NA62 Status Report to the CERN SPSC: Summary of the 2010 Activities and Plans for 2011

Abstract

The document reports the progress of experiment NA62 to study the rare decay $K^+ \to \pi^+\nu\bar{\nu}$ at the CERN SPS. The status of the analysis of the data collected by the Collaboration in 2007-2008 to study Lepton Universality in kaon decays is also given. The implications of the absence of SPS beams in 2012, as currently foreseen, are mentioned and the plan to mitigate for this lack of beam is presented. The overall construction schedule is reviewed and the status of the sub-detectors is presented.

1 Introduction

The precise determination of the branching ratio of reaction

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

continues to be one of the most interesting flavour physics observables. As the precision of the Standard Model (SM) prediction for the branching ratio continues to improve [1], we are now at the point that an extraction of the CKM parameter V_{td} from reaction (1) would be experimentally limited until a precision of 5% is reached. On the experimental front, the analysis of experiments BNL-E787/E949 to include the kinematical region below the $\pi\pi$ peak [2] was completed. This result shows the difficulty to address this kinematical region with stopped kaon decays and confirms the importance to make a definite measurement by employing in-flight kaon decays to avoid scattering in the stopping target and to keep a relatively large acceptance. From the broader point of view of quark mixing and CP-violation, we note that the measurement of B_s mixing [3, 4] provides a determination of the V_{td}/V_{ts} parameter which is already limited by the theoretical error (lattice QCD). This again stresses the importance to focus on observables like $K \to \pi\nu\bar{\nu}$ where the theoretical error is under good control. Overall the case for constraining the SM using information from kaon decays remains very important[1] and the case for a precision measurement of $K^+ \to \pi^+\nu\bar{\nu}$ appears to be stronger than ever. Plans to continue the study of reaction (1) with decays at rest in the post Tevatron Collider era exist [6] at Fermilab.

Since the last SPSC review, we have continuously optimized the experimental layout. The current setup and all the relevant parameters for the construction of the experiment have been collected in the Technical Design (TD) document [7]. The Collaboration has strengthened over the past year. In particular, a group from Comenius University (Bratislava, SK) has joined the experiment to contribute to the trigger system. Negotiations are under way with Institutions from Belarus and Romania. Collaborative aspects (Straw Tracker readout electronics) with the University of Heidelberg have also been identified.

[1]For instance, the improvements in the calculation of the B_K bag parameter [5] has strengthened significantly the constraint obtained from ϵ_K.

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2 Analysis of the 2007 - 2008 KE2 data sample

The main goal of the NA62 programme based on the 2007 data set is the measurement of the helicity suppressed ratio of purely leptonic charged kaon decays $R_K = \Gamma(K_{e2})/\Gamma(K_{\mu 2})$ with a record precision of 0.4%, which would improve the current measurement [8] by a factor of three. The ratio R_K is known to an excellent precision within the SM due to the cancelation of the hadronic uncertainties: $R_K^{\mathrm{SM}} = (2.477 \pm 0.001) \times 10^{-5}$ [9], and is highly sensitive to non-SM physics. In particular, enhancement of R_K by a few percent (relative) is possible in the MSSM with non-vanishing $e-\tau$ lepton mixing [10, 11], without contradicting any presently known experimental constraints.

The analysis has been focused on finalization of the preliminary NA62 result [12] based on 40% of the data sample announced in summer 2009. The following significant improvements have been introduced.

- The beam halo background subtraction procedure, based on control data samples, has been improved. Combined with other developments of reconstruction and selection, this has increased the available data sample by 17% to 60 k K_{e2} candidates, with the background contamination increasing from 8.0% to 8.8%, and without any significant change of the systematic uncertainties.
- A dedicated simulation of the inner bremsstrahlung radiative corrections to the $K_{\ell 2}$ decay has removed the corresponding systematic uncertainty.
- Detailed studies of the trigger performance led to the elimination of the systematic uncertainty due to dead time effects which was conservatively assigned to the preliminary result.
- Fine corrections for the local sources of positron identification and trigger inefficiency, and fine corrections to the background estimate induced by temporal variations of geometrical acceptance and radiative corrections have been evaluated.

The updated result with the relative precision improved from 0.65% to 0.5% was announced in summer 2010 [13]: $R_K = (2.486 \pm 0.013) \times 10^{-5}$. The corresponding paper is currently being reviewed within the the collaboration, and will be submitted in late 2010 or early 2011.

At the same time, significant preparatory work for the analysis of the remaining 60% of the 2007 data sample has been accomplished. Reprocessing of the whole physics data set has been completed; the beam geometry database has been produced; the electron identification efficiency analysis has been completed; the Monte-Carlo simulation software has been tuned to reproduce temporal variations of the beam and detector performance over the whole 2007 run; and the Monte-Carlo productions are on-going.

Data taking conditions have been varying significantly during the 2007 run. Alternative K^+ and K^- beams were used in order to collect control samples for beam halo background subtraction. Moreover, a lead (Pb) wall covering $\sim 20\%$ of the calorimeter geometrical acceptance was installed during a part of the run, as required for a measurement of the muon mis-identification probability. The four data samples corresponding to K^+ (K^-) decays with(without) the Pb wall are affected by different background conditions and systematic uncertainties, and are analyzed separately. In particular, the beam halo background is $\sim 1\%$ ($\sim 20\%$) in the K_{e2}^+ (K_{e2}^-) samples, and the presence of the Pb wall impairs detector hermeticity, increasing the $K_{e2\gamma}$ background from $\sim 1\%$ to $\sim 4\%$.

The sample of 60 k K_{e2} candidates used for the first phase of the analysis corresponds to the (K^+, no Pb) configuration, and has the optimal background conditions. With the currently adopted election procedure, the other K_{e2} samples consist of 62 k (K^+, Pb), 15 k (K^-, no Pb) and 18 k (K^-, Pb) candidates. The total K_{e2} sample amounts to 155 k candidates with a well-understood averaged background contamination of 14%, resulting in a combined R_K statistical uncertainty of 0.3%. The background conditions in the four data sets are illustrated in Fig. 1.

The precision of R_K measurements with the Pb wall samples is affected by an up to 0.5% relative uncertainty due to the limited knowledge of the $K_{e2\gamma}$ decay rate which is currently an external input [8]. A measurement of this decay, which is expected to improve the precision by a factor of about three, is being performed with the NA62 2007 data sample in order to decrease this uncertainty.

