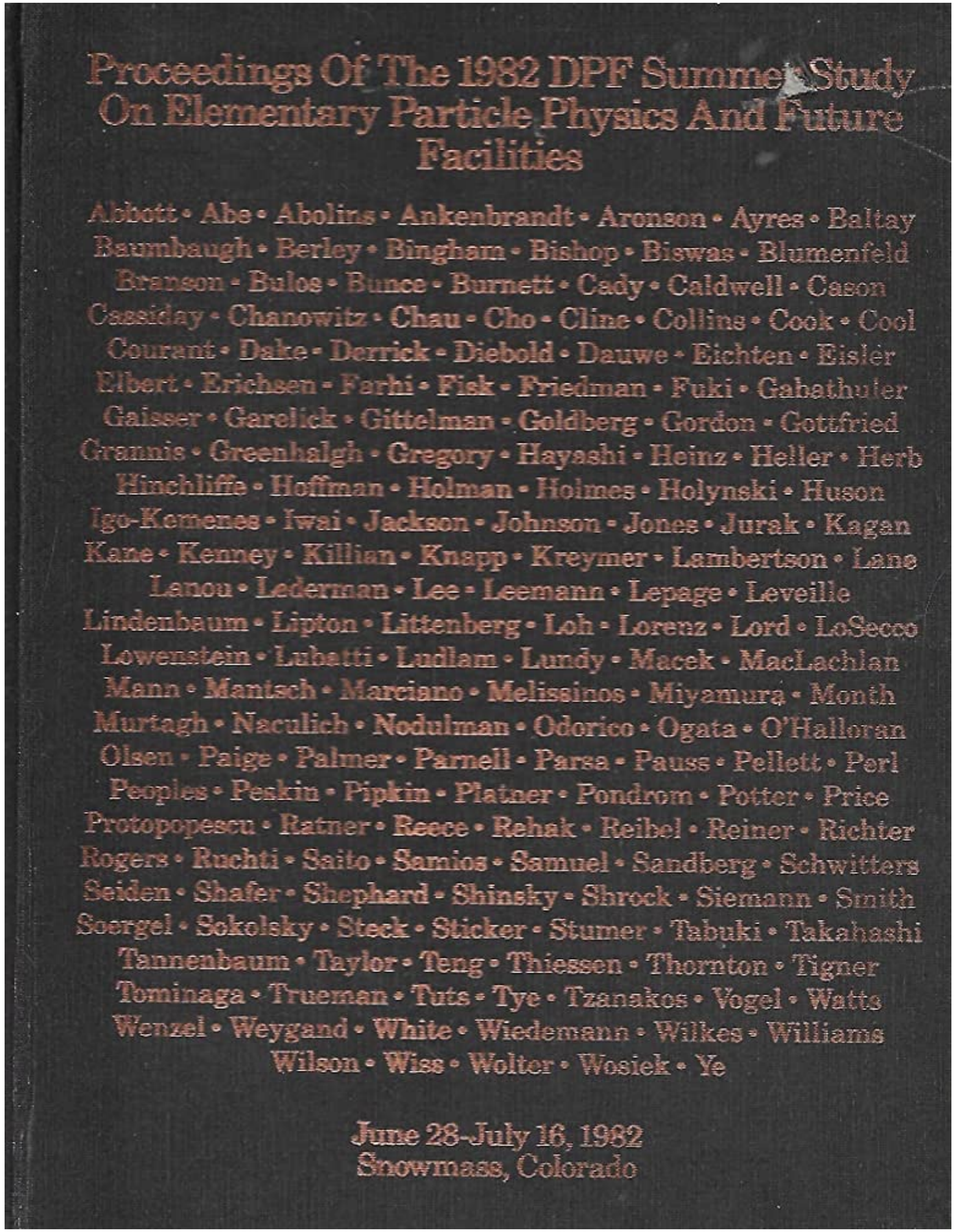
Supernova neutrinos at

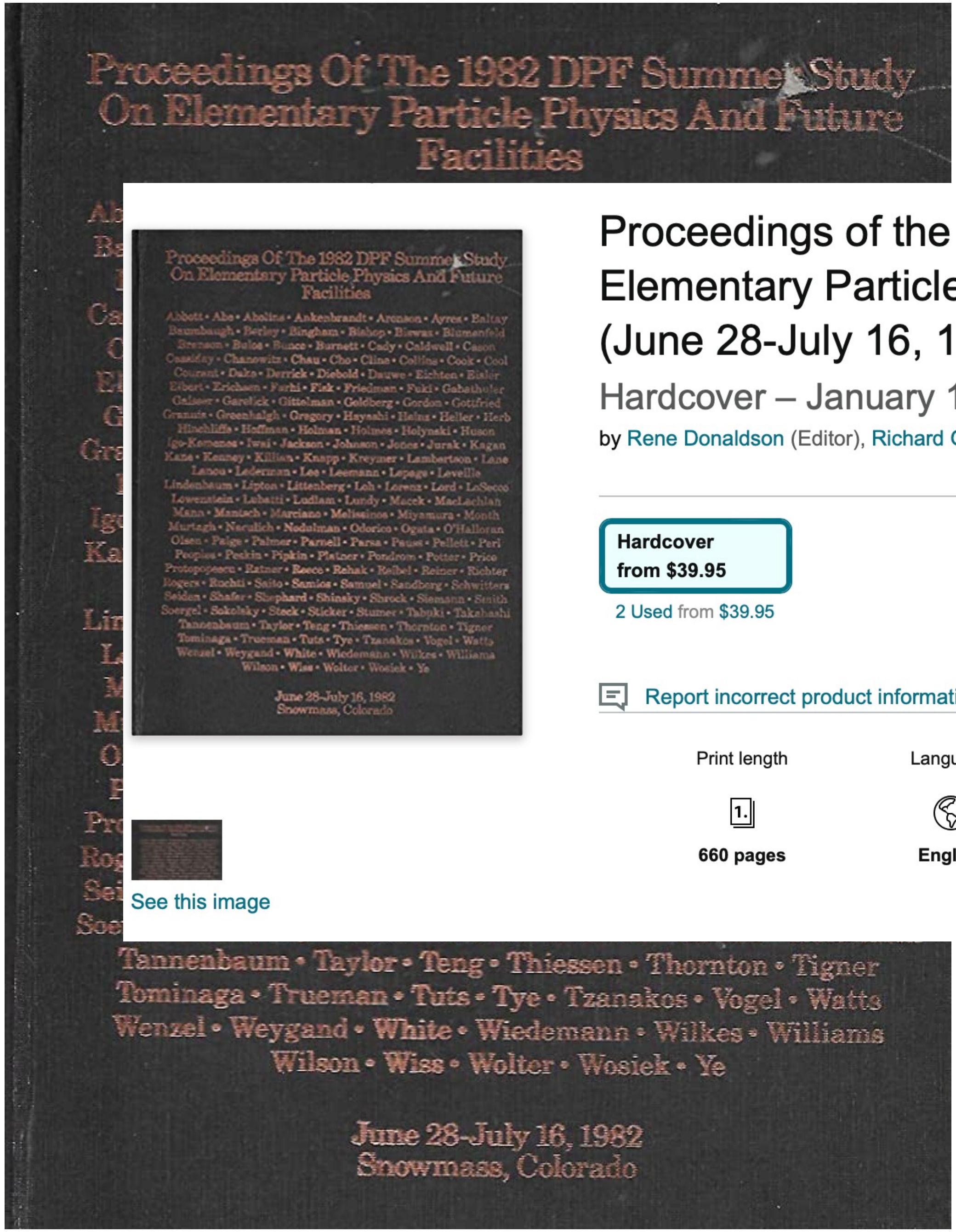
Erin O’Sullivan

SNnuD 2023



What is Snowmass?

Snowmass 1982: Three week retreat to plan strategy for particle physics



See this image

Proceedings of the 1982 DPF Summer Study on Elementary Particle Physics and Future Facilities (June 28-July 16, 1982, Snowmass, Colorado)

Hardcover – January 1, 1982

by Rene Donaldson (Editor), Richard Gustafson (Editor), Frank Paige (Editor)

