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NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

Status report on CHORUS experiment at CERN

E. Arik [b], N. Armenise [c], S. Aoki [o], A. Artamonov [q], R. Beyer [j], D. Bonekamper [r], J. Brunner [j], S. Buontempo [u], M.G. Catanesi [c], H. Chikawa [l], K.S. Chung [m], A. Cocco [u], A. Capone [v], M. de Jong [a], D. de Pedis [v], E. Di Capua [h], S. Di Liberto [v], U. Dore [v], A. Ereditato [u], E. Eskut [b], J.P. Fabre [j], D. Favart [p], R. Ferreira [j,*], G. Fiorillo [u], W. Flegel [j], D. Frekers [r], P. Gorbunov [q], G. Gregoire [p], G. Grella [x], M. Gruwé [e], C.H. Hahn [f], T. Hara [o], K. Höepfner [d], K. Hoshino [s], M. Kazuno [i], J.Y. Kim [g], M. Kobayashi [s], K. Kodama [n], J. Konijn [a], V. Khovansky [q], X. Lauwerys [p], V. Lemaitre [p], P. Lendermann [d], I.T. Lim [g], C. Luppi [h], P.F. Loverre [v], D. Macina [v], A.A. Mailov [b], F. Marchetti-Stasi [u], M.A. Mazzoni [v], F. Meddi [v], R. Meijer Drees [j], L. Michel [p], P. Migliozzi [u], C. Mommaert [e], M.T. Muciaccia [c], K. Nakamura [t], M. Nakamura [s], Y. Nakamura [s], T. Nakano [s], K. Nakazawa [k], K. Niu [s], K. Niwa [s], T. Okusawa [t], G. Onengüt [b], H. Øverås [j], V. Palladino [u], J. Panman [j], I.G. Park [m], T. Patzak [d], E. Pesen [b], G. Piredda [v], F. Riccardi [u], S. Ricciardi [h], G. Romano [x], D. Rondeshagen [r], G. Rosa [v], A. Rozanov [j], B. Saitta [h], R. Santacesaria [v], O. Sato [s], Y. Sato [y], M. Serin-Zeyrek [b], R. Sever [b], V. Shamanov [q], H. Shibuya [i], S. Simone [c], V. Smirnitsky [q], J.S. Song [m], G. Stefanini [j], P. Strolin [u], M. Teranaka [t], I. Tezuka [y], P. Tolun [b], N. Ushida [n], C.A.F.J. van der Poel [a], P. Vilain [e], J.L. Visschers [a], G. Wilquet [e], K. Winter [j], H. Wong [j], M.T. Zeyrek [b], P. Zucchelli [h]

[a] *NIKHEF, Amsterdam, Netherlands*
[b] *YEFAM, Ankara, Turkey*
[c] *INFN and University of Bari, Bari, Italy*
[d] *Humboldt University, Berlin, Germany*
[e] *IIHE (ULB-VUB), Brussels, Belgium*
[f] *Changwon National University, Changwon, South Korea*
[g] *Chonnam National University, Chonnam, South Korea*
[h] *INFN and University of Ferrara, Ferrara, Italy*
[i] *Toho University, Funabashi, Japan*
[j] *CERN, Geneva, Switzerland*
[k] *Gifu University, Gifu, Japan*
[l] *Kinki University, Higashiosaka, Japan*
[m] *Gyeongsang National University, Jinju, Korea*
[n] *Aichi University of Education, Kariya, South Japan*
[o] *Kobe University, Kobe, Japan*
[p] *Université Catholique de Louvain, Louvain-la-Neuve, France*
[q] *ITEP, Moscow, Russian Federation*
[r] *Münster University, Münster, Germany*
[s] *Nagoya University, Nagoya, Japan*
[t] *Osaka City University, Osaka, Japan*
[u] *INFN and University of Naples, Naples, Italy*
[v] *INFN and University of Rome, Rome, Italy*
[x] *INFN and University of Salerno, Salerno, Italy*
[y] *Utsunomiya University, Utsunomiya, Japan*

* Corresponding author.

