CLAS12 Hydra

Data Emulation &
RG-L Statistics

Darren W. Upton

Hydra Team

David Lawrence

EPSCI
Physics, CS, AI/ML

Thomas Britton

EPSCI
Physics, CS, AI/ML

Torri Jeske

EPSCI
Operations + Full Stack

Nataliia Matsiuk

Information + Records
Containerization, QA

Raiqa Rasool

EPSCI
CS, Full Stack Development

Darren Upton

ODU Physics Grad Student
Emulated images, clustering,
Siamese models

Jordan O'Kronley

UT Physics Graduate Student
Image clustering and siamese
models

EPSCI

HYDRA

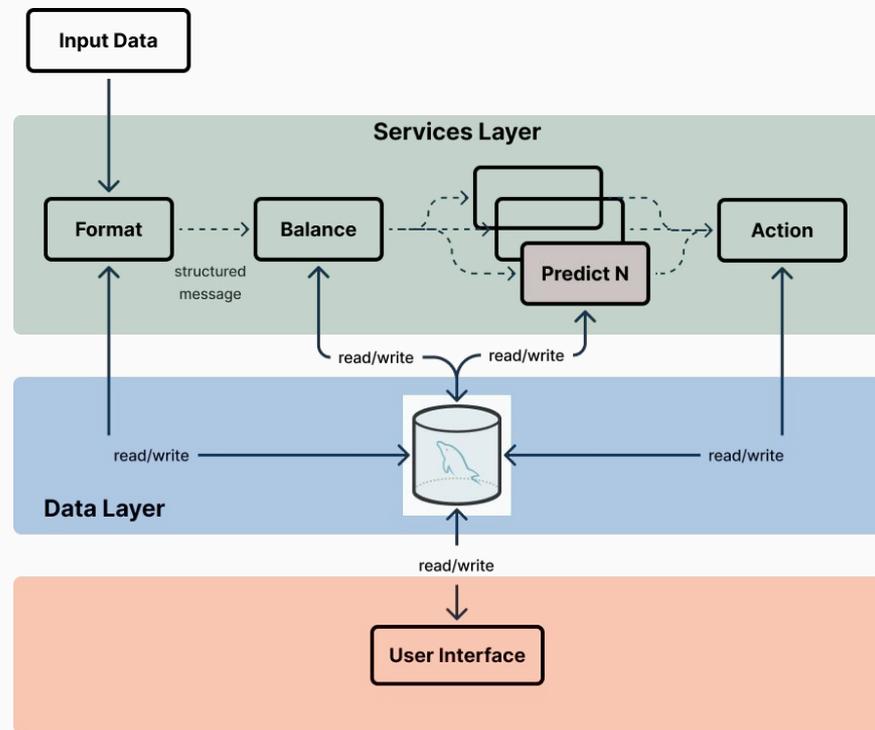❖ **Monitoring Workflow**
  ➢ Python-based modules handling image moving & ML workflow

❖ **Back End**
  ➢ SQL database communicates between front-end and back-end

❖ **Front End**
  ➢ Web-based UI for accessing info

Hydra - Run Page
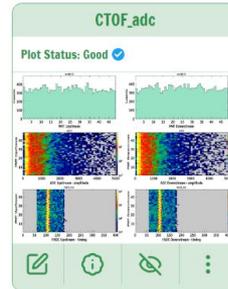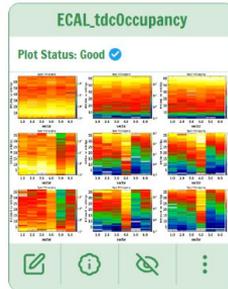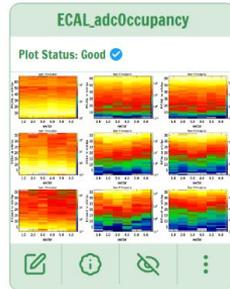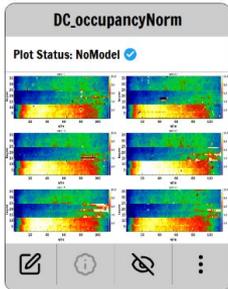
Hydra - Grafana Timeline

