GENERALIZED CHERENKOV RADIATION FROM TACHYONIC SOURCES

Edward B. Rockower, Ph.D.
invited speaker, Dept. of Physics, Bryn Mawr College
February, 1978

- INTRODUCTION AND REVIEW
  - THEORY
    - FASTER-THAN-LIGHT PARTICLES
    - CHERENKOV RADIATION
  - EXPERIMENTS
- DYNAMICS OF A TACHYONIC SOURCE
  - RELATION TO CHERENKOV RADIATION
- PROPERTIES OF GENERALIZED CHERENKOV RADIATION
  - KINEMATICS
  - DYNAMICS

References:
-- author's Ph.D. dissertation, Brandeis University, June, 1975
-- "A Relativistic Mass Tensor With Geometric Interpretation" by E. Rockower, Am. J. of Physics, 55, pp. 70 - 77 (1987)

ABSTRACT

“GENERALIZED CHERENKOV RADIATION FROM TACHYONIC SOURCES”

(A Dissertation Presented to the Faculty of the Graduate School of Arts and Sciences of Brandeis University, Waltham, Massachusetts.)

By Edward B. Rockower

We have investigated the possibility of a generalized Cherenkov radiation which might result from the coupling of a superluminal (tachyonic) source to a short range "massive" field. We have mainly focused on the properties of this "generalized Cherenkov radiation" by tachyons in a vacuum. The complementary problem of the source dynamics was also investigated and its relation to Cherenkov radiation elucidated. Our results include an equation for the acceleration of tachyons showing quantitatively the fact that force and acceleration can be in opposite directions for tachyons, and the relation of this equation to Cherenkov radiation.

The Lorentz boost transformation of the acceleration of a tachyon is derived and shown to admit of the possibility of reversal in sign. This is contrary to the case for ordinary particles, but necessary to the Lorentz covariance of Cherenkov radiation. The consequences of conservation of four-momentum during generalized Cherenkov radiation were then derived.

The subject of recoil of the particle was further pursued by a calculation of the trajectory resulting from Cherenkov radiation in configuration space for a classical tachyon, and more generally for each component of a wave packet in momentum space. The two are shown to be consistent and equivalent to the same Lorentz covariant energy loss rate for a tachyon. Reasons are presented which indicate a large value for this rate. We calculated the properties of the generalized Cherenkov radiation beginning with an analysis of the relation between the energy of the emitted massive particle and the angle of emission. The existence of a minimum value of the wave vector was derived, depending on the mass of the radiated field and thus absent for electromagnetic or other massless fields.

The details of calculations of the generalized Cherenkov radiation were then presented for a c-number non-recoiling source and for a quantum field theoretic model. They are shown to agree within certain approximations with each other and with the previously derived Lorentz covariant form of the energy loss rate. In addition we find that due to the presence of a k_{min} there is the possibility that the generalized Cherenkov radiation may be partially or wholly suppressed. This potentiality does not exist for electromagnetic or other massless Cherenkov radiation because of the absence of k_{min} in the latter cases.

The value of the power radiated in various directions is found for an arbitrary form factor. In the appendices of the dissertation, the form of Cherenkov radiation is found for accelerated particles and the details of the form factor for a tachyon are derived, among other results referred to in the text.

The application of our results was then made to the analysis of experiments already performed, resulting in conclusions different from those previously reported. We have also suggested new directions for experimental efforts based on our calculations.

ARGUMENTS AGAINST FASTER-THAN-LIGHT PARTICLES

"... VELOCITIES GREATER THAN THAT OF LIGHT HAVE NO POSSIBILITY OF EXISTENCE" ------ A. EINSTEIN (1905)

- $E = \dfrac{mc^2}{\sqrt{1 - v^2/c^2}}$ → INFINITE ENERGY BARRIER AT c

-- CLASSICAL IDEA OF CONTINUOUS CHANGES ALLOWED IN v

- PARADOXES — TRAVEL BACKWARD IN TIME -- $\Delta t' = (\Delta t - \dfrac{\bar{u} \cdot \Delta x}{c^2})\gamma$

