Clarence Wret

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Employment

2024-2032 **Royal Society University Research Fellow**, *Imperial College London*.
Fellowship focussing on the near-detector design for Hyper-Kamiokande, and analysis of T2K ND280 upgrade data on single-pion production, alongisde generator and theory development. Supporting one PDRA and 2 PhD students.

2023-2024 **Senior postdoctoral researcher**, *University of Oxford*.
Leading T2K near-detector DAQ development and integrating the upgraded detector systems. Convener of oscillation and near-detector analyses on T2K, joint atmospheric and beam analysis, and developing neutrino interaction models and uncertainties. Core consolidated grant.

2018-2023 **Postdoctoral researcher, Robert Marshak fellow**, *University of Rochester*.
Based at Fermilab, led detector development, reconstruction, and physics analysis. Convener and analyser in neutrino oscillation and near-detector analyses. Studying impact of neutrino interactions.

Responsibilities and experience

T2K I convened the oscillation analysis and the near-detector constraints groups 2019-2023, and remain a developer, analyser and manager of central analysis software. I have worked on the Bayesian simultaneous near-and-far detector oscillation analysis, leading development of the near-detector selections, data and simulation processing, the NEUT neutrino interaction generator, and other key packages. I wrote T2K's 2020 oscillation analysis into publication, and have sat on several paper-writing committees. I convene the single pion excess task force, and the group measuring the corresponding cross section in the upgraded ND280. I was responsible for the data acquisition and slow control of T2K's near detectors, and I led the successful integration of the upgraded near detector into the system. I also partook in its neutron test beam run at Los Alamos National Laboratory.

T2K+SK I convened the T2K beam and SK atmospheric joint oscillation analysis since its proposal until the end of the first analysis, and led one of the Bayesian analyses. Combining the experiments is a world-first; it increases statistics, lifts oscillation parameter degeneracies, and correlates and constrains shared uncertainties, leading to world-leading precision on numerous oscillation parameters, including the CP-violating phase. I studied the ND280 selections and developed the interaction model to enable ND280 to reliably constrain the SK atmospheric events, and have also worked on neutrino oscillation probability calculations. I was on the paper committee of the short paper, and am leading the writing of the long paper.

T2K+NOvA I significantly contributed to studying the neutrino interaction model, phase space matching, and aspects of overlap for the T2K-NOvA joint oscillation analysis. I represented both collaborations at the US-Japan Symposium of High Energy Physics in Hawaii in 2019.

DUNE I led the studies of the simulations for The Muon Spectrometer (TMS), critical for the day-one physics-ready DUNE near detector. I ran productions, formalised and written data products, geometries, reconstruction, and tracking algorithms, and was responsible for the TMS software and simulations in the near-detector software group. Separately, I was involved in the ArgonCube 2x2 demonstrator programme for the DUNE near detector, in which the MINERvA experiment was repurposed as a tracker for the demonstrator. I led the disassembly and storage of MINERvA modules, and worked on preparing the MINERvA DAQ for operations. For the DUNE Technical Design Report, I developed and implemented the neutrino interaction model used in the long-baseline neutrino oscillation analysis, and advised analysers on methods and statistical techniques from T2K.

Neutrino interactions I am one of the core authors and developers of NUISANCE (nuisance.hepforge.org) since its conception—an open-source framework providing users the ability to compare and tune multiple neutrino interaction generators to almost 400 published datasets. NUISANCE now has users from T2K, MINERvA, NOvA, DUNE, SBN, MicroBooNE, and the theory community, and is referenced by the Particle Data Group (PDG). I have also worked with theorists and phenomenologists to evaluate the effect of their models, and have implemented their models into neutrino interaction generators. I serve on the board of the Neutrino Scattering Theory Experiment Collaboration (NuSTEC), and convene the NuSTEC Workshops and Schools group. I co-organised the NuXTract workshop at CERN, the NuInt 2024 conference in Brazil, and a workshop at ECT* focussing on interpreting neutrino cross-section data. I have lectured on neutrino interactions and oscillations at the NuInt school and the 2024 CERN neutrino interaction summer school.

