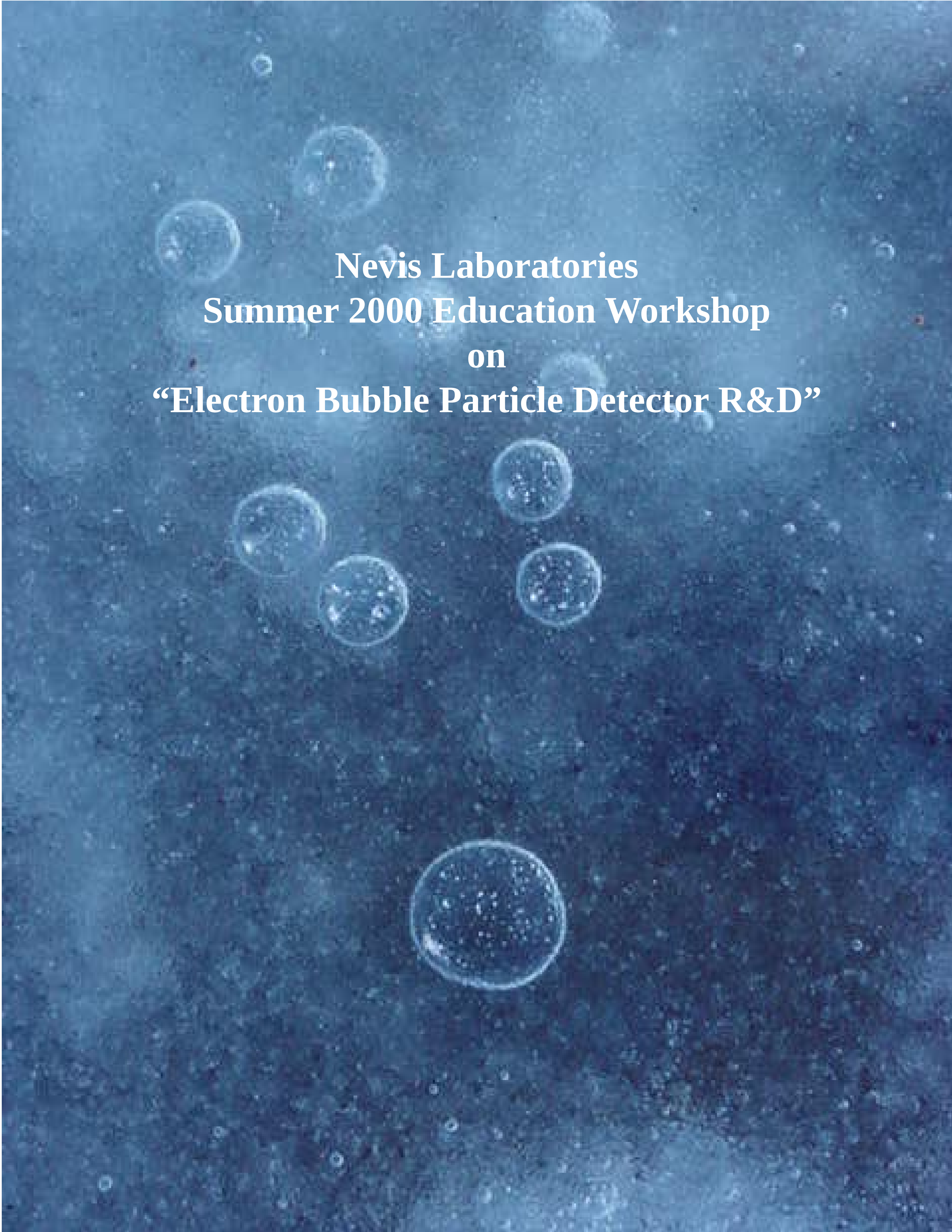
Nevis Laboratories
Summer 2000 Education Workshop
on
“Electron Bubble Particle Detector R&D”



Text and design: Jeremy Dodd
Cover Art: Jean Therrien
“Cryogenic Bubbles”, reproduced by permission of the photographer.

Nevis Laboratories Summer 2000 Education Workshop
on
"Electron-Bubble Particle Detector R&D"

Overview

During summer 2000, Columbia University's Nevis Laboratories hosted a two-month Workshop to study a new detector, using cryogenic liquid as the detecting medium, which could provide a compact and efficient solution for a next-generation neutrino detector. Possible applications of this technology for detectors at future colliding-beam facilities are also being noted.

Education and training were a major emphasis of the Workshop, with a team of ten high school students, undergraduates and high school teachers working alongside Nevis scientists and technicians to determine the critical physics and technology issues, and to develop a conceptual design for the detector. The two high school teachers are part of the QuarkNet program, and in addition to their research activities during the summer, they also developed curriculum material for use in the classroom, and made plans for a QuarkNet Associate Teacher Institute at Nevis next year.

