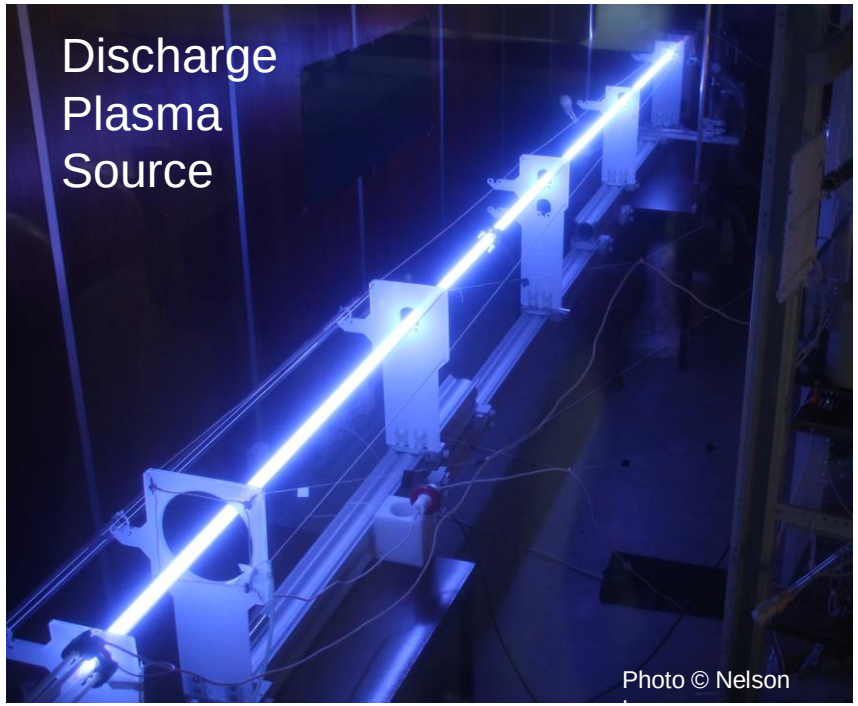
AWAKE **scalable** plasma sources R&D

3rd Townhall Meeting High Gradient Accelerator Plasma/Laser, May 31, 2021

Alban Sublet, on behalf of the AWAKE Plasma Sources R&D team



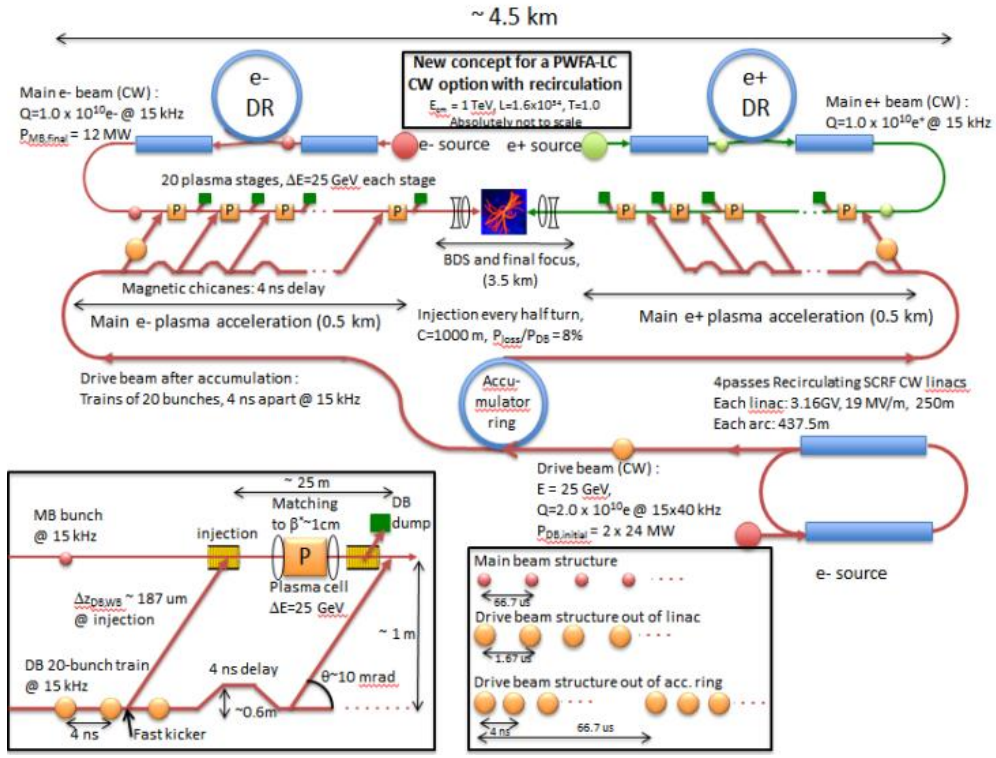
O. Grulke, B. Buttenschön (IPP-Greifswald), I. Furno, C. Stollberg, P. Guittienne (EPFL-SPC), O. Schmitz, M. Zepp, M. Granetzny, B. Elward (Univ. of Wisconsin)
N. C. Lopes, F. A. Silva, N. Torrado (IST-Lisbon), Z. Najmudin, B. Chen (IC-London),
C. Amoedo, A. Sublet, E. Gschwendtner (CERN)

