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NA48/2 and P-326 Status Report

1 Introduction

The purpose of this memorandum is three-fold:

1. **Provide a status report on the NA48/2[*] physics analysis**

   Physics results achieved since the last SPSC report by the NA48/2 Experiment are reported. These results and a brief outlook on the status of the remaining analyses are described in Section 2.

2. **Inform the SPSC on the status of the P-326[†] R&D**

   About a year ago, the CERN Research Board has endorsed the SPSC recommendation to support P-326 as R&D to address the feasibility of an in-flight experiment to address, among other things, the very rare decay $K^+ \to \pi^+ \nu \bar{\nu}$. The progress achieved so far is briefly summarised in Section 3.

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3. **Motivate the P-326 beam request for the full 2007 SPS run**

   According to the draft SPS schedule for 2007, the SPS will be operated exclusively as LHC injector only from mid November 2007 onward. This opens up the opportunity to have protons during a considerable amount of time in 2007 and to allow us to:

   - Perform test beams of the prototypes of the new detectors in an environment as close to the final one as possible.
   - Accumulate kaon decays to measure the $R(K)$ ratio as outlined in the SPSC-M-745 document which was submitted to the SPSC for information. This memorandum updates the information contained in M-745 taking into account further studies and the likely conditions which will be encountered during a 2007 run. These possibilities are proposed in Section 4.

The possibility to significantly improve the measurement of $R(K)$ already in 2007 is strengthening the Collaboration attracting new groups. In addition, the final state (one charged track + "nothing") is similar to that of $K^+ \to \pi^+ \nu\bar{\nu}$ thus allowing one to compare the expected kinematics resolution with actual data.

2 Status of the NA48/2 analysis

2.1 $K \to 3\pi$ decays

The main goal of the experiment is to search for direct CP-violation in $K^\pm \to (3\pi)^\pm$ decays, which is defined by the asymmetry $A_g = (g^+ - g^-)/(g^+ + g^-)$, where g^+ and g^- are the slope parameters describing, respectively, the linear dependence of the K^+ and K^- decay probabilities on the u kinematic variable (related to the *odd* pion energy in the CM system) of the Dalitz plots. A precise measurement of asymmetry parameters could allow to search for phenomena beyond the Standard Model (SM) predictions [1].

Measurements of charged CP-violating asymmetry based on the 2003 run were performed for both decays

$$K^\pm \to \pi^\pm \pi^+ \pi^- \tag{1}$$

and

$$K^\pm \to \pi^\pm \pi^0 \pi^0 \tag{2}$$

and the obtained results have been published in [2], [3]. Preliminary results, based on the whole accumulated statistics in 2003 and 2004 runs were obtained and presented at several conferences [4], [5], [6], [7], [8], [9], [10], [11] including the Rochester conference in Moscow [12]:

- the asymmetry measurement based on $3.1 \cdot 10^9$ selected decays (1) is:

  $A_g^c = (-1.3 \pm 1.5_{stat} \pm 0.9_{stat(trig)} \pm 1.4_{syst}) \cdot 10^{-4} = (-1.3 \pm 2.3) \cdot 10^{-4}$

- the asymmetry measured for $91 \cdot 10^6$ selected decays (2) is:

  $A_g^n = (2.1 \pm 1.6_{stat} \pm 1.0_{syst} \pm 0.2_{ext}) \cdot 10^{-4} = (2.1 \pm 1.9) \cdot 10^{-4}$.

The presented results are compatible with the data already published in [2], [3] and with the SM predictions [13]. The precision of these measurements is limited by statistics and is more than one order of magnitude better related to the results of other experiments [14]. The corresponding publication is in preparation. Thus the main goal of the NA48/2 experiment is achieved. However, an additional information for charged asymmetry study is available using a beam spectrometer KABES. The corresponding analysis will be continued.

Thanks to the record-breaking accumulated statistics of decays (2) and the high resolution of the liquid krypton electromagnetic calorimeter (LKr), a new effect was observed in the $2\pi^0$ mass spectrum, the so called "cusp effect", which is due to pion re-scattering $\pi^+\pi^- \to \pi^0\pi^0$ process. The study of the observed effect allows one to measure with a high precision a basic χPT parameter, the $\pi\pi$ scattering length [15]. The first result based on part of the statistics (2003 run) was obtained and published in [16] and reported at several conferences [17], [18], [19]:

$$(a_0 - a_2)m_{\pi^+} = 0.268 \pm 0.010_{stat} \pm 0.004_{syst} \pm 0.013_{ext}, \tag{3}$$

and

$$a_2 m_{\pi^+} = -0.041 \pm 0.022_{stat} \pm 0.014_{syst}. \tag{4}$$

These measurements were performed using an improved Cabibbo-Isidori theoretical framework [20] and neglecting the quadratic Dalitz plot slope parameter k as suggested by PDG 2005. If the correlation between a_0 and a_2 predicted by Chiral Perturbation Theory is taken into account the following result is obtained:

$$(a_0 - a_2)m_{\pi^+} = 0.264 \pm 0.006_{stat} \pm 0.004_{syst} \pm 0.013_{ext}. \tag{5}$$

From the same fit the following slope parameters of the Dalitz plot are extracted:

$$g_0 = 0.645 \pm 0.004_{stat} \pm 0.009_{syst} \tag{6}$$

$$h' = -0.047 \pm 0.012_{stat} \pm 0.011_{syst} \tag{7}$$

corresponding to the functional form

$$M_0 = 1 + (1/2)g_0 \cdot u + (1/2)h' \cdot u^2 \tag{8}$$

for the matrix element.

A more precise measurement of extended parameter sets describing the Dalitz plots

$$M_0 = 1 + (1/2)g_0 \cdot u + (1/2)h' \cdot u^2 + (1/2)k' \cdot v^2 \tag{9}$$

for both decays (1) and (2) is in progress. However, a preliminary result obtained for (2) decay is already available:

$$k' = 0.0097 \pm 0.0003_{stat} \pm 0.0008_{syst}. \tag{10}$$

The corresponding changes in the g_0 and h' parameters (6) and (7) are of order 2% and 25% respectively, while the scattering length parameters (3), (4) and (5) do not change in a significant way with respect to the $k = 0$ case. Thus, an introduction of an extended Dalitz plot parameter set should change the conventional description of decays (1) and (2) in the PDG.

2.2 Rare decays

More than a million of $K^{\pm}_{e4}$ decays ($K^{\pm} \to \pi^{-}\pi^{+}e^{\pm}\nu$) has been recorded during the 2003-2004 runs. The matrix element of this decay is described by a set of form-factors and five kinematic variables (Cabibbo-Maksymowicz variables [21]). The measured variation of the phase difference between $\pi\pi$ S and P waves with the invariant mass $M_{\pi\pi}$ allows to extract a value of $\pi\pi$ scattering length. It has been extracted in the framework of the universal band [22]. Based on part of accumulated statistics (2003 run), $3.7 \cdot 10^5$ decays were selected with a background contamination of $\sim 0.5\%$. A preliminary result was obtained (1) and reported at summer conferences [19], [23], [24]:

$$a_0 m_{\pi^+} = 0.256 \pm 0.008_{stat} \pm 0.007_{syst} \pm 0.018_{theor}. \tag{11}$$

For comparison a prediction using χPT [25] is $a_0 m_{\pi^+} = 0.220 \pm 0.005$.

