Activities for ICARUS Installation, Commissioning and Run

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Types of activities

1. Development and tests
2. Installation
3. Pre-commissioning
4. Commissioning
5. Detector operation
6. Data taking
7. Event reconstruction
8. Data analysis
9. Publications, presentation to conferences, outreach

Sub-systems

1. Wire chambers.
2. HV system.
3. Scintillation light readout system.
4. PMT Laser calibration.
5. CRT (split in bottom part, sides and top).
6. DAQ.
7. Trigger system.
8. Slow Control system.
9. Online monitoring.
10. LAr quality control system.
11. Cryogenics (responsibility of Fermilab, with control from the Collaboration).
12. Data storage and data transfer.
13. Event simulation: BNB; NuMI OA.
14. Event reconstruction: BNB; NuMI OA.
15. Data analysis (BNB).
16. Data analysis (NuMI).
17. Cosmic rays data taking and analysis.

Framework

1. Shared resources:
   a. Technical and technological skills.
   b. Infrastructures (laboratories, test stands, equipment).
   c. Manpower.
2. Dedicated resources (TBD according to the tasks).
3. Specific responsibilities:
   a. Sub systems (including software) design/development, procurement, installation.
   b. Sub systems pre-commissioning, commissioning, calibration, maintenance.
4. Shared responsibilities:
   a. Common goals.
      i. Time schedule and prioritization.
      ii. Data taking and data analysis.
   b. Internal communication and sharing of information.
   c. Publications and outreach.

Development and tests - 1

1. Racks outfitting & safety review (includes TPC, PMTs, CRT, trigger, …; does not include control system for cryogenics).
2. External signal layout: LV and HV cabling design, signals fan-out.
3. Databases design and programming for detector installation, operation and maintenance.
4. Production test of wires readout boards (in progress).
5. Production test of decoupling boards (in progress).
6. Test of PMTs readout boards (in progress).
7. Pre-production, production & test of CRT readout electronics and sensors (in progress).
8. Test of HV system for the PMTs (in progress).
9. Test of HV supply for the drift.
10. Test of HV supply for the wires biasing.
11. Set up of wire electronics test bench (flange, mini-crate, LV PS, optical read-out)
12. Slow controls communication software development (several sub-items/sub-systems).
13. Slow controls Graphical User Interface.
14. Slow controls database.

Development and tests - 2

1. Manuals, documentation and electronic logbooks design, write-up and accessibility (wiki pages, web pages, databases).
2. Software for PMTs DAQ (in progress).
3. Software for wires DAQ (in progress).
4. Software for CRT DAQ.
5. Software for data transfer.
6. Software and test of timing distribution (White Rabbit; in progress).
7. Trigger development: MC event study, software for trigger logic programming, trigger implementation and test (in progress).
8. Run control tools.
9. Software for online monitoring and logging.
10. Data quality monitor.
11. Tools for data storage and data recovery.
12. Software for detector calibration (several sub-items/sub-systems).
13. Software for beam monitoring.
14. Definition of procedures for handling of emergencies (blackouts, failures, etc. – includes risk analysis).

Installation - 1

1. Assembly of the cold shields (in progress).
2. Sealing of the cold vessel doors (in progress / done).
3. Installation of strain gauges on the cold vessels.
4. Cold vessels positioning (in progress).
5. Installation of chimneys, crosses and flanges.
6. Vacuum system (various phases).
7. Assembly of warm vessel top.
8. Flanges cabling of the wire chambers.
9. Flanges cabling of PMTs, including optical fibers for calibration.
10. Internal cabling of internal sensors (internal cryogenics).
11. HV resistors and HV feedthroughs installation.
12. Proximity cryogenics installation.
13. External cabling for the wire chambers (includes readout electronics installation).

Installation - 2

1. External cabling of PMTs.
2. Deployment of the laser calibration system.
3. External cabling of HV system for the drift.
4. External cabling of controls and sensors of the proximity cryogenics.
5. Racks installation (includes hardware for DAQ and CRT).
6. Power distribution and detector grounding (in progress).
7. Trigger system installation and cabling.
8. Networking design and deployment.
9. Additional hardware for slow controls installation and cabling.
10. Control room design and setup.
11. Installation of CRT mechanical supports (includes alignment campaign).
12. Installation of CRT modules.
13. CRT cabling (includes installation of the readout electronics and sensors).

Pre-commissioning - 1

1. Vacuum (leak tightness tests and initial commissioning):
   a. After sealing of the cold vessel doors;
   b. After installation of chimneys and sealing of the manholes;
   c. Before starting the cooling phase.
2. Cold shields pressure tests:
   a. Before moving the cold vessels in the final position;
   b. Before installing the warm vessel roof.
3. Connectivity tests of:
   a. Wires and decoupling boards.
   b. PMTs and optical fibers.
   c. HV.
   d. Internal sensors.
4. Noise and grounding tests of:
   a. Wires.
   b. PMTs.
   c. Cryogenics and related instrumentation.
   d. CRT.

Pre-commissioning - 2

1. Wires biasing tests.
2. DAQ and communication tests.
3. Slow controls test (not including cryogenics).
4. Timing and trigger distribution pre-commissioning
5. Test of cryogenics equipment, control system, data logging and display.
6. Test of the building safety system and start of its' operation.

