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Thoughts on Kaon Physics for 4-20

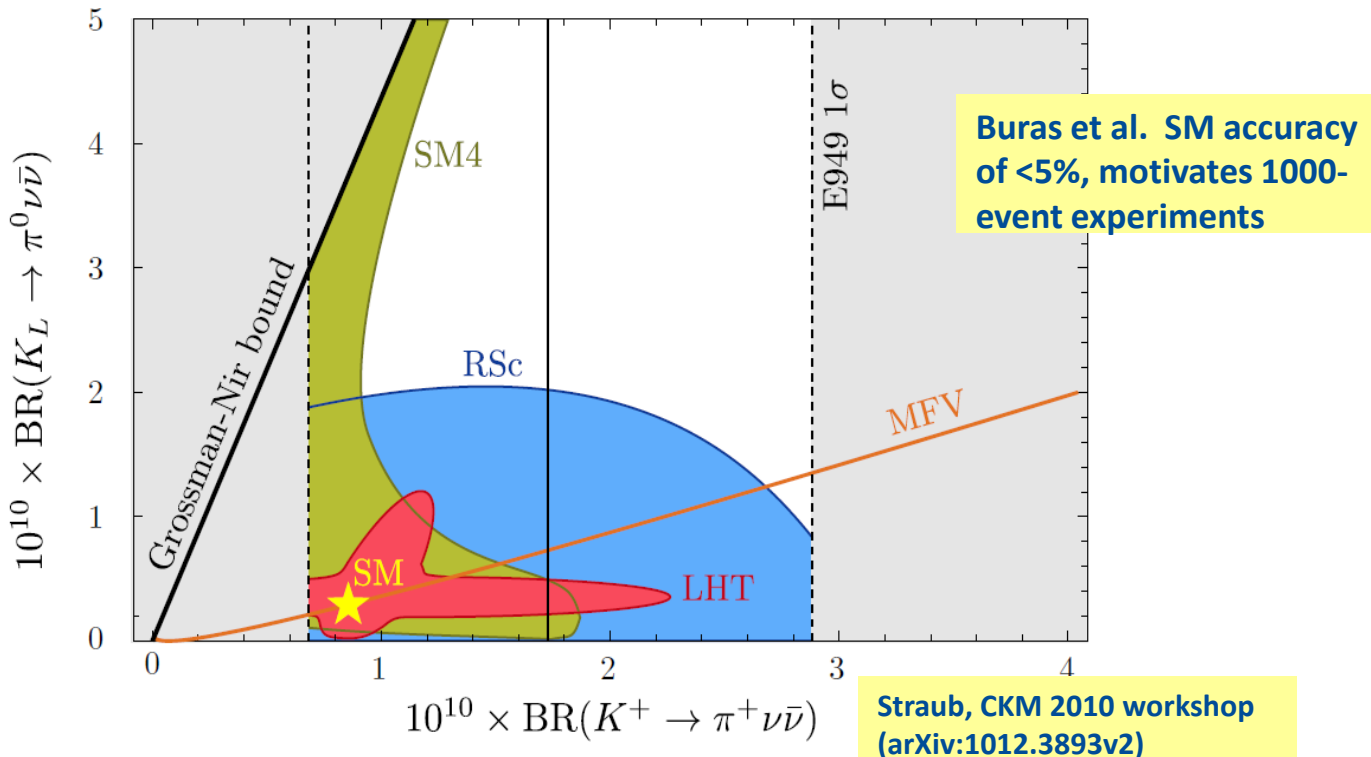
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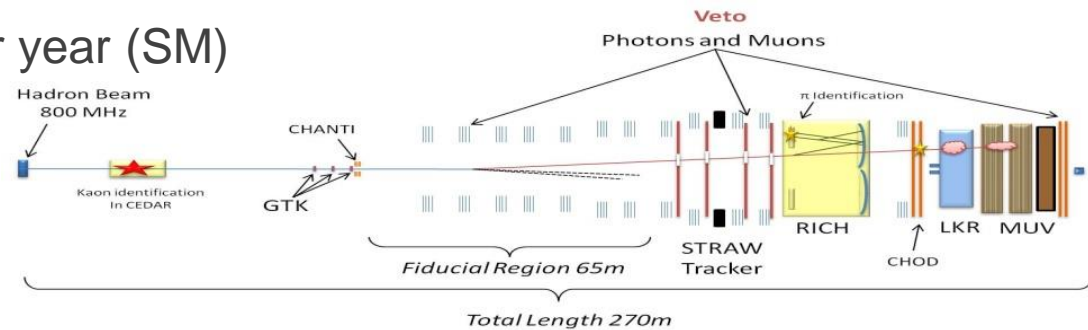
Why should you care?

