Status of the International Stellarator/Heliotron Profile Database

The ISHPDB Collaboration
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The International Stellarator/Heliotron Profile Database (ISHPDB) is a community effort aiming at a concise documentation of experimental data and modeling of stellarator reactor relevant issues. ISHPDB extends the global stellarator confinement database ISCDB. ISHPDB is jointly hosted by IPP and NIFS [1]. The effort is structured by physics topics led by the acknowledged experts in their respective fields. A first inter-machine study of 1-d data as part of ISHPDB was given in [2] proving the concept of ISHPDB to result in significant progress. More extended inter-machine studies on high-β physics, impurity transport, edge physics, aspects of neoclassical transport and configuration dependencies will be given at this conference. This contribution focuses on a survey of the ISHPDB topical structure. The resulting requirements for physics oriented documentation will be summarized. A physics motivated quality assurance of the database will be discussed. A proposal for the implementation of an ISHPDB database schema compliant with existing tokamak databases and its interfaces will be introduced.

Keywords: International Stellarator/Heliotron Profile Database, Confinement, Transport

1. From 0d to 1d: transport assessment in 3-d devices towards reactor capabilities.

A concise documentation of stellarator/heliotron device operation is necessary for system assessment aiming at viable stellarator/heliotron reactor concepts. Consequently, joint databases for global confinement time τ_E in 3d devices were initiated as a joint effort of the stellarator/heliotron community. The International Stellarator/Heliotron Confinement Database (ISHPDB) is intended to continue this activity and to serve as a common documentation for physics investigations in 3d magnetic confinement fusion devices.

The first joint energy confinement scaling study for 3d devices led to the ISS95 scaling [3] which was largely confirmed with a broader and more extended data-set in the ISS04 study [4]. A particular result of the latter study was the identification of the impact of the magnetic configuration.

In view of possible reactor assessments, the studies of the global (0d) scaling for τ_E showed a couple of open issues. In particular, the validity of scaling laws with respect to extrapolation was discussed by means of physical model assessments. Applied on global data, model comparison techniques indicated differences in the basic transport mechanisms between low and high-β data [5]. A detailed assessment of the impact of plasma β on transport, however, was hindered by a lack of local transport analyses and needs to be pursued. High confinement regimes were assessed in places [6], but a systematic investigation of the differences in transport in the different options for device operation was only recently started for the core electron confinement [7]. In this conference, this philosophy is

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extended to more detailed studies on the impact of the rotational transform and the shear [8] on confinement extending the 0d view by inclusion of profile information.

All recent global confinement studies [4-6] led to the conclusion that more detailed insight is required to perform a target-oriented assessment of performance measures in 3d devices. Nonetheless, global confinement data represent a relevant part of a full documentation form a basis for any comparative study.

This paper is a technical report summarizing the content and some infrastructure considerations of ISHPDB. This report summarizes also aspects from working group meetings with the intention to communicate these points to the community in order to discuss and possibly revise the concepts developed so far.

2. General strategy: physics issues towards a stellarator/heliotron fusion reactor

The status of ISPHDB is premature. For the moment being, files are collected and have to be stored in a common, reliable infrastructure allowing general access to the data. Nonetheless, the general structure is to be developed driven by the necessity from potential reactor assessments: issues resulting from this perspective define the necessities for a reasonable documentation and pragmatic approaches should be directed towards the goal of a common database for reactor assessments.

A common 1d profile database for stellarators and heliotron can be regarded as a documentation standard for performance studies. However, experience in respective tokamak databases [8] showed that documentation standards might vary from device to device, e.g. due to diagnostics availability. Moreover, different supplementary information is required for different issues, e.g. mode activity which is relevant to high-β discharges, but is less documented for quiescent H-modes.

Therefore, the requirement analysis for any documentation activity should start at relevant physics issues. Table 1 summarizes the high priority topics for inter-machine studies which were identified along community-open, dedicated workshops [9, 10].

The topic high performance operation is intended to study H-mode physics and further optimum confinement regimes in stellarators/heliotrons. Differently, the studies in high-β physics are much more advanced; a report will be given at this conference [11]. Similarly, comparative edge physics and divertor operation studies for LHD and W7-AS are underway [12]. A survey on the documentation of impurity transport studies will be given at this workshop as well [13]. CERC studies even serve as first input for the specific database [14]. Finally, confinement studies are intended to continue the global confinement documentation; an overlap to the previous topics is enforced to assure the continuation of the International Stellarator Confinement Database.

Physics Topics of ISHPDB
High Performance Operation
High β physics in 3-d devices
Edge physics and divertor operation
Impurity transport
Core electron root confinement (CERC)
Confinement studies

Tab.1 Summary of physics topics in addressed in the International Stellarator/Heliotron Profile Database ISHPDB.