Supervision I supervised two undergraduate students at Rochester (V. Parrish, now postdoc at MSU; J. Elias, now PhD at Rochester) on fitting neutrino interaction models to published MINERvA data using NUISANCE. On T2K I have supervised half a dozen PhD students on the oscillation analyses, implementing new selections, and systematic uncertainty models. I have supervised MINERvA PhD students on implementing alternative interaction models, and working with NUISANCE to make multi-generator predictions for publications.

Peer review I am an active reviewer for Physical Review D and European Physics Journal C.

Selected publications and notes

Publications "Constraint on the Matter-Antimatter Symmetry-Violating Phase in Neutrino Oscillations", *T2K collaboration*, Nature 580, 339-344 (2020). Contribution: near-detector analyser, developed interaction model and bias studies.

"First Joint Oscillation Analysis of Super-Kamiokande Atmospheric and T2K Accelerator Neutrino Data", *T2K and SK collaborations*, Phys.Rev.Lett. 134 (2025) 1, 011801. Contribution: Convener of analysis, developed interaction model, near-detector analysis, neutrino oscillation model.

"Measurements of neutrino oscillation parameters from the T2K experiment using 3.6×10^{21} protons on target", *T2K collaboration*, Eur.Phys.J.C 83 (2023) 9, 782. Contribution: chair of paper committee, convener of analysis, developed of interaction model and bias studies, near-detector analyser.

"Improved constraints on neutrino mixing from the T2K experiment with 3.13×10^{21} protons on target", *T2K collaboration*, Phys. Rev. D 103, 112008 (2021). Contribution: near-detector analyser, developed interaction model and bias studies.

"Long-baseline neutrino oscillation physics potential of the DUNE experiment", *DUNE collaboration*, Eur. Phys. J. C (2020) 80: 978. Contribution: developed interaction model, advised on analysis methods.

"Deep Underground Neutrino Experiment (DUNE), Far Detector Technical Design Report, Volume II: DUNE Physics", *DUNE collaboration*, FERMILAB-PUB-20-025-ND (2020). Contribution: developed interaction model, advised on oscillation analysis methods.

"NUISANCE: a neutrino cross-section generator tuning and comparison framework", *P. Stowell et al.*, JINST 12 P01016 (2017). Contribution: developer of framework and original idea, significant contributions to writing of paper.

"Theory of QED radiative corrections to neutrino scattering at accelerator energies", *O. Tomalak et al.*, Phys.Rev.D 106 (2022) 9, 093006. Contribution: used theory calculations to produce predictions against external data and contributed to section of paper.

"Comparisons and challenges of modern neutrino-scattering experiments", *M. Buizza Avanzini et al.*, Phys.Rev.D 105 (2022) 9, 092004. Contribution: generated, organised and studied multiple interaction generator predictions. Wrote significant parts of paper, and developed the goals of studies.

"A substandard candle: the low-ν method at few-GeV neutrino energies", *C. Wilkinson et al.*, Eur.Phys.J.C 82 (2022) 9, 808. Contribution: developed original idea, wrote significant parts of paper.

"Tuning the GENIE Pion Production Model with MINERvA Data", *P. Stowell et al.*, Phys. Rev. D 100 072005 (2019). Contribution: developed original idea, validated study, wrote the paper, and collaborated with MINERvA to publication.

"Nucleon binding energy and transverse momentum imbalance in neutrino-nucleus reactions", *MINERvA collaboration*, Phys. Rev. D 101, 092001 (2020). Contribution: significant role on review committee, and proposed follow-up studies.

"Measurement of the axial vector form factor from antineutrino-proton scattering", *MINERvA collaboration*, Nature 614 (2023) 7946, 48-53. Contribution: Reviewer on MINERvA, suggested improvements during development, validated data release, multi-generator comparisons.

