NF05: Neutrino Properties

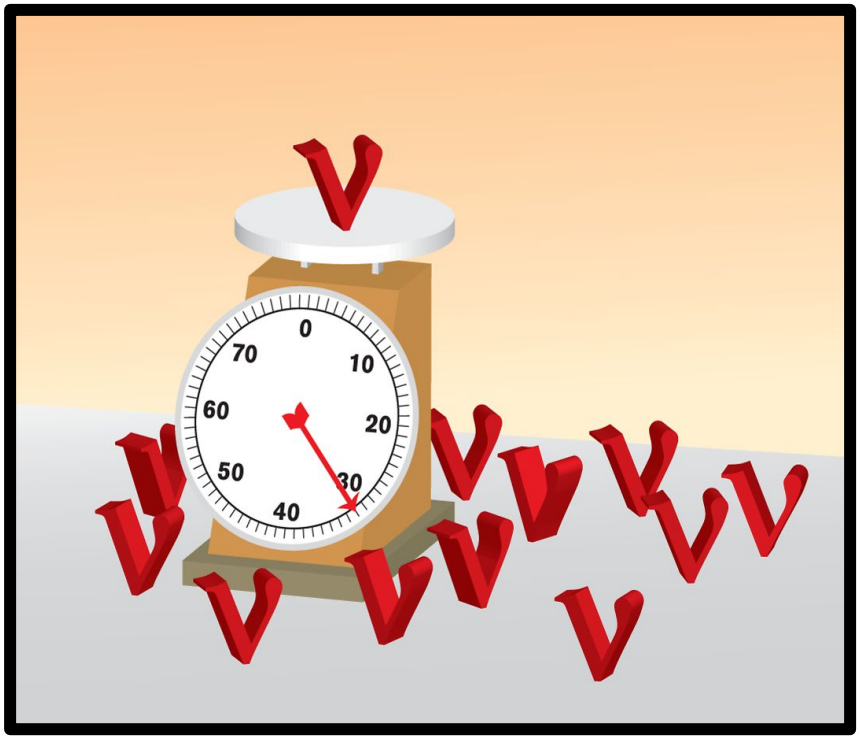
NF05 Conveners: Ben Jones, Lisa Kaufman, Carlo Giunti, Diana Parno

NF05 honorary co-conveners: Andrea Pocar (RF04), Julieta Gruszko

Group Scope

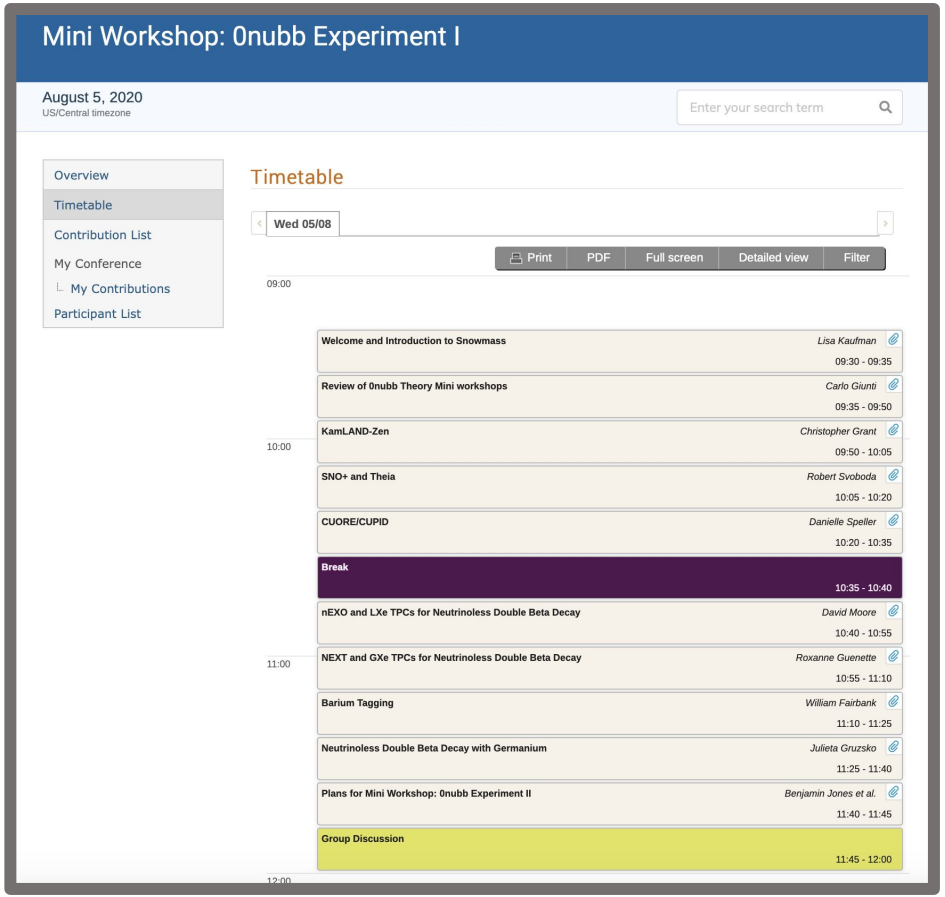
- **Neutrino Properties is a very broad term!**

