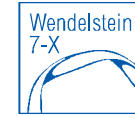


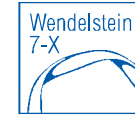
Updates of W7-X magnetic configuration database

Definition of a magnetic configuration and physics names of configurations



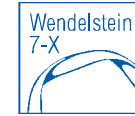
- Magnetic configuration is uniquely defined by coil geometries and coil currents.
- One out of ten identical W7-X half-modules (HMs) consists of 7 different coil types: 5 different non-planar (NPC) and 2 different planar coils (PC). Coils of each type are assembled in series. Hence, there are 7 independent 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 :
$$\frac{I_2}{I_1}, \frac{I_3}{I_1}, \frac{I_4}{I_1}, \frac{I_5}{I_1}, \frac{I_6}{I_1}, \frac{I_7}{I_1} @ \text{ e.g. } 2.52 \text{ T}$$
- **Physics Name** (e.g., **EJM001+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 ($B_{\text{axis}} @ \text{ phi}=0^\circ$)

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 appearance of configurations in DB



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

| Copy | MID | Physics Name | OP2.1 Reference | VMEC ID String | I ₁ [A] | I ₂ [A] | I ₃ [A] | I ₄ [A] | I ₅ [A] | I ₆ [A] | I ₇ [A] | iota (0) | mirror ratio at r=0 | B ₀ [T] | Status | Description | Configuration Analysis | OP1 Reference | Requested By | |
|------|-------|--------------|-----------------|---------------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|----------|---------------------|--------------------|--------|-------------|----------------------------------------------------------------|------------------|--------------|---------------------|
| | 20038 | AAM000+2520 | AAM000+2520 | 1043_1043_1128_1128_-0750 | -0750 | 11664 | 12166 | 12166 | 13157 | 13157 | 8748 | 8748 | 0.735 | -.005 | 2.52 | pending | Low-mirror, low-iota configuration to test kinetic... | | | Geiger, Joachim |
| | 20304 | AHM000+2544 | AHM000+2544 | 1043_1043_1128_1128_-0079 | -0079 | 12732 | 13276 | 13276 | 14365 | 14365 | 1000 | 1000 | 0.834 | -.001 | 2.544 | released | Paradigmatic configuration 'low mirror' for... | full FE analysis | | Langenberg, Andreas |
| | 20175 | AIM000+1750 | AIM002+1750 | 1043_1043_1128_1128_+0000 | +0000 | 8842 | 9220 | 9220 | 9976 | 9976 | 0 | 0 | 0.848 | 0 | 1.75 | released | Official 'low mirror' (AIM000) scaled to B ₀ =1.75T | | | Warner, Felix |
| | 20064 | AIM000+2520 | AIM000+2520 | 1043_1043_1128_1128_+0000 | +0000 | 12732 | 13276 | 13276 | 14365 | 14365 | 0 | 0 | 0.848 | 0 | 2.52 | released | Paradigmatic configuration 'low mirror' for X2... | full FE analysis | | Otte, Matthias |
| | 20081 | AIM000-2520 | AIM001-2520 | 1043_1043_1128_1128_+0000 | +0000 | -12732 | -13276 | -13276 | -14365 | -14365 | 0 | 0 | 0.848 | 0 | -2.52 | pending | Reversed field paradigmatic configuration 'low mir... | | | von Stechow, Adrian |
| | 20535 | AIM001+2506 | AIM003+2506 | 1043_1043_1128_1128_-0047 | -0047 | 12732 | 13276 | 13276 | 14365 | 14365 | -600 | -800 | 0.856 | 0 | 2.506 | pending | Low mirror AIM000+2520 with additional PC=-600 A | | | Andreeva, Tamara |

Unique CoDaC number of magnetic configuration (Logbook)

OP2.1 and OP1 references

Physics name according 1-JDB00-T0000.1 (Logbook)

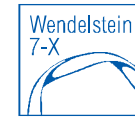
VMEC ID: $\frac{I_2 \times 1000}{I_1} - \frac{I_3 \times 1000}{I_1} - \frac{I_4 \times 1000}{I_1} - \frac{I_5 \times 1000}{I_1} - \frac{I_6 \times 1000}{I_1} - \frac{I_7 \times 1000}{I_1}$

