EPFL

IO Meeting

The EUROfusion Disruption Database

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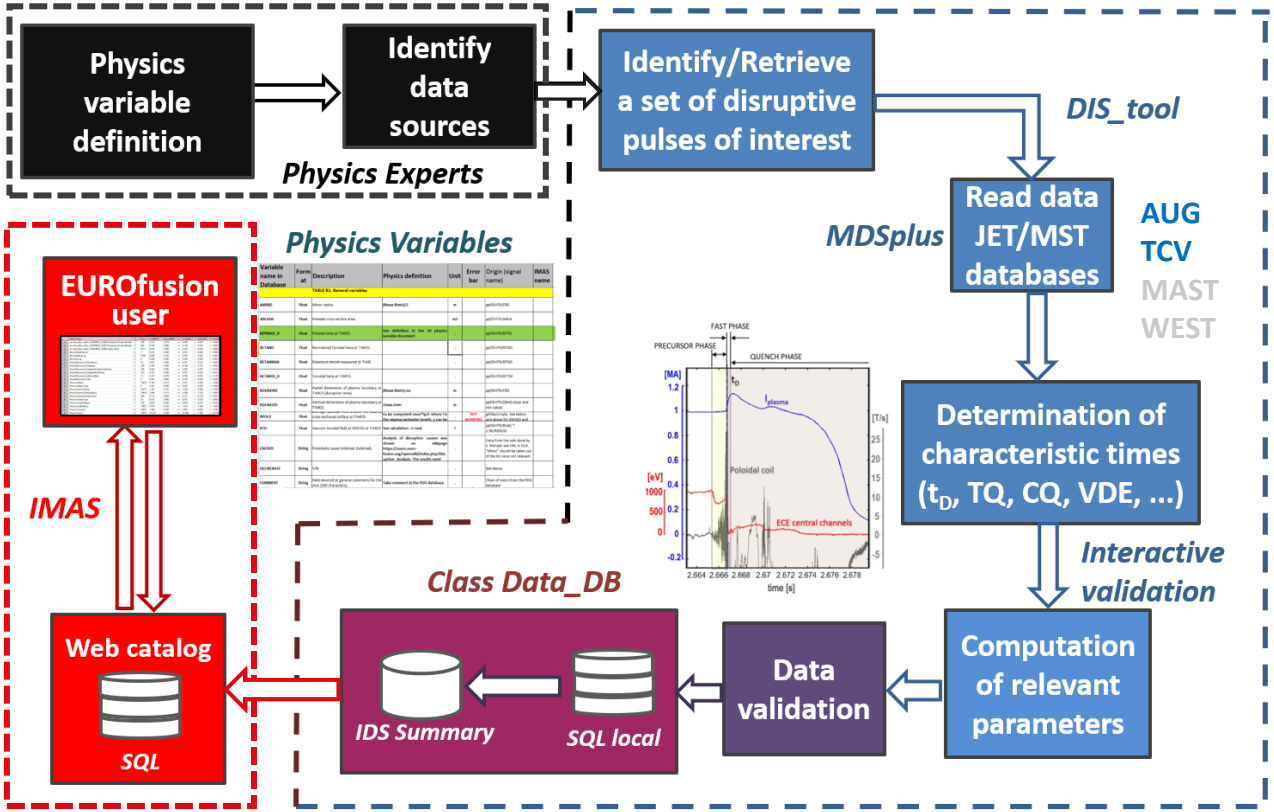
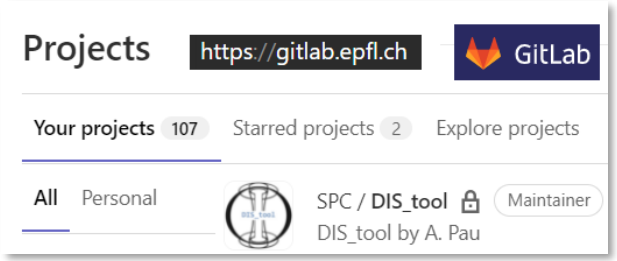
EUROfusion DDB workflow & main structure

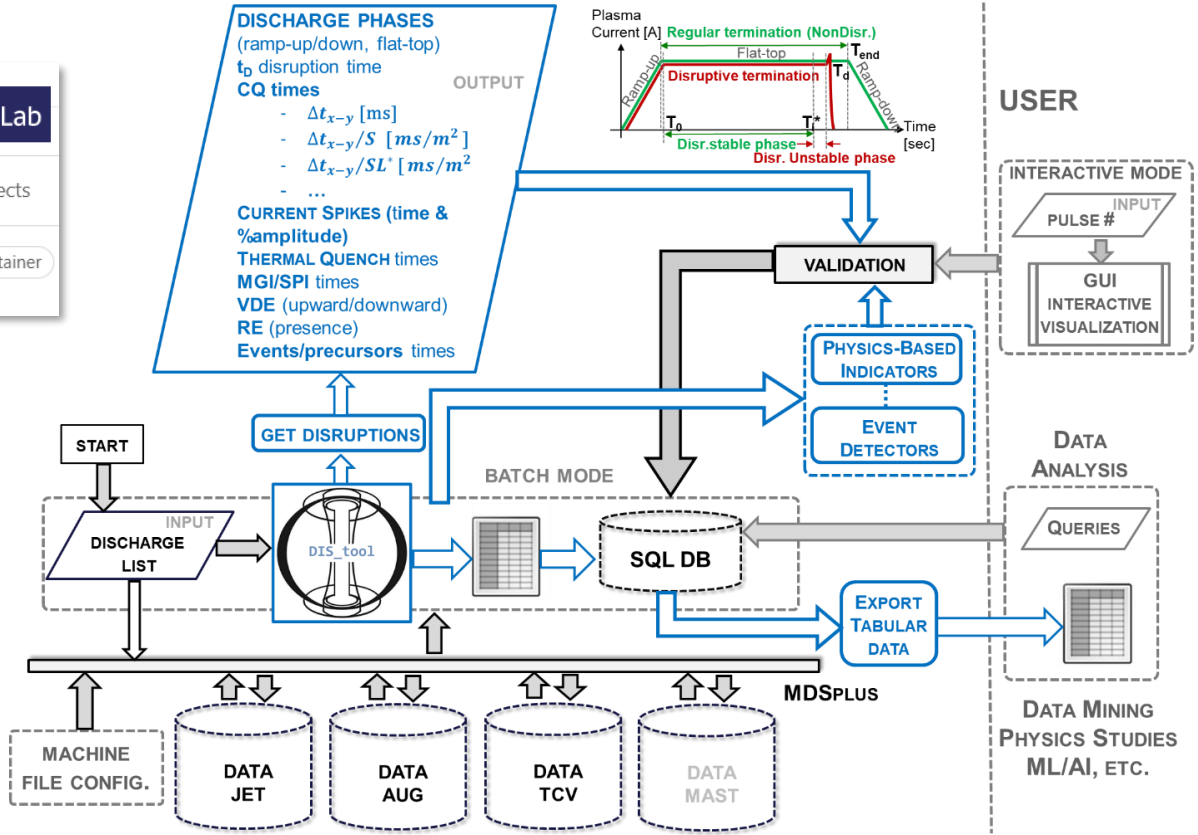
[*DIS_tool*] A.Pau et al., 2017 Fusion Eng.Des. 125 139–53



DIS_tool code architecture



- Project under **version control;**
- Regularly maintained by **SPC-EPFL** (full pipeline implemented on "**Lacs**");
- The code can be run as well on **FREIA**, **Heimdall** (CCFE) and **TOKI** (IPP) computing clusters.



