Kaon experiments: recent results and prospects

Cristina Lazzeroni

University of Birmingham

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UNIVERSITY OF BIRMINGHAM

European Research Council
Established by the European Commission

Kaon physics facilities

BNL
E865, E777, E787, E949

CERN
NA48, NA62

IHEP Protvino
ISTRA+, OKA, *KLOD*

FNAL
KTeV, *ORKA*

LNF
KLOE, KLOE-2

KEK/J-PARC
E391a, KOTO, *TREK*

A variety of experimental techniques:
K decay-in-flight (e.g. CERN), stopped **K⁺**, ϕ factory

KLOE: latest results

$\sigma(e^+e^- \to \phi) \approx 3\ \mu b$ $K_S, K^+ \leftarrow \phi \rightarrow K_L, K^-$

ϕ decay at rest provides monochromatic and pure kaon beams

Search for CP violation in $K_S \to \pi^0\pi^0\pi^0$

arXiv:1301.7623

$BR(K_S \to 3\pi^0) \leq 2.6 \times 10^{-8}$ @ 90% CL

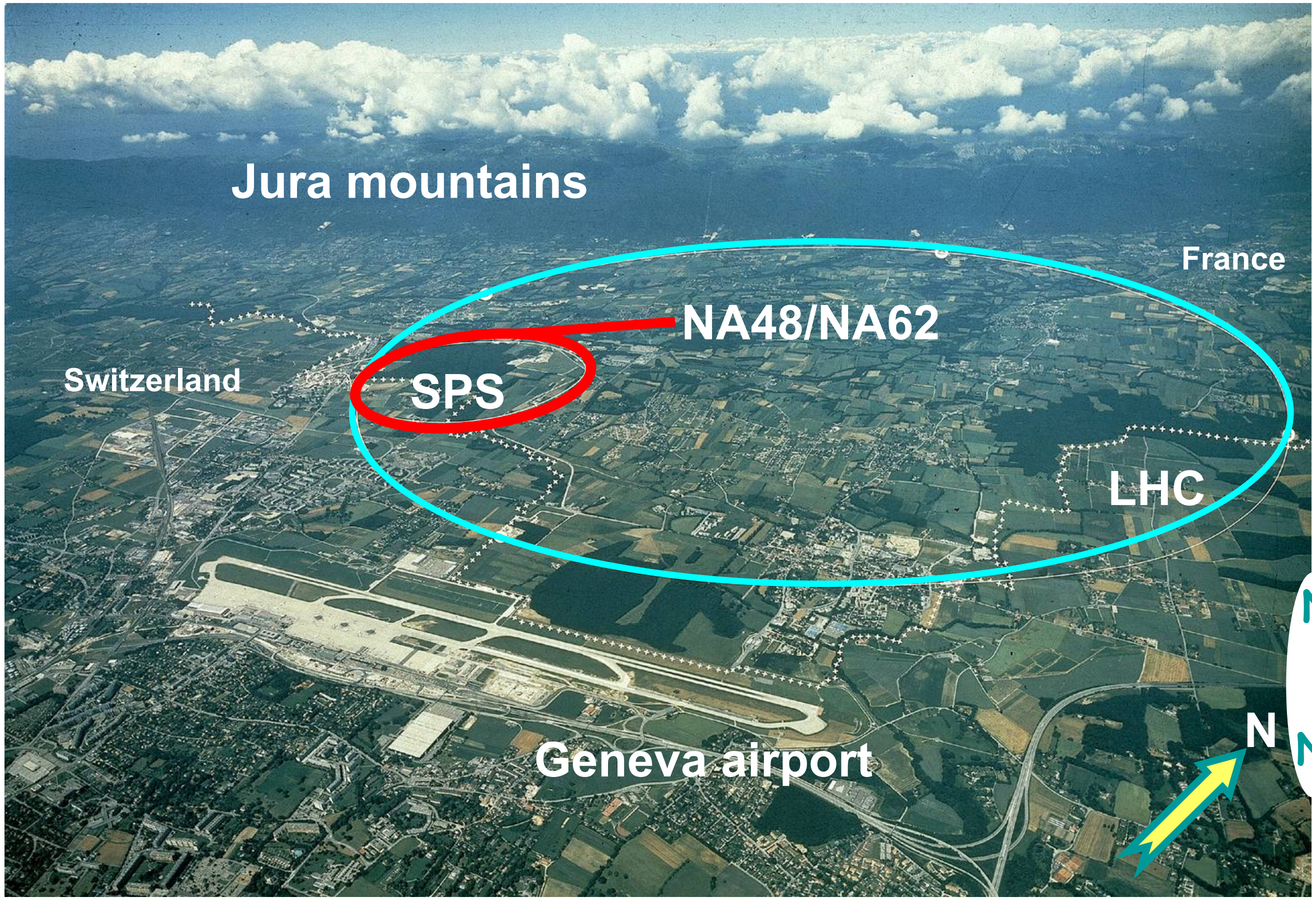
$|\eta_{000}| < 0.0088$ @ 90% CL

1.7 fb^{-1} of the KLOE data sample

KLOE preliminary

$BR(K^+ \to \pi^+\pi^-\pi^+) = (0.05526 \pm 0.00035_{stat} \pm 0.00036_{syst})$, $\Delta BR/BR = 9.2 \times 10^{-3}$

NA62, R_K Phase: recent results



Primary SPS protons (400 GeV/c): 1.8×10^{12}/SPS spill
Un-separated secondary positive beam
Composition: $K^+(\pi^+) = 5\%(63\%)$.
K^+ decaying in vacuum tank: 18%.

NA48 (discovery of direct CPV)

- 1997: ε'/ε: K_L+K_S
- 1998: K_L+K_S
- 1999: K_L+K_S | K_S HI
- 2000: K_L only | K_S HI
- 2001: K_L+K_S | K_S HI

NA48/1

- 2002: K_S/hyperons

NA48/2

- 2003: K^+/K^-
- 2004: K^+/K^-

NA62 (R_K)

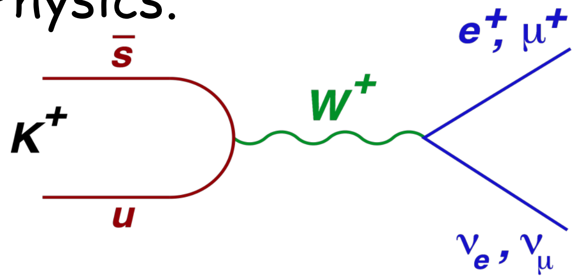
- 2007: $K^\pm_{e2}/K^\pm_{\mu2}$
- 2008: $K^\pm_{e2}/K^\pm_{\mu2}$

NA62

- 2007–2013: design & construction
- 2012: test run
- 2014: first data taking

R_K in the SM

A precise measurement of the ratio of $K \to l\nu_l$ leptonic decays provides an ideal test of SM and indirect search for New Physics.



Hadronic uncertainties cancel in the ratio $K_{e2}/K_{\mu2}$
SM prediction: excellent sub-permille accuracy

R_K is sensitive to lepton flavour violation and its SM expectation:

$$R_K = \frac{\Gamma(K^\pm \to e^\pm \nu)}{\Gamma(K^\pm \to \mu^\pm \nu)} = \frac{m_e^2}{m_\mu^2} \cdot \left(\frac{m_K^2 - m_e^2}{m_K^2 - m_\mu^2}\right)^2 \cdot (1 + \delta R_K^{\mathrm{rad.corr.}})$$

Helicity suppression: $f \sim 10^{-5}$

Radiative correction (few %) due to $K^+ \to e^+\nu\gamma$ (IB) process, by definition included into R_K

[V.Cirigliano, I.Rosell JHEP 0710:005 (2007)]

helicity suppression of R_K might enhance sensitivity to non-SM effects to an experimentally accessible level.

$R_K^{SM} = (2.477 \pm 0.001) \times 10^{-5}$

Phys. Rev. Lett. 99 (2007) 231801

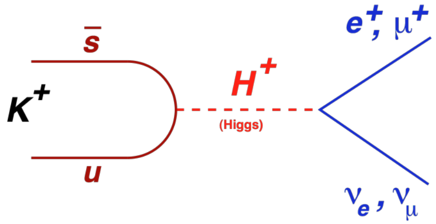
R_K beyond the SM

In the MSSM large tanβ scenario, the presence of LFV terms (charged Higgs coupling) introduces extra contributions to the SM amplitude ~1% effect
Girrbach and Nierste, arXiv:1202.4906

2HDM - tree level

$K^\pm \to l^\pm \nu$ can proceed via charged Higgs $H^\pm$ (in addition to $W^\pm$) exchange

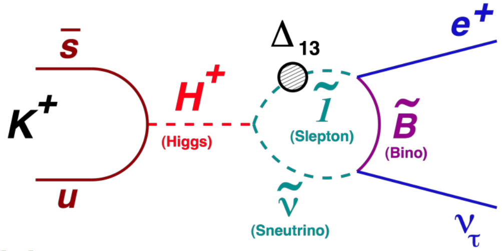
→ Does not affect the ratio R_K



2HDM - one-loop level

Dominant contribution to R_K: $H^\pm$ mediated LFV (rather than LFC) with emission of ν_τ

→ R_K enhancement can be experimentally accessible



PRD 74 (2006) 011701,JHEP 0811 (2008) 042

$$R_K^{LFV} = \frac{\Gamma_{SM}(K \to e\nu_e) + \Gamma_{LFV}(K \to e\nu_\tau)}{\Gamma_{SM}(K \to \mu\nu_\mu)}$$

$$R_K^{LFV} \approx R_K^{SM}\left[1 + \left(\frac{m_K^4}{m_{H^\pm}^4}\right)\left(\frac{m_\tau^2}{m_e^2}\right)|\Delta_{13}|^2 \tan^6\beta\right]$$

Much limited by the recent B and τ measurements
Fonseca, Romão and Teixeira, EPJC 72 (2012) 2228

Sensitive to SM extensions with 4th generation, sterile neutrinos
Lacker and Menzel, JHEP 1007 (2010) 006;
Abada et al., JHEP 1302 (2013) 048

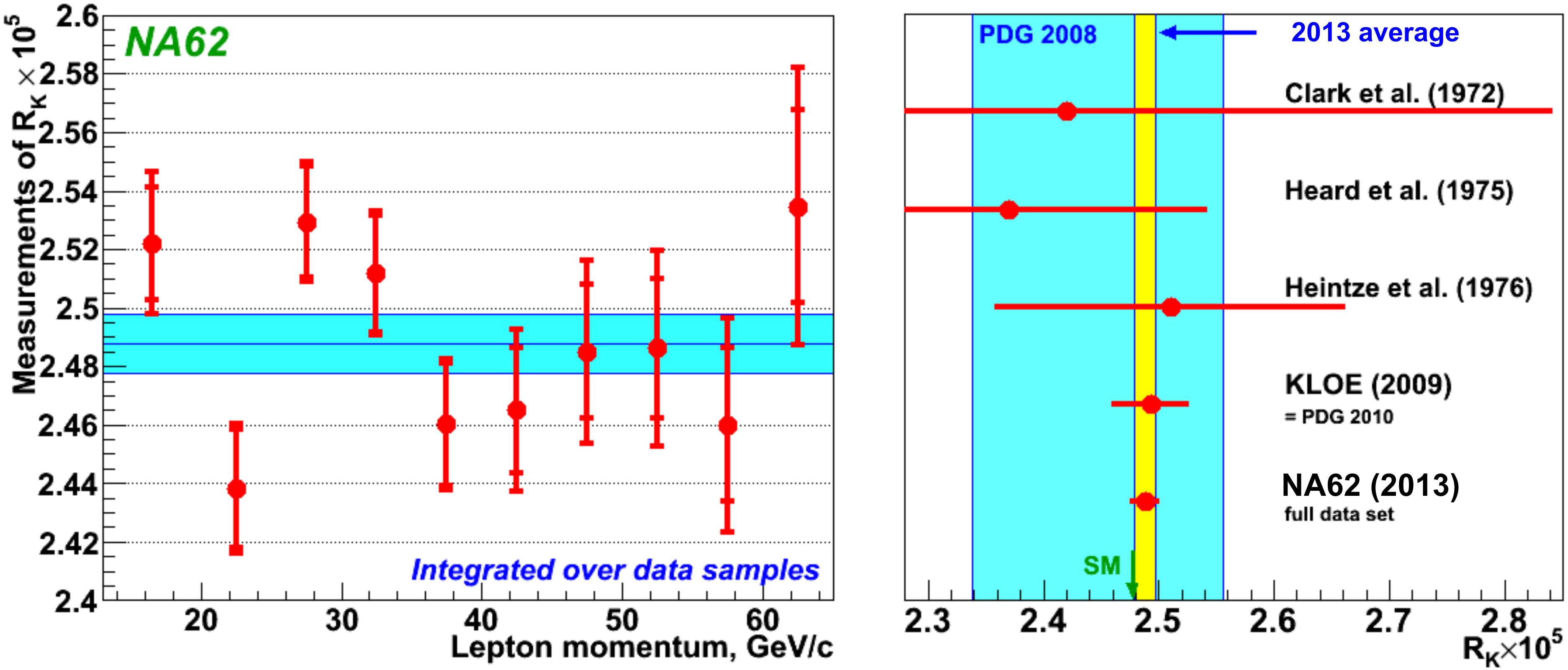
NA62 final result

$R_K = (2.488 \pm 0.007_{stat} \pm 0.007_{syst}) \times 10^{-5}$

$R_K = (2.488 \pm 0.010) \times 10^{-5}$

Strong UK leadership

[Phys. Lett. B 719 (2013) 326]



Independent measurements in lepton momentum bins

(systematic errors included, partially correlated)

World average	$R_K \times 10^5$	Precision
PDG 2008	2.447±0.109	4.5%
2013	2.488±0.009	0.4%

R_K: Future prospects

Strong UK leadership

Future NA62 (data taking in 2014–2015):

Hermetic veto (large-angle and small-angle veto counters) will strongly decrease the background.
Beam spectrometer (beam tracker plus beam Cherenkov) will allow time correlation between incoming kaons and decay products (improved PID).

