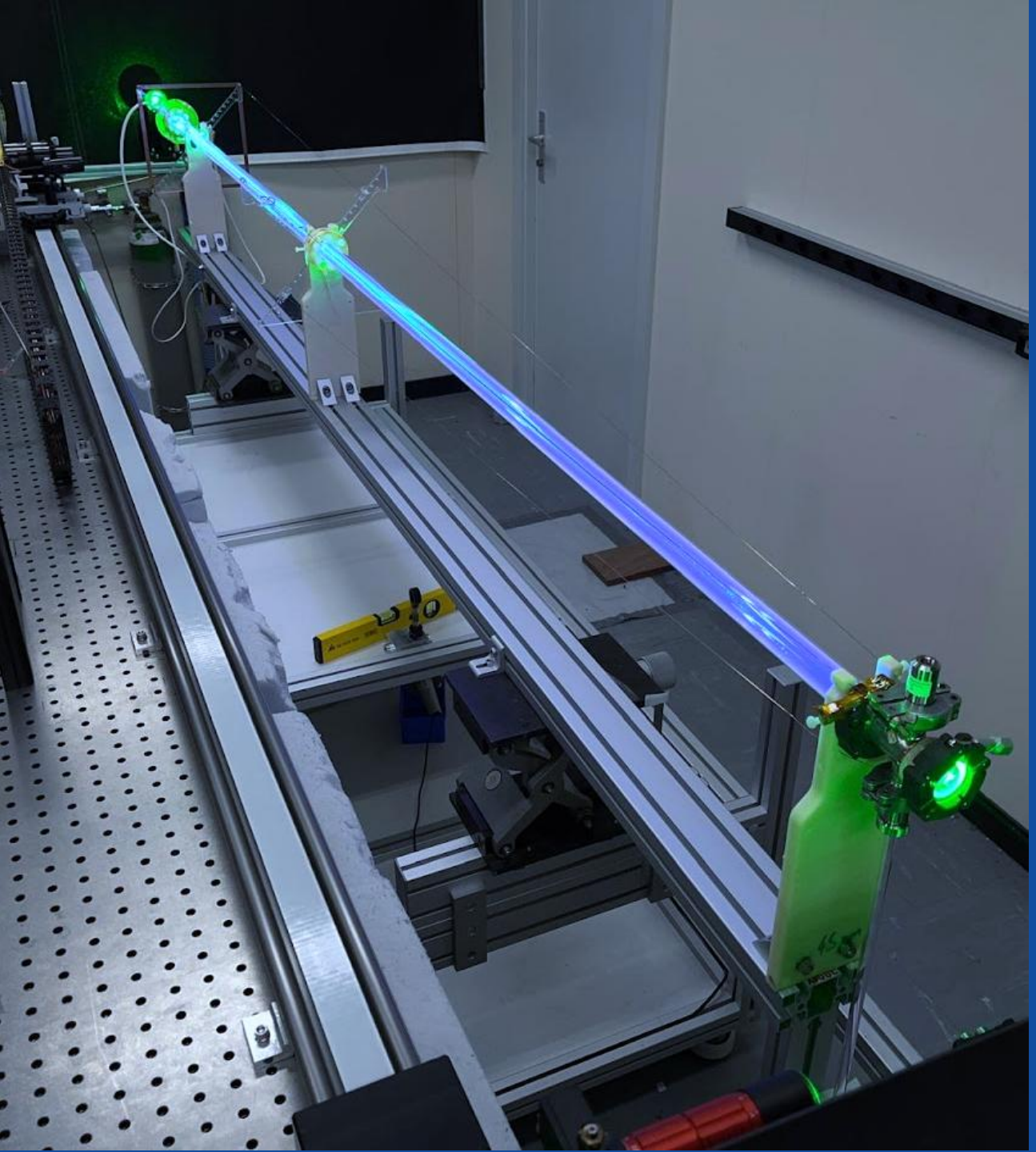

Local plasma density measurements of a Discharge Plasma Source for AWAKE using Thomson Scattering

Carolina Amoedo[1,2],
A. Sublet[1], M. Santos[1], C. Stollberg[3], R. Karimov[3], N.Torrado[1], F.Silva[4], N. Lopes[2]

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[2]GoLP/IPFN, Instituto Superior Técnico, Universidade de Lisboa, Lisbon, Portugal
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[4]INESC-ID, Instituto Superior Técnico, Universidade de Lisboa, Lisbon, Portugal

