Introduction to Particle Accelerators course 2024-2025

Tutorial 7 - 31.10.2024, BSP 626

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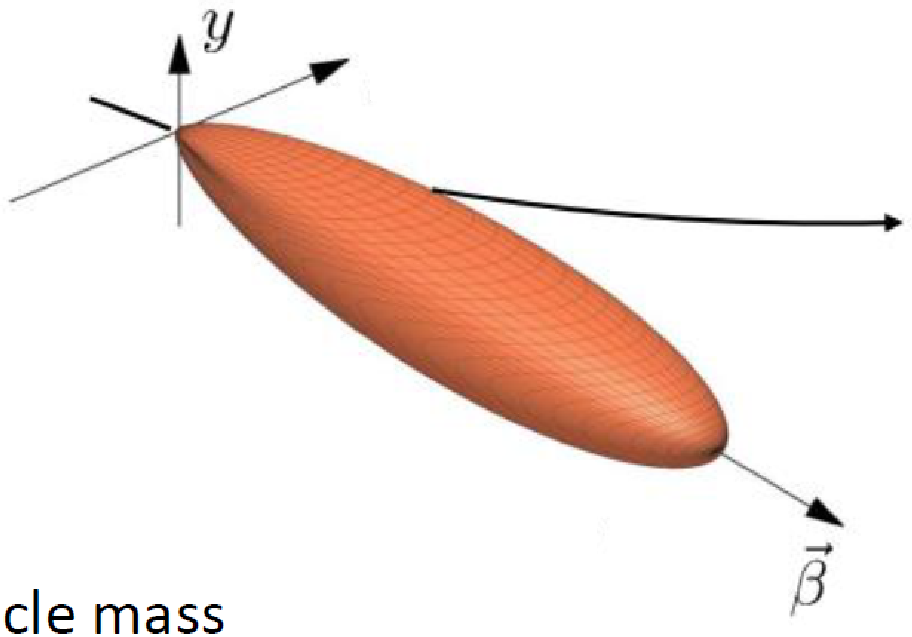
Quiz

Radiation power

The emitted radiation power scales with…



- *A.* E^{-3} and B
- *B.* E^{4} and ρ^{-2}
- C. The radiated power only depends on the particle mass
- D. r_0^{-1} (the electron radius) of the particle

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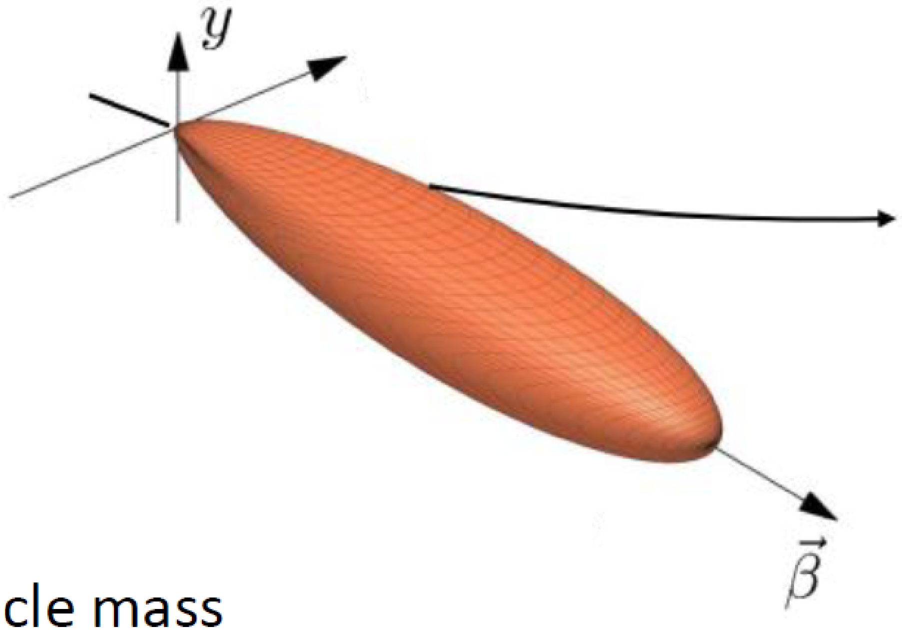
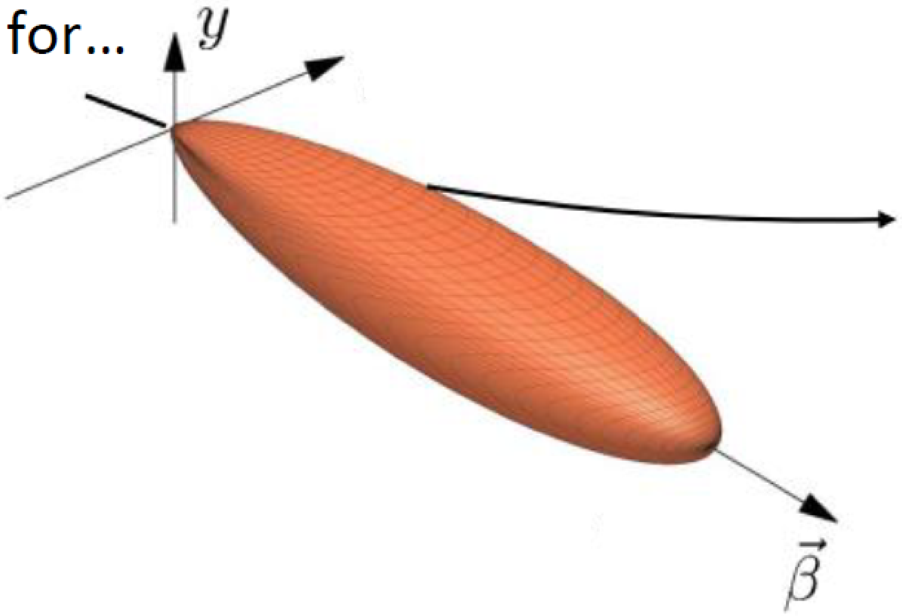
$$P_\gamma = \frac{2}{3} r_e c\, m_0 c^2 \frac{\gamma^4}{\rho^2}$$



