TUPME079

A Spectrometer for Proton Driven Plasma Wakefield Accelerated Electrons at AWAKE

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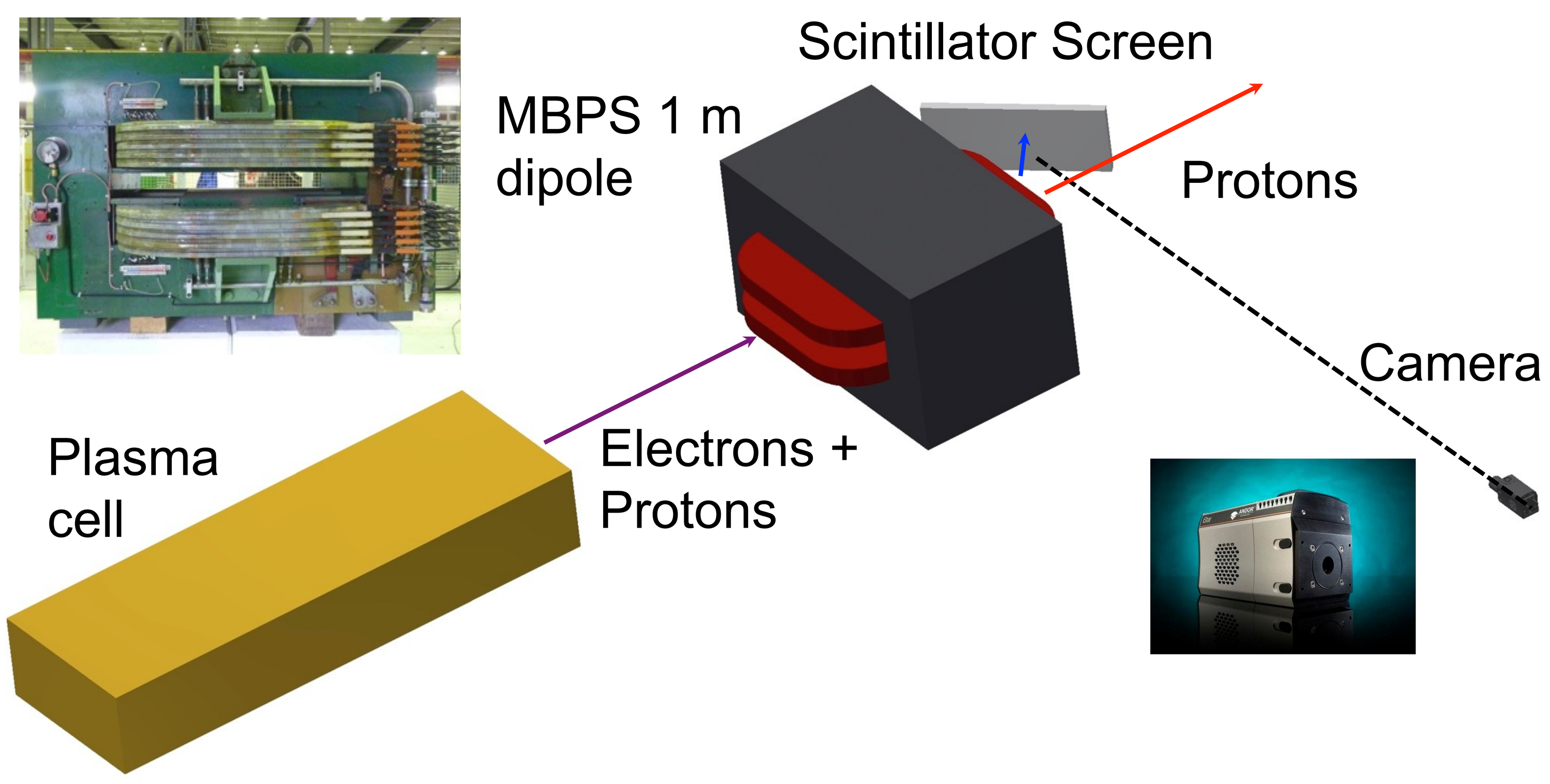
THE AWAKE EXPERIMENT

