Cherenkov Radiation

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Cherenkov Radiation:

Electromagnetic radiation emitted when a charged particle passes through a dielectric medium at a speed greater than the phase velocity of light in that medium

Electric field parallel to velocity of particle

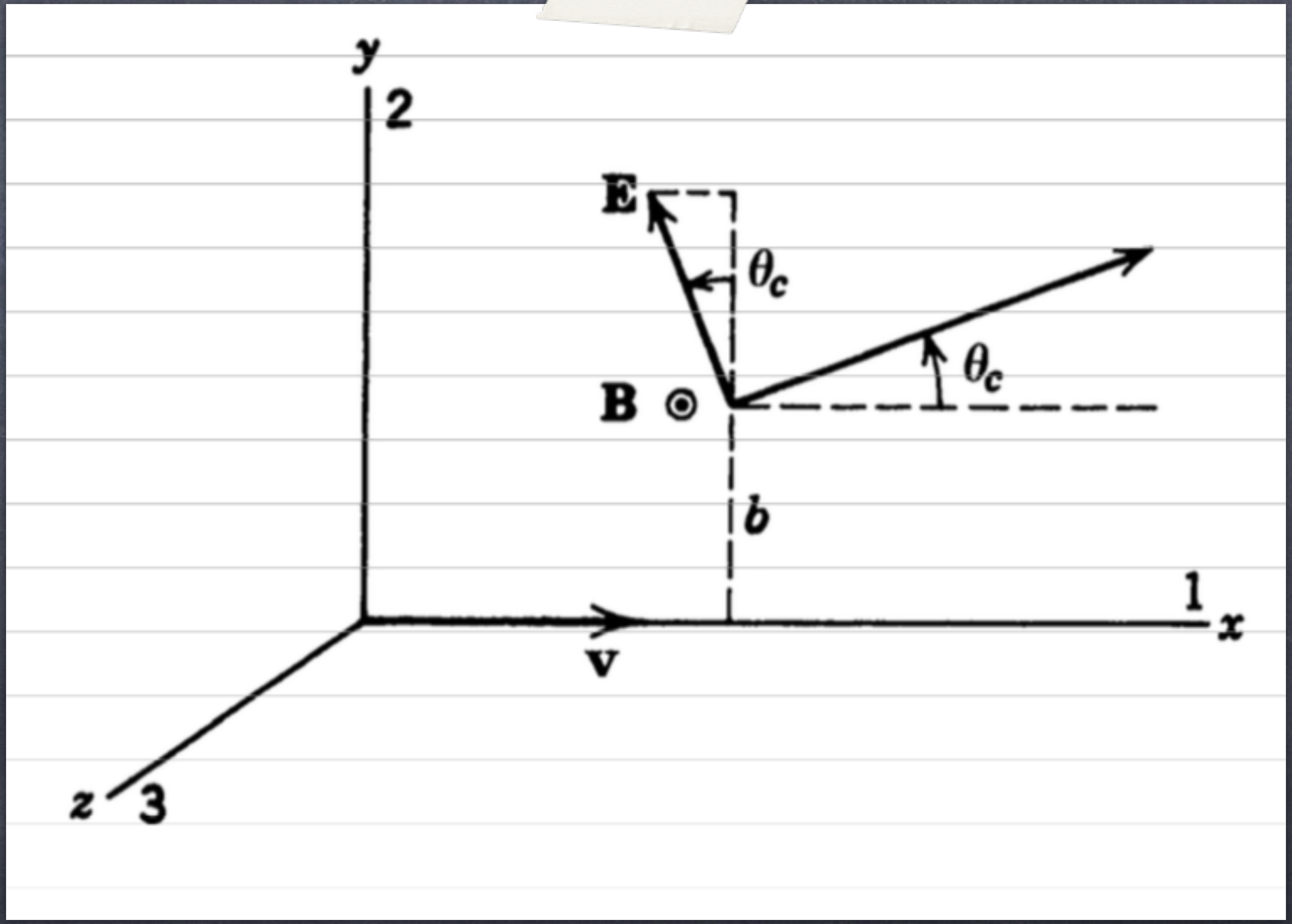
$$E_1(\omega,\ b) \to i\frac{ze\omega}{c^2}\left[1-\frac{1}{\beta^2\epsilon(\omega)}\right]\frac{e^{-\lambda b}}{\sqrt{\lambda b}}$$

Perpendicular Electric field

$$E_2(\omega,\ b) \to \frac{ze}{v\epsilon(\omega)}\sqrt{\frac{\lambda}{b}}e^{-\lambda b}$$

Magnetic field

$$B_3(\omega,\ b) \to \beta\epsilon(\omega)E_2(\omega,\ b)$$



$$\left(\frac{dE}{dx}\right)_{b>a} = -ca\ \mathrm{Re}\int_0^{\infty} B_3^*(\omega)E_1(\omega)d\omega$$

Energy loss of incident particle...