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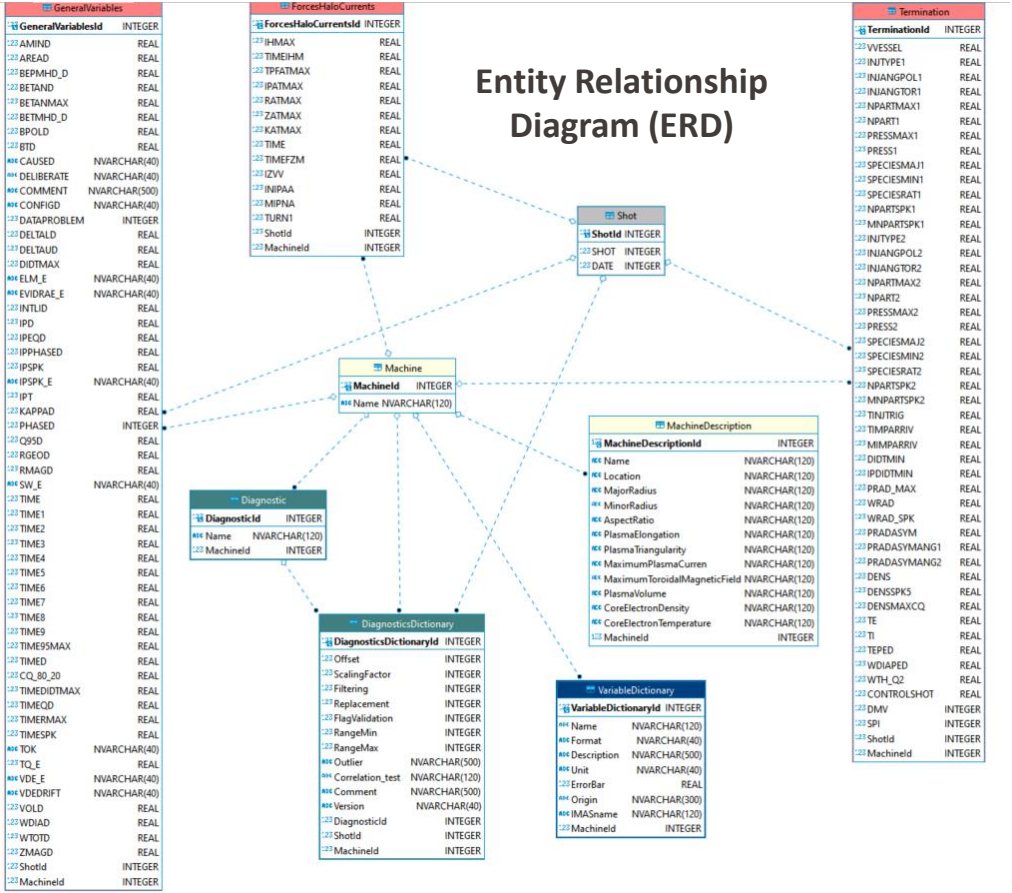
Multimachine DDB Design: SQL (1)



- **Normalized** Data Model;
- Easily accessible from **different languages** [Matlab, R, Python, IDL];
- **Checks** and **constraints** on mandatory fields -> **validation rules**;
- Connection with **objects** (defined as classes in ***DIS_tool***:
  - ***Set****(Machine_DB)*
  - ***Get****(data)*
  - ***Put****(data)*

```
classdef Data_DB
    % Class_Instance = Data_DB();
    % --------------------------
    % definition of disruption database objects
    %   structured database with methods to r/w database fields
    %

    properties
        machine(1,:) char %{mustBeMember(machine,{'AUG','JET','MAST','TCV'})}
        data struct
    end

    methods

        %% Initialize Shot Nodes
        function obj = InitializeNodes(obj,shotList)
            % obj = InitializeNodes(obj,shotList)
            % ------------------------------------

            if isempty(obj.data)
                dummy.init = 1;
                obj.data = dummy;
            end
            fprintf('Initializing shot nodes \n')
```

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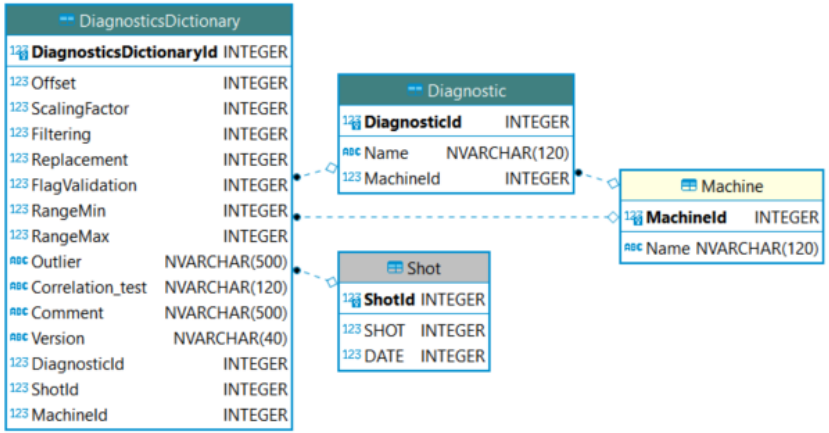
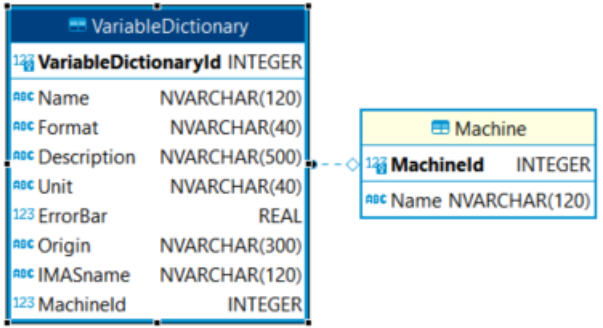
Multimachine DDB Design: SQL (2)



- **Variables** and **Diagnostics dictionaries** for entries validation;
- **Object** defined as instances of “superclasses” (**properties** and **methods** generically defined for each diagnostic and associated to **validation rules**;
- Generation of **configuration files** (spreadsheets, XML, JSON, etc.) read by DIS_tool and translated in **validation-rules**.
- **Data provenance**: mapping between object fields and tables/config. files -> reconstruct generated DB (including remote source/origin).

```
classdef DIAG
    % Class_Instance = DIAG();
    % --------------------
    % definition of DIAG object
    %   diag object (subclass) inherits properties & methods for generic data-sanity check

    properties
        label(1,:) char
        data % tabular data
        fields struct = struct('time','t','spatial_coord','x','data','z') % mapping [t,x,z] -> [nt,nx,nz]
        processing struct = struct('offset',[],'scaling_factor',[],'filtering',[],'replacement',[])
        validity struct = struct('validation',[],'range',[],'outliers',[],'correlation_test',[])
        provenance struct = struct('shot',[],'source',[],'units',[],'version',[])
    end
```



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Multimachine standardized event descriptors