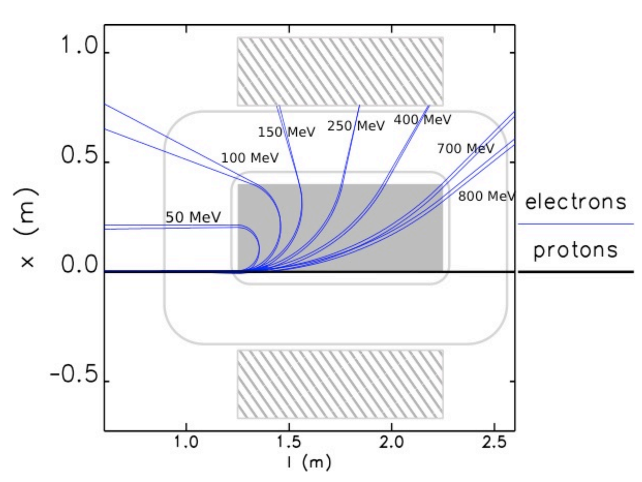
Proton bunches are the most promising drivers of wakefields to accelerate electrons to the TeV energy scale in a single stage. An experimental program at CERN — the AWAKE experiment — has been launched to study in detail the important physical processes and to demonstrate the power of proton-driven plasma wakefield acceleration. AWAKE will be the first proton-driven plasma wakefield experiment world-wide and will be installed in the CERN Neutrinos to Gran Sasso facility. An electron witness beam will be injected into the plasma to observe the effects of the proton-driven plasma wakefield simulations indicate electrons will be accelerated to GeV energies. In order to measure the energy spectrum of the witness electrons, a magnetic spectrometer will be installed downstream of the exit of the plasma cell.



SPECTROMETER DESIGN

The spectrometer has the following requirements:

1. Separate electrons from the drive beam protons.
2. Introduce a spatial distribution into the accelerated beam that is a function of energy.
3. Measure the intensity of the spatially distributed accelerated electrons to allow the mean energy and energy spread to be calculated.
4. Provide sufficient acceptance to prevent significant beam loss of accelerated electrons before the energy measurement.
5. Provide sufficient dynamic range to allow measurement of a range of electron energies from 0–5 GeV.
6. Measure the energy profile of the electron beam with sufficient resolution to demonstrate proton driven plasma wakefield acceleration of witness beam electrons.

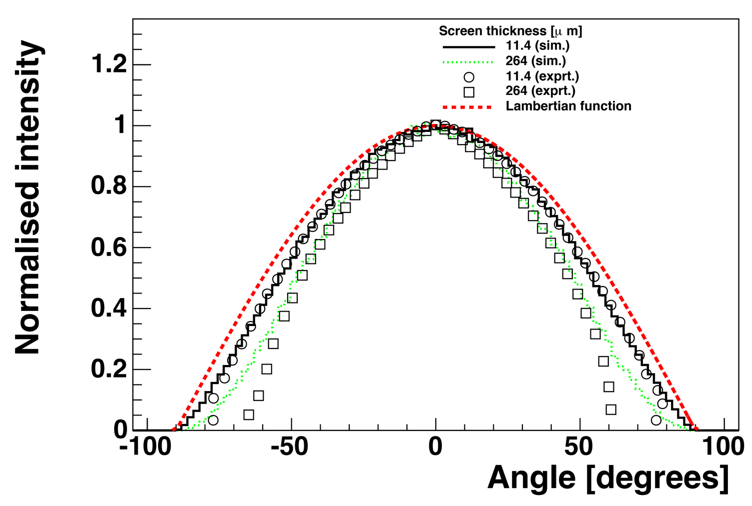


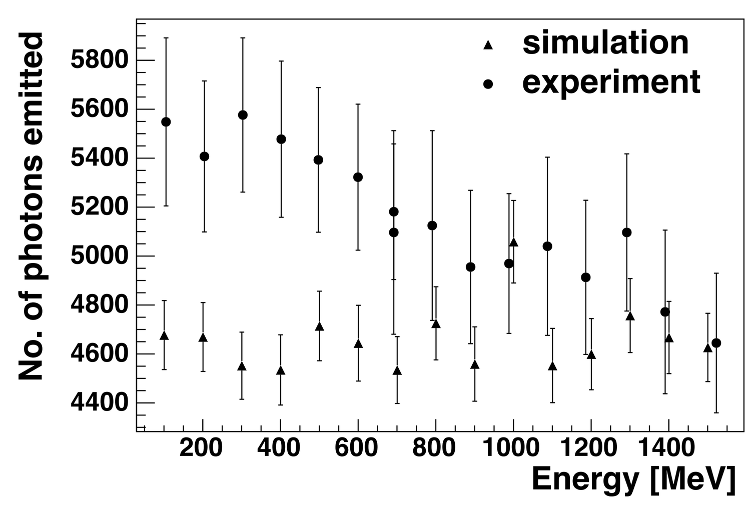
The spectrometer layout is shown above. A dipole magnet introduces dispersion into the witness beam that results in a horizontal spread that is correlated to the electron energy: the resulting electron trajectories for the nominal 1.8 T field of the MBPS dipole are shown to the left.

