THE AWAKE PRIMARY BEAM LINES

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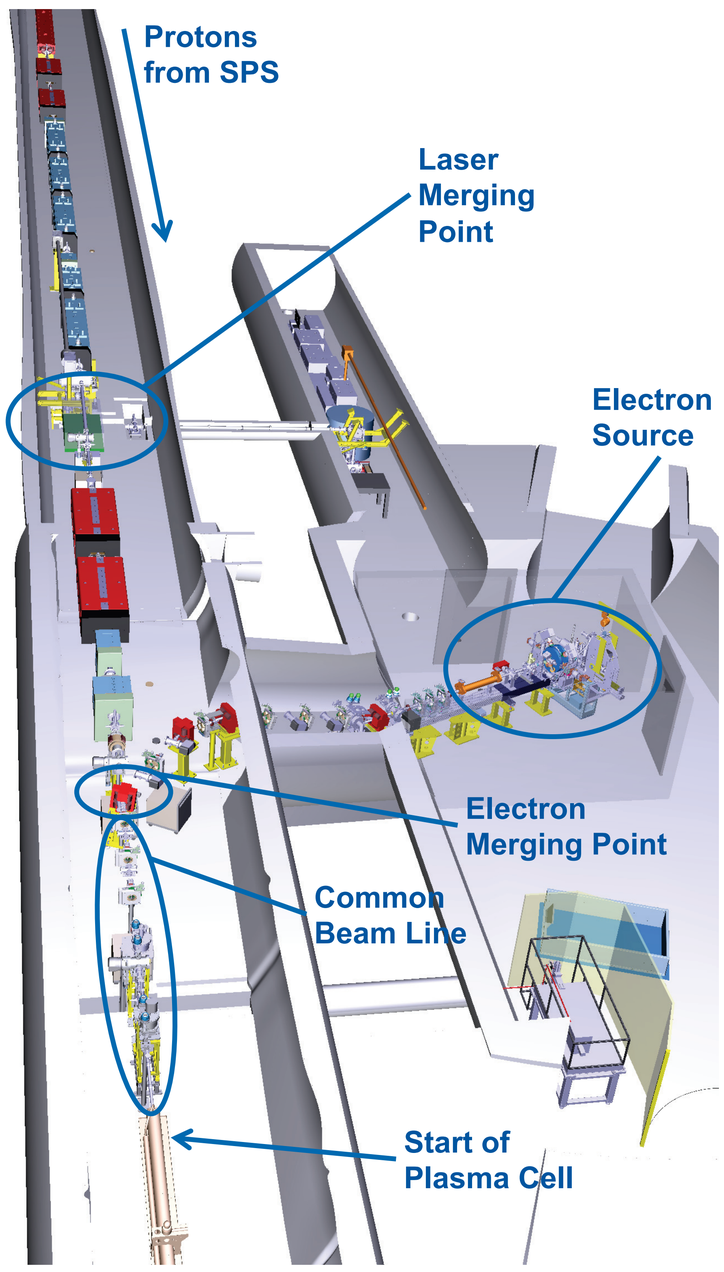
ABSTRACT

The AWAKE project at CERN is planned to study proton driven plasma wakefield acceleration with an externally injected electron beam. Therefore two transfer lines are being designed in order to provide the proton beam from the SPS and the electron beam at the plasma cell. The commissioning of the proton line will take place in 2016 for the first phase of the experiment, which is focused on the study the self modulation of the 12 cm long proton bunch in the plasma. The electron line will be added for the second phase of AWAKE in 2017, when the wakefield will be probed with an 10–20 MeV/c electron beam. The challenge for these transfer lines lies in the parallel operation of the proton, electron and laser beam. These beams, of different characteristics, need to be synchronized and positioned for optimized injection conditions into the wakefield. This task requires great flexibilities in the transfer line optics and special designs for the beam instrumentation as well as for the electron line magnets. The status of theses design will be presented in this paper.

