EUROfusion pedestal database: overview and status

L. Frassinetti

Over the years, support from:

- M. Owsiak and teams (ACH Poznan)
- F. Imbeaux (CEA)
- P. Bilkova, P. Bhom (IPP.CR)
- B. Labit and M. van Rossem (EPFL)
- M. Dunne (IPP)

WPTE team (in the first years)

WPPrIO: X. Litaudon (PL), G. Falchetto (PSO)

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OUTLINE

- Scope
- Overview
  - Key logic of the EUROfusion pedestal database
  - Definitions and selection rules
- Present status
  - Size of the database
  - Storage location
  - Access
- Future plans
- Publications

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Well established since 2020-21 after several years of discussions with pedestal experts and with the WPTE team

Scope

Creating a multi-machine database to investigate:

- pedestal structure:
  - what regulates pedestal gradients
  - what regulates pedestal width
  - ...
- pedestal stability:
  - systematic study of the role of parameters parameters (pedestal position, n_e^{sep}, η_e…)
  - systematic comparisons with the peeling-ballooning stability
  - understanding under which conditions pedestal is far from the PB boundary
  - systematic comparisons with pedestal predictions
- pedestal scalings:
  - pedestal height (of electron pressure, temperature, density)
  - pedestal width (of electron pressure, temperature, density)
  - n_e^{sep}
  - …
- Provide support to more general pedestal activties
  - training of NN or IA models
  - specific experimental investigations and studies

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Overview

- Around 200 parameters per entry
- Some of the key parameters are:
  - the pedestal structure of Te, ne, pe pre-ELM profiles (height, width, gradients, position…).
  - dimensionless parameters: ν^{*ped}, β_θ^{ped}, ρ^{*ped}
  - global plasma parameters (betas, stored energy, energy confinement, Prad, ELM frequency…)
  - engineering parameters (Ip, Bt, q95, gas rate, Pnbi, Pecrh, Picrh, Pohm, seeding rate and seeding specied, A_{eff}…
  - Shape and equilibrium: triangularity, elongation, squareness, R, a…
  - …
  - Full list on the WPPrIO wikis: https://wiki.euro-fusion.org/wiki/WPPrIO_wikipages:_DB_Pedestal

    with parameter names, definitions, units, ids names

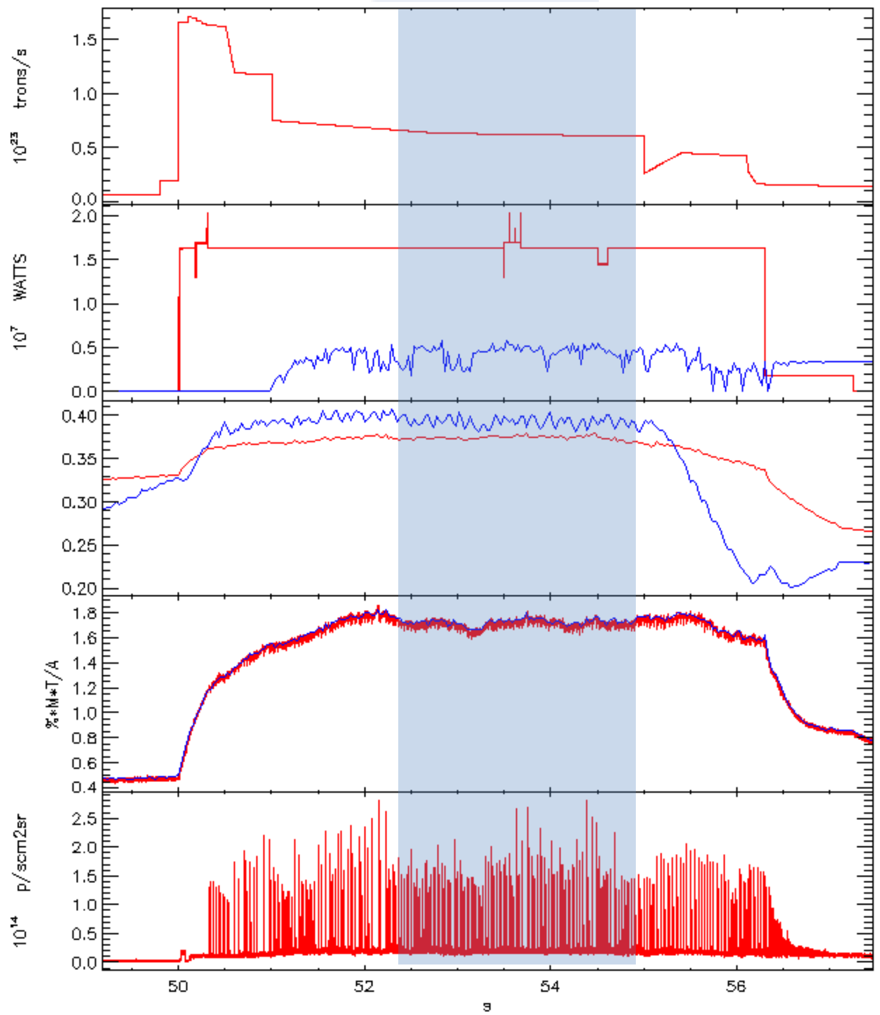
- No time evolution stored: the parameters of each entry are representative of a station phase during a fully developed H-mode. More details in the next slide

