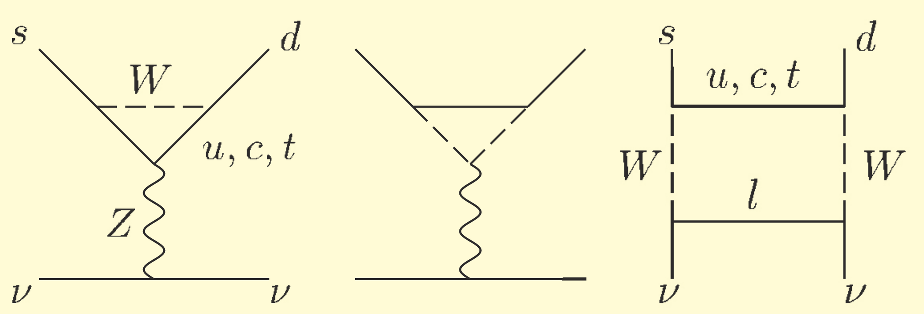
MEASUREMENT OF $K^+ \rightarrow \pi^+ \nu\bar{\nu}$ DECAY BRANCHING RATIO AT NA62

Birmingham, CERN, Dubna, Fairfax, Ferrara, Florence, Frascati, Mainz, Merced, Moscow, Naples, Perugia, Protvino, Pisa, Rome I, Rome II, Saclay, San Luis Potosi, Stanford, Sofia, Triumf, Turin

THEORETICAL FRAMEWORK

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

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



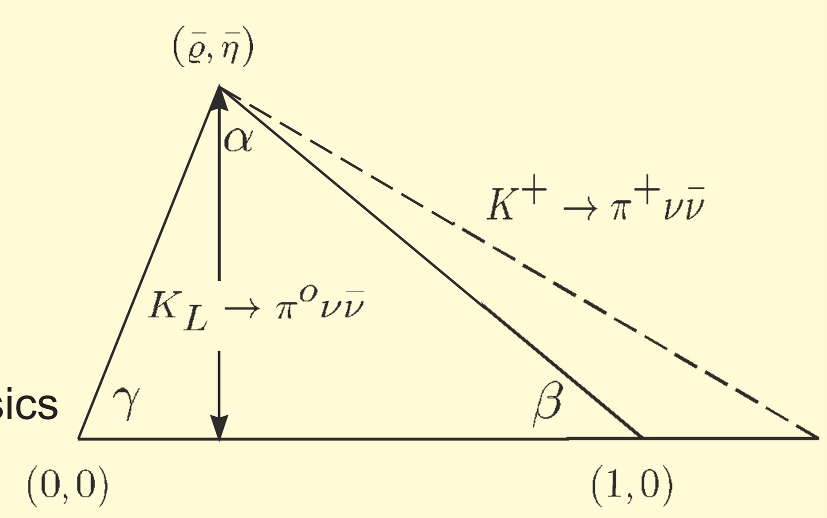
Predictions within SM:

$BR(K^+ \rightarrow \pi^+ \nu\bar{\nu}) = (1.6 \times 10^{-5})|V_{cb}|^4[\sigma\eta^2 + (\rho_c - \rho)^2] = (8.22 \pm 0.84) \times 10^{-11}$

$BR(K_L \rightarrow \pi^0 \nu\bar{\nu}) = (7.6 \times 10^{-5})|V_{cb}|^4 \eta^2 = (2.76 \pm 0.40) \times 10^{-11}$

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

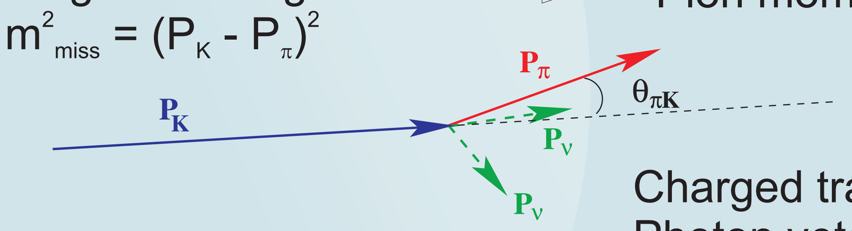
Present measurement: 3 events observed by BNL E949



