Cherenkov Radiation

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Eletromagnetismo

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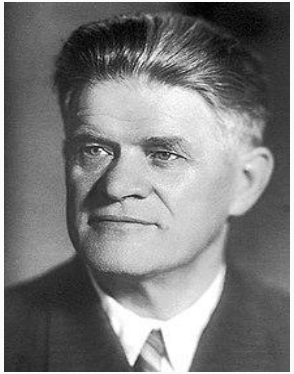
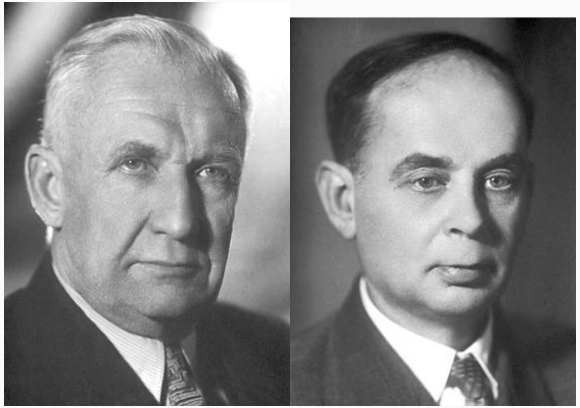
Historical Background

- Marie and Pierre Curie-1900
- Pavel Cherenkov- 1934
- Ilya Frank and Igor Tamm- 1937

Marie and Pierre Curie



Pavel Cherenkov



Igor Tamm and Ilya Frank

Cherenkov light

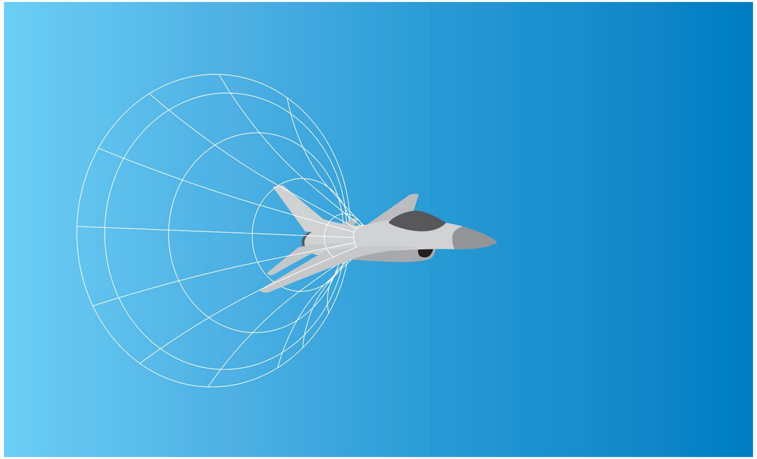


Figure 1: Jet breaks the sound barrier. Ref.6

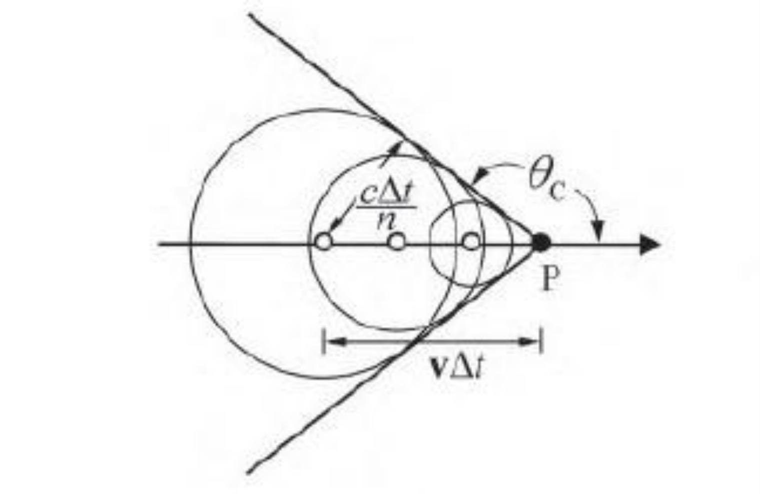


Figure 2: Spherical Waves. Ref.3

Theory

- Frank and Ilam propose a theory to explain the effect
- Special relativity
- Potentials and radiated energy

Theory

$$\cos\theta_c = \frac{1}{\beta_n}$$

$$\beta_n = \frac{vn}{c}$$

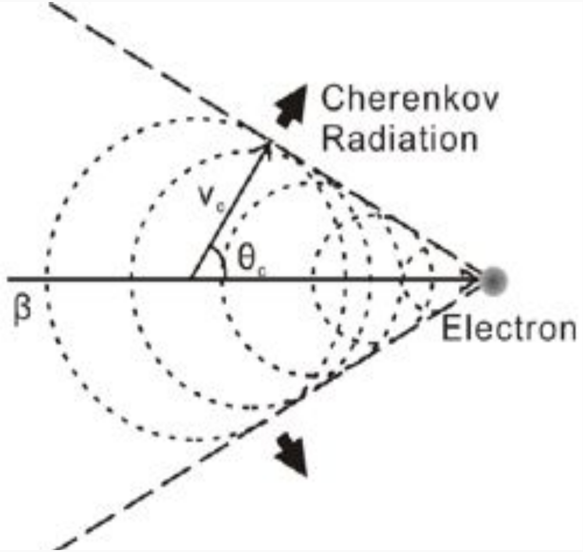


Figure 3: Cherenkov relation
Ref.7

Cherenkov in the water

- $n=1.33$
- $\theta=41^{\circ}$
- $v=2.3 \times 10^{8} m/s$

Theory

- Momentum conservation:

$$P^2 = P_0^2 + P_c^2 - 2P_0 P_c \cos\theta_c$$

- Energy conservation:

$$(P_0^2 c^2 + m_0^2 c^4)^{1/2} = (P^2 c^2 + m_0^2 c^4) + h\nu$$

Theory

- Angle in terms of the momentum and mass of the particle

$$\cos\theta_c = \frac{(P_c^2 + m_0^2c^4)^{1/2} + (n^2 - 1)h\nu}{2P_0cn}$$

$$\cos\theta_c = \frac{1}{\beta_n}$$

- Speed of the particle

$$v = \frac{P_0c^2}{(P_c^2 + m_0^2c^4)^{1/2}}$$

Theory: Potentials of Liénard-Wiechert

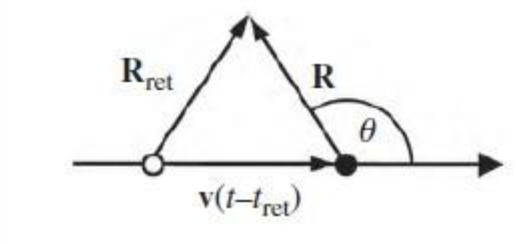
- Scalar potential

$$\phi(\mathbf{r}, t) = \frac{1}{4\pi\epsilon}\left[\frac{q}{R - \beta_n \cdot \mathbf{R}}\right]_{ret}$$

- Vector potential

$$\mathbf{A}(\mathbf{r}, t) = \frac{\mu}{4\pi}\left[\frac{qv}{R - \beta_n \cdot \mathbf{R}}\right]_{ret}$$

Theory: Potentials of Liénard-Wiechert



$$t - t_{ret} = \frac{-\mathbf{v}\cdot\mathbf{R} \pm \sqrt{(\mathbf{v}\cdot\mathbf{R})^2 - (v^2 - c_n^2)R^2}}{v^2 - c_n^2} \geq 0$$

Theory: Potentials of Liénard-Wiechert

- Conditions for the angle (v>c) : $\theta > \frac{\pi}{2}$

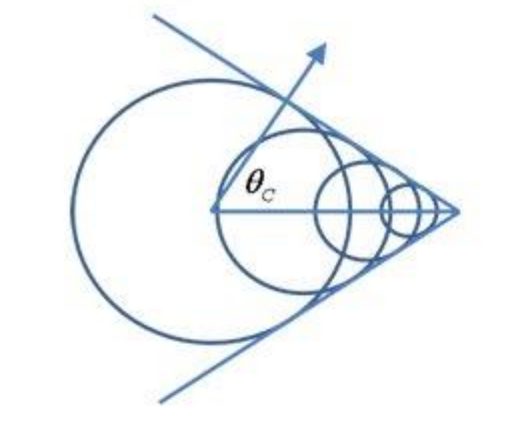


Figure 4:: Cherenkov cone .Ref.13

Radiated energy

$$\frac{d^2U_{rad}}{d\omega dA} = \frac{\mu q^2}{4\pi}\left(1 - \frac{c^2}{v^2n^2}\right)\omega$$