About $10 \cdot 10^3$ neutral K_{e4}^{00} decays ($K^\pm \to \pi^0\pi^0 e^\pm \nu$) were selected in the data of 2003 run with less than 3% background. This allowed us to measure the corresponding branching ratio (preliminary) [19], [23], [24], [26]:

$$Br(K_{e4}^{00}) = (2.587 \pm 0.026_{stat} \pm 0.0019_{syst} \pm 0.029_{ext}) \cdot 10^{-5}. \tag{12}$$

The external uncertainty corresponds to the precision of the normalization channel branching ratio (2). The obtained result is one order of magnitude more precise than existing data. This analysis will continue.

A study of charged kaon radiative decay $K^\pm \to \pi^\pm\pi^0\gamma$ was performed in order to test of high order χPT calculations. The dominant part of the amplitude is related to the Inner Bremsstrahlung (IB), however a contribution of the Direct Emission (DE) could be present as well, together with the interference term (INT) between these two amplitudes. An analysis was performed using part of the statistics (2003 run): $\sim 2.1 \cdot 10^5$ decays were selected in the region of: $T_\pi^* \leq 80MeV$, where T_π^* is the charged pion energy in the CM system. A preliminary result indicates the observation of DE amplitude and the first observation of an interference term (INT) [27], [28], [29]:

$$Frac(DE) = (3.35 \pm 0.35_{stat} \pm 0.25_{syst})\% \tag{13}$$

and

$$Frac(INT) = (-0.267 \pm 0.81_{stat} \pm 0.73_{syst})\%. \tag{14}$$

The analysis of other charged kaon rare decays is in progress.

2.3 Leptonic and semileptonic decays

A preliminary result on the semileptonic decay branching measurements

$$K^\pm \to \pi^0 e^\pm \nu \tag{15}$$

and

$$K^\pm \to \pi^0 \mu^\pm \nu \tag{16}$$

has been obtained [30], [31]:

$$\Gamma(K_{\mu 3}^\pm)/\Gamma(K_{e3}^\pm) = 0.6749 \pm 0.0035_{stat} \pm 0.0011_{syst} \pm 0.0021_{sys}. \tag{17}$$

and taking into account the known PDG data it leads to:

$$Br(K^{\pm}_{e3}) = (5.14 \pm 0.02_{stat} \pm 0.06_{syst})\%. \tag{18}$$

These measurements contribute to the resolving of long-standing problem related to the CKM unitarity.

A precise test of the SM prediction can be performed by a measurement of ration of leptonic decay branching ratios $\Gamma(K^{\pm}_{e2})/\Gamma(K^{\pm}_{\mu 2})$. The corresponding prediction of the SM is at the level of relative precision better than a permille. Preliminary result obtained in the NA48/2 experiment is [32], [33]:

$$\Gamma(K^{\pm}_{e2})/\Gamma(K^{\pm}_{\mu 2}) = (2.416 \pm 0.043_{stat} \pm 0.024_{syst}) \cdot 10^{-5}, \tag{19}$$

which is in reasonable agreement with the SM prediction. In Section 4 the prospects to measure more precisely this channel are discussed in depth. Analysis of charged kaon leptonic and semileptonic decays is continuing.

3 Status of the P-326 R&D

3.1 Consolidation efforts

It is often recognised that the NA48 detectors represents a unique world-wide facility. To remain useful as test bench towards the study of very rare kaon decays at the SPS, the LKr cryogenics, the LKr read-out, the detector controls and the DAQ system have to be consolidated.

The wisdom of the CERN PH and AT Departments has enabled us to launch the consolidation of the LKr calorimeter cryogenic system. This consolidation is currently being implemented and will make the operation of the LKr calorimeter compliant with the other LHC-era cryogenic installations at CERN.

The consolidation of the LKr read-out has also been launched with the design and construction of a prototype module, the Smart Link Module (SLM) which should allow us to replace the optical links as outlined in the next sub-section. Contrary to what one might have expected, the optical links turned out to be the weak ring of the LKr read out chain. We plan to replace parts of the online PC-farm and DAQ infrastructure.

As it became evident by exercising the tagged photon beam last October, we need to keep the facility up-to-date in order to be able to test the prototype detectors as they become available and also to measure the characteristics of the new beam.

3.1.1 The read-out of the Liquid Kripton Calorimeter

The CPD optical link [34] from the Calorimeter Pipeline Digitizer (CPD) module to the Data Concentrator (DC) was designed in 1996. The optical link modules have shown high failure rates due to their location in the hostile environment location just above the FASTBUS power supplies. In 2005 it was proposed to implement a new readout link with Low Voltage Differential Signaling (LVDS) levels and Gigabit Ethernet. For this a new CPD to LVDS card to replace the optical link card and a LVDS to Gigabit Ethernet Multiplexer module (SLM) have been developed. The Gigabit Ethernet links would be connected via network switches to read-out PCs. In order to correctly apply the zero suppression, preserving the informations near the cells over the threshold (halo expansion), the SLM modules will be able to communicate, again via the switches, between them and they will host the logic to process and pack the data. The bidirectional feature of the Ethernet link and the higher speed would make it possible to realise robust checking and to increase the control features in the CPD readout. Prototypes for both the CPD to LVDS card and for the SLM card have already been produced, and we are setting up a facility in Meyrin to test the new read-out chain. The facility will be ready by the end of 2006 and an attempt will be made to have the new LKr read-out system ready and tested for the beginning of 2007 run (end of May). Alternatively, the old read-out system will need to be maintained. The necessity to have available spares for the electronic modules involved in that read-out chain has also to be taken into account.

3.1.2 PC farm and data acquisition

The NA48 PC farm consists of five or more year old PCs. For the 2007 run an upgrade and/or replacement of both sub-detector PCs and event builder PCs is foreseen to match the new requests related to the longer duration of the spill (9.6 s). In particular the memories of the sub-detectors PCs need to be expanded in order to store all the data taken during a complete spill. Concerning the LKr sub-detector PCs, the replacement of the old PCs with new and more performant machines will meet the requirements of the new read-out. We are also exploring the possibility to upgrade and consolidate other aspects related to data acquisition and online software.

3.2 Beam

The beam design has been described in detail in the P-326 proposal. Since then no significant modifications to the design have been made. The only change is an adaptation of the beam spot at the Gigatracker to the requirements of the detector layout. As shown in the Fig. 2, 3 and 4, the full beam is now contained within a spot of 27×60 mm^2.

We wish to re-affirm the necessity of incorporating a CEDAR differential Cherenkov counter filled with H_2 at a pressure of $\simeq 3$ bar to tag the K component of the beam. Progress has been made in the choice of the Cherenkov light detectors capable of dealing with the high rate. We wish to stress that the quality of the experiment depends on the quality of the slowly extracted beam. The experiment profits from the highest possible SPS duty-cycle. We were delighted to see that at times, during the tagged photon test which took place last October, the SPS was operated at a duty cycle of 0.33, which was never achieved during the previous NA48 data taking.