$$= \Delta t \left(1 - \frac{\bar{u} \cdot \bar{v}}{c^2}\right)\gamma$$

where $\gamma = 1/\sqrt{1 - u^2/c^2}$

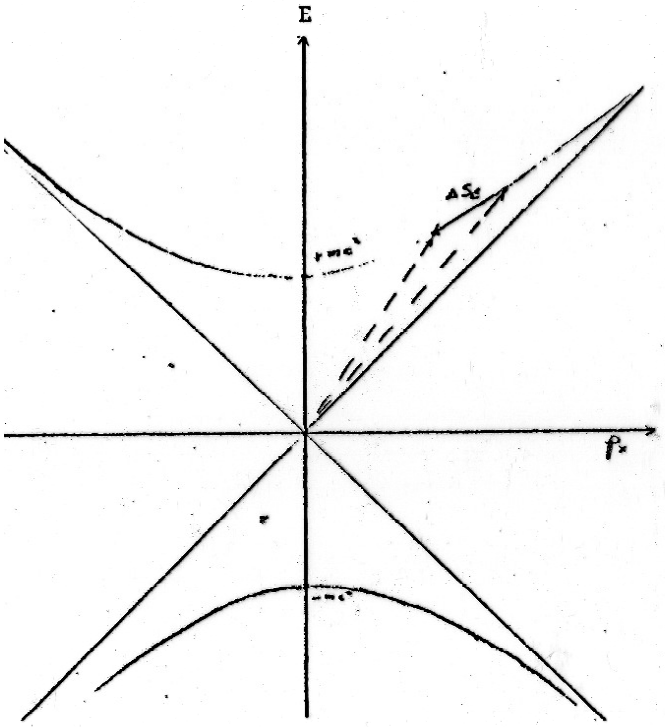
- IMAGINARY QUANTITIES IF $v > c$

- INSTABILITY RESULTING FROM CHANGE OF SIGN OF E UNDER L. T.

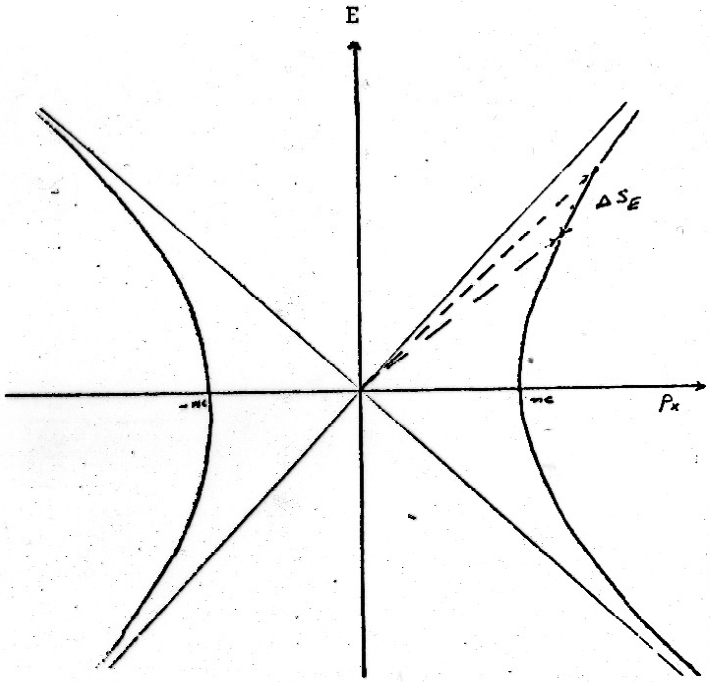
$$E' = (E - \bar{p}\cdot\bar{u}) = E(1 - \bar{v} \cdot \bar{u}/c^2)\gamma$$

- OTHERS WILL BE MENTIONED LATER

MASS HYPERBOLOIDS



$E^2 = \vec{p}^2 + m^2$



$E^2 = \vec{p}^2 - m^2$

WHY TACHYONS MIGHT EXIST

- QUANTUM MECHANICS → CREATE PARTICLES ALREADY TRAVELING AT GIVEN VELOCITY

- BILANIUK, DESHPANDE, AND SUDARSHAN (1962) -- PERHAPS THERE EXIST A THIRD CLASS OF PARTICLES WITH v ALWAYS GREATER THAN c

  — THE ENERGY BARRIER AT c LIMITS THEM TO $v > c$

- ANY IMAGINARY PARAMETERS, E.G. TACHYON MASS, $\mu = i\, m_T$ (where $m_T = |\mu|$) ARE NOT OBSERVABLES,

$$E = \frac{\mu c^2}{\sqrt{1 - v^2/c^2}} = \frac{m_T c^2}{\sqrt{v^2/c^2 - 1}}$$ IS REAL (SINCE $v > c$) AND OBSERVABLE.

