Plans for PMTs testing

G.L.Raselli for the PMT WG

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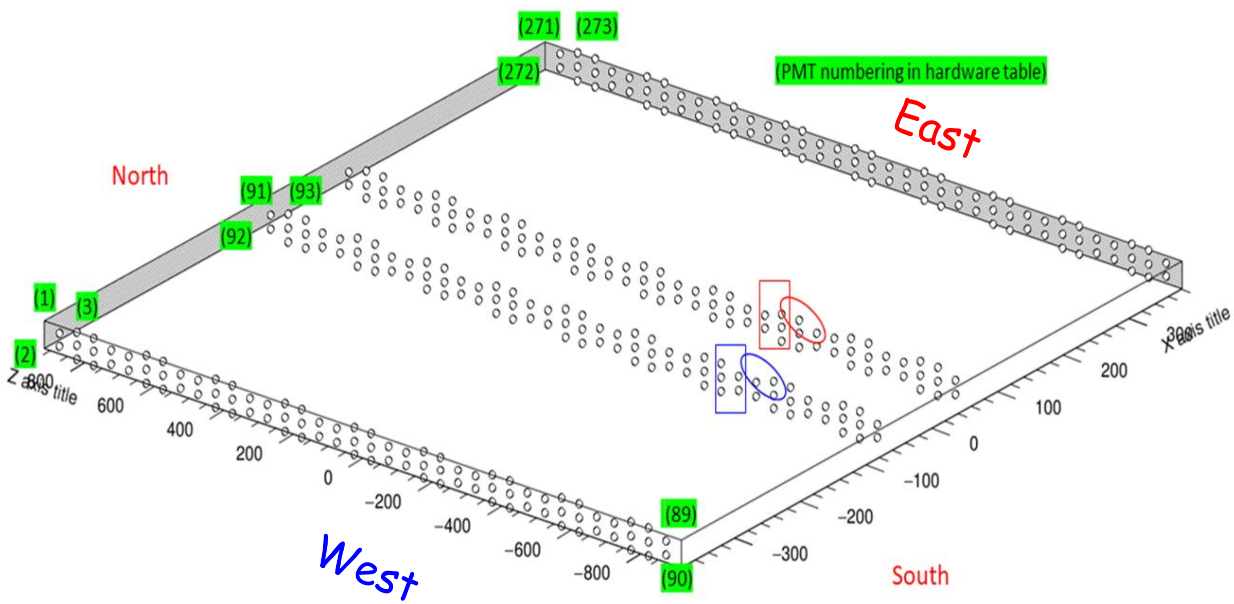
PMT activation

- A set of 16 PMTs (8 PMTs in each cryostat) will be activated at cryogenic temperature.
  - ✓ The identified PMTs are in WE and EW, marked by the blue and red shaped
  - ✓ On first day 8 in the WE will be turned on.
  - ✓ On second day 8 in the EW will be turned on.



PMT in the EW:

HV: CAEN SY1527

PMT2-RA2 ch 16-23

Signal: 5 channels in digitizer EW-BOT-B and 3 channels in EW-BOT-C

PMT in the WE:

HV: CAEN SY1527

PMT1-RA4 ch 16-23

Signal: 5 channels in digitizer WE-BOT-B and 3 channels in WE-BOT-C

- Work plan:

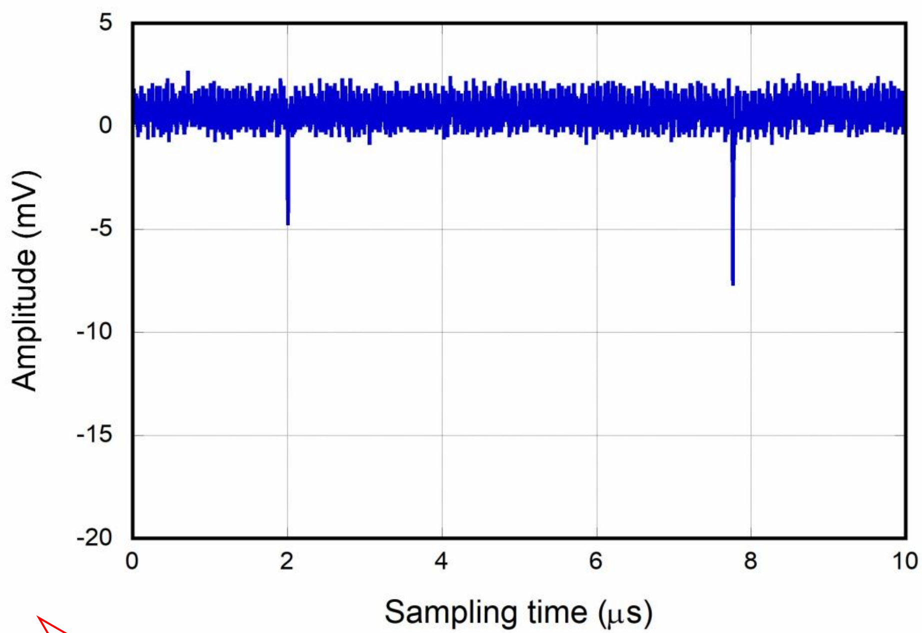
https://sbn-docdb.fnal.gov/cgi-bin/private/ShowDocument?docid=17740

