FORCE

Measurement of pion and Kaon production by 30 GeV protons off the T2K target in the NA49 apparatus at CERN

Joined request by

Prof. A. Ereditato
Physikalisches Institut der Uni. Bern (UNIBE)
Prof. A. Blondel (Principal )
DPNC, Section de Physique, Univ. de Genève (UNIGE) ;
Prof. A. Rubbia
Institute of Particle Physics ETHZ (IPP-ETHZ),

1. Research plan

The field of neutrino physics is certainly one of the most active in particle physics today, and for good reasons. It is by now well established that neutrinos have mass and that the three families mix. In the Standard Model, neutrinos are massless, and there is no question that massive neutrinos require either a new ad-hoc conservation law or new phenomena beyond the present framework, with a possible link to the grand unification scale via the see-saw mechanism.

A deep field of research is thus open, that could last several decades and culminate with the discovery of leptonic CP violation – a key ingredient in the understanding of the baryon-antibaryon asymmetry of the universe. Because observation of CP violation in neutrino oscillations requires appearance experiments, accessible at accelerators only, an important investment in accelerator-based neutrino beams and experiments is called for. The CHIPP Roadmap places neutrino physics as one of the three pillars of particle physics in Switzerland, and strongly recommends an active and visible participation of the Swiss groups in the J-PARC neutrino programme in Japan. The J-PARC neutrino experiment is now approved since December 2003 under the name of T2K experiment.

The neutrino group at UNIGE has participated in the T2K experiment since its early days in 2002, with participation in the design, R&D and now construction of the TPC modules for the ND280 near detector. The ETHZ group (A. Rubbia) and Prof. Ereditato have been involved for several years as well in the conceptual design of a Liquid Argon TPC fine-grained detector for the possible 2 km near detector location. In November 2006 the ETHZ and UNIBE groups officially joined UNIGE in T2K, as a follow up of their neutrino physics programmes at the CERN-Gran Sasso, making the Swiss group one of the important national components of the collaboration.

Since the T2K beam line, partly because of the very high foreseen intensity, comprises no device suited for absolute flux normalization, a measurement of pion and kaon particle production by 30 GeV protons on Carbon (the T2K conditions) would be highly beneficial to
the experiment. This can be done using the NA49 apparatus at CERN. A proposal to this effect was submitted in November 2006, and discussed at the SPSC on the 6th of February 2007. The Swiss groups have played a leading role in the promotion and writing of the neutrino-related part of the proposal. These measurements are of crucial importance for some of the measurements to be performed by the T2K experiment already in the first few years, and a first proton run capable of providing a first set of data for T2K was recommended to take place already in fall 2007 and approved at the CERN research board on the 21st of February 2007.

The agreed contributions of the Swiss groups to T2K are summarized in the attached draft MOU. They comprise:

- the mechanical construction and testing of the TPC readout modules (UNIGE)
- the responsibility of the refurbishment, shipping and field measurements for the ND280 magnet (ETHZ, UNIBE)
- the contributions to the upgrade of the NA49 spectrometer to allow precision measurements of the particle flux (all groups)

These contributions should be added a common interest in the R&D towards a fine grained detector for the 2 km near detector station.

The present FORCE request of 125 kCHF addresses only the Swiss groups contribution to the 2007 run of NA49 future, for which resources are needed in september 2007. We plan to submit another common FORCE request in september 2007 addressing extensively the other contributions.

**Participants**

Bern: A. Ereditato (Prof., group leader), M. Hess (Electr. Engineer), I. Kreslo (Postdoc), M. Messina (Oberassistent), U. Moser (Professor), C. Pistillo (Postdoc), B. Rossi (PhD student), N. Savvinov (postdoc), H-U. Schuetz (Mech. Engineer), NN (PhD student)

Geneva: A. Blondel (Prof., group leader), A. Bravar (MER=senior research and teaching scientist), M. Di Marco (Post doc), 2 PhD students, [+ part time: P. Bene (electronics engineer) ]

ETHZ: A. Badertscher (Senior Research scientist), W. Fetscher (Tit. Prof.), M. Laffranchi (Senior postdoc), L. Knecht (Mech. Technician), A. Marchionni (Senior Postdoc), A. Meregaglia (postdoc), G. Natterer (Electronic Engineer), A. Rubbia (Prof., group leader), T. Strauss (PhD student), T. Viant (Software Engineer) + request two additional PhD students.
2. The need for hadron production measurements for T2K

