Report of the Experimental Advisory Committee

B. Balantekin, U. Wisconsin; J. Dilling, TRIUMF; J. Martin, U. Toronto, K-T Knöpfle, MPI Heidelberg; K Scholberg, Duke Univ.; and A. J. S. Smith, Princeton Univ. (chair)

Sept 10, 2007

Introduction:

The SNOLAB Experimental Advisory Committee (EAC) met during the SNOLAB -2007 Workshop, held at the Creighton site Aug 22-23, 2007. Directors Tony Noble, David Sinclair, and Fraser Duncan made presentations on the construction, funding and scientific status of the lab. This was followed by a series of presentations on the several experiments proposed for the first round of activities at SNOLAB. The workshop agenda and slides from the presentations can be found at http://snolab2007.snolab.ca/snolab2007-programme.html

The committee was greatly impressed with the outstanding progress in preparing the laboratory for experiments; we wish to state strongly and clearly our view that SNOLAB is quickly developing into a unique world-class facility that satisfies all the requirements for the next generation of underground experiments, including great depth, low-backgrounds and cleanliness, generous cavern space, and services of all kinds. Construction will finish within the next few months, and the laboratory will be ready to receive the first round of experiments by the end of 2008.

Excavation of Phase I is complete and outfitting will be finished in the next few months. Funding for Phase II, the Cryopit, was recently announced, allowing construction work on this part of the laboratory to begin, with excavation and outfitting scheduled to be completed in 16 months. SNOLAB will therefore be ready to receive the first round of experiments by the end of 2008 and initial preparations for installation can begin during 2008.

Accordingly the Director has requested a detailed evaluation for the two largest proposed experiments SNO+ and DEAP/CLEAN, so that preparations can begin. He has also asked for advice on the scientific importance and state of readiness of 4 other experiments that have requested that space and resources be reserved for them: SuperCDMS, EXO, PICASSO, and HALO. Finally we comment on presentations given on behalf of experiments not requesting space at this time: ZEPLIN/ELIXIR, COBRA, and MAJORANA, We also thank Tasso Knoepfle for his interesting status report on the GERDA experiment at Gran Sasso.

Our recommendations and evaluations now follow:

I. Large experiments requesting space and resources.

I. 1. SNO+ Importance: "High" Readiness: "Soon."

SNO+ is a growing collaboration, currently including 40 members from 4 Canadian, 5 US and 2 European institutes. SNO+ plans a broad physics program comprising solar neutrino measurements, a neutrino-less double beta decay search with neodymium, a measurement of geo-neutrinos, neutrino oscillation measurements using anti-neutrinos generated in nearby reactors, and membership in the world-wide supernova watch.

SNO+ proposes to fill the existing SNO acrylic vessel (AV) with a new scintillator, linear alkyl benzene (LAB), containing a PPO fluor. LAB is compatible with acrylic and has a very high light output. The light output and attenuation has been measured by the collaboration to be stable over time (> 1 year). With the high light output and large coverage of the SNO photomultiplier tubes (PMTs), SNO+ will have a photoelectron yield/MeV 3-4 times that of KAMLAND. LAB has a density less than 1 g/cc, so the AV, immersed in a water shield, has to be held down rather than held up as it was in SNO when filled with D_2O. The engineering design for the hold-down system is well advanced. Engineering design of the scintillator purification plant is also well underway. Only minor upgrades in the SNO electronics and DAQ systems, and in the cover gas, glove-box and calibration systems will be necessary.

The much increased light output of SNO+ over SNO allows a measurement of the survival probability of lower energy solar neutrinos, in particular the pep neutrinos, whose flux in the Standard Solar Model is known to 1.5%. The pep neutrino energy lies at the "resonance" point between matter-dominated and vacuum oscillations of solar neutrinos. A run of 3 years will provide a 5% measurement of the pep neutrino survival probability and will be an important check of our current understanding of neutrino oscillation theory, or reveal new physics.

Compared with the KAMLAND results, a measurement of anti-neutrinos from local Ontario reactors should improve current errors on neutrino oscillation parameters, making use of the oscillation dip moving as L/E. A better measurement of geoneutrinos than that from KAMLAND can also be made, at the level that will provide an important test of geophysics models of the heating of the earth.

For the double beta decay measurement, the LAB scintillator will be loaded with a neodymium compound. Natural Nd contains 5.6% 150Nd, the isotope of interest, which has a high Q value for double beta decay above most backgrounds. It has been determined from R&D measurements that a loading of 0.1% provides the best compromise of loading fraction versus light output for achieving the best neutrino-less double beta decay sensitivity in a given running time. Higher loading reduces the light output and energy resolution, and therefore the sensitivity of observing a distortion in the end-point spectrum for 2-neutrino double beta decay. With natural Nd, a sensitivity to the neutrino mass scale of 80 meV can be reached after about 2 years of running. If enriched 150Nd can be obtained using the AVLIS facility in France, which is currently under investigation, up to

10 times more 150Nd could be loaded into the scintillator, which would improve the measurement sensitivity to 40 meV in the same time period.

