The ICARUS Project Status Report

September 24, 2001
First half-module delivery in Pavia (Feb 29, 2000)
## T600 chronology

<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sep 1999</td>
<td>Completed the site preparation in Pavia for the T600 cryostat</td>
</tr>
<tr>
<td>to Feb 29, 2000</td>
<td>Completion of the “clean room” and of the “assembly island”</td>
</tr>
<tr>
<td></td>
<td>Acceptance tests and delivery</td>
</tr>
<tr>
<td>Mar 2000</td>
<td>Begin the assembly of the internal detector mechanics.</td>
</tr>
<tr>
<td>Jul 2000</td>
<td>Completion of assembly and positioning of mechanical frames for the first half-module; begin wiring</td>
</tr>
<tr>
<td>[Aug 2000]</td>
<td>Acceptance tests and delivery in Pavia of the cryostat by AirLiquide of the second half-module</td>
</tr>
<tr>
<td>Feb 7, 2001</td>
<td>Completed the assembly of the first half-module internal detector</td>
</tr>
<tr>
<td>Feb 17, 2001</td>
<td>Half-module sealed!</td>
</tr>
<tr>
<td>Feb 21, 2001</td>
<td>Start the leak tests (cryostat in overpressure)</td>
</tr>
<tr>
<td>Apr 20, 2001</td>
<td>Start the vacuum pumping of the cryostat</td>
</tr>
<tr>
<td>May 1, 2001</td>
<td>Start the cooling phase</td>
</tr>
<tr>
<td>May 14, May 23</td>
<td>LAr filling</td>
</tr>
<tr>
<td>May 24, 2001</td>
<td>Start the LAr purification</td>
</tr>
<tr>
<td>Jun 2, 2001</td>
<td>Switch on the HV and start the data taking</td>
</tr>
<tr>
<td>Aug 1, 2001</td>
<td>STOP RUN and start the cryostat emptying</td>
</tr>
</tbody>
</table>
Internal structure assembly
Wire stretching sensor
LAr Scintillation Light Detectors

21 PMs (8””) coated with TPB
Wire installation
Sensors, purity monitors ans PMs behind the wires

Position meter

Wires before tensioning

Purity Monitors

PM
Wires crossing the spacers (wire pitch = 3mm)
The three wire planes at $0^\circ$, $\pm 60^\circ$ (wire pitch = 3mm)

and one PMT
Drift H.V. and field electrodes system

Drift distance: 1.5 m

Horizontal wires readout cables

Race-track

$-75$kV
Internal Detector view

Wire Chamber Side A

Wire Chamber Side B

Drift distance 1.5 m
Last view
Electronics for the first chamber
Readout Electronics for both chambers
External trigger system

Front side telescope
LAr purification circuit
Program of work during Pavia test (I)

- **Vacuum**: Leak rates and final vacuum level
- **Cryogenics**
  - Cool down speed
  - LN₂ consumption rates
  - Temperature uniformity
  - Cryostat walls deformation (under vacuum and after filling)
  - Pressure control
  - System stability (possible failures and relative consequences)
- **Purification**
  - Purity during and after filling
  - Filling speed
  - Gas and liquid recirculation rates
  - Final purity measurement and stability check (with purity monitors and C.R. tracks)
- **Mechanics**
  - Tensioning system movements during the cool down
  - Wires alignment (using C.R. tracks)
Program of work during Pavia test (II)

- HV system
  - Max drift field
  - Check field uniformity (using C.R. tracks)
- LV system
  - Check signals behavior (shapes).
  - System stability
- A.L. control system
  - Remote, Alarms handling
- Slow Control system (including HV control)
  - Remote, alarms handling
- Trigger systems
  - Performance measurements (efficiency, volume coverage, rates)
  - Flexibility
- Software
  - Data handling & reconstruction
  - Event Display
  - Analysis tools test
The most important phases

- **Clean up (vacuum): 10 days**
  - 7 days to find and recover the leaks
  - 3 days to reach $10^{-4}$ mbar

- **Cooling: 14 days**
  - 11 days for pre-cooling (down to -50 °C)
  - 3 days to reach -178 °C

- **LAr filling: 10 days**

- **True running time: 68 days**

- **Cryostat emptying: 7 days**

**Tot. 109 days**
Overall ...

- **109 total run days**
- **Controlled over 24 hours/day by 70 physicists**
- **Organised in 276 shifts (2 persons/shift)**
Vacuum curve

Total pumping time: 10 days
Final vacuum: $10^{-4}$ mbar
Walls behaviour during the vacuum phase

~1000 mbar  ~700 mbar  ~350 mbar  ~1 mbar  ~10^{-4} mbar

Walls displacement (mm)

April 12th  17th  22nd  27th

Stop pumping  Turbo

Total time: 12 days
Effective time: 47 hours
## Parameters of the cooling system

### Pre-cooling system

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Design value</th>
<th>Actual value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow rate</td>
<td>300 GN$_2$ m$^3$/hr</td>
<td>300 GN$_2$ m$^3$/hr</td>
</tr>
<tr>
<td>Max cooling speed</td>
<td>0.5 °C/hr</td>
<td>0.5 °C/hr</td>
</tr>
</tbody>
</table>

