CTU
CZECH TECHNICAL UNIVERSITY IN PRAGUE

FACULTY OF NUCLEAR SCIENCES AND PHYSICAL ENGINEERING CTU IN PRAGUE

GOLEM data analysis introduction

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Cadarache 03/2025

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Data loading from shot-homepage

GOLEM data and where to find them?

GOLEM data

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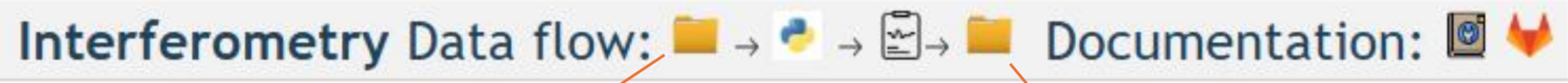
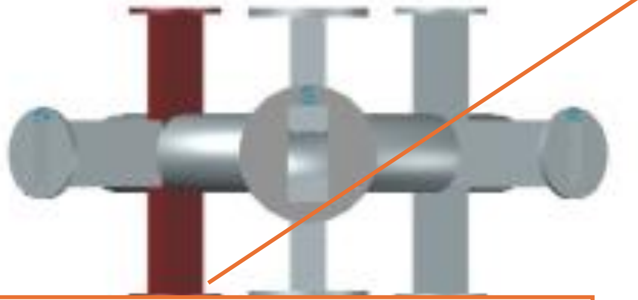
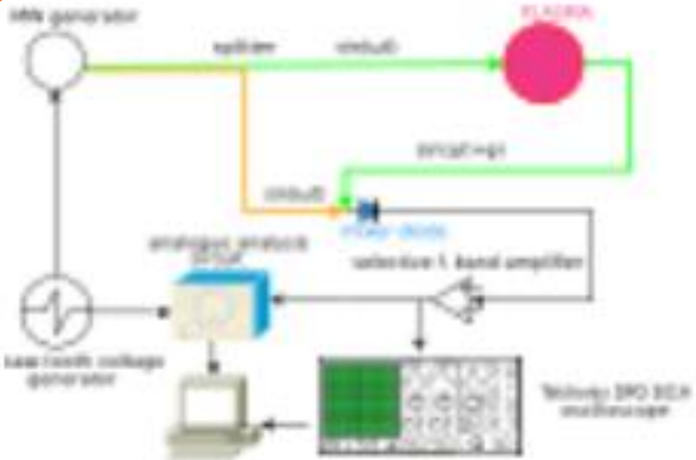
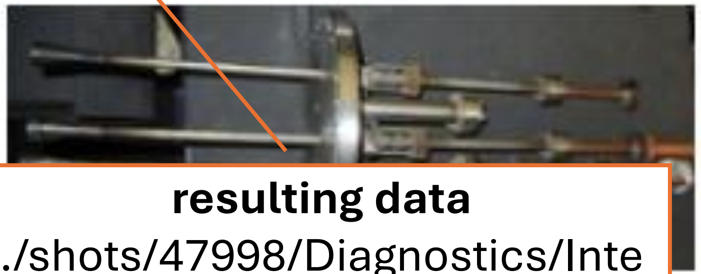
- **last shot:** http://golem.fjfi.cvut.cz/shots/0/
- **specific shot:** http://golem.fjfi.cvut.cz/shots/47998/ **(Master test yesterday)**









