The NA62 RICH detector

Antonio Cassese

Università degli studi di Firenze

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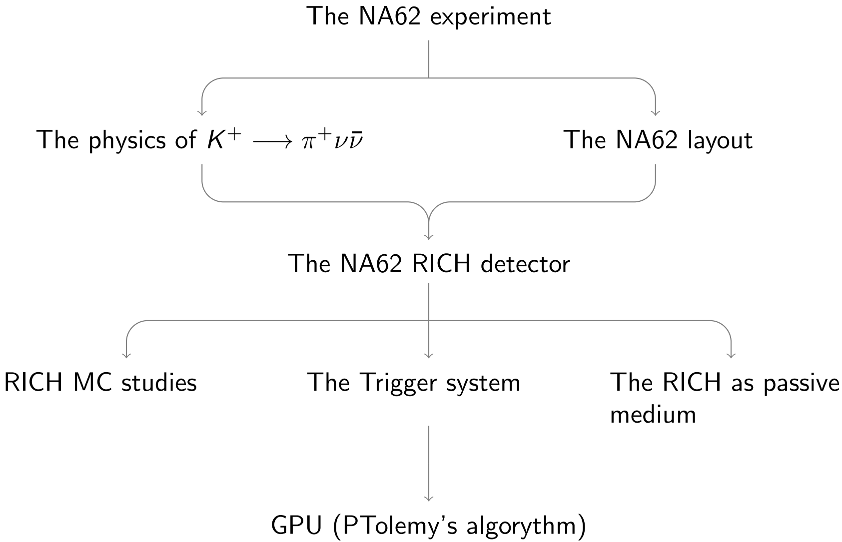
Overview

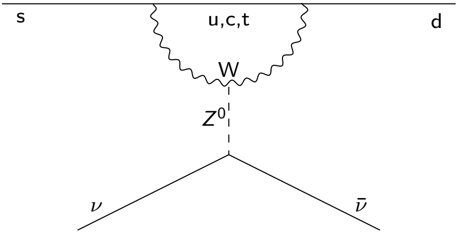

The NA62 experiment
The physics of $K^+ \longrightarrow \pi^+ \nu \bar{\nu}$
The NA62 layout
The NA62 RICH detector
RICH MC studies
The Trigger system
The RICH as passive medium
GPU (PTolemy's algorythm)

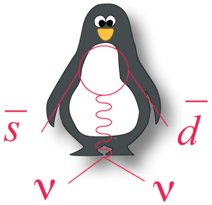
The NA62 experiment

The NA62 experiment at CERN

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

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

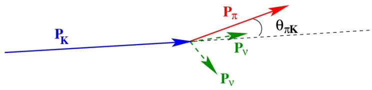




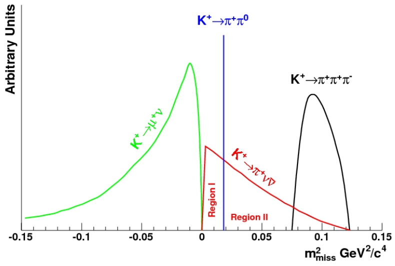
- Top quark contribution dominates
- FCNC processes forbidden at tree level
- $A(K^+ \longrightarrow \pi^+\nu\bar{\nu}) = \langle\pi\nu\bar{\nu}|\, H_{eff} \,|K\rangle = \frac{G_F}{\sqrt{2}} \sum_i V^i_{CKM} C_i(\mu) \langle\pi\nu\bar{\nu}|\, Q_i(\mu) \,|K\rangle$
- $C_i(\mu)$ short distance contributions
- $\langle\pi\nu\bar{\nu}|\, Q_i(\mu) \,|K\rangle$ long-distance contributions: can be extracted, thanks to the isospin symmetry, from the leading decay $K^+ \longrightarrow \pi^0 e^+ \nu$
- Thanks to the very accurate theoretical predictions, the measurement of these decays leads to very accurate constraints on any new physics model

Backgrounds rejection

- Main backgrounds:
  - BR $\left(K^+ \longrightarrow \mu^+\nu_\mu\right) \sim 63\%$
  - BR $\left(K^+ \longrightarrow \pi^+\pi^0\right) \sim 21\%$



