2012 NA62 Status Report to the CERN SPSC

Abstract

NA62 aims to study the rare decay $K^+ \to \pi^+ \nu\bar{\nu}$ at the CERN SPS. In this document we report the status of the detector construction and the general progress of the experiment since April 2011. A detailed description of the activities for the next 12-18 months is given, including the preparation of the 2012 technical run. We also report the final lepton universality result based on the full 2007-2008 sample and the status of physics analyses based on past NA48 data which are still ongoing.

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1 Introduction

The last year has witnessed good progress on the study of flavour changing neutral currents (FCNC) in charged leptons and quarks. The MEG experiment has published a new upper limit (90% CL) [1]. The new MEG result, $BR(\mu^+ \to e^+\gamma) < 2.4 \times 10^{-12}$, improves by about a factor of five the previous best limit. The LHCb experiment has reported evidence of direct CP-violation in charm decays [2] renewing the interest to study non-leptonic meson decays. On rare B decays, LHCb has clarified the situation on $B^0 \to K^*\mu^+\mu^-$ finding the differential cross-section in agreement [3] with the standard model (SM) prediction, and LHCb [4] and CMS have decisively improved limits on $B^0_{(s)} \to \mu^+\mu^-$.

As regions of the parameter space for new physics are being excluded at high p_T collider searches, the importance to explore rare processes sensitive to very high energy scales and for which firm theoretical predictions exist is increasingly recognised [5]. The situation for

$$K^+ \to \pi^+ \nu\bar{\nu} \tag{1}$$

is particularly interesting because of the robustness and precision of the SM prediction [6], and the vast opportunity for improvement on the experimental side [7]. Within the SM, the determination of the CKM parameter V_{td} from reaction (1) without input from lattice QCD remains an important objective. Beyond the SM, large effects on the rate of reaction (1) can be expected [8].

2 Preparation for the $K^+ \to \pi^+ \nu\bar{\nu}$ Analysis

The development of selection for $K^+ \to \pi^+ \nu\bar{\nu}$ using a *cut and count* method was the main topic addressed this past year. The main steps in order to reach this goal are:

1. definition of a set of cuts in order to exploit the kinematic rejection power;
2. definition of a set of cuts in order to suppress final states with more than one charged particle;
3. study of the photon rejection;
4. study of the pion/muon separation using calorimeters (LKr+MUVs) and the RICH.

Step 1 exploits the precise track reconstruction in the Gigatracker and in the Straw Spectrometer. The need of suppression of the non-Gaussian tails in the reconstructed kinematic variables requires a sophisticated and realistic Straw Spectrometer reconstruction. This reconstruction has been developed last year and makes use of the results from the 2010 straw test beam for the simulation of the digitization. It provides a precise and efficient reconstruction both in case of single-track and multi-tracks events. The tuning of the kinematic selection was performed on the $K^+ \to \pi^+\pi^0$ decay mode. The rejection power was tested using $K^+ \to \pi^+\pi^0$, $K^+ \to \mu^+\nu$ and $K^+ \to \pi^+\pi^+\pi^-$ decay channels. The signal acceptance was finally reevaluated. The results are in agreement with more naive estimations done in previous years. The background acceptances including track requirements, geometrical acceptance, pion momentum between 15 and 35 GeV/c and kinematic selection are: 4.4×10^{-5} for $K^+ \to \pi^+\pi^0$, 10^{-5} for $K^+ \to \mu^+\nu$, 0.7×10^{-6} for $K^+ \to \pi^+\pi^+\pi^-$. In particular the cut on the m^2_{miss} provides a suppression factor of about 5×10^3 for the $K^+ \to \pi^+\pi^0$, $> 10^4$ for $K^+ \to \mu^+\nu$ and about 10^4 for $K^+ \to \pi^+\pi^+\pi^-$.

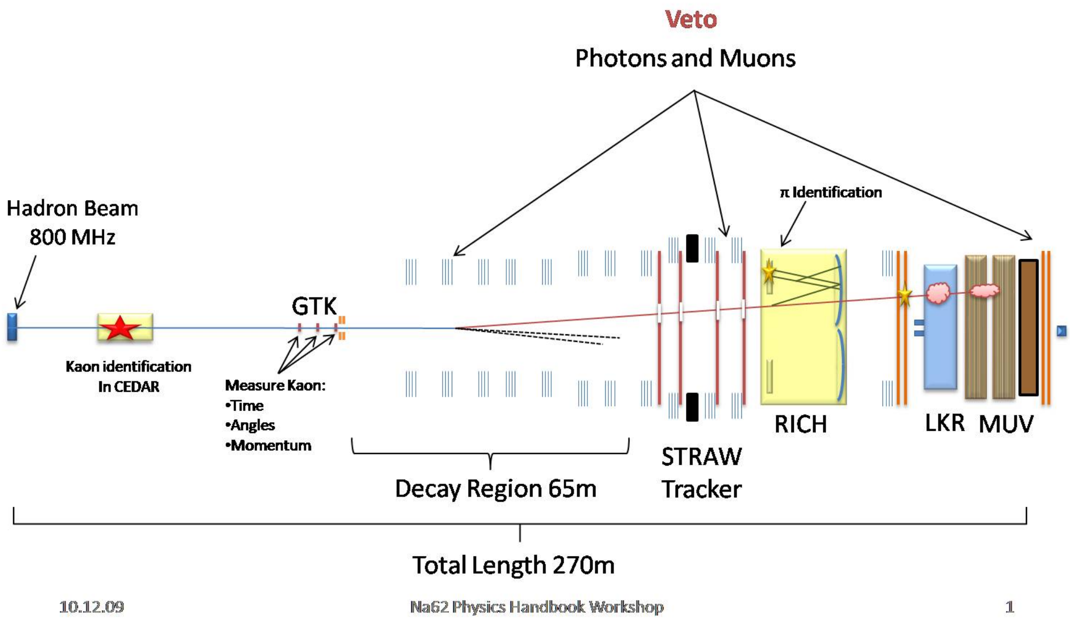


Figure 1: Layout of the NA62 detector.

Step 2 requires a careful simulation of the detector (see Fig. 1) response, of the active and passive material mainly between the Straw Spectrometer and the LKr (RICH, CHOD, LAV12, IRC region) and of the rate and the distribution of the accidentals. The selection against final states with more charged particles was tuned on the $K^+ \to \pi^+\pi^+\pi^-$ events surviving the kinematic cuts. The dangerous configurations are those with one π^+ reconstructed in the spectrometer and the other π^+ and the π^- in the hole of at least two straw chambers. The long lever arm between the fourth straw chamber and the MNP33 magnet is crucial to detect the π^- in the detector downstream of the magnet and to keep a good probability to detect the other π^+. The geometry guarantees full π^- detection, but two effects conspire against complete rejection: π^- decays, mainly upstream of MNP33, and π^- hadronic interactions. The analysis exploits the multiplicity in RICH, CHOD, LAV (mainly stations 9, 10, 11 and 12) and the IRC. It also uses of the capability of the spectrometer to reconstruct segments and to correlate them to the event vertex using variables like the impact parameter. The study is still on going: up to now the new cuts give a further 3.5×10^3 suppression factor for $K^+ \to \pi^+\pi^+\pi^-$, while keeping the signal acceptance above 10%. The signal acceptance includes the effect of the material (mainly delta ray production and hadronic interactions) and of the accidentals (segments from not fully reconstructed accidental tracks in the spectrometer and delta ray from beam pion decays). This analysis still does not take into account the LKr and MUVs calorimeters. They are expected to provide both a further rejection factor and the redundancy required to estimate the suppression factor directly from data.

Step 3 requires a careful simulation of the passive material up to the LKr. The analysis addresses the effect of the material on the detection of photons in the acceptances of the small angle calorimeters (IRC and SAC) and of the LKr. Because of the stringent requirements on the photon detection efficiency, the $K^+ \to \pi^+\pi^0$ background could suffer mainly from a potential photon loss in the material. The analysis makes use of photons from $K^+ \to \pi^+\pi^0$ events surviving the kinematic selection. The multiplicity selection previously described and a cut on the extra clusters in the LKr is applied on top of that for detecting the residual products of the photon interactions (electron/positron pairs and photons or pions, protons and neutrons in case of hadronic interactions). This study suggests that the photonuclear interactions in the RICH region mainly limit the efficiency of the detection of the photons in the IRC acceptance; the conversions in the third straw chamber mainly limit the efficiency of those in the SAC acceptance. The results of the analysis are: the effective detection inefficiency for photons in the IRC acceptance ranges from 10^{-3} (below 10 GeV) down to 10^{-4} (above 40 GeV). The effective detection inefficiency for photons in the SAC regions is about 10^{-3}. Photons in the LKr acceptance have 25% probability to interact in the material upstream of the LKr and 10^{-3} probability to interact hadronically. In most of the cases a simple electron/positron pair is produced and the LKr detects it. A dedicated study showed that in case of pair production in the chambers before the magnet, electromagnetic showers or hadronic interactions in the RICH material, the same $K^+ \to \pi^+\nu\bar{\nu}$ selection cuts previously described are enough to keep the photon detection inefficiency below the intrinsic inefficiency of the LKr. Taking into account the inefficiency of the LKr, the effective efficiencies of IRC and SAC and the intrinsic inefficiency of the LAV, the $K^+ \to \pi^+\pi^0$ surviving the $K^+ \to \pi^+\nu\bar{\nu}$ selection is estimated to be at a level of 5% of the SM signal. The photon analysis also shows that the selection developed in Step 1 and 2 is enough to keep the photon detection under control. As a consequence the signal acceptance remains unchanged with respect to the estimation done in Step 2.

Step 4 requires a full simulation of the LKr and the MUVs. The analysis just started using beams of pions and muons in the calorimeter acceptances. Signals in the last MUV station (MUV3) and cluster shape variables in LKr and the MUV are the main ingredients to separate pions and muons. A first study making use of MUV3 and cluster width in LKr and MUV1 reports a muon identification inefficiency of about 10^{-5} for a 90% pion acceptance. More refined studies are on going to increase the signal efficiency keeping a muon purity at the same level. In principle the level of muon purity already reached is in agreement (or even better) than the experimental requuirements.

2.1 2012 Plans

- Improvement of the *cut and count* $K^+ \to \pi^+\nu\bar{\nu}$ analysis:
  - The kinematic selection has to cope with the pile-up in the Gigatracker and in the Spectrometer. The timing of the subdetectors will play an essential role

in this game. To this end a simulation which includes the accidental overlay is under development. The Gigatracker reconstruction has to be tested in a multi-track environment. A further tuning of the kinematic selection is foreseen concurrently with an improvement of the Straw Spectrometer reconstruction. The improvement in the reconstruction will result as a consequence of the 2012 technical run, when a Straw Chamber will be tested in a realistic environment.

  - The simulation with accidental overlay will allow a more precise definition of the multiplicity selection and a better evaluation of the signal acceptance. The use of the RICH as multiple charged particle veto will be improved. To this end a more refined RICH reconstruction is under development. Finally the calorimeters will be included in the analysis.
  - The effect of the material on the detection of the photons in the LAV acceptance will be analyzed. The photon rejection analysis will be refined thanks to a more realistic LKr reconstruction, which is under development. The possibility to measure the photon detection efficiency directly from data will be investigated.
  - The study of the muon pion separation using the calorimeters will continue. More discriminating variables will be considered and the $K^+ \to \mu^+\nu$ channel will be used as testing ground. The analysis will also profit from the improvements of the reconstructions of the LKr and the MUV, which are under development.

- Reevaluation of the following Kaon decays surviving the $K^+ \to \pi^+\nu\bar{\nu}$ selection:
  - $K^+ \to \pi^+\pi^0(\gamma)$;
  - $K^+ \to \pi^+\pi^+\pi^-$;
  - $K^+ \to \mu^+\nu(\gamma)$;
  - $K^+ \to \pi^+\pi^-e^+\nu$, $K^+ \to \pi^+\pi^-\mu^+\nu$.
- Study of the beam induced backgrounds. The nuclear interactions in the third station of the Gigatracker may mimic the signal in case of concurrent mismeasurement of the track slope in the spectrometer. The identification of these events, based on the detection of the extra particles produced in the hadronic interactions, will be analyzed.
- Improvements in the evaluation of the signal acceptance. This improvement will profit from the improvements of the simulation of the beam, which, in turn, will be tuned properly using measurements of the beam shape to be done during the 2012 technical run.

3 Technical Run

We confirm our plans for a technical run (TR) in autumn 2012. This run is scheduled from the 26th of October to 3rd of December 2012. We plan to use the final K12 Hadron beam at lower intensities with the following detectors:

- CEDAR: Detector will be installed. 30-50% equipped with photo detectors and readout;
- GTK: will not participate in TR;
- CHANTI: participation with a prototype detector;
- LAV: expect eight modules installed. Readout of three modules;
- STRAW: expect one module (one module = 1/2 chamber) equipped with readout;
- RICH: will not participate in TR;
- CHOD: use existing NA48 CHOD with readout from LAV or RICH;
- IRC: possibility to install the detector in non-final position. Only provisional read-out;
- LKR: SLM readout for 40% of the calorimeter. Possibility to use CREAM prototype (depends on CAEN delivery schedule);
- MUV: Install MUV3 and MUV2. Expect partial readout;
- SAC: plan to install the detector. Only provisional readout;
- The vacuum tank will be closed after STRAW 1 with a temporary beam pipe connection up to LKR.

Compared to our plans 12 months ago, we had to reduce the expectations, in particular, for the STRAWs (due to delays in the construction) and for the MUV, where we preferred to slow down the construction of MUV1 to have more time to install and equip MUV2 and 3.

