The search for heavy neutrino in rare kaon decays

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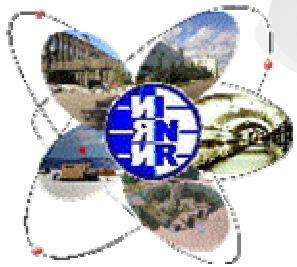

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Outline

- Heavy neutrino
- Experiment BNL E949
- Trigger
- Background study
- Expected sensitivity to heavy neutrino mass
- Conclusions

SM neutrino

Three types of neutrino

ν_e ν_μ ν_τ

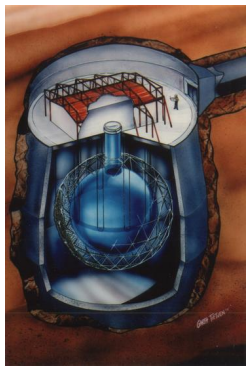
$L_e=+1$ $L_\mu=+1$ $L_\tau=+1$

$M_\nu=0$ $q=0$ $S=1/2$

$$\nu_l = \sum U_{li}\nu_i,\ l = e,\mu,\tau;\ i = 1,2,3$$

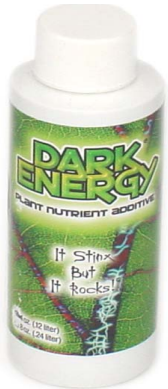
There is new physics beyond the Standard Model, but we don't know exactly what is it