The study of neutrino oscillation, or in more general terms, the study of neutrino masses and mixings is at present one of the most challenging topics in neutrino physics. From the recent results of neutrino oscillation and other experiments a clear picture emerges of the phenomenology of neutrino mass and mixing. Mixing between the second and third generation neutrinos are found to be close to maximal, while the one between the first and second is large, but not maximal. For the 1-3 mixing only upper limits are available. Recent experiments indicate unique solutions for the values of the atmospheric mass difference ($\Delta m_{23}^2$) and the `solar' mass difference ($\Delta m_{12}^2$) in a range such that there are chances to study CP violation in the neutrino sector in the future, provided the value of $\theta_{13}$ is large enough. High-precision measurements of the other angles will provide insight into the mixing mechanism.

The T2K experiment will study oscillations of an off axis neutrino beam between the J-PARC accelerator and the Super-Kamiokande detector. The first phase of the T2K experiment (2009 - 2014) is aimed at i) the discovery of the $\nu_\mu \rightarrow \nu_e$ transition and measurement of the unknown mixing angle $\theta_{13}$, ii) a more accurate determination of the atmospheric parameters $\theta_{23}$ and $\Delta m_{23}^2$ by measuring the $\nu_\mu \rightarrow \nu_\tau$ disappearance, and iii) the measurement of neutral current events to search for possible transitions to sterile neutrinos, with more than an order of magnitude better sensitivity compared to any previous experiment.

The neutrino beam is produced from the decays of pions and kaons created in the interactions of the 30 GeV J-PARC proton beam on a carbon target. In a second phase the proton beam energy can be increased up to 50 GeV. The resulting neutrino flux will be measured in the Super-Kamiokande detector located at a distance of 295 km from the neutrino source. T2K adopts an off axis beam (OAB) configuration, in which the beam axis is displaced by a few degrees from the far detector direction. The OAB method yields a low energy neutrino beam with a narrow energy spectrum and a small high-energy tail. The resulting beam intensity is 3 times higher compared to a momentum selected on axis beam. By varying the OAB angle the neutrino beam peak energy changes and it can be tuned to the oscillation maximum to maximize the sensitivity to the neutrino oscillation parameters. For the distance of 295 km and $\Delta m_{23}^2 = 3 \times 10^{-3}$ eV$^2$ the corresponding peak energy is about 0.8 GeV and the angle of the OAB is 2.5 degrees Figure 1 (left plot) shows the neutrino spectrum as a function of the neutrino energy at the near and far detector locations. A drawback of this method, however, is that the characteristics of the beam change rapidly with angle. Detailed understanding of the beam production and properties are therefore required to minimize the systematic uncertainties.

In a long baseline neutrino oscillation experiment, the neutrino flux is measured in a detector far from the neutrino source (far in this context means L/E >> 1, where L is the distance from the source and E the neutrino energy) and compared with a prediction based on the neutrino flux unmodified by oscillations. A deviation in the measured neutrino flux from the predicted one is interpreted as evidence for neutrino oscillation. A well-known technique to predict the neutrino flux at the far detector (Super-Kamiokande) is to measure the flux in a near detector (ND280), which intercepts the beam at a distance where the effect of oscillations is negligible. If both detectors are sufficiently far from the neutrino source they will accept the same solid angle. In this case the source can be considered point-like and the ratio of the fluxes in the two detectors is accurately predicted by the squared ratio of the distances from the source and
the flux ratio doesn't depend on the neutrino energy. In an ideal case, all systematic uncertainties would cancel out by using the measured spectra in the near detector. In practice, however, the near detector is different from the far detector in terms of solid angle acceptance, materials, and responses. The challenge in understanding the neutrino beam is that only the product of neutrino flux, neutrino cross section and detection efficiency is observable and the details of the production mechanisms of the beam have to be known and understood. The near detector sees the whole length of the pion decay channel under different angles: the closer its location to the decay tunnel the larger the sensitivity to the finite length of the decay tunnel and broader the accepted OAB angle. That leads to a complicated far-to-near spectrum ratio shown in Figure 2. The peak position is shifted to a higher energy at the far site than at the near site, resulting in a maximum in the flux ratio around 0.6 GeV and the positive slope in the flux ratio up to 1 GeV. The width of the energy distribution is also somewhat wider in the 280 m near detector than in the far detector. Moreover, in the presence of backgrounds, the background subtraction requires the knowledge of the neutrino flux spectrum. Since the appearance of electron neutrinos is a key measurement, it is critical to understand the flavor composition of the neutrino beam. \( \nu_e \) contamination of the neutrino beam is a significant source of background for the \( \nu_e \) appearance signal and \( \theta_{13} \) measurement. The subtraction of this background requires a precise prediction of the \( \nu_e \) energy dependent flux at Super-Kamiokande. The source of the \( \nu_e \) flux are the decays of kaons (K\(_{e3}\) channel), which are the dominant component, and the \( \pi \rightarrow \mu \rightarrow e \) decay chain (see Figure 1, right plot). Therefore, one has to characterize the production of kaons with high accuracy, as well. Note also that the high-energy tail in the \( \nu_\mu \) spectrum originates from kaon decays.

