Homework 1

1. Show explicitly that the expression for collider luminosity

$$\text{Luminosity} = \frac{N_1 \times N_2 \times \textit{frequency}}{\textit{Overlap Area}} = \frac{N_1 \times N_2 \times f}{4\pi\sigma_x\sigma_y} \times \textit{Correction factors}$$

is equivalent to the expression for fixed target luminosity.

$$\frac{\textit{Events}}{\text{second}} = \sigma_{\textit{process}} \circ \underbrace{\textit{Flux} \circ \textit{Target Number Density} \circ \textit{Path Length}}_{\textit{Luminosity}}$$

Tutorial exercise:

- The Fermilab Alvarez Linac accelerates protons to a *kinetic energy* of 400 MeV
  - a) Calculate the total energy of the protons in units of MeV
  - b) Calculate the momentum of the protons in units of MeV/c
  - c) Calculate the relativistic gamma factor
  - d) Calculate the proton velocity in units of the velocity of light.

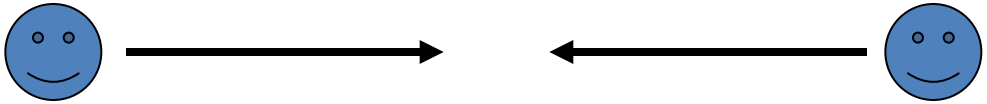
Particle collisions

- Two particles have equal rest mass m_0.

Laboratory Frame (LF): one particle at rest, total energy is E.

$$\mathbf{P_1} = (E_1/c, \mathbf{p_1}) \qquad \mathbf{P_2} = (m_0 c, \mathbf{0})$$

Centre of Momentum Frame (CMF): Velocities are equal & opposite, total energy is E_{cm}.

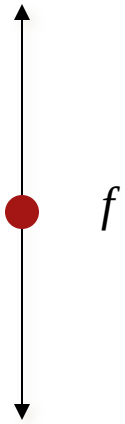


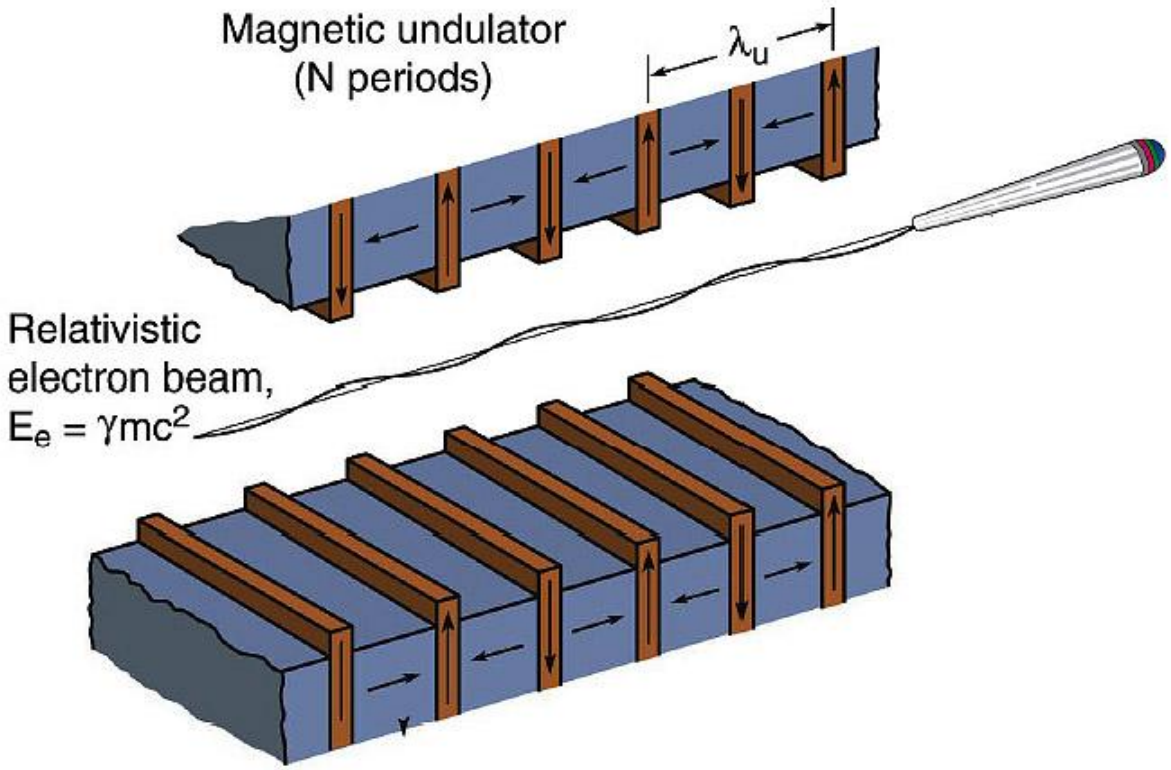
$$\mathbf{P_1} = (E_{\mathrm{cm}}/(2c), \mathbf{p}) \qquad \mathbf{P_2} = (E_{\mathrm{cm}}/(2c), -\mathbf{p})$$