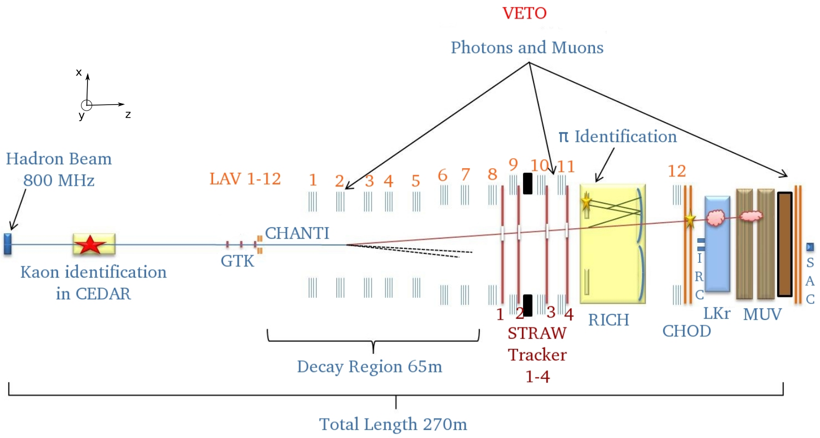
- $M^2_{miss} = \left(P_K - P_\pi\right)^2$



Channel	$\pi^+\nu\bar{\nu}$	$\mu^+\nu_\mu$	$\pi^+\pi^0$
BR	8×10^{-11}	63%	21%
M_{miss}	14.4%	8×10^{-6}	1.2×10^{-4}
γ veto	-	-	3.5×10^{-8}
μ veto	-	10^{-5}	-
RICH	-	5×10^{-3}	-
Total	1.15×10^{-11}	2.5×10^{-13}	8.8×10^{-13}
Ratio	1	2.2%	7.5%

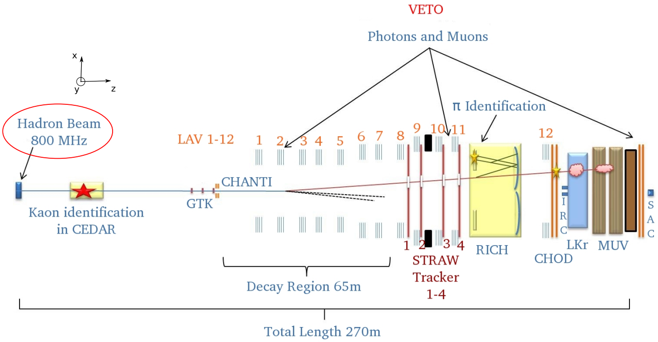
- Kinematic rejection (Gigatracker (K), Straw Chambers (π))
- PID (Cedar, RICH, MUV, CHANTI, CHOD)
- Photon rejection (LAV, LKr calorimeter, IRC, SAC)

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
1
2
3
4
STRAW
Tracker
1-4
RICH
I
R
C
CHOD
LKr
MUV
S
A
C
Decay Region 65m
Total Length 270m

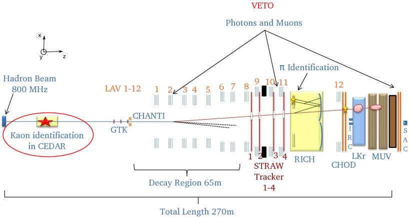
Target

- 400 GeV/c protons from SPS on beryllium target
- $\sim$ 6% of kaons
- 75 GeV/c kaons



Cedar

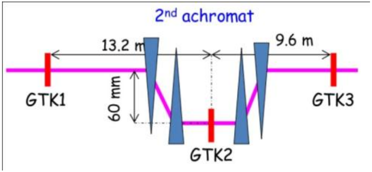
Cherenkov Differential Counter with Achromatic Ring Focus



- Differential Cherenkov counter for K tagging
- 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

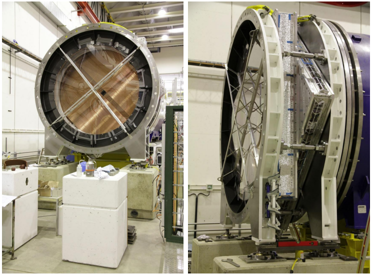
Kinematics

GTK (Kaons)



- 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 Chambers (pions)



- 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
- Total $X_0 \sim\ 0.1\%$ per view

Photon Veto

LAV

- 12 stations in vacuum to cover 8.5 to 50 mrad
- OPAL lead glass
- At least $\sim 18.6\ X_0$

SAC & IRC

- Covering up to 0 rad and LKr beam pipe

LKr

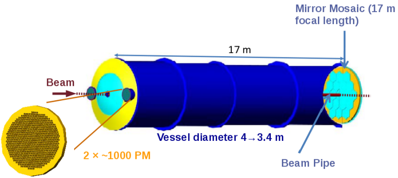
- Covering from 1 to 8.5 mrad region
- Use the existing LKr from NA48
- Inefficiency for detecting γ measured on data ($E_\gamma > 10$ GeV) $(1 - \varepsilon) < 8 \times 10^{-6}$
- New electronics

