# Joint BSM@ν Workshop Summary

*Feb. 12, 2022*

*Snowmass BSM@ν Joint Workshop*

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# BSM@ν Strategy, Thus far

**Overarching strategic goal : To ensure the BSM physics at neutrino experiments a solidly established area of study**

**➔ Accomplished!**

- Strategy
  - ✓ Ensure BSM@ν physics to be an official topic at all subsequent future Snowmass studies
  - ✓ Increase awareness and interests on BSM@ν physics within and outside the community
  - ✓ Ensure BSM@ν topics to take a prominent presence in all official documents ➔ P5 strategic plan, Science book, CDR, PDR, TDR, Review reports and presentations, etc
  - ✓ Form a strong collaborative group of experimentalists and theorists to continue developing and exploring new ideas and publish the work

# BSM Signature Categories

- Direct Observation Signatures
  - Requires high beam flux
  - Sufficiently large mass for interaction signatures
  - Sufficiently large volume for decay signatures
- Inferred Observation Signatures from both beam and cosmogenic sources
  - Leverage oscillatory behaviors
  - Large target mass FD for interactions
- What do we need to know?
  - Signal flux and realistic behaviors in the detector
  - Neutrino flux and their interactions in the detector as bck

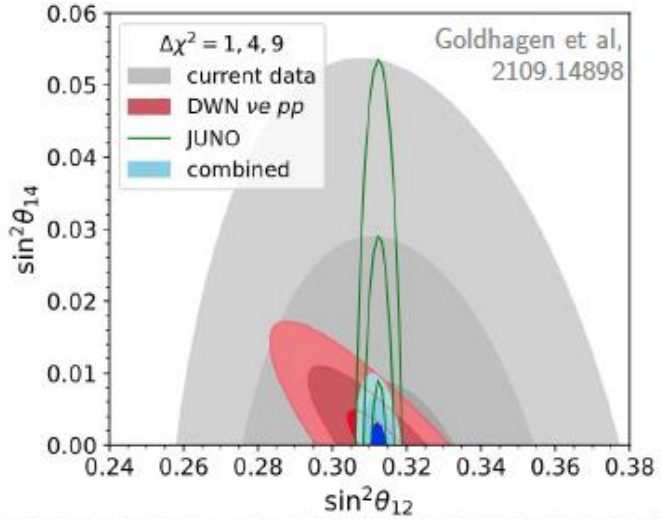
# Sub-topical White Papers

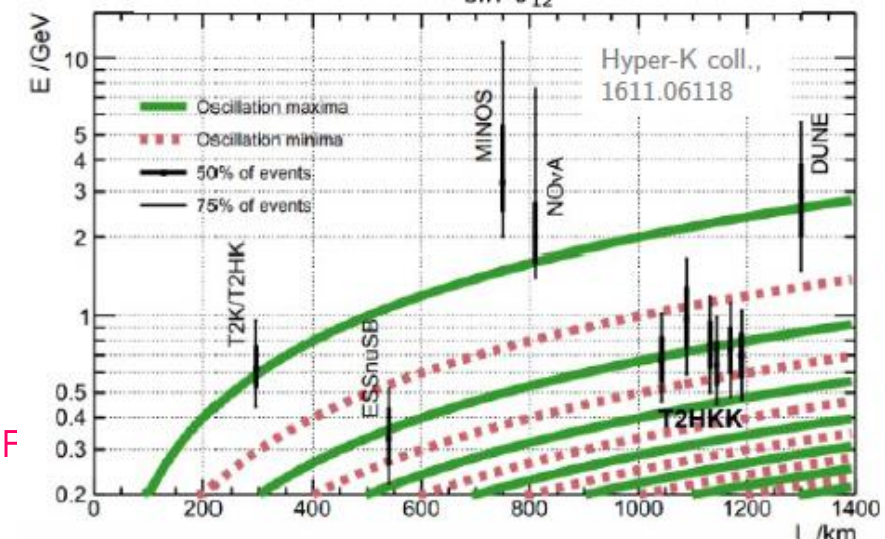
- Impressive progress have been made
- All six white papers are in excellent shape
  - Generating large interests
  - Working closely with other topical groups and frontiers
- Many new contributors have joined in at this workshop, helping to finalize the papers

# BSM Effects on $\nu$-flavor

Lead editors : Pilar Coloma, David Forero and Teppei Katori

Rich BSM physic topics in neutrino behaviors that can be explored in broad kinematic phase space