PRIMARY BEAM LINES LAYOUT

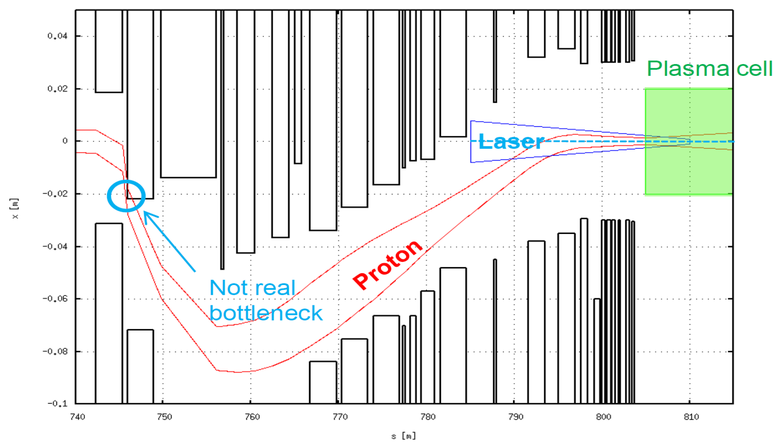


BEAM REQUIIREMENTS

Parameter	Protons	Electrons
Momentum [MeV/c]	400 000	10-20
Momentum spread [%]	±0.35	±0.5
Particles per bunch	$3 \cdot 10^{11}$	$1.25 \cdot 10^{9}$
Bunch length [mm]	120	1.2
Norm. emittance [mm·mrad]	3.5	2
Repetition rate [Hz]	0.033	10
1σ spot size at focal point [μm]	200 ±20	<250
β-function at focal point [m]	5	0.4
Dispersion at focal point [m]	0	0

PROTON BEAM LINE LAYOUT

In the proton transfer line, a 12 cm long bunch of 3×10^{11} protons from the SPS is transferred to the plasma cell of AWAKE. The major part of the line is the existing CNGS one and its end section has been modified to match the AWAKE requirements. At the position of the laser mirror a chicane has been introduced, so that the laser beam can be merged with the proton beam. The protons are then focused at the start of the plasma cell with a spot size of 200±20 µm. The beam positions at the mirror and around the plasma cell will be observed during operation as well as beam losses at the irises of the plasma cell. This measurements provide information about the injection conditions for the experiment and safe operation of the beam line.



ELECTRON BEAM LINE LAYOUT

The electron source is located in a room adjacent to the proton line tunnel. It will produce an electron beam of 10-20 MeV ± 0.5% with 10 Hz. Following the accelerator, a quadrupole triplet is used to match the electron beam into the transfer line. Two vertical dipoles with ±18° form an achromatic dog-leg in a tunnel with a slope of 20%. Like this, the electron beam is lifted to the level of the proton beam line, which is 1.16 m above the electron source. Two additional horizontal dipoles of 32° are needed to bend the electron onto the proton beam axis. The slope of the CNGS tunnel of 5.66% is achieved, by tilting the merging dipole by 3.2°. The common beam line with the proton beam consist mainly of the final focusing quadrupole triplet and diagnostics. Especially the angle and position of the electron beam in front of the plasma cell are observed. A special diagnostic for the synchronization of the proton, electron and laser beam will be installed already in the phase 1 beam line. At the focal point the electron bunch is focused to a spotsize of <250 µm to be injected into the plasma.