Procedure

- ✓ Check PMT HV and signal resistance with a multimeter.
- ✓ Start the 8 PMTs with low voltage, eg. 100V
  - ✓ Take the 8 PMT signals and input to the 8-ch oscilloscope;
  - ✓ Save some waveforms from the scope, the data can be used for noise reference.
  - ✓ Start epics to control the Bertan HV;
  - ✓ Start CAEN SY1527 HV terminal as well; Set the 8 channels (OFF) to 100 V;
  - ✓ Turn on the Bertan HV to 1000V, controlled & monitored by the epics tool;
  - ✓ Turn on the group in CANE SY1527 HV with 100V.
    - ✓ If no abnormal current both in Bertan and CAEN HV, we then continue.
- ✓ Raise the voltage to 1000 V from CAEN terminal: signals should be seen on the scope.
  - ✓ Wait for ~20 minutes to let the PMTs to stable, in the meantime, we can search signals in the 8 channels from the scope. Some waveforms can be saved.
    - ✓ If everything is stable, then continue to the next
- ✓ Increase the voltage to the nominal voltages of gain 10^7 from CAEN terminal.
  - ✓ Wait for ~15 minutes, during this time save some more waveforms from the scope
    - ✓ if stable, then insert the signals into the digitizers, DAQ can be started.
    - ✓ Continue seeing signals from digitizers (trigger rate 5 Hz from TPC).
  - ✓ Make an Elog entry, inform the shifter, start the usual DAQ routine.

PMT activities

- At the end of the procedure we will have 8+8 PMTs powered at the nominal voltage and connected to digitizers.
- In the following days the main activities on these PMTs will be focused on:
  - Verify that the PMT withstand the power supply in LAr, their gain stability and measure the light background signals.
  - To perform this task data will be acquired with random triggers and measuring/counting single electron pulses.



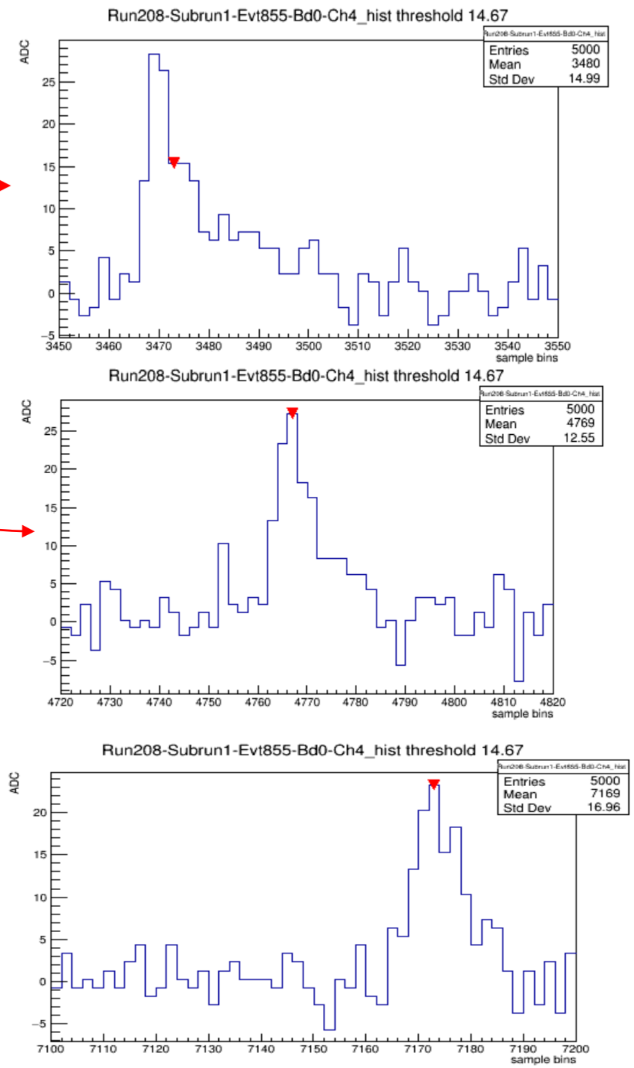
The amplitude distribution of these pulses will be used to monitor the gain stability of the tubes, while the frequency of the pulses will estimate the light background rate.