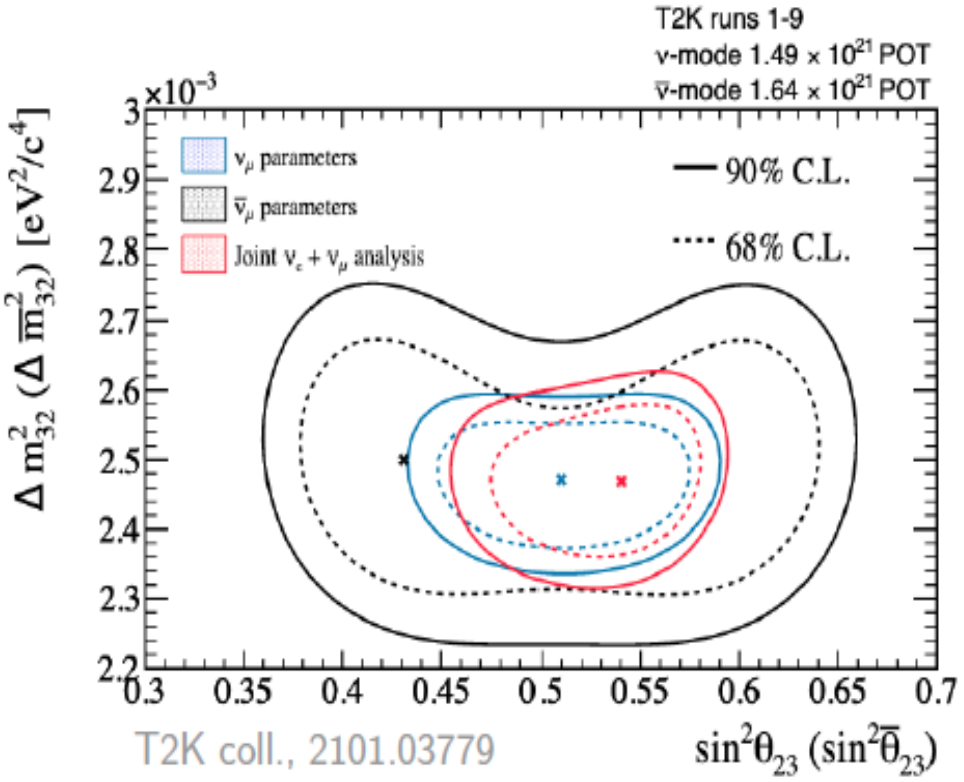

| Energy Range | Experiment |
|---|---|
| $< 10^3$ GeV | JUNO |
| $< 10^3$ GeV | DUNE |
| $< 10^3$ GeV | THEIA |
| $< 10^3$ GeV | WATCHMAN |
| $< 10^3$ GeV | Super-Kamiokande |
| $< 10^4$ GeV | Hyper-Kamiokande |
| $< 10^5$ GeV | ANTARES |
| $< 10^6$ GeV | IceCube/IceCube-Gen2 |
| $< 10^6$ GeV | KM3NeT |
| $< 10^6$ GeV | Baikal-GVD |
| $< 10^6$ GeV | P-ONE |
| $1 - 100$ PeV | TAMBO |
| $> 1$ PeV | Trinity |
| $> 10$ PeV | FET-N |
| $> 10$ PeV | IceCube-Gen2 |
| $> 10$ PeV | ARIANNA-200 |
| $> 20$ PeV | POEMMA |
| $> 100$ PeV | RNO-G |
| $> 100$ PeV | Auger/GCOS |
| $> 100$ PeV | ANITA/PUEO |
| $> 100$ PeV | Beacon |
| $> 100$ PeV | GRAND |