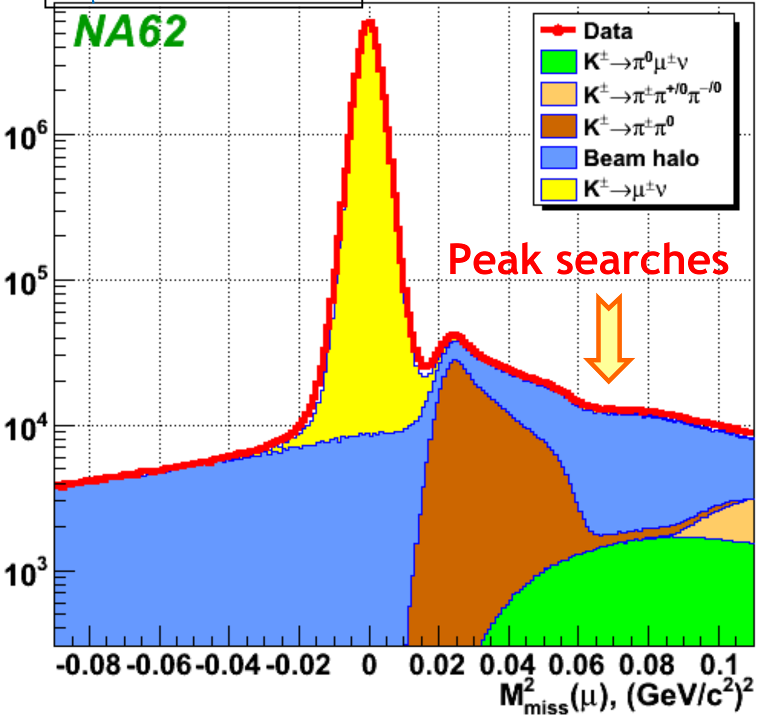
Only the $K_{\mu 2}$ ($\mu \rightarrow e$) background will remain: well known ~0.1% contamination.

Assuming an analysis at low lepton momentum and not using electron ID, measurement of R_K with much improved relative precision is feasible.

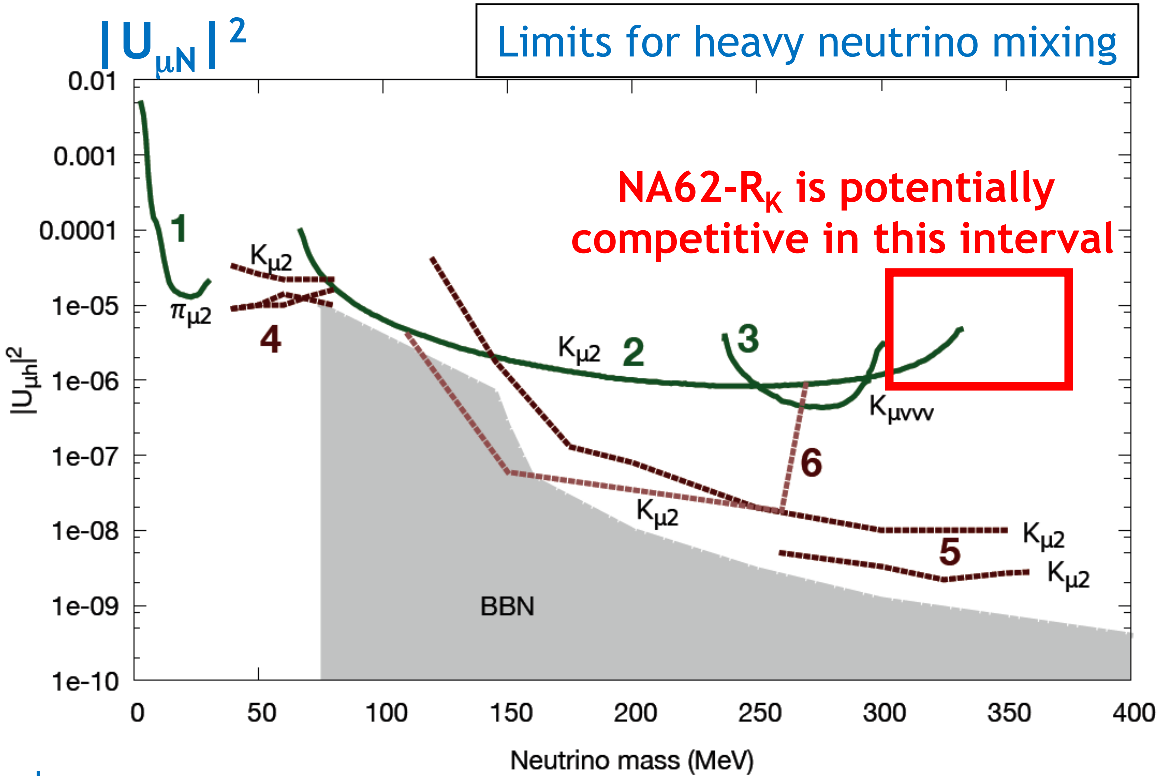
Required statistical uncertainty is ~0.05% → few million K_{e2} candidates.
Required kaon decay flux: $N_K \sim 10^{12}$
Expected NA62 flux: $N_K \sim 10^{13}$

$K_{\mu 2}$: heavy sterile neutrinos

$K_{\mu 2}$ candidates



Limits for heavy neutrino mixing



NA62-R_K subsample: 18.0M $K^+ \to \mu^+ \nu_\mu$

→ Search for heavy sterile neutrino: $K^+ \to \mu^+ N$

NA62-R_K Upper Limit if no backgrounds:

$|U_{\mu N}|^2 < 10^{-7}$, $100\ \mathrm{MeV}/c^2 < M_N < 380\ \mathrm{MeV}/c^2$

Sensitivity is limited by background fluctuation (mainly beam halo)

NA62-R_K is competitive at high M_N

Peak searches (long-lived ν_h)

1. PSI, PLB 105 (1981) 263.
2. KEK, PRL 49 (1982) 1305.
3. LBL, PRD 8 (1973) 1989.

Decay searches (short-lived ν_h)

4. ISTRA+, PLB 710 (2012) 307.
5. CERN-PS191, PLB 203 (1988) 332
6. BNL-E949, preliminary

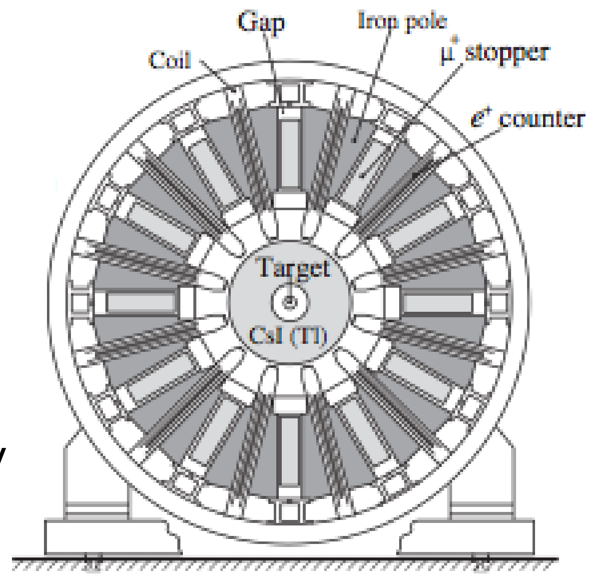
More info in Francis Newson's poster

Overview of TREK

TREK detector: Upgrade of E246 detector for the study of various Kaon decay channels at **J-PARC**.

installing/running FY2014/2015

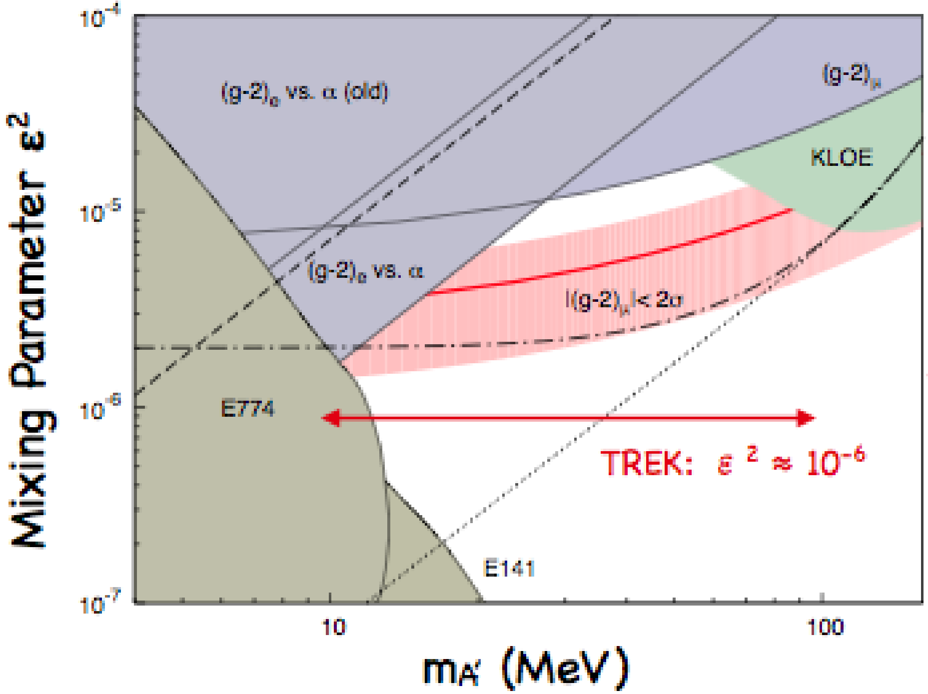
Search for lepton universality violation in a measurement of the ratio of the K_{e2} and $K_{\mu 2}$ decay widths	$K^+ \to e^+ \nu$ $K^+ \to \mu^+ \nu$ 0.25% precision
Search for a heavy sterile neutrino	$K^+ \to \mu^+ N$ $\lvert U \rvert < 2\ 10^{-8}$ for M<200 MeV
Search for dark light	$K^+ \to \pi^+ A' \to \pi^+ e^+ e^-$ $K^+ \to \mu^+ \nu A' \to \mu^+ \nu e^+ e^-$



M. Abe et al., Phys. Rev. D **73**, 072005 (2006)

SM extensions with massive gauge boson A'
Sensitivity: mixing parameter ~10^{-6} for 10<M(A')<100 MeV