- Opportunities to search for BSM physics
 - Prime example: Measuring both of $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ and of $K_L^0 \rightarrow \pi^0 \nu \bar{\nu}$ puts tight constraints on New Physics
 - No lose theorem: either explore flavor sector of NP or limits at high masses complementary to other searches

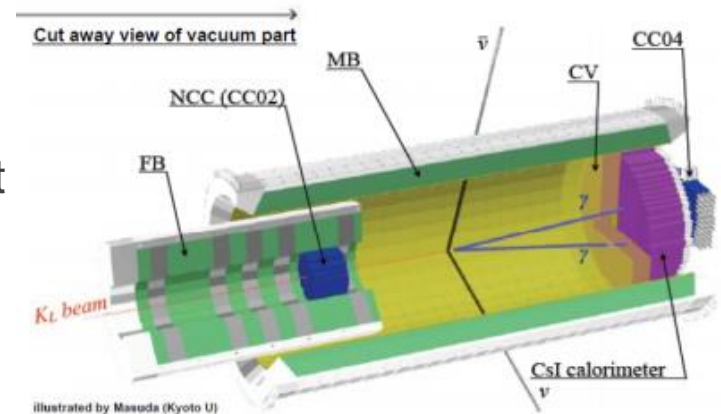


Current Experiments

- CERN NA-62 ($K^+ \rightarrow \pi^+ \nu \nu$)
 - Decay-in-flight experiment
 - Expect 10% measurement of $K^+ \rightarrow \pi^+ \nu \nu$ BR
 - $\sim 55 K^+ \rightarrow \pi^+ \nu \nu$ events per year (SM)
 - ~ 7 bg events per year
 - ~ 100 total events

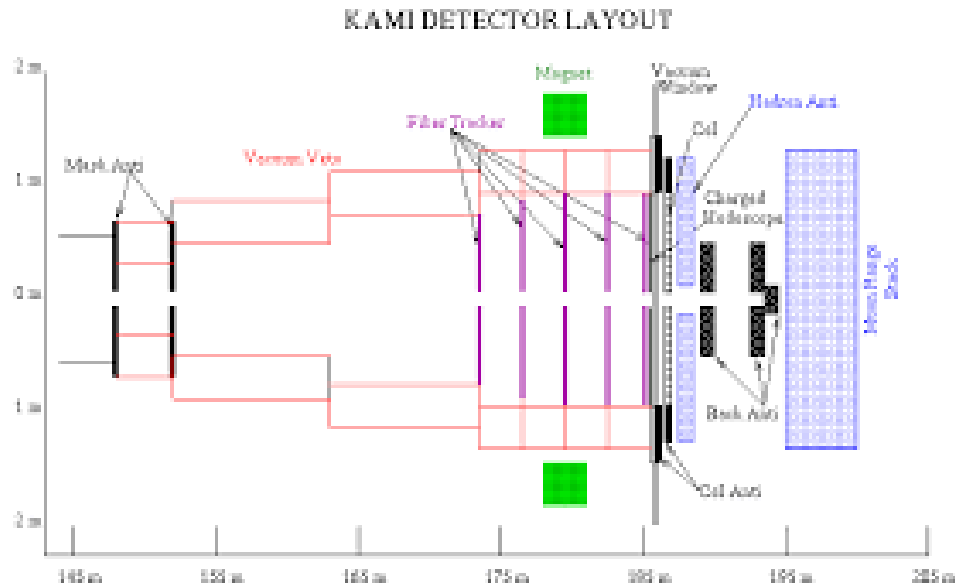


- J-PARC E14 “KOTO” ($K^0 \rightarrow \pi^0 \nu \nu$)
 - Pencil beam decay-in-flight experiment
 - Improved J-PARC beam line
 - 2nd generation detector building on E391 at KEK
 - Re-using KTeV CsI crystals to improve calorimeter
 - Expect $\sim 3 K^0 \rightarrow \pi^0 \nu \nu$ events (SM rate)



