Hardware Progress Report

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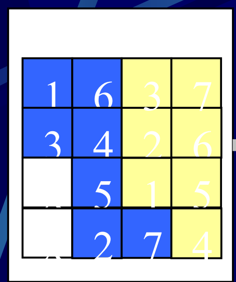
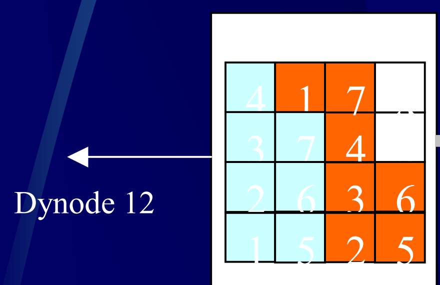
Introduction

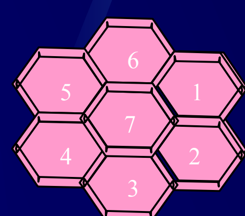
- This presentation will mainly focus on the latest progress with the solid-state photodetectors, namely SiPM, MRS and APD. It will also cover the latest news on cell measurements and electronics design.

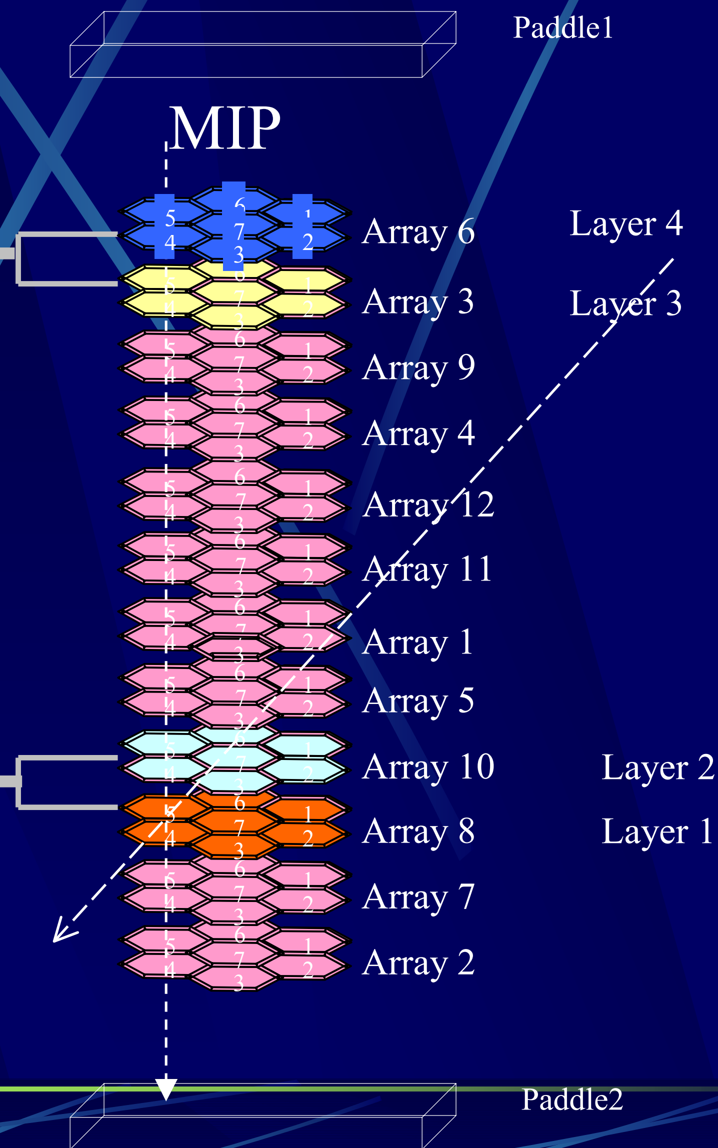
Calorimeter prototype cosmic test



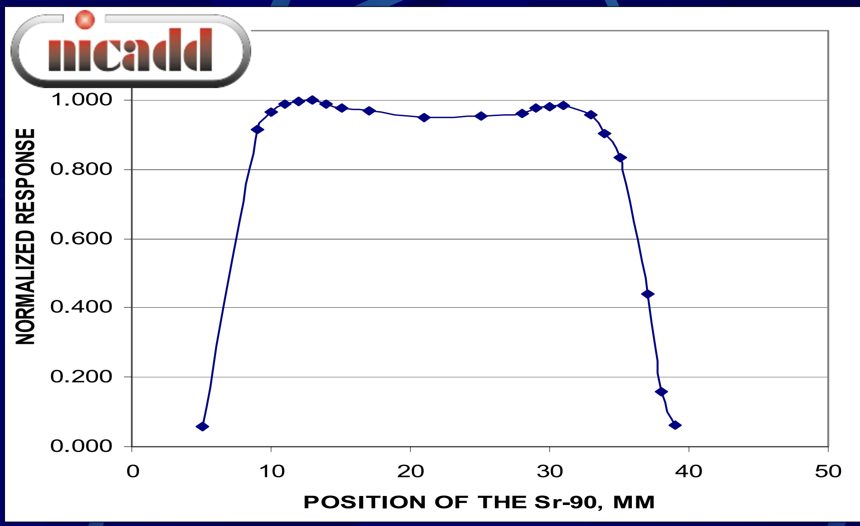
Schematics of the connection to Hamamatsu [1] 16 channel PMTs, up to 84 channels total

