Status and prospects of the AWAKE experiment

ICHEP, Seoul 2018

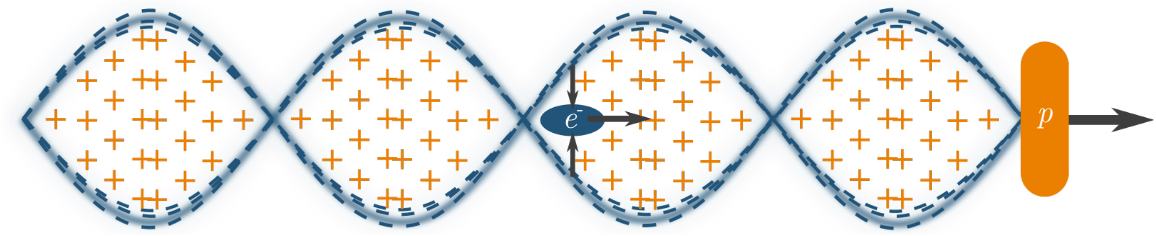
F. Keeble, UCL
On behalf of the AWAKE Collaboration

Who we are

AWAKE is an experiment to demonstrate proton driven plasma wakefield acceleration for the first time.

We aim to accelerate electrons to GeV energies to prove the technique's potential for HEP projects.

Plasma wakefield acceleration



Proton driven plasma wakefield acceleration

Previous plasma wakefield experiments have been driven by laser pulses and electron beams.

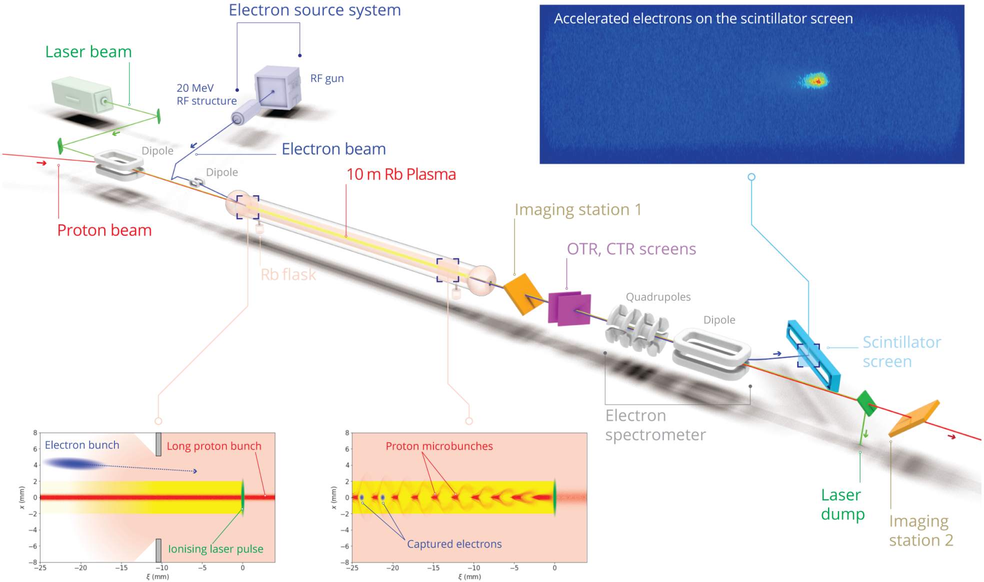
ILC/CLIC, 500 GeV with $2 \times 10^{10}\ e^{-} \rightarrow 1.6\,\mathrm{kJ}$

Producing high energy bunches in a single stage requires high drive beam energy.