Plug in fields...

$$-caB_3^*E_1 \rightarrow \frac{z^2e^2}{c^2}\left(-i\sqrt{\frac{\lambda^*}{\lambda}}\right)\omega\left[1-\frac{1}{\beta^2\epsilon(\omega)}\right]e^{-(\lambda+\lambda^*)a}$$

if λ has positive real part, this attenuates rapidly at large distances

But if λ is imaginary... exponential goes away!

$$-caB_3^* E_1 \to \frac{z^2 e^2}{c^2} \left(-i\sqrt{\frac{\lambda^*}{\lambda}} \right) \omega \left[1 - \frac{1}{\beta^2 \epsilon(\omega)} \right] \cancel{e^{-(\lambda+\lambda^*)a}}$$

NO DEPENDENCE ON a! Some energy escapes to infinity as radiation!

$$\lambda^2 = \frac{\omega^2}{v^2}\left[1 - \beta^2\epsilon(\omega)\right]$$

λ is imaginary if:

$\epsilon(\omega) \in \text{Reals}$

$\beta^2\epsilon(\omega) > 1$

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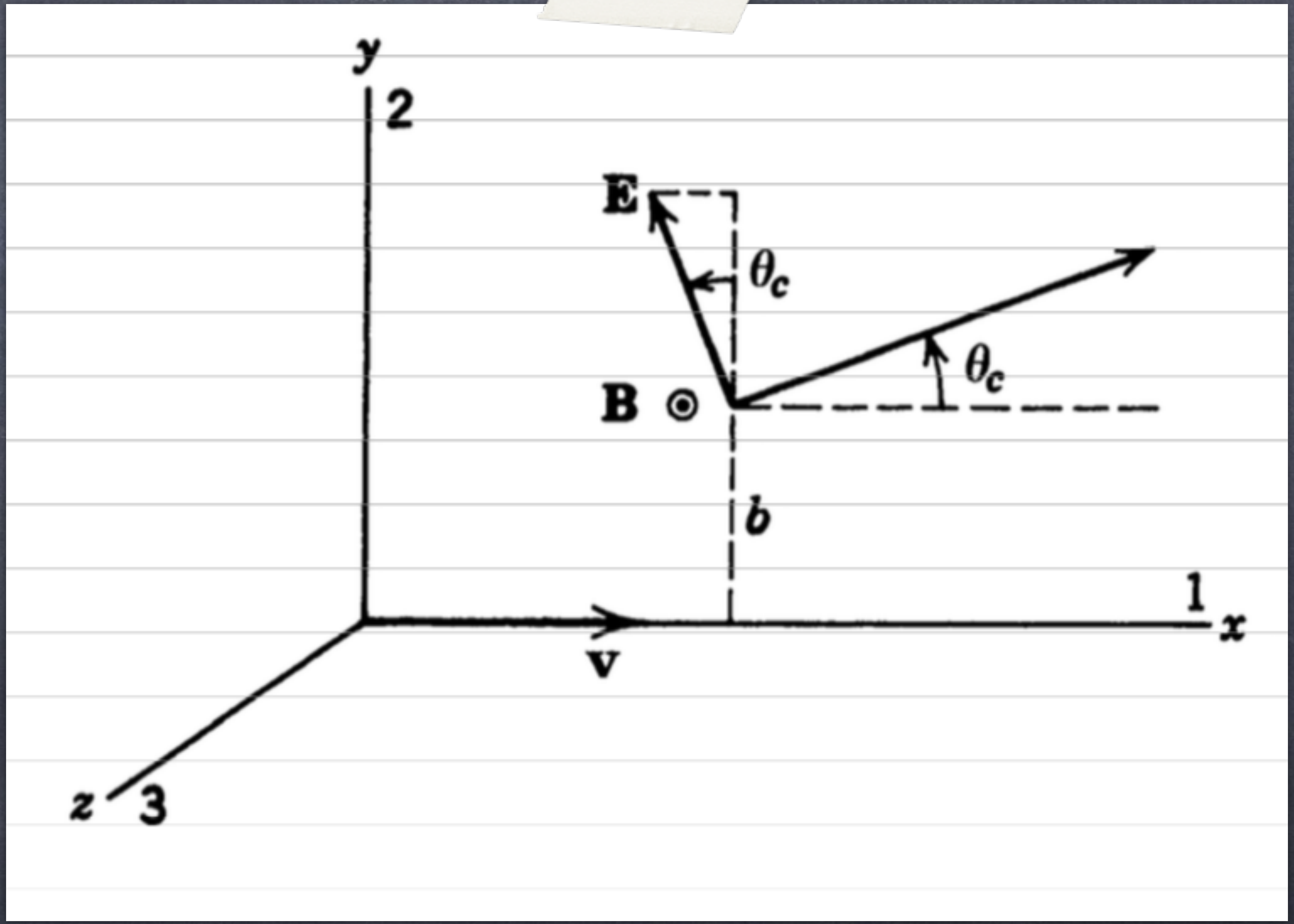
$$\beta = \frac{v}{c}$$

