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Bibliography

- [1] ALEPH, DELPHI, L3, OPAL, SLD, LEP ELECTROWEAK WORKING GROUP, SLD ELECTROWEAK GROUP, SLD HEAVY FLAVOUR GROUP collaboration, *Precision electroweak measurements on the Z resonance*, *Phys. Rept.* **427** (2006) 257 [hep-ex/0509008].
- [2] S. Bifani, S. Descotes-Genon, A. Romero Vidal and M.-H. Schune, *Review of Lepton Universality tests in B decays*, *J. Phys. G* **46** (2019) 023001 [1809.06229].
- [3] ATLAS collaboration, *Precision measurement and interpretation of inclusive W^+ , W^- and Z/γ^* production cross sections with the ATLAS detector*, *Eur. Phys. J. C* **77** (2017) 367 [1612.03016].
- [4] ATLAS collaboration, *Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC*, *Phys. Lett. B* **716** (2012) 1 [1207.7214].
- [5] CMS collaboration, *Observation of a New Boson at a Mass of 125 GeV with the CMS Experiment at the LHC*, *Phys. Lett. B* **716** (2012) 30 [1207.7235].
- [6] ATLAS collaboration, *Combined measurements of Higgs boson production and decay using up to 80 fb^{-1} of proton-proton collision data at $\sqrt{s} = 13\text{ TeV}$ collected with the ATLAS experiment*, .
- [7] G. Krnjaic, *Probing Light Thermal Dark-Matter With a Higgs Portal Mediator*, *Phys. Rev. D* **94** (2016) 073009 [1512.04119].
- [8] F. Bezrukov and D. Gorbunov, *Light inflaton Hunter’s Guide*, *JHEP* **05** (2010) 010 [0912.0390].
- [9] T. Asaka, S. Blanchet and M. Shaposhnikov, *The nuMSM, dark matter and neutrino masses*, *Phys. Lett. B* **631** (2005) 151 [hep-ph/0503065].
- [10] T. Asaka and M. Shaposhnikov, *The ν MSM, dark matter and baryon asymmetry of the universe*, *Phys. Lett. B* **620** (2005) 17 [hep-ph/0505013].
- [11] ATLAS collaboration, *Search for displaced vertices of oppositely charged leptons from decays of long-lived particles in pp collisions at $\sqrt{s} = 13\text{ TeV}$ with the ATLAS detector*, *Phys. Lett. B* **801** (2020) 135114 [1907.10037].
- [12] CMS collaboration, *Search for long-lived particles decaying to jets with displaced vertices in proton-proton collisions at $\sqrt{s} = 13\text{ TeV}$* , [2104.13474].

- [13] ATLAS collaboration, *Search for long-lived, massive particles in events with a displaced vertex and a muon with large impact parameter in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector*, *Phys. Rev. D* **102** (2020) 032006 [2003.11956].
- [14] CMS collaboration, *Search for heavy neutral leptons in events with three charged leptons in proton-proton collisions at $\sqrt{s} = 13$ TeV*, *Phys. Rev. Lett.* **120** (2018) 221801 [1802.02965].
- [15] CMS collaboration, *Search for heavy Majorana neutrinos in same-sign dilepton channels in proton-proton collisions at $\sqrt{s} = 13$ TeV*, *JHEP* **01** (2019) 122 [1806.10905].
- [16] LHCb collaboration, *Search for $A' \rightarrow \mu^+ \mu^-$ Decays*, *Phys. Rev. Lett.* **124** (2020) 041801 [1910.06926].
- [17] FASER collaboration, *Technical Proposal for FASER: ForwArd Search ExpeRiment at the LHC*, [1812.09139].
- [18] MATHUSLA collaboration, *Explore the lifetime frontier with MATHUSLA*, *JINST* **15** (2020) C06026 [1901.04040].
- [19] G. Aielli et al., *Expression of interest for the CODEX-b detector*, *Eur. Phys. J. C* **80** (2020) 1177 [1911.00481].
- [20] SHiP collaboration, *A facility to Search for Hidden Particles (SHiP) at the CERN SPS*, [1504.04956].
- [21] DUNE collaboration, *Long-baseline neutrino oscillation physics potential of the DUNE experiment*, *Eur. Phys. J. C* **80** (2020) 978 [2006.16043].
- [22] A. Berlin, S. Gori, P. Schuster and N. Toro, *Dark Sectors at the Fermilab SeaQuest Experiment*, *Phys. Rev. D* **98** (2018) 035011 [1804.00661].
- [23] LHCb collaboration, *Test of lepton universality in beauty-quark decays*, [2103.11769].
- [24] BABAR collaboration, *The BaBar detector*, *Nucl. Instrum. Meth. A* **479** (2002) 1 [hep-ex/0105044].
- [25] BELLE-II collaboration, *Belle II Technical Design Report*, [1011.0352].
- [26] NA62 collaboration, *The Beam and detector of the NA62 experiment at CERN*, *JINST* **12** (2017) P05025 [1703.08501].
- [27] S. Andreas et al., *Proposal for an Experiment to Search for Light Dark Matter at the SPS*, [1312.3309].
- [28] S. N. Gninenko, *Search for MeV dark photons in a light-shining-through-walls experiment at CERN*, *Phys. Rev. D* **89** (2014) 075008 [1308.6521].
- [29] ATLAS collaboration, *Search for new phenomena in events with an energetic jet and missing transverse momentum in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector*, *Phys. Rev. D* **103** (2021) 112006 [2102.10874].
- [30] ATLAS collaboration, *Search for dark matter and other new phenomena in events with an energetic jet and large missing transverse momentum using the ATLAS detector*, *JHEP* **01** (2018) 126 [1711.03301].

