HNLs, ALPs, and other DM searches
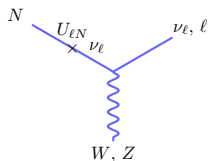
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Heavy Neutral Leptons

- A heavy 4th (Dirac or Majorana) neutrino

  'Heavy': Heavy enough not to naively disrupt BBN or unstable on cosmological timescales. Typically $m_N \gtrsim$ MeV (cf. sterile ν)

- Essentially couples to EW currents via mixing (matrix element $U_{\ell N}$)

- There is clear theoretical and experimental interest in HNLs

 | Past/Current expts | Future/proposed expts |
  | --- | --- |
  | DELPHI | DUNE |
  | CHARM, PS191, NuTeV ... | FASER |
  | NA62 | SHiP |
  | PIENU | MATHUSLA |
  | BESIII, CMS, ATLAS ... | CODEX-b ... |

- The PDG had a HNL listing, but didn't cover some of this data

Experimental Status

- Difficulty: experiments quote bounds in the mixing matrix element $|U_{\ell N}|^2$ as function of m_N
- But: Sensitivity typically scales with $(m_N)^{-n}$ up to kinematic endpoint
- Current status for eg $|U_{\mu N}|^2$

Approach 1: Where appropriate, quote a limit near natural kinematic endpoint of each expt (usually the max)

Approach 2: Otherwise, pick characteristic to quote $|U_{\ell N}|^2$ bound
(Only one $U_{\ell N} \neq 0$ at a time)
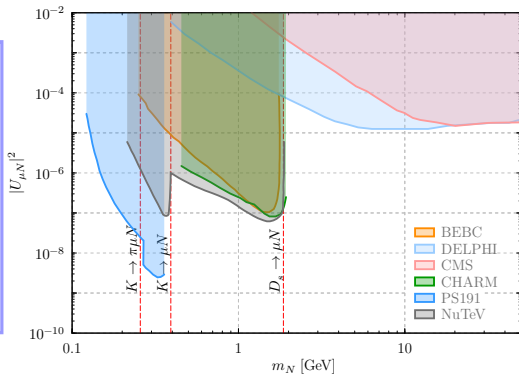
See also 1909.11198 for latest bounds below 100 MeV

New Listings

Limits on $|U_{ex}|^2$

Quoted limits are either the best limit near the kinematic threshold of the experiment, or a characteristic value in the mass range of the experimental sensitivity

VALUE	CL%		DOCUMENT ID		TECN	COMMENT
$< 2 \times 10^{-5}$	95	1	AAD	2019F	ATLS	$m_{\nu_x} \sim 15 - 40$ GeV
$< 1 \times 10^{-9}$	90	2	ABE	2019B	T2K	Near $m_K - m_e$ kin. thres.
$< 1 \times 10^{-4}$	90	3	ABLIKIM	2019AL	BES3	$m_{\nu_x} \sim 0.3 - 0.7$ GeV
$< 1 \times 10^{-8}$	90	4	AGUILAR-AREVA..	2018A	PIEN	$m_{\nu_x} \sim 60 - 120$ MeV
$< 3 \times 10^{-7}$	90	5	CORTINA-GIL	2018	NA62	$m_{\nu_x} \sim 200 - 400$ MeV
$< 3 \times 10^{-5}$	95	6	ABREU	1997I	DLPH	$m_{\nu_x} \sim 6 - 50$ GeV
$< 2 \times 10^{-5}$	95	7	ABREU	1997I	DLPH	Near $m_{\nu_x} \sim 3.5$ GeV
$< 1 \times 10^{-5}$	90	8	BARANOV	1993		Near $m_\pi - m_e$ kin. thres.
$< 2 \times 10^{-7}$	90	8	BARANOV	1993		Near $m_K - m_e$ kin. thres.
$< 1 \times 10^{-7}$		9, 10	BERNARDI	1988	CNTR	Near $m_\pi - m_e$ kin. thres.
$< 2 \times 10^{-9}$		11, 10	BERNARDI	1988	CNTR	Near $m_K - m_e$ kin. thres.
$< 1 \times 10^{-7}$	90	12	DORENBOSCH	1986	CHRM	Near $m_D - m_e$ kin. thres.
$< 1 \times 10^{-7}$	90	13	COOPER-SARKAR	1985	BEBC	Near $m_D - m_e$ kin. thres.