Overview

- No time evolution:
  - to quantify pedestal parameters with a reasonable accuracy the following process is used

    (note this is the standard approach used in pedestal physics):

    1. time interval with stationary engineering (Ip, Bt, gas, power, shape, divertor configuration…) and plasmas parameters (beta, Prad, f_{GW}, pedetsal height) are selected
    2. With this time interval, only pre-ELM profiles are selected
    3. The selected pre-ELM profiles are mapped on poloidal flux and an analytical fit is done using the combined profiles with a ”standard” modified tanh function [Groebner NF2001]
    4. From the fitting function, pedestal parameters are selected
- In some cases two or three entries per pulses, for example with:
  - Gas steps
  - Power steps
  - …



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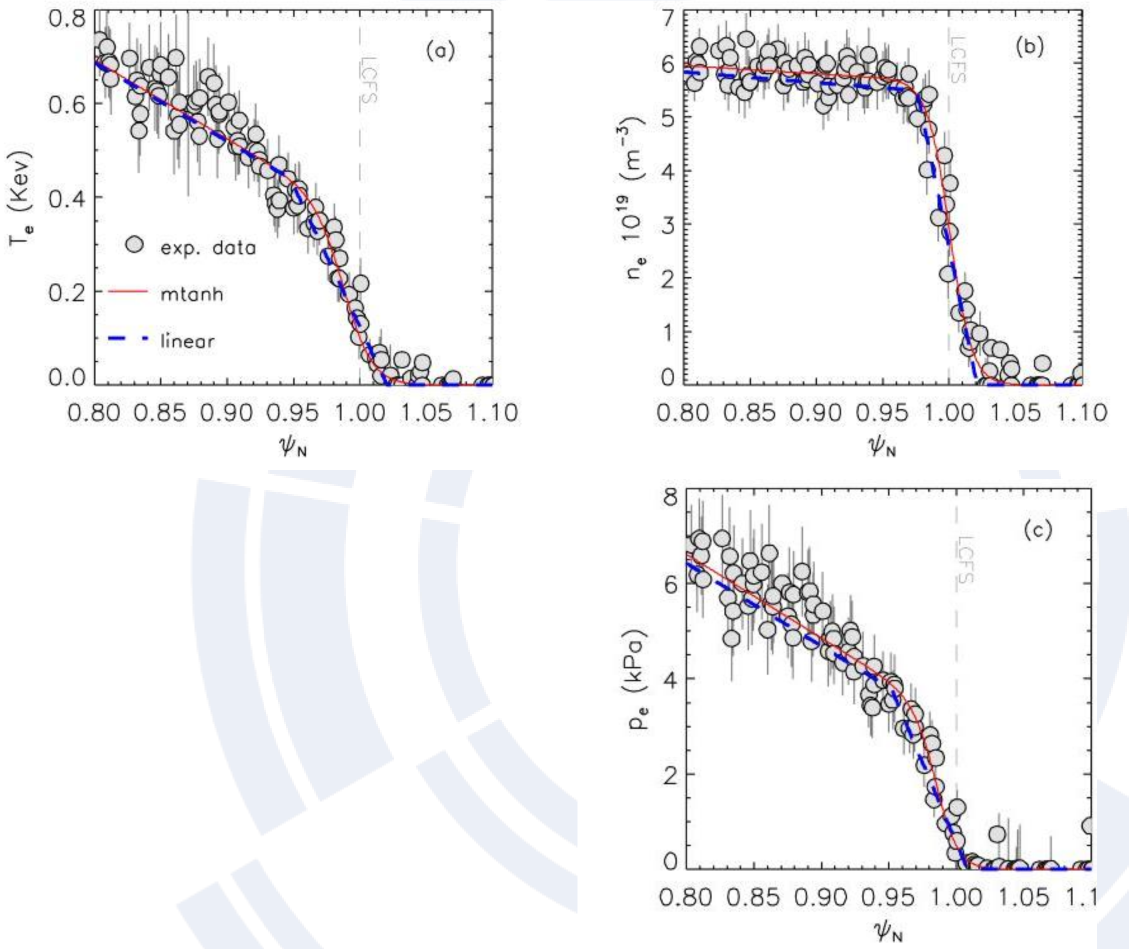