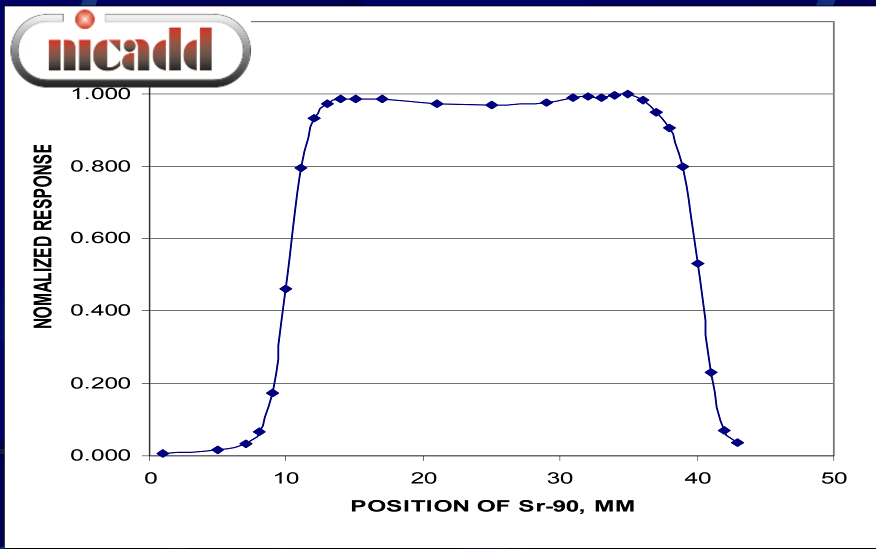




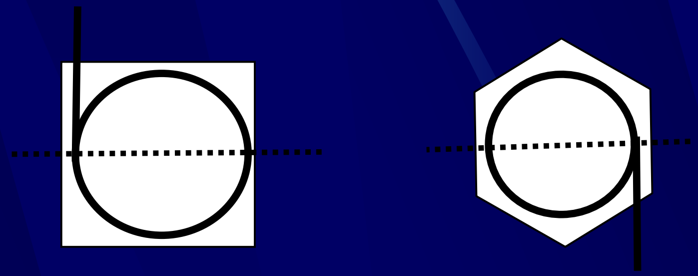


NORMALIZED RESPONSE OF SQUARE CELL WITH TAPERED SIGMA GROOVE

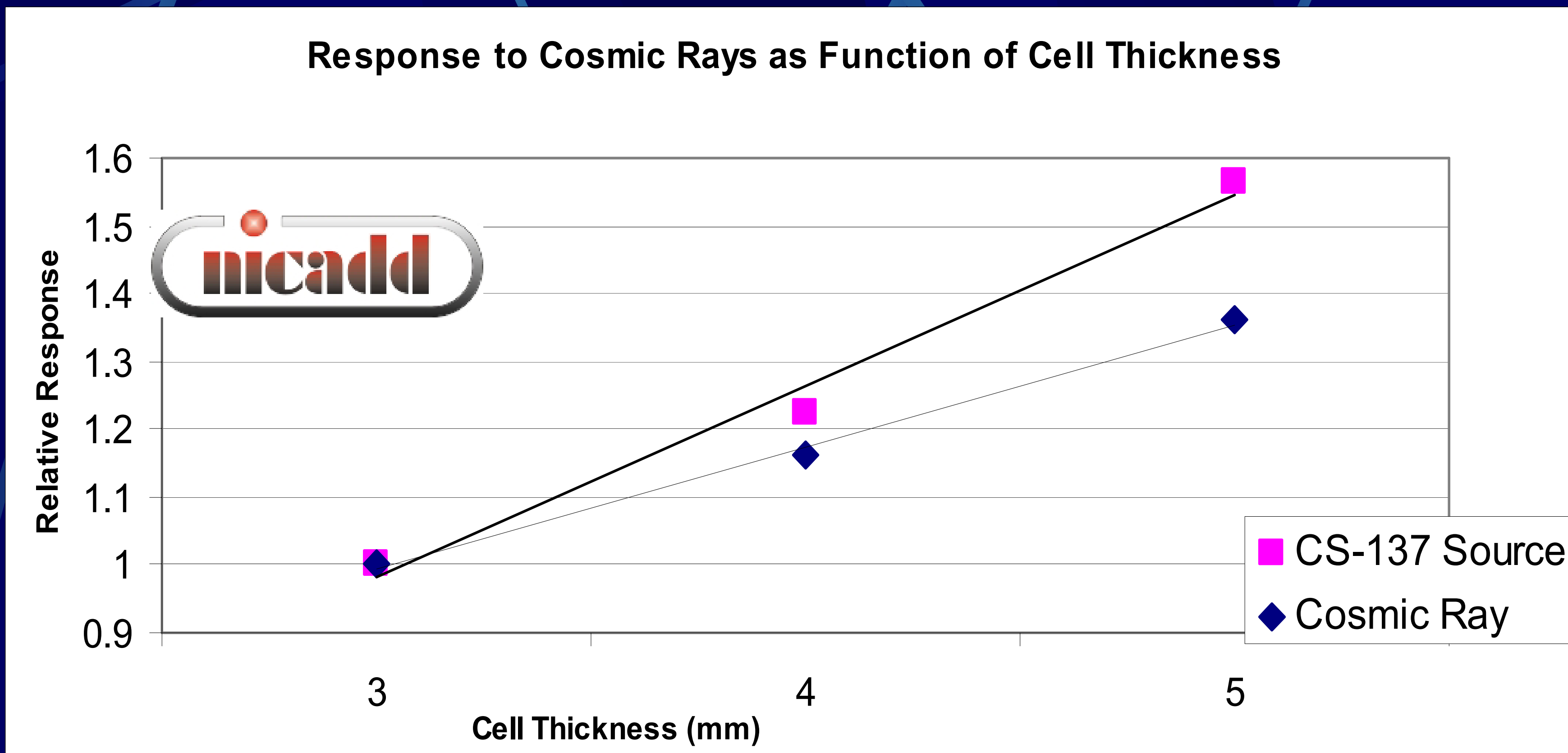




- A schematic of the square cell (top) and hexagonally shaped cell with WLS fiber embedded and glued inside the tapered sigma groove. Dashed line represents the scan direction.

