Deep Underground Neutrino Experiment (DUNE)

Submission for the 2020 Update to the European Strategy for Particle Physics

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The DUNE Collaboration[1]

The 2013 European Strategy for Particle Physics (ESPP) identified the long-baseline neutrino programme as one of the four scientific objectives that require international collaboration. This strong recommendation led to the formation of DUNE as an international collaboration in 2015, combining the efforts of LBNO in Europe, LBNE in the US, and many other global partners. DUNE is designed to be the world's premier neutrino observatory with the potential of answering fundamental questions about the nature of the neutrino and its impact on the matter-antimatter asymmetry in the Universe. The DUNE Collaboration now includes CERN and 14 of its member states. The CERN Neutrino Platform and several European funding agencies have played a crucial role in the design, construction, and operation of the ProtoDUNE detectors. We therefore recommend that the European Strategy update will identify DUNE as a priority of the future European neutrino programme.

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DEEP UNDERGROUND
NEUTRINO EXPERIMENT

1 Introduction

The Deep Underground Neutrino Experiment (DUNE) will be an international neutrino observatory designed to answer fundamental questions about the nature of elementary particles and their role in the universe. The DUNE experiment will consist of a far detector to be located about 1.5 km underground at the Sanford Underground Research Facility (SURF) in South Dakota, USA, at a distance of 1300 km from Fermilab, and a near detector to be located at Fermilab in Illinois. The far detector will consist of four liquid argon time-projection chambers (LArTPC) with a total fiducial mass of 40 kt. The liquid-argon technology allows us to reconstruct neutrino interactions with image-like precision and unprecedented resolution.

An Interim Design Report (IDR) published in 2018 describes the dual-phase (DP) and single-phase (SP) liquid-argon technologies and the physics reach of the DUNE experiment [1–3]. A Technical Design Report (TDR) describing for the DUNE far detector will be published in 2019.

The far detector will be exposed to the world's most intense neutrino beam originating at Fermilab. A high-precision near detector, located 575 m from the neutrino source on the Fermilab site, will be used to characterize the intensity and energy spectrum of this wide-band beam. The Long-Baseline Neutrino Facility (LBNF), hosted by Fermilab, provides the infrastructure for this pioneering set of detectors at the Illinois and South Dakota sites. LBNF assumes responsibility for the neutrino beam, the deep-underground site, and the infrastructure for the DUNE detectors.

DUNE represents the culmination of several worldwide efforts that developed independent paths toward a next-generation long-baseline (LBL) neutrino experiment over the last decade. The Collaboration was formed in April 2015, combining the strengths of the LBNE project in the USA and the LBNO project in Europe, adding many new international partners in the process.

The DUNE collaboration is a truly global organization comprising more than 1100 scientists and engineers from 32 countries, including CERN and 14 of its member states[2]. Approximately 400 of the collaborators are based at European institutions. Out of the 11 DUNE Consortia responsible for designing and building the core detector componnts, 7 are led by scientists from European institutions.

DUNE thus represents the convergence of a substantial fraction of the worldwide neutrino-physics community around the opportunity provided by the large investment[3] planned by the U.S. Department of Energy (DOE) and Fermilab to support a significant expansion of the underground infrastructure at SURF in South Dakota, and to create a megawatt neutrino-beam facility at Fermilab by 2026.

CERN has provided strong support for DUNE through its Neutrino Platform, which supports the two ProtoDUNE detectors, and through its commitment to provide the first DUNE cryostat.

The Proton Improvement Plan-II (PIP-II) upgrade at Fermilab will enable the accelerator to drive

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[2] Bulgaria, Czech Republic, Spain, Finland, France, Greece, Italy, The Netherlands, Poland, Portugal, Romania, Sweden, Switzerland, United Kingdom.

[3] $131M have been committed by the DOE in fiscal year 2019 alone.

the new neutrino beamline with a 80 GeV primary proton beam at a beam power up to 1.2 MW. A further planned upgrade of the accelerator complex will enable it to provide up to 2.4 MW of beam power by 2030. The PIP-II upgrade project will receive major contributions from the US, India, Italy, France, and the UK, as well as other European partners.

The LBNF/DUNE project has been developed to meet the requirements set out in the report of the Particle Physics Project Prioritization Panel (P5) adopted by the US community in 2014. It also takes into account the recommendations of the European Strategy for Particle Physics (ESPP) adopted by CERN Council in 2013, which classifies the long-baseline (LBL) neutrino program as one of the four scientific objectives that require international infrastructure.