Table adapted from Arguelles et al, 1912.09486

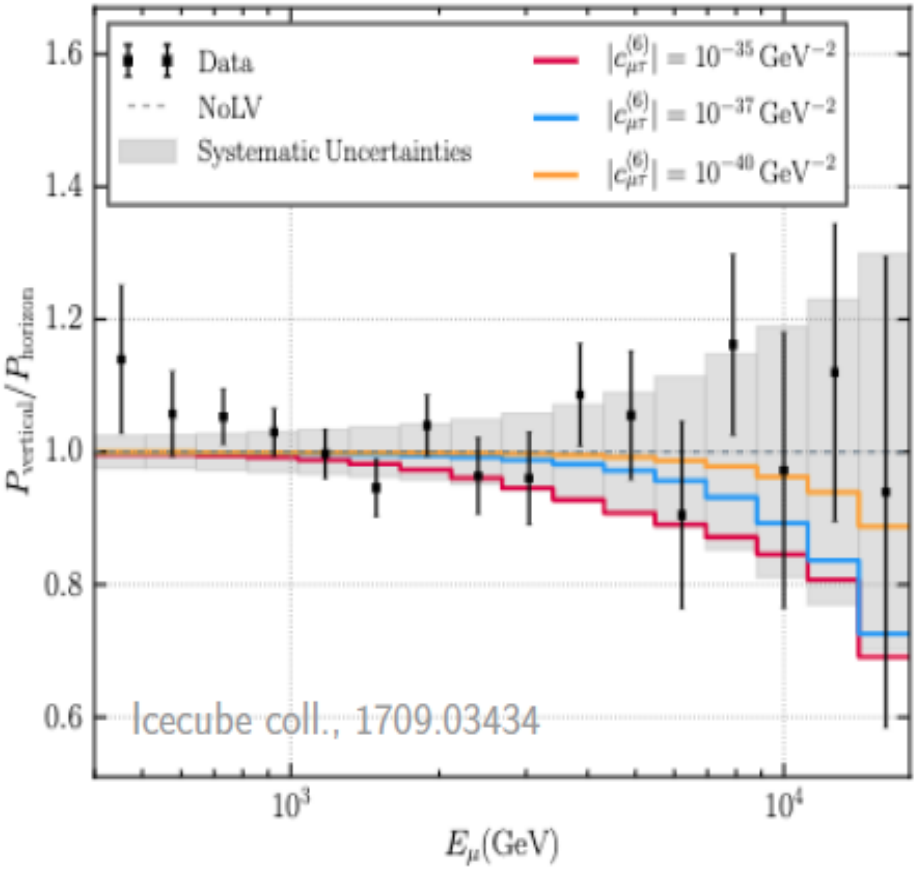
# BSM Effects on ν-flavor

## Test of fundamental symmetry

### CPT violation



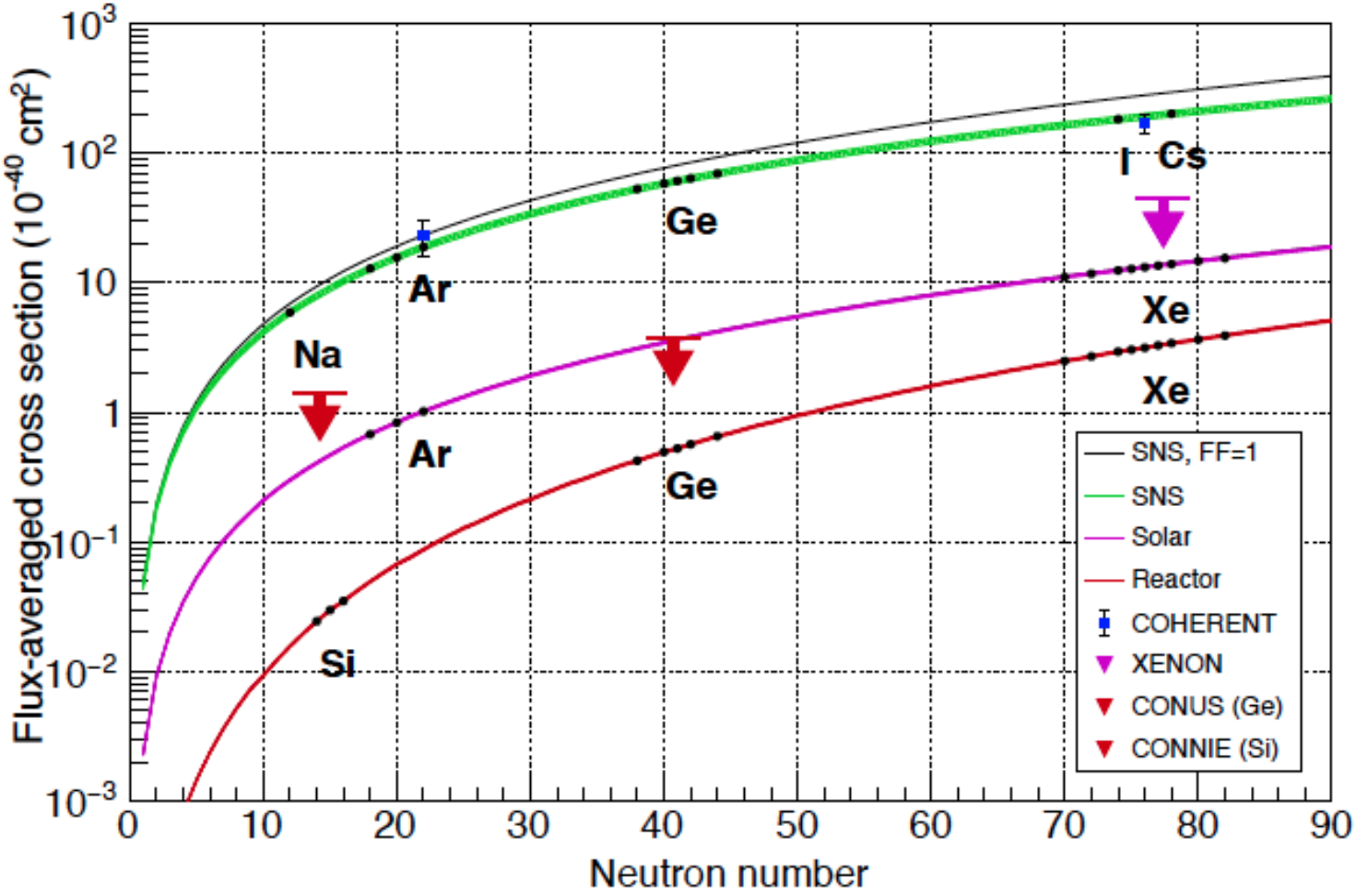

