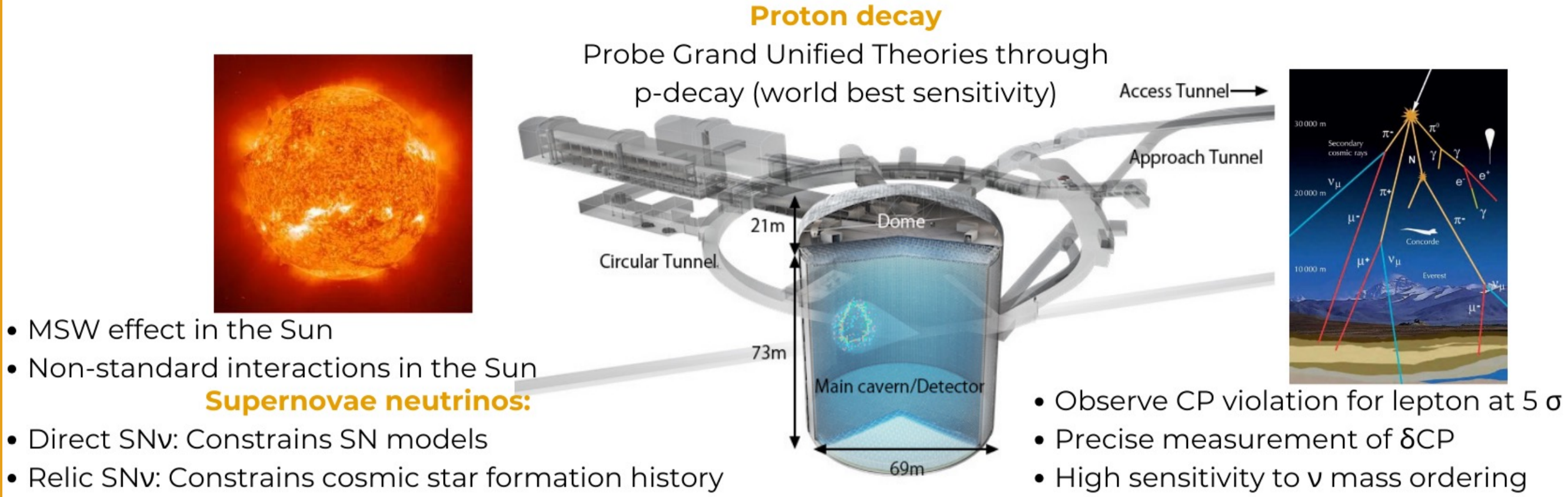


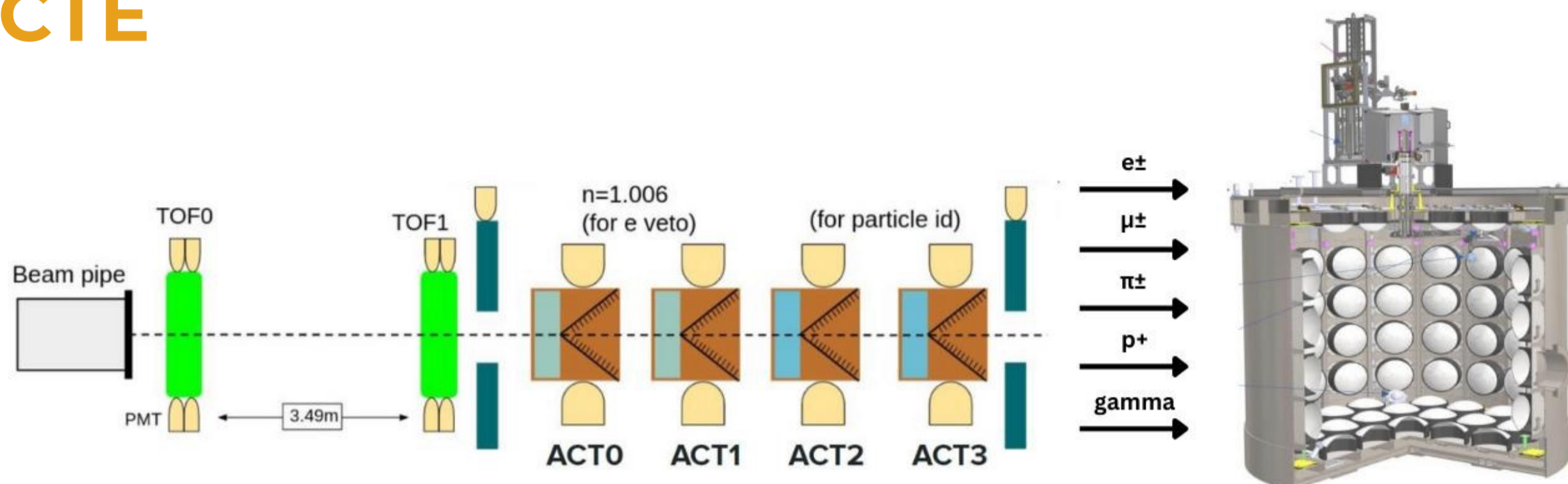
Introduction

The Hyper-Kamiokande experiment



	SK	HK
Site	Mozumi	Tochibora
Overburden	2700 m.w.e.	1700 m.w.e.
Number of ID PMTs	11129	20000
Photo-coverage	40%	20% (x2 efficiency)
Mass/Fiducial mass	50 kton / 22.5 kton	258 kton / 186 kton
Beam power	500 kW to 1 MW	1.3 MW

WCTE



Goals: to serve as a proof of technology and physics for Hyper-Kamiokande: measure important physical processes for water Cherenkov detectors: charged pion hadronic scattering, secondary neutron production, and Cherenkov light production from secondary particles. **Unique dataset for testing ML algorithms on the well-controlled data.**

Timeline:

- **Late 2024:** WCTE beam data-taking
- **2025:** gadolinium loading

Simulation

	WCTE	Hyper-Kamiokande
Energy	200-1000 MeV	100-1000 MeV
Direction	Isotropic	Isotropic
Position	Center of WCTE	Isotropic inside the detector

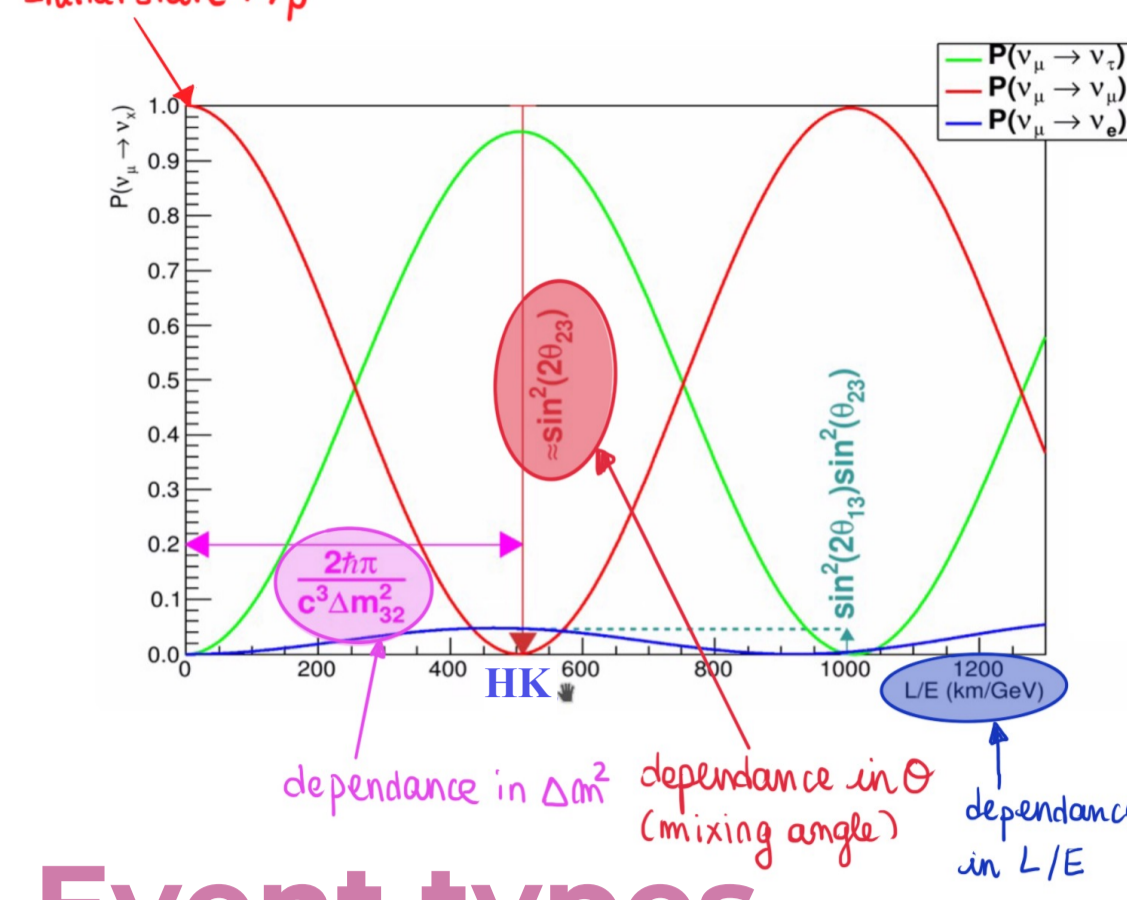
Enhanced Event Reconstruction at Hyper-Kamiokande and WCTE using Graph Neural Networks

on behalf of the Hyper-Kamiokande and WCTE collaborations:
Anna Ershova and **Christine Quach**
Laboratoire Leprince-Ringuet
CNRS-IN2P3 / Ecole polytechnique

GRANT software

The stakes behind reconstruction

Initial state: $\nu_\mu \rightarrow \nu_e$ Measure δCP : detect electron neutrino events



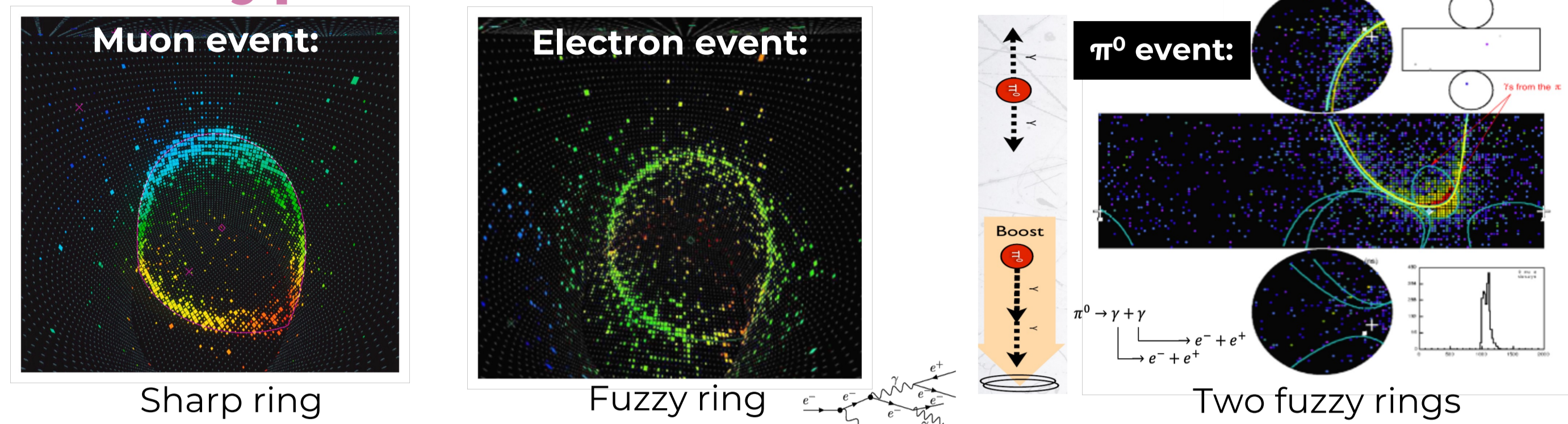
Variables to reconstruct:

- Energy
- Direction
- Vertex
- Particle identification
 - e^-/μ^-
 - e^-/π^0

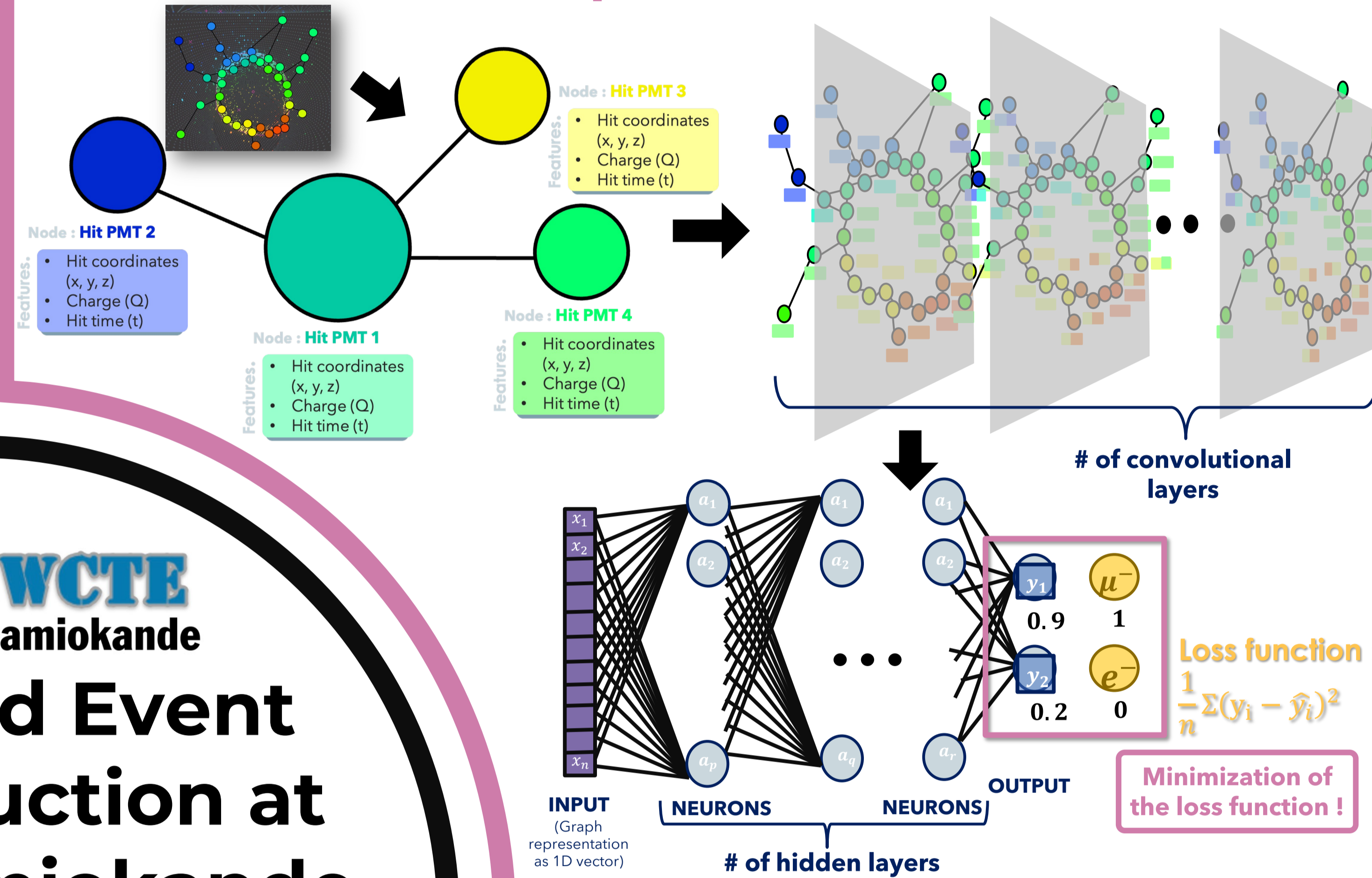
Background sources:

- Muon neutrinos
 - Cosmic ray muons
 - π^0
- ($\nu + N \rightarrow \nu + N + \pi^0$)

