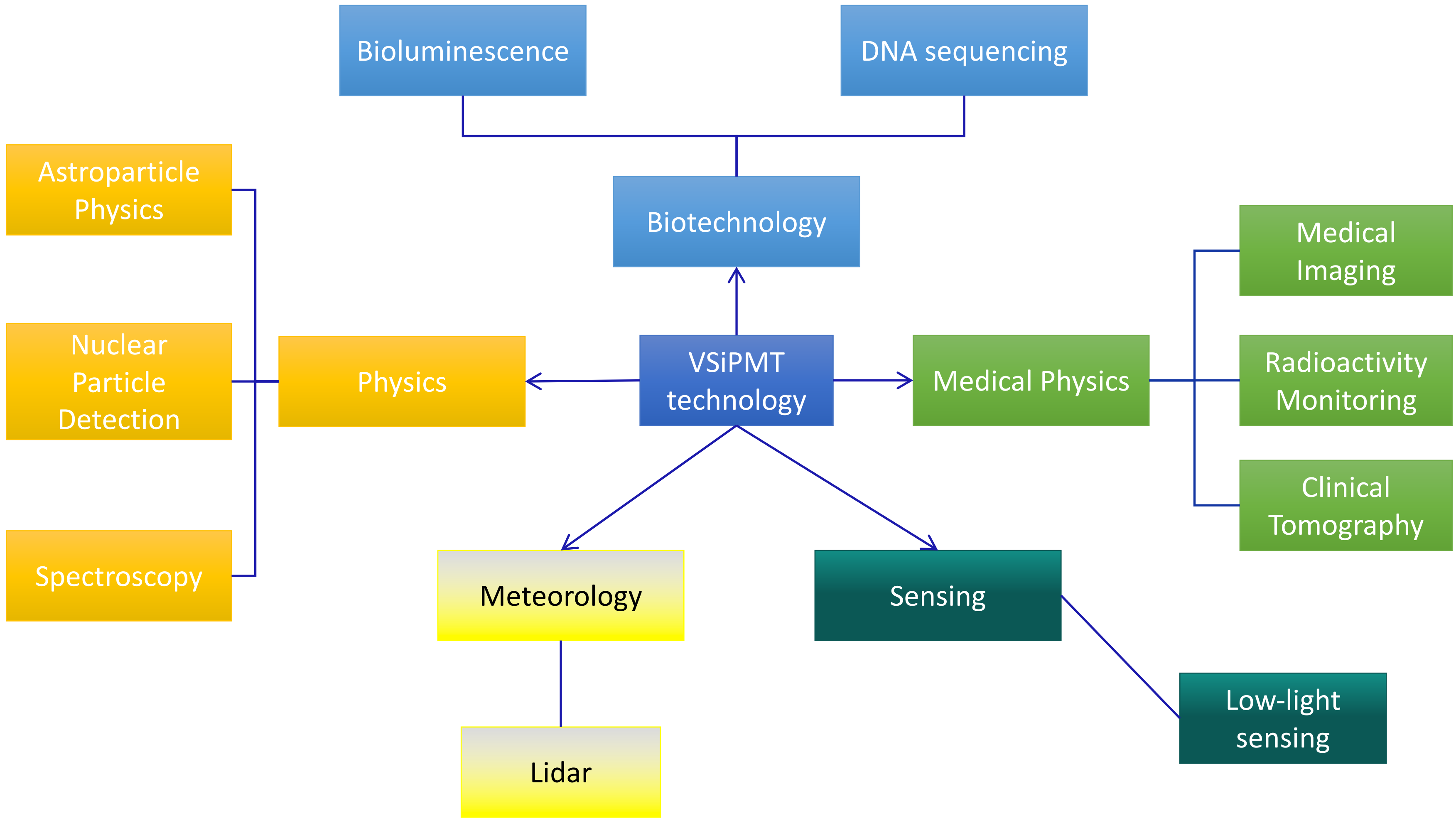
Low energy electron facility for the optimization of an innovative silicon based photodetector: the VSiPMT

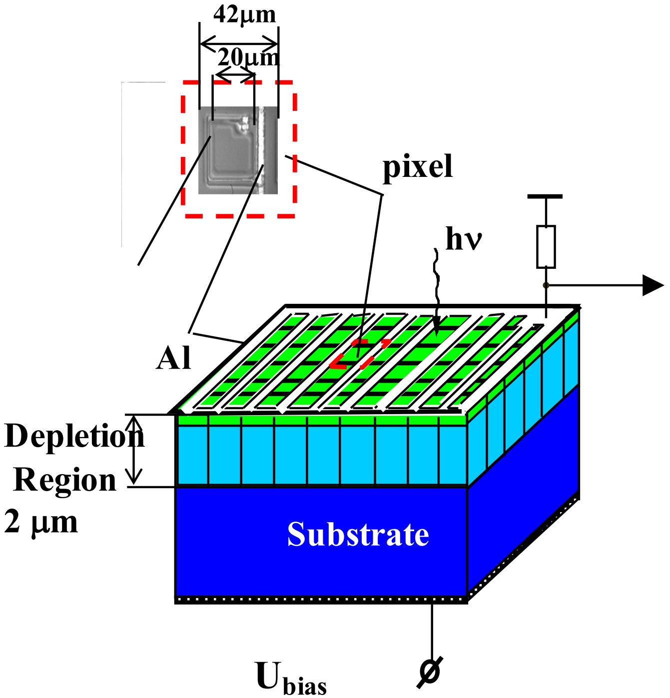
F.C.T. Barbato

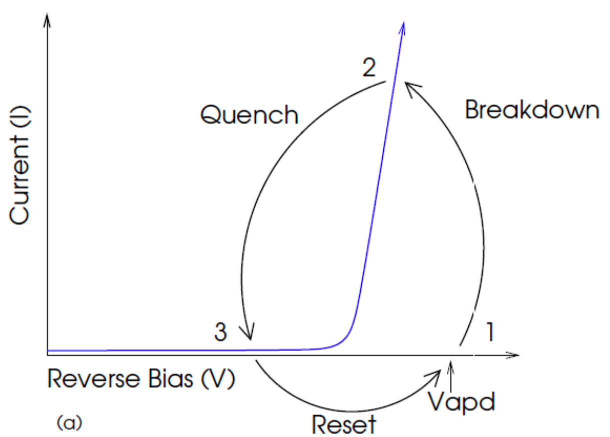
Workshop on basic research and interdisciplinary applications with small accelerators

