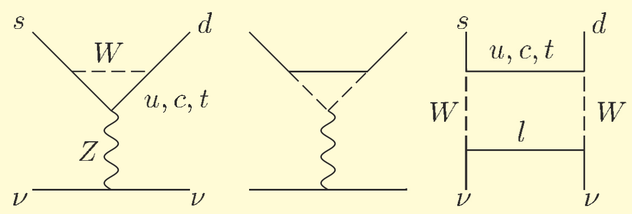
NA62 at CERN: a proposal to measure the branching ratio of the $K^+ \to \pi^+ \nu\bar{\nu}$ decay

Bern, Birmingham, CERN, Dubna, Fairfax, Ferrara, Florence, Frascati, Louvain, Mainz, Merced, Moscow, Naples, Perugia, Protvino, Pisa, Rome, San Luis Potosi, SLAC, Sofia, Turin, Vancouver

THEORETICAL FRAMEWORK

$K^+ \to \pi^+ \nu\bar{\nu}$ and $K_L \to \pi^0 \nu\bar{\nu}$ are exceptionally theoretically clear modes, dominated by short distance dynamics.

The leading SM contribution to $K \to \pi\nu\bar{\nu}$ is generated by top quark loops and can be computed with negligible theoretical uncertainty. The amplitudes can be described by Fermi-like coupling, where the hadronic matrix element can be precisely computed using the well measured $K \to \pi e \nu$ rates.



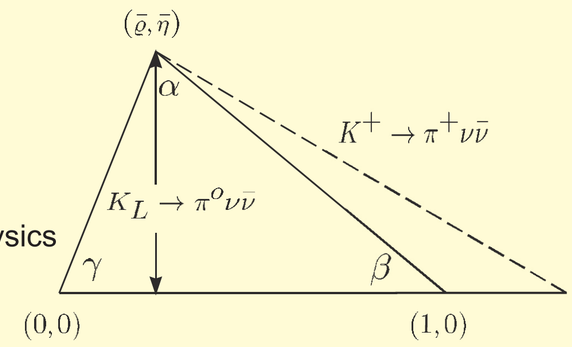
Standard Model Predictions:

$BR(K^+ \to \pi^+ \nu\bar{\nu}) \sim |V_{cb}|^4[\sigma\eta^2 + (\rho_c - \rho)^2] = (8.22 \pm 0.84) \times 10^{-11}$

$BR(K_L \to \pi^0 \nu\bar{\nu}) \sim |V_{cb}|^4 \eta^2 = (2.76 \pm 0.40) \times 10^{-11}$

Precise measurements of $BR(K \to \pi\nu\bar{\nu})$ offer:
- an independent way of determining the unitarity triangle
- opportunity to make precise test of SM and search for New Physics

Experimental status: 7 events observed by BNL E787,E949.
Desirable BR experimental accuracy: ~10%.

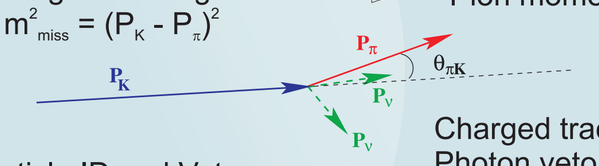


PRINCIPLE OF MEASUREMENT

Goal: O(100) events, ~10% background, 2 years of data taking

N(K decays) = 10^{13}
10% acceptance
⇒ Kaon decays in flight technique
400 GeV proton beam from CERN SPS
High energy K^+ beam (P_K=75 GeV/c)

Kinematical rejection
Single track signature
$m^2_{miss} = (P_K - P_\pi)^2$
⇒ Kaon momentum: beam tracker
Pion momentum: spectrometer

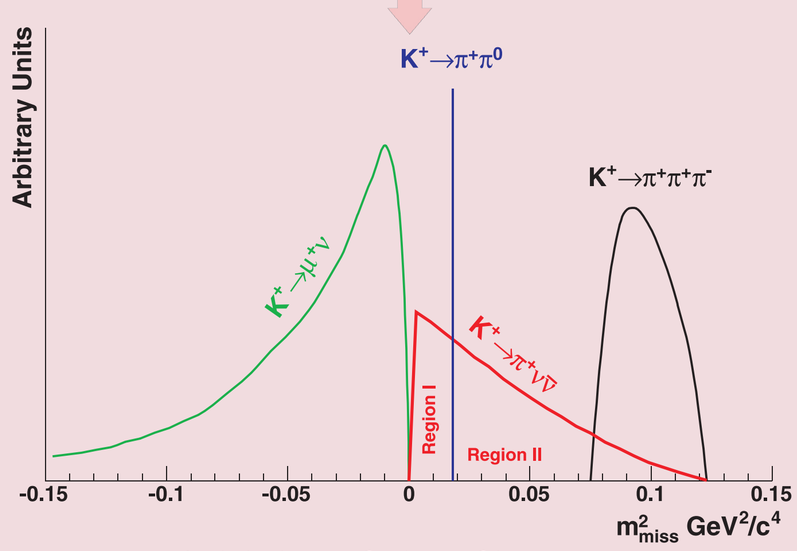


Particle ID and Veto
in addition to kinematical rejection
⇒ Charged track veto: spectrometer
Photon veto: calorimeters
Beam kaon ID: CEDAR counter
π/μ/e separation: RICH

Budget limitations
⇒ Use the existing NA48 infrastructure: beam line, exp.hall, LKr calorimeter.

