1 How can a wakefield be created in a plasma?

- Laser Pulse: The alternating em fields of a laser pulse create a force transverse to the axis of the laser pulse (see "Ponderomotive" force).
- **Particle beam:** The space charge of a negative particle bunch traversing the plasma, pushes the electrons outwards, whereas the space charge of a positive drive bunch sucks the electrons towards the beam axis. The comparably heavy plasma ions are unaffected by the particle bunch. The oscillating wakefield is created by the alternating collapse and expansion of the electron "bubble" created by the traversing particle beam.

2 What is the main difference between an electron and a proton drive beam?

An electron beam "blows out" the plasma electrons because of the same sign of the charge. The absence of plasma electrons around the drive beam axis creates a region of positive charge which attracts the electrons again. They start moving towards the beam axis, overshoot and move outwards again. This alternating process creates the plasma wakefield. A proton bunch creates the wakefield by the same alternating process, but the electrons are initially not pushed out, but sucked towards the drive beam axis.

3 Which properties has a proton drive bunch to fulfill?

- Low enough initial momentum spread
- Low enough growth of the momentum spread while propagating in the plasma: Since the plasma wavelenght is directly proportional to the rms length of the proton bunch, a fast growth of drivers momentum spread creates a plasma of different phase. This also creates a phase difference with a light electron witness bunch and efficiency of the acceleration is diminishing.

4 Why is the electron witness bunch not dissociating longitudinally and transversally?

Since the electrons of the plasma and the electrons in the witness bunch are the same particle species, the particles of the witness (trailling) bunch are always pushed away from the borders of the electron bubble in the plasma and towards the beam axis. This limits the transverse spread. The placement of the electron witness in the electron bubble of the plasma is shown in figure 1. The accelerating field in beam direction limits the longitudinal spread since slower electrons in the witness bunch see a stronger accelerating field and vice versa.



Figure 1: Placement of the electron witness (trailling) bunch inside the electron bubble. Picture taken from: https://cerncourier.com/a/harnessing-the-power-of-the-plasma-wakefield/