Anomalous Cherenkov rings in the DELPHI detector: A search for tachyons

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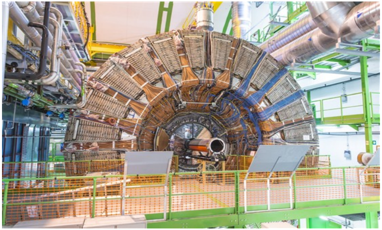
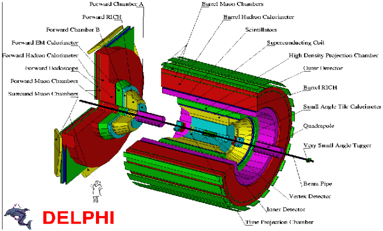




Outline

Introduction

- Physical interpretation of the anomalous Cherenkov rings observed with the DELPHI detector
  - arXiv:2001.08576
  - Retired HEP scientists?
  - Independent of DELPHI Collaboration
- Interpret large Cherenkov rings as tachyons
- Measure mass parameter

DELPHI and RICH

- DELPHI: Detector with Lepton, Photon and Hadron Identification
  - One of four main detectors at LEP
  - Operated from 1989 to 2000
  - Used RICH for PID
- DELPHI Barrel RICH:
  - Cherenkov angle: $\cos(\theta) = \frac{1}{n\beta}$
  - C_6F_{14} liquid radiator ($n = 1.273 \implies \theta_{\text{max}} = 667\,\text{mrad}$)
  - C_5F_{12} gaseous radiator($n = 1.00194 \implies \theta_{\text{max}} = 62\,\text{mrad}$)

DELPHI and RICH

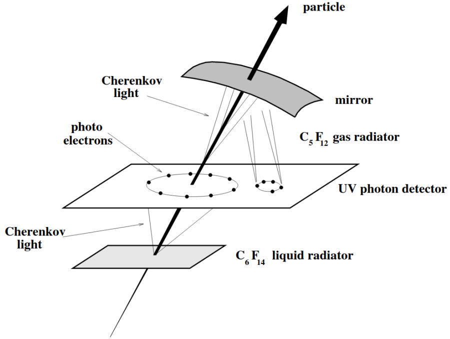


Figure 1: Principles of the DELPHI RICH detector

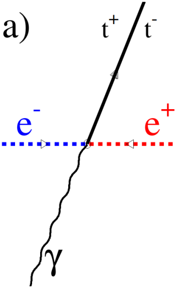
- DELPHI strategy: Fit rings with five mass hypothesis (e, μ, π, K, p) to obtain Cherenkov angle
- This paper: Fit each photon direction individually

Tachyon particles

- Particles moving at $v > c$
- $E^2 - p^2 = -\mu^2$
- μ: Mass parameter
- $\mu = p\sqrt{1 - n^2 \cos^2(\theta)}$

Event topologies and candidate selection

- Topology 1: $e^+e^- \to \gamma t^+ t^-$
  - High energy photon back-to-back with tachyons
  - Signature:
    - One neutral and one charged jet
    - Use $\mathrm{d}E\,/\,\mathrm{d}x$ to distinguish from single tracks
    - Charged jet should shower in EM calorimeter



Event topologies and candidate selection

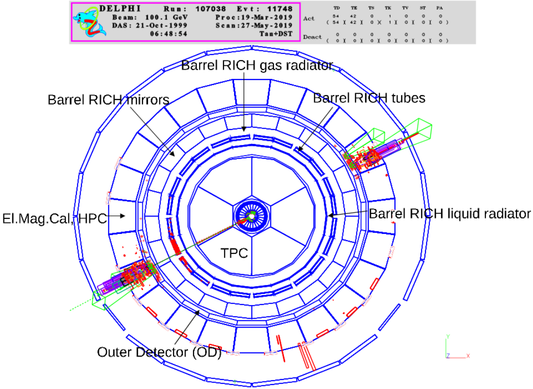
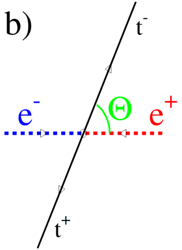
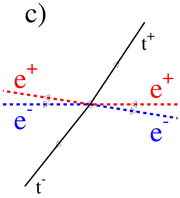