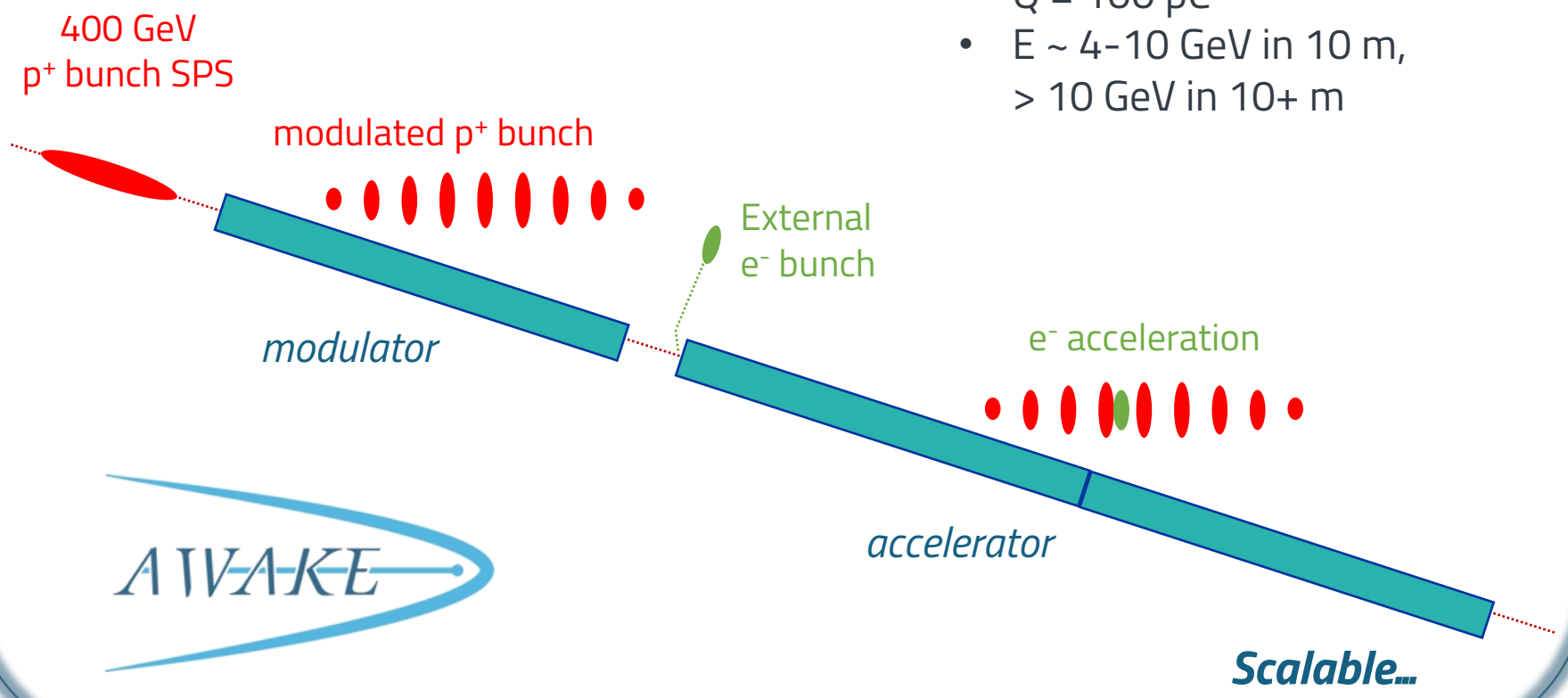

AWAKE
Thank you ☺

Introduction: AWAKE Proton Driven PWFA

AWAKE after ~2029-2030

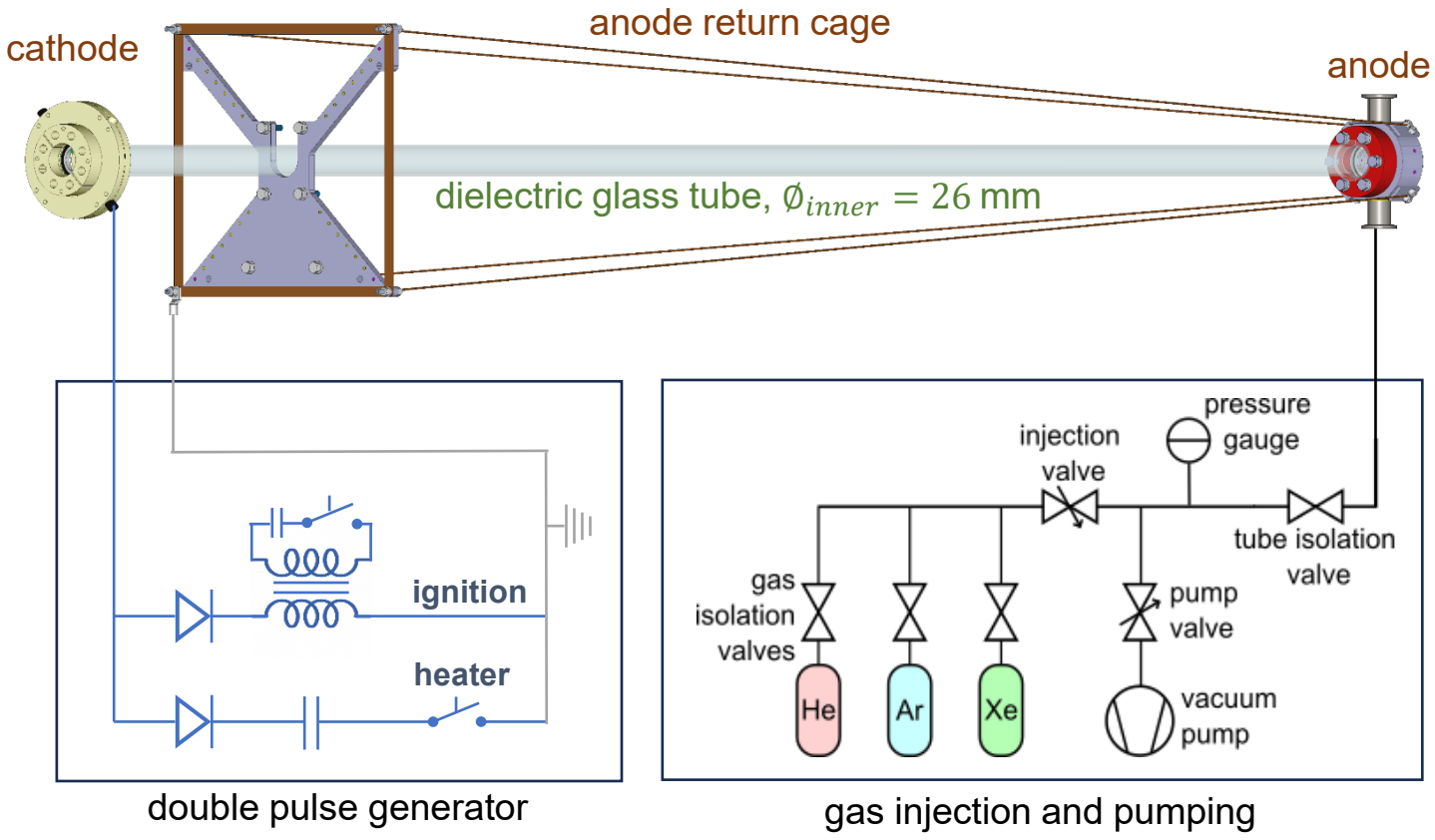
Expected parameter reach [1]:

- ε_N = (2-30) mm-mrad
- $\Delta E/E$ = 5-8%
- Q = 100 pC
- E ~ 4-10 GeV in 10 m,
  > 10 GeV in 10+ m



Motivation:

→ Discharge plasma [1]



- Jitter ~ 12 ns
- Plasma current variation < 0.5 %
- Pressure stability ±0.1%

[1] Torrado, N., et al., IEEE Trans. on Plasma Science 2023, 51, 12

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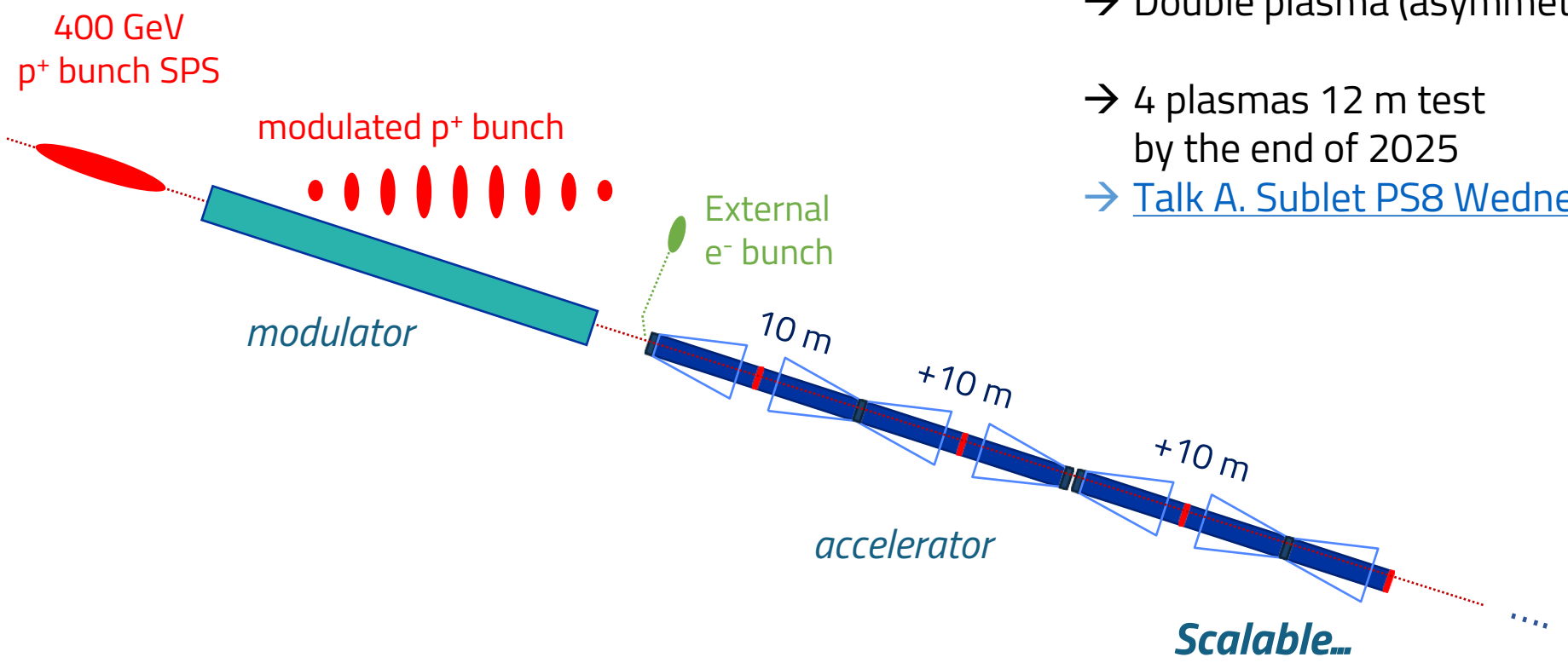


