ITPA Pedestal and Edge Group

Pedestal Profile Database structure (proposal)

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Thanks to Tony Leonard, Vasili Parail, Gary Porter, Alberto Loarte, and Arne Kallenbach for defining the requirements and suggesting formats for the divertor modeling data.

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1. General

The pedestal profile data resides on MDSplus trees which are provided by one or more different MDSplus servers.
The tree names and the server names are listed on the ITPA pedestal profile database web page http://itpa.ipp.mpg.de/pedestal_edge/profile_database.
The format is as much as possible identical to that of the International multi-tokamak confinement profile database (CPDB, http://tokamak-profiledb.ukaea.org.uk). Only proposed extensions to the CPDB are specified here.

The extensions to the profile database which we are proposing are driven by the following pedestal analysis goals:

a. Transport analysis and simulation will cover inter-ELM and other time periods in between events and as such must allow for strongly time varying profiles. To address this goal we will provide profiles and scalar data which time resolve the profile evolution in between events. Existing entries in the profile database covering phases of the discharge with mixed transport states, (e.g. PHASE=HGELM mixes ELM free and ELM transport states) are time averaged over the mixed states. This is appropriate for core transport analysis, but addressing the goals of the ETB studies requires time resolved profiles through the individual transport states. Although this difficulty could be addressed by, for example, identifying the inter-ELM period as ELM free (PHASE=H), global parameters, for example energy confinement times, in phases with mixed transport states are more meaningfully given in terms of machine performance as time averages. To address this difficulty we suggest creating two new branches .ONEDTR and .TWODTR to hold the profile and scalar data which Time Resolves the profile evolution in the individual transport states. The .ZEROD, .ONED, and .TWOD branches would also be included and will contain scalar data and profiles which are time averaged over the transport states in a given phase consistent with the traditional use of the database. This also requires adding entries which more clearly describe how data is selected and time averaged, as well as entries describing the type of events bounding the period over which the profiles are evolving. In addition we need to describe any remaining events which are averaged over in deriving the profiles (e.g. profile evolution between type I ELMs but averaged over type II ELMs).

b. Transport analysis and simulation of the edge will require a determination of the edge particle source. In general this is now only available through coupled core /divertor transport modeling. We wish to add sufficient divertor data to the database to allow for such modeling. This will require adding 2-D data in the divertor and more detailed data from individual machines, e.g. limiter geometry. We propose adding an additional branch .DIV to hold the data required for divertor transport modeling. To the extent possible the .DIV data will reflect the time evolution in individual transport states in a mixed phase. Divertor data averaged over transport states is not considered to be of primary interest and no separate branch for time averaged divertor data is suggested.

c. Analysis will also include study of stability of the ETB. This requires more complete equilibrium information be included in the database. The equilibria should be accurate to the standards of stability analysis, e.g. edge current density profiles should be determined as well as possible. We also wish to include enough data in real space to regenerate an equilibrium, allowing for such things as varying the edge current to test for proximity to a stability boundary. The detailed equilibrium data will be held in a separate branch .EQUIL .

d. As required for the transient conditions in the ETB, we have proposed additional nodes to define the time resolution of signals. The suggested relation of the time resolution between various branches is summarized here.
    1. .ZEROD: Time-independent data for overall characterization of a discharge or discharge phase. Data is averaged over events in phases of mixed transport states.
    2. .ONED: Data is averaged over events in phases of mixed transport states. All time dependent data should have the same time base as .TWOD. Points in this branch should have the same time resolution as .TWOD.
    3. .ONEDTR: Data time resolves different transport states in a mixed phase. All time dependent data should have the same time base as .TWODTR. Points in this branch should have the same time resolution as .TWODTR.
    4. .TWOD: Data is averaged over events in a phase of mixed transport states. All time dependent data has the same time base and to the extent possible the same time resolution. Data is given indicating the time resolution of individual signals.
    5. .TWODTR: Data time resolves different transport states in a mixed phase. All time dependent data has the same time base and to the extent possible the same time resolution. Data is given indicating the time resolution of individual signals.
    6. .EQUIL: Time dependent data has the same time base and time resolution as TWODTR if this data is given, otherwise the same time base and resolution as TWOD.
    7. .DIV: To the extent possible time dependent data has the same time base and time resolution as .TWODTR if this data is given, otherwise the same time base and resolution as .TWOD.
    8. .TRACES: This branch is intended to give a sence of the general time evolution

of the discharge without specific requirement on time resolution. As such it should not be compared in detail to the data in other braches and should not be used to extract parameters when time resolution is critical.

