NA62 experiment at CERN: status and recent results

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on behalf of the NA62 collaboration

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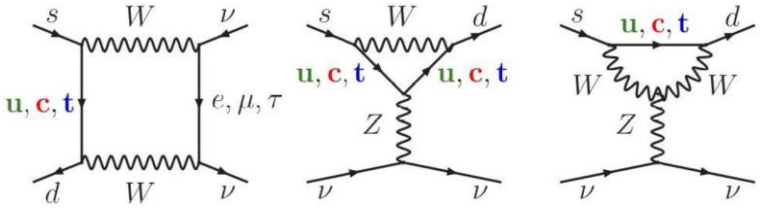
Motivation

- Very rare FCNC kaon decay, small and precisely calculated branching fraction

$$\mathcal{B}(K^+ \to \pi^+ \nu\bar{\nu}) = (9.11 \pm 0.72) \times 10^{-11}$$



- Branching fraction measured at BNL

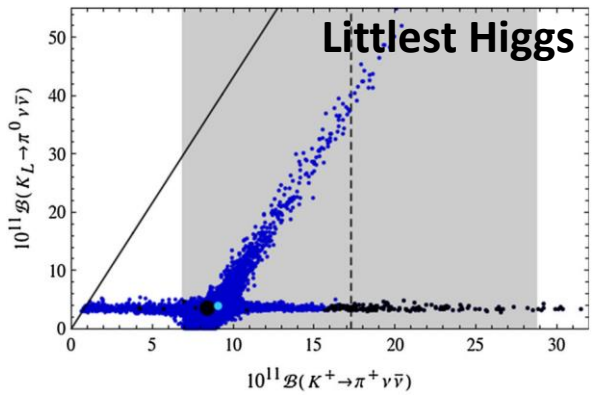
$$\mathrm{BR}(K^+ \to \pi^+ \nu\bar{\nu}) = (1.73\ ^{+1.15}_{-1.05}) \times 10^{-10}$$

BNL E787/E949: PRL101 (2008) 191802

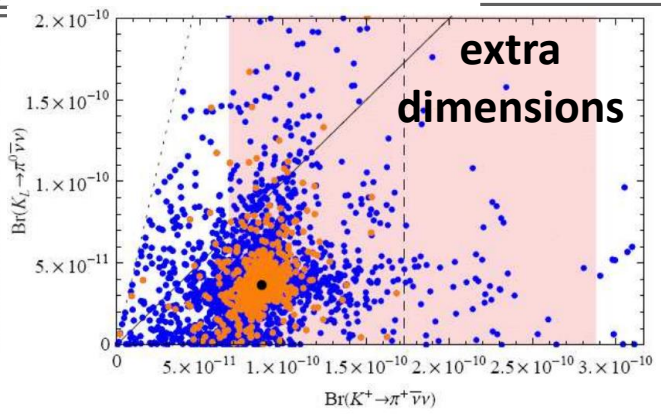
- Branching fraction sensitive to new physics effects …

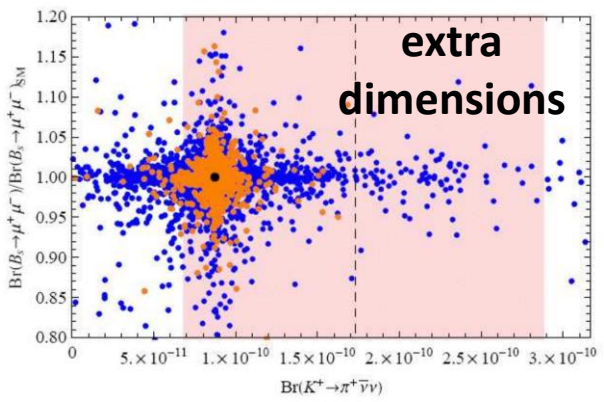
… and is correlated to other flavour observables