Alarm
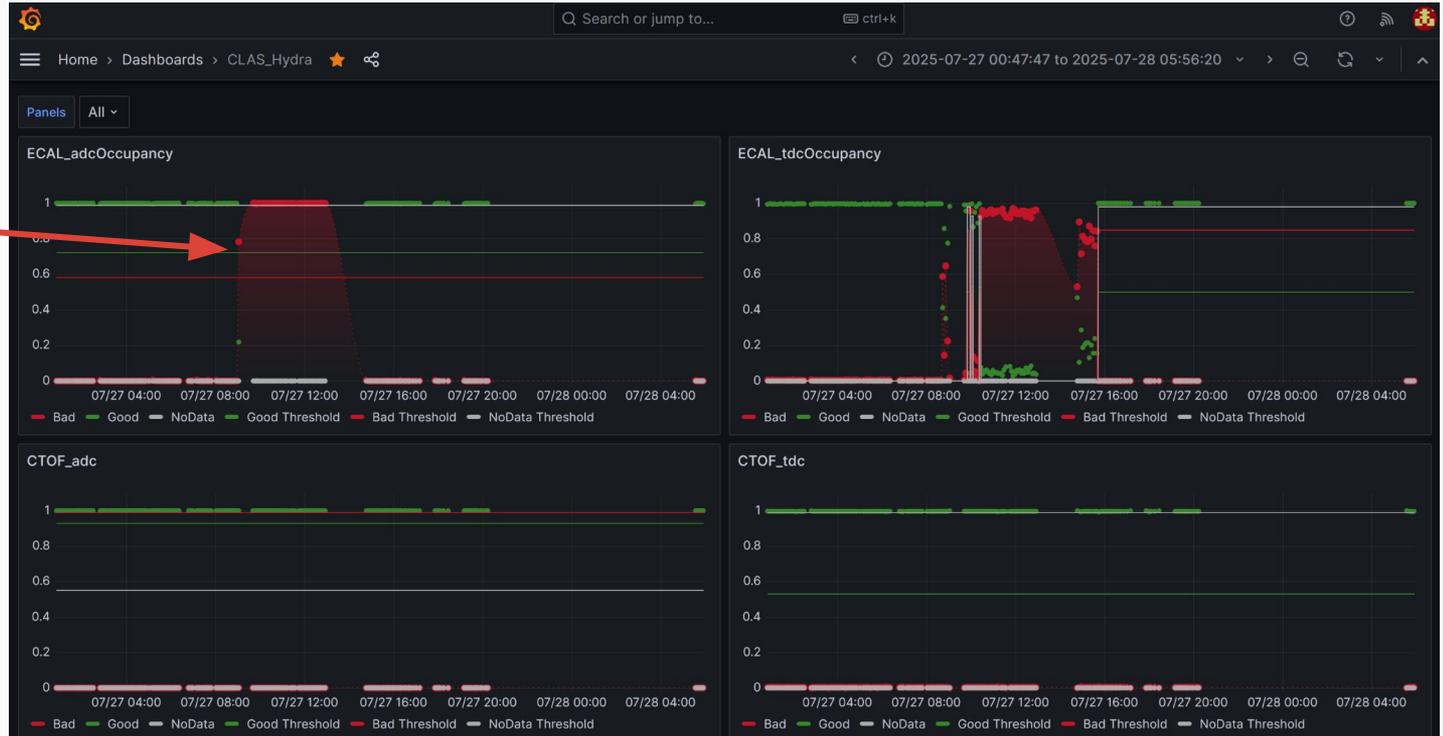
Data Augmentation for Hydra

Data Augmentation

- ❖ Making new data from existing data
- ❖ Image data rotated, cropped, or re-colored
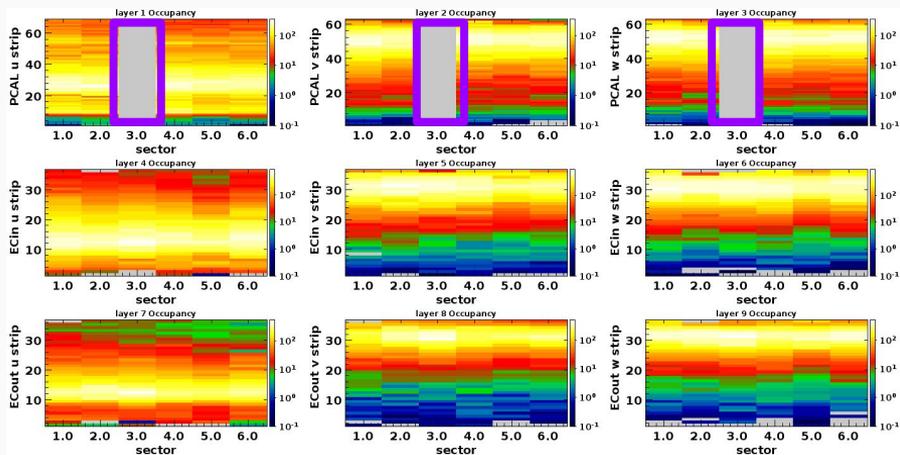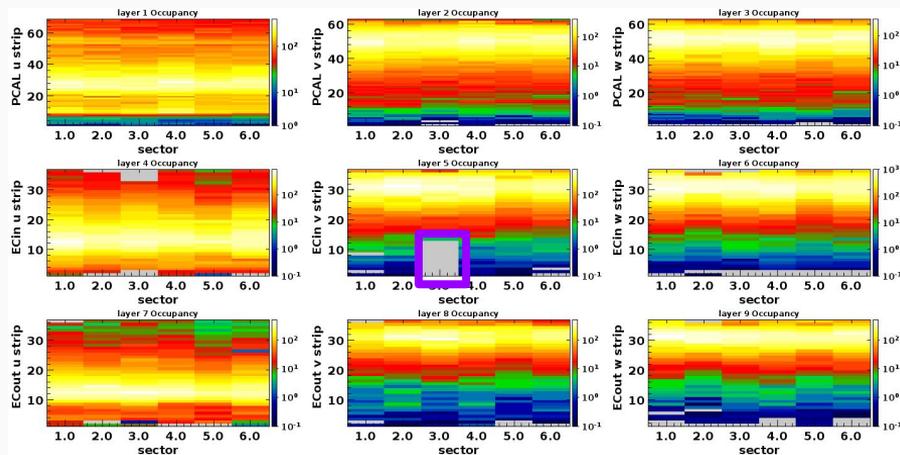- ❖ Not **that** easy for CLAS12

Edgar

Emulating Failures

- ❖ Generate pseudo-data using existing data
- ❖ Create new version CCDB table with crates or slots "knocked-out"
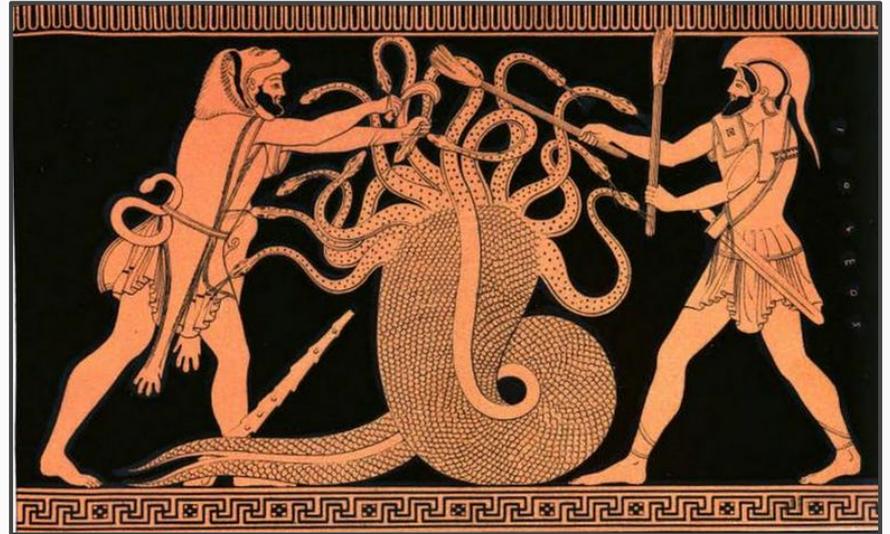- ❖ Run mon12 with only ECal for specific good run in RG-K

Crate 15

Crate 13, Slot 5

Iolaus

❖ Helped Heracles slay the Hydra by burning the neck stumps, preventing the heads from growing back

❖ Systematically perform knock-outs using CCDB tables & mon12

Results of First Pass

- ❖ I tested some models in-real time
  - ➢ (Sorry if you were confused on-shift)

