Fermilab

The University of Iowa

Total Absorption Dual Readout Calorimetry R&D

B. Bilki, Y. Onel, A. Para,
G. Pauletta, P.Rubinov, I. Vasilas, H. Wenzel

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Scope

- Focus on establishing a proof of concept for totally active hadron calorimetry.

- Evaluate the performance of:

  - Different crystal and glass samples
  - Different readout techniques

  to optimize the simultaneous collection of Čerenkov and scintillation light components for application of the Dual Readout technique to Total Absorption Calorimetry.

- Obtain a baseline for the detailed simulations of Čerenkov and scintillation light production in different crystals.

Beam Test at FTBF

One 5 x 5 x 5 cm^3 BGO crystal. Provides information about scintillation and Čerenkov light yield as a function of time, wavelength, position and photodetector type.

- All sides equipped with UV or visible filters
- Two sides viewed with PMTs (one through UV, one through visible filter)
- Remaining four sides equipped with 9 Hamamatsu SiPMs each, located at different positions
- 1 mm Hamamatsu MPPCs with 25, 50 and 100 micron pixels

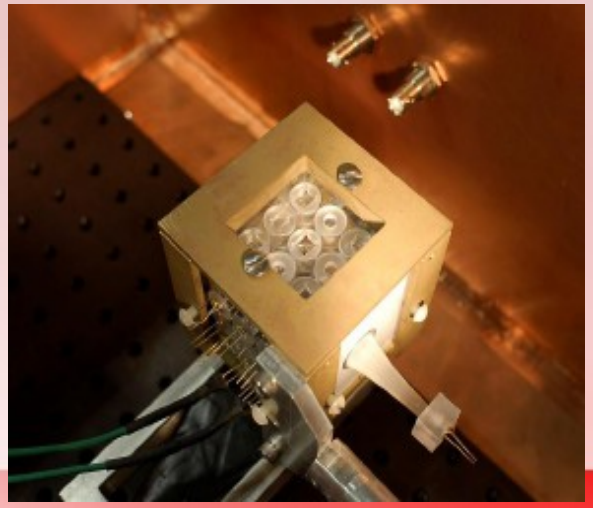
Beam Test at FTBF

Six BGO and six PbF_2 crystals.

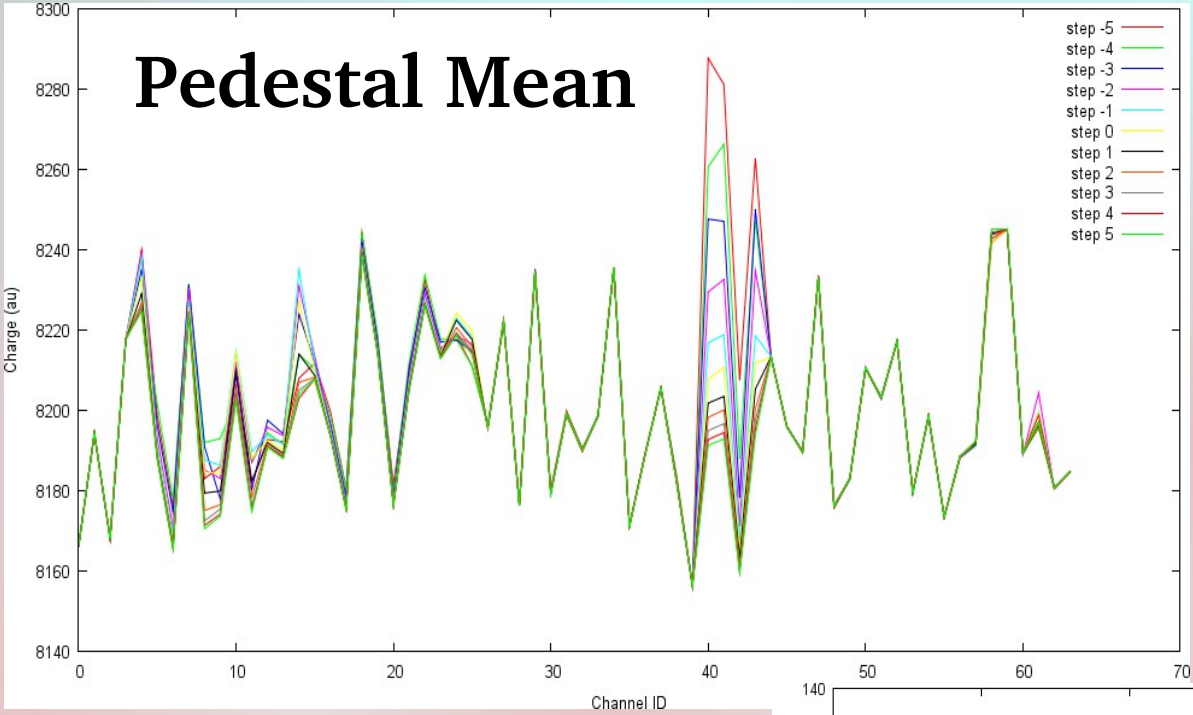
- All 5 cm length.
- 2 x 2 cm^2, 3 x 3 cm^2, 4 x 4 cm^2. 3 mm Hamamatsu MPPCs located at the center of the downstream face.
- Different wrapping (black paper/Tyvek) and different surface finishes to provide information about light collection for Čerenkov (PbF_2) and scintillation (BGO) as a function of crystal geometry and surface conditions.

Beam Test at FTBF

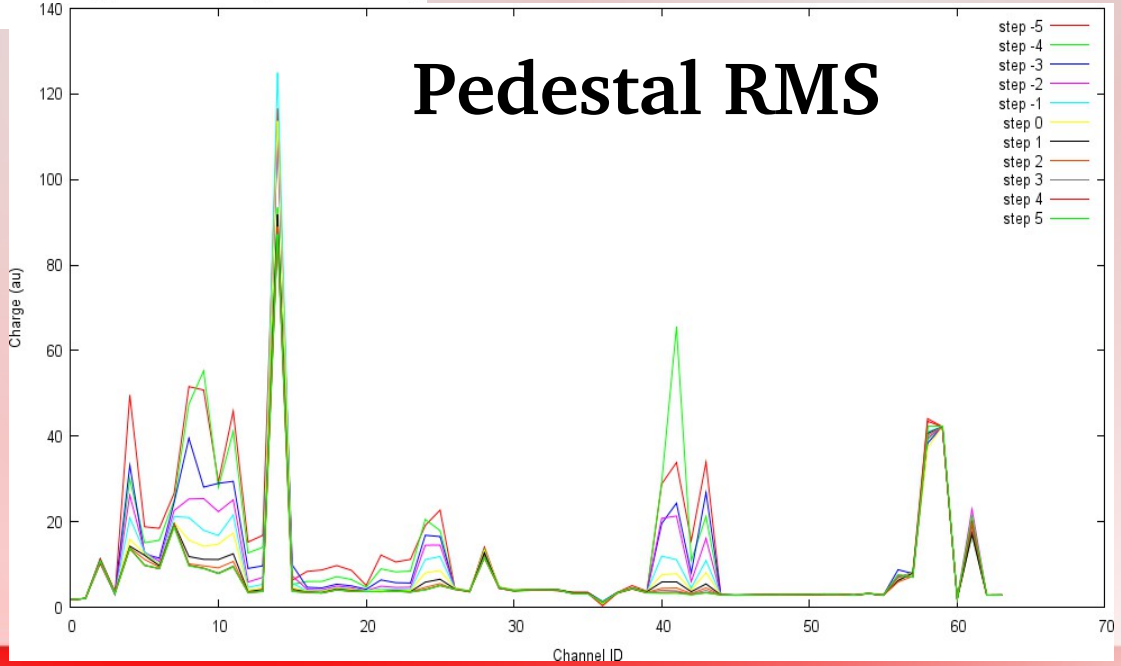
- 120 GeV/c primary proton beam
- Fermilab TB4 readout boards (provide 64 channels of waveform digitizers)