NA62 PRINCIPLE OF MEASUREMENT

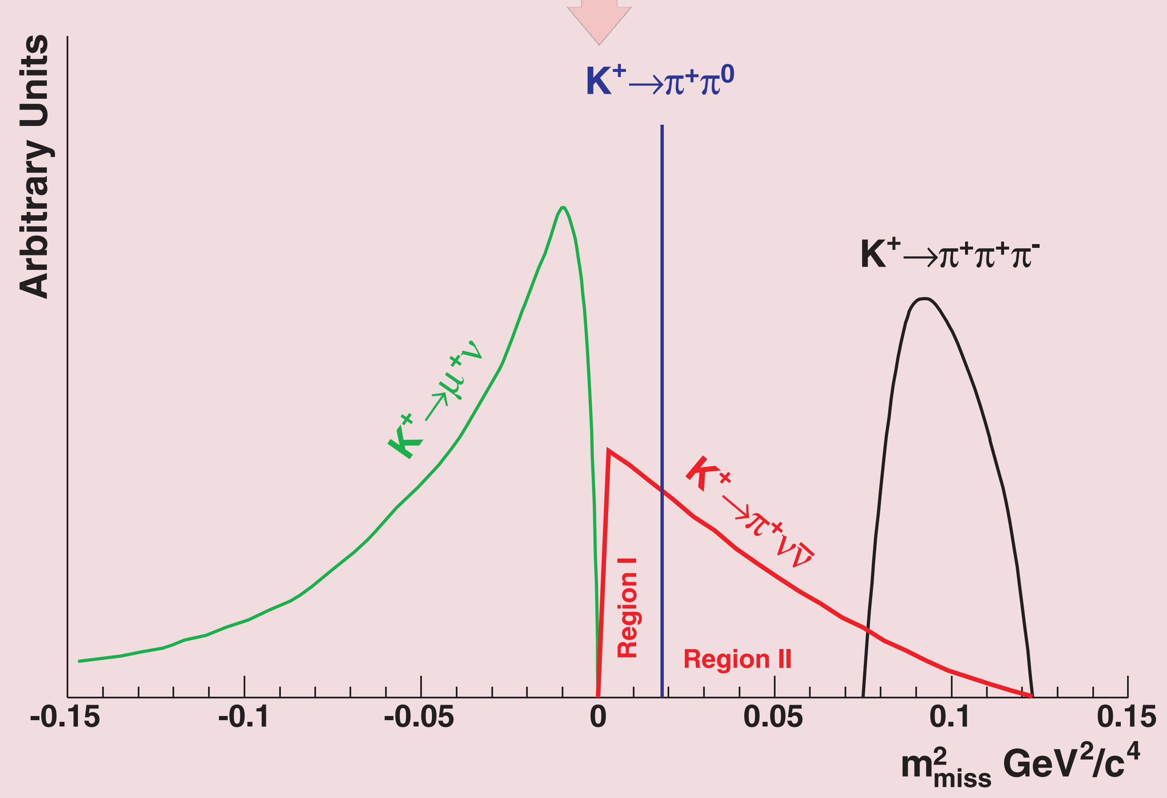
Goal: O(100) events with 10% background

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 π/μ/e separation: RICH
Budget limitations	Use the existing NA48 infrastructure: beam line, LKr calorimeter,...