- ❖ Improvements for occupancy plots
  - ➢ Okay-ish model generalization

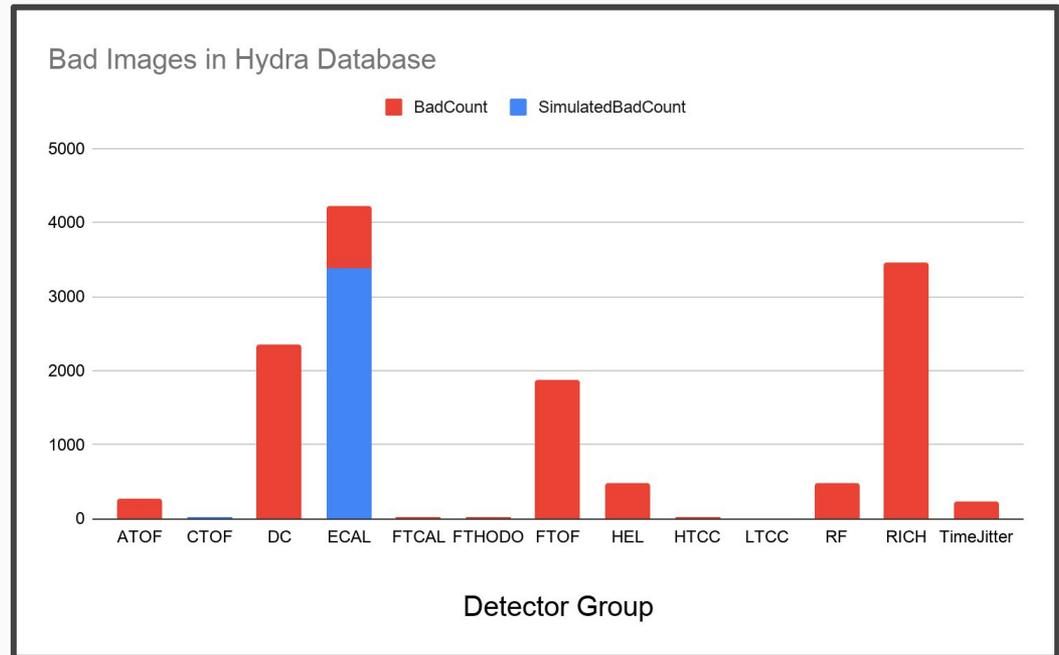- ❖ Not enough for some plots

- ❖ **What's causing this behavior?**

Checking with Unsupervised Clustering

❖ "Islands" cluster by target/beam **not** "good" or "bad"
❖ **Generalization will require sampling multiple "islands"**
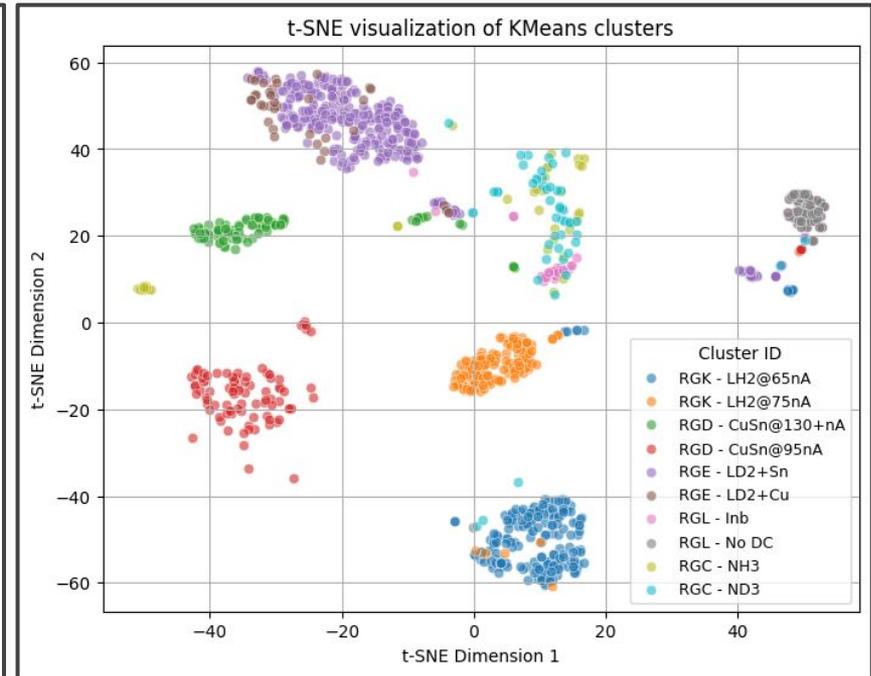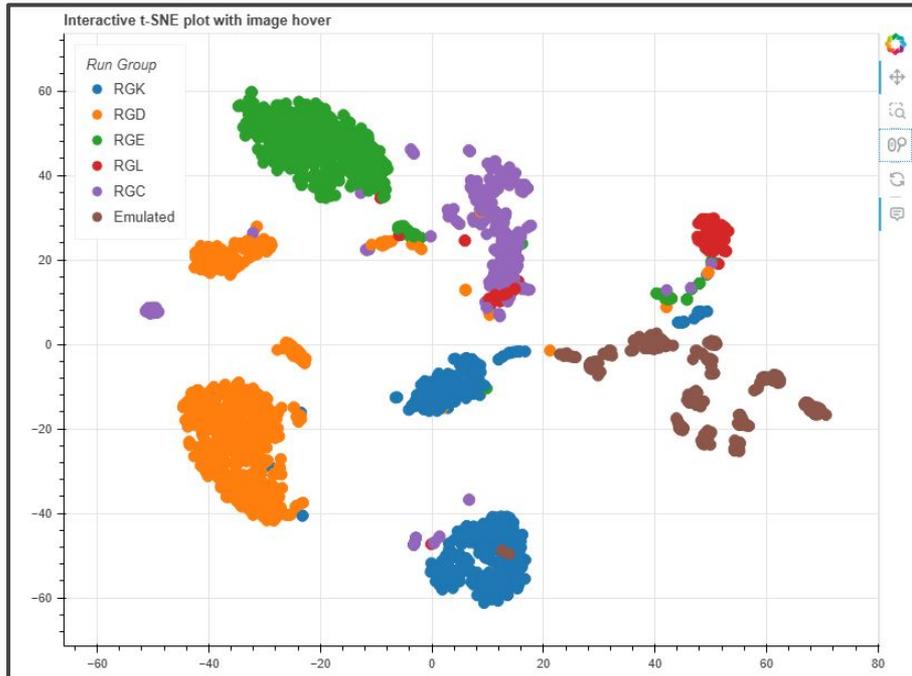
Status of Iolaus