By the end of the Workshop, the team had participated in the design of a small cryogenic test facility that will be built over the winter, fixed the conceptual design of a liquid helium solar neutrino detector, completed an experimental program of measurements of avalanche behavior in unquenched noble gases, and attended a comprehensive series of lectures on fundamental physics and detectors. The students and teachers were exposed to most aspects of the science research experience, from initial reading and literature searches, through experiment design and construction, data-taking and analysis, and finally in making presentations and writing reports for an audience of peers.

The students' appreciation and enjoyment of their summer research work was such that, in addition to our two returning QuarkNet teachers, three high school students and two undergraduates have already expressed a desire to continue working with us next summer. We look forward to building upon this year's success with a Second Nevis Workshop in summer 2001!

Outreach Activities at Nevis

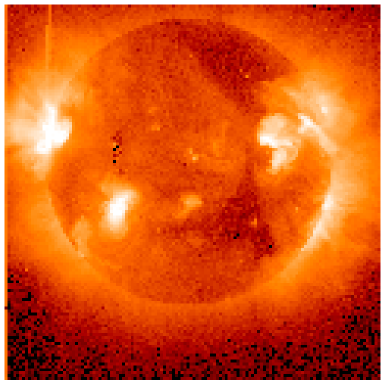
Nevis has had a summer program for undergraduate physics students since its origin. Most of them have been students at Columbia. Columbia undergraduates have also taken part in research during the academic year. Starting in 1997, we have agreed to mentor high school students in research projects of their own. In order to launch this program, we generated a "packet" of information about our laboratory, particle physics, detectors and accelerators, and Women in Physics, and distributed it to more than one hundred high school science teachers in our region. We have fielded many questions from teachers and students over the years that followed. In many cases, we have helped students find mentors in institutions closer to their homes than Nevis, or in research areas that correspond more nearly to their interests. We interview some of the students who seem a promising match to our possibilities, and have established long-term projects with a number of students. Some of them have learned modern physics in tutoring sessions with us, and then moved on to research mentors at the Columbia campus or at other institutions in our region, while others have moved into research projects at Nevis. The students begin by coming to Nevis during the school year every week or two for a tutoring session, where we go over elementary Modern Physics at the level of a non-calculus college course. Although most of the students have not taken *any* high school physics, we find that the material of Modern Physics, Relativity and Wave Mechanics, does not substantially depend on the material taught in the high school physics courses. The students study for a week or so, and come back with questions on the previous session, and start on the next stage. For our highly motivated students, this has been quite successful.

Some of the students have completed research projects at Nevis with outstanding results, including two students who have won top prizes for their work. Max Lipyanskiy was an Intel Science Talent Search Semifinalist in 1999, while Mike Lowinger won First Prize in the Communications and Electronics Association Competition 2000.

In the past three summers we started to function as an informal team, with high school students working with undergraduates and Nevis staff, and in one case with a high school teacher, and we found that combination very effective. The undergraduates have unique advantages as part of the mentoring team. This led us to set up our more formal Workshop this summer. We thought that a common focus on an ultimate goal would tie together the research of a number of students. We also wanted to choose a *new* project, so the students could see how a scientific collaboration gets started. Tying in nicely with the new Nevis initiative in cryogenic detector development, this led to the choice of the electron-bubble ("eBubble") detector as the focal point for the summer 2000 Workshop. Many of the seminars during the Workshop had a direct connection with this project.

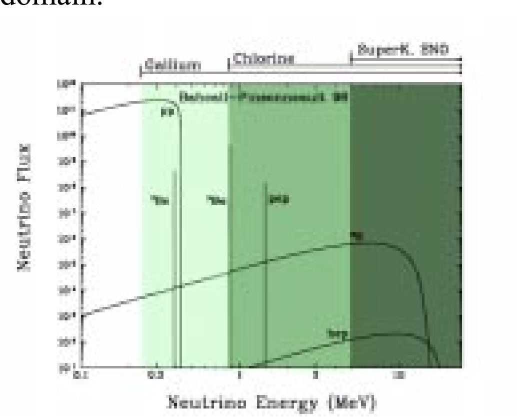
The Physics

The focus of the Summer Workshop was the investigation of a novel detector technology, which may have applications in future experiments to address critical questions in particle physics, astrophysics and cosmology. In particular, we are interested in the possibility of using cryogenic detectors deep underground to detect the interactions of neutrinos, from both natural and man-made sources.



