A1 **Titolo dell'attività di ricerca**

Vacuum Silicon PhotoMultiplier Tube (VSiPMT): A pioneering solution for new photodetectors.

A2 **Responsabile**
(aggiungere eventuale referente del Dipartimento se il Responsabile non è un afferente ad esso)

Responsabile Giancarlo Barbarino Referente per il Dip. Giancarlo Barbarino

A3 **Personale Dipartimento di Fisica** (Professori e Ricercatori)

Prof. Ordinari: Giancarlo Barbarino Prof. Associati: // Ricercatori universitari: // Tecnologo UniNA: Luigi Campajola. RTDA: // RTDB: //

A4 **Collaborazioni con altri enti**

ASI, INFN

A5 **Personale strutturato ricercatore o tecnologo altri enti convenzionati**

Riccardo Deasmundis (INFN)

A6 **Altro personale di ricerca (Assegnisti, Borsisti)**

Assegnisti: Carlos (Mollo) (INFN), Daniele Vivolo (Dip.), Felicia Barbato (Dip.) Borsisti Post-doc: // Borsisti: Elisabetta Nocerino

A7 **Dottorandi di Ricerca**

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B1 **Breve descrizione della linea di ricerca**
(max 1000 caratteri)

Photon detectors are indispensable in many areas of fundamental physics research, particularly in the emerging field of particle astrophysics (extensive air shower, water Cherenkov, liquid Argon experiments), nuclear and particle physics, as well as in medical equipment (positron emission tomography, PET), in human body checkup and biomedicine diagnostic systems, in industrial applications and in environmental measurement equipments. After about one century of standard technology (photocathode and dynode electron multiplication chain), the recent strong development of modern silicon devices has brought us to conceive a new generation of photodetectors based on an innovative technology, which is suitable for industrial mass production: the Vacuum Silicon PhotoMultiplier Tube (VSiPMT). Our proposal is based on the idea of focusing, collecting and multiplying the photoelectrons emitted by a photocathode on a p-n multi micro-pixel Si junction operated in Geiger mode (Geiger avalanche photodiode G-APD or SiPM) used as electron multipliers with

gains equivalent to those obtained by the dynode chain in a classical vacuum phototube.
We propose an innovative photodetector operating in reflection or in transmission mode by employing cesium iodide (CsI) for its wide gap and high efficiency of UV photocathode. Starting from the development of devices coated with CsI film deposited by thermal evaporation and/or ion beam sputtering in this research we want to explore other materials such as nanodiamond particles deposited by the innovative pulsed spray technique and bi/multi-alkali or semiconductor compounds, deposited by thermal evaporation and ion-beam sputtering in order to extend photon detection to the near UV-Visible spectral region. The problem of a conductive and transparent layer necessary for transmission mode photodetectors as in UV and in visible regions will be also covered and some technological solutions will be proposed for the final prototypes. Low power read out electronics for the VSiPMT will be integrated in a compact module, featuring both energy and time outputs and providing low and high voltage supplies, with active control of the SiPM bias voltage for temperature compensation.

B2 **Descrizione attività svolta nel triennio 2013-2015**
(max 2000 caratteri)

The first photomultiplier (PMT) dates to 1934 by RCA group. They were the first to integrate a photoelectric-effect and a secondary emission amplification stage in a vacuum tube. The PMTs used up to now in many researches, medical and industrial applications have the following drawbacks: divider power consumption, no single photon resolution,Transit Time Spread (TTS) not better than 1 − 2 ns. To overcome these disvantages, we invented a high-gain, silicon-based photodetector, the Vacuum Silicon Photomultiplier Tube (VSiPMT). The innovative idea is to replace the dynode chain of a PMT with a SiPM, acting as photoelectron multiplier with a gain of the order 10^6, similar to a PMTs gain. The VSiPMT feasibility started with a full Geant-4 simulation and the test of response of a special windowless (p-n) e-SiPM Hamamatsu to an electron beam. The e-SiPM showed well separated electron peaks: first proof of feasibility of the device. These results encouraged Hamamatsu to built for us two small area VSiPMT prototypes (equipped with e-SiPM 1mm^2 with 400 and 100 pixels respectively), tested in Naples laboratories. In VSiPMT, there is no divider and only three connections: two cables to supply power to the photocathode and the SiPM,respectively and the third for signal readout. In these prototypes the GaAsP small photocathode is 3 mm diameter with a spectral response between 300 and 750 nm. Signal quality, stability, photon counting capability, detection efficiency, gain, photocathode scan, Transit Time Spread, afterpulses and dark counts, linearity and dynamic range test has been measured using a picosecond pulsed laser. Photoelectrons coming from the photocatode need enough energy to enter into the SiPM to produce a signal. The high voltage is necessary to drive photoelectrons to the SiPM surface. Thus, differently from a classical PMT, once the efficiency is in plateau, there is no need for high voltage stabilization.