❖ Good progress for ECal emulation using previous and RG-L data
❖ Starting to move onto CTOF & DC
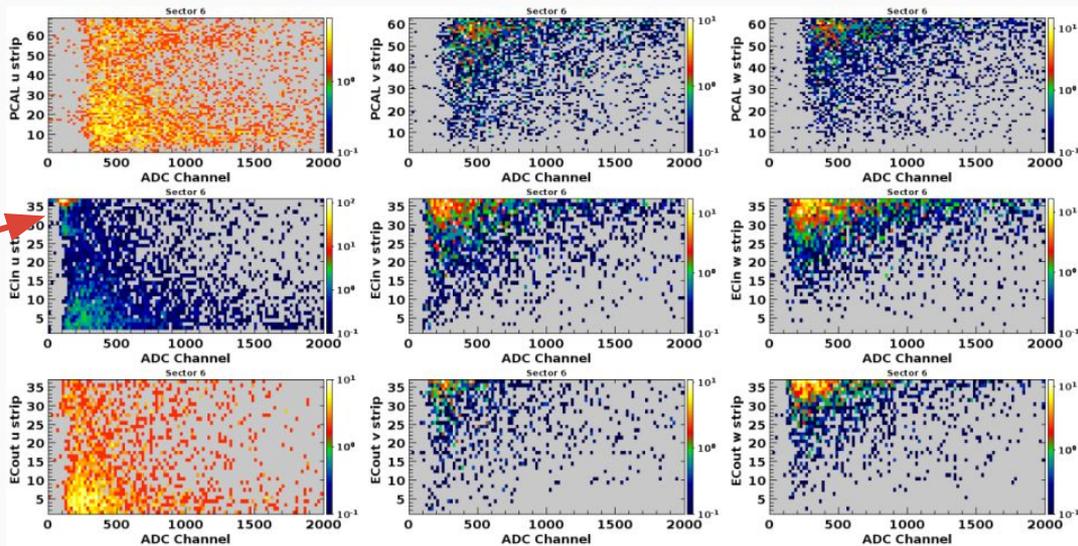

Bad Images in Hydra Database
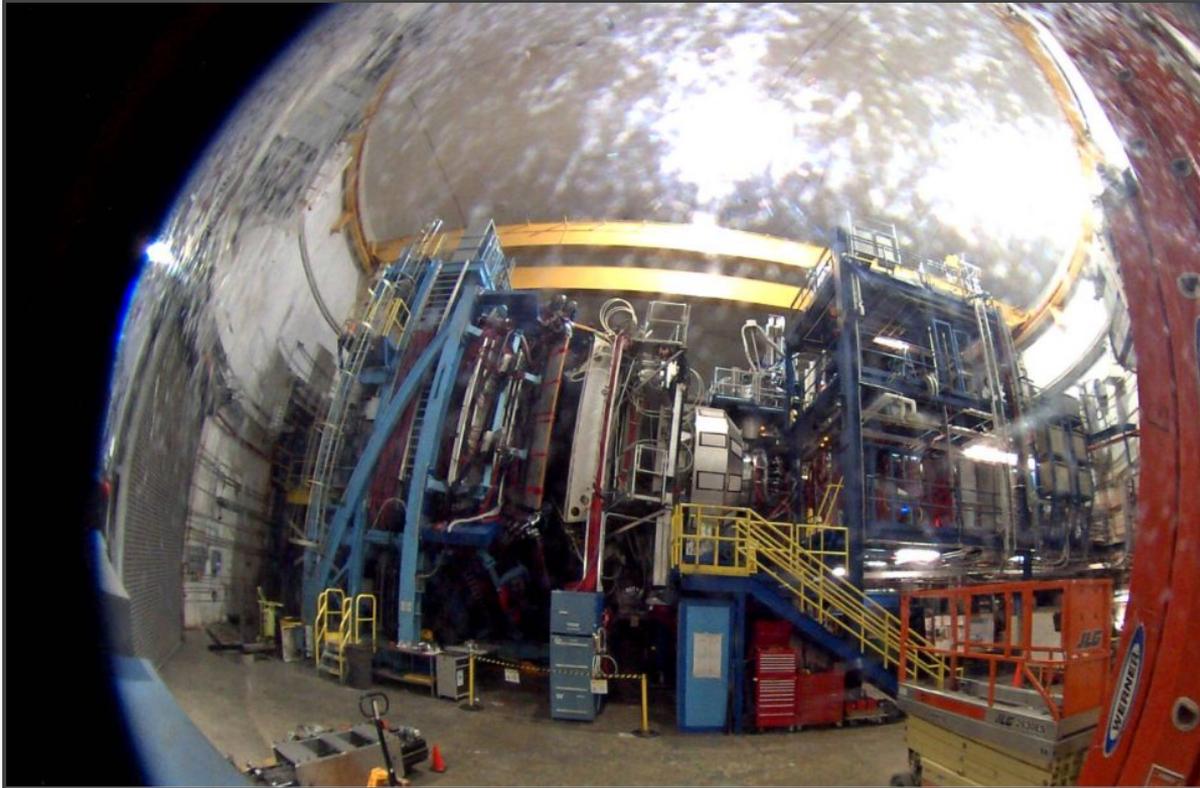
Hydra for RG-L

Overview of Hydra for RG-L

❖ Run Page showed 82 plots for RG-L
  ➢ Starting with ~30 models
  ➢ Up to ~65 models in production from Iolaus & better labeling