- PARADOXES ($\Delta t \longrightarrow -\Delta t$) AND INSTABILITIES ($E \longrightarrow -E$)

  — MAY DISAPPEAR WHEN INTERACTIONS ARE CONSIDERED

  — BILANIUK ET.AL. NOTED THAT CONDITIONS FOR REVERSAL IN SIGN OF Δt AND OF E ARE THE SAME ($\frac{\vec{u} \cdot \vec{v}}{c^2} > 1$) AND PROPOSED "REINTERPRETATION PRINCIPLE"

TACHYON PROCESSES

- BILANIUK ET.AL. (1962)

  — GEOMETRIC HUYGENS CONSTRUCTION

  — PARTICLE WITH SPACELIKE 4-MOMENTUM CAN DECAY INTO ITSELF AND PHOTON

  ➞ ELECTRICALLY CHANGED TACHYON MAY EMIT CHERENKOV RADIATION

  ∴ POSSIBLE MEANS OF DETECTING THEIR EXISTENCE

- FEINBERG (1967)

INERTIAL FRAME 1 (REST) — INERTIAL FRAME 2 ($\frac{u \cdot v_T}{c^2} > 1$)

TACHYON PROPERTIES

- $E = \dfrac{m c^2}{\sqrt{v^2/c^2 - 1}}$ → TACHYONS WILL SPEED UP AS THEY LOSE ENERGY

  HENCE A FORCE AND THE ASSOCIATED ACCELERATION CAN BE IN OPPOSITE DIRECTIONS

- IF TACHYON EMITS CHERENKOV RADIATION, IT WILL LOSE ENERGY AND SPEED UP

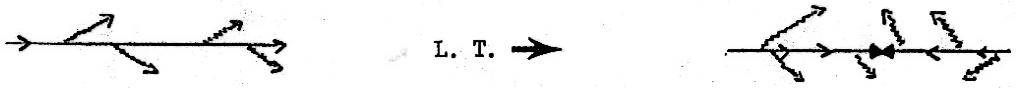
- INFINITE VELOCITY ↔ ZERO TACHYON ENERGY

  — ARE NOT LORENTZ COVARIANT NOTIONS

  → TACHYON WILL EVENTUALLY ACQUIRE NEGATIVE ENERGY

- REINTERPRET THIS AS AN INCOMING POSITIVE ENERGY ANTITACHYON WHICH ANNIHILATES THE ORIGINAL TACHYON AT THE ZERO ENERGY POINT.

  → LIMITED FREEDOM IN SPECIFYING INITIAL CONDITIONS EVEN FOR CLASSICAL TACHYONS



QUANTUM FIELD THEORY (TYPE I)

- KLEIN-GORDON EQUATION FOR NEGATIVE MASS SQUARED

$$(\delta_t^2 - \nabla^2 - m^2)\ \Phi = 0$$

HAS BASIC SOLUTIONS $(kx = wt - \bar{k} \cdot \bar{x})$

$$\frac{1}{(2\pi)^{3/2}}\ e^{\pm ikx}$$

WHERE

$$w = \sqrt{\bar{k}^2 - m^2}$$

- IF WE REQUIRE w TO BE REAL, $|\bar{k}| \geq m$ (TYPE I THEORIES)

  — SOLUTIONS DO NOT FORM A COMPLETE SET ON THE $t = 0$ HYPERSURFACE -- i.e., WE CANNOT FORM A DELTA FUNCTION

  — HENCE (1) WE LACK SOME FOURIER COMPONENTS NECESSARY TO SATISFY ARBITRARY INITIAL CONDITIONS FOR THE TACHYON FIELD,

  (2) WE CANNOT OBTAIN CANONICAL COMMUTATION RELATIONS AND

  (3) THERE ARE PROBLEMS WITH THE LOCALIZABILITY OF TACHYON WAVE PACKETS

QUANTUM FIELD THEORY (TYPE II)