2 Scientific Context

-context

Since the discovery of neutrino oscillations, neutrino physics has commanded worldwide attention given the ability to use neutrinos to provide guidance to what lays beyond the Standard Model. Even though it is the most abundant fermion in the Universe and the only neutral fermion, the neutrino remains an enigmatic particle that has not revealed all of its secrets yet. A deeper study of neutrino properties will lead to a better insight into fundamental questions about the nature of the Universe.

The spectacular discovery of neutrino oscillations in 1998, which led to the award of the 2015 Nobel Prize, had as an immediate consequence that at least two of the neutrino species must have a small but definite non-zero mass. However, the origin of the neutrino masses and details of neutrino oscillations are still a puzzle. Neutrino oscillations can be studied with a variety of neutrinos originating from difference sources, such as reactor and atmospheric neutrinos. Accelerator-based neutrino experiments, in particular, play a key role in the study of neutrino properties and are the only avenue for exploring the potential CP-violating nature of neutrinos.

Present long baseline neutrino experiments, NOvA and T2K, give hint at a potentially large CP-violating effect in the neutrino sector, i.e., a different oscillation behaviour for neutrinos compared to anti-neutrinos. This could turn out to be a key ingredient to explain the mystery of the matter anti-matter asymmetry in our Universe. CP violation can only be fully established and studied with very high statistics neutrino scattering samples, out of reach of current experiments, even when considering potential upgrades.

The next generation of neutrino experiments, and in particular DUNE, aim to discover CP violating effects in the neutrino sector. In addition, DUNE will measure CP violation and many other fundamental neutrino properties very precisely. The high statistics samples and precise measurements of DUNE will transform neutrino physics, entering an era of precision physics, where systematic uncertainties may determine the ultimate precision. The liquid-argon technology is particularly well suited to perform such precision measurements. Hence, these new experiments will not only get larger in size but will also become more sophisticated and complex. As a consequence, the experimental collaborations become larger and more international.

The European community has a long history in neutrino physics. Accelerator based neutrino experiments in Europe have led to important discoveries in the past, starting from the discovery of neutral currents at the CERN SPS. The West Area Neutrino Facility (WANF) at CERN has operated wide-band and narrow-band beams since 1977, for BEBC, CDHS, and the CHARM experiments, and in a later stage also CHARMII, CHORUS, and NOMAD. The physics topics for those experiments encompassed deep-inelastic neutrino scattering, the study of electroweak processes, neutrino oscillations searches, and searches for signals of physics beyond the Standard Model. Oscillations from muon neutrinos into tau neutrinos were observed using the long-baseline neutrino beam produced at CERN targeted at the Gran Sasso Laboratory in Italy. Low-energy solar neutrino measurements were also performed to a large extent by experiments at Gran Sasso. Many European institutions are also active participants in current neutrino experiments around the world.

The fully international DUNE Collaboration already has a large European participation. This participation is expected to grow in coming years, as more institutes and laboratories engage in the opportunity of using neutrinos to address fundamental questions in particle physics.

3 Objectives

DUNE seeks to address some of the most fundamental outstanding questions in physics: what is the origin of the matter-antimatter asymmetry in the universe, what are the underlying fundamental symmetries of the universe, is there a Grand Unified theory of the universe, and how do supernovas explode, creating the heavy elements necessary for life? To this end, the experiment has three primary physics objectives:

- precision measurements of the parameters that govern $\nu_\mu \to \nu_e$ and $\bar{\nu}_\mu \to \bar{\nu}_e$ oscillations,
- search for baryon number violation in a variety of processes, and
- detection of the ν_e flux from a core-collapse supernova should one occur in our galaxy during the lifetime of the DUNE experiment.

Additional scientific objectives include searches for physics beyond the Standard Model in new particles or interactions affecting neutrino oscillations and in direct searches, observation of ν_τ appearance, study of neutrino oscillation using atmospheric neutrinos, study of neutrino interactions with the DUNE near detector, and searches for signatures of dark matter. We summarize the projected physics potential for the long-baseline oscillation analysis in Section 3.1, for baryon number violation in Section 3.2, for supernova burst neutrinos in Section 3.3, and for other physics topics in Setion 3.4.