Energy loss for different particles

The energy loss per turn (for a given *E*) is the largest for…



A. Pb^{82+}

B. e^+

C. e^-

D. Ar^{6+}

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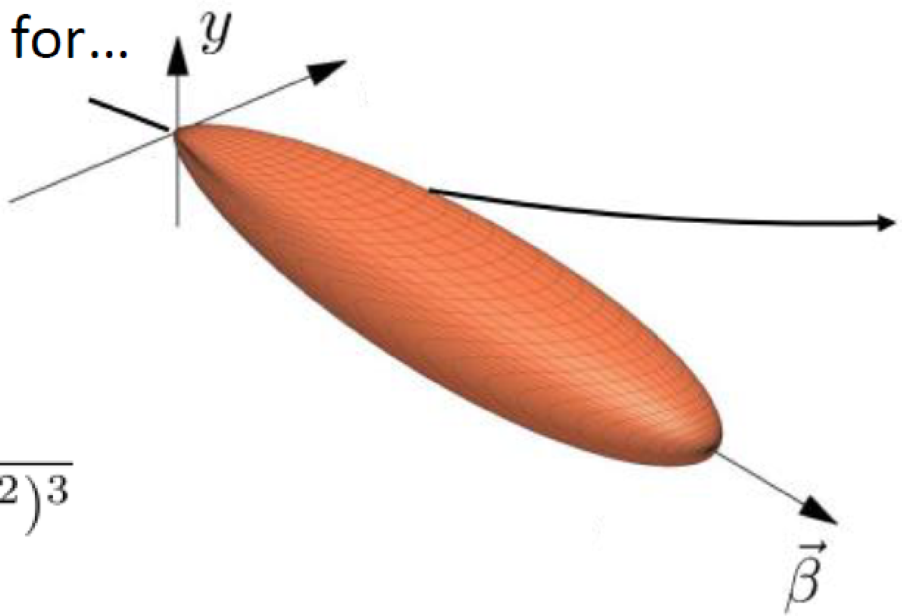

- A. Pb^{82+}
- *B.* *e^+*
- C. e^-
- D. Ar^{6+}

$$U_0 = C_\gamma \frac{E^4}{\rho}, \; C_\gamma = \frac{4\pi}{3} \frac{r_e}{(m_0c^2)^3}$$

Emittance

What effect increases the horizontal emittance ε_x?

A. Quantum excitations

B. Radiation damping

C. Stronger quadrupole magnets

D. Accelerating RF cavities

Emittance

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- A. **Quantum excitations**
- B. Radiation damping
- C. Stronger quadrupole magnets
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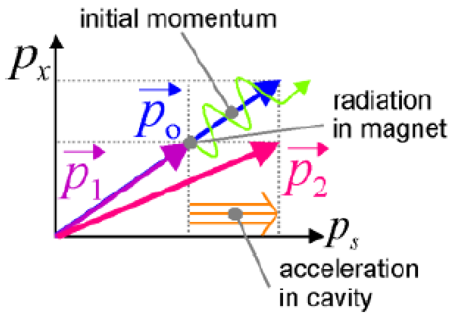
Horizontal emittance in electron storage ring:

↓radiation damping↓ ⇒ **equilibrium** ⇐ ↑quantum excitation↑

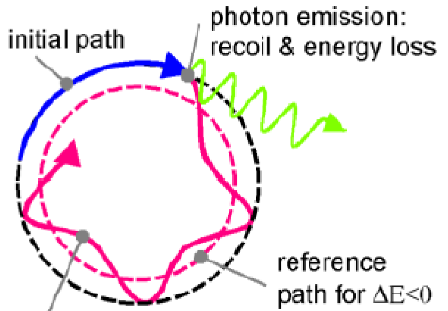
independent from initial conditions !

classical radiation damping



recirculation:
damping of transverse momenta

quantum excitation



particle oscillations: stochastic distribution of transverse momenta

R. Ischebeck

Operating without RF…!

Assume a lepton (electron) machine, (e.g. LEP, circumference 27 km) and a hadron (proton) machine (e.g. SPS, circumference 7 km) and the **same momentum** (100 GeV/c). After the RF system is switched off (or fails ...)

A. Both electron and proton survival times are short
B. Electron survival time is short, proton survival time is long
C. Electron survival time is long, proton survival time is short
D. Both electron and proton survival times are long

B is the correct answer

The energy loss per turn due to synchrotron radiation is (see lecture):

$$U_0[GeV] = C_\gamma \cdot \frac{E^4[GeV^4]}{\rho[m]} \quad \text{with} \quad C_\gamma = \frac{q^2}{3\epsilon_0 (mc^2)^4}$$

For the same energy and bending radius the energy loss scales with $1/m^4$

Some examples, CERN machines:

LEP 100 GeV[1]: $\tau \approx$ 40 μs (half a turn), energy loss per turn $\approx$ 3 %

SPS 100 GeV: $\tau \approx$ 12 hours

ISR[2] 30 GeV (1971 - 1983) : $\tau \approx$ 4 weeks (achieved)

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[1] in early days of LEP this was done to dump the beam, a "ping" on collimators

[2] circumference $\approx$ 1000 m, $I_{beam} \approx$ 30 A, beam dump was heared all right