SNOWMASS STATUS: NEUTRINO & UNDERGROUND FACILITIES FRONTIERS

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BNL SNOWMASS RETREAT

DECEMBER 17, 2021

INTRODUCTION TO NEUTRINO FRONTIER

- Conveners:
  - Patrick Huber (Virginia Tech)
  - Kate Scholberg (Duke)
  - Elizabeth Worcester (BNL)



- Information and contacts:
  - Official info: https://snowmass21.org/neutrino/start
  - Announcements: SNOWMASS-NEUTRINO-FRONTIER@FNAL.GOV
  - Conversations: Snowmass Slack #neutrinos channel
  - Many topical group mailing lists/channels

NEUTRINO FRONTIER TOPICAL GROUPS

- NF01: Neutrino Oscillations
- NF02: Sterile Neutrinos
- NF03: BSM
- NF04: Neutrinos from Natural Sources
- NF05: Neutrino Properties
- NF06: Neutrino Interaction Cross Sections
- NF07: Applications
- NF08→TF11: Neutrino Theory
- NF09: Artificial Neutrino Sources
- NF10: Neutrino Detectors
- +liaisons to all other frontiers
- +early career liaisons

Snowmass is a US community planning process, but international collaboration and context is critical. Effort was made to have representation from the international community in the topical group conveners.

NOTE ON NEUTRINO FRONTIER SCOPE

- In the Snowmass Neutrino Frontier, our goal is to report on the activities/interests of the entire neutrino community, including those aspects not traditionally labeled "particle physics" or not traditionally funded by US particle physics agencies. Therefore, our topical group activities and NF report **will** include:
  - Nuclear theory as relating to neutrino-nucleus interactions
  - Neutrinoless double beta decay
  - Neutrino mass measurements
  - Nuclear non-proliferation and other applications
  - Neutrinos from astrophysics sources

KEY QUESTIONS & DIRECTIONS FOR NEUTRINO FRONTIER

- Physics Topics:
  - Precision Neutrino Measurements
  - Physics Beyond the Standard Model
  - Neutrinos and the Cosmos
- Infrastructure/Tools:
  - Underground facilities
  - Detectors/Instrumentation/Sources
  - Event generators
  - Algorithms and computing
- Community Engagement
  - How can we improve the climate within our frontier (ethics, diversity, inclusion, career development)?
  - How can our frontier make contributions to society (education, public & political engagement, applications)?

See ”Extra Slides” for details

NOTE ON DUNE

- Letter from Jim Seigrist describing DOE stance on realizing full scope of DUNE:

> "The long-term P5 plan envisions two additional far detectors and a more intense beam than is currently being constructed. Design work performed to date on the DUNE experiment indicates that a more capable near detector will be needed to exploit these enhanced capabilities fully, or even the Phase I capabilities after sufficient statistics have been collected.
>
> HEP would like to put in place a process for discussion and evaluation of these upgrades. We understand that these upgrades are of different scales and timelines. For example, additional far detector mass as well as the Booster replacement will be contemplated as new projects by the next P5 subpanel, (expected to start its work in Fall 2022), and may not proceed until after Phase I is largely complete."

- Full scale far detector, 2.4 MW beam, and full near detector are not guaranteed and will need endorsement by the Snowmass process and the next P5 to be realized
- DUNE collaboration is developing their Snowmass messaging strategy internally
  - As NF conveners, it is not our place to do this for the collaboration, but we recognize the importance of DUNE for the whole NF community and are working closely with DUNE to ensure consistent

NF ACTIVITIES

- Snowmass contributions ("whitepapers")
  - Some summary whitepapers are being actively developed by topical groups, other whitepapers are contributed by individuals and/or collaborations
  - We are just wrapping up a series of mini workshops on NF whitepapers that took place throughout the fall
  - Whitepapers are due (submitted to arXiv) by March 15 (most should already be in advanced state)
- Frontier report (see next slides for structure & schedule)
  - Expect multiple rounds of drafts/community feedback
- Frontier workshop
  - March 16-18 at ORNL, decision on whether there will be a significant in-person component pending
  - Goal is to have substantive discussion of first round of report drafts
- Community Summer Study (CSS)
  - July 17-26 at University of Washington, Seattle
  - In the process of developing a goal for this workshop given that the reports will be largely complete

SNOWMASS REPORT STRUCTURE

2. Snowmass Summary Report (~50 pages) [audience: Snowmass community, science community, funding agencies]

1. Executive Summary: ~10 pages
2. Introduction
3. 10 Frontier Executive Summaries (a few pages per Frontier)
4. Executive Summaries of Multi-Frontier Topics
5. Conclusion

