Updates
of W7-X magnetic configuration database

Definition of a magnetic configuration and physics names of configurations

- Magnetic configuration is uniquely defined by coil geometries and coil currents.

- One out of ten identical W7-X half-modules (HMs) consists of 7 different coil types: 5 different non-planar (NPC) and 2 different planar coils (PC). Coils of each type are assembled in series. Hence, there are 7 independent coil currents (7 degrees of freedom) defining a magnetic configuration: I_1, I_2, I_3, I_4, I_5, I_6, I_7.

- In other words, each configuration is uniquely defined by its coil geometries and coil current ratios at a certain magnetic field :
  $\frac{I_2}{I_1}, \frac{I_3}{I_1}, \frac{I_4}{I_1}, \frac{I_5}{I_1}, \frac{I_6}{I_1}, \frac{I_7}{I_1}$ @ e.g. 2.52 T

- **Physics Name (**e.g., **EJM**001+2520**)** is used for communication between physicists: describes certain (plasma-physical) properties of the configuration in the following format (PLM specification number: 1-JDB00-T0000.1, IDM number: IPP_D_28YVHR):

  - "**3-letter-code**" (for three key properties of a configuration: mirror ratio, iota value at the magnetic axis and the third character the radial shift (expressed by the difference in currents of planar coils A and B))
  - an additional 3-digit sequence number for different variants of the same type
  - 4 values (and the sign) for the magnetic field on the axis (B_{axis} @ phi=0°)

DB Updates: name assignment

- In the previous DB version the algorithm for name assignment did not distinguish between configurations with 1A difference in coil currents. The 3-digit sequence numbers was different also for configurations with the same coil current ratios, but different magnetic field strength.

- Outcome after OP2.1: amount of configurations in DB rapidly increased and had no sense for physics discussions (30% of configurations were “identical”).

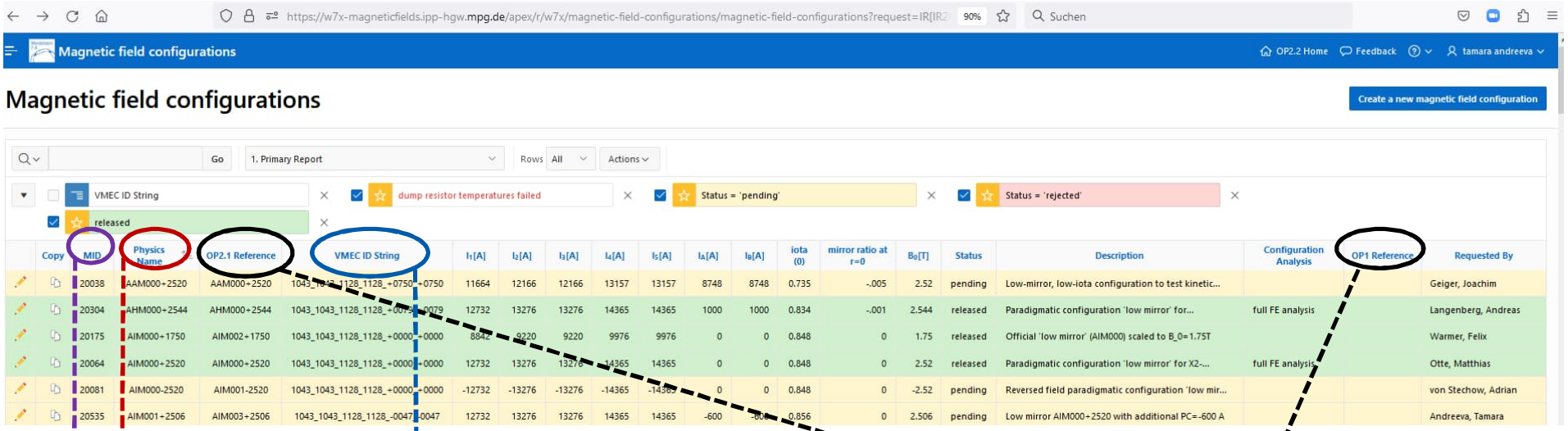
- Consistent algorithm for name assignment was developed by J. Geiger and implemented by C. Klug. This algorithm is based on coil current ratios and excludes assignment of different 3-digit sequence numbers for “identical” magnetic configurations (two configurations can be considered “identical”, if their coil current ratios are different less than 1‰).