2. **Structure of the MDSplus Tree.** Only new and changed nodes are shown.

```
:TOP
   |__ .COMMENTS
   |__ .ZEROD
   |      |__ :WEPED, :WIPED, :NE0, :NEPED, :NESEP, :DRNEPED,
   |      |__ :NM1,2,...0, :NM1,2,...PED, :NM1,2,...SEP, :DRNM1,2,...PED
   |      |__ :NIMP0, :NIMPPED, :NIMPSEP, :DRNIMPPED,
   |      |__ :TEPED, :TESEP, :DRTEPED, :TIPED, :TISEP, :DRTIPED,
   |      |__ :DWELM, :DNEPEDELM, :DNM1,2,...PEDELM,
   |      |__ :DNIPEDELM, :DTEPEDELM, :DTIPEDELM
   |      |__ :DELTAU, :DELTAL, :CLENOMOL, :CLENOMIL
   |__ .ONED(TR) (duplicate branch for time resolved profiles in mixed transport phase)
   |      |__ :WEPED, :WIPED, :NE0, :NEPED, :NESEP, :DRNEPED,
   |      |__ :NM1,2,...0, :NM1,2,...PED, :NM1,2,...SEP, :DRNM1,2,...PED
   |      |__ :NIMP0, :NIMPPED, :NIMPSEP, :DRNIMPPED,
   |      |__ :TEPED, :TESEP, :DRTEPED, :TIPED, :TISEP, :DRTIPED,
   |      |__ :DELTAU, :DELTAL, :CLENOMOL, :CLENOMIL
   |      |__ :TIME, :T_AVE
   |      |__ :TEVPREV, :TEVNEXT, :EVPREV, :EVNEXT, :AVEVENT
   |__ .TRACES  (signals as in ONED(TR) but time base spanning entire discharge)
   |__ .TWOD(TR) (duplicate branch for time resolved profiles in mixed transp. phase)
   |         |__ :VPROT, :VPROTXP, :VROTEB, :VROTEBXP,
   |         |__ :ZIMPROT, :AIMPROT, :TORQ
   |         |__ :yyPSI* (data and fit profiles to be given in poloidal flux as well as rho)
   |         |__ :yyXP* (sub-nodes locating measurements)
   |                  |__ :R, :Z, :NPTS, :DPTS, :TIME, :T_AVE
   |__ .EQUIL (detailed equilibrium data)
   |         |__ :PSIRZ, :PRESPSI, :PPRIMEPSI, :FPOLPSI, :FFPRIMPSI
   |         |__ :QPSI, :PSIBDRY, :RMAXIS,:ZMAXIS, :PSIMAG, :RXPT,:ZXPT
   |         |__ :RBDRY, :ZBDRY, :RCONTR, :ZCONTR
   |         |        |__:NPTS (same sub-node in :ZBDRY, :RCONTR,: ZCONTR)
   |         |__ .MAGNETICS (magnetic measurements to regenerate equilibrium fit )
   |                  |__ :BP, :PITCHANGLE, :PSILOOP
   |                  |        |__ :R, :Z (for all), (:BP also has), :THETA
   |                  |__ :IPFCOIL
   |                           |__ :R, :Z, :LH, :LV, :QH, :QV
   |__ .VESSEL ( detailed geometry of vacuum vessel inner surface)
   |         |__ :RLIM, :ZLIM
   |         |__ :RPUMP, :ZPUMP
   |                  |__ :NPTS (same sub-nodes in :ZPUMP)
   |__ .DIV (data for divertor modeling)
         |_ :NEDIV, :NM1DIV, :NM2DIV, :NM3DIV, :NIMPDIV, :TEDIV, :JSATDIV
         |__ :HEATFLUX, :NEUTPRES
         |       |__ :R, :Z (same sub-nodes in other .DIV nodes above)
           |__ :SPECTRO
         |       |__ :R, :Z, :REND, :ZEND, :SOLIDANG, :LINE
         |__ :BOLOM
                 |__ :R, :Z, :REND, :ZEND, :SOLIDANG
```

General proposals for MDSplus node and sub-node structure:

a. **Node types**: At the top level there are only structure nodes which contain the various branches of the tree. Nodes in the `.COMMENTS` and `.ZEROD` branches are time independent and are typically of `TEXT` or `NUMERIC` data types. Time dependent nodes and sub-nodes should be of `SIGNAL` type. Note that all data node types allow carrying the units with the node.

b. **Units:** The physical unit is stored with nodes and can be retrieved with `units_of(:yy*)`. Units should adhere to the MDSplus standard as defined on this web page http://www.mdsplus.org/old/tdi/tdi_misc_help.html , to allow them to be combined automatically in TDI functions (currently only partially implemented in TDI).

c. **Error bars:** Experimental and fit errors are stored with the SIGNAL type nodes and can be retrieved with `error_of(:yy*)`.

d. **Time base:** For time dependent signals, time is always the last axis (varying most slowly in memory).

e. **Overall averaging time window**: Typically, data for each time point of a time-dependent signal will be obtained by averaging data over a certain time interval. The time over which a signal is averaged is stored as an additional signal on the same level, `:T_AVE`., which itself is a time dependent SIGNAL node. The data at the k-th position is averaged over the following time interval:

```
TIME[k] - T_AVE[k]/2  <  t  <  TIME[k] + T_AVE[k]/2
```

The middle time of the averaging time interval is stored in `:TIME`. Normally the values of `:TIME` are identical to the time base of the signals in a branch. However, for time-resolved signals the time base can be used as an "effective time" to denote alignment with respect to bounding events (see decription of ONED nodes). In any case, `:TIME` contains the true mid-point of the averaging time interval.

	Variable	Description	Units	Node Type	Data type
1	`:T_AVE`	Duration of averaging time interval	s	Signal	Real
2	`:TIME`	Middle of the averaging time interval	s	Signal	Real

Nodes `:TIME` and `:T_AVE` will usually exist for the following branches: `.ONED`, `.ONEDTR`, `.TWOD`, `.TWODTR`.

