SEARCH FOR EXOTIC DECAYS WITH NA62

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NA62 Experiment

- Fixed-target experiment at CERN SPS (north area).
- Main goal: measure ultra-rare $K^+ \to \pi^+\nu\bar{\nu}$ with 10% precision.

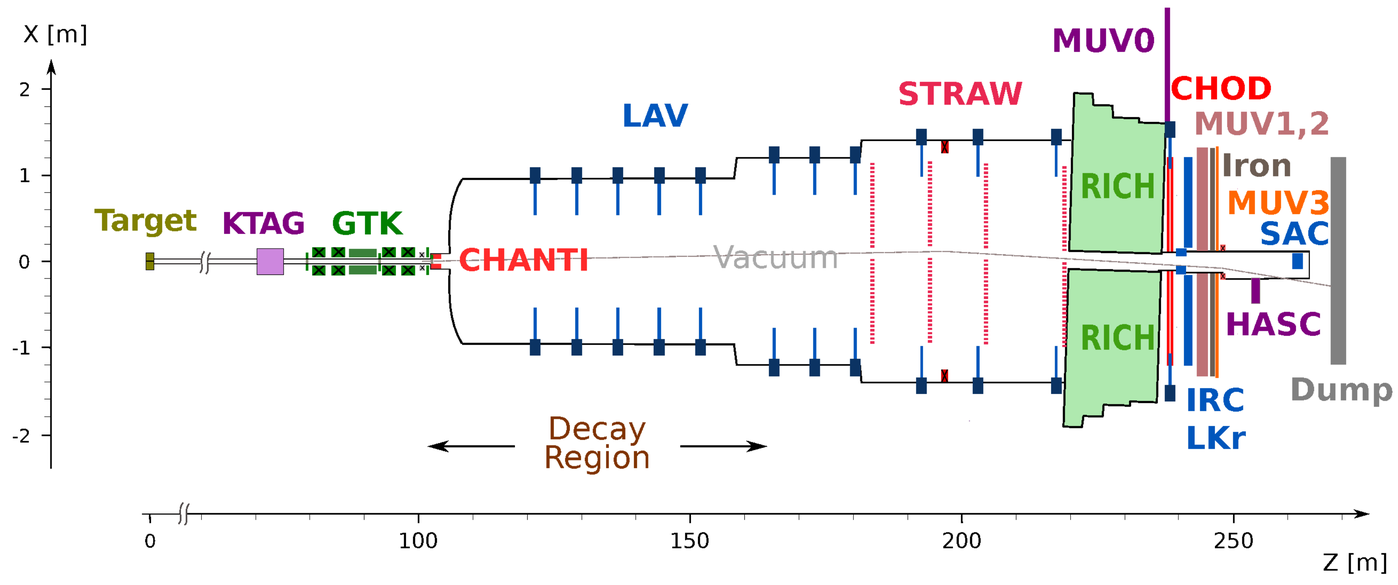

Figure 1: NA62 experimental setup.

- Primary p^+ beam 400 GeV/c impinges Be target, set of apertures (TAX) selects 75 GeV/c secondary beam (750 MHz with $\sim 6\%$ of K^+).
- K^+ tagged by KTAG (70 ps time resolution) and 3-momentum determined by Si pixel beam spectrometer GTK.
- K^+ decay-in-flight in 60 m long decay region.
- Decay products' 3-momenta are measured by STRAW tracker. RICH identifies π^+ and further hadron ID is given by combination of calorimeters LKr, MUV1, MUV2.
  Muon ID is provided by MUV3 placed behind iron wall.
- Photons can be vetoed by LKr and by LAV at large angles or by SAC/IRC at small angles.
- Overall experimental time resolution reaches $\mathcal{O}(100)$ps.
- Data-taking period 2016-2018:
  2016 results published [1], 2017 and 2018 data analysis ongoing.
  Next data-taking period starts 2021.