SPS, 400 GeV with $3 \times 10^{11}\ p \rightarrow 19.2\,\mathrm{kJ}$

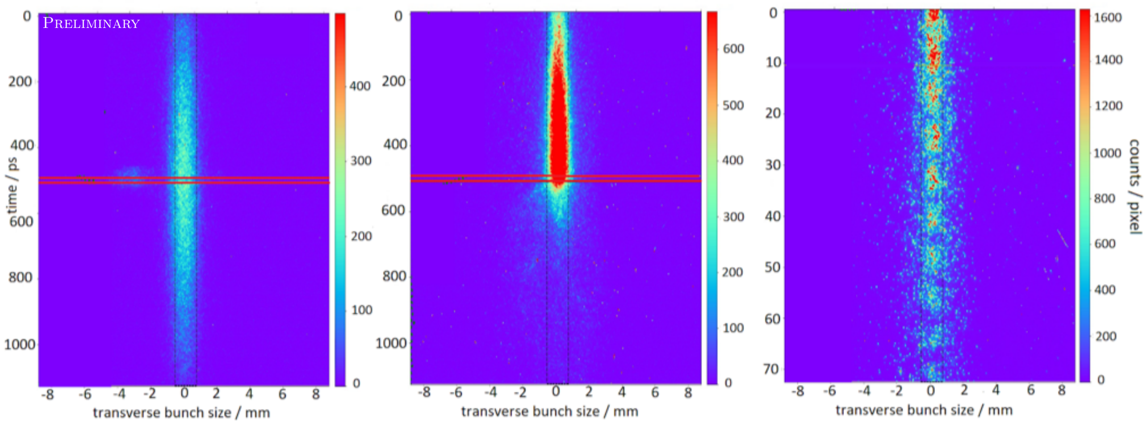
Proton drive beams can give high gradient ($> 1\,\mathrm{GV\,m^{-1}}$) acceleration over 100's of metres.

