MicroBooNE Commissioning Tasks and Durations
May 12, 2018

The following is the list of tasks that were completed to fully commission the MicroBooNE detector in 2015. The MicroBooNE commissioners were Bruce Baller and Matt Toups.

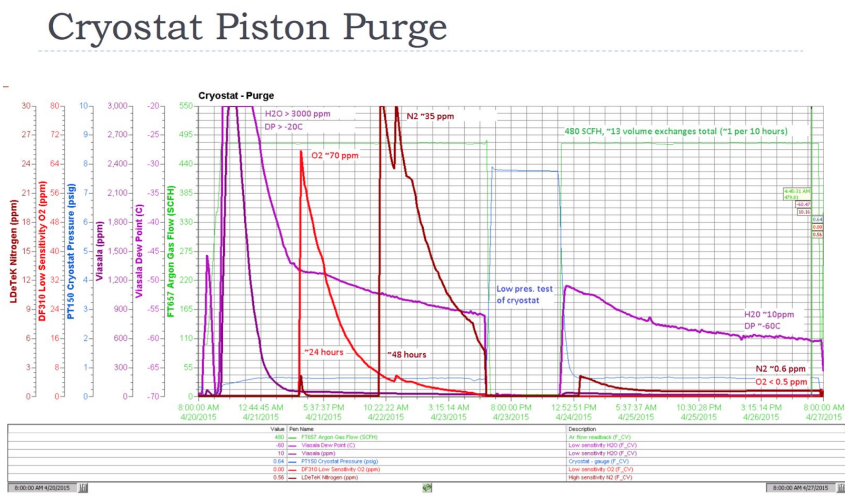
Scope:
The scope of MicroBooNE commissioning included the following deliverables

- All detector systems operational
- Detector in a state of routine data-taking
- Control room established and ready for shift-taking
- Shifter and technical documentation complete

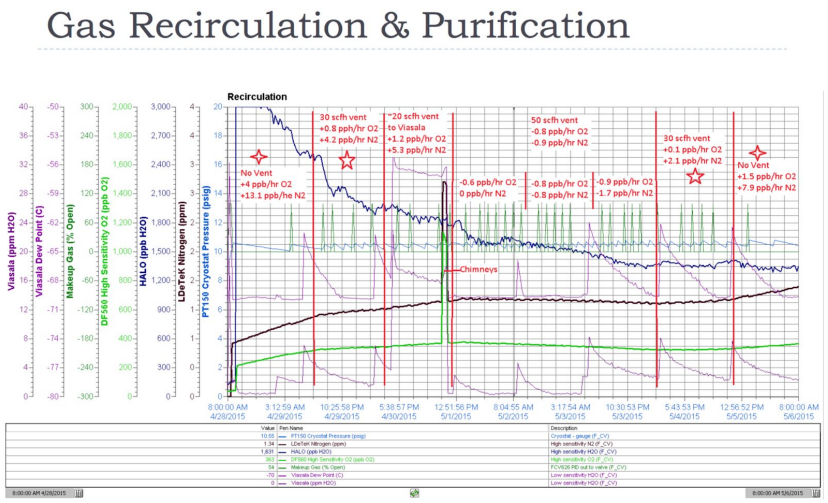
The commissioning process did not include calibration or detector physics studies. From start to finish, the entire commissioning process for MicroBooNE took place from January 5, 2015 to October 12, 2015. There were two decision points: ready to fill with argon and ready for beam.

Timeline:
Steps to Declare that MicroBooNE was **Ready to Fill** ...

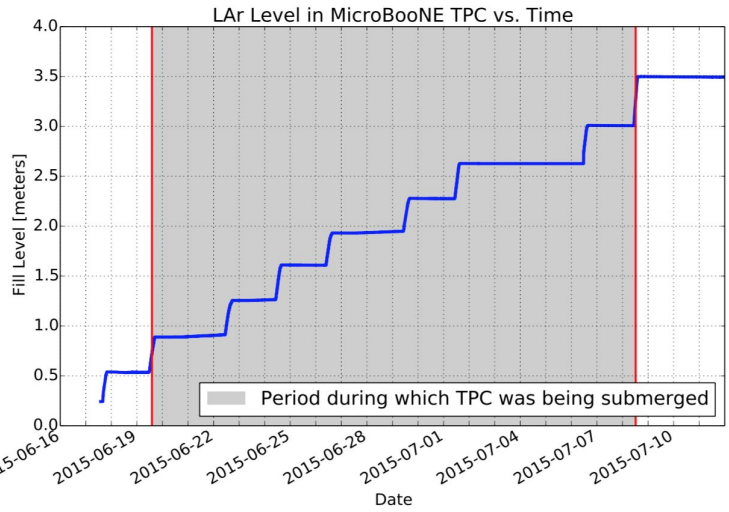
- Cryogenics system (~2.5 months prep, 1 month cooldown, 1 month argon fill and purification)
    - see MicroBooNE docdb #3947
    - 3 weeks: cryogenics system leak checks
    - 1 week: cryogenic system controls system tests
    - 3 weeks: cryogenics instrumentation and gas analyzer checkout
    - 1 week: argon gas piston purge (April 20-27, 2015)
        - O_2 contamination reduced by 3 orders of magnitude during the purge from 70 ppm → less than 0.5 ppm O_2