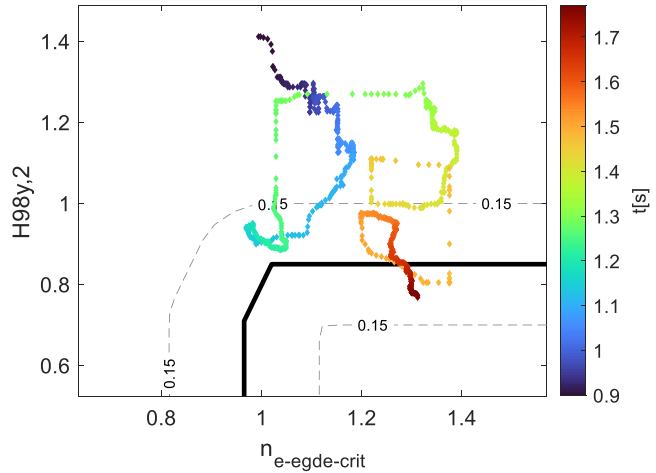
- **Objects** to detect events and reconstruct the chain of events leading to disruption (LM, Radiative Instabilities);
- **Automatized** run and **standardized** encoding for the different machines;

```
classdef Detector
    % Definition of disruption database objects
    % Superclass with generic properties and methods characterizing the detection

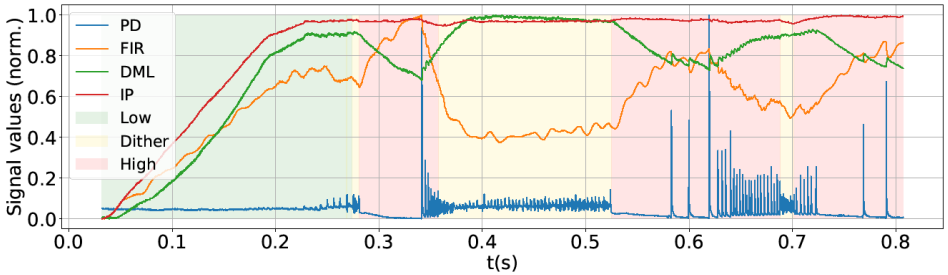
    properties
        Type_Detector(1,:) char {mustBeMember(Type_Detector,{'OffNormal','Disruptive','Instability','Transient'})} = 'OffNormal'
        Thresholds_Detection {mustBeNumeric}
        Method_Detection(1,:) char {mustBeMember(Method_Detection,{'Equal','LessThan','GreaterThan','GreaterThan&LessThan'})} = 'Equal'
        Detection_AssertionTime {mustBeNumeric}
        data struct
    end

    methods
        function obj = InitializeDetector(obj)
            dummy = [];
            if isempty(obj.data.time) || isempty(obj.data.signal)
                obj.data.time = dummy;
                obj.data.signal = dummy;
                fprintf('Initializing Detector with empty structure')
            else
```

Physics-based event descriptor



Data-driven event descriptor



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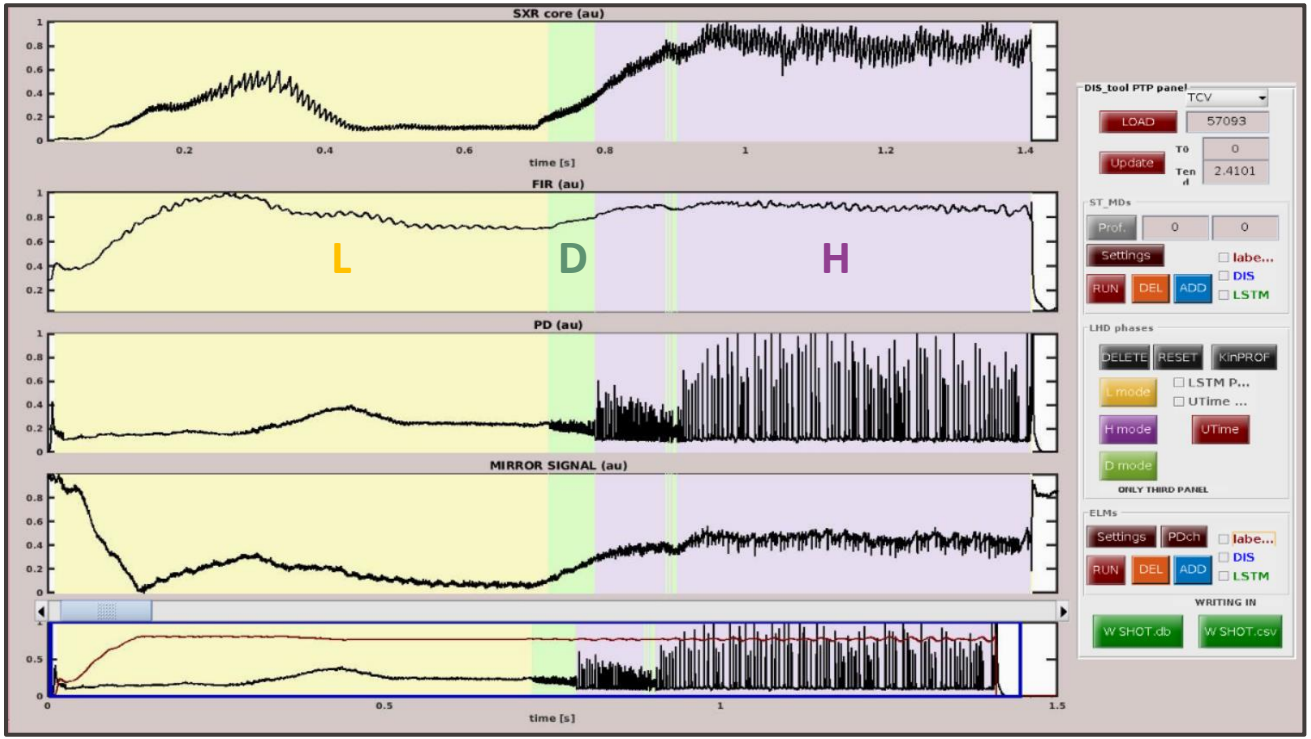
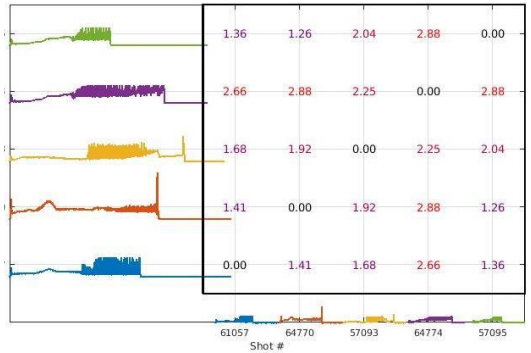
Confinement states and MHD Transient Events (1)

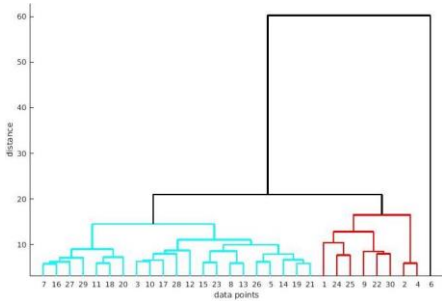
Confinement states



Dynamic time warping (DTW)



