Development of a Scintillator/Tungsten Electromagnetic Calorimeter with Silicon Photomultipliers

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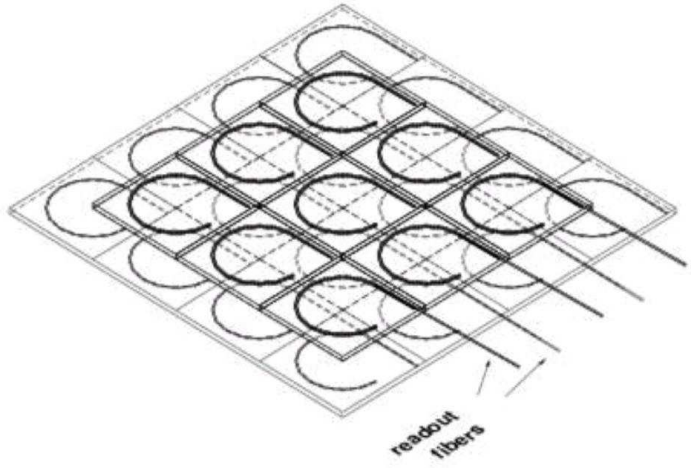
Outline

- Our design
- WLS fiber test
- Silicon photomultiplier studies
- Detector module studies with cosmic rays
- Future work and upgrades

Our design - basic overview



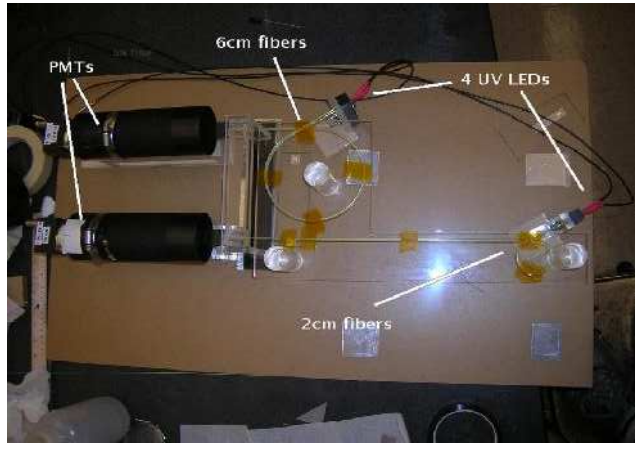
- 1/2-radiation-length Tungsten plate absorber (1.75mm)
- 2mm-thick scintillator sensitive material
- 5cm square scintillator tiles, offset by 2.5cm in each layer

- WLS fiber light guides
- SiPM detectors – easy to calibrate, small, low-voltage/low power, inexpensive

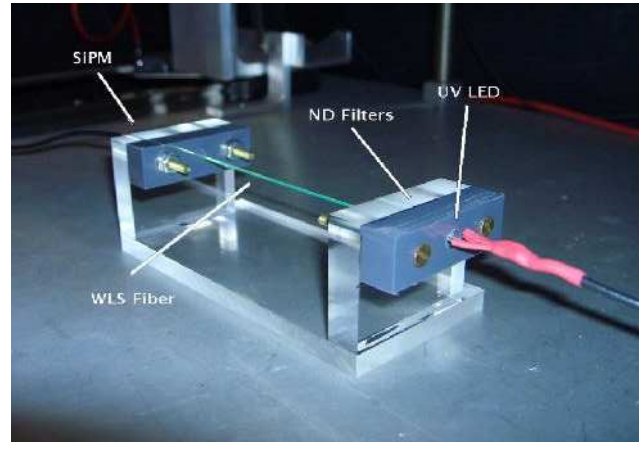
Our design - possible variations

- Tyvek vs. radiant mirror
- Orientation of WLS fibers
- Mounting SiPM’s on tiles
- Ganging multiple tiles together

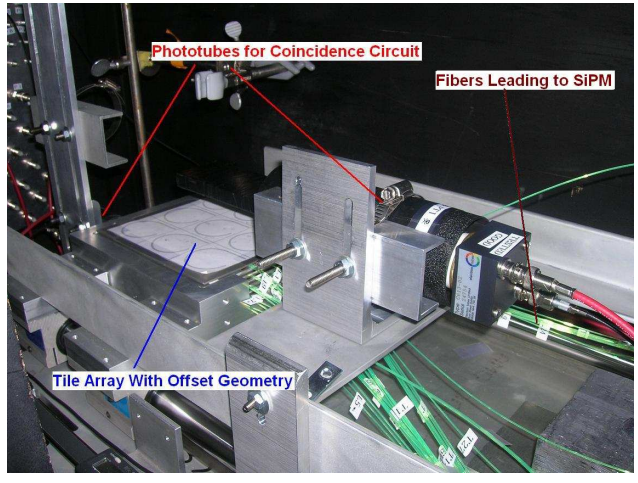
Testing our design



- WLS fiber stability



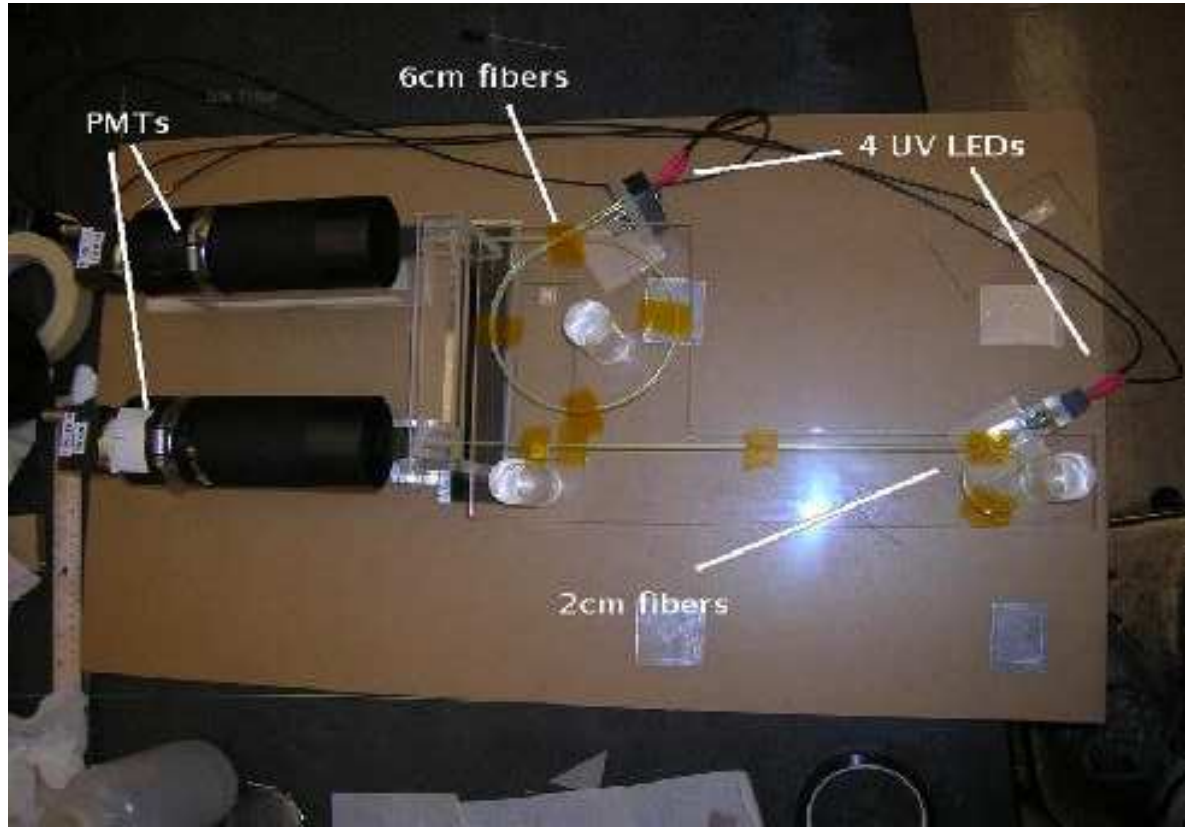
- SiPM performance



- sensitivity of tiles

WLS fiber long-term test

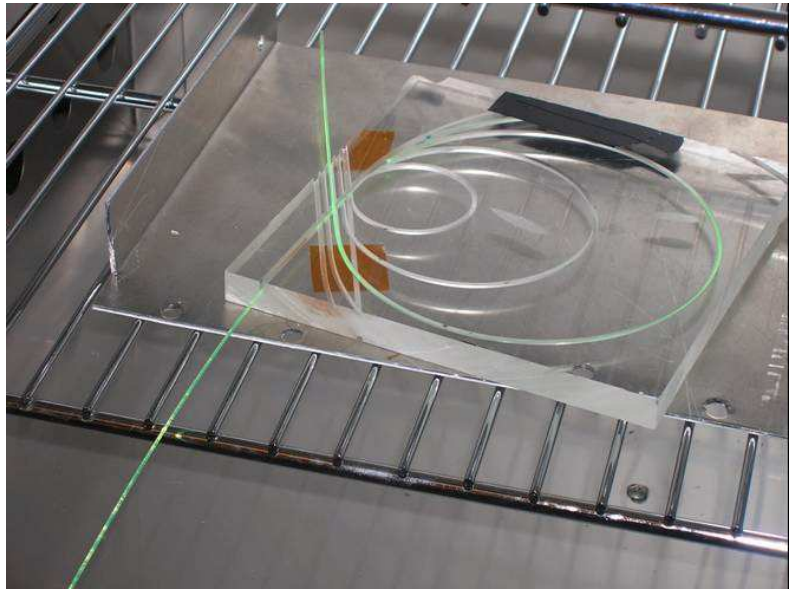
We have been observing the possible degradation of the WLS fiber over time for the last year. We have studied fibers bent at a radius of 2cm and 6cm, annealed and not annealed.

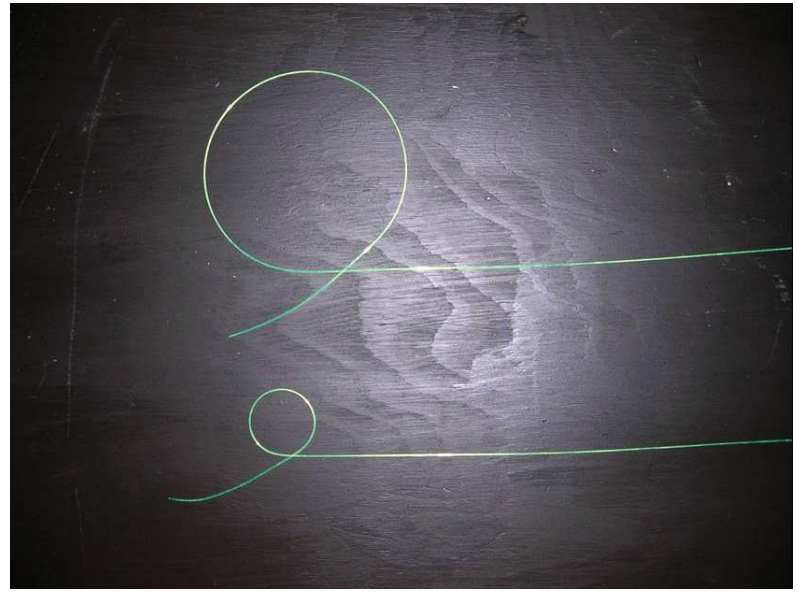


WLS fiber long-term test

Annealing process

- heat molds to 104C
- slide fibers into mold
- Fibers cool into shape

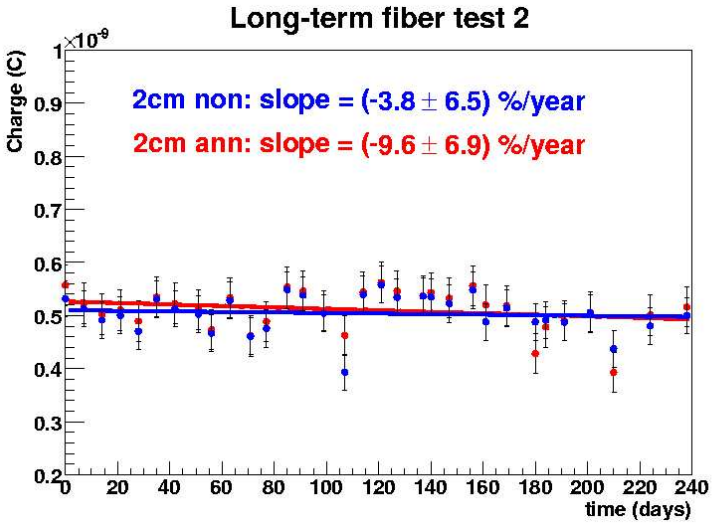


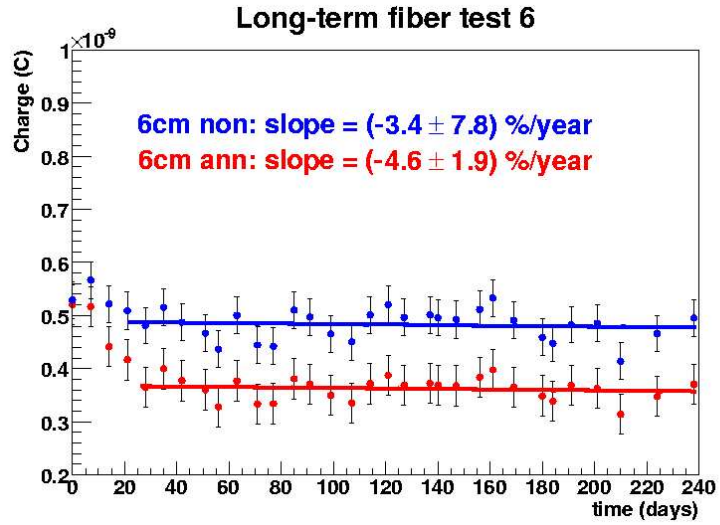


WLS fiber long-term test

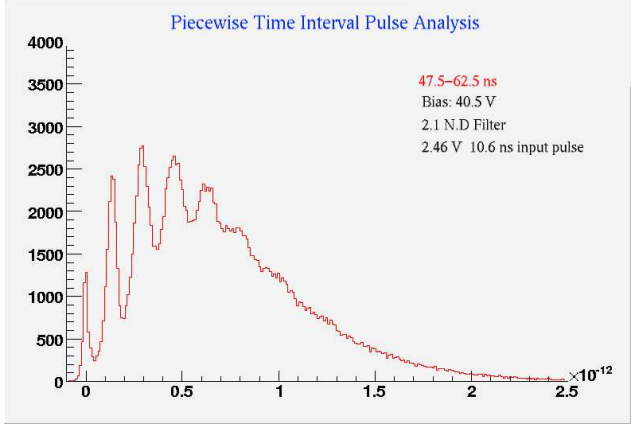
Results

- One year of data shows no significant degradation of fibers
- Uncertainty dominated by variation in LED output