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



Magnetic field configurations

OP22 Home Feedback tamara andreeva

Edit magnetic field configuration

Cancel Create as draft Create and submit for approval

Specify configuration by coil currents

Applicant: Andreeva, Tamara
Request Date: 18-01-2024

Configuration description

Reference ID from OP1

Physics Name: FTM000+1700
VMEC ID string: 1000_1000_1000_1000_0690_0690

Pre-check predicted dump resistor load passed

Configuration analysis: configuration exceeds the 2% deviation of the coil currents - needs detailed analysis

Show All Related configurations (scaled up currents) reversed configuration Check dump resistor loads (1-AA-T0085 Excel-Tool)

Related configurations (scaled up currents)

| MID | Physics Name | VMEC ID String | I_1 | ΔI_{1rel} | $I_{1rel} \cdot 0.1\%$ | min delta | max delta | I_2 | ΔI_2 | I_3 | ΔI_3 | I_4 | ΔI_4 | I_5 | ΔI_5 | I_6 | ΔI_6 | Status | Configuration analysis |
|-------|--------------|-------------------------------|-------|-------------------|------------------------|-----------|-----------|-------|--------------|-------|--------------|-------|--------------|-------|--------------|--------|--------------|----------|------------------------|
| 12061 | FTM000+2642 | 1000_1000_1000_1000_0690_0690 | 14875 | 0.6435 | 0.00064 | 0.64285 | 0.64414 | 14875 | 0.6435 | 14875 | 0.6435 | 14875 | 0.6435 | 14875 | 0.6435 | -10264 | 0.6430 | released | full FE analysis |

reversed configuration

no reversed configuration available

Copy to create reversed configuration

Check dump resistor loads (1-AA-T0085 Excel-Tool)

| NPC 1 [max 108 MJ] | NPC 2 [max 108 MJ] | NPC 3 [max 107 MJ] | NPC 4 [max 109 MJ] | NPC 5 [max 107 MJ] | PC A [MJ] | PC B [MJ] |
|--------------------|--------------------|--------------------|--------------------|--------------------|-----------|-----------|
| 41.980 | 40.819 | 40.549 | 39.732 | 39.152 | -6.401 | -5.455 |

MFC Status info

Status: draft
Status Date: 18-01-2024

Identical 3-letter code and vmec_id_string

Please check, if there are configurations with identical vmec_id_string and 3-letter-Code

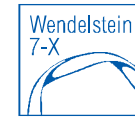
| MID | Physics Name | Status | I_1 [A] | I_2 [A] | I_3 [A] | I_4 [A] | I_5 [A] | I_6 [A] |
|-------|--------------|----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 20200 | FTM000+1700 | pending | 9571 | 9571 | 9571 | 9571 | 9571 | -6600 |
| 20053 | FTM000+2520 | released | 14187 | 14187 | 14187 | 14187 | 14187 | -978 |
| 20089 | FTM000+2520 | pending | 14188 | 14188 | 14188 | 14188 | 14188 | -979 |
| 12028 | FTM000+2522 | released | 14199 | 14199 | 14199 | 14199 | 14199 | -979 |
| 12061 | FTM000+2642 | released | 14875 | 14875 | 14875 | 14875 | 14875 | -10264 |
| 20085 | FTM000+2520 | pending | -14187 | -14187 | -14187 | -14187 | -14187 | 978 |

Similar configurations (2% currents deviation)

highlight full FE analysis

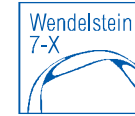
| MID | Physics Name | Status | VMEC ID String | I_1 [A] (+-2%) | ΔI_1 [A] | I_2 [A] (+-2%) | ΔI_2 [A] |
|-------|--------------|---------|-------------------------------|------------------|------------------|------------------|------------------|
| 20200 | FTM000+1700 | pending | 1000_1000_1000_1000_0690_0690 | 9571 (+-191.42) | 1 | 9571 (+-191.42) | |

- 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!

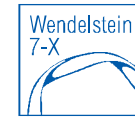


Thank you very much for your attention!

Discussion/ comments

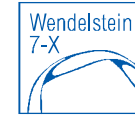


- C. Killer presented briefly the choice of magnetic configurations on W7-X proposal page <https://w7x-proposals.ipp-hgw.mpg.de/> One can choose there magnetic configurations according abbreviations „Standard“, „High Mirror“ etc.
- If a magnetic configuration already exists in the DB, but one needs another 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.



