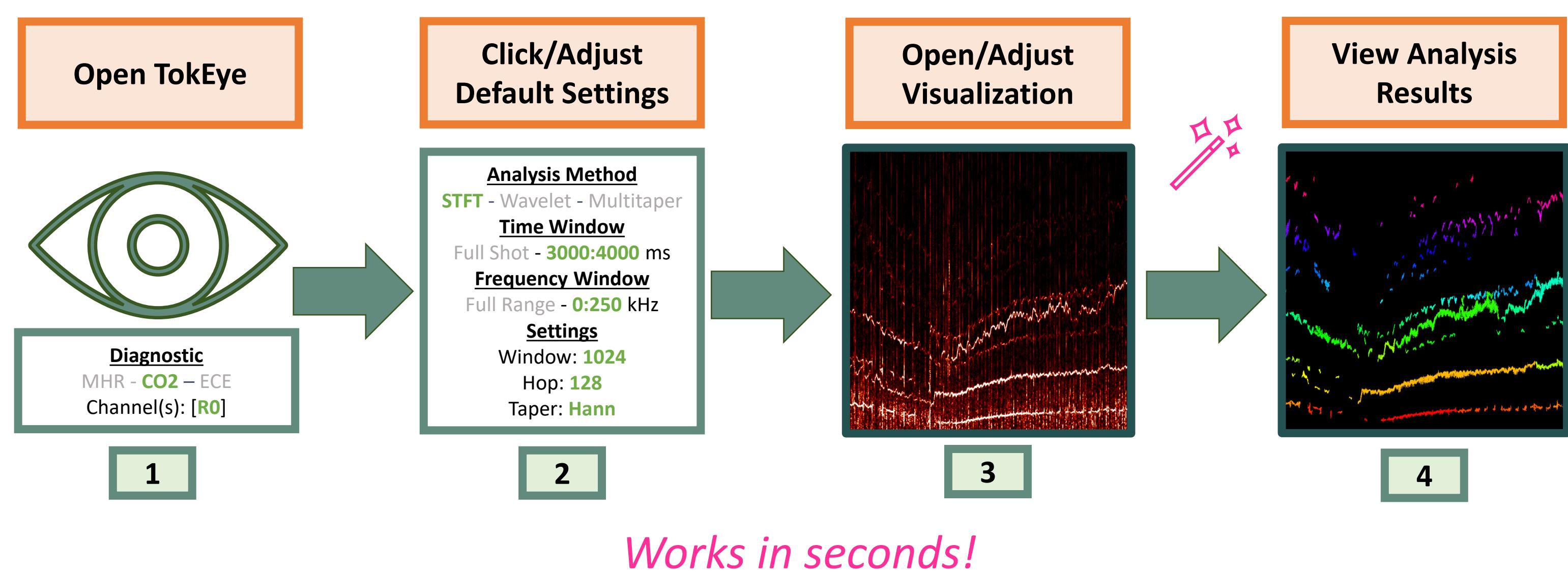


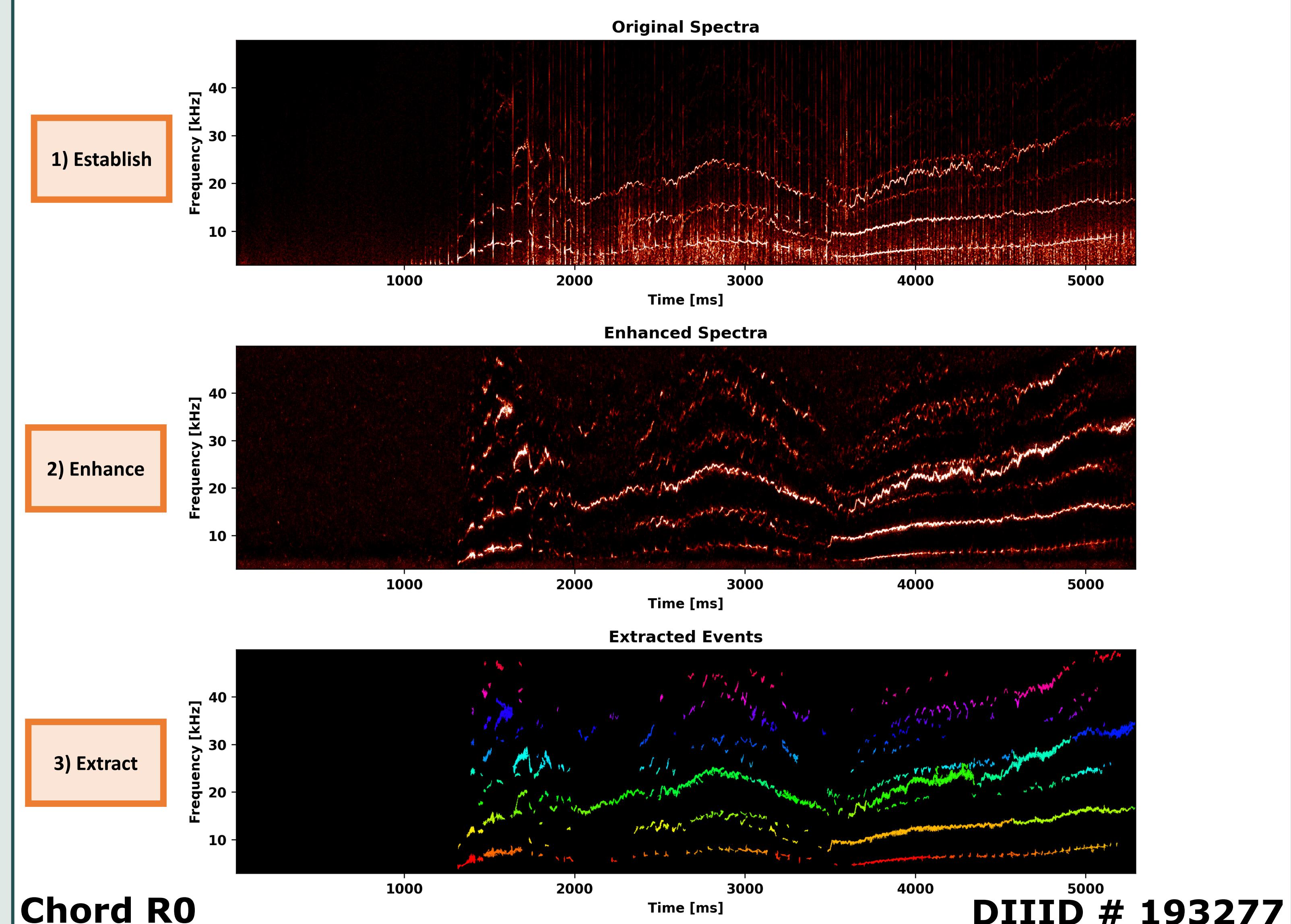
Motivation

- **Existing Analysis Limitations:** Most analysis tools are limited to specific diagnostics and require extensive manual tuning / transformations to extract meaningful information. This makes quick analysis difficult especially during experiments. [1]
- **Database:** As fusion data exceeds the petabyte scale, we want a way to automatically organize data for scientists and diagnosticians to search and analyze shots
- **Control:** During experiments, we need a way to output which out of the 100+ active signals are causing a response of interest
- **Artificial Intelligence:** Future large models need to understand fusion data, and would benefit from a dictionary of labeled events

