Neutrino Research Facilities - Details & Facts

Facility / Experiment	Location / Host	Website and reference	Main Purpose / Focus	Key Experiments (Current or Planned)	Interesting Facts / Notes
Super-Kamiokande (Super-K/SK)	Hida / Kamioka, Gifu Prefecture, Japan (Wikipedia)	https://www-sk.icrr.u-tokyo.ac.jp/en/sk/ (東京大学宇宙線研究所附属神岡宇宙素粒子研究施設)	Detect solar, atmospheric, and cosmic neutrinos; search for proton decay; study neutrino oscillations (Wikipedia)	Routine detection of neutrinos (natural sources) + data continues to feed global oscillation studies; historical support for accelerator-beam experiments from nearby sites (California Institute of Technology)	Tank contains ~50,000 tons of ultrapure water; helped establish that neutrinos have mass via oscillation - a discovery awarded the Nobel Prize. (Wikipedia)
Jiangmen Underground Neutrino Observatory (JUNO)	Kaiping,Jiangmen, Guangdong, China (Wikipedia)	(JUNO)-info via Wikipedia link (Wikipedia)	Determine neutrino mass hierarchy; high-precision measurement of neutrino oscillation parameters using reactor neutrinos (Wikipedia)	Reactor-antineutrino detection started in 2025 aims for precise mixing-angle and mass-difference measurements. (PHYSICS TODAY)	World’s largest transparent spherical neutrino detector; its results will clarify which neutrino mass ordering (normal vs inverted) is realized. (Wikipedia)
Deep Underground Neutrino Experiment (DUNE)	U.S. Fermilab (near-detector) → SURF, South Dakota (far detector, ~1300 km away) (fnal.gov)	https://www.dunescience.org/ (fnal.gov)	Long-baseline neutrino oscillations; determine mass ordering; search for CP violation in leptons; probe rare events (e.g. proton decay),astrophysical neutrinos. (arXiv)	In operation soon. Uses a powerful neutrino beam from Fermilab directed to far detectors deep underground at SURF. (arXiv)	With 4×17 kton liquid-argon far detectors planned, DUNE is among the largest neutrino experiments ever conceived bridging particle physics and cosmology. (arXiv)
IceCube Neutrino Observatory	Amundsen-Scott South Pole Station, Antarctica (Wikipedia)	http://icecube.wisc.edu/ (Wikipedia)	Detect high-energy cosmic neutrinos from astrophysical sources (supernovae, black holes, gamma-ray bursts)-neutrino astronomy (IceCube Neutrino Observatory)	Ongoing observations of cosmic neutrinos using a cubic-kilometer detector embedded in Antarctic ice. (Wikipedia)	First gigaton-scale neutrino detector; uses over 5,000 optical sensors in ice enabling “neutrino telescope” capability across the Universe. (Wikipedia)
Borexino Experiment	Laboratori Nazionali del Gran Sasso, Italy (Wikipedia)	Info via Borexino project pages (e.g. Wikipedia) (Wikipedia)	Detect low-energy (sub-MeV) solar neutrinos; study solar neutrino flux and neutrino oscillations at low energies (Wikipedia)	Operated ~2007-2021 has provided detailed solar neutrino data,improved understanding of solar neutrino processes and neutrino properties. (Wikipedia)	One of the world’s most radio-pure liquid-scintillator detectors; shielding by thousands of meters of rock reduced background noise and improved detection fidelity. (Wikipedia)
ANTARES Neutrino Telescope	Mediterranean Sea (off the coast of Toulon, France)-deep-sea setup ~2.5 km underwater (Wikipedia)	Info via ANTARES project pages (Wikipedia) (Wikipedia)	Directional detection of cosmic neutrinos (complementing IceCube), especially those from the Southern Hemisphere sky (Wikipedia)	Data taking continued until February 2022 provided valuable neutrino astronomy data via undersea Cherenkov detection. (Wikipedia)	Underwater telescopes use seawater as the detection medium enabling different sky coverage than ice-based observatories. ANTARES pioneered deep-sea neutrino detection. (Wikipedia)
Radio Neutrino Observatory Greenland (RNO-G)	Summit Camp, Greenland ice sheet (Wikipedia)	https://radio.uchicago.edu/index.php (RNO-G site) (Wikipedia)	Detect ultra-high-energy neutrinos (and cosmic rays) using radio antenna techniques – expanding the energy reach of neutrino astronomy (Wikipedia)	Recent deployment (2021–), aiming to capture very high-energy neutrinos beyond the reach of optical detectors. (Wikipedia)	Radio-detection approach over ice leverages the long radio attenuation length in cold ice efficient for rare, ultra-high-energy neutrino events. (Wikipedia)
KM3NeT (Cubic Kilometre Neutrino Telescope)	Deep Mediterranean Sea (multiple sites near France & Italy/Sea of Sicily) (Wikipedia)	http://www.km3net.org (official project site) (Wikipedia)	Detect cosmic and astrophysical neutrinos (both high-energy and lower-energy) using sea-water Cherenkov detection-neutrino astronomy from underwater array (Wikipedia)	Under deployment; initial observations already include detection of high-energy cosmic neutrino (2023) by ARCA sub-detector. (Reuters)	In 2025, KM3NeT recorded a record-breaking ultra-high-energy neutrino (~120 PeV)among highest energy neutrinos ever observed, suggesting origin from distant cosmic accelerators. (Reuters)
Main Injector Neutrino Oscillation Search (MINOS)	U.S.-Fermilab → Soudan Mine, Minnesota (bnl.gov)	Information via Fermilab & MINOS pages (see Fermilab neutrino experiments list) (bnl.gov)	Study neutrino oscillations over long baseline using accelerator produced neutrino beam and distant detector under ground (bnl.gov)	Provided measurements of mixing angles and oscillation parameters (muon ↔ tau neutrinos) over its operational period. (bnl.gov)	One of the early major long-baseline experiments that helped confirm neutrino oscillations beyond solar/atmospheric sources. (bnl.gov)
MicroBooNE (Liquid-Argon Time Projection Chamber experiment)	U.S.-Fermilab, Illinois (Wikipedia)	http://www-microboone.fnal.gov/ (project page) (Wikipedia)	Investigate neutrino interactions, search for “sterile neutrinos,” and test detector technology for future large-scale LArTPC experiments (Wikipedia)	Completed data runs (2015-2021); performed sterile-neutrino searches with two-beam configuration. (The University of Manchester)	First experiment to use one detector with two neutrino beams simultaneously for sterile neutrino searches improving sensitivity and reducing systematic uncertainty. (The University of Manchester)

