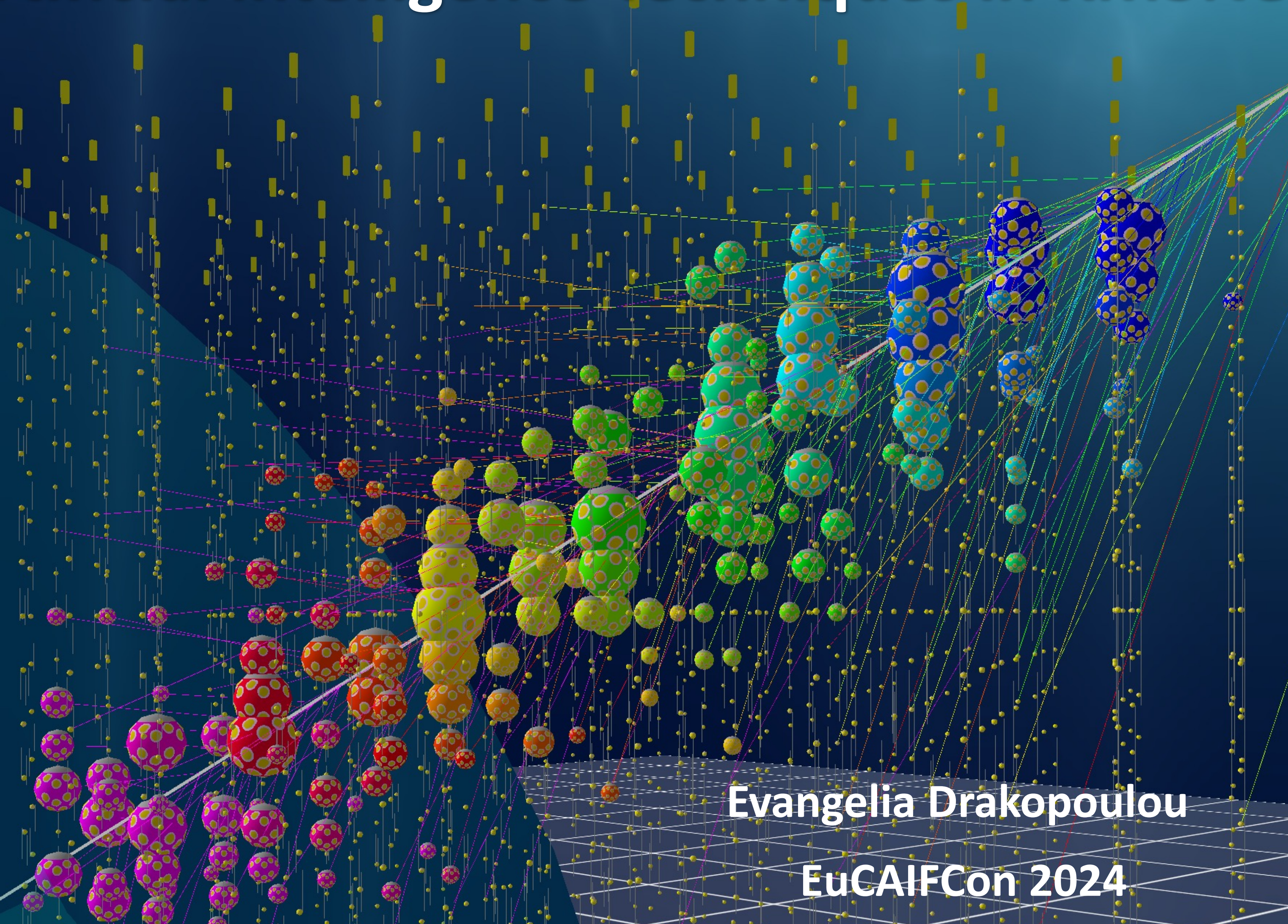




Artificial Intelligence Techniques in KM3NeT

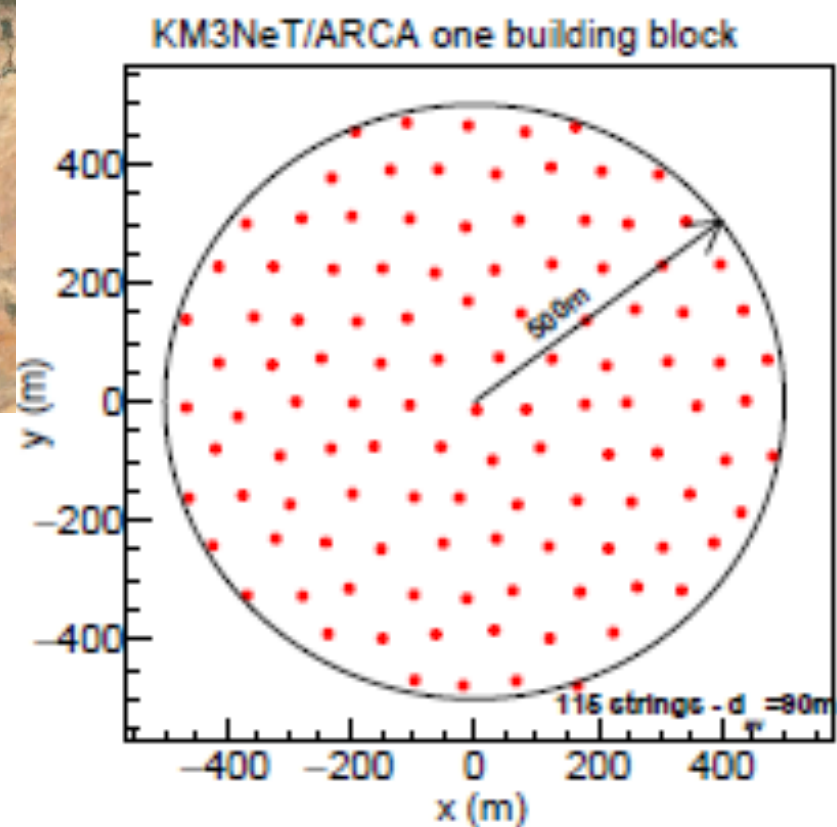


Evangelia Drakopoulou

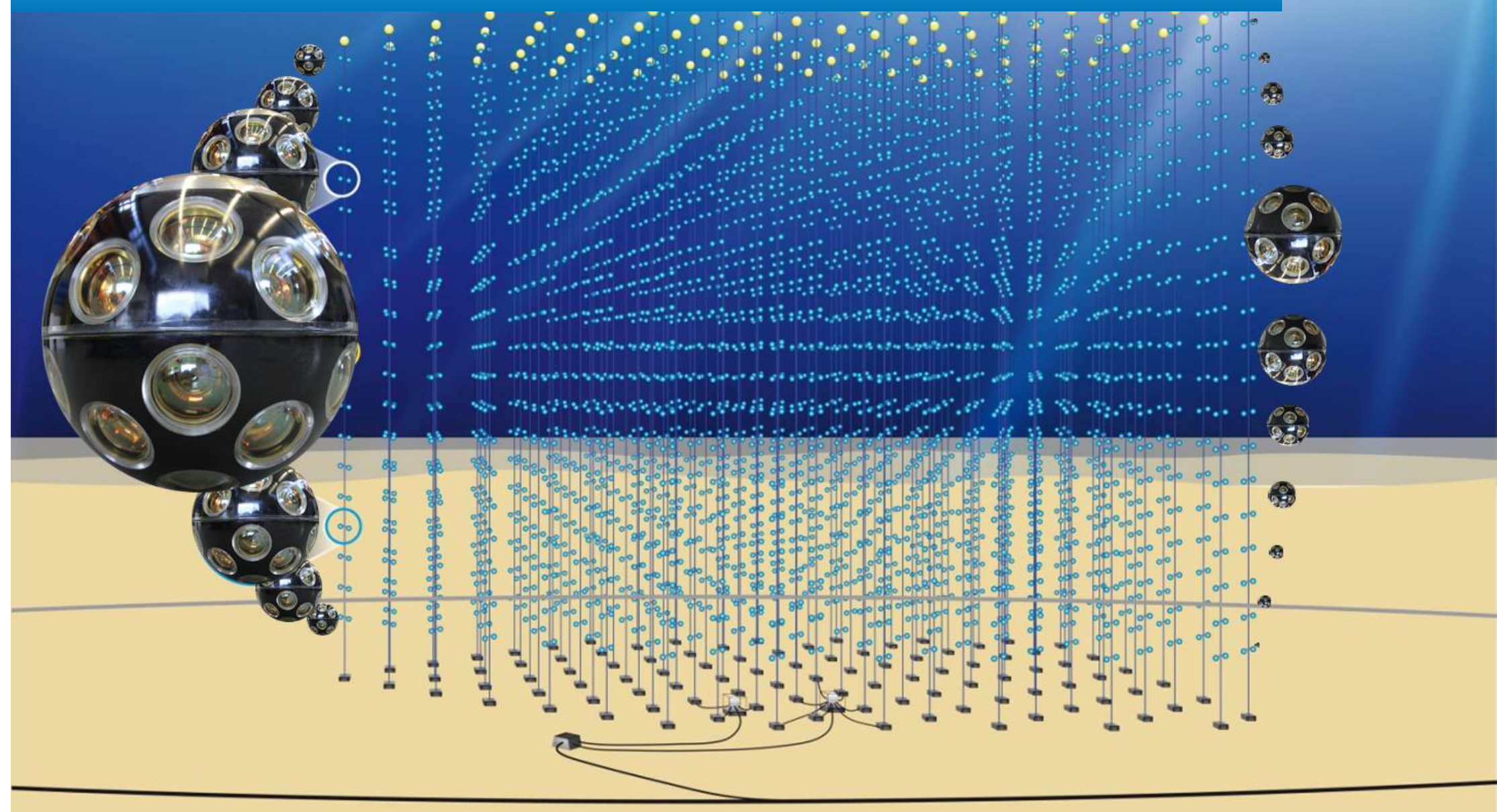
EuCAIFCon 2024



Identical technology for ARCA and ORCA



KM3NeT: an underwater neutrino telescope



ORCA

Particle Physics
Neutrino Oscillations
Mass Hierarchy

Currently 18 DUs deployed

2x

ARCA

Detection of neutrinos from astrophysical sources

