European Neutrino "Town" Meeting - panel 2

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Panel 2 – Report

Majorana/Dirac mass term, Heavy Neutral lepton searches from meV to ZeV, NSI, etc...

Possible questions for us to address:

- Which extensions of the SM can we probe (Majorana masses, light and heavy sterile neutrinos, neutrinos as dark matter)
- What are the relevant experiments ($0\nu2\beta$, SBL oscillations, SHiP and other fixed-target experiments, LHC and future colliders)
- What is needed from the theory community?
- What risks are involved (technological and physics-related)? How do you see this field develop?

Intro

- Neutrino oscillation program is going to complete the standard three neutrino picture.
- The origin of neutrino masses is still unknown. It can be probed through different and complementary searches.
- Several experimental anomalies should be addressed at the experimental level.

Synergies with Dark Matter experiments

- Liquid Noble gas direct dark matter searches have considerable overlap with neutrino experiments: similar technology, backgrounds, and same range of energy for events that are similarly very rare.
- There is potential for a large liquid Noble gas experiment.
- In the next ten years dark matter detectors will have to contend with background induced by neutrinos through coherent scattering.

Q1 What is needed for a next generation multi-purpose detector for DM & $0\nu2\beta$ ... ?

Q2 The neutrino platform has been successful with protoDUNE. Would this framework be suitable for synergies with dark matter detectors ?

Neutrinoless double beta decay

- Lepton number violation is well motivated by theory (neutrino mass, matter anti-matter asymmetry, ...). $0\nu2\beta$ probes large mass scale (meV to TeV) and well motivated models.
- Complementarity: direct searches, cosmology, and oscillation.
- Europe has a strong $0\nu2\beta$ community with world leading experiments focused on Ge-76, Se-82, Mo-100/Te-130, Xe-136
- Multiple isotopes needed to link $0\nu2\beta$ life-times to Majorana mass ($m_{\beta\beta}$).
- Next-gen experiments under preparation: LEGEND, CUPID, NEXT and possibly Super-NEMO based on previous successful experiments/prototypes.
- APPEC has setup a $0\nu2\beta$ committee (in contact with US NSAC) to evaluate potential reach and their risks

Q Is the physics reach of the next generation sufficient if the normal hierarchy is established ?

Short baseline experiments

- Very active field for both, accelerators and reactors. Precision experiments online and near future program.
- Combination of all oscillations channels with disappearance and appearance results in strong tension (even among experiments).
- Clarification possible in next few years when reactor experiments / SBNP will reach maximum sensitivity.

Q1 Under which circumstances should we consider the next generation precision experiments ?

Q2 Is the neutral current channel necessary ?

Q3 Is a combined analysis at the experiment level desirable to improve global fits ?

Beam dump experiments

- NA62 searches for HNL have reached interesting sensitivity.
- Future experiment SHiP could significantly improve NA62 sensitivity and can probe a slightly larger masses.
- Well motivated: a combination of SHiP, oscillation, and $0\nu2\beta$ decay experiments can test lowscale leptogenesis.
- Other future detectors for long-lived particle searches are MATHUSLA, CODEX-b, FASER, AL3X or milliQan.

Q1 Is the search for GeV scale HNL participating in Baryon asymmetry generation a strong enough motivation?

Q2 What about the 3.5 keV line ?

Q3 Are near detectors of future LBL experiments competitive ?

Neutrinos at colliders

LHC searches for HNL:

- LNV, exptl. effective, but theoretically unmotivated.
- All-leptonic final states comparable to LEP for $M_N < m_W$
- Displaced vertex searches emerging $\Rightarrow$ LHC LLP
- Large amounts of possible signal is lost in the backgrounds

FCC prospects for HNL searches:

ee Displaced vertex searches for long-lived HNL at the Z-pole

ee Electroweak precision measurements as tests of leptonic non-unitarity.

hh $\sim$same as LHC (even more data lost in backgrounds).

hh $\oplus$ MATHUSLA promising for long lived searches

eh Direct searches complement precision searches at ee

all Complementarity

Colliders, questions

Q1 What is so special about the energy range testable by colliders, compared to all the other experiments?

Q2 How can we prove that observed phenomena at high and low energies are connected?

Q3 Can we design suitable triggers for the LHC experiments?

Q4 Is the cost of collider projects justified compared to its usefulness?

KATRIN

- State-of-the-art tritium decay spectrometer; first data.
- Sensitivity to the absolute mass scale is 0.3 eV.
- With the TRISTAN upgrade sterile neutrinos with masses on the keV scale and $U^2 \sim 10^{-6}$ testable.

Q1 What would be the consequence on cosmology if KATRIN/TRISTAN detect a keV signal ?

Q2 How can we push down the limit of 0.3 eV ?
$\Rightarrow$ Panel 3

Coherent scattering

- First observation by COHERENT at the SNS neutron source last year, 40 years after being proposed.
- Exciting time ahead, many other experiments in preparation.
- Flavour-blind measurement complementary to neutrino oscillation measurements.

Q Is this opening a new direction in building neutrino detectors / low recoil detection ?

Concluding remarks

- BSM neutrino physics can be probed via multiple observational avenues.
- Strong complementarity among different experimental searches.
- Several anomalies or challenging astroparticle physics observations: eg. sterile neutrinos, 3.5 keV line, high-energy emergent events, ...
- ... we should keep an open mind with respect to exploratory proposals. History tells that new physics is likely to show up in unexpected places.

List of questions

Q1 What is needed for a next generation multi-purpose detector for DM&0$\nu 2\beta$ ... ?

Q2 The neutrino platform has been successful with protoDUNE.
Would this framework be suitable for synergies with dark matter detectors ?

Q3 Is the reach of the next generation $0\nu 2\beta$ experiments sufficient if the normal hierarchy is established ?

Q4 Under which circumstances should we consider the next generation precision SBL experiments ?

Q5 Is the neutral current channel necessary for the SBL ?

Q6 Is a combined analysis of SBL data at the experiment level desirable to improve global fits ?

Q7 Are GeV scale HNL that participate in Baryon asymmetry generation a strong e motivation for SHiP?

Q8 What about the DM interpretation of 3.5 keV line ?

Q9 Are near detectors of future LBL experiments competitive with beam dump experiments ?

Q10 What is so special about the energy range testable by colliders, compared to all the other experiments?

Q11 How can we prove that observed phenomena at high and low energies are connected?

Q12 Can we design suitable triggers for the LHC experiments?

Q13 Is the cost of collider projects justified compared to its usefulness?

Q14 What would be the consequence for cosmology if KATRIN were to detect a keV sterile neutrino signal ?

Q15 How can we push down the limit of KATRIN ? $\Rightarrow$ Panel 3

Q16 Does coherent scattering open a new direction in building neutrino detectors / low recoil detection ?

feedback welcome anytime!

Colliders, appedix