ICARUS Detector Status

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Detector status

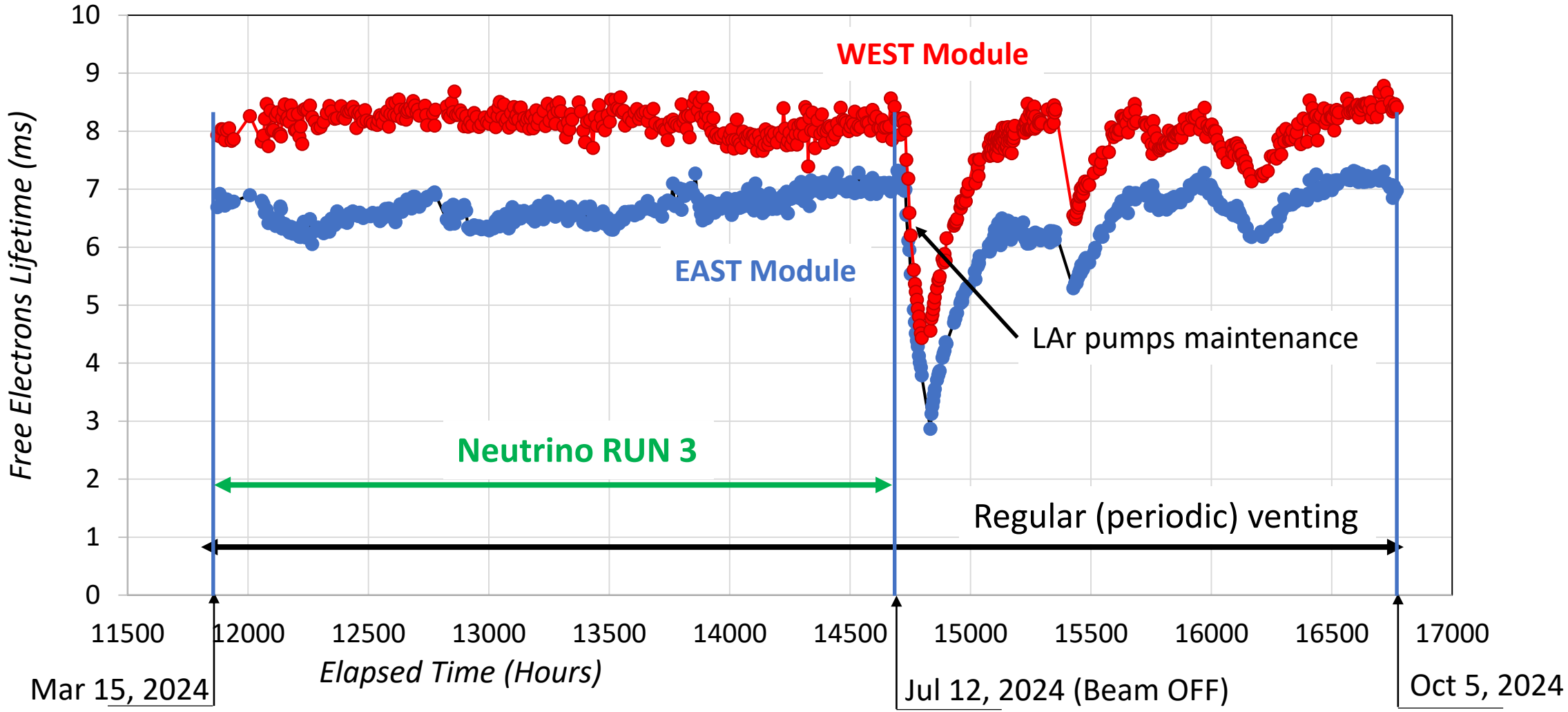
- The ICARUS detector continues to operate with remarkable stability and performance of all sub-components.
- Operation during Neutrino RUN 3 (Mar – Jul, 2024) proceeded without issues and exceptional performance.
- Regeneration of the warm filters was performed at the beginning of June, with no impact on data taking and on the free electrons lifetime.
- At the beginning of the summer shutdown, regular maintenance activities on cryogenic pumps took place.
- Several activities took place during the summer shutdown, mainly concerning regular maintenance and replacement of electronics, minor upgrades, optimizations and calibrations (see next slides). These activities are all completed except for the transition to the new version of the Linux (AL9) operating system of the servers (80% complete), that is both required and quite demanding.
- **Except for the completion of upgrades to the new version of Linux, all sub-systems are ready to start the next neutrino run.**