EPJ C76 (2016) no.4 182



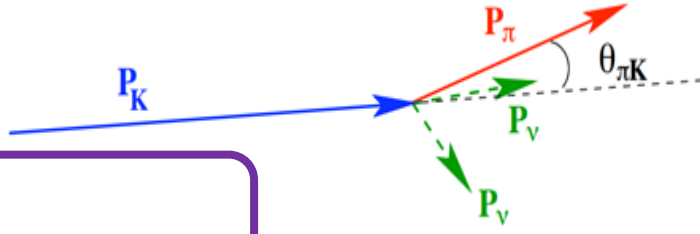
JHEP 0903 (2009) 108





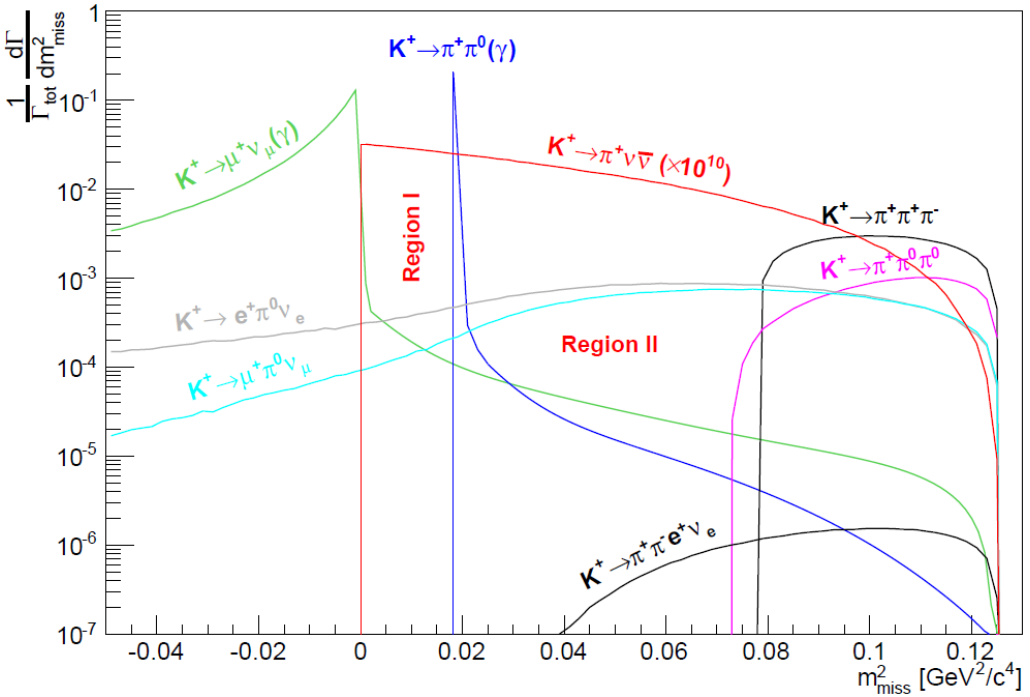
Measurement strategy

- NA62 is designed to measure the branching fraction at the 10% level …
  - Must have order of 10^{13} Kaon decays in the fiducial volume of the experiment
- … while keeping B/S at the ~0.2 level
  - Must have order of 10^{-12} background rejection
- Isolate signal decays based on **missing mass**
- **Dedicated 'vetoing' detectors** to remove background events

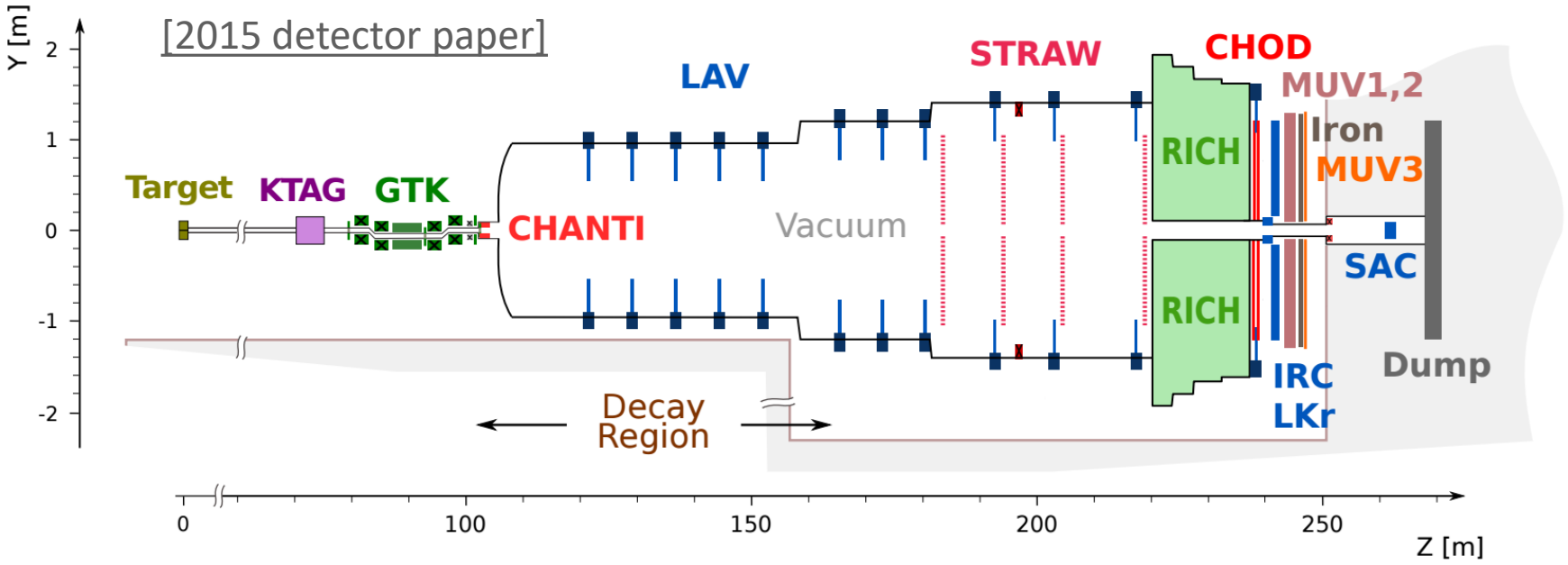


Decay backgrounds

Mode	BR
$\mu^+\nu(\gamma)$	63.5%
$\pi^+\pi^0(\gamma)$	20.7%
$\pi^+\pi^+\pi^-$	5.6%
$\pi^0 e^+\nu$	5.1%
$\pi^0\mu^+\nu$	3.3%
$\pi^+\pi^- e^+\nu$	4.1×10^{-5}
$\pi^0\pi^0 e^+\nu$	2.2×10^{-5}
$\pi^+\pi^-\mu^+\nu$	1.4×10^{-5}
$e^+\nu(\gamma)$	1.5×10^{-5}