The uncertainty on R_K achieved with K^- samples has a significant contribution owing to subtraction of the enhanced beam halo background. The selection and halo background estimation procedures are currently being optimised to minimize this uncertainty. In particular, the effects of the imbalance of the spectrometer field polarity in the data and control samples, and temporal variations of acceptance are being investigated. The combined relative uncertainty on R_K with the K^- sample due to halo background subtraction is expected not to exceed 0.3%.

The physics programme based on the 2007 data sample spans beyond precision measurements of $K^\pm \to \ell^\pm \nu(\gamma)$ decays. The uniquely large data set collected with minimum bias trigger requirements allows a number of other measurements, otherwise inhibited by the trigger selectivity, to be performed with exceptional precision. The measurements of the $K^+ \to \pi^0 \ell^+ \nu$ rates and form factors, and the radiative decay $K^\pm \to \pi^\pm \gamma\gamma$ have started. The possibility of searching for a sterile neutrino in the mass range of $50 - 350$ MeV/c^2, as suggested by [14], will be evaluated.

3 Technical Coordination

3.1 Work in the Experimental Area

To make room for the future experiment, the year 2010 started with the dismantling of the former NA60 experiment and NA48 beam line and detectors, i.e. beam magnets, Hadron Calorimeter, Muon Counters, AKL's and Drift Chambers. Several of the dismantled detectors were discarded, but some are refurbished and will be re-used in NA62 or in other experiments. For example, the NA48 Drift Chambers were delivered to JINR (Dubna) where they will serve the MPD experiment. The Magnet MNP33 was dismantled, refurbished and is in the process of being re-assembled in the new NA62 position (30 m upstream with respect to the former location). A ventilated tent was assembled, and will be used in the next three months to repair and clean the nineteen decay vacuum tank elements that will be re-employed in the future. Studies have been launched for the necessary upgrades of the infrastructure, both in the TCC8 and ECN3 caverns and in the surface buildings. Correspondingly a budget has been prepared.

3.2 Detector Integration and Survey

Important progress was made on the 3D CAD modeling of the new experiment. All relevant sub-detectors have been represented in CATIA and these models are used for installation and integration studies. In the next months the models will be extended to the auxiliaries and services. The spatial coordinates of several fiducial points in the experimental area have been re-measured, in order to establish reference coordinates for the future axis of the experiment. This reference axis has been defined as a straight line between the T10 target (located 15 m from the beginning of TCC8) and the exit of the LKR calorimeter (located 240 m further downstream)). Further fiducial marks along the experiment axis will then be used to position the beam elements and the sub-detectors.

3.3 Schedule

In March 2010 we gave a full schedule to the SPSC referees that includes 11 milestones (with reporting to the SPSC referees). The plan was for a technical Run in the summer of 2012 and a first physics Run in the autumn of 2012. Due to the modified LHC schedule (shut-down in 2012) we are presently re-examining our planning in order to incorporate a first "synchronization run", using muons with a limited number of sub-detectors, in the late autumn of 2011. Assuming that the present CERN accelerator schedule is confirmed, we plan to be ready for physics data taking in April 2013. A detailed schedule, incorporating the synchronization run, will be available for the forthcoming SPSC. Critical Areas: the synchronization run in November 2011 is 8 months earlier than the initially foreseen technical run causing an important reshuffling of activities. A number of items, in particular the DAQ and Trigger systems, have to be advanced significantly in time and need to be reinforced in manpower. The civil engineering for the new beam dump is scheduled for completion in the summer of 2011. Although this new beam dump is not needed for the synchronization run, the external excavation work must be finished before the beam time in October/November. Particular efforts are made to advance the final installations, and to minimize temporary solutions only needed for the synchronization run.

3.4 Technical Design Document

Over the last 18 months the NA62 collaboration has completed a Technical Design (TD) document that describes the design layouts and the expected performance of the experimental set-up in detail. It contains a description of:

- The high intensity K+ beam line and the beam defining detectors (CEDAR, GTK and CHANTI)
- The downstream detectors (Photon Veto, Straw Tracker, RICH, CHOD and MUV)
- The Readout and data handling

Printed Copies of the TD shall be available in the course of December 2010.

3.5 Safety

The major efforts were deployed to guarantee safety during the dismantling of NA48. Together with the EN/MEF group the potential risks of every important operation were assessed and corresponding control measures proposed in the framework of Work Packages analysis. The consequent recommendations were used during the execution of the work. Special attention was paid for the organization of safe movement of people and vehicles in ECN3. A new dressing code including mandatory wearing of helmet and safety shoes was established in the experimental area. A preparation of a Safety File is essential for safe functioning of future experiment. To facilitate this work a set of documents describing of the requirements for the Safety File of each individual sub-detector was developed together with DGS/SEE. The set includes the requirements for CEDAR, RICH, MUV, and LAV. The documents for the other sub-detectors are under preparation. Particular attention was given to the safety of the CEDAR and MUV. The Hydrogen gas used for the filling of the CEDAR represents significant fire hazard. Appropriate mitigation measures reducing the risk to an acceptable level were proposed and endorsed. Another risk of the CEDAR is a possible rupture of thin front and back windows. Adequate control measures were proposed. A possibility of use of Polystyrene as the main component of scintillator for MUV was assessed together with DGS/SEE. In 2011 the work on the experiment Safety File will continue with a goal to have the first version before the synchronization run (in particular for the detector participating in the run). Another important area of activity will be safety during installation of the first detector components in the experimental area.

4 Beam Line and Vacuum System

Preparations for the installation of the new beam line are advancing. Integration studies for beam and experiments are well advanced. Many of the magnets removed from the K12 and H10 beam lines have been refurbished already in view of their future use in the new K12 beam line. Design work for new components is under way. The final beam dump has been optimized in collaboration with radioprotection and civil engineering experts and a plausible and affordable design exists. Studies are ongoing concerning the layout and costing of a new cooling station for the T10 target and possibly the TAX beam dumps downstream of it. Progress has been made on studies of the vacuum tank and the vacuum system, in close collaboration with the vacuum group. The present preference is to use industrial-cryo pumps. Contacts have been made with industry to converge towards concrete proposals. Promising tests of cold traps have been made by the vacuum group, using a short section of the blue vacuum tank with some lead glass blocks inside. But the industrial pumps seem more attractive in terms of cost and ease of operation. Recently the possibility of providing some beam for a synchronization run in November 2011 have been explored. The option of providing muon beams at up to 10% of the nominal NA62 flux seem feasible, provided that:

1. The civil engineering work on the beam dump has been completed,
2. The refurbishment of the T10 target cooling station has been completed,
3. A 2 hours waiting time (maximum, to be re-evaluated by measurements after the first beam) before every access is enforced.