→ Double plasma (asymmetric) **[2]**

→ 4 plasmas 12 m test
by the end of 2025

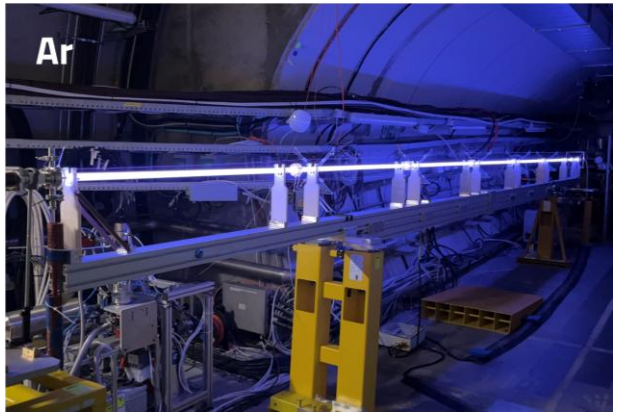
→ Talk A. Sublet PS8 Wednesday

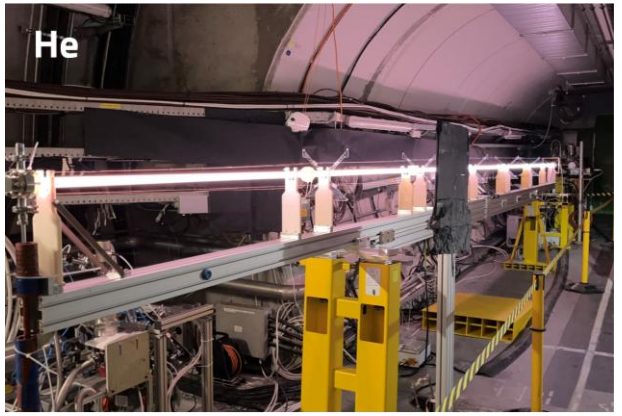
[1] Torrado, N., et al., IEEE Trans. on Plasma Science 2023, 51, 12
[2] Torrado, N., et al., Proceedings EAAC 2023

Motivation:

→ Discharge plasma [1] tested in AWAKE as *modulator* [2]

- *Flexibility in plasma ion species enabled study of ion-motion effect on SM* **[3]**
- Larger plasma radius allowed filamentation instability studies **[4]**





[1] Torrado, N., et al., IEEE Trans. on Plasma Science 2023, 51, 12
[2] C. Amoedo, in preparation (2025).
[3] Turner et al., PRL 134, 155001 (2025).
[4] Verra et al., Phys. Rev. E 109, 055203 (2024).

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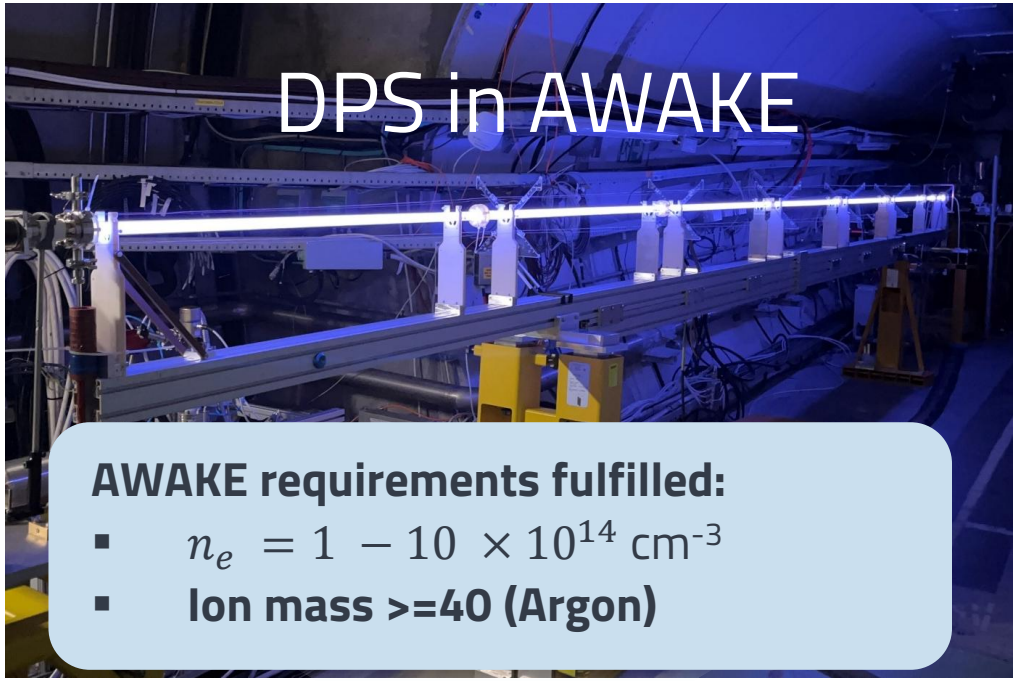
→ *Accelerator* requires scalable plasma to reach e- energies to 10-100 GeV and beyond



Extra requirements for *accelerator*:

- Length-scalable: 10-100 m
- **Longitudinal uniformity:** $\Delta n_e/n_e$**<0.25%**

[1] Torrado, N., et al., IEEE Trans. on Plasma Science 2023, 51, 12
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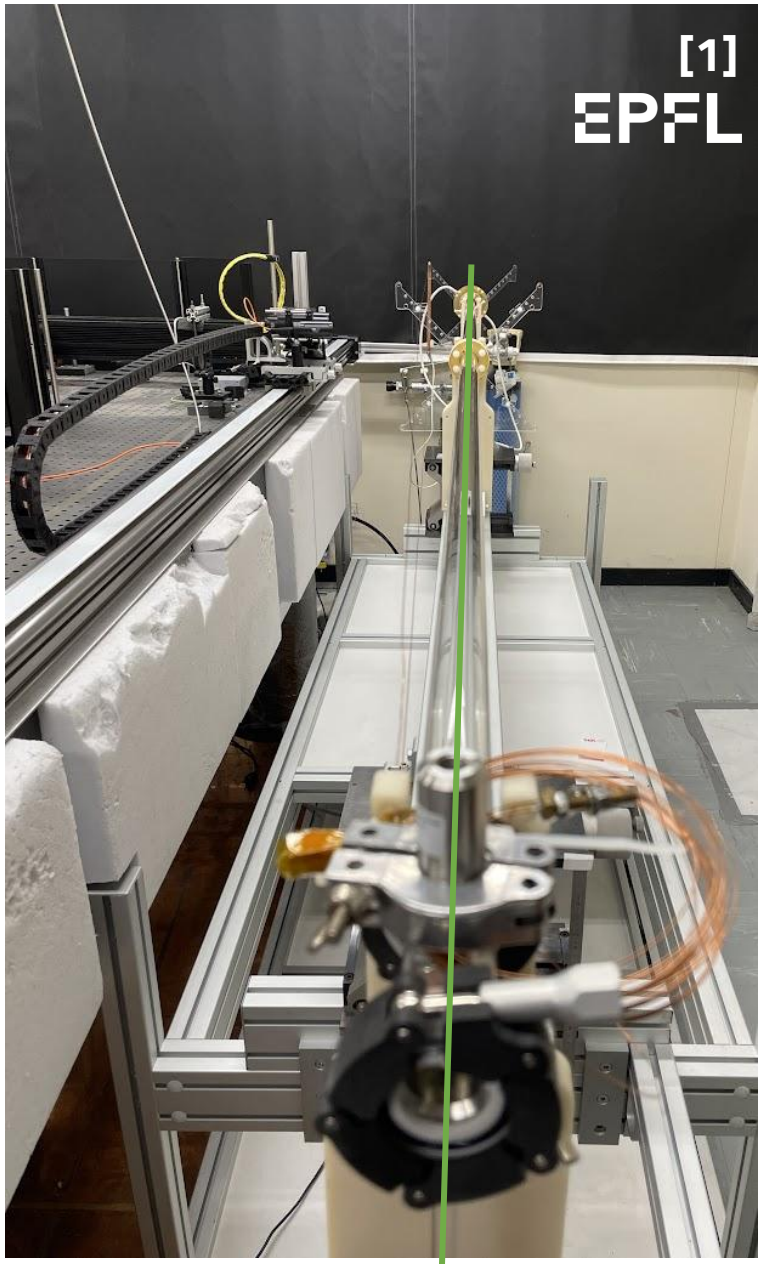
Local measurement with Thomson scattering:

→ Scattering of **laser light (ns)** on **free electrons of the plasma**

→ incoherent regime – gaussian distribution:

- → Width → T_e
- → Area → n_e (calibrated by Raman scattering in N_2)



Nd:YAG laser @ second harmonic (0.4 J/pulse, 7 ns)

[1] Stollberg et al., PPCF 66, 024002 (2024).

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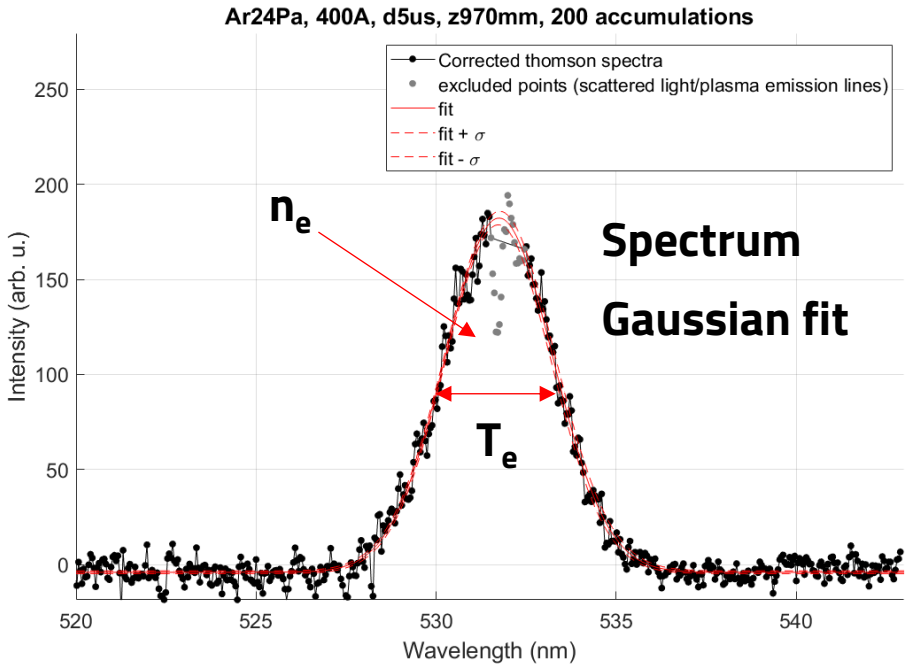

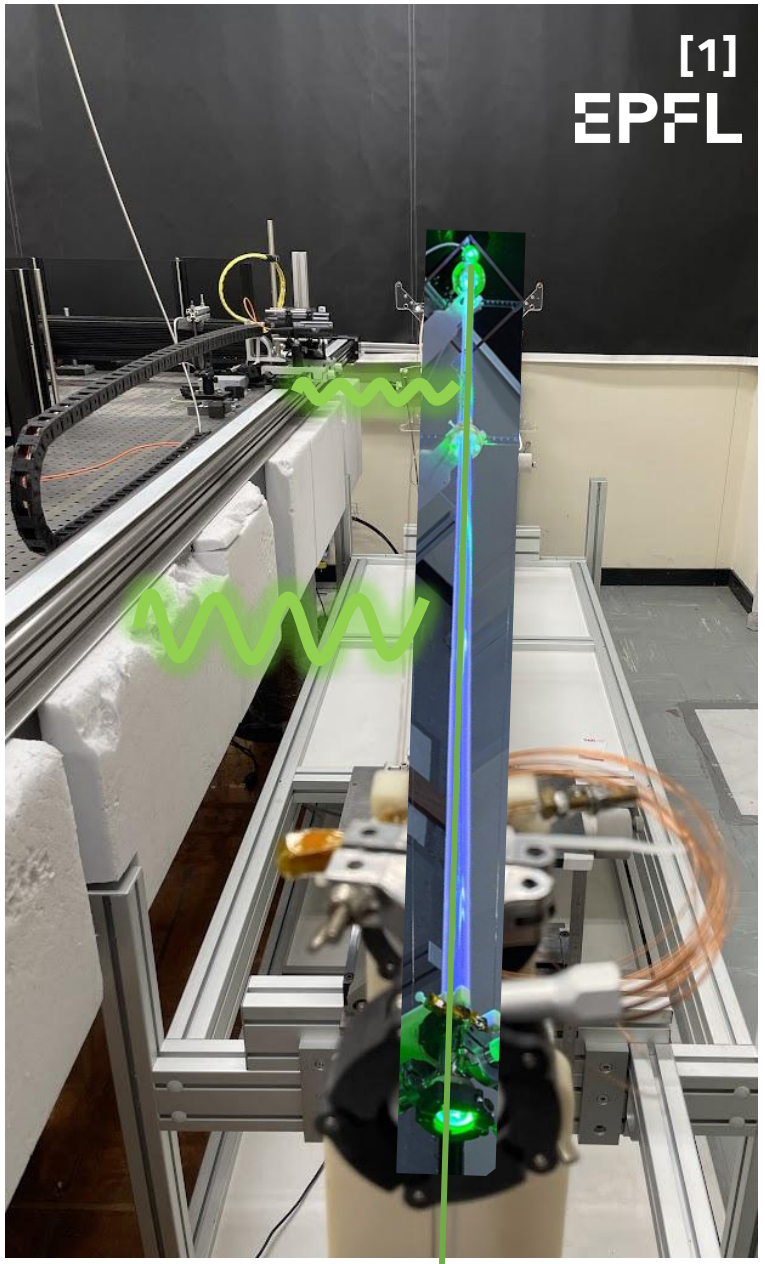

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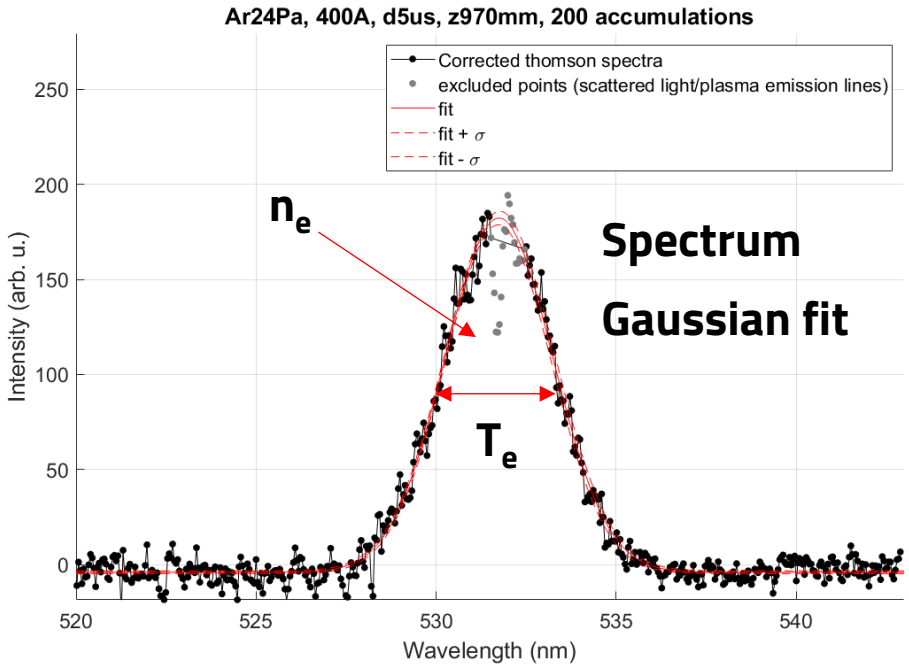