- IF WE INCLUDE ALL $\bar{k}$ VALUES (TYPE II THEORY)
  - EVEN THOUGH $v_g \equiv \frac{\delta E}{\delta \bar{p}} > c$, SIGNALS TRAVEL SLOWER THAN c
  - TYPE II THEORIES MAY HAVE CAUSAL PROPAGATION
    i.e., A CAUSAL GREEN'S FUNCTION CAN BE CONFINED TO THE INTERIOR OF THE LIGHT CONE
  - THERE EXIST UNSTABLE MODES OF THE FIELD
    - -- IMAGINARY w
    - -- KLEIN-GORDON EQUATION GOVERNS FLEXIBLE STRING EMBEDDED IN RUBBER (NEGATIVE "SPRING CONSTANT" CORRESPONDS TO TACHYON FIELD)

TACHYON SEARCHES

BASED ON $E^2 = \bar{p}^2 - m^2$

- ALVAGER AND ERMAN (NOBEL INSTITUTE-STOCKHOLM, 1965) WERE MOTIVATED BY BDS ARTICLE
  - RADIOACTIVE BETA DECAY OF THULIUM-170 AS POSSIBLE SOURCE OF ELECTRICALLY CHARGED TACHYONS
  - AT EQUAL VALUES OF $\bar{p}$, TACHYONS AND ORDINARY PARTICLES WITH EQUAL m WILL POSSESS DIFFERENT ENERGY
  - THEY ASSUMED NO CHERENKOV RADIATION
  - NO TACHYONS FOUND

- BALTAY et.al. (1970) -- MISSING MASS EXPERIMENT
  - TACHYONS HAVE SPACELIKE FOUR MOMENTUM ($p^2 < 0$)
  - ANTIPROTONS OR K^- PARTICLES WERE GIVEN OPPORTUNITY TO PRODUCE TACHYONS IN A BUBBLE CHAMBER
  - USING CONSERVATION OF ENERGY AND MOMENTUM THE INVARIANT MASS SQUARED OF ANY MISSING PARTICLES IS CALCULATED BASED ON MOMENTA OF OBSERVED PARTICLES
  - HOPEFULLY NOT SENSITIVE TO CONJECTURED PROPERTIES OF TACHYON INTERACTIONS
  - NO NEGATIVE MISSING MASS SQUARED WAS FOUND

TACHYON SEARCHES

BASED ON CHERENKOV RADIATION

- ALVAGER AND KREISLER (PRINCETON - PENN ACCELERATOR, 1968)
  - TACHYONS TO BE PRODUCED BY GAMMA RAYS IMPINGING ON LEAD
  - ENERGY GAINED FROM A STATIC ELECTRIC FIELD WAS TO BALANCE ENERGY LOST THROUGH CHERENKOV RADIATION
  - CALCULATIONS WERE NOT LORENTZ COVARIANT
  - LOOK FOR RADIATION AT THE CHARACTERISTIC CHERENKOV ANGLE

$$\cos\theta = \frac{c}{v_T}$$

  - NO EVIDENCE FOR TACHYONS

- DAVIS, ALVAGER AND KREISLER (1969)
  - TWO DETECTORS WITH ACCELERATING ELECTRIC FIELDS
  - LOOK FOR COINCIDENT COUNTS TO AVOID LARGE NUMBER OF SPURIOUS COUNTS FROM CORONA DISCHARGE
  - NO TACHYONS

TACHYON SEARCHES BASED ON

$v > c$

- LOOK FOR TACHYON PRECURSORS TO EXTENSIVE AIR SHOWERS (EAS) FROM HIGH ENERGY COSMIC RAYS
  - FASTEST ORDINARY PARTICLES HAVE $v \sim c$
  - FASTEST TACHYONS ARRIVE ALMOST IMMEDIATELY
  - USE TRANSIENT RECORDER -- WHEN EAS ARRIVES, LOOK AT PRECEDING TIME PERIOD FOR CORRELATIONS
- RAMANA MURTHY (1971)
  - 20 MICROSECONDS
  - COINCIDENCES FOUND DID NOT EXCEED CHANCE FLUCTUATIONS
- CLAY AND CROUCH (1974)
  - EAS OF $> 10^{15}$ eV
  - FIRST INTERACTIONS ABOUT 20 km w.p.
  - EAS ARRIVE 60 MICROSECONDS LATER
  - PRECEDING 105 MICROSECONDS EXAMINED
  - STATISTICALLY HIGHLY SIGNIFICANT EXCESS OF COUNTS FOUND
- LATER EAS SEARCHES NEGATIVE
- LATER ANALYSIS (PRESCOTT, 1976) INDICATES SYSTEMATIC INSTRUMENT ERROR IN CLAY AND CROUCH EXPERIMENT

