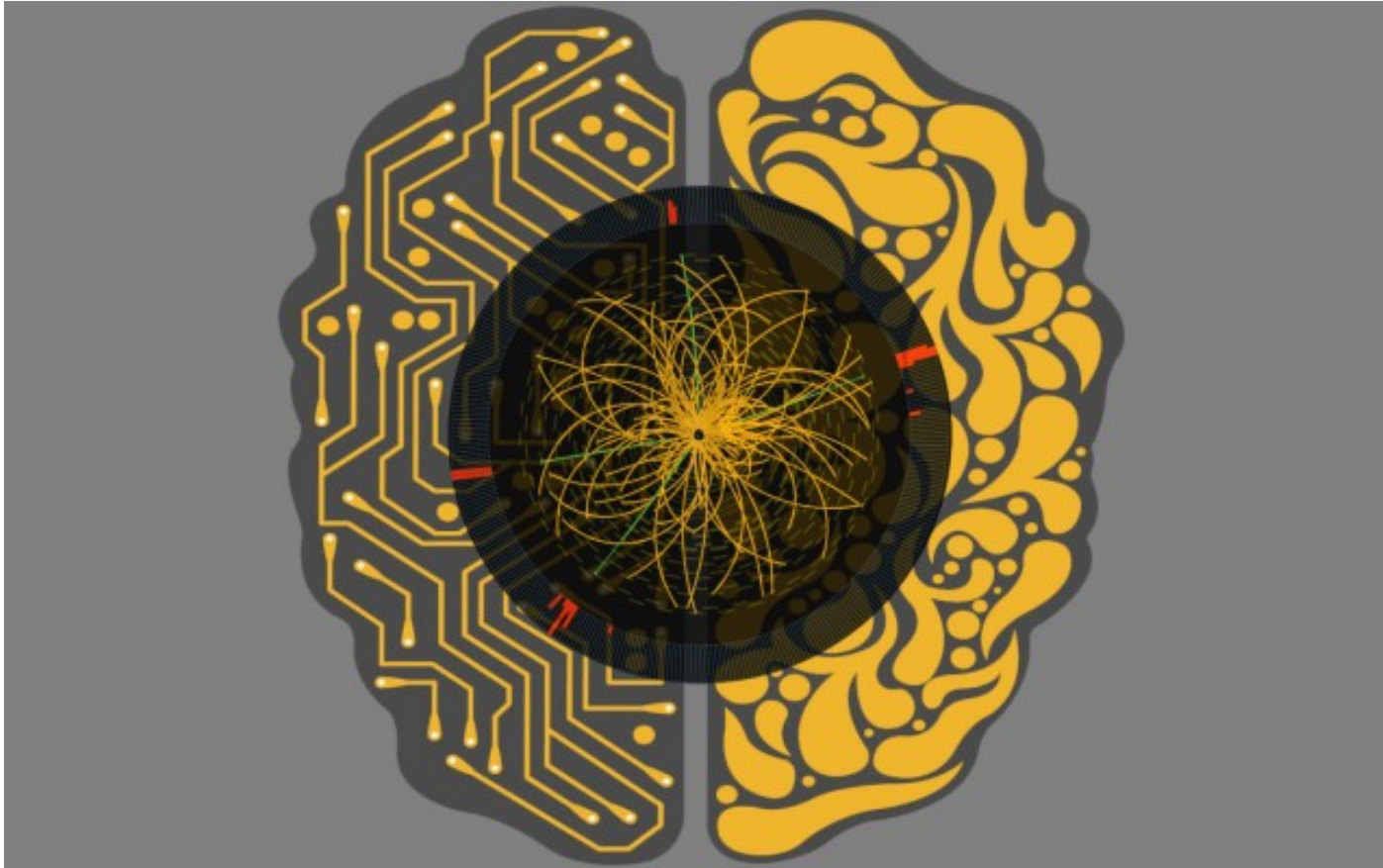


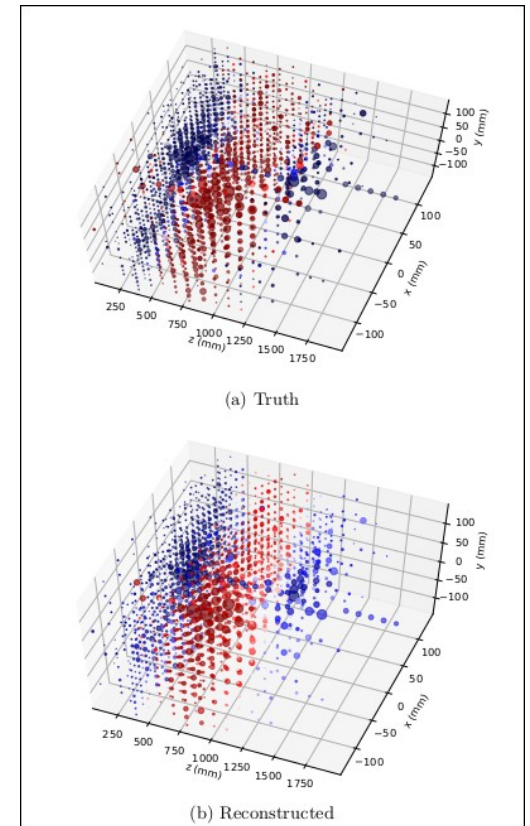
Machine Learning @



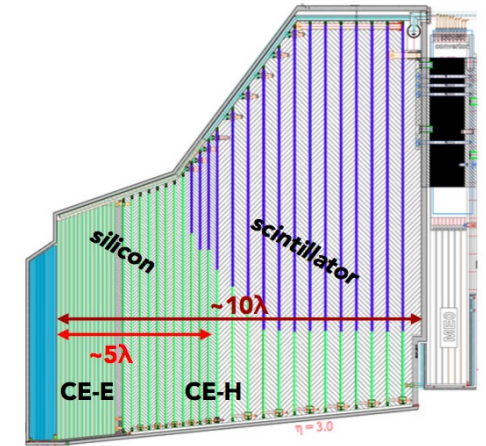
F. Magniette on behalf of LLR ML Group

The ML Group

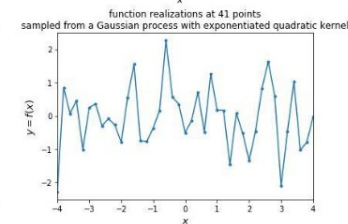
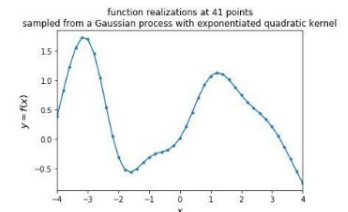
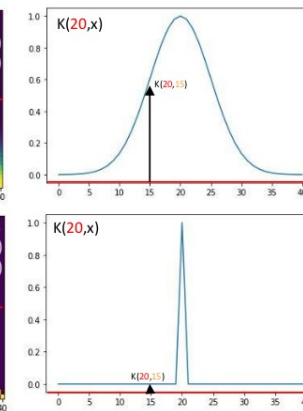
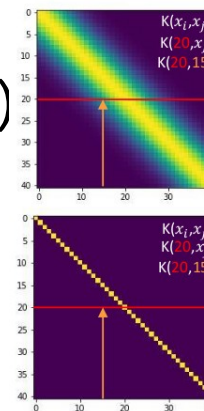
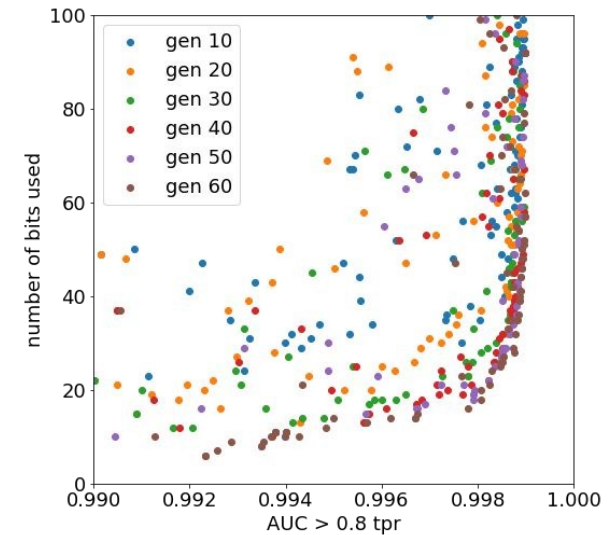
- Mixed group of ~15 persons (Researchers, Engineers, Students)
- Regular meetings (every 2 weeks)
- Directed by Jean-Baptiste Sauvan
- Lectures, exchange sessions, work meetings, seminars (Jan Kieseler CERN, Denis Lacroix IJCLab...)
- CMS/HGCal, Super-K, Electronics and IT Groups
- Connection with CMAP (Applied mathematics X lab)