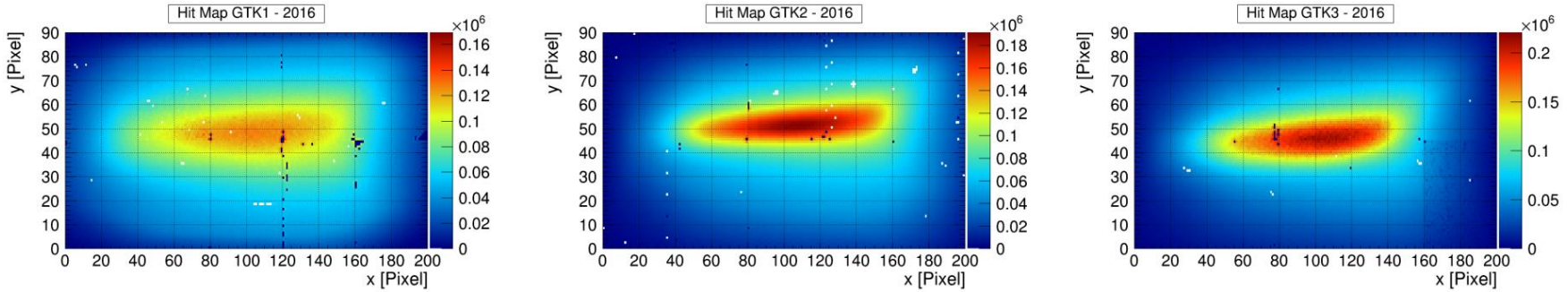
The NA62 detector



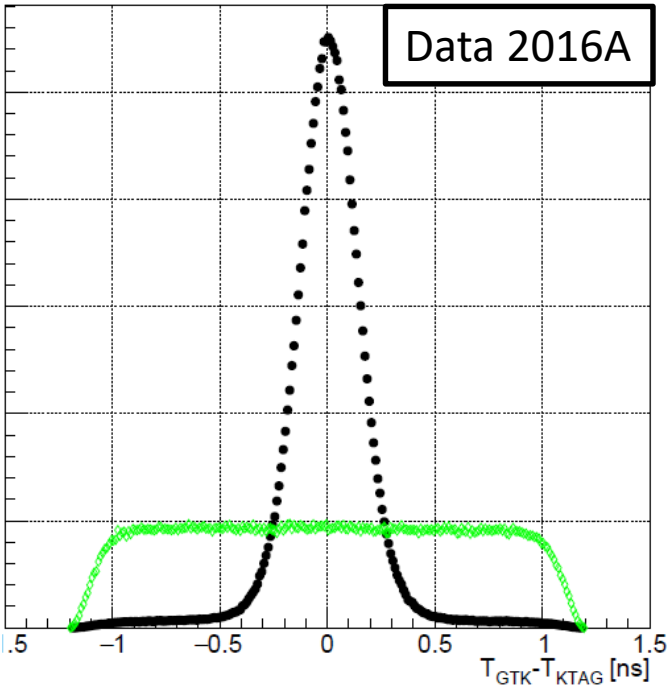
- **Principle detector systems**
  - **Kaon measurement and ID** (GTK, KTAG, CHANTI)
  - **Pion measurement and ID** (STRAW, CHOD, RICH)
  - **Photon vetoes** (LAV, IRC, SAC, LKR)
  - **Muon vetoes** (MUV system)
- In 2016 **5×10^{11} kaon decays** collected during **period A**
  2016A: 15th September – 4th November

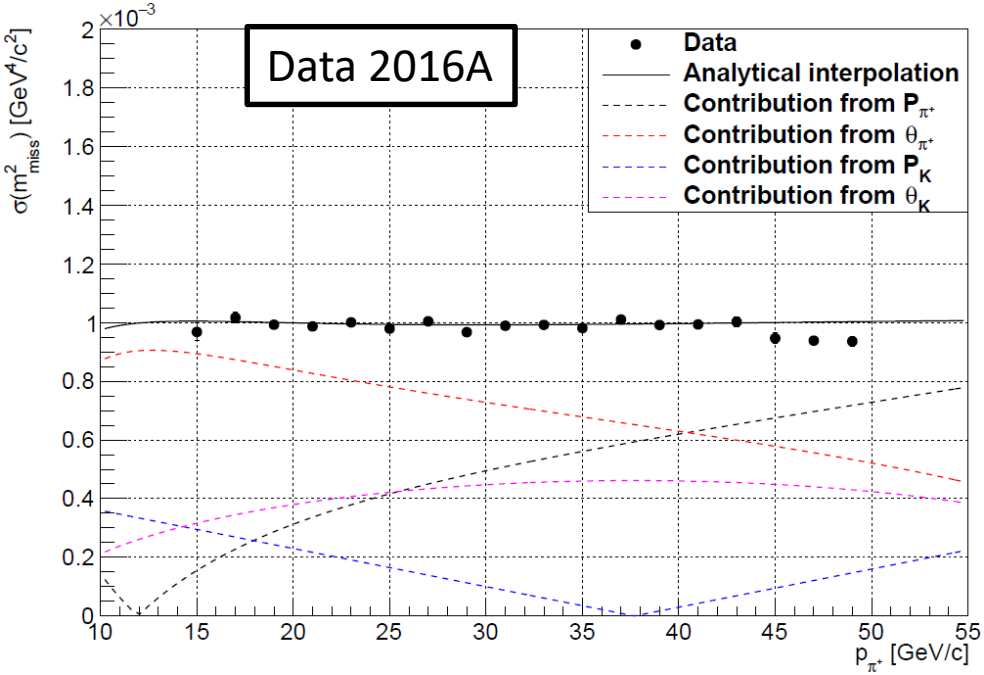
Performance of the GTK

- All GTK stations fully operational during 2016 Period A



- Time and m^2_{miss} resolution at design level (~130ps, ~0.001GeV^4/c^2)



