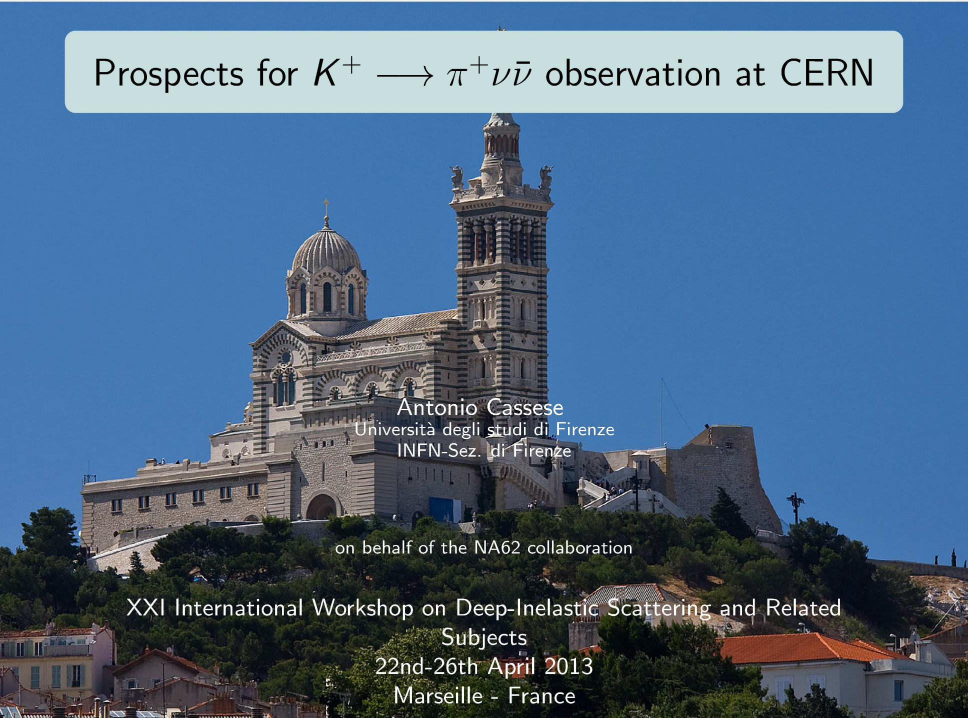
Prospects for $K^+ \longrightarrow \pi^+\nu\bar{\nu}$ observation at CERN



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on behalf of the NA62 collaboration

XXI International Workshop on Deep-Inelastic Scattering and Related Subjects
22nd-26th April 2013
Marseille - France

Outline

- NA62 experiment: Where (introduction)
- NA62 experiment: Why (physical motivations)
- NA62 experiment: How (experimantal strategy)
- 2012 Technical run
- NA62 experiment: When (conclusions)

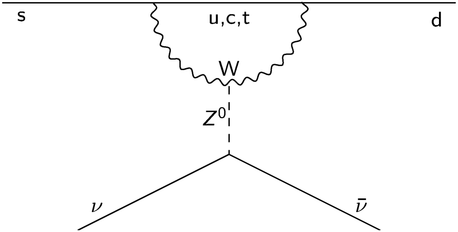
The NA62 experiment at CERN

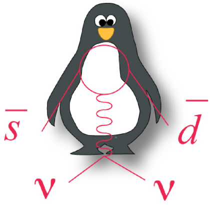
- Kaon physics
- 400 GeV/c protons from SPS on beryllium target
- Measurment at 10% level of BR $\left(K^+ \longrightarrow \pi^+ \nu\bar{\nu}\right) \sim 10^{-10}$
- "Golden channel", theoretically very clean (10%)
- Sensitive to physics beyond Standard Model

NA62 collaboration: Birmingham, Bratislava, Boston, Bristol, Bucharest, CERN, Dubna, Fairfax, Ferrara, Florence, Frascati, Glasgow, IHEP Protvino, INR Moscow, Liverpool, Louvain-la-Neuve, Mainz, Merced, Naples, Perugia, Pisa, Prague, Rome I, Rome II, San Luis Potosí, SLAC, Sofia, Turin

