Searches for Lepton Number Violation and resonances in the $K^\pm \to \pi\mu\mu$ decays

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on behalf of the NA48/2 collaboration

Motivations & Theory

Asaka-Shaposhnikov model (νMSM) [PLB 620 (2005) 17]

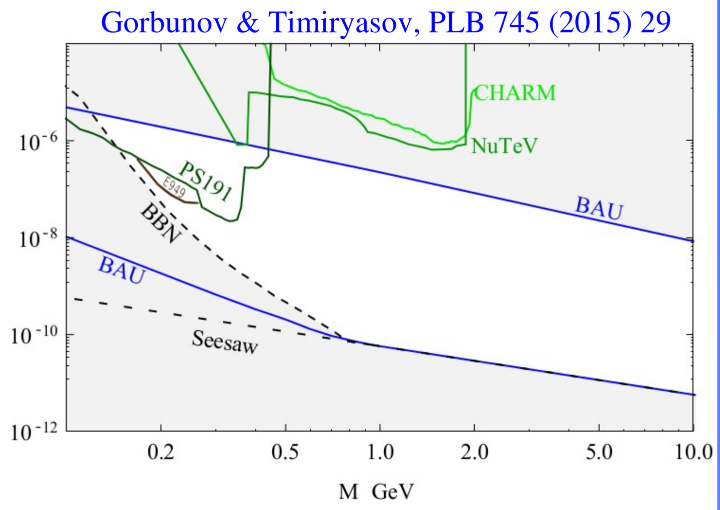
Adding **three sterile Majorana neutrinos** to the Standard Model (SM) it is possible to explain simultaneously:

- Dark Matter
- Baryon Asymmetry of the Universe (BAU)
- Low mass of SM ν

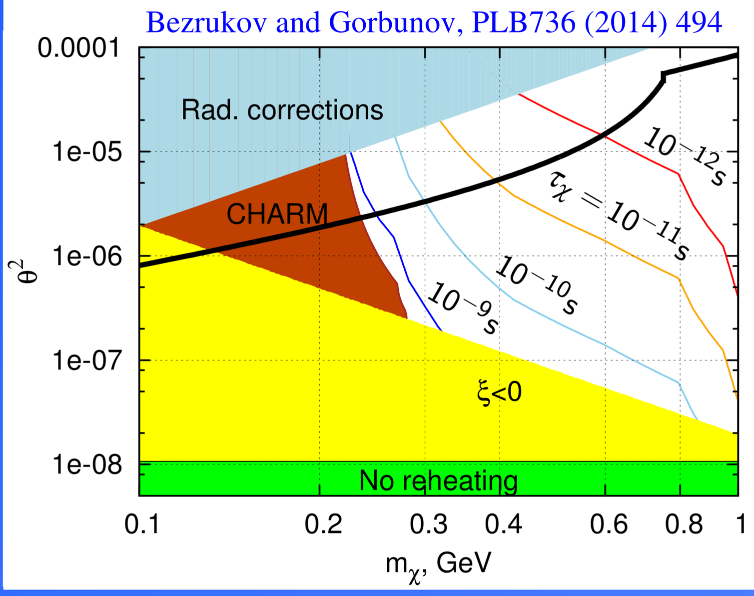
N_4 production in $K^\pm$ decays: $K^\pm \to \ell^\pm N$, $K^\pm \to \pi^0 \ell N$, …

N_4 decays for $m_4 < m_K - m_\ell$: $N \to \pi^\pm \ell^\mp$, $N \to \pi^0 \nu$, $N \to \nu_\ell \nu\bar{\nu}$, $N \to \ell_1^\pm \ell_2^\mp \nu_2$, $N \to \nu_1 \ell_2^+ \ell_2^-$

Gorbunov & Timiryasov, PLB 745 (2015) 29



Bezrukov and Gorbunov, PLB736 (2014) 494



Shaposhnikov-Tkachev model [PLB 639 (2006) 414]