ICARUS Cryogenics and Purification Status (M. Geynisman)

- All cryo subsystems are operational with no issues.
- The two argon pumps and two of the nitrogen pumps have been maintained; next service is planned for the next summer shutdown. The third nitrogen pump will be serviced before Christmas.
- Regular venting of the two modules, 2 times/day for 7 minutes, is still required to maintain the LAr purity.
- Regeneration of the warm GAr filters was performed in June.
- We are planning to have the argon refill before Christmas. It will take one day. When we refilled, last year, the argon purity remained above 5 ms in the East module and 6 ms in the West module. About one week was required to re-stabilize the argon purity.

Free electrons lifetime (Mar 2024 – Oct 2024)

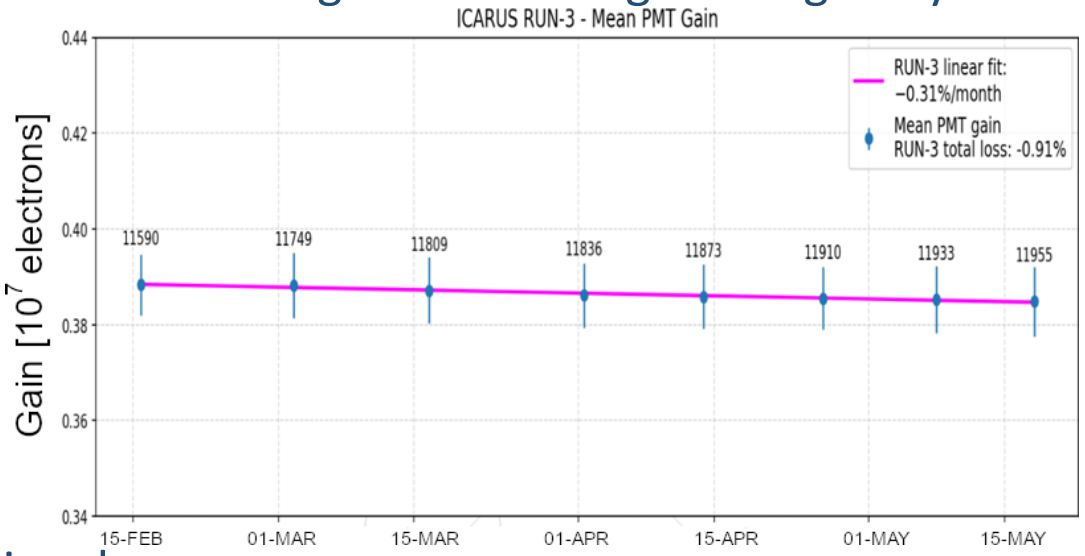
(C. Farnese, M. Artero Pons)



Light Collection System Status

(G.L. Raselli for the PMT WG)

- The scintillation light detection system is working smoothly since its activation with 357 active PMTs out of a total of 360.
- PMT gain during RUN3 was set to 0.385×10^7 with a spread of 1.8%. PMT gain and timing was regularly monitored during the whole data taking period.
- The previously observed 0.06% /day PMT gain reduction was reduced to ~ 0.02 % /day after the overburden installation (less background light). The adoption of new signal cables during the 2023 summer shutdown (lower PMT HV voltages) has further mitigated this effect, leaving a residual gain decrease of ~ 0.01% /day.



- Additional improvements have been recently applied to the light detection system, such as: installation of additional fan-tray on electronics, upgrade of the Laser calibration system, review of the system wiring.
- A problem was identified with the generation of discriminated signals (LVDS) by V1730 digitizers. An incorrect configuration register setting caused PMT signal discrimination to occur on the trailing edge of light pulses rather than the leading edge. This resulted in a loss of discriminated pulses for input widths below 12 ns. The issue has been corrected in preparation for RUN4.