Super-Kamiokande: Key Characteristics & Facts

Aspect	Detail / Description
Location & Depth	The detector is located in the Mozumi Mine under Mount Ikeno in the Kamioka region, Hida City, Gifu Prefecture, Japan about **1,000 meters underground**, to reduce background from cosmic-ray muons. (PMC)
Detector Type & Medium	It is a **water Cherenkov detector**: a huge stainless-steel cylindrical tank filled with ultra-pure water. (Wikipedia)
Tank Size & Water Volume	The tank is roughly **41.4 m tall** × **39.3 m diameter**, holding about **50,000 metric tons** of ultrapure water. (Wikipedia)
Photomultiplier Tubes (PMTs)	The inner detector (ID) is viewed by ~**11,100 × 20-inch PMTs** (sensitive light detectors), plus additional smaller PMTs in the outer detector (OD) for veto / background rejection. (Wikipedia)
Fiducial Volume (for Physics Analyses)	For reliable physics measurements, the "fiducial volume" (safe inner volume) is about **22.5 kilotons** of water i.e. the central region well-insulated from wall effects. (ScienceDirect)
Detection Principle	When a neutrino interacts with a water molecule in the tank, it can produce a charged particle that moves **faster than light in water** (though still slower than light in vacuum). This charged particle emits a cone of light called **Cherenkov radiation**. The PMTs on the wall detect this faint light ring; using the timing & intensity data, researchers reconstruct the event vertex, particle type (e.g. electron vs muon), direction, and energy. (東京大学宇宙線研究所附属神岡宇宙素粒子研究施設)
Scientific Goals / Research Themes	- Study **solar neutrinos**, **atmospheric neutrinos**, and **man-made (accelerator or reactor) neutrinos** (東京大学宇宙線研究所附属神岡宇宙素粒子研究施設) - Search for **neutrino oscillations** (i.e. neutrino flavor change) -a phenomenon first definitively confirmed at Super-K. (ScienceDirect) - Search for **nucleon (proton & neutron) decays** -a test of theories beyond the Standard Model (grand unified theories). (arXiv) - Detect neutrinos from **supernovae and other astrophysical sources** (including diffuse supernova neutrino background, DSNB). (Proceedings of Science) - Serve as far-detector for long-baseline accelerator neutrino experiments -e.g. in combination with neutrino beam from a distant accelerator. (University of Sheffield)
History & Operational Phases	Data-taking began in **April 1996 (SK-I)**. Since then, the experiment has gone through several phases (SK-I through SK-IV), including maintenance and upgrades. (Wikipedia)
Major Discoveries / Scientific Achievements	- **Discovery of neutrino oscillations** (atmospheric neutrinos) -firmly proving neutrinos have mass. (ScienceDirect) - Precision measurement of **solar neutrino flux and energy spectrum**. (ScienceDirect) - Strong **limits on proton decay lifetime**, constraining many Grand Unified Theories. (ScienceDirect) - Continuous monitoring for **supernova neutrinos**; potential to detect neutrino bursts from future supernova events. (Proceedings of Science)
Upgrade & Enhancements (SK-Gd Project)	In 2020, SK began the **SK-Gd upgrade**: dissolving a small concentration of **gadolinium (Gd)** salt into the ultrapure water. The addition of Gd dramatically improves the detector's ability to **tag neutrons**, which enhances sensitivity to **antineutrinos** (especially from supernovae and diffuse supernova neutrino background, DSNB). (IN2P3 Events Directory (Indico)) This upgrade positions Super-K to potentially make the first detection of the **DSNB** -a fossil neutrino background from all past supernovae - and better observe low-energy neutrino signals. (Proceedings of Science)
Collaborations & Global Role	Operated by the Kamioka Observatory / Institute for Cosmic Ray Research (ICRR), University of Tokyo, with contribution from ~**40 universities and institutes worldwide**. (東京大学宇宙線研究所附属神岡宇宙素粒子研究施設) It also serves as the **far detector** for long-baseline neutrino experiments, linking accelerator neutrino sources to deep underground detection. (University of Sheffield)
Why Underground? (Shielding / Background Reduction)	Placing the detector ~1,000 m underground (rock overburden) reduces flux of cosmic-ray muons by a huge factor (background suppression), thus enabling faint neutrino signals to be detected with minimal interference. (東京大学宇宙線研究所附属神岡宇宙素粒子研究施設)
Data Handling & Scale	Given the size and sensitivity, it records very large amounts of data. The system for data acquisition and archival handles huge volumes, enabling years of continuous observation and long-term studies. (Fujitsu)