Acceleration towards HEP energies

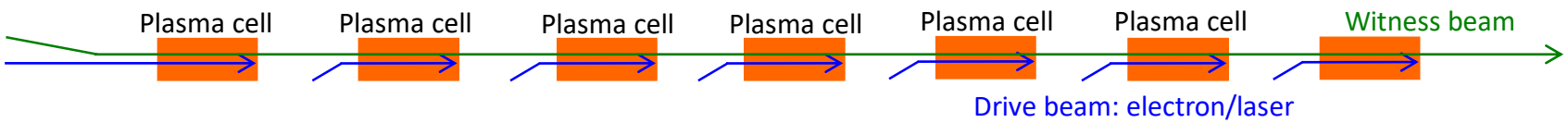
- Electron/laser driven plasma wakefield accelerator (PWA):
  - energy carried by the driver < 100 J
  - propagation length in the plasma < 1 m

→ Need **staging** to reach TeV:

Layout of a 1 TeV PWFA Linear Collider



E. Adli *et. al.*,arXiv:1308.1145 (2013)



→ Technical challenges: many stages, efficiency, timing, tolerances, etc.

Alternative AWAKE scheme

- AWAKE: proton beam driven PWA
  - SPS 400 GeV proton beam driver → 19 kJ

→ Allows to consider single stage to reach TeV energy range:

Application example: search for dark photons in beam dump experiments (like NA64 at CERN)

→ 33 GeV electron beam achievable with a **50 m plasma cell**

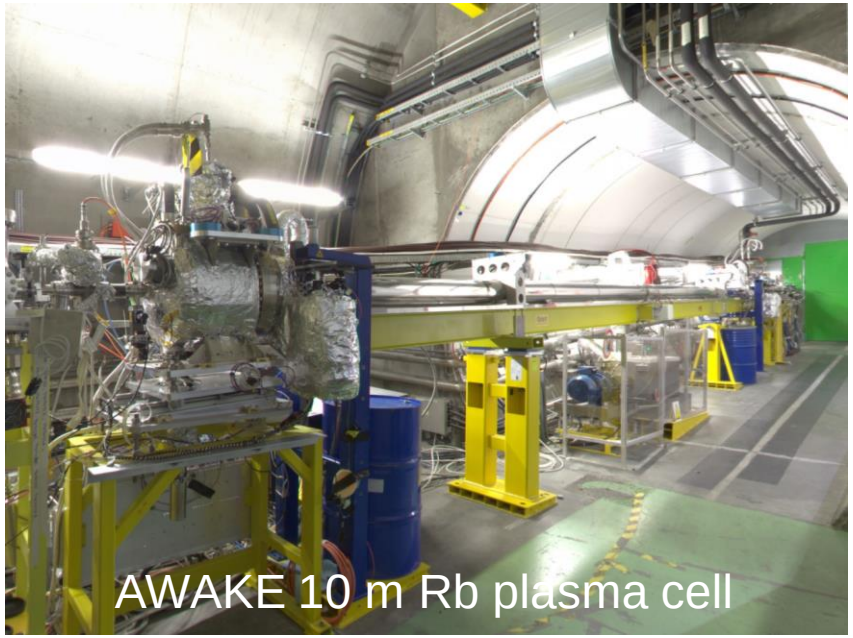
→ Dedicated AWAKE **plasma sources R&D program** and lab at CERN to design a scalable plasma cell

