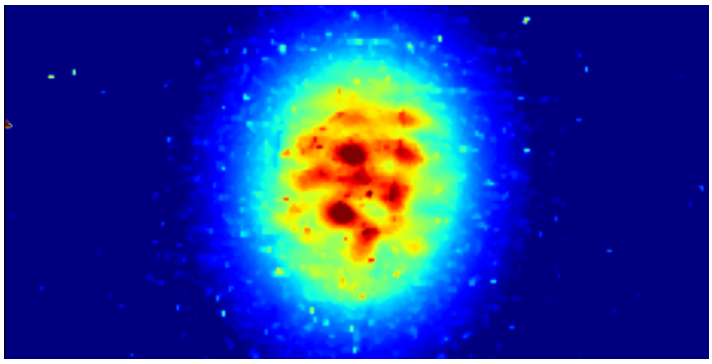
Filamentation Observed in Wakefield Acceleration

A particle-beam-generating method—called wakefield acceleration—uses proton bunches, which can fragment into high-density filaments as a result of their interactions with plasma, new experiments show.

By **Rachel Berkowitz**

Researchers at the AWAKE experiment at CERN in Switzerland are studying a potential way to accelerate electrons by firing a proton bunch into a plasma. However, one challenge facing this so-called wakefield acceleration is that instabilities can form in the proton bunch, degrading the beam's structure and reducing its quality and acceleration length. To investigate this behavior, Livio Verra and his colleagues in the AWAKE Collaboration injected a long proton bunch into a plasma and observed fragmenting of the bunch into narrow, dense strands [**1**]. The measurements indicate the conditions under which this so-called filamentation instability originates.

The researchers started their experiments by generating a plasma in a long, thin glass tube filled with argon gas. Into the end of the tube, they injected a stream of high-intensity proton bunches, delivered by the CERN Super Proton Synchrotron, in which each proton had an energy of 400 GeV. They placed metallic screens in the beam path before and after the tube of plasma and used them to capture snapshots of the proton bunches. From these transverse profiles, the team could identify structural changes within the bunch caused by the interaction with plasma.



Credit: AWAKE Collaboration

Verra and his colleagues observed narrow dots appearing near the center of the bunch, indicating that it had separated into threads. They determined that this filamentation appeared for proton bunches that had a radius 1.5 times larger than the plasma skin depth—a parameter that describes how deep radiation can penetrate into plasmas. The results indicate that the instability can be avoided by restricting the bunch radius below this threshold value.

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REFERENCES

1. L. Verra *et al.* (AWAKE Collaboration), "Filamentation of a relativistic proton bunch in plasma," **Phys. Rev. E 109, 055203 (2024).**