Using Conventional Beams To Drive Plasma Wakefield Acceleration

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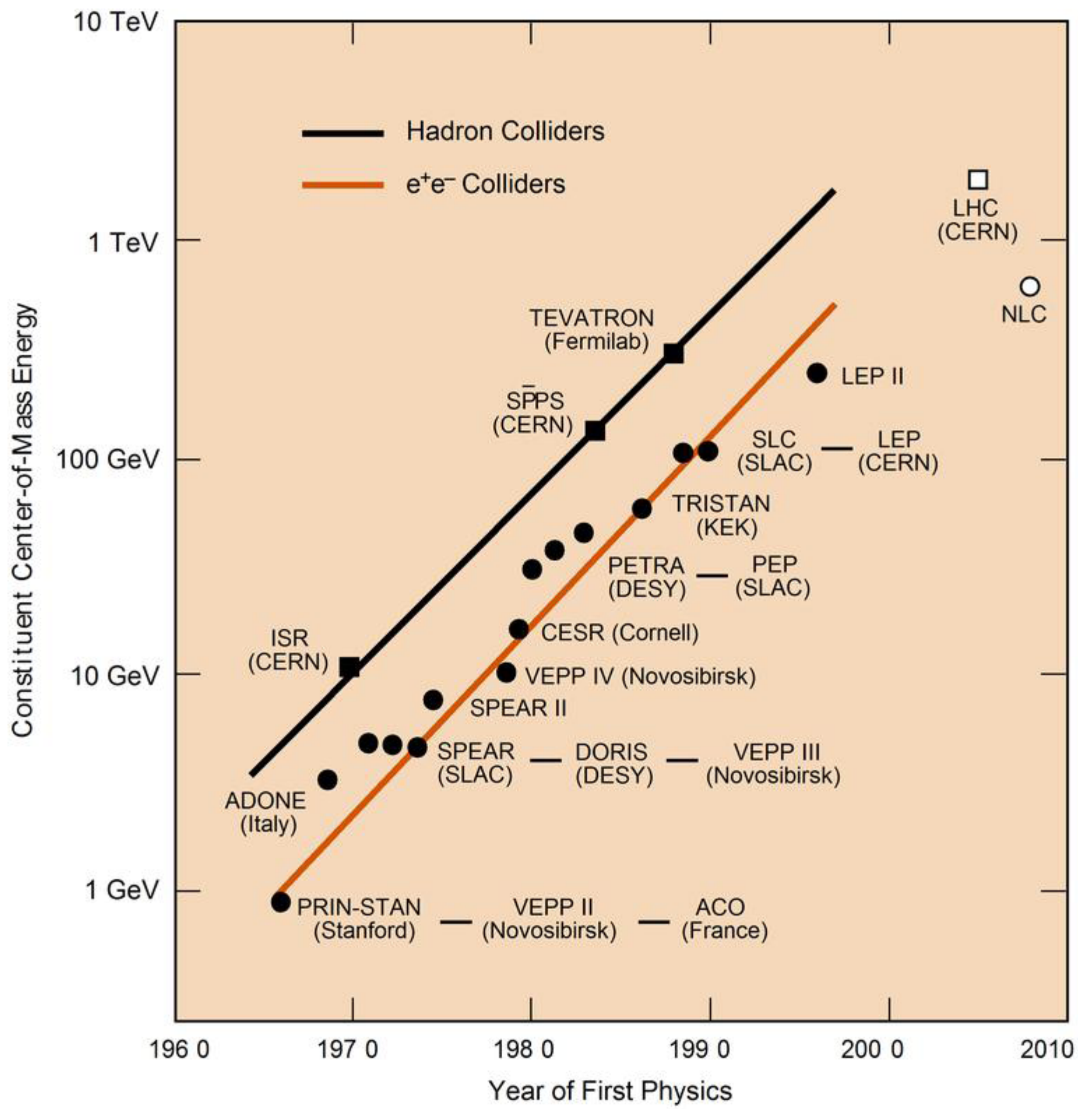
Current RF Accelerators

- Accelerate particles within a metal cavity.
- Electric fields greater than ~100 MVm^{-1} will ionize the metal itself.
- To reach higher particle energies one has to increase the length over which the particles are being accelerated.

Plasmas can support higher electric fields. A plasma of number density $n_e = 10^{16}\ cm^{-3}$ can support electric fields of $E = 10\ GVm^{-1}$.



The Livingston plot shows the switch on time of hadron and lepton colliders at the energy frontier as a function of achieved energy.