Figure 1: Left: Neutrino fluxes for a 2.5\(^0\) OAB beam as a function of the neutrino energy \( E_\nu \) at the near (full line) and the far detector locations (dashed line) predicted by the T2K beam Monte Carlo simulation. Right: Contributions to the electron neutrino flux from different parent decays. The exact composition depends on the relative production cross sections for the parent particles. The precise description of the beam requires measurements of \( \pi, K, \) and \( K^0 \) production.

It has become clear, given the available instrumentation in the T2K beam line, that a precise (2 - 3%) measurement of the pion and kaon production off the T2K production target is mandatory and that it would have a strong impact on the physics results. Given that the T2K experiment is a higher statistics one compared to K2K (100 times), the impact of the
systematic uncertainties is all the more relevant. There exist no data on hadro-production in the energy range of 25-50 GeV where the J-PARC PS is expected to operate.

The first obvious physics case is that the availability of an absolute flux determination will allow a measurement of total neutrino cross sections in the near detector, with the flux related uncertainties well defined from direct hadro-production measurements rather than from uncertain model extrapolations. The second motivation is the better evaluation of the far to near flux ratios (Figure 2) for muon neutrinos, to which the determination of the neutrino oscillation parameters $\Delta m^2_{23}$ and $\sin^2\theta_{23}$ is very sensitive, and for electron neutrinos, which constitute an irreducible background in the search for the $\nu_\mu \to \nu_e$ transition, which will determine the parameter $\theta_{13}$.

![Figure 2: The far-to-near ratio for the T2K ND280 as a function of reconstructed neutrino energy. Left the $\nu_\mu$ beam, showing the characteristic peak around 600 MeV due to broadening of the off-axis Jacobian peak in the ND280 detector. Right the $\nu_e$ beam, stemming mostly from charged and neutral kaons at high energy and muon decays at low energy. The slope and the ratio itself are sensitive to the K/$\pi$ ratio.](image)

The absence of data on particle production by 30 GeV protons off carbon implies that one has to rely on interpolations between other data points. For Carbon the nearest available points concern 12 GeV (HARP data for which no information is yet available on K production) and 158 GeV (from NA49 data). The data for the nearest nucleus available, Beryllium, are inconsistent for what concerns kaon production. The models implemented in Monte Carlo simulations lead to sizeably different predictions, the effects of which are quite visible on the calculated far-to-near ratio, as shown in Figure 3. These differences of up to 20% lead to sizeable (and poorly known) systematic errors on the determination of atmospheric parameters. A full discussion is given in a note prepared for the SPSC\textsuperscript{4}. The improvement to the T2K measurements of oscillation parameters can be summarized as follows:

- for the atmospheric measurements the statistical precision of T2K phase I (5 years at an average proton beam power of 0.75MW) is $\delta(\Delta m^2_{23}) = 3 \times 10^{-5}$ while the systematic error without the NA49 measurements could be as large as $\delta(\Delta m^2_{23}) = 10^{-4}$. For the mixing angle the statistical error is $\delta(\sin^2\theta_{23}) = 0.01$ while the systematic errors without the NA49 measurement could be as large as $\delta(\sin^2\theta_{23}) = 0.03$. The other systematic errors in these measurements are associated with normalization and event topologies and should be resolved by the near detector system with a precision comparable to the statistical error. The resulting improvement that the NA49 measurements can bring about are sketched in Figure 4.
for the $\nu_\mu \rightarrow \nu_e$ appearance search, the requirement on the far-to-near ratio to ensure a reliable prediction of the background to this search is a systematic precision of $\lesssim 10\%$. Without NA49, this error can be as large as 15%, and poorly estimated. The absence of NA49 measurements would degrade the sensitivity to $\theta_{13}$ (statistically $\sim 0.008$) by 10-20% in a rather unreliable way. Here the case is as much in the reliability of a possible discovery than in the achievable sensitivity.

