Executive Summary(Draft)

Many of the most compelling scientific issues in particle physics can only be addressed with experiments operating at underground facilities. For example, large underground facilities are needed for direct searches for dark matter and neutrinoless double beta decay (0νββ), and the scale and complexity of these experiments will continue to increase for the foreseeable future. The importance of underground experiments using solar, reactor, atmospheric and neutrinos from accelerators to elucidate neutrino properties is also expected to grow over the next decade.

Underground facilities are located in North America, Europe, Asia and Antarctica (under ice). In the last few years, new underground facilities have become operational in Canada (SNOLAB), China (China JinPing Deep Underground Laboratory – CJPL), Spain (Canfranc Laboratory, or Laboratorio Subterráneo de Canfranc – LSC) and in the United States (Sanford Underground Research Facility – SURF). Experiments continue to be operated or assembled at older underground facilities in Asia (list), Europe(list), the United States and under ice at the South Pole.

The world-wide particle physics community plans to expand underground capabilities over the next few years. Significant expansions are underway or planned in China (CJPL and JUNO), Korea (RENO50 and Yangyang Laboratory), Japan (HyperK), France (Modane extension), India (India Neutrino Observatory – INO), South America (Agua Negra Deep Experiment Site – ANDES) and possibly in Finland (Center for Underground Particle Physics – CUPP). If all of these plans are realized, general purpose space for underground experiments would roughly double by the end of the decade. There would be major new facilities for reactor experiments at moderate depths (JUNO and RENO50) and for a new class of very large facilities for long baseline neutrino experiments, proton decay and other physics. New experiments, which would require substantial facility improvements, are also proposed at the South Pole.

Plans for expansion of underground facilities in the United States are less developed. Currently, there are no approved plans with federal funding for expansion of underground capabilities at the Kimbalton Underground Research Facility (KURF), the Soudan Underground Laboratory, SURF or at the Waste Isolation Pilot Plant (WIPP). The Long Baseline Neutrino Experiment (LBNE) has provisional approval to be located on the surface at SURF but design work is underway in anticipation of achieving a global collaboration to allow LBNE to be sited deep underground at SURF.

The first generation experiments in direct dark matter detection (G1) are those operating and producing results by 2013, G2 the generation of experiments under construction now or in the near future, and G3 the larger experiments being considered for construction late in this decade. All the next generation (G2) dark matter experiments can be accommodated by existing or planned underground facilities, assuming no reduction in these facilities for the rest of the decade. Most G2 experiments are at facilities outside the U.S. US physicists are participating in most of the G2 experiments, and they started and are leading many of them. A G3 experiment is likely to be 5-10 x the volume of the G2 experiment of similar technology and mass reach. It seems likely that a facility with depth ≥ 3600 mwe (e. g. LNGS) will have sufficient depth for a G3 experiment but results from G2 experiments will be definitive. The U.S. does not now have an underground hall large and deep enough to house a large G3 experiment. Such a new hall in the U.S. would most naturally be at SURF. It is premature to develop plans for a facility dedicated to a large directional experiment.

Several 0νββ experiments are already under construction at existing underground facilities, all but one of these outside the U.S. US involvement is currently strong in many of these experiments. Next generation (“tonne scale”) 0νββ experiments can likely be accommodated by existing and planned facilities, but may face competition for space from G2/G3-scale dark matter experiments. It is likely that there will be at most one next-generation 0νββ experiment with large US involvement, which may or may not be sited within U.S. Depth requirements for tonne-scale 0νββ experiments depend on the choice of technology and are not yet entirely known. New information may be available on a 6-month to 2-year timescale. The path beyond tonne-scale experiments is not well-defined but may require new underground spaces and perhaps facilities.

There are worldwide efforts towards reactor experiments at medium baseline (~50km) and short-baseline (~10m). Detectors for reactor experiments at > 100m baseline require medium-depth underground laboratories (several hundred mwe overburden). There has been strong US involvement in recent reactor experiments overseas (KamLAND, Daya Bay, Double Chooz). Planning and R&D towards future reactor experiments overseas is underway with funding commitments from the host countries (RENO-50, JUNO). There may be U.S. involvement in these experiments. There may be synergistic efforts with nuclear non-proliferation activities in the U.S. In this regard, a new U.S. remote reactor monitoring initiative requires a 500-5000 mwe site to demonstrate sensitivity to reactor antineutrinos using a large Gd-water-Cherenkov detector. The 1600 mwe Fairport mine near Cleveland Ohio and the 2800 mwe Boulby mine in England are viable options. A kiloton-scale device will have world-class supernova sensitivity and upgrading to liquid scintillator may enable geo-antineutrino measurements.

There is an international effort to search for CP violation in the lepton sector. A massive detector in a neutrino beam is required. The search for nucleon decay is one of the most important topics in particle physics. Atmospheric neutrinos, observable in a large underground detector, are sensitive to all of the currently unknown neutrino oscillation parameters. The same detector could be used to advance the search for nucleon decay, the study of atmospheric neutrinos and other physics if the detector is located underground. This is the plan for Hyper-K (Japan) and LBNO (Finland). It would be a lost opportunity if this condition cannot be satisfied with LBNE.

There is a tremendous opportunity for physics and astrophysics from detection of a supernova neutrino (SN) burst. Many existing and planned detectors; SN capability typically comes “for free” if the detector are underground but very difficult on the surface. Bursts are rare (only every ~30 years): critical to gather as much information as possible. Diverse detector technologies, at different locations around the globe, enhance the physics reach. Broader low-E neutrino/nuclear physics experiments (large-scale solar n, geoneutrinos, low-E nuclear astrophysics) will require new underground spaces and perhaps facilities.

Underground space should be reserved for materials assay and storage. Selection of radiopure materials for shielding and detectors is a common need. The majority of such tests must be done underground, requiring sensitive detectors, expert personnel, and long - term storage of materials (e.g. Cu) sensitive to cosmogenic activation. Experimental needs worldwide far outstrip current assay capability. Operation as a user facility across multiple sites with existing expertise is the most efficient use of resources and personnel, and promotes prompt and open dissemination of results. In addition, underground space should be reserved for small prototype testing and generic R&D. New experiment technologies need to go underground to validate background performance. Investment in common use elements (shielding, muon veto, croygenics, radon mitigation) in a reconfigurable user space supports generic R&D and high-risk/high-reward ideas. There is enough infrastructure space for the future if existing US underground labs are included in the mix. Substantial past agency investment and future leverage of state and university funds make it cost effective and attractive to local users to maintain these sites for smaller experiments, generic R&D, and as elements of a centrally managed materials assay consortium.

In summary, a substantial expansion in non – U.S. underground capabilities is very likely to occur by the end of this decade. It is critical that U.S. scientists continue to be supported well enough to take full advantage of international and domestic underground facilities. An open access policy for all major underground facilities is needed. Key decisions in the next few years will shape the future of the U.S. underground science program. Among these are the G2 dark matter experiment selections, the future scope of the U.S. 0νββ effort, a decisive understanding if LBNE will be located underground, planning for underground facilities beyond LBNE and G2 DM, including at the South Pole and how to improve coordination of the U.S. underground science program. A central question to be addressed by P5 is: will the U.S. have one of the major underground facilities in the future?