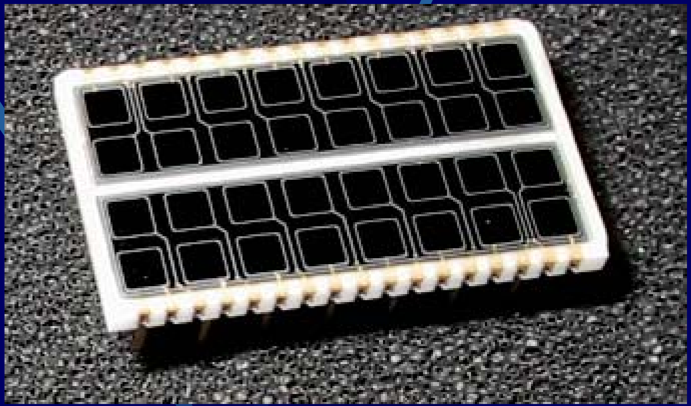


Comparing Cosmic Ray to Cs-137 Responses

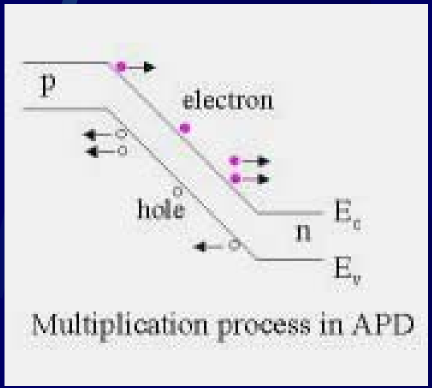


APD

- Avalanche Photo Diode (APD) is a solid-state Silicon-based photodetector that utilizes the avalanche effect for the amplification of the signal.



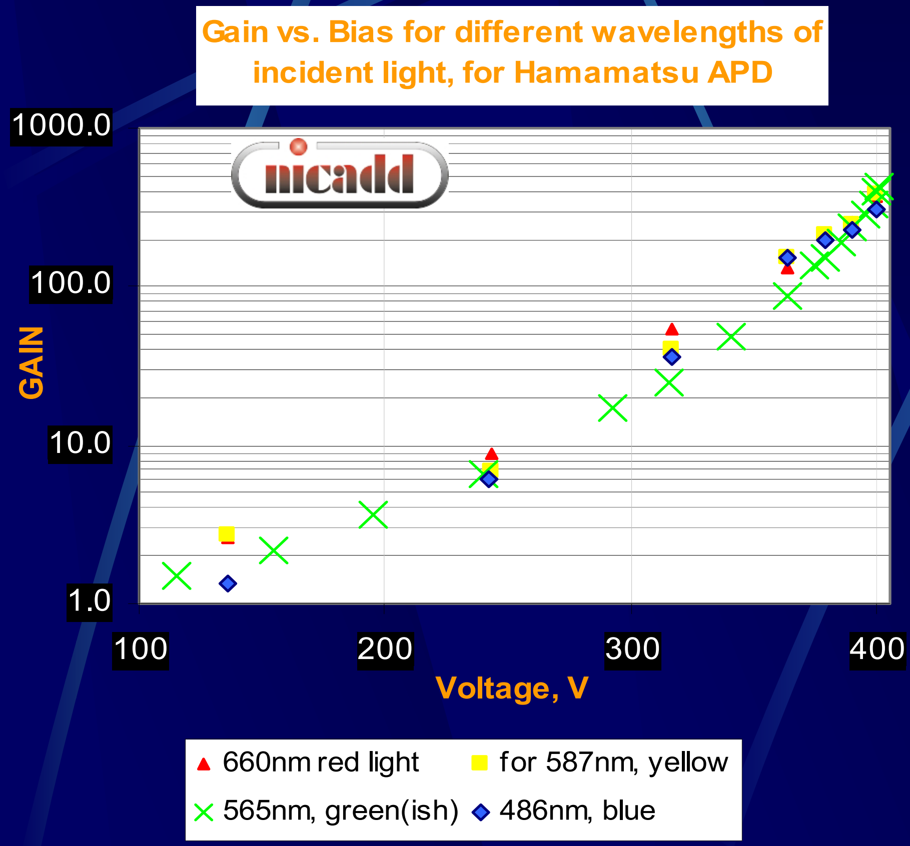
HAMAMATSU [1] S8550 Si APD, 32 channel matrix.



[5]

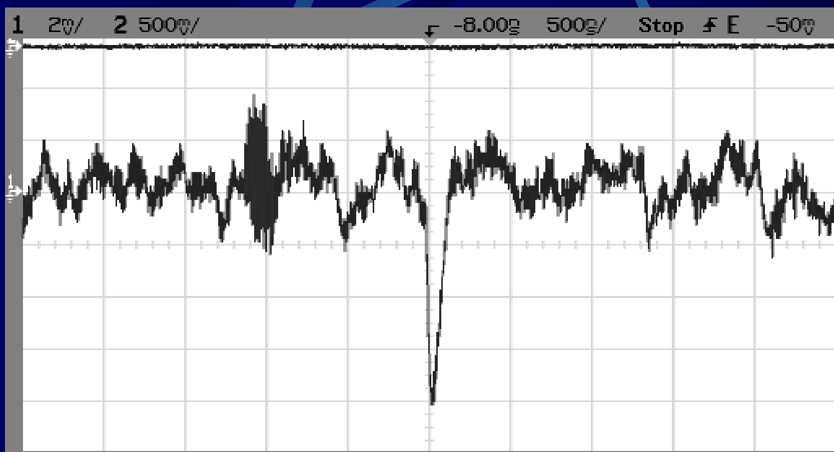
Amplification is achieved by impact ionization. A primary electron/hole produced by an incident photon, is accelerated by applied voltage and creates many secondary electrons and holes, contributing to the photodiode current – creating an avalanche.

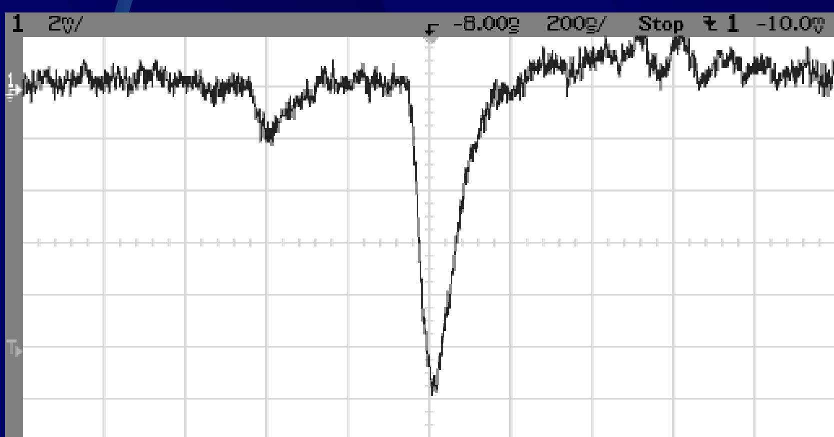
APD



- APDs combine high quantum efficiency, on average, of 85% at 500nm, with gain (amplification) of 200-350.
- Advantages: lower then PMT operational voltage, miniature sizes, effective, virtually nonexistent cross talk between matrix channels. By lowering ambient temperature, one can drastically improve performance and boost signal-to-noise ratio. Also gain can be increased this way.
- Known problems are higher dark current (noise) then in vacuum-tube based PMT. Also lower gain.