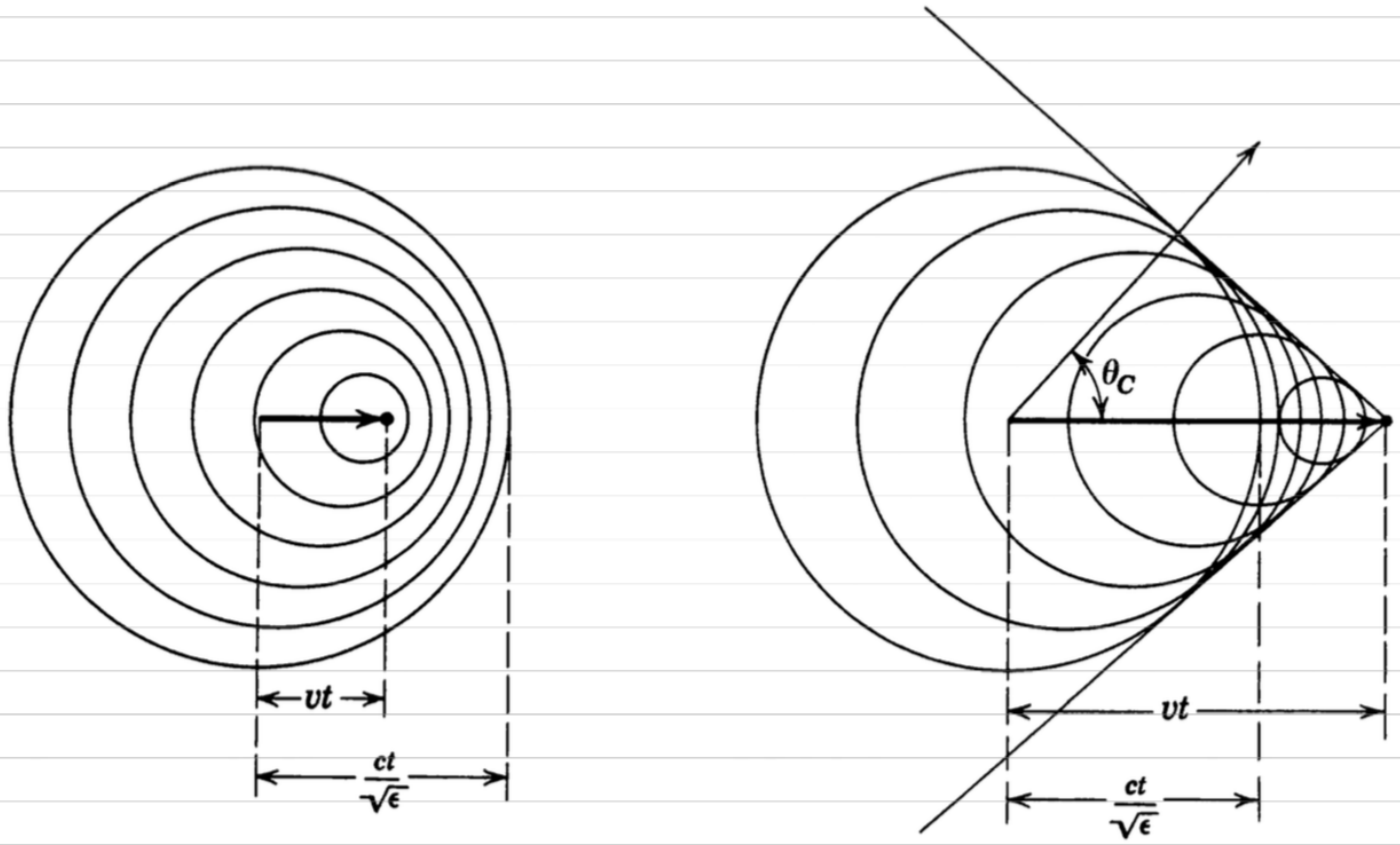
If particle speed is greater than speed of light in material, CHERENKOV RADIATION!