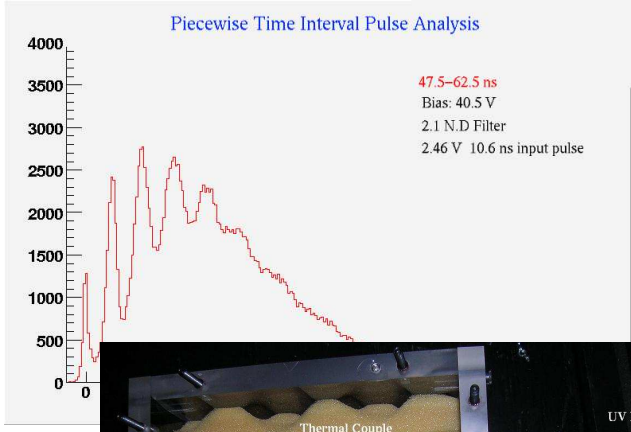


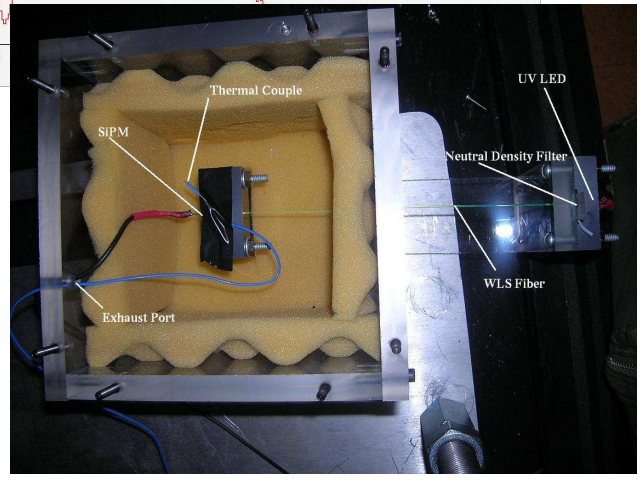
SiPM Studies



- Single-photon sensitivity

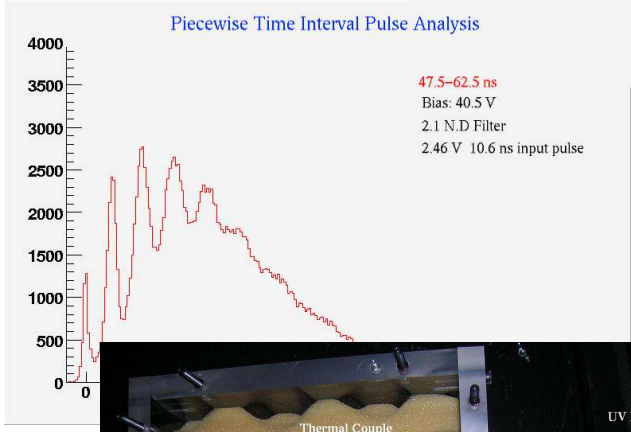
SiPM Studies

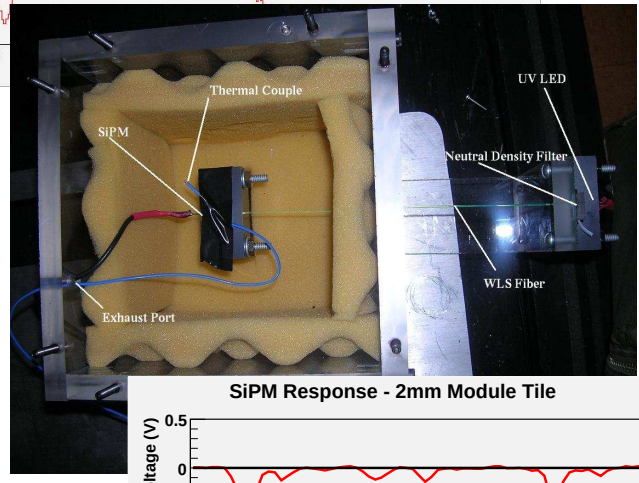


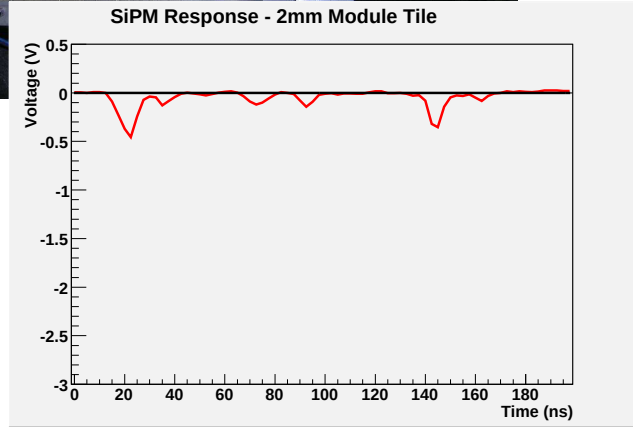


- Single-photon sensitivity
- Temperature Dependence

SiPM Studies





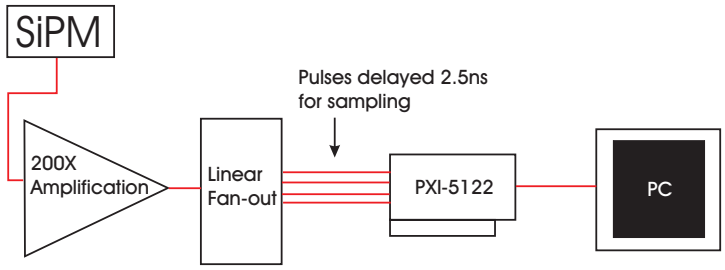


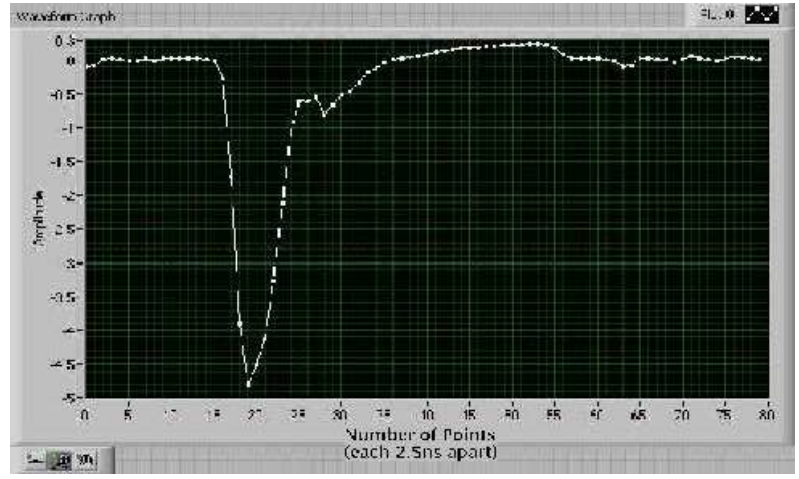
- Single-photon sensitivity
- Temperature Dependence
- Time resolution

SiPM Studies

Basic readout scheme

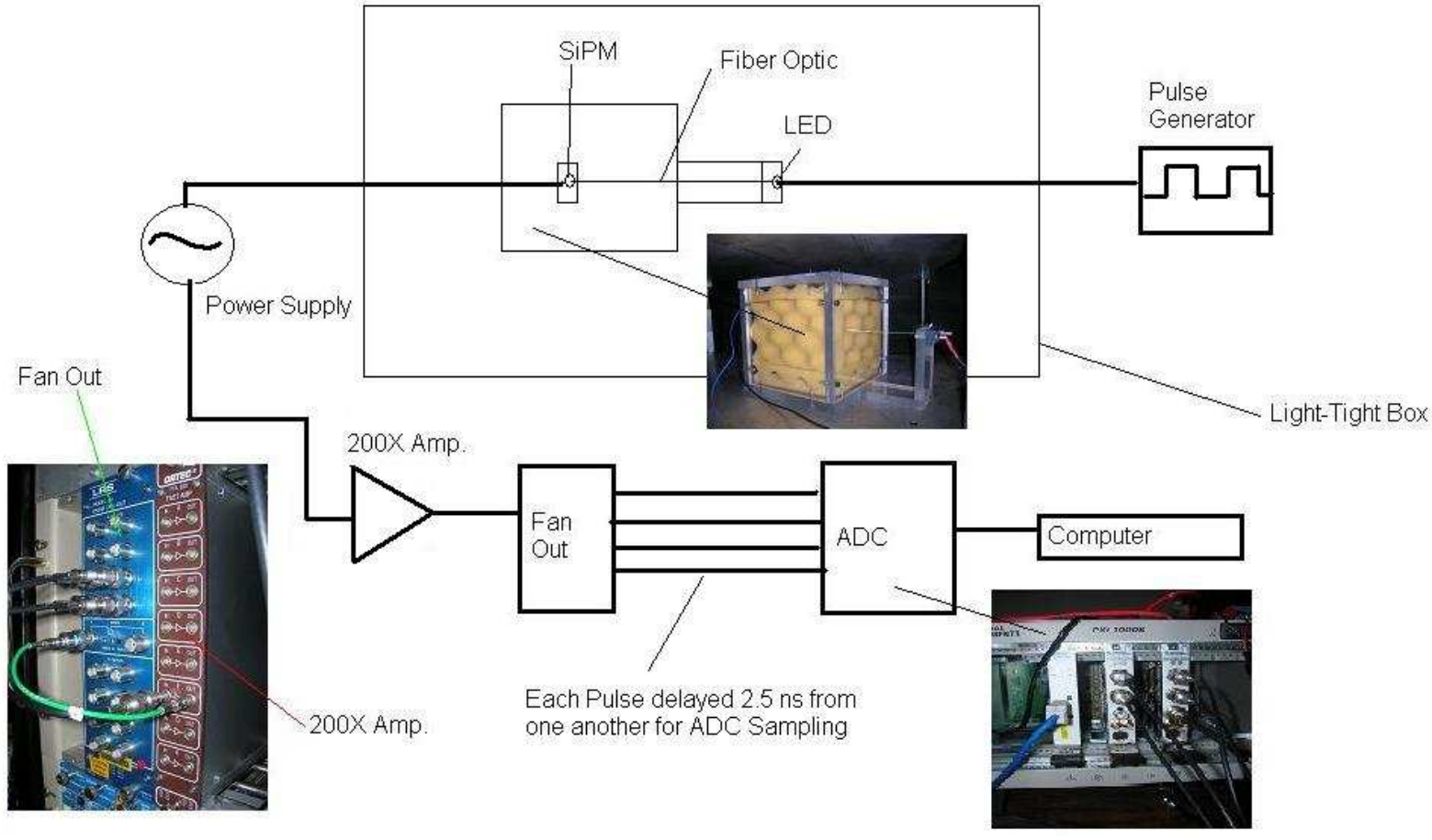
- Amplify signal from SiPM by 200
- Separate signal into 4 channels, each with a 2.5ns delay
- Read each channel at 10ns intervals
- Merge data from 4 channels



