Current and future experiments

1) What will the final results of NA62 be, in all channels considered? And what can HIKE add to it? Precision or also more channels? Which channels can HIKE observe/measure that NA62 could not?

K+ decays	NA62 current	NA62 final	HIKE Proposal
pi+nunu	35%	15%	~5%
pi+e+e-	10^4	10^5	> 5x 10+5 decays
pi+mu+mu-	3x10^4	10^5	> 5x 10+5 decays
Delta a+ FF	-	0.015	0.007
Delta b+ FF	-	0.047	0.015.
pi+ gamma gamma	1.8%	1%	few per mille
pi- mu+ e+		10-11	10-12 or below, O(10-13)
pi+ mu- e+		2x10-11	10-12 or below, O(10-13)
pi- mu+mu+		3x10-12	1x10-12 or below, O(10-13)
pi- e+e+		2x10-11	10-12 or below, O(10-13)
pi+mu+e-		10-11	10-12 or below, O(10-13)
pi-pi0e+e+		3x10-10	10-12 or below, O(10-13)
pi+pi0 mu e.	-	10-10	2x10-11
mu-nu e+e+		3x10-11	10-12 or below, O(10-13)
e- nu mu+mu+		10-11	10-12 or below, O(10-13)

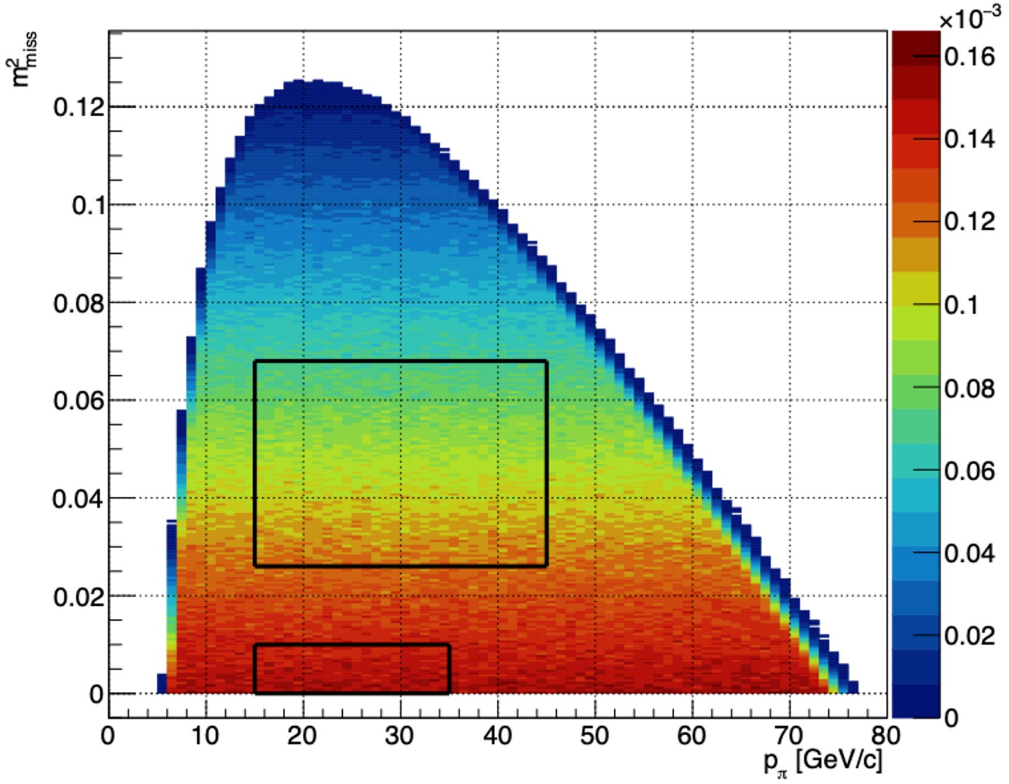
And all KL that are not accessible to NA62.