5 CEDAR

The CEDAR is a differential Cherenkov counter intended to provide positive kaon identification for the incoming beam particles. Since November 2009, the CEDAR group has continued to progress in the test and design of several aspects of the layout. As baseline solution, a readout design very similar to the RICH detector has been adopted. Simulation has shown that, considering the effect of signal, including dead time and buffer limitations of the readout chain, a hit loss probability as low as about 1% can be achieved, corresponding to a detection inefficiency per kaon of a few % for a minimum of 10 photons distributed in at least four spots. A preliminary design of the full readout chain has been developed, but not yet tested. Most of the efforts were concentrated in the mechanical design. The major mechanical considerations involved in modifying the CEDAR for use of NA62 are: 1) the mechanical rigidity must ensure optical stability; 2) the support must allow pre-amplifiers to be located adjacent to the PMTs to optmise signal processing; 3) cooling and insulation must be designed to ensure thermal stability; 4) a nitrogen blanket is required to eliminate any possibility of explosion in the event of a hydrogen leak, and the structure will incorporate sensors to monitor the temperate and the flow of nitrogen; 5) the CEDAR must be connected to the vacuum beam pipe at both ends in such a way that a hydrogen leak is not accompanied by any admixture of air to prevent risk of explosion. Because of the necessity to increase the size of the light spot, the new photo-detectors will be relocated away from the quartz window and light guides will be required to optimise the Cherenkov light collection onto their active surfaces. Therefore the mechanical structure will preserve the current optical stability while ensuring that all Cherenkov light reaches the PMTs. This requires the precision mounting of PMTs and optical components in a rigid, light-weight structure. Heat will be removed from PMTs and electronics and temperature will be maintained constant via a combination of heat removal and thermal insulation. Plans for 2011 include: build a prototype of the mechanics, covering one optical port which will be fully equipped with photo-detectors, and a prototype of the readout chain. In due time this should be tested with beam. Such test will allow us to verify the procedure for assembly of the mechanical structure and its compatibility with the photo-detectors and readout chain. Another important aspect is to test the integration of the readout to the full NA62 TDAQ system. Later during 2011, the front-end electronics alone will be exposed to a neutron beam at the University of Birmingham, UK, to verify its radiation hardness, consistent with our estimate of the neutron flux that will be present in the future NA62 beam line.

6 Gigatracker (GTK)

The Gigatracker (GTK) is the Silicon micro-pixel detector placed in the beam upstream of the decay region in order to track and time-stamp every incoming particle. During 2010 major progress has been achieved in many aspects of the project: chip prototype tests, cooling, mechanical integration, and DAQ. All these aspects are briefly discussed either in the next sub-sections or in the Trigger and DAQ section.

6.1 Chip prototype tests

The time resolution was considered one of the main challenges of the project and to probe the technical possibilities two options were pursued: Time-over-Threshold (ToT) and Constant Fraction Discriminator (CFD). In 2010 many efforts were devoted to the characterization of the ASIC prototypes which were submitted in 2009 to the foundry in 130 nm CMOS technology. The tests underwent through several phases:

1. electrical test;

2. laser beam;
3. beam test.

Both chips were extensively studied on the bench and then tested at the T9-PS in September 2010. A technical review committee was appointed, which scrutinized the architecture of both options. Based on the overall performances and on the test-beam results, it was decided to choose the ToT option. Indeed the results as from the test beam and represented in Fig. 2, are quite satisfactory and indicate a time resolution on a single Silicon matrix of about 175 ps (rms), which satisfies the NA62 specifications. The CFD option, which was affected by some hiccups, will be corrected for those technical problems and kept as back up solution.

6.2 Cooling and Mechanical Integration

During 2010 the prototyping studies continued on both the *vessel* and for the *micro-channel* cooling options. The gas *vessel* cooling is based on the thermal exchange between the ASIC chip and cold nitrogen flowing through a vessel with thin (50 μm) Kapton© walls surrounding the detector. The temperatures which have been obtained are well below 0° C, but the uniformity of the temperature over the detector has to be improved. The development of the *micro-channel* cooling went through different phases: a full scale prototype with silicon-on-pyrex has been assembled and fully tested. A silicon-on-silicon assembly is now ready for mechanical stress test. A first conceptual design of the detector integration inside the vacuum pipe has been developed. This has been an important step toward the final realization of the detector. Studies of the PCB layout are underway.

6.3 Plans for 2011

- Full size ASIC chip is expected to be ready for submission by end of September 2011.
- The thinning to 100 μm of the chip is studied at VTT and IZM in synergy with Alice, which has similar specifications.
- By the end of the year and based on the performances of the prototypes the final design of the cooling will be decided.
- By middle of the year the design of the DAQ will be ready.
- Studies of the design of the integration card will continue and will be finalized.

7 Straw Tracker

The Straw Tracker is intended to measure the momentum and the direction of charged tracks originating from kaon decays. After the successful test of the principle prototype in 2007 and 2008 when it was shown that good position resolution could be achieved with the straws operated in vacuum, the progress towards the finalization of the straw tube characteristics has been delayed by two problems:

- It was found that a several straw tubes prepared with a similar technique (ultrasound welded metalized PET) for another experiment were unfit to be operated under pressure. Further studies were required to understand the quality of the weld and the procedures for the straw fabrication.
- Once the qualification of the base PET material samples used for prototyping was completed, it was discovered that the same material would not longer be available for the construction of the full chambers because the manufacturer had discontinued its production. This required to restart the qualification of a new base material.

As already reported, following the performance validation of the first prototype, the next step has been the design and construction of a module incorporating alternative solutions for the straw tube fixation and position control. Given the length of the proposed straws (2.1 m) and the novelty to operate them with a differential pressure of about 1 bar (the straws are to be operated in the vacuum tank), particular emphasis is given to control the geometry of the tubes under pressure and to minimise the amount of passive material required to hold the straws in position. Good position control was achieved by means of ultra-thin spacers made of strung wires and Ultem© collars and a choice could be made for the solution to be applied to the final chambers. The engineering prototype was beam tested in June-July 2010. The beam test of the new straw prototype was performed in the SPS H6 beam line. Contrary to previous tests conducted in ECN3, the old NA48 drift chambers were not available as external tracking detectors to simplify the measurement of the r-t relation. To mitigate the lack of the chambers a beam Silicon micro-pixel telescope kindly prepared by the EUDET group was employed. Difficulties in the synchronization of separated read-out limited somewhat the use of this telescope. The prototype was read out using elements foreseen for the final front-end and read-out. The analysis of the data is progressing. Larger than expected electronics noise was observed. Difficulties encountered during the test beam have motivated further studies with cosmic rays in the lab before a final choice on the fronted electronics (foreseen in January 2011) can be made. The CERN team working on the straw has recently been strengthened with the arrival of an Applied Fellow and a Technical Student. The straw detector is supposed to be the main source of residual gas in the decay tank. Excellent interaction between the PH/DT and TE/VSC and EN/MEF groups has lead to the successful understanding of the expected outgassing load on the vacuum system. Simulations confirm that the specified level of vacuum quality will be achieved in the kaon decay region.