Although the topic list in Tab. 1 is open for revisions, the issues represent stellarator/heliotron specific subjects whose documentation requirements may differ from topic to topic or which might be different to requirements for tokamak databases. A more detailed revision of requirements will be provided in the next section and a resulting proposal for a database structure will be given below. For the moment being, the actual database development is planned to be performed in parallel to the physics studies.

In a first step, the database is a collection of human readable files. As a general guideline, the documentation is the done by scientific papers along with a delivery of all supplementary material to ISHPDB.

Along with the consideration of physics requirements, ISPHDB has to take care for the assurance of quality measures in the database. The definition of quality standards is a community exercise which has still to be done. An agreed procedure must incorporate general standards but also specific points with respect to the physics issue. In a first step, the definition of deliveries needs to be worked out.

3. Functional and technical requirements

In general, the content of ISHPDB covers typical fusion data. ISHPDB starts mandatory from the 0d dataset as used for ISCDB. Furthermore, a link to additional information describes more background which refers to the dataset like magnetic configuration specifications, descriptive documents explaining specifics of the discharge under consideration etc.. A more specific guideline on this point needs to be worked out.

Beyond 0d data, time traces of the documented discharges are part of the discharge documentation. Here, the energy content, applied heating, mean density, loop voltage, temperature signals (ECE, soft-X), mode activity (Mirnov coils) and H_α emission are valuable signals in general.

Space dependent data for electron density, electron and ion temperature, the radial electric field form finally the profile database. Moreover, measurements for Z_{eff} and further supplementary data necessary for transport analyses should be provided.

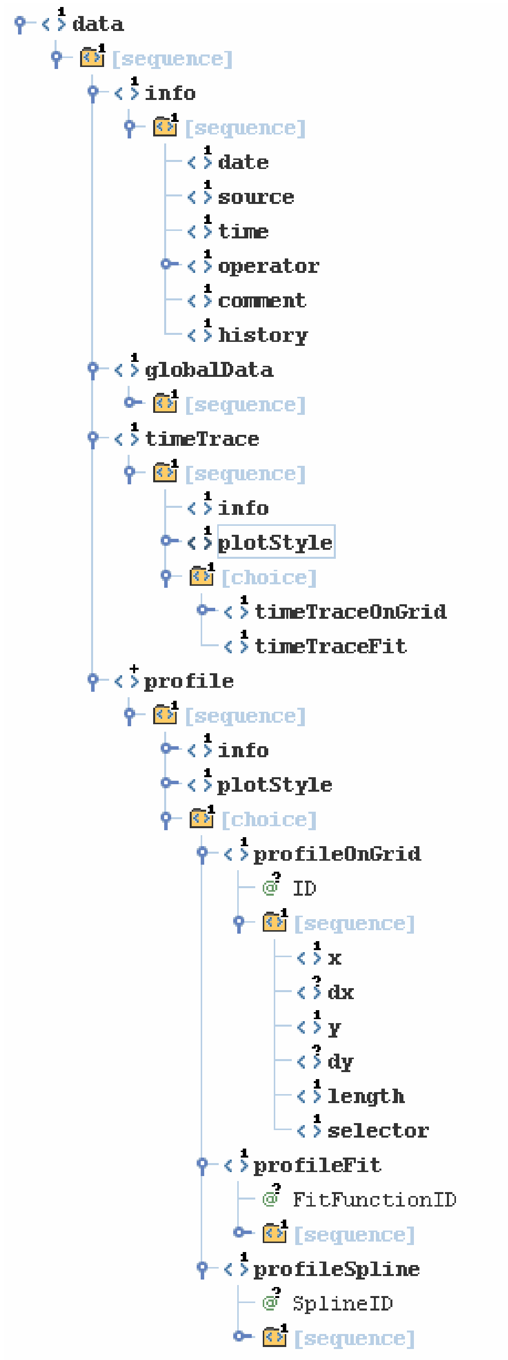

Fig.1 ISHPDB XML schema .

In addition to the data, the magnetic configurations used for mapping the data onto a common grid in flux surface coordinates should be provided. Edge physics data should be stored in real space coordinates.

All experimental data should be provided with their error. The squared standard deviation is used for weighting the data in fitting procedures. The used fit functions are to be chosen from a catalogue of standardized parametric functions [1] or by non-parametric fits.

Consequently, the database should be capable not only to store data with error bars but also parameters describing functional dependencies, e.g. to store also predictive results or outcome of interpretative transport analyses.