"Using world charged pion–nucleus scattering data to constrain an intranuclear cascade model", *E. S. Pinzon Guerra et al.*, Phys. Rev. D 99, 052007 (2018). Contribution: oversaw work on T2K, worked with analyser to test and implement analysis on T2K, contributed to paper writing.

Misc. "Behind the Paper: CP-violation in Neutrino Oscillations", Nature—On Your Wavelength (2020). Contribution: committee chair and T2K contact person.

Selected talks and posters

Conferences NuInt (Sao Paolo, 2024)): "Impact of neutrino interaction uncertainties on oscillation measurements" and "NUISANCE and global fits".

Exploring the Dark Side of the Universe (Ile de Noirmoutier, 2024): "Challenges in multi-experiment neutrino oscillation analyses".

NuInt (Seoul, 2022): "Constraining the neutrino interaction model using near detector data in the T2K experiment" and "Status of NUISANCE".

NuFact (Cagliari, 2021): "Neutrino interaction modelling and uncertainties for T2K analyses".

HEP Software Foundation, generator tuning (Online, 2023): "Neutrino interaction generator tuning and data analysis.".

NuSTEC, Neutrino-Nucleus Pion Production in the Resonance Region (Pittsburgh, 2019): "Impact of Neutrino-Nucleus Scattering Measurements on Resonance Modeling".

Tensions in Neutrino-Nucleus Scattering (Pittsburgh, 2019): "Tuning the GENIE interaction model to MINERvA single pion production data" and "Constraining systematics at T2K with near detector data".

NuFact (Blacksburg, 2018): "The Role of Cross Sections in the Oscillaton Analysis: The T2K Experience" and "Recent Cross Section Results from the T2K Experiment".

MINERvA+NOvA meeting (FNAL, 2018): "Comparing the MINERvA and NOvA nominal and tuned models with NUISANCE".

T2K+NOvA meeting (FNAL, 2018): "Comparing the T2K and NOvA nominal and tuned models with NUISANCE", "The T2K ND280 and SK acceptance maps" and "Selections entering T2K oscillation analyses at ND280 and SK".

NuInt and State of the Nu-tion workshop (Toronto, 2017): "NUISANCE, a framework for comparing and fitting neutrino interaction generators".

Schools NuSTEC summer school (CERN, 2024): "Impact of neutrino interaction uncertainties on oscillation measurements".

NuInt school (Sao Paolo, 2024): "Comparing neutrino interaction generators to each other and data, interactive practicum".

Seminars Los Alamos National Laboratory (2022); University of Chicago (2021); Caltech (2020): "Recent results from the Tokai-to-Kamioka (T2K) experiment".

Fermilab Neutrino Seminar Series (2019): "Neutrino interaction uncertainties in the GeV region: Past, Present, and Future".

Posters Neutrino (Online, 2022): "Sensitivity studies for the joint analysis of SK atmospheric and T2K accelerator neutrino oscillations", "Atmospheric oscillation probability calculation for the SK+T2K joint oscillation analysis", and "Developing the joint interaction and detector systematics in the SK+T2K joint oscillation analysis".

US-Japan Symposium on High Energy Physics (Honolulu, 2019): "Progress on the joint NOvA-T2K oscillation analysis".

NuInt (Toronto, 2017): "NUISANCE, NeUtrino Interaction Synthesiser Aggregating Constraints from Experiments".

Awards and Scholarships

Royal Society Univeristy Research Fellow: awarded 1.8M GBP eight year research programme. ECT* conference: awarded 13.9k EUR in 2024 to host workshop. Robert Marshak Fellowship: Awarded by the University of Rochester to support young scientists to pursue innovative research. Institute of Physics, NuInt: funded to present talk and poster on NUISANCE. NVIDIA GPU grant: to support promising GPU development. Stiftelsen Nya Gyllensteen, Stiftelsen AAA, Willinska Stiftelsen, Felix Neuberghs stipendiefond: awarded for academic merit at UCL and to encourage futher study.

