The CHarged ANTIcounter for the NA62 experiment at CERN

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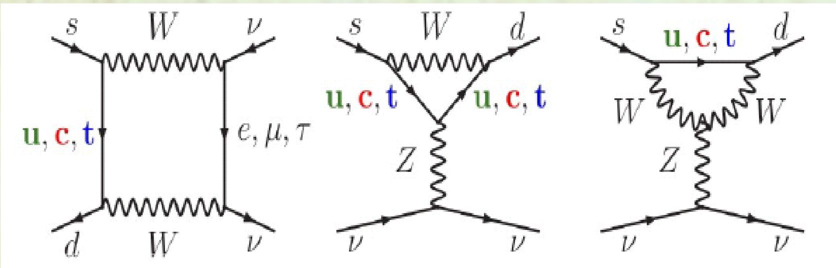
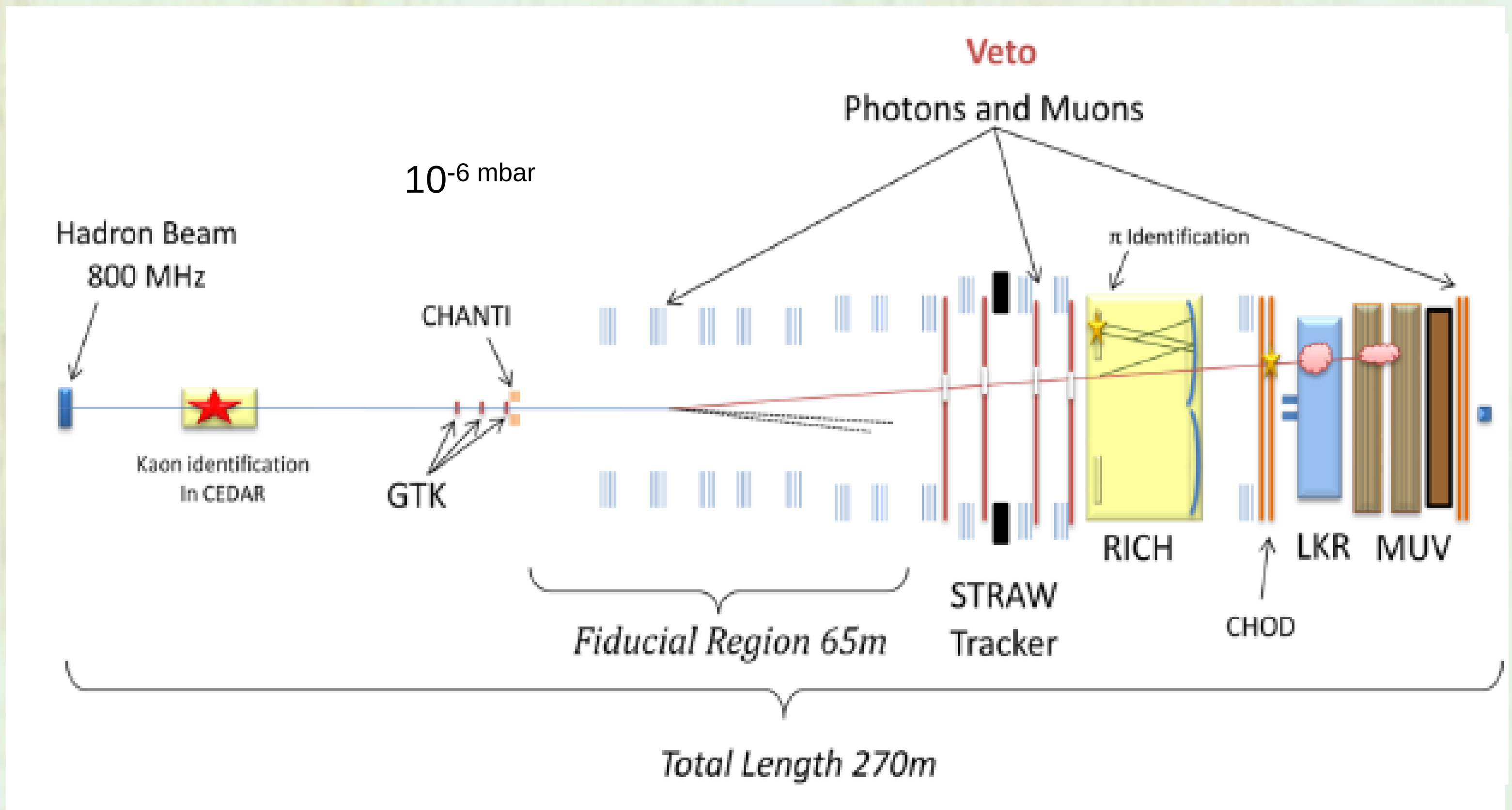
The NA62 experiment at the CERN SPS

