionization cooling channel is its compact structure to quickly shrink the muon beam 6-dimensional phase space, hence there is a strong restriction on the size of the RF system incorporating into the channel. On the other hand, a large size of RF field distribution is required from point view of the cooling performance.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

By introducing a traveling wave type RF system, the number of RF power coupling ports can be significantly reduced, which makes saving the space in longitudinal direction. By adding the nose on the cavity, the transverse size of the cavity can be smaller than the conventional pill box type cell.

What will be done in Phase I – typically, two to three sentences.

Design the traveling wave RF system and simulate the cooling performance. Optimize the shape of the cavity to reduce the size. Design the RF power coupler to induce and extract the RF power in the cavity.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

This RF system drastically improves the cooling performance in the helical cooling channel. Once we demonstrate the feasibility of the channel, the muon collider will be the main accelerator project.

Key Words: traveling wave RF, RF power coupler, helical cooling channel, muon collider

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

A new approach to the design of the magnet systems for colliding beam machines is being developed to improve their sensitivity to discovering new phenomena at the energy frontier.

Phase I-SBIR/STTR Fiscal Year 2009
(All information provided on this page is subject to release to the public.)

FIRM NAME:	RESEARCH INSTITUTION:
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NAME of PRINCIPAL INVESTIGATOR: **Dr. Rolland Johnson** PHONE NUMBER: **(757) 870-6943**

PROJECT TITLE: **38b Multipass Arc Design for Muon acceleration**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Neutrino Factories and Muon Colliders require rapid acceleration of short-lived muons to multi-GeV and TeV energies. A Recirculating Linear Accelerator (RLA) that uses a single return arc based on Non Scaling Fixed Field Alternating Gradient (NS-FFAG) lattice with combined function magnet to reduce the circumference and a single linac based on International Linear Collider (ILC) RF cavity technology can provide exceptionally fast and economical acceleration to allow both μ+ and μ- to pass through each high-gradient cavity several times in the same direction and sufficiently large momentum acceptance to allow large energy range and μ+/- to pass through the same string of magnets to improve cost-effectiveness with minimal muon decay. However, the technical feasibility, ultimate limitations, and cost effectiveness of such schemes have not been fully developed.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

A new concept of single arc and single linac will be developed to increase the number of passes that μ+/- will make in the RF cavities, leading to greater cost effectiveness and minimal muon decay. We will develop the optics and technical requirements to allow the maximum number of passes by using arc to accurately control returned beam phase in RF cavities, with adjustable pathlength structure and superconducting RF cavities to simultaneously accelerate μ+/-, with pulsed Linac quadrupoles.

What will be done in Phase I – typically, two to three sentences.

A single NS-FFAG arc and single-linac with pulsed focusing quadrupoles will be designed with combined function magnet and ILC-type SRF accelerating structures. Technical solutions for pathlength adjustment and fast pulsed quadrupoles will be investigated to determine feasibility and potential cost savings. Chromatic effects, optics mismatch sensitivity and orbit offset will be assessed and appropriate schemes will be designed.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

Future large scale facilities such as Neutrino Factories and Muon Colliders will benefit from optimized RLA designs in that their cost estimates and capabilities will be more reliable.

Key Words: recirculating linear accelerator, lattice design, muon-beam, collider

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

A new fast acceleration technique is being developed for future Neutrino Factories and Muon Colliders to take advantage of NS-FFAG and high gradient RF cavities that are being developed for the International Linear Collider.

2009 Phase I-SBIR/STTR

(All information provided on this page is subject to release to the public.)

FIRM NAME:	RESEARCH INSTITUTION:
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NAME of PRINCIPAL INVESTIGATOR: **Stephen Kahn** PHONE NUMBER: **(631) 344-2282**

PROJECT TITLE: **Magnetic Suppression of RF Breakdown in Vacuum**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Lattices for cooling muon phase space require high gradient rf fields and strong focusing solenoids. Vacuum filled rf cavities have shown serious breakdown problems when operating in high magnetic fields.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

There are indications that electrons from field emission at asperities on one of the cavity surfaces are focused by the magnetic field to the other side of the cavity where the surface is melted leading to the cavity breakdown. The proposed solution to the problems is to design the cavity so that its surface is parallel to the magnetic field in regions where the cavity electric field gradient is large.

What will be done in Phase I – typically, two to three sentences.

In phase I a study to optimize a design of vacuum cavity and coil system to minimize breakdown. Create a conceptual engineering design of this magnetic insulation system including the design of the coils and cavity that would be used in an experimental program in phase II. To perform experiments on the critical aspects of the HTS conductor that will likely be used in the design.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

This method of suppression of vacuum rf cavity breakdown in high magnetic fields should be beneficial in the design of muon cooling systems for muon colliders and neutrino factories. Intense muon beams can deliver many commercial and scientific applications. Additionally suppression of rf breakdown should have applications in other future particle accelerators.

