First Tests of Si Nanoparticle Coatings on Hamamatsu MPPCs

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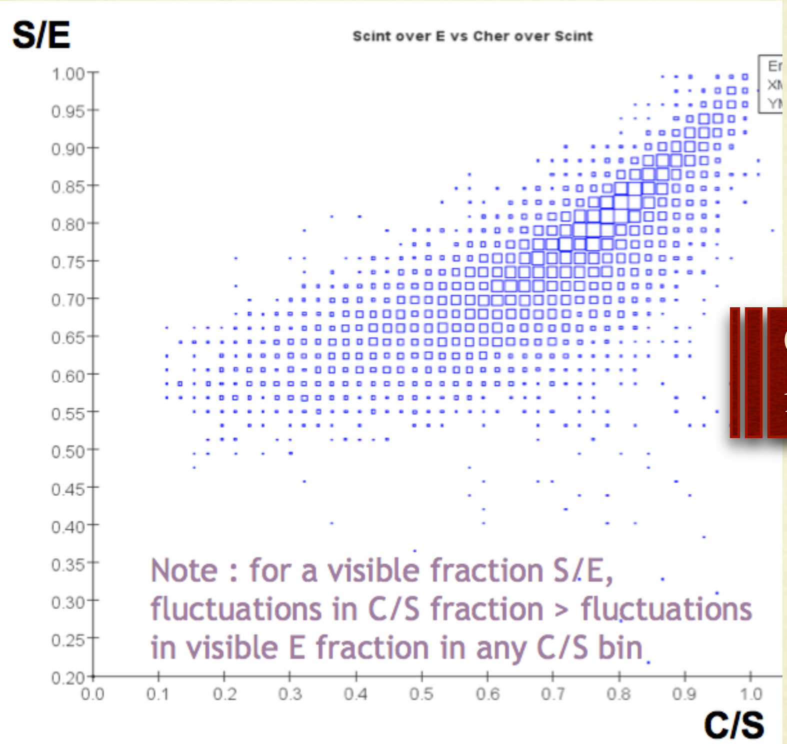
Motivation

- Need for a **thin** UV photosensor to read out Cerenkov light from a clear, dense crystal in a dual-readout homogeneous hadron calorimeter (proposed for future e+e- collider)(DOE Advanced Collider Detector R&D)
- Observation (M. Nayfeh, et al. at U of Illinois) that Si nanoparticles act as waveshifters, absorbing light in the UV range and re-emitting it as visible light
- Proposed a test of this property – measuring the response of a standard SiPM device to low wavelength light through a film coated with Si nanoparticles

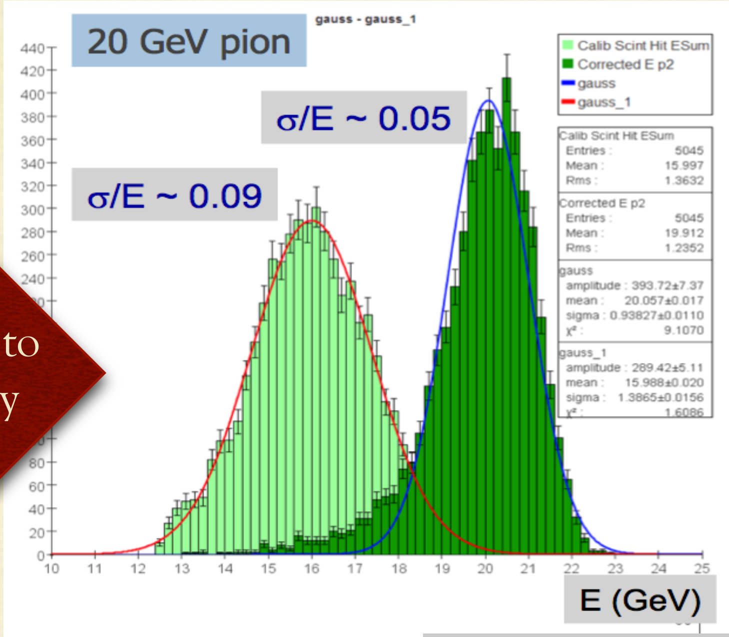
Dual-Readout Homogeneous Hadron Calorimeter R&D