raw data
./shots/47998/Devices/Oscilloscopes/TektrDPO3014-a/

resulting data
./shots/47998/Diagnostics/Interferometry/**Results/**

GOLEM data

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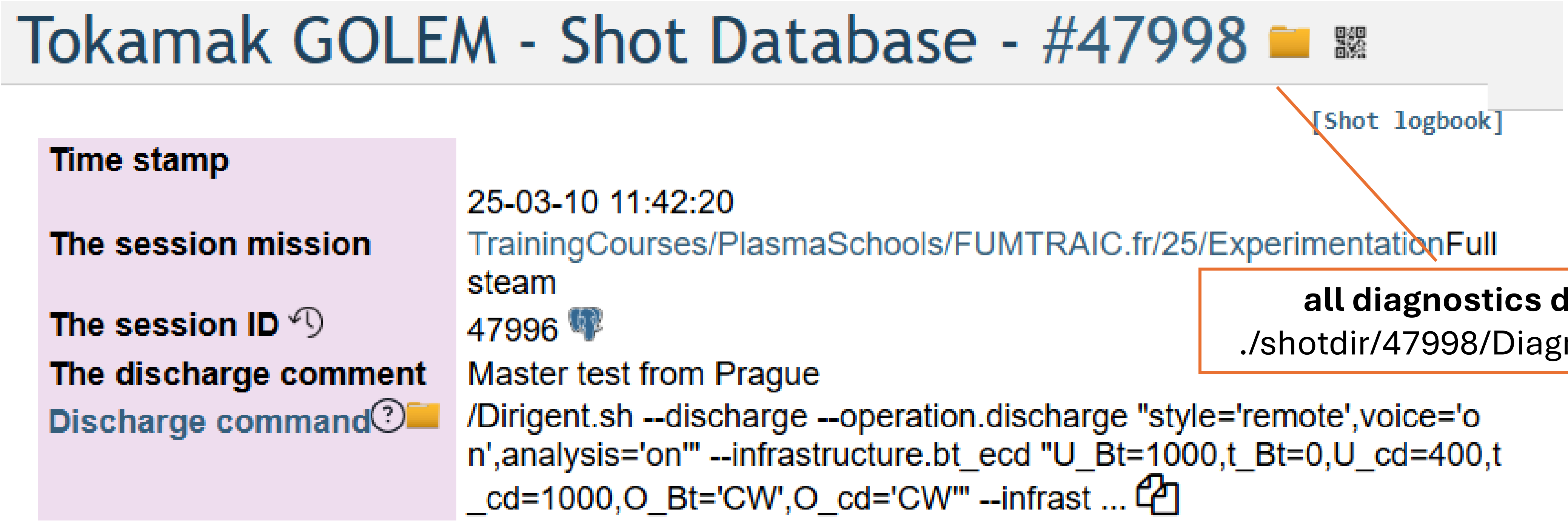
Tokamak GOLEM - Shot Database - #47998

[Shot logbook]

Time stamp	25-03-10 11:42:20
The session mission	TrainingCourses/PlasmaSchools/FUMTRAIC.fr/25/ExperimentationFull steam
The session ID	47996
The discharge comment	Master test from Prague
Discharge command	/Dirigent.sh --discharge --operation.discharge "style='remote',voice='on',analysis='on'" --infrastructure.bt_ecd "U_Bt=1000,t_Bt=0,U_cd=400,t_cd=1000,O_Bt='CW',O_cd='CW'" --infrast ...

all diagnostics data
./shotdir/47998/Diagnostics/

Data loading via pandas

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Array

- data_ULoop_URL = http://golem.fjfi.cvut.cz/shots/47998/Diagnostics/PlasmaDetection/U_Loop.csv
- import pandas as pd

  data = **pd.read_csv(url, delimiter=',' ,**

  index_col=0,

  names=["time", "data"])

We will then convert pandas.DataFrame into **xarray.DataArray**

Single value

- R_chamber_URL = http://golem.fjfi.cvut.cz/shots/47998/Production/Parameters/SystemParameters/R_chamber
- import pandas as pd

  number = **float(pd.read_csv(url,**

  header=None).values[0, 0])

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Basic diagnostics example

using Python to derive plasma current, electron temperature etc.