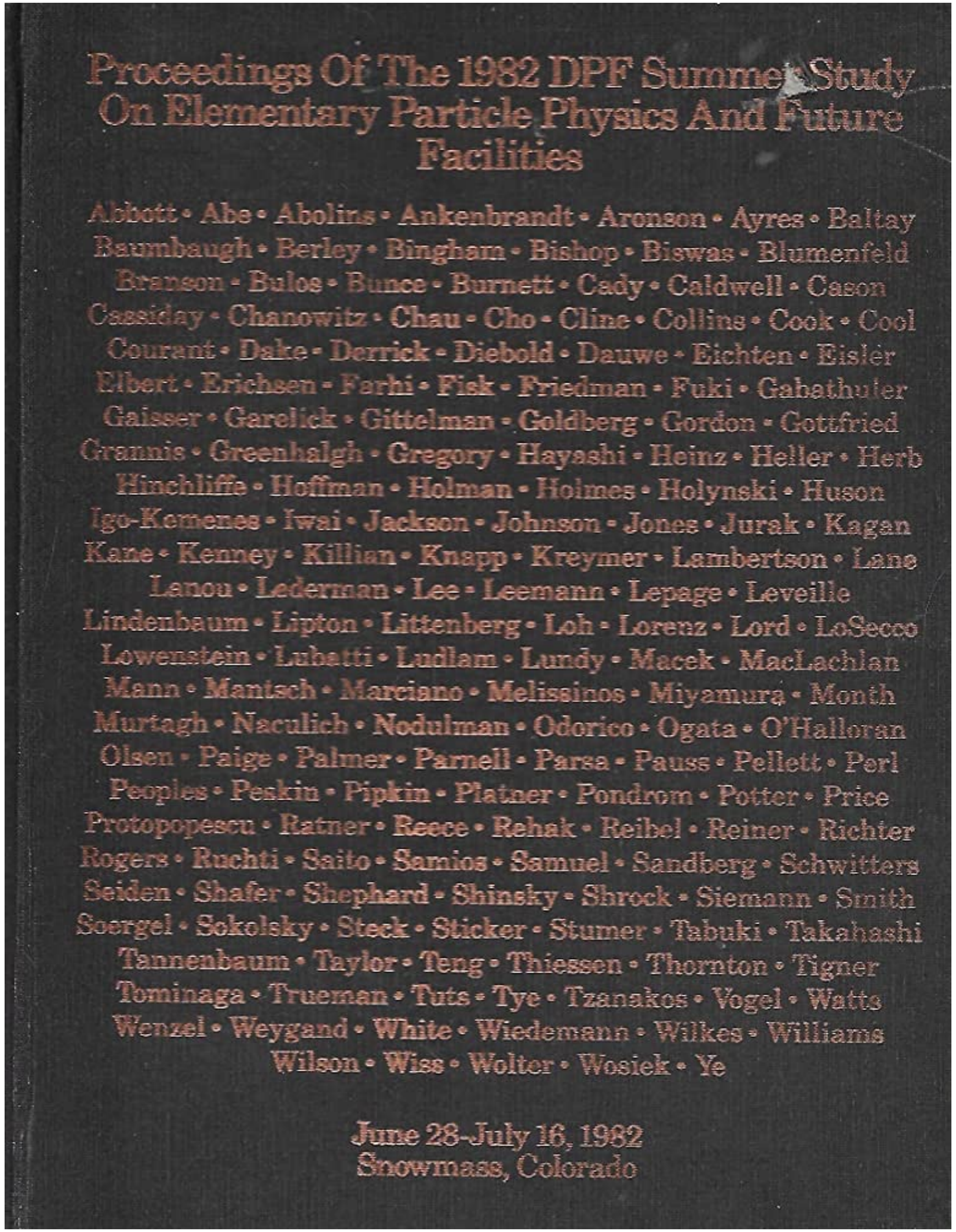
See all formats and editions

Hardcover
from $39.95

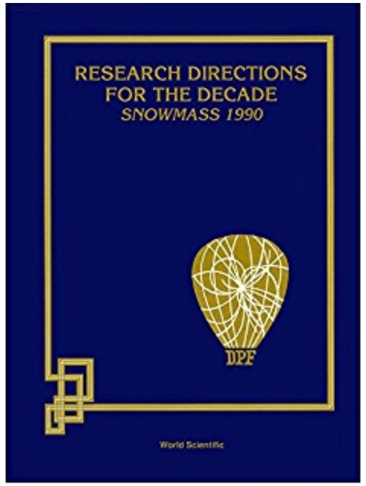
2 Used from $39.95

Report incorrect product information.

Print length	Language	Publisher	Publication date
660 pages	English	United States Deptartment of Energy	January 1, 1982



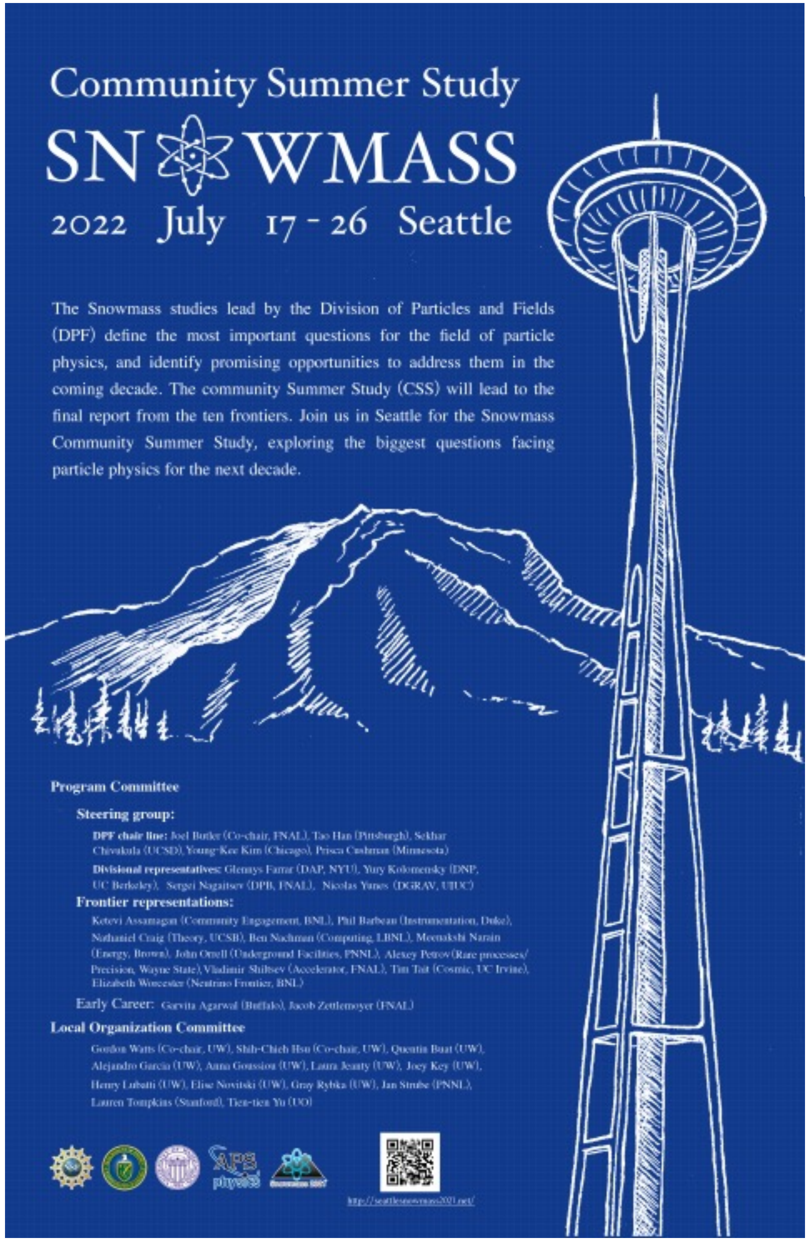
Outcome of first "Snowmass":
the superconducting supercollider



Many more planning meetings at Snowmass every 5-10 years

Final Snowmass Snowmass in 2001

2013, Not at Snowmass and new format: meetings through the year and a shorter in-person meeting