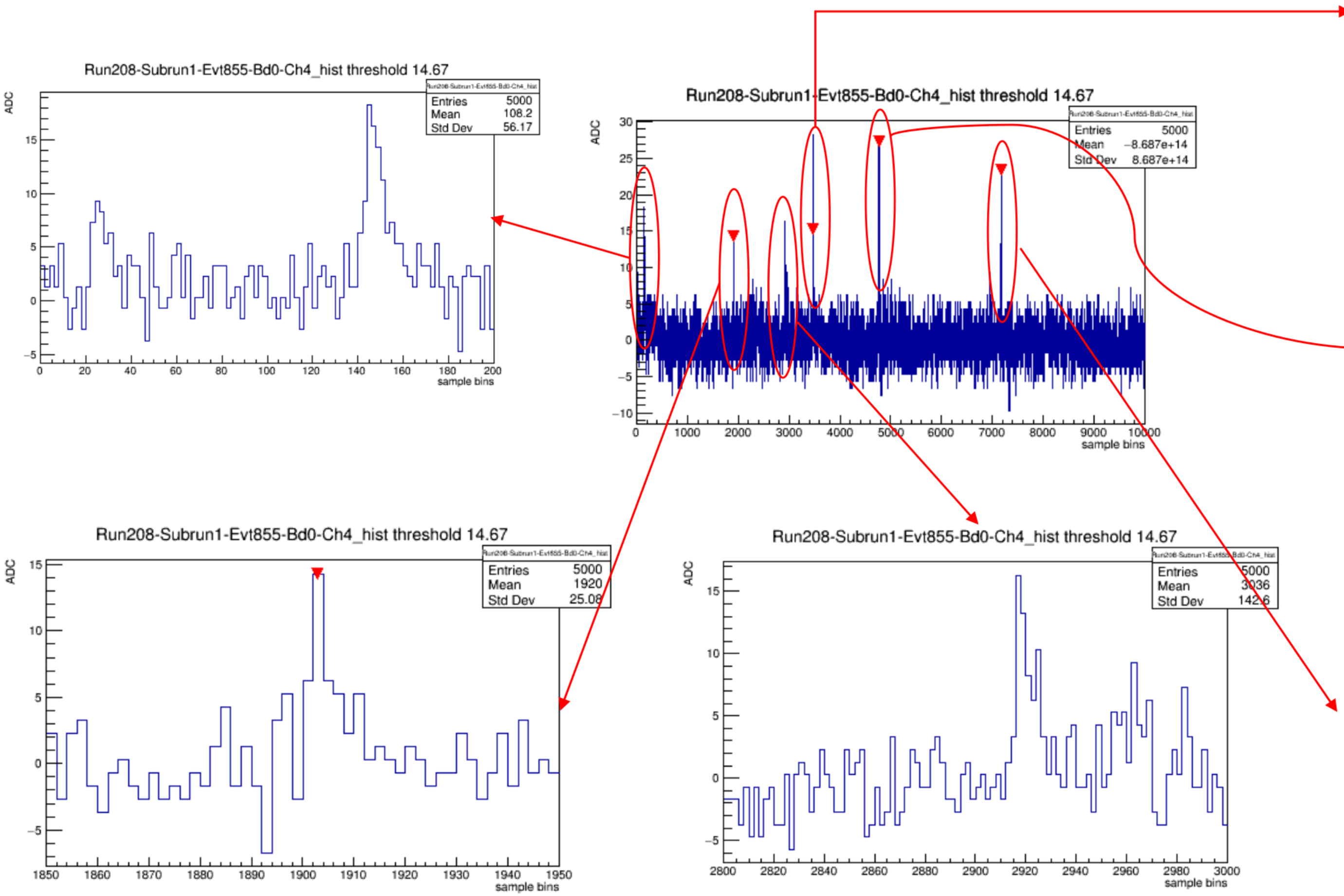
INTEREST: the frequency of background pulses as a function of the electric field.

  - During this phase the automatic software routine will be tuned-on.