3.3 Gigatracker

The main progress in the Gigatracker R&D, for what concerns the silicon pixels, can be summarised as follows:

- the requirements in sensor radiation hardness have been evaluated in more detail. Test diodes from prototype sensors wafers have been irradiated at various levels up to and exceeding the calculated nominal fluence and annealed following realistic scenarios. The results are being evaluated and a report is in preparation. An infrared laser test system has been set up to study depletion voltage and charge collection in the diodes;

- detector assemblies have been produced using the prototype sensors bump bonded to chips from the ALICE pixel readout wafers (0.25 μm CMOS). Tests have shown that the sensors are compatible with the flip-chip process and yield good quality detector modules;

- CMOS 0.13 μm has been retained as the technology of choice for the ASICs. This allows one to take advantage of the frame contract recently established by CERN with a major foundry services supplier, and of the corresponding libraries. The CMOS 0.13 μm process offers higher performance (density, speed, power) than the alternative option previously considered (CMOS 0.25 μm, used for the LHC detectors), which anyway will soon be discontinued in the European foundry;

- several major requirements in the pixel ASIC design, in terms of dimensions, power management and fast signal distribution, have been studied in some detail and a satisfactory concept has been defined. This has been possible in particular thanks to a modified beam design that allows for easier and more efficient layout of chip power and cooling;

- pixel ASIC architecture issues have been investigated and preliminary simulations have started;

- basic front-end analogue building blocks, aimed at testing the functional performance as well as the technology parameters, have been designed. They are being included in an imminent CMOS 0.13 μm MPW submission;

- a simple concept for cooling the detector has been simulated with finite-elements calculations which have confirmed the very preliminary initial estimates. Operation of the detector in vacuum, at a temperature sufficiently low to minimize radiation damage, should be feasible with a low-mass solution.

The Gigatracker material budget and detection efficiency have been studied as part of extensive simulations of the full experiment. The choice of design parameters has been verified to be suitable for the physics requirements.
At this stage, some of the most critical specifications have been understood and solutions have been identified or even worked out. However the tasks ahead are extremely challenging and require consolidating and strengthening the gigatracker silicon pixel development team at CERN, particularly in the perspective of the unexpected departure of one of the main designers. All efforts are being made to find a viable solution for which adequate support from the PH Dept. is essential.
The unique specifications of the Gigatracker have attracted a number of parties interested in other related areas, such as detectors for CLIC and for other applications. An MoU is being envisaged to establish collaborative agreements. Although the primary aim is the P-326 Gigatracker, the support of other partners may help in overcoming manpower and funding limitations.

3.4 Photon Vetoes

During the last year, the efforts of the Photon Veto Working Group have been concentrated on the following topics:

- for the large angle vetoes, the borrowing of existing prototypes and the construction of a lead/scintillating-fiber prototype for testing at the Frascati Beam Test Facility (BTF) in order to compare their performances in view of a technology choice;
- for the large angle vetoes, the implementation of a complete Geant4 simulation of the structures under study;
- for the LKr calorimeter, the measurement with a dedicated tagged photon run at the SPS of its inefficiency for photons energies below 10 GeV;
- for the Small Angle Calorimeter, the construction of a prototype based on a lead-scintillator shashlik structure and its testing during the electron run at the SPS.

3.5 Large angle vetoes

3.5.1 Prototype tests

During the last part of 2005 and the first months of 2006, the activity of the group was focused on the tuning of the test setup at the Frascati BTF. A small prototype of the KLOE calorimeter was used for this purpose. In addition, a small tile prototype (3.8 X_0) built in Protvino was tested with a NaI calorimeter as a tail catcher. From these tests, a rough measurement of the inefficiency for the detection of 0.5 GeV electrons has been obtained, but the main result is the understanding of the problems to be confronted for measurements of this type using the available BTF setup. At the same time, studies continued concerning the performance of the tagged photon beam, which will provide photons with energies ranging from 50 MeV to about 500 MeV

INFN and Fermilab have agreed to transport to Frascati for extensive tests the prototype calorimeter built for the CKM experiment. This detector is made with lead and scintillator tiles (80 layers). Upon arrival in Italy, it will undergo an extensive series of tests to measure its inefficiency, time response, and energy resolution for photons and electrons below 1 GeV. In parallel, in Frascati, construction is nearing completion of a lead/scintillating-fiber prototype for comparison with the tile solution. The lead/fiber prototype is U-shaped, with a fiber length of about 310 cm, an inner radius of 60 cm (equal to the inner radius of the first large angle veto counter as proposed), and a radial thickness of 12.5 cm, which is enough to contain showers with a minimal cost. The longitudinal structure differs from the standard KLOE design in that over the last 8.2 cm in depth, the scintillating fibers are alternated with lead wires. This solution provides better containment while minimizing cost and longitudinal dimensions. The construction of the structure is complete; approximately two months are needed to instrument it with light guides and PMs. Beam tests of this prototype (together with that on loan from CKM) are planned for the beginning of 2007. Results should be available by spring.

3.5.2 Geant4 simulation

Two simulation projects using Geant4 have been started in Rome. The first is aimed at the simulation of the whole set of large angle counters using parameterizations of the light response. This will allow performance evaluation (inefficiency, edge effects, etc.) with different geometries and materials. The second project is intended to accurately simulate the generation and transport of the light in one tile equipped with WLS fibers for light collection. A response matrix for many points on the surface is computed and could be used as input for the parameterization-based simulation, to better reproduce the real behaviour of the detector.

3.6 Liquid Krypton calorimeter

During the first two weeks of October 2006, data with a 25 GeV electron beam was taken with the NA48 detector in order to extend the measurement of the LKr photon detection efficiency obtained above 10 GeV with the 2004 $K^+ \to \pi^+\pi^0$ data down to a few GeV. Tagged photons were obtained from electron bremsstrahlung in the Kevlar window and in the material of the first two drift chambers. A total of $2.8{\cdot}10^8$ electrons were collected; data analysis is in progress and preliminary results may be available by the time of the open SPSC presentation.

3.7 Small angle vetoes

In the last hours of the October electron run, a prototype of the Small Angle Calorimeter was installed in the space between the two planes of the hodoscope and tested using electrons. The detector has a shashlik structure with layers of 1.5 mm (Pb) + 1.5 mm (Sci), for a total of $\approx 17\ X_0$. WLS fibers with a spacing of 9.5 mm longitudinally traverse the layers, exit from the rear face, and are group and read out by 4 PMs. The active area at the front face of the detector is $20{\times}20$ cm^2. About 10 million electrons have been collected with different impact positions on the SAC prototype. The analysis of the data is in progress.

3.8 Straw Tracker

To measure charged tracks six tracking detectors, each formed by 4-coordinate chambers composed of straw tubes, have to be built. The main properties of such tracking detectors are:

- spatial point resolution better than 130 μm per straw,
- less than 0.1% of radiation length for each coordinate station (0.5% radiation length for 1 chamber),
- straw detectors have to work in vacuum.

The goal of the Straw tracker P-326 R&D is to construct a prototype able to comply with the specifications. In addition, one needs to advance on the conceptual design of all detector constituents, including the electronics and the software, both for simulation and reconstruction. The description of the technical design parameters, together with pictures of the available samples and technical drawings of the prototype and of the electronics can be found in a separate document [35].