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Abstract

The WA95/CHORUS experiment at CERN is a dedicated $\nu_\mu - \nu_\tau$ oscillation search experiment. Using the wide band neutrino beam of the CERN-SPS accelerator, with an exposure of 2.4×10^{19} protons on the target, this experiment will explore the domain of small mixing angles down to $\sin^2 2\theta_{\mu\tau} \approx 3 \times 10^{-4}$ for mass differences $\Delta m^2 > 1$ eV^2, more than one order of magnitude better than the current limits. The conceptual design of the CHORUS experiment and data on the detector performances are reported.

1. Introduction

The search for $\nu_\mu - \nu_\tau$ oscillation will be performed by detecting the inclusive reaction $\nu_\tau N \to \tau^- X$ in a background of ν_μ induced charged and neutral current events. The conceptual design of the experiment is based on the detection of the characteristic decay topology of the short lived τ lepton (lifetime $\approx 3 \times 10^{-13}$ s) and on kinematical constraints related to the missing P_T of the undetected ν_τ in τ decays. A proven technique for this detection is the nuclear emulsion with a resolution of ≈ 1 μm [1]. In order to reduce the number of events to be scanned in the emulsion by a factor of ≈ 10, three sets of kinematical selection criteria will be used to enrich the events originating from the following three decay modes, $\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau$, $\tau^- \to h^-(n\pi^0)\nu_\tau$ and $\tau^- \to \pi^+\pi^-\pi^-(n\pi^0)\nu_\tau$. The expected statistical sensivity of the CHORUS experiment at 90% confidence limit to the mixing angle at large Δm^2 is $\sin^2 2\theta_{\mu\tau} \approx 3 \times 10^{-4}$, Fig. 1. If oscillations would occur at the present limit ($\sin^2 2\theta_{\mu\tau} = 5 \times 10^{-3}$, $\Delta m^2 > 40$ eV^2) we would observe 64 tau events and 1.7 background events.

2. Detector design and performance

The CHORUS detector, Fig. 2, consists of an emulsion target for the vertex detection and an electronic detector composed of a scintillating fiber tracker, a magnetic spectrometer, a high resolution calorimeter and a muon spectrometer, which is used to select events with a negative muon or negative pion and missing transverse momentum and to extrapolate tracks back to the exit point at the emulsion [2].

The emulsion target with a total mass of 800 kg is segmented into two times 2 stacks of 1.44×1.44 m^2 surface area. Two auxiliary emulsion changeable sheets (CS1 and CS2) and one emulsion special sheet SC are mounted in front of the first fiber tracker plane, Fig. 2. The scintillating fibre tracker planes, composed of ribbons of 500 μm diameter fibres arranged in 7 staggered layers, provide a precise tracking back to the changeable emulsion sheet. The number of detectable hits per projection plane for tracks traversing the ribbons at the far end (220 cm) is of 5.3 ± 0.3 hits per ribbon. The two-track resolution of 540 μm of the scintillating fibre tracking system is determined by the spot size resolution and track residual. The spot size is due to the intrinsic resolution of the optoelectronic readout chain, which consists of four image intensifiers followed by a CCD with 550×288 pixels (6 pixels per fibre) [3]. The measured FWHM is 410 μm in the readout direction of the CCD and 350 μm in the transverse direction. The track residual, defined as the deviation of the hit wrt the best-fitted trajectory, is of 350 μm at FWHM. The tracks measured with the fibre array predict the track position in the 2 changeable sheets within an area of (300 μm)^2 with an angular resolution of $\Delta\theta \approx 3$ mrad. The changeable sheets will be replaced every 20 days, in order to keep the muon background sources as low as possible: i) 5 mm^{-2} day^{-1} cosmics rays in the angular range ±250 mrad; ii) 7 mm^{-2} day^{-1} beam associated muons. Automatic scanning of the CSs will reduce the track position to an area of (10 μm)^2 at the special emulsion sheet. A computer assisted microscope is used to find the production vertex in the bulk emulsion (≈ 15 min). The search for the decay kink angle is then performed (≈ 5 min). Using this technique a total efficiency of about 5% for detecting one of the τ decay modes can be achieved.