- [31] CMS collaboration, *Searches for invisible decays of the Higgs boson in pp collisions at $\sqrt{s} = 7, 8, \text{ and } 13 \text{ TeV}$* , *JHEP* **02** (2017) 135 [1610.09218].
- [32] SND@LHC collaboration, *SND@LHC - Scattering and Neutrino Detector at the LHC*, Scientific Committee Paper CERN-LHCC-2021-003; LHCC-P-016, <https://cds.cern.ch/record/2750060>, Jan, 2021.
- [33] FASER collaboration, *Technical Proposal: FASERnu*, [2001.03073].
- [34] CRESST collaboration, *First results from the CRESST-III low-mass dark matter program*, *Phys. Rev. D* **100** (2019) 102002 [1904.00498].
- [35] DARKSIDE collaboration, *Low-Mass Dark Matter Search with the DarkSide-50 Experiment*, *Phys. Rev. Lett.* **121** (2018) 081307 [1802.06994].
- [36] P. Agrawal et al., *Feebly-Interacting Particles:FIPs 2020 Workshop Report*, [2102.12143].
- [37] A. Boyarsky, M. Ovchinnikov, O. Ruchayskiy and V. Syvolap, *Improved BBN constraints on Heavy Neutral Leptons*, [2008.00749].
- [38] I. Boiarska, K. Bondarenko, A. Boyarsky, V. Gorkavenko, M. Ovchinnikov and A. Sokolenko, *Phenomenology of GeV-scale scalar portal*, *JHEP* **11** (2019) 162 [1904.10447].
- [39] K. Bondarenko, A. Boyarsky, D. Gorbunov and O. Ruchayskiy, *Phenomenology of GeV-scale Heavy Neutral Leptons*, *JHEP* **11** (2018) 032 [1805.08567].
- [40] M. Cacciari, M. Greco and P. Nason, *The $P(T)$ spectrum in heavy flavor hadroproduction*, *JHEP* **05** (1998) 007 [hep-ph/9803400].
- [41] M. Cacciari, S. Frixione and P. Nason, *The $p(T)$ spectrum in heavy flavor photoproduction*, *JHEP* **03** (2001) 006 [hep-ph/0102134].
- [42] M. Cacciari, S. Frixione, N. Houdeau, M. L. Mangano, P. Nason and G. Ridolfi, *Theoretical predictions for charm and bottom production at the LHC*, *JHEP* **10** (2012) 137 [1205.6344].
- [43] M. Cacciari, M. L. Mangano and P. Nason, *Gluon PDF constraints from the ratio of forward heavy-quark production at the LHC at $\sqrt{S} = 7 \text{ and } 13 \text{ TeV}$* , *Eur. Phys. J. C* **75** (2015) 610 [1507.06197].
- [44] SHiP collaboration, H. Dijkstra and T. Ruf, *Heavy Flavour Cascade Production in a Beam Dump*, Dec, 2015.
- [45] C. Pitrou, A. Coc, J.-P. Uzan and E. Vangioni, *Precision big bang nucleosynthesis with improved Helium-4 predictions*, *Phys. Rept.* **754** (2018) 1 [1801.08023].
- [46] T. M. Bania, R. T. Rood and D. S. Balser, *The cosmological density of baryons from observations of $3\text{He}+$ in the Milky Way*, *Nature* **415** (2002) 54.
- [47] L. Sbordone et al., *The metal-poor end of the Spite plateau. 1: Stellar parameters, metallicities and lithium abundances*, *Astron. Astrophys.* **522** (2010) A26 [1003.4510].

- [48] C. Pitrou, A. Coc, J.-P. Uzan and E. Vangioni, *A new tension in the cosmological model from primordial deuterium?*, *Mon. Not. Roy. Astron. Soc.* **502** (2021) 2474 [2011.11320].
- [49] A. D. Dolgov, *Neutrinos in cosmology*, *Phys. Rept.* **370** (2002) 333 [hep-ph/0202122].
- [50] D. J. Fixsen, *The Temperature of the Cosmic Microwave Background*, *Astrophys. J.* **707** (2009) 916 [0911.1955].
- [51] PLANCK collaboration, *Planck 2018 results. V. CMB power spectra and likelihoods*, *Astron. Astrophys.* **641** (2020) A5 [1907.12875].
- [52] PARTICLE DATA GROUP collaboration, *Review of Particle Physics*, *Phys. Rev. D* **98** (2018) 030001.
- [53] J. Lesgourgues, G. Mangano, G. Miele and S. Pastor, *Neutrino Cosmology*. Cambridge University Press, 2, 2013.
- [54] Z. Hou, R. Keisler, L. Knox, M. Millea and C. Reichardt, *How Massless Neutrinos Affect the Cosmic Microwave Background Damping Tail*, *Phys. Rev. D* **87** (2013) 083008 [1104.2333].
- [55] PLANCK collaboration, *Planck 2018 results. VI. Cosmological parameters*, *Astron. Astrophys.* **641** (2020) A6 [1807.06209].
- [56] K. Bondarenko, A. Boyarsky, M. Ovchinnikov, O. Ruchayskiy and L. Shchutska, *Probing new physics with displaced vertices: muon tracker at CMS*, *Phys. Rev. D* **100** (2019) 075015 [1903.11918].
- [57] A. Boyarsky, O. Mikulenko, M. Ovchinnikov and L. Shchutska, *Searches for new physics at SND@LHC*, [2104.09688].
- [58] I. Boiarska, A. Boyarsky, O. Mikulenko and M. Ovchinnikov, *Blast from the past: constraints from the CHARM experiment on Heavy Neutral Leptons with tau mixing*, [2107.14685].
- [59] NOMAD collaboration, *Search for heavy neutrinos mixing with tau neutrinos*, *Phys. Lett. B* **506** (2001) 27 [hep-ex/0101041].
- [60] ARGONEUT collaboration, *New Constraints on Tau-Coupled Heavy Neutral Leptons with Masses $m_N=280-970$ MeV*, *Phys. Rev. Lett.* **127** (2021) 121801 [2106.13684].
- [61] T2K collaboration, *Search for heavy neutrinos with the T2K near detector ND280*, *Phys. Rev. D* **100** (2019) 052006 [1902.07598].
- [62] CHARM collaboration, *A Search for Decays of Heavy Neutrinos in the Mass Range 0.5-GeV to 2.8-GeV*, *Phys. Lett. B* **166** (1986) 473.
- [63] J. Orloff, A. N. Rozanov and C. Santoni, *Limits on the mixing of tau neutrino to heavy neutrinos*, *Phys. Lett. B* **550** (2002) 8 [hep-ph/0208075].
- [64] N. Sabti, A. Magalich and A. Filimonova, *An Extended Analysis of Heavy Neutral Leptons during Big Bang Nucleosynthesis*, *JCAP* **11** (2020) 056 [2006.07387].
- [65] P. Coloma, P. A. N. Machado, I. Martinez-Soler and I. M. Shoemaker, *Double-Cascade Events from New Physics in Icecube*, *Phys. Rev. Lett.* **119** (2017) 201804 [1707.08573].