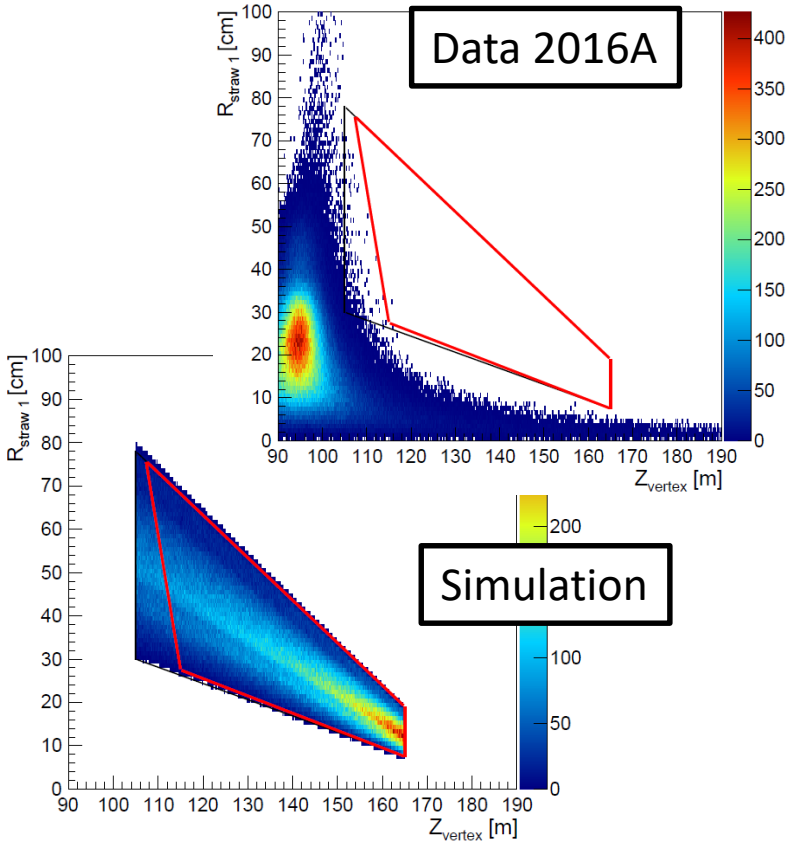


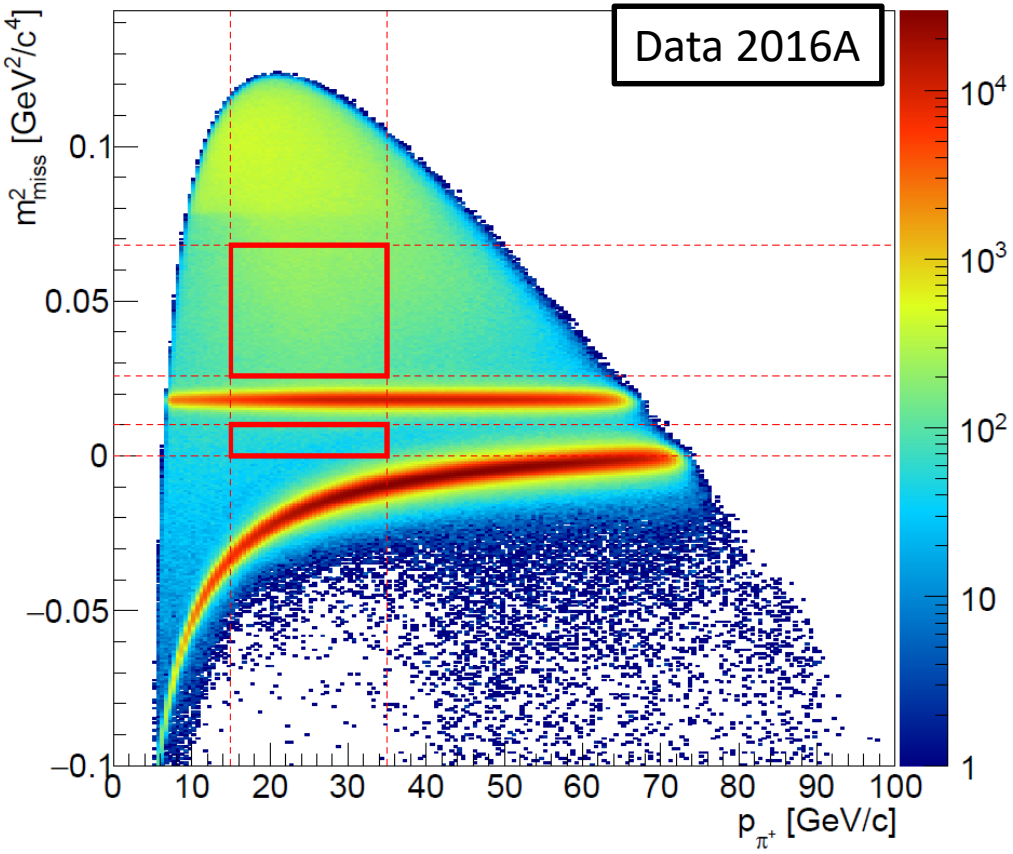
Signal regions

Fiducial regions are chosen to avoid background events:

- Position of Kaon decay inside vacuum decay volume …
  … with cut on pion position at first STRAW chamber to remove beam background

Search regions are defined in pion momentum and m^2_{miss}





Expected signal and background

- The expected number of signal events has been computed using $K^+ \to \pi^+\pi^0$ events collected via a control trigger using **5% of the 2016A** dataset

$$N_{\pi\nu\nu}^{exp} = D^{control} \cdot N_{\pi\pi}^{control} \cdot \frac{BR_{\pi\nu\nu}}{BR_{\pi\pi}} \cdot \frac{A_{\pi\nu\nu}}{A_{\pi\pi}} \cdot \epsilon^{trig} = 0.064$$

normalisation: $K^+ \to \pi^+\pi^0$

control trigger data passing the signal selection but the photon rejection

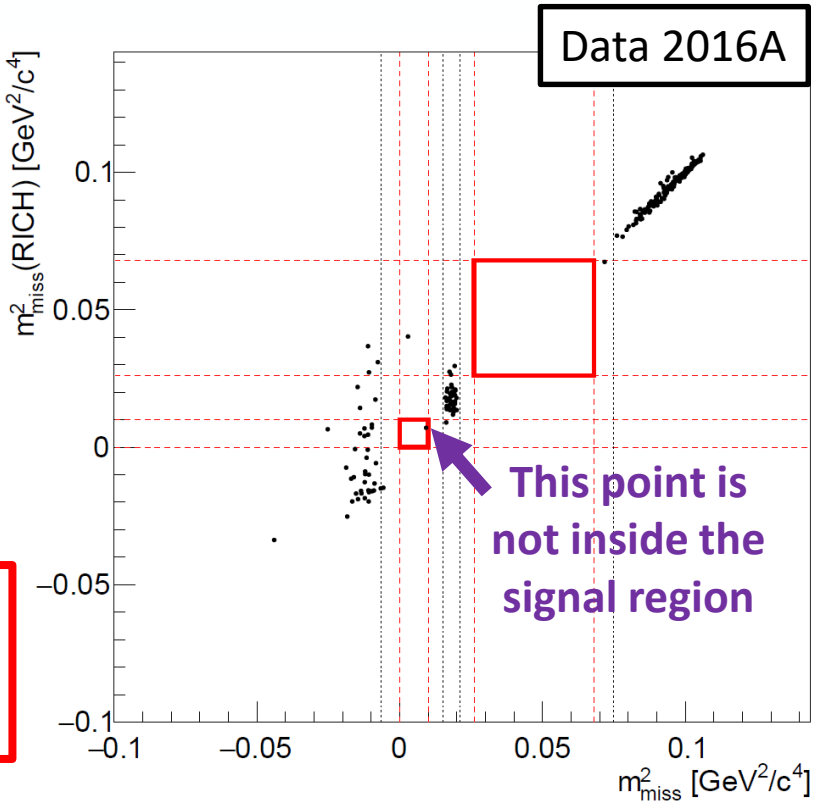
~ 0.6/0.86 from MC

~ 85% (preliminary) measured with data

- The background level from the three largest components is:

N($K^+ \to \pi^+\pi^0$)	**= 0.024**
N($K^+ \to \mu^+\nu$)	**= 0.011**
N($K^+ \to \pi^+\pi^+\pi^-$)	**= 0.017**
Total	**= 0.052**
Estimated B/S	**= 80%**

Many improvements in signal efficiency and background rejection expected in the near future

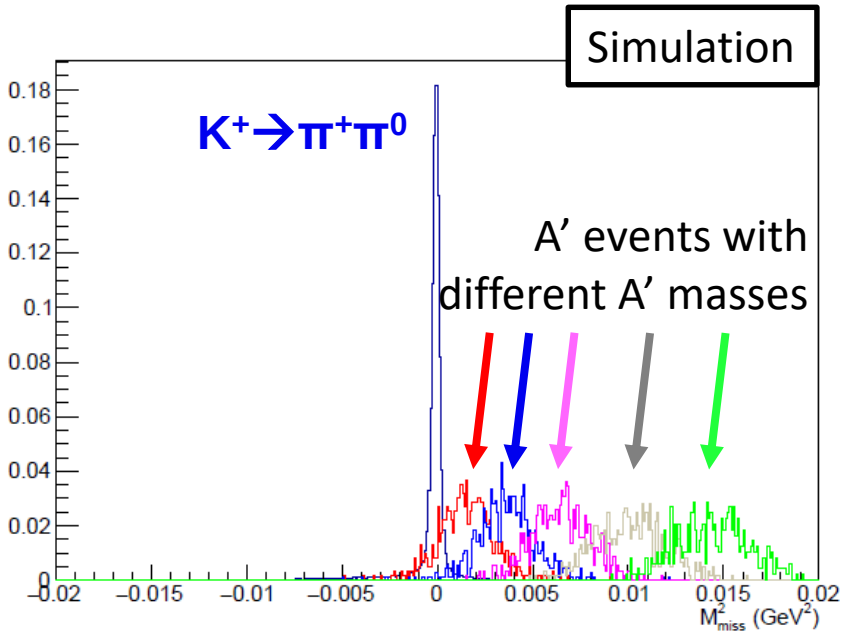


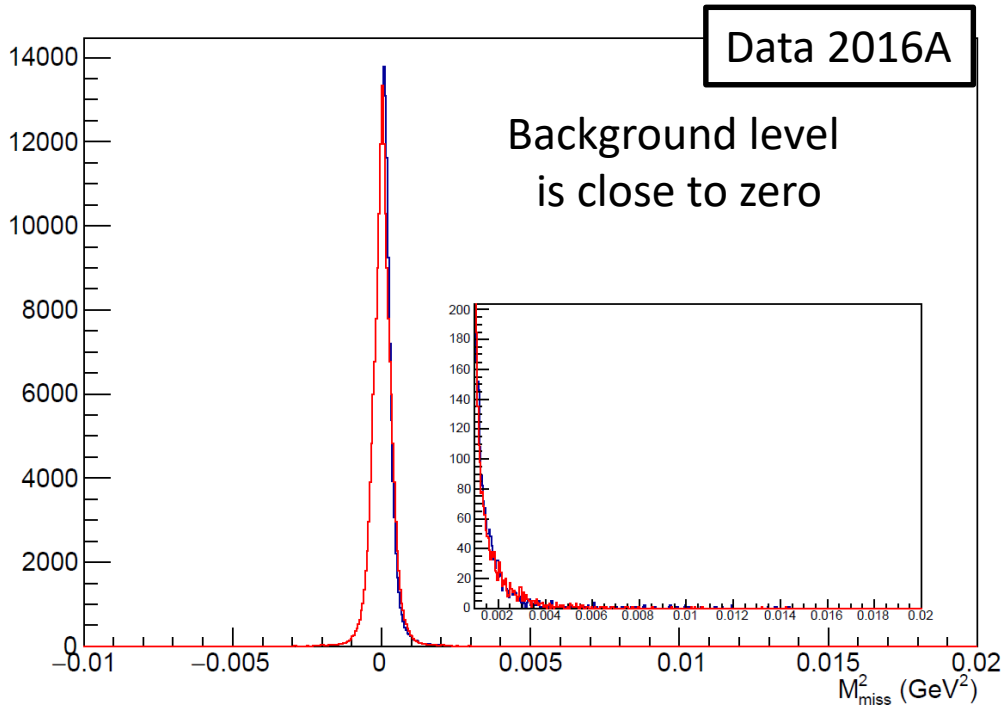
Search for invisible vector bosons

- SM extensions predict new U(1) gauge sector with **A'** mediating vector boson
- NA62 can search for **A'** in the decay **$K^+ \to \pi^+\pi^0$ with $\pi^0 \to A'\gamma$**

$$\mathrm{BR}\left(\pi^0 \to A'\gamma\right) = 2\epsilon^2 \left(1 - \frac{m_A^2}{m_{\pi^0}^2}\right)^3 \times \mathrm{BR}\left(\pi^0 \to \gamma\gamma\right)$$