Three additional diamond shaped fibre trackers are located one upstream and two downstream of the hexagonal magnet. An air core magnet is used to measure the charge and momentum of particles before entering the

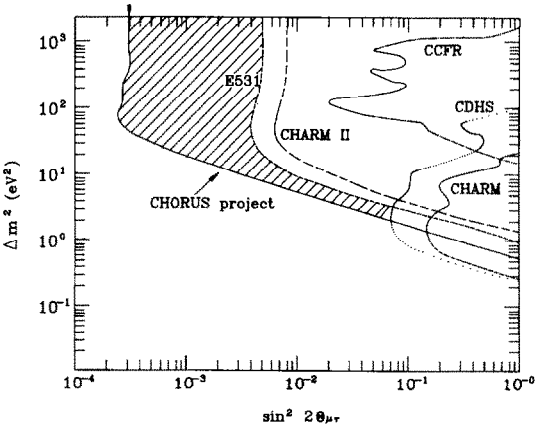

Fig. 1. Exclusion plot (90% CL) for $\nu_\mu - \nu_\tau$ oscillations showing results from previous experiments and the new area which can be explored by the CHORUS experiment.

calorimeter. The magnet-current can be pulsed (3200 A, 30 ms), producing a magnetic field of 0.12 T. The total measurement error, including direction measurement before the magnet and deflection measurement after, is of $[\Delta p/p]_{\text{meas}} = 1.6\%\ p\ (\text{GeV}/c)$, where the multiple scattering contribution accounts to 16%.

A high resolution calorimeter is used to determine the hadron shower direction and energy. Test beam results with electrons and pions with energies up to 15 GeV showed an energy resolution for electrons of $[\sigma(E)/E]_e = (13.8 + 0.4)\%\sqrt{E} + (0.1 \pm 0.1)\%$ and for pions of $[\sigma(E)/E]_\pi = (29.4 + 1.8)\%/\sqrt{E} + (2.4 \pm 0.6)\%$. The main features of the calorimeter design and performances can be found elsewhere [4].

The muon spectrometer for determination of charge and momentum of muons is equipped with 6 magnetized iron modules and 7 tracking sections. Each magnet module consists of 20 iron disks producing a 1.65 T magnetic field. The magnet gaps are filled with 4 scintillator planes per magnet, which provide trigger signals for penetrating tracks and complement the measurement of hadron energy leaking of the calorimeter. The tracking sections are composed each of one drift chamber with three planes of wires rotated by 60° wrt each other ($\sigma_{x,y} \approx 1.0$–1.5 mm) and eight streamer tube planes each of them equipped for wire readout and drift time measurements and for analog readout of the cathode strips. The efficiency for track finding is 96%. The measured momentum resolution is 12% for 5 GeV muons.

The trigger hodoscopes T, H and V (Fig. 2) are used to select neutrino interactions in the target and to reject background from cosmics, beam muons and neutrino interactions outside the target. A ν-trigger is defined by a hit coincidence in T and H consistent with a track with $\tan(\theta) < 0.25$ with respect to the neutrino beam. A veto is formed by any combination of a veto counter hit and a hit in T, with precise timing (2 ns at FWHM) to avoid vetos due to backscattering. The veto inneficiency is at the level of 10^{-3}. The measured ν-rate is 0.6 events per 10^{13} protons on the neutrino target for an effective mass of 2400 kg. The trigger logic is performed by a chain of VME-Programmable Logic Units, with high speed look up memories (12 ns). It operates in strobe mode, latching the input data on the leading edge and generating the output pattern with 20 ns delay. The trigger condition for T and H is performed by a VME-Hodoscope Logic Unit, which generates by a logic matrix operation the output decision. A VME/VSB-Logic Matrix Unit translates 32 trigger decisions into 16 readout signals, working in strobe mode as the PLU. The individual triggers and readout signals are enabled by masks addressable over VSB, which can be modified each time an event is being treated.