TREK: Dark photon



T. Beranek and M. Vanderhaeghen, Phys. Rev. D **87**, 015024 (2013)

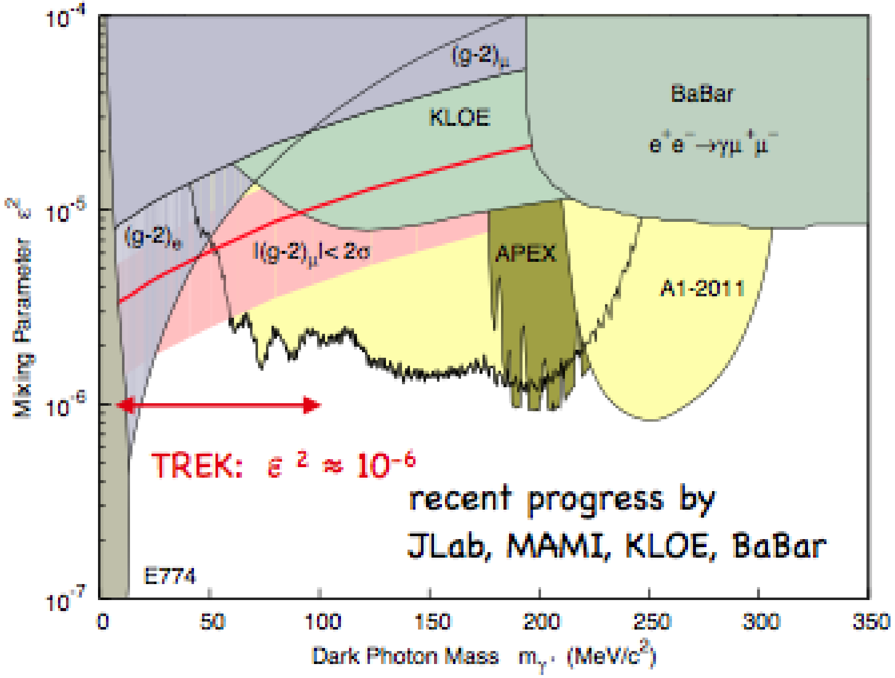


Fig. from M. Pospelov, PEB2013 workshop (2013)

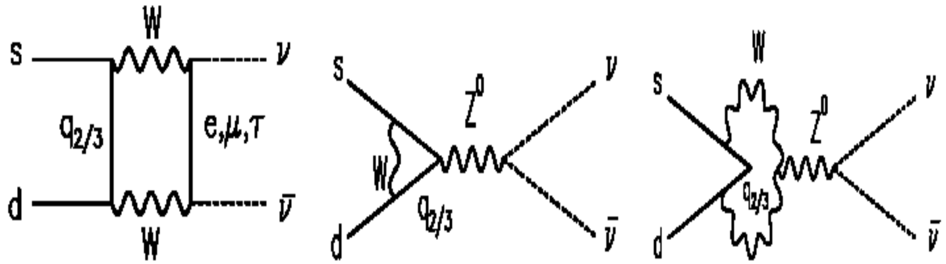
$K \to \pi \nu \nu$

$K\to\pi\nu\nu$: Theory in the Standard Model

- **FCNC loop processes**
- **SM precision surpasses any other**

FCNC process involving quarks

- **Short distance dynamics dominated**



$\lambda = V_{us}$
$\lambda_c = V_{cs}^* V_{cd}$
$\lambda_t = V_{ts}^* V_{td}$

$$x(q) \equiv \frac{m_q^2}{m_W^2}$$

$$B(K^+ \to \pi^+ \nu\bar{\nu}) = \kappa_+ \cdot \left[\left(\frac{\mathrm{Im}\,\lambda_t}{\lambda^5} X(x_t) \right)^2 + \left(\frac{\mathrm{Re}\,\lambda_t}{\lambda^5} X(x_t) + \frac{\mathrm{Re}\,\lambda_c}{\lambda} P_c(X) \right)^2 \right]$$

$$B(K_L^0 \to \pi^0 \nu\bar{\nu}) = \kappa_L \cdot \left(\frac{\mathrm{Im}\,\lambda_t}{\lambda^5} X(x_t) \right)^2$$

Charm contribution

Top contribution

$$\kappa_+ = r_{K^+} \cdot \frac{3\alpha^2 Br(K^+ \to \pi^0 e^+ \nu)}{2\pi^2 \sin^4 \theta_W} \cdot \lambda^8$$

The Hadronic Matrix Element is measured and isospin rotated

Brod et al., PRD 83 (2011) 034030

Mode	$BR_{SM} \times 10^{11}$
$K^+\to\pi^+\nu\nu(\gamma)$	7.81±0.75±0.29
$K_L\to\pi^0\nu\nu$	2.43±0.39±0.06

Theoretically clean, sensitive to new physics, almost unexplored

BNL E787/949: $K^+ \rightarrow \pi^+ \nu\nu$

Technique: K^+ decay at rest

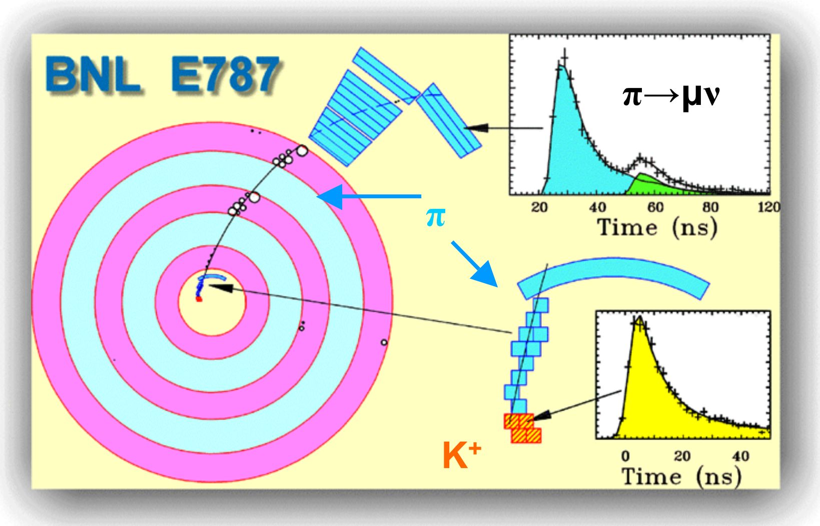
Data taking: E787 (1995–98), E949 (2002)

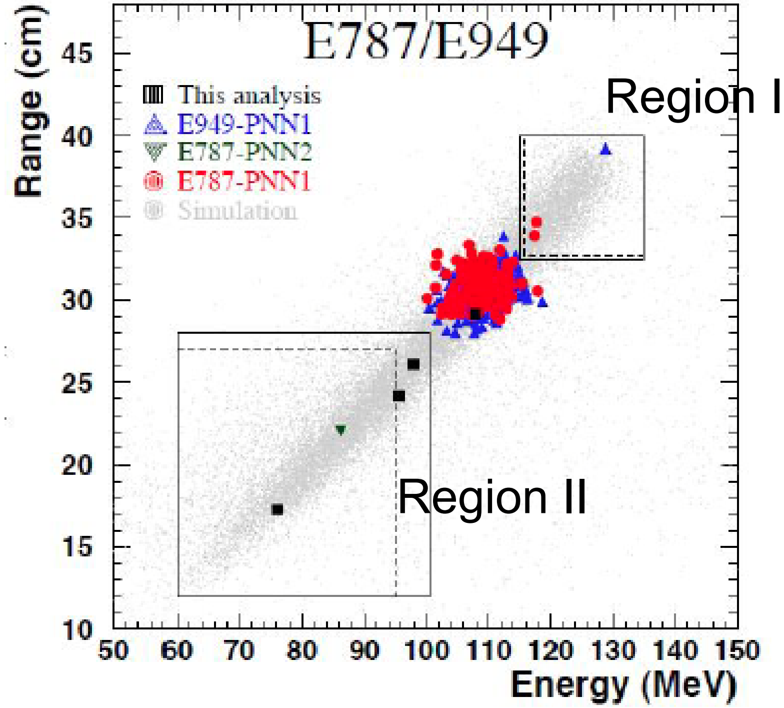
Separated K^+ beam (710 MeV/c, 1.6MHz)

PID: range (entire $\pi^+ \rightarrow \mu^+ \rightarrow e^+$ decay chain)

Hermetic photon veto system

1.8 x 10^{12} stopped K^+, ~0.1% signal acceptance





Background in Region 2 from the $K_{2\pi}$ decay with π^+ scattering in the target.

E787/E949: $BR(K^+ \rightarrow \pi^+ \nu\nu) = 1.73^{+1.15}_{-1.05} \times 10^{-10}$

PRL 101 (2008) 191802; PRD 79 (2009) 092004

- **7 observed candidates, 2.6 expected background**
- **Probability that 7 observed events are all background is 10^{-3}**
- **Still compatible with SM within errors**

NA62 @CERN: $K^+ \rightarrow \pi^+ \nu\nu$

NA62 aim: collect O(100) SM $K^+ \rightarrow \pi^+ \nu\nu$ decays with <20% background in 2 years of data taking using a novel decay-in-flight technique

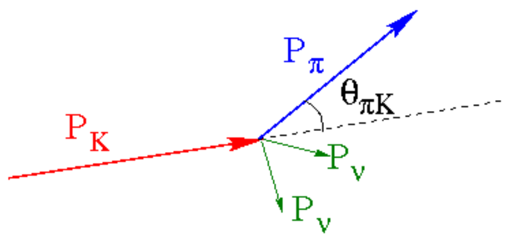
Decay signature: high momentum K^+ (75GeV/c) → low momentum π^+ (15–35 GeV/c)

Advantages: max detected K^+ decays/proton ($p_K/p_0 \approx 0.2$); efficient photon veto (>40 GeV missing energy); good π^+ vs μ^+ identification with RICH

Un-separated beam (6% kaons) → higher rates, additional backgrounds

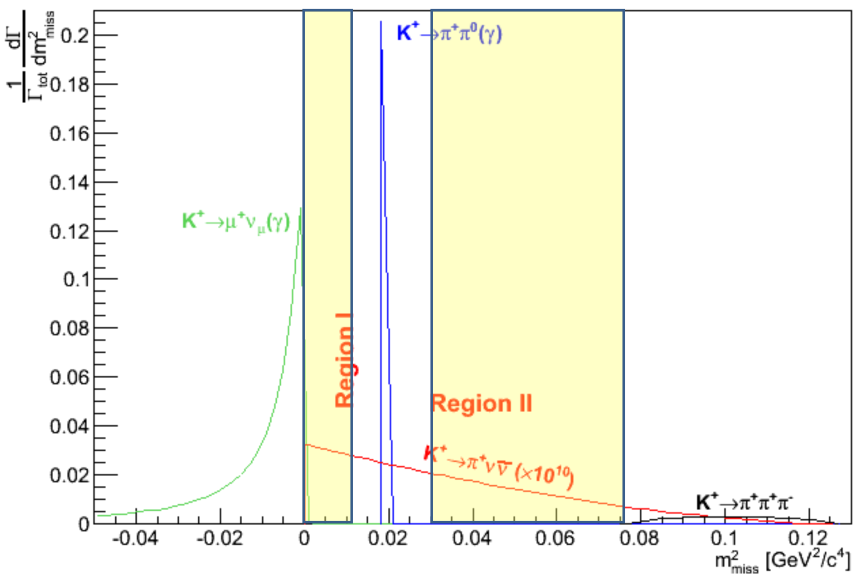
Kinematic variable:

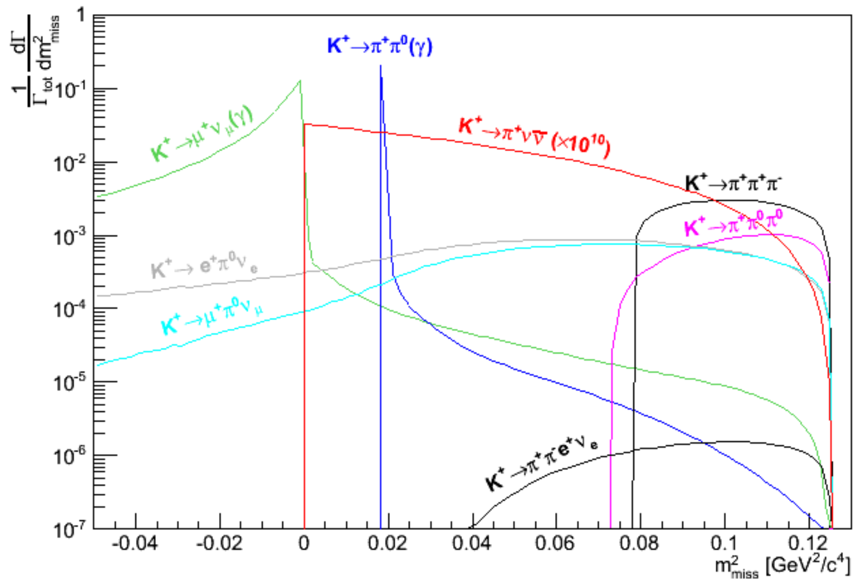
$$m^2_{miss} = (P_K - P_{\pi^+})^2$$



Backgrounds

K decays





Background

1) K^+ decay modes

2) Accidental single track matched with a K-like track

Accidental single tracks:

Beam interactions in the beam tracker

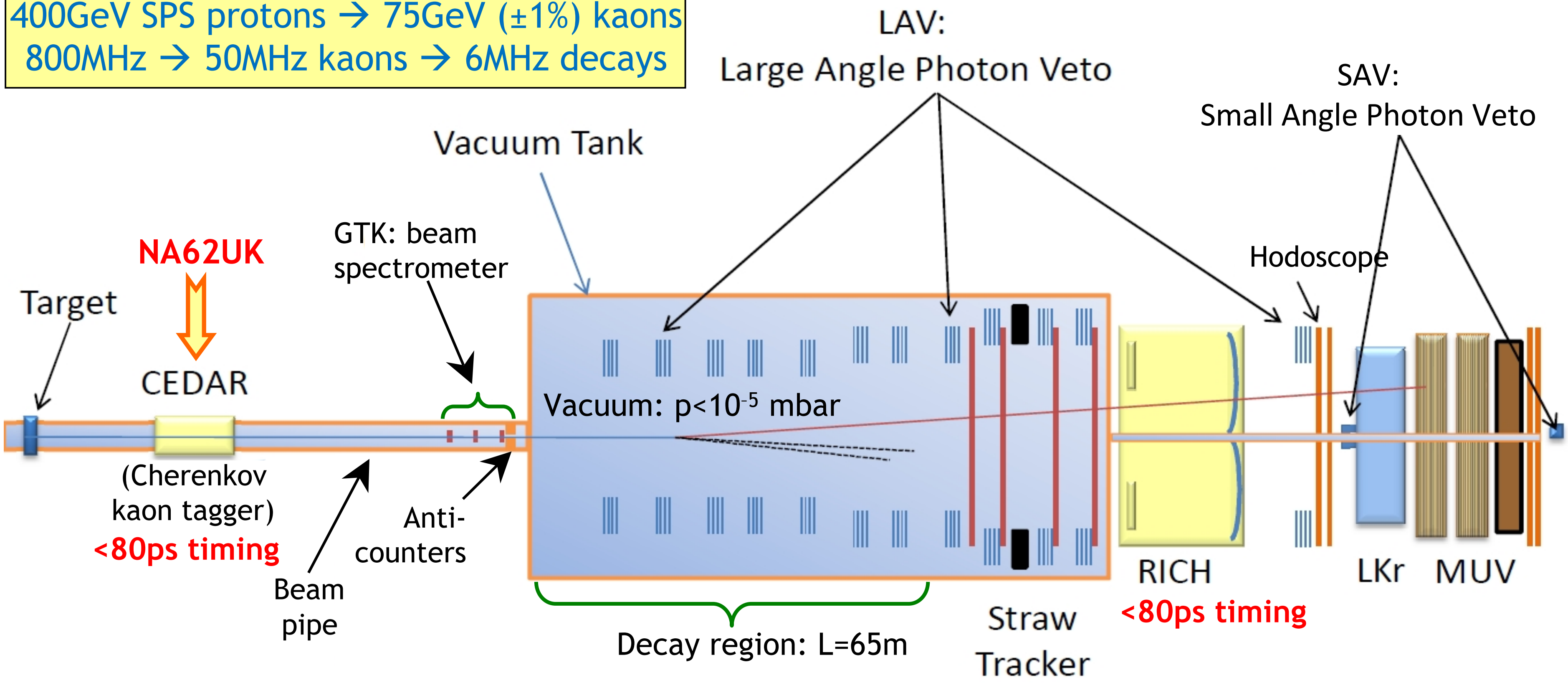
Beam interactions with the residual gas in the vacuum region.

Signal & backgrounds (events/year)	
Signal	45
$K^+ \to \pi^+\pi^0$	5
$K^+ \to \mu^+\nu$	1
$K^+ \to \pi^+\pi^+\pi^-$	<1
Other 3-track decays	<1
$K^+ \to \pi^+\pi^0\gamma$ (IB)	1.5
$K^+ \to \mu^+\nu\gamma$ (IB)	0.5
Total background	<10

The NA62 detector

Un-separated hadron ($p/\pi^+/K^+$) beam:
400GeV SPS protons → 75GeV (±1%) kaons
800MHz → 50MHz kaons → 6MHz decays

Total length: ~270m

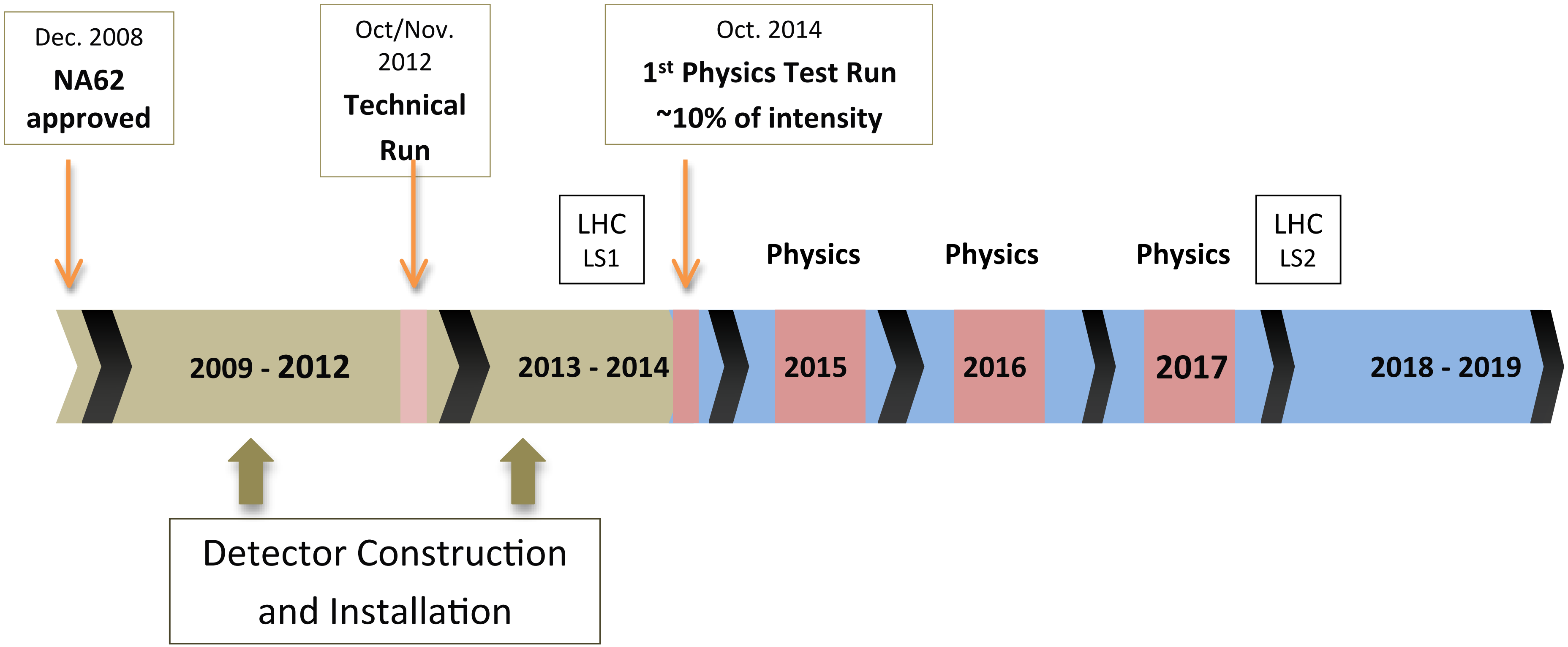


Kinematic rejection factors (limited by beam pileup and tails of MCS):
5×10^3 for $K^+\to\pi^+\pi^0$, 1.5×10^4 for $K\to\mu^+\nu$.

Hermetic photon veto: $\sim10^8$ suppression of $\pi^0\to\gamma\gamma$.

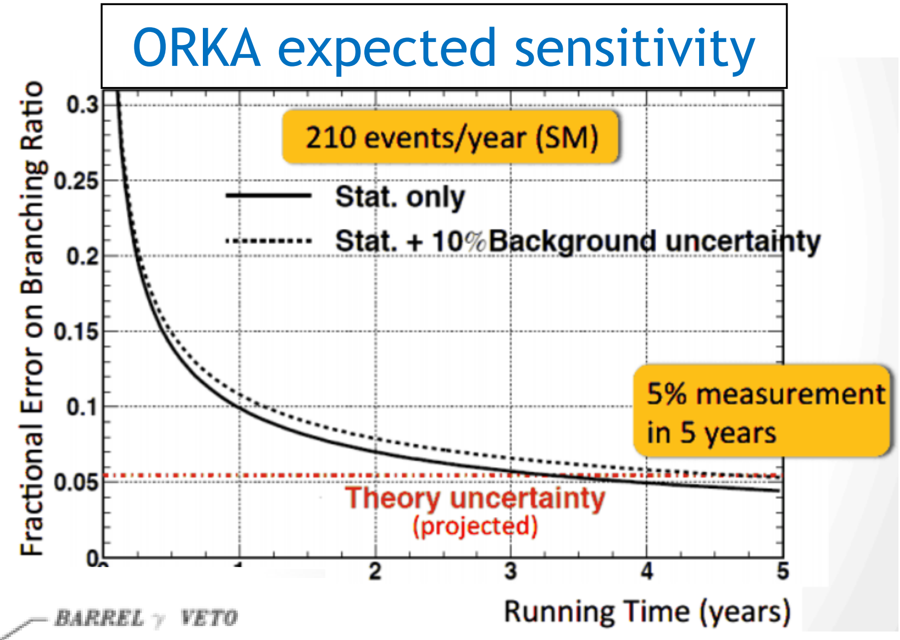
Particle ID (RICH+LKr+MUV): $\sim10^7$ muon suppression.

NA62 Timeline



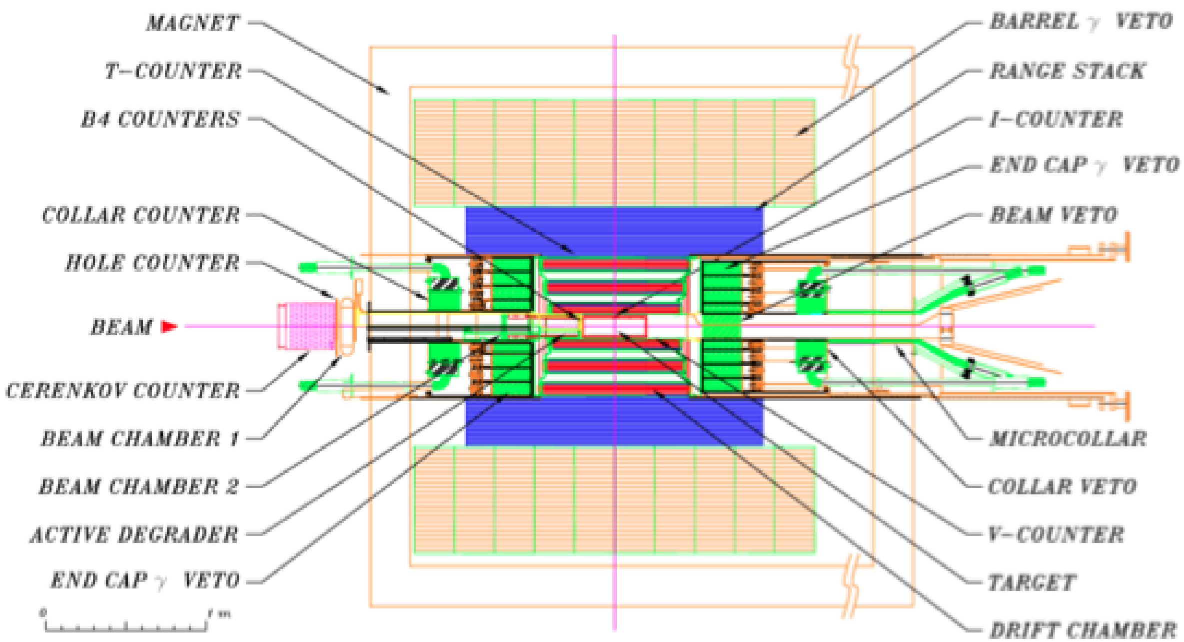
- 5 years of construction interleaved with a Technical Run in fall 2012
- In 2014 a first Run with full detector
- 3 years of Physics data taking before LHC Long Shutdown 2 (LS2)