SiPM Calibration



11 settings for the bias voltages

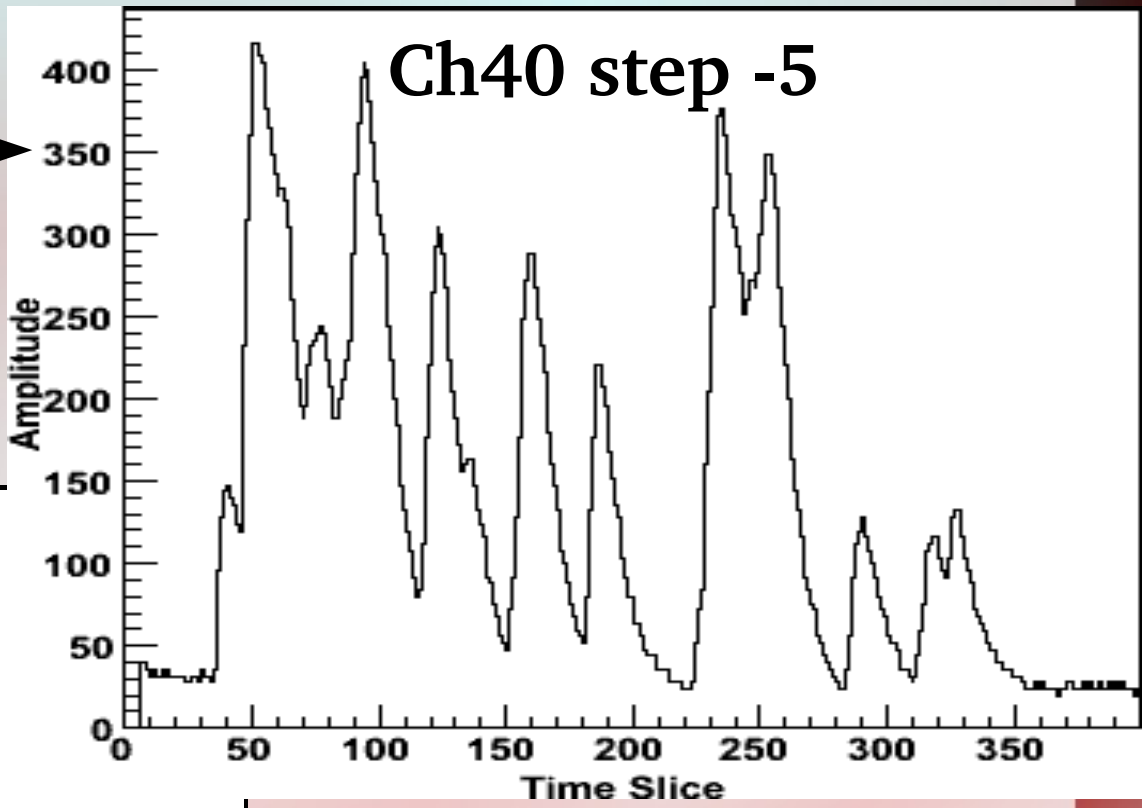


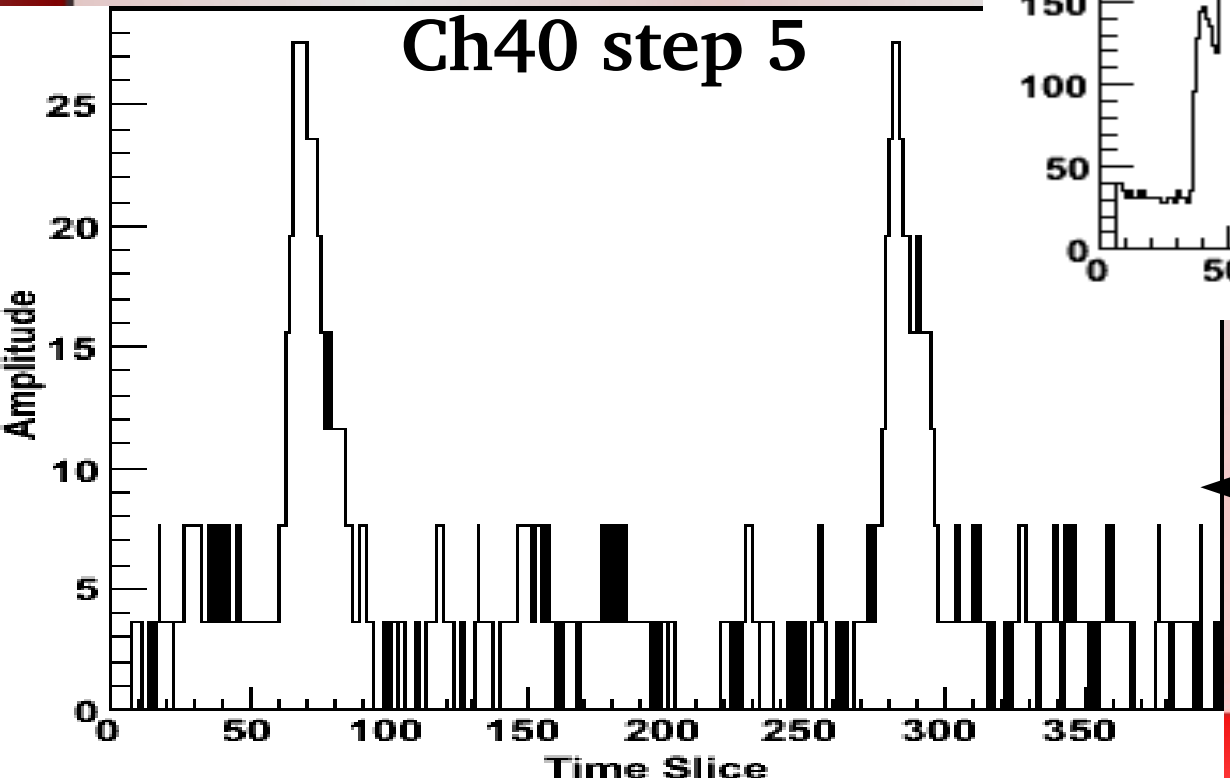
Ch0 : PMT (vis.)
Ch1 : PMT (UV)
Ch2 & Ch3 : Trigger PMTs
Ch4-Ch39 : BGO SiPMs
Ch40-Ch51 : Crystal Array SiPMs