The physics of $K^+ \longrightarrow \pi^+ \nu \bar{\nu}$

- FCNC loop processes: $s \longrightarrow d$ coupling and high CKM suppression





- Short Distance contribution dominates
- Top quark contribution computed at NLO QCD and 2-loop EW corrections
- c quark loop contribution computed at NNLO QCD and NLO EW corrections
- Correction for LD contributions
- Hadronic matrix elements can be extracted, thanks to the isospin symmetry, from $Br(K^+ \longrightarrow \pi^0 e^+ \nu)$
- Thanks to the very accurate theoretical predictions, the measurement of these decays leads to very accurate constraints on any new physics model

The $K^+ \longrightarrow \pi^+\nu\bar{\nu}$ decays SM and present experimental measurements

- Standard Model predictions [Brod, Gorbahn, Stamou, Phys. Rev. D 83, 034030 (2011)]:

$$\text{BR}(K^+ \longrightarrow \pi^+\nu\bar{\nu}) = (7.81 \pm 0.75 \pm 0.29) \times 10^{-11}$$

  - Parametric error dominated by V_{cb} , ρ
  - Pure theoretical error, mostly LD corrections

- Present experimental results [E787, E959]:

$$\text{BR}(K^+ \longrightarrow \pi^+\nu\bar{\nu}) = (1.73^{+1.15}_{-1.05}) \times 10^{-10}$$

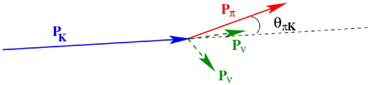
Decay in flight technique

Easy to have high intensity beam
Easy to veto high energy photons

Long detector and decay region
Event by event measurement of K momentum
Unseparated hadron beam

Signal signature

1 track (momentum and angle)
+ nothing



Backgrounds

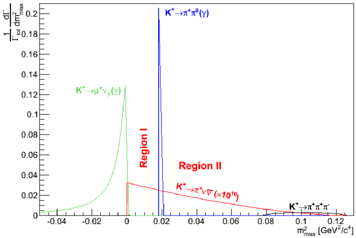
High background suppression:

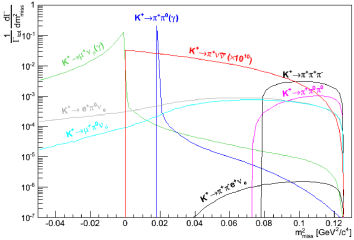
- Kinematic rejection
- PID
- Photon rejection

Decay	BR
$K^+ \to \mu^+\nu$ ($K_{\mu 2}$)	63.5%
$K^+ \to \pi^+\pi^0$	20.7%
$K^+ \to \pi^+\pi^+\pi^-$	5.6%
$K^+ \to \pi^+\pi^0\pi^0$	1.8%
$K^+ \to \pi^0\mu^+\nu$ ($K^+_{\mu 3}$)	3.3%
$K^+ \to \pi^0 e^+\nu$ (K^+_{e3})	5.1%

Charged track with:
$p < 35$ GeV/c
⇓
Other particles shares at least 40 GeV/c

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





- Kinematical constraint decays, well separated from signal, constitute 90% of BR defining 2 signal regions in the m^2_{miss} spectrum
- Signal region background contamination:
  - REGION I

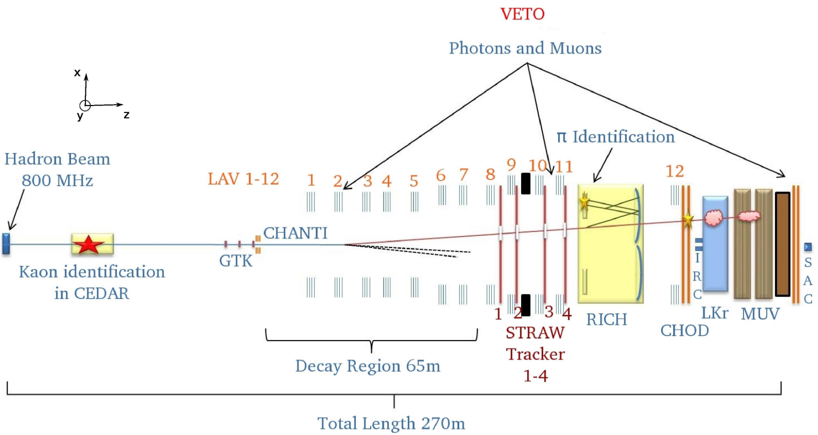
    Physical Radiative tails from $K^+ \longrightarrow \mu^+\nu_\mu$, semileptonics