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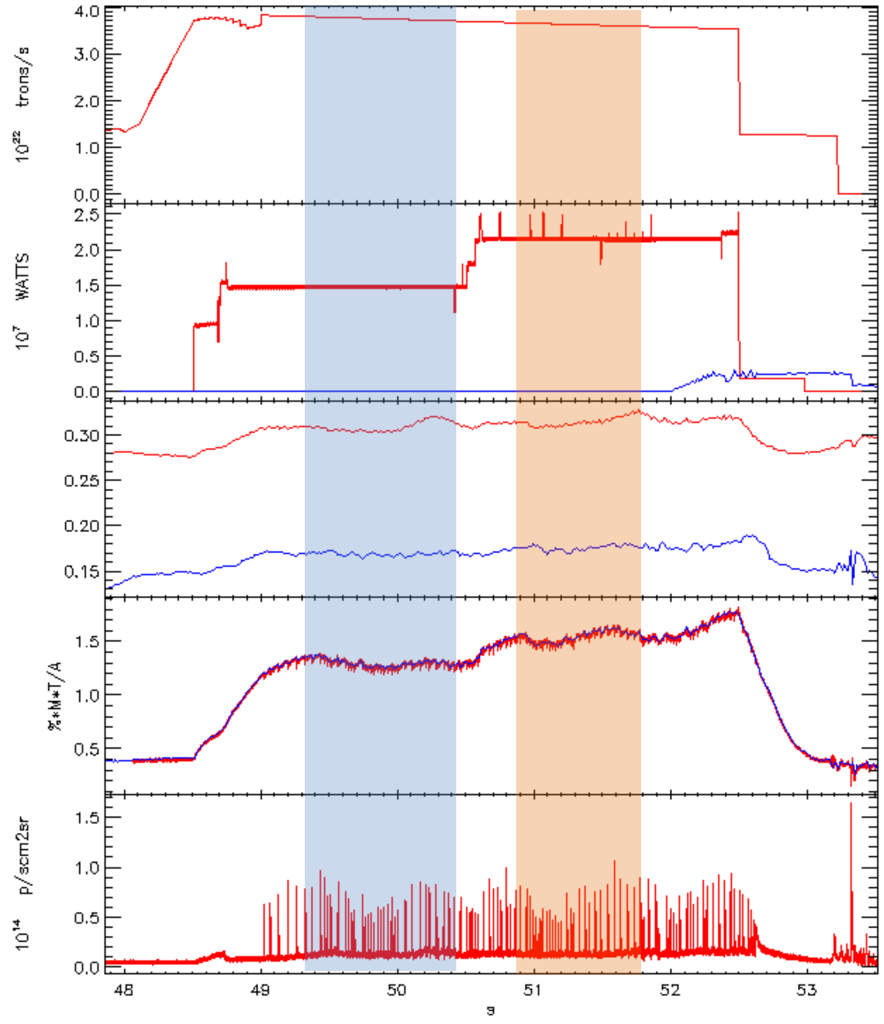
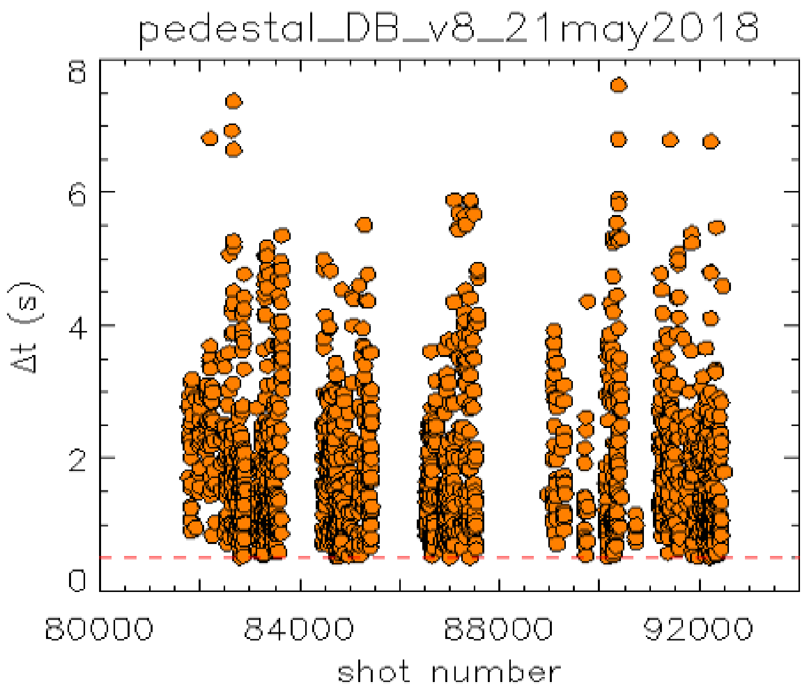
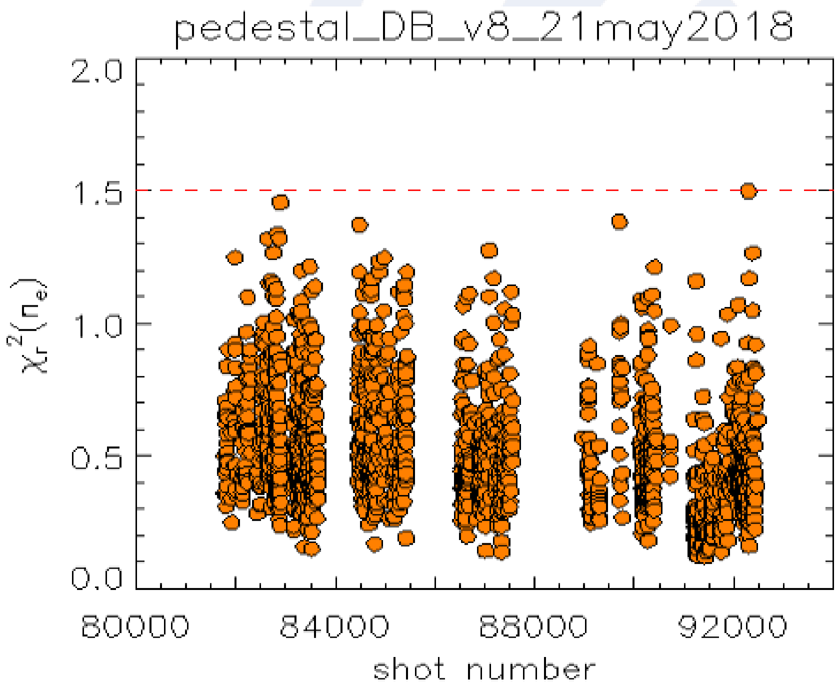