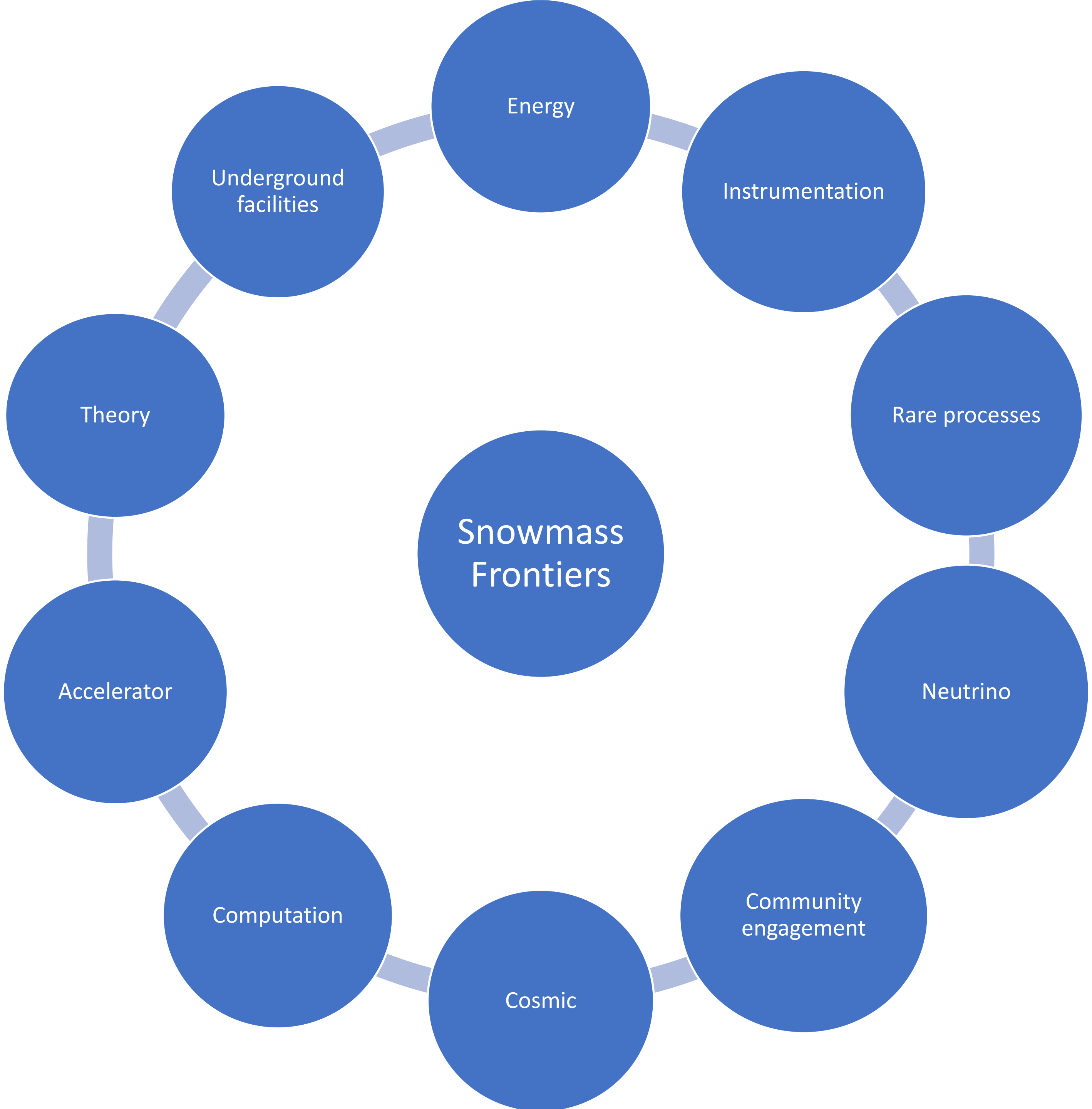


Snowmass 2021

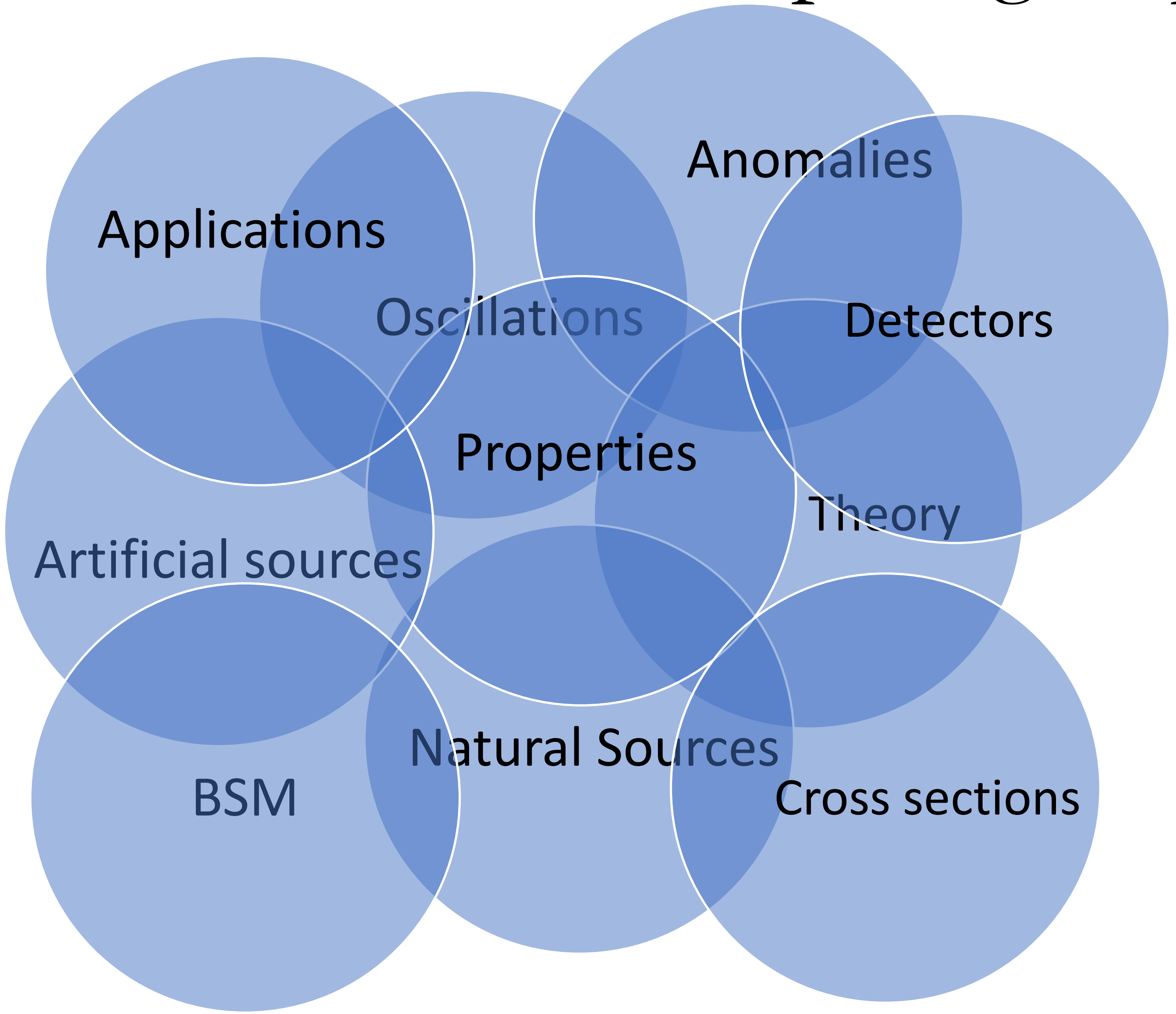
2021: Aimed for similar format to 2013. Small meetings leading up to 10 day meeting in Seattle

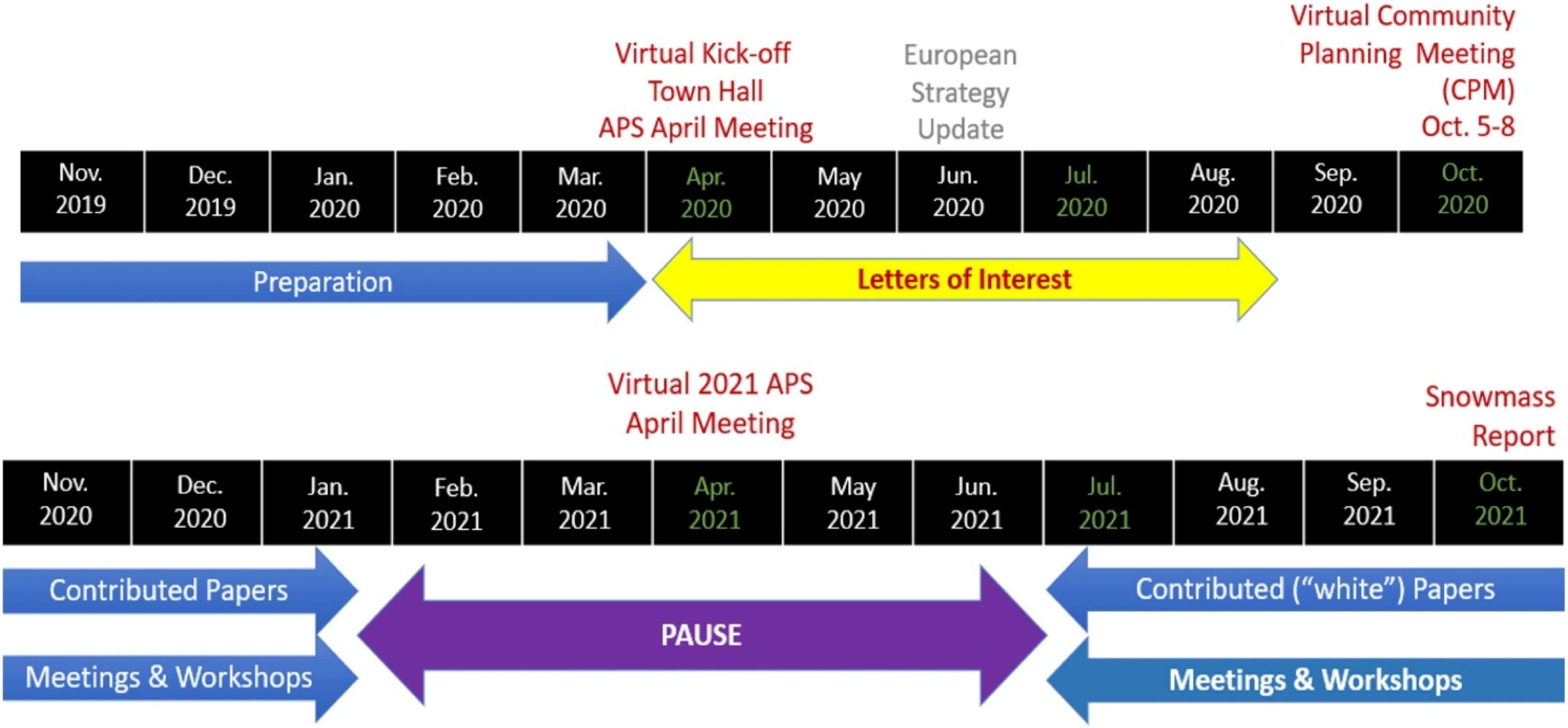
What is (modern) Snowmass:

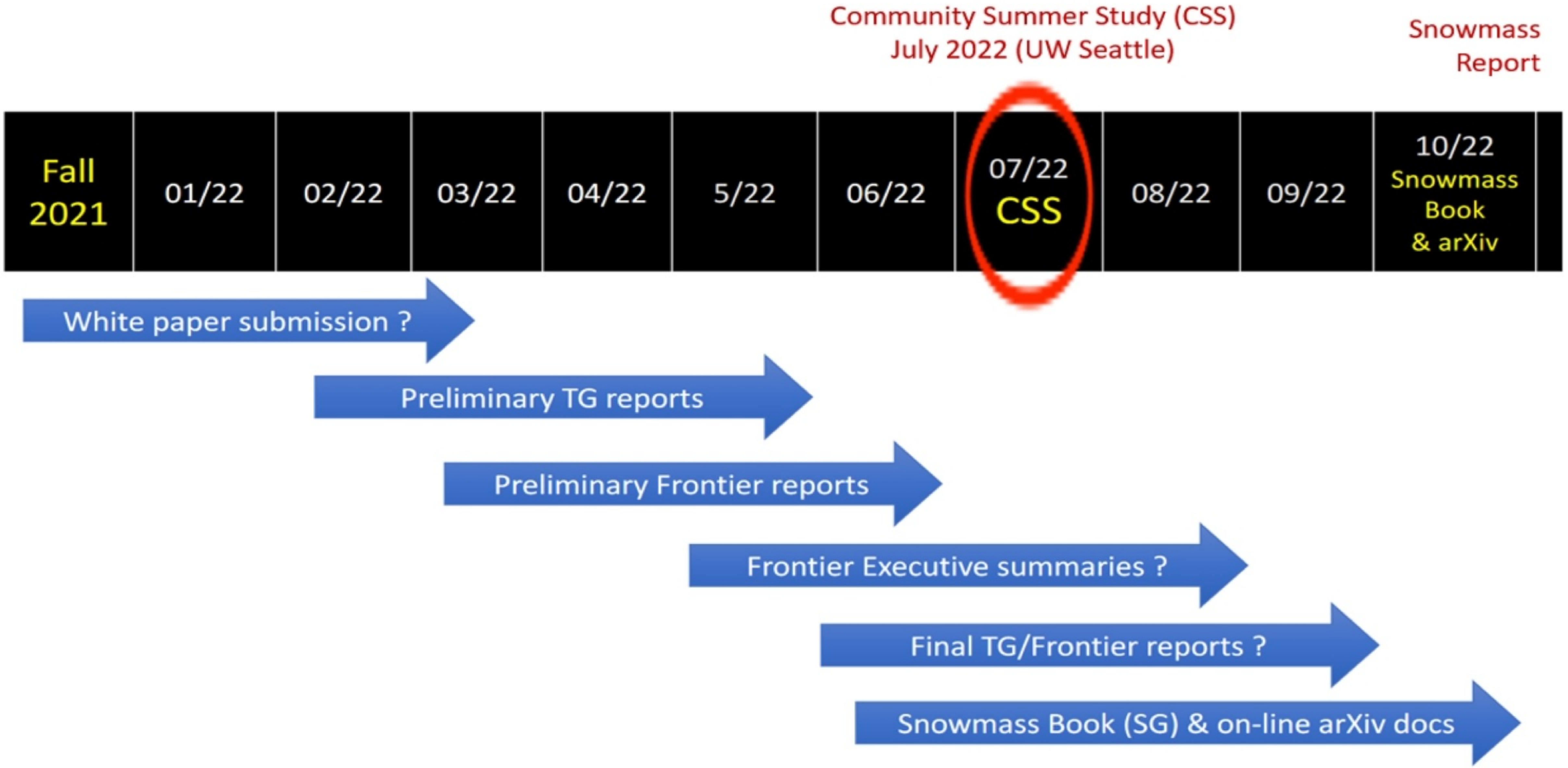
- Community-driven planning for future of particle physics
- Mainly particle physics in the US, but in a global context
- Also feeds into funding processes (P5, DOE, NSF), but is not only that


Snowmass
Frontiers
Energy
Instrumentation
Rare processes
Neutrino
Community
engagement
Cosmic
Computation
Accelerator
Theory
Underground
facilities

Neutrino Frontier Topical groups




Virtual Kick-off
Town Hall
APS April Meeting
European
Strategy
Update
Virtual Community
Planning Meeting
(CPM)
Oct. 5-8
Nov. 2019
Dec. 2019
Jan. 2020
Feb. 2020
Mar. 2020
Apr. 2020
May 2020
Jun. 2020
Jul. 2020
Aug. 2020
Sep. 2020
Oct. 2020
Preparation
Letters of Interest
Virtual 2021 APS
April Meeting
Snowmass
Report
Nov. 2020
Dec. 2020
Jan. 2021
Feb. 2021
Mar. 2021
Apr. 2021
May 2021
Jun. 2021
Jul. 2021
Aug. 2021
Sep. 2021
Oct. 2021
Contributed Papers
Meetings & Workshops
PAUSE
Contributed ("white") Papers
Meetings & Workshops


Community Summer Study (CSS)
July 2022 (UW Seattle)
Snowmass
Report
Fall
2021
01/22
02/22
03/22
04/22
5/22
06/22
07/22
CSS
08/22
09/22
10/22
Snowmass
Book
& arXiv
White paper submission ?
Preliminary TG reports
Preliminary Frontier reports
Frontier Executive summaries ?
Final TG/Frontier reports ?
Snowmass Book (SG) & on-line arXiv docs

Letters of interest

- Two pagers (+ references), describing ideas
- Total number of LoIs: > 1500
- LoIs to the neutrino frontier: 206
- LoIs that mention supernova neutrinos: 96

Snowmass 2021 Letter of Interest:

Supernova neutrinos and particle-physics opportunities

Primary topical groups:
NF08/TF11 (Theory of Neutrino Physics)
NF04 (Neutrinos From Natural Sources)

Other topical groups: TF08, TF09, CF3, CF7

Primary contact information:
Lucas Johns (University of California, Berkeley) [ljohns370@gmail.com]

Secondary contact information:
A. Baha Balantekin (University of Wisconsin, Madison) [baha@physics.wisc.edu]
George M. Fuller (University of California, San Diego) [gfuller@ucsd.edu]
O. E. Bronson Messer (Oak Ridge National Laboratory; University of Tennessee) [bronson@ornl.gov]
Amol V. Patwardhan (University of California, Berkeley) [apatwardhan2@berkeley.edu]
Manibrata Sen (University of California, Berkeley; Northwestern University) [manibrata@berkeley.edu]

Endorsers: Kevork N. Abazajian (University of California, Irvine), Carlos A. Argüelles (Harvard University), Eve Armstrong (New York Institute of Technology; American Museum of Natural History), John F. Beacom (Ohio State University), Nicole F. Bell (The University of Melbourne), Adam Burrows (Princeton University), Mauricio Bustamante (Niels Bohr Institute, University of Copenhagen), Sovan Chakraborty (Indian Institute of Technology, Guwahati), Vincenzo Cirigliano (Los Alamos National Laboratory), Sean M. Couch (Michigan State University), Basudeb Dasgupta (Tata Institute of Fundamental Research), Claire

Snowmass2021 - Letter of Interest
Q-Pix: Kiloton-scale pixelated liquid noble TPCs

Physics Opportunities in ANNIE

Multi-ton scale bubble chambers

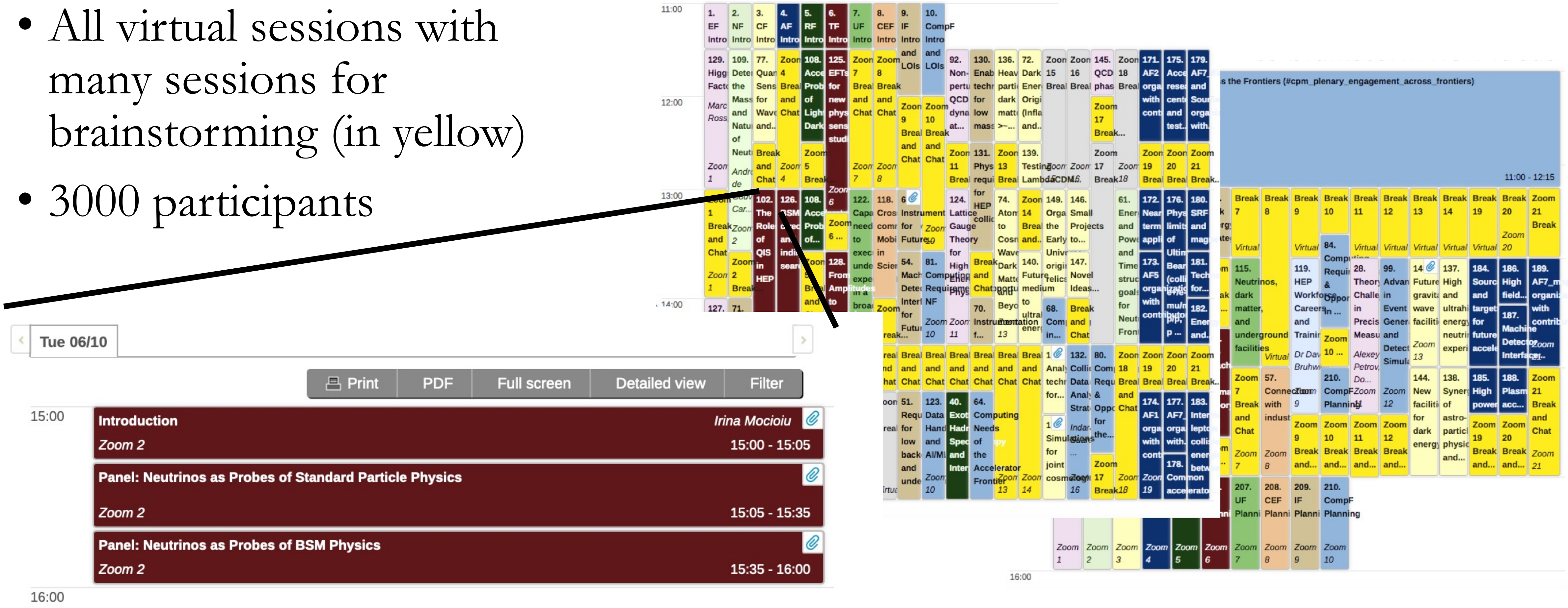
Wavelength-shifting Reflector Foils in Liquid Argon
Neutrino Detectors