AWAKE at CERN



Proton modulation results I

OTR images taken with a streak camera

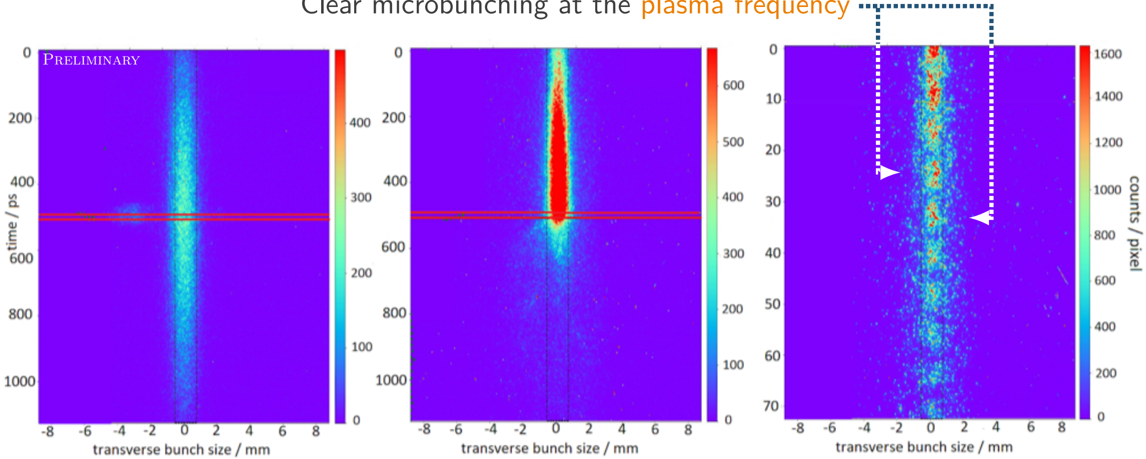


Protons and low power laser

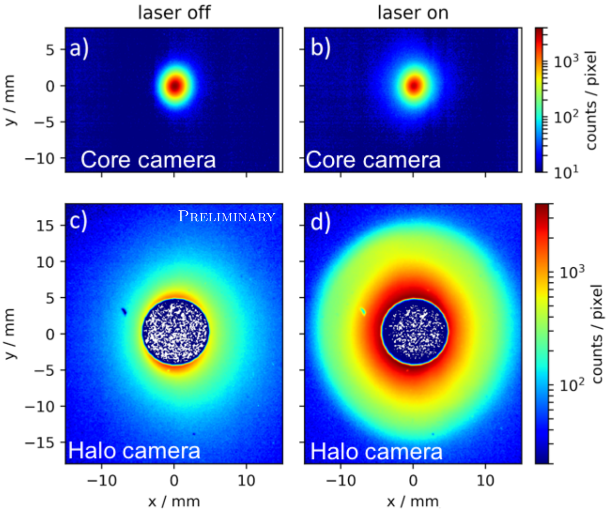
Protons and high power laser

Proton modulation results I

Clear microbunching at the plasma frequency

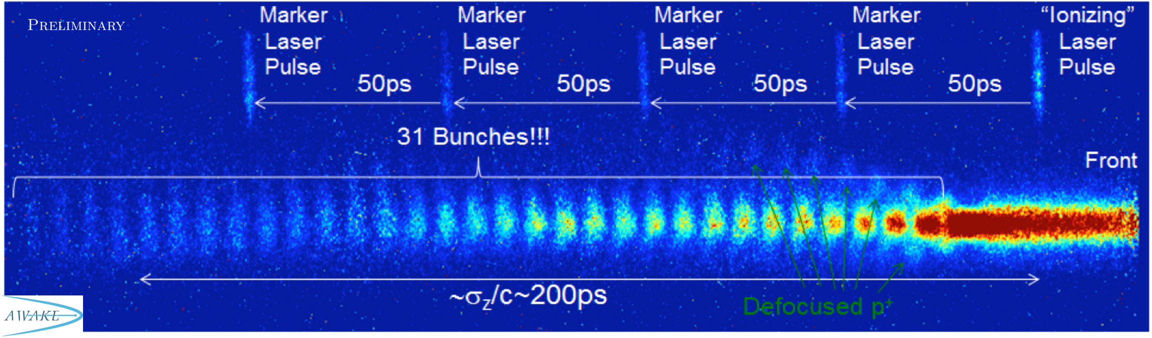


Proton modulation results II



Blown-out protons give clear evidence of strong transverse fields acting on the bunch.

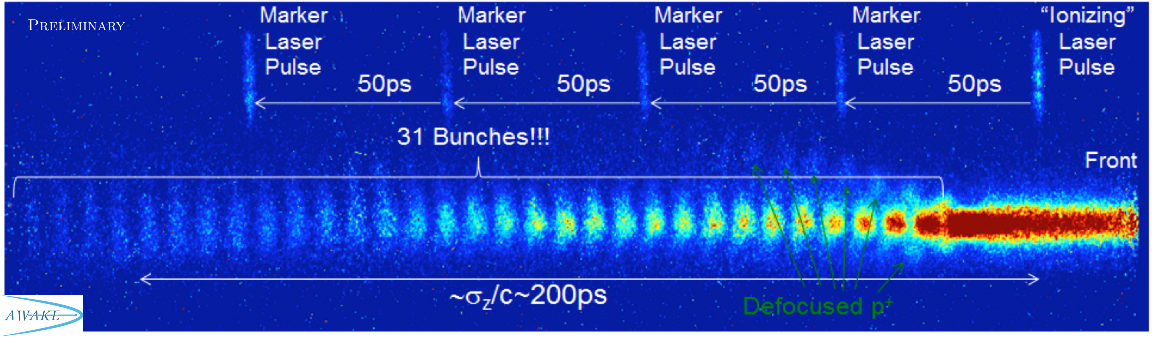
Proton modulation results III



Stitching together multiple streak camera images shows the full bunch train.

This is only possible because of how reproducible the self-modulation is.