TPC Status

(A. Guglielmi, M. Worcester for the TPC WG)

- The installation of Chebyshev low-pass filters on the frontend supply of the A2795 TPC has reduced by ~15 % the coherent noise propagating into the boards through +7 V line.
- Few general maintenance, interventions have been performed on the PS of Mini-crates, on the specific channels of the read-out boards replacing few preamplifiers and fuses.
- In particular, some unreliable contacts between Chebyshev filter and A2795 board randomly causing missing fragments in the Mini-crate read-out were fixed.
- The new test-stand installed on the mezzanine is operational, allowing to check anomalous TPC boards. It's now routinely used to inspect the noise and malfunctioning boards reading directly the wire signals of a Mini-crate without the need of DAQ, speeding-up the testing process.
- The deployed system includes dedicated software protocols focused on the TPC wire signals that allows also the intervention of TPC expert by remote.
- As a conclusion, the TPC is working properly in stable condition with a reduced coherent noise after the special filters installation on all the read-out electronics.

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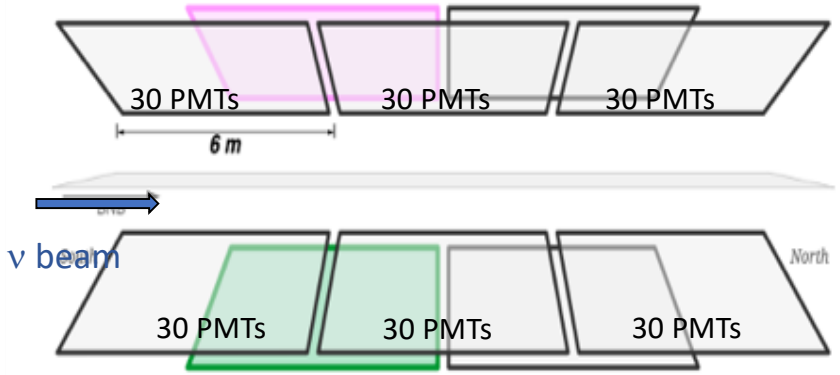
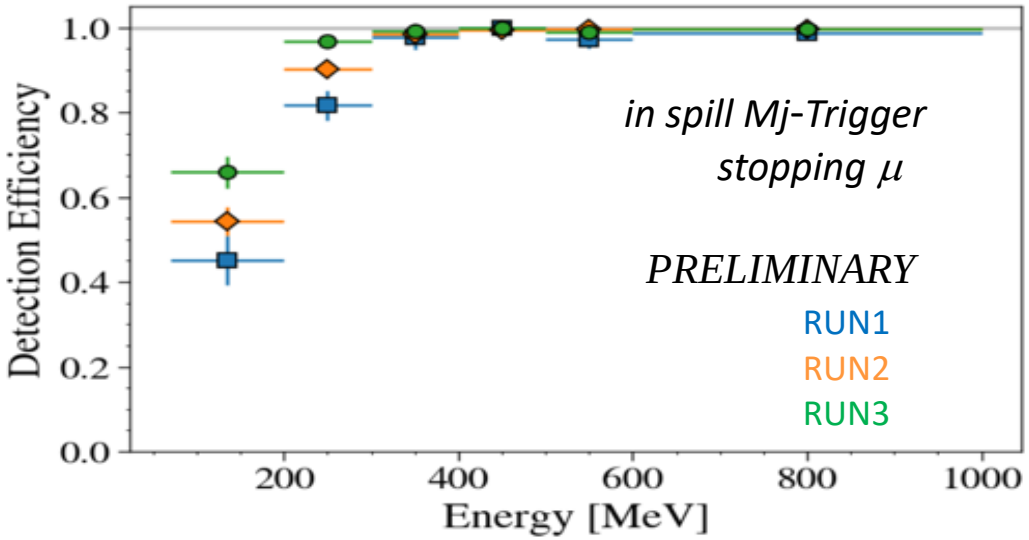
Trigger system evolution: from Run-1 '22 to Run-3 '24

(A. Guglielmi, for the Trigger W.G.)