The Sun, as viewed by the SOHO Extreme ultraviolet Imaging Telescope

For more than three decades, underground experiments measuring the flux of neutrinos from the Sun have found a significant deficit in the observed rate compared to the predictions of the Standard Solar Model. A possible explanation for this discrepancy is that (electron) neutrinos produced in the core of the Sun are modified along their path to Earth, transforming into another neutrino species via neutrino oscillations. Current experiments, relying on radiochemical techniques in gallium or chlorine, or on the production of Cerenkov radiation in water-based detectors, are mostly sensitive to the upper range of the solar neutrino energy spectrum, of order 1–10 MeV. However, this window encompasses only a small fraction of the total neutrino flux, about 98% of which is expected to have energies less than 1 MeV. Moreover, of the published experiments, only the Cerenkov detectors provide information about the energies of the incoming neutrinos. The next major goal of solar neutrino astronomy is to measure neutrino fluxes in this low energy region, and in particular to measure the flux from the dominant *pp* reaction, which peaks in the range of 200–300 keV. It would be very desirable to measure also the energy spectrum of the scattered electrons produced by neutrino interactions. These measurements will provide a simultaneous and critical test of stellar evolution theory and of neutrino oscillation solutions. The detection techniques we are investigating in the Nevis Workshop may have important applications in this domain.



The solar neturino spectrum (from J.N. Bahcall *et al*)

There is now strong evidence for neutrino oscillations from underground experiments. In addition to very long baseline measurements of low-energy neutrinos from the Sun, complementary regions of the oscillation parameter space can be explored using reactor and accelerator sources of neutrinos. Accelerator sources of muons are particularly attractive in this respect since the muon decay gives rise to both electron and muon neutrinos with known energy spectra, which can be directed to a distant experiment. These experiments will lead to new challenges for detectors, most notably in the requirement of a fine-grained structure over very large volumes, and we may anticipate that a technology based on the concept of slowly drifting electrons in cryogenic media will play an important role here also.

The features required of a detector that could measure neutrino interactions in this regime are: good spatial resolution at very low energies, in a large volume with the lowest possible background rates. The electron-bubble detector under study in the Nevis Workshop may provide a solution to these requirements.

The Electron-Bubble Detector

The physics arguments outlined above for measuring neutrino interactions give rise to the following requirements for an ideal detector:

- **Substantial mass**, varying for the different physics goals
- **Sensitivity to "small" particle energies**, therefore good energy resolution
- **Good spatial resolution**, to detect short-range tracks
- **Particle identification**, to distinguish e, p, n, γ
- **Capability to measure sign and momentum**, of charged particles
- **Track imaging**, in a large active volume
- **Read out of large number of volume elements**, at a reasonable data rate
- **Underground site**, to shield cosmic-ray backgrounds

The requirement of good spatial resolution is most easily met by working in a low- or moderate-density detection medium, with minimum diffusion. This implies that we will achieve better performance at low temperatures. The requirement of charged particle momentum measurement, via curvature in a magnetic field, suggests that a "light" (low-Z) material is preferred. Together, these constraints lead us to consider the detection of ionization tracks in liquids or solids at low temperature. In order to deal with the large number of individual three-dimensional volume elements (voxels), a high degree of serialization and multiplexing must be incorporated in the readout. Drifting the signals through one dimension of the detector volume on a timescale of seconds or longer would therefore be desirable.

Three cryogenic liquids, liquid helium, liquid hydrogen and liquid neon, have physical properties which lend themselves to meeting the properties of the ideal detector. The three liquids share a unique mechanism of electron transport. The small atoms have a low surface tension and a weak polarizability that causes the lowest energy state to be an electron localized in a vacuum-filled bubble of diameter 1-2 nanometers. The natural velocity of these nanoscale bubbles for reasonable electric fields is of order 1 cm/s - 1 m/s, giving the range of readout cycle times that we would like. The electron bubbles (eBubbles) have very long lifetimes in the liquid, and can be drifted to a detection plane where the particle tracks are imaged.

We are considering two techniques for detecting the eBubbles and imaging tracks: one electronic, the other optical. In the electronic case, detecting the charge simply by collection on an electrode in the liquid is difficult because, for low drift velocities, the current is small and the noise levels for appropriate integration times are large. We intend to transfer the electron from the bubble, through an interface, into a gas where it can undergo avalanche amplification. Once in the gas phase, the question of how much gain is available in these pure (unquenched) gases was addressed by a dedicated study during the Summer Workshop.

The electron bubbles have interesting optical properties, and their study may lead to advantageous methods of imaging. Our collaborator Tony Heinz is studying this aspect and gave a training seminar to our students during the Workshop.

Next summer, when we expect to have our test cryostat commissioned, the focus will be on the measurement of the fundamental properties of electron bubbles on tracks and our first try at electronic and optical imaging of the tracks.

Summer 2000 Workshop Participants

Ten students and teachers participated in the summer 2000 Workshop, joining Nevis physicists and technicians in the electron-bubble detector R&D program.

High School Students

Five high school students, from a broad spectrum of schools in lower New York State, attended the Workshop, working mostly on a full-time basis during July and August. All of the students are active in the NSF-supported Science Research in the High School program[1], which aims to give students the opportunity to participate in authentic scientific research and scholarship as part of their high school experience.

