Photoelectron statistics studies of PCAL prototype

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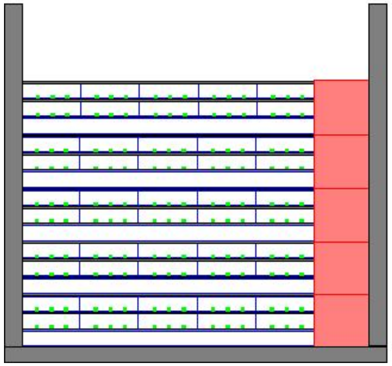
Outline

- Previous tests overview

  Prototype structure, DAQ scheme, results…
- New setup for photoelectron statistics studies

  Description of test setup, electronics, DAQ ...
- Measurements and results
- Summary and future planes

PCAL design

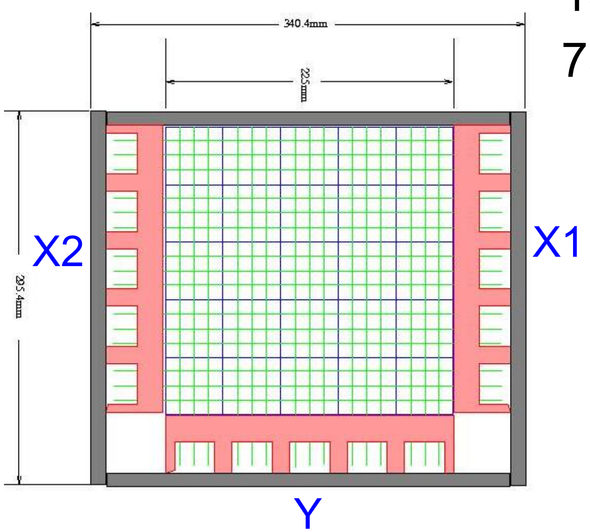


Pcal components:

- Fermi Lab scintilliator strip 45X10mm, 3 grooves
- WSF (KURARAY 1mm, SC)
- Lead 2.2mm
- Aluminum frame and support structure

Prototype Side View

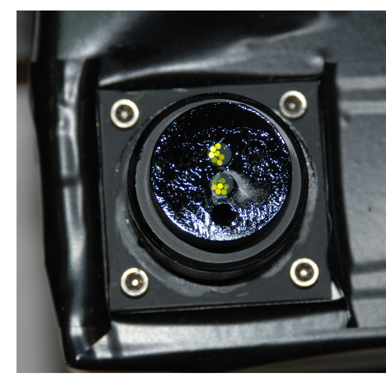
Prototype Top View



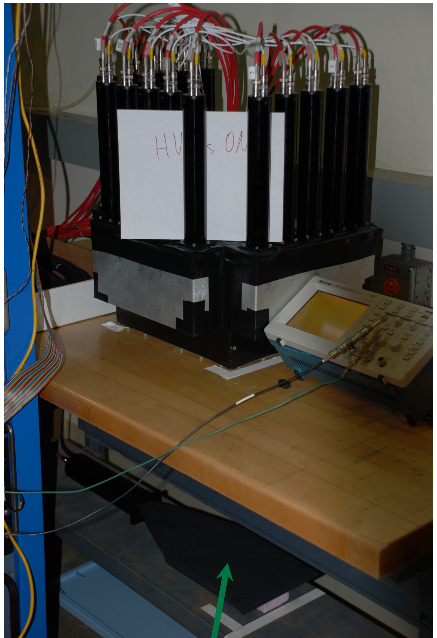
15 PMTs = 5(strips) × 3(planes) × 1(stack)

15 fibers = 3(fibers) × 1(strip) × 5(layers)

