

# Juan Montoya Sanchez

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## Areas of expertise

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Physics undergraduate specializing in high-energy physics, quantum computing, machine learning, statistical data analysis, cernROOT, Geant4, MadGraph, Python, C++, PennyLane.

## Technical Skills

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**Programming:** C++, Python, BASH, MicroPython,  $\text{\LaTeX}$ , SQL  
**HEP Software:** ROOT, Geant4, MadGraph5, uproot  
**ML & Quantum:** PyTorch, TensorFlow, scikit-learn, PennyLane  
**Scientific:** NumPy, SciPy, Pandas, Matplotlib, Jupyter, COMSOL, OriginLab  
**Tools & Systems:** Git, Linux, Overleaf

## Education

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Universidad de Antioquia - Medellín, Colombia. 2019 – Expected 2026

- Bachelor's degree in Physics GPA: 3.85/5.0
- **Relevant coursework:**
  - Physics:** Quantum Mechanics, Particle Physics, Statistical Mechanics, Electrodynamics
  - Computing:** Computational Physics, Introduction to Quantum Computing, Big Data Analysis
  - Mathematics:** Linear Algebra, Differential Equations, Numerical Analysis
  - Experimental:** Electronics, Data Acquisition Systems, Signal Processing

## Research Experience

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**Undergraduate Research Assistant**, Phenomenology and Fundamental Interactions Group (GFIF) — Universidad de Antioquia 2024 – Present

- Developed C++ ROOT scripts to characterize geometric and energetic properties of b-jets and  $\bar{b}$ -jets at low  $p_T$  ( $< 30$  GeV), reading branches from .root files, performing necessary calculations, and generating visualization plots
- Project code available at **GitHub**

**Research Intern**, Condensed Matter Group — Universidad de Antioquia 2023 – 2024

- Contributed to research on quantum dots, focusing on their electronic and optical properties under external fields:
  - **Structural modifications in GaAs/AlGaAs tetrapod nanocrystals under applied pressure and temperature: Electron-impurity properties**  
*Physics Letters, Section A: General, Atomic and Solid State Physics, 2025*
    - \* **My contribution:** Performed temperature and pressure-dependent calculations for electron-impurity interactions. Analyzed structural modifications using COMSOL and developed visualization scripts for data representation. Collaborated on manuscript preparation and revision. Designed the final figures using Inkscape.
  - **Electronic and optical properties of tetrapod quantum dots under applied electric and magnetic fields**  
*European Physical Journal Plus, 2024*
    - \* **My contribution:** Ran half of the COMSOL simulations and exported both numerical and graphical data. Processed simulation outputs in OriginLab, improved figure clarity and references in Overleaf with  $\text{\LaTeX}$ , and created final figures in Inkscape.
  - **Hopf-link GaAs-AlGaAs quantum ring under geometric and external field settings**  
*Physica E: Low-Dimensional Systems and Nanostructures, 2024*
    - \* **My contribution:** Verified the correct implementation of the potential model in COMSOL and Python. Adjusted the manuscript format in Overleaf to meet the journal's guidelines.

## Conferences & Presentations

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**9<sup>th</sup> Colombian Meeting on High Energy Physics (COMHEP)** Pasto, December 2024

- Oral Presentation: *Systematic Study of the Structure of  $b$ -Jets and  $\bar{b}$ -Jets at Low  $p_T$  ( $< 30$  GeV)*. Presented the results of the C++ ROOT script developed during my undergraduate research assistantship.
- One of the leaders at the CMS Masterclass activity in Pasto on December 3, 2024. I was responsible for explaining to the attendees how to classify events using graphical tools.

**ICTP Physics Without Frontiers: Colombian Network for High Energy Physics School** Ibagué, December 2023

- Attended theoretical and experimental HEP lectures, covering tools such as MadGraph5, applications of neural networks for Higgs signal and background discrimination, and Compton scattering.
- Collaboratively developed a neural network for Higgs signal and background discrimination, where I was responsible for cross-validation. After the school, I attended the **8<sup>th</sup> COMHEP in 2023**.

## Personal Projects

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**LowPt-Jet-Qml** — Quantum Machine Learning for Particle Physics [GitHub link](#) 2025.

- Implemented and compared Quantum Machine Learning techniques with classical ML for low-pT b-jet tagging
- Developed quantum neural networks using PennyLane with Angle Embedding for 16-qubit circuits
- Analyzed datasets from different PT ranges using uproot, evaluating models with AUC and tagging power metrics

**SensorArray** — Experimental Physics Course Final Project [GitHub link](#) 2025.

- Designed and built a data acquisition system with multiple phototransistors for laser pattern detection
- Implemented MicroPython code for ESP32 microcontroller to collect and process sensor data
- Developed signal processing algorithms for real-time analysis of light patterns

**Biospeckle-ML** — *First Place Winner, Physics Experimental Fair* [GitHub link](#) 2024.

- Designed and built an optical system to capture biospeckle phenomenon in blueberries.
- Developed C++ algorithms with OpenCV for image processing and statistical pattern analysis
- Using scikit-learn and PyTorch, created a neural network classifier achieving 89% accuracy in blueberry quality assessment
- Presented statistical validation of results with rigorous hypothesis testing and confidence intervals

**United Nations Datathon 2024**— Sustainable Tourism Analysis, Second Place Winner in student category [GitHub link](#) Medellín, November 2024

- Developed a data analysis pipeline for assessing tourism impact on Medellín's sustainable development
- Collected, cleaned and preprocessed multidimensional urban datasets using Python
- Created interactive visualizations with GeoPandas and Plotly to represent spatial patterns
- Collaborated in a multidisciplinary team to present findings to UN Development Program representatives

**NASA Space Apps Challenge 2024** – Community Mapping [GitHub link](#) Medellín, October 2024

- Led data acquisition and processing for a socioeconomic mapping project of Medellín
- Gathered demographic, economic, and infrastructure data from multiple government sources
- Collaborated with frontend developers to ensure seamless data visualization in the final application