7.1 Main Achievements in 2010

1. Completion of the 64-straw prototype
2. Finalization of the design of the full chambers (Milestone successfully achieved on September 1, 2010)
    - final straw layout (distance between neighboring straws 17.6 mm)
    - chamber structure
    - straw end-pieces
    - spacer for straw positioning
    - straw assembly tooling

- web (connection between straw and FE)
- cover with HV, signal and gas connections
- grounding scheme
- FEM calculation of chamber deformation and stresses

3. The frame for the first half chamber (Module 0) was ordered. It is expected to be delivered at CERN, fully assembled, at the beginning of December 2010
4. Straw material: Decision on the base material, Hostaphan RNK 2600 (PET), and procurement of the full quantity needed for the straw production.

7.2 Plans and for 2011

1. Choose the final solution for the frontend and readout electronics by December 2011
2. Construct Module 0
3. Test beam the prototype in the spring with final frontend, TDC and readout scheme
4. Integrate Module 0 in the 2011 synchronization run. The number of fully equipped channels to be read out is still to be decided.
5. Design/decide on:
    - Interface part between chamber and blue tube
    - Services
    - Support for chamber in the experiment
    - Installation tooling
6. Start building the gas system so that the final distribution can be used in the synchronization run.

8 RICH

The RICH detector, filled with Neon at atmospheric pressure, is needed to fulfill the following tasks:

- Separate from between 15 and 35 GeV/c momentum providing a muon suppression factor of at least 10;
- Measure the pion crossing time with a resolution of about 100 ps;
- Produce the L0 trigger for a charged track.

During the past 12 months the conclusions of a series of test beam measurements with the full length RICH prototype have been published [15], confirming the predictions of the simulation and matching the experiment requirements. The detector will be equipped with 2000 photomultipliers (Hamamatsu R7400U-03 types): about 1800 pieces have been already received, the last batch will be collected at the beginning of 2011. HV dividers (sockets) for the PMs will be ordered in 2011; all the needed HV supply (CAEN HV boards and mainframes) have been received, few spares will be ordered in 2011. The front-end electronics, tested during the test beam, is in order and will be shipped in 2011.

The detector needs 20 spherical mirrors of high optical quality and of hexagonal shape which have been ordered at the end of 2009, their construction is on schedule and they are expected at CERN by the end of 2010 for aluminization and coating. The mirror support system is under development with several prototypes built and under review by a dedicated committee: the design will be finalized at the beginning of 2011 and built in the course of the year.

The RICH vessel is a quite demanding object: 4 cylindrical sections of increasing diameter (between 3.4 m and 3.9 m) and 17 m total length made in construction steel. The design is well advanced, it will be finalized in the coming weeks and the vessel will be built in the course of 2011. The gas system uses inexpensive CO_2 as transit gas to fill the vessel ($\approx$ 200 m^3).The CO_2 is then filtered out while the Neon is injected. The gas system will be made by the gas team in PH/DT employing proven techniques developed for the LHC experiments.

9 Photon Vetoes

The Large Angle Veto (LAV) is to be composed of 12 stations situated between 120 and 240 m from the target along the beam axis. The first eleven stations are part of the vacuum decay tube, while the last one is located outside the vacuum tank. The LAV stations have a diameter going from 2 to 3 m. The basic building blocks of these detectors are lead glass crystals with attached photomultipliers (PMT) from the former OPAL electromagnetic calorimeter. Four blocks (lead glass crystals + PMT's) are mounted on a common support structure forming an azimuth segment. Inside the vacuum tube the azimuth segments are assembled forming a complete ring of lead glass blocks. Each LAV stations is made up of 4 or 5 rings, which are staggered in azimuth providing complete hermeticity of at least three blocks in longitudinal direction.

9.1 2010 Achievements

During 2010 and the first months of 2011 the plan foresees to build and test four LAV stations with the smaller diameter A2-A5. A1 was already assembled in 2009. This is slightly behind the initial plan but still in line with the installation schedule. Currently, the A2 and A3 stations has already been assembled and A2 has been tested in the T9 beam at CERN this summer. The test beam has been performed using the final layout and the final frontend electronics prototype. The front end electronics is based on the Time over Threshold (ToT) and will allow us to have a time resolution of about 1 ns and an energy resolution of the order of 10%. The T9 beam is composed by electron pion and muon with energy between 0.3 and 10 GeV, the T9 Cherenkov counter has been used to select electron samples with different energy. The analysis is in progress and the preliminary results show that we have a good linearity a good time and energy resolution. In Fig. 3 is shown the linearity obtained computing the energy from the time over threshold compared with the one from the charge, while in Fig. 4 the energy resolution is shown. The Q vs T parameterizations is obtained by a polynomial fit of the charge versus the ToT spectra for all the lead-glass. The energy resolution at small energy obtained from the ToT is even better than the one obtained from the charge measurement. We are also progressing on the mechanics and electronics. The final drawing for the intermediate diameter vessels (A6-A8, A11) are ready and the bid has been assigned, the construction of the vessels will start at the Fantini factory by the end of 2010. The frontend electronics is also fixed and the production will start beginning of 2011. A lot of progress has also been done on the simulation: the complete geometry and the detailed simulation of the lead-glass signal is now included in the NA62 Monte-Carlo.

9.2 Plans for 2011

During 2011 we plan to construct and test four new modules, i.e. A6-A8 (intermediate diameter) and A11 (large diameter). For the synchronization run, seven vessels will be installed. In parallel, half of the frontend electronics will be produced, tested and installed. The plan is to readout at least 3 LAVs, depending on the number of TEL62 boards that will be available by that time. The mechanics and the tools for A9, A10, A12 will be defined and the bid procedure will be started. We will also start testing the final readout elements, so that the full chain (final crates, final frontend boards, final TEL62 boards) can be ready for the synchronization run.