HGCAL L1 trigger primitives generation

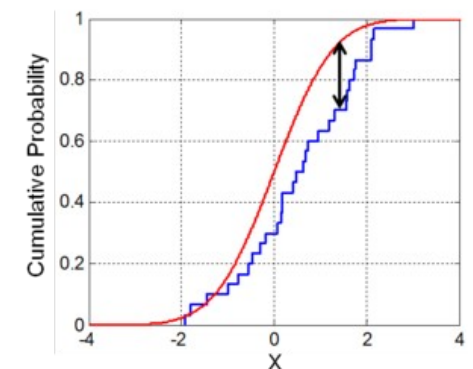
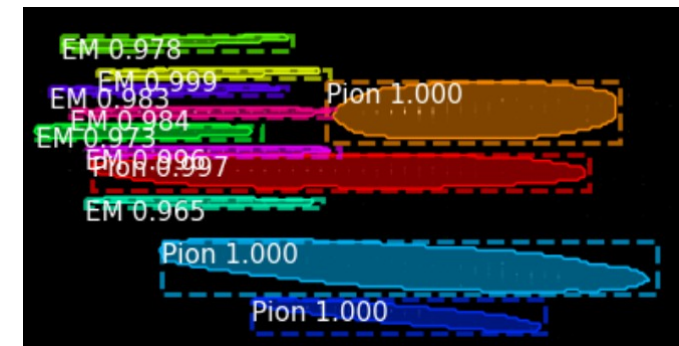
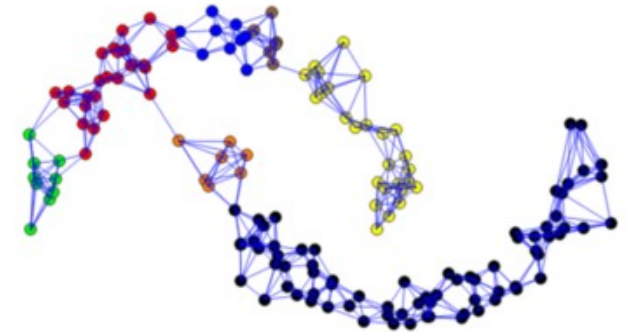


- Under supervision of Jean-Baptiste Sauvan for reconstruction and identification of energy clusters in HGCAL
- Alexandre Hamiki PhD (2019-) ANR HiGrants
 - DNN & BDT hyper-parameters optimization and comparison
 - Multi-objectives optimization (Genetic algorithms)
 - Pareto front: performance/resource tradeoff
- Elena Ferro internship (2020)
 - Bayesian optimization of hyper-parameters
 - Noise modelling (Kernel choice)
- Nived Puthumana Meleppattu (M1 Internship)
 - Differential programming for trigger algorithms
 - Calibration model
 - DNN integration in prospective



