Introduction to the Neutrino Theory Network - NTN

Marcela Carena
Fermilab/UChicago
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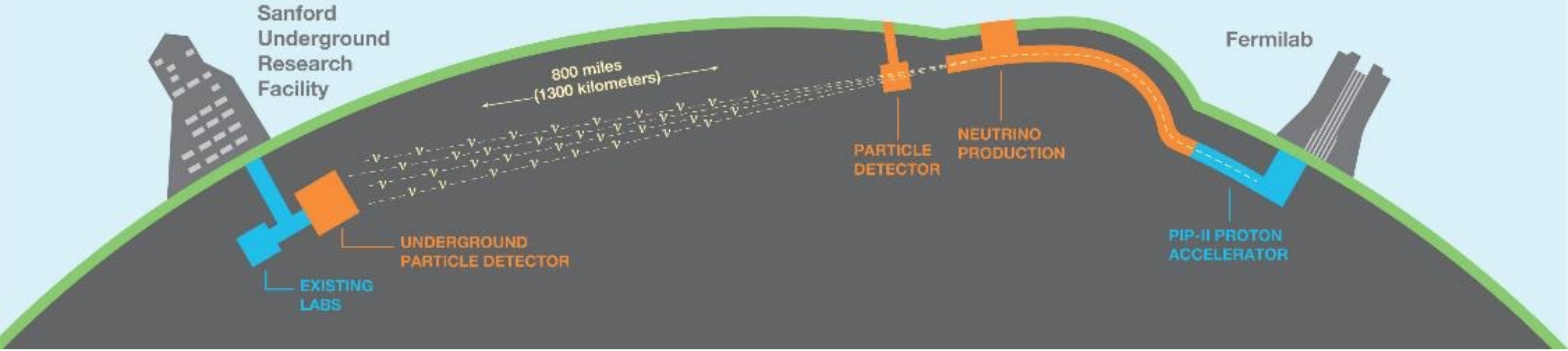
DEEP UNDERGROUND NEUTRINO EXPERIMENT



The goal of DUNE: do for neutrinos what the LHC did and continues doing for the Higgs boson

The goal of NTN: maximize the physics discoveries of the US neutrino program and answer deep, long-standing questions in neutrino physics

Neutrino Theory Network rationale and development

The DOE HEP experimental neutrino program is the largest U.S.-based activity in the P5 plan, and LBNF/DUNE is called out as the highest priority project in its timeframe

The network has been conceived to strengthen the U.S.-based neutrino theory effort to the level needed to support the DOE experimental neutrino program anchored by LBNF/DUNE.

- Discussions with DOE HEP theory project manager Bill Kilgore started in 2017
- Developed as a community grassroot effort after initial DOE kick-off support
- In 2018 a Scientific Steering Committee and a Scientific Advisory Board were formed to help develop NTN activities and guide their implementation

Neutrino Theory Network overall Goals

- Develop a more robust and diverse US neutrino theory community to strengthen its impact on the US neutrino experimental program
- Answer deep, long-standing questions about the particle nature of neutrinos, their interactions with matter, and their capabilities to reveal new physics
- Develop new capabilities and new tools for neutrino experiments to expand their scientific reach and enable discoveries

Neutrino Theory Network Governance

Scientific Steering Committee:

9 scientists with broad scientific expertise, including neutrino physics.

Role:

- Define the scientific directions of the NTN efforts and goals
- Decide on the support strategies and methods of their implementation
- Receive recommendations from the SAB on scientific merit of proposals and make determinations on support allocations

Scientific Advisory Board:

Up to 12 theorists and experimentalists with strong expertise in neutrino physics .

Role:

- Review proposals sent to NTN for support

- this includes the NTN Fellowship program, workshops, collaborative activities among neutrino theorists –

- Make recommendations to the SSC for support allocations

Neutrino Theory Network Governance

Scientific Steering Committee

John Beacom (Ohio State University)
Marcela Carena, chair (Fermilab/U. Chicago)
Joseph Carlson (Los Alamos)
Alex Friedland (SLAC)
Graciela Gelmini (UCLA)
Yuval Grossman (Cornell University)
Patrick Huber (Virginia Tech)
Hitoshi Murayama (UC Berkeley, Tokyo U. IPMU)
Noemi Rocco (Fermilab)

Scientific Advisory Board

Alberto Gago (PUC-Peru)
Andre de Gouvea, chair (Northwestern U.)
Roxanne Guenette (Manchester U..)
Alessandro Lovato (Argonne)
Olga Mena (IFIC-Valencia)
Pedro Machado (Fermilab)
William Marciano (Brookhaven)
Ornella Palamara (Fermilab)
Sanjay Reddy (INT, U. Washington)
Kate Scholberg (Duke U.)
Irene Tamborra (Bohr Inst.)

Prior membership

SSC: Andreas Kronfeld (Fermilab); **SAB**: Belen Gavela (UAM/IFT), Renata Funchal (USP), Chang-Kee Jung (Stony Brook), Cecilia Lunardini (Arizona State)

Neutrino Theory Network Functioning

SSC and SAB members are to be rotated regularly every 3+ years, but not simultaneously to ensure continuity.