10 Liquid Krypton Calorimeter (LKR)

10.1 Consolidation of the LKR readout

Following the installation of all the SLM (Smart Link Modules) at the place of the old Data Concentrator and CES RIO readout for the CPD modules, a commissioning campaign for the readout software has been performed at the end of 2009. Focusing on a subset of the readout modules, the readout software has been debugged and the expected performance of 10 KHz non-zero suppressed trigger rate has been achieved. Based on these basic blocks, we are currently writing a software suite to be able to run automatically the LKR readout on 14 PCs connected to the 56 SLM installed, merging all the event fragments and optionally doing zero suppression. This software will be used to read the calorimeter in the 2011 synchronization run. In view of the this run, we are also developing an interface between the NA62 trigger system and the old NA48 interface, still used to drive the CPD system. This interface is based on a daughter board for the TELL1 board, which has an FPGA, the interface chip for the NA48 TAXI protocol and few Ethernet links which could be used, together with suitable FPGA firmware, to implement L0 logic in the relatively simple configuration of the 2011 run.

10.2 Definition of the specification for the final NA62 LKR readout

The need to have a readout system capable to read the LKR calorimeter at a L0 rate of 1 MHz, with a further reduction by the L1 conditions, have led to the definition of a new system based on modern components. Indeed, the availability of 14-bit 40 Mhz FADC with serial outputs (8 channels/chip) simplifies the design of the readout board. This board, called CREAM (Calorimeter READout Module), is a 1-slot wide 6U VME64x module. It houses 32 channels (4 ADC chips). Each ADC readout channel has a dedicated serial LVDS link to a FPGA serving 32 channels. The FPGA acquires ADC raw data at

40MHz, performs primary treatment-formatting and interfaces data to a DDR2 SODIMM memory module for temporary storage. 8x2 or 4x4 trigger sums are sent to the trigger system which perform the computation needed for L0 assert. Data are continuously digitized and buffered inside the FPGA, where the trigger sums are prepared. At the arrival of a L0, a number of samples (typically 8) are transferred to a specific buffer in the DDR2 memory. Only the data belonging to accepted L1 triggers are moved (after formatting and optional zero suppression) to the event building PCs. A preliminary market survey has been performed by PH/ESE to identify interested manufacturers. A detailed specification document is under preparation for the tender. It is planned to have two prototypes by end 2011 and the production by the end of 2012.

10.3 Simulation

Simulation work has been performed with the latest version of the NA62 Geant-based Montecarlo (NA62MC) to study the cell hit rates in the calorimeter. Additional work is underway to study the reduction factors on the 10 MHz rate of particles of the various conditions contributing to the L0.

10.4 Cryogenics

The cryogenics installation of the LKR calorimeter has been running for about 14 years and needs continuous maintenance. This is sometimes complex as it was foreseen to regularly empty and warm up the cryostat. This operations have never been done in the past 12 years in view of possible negative side effects in terms of damages of the cold electronics. Recently a Work Package for the operation and maintenance of the cryogenic system of the NA62 liquid krypton calorimeter has been prepared and agreed between the Collaboration and the TE/CRG group.

11 Muon Veto (MUV)

The Muon Veto (MUV) is essential to suppress kaon decays with muons in the final state. The design of the MUV1 module was finished at the end of 2009. The module will be an iron-scintillator sandwich calorimeter, 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. The scintillators are produced 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. Tests of prototype strips, produced by this new method, have been performed and showed similar or even better behaviour in terms of light output (10-12 photo-electrons with WLS fibre read-out) than strips produced by extrusion. The set-up for the mass production for the MUV1 scintillators is currently underway and will be completed in November 2010. The total number of strips is expected to be produced by early spring 2011.

The construction of the MUV1 module then takes place at Mainz University and is planned to be finished by the beginning of 2012. For the fast muon veto detector (MUV3), after several tests the design has been decided. It will consist of scintillating tiles of 22x22 cm^2 cross-section and 5 cm thickness. On the backside, each tile will be simultaneously read-out by two PMTs. The use of two PMTs suppresses possible erroneous signals from Cherenkov radiation of particles crossing the PMT windows. A prototype module with one tile was successfully tested in a beam test in August 2010. The achieved time resolution in this run was 0.5-0.6 ns, well below the requirement of at most 1 ns. The MUV3 design is relatively simple and several components (PMTs, CFD's, cables) are still available from the old NA48 AKL and other sub-detectors. It is therefore planned to install the whole or a major fraction of the MUV3 detector already for the synchronization run end of 2011.

12 Trigger and DAQ

During 2010 most sub-detectors drafted or consolidated their plans for the readout system. The Gigatracker and the LKr calorimeter systems pursued their original plans to develop dedicated subdetector-specific readout systems.

- GTK

  For the Gigatracker, the specifications for the DAQ (off-detector read-out) have been completely defined, as well as the block diagram of the baseline design: each GTK ASIC will be served by a host card with two Altera FPGA on board. Test on the bench of the ALTERA transceivers for high speed data links are underway. Details of each block have been singled out. The controller of the GbE connections (data transmission to DAQ PC farm) has been implemented and the transmission performances are under test.

- LKR

  The original CARE project for the LKR readout system was dropped in favour of a complete redesign called CREAM which does not re-use parts from NA48. The system is based on new 40 MHz digitizers and a scheme in which it will be the only sub-detector being read-out after a L1 trigger decision has been devised. Detailed specifications are being prepared at present.

- COMMON TDC-BASED SYSTEM

  The development of a common TDC-based TDAQ system for most of the remaining sub-detectors continued. After being used in the RICH test beam in 2009, the 128-channel prototype system was used in two 2010 test beams: extensively as the readout system in the Straw Tracker test beam, and marginally as a backup system in the LAV test beam. While the prototype system lacks many of the firmware features required for the final system, the tests allowed to identify some issues and to partly assess the suitability of the system for NA62. Some laboratory tests with the TDC-based system were performed to assess segmentation issues for the CEDAR related to the rate capability.

  A third-version of the TDC daughter-cards was developed and tested satisfactorily in the lab; some difficulties with the identification of suitable and affordable signal cables required a fourth version to be developed, the first prototypes of which just became available. Development and debugging of the firmware progressed on the compatible earlier version. After tests in the lab, a small pre-production of TDC cards will be launched: such cards will be both used in independent lab tests by sub-detector groups for assessing the validity of the system, and possibly used in a technical run at end of 2011.