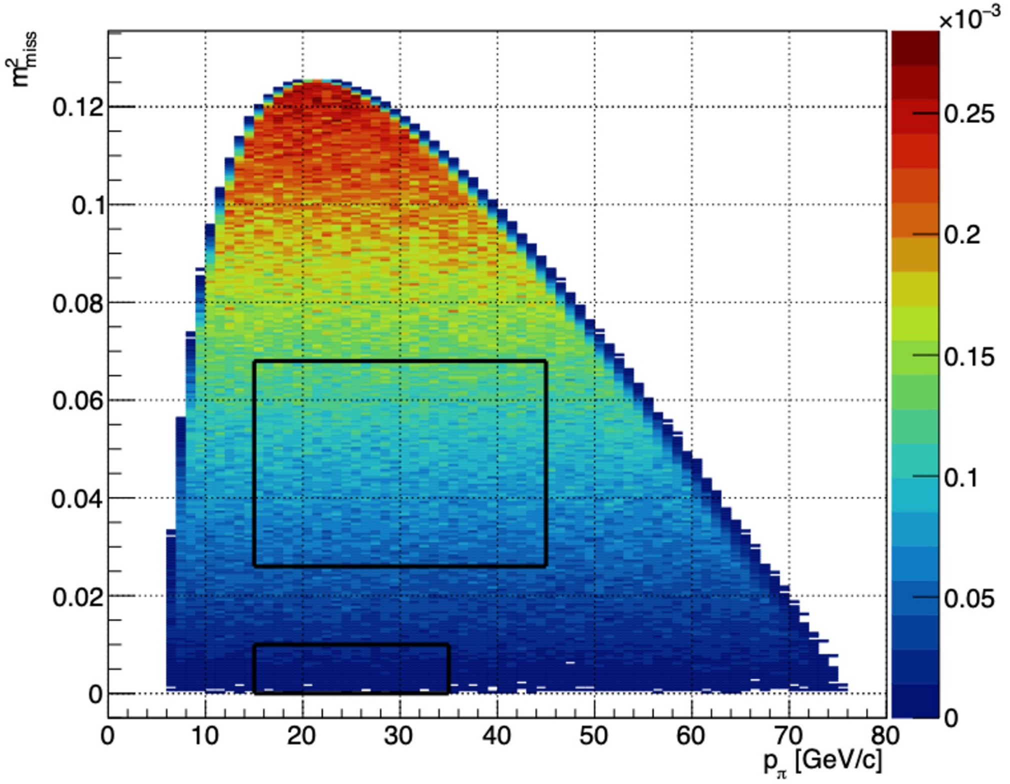
Anything useful that theory would like us to do, that is not in the list and in what was shown ?
For example KL to gamma gamma ?

Current and future experiments

2) Which FIPs scenarios (standard and non-standard) ? or scalar/vector amplitude can HIKE/KOTO investigate in the neutral kaon mode?
KL->pi0 X (X decaying to invisibles, photons, leptons), pipi a . Anything else ?

Vector/scalar for pi+nunu:





Current and future experiments

2) Which FIPs scenarios (standard and non-standard) ? or scalar/vector amplitude can HIKE/KOTO investigate in the neutral kaon mode?
KL->pi0 X (X decaying to invisibles, photons, leptons), pipi a . Anything else ?