(see A. Caldwell “Particle Physics possibilities with AWAKE-like technology” for HEP applications)

Scalable plasma sources

- Present AWAKE 10 m plasma cell: Rb vapour ionized by TW laser

→ Limitation: laser pulse energy depletion for length > 10 m


AWAKE 10 m Rb plasma cell

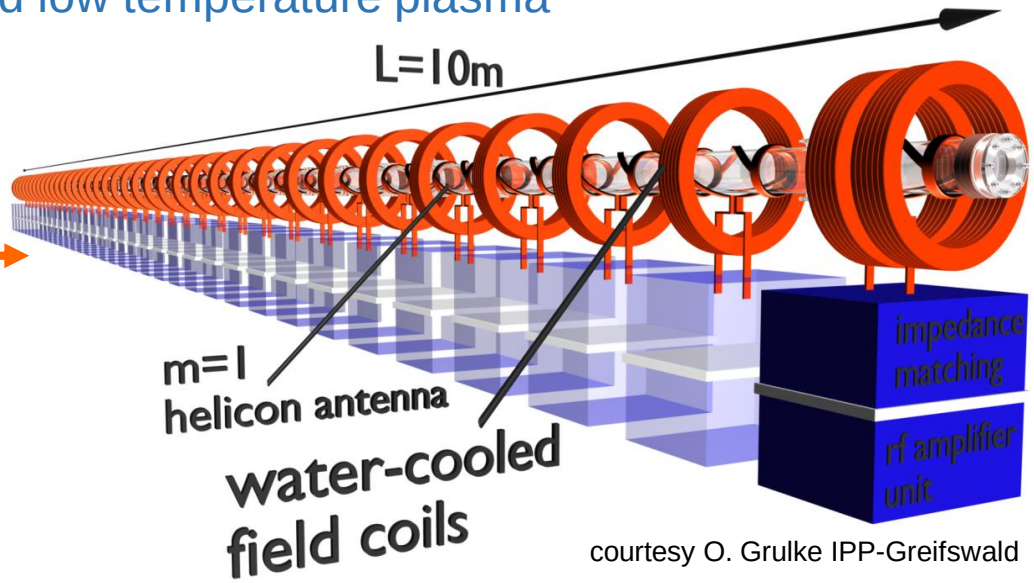
→ Beyond 10 m, we need:

1. A modular approach that allows scalability
2. Source with efficient plasma production to reach high density and low temperature plasma

→ Two technologies identified:

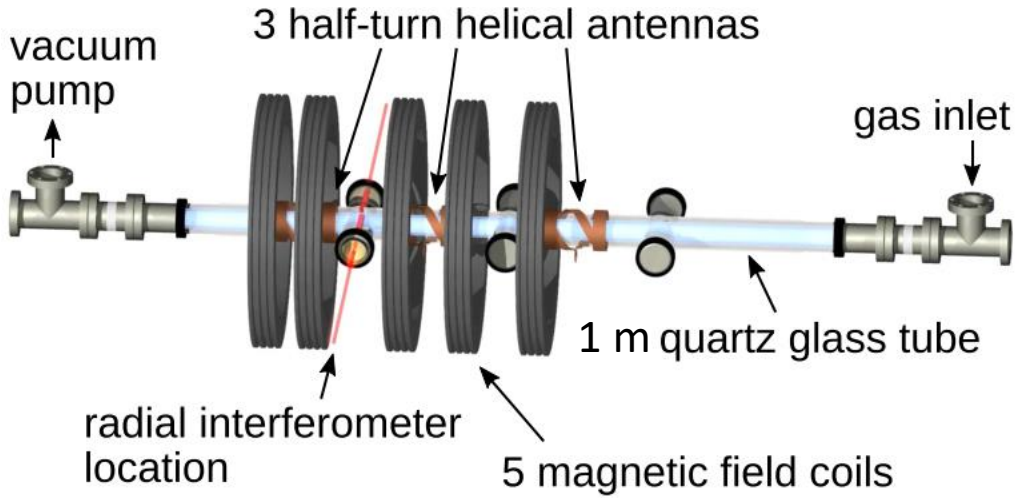
- Helicon Plasma Source → RF wave heated plasma
- Discharge plasma source → pulsed arc plasma discharge

→ Challenge: demonstrate scalability within AWAKE specifications



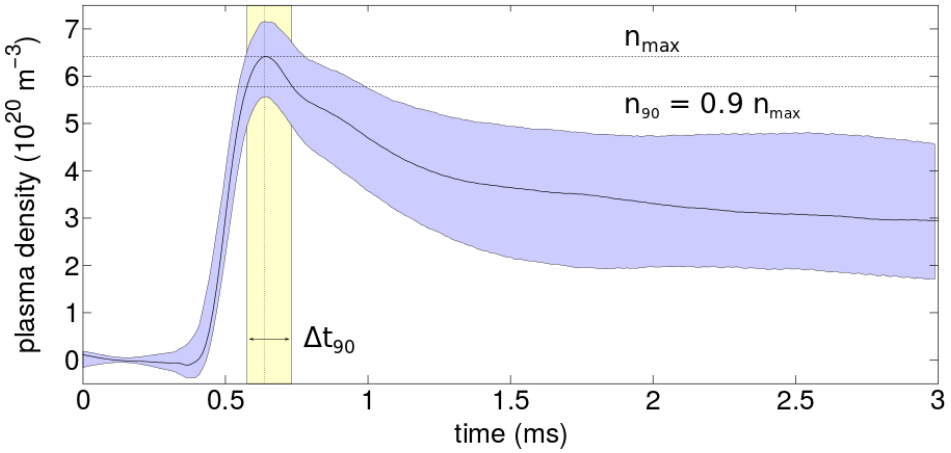
courtesy O. Grulke IPP-Greifswald

Helicon Plasma Source (HPS)



- Magnetized (B ≤ 130mT) quartz glass vacuum tube filled with 1-10 Pa Ar
- Modular RF power systems with individual amplifier/matching/antennas (3-4x 12kW @ 13.56MHz for 1 m cell)
- Distributed antennas along the tube to couple the RF power