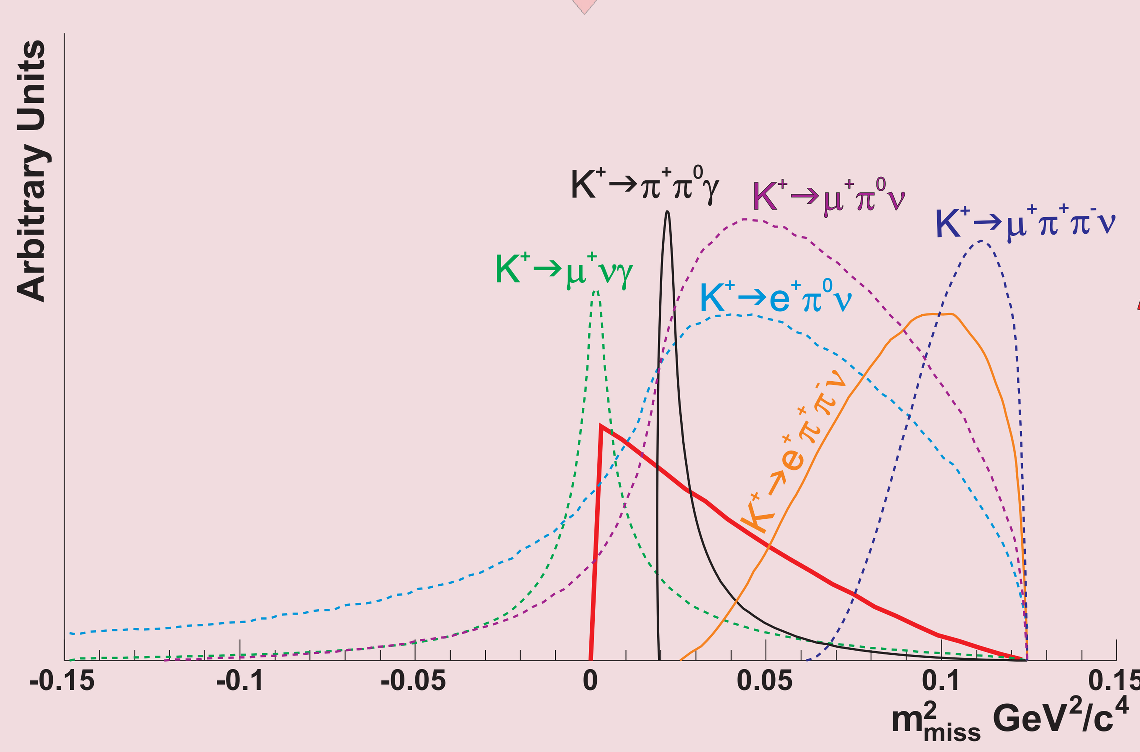
BACKGROUND

Kinematically constrained background (92% of total backfround)



Define signal region
$K^+ \rightarrow \pi^+ \pi^0$ forces to split in two parts
Region I and II

Background not constrained kinematically (8% of total background)



Span across the signal region
Lower branching fractions
Rejection relies on vetoes/ID

NA62 SCHEDULE

- September 2005: presented at CERN SPSC
- December 2005: R&D endorsed by CERN Research Board
- Start of the Gigatracker project
- Start of test beams at CERN in 2006
- 2007: prototypes construction and test at CERN and Frascati beams
- 2008 – 2010: Technical design and construction
- 2011: Start of data taking

Signal (acc=14.4% flux = 4.8×10^{-12} evts/year)	55 events/year
$K^+ \rightarrow \pi^+ \pi^0$	4.3%
$K^+ \rightarrow \mu^+ \nu$	2.2%
$K^+ \rightarrow e^+ \pi^+ \pi^- \nu$	~3%
Other 3 – track decays	~1.5%
$K^+ \rightarrow \pi^+ \pi^0 \gamma$	~2%
$K^+ \rightarrow \mu^+ \nu \gamma$	~0.7%
$K^+ \rightarrow e^+(\mu^+) \pi^0 \nu$, others	negligible
Total bckg.	~13.5%

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 is made 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 Lead glass) built and tested. Inefficiency below the requirement for the LAV system.