Selection rules

- stationary phase at least $2\tau_E$ long. Stationary phase checked on engineering parameters and the main plasma parameters (b_N, impurity content, line-integrated density, ELM frequency)
- Good quality of the fits. Quantified as $\chi_r^2 < 1.5$

- Example from JET:





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- **Publications**

Present status

- Size
  - JET: 5900 entries (all available H-modes with good pedestal data)
  - TCV: 490 entries (provided by B. Labit, M. van Rossem)
  - AUG: 200 entries (EUROfusion shots with H-modes from WPMST1 campaigns, provide by M. Dunne)
  - MAST-U: 100 entries (all EUROfusion shots with H-modes and good pedestal data till June 2025)

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- Location: **EUROfusion gateway (EFGW)**
  - In autumn 2025, EFGW started to be available (I got access to EFGW only from the end of November).
    - Several issues to be solved but by Dec 20 the main part of the database has been stored on the EFGW
    - Due to the limited time EFGW was available, improvements are still necessary
      - profiles are not stored
      - Some parameters are not available yet in all machines
  - The database is stored on EFGW in IMAS:
    - **JET**: /afs/eufus.eu/user/g/g2lfrass/imasdb/pedestalDB_JET 540GB
    - **TCV**: /afs/eufus.eu/user/g/g2lfrass/imasdb/pedestalDB_TCV 84MB
    - **AUG**: /afs/eufus.eu/user/g/g2lfrass/imasdb/pedestalDB_AUG 22MB
    - **MAST-U**: /afs/eufus.eu/user/g/g2lfrass/imasdb/pedestalDB_MASTU 54MB