4 Beam Line and Infrastructure

4.1 Civil Engineering and New Beam Dump

A very significant achievement during the last 12 months was the completion of the new beam dump in February this year. The civil engineering work consisted of excavating behind the downstream end of ECN3, so that the cavern could be lengthened by a 10 m long tunnel and a 2.8 m long beam dump (see Fig. 2). A particular difficulty was the passage of the liquid N_2 supply line (unique supply for the LKr) in the sector that had to be excavated. In order to prevent any damage the civil engineering group has installed a custom-made support structure to sustain the pipeline while the surrounding earth was removed. At the moment of backfilling and compressing the soil a small movement in the adjacent walls of the surface building (B918) was observed. According to a first analysis this movement is caused by the pressure caused by the soil. To relieve the pressure on the wall, a part of the accumulated earth was removed behind the building. The investigations are still ongoing, but CERNs civil engineering group is optimistic that no important damage happened to the structure of the building.

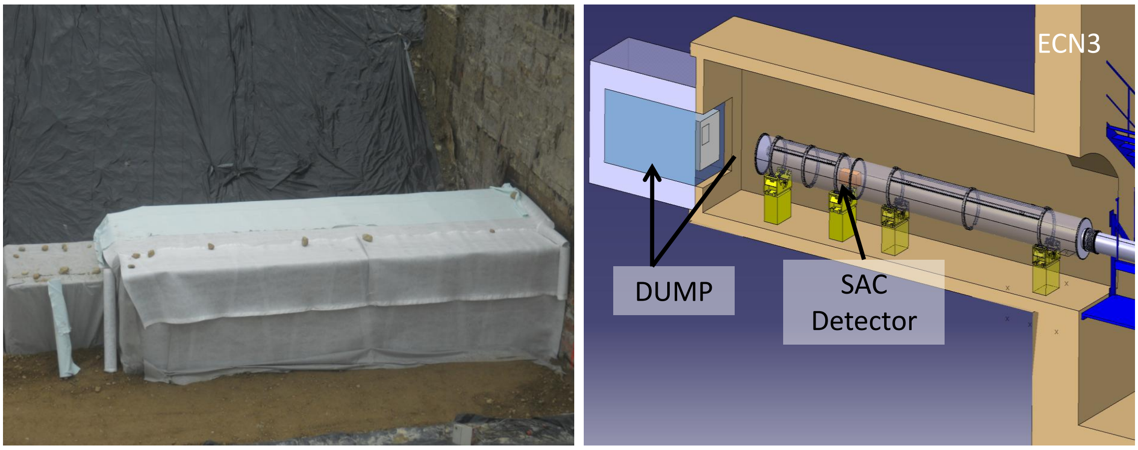


Figure 2: New tunnel and beam dump from outside (left) and in the 3D model (right)

5 Beam Line

The design work on the future K12 beam line is completed, and the parts are in the stage of fabrication or already available. For example the delivery of the TAX blocks is expected for June and some specific beam tube parts are under fabrication at CERN. The installation work started in autumn last year, but was interrupted during the shutdown due to crane problems in TCC8 and due to competing work on the LHC and the injectors. End of March we foresee to install the MBPL bending magnet situated after the muon detectors (MUV). The installation work in TCC8 will continue beginning of May, and is expected to finish by summer. A critical item for the completion is the new cooling plant for the T10 target. The design work of the plant is completed and an adequate location has been found (PPX gallery towards B912). EN/CV expects to sign the installation contract end of March, and the firm should complete the installation in August 2012.

6 Vacuum System

In February this year the tender for the future vacuum system was sent to the firms selected in the Market Survey. It is expected that CERN can place the order in April. The future contractor shall then provide and install three cryo pumps by August 2012. A first test of a cryo pump (on loan from one of the potential bidders) has been done successfully by pumping on three consecutive vacuum tanks. Using an existing LAV detector prototype, it was demonstrated that the cryo pump has no negative temperature influence on the neighbouring LAV detectors. In the next couple of weeks the vacuum tests will continue on the 70 m long vacuum tank section already installed in TCC8.

7 Installation Work and Schedule

During the last 12 months the collaboration and the technical staff from CERN have worked under high pressure on the preparation for the new experiment and its environment. Under the following four headings we report the main achievements and problems.

7.1 Infrastructure

The electrical installation in the surface and underground areas have been completely revised and are being consolidated at the moment. The installation work is progressing well and is expected to finish by end of March. The design of a new HVAC system for TCC8 and ECN3 taking into account the requirements from safety protection has made progress. However, the work load of EN/CV does not allow to have this system installed before December 2013.

During the recent installation work we have suffered from several breakdowns of both cranes in the underground areas TCC8 and ECN3. As the cranes are quite old one cannot exclude that these problems re-occur in the forthcoming months when they will be very heavily used. In the longer term, a full refurbishment of both cranes is crucial and has been requested to start after the TR.

7.2 Services

The electronic racks (for the detector readout) and the connecting cable trays have been positioned and installed. The cable and fibre network for readout and detector control system (DCS) have been defined and the installation is ongoing. The clock, DAQ and network fibres will be blown in April. The long distances cables for DCS will be installed between April and June. The electronic crates for the technical run were ordered and are expected for April, the detector cabling will start thereafter.

7.3 Surface Building (B918)

The surface building is still under refurbishment (electrical system, HVAC, painting), and the work progress is in line with our schedule. The equipment installation has started in the PC Farm room where standard air cooled electronic racks and network equipment have been installed. The water cooled PC farm racks have been ordered and the delivery is expected for May. We anticipate to use the PC farm room, the gas area and the control room as of June 2012.

7.4 Detector Installation

The detector installation is progressing well and on time with respect to our schedule (Fig. 3). Beginning of this year we have successfully installed nine vacuum tank elements and five LAV detectors in TCC8 (60 m long section) as shown in Fig. 4.

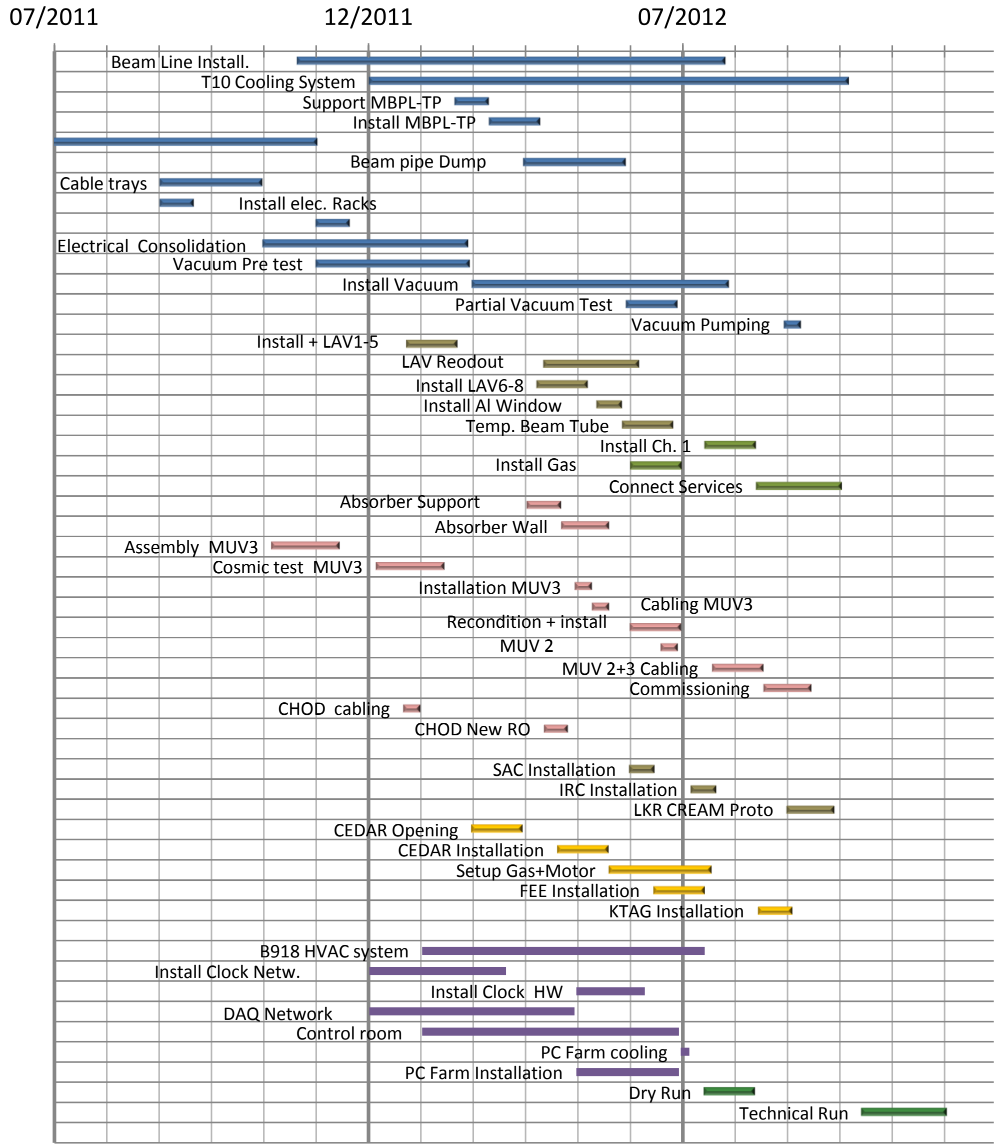


Figure 3: NA62 installation schedule.

It is interesting to note that we have changed - compared to NA48- the anchoring scheme of the tank. The vacuum tanks, the LAVs, the Straw Chambers and the RICH form a solid mechanical assembly with a total length of 132 m. They will be anchored in a single point in front of STRAW 1, all other parts can slide (on the floor) or flex to compensate small movements caused by the vacuum forces or temperature expansions.

The NA48 CHOD has been re-conditioned and re-cabled to the new electronic rack. For the readout either the RICH or the LAV frontend electronics can be used. We are presently preparing the installation of the MUV planned for April and May. The installation programme remains very tight, and is limited to a large extent by the manpower available at CERN.

Figure 4: Installed vacuum tanks and LAV detectors in TCC8.

8 KTAG (Upgrade of the original CEDAR)

The KTAG is the setup to be added to the existing CEDAR in order to operate at the NA62 rates (approx. 50 MHz of kaon tagging). The KTAG includes upgraded optics, photo-detectors, associated mechanics and electronics. Since the last report, the object CEDAR-West01 has been identified as the CEDAR to be used in NA62. During the past 12 months the design of KTAG (Fig. 5) has been finalised following extensive simulation of the light paths of photons produced in the Cerenkov gas and modelling of the optics to produce uniform illumination of the array of photomultipliers (PMs). Cerenkov light passing through each of the 8 quartz windows, fitted with a lens cap, is refocused onto a spherical mirror and reflected radially outwards onto a lightguide to channel the light onto the active surfaces of the PMs. Nitrogen is flushed through the inner chamber, in which the mirrors and lenses are situated, and flows outwards to give an inert atmosphere surrounding the lightguides and electronics. An insulating, light-tight, Faraday cage [not shown] surrounds the detector and active temperature regulation minimises any heat transfer to the gaseous radiator.

In order to ensure optimal K^+ tagging efficiency of the detector with the hydrogen radiator, the number of PMs has been increased from 32 to 64 per octant and this will improve the K^+ time-stamp resolution and hence reduce background in associating the daughter π^+ with the K^+. The design of the lightguide is key to ensuring maximum light collection efficiency and cones with highly reflective surfaces have been cut into a spherical shell such that all conical axes point back to the virtual source of light. This

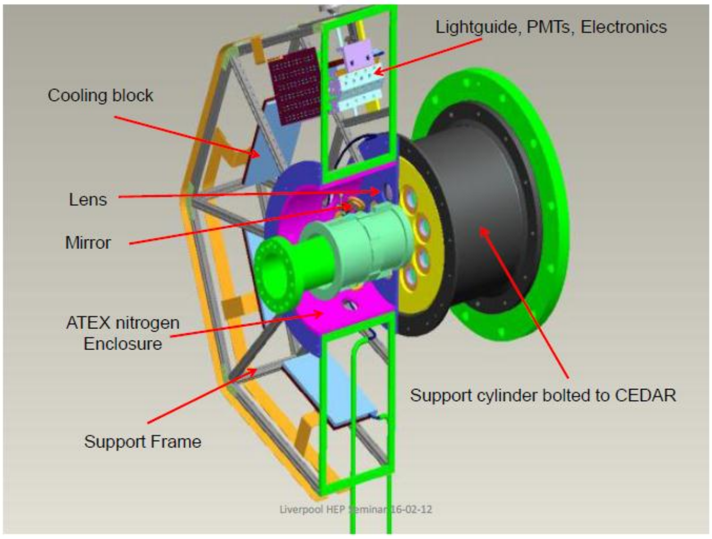


Figure 5: KTAG design model.

technique was successfully prototyped (Fig. 6) during the October 2011 test run, which demonstrated the operation of the CEDAR (using a nitrogen radiator) with both the original PMs and the new PMs and readout electronics.

