New proposed SiPM set-ups

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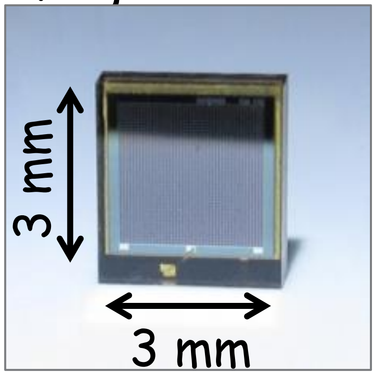
SiPMs for scintillation light detection in LAr

- A Silicon Photo-Multiplier (SiPM) is segmented in tiny Geiger Mode Avalanche Photo-Diode (GM-APD) cells (~ 50 μm) and connected in parallel trough a decoupling resistor, which is also used for quenching avalanches in the cells photodiode.

- SiPMs-based photo-detectors are insensitive to magnetic fields, thus being suitable to be deployed in a detector magnetized with ~ 1 T field.



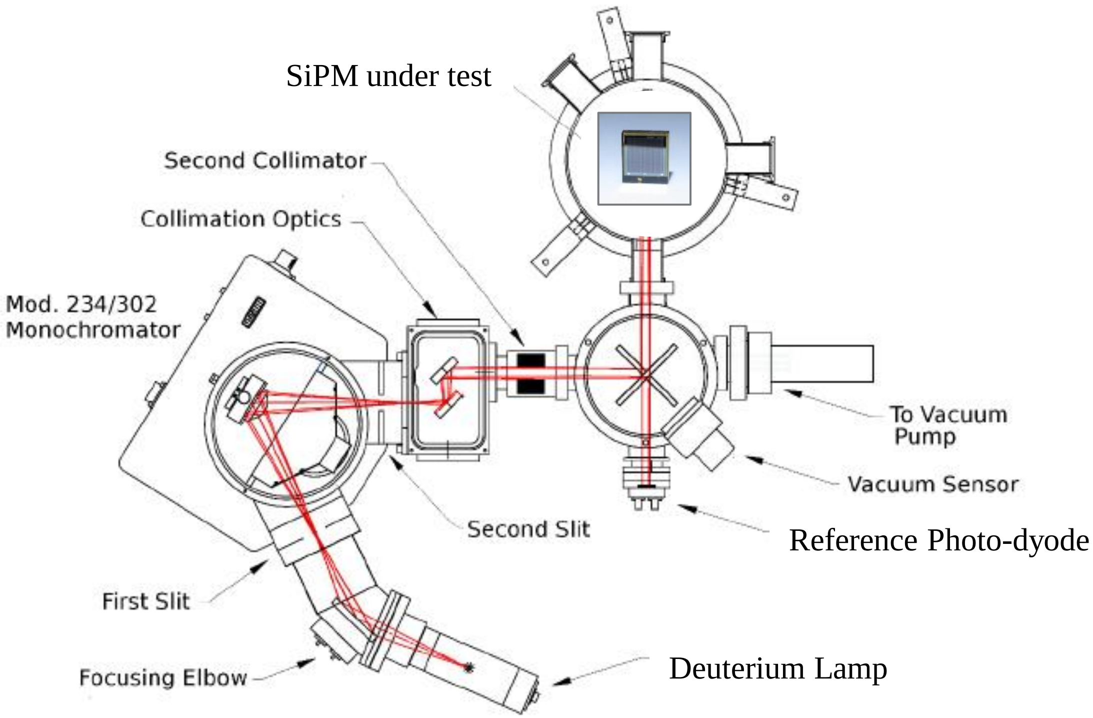
- In principle output charge is proportional to the number of of incident photons.

- PROS: noise level drops by lowering the temperature (from 200 kHz/mm^2 at room temperature to ~ Hz/mm^2 at LAr temperature).

- CONS: limited sensitive surface (1x1 mm^2, 3x3 mm^2, 6x6 mm^2 area); limited sensitivity below λ ~ 350 nm; sensitive to thermal stresses.