- 1 week: gas recirculation and purification (April 28 - May 6, 2015)



- 4 weeks: cool down at a rate of ~8K/day (May 20 - June 17, 2015)
  - cool down took 28 days to get from 300 K → 100 K
  - Noise levels measured in the TPC during cooldown
    - Drift HV, wire bias, and PMT systems were off
    - Noise was measured on collection plane wires only
    - This established a baseline noise level for the cold detector
    - MicroBooNE Public Note #1001
- 3 weeks: liquid argon fill (June 18 - July 10, 2015)
  - Mon-Wed-Fri delivery (3 days/week)
  - 1 truck/day, ~3,000 gallons/load, 8 hours per truck to unload
  - Total of 9 truckloads, 3 weeks to fill MicroBooNE with 170 tons of liquid argon with a pause in middle due to no deliveries during July 4 holiday



    - 10 days: liquid argon purification
        - O_2 contamination reduced to 100 ppt in this stage
        - No record of how long it took to commission purity monitors and develop purity monitor analysis; purity monitors were tested prior to installation
        - MicroBooNE Public Note #1003
- Detector ready for fill:
    - Baseline noise data was taken during cooldown (see above)
    - 2 days: Wire bias ramped to nominal settings for 70 kV as a test (March 10, 2015)
        - Monitored noise levels on wire planes during bias voltage ramp
        - A number of channels that were not previously noisy were noisy after the wire bias was applied
        - New procedures were put in place to energize one feedthrough at a time and in a particular wire plane order
        - Set of wires appeared to be correlated after wire bias ramp up to nominal
    - 5 weeks: noisy/touching TPC wire investigation
        - Included look inside the detector with custom-built camera system (https://arxiv.org/abs/1507.02508) and measurement of V vs. I curves for each feedthrough
    - PMTs and drift HV were not energized until after argon fill

Steps to Declare that MicroBooNE was **Ready for Beam** (after argon fill)

- Cryogenics
    - Nitrogen contamination verified to be at/below spec
    - Argon purity verified to be at/below spec
    - Continual argon purity monitoring automatically logged in electronic logbook (eventually switched from using in-vessel purity monitors to using cosmics)
    - Lines of communication defined with cryogenics liaison identified between the Fermilab Cryogenics team and MicroBooNE Run Coordinator
        - List of alarms that require 24/7 response pre-defined
        - On-call list defined and articulated to experiment
- PMTs (~1 month)
    - Measured and equalized PMT gains, studies of gain stability
    - Timed-in PMT signals, measured timing delays of PMT cables
    - Observed scintillation light at 0 drift field
    - Observed scintillation light at nominal drift field (after drift HV system operational)
    - Determined nominal operating PMT voltages
    - Measured discriminator firing vs. total PE to establish trigger threshold
- DAQ (~9 months)
    - Started exercising the DAQ 5 months prior to start of beam data-taking so could collect data with different ASIC gains/shaping times to establish default config
        - Included full event processing and storage to tape
    - Established data acquisition system stable with average uptime >95%