*[Supernova Burst and Other Low-Energy
Neutrino Physics in DUNE]*

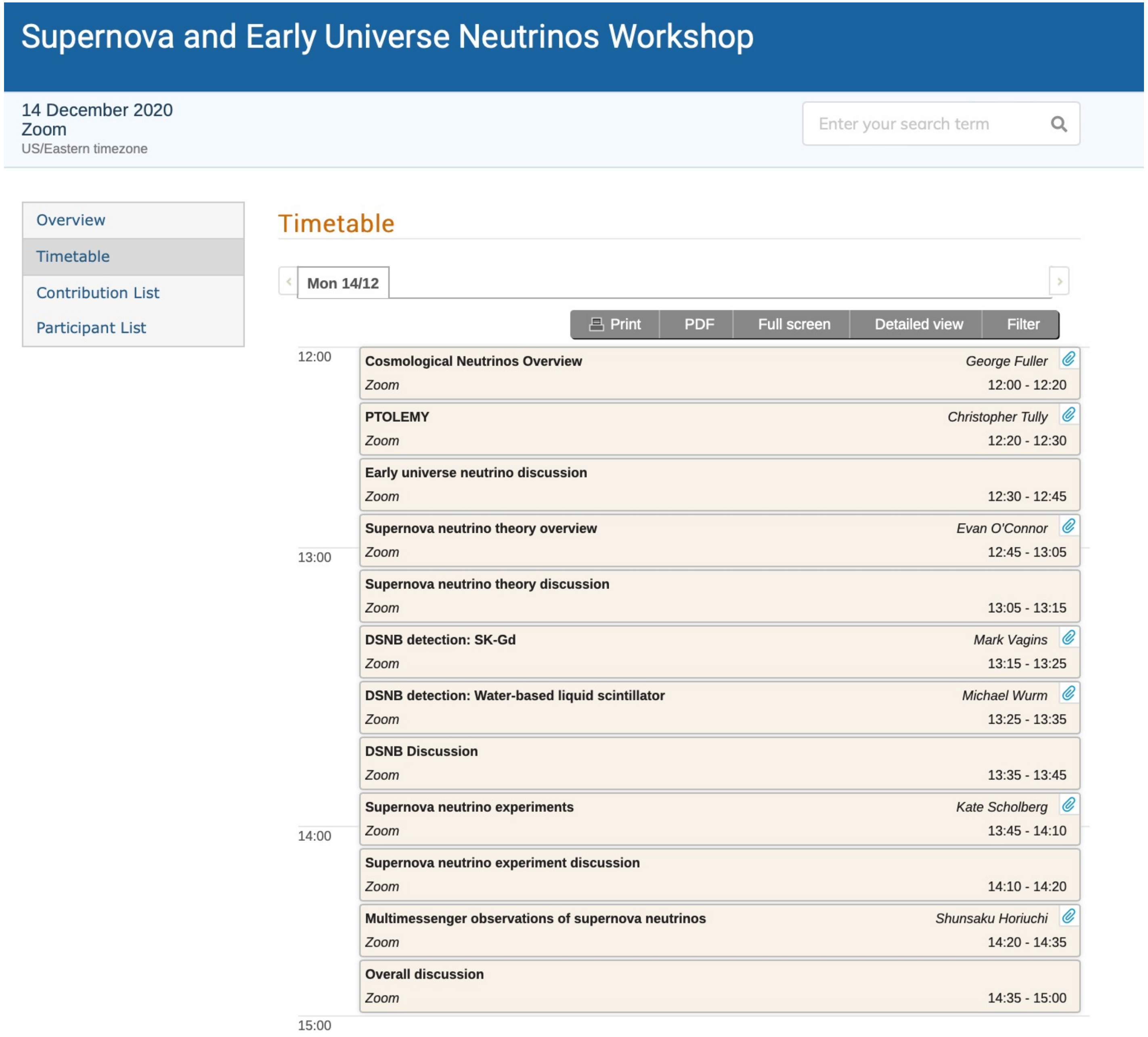
Snowmass2021 — Letter of Interest: a kiloton-scale gadolinium-doped water detection concept for Neutrino Experiment One at the Advanced Instrumentation Testbed in Northern England

Community planning exercise: Oct 5-8, 2020

- All virtual sessions with many sessions for brainstorming (in yellow)
- 3000 participants



- Late 2020-early 2021: small (virtual) workshops
- Start to focus on main topics of the community study



The neutrino frontier whitepapers (87 papers each roughly 20 pages long)

arXiv:2203.05525

Passive low energy nuclear recoil detection with color centers – PALEOCCENE

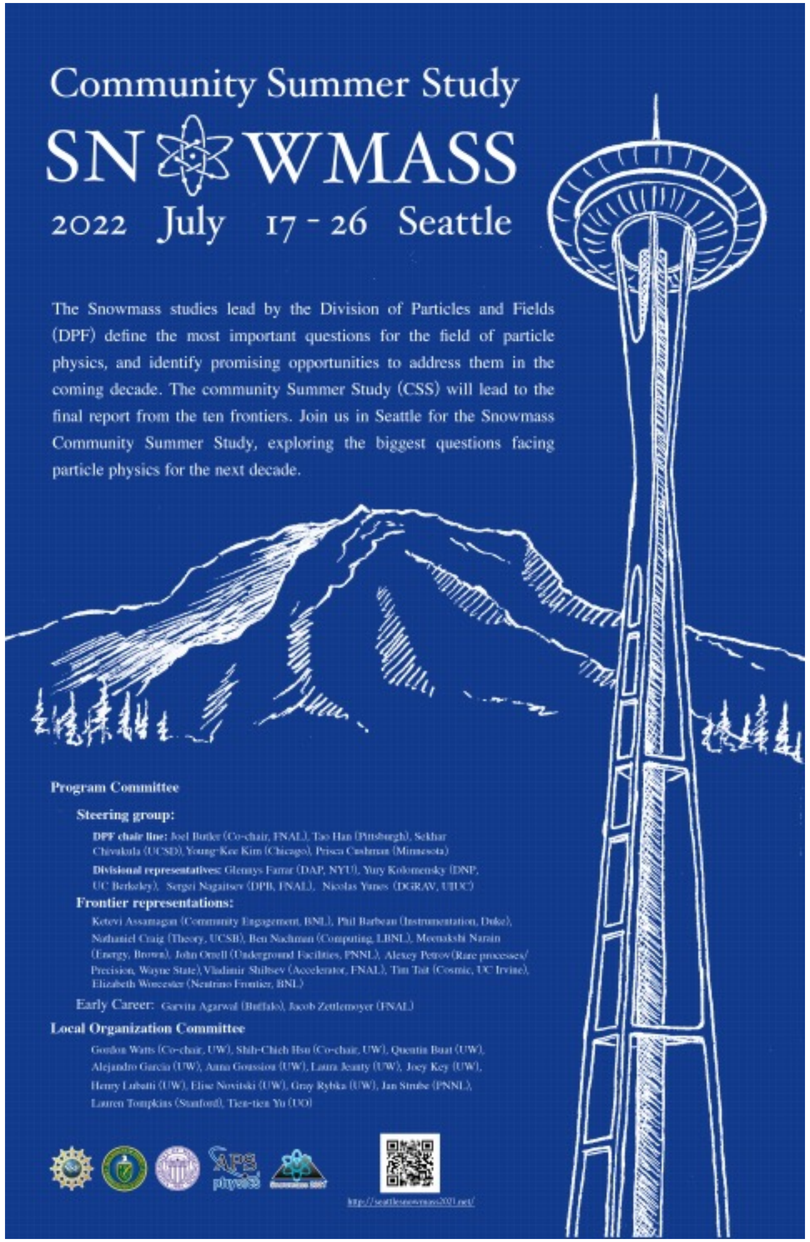
aXiv:2202.12839

THEIA: Summary of physics program

Snowmass White Paper Submission

arXiv:2203.07377

Synergy between cosmological and laboratory searches in neutrino physics



1400 participants (750 in person)