PID

MUV

- MUV1 and MUV2: iron-scintillator sandwich calorimeters with 24 (MUV1) and 22 (MUV2) layers of scintillator strips
- MUV3 after iron wall: fast trigger signals

RICH

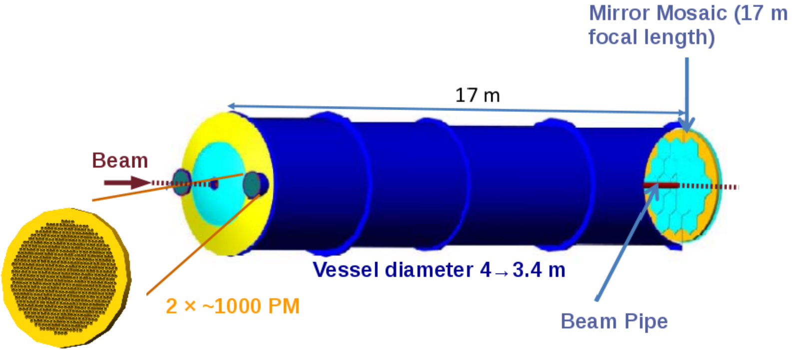


- π/μ separation between 15 and 35 GeV/c ($\lesssim 10^{-2}$)
- Event time with resolution of $\sim$ 100 ps
- L0 trigger signals

The NA62 RICH Detector

RICH layout

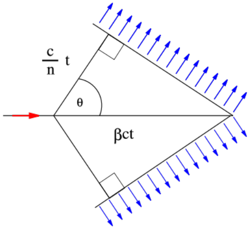
Filled with neon at atmosferic pressure



RICH basic principles

Cherenkov radiation

- Charged particles with velocity greater than the velocity of light in the medium emit light in a cone
- $cos\theta_C = \frac{1}{n\beta}$

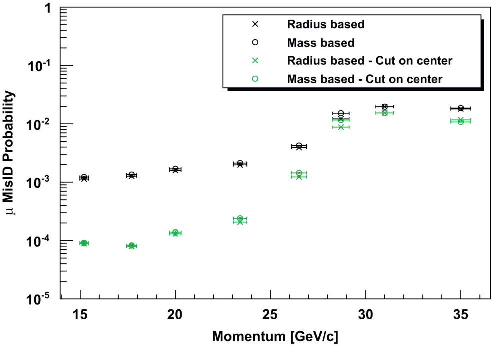


RICH

- Mirrors mosaic with 17m of focal length: map parallel rays into one point in the focal plane
- Moving in φ there is a ring in the focal plane for each particles
- $\sim$ 20 photons for particles with $\beta = 1$
- Photons detected by PMs (hits)
- Hits used to reconstruct the ring (radius r_C)
- $r_C = f\theta_C$

RICH MC studies

- π/μ separation:
  - MC/test beam comparison



Integrated μ suppression factor $(15 < p < 35$ GeV/c) better than 10^{-2}

- RICH as veto in multi charged events

π/μ separation

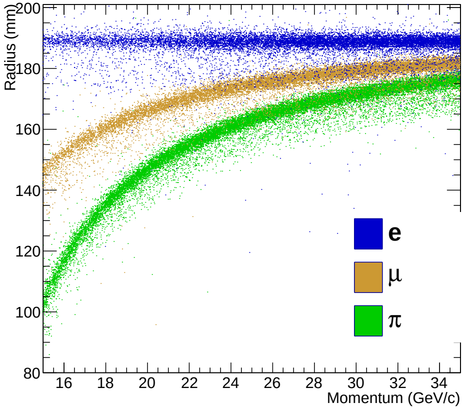


Figure: Reconstructed radius vs charged track momentum for K_{e2} (blue), $K_{\mu 2}$ (brown) and signal events (green)

Results

$$r_C = f \tan\theta_C \simeq f\theta_C$$

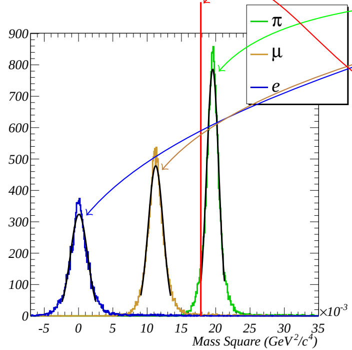
$$\theta^2_{max} - \theta^2_C \simeq \frac{m^2}{p^2}$$

Fit the peaks:

$K^+ \longrightarrow e^+\nu_e$

$K^+ \longrightarrow \mu^+\nu_\mu$

$K^+ \longrightarrow \pi^+\nu\bar{\nu}$



Apply a cut between the μ and π peak

An intagrated muon suppression factor, of $(1.1 \pm 0.1)\%$ has been found, in agreement with what has been found in the 2009 test beam

Multi charged track event

- N_{hits}
- χ^2
- Distance between each pair of hits

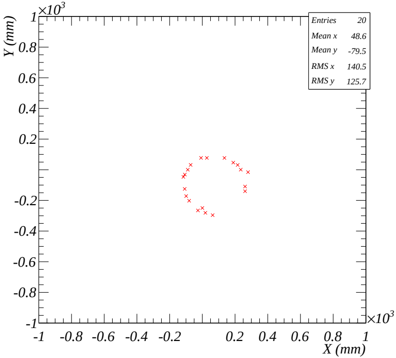


Figure: $K^+ \longrightarrow \mu^+\nu_\mu$ event

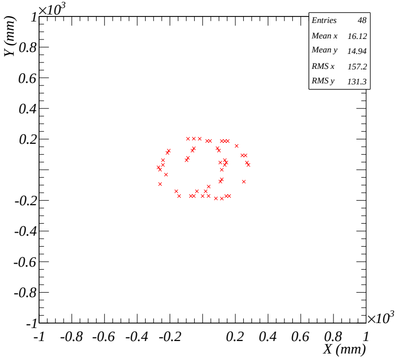


Figure: $K^+ \longrightarrow \pi^+\pi^+\pi^-$ event

Multi charged track event

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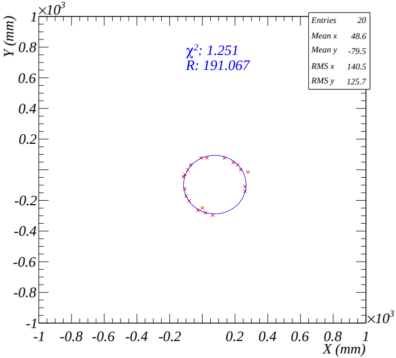

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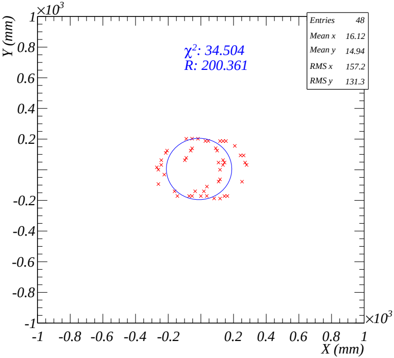

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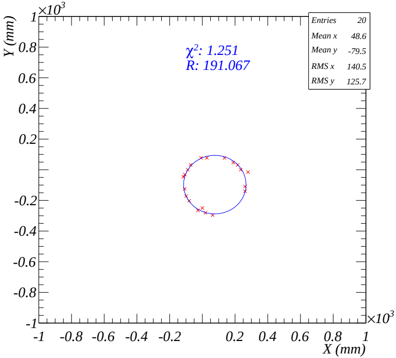

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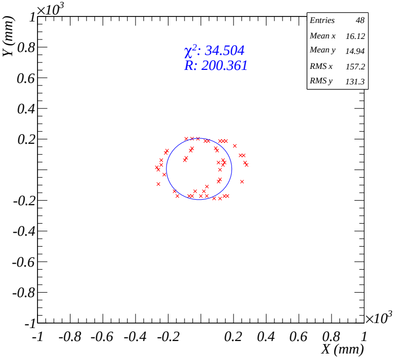

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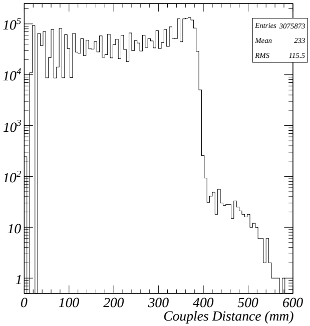
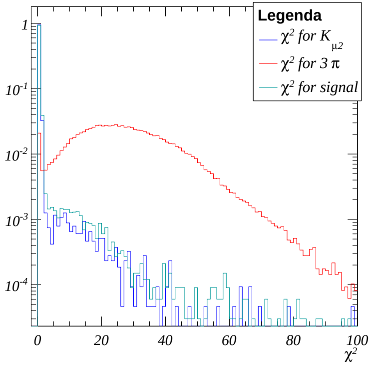


