Light collection system for ICARUS-T600

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OUTLINE

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- Description of the PMT light detection system.
- Upgrade activities at CERN.
- System deployment at FNAL.
- Description of the PMT data acquisition system.
- Main installation tasks and timescale.
- Conclusions.

PMT WG people list:

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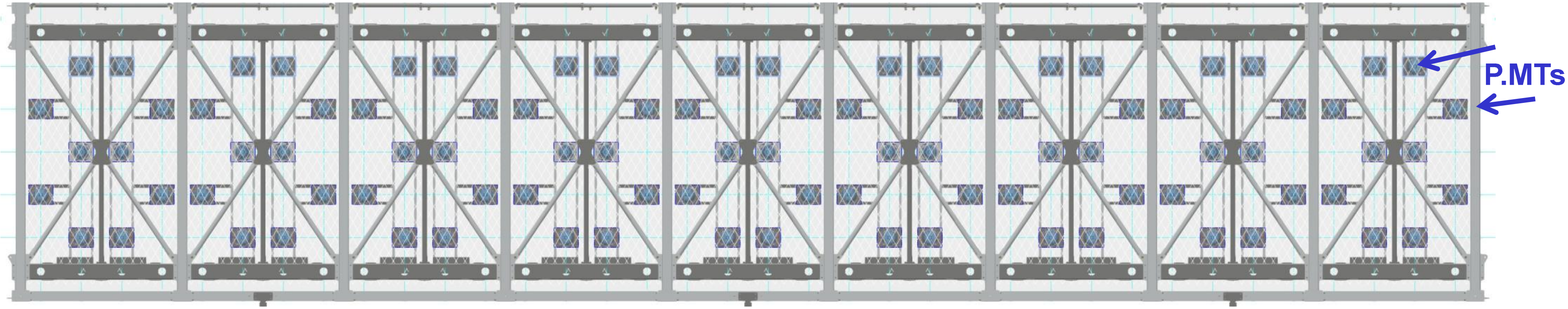
T600 light collection system

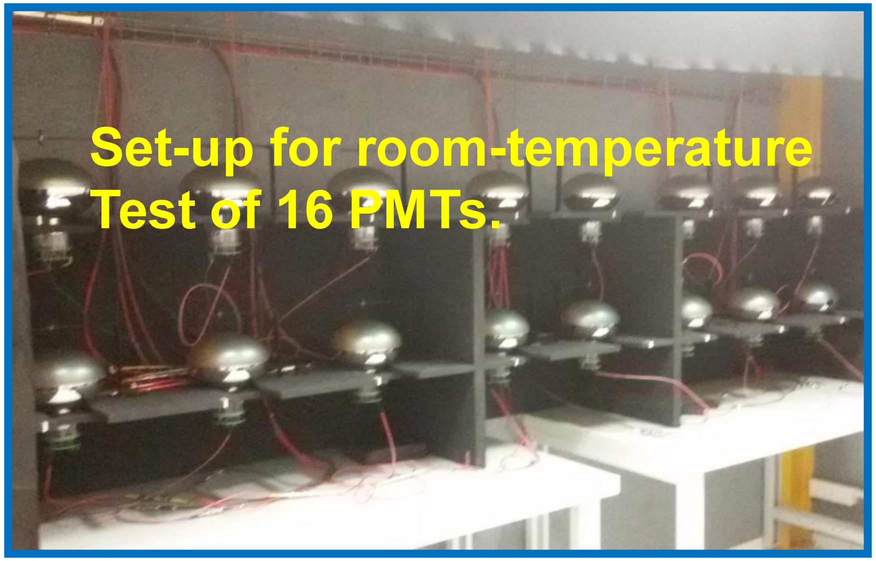
- The ICARUS T600 light collection system consists of 90 PMT 8" HAMAMATSU R5912-MOD for TPC, installed behind each wire planes (total 360 PMTs);
- This configuration allows for a photo-cathode coverage of 5% of the wire plane area and a light collection of 15 phe/MeV;
- Monte Carlo simulations demonstrate that this PMT deployment permits to trigger low energy events (<100 MeV) with fairly high threshold/multiplicity. It offers an event longitudinal localization better than 0.5 m and allows an initial classification of different interaction topologies (μ-tracks vs e.m. showers).