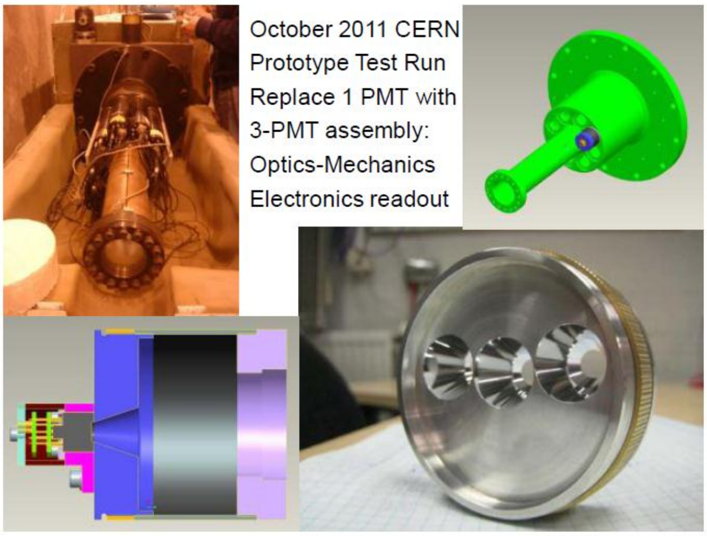


Figure 6: Prototype lightguide and other elements.

Fabrication of detector parts is on schedule to construct one half of the detector in readiness for the TR in October 2012. The support cylinder, off which KTAG will be cantilevered, has been delivered to CERN ready to be bolted onto the CEDAR flange, and a second is mounted on a support frame in Liverpool to accept the detector framework during the coming weeks. The nitrogen enclosure is awaiting fabrication and the cooling plates and chiller are being designed. Work is nearing completion on the integration of the electronics and cabling with the mechanics support, and detailed design has commenced of the "drawer mechanism" to enable the entire sub-unit of an octant to be withdrawn speedily for servicing or repair. Lenses have been purchased and highly-reflecting spherical mirrors are being prepared at CERN. Insulation material for the environmental chamber has been selected to be compliant with CERN flammable safety standards and an installation scenario for KTAG has been agreed with the NA62 Technical Coordinator. In October 2011 a test beam was performed at CERN with several objectives. The first task was to become familiar with the operation of the actual CEDAR to be used in NA62 and confirm its suitability. Then, detailed measurements were made of new hardware and electronics designed for NA62. The test was organized into three phases. First, the CEDAR detector was installed with its original PMs and readout system. Once all the alignment procedures had been carried out, PM efficiencies were measured and a Pressure Scan was performed so that the resolution of the detector could be observed. Next, the new front end and readout electronics were installed and independent measurements of the same PMs were made. Finally, one of the original PMs was replaced with the new technology chosen for NA62 and further investigations were carried out, including measurements of time distributions for the PM response. The test was very successful and the new PM and readout electronics were validated. However, the performances of the preamplifier proved to be sub-optimal, due to the necessity of using rad-hard components. After the test beam, and following discussions with the designer of the NINO chip and after checking that the NINO board is already rad-hard (at least for the fluxes foreseen in NA62), the decision was taken to eliminate the preamplifier board and use a custom PM socket plus a differential connection to readout the PM directly with the NINO chip. Such solution has been successfully tested in laboratory and will be employed in the Test Run in 2012. Further tests have been performed in the laboratory to establish the maximum affordable readout rate, under realistic conditions such as random kaon arrival time. Even if the losses due to the limited size of the TDC buffers are not negligible in general, the configuration with 64 PMs will allow to achieve the required $\geq$95% efficiency. Still, more tests are currently under way, running TEL62 with 80MHz clock rather than 40MHz clock, and with a different distribution of signals over the board, in order to enlarge the safety margin during running times. Finally, the replacement of the motor controls (hardware and software) has been taken under the UK responsibility and work has started to identify the correct controls and mode of operations. The routine operations will be controlled as part of the experiment's DCS system. The plan for 2012 is to participate in the TR with 4 octants equipped with 32 PMs each, with the KTAG system as described above, new readout electronics and new motor control systems. In addition, we plan to test as soon as possible the single-event-upset rate for the TEL62 in a muon beam.

9 Gigatracker (GTK)

We present a brief status report on the following items: 1) Sensor production and bump-bonding; 2) Front-end cooling ; 3) ASIC development, GTK carrier and power supplies, 4) Mechanical integration, 5) "Off-detector" readout electronics. We focus mainly on the progres made during the last six months and on the expected developments in 2012.

9.1 Sensor production and bump-bonding

- For completeness, we recall that the production of p-in-n sensor wafers, which are considered the base solution, has been completed in 2010 at FBK (Trento, Italy). The bump-bonded prototype assemblies were successfully tested in the lab and in a dedicated test-beam. For sake of completeness, the results have been discussed in the previous SPSC review and based on those we chose the base front-end solution.

- However, we want to pursue also the n-in-p configuration, for which the front-end is fully compatible.The production of n-in-p wafers based on the existing layout has been started in 2011 at FBK. Different combinations of p-stop and p-spray insulations have been implemented in the production batch, in order to investigate the best solution for high-voltage stability. A standard electrical characterization has been done on sample structures (diodes, test pixel matrices) and irradiation following the expected NA62 run scenario is planned for the beginning of March 2012 at the Louvain-la-Neuve Cyclotron. Post-irradiation characterization and annealing will follow at CERN. Bump-bonding to prototype read-out chips and testing for a complete assembly characterization will be carried out in the following months.

- The existing p-in-n bump-bonded assemblies have been tested up to 400-500 V bias voltage in the laboratory test setup: a further increase on individual assemblies in the test-beam lead to a non-functioning of the chip. Visual inspections indicate that the most likely cause is a discharge that occurred between the sensor and the chip due to the high electric field. A new set of bump-bonded assemblies has been ordered to IZM (Berlin, Germany) that includes the deposition of an insulating layer (Benzocyclobutene or BCB) on the read-out chips, in the regions facing the sensor edges, to increase the stability at higher bias voltage. In addition to that, some samples have been treated with an under-fill material between the sensor and the chips. Characterization of these samples is ongoing.

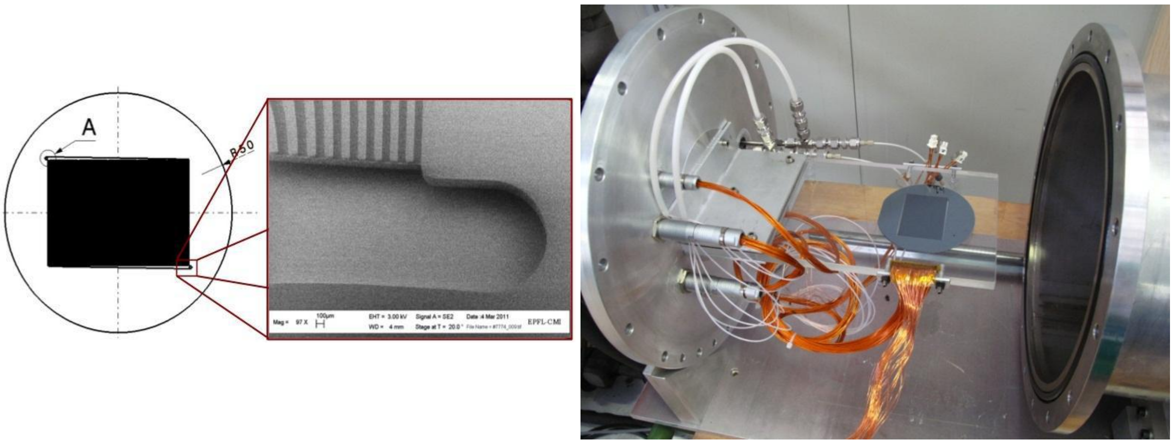
- Bump-bonding of 100 μm thin chips to full-size sensors has to be demonstrated. Since the final GTK read-out chip (0.13 μm CMOS IBM processing) will not be available before the second half of 2012, feasibility studies have been started using dummy wafers. Processing of 10 dummy sensor wafers (200 μm thick) has been completed in 2011 at FBK. A basic layout of the final read-out chip (approximate overall dimensions, top metal and passivation of pixels and bonding pads) was made available as gds file from the GTK electronics designers to IZM, that used it to produce dummy read-out chip wafers. The complete sequence of processing steps (thinning of read-out chip wafers and bonding to the full-size sensors) has been tested by IZM on those dummy components, in a synergy work with the ALICE silicon tracker upgrade programme. Delivery of the first samples is expected for March 2012.

- Irradiation of prototype bump-bonded assemblies will be performed this year. The modification of the read-out PCB to insert a removable daughter card housing the assembly has been completed. This characterization will be crucial to study sensor and chip behaviour at different fluences: time resolution and efficiency degradation, plus system stability up to the maximum fluence.

- A "Call for Tender" for the final assembly production (i.e. large sensor bump-bonded to 10 thinned readout chips) will be launched this year, after the definition of a detailed process description and process development steps. Production of sensor wafers in sufficient amount for the complete NA62 experiment lifetime (in the order of 40 wafers, but strongly dependent on the bump-bonding yield) will be launched as well.

9.2 Micro-channel Cooling

In December 2011 we have chosen the micro-channel technique as the baseline solution for the front-end cooling. Prototypes of the GTK cooling device, produced in the Micro-Technology Center of EPFL have been submitted to testing in realistic operational conditions at CERN. The layout of the experimental tests device is the single inlet single outlet configuration with holes at one corner of the manifolds (Fig. 7 a). The test setup (Fig. 7 b) consists of a vacuum vessel, a vacuum pump, a hydraulic circuit providing the C_6 F_{14} at controlled temperature and mass flow and a series of monitoring sensors for pressure, mass flow rate and temperature. Hydraulic and thermal tests have been performed.



a) b)

Figure 7: a) Layout of the experimental tests device; b) Experimental cooling wafer inside the vacuum vessel.

From the hydraulic point of view, the devices have been proved to fail at a maximum pressure of 18 bars and have been submitted to long term and cycled tests up to 12 bars in vacuum without any observable deterioration, which provides a comfortable safety margin with respect to the five bars maximum operational pressure foreseen for the final device. One of the devices under test has cumulated more than one month of operation in varying conditions, including the simulation of abrupt electrics and hydraulics failures. In order to analyze the thermal performance of the produced devices, a ceramic heater simulating the power by the chips has been glued on the surface of the cooling silicon wafer (Fig. 8).

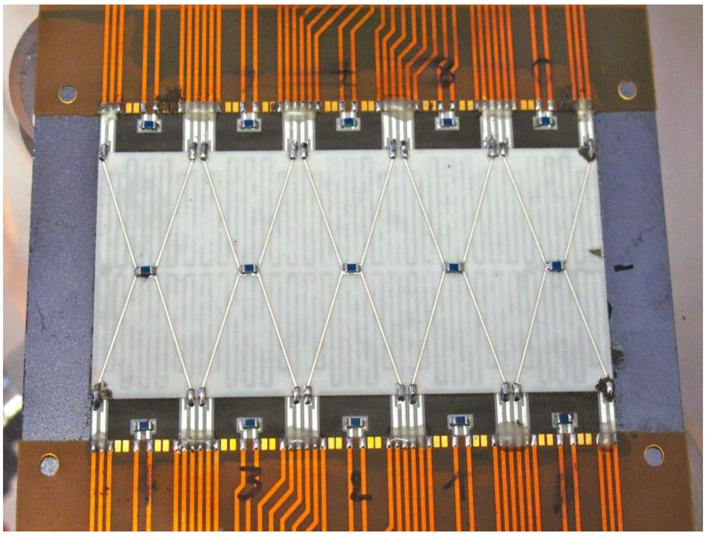


Figure 8: Prototype cooling wafer with the ceramic heater glued on top.

The ceramic mock-ups have been equipped with 20 resistive heaters, simulating the thermal behaviour of the digital and the analog part of the 10 chips, thus allowing powering independently the region simulating the bump-bond connections to the sensor, where the power density is expected to be in the range 0.51 W/cm^2, from the region simulating the digital periphery of the module, where power densities up to 4 W/cm^2 are expected. (Fig. 9 (a), (b) and (c)). The temperature distribution on the surface of the module is monitored by 15 RTD probes (Fig. 9(d)).

Fig. 10 reports a typical temperature distribution on the outer surface of the mock-up with the most pessimistic assumption for the full power distribution but only 80 % of the nominal flow rate (8 g/s instead of the expected 10 g/s), due to an intrinsic limitation of the cooling plant available at present for the test. In these tests, the fluid enters the cooling device at -20 ° C and leaves at -15 °C. For a fluid inlet temperature of about -17.5 °C, the temperature measured at the surface of Heater 2, which dissipates 1W/cm^2 is comprised between -14 °C and -13 °C. In this case, the temperature difference ΔT between the coolant and the hottest region on the surface of the heater is of the order of 4 °C. This shows the great potential of microfluidic cooling plates with respect to other cooling systems presently in use. The temperature difference ΔT increases to about 5 °C and 8.5 °C for Heater 1 and Heater 3, respectively, which both dissipate 4 W/cm^2. The temperature uniformity over the whole surface of the heaters (digital and analog part altogether) is slightly above 7 °C. This value goes down to the level of 1 °C if one considers only the area simulating the surface of the sensor.