- [66] FASER collaboration, *FASER's physics reach for long-lived particles*, *Phys. Rev. D* **99** (2019) 095011 [1811.12522].
- [67] J. Beacham et al., *Physics Beyond Colliders at CERN: Beyond the Standard Model Working Group Report*, *J. Phys. G* **47** (2020) 010501 [1901.09966].
- [68] C. O. Dib, J. C. Helo, M. Nayak, N. A. Neill, A. Soffer and J. Zamora-Saa, *Searching for a sterile neutrino that mixes predominantly with ν_τ at B factories*, *Phys. Rev. D* **101** (2020) 093003 [1908.09719].
- [69] B. Batell, J. A. Evans, S. Gori and M. Rai, *Dark Scalars and Heavy Neutral Leptons at DarkQuest*, *JHEP* **05** (2021) 049 [2008.08108].
- [70] G. Cvetič and C. S. Kim, *Sensitivity bounds on heavy neutrino mixing $|U_{\mu N}|^2$ and $|U_{\tau N}|^2$ from LHCb upgrade*, *Phys. Rev. D* **100** (2019) 015014 [1904.12858].
- [71] E. J. Chun, A. Das, S. Mandal, M. Mitra and N. Sinha, *Sensitivity of Lepton Number Violating Meson Decays in Different Experiments*, *Phys. Rev. D* **100** (2019) 095022 [1908.09562].
- [72] M. Atkinson, P. Coloma, I. Martinez-Soler, N. Rocco and I. M. Shoemaker, *Heavy Neutrino searches through Double-Bang Events at Super-Kamiokande, DUNE, and Hyper-Kamiokande*, [2105.09357].
- [73] KM3NET collaboration, *Letter of intent for KM3NeT 2.0*, *J. Phys. G* **43** (2016) 084001 [1601.07459].
- [74] CHARM collaboration, *A Search for Decays of Heavy Neutrinos*, *Phys. Lett. B* **128** (1983) 361.
- [75] CERN-HAMBURG-AMSTERDAM-ROME-MOSCOW collaboration, *A Detector for Neutral Current Interactions of High-energy Neutrinos*, *Nucl. Instrum. Meth.* **178** (1980) 27.
- [76] A. Diddens, M. Jonker, J. Panman, F. Udo, J. Allaby, U. Amaldi et al., *Performance of a large system of proportional drift tubes for a fine-grain calorimeter*, *Nuclear Instruments and Methods* **176** (1980) 189.
- [77] O. Ruchayskiy and A. Ivashko, *Experimental bounds on sterile neutrino mixing angles*, *JHEP* **06** (2012) 100 [1112.3319].
- [78] M. Chrzaszcz, M. Drewes, T. E. Gonzalo, J. Harz, S. Krishnamurthy and C. Weniger, *A frequentist analysis of three right-handed neutrinos with GAMBIT*, *Eur. Phys. J. C* **80** (2020) 569 [1908.02302].
- [79] DELPHI collaboration, *Search for neutral heavy leptons produced in Z decays*, *Z. Phys. C* **74** (1997) 57.
- [80] SHiP collaboration, *Sensitivity of the SHiP experiment to Heavy Neutral Leptons*, *JHEP* **04** (2019) 077 [1811.00930].
- [81] P. Gondolo, G. Ingelman and M. Thunman, *Charm production and high-energy atmospheric muon and neutrino fluxes*, *Astropart. Phys.* **5** (1996) 309 [hep-ph/9505417].

- [82] S. Alekhin et al., *A facility to Search for Hidden Particles at the CERN SPS: the SHiP physics case*, *Rept. Prog. Phys.* **79** (2016) 124201 [1504.04855].
- [83] C. Argüelles, P. Coloma, P. Hernández and V. Muñoz, *Searches for Atmospheric Long-Lived Particles*, *JHEP* **02** (2020) 190 [1910.12839].
- [84] ATLAS collaboration, *Search for exotic decays of the Higgs boson into long-lived particles in pp collisions at $\sqrt{s} = 13$ TeV using displaced vertices in the ATLAS inner detector*, [2107.06092].
- [85] LHCb collaboration, *Search for Majorana neutrinos in $B^- \rightarrow \pi^+ \mu^- \mu^-$ decays*, *Phys. Rev. Lett.* **112** (2014) 131802 [1401.5361].
- [86] ATLAS collaboration, *Search for long-lived particles produced in pp collisions at $\sqrt{s} = 13$ TeV that decay into displaced hadronic jets in the ATLAS muon spectrometer*, *Phys. Rev. D* **99** (2019) 052005 [1811.07370].
- [87] ATLAS collaboration, *Search for long-lived, massive particles in events with displaced vertices and missing transverse momentum in $\sqrt{s} = 13$ TeV pp collisions with the ATLAS detector*, *Phys. Rev. D* **97** (2018) 052012 [1710.04901].
- [88] CMS collaboration, *Search for long-lived particles with displaced vertices in multijet events in proton-proton collisions at $\sqrt{s} = 13$ TeV*, *Phys. Rev. D* **98** (2018) 092011 [1808.03078].
- [89] CMS collaboration, *Search for new long-lived particles at $\sqrt{s} = 13$ TeV*, *Phys. Lett. B* **780** (2018) 432 [1711.09120].
- [90] CMS collaboration, *Search sensitivity for dark photons decaying to displaced muons with CMS at the high-luminosity LHC*, CMS Physics Analysis Summary CMS-PAS-FTR-18-002, 2018.
- [91] CMS collaboration, *First Level Track Jet Trigger for Displaced Jets at High Luminosity LHC*, CMS Physics Analysis Summary CMS-PAS-FTR-18-018, 2018.
- [92] ATLAS, CMS collaboration, *Report on the Physics at the HL-LHC and Perspectives for the HE-LHC*, in *HL/HE-LHC Physics Workshop: final jamboree Geneva, CERN, March 1, 2019*, 2019, [1902.10229].
- [93] Y. Gershtein, *CMS Hardware Track Trigger: New Opportunities for Long-Lived Particle Searches at the HL-LHC*, *Phys. Rev. D* **96** (2017) 035027 [1705.04321].
- [94] S. Bobrovskiy, W. Buchmuller, J. Hajer and J. Schmidt, *Quasi-stable neutralinos at the LHC*, *JHEP* **09** (2011) 119 [1107.0926].
- [95] S. Bobrovskiy, J. Hajer and S. Rydbeck, *Long-lived higgsinos as probes of gravitino dark matter at the LHC*, *JHEP* **02** (2013) 133 [1211.5584].
- [96] E. Izaguirre and B. Shuve, *Multilepton and Lepton Jet Probes of Sub-Weak-Scale Right-Handed Neutrinos*, *Phys. Rev. D* **91** (2015) 093010 [1504.02470].
- [97] I. Boiarska, K. Bondarenko, A. Boyarsky, S. Ejima, M. Ovchinnikov, O. Ruchayskiy et al., *Probing baryon asymmetry of the Universe at LHC and SHiP*, [1902.04535].