SiPM Calibration

Pedestal waveforms after pedestal subtraction (zero suppressed)

Highest bias voltage



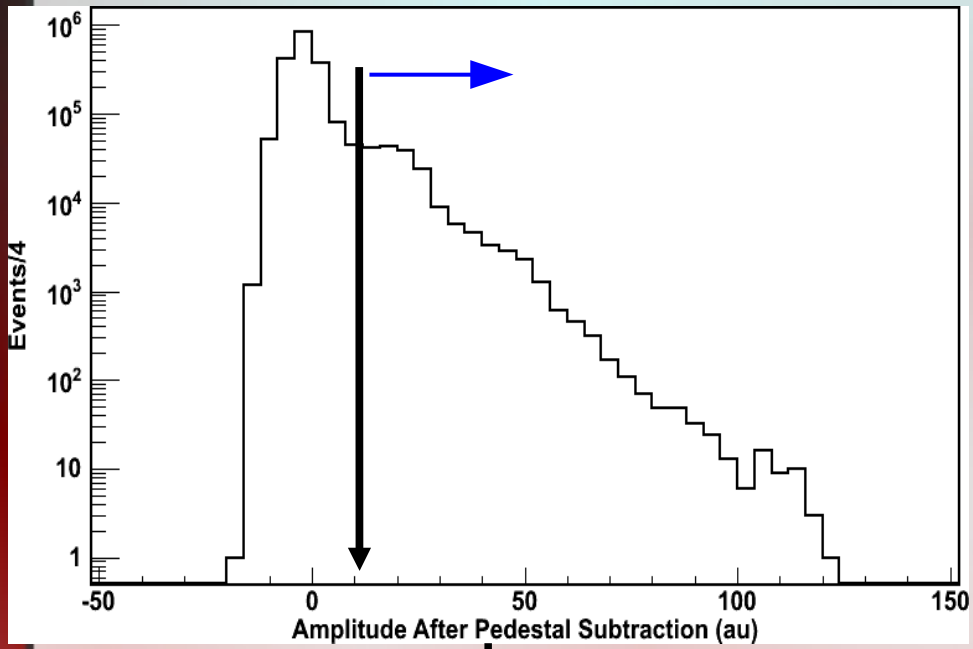


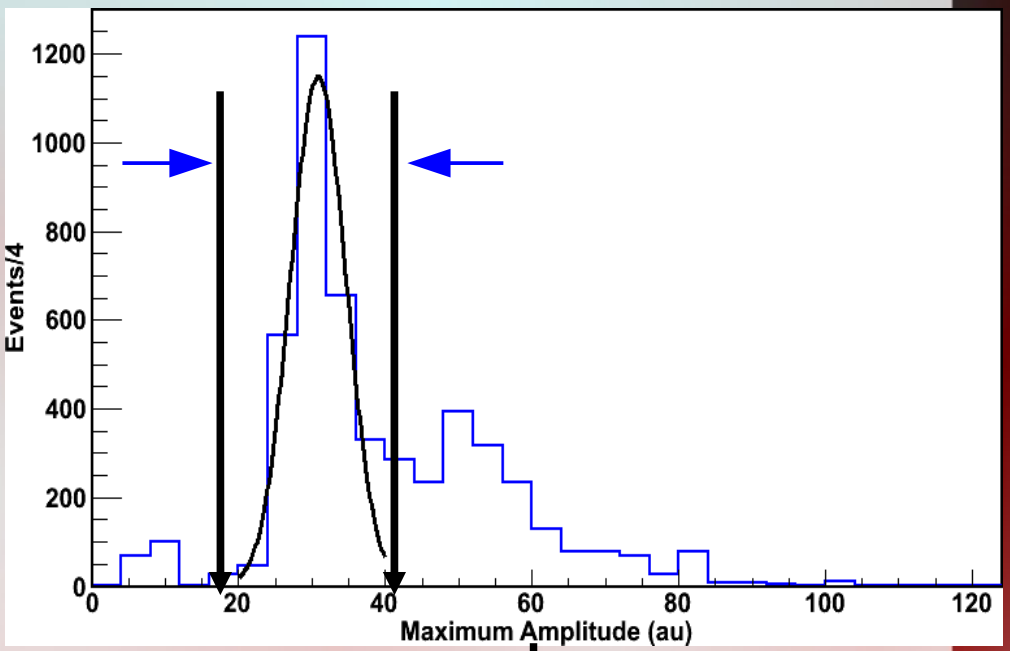
Each time slice ~ 4.5 ns

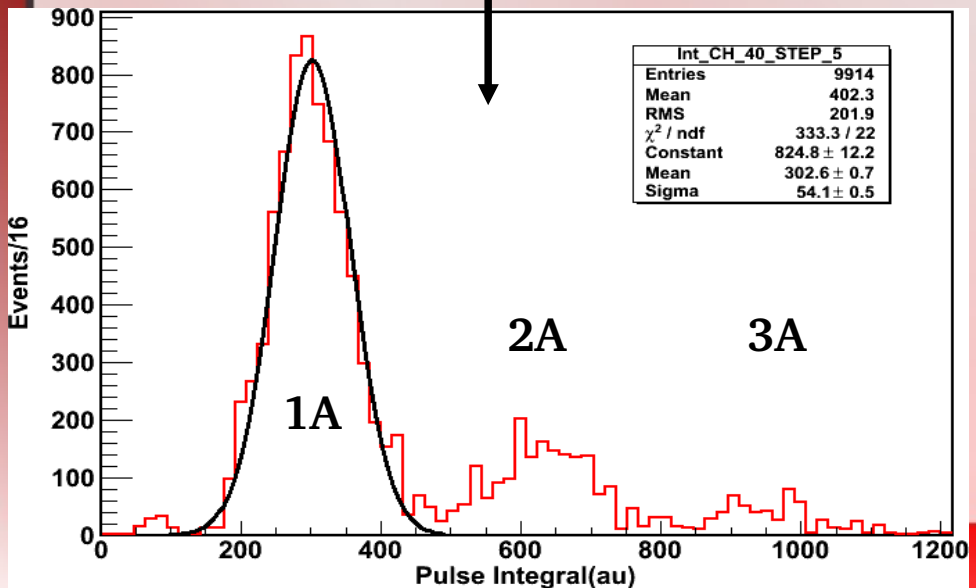
Lowest bias voltage

