ICARUS: a status report on the T600 detector construction and its data acquisition system

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Doktorandenseminar 3-5 October 2000
Detect electrons produced by ionizing tracks crossing the LAr

Electron-ion pairs are produced. Electrons give the main contribution to the induced current due to the much larger mobility.

\[ I_0 = \frac{e(v^+ + v^-)}{d} \]

A set of wires at the end of the drift give a sampling of the track. No charge multiplication occurs near the wires; electrons can be used to induce signals on subsequent wires planes with different orientations → 3D imaging.
ICARUS liquid argon imaging TPC (I)
ICARUS liquid argon imaging TPC (II)

"Bubble" size \( \approx 3 \times 3 \times 0.2 \text{ mm}^3 \)

Energy deposition measured for each point
The ICARUS graded strategy

The detector is continuously sensitive, thus allowing to easily simultaneously collect atmospheric neutrinos, CNGS and other rare events like proton decay

**BUT...**

this physics programme requires large detector masses!

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Lab activities

- **small scale prototypes**
  - 15 ton
    - tested 1999-2000
  - 600 ton
    - full test expected before end of 2000
  - 1400 ton
    - full test expected before end of 2000
The ICARUS technique - challenges

- **Liquid Argon environment in big volumes:**
  - Cool and maintain the temperature of the detector at $T=90\text{K}$ with $T$ uniformity of $\pm 1\text{K}$ (uniform drift velocity)
  - Temperature gradient during cooling implies mechanical stress $\Rightarrow$ e.g. chamber wires contraction

- **Long drift path $\Rightarrow$ drift electron lifetime $>$ 1ms:**
  - Clean elements (chamber structure, cryogenic instrumentation, limited degassing cables, ..)
  - Reach a purity of LAr at the level of $< 0.1 \text{ ppm } O_2$ equivalent

These goals have been reached in laboratory environment and now they have also been reached at the industrial scale for the T600 detector thanks to the cooperation with specialized industries:

$\Rightarrow$ **Air Liquide for Cryostat and Argon purification**
$\Rightarrow$ **BREME Tecnica for internal detector mechanics**
$\Rightarrow$ **CAEN for readout electronics**
ICARUS 15 ton (10m³) prototype (1999-2000)

- A recent major step of the R&D program has been the construction and operation of a 10m³ prototype

1. Test of the cryostat technology
2. Test of the “variable-geometry” wire chamber
3. Test of the liquid phase purification system; purity level exceeded 2ms electron lifetime
Cryogenic circuit

GAr purification circuit

LAr purification circuit

LN2 circuit

COOLING
View of the ICARUS T15 internal detector
Cooling 15 ton prototype March '99

**Temperature / Spring movement**

- **Confirmation of the functionality of the variable geometry mechanics**

- **LAr purity**

  - **Lifetime evolution**

  - The electrons lifetime (defined as the mean time spent by a free electron in the LAr before being captured by an electronegative impurity), after about 4 days of recirculation, was between 2 ms to 3 ms.

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ICARUS T15 @ LNGS

* The second test phase of the T15 prototype has in addition provided:

1. Long-term test of the cryostat technology
2. Test of trigger via scintillation light
3. Large scale test of final readout electronics

→ First operation of a 15 ton LAr mass as an actual “detector”
ICARUS 15 ton prototype - internal detector

- Photomultipliers
- Purity Monitors
- Cathode

Two wire planes (induction + collection)
928 wires/plane, all connected for readout
Internal volumes layout

- **Top View**
  - Cathode
  - Wires

- **Lateral View**
  - Imaging region (35 cm drift)
  - External trigger

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Tracks in 15 ton prototype

Drift Wires

40 cm

256

Wires #

Drift Time (μs)

0

400

ICARUS -10m3@LNGS - Run 360 evt 0

76 cm

256

Wires #

Drift Time (μs)

0

400

ICARUS -10m3@LNGS - Run 276 evt 12

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The ICARUS T600 module

**Under construction**

Number of independent containers = 2
Single container Internal Dimensions: Length = 19.6 m, Width = 3.9 m, Height = 4.2 m
Total (cold) Internal Volume = 534 m³
Sensitive LAr mass = 476 ton

Number of wires chambers = 4
Readout planes / chamber = 3 at 0°, ±60° from horizontal
Maximum drift = 1.5 m
Operating field = 500 V / cm
Maximum drift time ≈1 ms
Wires pitch = 3 mm
Total number of channels = 58368
Status of the T600 assembly

After the delivery of the first half-module, at the end of February 2000, we started the assembly of the internal detector mechanics. The mechanical frame, holding the wires and all the other detector components, has been positioned and aligned to within 0.2 mm over the full detector length (19 m).

Wires positioning in the first half-module started in the second half of August and is now going on very quickly (about 500 wires/hour).

The central cathode, all the auxiliary instrumentation that goes behind the chambers and part of the cables (for electronics and wires test) were installed before.

Signal cabling will follow as soon as wires will be tensioned. Installation of race-tracks and HV divider chain will complete the assembly of the internal detector.