Event types

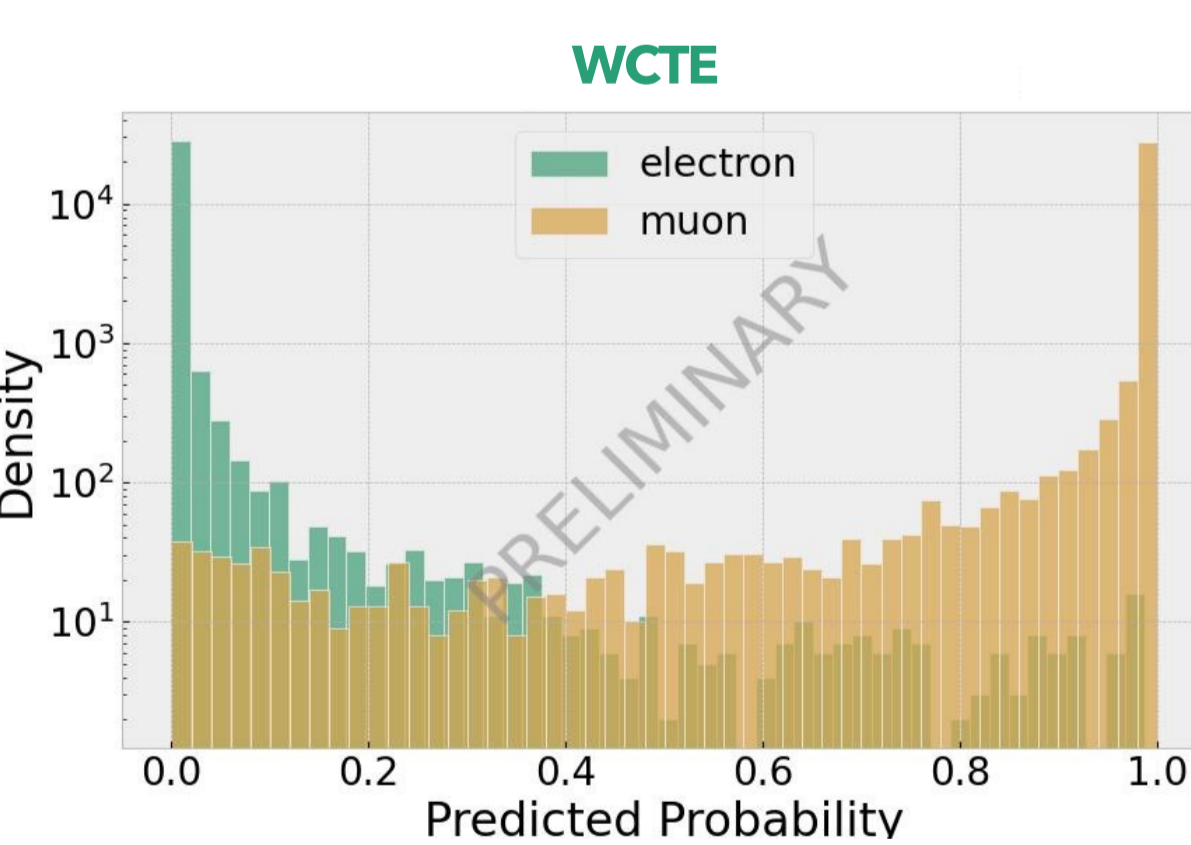
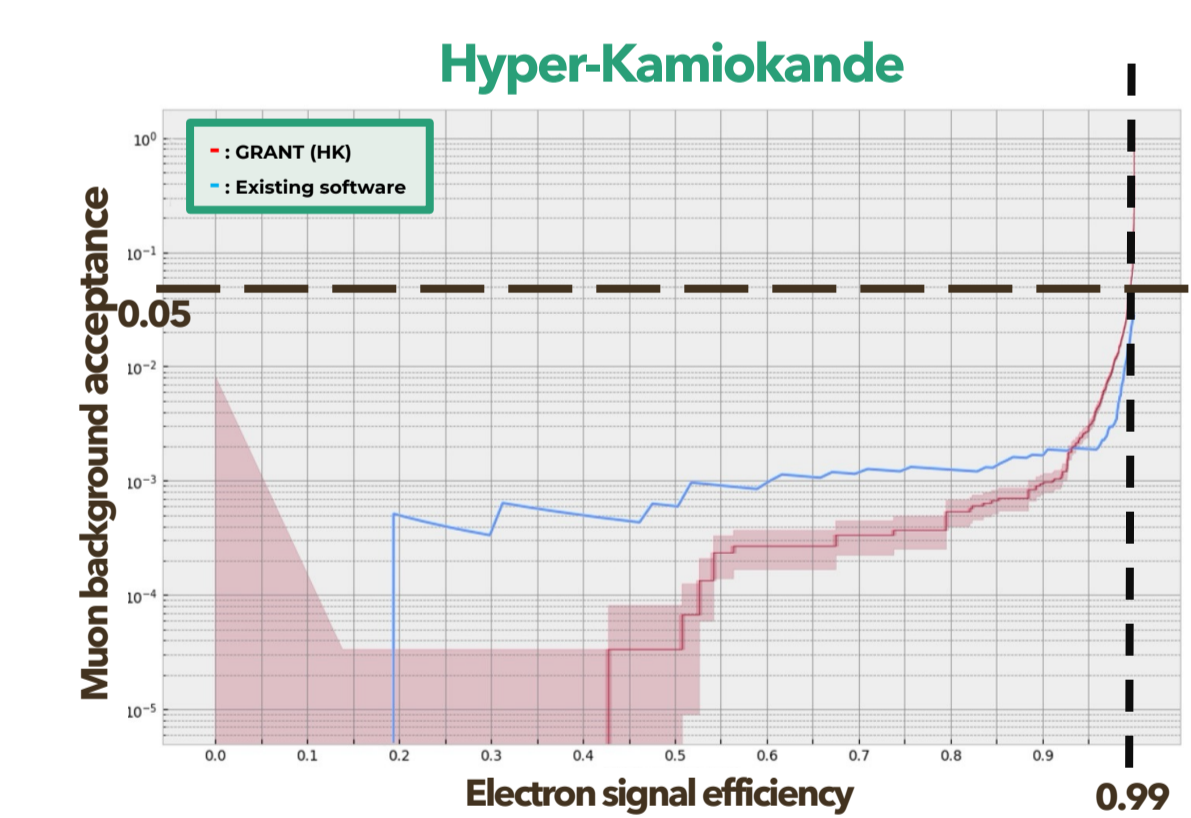