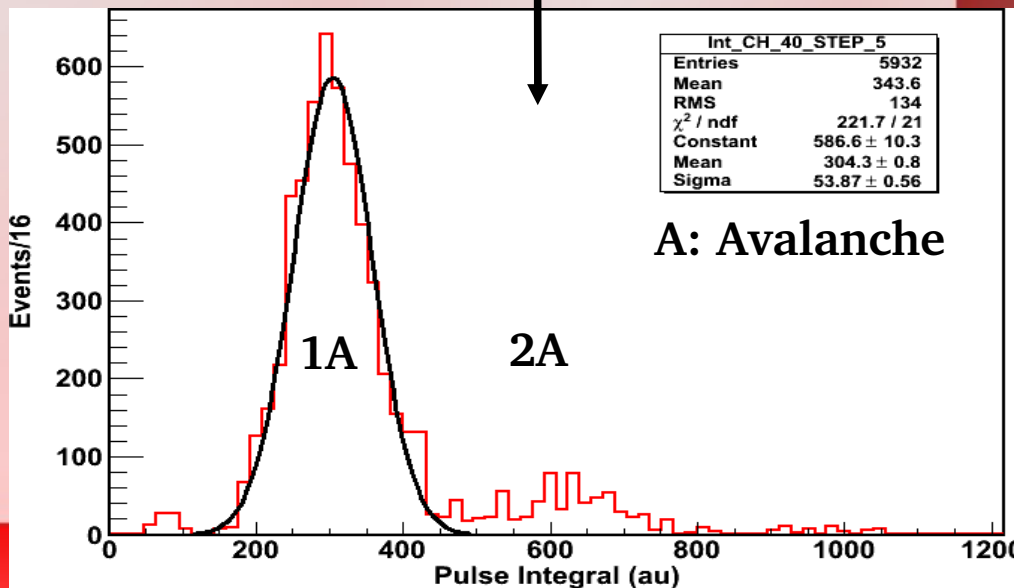
SiPM Calibration

Pedestal waveforms after pedestal subtraction

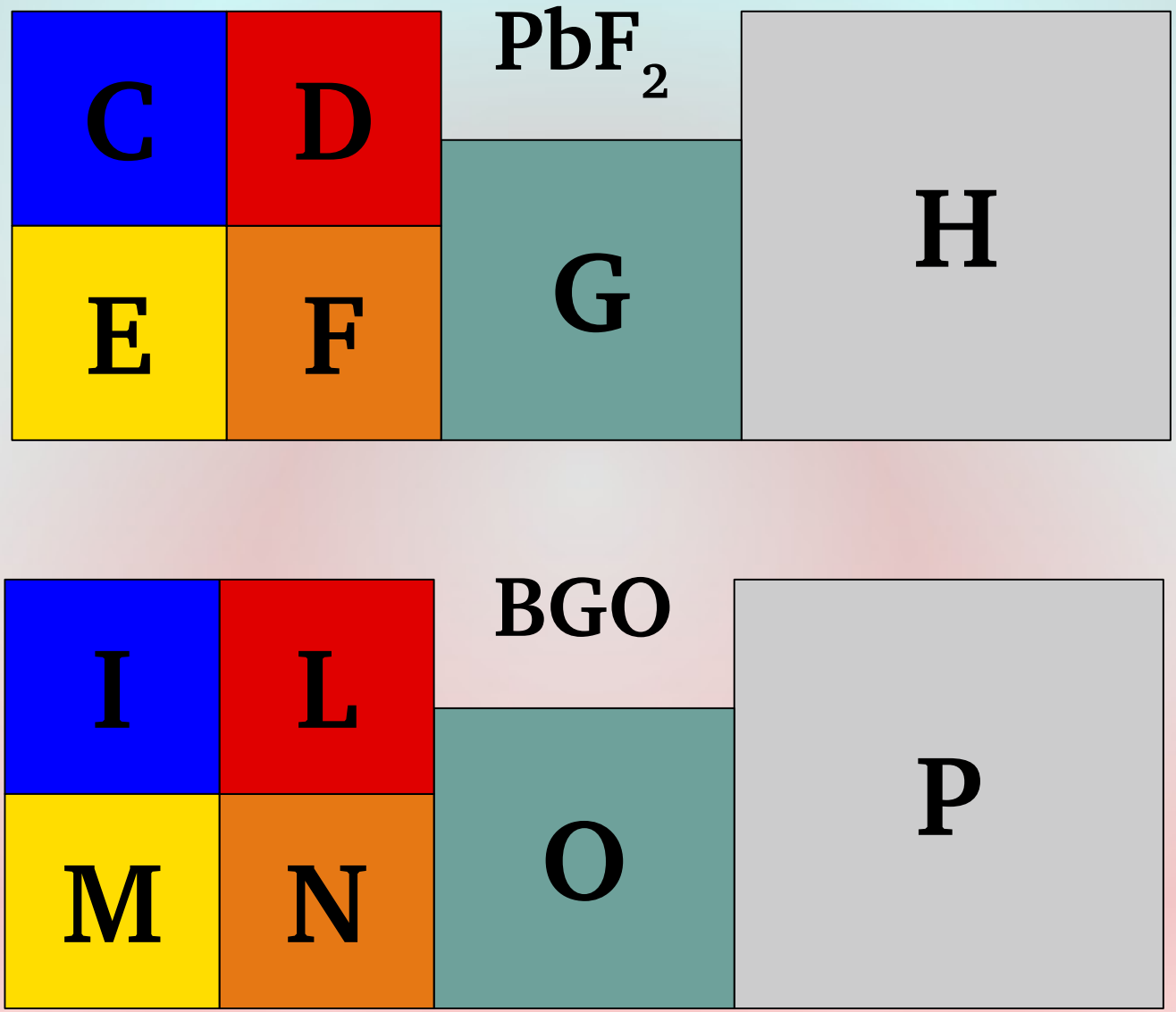






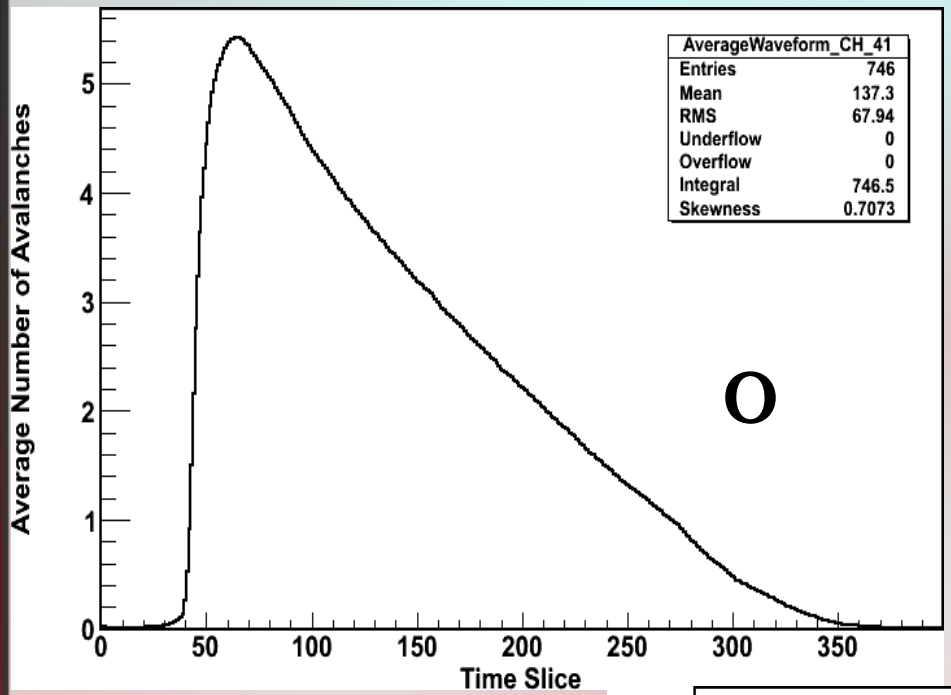


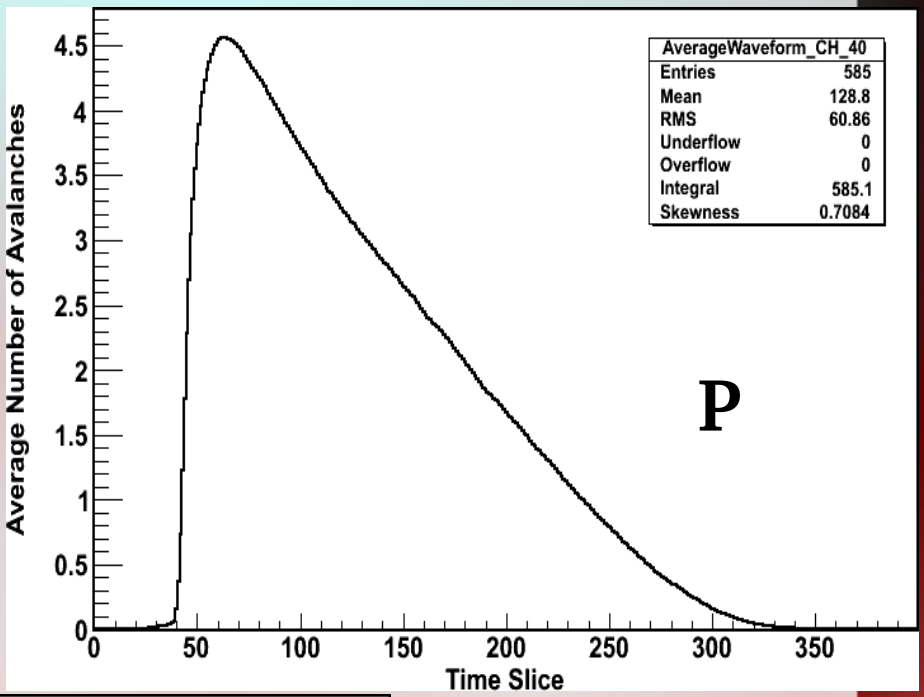
Crystal Arrays