### Cooling system

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Design value</th>
<th>Actual value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow rate</td>
<td>30 LN$_2$ m$^3$/hr</td>
<td>36 LN$_2$ m$^3$/hr</td>
</tr>
<tr>
<td>Cooling speed</td>
<td>2 °C/hr</td>
<td>2.5 °C/hr</td>
</tr>
<tr>
<td>Max gradient on the cryostat</td>
<td>Not specified</td>
<td>120 °C</td>
</tr>
<tr>
<td>Max gradient on int. det. segments</td>
<td>50 °C</td>
<td>40 °C</td>
</tr>
<tr>
<td>Max difference cryostat - int. detector</td>
<td>120 °C</td>
<td>100 °C</td>
</tr>
<tr>
<td>Max gradient in LAr</td>
<td>1 °C</td>
<td>&lt; 0.7 °C</td>
</tr>
</tbody>
</table>
Cooling Phase

Temperatures during cooling phase

-200 -175 -150 -125 -100
-75 -50 -25
0 25

May 1st 3rd 5th 7th 9th 11th 13th 15th 17th 19th 21st 23rd 25th 27th 29th 31st

Time (days)

-200 -175 -150 -125 -100
-75 -50 -25
0 25

May 1st 3rd 5th 7th 9th 11th 13th 15th 17th 19th 21st 23rd 25th 27th 29th 31st

Time (days)

Internal Temperatures

External Temperatures
Springs movement during cooldown

Wires displacement less than 300 m !!
Liquid Argon Level during filling phase

Filling Speed $\sim 2 \text{ m}^3 / \text{hr}$

May 14th, @ 15:00   Time (Days)   May 25th
Wall displacement during the filling phase

Walls displacement during filling phase

Displacement (mm)

Time (days)

May 14th 16th 18th 20th 22nd 24th
All waiting for ...
… the “big” event
A spectacular event showing a dense Air Shower formed by hundreds of parallel tracks (muons and pions) and low energy \( \gamma \)’s converting into electrons. Also visible in the zoom views a hadr. shower, an el.m. shower and a muon bundle.

T600 test @ Pv: Run 308 - Evt 4 (July 2nd, 2001)
El.m. shower

Full 2D View from the Collection Wire Plane

Zoom views

1

stop and decay in $e$

2

Detail of a long (14 m) track with $\gamma$-ray spots

3

El.m. shower

T600 test @ Pv: Run 201 - Evt 12
Full 2D view from the Collection Wire Plane

Zoom View

T600 test @ Pv: Run 308 - Evt 7

Large el.m. shower
# Recorded Triggers

### All runs (550 on tapes):

<table>
<thead>
<tr>
<th>trigger type</th>
<th># trig. progr.</th>
<th># trig. taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 BIGTRACK</td>
<td>1500</td>
<td>4859</td>
</tr>
<tr>
<td>2 VERTICAL TRACKS</td>
<td>2950</td>
<td></td>
</tr>
<tr>
<td>3 PMTS LOW ENERGY</td>
<td>2000</td>
<td>8175</td>
</tr>
<tr>
<td>4 PMTS HIGH ENERGY</td>
<td>600</td>
<td>1292</td>
</tr>
<tr>
<td>5 TEST PULSE</td>
<td></td>
<td>4287</td>
</tr>
<tr>
<td>6 VARIOUS TESTS</td>
<td></td>
<td>1379</td>
</tr>
<tr>
<td>7 &quot;LIFETIME&quot; MEASUREMENTS</td>
<td></td>
<td>1964</td>
</tr>
<tr>
<td>8 DAEDALUS TESTS</td>
<td></td>
<td>1278</td>
</tr>
<tr>
<td>9 &quot;STOP&quot;</td>
<td></td>
<td>774</td>
</tr>
<tr>
<td>10 SPECIAL PMT TESTS</td>
<td></td>
<td>201</td>
</tr>
<tr>
<td>11 TECHNICAL TRIGGER TYPE</td>
<td></td>
<td>611</td>
</tr>
<tr>
<td><strong>GRAND TOTAL</strong></td>
<td></td>
<td><strong>27770</strong></td>
</tr>
</tbody>
</table>

### Golden runs (360 on tapes):

Golden runs include 2 chambers, reduced noise etc; from run 500.