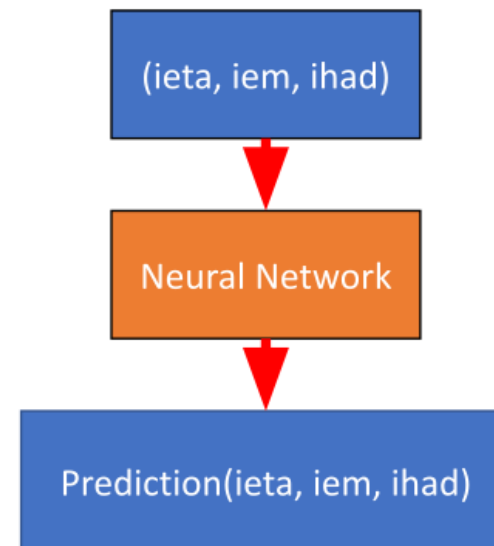
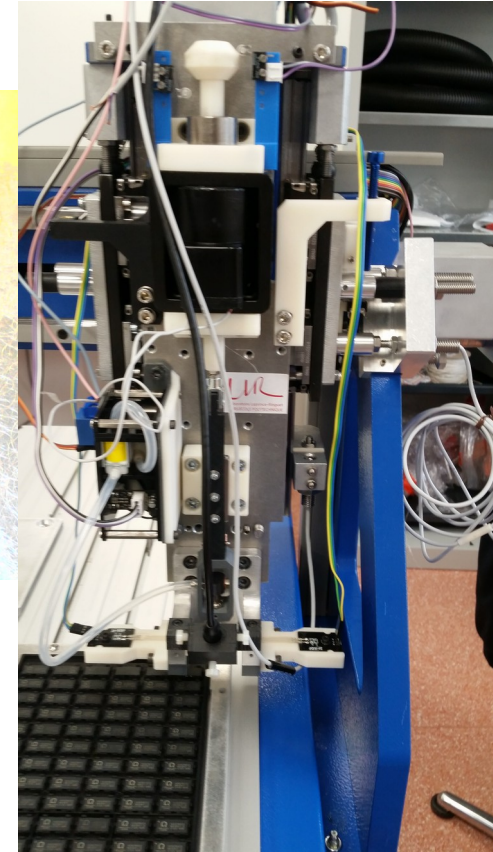
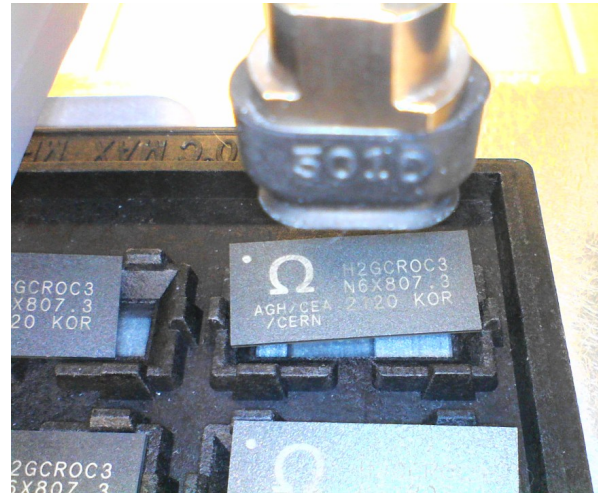
Offline HGCal

- Under supervision of Florian Beaudette
- Work of Shamik Ghosh (postdoc) and Alessandro Tarabini (PhD)
 - Electromagnetic vs Hadron showers classification with GNN (DGCNN)
 - Cleaning of EM showers
 - Integration in TICL
 - Intern supervision on HGCal simulation with GAN's (Pushkar Sharma)
- Work of Gilles Grasseau
 - Segmentation by Mask R-CNN model
 - Conference CHEP'19
 - Selected for funding by the Google Summer of Code program (through the HSF)
- Work of Arnaud Chiron
 - Simulation testing framework decision help system
 - Histograms comparison
 - Kolmogorov-Smirnov Test
 - Anomaly detection with auto-encoders



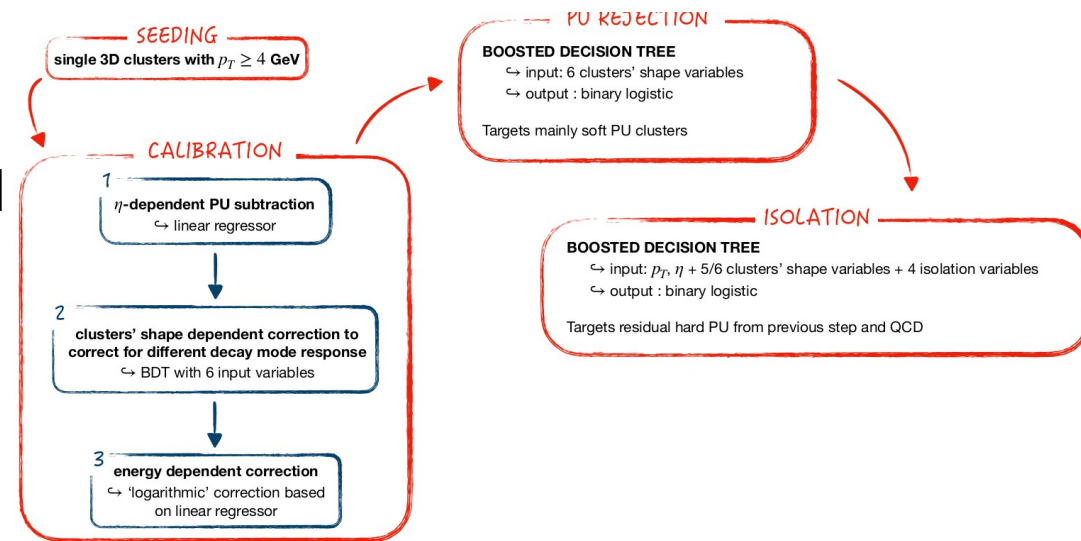
HGCal test robot & Trigger

- Under supervision of Olivier Davignon
- Work of Walid Daoud & Shamik Ghosh
 - Detection of mispositionned chips on the robot plateau
 - Camera acquisition
 - Convolutional networks
- Work of Théophile Le Clerc, Elena Vernazza & Jona Motta
 - Jet calibration @L1 with NN