Neutrino Oscillation



Dominance of matter over antimatter

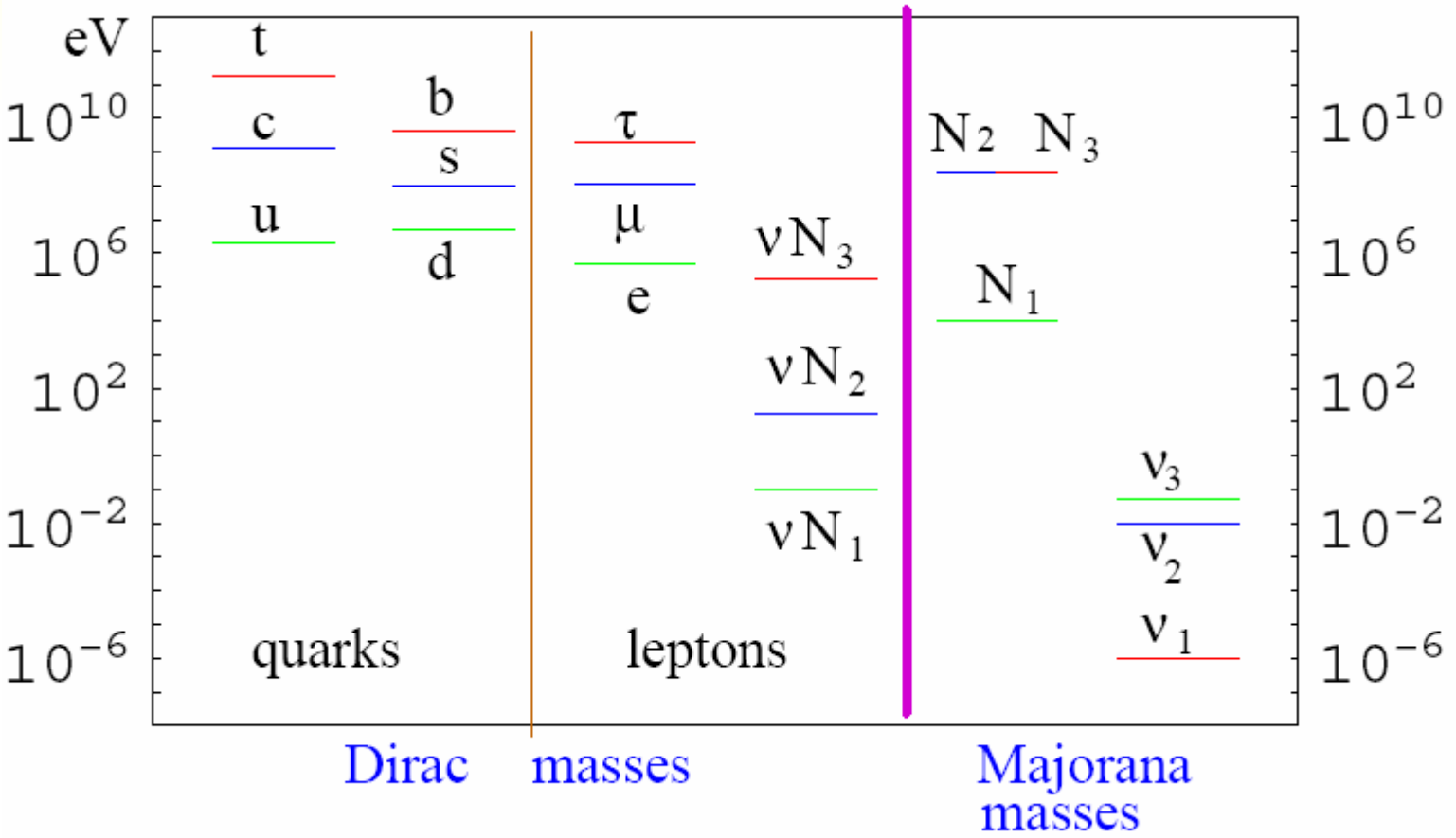
Dark matter and dark energy



νMSM

arXiv:0804.4542v2 [hep-ph]
arXiv:0901.0011v2 [hep-ph]

SM + 3 neutral right-handed heavy leptons



How to find heavy neutrino?

Mesons decays

The search for additional peak

$$\Gamma(M^+ \to l^+ \nu_h) \sim \Gamma(M^+ \to l^+ \nu_l) |U_{lh}|^2$$

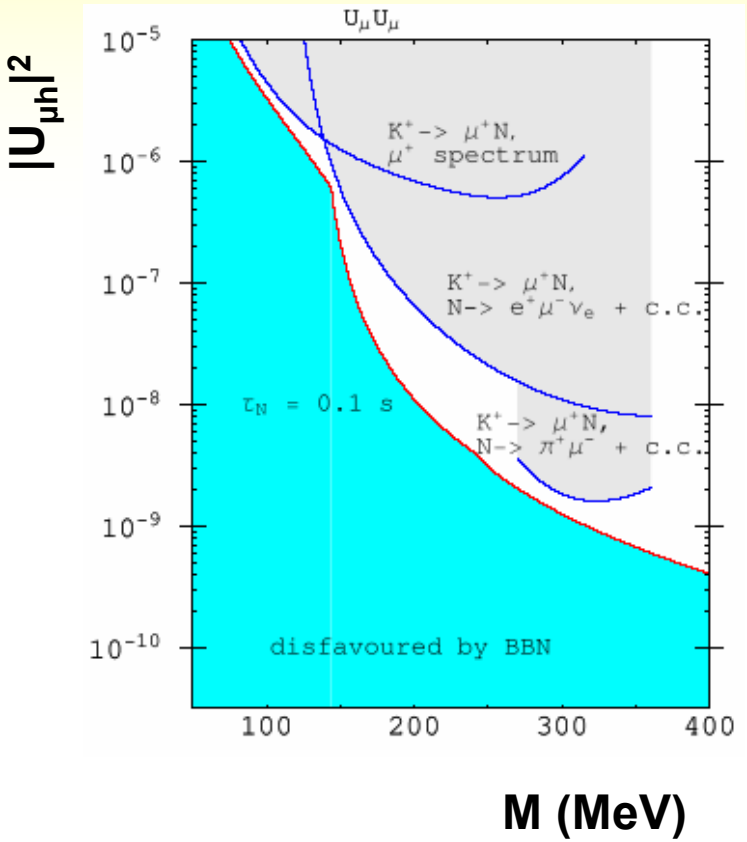
Heavy neutrino decays

"Nothing"$\to$ leptons and hadrons

$$N \to e^+ e^- \nu_\alpha, N \to \mu^\pm e^\mp \nu_\alpha, N \to \mu^+ \mu^- \nu_\alpha$$