Clustering



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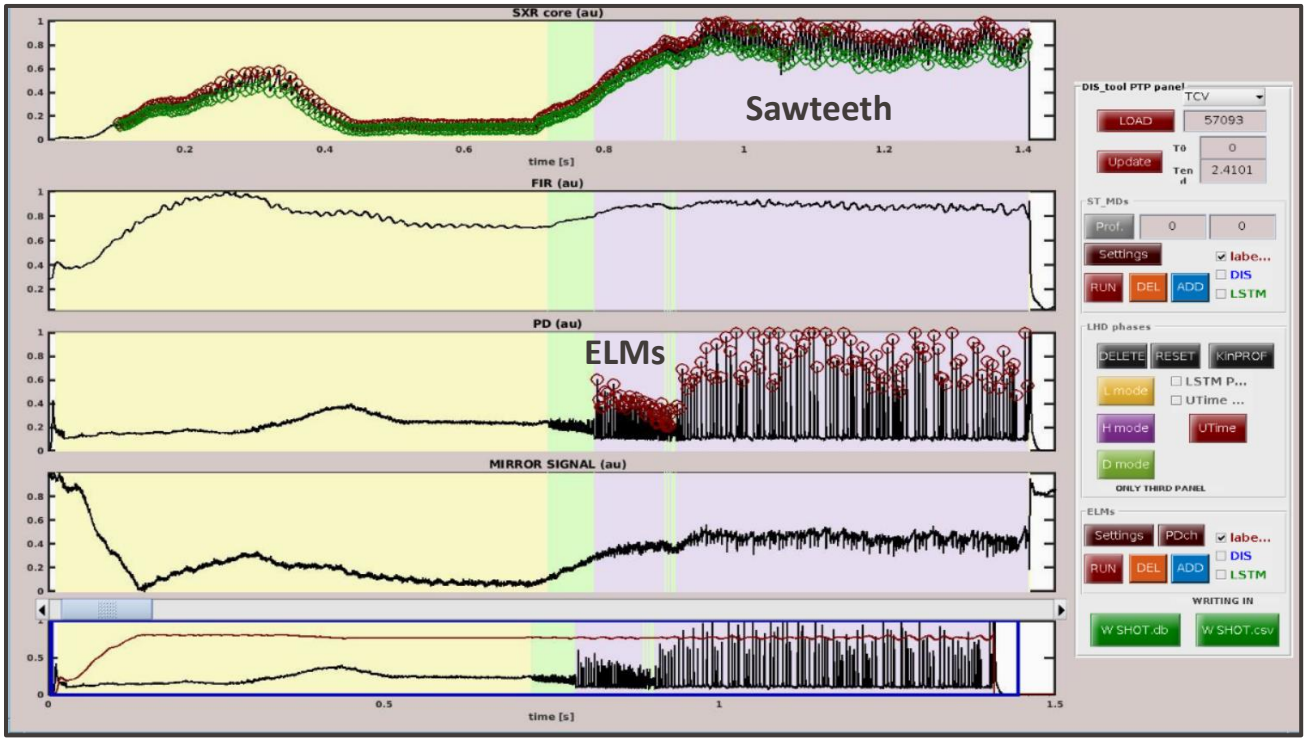
Confinement states and MHD Transient Events (2)

Transient events



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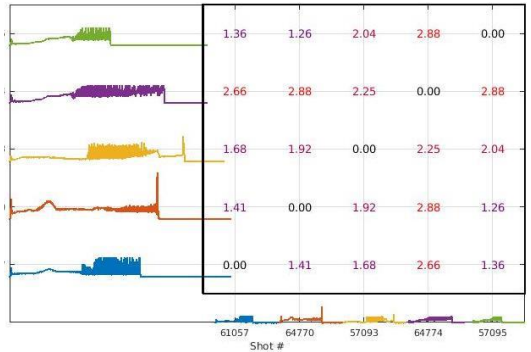

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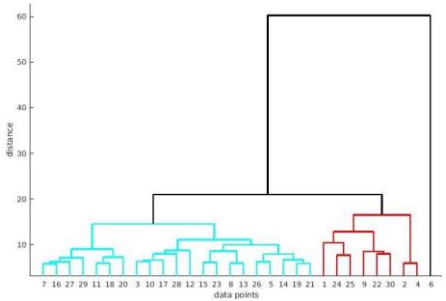

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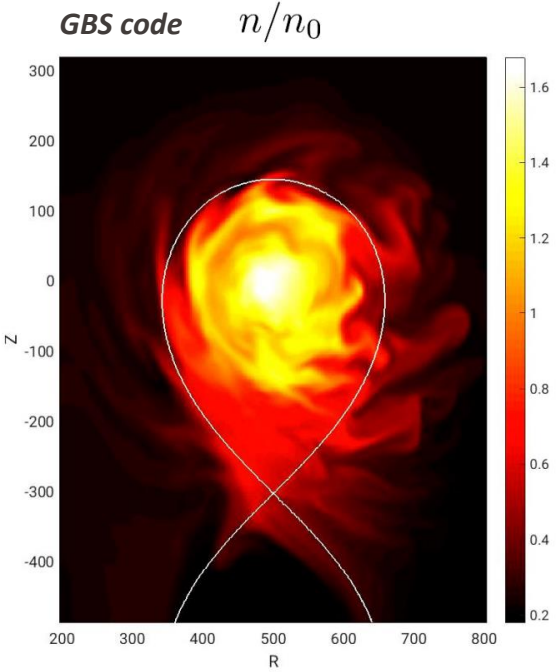
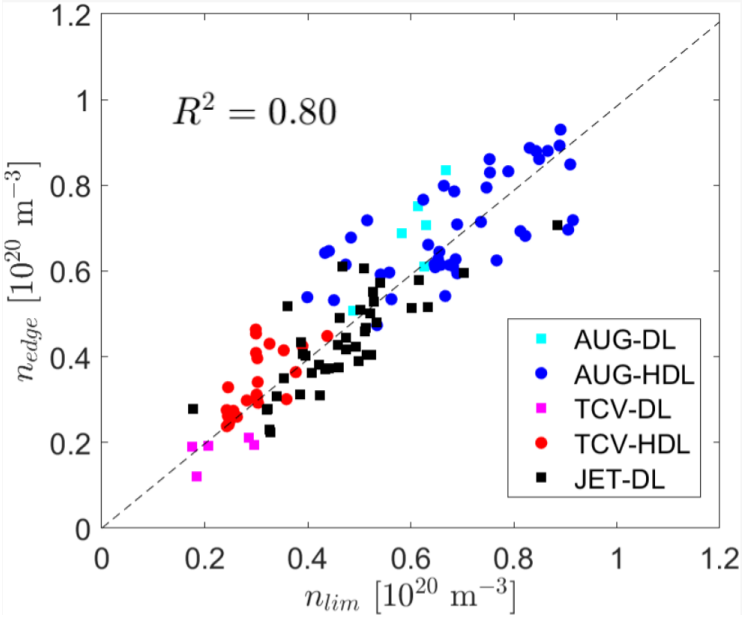
Modeling: Density Limit First Principle-based scaling

- ***First Principle model*** from drift-reduced *Braginskii equations;*
- ***Turbulent transport*** driven by *resistive ballooning modes;*
- ***Density limit*** (loss of confinement and cooling of the plasma core from the edge): $L_p \sim a$