Figure 3: Comparison of different hadro-production model predictions for the far-to-near flux ratio. Model predictions differ by 20%, while T2K requires this ratio to be determined to 2-3% uncertainty only.

Figure 4 Left: Present measurements of atmospheric parameters. Right, present situation for the yet unknown mixing angle $\theta_{13}$. The expected precision from T2K phase I is shown on both graphs. The improvements to the atmospheric parameter measurements brought about by the NA49 measurements are sketched on the left panel.
3. The NA49 apparatus

Several opportunities to measure the pion and kaon yields in the phase space of T2K have been explored: the COMPASS experiment at CERN, the MIPP experiment at Fermilab, and the NA49-future experiment at CERN. Figure 5 shows the angle vs. momentum distributions of pions and kaons yielding the neutrinos observed in the near detector and Super Kamiokande. From this figure it is clear that an apparatus with very large angular acceptance at relatively low momenta and excellent particle identification capabilities in this range is needed. The most promising option is the use of the upgraded NA49 detector at CERN. Monte Carlo studies have indeed shown that NA49 apparatus has the acceptance, tracking resolution, and particle ID capabilities needed for this measurement (Figure 6).

Figure 5: Angular and momentum distribution of pions (left) and kaons (right) yielding the T2K neutrino beam observed in the near detector and Super Kamiokande.

Figure 6: Acceptance of the NA49 ToF in the $\theta$ vs. $p$ plane for charged pions for a magnetic field integral of 1 Tm. Left, nominal disposition of the ToF wall. Right, ToF wall fully closed. In the phase space of the T2K beam, the overall acceptance is around 15%.
The NA49 experimental apparatus at CERN is a large acceptance hadron spectrometer (Figure 7). The core of the experiment are the Time Projection Chambers with an overall volume in excess of 40 m$^3$ and 180,000 readout pads. Two TPCs are placed in the magnetic field of two super-conducting dipole magnets (VTPC-1 and VTPC2 in Figure 7). This allows precise measurement of the particle momenta p with a resolution $\sigma(p)/p^2 \sim (0.4 - 7) \times 10^{-4}$ (GeV/c)$^2$. Other two TPCs (MTPC-L and MTPC-R) are position downstream of the magnets on each side of the beam and are optimized for high precision measurement of ionization energy loss $dE/dx$ (relative resolution around 4%) which provides a mean of determining the particle mass. The particle identification capability of the TPCs is augmented by two Time of Flight scintillator detector arrays consisting of 1,700 elements (with phototubes) with a resolution $\sigma \sim 70$ ps. The trajectory of incident beam particles is measured with 3 sets of proportional chambers. Beam particles are identified with a beamline Cerenkov counter. Events are selected with a simple interaction trigger formed of several scintillating counters position on the beamline upstream and downstream of the target.

![Figure 7: Artist view of the NA49 apparatus (left) and top view (right) showing the tracking TPCs and Time of Flight walls.](image)

The NA49-future physics program consists of three subjects:
1. measurement of hadro-production in proton-carbon interactions needed for the T2K experiment;
2. measurements of hadro-production in proton-proton and proton nucleus interactions as a reference to nucleus-nucleus collisions;
3. measurements of hadro-production in nucleus-nucleus collisions with the aim of identifying the critical point of strongly interacting matter.

