



# EuPRAXIA – Plasma source simulations

**Maxence Thévenet**

Theory & simulation – team leader

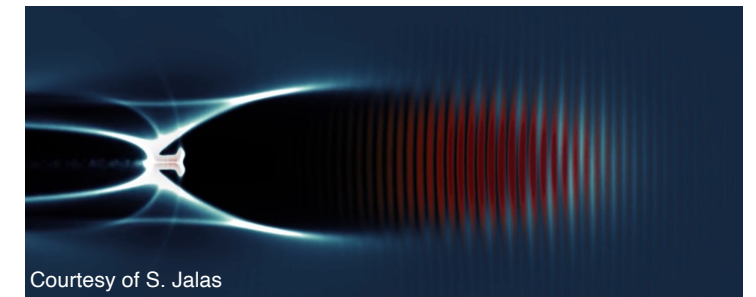
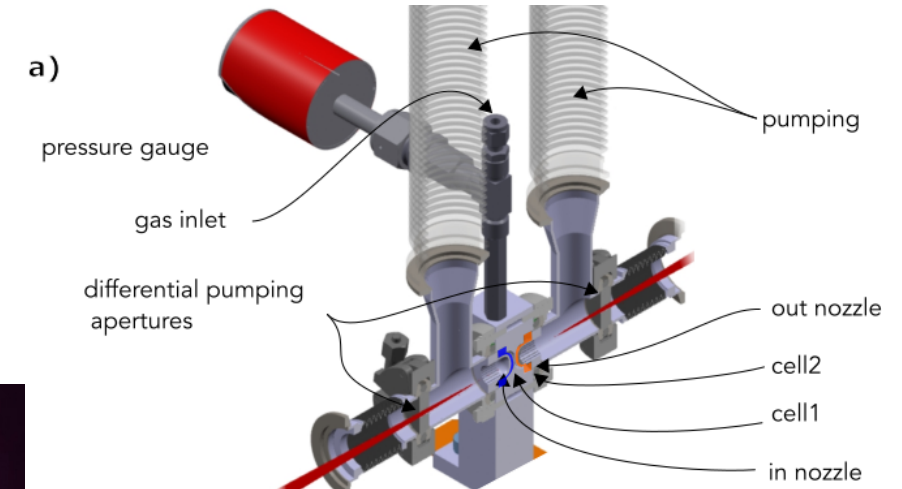
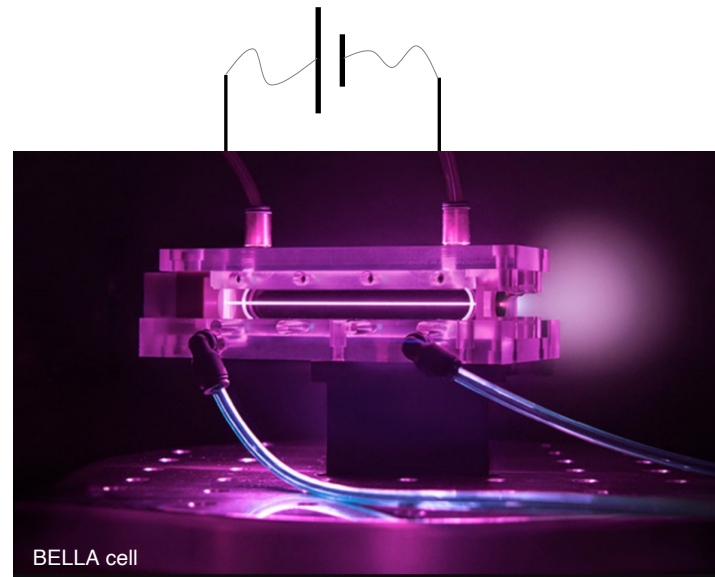
*Workshop on plasma components & systems for EuPRAXIA, DESY, January 2025*

# What to simulate and why?

- **Shape gas** (Gas cell, gas jet)
- **Shape plasma** (Laser or discharge)
- **Do wakefield** (PWFA, LWFA)
- **Sustain operations**