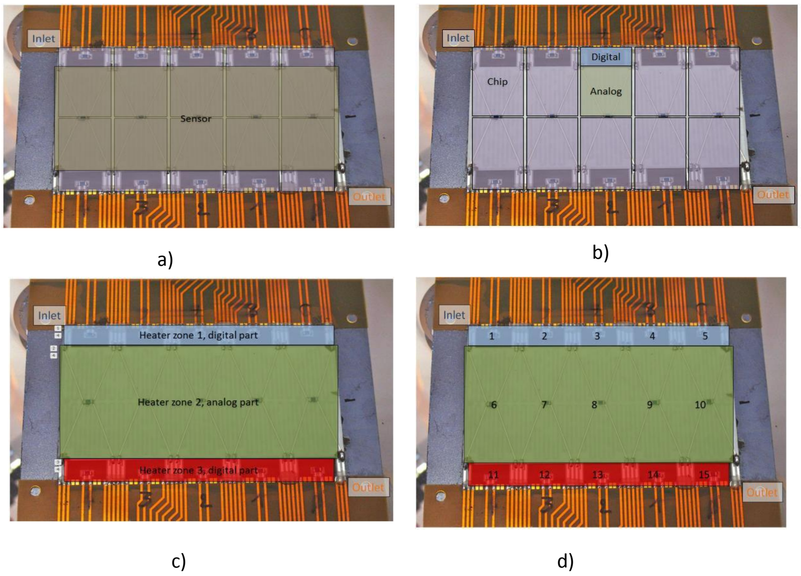


Figure 9: Ceramic heater and configuration of the thermal tests.

A new generation of silicon cooling devices is presently in production at EPFL. This will include a geometrical layout with two inlets and two outlets for a further reduction of the pressure drop and a more uniform flow distribution in the micro-channels, and a thickness of silicon reduced to the target value of 150 μm in the acceptance area. A detailed study (Fig 11) of the full set of jigs required for the assembly and integration of the GTK module and its silicon cooling plate has been performed. First prototypes of the jigs are now under production and testing.

9.3 ASIC Design

The design of the following blocks are considered terminated: Analog/digital pixel cell, inPixel configuration, transmission driver, line and receiver. The basic building block, the double column, has been laid out and DRC and LVS checks have been passed. SPICE simulations verify the functionality. Presently the needs for the power supply (traces and IO pairs) are being investigated. The *hitArbiter* circuit is finalized but needs optimisation of the interface and pin location. The DLL is finalized, the DLL state machine has been fully qualified and will be updated for final layout and interface compatibility. The TDC has been functionally verified, placed and routed. Optimisations are ongoing. The configuration scheme in the double column is terminated (functional and layout). The global controller and interface is being functionally optimized. The PLL and serializer for the digital read-out has been laid out and verification and assembly process is ongoing. The digital processing logic for the read-out has been provided and is being functionally verified. The effort is now concentrated on finalizing the building blocks, assembling the full ASIC and functional verification.

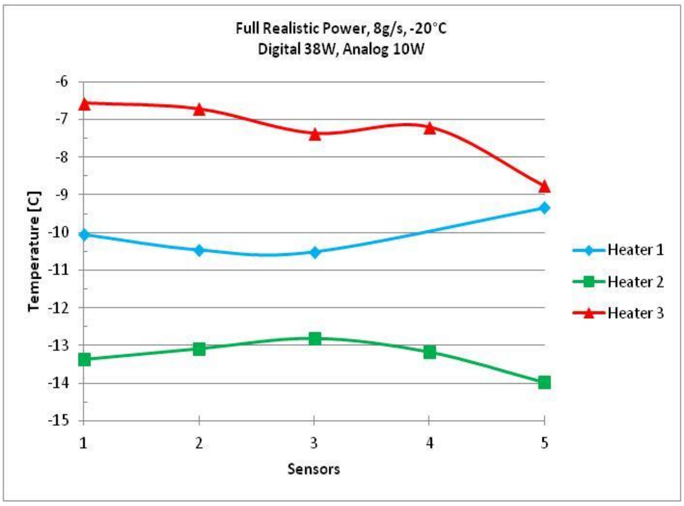


Figure 10: Example of the test device thermal performance.

9.4 GTK carrier

A complete electro-mechanical integration scheme has been worked out. Initially the collaboration pursued two cooling options in parallel. The electro-mechanical integration design allowed both cooling options to be implemented. Dummy detector assemblies were designed and produced, which included thermal loads according to the ASIC power dissipation and 15 heat sensors. These dummy assemblies enabled the cooling teams (gas cooling and micro-channel cooling) to test the performance parameters in a way permitting a direct comparison and consequently allowed the collaboration to take a decision in favour of the micro-channel cooling option. The dummy assemblies also resemble the final object in terms of mechanical dimensions, allowing detector integration studies to take place. A test board for the GTK carrier was designed to evaluate the signal transmission. The board allows loop back testing of high speed signals in realistic environments (trace width, wire bonds). It was established that the transmission of 3.2 Gbit/s signals over the required 25 cm seems feasible with the reservation that at present the test only could be conducted using commercial electrical drivers as the final components are not yet available. Investigations on optical components to transmit and receive non DC balanced optical signals for the jitter free transmission of timing reference signals were conducted. The design and production of a mechanical equivalent GTK carrier dummy card was conducted to allow the mechanical integration studies to proceed. This card has been produced and delivered to the mechanics team. A

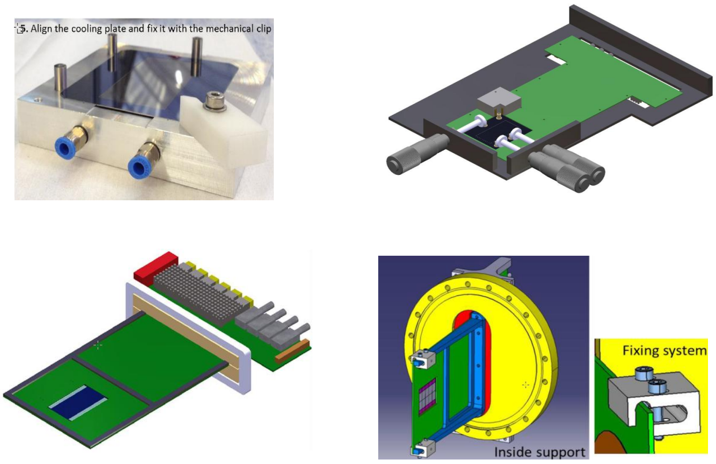


Figure 11: Assembly and integration jigs for the GTK module and micro-channel cooling plate.

sensor assembly test card was designed and produced which allows the assemblies to be connected and removed again during irradiation test.

A low voltage and high voltage distribution system has been proposed to the collaboration and accepted. The modification of existing commercial modules has been started.

9.5 Mechanical Integration

The last changes have been made to keep the same references points fixed during the bonding of the PCB on the tightness flange and after its introduction inside the Vessel. The last design with two rails fixed on the vessel to guide the PCB has been done to avoid all misalignment possibilities of the detector after installation inside the vessel . This system was replaced by a rigid frame mounted directly on the tightness flange. Two small guides near the detector allow an adjustment of the position. For the tightness between PCB and flange, a system already used on TOTEM with a bonding on both side of the flange, was chosen. The design has been finalized and in coordination with the CHANTI vessel to have the same assembly which fits GTK 1, 2 and 3. A sketch is shown both front and rear view in Fig. 12 a) and b). The next step is to test the precision of the bonding procedure. In parallel, the construction of the first vessel will start in a few days.

9.6 Off-detector Electronics

The *off-detector* electronics has the main task of receiving the data pushed by the *on-detector* GTK ASICs, save it on temporary buffers for the L0 trigger latency time, select the GTK data matching the L0 trigger request and send packets of events to the sub-detector PCs. These functions are performed by electronic modules dubbed "GTK-RO".

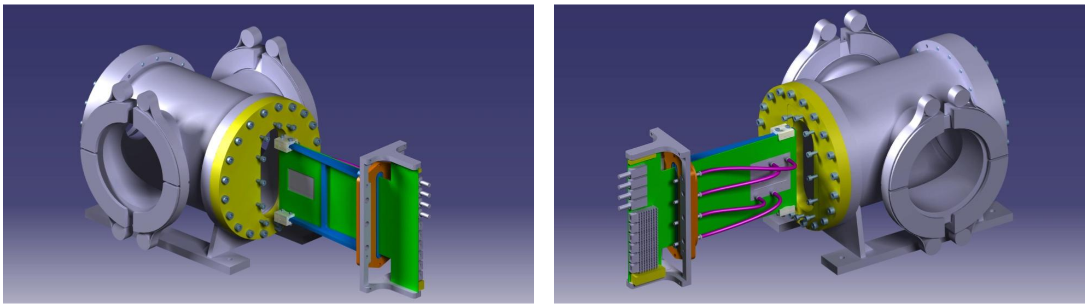


Figure 12: Sketch of a vessel: a) front view; b) rear view

The baseline design foresees that each on-detector ASIC is served by one "GTK-RO" module. The latter is in fact made of two decked units: the mother board, which is a 6U VME card hosting the main functional blocks, and a daughter card featuring the TTC interface block and various timing functions necessary to the operation of the connected ASIC. During 2011 the feasibility of the GTK-RO module has been studied by means of suitable development kits (namely the DE4 from Terasic). The first version of the GTK-RO schematic was prepared by May 2011 and, after a few reviews and interactions with the layout contractor, a final version of the schematic was submitted in September 2011. The resulting board layout has been finalized in January 2012 and the first two prototypes of the motherboard have been received on Feb 24th 2012 (Fig. 13). Most of the components needed for the final production of the GTK-RO motherboards have been procured in 2011. During 2011 progresses were also made in the development of the lower level of the software stack needed to exchange data between the GTK-RO cards and the DAQ PCs.

Concerning the hardware development, the activities foreseen for 2012 consist of:

- debugging the GTK-RO motherboard prototypes;
- determine what adjustments would eventually be needed and sign off on the production of the full lot of GTK-RO modules (35 units);
- test, by means of evaluation boards or dedicated ancillary PCBs, the functional

Figure 13: The prototype GTK-RO motherboard.

blocks to be implemented on the TTC interface / timing generator daughter cards;

- define the schematic of the GTK-RO daughter cards;
- launch daughter card prototyping and component procurement;
- learn how to operate the LTU ("Local Trigger Units") modules acquired in 2011 to generate the TTC timing signals;
- test daughter card prototypes by means of the LTU modules;
- sign off for daughter card productions.

Concerning the software development, the activities foreseen for 2012 consist of:

- debugging the custom Ethernet protocol drivers developed in 2011/2012;
- develop the programmes running on the DAQ PC to collect data from the GTK-RO cards compact it and push it forward to higher levels of the DAQ system;
- install DIM ("Data Information Management") servers on the DAQ PCs (or dedicated "slow control" PCs). A DIM server application receives commands from the "Detector Control System" (DCS) of NA62 and forwards to it the status information collected from the subdetectors;

- develop the protocol needed to exchange DCS command and configuration / status data between a "DCS interface" application running on the DAQ or a dedicated PC and the linked GTK-RO cards.

The goal for 2012 is to launch the full production of the GTK-RO modules and have all the element of the DAQ system up to the DAQ PCs properly operating with simulated GTK data stream and L1 trigger generated via software by means of the LTU module.

10 Straw Tracker

The Straw Tracker is intended to measure the momentum and the direction of charged tracks originating from kaon decays. Recent progress involves:

- The mass production of straws in Dubna including quality control is proceeding. About 2 000 straws have been already manufactured;
- Validation of the mechanical parts for module assembly (frames, straw spacers, manifolds, covers etc.);
- Completion of the straw installation in module 1, including quality control e.g., gas tightness, straw straightness and straw tension (Fig. 14);
- Procurement of the first five modules frames;
- Validation of the electrical connections (signal and high voltage distribution) to the straws using the so-called webs. The measured cross-talk between channels ($\leq 3\%$);
- The FPGA-based TDC have been integrated on the front-end board (cover) and the first tests are successful;
- The first version of the straw readout board (SRB) is tested and working.

The plans for the remainder of 2012 include:

- Testing of module 1 after the completion of the wiring and followed by the integration of the two interface parts and services;
- Design of the full SRB, mezzanine board for the TEL62 and firmware development, in order to complete the readout chain;
- Procurement of the remaining detector components and the start of the production of the remaining modules;
- Cosmic-rays tests of the 64-straw prototype using an independent tracker based on four Micromegas modules. The detector operation will also be tuned;
- Beam test (June) with the 64-straw prototype and final front-end (with FPGA as TDC on the cover). The aim is to study and tune the performance of the FPGA-based TDC read-out.
- Presence at the summer dry run in order to integrate the straw readout into the NA62 DAQ;
- Participation in the TR in the fall of 2012 with the fully equipped module 1;

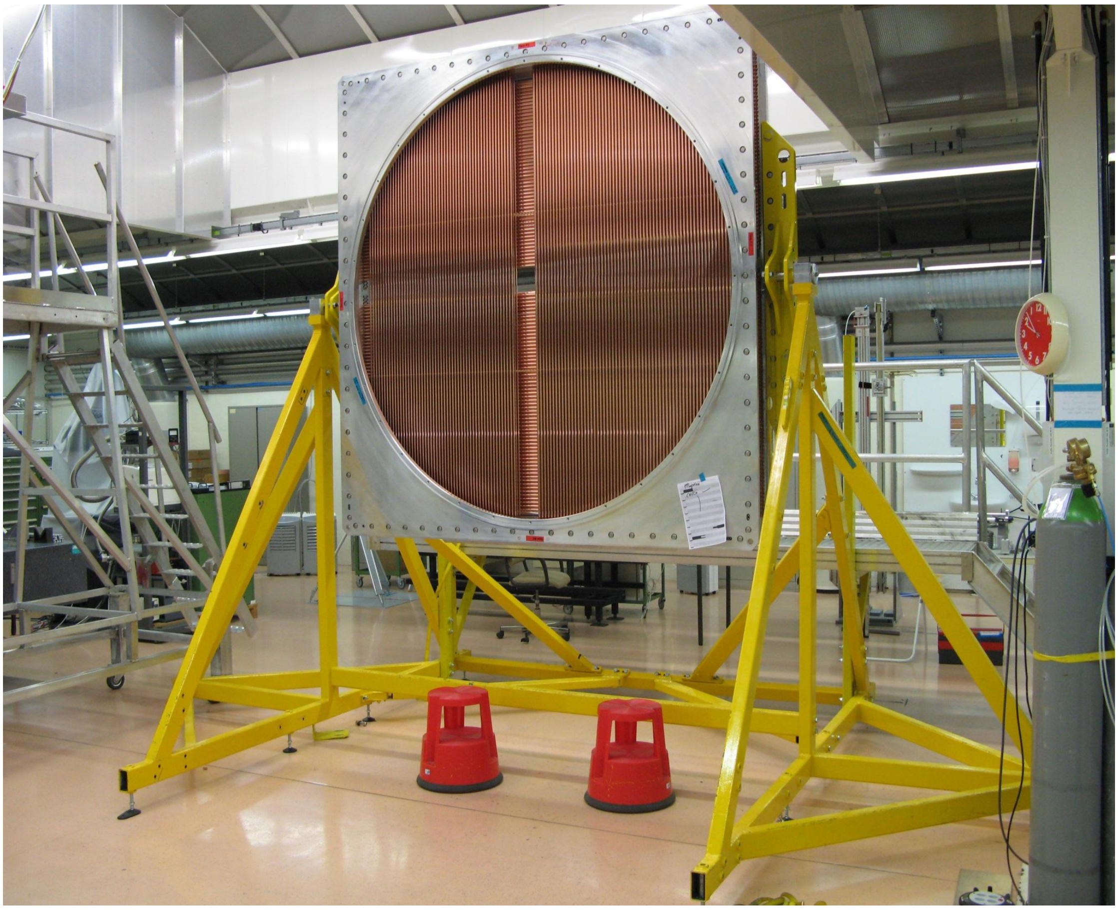


Figure 14: Completion of the straw installation after verification of straw straightness and leak tightness.