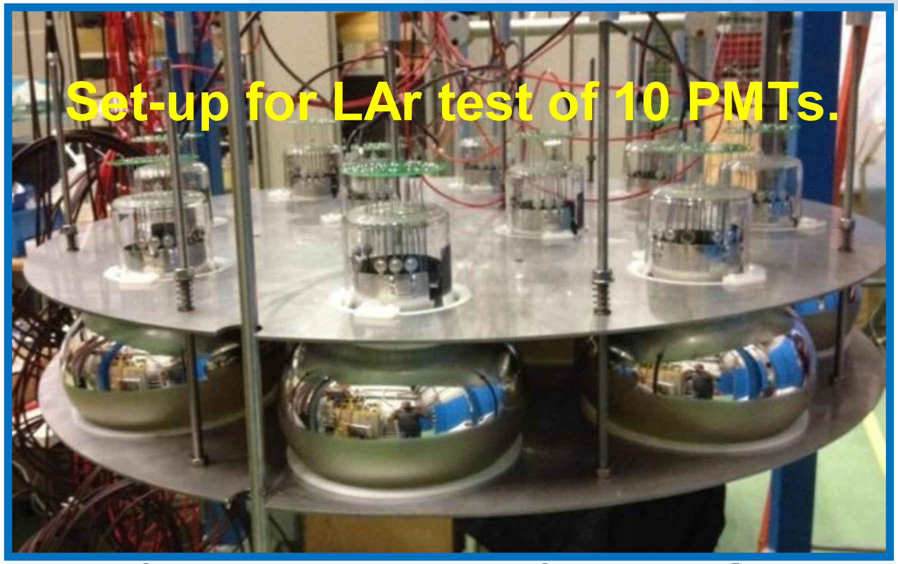


Z axis (beam direction)

Upgrade of the light collection system

- 400 PMTs were tested at room temperature and directly in a LAr bath to evaluate the parameter variation at cryogenic temperature.
- Test were carried out at CERN in dedicated areas where a dark-room and a cryogenic facility were arranged.

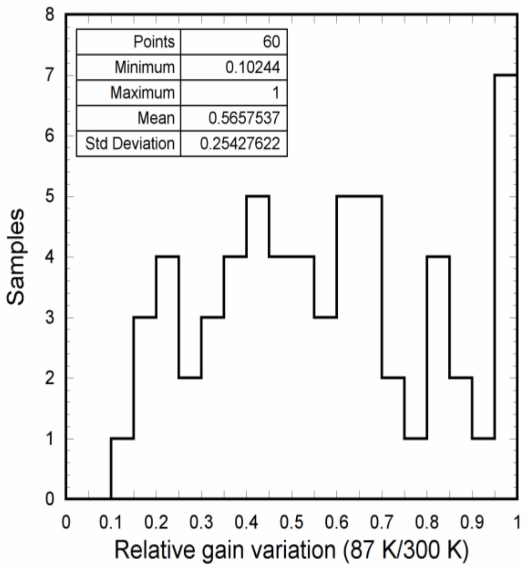


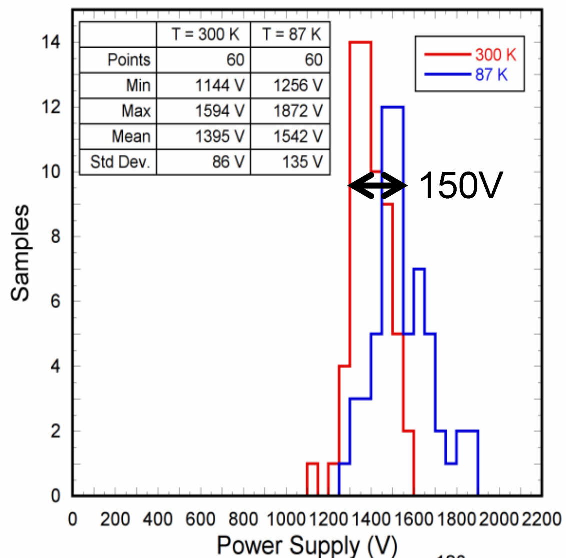


- Test carried out by illumination of the PMT surface by means of a LASER diode (405 nm) and optical fibers. A standard electronic chain (PRE+AMPL+MCA) was adopted.