75-GeV unseparated beam 5×10^{12} K^+ decays in FV/y





SM theoretical framework for $K^+ \rightarrow \pi^+ \nu\bar{\nu}$

- FCNC loop process, short distance dominated
- Hadronic matrix element from the BR(K_{e3})
- Theoretically clean |Vtd| dependence
- Perfect probe for New Physics, complementary to LHC.
- **SM Prediction (0.781 ± 0.075 ± 0.029) x 10^{-10}**

(Brod, Gorbahn, Stamou: PRD83(2011) 034030, arXiv 1009.0947)

- **Experiment (1.73 ± 1.10) x 10^{-10}**

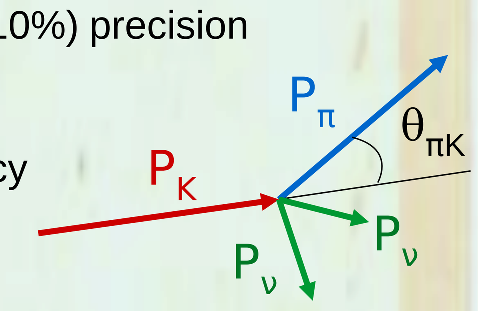
(BNL E787/E949: PRL101 (2008) 191802, arXiv 0808.2459)

Measurement principle

Goal : measure BR($K^+ \rightarrow \pi^+\nu\bar{\nu}$) with O(10%) precision
- O(100) SM events
- high intensity kaon beam
- large background rejection + redundancy

High momentum kaon decay in flight
- one K$^+$ track, one π$^+$ track
- kinematic variable $m^2_{miss} = (P_K - P_\pi)^2$
- momentum measurement + PID + veto

Momentum: Kaon tracker (GTK) + pion tracker (STRAW)
Particle identification: kaon identification (CEDAR) + π/μ/e identification (RICH)
Veto against: beam induced accidentals (CHANTI) multiple charged particle decays (STRAW, CHOD) photons and muons (LAV, LKr, IRC, SAV and MUV)