APD



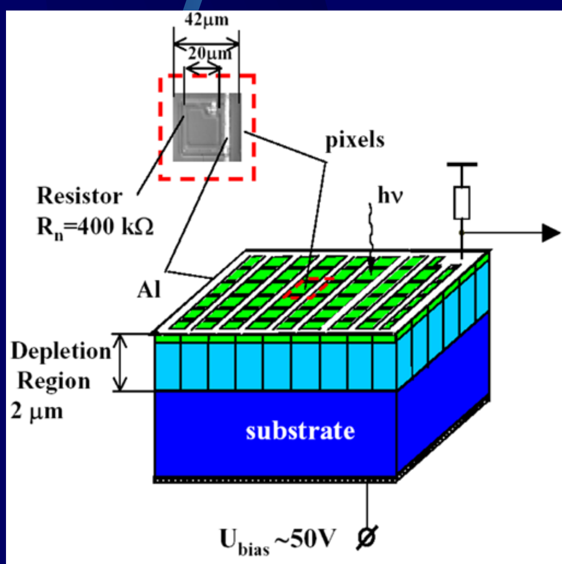


- MIP signal from a cosmic ray event, obtained from a 5 mm thick scintillating cell with APD S8550, bias voltage of 393 V. Signal amplitude here is ~8 mV with noise of ~2 mV; signal width is ~100 nsec. CMS [2] preamplifier was used.
- Signal using Sc90, same cell and bias as above . Smaller peak (~2 mV) possibly corresponds to a single e^- detection, larger one (~12 mV) – to the simultaneous detection of several e^-.

SiPM and MRS

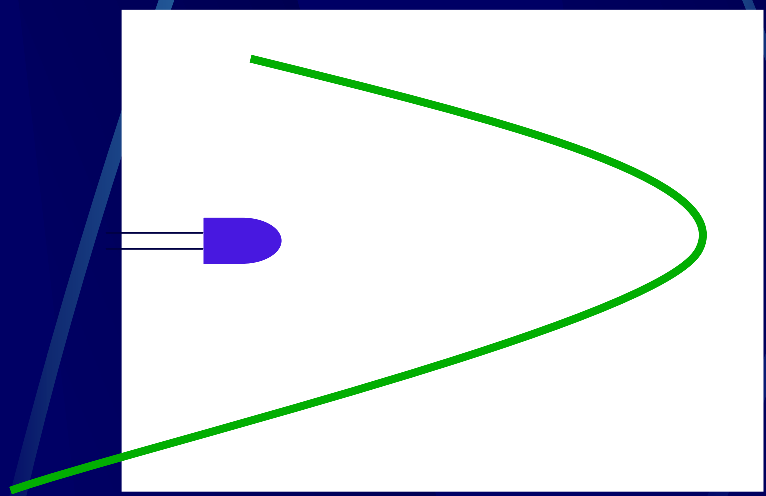
Silicon Photomultiplier [3] (SiPM - left) and Metal/Resistive layer/Silicon photodiode [6] (MRS - right) are the multi-pixel solid-state devices, in which every pixel functions in Geiger counter mode (from different Russian vendors).

Main features of these devices are high gain (up to 10^6 times) and ~15% QE at 500nm, similar to vacuum PMT, small size (active area of ~1mm^2) and low bias voltage of about 50-60 volts, which is favored over bias of ~400V in case of APD and ~1200V in PMT case.



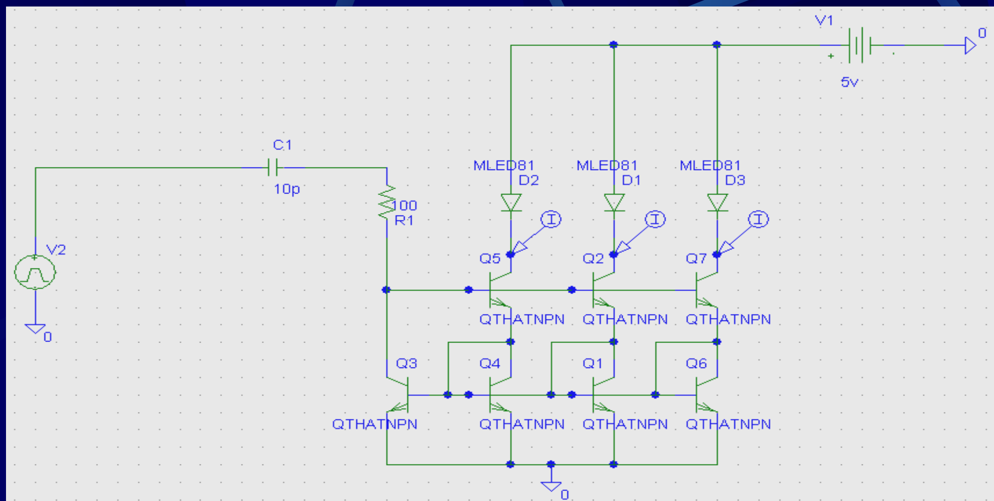
SiPM schematics [3].