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Summary

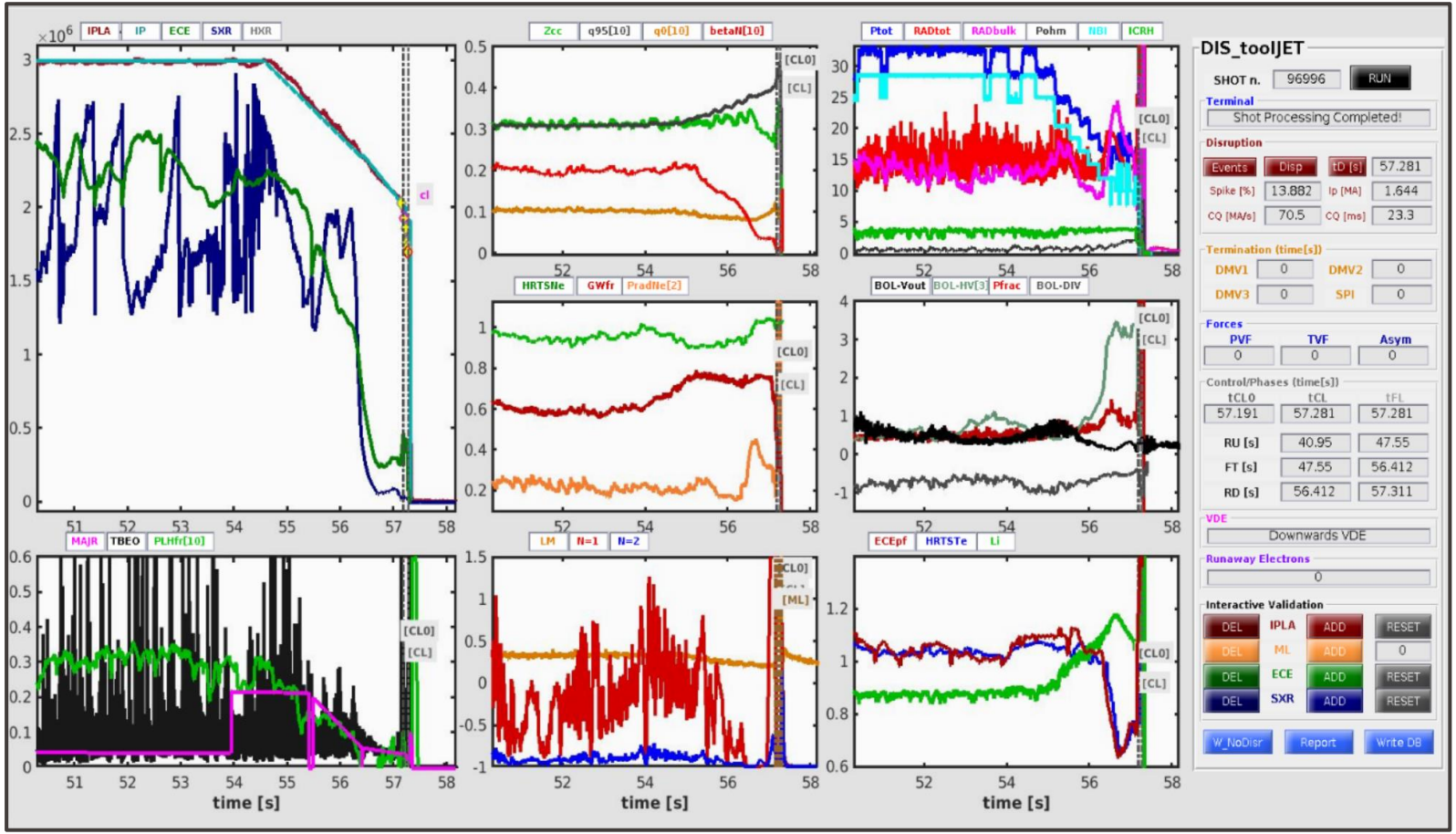
- **DB construction *workflow*** finalized in a **standardized**/generic way (consistent data validation, provenance tracking and potential easy extension to other devices and/or other “tasks”);
- ***Object-oriented*** philosophy and integration with **SQL - Relational Normalized Data Model** for easy integration and efficient data retrieval;
- Prototype DBs supporting **disruption studies**(TCV-AUG-JET): ***scenario development***, ***disruption avoidance*** experiments, ***modeling*** and disruption prediction (**AI** and **ML**).
- **Fundamental mission of DBs**: makes sure “extrapolations” reflect what is in the data (!!)
  - Too many **extrapolations** are currently “validated” on dedicated experiments with very specific conditions (avoid physics and statistics **data-bias!**)
  - Still difficult to :
    - **extract** and **process efficiently** the huge amount of information available;
    - give consistent and **reliable statistics** about main phenomenology and causes on the various devices;
    - (“**data-centric”** concept: data as primary and permanent asset in many fields of science and big companies to drive R&D!).

Looking forward…

- **Document** the developed framework in a **technical publication** and provide a first ***demonstration DB*** for JET high-performance recent campaigns for the main scenarios under development (Baseline and Hybrid).
- Provide **a first mapping into IDS**: the overall pipeline has already been developed and currently under test on a SPC dedicated server with some IMAS/IDS functionalities installed.
- Next (mainly technical) steps to be discussed, as importing the whole pipeline on the **Gateway** once the DB is validated.
- Increase number of shots validated: **many requests** and **activities** which would significantly benefit from having a well-structured and validated multi-machine Disruption DB.
  - **Massive amount of work to do things in a consistent way (full-time job for several people!)**

Backup slides

Configurable GUIs for visual validation (1)



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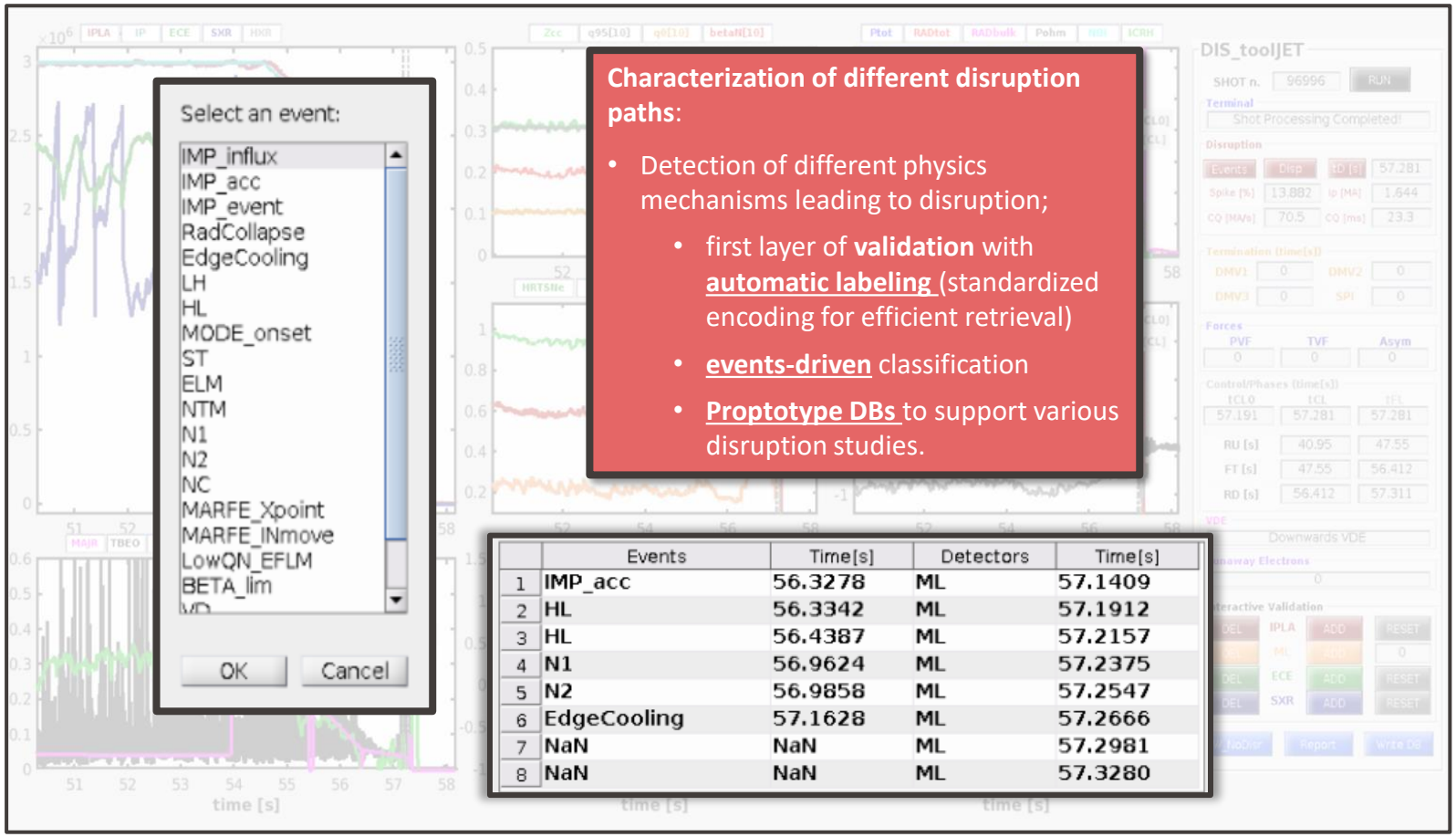
Configurable GUIs for visual validation (1)



Characterization of different disruption paths:

- Detection of different physics mechanisms leading to disruption;
  - first layer of **validation** with **automatic labeling** (standardized encoding for efficient retrieval)
  - **events-driven** classification
  - **Proptotype DBs** to support various disruption studies.