11 RICH

The RICH detector is needed to suppress the μ^+ contamination in the π^+ sample by a factor of at least 100 between 15 and 35 GeV/c momentum, to measure the pion crossing time with a resolution of about 100 ps and to produce the L0 trigger for a charged track. The detector will consist of a 17 m long tank, filled with neon gas at atmospheric pressure, with a mosaic of 20 spherical mirrors with 17 m focal length, placed at the downstream end, and 2000 photomultipliers placed at the upstream end. The RICH vessel execution drawings are in the final phase of preparation, and the tendering starts in May this year.

The RICH will consist of a vacuum proof vessel, made of construction steel, subdivided into four sections of decreasing diameter between 3.9 m (upstream end) and 3.2 m (downstream).

The vessel is expected to be installed in late spring 2013. An aluminum beam pipe will span the length of the RICH to keep undecayed beam particles in vacuum in order to avoid interactions. The dimension of the beam pipe is under study to satisfy requirements of stiffness and transparency to photons. An aluminum honeycomb panel will be placed in front of the downstream end-cap of the vessel to support the mirror mosaic; this panel, 50 mm thick and divided into two halves, was designed to be stiff enough for the 400 kg load of the mirror mosaic but at the same time as transparent as possible to photons to be seen from the downstream LKr calorimeter. The mirror mosaic (Fig. 15) will be made with 18 spherical mirrors of hexagonal shape (350 mm side) and 2 of semi-hexagonal

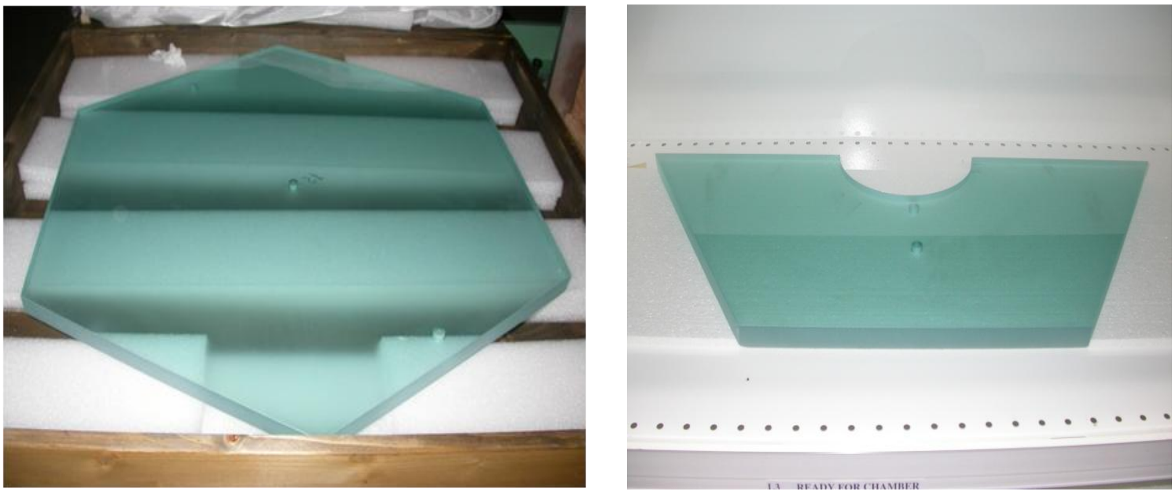


Figure 15: A hexagonal (left) and semi-hexagonal (right) RICH mirror before aluminization

shape to be put close to the beam pipe. All the mirrors are manufactured, their optical quality has been tested and they are now at CERN where they will be aluminized in the coming weeks. The mirror system installation is foreseen for summer 2013. A mirror alignment system, based on piezo-motor actuators is under development.

Pure neon gas will be injected into the vessel after vacuum has been established inside; a system of gas purification and recirculation is also considered as a backup solution. The photomultipliers will be placed onto two disks 780 mm in diameter each, closing off two cylinders protruding from a trumpet shaped flange connecting the largest section of the vessel with the upstream vacuum tank. Each disk will be made in two parts, both in aluminum: the inner part, 23 mm thick, separates neon from air by means of 12.7 mm wide, 1 mm thick quartz windows and collects the incoming light with a Winston cone; the outer part holds the photomultipliers. These disks (Fig. 16) have been machined in the mechanical workshop at the University of Firenze in the fall 2011 and are now at CERN for the gluing of the quartz windows and Mylar foils used to increase the reflectivity of each Winston cone.

About 2000 Hamamatsu R7400-U03 photomultipliers have been bought, delivered and tested; a further spare batch of 150 PMs has been ordered. PM HV-dividers will be custom made in the coming months; all the required HV power supplies have been already purchased and are available. The photomultiplier readout electronics will be

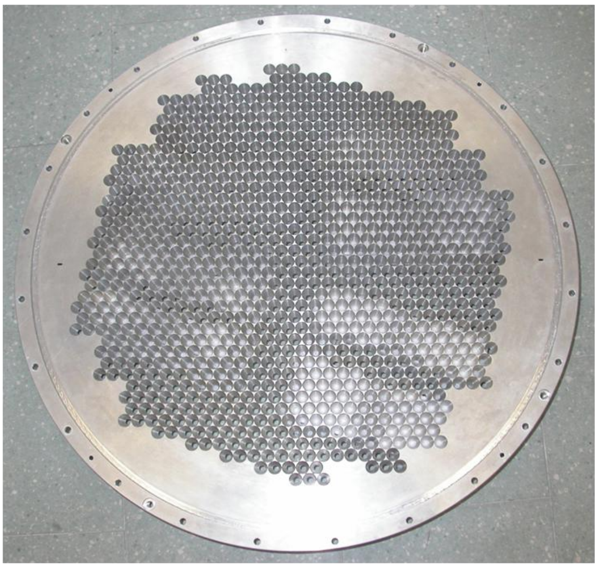


Figure 16: One of the two RICH aluminum disk separating the Neon gas from the PMs.

custom made: an executive design is under development and production will be completed by mid 2013; the readout electronics, based on the NINO ASIC, has been extensively checked in two test beam runs with a RICH prototype and a new version is needed only to provide the proper channel multiplicity required by the NA62 DAQ system.

We remind the reader that a full-length RICH prototype was built to demonstrate the feasibility of the RICH project and was tested in 2007 with 96 PMs and in 2009 with 414 PMs: the results of the 2007 and 2009 prototypes test beams have been published in [16] and [17], respectively.

12 Photon Vetoes

The Large Angle Veto (LAV) system is composed of 12 stations situated from 120 m to 240 m downstream of the target along the beamline. The first 11 stations are integrated into the vacuum decay tube, while the last station is located outside the vacuum tank. There are three sizes of LAV stations in the vacuum tube, with diameters from 2 m to 3 m. The basic building blocks of these detectors are lead-glass crystals with attached photomultipliers (PM), formerly part of the OPAL electromagnetic calorimeter. Four blocks (lead-glass crystals + PMs) are mounted on a support structure forming a segment in azimuth of a layer of the detector. These segments are assembled inside the vacuum tube to form a complete layer, or ring, of lead glass blocks. Each LAV station consists of 4 or 5 rings, which are successively staggered in azimuth, providing complete hermeticity to a depth of at least three blocks in longitudinal direction. Two small angle veto systems (IRC and SAC) together with the LKr calorimeter complete the NA62 Photon Vetoes. In the period from April 2011 through the first few months of 2012, much progress has been made on construction, electronics, and simulation. During the past year, the three LAV stations of medium diameter A6-A8 have been assembled, tested, and transported to CERN. Modifications to the design of the LAV feet have been made to incorporate gliding slabs (Permaglide) to allow for small movements (up to a few mm) due to thermal expansion and contraction after the LAVs are installed, and the modifications have been implemented on all LAVs previously produced. The LAV installation procedure was defined, the necessary equipment was manufactured, and in February this year, the first five LAV stations were installed into the vacuum line (Fig. 4). The installation went smoothly and lasted three weeks. In addition, the final drawings for the larger diameter vessels A9-A10 have been finished and the contract for their production has been assigned. The construction of these vessels by Fantini SpA will commence in spring 2012. The design of the front-end electronics has been frozen and the production started; excellent results were obtained in tests of the first boards to be produced. We have also started to write the firmware for the board controller and for the TEL62. Much progress has also been made on the simulation of the system. The representation of the geometry of the LAV detectors in the NA62 Monte Carlo has been updated and completed. In order to better understand the performance of the detector and the electronics, a detailed signal simulation and digitization procedure has also been developed. As input, this procedure obtains from GEANT4 the number of photons on the photocathode of the PM, their energies, and their arrival times. The behavior of the R2238 PM is then simulated, including such aspects as the photocathode quantum efficiency as a function of the wavelength, the multiplication process in the 12 dynodes, the output RC circuit, and the cables. The simulated signal is then processed by the simulation of the front end which, taking into account thresholds and hysteresis, produces simulated leading and trailing times for pulses, allowing the calculation of the time over threshold (ToT). To validate the simulation, the curve of ToT vs integrated PM charge has been compared with test beam data. The result is shown in Fig. 17. Very good agreement with the data is obtained over a large range in charge from a few pC to 100 pC. Using this detailed simulation, a first study of the photon detection efficiency has been performed. The results are shown in Fig. 18.

In 2011 the mechanical design of IRC has been completed by the Sofia engineers and all the material has been procured except the scintillators slabs. The plan is to complete the assembly by the TR. The front end electronics for IRC and SAC will not be ready for the TR and we are planning to use LAV front end board instead. The mechanics for SAC prototype installation is finalized, this will allow the SAC installation in the beam dump pipe using a remotely controlled table.

We plan to install A6-A8 by April 2012. By the time of the TR, eight vessels will be installed. In parallel, half of the front-end electronics will be produced, tested, and installed. The plan is to read out 3 LAV stations during the dry run and the beam period in 2012. The exact number of stations to be read out will depend on the number of TEL62s that are available. During 2012 through mid-2013, we plan to build test and install A11, A9, and A10, and to finalize the mechanical design for A12. We plan to do the commissioning of the full veto system by the end of 2013 to be ready for 2014 data taking. Finally, the MC simulation will be validated with a detailed comparison with data from test beam. Methods to assess the detector performance will be developed, in particular exploiting the closed kinematics of $K^+ \to \pi^+\pi^0$ decays. The implementation of these diagnostics will run both on data and MC events, allowing comparison. A detailed study of the expected LAV performance as a function of detector and run conditions (electronic noise, muon beam halo, dead and noisy channels, miscalibration of FEE threshold) will be performed. The front end electronics for SAC and IRC will be finalized to be ready

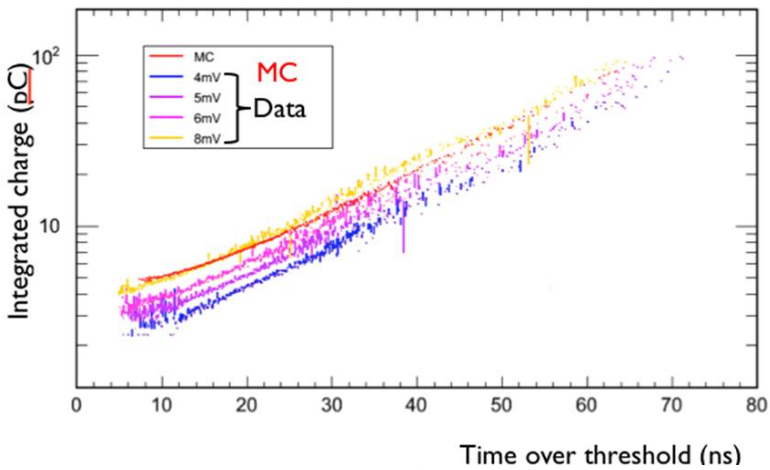


Figure 17: Data vs. Monte Carlo comparison for the Time over Threshold response as a function of input charge.

to start the construction in 2013.

