



CTU

CZECH TECHNICAL
UNIVERSITY
IN PRAGUE

Measurements of Magnetic Fields @GOLEM

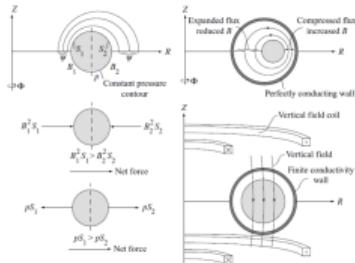
in Support of Plasma Position Stabilization

PRPLA 2024/2025, intro. pres.

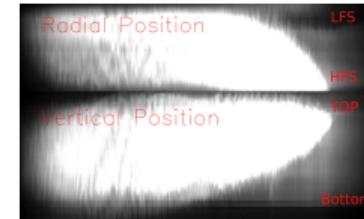
Daniela Kropáčková

Plasma Position @GOLEM

Theory:

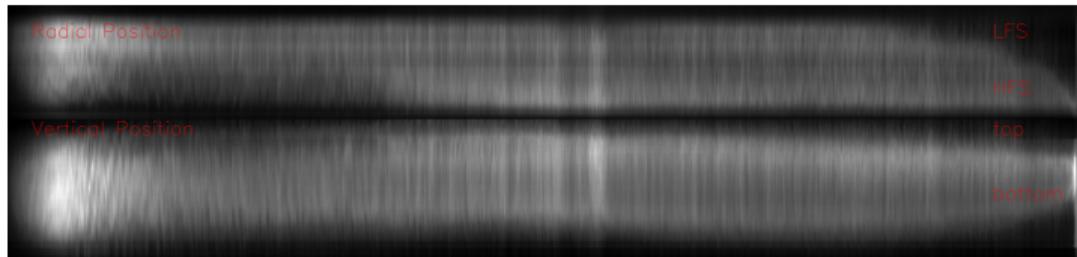


Reality:



#39121; $t_{\text{dur}} = 7, 2 \text{ ms}$

With the help of external stabilization:



#39125; $t_{\text{dur}} = 20, 76 \text{ ms}$

Motivation

- What factors influence plasma position? What causes its movement toward the top and HFS? Is it already clearly identified?
- What are the current capabilities and limitations of plasma position stabilization?
 - sufficient mag.field strength and dynamic response?
- What aspects of stabilization could be optimized or improved?

Brief Theoretical Background

What do we (not)know, (not)have,...

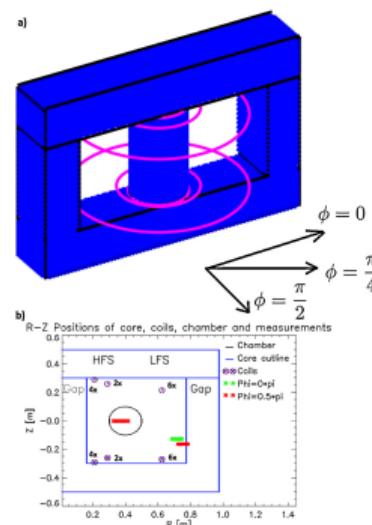
Factors Influencing Plasma Position and Its Stabilization

Iron Transformer Core

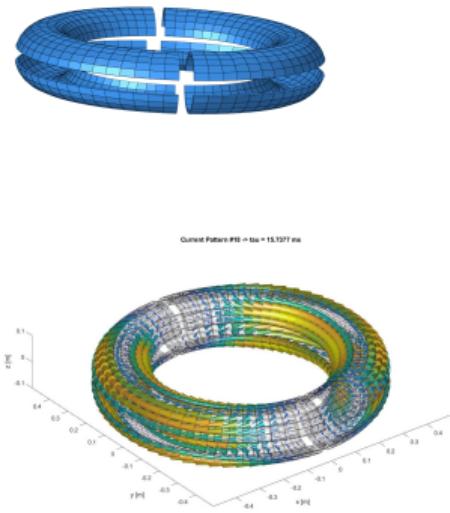
- Affects mag. field in its vicinity
- Potential reason of plasma movement toward HFS

Copper Shell

- Time constant:
 - $\tau_{cs} = 15.74 \text{ ms}$, Kubincová (2021)
 - $\tau_{cs} = 1.8 \text{ ms}$, Valovič (1989)
- Affects mag. field generated by external stabilization coils



Markovič et al. (2015)



Yanovskiy (2021)