    Experimental Resolution tails from $K^+ \longrightarrow \mu^+\nu_\mu$ and $K^+ \longrightarrow \pi^+\pi^0$
  - REGION II

    Physical Radiative tails from $K^+ \longrightarrow \mu^+\nu_\mu$ and $K^+ \longrightarrow \pi^+\pi^0$, semileptonics, rare decays

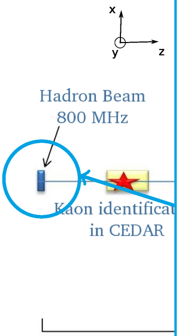
    Experimental Resolution tails from $K^+ \longrightarrow \mu^+\nu_\mu$, $K^+ \longrightarrow \pi^+\pi^0$ and $K^+ \longrightarrow \pi^+\pi^+(\pi^0)\pi^-(\pi^0)$

NA62 layout



VETO
Photons and Muons
x
y
z
π Identification
Hadron Beam
800 MHz
LAV 1-12
1
2
3
4
5
6
7
8
9
10
11
12
CHANTI
GTK
Kaon identification
in CEDAR
I
R
C
S
A
C
1
2
3
4
STRAW
Tracker
1-4
RICH
CHOD
LKr
MUV
Decay Region 65m
Total Length 270m

Beam



Beam

Primary beam

- 400 GeV/c protons from SPS on beryllium target
- 3×10^{12} protons/pulse on target

Secondary beam

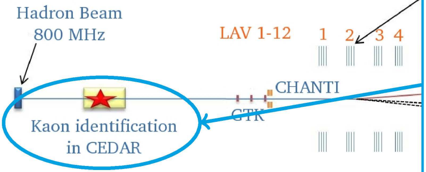
- 75 GeV/c kaons ($\Delta P/P \sim 1\%$)
- $\sim 6\%$ of K^+
- Rate beam tracker 750 MHz, area 16 cm^2

Downstream

- Rate downstream 10 MHz (K^+ decays mostly)
- K decay rates / year: 4.8×10^{12}

Kaon tagging: Cedar

Kaon tagging @ 75GeV/c

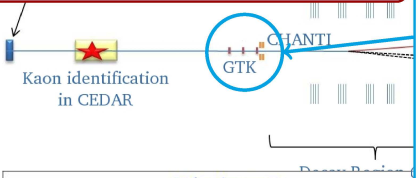


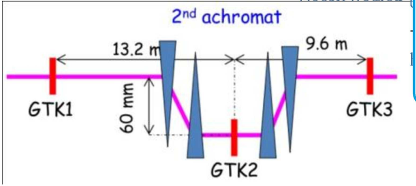
Cedar

- Differential Cherenkov counter (ČErenkov Differential counter with Acromatic Ring focus)
- Very high rate environment
- Upgraded version of the CEDAR built for the SPS secondary beams
  - Pressurized H2 (3.6bar) instead of Nitrogen
  - New photo detectors and electronics
- Vary gas pressure and diaphragm aperture to select Kaons
- 100 ps time resolution

Kinematic: GigaTracKer (GTK)

- P_K measurement, $\frac{\Delta P_K}{P_K} \approx 0.21\%$
- θ_x and θ_y measurement, $\Delta\theta_x = \Delta\theta_y \approx 0.014\,\text{mrad}$