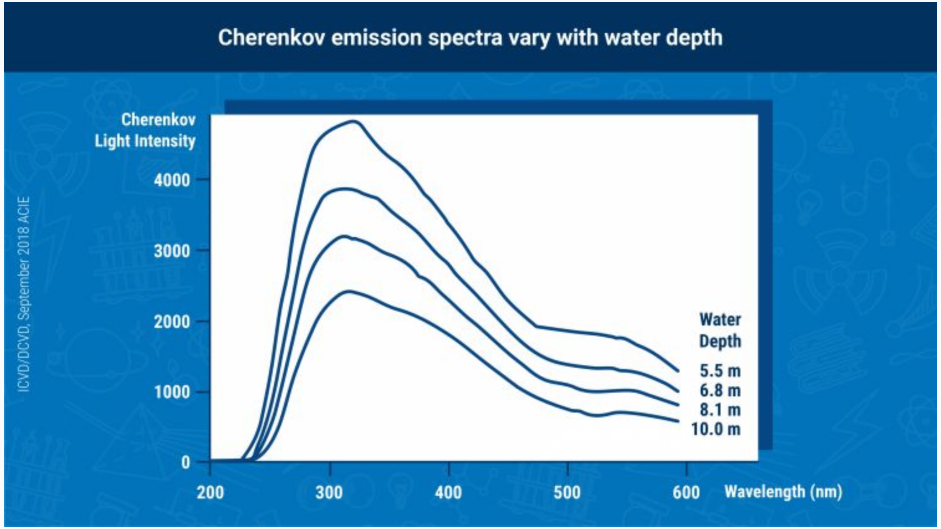


Figure 5: Cherenkov emission spectra .Ref.9

Applications

- Nuclear reactors
- Astrophysics and detectors

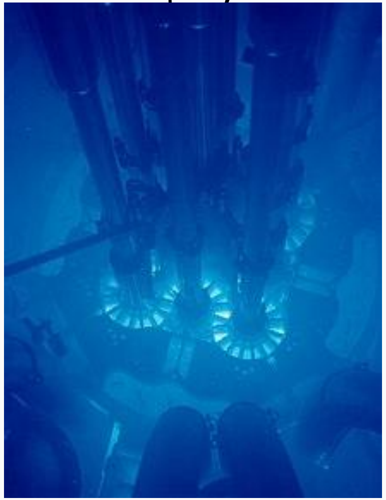


Figure 6: Emission of Cherenkov light. Ref.5

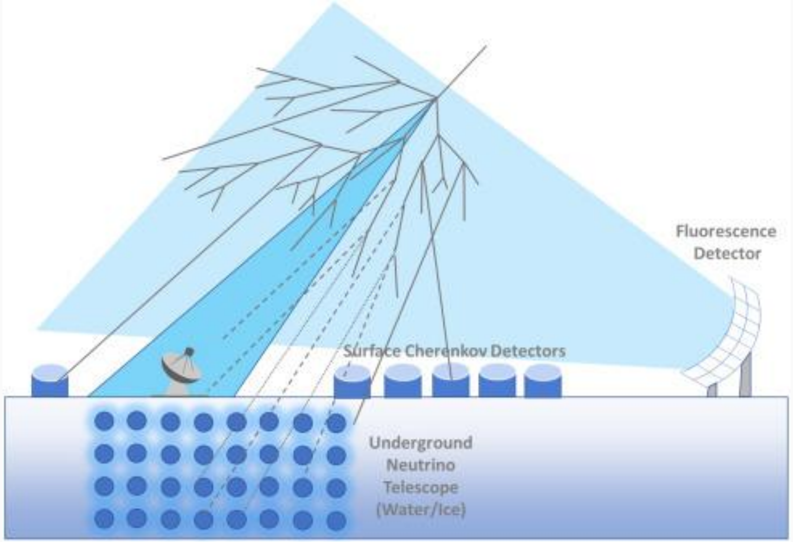


Figure 7: Emission of Cherenkov light in a particle shower. Ref.8

Applications

- CTAO
  - Three telescopes
  - Photomultipliers

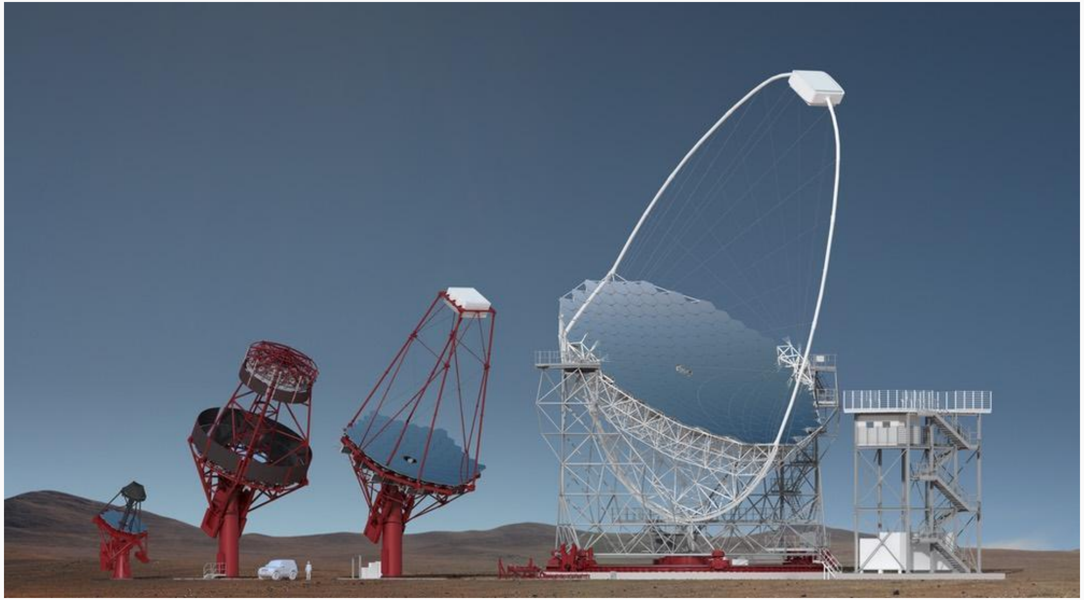


Figure 8: Future telescopes in CTAO: Ref.14

Conclusion

- More applications
  - Medical
- Other experiments
  - H.E.S.S, Super-Kamiokande, IceCube.

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Thank you!