The main goal of the hadro-production measurements for T2K are the following:
1. predict the far to near spectrum ratio for $\nu_\mu$ and $\nu_\tau$ with the required precision
2. predict the near spectrum to be compared with the near detector (ND280) measurements with the required precision

The proposed measurements will be performed over a period of five years. During 2007 and 2008 hadro-production data for the T2K experiment will be taken. In particular, during the 2007 run the whole experimental setup will be brought back to operation and a first data set of $3 \times 10^6$ events will be collected. In 2008 systematic studies of charged pion, charged and neutral kaon production at the energies of the J-Parc proton synchrotron (30 to 50 GeV) will be performed. A sample of $2 \times 10^7$ events is expected.
4. Status of the project and requirements for the first run

The NA49-future collaboration has submitted a proposal to CERN\(^2\) to “Study Hadron Production in Hadron-Nucleus and Nucleus-Nucleus Collisions at the CERN SPS” in November 2006. An addendum followed in January 2007. The proposal has been formally presented to the SPSC on the 6\(^{th}\) of February, 2007 by M. Gazdzicki (NA49 spokesperson).

The SPSC has recommended the approval of a first proton run for the fall of 2007. On the 21\(^{st}\) of February the CERN Research Board has formally approved this first proton run. Further approvals will be granted on the base of the 2007 performance and timely analysis of the data collected.

The last time the experiment took data was in 2002. The NA49 apparatus has been tested in a 5 days long test run in August 2006. The performance of the NA49 TPCs has not shown any sign of degradation since the beginning of the NA49 experiment in 1994. In addition, this test demonstrated the ability of the new collaboration to operate the NA49 apparatus. All the NA49 equipment is still in very good shape and functioning. Due to the aging, however, refurbishment and repair of some components is necessary. Also, to deal with higher event rates, an important upgrade of readout electronics is needed. The total estimated cost for the repairs and upgrades is around 1.5 - 2.0 MCHF. For comparison, the total cost of experiment was around 20 MCHF (1994 value). The cost of operation and maintenance of the experiment is estimated to be around 150 kCHF per year.

The following upgrades / repairs are planned for the 2007 proton run (for more details, including cost estimates, see Table 5 in the proposal\(^2\) and Table 2 in the addendum):

- repair of the TPC gas system
- upgrade of the TPC cooling system (electronics)
- upgrade of the ToF readout
- development of a new slow control and monitoring system for the TPCs
- upgrade of the DAQ and migration to the CERN Central Data Recording
- refurbishment of the Beam Position Detectors
- production of graphite targets
- production of prototype electronics for the upgrade of the TPC readout
- trigger

The estimated cost of upgrades, maintenance and running for 2007 is summarized the following table. The total cost of maintenance and operation of the experiment for the following years is estimated around 150 kCHF per year.

<table>
<thead>
<tr>
<th>item</th>
<th>cost (kCHF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pool electronics</td>
<td>60</td>
</tr>
<tr>
<td>TPC maintenance and gas</td>
<td>30</td>
</tr>
<tr>
<td>upgrade of the TPC cooling system (electronics)</td>
<td>20</td>
</tr>
<tr>
<td>upgrade of the ToF readout</td>
<td>20</td>
</tr>
<tr>
<td>TPC slow control and monitoring</td>
<td>33</td>
</tr>
<tr>
<td>data acquisition (DAQ) and data recording (DCR)</td>
<td>5</td>
</tr>
<tr>
<td>Beam Position Detectors</td>
<td>10</td>
</tr>
<tr>
<td>graphite targets</td>
<td>15</td>
</tr>
</tbody>
</table>
Since spring 2006, the Swiss groups involved in T2K (University of Bern, University of Geneva, and ETH Zurich) have taken the leadership of the work on the neutrino beam properties within the T2K collaboration, edited the neutrino part of the NA49-future proposal, and worked intensely to build up the NA49-future collaboration on the neutrino side. A team sufficiently strong to carry out the measurement and to perform the analysis is being assembled. We are leading the preparations for the 2007 proton run, and in particular the studies and optimization of the NA49-future apparatus and trigger configuration with respect to the neutrino requirements. We plan to contribute to the analysis of the data that will be taken in 2007 and 2008.

The TPCs are the core of the experiments. The correct functioning and operation of these detectors is mandatory for collecting a high quality level data sets. We plan to contribute to all aspects of the refurbishing, repair, upgrade, maintenance, and operation of the TPCs for the 2007 run, in particular the gas system, electronics cooling system, and monitoring (slow control).