13 Charged Hodoscope (CHOD)

The NA62 experimental setup comprises a fast scintillator system, called Charged Hodoscope (CHOD), to detect tracks with precise measurements of the arrival time and impact point, to provide a fast signal to drive the trigger and data acquisition (TDAQ) system and to suppress background signals when used in anti-coincidence.

The CHOD will have to cope with rates of about 11 MHz, measuring the particle arrival time with an online accuracy better than 1 ns, in order to suppress the effect of accidental events with respect to the physics signals. Fast timing capability should be provided, to complement the RICH information, identifying charged tracks both offline and online at L0 trigger. Effective vetoing of photon conversions or photonuclear interactions producing low energy hadrons in the detector material (especially in the RICH) should be possible, to complement LKr photon detection capability at low energy both offline and online, at L0 trigger. The acceptance of the detector will allow to complement MUV and RICH detectors in identifying muons at L0 trigger.

Fig. 19 shows the layout and the dimensions of the NA48 hodoscope which NA62 will employ as CHOD in 2012. The detector consists of two planes of 64 vertical (V-plane) and 64 horizontal (H-plane) plastic scintillators installed along the K12 beam line, upstream of the LKr calorimeter. The planes are centered on the beam direction with 121 cm external radius and 12.8 cm inner radius, suitable to contain the vacuum beam tube. The counters are made of BC408 plastic scintillator, 2 cm thick ($\approx$0.1 X_0), with lengths decreasing from 121 cm, closest to the beam pipe, to 60 cm and variable widths (6.5 cm for counters closest to beam line where the particle flux is higher and 9.9 cm for outer counters). Each plane consists of 4 quadrants made of 16 counters, providing a logic

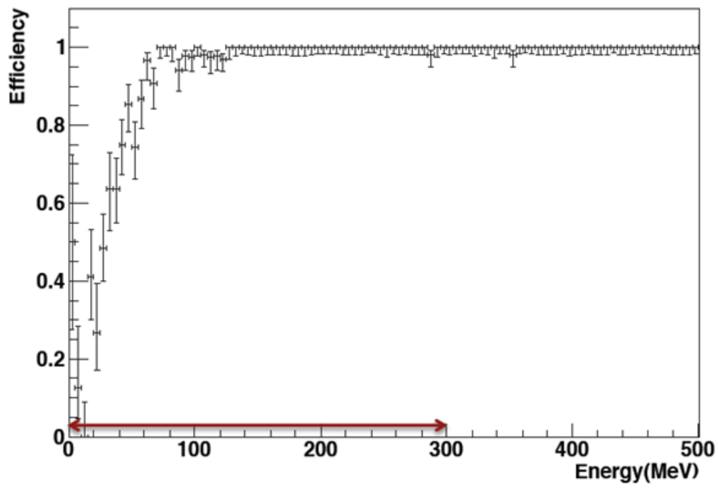


Figure 18: Photon detection efficiency of the LAV detectors obtained from the full GEANT4 simulation.

structure suitable for track triggering. Plexiglass light guides with fishtail shape, 20 cm long, drive the scintillation light from one side of each counter to Philips photomultipliers (PM) type XP2262B (now produced by Photonis - ET Enterprises Ltd.).

In NA48 the CHOD online time resolution was about 4 ns, limited by the counter dimensions and by the fact that the scintillation light is read from one side only. This value is reduced to 200 ps per counter, after correcting offline for slewing and impact point effects. The event time resolution, depending on the number of hit counters (at least 2 per track), has a time resolution better than 200 ps. The track detection inefficiency, mainly due to geometrical gaps in the coincidence of the 2 planes, which were slightly displaced to reduce this effect, was kept at the 10^{-3} level. The mechanical supports holding the two hodoscope planes ensure good accuracy on the transverse coordinate adjustment: a precision of 1 mm in x and y and on the relative alignment of the 2 planes is provided via screws at the support feet, driven by trigger efficiency requirements.

The above performance, typical of the CHOD in the NA48 experiment, should be strongly improved in NA62. This will be achieved by exploiting the features of the new NA62 TDAQ system, which allows to correct the track time at the online stage on Field Programmable Gate Arrays (FPGA) integrated within the TEL62.

In 2012 the CHOD PMs will be individually powered at negative voltages of $\leq$ 2000 V. The HV system bought to power the RICH detector PMs will be available in 2012, since the RICH will not be present at that time. This HV system fulfills the CHOD requirements: negative polarity; up to 3.5 kV output voltage; 3 mA current full scale, with 500 nA resolution; 500 mV Voltage Set/Monitor resolution; SHV coaxial connectors. Hence, the CHOD HV system in 2012 will consist of 2 CAEN SY1527 main frames (16 slots), each one powering one the two CHOD planes, and 8 CAEN 24-channels A1535S boards, 4 per frame, each one powering one of the eight CHOD quadrants (only 16 channels per module will be used). This system has already been installed in the ECN3 experimental area, close to the detector.

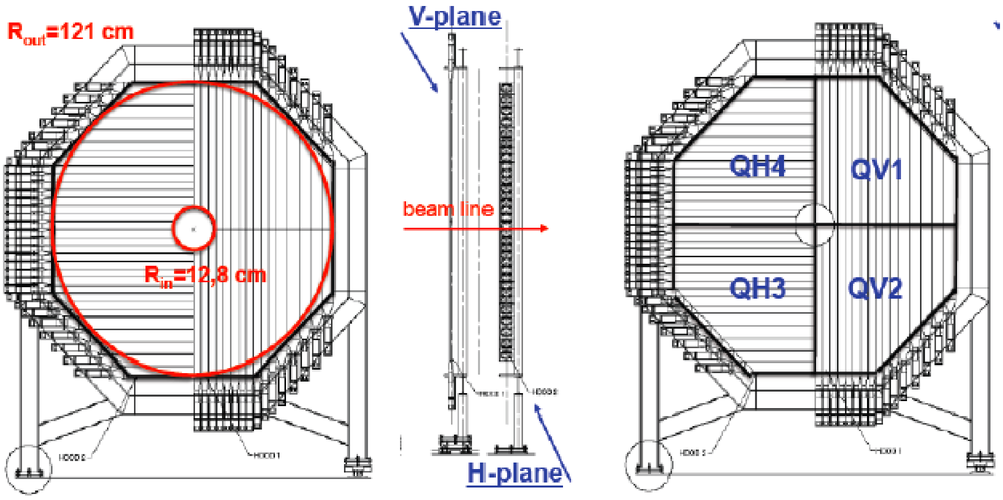


Figure 19: The NA62 CHOD in 2012: the sections of two half planes, one with horizontal counters (H-plane) and the other with vertical counters (V-plane) are shown. From left to right: design and dimensions, position along the beam, logical structure and quadrant division of the two planes.

The front-end electronics (FEE) developed in NA62 for the LAV, consisting of ToT discriminators with double threshold setting availability, is suitable for the CHOD. In 2012, 4 LAV FEE modules are needed for the CHOD. One TEL62 board with two TDCB, available from the RICH electronics, will house the whole CHOD signals. In principle, a single TDCB (128 channels) could house the whole CHOD. However, the double threshold feature of the LAV FEE requires the use of two TDCB, since two output signals (one per threshold) are provided per each analogue input signal. Hence, 256 signals will feed the TEL62 module and each TDCB will treat the signals of one hodoscope plane.

A track signal recorded in the CHOD in 2012 will be given by the coincidence between 1 vertical and 1 horizontal counter in two consecutive quadrants. Up to [(16x16)x4]=1024 sub-coincidences of the 2 CHOD planes can be built in this way. The firmware of this Pretrigger Logic will be implemented within the TEL62 FPGA and used to select one or more tracks at the L0 trigger. The sub-coincidence signal will also define the position of the track impinging the hodoscope and will allow to correct the CHOD hit time taking into account the impact point on the detector. This correction will be implemented online, within the FPGA of the TEL62. The use of ToT discriminators will allow a rough online correction of the time of small signals due to slewing effect.

The major limitation to the use of the NA48 CHOD in the NA62 experiment is given by the particle rate. In fact, the counter dimensions are not optimized to be used in NA62 being too large, in particular in the regions near to the beam line where the rate in each counter will be too high to be handled by the new NA62 TDAQ electronics. However, the experience gained during the 2012 runs will be very important to study an optimal detector layout in view of the NA62 physics runs. As alternative, the use of a NINO front end is being considered.

14 Liquid Krypton Calorimeter (LKr)

14.1 LKr readout for 2012

We reported in the past the ongoing activities to restart the old NA48 readout system for the 2012 run. The production of the refurbished power supplies has been completed and 11 units were delivered to CERN. Ten of them have been installed in the experiment: as the other old power supplies are either broken or unreliable, we decided to equip with the new power supplies about 5000 channels in the central part of the calorimeter. The ten power supplies were not fully tested, due to the lack of cooling water, and we plan to complete their commissioning during March 2012. At the same time, we need to rewire the Fastbus readout chain and to check and mend individual channels. The firmware to use the TALK board as an interface between the old and the new trigger system has been completed (Fig. 20) and the plan is to test it at the experiment during the spring. Also the software interface between the LKr readout PCs and the L1/L2 PC farm has been defined and it will be implemented in time.

Figure 20: The NA62 TALK board.

14.2 New LKr readout

The tender for the CREAM modules has been assigned in September 2012 to CAEN Spa. Since then, several iterations of discussion have taken place to define the details of the boards. The design of the input analog shaper has been analyzed in detail and

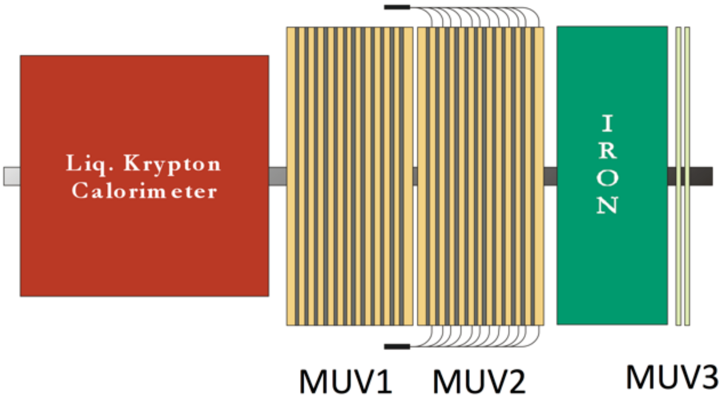


Figure 21: General set-up of the three muon veto detectors MUV1, MUV2, and MUV3.

a one-channel prototype on a breadboard has been mounted and tested. The measured noise of this channel is around 1.34 LSB rms and the number of effective bits in the ADC measurement is 10.5, as it was specified in the tender document. The type of FPGA has been defined. On the firmware side, discussions focused on the network protocols needed to request and transfer the data as well as on the performance of the different technical solutions. It is still expected to have the first prototypes by beginning of July 2012, to be thoroughly tested at CERN and to have the production done during 2013, to complete the installation by the end of the year. In parallel, the design of the board distributing clock and L0 trigger information is being developed at CERN. An early purchase of the required crates is under way, while the network equipment will be bought at a later stage.

14.3 Cryogenics and vacuum

In the previous report we outline the need to replace the guillotine valve at the exit of the calorimeter, valve needed to keep the vacuum inside the LKr internal tube when the other parts of the beam pipe are removed. This operation has been performed with all the necessary care, with the installation of a commercial pneumatic valve.

15 Muon Veto (MUV)

The Muon Veto (MUV) is essential to suppress kaon decays with muons in the final state. It consists of three independent subsequent modules, called MUV1, MUV2, and MUV3 in the order of their longitudinal position (Fig. 15). While MUV1 and MUV2 are iron scintillator sandwich calorimeters, the MUV3 detector consists of thick scintillator tiles for fast and efficient muon detection on the hardware trigger level.

All MUV detectors will use the same CAEN HV system as the LAV detectors. The HV modules have been ordered in 2011 and will be available for the 2012 TR. MUV1 and MUV2 have similar requirements as the LAV detector and therefore will make use of the LAV FE electronics. The MUV3 detector does not need to provide pulse height, but only timing information, and will therefore reuse the NA48 AKL anti-counter electronics.

15.1 MUV1

The MUV1 module is made of 25 iron and 24 scintillating layers with in total almost 1100 scintillating strips. The strips are read-out with WLS fibres on both ends. For the production of the MUV1 scintillators, the Protvino group has developed a new technique by melting polystyrene granulate together with the scintillating additives in vacuum at high temperature. This method allows the production of 270 cm long strips, needed for the MUV1, but avoids the usual time and manpower consuming procedure of extruding strips from large blocks. After several performance tests and improvements of the production procedure in 2011, the mass production for the MUV1 scintillators has started and is being completed at the moment.

All necessary tools for the construction of the MUV1 module have been developed. The construction is being done at Mainz University and is planned to be finished in 2012. Because of the short time scale, the MUV1 will not participate in the 2012 TR.

In addition, a full MUV1 Monte Carlo simulation has been implemented in 2011. One important outcome of the simulation is an expected additional muon suppression factor of 5-10 by measuring the shower shapes in the MUV1 detector.

15.2 MUV2

Since the MUV2 is a former NA48 hadron calorimeter module, only the PMs need to be tested for operation in NA62. The tests have been performed in Mainz at the end of 2011. Practically no degradation was seen with respect to the initial calibration in 1994. The MUV2 will take part in the 2012 TR.