❖ **Let's see two specific events where Hydra spotted issues!**

Hydra Case Study #1

❖ Hydra alarm upon return
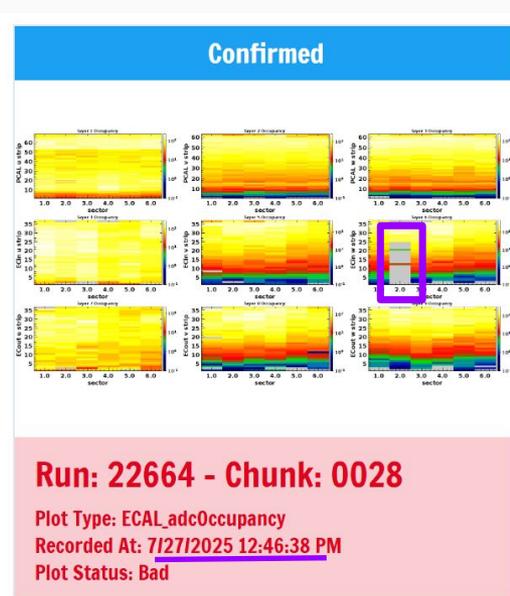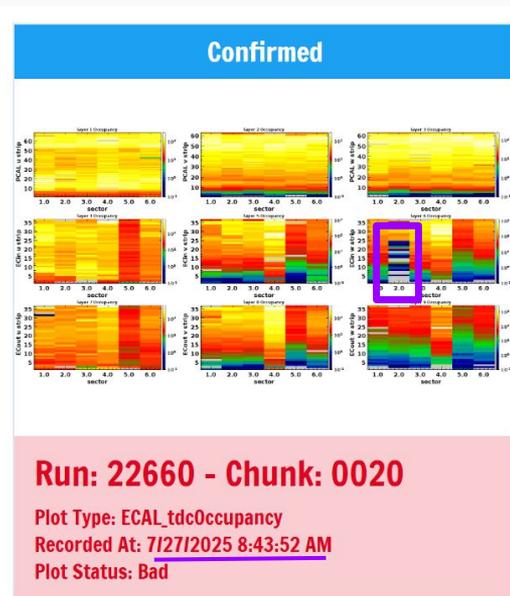- ➢ Jumpy timeline
- ➢ Hotspot

# Hydra = Over-Engineered Light Detector

Hydra Case Study #2

❖ Chunk of ECAL sector 2 out starting at 08:40 (lasted ~4.5 hours)
  ➢ Caused by issues with HVECAL2 board 6
❖ Missed until Dan called at 10:40 because no monitor showing Hydra in counting house…

Run: 22660 - Chunk: 0020
Plot Type: ECAL_tdcOccupancy
Recorded At: 7/27/2025 8:43:52 AM
Plot Status: Bad

Run: 22664 - Chunk: 0028
Plot Type: ECAL_adcOccupancy
Recorded At: 7/27/2025 12:46:38 PM
Plot Status: Bad

Compiling "Hydra Events"

❖ Instances where at least 1 Hydra model alarmed

❖ Broken down into three types
  ➢ Quick (< 1 hour)
  ➢ Reset with new run (1-2 hr)
  ➢ Caught by non-shifters (>2 hr)

❖ **Analysis ongoing!**

Total ~55 hours
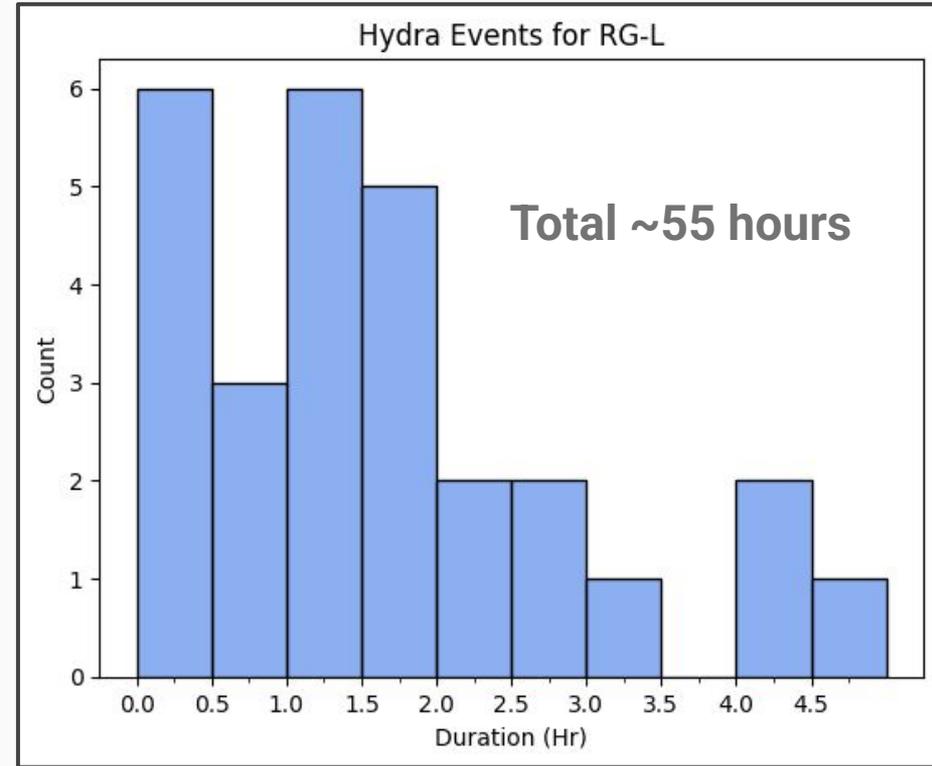
Lessons from 2025

❖ **Hydra only helps when it stays up on a monitor**

❖ Emulation via Iolaus can be performed once "good" runs exist

❖ Grafana timelines help spot small issues (even single hot pixel)

Moving Forward

❖ Use **Iolaus for the DC** & other detectors without active models
  ➢ Work with Florian to craft approach aided by clustering