Proton modulation results III



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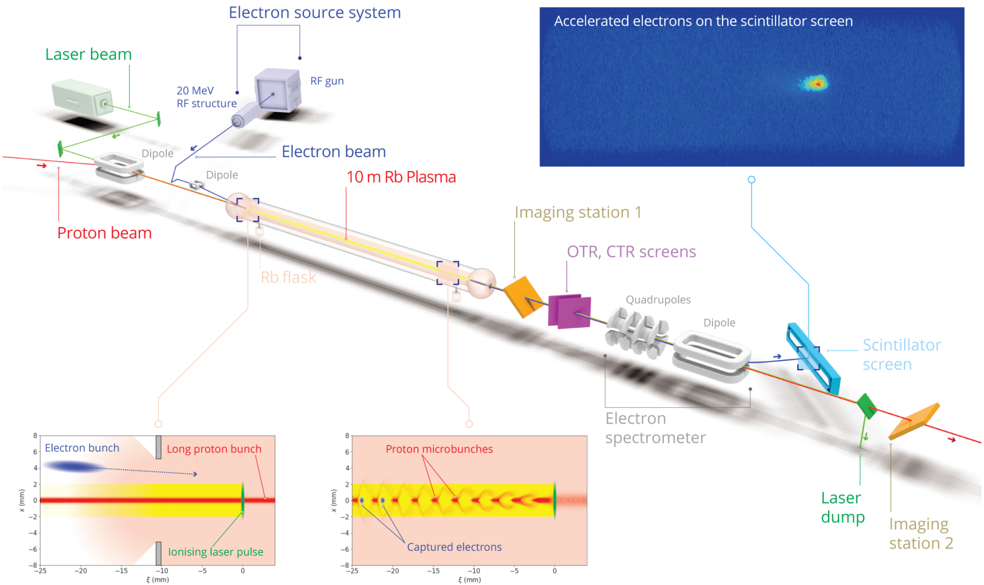
More self-modulation details in two upcoming papers.

Electron acceleration

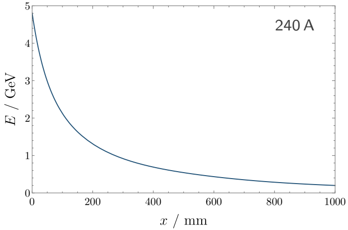
[redacted] AWAKE [redacted] is [redacted] doing [redacted] very [redacted] well [redacted]

Electron acceleration results

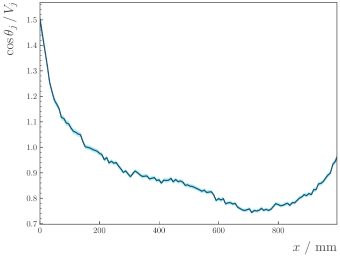

Electron source system
Laser beam
20 MeV
RF structure
RF gun
Accelerated electrons on the scintillator screen
Dipole
Electron beam
Dipole
10 m Rb Plasma
Proton beam
Imaging station 1
OTR, CTR screens
Rb flask
Quadrupoles
Dipole
Scintillator screen
Electron spectrometer
Laser dump
Imaging station 2
Electron bunch
Long proton bunch
Ionising laser pulse
x (mm)
ξ (mm)
Proton microbunches
Captured electrons
x (mm)
ξ (mm)

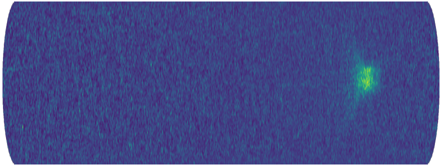
Spectrometer analysis recipe

Position ↔ energy conversion



Geometric corrections





CCD count ↔ charge conversion

Background subtraction

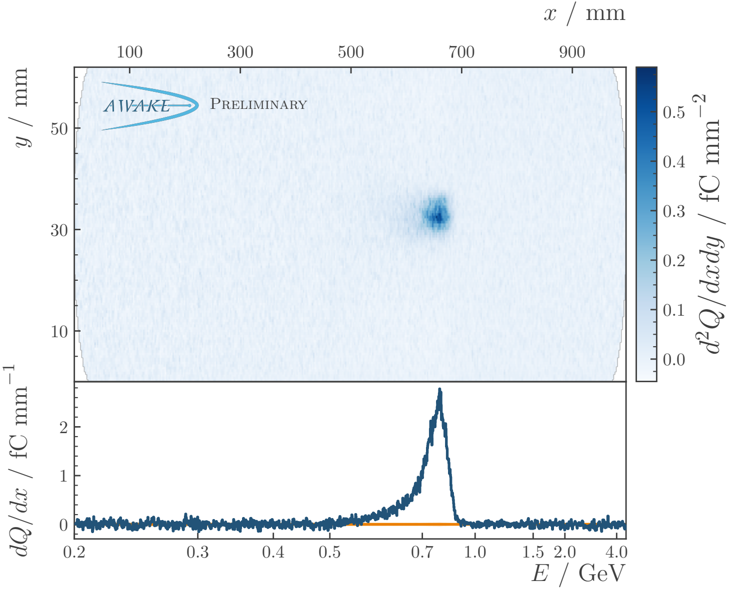
Electron acceleration results I

Event at $n_{pe} = 1.8 \times 10^{14}\,\text{cm}^{-3}$ with a 5% / 10 m density gradient.