In an advanced version of the database, versioning is an essential feature to allow iterative evaluation steps. This is also important for the assessment of model assumptions, e.g. different mappings. Consequently, changes in different versions should be tracked. Search capabilities with respect to numerical, cardinal (e.g. $5*10^{19}$ m^{-3} < n_e < $2*10^{20}$ m^{-3}) and ordinal criteria (e.g. ECRH vs. NBI heating) should be possible as well as physics criteria (e.g. high-β discharges).

Technical requirements referring to the deployment of the database will be specified after exploring the first specific datasets to be included in a database. At present, both the National Institute for Fusion Science (Toki, Japan) and the Max-Planck-Institut für Plasmaphysik (Greifswald, Germany) offer to host the resources publicly and to develop web based interfaces to allow the community access the stored data.

4. A tentative database schema

Fig. 1 shows a tree structure representing a proposal for the ISHPDB data structure. For the description XML schema [15] was used. With the XML schema definition, which was chosen for convenience, all data files can be checked for consistency automatically. Moreover, there are a number of computing tools available to generate automated codes and interfaces to application programming.

As a general approach, data descriptive data fields form the header of the entries (e.g. data, source etc.). Then the three data categories form the data entries (globalData, timeTrace, profile). For profiles, choices between data on a grid, parametric functions and non-parametric functions are allowed. The specific entries are due to data presently available and are adjusted to match with the ITER profile database [16].

The schema works with experimental profile data from CERC studies as well as data from predictive calculations for W7-X.

A first exercise to create working interfaces is the adaptation of the ITER profile database interface definition employed for TASK analyses on LHD [14].

5. Summary and Outlook

ISHPDB aims at an extension of the stellarator/heliotron confinement database ISCDB with particular emphasis on reactor relevant issues. Starting from physics studies focused on stellarator specific topics, a requirement analysis both for data base structures and data handling procedures has been performed and will be extended along with practical experience.

A first case study was performed leading to an inter-machine comparison of core electron root confinement [7]. In this workshop, seven contributions were submitted as a result from the ISHPDB collaboration covering inter-machine studies on the impact of rotational transform and shear [8], extensions of the existing database with respect to high beta operation [11], intermachine studies of impurity transport [13] and comparisons of plasma edge physics in divertor operation [12]. Therefore, it can be concluded that ISHPDB is a living community exercise addressing relevant topics for the stellarator/heliotron community. A series of working group meetings was implemented and is agreed to be continued to follow the topics and general issues (see also [14]); since fall 2006 two meetings were held, a continuation is foreseen. The meetings are open to the community and a permanent revision of topics addressed is part of the database discussion.

The next specific technical step is the provision of the submitted data through a web interface allowing a general access to the data. An important task for the near future is the general agreement on quality assurance measures, i.e. the definition which data are to be provided and to define quality standards for the delivered data. This exercise is reasonably done with the data from this workshop.

For the moment being, responsible officers at the National Institute for Fusion Science (Toki, Japan) and Max-Planck-Institut für Plasmaphysik (Greifswald, Germany) are identified for receiving data and for processing data files [17]. These contact persons can be asked for any further details.

This work contributes to the International Stellarator Profile DataBase (ISHPDB) under auspices of the IEA Implementing Agreement for Cooperation in the Development of the Stellarator Concept (1992).

References

[1] http://www.ipp.mpg.de/ISHPDB and http://ishpdb.nifs.ac.jp
[2] M. Yokoyama et al., Fusion Sci. Technol. **50**, 395 (2006).
[3] U. Stroth et al., Nucl. Fusion **36**, 1063 (1996).
[4] H. Yamada et al., Nucl. Fusion **45**, 1684 (2005).
[5] A. Dinklage et al, Nucl. Fusion **47**, 1265 (2007).
[6] A. Dinklage et al, Fusion Sci. Technol. **51**, 1 (2007).
[7] M. Yokoyama, Nucl. Fusion **47**, 1213 (2007).
[8] E. Ascasibar et al., this conference, paper I-01
[9] http://p-grp.nucleng.kyoto-u.ac.jp/ktscwgm2006/
[10] http://www.ipp.mpg.de/ISS/CWGM2007/cwgm.html
[11] A. Weller et al., this conference, paper P1-039
[12] Y. Feng et al., this conference, paper I-06
[13] K. McCarthy et al., this conference, paper I-18
[14] H. Funaba et al, this conference, paper P-040
[15] http://www.w3.org/XML/Schema
[16] The ITER 1D Modelling Working Group, Nucl. Fusion **40**, 1955 (2000).
[17] Please send data files in copy to funaba@lhd.nifs.ac.jp and dinklage@ipp.mpg.de (subject ISHPDB).