The RICH Detector At STAR

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The STAR-RICH Collaboration (Yale - Bari - CERN)

• Accessible Physics
• Device Characteristics
  – construction
  – components
• Heavy Ion Environment
• Particle Identification
STAR Detector

- STAR optimized for Au-Au at 200 GeV A
- Characterization of Global Observables
- PID by Several Detectors

- RHIC Provides Access to Hard Processes in Nuclear Environment
  – How to Access the “Hard Physics” at RHIC?
Accessible Physics at RHIC

- **Hard Processes** in Nuclear Environment
- **Must Access High** $P_T$ Region
- **Parton Energy Loss** in Dense Matter
  - Effects of the Medium
- **Species/Flavor Dependence** of Observables

Design Goals and Constraints

• Considerations for High $P_T$ PID in Heavy Ion Collisions
  – ALICE and STAR are Nearly Identical
    • High Multiplicity...
    • Low Rate
  – $p_T > 2$ GeV/c
  – High Radiation-Flux Environment
  – Presence of Magnetic Field

• Requirements
  – 2-Dimensional Read-out
    • Environment
  – Surface Conversion/Emission
    • Large Range of Incident Track Angles

• At “High” $P_T$
  – Small Rates
  – Inclusive Measurements
  – Single Arm Detector
Components

- Developed by CERN RD-26 in ALICE framework headed by F. Piuz, E. Nappi, G. Paic
- ALICE RICH Prototype Module (1 m²)

- Radiator
  - $C_6F_{14}$ Liquid
- Photo Converter
  - CsI
  - $\lambda < 210$ (nm)
- Ionization Detector
  - MWPC pad chamber
  - $CH_4$ Gas
Device Characteristics

- Extend PID beyond TPC TOF:
  - $1 < p < 3 \text{ GeV/c} \quad \pi K$
  - $2 < p < 5 \text{ GeV/c} \quad p$

- $160 \times 85 \text{ cm}^2 \Rightarrow 1 \text{ m}^2$
- Radial Distance of 2.4 m
- $|y| < 0.2$
Pad Chamber

- **2-D Cathode Pad Readout**
  - 500 nm CsI Layer on Pads
    - 8.0 x 8.4 mm²
    - 15360k pads
  - **Dynamic Range**
    - Single Electron
    - MIP detection
    - Chamber Stability
    - Limit Feedback Photons
- **CH₄ Chamber Gas**
  - Quenching
  - High Photo-Electron Emission Efficiency
Electronics

- **GASSIPLEX** CMOS 1.5 μm technology
  - Charge Pre-amp, Shaper, and Track and Hold Stage
  - **Pad Readout ONLY**
  - 11 bit Dynamic Range ⇒ .17 fC/channel
- Event Rate allows 700 ns Integration
  - **Multiplexed 16 Analog Channels MCM⇒**
    - Maximum Read-out Rate ⇒ 100 kHz
    - STAR Trigger Rate ⇒ 1-2 Hz
  - Heat Generation
    - 6mW channel⁻¹ ⇒ ~100 W/16k channels
    - concern for liquid dn/dT = 5x10⁻⁴ °C⁻¹

ALICE prototype
Radiator

- Liquid C₆F₁₄
  - Index of Refraction ≈ 1.29
  - $p_{th} = 1.26 \text{ mc (GeV/c)}$
- Match Spectral Sensitivity of CsI

![Graph showing relative light production and expected ring radius for particles.](image)

- Expected Ring Radius
  - *Proximity Focussing*
  - *Normally Incident Tracks*

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Gas Requirements

- **O₂ & H₂O hazardous to CsI**
- **Must Deliver Clean Anhydrous Gas**
  - CH₄ Flow Rate of ≤ 30 l hr⁻¹
  - Ar Purge/Buffer Flow at 60 l hr⁻¹

Exposure Limits Test Allow Shipment
- 24 hours: 10000 ppm O₂
- 18 hours: 18000 ppm O₂
- 40 ppm H₂O