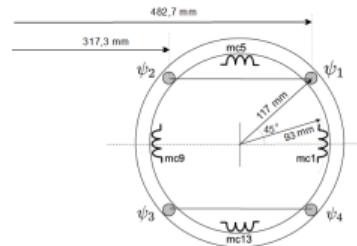
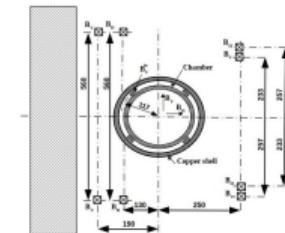
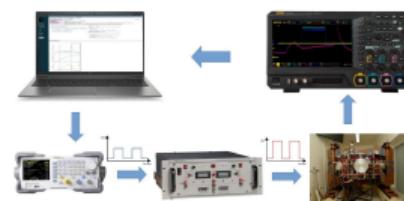
Plasma Position Stabilization Windings

External Stabilization

- To stabilize plasma in horizontal and vertical direction; (4x8)
- Current amplifier:
 - Vertical: 5xKepco - max 100A
 - Horizontal: 4xKepco - max 80A

Inner Quadrupole

- Previously used to stabilize the plasma in the horizontal direction
- Also utilized for vertical magnetic field measurements
- Located between copper shell and vessel; (4x1)



Objectives

- Measurements of magnetic fields generated on GOLEM
- Comparison with simple models such as
 - B-S. model (no dynamic) Havlíček (2015):

$$\vec{B} = \frac{\mu_0}{4\pi} I \int \frac{d\vec{I} \times (\vec{r} - \vec{r}_l)}{|\vec{r} - \vec{r}_l|^3}$$

$$B_m(x_{ij}) = \mathbf{F}_m(x_{i,j}) \cdot I$$

- S-S model Kubincová (2021)

$$\begin{pmatrix} \dot{\xi}_{cs} \\ \dot{\xi}_{vv} \end{pmatrix} = \begin{pmatrix} -\frac{1}{\tau_{cs}} & M \\ M & -\frac{1}{\tau_{cs}} \end{pmatrix} \begin{pmatrix} \xi_{cs} \\ \xi_{vv} \end{pmatrix} + \begin{pmatrix} b_{cs} \\ b_{vv} \end{pmatrix} I_{PFC}$$

$$B = \begin{pmatrix} k_{cs} & k_{vv} \end{pmatrix} \begin{pmatrix} \xi_{cs} \\ \xi_{vv} \end{pmatrix} + k_{PFC} I_{PFC}$$

- Approach used in Valovič (1989)

Experiments

Experimental Setup

What:

- Magnetic fields generated by individual windings
- Different configuration (CW x ACW)



How:

- MSL Hall probe (+ MC, saddle coil)
- Step response

Minutes of the exp.:

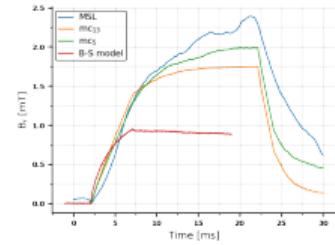
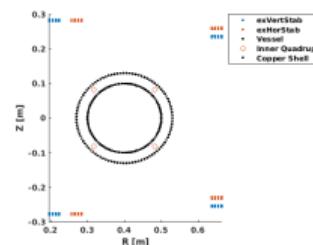
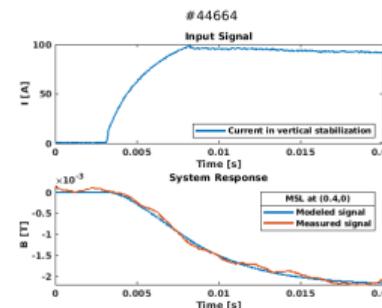
- Step response of external stabilization
- Standard settings for B_t and E_t windings
- MSL located at $z = 0$, $r = \{-85, 0, 85\}$ mm

Some results:

- The signals on the MC coils and the MSL probe are in fairly reasonable agreement

What to improve:

- Check that the current in the coils is recorded for at least 40 ms (*should already be by default*).
- Inner quadrupole; (Saddle coil - just to compare data obtained in Kubincová (2021))