Basic diagnostics example

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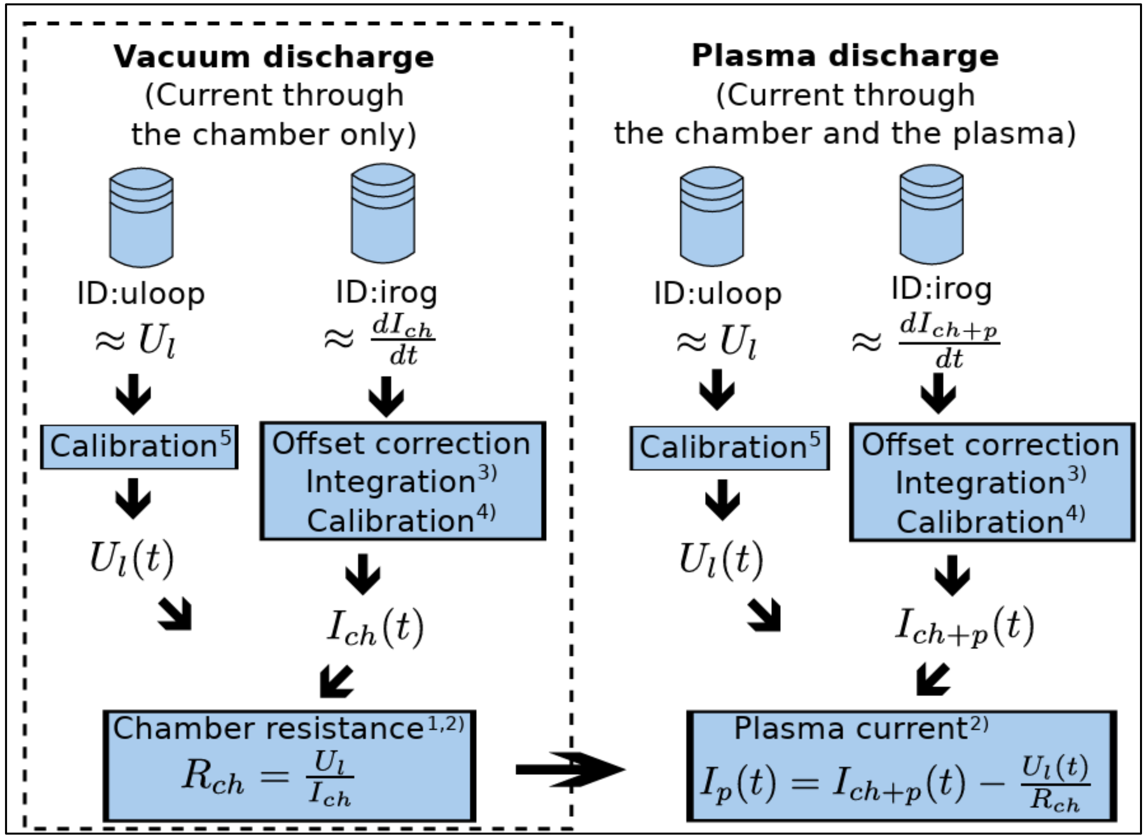
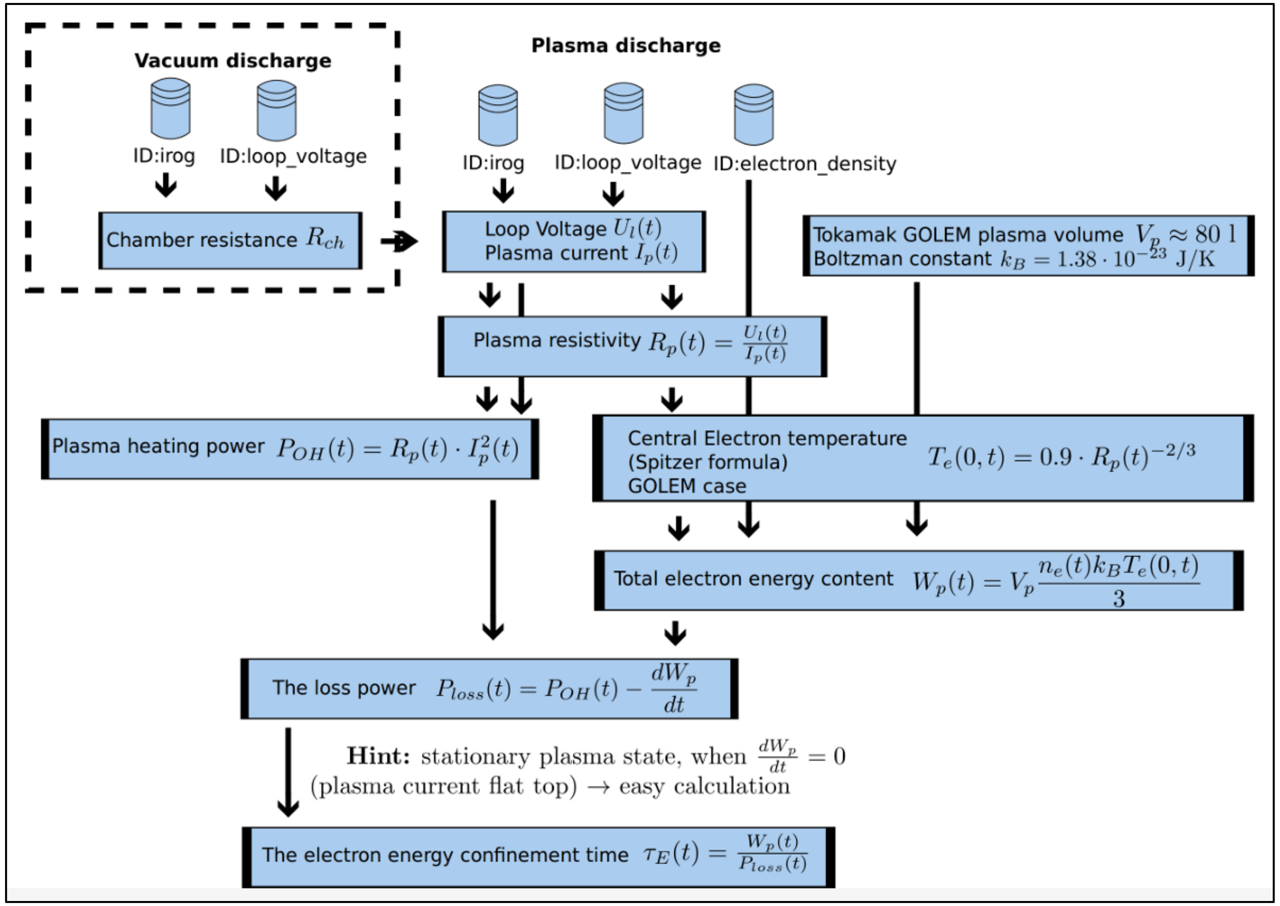
- http://golem.fjfi.cvut.cz/wiki/Education/ExperimentMenu/1stLevelBasic/ElectronEnergyConfinementTime/latexsrc.pdf