The SLAC Experiment

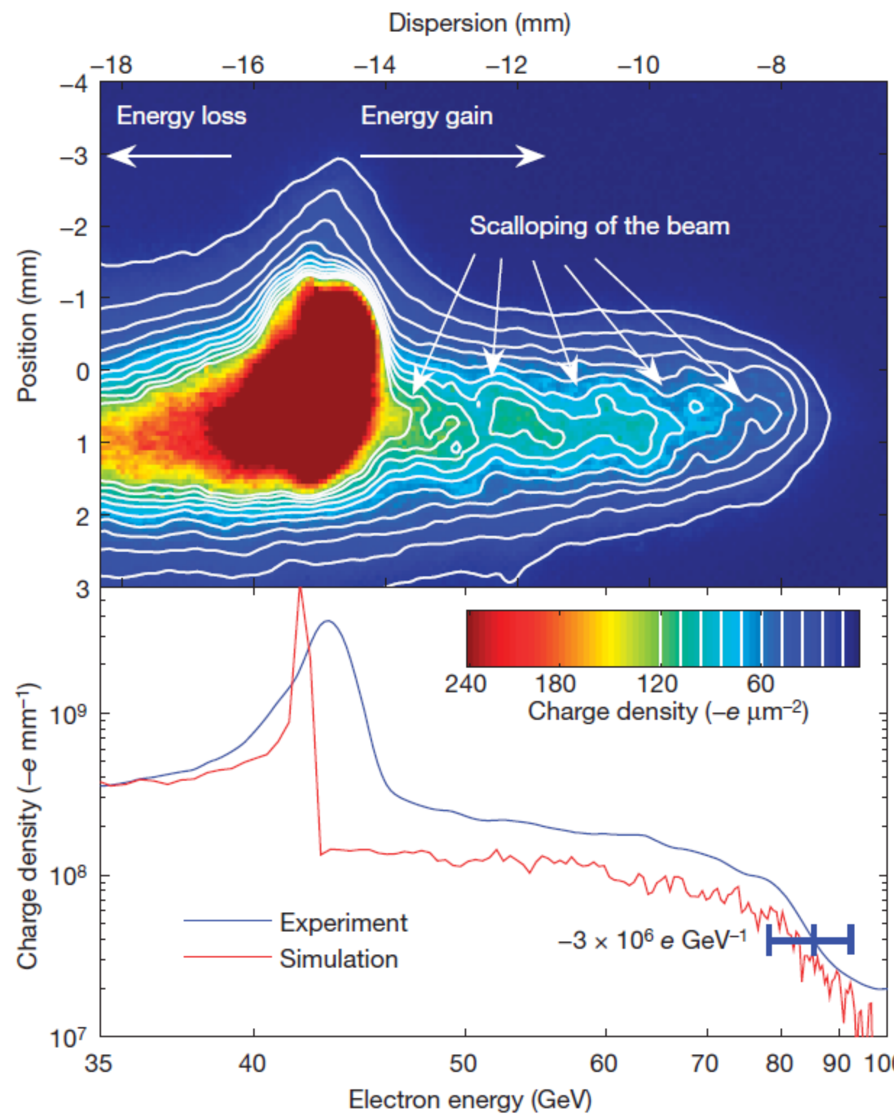
Stanford Linear Accelerator Center (SLAC).

Slac Beam Parameters	Plasma Parameters
• E = 42 GeV • σ_z = 15 um* • σ_r = 10 um • Q = 3 nC	• $n_e = 2.7e23\ cm^{-3}$ • λ_p = 100 um • Element = Lithium • Cell = Oven

The Slac beam was compressed from σ_z = 6 mm to σ_z = 15 um using a ~10m magnetic chicane, making it suitable wakefield driver.

E_{avg} = 52 GVm^{-1} over 85cm.
84 GeV electrons generated!

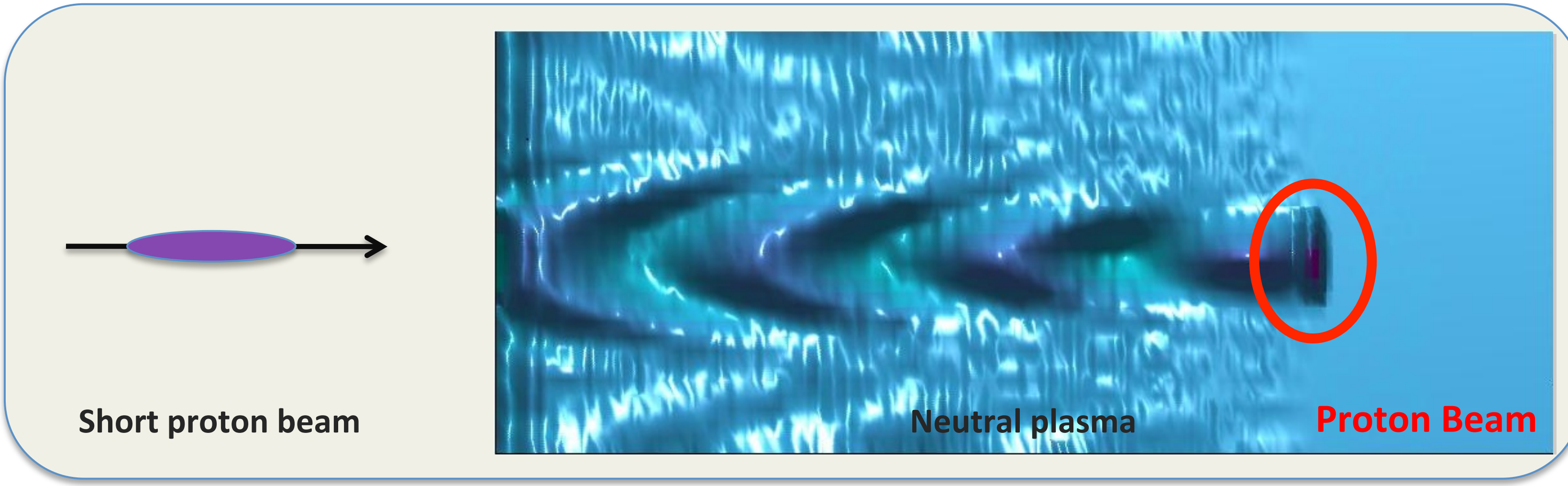
They achieved energy gain of the 3-km-long SLAC accelerator in 85 centimetres. Although the luminosity was greatly reduced.