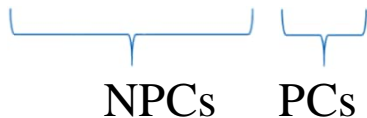
Additional slides

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



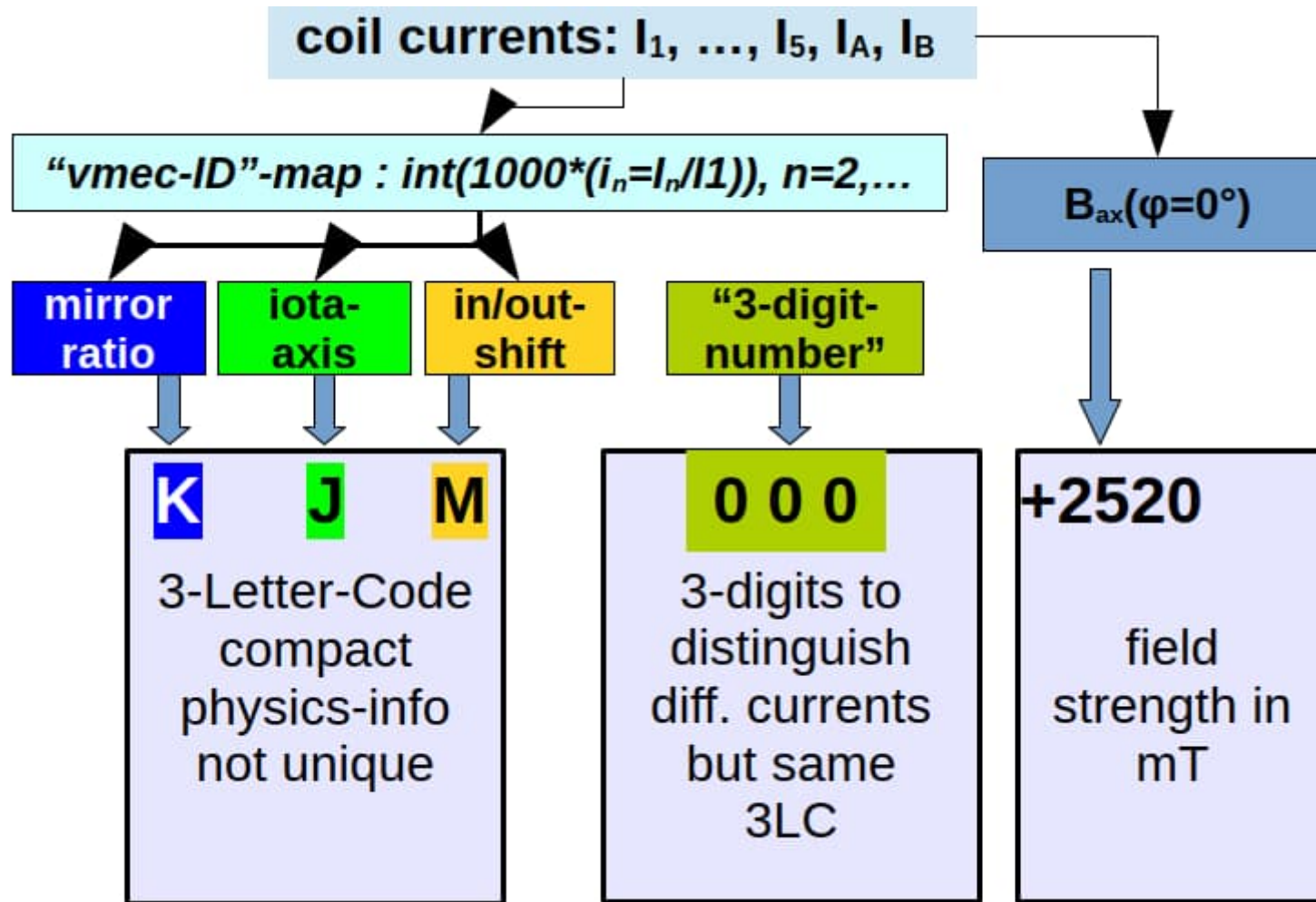
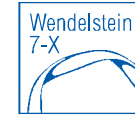
In other words, each configuration is uniquely defined by its coil current ratios and a magnetic field (configurations with identical coil current ratios have identical geometry of mag. field):

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

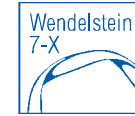
Two configurations can be considered identical if their coil current ratios are different less than 1‰:

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

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 $\Phi=0$ (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)!