3.8.1 Straw material, production technology and straw tests.

To operate in vacuum, the straws have to keep their shape under one bar relative pressure. They should not be damaged by pressure changes and they should have low gas leak to comply with the specifications of the vacuum tank. These strong demands imply a very accurate choice of the material and of the straw production technology. As previous experience shows, straw tubes can be produced both from Kapton or Mylar films. The stretch necessary to break Mylar (σ_{cut}) is in the range between 450 - 540 MPa. The safety work condition, $\sigma \leq 0.1\sigma_{cut}$, defines the minimum film thickness to be of about 10 μm for a 10 mm straw diameter. As a tradeoff between performance and technological constraints, a thickness of about 35 μm is acceptable. The situation is similar for Kapton film.
The winding technology for straw production was studied in detail in [36]. It is found that wound straws continue to elongate under stress. To avoid this problem, a new technique based on ultrasonic welding along the tube has been tried. Since Kapton films can not be welded by ultrasonic, 36 μm Mylar film (DuPont) covered by Al on both sides has been chosen. An existing welding apparatus is now being upgraded by using a more powerful head and a computer controlled welding patch. Using this device, about 100 straws of 2300 mm length and (9.80 ± 0.05) mm diameters have been produced at a rate $\approx$40 cm/minute.

Long term straw elongation tests were started in February, 2006: three tubes produced from 23 μm thick Mylar film were stretched with 1, 2 and 3 kg forces. The elongations of these tubes was found to be 7.5, 14 and 22 mm. After 8 months of continuous stress the elongations of the tubes have remained constant.

3.8.2 Design of a straw plane

The diameter of each tube is ≈10 mm and each tube does not touch the others. Each view is formed by four staggered layers to provide optimum space-point measurements. It can be shown that the total amount of material crossed by a charged track is only 8% larger than the case where two staggered planes in which the tubes are packed together. The possibility of using detector elements of BTeV Frascati group [37] and COSY-TOF collaboration [38] is being studied.

3.8.3 Design of a straw prototype

The goals of the straw prototype design and production are:

1. measure straw spatial resolution and rate capability by using a radioactive source;
2. check of detector conceptual design such as straws pre-tension, end-plugs and wire support plug design, straws and wires positioning;
3. test the technology of wires and straws positioning with accuracy better than 0.2 mm over all detector sensitive area;
4. test the technology of wire insertion through straw and measurement wire tension;
5. test of different gas mixture, gas system layout, HV system layout, electronics layout;

The prototype consists of 48 straws arranged in 6 layers. Each layer has 8 tubes. The diameter of each straw tube is 9.8 mm and the lateral distance between tubes is 14.0 mm. Straws will be pre-tensioned by special turning screws on a vacuum end-plate and glued in both end-plates. Input/output gas connectors and electronics box there are on the end-plate on the STP side. The electronics box has connectors for 3 HV boards connected to 3 preamplifiers with 16 channels each. Each HV board is connected with 16 straws by flat cable. On vacuum end-plate straws are connected on gas consistently in each layer.
The straws are fixed along their length by 2 additional support plates with holes similar to the end-plate ones. These plates will be mounted in the region of wire support plugs at

about 70 cm inside the straw. Straw support plates will be adjusted according to external X-Y reference points on end-plates and glued to the frame. Expected precision of straws positioning according to external reference points will be about 0.2 mm ($\sigma \approx 60$ μm).
The design of the straw end-plugs is in progress. A copper bush is used for straw grounding and a twister for high precision ($\simeq 10$ μm) wire positioning. Straw end-plugs will be fixed at the end-plate holes with accuracy about 50 μm ($\sigma \approx 15$ μm). The end-plug and straw glued together by conductive glue.
The internal part of end-plugs is made from ULTEM insulator. Holes with 4 mm diameter are provided for the twisters. Holes with 1 mm in diameter are made to house the special copper tubes where the wires will be crimped. Holes with 2 mm in diameter are foreseen for the gas flow.
It will be planed to test the following gas mixtures in the prototype:

- $CF_4 - CO_2 - isoC_4H_{10}$ (10%:80%:10%) with a drift time of about 200 ns and expected spatial resolution per straw of less than 100 μm;
- $CF_4 - Ar - C_2H_6$ (5%:85%:10%) with a drift time of about (60-100) ns and expected spatial resolution per straw of about 130 μm.

The gas flow should be 10 volumes per day and the expected gas gain $\approx 2 \times 10^4$. The 30 μm wire is positioned inside a straw by 4 twisters: 2 into each end-plug and 2 into each wire support plug. Different design of wire support inside straw are being tested. The electronics for the prototype consist of:

1. Front-end electronics;
2. CAMAC crate serving the trigger signals;
3. VME crate , equipped with controller and TDC cards;
4. PC with a PCI card supporting S-Link.

The signal transmission between the front-end and digital read-out parts is made using LVDS level, which permit to minimize the noises and transmit signals to a distance of 50 m without distortions.
The front-end printed circuit board contains of 16 channels based on the AS02MT8 microchip. This amplifier, thank to his high stability, low noise, threshold linearity characteristics and relative low cost (1$ per channel) looks like a very good solution. In addition,

Item	Description	Date
1.	Procurement of anode wire, mylar, glues, o-rings, alignment sensors	August 06
2.	Mylar metallization (Al)	September 06
3.	Production set of ≈ 100 straws at Dubna	October 06
4.	Ultrasonic tooling preparation	Oct.-Dec. 06
5.	Production straw end-plugs, wire support plugs, twisters, end-plates	Nov.-Dec. 06
6.	Prototype frame assembling and adjustment, frame 3-D geometry check	January 07
7.	Straws gas leakage test	February 07
8.	Prototype assembling	March-April 07
9.	Cosmic test at Dubna facility	May 07

Table 1: Straw Tracker scheduled activities during 2006 and 2007

low input impedance, quite high sensitivity and short time integration will allow high loading (high rate) without too large straw gas amplification. This amplifier is already used in "OKA" experiment (IHEP, Protvino) [39, 40].
The choice of the preamplifier has been made after comparison studies made on two amplifiers: ASD8, used in HERA experiments and AS02PMT8, designed in Minsk. Our estimations show that the AS02OMT8 better matches the needs of the proposed straw detector because it is produced using the low-noise technology "ISOPLANAR II". This technology permits the production of transistors n-p-n with frequency cutoff $F_t \geq 300$ GHz and current gain $\beta \geq 150$. This technology shows a good radiation resistance. The 1.5 μm bipolar technology presents a very low current consumption (P $\leq$ 170 mW/channel). This parameter is very important since in the experiment the straws have to operate in vacuum with obvious cooling problems. The prototype design and test schedule for 2006-2007 is shown in Table 1.