## Why simulations?

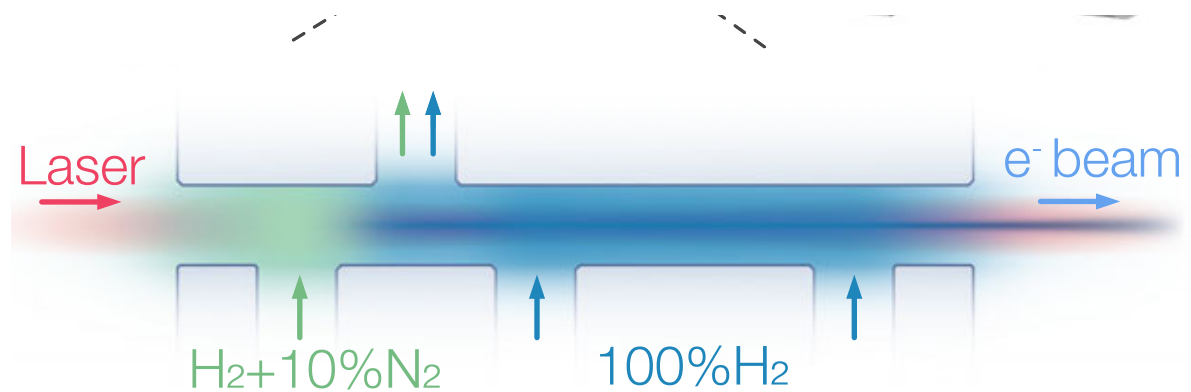
- Test designs
- Virtual diagnostics
- S2E simulations
- ...



Eupraxia Technical Status Report on Plasma Components and Systems

# Simulation of gas source relatively well-controlled

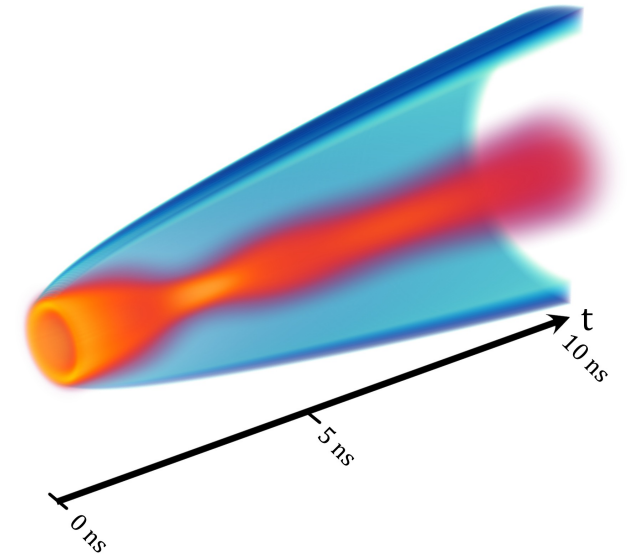
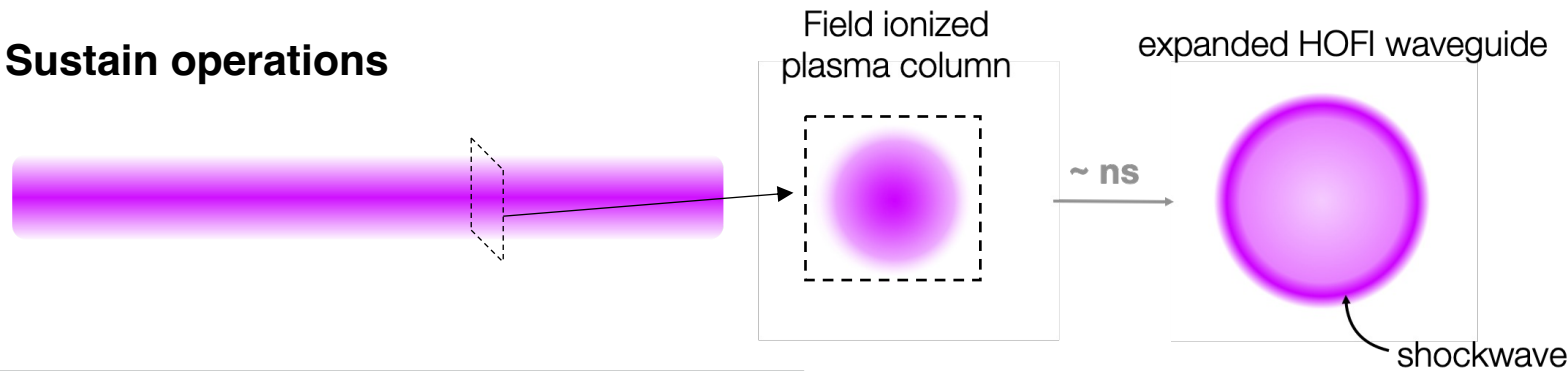
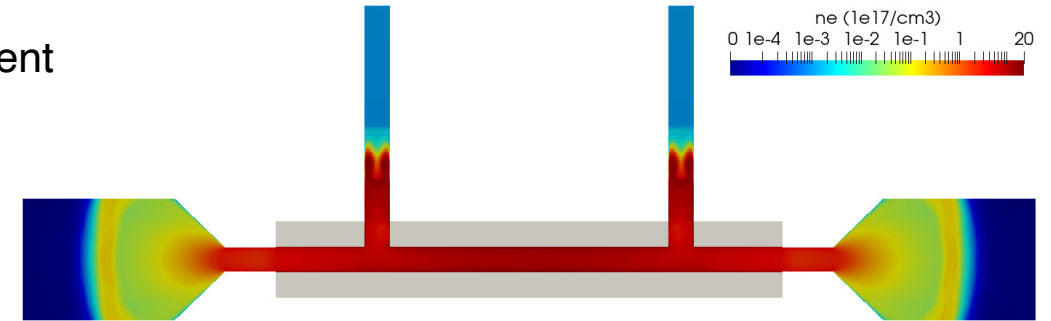
- **Shape gas** (Gas cell, gas jet)  
*Capture/injection, acceleration, guiding*  
Fluid dynamics: OpenFOAM, COMSOL-Multiphysics, ANSYS-fluent  
TRL: 7+
- **Shape plasma** (Laser or discharge)
- **Do wakefield** (PWFA, LWFA)
- **Sustain operations**