Photon detection



SiPM





CHARACTERISTICS

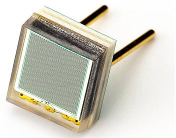
- Matrix of independent pixels arranged on a common substrate
- Each pixel operates in a self-quenching Geiger mode
- Each pixel produces a standard response independent on number of incident photons (arrived within quenching time)
- One pixel – logical signal: 0 or 1
- SiPM at whole integrates over all pixels SiPM response = number of fired pixels
- Dynamic range ~ number of pixels

The goal: using the SiPM on big surfaces

PMT PHOTOCATHODE

+

SIPM

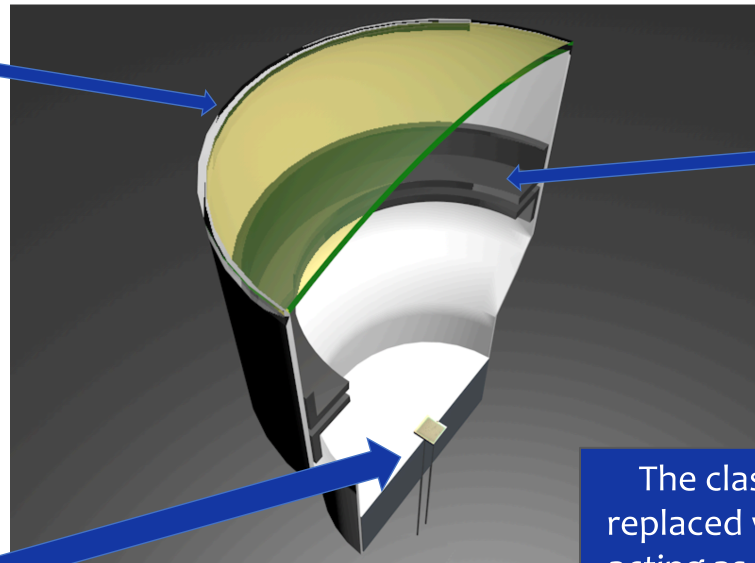


<u>VacuumSiliconPhotoMultiplierTube:</u>
an hybrid solution for a large area photodetector with excellent performances

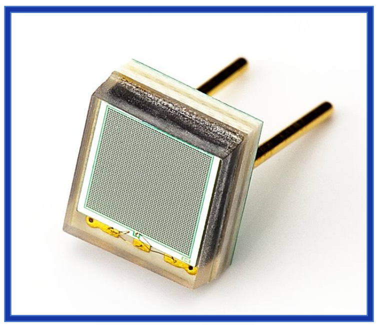
VSiPMT

Photocathode

Focusing Ring



SiEM



The classical dynode chain of a PMT is replaced with a special windowless SiPM, acting as an electron multiplying detector (SiEM).

An innovative design for a modern hybrid photodetector based on the combination of a Silicon PhotoMultiplier (SiPM) with a hemispherical vacuum glass PMT standard envelope

Advantages

The classical dynode chain of a PMT is replaced with a SiEM, acting as an electron multiplying detector.

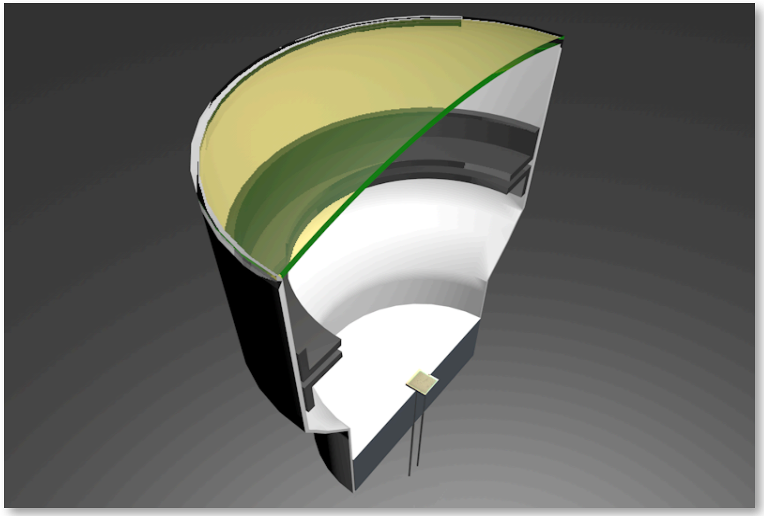
excellent photon counting

high gain (>10^6)

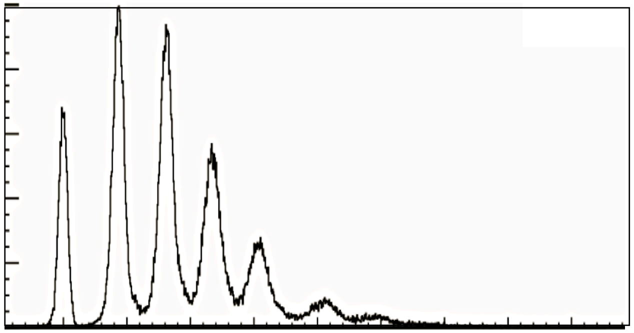
low power consumption (nW)

small TTS (<ns)

simplicity, compactness and robustness



Thanks to the digital output of the SiEM the resolution of the whole device will be improved with respect to a classical PMT



Advantages

The classical dynode chain of a PMT is replaced with a SiEM, acting as an electron multiplying detector.

- excellent photon counting
- high gain ($>10^6$)
- low power consumption (nW)
- small TTS (<ns)
- simplicity, compactness and robustness

The BIGGEST DIFFERENCE with respect to other hybrids (HPDs)

In a VSiPMT the gain is equal to that of the SiEM.

An adequate HV is necessary to confer to the photoelectrons the right energy to enter in the silicon bulk.