3.1 Long-Baseline Oscillation

DUNE will explore disappearance of muon neutrinos and appearance of electron neutrinos in a muon-neutrino dominated wideband beam at a baseline of 1300 km. One of DUNE's unique capabilities is to make precision measurements of Δm^2_{32}, $\sin^2\theta_{23}$, $\sin^2 2\theta_{13}$, and $\delta_{\rm CP}$, in a single experiment. This is possible because at baselines larger than ∼1000 km, the asymmetry in $\nu_\mu \rightarrow \nu_e$ and $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ from matter effects is significantly larger than the maximum possible matter-antimatter asymmetry associated with $\delta_{\rm CP}$, thus allowing us to disentangle these otherwise degenerate effects. Sensitivity to the neutrino mass ordering, the discovery of CP violation (defined as measurement of a value of $\delta_{\rm CP}$ not equal to 0 or π), and precision measurements of oscillation parameters have been evaluated using detailed Monte Carlo simulations.

With seven years of operation, DUNE will unambiguously determine the neutrino mass ordering for all possible values of $\delta_{\rm CP}$, will measure $\delta_{\rm CP}$ with a resolution of ∼10-20 degrees (depending on the true value of $\delta_{\rm CP}$), and determine the θ_{23} octant for values of $\sin^2\theta_{32}$ less than 0.43 and greater than 0.59. Precision measurement of neutrino oscillation parameters at DUNE requires that event rates in each of the four samples ($\nu_\mu \rightarrow \nu_\mu$, $\bar{\nu}_\mu \rightarrow \bar{\nu}_\mu$, $\nu_\mu \rightarrow \nu_e$, and $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$) be known to better than 10% with relative uncertainties among the samples at the order of a few percent. Uncertainties from flux, neutrino interaction models, and detector effects will be constrained by external data and the DUNE near detector.

3.2 Baryon Number Violation

The DUNE far detector will be sensitive to a range of baryon number violating processes, in many cases complementing the sensitivity of large water detectors. The LArTPC technology is expected to be well suited for observing nucleon decays into charged kaons, which can be identified by their distinctive dE/dx signature as well as by their decays. A particularly interesting mode for the proton decay search with DUNE is $p^+ \rightarrow K^+\overline{\nu}$; work is underway to determine how best to exploit LArTPC reconstruction capabilities to distinguish this decay mode from the primary background that arises from misidentification of protons in charged current atmospheric ν_μ interactions.

DUNE is also expected to be well suited to searches for neutron-antineutron oscillations followed by annihilation of the resulting antineutron with a neutron or a proton. This annihilation event will have a distinct signature of a vertex with several emitted light hadrons, with total energy of twice the nucleon mass and net momentum zero. The ability of the LArTPC to reconstruct these hadrons correctly and measure their energies is key to the identification of signal events. DUNE is also expected to have good sensitivity to other nucleon decay modes, including $p^+ \rightarrow e^+\pi^0$, $p \rightarrow l^+K^0$, and $n \rightarrow K^+e^-$. The excellent resolution and lower detection thresholds of liquid-argon detectors, which can detect particles below the Cherenkov threshold, will give access to nucleon decay channels in a way that previous experiments have not.

3.3 Supernova Burst Neutrinos

The DUNE LArTPC far detector has unique sensitivity to the electron-neutrino (ν_e) component of a core-collapse supernova flux, via the absorption interaction on ^{40}Ar: $\nu_e +^{40} Ar \rightarrow e^- +^{40} K*$. This is complementary to existing water and scintillator detectors, which are primarily sensitive to electron antineutrinos via inverse beta decay, and to information from other sources of multi-messenger astronomy. About 3000 events would be expected in DUNE's 40-kt fiducial mass liquid argon detector for a supernova at a distance of 10 kpc. While ν_e absorption should represent $\sim$90% of the supernova burst signal, there are other channels of interest, including ν_e charged current, elastic scattering on electrons (which provides pointing information), and neutral-current interactions which result in final-state deexcitation γs. Each of these channels has a distinctive signature in the detector.

Observation of the core-collapse neutrino burst in DUNE will provide critical information on key astrophysical phenomena: DUNE could observe the neutronization burst, heralding the formation of a compact neutron star remnant, and shock wave effects, shock instability oscillations, turbulence effects, and transitions to quark stars could all produce observable features in the energy, flavor, and time structure of the neutrino burst. Furthermore, detection of the supernova burst neutrino signal in DUNE will provide information on neutrino properties; as an example, the level of suppression of the neutronization burst varies depending on the true neutrino mass ordering.