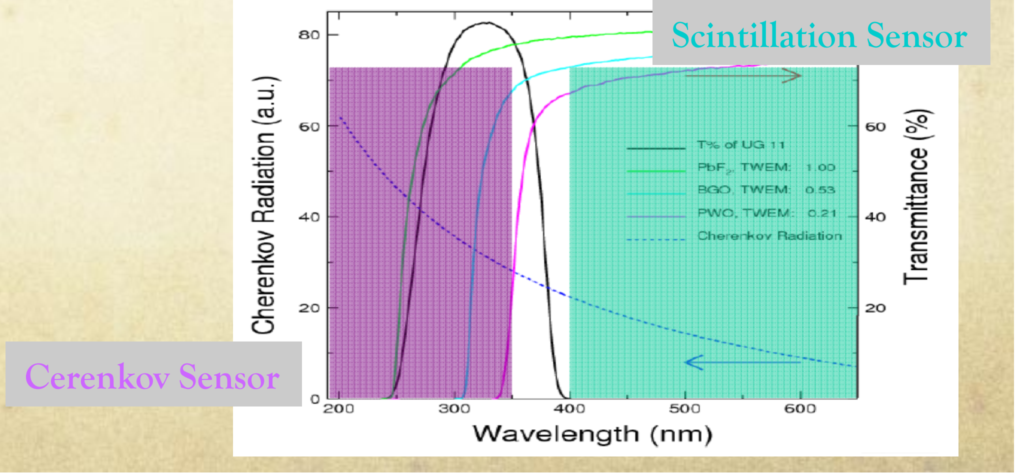


Note : for a visible fraction S/E, fluctuations in C/S fraction > fluctuations in visible E fraction in any C/S bin

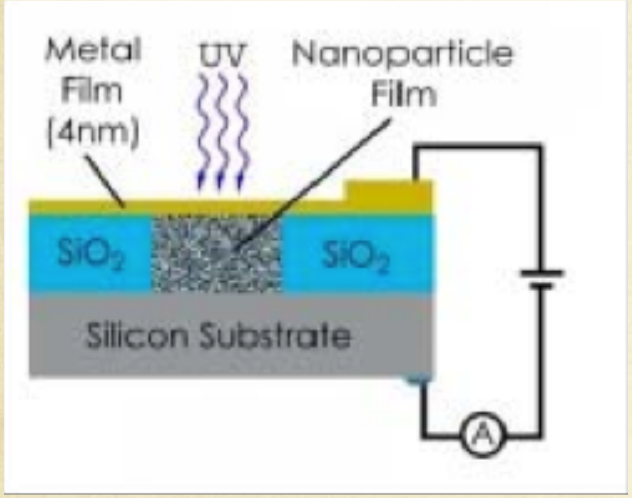
S (e calibrated scintillator response)
-> em and had visible energy
C (e calibrated cerenkov response)
-> ~em part of shower
C/S ~ em fraction of visible energy
S/E = total fraction of energy seen