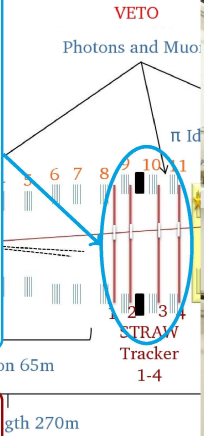


GTK

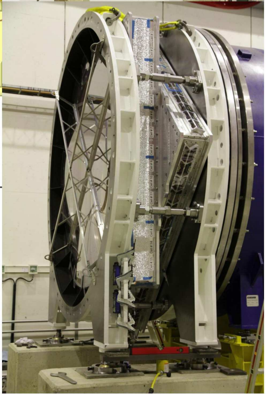
- 3 Si pixel stations before the decay volume
- Geometry matching the beam shape
- Excellent space resolution (300×300 μm pixels)
- Low material budget:
  200 μm sensor + 300 μm chip ($< 0.5\%\ X_0$)
- Excellent time resolution (200 ps/station)

Straw

- 4 straw chambers in vacuum
- 1 magnet (NA48 magnet, 256 MeV/c P_t kick)
- 4 views per chamber
- 4 staggered layers of tubes per view
- 9.6 mm Mylar tubes 2.1 m long
- Total $X_0 \sim$ 0.1% per view



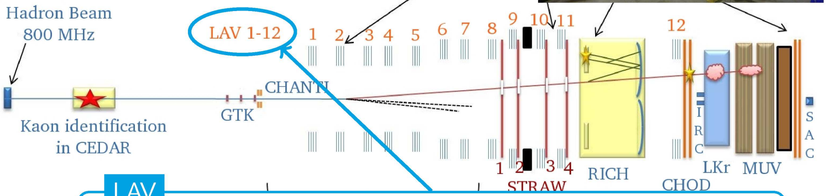
- p_π measurement, $\frac{\Delta p_\pi}{p_\pi} =\lesssim 1\%$
- θ_π measurement, $\Delta\theta_\pi \lesssim 66\mu$rad



NA62

Photon veto: Large Angle Veto (LAV)

Veto for large angle photons



LAV

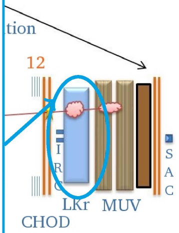
- 12 stations in vacuum to cover 8.5 to 50 mrad
- OPAL lead glass (Schott SF57) read with R2238 76-mm PMs
- At least $\sim 18.6\ X_0$

Photon veto: Liquid Kripton calorimeter (LKr)

Veto for forward photons

LKr

- Covering from 1 to 8.5 mrad region
- Use the existing LKr from NA48
- Depth 1.25 m, 27 X_0
- Very good time resolution: 100 ps
- Inefficiency for detecting γ measured on data ($E_\gamma > 10$ GeV) $(1 - \varepsilon) < 8 \times 10^{-6}$
- New electronics



IRC & SAC

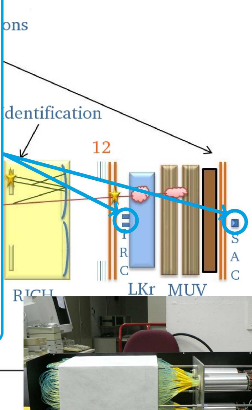
- Covering up to 0 rad and LKr beam pipe

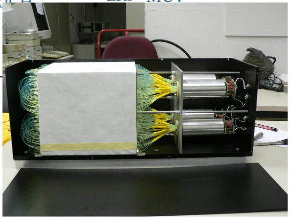
SAC

- After the beam dump
- Detects neutral particles down to 0 degrees

IRC

- Around the beam pipe in front of LKr
- Cover the angular region close to the inner LKr





Veto for small angle photons

PID: MUon Vetos (MUVs)

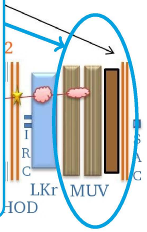
MUV

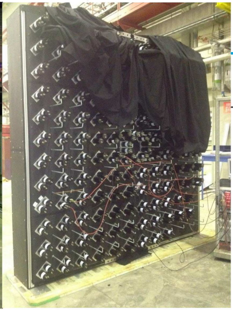
MUV1 & MUV2

- Iron-scintillator sandwich calorimeters with 24 (MUV1) and 22 (MUV2) layers of scintillator strips
- Alternating horizontal and vertical scintillator strips coupled to PMs

MUV3

- After iron wall: fast trigger signals
- < 1 ns time resolution (test beam result)