3.4 Other Physics Topics

The oscillated atmospheric neutrino flux contains all flavors of neutrinos and antineutrinos, is very sensitive to matter effects and to both Δm^2 parameters, and covers a wide range of L/E, where L is the baseline and E the neutrino energy. These events will be available for analysis immediately upon commissioning of the detector, so represent an important aspect of DUNE's early sensitivity to oscillation physics, before the neutrino beam is available. The measurements of oscillation parameters from atmospheric neutrinos are complementary to and have similar detector performance requirements to those from accelerator neutrinos.

DUNE also has significant sensitivity to physics beyond the standard model, both in deviations from the PMNS neutrino mixing paradigm, such as non-standard neutrino interactions, non-unitarity in the PMNS matrix, violations of Lorentz or CPT symmetry, active-sterile neutrino mixing, distortions due to large extra dimensions and neutrino trident production, and in searches for new particles, including low-mass dark matter, boosted dark matter, and heavy neutral leptons. Some of these measurements make use of the near-far oscillation data while others will be performed using the near detector alone. Finally DUNE's highly capable near detector will make precision measurements of neutrino interactions and probes of electroweak physics in addition to providing critical constraints of systematic uncertainty for the oscillation analysis.

4 Methodology

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The DUNE experiment consists of three components: (1) a high-power, broadband neutrino beam, (2) a capable near detector consisting of multiple detector elements, and (3) a deep-underground modular liquid-argon TPC far detector with at least 40 kt of fiducial mass. Prototypes of both the single and dual phase LArTPCs have been constructed at the CERN Neutrino Platform; the status of these protoDUNE detectors will be discussed in Section 5.2.

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4.1 LBNF Neutrino Beam

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DUNE's accelerator neutrino program depends upon LBNF's powerful 1.2-MW neutrino beam utilizing the PIP-II upgrade of the Fermilab accelerator complex, upgradeable to 2.4 MW. The primary beam will have proton energies in the range 60-120 GeV, with the 120-GeV beam corresponding to 1.1×10^{21} protons-on-target per year. The neutrino beam will be created with a standard horn-focusing technique. The design of the target, focusing horns, and decay region have been optimized to maximize DUNE sensitivity to CP violation using a genetic algorithm. European institutions are making important contributions to the design and construction of core components of the accelerator program.

4.2 Near Detector

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The DUNE near detector design is still being developed by the collaboration. The design concept is that the near detector will be composed of a segmented liquid-argon TPC and a multi-purpose detector (MPD). The multi-purpose detector includes a high-pressure gaseous argon TPC, an electromagnetic calorimeter, and a 3D projection scintillator detector; some portion of the MPD will be magnetized using a newly built dipole magnet. The design of the LArTPC will be based on the ArgonCube concept using pixelated readout. The LArTPC will be moved transverse to the beam direction to provide off-axis near detector samples ("DUNE-Prism concept"); work is ongoing to determine whether or not other near detector elements will be movable. Details of detector size, geometry, and design are still being studied. Significant opportunities remain to contribute to the design and construction of the near detector. There is significant interest from European institutions in developing and building core components of the DUNE near detector, e.g., the calorimeter, magnet system and gaseous TPC.

4.3 Far Detector

4.3.1 Single Phase Liquid Argon TPC

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The single-phase (SP) technology was pioneered by the ICARUS experiment and, after several decades of worldwide R&D, is now a mature technology. It is the technology used for all three detectors in Fermilab's short-baseline program: the currently operating MicroBooNE, SBND, which is currently under construction, and the refurbished ICARUS detector. In the SP technology, ionization charges are drifted horizontally in liquid argon and read out on wire planes (anode planes assemblies, APAs) in the liquid. In DUNE there are three wire planes; biases are applied to the wires such that induction signals are observed on the first two planes and signal is collected on the third plane. The maximum drift length in the DUNE SP module is 3.53 m and the nominal drift field is 500 V/cm, corresponding to a cathode high voltage of 180 kV. There is no signal amplification in the liquid, so readout with good signal-to-noise requires very low-noise electronics. DUNE will have "cold electronics" in which the amplification, signal shaping, ADC, and multiplexing electronics are mounted on the anode planes and immersed in liquid argon. In one DUNE 10-kt module, there will be 150 anode plane modules, corresponding to 384,000 channels. The photon detection system is integrated into the anode plane assemblies.