Ian Blumenfeld1, Christopher E. Clayton2 et al. Energy doubling of 42 GeV electrons in a metre-scale plasma wakefield accelerator. Vol 445| 15 February 2007| doi:10.1038/nature05538

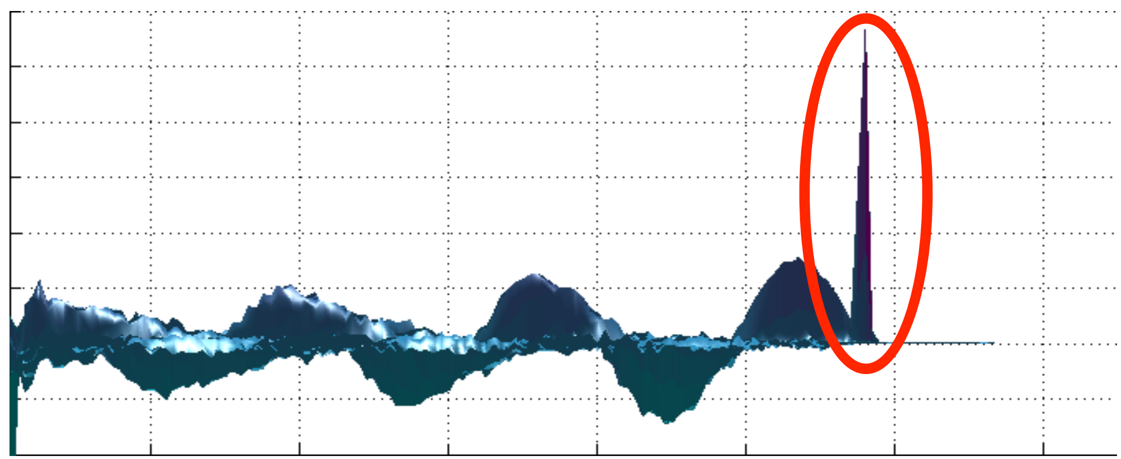
What is PWA?