The need for an upgraded version of the LHCb base board TELL1 on which the project is based emerged during the review of the TDAQ project in mid 2009: the upgrade was strongly suggested by the obsolescence of some TELL1 components, coupled with the need to handle the board production fully within the experiment, after the end of LHCb commissioning. Such an upgrade also has the side benefit of allowing to acquire complete expertise and knowledge of the new board within NA62. Driven by the requirements of compatibility with the old board plus cost and time constraints, the design of the new TEL62 board started as a minimal upgrade of the most crucial components but ended up in the design of a board which - while still heavily based on the TELL1 design, with unavoidable compromises - is a quite different and much more powerful board, considered suitable for use on a ten-year timescale within NA62. The new TEL62 board features are described in an internal NA62 note which was circulated also outside the experiment for comments. Most of the critical components which were not changed from the original board were secured by the TDAQ group for the whole amount of boards needed by the experiment. The design of the new board is almost ready, PCB layout work will be done at CERN in the following weeks, and the first prototypes should be ready by the beginning of 2011. After extensive laboratory tests, a small-scale pre-production of a few boards can be foreseen during 2011, tightly matching the timescale for a technical run at the end of the year.

The most critical issue on this project appears to be the manpower for the development of the firmware, both for the common part and for the sub-detector tailoring; only a very simplified firmware might be available during 2011. The non-radiation hardness of the electronics should not be an issue given the radiation level and the foreseen placement of electronic racks, but specific tests will be foreseen.

The Straw Tracker group also started the development of a possible specific readout system, based on the development of a new carrier board and the implementation of TDCs within FPGAs: such solution is thought to be cheaper for a system requiring only limited resolution. The common TDC-based solution is however still left open as a backup; a decision on the road to be pursued will have to be taken at the beginning of 2011. Only a few (small channel count) sub-detectors have not yet completely figured out their readout scheme.

- LKR TRIGGER

  As a consequence of the change in the LKR readout scheme, the design of the calorimeter L0 trigger system interface was changed to digital, thus avoiding the need for the development of new ADC cards for such system. The design of the LKr L0 trigger system, also based on TEL62 carrier boards, was consolidated, and the development of two new daughter-cards for high-speed interconnection progressed to the level where prototypes of such boards are available. During 2011 the TEL62 firmware for the handling of such boards will be developed, as well as a new data-receiver board interfacing to the LKr readout system.

- CLOCK/TRIGGER SYSTEM

  The scheme for clock and L0 trigger distribution using the common TTC system developed for LHC was designed: as interfaces between the central L0 Trigger Processor and the clock/trigger distribution network, a slightly modified version of the ALICE LTU boards was developed, and prototypes are being tested now. Clock distribution modules were manufactured at CERN for NA62, and the entire (final) clock/trigger distribution network should be installed in the area during 2011. The development of the control software for the central clock/trigger distribution was started. A scheme for the distribution of burst timing signals via TTC was also agreed.

- L0 TRIGGER PROCESSOR

  The requirements for the central L0 Trigger Processor (L0TP) were clarified and are being drafted, but progress was limited on this item, and different options are still being considered for its implementation. The hardware functionalities which will anyway require the development of a custom board were identified, and a conceptual design of such a board, usable with any implementation of the L0TP, was drafted. Some laboratory tests were started in the third quarter of 2010 to assess the possibility of implementing the L0TP into a PC; preliminary results looked encouraging and suggested pursuing this path further. No L0TP can be available for a 2011 technical run, and a replacement suitable for working at low rates must be identified.

- CRATES

  Some effort was put into the definition of common solutions for electronic crates: this resulted in the identification of two quite similar crate configurations, housing TEL62 boards and sub-detector front-end boards with a common card and power format. Some crates of such kind will be bought, tested when the new TEL62 boards are available, and then established as common CERN items and installed.

- ONLINE AND SOFTWARE

  Software tools were identified which are suitable for the development of the NA62 online system: widespread expertise exists at CERN on such solutions which are extensively used in LHC experiments, and the development (or adaptation) of the required pieces of software to NA62 will take place starting 2011.

- HIGHER-LEVEL TRIGGERS

  Long due simulation activity resumed in the second part of 2010, leading to a better knowledge of the expected L0 trigger rates, and to the start of the work for the definition of software trigger capabilities and requirements. The official Monte Carlo program started flanking private "toy" solutions for trigger simulation studies, and more improvements in the usability of common software tools are expected in 2011. While such work still needs heavier involvement from sub-detector groups, it is expected that during 2011, as construction activities progress and become more routine, it can increase and lead to the definition of suitable trigger algorithm to be tested on Monte-Carlo data.

- RUN IN 2011

  If the required manpower can be found for the testing and the firmware development for TEL62 boards, a small-scale technical run at the end of 2011 focused on the testing of the interconnection and synchronization of a few TDAQ sub-system prototypes would be useful. For the purposes of the TDAQ one would foresee the availability of part of the fast MUV plane and possibly the existing NA48 charged hodoscope equipped with prototypes of the common TDC-based TDAQ system. The involvement of (part of) the existing (NA48) LKr calorimeter electronics would be made possible by the use of an interface board which is currently being developed. A side project within NA62 involved R&D on the possible use of GPUs (graphic processors) as either an aid or a replacement for some parts of the default solutions based on custom electronics: on the timescale of a possible 2011 run, such solutions might offer the possibility of implementing some (lower rate) trigger system while the final system is not yet available.

13 Detector Control System

During the past year the work on Detector Control System (DCS) was carrying out in close collaboration with EN/ICE group and concentrated on the following main directions:

- Prototyping
  - A prototype system was developed for long term vacuum test of LAV1 station (the test started in January 2010).
  - The system was re-used for the beam test of the LAV2 in the summer of 2010
- Collection of user requirements and preparation of "User Requirement Document (URD)"
  - A survey of sub-detector user requirements was completed at the end of 2009
  - The first version of the URD was prepared and uploaded to the EDMS
  - Final State Machine model of detector operation was elaborated and will be soon included in the URD soon
- Hardware choice and procurement
  - Procurement of the ELMBs and corresponding CANbus infrastructure equipment is completed
  - The type of front-end PC was selected and two KISS 4U PCI-760 industrial PCs were purchased
- Development of a vertical slice prototype for control of LKR calorimeter LV and HV power suppliers
  - Detailed specification was prepared
  - A prototype program of HV control was developed
  - An ORACLE DB account was set on central IT ORACLE service
  - A mockup applications were developed for Recipes Editor and LV control

In 2011 the group is planning to:

- Finalize the URD
- Finish the vertical slice prototype
- Make a final choice and procure supervision PCs
- Design and develop a pre-production version of the DCS for the synchronization run.