C/S correction to measured energy

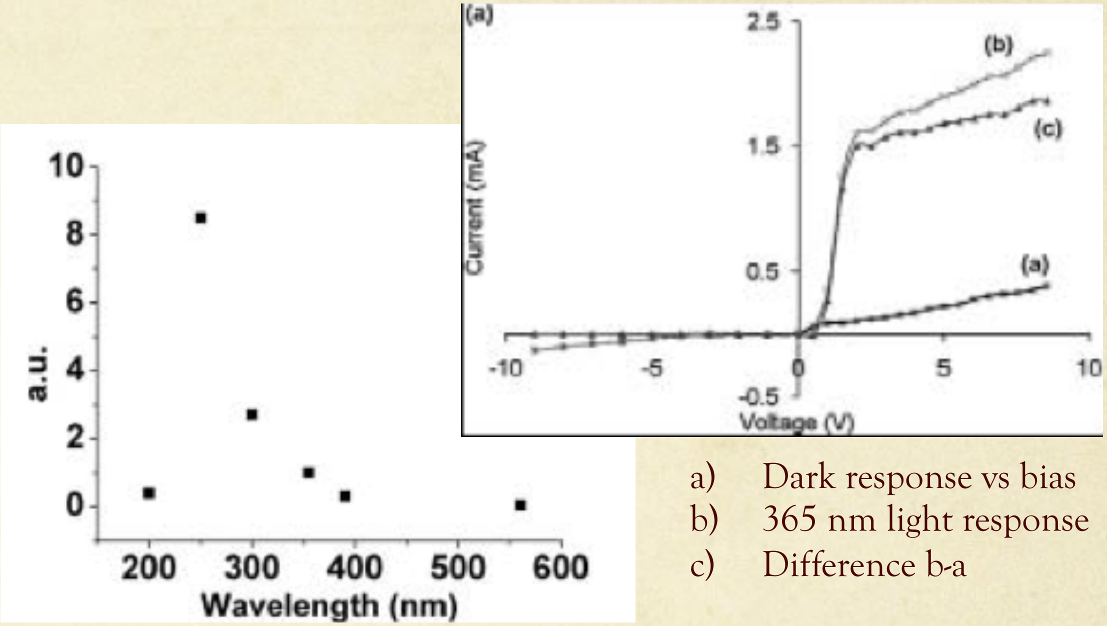




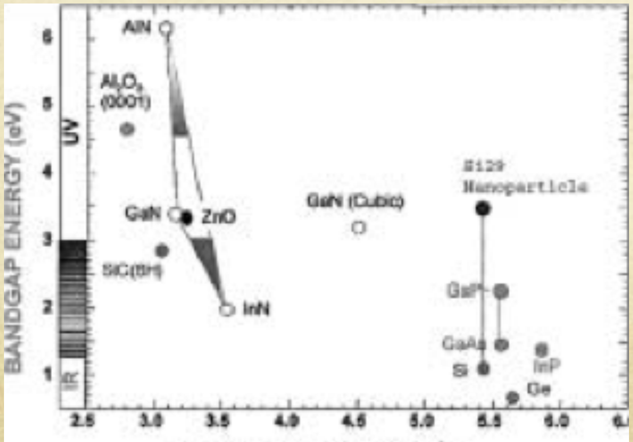
Si Nanoparticle UV Sensor



Nanoparticle photodiode



a) Dark response vs bias
b) 365 nm light response
c) Difference b-a



Normal Si has a Band Gap of 1.1 eV -> 1100 nm wavelength

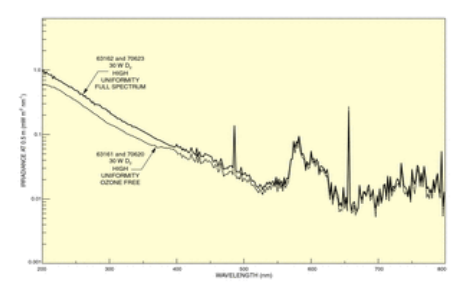
Si nanoparticles increase the Band Gap to ~3.6 eV -> 344 nm wavelength

Detected UV light shifted to
~650 nm (3 nm particles)
~450 nm (1 nm particles)

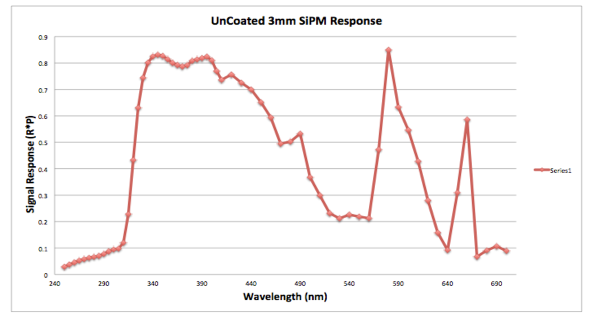
O.M. Nayfeh, et al, IEEE Photonics Technology Letters, Vol. 16, No. 8, August 2004

Test Procedure

- Used a 30 Watt D_2 lamp with wavelengths >160 nm scanned through a monochromator

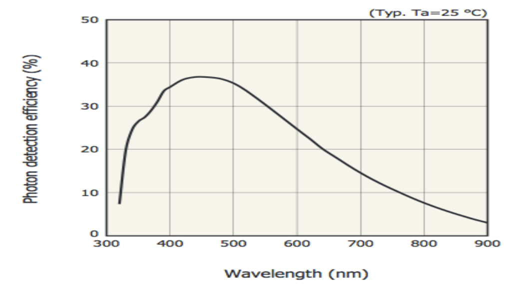


- Scanned in 5 nm intervals from 150 nm to 400 nm, 10 nm intervals from 400 nm to 700 nm