Vladimir Baranov
Senior, New Rochelle High School

Phil Harris
Senior, Byram Hills High School

[1] http://www.albany.edu/tree-tops/rshs/index.html

Derek Lacarrubba
Senior, John Jay High School

Geoff Shraga
Junior, Bronx High School of Science

Nick Litombe
Junior, Fox Lane High School

High School Teachers

Nevis Labs became a QuarkNet site in 2000. QuarkNet is a rapidly expanding network of particle physicists and high school teachers, providing high school students with first-hand experience of science research and allowing them to interact with real-life scientists. The five-year program[2], supported by the NSF and DOE, aims to bring students and teachers from as many as 600 US high schools to the forefront of research in particle physics. Through collaborations between university research teams and local high school teachers, QuarkNet will help high school students to learn about fundamental physics, encourage inquiry-oriented investigation in the classroom, and ultimately involve the students in Web-based analysis of real data. We recruited our two QuarkNet lead teachers at the beginning of 2000, and they joined the electron-bubble research Workshop for eight weeks starting in early July.

Bill Metzler
Highland High School

[2] http://quarknet.fnal.gov/

Eric Tucker
John Jay High School

Undergraduate Students

Three undergraduate students, two from Columbia and one from Northwestern, joined the 2000 Workshop. The students are all prospective physics majors, and in addition to their research work, they also played an important role in mentoring the high school students during the Workshop. This experience enriches the education of the undergraduates at the same time as offering a very intensive training to the high school students. The Columbia Physics Department is intending to establish a formal Mentoring Program by which undergraduates would earn course credit through their mentoring of high school students, and we expect that our Workshop this summer will provide a valuable starting point for this new initiative.

David Guarrera
Junior, Northwestern University

Ben Howell
Junior, Columbia University

Max Lipyanskiy
Sophomore, Columbia University

Nevis Scientists and Technicians
Bill Willis, *Professor*
Jeremy Dodd, Mikhail Leltchouk, *Associate Research Scientists*
Al Teho, *Designer*
Joe Capone, *Electronics Technician*
Ralph Gardner, Paul Betts, Bert Calugay, David Thomas, *Experimental Machinists*

BNL/Columbia/NYU Collaborators
The work on the new detectors that was the focus of the Workshop is a collaboration with Lin Jia, Veljko Radeka, Pavel Rehak, Valeri Tcherniatine, Lee Wang and Bo Yu of Brookhaven National Laboratory, Elena Aprile and Tony Heinz of Columbia, and Rost Konoplich of New York University, and we acknowledge their many essential contributions.

The QuarkNet Connection

Inaugurating Nevis Labs as a QuarkNet site in 2000, our two QuarkNet lead teachers joined the Summer Workshop for eight weeks, starting in early July. They took part in the Working Groups, working closely with the undergraduates and high school students on various aspects of the electron-bubble detector program.

In addition to their research work, the teachers spent a significant fraction of their time developing activities that could be included in, and enhance, their high school science curriculum. The Workshop series of introductory lectures, seminars and training sessions covered many topics at the forefront of particle physics research, and provided a broad overview of our current understanding of matter and energy, as described by the Standard Model. Both of our lead teachers will be including the Standard Model in their classes this year. We have been compiling a "library" of printed and Web-based material relating to particle physics over the years of our Outreach activities, and these resources were also very helpful to the teachers in their curriculum development work.

During the present school year, our teachers plan to devote several class and laboratory periods to topics in Modern Physics, and particle physics in particular. Current plans include a class on Special Relativity, lab sessions on the Conservation of Momentum and the Photoelectric Effect, and a 3-day module (also including lab work) on Particle Physics. The lab session on Conservation of Momentum will make use of data from Fermilab, with students inferring the existence of the top quark from their application of conservation laws to experiment event displays. For the Photoelectric Effect lab, we will work with the teachers to collect the needed components in a kit which can be easily assembled, at a reasonable cost. The module on Particle Physics will include students working in teams on computer-based activities such as The Particle Adventure[3], or an interactive simulation of a particle tracking chamber. Students will also be asked to do individual reports, oral or written, on some aspect of particle physics. These are just some of the ways our QuarkNet teachers are bringing particle physics research directly into their classrooms.

Following the QuarkNet model, we will be hosting a three-week Associate Teacher Institute at Nevis next year. Ten high school teachers will join us for a program of lectures and seminars, lab work, curriculum discussion and development, and field trips. Planning for the 2001 Institute is already well

[3] http://ParticleAdventure.org/
[4] http://www.nevis.columbia.edu/~quarknet/

advanced[4], and our Lead Teachers have begun recruiting from among their colleagues in the Lower New York and Tri-State areas. We hope to “catch” a corresponding increase in the number of high school students in the widening Nevis QuarkNet during 2001 and beyond!

The Workshop

The Workshop was held over a two-month period in July and August of 2000 at Columbia University’s Nevis Laboratories. Most of the participants attended on a full-time basis, dividing their time between structured activities (lectures, training sessions and group meetings) and individual research work (plus curriculum development in the case of the teachers).