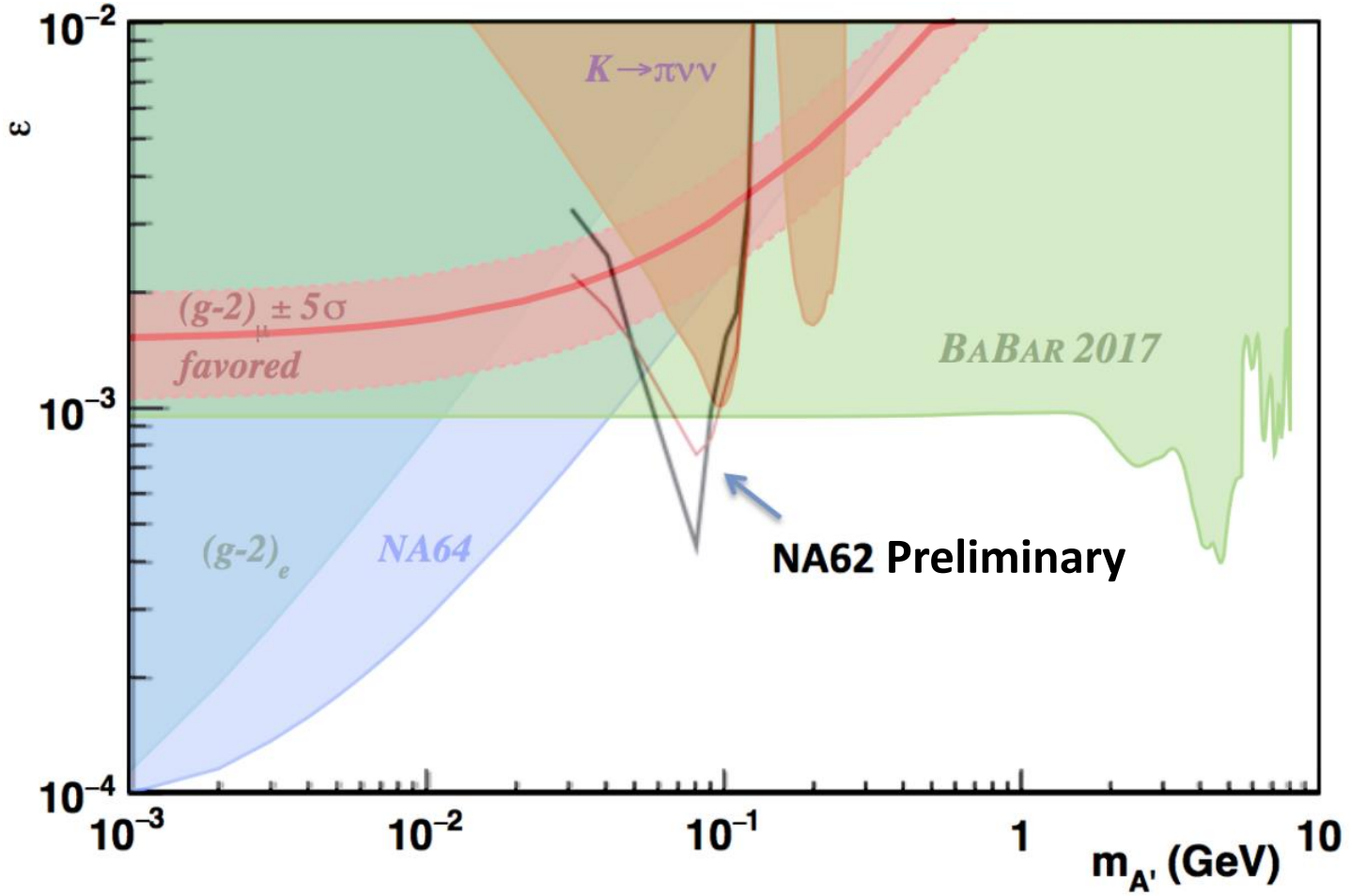
- Analysis strategy: peak search in missing mass: $M^2_{\mathrm{miss}} = (P_K - P_\pi - P_\gamma)^2$