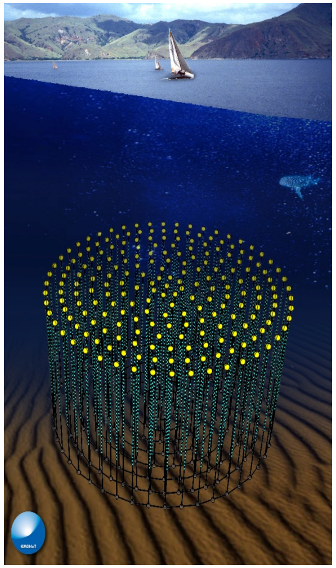
A new generation photodetector for astroparticle physics: the VSiPMT, G. Barbarino et al., DOI: 10.1016/j.astropartphys.2015.01.003

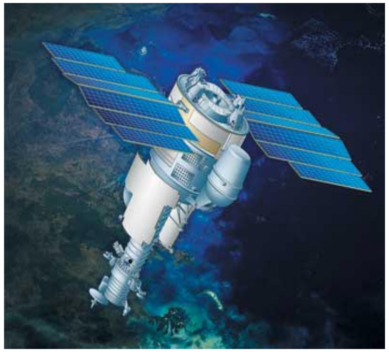
Advantages

The classical dynode chain of a PMT is replaced with a SiEM, acting as an electron multiplying detector.

- excellent photon counting
- high gain (>10^6)
- **low power consumption (nW)**
- small TTS (<ns)
- simplicity, compactness and robustness

The absence of the voltage divider leads to a much lower power consumption





GREAT DEAL for such experiments operating in hostile environments (underwater, ice, space)

Advantages

The classical dynode chain of a PMT is replaced with a SiEM, acting as an electron multiplying detector.

- excellent photon counting
- high gain ($>10^6$)
- low power consumption (nW)
- **small TTS (<ns)**
- simplicity, compactness and robustness

In the VSiPMT the TTS is simply due to the electron trajectories between the photocathode and the SiEM and so we systematically expect a lower TTS with respect to a classical PMT.

The TTS is smaller for the VSiPMT than for a standard PMT.

Advantages

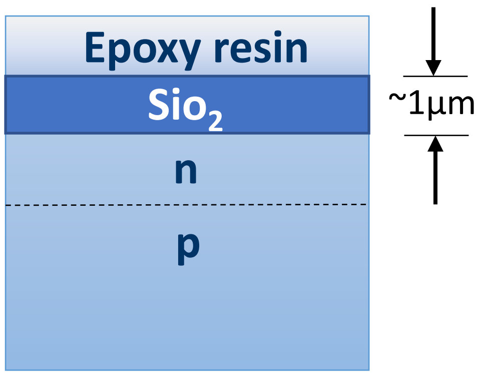
The classical dynode chain of a PMT is replaced with a SiEM, acting as an electron multiplying detector.

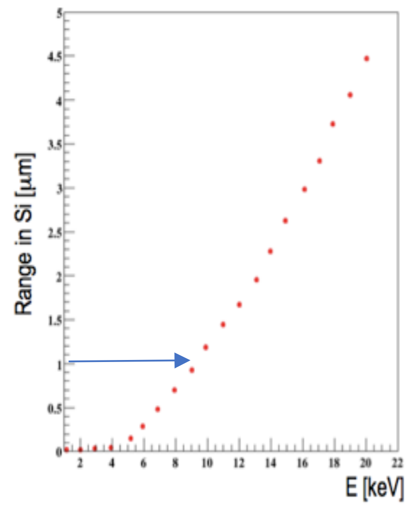
- excellent photon counting
- high gain (>10^6)
- low power consumption (nW)
- small TTS (<ns)
- simplicity, compactness and robustness

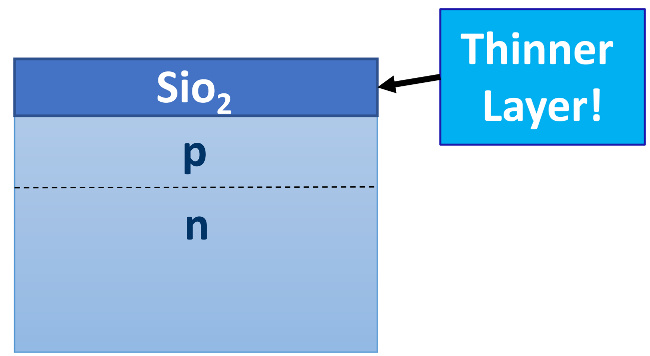
The VSiPMT is more compact and simpler having **ONLY 3 OUTPUT CONNECTIONS**: HV, SiPM bias voltage and the output signal.

SiEM

SIPM → SIEM







SiEM (Silicon Electron Multiplier) → **Special SiPM:**

- No epoxy resin
- Thinner SiO_2 layer
- P over n junction

Nuclear Instruments and Methods in Physics Research A 725 (2013) 162–165
Contents lists available at SciVerse ScienceDirect
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journal homepage: www.elsevier.com/locate/nima

VSiPMT for underwater neutrino telescopes

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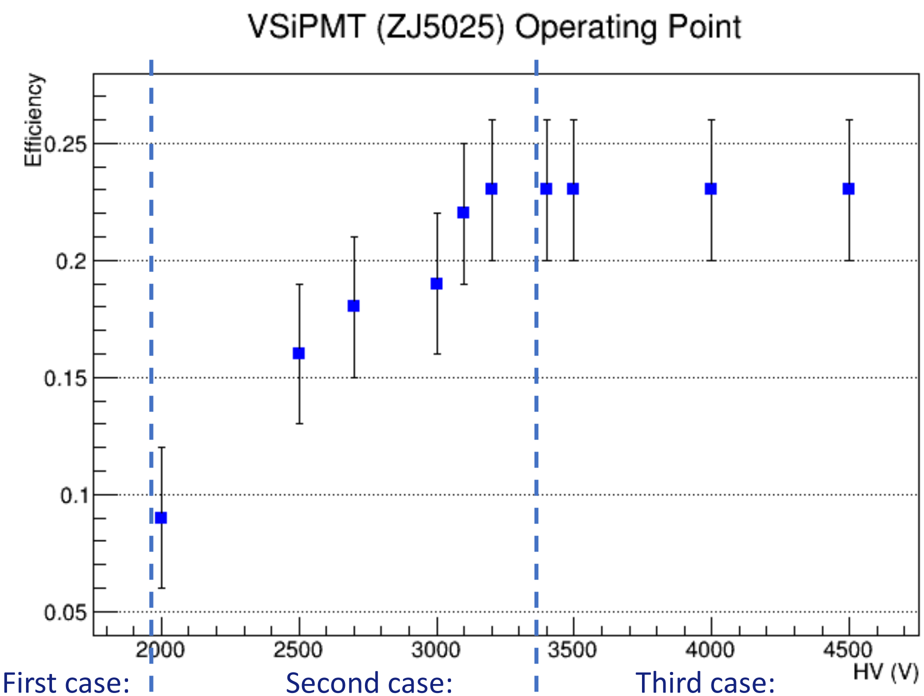
[b] Istituto Nazionale di fisica Nucleare, sezione di Napoli, Complesso di Monte S. Angelo Ed. 6, via Cintia 80126 Napoli, Italy