Access (EFGW)

- Scripts to read the database are on the EFGW
  - /afs/eufus.eu/user/g/g2lfrass/imasdb/read_EUROfusion_pedestalDB.py
    - python read_EUROfusion_pedestalDB.py JET 100247 pedestal_fits.mtanh.t_e.pedestal_height,global_quantities.ip,global_quantities.power_steady

```
<g2lfrass@viz05 ~/imasdb>python read_EUROfusion_pedestalDB.py JET 100247 pedestal_fits.mtanh.t_e.pedestal_height,global_quantities.ip,global_quantities.q_95

 Shot 100247 - run 0 - time = [49.39s-49.95s]
   pedestal_fits.mtanh.t_e.pedestal_height
       value    : 399.39820766448975
       error    : 23.870099335908889
       source   : Source: PPF=Data: T003/pbohm   /505    Equilibrium: EHTR/JETPPF/146    Original HRTS data: HRTS/jetppf/80    Date of the fit: Thu Sep 22 20:17:53 2022
   global_quantities.ip
       value    : -1964043.625
       error    : -11371.3916015625
       source   : Source: PPF=Data: MAGN/IPLA/jetppf/  9
   global_quantities.q_95
       value    : 3.456517457962036
       error    : 0.042443297880348195
       source   : Source: PPF=Data: EFIT/Q95/jetppf/ 20
```

    - python read_EUROfusion_pedestalDB.py MASTU 49172 pedestal_fits.mtanh.t_e.pedestal_height,global_quantities.ip

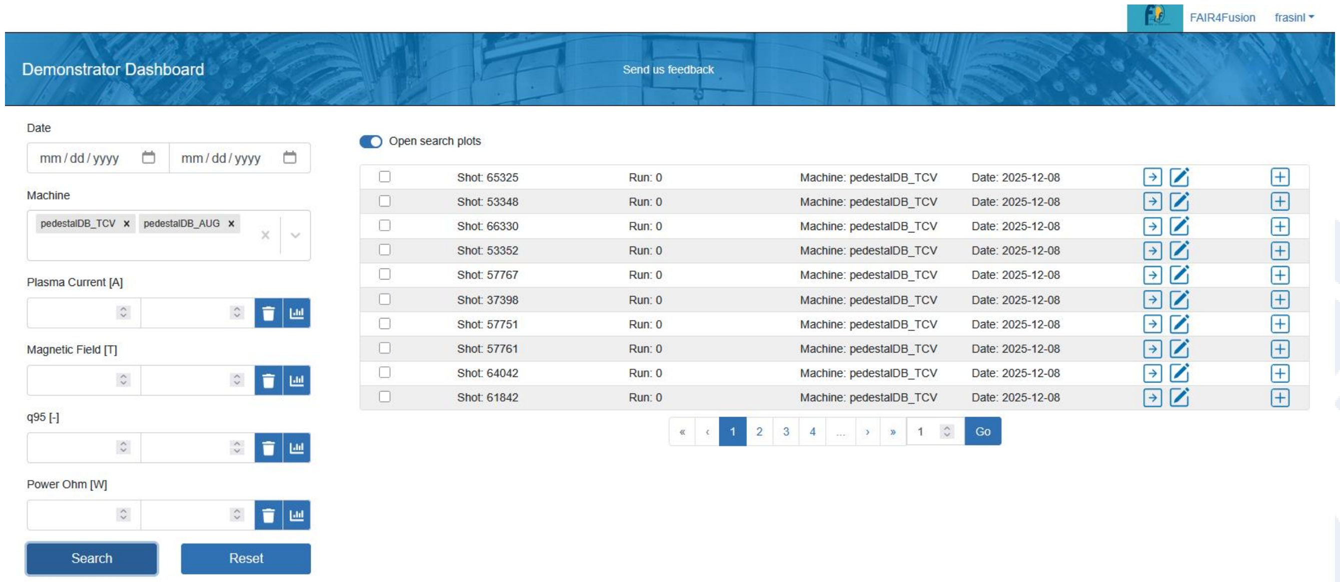
```
<g2lfrass@viz05 ~/imasdb>python read_EUROfusion_pedestalDB.py MASTU 49172 pedestal_fits.mtanh.t_e.pedestal_height,global_quantities.ip,global_quantities.q_95

 Shot 49172 - run 0 - time = [0.28s-0.50s]
   pedestal_fits.mtanh.t_e.pedestal_height
       value    : 209.95499193668365
       error    : 10.881969785224037
       source   : Source: PPF=TS_49172_T012.sav
   global_quantities.ip
       value    : 743.0400390625
       error    : 4.914982318878174
       source   : Source: PPF=TS_49172_T012.sav
   global_quantities.q_95
       value    : -6.598109245300293
       error    : 0.08196742887682615
       source   : Source: PPF=TS_49172_T012.sav

 Shot 49172 - run 1 - time = [0.60s-0.70s]
   pedestal_fits.mtanh.t_e.pedestal_height
       value    : 148.39812928856476
       error    : 8.15686583518982
       source   : Source: PPF=TS_49172_T013.sav
   global_quantities.ip
       value    : 743.4151000976562
       error    : 3.737205982208252
       source   : Source: PPF=TS_49172_T013.sav
   global_quantities.q_95
       value    : -6.389841900634766
       error    : 0.04809904471039772
       source   : Source: PPF=TS_49172_T013.sav
```