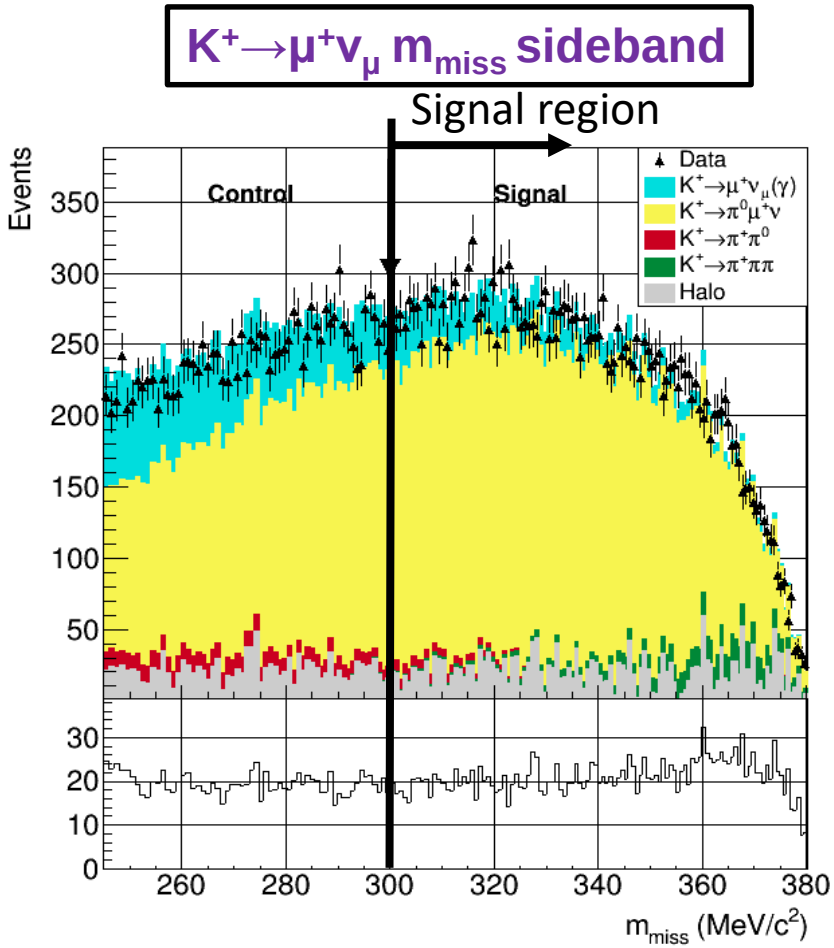
Search for invisible vector bosons

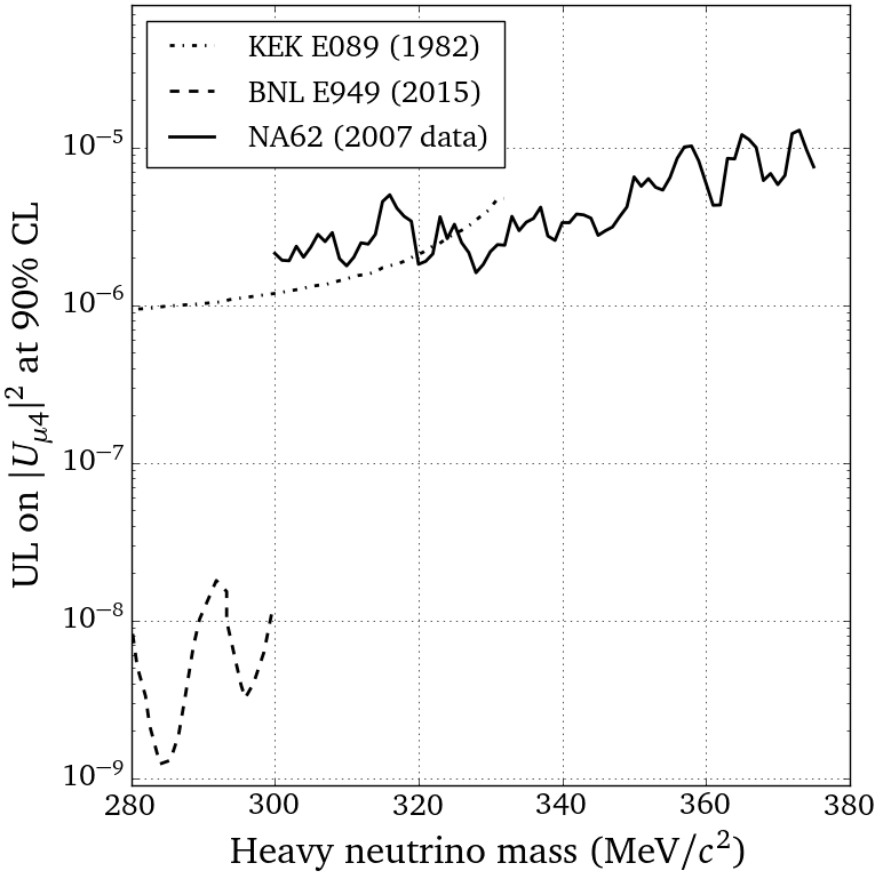
- Current experimental limits, 2016A dataset corresponding to **1.5x10^{10}** K^+ decays (3% of 5x10^{11} collected in 2016A)



Searches for heavy neutrino production

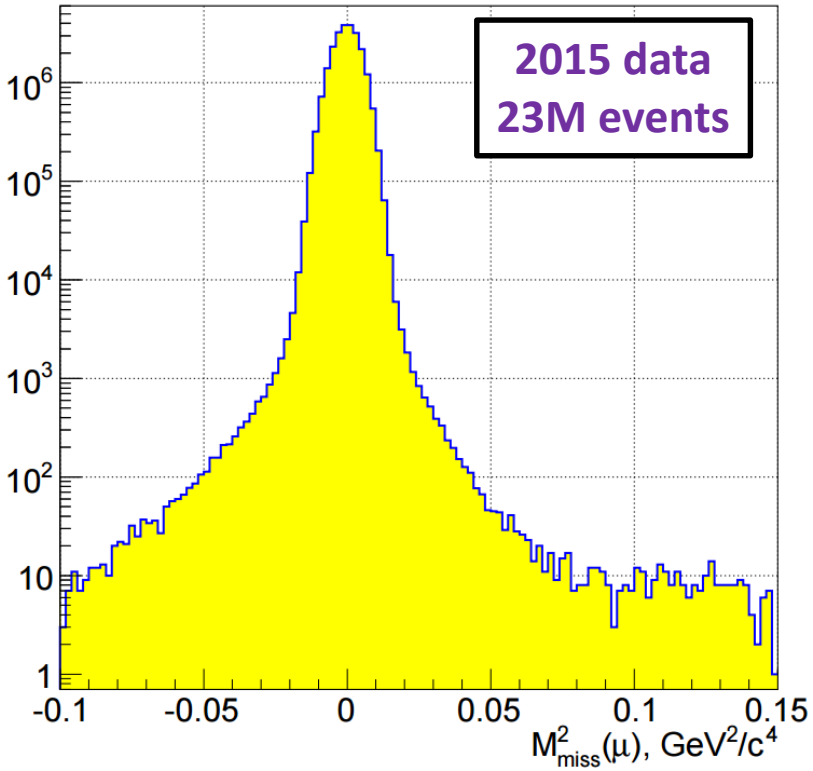
- In 2007 NA62 (with a different experimental setup) collected about **8M $K^+ \to \mu^+ \nu_\mu$** decays**,** with a **few hundred background events** in the signal region
- These events are used to set the worlds best limit on heavy neutrino production in the $325 < m_h < 375$ MeV/c^2 regions

