Examination 2017 for Beam Diagnostics

Please answer the question within a few sentences or a short calculation; please write clearly and readable. A maximum 20 points can be achieved.

1 Methods of current measurements at different accelerators *(maximal 4 points)*

For the below mentioned proton accelerators and beam parameters an appropriate method for current measurement should be chosen; give the main argument for your choice:

a) Behind the ion source with an energy of 100 keV, a beam current of 100 mA and a pulse duration of 1 ms.

b) Behind the ion source with the same parameter as under **a)** but a current of 10 nA.

c) Behind a proton LINAC with an energy of 100 MeV, a beam current of 100 mA and a pulse duration of 1 ms.

d) The permanent monitoring during the 1 s long acceleration within a synchrotron from an energy of 100 MeV to 1 GeV and a current of the circulating beam of about 100 mA.

e) Behind the synchrotron in a transport line where 10^{12} protons are extracted within 10 s.

f) The same parameters as under **e)** but with a duration of only 1 μs.

2 Slow extraction current determination *(maximal 2 points)*

In a synchrotron a current of 100 μA protons with an energy of 1 GeV and 1 μs revolution time is stored. The de-bunched beam is extracted slowly within 1 s. ($e = 1.6 \cdot 10^{-19}$ C)

a) What is the extracted particle current in units of Ampere? Additionally, give the number of extracted particles per second.

b) How would you measure this extracted current? Describe briefly its underlying physical process.

3 Profile determination in a synchrotron by a SEM grid *(maximal 4 points)*

The beam profile at injection into a synchrotron is measured with a SEM-grid. It is performed with a 1 GeV proton beam. The SEM grid is made of aluminum ribbons with 10 μm thickness in beam direction. Assume that the ribbons covering the full transverse space, i.e. the beam particles are penetrating the material each revolution. The energy loss is $dE/dx = 0.477$ MeV/mm.

a) Calculated the energy loss per turn.

b) How many turns can be measured before the particles are scattered out of the longitudinal acceptance of $\Delta E/E \simeq 10^{-3}$?

c) For protons with an energy of 100 GeV the energy loss is larger, namlely $dE/dx = 0.683$ MeV/mm. Are more or less revolutions detectable with the SEM grid before leaving the acceptance? Justify the answer.

d) Propose a profile measurement method, which is non-destructive and describe it briefly. Assume that the signal strength is sufficient for it.

4 Emittance measurement of high energetic beams *(maximal 4 points)*

In a transfer line the emittance of a proton beam of 1 GeV kinetic energy has to be determined from profile measurements. Assume that the first profile measurement device is exactly at the waist of the beam (i.e. the beam has its focus there). The profile at this waist has a width of $x(s_0) = 3$ mm. A second beam profile of width $x(s_1) = 9$ mm is measured at a distance $s = s_1 - s_0 = 10$ m downstream with no optical element in between.

a) What condition for one of the beam matrix elements is fulfilled at a beam waist?

b) Determine the emittance value ϵ for this beam.

c) What is the normalized emittance of this beam?

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5 Emittance determination along a transport line *(maximal 2 points)*

The emittance of the beam can be determined by profile measurements along a transport line. Consider the case that the transport line includes a dipole.

a) What does this mean in terms of transverse-longitudinal coupling?

b) How many measurement locations are at least required for the determination of the emittance? Give a reason for your choice.

6 Synchrotron lattice function measurement *(maximal 4 points)*

a) Describe briefly a method for tune measurement at a synchrotron.

b) What is the type of excitation and how is the beam position measured?

c) Give the advantages and disadvantages of your chosen device.

d) Describe a method to determine the chromaticity of a synchrotron lattice?