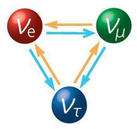
Search for heavy neutral lepton production at the NA62 experiment

Elisa Minucci on behalf of the NA62 Collaboration

Why looking for Heavy Neutral Leptons (HNLs)?

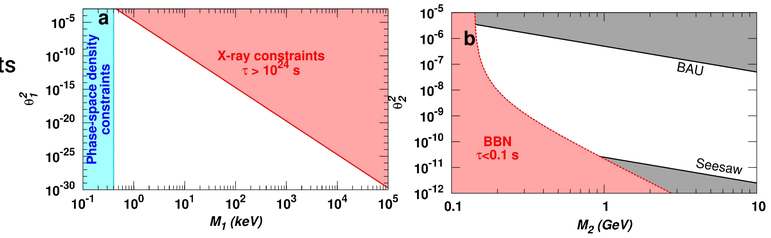
Open theoretical issues such as **non-zero neutrino masses, baryon asymmetry, dark matter** find a solution in **Standard Model extention** adding right-handed (sterile) neutrinos (mixing with SM flavor states).



A simple model: **νMSM** introduces 3 right-handed neutrinos N_i where N_1 mass is expected O(10) keV/c^2 (DM candidate) and $N_{2,3}$ masses O(1)GeV/c^2 (additional CPV-phases to account for baryon asymmetry)

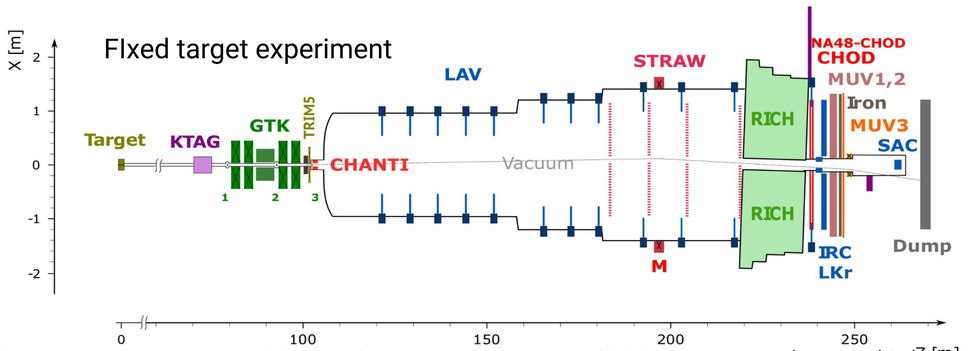
[Ann.Rev.Nucl.Part.Sci.59 (2009) 191

Astrophysical and cosmological constraints on M_i



The NA62 experiment at CERN SPS

- **Main goal: measure the ultra-rare $K^+ \to \pi^+ \nu\bar{\nu}$ with 10% precision.**
- **Data taking period 2016-2018**



- **High beam intensity**
  primary p^+ beam 400 GeV/c onto a Be target → selected 75 GeV/c secondary beam (750MHz with K^+(6%)/π^+/p^+)
- Overall experimental **time resolution** reaches **O(100)ps**

Tracking

K^+ 3-momentum measured by Si pixel beam spectrometer GTK.

Downstream track 3-momentum measured by a STRAW tubes spectrometer

Particle Identification

K^+tagged by KTAG (70ps time resolution)

Downstream tracks: $\pi^+/\mu^+/e^+$ identified using RICH and calorimeters LKr, MUV1, MUV2

Muon ID is provided by MUV3 placed behind iron wall

Photon veto

Photons can be vetoed by LKr and by LAV at large angles or by SAC/IRC at small angles

Trigger

Hardware L0 trigger (1MHz rate), Software L1 trigger (1 kHz rate)
Several trigger chains running in parallel

HNLs production in Kaon decays

Master formula:

$$\Gamma(K^+ \to l^+ N) = \Gamma(K^+ \to l^+ \nu) \times \rho_l(m_N) \times |U_{l4}|$$

- HNL prod. is enhanced kinematically wrt SM decays
- Helicity suppression relaxed in the $K \to eN$ case: factor $O(10^5)$ enhancement

$\Gamma(K^+ \to l^+ \nu)$ →width of K^+ SM leptonic decay

[R.Shrock, Phys.Rev D24 (1981) 1232]

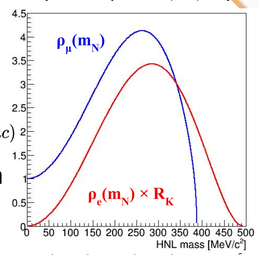
$\rho_l(m_N)$ → kinematic factor

$$\rho_l(m_N) = \frac{(x+y)-(x-y)^2}{x(1-y)^2} \times \sqrt{\lambda(1,x,y)}$$

$$x = (m_l/m_K)^2,\ y = (m_N/m_K)^2$$

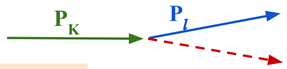
$$\lambda(a,b,c) = a^2 + b^2 + c^2 - 2(ab + bc + ac)$$