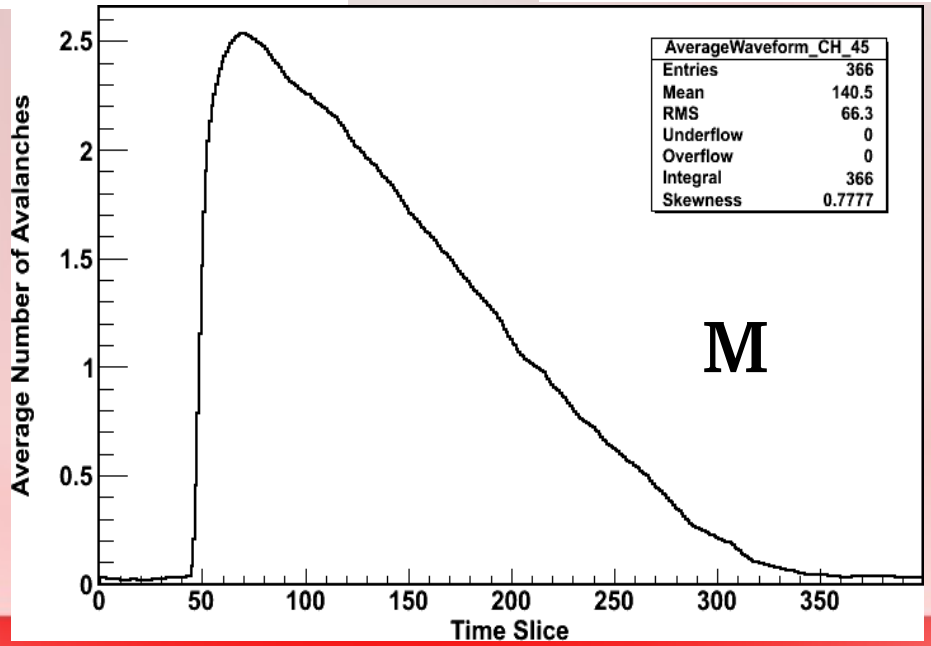


3 mm Hamamatsu MPPCs reading out each crystal

BGO Crystal Array

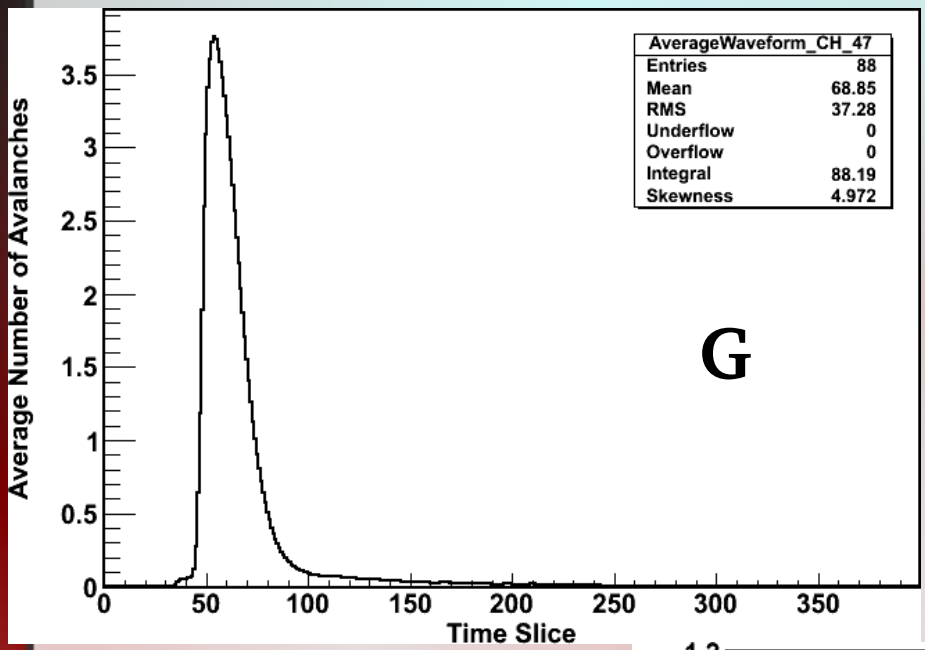


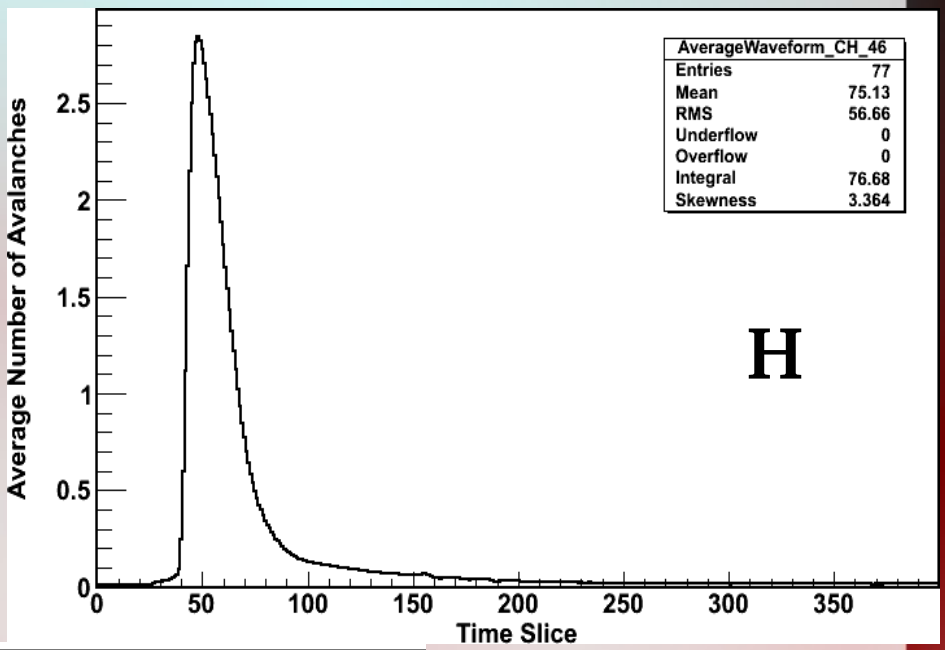


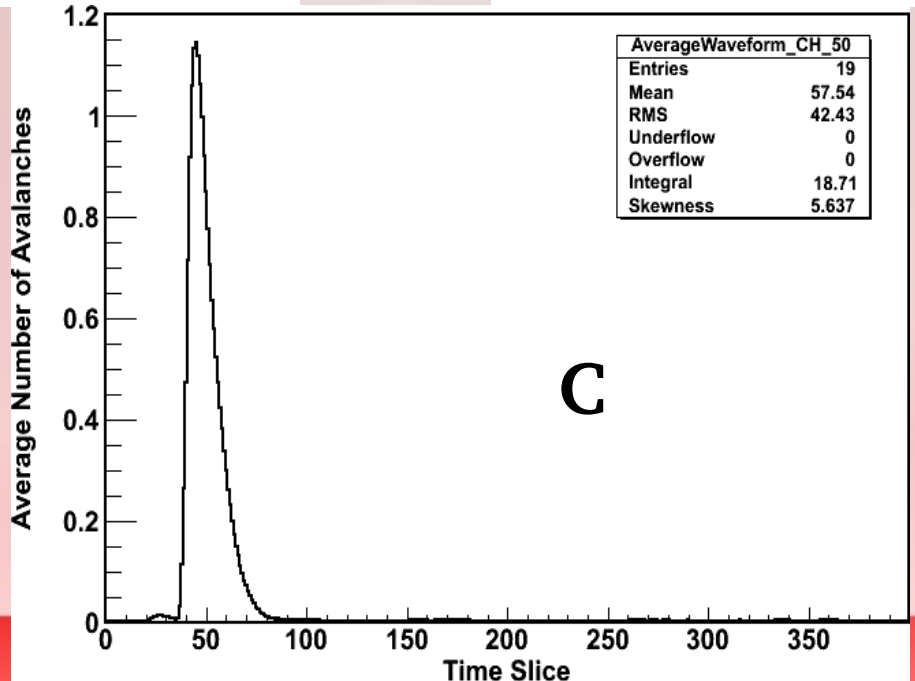


Average Waveform/Event in units of avalanches.