Novel particle acceleration technique

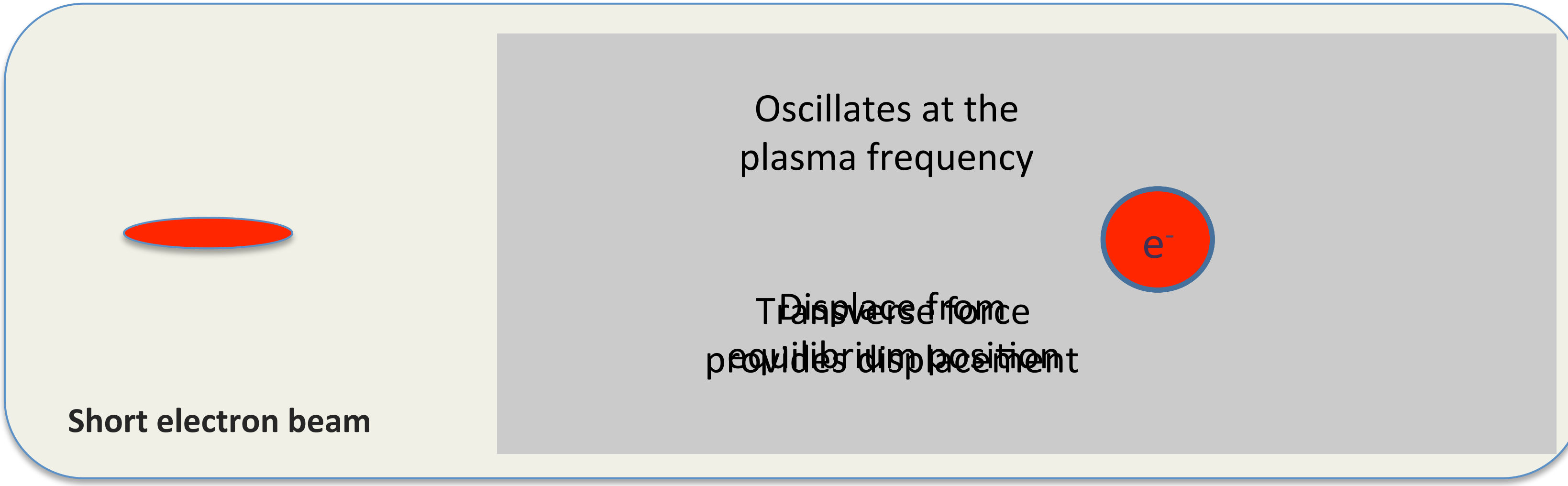


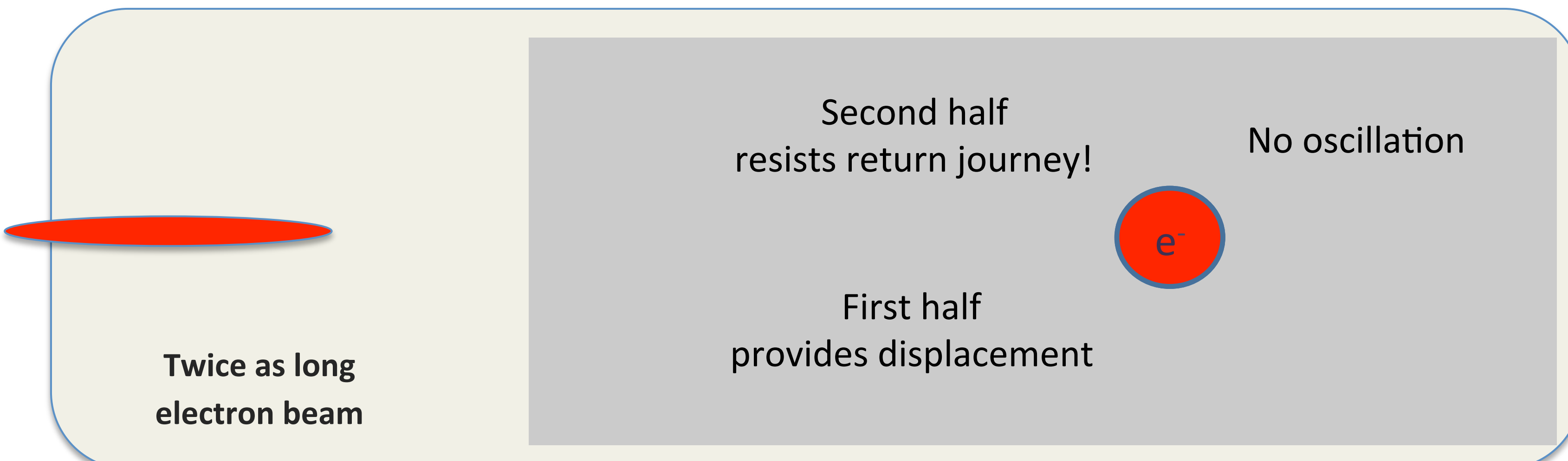
Can also drive wakefields with:

- Electrons
- Photons
- Positrons
- Muons (in principle)



Driving a strong wakefield





Driver beam length important!

The Diamond Light Source

The Diamond light source at RAL uses a 3 GeV electron beam to generate soft x-rays. The beam is generated by a 90 KeV electron gun that injects them into the Linac, which brings it to ~ 100 MeV. The booster then brings it to 3 GeV then finally the storage ring maintains the energy whilst cooling the beam.

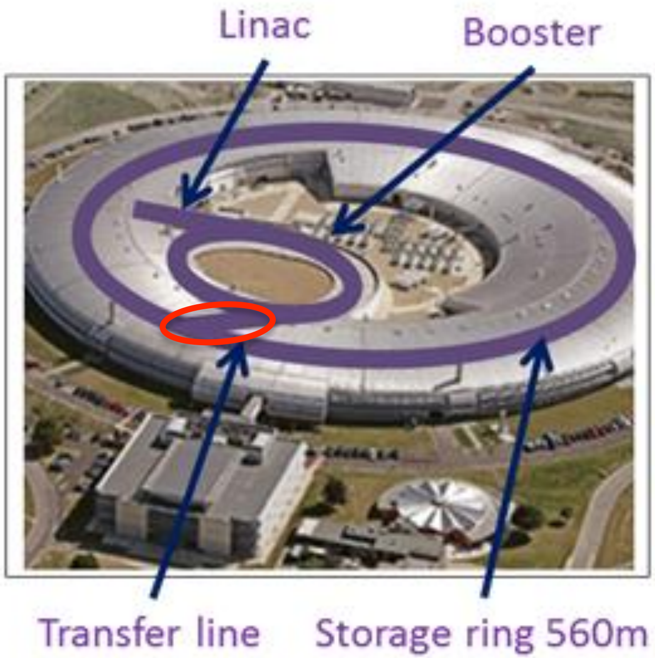
Beam length: σ_z = 2.6 cm -> too long to drive a wakefield. (λ_p ~ 100 um).

A proof of principle experiment has been proposed to micro-bunch the beam using a laser-driven wakefield.

A micro-bunched beam is an effective wakefield driver, each bunch resonantly drives the wakefield.