→ AWAKE density demonstrated at IPP-Greifswald



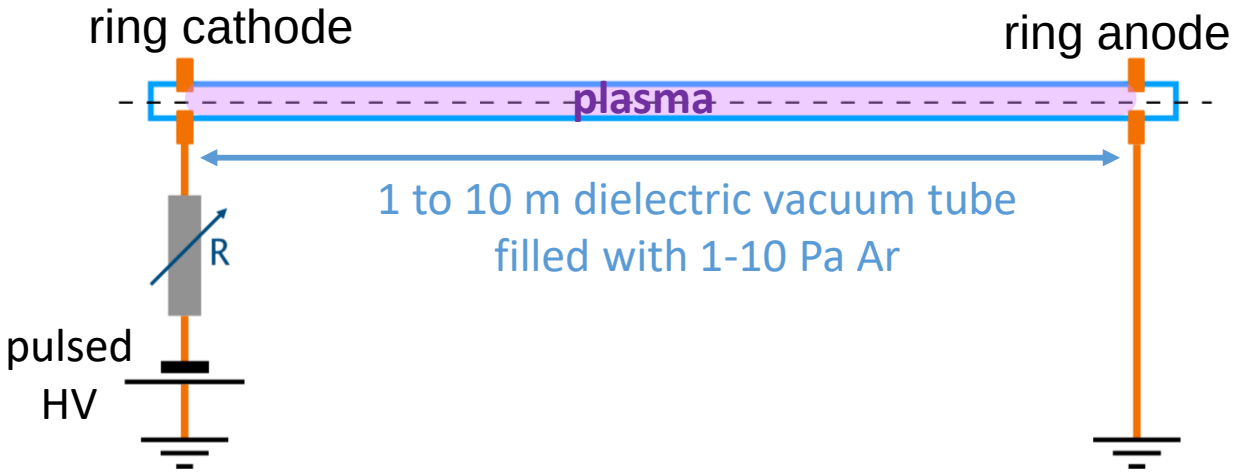
B. Buttenschön *et al* 2018 *Plasma Phys. Control. Fusion* **60** 075005

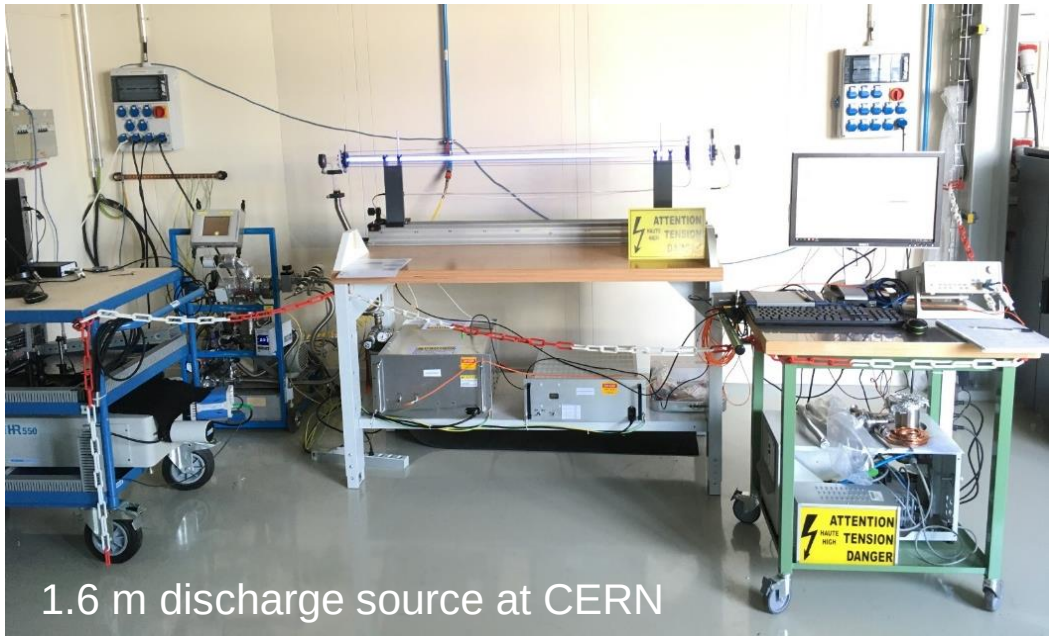
https://doi.org/10.1088/1361-6587/aac13a

→ assess plasma longitudinal uniformity → **plasma diagnostics**

→ **1 m core module** scalable to arbitrary length

Discharge Plasma Source (DPS)



