Curriculum Vitae

Personal information

Name: **Matteo Borghesi**
Date and place of birth: **December 4th, 1992, Milan**
Nationality: **Italian**

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Current position

jun 2023 - present	Researcher at the University of Milano-Bicocca, Italy (RTDa PNRR). Topic: *Integration of superconducting quantum devices*

Education

nov 2018 - feb 2022	Ph.D in Particle Physics, University of Milano-Bicocca. Thesis: *Toward the first neutrino mass measurement of HOLMES*. Final grade: passed, cum Laude;
oct 2015 - mar 2018	M.Sc in Particle Physics, University of Milano-Bicocca. Thesis: *Study of the performance of Transition Edge Sensors for the HOLMES experiment.* Final grade: 110/110, cum Laude;
sep 2012 - feb 2016	B.Sc. in Physics, University of Milano-Bicocca. Thesis: *The Cherenkov radiation and its application in RICH detectors.* Final grade: 101/110.

Fellowships

oct 2022 - jun 2023	Post-Doctoral Research Scientist at the University of Milano-Bicocca, Italy (Assegno di ricerca tipo A2). Title: *Probing an alternative approach to measure the neutrino mass.*
apr 2022 - oct 2022	Post-Doctoral Research fellowship at University of Milano-Bicocca (Assegno di ricerca tipo B). Title: *Setup of the 32 detectors for the first neutrino mass measurement of HOLMES*;
jun 2018 - nov 2018	Selected for a research scholarship at University of Milano-Bicocca. Title: *Optimization of the signal processing procedures of low temperature detectors signals for the neutrino mass measurement.*

Awards

2022	Best PHD thesis in Astroparticle physics (Premio Bruno Rossi), INFN CSN2.
2022	Young Research Talent Award (Premio giovani Talenti), second plance amongst 22 admitted, University of Milano-Bicocca.

Main research activities

2023 - present	**JUNO** experiment (international project co-founded by INFN);
2023 - present	**BAUSCIA** experiment (international project founded by University of Milano Bicocca, Dipartimento di eccelleza);
2022 - present	**qubIT** project (national project founded by INFN, CSN5);
2021 - present	**DARTWARS** project (international project co-founded by INFN and by the European Union);
2020 - 2022	**KIDS-RD** project (national project founded by INFN, CSN5);

2020 - present	**PTOLEMY** experiment (international project co-founded by INFN);
2018 - present	**HOLMES and HOLMES+** experiment (ERC Advanced Grant Agreement no. 340321, PI: Prof Stefano Ragazzi, co-founded by INFN, CSN2).

Responsabilities

2025 - present	**Local Pi** for HOLMES+;
2024 - present	**Member of the Institutional Board** for PTOLEMY;
2025 - present	**Leader of the analysis team** for the HOLMES+.

Presentations at Conferences

jan 2025	"Global Young Scientist Summit ", Singapore. **Talk** on *The hunt for neutrino mass*;
jun 2024	"Neutrino 2024 – XXXI International Conference on Neutrino Physics and Astrophysics ", Milano. **Poster** on *The first neutrino mass limit of HOLMES*;
feb 2024	"NuMass 2024 – Determination of the absolute (anti)-neutrino mass ", Genova. **Talk** on *HOLMES status*;
sep 2023	"TAUP 2023 – XVIII International Conference on Topics in Astroparticle and Underground Physics ", Vienna. **Talk** on *The first neutrino mass measurement of HOLMES*;
jun 2023	"HPXM2023 – High Precision X-Ray Measurements ", Frascati. **Invited talk** on *Measuring the temperature of X-rays with superconducting detectors*;
jun 2022	"NuMass 2022 – Determination of the absolute (anti)-neutrino mass ", Milano. **Talk** on *An updated overview of the HOLMES status*;
mar 2022	"15th Pisa Meeting on Advanced Detectors ", La Biodola. **Posters** on *Toward the first neutrino mass measurement of HOLMES* and *Design and preliminary characterizations of traveling wave parametric amplifiers for DARTWARS*;
jul 2021	"19th International Workshop on Low Temperature Detectors ", Virtual Only Event. **Poster** on *Signal processing and data analysis for the Holmes experiment*;
jun 2020	"Neutrino 2020 ", Virtual Only Event. **Poster** on *Updates on the HOLMES experiment*;
feb 2020	"ECT* workshop, Determination of the effective electron (anti)-neutrino mass ", at Trento. **Talk** on *Updates on the HOLMES detector array fabrication*;
jul 2019	"18th International Workshop on Low Temperature Detectors ", at Milano. **Poster** on *Analysis techniques for the signal processing of the HOLMES detectors*;
sep 2017	"103 Congresso della società italiana di Fisica ", at Trento. **Talk** on *Transition Edge Sensors for direct neutrino mass measurement: The HOLMES experiment.*

Teaching activities

2023 - 2024	**Teaching** assistant for "Laboratorio II"(bachelor course, Physics) at the University of Milano-Bicocca;
2022 - 2023	**Tutoring** assignment for "Preparazione di esperienze didattiche"(master course, Mathematics) at the University of Milano-Bicocca;
2022 - 2023	**Tutoring** for the "Laboratorio di stato solido e tecnologie quantistiche"(master course, Physics) at the University of Milano-Bicocca;
2021 - 2022	**Tutoring** for the "Laboratorio di stato solido e tecnologie quantistiche"(master course, Physics) at the University of Milano-Bicocca;
2021 - 2022	**Teaching** assistant for the "Fisica"course (bachelor course, Computer Science) at the University of Milano-Bicocca;

2020 - 2021	**Teaching** assistant for the “Fisica”course (bachelor course, Computer Science) at the University of Milano-Bicocca;
2019 - 2020	**Tutoring** assignment for “Laboratorio I”(bachelor course, Physics) at the University of Milano-Bicocca.
2018 - 2019	**Tutoring** assignment for “Laboratorio I”(bachelor course, Physics) at the University of Milano-Bicocca.

Organization of international conferences

jun 2023	“XXXI International Conference on Neutrino Physics and Astrophysics (Neutrino 2024)", international conference at Milano (over 800 people, 71 scientific talks and around 460 posters). Member of the local organizing committee. https://agenda.infn.it/event/37867/
feb 2023	“Determination of the absolute electron (anti)-neutrino mass (Numass 2023) ”, international workshop at Genova (40 people, 35 talks). Member of the local organizing committee and of the Scientific board. https://agenda.infn.it/event/38742/
jun 2022	“Determination of the absolute electron (anti)-neutrino mass (Numass 2022) ”, international workshop at Milano (55 people, 39 talks). Member of the local organizing committee and of the Scientific board. https://agenda.infn.it/event/28684/

Peer review activities

2022 - present	**Reviewer** for Nuclear Instruments and Methods in Physics Research, section A (NIM-A);
2020 - present	**Reviewer** for Journal of Applied Physics (JAP).

Scientific performances

- **42 publications** in peer-reviewed international journals, with **189 citations** (source scopus, jan 2025);
- **H-index:** 9 (source scopus, jan 2025).

Research activities

My main scientific interest is experimental particle physics. However, I have an eclectic attitude, which I have adopted both through my academic studies and during my PhD. I believe that it is crucial to develop a critical spirit on the major physics topics which proves to be pivotal even in the specific day-to-day tasks.
I had a well-balanced instruction and my research career is based both on experimental and analytic work. During my PhD I had the opportunity to face many experimental challenges and to learn from scratch signal processing, advanced programming, microwave readout and cryogenics. The latter is quite a big field, but thanks to the facilities and the experties already present in Milano-Biccocca, combined with the close connection with majour national and international insitutions (LNGS, FBK, NIST to name a few), allowed me to acquire a comprehensive competence on the topic. All of these knowledges are of paramount importance not only for particle physics, but also for the detection of high frequency gravitational waves and in the field of superconducting Quantum Technologies.

Micro-calorimeter for the direct measurement of the Neutrino Mass: Since 2017 I have been a proactive member of the workteam involved in the HOLMES experiment (ERC Advanced Grant n.340321, PI: Prof. Stefano Ragazzi). The primary goal of this experiment is the development of a new technique for the direct calorimetric measurement of the neutrino mass using the electron capture decay of 163-Holmium. This experiment employs $O(100)$ microcalorimenter detectors based on Mo/Cu TES (Transition Edge Sensor) on a SiN_x membrane with gold absorbers. This kind of detector works

at very low temperatures (about 100 mK), so that an interaction in the absorber produces a detectable temperature rise proportional to the energy deposited. The HOLMES detectors not only need a fast recovery time, i.e. the time needed to cool down the thermometer to its base temperature, to reduce the amount of dead time but also a quick time response to discriminate between two nearly coincident interactions.
Various fabrication steps are needed to implant the required amount of radioactive isotope inside the microcalorimeter absorbers. One of the results achieved during my PhD represented a milestone in the detector testing and development. I setup a deposition chamber and optimized its parameters in order to achieve the desired gold deposition rate. This deposition chamber will be used to enclose the Ho atoms inside the gold absorbers. I also successfully carryed out a wet etching KOH procedure to homogeneously release the membrane on the detector array. Both these processes represent crucial phases in the detectors fabrication process. Afterwards, I tested the quality of the procedures by checking the performances of the resulting detectors.
At the same time, I developed a modular and robust analysis software for signal processing and data analysis, now used by the whole HOLMES collaboration for the analysis of low temperature detectors. Since the main bkg source of HOLMES is expected to be due to unresolved pile-ups, I dedicated a great effort in developing a novel technique based on unsupervised learning techniques and Singular Value Decomposition aimed at discriminating such events. To validate this algorithm, I also developed a routine capable to solve the differential equations governing the TESs response, so to simulate realistic signals. As a result of my work, the target time resolution was finally achieved, lower than the sampling time of the signals.
I have also developed a Bayesian routine for parameter estimation using a software called STAN. I used this tool to estimate the expected background contribution due to natural radioactivity and cosmic rays, obtaining an estimate consistent with simulations. The results of my work, both in software and hardware, enabled the initiation of the first phase of the HOLMES experiment: a low-dose setup on a 64-pixel array. The first measurement campaign with the implanted detectors began at the end of 2023 and validated all the analysis routines developed so far: a remarkable total duty cycle of 82% was achieved, with channels perfectly stabilized during the 3-5 days of each measurement sub-interval.
The obtained spectrum is the highest-statistics and most resolved spectrum of holmium ever measured to date, allowing the study of the individual structures that make up the final spectrum and thus estimating the future sensitivity of a calorimetric experiment with this isotope.
With the collected data, I then used the software I developed to obtain a Bayesian limit on the electron neutrino mass of 30 eV at a 90% credibility region.
Since 2019, I have been the coordinator of the analysis team, managing the workflow and the repository on GitHub, and as of 2025, I have officially become the local representative of the INFN HOLMES+ project at the Milan-Bicocca section. In recent years, I have also supervised all measurements conducted in the cryogenic laboratory. Recently, I have started playing a significant role in the DAQ and read-out working group.
Due to multiple synergies, I have also joined the PTOLEMY collaboration, assuming a role in the "Institutional Board" for the Bicocca group starting in 2024. This project has the ambitious goal of detecting the cosmic neutrino background for the first time. This would enable a measurement of the neutrino mass with unprecedented sensitivity, on the order of O(10) meV, using an innovative electromagnetic filter that is expected to reduce the experimental volume by more than two orders of magnitude compared to the KATRIN experiment.
Currently, I am developing a cryogenic and monochromatic electron source, which will validate TES as ultra-high-resolution detectors for low-energy electrons. The prototype of this source was tested at the end of 2024, yielding very satisfactory results: we are the third group in the world to have measured low-energy electrons with thermal detectors. These detectors were read using the same technique that will be employed by PTOLEMY for the final detector array.

Neutrino Oscillations: Since 2023, I have been participating in the JUNO experiment, aimed at measuring neutrino oscillations from reactors. The main result of JUNO will be the first-ever determination of the neutrino mass hierarchy.
Precisely knowing the unoscillated neutrino spectrum is crucial for predicting the hierarchy. For this

reason, JUNO will also have a smaller detector, TAO, placed near the antineutrino source, which will measure antineutrinos from 2 of the 8 reactors. TAO represents a fundamental step in achieving the precision required by JUNO, but it is likely that its data will need to be complemented with theoretical models.
As part of the collaboration, I have developed a software tool (RenShape) for predicting the unoscillated reactor neutrino spectrum using the "summation method." This method calculates the final spectrum shape by summing hundreds of antineutrino spectra resulting from the decay chains of 235U, 238U, 239Pu, and 241Pu. The results obtained with my model are comparable to the state-of-the-art in the literature, with the key difference that the entire software is now publicly available on GitHub. Its easy accessibility and open-source philosophy will allow validation and improvement of its predictions, also thanks to the arrival of new data from nuclear databases.
Currently, I am studying the precision with which TAO and RenShape can both predict the unoscillated spectrum and identify and correct the spectrum of those nuclides still affected by the "pandemonium effect."

Dark matter and gravitational waves: Thanks to the knowledge I acquired while working on HOLMES, particularly in cryogenics and the use of radiofrequency readout systems, since 2023, I have also been involved in the BAUSCIA experiment, which is part of the BiCoQ Excellence Departments project.
BAUSCIA will use small resonant piezoelectric quartz masses cooled to cryogenic temperatures to measure high-frequency gravitational waves, in the range of 100 kHz to tens of MHz. The project lies at the intersection of observational cosmology and particle physics, as some sources of gravitational waves at these frequencies are also dark matter candidates, such as primordial black holes and axions. I have been involved in BAUSCIA since its early development stages. Currently, I am working on the characterization of the resonant masses, handling both data acquisition and analysis. In the future, I will partecipate in the implementation of the first gravitational antenna system using an RFSoC-based readout system and amplification with DC-SQUIDs.

Quantum technologies: Thanks to the know-how acquired in the setup and readout of superconducting microwave resonators and superconducting low temperature detectors, I gained an extensive expertises in the following topics: superconductivity, single photon detection, Superconducting Quantum Interference Devices (both rf-SQUID and dc-SQUID) and microwave readout. My skills are being spent to design and simulate a readout system for a matrix of trasmon qubit, in collaboration with the University of Florence, FBK and INFN-Frascati.
From 2021 I'm part of the DARTWARS collaboration (Detector Array Readout with Traveling Wave AmplifieRS). DARTWARS is a three years project that aims to develop high performing innovative Traveling Wave Parametric Amplifiers (TWPAs) for low temperature detectors and qubit readout (C-band). TWPAs will allow to infer with high fidelity the state of multiple of qubits at the same time. This amplifiers will also be useful in the field of particle physics, potentially lowering the sensitivity of future experiments regarding neutrinos, dark matter and CMB. Our group is responsible for the design and characterization of the devices. The first prototype of a KITWPA will be ready in 2023, while in 2022 I characterized a KITWPA already available in the laboratory linked to a superconducting qubit.
In 2021 I joined the qubIT project. Its goal is to realize an itinerant single-photon counter exploiting Quantum Non Demolition (QND) measurements and entangled qubits in order to surpass current devices in terms of efficiency and low dark-count rates. The resulting device will have direct applications not only in quantum computing, but also in Axion dark-matter experiments, further demonstrating the strong link between quantum technologies and experimental physics.