- Consequence of updates

- new name assignment procedure will help to avoid misunderstandings in future;
- in some cases present physics names in DB are slightly different as they were in OP2.1 w.r.t. 3-digit sequence numbers;
- the references for OP2.1 and OP1 physics names are included in DB;
- DB updates include improvements of the user interface for magnetic configuration generation and allow to check for identical (1‰ criteria for coil current ratios) or similar (2% current deviations) configurations .

Current appearence of configurations in DB

- DB address: https://w7x-magneticfields.ipp-hgw.mpg.de



VMEC ID: $\frac{I_{2*1000}}{I_1}_\frac{I_{3*1000}}{I_1}_\frac{I_{4*1000}}{I_1}_\frac{I_{5*1000}}{I_1}_\frac{I_{6*1000}}{I_1}_\frac{I_{7*1000}}{I_1}$

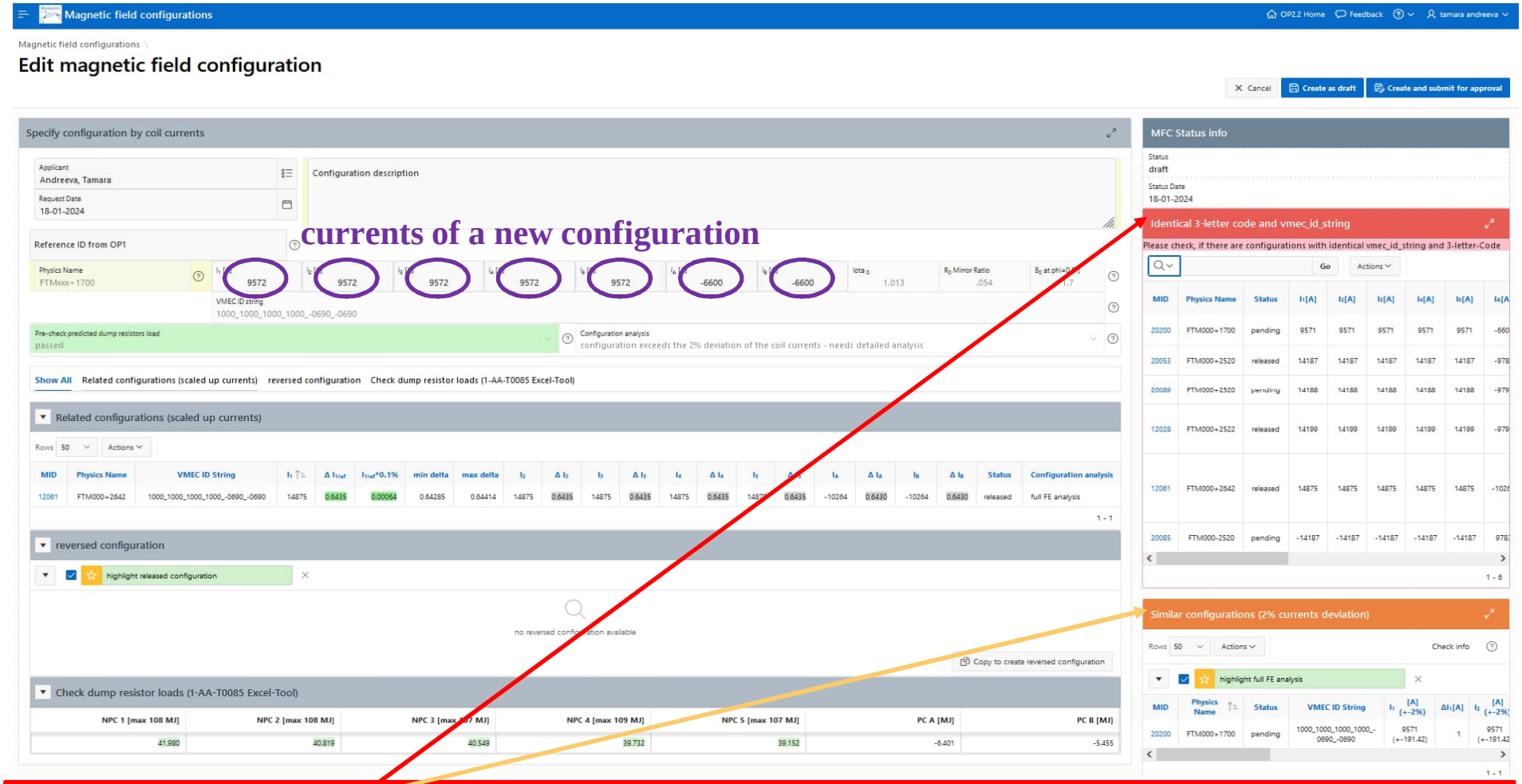
Creating a new configuration:
don‘t create identical configurations!

