STATUS OF ICARUS

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The ICARUS detector is a liquid argon time projection chamber. It provides three dimensional imaging and calorimetry of ionizing particles over a large volume, with high granularity. Its Physics program includes the study of atmospheric, solar, supernovae and beam neutrinos as well as proton decay searches.
The ICARUS technology has reached maturity with the construction and test (during summer 2001) of a 600 ton detector, demonstrating the feasibility of building large mass devices relevant for non-accelerator physics. During this test run, more than 27000 cosmic ray events have been acquired. These data allow to assess the detector performance, i.e. the spatial reconstruction, calorimetry and particle identification.

1 Introduction

The ICARUS technology, first proposed by C. Rubbia[1] in 1977, combines the characteristics of a bubble chamber with the advantages of electronic read-out. The detector is an ideal device to study particle interactions: it is continuously sensitive, self-triggering, cost effective, simple to build in modular form and sufficiently safe to be located underground (no pressure, no flammable gas, etc.). This detector is also a superb calorimeter of very fine granularity and high accuracy.

A number of test devices of increasing dimensions have been successfully operated over the years. The latest step on this graded path, the ICARUS T600 detector, has been fully tested on surface conditions during 2001. The technical aspects of the system have been checked during this run, and the acquired data is being used to assess the spatial and calorimetric reconstruction capabilities of the detector. In this paper we briefly summarize the results from the T600 technical run and the status of data reconstruction.

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2 The ICARUS T600 detector

2.1 Detector description

ICARUS T600 [2] is a large cryostat divided in two identical, adjacent half-modules of internal dimensions $3.6 \times 3.9 \times 19.9$ m^3 each, containing more than 300 t of liquid argon (LAr). Each half-module houses an internal detector (composed by two Time Projection Chambers –TPC–, the field shaping system, monitors, probes, PMT's) and is externally surrounded by a set of thermal insulations layers. Each TPC is formed by three parallel planes of wires, 3 mm apart, oriented at $0, \pm 60°$ angles, of 3 mm pitch parallel wires, positioned onto the longest walls of the half-module (see figure 1). A high voltage system produces a uniform electric field, perpendicular to the wire planes, allowing the drift of the ionization electrons (the maximum drift path is 1.5 m).

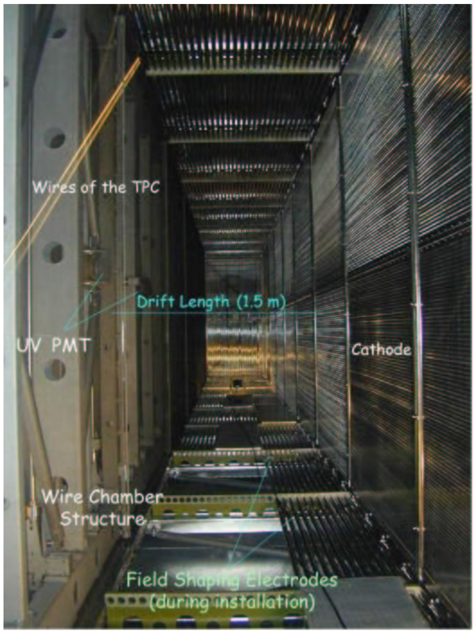

Figure 1: Internal view of the T600 first half-module

2.2 Physics program

The initial physics program with the T600 module at Gran Sasso has been reported elsewhere [3]. In this phase the available mass is limited, however the high efficiency and the detailed information which can be collected for each event will allow to initiate the study of some of the fundamental issues of underground physics: the study of neutrino physics, with solar, atmospheric and supernova neutrinos, and the study of nucleon decay.

2.3 The test run in Pavia

A full above-ground test of the T600 experimental set-up has been carried out in Pavia (Italy) during the period April-August 2001. One T600 half-module has been fully instrumented to allow a complete test in real experimental conditions. All technical aspects of the system, cryogenics, mechanics, LAr purification, read-out chambers, scintillation light detection, electronics, and DAQ have been tested, and found to be satisfactorily in agreement with expectations.