Key Words: rf breakdown, muon beam, muon-collider, neutrino factory

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

A vacuum rf cavity imbedded in a solenoid magnetic field is being developed to maximize the accelerating gradient by keeping the magnetic field parallel to the cavity wall.

Phase I-SBIR/STTR Fiscal Year 2009

(All information provided on this page is subject to release to the public.)

FIRM NAME:	RESEARCH INSTITUTION:
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NAME of PRINCIPAL INVESTIGATOR: **Dr. Robert Abrams** PHONE NUMBER: **(630) 840-6317**

PROJECT TITLE: **33a 3D Pixel IC Electronics for Ring-Imaging Cherenkov Detectors**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Ring-imaging Cherenkov counters, which are used to measure velocity and enable particle identification (in conjunction with a separate measurement of momentum) are large, complex, and expensive detectors, often containing hundreds or thousands of photomultiplier tubes. A smaller, less costly type of detector is needed.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

3-dimensional integrated circuits (3D IC), which consist of multi-pixel photosensitive receivers with integrated electronics, can replace the large systems of photomultiplier tubes that are in Cherenkov detectors. The circular rings of Cerenkov light are focused onto a 3D IC. The signals from the active pixels are processed by the 3D ICs and the corresponding pattern of signals identifies the Cerenkov ring(s). A single 3D IC can replace hundreds of discrete photomultiplier tubes and racks of electronics.

What will be done in Phase I – typically, two to three sentences.

In Phase I the feasibility and the range of applicability of the techniques will be studied and evaluated. Simulations of a prototype detector will be carried out, to determine the requirements for the 3D IC design and the algorithms for recognizing the pattern of rings. In Phase II, prototype 3D ICs will be designed, built and tested.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

Many particle physics experiments require identification of particular particle types in the presence of other particle types. The MANX experiment, which is being proposed at Fermilab, requires identification of muons in a beam that contains pions and electrons. Other applications include medical scanning, and other industrial processes.

Key Words:

Particle detectors, Cherenkov counters, multi-pixel detectors

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

A new type of integrated circuit is being developed for detecting Cerenkov radiation from fast-moving particles, which reduces the size and cost compared to conventional detectors..

Phase I-SBIR/STTR Fiscal Year 2009

(All information provided on this page is subject to release to the public.)

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NAME of PRINCIPAL INVESTIGATOR: **Dr. Rolland Johnson** PHONE NUMBER: **(757) 870-6943**

PROJECT TITLE: **38b Cryogenic Pulse Compressors for Muon Accelerators**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Muon Colliders and Neutrino Factories, examples of future energy frontier muon accelerators, can be made affordable and practical with a new technique based on high-gradient RF cavities filled with dense hydrogen gas. To fully exploit this conceptual breakthrough, new high power RF sources are needed.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

The novel idea of using pressurized RF cavities for muon accelerators leads to conceptually simple designs with better beam cooling and several engineering advantages, including the potential of much higher accelerating gradients. This proposal is to develop power sources for these high gradient RF cavities based on pulse compression techniques using cryogenic energy storage cavities.

What will be done in Phase I – typically, two to three sentences.

The goal of Phase I is to design a complete cryogenic pulse compressor system to be built, tested, and used to develop switching techniques and coupling strategies in Phase II. Critical technical issues relevant to RF power in muon accelerators will be identified for computational and experimental investigation in Phase II.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

Cooling and accelerating muons using a gaseous absorber and pressurized high-gradient RF cavities is a conceptual breakthrough. It can make Neutrino Factories affordable and Muon Colliders possible. New power sources for these cavities are needed to fully capitalize on their superior breakdown suppression and low temperature operation. Improvements in the power levels and maximum cavity gradient will lead to a shorter accelerator chain with significant cost savings and better efficiency.

Key Words:

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

Neutrino Factories and Muon Colliders, new machines needed to study the fundamental forces of nature, can take advantage of a new technique to accelerate muons through dense hydrogen gas. Cryogenic energy-storage cavities are being developed to power these accelerators to improve efficiency and to lower costs.

