Andrei Puiu

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Gran Sasso Science Institute, Astroparticle Physics

Scopus Author Identifier: Scopus 56513772800 **ORCID-iD:** 0000-0003-1143-224X

Research career

12/2019 - Ongoing **Ricercatore a Tempo Determinato tipo A**
(art. 24, comma a, della Legge 30 dicembre 2010, n. 240)
Settore concorsuale 02/A1 - SSD FIS/01
Gran Sasso Science Institute

01/2019 - 11/2019 **Assegno di ricerca tipo A2 (renewal)**
(art. 22 della Legge 30 dicembre 2010, n. 240)
Title: “HOLMES: measuring the neutrino mass with ^{163}Ho”
Università degli Studi di Milano - Bicocca

01/2017 - 12/2018 **Assegno di ricerca tipo A2**
(art. 22 della Legge 30 dicembre 2010, n. 240)
Title: “HOLMES: measuring the neutrino mass with ^{163}Ho”
Università degli Studi di Milano - Bicocca

Sholarship

01/2014 - 12/2016 **PhD scolarship, Ministry of Education**
recipient, after public competition at *Università degli Studi di Milano - Bicocca*

Education

04/2017 **PhD in physics and astronomy**
Thesis title: "HOLMES: an experiment for a direct measurement of neutrino mass", Evaluation: Excellent
Advisor: [redacted]
Università degli Studi di Milano - Bicocca

07/2013 **Master degree in physics**
Thesis title: "Metodi di abbattimento delle contaminazioni superficiali in esperimenti bolometrici", final mark: 110/110 cum laude
Advisor: [redacted], co-advisor: [redacted]
Università degli Studi di Milano - Bicocca and Laboratori Nazionali del Gran Sasso

09/2010 **Bachelor degree in physics**
Tesi dal titolo: "Misure bolometriche su Ossido di Tellurio", final mark: 103/110
Advisor: [redacted], co-advisor: [redacted]
Università degli Studi di Milano - Bicocca

Other awards

Premio Giovani Talenti dell'Università degli Studi di Milano-Bicocca con il Patrocinio dell'Accademia Nazionale dei Lincei - Edizione 2018
Winner of Young scientists' award *Per i suoi contributi a due importanti esperimenti di fisica delle particelle senza acceleratori con un notevole supporto tecnico nella realizzazione degli stessi e nella interpretazione dei dati*

Abilitazione Scientifica Nazionale

Settore Concorsuale 02/A1 Fisica Sperimentale delle Interazioni Fondamentali, Fascia: II, **abilitato**. From: 26/04/2021 to: 26/04/2030

Teaching

AY 2020/2021 — Professor of the course **"Cryogenics sensors and related electronics"**
PhD course in Astroparticle Physics, GSSI

AY 2020/2021 — Professor of the course **"Radiation Measurements"**
PhD course in Astroparticle Physics, GSSI and LNGS

AY 2019/2020 — Professor of the course **"Cryogenics sensors and related electronics"**
PhD course in Astroparticle Physics, GSSI

AY 2019/2020 — Assistant Professor of the course **"Physics 1" (FIS/01)**
Computer Science degree at Università degli Studi di Milano-Bicocca
8 CFU

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Computer Science degree at Università degli Studi di Milano-Bicocca
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AY 2014/2015 — Assistant Professor of the course **"Physics 1" (FIS/01)**
Computer Science degree at Università degli Studi di Milano-Bicocca
8 CFU

Students' advisor

Co-advisor of two master theses i Physics
Co-advisor of two bachelor theses in Physics

All the theses I have supervised were devoted to detector design, detector production, characterisation and data analysis for their performance evaluation. I have supervised students working with large low temperature calorimeters, micro-calorimeters, Transition Edge Sensors and SQUIDs and related readout

Scientific responsibilities and coordination activity

2021 - Ongoing **INFN local coordinator of COSINUS**
The COSINUS experiment aims at performing a direct detection of Dark Matter via nuclear recoils on NaI crystals operated as low temperature calorimeters with dual readout for particle identification
Groups: GSSI, INFN-LNGS, INFN ROMA1, MPI Muenchen, HEPHY Wien and Helsinki Institute of Physics
People managed: **5**
Funds managed: **250 keur/yea**r

2020 - Ongoing **COSINUS Crystal production coordinator**
Coordinator of the working group for crystal production and handling. We are collaborating with SICCAS, the Shanghai Institute Of Ceramics of the Chinese Academy Of Sciences to produce the crystals for COSINUS. It is not a trivial matter since the NaI crystals are the hearth of the low temperature calorimeters. I coordinate the prototype production and the tests in order to establish the final procedure for crytsal growth, cutting and polishing that will guarantee the target performance of the detector
People coordinated: **6**

2019 - Ongoing **PTOLEMY cryogenics coordinator**
I am responsible for the cryogenic infrastructure of PTOLEMY, which aims at detecting very low energy electrons using Transition Edge Sensors detectors mounted in a dilution refrigerator integrated in a very complex environment with a spectrometer to which the detectors must have a line of sight. We at LNGS are in charge of adapting a conventional dilution refrigerator to the scientific purposes of PTOLEMY.

2019 - Ongoing **COSINUS Muon veto coordinator**

Coordinator of the muon veto working group. The veto aims at identifying the muons travelling trhough the water tank surrounding the detector and the e/m showers generated inside the veto itself and in the surrounding rock of LNGS, in order to reduce the background in the region of interest of the nuclear recoils.
People coordinated: **4**

2019 - Ongoing **Run coordinator for COSINUS r&d runs at LNGS**
I coordinate the experimental activity of COSINUS at Gran Sasso. To define the final configuration of the COSINUS module it is crucial to test every component and to integrate them in order to reach the desired threshold and particle discrimination.
Groups: GSSI, INFN-LNGS, MPI-Munchen and HEPHY Wien.
People coordinated: **7**

2016 - 2019 **Responsible for the multiplexing system for HOLMES**
Whithin HOLMES I was in charge of testing the performances in terms on noise, bandwidth and readout power needed for the RF-SQUIDs of HOLMES. This is a unique readout method which was applied for the very first time to 6 keV TES. We achieved a multiplexing factor as high as 30.
Groups: Università di Milano-Bicocca, NIST Boulder Co.
Numero di persone gestite: **3**

Principali collaborazioni scientifiche

2019 - Ongoing	**COSINUS** (Cryogenic Observatory for SIgnals seen in Next-generation Underground Searches)
2018 - Ongoing	**PTOLEMY** (Pontecorvo Tritium Observatory for Light, Early-Universe, Massive-Neutrino Yield)
2015 - Ongoing	**CUPID-0 and CUPID** (CUORE Upgrade with Particle IDentification)
2015 - Ongoing	**CUORE** (Cryogenic Underground Observatory for Rare Events)
2017 - 2019	**SINGLE** (Single photon sensitive cryogenic light detectors)
2015 - 2019	**KIDS_RD** (High resolution X-ray spectroscopy with Kinetic Inductance Detectors)
2014 - 2019	**HOLMES** (Electron capture decay of ^{163}Ho to measure the neutrino mass)

Produzione scientifica

- Co-author of **89 publications** in in international peer-reviewed journals, with **642 citations** (source: Scopus, June 2021):

- **14 presentations** of my research activity in international conferences, international workshops

- **h-index: 15** (source: Scopus, June 2021)

Editor and reviewer activity

2019 - ongoing — **Member of the reviewer board** for *European Physics Journal C*

2016 - Ongoing — **Member of the reviewer board** for *Journal of Low Temperature Detectors*

2019 - 2020 — **Guest editor** of the special issue "*Low Temperature Detectors LTD18, Part I, II and III*" della rivista *Journal of Low Temperature Physics (JLTP)*

Workshop and conferences organisation

2019 — **Member of the Scientific and Organisation Committee** for the conference *"18^{th} International Workshop on Low Temperature Detectors, Cryogenic detectors for radiation and particles, and their applications" (LTD18).* The conference is one of the most relevant in the low temperature detectors field and was held in Milan from 22 to 26 July 2019. Over 400 people from all over the world participated. I was coordinator of the scientific sector " Low Temperature Detector development and physics "

2016 — **Member of the organising committee** for the *"5^{th} Workshop on the Physics and Applications of Superconducting Microresonators" (WPASM5).* The workshop was held in Milan from 22 to 24 July 2016. 55 people from all over the world partecipated, with a total of 31 presentations.

Contributions of invited talks and seminars

2021 **A review of direct neutrino mass searches**, invited seminar at Royal Holloway, University of London, host: Dr. Alexander Deisting

2020 **Direct neutrino mass measurement with HOLMES**, invited seminar at University of Zuerich, UZH, host: Prof. Laura Baudis

2018 **Holmes, the challenge of measuring the neutrino mass**, invited seminar at Forschungszentrum Juelich, host: Prof. Livia Ludhova

2018 **Direct neutrino mass measurement with Transition Edge Sensors and Kinetic Inductance Microwave Detectors**, invited talk at *The International Workshop on Prospects of Particle Physics: Neutrino Physics and Astrophysics* organised by JINR, Valday, Russia, 2-7 February

Contributions in international conferences

2021 ◦ **COSINUS: a NaI-based cryogenic scintillating calorimeter for DARK MATTER search** presentation at *IThe International Workshops on Weak Interactions and Neutrinos)*, University of Minnesota, June 7 – 11, 2021

2020 ◦ **COSINUS, Dark Matter searches with NaI calorimeters** presentation at the conference *The XXIX International Conference on Neutrino Physics and Astrophysics*, FermiLab, June 22 July 2

2019 ◦ **Transition Edge Sensors for HOLMES** oral presentation at the *18th International Workshop on Low Temperature Detectors (LTD18)*, Palazzo della Regione, Milan, Italy, 22-26 July

2018 ◦ **The HOLMES experiment** oral presentation for the conference *Incontri di Fisica delle Alte Energie*, University of Milano-Bicocca, Milan, Italy, 4-6 April

2017 ◦ **Updates on the Transition Edge Sensors and multiplexed readout for HOLMES** presentation at *17th International Workshop on Low Temperature Detectors (LTD17)*, Kurume, Giappone, 17-21 July

◦ **Direct neutrino mass measurement by the HOLMES experiment** oral presentation at *EXSA workshop on Quantitative methods in X-ray spectrometry*, Berlin, Germany, 10-13 October

2016 ◦ **Development of Transition Edge Sensors with rf-SQUID based multiplexing system for the HOLMES experiment** presentation at *The XXVII International Conference on Neutrino Physics and Astrophysics (Neutrino 2016)*, London, UK, 4-9 July

2015 ◦ **HOLMES, an experiment for a direct measurement of neutrino mass** presentation at *XVI Neutrino Telescopes Workshop Palazzo Franchetti*, Venice, Italy, 2-6 March

2015 ◦ **Development of the rf-SQUID based multiplexing system for the HOLMES experiment** presentation at *The International Workshop on Low Temperature Detectors (LTD16)*, Grenoble, France, 20-24 july

Terza missione activities

2019 ◦ **Responsible** for the public visits to the Cryogenics Laboratory at Università degli Studi di Milano-Bicocca for first year students of the master degree in physics

◦ **Responsible** for the public visits to the Cryogenics Laboratory at Università degli Studi di Milano-Bicocca organised during the Conferenza Italiana Studenti di Fisica

2018 ◦ **Incontri con la Scienza**, Seminars at ”Liceo Scientifico A. Volta”, Milan. Lecture on neutrino experiments and neutrino physics, host: prof. Pierangela Lentini

2017 ◦ **Incontri con la Scienza**, Seminars at ”Liceo Scientifico A. Volta”, Milan. Lecture on the discovery of the neutrino and the solar neutrino problem, host: prof. Pierangela Lentini

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Scientific Activity

Since my bachelor thesis I have had the chance to study the performances and perform various type of measurements with very low temperature detectors. During my scientific carreer I have dealt with several type of detectors and sensors with different purpouses: small and fast calorimeters coupled to Transition Edge Sensors (TES) with multiplexed RF−SQUID readout for the direct measurement of the neutrino mass, silicon detectors coupled to different type of absorbers such as tin and gold for preliminary studies on what would have become the HOLMES experiment, as well as large calorimeteres with TeO_2, ZnSe and BGO absorbers coupled to Germanium Neutron Trasmutation Detectors (Ge−NTD) for neutrinoless double beta decay and dark matter studies. Besides, I had the chance to take part in research and development activies on novel superconductive Kinetic Inductance Detectors (KIDs) which have potential applications in several experiments.

Direct measurement of the neutrino mass: HOLMES

The only experimental method for an independet measurement of the neutrino mass is the kinematic measurement of the decay products of a single β decay or an electron capture. The detectors used for the direct measurement of the neutrino mass must achieve very high performances in order to reach the required sensitivity. The best choice are very low temperature calorimeteres, that fulfill all the experimental needs. Since the beginning of my PhD scholarship I joined the HOLMES collaboration (ERC Advanced Grant n.340321, PI: Prof. [redacted]). The goal of HOLMES is to perform a the most sensitive measurement ever achieved by a calorimetric experiment, with a sensitivity as low as 1 eV on the netrino mass using the electron capture spectrum of ^{163}Ho, setting the grounds for a larger scale experiment. The challenge is to operate a 1000 detectors array of Transisiton Edge Sensors based calorimeters. Each detector will be implanted with 300Hz of ^{163}Ho in order to reach the target sensitivity whiting a three year long measurement. The number of detectors and the very high activity set very high standards for the detector and the detector performance. Each detector must have a very good energy and time resolution (3 eV and 10 μs at 2.8 keV) and the only feasible readout is a multiplexed one, which in the case of HOLMES was based on microwave SQUIDs. I have coordinated the development and the commissioning of the multiplexed readout for HOLMES, produced in cooperation with the Quantum Sensors Group of NIST, Boulder, Co and tested for the first time in Milano-Bicocca, as shown in A. Puiu *et al. JLTP 184 (1-2), 45-51*. In the paper B. Alpert *et al.*, *Eur. Phys. J. C* (2019) 79:304 we show the great performances achieve of the d at the end of my r&d activity for the HOLMES calorimteres and RF-SQUID readout.

Neutrinoless double beta decay searches: CUPID-0, CUPID and CUORE

CUORE (Cryogenic Underground Observatory for Rare Events) and CUPID (CUORE Upgrade with Particle IDentification) are experiments aiming at observing for the first time the neutrinoless double beta decay ($0\nu\beta\beta$), the only process that could shine a light on the Majorana nature of the neutrino as well as investigating its absolute mass scale. CUORE uses TeO_2 based low temperature calorimeters to search for the decay of ^{130}Te, while CUPID will use $LiMoO_4$ crystals enriched in ^{100}Mo. Despite all the difficulties of operating 1000 or more large calorimeters at 10 mK, the advantages are undisputable: a very large active mass, high detection efficiency and excellent energy resolution. Moreover CUPID will use scintillating calorimeters in order to perfrom event-by-event particle identification, that will further reduce by two order of magnitude the $2\times10^(- 2)$ counts/keV/kg/y low background achieved by CUORE.

My main contribution to large cryogenic experiments for the search of $0\nu\beta\beta$ was in the CUPID-0 experiment, the pilot experiment for CUPID, the first large array of scintillating calorimeteres. CUPID-0 was an array of 30 ZnSe based scintillating calorimeters enriched in ^{82}Se. Each crystal is coupled to a Neutron Transmutation Doped (NTD) thermomether for the readout of the phonon signal, while two Ge-based cryogenic light detectors are faced to the crystals for reading out the light signal. I took part in the construction of the detector, which has shown unprecedented performances in terms of particle identification and background rejection, reaching for the first time $3\times10^(- 3)$ counts/keV/kg/y. After the detector was mounted I managed the complex cryogenic infrastructure during the cool-down and the complicated debugging that has lead to a two year long stable data taking for phase one and one year and a half for phase two. The detector performance allowed us to perform several analyses that, besides setting the best limit on the half-life of the neutrino-less double beta decay of ^{82}Se to its fundamental state, have investigated the decays on excited states as well as the double beta decay of the Zn isotopes as shown in the various publications O. Azzolini *et al. Physical review letters 120 (23), 232502*, O. Azzolini *et al. Physical Review Letters 123 (3), 032501*, O. Azzolini *et al. The European Physical Journal C 78 (11), 888*.

Dark Matter Searches

COSINUS aims to provide a model–independent cross–check of the long-standing DAMA/LIBRA claim on the observation of dark matter by using the same target material, but in a different experimental approach. Operating sodium iodide (NaI) scintillating crystals as low-temperature scintillating calorimeters has the distinct advantage of providing a lower energy threshold for nuclear recoil events as expected from dark matter particle interactions combined with particle discrimination. The dual readout of phonon and light allows us to provide background rejection on an event-by-event basis, a unique feature in comparison with other NaI–based dark matter searches. In order to achieve the target background it is crucial to shield the neutrons reaching the detector. This is done by surrounding the dilution refrigerator where the detectors are installed with a 7 meters high and wide active water Cherenkov veto. I designed the veto in order to achieve the 99.99% identification of muons and 70% of the showers crossing the water tank, that will lower the background down to 10^{-2} counts/keV/kg/year in the nuclear recoil band. After the Cherenkov veto design was finalised I started coordinating the crystal production in close collaboration with SICCAS. The Institute and us are working very closely to define the best production process for the NaI crystals. Being employed as low temperature calorimeters, the crystal quality is of major importance, since the lattice structure directly affects the phonon production and transportation. I coordinate and perform several tests both at room temperature as well as at lower temperature to validate the growth techniques, the cutting and polishing and, most important, we investigate the performances for different Thallium doping concentrations. Within COSINUS I am also the run coordinator for the very low temperature measurements, being in charge of the prototypes design and construction, as well as the maintenance and improvement of the dilution refrigerator, of the cold (SQUIDs for TES readout) and warm electronics (JFETs for NTD readout), the data acquisition and the analysis.

Research and development acitivities in low temperature calorimeters

Besides my main contributions to larger experiments I took part in several research and development activities for low temperature calorimeters bringing innovation to several detection techniques and methods. Whitin the $0\nu\beta\beta$ searches, very promising technique for detecting the light of scintillating crystals, or the Cherenkov light emitted by electrons in TeO_2 crystals is the use of Silicon light detectors amplified with the Neganov-Luke effect. Such detectors are sensible enough to allow the successful discrimination of beta/gamma events from the alpha background that represents the current major limit on the sensitivity for the search of neutrinoless double beta decay. The Si light detector is normally employed in thermal mode, coupled to a sensitive NTD-Ge thermistor; this operation mode is not sufficient though for detecting the few tens of Cherenkov visible photons emitted per MeV deposited in the crystal. A brilliant possibility is to exploit the Neganov-Luke effect, which enhances the thermal signal in the detector by applying a static electric field across the Si slab. When a photon emitted from the crystal hits the Si detector it generates electron/hole pairs, which are accelerated in the electric field and produce a stronger thermal signal by scattering on the lattice. We have proved the feasibility of this technique which has been scaled to Si slabs with dimension matching the ones of the CUORE crystals, i.e. 5×5 cm^2 and in a dedicated run at the experimental facility in Hall C of the LNGS is due to be done in the near future. My main contribution was to the assembly of the experimental setup of the detectors and to the special high voltage bias lines that run from room temperature to the 10 mK stage of the ^3He-^4He dilution refrigerator in Milan where the measurements were performed; I also took part in data taking control tasks and subsequent data analysis activity that has lead to the pubblications M Biassoni *et al. The European Physical Journal C 75 (10), 480* and L Gironi*et al. Physical Review C 94 (5), 054608.*

From 2015 to 2019 I have participated in the development of superconductive Kinetic Inductance Detectors (KIDs) within the KIDS_RD INFN Gr. V research activity which aimed at developing KIDs sensitive to thermal phonons. The goal is to use the KID, which is normally operated as a non-equilibrium detector, as a temperature sensor, in order to maximise its detection efficiency and energy resolution. This would allow to couple the thermal KIDs to a wide variety of absorbers to build calorimeters suitable for many applications such as the direct measurement of the neutrino mass, neutrinoless double beta decay, dark matter, axions etc. In KIDS_RD I was in charge of the detector construction and subsequent cryogenic tests of the devices micromachined in collaboration with Fondazione Bruno Kessler (FBK). Our joint project was able to produce detectors able to resolve single photons with high signal to noise ratio, which was published in R. Mezzena *et al.*, *J. Low. Temp. Phys.* (2020) 199:73–79.

From 2018 I am part of the PTOLEMY collaboration. This project has the ambitious goal of revealing the cosmic neutrino background (CνB) for the first time, thanks to an experimental setup made up of several stages: from a high activity Trtitum source the emitted electrons are guided towards an active filtering stage where they are selected according to a tun-able electrostatic potential. At the end of the spectrometer the energy of the selected electrons is measured with a low temperature calorimeter array. This consists of a matrix of TES, which are designed to measure low energy electrons with very high energy resolution. In the project I actively collaborate in the design of cryogenic detectors and of the complex cryogenic system that has to maintain the 10 mK base temperature with a line of sight towards the spectrometer which will be kept at 4 K (M. Rajteri *et al.*, *J. Low. Temp. Phys.* (2020) 199: 138–142).

Le dichiarazioni rese nel presente curriculum sono da ritenersi rilasciate ai sensi degli artt. 46 e 47 del D.P.R. 445/2000

[redacted]