Event → Graph → Reconstruction



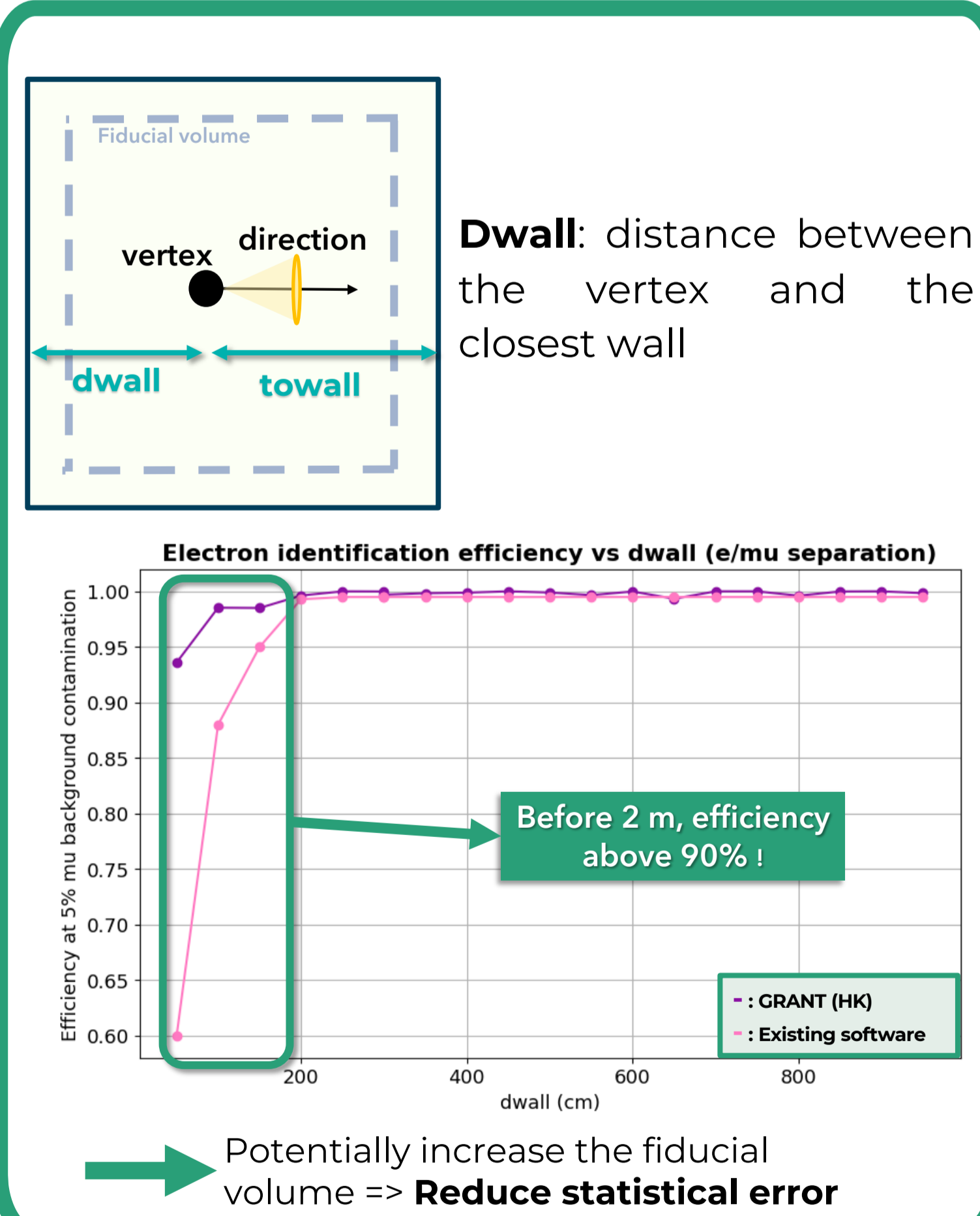
Particle identification

e^-/μ^- classification

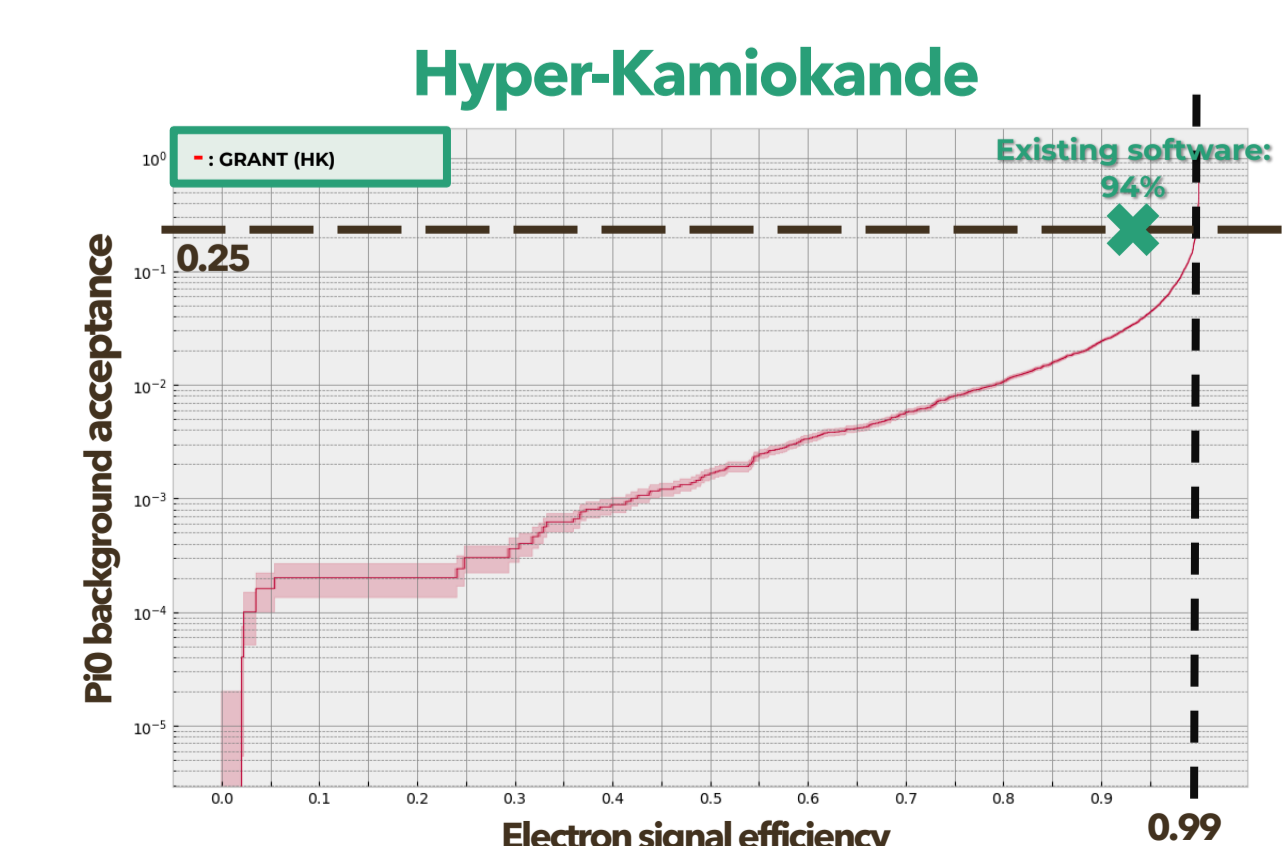


99% e^- signal efficiency at a 5% μ^- background