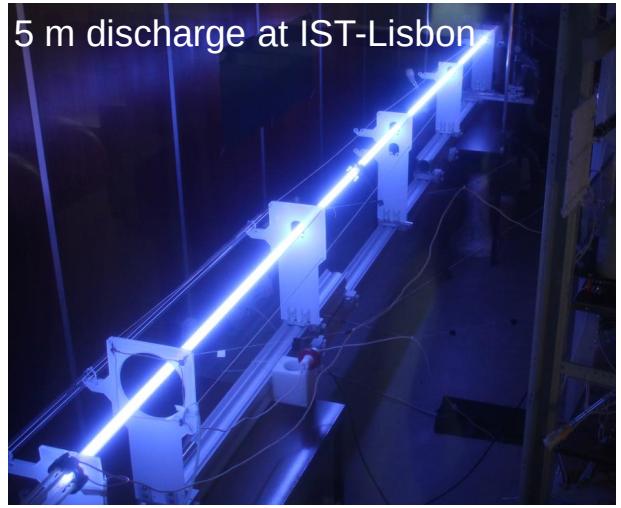


1.6 m discharge source at CERN

- Pulsed high voltage (~ 2-20 μs) power supplies designed by IST-Lisbon:

→ 100 kV ignition to strike an arc + “heater” to increase discharge current up to ~ 1 kA and thus plasma density

- 1.6 m reference cell operational at CERN lab
- 5 m discharge demonstrated in IST-Lisbon test tube
- 10 m discharge to be tested in summer 2021 at IST-Lisbon.


5 m discharge at IST-Lisbon

→ assess plasma density and uniformity → **plasma diagnostics**

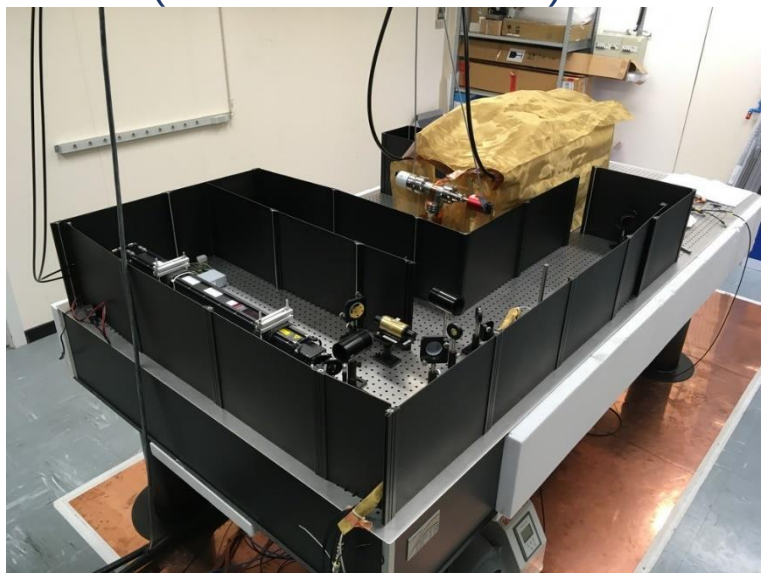
→ scalability: **10 m core modules** to be connected together and synchronised

Q&A: key R&D needs achievable in existing R&D facilities

- **measure** $n_e = 7 \times 10^{20}$ m^{-3} within 0.25 % uniformity over 10 m (starting on 1 m cell setup at CERN)

→ Addressed by collaboration institutes: dedicated **plasma diagnostics** prepared for CERN plasma sources lab

CO_2 interferometer, CERN 1 m cell (from IPP-Greifswald)



B. Buttenschön *et al,* 2018 *Plasma Phys. Control. Fusion* **60** 075005
https://doi.org/10.1088/1361-6587/aac13a

Thomson scattering (EPFL-SPC)

R. Agnello *et* al, 2020, Journal of Plasma Physics, 86(3), 905860306,
https://doi.org/10.1017/S0022377820000173

Laser Induced Fluorescence (University of Wisconsin - Madison)*

J. Green *et al*, Physics of Plasmas 27, 043511 (2020)
https://doi.org/10.1063/1.5129232

- **optimize** accordingly the source design to achieve these nominal parameters in a long source.