B3 **Descrizione attività programmata nel triennio 2016-2018**
(max 2000 caratteri)

In this project two VSiPMT prototypes with photocathodes of 1-3 inches diameters working in reflection and transmission modes will be manufactured. It follows the list of each item with the responsibility of each Research Unit (RU):
• reflective layers and photocathode will be realized by the RUs of UniBA and CNR,
• focusing system will be solved by RU of UniNA,
• special windowless e-SiPM, (SiPM for electrons) will be cured by RU of UniNA and FBK-SRS (Silicon Radiation Sensor) sub-unit (cost D UniNA).
• vacuum envelope will be realized by national Industries supervised by RU of UniNA,
• ancillary electronics will be carried out by RU of PoliBA.
All the components, as vacuum glass or ceramic envelope, photocathode, electrostatic focusing system and e-SiPM will be implemented and assembled all together with accurate and specialized technologies present in our laboratories and related industries.

Collaboration with HAMAMATSU industry

Specifications of our home-prototypes are discussed with Hamamatsu that has produced for us the first two prototypes of VSiPMT, one inch and two inches. These pioneering industrial prototype work very well demonstrating the goodness of our idea. In a recent meeting In Naples with Hamamatsu new prototypes are been scheduled.

C1 **Pubblicazioni scientifiche nel triennio 2013-2015**
(indicare il numero complessivo nel triennio e elencare le più significative (max 10))

N. complessivo: 1

Pubblicazioni più significative:

Barbarino G., in: A new generation photodetector for astroparticle physics: The VSiPMT. ASTROPARTICLE PHYSICS, vol. 67, p. 18-25, ISSN: 0927-6505, doi: 10.1016/j.astropartphys.2015.01.003

C2 **Presentazioni a Conferenze internazionali e nazionali**
(solo se lo speaker è tra il personale elencato nel punto A3)
G.Barbarino in:
ASI dicembre 2016: Towards a new generation of photodetector: the VSiPMT (Vacuum Silicon PhotoMulTiplier
Felicia Barbato in:
▪ *Towards a new generation of photodetectors: the VSiPMT (SIF 2013, Trieste, and NDIP 2014, Tours)*

- *Vacuum Silicon Photomultiplier Tube: recent developments (SIF 2014, Pisa)*
- *The VSiPMT Project (IFAE 2015, Rome)*
- *Progress in the realization of a larger prototype of VSiPMT (Photodet 2015, Moscow)*
- *Research and development for the realization of a large area photon counter: the VSiPMT (RICAP 2016, Frascati)*
- *R&D of a pioneering system for a high resolution photodetector: the VSiPMT (RICH 2016, Bled)*

Daniele Vivolo in:

- *VSiPMT –TIP 2014 Amsterdam*
- *VSiPMT –Photodet 2015 Mosca*

F.DiCapua in:
IEEE-NSS Strasburgo 2016: "VSIPMT : an hybrid approach to high resolution photodetector"
C.Mollo in:
IEEE NSS/MIC and RTSD: A feasibility study of a 3-inch Vacuum Silicon Photo Multiplier Tube

C3 **Presentazioni di brevetti internazionali e nazionali**

(Barbarino et al. in NIM vol. 594, p. 326-331, 2008, and G.Barbarino-VSiPMT photodetector, patent: PCT/IT2014/000174).

D1 **Progetti di ricerca attivi**
(Progetti di Enti di ricerca, Progetti Europei, Progetti MIUR, PON, POR, …)

ASI experiment.