  - /afs/eufus.eu/user/g/g2lfrass/imasdb/create_csv_EUROfusion_pedestalDB.py
    - python create_csv_EUROfusion_pedestalDB.py TCV pedestal_fits.mtanh.t_e.pedestal_height,global_quantities.ip,global_quantities.power_steady TCV_DB_table

Access (alternatives)

- Link with the DMP project:
- on dmp.eufus.eu:
  - Data upload on the dashboard
  - Web interface to browse through the database

    https://dmp.eufus.eu/dashboard/



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- On dmp.eufus.eu:
  - Web interface to browse through the database

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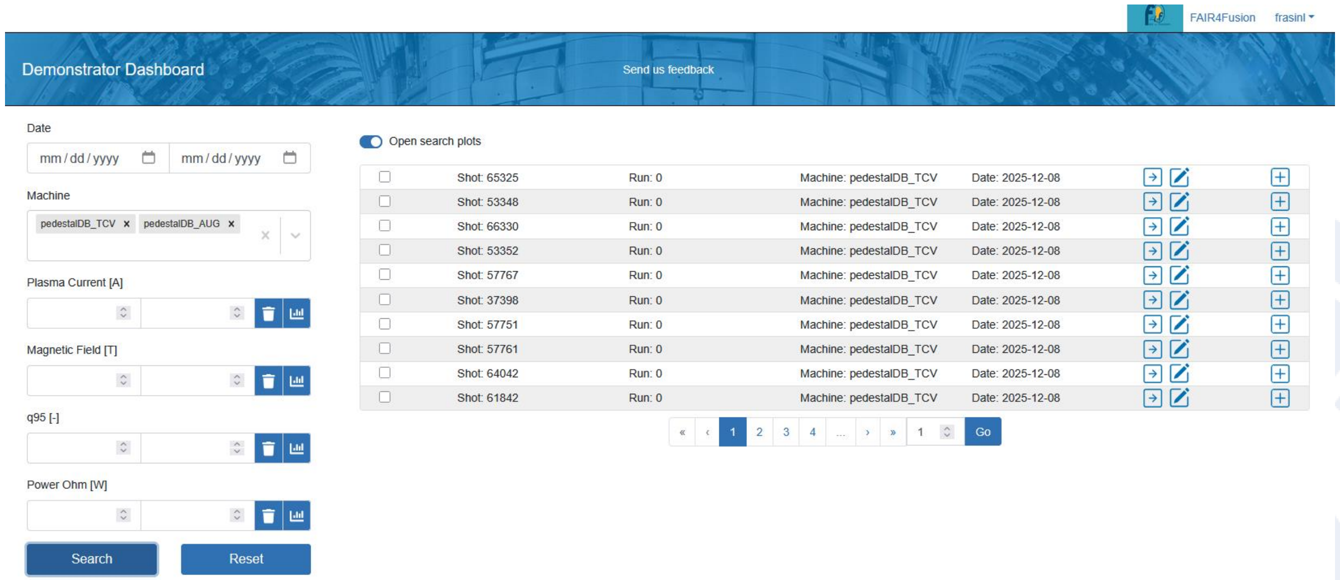
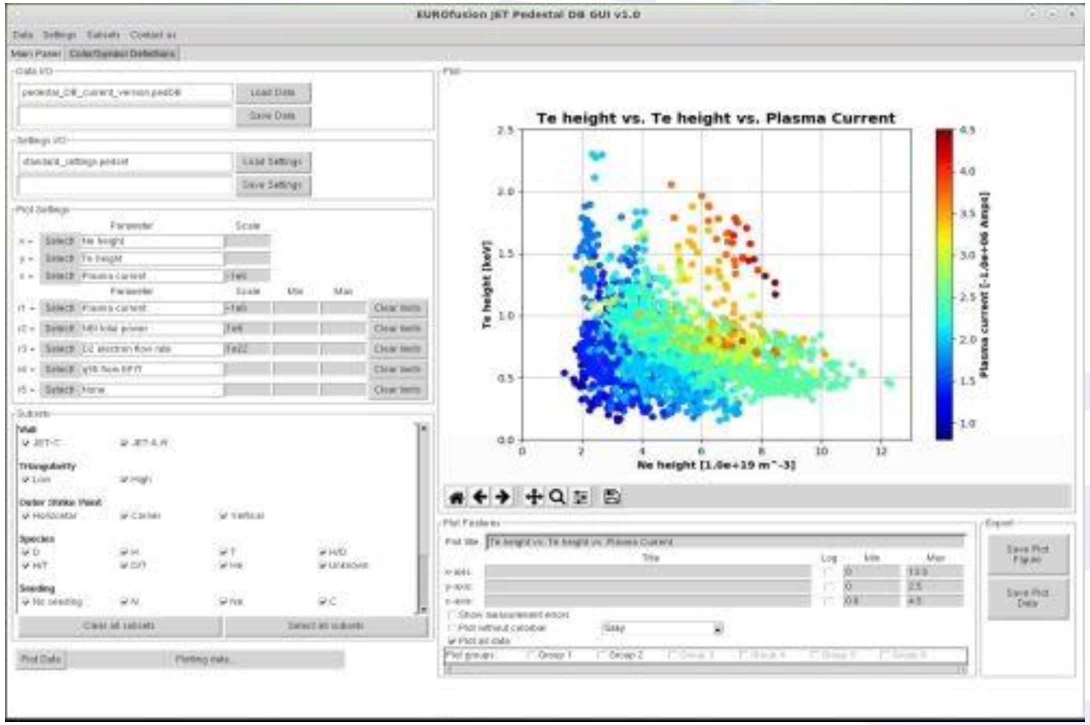
- From JDC (only for JET)
  - GUI
  - the goal of the GUI is to:
    - have an easy quick way to obtain simple plots of the JET pedestal database
    - quickly identify shots with specific parameters
    - save the plotted data in a csv file (so that the user can plot the data in his/her own way)