acceptance, for both Hyper-Kamiokande and WCTE.

Impact on physics analysis

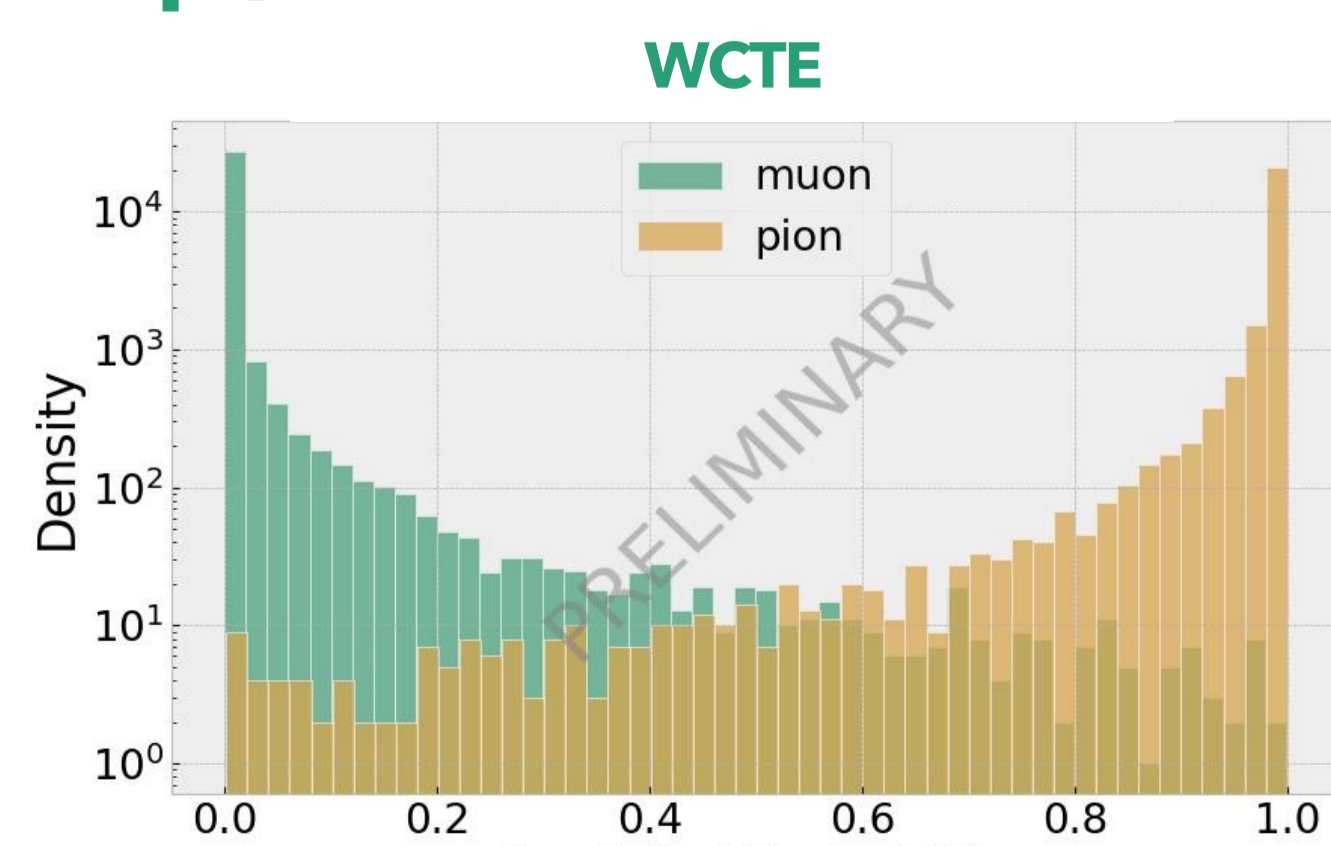


e^-/π^0 classification



99% e^- signal efficiency at a 25% π^0 background acceptance.