3.9 RICH

A RICH detector is mandatory in the P-326 setup in order to reach a π-μ separation at the desired level (at least 3 sigmas) in the momentum range 15-35 GeV/c: this requirement strongly suggests to use Neon gas at atmospheric pressure as the radiator medium (the pion momentum threshold for full efficiency detection is just 15 GeV/c). In order to produce enough photoelectrons and have good Cherenkov angle resolution, the maximum length of the detector is recommended: the available space in the present P-326 setup between the last straw chamber and the LKr calorimeter is 18 m. The RICH detector will consist of a 18 m long vessel, 2.8 m in diameter, with the beam pipe going through it, with a spherical mirror

(subdivided in about 40 hexagonal pieces) at the downstream end, with a focal length of 17 m (just to have some safety margin in the adjustment); a matrix of photomultipliers, with a 18 mm granularity, will be placed at the upstream end. In order to avoid the beam pipe shadow, the whole spherical mirror will be divided into two halves, pointing to two different photon detector regions: the number of needed photomultipliers is about 2000.
The RICH, thanks to its intrinsic response speed, will also be used to give the track crossing time with a resolution of 100 ps in order to disentangle the tracks pileup in the Gigatracker detector.
The prototype foreseen for the 2007 test is meant to verify the performances expected for the final detector. It will consist of a 18 m long stainless steel vessel, 55 cm in diameter and no beam pipe crossing it, filled with about 4 m^3 Neon gas at atmospheric pressure. At the downstream end a single spherical mirror, with a 50 cm diameter and a 17.8m focal length, will be placed. At the upstream end the photomultipliers matrix with 18 mm granularity will be placed but only 54 PMs will be used, positioned around the expected pion Cherenkov ring position. This approach is feasible because we plan to use a well collimated and monochromatic 75 GeV/c momentum beam with 70% pions, 20% electrons, 6% Kaons, 2% protons and 1% muons. Protons are below Cherenkov threshold, while pions, muons and electrons at 75 GeV/c momentum have essentially the same Cherenkov angle; Kaons are well separated by the rest. The aim of the 2007 test run with this prototype is to verify that the Cherenkov angle resolution, the number of photoelectrons and the time resolution are as predicted by the simulation so that we can be confident to reach a 3 sigmas π-μ separation in the final apparatus between 15 and 35 GeV/c momentum. The possibility to tag the electrons in the beam with a small angle calorimeter is considered; it is also possible that in a second part of the test the 54 PMs will be moved from the expected pion Cherenkov ring to the Kaon one.
We plan to use Hamamatsu R7400-U04 Metal package photomultipliers for their small diameter (16 mm), good quantum response up to the near ultraviolet, optimum time resolution (100 ps) and reasonable cost. The full electronic chain foreseen for the final apparatus will be used for the test (preamplifier, shaper-discriminator, fast TDC), together with the HV power supply needed to guarantee the 800-1000 V required by the PMs.
The prototype will be placed in the K12 beam line just downstream of the present NA48/2 second Kabes position, where about 20 m long space can be made available. The test should last 2-3 weeks (depending on the activities foreseen before it), at the very end of the SPS availability period.

3.10 Software

The challenging goal of rare kaon decay measurement implies strong requirements on both Monte-Carlo and reconstruction software. It is expected that very large MC and down-scaled data samples should be produced for particular background kaon decays ($\sim 10^{10} \div 10^{11}$ events) for detailed studies of background suppression with different kinematic and "veto" selections. Even for small number of secondary particles produced in main background decay channels, the task of large MC samples production looks very challenging and requires optimization of Monte-Carlo algorithms in terms of CPU and data storage.

The reconstruction software should be designed in the way, which makes it usable for both, off-line and on-line processing. The last implies special requirements on the time-performance of reconstruction algorithms: they should provide (at least partial) very fast events reconstruction to be used in the on-line software trigger system.

3.11 Monte-Carlo system

The Monte-Carlo system should provide, in general, the convenient tool for:

- geometry optimization;
- detailed study of sub-detector responses in the stand-alone mode as well as in the complete setup;
- study of different backgrounds related with:
  - non-signal kaon decays
  - beam-material interactions (with residual gas in the Decay Volume and with elements of the experimental setup)
- study of systematic effect introduced by physics models implemented in different MC engines (GEANT3 and GEANT4)

The developed Monte-Carlo software is designed in Object-Oriented approach with C++ as a programming language, completely within the ROOT framework. It is based on ROOT Geometry package (TGeo) and Virtual Monte-Carlo (VMC) interface. The last package provides a convenient interface to different MC engines (GEANT3, GEANT4 and FLUKA), which provides the possibility to choose particular MC engine "on-fly" to perform the study of systematic effects mentioned above.

The description of materials, geometry and MC hit structures is supported via user-friendly XML interface, which simplifies significantly the definition of complex geometry even to users not familiar with details of GEANT and ROOT tools usage. The current version of the geometry description reflects up-to-date knowledge of the sub-detector's materials, design and signal processing methods. The designed XML description scheme provides very flexible mechanism for geometry optimization as well as configuration of complete experimental setup and MC run parameters suitable for different tasks.

The current version of MC software was successfully tested with GEANT3 and GEANT4 MC engines. Special efforts were devoted to optimization of event generation and output packing to meet very hard requirements of large MC samples production and storage.

The current status of MC software can be summarized as follows:

- **Framework:** Object-Oriented, ROOT-based, TGeo+VMC;
- **User Interface:** XML-based with "loaded-by-demand" user-created shared libraries;
- **Tested with:** GEANT3, GEANT4
- **Production rate:** $\sim 4 \cdot 10^5$ events/day at 3 GHz CPU

3.12 Reconstruction software

The reconstruction software, developed at the stage of the proposal preparation, consists of all basic components:

- beam and secondary tracks reconstruction;
- vertex fitting and pile-up elimination algorithms;
- clustering procedures for calorimeters;
- photon and muon veto analysis and production of "veto decisions".

This software was created in FORTRAN and, using special optimization methods, provides good time performance with mean rate of events reconstruction ($\sim$ 1 ms/event), which makes it reasonable for on-line triggering.

Nevertheless, the main stream of the reconstruction software development consists in the switching to the Object-Oriented programming within ROOT framework. Currently, the ROOT-based C++ interface is created which makes possible complete reconstruction and analysis of MC data.

3.13 2007 development

Next year seems to be very important for software development because of important issues concerning complete setup and sub-detectors optimization should be studied, as well as detailed analysis of physics performance should be done on the basis of large MC sets. Concerning Monte-Carlo system, the following steps will be performed:

- development of XML-based interface with new features;
- optimization of complete MC software to improve time performance;
- implementation of detailed digitization schemes;
- development of Graphic User Interface (GUI);
- development of event display (ED).

These steps should result in the version of MC system, which will be used for mass production, as well as will incorporate elements suitable for on-line physics monitoring (GUI and ED).

Reconstruction/Analysis software should be completely re-written within Object-Oriented approach with ROOT as a programming framework:

- design of data structures based on ROOT-supported containers, which should implement the relevant Event Model;
- development and optimization of the reconstruction algorithms;
- design of algorithms and methods suitable for on-line software trigger;
- design and development of the Physics Analysis Framework, which should provide batch and interactive modes of the analysis;
- design of GUIs for reconstruction and analysis.

The last but not least important issue consists in the full-scale integration into GRID environment. This should provide us with the possibility of mass MC production.

The fulfillment of the above tasks should result in the software release which is developed and maintained within single framework (ROOT), provides flexible interfaces (based on XML and GUIs), and satisfies basic requirements concerning time and data storage performance.