15.3 MUV3

The fast muon veto detector (MUV3) has been constructed in 2011. It consists of scintillating tiles of 22x22 cm^2 cross-section and 5 cm thickness, which have been produced at IHEP, Protvino, in 2011. On the backside, each tile will be simultaneously read-out by two PMs, which suppresses possible erroneous signals from Cherenkov radiation of particles crossing the PM windows. The frame has been produced by the Pisa group and was assembled at CERN in fall 2011. The whole detector is currently being installed in the beam-line. For the read-out, the MUV3 reuses both the PMs and the front-end electronics of the NA48 AKL detector. The PMs have been tested in Mainz together with the MUV2 PMs and found to be in very good condition. Also the MUV3 will take part in the 2012 TR.

16 Trigger and DAQ

As expected, the activities in the TDAQ working group increased during last year. A focus to such activities was provided by scheduling a "dry run" at CERN as a first TDAQ-specific integration test. Such run will start on July 15th, 2012 and last for three weeks: no beam will be present, but it is expected that the whole basic infrastructure will be available, including the distribution of experiment clock and (fake) SPS timing signals, networking for control and data acquisition and a minimal run control system. The goal of the run is to integrate most of the prototype elements (including some of the final modules) of the entire TDAQ system, to test its features and implementation, discover potential issues, and - last but not least - arrange a working data-taking system to be used during the subsequent test run with sub-detectors and beam later in the year. For this reason all sub-detectors participating to the TR must already have their DAQ systems installed and tested during the dry run. The data acquisition approach for most of the sub-detectors is now rather well defined:

- The Ferrara group is designing a dedicated readout system for the Gigatracker, closely linked to the integrated detector electronics; no integration of this system is expected in 2012; details are discussed in the Gigatracker report.
- The CERN group is designing a dedicated readout system for the LKr electromagnetic calorimeter (CREAM), which is also not expected in 2012; details are discussed in the LKr report. Nevertheless, the LKr is expected to be readout in 2012 using the existing NA48 system, for which an interface board (TALK) was designed and built.
- The Straw group took the decision to go on with the development of a dedicated DAQ system. Some prototypes of part of the straw DAQ system might be available during the runs of 2012.
- All remaining sub-detectors are expected to be readout using the common system under development in Pisa since some years, based on newly designed high-performance TDC daughter-cards and generic data acquisition and trigger motherboards TEL62.

After a long prototyping phase, TDC cards were produced in a limited number and distributed to sub-detectors in fall 2011 for validation; the performance of the boards was tested in the laboratory also with high rates, and their firmware is being finalized. A second small production to complete the set required for 2012 runs is being produced now. The TEL62 board is a vastly upgraded version of the LHCb TELL1 board; a first prototype was built in summer 2011 and thoroughly tested in the laboratory with success. A limited batch of 15 boards to be used in the 2012 runs is presently being manufactured. A concern is related to the development of the firmware for the TEL62, a job for which contribution from each sub-detector using the system is long expected but could not be provided yet. A rather limited-capability firmware is being prepared for 2012, which should allow the testing of the basic DAQ functionality but no integrated L0 trigger generation, which is deferred to 2013. The above systems will be installed in the experimental hall and are not radiation-hard; while we do not expect radiation to be an issue in NA62, specific tests of the digital electronic boards in a muon flux comparable to the one expected by the experiment is a long-standing need, and should be performed this year by the Birmingham group. Among the sub-detectors using the common TDAQ system, at least two front-end electronic systems are well developed: one for the RICH and a newly designed one for the LAV; the latter will also be used for several other sub-detectors (at least in 2012), and boards are in production now; part of the MUV will also use a front-end derived from an existing NA48 one. The common infrastructure includes the clock and trigger distribution system, based on the LHC TTC system. The Birmingham group produced a NA62-specific version of the ALICE Local Trigger Unit: all the required modules for NA62 were produced, tested and distributed to sub-detectors. New TTCex optical clock driver modules were produced at CERN, and found to have an unexpected design error which makes them unsuitable for

NA62 (but not for 2012): enough modules are available for 2012, and CERN will replace these with redesigned ones in 2013. Optical fibres and splitters have been ordered and will be installed soon in the experimental area. Concerning the hardware L0 trigger, independent Monte Carlo studies confirmed the estimates of the expected rates. Besides TEL62, other elements involved in the L0 trigger are the LKr/L0 trigger system and the central L0 Trigger Processor (L0TP). The former system is being developed in Roma Tor Vergata and consists of 3 different daughter-cards to be installed on TEL62. Two of the three were designed and prototypes were built and tested: they are expected to be integrated into the dry run using simulated input data. The third (input) board is waiting for the finalization of the CREAM readout system which should feed it, and is expected for 2013. The L0TP is the least advanced element of the TDAQ project; while two new groups (Ferrara and Torino) started being involved in it during last year. The present scheme involves a dedicated smart network card to be implemented on a FPGA development board mounted on a PC: hardware latency tests were performed which seem to indicate the feasibility of this approach, but no development of the real-time software has happened yet. While no proper L0 trigger generation will be implemented in 2012 runs, the functionality of the L0TP will be handled by the TALK board used to interface the old LKr calorimeter readout; in this way the L0 trigger transport infrastructure can be tested. A significant amount of work was done in Mainz for the development of an integrated PC farm control software to perform event building and L1/L2 triggering. This development led to a reconsideration of the structure of the high-level trigger fabric, which might now avoid dedicated sub-detector PCs and centralize L1/L2 and event building for the same event on a single farm node. The Pisa group is contributing high-performance low-level software for the farm. The online and run control system was discussed at length and the Louvain group has started to work on it with CERN support. A prototype system will be developed, based on existing software components used by LHC experiment: only the minimal functionality required in 2012 runs will be implemented initially, but the design will be scalable to the needs of the full experiment. Detailed Monte Carlo simulation on the LKr/L0 trigger and on the L1/L2 trigger algorithms are still missing.

17 Online Computing

The computing model of the experiment has been more clearly defined, as the sub-detectors have been finalizing their readout electronics, and the details of the entire TDAQ chain have been elaborated. With respect to the very general scheme presented in the Technical Design, the layout of the online network and computing environment has been defined (Fig. 22). The main characteristics are the following:

- All the sub-detectors readout boards, mainly based on the TEL62, excluding the Liquid Krypton readout system (CREAM), will transmit data on Ethernet links, generally at 1 Gb on copper. Those links will be aggregated already in the experimental cavern by small "local" switches and 10 Gb optical fibers will route data upstairs to the NA62 computing room.

- A main switch/router with high-bandwidth and up to 96x 10 Gb ports will receive all the fibers from the readout on one side and will be connected to the online farm computers on the other. The online farm machines will then receive fragments from the sub-detector boards, upon L0 distribution from the L0 central trigger processor, and will run the L1 algorithm at the level of sub-detectors and - on the same machine - the L2 and event-building on the L1-accepted events. Intelligent routing of the data to the L1 PC's will ensure that all the fragments belonging to one event will be elaborated in a single machine.

- This new scheme with an univocal data-path from the readout boards to the PC running the L1/L2 processes allows one to use a tree structure and link-aggregation. This allows more flexibility at the level of the online farm and also leaves open the possibility of increasing the computing power for the sofware trigger levels (L1/L2).

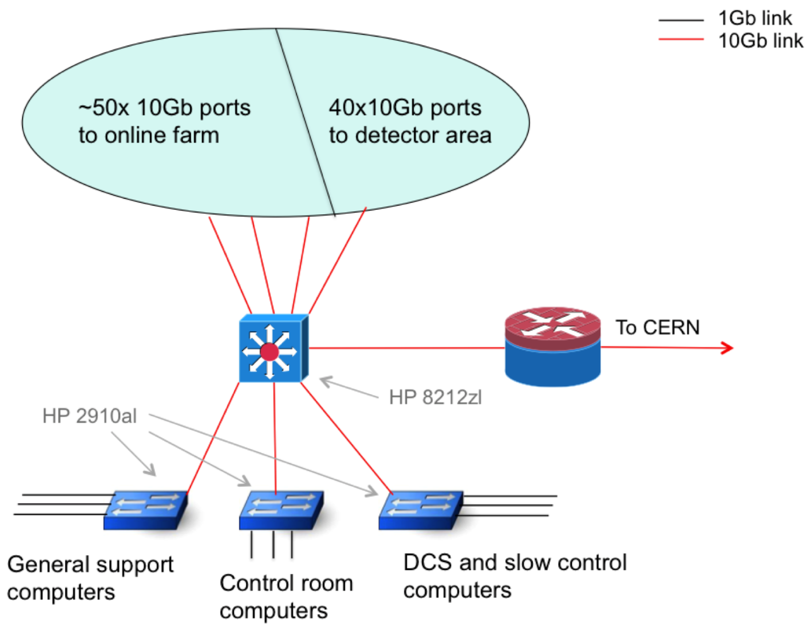


Figure 22: NA62 Online Network Model.

As the refurbishment of building 918 is being completed and the computing room equipped, the PC racks (with refrigerating doors) will be soon installed, in order to host the first network and computing hardware. The network infrastructure, including the main 10 Gb fiber-bundles from the experimental cavern to the computing room is under completion, so that the installation of the network devices, including the main central switch, will be started in the next weeks. A few high-performance PC's will be installed starting from May 2012, as a first building block of the online farm. Also a local dedicated storage will be prepared, both for hosting all the services and software for the online environment, and for the handling of the data collected during the dry and technical run in 2012.

The TR will be also an unique opportunity of testing the farm networking scheme as well as exercising the software triggers at high data-bandwitdh, possibly with different level of link aggregation.

The upgrade of the high-speed connection to the CERN technical network, to the general purpose network is also under way, in order to ensure a redundant connection to the CERN-IT main data center (essential for tape storage).

18 Detector Control System (DCS)

18.1 Definition of Users Requirements (URD)

Essential effort was made for clarification, definition and documentation of user requirements for DCS. This includes both general and individual sub-detector requirements. An example of typical sub-detector URD was prepared and uploaded to EDMS. A generic multi-channel table was designed and proposed to the users. The DCS group held two User's meetings. The requirements of a few sub-detectors were discussed on dedicated group meetings. An e-mail survey was conducted for clarification of some important questions. The definition of user requirements for the 2012 TR is close to finalization.

18.2 LAV Temperature Monitoring

The LAV temperature monitoring is one of the first DCS prototypes used for permanent temperature monitoring of LAV modules stored in ECN3. In case of abnormal temperature the monitor generates an alarm, which is distributed via a SMS system to responsible persons. The system includes many elements of the future DCS, in particular:

- Archiving of temperatures in an Oracle DB;
- Email and SMS in case of alarm;
- Daily mail reports;
- Access control;
- System Integrity (communication controls);
- Trending.

The monitor is permanently maintained and adapted to changes in the area. In January 2012 it warned about abnormal low temperature in the area. This allowed us to take appropriate measures, preventing any damage to the detectors as it occurred in similar conditions in 2010.

18.3 LKr calorimeter vertical slice

The LKr calorimeter vertical slice provides almost all functionalities of the full detector control system. It controls HV and LV power supply systems of the calorimeter. It allows validating hardware and software solution which will be used for building the final system. To minimize the effort, it was decided to keep as many old cables and patch panels as possible. The work was done in a few steps:

1. **Hardware development**

   During the first stage of the project old control hardware was replaced by modern equipment supported by CERN control community. The ELMBs are used for reading all analog values. To allow an integration of the ELMBs in an old G64 crate a custom made motherboard was developed and produced. The ELMB are powered by CAN branch power supply, which is also used for CANbus connection. Digital I/O channels are treated with a PLC. The corresponding patch panel holding the

PLC and the I/O cards was designed and integrated closest to the old control rack. The old HV power supply was replaced by modern CAEN SY2527. A two-level computer scheme is used in the application. Front-end KONTRON KISS 4U computer is located in ECN3 (electronic barrack). The back-end HP ProLiant BL460c G7 server is hosted in the CERN Control Centre (CCC) farm area. A user interface access is possible from any office PC. The hardware layout is presented in Fig. 23.

2. **Software development**

   The "LKr vertical slice" application, which forms the initial part of the complete Detector Control System for NA62 was implemented following the standard JCOP and UNICOS solutions and recommended technologies, wherever possible. Following the experience in the development of the Detector Control Systems for the LHC experiments, the JCOP Framework Finite State Machine (FSM) tool was applied to implement hierarchical control of the NA62 detector. Two models corresponding to diverging requirements needed to be developed and implemented in parallel. The parameters that define the configuration of the devices for various run types (such as voltage setpoints, alert thresholds) are now stored in the Oracle Configuration Database in form of recipes. The integration of custom legacy devices of the LKr detector was a major challenge, and was achieved by applying standardized interfacing technologies. In particular, the VME-based LKr high-voltage monitoring system was integrated with PVSS using the DIM protocol. The LKr low-voltage system (preamplifiers and transceivers) hardware required even more attention. A hybrid system based on Siemens S7 Programmable Logic Controllers (for the commanding and interlock part) and ELMB (for analog-value readout) was implemented on the hardware level, and then smoothly integrated into the "LKr vertical slice" PVSS application thank to the power of UNICOS and JCOP projects. To achieve the milestone of the complete production-ready LKr Vertical Slice application, and assure future maintenance, significant effort was put into streamlining and cleaning up the code, and packaging it into the components, following the best practices and recommendations of EN/ICE.