2201.07805

Decay \ Model	2.1 Higgs portal	2.2 ALP	2.3 Heavy Neutral Lepton	2.4 Dark Photon	2.5 Leptonic Force (X)	2.6 Strongly Int. Neutrino	2.7 GN Violation	2.8 Two dark sector particles	2.9 Dark Baryons	2.10 More exotic	2.11 Heavy New Physics
4.1 $K \to \pi$+inv	✓	✓	–	✓	–	✓	✓	✓	–	–	✓
4.2 $K \to \pi\pi$+inv	CP viol.	axial coupl.	–	✓even massless	–	–	–	–	–	–	–
4.3 $K \to \pi\gamma$+inv	possible in extensions	possible in extensions	–	✓even massless	–	–	–	–	–	–	–
4.4 $K \to 2\pi\gamma$+inv	–	–	–	$\pi^0 \to \gamma A'$	–	–	–	–	–	possible	–
4.5 $K \to \pi\gamma\gamma$	negligible (✓dilaton)	✓prompt	–	–	–	–	lifetime loophole	–	–	–	–
4.6 $K \to \pi\ell_\alpha\ell_\alpha$	✓prompt	✓prompt	–	✓	–	–	lifetime loophole		–	–	–
4.7 $K \to \pi\pi\ell_\alpha\ell_\alpha$	CP viol.	axial coupl. & prompt	–	✓	–	–	–	–	–	–	–
4.8 $K \to \pi\ell_\alpha\ell_\alpha\ell_\beta\ell_\beta$	–	–	–	–	–	–		A', MeV axion, also $K \to \pi 2\ell_\alpha 2\ell_\beta$inv	–	–	–
4.9 $K_L \to \gamma$+inv	–	–	–	✓	–	–	–	–	–	–	–
4.10 $K \to \pi\gamma, 3\gamma$	–	–	–	–	–	–	–	–	–	Lorentz viol.	–
4.11 $K_L \to \gamma\gamma$+inv	–	–	–	–	–	–	✓(Table 2)	–	–	–	–
4.12 $K_{S,L} \to \ell^+\ell^-$+inv	–	–	–	–	–	–	possible	possible	–	–	$K_S \to \mu\mu$
4.12 $K_{S,L} \to 2\ell 2\gamma$	–	–	–	–	–	–	possible	possible	–	–	–
4.13 $K^0 \to 4\ell$	–	–	–	–	–	–	possible	possible	–	–	–
4.14 $K^+ \to \ell^+$+inv	–	–	✓	–	✓($X \to$inv)	✓	–	–	–	–	–
4.15 $K^+ \to 3\ell$+inv	–	–	possible	–	✓($X \to \ell\ell$)	–	–	$U(1)$+HNL	–	–	–
4.16 $K^+ \to \ell\gamma\gamma$+inv	–	–	$K^+ \to \pi^0\ell^+N$ ($m_N \lesssim 20\,\text{MeV}$)	–	possible ($X \to 2\gamma$)	possible	–	possible	–	–	–
4.17 LFV	–	–	–	–	–	–	–	–	–	FV ALP, Z'	FV ALP
4.18 LNV	–	–	✓($K^+ \to \ell^+N$, $N \to \pi^-\ell^+$)	–	–	–	–	–	–	–	✓(Maj. HNL)
4.19 Rare K_S decays	$K_S \to \pi(\pi)2\ell$	$K_S \to \pi(\pi)2\ell$, $\to \pi(\pi)2\gamma$	–	$K_S \to A'\gamma$ $\to A'\gamma\pi$	–	–	–	$K_S \to 4\ell$	–	$K_S \to 2\gamma$+inv	$K_S \to \mu\mu$
4.20 Dark Shower	–	–	–	–	–	–	–	–	–	✓	–
5 Hyperon	$B_1 \to B_2\varphi$	Table 8 $B_1 \to B_2 a$	–	Table 1 $B_1 \to B_2 A'$		–	–	–	Table 4 $B \to \gamma/M$+inv	–	–

Current and future experiments

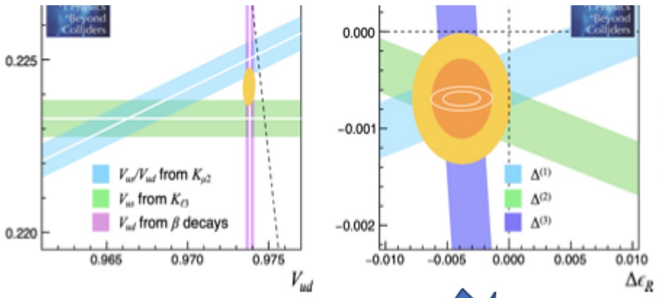
3) What can current and planned kaon experiments do to scrutinize and/or improve existing results for tree-level and hadronic decays?