- [98] M. Drewes and J. Hajer, *Heavy Neutrinos in displaced vertex searches at the LHC and HL-LHC*, *JHEP* **02** (2020) 070 [[1903.06100](#)].
- [99] CMS COLLABORATION collaboration, *Search for long-lived particles that decay into final states containing two muons, reconstructed using only the CMS muon chambers*, Tech. Rep. CMS-PAS-EXO-14-012, CERN, Geneva, 2015.
- [100] CMS collaboration, *The CMS Experiment at the CERN LHC*, *JINST* **3** (2008) S08004.
- [101] CMS collaboration, *Performance of the CMS muon detector and muon reconstruction with proton-proton collisions at $\sqrt{s} = 13$ TeV*, *JINST* **13** (2018) P06015 [[1804.04528](#)].
- [102] CMS collaboration, *The CMS muon project*, Technical Design Report CERN-LHCC-97-032, CMS-TDR-3, 1997.
- [103] CMS collaboration, “Muon detectors.”
<http://cms.web.cern.ch/news/muon-detectors>.
- [104] CMS collaboration, *Muon Reconstruction and Identification Improvements for Run-2 and First Results with 2015 Run Data*, CMS Detector Performance Summary CMS-DP-2015-015, 2015.
- [105] ATLAS collaboration, *Search for heavy neutral leptons in decays of W bosons produced in 13 TeV pp collisions using prompt and displaced signatures with the ATLAS detector*, *JHEP* **10** (2019) 265 [[1905.09787](#)].
- [106] CMS collaboration, *Measurement of b hadron lifetimes in pp collisions at $\sqrt{s} = 8$ TeV*, *Eur. Phys. J. C* **78** (2018) 457 [[1710.08949](#)].
- [107] CMS collaboration, *Muon ID performance: low- p_T muon efficiencies*, CMS Detector Performance Summary CMS-DP-2014-020, 2014.
- [108] CMS collaboration, *Muon Identification performance: hadron mis-Id measurements and RPC Muon selections*, CMS Detector Performance Summary CMS-DP-2014-018, 2014.
- [109] CMS collaboration, *Performance of Electron Reconstruction and Selection with the CMS Detector in Proton-Proton Collisions at $\sqrt{s} = 8$ TeV*, *JINST* **10** (2015) P06005 [[1502.02701](#)].
- [110] G. Cottin, J. C. Helo and M. Hirsch, *Displaced vertices as probes of sterile neutrino mixing at the LHC*, *Phys. Rev. D* **98** (2018) 035012 [[1806.05191](#)].
- [111] ATLAS collaboration, *Measurement of $W^\pm$ and Z -boson production cross sections in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector*, *Phys. Lett. B* **759** (2016) 601 [[1603.09222](#)].
- [112] C. Degrande, O. Mattelaer, R. Ruiz and J. Turner, *Fully-Automated Precision Predictions for Heavy Neutrino Production Mechanisms at Hadron Colliders*, *Phys. Rev.* **D94** (2016) 053002 [[1602.06957](#)].
- [113] J. Alwall, R. Frederix, S. Frixione, V. Hirschi, F. Maltoni, O. Mattelaer et al., *The automated computation of tree-level and next-to-leading order differential cross sections, and their matching to parton shower simulations*, *JHEP* **07** (2014) 079 [[1405.0301](#)].

- [114] K. Hagiwara, T. Li, K. Mawatari and J. Nakamura, *TauDecay: a library to simulate polarized tau decays via FeynRules and MadGraph5*, *Eur. Phys. J. C* **73** (2013) 2489 [1212.6247].
- [115] G. Cottin, J. C. Helo and M. Hirsch, *Searches for light sterile neutrinos with multitrack displaced vertices*, *Phys. Rev.* **D97** (2018) 055025 [1801.02734].
- [116] I. Antoniadis, A. Boyarsky, S. Espahbodi, O. Ruchayskiy and J. D. Wells, *Anomaly driven signatures of new invisible physics at the Large Hadron Collider*, *Nucl. Phys. B* **824** (2010) 296 [0901.0639].
- [117] A. Alloul, N. D. Christensen, C. Degrande, C. Duhr and B. Fuks, *FeynRules 2.0 - A complete toolbox for tree-level phenomenology*, *Comput. Phys. Commun.* **185** (2014) 2250 [1310.1921].
- [118] N. D. Christensen and C. Duhr, *FeynRules - Feynman rules made easy*, *Comput. Phys. Commun.* **180** (2009) 1614 [0806.4194].
- [119] M. Ovchinnikov, “Chern-Simons portal.”
- [120] I. Boiarska, K. Bondarenko, A. Boyarsky, M. Ovchinnikov, O. Ruchayskiy and A. Sokolenko, *Light scalar production from Higgs bosons and FASER 2*, *JHEP* **05** (2020) 049 [1908.04635].
- [121] P. Obul, S. Dulat, T.-J. Hou, A. Tursun and N. Yalkun, *Next-to-leading order QCD and electroweak corrections to Higgs-strahlung processes at the LHC*, *Chin. Phys. C* **42** (2018) 093105 [1801.06851].
- [122] Y. Gershtein, S. Knapen and D. Redigolo, *Probing naturally light singlets with a displaced vertex trigger*, [2012.07864].
- [123] P. Bechtle, S. Heinemeyer, O. Stal, T. Stefaniak and G. Weiglein, *Probing the Standard Model with Higgs signal rates from the Tevatron, the LHC and a future ILC*, *JHEP* **11** (2014) 039 [1403.1582].
- [124] J. de Blas et al., *Higgs Boson Studies at Future Particle Colliders*, *JHEP* **01** (2020) 139 [1905.03764].
- [125] B. W. Lee and S. Weinberg, *Cosmological Lower Bound on Heavy Neutrino Masses*, *Phys. Rev. Lett.* **39** (1977) 165.
- [126] A. Berlin and F. Kling, *Inelastic Dark Matter at the LHC Lifetime Frontier: ATLAS, CMS, LHCb, CODEX-b, FASER, and MATHUSLA*, *Phys. Rev. D* **99** (2019) 015021 [1810.01879].
- [127] B. Batell, P. deNiverville, D. McKeen, M. Pospelov and A. Ritz, *Leptophobic Dark Matter at Neutrino Factories*, *Phys. Rev. D* **90** (2014) 115014 [1405.7049].
- [128] P. Coloma, B. A. Dobrescu, C. Frugiuele and R. Harnik, *Dark matter beams at LBNF*, *JHEP* **04** (2016) 047 [1512.03852].
- [129] B. Batell, A. Freitas, A. Ismail and D. McKeen, *Probing Light Dark Matter with a Hadrophilic Scalar Mediator*, *Phys. Rev. D* **100** (2019) 095020 [1812.05103].