### Lorentz violation



# CEνNS

## Lead editors : Louis Strigari, Phil Barbeau and Raimund Strauss

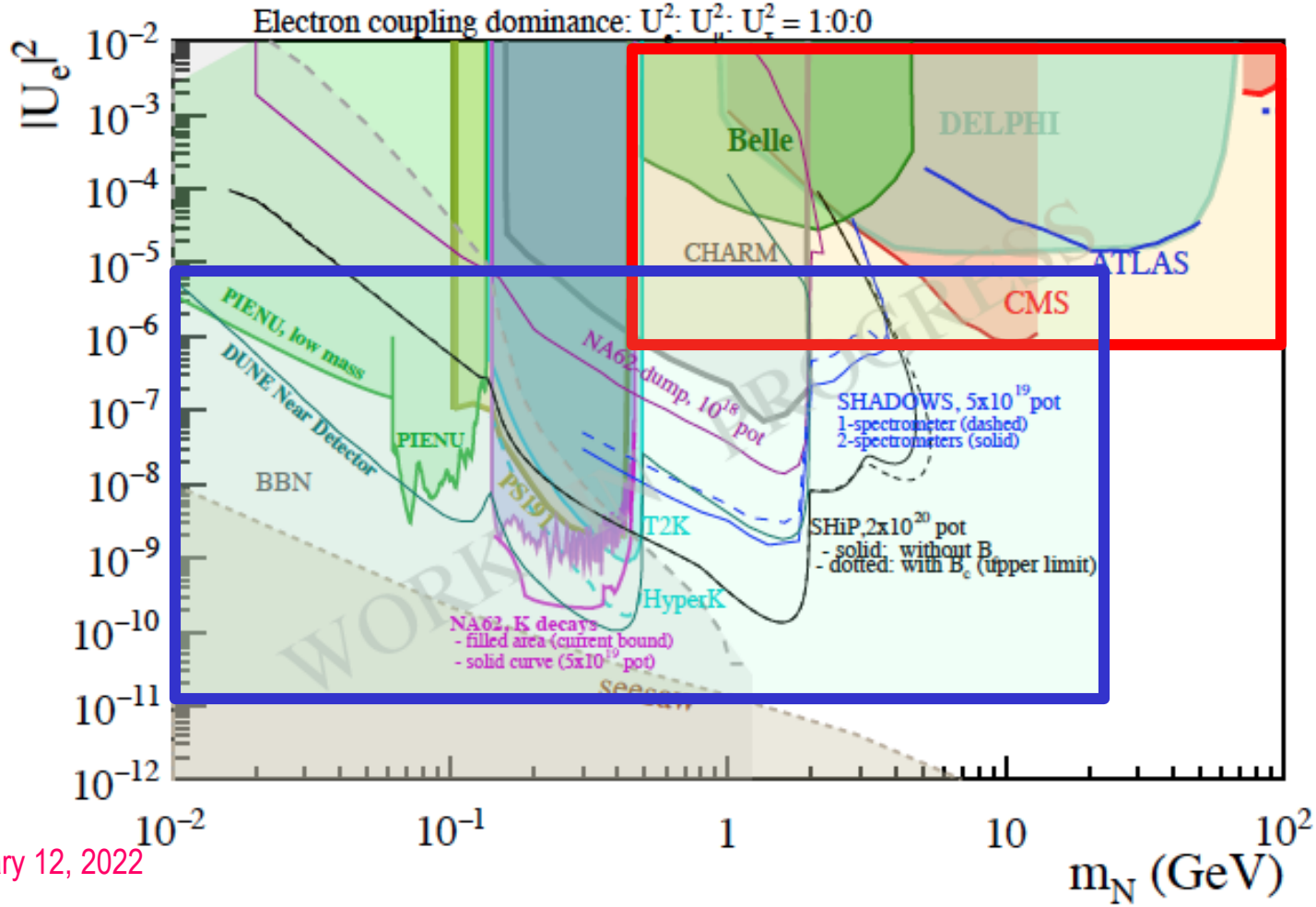
CEνNS is important physics and an essential testing ground for BSM at as low E as possible in many nuclei