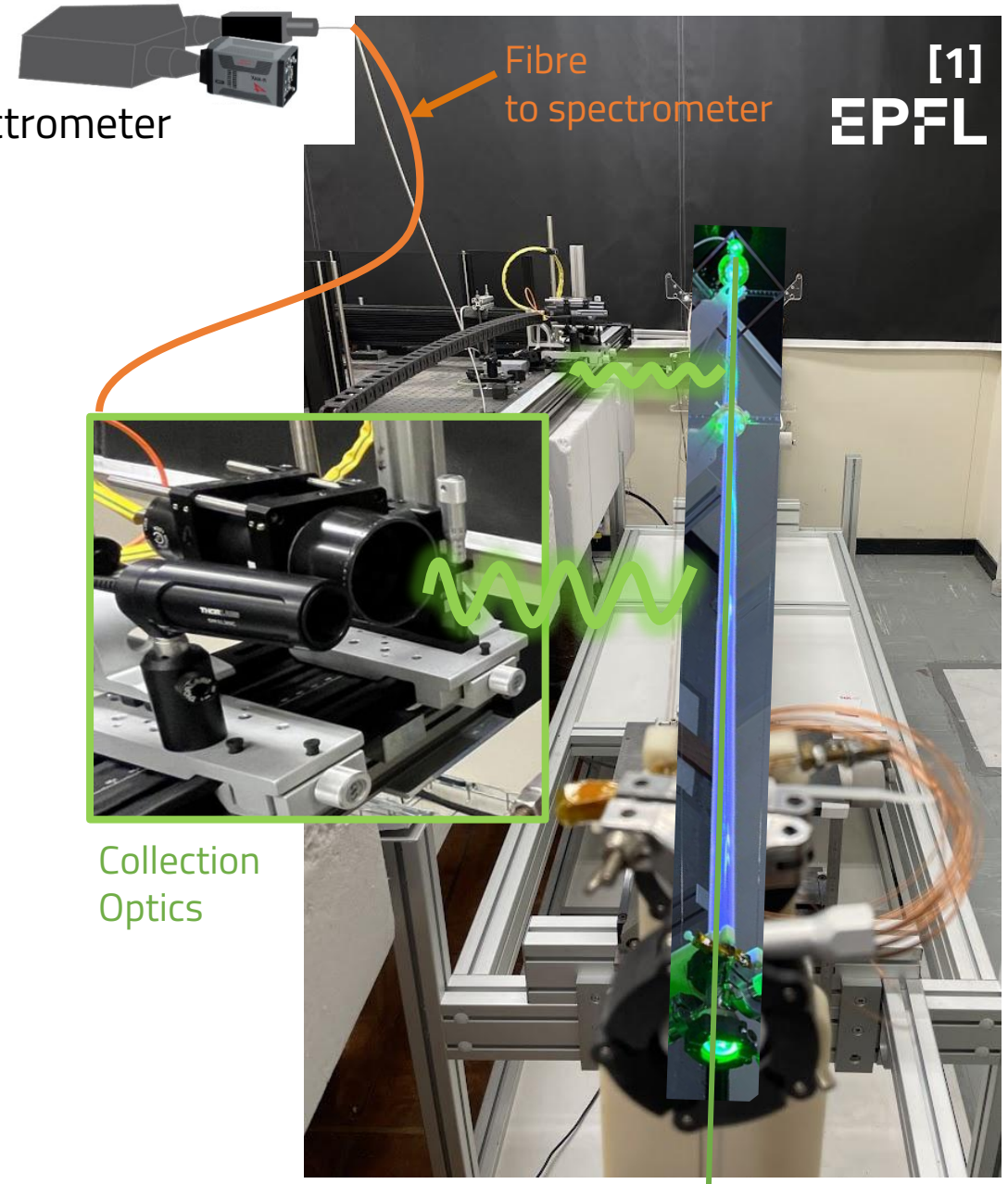

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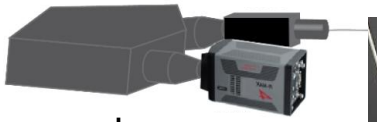

spectrometer

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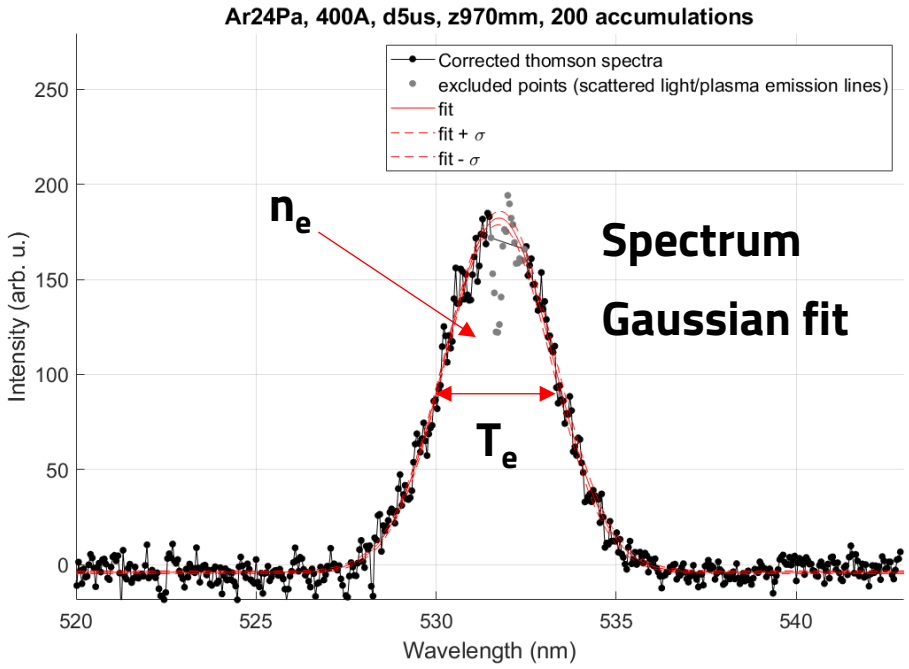
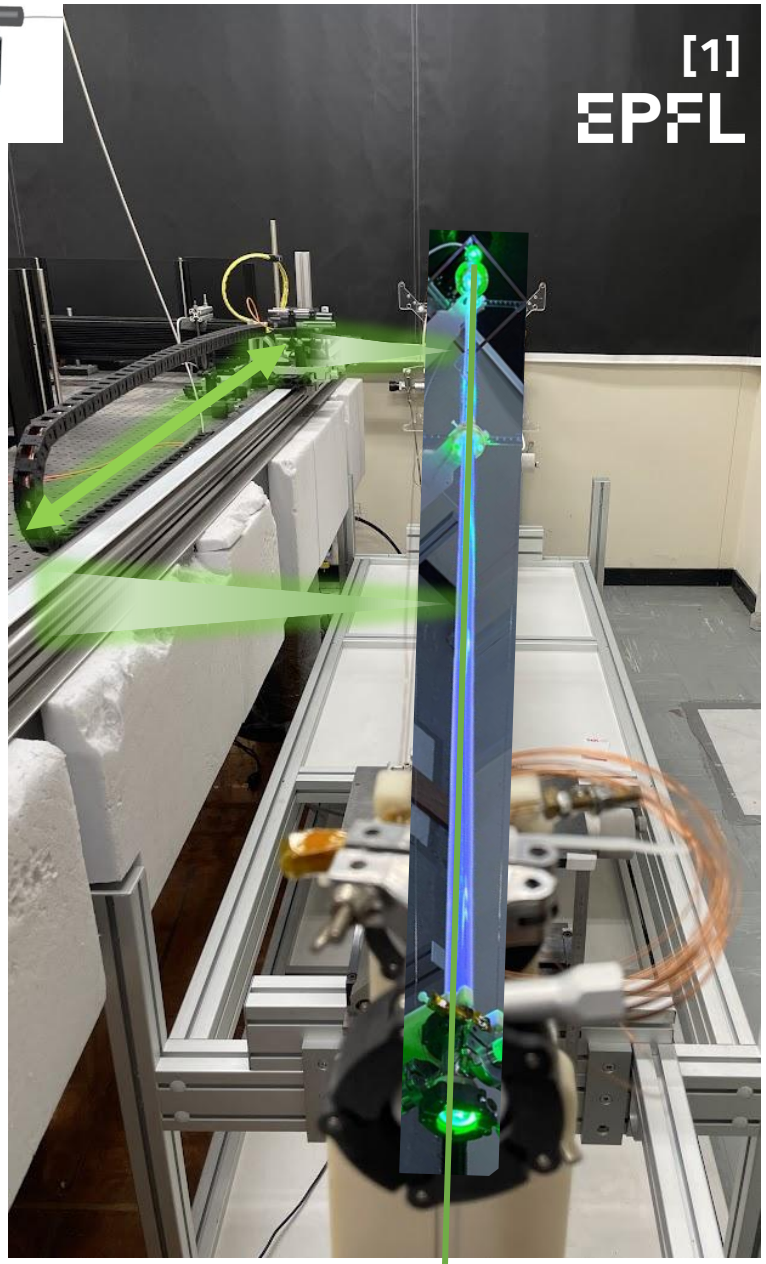