$$N \to \pi^0 \nu, \pi e, \pi \mu, K e, K \mu ...$$

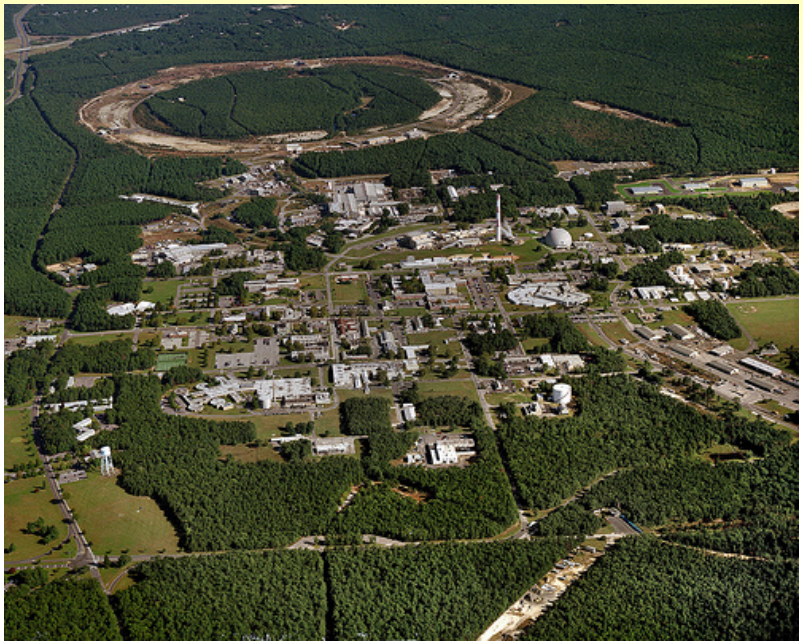
Current limits



There was suggested to use E949 data to study heavy neutrino mass region from 150 MeV to 270 MeV in decay channel

$$K^+ \to \mu^+ \nu_H$$

Experiment BNL E949



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

Phys. Rev. D 79, 092004 (2009)

SM expectation

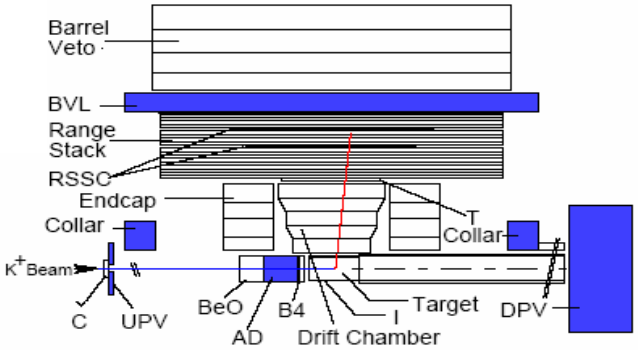
$$\mathcal{B}_{SM}(K^+ \to \pi^+ \nu\bar{\nu}) = (0.85 \pm 0.07) \times 10^{-10}$$

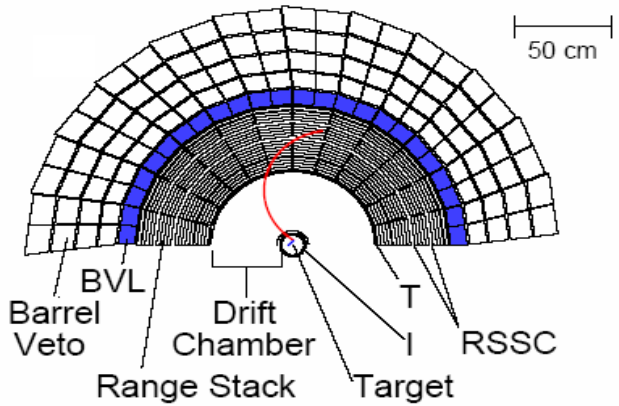
E949 + E787

4 + 3 (from E787) = 7

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

The Detector





- ~700 MeV/c kaon beam is slowed down by BeO и AD
- K^+ stops and decays in scintillating fiber target
- Measure π^+ momentum in UTC, energy and range in target and Range Stack(RS)
- π^+ stops and decays in RS – observe $\pi^+ \rightarrow \mu^+ \rightarrow e^+$ decay chain
- Veto photons: BV – BVL, RS, EC, CO, USPV, DSPV