JUNO: Key Characteristics & Facts

Attribute	Detail
Name / Acronym	Jiangmen Underground Neutrino Observatory (JUNO) (Wikipedia)
Location	Underground near Jiangmen city, Guangdong Province, China – about 700 meters below ground under granite overburden. (ScienceDaily)
Official Website	juno.ihep.cas.cn (official site) (juno.ihep.cas.cn)
Detector Type & Medium	Large-scale **liquid-scintillator (LS)** detector housed in a spherical acrylic vessel. (arXiv)
Active Detector Mass / Volume	Contains **20,000 tonnes** of liquid scintillator. (Wikipedia)
Vessel Dimensions	The central acrylic sphere is ~ **35 meters in diameter**. (institutosaphir.cl)
Photomultiplier Tubes (PMTs) / Sensor Array	~ **43,200 PMTs** in total: ~17,600 large 20-inch PMTs + ~25,600 smaller 3-inch PMTs, giving very high photocathode coverage. (juno.mi.infn.it)
Surrounding Shield / Veto System	The scintillator sphere is immersed in a large water pool with additional PMTs acting as a muon-veto / shielding layer. (Wikipedia)
Baseline / Reactor Source Distance	JUNO sits ~52–53 km away from two nuclear reactor complexes (Yangjiang & Taishan). (Wikipedia)
Principal Scientific Goals / Research Aims	- Determine the **neutrino mass ordering / hierarchy** (which neutrino mass eigenstate is heaviest/lightest) by studying reactor-antineutrino oscillations. (juno.mi.infn.it) - Perform **precision measurement** of neutrino oscillation parameters (mass-splittings, mixing angles) with very high accuracy (sub-percent to percent level). (ScienceDirect) - Detect and study other neutrino sources: solar neutrinos, atmospheric neutrinos, geo-neutrinos (from Earth) and supernova neutrinos. (UC Irvine News) - Enable long-term physics program, including possible searches for physics beyond Standard Model (e.g. exotic neutrino behaviors). (Phys.org)
Energy Resolution / Sensitivity	Designed to achieve ~ **3% energy resolution at 1 MeV** a benchmark for high-precision neutrino energy measurements. (juno.mi.infn.it)
Expected Neutrino Detection Rate	After startup, projected to detect ≈ **40-60 neutrinos per day** from reactor + background + other sources. (cnrs.fr)
Scientific Lifetime / Operational Timeline	The detector began formal data-taking in **August 2025**. Planned for decades-long data collection (life expectancy ~30 years). (Chinese Academy of Sciences)
Collaboration & Scale	International collaboration involving **hundreds of scientists** from many institutes across various countries. (Wikipedia)
Shielding and Background Suppression	700 m underground rock overburden + external water pool + veto PMTs – reduces cosmic muon background and external radioactivity to allow clean neutrino detection. (TUM)
Multi-Purpose Detector Capabilities	Reactor-antineutrinos, solar/atmospheric neutrinos, geo-neutrinos (from Earth), supernova neutrinos, and potential exotic neutrino phenomena. (www-subatech.in2p3.fr)
Status (as of 2025)	Fully constructed, filled with scintillator, and operational. First physics data already being collected. (Chinese Academy of Sciences)
Unique / Notable Features	- It is **the world's largest transparent liquid-scintillator neutrino detector** currently in operation. (cnrs.fr) - Combines large volume with high energy resolution ideal for probing subtle oscillation effects and neutrino mass hierarchy. - Its baseline (approx 52–53 km reactor distance) is optimized to sample neutrino oscillation patterns in a way that gives high sensitivity to the mass ordering question less influenced by matter effects. (University of Warwick) - Because of its scale and design, JUNO is also well-suited for long-term neutrino astronomy (solar, geo, supernova) and future physics beyond the Standard Model. (Physics World)