	Events	Time[s]	Detectors	Time[s]
1	IMP_acc	56.3278	ML	57.1409
2	HL	56.3342	ML	57.1912
3	HL	56.4387	ML	57.2157
4	N1	56.9624	ML	57.2375
5	N2	56.9858	ML	57.2547
6	EdgeCooling	57.1628	ML	57.2666
7	NaN	NaN	ML	57.2981
8	NaN	NaN	ML	57.3280

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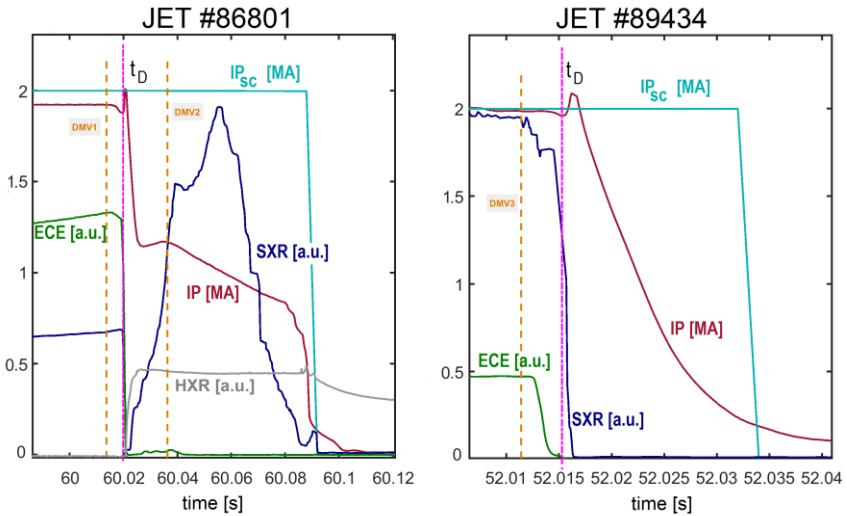
Detectors: REs detection with statistical test (1)

- $\Delta t_{x-y} = \frac{t_y - t_x}{(x-y)\%}$ [ms] Linear Current Quench Extrapolated Time (LCQET)
- $\Delta t_{x-y}/S$ [ms/m^2] LCQET normalized by the plasma cross section
- $\Delta t_{x-y}/SL^*$ [ms/m^2] LCQET normalized by the plasma Self Inductance L* $[L^* = \ln\left(\frac{8R}{a}\right) - 1.75]$