LACK OF THEORETICAL HELP FOR EXPERIMENTALISTS

- PREVIOUS EXPERIMENTS BASED ON CONFLICTING, INCONSISTENT OR NONCOVARIANT ASSUMPTIONS (NOT "FEW" AS CLAIMED)
  - CHARGED BUT NOT CHERENKOV RADIATING
  - CHERENKOV RADIATION RATE NOT LORENTZ COVARIANT
  - CHERENKOV RADIATION OF MASSIVE FIELDS NOT CONSIDERED
- ABSENCE OF A COHERENT QUANTUM FIELD THEORY OR S MATRIX THEORY OF INTERACTING TACHYONS
- INVESTIGATE PROPERTIES RESULTING FROM "REASONABLE" ASSUMPTIONS
- SOME IDEA OF TACHYON BEHAVIOR NEEDED TO DESIGN SUCCESSFUL EXPERIMENTS
  - EVEN MORE CRUCIAL THAN FOR ORDINARY PARTICLES
  - ALSO NEEDED FOR INTERPRETATION OF EXPERIMENTS

DYNAMICS OF A TACHYONIC SOURCE

- CHERENKOV RADIATION SINGULARLY CHARACTERISTIC OF TACHYONS
  - PARTICULARLY RELEVANT TO THEIR DETECTION
- ELECTROMAGNETIC AND GRAVITATIONAL CHERENKOV RADIATION HAVE BEEN CONSIDERED BY OTHERS
  - EXTENSION TO GENERALIZED CHERENKOV RADITION OF SHORT RANGE (MASSIVE) FIELDS
  - LORENTZ COVARIANT TREATMENT
- FIRST -- GENERAL ANALYSIS OF GENERALIZED CHERENKOV RADIATION EMPHASIZING BEHAVIOR OF THE SOURCE

ACCELERATION VS. FORCE -- CLASSICAL PARTICLE

- $E^2 = \bar{p}^2 c^2 - m_T^2 c^4 \rightarrow E = \dfrac{mc^2}{\sqrt{\dfrac{v^2}{c^2} - 1}}$ (TACHYON)

- $\bar{v} = \bar{p} \dfrac{c^2}{E}$ (IN GENERAL)

- $\dfrac{d\bar{v}}{dt} = \dfrac{d\bar{p}}{dt} \dfrac{c^2}{E} - \dfrac{\bar{p} c^2}{E^2} \dfrac{dE}{dt}$

✓ NOW USE: $\dfrac{dE}{dt} = \bar{F} \cdot \bar{v}$ & $\dfrac{d\bar{p}}{dt} = \bar{F}$

- HENCE:

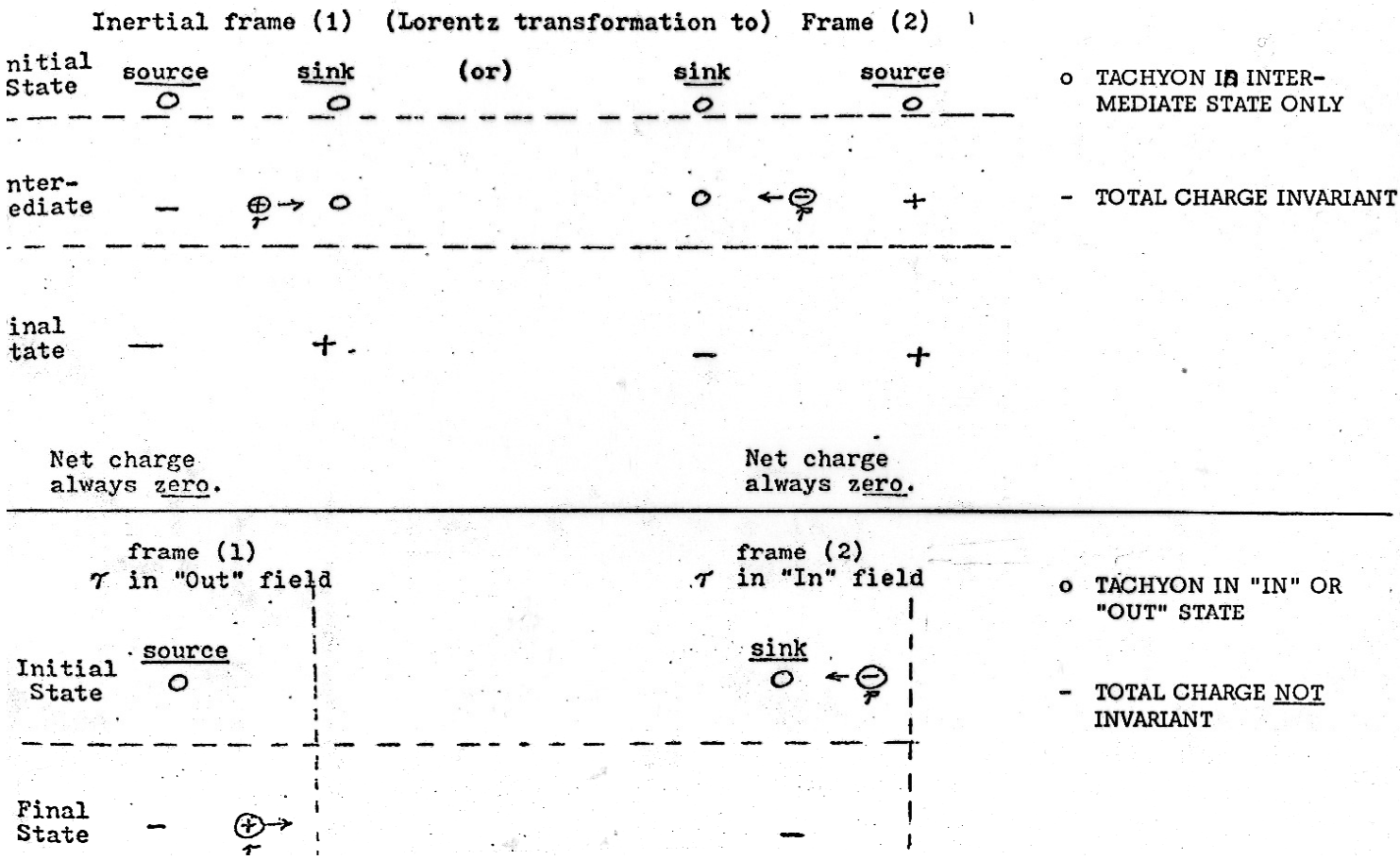
$$\frac{d\bar{v}}{dt} = \bar{F} \frac{c^2}{E} - \bar{p} \frac{c^2}{E^2} \bar{F} \cdot \bar{v}$$

OR $\boxed{\dfrac{d\bar{v}}{dt} = \dfrac{c^2}{E} \bar{F} \cdot \left(\bar{\bar{1}} - \dfrac{\bar{v}\bar{v}}{c^2} \right)}$

$\rightarrow m_l, m_t$

- 1/6 PRECESSION OF PERIHELION OF MERCURY, ETC.

A PROBLEM WITH FREE TACHYONS



LORENTZ COVARIANT FORM OF ENERGY LOSS

- ASSUME ENERGY LOSS LORENTZ COVARIANT FUNCTION OF $\bar{p}$, E AT EACH INSTANT
- MOTION APPROXIMATELY RECTILINEAR IN OBSERVER'S FRAME
- NO PREFERRED REFERENCE FRAME

  → SEEK SOME INVARIANT WAY OF SAYING THE "RATE" OF "ENERGY" LOSS IS CONSTANT

  — INDEPENDENT OF p & t.