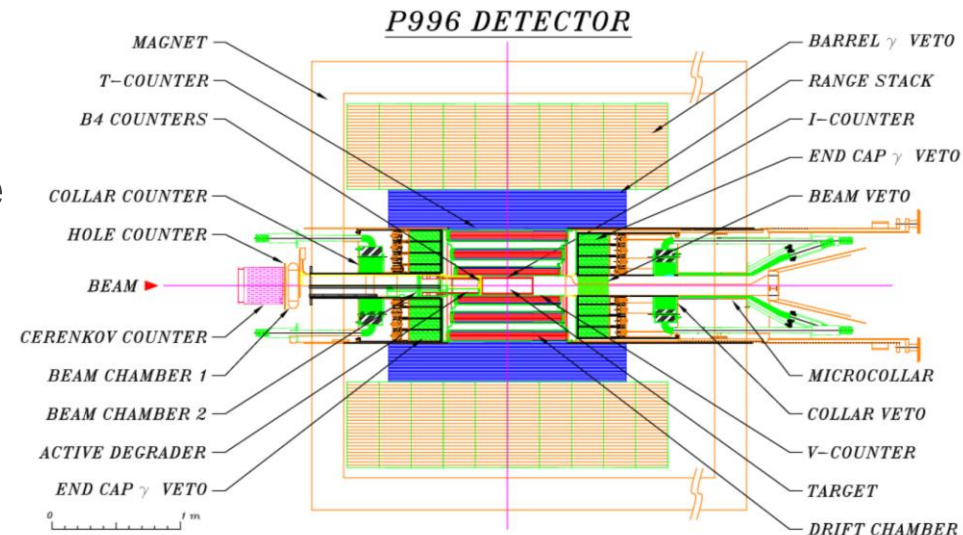
Prior Fermilab Proposals: $K_L^0 \rightarrow \pi^0 \nu \nu$

- KAMI
 - Early 2000's
 - In flight decays from MI beam
 - Lots of other people are experts



Prior Fermilab Proposals: $K^+ \rightarrow \pi^+ \nu \nu$

- ORKA
 - Proposed ~2013, killed by P5
 - 1000 event sensitivity in 3-year run
 - \$70M estimated cost
 - Almost CD1 level of estimating
 - Similar to BNL E787/949
 - Stopped kaons, single track out, veto on everything else
 - Would have sent 120 GeV MI beam to CDF hall
 - Reuse CDF solenoid
 - It is still mothballed
 - \$10M to extend Main Ring remnant from A0 to B0



Other topics

- Many other channels to be explored:
 - ▶ $K^+ \rightarrow \pi^+ + \text{missing energy}$
 - ▶ $K^+ \rightarrow \pi^+ \nu \bar{\nu}(1)^{T,P}$
 - ▶ $K^+ \rightarrow \pi^+ \nu \bar{\nu}(2)^{T,P}$
 - ▶ $K^+ \rightarrow \pi^+ \nu \bar{\nu} \gamma$
 - ▶ $K^+ \rightarrow \pi^+ X^P$
 - ▶ $K^+ \rightarrow \pi^+ \tilde{\chi}_0 \tilde{\chi}_0(\text{FF})^P$
 - ▶ $K^+ \rightarrow \pi^+ \pi^0 + \text{missing energy}$
 - ▶ $K^+ \rightarrow \pi^+ \pi^0 \nu \bar{\nu}^{T,P}$
 - ▶ $K^+ \rightarrow \pi^+ \pi^0 X$
 - ▶ $K^+ \rightarrow \mu^+ + \text{missing energy}$
 - ▶ $K^+ \rightarrow \mu^+ \nu_h$ (heavy neutrino) T
 - ▶ $K^+ \rightarrow \mu^+ \nu M$ ($M = \text{majoran}$)
 - ▶ $K^+ \rightarrow \mu^+ \nu \bar{\nu}$
 - ▶ $K^+ \rightarrow \pi^+ \gamma^{TP}$
 - ▶ $K^+ \rightarrow \pi^+ \gamma \gamma^P$
 - ▶ $K^+ \rightarrow \pi^+ \gamma \gamma \gamma$
 - ▶ $K^+ \rightarrow \pi^+ \text{DP}; \text{DP} \rightarrow e^+ e^-$
 - ▶ K^+ lifetime
 - ▶ $\mathcal{B}(K^+ \rightarrow \pi^+ \pi^0) / \mathcal{B}(K^+ \rightarrow \mu^+ \nu)$
 - ▶ $K^+ \rightarrow \pi^+ \pi^0 e^+ e^-$
 - ▶ $K^+ \rightarrow \pi^- \mu^+ \mu^+$ (LFV)
 - ▶ $\pi^0 \rightarrow \text{nothing}^{T,P}$
 - ▶ $\pi^0 \rightarrow \gamma \text{DP}; \text{DP} \rightarrow e^+ e^-$
 - ▶ $\pi^0 \rightarrow \gamma X$

T E787/E949 Thesis ; P E787/E949 Publication; DP \equiv Dark Photon

Opportunities

- \$10M
 - 8-120 GeV beam line to B0
 - Accumulator as new stretcher ring to run parallel with Mu2e
- \$100M
 - Recycler style 8 GeV stretcher ring in Tevatron tunnel
 - 12 booster batches circulate for 1 minute cycles