18.4 Plans for the next 12-18 months

The DCS group is working now on a version of control system for the 2012 TR. The system will include control of CHOD, LKr, five LAV stations, CEDAR, MUV2, MUV3, and IRC/SAC. The application will have ready all functionalities of the final system. The pre-production version will be delivered in June for extensive tests during the TDAQ dry run in summer 2012. The production version will be ready in the middle of September, about one month before the TR. After the TR the group will continue the work to integrate the remaining sub-detectors with the goal to deliver a first version of the full DCS at the end of 2013, and final version in spring of 2014.

19 Offline Software

The NA62 offline software, although still in the development stage, is already being used for trigger, background and sensitivity studies. The simulation, mostly based on Geant4, currently includes all the subdetectors with their active volumes and most of the critical

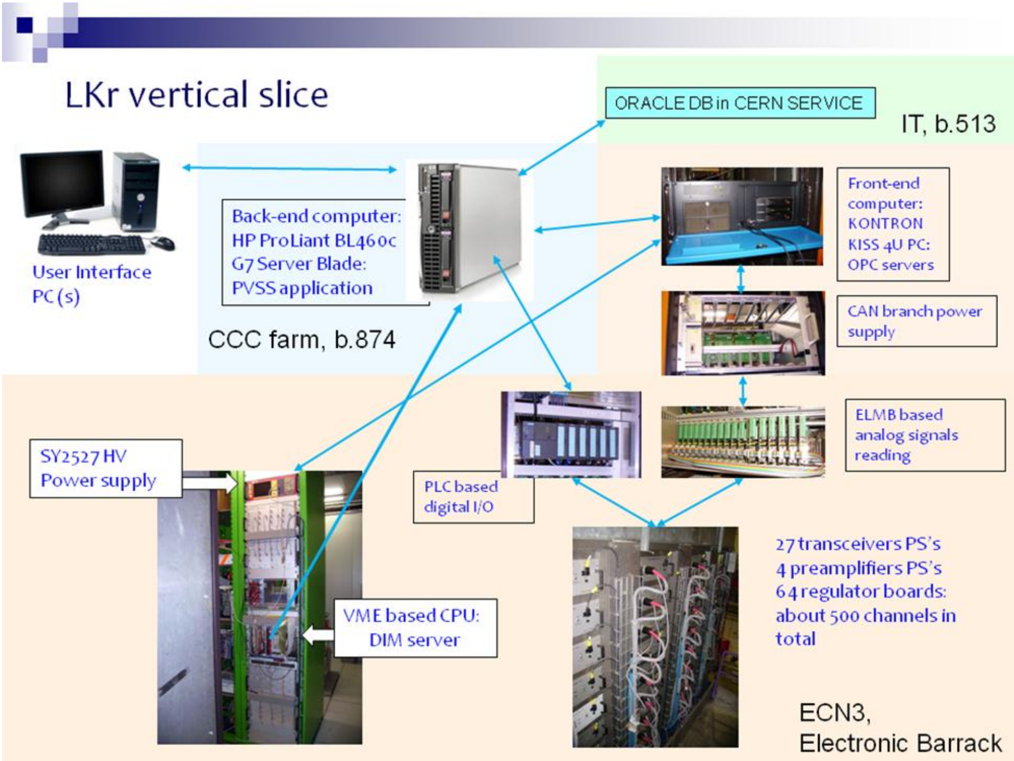


Figure 23: Hardware layout for LKr calorimeter vertical slice application

passive material. The reconstruction framework is reaching its architectural maturity, while the individual subdetector modules are being implemented. An offline database has been developed and partially tested, along with its interface to the simulation; its performance scaling shows it is a viable solution for the future. The setup and usage of GRID sites within the collaboration is being tested.

In the near future a first production release should be prepared, finalizing the existing software to the current level of understanding for the detectors; it is foreseen to have such tool ready for the October TR, to be able to test, even though with a partial installation and readout of the experiment, the full chain up to the physics analysis. An analysis framework is currently being designed to complete the tool set for the offline software.

20 Analysis of the 2007 data

The main goal of the NA62 physics programme based on the 2007 data sample is a precision measurement of the helicity suppressed ratio of the charged kaon leptonic decay rates $R_K = \Gamma(K^\pm \to e^\pm\nu)/\Gamma(K^\pm \to \mu^\pm\nu)$. The SM value of R_K has been computed to a high precision, thanks to cancellation of the hadronic uncertainties: $R_K^{\rm SM} = (2.477 \pm 0.001) \times 10^{-5}$ [9]. Such precision and the suppression of the SM contribution make R_K highly sensitive to non-SM physics. In particular, R_K enhancement by $\mathcal{O}(1\%)$ is possible in the MSSM [10], which represents a unique probe into mixing in the righthanded slepton sector [11]. On the other hand, R_K is sensitive to the neutrino mixing parameters within the SM extensions involving a fourth generation [12].

The first stage of the NA62 R_K analysis consisted of a measurement based on a partial data sample (about 40% of the total collected kaon flux) with the most favourable background conditions. The final result was announced in 2010 and published in early 2011 [13]: $R_K = (2.487 \pm 0.013) \times 10^{-5}$.

The second stage, started in late 2010, involved extending the analysis to the full data sample. Unlike the analysed partial data sample, the complete 2007 data set contains the K^- decay data (17% of the total collected useful kaon flux) affected by higher beam halo background (as the beam muon scrapers have been optimized for the K^+ beam), as well as data collected with a $9.2X_0$ thick lead (Pb) wall installed in front of the LKr electromagnetic calorimeter and covering about 20% of its geometrical acceptance (55% of the collected useful kaon flux; the Pb wall presence weakened the photon veto, but allowed a crucial direct measurement of the muon mis-identification probability). Collecting these samples with less advantageous background conditions added to the challenges of the analysis, but allowed direct measurements of the main backgrounds, eventually improving the overall precision.

Consequently, significant efforts were invested into detector calibrations and Monte-Carlo productions relevant for the additional data sets, optimization of the data-driven beam halo estimation techniques in both K^+ and K^- samples (including reprocessing and analyzing a dedicated control data sample collected in 2008), and further studies of the backgrounds with photons in the final state. Additionally, combining the data samples involved accounting for the correlations of the systematic uncertainties between the measurement in the individual data taking periods.

The result based on the total 2007 data set (0.15M $K^\pm \to e^\pm\nu$ candidates with 11% background contamination) was first announced at the EPS 2011 conference [14]: $R_K = (2.488 \pm 0.010) \times 10^{-5}$. The achieved precision is three times better than that of the 2010 world average [15], and meets the original NA62 proposal goal. The $K^\pm \to e^\pm\nu$ and $K^\pm \to \mu^\pm\nu$ spectra are shown in Fig. 24, while the stability of the result as a function of track momentum and data taking conditions is presented in Fig. 25. The draft of the final paper is currently under internal review within the collaboration.

While the main goal of the 2007 experiment has been successfully achieved, other analyses based on the 2007 data set are progressing. They include measurements of the structure-dependent radiative $K^\pm \to e^\pm\nu\gamma$ decay and the rare $K^\pm \to \pi^\pm\gamma\gamma$ decay, and searches for sterile neutrinos in the $50 - 350$ MeV/c^2 mass range. Some of the results are expected to be presented in 2012.

21 Publications

Since the last NA62(NA48/2) SPSC review in April 2011, the collaboration has completed the analysis of the full data set recorded in 2007-2008 in terms of R_K measurement. Another analysis of 2003-2004 data (Ke4 Branching fraction and normalization form factor) is also finalized. More analyses of both NA62 and NA48/2 data are in progress and are being presented as preliminary results at winter conferences. More should be ready to be shown at summer conferences.

NA62 Collaboration

- "Test of Lepton Flavour Universality in $K^+ \to l^+\nu$ Decays" : Phys. Lett. B698

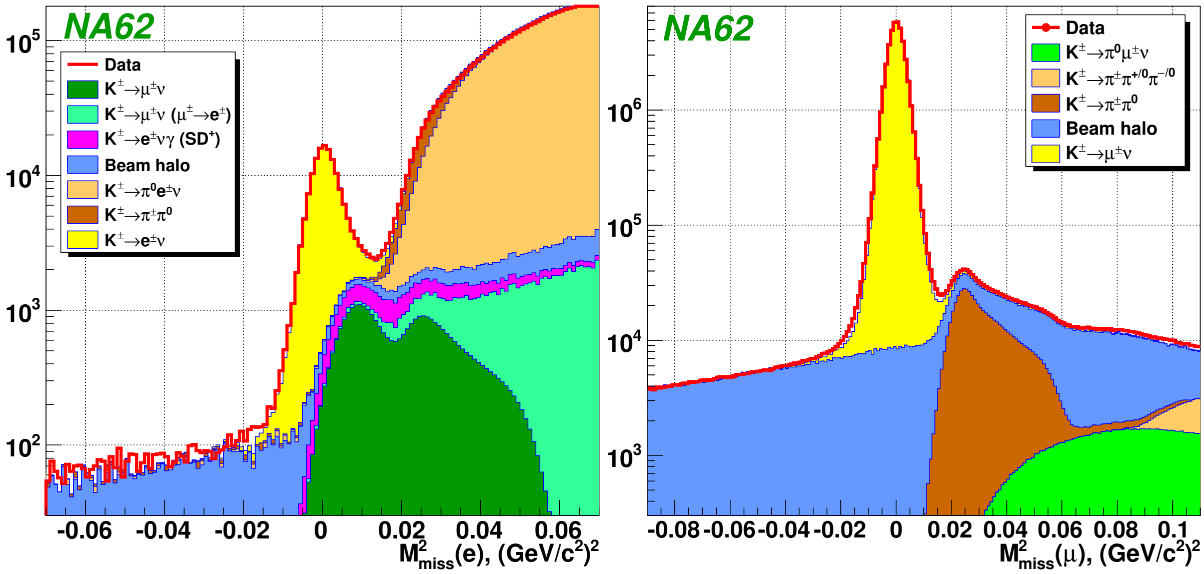


Figure 24: Distributions of reconstructed squared missing masses $M^2_{\rm miss}(e)$ (left) and $M^2_{\rm miss}(\mu)$ (right) of the $K^\pm \to \ell^\pm\nu$ candidates compared with the sums of normalized estimated signal and background components. The small discrepancies are mainly due to the limited precision of the beam simulation, and are accounted for by the systematic uncertainties.

(2011), 105 (April 4,2011)

- Draft currently under internal review within the Collaboration: "Precision Measurement of the Ratio of the Charged Kaon Leptonic Decay Rates"

NA48/2 Collaboration

- Draft currently under internal review within the Collaboration: "New Measurement of the $K^\pm \to \pi^+\pi^-e^\pm\nu$ (Ke4) decay Branching Ratio and Hadronic Form Factors"

22 Conferences

The collaboration is actively contributing to major international conferences and topical workshops with NA62 detector contributions and recently published and preliminary physics results from NA62 and NA48/2 data analyses.

In the past year (April 2011 to April 2012), the collaboration speakers presented 30 contributions to physics conferences and 24 contributions to instrumentation conferences. More contributions are foreseen in future 2012 conferences.

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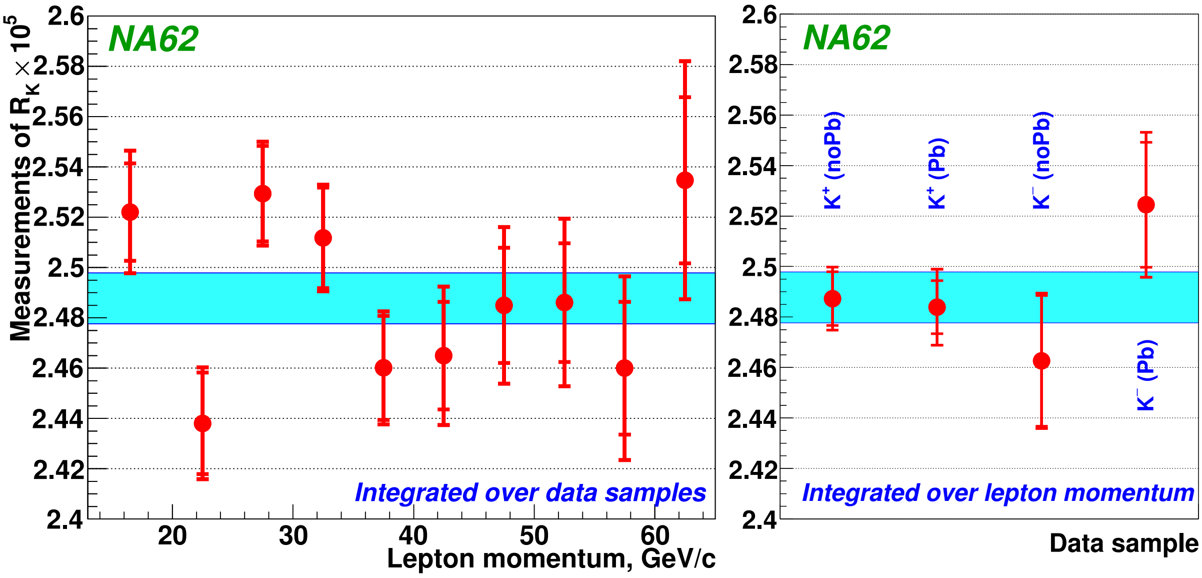

Figure 25: The stability of the R_K measurement versus lepton momentum and for the independent data samples (the four samples correspond to the combinations of the two beam signs and the Pb wall being installed or not). Statistical and total errors of individual points are indicated with horizonal ticks. The result of the combined fit is shown by horizontal bands.

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