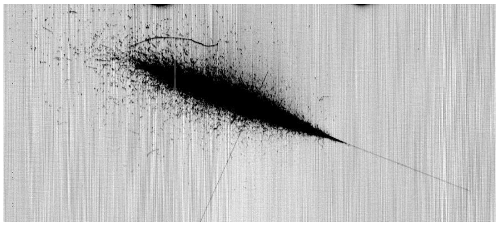

Figure 2: Electromagnetic shower event from the ICARUS T600 first half-module test. Event real dimensions: 3.7×1.7 m^2

During the test run, a very large amount of cosmic ray events has been recorded with different configurations of a dedicated trigger system. A systematic visual event scanning is being carried out in order to build an inventory of the acquired data. The current status is shown in Table 1. An example of a large electromagnetic shower event acquired during the T600 test is shown in figure 2.

3 ICARUS data reconstruction

Like a bubble chamber, the ICARUS detector provides a measurement of the total ionization loss of a track with very high sampling. Charged particles traversing the LAr sensitive volume

Table 1: Results from the ICARUS T600 test run inventory. Event categories are not exclusive.

Event category	Number of events
Shower	651
Muon decay/stopping	1935
Hadron interaction	704
V_0	46
Long track	311
Muon bremsstrahlung	1339
Multiple showers	695
Multiple muons	138
Total scanned	3098

produce ionization electrons in a number proportional to the energy transferred from the particle to the LAr. The ionization electrons drift perpendicularly to the wire planes pushed by the electric field, inducing a signal (*hit*) on the neighbor wires while approaching the different wire planes. By extracting the physical information contained in the wires output signal, i.e. the energy deposited by the different particles and the point where such a deposition has occurred, it is possible to build a complete three dimensional spatial and calorimetric picture of the event.

3.1 Three dimensional reconstruction

Each wire plane constrains two spatial degrees of freedom of the hits, one common to all the wire planes (the drift time) and one specific for each plane (the wire coordinate). The redundancy on the drift time coordinate allows the association of hits from different planes to a common charge deposition, and together with the wire coordinates from at least two planes, allow the spatial reconstruction of ionizing tracks. Figure 3 shows a kaon decay candidate event acquired during the T600 test. The identification and association of hits found in the wire output signal of the different wire planes (left) allow the three dimensional reconstruction of the event (right).

3.2 Particle identification

The energy released by ionizing particles per unit length (dE/dx) is, for a given medium, a function of the particle type and its momentum. In the ICARUS detector, a dE/dx measurement is performed for a large number of points along a given track. Particle momentum can be measured from range (for stopping particles) or multiple scattering measurement, providing a method for particle identification. Figure 4 shows the measured dE/dx vs range for the $K^{\pm}$ and $\mu^{\pm}$ candidates in figure 3, proving the discrimination power of this kind of detector.

4 Conclusions

The ICARUS T600 has been successfully tested, demonstrating the maturity of the ICARUS technology. The acquired data is been used to assess the performance of the reconstruction tools. The data taking start up in underground conditions at LNGS is foreseen for the beginning of 2003.

References

1. C. Rubbia; “The Liquid-Argon Time projection Chamber: a new concept for Neutrino Detector”, **CERN-EP/77-08** (1977).
2. ICARUS Collaboration; “A first 600 ton ICARUS detector installed at the Gran Sasso Laboratory”, Addendum to Proposal by the ICARUS Collaboration, **LNGS-95/10** (1995).
3. ICARUS Collaboration; “A second-Generation Proton Decay Experiment and Neutrino Observatory at the Gran Sasso Laboratory”, **LNGS-P28/2001** (2001).