PMT test results

Measurements include: signal characteristics, gain variation, saturation effects, photocathode uniformity, timing characteristics…



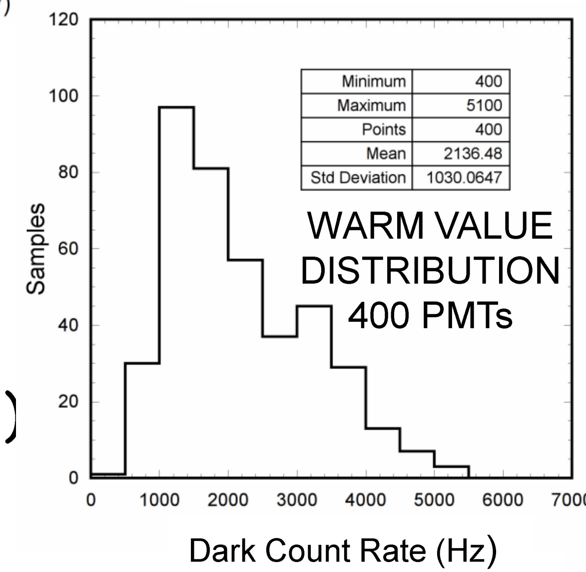


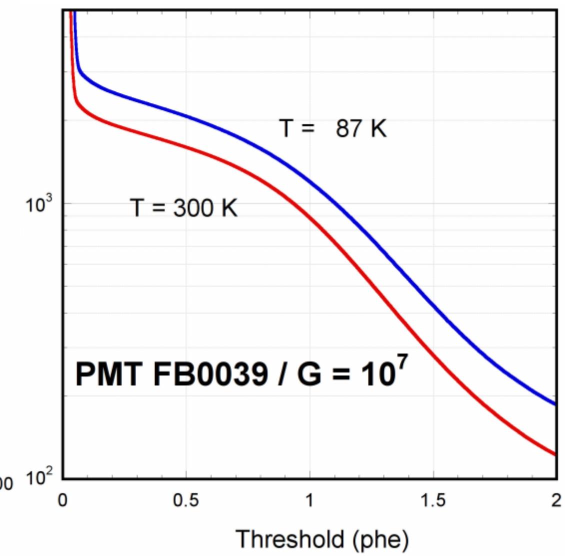
A gain variation was experienced for almost all the 60 units at 87K, with a mean reduction of ~50%. An increase of the HV supply (150V) is enough to restore the nominal value.

arXiv: 1807.08577 submitted to JINST

Dark count rate is also affected by the temperature, with a factor 2 increase at 87K with respect to the nominal values at room temperature (well known effect in literature though not yet completely explained)

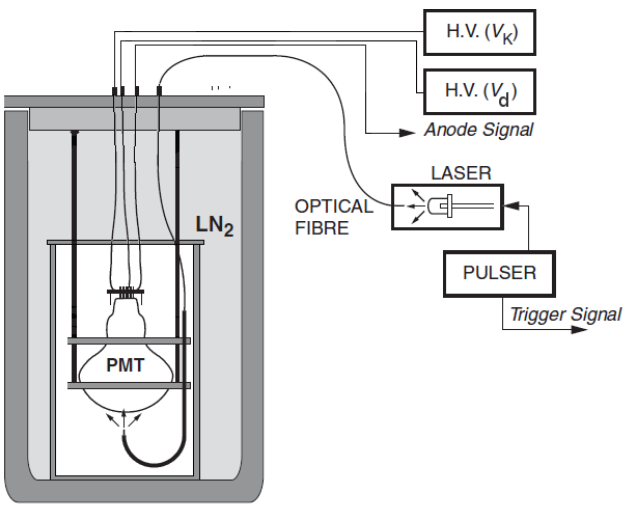
All the tested PMTs were rated for installation in the T600

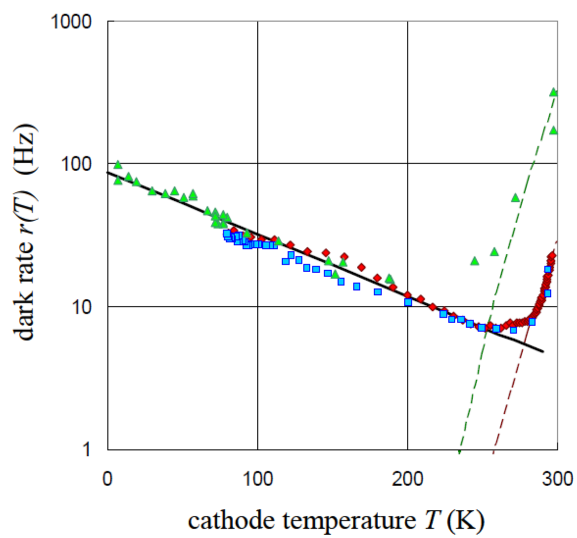




Dark Rate at Cryogenic Temperature

Dark Counts rate for PMTs working at room and at cryogenic temperature were measured with 1×10^7 gain, 0.3 phe threshold. The PMT was housed inside a stainless steel vacuum chamber, in a LN2 bath, to avoid Cherenkov emission and other radiation.