14 Network and Computing

The data processing model is strongly connected with the Trigger & DAQ architecture, and has been designed accordingly, taking into account the data-flow from the sub-detectors to the permanent storage for reconstruction and analysis. The data-flow from the readout boards - for almost the sub-detectors the TEL62, evolution of the TELL1 board - to the three-level trigger system and to the permanent storage (tapes) is described with some detail in the TD. The Event Data Model has also been defined, in order to estimate the data formats and the total amount of data produced by the experiment; we have identified the binary RAW format, and the reconstruction elements format (RECO), to which we have to add the summary data for analysis, and the calibration streams for calibration tasks. In addition to data coming from the readout of the sub-detectors, meta-data should be considered. The main three types of meta-data produced by the experiment will be: conditions of the detector, stored in the appropriate data-base, connected to the detector control system (DCS), run and trigger configurations, and the calibration metadata. The event data model is strongly connected with the model of the event reconstruction, we have designed different scenarios, including a partial or completely tier-ed model based on Grid infrastructure and use of off-site computing resources.

A dedicated online farm will be in any case needed for performing the event building and Level-2 filtering, and for streaming data to the data storage without back-log during data-taking. Additional machines will be hosted in the ECN3 cavern, in order to handle the DCS of the different sub-detector, and will be connected again by Ethernet links to a network switch downstairs, linked with 10 Gigabit/second links to the main network switch in the computing room. All the machines in the L1 farm will be on an experiment private network, while dedicated gateway machines will be connected to the CERN general purpose network (GPN). Having fixed the maximum trigger rate to 1 MHz at the output of the L0, and 100 kHz at the output of the L1, we have a L2 rate of order of few kHz. On the other hand of the data processing, the Data Logging System, the maximum speed of event logging to tape can be fixed at 100 MB/s (per tape drive, we assume 1 fully dedicated tape drive). The maximum event rate of the DLS, in an operational model in which raw data is assembled by the event-building processes and then directly transferred to tape (of course with suitable disk-buffers in order to profit of the SPS extraction cycle), is fixed then by the event size. Then, assuming a SPS cycle of 9.6 flat-top each 30 seconds, which is the one with higher live-time of the fixed-target experiments, a duty-cycle of 0.3 can be considered. In order to estimate the size for the different formats of data, we start from the raw data and make educated guesses for the other data formats (reconstruction, analysis reduced data). The data through-put can be deduced from the sub-event format and from the expected rates (1 MHz at the output of the L0), out from each of the sub-detectors. The detailed break-out of each sub-detector data-flow is described in the technical document; we can foresee an overall data volume of order 1 PB/year, including also control samples and dedicated calibration streams. Concerning networking, we plan to use switched Ethernet technology to transfer data from the sub-detector electronics to the online processing farm. To have a uniform system we intend to use 10 Gigabit Ethernet as backbone (to reduce the number of fibers to be deployed) and Gigabit Ethernet everywhere (GbE), even for tasks that require much less bandwidth (DCS for example). One possible exception to this rule will be the CCPC on TELL1 boards for which we may need to use 100Mbps (Fast-Ethernet, FE) transceivers instead of GbE ones. To facilitate the maintenance of the computers, we plan to keep as many as possible of them "up-stairs", i.e. in a dedicated computing room in building 918 next to the NA62 main control room (approximately half of the surface formerly dedicated to the NA60 control room), rather than "down-stairs", i.e. in the ECN3 experimental area. Moreover, due to the position of the sub-detectors all along the decay region, the readout boards are not concentrated in the same area, but are spread along the more than 100 m long underground experimental zone. For this reason we plan to split the network in two branches: a pit (ECN3) networking structure and a ground level (building 918) one, with optical fibers connecting the two. In the experiment pit, we plan to have a central star point in the electronics barrack sitting on top of the Liquid Krypton calorimeter. Starting from there we will have connections to all sub-detectors along the NA62 line and to the computer room in building 918. We plan to concentrate several connections from single station/subdetector running 1 GbE Ethernet into 10 GbE connections using "local" switches (i.e. switches placed in the sub-detector electronic racks). This way we reduce the number of fibers between the electronics barrack and single sub-detectors. In the electronics barrack we will connect the fibers coming from the sub-detectors to the bundle of fibers leading upstairs, to the main switch. The estimated number of 10 GbE fibers connecting the electronics barrack to building 918 is 80 (couples, including a safety factor).

Concerning the surface network (building 918), it will consist of a main switch placed inside the computer room. This will be connected to the 10 GbE fibers going to the experiment area and to the roughly 300 computers forming the online system (L1 PCs, L2/L3, event reconstruction). Moreover it will be connected to a 10 GbE optical fiber going to the main IT facility to transfer the data to be put on tape. Our plan is to realize the backbone of the network infrastructure and the first building block of the online farm already for the "synchronization run" that could take place in year 2011. In particular, the deployment of the fibers should be done very early, in order to be done in parallel with the refurbishing of the building 918, and the preparation of the computing room for the farm. For such installation we plan to use computer and switches of the same kind of what will be used for the real experiment, so that all this items will actually be reused. The only exception will be the main switch: we do not consider to buy for the synchronization run the real switch, since in this run we will have to deal with a small number of fibers.

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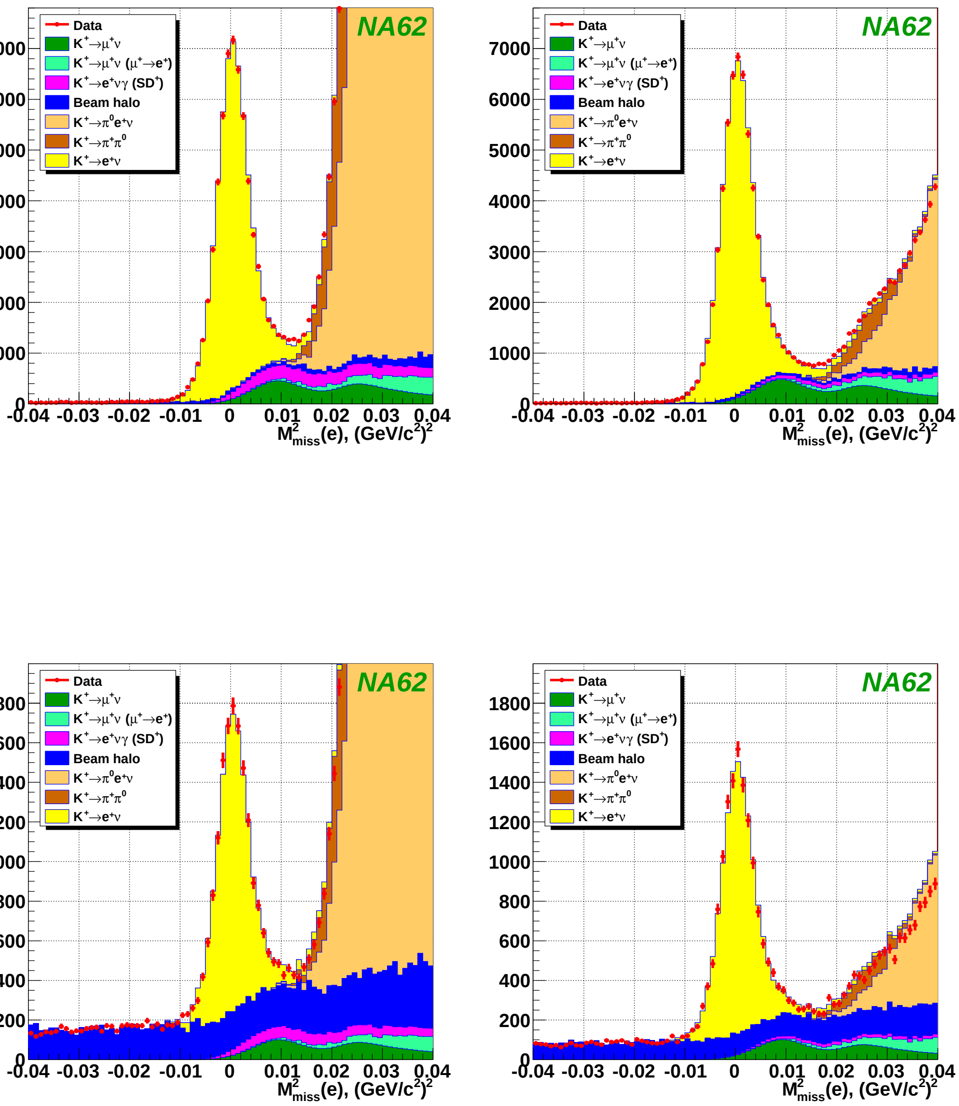