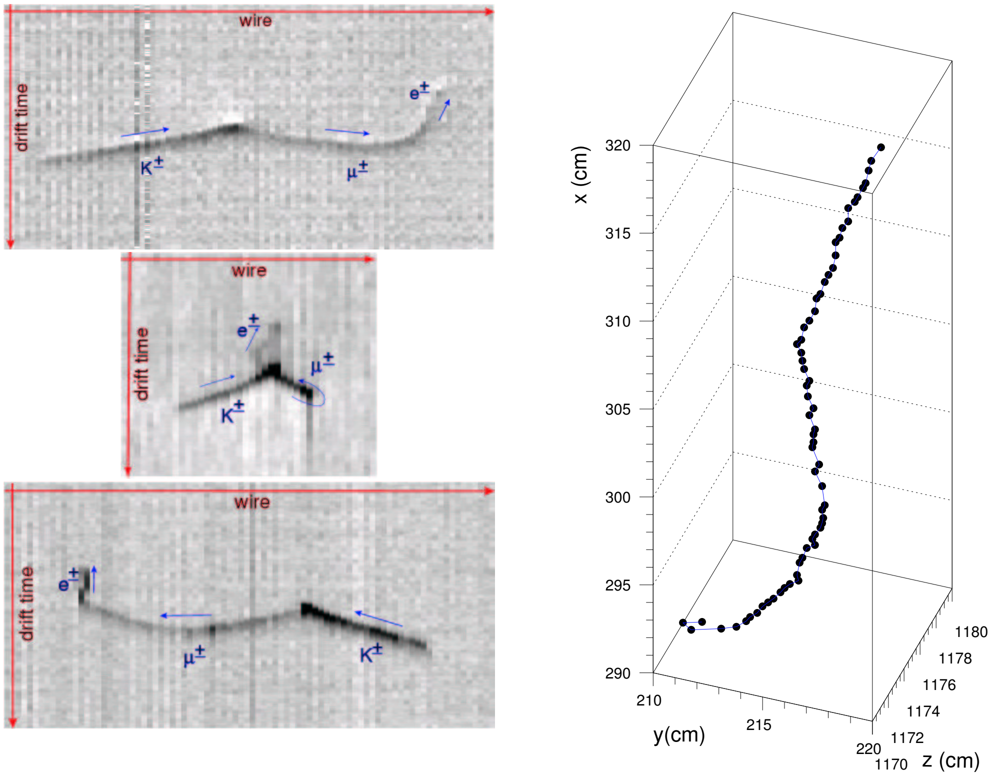

Figure 3: $K^{\pm}$ decay candidate from the T600 half-module test run. Left: Gray scale representation of the output signal in the wire (horizontal) vs drift time (vertical) plane for the three wire planes. Right: Three dimensional reconstruction of the event.

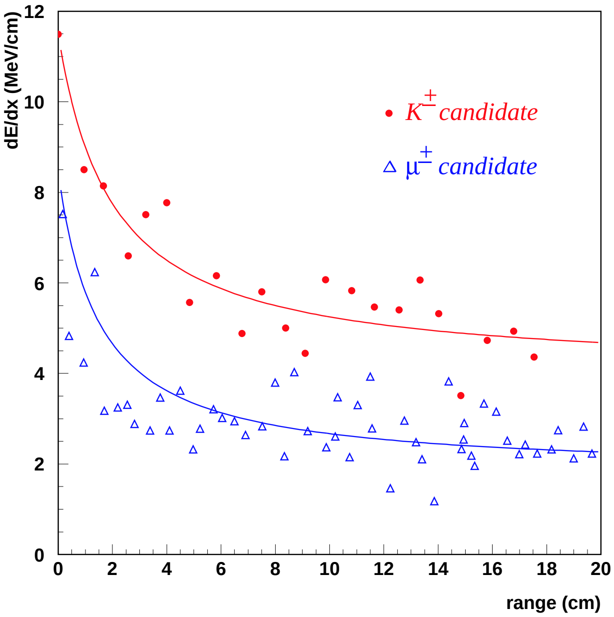

Figure 4: Measured dE/dx vs range for $K^{\pm}$ and $\mu^{\pm}$ candidates in figure 3.