Typically, all signals in one branch will have the same definitions of the averaging time interval, and the global values of `:TIME` and `:T_AVE` apply. However, if there are signals with individual definitions of the averaging time window (not encouraged) then this signal can have individual `:TIME` and `:T_AVE` sub-nodes.

In the remainder of the document, the individual tree branches are described.

I. **.COMMENTS**: "Comments" nodes

As defined in the CPDB.
Use comment nodes to indicate context and possibly range of validity of the discharge data.

II. **.ZERO D**: Scalar database nodes. In phases of mixed transport states, e.g. ELMing H-mode, the ZEROD data should be time averaged over the different transport states.

Additional nodes to be added to .ZEROD to address ETB issues

	Variable	Description	Units	Node Type	Data type
1	:NE0	Electron density on magnetic axis	1/m^3	Signal	Real
2	:NM1,2,..0	Main ion density on magnetic axis	1/m^3	Signal	Real
3	:NIMP0	Main impurity density on magnetic axis	1/m^3	Signal	Real
4	:NEPED	Electron density at top of H-mode pedestal	1/m^3	Signal	Real
5	:NESEP	Electron density at separatrix	1/m^3	Signal	Real
6	:DRNEPED	Distance in psi space between top of pedestal and separatrix	1	Signal	Real
7	:NM1,2,..PED	Main ion density at top of H-mode pedestal	1/m^3	Signal	Real
8	:NMSEP	Main ion density at separatrix	1/m^3	Signal	Real
9	:DRNM1,2,..PED	Distance in psi space between top of pedestal and separatrix	1	Signal	Real
10	:NIMPPED	Main impurity density at top of pedestal	1/m^3	Signal	Real
11	:NIMPSEP	Main impurity density at separatrix	1/m^3	Signal	Real
12	:DRNIMPPED	Distance in psi space between top of pedestal and separatrix	1	Signal	Real
13	:TEPED	Electron temp at top of H-mode pedestal	eV	Signal	Real
14	:TESEP	Electron temp at separatrix	eV	Signal	Real
15	:DRTEPED	Distance in psi space between top of pedestal and separatrix	1	Signal	Real
16	:TIPED	Ion temp at top of H-mode pedestal	eV	Signal	Real
17	:TISEP	Ion temp at separatrix	eV	Signal	Real
18	:DRTIPED	Distance in psi space between top of pedestal and separatrix	1	Signal	Real
19	:WEPED	Electron energy in H-mode pedestal	J	Signal	Real
20	:WIPED	Ion (main+impurity) energy in H-mode ped	J	Signal	Real

	Variable	Description	Units	Node Type	Data type
21	:DWELM	Energy loss at ELM	J	Signal	Real
22	:DNEPEDELM	Change in pedestal electron density at ELM	1/m^3	Signal	Real
23	:DNM1,2,..PEDELM	Change in pedestal main ion density at ELM	1/m^3	Signal	Real
24	:DNIPEDELM	Change in ped main imp density at ELM	1/m^3	Signal	Real
25	:DTEPEDELM	Change in pedestal electron temp at ELM	eV	Signal	Real
26	:DTIPEDELM	Change in pedestal Ion temp at ELM	eV	Signal	Real
27	:DELTAU	Upper triangularity	1	Signal	Real
28	:DELTAL	Lower triangularity	1	Signal	Real
29	:CLENOMOL	Connection length from plasma outer midplane to divertor strike point for the 0.5cm flux tube	m	Signal	Real
30	:CLENOMIL	Connection length from plasma inner midplane to divertor strike point for the 0.5cm flux tube	m	Signal	Real

The scalar pedestal top values :yyPED and position of the top of the pedestal with respect to the separatrix, :DRyyPED are obtained from the fits to the edge pedestal profiles using a modified form of a hyperbolic tangent fit to points near the separatrix in poloidal flux space. The functional form for the fit function is given by

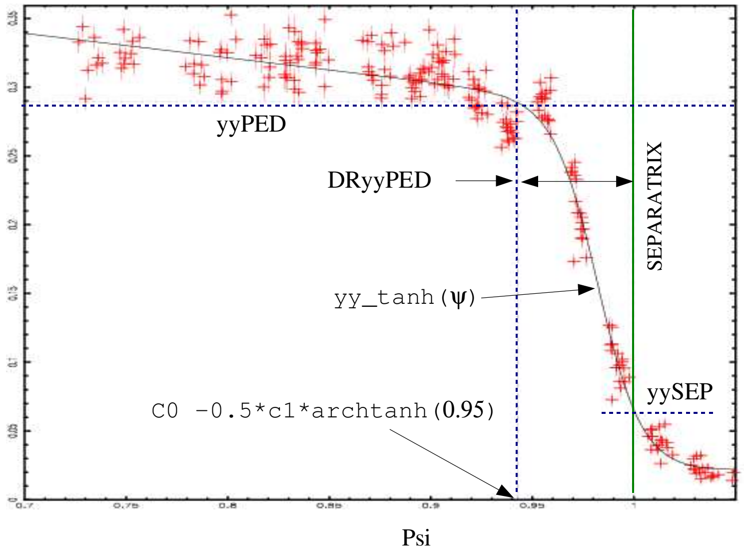
$$yy_{\tanh}(\psi)=\frac{(c_2+c_3)}{2}\left[\frac{(1+c_4\psi)e^{\xi}-e^{-\xi}}{e^{\xi}+e^{-\xi}}\right]+\frac{(c_2-c_3)}{2},\xi=\frac{2(c_0-\psi)}{c_1}$$

and the location of the top of the pedestal is given by

$$\psi_{PED}=c_0-0.5\ c_1\ \text{artanh}(0.95)$$

This is shown graphically in the figure below.