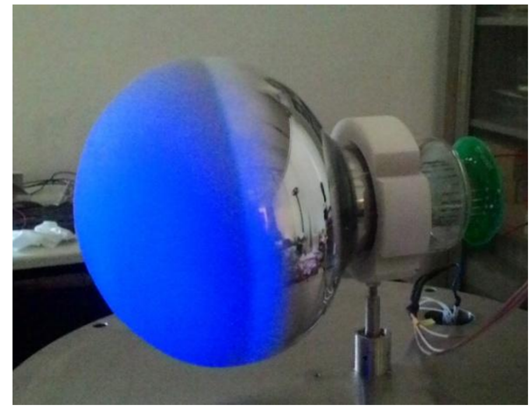


Non-Thermal Dark Rate effects have been experienced by many authors. While the source of this emission is found in the photocathode, <u>its nature and its features are not yet understood.</u>

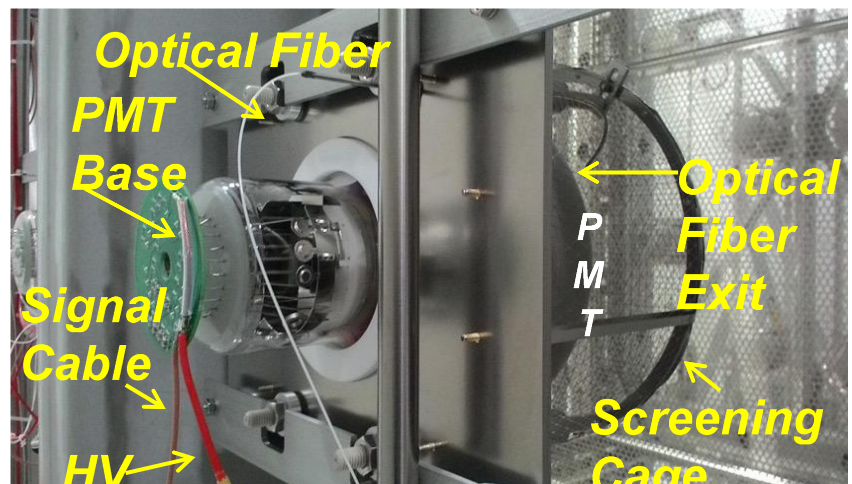
The increase of dark rate with falling temperature is a well known effect, referred as Non-Thermal Dark Rate, and it was observed for the first time in 1963 (*J.P. Rodman and H.J Smith. Appl. Optics 2 , 181 1963*). A recent description (2008) can be found in *H.O. Meyer, Dark Rate of a Photomultiplier at Cryogenic Temperatures, arXiv:0805.0771v1.*

Preparation and test of the light detection devices at CERN

- A total of 400 PMTs, delivered by Hamamatsu at CERN, were equipped with a customized cryogenic base.
- All PMT's were tested at room temperature; 60 units directly in a LAr bath to evaluate the change at cryo temperature of gain, linearity & dark counts.
- *All PMTs were rated compliant with requirements for installation in T600.*
- 360 PMTs were uniformly coated by evaporation with ~200 μg/cm^2 of Tetra-Phenyl-Butadiene (TPB) to detect the λ = 128 nm LAr scintillation light.

