# KAONS AND LIGHT NEW PHYSICS



* The idea is to discuss what are the opportunities of

$5 \cdot 10^{14}$ $K_S$
$10^{14}$ $K_L$ × 10% acceptance
$2 \cdot 10^{14}$ $\Lambda$'s

* What we got so far $K^+ \to \pi^+ \nu\bar{\nu}$

$K^+$ $6 \cdot 10^{12}$ $K^+$ NA62 (main trigger stream)

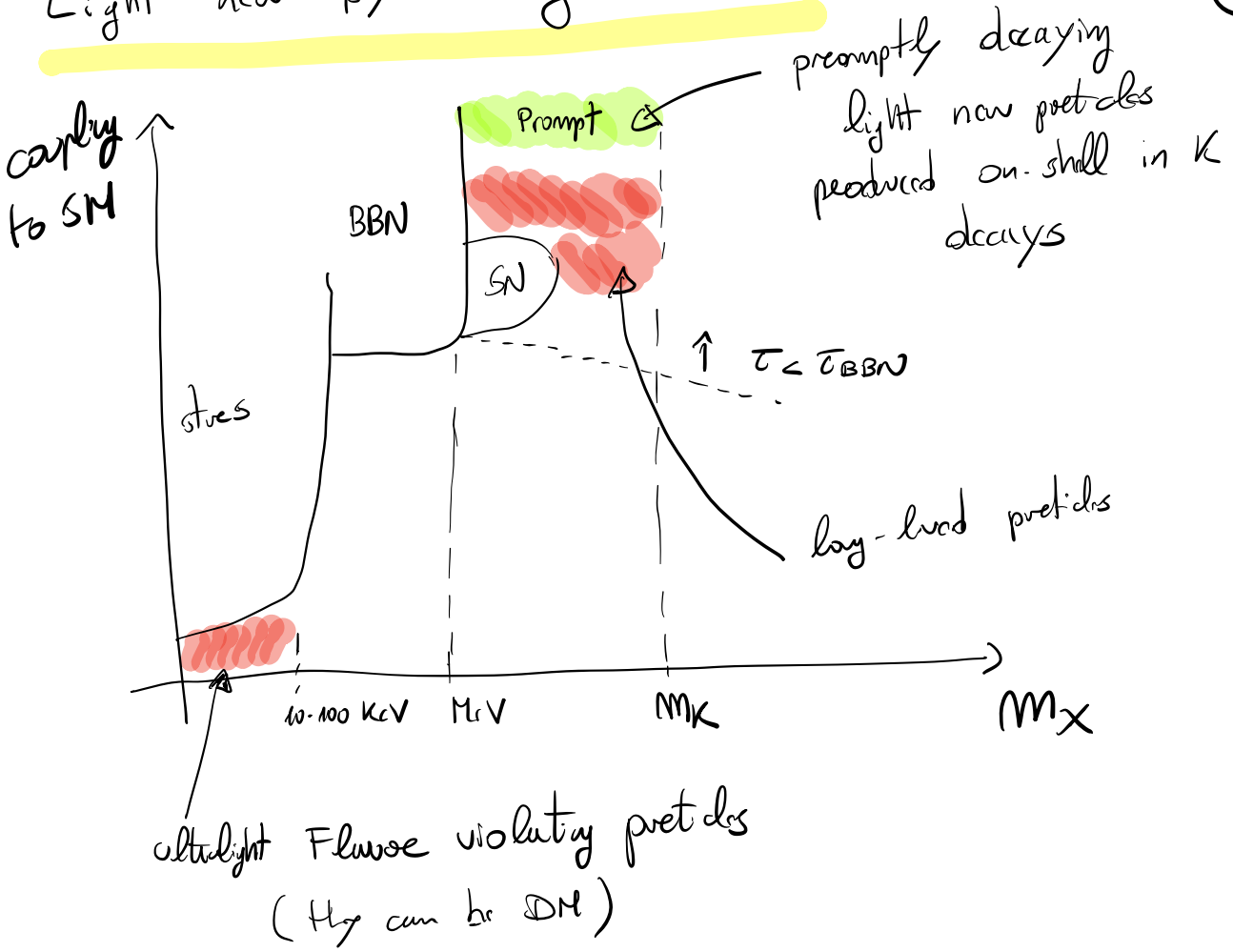
the other trigger streams are prescaled:

- di-muon 50%
- di-electrons 1/6
- minimum bias 1/600

$K_L$ $4 \cdot 10^{11}$ $K_L$ KOTO all the rest is vetoed!

for $K_L \to \pi^0 \nu\bar{\nu}$

# Light new physics generalities



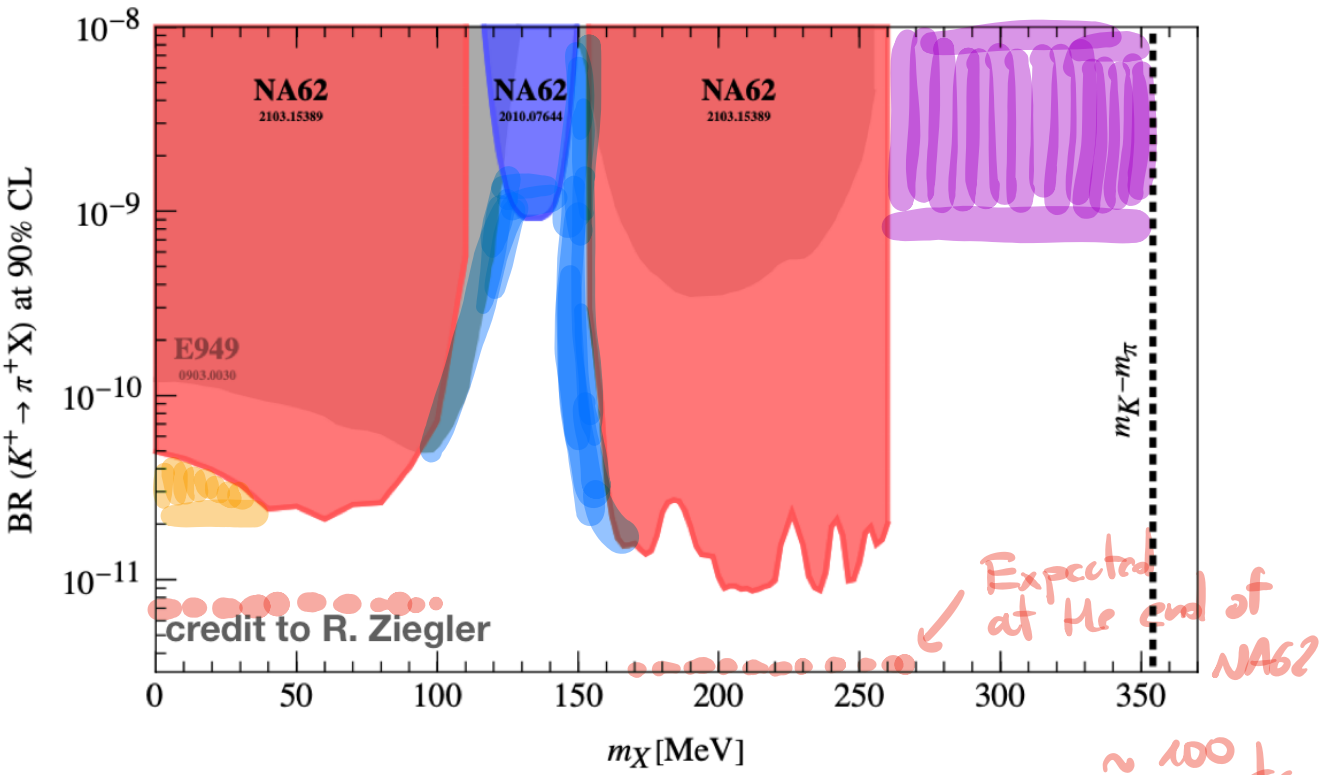

* INVISIBLE CHANNELS are more motivated
  - a new particle below the K mass is likely to be long-lived.

## GOAL to maximize $\Gamma_{light}\,\tau_K$

$\tau_L = 51$ ns ✓, $\tau_K = 12$ ns ✓, $\tau_S = 0.09$ ns ✗

INVISIBLE SEARCHES

$K^+ \to \pi^+ \nu\bar{\nu} \implies K^+ \to \pi^+ X$



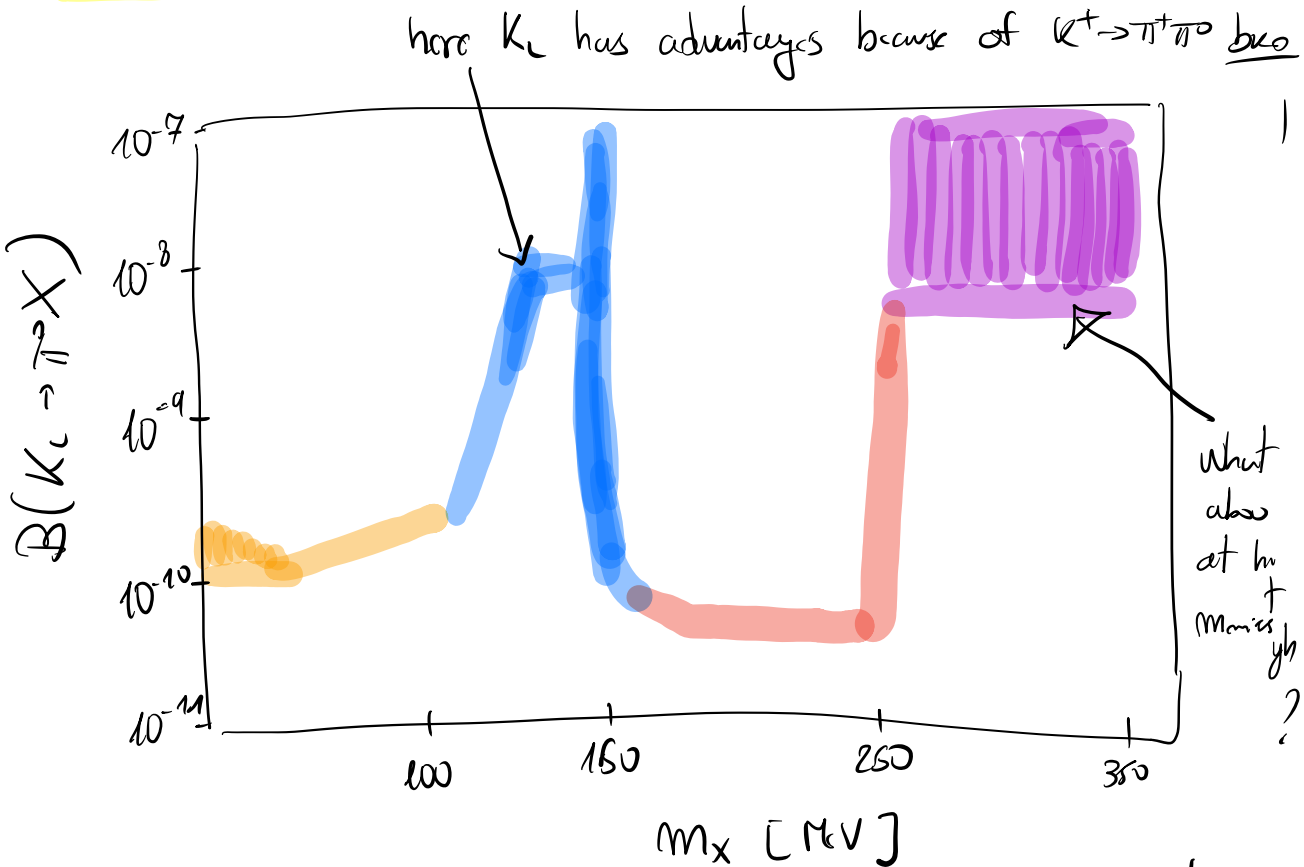

What can be improved?

- optimization for $K \to \pi X$ in high missing mass
- mass window optimization
- new bump hunt in missing mass over $K \to 3\pi$ bkd.

For $K \to \pi X$ Grossman - Nir bounds from above the $K_L \to \pi_0 X$

THE QUESTION IS IF THERE ARE OPPORTUNITIES WITH $10^{14}$ $K_L$ ?

$$B(K_L \to \pi^0 X) < 4.3\, B(K^+ \to \pi^+ X)$$




Probably $K_L \to \pi^0 X$ is challenged by $K_L \to 3\pi$ at high $m_{miss}$

## Concerns

From what I understand this experiment will be exposed to huge bkds from $\Lambda \to n\pi^0$

$\Rightarrow$ Resolution on $MM^2_{miss}$ required to be a comparison with KOTO + NA62

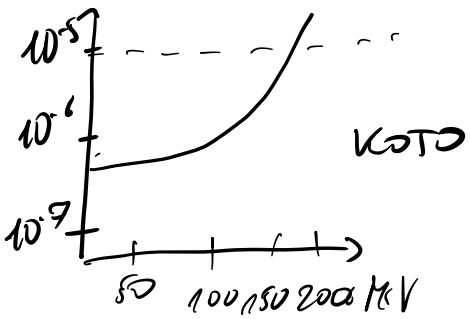
overall it looks difficult to do better than $K^+$

# $K \to \pi\pi X$

KSTNA+

1 $K^+ \to \pi^+\pi^0 X$ $BR < 10^{-5}$

2 $K_L \to \pi^0\pi^0 X$




NA62 can improve 2 orders of magnitude over KSTNA+

→ ALSO here $K^+$ or set to dominate ?

# More missing energy from muonic forces (7)

Motivation: g-2, DM freeze-out invisible in Direct Detection

LOTS of $K \longrightarrow$ LOTS of $\mu$

$K^+ \to \mu^+ \nu$ ✗

$K_L \to \pi^- \mu^+ \nu$ ✗

$K_L$ disfavored by # of bodies

# WHAT ABOUT THE PROMPT REGION ?

Here there are a lot of interesting measurements to be done...

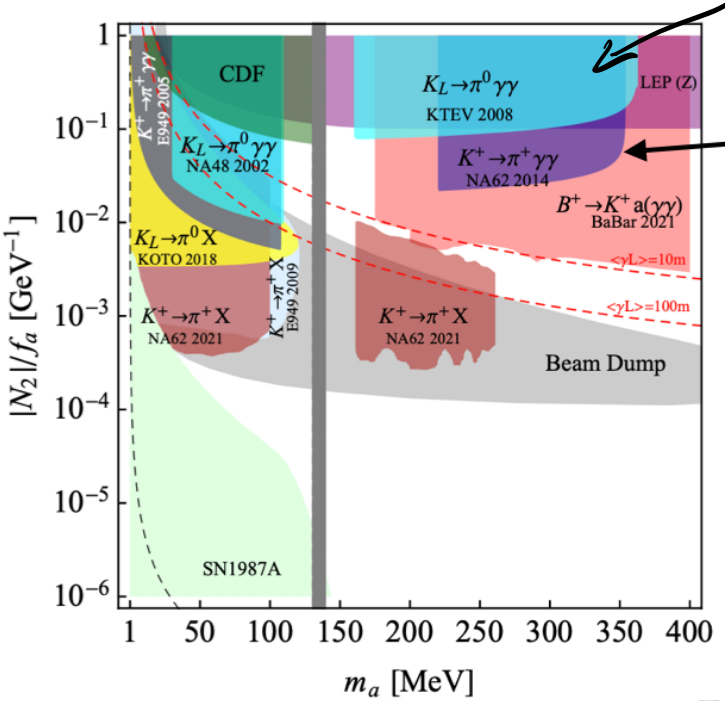
## CATEGORIES :

- RESONANCE + 1 pion
- RESONANCE + 1 muon

  ⇕

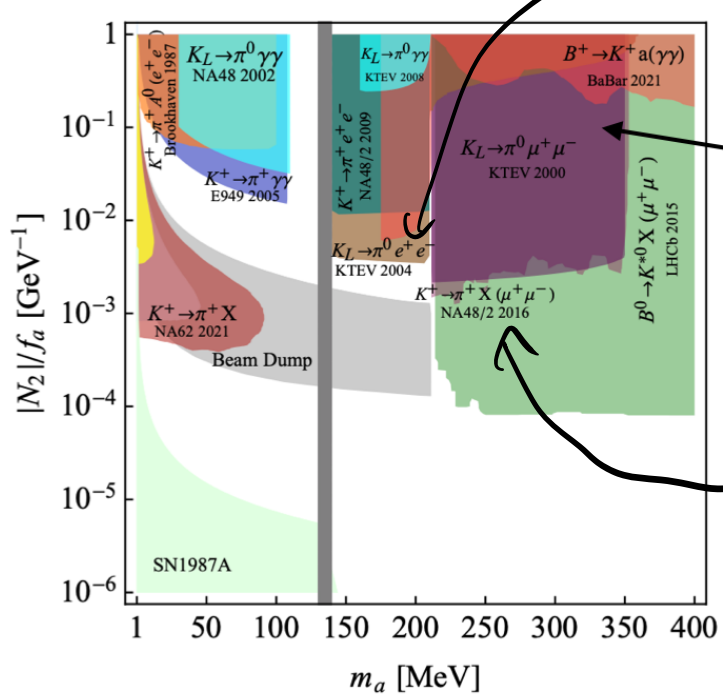
  here $K^+$ will always be better because it is less expensive to emit a $\mu^+$

# RESONANCE + 1 pion




$\pi^0\gamma\gamma$

$\pi^+\gamma\gamma$




$\pi^0 e^+e^-$

$\pi^0\mu^+\mu^-$

$\pi^+\mu^+\mu^-$

# NON-MINIMAL SCENARIOS

With more than 1 particle in the hidden sector we can have signals in $K_L$ without signals in $K^+$

( IMPORTANT TO KEEP in MIND )

Examples:

$X_i X_j \bar{s} d$

$K_L \to X_1 X_2$ , $X_2 \to \gamma\gamma$

$X_2 \to \gamma X_1$

$K_L \to X_2 X_2$ / ...

$K_L \to X_1 X_2$ / $X_2 \to \overline{\Pi} X_1$

Models explored for $M_c$

KOTO anomaly !

Hostert, Kuncta Pospelov 2005.07102

Ziegler, Zupan, Tuzcu 2005.00451

etc ...

# Summary

- The "HIKE" proposal probably suffers for similar dark sector targets w.r.t. KOTO, NA62 even if further studies of sensitivity are required.

- NEW INTERESTING measurements are expected for prompt resonances + non minimal models