Computing

Languages Developer experience in C, C++, Fortran, CUDA, python, bash. Formal training in C++ and CUDA. Frequent user of javascript, html5, and Arduino IDE.

Accelerators Developer of OpenMP accelerated code for multi-threaded applications. Implemented CUDA and OpenMP in oscillation analysis framework on T2K. Rudimentary use of OpenACC for GPGPU applications. OpenMP and CUDA implementations on T2K reduced analysis times by $\times 14$.

HEP tools Experienced user of neutrino interaction generators NEUT, GENIE, and NuWro. Developer of the NEUT generator, experience in model development, and Monte Carlo methods. Experienced user of GEANT4 and edep-sim for detector design, using GDML geometries. Experienced user of the ROOT and CERNLIB libraries.

Profilers, debuggers Frequent user of debuggers such as gdb and cuda-gdb. Extensively used optimisation profilers like valgrind, gperftools, and the NVIDIA visual profiler. Implemented Continuous Integration/Development (CI/CD). Administration tools: nagios, ansible, puppet.

Others Deployed, benchmarked and maintained frameworks on world-leading super-computing clusters, such as ORNL Frontier and Summit, NERSC Cori and Perlmutter, and the Digital Research Alliance of Canada clusters. Experienced git, svn, and cvs user. Experienced Debian Linux and Windows user. Experienced LaTeX user. Experienced Arduino and Rapsberry-pi user.

Education

10/2014 — 07/2018

Experimental High Energy Physics, PhD, *Imperial College London*.

Studied neutrino interaction modelling and using the near detectors on T2K to minimise uncertainties in the oscillation analyses. On-site ECal expert for the ND280 detector during my stay in Japan. Funding provided through the UK Science and Technology Facilities Council (STFC), Institute of Physics (IoP), and NVIDIA.

PhD thesis

Title *Neutrino Oscillations, Near-detector Fitting and Interaction Physics at T2K*

Supervisor Dr. M. O. Wascko

Description **Near-detector analysis for the neutrino oscillation group:** My PhD thesis provided oscillation analyses at T2K with constraints on systematics using external and near detector neutrino data. The analysis was fully adopted by T2K's 2018 oscillation analysis, published in Nature. I was responsible for the near-detector analysis, which reduced uncertainty on neutrino event rates at SK from 14% to 4%. I also made substantial improvement to the framework in terms of efficiency and methodology.
External neutrino scattering data: I investigated the current models' ability to predict published data and provided updated constraints on single pion production parameters for T2K. This machinery grew into the NUISANCE project.
Generator development: I extensively worked with M. Kabirnezhad implementing a single pion production model for T2K and SK. I also extended the existing Rein-Sehgal implementation.
Detector experience and hardware: I was assigned ECal expert for the T2K ND280 detector during my long-term stay in Japan. I was supported with hardware from NVIDIA.

Teaching and outreach

Supervision I supervised three Master's students during my PhD, working on evaluating methods of neutrino energy reconstruction in a high pressure time projection chamber for DUNE.

Outreach Organised student seminars and "coders club" events for the Imperial HEP group. Volunteered for Royal Society's LHCb and ALPHA "anti-matter matters" stall at the Imperial College Festival. Local helper for Neutrino 2016.

09/2010 — 06/2014

Theoretical Physics, MSci., *University College London*, *First class Hons.*.
Thesis on global neutrino oscillation fits. Focus on high energy physics and cosmology.

Master's thesis

Title *Determining the Neutrino Mass Hierarchy from Global Neutrino Oscillation Experiments*

Supervisors Prof. J. Thomas, CBE

Description I developed a custom three flavour neutrino oscillation fitter, used to perform joint fits and sensitivity studies with public neutrino oscillation data from reactor (Daya Bay, RENO, Double Chooz, KamLAND) and accelerator (MINOS, T2K) experiments to study the neutrino mass hierarchy. I assisted in PMT R&D for the CHerenkov detectors In mine PitS experiment (CHIPS).