4.3.2 Dual Phase Liquid Argon TPC

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The dual-phase (DP) technology was pioneered at large scale by the WA105 DP Demonstrator Collaboration at CERN [4]. It is less established than the SP technology but offers a number of potential advantages and challenges. Here, ionization charges are drifted vertically in liquid argon and transferred into the gas above the liquid. The signal charges are then amplified in the gas phase using large electron multipliers (LEMs). This gain reduces the requirements on the electronics, removing the requirement that the electronics be immersed in liquid argon, and makes it possible for the DP module to have a longer drift and larger fiducial volume for a given cryostat size. The longer drift requires a correspondingly higher voltage; the maximum drift length in the DP module is 12 m and the nominal drift field is 500 V/cm, corresponding to a cathode high voltage of 600 kV. One DUNE 10-kt module will have 153,600 readout channels arranged in two perpendicular collection views, with the readout electronics mounted on the roof of the cryostat. The photon detection system is composed of PMTs mounted on the bottom of the cryostat.

4.3.3 DAQ

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The four 10-kt far detector modules will be read out by a unified data acquisition system (DAQ). DUNE's physics goals extend beyond beam-related interactions, including cosmic-ray muons and atmospheric neutrino interactions; taken together, recording their activity will dominate the data rate. The DAQ must also record data with sensitivity to rare interactions, such as baryon number violating processes, and interactions from the products of supernova bursts. The pre-trigger data rate for each 10-kt module is expected to be as much as 1.5 TB/s. The ultimate limit on the output data rate of the DAQ is set by the available bandwidth of tape, disk and processing capacity; this limit is estimated to be about 30 PB/year or 8 Gbit/s steady state rate. Extrapolating to four detector modules, this requires a DAQ data reduction factor of almost four orders of magnitude which is achieved through a simple self-triggered readout strategy. In order to meet these demands, the DAQ design, which is still under development, includes high throughput FELIX PCIe hardware as well as additional FPGA and CPU resources. The disk buffer at the far detector is planned to be 300 TB in size and the data link from SURF to Fermilab will support 100 Gbit/s.

4.3.4 Computing

The DUNE science programme is expected to produce raw data volumes similar in scale to the data volumes that current LHC Run-2 experiments have recorded. Baseline predictions for these data are 30–60 PB of raw data per year. The difference is that DUNE event counts are lower but each "event" may be GB (beam interaction) or TB (full supernovae readout) in size.

DUNE, along with all HEP experiments, recognises that these projected data rates for the future will be challenging for computing resource provision if current funding trends persist. The collaboration plan (described in the Addendum) is to work closely with other collaborations worldwide on shared solutions to make most efficient use of global resources.

5 Opportunities, Expected Challenges, and Readiness

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5.1 Opportunities and Challenges

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There is a set of challenges and opportunities related to the physics goals of the experiment and the liquid-argon detector technology.

The DUNE detector will need to be sensitive to several different processes with very different rates, topologies and event sizes. Neutrino oscillation measurements require a near detector operating in a high rate environment and far detectors in which beam-coincident events are rare but in time with the beam spill and of sufficient energy to be readily recognizable.

Supernova physics, atmospheric neutrinos, proton decay, neutron conversion and solar neutrinos are generally at lower energy and asynchronous, making reconstruction more difficult and requiring an internal or external trigger. In particular, supernovae signals will consist of a large number of low-energy interactions spread throughout the far detector volume over a time period of 1-30 seconds. Buffering and storing 10 seconds of data is a significant challenge for the data acquisition system.

Continuous calibration of the detectors will be necessary for achieving the physics goals. Cosmic ray muons, atmospheric neutrino interactions and Ar-39 radioactivity will provide a substantial sample for energy and position calibration, as well as electron lifetime and recombination monitoring. Dedicated calibration runs with a laser system, external pulsed neutron sources and possibly radioactive sources will also be of critical importance.

Reconstruction of liquid-argon data is complex and requires the development of automated algorithms. Such algorithms have been developed and tested using existing liquid-argon detectors such as ProtoDUNE and MicroBooNE. The nature of liquid-argon data makes it particularly suitable for the application of novel deep-learning techniques.