# Heavy Neutral Leptons

Lead editors: Ian Shoemaker and Albert de Roeck

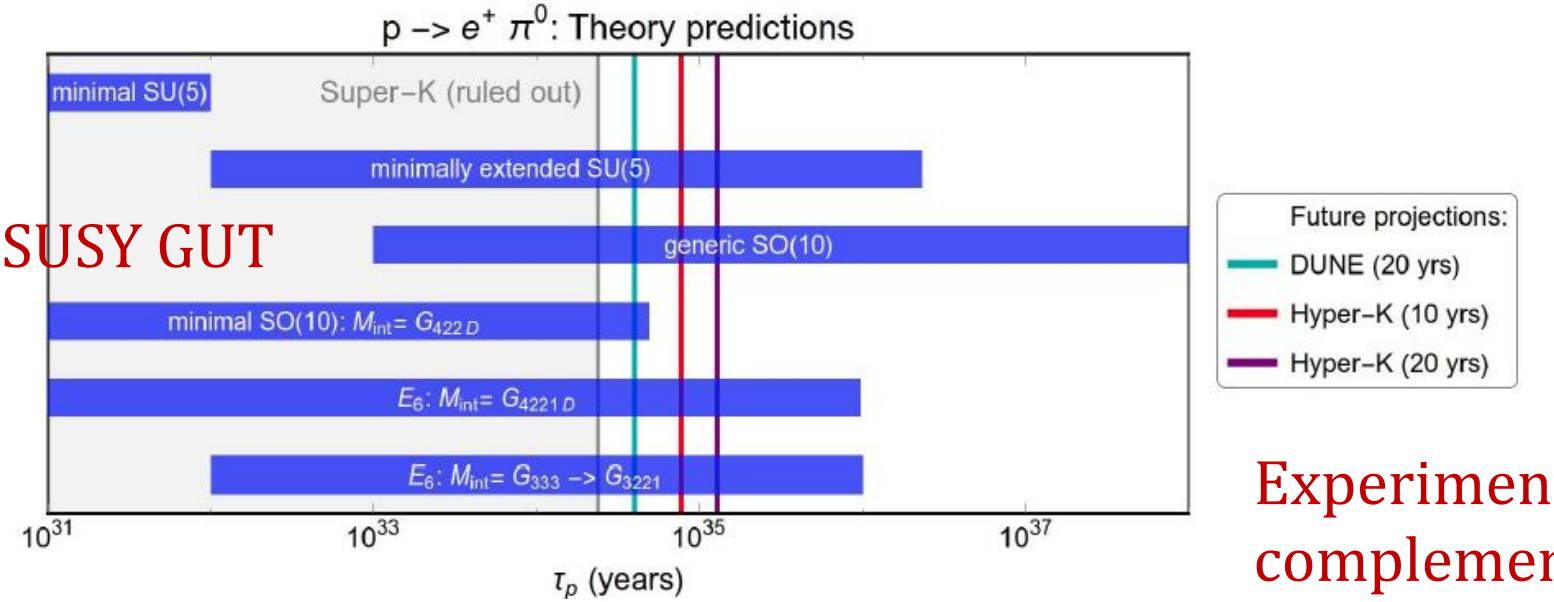
Collider and fixed target experiments – DUNE, NA62, SHiP & SHADOWS - compliment each other