PbF_2 Crystal Array

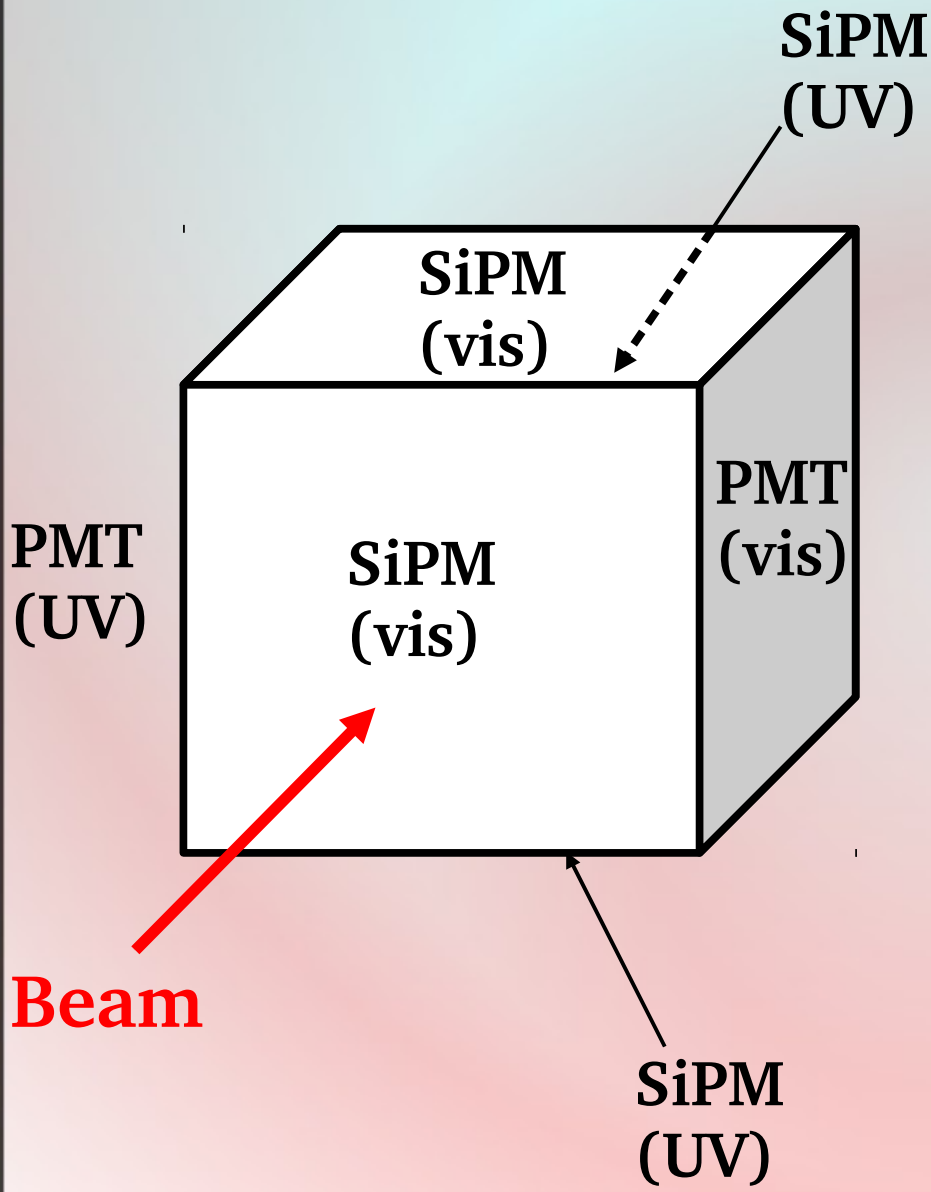




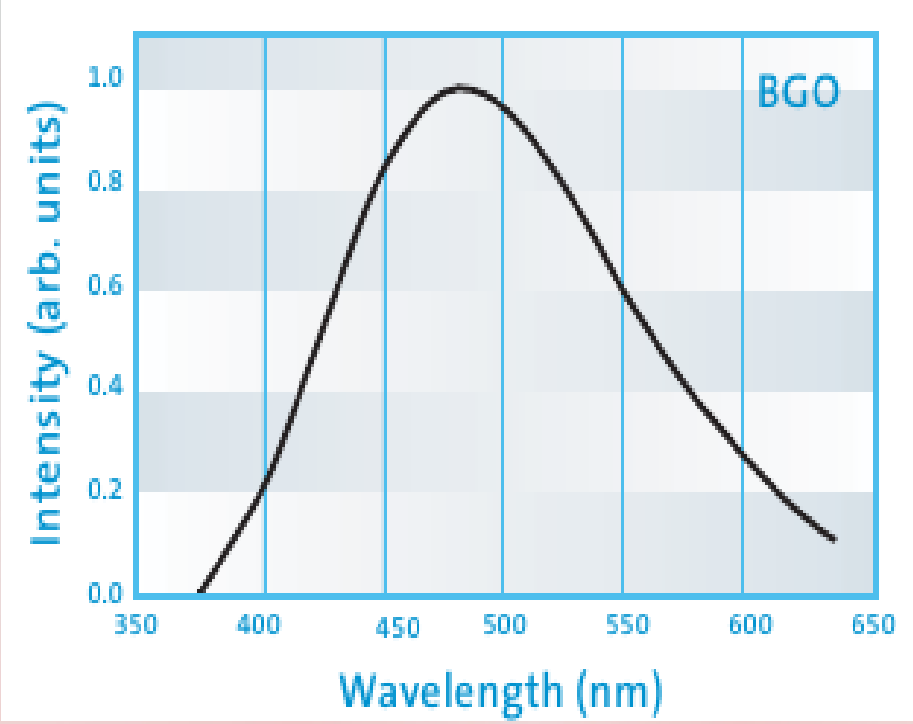


Average Waveform/Event in units of avalanches.