<table>
<thead>
<tr>
<th>trigger type</th>
<th># trig. progr.</th>
<th># trig. taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 BIGTRACK</td>
<td>1000</td>
<td>4142</td>
</tr>
<tr>
<td>2 VERTICAL TRACKS</td>
<td>1000</td>
<td>2727</td>
</tr>
<tr>
<td>3 PMTS LOW ENERGY</td>
<td></td>
<td>4037</td>
</tr>
<tr>
<td>4 PMTS HIGH ENERGY</td>
<td>100</td>
<td>181</td>
</tr>
<tr>
<td>5 TEST PULSE</td>
<td>500</td>
<td>3635</td>
</tr>
<tr>
<td>6 VARIOUS TESTS</td>
<td>400</td>
<td>555</td>
</tr>
<tr>
<td>7 &quot;LIFETIME&quot; MEASUREMENTS</td>
<td>500</td>
<td>1849</td>
</tr>
<tr>
<td>8 DAEDALUS TESTS</td>
<td>1000</td>
<td>1278</td>
</tr>
<tr>
<td>9 &quot;STOP&quot;</td>
<td>300</td>
<td>774</td>
</tr>
<tr>
<td>10 SPECIAL PMT TESTS</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>11 UNKNOWN TRIGGER TYPE</td>
<td></td>
<td>222</td>
</tr>
<tr>
<td><strong>GRAND TOTAL</strong></td>
<td></td>
<td><strong>19400</strong></td>
</tr>
</tbody>
</table>

**Data taking run duration:** 2 months

**Event size:**
- ~ 100 Mbytes/chamber

**Recorded data:**
- ~ 5 Tbytes
- 100 DLTs (50 Gbytes/DLT)
Maximum electron lifetime: 1800 s

Electron lifetime

Monitor n.3 (GaAs - Back High)

LAr recirculation OFF

GAr recirculation OFF

Updated Aug 1, 2001 09:40

hours since May 24th 0:00
## LN$_2$ Consumption

### Measured T600 consumption

<table>
<thead>
<tr>
<th>Contributions</th>
<th>l/h</th>
<th>comments</th>
<th>What to do</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulation losses</td>
<td>800</td>
<td></td>
<td>Panels modification</td>
</tr>
<tr>
<td>LN$_2$ forced circulation</td>
<td>200</td>
<td></td>
<td>change LN$_2$ circuit</td>
</tr>
<tr>
<td>$GAr$ purification</td>
<td>280</td>
<td>4 active purifiers</td>
<td></td>
</tr>
<tr>
<td>LAr purification</td>
<td>250</td>
<td>2 active pumps</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1530</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### T600 @ LNGS estimate consumption

| Present situation (no LAr purification) | 1280 | ~50 | ~500 |
| Improved insulation...                | 480  | ~20 | ~200 |
| ...and with LAr purification          | 740  | ~30 | ~300 |

(Liquefaction efficiency ~10%)
1 The passive solution:
   – To better satisfy the safety requirements.

2 The modularity:
   – To enable the transportability.

Due to the modularity, during the cool-down the insulation panels tend to split and the insulation performance decreases.

But:

The modularity is no more needed in the next installation.
Nomex insulation panels
How to improve the insulation performances

Current solution

-185°C

17.1°C

16.1°C

15.6°C

Tested evacuated panel

-185°C

20.0°C

18.8°C

18.7°C

Foreseen evacuated panel

-176°C

17.1°C

16.1°C

15.6°C
New type of insulation on the second half-module

Evacuated, Nomex reinforced, insulation panels
New External Cooling Circuit

- Cooling panels
- Roofix
- Nomex Insulation

25 mm

40 mm
How to install an array of T600 in Hall B

(presented in 1997)
T2400 cross layout: zero approximation
<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar 2000</td>
<td>In a first meeting LNGS it was requested to verify how to put the T600 in the Hall B.</td>
</tr>
<tr>
<td>Mar 2000</td>
<td>After an inspection “in situ”, the ship agent (Fumagalli Trasporti) presented a positive report on this subject.</td>
</tr>
<tr>
<td>Mar-Jul 2000</td>
<td>During some meetings between ICARUS collaboration members, Air Liquide and the LNGS staff were discussed the guidelines for the ICARUS apparatus installation in the GS environment, in particular regarding the safety aspect.</td>
</tr>
<tr>
<td>Sep 2000</td>
<td>Air Liquide produced the first draft for the “Safety Document”, delivered to the GS.</td>
</tr>
<tr>
<td>Oct 2000</td>
<td>LNGS Authority approved this “first approximation draft” and asked for some more details; it was also announced the intention of LNGS to start an independent “HAZOP” analysis.</td>
</tr>
<tr>
<td>From Nov 2000</td>
<td>In other successive meetings between ICARUS collaboration, Air Liquide and the LNGS Staff the specific contents of the Safety Document were discussed: in particular with respect to the risk analysis (earthquake, fire, rupture of one of the LAr cryostats), the gas exhaust, the requested space (for the storage, the assembly of the components and the installation), the foreseen electrical power consumption …</td>
</tr>
<tr>
<td>Sep 2001</td>
<td>Air Liquide was asked for a more detailed risk analysis and further seismic computations. Up to now the Gran Sasso Authority has not yet defined a specific plan in matter of cryogenics.</td>
</tr>
</tbody>
</table>

The work is in progress: nevertheless most of the studies for the future installation of the T600@LNGS are site-dependent: HALL B or HALL C?