The 0.5 cm flux tube intersects a point 0.5 cm outside of the separatrix at the outer midplane.



I. **.ONED**: Scalar parameters as a function of time. Data in the ONED nodes should be given at the profile times in .TWOD, and should also reflect the time resolution of the .TWOD data. In the case where profiles time resolve the the different transport states of a mixed phase (e.g. Type I ELMs with profiles which resolve the time evolution between ELMs) the time resolved data is to be put in a separate branch .ONEDTR and the .ONED branch is reserved for data averaged over the different transport states in a mixed phase.

a) Additional nodes to be added to .ONEDTR, .ONED to address ETB issues

	Variable	Description	Units	Node Type	Data type
1	:NE0	Electron density on magnetic axis	1/m^3	Signal	Real
2	:NM1,2,..0	Main ion density on magnetic axis	1/m^3	Signal	Real
3	:NIMP0	Main impurity density on magnetic axis	1/m^3	Signal	Real
4	:NEPED	Electron density at top of H-mode pedestal	1/m^3	Signal	Real
5	:NESEP	Electron density at separatrix	1/m^3	Signal	Real
6	:DRNEPED	Distance in psi space between top of pedestal and separatrix	1	Signal	Real
7	:NM1,2,..PED	Main ion density at top of H-mode pedestal	1/m^3	Signal	Real
8	:NM1,2,..SEP	Main ion density at separatrix	1/m^3	Signal	Real
9	:DRNM1,2,..PED	Distance in psi space between top of pedestal and separatrix	1	Signal	Real

	Variable	Description	Units	Node Type	Data type
10	:NIMPPED	Main impurity density at top of pedestal	1/m^3	Signal	Real
11	:NIMPSEP	Main impurity density at separatrix	1/m^3	Signal	Real
12	:DRNIMPPED	Distance in psi space between top of pedestal and separatrix	1	Signal	Real
13	:TEPED	Electron temp at top of H-mode pedestal	eV	Signal	Real
14	:TESEP	Electron temp at separatrix	eV	Signal	Real
15	:DRTEPED	Distance in psi space between top of pedestal and separatrix	1	Signal	Real
16	:TIPED	Ion temp at top of H-mode pedestal	eV	Signal	Real
17	:TISEP	Ion temp at separatrix	eV	Signal	Real
18	:DRTIPED	Distance in psi space between top of pedestal and separatrix	1	Signal	Real
19	:WEPED	Electron energy in H-mode pedestal	J	Signal	Real
20	:WIPED	Ion (main+impurity) energy in H-mode ped	J	Signal	Real
21	:DELTAU	Upper triangularity	1	Signal	Real
22	:DELTAL	Lower triangularity	1	Signal	Real
23	:CLENOMOL	Connection length from plasma outer midplane to divertor strike point for the 0.5cm flux tube	m	Signal	Real
24	:CLENOMIL	Connection length from plasma inner midplane to divertor strike point for the 0.5cm flux tube	m	Signal	Real

b) The **time base of signals** in the .ONED branch is the middle of the integration time window used to derive the data.
The time base of signals in the .ONEDTR branch can be the actual time of measurement (for single, instantaneous measurements) or an “effective” time, if several time windows with respect to repeated events are co-added. The “effective” time is chosen such that the timing relative to bounding events (see next paragraph) is correctly represented.

c) **Bounding events**: Additional nodes are required to define the time of and type of the previous and next event which bound an interval over which the profiles are evolving for data in the .ONEDTR and .TWODTR branches. These are signal nodes as a function of the profile times.

	Variable	Description	Units	Node Type	Data type
25	:TEVPREV	Time of previous event	s	Signal	Real

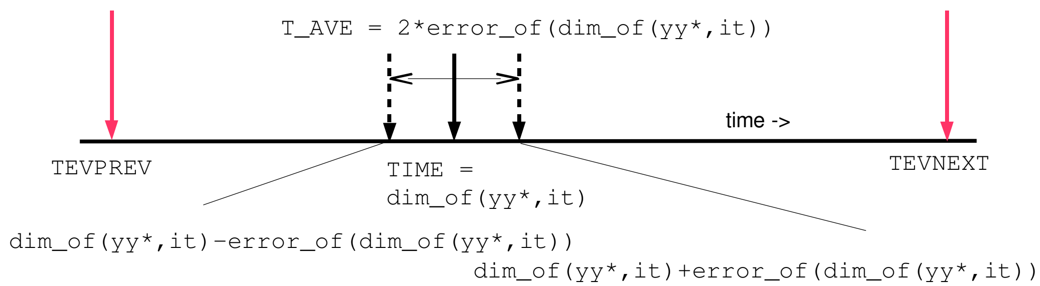
	Variable	Description	Units	Node Type	Data type
26	:TEVNEXT	Time of next event	s	Signal	Real
27	:EVPREV	Type of event before sampling window	1	Signal	String
28	:EVNEXT	Type of event following window	1	Signal	String

The codes that denote the types of events in EVPREV and EVNEXT are listed below (next paragraph). The timing sequence is shown in the figure below, where it is the index of the time axis.