4 Measurement of the Ratio $\boldsymbol{\Gamma(K \to e\nu)/\Gamma(K \to \mu\nu)}$

Despite the poor theoretical control on the meson decay constants, ratios of leptonic decay rates of pseudoscalar mesons, such as $R_K = \Gamma(K \to e\nu)/\Gamma(K \to \mu\nu)$ can be predicted with high accuracy within a given model, and have been traditionally considered as tests of the $V - A$ structure of weak interactions through their helicity suppression, and of $\mu - e$ universality. The Standard Model prediction is [41]

$$R_K(SM) = (2.472 \pm 0.001) \cdot 10^{-5} \tag{20}$$

A recent article [42] points out that, somewhat unexpectedly, contributions by lepton flavour violating effects predicted in SUSY models induce violations of $\mu - e$ universality shifting the above ratio from the precisely known SM value by a relative amount which can be in the percent range. The helicity suppression of the SM contribution is actually what makes such decays sensitive to new physics beyond the SM.
As stressed in [42] such effects, possibly of order 10^{-2}, and arising mainly from charged Higgs exchange with large lepton flavour violating Yukawa couplings, do not decouple if SUSY masses are large and exhibit a strong dependence on the $\tan\beta$ parameter. For large (but not extreme) values of this parameter, not excluded by other measurements, the interference between the SM amplitude and a double lepton-flavour violating contribution could produce, in the example quoted, a -3.2% effect.
Corresponding effects in the leptonic decays of the charged pion are expected to be much below the present experimental limits. Other experimental constraints, such as those from lepton flavour-violating τ decays, were also shown in [42] to be not competitive with the case of K leptonic decays.
The world average [43] of published R_K measurements is

$$R_K(exp) = (2.44 \pm 0.11) \cdot 10^{-5} \tag{21}$$

far from the precision required for testing any new physics contribution.

In the original NA48/2 proposal [44] the measurement of K leptonic decays was not even mentioned as a secondary goal because of its apparent triviality. Nevertheless, triggers collecting such decays were implemented. However, they were not at all optimized and had to be highly downscaled.

An analysis of the corresponding data collected during the 2003 run was performed [45] and presented at the HEP2005 Europhysics conference in Lisbon [46]. The preliminary result, with a sample more than 4 times larger than the previous world sample (about 4000 K_{e2} decays), is

$$R_K(exp) = (2.416 \pm 0.043_{stat} \pm 0.024_{syst}) \cdot 10^{-5} \tag{22}$$

A significant ($\sim 15\%$) amount of background due to misidentified $K_{\mu 2}$ decays was observed and subtracted.

While this measurement is dominated by the statistical error, the systematic uncertainty on the ratio of trigger efficiencies ($\pm 0.8\%$) could not be reduced because of the significant inefficiency of the unoptimized and downscaled K_{e2} trigger, and of the lack of a sufficiently large control sample.

During the 2004 run a short (56 hours) special run with simplified trigger logics and $\sim 1/4$ nominal beam intensity was performed, dedicated to the collection of semi-leptonic $K^{\pm}$ decays for a measurement of $|V_{us}|$. About 4000 K_{e2} decays were also extracted from these data. The preliminary result from the analysis of these data is consistent with the 2003 value, and comparable to it in terms of errors, although for the 2004 data the trigger efficiency was under better control and was affected by a smaller uncertainty.

While the analyses of the 2003 and 2004 data are continuing, it is not expected that significant improvements in the error will be obtained from the presently available data samples.

The NA48 apparatus includes the following subsystems required for the measurement of R_K:

- A magnetic spectrometer, composed of four drift chambers and a dipole magnet (MNP33);
- A scintillator hodoscope consisting of two planes segmented into vertical and horizontal strips, providing a fast Level-1 (L1) trigger for charged particles.
- A liquid krypton electromagnetic calorimeter (LKr) with a L1 trigger system.

In the analysis of the 2003-04 data K_{e2} decays were selected using two main criteria:

- The charged particle behaviour must be consistent with that expected from an electron ($0.95 < E/p < 1.05$, where E is the energy deposited by the charged particle in LKr and p is its momentum, as measured by the magnetic spectrometer).

- If the electron mass is assigned to the charged particle track, the invariant mass of the system recoiling against it (denoted by M_X) must be zero within errors, as expected for a neutrino.

The main background was found to consist of $K_{\mu 2}$ decays in which the muon suffered a catastrophic energy loss in LKr and satisfied the requirement $0.95 < E/p < 1.05$. This background was present in the region of particle momenta $p > 25$ GeV/c, where the M_X resolution provided by the magnetic spectrometer was insufficient to separate K_{e2} from $K_{\mu 2}$ decays. For $p < 25$ GeV/c the missing mass resolution allowed the selection of a pure sample of $K_{\mu 2}$ decays. The distribution of the E/p ratio for these muons (Fig. 5) has a tail which extends to $E/p \sim 1$. The fraction of muons satisfying the electron identification requirement $0.95 < E/p < 1.05$ is measured to be $\sim 5 \cdot 10^{-6}$.

For the 2007 run we plan to improve the spectrometer momentum resolution by increasing the MNP33 momentum kick from 120 MeV/c (the value used during the 2003-04 runs) to 263 MeV/c. In order to keep the two simultaneous positive and negative beams within the vacuum pipe while traversing the apparatus we increase at the same time the beam momentum from 60 to 75 GeV/c (the planned value for P-326), and we steer the two beams in directions opposite to the spectrometer deflections using the TRIM3 dipole located before the entrance of the decay volume.

K_{e2} decays will be selected by a L1 trigger consisting of the coincidence between signals from the two hodoscope planes (denoted by Q_1), in coincidence with an energy deposition of at least 10 GeV in LKr ($E >$10 GeV). From the analysis of the 2004 data we know that this trigger is very efficient (> 0.99 at 90% CL) for electron momenta $p > 15$ GeV/c, as measured using K_{e2} events collected with an unbiased trigger consisting of Q_1 alone downscaled by a factor of 50.

The same downscaled Q_1 trigger will be used to collect $K_{\mu 2}$ decays. It will be combined in OR with the K_{e2} trigger, and the beam intensity will be adjusted to obtain a total trigger rate of 10^4 Hz, which saturates the data acquisition system.

Fig. 6 shows the M_X^2 versus momentum distribution for K_{e2} and $K_{\mu 2}$ decays for the 2004 data, together with the predicted distributions for the 2004 run and for the proposed 2007 run, as obtained from a MonteCarlo simulation (for $K_{\mu 2}$ decays the electron mass is assigned to the muon). In the 2007 run, for electron momenta up to 35 GeV/c the $K_{\mu 2}$ contamination to the K_{e2} signal is reduced to a negligible level thanks to the improved spectrometer momentum resolution (see Fig. 7a). Using a lower limit of 15 GeV/c for the electron momentum, and taking into account the detector acceptance, this means that $\sim 43\%$ of the K_{e2} events will be kinematically background free (see Fig. 7b).