- Early in Snowmass we defined our groups scope as the following topics not covered elsewhere:
  - **Direct neutrino mass measurements**
  - **Dirac vs Majorana nature**
  - **Electromagnetic properties**



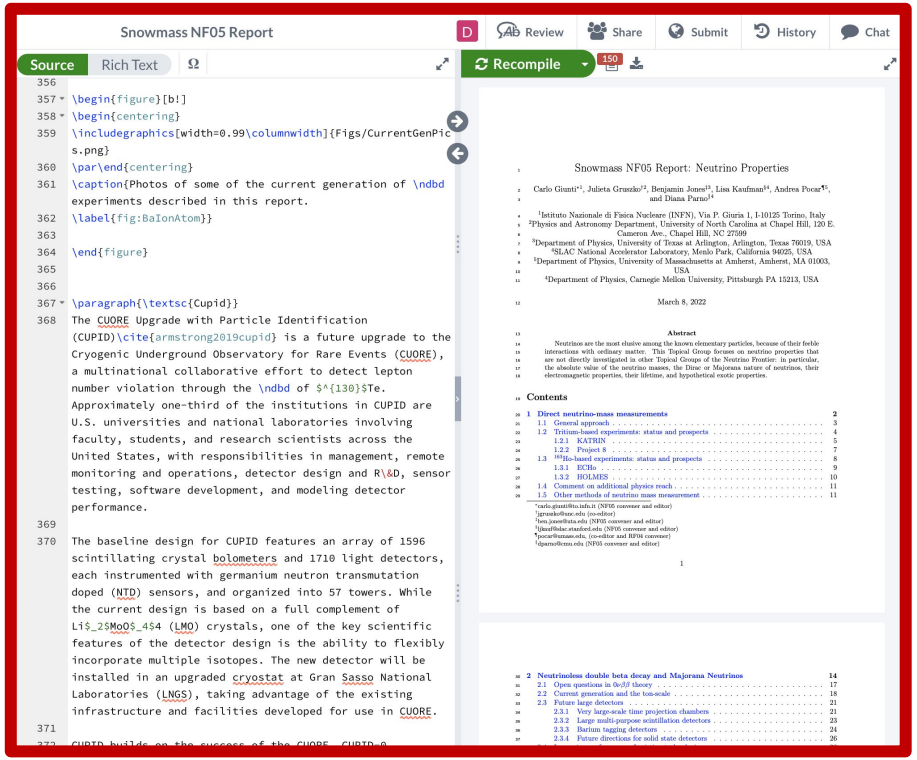
- **Input for the NF05 report was sought via:**
  - 6 summer half-day workshops in Summer 2020
  - A workshop on the ton-scale future of 0nubb in Dec 2020
  - Snowmass LOIs
  - A fairly small number of whitepapers (not all of them yet in our hands)

- Everything presented in one of these formats **that we have received** is covered in our report draft.