K→πνν experiments: ORKA



<u>ORKA @ FNAL Main Injector</u> (K^+):

Builds on BNL stopped-kaon technique
Expect ~100 times higher sensitivity
(x10 from beam and x10 from detector)
Goal: $O(10^3)$ SM $K^+ \to \pi^+ \nu\nu$ events
Fits inside the CDF solenoid
Re-use CDF infrastructure



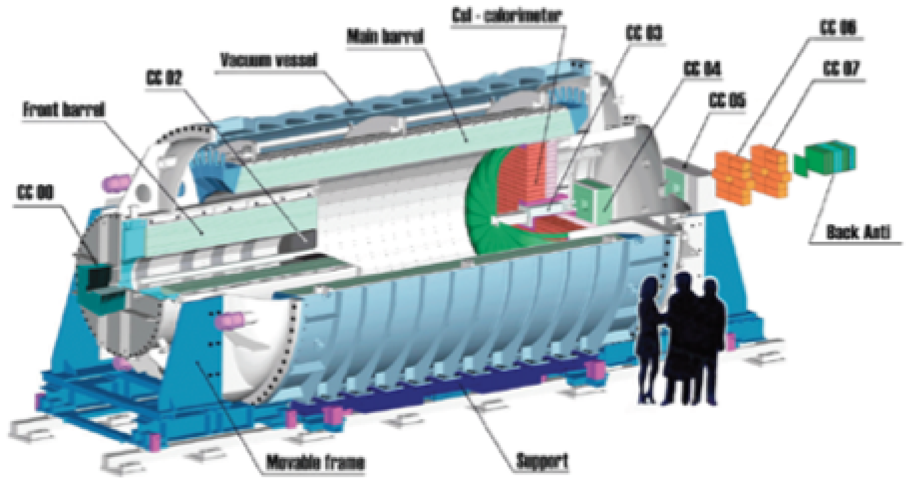
Stage I approval:
US Flavour community and funding agencies are working to find a way to make it possible

K→πνν experiments: KOTO

<u>KOTO @ J-PARC</u> (K_L):

E391a: BR<6.8×10^{-8} @ 90%CL
Expect ~10^3 times higher sensitivity

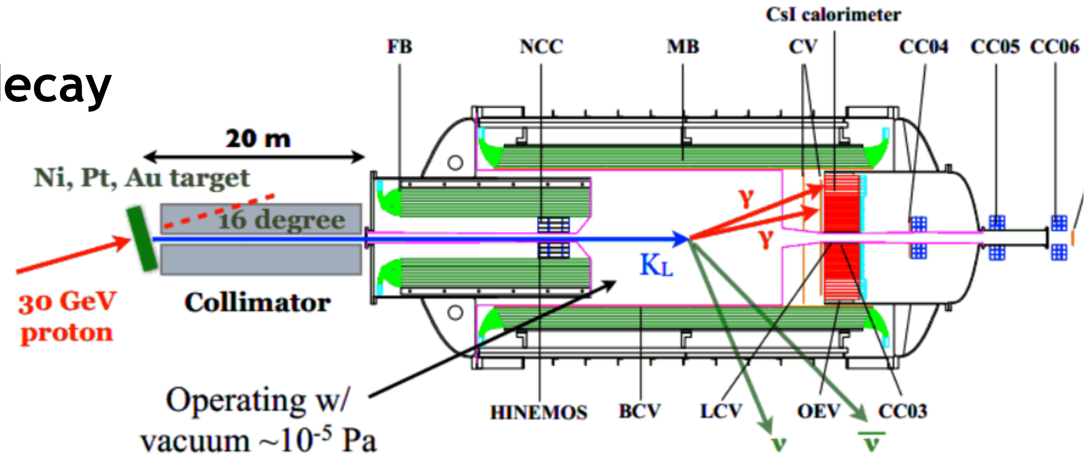
Builds on KEK E391a technique
Detector construction finished
Data taking: 2013–2017



Collimators to suppress halo neutrons - main background in E391a (n + detector →π^0)

Pencil beam: can reconstruct decay vertex assuming π^0 mass

Goal: ~3 SM $K_L \to \pi^0 \nu\nu$ events
Possible step 2: ~100 SM events



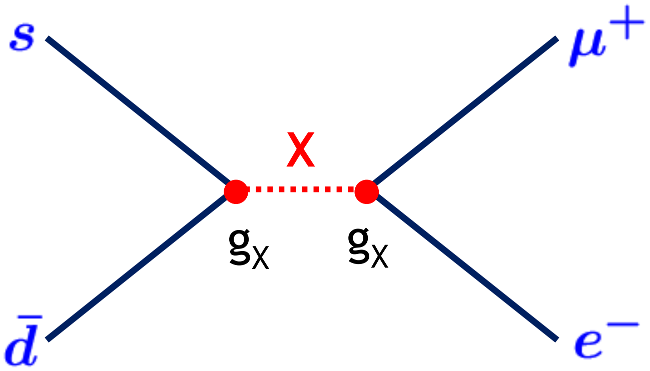
Lepton Flavour/Number violation

LFV in kaon decays

Copious production: high statistics
Simple decay topologies: clean experimental signatures

High NP mass scales accessible for tree-level contributions

Example: $K_L \to \mu^+ e^-$



Dimensional argument:

$$\frac{\Gamma_X}{\Gamma_{SM}} \sim \left(\frac{g_X}{g_W} \cdot \frac{M_W}{M_X} \right)^4$$

For $g_X \approx g_W$ and $\mathcal{B} \sim 10^{-12}$:

$$M_X \sim 100 \text{ TeV}$$

LFV in $K^{\pm}$ decays

Mode	UL at 90% CL	Experiment	Reference
$K^+ \to \pi^+ \mu^+ e^-$	1.3×10^{-11}	BNL E777/E865	PRD 72 (2005) 012005
$K^+ \to \pi^+ \mu^- e^+$	5.2×10^{-10}	BNL E865	PRL 85 (2000) 2877
$K^+ \to \pi^- \mu^+ e^+$	5.0×10^{-10}	BNL E865	PRL 85 (2000) 2877
$K^+ \to \pi^- e^+ e^+$	6.4×10^{-10}	BNL E865	PRL 85 (2000) 2877
$K^{\pm} \to \pi^{\mp} \mu^{\pm} \mu^{\pm}$	1.1×10^{-9}	CERN NA48/2	PLB 697 (2011) 107
$K^+ \to \mu^- \nu e^+ e^+$	2.0×10^{-8}	Geneva-Saclay	PL 62B (1976) 485
$K^+ \to e^- \nu \mu^+ \mu^+$	no data		

CERN NA48/2 sensitivities for these 3 modes are similar to those of BNL E865

Expected NA62 single event sensitivities: ~10^{-12} for $K^{\pm}$ decays

NA62 is capable of improving on all these decay modes

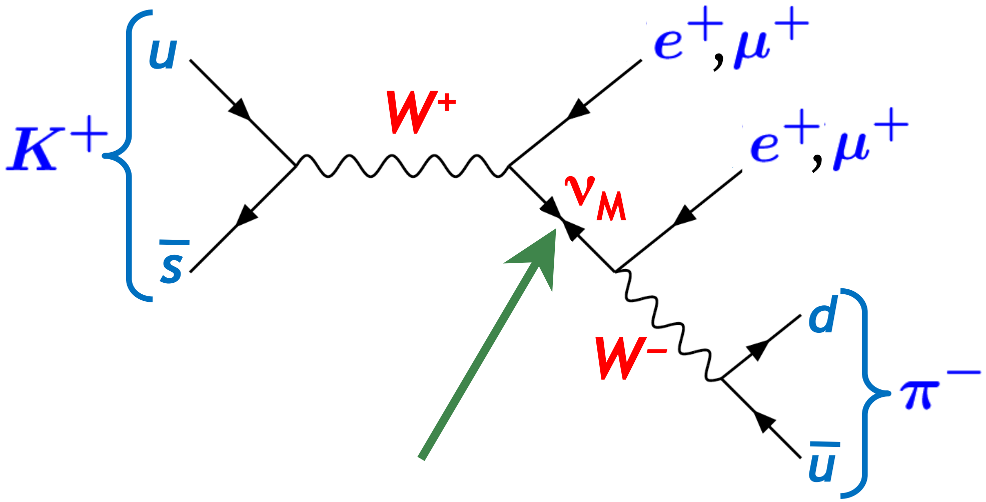
e.g. 2003-4 data $K^+ \to \pi^- \mu^+ \mu^+$: $\mathcal{B}(K^{\pm} \to \pi^{\mp} \mu^{\pm} \mu^{\pm}) < 1.1 \times 10^{-9}$ @90% CL

Precision limited by background from $\pi^{\pm} \to \mu^{\pm} \nu$ decays in spectrometer, despite SES ≈ 3×10^{-11}

In future, no $K_{3\pi}$ background expected due to high spectrometer P_T (270 vs 120 MeV/c) and improved $\pi\mu\mu$ mass resolution (1.1 vs 2.6 MeV/c^2)