❖ Continue collecting stats from previous run periods
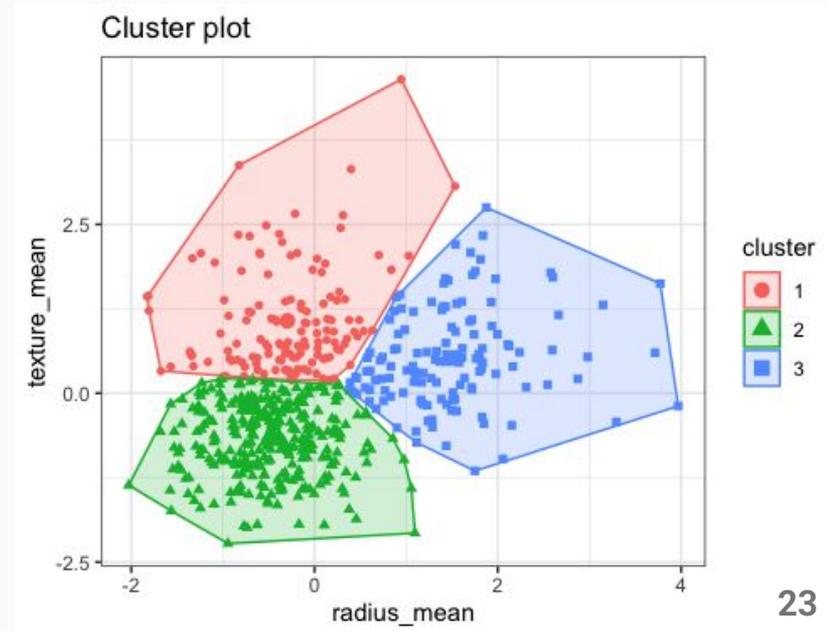 ➢ Try using Will's project for an LLM trained on CLAS12 log book
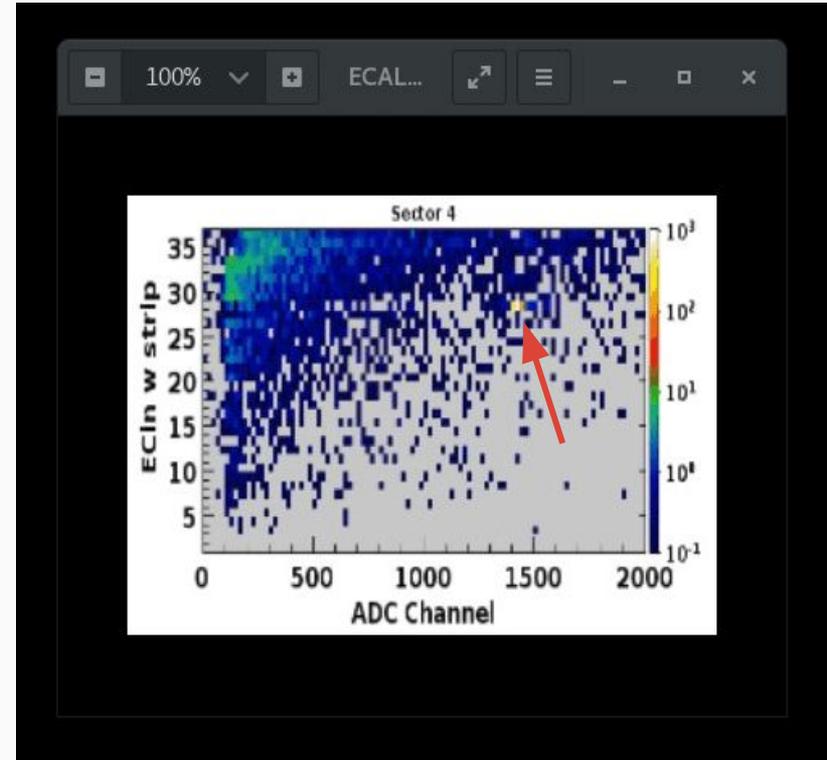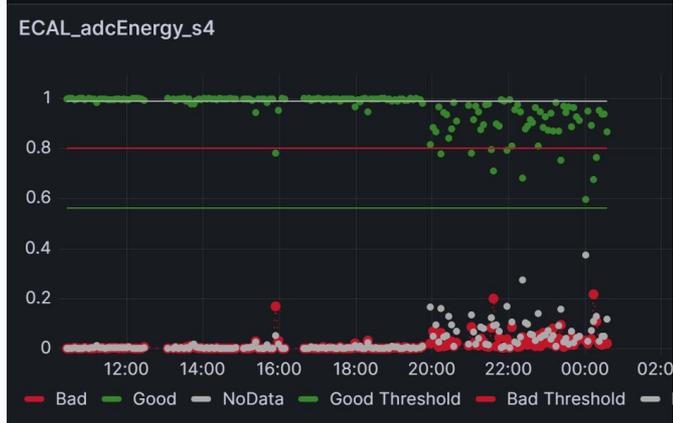
Edgar

Appa
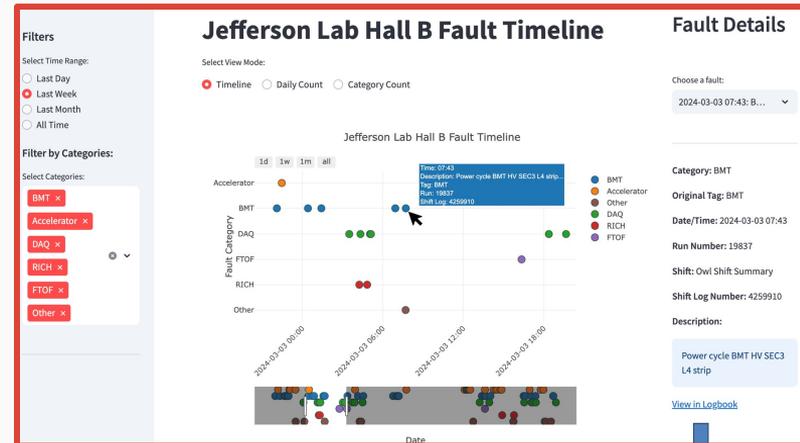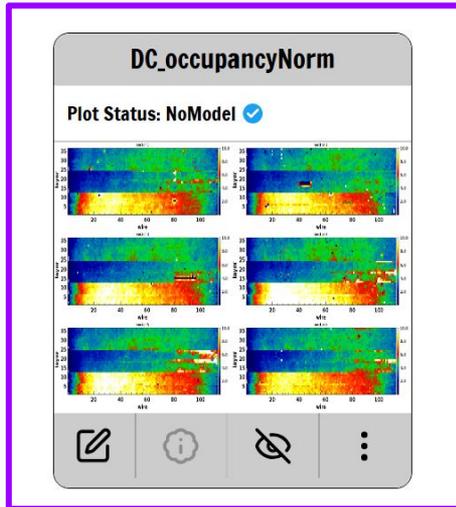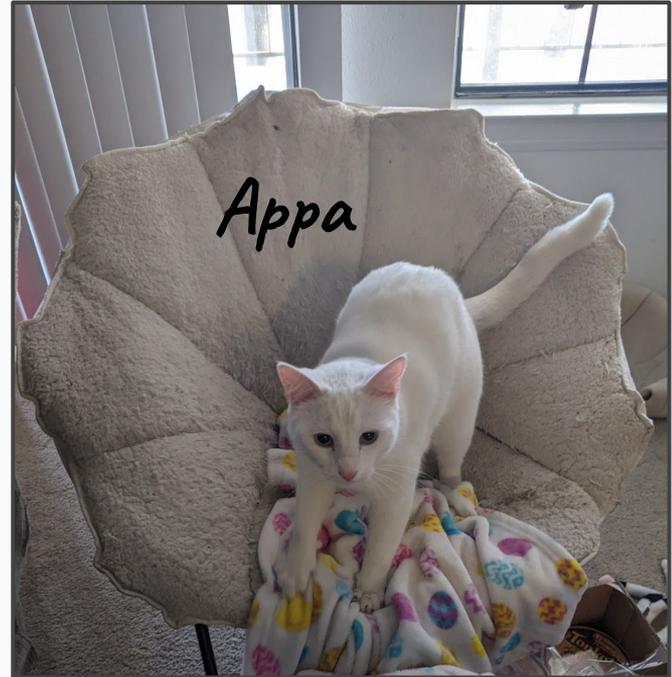
Backup Slides