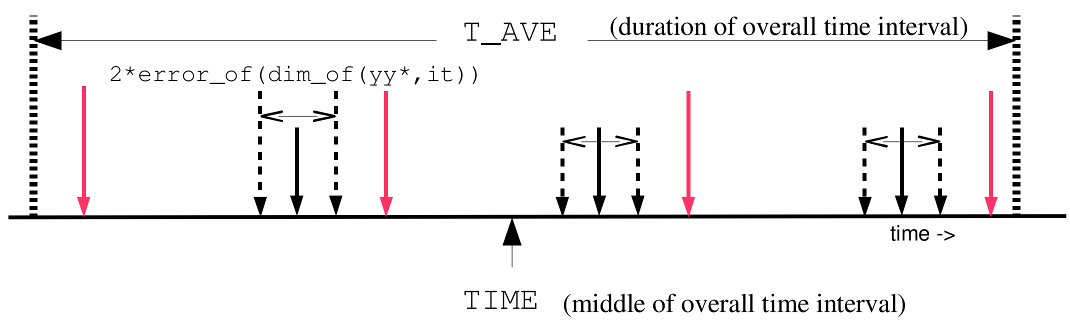
The actual time resolution of a signal is stored as an uncertainty of the time axis and can be retrieved with `error_of( dim_of(yy,it) )`, where it is the index of the time dimension. The data at the k'th time point is averaged over the time interval `dim_of(yy*,it)-error_of(dim_of(yy*,it))` ... `dim_of(yy*,it) + error_of(dim_of(yy*,it)).`

Examples.

First example: One measurement interval in between two bounding events:

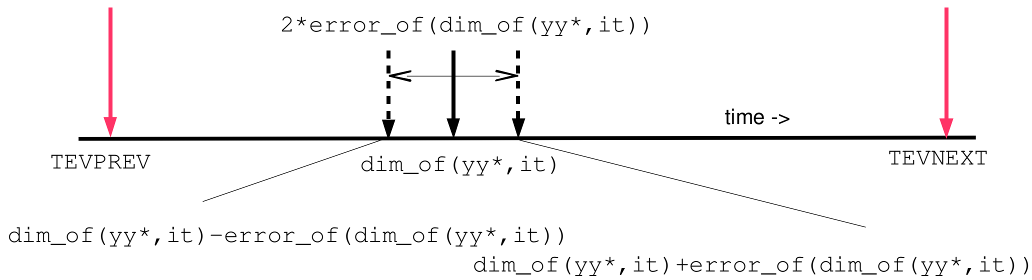


Second example: Multiple averaging time intervals around repetitive events:



Co-addition of the individual sampling intervals leads to a common time sequence, which is expressed with respect to the bounding events in each cycle.

Note that in this case, since global and event-relative time windows are different:



TIME is *not* equal to dim(yy*,it) and
T_AVE is *not* equal to 2*error_of(dim_of(yy*,it)).

A time history in between events is represented by different values of the time base dim(yy*,it), while typically TEVPREV and TEVNEXT remain the same for different data time slices. In this way, a coherent time evolution can be represented, even if the underlying data originates from co-addition of several repeated events.

d) In the same sense that PHASE represents the type of events averaged over in the usual treatment of mixed transport states, in the case where we are resolving the profile evolution in a particular state (e.g. profile evolution between type I ELMs) we may still be averaging over other events (e.g. mixed Type I, Type II ELMs). We use the variable AVEVENT to designate this residual event which is averaged over.

	Variable	**Description**	**Units**	**Node Type**	**Data type**
29	:AVEVENT	Type of event averaged over (see table blow)	1	Signal	String

The type of event used as timing reference is coded in the variable :AVEVENT, a string signal. The following list defines a set of event types used in :EVPREV and :EVNEXT as well as :AVEVENT. More event types can and probably will be defined in future, and those extensions should be added to this list, whenever useful.

Event code	**Description**
LH	L-mode to H-mode transition
HL	H-mode to L-mode transition
T1ELM	Type I ELM
T2ELM	Type II ELM
T3ELM	Type III ELM
GELM	Grassy ELM (as defined for JT-60U)
ELM	ELM of unspecified type
QCM	Quasi Coherent Mode
EHO	Edge Harmonic Oscillation
PELLET	Injection of a pellet

II. **.TRACES** – time traces for the entire discharge

In addition to the `.ZEROD` and `.ONED` branches, which contain scalar data for the times of interest (i.e. time points for which profiles are supplied) it is possible to store complete time traces which cover the entire discharge.
This data can be used as to review the overall history of the discharge and may provide a context for the profile and equilibrium data in the other nodes.
The node names in `.TRACES` are as defined for `.ONED` (and the CPDB), the only exception being the larger number of time points. Time bases of the various `.TRACES` nodes do not need to be identical, i.e. different signals can be stored with different time resolution.