Exercise: Relate E to E_{cm}

Undulator radiation: What is λ_{rad} in terms of $\lambda_{undulator}$

An electron in the lab oscillating at frequency, *f*,
emits dipole radiation of frequency *f*





What about the relativistic electron?

Exercise from Whittum

- **Exercise:** A charged particle has a kinetic energy of 50 keV. You wish to apply as large a force as possible. You may choose either an electric field of 500 kV/m or a magnetic induction of 0.1 T. Which should you choose
  - (a) for an electron,
  - (b) for a proton?

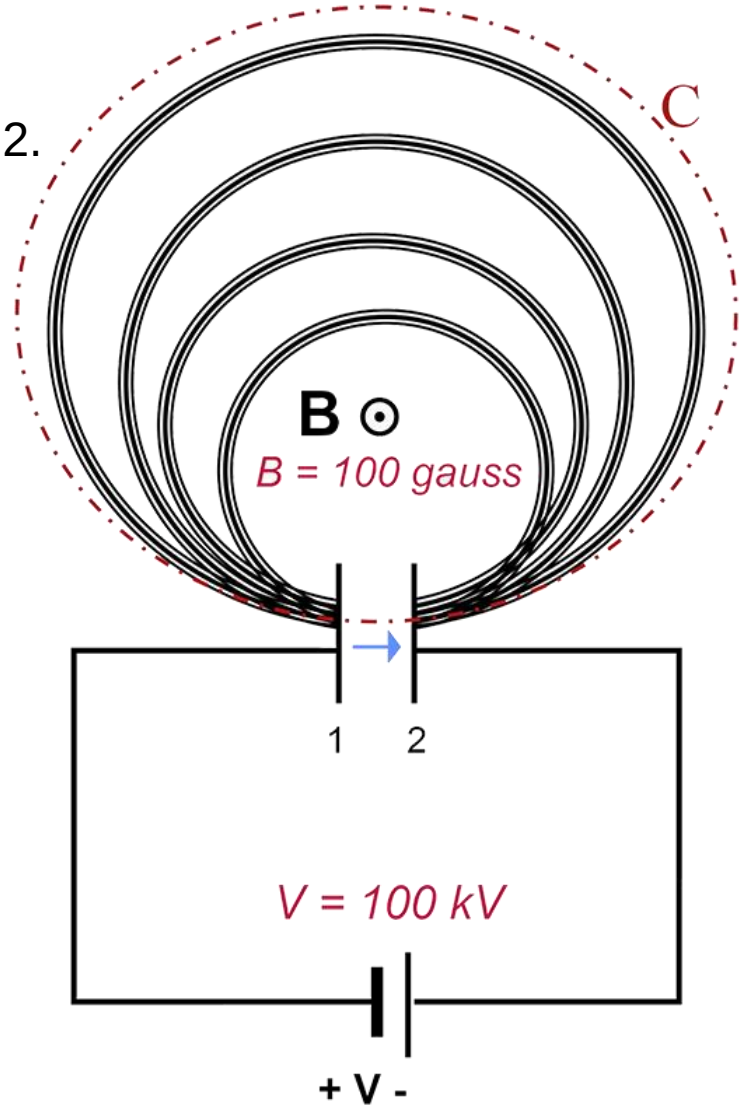
Possible high energy DC accelerator?

At t = 0 the ion source at 1 injects a proton of energy E_o in the gap pointed at a hole in plate 2. The entire device is imbedded in a constant magnetic (dipole) field, B, pointing out of the surface.

Exiting the plate 2, the proton enters the innermost virtual beam pipe.

If B = 100 Gauss and E_o = 100 keV, what is the radius of the first orbit?

After 10,000 revolutions, what is the energy of the proton as it leaves plate 2.



Traversing the SLAC linac

- Electrons are injected into the 3 km SLAC linac at 5 MeV. The linac operates at constant gradient to bring the electrons to 50 GeV at the end of the linac.
- If you were riding on the electron, how long would it take on your clock for the electron to get to the end of the linac?