# Baryon Number Violation

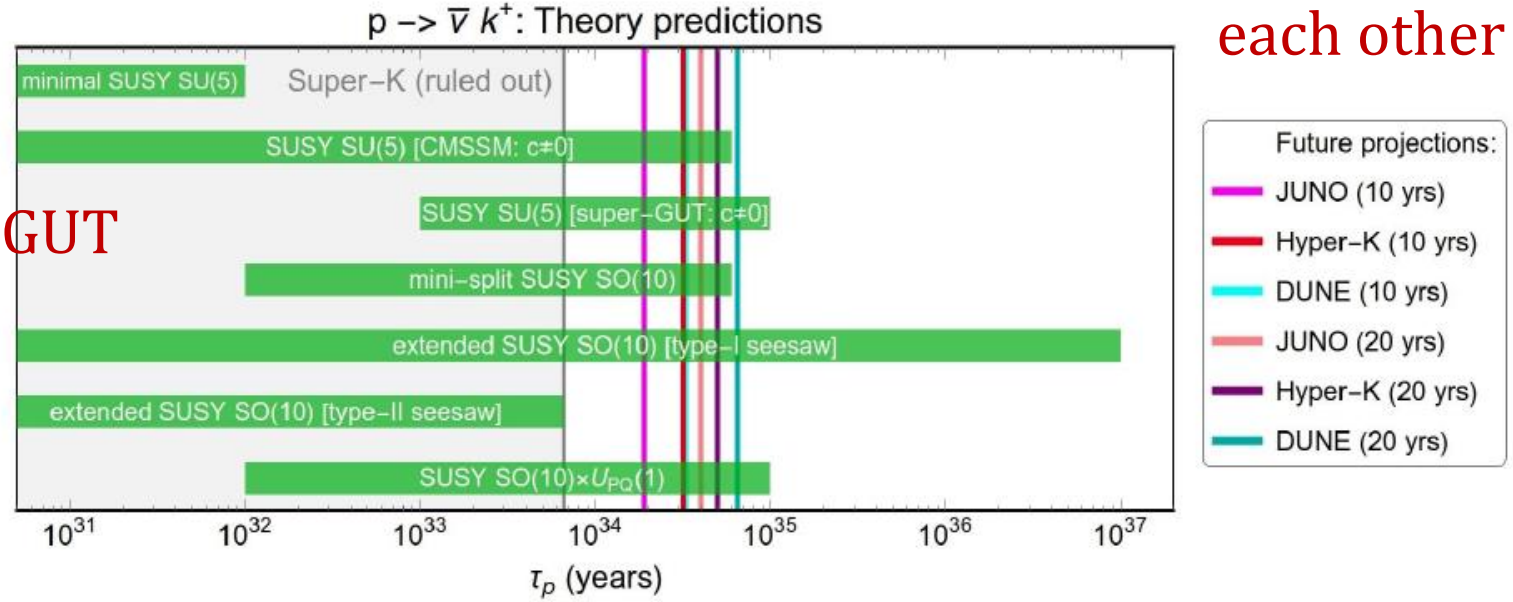
## Lead editors: Lisa Koerner and Bhupal Dev

Non-SUSY GUT




Experiments complement each other

SUSY GUT

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# Cosmogenic BSM Particles

Lead editors: Yun-tse Tsai and Doojin Kim

- New opportunities on probing cosmogenic BSM particles (BDM, iBDM, etc) with the operating and future neutrino experiments, leveraging the large detector mass
- Discuss consistency and complementarity among different detection technologies
- Describe techniques developed for new detection technologies (e.g. LArTPCs)
- Summarize analysis strategies