Information

- All information are on the pedestal database wiki on the WPPrIO pages:
  - https://wiki.euro-fusion.org/wiki/WPPrIO_wikipages:_DB_Pedestal
- List of parameters with IMAS names are:
  - In this pdf file https://wiki.euro-fusion.org/images/b/bf/EUROfusion_pedestalDB_variables_list_Dec2025_v1.pdf
  - listed at this link:
    https://wiki.euro-fusion.org/wiki/WPPrIO_wikipages:_DB_Pedestal#Appendix:_Tables_with_parameters,_units_and_IMAS_names

- Tutorial and user manual for the JDC GUI (JET only):
  - http://wiki.jetdata.eu/pages/tfiospti/TFmeetings/2021/20210722/Pedestal_DB_GUI.pdf
  - https://wiki.jetdata.eu/tf/index.php?title=EUROfusion_JET_Pedestal_database_GUI

Next steps

- **Preparation of a user agreement**
  - It was agreed in 2023 that the agreement would have been prepared by the PMU
  - Decide how to ensure the users will sign the agreement
- **Finalization of present version:**
  - cross-check all parameters are on EFGW
  - include profile data
- **Extensions:**
  - extend the MAST-U part of the database with the new EUROfusion shots
  - extend the TCV part of the database with the new EUROfusion shots, assuming support from the local team
  - extend the AUG part of the database with the new EUROfusion shots, assuming support from the local team
- **Updates and support:**
  - update the JET part of the database upon request from the users
  - store the new data into the IMAS format on the New Gateway server
  - maintain the tools to access the database up-to-date.
  - provide support to the users.
- **Advertise:**
  - The JET part of the database on the JDC has been widely advertised (several TFM presentations)
  - The database on the EFGW is ready only since December. No large advertisement done yet