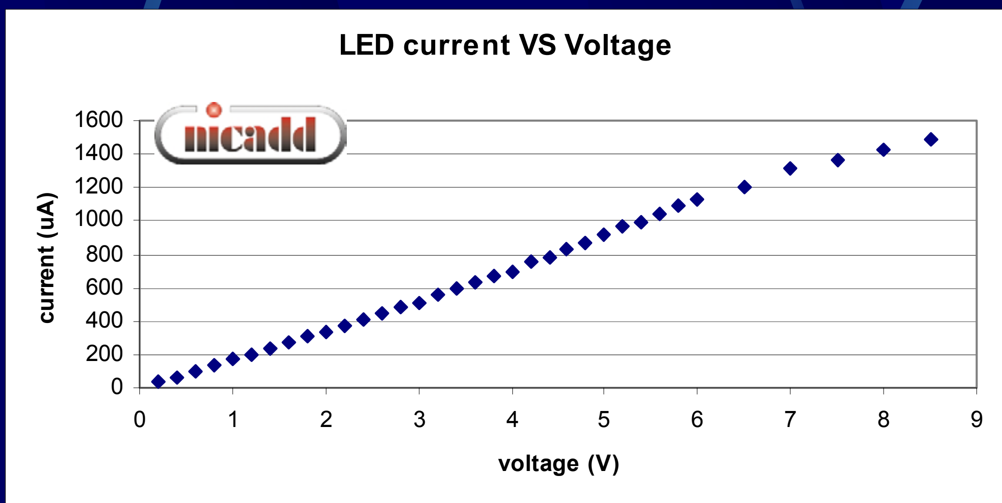
LED Measurements



- Blue LED (468nm) was used to excite the WLS fiber in order to reproduce light output as close to the output of the scintillating cell as possible. Note that no blue light reaches the photodetector.

LED driver

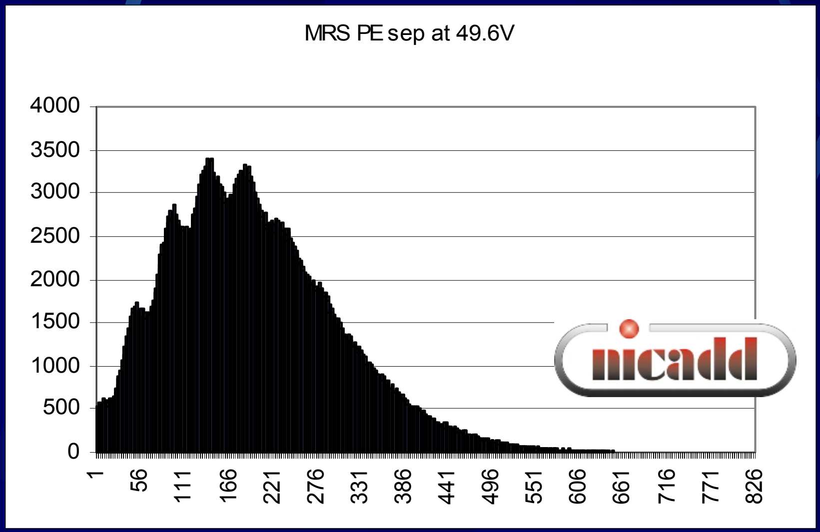


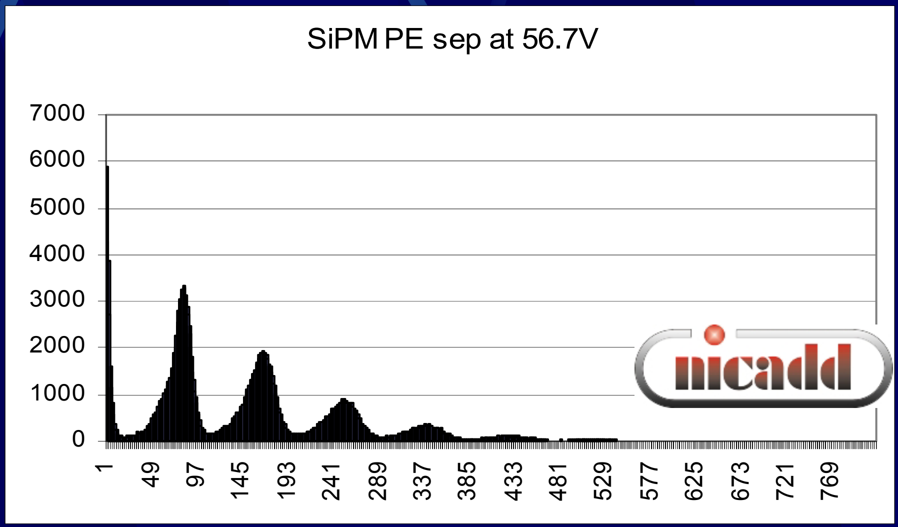


- The output pulse is controlled by the generator
- Multiple LEDs connected
- Current is kept constant on all LEDs
- Linear voltage-current-light output is achievable by this circuit

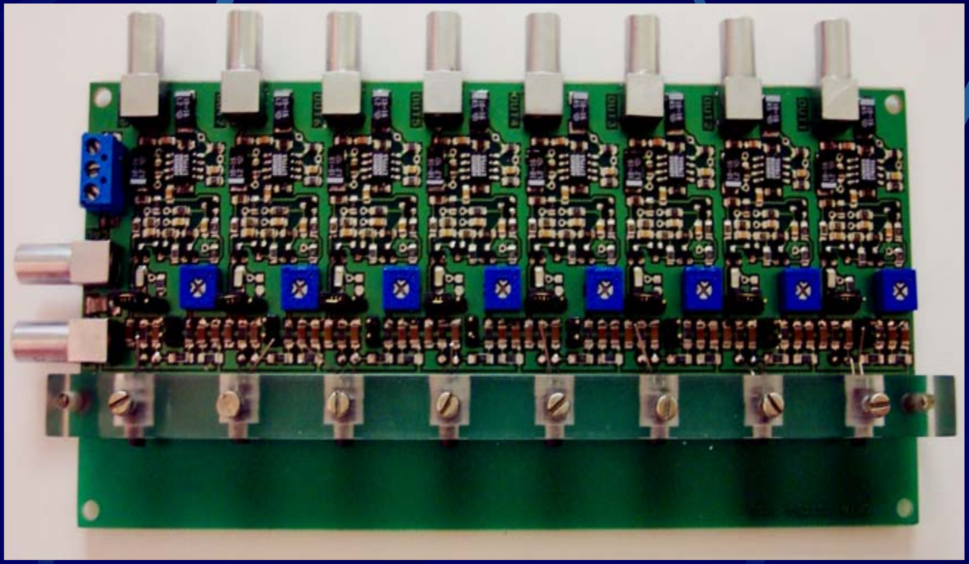
LED Measurements

- The signal of the same intensity is supplied to all devices tested (pedestal is at the 0th channel)