Clustering via Unsupervised Learning

❖ Map images into feature space using an ML model for images
❖ Apply k-means clustering to determine groups
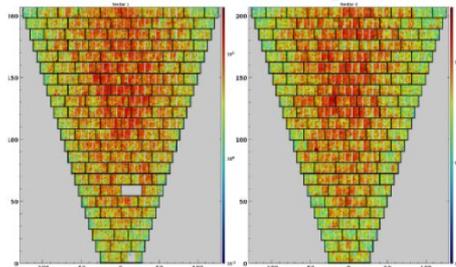❖ Reduce dimensionality using TSNE for visualization

Cluster plot

❖ Single hot pixel

GradCAM Heat Maps

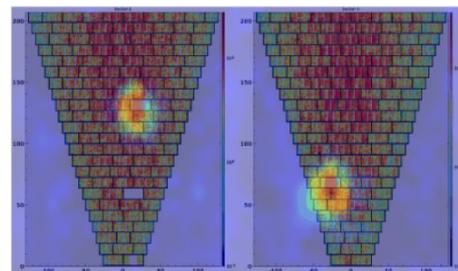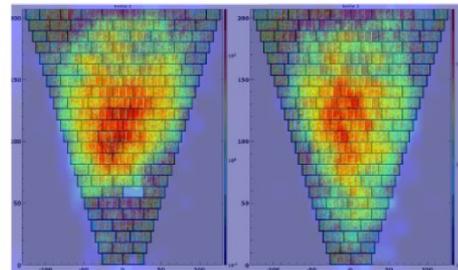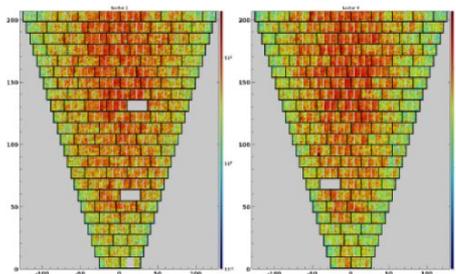"Why did Hydra say this was bad?"

Bright spots indicate important regions of the image for the given classification.

These are very sensitive to how well the model is trained.
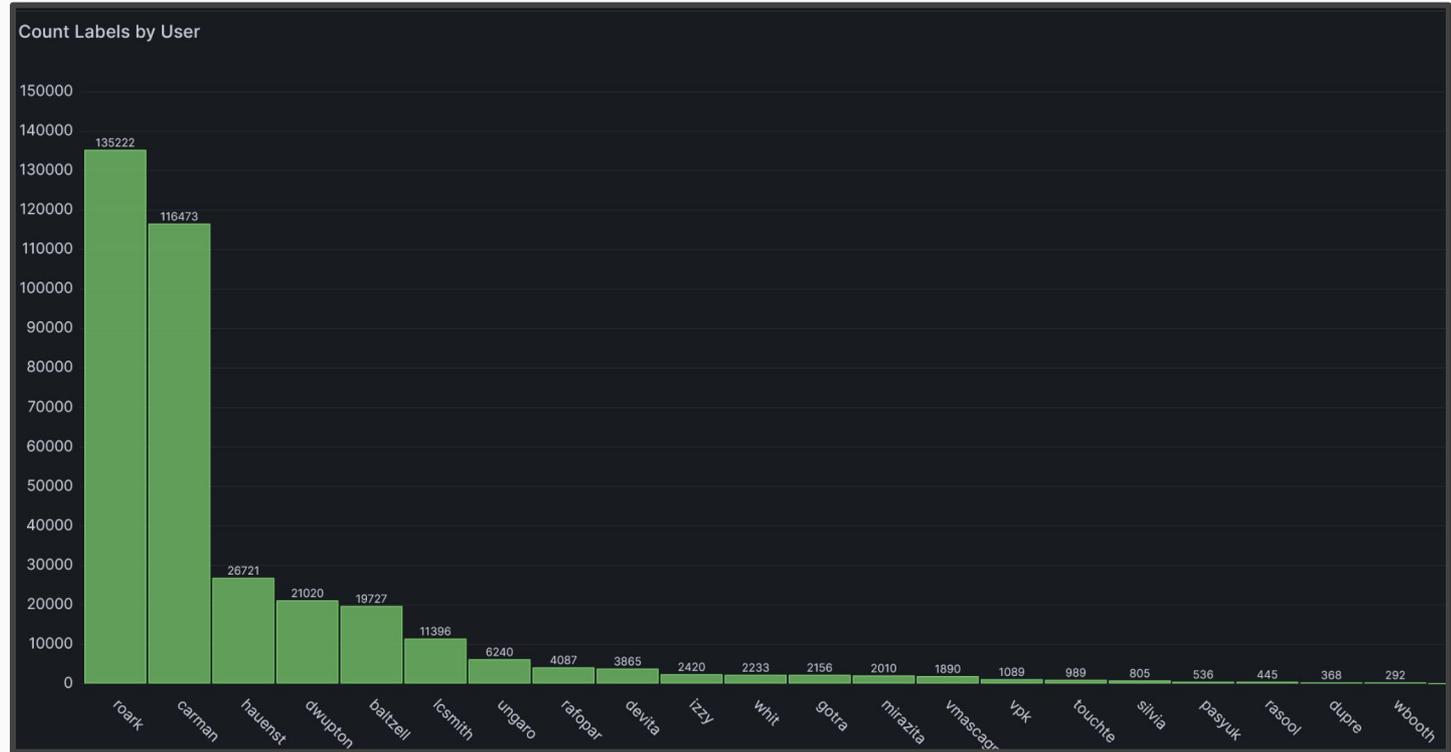
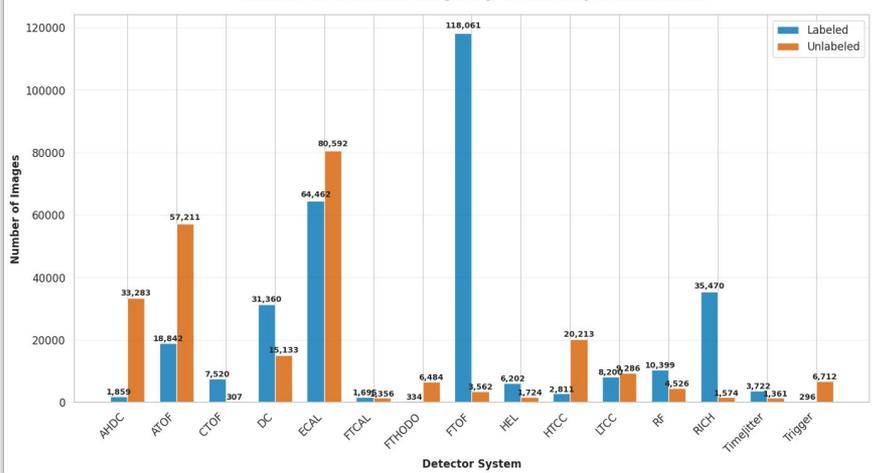