Publications

- Key publications directly related to the database
  1. "The EUROfusion JET-ILW pedestal database", L. Frassinetti et al., 45thEPS Conference on Plasma Physics, Prague 2018, P4.1027
  2. "Pedestal structure, stability and scalings in JET-ILW: the EUROfusion JET-ILW pedestal database": L. Frassinetti et al 2021 Nucl. Fusion, 61 016001 (must be cited if any data from the DB are used)
  3. "H-mode physics studies on TCV supported by the EUROfusion pedestal database": B. Labit et al 2021 IAEA FEC. EX/P4-17
- Publications in which the EUROfusion pedestal database has been used (not a comprehensive list)

Autor		Title	Journal/conference		DOI	ID
Gillgren	A.	Enabling adaptive pedestals in predictive transport simulations using neural networks	Nucl. Fusion 62 096006 (2022)	paper	10.1088/1741-4326/ac7536	30485
Saarelma	S.	Self-consistent pedestal prediction for JET-ILW in preparation of the DT campaign	Phys. Plasmas	paper	https://doi.org/10.1063/1.5096870	
Kit	A.	Developing deep learning algorithms for inferring upstream separatrix density at JET	Nuclear Materials and Energy 22 December 2022	paper	https://doi.org/10.1016/j.nme.2022.101347	
Kit	A.	Supervised learning approaches to modeling pedestal density	Plasma Phys. Control. Fusion 65 045003 (2023)	paper	10.1088/1361-6587/acb3f7	31230
Kit	A.	Enabling online pedestal stability analysis with machine learning	27th Joint EU-US Transport Task Force Meeting (TTF 2023), Nancy, France.	poster		35313
Clarte	G.	Maximizing Pedestal Pressure Height through Bayesian Optimisation	4th International Conference on Data Driven Plasma Science (ICDDPS-4), Okinawa, Japan, 2023.	poster		33423
Jarvineen	A.	Representation learning algorithms for inferring machine independent latent features in pedestals in JET and AUG	4th International Conference on Data Driven Plasma Science (ICDDPS-4), Okinawa, Japan, 2023.	poster		
Gillgren	A.	Investigating pedestal dependencies at JET using an interpretable neural network architecture	Nuclear Fusion	Paper	https://doi.org/10.1088/1741-4326/adcbc2	39043
Panera	A.	EuroPED-NN: uncertainty aware surrogate model	Plasma Physics and Controller Fusion	Paper	10.1088/1361-6587/ad6707	36778
Jarvineen	A.	Scalable simulation-based inference framework for large-scale model validation in fusion	Joint Runaway Electron Modelling (REM) and WPTE RT03 Analysis meeting, Lausanne, Switzerland.	oral		40525
Jarvineen	A.	Scalable simulation-based inference framework for large-scale model validation in fusion	51st EPS Conference on Plasma Physics (EPS 2025), Vilnius, Lithuania.	poster		39664
Jarvineen	A.	Developing machine learning facilitated pedestal models	30th IAEA Fusion Energy Conference (FEC)	Poster		39762
Jarvineen	A.	Towards scalable large-scale model validation with data science	9th Asia-Pacific Conference on Plasma Physics (AAPPS-DPP2025), Fukuoka International Congress Center, Japan.	oral		40738
Buncrona	A.	Machine learning surrogate model for peeling-ballooning pedestal MHD stability	51st EPS Conference on Plasma Physics (EPS 2025), Vilnius, Lithuania.	poster		39681
Niemäla	A.	Machine learning methods for modelling local, linear gyrokinetic simulations of MAST-U pedestal turbulence	51st EPS Conference on Plasma Physics (EPS 2025), Vilnius, Lithuania.	poster		39694
Buncrona	A.	Machine learning surrogate model for ideal peeling-ballooning pedestal MHD stability	Phys. Plasmas	Paper	10.1063/5.0282085	40403
Silvagni	D	A predictive formula for the H-Mode separatrix density: Bridging regression and physics-based models across C-Mod, AUG and JET tokamaks	67th APS DPP Annual Meeting, Long Beach (CA), USA.	oral		40810
Silvagni	D	A predictive formula for the H-mode electron separatrix density: Bridging regression and physics-based models across C-Mod, AUG and JET tokamaks	Nucl. Fusion	submitted		41795
Gillgren	A.	Interpretability guided transfer learning approaches for tritium pedestal predictions	Nucl. Fusion	submitted		41783