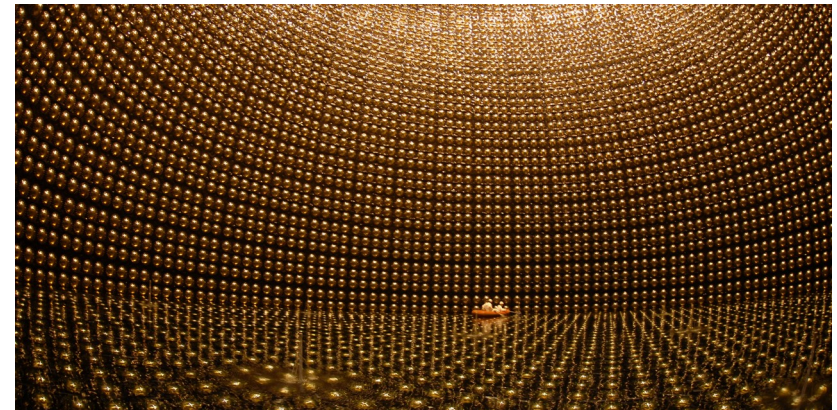
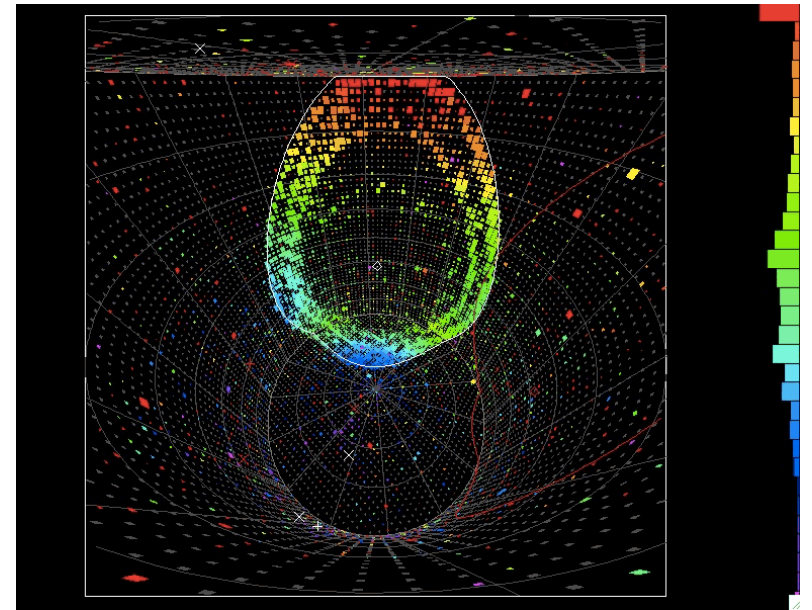
CMS L1 trigger with HGCAL data

- Under supervision of Alexandre Zabi
- Work of Jona Motta (PhD)
 - Tau reconstruction algorithm based on HGCAL data
 - BDT over interest variables (14)
 - Bayesian hyper-parameters optimization
 - FPGA transfer with Conifer
- Collaboration with Imperial College (with Alex Tapper)
 - 2 PhDs to start in 2022/2023 (1 LLR, 1 IC)
 - Integration of ML in the CMS L1 trigger



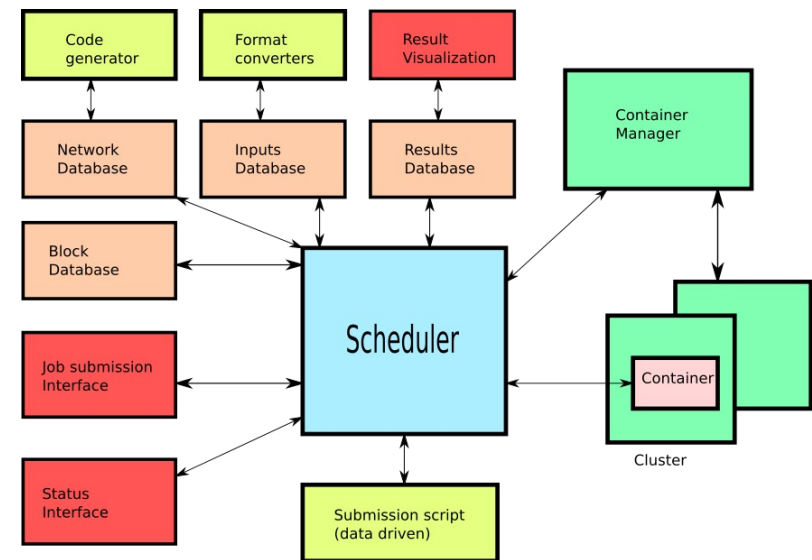
Super-Kamiokande

- Under supervision of Pascal Paganini
- Improve background rejection for lowering the energy cut (open the DSNB window)
- Work of Alberto Giampaolo (PhD) & Antoine Beauchêne (PhD)
 - Graph convolution tests
 - Simulations for classification DSNB vs background



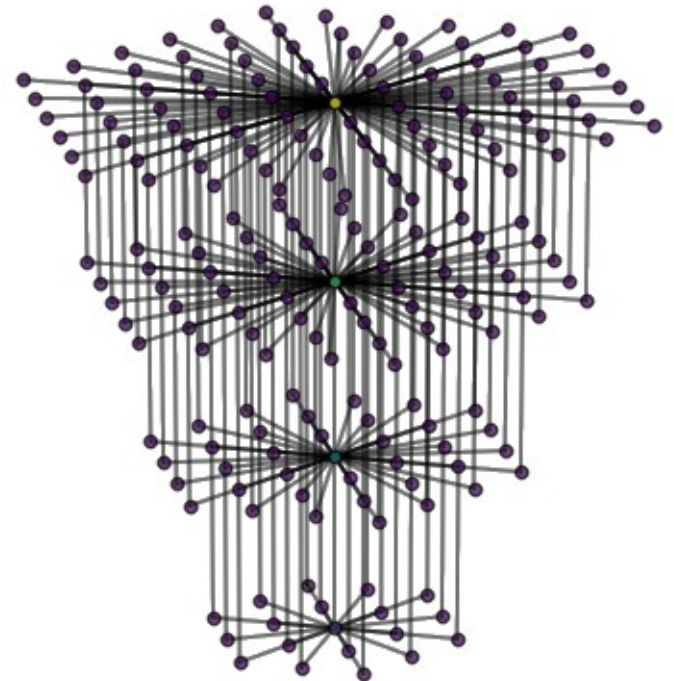
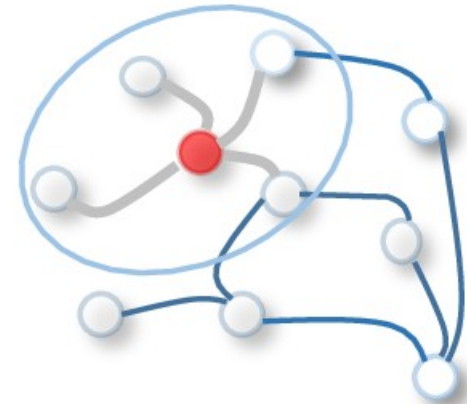
IT developments