The front-end of the data acquisition [5] is based on VME-bus hardware with 36 CPUs running the OS-9 real time kernel. All detector sub-systems (tracker, trigger, spectrometer, calorimeter) are VME, VSB and CAMAC based and are equipped with a CES FIC 8234 VME controller. They are connected via a standard VME Inter Crate bus CES VIC 8251 to the main event builder EVB system. The REMOS object oriented multiprocessor real time environment, developped by our group, coordinates all the activities of the detector sub-systems (readout, collection, validation, compression and storage of digitized data) [6]. The optoelectronic readout of the fibre tracker is equipped with an array of 29 Eltec SL30 VME image processors, that read the image data from the 58 CCD cameras' frame buffers. The data is taken in buffered mode and sequenced by the time-structure of the neutrino beam. In a 14.4 s SPS-cycle there are two 6 ms bursts, separated by the 2.5 s. This sequencing is done by an interrupt handler, which, in addition, records the readout signals and can change the data taking conditions inside the neutrino

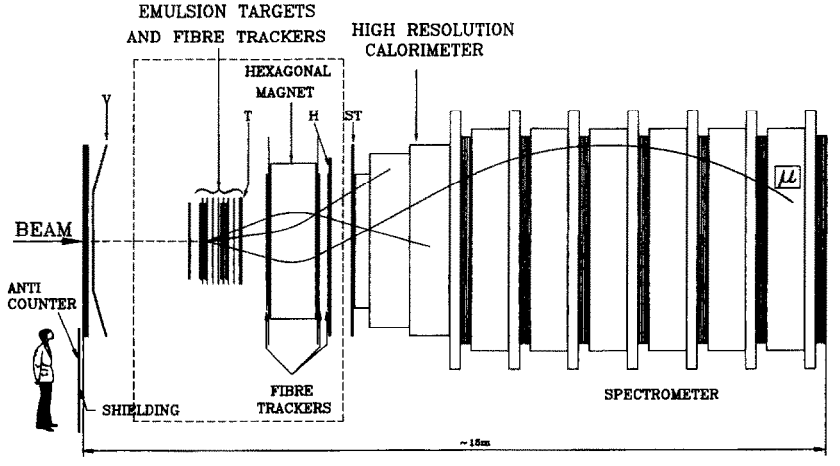

Fig. 2. Detector of the CHORUS experiment, consisting of emulsion target and a scintillating fiber tracker, hexagonal magnet, high resolution calorimeter and muon spectrometer.