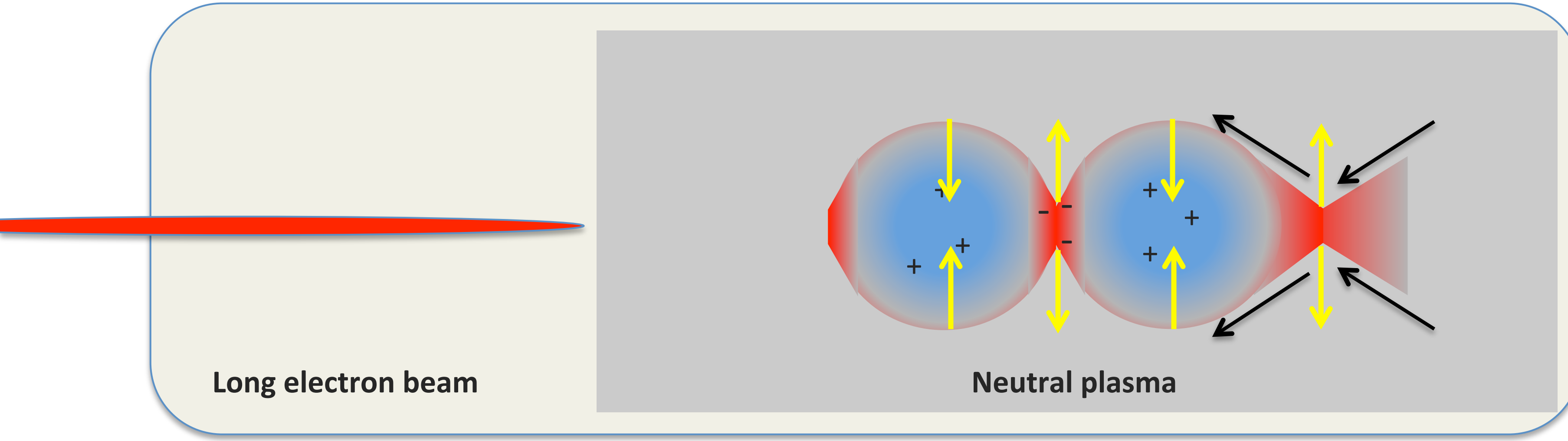
A micro-bunched Diamond beam could be used to:

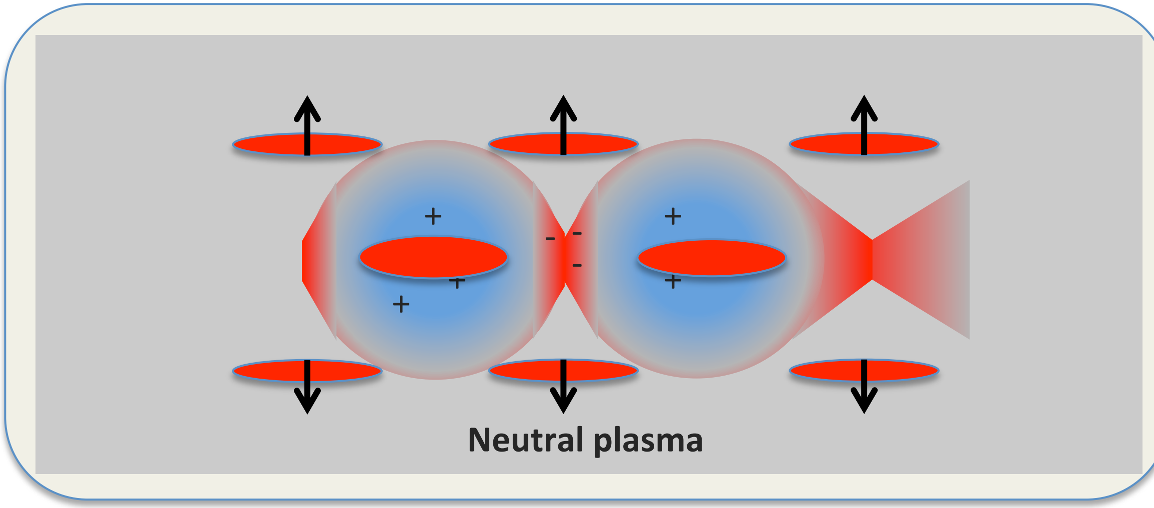
- Generate a higher energy electron beam
- Create a poor mans FEL using betatron oscillations within the wake



The Diamond light source, RAL.