- [130] S. Naaz, J. Singh and R. Singh, *DUNE prospect for leptophobic dark matter*, [2004.10996].
- [131] B. A. Dobrescu and C. Frugiuele, *GeV-Scale Dark Matter: Production at the Main Injector*, *JHEP* **02** (2015) 019 [1410.1566].
- [132] National institute of standards and technology, “Stopping power and range tables for protons in various materials.”
- [133] F. Kling, *Forward Neutrino Fluxes at the LHC*, [2105.08270].
- [134] P. deNiverville, C.-Y. Chen, M. Pospelov and A. Ritz, *Light dark matter in neutrino beams: production modelling and scattering signatures at MiniBooNE, T2K and SHiP*, *Phys. Rev. D* **95** (2017) 035006 [1609.01770].
- [135] L. Buonocore, C. Frugiuele, F. Maltoni, O. Mattelaer and F. Tramontano, *Event generation for beam dump experiments*, *JHEP* **05** (2019) 028 [1812.06771].
- [136] CRYSTAL BARREL collaboration, *Search for a new light gauge boson in decays of π^0 and η* , *Phys. Lett. B* **333** (1994) 271.
- [137] BNL-E949 collaboration, *Study of the decay $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ in the momentum region $140 < P_\pi < 199 \text{ MeV}/c$* , *Phys. Rev. D* **79** (2009) 092004 [0903.0030].
- [138] NA62 collaboration, *Search for production of an invisible dark photon in π^0 decays*, *JHEP* **05** (2019) 182 [1903.08767].
- [139] MINIBOONE DM collaboration, *Dark Matter Search in Nucleon, Pion, and Electron Channels from a Proton Beam Dump with MiniBooNE*, *Phys. Rev. D* **98** (2018) 112004 [1807.06137].
- [140] CDF collaboration, *A Search for dark matter in events with one jet and missing transverse energy in $p\bar{p}$ collisions at $\sqrt{s} = 1.96 \text{ TeV}$* , *Phys. Rev. Lett.* **108** (2012) 211804 [1203.0742].
- [141] S. Caron, J. A. Casas, J. Quilis and R. Ruiz de Austri, *Anomaly-free Dark Matter with Harmless Direct Detection Constraints*, *JHEP* **12** (2018) 126 [1807.07921].
- [142] J. A. Dror, R. Lasenby and M. Pospelov, *Dark forces coupled to nonconserved currents*, *Phys. Rev. D* **96** (2017) 075036 [1707.01503].
- [143] J. A. Dror, R. Lasenby and M. Pospelov, *New constraints on light vectors coupled to anomalous currents*, *Phys. Rev. Lett.* **119** (2017) 141803 [1705.06726].
- [144] P. Ilten, Y. Soreq, M. Williams and W. Xue, *Serendipity in dark photon searches*, *JHEP* **06** (2018) 004 [1801.04847].
- [145] A. Boyarsky, O. Ruchayskiy and M. Shaposhnikov, *Observational manifestations of anomaly inflow*, *Phys. Rev. D* **72** (2005) 085011 [hep-th/0507098].
- [146] A. Boyarsky, O. Ruchayskiy and M. Shaposhnikov, *Anomalies as a signature of extra dimensions*, *Phys. Lett. B* **626** (2005) 184 [hep-ph/0507195].
- [147] R. Rayaprolu, S. Möller, C. Linsmeier and S. Spellerberg, *Simulation of neutron irradiation damage in tungsten using higher energy protons*, *Nuclear Materials and Energy* **9** (2016) 29.