Acceleration to $\sim$ 800 MeV. The energy is dependent on n_{pe} and on the gradient.

Capture efficiency not yet optimised, leading to low accelerated bunch charge of $\sim$ 0.2 pC. We're working to improve this now.

Spectrometer quadrupoles were focusing at $\sim$ 600 MeV here.

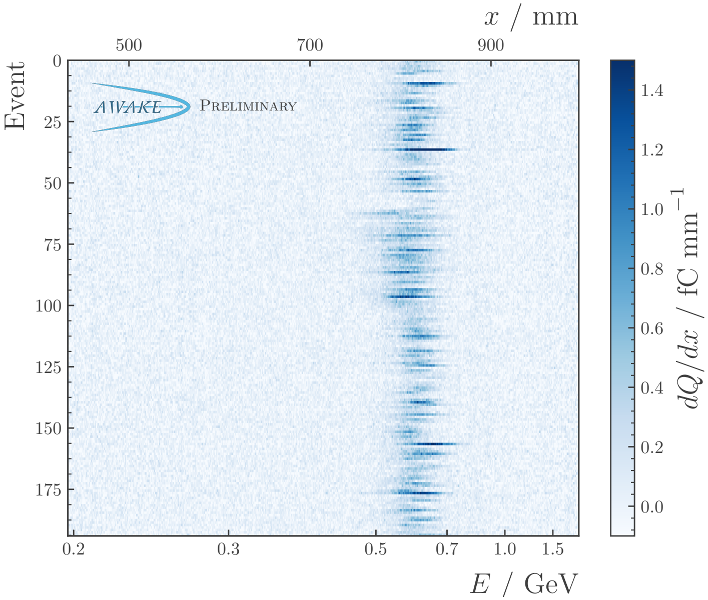


Electron acceleration results II

Consecutive electron injection events at $n_{pe} = 1.8 \times 10^{14}\,\text{cm}^{-3}$.

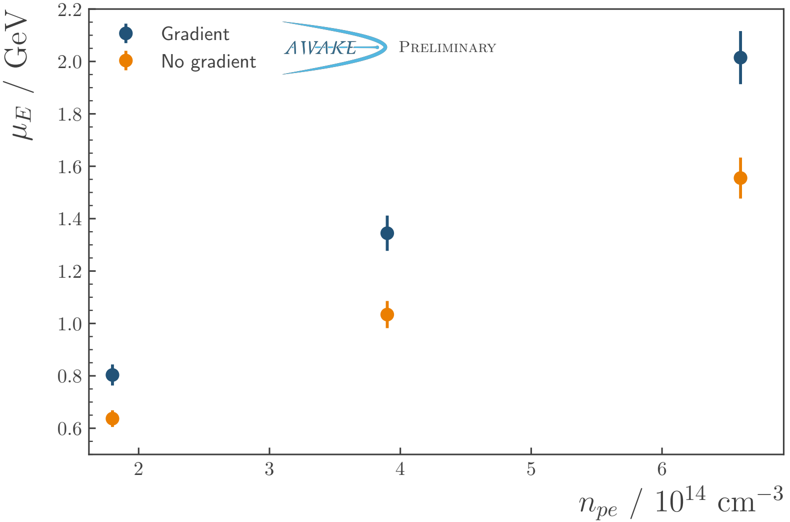
Quadrupole scan performed over this period and other parameters held constant.

This stability is crucial for further development.