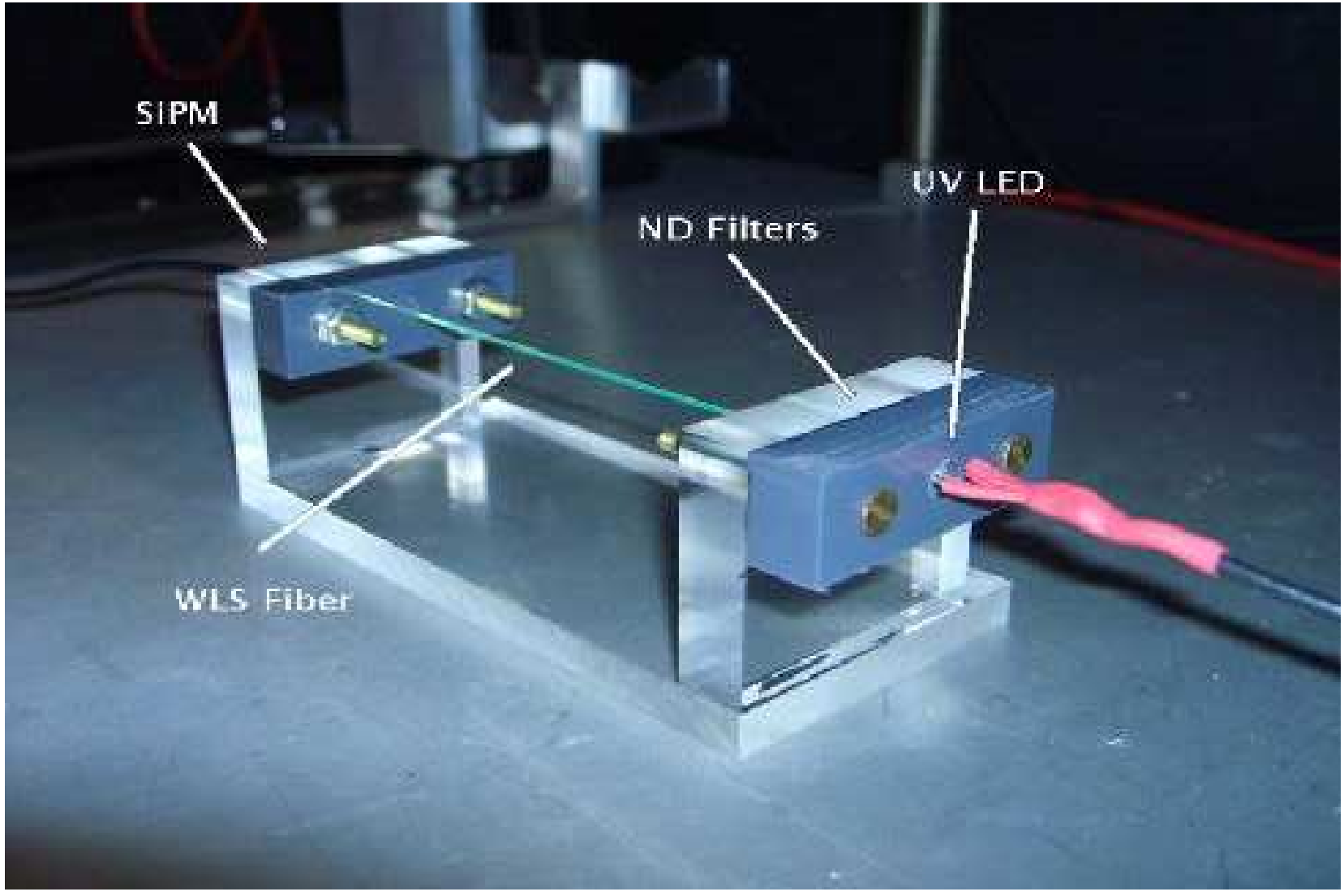


SiPM Studies - setup

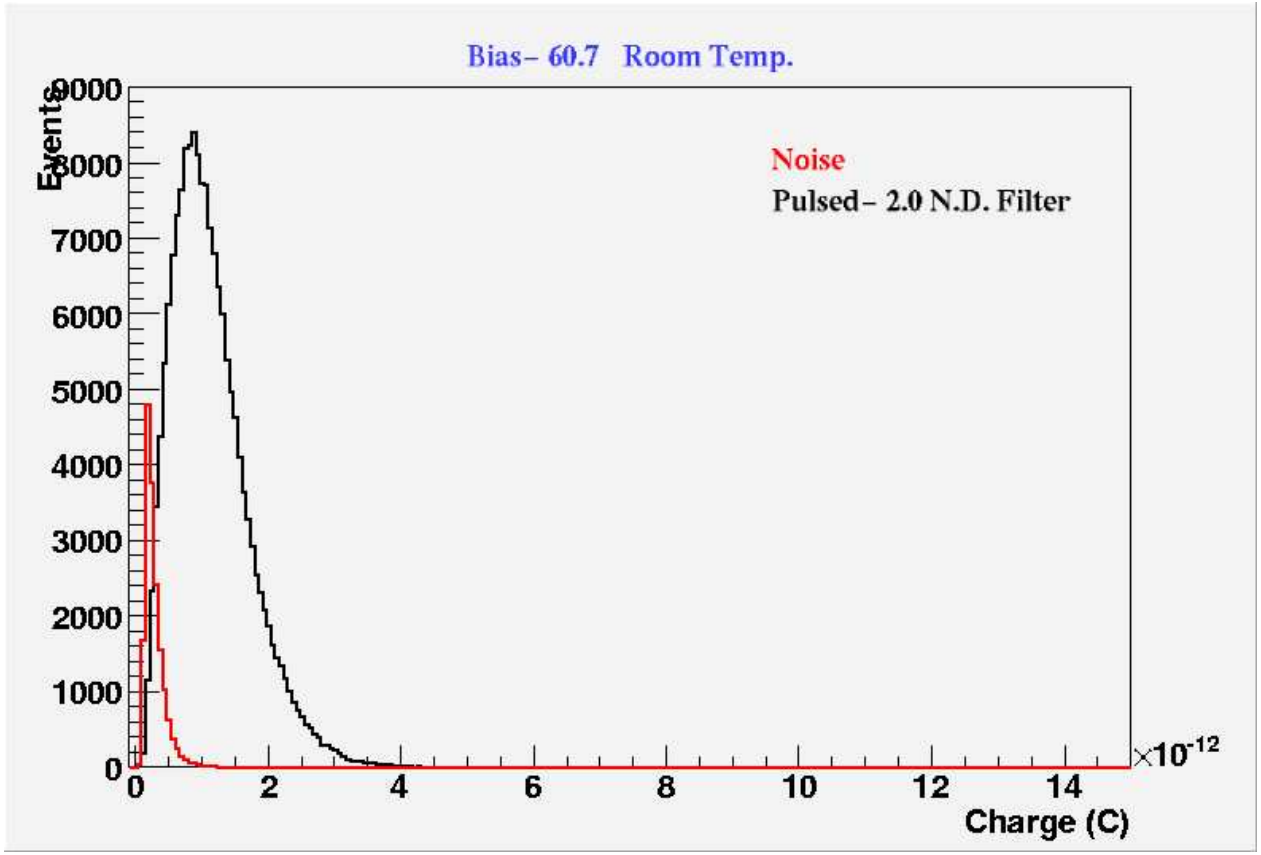
- We drive a single SiPM with an ultraviolet LED coupled to WLS fiber with neutral-density filters to control light input



SiPM Studies - setup

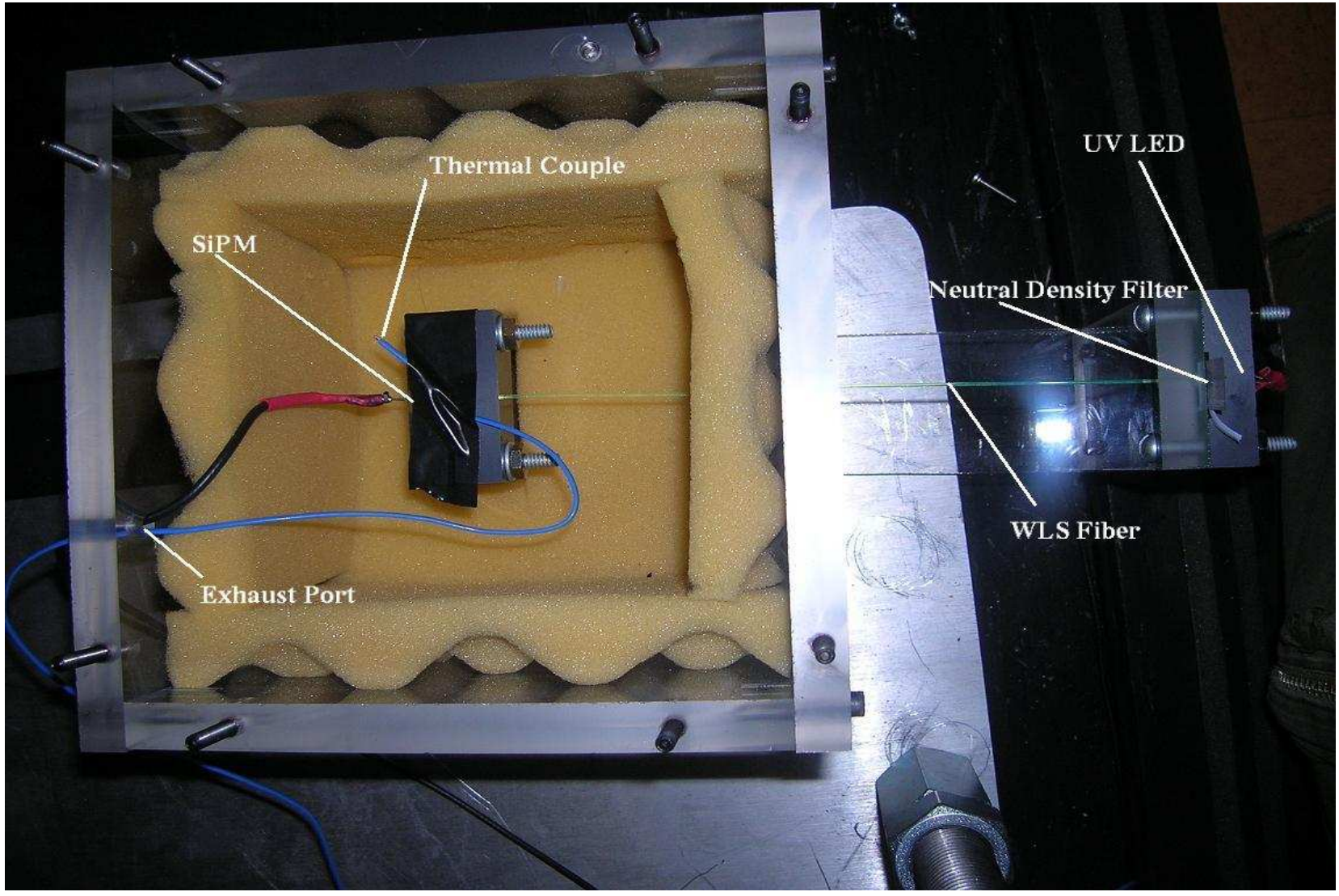


SiPM Studies - initial results



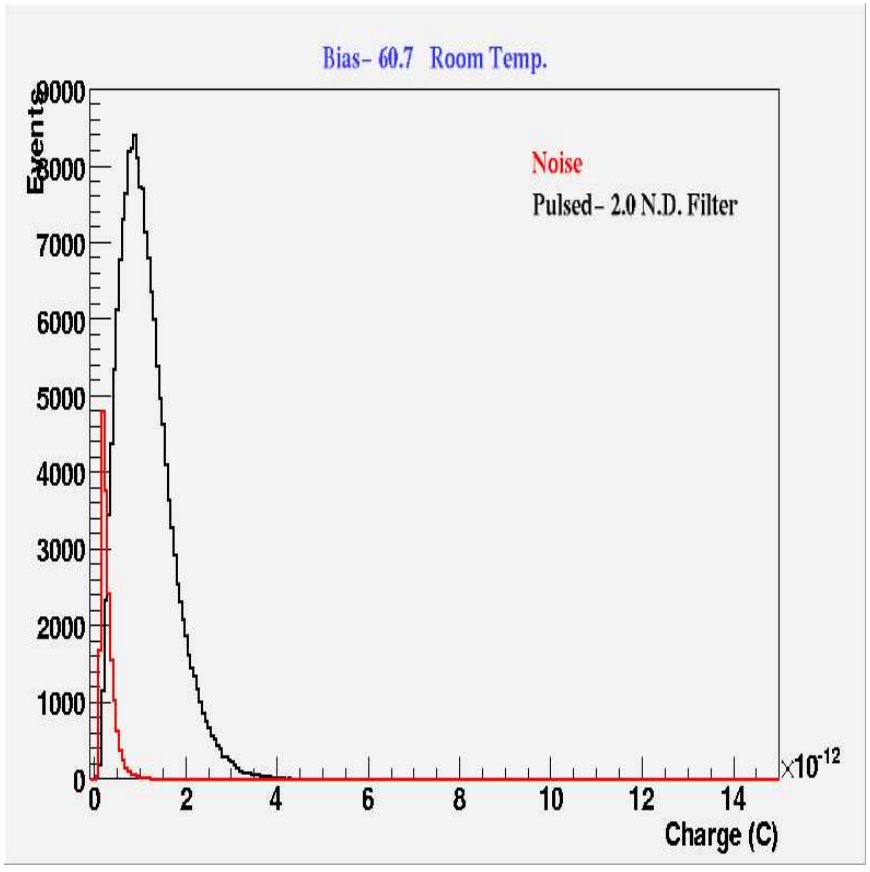
- Early results demonstrated ability to sense very low light levels, but did not show resolution on the single-photon level

