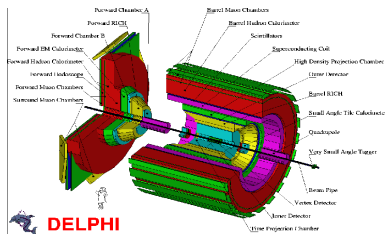
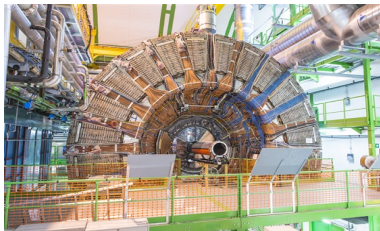


Anomalous Cherenkov rings in the DELPHI detector: A search for tachyons

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- 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: 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 ($n = 1.273 \implies \theta_{\max} = 667 \text{ mrad}$)
 - C_5F_{12} gaseous radiator ($n = 1.00194 \implies \theta_{\max} = 62 \text{ mrad}$)

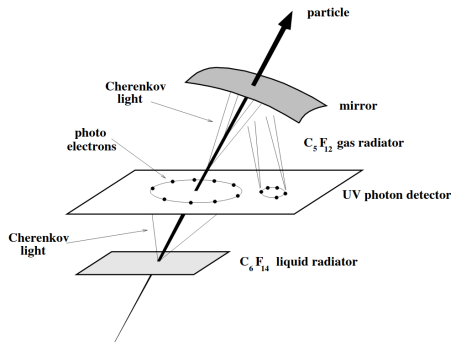


Figure 1: Principles of the DELPHI RICH detector

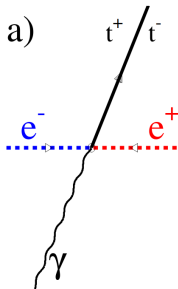
- DELPHI strategy: Fit rings with five mass hypothesis (e , μ , π , K , p) to obtain Cherenkov angle
- This paper: Fit each photon direction individually

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: $e^+e^- \rightarrow \gamma t^+ t^-$
 - High energy photon back-to-back with tachyons
 - Signature:
 - One neutral and one charged jet
 - Use dE/dx to distinguish from single tracks
 - Charged jet should shower in EM calorimeter



Event topologies and candidate selection

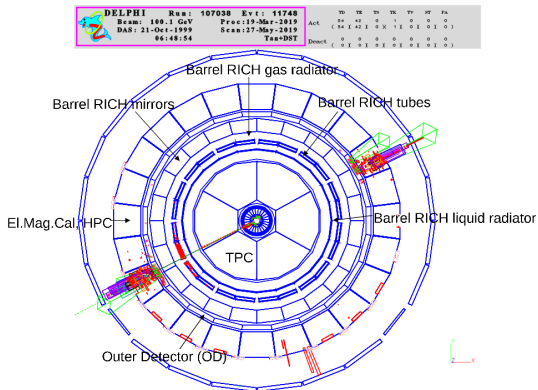
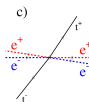
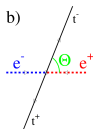


Figure 2: $e^+e^- \rightarrow \gamma t^+ t^-$ event

Event topologies and candidate selection

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



Event topologies and candidate selection

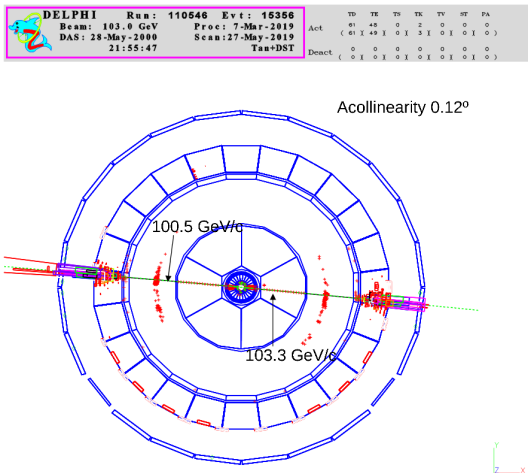
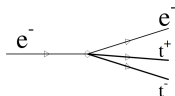