M. Kirchen et al., PRL 126, 174801 (2021)

# Plasma shaping modelling is still a research topic

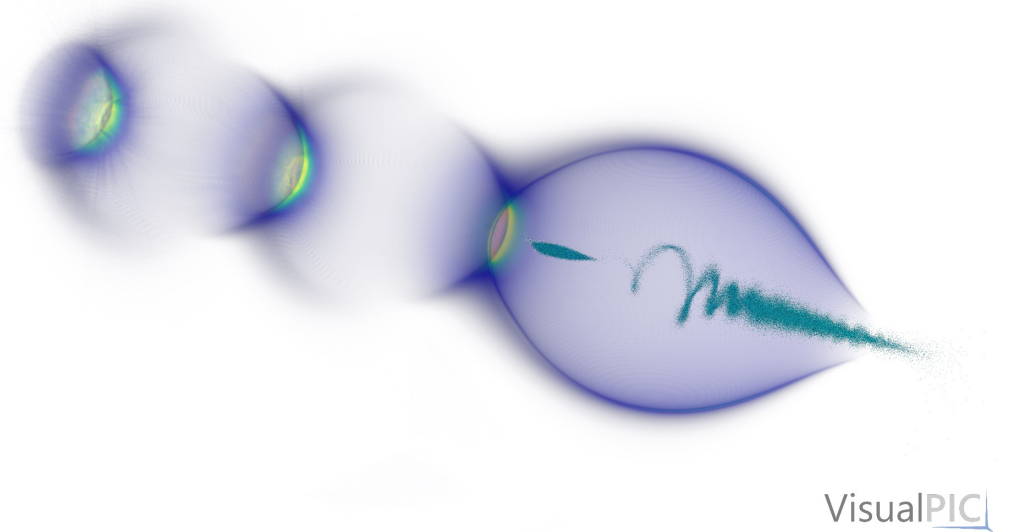
- **Shape gas** (Gas cell, gas jet)  
*Capture/injection, acceleration, guiding*  
Fluid dynamics: OpenFOAM, COMSOL-Multiphysics, ANSYS-fluent  
TRL: 7+
- **Shape plasma** (Laser or discharge)  
*Create plasma, injection, guiding, plasma optics*  
EM, discharge, plasma hydrodynamics  
TRL: 3-9
- **Do wakefield** (PWFA, LWFA)
- **Sustain operations**