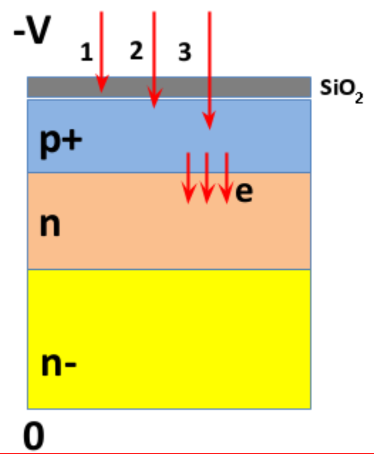
Work function



First case: $\epsilon = 0$

Second case: $\epsilon < 1$

Third case: $\epsilon = 1$



Efficiency is highly stable over 3200 V.
No need for high voltage stabilization.

ELSEVIER
Astroparticle Physics
Volume 67, July 2015, Pages 18-25

A new generation photodetector for astroparticle physics: The VSiPMT

G. Barbarino [a, b], F.C.T. Barbato [a, b], L. Campajola [b], F. Canfora [a, b], R. de Asmundis [a], G. De Rosa [a, b], F. Di Capua [b], G. Fiorillo [a, b], P. Migliozzi [a], C.M. Mollo [a], B. Rossi [a], D. Vivolo [a, b]

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https://doi.org/10.1016/j.astropartphys.2015.01.003

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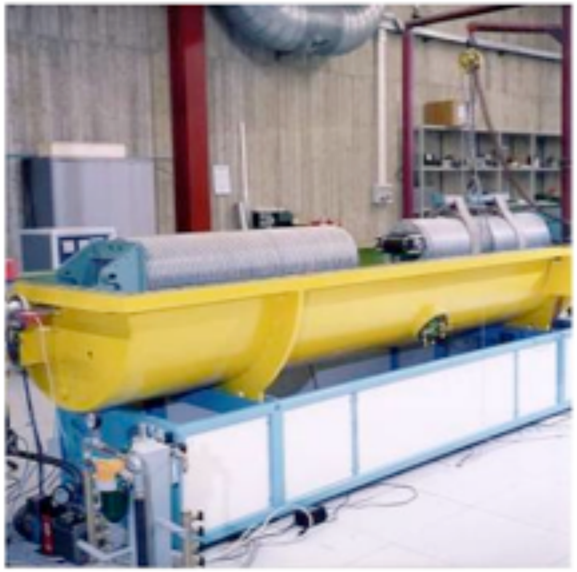
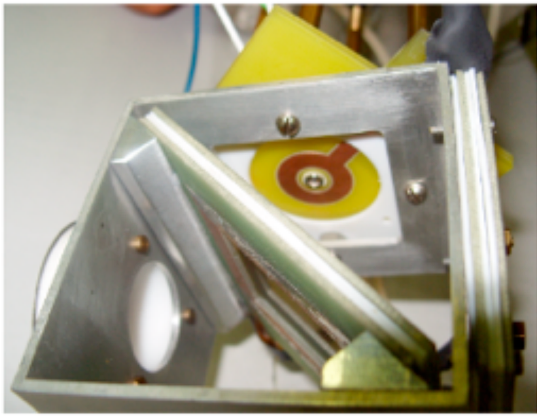
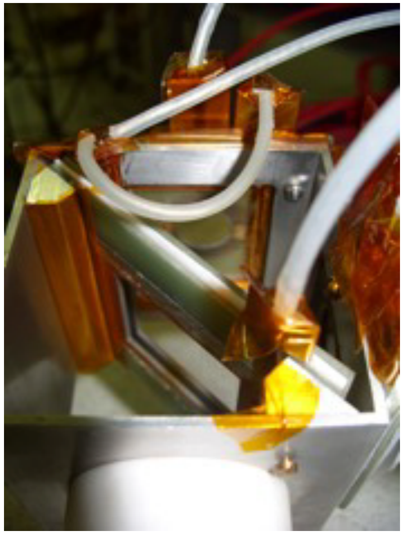
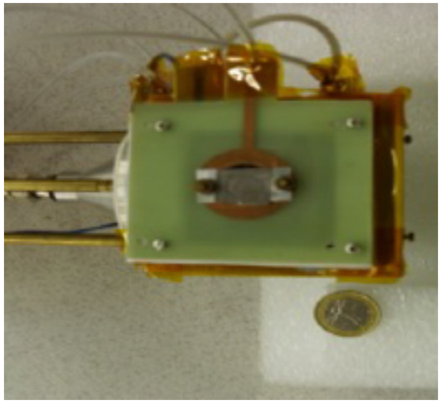


<u>SISTEMA DI ESTRAZIONE DI UN FASCIO DI ELETTRONI:</u>

- Fasci di carbonio e protoni
- Target di Carbonio di 30 µg/cm2
- Specchio elettrostatico
- MPPC S10943-8702 Hamamatsu (Serie Speciale senza resina)