IceCube Neutrino Observatory : Key Characteristics & Facts

Attribute	Detail
Name / Acronym	IceCube Neutrino Observatory (IceCube) (Wikipedia)
Location	Amundsen–Scott South Pole Station, Antarctica (Wikipedia)
Detector Volume / Medium	A full **cubic-kilometer** of Antarctic ice (ice acts as the detection medium) (IceCube)
Deployment Depth	Optical sensors embedded at depths between ~1,450 m and ~2,450 m below the ice surface (Wikipedia)
Optical Modules / Sensor Array	**5,160 Digital Optical Modules (DOMs)** on 86 vertical strings; each DOM houses a PMT + data acquisition electronics. (Wikipedia)
Complementary Sub-Detectors	Includes **IceTop** surface array (for cosmic-ray/shower detection) and **DeepCore** – a denser inner array optimized for lower-energy neutrinos (~GeV-scale) (Wikipedia)
Year of Completion / Status	Construction completed **December 18, 2010**; now fully operational. (Wikipedia)
Primary Scientific Goals / Research Aims	– Detect **high-energy cosmic neutrinos** (TeV–PeV and above) from astrophysical sources (supernovae, active galactic nuclei, gamma-ray bursts, etc.) (IceCube) – Study **atmospheric neutrinos** and neutrino oscillations (especially via DeepCore for lower energies) (Wikipedia) – Contribute to **multimessenger astronomy**: correlating neutrinos with electromagnetic / cosmic-ray observations to identify cosmic sources. (IceCube) – Search for new physics: dark matter annihilation signals, exotic particles, neutrino flavor composition, and physics beyond the Standard Model. (ccapp.osu.edu)
Detection Principle	When a high-energy neutrino interacts with the ice, it can produce a charged lepton (muon, electron, or tau). If sufficiently energetic, that lepton travels faster than light does in ice – producing **Cherenkov radiation** (a cone of blue-UV light). The DOMs detect this faint light; from timing & intensity of detected light, the track/direction/energy of the original neutrino can be reconstructed. (Wikipedia)
Energy Sensitivity / Range	Primarily sensitive to **high-energy neutrinos**: from ~100 GeV up to PeV and beyond (10^11 to ~10^21 eV in some searches). (Wikipedia) With DeepCore: can detect lower-energy (few tens of GeV) atmospheric neutrinos, enabling oscillation studies. (Wikipedia)
Sky Coverage / Observation Scope	Full-sky neutrino observations thanks to global reach of Earth and ability to detect up-going neutrinos post-transit through Earth, making IceCube a full-sky neutrino telescope. (Wikipedia)
Major Discoveries & Achievements	– First unambiguous detection of **very-high-energy cosmic neutrinos** (beginning 2013), opening the field of neutrino astronomy. (IceCube) – In 2024, reported detection of **seven candidate astrophysical tau-neutrinos** that passed through Earth demonstrating flavor composition studies and expanding neutrino astronomy reach. (VISION IAS)
Scientific Collaboration & Management	Run by the IceCube Collaboration, with lead institution University of Wisconsin–Madison; supported by the National Science Foundation (NSF) and many international partners. (NSF - U.S. National Science Foundation)
Unique / Notable Features	– First and **only cubic-kilometer scale** neutrino telescope in the world. (IceCube) – Uses **natural Antarctic ice** as the detection medium exploiting its clarity and vast volume at depth, avoiding construction of massive man-made tanks. (Wikipedia) – Extremely large detection volume gives sensitivity to rare, very high-energy neutrino events from across the Universe enabling astrophysical neutrino source studies. (NSF - U.S. National Science Foundation) – Multipurpose design (IceTop + DeepCore + main array) allows studying atmospheric neutrinos, cosmic rays, neutrino oscillations, and astrophysical neutrinos in a single facility. (Wikipedia)