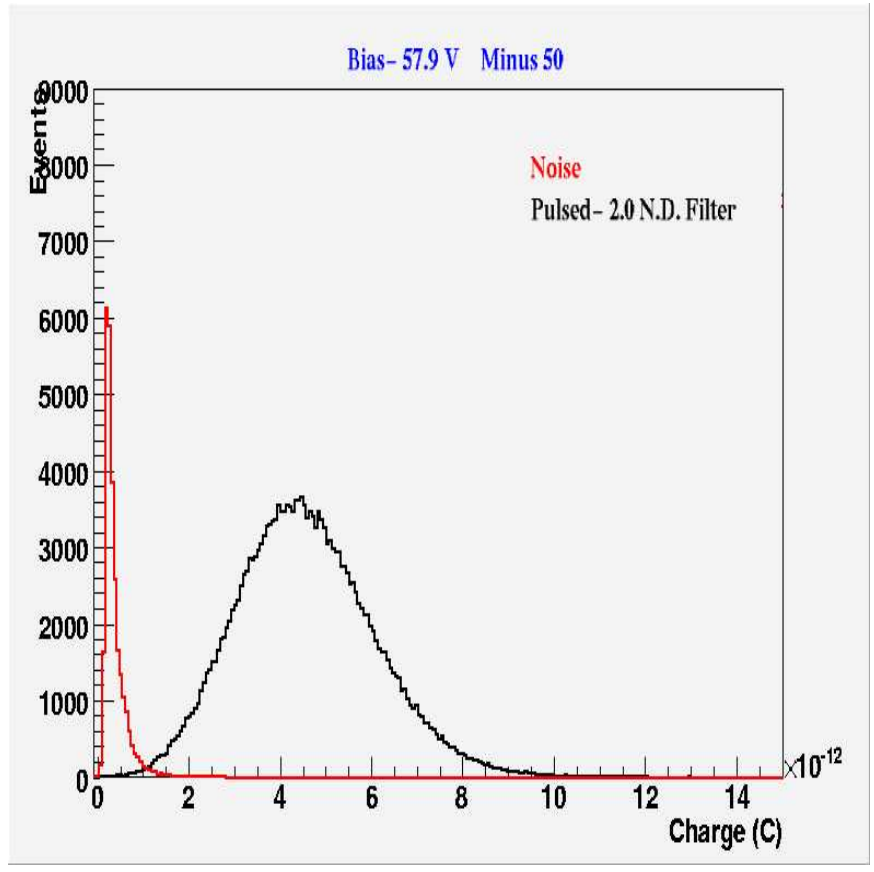
SiPM Studies - cold setup



SiPM Studies - low-temperature results

- Cold-temperature tests demonstrated improved signal for similar noise (but still no single-photon resolution)





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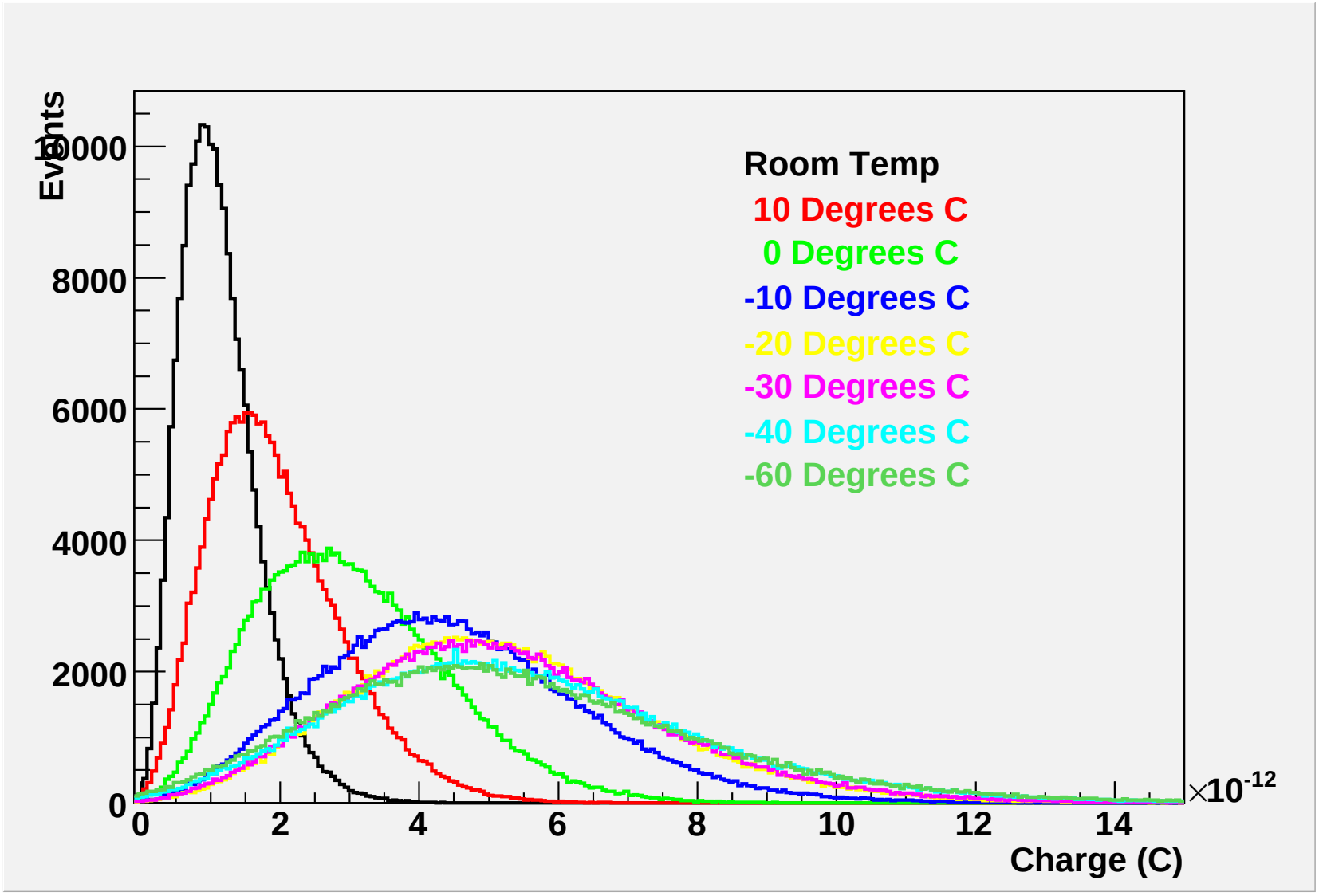
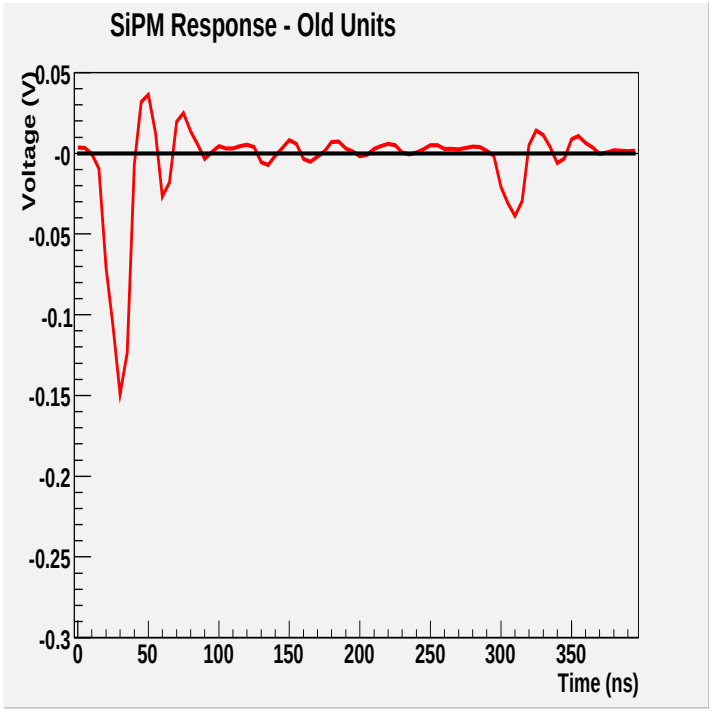
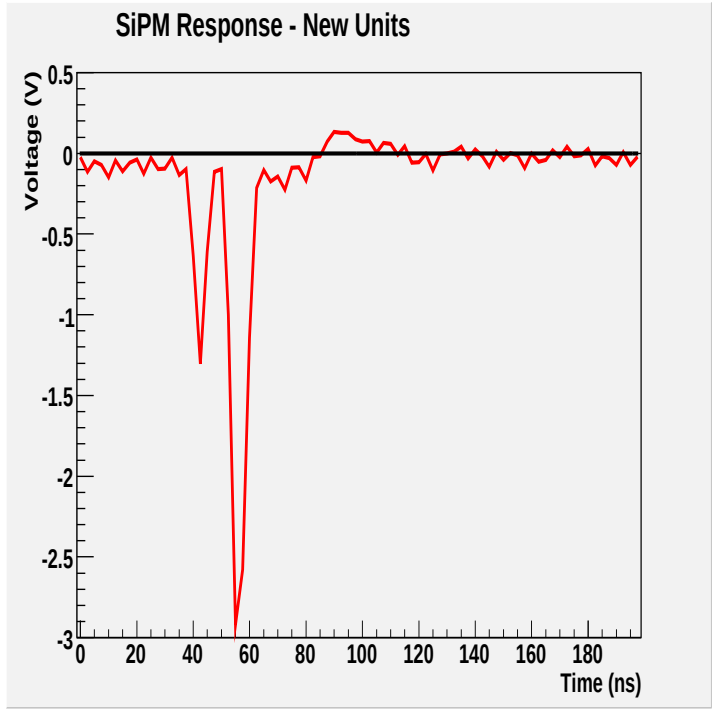