The physics performance of the TPC is a function of many intertwined detector parameters: argon purity, drift distance, electric field strength, and noise levels in the readout electronics. The stability of the high voltage is a crucial condition for stable operation. The pitch of the Anode Plane Assemblies (APAs) for single-phase TPCs and of the Charge Readout Planes (CRPs) for dual-phase TPCs determined their resolution. the Other challenges relate to the assembly of the detector in a deep-underground laboratory and the requirement of long-term reliability for the detectors which will not be accessible over decades of operation.

The photon detector systems provide timing based on the scintillation light produced in the argon and can also be used for direct calorimetry in supernova events. It needs to achieve good timing resolution and light yield. Novel designs, such as the ARAPUCA light traps, are being studied.

DUNE is the first science project of this scale in the USA that will be built with large international participation and as an international collaboration. This requires a new organizational and governance model that takes into account the international nature of the project. The model used by CERN for managing the construction and exploitation of the Large Hadron Collider (LHC) and its experiments served as a starting point for the joint management of LBNF and the DUNE experimental program. DUNE is a fully international project organized by the DUNE collaboration with appropriate oversight from all international stakeholders.

5.2 ProtoDUNE

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The two ProtoDUNE detectors at CERN (NP02 and NP04) serve a critical role in validating the designs of the DUNE far detectors and in. The construction of the ProtoDUNE-SP detector (NP04) was successfully completed, on schedule, in July 2018, and the detector has been collecting valuable hadron-beam and cosmic-ray data. The ProtoDUNE-DP detector (NP02) is in the final stages of assembly. We expect to close the ProtoDUNE-DP cryostat with two of four charge readout planes (CRPs) installed in the first half of 2019, with cosmic-ray data collection beginning in Summer 2019. The two ProtoDUNE detectors are located in two similar cryostats. However, the single and dual-phase cryostats each have a unique arrangement of feedthroughs on the top face that are specific to the technologies being tested.

The current schedule allows initial data from both ProtoDUNE detectors to provide the information required for finalizing the DUNE far detector TDR in 2019. Future needs for ProtoDUNE-SP and DP running after Long Shutdown 2 (LS2) have been identified in a proposal submitted to the CERN SPSC in October 2018. Additional running would allow us to complete the beam-based program described in the original protoDUNE proposals [Ref]. We also expect some changes to the components to be installed in DUNE for both readout technologies independent of the results of this initial data collection. We therefore believe it will be critical to operate the ProtoDUNE detectors again following LS2 to perform a test of the exact hardware to be installed in the DUNE cryostats in South Dakota.

There are some aspects of the design that cannot be directly tested in the protoDUNE cryostats, mainly related to the 12m height of the final DUNE detector. These include the full 12m drift for the DP detector and the two-APA assembly for the SP detector. Dedicated tests of these design aspects will have to be performed elsewhere.

Future ProtoDUNE running will provide unique samples of known particle interactions in the single and dual phase detectors that may prove critical to analyzing data from the DUNE far detectors. These data sets can be used for calibration, and for algorithm development and validation. There are also unique physics measurements that can be performed, for example, the determination of hadron-argon cross sections and searches for boosted dark matter.

6 Summary

The 2013 European Strategy for Particle Physics (ESPP) identified the long-baseline neutrino programme as one of the four scientific objectives that require international collaboration. This strong recommendation led to the formation of DUNE as an international collaboration in 2015. The DUNE Collaboration now includes CERN and 14 of its member states, with approximately 400 European collaborators, and has a fully international governance model.

The DUNE experiment has three primary physics objectives: (i) the discovery of leptonic CP violation; (ii) Search for baryon number violation and (iii) detection of neutrinos emitted by a core-collapse supernova. This physics programme is enabled by the combination of a high-intensity neutrino beam, a powerful multi-purpose near detector and the precision imaging liquid-argon technology of the far detector.

7 Recommendations

We recommend that the European Strategy for Particle Physics identifies the long-baseline neutrino physics programme pursued by the DUNE Collaboration as one of its strategic goals and priorities.

We also recommend that the European Particle Physics community recognizes the importance of the continued long-term support of the DUNE and LBNF infrastructure enabling this programme through CERN and its Neutrino Platform, and through the funding agencies of its member states.

References

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