Borexino: Key Characteristics & Facts

Attribute	Detail
Name / Acronym	Borexino (Wikipedia)
Location	Gran Sasso mountain, Hall C of LNGS, Italy — deep underground under ≈ 1,400 m of rock (≈ 3,800 m water-equivalent) for cosmic-ray shielding. (INFN Linguistics)
Official Website	https://borex.lngs.infn.it/ (Borexino)
Detector Type & Medium	Large-volume liquid-scintillator (LS) detector using ultra-pure organic scintillator (pseudocumene + PPO). (arXiv)
Active / Target Mass (Scintillator)	278 tonnes of scintillator (≈ 315 m³) in total, with a typical fiducial (analysis) mass ~100 tonnes to ensure lowest background. (Wikipedia)
Detector Geometry / Shielding Structure	Concentric-shell design: inner nylon vessel holds LS; surrounding buffer liquid and water shields provide radiation shielding. Stainless-steel outer sphere and large water tank provide external shielding and cosmic-muon veto. (CERN Courier)
Photomultiplier Tubes (PMTs) / Sensor Array	~2,200–2,400 PMTs inside the inner detector (for LS detection); additional external PMTs in water buffer serve muon-veto / external background suppression. (CERN Courier)
Detection Technique / Reaction	Neutrino–electron elastic scattering: solar (and other) neutrinos scatter off electrons in LS; recoil electrons produce scintillation light detected by PMTs. (arXiv)
Energy Sensitivity / Threshold	Sensitive to low-energy (sub-MeV to few MeV) neutrinos — including pp, ^{7}Be, pep, ^{8}B solar neutrinos — thanks to exceptional radiopurity and low threshold design. (arXiv)
Operational Period	Data-taking from 2007 (start) until October 2021 (end) (Wikipedia)
Primary Scientific Goals / Research Aims	- Real-time spectroscopy of low-energy solar neutrinos: pp, ^{7}Be, pep, ^{8}B, CNO. (INFN Linguistics) - Test and improve solar models (e.g. solar fusion processes, solar composition, metallicity) via neutrino flux measurements. (Princeton University) - Study neutrino oscillation properties (survival probability, MSW effects) at low energies. (arXiv) - Detect neutrinos from other sources: geo-neutrinos (from Earth), antineutrinos from reactors, supernova neutrinos; and contribute to global neutrino astronomy via participation in alert networks (e.g. supernova early warning). (INFN Linguistics) - Searches for rare processes beyond standard neutrino physics (e.g. exotic neutrino interactions, dark matter-related signatures, axions / axion-like particles). (Borexino)
Major Milestones / Achievements	- First real-time detection and spectroscopy of ^{7}Be solar neutrinos (since 2007), with precision better than 5%. (arXiv) - First direct real-time detection of pp solar neutrinos (lowest-energy solar neutrinos) in 2014–2015. (arXiv) - First detection of CNO-cycle solar neutrinos (2020) — confirming the solar CNO fusion path, important for stellar physics. (Princeton University) - Measurement of ^{8}B solar neutrinos down to low energy threshold (~3 MeV) — expanding solar neutrino spectrum coverage. (arXiv) - Detection of geo-neutrinos (antineutrinos from Earth's interior) — enabling studies of Earth's radiogenic heat and composition. (INFN Linguistics)
Radiopurity & Background Suppression	Exceptional radiopurity — among the cleanest (lowest-radioactivity) large-volume detectors in the world. Built with multi-layer shielding (buffer liquids, water tank, external veto), extensive scintillator purification, and deep underground location to minimize cosmic-ray muon background. (CERN Courier)
Limitations / Challenges	Despite purification, residual backgrounds (e.g. cosmogenic isotopes like ^{11}C, background from muons/neutrons) required careful tagging and subtraction, especially for sub-MeV neutrino detection. (arXiv) Because of small interaction cross-section, very large mass and ultra-low background needed — making construction and maintenance technically demanding. (arXiv)
Experiment Status (as of 2025)	Official data taking ended in October 2021. Final published results include solar pp, ^{7}Be, pep, CNO, and ^{8}B neutrino measurements; geo-neutrinos; and searches for rare processes. (Wikipedia)
Scientific and Historical Significance	Borexino provided **complete real-time spectroscopy of the Sun's neutrino output** across most of its fusion processes — pp chain and CNO cycle — significantly improving our understanding of solar physics and neutrino properties. Its ultra-low background liquid scintillator technology set benchmarks for neutrino and rare-event experiments. (Princeton University)

ANTARES : Key Characteristics & Facts

Attribute	Detail
Name / Acronym	ANTARES (Astronomy with a Neutrino Telescope and Abyss environmental RESearch) (CERN Document Server)
Location	Mediterranean Sea, ~40 km off the coast of Toulon, France — deep-sea bed at ~2,475–2,500 m below sea level (arXiv)
Operational Period	Data taking from 2007/2008 (first lines deployed ~2006) until February 2022. Decommissioned in 2022. (ScienceDirect)
Detector Type & Medium	Underwater (sea-water) Cherenkov detector: uses the deep-sea water as the detection medium. (arXiv)
Array Configuration	12 vertical “lines” (strings) anchored to seabed. Each string hosts multiple storeys/modules. (Wikipedia)
Optical Modules / Sensors	Total of 885 optical modules (OMs) (photomultiplier tubes inside pressure-resistant glass spheres) across the array. (Wikipedia)
Instrumented Volume / Effective Volume	Approximately 0.01 km^3 (i.e. ~(10^{-2}) cubic kilometers) instrumented for detection. (Zenodo)
Detection Principle	When a high-energy neutrino interacts near the detector, it can produce a charged particle (like a muon). That charged particle travels faster than light in water, producing Cherenkov radiation (a cone of faint blue light). The OMs detect this light; the timing and spatial pattern allow reconstruction of the particle (and hence neutrino) direction and energy. (antares.in2p3.fr)
Primary Scientific Goals / Research Aims	- Detect high-energy cosmic neutrinos (astrophysical sources) from extra-galactic or galactic accelerators (e.g. supernova remnants, active galactic nuclei, gamma-ray bursts) (CERN Document Server) - Study atmospheric neutrinos & neutrino oscillations. (Proceedings of Science) - Search for neutrinos from exotic processes: e.g. annihilation of dark matter in Sun or Galactic Centre, other rare processes beyond Standard Model. (EPJ Conferences) - Provide data for multi-messenger astronomy: coordinate with gamma-ray, gravitational wave, cosmic-ray, and electromagnetic observatories to identify cosmic events. (antares.in2p3.fr)
Energy Sensitivity Range	Sensitive to neutrinos from a few GeV (tens of GeV) up to PeV energies — suitable for high-energy neutrino astronomy. (Zenodo)
Sky Coverage / Directional Advantage	Because located in Northern Hemisphere sea, it had good view of the Southern sky — complementary to Antarctic-based detectors like IceCube. (Wikipedia)
Multidisciplinary / Environmental Science Use	Besides neutrino physics, ANTARES supported marine and Earth sciences — e.g. oceanographic studies, acoustic detection R&D, environmental monitoring. (ScienceDirect)
Legacy & Successes	- First operational undersea (seawater) neutrino telescope worldwide — demonstrated feasibility of deep-sea neutrino astronomy. (arXiv) - Over ~15 years of data taking, contributed significantly to searches for cosmic neutrinos and multi-messenger astrophysics. (appec.org) - Provided a blueprint and technical heritage for next-generation Mediterranean neutrino telescopes such as KM3NeT. (KM3NeT)
Reason for Decommissioning	With KM3NeT infrastructures reaching sufficient sensitivity and coverage, ANTARES was decommissioned in 2022 to allow smooth transition to next-generation undersea neutrino telescopes. (antares.in2p3.fr)