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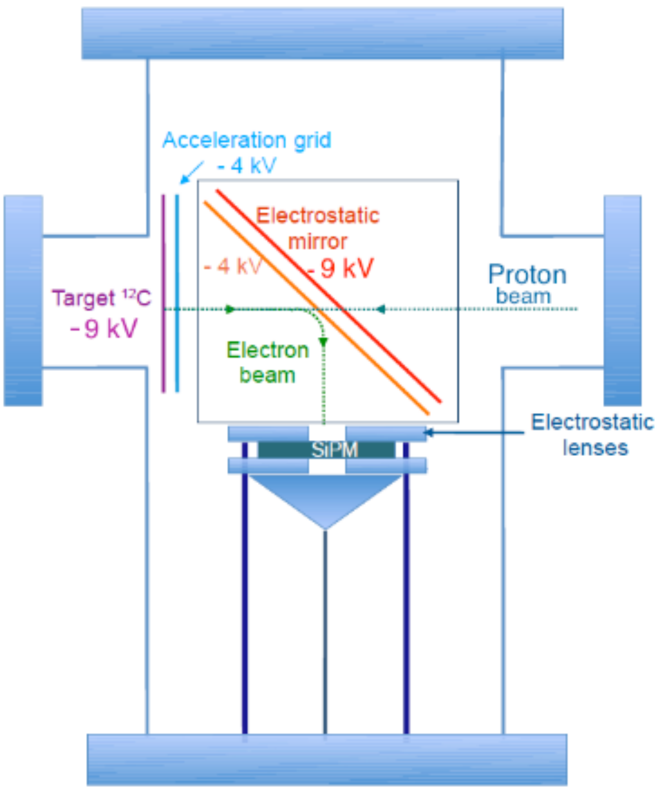
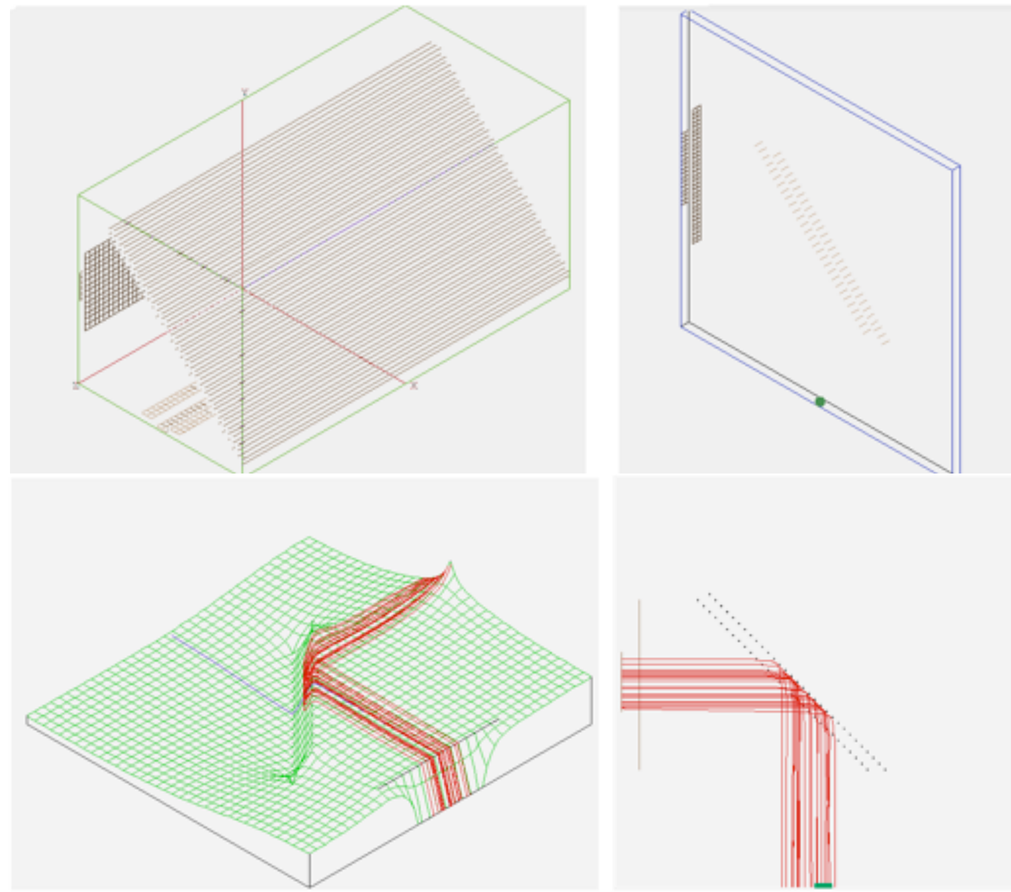
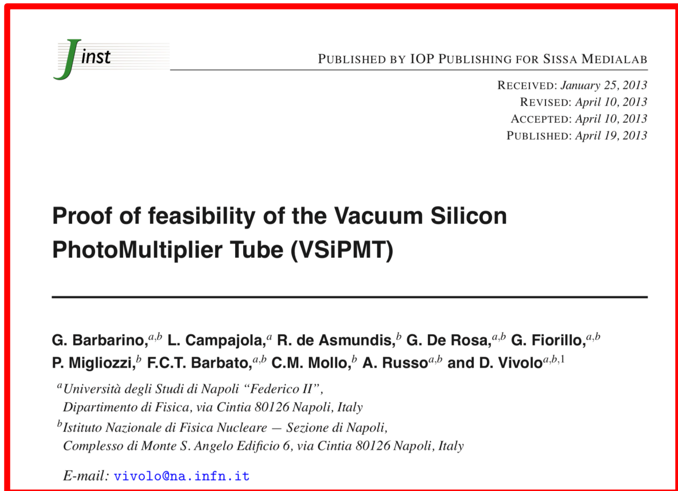


SIMULAZIONI CON SIMION 8.0



La prova di fattibilità



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Proof of feasibility of the Vacuum Silicon PhotoMultiplier Tube (VSiPMT)

G. Barbarino,[a,b] L. Campajola,[a] R. de Asmundis,[b] G. De Rosa,[a,b] G. Fiorillo,[a,b] P. Migliozzi,[b] F.C.T. Barbato,[a,b] C.M. Mollo,[b] A. Russo[a,b] and D. Vivolo[a,b,1]