- NA62 / HIKE:
  - Cabibbo anomaly:
  - RK: order 1 per mille precision

- KOTO / KOTO-II
  - ?

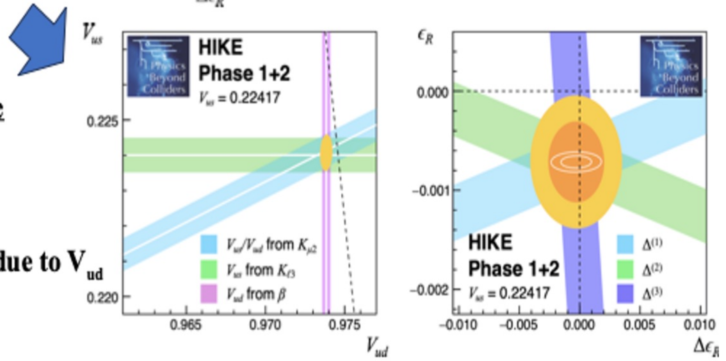
- LHCb:
  - Measurement of the K mass with K-> pi pi pi
  - Improve KS-> pi mu nu ?
  - KS-> gamma gamma?

- Case for a new phi-factory???



V_{us} from kaon and tau decays,
V_{ud} from super-allowed beta decays

Constraints from CKM unitarity on the contributions to the leptonic and semileptonic kaon decay amplitudes from right-handed quark currents



HIKE can clarify the origin of the Cabibbo angle anomaly
In the scenario illustrated,
HIKE resolves tension between $K_{\mu 2}$ and K_{l3} but confirms anomaly due to V_{ud}

The average of the six charged kaon mass measurements which we use in the Particle Listings is

$$m_{K^\pm} = 493.677 \pm 0.013 \text{ MeV } (S = 2.4) , \quad (1)$$

where the error has been increased by the scale factor S. The large scale factor indicates a serious disagreement between different input data. The average before scaling the error is

$$m_{K^\pm} = 493.677 \pm 0.005 \text{ MeV} ,$$

$$\chi^2 = 22.9 \text{ for 5 D.F., Prob. } = 0.04\% , \quad (2)$$

where the high χ^2 and correspondingly low χ^2 probability further quantify the disagreement.