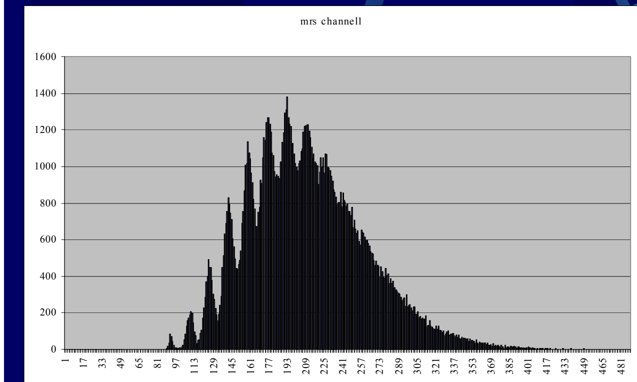


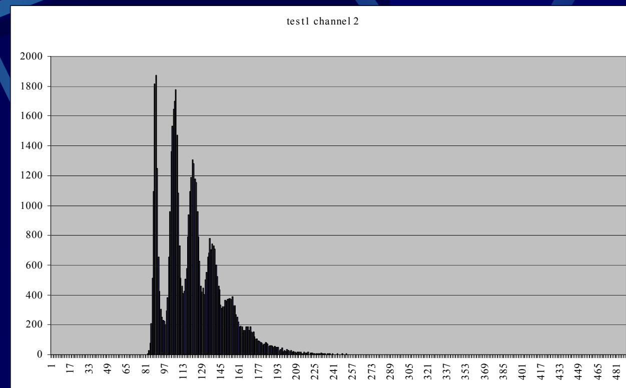
MRS RESULTS

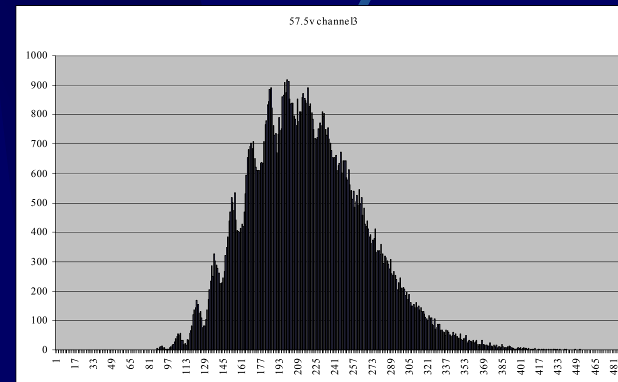


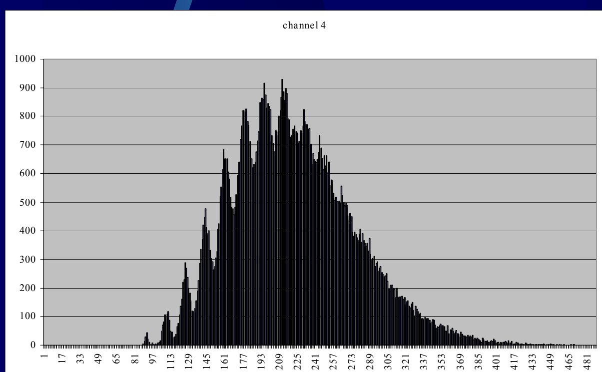
- 8 channel board from CPTA was tested
- 7 channels are operational, 8th channel's amplifier seems to be problematic
- Data was collected from all channels using LED box with the same signal supplied consequently to all channels

