Beam Position Detection of a Short Electron Bunch in Presence of a Longer and More Intense Proton Bunch for the AWAKE experiment

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E. Senes[1], P.N. Burrows[1,2], R. Corsini[1], W. Farabolini[1], T. Lefevre[1], A. Gilardi[3], M. Krupa[1], S. Mazzoni[1], C. Pakuza[1,2], M. Wendt[1]

[1] CERN, Geneva, Switzerland, [2] JAI and University of Oxford, Oxford, UK, [3] Lawrence Berkley National Laboratory, Berkley, California, USA

The Advanced WAKefield Experiment (AWAKE)

1 The AWAKE ingredients

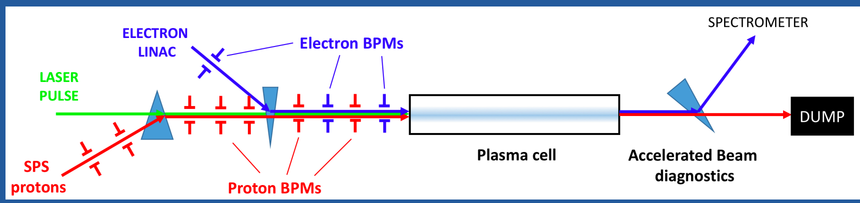
Low energy electron beam	0.1-0.6 nC, 4-20 ps
High energy proton beam	48 nC, 1 ns
Rubidium plasma	Rb vapour + laser

2 Proton Bunch Self-Modulation

The 1-ns proton bunch is fragmented in a train of microbunches in the propagation in the first few metres of plasma

3 Plasma Wakefield Acceleration

The electron beam is introduced in the wake of the microbunches train, and gets accelerated



The Problem:

The more intense proton beam overshadows the electrons in the common beamline

Beam position monitors for co-propagating beams

Cherenkov Diffraction-based BPMs

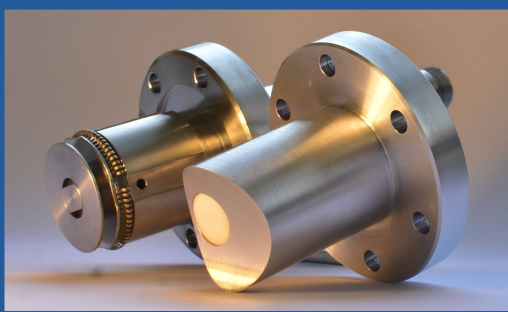
Radiation generation

- Cherenkov Diffraction Radiation (ChDR) is polarization radiation that is produced in a dielectric material when a particle is passing in the vicinity while travelling faster than the speed of light in the dielectric
- **Non-interceptive** diagnostic technique
- High photon fluence
- ChDR is emitted at the characteristic Cherenkov angle

$$\cos(\vartheta_{ch}) = \frac{1}{\beta n}$$

Mechanical design

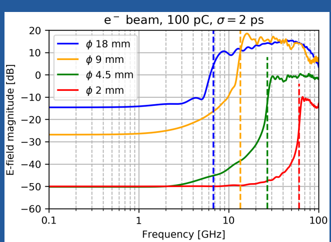
- Ceramic cylindrical ChDR radiator in a metallic flanged body for integration
- Radiator oriented at the Cherenkov angle to limit internal reflections



A ChDR radiator button (front) compared to a conventional capacitive button (back)

Electromagnetic design

- ChDR produced broadbandly at the radiator surface
- The radiator shape confines the EM field internal propagation
- Similar cutoff effect to waveguides
- Large CST Studio simulation campaign to study the emitted radiation properties as function of the geometry



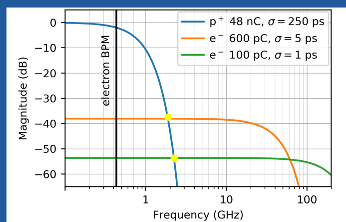
Spectra of emission at the end of the radiator for PTFE using a 100 pC electron beam

- For cylindrical radiators, **the diameter is the key parameter**
- Selecting the diameter is a **trade-off** between **power** emitted and cutoff **frequency**
  - Larger diameters allow for the propagation of lower frequency radiation
  - Smaller diameters will limit the radiated power

Sensitivity to bunch length

The EM field of the electron and proton bunch are radically different

- Different extension of the coherent spectrum depending on bunch length
  - **Protons:** stronger at low frequency, but quick decay
  - **Electrons:** more modest magnitude, but constant for tens of GHz
  - Same spectral power **point** at about 2 GHz

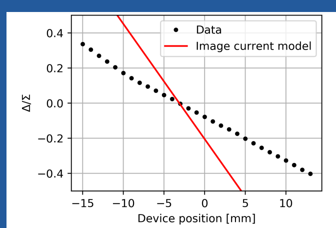


Proton and electron beam spectra

Experimental tests

Experimental test at the CERN Linear Electron Accelerator for Accelerator Research (CLEAR)

- Electron single bunch beam, 50-400 pC, and variable length of 1.1 – 4.8 ps (1σ)
- Flexible detection system in the Ka-band based on Schottky diodes working at 30.0 GHz, with 300 MHz BW
- Test in air
- Roughly half the sensitivity than the ideal wall current model for traditional BPMs



Measured position sensitivity

Future developments

- Test in vacuum
- Radiator to waveguide transition

eugenio.senes@cern.ch, IBIC 2021, 13 – 17 Sep 2021, Virtual Conference