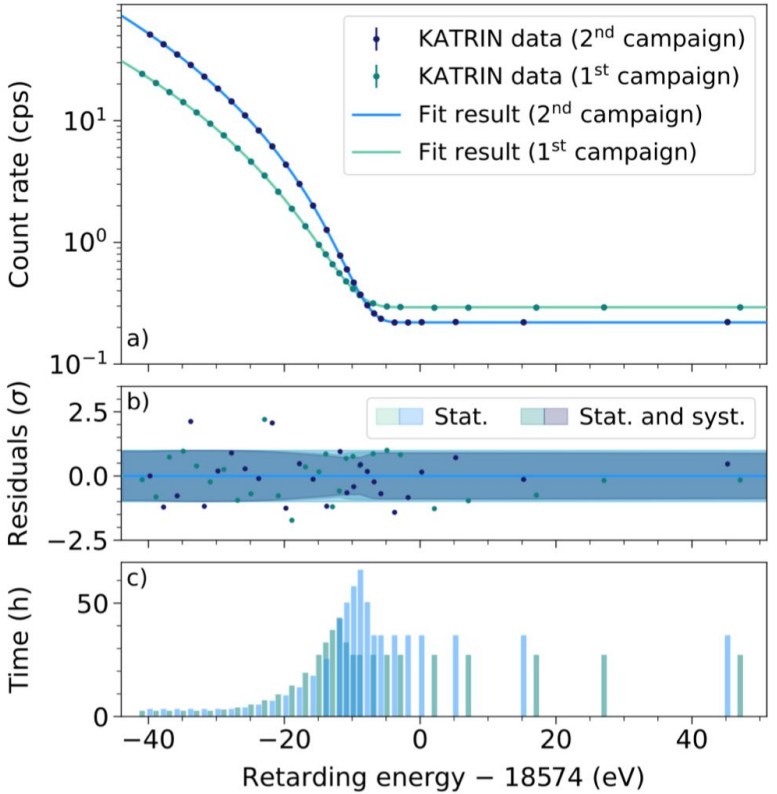
Report status

- Advanced draft in overleaf: 43 pages of text + 248 references.
- We have a few sections still to complete, expect it to top out around 46pages + 18pg of refs
- We have generally tried to be brief and where other white papers exist, or topic area is covered by another group, refer rather than rewrite.
- This means **topics that have white papers take less space in our report than ones without white papers.**
- We encourage readers not to equate length of text with importance of topic; instead consider it correlated to well-documented-elsewhere-ness.



Motivating considerations: Direct Neutrino Mass

- Community is fairly unified in its vision for direct neutrino mass.
- Two main experiments in tritium:
  - KATRIN (present gen)
  - Project8 (next gen)
- Two main experiments in Holmium:
  - ECHo
  - HOLMES
- Plus connections to other BSM physics searches
- And brief mention of other approaches to this question (cosmology, etc)

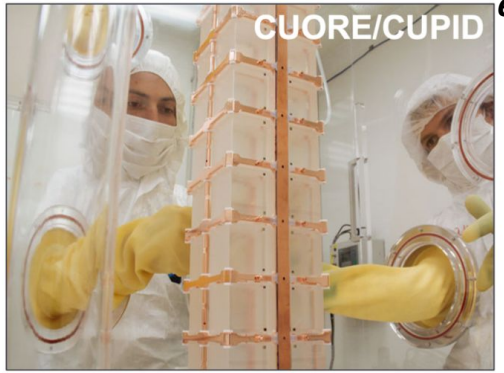


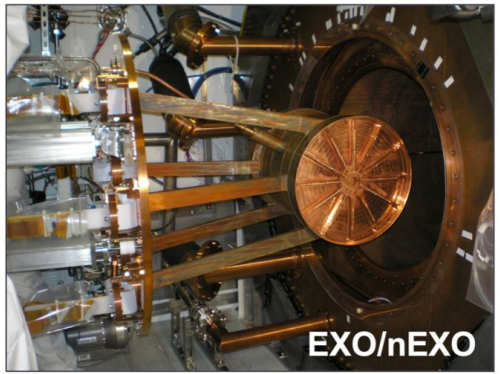
Motivating considerations: 0nubb

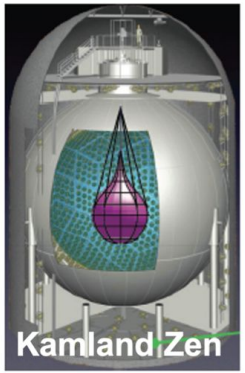
- On the contrary, a rather wider array of perspectives exists in 0nubb.