RNO-G: Key Characteristics & Facts

Attribute	Detail	Reference
Name / Acronym	Radio Neutrino Observatory – Greenland (RNO-G)	Project site & overview. (Radio Neutrino Observatory)
Location (site)	Summit Station (Summit Camp), Greenland Ice Sheet (apex region)	Project site & science page. (RNO-G)
Detection Medium & Technique	Cold polar glacial ice; radio-antenna detection of Askaryan radio pulses produced by UHE neutrino-induced cascades in ice.	Design paper & project science overview. (VUB Research Portal)
Detector Configuration (station design)	Autonomous stations each combining a deep component (antennas in boreholes down to ~100 m) and a surface/shallow component (high-gain LPDAs, shallow antennas / trenches). Each station aggregates signals from ~24 antennas (deep + surface) and has local DAQ/power/comms.	JINST design paper; PoS status papers (first-station hardware & layout). (VUB Research Portal)
Planned Array Size & Coverage	Planned 35 stations distributed over ~50 km² (final design); deployment staged across seasons.	PoS / project status & design documents. (Proceedings of Science)
Stations deployed (field status)	First stations: Amaroq (first), followed by Nanoq, Avinngaq — 7 stations installed and collecting data during 2021–2022 seasons; subsequent field seasons (2023–2025) increased count (reports show 7 → 8+ in later updates). Status evolving with seasonal deployments.	Project status & conference reports summarizing station counts and first results. (Proceedings of Science)
Power & Operation Mode	Stations designed to operate autonomously (solar + battery; some stations include wind/backup). Because of polar night, power strategy includes low-power modes and battery buffering; some stations switch to limited operation in winter.	Instrument reports and operational-status papers describing power constraints and modes. (Proceedings of Science)
Instrumented / Effective Volume	Effective target volume is large and determined by radio attenuation length in cold ice and station spacing; sensitivity trades off station density vs. volume — design projects sensitivity to UHE neutrinos across many km³ equivalent target volume for EeV-scale events. (Exact instrumented volume depends on final array geometry.)	Sensitivity / design discussions in JINST design paper. (VUB Research Portal)
Energy Sensitivity / Target Range	Optimized for ultra-high-energy (UHE) neutrinos: roughly ≥10 PeV (10^{16} eV) up to EeV (10^{18} eV) scales — complements optical detectors (IceCube, KM3NeT) at the highest energies.	Design & sensitivity analyses. (VUB Research Portal)
Primary Scientific Goals	• Detect cosmogenic / astrophysical UHE neutrinos (PeV → EeV) • Measure or set limits on UHE neutrino flux (cosmogenic models) • Provide pointing and energy reconstruction at UHE to support multi-messenger studies • Prototype and demonstrate radio detection tech to inform IceCube-Gen2 radio component	Project science goals and white-paper style design documents. (RNO-G)
Key Technical Features	• Deep borehole antennas (~100 m) + shallow surface antennas (LPDA) per station• Phased-array / trigger strategies for improving sensitivity and lowering threshold• Low-power electronics, wireless comms to Summit Station; autonomous station operation & remote monitoring	JINST design + PoS operational descriptions. (VUB Research Portal)
First Science / Early Results	Early analyses published from first 7 stations (2021–2022): instrument performance, noise characterization, calibration strategies, and first search limits / sensitivity studies. Conference proceedings report first results and data quality.	PoS status & first-results proceedings; ScienceDirect instrument analyses. (Proceedings of Science)
R&D / Relationship to Other Experiments	Builds on lessons from ARA, ARIANNA, ANITA, RICE; serves as prototype / pathfinder for IceCube-Gen2 radio array (scalable radio detection concept).	Design and motivation sections. (VUB Research Portal)
Deployment Timeline (summary)	Design paper published 2021; initial stations deployed 2021–2022; project staged deployment planned through mid-2020s to reach ~35 stations; status updates presented at ICHEP/ICRC conferences (2023–2025).	JINST design + PoS & conference status updates. (VUB Research Portal)
Major Publications / Technical References	• Design & Sensitivity (JINST, 2021): *Design and Sensitivity of the Radio Neutrino Observatory in Greenland (RNO-G)* — arXiv / JINST. • Status & results: RNO-G collaboration conference proceedings (PoS ICHEP2024, ICRC updates 2023–2025). • Project website (instrument pages, talks, publications list).	JINST design (arXiv/JINST) + PoS proceedings + project website. (VUB Research Portal)
Limitations / Challenges (notable)	• Extremely low expected UHE neutrino flux → requires very large exposure and long observation time. • Arctic deployment logistics (power, seasonal access, harsh environment). • Radio background (anthropogenic/solar/thermal) and station self-noise must be mitigated in hardware/processing.	Operational reports & status documents discussing challenges. (Proceedings of Science)
Current Public Status (as of 2025)	Under construction / commissioning with multiple stations operating (7–8 in initial seasons), collecting data and publishing first performance / sensitivity results; ongoing seasonal deployments aim to expand toward the 35-station baseline.	Latest collaboration status & proceedings (2023–2025). (Proceedings of Science)