Figure 1: NA62 2007 KE2 samples. Preliminary data/MC comparison of the squared missing mass $M_e^2 = (P_K - P_e)^2$ spectra for the four data samples showing the differences in background conditions. Top (bottom) rows: K^+ (K^-) candidates. Left (right) columns: configurations with (without) the Pb wall.

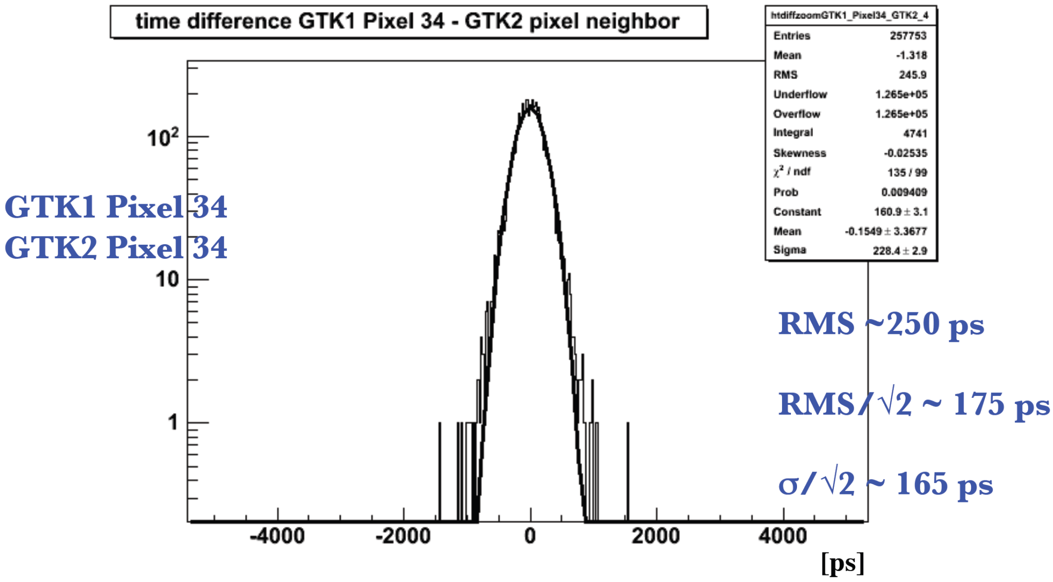

Figure 2: Time Correlation between two GTK stations (GTK1-GTK2). These results (NA62, Preliminary) were obtained by the ToT EOC prototypes with beam particles at the PS-T9.

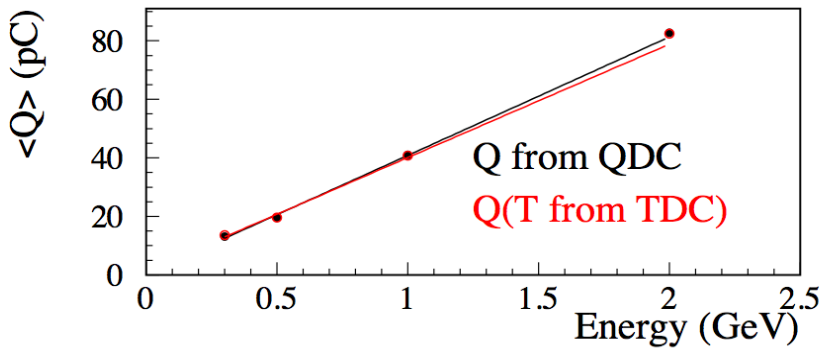

Figure 3: Comparison of the linearity of the LAV (A2) response between the QDC and the TOT read-out.

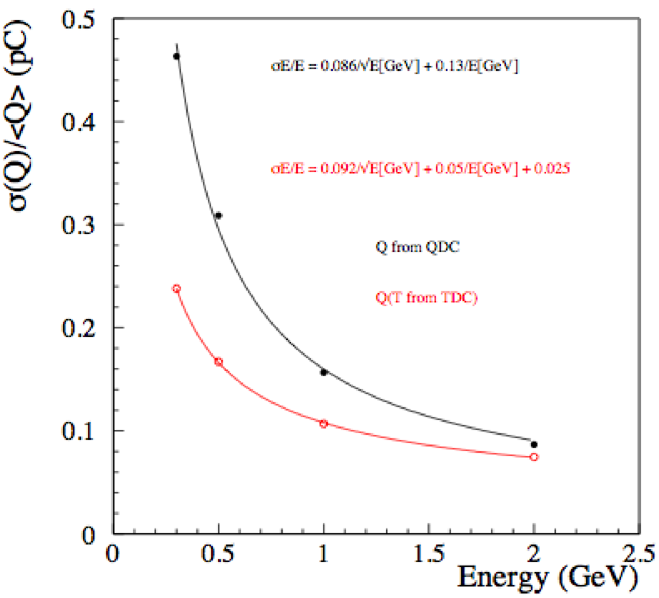

Figure 4: Energy resolution of the LAV (A2) exposed to the PS-T9 electron beam.