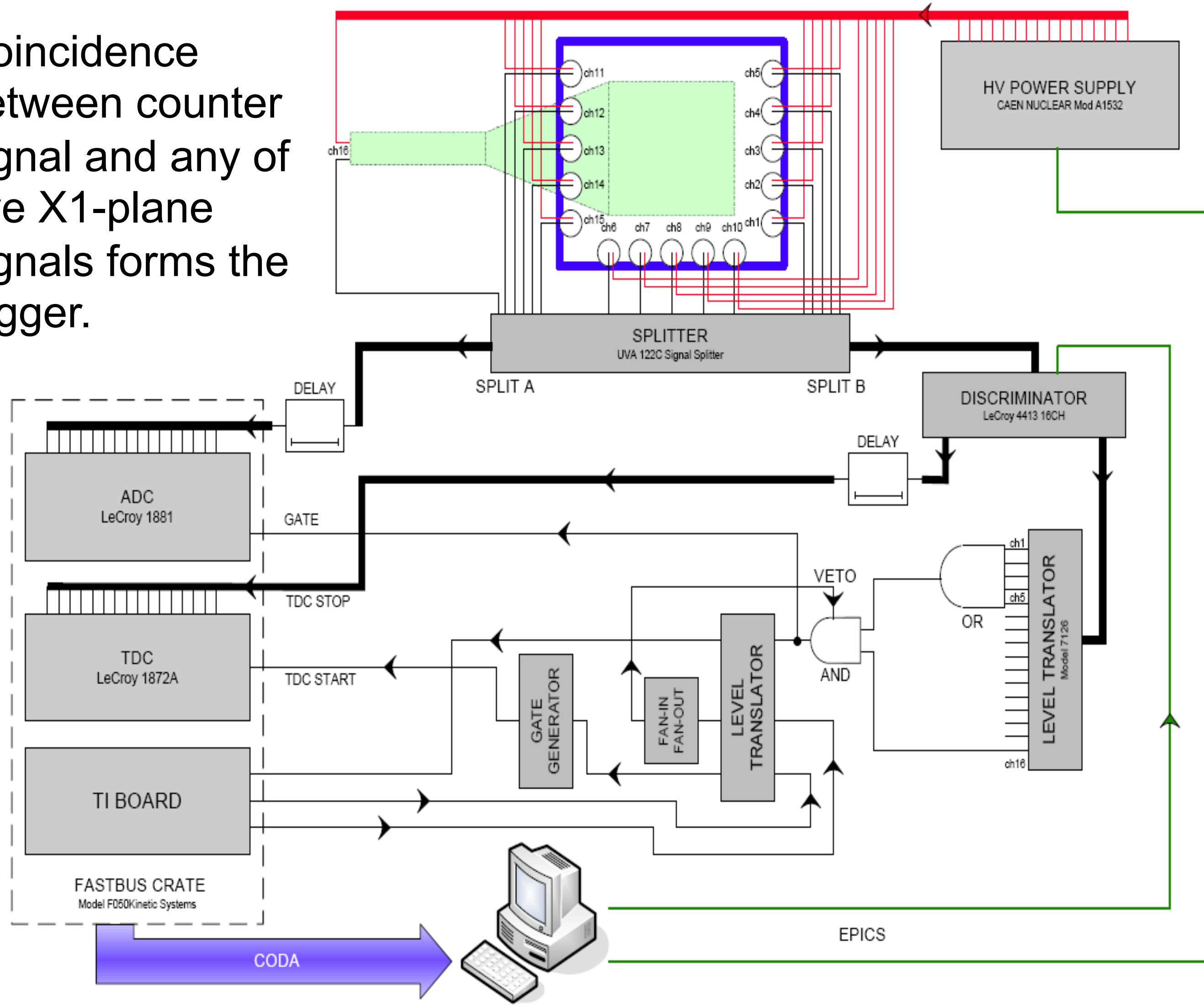
75 scintillator strips, 225 fibers and 15 lead plates



Test setup



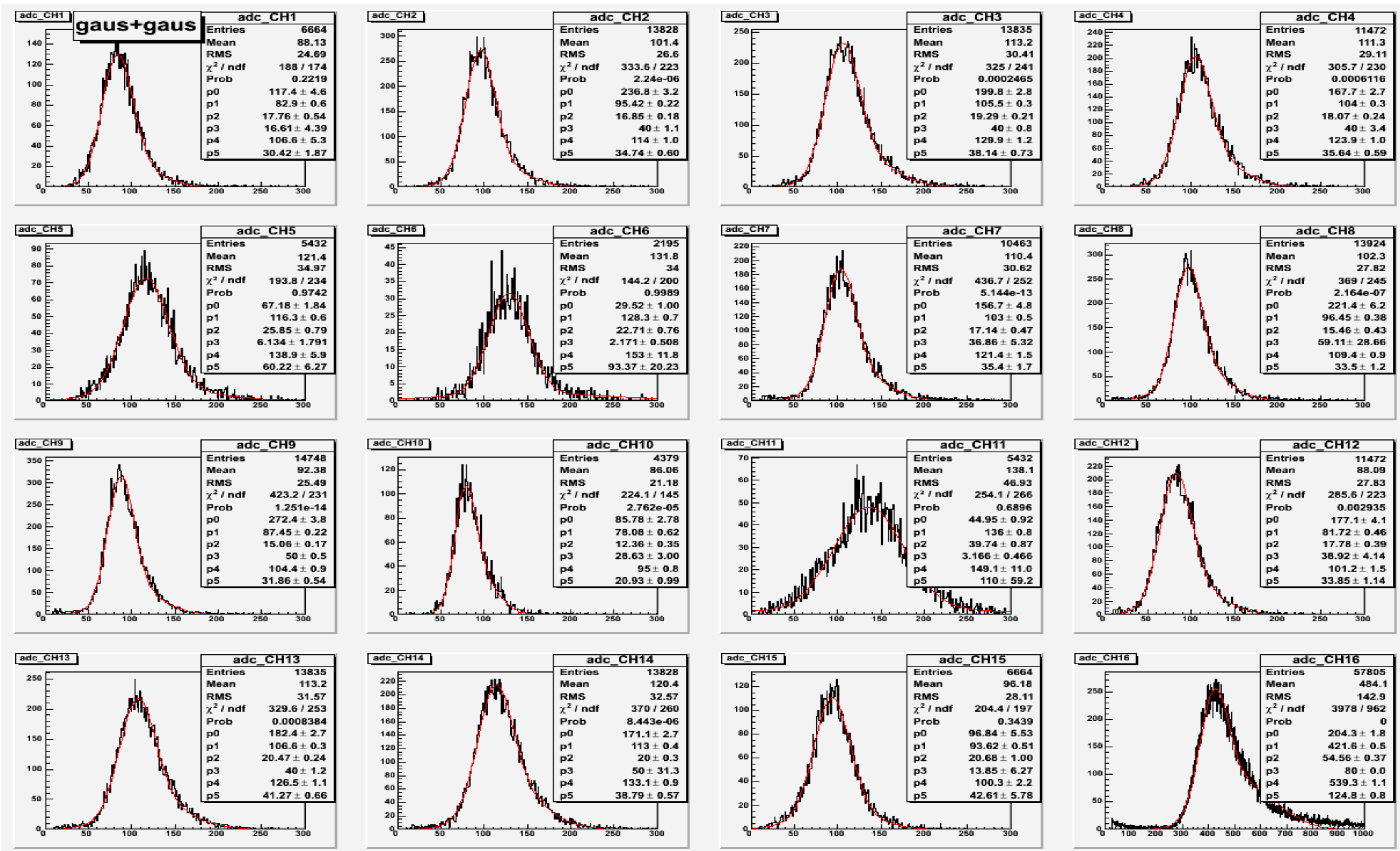
Coincidence between counter signal and any of five X1-plane signals forms the trigger.