- Under supervision of Frédéric Magniette
- Work of Frédéric Magniette, Alexandre Hakimi & Michael Mellin
 - Development of a training framework : Innate
 - Training distribution over a GPU cluster
 - Simplified syntax compatible with Keras & Pytorch
- Work of Anne Garcia & Michael Mellin
 - Administration of GPU cluster
 - Modules management (ML & QML)
- Work of Emilia Bechava
 - Production of ML dedicated simulations (HGCal like)



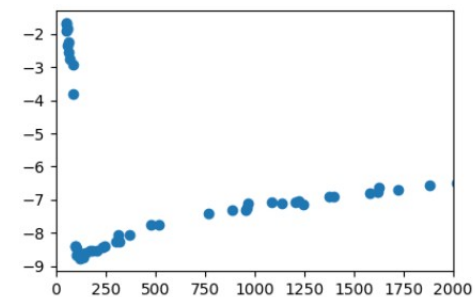
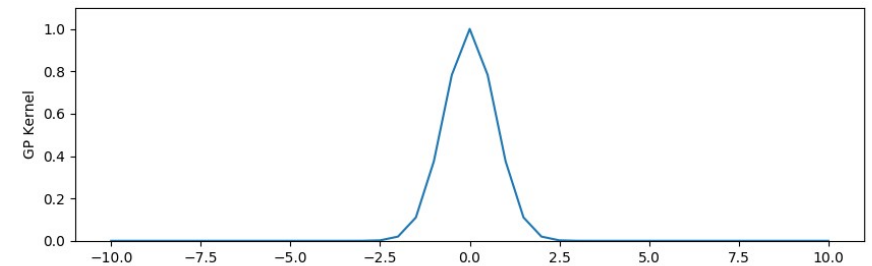
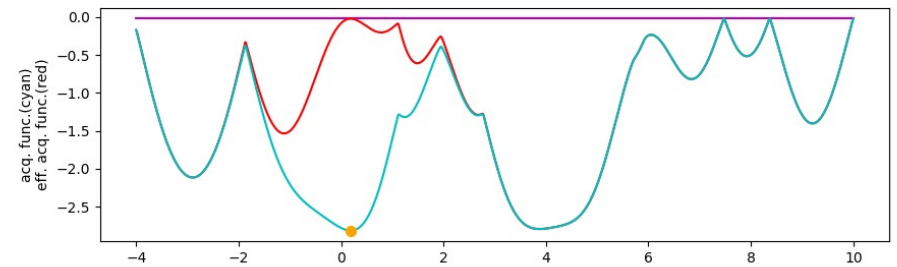
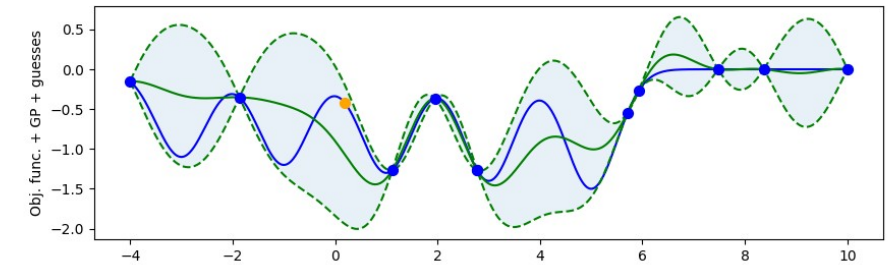
Graph convolution

- Under supervision of Frédéric Magniette
- Build a graph from hits with a dedicated rule
→ convolution
- Work by Frédéric Magniette (2020-21)
 - Optimized, symmetry aware, graph construction algorithm (DIRAD)
 - Electromagnetic particle classification by graph convolution
- Work by Michael Mellin (2021)
 - Energy regression with graph convolution
 - Comparison with quadratic regression
- Work by Mattéo Papin (School 42 Intership)
 - Framework development for graph building / convolution algorithms comparison



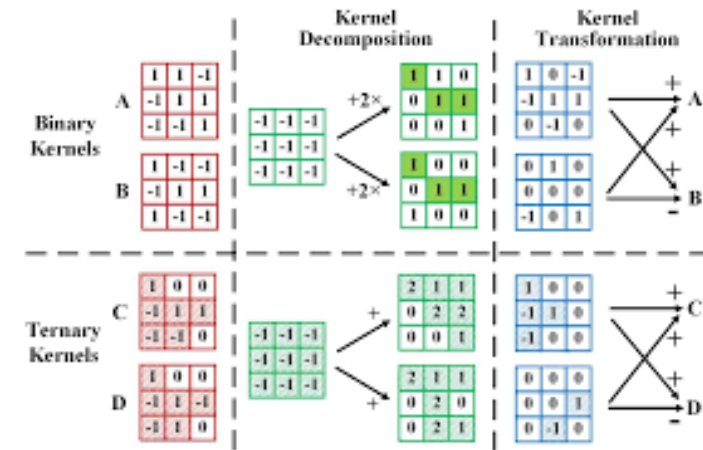
Bayesian Optimization

- Work of Frédéric Magniette
 - Development of a parallel bayesian optimization algorithm
 - Asynchronous version
 - Implementation in a distributable library
 - Performance study
 - Hyper-parameters optimization



