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(Draft) Fast Muon Veto Detector Prototype for NA62 experiment

1. NA62 experiment

NA62 setup is intended to find out and measure utra-rare kaon decay $K^+ \to \pi^+\nu\overline{\nu}$. According to Standard Model the decay has probability $Br = 10^{-10}$ and it is determined by the CKM matrix element $|V_{td}|$ (currently estimated value is $(8.74^{+0.26}_{-0.37}) \cdot 10^{-3}$). The NA62 experiment aims to measure this value within 10% accuracy by detecting ≈ 80 events during 2 years. Thus it will be precise test for Standard Model.

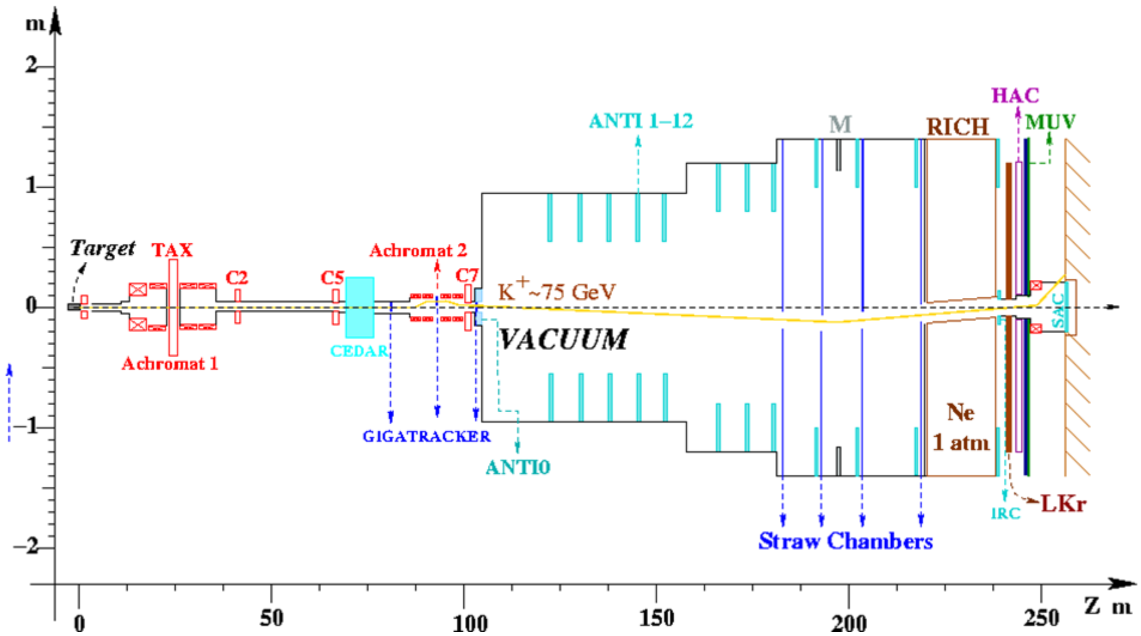

Figure 1: Scheme of NA62 setup

The most probable background to $K \to \pi^+\nu\overline{\nu}$ is $K \to \mu\nu$ in case the μ is misidentified as π. To fullfil the goal of the experiment a system of particle identification, containing large cherenkov detector (RICH), electromagnetic calorimeter (LKr), hadron calorimeter (HAC) and fast muon veto detector (FMUV , denoted as MUV on fig. 1, also called as MUV-3), was designed for the setup (see fig. 1).

So 2 purposes of FMUV are as follows:

- to reduce trigger rate by a factor of ≈ 10;
- to help HAC reject background due to $K \to \mu\nu$ decay with overall rejection factor of 100.

1.1. Trigger L0 requirements for FMUV time resolution

Kaon decays are distributed randomly in time: so, decay $K^+ \to \pi^+\nu\overline{\nu}$ can be accompanied by decay $K \to \mu\nu$. If μ from the decay $K \to \mu\nu$ are detected, the decay $K^+ \to \pi^+\nu\overline{\nu}$ will be rejected by trigger. To minimize the probaility of this vetoing one can select minimal time interval for required efficiency of μ rejection. This leads to dead time of the setup T_D, calculated by $T = 1 - e^-\delta\, r$, where δ is veto time interval and r is effective muon rate [Hz].