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Determination of Cerenkov Angle

- **Test Beam Determination**
  - 350 GeV/c $\pi^-$
  - Normal Incidence

**Resolution**
- 12.0 mrad single $\gamma$
- 3.0 mrad ring average
Hough Transform

- The Hough Transform Method (HTM) represents an efficient implementation of a generalized template matching strategy for detecting complex patterns in binary images
  - look for **local maxima** in a **feature parameter** space

\[
(x, y) \rightarrow ((x_p, y_p, \theta_p, \phi_p), \eta_c)
\]

- photon Cerenkov angle
- cluster coordinate
- impact track parameter known

solution in one dimensional mapping space \( \eta_c \)

N. DiBari
Pattern recognition with Hough Transform

Efficiency and contamination as a function of the particle momentum (ALICE simulation)

- 15% occupancy
- normal incidence
Analysis and Towards PID

Do not look for “Rings”
Look for photons in band where expected for various mass hypotheses

Charge On Pad

Hits After Cluster Finding

MIP Projection

RICH sits outside a very powerful tracking detector

Particle Identification
Chamber Alignment

- **Track Extrapolation**
  \[ \Rightarrow \sigma_{\text{drift}} = 2.7 \text{ mm} \]
  \[ \Rightarrow \sigma_{\text{bend}} = 3.1 \text{ mm} \]

- **Near Expected Resolution**
  - 8.0 x 8.4 mm\(^2\) pads
    - center of gravity method
  - 4 mm anode wire pitch
  - 2 mm anode-cathode spacing
Cluster Characteristics

- **Dynamic Range of Chamber**
  - Single Electron Detection
  - Minimum Ionizing Particles
  - Chamber Stability

Characteristics of “Associated MIPS”

- **Single Photo Electrons**
- **Tracks**
- **Saturated Pads**

High Chamber Gain Introduces Photon Background From Avalanche:
**Feedback Photons**
The STAR Environment

- TPC Extrapolation Capabilities
  - in drift direction
  - close to resolution of chamber

The Large Range of Track Incident Angle on Radiator Affects the Ring Shape and Character
Cerenkov “Ellipses”

- **Effect of:**
  - Track Incidence Angle
  - Proximity Focussing

- **Ring Azimuth Angles**
  - 180° “Constant Angle”
  - 90° Characterization
  - 60° Allows Uniform Treatment

![Graphs showing Cerenkov ellipses](image)
Golden Event

- Illustrative Example
- Separation Possible
  - Signal/Background is Large
  - Proximity Focussing produces “Rings”
- Both Pion and Kaon Emerge
- Size of MIP and $\gamma$
Event Characteristics

Number of tracks p > 1 GeV/c in rich vs number of primaries

Occupancy < 5%

Peripheral

Central

Run: 1185017  Event: 204

Run: 1185017  Event: 137

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Method For PID I

- **Track Quality Cuts**
  - Primary TPC Track
  - Extrapolated Point Detected
  - Small Residual

- **Track-by-Track Observables**
  - Number of Hits
  - Area on Pad Plane
  - Density of Hits in Fiducial
  - Evolution of Number of Hits
    - $d$ distribution

Proton “Candidates”

$$2 < pT < 2.5 \text{ (GeV/c)}$$

(+) Mean = 7.62

(−) Mean = 7.36

Preliminary
Method For PID II

- **NOT** Track-by-Track
- “Statistical” Ring Photons
- Reduced Sensitivity to:
  - Absolute Ring Positions
  - Spread of Photons in Ring
- **Non-Trivial background**
  - Shape of photon Spectrum
    - Signal
    - BackGround
- Complementary Method

2 < p_{T} < 2.5 (GeV/c)
Accomplishments

• 8 year R&D project has been successful
  – Prototype RICH Chamber in operation at STAR
  – Performance as Expected

• Several Particle Identification Techniques
  – Consistent Results
  – Controlled Systematics

• Statistical Limitation at Present
People

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