10 days of intense discussion sessions

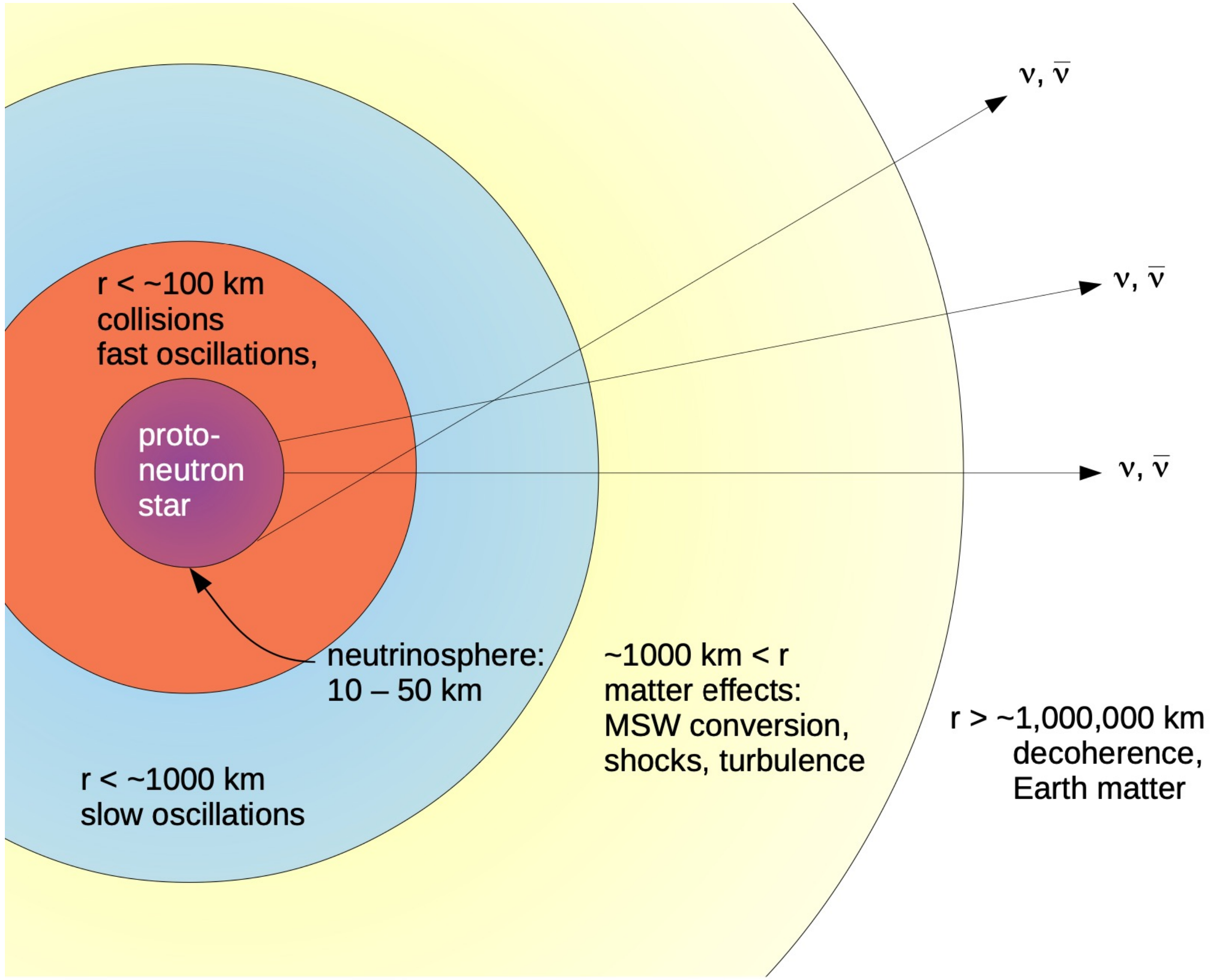
Snowmass Neutrino Frontier: NF04 Topical Group Report

Neutrinos from natural sources

Submitted to the Proceedings of the US Community Study on the Future of Particle Physics (Snowmass 2021)

Y. Koshio[1], G.D. Orebi Gann[2], E. O'Sullivan[3], and I. Tamborra[4]

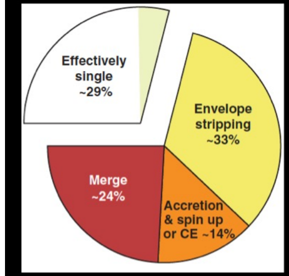
Theoretical developments for the next decade: flavour conversions and improved landscape of long-time models



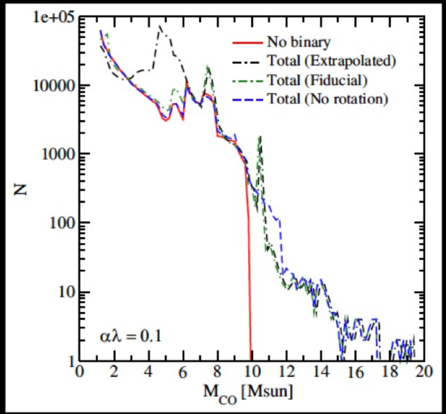
Theoretical developments for the next decade: improved DSNB models

Select other effects

Binaries: are common and can enhance progenitor numbers

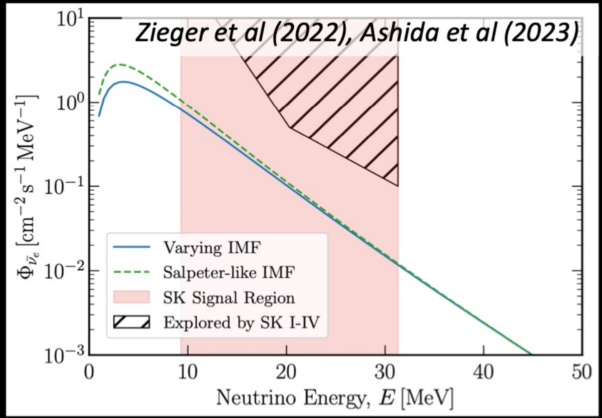


Sana et al (2012)



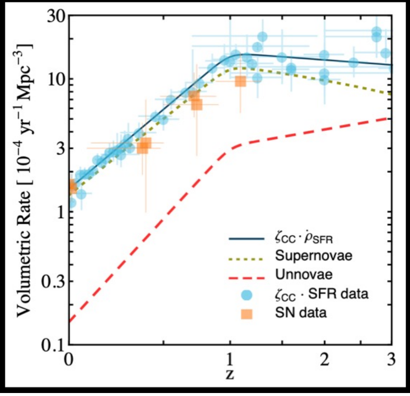
Horiuchi et al (2021)

Non-Universal IMF: may be environmentally dependent



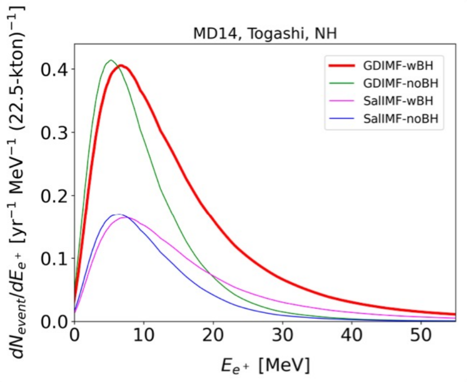
Variable BH fraction: may be more common at high redshifts

Eg Yuksel & Kistler (2014)



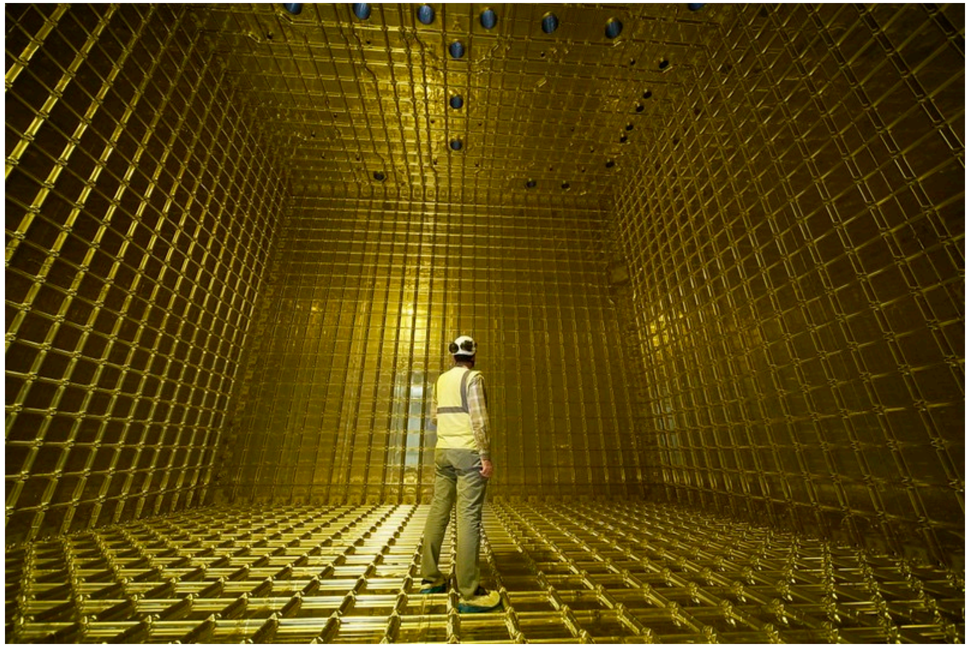
Various BSM physics

Eg de Gouvea et al (2019)



Experimental developments for the next decade: moving beyond electron anti-neutrinos