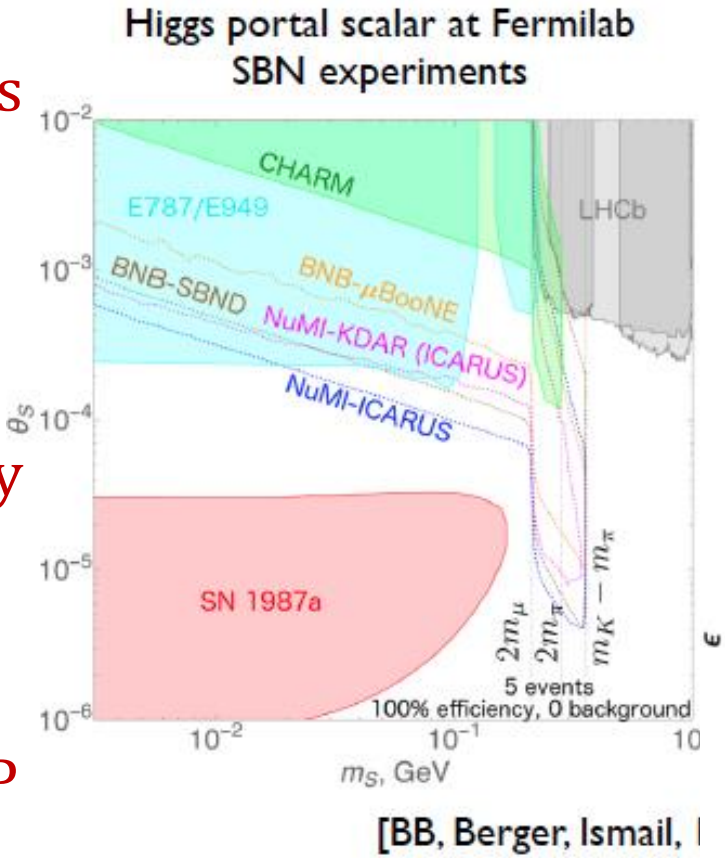
Contents

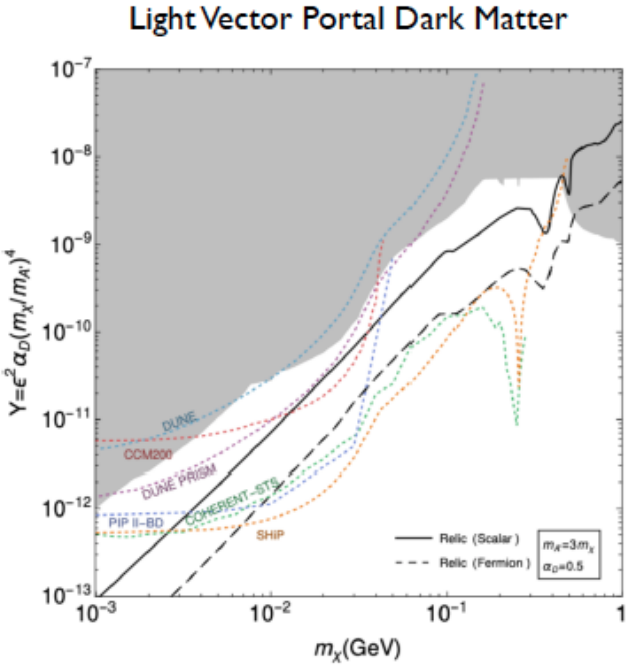
# Dark Sector Particles in the Beam

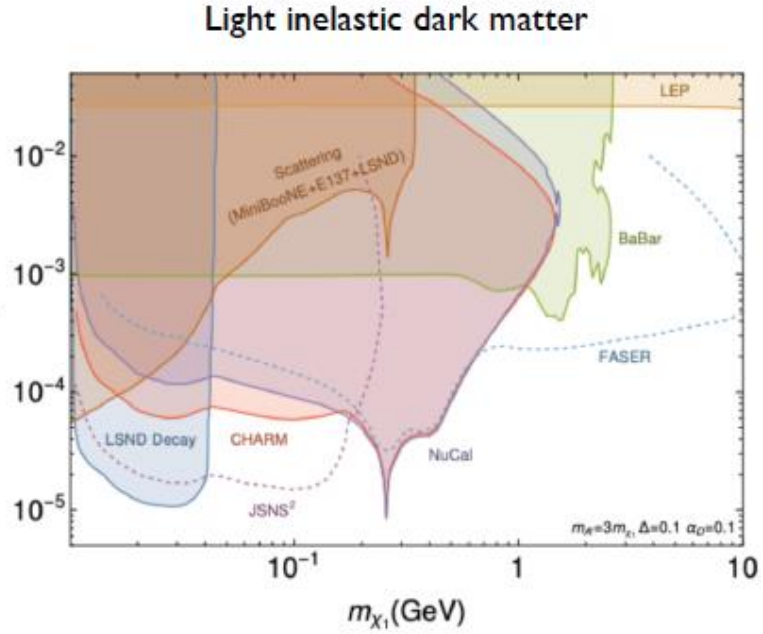
Lead editors : Brian Batell and Jae Yu

Set of new particles which do not experience the known forces; Weakly coupled to visible sector through a mediator or "portal"

Numerous opportunities to create dark sector particles, thanks to high intensity proton beams ➔ Toward the beams of DSP




February 12, 2022

# Shared Interests with Other TG's & TF's

## Joint TG's and TF's : NF01, NF02, RF06 and TH11

- Natural to have many shared interests across different TG's within NF and with other TF's
- Want to avoid duplicate efforts that could distract the focus and attention
- We have much clearer distinctions between these groups to ensure the focus of WP's and reports
  - Still some overlapping topics but at the level of directing attention to the relevant WP's
- Joint TG's and TF's at this workshop ensures capturing all physics topics and contributions of all interested members

# Contributed Talks

- Total of 19 contributed talks by **junior colleagues**
- A healthy mixture of experiment and theory talks
- Five talks on BSM search analyses using existing data
- Several new ideas on upcoming and future experiments

| | | | |
|---|---|---|---|
| | MicroBooNE's Low Energy Excess Search: First Results | Tau Neutrino Identification at IceCube for Unitary Violation | Searches for Nonstandard Neutrino Oscillations at |
| 12:00 | Searching for Beyond the Standard Model Physics with | BSM Oscillation Searches at the IceCube Neutrino | BSM Physics Potential of th PROSPECT-II Experiment |
| | New Proton Beam Dump Experiments at Fermilab: | IceCube Sterile Neutrino Searches | Hidden Sector Searches With Low-Threshold Reactor- |
| | Opportunity to study physics beyond standard neutrino | Search for Quantum Gravity Using Astrophysical Neutrino | Searching for Neutrinoless Double Beta Decay with |
| | BSM searches in LAr using MeV-scale reconstruction | Towards Probing the Diffuse Supernova Neutrino | Study of invisible neutrino decay at ESSnuSB |
| 13:00 | Decays of New-Physics Particles at the DUNE Near | Model-Independent Search f sub-MeV Sterile Neutrinos | Improving CP Sensitivity wit Muon Decay at Rest |
| | Break | Exploring Fundamental Physics with Atmospheric | Break |