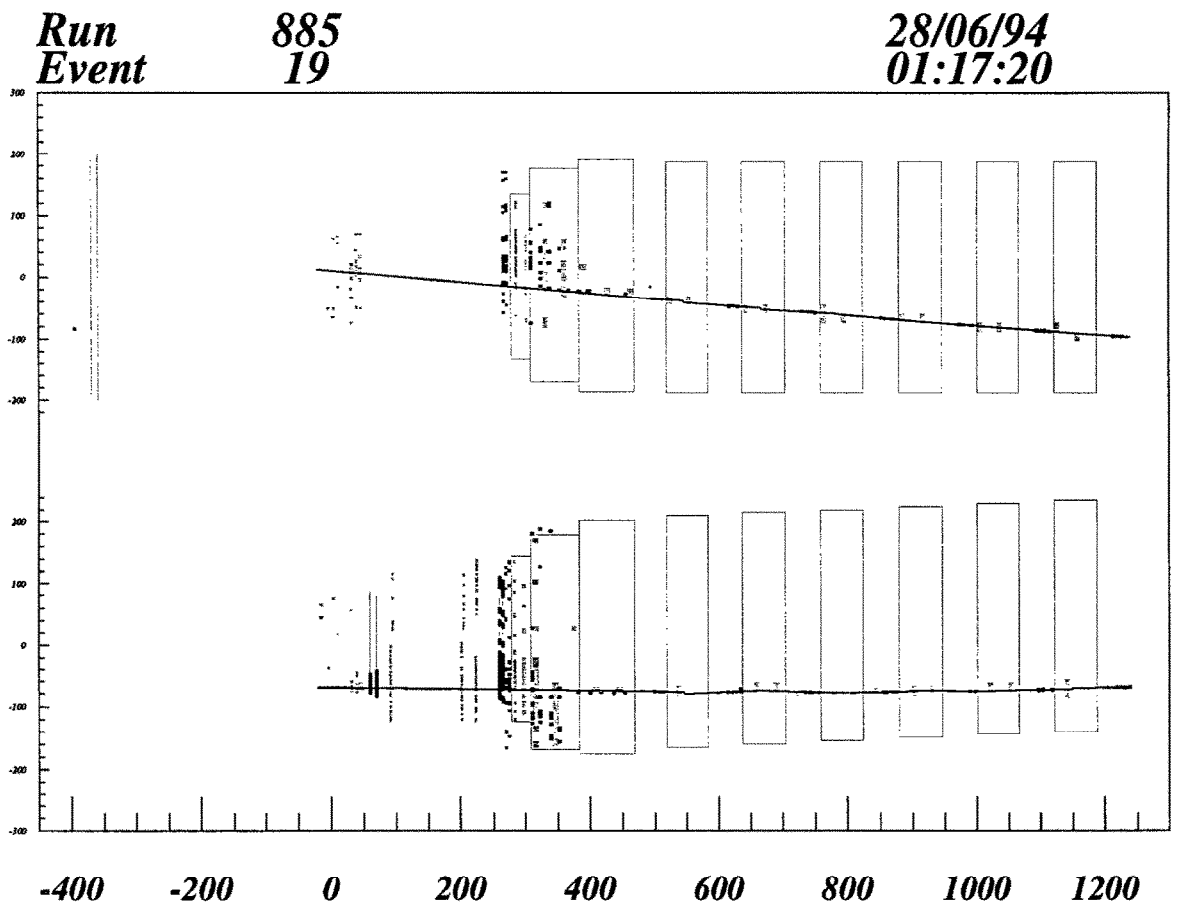

Fig. 3. Typical charged current interaction event in the emulsion target with a reconstructed muon.

burst by accessing the trigger Logic Matrix Unit. The EVB is linked to a cluster of six IBM RS 6000 workstations running the UNIX operating system, where the run control and monitoring is done. The event rate is low, but each event contains a large amount of raw data. We take at most two neutrino events per burst, corresponding to about 20 Mbyte of fibre pixel data, and about 15 kbyte of calorimeter, spectrometer and streamer tube data. The event data flow is channeled through the VIC bus with an average speed of 5 Mb/s. The deadtime of the experiment is less than 10% per burst, where the main contributing sources are the CCD conversion and readout (5%); ADC/TDC conversion times (2.5%); and, the busy time of the interrupt handler (1%).

After a successful test run of the detector with the upgraded neutrino beam in November 1993, the data taking started in the beginning of May 1994. In Fig. 3 is shown a typical charged current interaction in the emulsion target with a reconstructed muon.

References

[1] S. Aoki et al., Nucl. Instr. and Meth. B 51 (1990) 466;
K. Kodama et al., New techniques for emulsion analysis in a hybrid experiment, to be submitted to Nucl. Instr. and Meth.

[2] N. Armenise et al., CHORUS Collaboration, CERN-SPSC/90-42;
M. de Jong et al., CHORUS Collaboration, CERN-PPE/93-134.

[3] S. Aoki et al., CERN-PPE/93-189.

[4] G. Fiorillo, these Proceedings (6th Pisa Meeting on Advanced Detectors, La Biodola, Isola d'Elba, Italy, 1994) Nucl. Instr. and Meth. 360 (1995) 197.

[5] G. Carnevale et al., The CHORUS data acquisition system, to be published in proc. CHEP'94 conf., San Francisco, USA, 1994.

[6] G. Carnevale et al., REMOS: a portable object oriented environment for multiprocessor real time applications, to be published in Proc. CHEP'94 conf., San Francisco, USA, 1994.