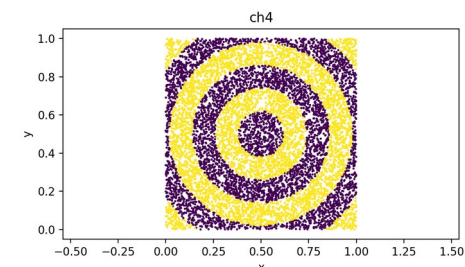
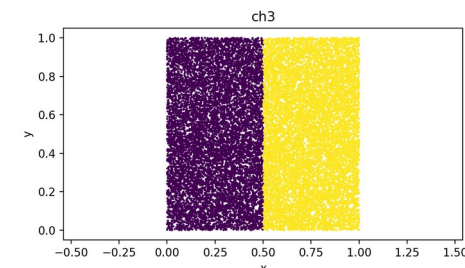
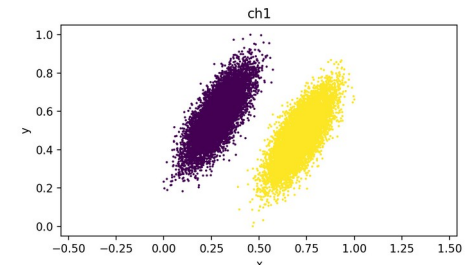
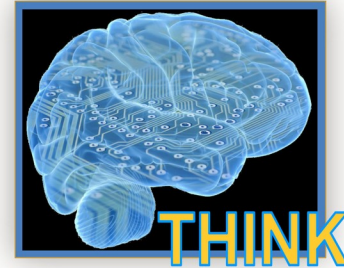
FPGA implementation

- Under supervision of Jean-Baptiste Sauvan
- Qkeras use for particle classification (EM/ pileup/Hadron)
- FPGA implementation with HLS4ML
- Work of Elena Ferro
 - Quantization performance impact studies
 - CNN on raw data
- Collaboration with Split University
 - Dense MLP on raw data (2021-22)



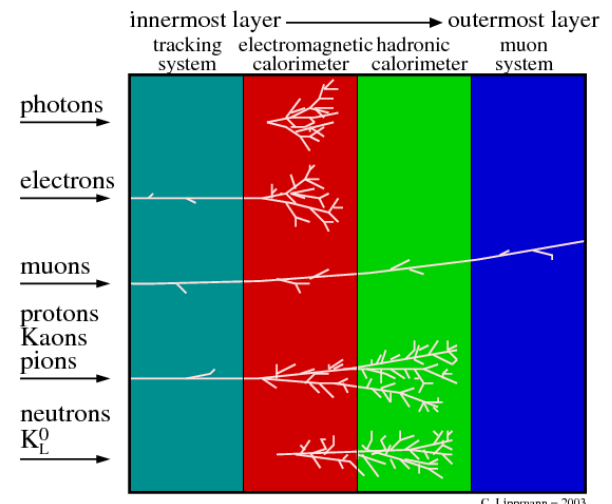
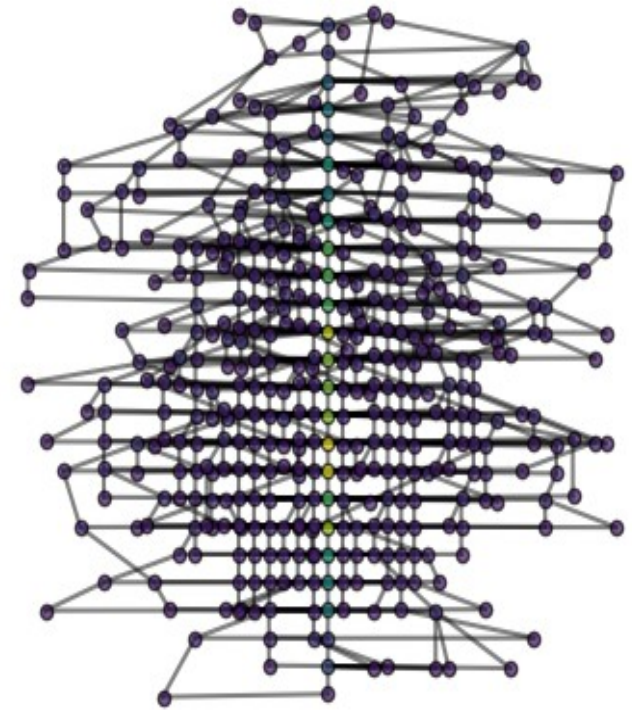
THINK Group

- Multi-hardware DNN implementability study, under supervision of Jean-Pierre Cachemiche (CPPM)
- Participation of Jean-Baptiste-Sauvan & Frédéric Magniette
- Pytorch Lecture (F. Magniette)
- Quantization and FPGA implementation presentation (J-B. Sauvan)
- Parallel Bayesian optimization library
- 2D Challenges
- Collaboration with CPPM on ImXGam project (Yannick Boursier)



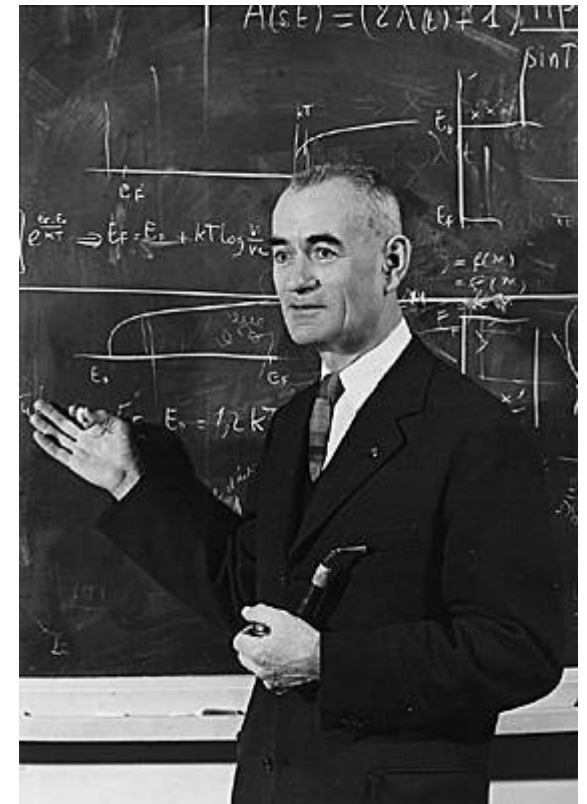
ANR OGCID

- Optimized Graph Convolution for particle Identification
- PI Frédéric Magniette
- Participation of F. Beaudette, J-B. Sauvan, P. Paganini, E. Becheva, F. Beaujean, S. Ghosh
- Joint study of graph building algorithm and graph convolution architecture
- Data simulations from Super-Kamiokande and HGCaI like
- Classification, regression, disentanglement
- Optimization, Quantization, FPGA implementation and Parallelization
- Open data and open-source codes