III..**TWOD**: Profiles. The .TWOD branch contains profiles, which can be taken at different times in the discharge and which have a time base (dim_of(yy*,1)) that corresponds to the actual time in the discharge.
In the case where profiles time resolve the different transport states of a mixed phase (e.g. Type I ELMs with profiles which resolve the time evolution between ELMs) the time resolved data is to be put in a separate branch, .TWODTR. The time base of signals in the TWODTR branch is an effective time which describes the positioning of the sampling window with respect to bounding events (see above).
The difference between the .TWODTR and the .TWOD branches is that .TWOD is reserved for data averaged over the different transport states in a mixed phase.

a) Profile nodes stored in the pedestal profile database are:

yyXP	Experimental data vs. rho-toroidal
yy	Profile fit vs. rho-toroidal

The rho-toroidal space was selected for transport analysis to facilitate mapping in the plasma core near the magnetic axis, however this coordinate is difficult to use near the sparatrix where it has infinite derivative with respect to R and it is undefined outside the separatrix. We suggest adding profiles in poloidal flux space which is more regular in the pedestal region and defined outside the separatrix.

yyXPPSI	Experimental data vs. normalized poloidal flux
yyPSI	Profile fit vs. normalized poloidal flux

where yy=TE,TI,...

b) Core transport analysis nodes (Q*, S*, CUR*) are not required for some aspects of ETB analysis and are optional.

c) The values of the time base are representative for the profile in question. Obtaining accurate profiles in most cases requires time averaging experimental data. In the case where profiles are time averages of experimental data, including the case where data is combined from discontinuous time intervals (and possibly from different discharges) representing a particular phase in the profile evolution, the values of the profile time base, given in dim_of(yy*,1), can be effective, rather than real, times which are representative of the profile evolution. In this case the average effective time in a given discharge phase is chosen to correspond to the .ONED time slice representative of that phase.

d) Since each time point in a profile may represent the averaging of different number of experimental points, for experimental data the radial position of an experimental profile, dim_of(yyXP*,0), can be one-dimensional or two-dimensional. One-dimensional dimensions contain the time independent radial coordinate for each radial index. Two-dimensional dimensions contain time-dependent radius information, with the first index being the position index and the second index the time index (corresponding to the time dimension of the signal itself). Since the number of data points may vary with time, a sub-node, :NPTS, to yyXP* is added to specify this number. NTPS is stored as a signal node as a function of the profile time (`dim_of(NPTS,0)=dim_of(yyXP*,1)`). `yyXP*` and `dim_of(yyXP*,0)` have second dimension of length max(`:NPTS`) with values of 0 in places where no data is given.

	Variable	Description	Units	Node Type	Data type
	`:yyXP:NPTS`	Number of radial data points per time point	1	Signal	Int

e) In order to facilitate the reconstruction of equilibrium for stability analysis additional sub-nodes are added to all experimental profiles:

	Variable	Description	Units	Node Type	Data type
	`:yyXP:R`	Radial location of the measurement point	m	Signal	Int
	`:yyXP:Z`	Vertical location of the measurement point	m	Signal	Int

These positions relate to the flux grid and limiter locations given in the `.EQUIL` and `.VESSEL` branchs. This also locates the data outside the separatrix in 2D for divertor modeling. As with the rho or psi location, dim_of(yyXP*,0), these axes can be two dimensional arrays in the case where the number of points or mapping varies with time.

f) Experimental profiles can be composed of data from different diagnostics. In order to trace the data source, profile nodes can have sub-nodes with diagnostics descriptions. These sub-nodes are typically numeric or text nodes that contain arrays of numbers or strings, with one entry for each contributing diagnostic. In addition, a two-dimensional index array contains the number of data points for each diagnostics. This is an optional node.

	Variable	Description	Units	Node Type	Data type
	`:yyXP:DPTS`	Number of data points per diagnostic per time point n(diag index, t)	1	Signal	Int

g) Nodes related to the structure of the radial electric field in the pedestal, which may have been part of .TWOD at one point, are to be added. These assume the electric potential is a flux function.

	Variable	Description	Units	Node Type	Data type
1	`:VPROT(PSI)`	Fit to Poloidal velocity * BT/(RBp)	rad/s	Signal	Real
2	`:VPROTXP(PSI)`	Exp Poloidal velocity * BT/(RBp)	rad/s	Signal	Real
3	`:VROTEB(PSI)`	Er/(RBp) (typically derived from radial force balance for impurities)	rad/s	Signal	String

	Variable	Description	Units	Node Type	Data type
4	:VROTEBXP(PSI)	Er/(RBp) data (typically no direct measurement)	rad/s	Signal	String
5	:ZIMPROT	Charge of impurity used for rotation measurements	1	Numeric	Int
6	:AIMPROT	Mass number of impurity used for rotation measuremtns	1	Numeric	Int
7	:TORQ	Torque density from transport analysis	Nt/m^2	Signal	Real

IV..**EQUIL** - Equilibrium on (R,z) grid

These nodes implement a generic representation of the plasma equilibrium. Output from the more typical (R,z) grid equilibrium code is accomidated by giving the poloidal flux on the grid :PSIRZ, while the results of newer flux coordinate (inverse solver) codes (which are more suitable for ETB studies) is provided by giving the geometry of each flux surface :RCONTR, :ZCONTR. The mapping from the (R,z) grid to flux geometry representation should be provided through these nodes for either type of equilibrium code in use. For all nodes dim_of(:yy,last) = time. Where time should be the .TWOD profile times. The time averaging interval is denoted as in the .ONED and .TWOD data.