- [148] D. E. Soper, M. Spannowsky, C. J. Wallace and T. M. P. Tait, *Scattering of Dark Particles with Light Mediators*, *Phys. Rev. D* **90** (2014) 115005 [1407.2623].
- [149] A. Buckley, J. Ferrando, S. Lloyd, K. Nordström, B. Page, M. Rüfenacht et al., *LHAPDF6: parton density access in the LHC precision era*, *Eur. Phys. J. C* **75** (2015) 132 [1412.7420].
- [150] S. Tulin, *New weakly-coupled forces hidden in low-energy QCD*, *Phys. Rev. D* **89** (2014) 114008 [1404.4370].
- [151] F. Kling, *Probing light gauge bosons in tau neutrino experiments*, *Phys. Rev. D* **102** (2020) 015007 [2005.03594].
- [152] T. Pierog, I. Karpenko, J. M. Katzy, E. Yatsenko and K. Werner, *EPOS LHC: Test of collective hadronization with data measured at the CERN Large Hadron Collider*, *Phys. Rev. C* **92** (2015) 034906 [1306.0121].
- [153] C. Baus, T. Pierog, and R. Ulrich, “Cosmic Ray Monte Carlo (CRMC).”
- [154] A. Faessler, M. I. Krivoruchenko and B. V. Martemyanov, *Once more on electromagnetic form factors of nucleons in extended vector meson dominance model*, *Phys. Rev. C* **82** (2010) 038201 [0910.5589].
- [155] A. Ismail, R. Mammen Abraham and F. Kling, *Neutral current neutrino interactions at FASER ν* , *Phys. Rev. D* **103** (2021) 056014 [2012.10500].
- [156] CMS collaboration, *Measurement of charged pion, kaon, and proton production in proton-proton collisions at $\sqrt{s} = 13$ TeV*, *Phys. Rev. D* **96** (2017) 112003 [1706.10194].
- [157] ATLAS collaboration, *Measurement of $D^{*\pm}$, $D^\pm$ and $D_s^\pm$ meson production cross sections in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector*, *Nucl. Phys. B* **907** (2016) 717 [1512.02913].
- [158] LHCb collaboration, *Measurement of B meson production cross-sections in proton-proton collisions at $\sqrt{s} = 7$ TeV*, *JHEP* **08** (2013) 117 [1306.3663].
- [159] CMS collaboration, *Measurement of the total and differential inclusive B^+ hadron cross sections in pp collisions at $\sqrt{s} = 13$ TeV*, *Phys. Lett. B* **771** (2017) 435 [1609.00873].
- [160] P. Nason, S. Dawson and R. K. Ellis, *The One Particle Inclusive Differential Cross-Section for Heavy Quark Production in Hadronic Collisions*, *Nucl. Phys. B* **327** (1989) 49.
- [161] F. Riehn, H. P. Dembinski, R. Engel, A. Fedynitch, T. K. Gaisser and T. Stanev, *The hadronic interaction model SIBYLL 2.3c and Feynman scaling*, *PoS ICRC2017* (2018) 301 [1709.07227].
- [162] W. Bai, M. Diwan, M. V. Garzelli, Y. S. Jeong and M. H. Reno, *Far-forward neutrinos at the Large Hadron Collider*, *JHEP* **06** (2020) 032 [2002.03012].
- [163] FASER collaboration, *Detecting and Studying High-Energy Collider Neutrinos with FASER at the LHC*, *Eur. Phys. J. C* **80** (2020) 61 [1908.02310].
- [164] B. Batell, J. L. Feng and S. Trojanowski, *Detecting Dark Matter with Far-Forward Emulsion and Liquid Argon Detectors at the LHC*, *Phys. Rev. D* **103** (2021) 075023 [2101.10338].

- [165] A. Fedynitch, F. Riehn, R. Engel, T. K. Gaisser and T. Stanev, *Hadronic interaction model sibyll 2.3c and inclusive lepton fluxes*, *Phys. Rev. D* **100** (2019) 103018 [1806.04140].
- [166] T. Fujiwara, T. Kugo, H. Terao, S. Uehara and K. Yamawaki, *Nonabelian Anomaly and Vector Mesons as Dynamical Gauge Bosons of Hidden Local Symmetries*, *Prog. Theor. Phys.* **73** (1985) 926.
- [167] H. Kuwabara and T. Hatsuda, *phi meson in nuclear matter*, *Prog. Theor. Phys.* **94** (1995) 1163 [nucl-th/9507017].
- [168] K. Nakayama, J. W. Durso, J. Haidenbauer, C. Hanhart and J. Speth, *phi meson production in proton proton collisions*, *Phys. Rev. C* **60** (1999) 055209 [nucl-th/9904040].
- [169] A. I. Vainshtein and V. I. Zakharov, *Remarks on Electromagnetic Form-Factors of Hadrons in the Quark Model*, *Phys. Lett. B* **72** (1978) 368.
- [170] A. Boyarsky, M. Ovchinnikov, N. Sabti and V. Syvolap, *When feebly interacting massive particles decay into neutrinos: The Neff story*, *Phys. Rev. D* **104** (2021) 035006 [2103.09831].
- [171] Y. I. Izotov, T. X. Thuan and N. G. Guseva, *A new determination of the primordial He abundance using the He I $\lambda 10830$ A emission line: cosmological implications*, *Mon. Not. Roy. Astron. Soc.* **445** (2014) 778 [1408.6953].
- [172] E. Aver, K. A. Olive and E. D. Skillman, *The effects of He I $\lambda 10830$ on helium abundance determinations*, *JCAP* **1507** (2015) 011 [1503.08146].
- [173] A. Peimbert, M. Peimbert and V. Luridiana, *The primordial helium abundance and the number of neutrino families*, *Rev. Mex. Astron. Astrofis.* **52** (2016) 419 [1608.02062].
- [174] V. Fernández, E. Terlevich, A. I. Díaz, R. Terlevich and F. F. Rosales-Ortega, *Primordial helium abundance determination using sulphur as metallicity tracer*, *Monthly Notices of the Royal Astronomical Society* **478** (2018) 5301–5319.
- [175] M. Valerdi, A. Peimbert, M. Peimbert and A. Sixtos, *Determination of the Primordial Helium Abundance Based on NGC 346, an H II Region of the Small Magellanic Cloud*, *Astrophys. J.* **876** (2019) 98 [1904.01594].
- [176] Y. I. Izotov, F. H. Chaffee, C. B. Foltz, R. F. Green, N. G. Guseva and T. X. Thuan, *Helium abundance in the most metal-deficient blue compact galaxies: I Zw 18 and sbs 0335-052*, *Astrophys. J.* **527** (1999) 757 [astro-ph/9907228].
- [177] K. A. Olive and E. D. Skillman, *A Realistic determination of the error on the primordial helium abundance: Steps toward non-parametric nebular helium abundances*, *Astrophys. J.* **617** (2004) 29 [astro-ph/0405588].
- [178] M. Pospelov and J. Pradler, *Metastable GeV-scale particles as a solution to the cosmological lithium problem*, *Phys. Rev. D* **82** (2010) 103514 [1006.4172].
- [179] K. Kohri, *Primordial nucleosynthesis and hadronic decay of a massive particle with a relatively short lifetime*, *Phys. Rev. D* **64** (2001) 043515 [astro-ph/0103411].