Adding **a scalar field** (inflaton χ) with scale-invariant couplings to the νMSM it is possible to also explain:

- Universe homogeneity
- Isotropy on large scales/structures on smaller scales

χ production in $K^\pm$ decays: $K^\pm \to \pi^\pm \chi$

χ decays for $m_\chi < m_K - m_\pi$: $\chi \to \ell^+\ell^-$, $\chi \to \gamma\gamma$, $\chi \to \pi\pi$

→ **Search new particles in $K^\pm \to \pi\mu\mu$ decays!**

The NA48/2 detector

Narrow momentum band $K^\pm$ beams: $P_K = 60$ GeV/c, $\delta P_K/P_K \sim 4\%$ (rms)

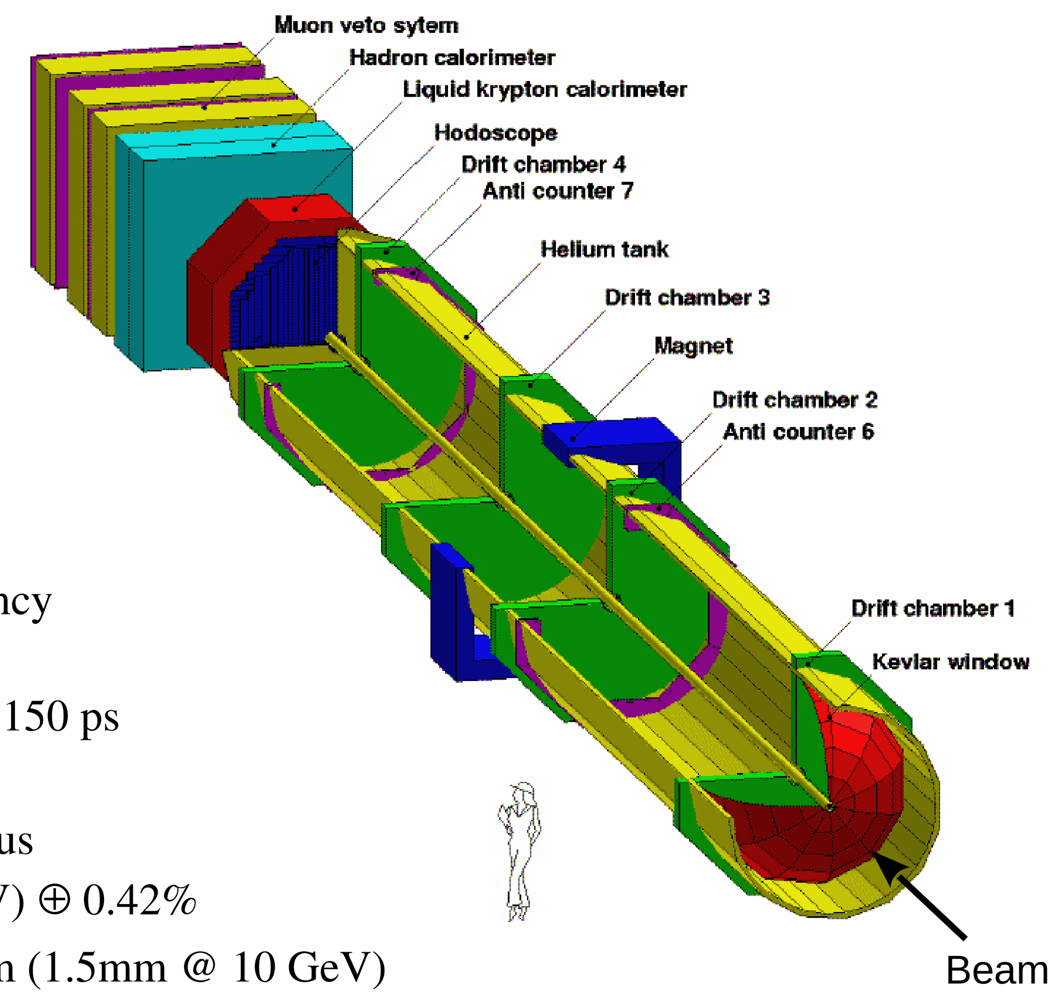
Nominal $K^\pm$ decay rate: ~ 100 kHz

Simultaneous K^+/K^- beams

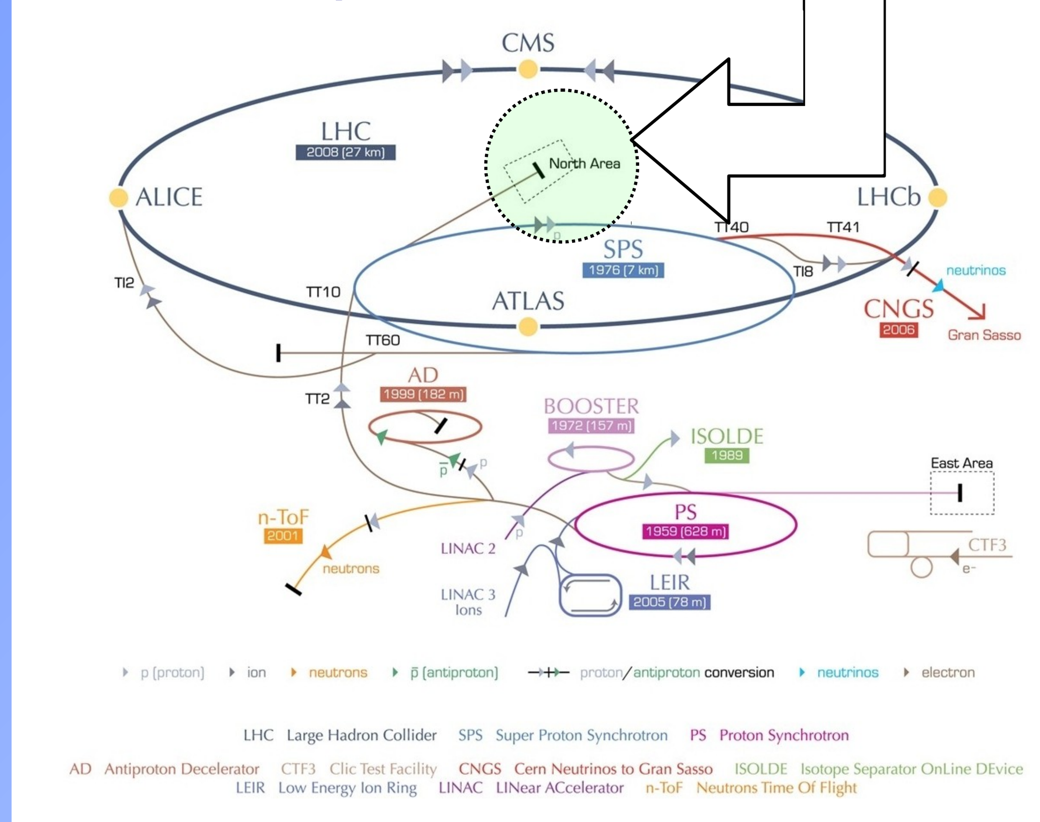
Main triggers: 3-track vertex, $K^\pm \to \pi^\pm\pi^0\pi^0$

Principal sub-detectors:

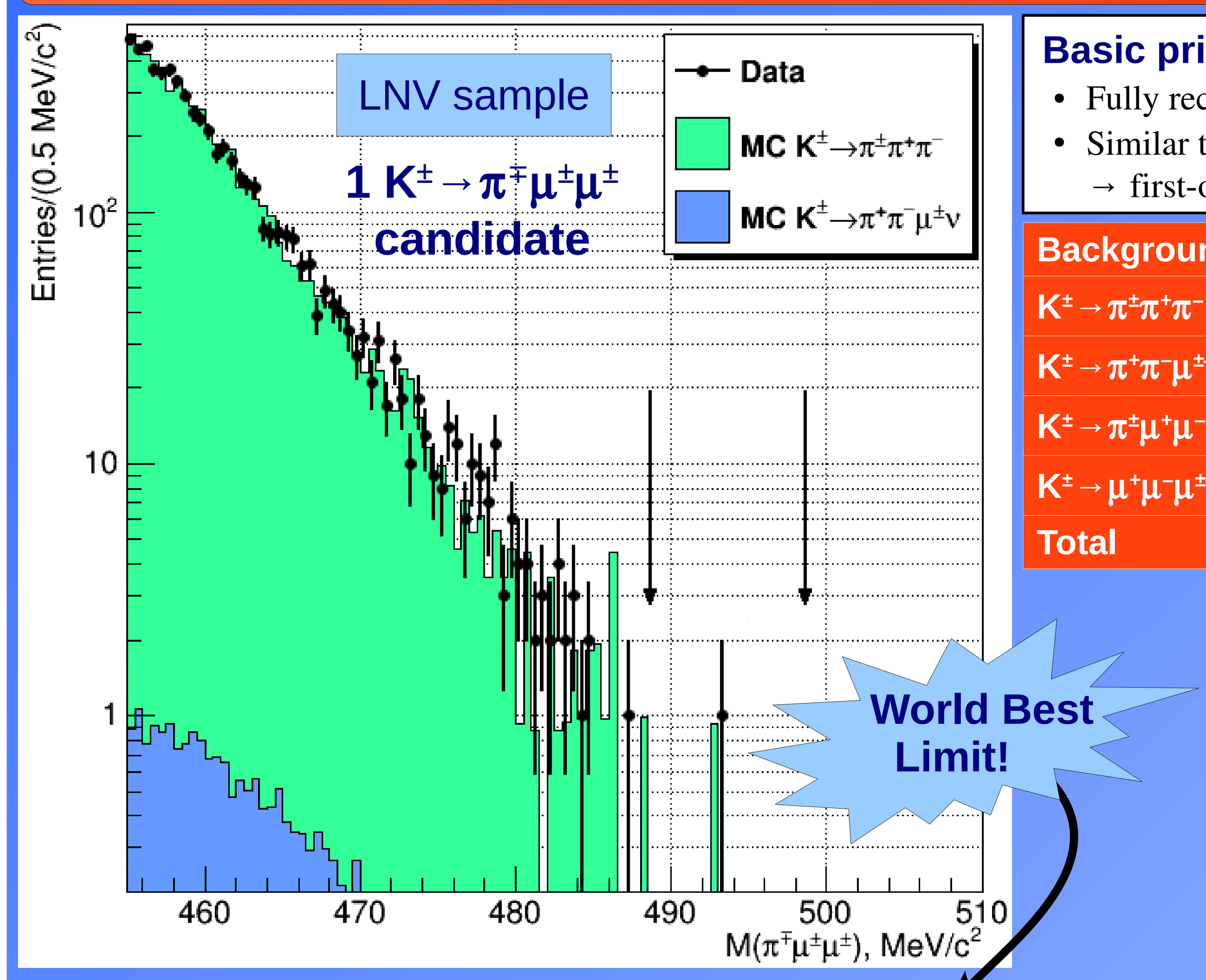
- **Spectrometer (4 DCHs)**
  $\sigma_p/p = 1.02\% \oplus 0.044\%\, p(\mathrm{GeV})$
  4 views/DCH: redundancy → efficiency
- **Scintillator Hodoscope**
  Fast trigger, time measurement $\sigma_t \sim 150$ ps
- **LKr EM calorimeter**
  High-granularity, quasi-homogeneous
  $\sigma_E/E = 3.2\%/\sqrt{E(\mathrm{GeV})} \oplus 9\%/E(\mathrm{GeV}) \oplus 0.42\%$
  $\sigma_x = \sigma_y = 4.2\mathrm{mm}/\sqrt{E(\mathrm{GeV})} \oplus 0.6\mathrm{mm}$ (1.5mm @ 10 GeV)