We plan to measure directly the fraction of $K_{\mu 2}$ faking K_{e2} decays at all momenta, including the region $p > 35$ GeV/c for which the kinematic separation based on the missing mass is not effective. To perform this measurement in parallel with data taking, we plan to insert a ~5 cm thick between the two hodoscope planes near the center and below the beam pipe, covering six 6.5 cm wide vertical hodoscope counters. The requirement that charged particles traverse the lead without interacting and that the missing mass, calculated assuming the muon mass for the charged particle, is consistent with zero selects a pure sample of $K_{\mu 2}$ decay, for which the muon E/p distribution can be directly measured in the region of interest for the evaluation of the $K_{\mu 2}$ contamination to the K_{e2} signal. These muons will be collected by the same trigger used for K_{e2} decays. We expect to collect a total of ~6000 muons from $K_{\mu 2}$ decay in the momentum interval from 15 to 65 GeV/c traversing the lead plate and satisfying the electron identification requirement $0.95 < E/p < 1.05$. Of these, ~4300 will have momenta above 35 GeV/c, where the missing mass resolution is not sufficient to separate K_{e2} from $K_{\mu 2}$ decays.

The presence of the lead plate will reduce the momentum averaged K_{e2} acceptance by $\sim 18\%$. However, we expect that the K_{e2} trigger rate will be reduced roughly by the same amount, thus this loss of acceptance can be compensated by a small increase of the beam flux which will keep the overall trigger rate to the maximum level allowed by the data acquisition capability.

Table 2 lists the relevant parameters describing the running conditions of the special 56-hour run in 2004 and of the proposed 2007 run (for 2007 we have assumed the SPS cycle required for CNGS operation). From a 120-day run, with a conservative running efficiency of $\sim 60\%$ which includes scheduled and unscheduled beam-off time and possible detector malfunctionings, we expect to collect about 150,000 genuine K_{e2} events. Of these, ~64,000 have $p < 35GeV/c$ and will be practically background free, while the ~86,000 events with $p > 35GeV/c$ will have an average $K_{\mu 2}$ contamination of $\sim 15\%$ which will be measured as explained above.

In conclusion, we propose a measurement of the $K_{e2}/K_{\mu 2}$ ratio based on a total sample of ~150,000 K_{e2} events. Of these, $\sim 43\%$ will be practically background free, while the remainder are affected by a 15% contamination from $K_{\mu 2}$ events, which is directly measured with an uncertainty of $\pm 1.5\%$. The overall statistical error, which includes the statistical uncertainty on the background measurement, is expected to be 0.28%, with an increase of only $\sim 10\%$ with respect to the ideal case of a background free measurement.

	2004 special run	2007 run
SPS duty cycle (s/s)	4.8/16.8	9.6/39.6
Eff.$\times$ no. of days	$\sim 0.9 \times 2.3 = 2.1$	$\sim 0.6 \times 120 = 72$
Eff. no of pulses	$1.08 \cdot 10^4$	$1.6 \cdot 10^5$
Protons per pulse	$2.5 \cdot 10^{11}$	$1.5 \cdot 10^{12}$
K12 beam: p (GeV/c)	± 60	± 75
Acceptance (mr^2)	0.36×0.36	0.18×0.18
$\Delta\Omega$ (sr)	$4 \cdot 10^{-7}$	$1 \cdot 10^{-7}$
$\Delta p/p$ effective (%)	± 3	± 2.5
RMS (%)	~ 3.0	~ 1.8
TRIM3 x' (mr)	0	∓ 0.3
p_T (MeV/c)	0	∓ 22.5
MNP33 x' (mr)	± 2.0	± 3.5
p_T (MeV/c)	± 120	± 263
Triggers/pulse	45,000	96,000
Good K_{e2}/pulse	~ 0.37	~ 0.94
Good K_{e2} (total)	4000	150,000

Table 2: Comparison of the 2004 running conditions with those proposed for the 2007 run

Thanks to the increased statistics with respect to the 2004 data, the uncertainty on the trigger efficiency will be reduced to less than ±0.2%. Thus the proposed run in 2007 should provide a measurement of R_K with a total uncertainty (statistics and systematic errors combined in quadrature) of ±0.34%. Such a measurement might detect new physics beyond the SM, or, if agreement with SM predictions is found, will rule out some region of parameter space in realistic SUSY models.
The computing resources required for a long 2007 run have been estimated and iterations are taking place with our CERN-IT contacts.

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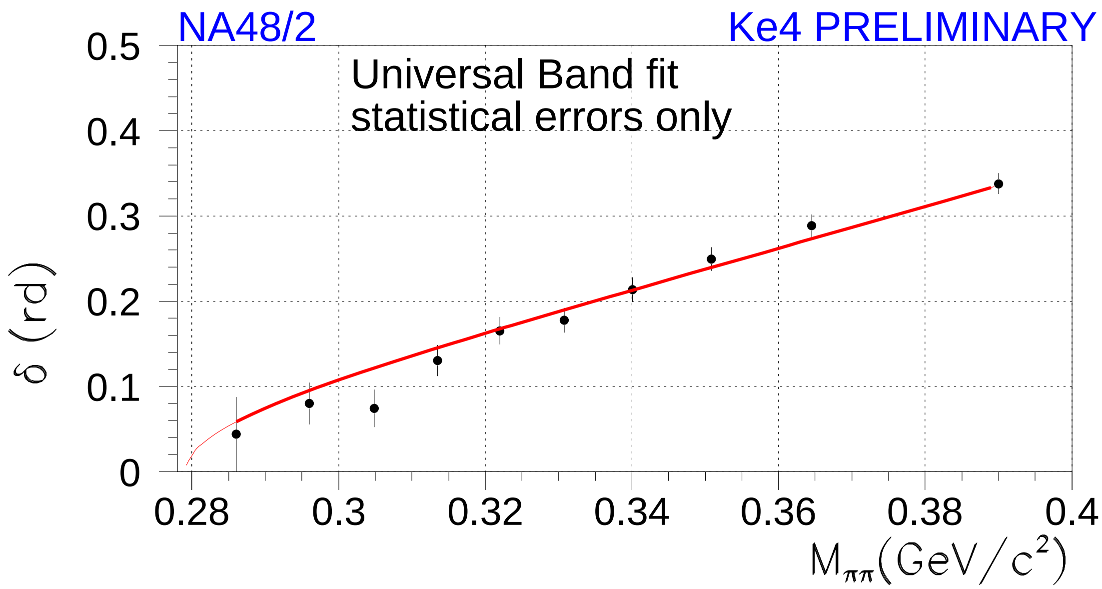

Figure 1: Phase difference vs $M_{\pi\pi}$

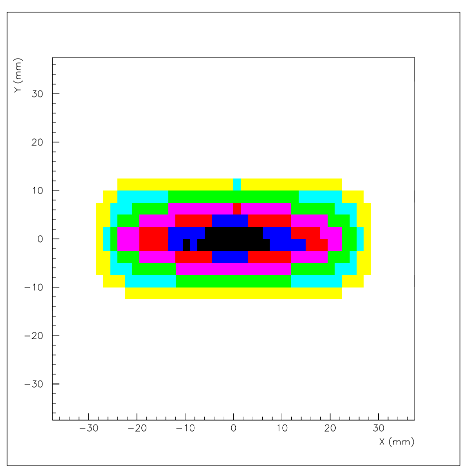

Figure 2: A cross section of the P-326 beam at the longitudinal position where it crosses the third gigatracker station