- DURING AN INTERVAL OF TIME A COMPONENT OF A TACHYON WAVE PACKET $(E_1, \bar{p}_1)$

  — RADIATES ENERGY E AND MOMENTUM $\bar{p}$
  — MOVES TO POINT $(E_2, \bar{p}_2)$
  — CONSTRAINED TO REMAIN ON MASS HYPERBOLOID — $E^2 = p^2 - m^2$

- INVARIANT DISTANCE IN 4-MOMENTUM SPACE

$$\left(\Delta S_E\right)^2 = \left(\Delta E\right)^2 - \left(c\Delta\bar{p}\right)^2$$

- LAPSE OF INVARIANT PROPER DISTANCE ASSOCIATED WITH MOVE ON HYPERBOLOID IS ds
- INVARIANT STATEMENT OF CONSTANCY OF RATE ALONG TRAJECTORY IN MOMENTUM SPACE

  — $\frac{dS_E}{ds} = -f$

- $$\frac{dS_E}{ds} = \frac{\left[\left(\frac{dE}{cd\bar{p}}\right)^2 - 1\right]^{1/2} \; c|d\bar{p}|}{ds}$$

- NOW USE $\frac{dE}{d\bar{p}} = \bar{v}$ & $ds^2 = d\bar{x}^2 - c^2dt^2$
$= c^2\left(\frac{v^2}{c^2} - 1\right) dt^2$

- HENCE

$$\frac{dS_E}{ds} = \frac{\sqrt{\frac{v^2}{c^2} - 1}}{\sqrt{\frac{v^2}{c^2} - 1}} \frac{d\bar{p}}{dt} = \boxed{\frac{d\bar{p}}{dt} = -f}$$

OR MULTIPLY BY: $\frac{\frac{dE}{|d\bar{p}|}}{\frac{}{|\bar{v}|}} = 1$

$$\frac{dS_E}{ds} = \boxed{\frac{dE}{dx} = -f}$$

- I.E., A TACHYON LOSES A CONSTANT AMOUNT OF ENERGY PER UNIT PATH LENGTH & FORCE OF RADIATION REACTION IS CONSTANT, INDEPENDENT OF $\bar{v}$.

- NEED TO EVALUATE f.

GENERALIZED CHERENKOV RADIATION — THE FIELD

- ORDINARY ELECTROMAGNETIC CHERENKOV RADIATION
  - SIMPLE GEOMETRIC CONSTRUCTION
  - $\cos\theta = \frac{c}{v}$

- FIRST CONSIDER HOW IT IS POSSIBLE FOR A GENERALIZED CHARGE IN UNIFORM RECTILINEAR MOTION TO GENERATE EXCITATIONS IN THE MASSIVE Pi FIELD TO WHICH IT COUPLES.
  - SHORT RANGE FIELD MAKES US QUESTION THE ABOVE GEOMETRIC APPROACH

- SIMPLEST SITUATION — POINT CHARGE "G" ADIABATICALLY SWITCHED ON AND THEN OFF
  - $\rho(\bar{r}, t) = g \int \delta^3(\bar{r} - \bar{v}t) e^{-\alpha|t|}$
  - TAKE THE FOURIER TRANSFORM

    $\rho(k, w) = 2\pi g \, \delta(w - \bar{k} \cdot \bar{v})$

- FOURIER COMPONENTS OF ρ WHICH COUPLE TO REAL QUANTA OF "pi" FIELD, w & $\bar{k}$ MUST ALSO SATISFY BOTH

  $\underline{w^2 = \bar{k}^2 + m_\pi^2}$ & $\underline{w = \bar{k} \cdot \bar{v}_T}$

- SOLVING FOR $\vec{k}$
  - $|\vec{k}| = \dfrac{m_\pi c}{\sqrt{\dfrac{v_T^2}{c^2}\cos^2\theta - 1}}$
  - which is imaginary unless $v_T > c$
- $|\vec{k}|$ TAKES ON ITS MINIMUM VALUE WHEN $\cos\theta$ IS ONE.
  - THE MINIMUM MOMENTUM OF AN EMITTED pi PARTICLE (IN FORWARD DIRECTION) IS.

    $$|k_m| = \frac{m_\pi c}{\sqrt{\dfrac{v_T^2}{c^2} - 1}}$$

    (NOTE: NO MINIMUM EXISTS IF $m_\pi = 0$)
- WE ALSO FIND:

  $$\cos\theta = \frac{c^2}{v_\pi v_T} \longleftrightarrow p_\mu^\pi \; p_\mu^T = 0$$

  - FOR PHOTONS $v_\pi \to c$ AND ONLY ONE ANGLE
  - HERE THERE IS A RANGE OF ANGLES
  - → RELATION BETWEEN ENERGY OF pi and θ
- THESE ARE NECESSARY BUT NOT SUFFICIENT CONDITIONS FOR EXISTENCE OF CHERENKOV RADIATION OF MASSIVE FIELDS