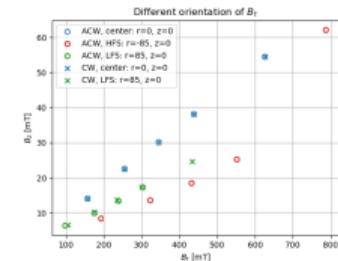
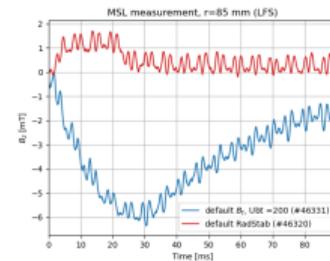
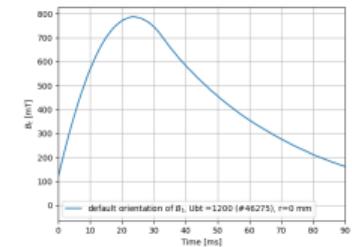
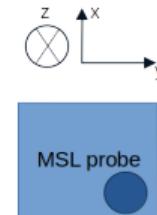
Minutes of the exp.:

- More focused on the stray fields generated by B_t winding
- MSL located at $z = 0$, $r = \{-85, 0, 85\}$ mm
- Inner quadrupole
- ACW, CW orientation of B_t and E_t

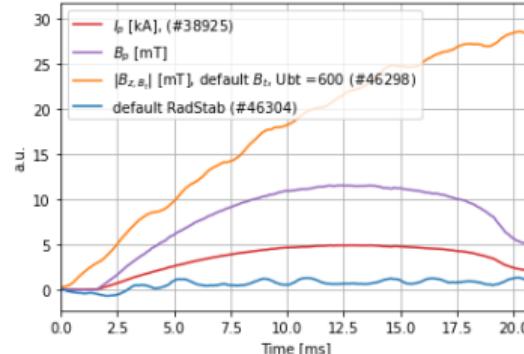
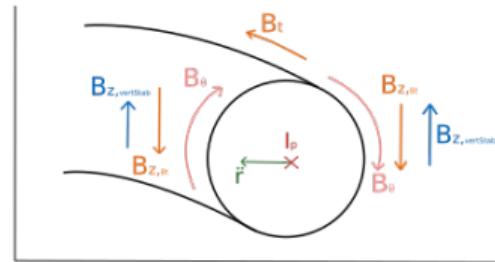
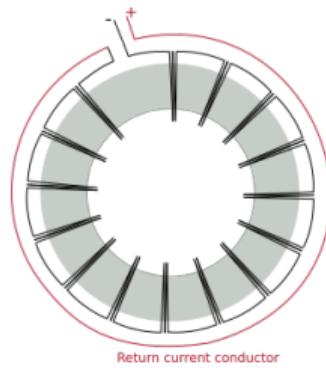
Some results:

- Default B_t orientation seems to be ACW
- Stray fields generated by B_t winding significantly exceed mag. field generated by external stabilization
- The stray fields seem to be strongest in the center and lowest on HFS
- Mag. field generated by inner quadrupole is (unfortunately) almost negligible

MSL probe: fields orientation (port view)



- Stray fields generated by B_t windings may also significantly affect the plasma position, along with the influence of the iron core effect
- A similar situation applies for B_r (not shown)
- The origin of the stray field from the windings could be due to insufficient compensation of the 'return conductor' or misalignment of the TF coils



PRPL Roadmap

23.10.2023:

- First contact with Dr. Šuran

2.11.2023:

- First visit to IPP,CR
- Probe commissioning

6.11.2023:

- SW probe test on GOLEM
- successful

14.11.2023:

- Second visit to IPP,CR
- Trigger test
- Transport probe to GOLEM

14.12.2023:

- First test on GOLEM
- Failed connection to PC

8.4.2024:

- Transport PC from IPP,CR

9.4.2024:

- First successful test

26.4.2024:

- First measurements

16.-17.9.2024:

- Second measurements

PRPL 2023/2024:
Probe commissioning&Measurements



PRPL 2024/2025:
Data Processing

18.11.2024:
- Intro. Presentation

Next Steps

- Data processing:
 - SS model identification for second session
 - Model comparison
 - Better interpretation and summary of results
 - ...
- Potentially additional experiments (with plasma) at the beginning of the next year (2025)

References

- Havlíček, J. (2015). *Study of Equilibrium Magnetic Configuration in Tokamak Type Devices*. PhD thesis, Charles University in Prague.
- Kubincová, A. (2021). Pokročilá rekonstrukce vertikální pozice plazmatu na tokamaku Golem.
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- Valovič, M. (1989). Control of plasma position in the CASTOR tokamak. *Czechoslovak Journal of Physics B*.
- Yanovskiy, J. (2021). soukromá komunikace.