IceCube - Neutrinos in Deep Ice

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Machine Learning Operations
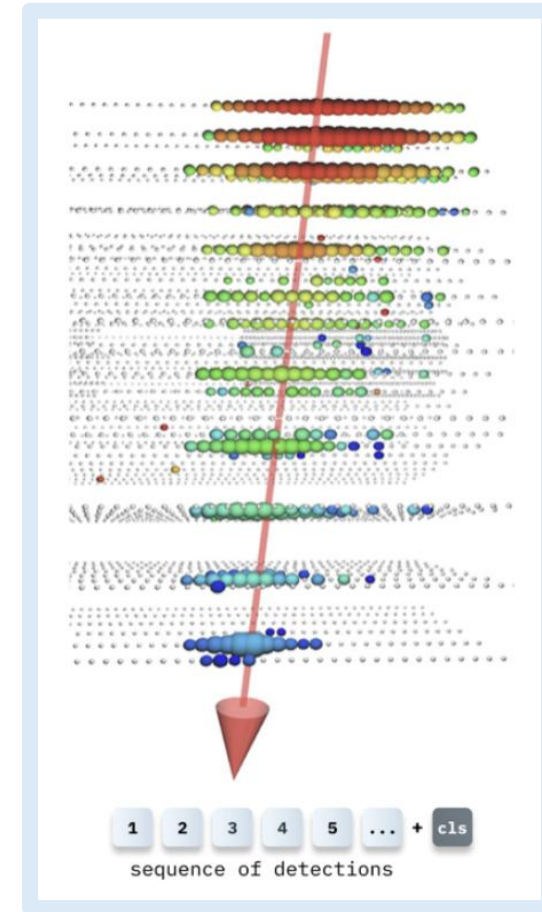
FS 2025

Purpose/Task of the ML System [1/2]

- Neutrinos are abundant particles in our universe emitted by violent astrophysical events

- Hard to dected since they rarely interact with matter

- The IceCube Neutrino Observatory

  - A detector array spanning a cubic kilometer of Antarctic ice

  - Detects the directions of neutrino traces using photon detections

  - Enables determination of the neutrinos' origin, thereby helping locate astrophysical events
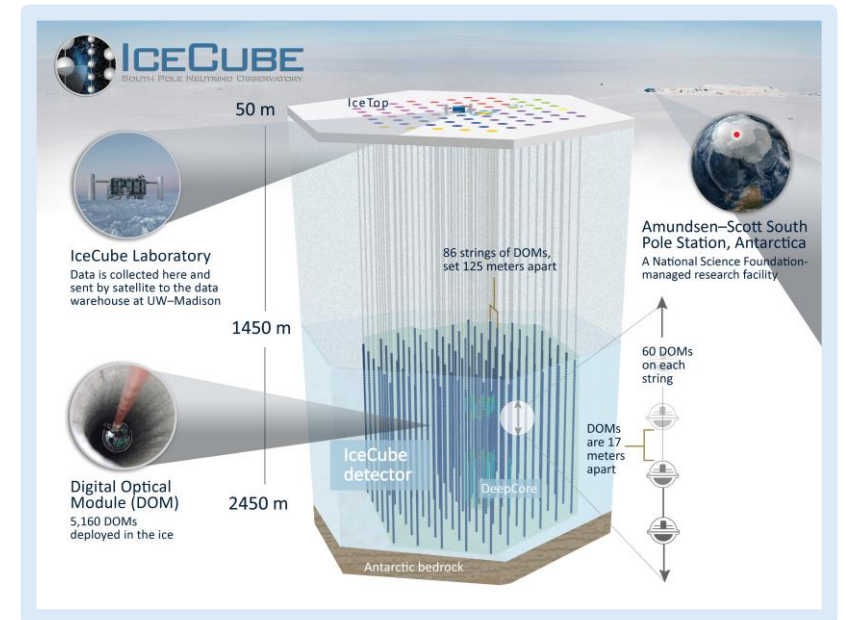
Detector Array in the Ice