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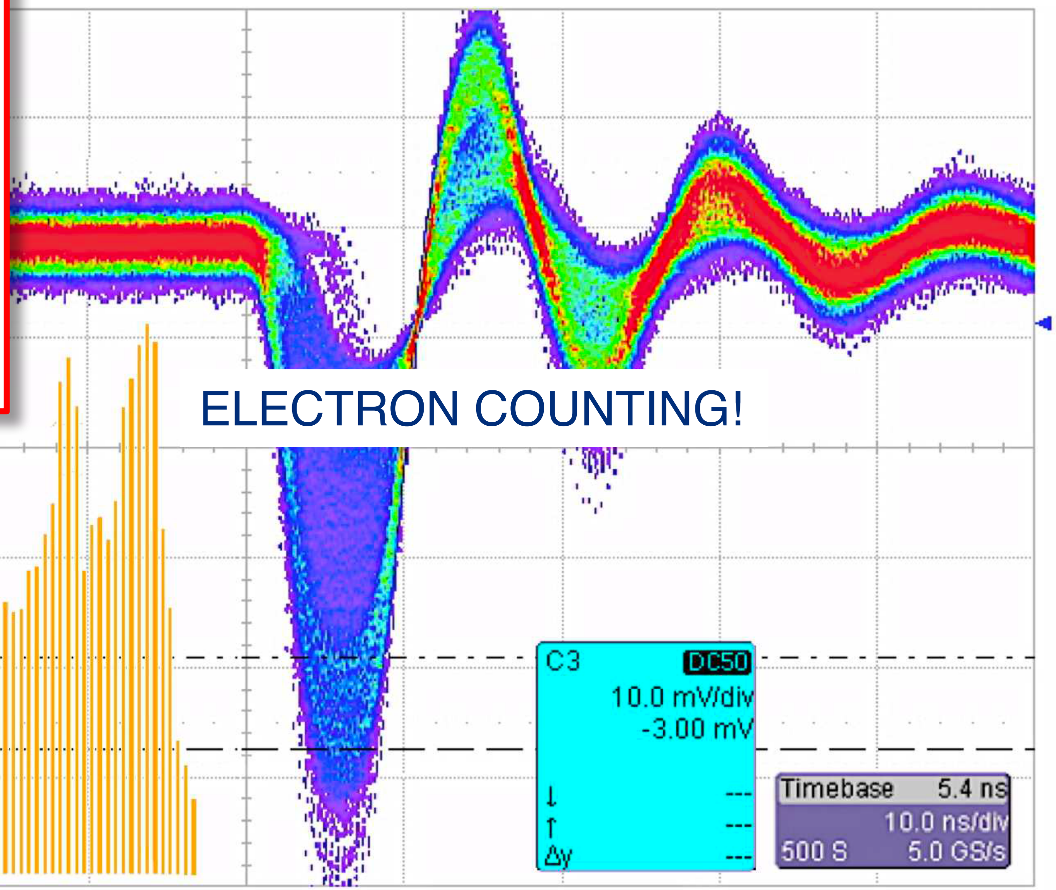
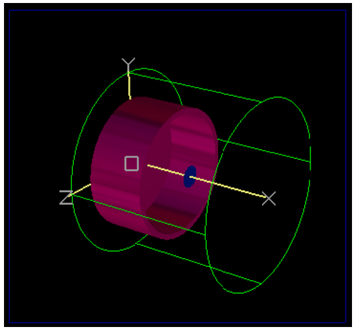
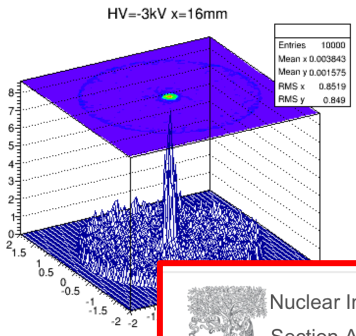
E-mail: vivolo@na.infn.it



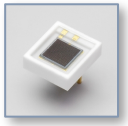
R&D

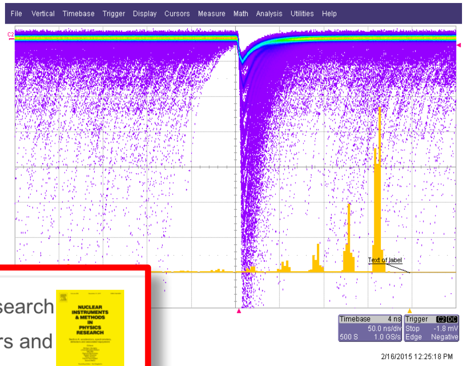
SimION 8.0 based simulations

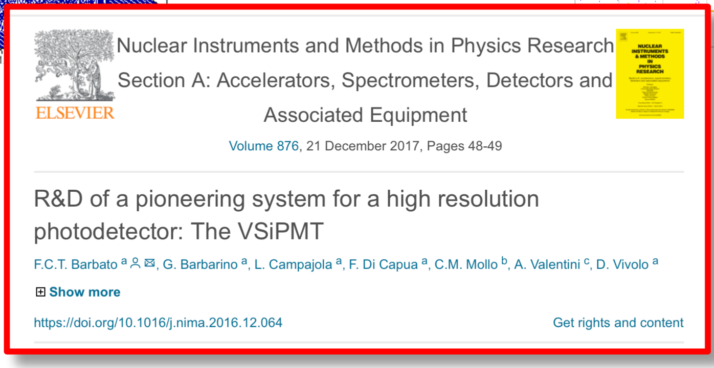




Selected SiEM






Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment

Volume 876, 21 December 2017, Pages 48-49

R&D of a pioneering system for a high resolution photodetector: The VSiPMT

F.C.T. Barbato [a], G. Barbarino [a], L. Campajola [a], F. Di Capua [a], C.M. Mollo [b], A. Valentini [c], D. Vivolo [a]

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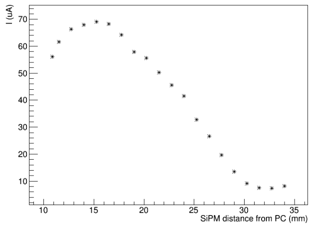
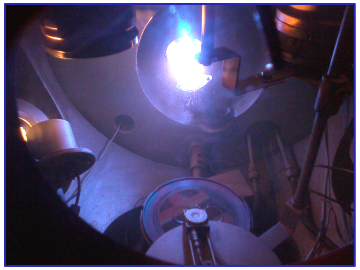
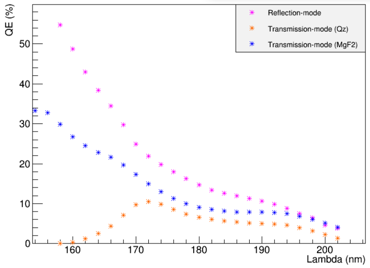
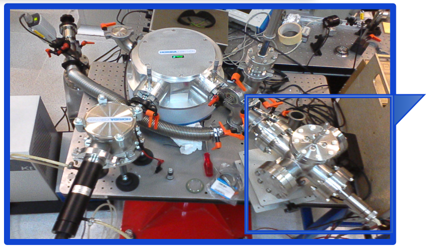