Basic diagnostics example

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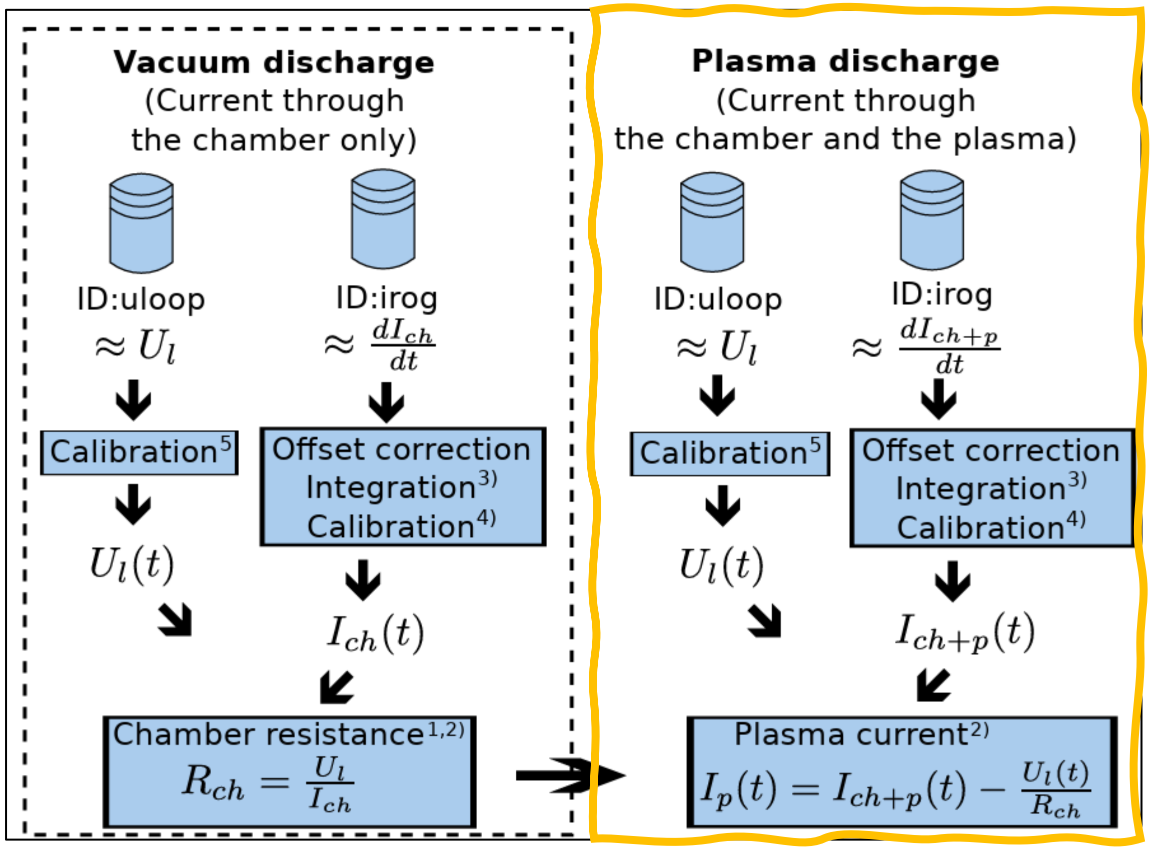
