Homework A.2 : Particle source

Answer the following questions. Please use $e = 1.60 \times 10^{-19}$ C as electronic charge, $\hbar = 1.05 \times 10^{-34}$ J.s for Planck constant, $m_0 = 0.511$ MeV for electron static mass, $c = 3.00 \times 10^8$ m/s for velocity of light.

Q.A2.1 According to several technical limitations, the size of the cathode active area is 8mm in radius. The laser is illuminated on the cathode with the same area and the intensity is flat. To extract the beam, 250kV bias voltage is applied between the cathode and anode with 100mm gap. To extract the required bunch charge 3.2nC, how much is the appropriate laser bunch length? Please assume that the extractable current density from the gun is limited by space charge effect.

Q.A2.2 How much energy spread ($\Delta E/E$) is expected if we inject directly the bunch to 1.3 GHz RF accelerator? Please assume that the bunch centre is on crest and ignore beam-loading effect of the accelerator and space charge effect.

Q.A2.3 The energy spread of calculated in Q.A2.2. is likely to be larger than DR acceptance in energy (1.5% full width). We need bunching prior to the RF acceleration. As the bunching RF cavity, we employ a 325MHz RF cavity. The shunt impedance of the cavity is 1.0×10^6ohm and input RF power is 5.0 kW. What is the distance from the cavity to the first accelerator? Please assume only the linear term in the bunching.

Q.A2.4 How much bunch length is expected after the bunching? Please assume only the linear term. Laser wavelength for the beam generation is 700nm and the band gap of the GaAs crystal is 1.4 eV. Please ignore contribution from the cathode temperature.

Q.A2.5 By considering the next higher order on the energy modulation, the bunching performance is not good as expected obtained in Q.A2.4. How much extra bunch length is expected by this non-linearity?

Q.A2.6 By assuming the bunch length obtained in Q.A2.5, how much energy spread is expected at 5.0 GeV when we employ 2.6 GHz RF accelerator? Is this acceptable by DR (70mm z, 1.5% energy spread)?

Q.A2.7 Gamma ray energy threshold for the e+ and e- pair-creation is 1.02 MeV, but more than 10 MeV gamma ray is required for efficient pair creation. Please explain the reason.

Q.A2.8 Let us assume 20 MeV gamma ray energy as 1st cut off is required for positron generation. How much drive beam energy is required for undulator radiation and laser-Compton scattering, respectively? Please assume 10mm undulator period, $K = 1$, and 1μm laser wavelength for each methods.

Q.A2.9 Conventional choice of e+ booster is S-band (2.6 GHz) because a wide variety of device such as klystrons, wave-guides, are available. However, DR acceptance in z-δ (70mm in z, 1.5% in δ) can be used not fully with the S-band e+ booster. Please explain the reason.

Q.A2.10 If we optimize the system by adjusting the accelerator RF frequency, what is the most optimized frequency? Please ignore energy spread of initial positron distribution and consider only energy spread by RF curvature.

Q.A2.11 Shower maximum in radiation length of Brems-strahlung process is proportional to $\ln E$, where E is the initial beam energy of electron. Please explain the reason.

Q.A2.12 Positrons at the end of the injector section (250 MeV) are distributed ±20ps in z and ±20MeV in energy. Please show this bunch does not fit to the DR acceptance (5.0 GeV energy, 1.5% in energy spread, and 70 mm in z) by assuming S-band 2.6 GHz accelerator for e+ booster.

Q.A2.13 By considering an EC(Energy Compressor) before DR injection, the beam phase-space distribution can be fit to DR acceptance. Please show that EC with $R_{56} = 0.9$ gives a good matching of the beam given in Q.A2.10.