Sensitivity to Majorana neutrino

$$K^+ \to \pi^- \ell_1^+ \ell_2^+, \quad \ell = e, \mu$$

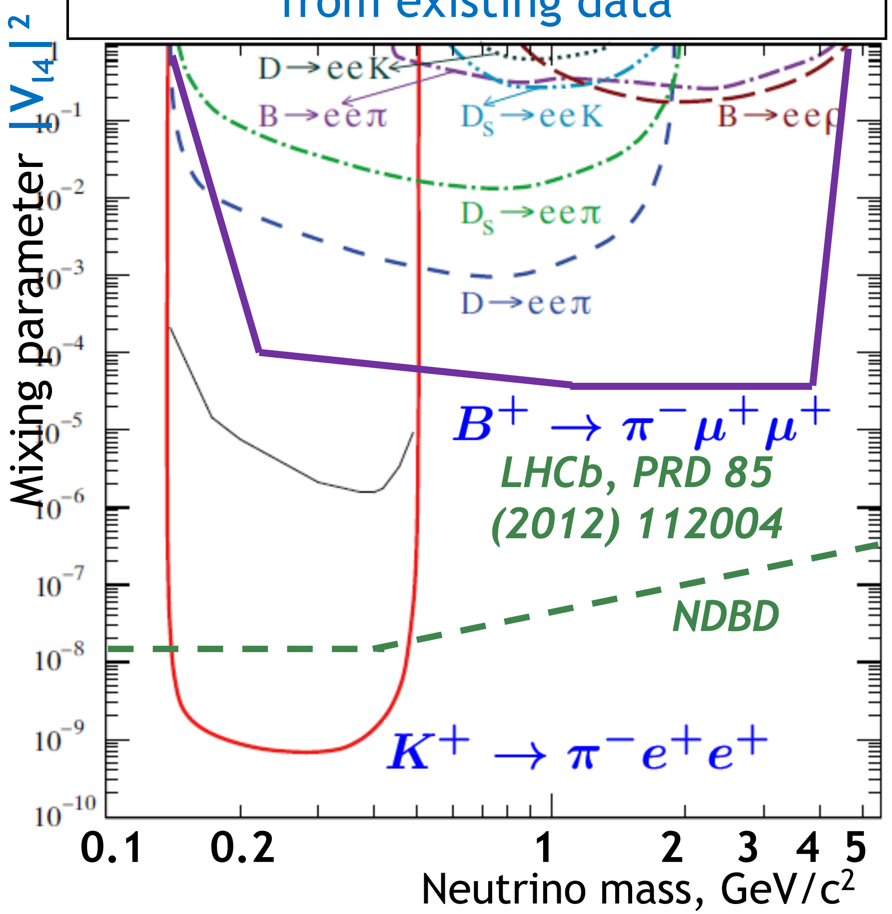


resonant enhancement for

$$m_\pi \lesssim m_\nu \lesssim m_K$$

Littenberg and Shrock, PLB491 (2000) 285

Majorana neutrino exclusion regions from existing data



Plot from Atre et al., JHEP 0905 (2009) 030

Summary

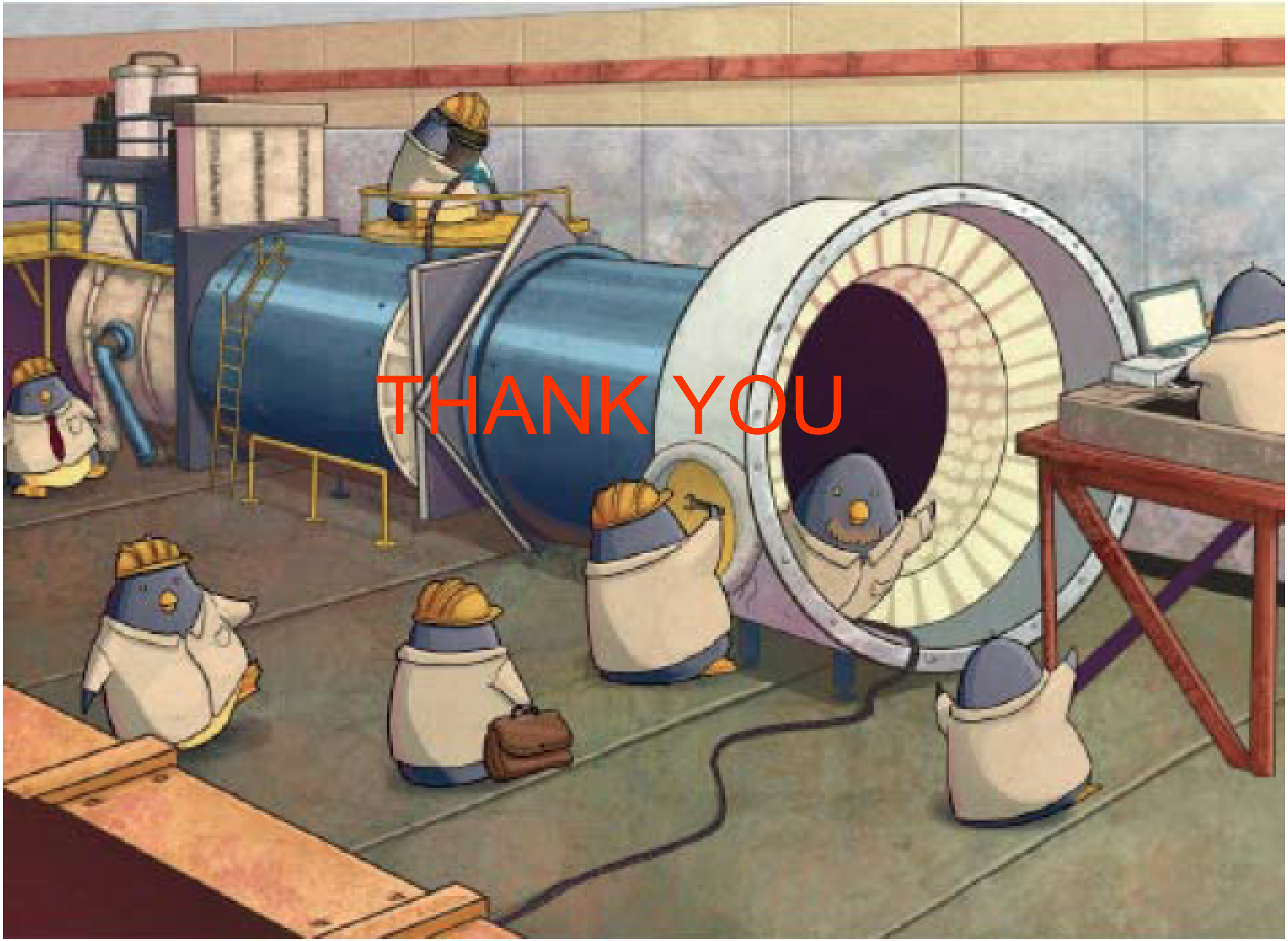
Several kaon existing experiments producing results
(only a selection shown here)
Several **planned experiments** around the world: **KLOE-2, NA62, TREK, KOTO, ORKA, KLOD**

Diverse physics programme:

- CP violation, T violation
- Ultra-Rare Decays
- Lepton Flavour/Number violation
- Search for heavy/Majorana neutrinos
- Branching ratios, QCD tests, form factors etc. (not shown)

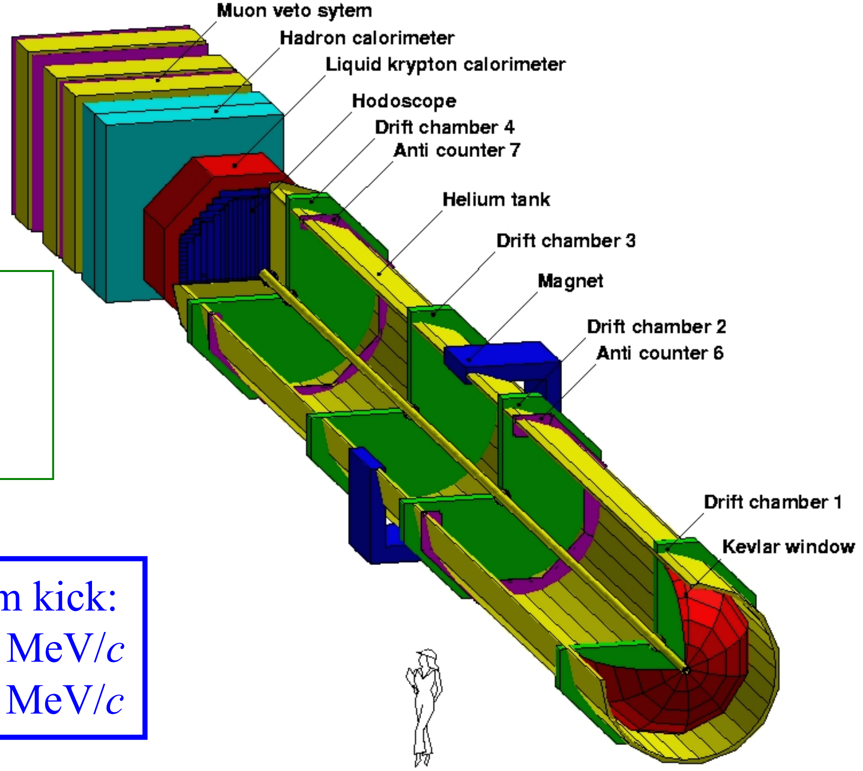
NA62@CERN (construction/commissioning):

expected single event sensitivity for K^+ decays: $\sim 10^{-12}$
preparing for the physics run in 2014 (low intensity)
with a rich physics programme



Spares

Detector



Magnetic spectrometer:
$\sigma_p/p = (1.0 \oplus 0.044\ p)\%$ [GeV/c] 2004
$\sigma_p/p = (0.48 \oplus 0.009\ p)\%$ [GeV/c] 2007

Trigger Hodoscope:
σ_t=150ps

Momentum kick:
2004: 120 MeV/c
2007: 265 MeV/c

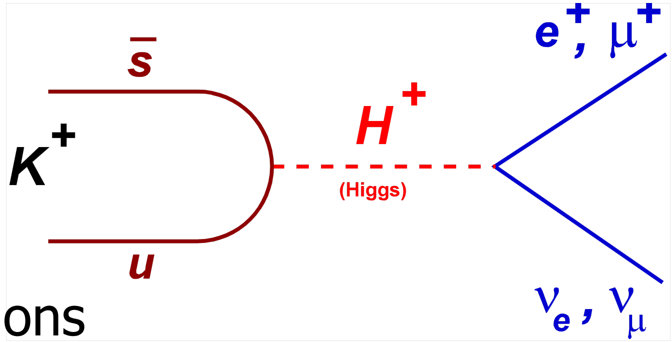
LKr electromagnetic calorimeter:
$\sigma_E/E = (3.2/\sqrt{E} \oplus 9.0/E \oplus 0.42)\%$
(E in GeV)
$\sigma_x = \sigma_y \sim 1.5$mm for E=10 GeV
$\sigma(M_{\pi\pi^0\pi^0}) = 1.4$ MeV/c^2
E/p ratio used for e/π discrimination

- ~100 m long decay region in vacuum
- Similar acceptance between K^+ and K^- beams checked reversing magnetics fields
- Pion decay products, from the hadronic beam, remain into the beam pipe

Leptonic meson decays: $P^+ \to l^+\nu$

SM contribution is helicity suppressed:

$$\Gamma(P^+ \to l^+\nu) = \frac{G_F^2 M_P M_l^2}{8\pi}\left(1 - \frac{M_l^2}{M_P^2}\right)^2 f_P^2 |V_{qq'}|^2$$



Sizeable tree level charged Higgs ($H^\pm$) contributions in models with two Higgs doublets (2HDM including SUSY)

PRD48 (1993) 2342; Prog.Theor.Phys. 111 (2004) 295

(numerical examples for M_H=500GeV/c², tanβ = 40)

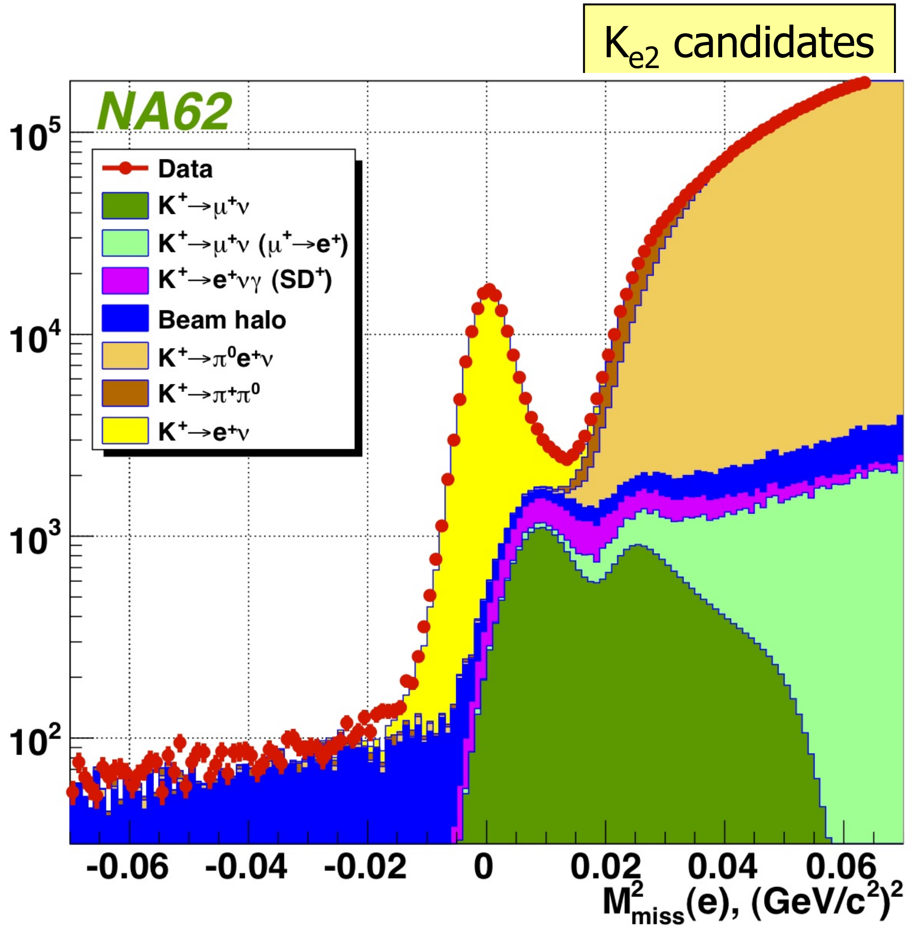
$\pi^+ \to l\nu$: $\Delta\Gamma/\Gamma_{SM} \approx -2(m_\pi/m_H)^2\, m_d/(m_u+m_d)\, \tan^2\beta \approx 2\times10^{-4}$

$K^+ \to l\nu$: $\Delta\Gamma/\Gamma_{SM} \approx -2(m_K/m_H)^2 \tan^2\beta \approx 0.3\%$