During the first week of the Workshop, Nevis physicists gave a number of lectures providing an overview of the electron-bubble detector program, and introducing students to the basic concepts and techniques of modern particle physics. This was followed throughout July by a series of Training Seminars, given by invited experts, on the physics and detector issues most relevant for our detector R&D work. The goal of these seminars was to provide enough background knowledge to allow the Workshop participants to start work on their respective research topics.

During July we also established a number of Working Groups, described in more detail below, each of which was assigned to cover one topic of importance for the eBubble detector. Each team worked toward a set of defined goals for a period of about six weeks, culminating in a final oral presentation and written report summarizing the findings and conclusions of the Working Group.

The second half of the Workshop also featured a series of general-interest lectures, focusing on the Nevis Labs program of particle, nuclear and astrophysics experiments. In addition to lectures by Nevis faculty members and staff scientists, we invited two colleagues from Hampton University who have a particular interest in Education and Outreach activities to speak to us.

Training Seminars

Prof. Elena Aprile, Columbia University *Liquid Xenon Drift Detectors*
Prof. Tony Heinz, Columbia University *Lasers*
Dr. Lin Jia, Brookhaven National Laboratory *Cryogenics*
Dr. Rost Konoplich, New York University *Neutrino Physics*
Dr. Ven Polychronakos, Brookhaven National Laboratory *Wire Chambers*
Dr. Veljko Radeka, Brookhaven National Laboratory *Signals and Noise*
Dr. Dave Rahm, Brookhaven National Laboratory *Bubble Chambers*
Dr. Pavel Rehak, Brookhaven National Laboratory *Electronics*

Lectures

Prof. Keith Baker, Hampton University *The ATLAS Experiment*
Dr. Ken Cecire, Hampton University and QuarkNet *QuarkNet*
Prof. Brian Cole, Columbia University *PHENIX and Heavy Ion Physics*
Prof. Hal Evans, Columbia University *The D0 Experiment*
Prof. Frank Sciulli, Columbia University *HERA Physics and the ZEUS Experiment*
Dr. Bill Seligman, Nevis Laboratories *The Structure of the Proton*
Prof. Stefan Westerhoff, Columbia University *HiRes and Cosmic Ray Physics*

Working Groups

One of the primary goals of the Workshop was to define the Conceptual Design of a next-generation solar neutrino detector based on the imaging of electron bubbles in cryogenic liquids. Since there are several distinct physics and technology topics of importance to our overall goal, we decided to form a number of Working Groups, each devoted to researching one particular aspect of the eBubble detector.

Each Working Group was composed of high school students, undergraduates, high school teachers and a staff scientist, with typically four or five members in each team. A student Convenor for each group was responsible for calling and running weekly meetings, writing brief minutes, and collecting and distributing copies of material presented during the meetings. Team members were asked to make presentations of their previous week's work, with the aid of simple slides, allowing them to gain experience in public speaking and in making presentations to a scientific audience. The Working Group meetings were open to all Workshop participants, with discussion actively encouraged, which frequently resulted in lively debate!

The Working Groups were also asked to study the published literature on their topic, and to collect articles of interest to be deposited in an electronic Workshop Library. At the end of the Workshop, the teams gave concluding oral presentations, and prepared final written reports summarizing their summer research work.

Summaries of the individual Working Group reports are included below:

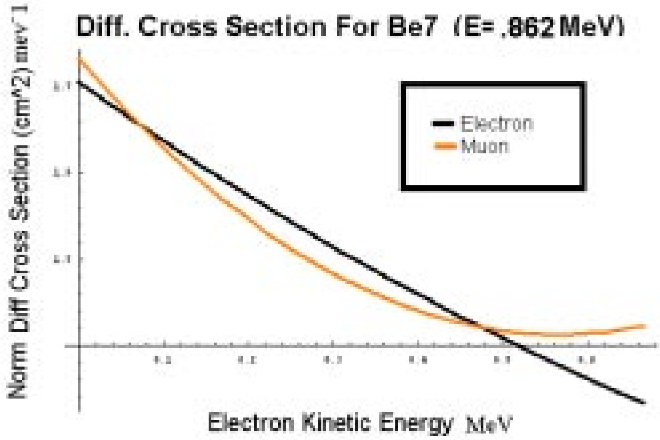
Physics and Simulation
Convenor: Max Lipyanskiy

The Physics Working Group focused its attention on the ultimate physics goals of our detector effort, namely on the interactions of neutrinos from natural sources such as the Sun and supernovae, and from man-made sources such as accelerator beams and nuclear reactors. The group focused in particular on the processes by which neutrinos scatter off atomic electrons in the detecting medium, resulting in recoil electrons which can be measured experimentally.

In order to be able to fix the parameters of a conceptual design, we defined a set of physics requirements based on the detection of 500 solar electron-neutrino scattering events per year in the useful volume of a liquid helium detector. Since we are most interested in the low-energy region of the neutrino spectrum, we chose to concentrate on the monoenergetic ^{7}Be lines (at 0.86 and 0.38 MeV), assuming a flux of 50% of the Standard Solar Model prediction, to take into account the observed disappearance of electron neutrinos from the Sun.

