

**Interaction of particles with matter
Examination
1 hour**

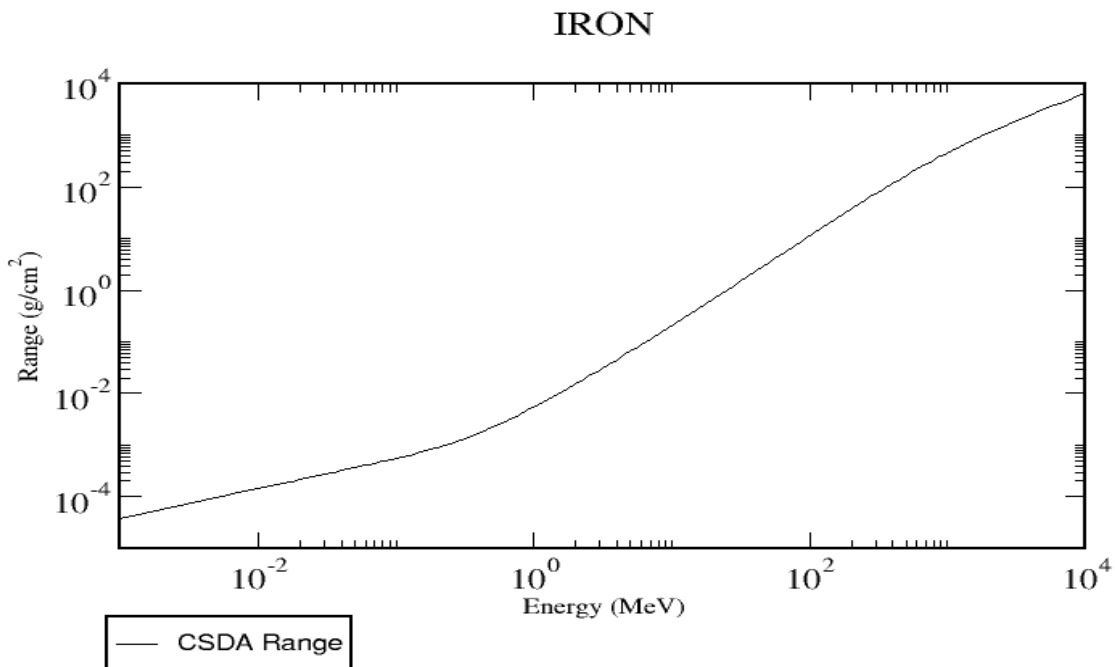
Lecture notes, lecture documents and pocket calculators are authorized.

In all questions (except for question 7), quantities should be computed using the formulas found in lectures. Values that can be found in tables or on curves can be used to check, at first order, the correctness of answers.

Effect of an iron plate left in a proton beam :

A well-collimated 10 GeV (kinetic energy) proton beam perpendicularly hits a 2 mm-thick iron plate (for iron, $Z=26$, $A=55.85$ g, $\rho=7.87$ g cm^{-3}) :

- 1) Compute β and γ , the proton relativistic coefficients ($m_p=938.3$ GeV).
- 2) Briefly describe the main physical phenomena that can potentially affect the proton beam features.
- 3) Check with the help of the proton range curve shown down here that the beam passes through the plate ? Quantitatively justify your answer.



- 4) Verify that the medium energy condition ($2m_e \gamma / m_0 \ll 1$) is satisfied for these protons.
- 5) Compute the maximal kinetic energy that can be transferred to an atomic electron in one collision ?
- 6) In case the beam passes through the plate, compute its average energy when exiting the plate. In a first approach, we will neglect low energy and density corrections.
- 7) Compute δ , the density correction term and deduce the relative contribution (in %) it would have on the energy loss. (Make use of the parameter table of lecture slide 15).
- 8) The energy resolution of the beam is 1%. How visible is the beam energy loss when compared to the energy resolution ?
- 9) Compute the radiation length of iron.
- 10) Compute θ_0 , the angular fluctuation induced by multiple scattering.
- 11) Protons are measured in a detector whose angular resolution is given by :
$$\sigma_\theta (\text{mrad}) = 20 / \sqrt{E (\text{GeV})}$$
 , compare the multiple scattering term to the detector angular resolution.
- 12) General conclusion : would the plate degrade in a noticeable way the features of the proton beam ?