- We have tried to ensure they are all represented
  - *Or at least, all the ones with US involvement!*

Current gen experiments:

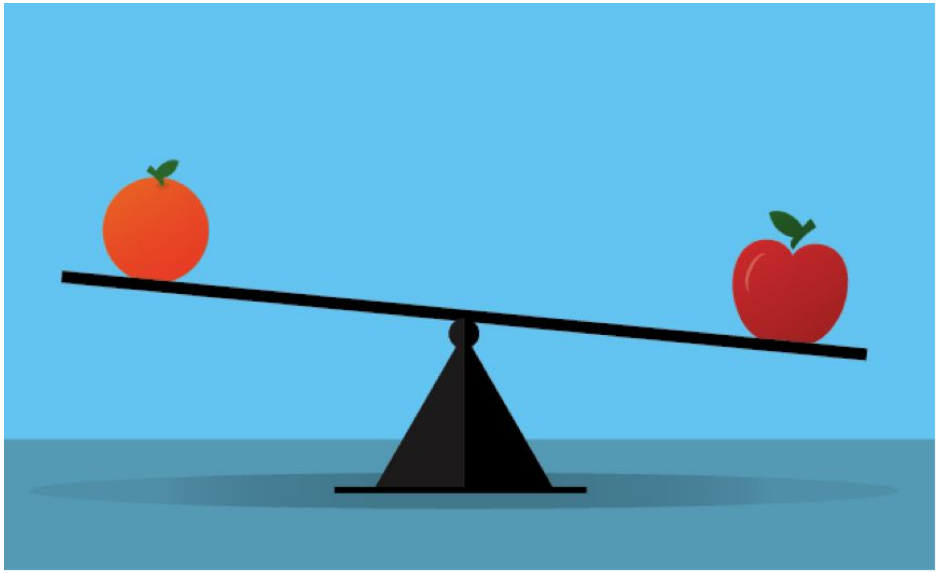




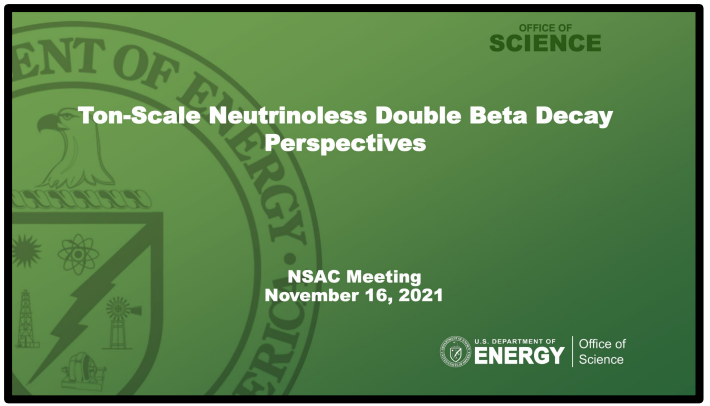


Motivating considerations: 0nubb

- We have opted **not** to attempt to quantitatively compare different detectors yet to be built.
- While we can easily ask collaborations for the vital statistics of their future detector, we cannot correct for varying robustness of those projections.
- There seemed to us little value in an exercise comparing different levels of optimism in backgrounds of unbuilt detectors.