Local Measurement
5x5x5 mm^3



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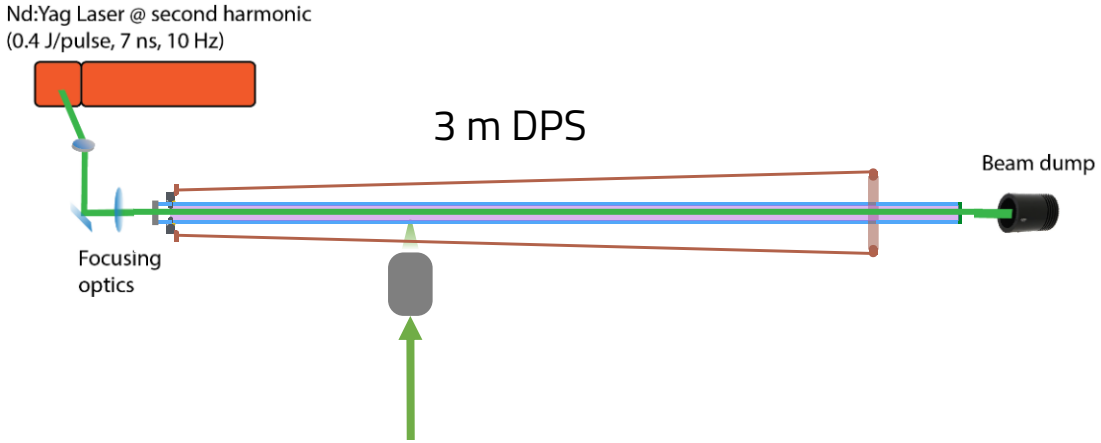
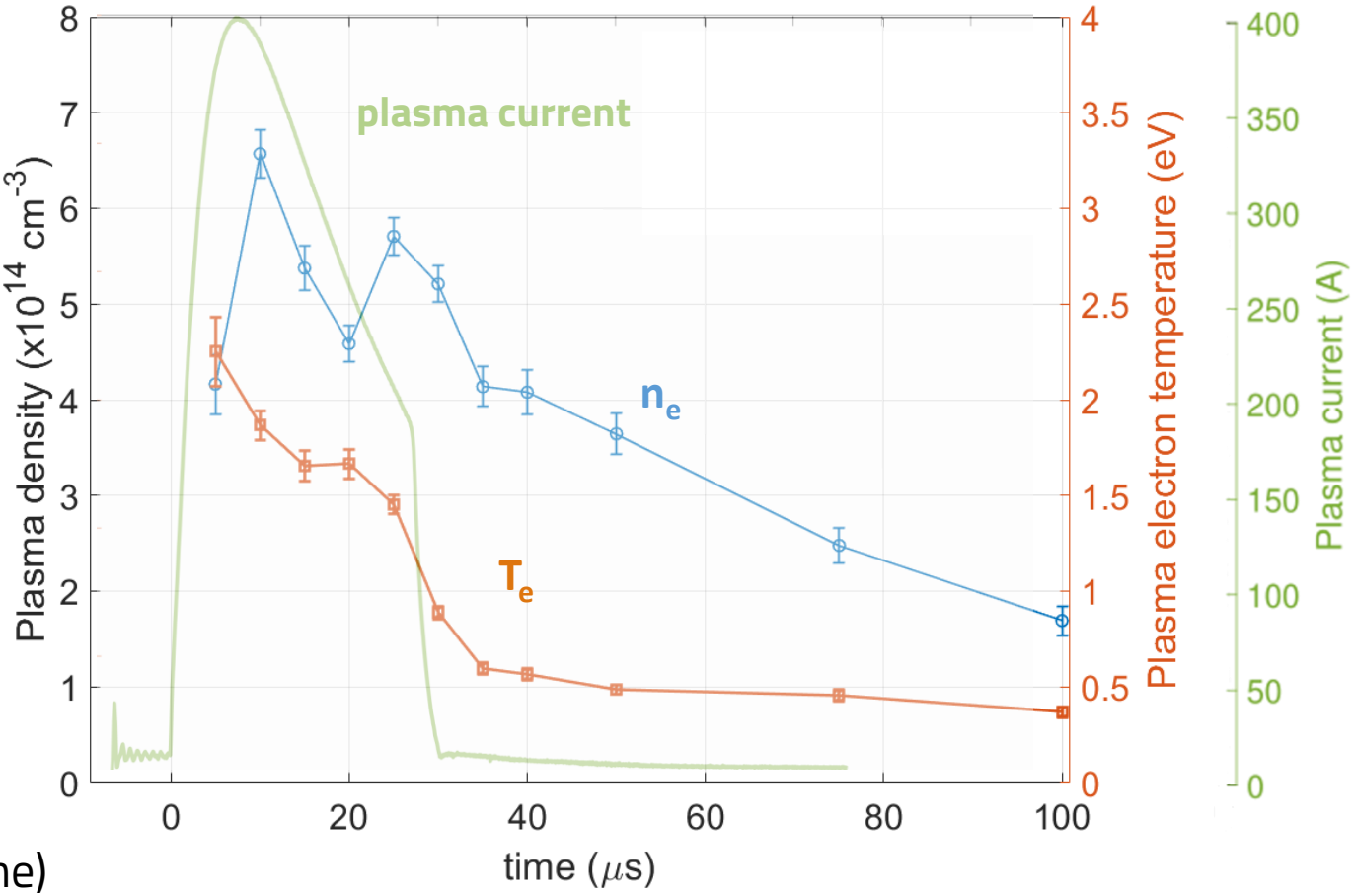
Timescan with TS at ~ 1 m