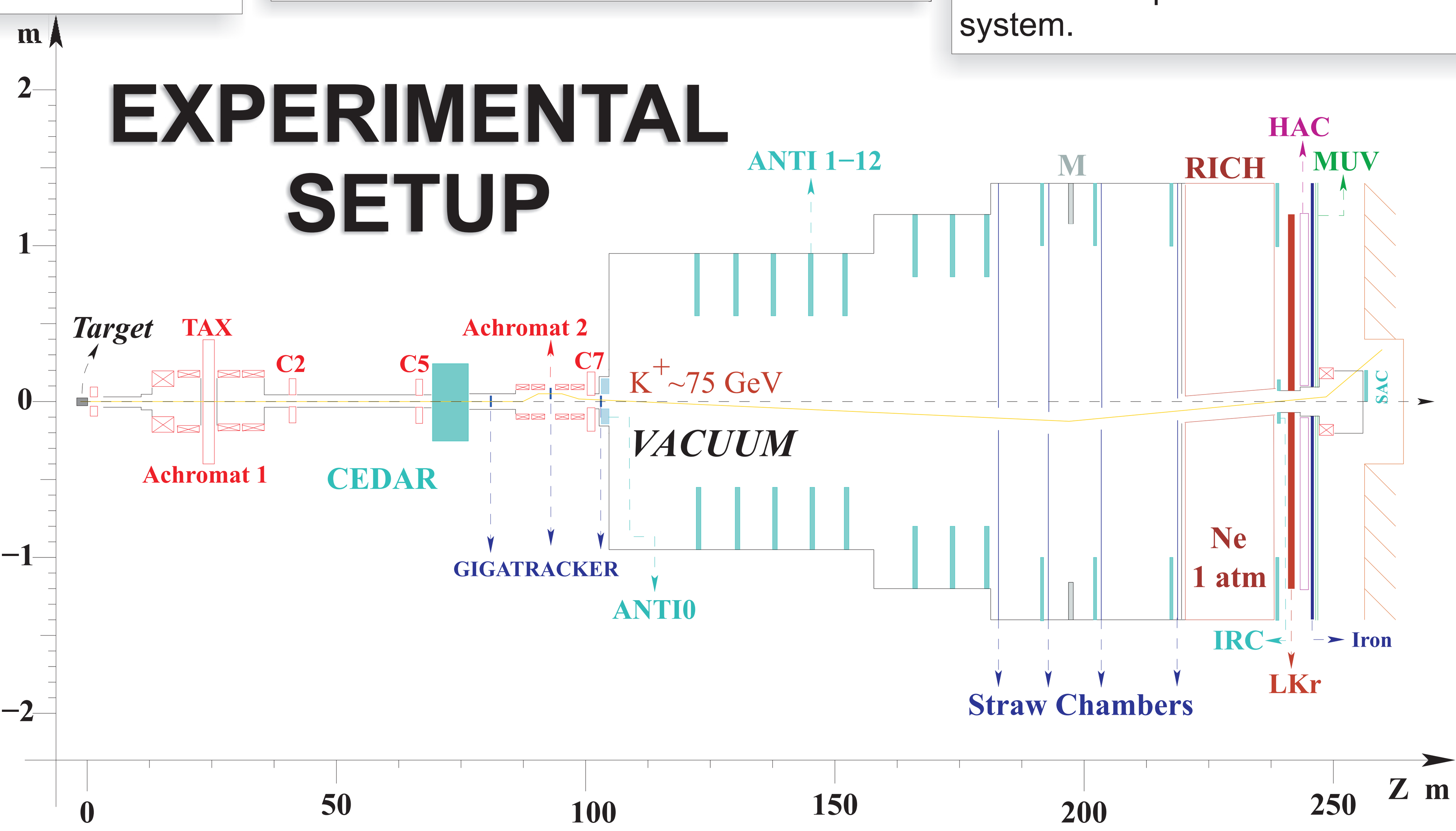
RICH

A gas Ring Imaging Cherenkov counter providing muon/pion separation providing suppression factor for muons of <10-2 in momentum interval (15-35 GeV/c). Measure pion crossing time with resolution ~100 ps. Triggering of charged track. Velocity spectrometer (redundancy). 18 m long tube (2.8 m diameter) filled with Ne @ 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 = 1.2%)
Fraction of Kaons ~ 6.6%
e^+ component suppressed
Beam acceptance = 12 μstr
Integrated average rate = 760 MHz
Kaon decays / year = 4.8×10^{12}

EXPERIMENTAL SETUP



LKR

The high-performance electromagnetic calorimeter built for the NA48 experiment acting as photon veto in the forward region. Inefficiency $\eta < 10^{-5}$ for $E_\gamma > 10$ GeV (dedicated test run in 2004); $\eta < 10^{-3}$ for $E_\gamma = (2.5;5.5$ GeV); $\eta < 10^{-4}$ for $E_\gamma = (5.5;7.5$ GeV) and $\eta < 5.10^{-5}$ for $E_\gamma = (7.5;10$ GeV) (dedicated 2006 run).

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.

MUD

A hadron calorimeter and muon detector capable of identifying muons with very small inefficiencies.

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 - 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.

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}.

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