σ, ns	Veto time interval, ns	**dead time** if s=10	**dead time** if s=100
1.75	5.7	5.1%	8.0%
1.2	3.9	3.6%	5.5%
0.9	3.0	2.7%	4.2%

Table 1: Loss of the full setup acceptance due to FMUV time resolution. We assume $r = 9.2\ MHz$ here.

Let us suppose that time is distributed as gauss with width σ. Assuming FMUV should suppress muon background by a factor of 10 or 100, well choose Veto time interval $\delta = 2 \times 1.64\,\sigma$ or $2 \times 2.58\,\sigma$ accordingly. That's why the FMUV detector should be very "fast", e.g. have small σ: the more σ — the more dead time!

Effective muon rate at MuV is usually reported to be $r = 9.2\ MHz$. Appropriate dead time for different σ and rejection factor $s = 10$ and $s = 100$ are shown in table 1.

2. Current FMUV design

To provide reasonably good time resolution $\sigma_t \sim 1\ ns$ with minimal registration channels, design of FMUV detector was chosen as follows: scintillation plates of size $\geq 40 \times 40\ cm^2$, where light is collected by WLS-fibers which are put in grooves cut in the plates.

The prototype of FMUV detector, which consists of 1 quadrant, was manufactured. Full FMUV detector will consist of 4 quadrants. The prototype at the time of manufacturing is shown on fig. 2.