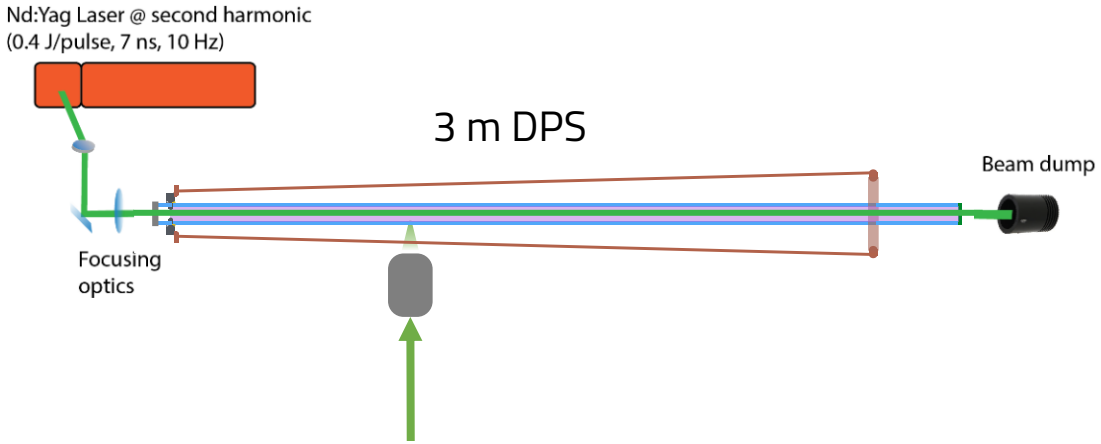




→ change time delay between the ns laser and the start of the discharge

↳ discrete measurement of the local n_e/T_e (in time) (50 accumulations per point)

Timescan with TS at ~ 1 m



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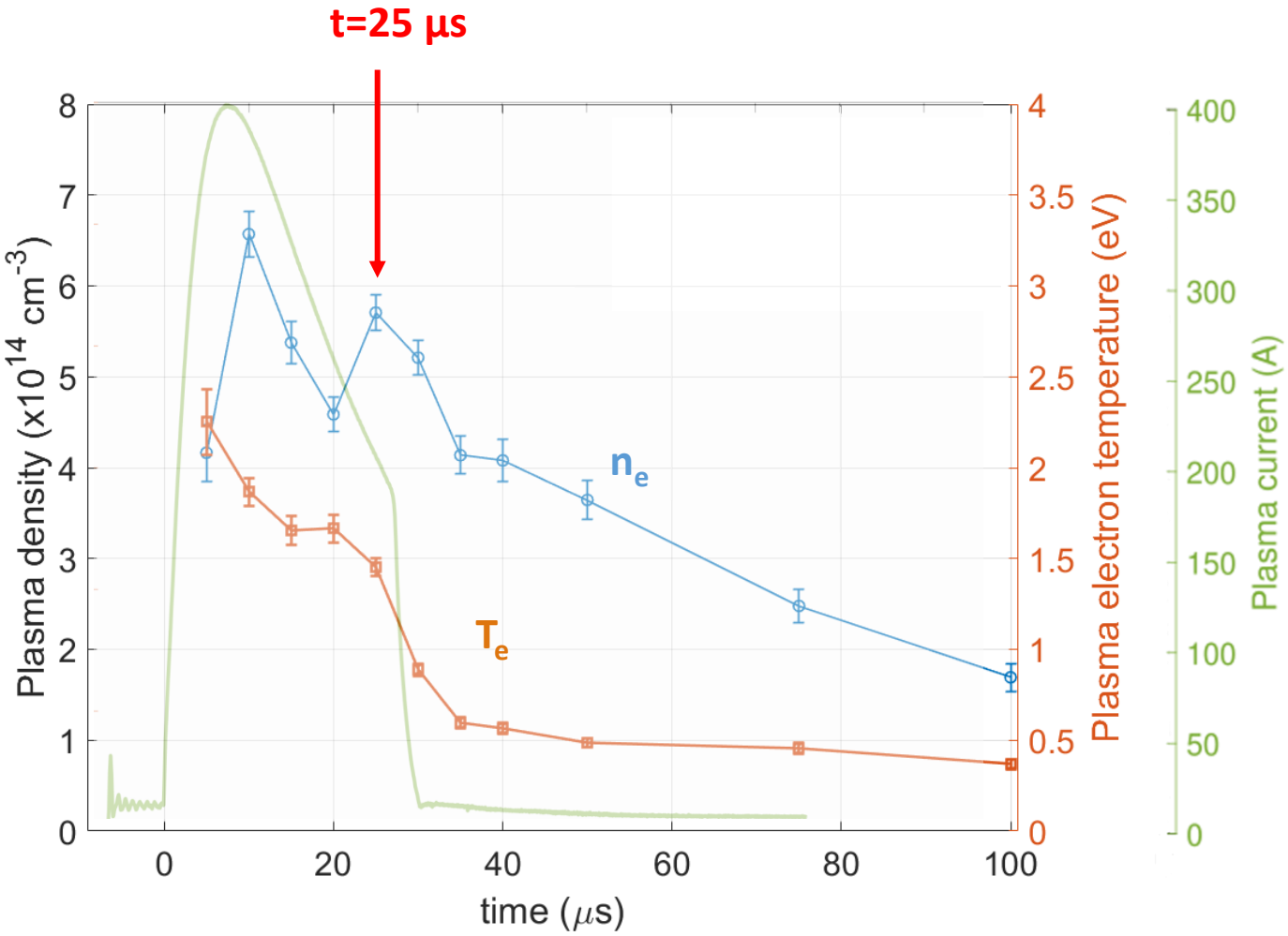