$$\boxed{v > \frac{c}{\sqrt{\epsilon(\omega)}}}$$

$$\tan\theta_c = \frac{-E_1}{E_2}$$

If you know the fields, you can get the angle



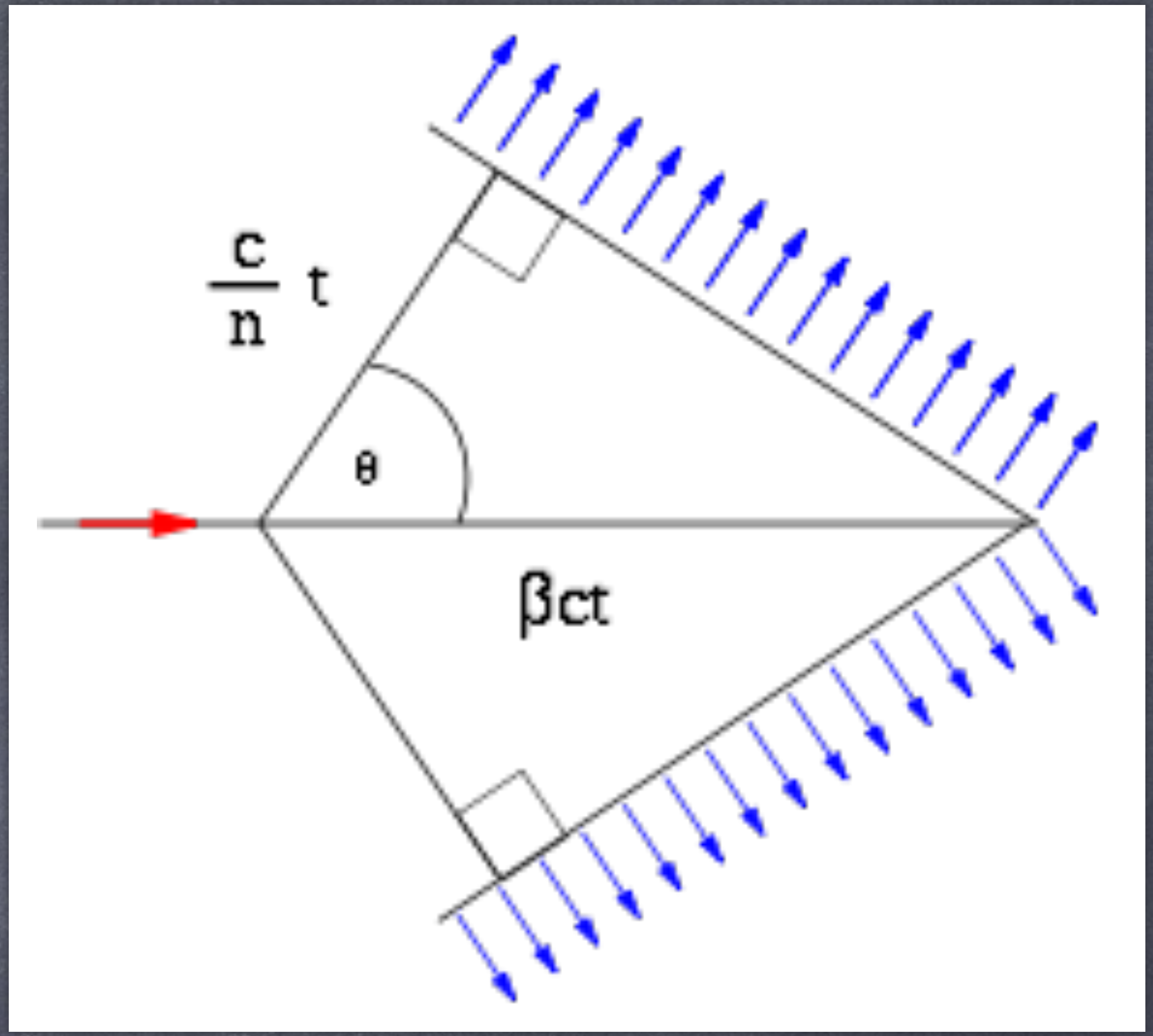


$v < c/\sqrt{\epsilon}$ $\qquad$ $v > c/\sqrt{\epsilon}$

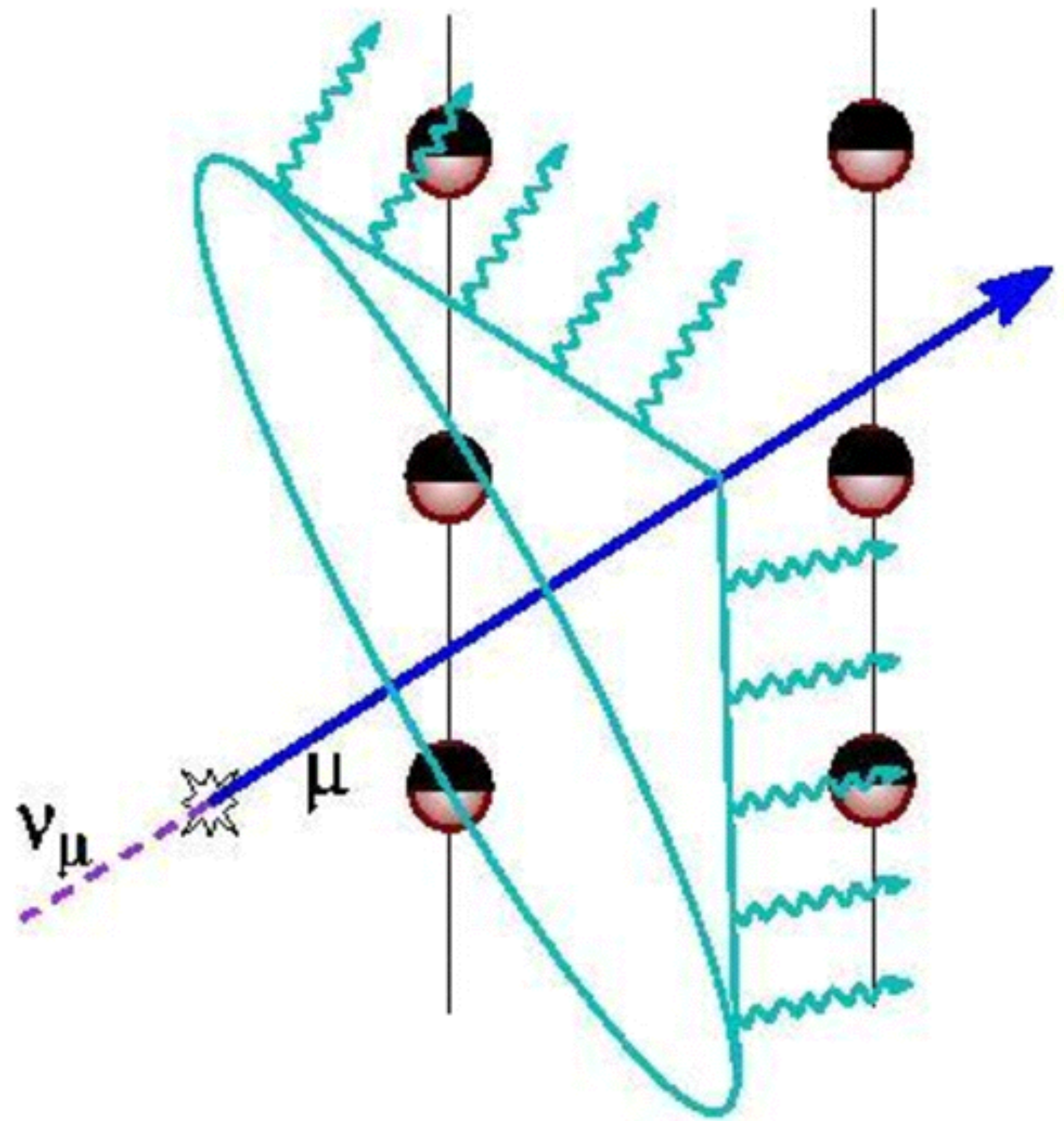
Figure 13.5 Cherenkov radiation. Spherical wavelets of fields of a particle traveling less than and greater than the velocity of light in the medium. For $v > c/\sqrt{\epsilon}$, an electromagnetic "shock" wave appears, moving in the direction given by the Cherenkov angle θ_C.