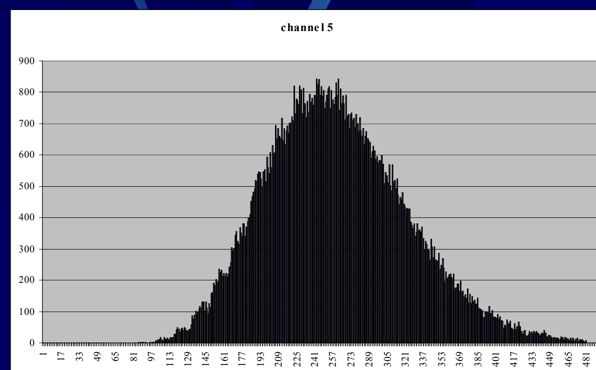
MRS RESULTS

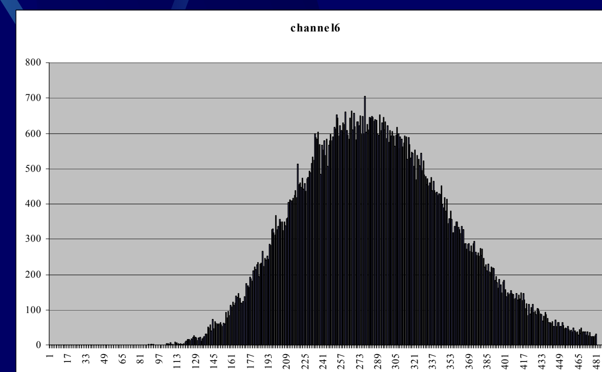


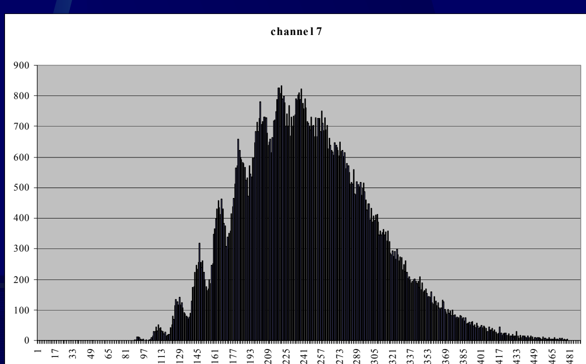






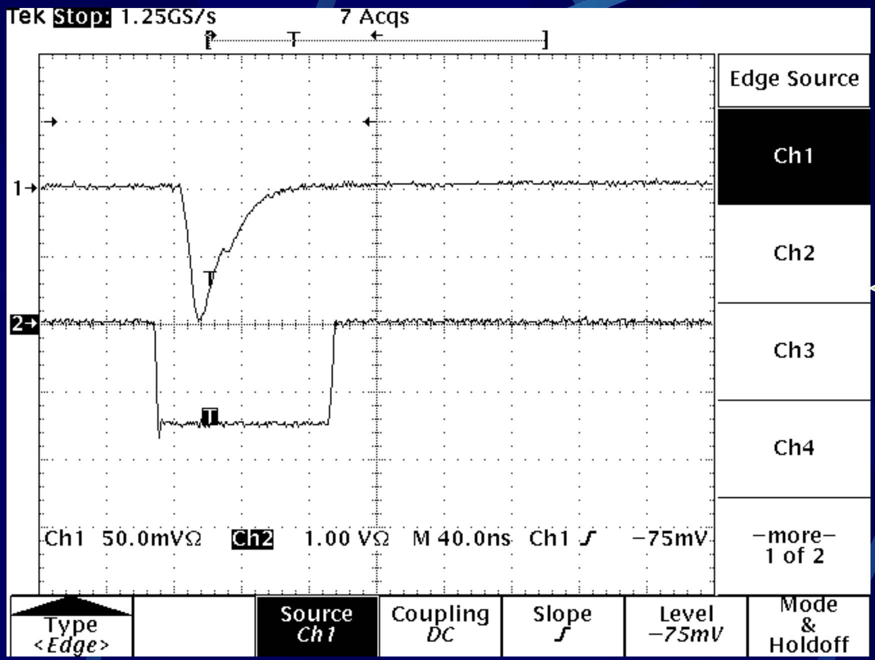






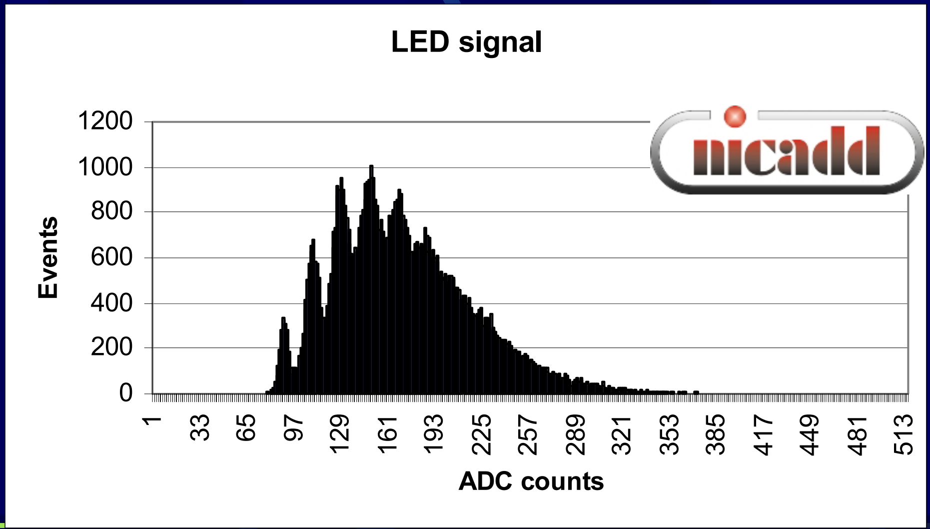
Data was taken at 57.5V supplied to the board, using signal from blue LED with WLS fiber, gate 60ns. Need working point (study is in progress).