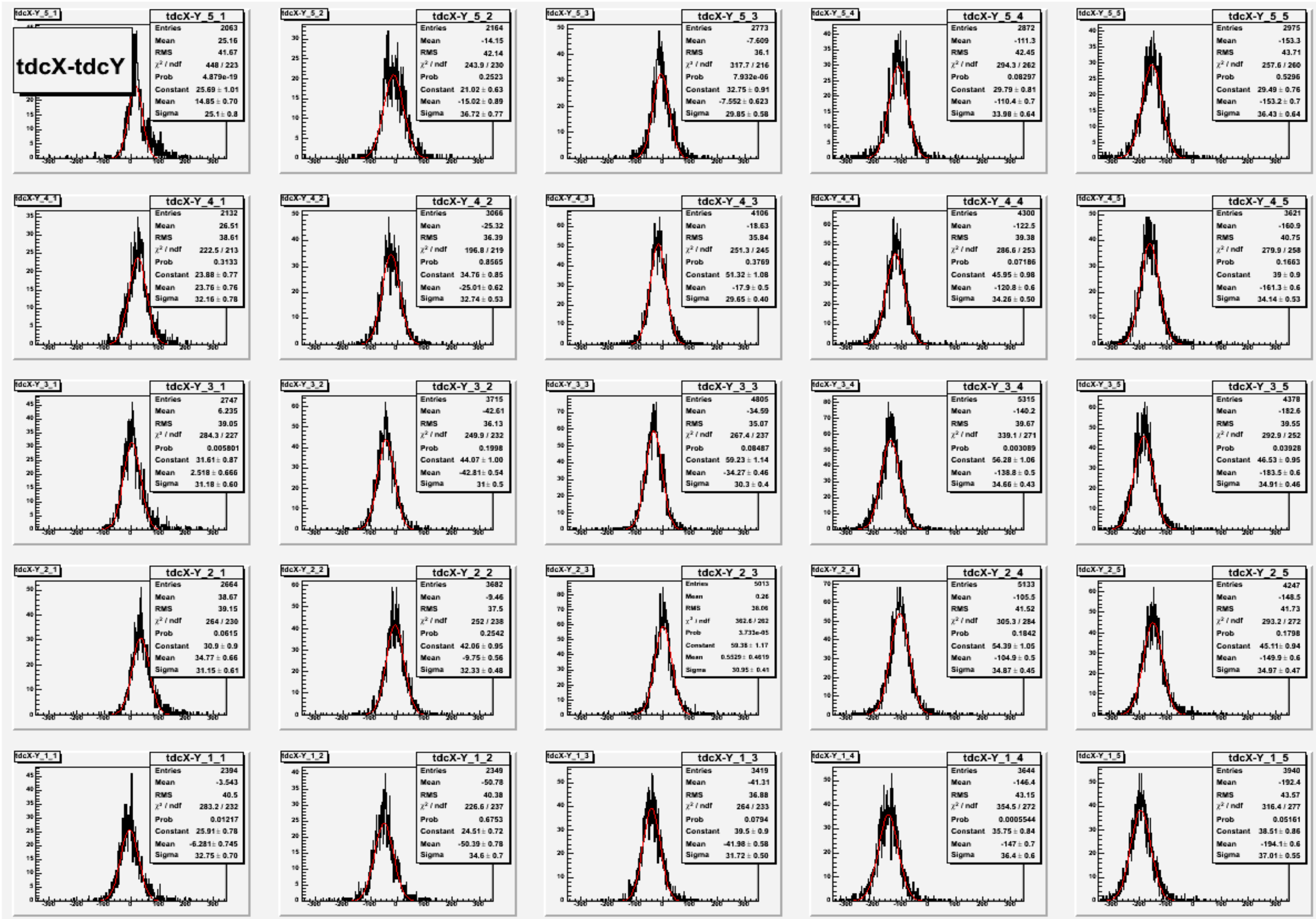
Counter consist of scintillator plate (20×22cm), conventional lightgide and PMT.

To calibrate the prototype response to energy deposition of *Minimum Ionizing Particles* (MIPs) has been studied.

For each PMT, a MIP's peak position, at given HV, was determined using two Gaussian fit to the ADC distribution.



Time resolution has been estimated as a difference of TDC values between corresponding channels when criteria for MIP was satisfied.