Installation of thermal insulation and cryogenic system is proceeding in parallel with the internal detector assembly.
First half-module delivery in Pavia

February 2000
Second half-module positioned on the insulation in Pavia

August 2000
Assembly of the T600 internal detector (clean room)
T600 internal detector: mechanical frame
T600 internal detector: view of the cathode
Wire installation in T600 first half-module.
T600 internal detector: sensors

60° wire plane
3 mm wire pitch

Position meter
Purity Monitors
PMT
Wires separators
T600 detector: view of the roof during the insulation assembly

Chimneys
Signal feedthroughs flange
Electronics racks

Digital crate

Link cables

Analog crate
The T600 readout chain

CAEN-V789 board: 2 Daedalus VLSI * 16 input channels (local self-trigger & zero suppression) + memory buffers + data out on VME bus

CAEN-V791 board: 32 pre-amplifiers + 4 multiplexers (8:1) + 4 FADC's (10 bits - 20 MHz)

Decoupling board: HV distribution and signal input

One rack fully tested and optimized with real on-line data from the 50 liter LAr TPC
Input signals & pre-amp feedback RC

- **External & Internal planes:**
  - Approx. unipolar input signal
  - Width $\geq 3 \, \mu s$
  - Short RC
    ("quasi-current" mode) to minimized pile-up

- **Middle Plane:**
  - Bipolar signal
  - Long RC
    ("quasi-charge" mode) to get triangular signals
Daedalus chip as on-line zero suppressor and local trigger enabler

**ANALOGUE**

- MUX 8:1
- ADC
- RAM
- DAEDALUS CHIPS 2 • 16 ch
- VME INTERFACE

**DIGITAL**

- EVENT FIFO

Daedalus feature:
Varying rise-time front-edge finder

Raw data (ext. trigger)

Reduced data

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T600 wire numbering and event size

Induction 1 $[0 \div 2111]$  
Induction 2 $[0 \div 5727]$  
Collection $[0 \div 5727]$  

Induction 1 $2112 \times 4096 \times 2B \approx 17$ MB  
Induction 2 $5728 \times 4096 \times 2B \approx 47$ MB  
Collection $5728 \times 4096 \times 2B \approx 47$ MB  

Total event size 111 MB/chamber
Trigger system

- Despite the detector is self-triggerable, for the first run of T600 in Pavia we have foreseen a DAQ system able to acquire full drift events and to apply some preliminary filtering on the data.

- The trigger will be a combination of signals coming from:
  - **Scintillators**, located outside the detector, for long tracks and localized muons detection.
  - **PMTs**, located inside the detector, useful to test scintillation light trigger efficiency. The chosen PMTs (8” EMI, with special treated bialkali photocathode to work at cryogenic temperature) have a wavelength shifter (TPG = TetraPhenylButadiene) deposited on the glass window in order to shift the VUV wavelength of LAr ($\lambda=128$ nm) to visible light.
  - **Daedalus** chips, to test and tune the standalone triggering procedures.
DAQ system layout (T600 semi-module readout)

FE = Fast Ethernet
GE = Giga Ethernet

PCs utilities

PC builder, filter scan, monitor
200 GB disk

CPU

f/end electronics

24x

100Mb/s

1Gb/s

1Gb/s

Fe / GE

GE / GE

GE / FE

PC builder, filter scan, monitor
200 GB disk

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Scanning offline display “Qscan”

- Runs under Linux, uses Qt C++ libraries
- Display all ICARUS prototypes events
- Show different images of the same event (raw data, filtered view, simulation of new readout electronics on full drift events)
- Several tools (zoom, single wire signal, wires 3D view, test of Daedalus efficiency, saving of images in many graphic formats, event selection, RMS and FFT calculation on wires)
Example: 50L event (I)

Raw image

Filtered image

induction view

collection view

128 readout wires

Time (400 ns/sample)
46 cm max. drift distance

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Example: 50L event (II)

- Induction view
- Collection view
- Daedalus filtered image
- Zero skipping simulation image

128 readout wires

Time (400 ns/sample)
46 cm max. drift distance

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Wires displays

- Single wire display
- Zoom/unzoom on wire
- Display view and wire coordinates

- 3D wires display
- Highlights tracks
- Easy to see correlated noise (e.g. HV ripple)
Wires RMS and FFT displays

**RMS display:**
- Useful for wires test and noise measurements
- Easy to localize signal

**FFT display:**
- Information on noise components
T600 online display “Qdisp”

- Runs under Linux, uses Qt C++ libraries
- Common routines with Qscan
- 4 screens to display two main views (± 60° wires), only one control bar
- Testing MultiHead solutions: Matrox G400 graphic card (Dual Head display support), XFree86 4.0.1 (Xinerama configuration), max. resolution per screen 1280x1024 ⇒ total resolution 5120 x 1024
Online display example

- 4 screens full image (5727 wires x 4096 samples ⇒ 18 m x 1.5 m)
- Images are view from top of the T600 detector
- Possibility to use new high resolution 42" Plasma Displays for better performances
- Possibility to zoom image until detector resolution
Conclusions

- T600 construction is advanced:
  - Two wires planes already positioned on the two chambers
  - Installation of electronics racks will start in a few days
  - Online and offline DAQ programs (event filtering algorithms, event display programs, slow control system, etc..) are being extensively tested on simulated data and on data coming from the 10 m³ prototype. The control room, that contains only PCs, communications and storage units, is going to be setup starting from next week
- Startup procedures for the operation of the T600 (vacuum pumping) are expected to start at the beginning of November

Will the 18 m long track be our Christmas gift?