38. ADVANCED CONCEPTS AND TECHNOLOGY FOR HIGH ENERGY ACCELERATORS

The DOE High Energy Physics (HEP) program supports a broad research and development (R&D) effort in the science, engineering, and technology of charged particle accelerators, storage rings, and associated apparatus. As high energy physics facilities get bigger and more costly, the DOE HEP program seeks to develop advanced technologies that can be used to reduce the overall machine size and cost. Grant applications are sought only in the following subtopics. (Relevance to applications in HEP must be explicitly described in the submitted grant applications.)

b. Technology for Muon Colliders and Muon Beams—Grant applications are sought for the development of novel devices and instrumentation for use in producing intense low energy muon beams suitable for precision muon experiments, and intense high energy muon beams suitable for neutrino factories and/or muon colliders. Approaches of interest include the development of: (1) new concepts for the generation, capture, acceleration, and colliding of intense muon beams; (2) concepts or devices for ionization cooling, including emittance exchange processes; (3) improved simulation packages for studying ionization cooling of muon beams; (4) novel cooling schemes of optical stochastic cooling, coherent electron cooling, and paramteric ionization cooling; (5) concepts or devices for manipulation and control of the longitudinal phase space of large emittance muon beams, including bunching, phase rotation, and bunch merging; (6) concepts or devices for producing intense polarized muon beams; (7) large aperture kickers for injection and extraction in muon cooling rings; (8) concepts and prototyping elements for cost effective rapid acceleration, e.g., 1 T/s pulsed magnets; (9) instrumentation for muon cooling channels that have muon intensities of 1012 muons/pulse; or (10) fast (on the order of 10 picosecond) timing detectors for muon cooling experiments with low muon intensity (on the order of 105 muons/second).

Phase I-SBIR/STTR Fiscal Year 2009

(All information provided on this page is subject to release to the public.)

FIRM NAME:	RESEARCH INSTITUTION:
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NAME of PRINCIPAL INVESTIGATOR: **Dr. Robert Abrams** PHONE NUMBER: **(630) 840-6317**

PROJECT TITLE: **35a Compact Ring-Imaging Cerenkov Detector**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Ring-imaging Cerenkov counters, which are used to measure velocity and enable particle identification (in conjunction with a separate measurement of momentum) are large, complex, and expensive detectors, often containing hundreds or thousands of photomultiplier tubes. A smaller, less costly type of detector is needed.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

Cerenkov radiation can be focused onto a small, multi-pixel photosensitive receiver such as a multi-channel plate. Multi-channel plates are currently available with up to 1000 elements (pixels) and the corresponding pattern of signals can be processed to identify the Cerenkov ring(s).

What will be done in Phase I – typically, two to three sentences.

In Phase I the feasibility and the range of applicability of the techniques will be studied and evaluated. Radiator materials and optical requirements will be determined, and the required resolution of the multi-pixel receiver will be determined. Simulations of a prototype detector will be carried out, to determine the ranges of momenta at which various particles can be identified. In Phase II, prototype detectors will be built and tested.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

Many particle physics experiments require identification of particular particle types in the presence of other particle types. The MANX experiment, which is being proposed at Fermilab, requires identification of muons in a beam that contains pions and electrons in the momentum range 300-400 MeV/c. Other experiments may have different requirements.

Key Words:

Particle detectors, Cerenkov counters, multi-pixel detectors

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

A new technique for detecting Cerenkov radiation from fast-moving particles, which reduces the size and cost over existing detectors, is proposed.

Phase I-SBIR/STTR Fiscal Year 2009

(All information provided on this page is subject to release to the public.)

FIRM NAME:	RESEARCH INSTITUTION:
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NAME of PRINCIPAL INVESTIGATOR: **Dr. Robert Abrams** PHONE NUMBER: **(630) 840-6317**

PROJECT TITLE: **33a 3D Pixel IC Electronics for Ring-Imaging Cherenkov Detectors**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Ring-imaging Cherenkov counters, which are used to measure velocity and enable particle identification (in conjunction with a separate measurement of momentum) are large, complex, and expensive detectors, often containing hundreds or thousands of photomultiplier tubes. A smaller, less costly type of detector is needed.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

3-dimensional integrated circuits (3D IC), which consist of multi-pixel photosensitive receivers with integrated electronics, can replace the large systems of photomultiplier tubes that are in Cherenkov detectors. The circular rings of Cerenkov light are focused onto a 3D IC. The signals from the active pixels are processed by the 3D ICs and the corresponding pattern of signals identifies the Cerenkov ring(s). A single 3D IC can replace hundreds of discrete photomultiplier tubes and racks of electronics.

What will be done in Phase I – typically, two to three sentences.

In Phase I the feasibility and the range of applicability of the techniques will be studied and evaluated. Simulations of a prototype detector will be carried out, to determine the requirements for the 3D IC design and the algorithms for recognizing the pattern of rings. In Phase II, prototype 3D ICs will be designed, built and tested.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

Many particle physics experiments require identification of particular particle types in the presence of other particle types. The MANX experiment, which is being proposed at Fermilab, requires identification of muons in a beam that contains pions and electrons. Other applications include medical scanning, and other industrial processes.