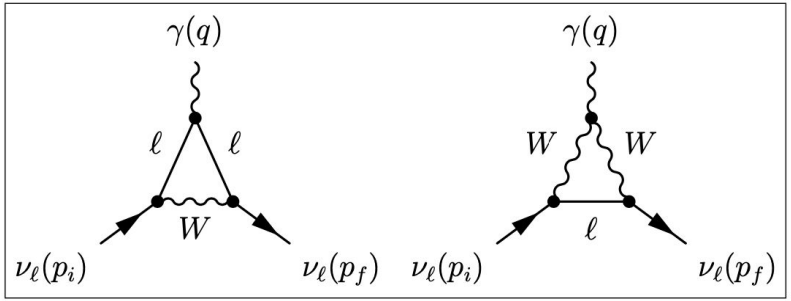


- There is an ongoing process within DOE NP concerning realization of at least one ton-scale 0nubb experiment, and ideally more than one, within the next decade.
- This process has been proceeding with potentially quite consequential steps during this Snowmass process.
- **We have endeavored not to interfere.**
- We briefly review current-gen and ton-scale in our report, but primarily focus on the possible beyond-ton-scale future.
- The main message to convey is that:
- **Searches for 0nubb are a critical pillar of the world neutrino physics program; continued investment is needed to realize both this generation and the next generation of experiments.**



Motivating considerations: Electromagnetic Properties

- No major experiment in the US pursues electromagnetic properties as its primary goal.
- Nevertheless, they are important fundamental properties of neutrinos, accessible mainly through low energy neutrino scattering.
- A brief review of theoretical and experimental status is given.
- The most programmatically relevant aspect is probably connections to CEvNS, which is covered here in brief.



Method	Experiment	Limit [e]	CL	Year	Ref.
Neutrality of matter	Bressi et al. [220]	$Q_{\nu_e} \in (-3.8, 2.6) \times 10^{-21}$	68%	2014	[177]
Reactor $\bar{\nu}_e\, e^-$	TEXONO [221]	$\lvert Q_{\nu_e}\rvert < 3.7 \times 10^{-12}$	90%	2006	[222]
	GEMMA [195]	$\lvert Q_{\nu_e}\rvert < 1.5 \times 10^{-12}$	90%	2013	[223]
	TEXONO	$\lvert Q_{\nu_e}\rvert < 1.0 \times 10^{-12}$	90%	2014	[224]
Accelerator $(\nu_\mu, \bar{\nu}_\mu)\, e^-$	LSND [181]	$\lvert Q_{\nu_\mu}\rvert < 3 \times 10^{-9}$	90%	2020	[225]
Beam Dump	BEBC [196]	$\lvert Q_{\nu_\tau}\rvert < 4 \times 10^{-4}$	90%	1993	[226]
Accelerator $(\nu_\tau, \bar{\nu}_\tau)\, e^-$	DONUT [198]	$\lvert Q_{\nu_\mu}\rvert < 4 \times 10^{-6}$	90%	2020	[225]
CEvNS	COHERENT [185, 186]	$Q_{\nu_e} \in (-14, 34) \times 10^{-8}$ $Q_{\nu_e} \in (-10, 12) \times 10^{-8}$ $\lvert Q_{\nu_{e\mu}}\rvert < 17 \times 10^{-8}$ $\lvert Q_{\nu_{e\tau}}\rvert < 27 \times 10^{-8}$ $\lvert Q_{\nu_{\mu\tau}}\rvert < 20 \times 10^{-8}$	95%	2020	[187]
	CONUS	$\lvert Q_{\nu_e}\rvert < 3.3 \times 10^{-12}$	90%	2022	[199]
Solar $\nu_e\, e^-$	XMASS-I	$\lvert Q_{\nu_e}\rvert < 7.3 \times 10^{-12}$ $\lvert Q_{\nu_\mu}\rvert, \lvert Q_{\nu_\tau}\rvert < 1.1 \times 10^{-11}$	90%	2020	[204]

Table 5: Experimental limits for the neutrino electric charges.

Other.

- Finally we make a very brief, passing reference to these two topics, though expect they mostly reside within the NF03 group purview.

What did we miss?

- We will circulate report draft soon. If we missed something tell us!
- If you don’t like the text about your experiment, reach out with a replacement!
- Our main goal was inclusivity and to ensure nothing that was contributed to Snowmass was omitted, while presenting an organized view of a busy and active area.
- Your feedback welcome!