    - GUI created to allow capability for shifters to start/stop runs and change run configuration without DAQ expert intervention
    - Merging of data streams ready and demonstrated that included matching of detector and beam timestamps
    - Databases to store detector and beam quantities ready and functional
    - Huffman compression implemented for data compression
    - DAQ monitoring metrics defined and plotted for shifters
    - Offline readiness review held 8 months before start of data-taking
        - Charge: https://microboone-docdb.fnal.gov/cgi-bin/private/RetrieveFile?docid=5097&filename=MicroBooNE_ORR_Charge.pdf&version=1
- Drift High Voltage (~2 weeks, not including prep work)
    - Filter pot tested and operated for 1 month
    - Drift HV GUI developed for control of drift HV by experts
    - Drift HV power supply tested and slow controls verified
        - It was important to have data logged in slow controls during HV ramps so could go back and study this later, especially if there were problems
    - Tested connection to the TPC at LArTF with low drift HV
    - History of initial drift HV ramps (~2 weeks with each ramp taking 1 day)
        - August 6, 2015: drift HV ramp from 0 kV to 58 kV
        - August 17, 2015: drift HV ramp from 58 kV to 70 kV
        - August 18, 2015: drift HV ramp from 70 kV to 80 kV, trip at 78 kV
        - August 24, 2015: drift HV ramp from 0 kV to 75 kV, current draw at 75 kV and 74 kV, ramped down to 70 kV
        - August 27, 2015: drift HV ramp from 0 kV to 52 kV, current draw at 50 kV, ramped down to 45 kV
        - August 28, 2015: drift HV ramp from 0 kV to 70 kV
        - Study of impact of drift field on physics quantities to determine set point
        - September 21, 2015: drift HV ramped up final operating voltage of 70 kV
    - Established stable drift high voltage with small/no current fluctuations
    - Wire bias calculated and set to match transparency condition for given drift HV
- Electronics
    - Default ASIC (gain, shaping time, leakage current) and wire bias settings defined
- Operations
    - Control room established with the following monitoring capabilities:
        - Slow controls
        - Event display
        - Online monitoring
            - Raw ADC spectra, pedestals, pedestal widths
            - Measure of activity per wire
            - Noise levels
            - PMT pedestals, pedestal widths, timing

                - Timing information (event numbers across crates, cards, channels)
            - Offline monitoring of data being written/stored to tape
            - DAQ run start/stop control and error messaging
            - Beamline monitoring
            - Cryogenics system monitoring
            - Real-time camera view inside detector hall
            - Google Hangout account to allow shifters to communicate with experts via a chat window
        - 24/7 shifts started as soon as cryogenics system was operational, 4 months before start of beam data-taking
        - Electronic logbook established to keep track of all commissioning tasks and data-taking with categories defined for each sub-system to allow easy lookup
            - http://dbweb5.fnal.gov:8080/ECL/uboone/U/login
        - Online wiki page created with instructions for shifters and system experts
            - https://cdcvs.fnal.gov/redmine/projects/uboone-operations/wiki
            - Includes a Run Plan that is updated daily by the Run Coordinator
            - Format for each system: Overview, Troubleshooting, Experts Only
        - Online shift sign-up calendar and shift point tracking system created
            - https://dbweb6.fnal.gov:8443/ECL/uboone/U/login?message=Login%20required&ret_url=/ECL/uboone/C/show_month
        - List of system experts and their contact information defined and created for shifters
        - Run Coordinator schedule and term limits defined
        - Weekly operations meetings scheduled
- Beam
    - Established beam timing signals to DAQ
    - Integrated beam data into detector data stream
    - Beam monitoring in place and functional with beam performance metrics/plots
    - Lines of communication defined with a beam liaison identified between the Accelerator Division and the Run Coordinator
- Completion of Commissioning Review (2 days + 3 weeks to respond to recommendations)
    - September 24-25, 2015
    - https://microboone-exp.fnal.gov/at_work/operations/commissioning-reviews.html
    - Each subsystem (there were 14 on MicroBooNE) was assigned a system lead who had to provide a documented list of deliverables and a technote. All system leads were also required to have shifter documentation complete in time for the review.
        - Deliverables = defines what each system can deliver by the start of initial physics run
        - Technote = documents the status of the deliverables and demonstrates the readiness of the system prior to the review

    - A set of 2-3 reviewers were assigned to each system and were given a charge
        - Charge: https://microboone-docdb.fnal.gov/cgi-bin/private/RetrieveFile?docid=4714&filename=Commissioning%20Review%20Charge.pdf&version=1
    - Each system lead had to present the readiness of their system at the review
    - Reviewer reports were due within 3 days after the review. The MicroBooNE Commissioning Review triggered 105 review recommendations which were each tracked to completion by the MicroBooNE Commissioners
    - The MicroBooNE Commissioning review was held 3 weeks before the start of beam to allow the teams to respond to reviewer comments.
- The PMT-based trigger was implemented and commissioned in February 2016 which included a ~3 month period evaluating a change in approach from a hardware to software-based trigger.
- End