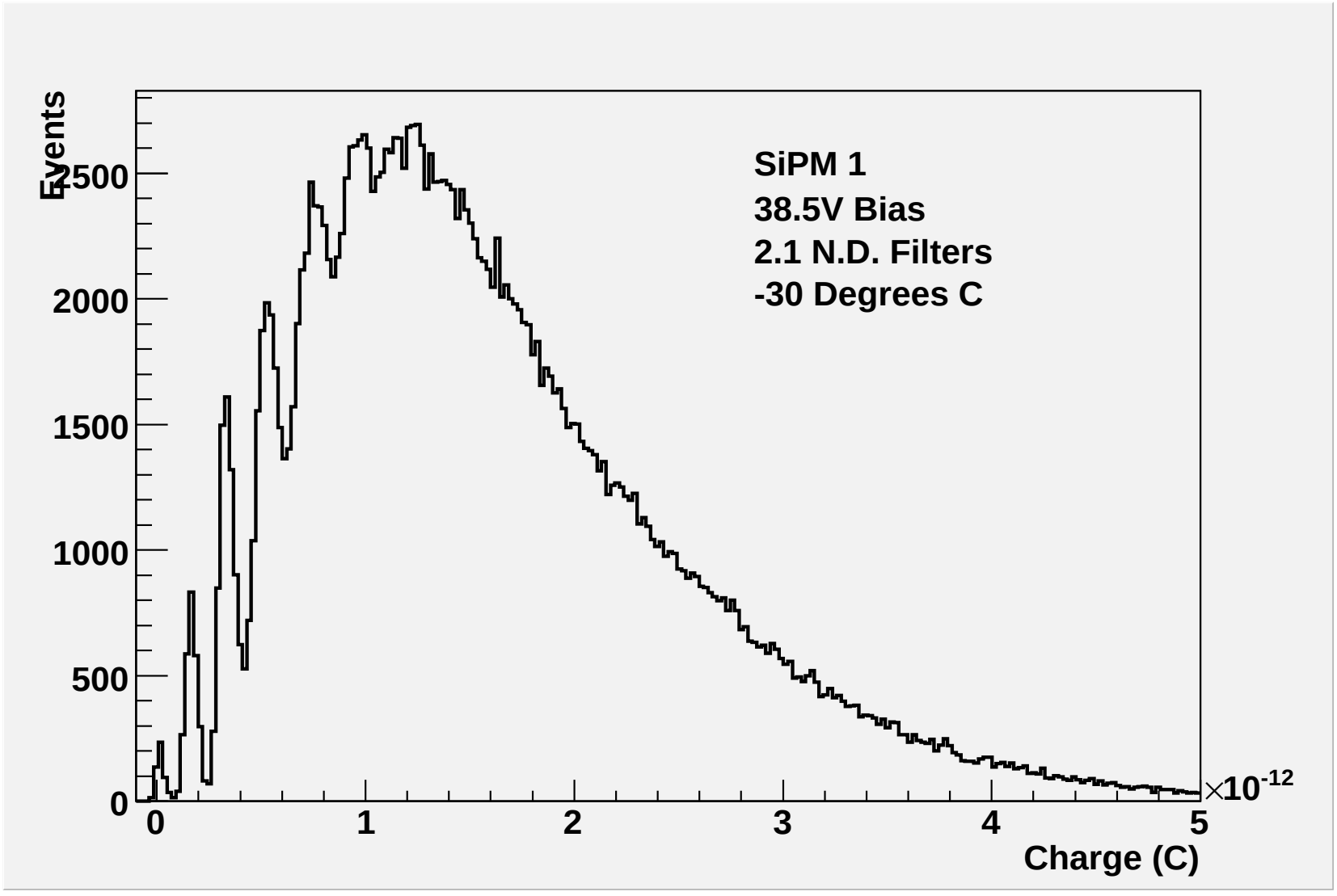
SiPM Studies

- New devices have much more stable response and better gain



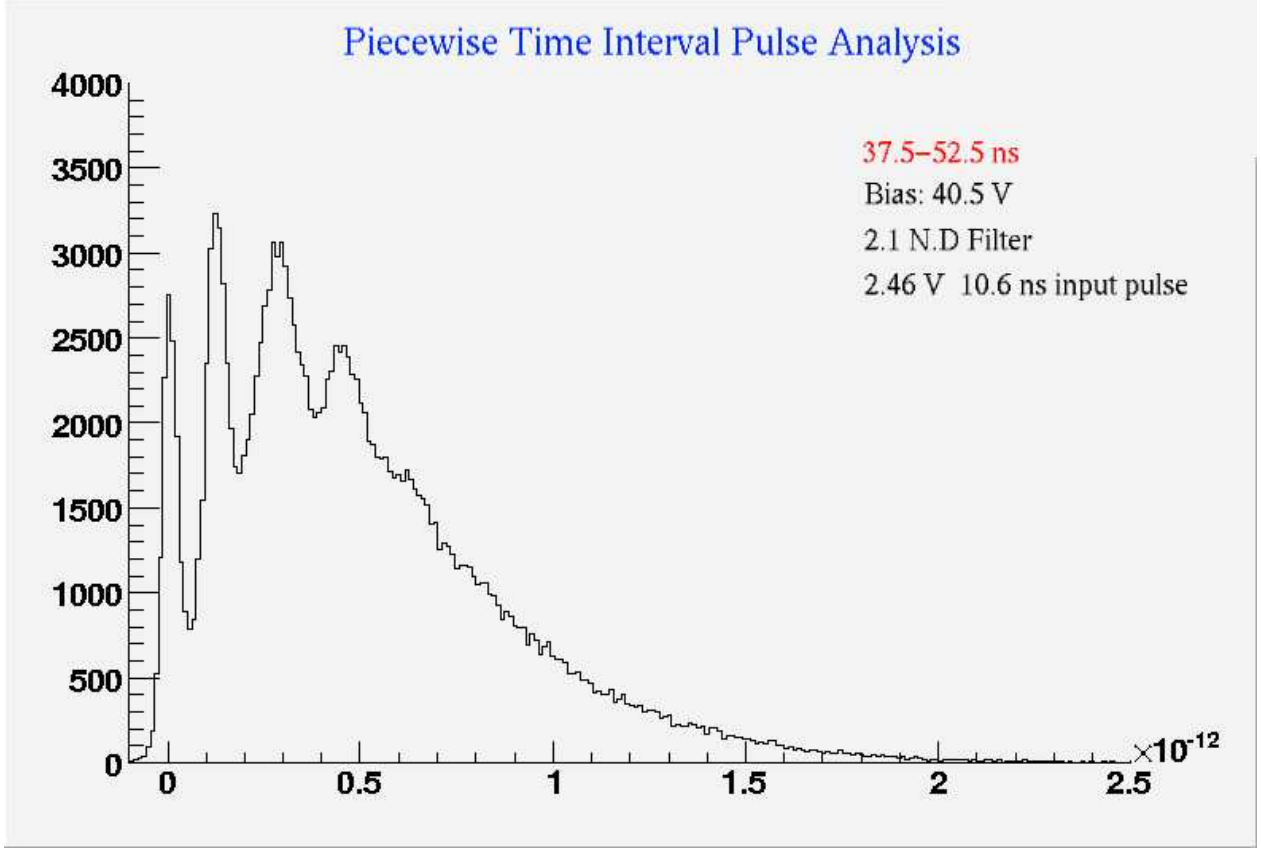


SiPM Studies - Single-photon separation!



SiPM Studies - time resolution

- Reading pulse in 10ns slices, we can still separate photons



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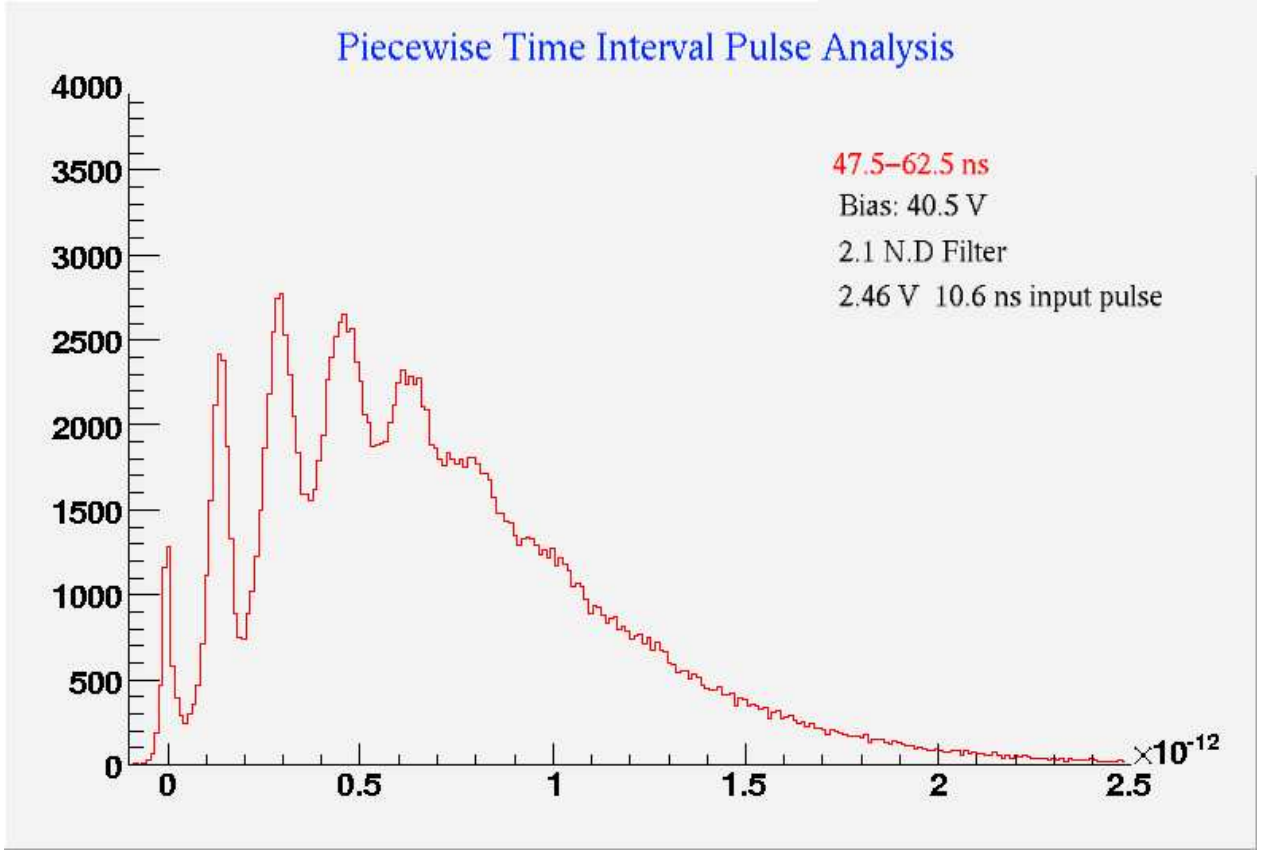

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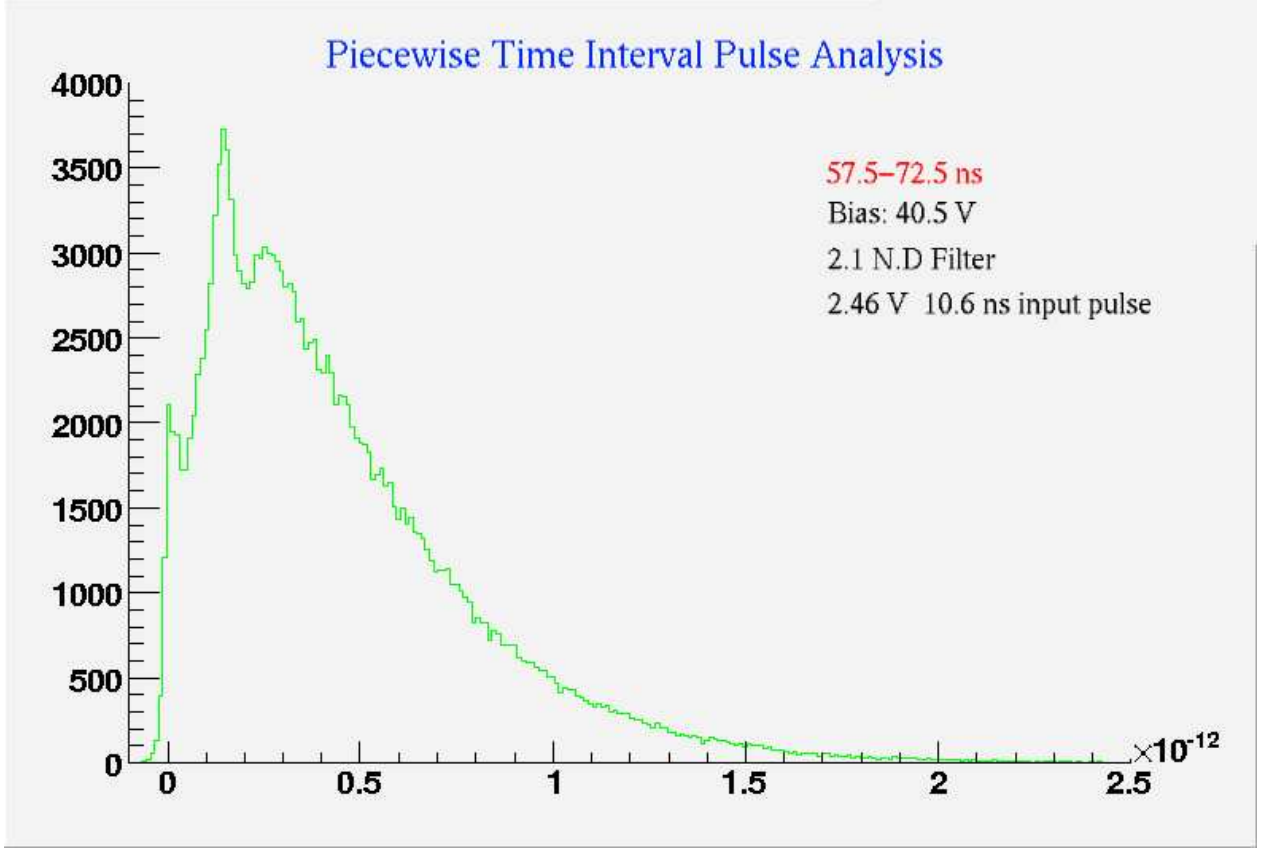

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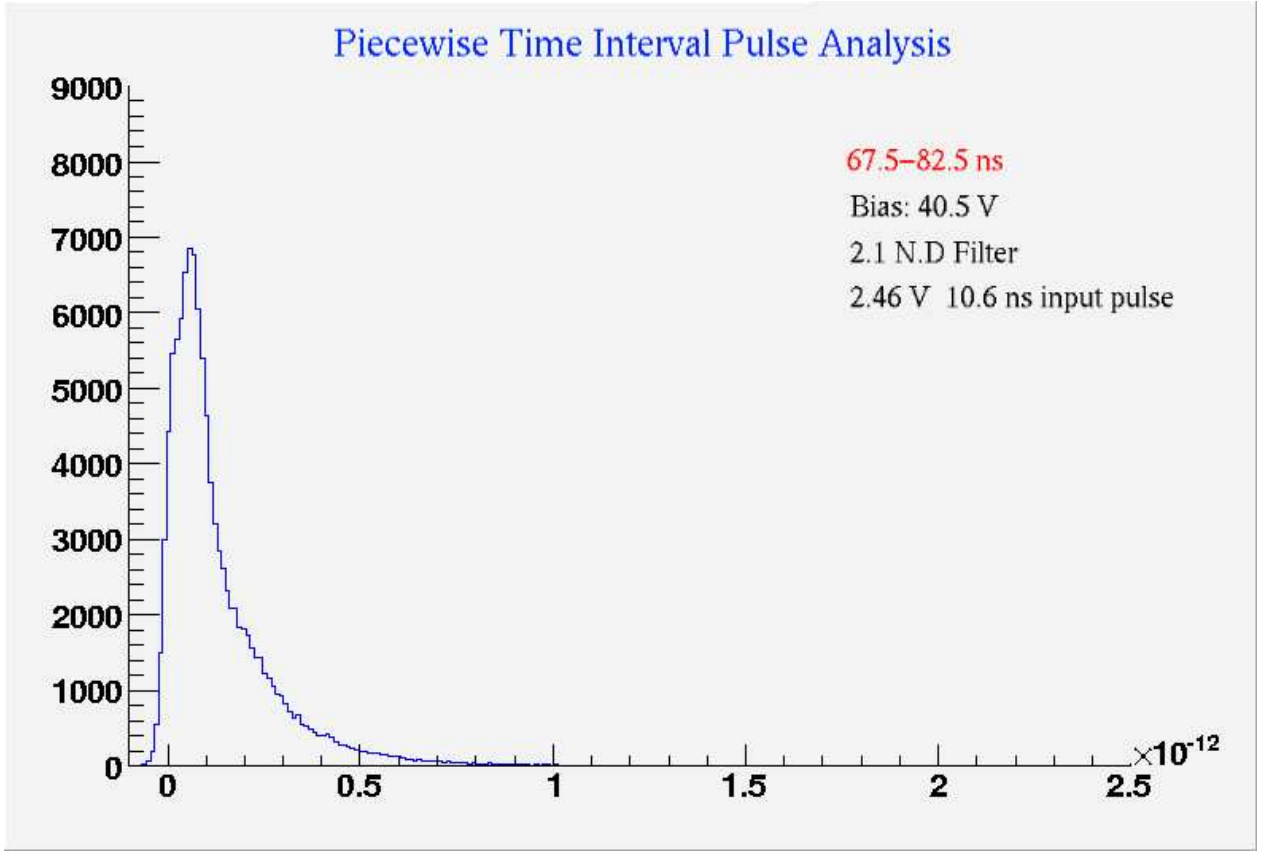