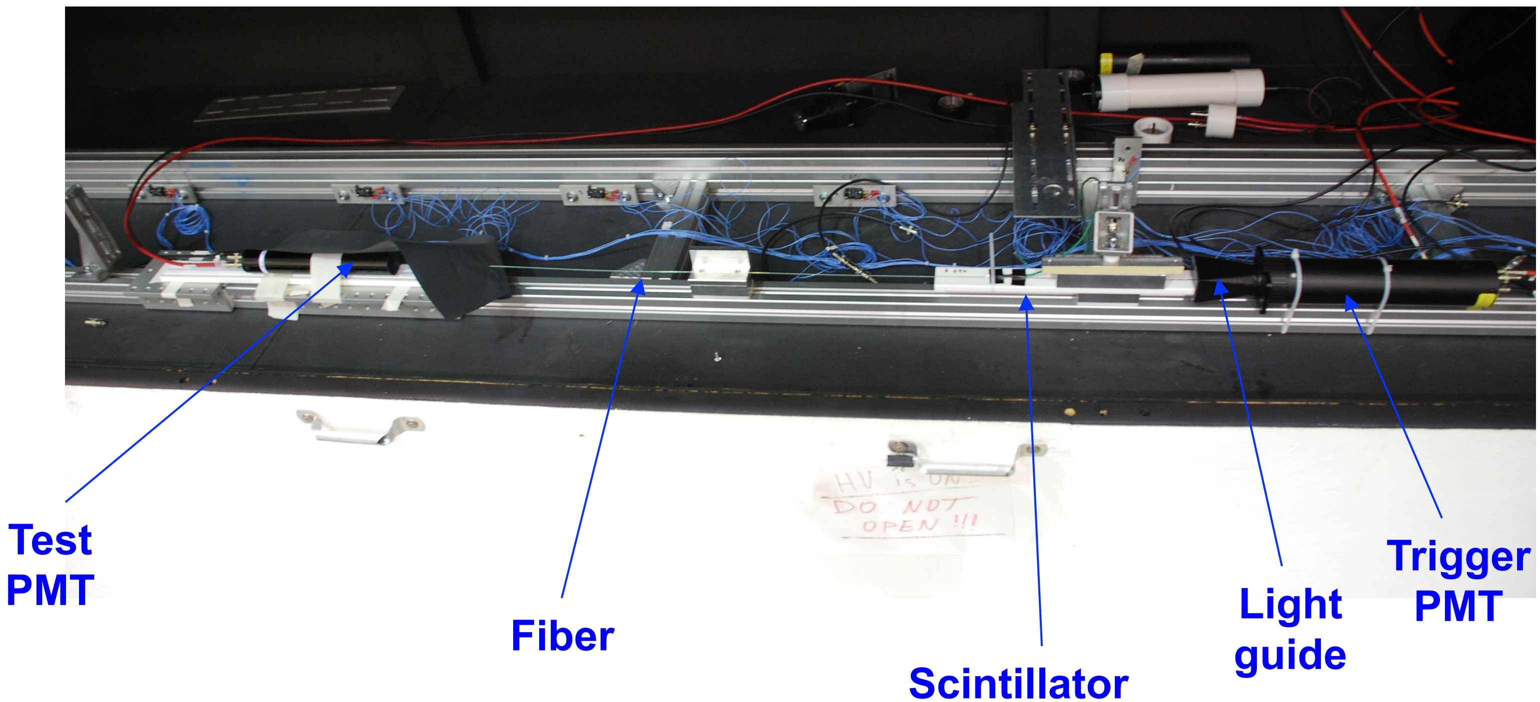


The main goals of the test are:

- to identify the position of single photoelectron peak for individual PMT
- in conjunction with previous results to determine the absolute light yield