Key Words:

Particle detectors, Cerenkov counters, multi-pixel detectors

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

A new type of integrated circuit is being developed for detecting Cerenkov radiation from fast-moving particles, which reduces the size and cost compared to conventional detectors..

a. 2009 Phase I-SBIR/STTR Cover Page/Summary

(All information provided on this page is subject to release to the public.)

FIRM NAME:	RESEARCH INSTITUTION:
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NAME of PRINCIPAL INVESTIGATOR: **Robert J. Abrams** PHONE NUMBER: **(630) 840-6317**

PROJECT TITLE: **Electronic Instrumentation for Multi-Pixel Photon Counters**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences:

The Multi-Pixel Photon Counter (MPPC), or Silicon Photomultiplier (SiPM), which has potential for improving performance, lowering costs, and enabling high density detectors for applications such as high-energy physics experiments, has recently become available commercially. However, there is a need for associated electronic instrumentation for signal processing to utilize the capabilities of these detectors, and to further extend and refine them.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects.

The need for supporting electronics is addressed by developing application-specific integrated circuits (ASICs) that will have the functions that are needed to support the use of MPPCs in large-scale high energy physics experiments.

What will be done in Phase I – typically, two to three sentences.

MPPCs will be tested and evaluated to determine their operational characteristics using light sources, source tests, cosmic rays and beam tests. Test results will be used to develop requirements and to design a prototype electronics platform to process signals from MPPCs, as a step towards the development of ASICs for MPPC systems. Implementation of ASICs will be completed in Phase II.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

MPPCs have potential for use in high energy physics, nuclear physics, and medical imaging applications for detecting light that is emitted from scintillation counters and Cherenkov counters. They may also be used for other commercial applications that require detection of very low light levels.

Key Words: MPPC, ASIC, SiPM, photon detector

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

Advanced electronics are being developed for Multi-Pixel Photon counters (MPPCs), a new type of solid state photon detector with the potential to revolutionize traditional technologies to detect low light levels from scintillation detectors for high energy and nuclear physics and medical imaging.

Phase I-SBIR/STTR Fiscal Year 2009

(All information provided on this page is subject to release to the public.)

FIRM NAME:	RESEARCH INSTITUTION:
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NAME of PRINCIPAL INVESTIGATOR: **Dr. Robert Abrams** PHONE NUMBER: **(630) 840-6317**

PROJECT TITLE: **35a Scintillating Fiber Detector Operation in Liquid Helium**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

Particle detectors that operate inside a liquid helium environment are needed for tracking and beam profiles in muon cooling channel studies and experiments requiring intense muon beams. Extending the use of scintillating fiber detectors in liquid helium requires systematic study of several potential problems due to the extremely cold environment.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

Light output as a function of temperature and over a number of cooling cycles will be measured. Possible crazing and/or surface damage of the fibers after repeated cooling cycles will be studied. Techniques of construction, support and alignment of fiber arrays will be developed. Methods to join scintillating fibers with clear fibers at low temperatures, and methods to extract the optical signals from the cryostat will be developed. Possible incorporation of optical receivers and digitizers in the liquid helium will be investigated.

What will be done in Phase I – typically, two to three sentences.

In Phase I characterization of single scintillating fibers and light output using radioactive sources will be measured. Prototype planes of fibers will be constructed and efficiencies will be measured using cosmic rays and in a test beam. A number of fiber joining techniques will be tried and tested. In Phase II the emphasis will be on creating optimized designs and study of integrated electronics.

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COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

The MANX experiment, which is being proposed at Fermilab requires measurement planes within the helical solenoid muon cooling channel. Such a channel could be used as an initial muon cooling element for a muon collider or a neutrino factory. In addition, a cooling channel is envisaged to enhance an intense stopping muon beam for experiments such as the Mu2e experiment at Fermilab

Key Words:

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)

Scintillating fiber particle detectors that operate at liquid helium temperatures are needed for particle physics experiments and for future particle accelerators.

Phase I-SBIR/STTR Fiscal Year 2009

(All information provided on this page is subject to release to the public.)

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NAME of PRINCIPAL INVESTIGATOR: PHONE NUMBER:

PROJECT TITLE: **SLAC 04a Super Ansys**

TECHNICAL ABSTRACT (Limit to space provided)

Statement of the problem or situation that is being addressed - typically, one to three sentences.

General statement of how this problem is being addressed. This is the overall objective of the combined Phase I and Phase II projects - typically, one to two sentences.

What will be done in Phase I – typically, two to three sentences.

COMMERCIAL APPLICATIONS AND OTHER BENEFITS as described by the applicant. (Limit to space provided).

Key Words:

SUMMARY FOR MEMBERS OF CONGRESS: (LAYMAN'S TERMS, TWO SENTENCES MAX.)