- Presently (Run-3) the Main Trigger system relies on the fired PMTs multiplicity inside one of five 6 m longitudinal overlapped slices (30 PMTs left + 30 PMTs right) in coincidence with BNB (1.6 μs), NuMI (9.5 μs) spills:
  - In-spill: events collected by >=4 fired PMT pairs (Majority Mj = 4, 13 phe thr.) in a 6 m slice;
  - Out-of-spill: cosmics crossing TPCs during 1 ms e^- TPC drift time recorded by Mj = 7.
- Stopping cosmic muons were collected without any request on PMTs (Min-Bias Trigger): trigger efficiency is evaluated by recognizing fired PMTs from their waveforms for different PMT-majorities (Mj Trigger emulation):





✓ RUN1: Mj =5 in-spill, Mj =10 out-of-spill, fired PMTs in 3 tiled 6 m slices

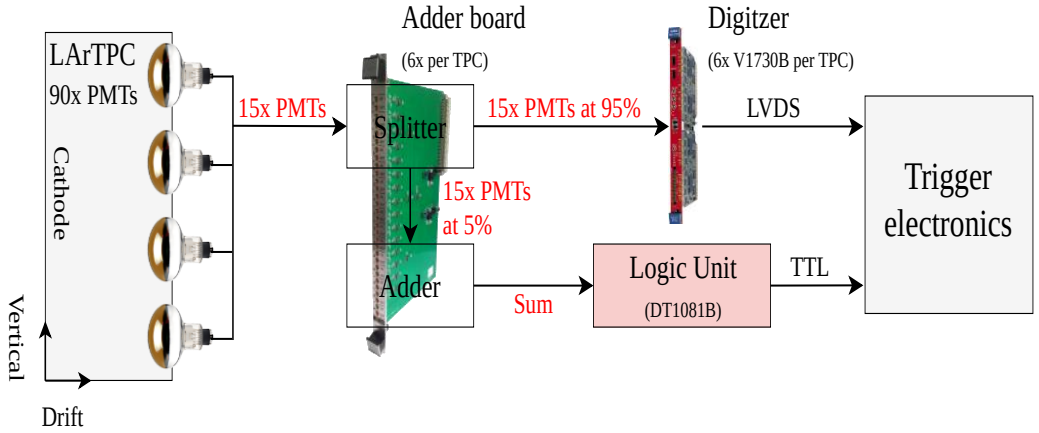
✓ RUN2: Mj =5 in-spill, Mj =9 out-of-spill, adding 2 overlapped slices

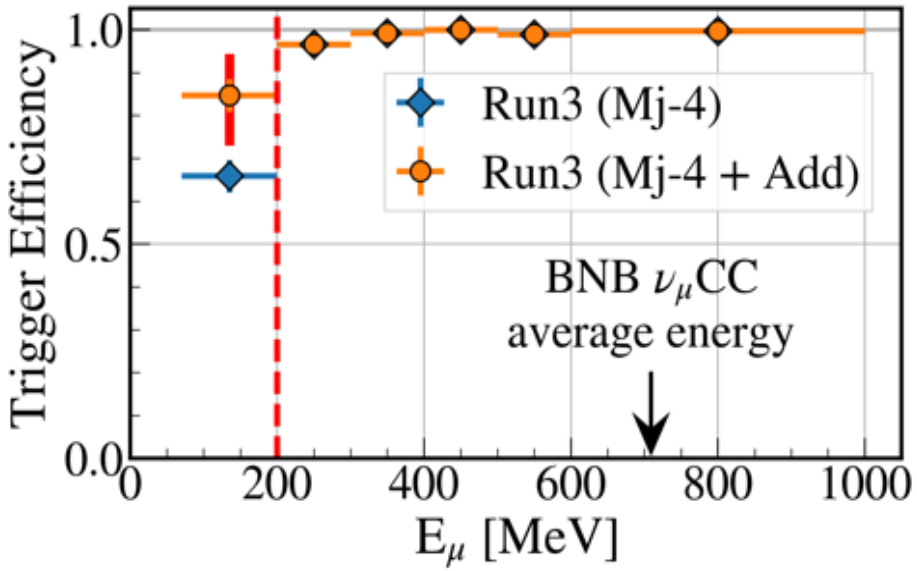
✓ RUN3: Mj =4 in-spill, Mj =7 out-of-spill, fired PMTs in 5 overlapped slices, plot doesn't include PMT Adders trigger source

RUN-3: additional PMTs adders trigger source

(A. Guglielmi, G. Petrillo, for the Trigger W.G.)