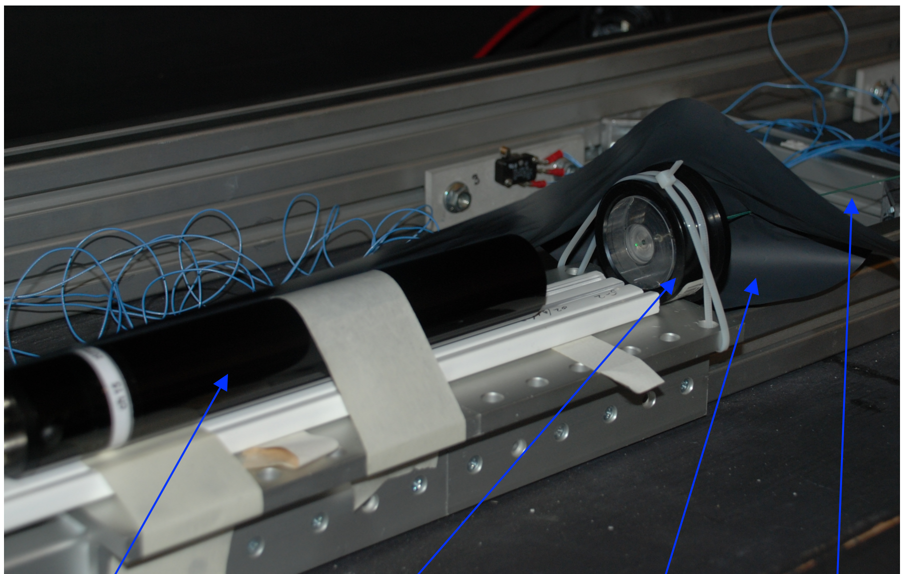
New setup

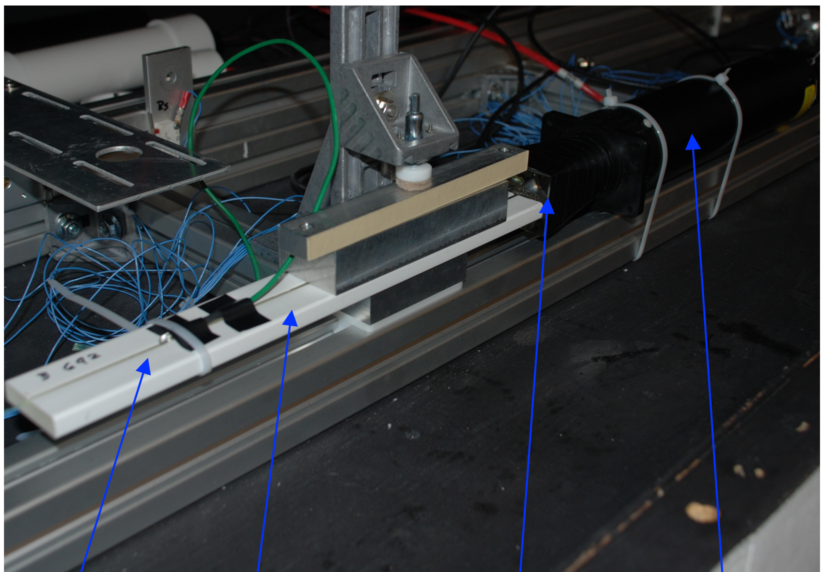
- Setup was placed in long dark box (EEL building at JLab)
- Scintillator strip with one fiber glued in were secured inside the box
- The trigger PMT was attached directly to the end of scintillator strip through acrylic light guide
- Fiber was extended about 40 cm from other end of the scintillator in order to connect to the photo-cathode of a test PMT



New setup

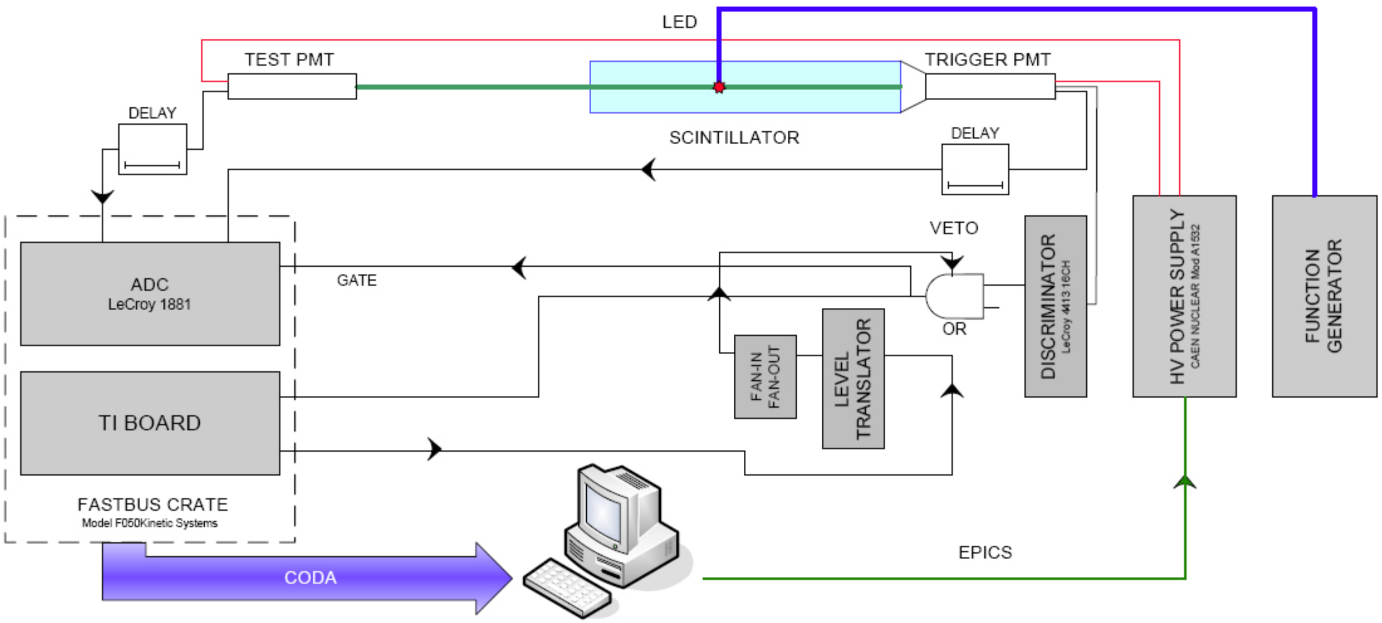
- To secure the fiber on test PMT adapter with thin metallic tube was used. The inner diameter of tube was chosen to have a tight fit for fiber.
- Test PMT was covered with black paper in such a way that only fiber light can get in.
- LED attached on top of the scintillator bar was used as a light source.





DAQ

- Readout electronics consisted of the LeCroy 1881 ADC and discriminator.
- As a gate for ADC, discriminated pulse from the trigger PMT was used.
- Signals of the test and the trigger PMTs were delayed and connected to the ADC inputs.
- The ADC information was read out using the standard CLAS DAQ software.
- LED's signal frequency, amplitude, width etc. are managed by signal function generator.



Measurements

- The single photo-electron (SPHE) peak was identified by decreasing the amount of light going to test PMT.