The main disagreement is between the two most recent and precise results,

$$m_{K^\pm} = 493.696 \pm 0.007 \text{ MeV} \quad \text{DENISOV 91}$$

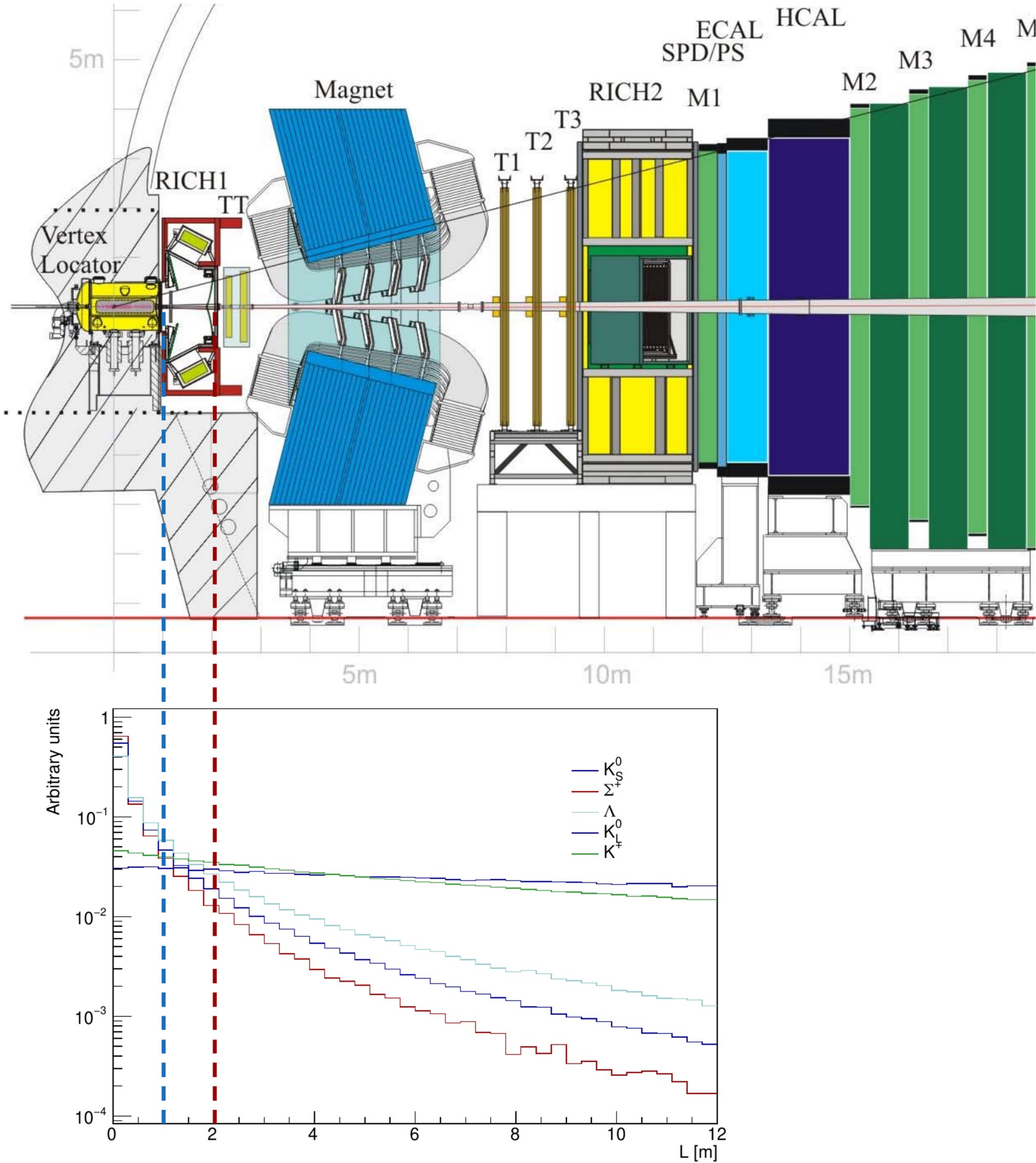
$$m_{K^\pm} = 493.636 \pm 0.011 \text{ MeV } (S = 1.5) \quad \text{GALL 88}$$

Current and future experiments

4) Which precision can LHCb reach in the measurement of a_s in KS → pi0 l+ l- ?
5) Which precision can LHCb reach in the measurement of KS to mu mu ?
6) Can LHCb measure the KS-KL → mu mu interference?
7) How can the LHCb trigger and DAQ be further improved to enhance KS physics? and K+?

-> For current LHCb these will be answered in Radoslav’s talk on Thursday!
-> Reconstruction: other track types (exploit later decaying KS and hyperons)
-> What are the main limitations of LHCb Upgrade++? Luminosity? Acceptance?

Ultimate precision at an “LHCb”-like experiment? What could be done (with inf. money)
[perhaps even FCC-flavour experiment?]



Current and future experiments

8) Is there anything to be learned from strange hyperon physics at LHCb that is not covered yet by the kaon sector?

- Complementary couplings?
- Soft QCD?
- Semileptonics + Radiative
- DeltaS = 2 (Xi-> p pi …)
- Is there any competition (in a remote future)?
- Eta decays? (-> Recent CMS eta-> 4 mu paper)

9) In which aspects is HIKE unique for heavy neutral lepton searches?
10) Which unique roles do HIKE, KOTO-II and LHCb Phase 2 play?
K+/KL KL KS +Hyperons

- How do HIKE and KOTO-II compare on KL?