The NA48/2 experiment at CERN



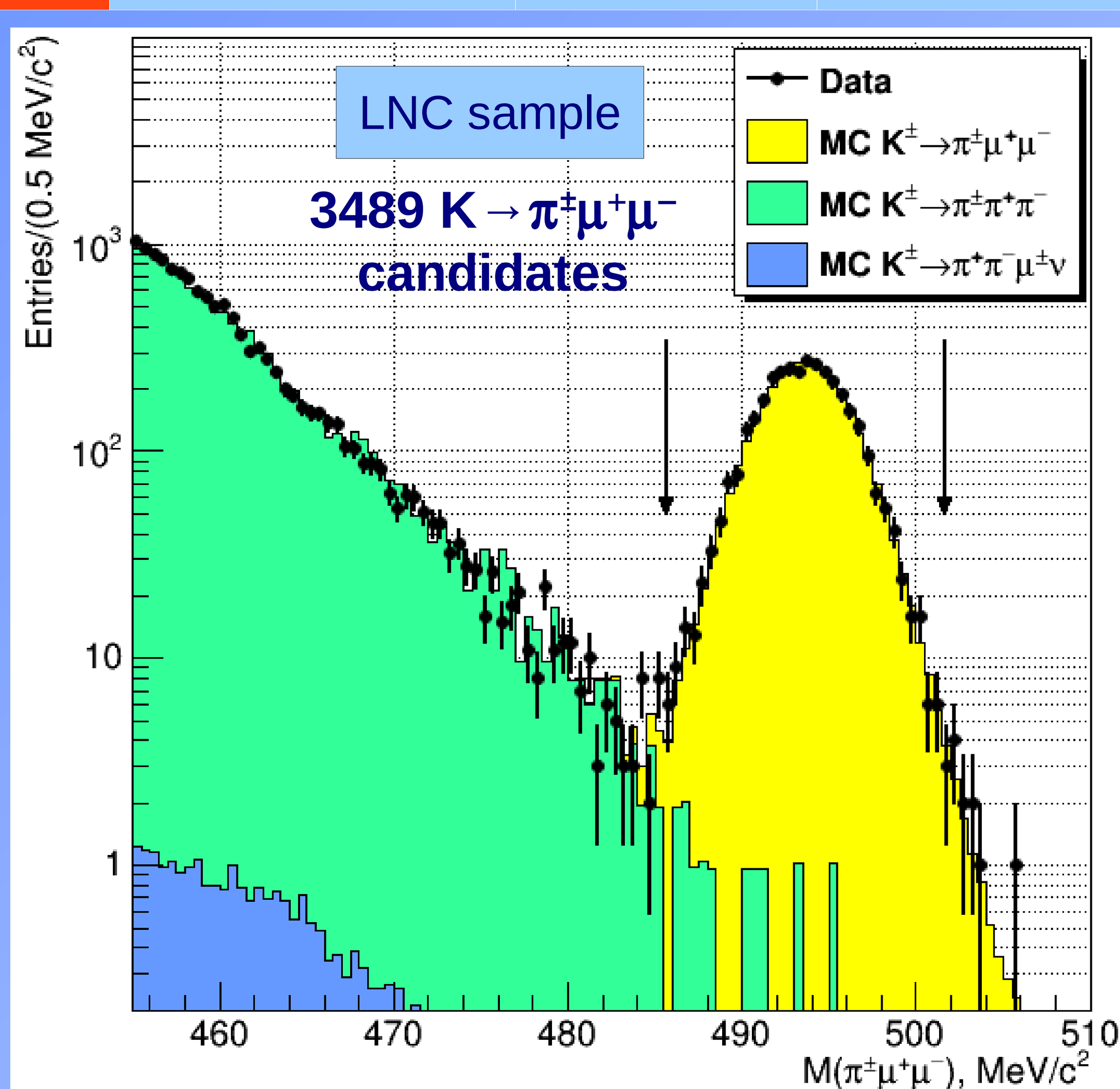
$K^\pm \to \pi\mu\mu$ selections & Backgrounds