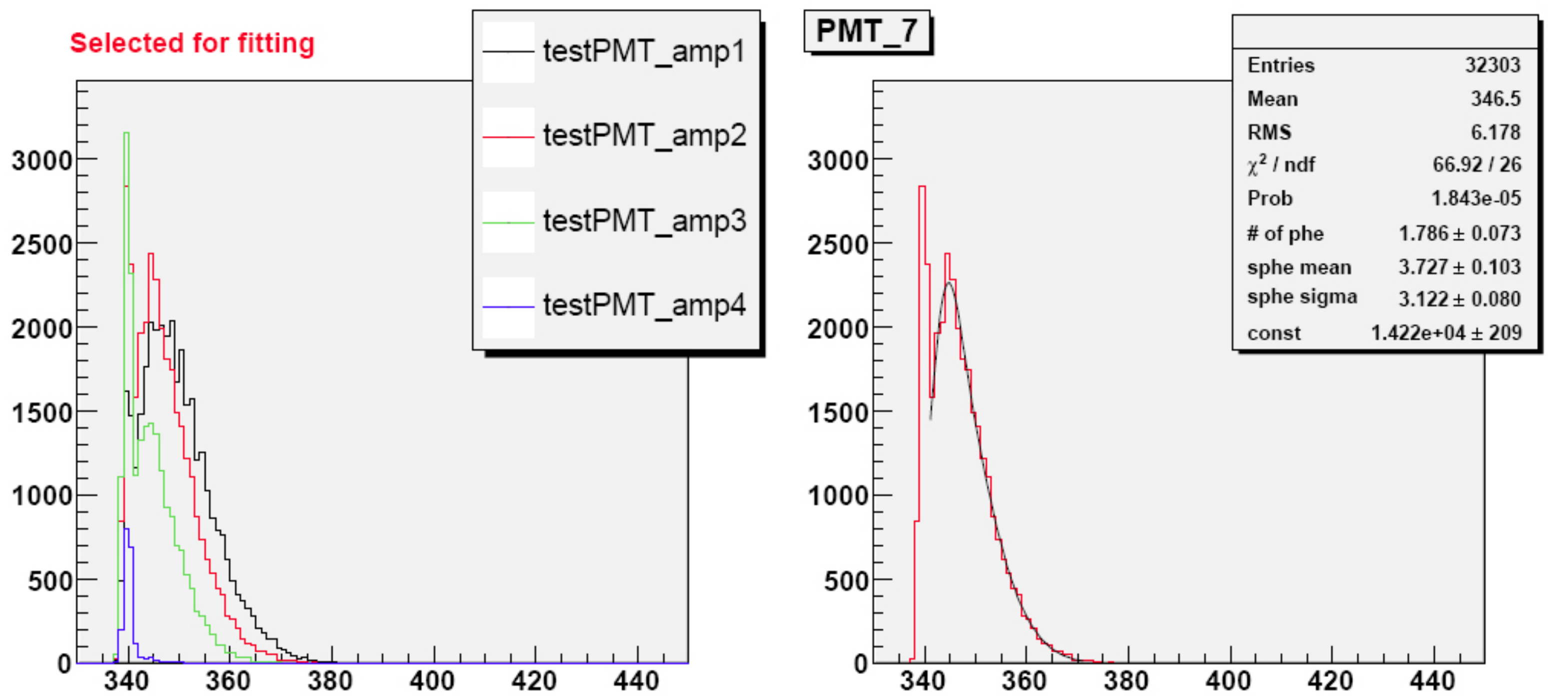
- The peak was attributed to the SPHE distribution when only a single peak remains in the spectrum above the pedestal and further decrease of the light only changes the height of the peak but not the position.

- For each given PMT 3 series by 4 measurements were done

- Setup remained unchanged for each PMT

Measurements

- Amount of light was decreased by decreasing the amplitude of the signal sent to LED.
- The tests were done at 4 values of LED amplitude (from high to small) at nominal HV which was used in cosmic test of prototype.



Fitting

Each ADC spectrum was fitted with a sum of the Poisson probabilities of the number of photoelectrons convoluted with a Gaussian function representing the ADC distribution for a given number of photoelectrons.

$$A = c \cdot \sum_i P_i(n_{pe}) \times G_i(n_{ch})$$

$$P_i(n_{pe}) = \frac{n_{pe}^i \cdot e^{-n_{pe}}}{i!}$$

$$G_i(n_{ch}) = \frac{1}{\sigma_1 \cdot \sqrt{i}} \cdot e^{-\left(\frac{n_{ch} - a_1}{\sigma_1 \cdot \sqrt{2i}}\right)^2}$$

Fit parameters:

c – overall normalization

n_{pe} – average number of ph.e.