# Timelines to Consider

- The documents we work on should provide info to help making strategic plan ➔ long term visions must be incorporated
- What would the $\nu$ world be like in 2030s?
  - Existing experiments will have increased their exposure
  - Most of the experiments currently in design or in construction will be taking data
    - SBN experiments will have been taking data over 5 years together
    - DUNE (2 FD's) and Hyper-K will have started operating
  - Signal simulations and $\nu$-N modeling would have improved
    - But at what level and what is missing?
- What should the $\nu$ world be like in 2040 – 2050?
  - What capabilities should the experiments have to support BSM?
    - Accelerators and detectors

# Sub-topical White Papers

- Impressive progress have been made
- All six white papers are in excellent shape
  - Generating large interests
  - Working closely with other Topical groups and frontiers
- Many new contributors have joined in at this workshop, helping to finalize the papers
- Need to be cleaned up to be in a releasable shape in the archives
- Executive summaries (~ 2 pages each) still needed for topical group report draft due **March 11**

# Signals and Backgrounds

- Currently running experiments looking into their data for BSM physics ➔ essential for quanttiative feedback
- Most studies on BSM physics in future $\nu$ experiments thus far primarily at the phenomenological level
- Sufficient demonstration of BSM@$\nu$ needs to be accompanied with more realistic studies
  - Signals ➔ Tools must be able to incorporate numerous new signatures with ease, a good verifiability and cross check, and the output be easily fed into the full detector simulations
  - Backgrounds ➔ The $\nu$-N interaction model must be improved to reduce uncertainties in $\nu$ interaction background

# Workshop Goals

This workshop was the 2nd in the series of the BSM@ν after the 2019 Arlington workshop (d%^&* COVID!)

- Goals of this workshop
  - ✓ Discuss activities and progress on Snowmass studies on new physics opportunities at neutrino experiments
  - ✓ Provide a status update of sub-topical groups activities and remaining studies including timelines, if incomplete
  - ➢ **Finalize sub-topical group whitepapers**
  - ➢ **Generate first drafts of topical frontier group reports** (NF01, NF02, NF03, RF06 & TF11) on new physics opportunities
  - ✓ Ensure capturing and integrating all BSM physics opportunities
  - ✓ Define clear timelines for completing the sub-topical group whitepapers and topical group reports

# Snowmass Dates to Keep in Mind

- Community feedback meetings for report input: Jan-Mar
- Topical Group Report drafts due for community (NF): **March 11**
- Community feedback period on first TG drafts: Mar. 11-Apr. 10
- NF Workshop @ ORNL : March 16-18
- Preliminary (TG & Frontier) Reports due (NF): **May 10**
- Preliminary (TG & Frontier) Reports due (Snowmass): May 31
- Community feedback period: June 1 – July 26
- Community Summer Study (Seattle): **July 17-26**
- Final (TG & Frontier) Reports due (NF): **Sept 9**
- Final (TG & Frontier) Reports due (Snowmass): Sept 30

# The next BSM@ν Strategy

## Overarching strategic goal : To ensure the BSM@ν a science driver and a primary goal of future ν experiments

- Strategy
  1. Ensure extracting large number of quantitative BSM physics results from experiments based on data prior to the start of next Snowmass
  2. Further increase and strengthen awareness and interests on BSM@ν physics within and outside the community
  3. Ensure BSM@ν topics to take an essential presence in all official documents ➔ P5 strategic plan, CDR, PDR, TDR, Review reports and presentations, etc
  4. Enhance collaboration of experimentalists and theorists, with the NP community, to continue developing and exploring new ideas, improve tools and publish the work

# Summary

- The joint workshop was a smashing success!
- It clearly demonstrated an explosive growth of interests in the community (44➔141 participants)
  - The large number of junior participants shows a clear path for continued growth
- To produce quantitative results, the tools for the signal studies and improved $\nu$-N interaction modelling for background studies are essential
  - Collaboration with NP community critical
  - The insufficient resource issues for tools development must be addressed ASAP