- A 2nd independent trigger, based on total light signal instead of fired PMTs multiplicity, was deployed to further increase efficiency at low E:
  - 24 custom Adder boards summing up 5% of signals from 15 adjacent PMTs;
  - Analog-sum signals are discriminated/fed into Trigger logic in OR condition with Mj.





PRELIMINARY: low stat measurement with stopping muons

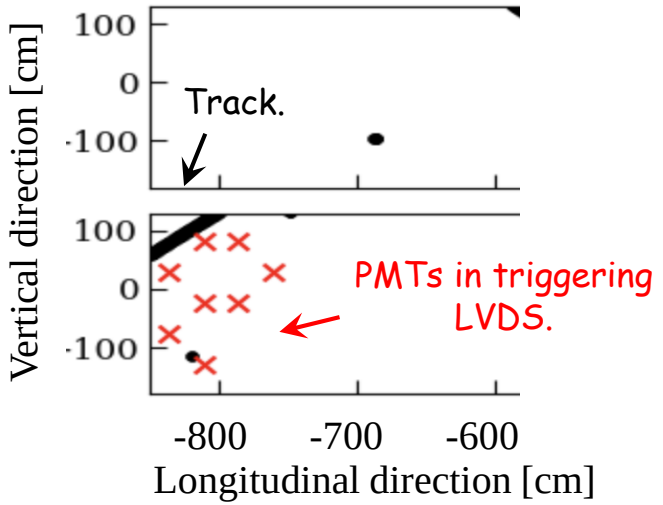
first hints: + 20% efficiency E <200 MeV

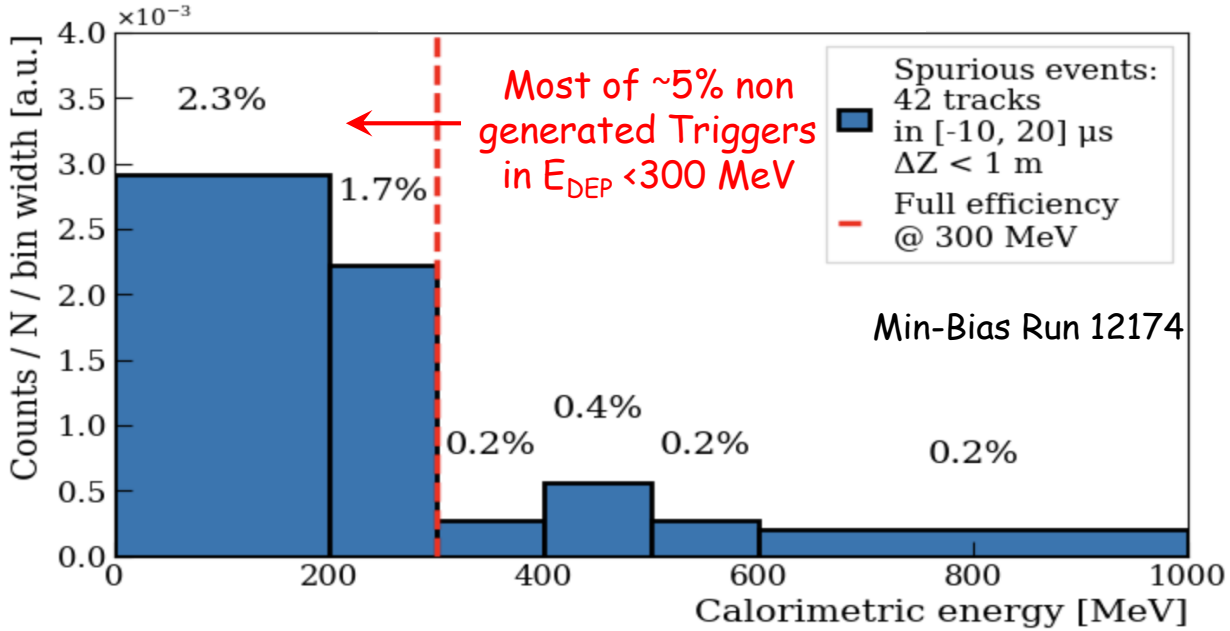
- Out-of-spill cosmics collected with Mj =7 + Adders during 1 ms TPC drift time increased from ~8 kHz (RUN2) to ~11 kHz (RUN3), improving cosmics recognition/rejection.