a_1 – position of sphe in units of ADC channel

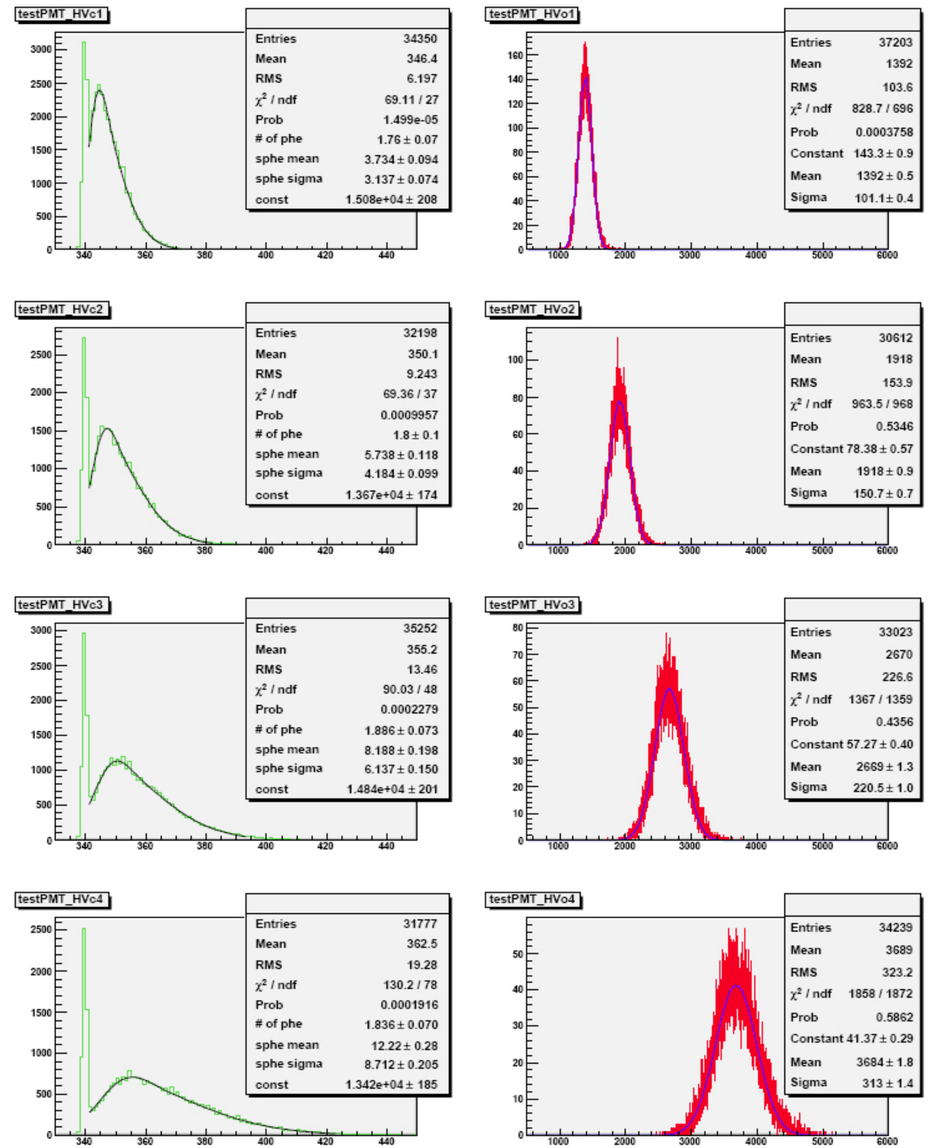
σ_1 – standard deviation of sphe in units of ADC channel

Measurements

Since the position of SPHE peak at nominal HV was too close to pedestal it was decided to perform another sets of measurements to minimize uncertainties due to bad fit values.

With LED amplitude attributed to SPHE spectra 4 measurements with different HV settings have been done.

In order to check gain curve behavior another 4 measurements have been done with the same HV setting but black paper was removed from test PMT.



Fitted ADC spectra of test PMT (left – SPHE closed; right – opened)

Measurements

To determine position of SPHE peak position the ratio

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$$N_{ph} = k \cdot \frac{A^{open}}{A^{close}}$$

$$k = \frac{Tr(HV^{i})}{Tr(HV^{1})}$$

has been plotted as a function of HV and fitted.

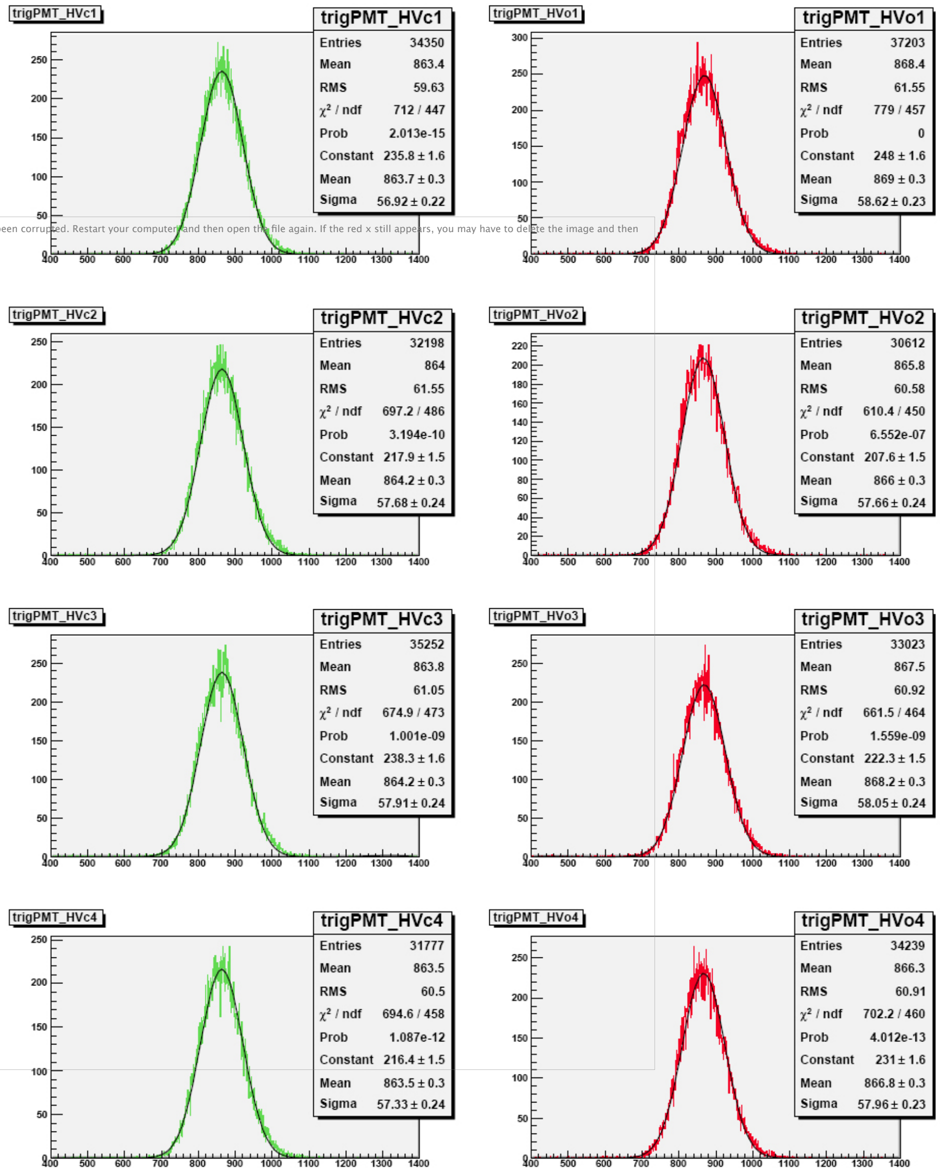
A^{open} - mean of ADC distribution for opened PMT above pedestal