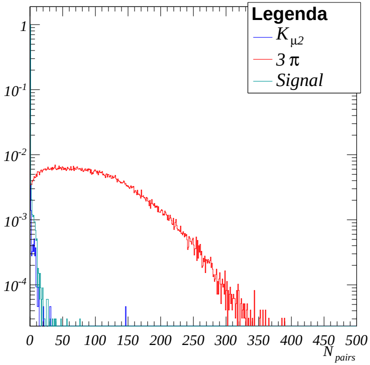
Figure: $K^+ \longrightarrow \mu^+\nu_\mu$ events

Distributions

χ^2 analysis



Distance between each pair of hits



Results

χ^2 analysis

- $K^+ \longrightarrow \pi^+\pi^+\pi^-$ rejection efficiency of $\sim 95\%$
- Signal detection efficiency of $\sim 98\%$

Distance between each pair of hits

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- Signal detection efficiency of $\sim 99\%$

- A complete analysis has been performed
- A cut involving the total number of hits in the RICH, the χ^2 and N_{pairs} has been applied, showing the necessity of the RICH multiplicity cut

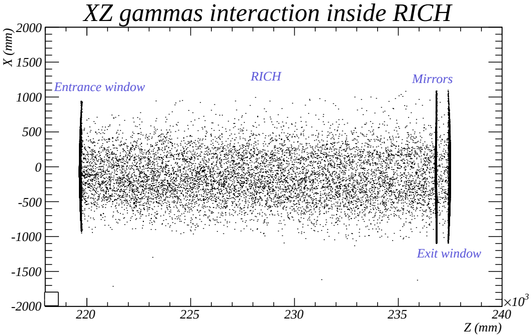
RICH as a passive medium in the $K^+ \longrightarrow \pi^+\pi^0$ background

- Goal of this analysis is to show that the inefficiency on the detection of the single photon in the forward region (inside the LKr acceptance) is not affected by the interaction of the gamma in the material before the LKr
- Inefficiency of the LKr depends on the energy:

Energy	< 1 GeV	$1 - 5.5$ GeV	$5.5 - 7.5$ GeV	$7.5 - 10$ GeV	> 10 GeV
Inefficiency	Fully inefficient	$\sim 10^{-3}$	$\sim 10^{-4}$	$\sim 5 \times 10^{-5}$	$\sim 8 \times 10^{-6}$

Table: Inefficiency of LKr as a function of the energy

Gammas interactions vertex in RICH material



Interactions inside the RICH ($\sim$ 22.8%):

- $\sim 3 \times 10^{-4}$ beam pipe and vessel
- $\sim$ 4.5% entrance and exit windows
- $\sim$ 14.7% mirrors
- $\sim$ 3.6% neon

Results

Energy	$1 - 5.5$ GeV	$5.5 - 7.5$ GeV	$7.5 - 10$ GeV	> 10 GeV
LKr Inefficiency	$\sim 10^{-3}$	$\sim 10^{-4}$	$\sim 5 \times 10^{-5}$	$\sim 8 \times 10^{-6}$
Inefficiency due to material	$(2.1\pm0.5)\times10^{-4}$	$(1.4\pm0.5)\times10^{-4}$	$(5 \pm 2) \times 10^{-5}$	$(3.7\pm1.6)\times10^{-6}$
"Undetected" gammas	18	9	4	5

- CHOD fundamental to reach the requests on the inefficiency introduced by gammas interactions before reaching the LKr
- Is it? With new LKr reconstruction...
- Reconstruction analysis shows good behaviour

NA62 trigger system

Charged particles rate within the geometrical acceptance

10 MHz

L0 trigger ↓ Hardware trigger

1MHz

L1 trigger
single subdet ↓ Software trigger

100KHz

L2 trigger
complete reco ↓ Software trigger

Tens of KHz

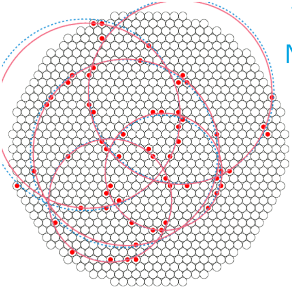
The RICH in the trigger system

- Center and radius of the Cherenkov rings are related to the angle and the velocity of the particle
- This information can be employed at trigger level to increase the purity and the rejection power for many triggers
- Ring reconstruction useful at both L0 and L1 levels
- Because of the high rate significant computer power required:

GPUs offer a simple solution of the problem

- SIMD architecture (Single Instruction Multiple data)
- Paralizzation & fast algorithms
- Less processors needed

Almagesto algorithm based on Ptolemy's theorem: "A quadrilater is cyclic (the vertex lie on a circle) if and only if is valid the relation: AD*BC+AB*DC=AC*BD"



Trackless

Non iterative

High resolution


Thank you for your attention
Waiting for Windows...