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            else
```

- **Objects** to detect events and reconstruct the chain of events leading to disruption (LM, Radiative Instabilities);
- **Automatized** run and **standardized** encoding for the different machines;

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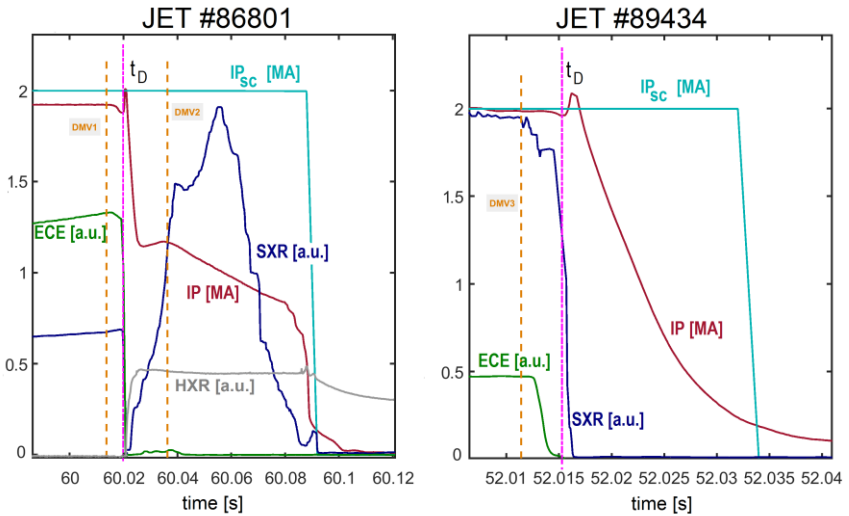
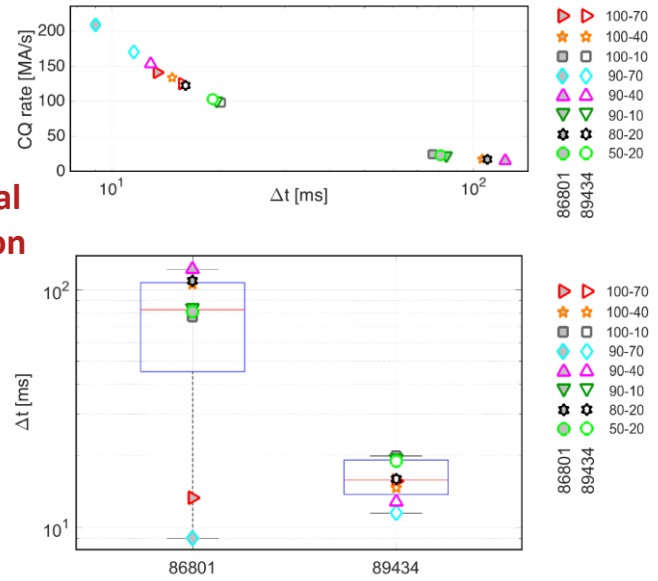
Detectors: REs detection with statistical test (2)

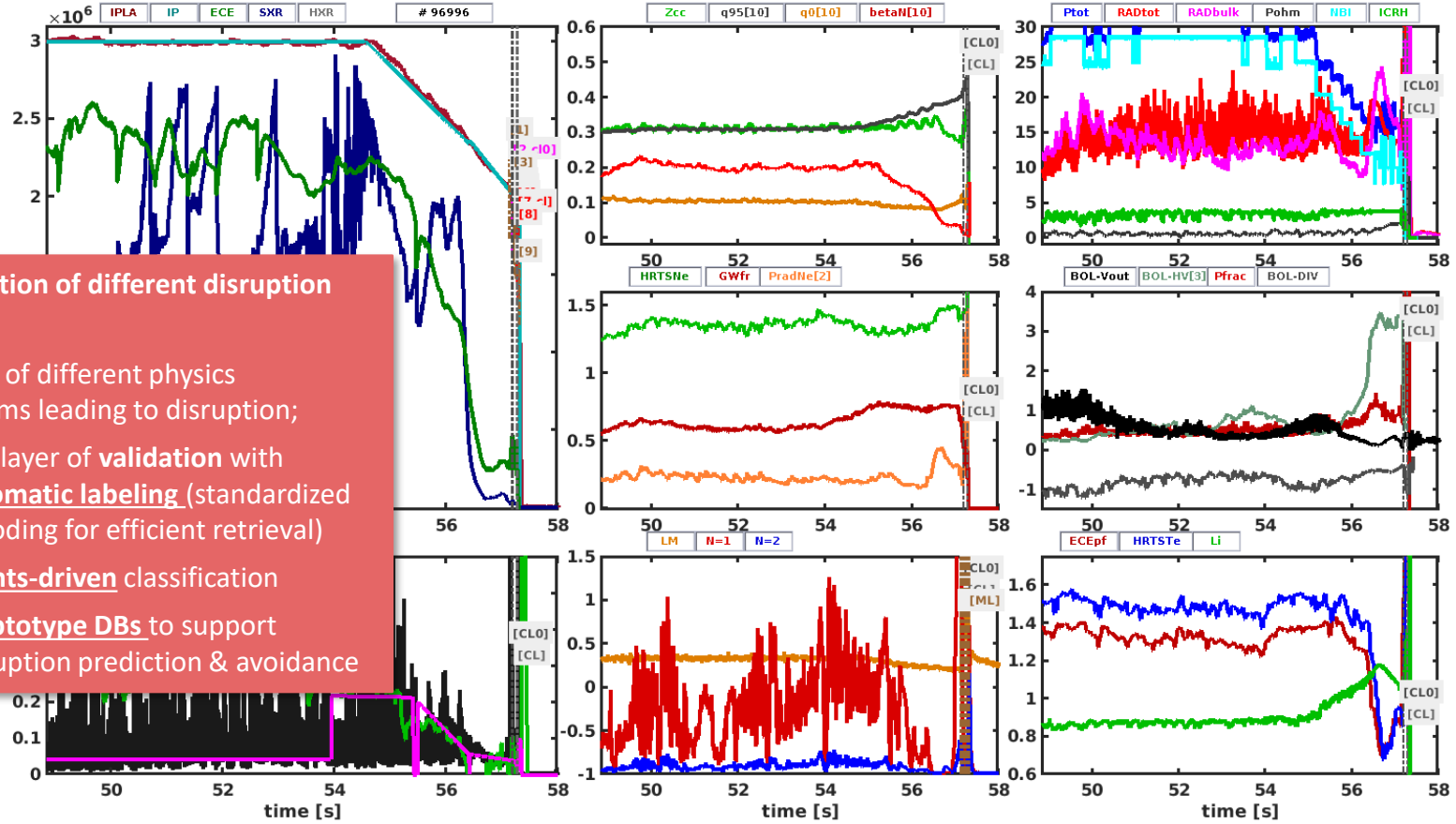
- $\Delta t_{x-y} = \frac{t_y - t_x}{(x-y)\%}$ [ms] Linear Current Quench Extrapolated Time (LCQET)
- $\Delta t_{x-y}/S$ [ms/m^2] LCQET normalized by the plasma cross section
- $\Delta t_{x-y}/SL^*$ [ms/m^2] LCQET normalized by the plasma Self Inductance L* $[L^* = \ln\left(\frac{8R}{a}\right) - 1.75]$



Statistical dispersion [MAD]



“Baseline” scenario terminations at JET & AUG



Characterization of different disruption paths:

- Detection of different physics mechanisms leading to disruption;
  - first layer of **validation** with **automatic labeling** (standardized encoding for efficient retrieval)
  - **events-driven** classification
  - **Proptotype DBs** to support disruption prediction & avoidance

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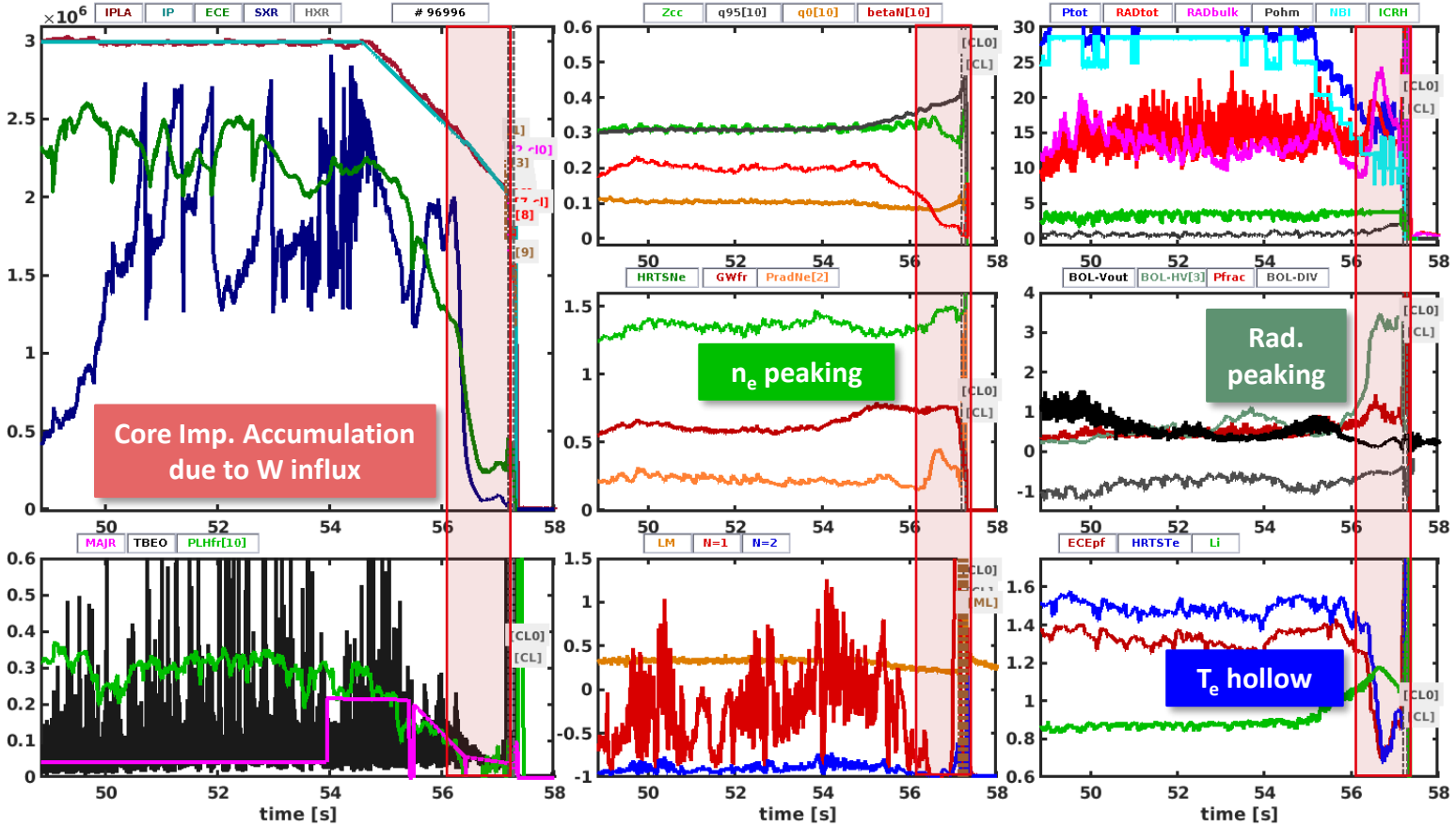
“Baseline” scenario terminations at JET & AUG



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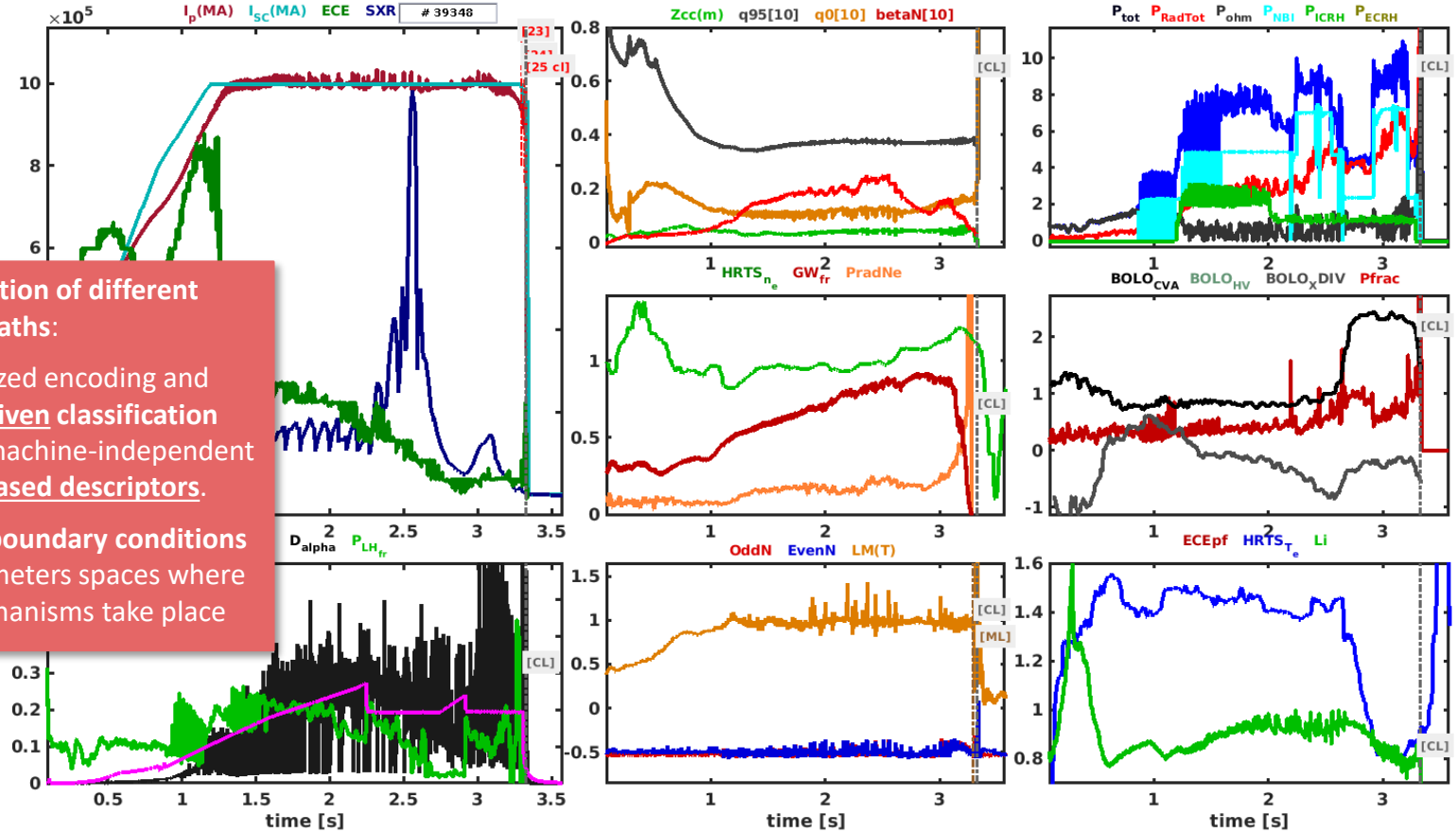

Characterization of different disruption paths:

- Standardized encoding and **events-driven classification** through machine-independent **physics-based descriptors**.
- Study of **boundary conditions** and parameters spaces where such mechanisms take place

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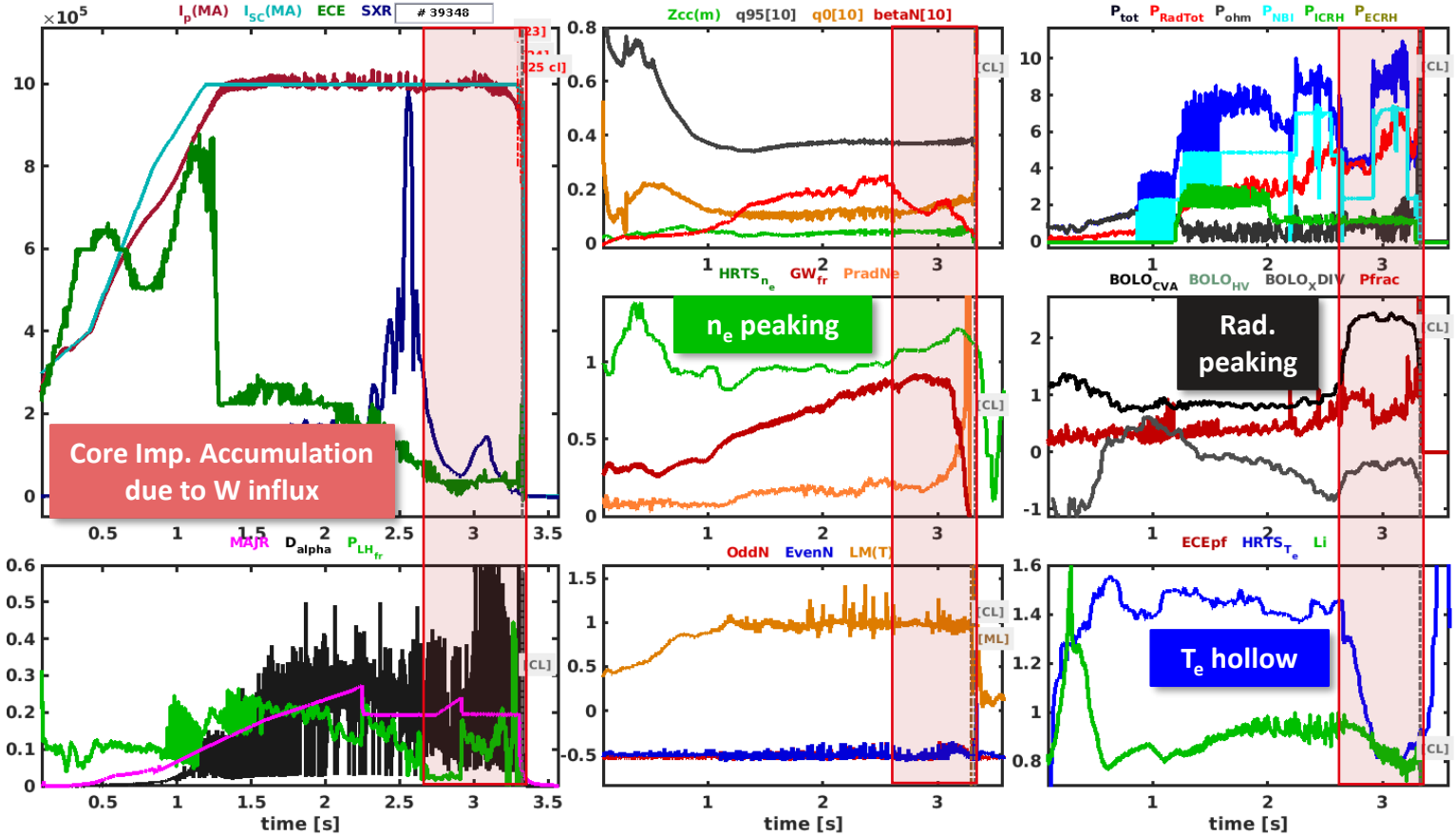
“Baseline” scenario terminations at JET & AUG



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