Wrap-Up

Edda Gschwendtner, CERN

AWAKE External Review, 5/2/2024, CERN
AWAKE Run 2 Well-Defined Scientific Roadmap – Milestones

International collaboration, well organized, with strong contributions from the collaborating institutes.

Unique proton-driven PWFA experiment at CERN and part of the European Strategy for Particle Physics Roadmap.

Run 2a (2021-2022): OPTIMIZATION: demonstrate the seeding of the self-modulation of the entire proton bunch with an electron bunch

Run 2b (2023-2024): STABILIZATION: maintain large wakefield amplitudes over long plasma distances by introducing a step in the plasma density

(2025-2027): CNGS dismantling, CERN Long Shutdown LS3, installation of Run 2c

Run 2c (2028-2031): QUALITY: demonstrate electron acceleration and emittance control of externally injected electrons.

Run 2d (2032-LS4): SCALABILITY: development of scalable plasma sources to 100s meters length with sub-% level plasma density uniformity.

Once AWAKE Run 2 is demonstrated: First particle physics application of the AWAKE-like technology.
AWAKE Run 2 Technological Advancements

New electron-source:
- S-band e-gun with X-band accelerator, Prototyping with CLIC/CLEAR

✓ Address key challenges of plasma wakefield community
✓ External injection, scalable plasma source development
✓ Benefit of accelerator technology expertise at CERN
✓ Synergy with future electron/positron colliders at CERN

Beam Instrumentation

BPMs 10 µm resolution
AWAKE Scientific Merit

Wakefield growth due to SM

Proton bunch self-modulation

Seeding with relativ. ionization front

Seeding with electron bunch

Filamentation instability

Ion motion, Sim/Meas

Accelerated electrons

Increase e-energy with density gradients

Effect of density step on accelerated electrons

Beam-hose instability

✓ All milestones achieved – plus additional ones.
✓ Relevant studies for general plasma wakefield acceleration concepts.
✓ Many prizes, thesis and publications in high impact journals.
Expected parameters:
• Normalized emittance: (2-30) mm mrad
• $Q_e = 100$ pC
• $dE/E \sim \%$
• Energy gain:
  • Run 2c: $E \sim 4$-10 GeV, 10m
  • Run 2d: $E > 10$ GeV, 10+ m

✓ AWAKE simulation results provide confidence that the Run 2c/d goals are achievable.
✓ Expected parameters after Run 2 are in line with beam parameters for first particle physics applications.

Developments shared with other plasma-based accelerators:

◊ Externally inject an e⁻ bunch  ↔  injection, staging
◊ Acceleration to multi GeV level  ↔  large energy gain
◊ Control e-bunch quality: $E$, $\Delta E/E$, $Q$, $\varepsilon_N$  ↔  quality!!
◊ Plasma source: length, density uniformity, reproducibility, tunability  ↔  staging, >1 plasma
◊ Development of diagnostics: plasma density, bunch parameters ($\varepsilon_N$)  ↔  quality

Ex: Broad tolerances for SMI control with a density step
The Review Panel is tasked with the following evaluations:

1. Assess the feasibility and coherence of the full AWAKE Run 2 roadmap.

2. Evaluate the scientific merits of the accelerator physics and technological advancements expected from the AWAKE Run 2c and 2d programmes, their complementarity with other ongoing initiatives, and their impact on the overall PWFA field.

3. Evaluate whether by the end of the AWAKE Run 2c and 2d programmes all technologies and beam parameters required to allow for a future particle physics experiment based on proton driven wakefield acceleration will have been demonstrated.

4. Determine whether AWAKE is the most appropriate facility for the realization of the anticipated advancements of AWAKE Run 2c and 2d.