A scintillator screen is mounted at 45° to both the proton beam axis and the exit face of the dipole magnet, level with the downstream face of the dipole coils. In common with other plasma wakefield experiments, Terbium-doped Gadolinium OxySulfide screens (more commonly known by the trade names LANEX, DRZ or P43) have been selected for use in the AWAKE spectrometer. An Andor iStar 340T intensified CCD camera is then used to record the light emitted by the accelerated electrons impacting on the scintillator: this is mounted at 45° to the surface of the screen and therefore 90 deg. to the proton beam axis. Work is ongoing to determine the optimum camera distance and position with respect to the screen.

SCINTILLATOR SIMULATION

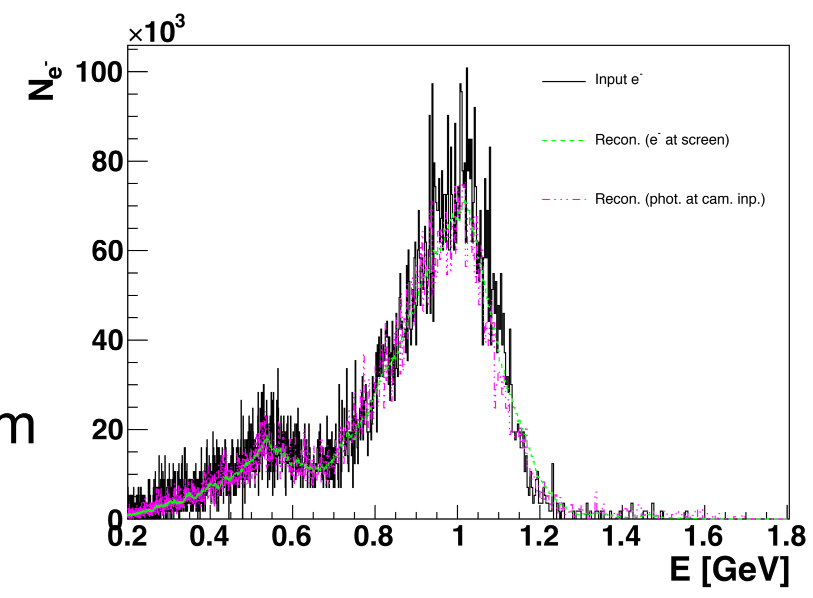
A Geant4 simulation of the GadOx scintillator screen has been written in order to simulate the output and spatial distribution of the emitted photons as part of a complete start-to-end simulation of the spectrometer system. The relevant electromagnetic and physics processes are turned on, including scintillation and the relevant optical process, with parameters derived from experimental sources. The screen is composed of a backing layers with a front scintillation layer of phosphor grains in an adhesive binder. The most important optical processes included are reflection and refraction at boundaries of changing refractive index which greatly affect both the light output and the angular distribution of the emitted photons. The microscopic density profile of the screen is approximated by composing the screen of layers of pure GadOx interleaved with layers of pure binder material. The simulated angular distribution as a function of screen thickness and the light output as a function of energy both show reasonably good agreement with measurement: these are shown below.





SIMULATION USING BDSIM

BDSIM is a Geant4 and C++ based particle tracking package for beam line simulation. It combines fast particle tracking routines with a powerful geometry description framework using a high level description language, GMAD. Since GMAD is an extension of MAD, this allows complex accelerator descriptions to be loaded with just a few modifications. BDSIM includes standard parameterised geometry and field descriptions for many common accelerator components such as magnets and collimators. It also allows for bespoke creation of user-defined beam line elements.



The AWAKE spectrometer is simulated using BDSIM by defining the beam line from the exit of the plasma cell to the CCD camera, including the simulated camera readout response. A possible witness electron spectrum was tracked from the exit of the plasma cell through the entire geometry to the scintillator screen including any secondary interaction processes along the way such as electromagnetic showers in the beam pipe walls, residual vacuum gas and other materials using a preliminary vacuum chamber geometry. The resulting particle distributions are shown above.

CONCLUSIONS

A Geant4 simulation of the scintillator screen has been tuned to give reasonable agreement with measurements of the light output as a function of beam energy and angular distribution. Preliminary results of the spectrum generated by the system in response to a possible witness electron distribution have been generated and appear to reconstruct the input spectrum. Future studies will include upstream sources of background such as particle scattering in the plasma cell to inform the design of the spectrometer vacuum system and any upstream collimation.

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