Dark sector searches at NA62

Thanks to high energy primary beam, hermetic detector system and the first-rate timing resolution allowing collecting of large statistics NA62 is competitive in the search for BSM particles (HNL, dark photons, ALPs). Dark sector searches can be performed at NA62 in three different ways:

- K^+ decays into weakly interacting exotics (search for bump in missing invariant mass).
- Non-interacting p^+ from primary beam can interact in copper front of TAX and produce weakly interacting exotics. If these reach the decay volume and decay out of the main beam they can be recorded using dedicated 'parasitic' trigger running simultaneously with the main kaon trigger.
- 'Beam-dump (BD) mode': beryllium target is removed and primary beam is impinged directly onto TAX (cannot be operated simultaneously with kaon physics mode).

Heavy neutral leptons (HNL)

νMSM introduces 3 additional right-handed neutrinos N_i in order to explain the baryon asymmetry and SM neutrino masses, where the lightest N_1 mass is expected $\mathcal{O}(10)$ keV/c^2 (DM candidate) and $N_{2,3}$ masses $\mathcal{O}(1)$ GeV/c^2.

Search for HNL in decays $K^+ \to \mu^+ N$ and $K^+ \to e^+ N$ measured during 2015 commissioning run at NA62 led to new exclusion limit in the ($|U_{l4}|^2$,HNL mass) plane shown in fig.2.

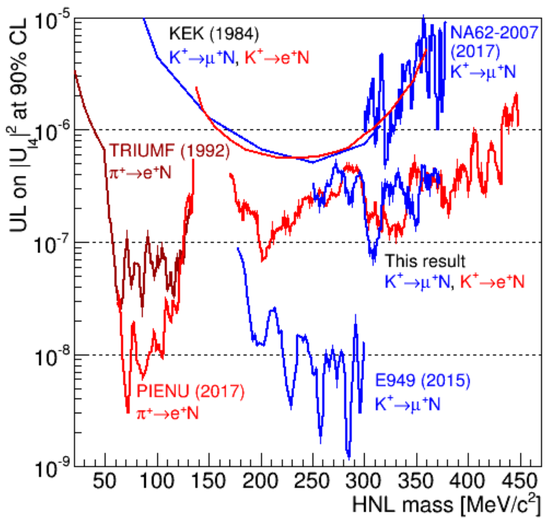

Figure 2: NA62 result for HNL exclusion limits (@90% CL) from 2015 data sample [2].

Major improvement (by factor $\mathcal{O}(100)$) from 2016-2017 datasets is expected.

Axion-like particles (ALP)

General pseudoscalar (in most models pNGB after SSB of axial U(1)) with possible coupling to all SM fields.

Charged lepton final states (e.g. $ALP \to \mu\mu$) can be searched in the 'parasitic mode'.

Case of predominant coupling to γ must be searched in 'Beam-dump mode' (no charged particles in decay volume allowed), where dominant ALP production at TAX is via Primakoff effect with decay $ALP \to \gamma\gamma$ in decay volume. For expected NA62 sensitivity see fig.3.

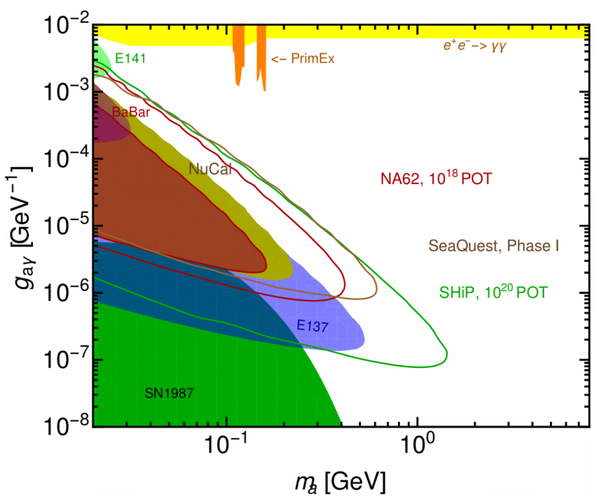

Figure 3: NA62 prospect on sensitivity (@90% CL) at 10^{18} *POT* ($\sim$ 3 months of data-taking) in 'Beam-dump mode' for ALPs coupled to 2γ [3].