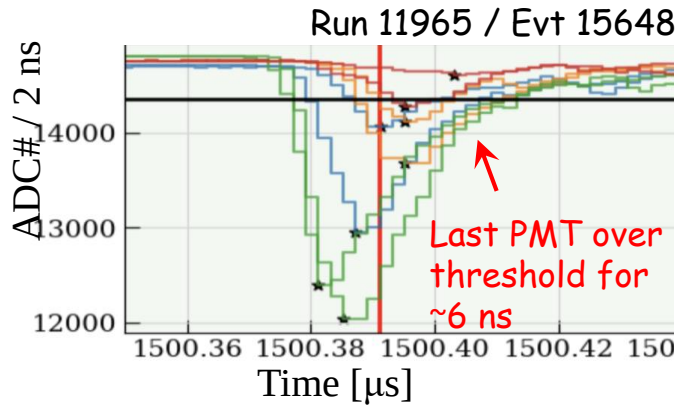
Run-1, 2 Trigger Investigation

(A. Guglielmi,
for the Trigger W.G.)

- Several detailed studies of the trigger system implemented in Run-1, Run-2 have been performed to assess the measured efficiencies and related systematics.
- A discrepancy between emulation and trigger hardware triggered events, led to discover a misconfiguration of V1730 PMT digitizers, triggering on PMT signal trailing-edge instead of the leading one as used in the trigger emulation
- This misconfiguration should explain the ~ 5% of missing hardware triggers w.r.t. the emulated ones in Min-Bias runs. The 4% refers to E_{DEP} <300 MeV tracks at TPC borders with short (< 12 ns) PMT signals close to PMT threshold.







Work in progress with increased event statistics

Beam gate investigation on Run-3 and next Run-4

(A. Guglielmi, for the Trigger W.G.)

- The small efficiency reduction at low E due to previous misconfiguration of V1730 PMT digitizers is well recovered by the addition of the PMT Adders Trigger in Run-3.
- However, the 2nd part of Run-3 from April 30th was affected by a different and unexpected White Rabbit network signals distribution which prevented the correct gates opening by the SPEXI board.
- As a consequence, an average of ~0.3 % of BNB spills and ~7 % of NuMI spills were non acquired due to the missed generation of the beam gate.
  - The corresponding acquired beam POT reduction must be quantified run by run, as it depends on the accelerator's conditions.
- Trigger studies for Run-1, 2, 3 are ongoing to finalize trigger efficiencies and collected POT statistics to account for the V1730 digitizers and SPEXI board issues. The associated Trigger systematics is expected to be < 5 % for E_{DEP} <300 MeV and < 1 % for E_{DEP} > 300 MeV where the trigger efficiency saturates. The note describing the trigger system/features in Run-1 and Run-2 is underway.
- The observed issues have been fixed prior Run-4 and several controls have been implemented/activated to avoid these issues in the future.

(A. Guglielmi, for the Trigger W.G.)

Monitor of Enable and Beam Gate production by SPEXI

- A monitor has been introduced in LabView code to verify the correct production of Enable and Beam gate from the SPEXI board upon receiving Early Warning signals from MI12 (BNB) :
  - Signals from MI12 (Early Warning (EW) and Early Early Warning (EEW)) are fed into one Trigger FPGA and the counts of the Beam and Enable gate generated by the SPEXI board are compared to the MI12 EW direct signals: discrepancies in the counts will provide info of gates' losses;
  - In the monitor, the gate counts are shown in the Real Time Controller main .vi every minute along with an integral value starting from the beginning of the run;
  - At the moment only BNB (MI12 signals) can be monitored: the NUMI monitoring requires some hardware installation by the Accelerator Division (AD).
  - Some additional checks on trigger in/off-spill are being investigated.