Backgrounds for all these measurements must be kept under control. SNO+ has advantages including the great depth of SNOLAB, the considerable expertise built up from the SNO experiment, the demonstration that the LAB scintillator can be purified by x1000, and can be continuously purified during running, and that the Nd compound can be purified by x1000 per purification pass. SNO+ presented a convincing case that the necessary background levels can be achieved.

The collaboration sees the double beta decay physics as the top priority and plans to run with Nd as early as possible, starting in 2010. The neutrino running would come second.

Recommendations The committee views the SNO+ program as a unique opportunity in astroparticle physics. The experiment builds on a huge investment in the SNO experiment and infrastructure and has the possibility of being the first experiment to reach well below 100 meV in the neutrino mass scale. In addition, SNO+ should be the most sensitive experiment for making the important pep measurement. The physics impact of SNO+ at SNOLAB could well be dramatic.

An early start is important. Sufficient funding for the remaining R&D seems to be in place. Capital requests on the scale of $2M to NSERC and $10M to CFI will be submitted this fall and it is realistic to think that they will be successful on the time-scale required. Further funding, not well-known at this time, will be required to obtain enriched Nd. If the funding comes through as planned, the AV could be filled with scintillator early in 2010. The committee urges the collaboration to continue its effort in building up the personnel committed to the experiment, and to pursue the enriched Nd option as vigorously as possible.

I. 2. DEAP/CLEAN Importance: “High”
Readiness: “Ready for funding soon, dependent on DEAP 1 PSD results.”

The DEAP/CLEAN collaboration is planning a single phase noble gas experiment for a dark matter search, with a sensitivity goal two or three orders of magnitude larger than current best limits. Potential targets are argon and neon, and discrimination between nuclear recoils and electron/gamma background can be achieved via pulse shape discrimination, and further reduced via fiducialization. There has been impressive progress on R&D and engineering design in the past year. The collaboration currently has a 7-kg argon prototype (DEAP-1 at Queen's) and a 4-kg neon prototype (micro-CLEAN at Yale) in operation. The pulse-height discrimination (PSD) has already been demonstrated to a level of 10^{-6} in DEAP-1, and they expect that it will be possible to demonstrate a two order of magnitude improvement at the Queen's site (on the surface). A further order of magnitude will be required for success with the 1000 kg detector underground.

The main focus of the document submitted to SNOLAB is a rapid scale-up to a 1000 kg detector for siting in the cube hall. They are considering two options for the thermal shield: one is a conventional cryostat, and the second is a novel technique which involves freezing PMTs directly into ice. The former is a well-understood technology, and also has the advantage of allowing the use of neon in the detector; multiple targets will be highly desirable in the case of a dark matter signal. However a conventional cryostat will require PMTs to be operated at cryogenic temperatures, which decreases light yield and would require specialty PMTs; furthermore there is a greater mass of potential background source near the target volume. The second option, freezing the PMTs in ice, has some advantages: it allows relatively warm operation of PMTs, which increases light yield, and involves a smaller mass near the target region. However the ice shield is a new technique and presents some risks, and furthermore it precludes the use of neon because there would be excessive heat load on the cryogen at liquid neon temperatures. The collaboration will make the thermal shield technology decision in the fall.

A second activity of the DEAP/CLEAN collaboration is a 100 kg fiducial scale miniCLEAN detector. The design of this detector employs a conventional cryostat and will allow either argon or neon fill. Its timeline is parallel to that of the 1000 kg detector. Although there are many commonalities with the 1000 kg scale detector, miniCLEAN seems a fairly separate effort and may be sited at DUSEL rather than SNOLAB. There is no immediate request for space for miniCLEAN at SNOLAB.

Recommendation: The EAC strongly endorses the DEAP/CLEAN project, on the assumption that the anticipated PSD level can be demonstrated with the DEAP-1 detector at the surface. We rate the scientific priority as "High" and the readiness to be "Ready Soon", assuming funding can be procured. We also encourage discussion of the siting of the miniCLEAN detector at SNOLAB.

II. Moderate sized experiments seeking space and resources.

II. 1. SuperCDMS Importance “High.”
Readiness: “Soon.”

SuperCDMS will be a proven extension of the most successful CDMS program which has delivered until very recently the best limits for the WIMP-nucleon cross section as a function of WIMP mass. The discrimination strategy between electrons and nuclear recoils is based on cryogenic position sensitive Ge detectors which measure both the ionization and the athermal phonons caused by a scattering event. The sensitivity goal for the SuperCDMS 25 kg experiment of 1.3×10^{-45} cm^2 is two orders of magnitudes better than the best value published so far, and about one order of magnitude better than expected for the present CDMS II 5-T run. The exploration of this new region provides a high discovery potential and could be complementary to searches at LHC.