Pulse Finding and Dark Rate Measurements

- The ROOT's TSpectrum class is a good tool to do pulse finding
- It performs well but not ideal





Correction: x-axis is in ns not bins

Gain Measurement

- We have high (low) charge distributions for different PMTs, representing large (small) npe input.
- -- determine whether high or low charge by requiring >=1% events in the pedestal region (charge ~0)
- For large charge distributions:

$$S_{\text{ideal}}(x) = \sum_{n=0}^{\infty} \frac{\mu^n e^{-\mu}}{n!} \frac{1}{\sigma_1\sqrt{2\pi n}} \exp\left(-\frac{(x-nQ_1)^2}{2n\sigma_1^2}\right),$$

- parameters: μ: mean npe; $Q_1(\sigma_1)$: charge peak (width) of 1 pe signal; one scale factor (not shown)

- For small charge distributions (usually with pedestal peak), we express pedestal and background with Gaussian and exponential functions (Milind, JINST 2020 *JINST* **15** P02001)

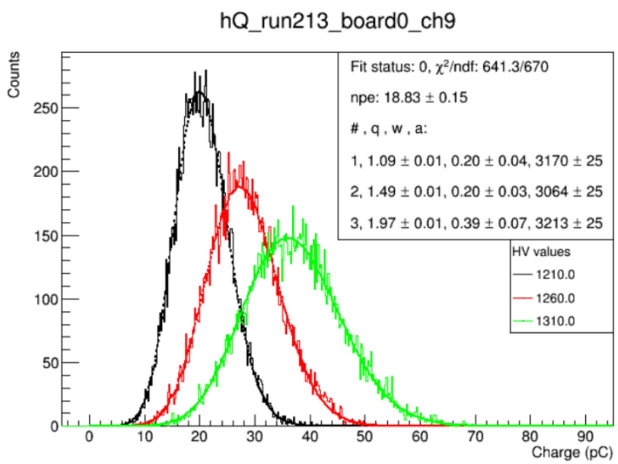
$$\begin{aligned} P_Y(x) = \;& e^{-\lambda} \times ((1-w)N(x; q_0, \sigma_0) + wE_N(x; q_0, \sigma_0, c_0)) \\ &+ \lambda e^{-\lambda} \times \left((1-w)N(x; \mu + q_0, \sqrt{\sigma^2+\sigma_0^2}) + wE_N(x; \mu + q_0, \sqrt{\sigma^2+\sigma_0^2}, c_0)\right) \\ &+ \sum_{k=2}^{\infty} \frac{\lambda^k e^{-\lambda}}{k!} \times \\ &\left((1-w)N(x; k\mu + q_0, \sqrt{k\sigma^2+\sigma_0^2}) + wE_N(x; k\mu + q_0, \sqrt{k\sigma^2+\sigma_0^2}, c_0)\right) \quad (2.13) \end{aligned}$$

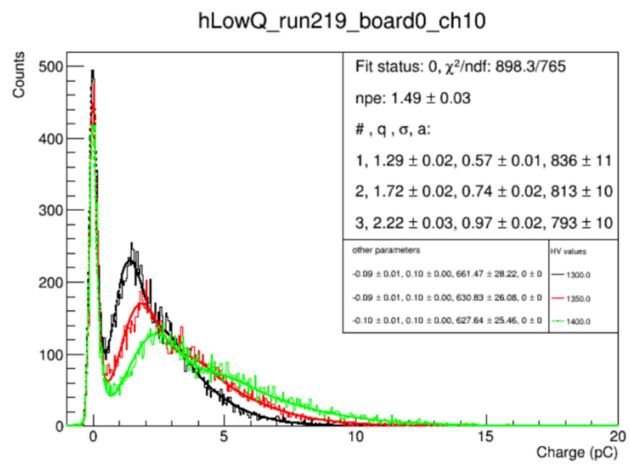
Approximation → $a * S_{ideal}(\mu, Q_1, \sigma_1) + a_{ped} * E_N(m_{ped}, \sigma_{ped}, c0_{ped})$

- In the approximation, the $e^{-\lambda}$ normalization constrain is removed, practically it works better in the joint fit.
- We use joint fit to charge distributions for each PMT at 3 HV points, with the assumption that the *mean npe* is the same.