• • • We do not use the following data for averages, fits, limits, etc. • • •

		14	PARK	2016	BELL	$m_{\nu_x} \sim 0.2 - 1.4$ GeV

[1] Limit from prompt lepton number violating trilepton search.

[2] $K^+ \to e^+ \nu_x$, with ν_x decay through U_{ex}. ABE 2019B also considers bounds on $|U_{\ell x} U_{\ell' x}|$ for combinations of lepton flavors in the ν_x decay final state.

We are also exploring an HNL mini-review

Axion-like Particles

- Typically any pseudoscalar coupled to dim-5 operators, including $F\tilde{F}$, $G\tilde{G}$ or $\bar{q}\gamma^5 q$, ...

- ALP mass may cover huge range, depending on motivation. Eg $m_a \sim 10^{-22}$ eV to ~ 10 GeV

- Experimental interest even greater than HNLs, and experimental current bounds are complex

Having an ALP listings would likely be useful to the community. Investigating an appropriate way to do this.
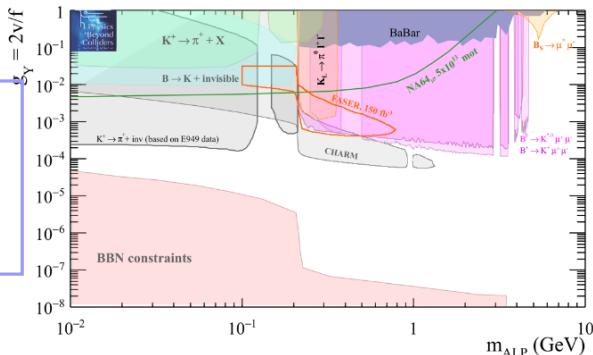
Physics Beyond Colliders BSM working group [1901.09966]

DM Searches

New Nodes in S030 WIMP and Dark Matter Searches

Galactic WIMP seaches
Pre-existing NODEs for M_{X0} = 20, 100, 1000 GeV
Added limits on cross-sections for M_{X0} < 5 GeV

- Spin Independent on Nucleon (32 measurements)
- Spin Dependent on Proton (10 meas.)
- Spin Dependent on Neutron (12 meas.)
- On electrons (8 meas.)
- On nuclei (0 measur.)

Other pre-existing NODEs in S030)
- Miscellaneous results from underground DM searches
- X^0 annhilation cross section
- DM particle (X^0) production in hadron collisions

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DM Searches

New NODE for OTHER DARK MATTER CANDIDATES?
Theory proposals

- **Bose Einstein Condensate Dark Matter**
  - D. Ivanov, S. Liberaty (TH) *JCAP* 07 (2020) 065
  - M. Carciun et al. *Eur.Phys.J.C* 80 (2020) 8, 735
- **(Heavy) Fermionic DM (10^8-10^{10} GeV)**
  - G. Lazarides, Q. Shafi. *Phys.Lett.B* 807 (2020) 135603
- **Non-Abelian Vector Bosons as F(eebly)IMP**
  - Berman et al *JCAP* 02 (2020) 029.
- **Decaying dark matter**
  - K. Enqvit et al. *JCAP* 04 (2020) 015
- **Non-Thermal DM**
  - A. Biswas et al. *JCAP* 03 (2020) 043
- **Milli-charged DM**
  - A. P. Gautham. *JCAP* 03 (2020) 039
- **Macroscopic DM**
  - J. S. Sidhu and G. D. Starkman *Phys.Rev.D* 101 (2020) 8, 083503
- **Compact DM Objects moving in the Earth**
  - C. J. Horowit, R. Widmer-Schnidrig. *Phys.Rev.Lett.* 124 (2020) 5, 051102

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Thanks!