Q 1:

Using $\Delta x \Delta p \geq \frac{\hbar}{2}$, p_{min}:

$$\begin{aligned} p_{min} &= \frac{\hbar}{2x} \\ &= \frac{\hbar}{2r} = 5.271 \times 10^{-21} J \\ E_{min} &= \sqrt{p_{min}^2 c^2 + m_e^2 c^4} \\ &= 1.51 \times 10^{-10} J = 98.8\ MeV \\ &98.8\ MeV >> 17\ keV \text{ tritium} \end{aligned}$$

Q 2:

$$F_g = \frac{Gm^2}{r^2}; \quad F_e = \frac{ke^2}{r^2}$$

$$\frac{F_g}{F_e} = \frac{Gm^2}{ke^2} = 2.4 \times 10^{-43}$$

Q 3:

1. Volume has 3 spatial dimension, so only the dimension along the direction of motion will experience length contraction
$$V' = a^3; \quad V = a^2 \frac{a}{\gamma} = \frac{V'}{\gamma}$$
2. For the density, only the volume will be affected by the same effect in part 1, so:
$$\rho = \frac{N}{V} = \frac{N\gamma}{V'}$$

Q 4:

$$a)\ v = \frac{d}{t'} \implies d = vt' = 0.998c \times 2.2 \times 10^{-6} = 658m; \quad \underline{\text{Will not}} \text{ make it}$$

$$b)\ \gamma = \frac{1}{\sqrt{1 - 0.998^2}} = 15.8 \implies t = \gamma t' \implies d = 0.998c \times 15.8 \times 2.2 \times 10^{-6} = 10400m; \quad \underline{\text{Will}} \text{ make it}$$

$$c)\ \gamma = \frac{1}{\sqrt{1 - 0.998^2}} = 15.8 \implies t = \gamma t' \implies d = 0.998c \times 15.8 \times 2.6 \times 10^{-8} = 123m; \quad \underline{\text{Will not}} \text{ make it}$$

Q 5:

a) Real Particles: **Timelike**

b) Massless Particles: **Lightlike**

c) Virtual Particles: **Anything**