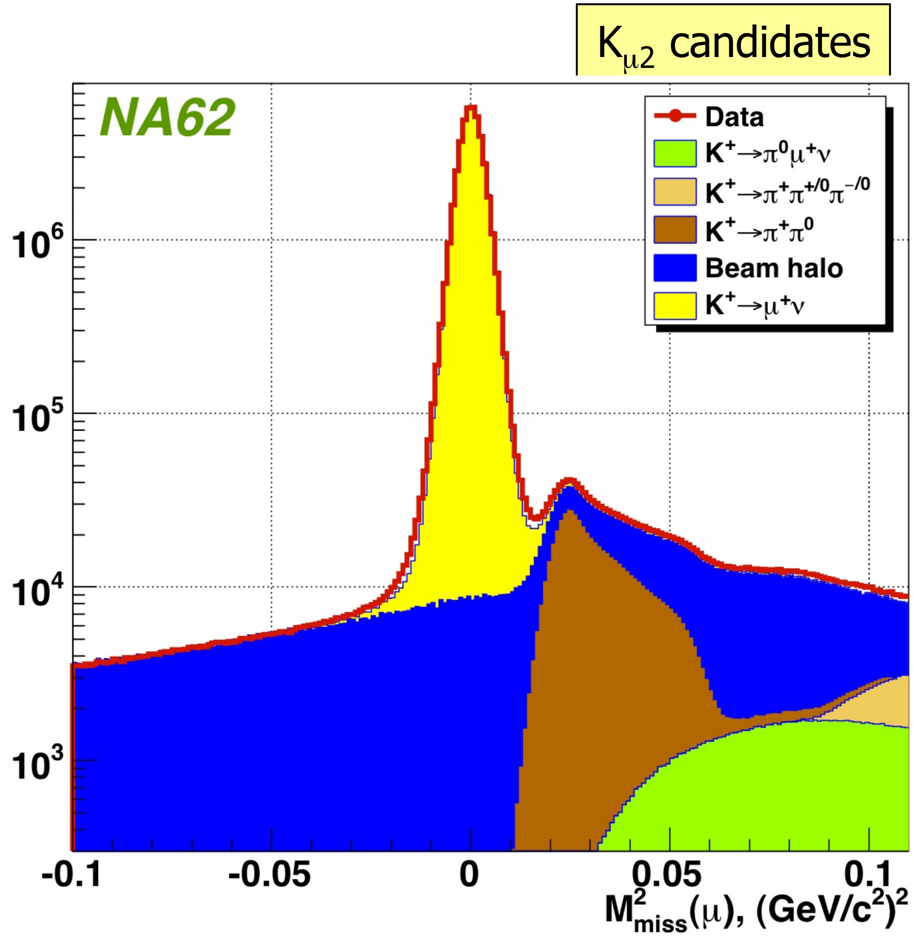
$D^+_s \to l\nu$: $\Delta\Gamma/\Gamma_{SM} \approx -2(m_D/m_H)^2\, (m_s/m_c) \tan^2\beta \approx 0.4\%$

$B^+ \to l\nu$: $\Delta\Gamma/\Gamma_{SM} \approx -2(m_B/m_H)^2 \tan^2\beta \approx 30\%$

NA62 data set for R_K



145,958 $K^+ \to e^+\nu$ candidates.
Positron ID efficiency: (99.28±0.05)%.
B/(S+B) = (10.95±0.27)%.



42.817M candidates
with low background
B/(S+B) = (0.50±0.01)%

CKM Unitarity and Rare Kaon Decays

The unitarity of the CKM matrix can be expressed by triangles in a complex plane: there are six triangles but one is more "triangular":

$$V_{ud}V^*_{ub} + V_{cd}V^*_{cb} + V_{td}V^*_{tb} = 0$$

$\lambda_t = V_{td}\, V^*_{ts}$
$Im\, \lambda_t = A^2 \lambda^5 \eta$
$Re\, \lambda_t = A^2 \lambda^5 \rho$

It is customary to employ the Wolfenstein parameterization:

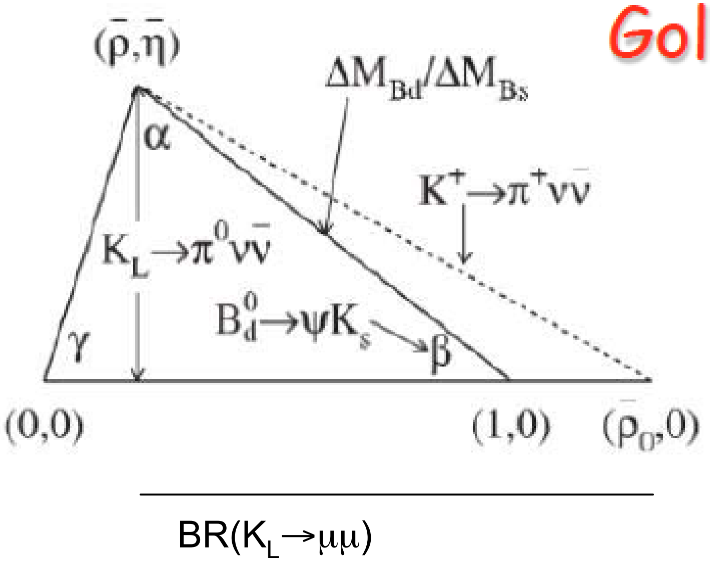
$V_{us} \sim \lambda$ $\quad V_{cb} \sim \lambda^2 A$ $\quad V_{ub} \sim \lambda^3 A(\rho - i\eta)$ $\quad V_{td} \sim \lambda^3 A(1-\rho - i\eta)$

The "Standard" Unitarity Triangle

$$V^*_{ub}V_{ud} + V^*_{cb}V_{cd} + V^*_{tb}V_{td} = 0$$

The "Kaon" Unitarity Triangle

$$V^*_{us}V_{ud} + V^*_{cs}V_{cd} + V^*_{ts}V_{td} = 0$$



Golden modes

$K^+ \to \pi^+ \nu\bar\nu$	$\lvert V^*_{ts} V_{td} \rvert$
$K_L \to \pi^0 \nu\bar\nu$	$Im\,(V^*_{ts} V_{td}) \propto \eta$
$B_d \to \Psi K_s$	$\sin 2\beta$
$\frac{\Delta m_d}{\Delta m_s} = \frac{B_d - \bar{B}_d}{B_s - \bar{B}_s}$	$\lvert V_{td} / V_{ts} \rvert$

The NA62 Beam

Primary Beam:

- 400 GeV/c protons
- $3\ \ 10^{12}$ protons/pulse (3 NA48/2)
- 4.8/16.8 s duty cycle

Secondary Beam:

- 75 GeV/c momentum ($\Delta p/p \sim 1\%$)
- Beam acc.: 12.7 mstr (32 NA48/2)
- Total rate: 800 MHz
- $K^+ \sim 6\%$
- $4.5\ \ 10^{12}$ K^+decays/y (45 NA48/2)

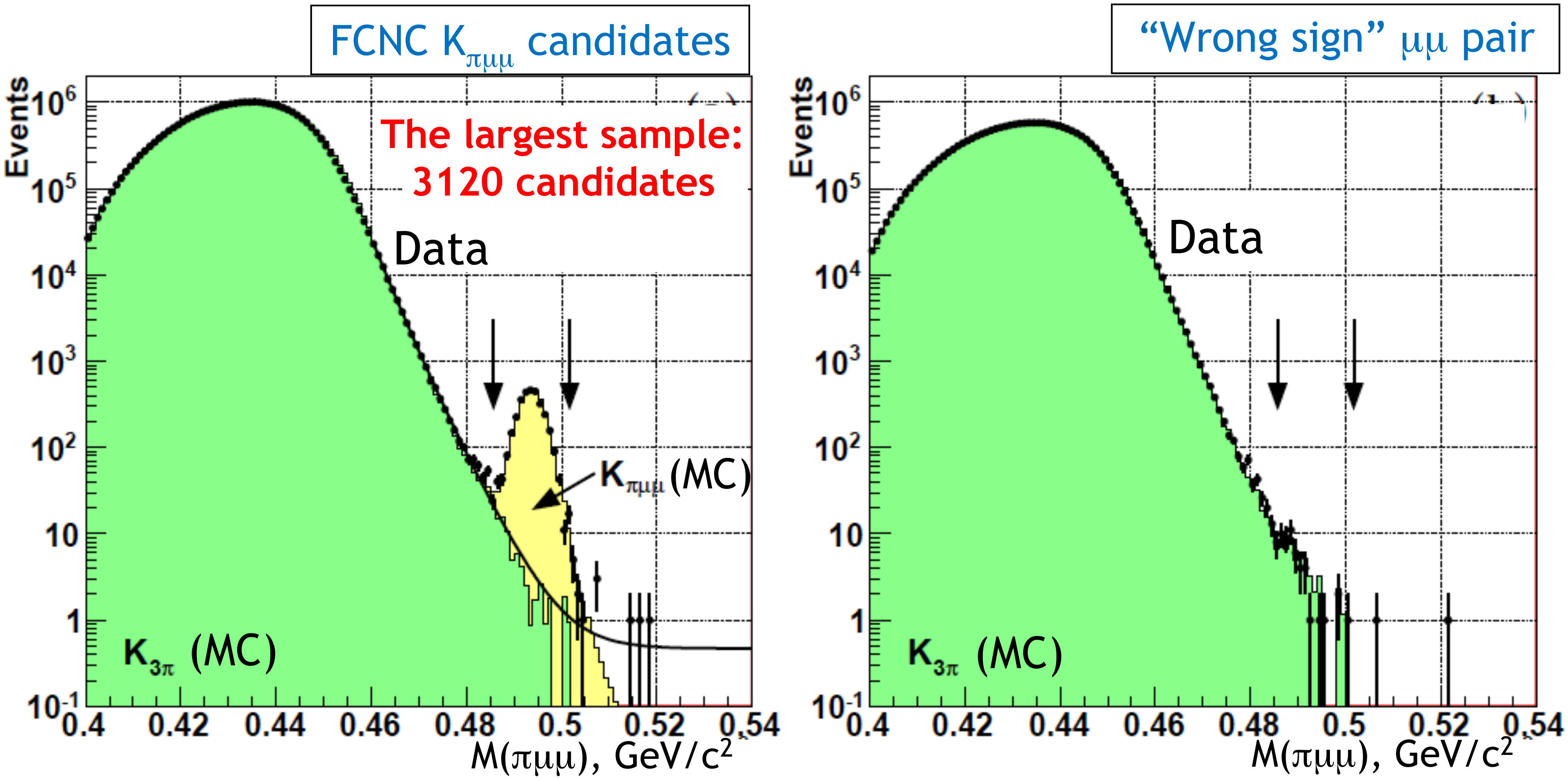
Only 6% K^+ but:

- protons and positrons don't decay…
- pions and muons decays cannot mimic K^+ decays
- but beam-gas interactions do!!

Keep vacuum at 10^{-6} mbar:
use existing NA48 decay tank

- Size @ beam tracker: 5.5 x 2.2 cm^2
- Rate @ beam tracker: 800 MHz
- Rate @ KTAG: 50 MHz
- Rate downstream 10 MHz (K^+ decay mainly)
- Angular spread in X and Y < 100 μ rad

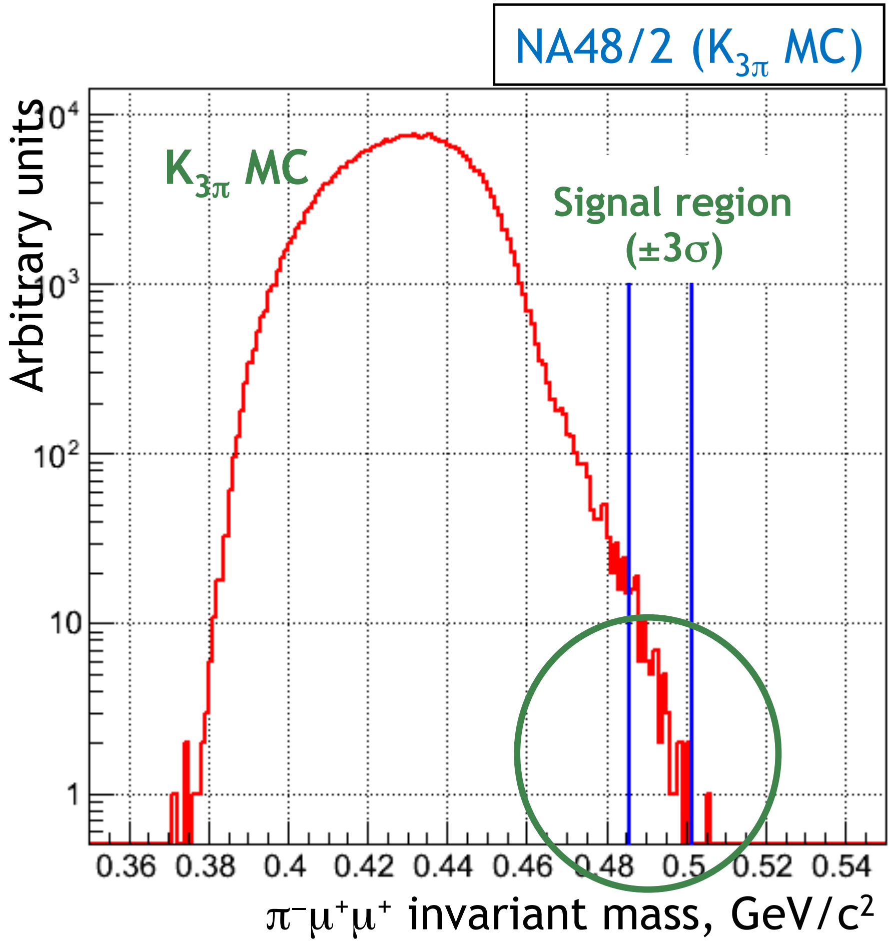
NA48/2 $K^\pm \to \pi^\mp \mu^\pm \mu^\pm$ upper limit