ICARUS DAQ Status Overview

(D. Torretta, G. Savage for the DAQ/Online team)

- In a nutshell: the daq is ready for Run-4!

- Running ***sbndaq*** *v1_10_01 release* as default since August.
  - Testing sbndaq v1_10_02 (with SBND only changes) is underway.
- Running the daq from Spack areas on ***icarus-evb01***: Spack replaced ups/products settings and allows running with mixed OS systems, like SL7 and AL9, at the same time.
- Most hardware components' boardReaders have been tested and are now running on AL9 nodes (see next slide from Geoff) except: CRT bottom boardReader and the WR boardReader, this latter will stay at SL7.
- Run configurations have been updated to reflect the hardware changes and the PMT LVDS fix (see trigger report).
- The OM (Online Monitor) required a new release of the ***sbndqm*** code (v1_03_00) to include latest releases of other packages like *icaruscode, LarSoft, artdaq, artdaq_code*… The release was successfully built and tested by M. Vicenzi and G. Luckhanin. Thanks!
- Several other tasks were successfully completed or are underway and should be completed by the beam return, as detailed in the next slide.

ICARUS Online computing transition to AL9 (I)

(D. Torretta, G. Savage for the DAQ/Online team)

- Transition ICARUS online computing to AlmaLinux9 (AL9), Linux version supported by Fermilab.
  - ➢ No more security updates for SLF7, previous Linux version.
- ✓ Setup infrastructure to operate DAQ on AL9 and SLF7 servers.
- ✓ Setup and run infrastructure on AL9 – tested and worked, but …
  - ✓ DAQ VNC, daqinterface, run control, msg viewer (icarus-ops01).
    - ✓ Some issues with window manager defaults on AL9.
  - ✓ Event builder (icarus-evb05).
- Test board readers on AL9
  - ✓ Moved fibers and cables to different servers for testing (Anna, Matteo, Harry).
  - ✓ PMT (icarus-pmt04).
  - ✓ TPC (icarus-tpc25).
  - ✓ CRT Side (icarus-crt10).
  - ✓ CRTTOP (icarus-pmt04).
  - ✓ trigger (icarus-clk02).
  - ✓ CRT bottom (icarus-crt10).

ICARUS Online computing transition to AL9 (II)

(D. Torretta, G. Savage for the DAQ/Online team)

- Summary:
  - Servers at AL9 (52/64):
    - Board reader - pmt (5), crttop (3), crt side (9), tpc (28), nfs (2), gateway (2), evb05, ops01+02.
  - Servers remaining at SLF7 (12):
    - database (3), dcs01, clk01+05 (white rabbit), evb01-04 (dqm), evb06 (grafana), crt11 (bottom).
  - Icarus has a variance to run SLF7 servers for another year. Any component that can't be transition to AL9 will continue to run on SLF7 for the next year.

ICARUS Cosmic Rays Tagger (CRT)