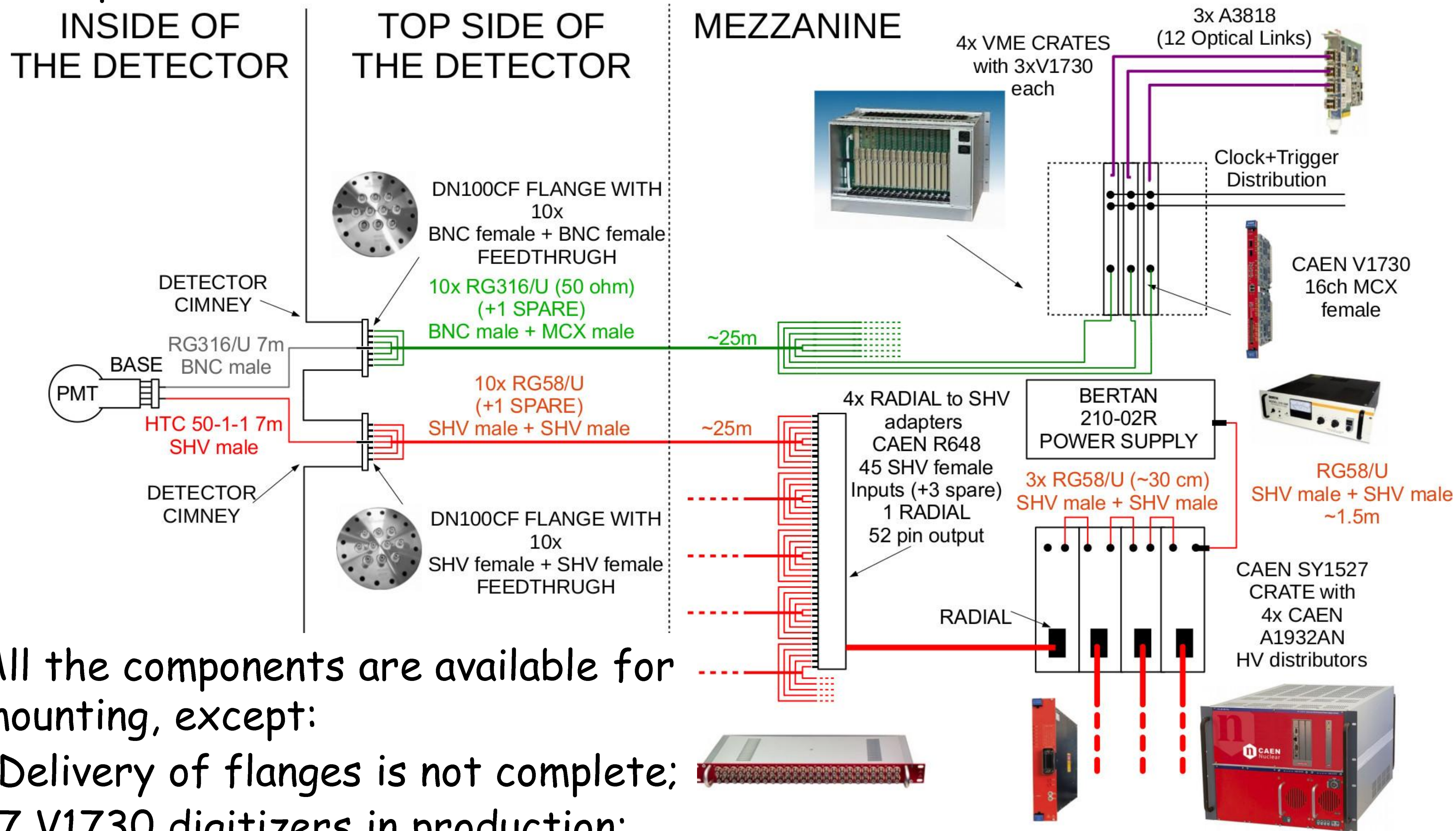


- New mechanical supports for the PMT installation were prepared. Each device is set inside a wire screening cage to prevent induction of PMT pulses on the facing TPC Collection wire planes.
- The PMT timing/gain equalization is performed by using light pulses from a Laser source (Hamamatsu PLP10, λ=405 nm, FWHM <100 ps, peak power ~400 mW). For each PMT, a 50 μm optical fiber allows the illumination of the photocathode.