$|U_{l4}|$ → mixing matrix elemen

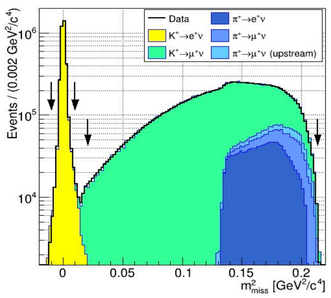


$R_K = \Gamma(K^+ \to e^+\nu)/\Gamma(K^+ \to \mu^+\nu) \sim O(10^{-5})$

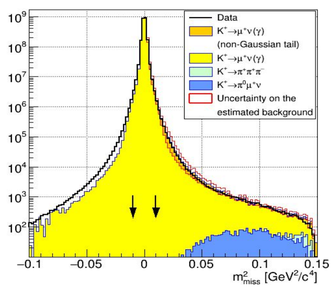
Analysis strategy



Peak search in $m^2_N = m^2_{miss} = (P_K - P_l)^2$

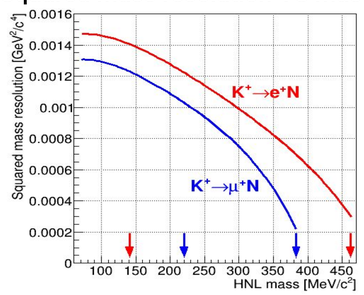


e-mode
$N_K = (3.52 \pm 0.02) \times 10^{12}$



μ-mode
$N_K = (4.29 \pm 0.02) \times 10^9$

Squared mass resolution VS mass



Selection for each m_N includes a "mass window" condition: $|m-m_N|<1.6\sigma$

Bkg is proportional to mass resolution

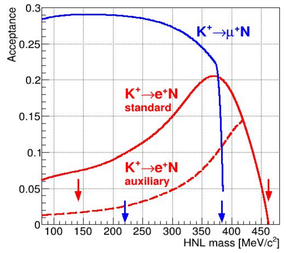
Resolution crucial to resolve possible m_N splitting

Single Event Sensitivity

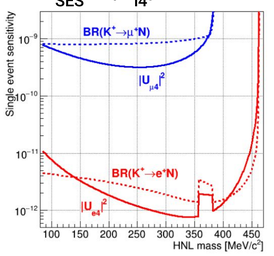
$$Br_{SES} = 1/(N_K \times A)$$

$$|U_{l4}|^2 = Br_{SES} / [Br(K^+ \to l^+\nu) \times \rho_l(m_N)]$$

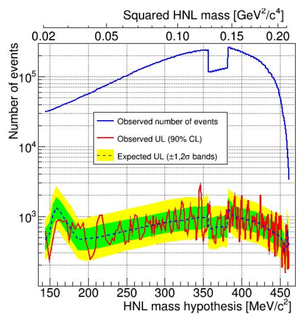
Acceptance VS mass

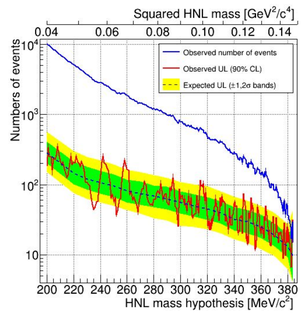


Br_{SES} & $|U_{l4}|^2$ VS mass

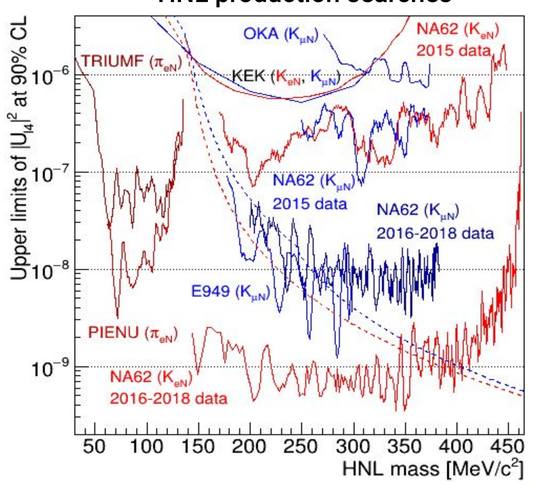


Upper Limits on $Br(K^+ \to l^+ N)$





HNL production searches



[Phys. Lett. B 807 (2020) 135599]
[Phys. Lett. B 816 (2021) 136259]