Heavy neutrino trigger

$K^+ \to \mu^+ \nu_H$ has the same experimental signature as $K^+ \to \pi^+ \nu\bar{\nu}$

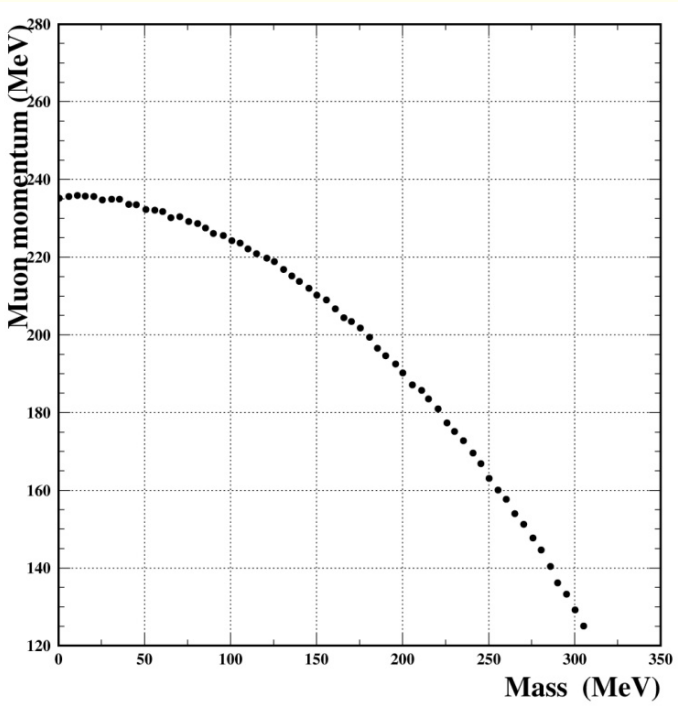
single charged particle + "nothing" → use standard E949 trigger

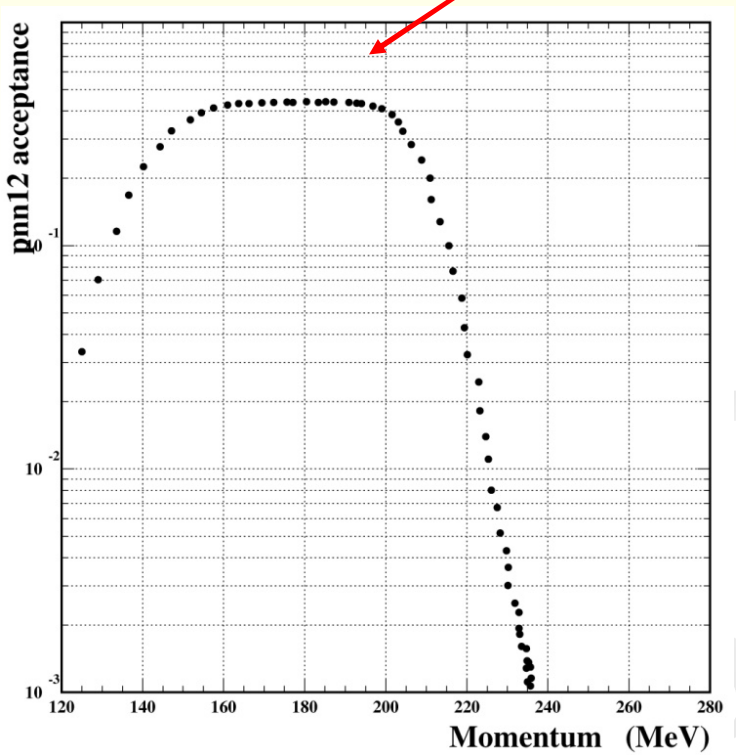
- Wait at least 2 ns for K^+ decay
- Stopping layer in RS between 6 and 18
- Photon veto: no showers in RS, Barrel,…
- π^+ identification: online check $\pi^+ \to \mu^+$ decay chain in the stopping counter