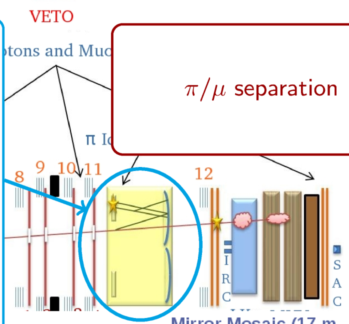


Muons veto

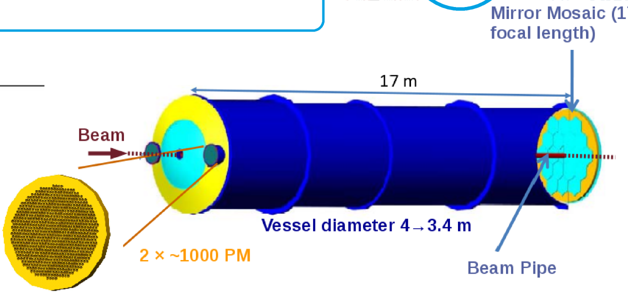
PID: Ring Imaging CHerenkov detector (RICH)

RICH

- π/μ separation between 15 and 35 GeV/c ($\lesssim 10^{-2}$)
- Event time with resolution of $\sim$ 100 ps
- L0 trigger signals
- Filled with Ne at atmospheric pressure
- Vacuum proof vessel



π/μ separation

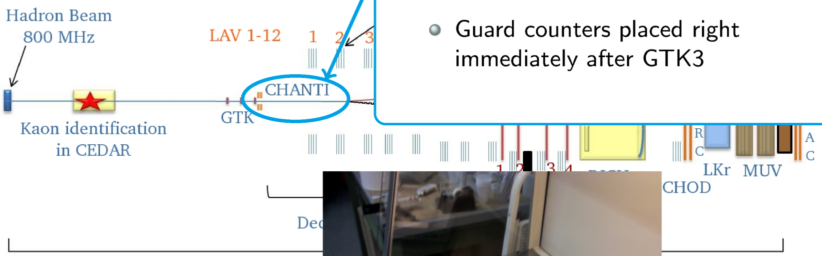


Charged particles veto: CHANTI

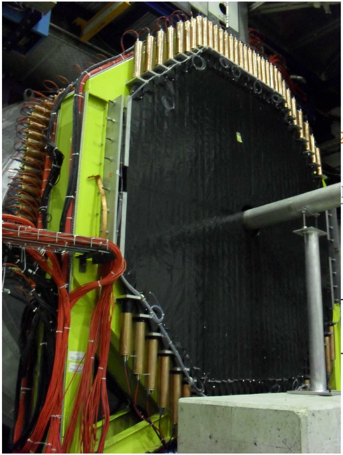
Charged particles veto close to beam or from GTK

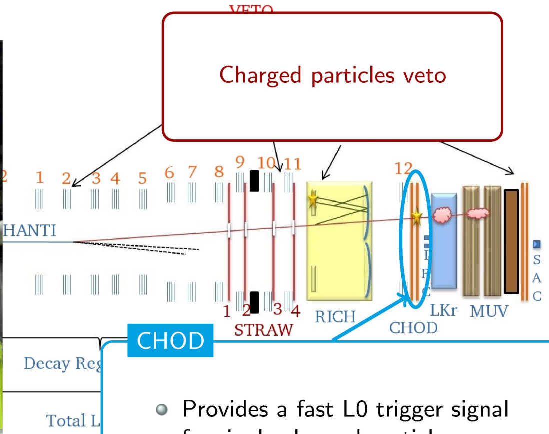
CHANTI

- Identify inelastic interactions in the collimator and the GTK
- Identify beam halo μ in the region closest to the beam
- Guard counters placed right immediately after GTK3