Basic principles of the searches

- Fully reconstructed final states, 3-track vertex topology
- Similar topology to normalisation channel $K^\pm \to \pi^\pm\pi^+\pi^-$
  → first-order cancellation of systematic effects (trigger inefficiency, etc)

Background	Branching Ratio	LNV sample	LNC sample
$K^\pm \to \pi^\pm\pi^+\pi^-$	$(5.59\pm0.04)\times10^{-2}$	0.867±0.867	10.87±3.07
$K^\pm \to \pi^+\pi^-\mu^\pm\nu$	$(4.5\pm0.2)\times10^{-6}$	0.027±0.015	0.018±0.012
$K^\pm \to \pi^\pm\mu^+\mu^-$	$(9.4\pm0.6)\times10^{-8}$	0.257±0.026	3424±220
$K^\pm \to \mu^+\mu^-\mu^\pm\nu$	1.35×10^{-8}	0.012±0.001	0.037±0.003
Total	–	1.163±0.867	3435±220



$BR(K^\pm \to \pi^\mp\mu^\pm\mu^\pm) < 8.6 \times 10^{-11}$ @ 90% C.L.

Selected data samples:

- **LNV:** 3-track vertex topology, one pion and two same-sign muons
- **LNC:** 3-track vertex topology, one pion and two opposite-sign muons

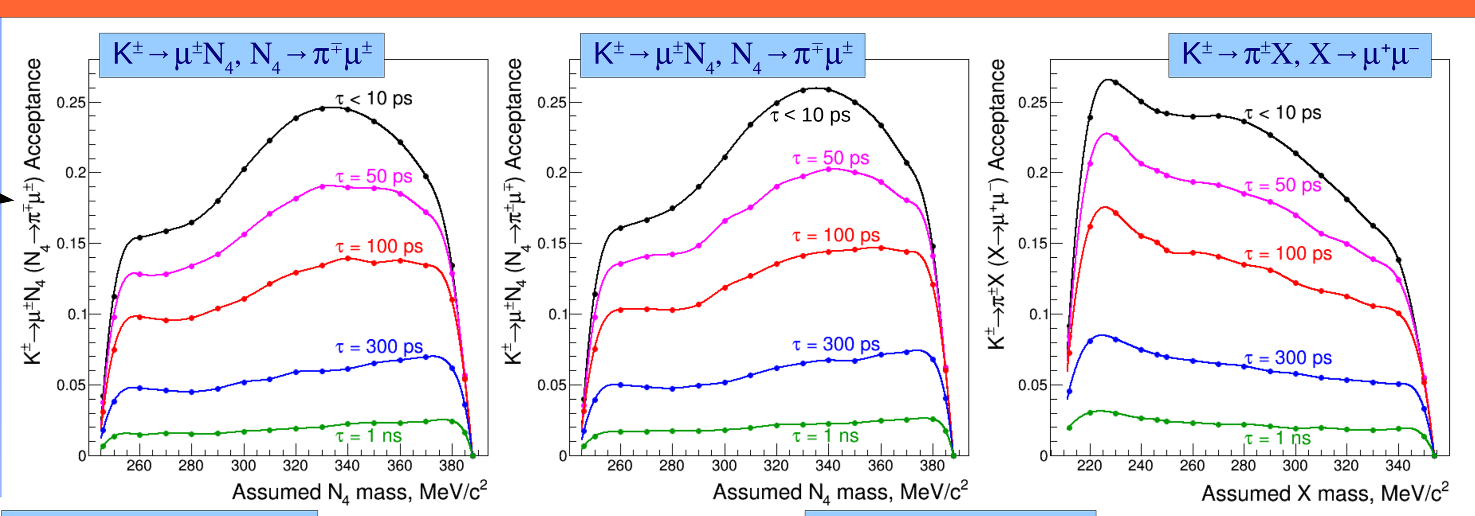
Search for 2-body resonances:

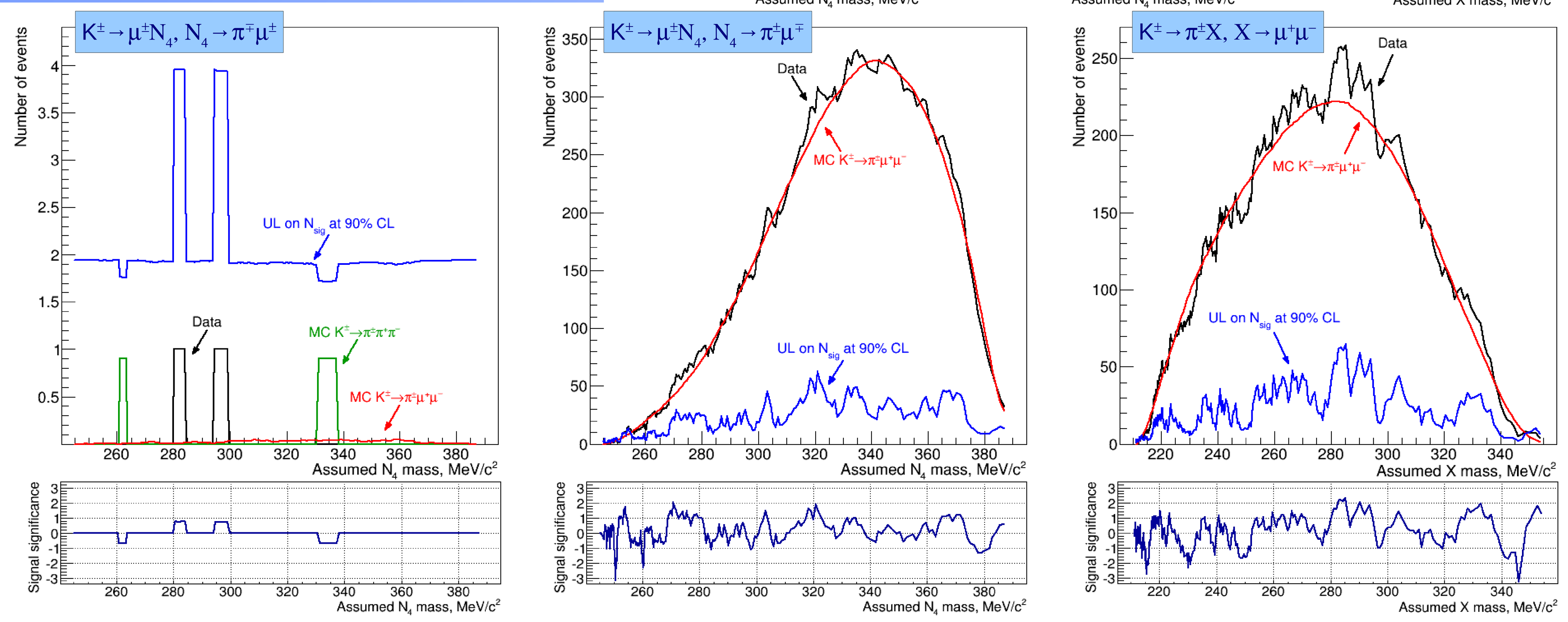
- Based on selected $K^\pm \to \pi\mu\mu$ candidates (LNV & LNC).
- Variable step = $0.5\sigma(M_{res})$ and window = $\pm 2\sigma(M_{res})$
- For each M_{res}: N_{obs} in data vs N_{exp} from MC → $UL(N_{sig})$
- Rolke-Lopez statistical method for each mass hypothesis M_{res}

Search for resonances – Results

Acceptances vs resonance mass and lifetime from dedicated MC simulations

$$signal\ significance = \frac{N_{obs} - N_{exp}}{\sigma(N_{obs}) \oplus \sigma(N_{exp})}$$





Upper Limits on BR products