Micro-bunching with a wakefield



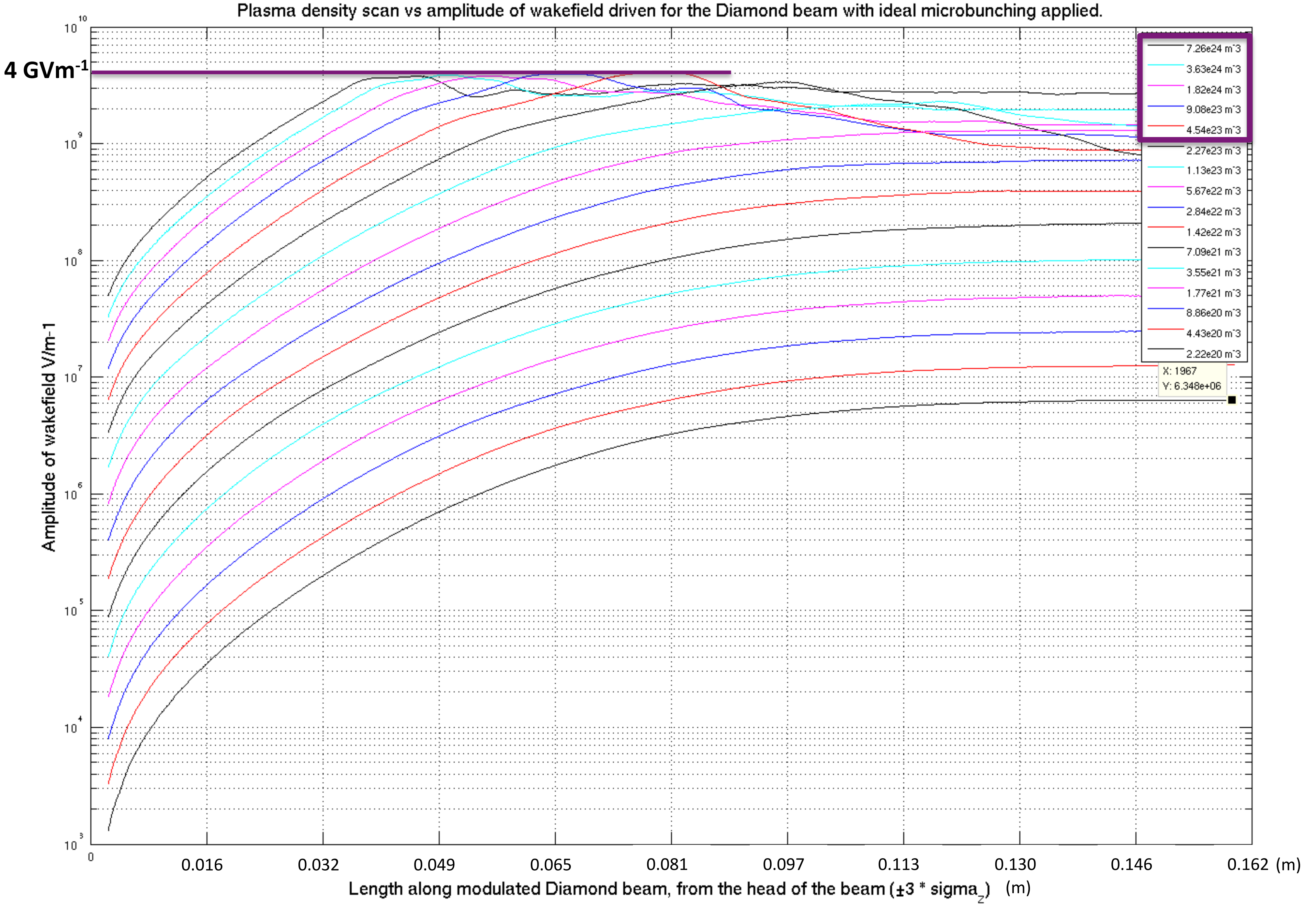


- Micro-bunches are spaced λ_p apart.
- Charge density increased.
- Micro bunch lengths are much closer to the ideal driver length of: $\sigma_{ideal} = \lambda_p / \pi \sqrt{2}$

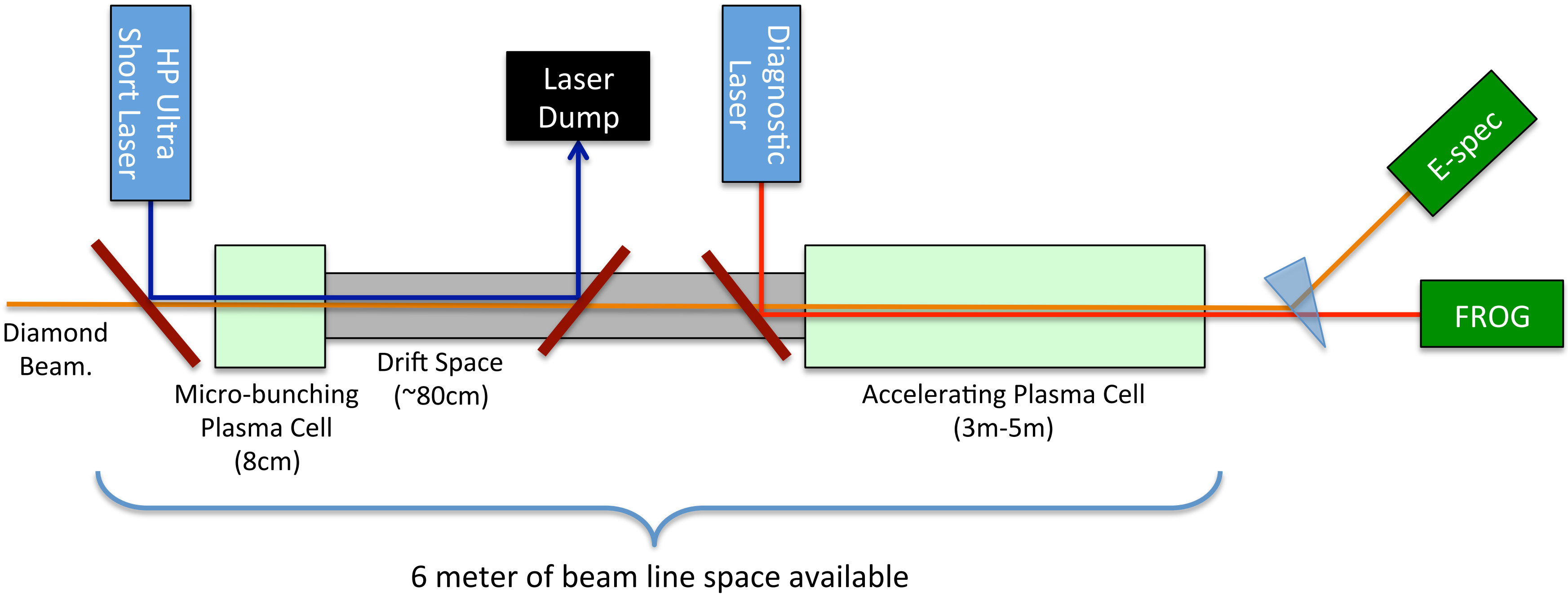
These properties then allow the micro-bunched beam to drive a wakefield much more effectively.