Figure 2: $e^+e^- \to \gamma t^+ t^-$ event

Event topologies and candidate selection

- Topology 2a: $e^+e^- \to t^+t^-$
- Topology 2b: $e^+e^- \to e^+e^-t^+t^-$
  - Tachyon pair production
  - Signature:
    - Both tracks should have showers in EM calorimeter
    - Tracks in opposite directions and opposite charge





Event topologies and candidate selection

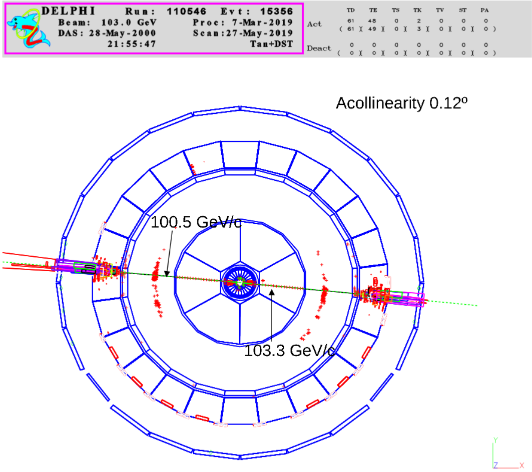
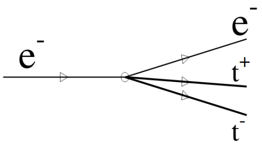


Figure 4: $e^+e^- \to t^+t^-$ event

Event topologies and candidate selection

- Topology 3: $eX \rightarrow eX' t^+ t^-$
  - $e^{\pm}$ interaction with matter to produce tachyons
  - Signature:
    - Two jets, one with a single track, one with 3 charged tracks
    - All tracks should shower in EM calorimeter
    - Some tracks with non-zero impact parameters in the three-particle jet

d)



Event topologies and candidate selection

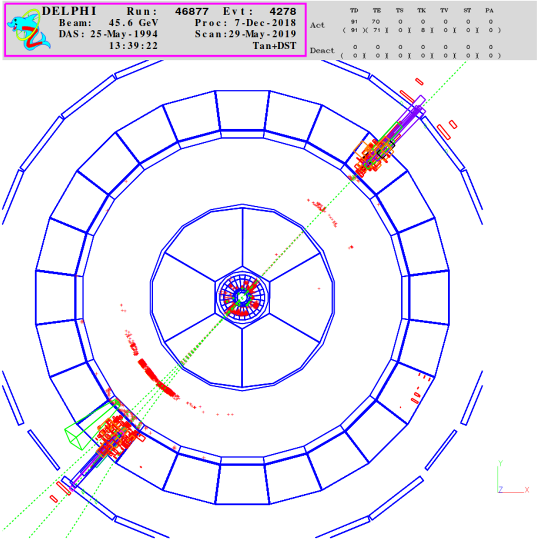


Figure 5: $eX \rightarrow eX' t^+ t^-$ event

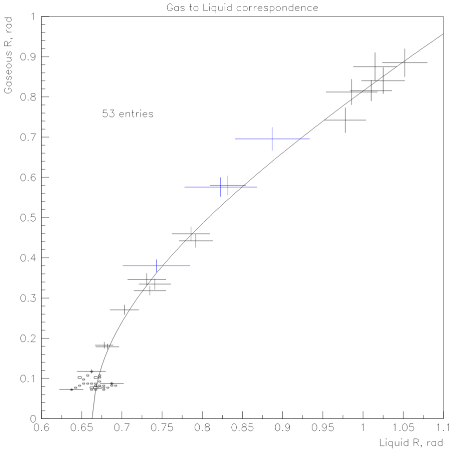
Event topologies and candidate selection

- Other general selection criteria: No hadrons, no muons, good track quality, etc...
- Result after selection:
  - 53 event with at least one anomalous Cherenkov ring
  - 29 candidates had two anomalous rings per track