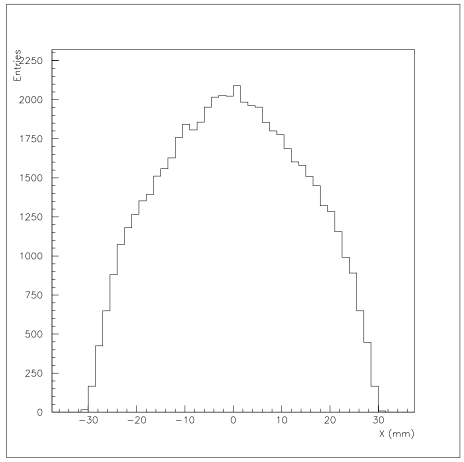

Figure 3: Horizontal projection of the P-326 beam at the longitudinal position where it crosses the third gigatracker station

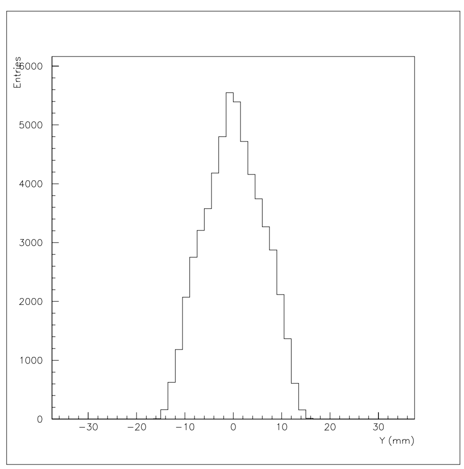

Figure 4: Vertical projection of the P-326 beam at the longitudinal position where it crosses the third gigatracker station

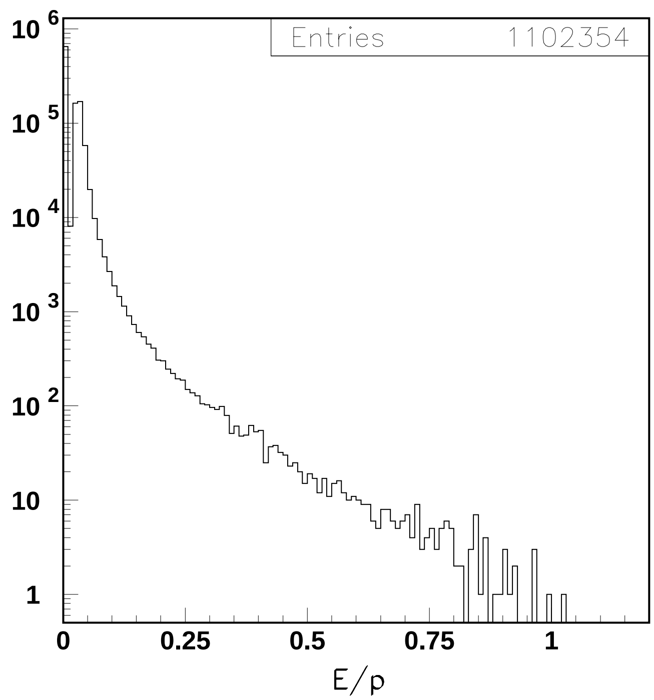

Figure 5: E/p distribution for kinematically selected muons from $K_{\mu 2}$ decay. The selection criteria are $p < 25 GeV/c$ and $|M_X^2| < 0.015 (GeV/c^2)^2$. In the M_X^2 calculation the muon mass is assigned to the charged particle.

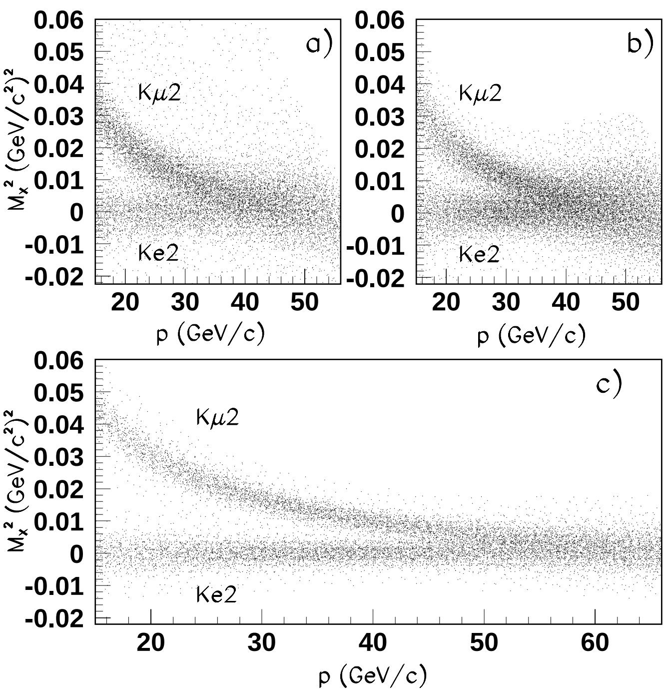

Figure 6: M_X^2 versus p distributions: a) 2004 data:selected K_{e2} and a sample of $K_{\mu 2}$ events; b),c) MonteCarlo predictions for equal numbers of K_{e2} and $K_{\mu 2}$ decays: b) 2004 running conditions; c) 2007 running conditions. In the M_X^2 calculation the electron mass is assigned to the charged lepton.

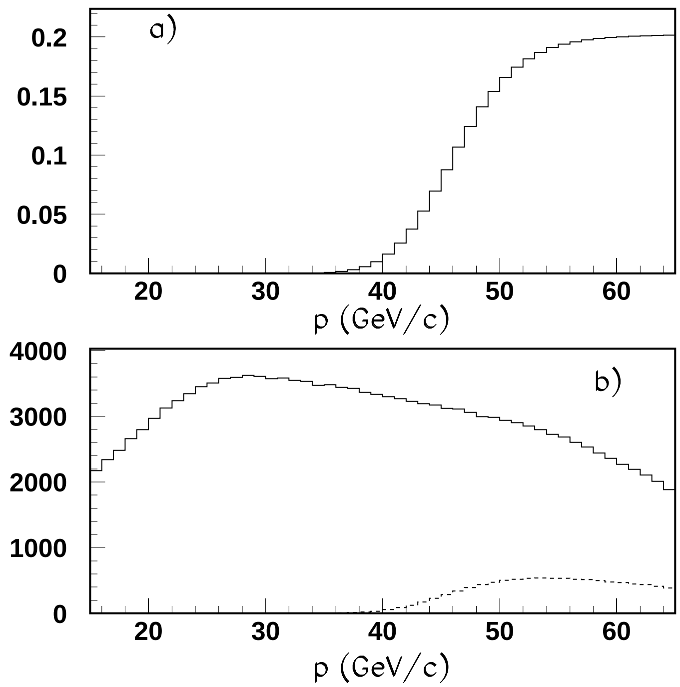

Figure 7: a) Ratio between the number of $K_{\mu 2}$ events faking K_{e2} events and the number of genuine K_{e2} events versus momentum; b) expected momentum distribution of genuine electrons from K_{e2} decay (full histogram), and of fake electrons from $K_{\mu 2}$ decays (dashed histogram).