Trigger acceptance

Use MC simulation of $K^+ \to \mu^+ \nu_H$

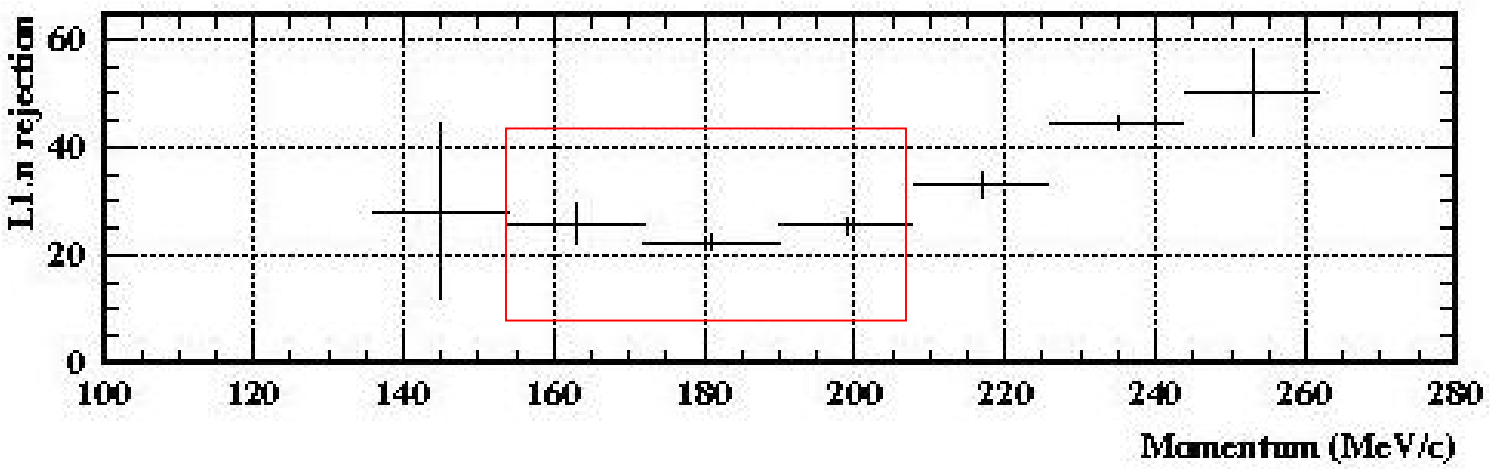
MC simulation doesn't take into account online pion identification