μ^-/π^- classification

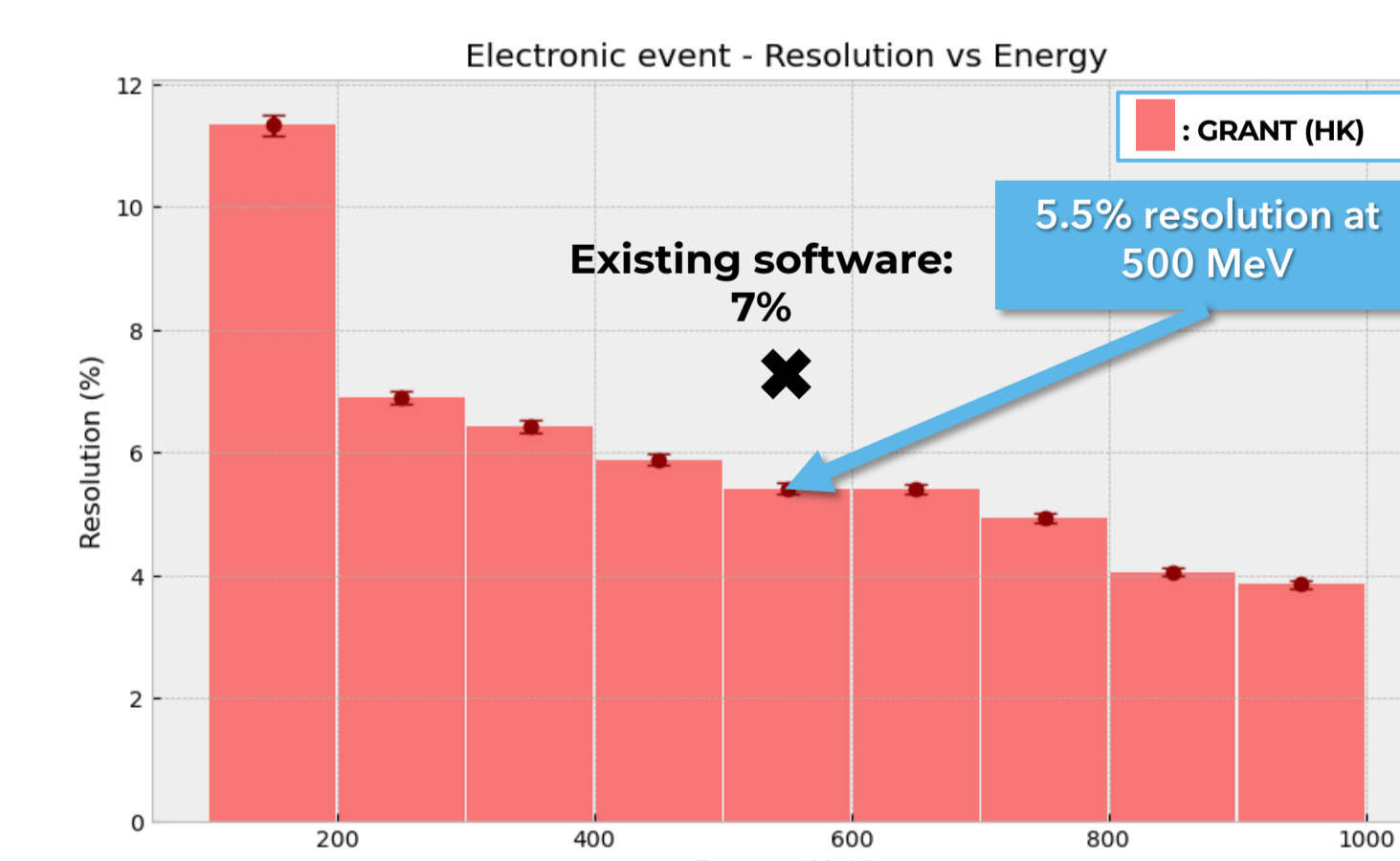
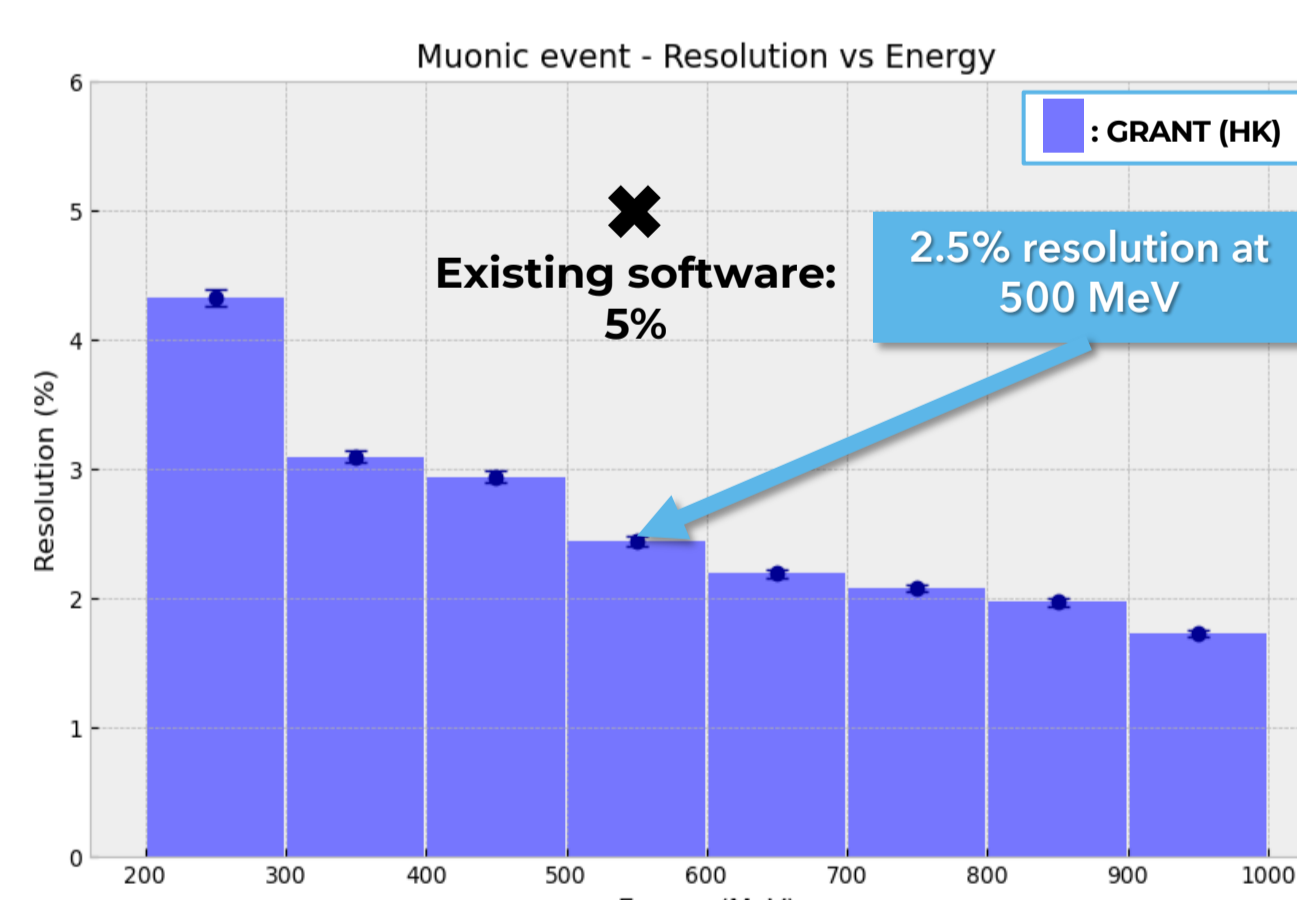