* Funded by the National Science Foundation under grant PHYS-19033116
AWAKE project and helicon plasma cell development in particular is also presented in U.S. 2021 Snowmass process under AF6 “Advanced Accelerator Concepts”

Q&A: additional support/resources

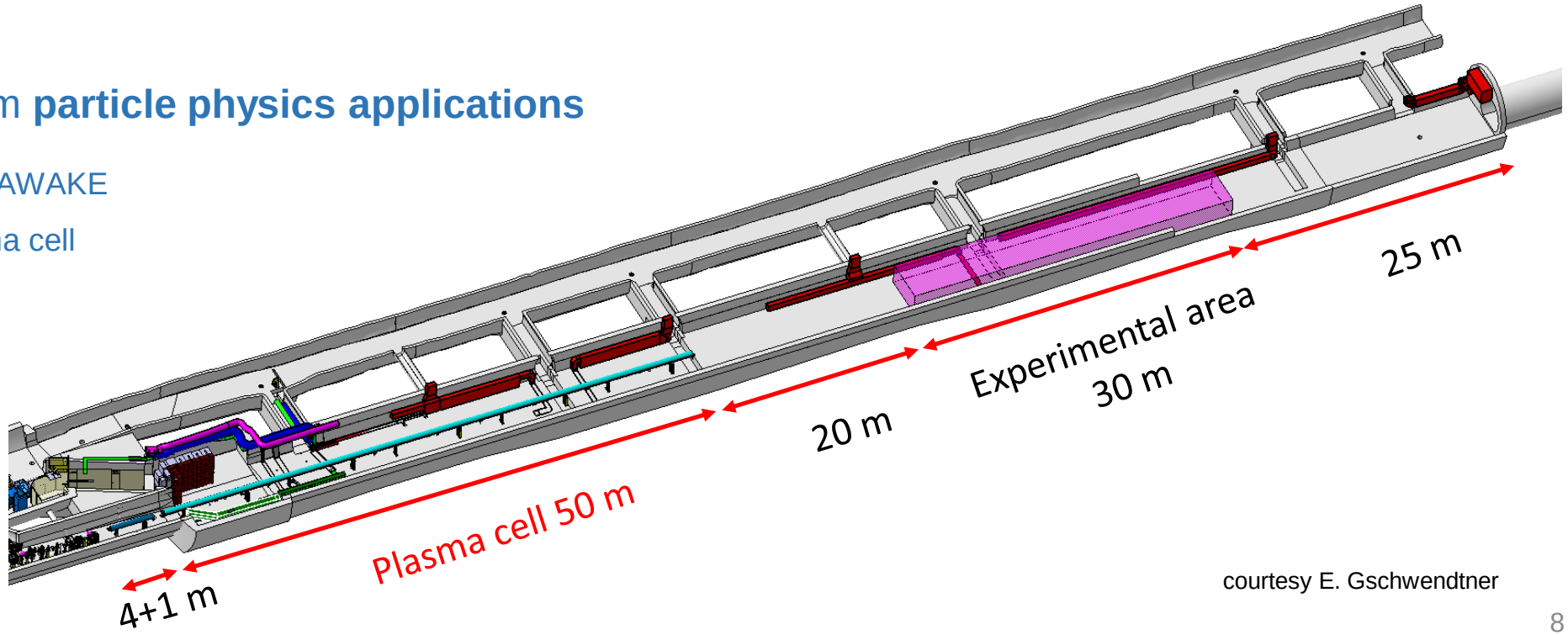
→ **Technical development and funding** in view of long plasma cell (≥ 10 m) in AWAKE tunnel:

- Development of pulsed RF/DC power supplies → optimize energy conversion
- Design of interfaces with Rb cell and experiment → long plasma cell boundaries
- Cabling, synchronization and diagnostic/monitoring of plasma cell → control/feedback scheme
- ...

→ And towards medium term **particle physics applications**

Example: NA64-like experiment @ AWAKE

33 GeV electron beam / 50 m plasma cell



courtesy E. Gschwendtner

Q&A: timeline and budget