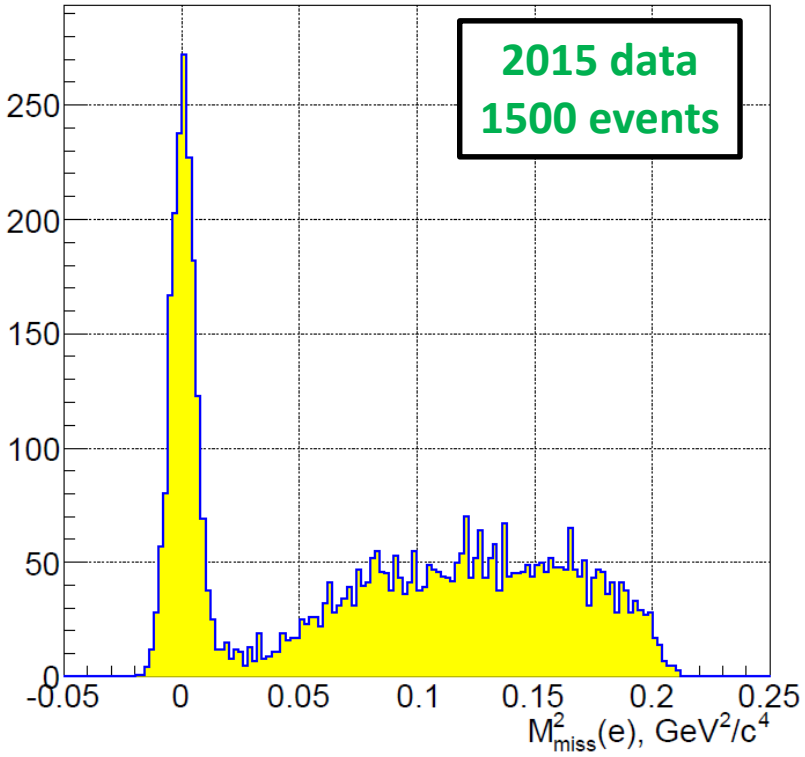




Searches for heavy neutrino production

- In 2015 NA62 collected five days of minimum bias data
- **Preliminary analysis of the data shows:**
  - Around **23M $K^+ \rightarrow \mu^+ \nu_\mu$ decays** (**1500 $K^+ \rightarrow e^+ \nu_e$ decays**) satisfy the trigger and selection criteria with a background level 100x lower than in NA62 2007
  - Can set worlds most stringent limits on heavy neutrino production



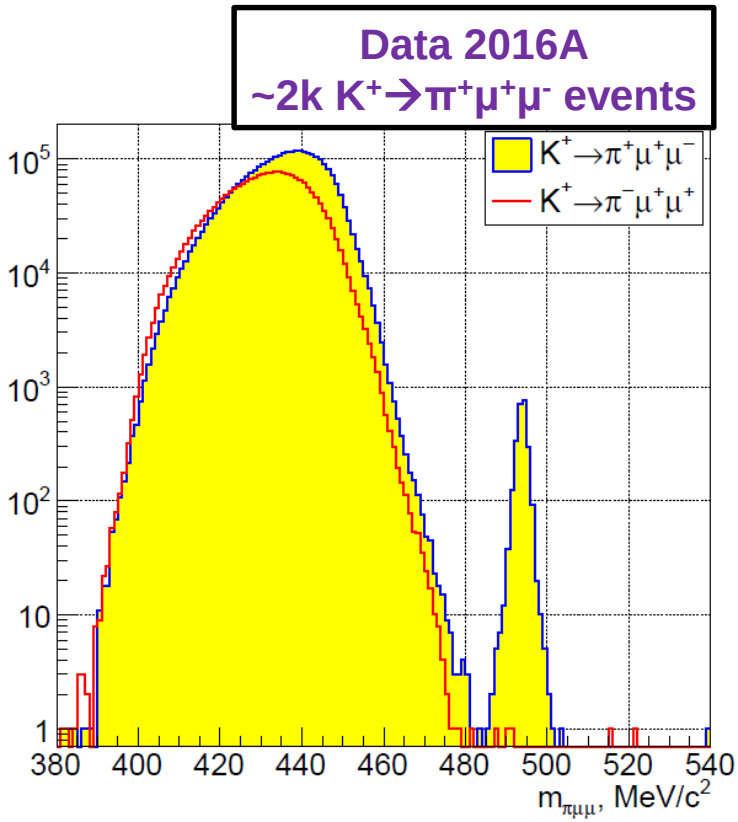


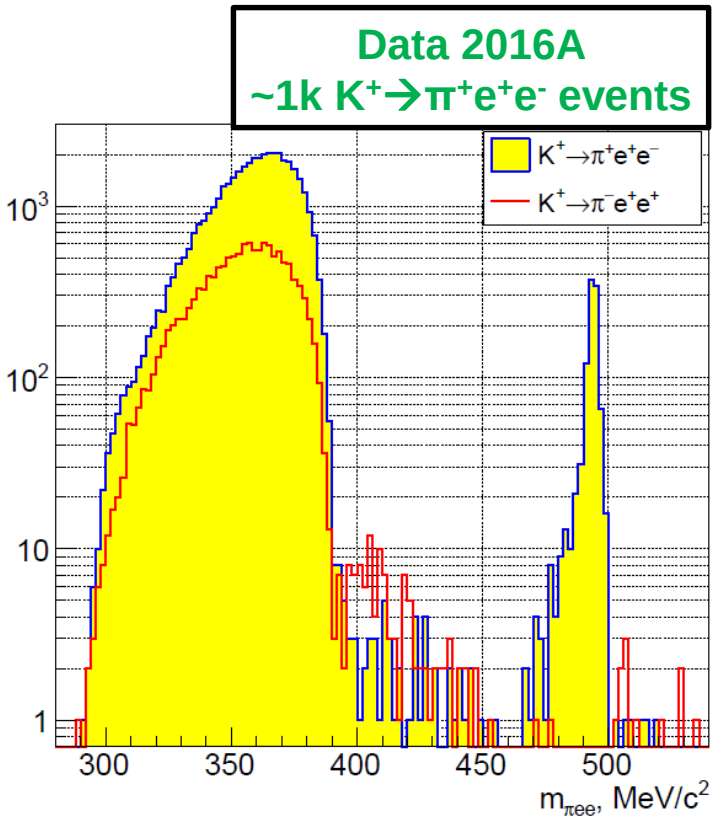
Three-track samples

The three-track decays $K^+ \to \pi\mu\mu$ and $K^+ \to \pi ee$ can be used to probe lepton universality, as well as new particles e.g. heavy (majorana) neutrinos and inflatons

Event yields from the 2016A dataset expected to be comparable to that of NA48/2 (currently the worlds largest sample) but with much lower background level

Tests of lepton number (flavour) violation with $K^+ \to \pi^- \ell^+ \ell^+$ **($K^+ \to \pi\mu e$)**





Summary

The status of rare kaon decay analyses at NA62 was presented

- The GTK is now operating at design performance
- With a (preliminary) cut-based analysis the efficiency is rather low, level of background is larger than expected
- Plenty of improvements are expected, stay tuned for more

Prospects for a search for the dark photon A' were presented

- Based on 3% of 2016A sample, experimental limits are more stringent than existing limits in a small, but interesting, region of A' mass

A measurement of heavy neutrino production at NA62 (2007) was presented

- Journal publication is in preparation

Event samples from 2015 and 2016 were presented

- Expect more results from $K^+ \rightarrow \ell^+ \nu_\mu$ and $K^+ \rightarrow \pi\ell\ell$ in the coming years