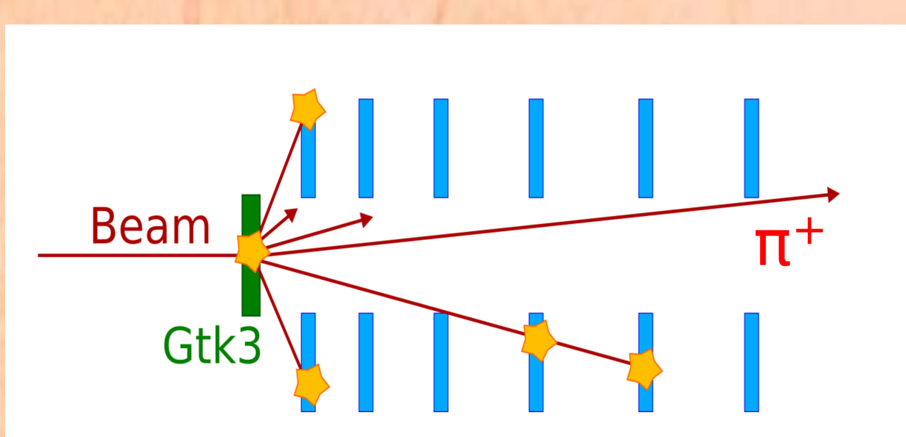


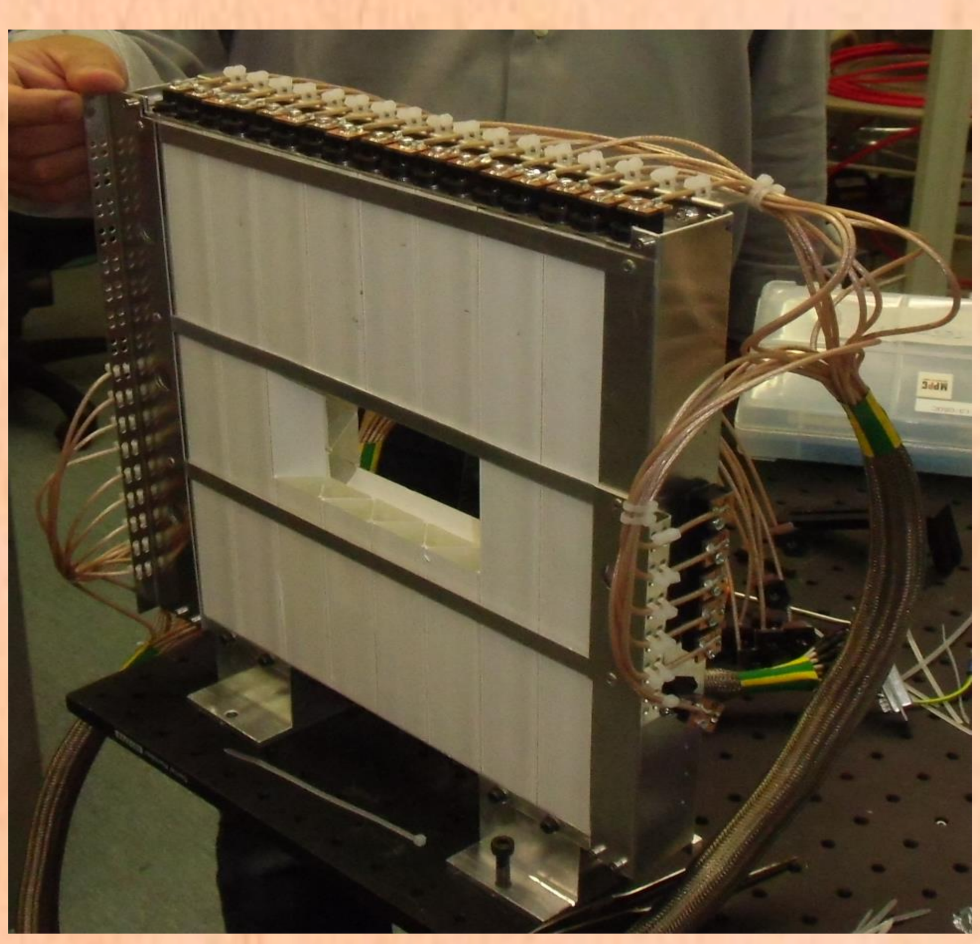
Schedule

- R&D completed in 2010
- 2010-2014: construction
- October 2014: Pilot run
- July 2015: Physics data taking