Commissioning

1. Vacuum (also part of pre-commissioning).
2. Cryogenic system commissioning
3. Cooling (verify the thermal status of detector, verify the quality of the argon gas).
4. Filling with LAr (verify the thermal status of detector and readout the level sensors; verify the quality of LAr).
5. Thermal stabilization (verify the thermal status of the detector).
6. Detector commissioning:
   a. HV for the drift.
   b. wires biasing.
   c. PMT system.
   d. wires readout.
   e. trigger and timing.
   f. data taking and transfer (including CRT).
   g. measurement of LAr purity.
   h. CRT (bottom, sides and top are commissioned separately).

Detector operation

1. Run coordination (includes data taking).
2. Periodic calibration (several sub-items/ sub-systems).
3. LAr-purity monitoring.
4. Hardware status (through slow controls - cryogenics is included).
5. Regular maintenance (several sub-items/ sub-systems – does not include cryogenics).
6. Organization of experts on call.
7. Interface with Fermilab services and infrastructures.

Data Taking - 1

- Main issue of the data taking is the preparation of a trigger to select genuine neutrino interactions while rejecting fake events mainly induced by PMT noise and cosmic events.
- The adopted trigger system exploits flexible FPGA programmable tables which allow to Collaboration to directly implement even complex logic to be studied/tuned directly on the real events to match the actual experimental conditions. As a first hint MC events can be used to develop an initial logic based on the internal PMT signals.
- Therefore data taking with both BNB and NuMI OA beams can initially start by opening gates in coincidence with the proton beam extractions to record all spills, ~5 Hz trigger rate largely compatible with the new DAQ system.
- This will allow the Collaboration to check DAQ functionality and define trigger logics based on the internal PMT signals optimizing the efficiency for the neutrino event collection and background rejection.
- The goal: approaching ~ 0.2 Hz of *ν interactions + in spill c. ray events* which would result in ~ 4 PB of data for the total 6.6 10^{20} pot exposure if the full ICARUS-T600 detector is read-out (~70 MB event size).
- In perspective this scheme will safely allow to include CRT signals in the trigger logic in order to reduce the data throughput.
- Data taking of out-of-spill events will also be performed in order to study the cosmogenic background and ancillary measurements.

Data Taking - 2

- An initial data pre-processing will also be studied by the Collaboration in order to reduce the data amount to be saved at Fermilab and copied/transferred in EU.
- The *Slow Control System* will allow to check regularly each sub-detector all along the data taking period.
- A *Data Quality Monitor* will be active to:
  - Check S/N on PMT system, TPC wires and CRT;
  - Verify the correctness of event building process ;
  - Monitor T600 time alignment (White Rabbit) with respect to the beam timing. Periodically, the internal PMT timing will be precisely calibrated with the laser system.
- LAr-purity will be daily measured during normal detector operation by analyzing ~ 1000 crossing muons. Cosmic muons will also be used to set the time alignment of CRT with internal PMT system.
- Dedicated shifts have to be organized by the Collaboration to run ICARUS-T600 detector, monitor the different sub-systems to cope with all the specific requirements of the data taking, from the DAQ to data storage/transfer.

MC event simulation

1. MC event simulation with realistic description of all sub-systems is needed to develop and validate the reconstruction tools before start of operations
2. TPCs:
   a. Geometry of cryostats and wires (available), inner mech. structures (in progress);
   b. Generation and drift of e-ionization in the LAr-TPC, including electronic shaping of the wire signals (available).
3. Inner PMTs:
   a. Geometry of PMT array (simulated as discs), realistic description (in progress);
   b. First parameterization of light amplitude on PMTs, including electronic response (available), detailed simulation of time distribution (in progress).
4. CRT:
   a. Geometric layout (available);
   b. Signal simulation (in progress).
5. At present ~ 10^4 simulated event samples have been prepared (BNB νs, single particles, cosmic rays in the drift). A much larger MC event production is required.
6. MC simulations are based on GEANT4 code as embedded in LArSoft framework. A second independent simulation code based on different physical process description would be highly beneficial to the data analysis.

Event Reconstruction -1

1. Reconstruction of TPC charge signals (in progress with MC)
   a. Wire signal reconstruction, determination of charge amplitude in the different views.
   b. Study space charge effects on hit position and charge reconstruction.
   c. Track reconstruction.
   d. Event vertex reconstruction.
   e. Particle identification.
   f. Calorimetric reconstruction of the deposited energy.
   g. Muon momentum from multiple Coulomb scattering.
   h. E-m shower identification and reconstruction.
   i. Invariant mass reconstruction of gamma pairs.

2. Reconstruction of inner light signals:
   a. Separation in different "flashes" due to events overlapping in the same drift window (in progress with MC).
   b. Identification of the light flash associated to the trigger.
   c. Reconstruction of amplitude and time distribution of the light in a flash:
      i. Event position from PMTs and time reconstruction (in progress in MC)
      ii. Event classification with light.

Event Reconstruction -2

1. Reconstruction of CRT detector signals:
   a. Identification of the signal associated to different cosmic rays overlapping during the drift time of the TPC;
   b. Identification of the CRT signals overlapping to the triggering event;
   c. Position and time of particles crossing the CRT layers.

2. Correlation between inner light and CRT information:
   a. Distinction of incoming from outgoing particles from the CRT-PMT time difference;
   b. Enforcing the fast localization of the triggering event inside the TPC.

3. Correlation between CRT, PMTs and TPC event reconstruction for validation of event candidates and possible exploitation of precise timing for beam events.

4. Tools to monitor general detector performance with cosmic muons:
   a. LAr-purity measurement;
   b. General conditions of TPC electronics: noise and signal amplitude;
   c. Monitor time calibration.

5. Event Display with additional interactive functionalities and including CRT and PMT information has to be prepared.