Currently 28 DUs deployed



Detection Unit (DU)

Machine and Deep Learning Projects in KM3NeT (non exhaustive list)

GNNs:

- [Development of detector calibration and graph neural network-based selection and reconstruction algorithms for the measurement of oscillation parameters with KM3NeT/ORCA](#) (D. Guderian, PhD Thesis)
- [Data reconstruction and classification with graph neural networks in KM3NeT/ARCA6-8](#) (F. Filippini et al., PoS(ICRC2023)1194)
- [Cosmic ray composition measurement using Graph Neural Networks for KM3NeT/ORCA](#) (S. Reck, PhD Thesis)
- [Optimisation of energy regression with sample weights for GNNs in KM3NeT/ORCA](#) (B. Setter, MSc Thesis)
- [Tau neutrino identification with Graph Neural Networks in KM3NeT/ORCA](#) (L. Hennig, MSc Thesis)

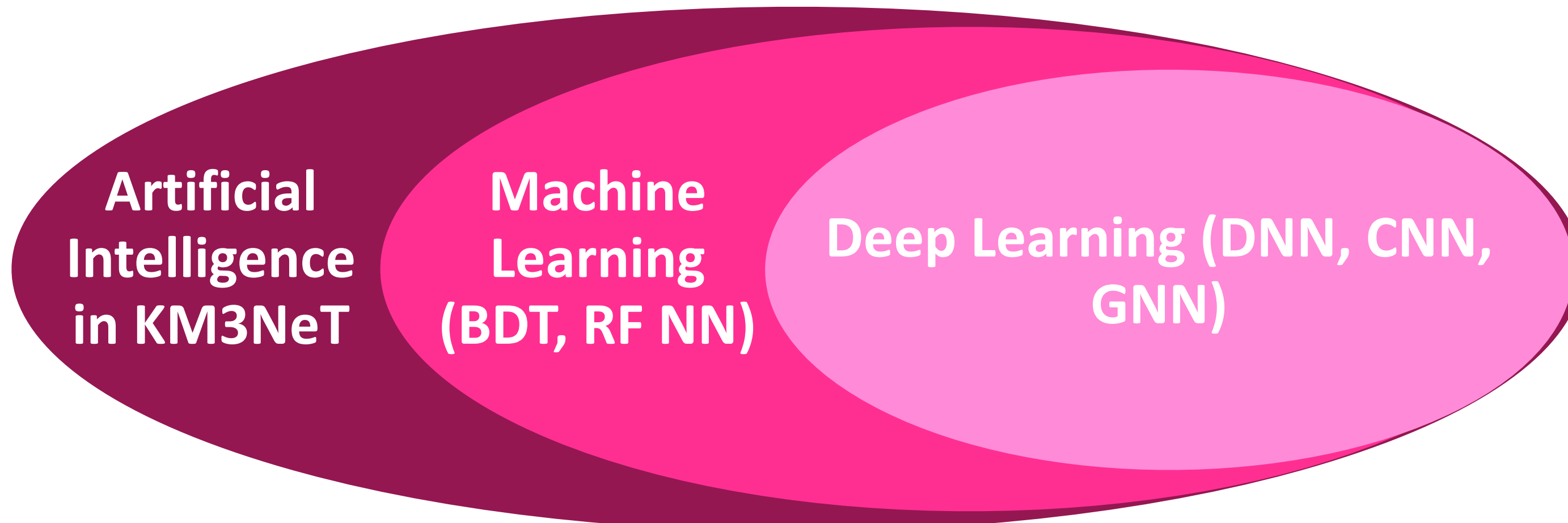
CNNs:

- [Event reconstruction for KM3NeT/ORCA using convolutional neural networks](#) (M. Moser, JINST 15 P10005)

Fully-connected NNs:

- [Deep Neural Networks for combined neutrino energy estimate with KM3NeT/ORCA6](#) (S. Peña Martínez, PoS(ICRC2023)103)

and several Machine Learning-based projects (e.g. BDTs, RFs) as part of online and offline physics analyses ...



Artificial Intelligence techniques in KM3NeT
Evangelia Drakopoulou on behalf of the KM3NeT Collaboration

Abstract: KM3NeT is a research infrastructure housing two underwater Cherenkov telescopes located in the Mediterranean Sea. It consists of two configurations which are currently under construction: ARCA with 230 detection units corresponding to 1 cubic kilometre of instrumented water volume and ORCA with 115 detection units corresponding to a mass of 7 Mton. The ARCA (Astroparticle Research with Cosmics in the Abyss) detector aims at studying neutrinos with energies in the TeV-PeV range coming from distant astrophysical sources, while the ORCA (Oscillation Research with Cosmics in the Abyss) detector is optimised for atmospheric neutrino oscillation studies at energies of a few GeV. Artificial intelligence is increasingly used in KM3NeT for data processing and analysis, aiming to provide a better performance on event reconstruction and significantly faster inference times compared to traditional reconstruction techniques. Classical machine learning algorithms, mainly decision trees for event-type classification, have been in use since the beginning of the project. These have been followed by deep learning algorithms such as Convolutional Neural Networks (CNNs) and recently Graph Neural Networks (GNNs), which have been successfully employed for event classification and neutrino property regression tasks. In this contribution, the artificial intelligence techniques used in KM3NeT, the advances in the various physics analyses as well as the impact on the physics reach of KM3NeT detectors will be presented.

Artificial Intelligence Techniques
Machine and Deep Learning techniques are extensively used in KM3NeT for the discrimination between signal and background events, the distinction between different event topologies (classification) and for the reconstruction of the particle vertex, direction and energy (regression).

Graph Neural Networks (GNNs)
Graph Representation:

- Each hit is one vertex in the graph
- Each vertex has connections to its k nearest neighbours
- Distance between vertices A and B measured by Euclidean distance

KM3NeT uses GNNs based on ParticleNet, the OrcaNet.

Direction Reconstruction for ARCA6 (with 6 DUs)
Muon bundle multiplicity reconstruction

Convolutional Neural Networks (CNNs)
CNNs based on TensorFlow were explored first for event classification and neutrino property regression tasks for ORCA.

Boosted Decision Trees (BDTs)
A BDT from the TMVA package is used to discriminate the signal (muon (anti)neutrinos) from background (atmospheric muons) events.

Summary

- KM3NeT/ARCA and KM3NeT/ORCA are currently under construction.
- A plethora of Machine and Deep Learning techniques have been successfully used for event classification and neutrino property regression tasks for both the full geometry of KM3NeT detectors with 115 detection units and the partial geometries with the first detection units deployed.
- Results of the Artificial Intelligence-based algorithms are promising.