A^{close} - mean of SPHE peak above pedestal

$Tr(HV^{i})$ – mean of ADC spectra for *i-th* HV setting

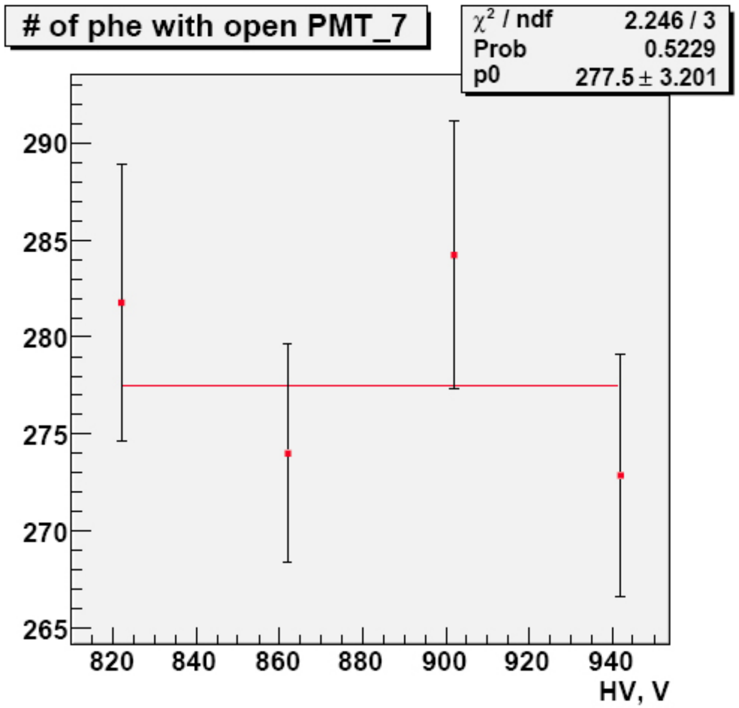
$Tr(HV^{1})$ – mean of ADC spectra for nominal HV setting

$$A^{SPHE} = \frac{A^{open}_{HV1}}{\overline{N}_{ph}}$$



Fitted ADC spectra of trigger PMT (left – SPHE closed; right – opened)

Measurements



MIP position in ADC channels 102.9

Single phe position in ADC channels 3.79201

Number of phe per 1MeV 8.15 ± 0.002

$$Nphe = \frac{3 \cdot A^{MIP}}{10MeV \cdot A^{SPHE}}$$

The absolute light yield was determined with respect to results of MIP energy deposition.

Mean of the MIP spectra corresponds to 10 MeV energy depostion.

Splitter used in cosmic test splits PMT signal as 1:2

Summary of the results

CH #	PMT	TYPE	PLANE	# OF FIBERS	HV, (V)	ADC, (ch)	SPHE, (ch)	Nphe
1	HAMAMATSU	R6095	X1	15	786	82.9 ± 0.5	3.3	7.5
2	HAMAMATSU	R6095	X1	15	791	95.4 ± 0.2	2.9	9.7
3	HAMAMATSU	R6095	X1	15	841	105.5 ± 0.3	4.3	7.2
4	HAMAMATSU	R6095	X1	15	825	104.0 ± 0.3	3.8	8.1
5	HAMAMATSU	R6095	X1	14	855	116.3 ± 0.6	5.1	6.7
6	HAMAMATSU	R6095	Y	15	865	128.3 ± 0.7	3.4	11.3
7	HAMAMATSU	R6095	Y	14	822	102.9 ± 0.5	3.7	8.1
8	HAMAMATSU	R6095	Y	15	818	96.4 ± 0.3	2.2	12.8
9	HAMAMATSU	R6095	Y	15	762	87.4 ± 0.2	2.9	8.8
10	HAMAMATSU	R6095	Y	15	733	78.0 ± 0.6	1.9	11.9
11	PHOTONIS	XP2802	X2	15	1024	135.9 ± 0.8	11.2	3.6
12	PHOTONIS	XP1912	X2	10	1277	81.7 ± 0.4	7.4	3.3
13	HAMAMATSU	R7899EG	X2	15	1395	106.6 ± 0.3	7.0	4.5
14	Electron Tubes	9124B	X2	15	1051	112.9 ± 0.3	4.4	7.6
15	HAMAMATSU	R7899EG	X2	15	1478	93.6 ± 0.5	4.3	6.4

Future plans

- Beam test