Preliminary tests on few SiPM devices

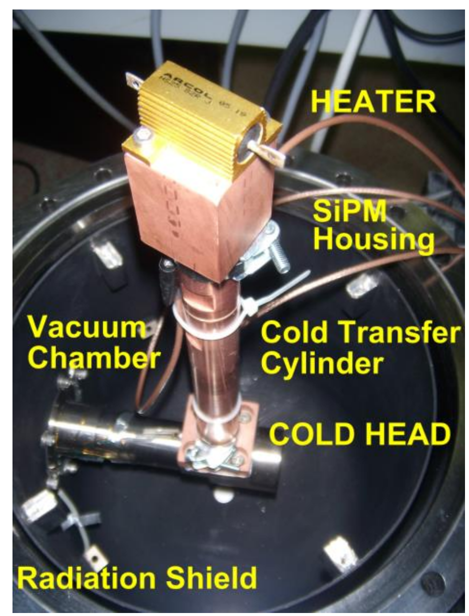
- Trends of spectral sensitivity at VUV wave-length and at room temperature have been preliminarily measured on a number of SiPM models.



Main components of the measuring apparatus:

- Deuterium lamp
- Monochromator
- Reference Photo-dyode
- Vacuum Chamber

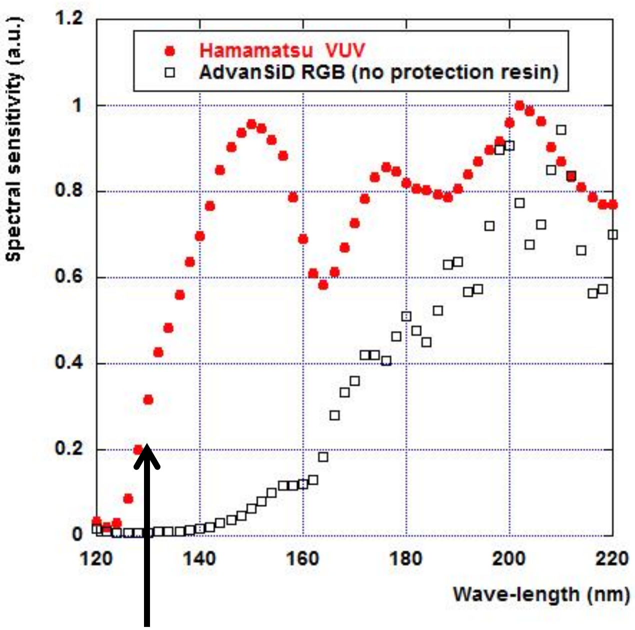
- Moreover, a cryo-pump coupled to a cold head is already available to characterize single SiPMs also at LAr temperature



Preliminary tests on few SiPM devices

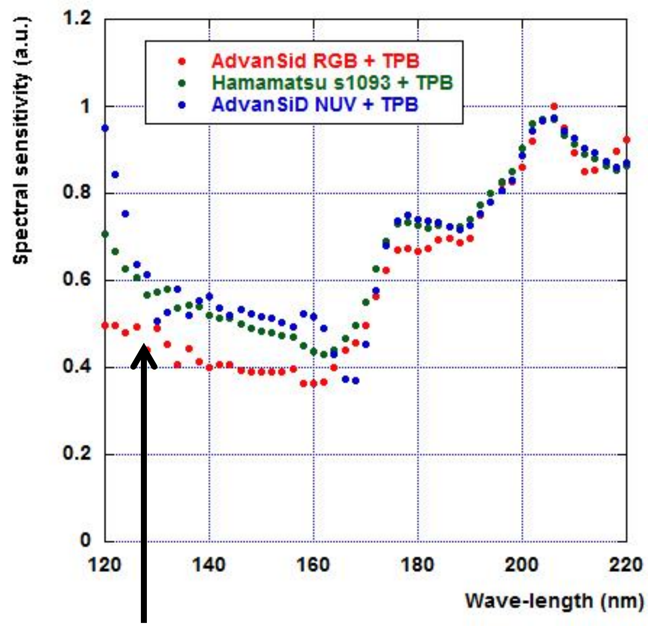
- SiPM spectral sensitivities are normalized to their on maximum: plots are just meant to give an idea of the trends. VUV SiPMs kindly provided by M. Bonesini.