Micro-bunched driver beam.

Potential Accelerating Fields



Diamond Experimental Schematic



Diamond Beam Parameters

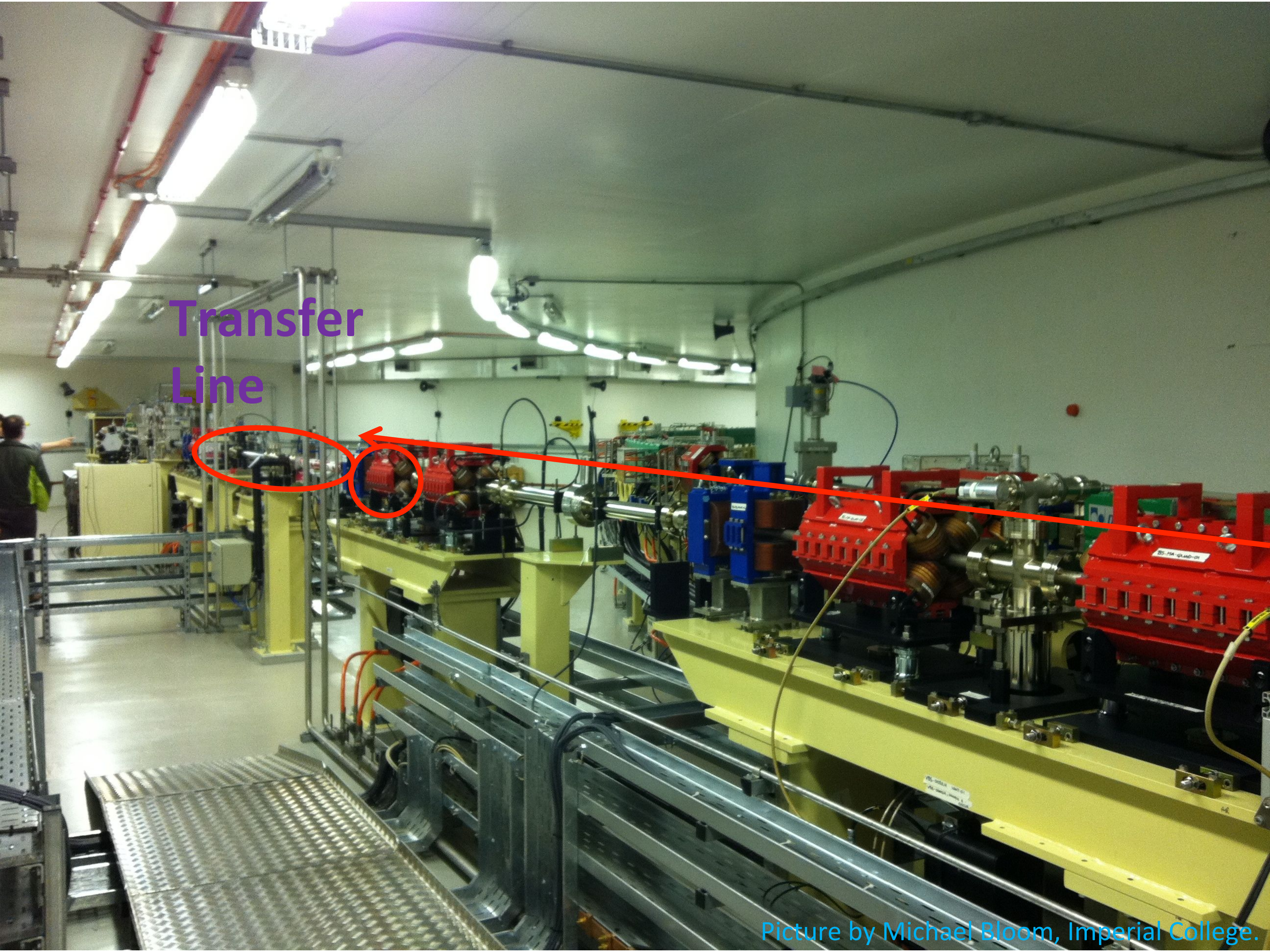
- E = 3 GeV
- ε_p = 140 nm mrad
- σ_E / E = 0.0007
- σ_z = 2.6 cm
- Q = 2 nC