Figure 4: $e^+e^- \rightarrow t^+t^-$ event

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

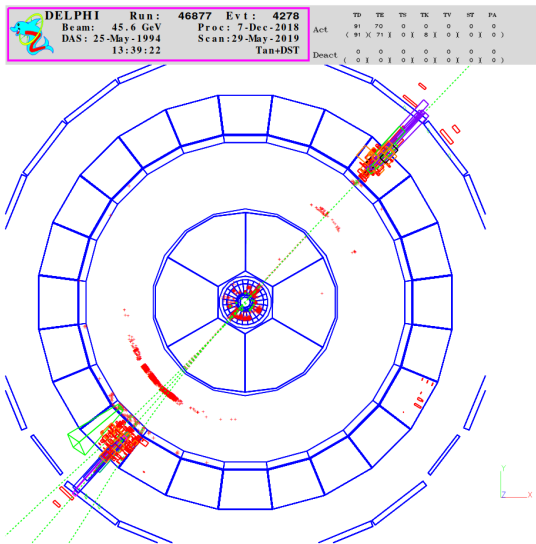


Figure 5: $eX \rightarrow eX' t^+ t^-$ event

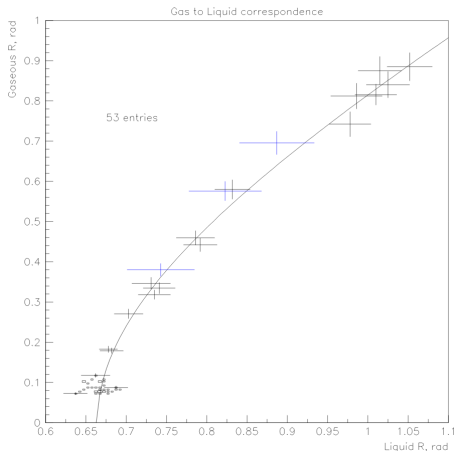
Event topologies and candidate selection

- Other general selection criteria:
 - Non-hadronic events
 - No muons
 - Good quality tracks inside geometric acceptance
 - Kinematic cuts to reduce background
- 395 candidates satisfied all these criteria
- 53 candidates had at least one anomalous Cherenkov ring with background below 10%
- 29 candidates had two gaseous anomalous rings per track
- Require background event probability less than 10^{-3} :
 - 9 events in topology 1
 - 6 events in topology 2
 - 12 events in topology 3

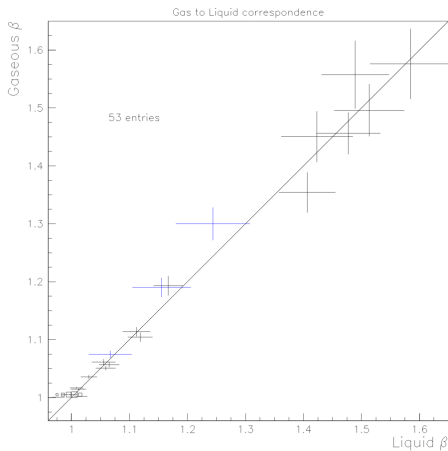
Correlation between RICH detectors

- 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
- Found excess events at $\mu = 0.28 \text{ GeV}$ and $\mu = 5 \text{ GeV}$

Tachyon mass parameters

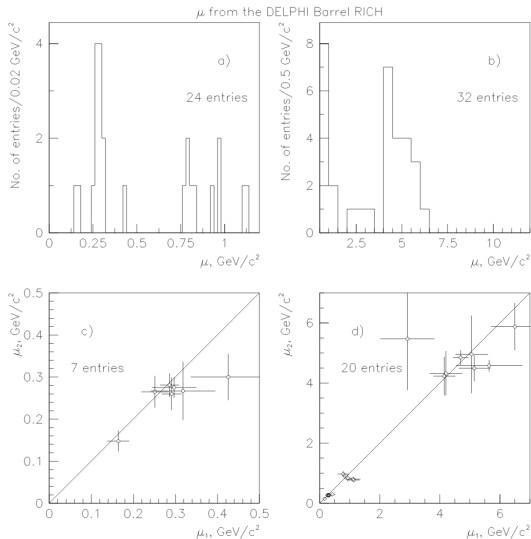


Figure 7: Tachyon mass parameters μ

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

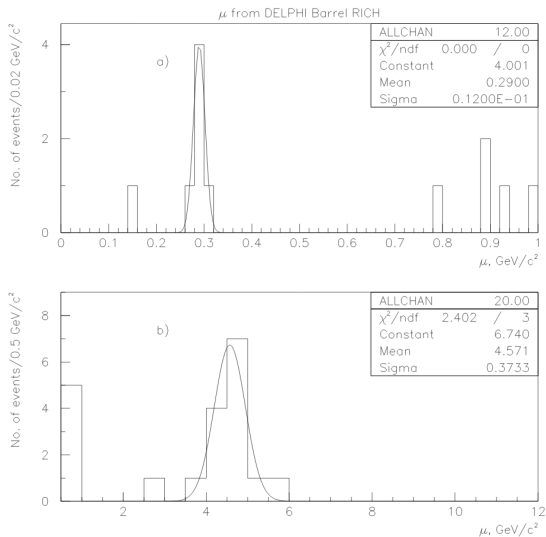


Figure 8: Tachyon mass parameters μ after kinematic fit

- 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 ± 0.01) GeV and (4.6 ± 0.2) 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