Rejection of K$^+$ inelastic interactions: CHarged ANTIcounter

The CHarged ANTI is required in order to reduce the critical background induced by inelastic interaction of the beam with the collimator and the Gigatracker (GTK) stations. The most critical events are the ones in which the inelastic interaction takes place in the last GTK station (GTK-3). In such cases pions, or other particles produced in the interaction, if emitted at low angle, can reach the straw tracker and mimic a K decay in the fiducial region. If no other track is detected, these events can appear like a signal event, one single π$^+$ in the final state.
Kaon inelastic interactions with GTK-3 happens in about 1/10^3 cases. Given the flux of K mesons crossing the GTK-3 (8×10^{13} in two years data taking) the combined rejection factor of the analysis cuts and the CHANTI veto must be of order of 10^{-11}.
CHANTI is a series of six "guard rings" covering hermetically the angular region between 49 mrad and 1.32 rad from GTK-3. To achieve this the six stations are placed at 27-85-200-430-890-1810 mm from GTK-3 surface. All of them have to be operated in a 10^{-6} mbar vacuum.
The expected rate on CHANTI is about 8 MHz, where almost 2 MHz is due to muon halo. Even if it is not intended as a trigger veto at L0 its time resolution must be better than 2 ns to keep the random veto rate at an acceptable level.