HP Ultra Short Laser

- λ = 1.06 um
- σ_r = 20 um
- E = 1 J
- I = 1e16 Wcm^{-2}
- τ = 50 fs

Plasma Parameters

- Ne = 1.11e23 cm^{-3}
- λ_p = 100 um
- Element = Xenon
- Cell = ~Discharge



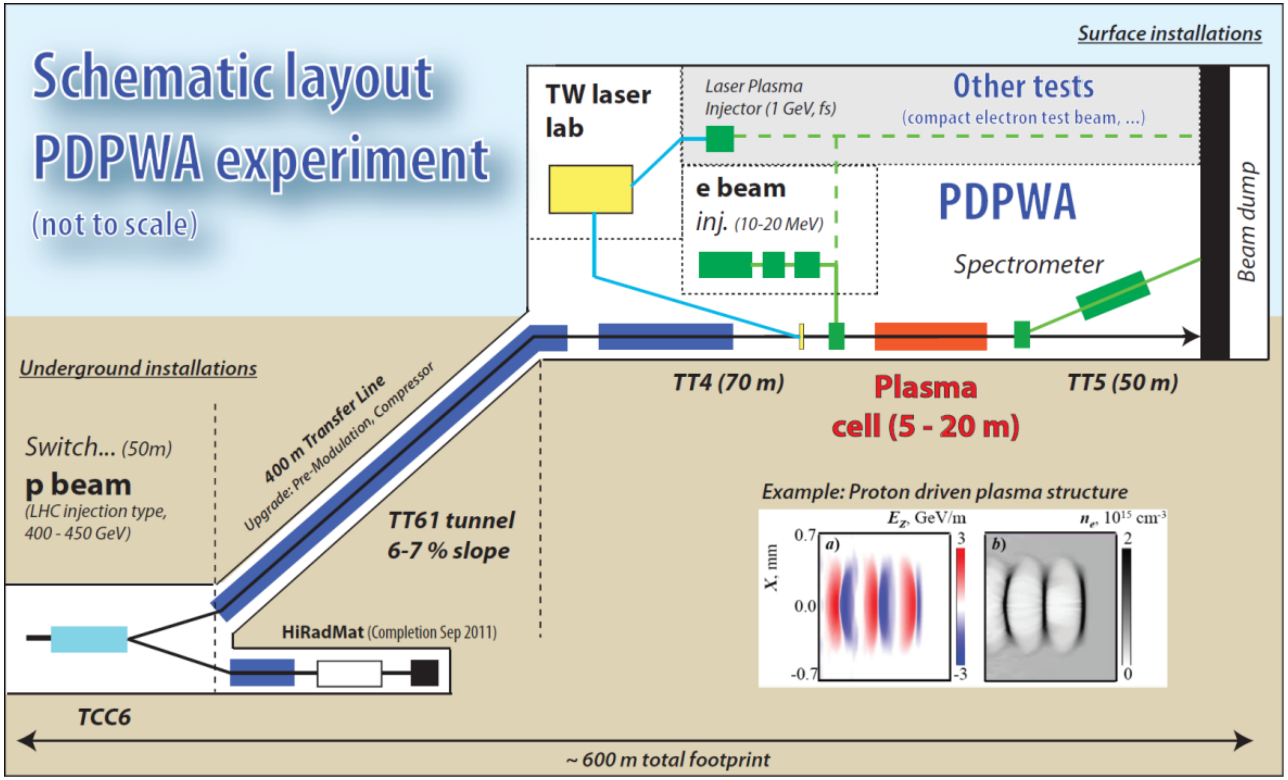
Picture by Michael Bloom, Imperial College.

The AWAKE Experiment

The Super Proton Synchrotron beam at CERN Feeds the LHC.
Collaboration led by Allen Caldwell aims to use the SPS beam to drive PWA.
Initial goal is to observe the energy gain of 1 GeV in 5 m plasma.
A plan for reaching 100 GeV within 100 m plasma will be developed based on the proof of principle experiment.

- A laser pulse creates an ionisation front that causes the SPS beam to drive a wakefield and self-modulate.
- SPS beam becomes an effective wakefield driver.
- e- then injected into wakefield and accelerated.

For more detail, Scott Mandry is presenting a poster on the AWAKE experiment.



Earlier schematic of the Awake SPS experiment

In Conclusion

- Conventional beams are too long to drive effective Plasma Wakefield Acceleration.
- Can micro bunch beams using wakefields to make them effective drivers.
- Can then use micro-bunched beam to generate a higher energy beam.

- Experiment being planned by the AWAKE collaboration at CERN, I'm working on a proposal for a PWA experiment at Diamond.

Thanks for listening