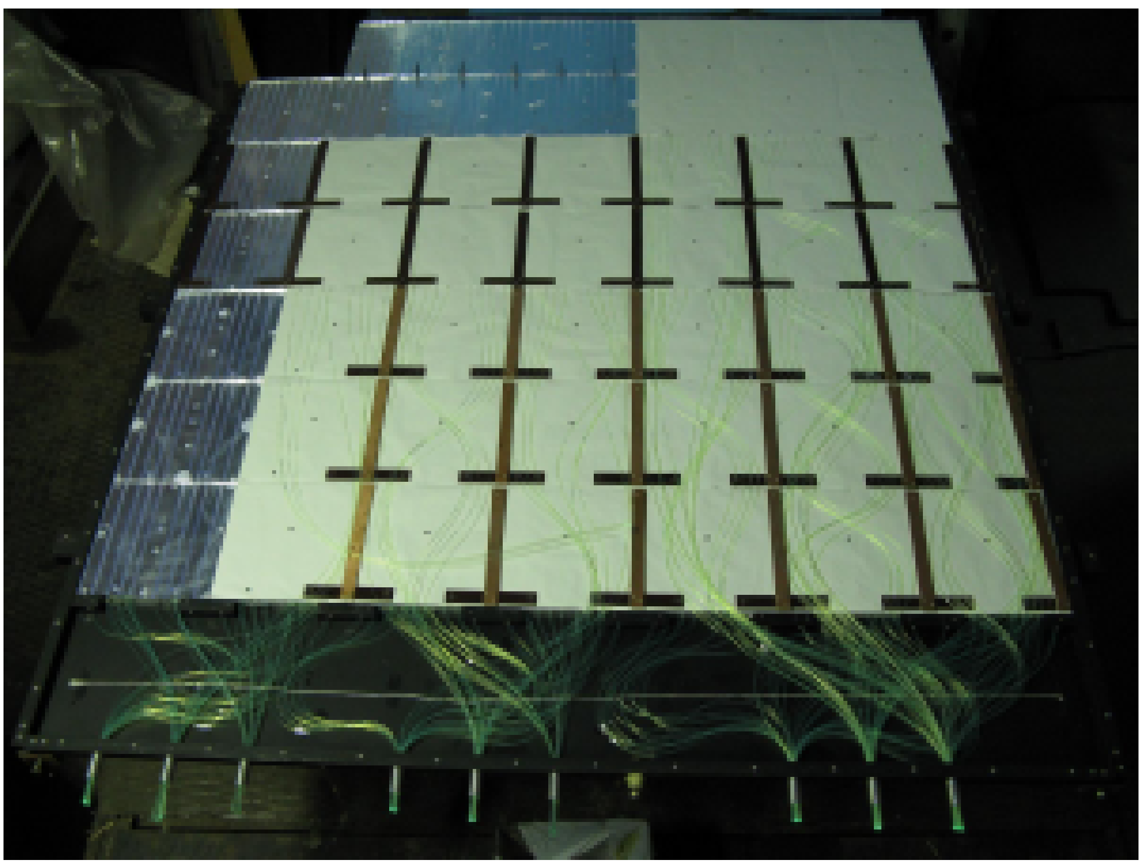

Figure 2: Photography of FMUV prototype

The prototype consists of 9 pad of non-equal size. 4 pads near beam have size $40 \times 40\ cm^2$, peripheral pads larger: 4 pads $40 \times 60\ cm^2$, 1 pad $60 \times 60\ cm^2$.

Each pad assembled from $20 \times 20\ cm^2$ scintillation plates. Each scintillation plate contains 8 grooves with WLS-fibers put in it. In bounds of 1 pad WLS-fiber is in optical contact with appropriate scintillation plate, then it lead out over light-reflected surface. All fibers from 1 pad are gathered in 1 bundle and then connected to 1 PMT.

3. FMUV prototype tests

The prototype was tested during runs of NA62 setup (preliminary in 2008 and finally in 2009 year). It was placed at the back of the setup, behind HAC separated by 2 meter of iron between them, where it is supposed to stay during future experiment. Tests were performed during muon runs.

We had used unique electronics of former NA48 experiment (channels of NA48 Neutral Hodoscope). PMB, 'pipeline memory board', developed specifically for hodoscopes, allows both definition of time and amplitude of signal. Using constant fraction discriminator (CFD) helps to reduce dependence of time definition on amplitude. Each channel utilize 2 Flash ADC (FADC) with sample period of 25 ns for digital conversion. Signal from PMT is shaped and then divided into 2 parts:

- one is digitized by FADC, then during offline processing an amplitude of signal is calculatead as maximum of parabola plotted throw maximum point and 2 points around it;
- another goes to CFD , which starts *ramp*. Ramp is digitized by 2nd FADC; during offline processing it is fitted by straight line, point of this line at some constant amplitude defines the time of signal.

This scheme is called *Flash TDC*.

Charged hodoscope was used for time measurement, e.g. time of FMUV response was defined as

$$t_{\mathsf{FMUV}} = t^E_{\mathsf{FMUV}} - t^E_{\mathsf{CHOD}},$$

where t^E denotes time obtained from electronics, which is distributed randomly in $[t_0; t_0 + 25\ ns]$ range, so each channel time should be aligned by its t_0 separately.

4. Measured detector parameters

Data obtained were processed using standard NA48 system. We used such an information as amplitude and time for channels of FMUV and CHOD . Tracks from track system were available only during 2008 year run; in 2009 year run we reconstruct coordinates of track from CHOD ; for that condition $n_x = 1$ and $n_y = 1$ was demanded, where n_x and n_y are number of fired CHOD strips in x- and y-planes.

4.1. t(X) dependence

Effective speed of light depends on CFD work.

4.2. Detector efficiency

4.3. Prediction of time resolution from $\sigma_t(A)$ dependence

5. Study of measurement errors

Possible corrections: t(A), ramp, σ of charged hodoscope.

$$\sigma^2_{full} = \sigma^2_{own} + \sigma^2_{t(A)} + \sigma^2_{ramp} + \sigma^2_{Ch.Hod.}$$

5.1. Time resolution of CHOD

5.2. FMUV $t(A)$ dependence

5.3. Calibration of up/down ramp

6. Results Analysis

Various PMT's were used in FMUV prototype: FEU-85, FEU-115M, Hammamatsu R789920.

6.1. Possible inefficiency due to high rates

Conclusions