K. Oubriere et al., Science & Applications 11, 180 (2022)  
M. Mewes et al., PRR 5, 033112 (2023)  
B. Miao et al., PRAB 27, 081302 (2024)  
G. A. Bagdasarov et al., PRR 4, 013063 (2022)  
M. Mewes et al., *in preparation*

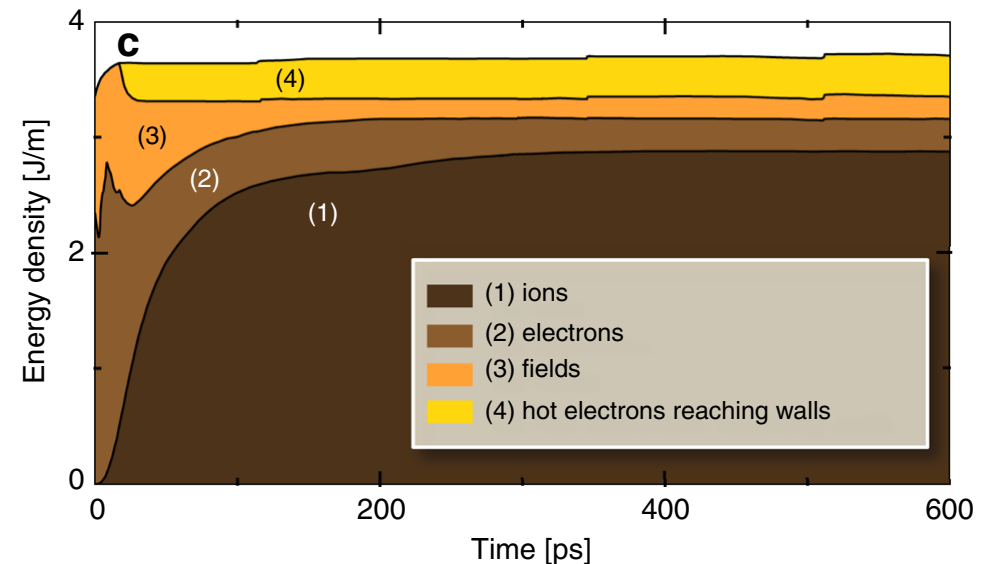
# Simulate wakefield: bread and butter

- **Shape gas** (Gas cell, gas jet)  
*Capture/injection, acceleration, guiding*  
Fluid dynamics: OpenFOAM, COMSOL-Multiphysics, ANSYS-fluent  
TRL: 7+
- **Shape plasma** (Laser or discharge)  
*Create plasma, injection, guiding, plasma optics*  
EM, discharge, plasma hydrodynamics  
TRL: 3-9
- **Do wakefield** (PWFA, LWFA)  
*Get these electrons*  
Kinetic plasma: PIC, QS-PIC  
TRL: 7+
- **Sustain operations**



# Large challenges towards simulating production operation

- **Shape gas** (Gas cell, gas jet)  
*Capture/injection, acceleration, guiding*  
Fluid dynamics: OpenFOAM, COMSOL-Multiphysics, ANSYS-fluent  
TRL: 7+
- **Shape plasma** (Laser or discharge)  
*Create plasma, injection, guiding, plasma optics*  
EM, discharge, plasma hydrodynamics  
TRL: 3-9
- **Do wakefield** (PWFA, LWFA)  
*Get these electrons*  
Kinetic plasma: PIC, QS-PIC  
TRL: 7+
- **Sustain operations**  
*Rep rate & heat management, up time, stability, laser damage*  
Diverse methods  
TRL: 1-9



R. Zgadzaj et al., Nat. Comm. 11, 4753 (2020)

- **Shape gas** (Gas cell, gas jet)
- **Shape plasma** (Laser or discharge)
- **Do wakefield** (PWFA, LWFA)
- **Sustain operations**

## Conclusion & perspectives

- Simulation components exhibit different TRL
- Challenges: space/time scales, multi-physics
- S2E simulations become the norm, openPMD helps
- New questions towards actual production
- Looking around: the Fusion community tackles similar problems

Thank you for your attention