BACKGROUNDS

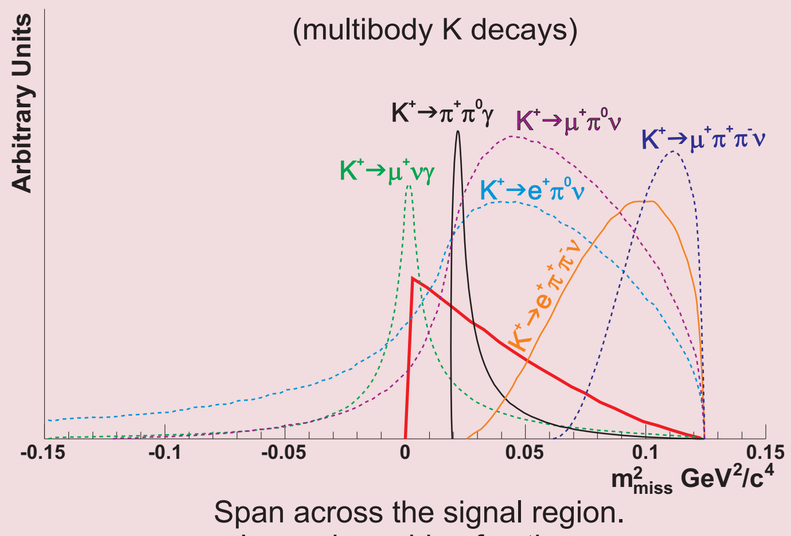
Kinematically constrained (BR=92%)



Dictate the definition of the signal region;
the $K^+ \to \pi^+\pi^0$ peak forces to split it into 2 parts
(Region I and Region II).

NOT kinematically constrained (BR=8%)

(multibody K decays)



Span across the signal region.
Lower branching fractions.
Rejection relies on veto and PID techniques.

