



M2 (or final year engineering school) Internship  
**Geometric Deep Learning for high-energy particle tracking**

Over the past decade, there has been a groundbreaking shift in data science and machine learning, particularly in the realm of deep learning methodologies. At the ATLAS experiment[1] at the Large Hadron Collider (LHC) at CERN [2], innovative approaches based on Geometric Deep Learning (GDL) [3-4] are explored to face the deluge of data expected in the coming years where the rate of collisions in LHC will be increased far beyond the initial design [5]. The Laboratoire des 2 Infinis (L2IT) is a young laboratory created in 2020 in Toulouse to conduct research in fundamental physics with new numerical and theoretical approaches to data analysis. Within the ATLAS collaboration the L2IT team plays a major role in research and development to build a new generation algorithm based on Graph Neural Networks (GNNs) for charged particle tracking. This collaborative effort with the Lawrence Berkeley National Laboratory (LBNL) Exa.Trkx project [6] team has resulted in publications at major international conferences [7-9].

We are offering an internship opportunity for students pursuing a Master's degree or in their final year of an engineering school program to join our Machine Learning Research and Development (ML R&D) team. This internship will concentrate on exploring novel GNN architectures that operate in a multi-scale and multi-topological graph context, aimed at achieving faster and highly efficient particle track reconstruction.

Summary of the Internship Tasks:

- Review of literature on Graph Neural Networks (GNNs)
- Implementation, training, and evaluation of advanced GNN models operating in a multi-scale and multi-topological context
- Presentation of results in weekly collaboration meetings
- Integration of the code in the existing open-source collaboration framework [10]
- Compilation of a report or scientific article detailing the obtained results

Why Join Us:

If you are a student in computer science, data science, or physics with a robust focus on machine learning, and you seek to undertake your internship in an intellectually stimulating academic research environment, this opportunity is for you. The internship will be carried out in the "Computing, Algorithm, and Data" team at L2IT, under the direct supervision of a computer science research engineer. You will have the chance to apply and significantly enhance your skills in deep learning methods and advanced neural network architectures while contributing to our R&D effort in a highly dynamic research environment in a major international collaboration. L2IT regularly have openings for PhD theses.

Required Skills:

- Advanced level in Python and its scientific/data science packages (numpy, pandas, etc.)
- Strong knowledge of Deep Learning, including at least some experience with PyTorch
- Git version control
- Proficiency in navigating Linux environments
- Autonomy and creativity

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L2IT website : <https://www.l2it.in2p3.fr>

[1] ATLAS experiment), url: <https://atlas.cern>

[2] CERN), url: <https://home.cern/>

[3] G. DeZoort, P.W. Battaglia, C. Biscarat, J.R. Vlimant, Nature Rev. Phys. 5, 281 (2023)

- [4] J. Shlomi, P. Battaglia, J.R. Vlimant, Machine Learning: Science and Technology 2, 021001 (2020)
- [5] Apollinari et al., High-Luminosity Large Hadron Collider (HL-LHC), url: <https://cds.cern.ch/record/2284929>
- [6] HEP advanced tracking algorithms at the exascale (Project Exa.TrkX), url: <https://exatrnx.github.io/>
- [7] C. Rougier et al., ATLAS ITk Track Reconstruction with a GNN-based Pipeline, CTD2022, Princeton, USA), url: <https://doi.org/10.5281/zenodo.8187248>
- [8] X. Ju et al., Physics Performance of the ATLAS GNN4ITk Track Reconstruction Chain, CHEP2023, Norfolk, USA), url: <https://indico.jlab.org/event/459/contributions/11414/>
- [9] S. Caillou et al., Novel fully-heterogeneous GNN designs for track reconstruction at the HL-LHC, CHEP2023, Norfolk, USA), url: <https://indico.jlab.org/event/459/contributions/11713/>
- [10] GNN4ITk Team, A Charged-particle geOmetric Reconstruction Network (ACORN), 2023, url: <https://github.com/GNN4ITkTeam/CommonFramework>