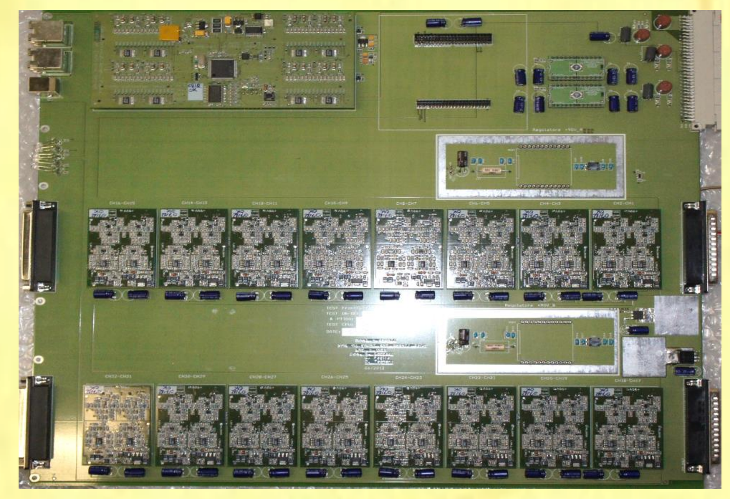


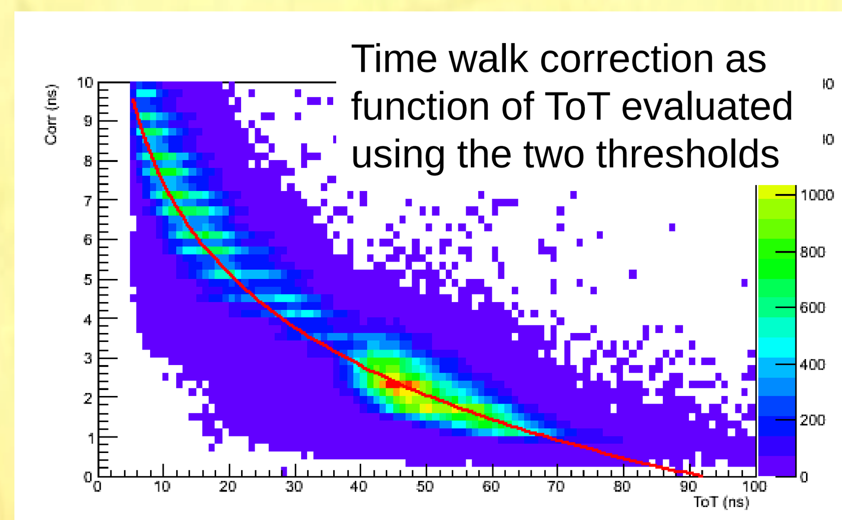
CHANTI Front-End Electronics

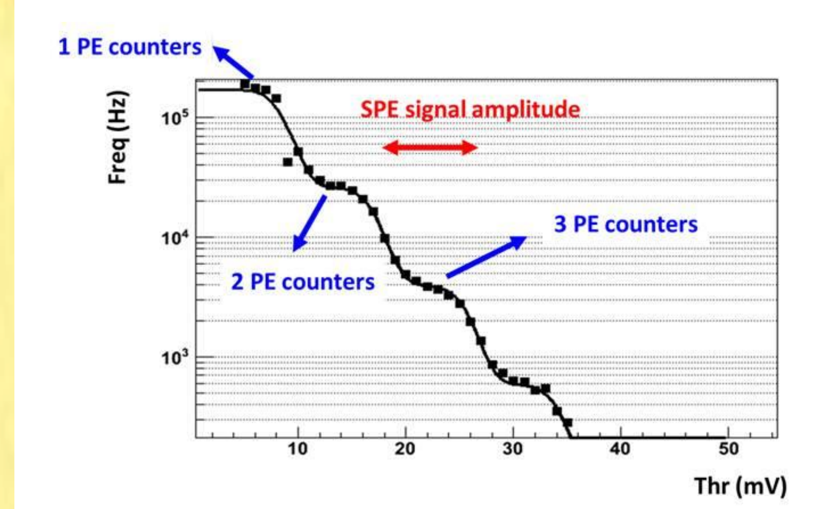
A dedicated FEE board has been designed. It is both used to set the bias voltage of the MPPCs and to read their current. It also gives fast amplification of the signal before passing them in input to a comparator board (so called ToT board) which gives an LVDS output of duration equal to the time a signal is above a given threshold. Actually the ToT board is able to give two LVDS outputs for each analog input corresponding to different adjustable level thresholds. This feature can be used to correct for time walk effects. The main FEE board features are:

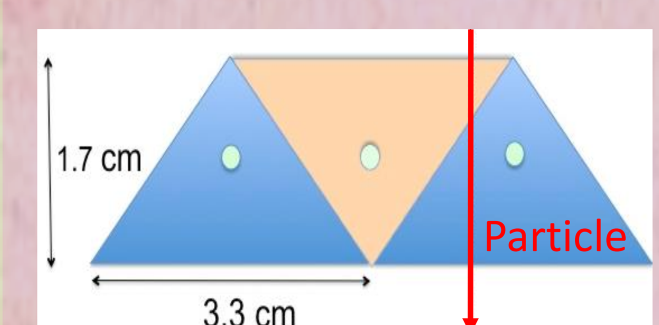
- Bias setting at 10 mV precision and very stable with temperature/time
- Current reading at nA precision
- Fast 25X amplification of analog signal
- Temperature measurement via pt100 probes
- 32 channels in a VME 9U form factor

A careful calibration procedure for the FEE boards has been setup in order to precisely control and readout the value of the voltage bias; another calibration of the thresholds for the ToT board has been performed. Finally, a threshold scan is done for each of the readout SiPMs of the CHANTI system by counting the dark rate at different values of the threshold. Since the SiPM dark rate diminishes by roughly one order of magnitude as the threshold is raised of an amount equivalent to one photoelectron amplitude, a fit of this threshold scan with a proper step function can determine the amplitude (in mV) of the single photoelectron peak for each channel.




Time walk correction as function of ToT evaluated using the two thresholds





Structure

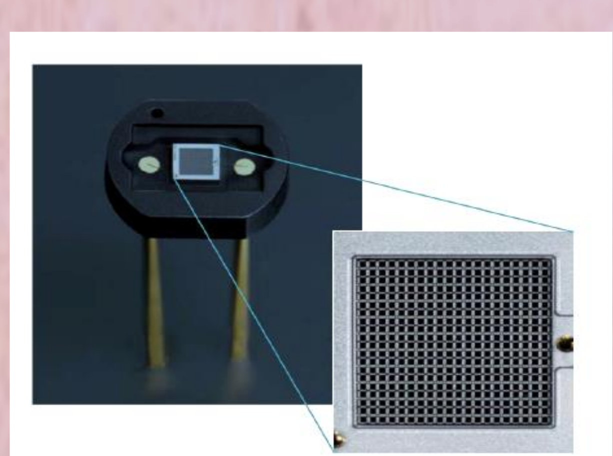
Each station is made up of two layers, X and Y.
Y (X) layer is composed of 24 scintillator bars arranged parallel to X (Y) direction. Each bar is triangularly shaped with a 1.7 mm diameter hole. The triangular shape allows a gap-free assembly. The amount of light shared between two adjacent bars depends on the impact point of the particle. Bars are produced at FNAL–NICADD facility.