Hamamatsu VUV SiPM



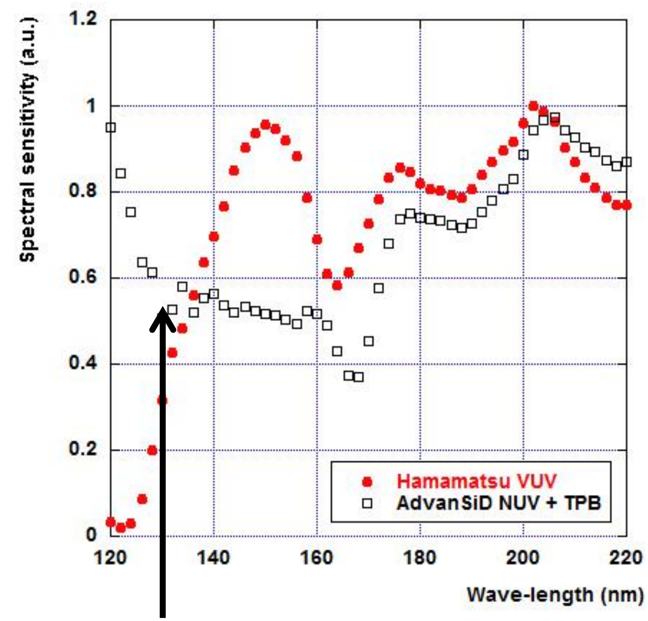
λ = 128 nm: no peak visible

NUV/RGB TPB-coated SiPMs



TPB increases sensitivity at VUV

VUV SiPM vs TPB-coated SiPM

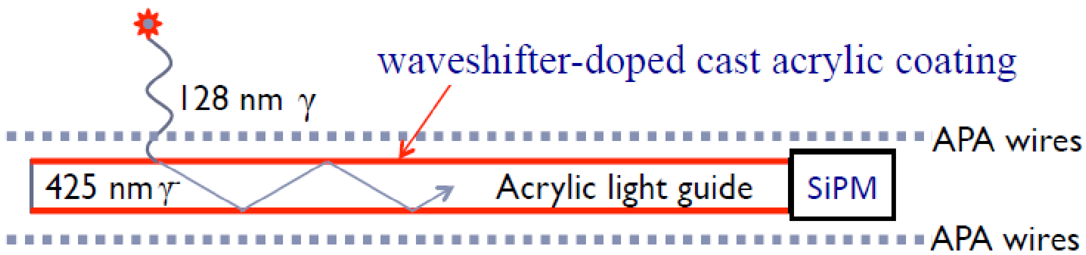


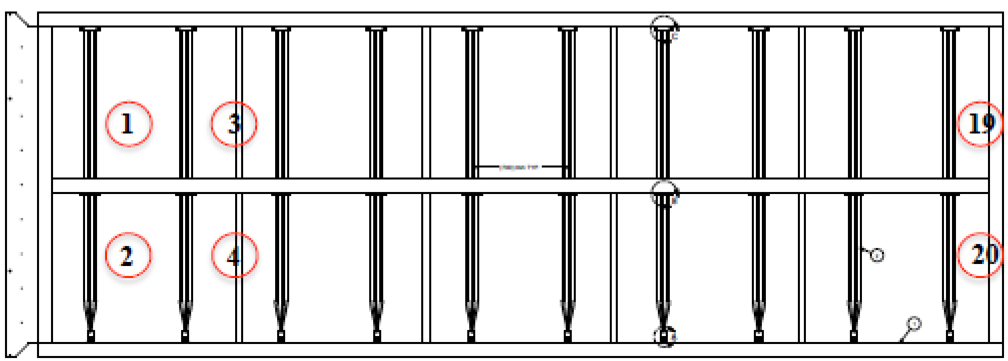
NUV with TPB coating seems better than VUV model

- The use of the TPB or of other coatings to shift the VUV light to match the spectral sensitivity of the adopted SiPMs could be an option, but it has to be carefully studied.

Some ideas for a SiPM-based photo-detection system

1) Long (~ 3 meters) light guides read at both sides by SiPMs arrays, vertically deployed with suitable step behind the ICARUS T600 wire planes, like LBNE proposes:





LBNE R&D design

- PROS: large photon collection area is available.
- CONS: it seems difficult using 3 meter long bars to localize cosmic background tracks through isotropic scintillation light.
- CONS: light auto-absorption inside the guide from TPB coating limits the photon transport → requires tests in laboratory.

Some ideas for a SiPM-based photo-detection system

2) Alternatively, small light guides (~ 10 x 10 cm^2) read at one side by SiPMs arrays, with thick photo-detection matrix, can be considered.