- [180] Y. I. Izotov, G. Stasinska and N. G. Guseva, *Primordial 4He abundance: a determination based on the largest sample of HII regions with a methodology tested on model HII regions*, *Astron. Astrophys.* **558** (2013) A57 [1308.2100].
- [181] A. Fradette and M. Pospelov, *BBN for the LHC: constraints on lifetimes of the Higgs portal scalars*, *Phys. Rev. D* **96** (2017) 075033 [1706.01920].
- [182] A. Fradette, M. Pospelov, J. Pradler and A. Ritz, *Cosmological beam dump: constraints on dark scalars mixed with the Higgs boson*, *Phys. Rev. D* **99** (2019) 075004 [1812.07585].
- [183] J. J. Bennett, G. Buldgen, M. Drewes and Y. Y. Wong, *Towards a precision calculation of the effective number of neutrinos N_{eff} in the Standard Model I: The QED equation of state*, *JCAP* **03** (2020) 003 [1911.04504].
- [184] M. Escudero Abenza, *Precision early universe thermodynamics made simple: N_{eff} and neutrino decoupling in the Standard Model and beyond*, *JCAP* **05** (2020) 048 [2001.04466].
- [185] J. J. Bennett, G. Buldgen, P. F. de Salas, M. Drewes, S. Gariazzo, S. Pastor et al., *Towards a precision calculation of N_{eff} in the Standard Model II: Neutrino decoupling in the presence of flavour oscillations and finite-temperature QED*, [2012.02726].
- [186] J. Froustey, C. Pitrou and M. C. Volpe, *Neutrino decoupling including flavour oscillations and primordial nucleosynthesis*, *JCAP* **12** (2020) 015 [2008.01074].
- [187] K. Akita and M. Yamaguchi, *A precision calculation of relic neutrino decoupling*, *JCAP* **08** (2020) 012 [2005.07047].
- [188] M. Kawasaki, K. Kohri and N. Sugiyama, *Cosmological constraints on late time entropy production*, *Phys. Rev. Lett.* **82** (1999) 4168 [astro-ph/9811437].
- [189] M. Kawasaki, K. Kohri and N. Sugiyama, *MeV scale reheating temperature and thermalization of neutrino background*, *Phys. Rev.* **D62** (2000) 023506 [astro-ph/0002127].
- [190] M. Kawasaki, K. Nakayama and M. Senami, *Cosmological implications of supersymmetric axion models*, *JCAP* **03** (2008) 009 [0711.3083].
- [191] T. Hasegawa, N. Hiroshima, K. Kohri, R. S. L. Hansen, T. Tram and S. Hannestad, *MeV-scale reheating temperature and thermalization of oscillating neutrinos by radiative and hadronic decays of massive particles*, *JCAP* **12** (2019) 012 [1908.10189].
- [192] G. M. Fuller, C. T. Kishimoto and A. Kusenko, *Heavy sterile neutrinos, entropy and relativistic energy production, and the relic neutrino background*, [1110.6479].
- [193] S. Hannestad, *What is the lowest possible reheating temperature?*, *Phys. Rev.* **D70** (2004) 043506 [astro-ph/0403291].
- [194] A. D. Dolgov, S. H. Hansen, G. Raffelt and D. V. Semikoz, *Heavy sterile neutrinos: Bounds from big bang nucleosynthesis and SN1987A*, *Nucl. Phys.* **B590** (2000) 562 [hep-ph/0008138].

- [195] O. Ruchayskiy and A. Ivashko, *Restrictions on the lifetime of sterile neutrinos from primordial nucleosynthesis*, *JCAP* **1210** (2012) 014 [1202.2841].
- [196] G. B. Gelmini, M. Kawasaki, A. Kusenko, K. Murai and V. Takhistov, *Big Bang Nucleosynthesis constraints on sterile neutrino and lepton asymmetry of the Universe*, *JCAP* **09** (2020) 051 [2005.06721].
- [197] L. Mastroiuto, P. D. Serpico, A. Mirizzi and N. Saviano, *Massive sterile neutrinos in the early universe: From thermal decoupling to cosmological constraints*, [2104.11752].
- [198] M. Escudero, *Neutrino decoupling beyond the Standard Model: CMB constraints on the Dark Matter mass with a fast and precise N_{eff} evaluation*, *JCAP* **02** (2019) 007 [1812.05605].
- [199] PLANCK collaboration, *Planck 2018 results. VI. Cosmological parameters*, *Astron. Astrophys.* **641** (2020) A6 [1807.06209].
- [200] PLANCK collaboration, *Planck 2018 results. V. CMB power spectra and likelihoods*, *Astron. Astrophys.* **641** (2020) A5 [1907.12875].
- [201] E. W. Kolb and M. S. Turner, *The Early Universe*, vol. 69. *Front.Phys.* 69 (1990) 1-547, 1990.
- [202] M. Fabbrichesi, E. Gabrielli and G. Lanfranchi, *The Dark Photon*, [2005.01515].
- [203] S. Dumitru, B. A. Ovrut and A. Purves, *The R-parity Violating Decays of Charginos and Neutralinos in the B-L MSSM*, *JHEP* **02** (2019) 124 [1810.11035].
- [204] K. J. Kelly and Y. Zhang, *Mononeutrino at DUNE: New Signals from Neutrinophilic Thermal Dark Matter*, *Phys. Rev. D* **99** (2019) 055034 [1901.01259].
- [205] M. Shaposhnikov, *A Possible symmetry of the nuMSM*, *Nucl. Phys.* **B763** (2007) 49 [hep-ph/0605047].
- [206] M. B. Gavela, T. Hambye, D. Hernandez and P. Hernandez, *Minimal Flavour Seesaw Models*, *JHEP* **09** (2009) 038 [0906.1461].
- [207] A. Boyarsky, O. Ruchayskiy and M. Shaposhnikov, *The Role of sterile neutrinos in cosmology and astrophysics*, *Ann. Rev. Nucl. Part. Sci.* **59** (2009) 191 [0901.0011].
- [208] S. Ejima, M. Shaposhnikov and I. Timiryasov, *Parameter space of baryogenesis in the ν MSM*, *JHEP* **07** (2019) 077 [1808.10833].
- [209] J. Klarić, M. Shaposhnikov and I. Timiryasov, *Uniting Low-Scale Leptogenesis Mechanisms*, *Phys. Rev. Lett.* **127** (2021) 111802 [2008.13771].
- [210] A. D. Dolgov, S. H. Hansen, G. Raffelt and D. V. Semikoz, *Cosmological and astrophysical bounds on a heavy sterile neutrino and the KARMEN anomaly*, *Nucl. Phys.* **B580** (2000) 331 [hep-ph/0002223].
- [211] A. D. Dolgov and F. L. Villante, *BBN bounds on active sterile neutrino mixing*, *Nucl. Phys.* **B679** (2004) 261 [hep-ph/0308083].
- [212] A. C. Vincent, E. F. Martinez, P. Hernández, M. Lattanzi and O. Mena, *Revisiting cosmological bounds on sterile neutrinos*, *JCAP* **04** (2015) 006 [1408.1956].