The team first studied the kinematics of neutrino-electron scattering, making use of 4-vectors and special relativity to determine the maximum possible energy transfer and the distribution of electron scattering angle. The group also determined scattering cross-sections, including differential cross-sections as a function of electron kinetic energy and scattering angle, for the ^{7}Be solar neutrinos of interest. These calculations were used to compute event rates for solar neutrinos in a liquid helium detector. Assuming our benchmark of 500 interactions per year, the Physics and Conceptual Design groups worked together to determine that a detector having a fiducial mass of approximately 5 tons would be required. The Physics group then calculated the event rate as a function of the kinetic energy of the scattered electron. This is important since if we wish to measure the *energy* of the incoming neutrino with a certain precision, there is a corresponding minimum track length, and therefore minimum energy, required for the scattered electron. Having determined solar neutrino event rates in a 5-ton LHe detector, the group went on to calculate event rates in the same device from accelerator and reactor sources.

We are grateful to Rost Konoplich of NYU, who played an invaluable role in advising the Physics Working Group.



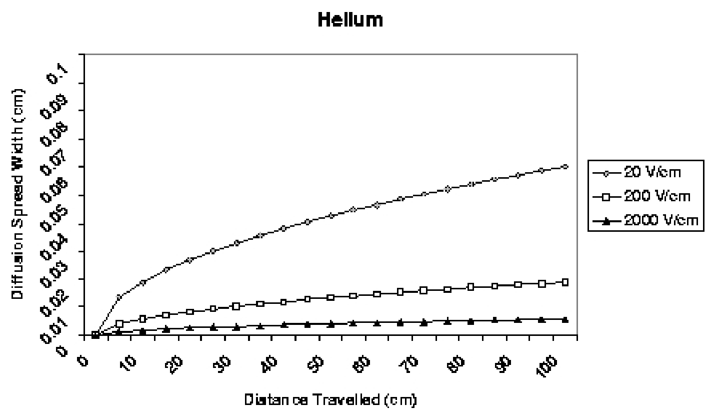
The cross-section as a function of electron recoil energy for "7Be" solar neutrinos, as determined by the Physics Working Group

Electron Drift in Liquids
Convenor: Ben Howell

The Liquid Drift Working Group concentrated on the subject of electron and ion drift in different liquids, including topics such as drift velocity, spatial diffusion, charge yield as a function of velocity and electric field, attachment on impurities and recombination. The first task of this group was to calculate electron drift velocities as a function of electric field strength in the liquids of interest for our eBubble detector, namely liquid helium, liquid neon and liquid hydrogen.

Working in collaboration with the Conceptual Design Group, the team determined the optimal dimensions of a liquid helium detector having the sensitive mass (5 tons) specified by the Physics Working Group, taking into account self-shielding considerations. The detector geometry selected was a cylinder, having a diameter of about 3 meters and height roughly 6.5 meters. The ionization charge (due to the recoil electrons), drift time and spatial diffusion in such a detector were calculated as a function of drift voltage. Team members created, and learned to use, spreadsheets to calculate these quantities for a number of liquids under a variety of operating conditions. This helped the students gain a more intuitive understanding of which physical parameters are most important for the eBubble drift detector.

Using the condition that we would like to measure a 200 keV recoil electron with an angular error of less than 20 degrees as a benchmark, the team examined factors affecting the measurement of electron energy and angle, focusing in particular on the issues of recombination and multiple scattering. These factors determine the accuracy with which we can reconstruct the energy of the incoming neutrino, and are also important when considering signal and noise characteristics of the detector readout, addressed by the Electronics Working Group below.



Diffusion in liquid helium, calculated by the Electron Drift Working Group

Electronic Detection
Convenor: Derek Lacarrubba

The Electronics Working Group studied the physics of charge collection, signal formation and noise. The mechanism of avalanche gain was investigated in detail, with input from experimental measurements made in the Proportional Wire Chamber Lab (see below), and the unusual constraints of its application in the eBubble detector examined. The team also learned about the electronics needed to amplify and shape the detector signals, and made measurements of the noise on mockup circuits designed to mimic the behavior of the actual proportional wire chamber.