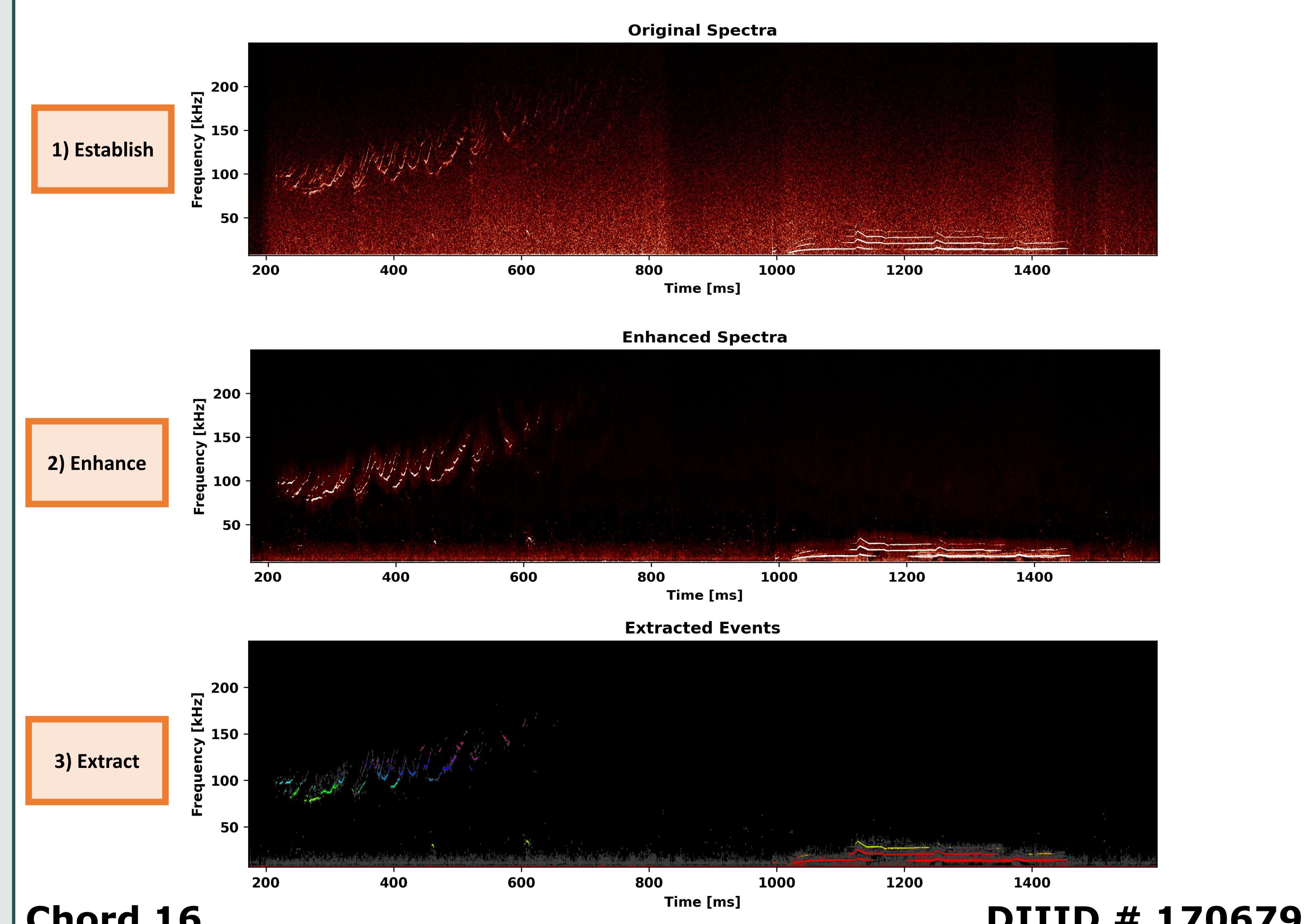
Software Usage Overview



Behind the Scenes: CO2 Interferometer Tearing Mode Shot



Behind the Scenes: ECE Alfvén Eigenmode Shot Extraction



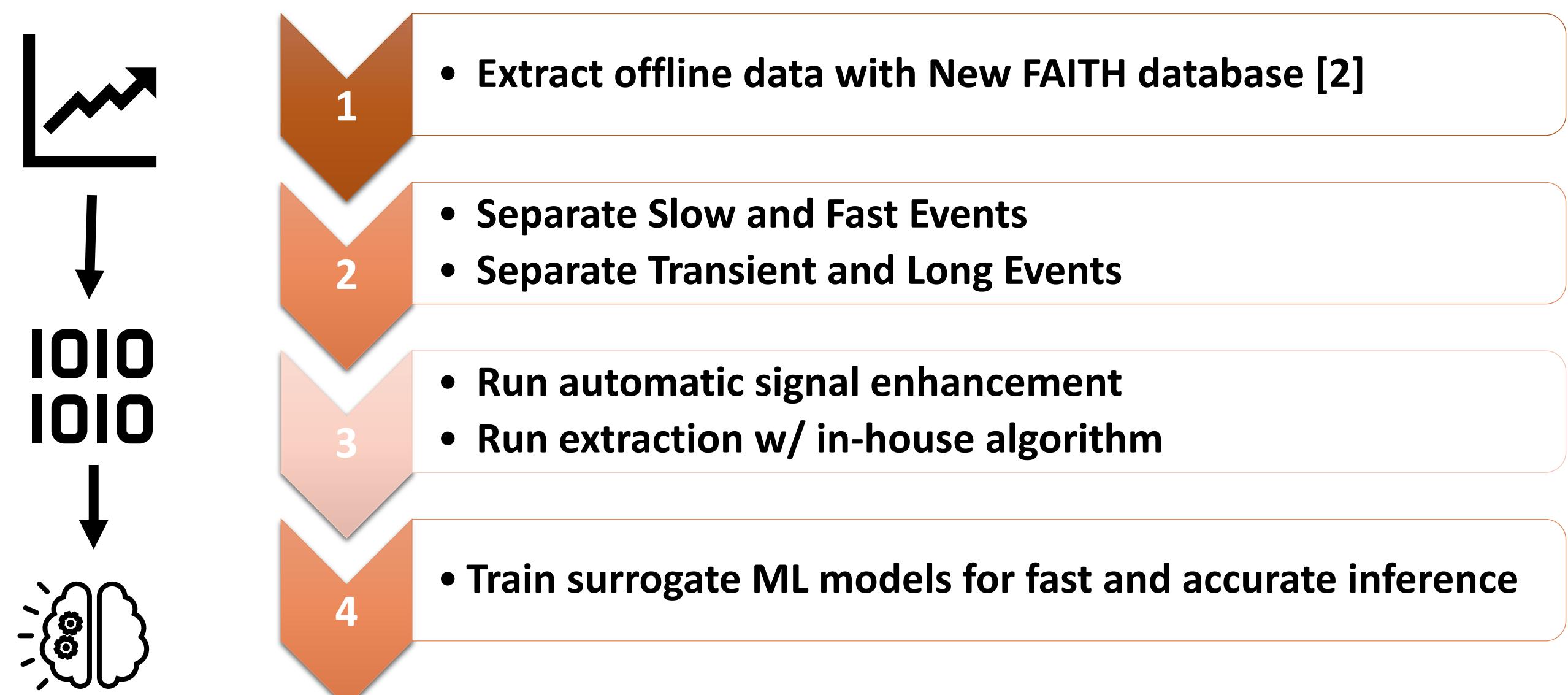
This work was made possible by the Department of Energy under DE-FC02-04ER54698, DE-SC0024527 and Princeton Laboratory for Artificial Intelligence under Award 2025-97.

How It Works

2 Key Components to this Tool

- 1) Offline Automated Training and Refinement
- 2) Direct Real-Time Usage

Offline Training and Refinement



How Does Event Separation Work?

An optimizer standardizes fractal-like events at each time step. Based off techniques in audio processing, neuroscience, and spectroscopy.

How Does Signal Enhancement Work?