3. Snowmass Book (~500 pages) [audience: Snowmass community + P5 Committee] (see Snowmass 2013 Report)

1. Snowmass Summary Report (~50 pages)
2. Frontier Summaries (< 50 pages per Frontier)
3. Multi-Frontier Topic Summaries (~10 pages per Topic)

4. Reports of Ten Frontiers [audience: Frontiers & Topical Groups] - web based (see Snowmass 2013 webpage)

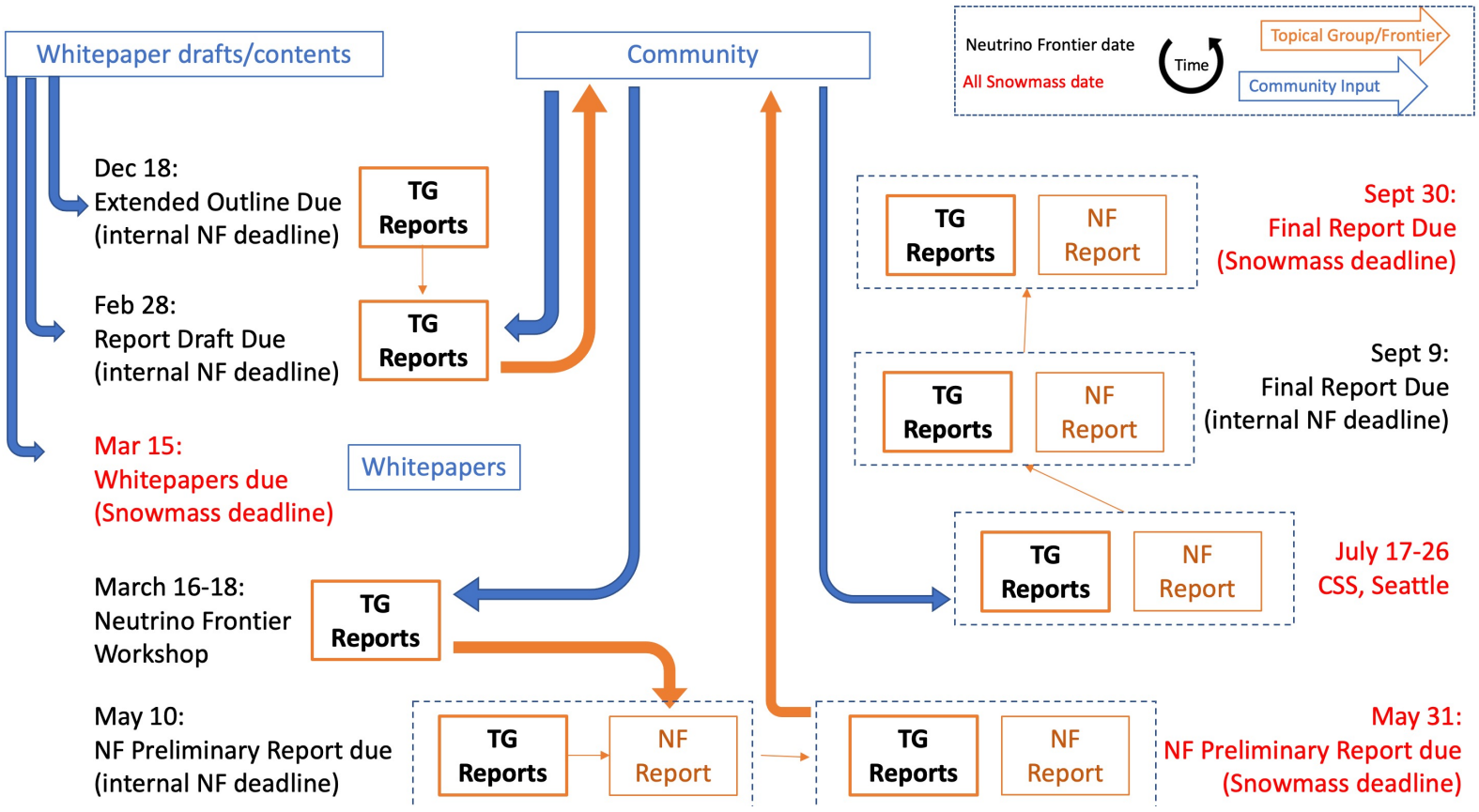
- Each Frontier Summary: < 50 pages
- Topical Group Reports (some groups could be combined): < a few tens of pages per report

5. Reports of Multi-Frontier Topics [audience: Frontiers & Topical Groups]

- Each Multi-Frontier Topic Summary: ~10 page
- Multi-Frontier Topics are topics spanning multiple Frontiers such as Dark Matter and Quantum Science.