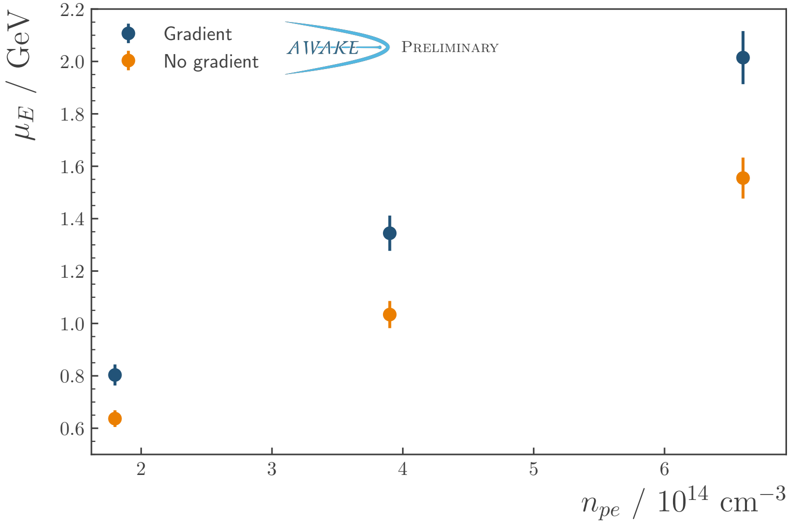


Electron acceleration results III

Acceleration up to 2 GeV has been achieved.

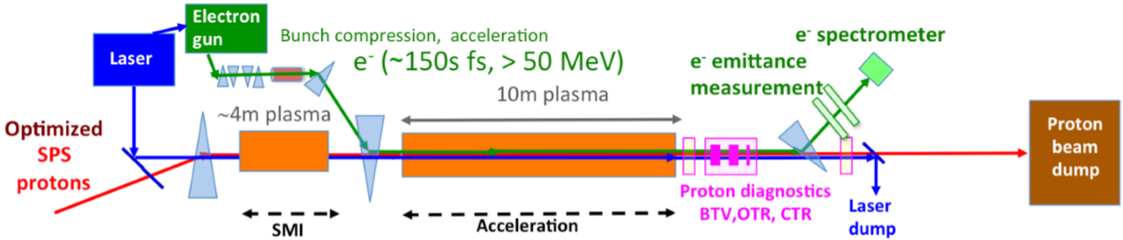


Charge capture decreases with n_{pe}.



Into the future

AWAKE Run 2



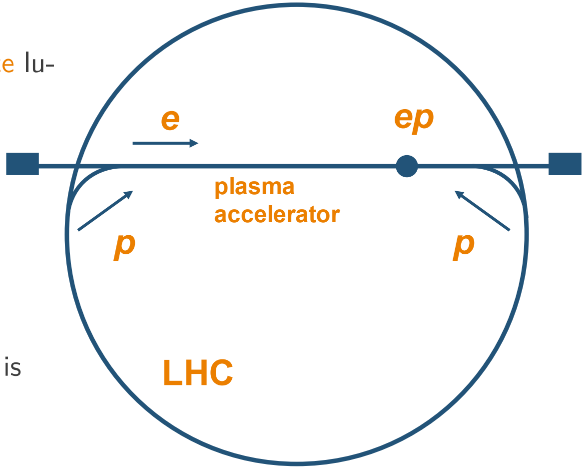
- Demonstrate the use of scalable plasma cells.
- New diagnostics for plasma, protons and electrons.
- Achieve high energy and high charge capture whilst preserving emittance.

Future HEP projects

Considering options for high energy but moderate luminosity e^- bunches.

Fixed target experiments, such as dark matter searches, are being considered.

An ep collider looking at saturation (and more) is a leading prospect.



Caldwell & Wing, Eur. Phys. J. C (2016) 76

We'd like to hear suggestions, both big and small.

Summary

AWAKE has demonstrated proton-driven plasma wakefield acceleration for the first time.

- Acceleration to 2 GeV has been observed.
- The reproducibility of the acceleration is already very promising for the future.
- Only small amounts of charge have been captured so far.
  - We're working to improve the injection electron beam.
  - We will begin scanning the available parameters (injection angle, focal point, etc.) to maximise the charge.
- We're increasingly looking beyond this year to AWAKE run 2.
- There are many good applications for this technology and we're open to suggestions.

These are only the first results and there will be many more coming soon.

BACKUP

2 GeV projection