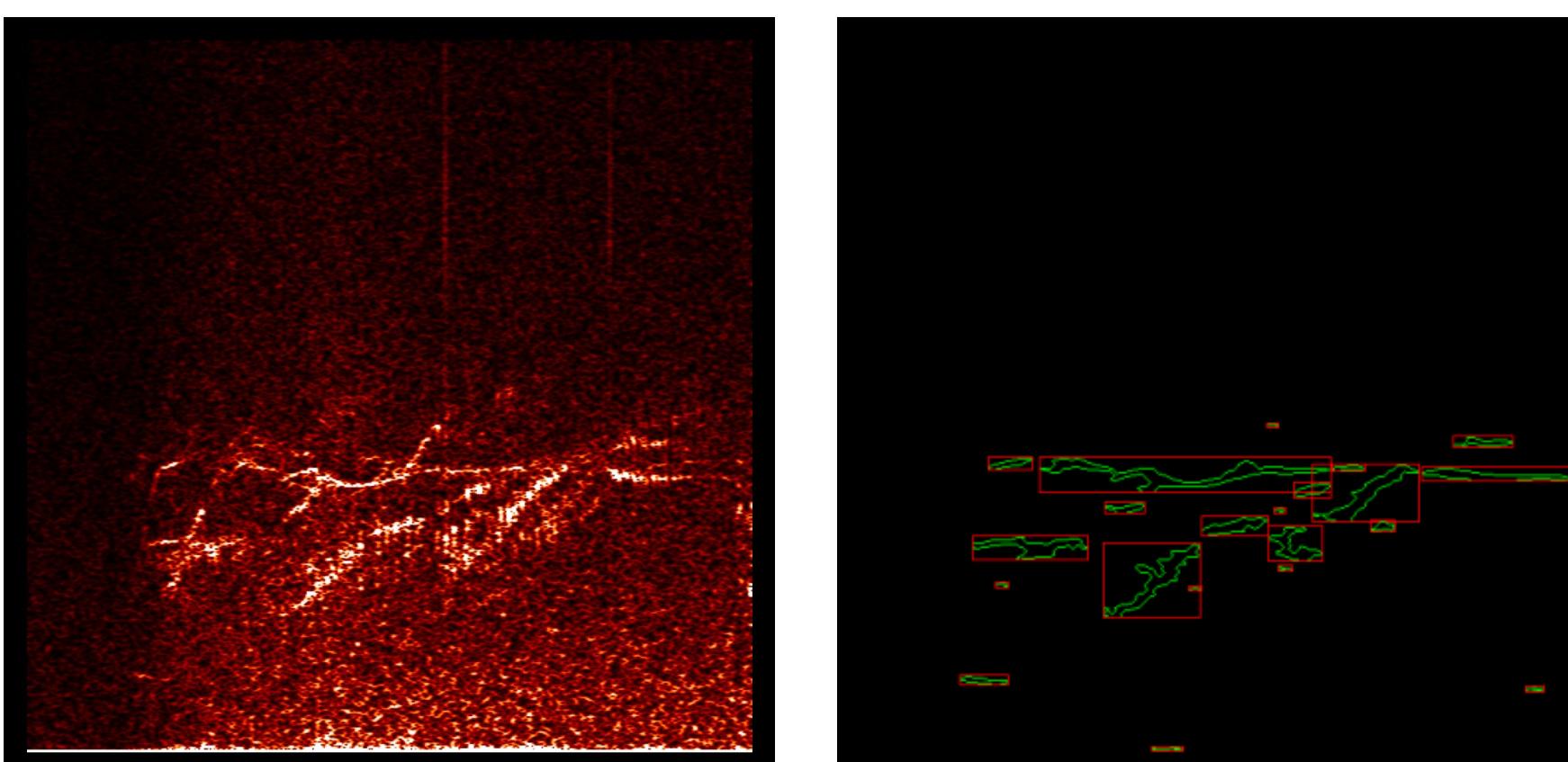
Iterative auto/cross-correlation analysis (can scale with as much data as wanted with no significant memory issue). Based on techniques in image processing.

How Extraction Work?

An optimal threshold which distinguishes background and foreground.

Additional Integrations + Demonstrations

Alfvén Eigenmode Localizer + Chat DIII-D v2-alpha



11 events detected around 120 kHz at 2500ms on shot 170660 for ECE # 5 -- Finetuned Google Gemma

5,000 Processed Shots and Counting!

Currently Supported Diagnostics

- **Fast Magnetic Coil Diagnostics** (low noise, high artifacts)
- **Electron Cyclotron Emission** (high noise, low artifacts)
- **CO2 Interferometers** (variable noise, variable artifacts)

Conclusions, Future Work and References

Summary

- Automated enhancement and labeling tool for fusion signals

Immediate Next Steps

- Uniform database for all diagnostics
- Set up general GitHub repository
- Set up control room ready software

Future planned work

- Incorporate non-fluctuation information (amplitude events)
- Incorporate more diagnostics (ECE-I, BES, RIP,...)
- Incorporate diagnostic phase interactions (spatially dependent modes)
- Fine-tune / calibrate analysis

Related Posters and Presentations

Kouroche Bouchiat	: AI Foundation Model for Fusion
Peter Steiner	: Finding Hidden Physics with ML on CER Diagnostic
Alvin Garcia	: Alfvén Eigenmode Control
Azarakash Jalalvand	: An Improved Diag2Diag

We would love to work together to enhance your diagnostic analysis workflow!

Please email nathaniel@princeton.edu, ekolemen@pppl.gov or visit our website