	Variable	**Description**	**Units**	**Node Type**	**Data type**
1	:PSIRZ	Flux matrix Psi (R,z,t)	Wb/rad	Signal	Real
2	:PRESPSI	Pressure vs. Psi	Pa	Signal	Real
3	:PPRIMEPSI	p' vs. Psi	Pa/Wb/rad	Signal	Real
4	:FPOLPSI	F vs. Psi	Wb/rad/m	Signal	Real
5	:FFPRIMPSI	FF' vs. Psi	Wb/m^2	Signal	Real
6	:QPSI	q vs.Psi	1	Signal	Real
7	:RBDRY	R coordinate of boundary, R(index,t)	m	Signal	Real
9	:ZBDRY	z coordinate of boundary, z(index, t)	m	Signal	Real
10	:PSIBDRY	poloidal flux at boundary, Psi(t)	Wb/rad	Signal	Real
11	:RMAXIS	R coordinate of magnetic axis, R(t)	m	Signal	Real
12	:ZMAXIS	z coordinate of magnetic axis, z(t)	m	Signal	Real
13	:PSIMAG	poloidal flux at magnetic axis, Psi(t)	Wb/rad	Signal	Real
14	:RXPT	R coordinate of active X-point, R(t)	m	Signal	Real
15	:ZXPT	z coordinate of active X-point, z(t)	m	Signal	Real
16	:RCONTR	R coordinate of flux surface vs. Psi, R(index, psi, t)	m	Signal	Real
17	:ZCONTR	R coordinate of flux surface vs. Psi, R(index, psi, t)	m	Signal	Real

The limiting flux surface location given in :RBDRY and :ZBDRY have dim_of(:yy,0) = and index denoting which point on the boundary. Since the number of boundary points can vary as a function of time a subnode, :NPTS, indicating the number of boundary points as a function of time is added to :RBDRY and :ZBDRY. The value arrays are padded with 0 to max(:NPTS). Similarly for the R and Z coordinate of the individual flux surfaces given in :RCONTR and :ZCONTR , but in this case :NPTS is a function of poloidial flux as well as time. Note also that the geometry of the surfaces is to be defined at the same poloidal flux values as the other .EQUIL points.

	Variable	Description	Units	Node Type	Data type
	:RBDRY:NPTS :ZBDRY:NPTS	Number of boundary points per time point, :NPTS(t)	1	Signal	Int
	:RCONTR:NPTS :ZCONTR:NPTS	Number of boundary points per time point, :NPTS(psi,t)	1	Signal	Int

V..EQUIL.MAGNETICS : Magnetic measurements

A proposal for a generic equilibrium data structure is given below. In case the equilibrium is to be reconstructed entirely from data in the tree structure, magnetic measurements can be included. The raw magnetics data and the equilibrium information below is sufficient, e.g. to recreate the common eqdsk file used in transport and stability analysis. This branch is taken to be optional.

Experimental data for poloidal magnetic field measurements are given in :BPR and :BPZ for the radial and vertical components of the field at the magnetic probes. Poloidal flux loop measurements are given in .PSILOOP. Internal measurments of the pitch angle between the toroidal and vertical field from MSE is given in :PITCHANGLE. :IPFCOIL gives the poloidal field shaping coil current with the geometry of the poloidal field coils as subnodes. All nodes have dim_of(:yy,0) = an index denoting the measurement point (these correspond in the case of :BPR and :BPZ which are obtained from the same measurements) and dim_of(:yy,1) = time. Where time should be the .TWOD profile times. The time averaging interval is denoted as in the .ONED and .TWOD data.

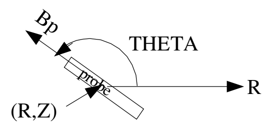
	Variable	Description	Units	Node Type	Data type
1	:BP	Radial component poloidal field at magnetic probe	T	Signal	Real
2	:PSILOOP	Poloidal flux loop measurement	Wb	Signal	Real
3	:PITCHANG	Pitch angle between Bt and Bp from MSE	rad	Signal	Real
4	:IPFFCOIL	Polodal field (shaping) coil current	A	Signal	Real

a. All nodes have R and Z subnodes giving the location of the measurements which are a function of the measurement index, or the location of the corner of the coil(see below) in the case of :IPFFCOIL .

	Variable	Description	Units	Node Type	Data type
	:yy:R	R location of measurement or pfcoil	m	Signal	Real
	:yy:Z	Z location of measurement or pfcoil	m	Signal	Real

b. The :BP node has an additional subnode, :THETA, indicating the orientation of the magnetic probe and show in the diagram below.

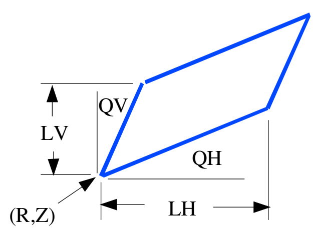
	Variable	Description	Units	Node Type	Data type
	:BP:THETA	poloidal orientation of measurement	m	Signal	Real



c. The poloidal field shaping coil current, `:IPFFCOIL`, also has subnodes giving the coil dimensions and orientation

	Variable	Description	Units	Node Type	Data type
	`:IPFCOIL:LH`	Horizontal width of coil	m	Numeric	Real
	`:IPFCOIL:LV`	Height of coil	m	Numeric	Real
	`:IPFCOIL:QH`	Horizontal angle of coil base	rad	Numeric	Real
	`:IPFCOIL:QV`	Vertical angle of coil side	rad	Numeric	Real

The meaning of sub-nodes describing the poloidal cross section of poloidal field coils is illustrated in the following figure:



VI..VESSEL – Description of the material surfaces

To support the work on divertor modeling the geometry of the inner surface of the vessel should be given in detail including any ducts and the pump surfaces in the nodes :RLIM,:ZLIM. The subsegments of this boundary which represent the pumping sufaces are given in :RPUMP,:ZPUMP.

