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ON BEHALF OF THE NA62 COLLABORATION

THE NA62 EXPERIMENT AT CERN: STATUS AND RECENT RESULTS
THE NA62 COLLABORATION

~30 institutes, ~200 participants form:

Birmingham, Bratislava, Bristol, Bucharest, CERN, Dubna, Fairfax, Ferrara, Firenze, Frascati, Glasgow, Liverpool, Louvain, Mainz, Merced, Moscow, Napoli, Perugia, Pisa, Prague, Protvino, Roma I, Roma II, San Luis Potosi, Sofia, Torino, TRIUMF, Vancouver UBC

NA62 experiment is located at north area (NA) of CERN. Protons are extracted from the SPS with p=400 GeV/c producing a secondary beam of hadrons (~6% are kaons).

Main goal is to measure the $K^+ \rightarrow \pi^+ \nu \nu$ branching fraction with high precision.
MOTIVATION

- Ultra rare kaon decay with very clean theoretical prediction within the SM framework:
  \[ BR(K^+ \rightarrow \pi^+ \nu \bar{\nu}) = (9.11 \pm 0.72) \times 10^{-11} \]
  Buras et al., JHEP 1511 (2015) 033

- The only experimental measurement from E787/E949 has large uncertainty:
  \[ BR(K^+ \rightarrow \pi^+ \nu \bar{\nu}) = (1.73^{+1.15}_{-1.05}) \times 10^{-10} \]

- Sensitive to new physics effects... (see next slide)
BEYOND THE SM

- Models with general LH and RH NP couplings
- Models obeying CMFV
- Constraint from $\epsilon_K$ if only RH or LH couplings are present
• Kaon ID and direction (KTAG, GTK, CHANTI)

• Pion ID and direction (STRAW, CHOD, RICH)

• Photon veto (LAV, LKr, IRC, SAC)

• Muon veto (MUV1,2,3)
DATA COLLECTION

- 2015: minimum bias (~1% intensity) and test data: most systems commissioned and meet the design requirement

- 2016: 3 May - 14 Nov. (~40% of nominal intensity). Focused on the main decay mode \( K^+ \rightarrow \pi^+ \nu \nu \), but can be used also for other rare/forbidden decays: \( K^+ \rightarrow n \ell \ell \) \((\ell = e, \mu)\), \( \pi^0 \rightarrow \nu \nu \), \( K^+ \rightarrow l^+ N \), \( K^+ \rightarrow \pi^+ A' \),...

- 2017: data taking started in May

- 2018: data taking approved
**THE STRATEGY**

NA62 is expected to collect $O(100)$ SM events with $<20\%$ background in three years of data taking $\Rightarrow$ must have order of $10^{12}$ background rejection:

- Isolate signal decays based on missing mass (high rejection by kinematics)
- Use veto to reject other background

\[
M_{miss}^2 = (P_K - P_\pi)^2
\]
**SIGNAL REGIONS**

- Design kinematical resolution on $m_{\text{miss}}^2$ has been achieved ($10^{-3}$ GeV$^2$/c$^4$)

- Measured kinematical background suppression: $6 \times 10^{-4}$ ($K^+ \rightarrow \pi^+\pi^0$), $3 \times 10^{-4}$ ($K^+ \rightarrow \mu^+\nu$)

- Further background suppression:
  - PID (calorimeters/cherenkov detectors): $\mu$ suppression $< 10^{-7}$
  - Hermetic photon veto: $\pi^0 \rightarrow \gamma\gamma$ suppression $< 10^{-7}$
PRELIMINARY RESULTS

- 5% of 2016 data: $2.3 \times 10^{10}$ kaon decays
- No events found in the signal regions
- Expect 1.3 SM events from full 2016 data set
- Preliminary statements on background: B/S < 0.9
- Analysis in progress to increase signal acceptance and improve background suppression
2016 DATA BEYOND THE “GOLDEN” MODE

- Dedicated triggers for 3-track decays with leptons
- Expect to improve world limits on LFV/LNV $K^+$ and $\pi^0$ decays
SEARCH FOR HEAVY NEUTRINO WITH 2015 DATA
WHY DO WE NEED HNL?

Neutrino oscillation

Baryon asymmetry of the Universe

Dark matter and dark energy

\[ \nu_{\text{MSM}}: \text{SM} + 3 \text{ right-handed neutrinos} \]

\[ m_1 \sim 10 \text{ keV} \]

\[ m_{2,3} \sim 100 \text{ MeV} - 100 \text{ GeV} \]

T. Asaka and M. Shaposhnikov


There is new physics beyond the Standard Model, but we don’t know exactly what is it.
**HOW TO FIND HNL?**

- **Meson decays**

  Search for extra peaks in lepton distributions (momentum, energy, missing mass, ...)

  \[
  \Gamma(M^+ \rightarrow l^+ \nu_H) = \rho \times \Gamma(M^+ \rightarrow l^+ \nu_l) \times |U_{lH}|^2
  \]


- **Heavy neutrino decays**

  "Nothing" $\rightarrow$ leptons and hadrons

  \[
  \nu_H \rightarrow e^+ e^- \nu_\alpha, \nu_H \rightarrow \mu^\pm e^\mp \nu_\alpha, \nu_H \rightarrow \mu^+ \mu^- \nu_\alpha,
  \]

  \[
  \nu_H \rightarrow \pi^0 \nu, \pi e, \pi \mu, K e, K \mu, ...
  \]
DATA SAMPLE

- Minimum bias (~1% intensity) in 2015
- Kaon decays in FV: \((3.01 \pm 0.11) \times 10^8\)
- Beam tracker is not available: kaon momentum is estimated as beam average
PEAK SEARCH

- Scan region $170 < m < 448$ MeV/c$^2$, mass step = 1 MeV/c$^2$
- Signal search window for each mass hypothesis $\pm 1.5\sigma$
- Background estimate: polynomial fit outside signal window
- Background stat. errors are estimated with MC
- Upper limit for each mass is obtained from numbers of observed and expected events and their uncertainties
RESULTS

Local signal significance never exceeds 3\(\sigma\): no heavy neutrino signal is observed
RESULTS

- Reached $10^{-6} - 10^{-7}$ limits on $|U_{e4}|^2$ in the 170–448 MeV/c$^2$ mass range
- Major improvements are expected with high intensity 2016 data
CONCLUSION

- Detector is fully operated since Sept. 2016 and data is taking now @50% of nominal intensity
- \( \sim 10^{11} \) kaon decays has already collected in 2016
- The \( K^+ \rightarrow \pi^+ \nu\nu \) is on-going and \( O(1) \) SM events are expected from total 2016 data sample
- First physics result from 2015 minimum bias data: search for heavy neutrino production in \( K^+ \rightarrow e^+N \) decays in mass range 170–448 MeV/c\(^2\): no observed signal, set upper limits at \( 10^{-6} \)–\( 10^{-7} \) level