Charged particles veto: CHOD



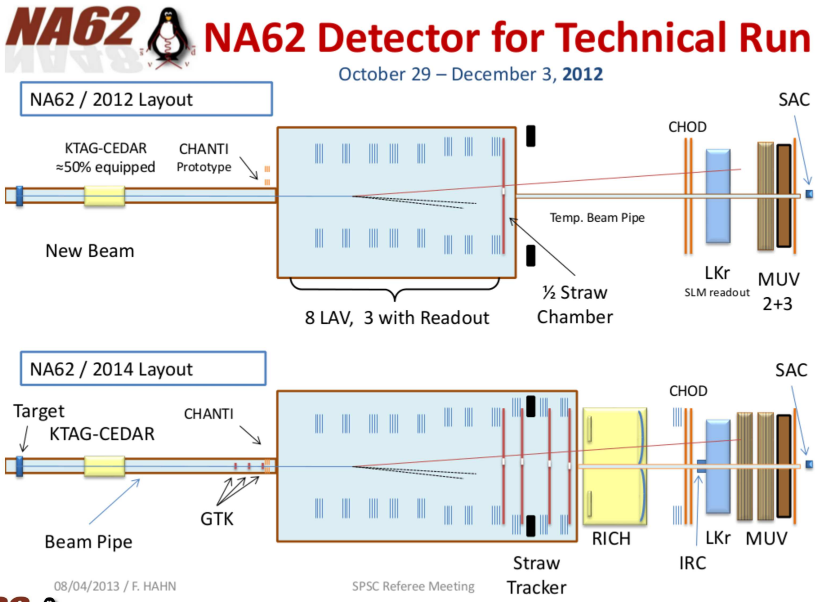


Charged particles veto

CHOD

- Provides a fast L0 trigger signal for single charged particle
- Vetoes multiple charged particle events

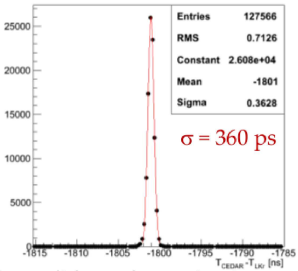
Technical run schematic



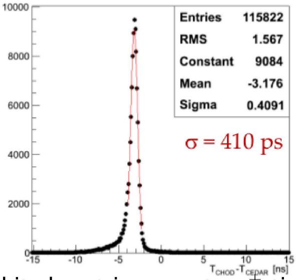
Technical run

- Test of the response of the sub-detector systems, using pure kaon decays
- $K^+ \longrightarrow \pi^+\pi^0$ events analysis:
    - Timing correlations between sub-detectors
    - Test response to pions and photons

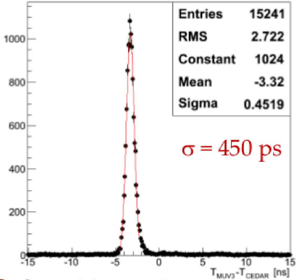
Timing correlations



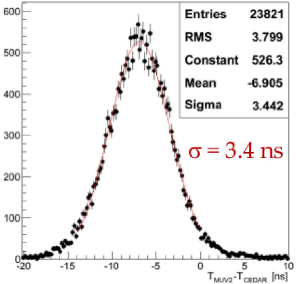
CEDAR candidate closest in time to π^0



CHOD hit closest in space to π^+ time

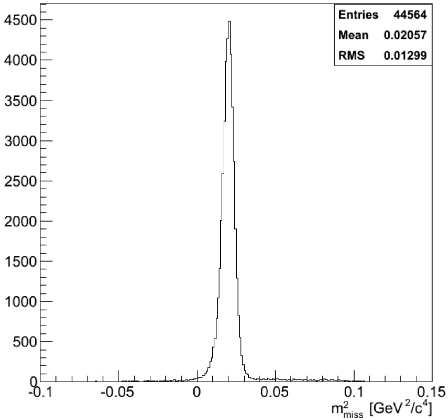


Muon trigger



Muon trigger

Missing mass



$$m^2_{miss} = (P_K - P_{\pi^0})^2$$

$$m^2_{miss} = 0.0198 \pm 0.0003 GeV^2/c^4$$

(PDG : 0.0195)

Conclusions

- NA62 is a challenging kaon experiment
  - Golden quality precision physics
  - Complementary to the high-energy approach for New Physics searches
  - Collect O(100) events in two years providing a 10% precision on BR
  - Key points: high intensity beams, excellent resolutions, hermetic coverage, particle Identification, redundancy of information
- Good response from 2012 Technical Run

DATA TAKING STARTING VERY SOON (end of 2014)


Thank you for your attention