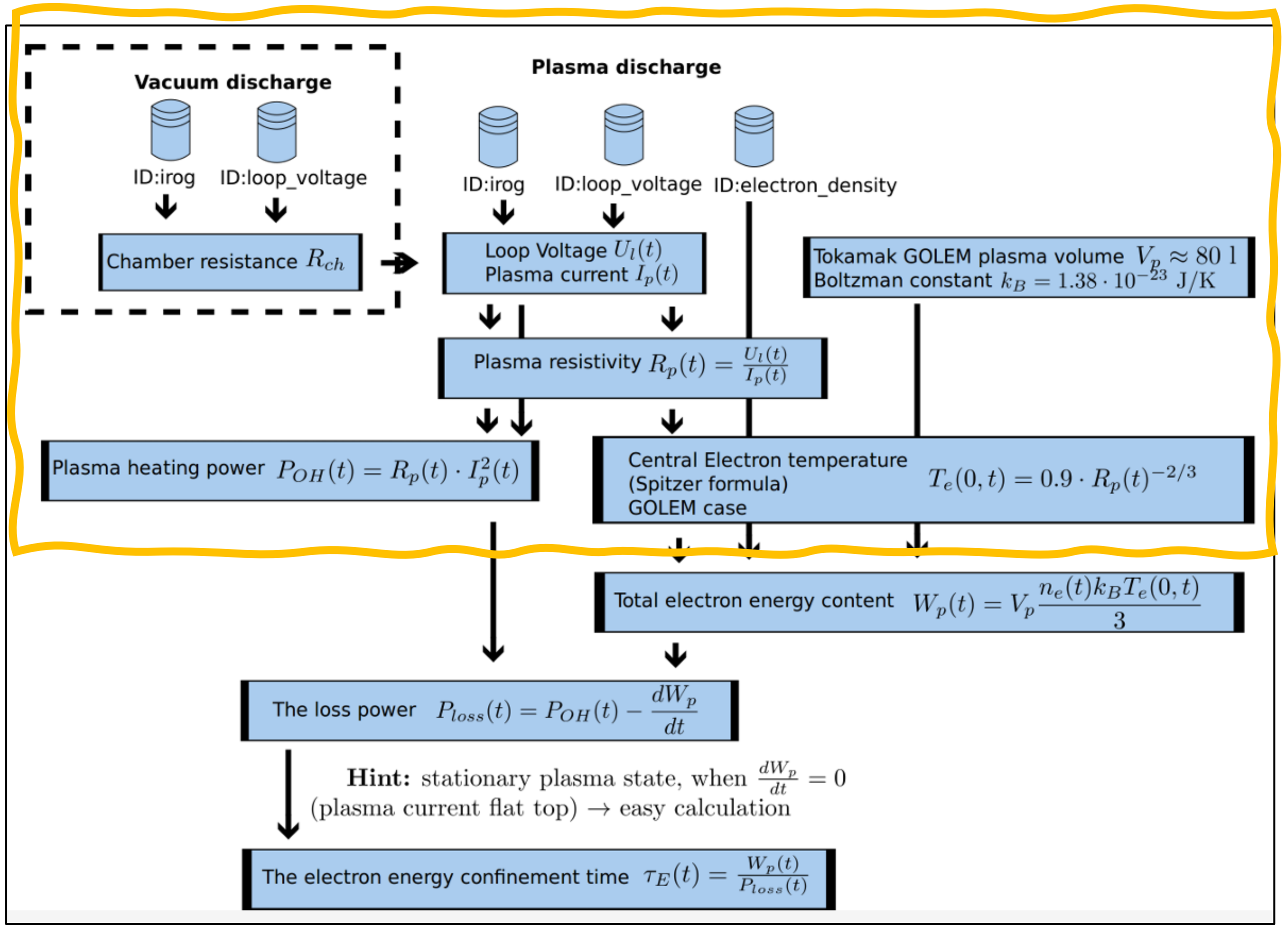
- http://golem.fjfi.cvut.cz/wiki/Education/ExperimentMenu/1stLevelBasic/ElectronEnergyConfinementTime/latexsrc.pdf