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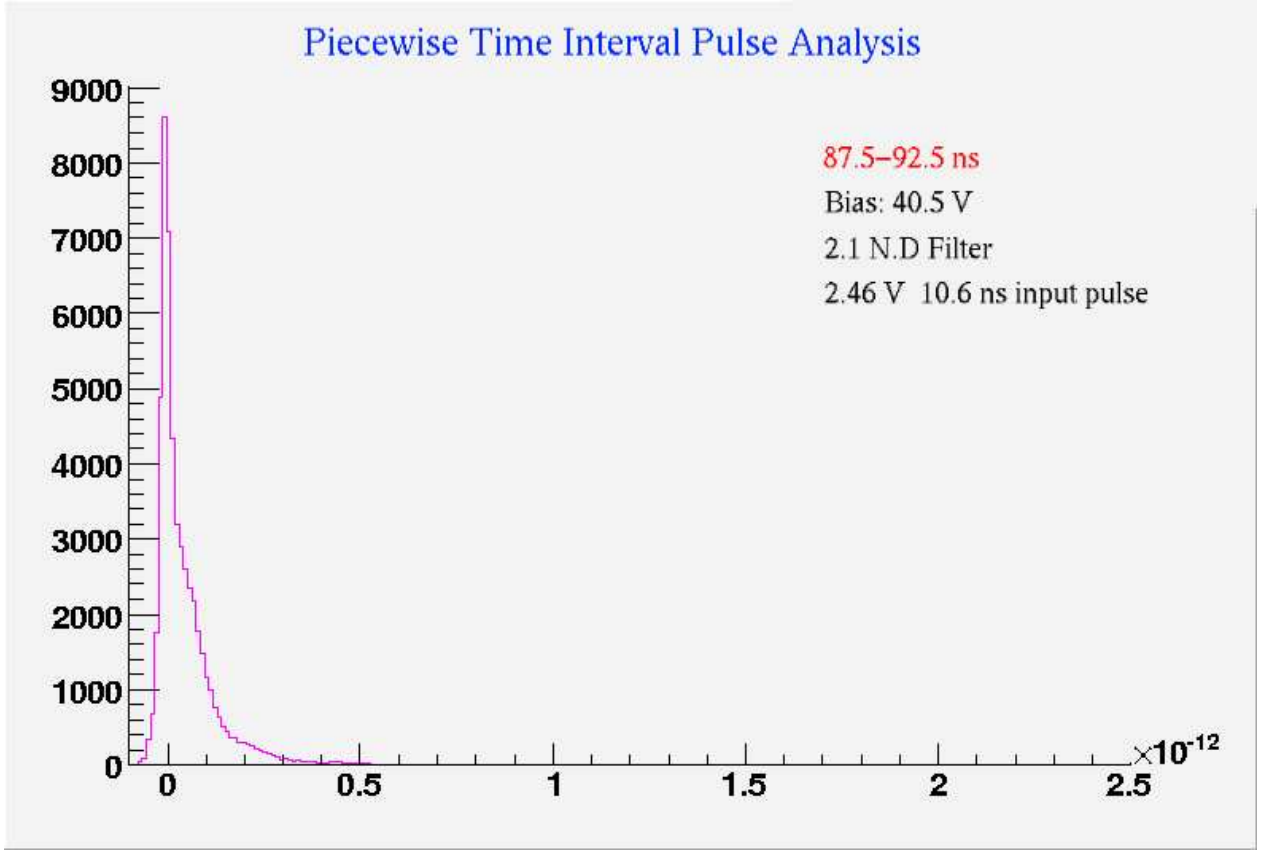


SiPM Studies - time resolution

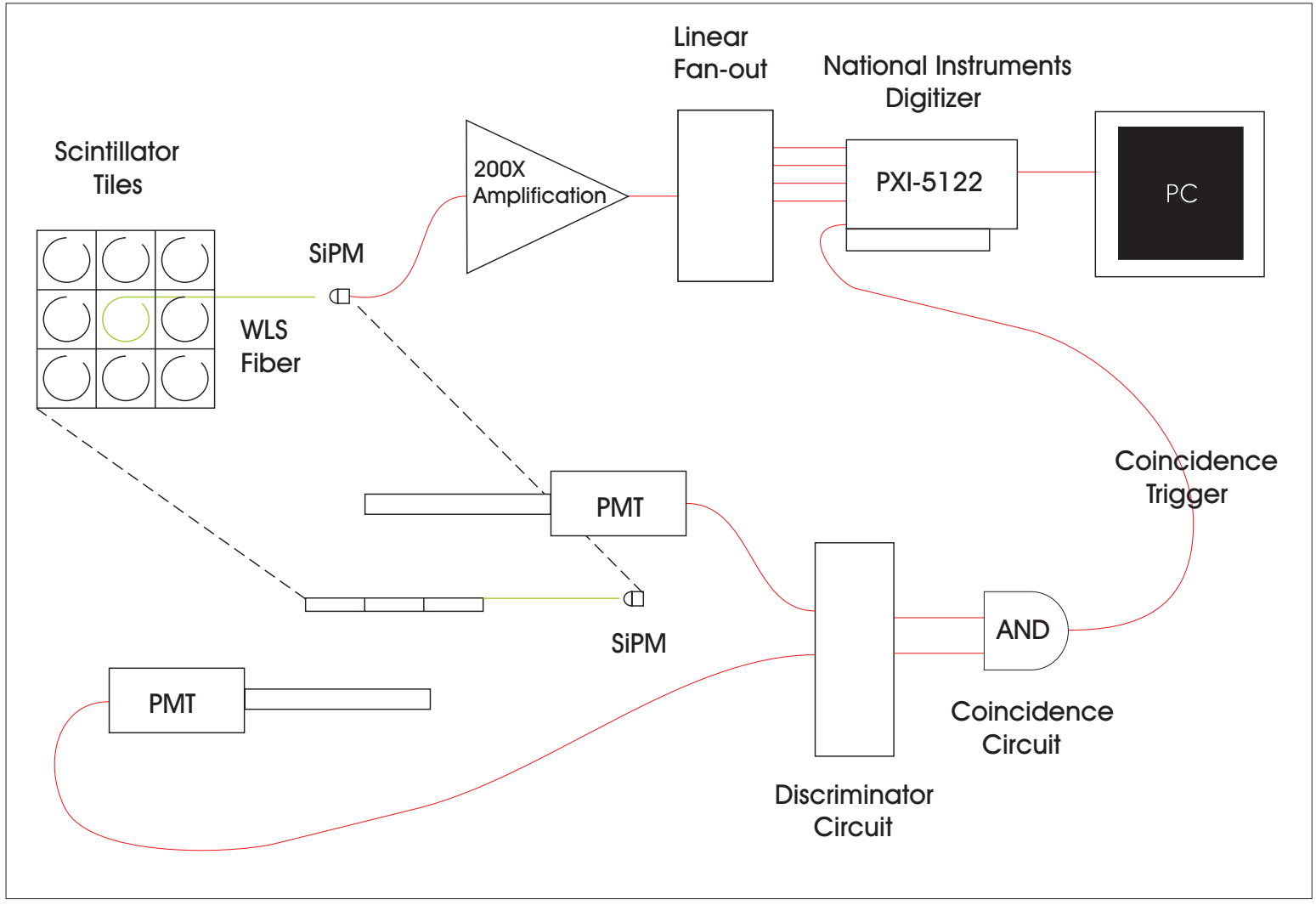
- Photons from LED arrive over a 40ns time interval
- Response of SiPM is about 10ns
- Performance is similar in each of the SiPM's we studied

Detector module tests

We use cosmic rays to test our calorimeter module.

- Particles ionize scintillator in triggers and module tile
- Triggers deposit light in PMT's
- Coincidence in PMT signals used as trigger for data collection
- Signal from tile converted by SiPM; data collection same as for SiPM tests

Detector module tests



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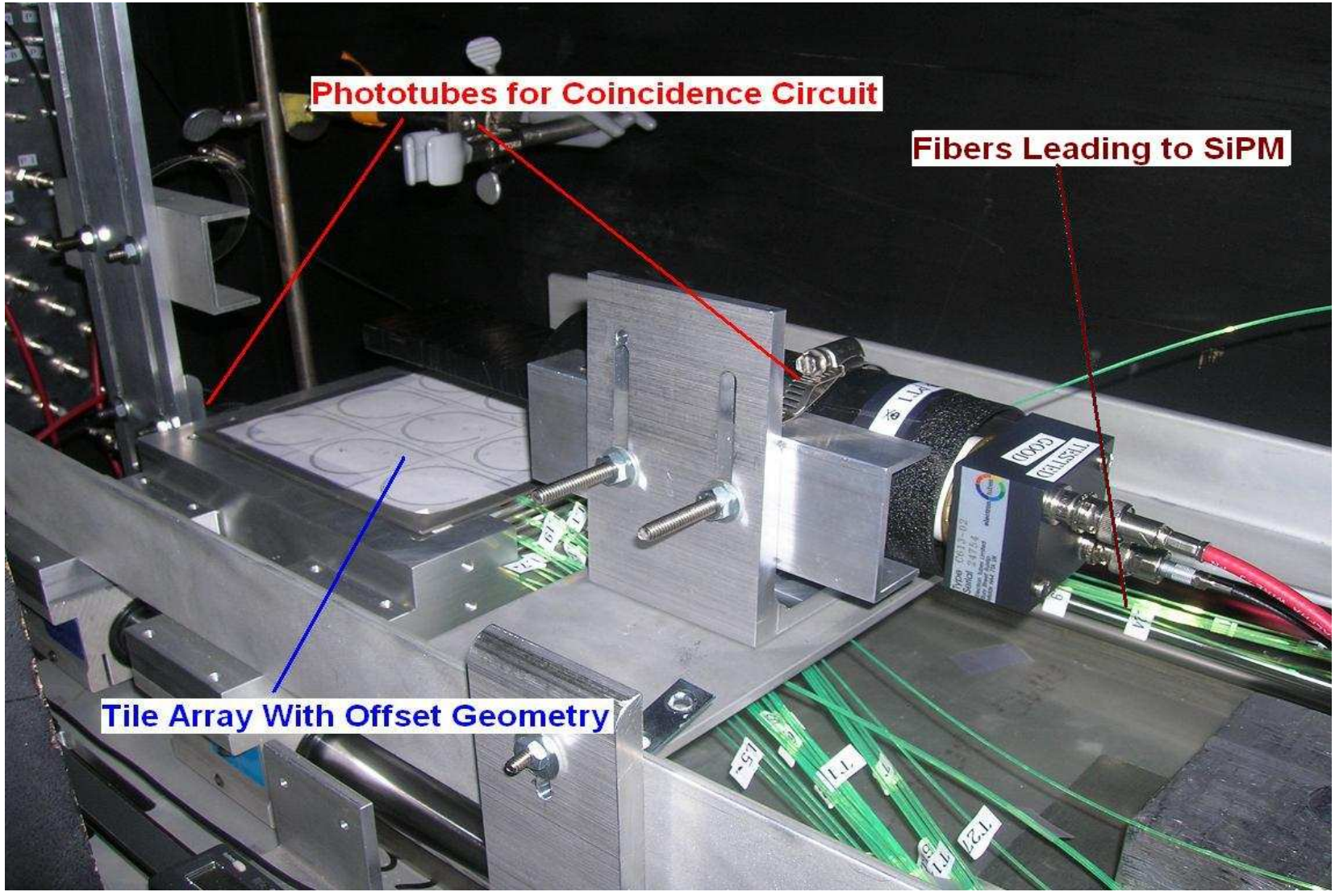
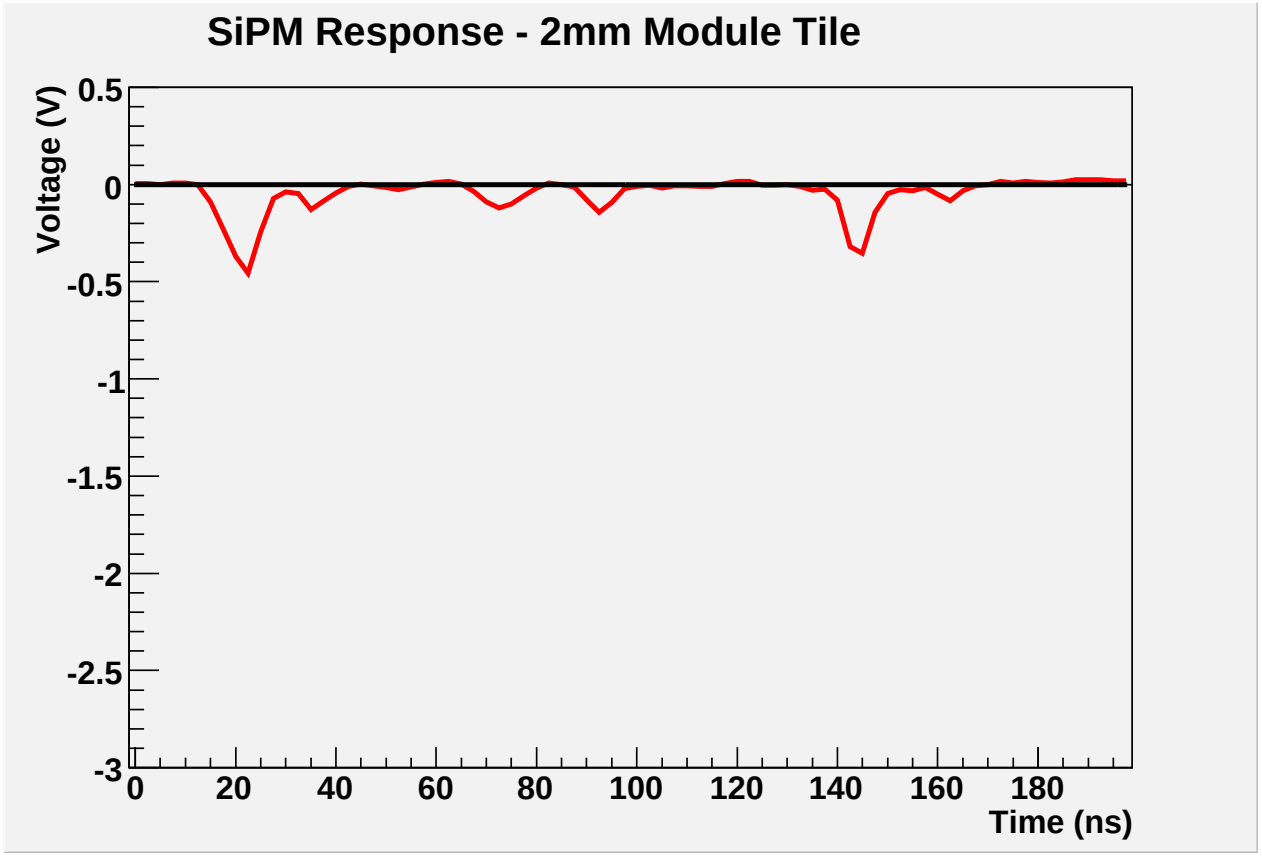