During its inception, the NTN governance was chosen based on expertise, diversity of scientific areas, geographical diversity and availability.

A more structured succession plan is under development.

The NTN is supported by Fermilab theory administrator and lab business side

Significant efforts from Scientists Carena (PI), Machado, Rocco and De Gouvea

Focus Research Areas of NTN

Neutrino Phenomenology:

- Expand the sensitivity of the SBN program and DUNE to explore a broad class of new physics models in which new particles are produced in the beam or in the neutrino-nucleus interactions, e.g. axion-like particles, dark neutrinos, heavy neutral leptons, and dark matter. Study specific signatures of such models at liquid argon detectors.

- Perform sensitivity studies, accounting for realistic neutrino-nucleus interaction models, to identify promising scenarios that can be searched for in neutrino experiments and guide fruitful experimental efforts.

- Perform synergetic efforts between groups working on neutrino-nucleus interactions and phenomenology to estimate how specific uncertainties such as the uncertainties on modeling resonance scattering or the shallow inelastic region, can affect the determination of oscillation parameters, such as the CP violating phase or the reach for relevant BSM scenario

Focus Research Areas of NTN

Neutrino Nucleus Interactions :

- Establish interdisciplinary collaborations between theorists and experimentalists to fully exploite the capabilities of liquid argon detectors.
- Propose observables to constrain the accuracy of theoretical models and simulations in the kinematical regions relevant for DUNE.
- Support advances in both lattice QCD and nuclear many-body methods aimed at significantly reducing uncertainties in the determination of neutrino-nucleus interactions
- Improve several aspects of neutrino event generators to ameliorate the accuracy of cross-section predictions and therefore in the determination of mixing parameters, e.g.
  - promote generators that can be more easily expanded and generalized to the newest developments in the field.
  - improve the precision of neutrino event generators, leveraging on computational techniques developed by the collider community and exploiting similarities between neutrino and electron scattering physics.
  - focus attention at the interface of high energy and nuclear physics.

Fermilab

Focus Research Areas of NTN

Astrophysical Neutrinos:

- Perform theoretical work to disentangle unknown neutrino physics from unknown astrophysics
- Aim at understanding supernovae well enough to enable tests of new physics beyond the reaches of the terrestrial probes
- Help experiments be better prepared to measure a neutrino burst from a Milky Way supernova
- Explore what governs neutrino mixing at high densities, including that of neutrinos themselves
- Connect cosmology measurements about neutrinos - neutrino masses and the number of flavors- with laboratory measurements — in particular in case of discrepancies.

Current NTN Core Activities

NTN Fellows Program:
Open the field to future leaders of the field

NTN Workshops, Schools and Visitors Program (short to medium term visits) enabling collaborations and educating a new workforce

Possible expansion of Core Activities

Goal: Retain NTN Fellows in academia and help attracting and training students at universities that are currently not doing neutrino physics
➔Possibly by NTN Seeded Faculty Positions

Goal: strengthen the community, source new collaborations and projects in a more comprehensive way
➔ New yearly NTN Program (NTN-ViP) in rotating institutions

NTN Activities

Years 2018 – 2019

- Supported 12 PIs to organize topical workshops and for collaborative short-and longer-term visits in the areas of neutrino nucleus interactions, neutrino phenomenology and astrophysics

Years 2019 – 2020 (covid impacted)

- Supported 7 PIs , to partially support students, postdocs and collaborative activity in the areas of neutrino nucleus interactions, phenomenology and astrophysics

NTN Activities

Years 2020-2021

Started the NTN Fellowship Program

- Support for 2 NTN Fellows for 3 years/each, who started in the fall of 2021

  Zahra Tabrizi (Northwestern, Neutrino Phenomenology)

  Bijaya Acharya (Oak Ridge, neutrino-nucleus interactions)

Years 2021-2022

- Support for 2 NTN Fellows for 3 years/each who will start in the fall of 2022

  Payel Mukhopadhyay (UC Berkeley, astrophysics)

  Ryan Plestid (Caltech, neutrino phenomenology and neutrino interactions)

- NTN Workshop at Fermilab, June 21-23, 2022: https://indico.fnal.gov/event/54395/timetable/#20220621

  Broad community participation - theorists and experimenters – and many talks highlighting the relevance of NTN activities to the US experimental neutrino program

NTN Activities moving forward

Years 2022 -2023

- Support 2 NTN Fellows for 3 years/each, who will start in the fall of 2023
- Support workshops/schools and collaborative visits.
- New yearly NTN Program (NTN-ViP) in rotating institutions

Discuss possibility of seeding a faculty position in neutrino physics relevant to NTN scientific goals at a US University as opportunity to keep NTN Fellows in the field and enhance diversity pipelines.

- Recent NTN DOE Review to evaluate past activities and define expected deliverables of a core NTN program for the next 5 – 10 years. Positive feedback from closeout session and expecting final report.
- Making the NTN program a base HEP program is essential to assure the continuity of these efforts in maximizing the physics discoveries of the US neutrino program and answering deep, long-standing questions in neutrino physics