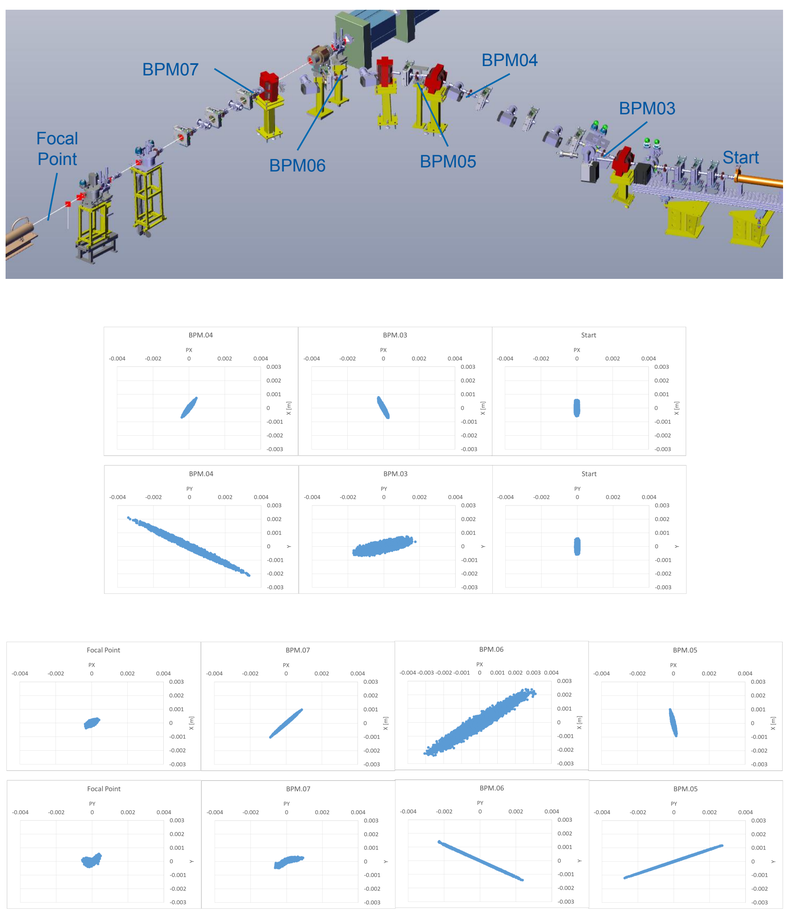
COMMON BEAM LINE AND INJECTION

Special studies are on going for the common beam line of the electron and the proton beam. This includes:

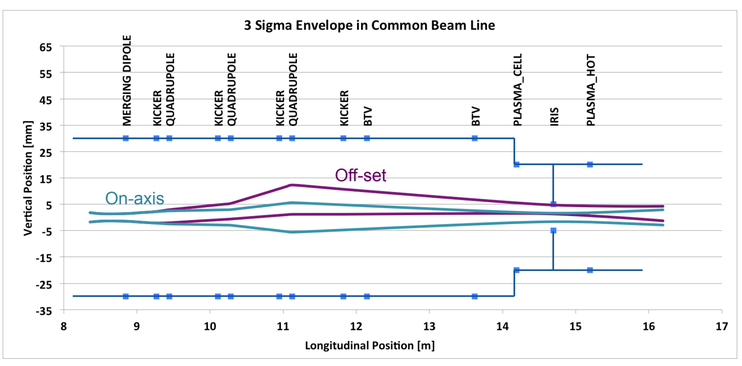
1. Stability studies of the electron beam at the focal point
2. Diagnostic of the electron beam in the presence of the proton beam
3. Effects of the proton beam on the electron beam – wakefields and beam-beam effects
4. Acceptance simulations of the electron injection into the plasma

The simulations of beam-beam effects and the plasma acceptance* have shown that flexible optics in the common beam line are needed to optimize the electron capture efficiency of the wakefields. An offset of the electron beam axis to the one of the protons can be introduced by the correctors. Like this, beam-beam effects can be reduced and the injection point (angle and position) can be varied.

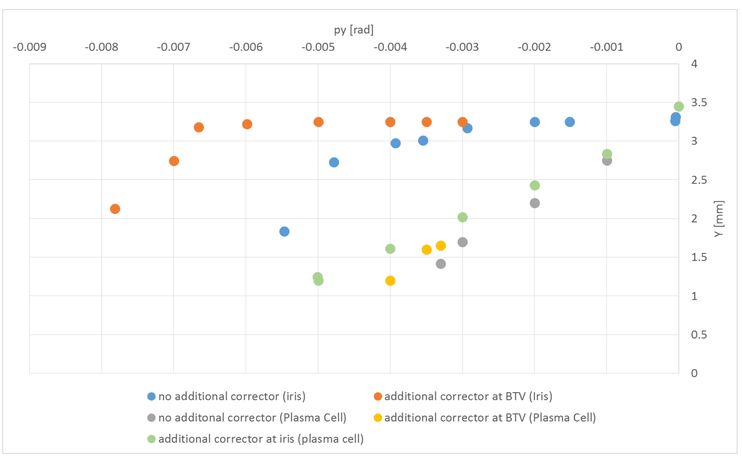
Tracking Simulation of Electron Line



On-axis Injection with Off-set Option



Phase Space Scan at the Focal Point



* see also publications of U.Dorda and A.Petrenko

Current Status and Outlook

The design of the proton transfer line has been finished and the magnets have been installed. The commissioning of the full line is planned for summer 2016 and beam on plasma (phase 1) from Q4 2016 on.

The baseline design of the electron transfer line has been studied and specifications have been defined. Designs for its magnets have been developed and studies on beam dynamic effects and the diagnostics in the presence of the protons are ongoing.

The installation of the phase 2 beam line planned for the beginning of 2017 in parallel with the phase 1 operation. Electrons and protons will be send to the plasma cell in Q4 2017.

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