Single BGO Crystal



BGO Emission Spectrum

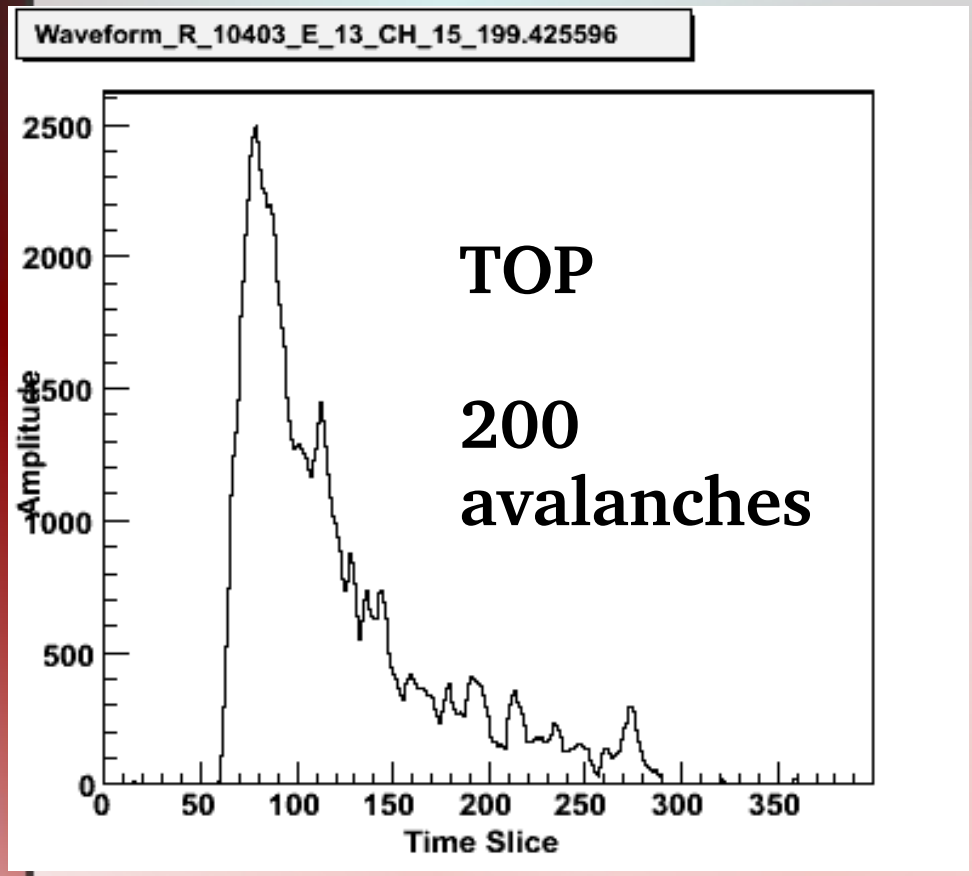


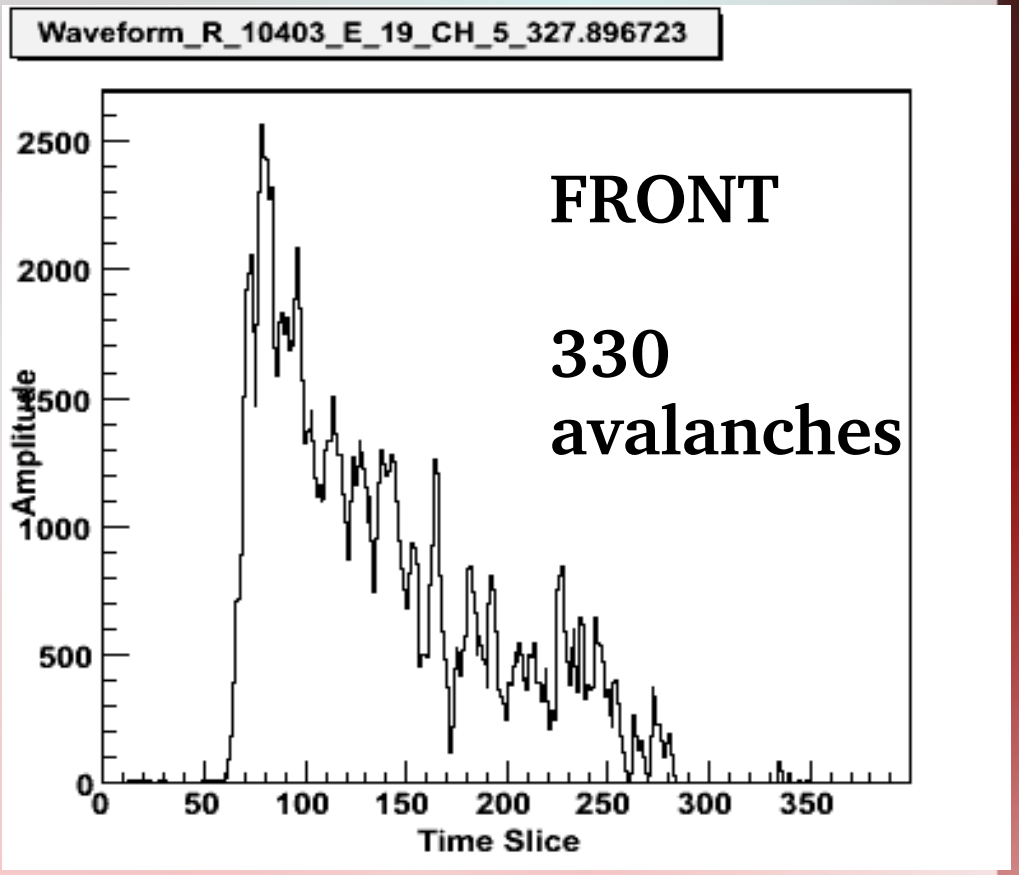
vis → Scintillation

UV → Čerenkov

Single BGO Crystal – Visible Filter Sides

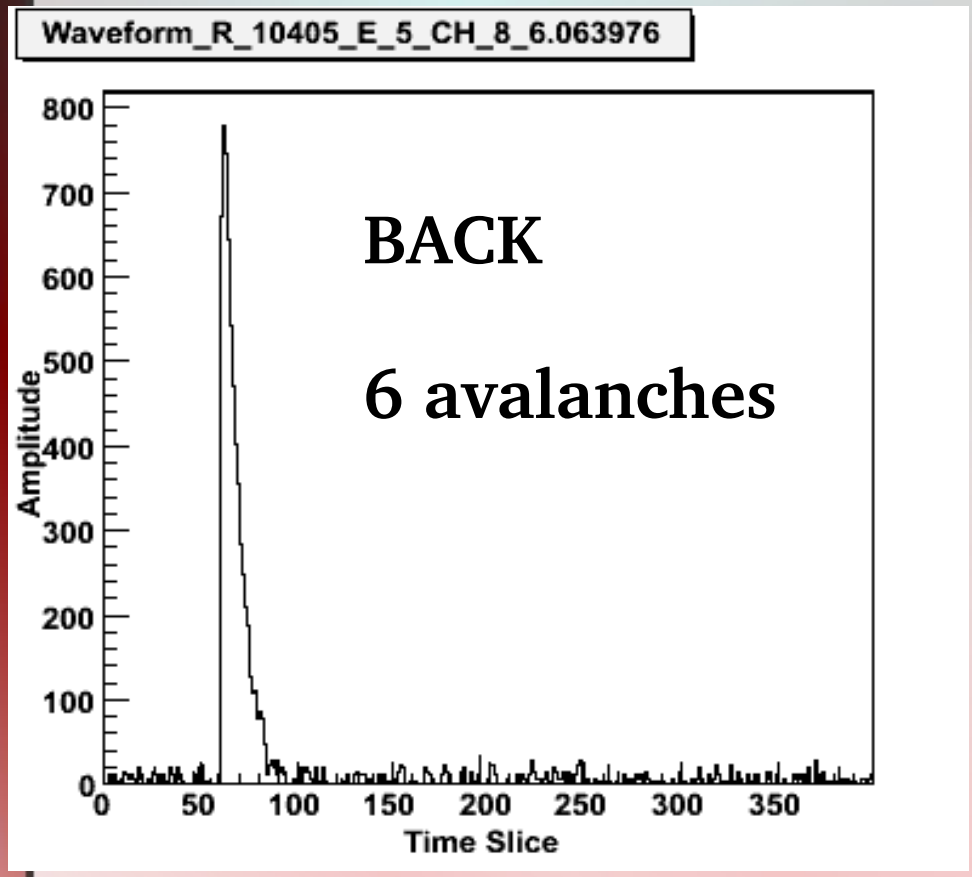
Single event waveforms

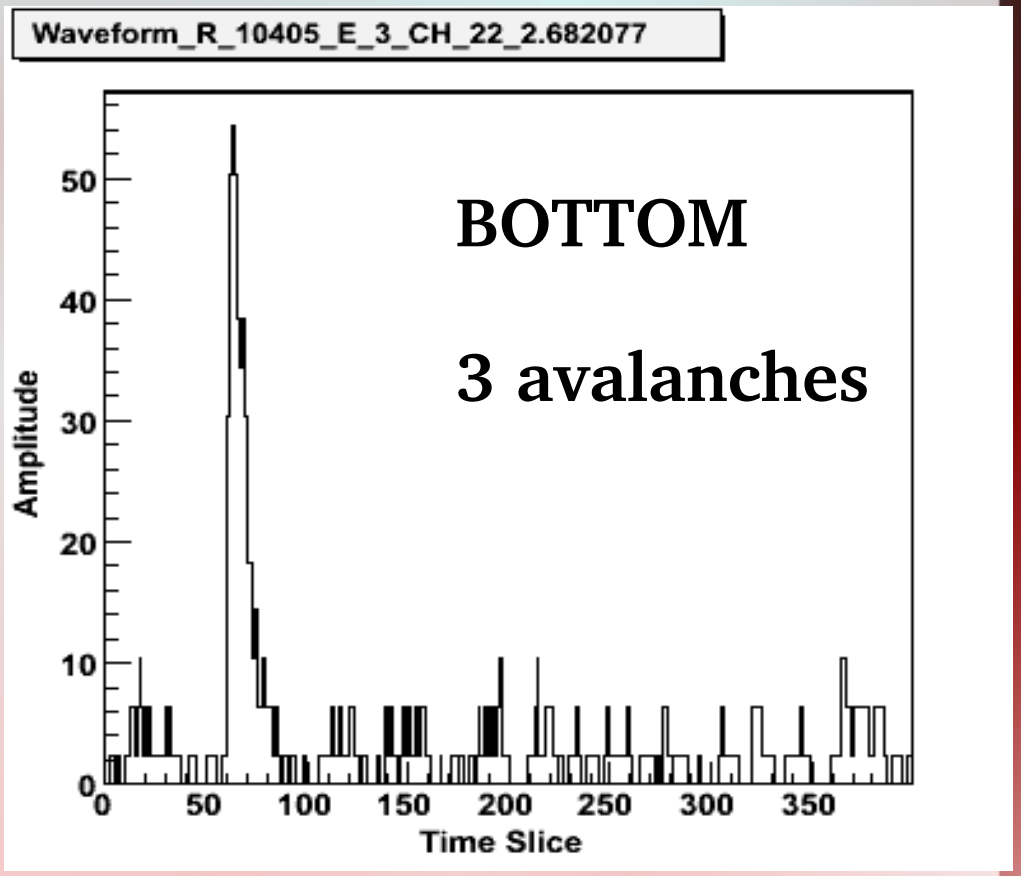




Single BGO Crystal – UV Filter Sides

Single event waveforms





Conclusions

Preliminary analyses indicate that:

- **The Čerenkov and scintillation signals are observed with the SiPMs directly coupled to the crystals.**

- **Filters provide measurable separation of the two signals.**

A lot of data to:

- **Study the spatial and timing structure of the two kinds of light production,**

- **Study the effects of type, shape, surface finish and optical coupling of the crystals on these two mechanisms,**

- **Perform detailed simulations of light production and collection both for Čerenkov and scintillation components.**