Or if you know the speed of the particle and dielectric constant, you can get the angle

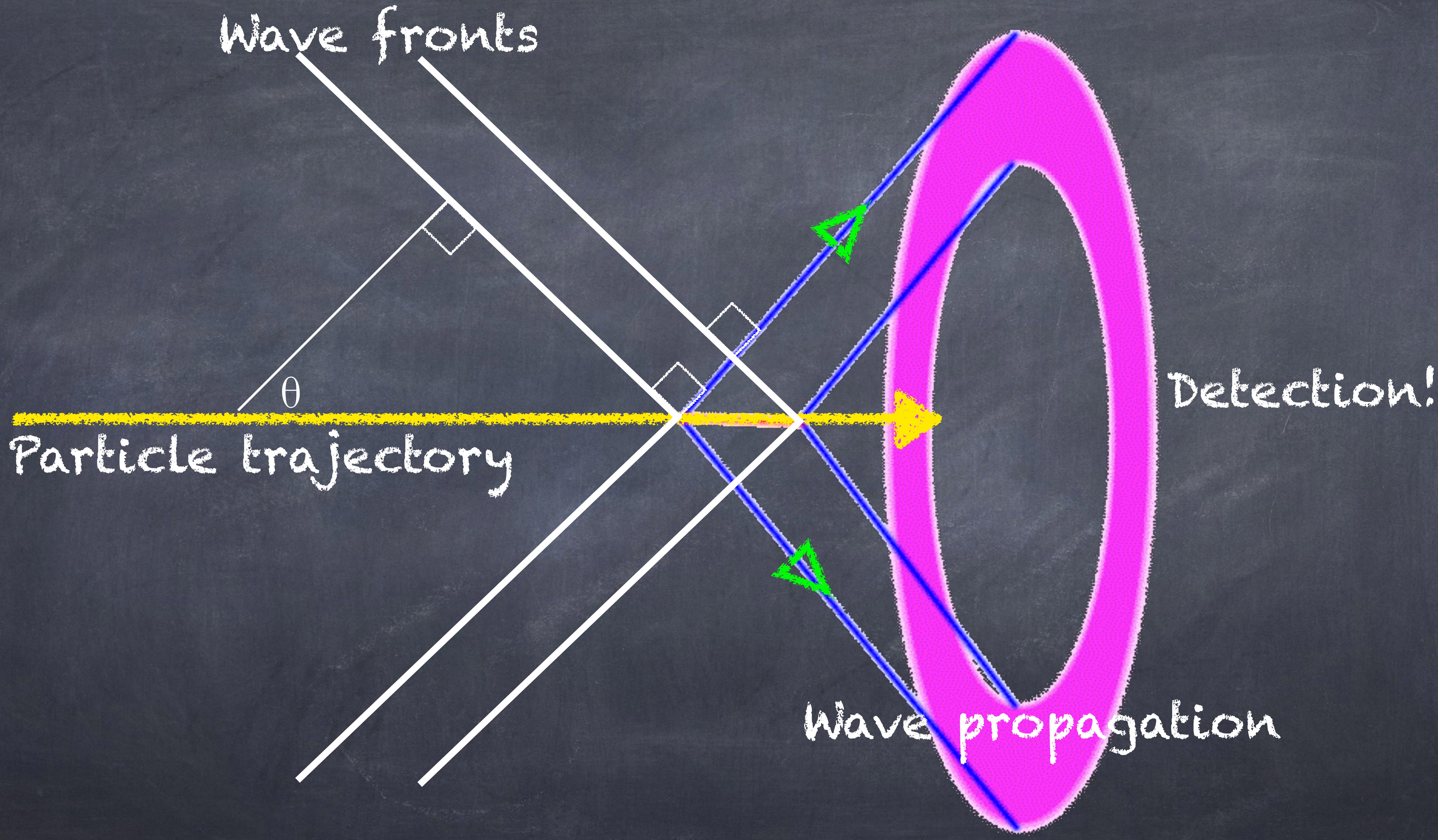
$$\cos\theta_c = \frac{1}{\beta\sqrt{\epsilon(\omega)}}$$