Spitzer's formula

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The time evolution of the central electron temperature $T_e(0,t)$ is calculated from equation based on Spitzer's resistivity formula (see eg. [Brotankova, J., 2009],[Wesson, 2004]):

$$T_e(0,t) = \left(\frac{R_0}{a^2} \frac{8Z_{eff.}}{1544} \frac{1}{R_p(t)} \right)^{2/3}, [eV; m, \Omega]$$

For particular case of the GOLEM tokamak it says:

$$T_e(0,t) = 0.9 \cdot \left(\frac{I_p(t)}{U_l(t)} \right)^{2/3}, [eV; A, V]$$

Python demonstration

Will everybody use Python? Do you know how to install new libraries?

Electric probes setups

Langmuir probes and Ball-pen probes

Motivation

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- Goal: study **plasma edge** properties
- Diagnostics by electric probes
  - standard: Lamgmuir probes (LP)
  - novel: Ball-pen probes (BPP) by Jiří Adámek, Ph.D.
  - **I-V characteristic determines certain plasma properties**
  - **→ calibration allows direct properties measuremen**
- **Modes of operation**
  - I-V characteristics voltage sweep
  - floating potential setup
  - Isat (ion saturated current) measurement

I-V characteristic terminology

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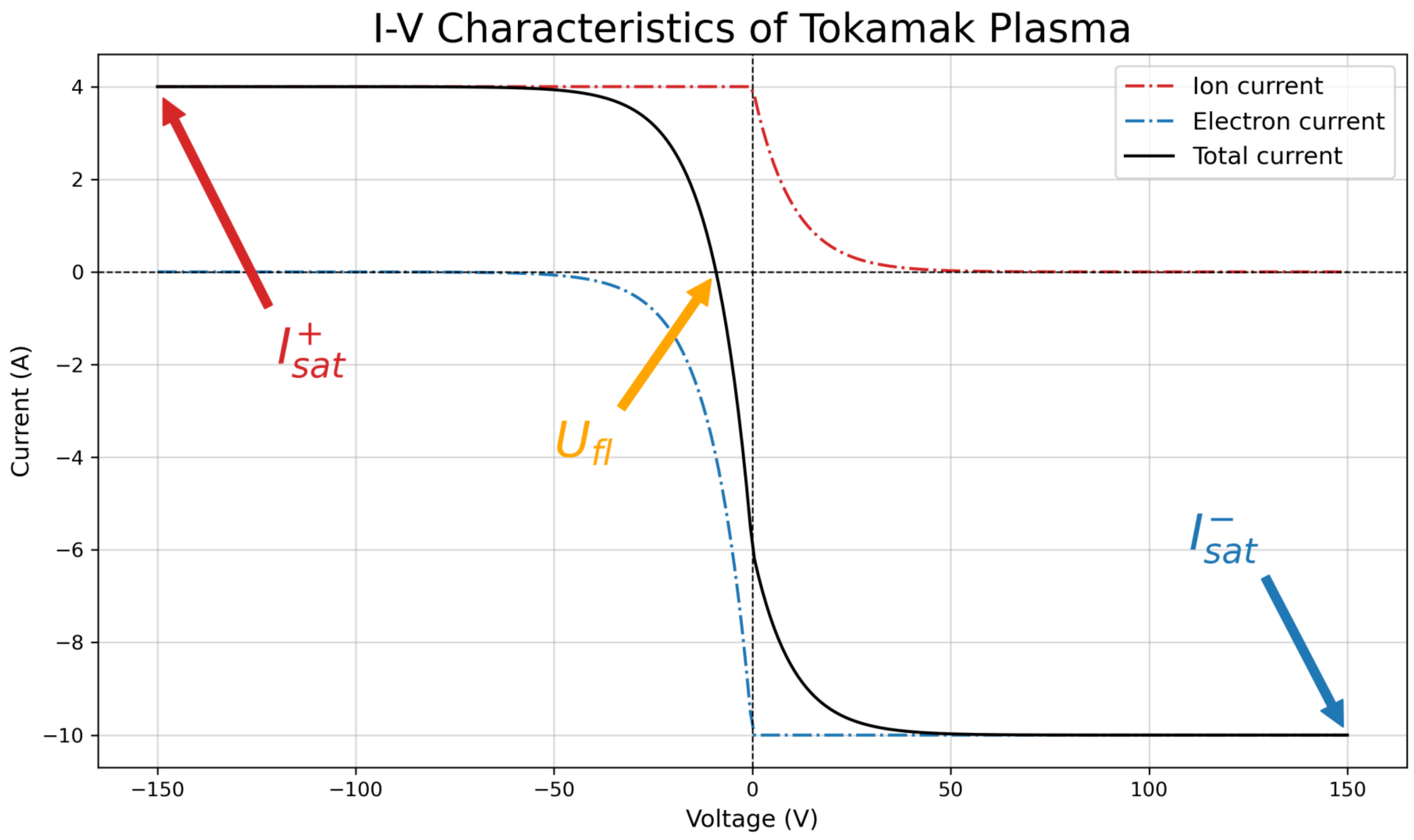
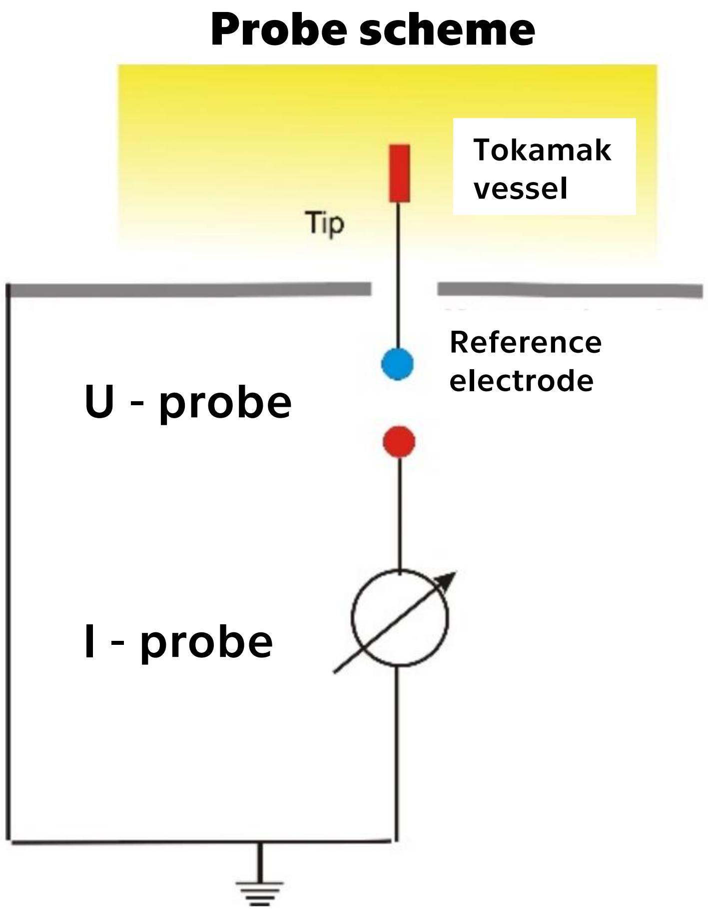
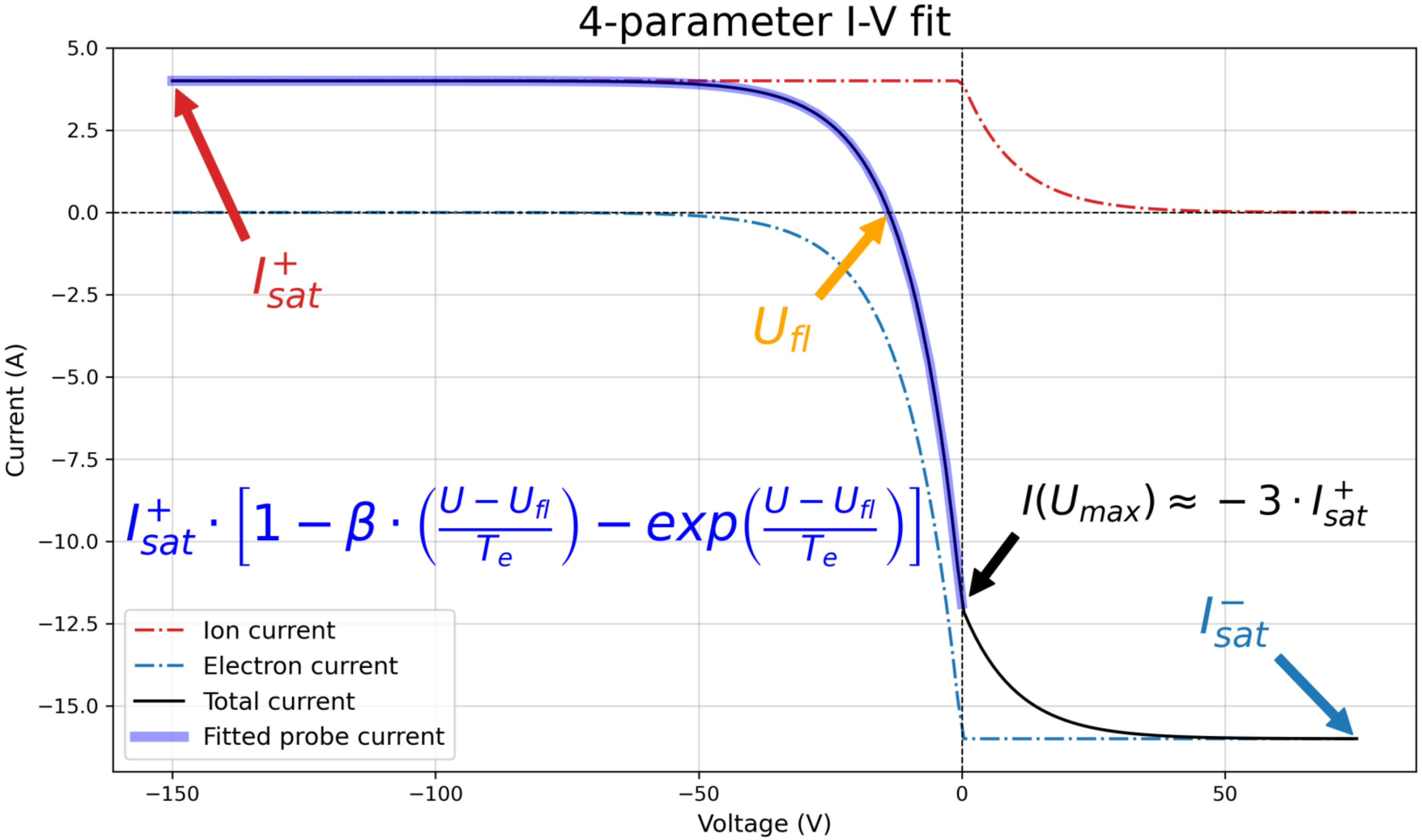