	Variable	Description	Units	Data type
1	:RLIM	R-coordinate of in-vessel structures (poloidal section)	m	Real
2	:ZLIM	z-coordinate of in-vessel structures (poloidal section)	m	Real
3	:RPUMP	R coordinates of pumping surfaces (2D)	m	Real
4	:ZPUMP	z coordinates of pumping surfaces (2D)	m	Real

These points have dim_of(:yy,0) = an index denoting which point on the surface. The pumping surface location given in :RPUMP and :ZPUMP have dim_of(:yy,1) = an index denoting which pumping surface. Since the number of points tracing a pumping surface can vary with the surface a subnode, :NPTS, indicating the number of surface points as a function of pump index. The value arrays are padded with 0 to max(:NPTS).

	Variable	Description	Units	Node Type	Data type
	:R(z)PUMP:NPTS	Number of pump surface points per index	1	Signal	Int

VII. **.DIV**: Nodes for divertor, core/divertor modeling

The following types of data are required for divertor modeling: 1) Point measurements of kinetic quantities (ne, Te, Ti, ni,...), and jsat in the SOL and at the divertor plates, 2) Heat flux data at the divertor plates, 3) Chord integrated measurements of spectroscopic lines (D-alpha, CIII...) and total radiation (bolometry), 4) Neutral pressure measurements in the main chamber and divertor, 5) Identification of pumping surfaces (already defined in `.VESSEL`). New nodes are given below.

	Variable	Description	Units	Node Type	Data type
1	`:NEDIV`	Electron density	1/m^3	Signal	Real
2	`:NM1DIV`	Primary main ion density	1/m^3	Signal	Real
3	`:NM2DIV`	Secondary main ion density	1/m^3	Signal	Real
4	`:NM3DIV`	Tertiary main ion density	1/m^3	Signal	Real
5	`:NIMPDIV`	Primary impurity density	1/m^3	Signal	Real
6	`:TEDIV`	Electron temperature	eV	Signal	Real
7	`:TIDIV`	Ion temperature	eV	Signal	Real
8	`:JSATDIV`	Ion saturation current density	A/m^2	Signal	Real
9	`:HEATFLUX`	Heat flux to divertor plates (by IRTV thermography)	W/m^2	Signal	Real
10	`:NEUTPRESS`	Neutral pressure	Pa	Signal	Real
11	`:SPECTRO`	Spectroscopic cord measurements	1/m^2/s/strad	Signal	Real
12	`:BOLO`	Bolometery	W/m^2/strad	Signal	Real

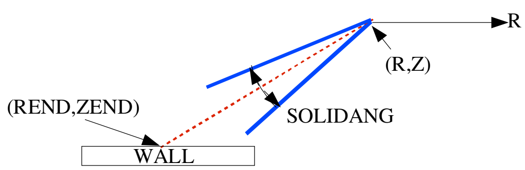
All nodes have `dim_of(:yy,0)` = index indicating measurement point, and `dim_of(:yy,1)` = time, where time corresponds to the profile times in `.TWOD`. The time averaging interval is denoted as in the `.ONED` and `.TWOD` data.

All nodes have sub-nodes `:R` and `:Z` denoting measurement locations. In the same way that core profile data may be accumulated from discontinuous time windows with slightly different equilibrium by mapping to equilibrium at the time of the measurement and accumulating data in flux space, even more variation in the equilibrium may occur for 2D divertor measurements which often require intentional sweeps of the equilibrium or strike point positions. This is to be accomidated by first mapping the measurment to flux space using the equilibrium at the time of the measurement and then from this flux value and other geometric considerations (e.g. must be on the divertor plate) the flux value is mapped back to R,Z space using the equilibrium given in `.EQUIL` at the effective time of the measurement. To allow for this `:R` and `:Z` can be a function of time where `dim_of(:R,0)` = measurement index and `dim_of(:R,1)` = time.

	Variable	Description	Units	Node Type	Data type
	`:yy:R`	R location of point measurement or location of aperature or lens for chord measurement	m	Signal	Real
	`:yy:Z`	Z location of point measurement or location of aperature or lens for chord measurement	m	Signal	Real

For chordal spectorscopic and bolometer measurements the `:R` and `:Z` are taken to be the lens or aperature of the view. For these measurements two additional sub-nodes to define the view chord. Combining data from shifted equilibria is accomplished through time dependent sight line locations although this level of detail may not be required in general.

	Variable	Description	Units	Node Type	Data type
	`:yy:REND`	R where view chord intersects wall	m	Signal	Real
	`:yy:ZEND`	Z where view chord intersects wall	m	Signal	Real
	`:yy:SOLIDANG`	Solid angle of view	m	Signal	Real



In addition `:SPECTRO` has an additional sub-node indicating the spectral line.

	Variable	Description	Units	Node Type	Data type
	`:SPECTRO:LINE`	Spectral line	1	Signal	String