The financial request for 2007 from the Swiss groups is summarized in the Table below. Neutrino groups from T2K in Na49-future will contribute around ½ of the required funds for the upgrade and maintenance of the experimental apparatus. This figure doesn’t include the equipment specifically required for the Heavy Ion program. These required funds are essential to bring the NA49 apparatus back to top performance and full efficiency.

<table>
<thead>
<tr>
<th></th>
<th>UNIGE</th>
<th>UNIZE</th>
<th>ETHZ</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>common fund</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>TPC maintenance + gas</td>
<td>20</td>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>TPC cooling system</td>
<td></td>
<td>20</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>TPC monitoring</td>
<td></td>
<td></td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>pool electronics</td>
<td>16</td>
<td>16</td>
<td>13</td>
<td>45</td>
</tr>
<tr>
<td>Total</td>
<td>41</td>
<td>41</td>
<td>41</td>
<td>123 kCHF</td>
</tr>
</tbody>
</table>

**TPC gas system and its infrastructure**

The Time Projection Chambers are the main components of the NA49 experimental apparatus. There are four TPC modules: two modules, referred to as VTPC1 and VTPC2, are located in line in the magnetic field downstream of the target, two big TPCs (Figure 7), referred to as MTPC-l and MTPC-R, are located behind the magnet on each side of the beam. The gas volume of each large TPC is around 16 m³. The operation of a Time Projection Chamber requires filling with an appropriate gas mixture, not containing electronegative additives like oxygen. The level of naturally occurring impurities should be controlled. The system providing the controlled gas mixture to the TPC should assure stability of the gas mixture composition with sufficient purity over long running periods.
During the whole NA49 experiment (1994-2002) all TPCs performed very well with a very low failure rate. The automated gas mixing/filling system, the drift velocity and gas gain stability monitoring system were well designed and made with high quality. They were filled with and Ar/CO$_2$/CH$_4$ gas mixture. During the whole NA49 experiment (1994-2002) all TPCs performed very well with a very low failure rate. The automated gas mixing/filling system, the drift velocity and gas gain stability monitoring system were well designed and made with high quality.

The whole system was made operational in August 2006 for the first time after four years in stand-by. The NA49-future experimental team gained the necessary expertise on the technical aspects of the TPC operation and the TPC gas and high voltage supply systems during this test period. The full gas mixing system was used in all designed modes of operation and using all functionality: purge with the selected and controlled gas mixture, recirculation with the TPC bypass and through the TPC, recirculation with automatic control of gas overpressure in the TPCs, recirculation with filtering (for the run filters were not regenerated after their last use in 2002), monitoring of oxygen level and humidity in all TPCs, activation of the drift velocity monitor (for MTPC-L and VTPC2 only).

During the test run period the TPCs were filled with an Ar/CO$_2$ gas mixture. The tests showed that the TPCs can be efficiently operated with this gas mixture. The reasons to choose this mixture are: a) simpler gas system with two components rather than three, which can be better stabilized over long data taking periods, b) no use of flammable gases, which represents several advantages from the safety point of view, and c) cost effectiveness. As the charge loss rate in the presence of oxygen traces is proportional to the content of the CO$_2$, the CO$_2$ amount was lowered to 5%. This level of CO$_2$ provides also sufficient quenching power to the gas mixture. The nominal drift voltages were applied to all TPCs: 19 kV and 13 kV for MTPC and VTPC, respectively. The applied drift field provided drift velocities which allowed charge collection from the whole TPC depth, thus the whole volume of each TPC was active. In this range, drift velocities are unsaturated, i.e. they change almost linearly with electric field. The exact measurement and control of drift velocity and its correction for pressure and temperature variations therefore becomes a key issue to achieve a high quality level of experimental data.
Although no major upgrade of the gas system is needed, a full revision and servicing of all elements of the gas system is needed. Four compressors need to be serviced, the spare one will be repaired or replaced by a new one. 10 units of gas flow meters/controllers providing the control of the working gas mixture will be re-calibrated. Two oxygen sensors will be cleaned; the purchasing of a spare oxygen sensor is planned. Two existing oxygen control units will be re-calibrated. Functionality of the humidity control units will be validated; the purchasing of new control units with remote monitoring is considered. All six gas filters have to be regenerated to provide oxygen cleaning capabilities; the work will be done in the existing NA49 gas cage as the stand for the filter regeneration exists there and is operational. Five drift velocity detectors exist and will be used, 3 of them need repair (replacement of broken wire in the single wire counter, two charge amplifiers should be fixed). The status of the gas gain monitor (8 double units) has to be checked. There is a good chance that no intervention will be needed; eventual intervention should not cause technical problems and should be easy to make using existing resources. In additional 30 standard premix Ar/CO$_2$ gas bottles are required for the one month long run in 2007.