Light detection system deployment

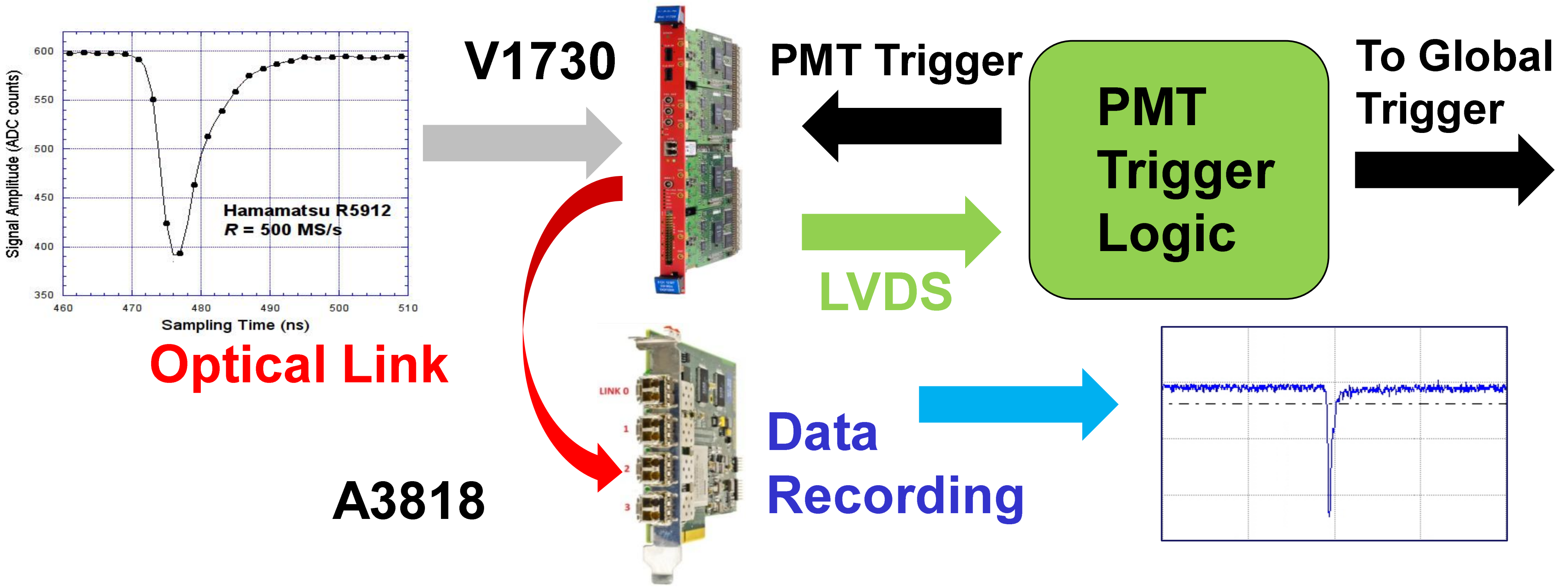
- For each T300 module the following instrumentation deployment has to be accomplished.



- All the components are available for mounting, except:
  - Delivery of flanges is not complete;
  - 7 V1730 digitizers in production;
  - Cable are in ordering.

PMT DAQ Electronics

- The scintillation light data acquisition and recording is equivalent to an oscilloscope channel for each PMT.
- This is performed by means of CAEN V1730B (500MS/s, 14-bit). Recorded signals will be available through optical links (A3818 board).
- Moreover the V1730B boards will generate a set of discriminated output signals (LVDS) which will be available for triggering purposes.