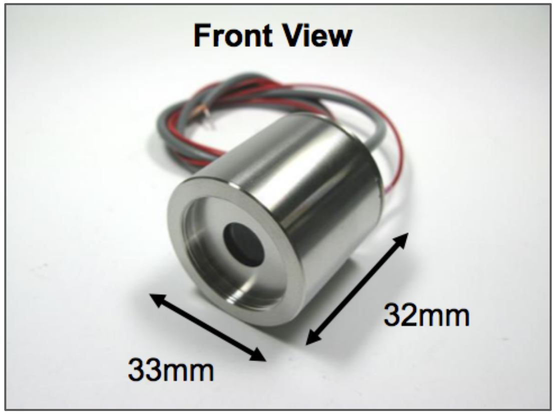


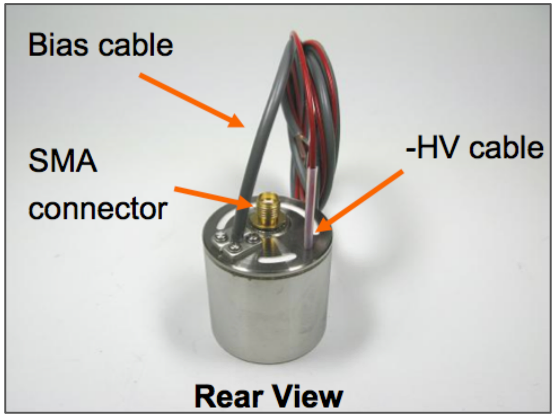
Photocathode deposition



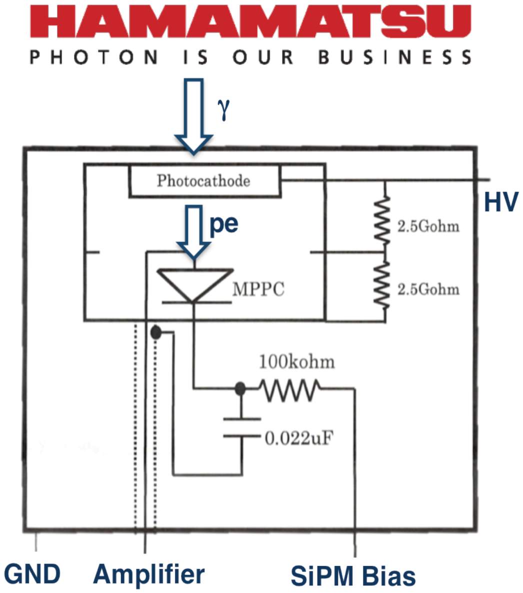
Prototyping and tests

The industrial prototypes





Borosilicate glass entrance window	7x7 mm²
GaAsP photocathode	3 mm ø

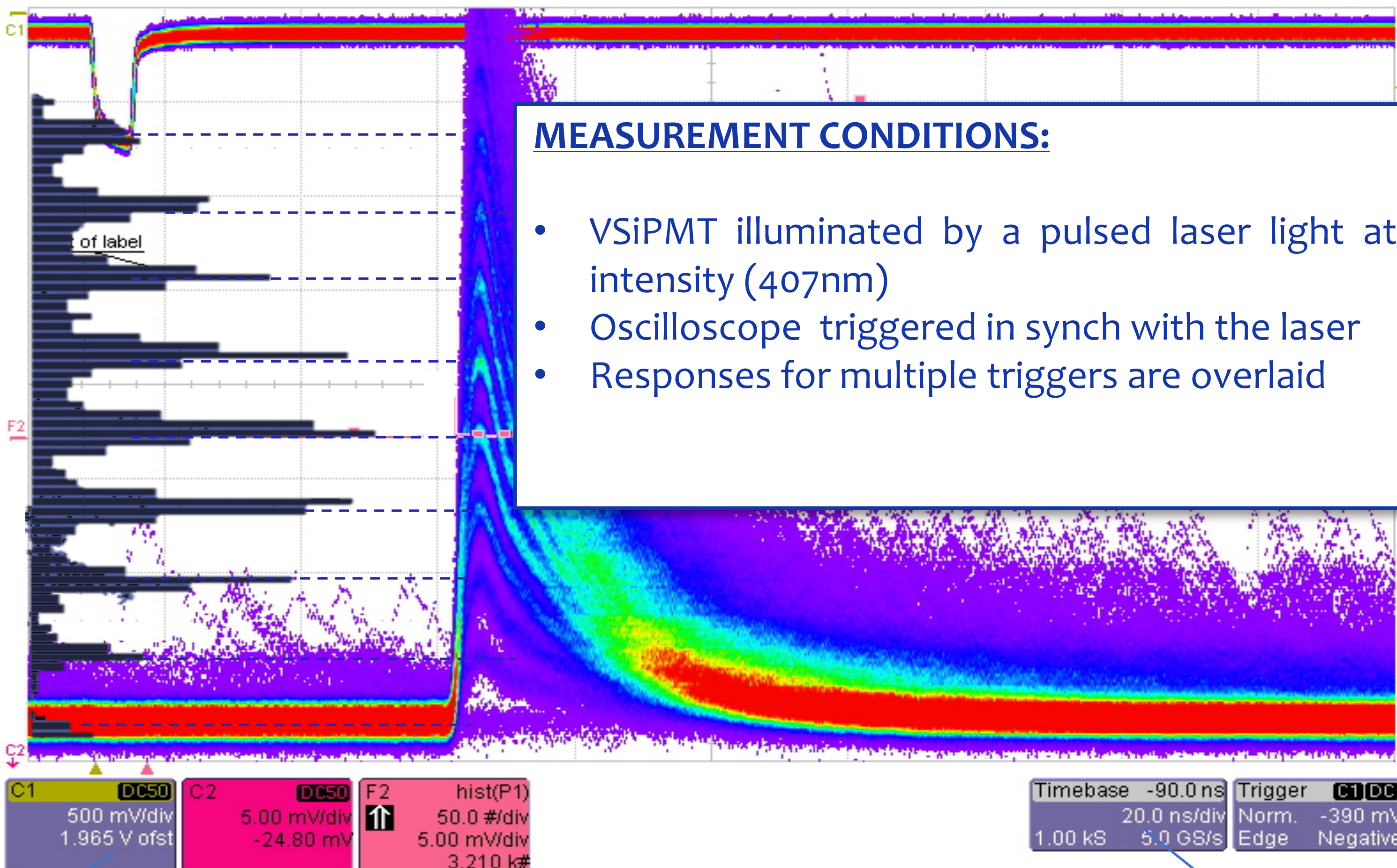


2 prototypes:

MPPC 1 mm² / 50 μm / 400 pixels

MPPC 1 mm² /100 μm / 100 pixels

Waveform and spectra



MEASUREMENT CONDITIONS:

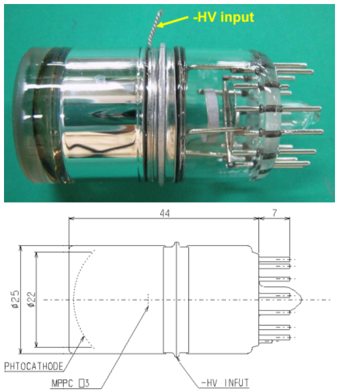
- VSiPMT illuminated by a pulsed laser light at low intensity (407nm)
- Oscilloscope triggered in synch with the laser
- Responses for multiple triggers are overlaid

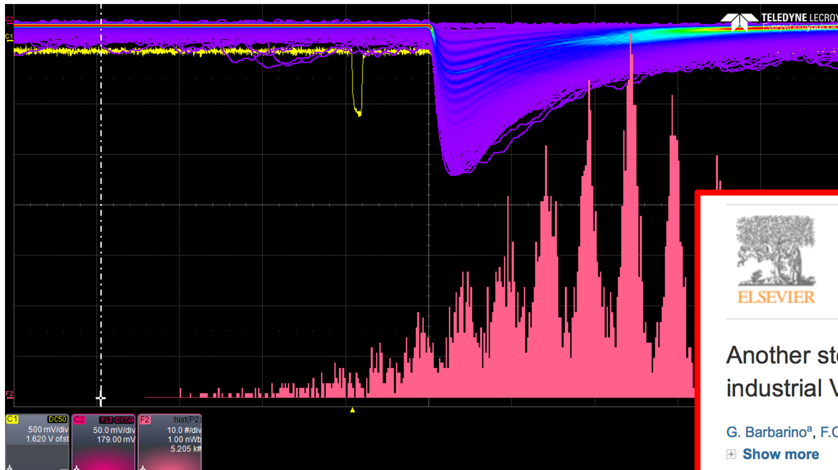
5 mV/div

20 ns/div

Excellent photon counting capability

The new industrial prototypes





1-inch

Astroparticle Physics
Available online 6 January 2018
In Press, Accepted Manuscript — Note to users

Another step towards photodetector innovation: the first 1-inch industrial VSiPMT

G. Barbarino[a], F.C.T. Barbato[a], C.M. Mollo[b], E. Nocerino[a], D. Vivolo[b], A. Fukasawa[c]
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https://doi.org/10.1016/j.astropartphys.2018.01.001
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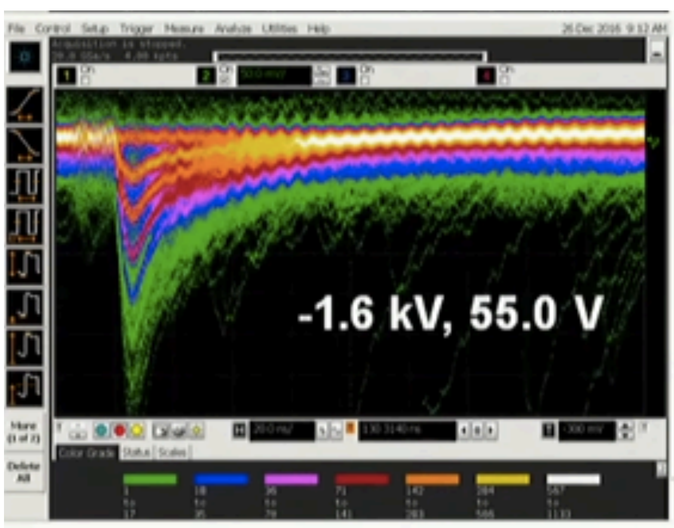

2-inches

Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment
Available online 13 December 2017
In Press, Corrected Proof

Development of a new 2-inch hybrid photo-detector using MPPC

A. Fukasawa[a], Y. Hotta[a], T. Ishizu[a], Y. Negi[a], G. Nakano[a], S. Ichikawa[a], T. Nagasawa[a], Y. Egawa[a], A. Kageyama[a], I. Adachi[b], G. Barbarino[c, d], F.C.T. Barbato[c, d], L. Campajola[c], R. de Asmundis[d], F. Di Capua[c, d], C.M. Mollo[d], E. Nocerino[c], D. Vivolo[d] … G. De Rosa[c, d]
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https://doi.org/10.1016/j.nima.2017.11.087
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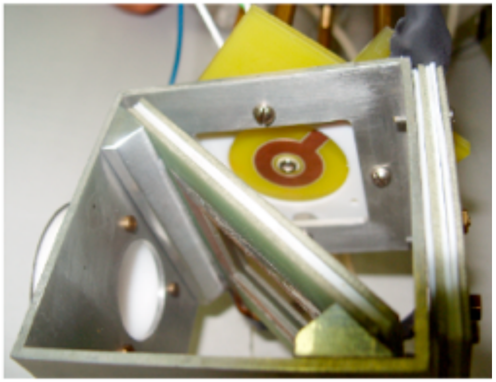
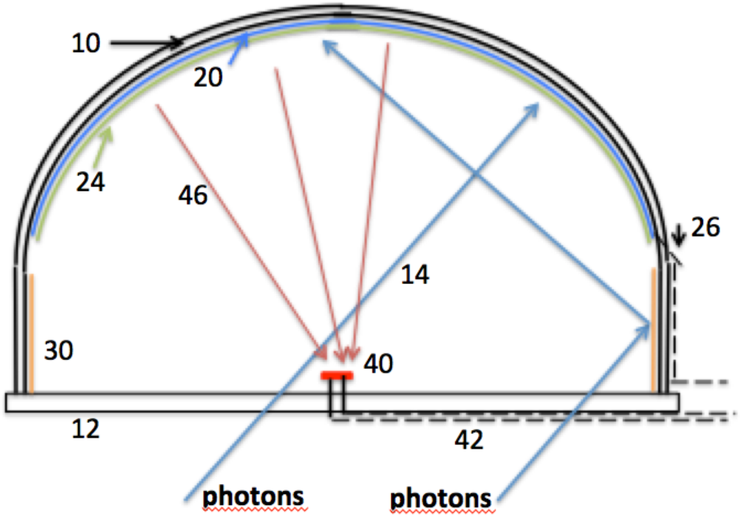
Technological transfer

SiEM characterization



A **new** higher efficiency VSiPMT **design** that we want to realize with Italian companies.



Turning a SiPM in a SiEM is NOT a standard process.
Necessity to test the SiEMs.

The proposed facility will be the only reference for Hamamatsu

Look for funding to produce VSiPMT in Italy!

Grazie