The total estimated cost for this work is around 20.000 CHF.

The front end electronics is directly connected to the TPC. Proper cooling of the electronics is mandatory in order to guarantee the temperature stability of the TPCs. The cost of the revision, repair, and replacement of faulty components of the water cooling system is expected to be of 20.000 CHF.

**TPC slow control and monitoring**

The Slow Control system (SC) of the NA49 experiment was developed more than 10 years ago as a set of separate NI LabVIEW v.4.1 based applications. Among them one can distinguish:

- a program for low voltage control and temperature monitoring of the TPCs,
- a general program for monitoring TPC related parameters,
- a program for control of the TOF detector,
- a program for monitoring the other detectors, scalers, and trigger.

This system is not functioning properly any more and will be replaced with a state of the art control system. In addition slow control data will be saved in a data base easily accessible during the analysis of the experimental data. Moreover additional TPC parameters, like the oxygen and humidity content, gas flow, compressor status, and overpressure in the TPC will be monitored and recorded. The new SC system will be based on EPICS2 (Experimental Physics and Industrial Control System). EPICS is a set of open source software tools, libraries and applications developed over the 10 past years.

A two step upgrade procedure is suggested. First, for the 2007 run it is planned to deploy a new DCS based on EPICS, but with existing LabVIEW applications integrated with it. This integration requires porting of all applications to LabVIEW v.8.x running on PCs with Linux, change of the communication modules to reflect hardware replacements and addition of network capabilities. In a second phase for the 2008 run the LabVIEW applications will be coded in C/C++ and will be included into the general EPICS architecture as IOC (Input Output Controllers).
The following hardware changes are necessary:
• replace all MacIntosh computers by one PC with a dual core processors running Linux;
• replace CAMAC crate controllers and the VME embedded controller by the CAMAC Ethernet Controller C111C (produced by CAEN) and a VME embedded computer with PPC processor (manufactured by CES);
• add to the system a GPIB card by National Instruments.

The total cost of the hardware upgrade is estimated to be 33 kCHF. The cost will be shared between the Swiss groups (ETHZ, 23 kCHF) and the Warsaw University of Technology.

TPC readout upgrade

The TPC readout electronics was developed about 15 years ago and is based on relatively old technology. The maximum readout speed is around 10 events / second. In order to achieve the event rates and statistics required for the physics program outlined in the NA49-future proposal the TPC readout speed has to be increased by at least a factor of 10. The Swiss groups are already collaborating with CERN and the KFKI Research Institute for Particle and Nuclear Physics in Budapest in the design and production of prototype electronics for the upgrade of the TPC readout system to be tested this fall.

Two scenarios are presently under study:
1. replacement of all the digital data handling part downstream of the front end electronics;
2. replacement of all TPCs electronics (including the front end).

During the 2007 run two sectors of a MTPC will be equipped with prototype electronics. That will allow us to extensively test both systems during the 2007 run. A final decision will be made in the fall of 2007. Funds in the order of 40,000 CHF to carry on the prototyping of the new readout electronics have been asked for in a separate request.

A separate FORCE request covering also the upgrade of the TPC readout electronics will be submitted this fall.

1 Particle Physics in Switzerland : Status an outlook of research and education, the CHIPP roadmap, http://www.chipp.ch/chipp-meet-roadmap.html

2 Study of Hadron production in Hadron-Nucleus and Nucleus-Nucleus production at the CERN SPS , The NA49 Future Collaboration CERN-SPSC-2006-034 SPSC-P-339 (Nov. 3 2006); Addendum (30 January 2007) attached documents

3 Summary of proposed Swiss contributions to the T2K experiment (draft internal MoU) 20.10.06 attached document

4 Impact of NA49 measurements on T2K experiment, Ken Sakashita, Takeshi Nakadaira, T.Kobayashi (KEK) Alain Blondel and Alessandro Bravar (Geneva), memorandum to the SPSC chair, attached document

5 Requête subside FNS no 200020-113491