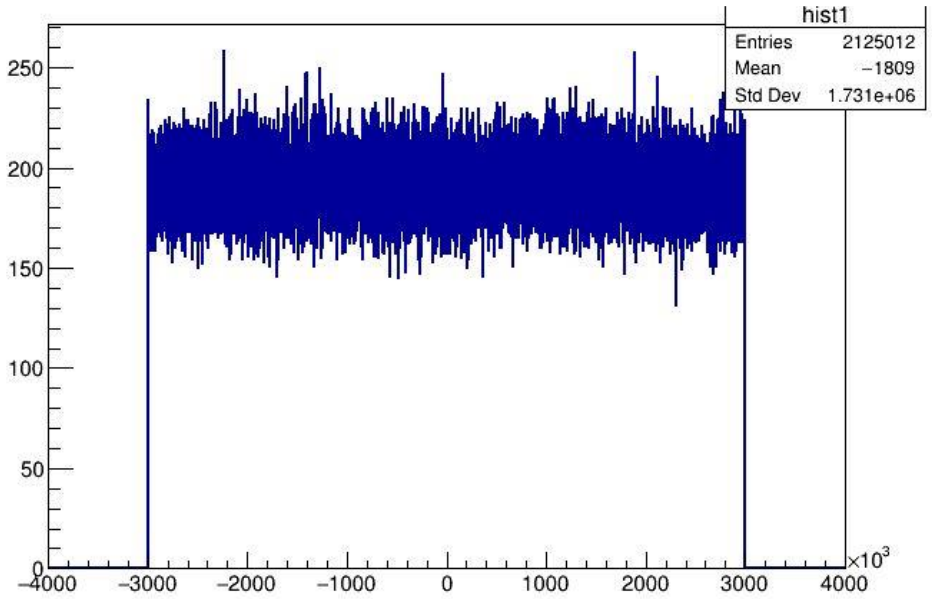
(M. Betancourt, L. Patrizii for the CRT WG)

- Top, Side and Bottom CRT taking data
- Commissioning of Bottom CRT complete. Analyzing data from RUN-3.

- New scintillator modules
- Silicon photomultiplier (SiPM)-based readout

- Repurposed MINOS modules
- SiPM-based readout

- Repurposed Double Chooz modules
- Photomultiplier tube (PMT)- based readout



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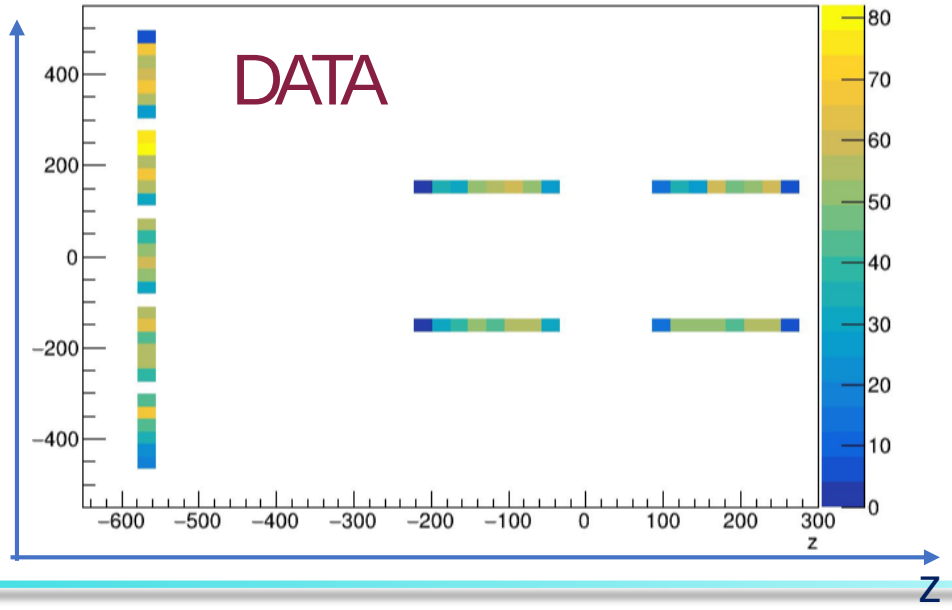

Axel Campos

Conclusions

- The T600 detector and all subcomponents, continue to operate with remarkable stability and performance.
- During the summer, regular maintenance was performed on the cryogenic pumps. No interruption of LAr circulation is foreseen during RUN-4.
- Also, during the summer shutdown all sub-systems have been inspected and maintained, with some minor bug fixes and upgrades, but with no major changes with respect to RUN-3.
- DAQ stability continues to improve, although the data taking efficiency is already very high (> 97%).
- Also the trigger continues to improve, with another reduction of threshold for RUNU-4.
- Transition to the new version of Linux (AL9) for most of the servers has been completed.
- **All sub-systems have declared readiness for the next neutrino run (RUN-4) which is expected to start in November with BNB.**
- ICARUS is operating in nominal detector conditions since more than 4 years breaking the previous record of 3.5 years established in Gran Sasso.