The expected improvement factors relative to CDMS II result from the use of larger sensors with increased phonon sensor coverage and new electrode design, enhanced rejection of background by advanced data analysis, and the reduction of surface impurities due to Rn daughters. In order to take full advantage of the increase in sensitive mass, SuperCDMS is aiming at maintaining a zero background experiment. Thus, to fully exploit the potential of SuperCDMS, its installation is foreseen to be at SNOLAB where the large overburden of 6060 mwe reduces the cosmogenic fast neutron background by about a factor of 600 as compared to Soudan (2090 mwe), the location of CDMS II.

Space and technical support for SuperCDMS in SNOLAB was granted by SNOLAB's director in 2005, and the CDMS collaboration has submitted a LOI to perform the SuperCDMS 25 kg experiment at SNOLAB. A distinct part of the ladder laboratory has been assigned to SuperCDMS and tailored such to accommodate its specific spatial needs. Installation is expected to start in the second half of 2009. A first breakdown of SuperCDMS activities at SNOLAB in 2008-2010 has been worked out.

Funding for SuperCDMS is available from DOE and NSF for two years starting in FY07. It will allow the construction of the first two of seven new supertowers and their operation at Soudan. Further review in FY08 is needed for the funding of the full project. A detailed proposal submitted last fall to NSF describes in detail the planned SuperCDMS 25 kg experiment at SNOLAB. It is encouraging that Fermilab has granted stage I approval for this project, and considers the purchase of long lead items like the cryosystem in order to keep the project on schedule and maintain its leading position.

So far, only one Canadian experimental group (W. Rau, Queen's university) participates in CDMS. The SuperCDMS collaboration explicitly welcomes further Canadian research groups to join the project in all areas of interest, underlining at the same time the benefits resulting from a strong on-site presence at SNOLAB during the installation and commissioning phase.

The EAC congratulates CDMS on its progress in the development of larger sensors of improved performance and the clear identification of a major background process.

Recommendations
i) SNOLAB should provide all the support which is needed to warrant the timely installation of SuperCDMS at the reserved location in the ladder laboratory
ii) SNOLAB should create and support activities which could stimulate a larger participation of Canadian research groups in SuperCDMS.

II. 2. EXO. Importance "High."
Readiness: "in the foreseeable future."

The EXO detector project for SNOLAB is a double beta decay experiment based on the detection of the decay of 136Xe and the identification of the daughter nucleus barium. The single ion detection will overcome background contamination which plagues other double beta decay experiments and has the potential to reach an effective neutrino mass level of 10-50 meV. The proposed experiment for SNOLAB is based on a gaseous Xe-detector system. The EXO collaboration is also pursuing a detector system based on liquid Xe, which is under construction at the WIPP site. The scientific merits of the experiment are excellent and the proponents of the EXO experiment at SNOLAB have received NSERC support for R&D. The experiment fits very well into the SNOLAB experimental program and could be hosted. At the present stage some technical challenges still have to be overcome, but good progress has been achieved. At present, a 200 kg Xe detector is envisaged, which could later be scaled to a 1 ton (or even larger) system.

The committee supports the efforts and endorses the experimental proposal. This approach has unique capabilities, which are complementary to other double beta decay experiments. The committee recommends further support to fully develop the concept and demonstrate feasibility. Once this is achieved, space could be made available in SNOLAB. The committee encourages the collaboration to include more partners, in particular from the AMO community, to strengthen the effort generally and to cover gaps in expertise.

II. 3. PICASSO. Importance: Short term, "High;" Longer term: "Medium"
Readiness: "Ready and running"

The PICASSO experiment made significant progress since their last presentation to the EAC. They installed four detectors; finished fabrication of eight detector modules; introduced a new purification procedure primarily to suppress the internal alpha contamination; and developed a new data acquisition system. There is strong physics interest in putting limits on spin-dependent WIMP interactions and the EAC is very enthusiastic about this physics. We recommend keeping the experiment running provided that its footprint does not conflict with the rest of the SNOLAB program. At the moment EAC does not make a recommendation to commit space in the cube hall, but wishes to reassess the scientific progress of the experiment within a year or two. We encourage the collaboration to finish the analysis of the existing data and publish it in a timely manner.

II. 4. HALO: Importance: "Medium"
Readiness: "Could (should!) be ready soon."

The committee endorses the physics, but urges the proponents to construct it in a timely fashion. Like all experiments HALO can only succeed if the necessary manpower and intellectual drive are found soon. We remark that it would make an excellent and exciting PhD project for a good student.

III. EXPERIMENTS not requesting SNOlab approval or resources at this time, but which conceivably might do so in the future,

III. 1. We were pleased to hear of the progress of ZEPLIN, and note that its successor ELIXIR may be a candidate for SNOLAB in the future.

III. 2. We note the good progress of COBRA R&D and would be happy to receive a request in the future.

III.3. MAJORANA has released its hold on SNOLAB space. Furthermore it appears that the likelihood of MAJORANA's coming to SNO is not sufficient at this time to hold space for it. Should this situation change the committee would be pleased to consider a request at that time.

III. 4. We note that the LUX collaboration did not make a presentation, and suggest that the laboratory ascertain their intentions.