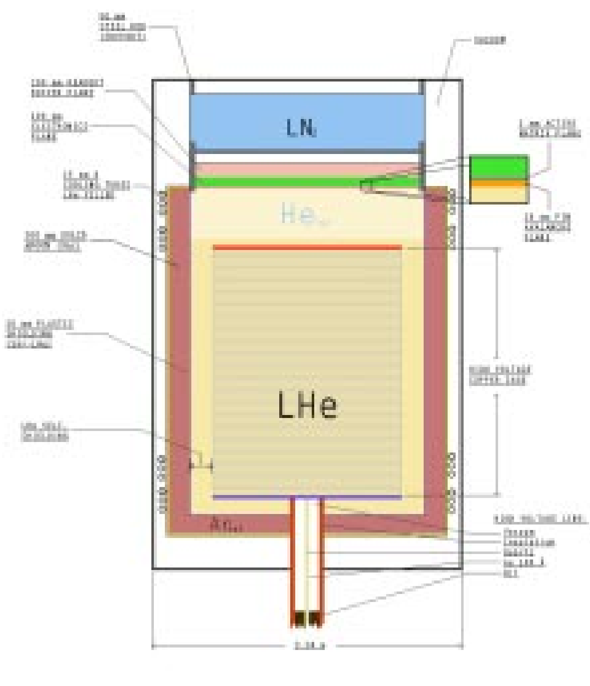
The group focused initially on the mechanism of avalanche gain, calculating the ionization expected in a variety of "standard" wire chamber gases, and gas mixtures, along a minimum-ionizing particle track. The charge amplification due to avalanching in an argon/methane gas mixture was estimated from measurements made in a single-wire proportional chamber setup. Avalanche behavior in unquenched gases, and in other chamber geometries, was also studied and is described in the section on the Proportional Wire Chamber lab.

Noise measurements were made on a mockup of the single-wire chamber, using a circuit containing the appropriate "detector" capacitance and series and parallel resistance. Students learned how to use an oscilloscope to study and measure noise characteristics as function of signal measurement time, and compared their results with theoretical expectation.

The options for detecting signals from the eBubble detector electronically were explored, with expert help, resulting in the recommendation of an active matrix array readout architecture for the conceptual design.

Conceptual Design
Convenor: Vlad Baranov

This group was an extension of the Physics Working Group, and was charged with producing a conceptual design of a liquid helium solar neutrino detector. In addition to determining a number of key physics and mechanical parameters, the group produced several visual models of the detector to aid in the design process, and to pinpoint possible problem areas in the design. The students working in this team gained an insight into many of the mechanical and engineering issues involved in constructing a large cryogenic detector deep underground. Some of the topics touched upon included: choice of materials, mechanical supports, pressure vessels, cooling, high voltage supplies, thermal and electrical insulation, purification issues, background radioactivity, safety, and many others. Visual models were assembled in a commercial graphic arts package (Adobe Photoshop) initially, before transferring the design to a Computer Aided Design software package (AutoCAD) for subsequent development. The students thus gained valuable CAD design experience.



Conceptual Design for a liquid Helium
solar neutrino detector.

Literature
Convenor: David Guarrera

In starting a new detector R&D program, we wanted to establish a comprehensive reference library of published material that could be used both by our research scientists and collaborators, and by students in the Summer Workshop. Many of the articles of interest are in old or obscure journals, not easily accessible, and so we wanted to make them readily available in both electronic and hardcopy format. The Literature Working Group was responsible for searching the journal databases for articles relevant to each aspect of the eBubble detector, and for soliciting requests for articles from each of the other Working Groups. Members of the team would then locate the articles, either through an online search (for recent publications) or via the Columbia University library stacks and archives (for older material), and make a copy for deposit in the eBubble Library. This provided the students with extensive experience in using databases, searching catalogs and in performing library research work.

After researching options for electronic archival and indexing of papers, we selected a commercial package (Adobe Acrobat) for our electronic library. This platform supports document storage in a variety of portable formats, and provides a searchable index for easy access to articles of interest. The

Literature team entered each of the articles collected into this system. For those articles only available in hardcopy, articles were first scanned and then converted to the standard format. At present, the library contains more than seventy papers, and will be augmented throughout the lifetime of the eBubble detector project.

Proportional Wire Chamber Lab
Student Researcher: Phil Harris

The avalanche gain that is available in pure noble gases (without the usual admixture of quenching agents to absorb photons produced in the avalanche) remains largely an open question. This is an important issue for any electronic readout of the eBubble detector, since we will need to amplify the signals induced in the detecting liquid, and that amplification is not easily obtained from the liquid phase. At the cryogenic temperatures of interest, gases which might otherwise act as quenching agents have negligible vapor pressure, and so we must look to achieving adequate gain in gases of high purity.

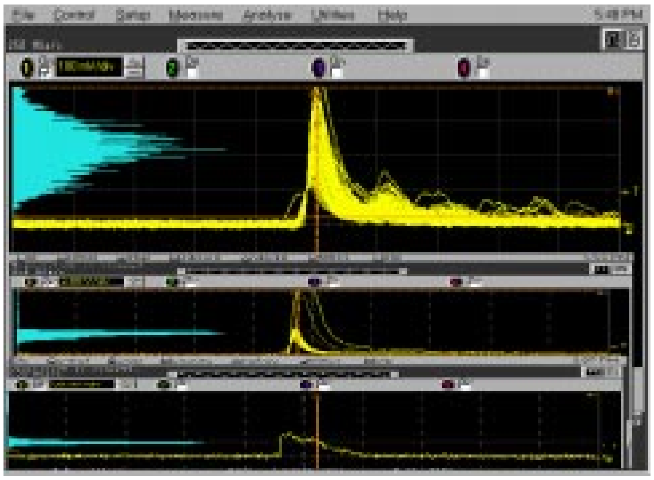
In order to address this question, one of the high school students, Phil Harris, made avalanche gain in gases the subject of a dedicated laboratory study during the Workshop. This also formed a major part of the activity of the Electronics Working Group.