- [213] D. Notzold and G. Raffelt, *Neutrino Dispersion at Finite Temperature and Density*, *Nucl. Phys. B* **307** (1988) 924.
- [214] A. D. Dolgov and S. H. Hansen, *Massive sterile neutrinos as warm dark matter*, *Astropart. Phys.* **16** (2002) 339 [hep-ph/0009083].
- [215] L. Husdal, *On Effective Degrees of Freedom in the Early Universe*, *Galaxies* **4** (2016) 78 [1609.04979].
- [216] K. Abazajian, G. M. Fuller and M. Patel, *Sterile neutrino hot, warm, and cold dark matter*, *Phys. Rev. D* **64** (2001) 023501 [astro-ph/0101524].
- [217] J. Edsjo and P. Gondolo, *Neutralino relic density including coannihilations*, *Phys. Rev. D* **56** (1997) 1879 [hep-ph/9704361].
- [218] A. Boyarsky, M. Ovchinnikov, O. Ruchayskiy and V. Syvolap, *Constraints on MeV-GeV scale feebly interacting particles from primordial nucleosynthesis, to appear* (2020) .
- [219] J. Kersten and A. Y. Smirnov, *Right-Handed Neutrinos at CERN LHC and the Mechanism of Neutrino Mass Generation*, *Phys. Rev. D* **76** (2007) 073005 [0705.3221].
- [220] D. Gorbunov and M. Shaposhnikov, *How to find neutral leptons of the ν MSM?*, *JHEP* **10** (2007) 015 [0705.1729].
- [221] K. Bondarenko, A. Boyarsky, J. Klaric, O. Mikulenko, O. Ruchayskiy, V. Syvolap et al., *An allowed window for heavy neutral leptons below the kaon mass*, [2101.09255].
- [222] R. K. Ellis et al., *Physics Briefing Book: Input for the European Strategy for Particle Physics Update 2020*, [1910.11775].
- [223] NA62 collaboration, *Search for heavy neutral lepton production in K^+ decays to positrons*, *Phys. Lett. B* **807** (2020) 135599 [2005.09575].
- [224] D. Gorbunov, I. Krasnov, Y. Kudenko and S. Suvorov, *Heavy Neutral Leptons from kaon decays in the SHiP experiment*, *Phys. Lett. B* **810** (2020) 135817 [2004.07974].
- [225] P. Ballett, T. Boschi and S. Pascoli, *Heavy Neutral Leptons from low-scale seesaws at the DUNE Near Detector*, *JHEP* **03** (2020) 111 [1905.00284].
- [226] DUNE collaboration, *Deep Underground Neutrino Experiment (DUNE), Far Detector Technical Design Report, Volume II: DUNE Physics*, [2002.03005].
- [227] P. Coloma, E. Fernández-Martínez, M. González-López, J. Hernández-García and Z. Pavlovic, *GeV-scale neutrinos: interactions with mesons and DUNE sensitivity*, *Eur. Phys. J. C* **81** (2021) 78 [2007.03701].
- [228] SIMONS OBSERVATORY collaboration, *The Simons Observatory: Science goals and forecasts*, *JCAP* **1902** (2019) 056 [1808.07445].
- [229] K. Abazajian et al., *CMB-S4 Science Case, Reference Design, and Project Plan*, [1907.04473].
- [230] PARTICLE DATA GROUP collaboration, *Review of Particle Physics*, *PTEP* **2020** (2020) 083C01.

- [231] W. Hu and M. J. White, *The Damping tail of CMB anisotropies*, *Astrophys. J.* **479** (1997) 568 [astro-ph/9609079].
- [232] S. Bashinsky and U. Seljak, *Neutrino perturbations in CMB anisotropy and matter clustering*, *Phys. Rev. D* **69** (2004) 083002 [astro-ph/0310198].
- [233] N. Sabti, J. Alvey, M. Escudero, M. Fairbairn and D. Blas, *Refined Bounds on MeV-scale Thermal Dark Sectors from BBN and the CMB*, *JCAP* **01** (2020) 004 [1910.01649].
- [234] G. B. Gelmini, A. Kusenko and V. Takhistov, *Possible Hints of Sterile Neutrinos in Recent Measurements of the Hubble Parameter*, [1906.10136].
- [235] L. Verde, T. Treu and A. G. Riess, *Tensions between the Early and the Late Universe*, *Nature Astron.* **3** (2019) 891 [1907.10625].
- [236] G. Efstathiou, *A Lockdown Perspective on the Hubble Tension (with comments from the SHOES team)*, [2007.10716].
- [237] L. Knox and M. Millea, *Hubble constant hunter’s guide*, *Phys. Rev. D* **101** (2020) 043533 [1908.03663].
- [238] S. Vagnozzi, *New physics in light of the H_0 tension: An alternative view*, *Phys. Rev. D* **102** (2020) 023518 [1907.07569].
- [239] E. Di Valentino, O. Mena, S. Pan, L. Visinelli, W. Yang, A. Melchiorri et al., *In the Realm of the Hubble tension – a Review of Solutions*, [2103.01183].
- [240] B. Audren, J. Lesgourgues, K. Benabed and S. Prunet, *Conservative Constraints on Early Cosmology: an illustration of the Monte Python cosmological parameter inference code*, *JCAP* **1302** (2013) 001 [1210.7183].
- [241] T. Brinckmann and J. Lesgourgues, *MontePython 3: boosted MCMC sampler and other features*, [1804.07261].
- [242] A. G. Riess, S. Casertano, W. Yuan, J. B. Bowers, L. Macri, J. C. Zinn et al., *Cosmic Distances Calibrated to 1% Precision with Gaia EDR3 Parallaxes and Hubble Space Telescope Photometry of 75 Milky Way Cepheids Confirm Tension with Λ CDM*, [2012.08534].
- [243] P. Elmfors, D. Grasso and G. Raffelt, *Neutrino dispersion in magnetized media and spin oscillations in the early universe*, *Nucl. Phys. B* **479** (1996) 3 [hep-ph/9605250].