PRESCRIBED C# SOURCE

- $H = H_0 + H_1 = \frac{1}{2} \int d^3r \left[\dot{\phi}^2 + (\nabla\phi)^2 + m_\pi^2 \phi^2 - 2g \rho(\bar{r}, t) \phi\right]$

  $\rho(\bar{r}, t) = \rho_0 (x, y, (z-vt)/\gamma_v)$, $|\gamma_v| = \frac{1}{\sqrt{\frac{v^2}{c^2} - 1}}$

- $\phi^{out} = \phi^{in} + \iint \Delta (\bar{r} - \bar{r}', t - t') \rho(\bar{r}', t) \, d^3\bar{r}' \, dt'$

- SOLVE FOR ENERGY LOSS:

  $$\frac{dE}{dt} = \frac{v}{4\pi} \int_{m_\pi}^{\infty} k_z \left|\rho_0 \left(\sqrt{k_z^2 - m_\pi^2}, k_z\right)\right|^2 dk_z$$

- I.E., $\frac{dE}{vdt} = \frac{dE}{dx}$ = CONSTANT AS PREDICTED.

STOCHASTIC SPINLESS QUANTUM THEORY

- $H = H_\tau + H_\pi + H_{int}$ (EFFECTIVE HAMILTONIAN — GENERATE AN ELEMENTARY PROCESS)
- NEITHER H_τ NOR TACHYON STATISTICS NEED BE SPECIFIED FOR LOWEST ORDER PERTURBATION THEORY CALCULATION
- $H_{int} = -\int d^3\bar{r}\, \eta(\bar{r}, t)\, \phi(r, t)$

  where $\eta(r, t) = \int \psi^+_{(y)} \psi(y)\, K(x-y)\, d^4y$
- EOM FOR ϕ

  $(\partial_t^2 - \nabla^2 + m_\pi^2)\phi(x) = \eta(x)$
- $S_{fi} = \langle p_\tau k_\pi ; \text{out} | p_\tau, \text{in} \rangle$
  - USE LSZ REDUCTION SCHEME
  - TACHYON CREATION & ANNIHILATION OPERATORS APPEAR IN COMBINATION & BETWEEN VACUUM STATES SO THAT THEIR STATISTICS ARE NOT RELEVANT
- AFTER MUCH LABOR AGAIN OBTAIN

  $\frac{dE}{dx} = \text{CONSTANT}$

FURTHER ANALYSIS OF dE/dx EQUATION

- EACH DERIVATION CONFIRMS EXISTENCE OF $|\bar{k}_{min}|$
- LOOK AT A SPHERE IN k SPACE FOR ρ with $k_{max} \sim \frac{1}{r_o}$ ETC.
- OBTAIN $\frac{dE}{dt} = \frac{vg^2}{16}\left(k_{max}^2 - m_\pi^2\right)$
- HENCE IF $m \gtrsim k_{max} \rightarrow$ NO GENERALIZED CHERENKOV RADIATION
  - IN GENERAL NO SHARP CUTOFF IN k SPACE
    - (1) IF $m_\pi >> k_o$ — NO GENERALIZED CHERENKOV RADIATION
    - (2) IF $k_o >> m_\pi$ — RADIATION UNINHIBITED BY CUTOFF
    - (3) $k_o \approx m$ — SMALL AMOUNT OF RADIATION
- FOR THIN SPHERICAL SHELL WE OBTAIN $dE/dx = \infty$ AS DID SOMMERFELD IN 1904

CONSISTENCY WITH ORDINARY CHERENKOV RADIATION

- CONSIDER ELECTRICALLY CHARGED TACHYON IN VICINITY OF STATIC CHARGE
- $\frac{d\bar{v}}{dt} = \frac{c^2}{r^3}\,\bar{r}\cdot\,\bar{\bar{I}} - \frac{\bar{v}\,\bar{v}}{c^2}$
- ACCELERATION OF TACHYON IN RADIAL DIRECTION CHANGES SIGN WHEN:

  $$\cos\theta = \pm\frac{c}{v_r}$$

- TACHYON ACCELERATION TOWARDS STATIC CHARGE AFTER CHERENKOV CONE PASSES.
- KNOWN THAT FORCE ON STATIC CHARGE IS TOWARDS MOVING PARTICLE.