Dark photons (DP)

DP A' is gauge boson introduced with additional U(1) symmetry and would mix with SM photon in interaction $\mathcal{L}_{int} \sim \frac{\epsilon}{2\cos(\theta_W)} F'_{\mu\nu} B^{\mu\nu}$, where ϵ is the kinetic mixing.

Search for DP at NA62 in 'kaon physics mode' in decay chain $K^+ \to \pi^+\pi^0$ and $\pi^0 \to \gamma A'$ resulted in exclusion shown in fig.4.

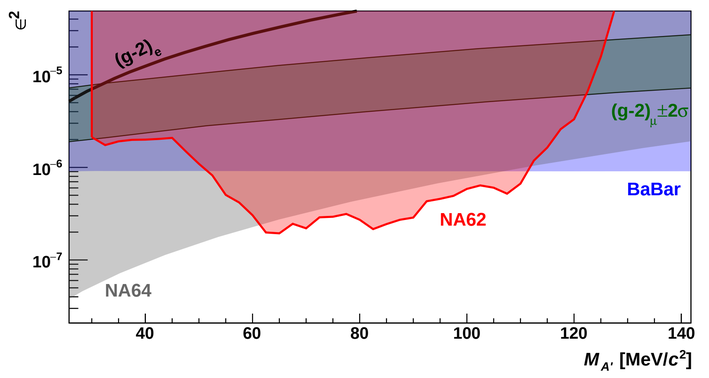

Figure 4: NA62 result for DP exclusion limits (@90% CL) from decay $\pi^0 \to \gamma A'$ [4].

Study of DP production via other meson decays (D, η, η', ϕ, ρ, ω) and in Bremsstrahlung-production directly at the beryllium target will be performed in the future, for expected sensitivity see fig.5.

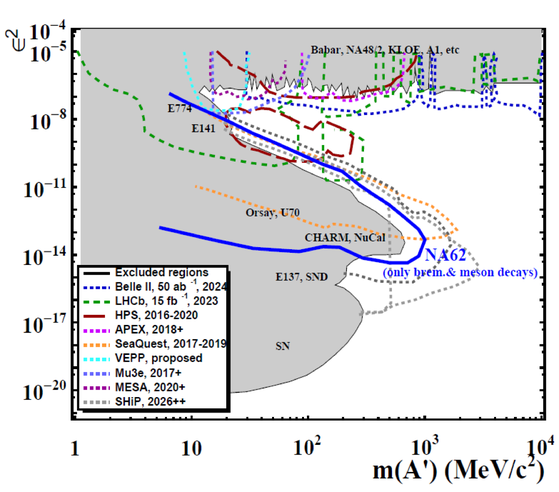

Figure 5: NA62 prospect on sensitivity (@90% CL) for DP (based on DP production at Be target for 10^{18} *POT* from meson decays and Bremsstrahlung).

References

[1] First search for $K^+ \to \pi^+\nu\bar{\nu}$ using the decay-in-flight technique. NA62 Collaboration. Phys. Lett. B **791** (2019). arXiv:1811.08508 [hep-ex].
[2] Search for heavy neutral lepton production in K^+ decays. NA62 Collaboration. Phys. Lett. B **778** (2018). arXiv:1712.00297 [hep-ex].
[3] Light in the beam dump. ALP production from decay photons in proton beam-dumps. B. Döbrich, J. Jaeckel, T. Spadaro. JHEP 1905 (2019) 213. arXiv:1904.02091 [hep-ph].
[4] Search for production of an invisible dark photon in π^0 decays. NA62 Collaboration. JHEP 1905 (2019) 182. arXiv:1903.08767 [hep-ex].

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