99% μ^- signal efficiency at a 5% π^- background acceptance.

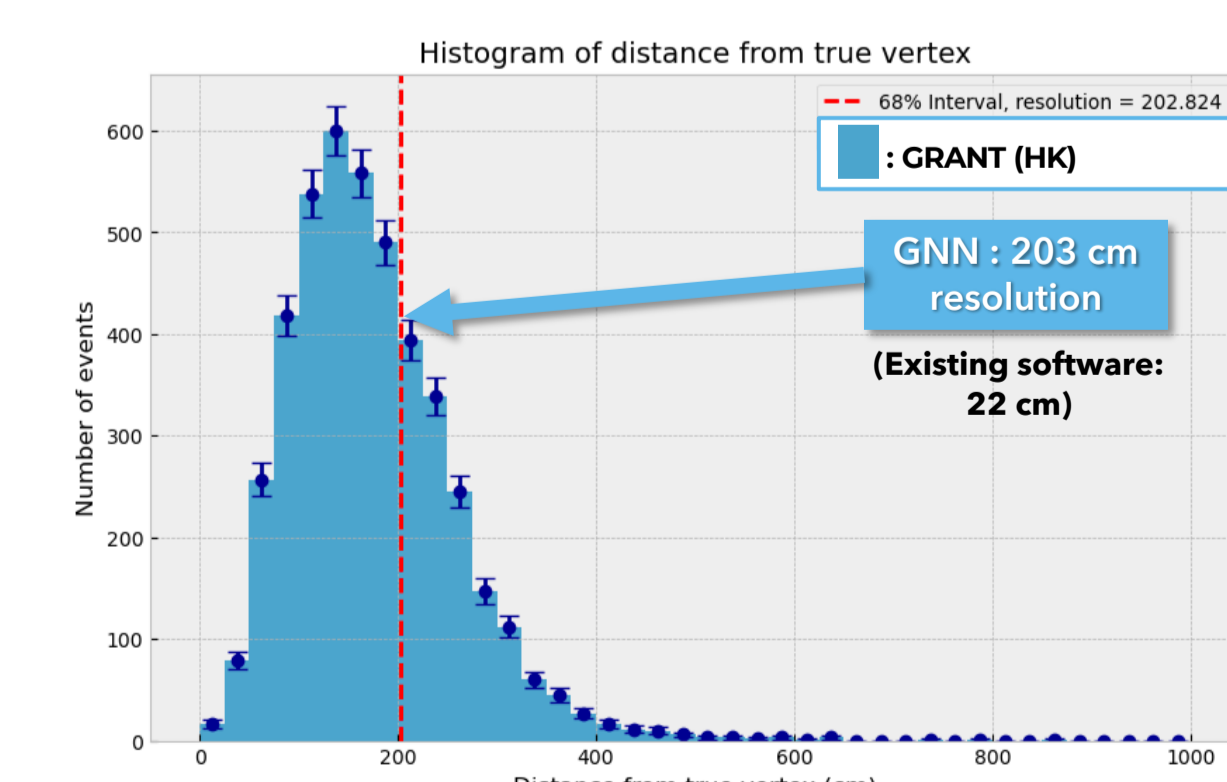
Kinematic variables

Energy reconstruction

	GRANT	Existing software
Resolution	Electron: 5.5% Muon: 2.5%	Electron: 7% Muon: 5%
Bias	Electron: 1.5% Muon: 0.5%	Electron: 0% Muon: 0%



Vertex reconstruction



Resolution at the 68% confidence interval: 203 cm for Hyper-K.

It is a very preliminary result, but we could attest the **good functioning** of GRANT for **multi-dimensional reconstruction.**

Future plans

GRANT has a **high potential** for precise particle classification. We focus on **further enhancing the performance** and reliability of the classification models.

The key steps are:

- **Apply models to data:** validate their robustness and generalizability.
- 1 ring: add μ^-/π^- , e^-/γ , μ^-/μ^- , e^-/π^0 classification and **simultaneous vertex and direction regression.**
- Multi-ring: add **ring counting algorithm.**
- Build a unified particle classifier