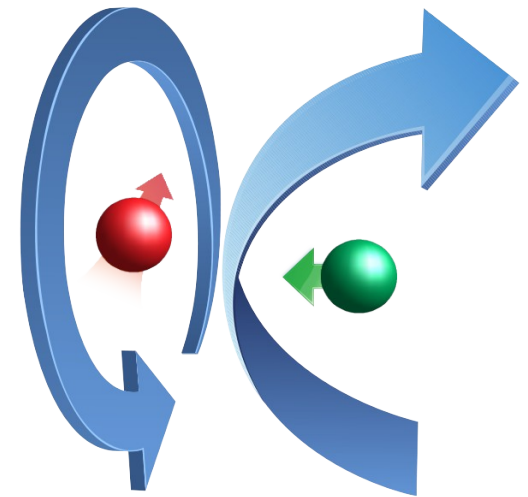
Lectures

- A lot of lectures has been developed for the ML Group (F. Magniette)
- Aggregated in a full course including practical sessions
 - Ecole des électroniciens of IN2P3 session
 - IJCLab session



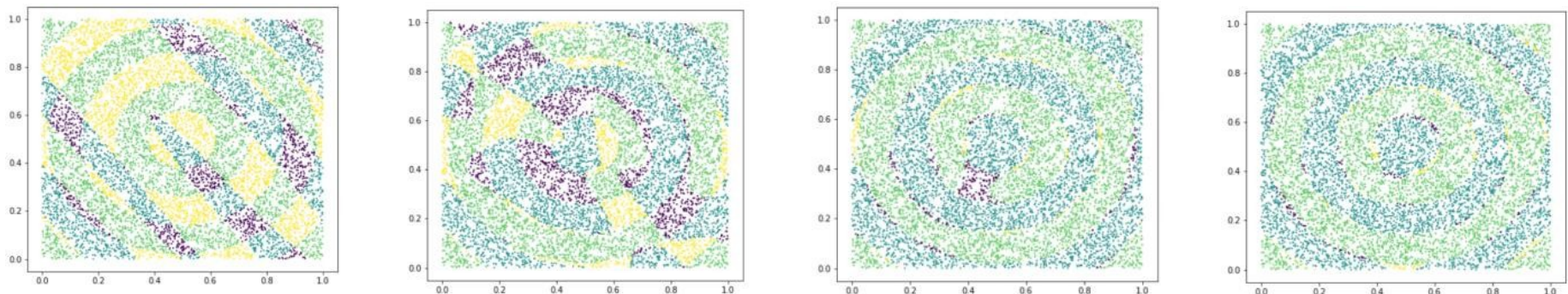
QC2I

- LLR is an active member of QC2I
- 6 members of QC2I @ LLR
- F. Magniette head of the QML
thematics (previously A. Sartirana)
- Interests in QML
 - QNN classifiers
 - Re-uploading techniques
 - Classical / quantum ML model
convergence
- <https://qc.pages.in2p3.fr/web/>



Re-uploading QNN Tests

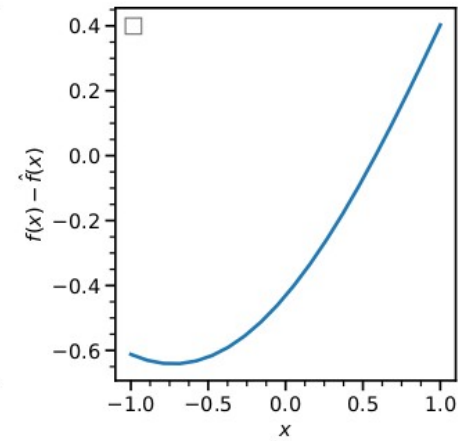
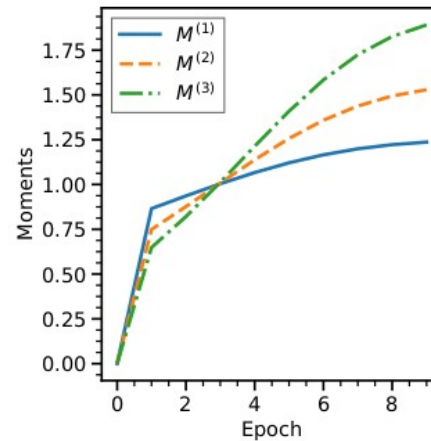
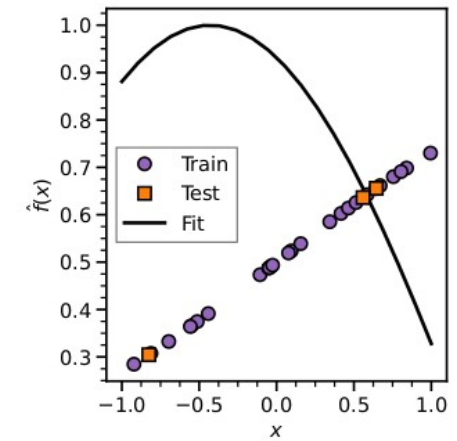
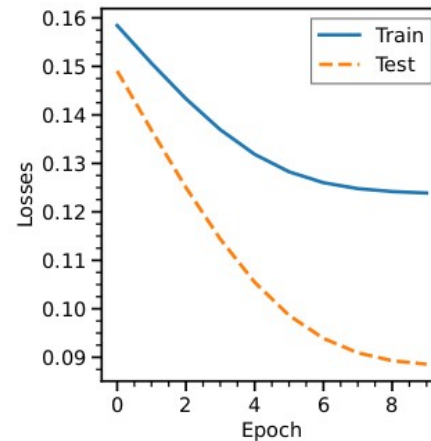
- Definition of benchmarks 1D,2D, 3D → binary classification (F. Magniette)
- Definition of physical benchmark (variables of interest from showers)
- Work of Andrea Sartirana, Frédéric Magniette and Yann Beaujeault-Taudière (Postdoc 21-23 LLR/IJCLab)
 - Simulation of re-uploading learning circuits on benchmarks
 - Very performant technique