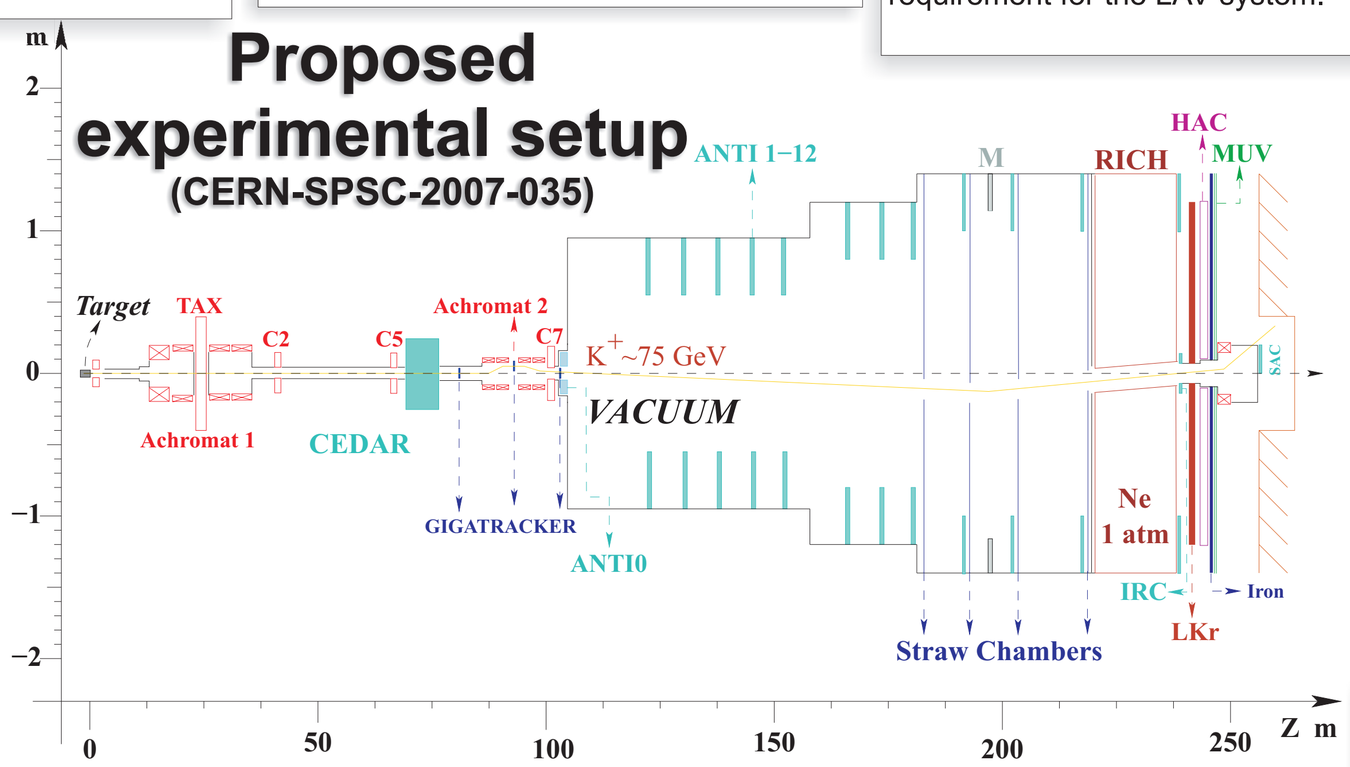
NA62 SCHEDULE

- Dec 2005: R&D endorsed by CERN Research Board
- 2006 – 2009: prototype construction and test beams (CERN, Frascati)
- 2008 – 2010: technical design and construction
- 2011: expected start of data taking

Events/year	Total	Region I	Region II
Signal (acc=17%)	65	16	49
$K^+ \to \pi^+\pi^0$	2.7	1.7	1.0
$K^+ \to \mu^+\nu$	1.2	1.1	<0.1
$K^+ \to e^+\pi^+\pi^-\nu$	~2	negligible	~2
Other 3 – track decays	~1	negligible	~1
$K^+ \to \pi^+\pi^0\gamma$	1.3	negligible	1.3
$K^+ \to \mu^+\nu\gamma$	0.5	0.2	0.2
$K^+ \to e^+(\mu^+)\pi^0\nu$, others	negligible	-	-
Total bckg .	<9	3.0	<6

Proposed experimental setup

(CERN-SPSC-2007-035)



GIGATRACKER

Thin silicon micro-pixel detectors for (redundant) momentum measurement of the incoming beam with sub-nanosecond time resolution to provide a tight time coincidence between the incoming kaon and the outgoing pion. The detector consists of three silicon pixel stations placed along the beam line. Prototyping phase: 2008-2009, construction phase: 2009-2011.

CEDAR

A differential Cherenkov counter (an upgraded form of the CEDAR built for the SPS secondary beams) placed on the incoming beam to tag the minority particles of interest (kaons).

LAV

A set of ring-shaped anti-counters surrounding the vacuum tank and providing full coverage for photons originating from the decay region with angles as large as 48 mr. Three prototypes (fiber, CKM and Pb glass) built and tested. Inefficiency below the requirement for the LAV system.

RICH

A gas Ring Imaging Cherenkov counter for muon/pion separation providing suppression factor for muons of <1% in momentum interval 15-35 GeV/c. Measurement of pion crossing time with resolution ~100ps. Triggering of charged track. Velocity spectrometer. Dimensions: 18 m long tube (2.5 m diameter) filled with Ne (at 1 atm), two 17 m focal length mirrors.

BEAM

P_{proton} = 400 GeV/c.
N_{proton}/pulse 3.3×10^{12} (3.3×NA48/2).
Duty cycle 4.8/16.8 s.
P_K = 75 GeV/c (ΔP/P = 1.1%).
Fraction of kaons ~ 6.6%.
e^+ component suppressed.
Beam acceptance = 12 mstr.
Area @ beam tracker = 58×24 mm^2
Integrated average rate = 760 MHz.
Kaon decays / year = 4.8×10^{12}

LKR

The high-performance electromagnetic calorimeter built for the NA48 experiment acting as photon veto in the forward region. Inefficiency $\eta < 10^{-5}$ for E>10 GeV [dedicated test run in 2004]; $\eta < 5 \times 10^{-5}$ for E=(7.5;10 GeV); $\eta < 10^{-4}$ for E=(5.5;7.5 GeV); $\eta < 10^{-3}$ for E=(2.5;5.5 GeV) [dedicated test run in 2006].

CHANTI

A set of ring anticounters after the last Gigatracker station to form a "guard ring" and a large one around the beginning of the decay volume to veto charged particles coming from the collimator.

IRC, SAC

Intermediate ring (at the entrance of the LKR calorimeter) and small angle photon veto (after the muon deflecting magnet) calorimeters covering the angular regions around and in the beam. SAC prototype tested during 2006 - upper limit on inefficiency 6.4×10^{-5}.

MUD

A hadron calorimeter and muon detector capable of identifying muons with high efficiency.

STRAW

A magnetic spectrometer measuring the direction of the out-going pion and its momentum. Chambers of straw tubes are proposed as the tracking detector for their capability to operate in vacuum. The straw tracker contains four chambers and each chamber has four views. Prototype tested in 2007/08; ongoing analysis of collected data.

TRIGGER

Level 0 (hardware): ~10 MHz input; 1 MHz output; RICH minimum multiplicity, MUV and Lkr veto
Level 1/2 (software): 1 MHz input; O(kHz) output; L1: single subdetectors; L2: whole event.
Main work on possible solutions on L0 hardware.

PANIC 08 (Eilat, Israel)
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