Optimal mass region for analysis from 160 MeV to 260 MeV

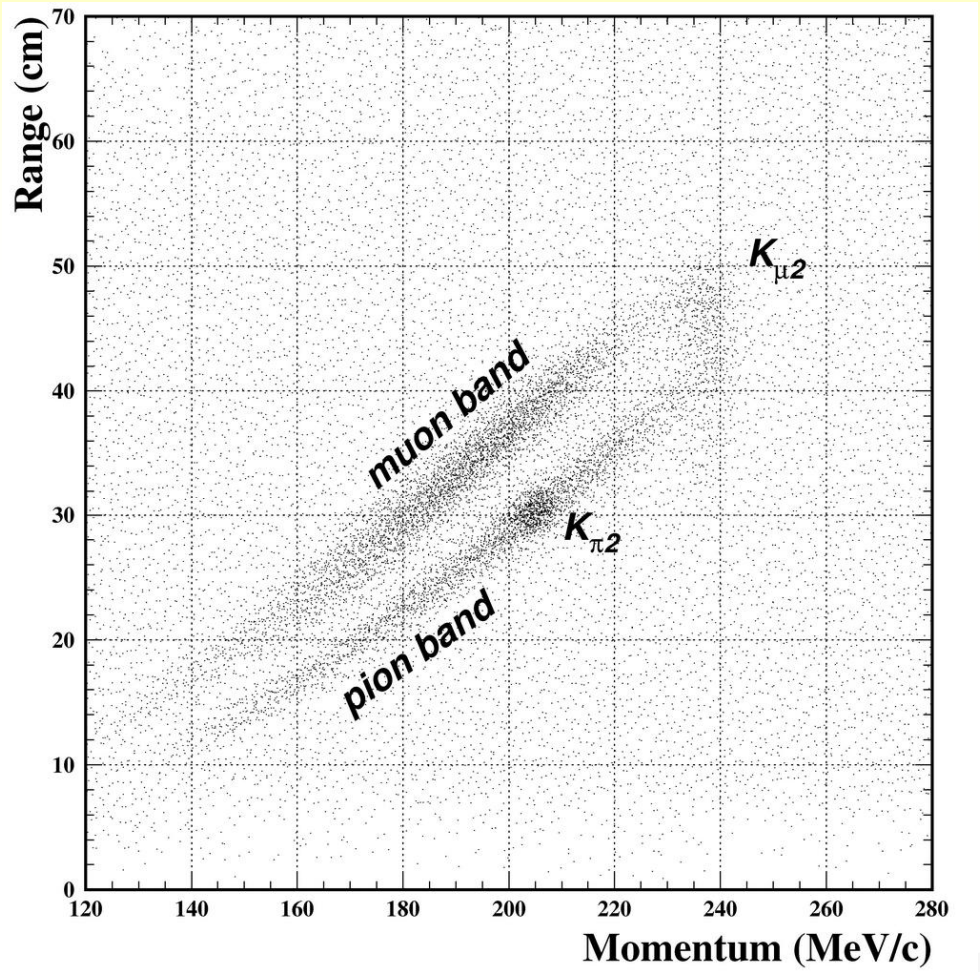
Online muon rejection



For signal region online muon rejection is almost constant and equals 24.82

Total trigger acceptance for muons is equal to 1.73×10^{-2}

Background sources



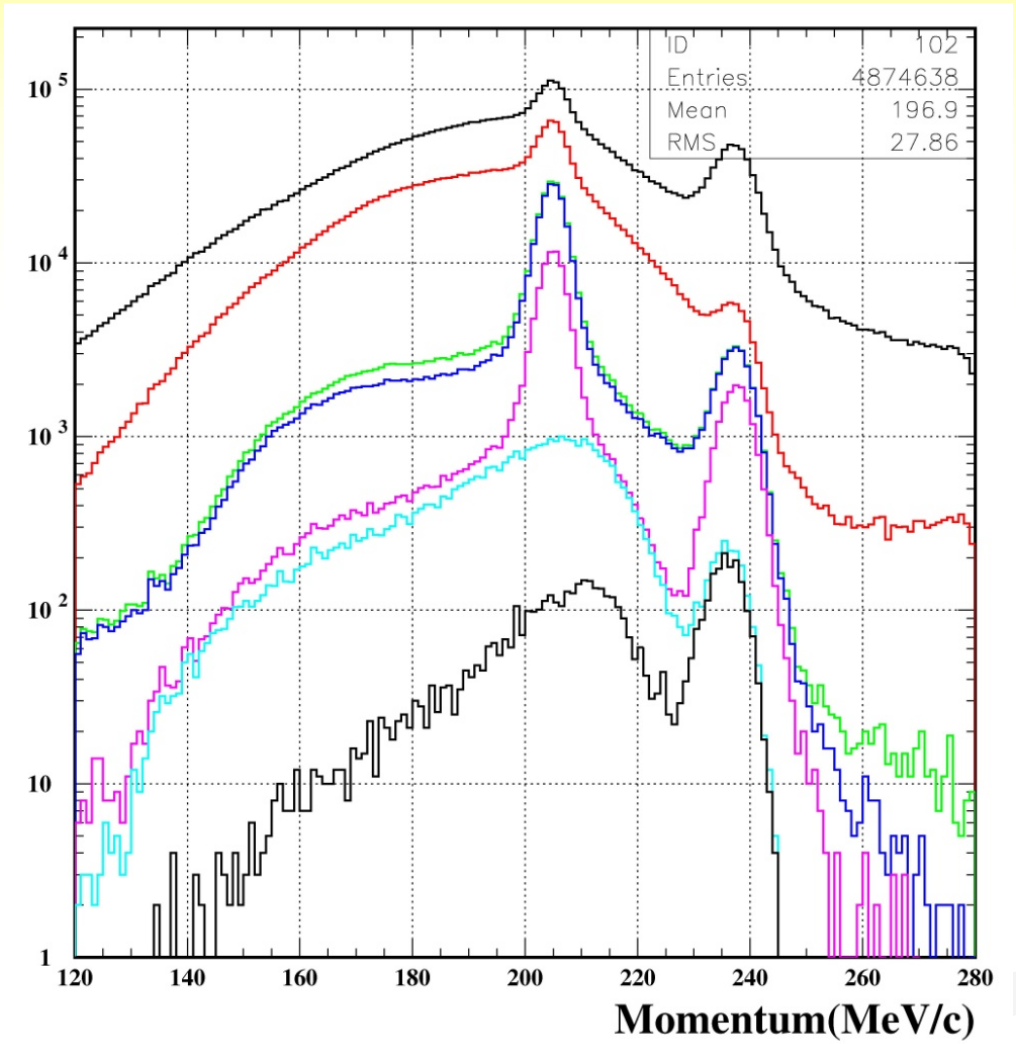
- Muon band: generally $K_{\mu 2\gamma}$, $K_{\mu 3}$ decays
- Pion band: $K_{\pi 2\gamma}$, $K_{\pi 2}$ in which pion scattered in the target or RS and beam pion

MC simulation of background sources

Process	Trigger+cuts rej	BR	Total rejection
$K_{\mu\nu\gamma}$	$\sim 10^4$	6.2×10^{-3}	$\sim 10^7$
$K_{\mu 3}$	$\sim 10^7$	3.35×10^{-2}	$\sim 10^9$
Only $\pi\nu\nu(1+2)$ trigger			
$K_{\pi 2\gamma}$	$\sim 5 \times 10^4$	2.75×10^{-4}	$\sim 2 \times 10^9$

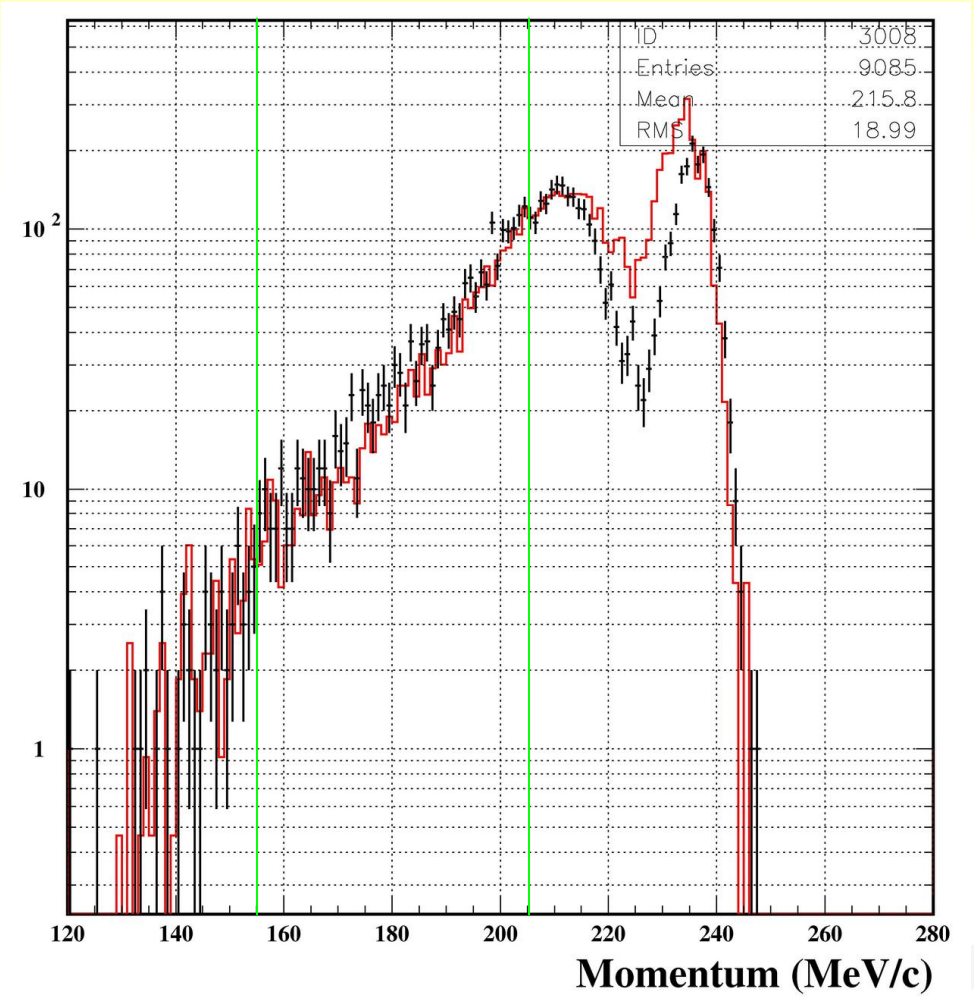
$K_{\pi 2\gamma}$ can be ignored due to 3 gamma in the final state and the strong range-momentum rejection of pions (~500). So the $K_{\mu 2\gamma}$ is the dominant background source for decay into heavy neutrino.

1/20 of real data



- after trigger
- after kinematics
- after beam
- after DELCO2
- after target
- after inv RNGMOM
- after PV, 90% Acc.

MC data vs Real data



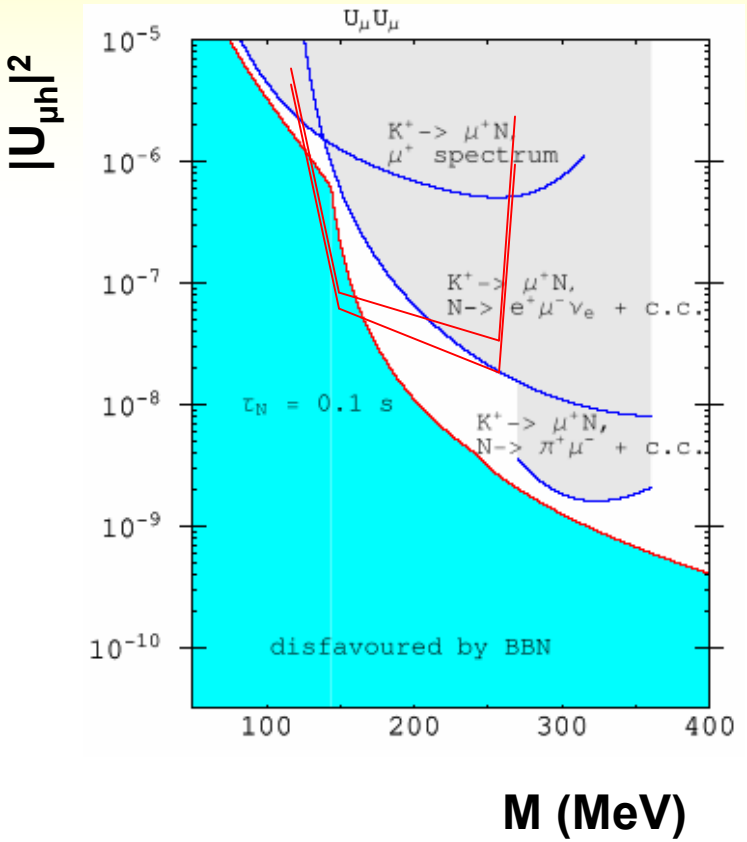
1/20 E949 data after trigger and some offline cuts

Simulated $K_{\mu 2\gamma}$ events after trigger and some offline cuts

MC is consistent with real data in the region $P_\mu < 210$ MeV/c

$P_\mu > 210$ MeV/c is under investigation

Expected sensitivity



Total stopped kaons ~1.6×10^{12}

Total initial acceptance ~10^{-3}

Conclusions

- According to νMSM there is a possibility of existence of heavy neutrino with mass above pion mass
- It was suggested to use E949 data to search for $K^+ \to \mu^+ \nu_H$ decay
- Expected sensitivity is about 10^{-7}-2×10^{-8} and depends on heavy neutrino mass
- First result ~ end of 2010

Thank you!