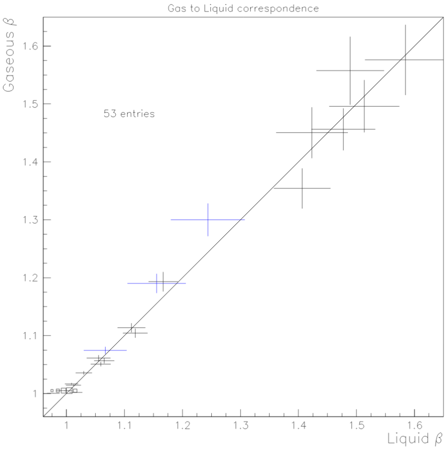
Correlation between RICH detectors

- From Cherenkov angle formula:
  - $n_1 \cos(\theta_1) = \frac{1}{\beta} = n_2 \cos(\theta_2)$
  - Can plot this as a line in the θ_1 vs θ_2 plane
- Or plot the predicted speeds β_1 and β_2

Correlation between RICH detectors



(a) Gas to liquid angle correlation



(b) Gas to liquid speed correlation

Tachyon mass parameters

- Calculate the mass parameters μ from Cherenkov angles
- Find correlation between Cherenkov radiators
- Found excess events at $\mu = 0.28\,\text{GeV}$ and $\mu = 5\,\text{GeV}$

$$\mu = p\sqrt{1 - n^2\cos^2(\theta)}$$

Tachyon mass parameters

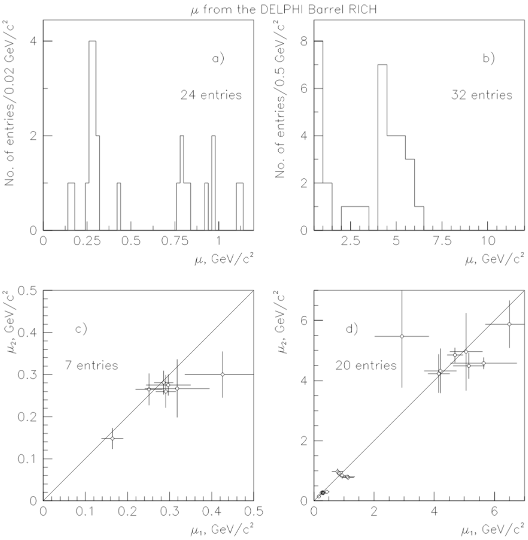


Figure 7: Tachyon mass parameters μ

Kinematic fit

- Do an over-constrained kinematic fit
- μ is unknown
- Constraints:
  - Energy-momentum conservation
  - $\mu = p\sqrt{1 - n^2 \cos^2(\theta)}$

Kinematic fit

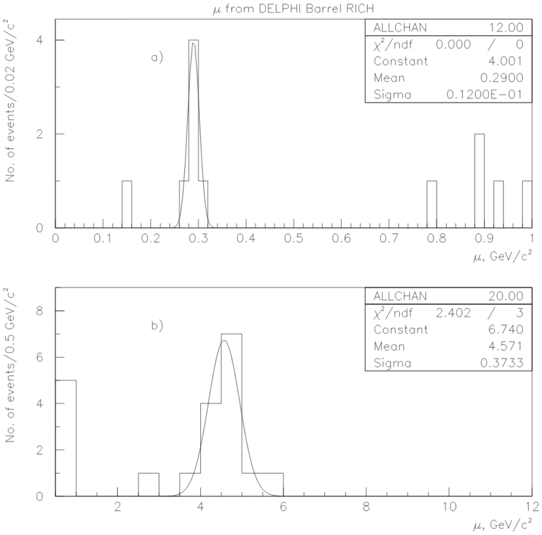


Figure 8: Tachyon mass parameters μ after kinematic fit

Conclusion

- Anomalous Cherenkov rings at DELPHI have been interpreted as tachyon signals
- Strong correlations between the gaseous and liquid RICH radiators were found
- Tachyon mass parameters show an excess at $(0.29 \pm 0.01)\,\text{GeV}$ and $(4.6 \pm 0.2)\,\text{GeV}$
- Further experiments are needed to confirm or refute these findings
    - $\gamma\gamma$ interactions (topology $2b$) at ALICE could study this with their RICH, with a Z^2 enhancement in cross section
    - LHCb, with high RICH Cherenkov angle resolution, could use low multiplicity events