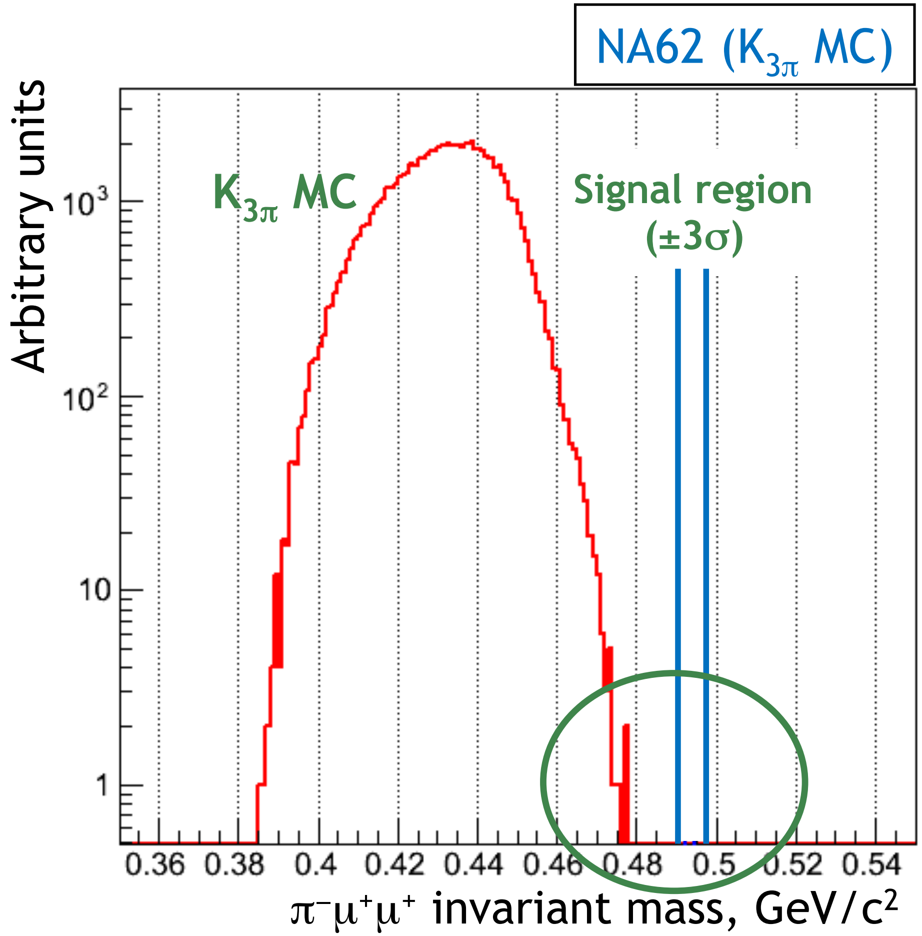


$N_{data} = 52$
$N_{bkg} = 52.6 \pm 19.8_{syst.}$ ⟹ $\mathcal{B}(K^\pm \to \pi^\mp \mu^\pm \mu^\pm) < 1.1 \times 10^{-9}$ @90% CL

Precision limited by background from $\pi^\pm \to \mu^\pm \nu$, despite SES ≈ 3×10^{-11}.
Flat phase space assumed (rather than Majorana neutrino exchange).
A dedicated re-analysis has a potential sensitivity of ~10^{-10}.

$K^{\pm} \rightarrow \pi^{\mp}\mu^{\pm}\mu^{\pm}$ at NA62





NA48/2: $K_{3\pi}$ background to $K_{\pi\mu\mu}$ due to $\pi^{\pm} \rightarrow \mu^{\pm}\nu$ decays in the spectrometer

NA62: no $K_{3\pi}$ background expected due to high spectrometer P_T (270 vs 120 MeV/c) and improved $\pi\mu\mu$ mass resolution (1.1 vs 2.6 MeV/c^2)

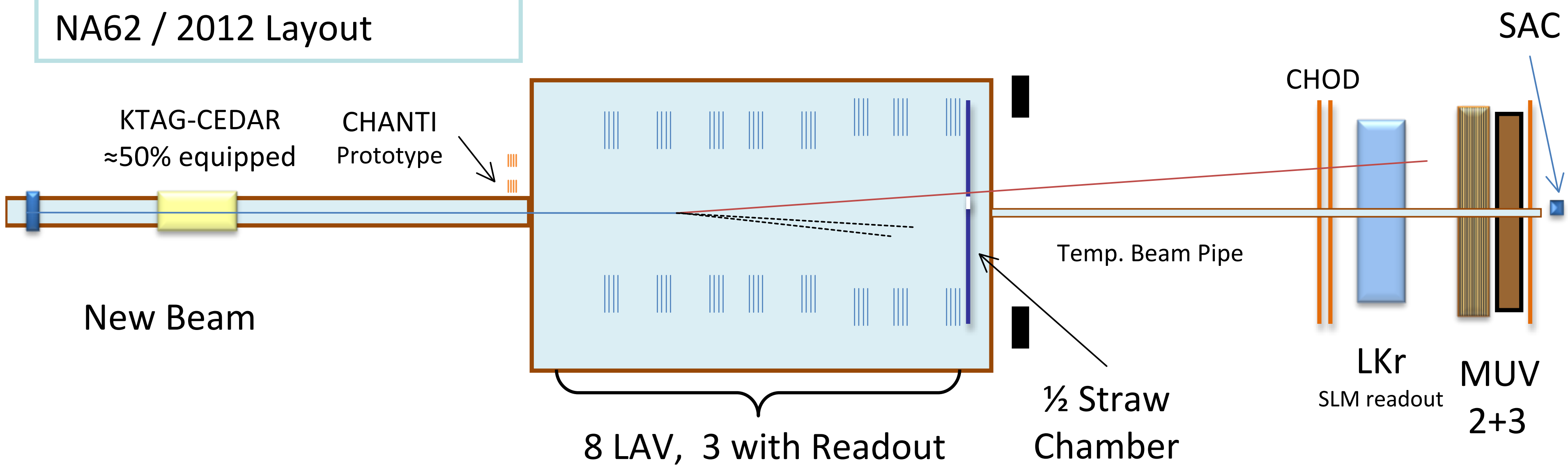
Prospects for LFNV Searches in K^+ and π^0 decays at NA62

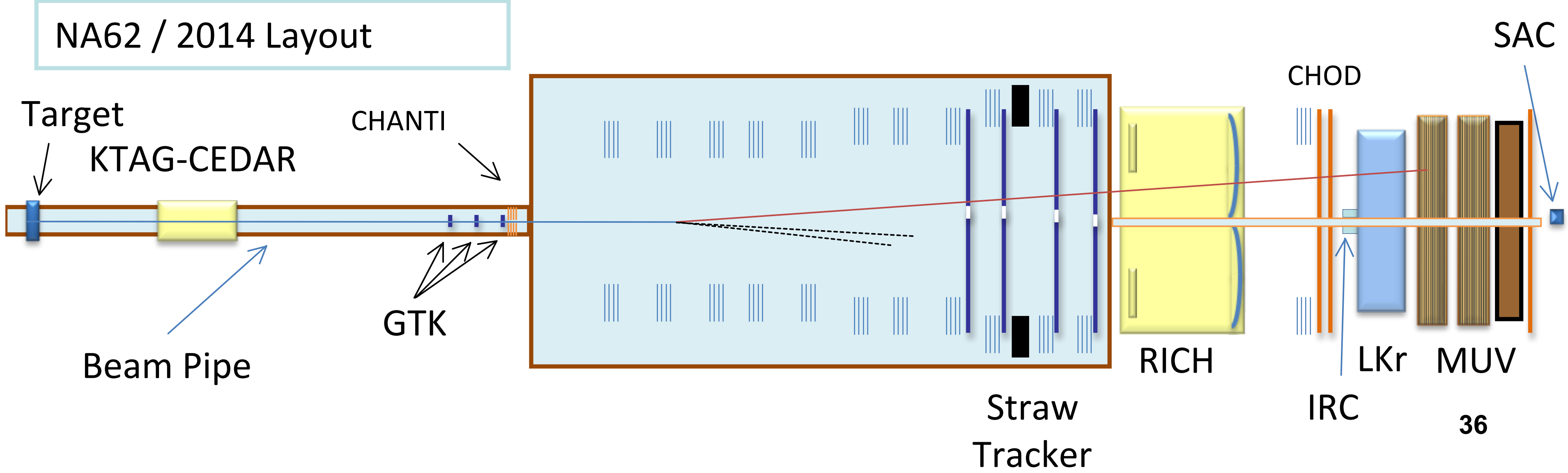
Decay mode	Physics Interest	UL at 90% CL (Experiment)
$K^+ \to \pi^+ \mu^+ e^-$	LFV	$< 1.3 \times 10^{-11}$ (BNL E777/E865)
$K^+ \to \pi^+ \mu^- e^+$	LFV	$< 5.2 \times 10^{-10}$ (BNL E865)
$K^+ \to \pi^- \mu^+ e^+$	LFNV: $\Delta L_\mu = \Delta L_e = -1$	$< 5.0 \times 10^{-10}$ (BNL E865)
$K^+ \to \pi^- e^+ e^+$	LNV: $\lvert\Delta L_e\rvert = 2$	$< 6.4 \times 10^{-10}$ (BNL E865)
$K^+ \to \pi^- \mu^+ \mu^+$	LNV: $\lvert\Delta L_\mu\rvert = 2$	$< 1.1 \times 10^{-9}$ (NA48/2)
$K^+ \to \mu^- \nu_\mu e^+ e^+$	LNV: $\lvert\Delta L_e\rvert = 2$ or LFV	$< 2.8 \times 10^{-8}$ (Geneva-Saclay)
$K^+ \to e^- \nu_e \mu^+ \mu^+$	LNV: $\lvert\Delta L_\mu\rvert = 2$ or LFV	No Data
$\pi^0 \to \mu^\pm e^\mp$	LFV	$< 3.6 \times 10^{-10}$(KTEV)

- Total number of decays in fiducial volume: 1.2×10^{13} K^+ & 2.5×10^{12} π^0
- Expected Acceptance O(10%)

NA62 SINGLE-EVENT SENSITIVITY(*): ~ 10^{-12} ON K^+ DECAY ~ 10^{-11} ON π^0 DECAY

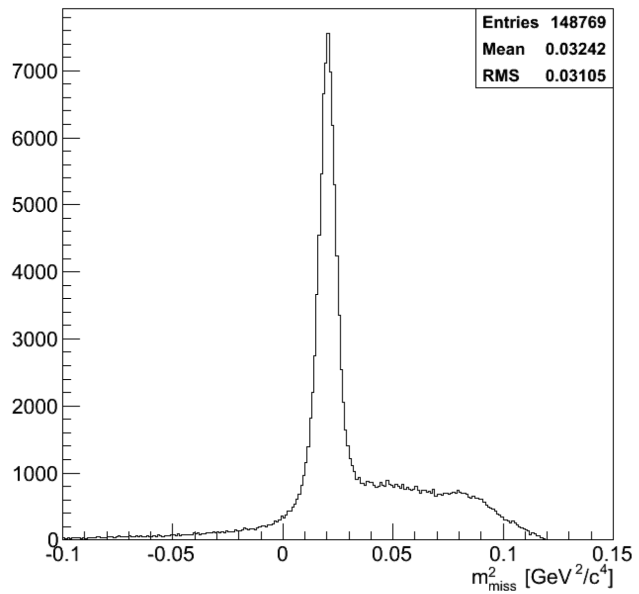
NA62 Detector 2012 and 2014





$K^+ \to \pi^+\pi^0$ Sample in 2012

Exploit the timing and spatial correlations between the subdetectors to define a Kaon candidate, pion candidate and a muon candidate.



Selection based on LKr (π^0 vertex assuming π^0 mass, and assumed kaon direction)

$$P_{\pi^+} = (P_K - P_{\pi^0}) \to P^2_{\pi^+} = m^2_{\pi^+} \text{ for } K^+ \to \pi^+\pi^0$$

Using time-correlation and signal from New KTAG and MUV: