

DEFUSE

A scalable framework for the multi-machine analysis of disruptions and off-normal events.

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Swiss Plasma Center · EPFL · for the DEFUSE collaboration

DEFUSE Seminar

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Why multimachine disruption and event databases?

Fusion experiments produce vast, heterogeneous, multi-modal data across devices and campaigns. Different diagnostics, naming conventions and legacy systems make cross-machine studies costly.

SCIENTIFIC EXPLOITATION

Cross-machine statistics

Scaling laws · physics mechanisms
· extrapolation to ITER and DEMO.

DOWNSTREAM TASKS

AI/ML & control

Prediction · ML training · simulation
· control-oriented monitors.

REPRODUCIBILITY

FAIR provenance

Versioned workflows · audit trails ·
standardized metadata.

COLLABORATIVE VALIDATION

Expert consensus at scale

Standardized labels · shared
templates · rollback & review.

BOTTLENECK

Fragmented data + local conventions block cross-machine science.

TARGET

Validated multi-machine databases with shared semantics.

DEFUSE supported databases

Disruption Database

Validated multi-machine disruption database covering TCV, JET-ILW, AUG, MAST ~ several thousands of disruptions validated.

L-H transition database

Conf. state database of ~1k discharges including JET & TCV experiments. Data-driven models with calibrated uncertainty (JET-PPF)

<https://zenodo.org/records/14996664>

<https://zenodo.org/records/16631053>



Pedestal database

Fit Summary	
Shot:	63847
Time:	1.0503 s
Signal:	Te_ho

Pedestal Parameters	
Height:	156.26 eV
Position:	0.9999
Width:	0.0284
Offset:	6.39 eV

Fit Quality	
RMSE:	13.384
R ² :	0.9879
Outliers:	5 (14.3%)

Core Fit	
Polynomial order:	5

SOL Decay	
Applied:	true
λ_{SOL} :	0.300
ρ_{sep} :	1.00

Auto Boundary	
Detected:	$\rho = 0.710$

Validation for EUROfusion WPTE campaigns & IMAS-ready for Gateway storage.
Automated initial fit and outlier rejection based on Gaussian Process Regression (GPR) and principled Uncertainty Quantification (UQ)

DEFUSE in one slide

Disruption & Events analysis Framework for FUSion Experiments — production stack for EUROfusion multi-machine databases

SOURCES



MDSplus · HDF5 · IMAS / IDS · UDA

SEMANTIC BACKBONE

TOKAMAKS_library.json

Diagnostics · DATA_dictionary · IMAS map

EVENTS_library.json

Catalogues · detectors · disruption defs

CURATION & ANALYSIS

QualityDATA

checks · scoring · masks

Disruption pipeline

tD · TQ/CQ · VDE · RE · forces

Detector / Observer

batch + checkpoints

Plasma states

IP segments · MAGN · CONF transitions

STORAGE & EXPORT

SQL / SQLite

MongoDB

HDF5 / NetCDF

Parquet / Xarray

Validation · git tags · audit log

IN NUMBERS

~10k disruptions

JET-ILW ~6k (Ip>750 kA) + TCv ~4k (Ip>50 kA).

x00+ signals/machine

Unified DATA_dictionary across various machines.

<30 s/shot

End-to-end, parallel batch with checkpoints.

3 languages

MATLAB + Python OOP, C++, shared JSON libraries.

DESIGN PRINCIPLE

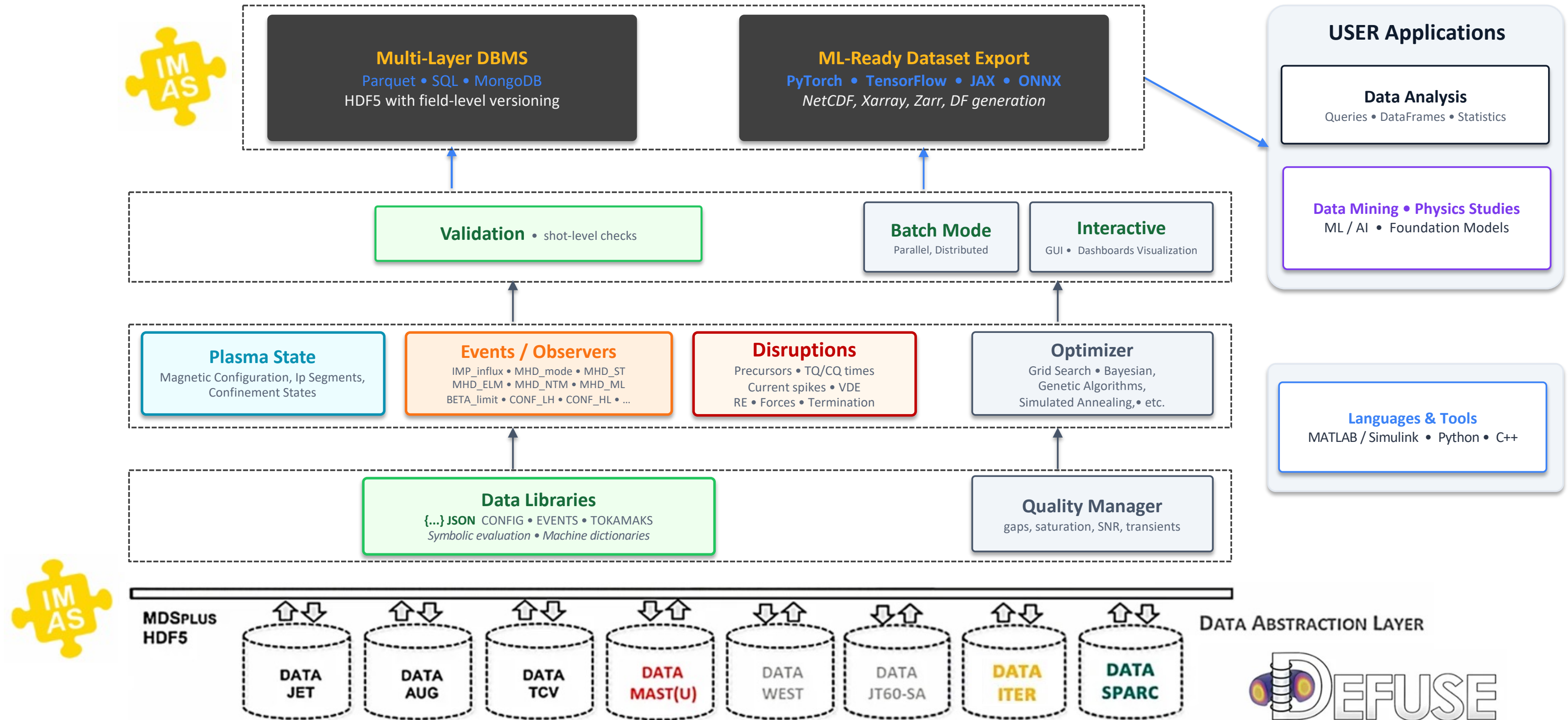
Adding a machine = writing a JSON dictionary,

- NOT rewriting the algorithms/ analysis (machine-agnostic = reusable)
- fine-tune observers and detectors for plasma state and events with built-in optimizers

OPEN & REPRODUCIBLE

Apache 2.0 / LGPL · gitlab.epfl.ch · GitHub mirror · CI/CD · ~80% test target

DEFUSE: a scalable framework for fusion experiments



Data abstraction layer: JSON data libraries: TOKAMAKS and EVENTS

Two human-editable libraries describe every machine and every observable phenomenon.

TOKAMAKS machines, signals, conventions

```

▼ object {3}
  ▶ Dictionaries_info {6}
  ▶ Table_DATA {41}
  ▼ machine_template {8}
    ▶ DATA_dictionary {2}
    ▶ DATA_processing {5}
    ▶ DIAG_dictionary {12}
      Data_access : local
      Data_format : hdf5
      Test_access : local
    ▶ Release {5}
      version : 24
  
```

```

  ▶ FIR {3}
  ▶ FIR_LIDs {3}
  ▶ FIR_ref_core {3}
  ▶ AXUV {3}
  ▶ BOLO {3}
  ▶ SXR {3}
  ▶ TS {3}
  ▼ TSu {3}
    info_tag : TS upgrade with more measurements points
    ▼ geometry {2}
      ▼ los {2}
        ▶ rchord [109]
        ▶ zchord [109]
      ▶ rho_grid [67]
      coord_type : RZ, rho_pol
  ▶ CXRS {3}
  ▶ BOLOu {3}
  ▶ AXUVu {3}
  
```

```

▼ BETAN {8}
  Name : BETAN
  Format : 1D
  Description : normalized toroidal beta
  Units : a.u.
  ErrorBar : null
  ▼ Origin {3}
    ▼ variables [4]
      0 : BZERO
      1 : a_minor
      2 : IPLA
      3 : BETAT
    ▼ coefficients {1}
      k : 100000000
    ▼ expressions [1]
      0 : k * abs((BETAT ./ IPLA) .* BZERO .* a_minor)
  IMAS : /equilibrium/time_slice(itime)/global_quantities/beta_normal
  MachineID : 3
  
```

JSON plugin symbolic evaluation

Data abstraction layer: JSON data libraries: TOKAMAKS and EVENTS

Two human-editable libraries describe every machine and every observable phenomenon.

EVENTS observables, detectors, expected chains

▼ object {6}

▶ **Catalog {27}**

▶ Disruptions {5}

▶ Detectors {4}

▶ **Discharge {8}**

▶ Release {5}

version : 3

▼ object {6}

▼ Catalog {27}

inf : Generic Catalog including basic categorization of phenomenology and physics
o_t mechanisms of interest describing characteristic events. Typical timescales
ag are in general machine-dependent. Reference for Detectors instantiation

▶ acronyms {29}

▶ Fields [24]

▶ IMP_influx {4}

▶ IMP_accumul {4}

▶ IMP_event {4}

▶ RAD_collapse {4}

▶ MHD_mode {4}

▶ MHD_NTM {4}

▶ MHD_N1 {4}

▶ MHD_N2 {4}

▶ MHD_ML {4}

▶ MHD_ST {4}

▶ MHD_ELM {4}

▶ MHD_EFLM_lq_lne {4}

▶ BETA_limit {4}

▶ CONF_LH {4}

▶ CONF_HL {4}

▶ DETACH {4}

▶ EDGE_cooling {4}

▶ MARFE {4}

▼ Discharge {8}

inf : DATA dictionary for discharge segmentation in phases of interest wrt
o_t reference plasma current IP, magnetic configuration, confinement states and
ag control segments.

▶ Acronyms {7}

▶ Fields [4]

▶ IP_segments {4}

▶ BAFFLES {4}

▶ MAGN_conf {4}

▶ CONF_states {4}

▶ CTRL_segments {1}

DEFUSE tools – JSON editor

The screenshot displays the DEFUSE JSON Config Editor interface. At the top, the browser address bar shows '127.0.0.1:8765'. The main header includes the title 'DEFUSE JSON Config Editor' and the current file path 'DEFUSE_Dir.json (root) (DEFUSE_Dir.json)'. Below the header, there are several control buttons: 'Browse', 'Up', 'Select folder', 'Open Folder', 'Select JSON file', 'Open File', 'Validate', and 'Save'. A 'Load' button and a 'Browse dir (repo-relative)' button are also present.

The central area features a file tree view with a search bar. The tree structure is as follows:

- object ▶ tool_folders ▶
 - object {12}
 - ▶ tool_folders [18]
 - ▼ local_folders [2]
 - 0 : DEFUSE_tests/data_tests
 - 1 : DEFUSE_Data_DB/DB_parquet
 - ▼ server_folders {14}
 - Root : /Lac8_D/DEFUSE
 - Event_Detection : /Lac8_D/DEFUSE/Event_Detection
 - DEFUSE_DB : /Lac8_D/DEFUSE/DEFUSE_DB
 - Figures : /Lac8_D/DEFUSE/Figures
 - Parquet : /Lac8_D/DEFUSE/DEFUSE_DB/DB_parquet
 - Parquet_ML : /Lac8_D/DEFUSE/DEFUSE_DB/DB_parquet/Parquet_temp
 - Mat : /Lac8_D/DEFUSE/DEFUSE_DB/DB_mat
 - MatRS : /Lac8_D/DEFUSE/DEFUSE_DB/DB_same_time_2ms
 - RE : /Lac8_D/DEFUSE/DEFUSE_DB/RunawayElectrons
 - SQL_db : /Lac8_D/DEFUSE/DEFUSE_DB/SQL_db
 - DB4analysis : /Lac8_D/DEFUSE/DEFUSE_DB/DB4analysis
 - HDF5 : /Lac8_D/DEFUSE/DEFUSE_DB/DB_mat
 - Repo_DB : /Lac8_D/DEFUSE/DEFUSE_DB/DB_mat/Repo
 - Repo_DB_local : C:\\Users\\aless\\Downloads\\DATA
 - ▶ Reports_folder [1]
 - ▶ rapdens_folder [1]

Reference data formats

One pipeline, several materializations — each tuned to a downstream applications.

.h5

HDF5

Per-shot signal archive

Hierarchical groups: /shot/<machine>/<signal>

Native units, time-base, attributes preserved

Best for chunked random access & physics inspection

Versioning

USED BY

Quality manager · validation dashboards · IMAS bridge

.parquet

APACHE PARQUET

Columnar slices for ML

One row per (shot, t), columns are signals

Compressed, partitioned by machine + campaign

Loads in seconds with PyArrow / Polars / Spark

USED BY

Disruption predictors · cross-machine ML studies

.nc

NETCDF / XARRAY

Labelled multi-dim arrays

Dims: time, channel, rho

CF-conventions metadata; opens in any analysis tool

Drop-in for IMAS-style profile analyses / Zarr

USED BY

Profile diagnostics · IMAS interop · publications

ONE SOURCE OF TRUTH All three products are deterministic exports of the same DEFUSE entries — pipeline writes once, consumers pick the format that fits the workload

Reference data products

DEFUSE HDF5 Viewer
No registered files ↕
Open
src/defuse/DEFUSE_tests/c
Browse
↑ Up
— folder — ↕
→
TCVno63847.h5 ↕
Load

- TM (2)
 - x [8x1]
 - z [8x7755]
- cam
 - los (3)
 - ch... [64x1]
 - rc... [64x2]
 - zc... [64x2]
 - t [1x7755]
 - x [64x1]
 - z [64x7755]
 - time [34x1]
- BOL0u (2)
 - signal [1x2]
 - time [1x2]
- BZERO (2)
 - signal [1x1788]
 - time [1x1788]
- DELTA (2)
 - signal [1x1788]
 - time [1x1788]
- DELTA_BOTTOM (2)
 - signal [1x1788]
 - time [1x1788]
- DELTA_TOP (2)
 - signal [1x1788]
 - time [1x1788]
- DML (2)
 - signal [1x57692]**
 - time [1x57692]
- ECEcore (2)
 - signal [1x23775]
 - time [1x23775]
- ECRH (2)
 - signal [1x20723]
 - time [1x20723]

DATASET signal /SIG/DML/signal

SHAPE
1 × 57692

TYPE
float32

DIMENSIONS
2

SIZE
57,692

STORED
201.5 KB

CHUNKS
1x14423

COMPRESSION
gzip

FILL VALUE
0

Data Preview ↻ Reload

⚠ Showing first 10,000 of 57,692 elements. Full shape: 1 × 57692.

#	0	1	2	3	4	5	6	7	8	9	10	11	12	13
0	0.00000396298	0.00000249436	0.00000229708	0.00000318124	0.00000508073	0.00000267952	0.00000306230	0.00000460539	0.00000284421	0.00000394602	0.00000356779	0.00000334611	0.00000328938	0.00000367114

Visualisation

Type: Line trace X axis: time [1x57692] Colour: blue ⚠ 10,000 / 57,692 pts

signal [57692 float32]

Reference data products

DEFUSE HDF5 Viewer No registered files src/defuse/DEFUSE_tests/c — folder — TCVno63847.h5

DATASET z /SIG/Te_rho/signal/raw/z

SHAPE: 148 × 109 TYPE: float32 DIMENSIONS: 2 SIZE: 16,132 STORED: 28.2 KB CHUNKS: 148×109 COMPRESSION: gzip FILL VALUE: 0

Data Preview

Showing first 10,000 of 16,132 elements. Full shape: 148 × 109.

#	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
0	-1	-1	-1	-1	-1	-1	-1	16.8913	11.9528	14.4798	17.6714	15.2160	18.5033	-1	21.1006	16.7011	20.9657	20.8119	23.1567	-1	-1	-1	-1
1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
3	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	19.1253	-1	-1	-1	-1	121.654
5	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	83.8876	93.4235
6	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	11.9558	20.8078	-1	-1	83.1355	130.430
7	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	12.1228	19.5983	26.1984	35.0999	-1	-1	100.061	122.291
8	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	19.9375	24.5614	39.0747	-1	81.6017	109.281	117.596

Visualisation

Type: Colorscale: 10,000 / 16,132 pts

z [148 × 109 float32]

Quality manager: signal reliability as metadata

Every sample carries a quality score next to its value — never silently masked.

Four-level scoring

Good

Trusted. Within validity range, redundancy agrees, dependencies healthy.

Acceptable

Caution. Out-of-range spikes, suspicious slope, partial sensor loss.

Poor

Unreliable. Sensor saturated, NaN bursts, calibration flag raised.

∅

Missing. Signal absent for shot — explicit, never silent.

HOW A SCORE IS ASSIGNED

Range & physics checks. Bounds from JSON validity , plus shape/derivative tests.

Redundancy. Compare with parallel diagnostics; disagreement degrades score.

Statistics. Outliers vs. campaign-level baseline; long quiescent gaps flagged.

Dependency rule. A derived signal can never be better than its worst input.

STORAGE MODEL

Quality is a parallel time-series , not a mask. Users see why a sample is downgraded — and ML pipelines can choose to weight, exclude, or impute.

Quality manager: signal reliability as metadata

Every sample carries a quality score next to its value — never silently masked.

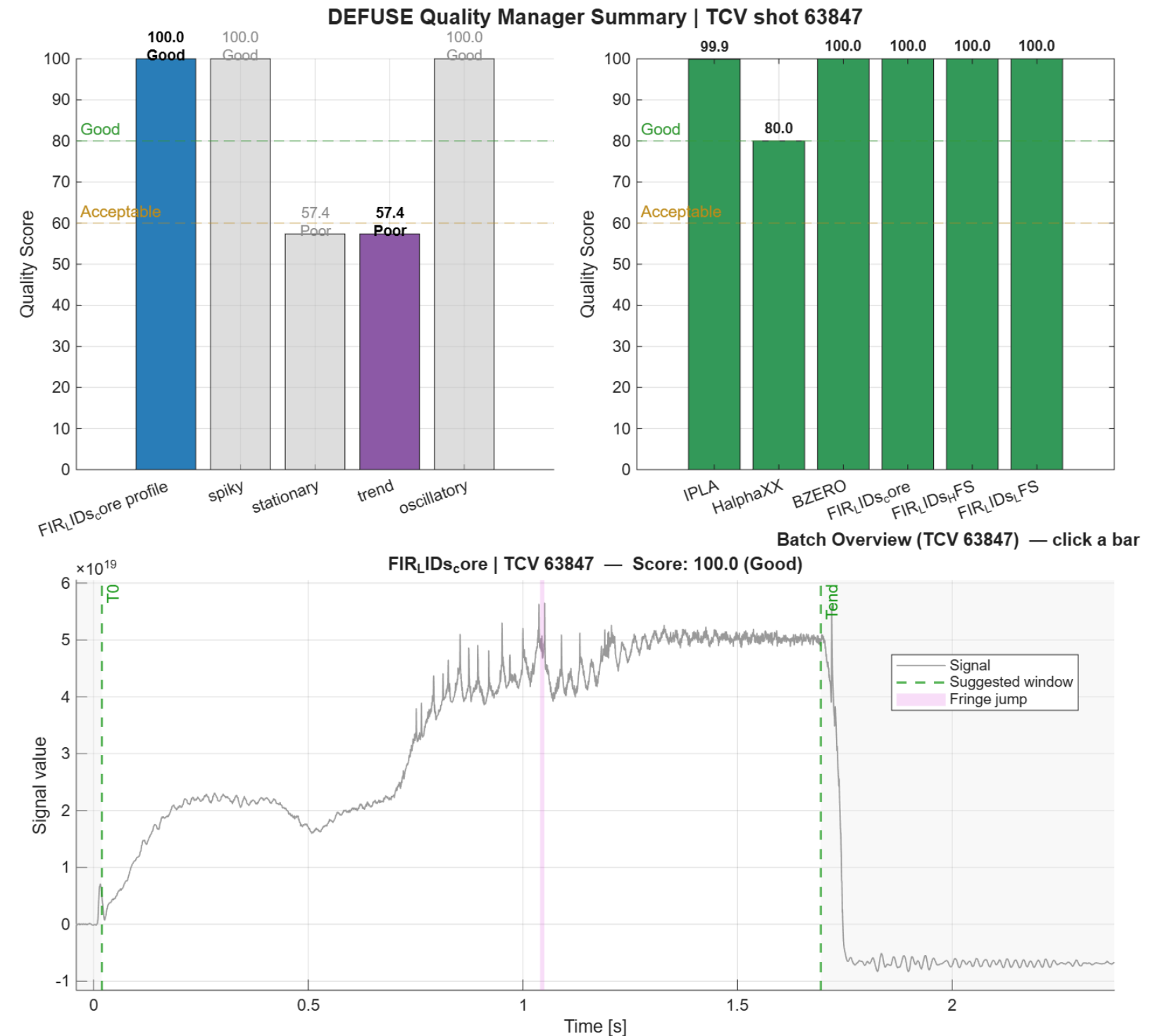
HOW A SCORE IS ASSIGNED

Range & physics checks. Bounds from JSON validity , plus shape/derivative tests.

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Statistics. Outliers vs. campaign-level baseline; long quiescent gaps flagged.

Dependency rule. A derived signal can never be better than its worst input (propagation)



Processing pipeline: build, clean, label, normalize

A deterministic four-stage pipeline takes raw signals to ML-ready, validated entries.

01

BUILD

Acquire & abstract

Pull from MDSplus / JPF / Shotfile

Apply unit + sign normalization

Persist per-shot HDF5 cache

02

CLEAN

Quality & gaps

Range / shape / redundancy checks

Score every sample ($A \rightarrow D, \emptyset$)

Mark gaps; never silently impute

03

LABEL

Events & states

Run observers + detectors

Build chain-of-events

Stamp plasma-state transitions

04

NORMALIZE

DB & export

Write SQL/NoSQL entries with schema validation

Materialize Parquet/NetCDF for ML

Provenance: code rev + JSON rev + run id

DETERMINISM

Same shot + same JSON revs \rightarrow same entry, byte-for-byte. Caches keyed on input hashes.

RESUMABILITY

Each stage checkpoints; failed shots restart at the failed stage, not from raw data.

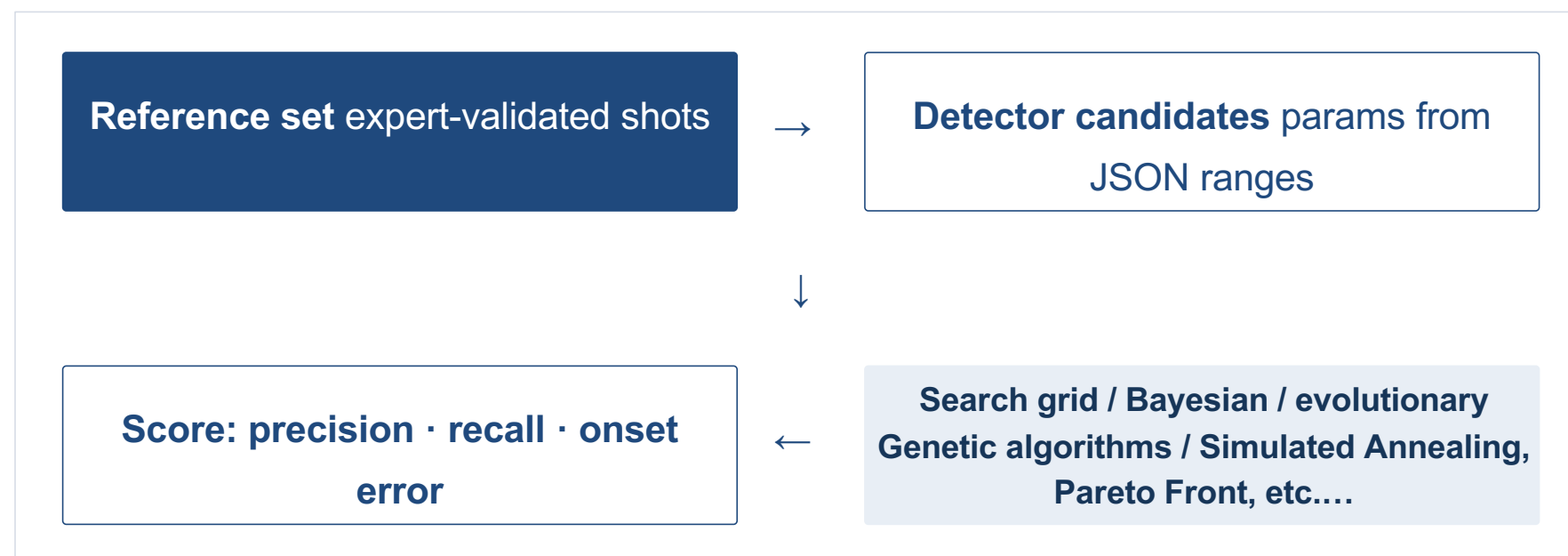
PARALLELISM

Embarrassingly parallel per shot; Datastores and Dask backends supported.

Optimization layer: tuning observers and detectors

Detectors are not hand-coded — their parameters have to be optimized against curated reference shots.

Optimization loop



The same machinery tunes per-machine overrides

JET locked-mode threshold differs from TCV's, the optimizer finds it.

WHAT GETS TUNED

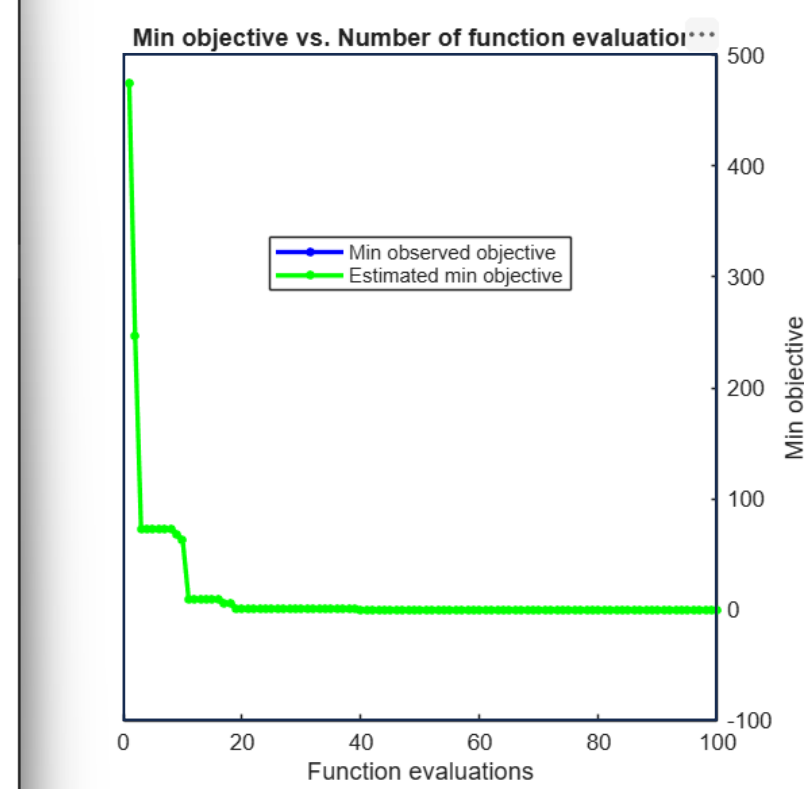
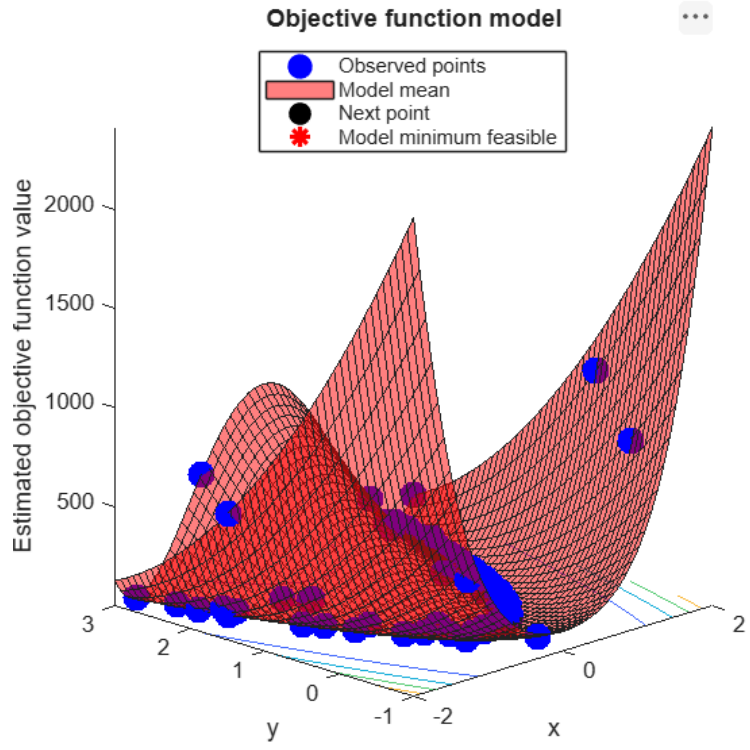
- Thresholds & hysteresis** on observer time-series
- Smoothing windows**, derivative kernels
- State-machine timeouts** for multi-step detectors
- Per-machine overrides** for shared event definitions

OUTPUTS

- Tuned params JSON, versioned alongside the event
- Confusion matrix & ROC against the reference set
- Drift report when re-tuned on a new campaign

DISCIPLINE Tuning is always against a held-out validation set .

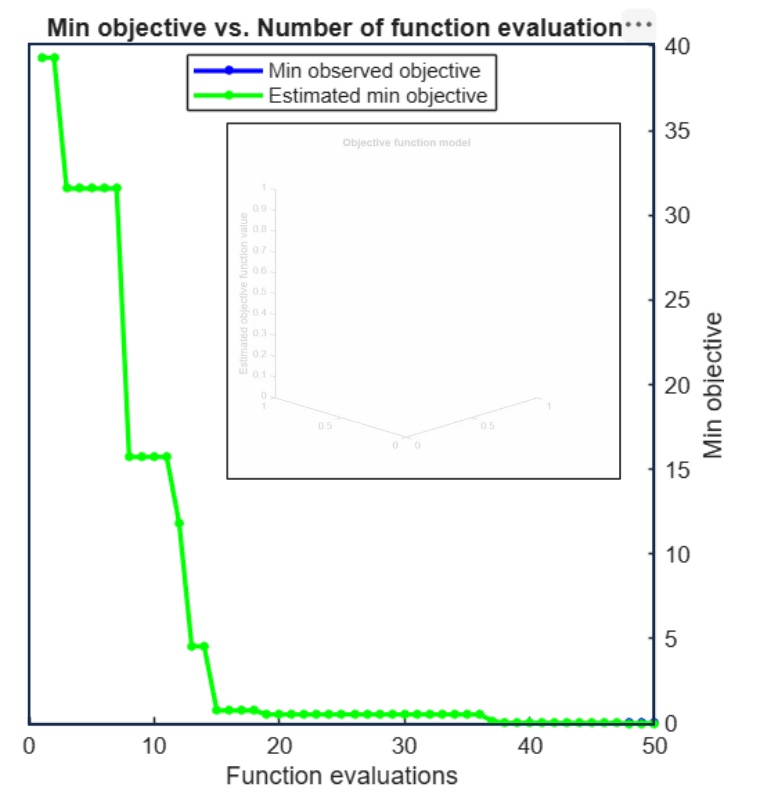
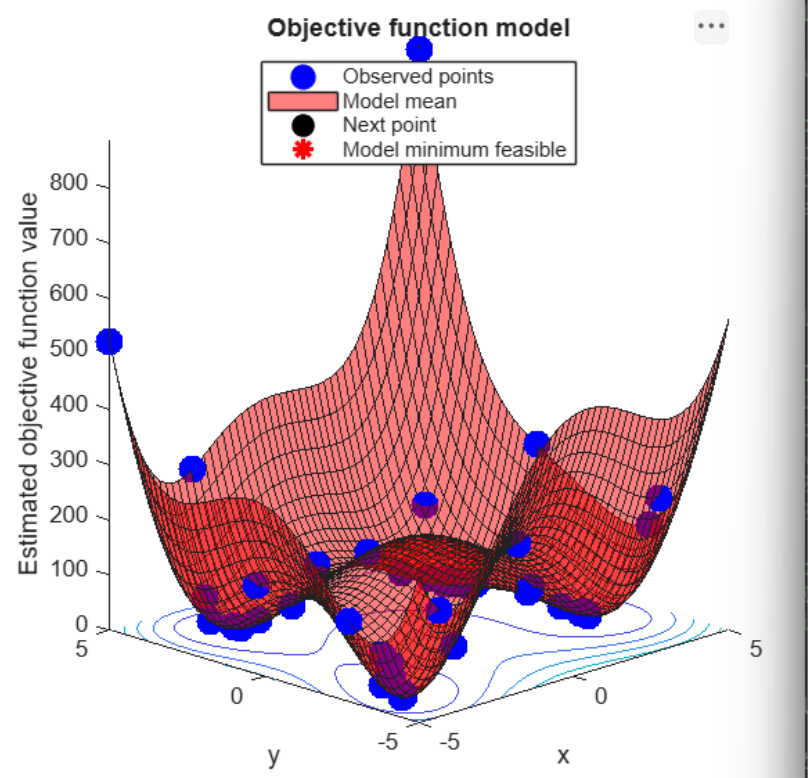
Optimization layer: tuning observers and detectors



WHAT GETS TUNED

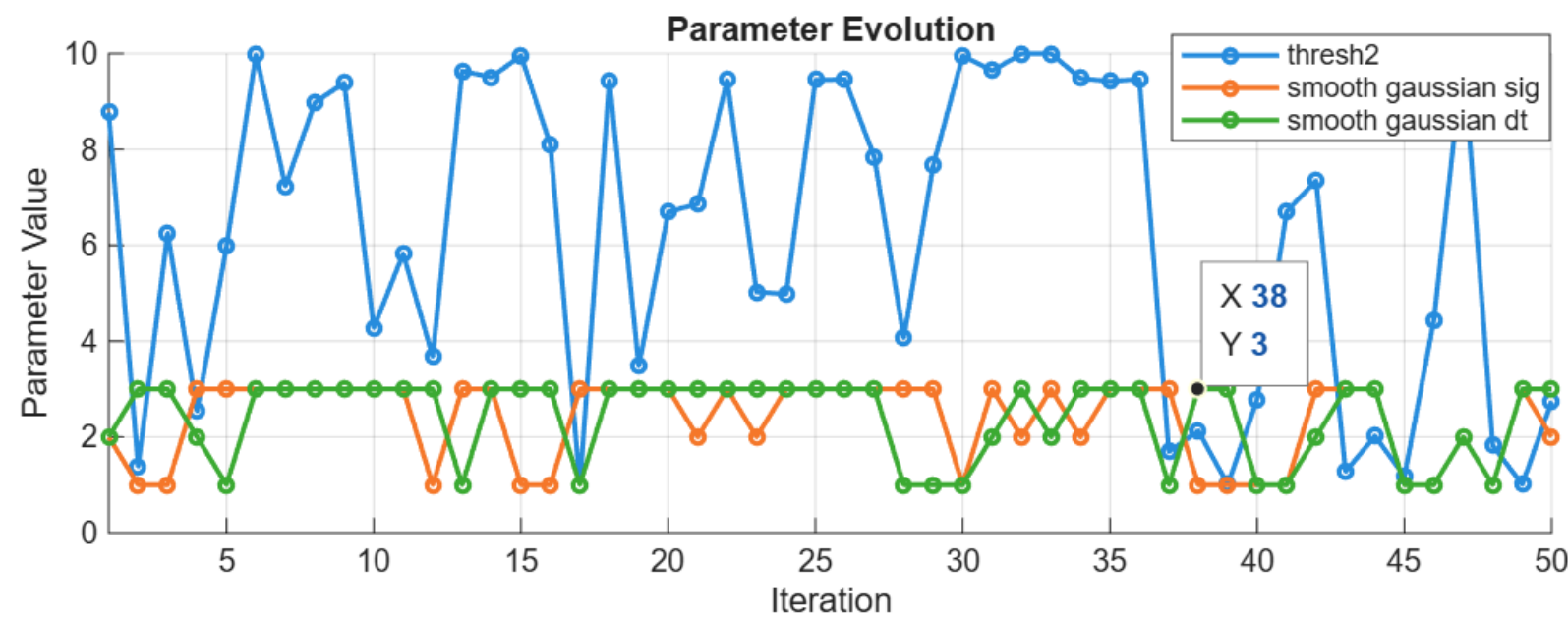
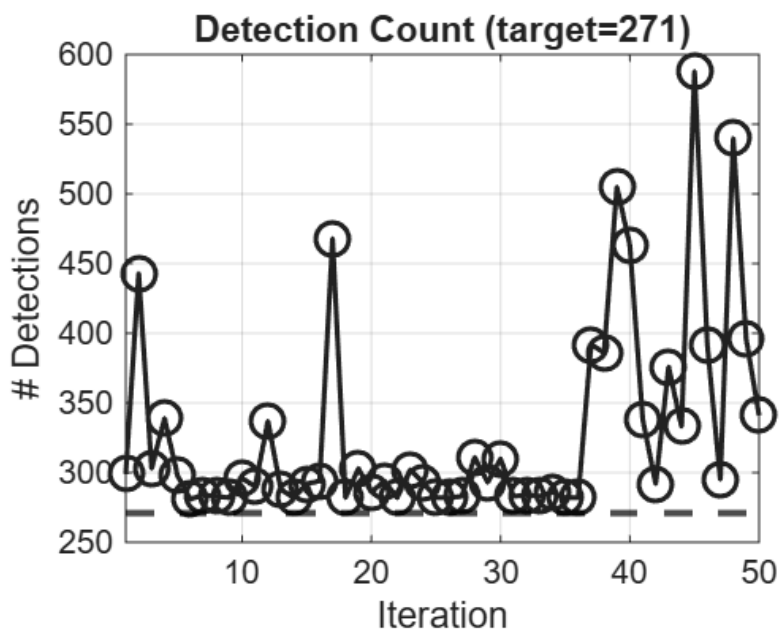
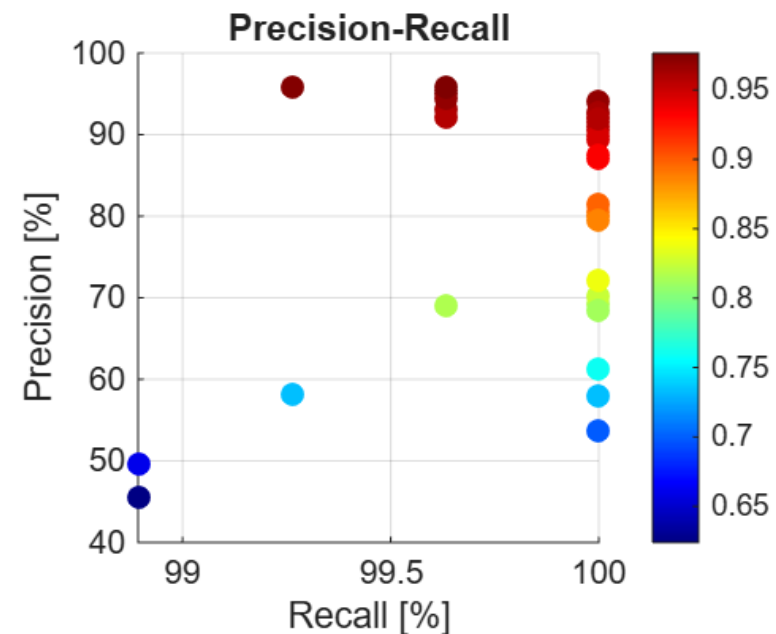
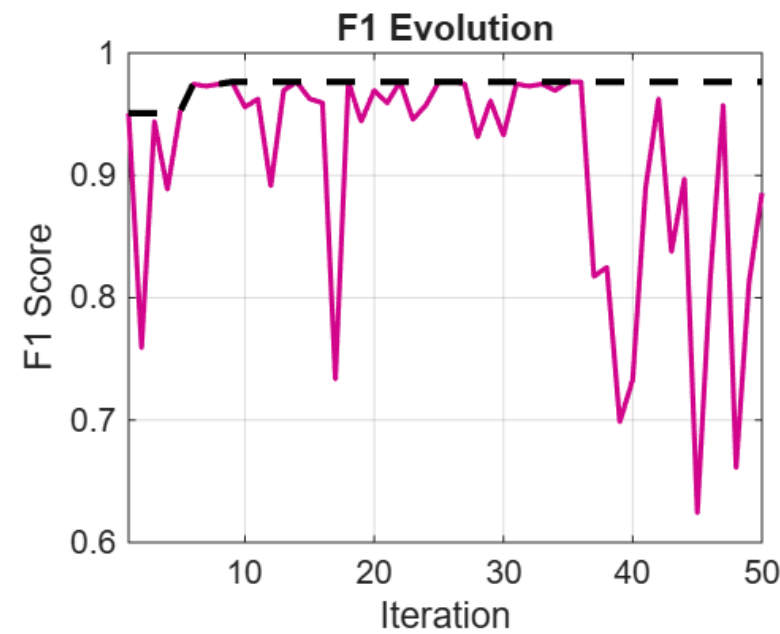
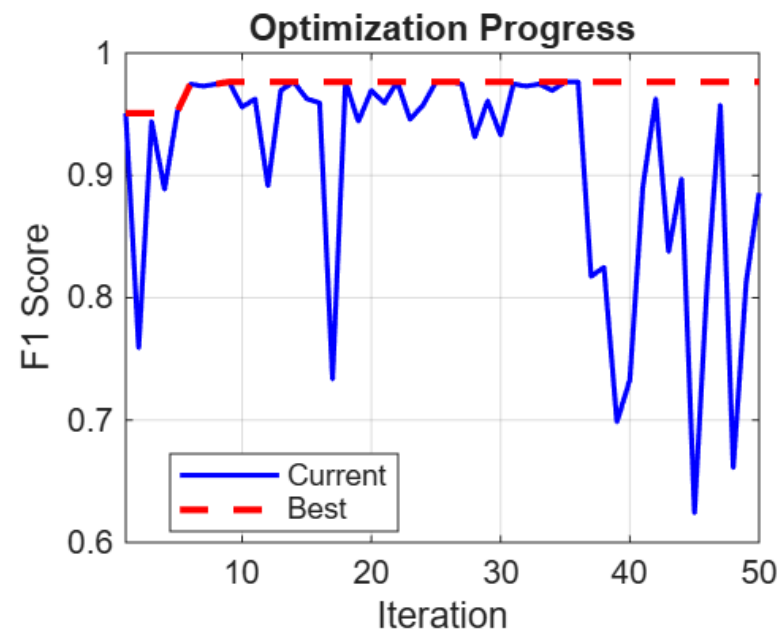
- Thresholds & hysteresis**
- Smoothing windows, derivative kernels**
- Assertion times**

```
Catalog_with_dictionary {46}
  ▶ Fields [39]
  ▶ DUMMY {12}
  ▼ ELM0 {12}
    label : ELM0
    machine : TCV
    Type : Transient
    ComparisonMethod : GreaterThan
    Threshold : 20
    timeRef : null
    AssertionTime : 0.0001
    minDelta : 0.004
    maxDelta : 1
    t_offset : 0.1
    diag : value
    model : physics-based
```



Optimization layer: tuning observers and detectors

Bayesian Optimization (Iter 50/50) - Best F1 = 0.9765



WHAT GETS TUNED

Thresholds & hysteresis

Smoothing windows, derivative kernels

Assertion times

Catalog_with_dictionary {46}

▶ Fields [39]

▶ DUMMY {12}

▼ ELM0 {12}

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machine : TCV

Type : Transient

ComparisonMethod : GreaterThan

Threshold : 20

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AssertionTime : 0.0001

minDelta : 0.004

maxDelta : 1

t_offset : 0.1

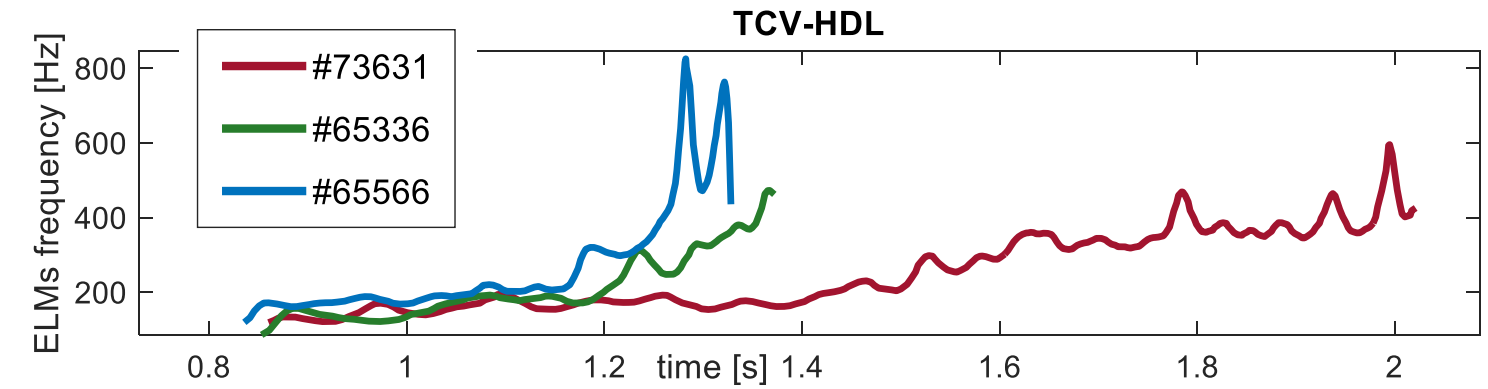
diag : value

model : physics-based

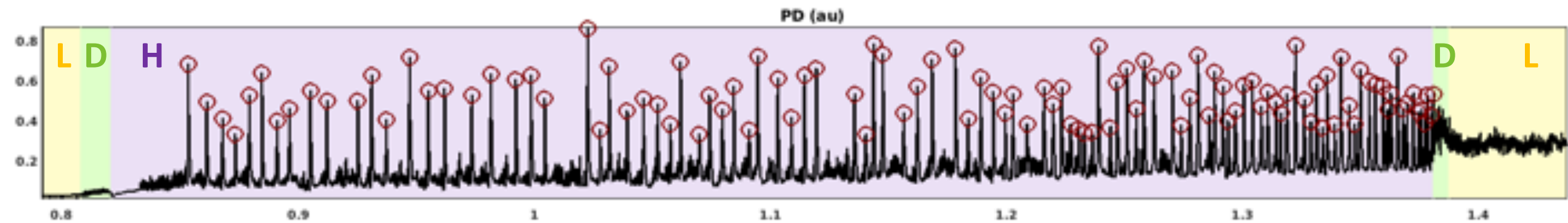
Edge Localized Modes (ELMs)

ELMs in different regimes

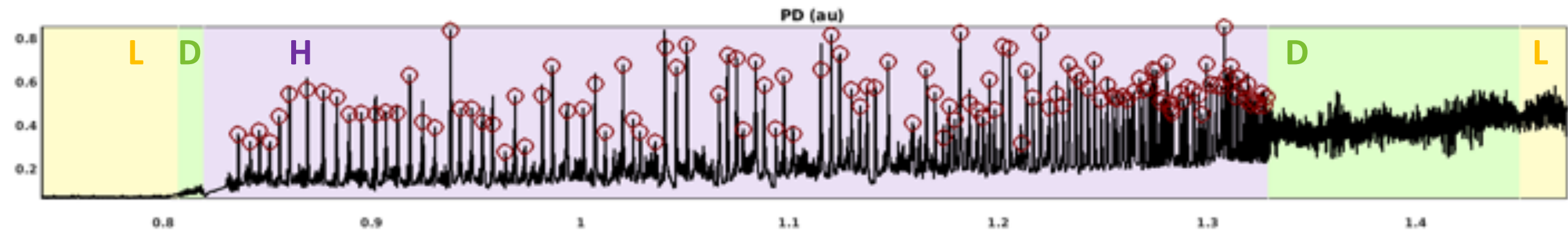
- Characterization of different **ELMs regimes** and **confinement state transitions**



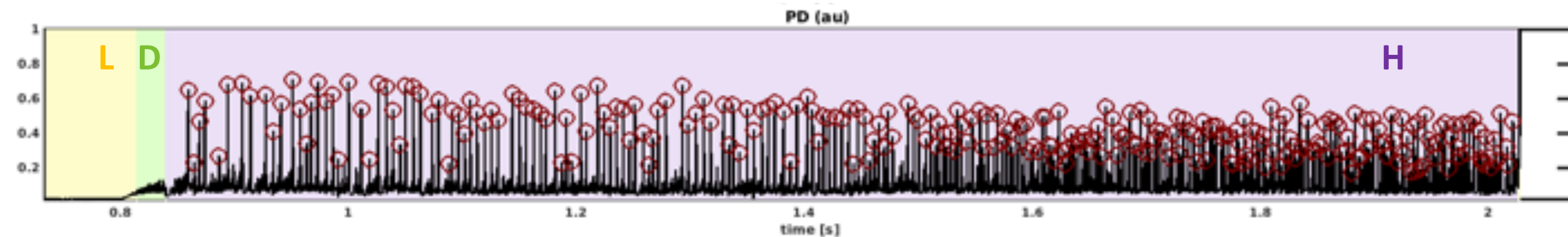
FEEDFORWARD
#65336



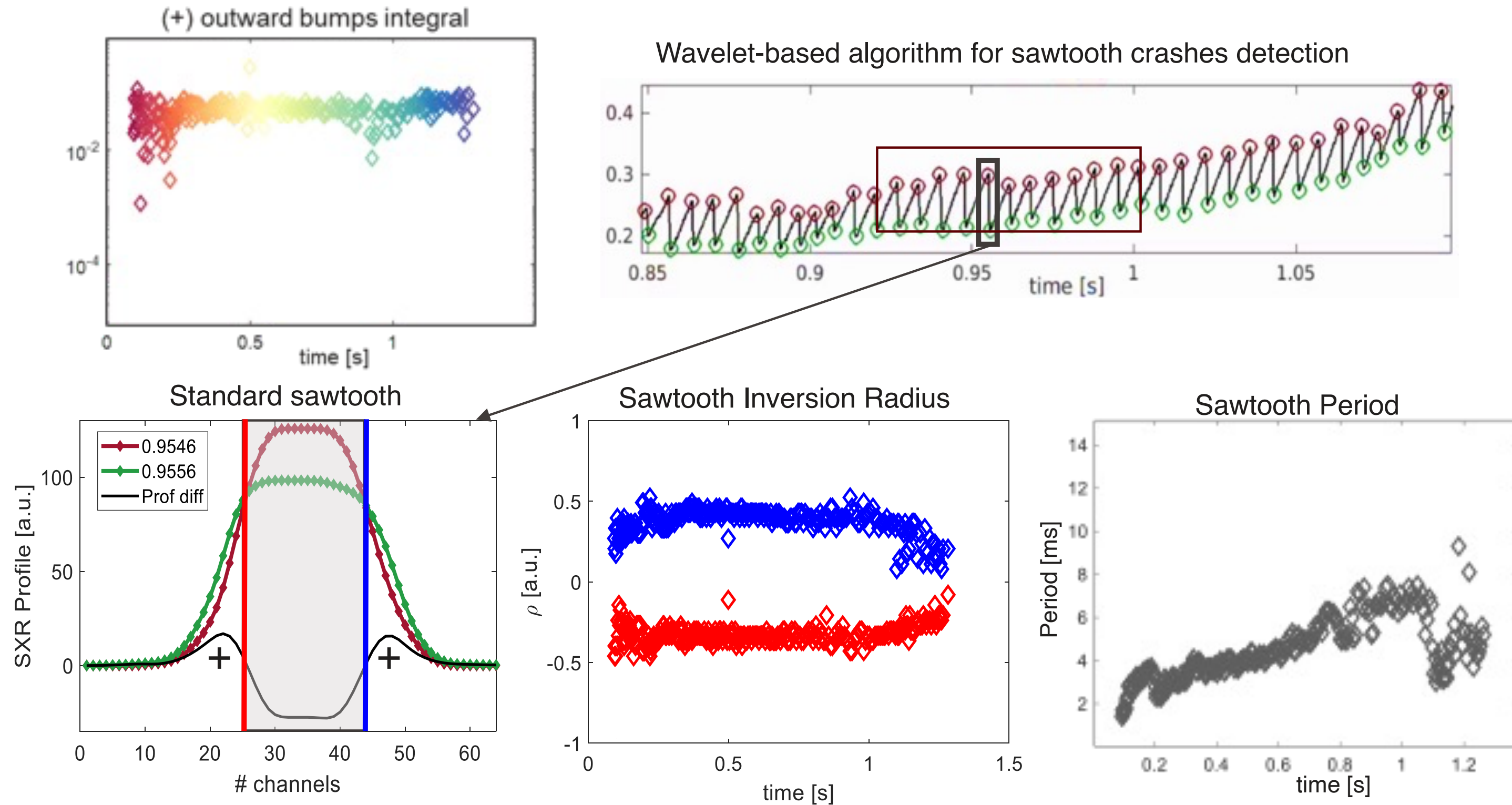
DISRUPTION AVOIDANCE
#65566



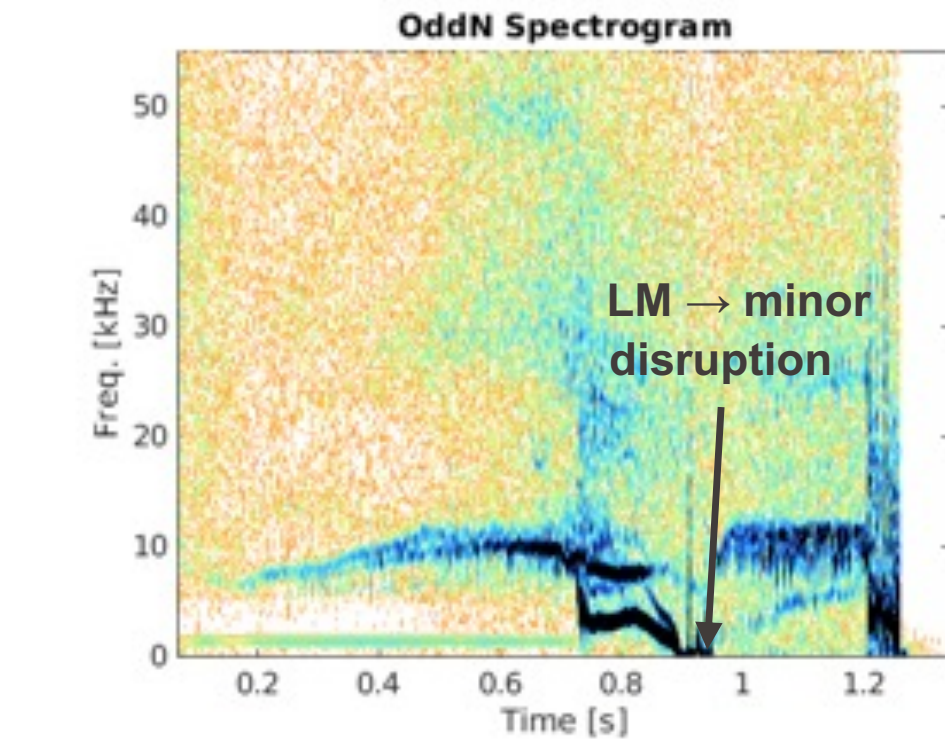
PROXIMITY CONTROL
73631



Sawtooth crashes and minor disruptions

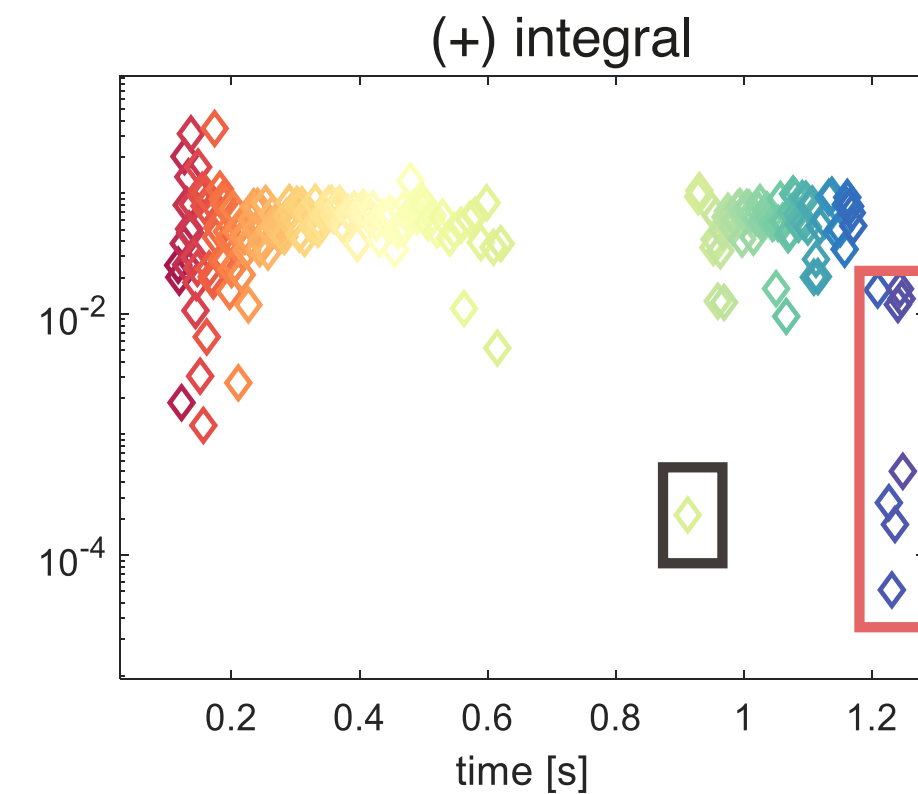
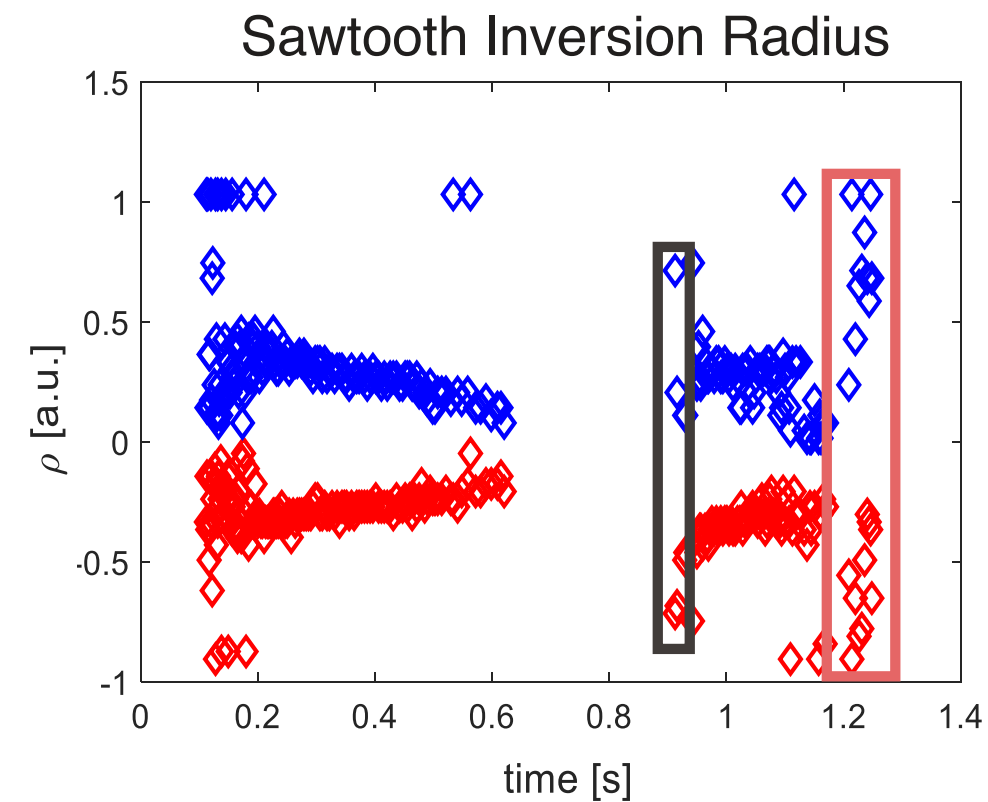
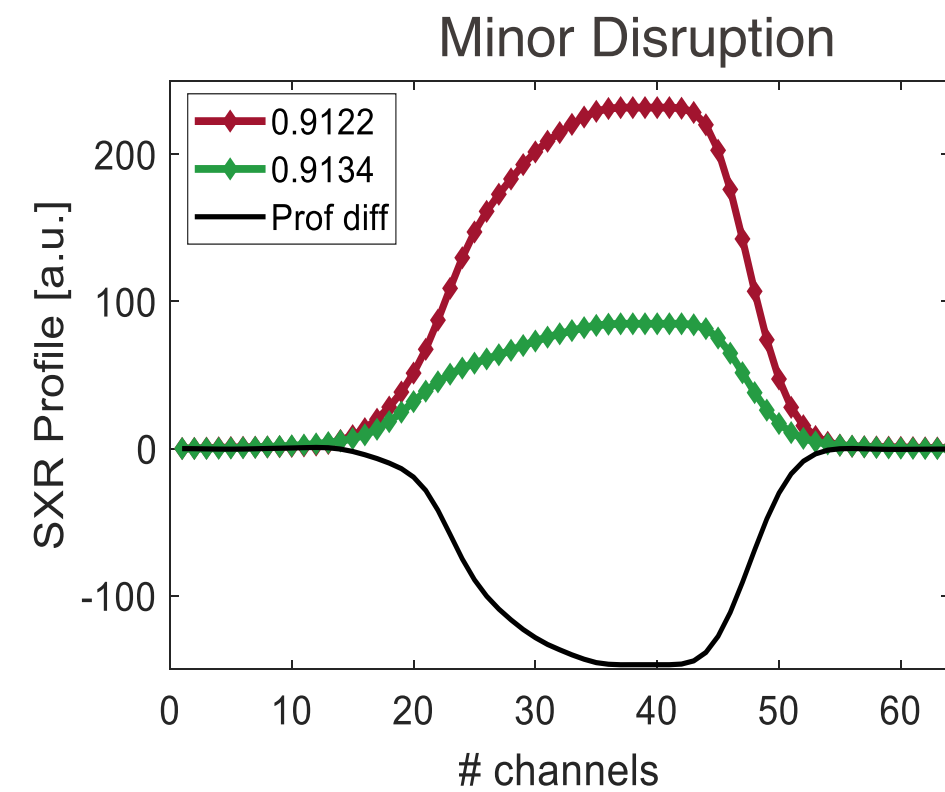


Sawtooth crashes and minor disruptions

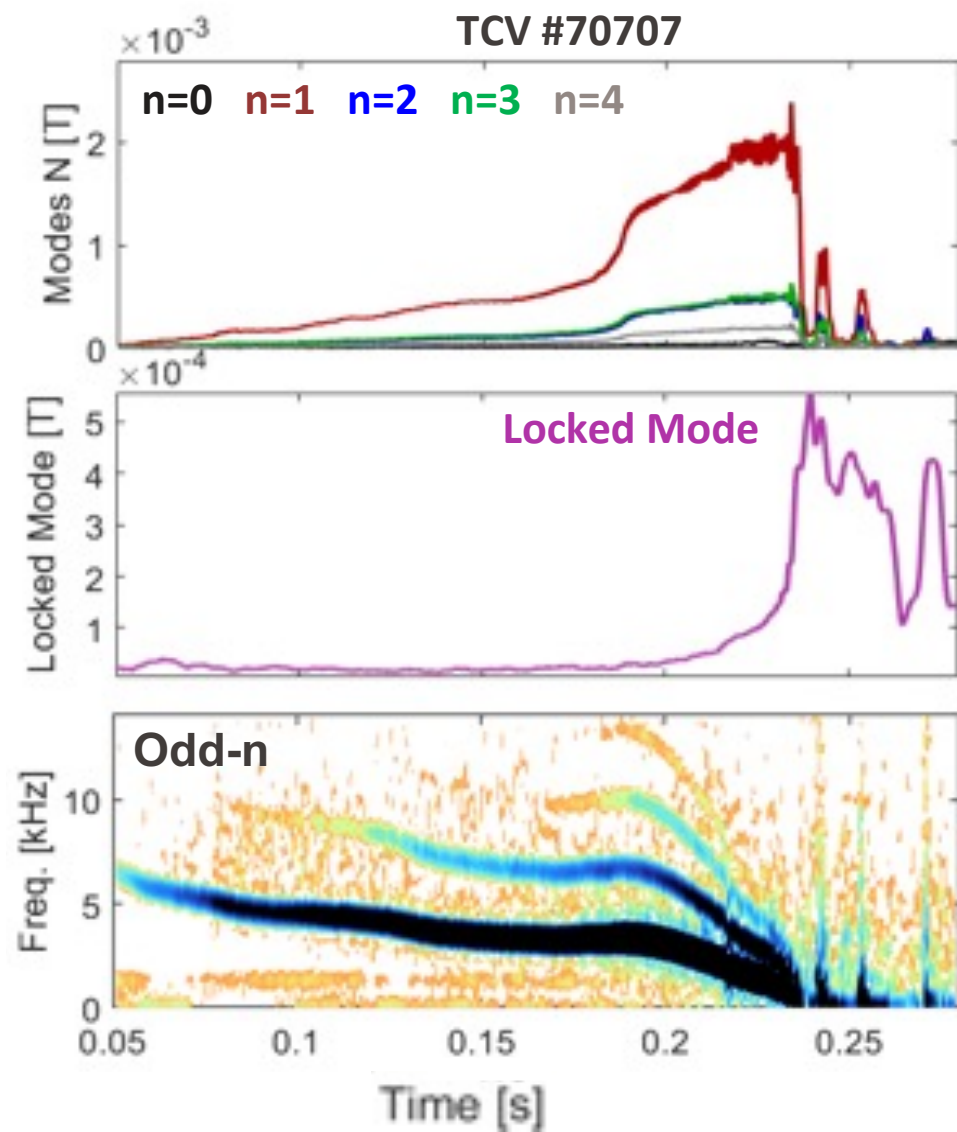


SAWTOOTH AND MINOR DISRUPTIONS, DETECTION AND VALIDATION

- Changes in **sawtooth dynamics** consistently correlate with characteristic phases preceding different **disruption types** (density limit, impurity accumulation, etc.)
- **sawtooth crashes** can be distinguished reasonably well from **minor disruptions** or other spurious events having access to sufficiently spatially resolved **radial profiles**.



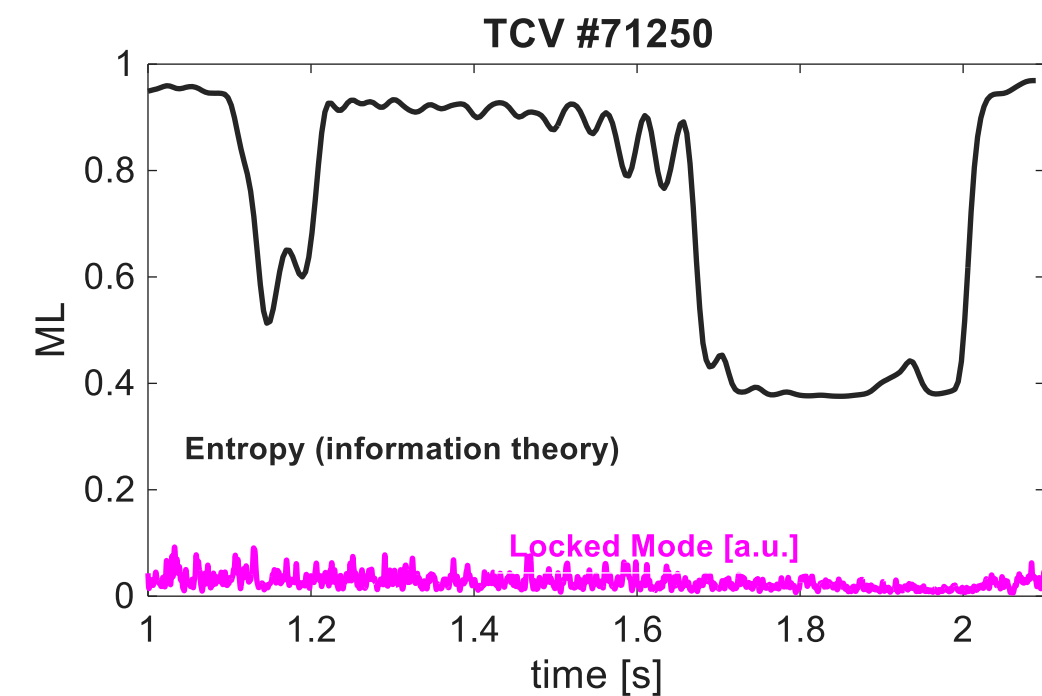
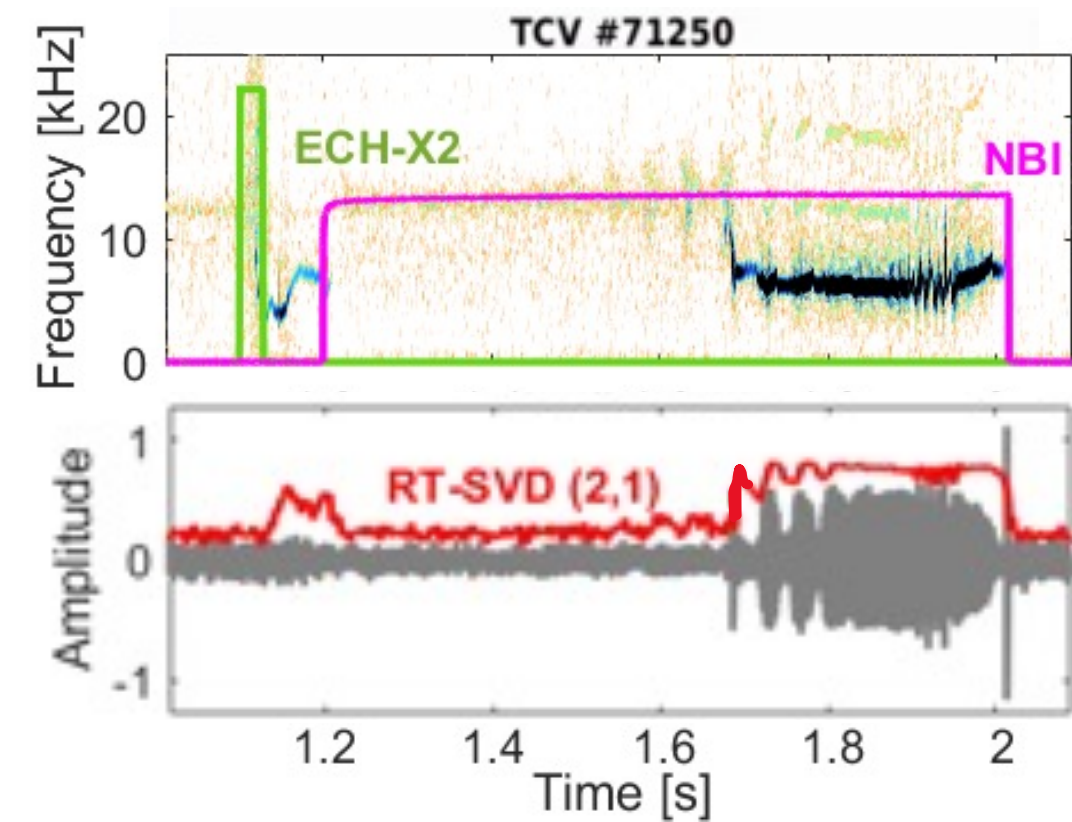
MHD markers and detectors



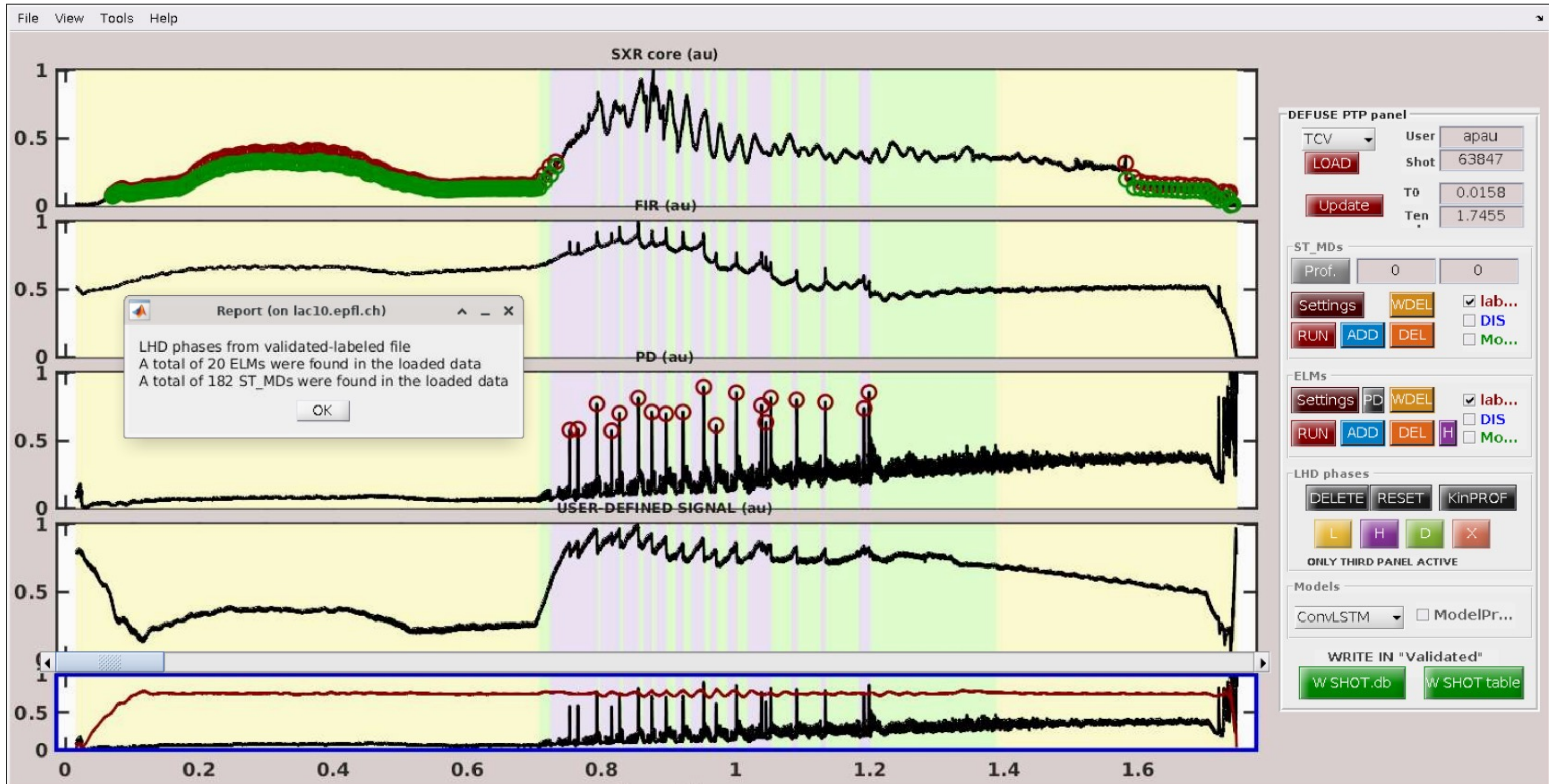
MHD INSTABILITIES DETECTION

- Calculation of (m, n) **mode likelihood** from SVD and fourier decomposition
- Various indicators for extracting relevant mode features (track **amplitude**, **frequency**)

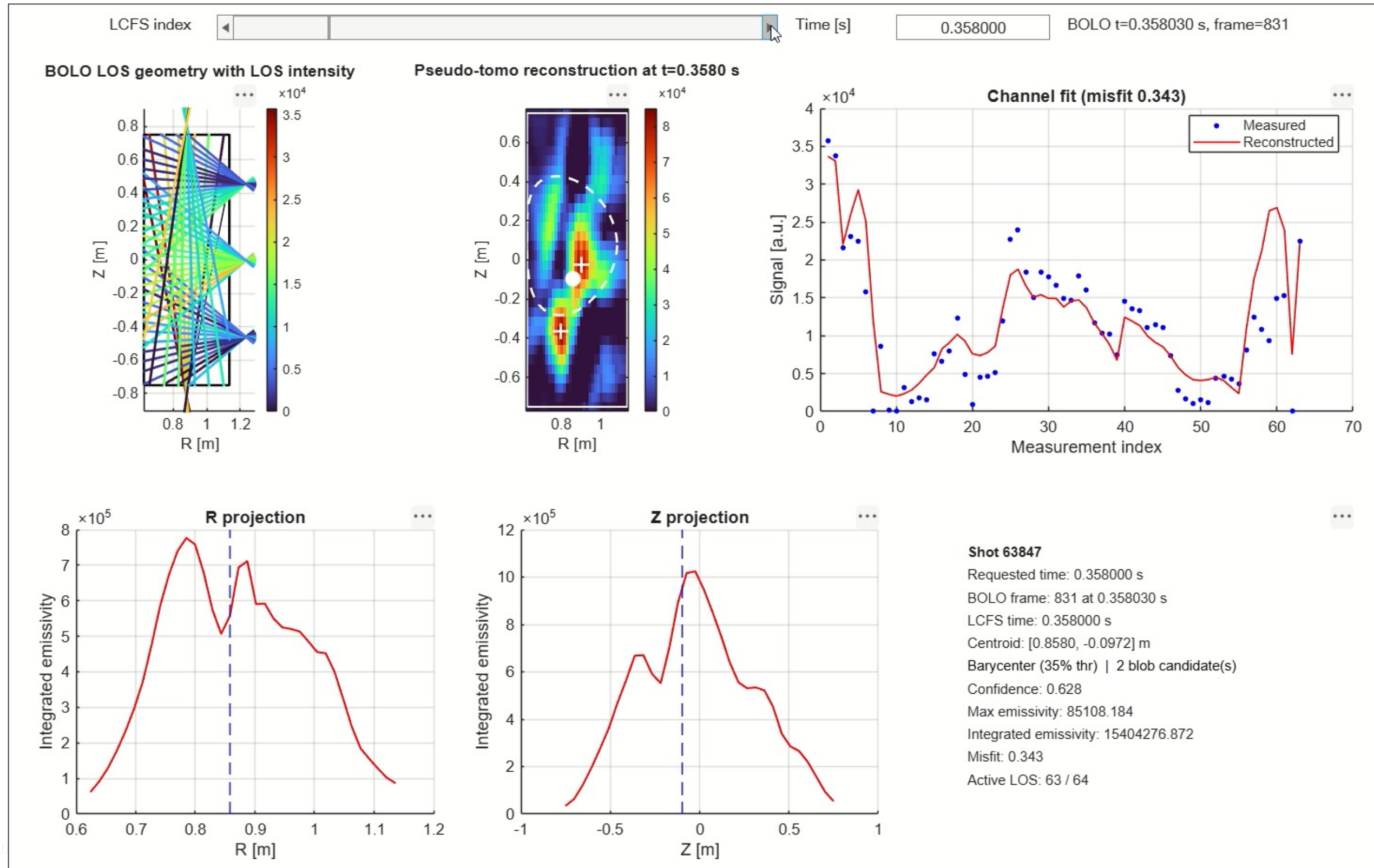
- Future work: calculation and tracking of the **island width** (targeting RT applications).



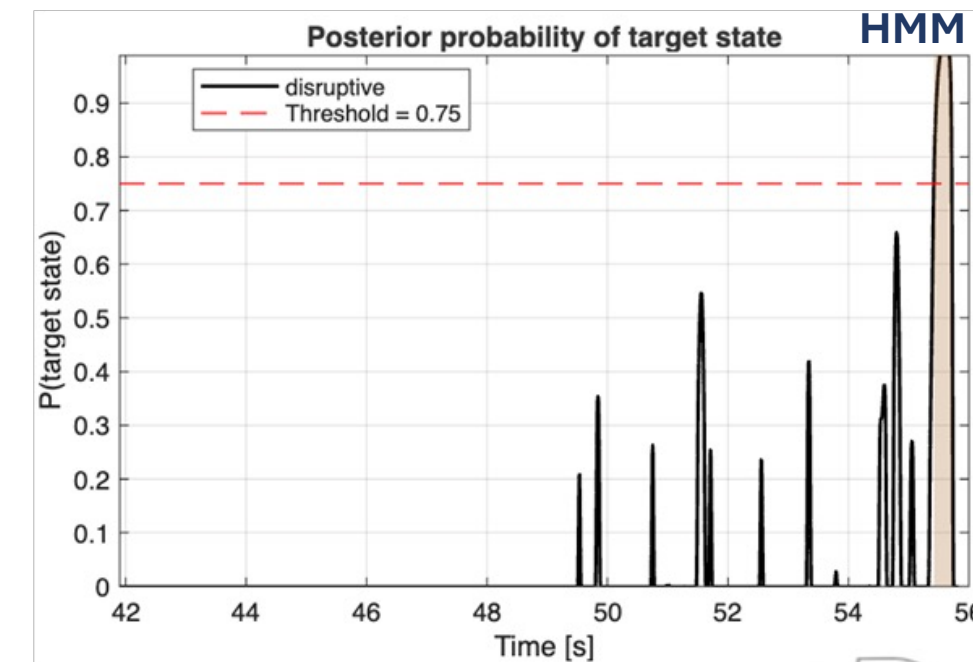
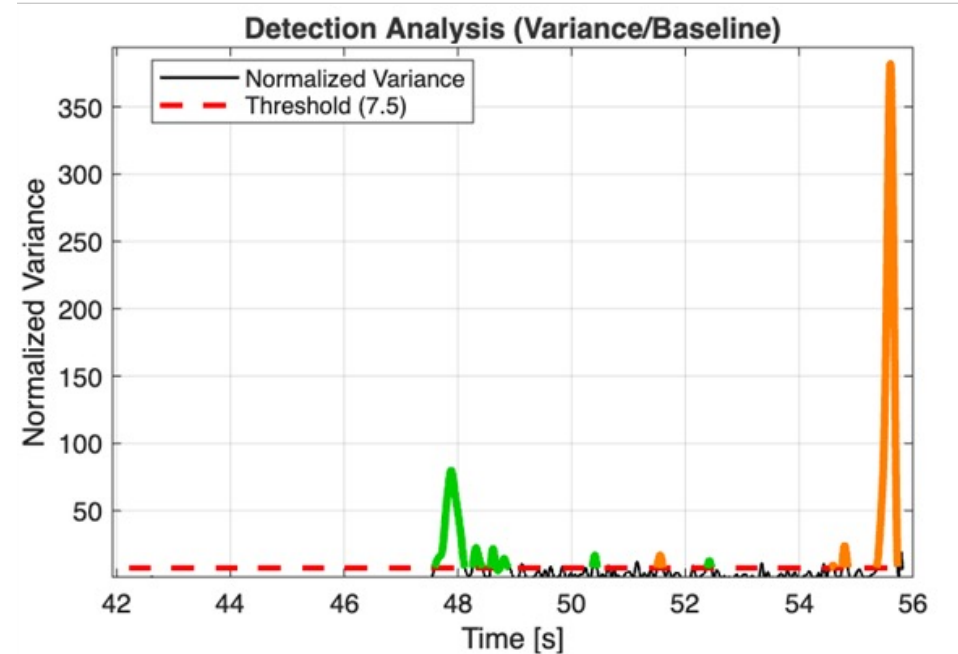
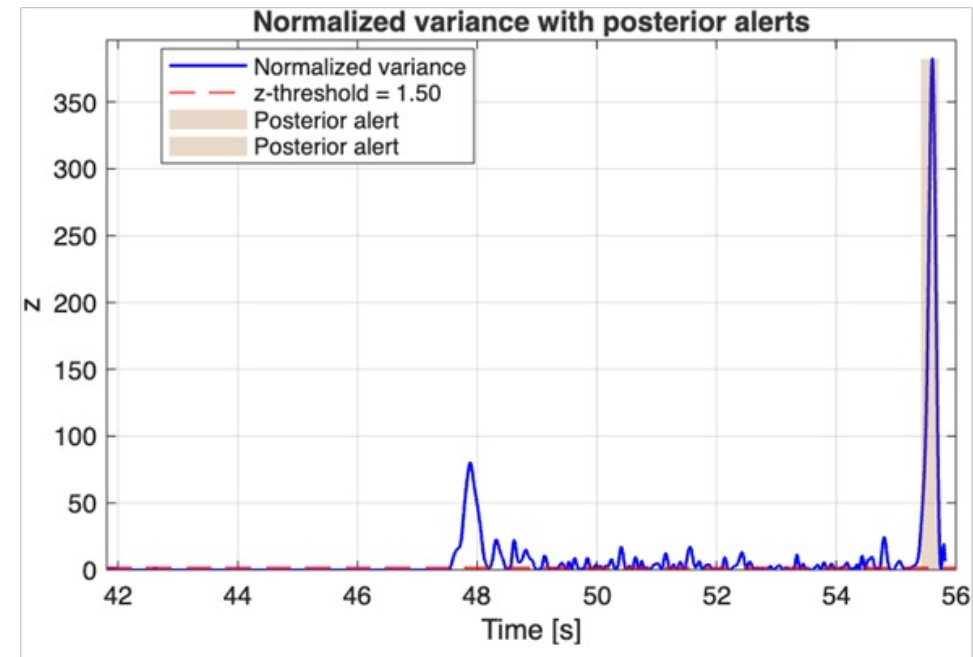
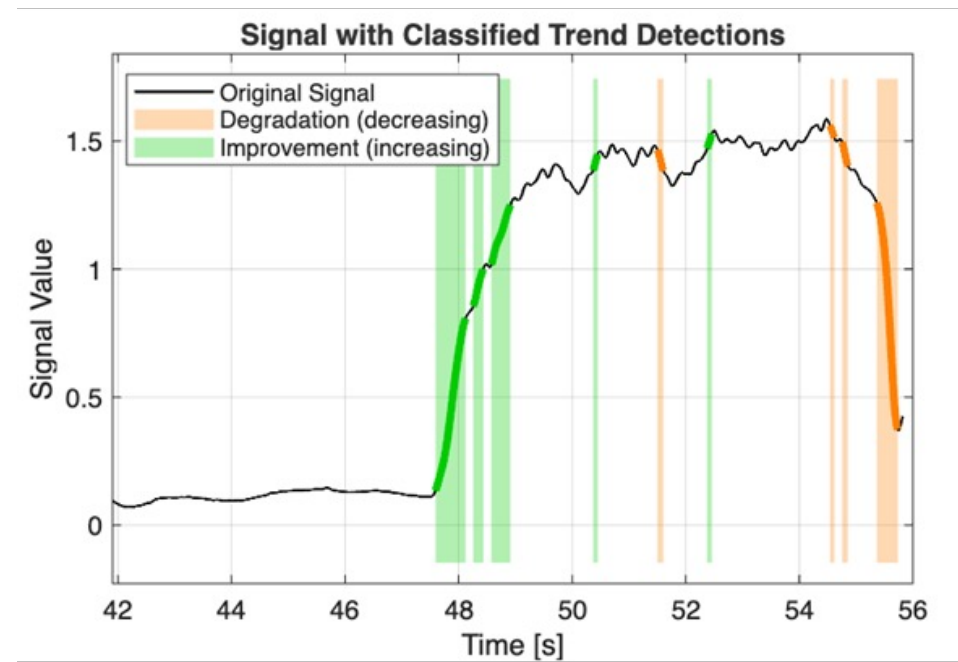
DEFUSE Graphical Users Interfaces



Radiative instabilities tracking

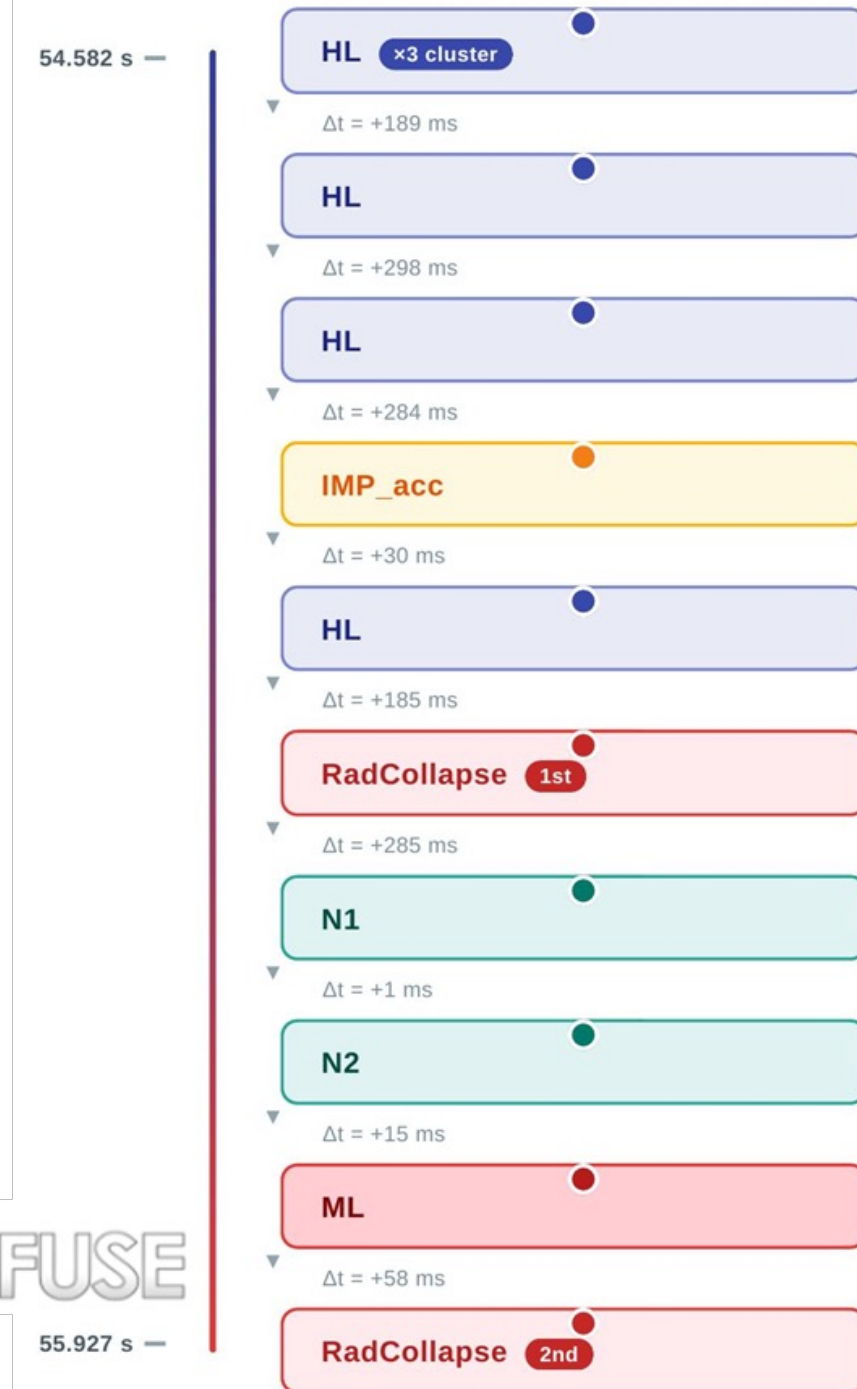


Automated chain of events characterization



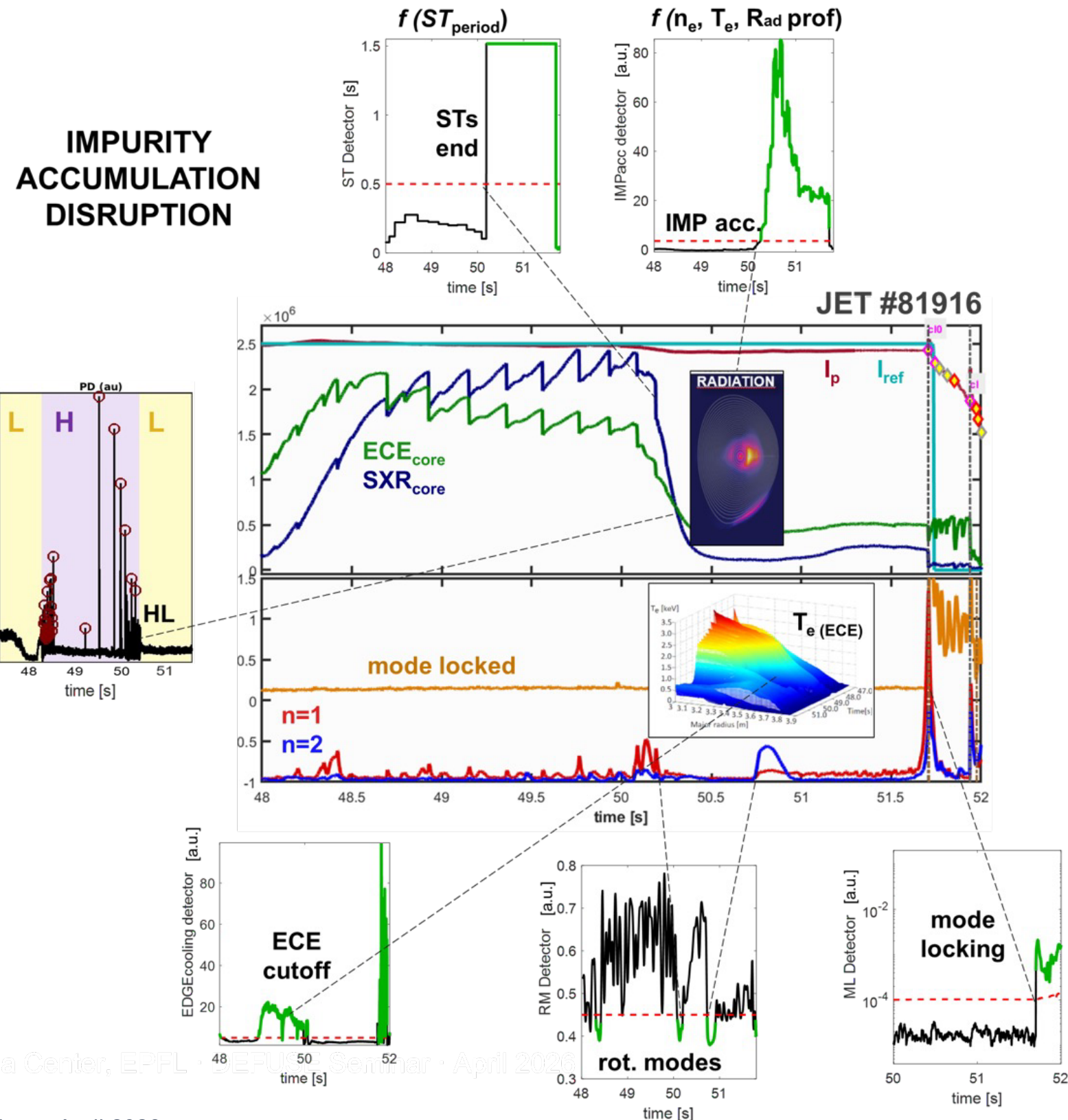
JET #97806 — State / Event Transition Sequence

HMM-inferred event chain | 3-state model | 3-feature emissions

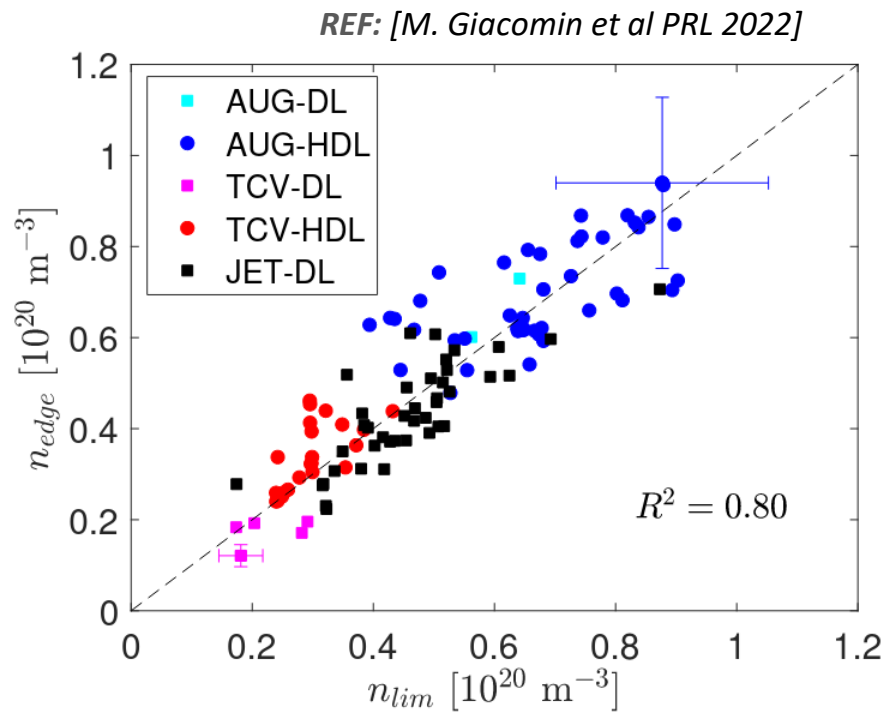


Next steps: include dependence on control action & actuators availability

Automated chain of events characterization



Density Limit First-Principles Scaling



1. P_{SOL} dependence of n_{eLIM}
2. $n_{eLIM}^{ITER} \approx 2 \cdot n_{eGW}^{ITER}$

Events dashboard

Why Collaborative?

Mixture of physics experts

Validation requires device-specific domain expertise. No single person can label all events accurately — orchestrated collaborative review is essential.

Interactive validation

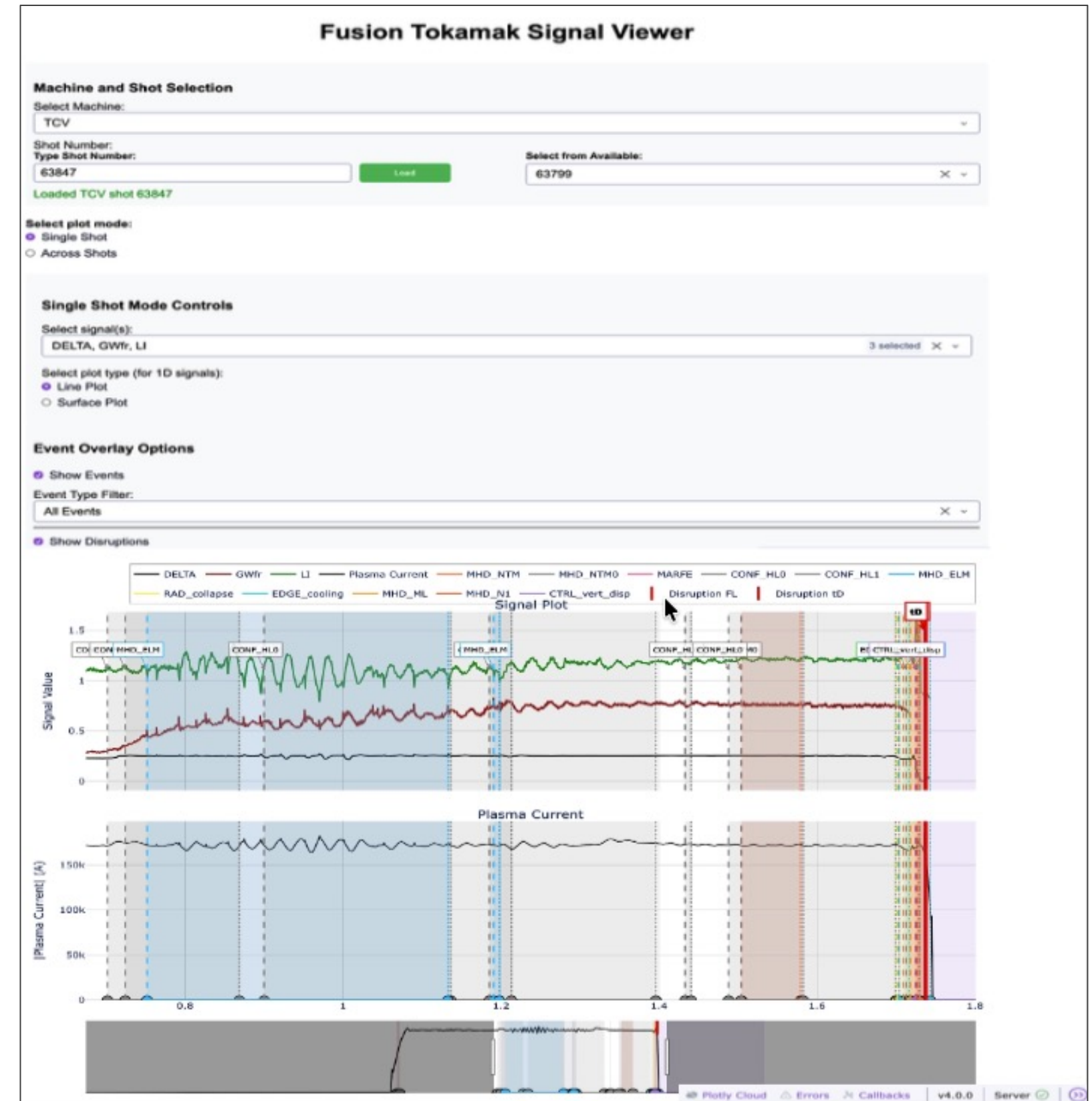
Automated detectors provide initial labels; experts validate and correct through interactive GUIs and SQL-baked dashboards for advanced visualization.

User annotation & review

Multiple experts contribute annotations on specific discharges. Iterative refinement with versioning ensures long-term database quality and traceability.

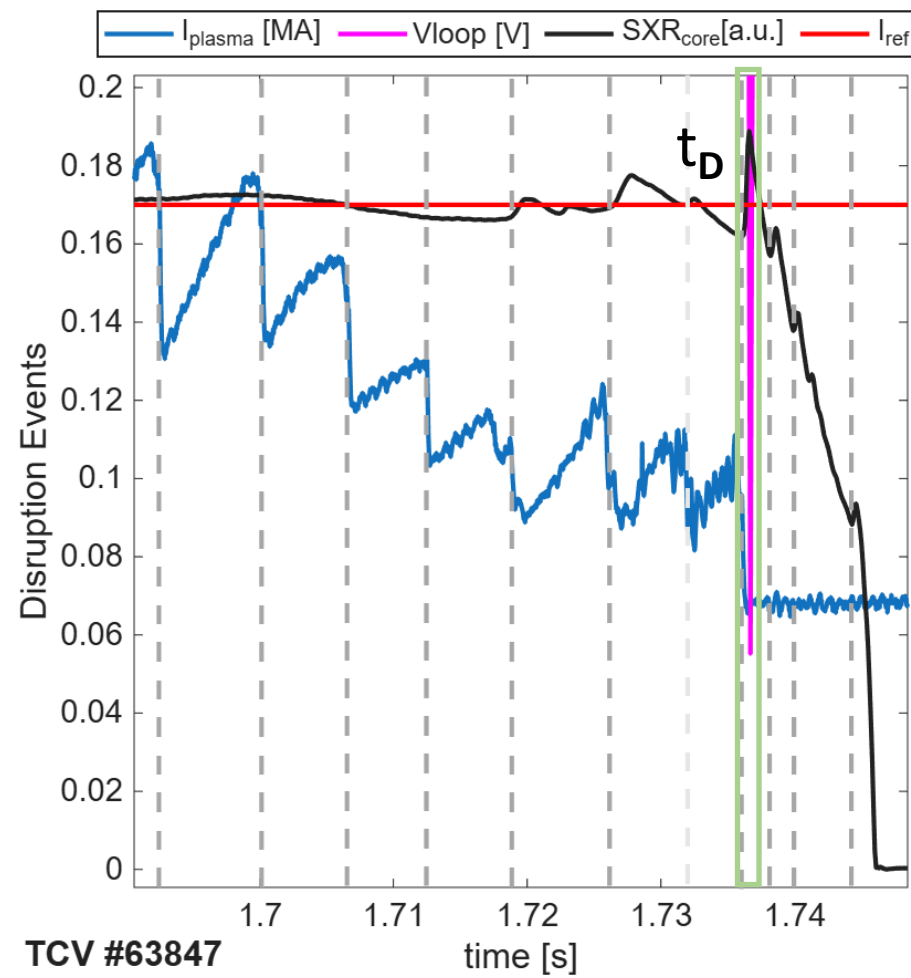
Integration with DMP-IMAS catalogues

Web-based dashboards and advanced visualization utilities can be integrated with DMP-IMAS catalogues

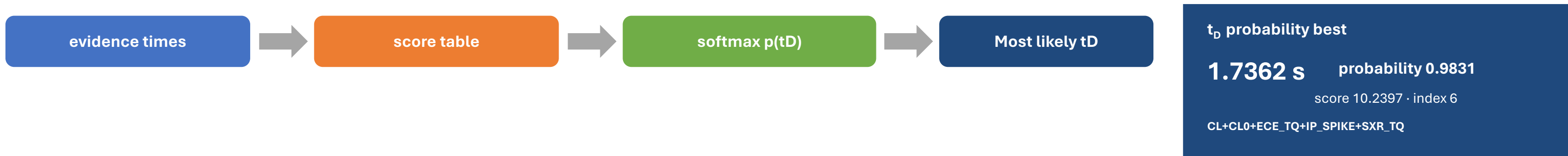


Automated disruption time identification

A single timestamp becomes an inspectable ranking over disruption-time candidates.



time	label	source	score	p(tD)
1.6926	ECE_TQ+SXR_TQ	ECE+SXR	2.571	0.00046
1.7002	SXR_TQ	SXR	1.307	0.00013
1.7067	SXR_TQ	SXR	1.300	0.00013
1.7126	SXR_TQ	SXR	1.300	0.00013
1.7259	SXR_TQ	SXR	1.302	0.00013
1.7362	CL+CL0+ECE_TQ+IP_SPIKE+SXR_TQ	ECE+IP+IP_CONTROL+SXR	10.240	0.98313
1.7372	VL	VLOOP	4.967	0.00504
1.7384	FL+IP_SPIKE	IP+IP_CONTROL	5.689	0.01038
1.7400	IP_SPIKE	IP	2.009	0.00026
1.7445	IP_SPIKE	IP	1.745	0.00020



SQL performance: JSON fields and transactions

DEFUSE SQL DB Browser
TCV machine database (src/defuse/DEFUSE_Data_DB/TCV.db) ↕ Connect
src/defuse/DEFUSE_Data_I ↕ Browse Up Select folder ↕ Open Folder Select DB file ↕ Use DB apau Password

TABLES

audit_log 1

shots 3946

sqlite_sequence 1

users 2

SHOTS

6384

no56384 json

no63843 json

no63844 json

no63847 json

no63848 json

no63849 json

SELECT Query Run Export JSON 2628 row(s), 2 column(s) Limit 3946 ↕

All shots with disruption time ↕ Load Example

```
SELECT
  shotID,
  json_extract(jsonData, '$.Disruptions.tD') AS disruption_time_s
FROM shots
WHERE json_extract(jsonData, '$.Disruptions.tD') IS NOT NULL
ORDER BY shotID
```

shotID	disruption_time_s
no58070	0.338
no58071	0.338
no58072	0.2839
no58073	0.1642
no58077	1.2296
no58093	2.4988
no58095	1.3277
no58096	1.825
no58097	2.4951
no58101	1.1478
no58106	1.8579
no58108	1.2588
no58111	1.826
no58112	1.8294
no58113	1.4612
no58118	1.2497
no58130	0.1484
no58132	1.6114
no58138	1.3381
no58140	0.7737
no58141	0.7183

JSONB FIELDS

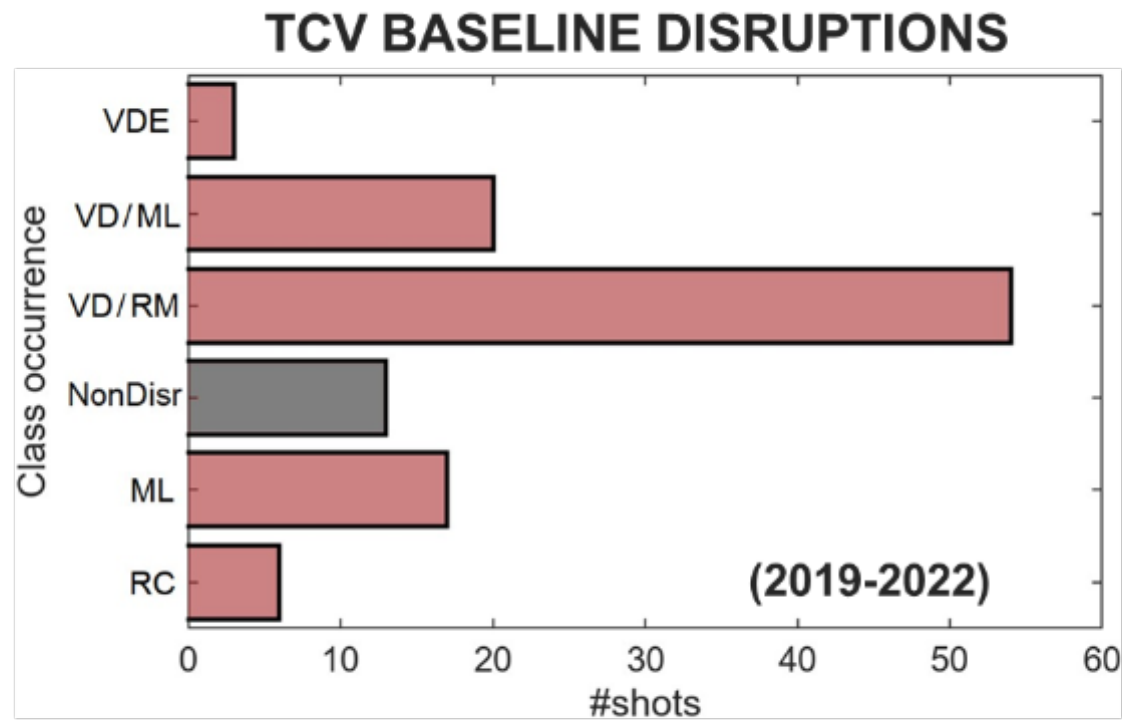
Queryable attributes

TRANSACTIONS

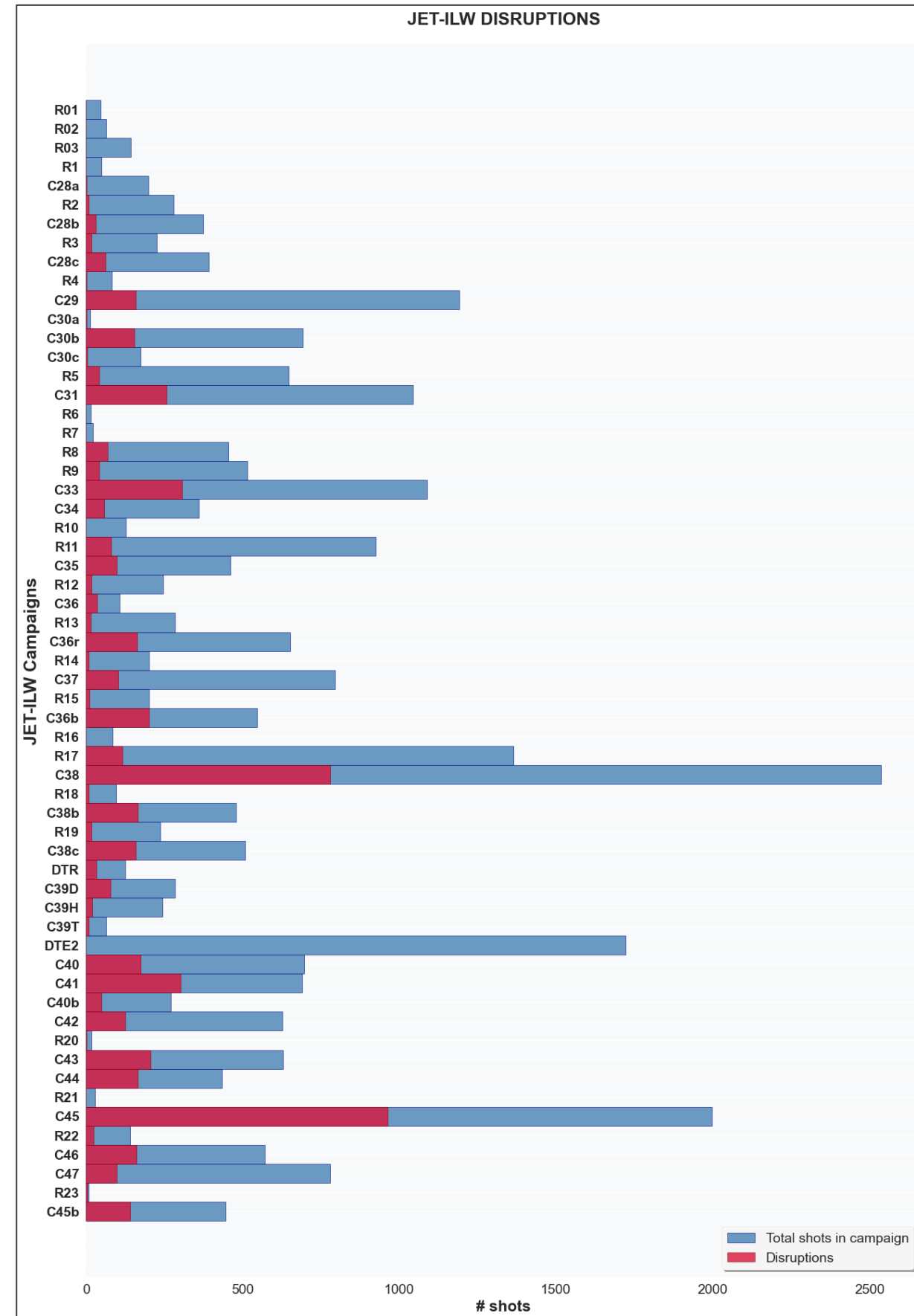
Atomic writes

One transaction per shot - all-or-nothing commit

Disruption overview statistics

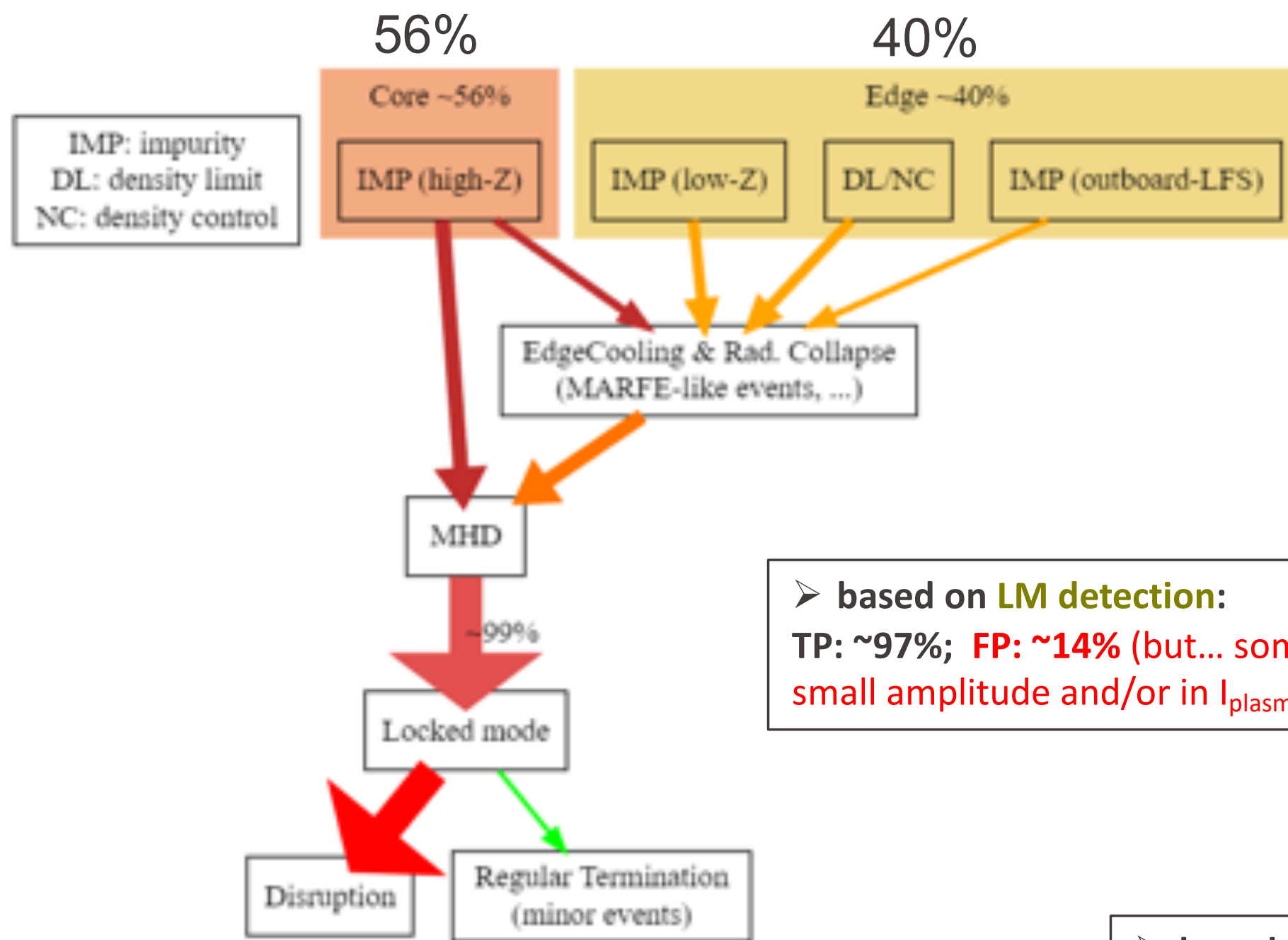


- VDE:** Vertical Displacement Event
- VD/ML:** Vertical Displacement & Mode Locked
- VD/RM:** Vertical Displacement & Rotating Mode (2,1)
- NonDisr:** Regular Termination
- ML:** Mode Locked
- RC:** Radiative Collapse



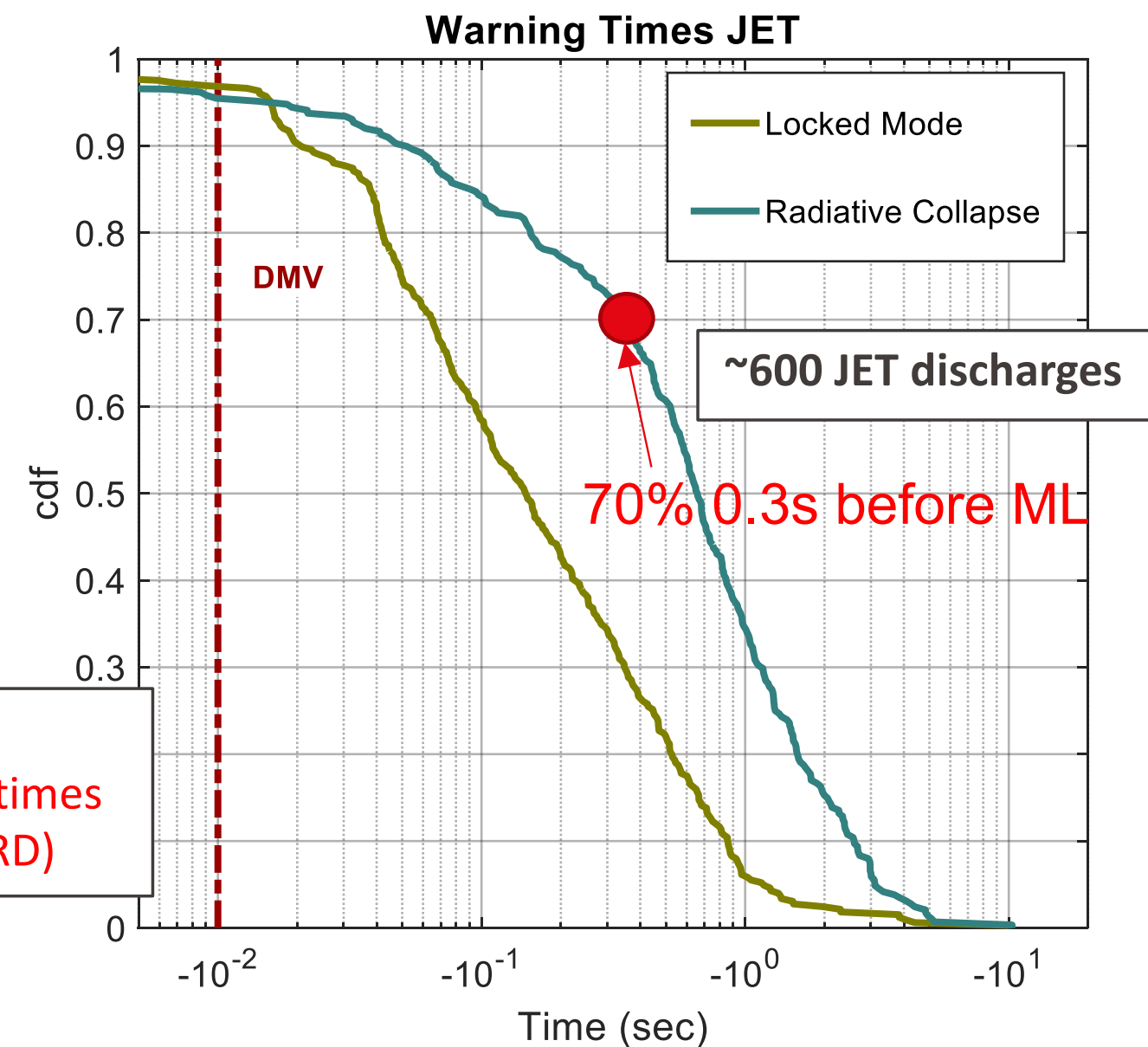
Backup slides

Automated Events Graph



➤ based on **LM detection**:
 TP: ~97%; **FP: ~14%** (but... sometimes small amplitude and/or in I_{plasma} RD)

➤ based on **RC detection** (Imp. Influx/acc., cooling edge, etc.):
 TP: ~96%; **FP: large%** (but.... most of the times transient when switching-off heating power)



Thermal collapse detector and disruption events