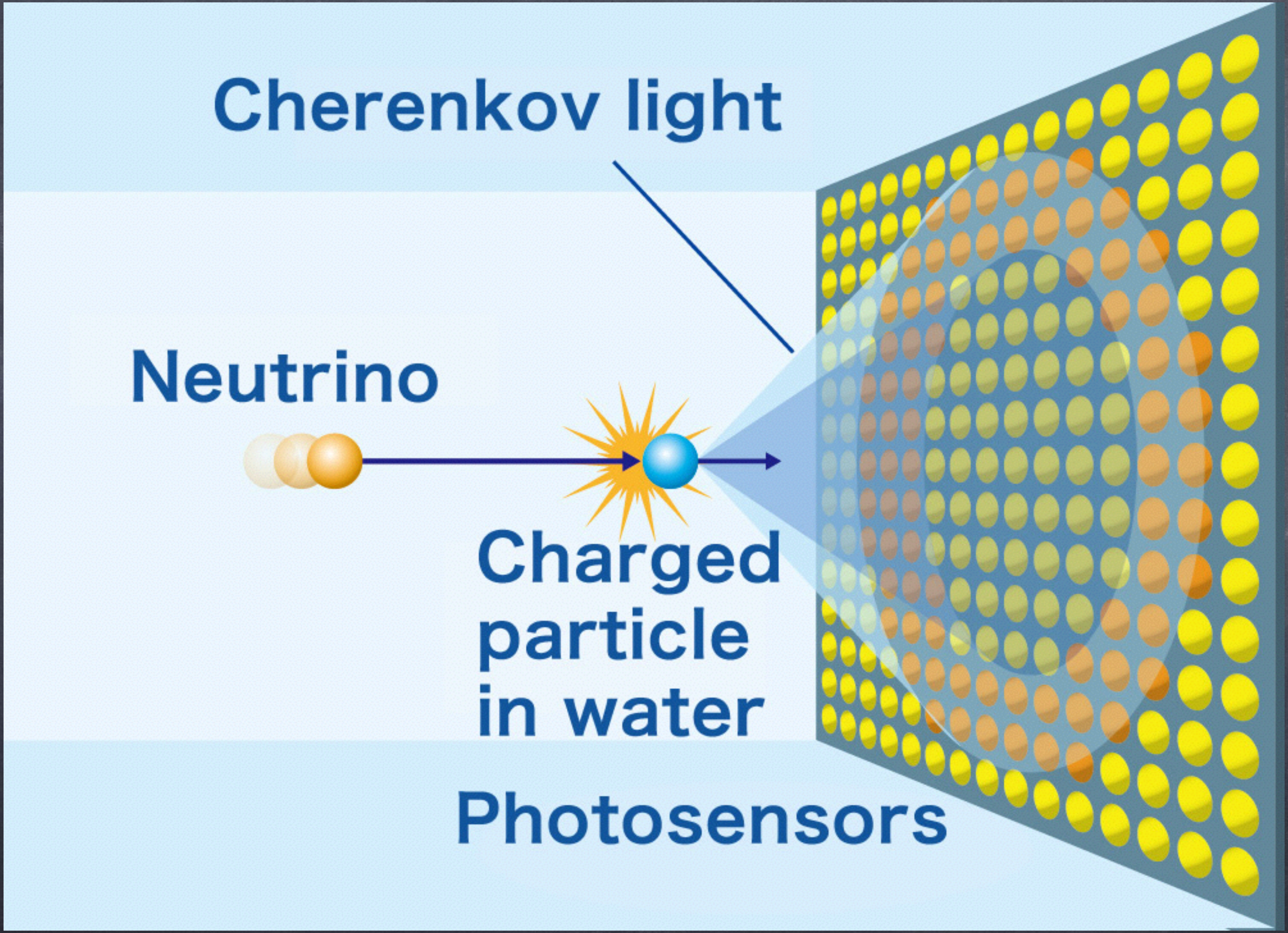


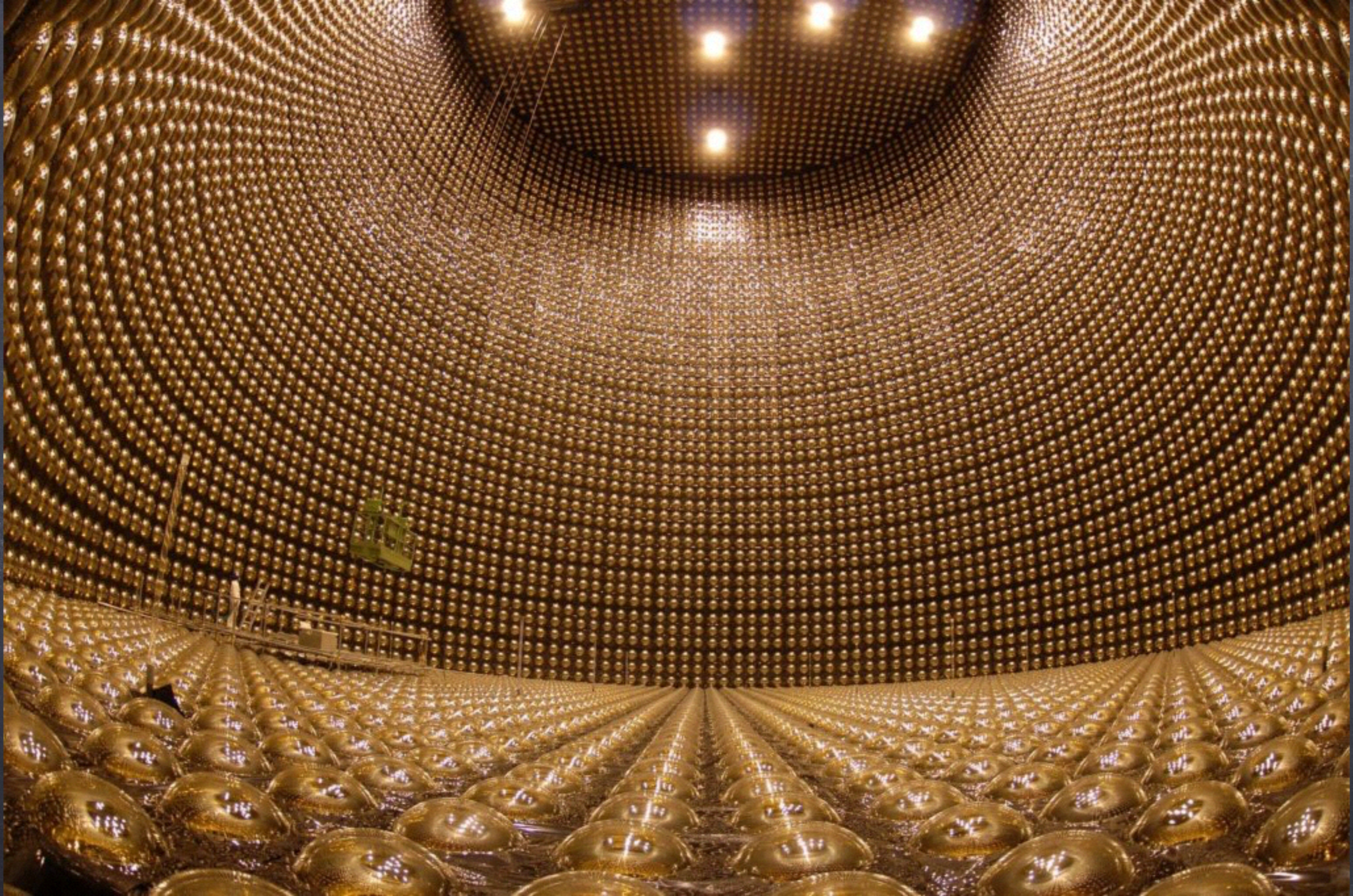
$\frac{c}{n}t$
θ
βct



ν_μ
μ


Wave fronts
θ
Particle trajectory
Detection!
Wave propagation


Cherenkov light
Neutrino
Charged
particle
in water
Photosensors



Super Kamiokande