Fit of LP IV-characteristics

- **P. Macha et al 2023 Nucl. Fusion 63 104003**
- 4-parameter fit of the ion-branch
  - I_{sat}^{+} ion saturated current
  - U_{fl} floating potential
  - T_e electron temperature
  - β sheath expansion coefficient
- sheath expansion effect
  - Debye sphere broadening due to high $|U|$
- this fit mostly includes negative *U*
  - $U_{max} \equiv U(I \approx -3 \cdot I_{sat}^{+})$
  - **for LP** (high +voltage can damage the probe)



Floating potential

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- probe not grounded ➔ charged by plasma ➔ measure Ufl voltage with 0 current

- Generally:
  - α calibration constant
  - Φ plasma potential

$$U_{fl} = \Phi - \alpha T_e$$

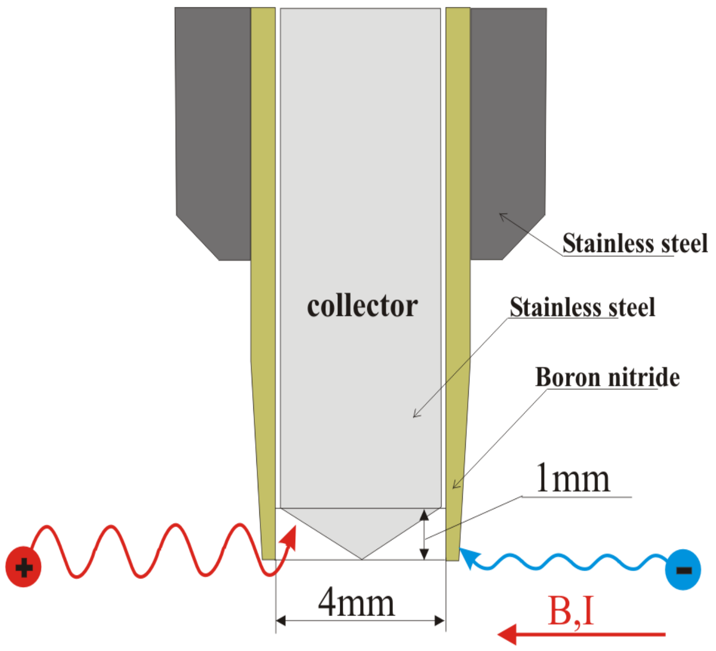
- Calibration constant

$$\alpha = \ln\left(I_{sat}^{-} / I_{sat}^{+} \right)$$

- Ball-pen probe
  - electron flow geometrically shielded $\Rightarrow \Gamma_e \approx \Gamma_i$

$$\Rightarrow U_{fl}^{(BPP)} \cong \Phi$$

Ball-pen probe



T_e and Φ measurement

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$$\boldsymbol{U_{fl} = \Phi - \alpha T_e}$$

T_e measurement

- combined probe ➔ $\alpha^{(LP+BPP)}$
  - from LP I-V characteristic
  - **already calibrated**

$$U_{fl}^{(LP)} = U_{fl}^{(BPP)} - \alpha^{(LP+BPP)} T_e$$

$$\boldsymbol{T_e} = \frac{U_{fl}^{(BPP)} - U_{fl}^{(LP)}}{\alpha^{(LP+BPP)}}$$

n_i measurement

- using I_{sat}^{+} , T_e measurement

$$\boldsymbol{n_i} = f(T_e, I_{sat}^{+}) = I_{sat}^{+} \cdot c_s^i$$

$$c_s^i = \frac{\gamma\, k_B\, T_i}{m_i}$$

Thank you for your attention

And good luck with your data analysis!