KM3NeT (Cubic Kilometre Neutrino Telescope) Key Characteristics & Facts

Attribute	Detail	Reference
Name / Acronym	KM3NeT — Cubic Kilometre Neutrino Telescope	KM3NeT research overview: https://www.km3net.org/research/ (KM3NeT)
Location (site)	Deep-sea sites in the Mediterranean Sea: off Toulon (France) and off Sicily (Italy)	KM3NeT on Wikipedia: https://en.wikipedia.org/wiki/KM3NeT (Wikipedia)
Detection Medium & Technique	Deep seawater; detection of Cherenkov light from charged particles created by neutrino interactions	KM3NeT detector description: https://www.km3net.org/research/detector/ (KM3NeT)
Detector Configuration (overall design)	Arrays of vertical Detection Units (DUs) holding Digital Optical Modules (DOMs) distributed in 3D under the sea	KM3NeT detector overview: https://www.km3net.org/research/detector/ (KM3NeT)
Digital Optical Module (DOM)	Glass sphere with 31 photomultiplier tubes (PMTs) and integrated electronics for timing/position calibration	DOM specs summary: https://www.emergentmind.com/topics/km3net-neutrino-telescope (Emergent Mind)
Main Sub-Detectors	Two main arrays: ARCA for high-energy, ORCA for low-energy neutrinos	KM3NeT research overview: https://www.km3net.org/research/ (KM3NeT)
ARCA – Scientific Focus	High-energy cosmic neutrino detection and neutrino astronomy with sparse array	KM3NeT detector page: https://www.km3net.org/research/detector/ (KM3NeT)
ORCA – Scientific Focus	Atmospheric neutrino oscillations and neutrino mass ordering with denser array	KM3NeT detector page: https://www.km3net.org/research/detector/ (KM3NeT)
Detector Depth	Approximately 3500 m (ARCA) and 2450 m (ORCA) below sea level	KM3NeT on Wikipedia: https://en.wikipedia.org/wiki/KM3NeT (Wikipedia)
Planned Instrumented Volume	ARCA ~1 km³ instrumented; ORCA smaller, denser array	KM3NeT technical report (TDR): https://km3net.org/wp-content/uploads/2015/07/KM3NeT-TDR-Part3.pdf (KM3NeT)
Energy Sensitivity / Target Range	ORCA: GeV range; ARCA: TeV to PeV and higher	ORCA calibration & specs: https://www.mdpi.com/2673-9984/8/1/44 (MDPI)
Primary Scientific Goals	Detect astrophysical neutrinos • Study neutrino oscillations • Determine neutrino mass ordering • Contribute to multimessenger astronomy	KM3NeT science overview: https://www.km3net.org/research/ (KM3NeT)
Data Transmission & Operation	Continuous optical fibre links to shore for timing-synchronized data readout and processing	Detector description: https://www.km3net.org/research/detector/ (KM3NeT)
Calibration & Positioning	Acoustic positioning, tilt/compass sensors, timing LEDs for precise DOM location & timing	DOM specs overview: https://www.emergentmind.com/topics/km3net-neutrino-telescope (Emergent Mind)
Complementarity	Northern Hemisphere neutrino telescope complementary to IceCube at the South Pole	Contextual cross-comparison articles (KM3NeT vs IceCube) — general literature
Current Status (as of 2025)	Under construction with multiple Detection Units installed and operational, collecting physics data	Expansion news: https://www.nikhef.nl/en/news/record-expansion-for-km3net-neutrino-telescope/ (Nikhef)
Major Publications / References	Technical Design Report and collaboration papers — see KM3NeT publications list	Publications portal: https://www.km3net.org/about-km3net/publications/pubblication/ (KM3NeT)
Key Challenges	Deep-sea deployment logistics, long-term reliability, optical background noise & large data volume	Operational context in collaboration reports and design discussions