Scintillator bar characteristics

- Good LY
- Radiation hardness (5% degradation observed after 1Mrad γ irradiation)
- Fast response (τ few ns)
- TiO_2 co-extruded coating

WLS fiber

Light is collected by means of one Bicron BCF92 WLS fiber placed inside each bar. The fiber is read only at one side, on the other side it is mirrored. BCF92 main features:
- Attenuation length > 3.5 m
- Decay time 2.7 ns
- Emission peak 492 nm



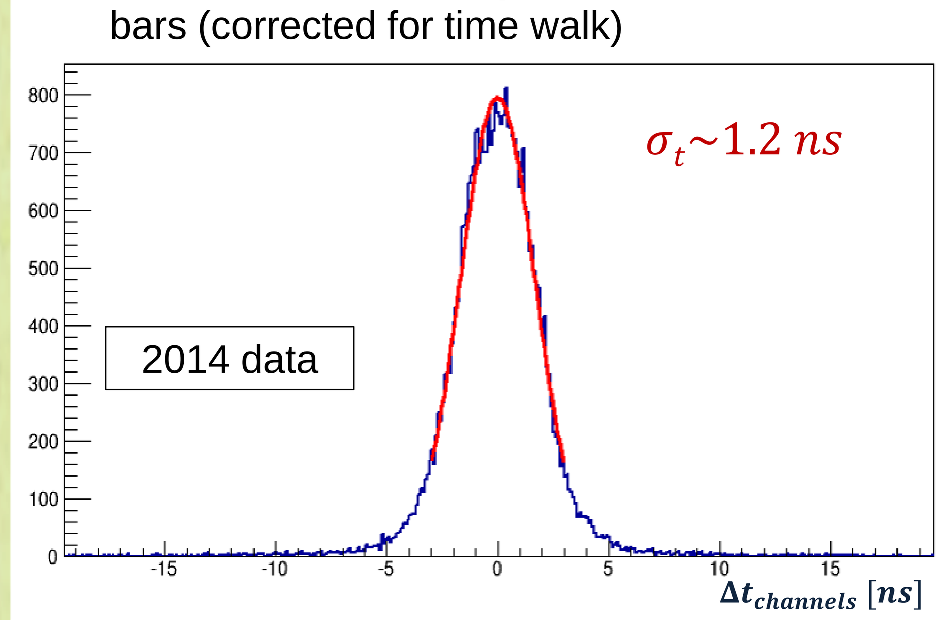
Photon detection: MPPC

Each fiber is read by a Hamamatsu MPPC (1.3×1.3 mm^2; 50μm pixel)
- HV of the order of 70 V and leakage current of the order of few nA
- Sustain higher rates wrt ordinary PMTs
- With 3.5 pe threshold dark rate of about 100 Hz/channel at room temperature

CHANTI performances: NA62 run 2014

The CHANTI took part to the Pilot Run in October 2014 together with the other detectors of NA62. Most of the running was done at 5% of nominal beam intensity, but during some periods the intensity was increased to 20%. A rate of 100 kHz/channel has been measured during the data taking on the hottest bars close to the beam hole, as expected with the limited intensity of the beam. The time and spatial resolution have been measured by means of muon halo tracks. Single station efficiency has been measured above 99.9% as expected from laboratory tests performed on the detector prototype using cosmic rays.

Time difference among two bars (corrected for time walk)



Difference between X position on different CHANTI stations for straight muon