Heavy neutral lepton (HNL) production searches at NA62

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Neutrino Minimal Standard Model

- SM extension accounting for baryon asymmetry of universe (BAU), dark matter (DM), neutrino masses and oscillations
- 3 additional right-handed, singlet, Majorana HNLs (not observed yet)
- \( N_\nu \) mass 0(10 keV/c)
- Good DM candidate
- \( N_{e,\mu} \) mass 0(1 GeV/c) [2]
- \( B(K \to \mu N) \) depends on \( B_{\text{obs}}(K \to \mu N) \)
- HNL-lepton coupling \( U_{\nu \ell} \), and kinematic factor [2]

Previous measurements

- Production searches:
  - Look for peaks in missing mass distribution
  - Decay-model independent
  - Sensitive to long-lived HNLs
- Previous measurements in \( K \to \mu N \)
- 90% CL upper limits (UL) on HNL-muon coupling \( U_{\mu N} \):
  - KEK B000 (1982) [3]: (10\(^{-9}\), 10\(^{-8}\)) for \( m_{\mu} \) in (70, 300) MeV/c\(^2\)
  - BNL E949 (2015) [4]: (10\(^{-9}\), 10\(^{-8}\))
  - NA62 (2017) [5]: (2x10\(^{-9}\), 10\(^{-8}\)) for \( m_{\mu} \) in (300, 375) MeV/c\(^2\)

HNL production searches at NA62

- Fixed-target experiment at CERN SPS:
  - SPS 400 GeV/c p beam onto Be target → 75 GeV/c \( K^+ \)
  - In-flight \( K \) decays in 60 m long fiducial volume (FV) [1]
  - Data taking (2015-2018) with possibility to extend beyond 2021
  - Measure \( B(K \to \mu N) \) with 20% precision to study CKM matrix element \( V_{\mu N} \)
  - Perform hidden sector searches in presence of \( K \) (axions, dark photons, HNLs)

Event selection

- One positive track with momentum in (5, 70) GeV/c, in time with kaon
- No activity in photon veto systems
- Positrons and muons identified through energy-momentum ratio [1]

Data-MonteCarlo comparison

- Squared missing mass: \( m^2_{\text{miss}} = (\vec{P} - \vec{P}_\mu)^2 \) (SM \( K \to \mu N \) peak at \( m_{\text{miss}} = 0 \))
- HNL signal regions:
  - \( 170 < m_{\mu} < 448 \) MeV/c\(^2\) for \( K \to eN \) and \( 250 < m_{\mu} < 373 \) MeV/c\(^2\) for \( K \to \mu N \) [1]

Technique, results and future prospects

- Mass scans performed in HNL signal regions with step size of 1 MeV/c\(^2\)
- For each HNL mass hypothesis, background evaluated from sidebands of data
  - No statistically significant HNL production signal observed
  - UL on \( B(K \to \mu N) \) established for each HNL mass hypothesis
  - UL on coupling computed from UL on \( BR \)
  - UL on \( |U_{\mu N}|^2 \) is (10\(^{-9}\), 10\(^{-8}\)) for \( m_{\mu} \) in (170, 448) MeV/c\(^2\) and on \( |U_{\mu N}| \) in (10\(^{-9}\), 10\(^{-8}\)) for \( m_{\mu} \) in (300, 373) MeV/c\(^2\) [1]
- Results improve world existing limits on HNL production searches on \( |U_{\mu N}| \)
  - (over whole mass range) and on \( |U_{\mu N}| \) (for masses above 300 MeV/c\(^2\))
- 2016-2018 data collected by NA62 much larger than 2015 sample
- Opportunity to further improve existing limits on \( |U_{\mu N}| \) and \( |U_{\mu N}| \)


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