Main Injector Neutrino Oscillation Search (MINOS): Key Characteristics & Facts

Attribute	Detail	Reference (Hyperlink)
Name / Acronym	Main Injector Neutrino Oscillation Search (MINOS)	MINOS experiment overview: https://www.fnal.gov/projects/minos/
Host Laboratory	Fermi National Accelerator Laboratory (Fermilab), USA	Fermilab experiments page: https://www.fnal.gov
Primary Objective	Study neutrino oscillations, particularly ν_μ disappearance, to measure oscillation parameters	MINOS physics goals: https://www-numi.fnal.gov
Neutrino Source	NuMI (Neutrinos at the Main Injector) beamline at Fermilab	NuMI beam description: https://www-numi.fnal.gov
Baseline (Distance)	735 km between Near Detector (Fermilab) and Far Detector (Soudan Mine, Minnesota)	MINOS baseline description: https://en.wikipedia.org/wiki/MINOS
Detection Technique	Long-baseline accelerator neutrino experiment using magnetized tracking calorimeters	Detector overview: https://www-numi.fnal.gov
Detection Medium	Iron-scintillator sampling calorimeter	Detector technology: https://cds.cern.ch/record/815249
Detector Configuration	Two detectors: Near Detector (~1 km from source) and Far Detector (735 km away, underground)	Experiment layout: https://en.wikipedia.org/wiki/MINOS
Far Detector Location	Soudan Underground Mine State Park, Minnesota, USA (~705 m underground)	Soudan Mine description: https://en.wikipedia.org/wiki/Soudan_Mine
Detector Mass	Near Detector: ~980 tons; Far Detector: ~5.4 kilotons	MINOS detector specs: https://cds.cern.ch/record/815249
Magnetic Field	Toroidal magnetic field (~1.3 T) enabling charge and momentum measurement	Detector instrumentation: https://cds.cern.ch/record/815249
Energy Range	Optimized for neutrino energies of ~1–10 GeV	MINOS beam & energy range: https://www-numi.fnal.gov
Primary Measurements	• ν_μ disappearance • Δm^2_{32} and $\sin^2(2\theta_{23})$ • ν vs. $\bar{\nu}$ comparison	MINOS results summary: https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.101.131802
Scientific Significance	Provided precision measurements confirming atmospheric neutrino oscillations	Physics impact review: https://journals.aps.org/prd/abstract/10.1103/PhysRevD.74.072003
Operation Period	Data taking from 2005 to 2012	Experiment timeline: https://en.wikipedia.org/wiki/MINOS
Successor Experiments	MINOS+ (extended run with higher-energy beam); followed by NOvA and DUNE	Fermilab neutrino program: https://neutrinos.fnal.gov
Major Publications	• First oscillation results (Phys. Rev. Lett.) • Final combined oscillation analyses	APS journals & CERN CDS: https://cds.cern.ch
Limitations / Challenges	Limited sensitivity to CP violation and mass hierarchy compared to next-generation experiments	Review articles on long-baseline experiments
Current Status	Completed; legacy experiment with archived data and published final results	Fermilab MINOS archive: https://www.fnal.gov/projects/minos/

MicroBOONE (Liquid-Argon Time Projection Chamber experiment): Key Characteristics & Facts

Attribute	Detail	Reference (Hyperlink)
Name / Acronym	MicroBooNE – Micro Booster Neutrino Experiment	MicroBooNE overview: https://microboone.fnal.gov
Host Laboratory	Fermi National Accelerator Laboratory (Fermilab), USA	Fermilab experiments: https://www.fnal.gov
Experiment Type	Short-baseline accelerator neutrino experiment	MicroBooNE experiment page: https://microboone.fnal.gov/about/
Primary Objective	Investigate the low-energy excess observed by MiniBooNE and study neutrino–argon interactions	Physics goals: https://microboone.fnal.gov/science/
Neutrino Source	Booster Neutrino Beam (BNB) at Fermilab	BNB description: https://www-boone.fnal.gov
Baseline (Distance)	~470 m from neutrino source to detector	MicroBooNE layout: https://en.wikipedia.org/wiki/MicroBooNE
Detection Technique	Liquid-Argon Time Projection Chamber (LArTPC) providing 3D imaging and calorimetry	LArTPC technology overview: https://lar.bnl.gov
Detection Medium	Liquid argon (ultra-pure)	Detector description: https://microboone.fnal.gov/detector/
Detector Configuration	Single LArTPC with wire planes and optical system for scintillation light detection	Detector design: https://microboone.fnal.gov/detector/
Active Detector Mass	~85 metric tons of liquid argon (total cryostat ~170 tons)	Detector specifications: https://microboone.fnal.gov
TPC Dimensions	~10.4 m (length) × 2.3 m (height) × 2.6 m (width)	Technical design details: https://cds.cern.ch/record/1613032
Readout System	Three wire planes (induction and collection) with mm-scale spatial resolution	Instrumentation paper (JINST): https://iopscience.iop.org/article/10.1088/1748-0221/12/02/P02017
Energy Sensitivity / Range	Optimized for sub-GeV to few-GeV neutrinos	BNB & detector performance: https://microboone.fnal.gov/science/
Primary Measurements	• Electron-like vs photon-like event separation • Neutrino–argon cross sections • Nuclear effects in argon	MicroBooNE results: https://microboone.fnal.gov/publications/
Scientific Significance	Demonstrated LArTPC imaging at scale and clarified MiniBooNE low-energy excess	Key results summary: https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.128.241801
Operation Period	Data taking from 2015 to 2021	Experiment timeline: https://en.wikipedia.org/wiki/MicroBooNE
Role in SBN Program	Part of Fermilab Short-Baseline Neutrino (SBN) program with SBND and ICARUS	SBN program overview: https://sbn.fnal.gov
Technology Legacy	Pathfinder for large LArTPC detectors such as DUNE	DUNE technology context: https://www.dunescience.org
Major Publications / References	• Detector paper (JINST) • Physics results (PRL, PRD) • Public data & notes	Publications portal: https://microboone.fnal.gov/public