Frontier Summary: <50 pages *(NF conveners)*
Topical Group Reports: 10s of pages per topical group *(Topical Group Conveners)*

NF REPORT TIMELINE/FLOWCHART



UNDERGROUND FACILITIES FRONTIER

Laura Baudis (U. Zurich)

Jeter Hall (SNOLAB)

Kevin Lesko (LBNL)

John Orrell (PNNL)

- Underground Facilities for Neutrinos
- Underground Facilities for Cosmic Frontier
- Underground Detectors
- Supporting Capabilities
- Synergistic Research
- Integrated Strategy for Underground Facilities and Infrastructure

- Understand current and planned underground facilities, underground space for experiments, and supporting capabilities
- Develop requirements and wishes for the future experiments and in particular new frontiers (e.g. QIS)
- Develop synergistic relationships among experiments (shared space, parallel use, partnerships, shared technology)
- R&D space and growth of new technologies
- Understand underground space requirements in closely related fields (nuclear astrophysics, $0\nu\beta\beta$, …)
- Create a vision for underground facilities in the coming decades

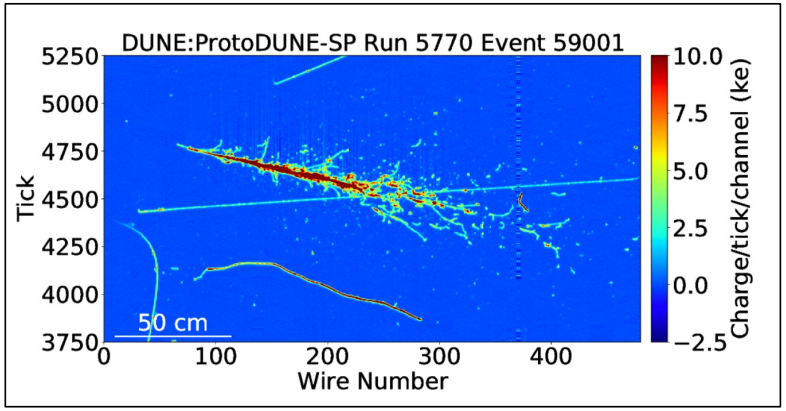
SUMMARY

- Organization and initial survey of community activities completed in 2020
  - Strong, international team of topical group conveners and liaisons
  - Many topical group and whitepaper workshops already held
- Neutrino Frontier addressing wide range of physics topics and infrastructure/tools
  - Precision neutrino properties and oscillations, physics beyond the Standard Model, astrophysics/cosmology, neutrino-nucleus interactions, computing, machine learning, applications, advanced detectors, underground facilities
- Neutrino Frontier upcoming activities:
  - **Whitepaper deadline coming up soon (March 15)**
  - **NF Workshop at ORNL March 16-18**
  - **Report drafts beginning now – community feedback is very important**
- Underground Facilities Frontier primarily focused on overlap with other frontiers with the goal of developing a visionary plan for US Underground Physics Program

EXTRA SLIDES

PRECISION NEUTRINO MEASUREMENTS

- The primary physics goals of many neutrino experiments are precision measurements of neutrino oscillation parameters: Δm^2_{21}, Δm^2_{32}, θ_{12}, θ_{13}, θ_{23}, δ_{CP}
- Measurements of neutrino interactions and development of neutrino interaction models are essential for precision measurements and BSM searches involving neutrino detection
- The last Snowmass/P5 developed a plan for US-based precision neutrino oscillation measurements → DUNE
  - We are in the process of implementing this plan
  - **Critical that full scope of previous P5 vision be realized**
- Worldwide efforts also coming online in next decade
  - Complementarity, increased focus on combined analyses
- Next-next generation experiments starting to be discussed
- Similar story for neutrino property measurements