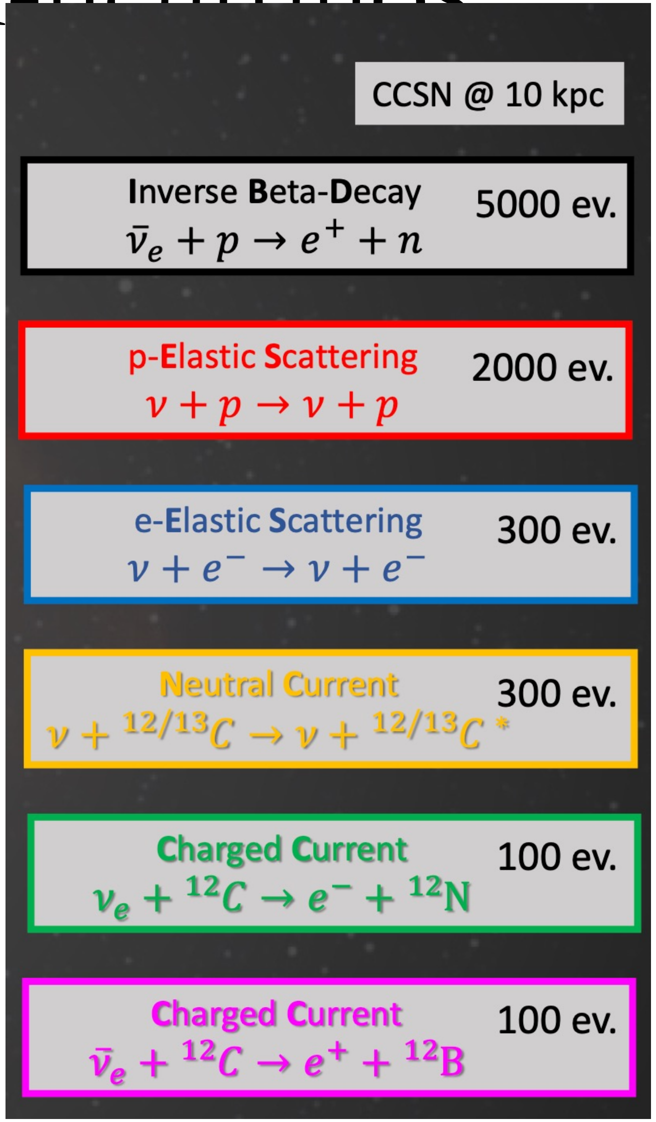
Juno, Achim Stal



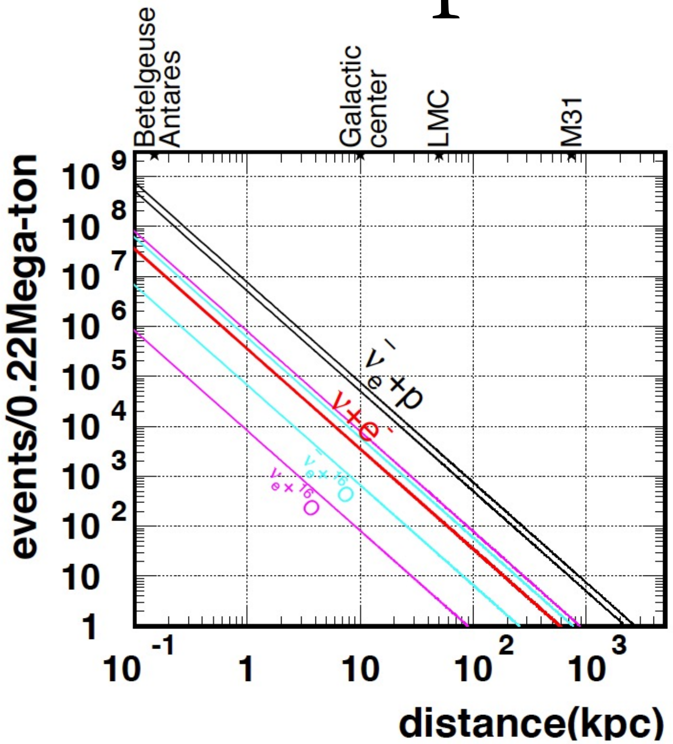
Dune: electron neutrino measurement

$$\nu_e + {}^{40}Ar \rightarrow e^- + {}^{40}K^*$$

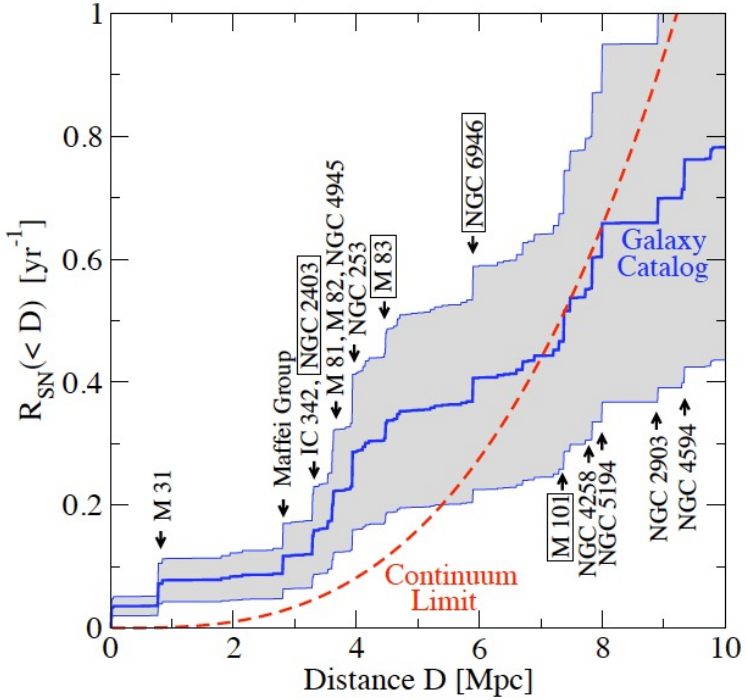
Coherent scattering: RESNOvA, dark matter detectors, scintillator



Experimental developments for the next decade: expanding the detection horizon



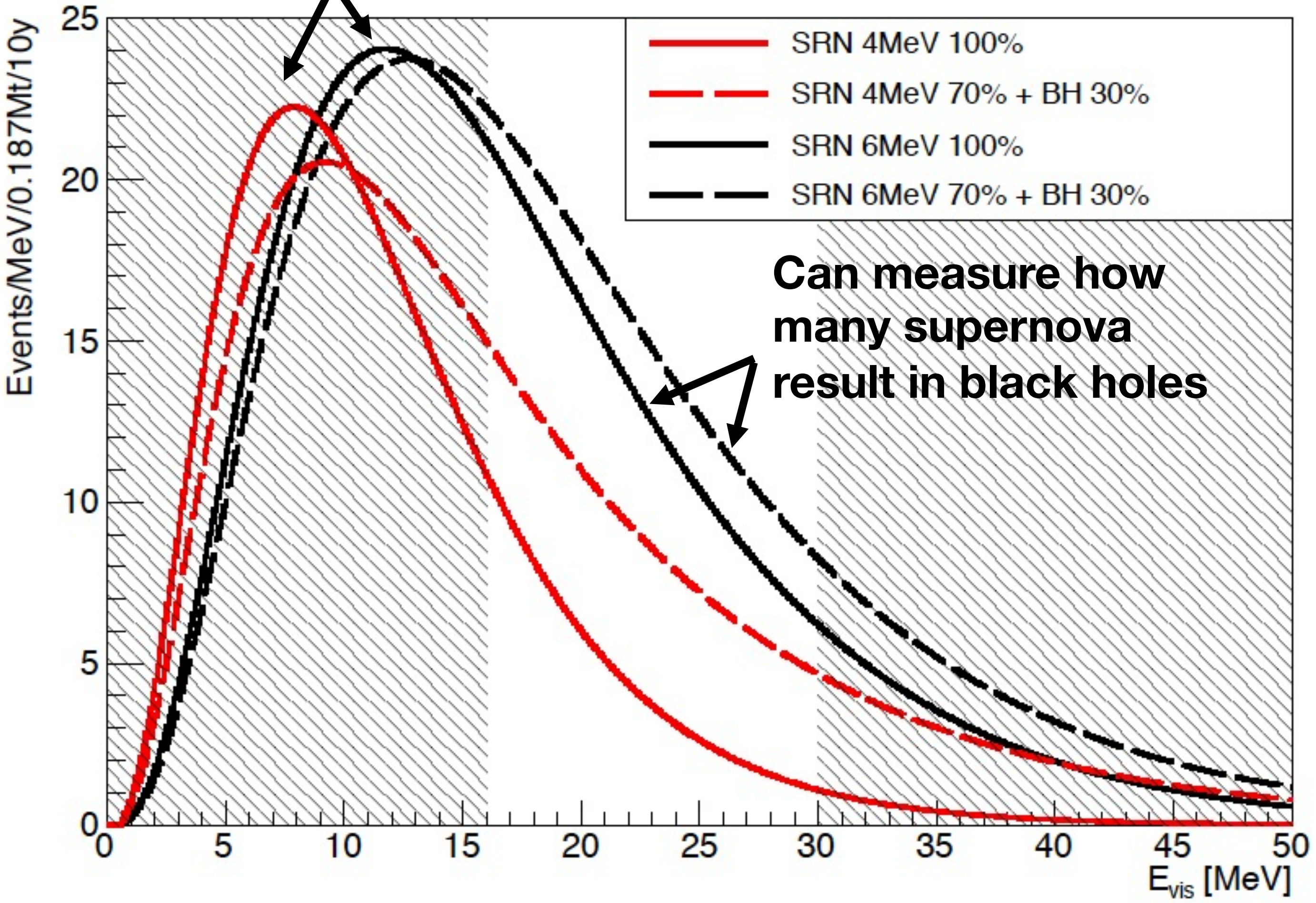
Ando, Beacom, Yüksel 05



Hyper-K will probe to greater distances,
where the SN rate is ~ 1/decade instead of ~2-3/century