See next trigger presentation for details

Light detection system: installation milestones

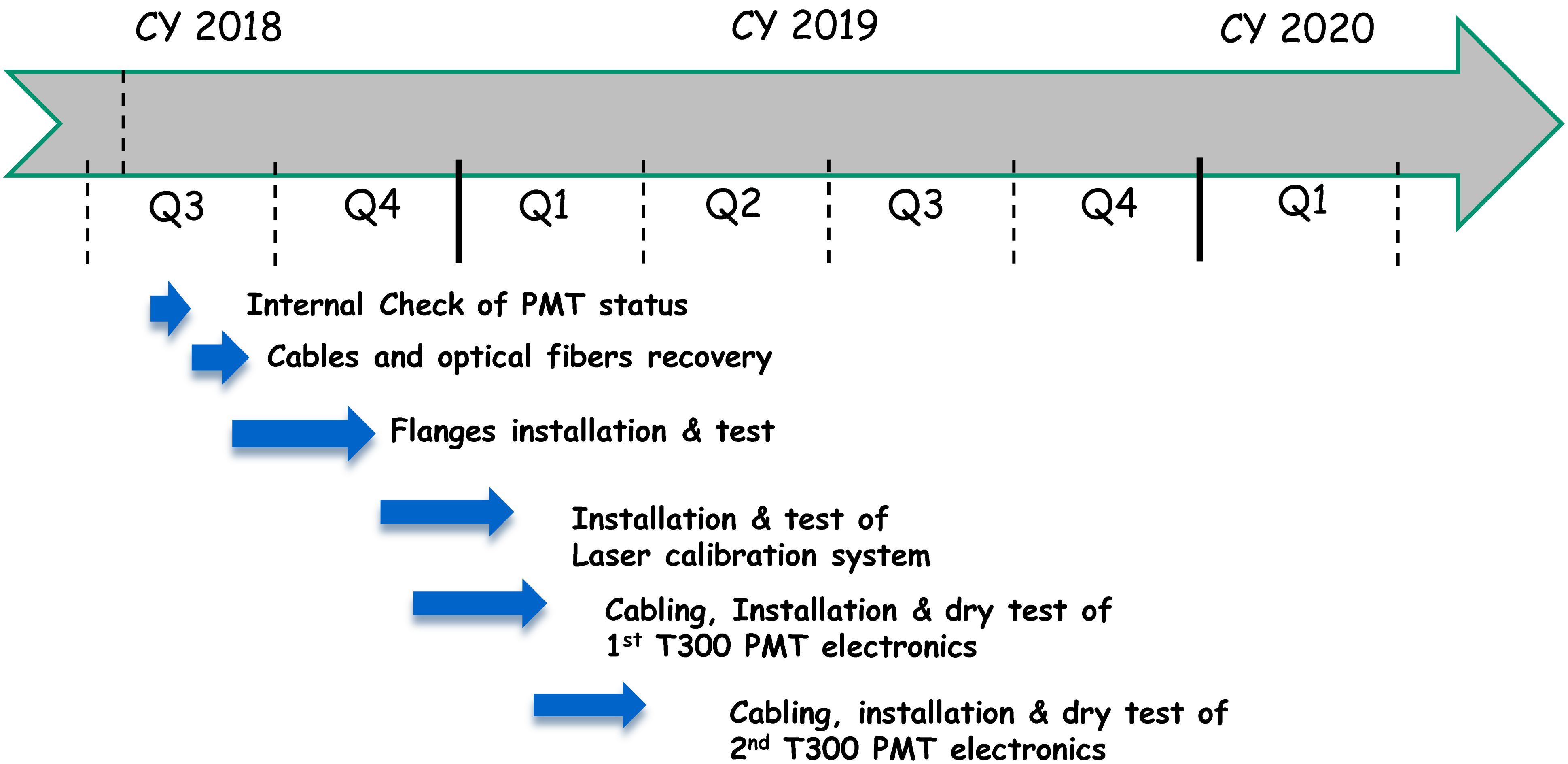
- Signal cables and optical fibers deployment and fastening along the TOP chimneys. Check of cable continuity.

first two week of September 2018

- Installation of internal optical splitters and optical feed-through flanges. Check of optical connection.
- Signal cables and optical fibers mounting on the feed-through flanges. Check of cable/optical continuity; PMT local activation.
- Connection to external cabling and optical fibers. Check of cable/optical continuity;
- Installation of HV power supply system.
- Installation of the PMT DAQ system: VME crates, digitizers, optical links, cabling. Activation of the whole light detection system.
- Installation of the timing calibration system: Laser, optical switch. Activation of the whole light calibration system.

The precise timeline has to be arranged with the other ICARUS installation tasks (see C. Montanari).

PMT electronics: timeline



Light detection system: online, software & slow control tasks

- Other important activities concern:
  - Development of software for the PMT signal recording and integration on the detector DAQ system (see presentations on DAQ and Trigger);
  - Development of software for PMT signal analysis (see presentation on software);
  - Development of the light detection system calibration and monitoring (procedure, signal reconstruction algorithm…).
  - Deployment of the light detection system slow control (see presentation on slow control).
- In addition a number of tests are being performed to improve the performance of the light detection system and to get familiar with the different subsystems before operating at FNAL:
  - Study of the synchronization between different boards;
  - Study of the Laser calibration protocol finalized to a precise PMT signal synchronization.

CONCLUSIONS

- The T600 light detection system is devoted to:
  - Identify precisely the time of occurrence (t_0) of each interaction;
  - Identify the event topology for fast selection purposes;
  - Generate a trigger signal to enable the event read-out by combining the PMT signal pattern to the BNB/NuMI beam spills (≈1 ns precision) and the veto from the external Cosmic Ray Tagger (CRT).
- A great effort has been devoted at CERN to the upgrading of the light detection system.
- A lot of work has to be accomplished here at FNAL to complete the mounting and make operative the system.

… more people welcome!!!