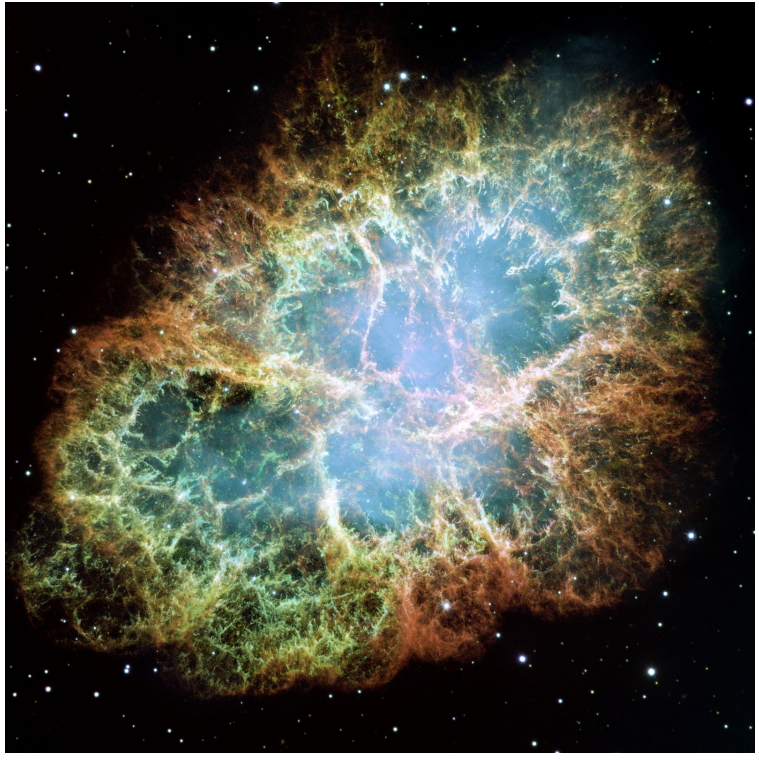
NEUTRINOS & PHYSICS BEYOND THE STANDARD MODEL

- Neutrinos are the least accurately studied particles within the SM and thus can hide large-ish BSM signals
- Much of neutrino-related BSM is connected to dark sectors
- eV-scale sterile neutrino searches are being intensely pursued
- Neutrino sources typically are also neutral meson and photon sources → "neutral" BSM searches
- Neutrino detectors often useful for non-neutrino BSM searches
- Close relationship between theory and experiment needed to make progress

ICARUS at SBN

NEUTRINOS & ASTROPHYSICS/COSMOLOGY

- Neutrinos from astrophysical sources are probes of BSM physics
- Neutrinos are tools to learn about astrophysical objects, as a component of multi-messenger astronomy
- Properties of neutrinos are deeply entwined with cosmology
- Neutrino detectors can be used to search for dark matter
- Dark matter instrumentation is also relevant for neutrino detection



INFRASTRUCTURE/TOOLS

- Frameworks for theoretical calculations and implementation of models (ie: generators) are critical tools
- Neutrino experiments are becoming increasingly computing intensive
  - Large datasets, significant computing resources needed for simulation, implementation of machine learning algorithms, systematics evaluation
- Neutrino cross-sections are very small: precision measurements and discovery potential require powerful neutrino sources, massive detectors, attention to reducing background
- Significant overlap in detector technology and underground facility needs among dark matter, $0\nu\beta\beta$, and neutrino oscillation experiments
- Advanced detectors/sensors being developed for next-next generation experiments

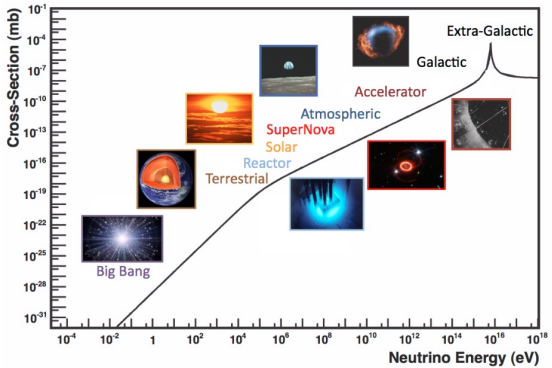


Photo: *Matthew Kapust*

COMMUNITY ENGAGEMENT

- The neutrino frontier embraces our obligations to our colleagues and to society at large
- NF early-career physicists have been very active in SEC leadership and are fully embedded in NF activities
- NF has a topical group for Applications
- Many institutions central to NF (including Fermilab and SURF) have active social media, community outreach, environmental awareness, site tours, cultural, and education programs in place
  - How can we better communicate with communities who don't seek us out?
  - Are we making sure to be good citizens of the communities where we build our experiments?
- We all have work to do on justice, inclusion, and diversity - we are learning, listening, organizing, and trying to do better: particlesforjustice.org is a great resource