- PROS: good light localization is provided.
- CONS: small light signals are available: the geometrical efficiency for photon transport inside the guide is very critical.

Some ideas for a SiPM-based photo-detection system

3) SiPM-based units directly coupled to the LAr volume. As an exercise:

- 128 (3 x 3 mm^2) SiPM array
  16 x 8 SiPM slab with ~ 1100 mm^2 area (2.5 x 5 cm^2).
- Noise: some kHz, comparable to ICARUS PMTs.
- Quantum efficiency at cryo temperature ~ 10%.
- From LNGS experience a m.i.p. release about 1000 phe on a single PMT: scaled to the 128 SiPM unit hypothesis this means ~ 100 phe per unit.

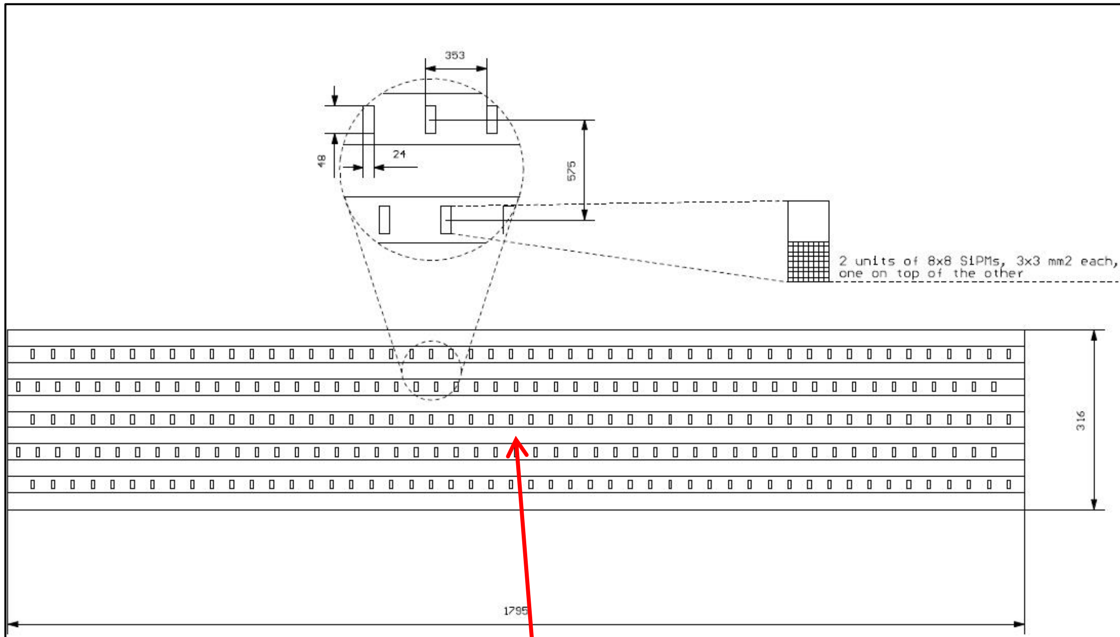
With 250 units per TPC disposed in five rows of 50 units each, the granularity of the photo-detection matrix would be ~ 40÷50 cm, with a total cost for the ICARUS T600 of ~ 1M€ + electronics costs.

- PROS: dense photo-detection matrix is available.
- PROS: light signal is comparable with usual PMT ones.

- CONS: laboratory tests are needed to check the noise level and the gain of a large array of SiPMs connected in series/parallel.

Some ideas for a SiPM-based photo-detection system

A very preliminary sketch of this last exercise:



Front view of the SiPM unit matrix

Isometric view of the photo-detection matrix with wire plane position

R&D program

- Simulation and tests on wave-length-shifted light guides coupled to SiPM arrays; study of the materials used to reflect/diffuse the converted light inside the guide is mandatory, as well as of the optical coupling between the guide and the SiPMs.

- Characterization and test of the 128 SiPM unit at room and cryogenic temperature in different configuration of connection of the single devices (series/parallel). Study of associated electronics.

- Test on the wave-length shifter deposition, either on the light guides or on the SiPMs. TPB is the standard solution, but new materials could be also studied.

- Study of algorithms for the event localization with the scintillation light. FLUKA simulations of the scintillation light produced and propagating inside the ICARUS T600 by cosmic ray tracks in several background conditions are needed.