this is a normal image

this is a bad image

Heat maps are produced from mixed layers in InceptionV3+CBAM
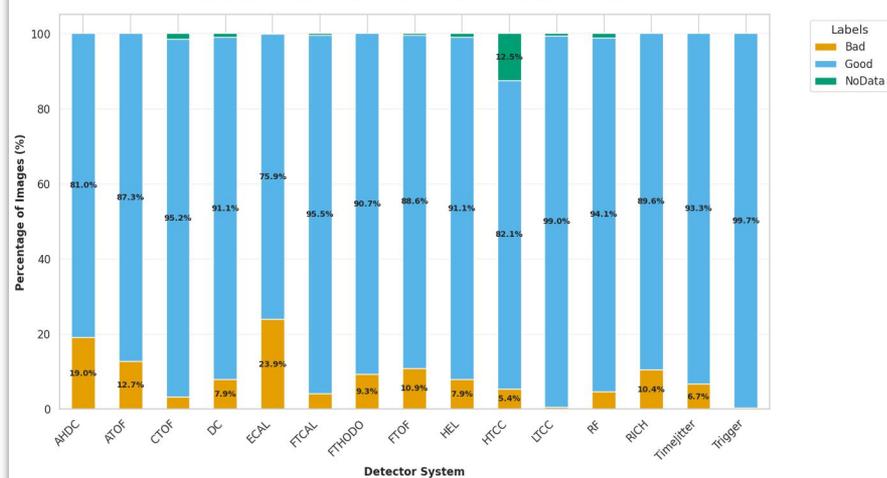
Labeling Stats

Count Labels by User
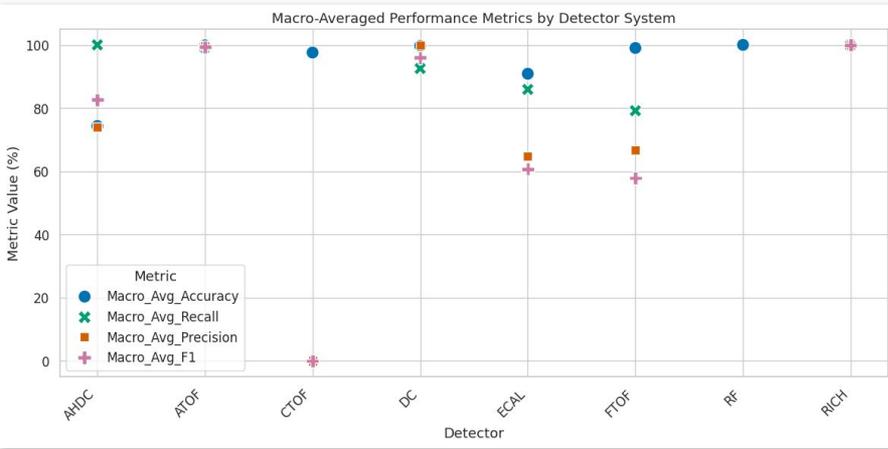
Labelling Stats

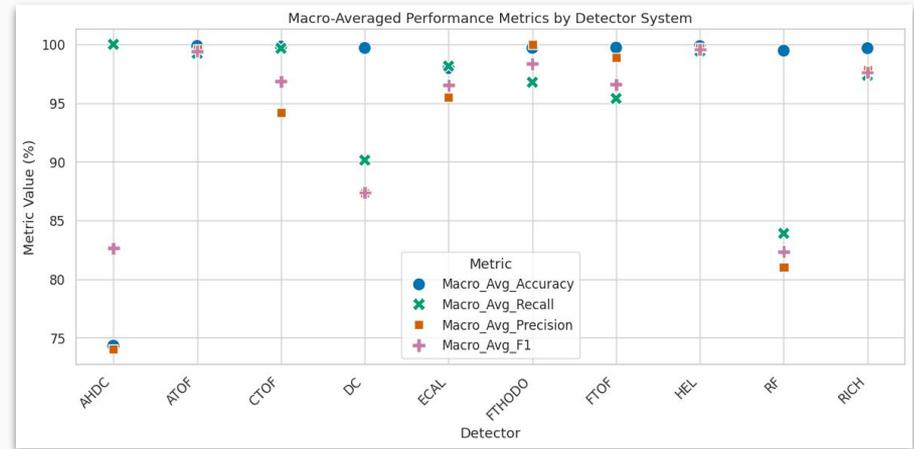**Labeled vs Unlabeled Images by Detector System (Counts)**

Distribution of Image Labels by Detector System (Percentage)

Model Performance Metrics

RGL-specific

All time performance on Bad images

Siamese Models

Siamese models learn to compare two inputs (in our case images) and determine how *similar* they are.

Think of this as Hydra's equivalent to the shift crew comparing images to their reference.

Jordan O'Kronley

UT Physics Graduate Student
Image clustering and siamese models