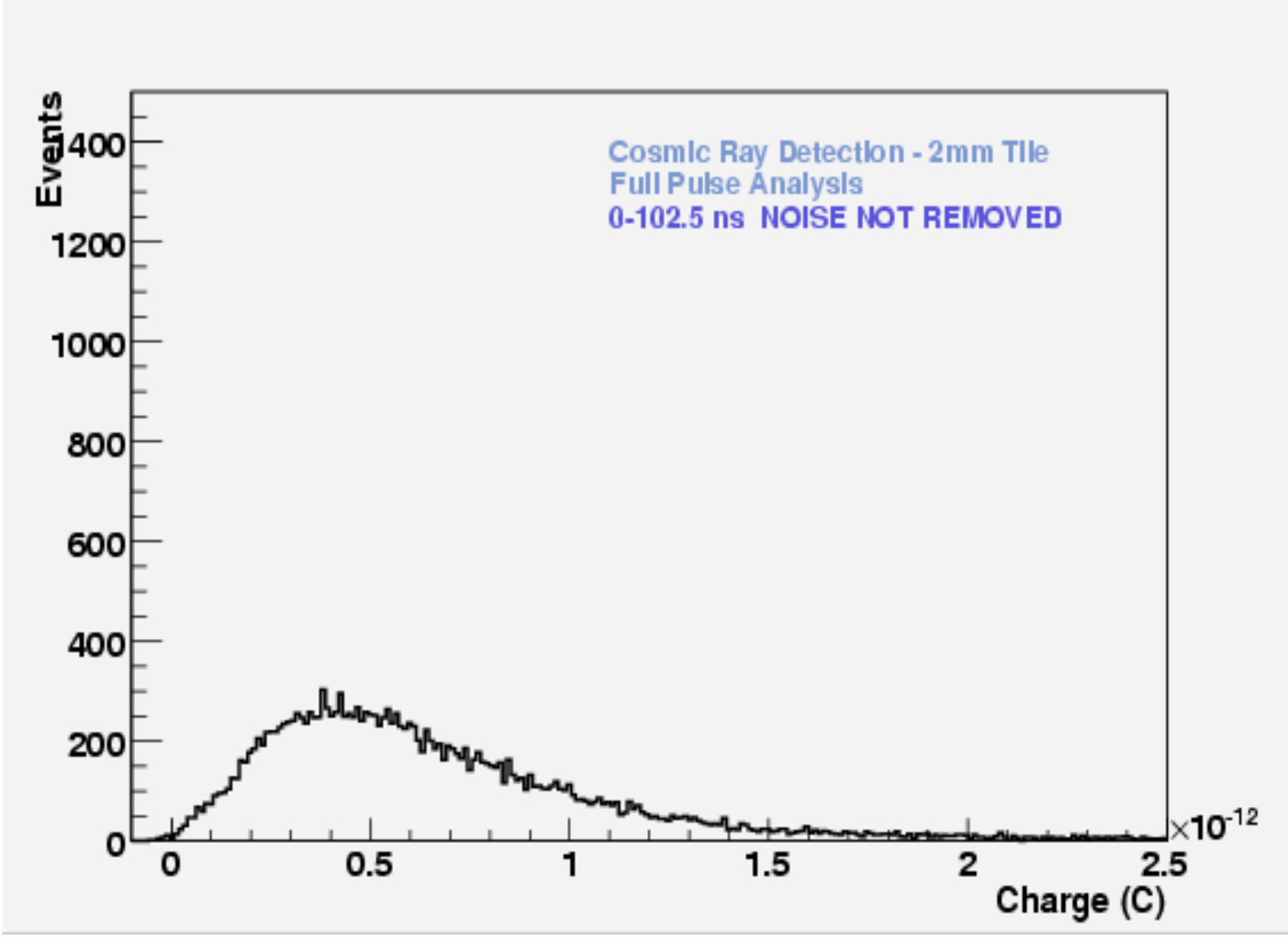
Detector module tests

We observe a signal of several photons over 100ns



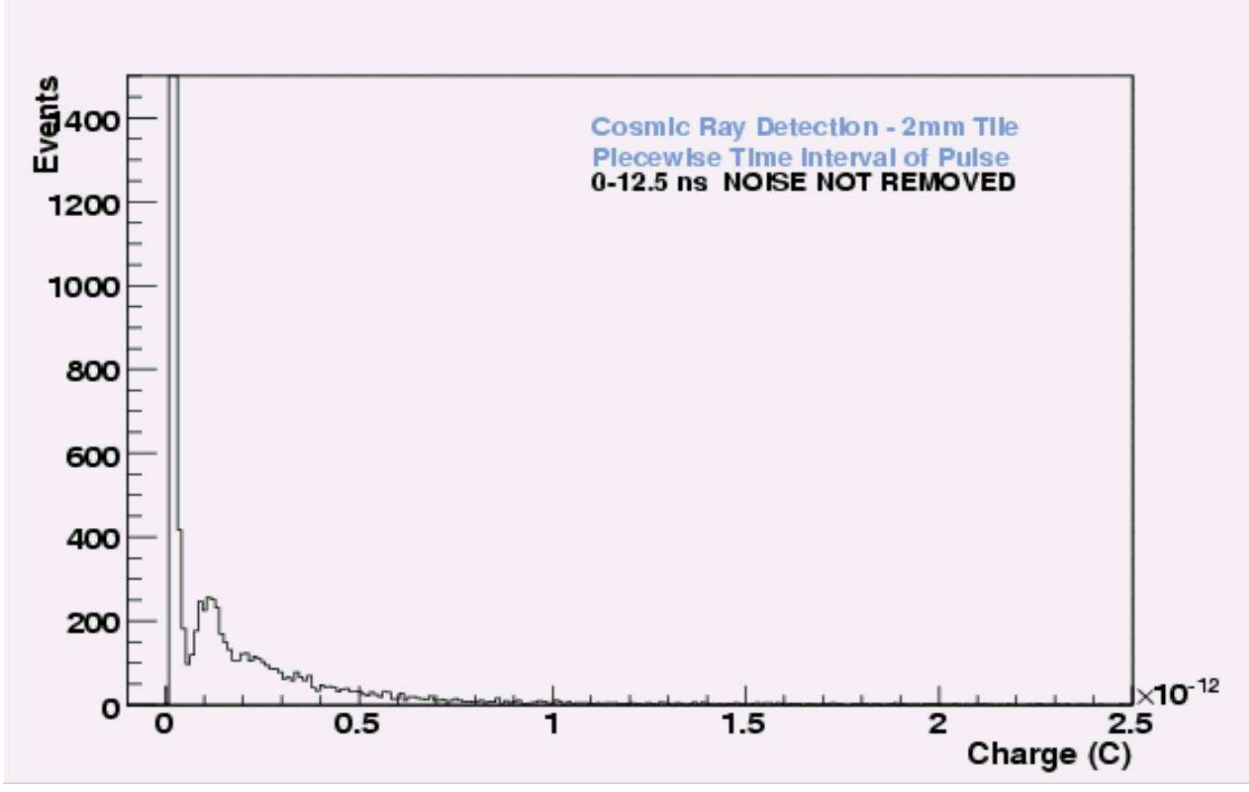
Detector module tests

Integration of the entire pulse results in noise that fades the single-photon resolution



Detector module tests

- Reading pulse in 10ns slices, we can again separate photons



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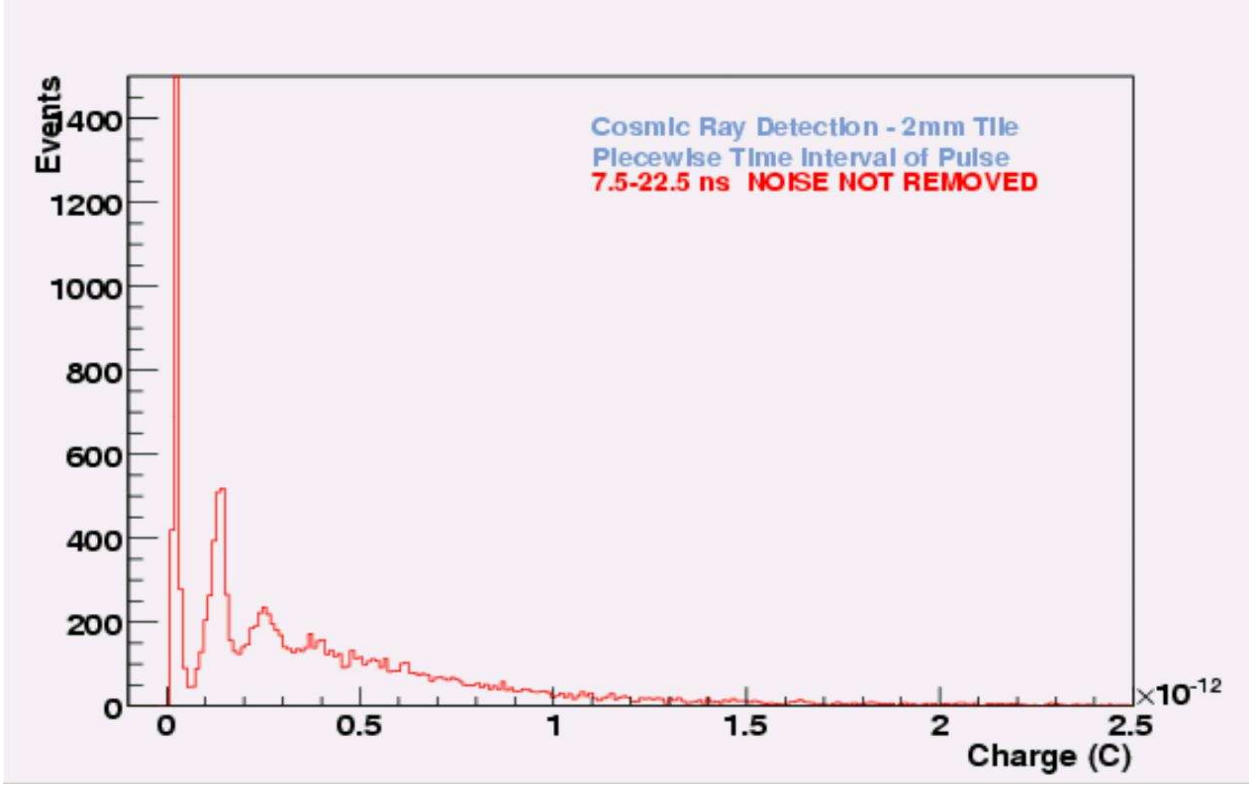

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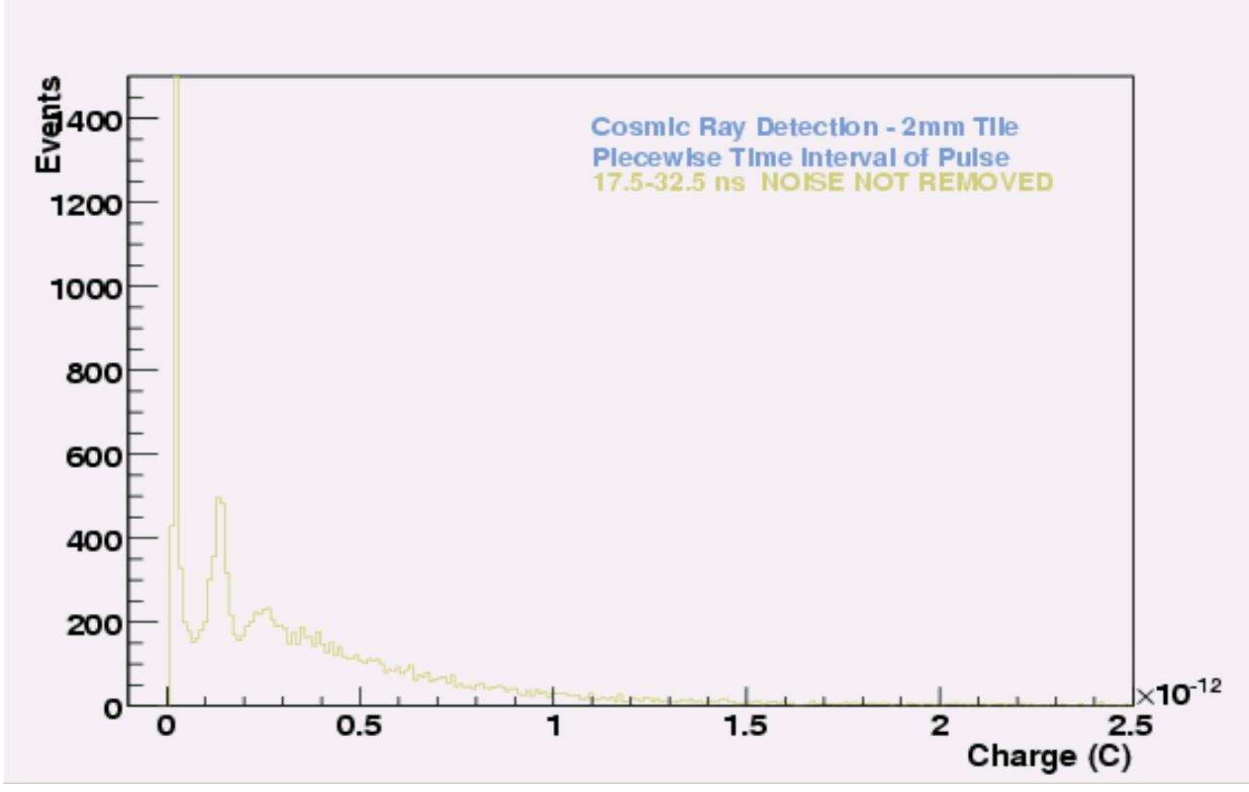