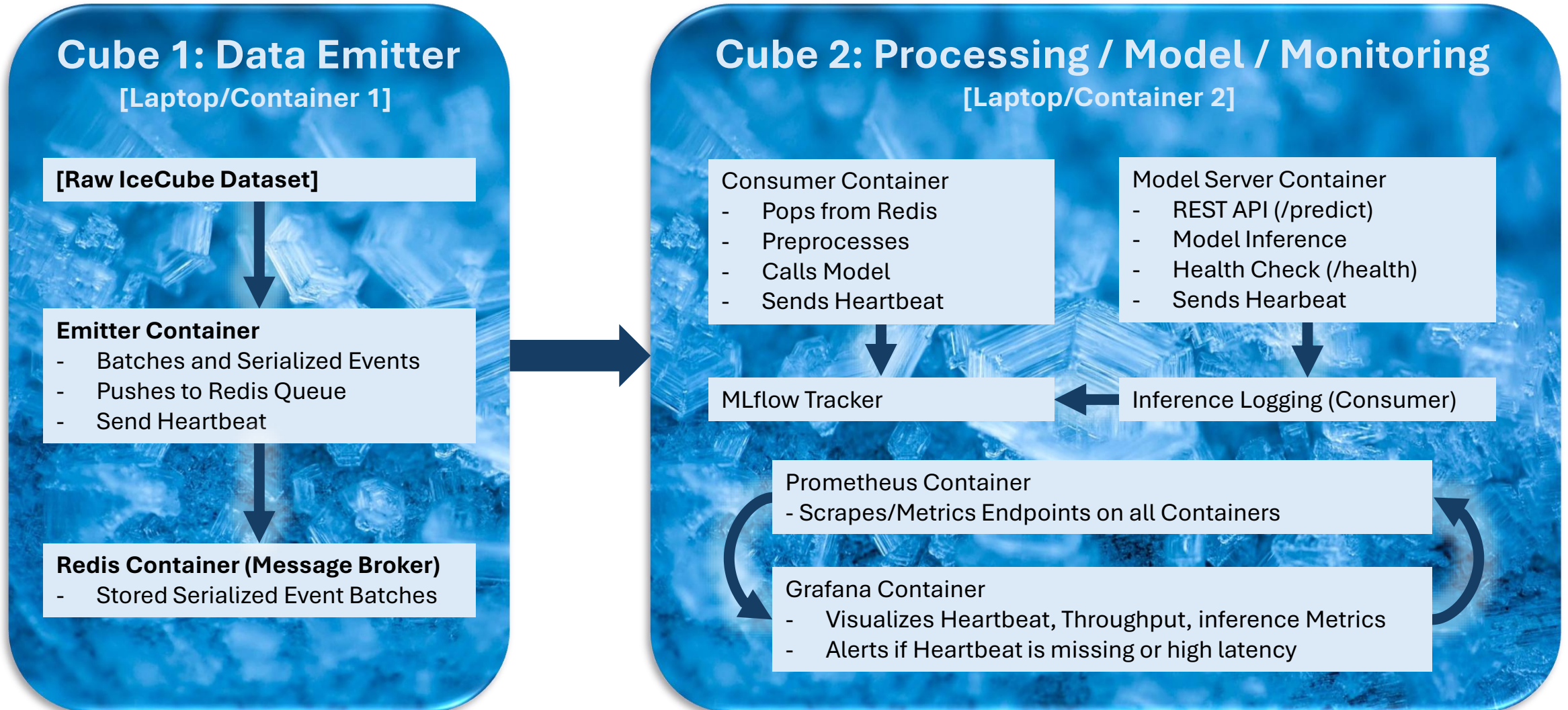# Purpose/Task of the ML System [2/2]

- **The Kaggle Challenge's 2nd Place Model**
  - Solves a regression task
  - It takes as input the time-series of DOM (photomultiplier) hits for each event and outputs a 3D unit vector corresponding to the incoming neutrino's direction
  - Is already pretrained

- Disclaimer: The current model is provisional and may be changed in future stages

3D Unit Vector

Overview of Components/Pipeline/System Setup

Cube 1: Data Emitter
[Laptop/Container 1]

[Raw IceCube Dataset]

Emitter Container
- Batches and Serialized Events
- Pushes to Redis Queue
- Send Heartbeat

Redis Container (Message Broker)
- Stored Serialized Event Batches

Cube 2: Processing / Model / Monitoring
[Laptop/Container 2]

Consumer Container
- Pops from Redis
- Preprocesses
- Calls Model
- Sends Heartbeat

Model Server Container
- REST API (/predict)
- Model Inference
- Health Check (/health)
- Sends Hearbeat

MLflow Tracker

Inference Logging (Consumer)

Prometheus Container
- Scrapes/Metrics Endpoints on all Containers

Grafana Container
- Visualizes Heartbeat, Throughput, inference Metrics
- Alerts if Heartbeat is missing or high latency

Purpose of the ML Ops Pipeline

- **Goal**: Build pipeline which processes data stream

- Simulates the constant data flow

- Two containers that communicate with each other
  - **Emitter container (Cube 1)** simulates data sensors
  - **Processing module (Cube 2)** simulates the remaining steps of the pipeline

- Disclaimer: Our aim is **<u>NOT</u>** to optimize ML performance, but to explore how the IceCube data processing might be structured

List of Tools to be used

Tool	Motivation	Additional Notes
Python	• Familiar and flexible language • Easy extendable due to the abundance of libraries • Selected model is built with PyTorch	We aim to use mostly open-source tools. * potentially subject to change with similar tools
Docker*	• Easy to deploy • Ensures reproducibility • Allows containerization of each component	
Redis Community Edition	• Easy to use que system • Relatively fast deployment	
MLflow	Used to log result of model interference	
Promotheus	• Scrapes metrics (total requests, latency, etc.) from the different containers (including heartbeat) • Can define alert rules	
Grafana	• Dashboard build upon Promotheus • Displays metrics	
Flask*	Server used to serve the model via REST API	

Sources

- [Title Slide Picture](#) [Slide 1]

- [IceCube Neutrino Observatory](#) [Slide 2]

- [Detector Array in the Ice](#) [Slide 2]

- [Kaggle Challenge](#)
  - [2nd Place Model](#) [Slide 3]

- [3D Unit Vector](#) [Slide 3]

- [Ice Pattern](#) [Slide 4]