Axial scan n_e at t=25 µs

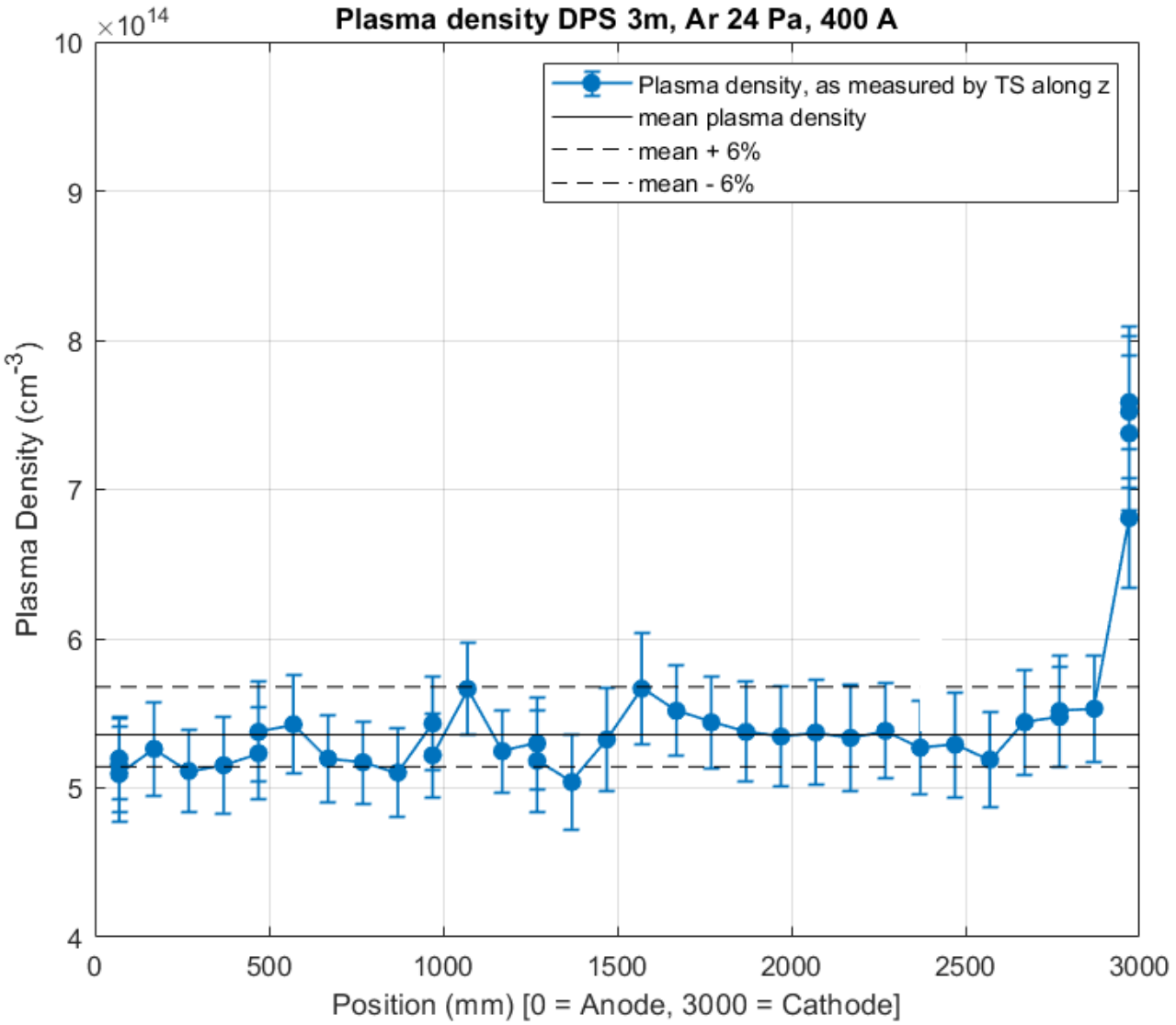
→ n_e measured every 10 cm, along 3 m
(50 accumulations per point)

→ **Fit error:** 5 % per point

→ Near cathode (first 10 cm):
higher density and stronger fluctuations

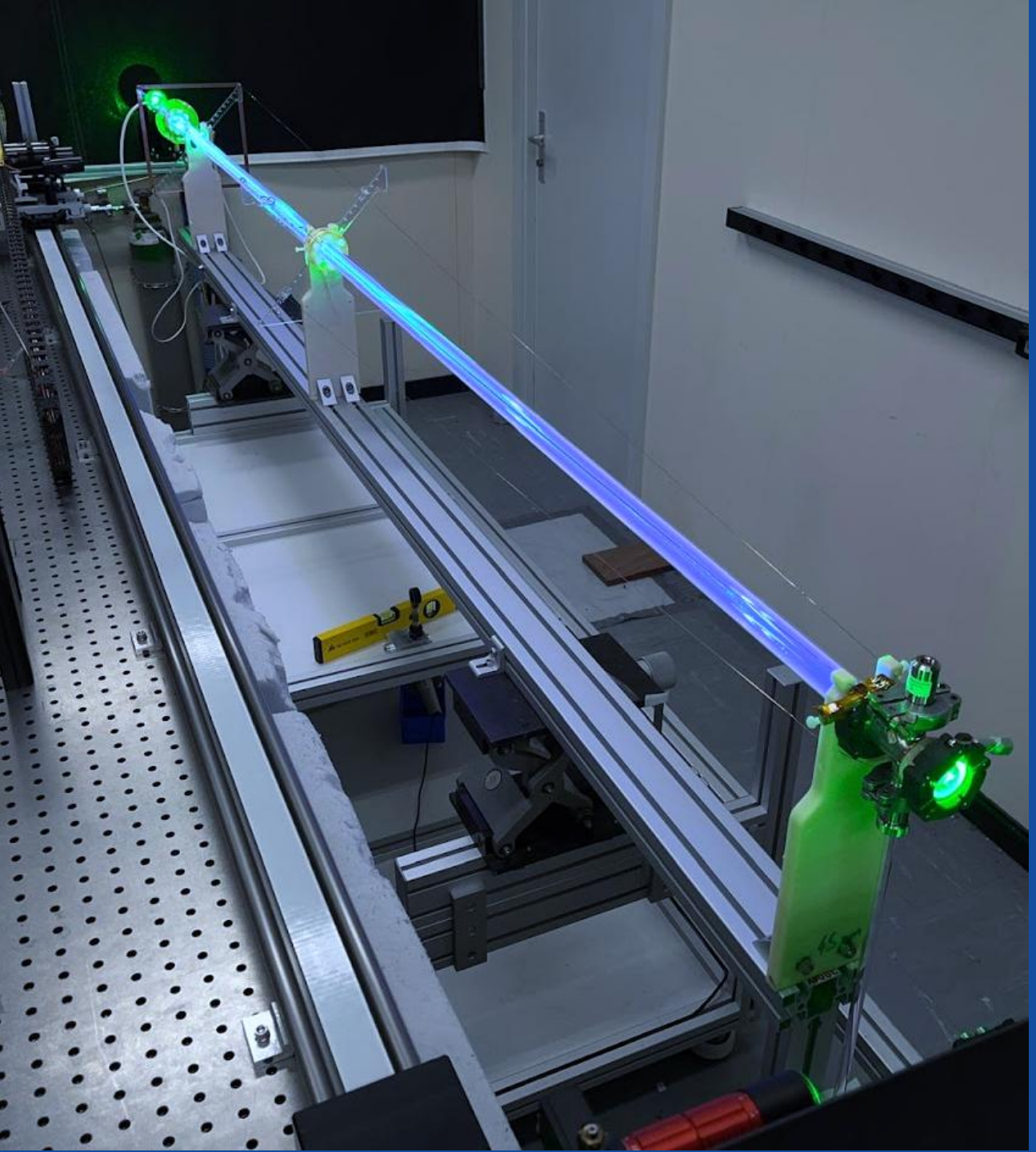
→ Excluding cathode region:
uniformity within ±6%

(comparable to diagnostic precision)



Conclusions:

- **AWAKE has well-defined program towards first particle physics applications**. AWAKE R&D is relevant for other PWFA: beam quality, external injection, **long plasma sources.**
- **Discharge Plasma Source (DPS) successfully built and characterized:** Longitudinal interferometry measured electron densities from $1–20\times10^{14}$ cm^{-3} in He, Ar, and Xe.
  - **Excellent plasma stability and reproducibility:** <0.2% pressure and <0.5% current variability lead to <2% peak density fluctuation.
  - **Axial profile measurement** shows **uniformity within ±6%** along the 3 m length (excluding the cathode).
- **First test of an alternative plasma source in AWAKE:** Self-modulation successfully demonstrated in a discharge plasma; smooth integration enabled studies on ion motion, filamentation, and light diagnostic for the wakefield.



Thank you for your attention

From the AWAKE scalable plasma source collaboration:
C. Cobo, L. Forrester, Z. Najmudin (IC-London)
I. Furno (EPFL), M.Santos (CERN)

And specially to AWAKE DPS-run team:
Edda Gschwendtner, Nikita van Gils, Arthur Clairembaud, Erwin Walter, John Farmer, Fern Pannell, Giovanni Zevi Della Porta, Livio Verra, Marlene Turner, Ans Pardon, Eloïse Guran, Stefano Mazzoni, Eugenio Senes, Jan Pucek, Jan Mezger, Michele Bergamaschi, Patric Muggli