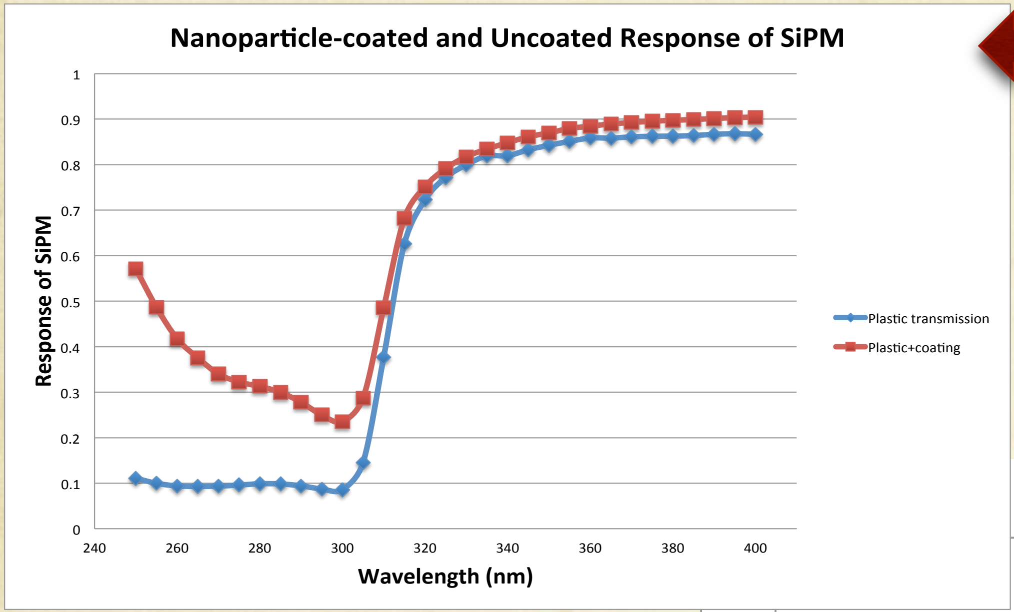


- Nanoparticles deposited on a thin plastic film positioned at the surface of the SiPM (3 mm X 3 mm Hamamatsu MPPC)

- Measured current through a resistor with SiPM in photovoltaic mode (no bias voltage) – amplification of ~ 10^6



Results



SiPM response for light through plastic film only (blue)

SiPM response for plastic + nanoparticle coating (red)

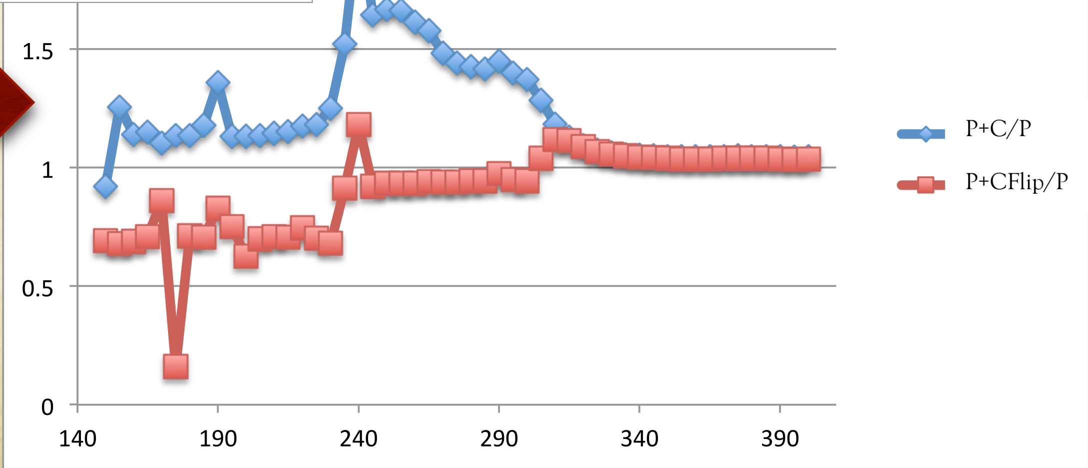
Both divided by the response for no plastic film

SiPM response for nanoparticle coating + plastic film (blue)

SiPM response reverse order (red)

Both divided by the response for plastic only

Extended to lower wavelength



Summary and Future R&D

- Si nanoparticles are able to absorb UV light and re-emit it in the visible range – extending the effective low wavelength response of a standard SiPM
- Plan to continue direct coating tests on SiPMs with controlled nanoparticle thickness and size (1 nm particles -> max emission ~450 nm)
- Will measure response vs nanoparticle coating thickness -> UV response, visible blindness?
- Plan to test a photodiode using Si nanoparticles deposited on P-type Si substrate
- Will optimize for **thinness** of photosensor with an active area of ~few cm^2