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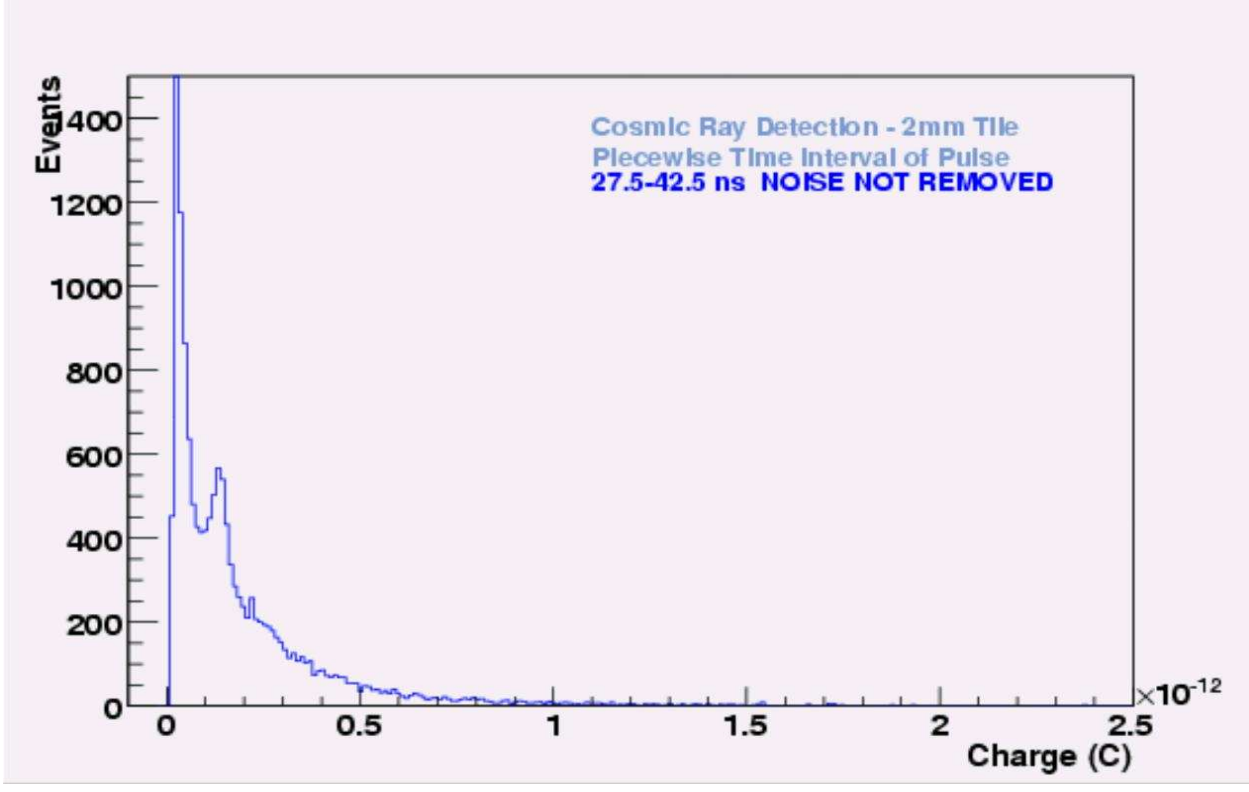

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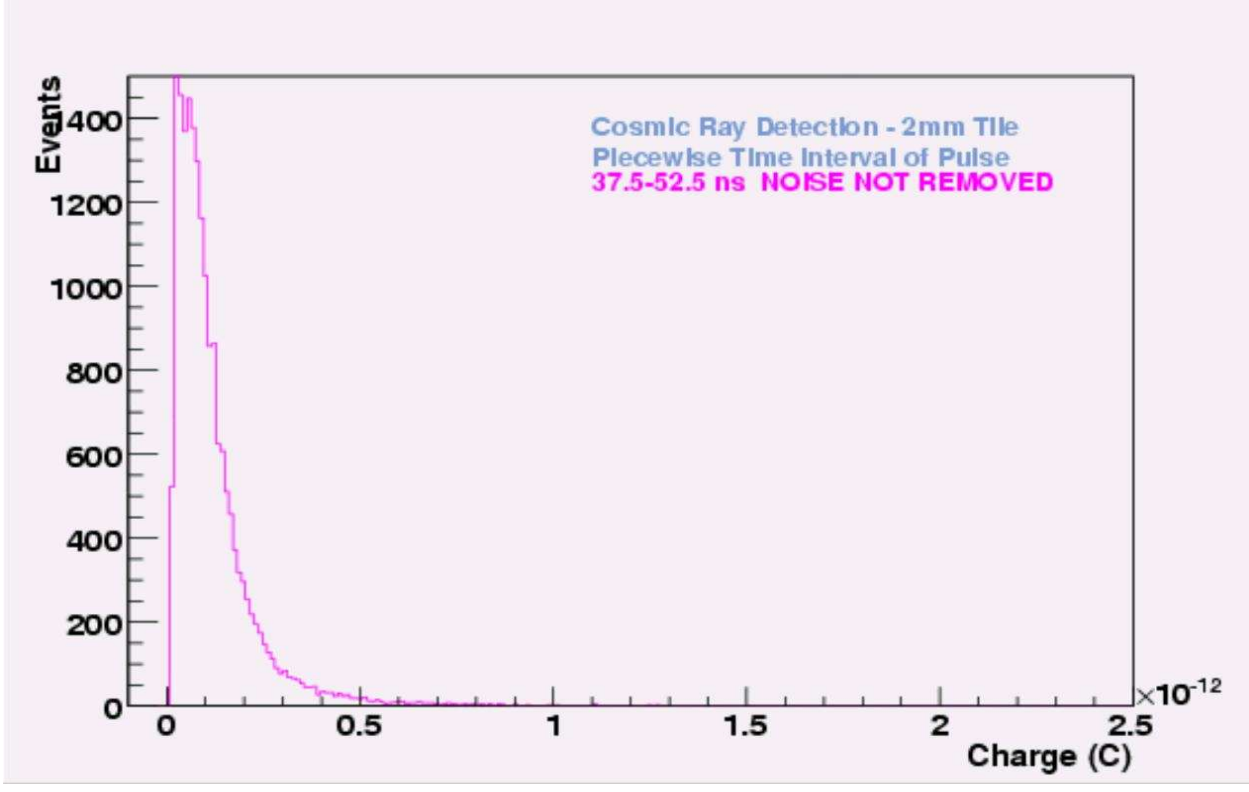

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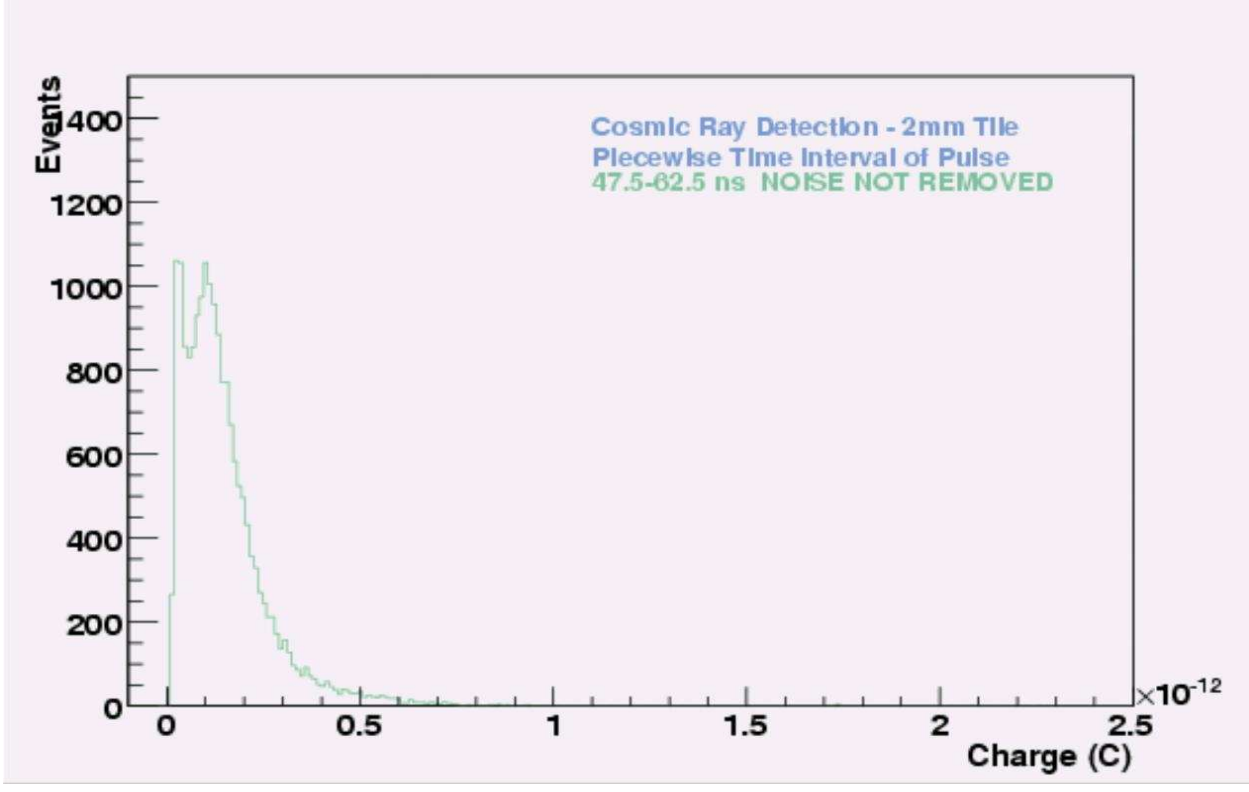

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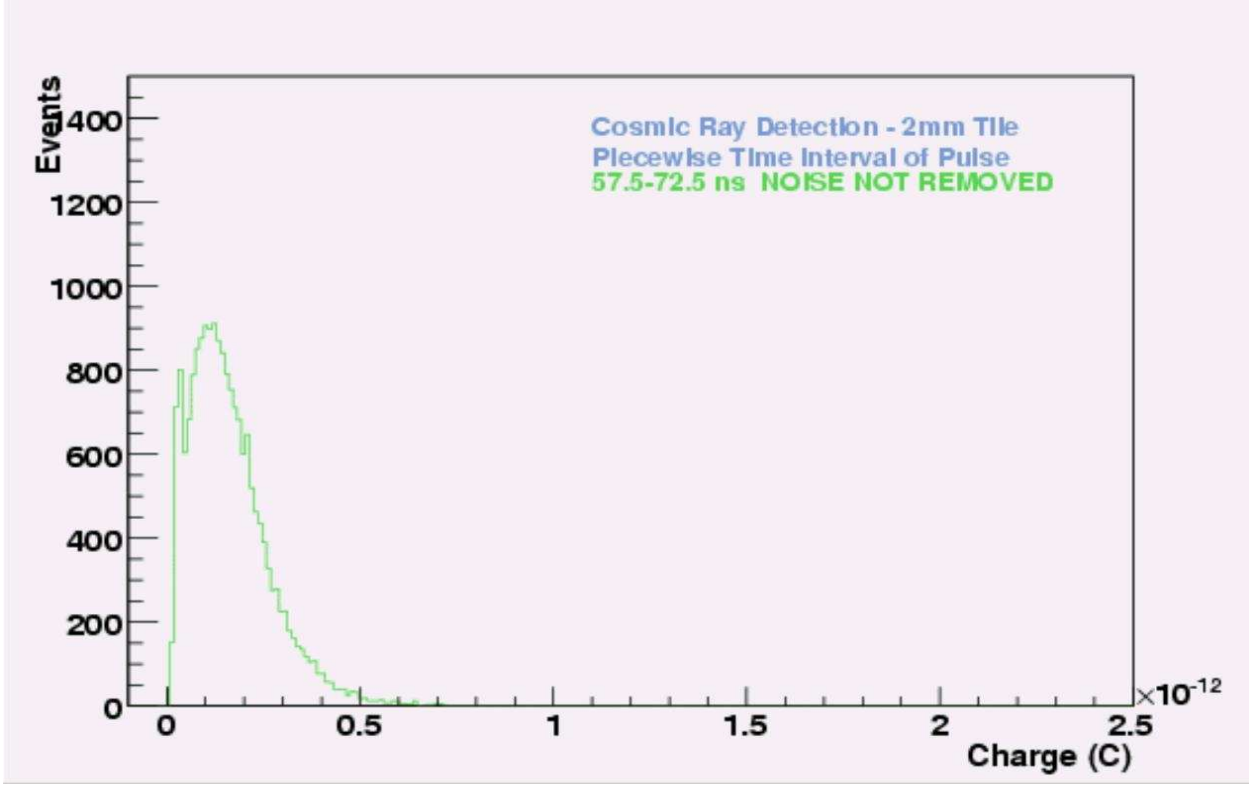

Future Plans

- Improve data analysis
  - Better peak finding
  - Account for pedestal voltage
  - In principle, this can be solved by better electronics
- Study uniformity of tile response
  - Need code to calibrate SiPM response
- Investigate feasibility of ganging tiles
  - Light guides?
  - Larger SiPM surface area?
- Incorporate findings into ongoing simulation studies