TutoQML

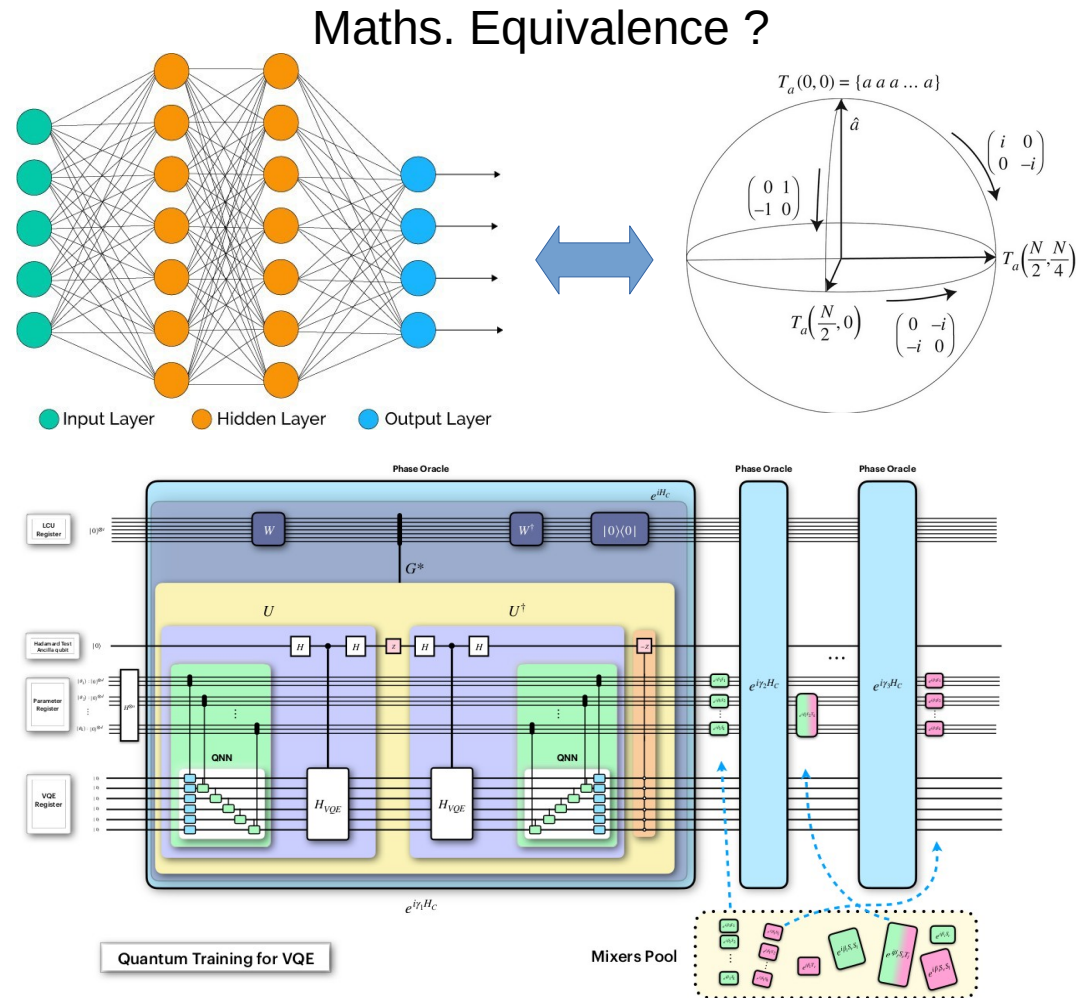


- Under supervision of F. Magniette and Denis Lacroix (IJCLab)
- P2IO Grant
- 2 year post-doc Yann Beaujeault-Taudiere (since 1st December 2021)
- Model expressivity testing framework on benchmarks

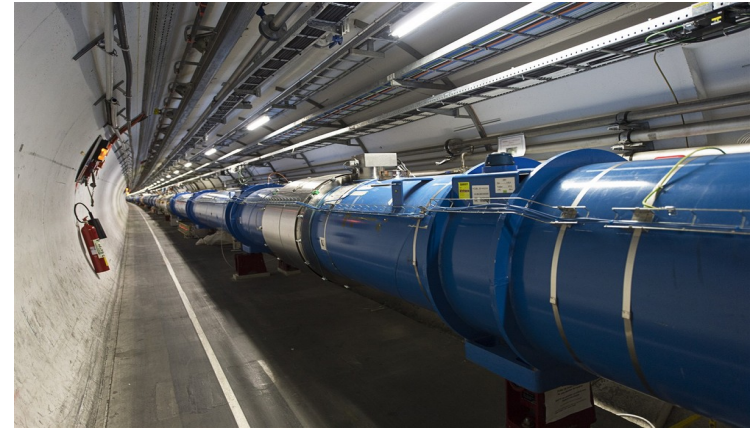


QML Theoretical works

- Under supervision of F. Magniette
- Theoretical work on QC/DNN models identification, Yann Beaujeault-Taudière. Results to publish
- Grover algorithm adaptation to QNN parameters optimization Mickael Zodros (ENS Rennes Internship)



Perspectives



- Ubiquity of the ML techniques inside the detectors and accelerators
- Develop specific adapted techniques for HEP
- Be ready for the QML revolution
- Build a common culture across the Physics and IT communities
- Integration of ML and QML in the teaching programs