$N(x; q_0, \sigma_0)$ is the Normal function

$E_N(x; q, \sigma, c) = \frac{\sigma}{c} \cdot \sqrt{\frac{\pi}{2}} \cdot e^{\frac{1}{2}\frac{\sigma^2}{c^2} - \frac{x-q}{c}} \cdot \text{erfc}[\frac{1}{\sqrt{2}} \cdot (\frac{\sigma}{c} - \frac{x-q}{\sigma})]$ is exp-mod Gaus

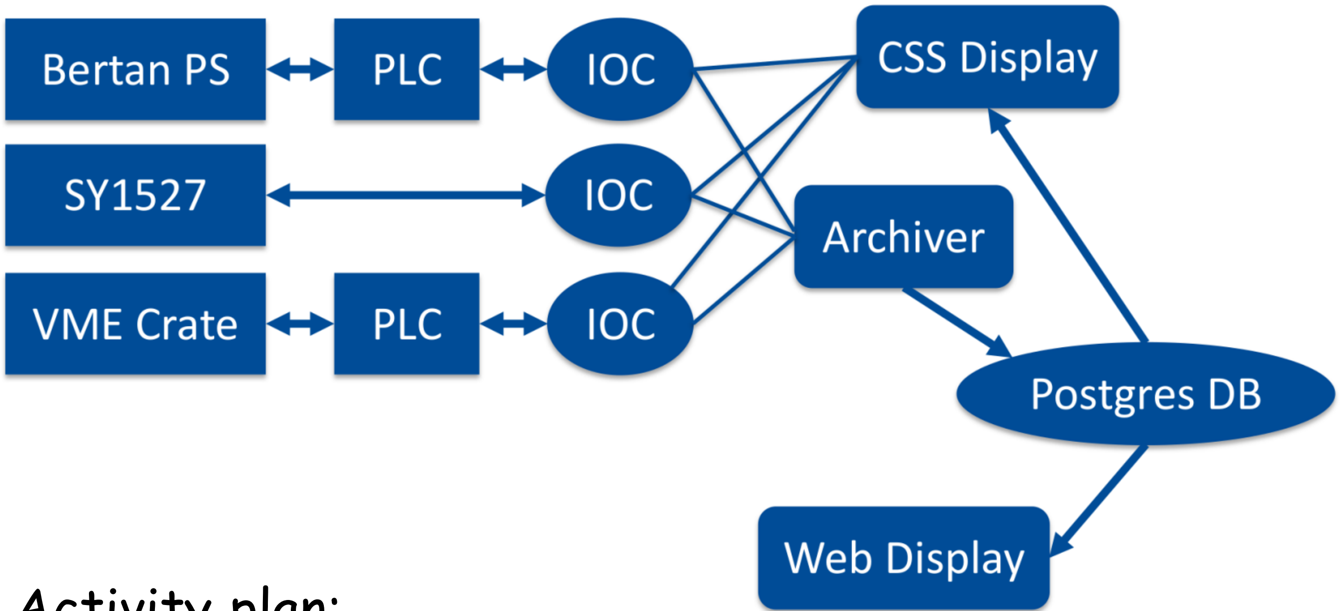




Check of electronics

- The activation of 16 PMT will permits a number of checks of various electronic subsystems. Among them:
  - Checks of the PMT system digitizers with actual PMT data:
    - ✓ Check if the digitizers dynamic range is adequate to acquire both the components of the LAr scintillation light, or the PMT nominal gain has to be changed;
    - ✓ Baseline stability (this task is in progress);
    - ✓ Effect of long cables on signal shape;
    - ✓ S/N ratio.
  - HV voltage distribution system:
    - ✓ Slow control system;
    - ✓ Design a GUI for monitoring.
- Additional electronics test will be possible in the (near) future, when the access of the FD building will be permitted again:
  - Threshold and LVDS setting (additional cabling needed);
  - Laser activation and setting (presence of expert needed);
  - Activation of additional PMTs.

Slow control update



EPICS Clients for experts
- Command line tools
- Python interface
- Web display

EPICS Clients for DCS
- Archiver
- Alarm Handler

EPICS Clients for shifters
- Control System Studio – user interfaces

- Activity plan:
  - ✓ Verify the DCS for PMT HV (power on/off, ramps, interlocks…);
  - ✓ Add tested features in a GUI;
  - ✓ Configure the archiver to archive all the HV channels;
  - ✓ Write documentation;
  - ✓ Take some data (are we getting signals in the PMTs we expect?).

https://sbn-docdb.fnal.gov/cgi-bin/private/ShowDocument?docid=18221

Final remarks

- At the end of this initial activation procedure we will have 16 PMTs (8 for each cryostats) powered on and with data taking running.
- Data will be available for analysis, tests and to check simulation programs.
- In this presentation only the very preliminary test plan has been introduced, but a much more complete work can be carried out.

- Any suggestion is welcome.