- Interface is similar to the previous one, but includes a possibility to check for identical (1‰ criteria for coil current ratios) or similar (2% current deviations) configurations.

- To create a new configuration, enter coil currents and click afterwards somewhere in the editing field to activate the lists of already existing identical or similar configurations (otherwise these lists will not appear and you will see only headers).

- Since 1A different configurations programmatically can be introduced in DB, always check in these lists whether necessary for you configuration is already available in the DB and **DO NOT CREATE UNNECESSARY IDENTICAL CONFIGURATIONS!!!**

Creating a new configuration



- **To activate/ to see both lists click somewhere in the editing field with a mouse!**
- **Check for identical configurations. If there are any with the necessary field strength – take them!**

Thank you very much for your attention!

Discussion/ comments

- C. Killer presented briefly the choice of magnetic configurations on W7-X proposal page https://w7x-proposals.ipp-hgw.mpg.de/ One can choose there magnetic configurations according abbreviations „Standard“, „High Mirror“ etc.

- If a magnetic configuration already exists in the DB, but one needs another magnetic field strength, one needs to introduce this configuration in the DB. It will have the same three-letter-code, but another magnetic field strength.

- All VMEC calculations are performed with CAD (ideal) geometries.

- PC corrections regarding as-built coil geometries can be evaluated on the basis of vacuum flux surface measurements. These measurements were not performed in OP2.1. The only data available are OP1 measurements for Standard and High iota configurations. For all other configurations these corrections are not known. New vacuum flux surface measurements are planned at the end of 2025.

Additional slides

Identical configurations: 1‰ criteria for coil current ratios

One out of ten identical W7-X half-modules (HMs) consists of 7 different coil types: 5 different non-planar and 2 different planar coils. Coils of each type are assembled in series. Hence, there are 7 independent coil currents defining a magnetic configuration:

$I_1, I_2, I_3, I_4, I_5, I_6, I_7$ 7 degrees of freedom

NPCs PCs

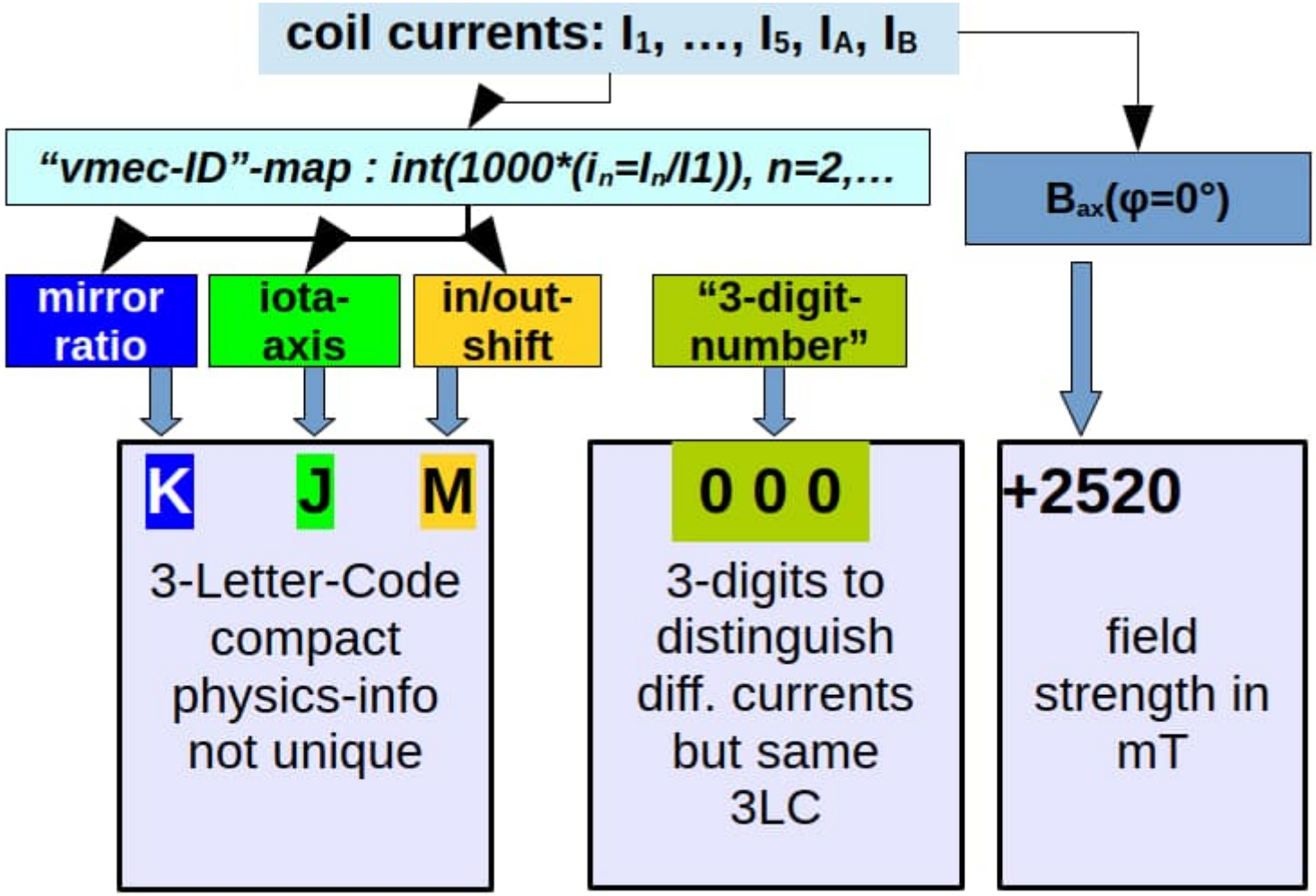
In other words, each configuration is uniquely defined by its coil current ratios and a magnetic field (configurations with identical coil current ratios have identical geometry of mag. field):

$\frac{I_2}{I_1}, \frac{I_3}{I_1}, \frac{I_4}{I_1}, \frac{I_5}{I_1}, \frac{I_6}{I_1}, \frac{I_7}{I_1}$ @ e.g. 2.52 T

Two configurations can be considered identical if their coil current ratios are different less than 1‰:

$$\Delta\frac{I_n}{I_1} \cdot 1000 \leq 1, n = 2 \div 7, \quad \Delta\frac{I_n}{I_1} = \left| \left(\frac{I_n}{I_1}\right)^{new} - \left(\frac{I_n}{I_1}\right)^{old} \right|$$

Algorithm for Physics Name **assignment (J. Geiger)**



Nomenclature for Magnetic Configurations at W7-X (1-JDB00-T0000.1)

"The ID will be provided by the theory department. It consists of 3 characters, 1 digit and 3 numbers. The first character represents the mirror ratio, the second character the iota value at the magnetic axis and the third character the radial shift (expressed by the difference in currents of planar coils A and B) according to Table 1. These three configuration parameters can be directly determined from the set of 6 coil current ratios. Note that there is no 1-to-1 mapping between a 3- and a 6-dimensional space.
The digit is either "+" for positive magnetic field direction and "–" for negative field direction. (The definition of the positive direction is given in 1-AA-R0004). The three numbers characterize the magnetic field strength at the toroidal angle Φ=0 (ECRH launch position) in centi-Tesla. Because the 3-letter-ID is discrete, new configurations which result in an existing ID will get an additional index with 3 numbers. This index will only be included, if it differs from 000. The letters XYZ are reserved for special configurations, which do not fit into the system."

For example:
High iota reference configuration @ 1.7 T and @ 2.522 T is still the same configuration (with the same physics ID)!