Experimental developments for the next decade: DSNB

Can measure average temperature of the supernova



Can measure how many supernova result in black holes

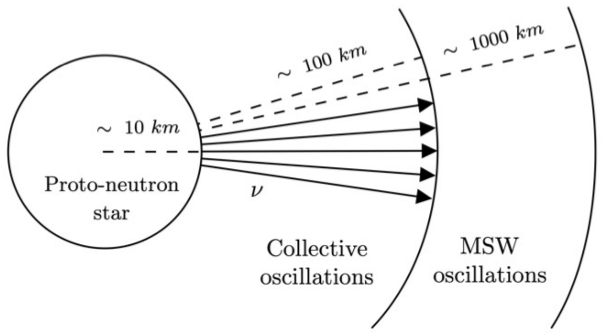
Quantum Computing simulation for Collective Neutrino Oscillations [1]

Valentina Amitrano, Alessandro Roggero, Francesco Turro, Piero Luchi and Francesco Pederiva

Physics department University of Trento, INFN-TIFPA Trento Institute of Fundamental Physics and Applications

Motivations

- **Core-collapse supernovae** of massive stars $M \gtrsim 8M_\odot$ emit a huge number of neutrinos ($\sim 10^{58}$).
- The physics of matter under extreme conditions is strongly **flavor-dependent** (nucleosynthesis, neutron-proton ratio, spectrum splits...).
- Interesting quantum many-body problem governed by the weak interaction.
- Describing the full dynamic is very complicated due to the **collective neutrino oscillations** that make the equation non linear.



- We want to simulate the real time evolution:

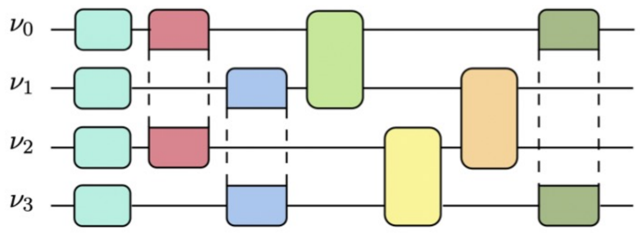
$$|\Psi(t)\rangle = U(t)\,|\Psi_0\rangle \ , \quad U(t) = e^{-iHt} \, . \qquad (1)$$

Unitary implementation

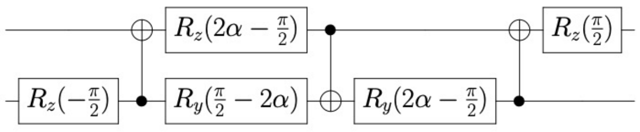
- To perform the quantum simulation we need a **quantum gate decomposition** of the $U(t)$ operator ($2^N \times 2^N$ unitary matrix on the flavor basis):
- Divide 1-body and 2-body parts that commute:

$$U(t) = U_2(t)U_1(t) \, . \qquad (5)$$

- Approximate the 2-body part as a product of pair interactions.



- Each 2-qubit gate $u_{ij} = e^{i\alpha(X\otimes X + Y\otimes Y + Z\otimes Z)}$ can be implemented as [3]:



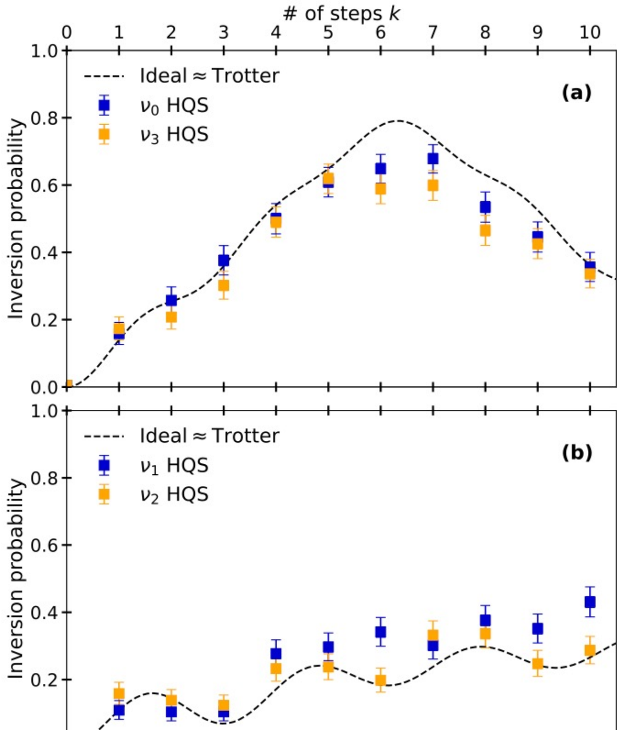
- The order in which the pairs interact changes the error due to the commutators.

Multiple steps evolution

- Evolve the system until T applying $k = T/dt$ Trotter steps:

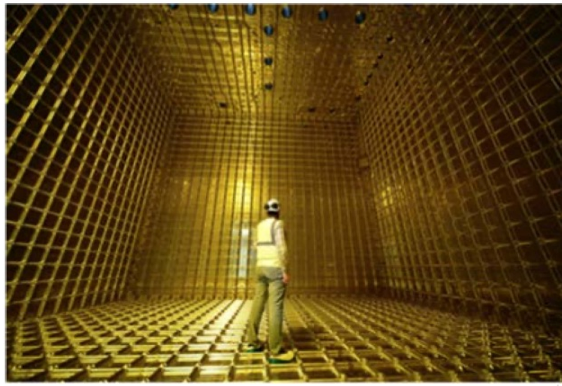
$$|\Psi(T)\rangle = U_2(dt)^k U_1(dt)^k\,|\Psi_0\rangle \, . \qquad (6)$$

- Real quantum machine results:



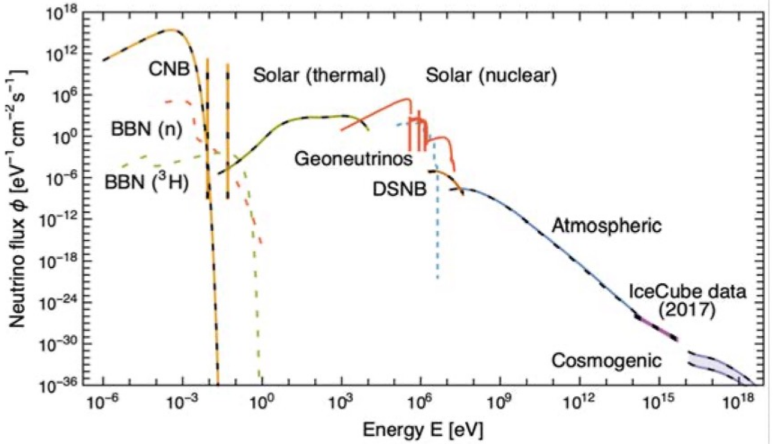
Other themes from the meeting

Neutrino Frontier



* We need to **finish DUNE**, and its broad physics program.
  Both Phase I and Phase II are required to complete the original DUNE design.
* We are excited about long-term, broader possibilities that make use of our investment in the facility and could expand the DUNE scope beyond that originally envisioned.
* A healthy program of projects of different sizes and time scales, with wide-ranging connections is highly desired and very much needed.

Impacts everywhere! But if we have to choose it's the Cosmic Frontier, due to deep connections and intertwined BSM searches in multiple areas.



Neutrinos are tools for astrophysics and cosmology. Astrophysics and cosmology provide insight into NF physics.

U.S. Particle Physics

Ongoing

About Particle Physics | Resources for Physicists | Particle Physics in the United States | 2023 P5

2023 P5

P5 (Particle Physics Projects Prioritization Panel) reports to HEPAP (High-Energy Physics Advisory Panel) that advises High-Energy Physics of DOE Office of Science and Division of Physics of NSF. We will build on the "Snowmass" community study to hash out priorities for the next 10 years within 20-year context.

Charge

The charge to P5 was issued by Dr. Asmeret Asefaw Berhe, Director of Office of Science, Department of Energy, and Dr. Sean L. Jones, Assistant Director, Directorate for Mathematical and Physical Sciences, National Science Foundation, to the HEPAP chair JoAnne Hewett on November 2, 2022. The P5 report is expected to be released in October 2023.

Prospects for Snowmass 2030?
Not too early to start thinking of this

- Where will we be going as a community?
- New experimental techniques on the horizon?
- Better integration with other communities (computing, astro)?

P5 Preliminary timeline

- Form panel by early Fall
  - Call for nominations for P5 members in early Aug 2022
  - Panel members wear a community hat
- Hold hybrid in-person/virtual townhalls in Fall 2022
  - Aim for further community input and further information on potential future projects
  - Opportunity for each panel member to start with equal footing covering all frontiers
- Deliberations Winter/Spring 2023
  - Will provide ample opportunity for further community input
- Aim for report late Spring/Early Summer 2023 for HEPAP to approve and submit to DOE/NSF