MRS RESULTS

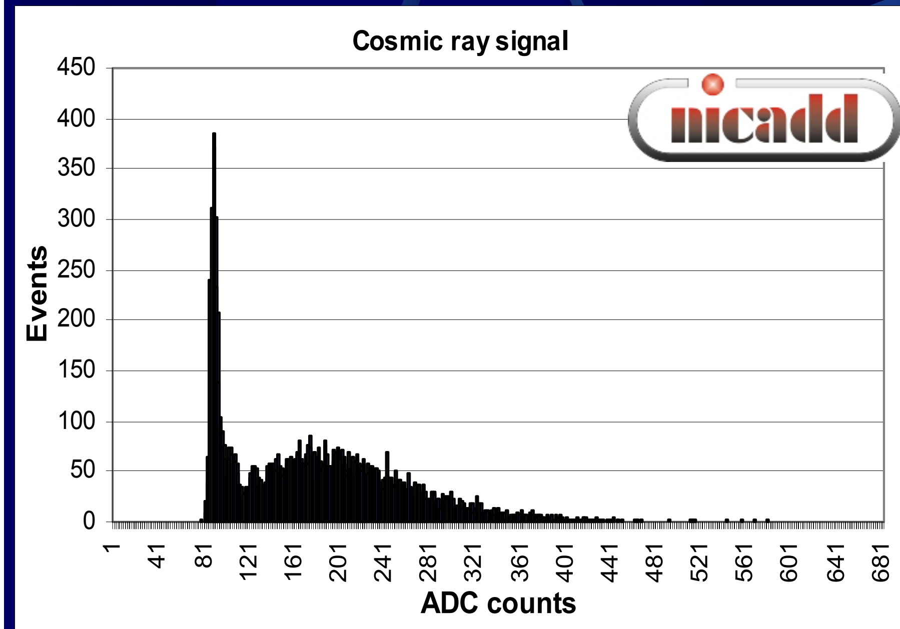


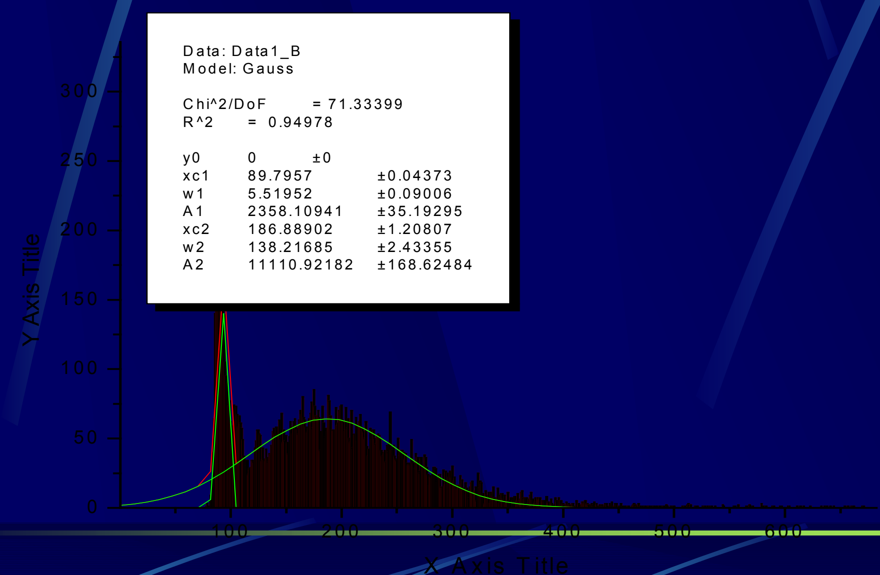
- Cosmic ray signal, using channel #4, at 50.55V, gate ~100ns

LED signal using channel #4, at 50.55V, gate ~100ns



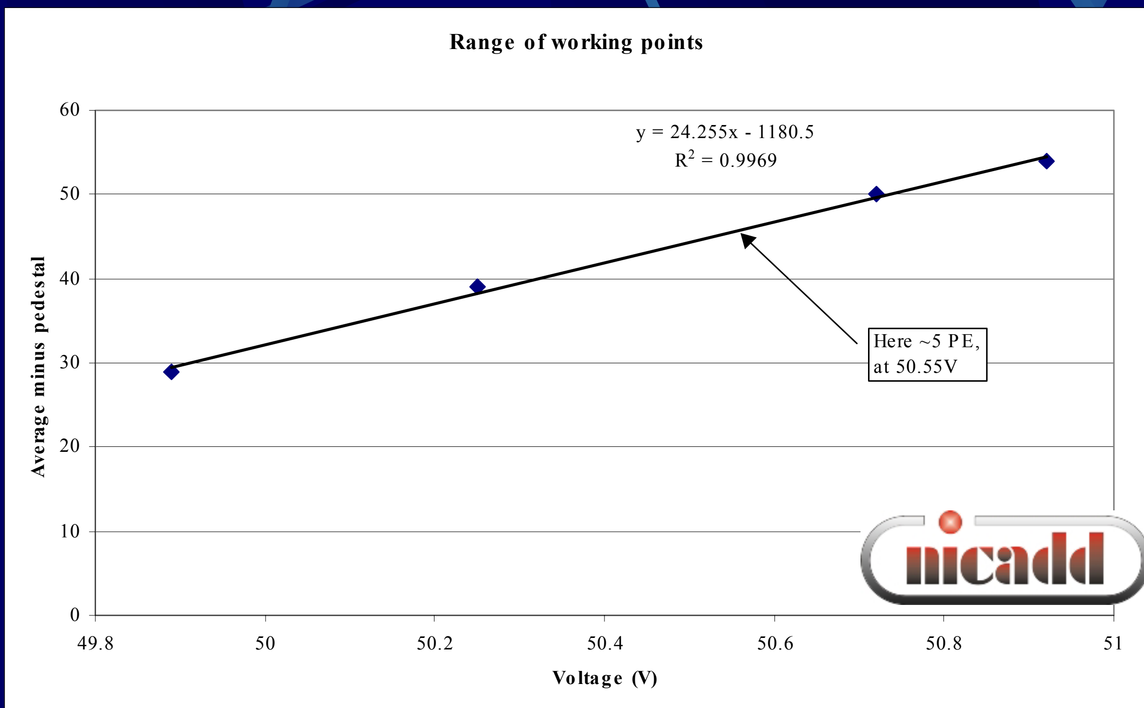
MRS RESULTS





- Cosmic ray signal at channel #4, at 50.55V, gate ~100ns, used square, 5mm thick, cell with Kuraray [4] Y-11 round 0.94mm WLS fiber, extruded scintillator, straight hole. Double-coincidence trigger used. Get ~5 PE.

MRS RESULTS



- All points in this graph, which are the position of the average of signal minus pedestal vs. bias voltage applied, lie in linear response range of the MRS.

Test Stand News

- New Test Stand for Muon and Tail Catcher R&D program is functioning. All 12 channels of ADC are functioning and all 12 pedestals are acquirable. A multichannel spreadsheet program for DAQ is used, which was partially written and installed by Robert D Angstadt.

Conclusions

- Solid-state photodetectors seem to be a reasonable replacement for the PMTs for the digital systems
- Miniature sizes and relatively low bias voltage of MRS and SiPM, combined with high gain, make them an appealing choice whereas extremely low-gain and temperature sensitive APD is less appealing
- A comparative study is in progress, in order to choose between the detectors presented in this report

References

[1] HAMAMATSU CORPORATION, 360 Foothill Road, P.O.BOX 6910, Bridgewater, NJ 08807-0919, USA; 314-5, Shimokanzo, Toyooka-village, Iwata-gun, Shizuoka-ken, 438-0193 Jap1.

[2] CMS The Hadron Calorimeter Project Technical Design Report CERN/LHCC 97 CMS TDR 2, 20 June 1997.

[3] B.Dolgoshein et al, *The silicon photomultiplier and its possible applications,* Nucl.Instrum.Meth.A504:48-52,2003

[4] Kuraray America Inc., 200 Park Ave, NY 10166,USA; 3-1-6, NIHONBASHI, CHUO-KU, TOKYO 103-8254, JAPAN.

[5] Mim Lal Nakarmi, "DETECTOR" (http://www.phys.ksu.edu/~mnakarmi/detector/detector.html)

[6] M. Golovin at.al, *NEW RESULTS ON MRS APDS* Nucl.Instrum.Meth.A387:231-234,1997