The single-wire proportional chamber setup.

Phil's initial goal was to measure the gain due to avalanche processes in a conventional single-wire chamber, the so-called Proportional Wire Chamber geometry. Phil designed, assembled and commissioned his Wire Chamber lab setup in the first three weeks of the Workshop. This involved assembling and stringing the chamber itself, providing suitable gas and high voltage supply systems for the detector, designing and fabricating the "on-chamber" signal pickup circuits, using signal shaping and amplifying electronics, and learning to use and analyze data from a sophisticated oscilloscope.

Once the chamber had been assembled and debugged, Phil started a series of measurements with a "standard" counting gas – a mixture of argon and methane – to gain experience with each aspect of the experimental setup, and to measure the avalanche gain in this (quenched) gas as a reference point for subsequent studies. Phil concluded that the avalanche gain in the argon/methane mixture was of order 10^3-10^4 (depending on the applied voltage), in agreement with typical values obtained for this gas.

Having successfully observed and quantified the avalanche mechanism in a standard quenched gas, we then turned to studying the pure noble gases: argon, neon and helium. The same single-wire chamber apparatus was used in each case. The lack of a quenching gas is expected to give rise to instabilities in these pure gases, and so the aim of these measurements was to ascertain whether there exists a regime of stable operation for each gas, and if so, to measure the corresponding gain. For argon, it appears that stable operation and proportional behavior (with a gain of 10^2-10^3) occur over a limited voltage range. For neon and helium, the gases were much more unstable. "Semi-proportional" behavior does seem to occur over a very restricted voltage range for neon, and an even more limited region for helium. This is being studied further.



Pulseheight distributions from avalanches in pure Argon gas.

In order to better understand the effects of photon-induced instabilities on avalanching in pure gases, we would like to explore non-traditional chamber geometries. During the Workshop, we discussed what might be learned from a two-wire, cylindrical-geometry chamber and from a single-pin, spherical-geometry chamber. Based in part on conclusions from the single-wire measurements, the Working Group designed and constructed a small pin chamber, which is now being tested by Phil. This will provide us with important information on the feasibility of a pin-geometry readout, with adequate gain, for the eBubble detector. We are interested in particular in the possibility of using "micro-pin" devices, such as those developed by our colleagues at Brookhaven National Laboratory, for reading out the detector.

Phil Harris is continuing his research at Nevis into the school year. He expects to complete his work during the fall and will be submitting his project to science research competitions such as those supported by Intel, Siemens and others. We have high hopes that he will be a winner!

Electron-bubble cake celebrating the end of the Summer 2000 Nevis Workshop!

Summer 2000 Nevis Workshop Schedule:

July

Sun	Mon	Tue	Wed	Thu	Fri	Sat
2	3	4	5 Start of Workshop	6 B. Willis Intro talk; Lit. W.G.	7 Electronics W.G.	8
9	10 Electronics and Liquid W.G. visit to P. Rehak at BNL	11 R. Kornoplich Seminar I on Neutrinos; Lit. W.G.	12 Electronics W.G.; eBubble drift design Meeting	13 B. Willis eBubble Imaging; Liquid Drift W.G.	14 V.Polychronakos Seminar on Detectors for Electrons in Gas	15
16	17 HS Curriculum Discussion	18 V. Radeka Seminar on Signals and Noise	19 Electronics W.G.	20 L. Jia Seminar on Cryogenics	21 R. Kornoplich Seminar II on Neutrinos	22
23	24	25	26 Electronics W.G.	27 T. Heinz Seminar on Laser Optics	28 E. Aprile Seminar on LXe Detector; Nevis lunch!	29
30	31 Physics W.G.: Solar Neutrino Detector Design					

August

Sun	Mon	Tue	Wed	Thu	Fri	Sat
	31	1 Liquid Drift W.G.	2 B. Seligman Lecture on Proton Structure; Electronics W.G.	3 S. Westerhoff Lecture on HiRes	4 Lit. W.G.	5
6	7 K. Cecire Lecture on QuarkNet; Physics W.G.	8 Liquid Drift W.G.	9 Electronics W.G.	10 K. Baker Lecture on the ATLAS Experiment	11 Proportional Chamber Status Report	12
13	14 Liquid Drift W.G.	15 BNL trip	16 D. Rahm Seminar on Bubble Chambers	17 QuarkNet Discussion; Electronics W.G.	18 Physics W.G.	19
20	21 Plan for next 10 months; Literature W.G. Report	22 Physics W.G. Report	23 Liquid Drift W.G. Report	24 Electronics W.G. Report	25 End of Workshop; Party!	26
27	28	29	30	31		

Acknowledgments

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