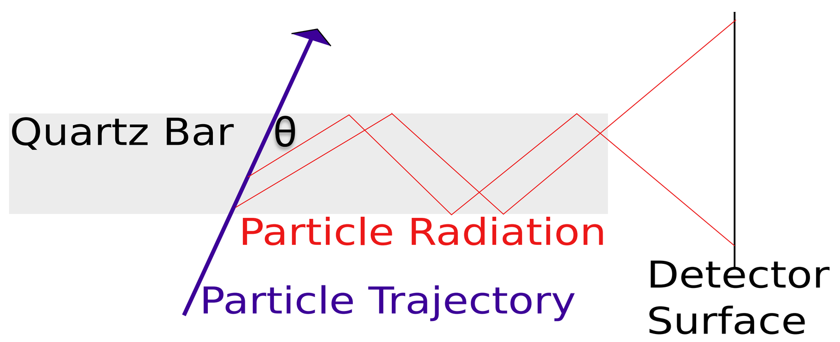
Modeling a DIRC Detector for High-Multiplicity Collisions

Wilka Carvalho, Axel Drees, Alan Dion
Department of Physics and Astronomy, Stony Brook University

Introduction

Motivation:
- The Particle Detector at the Relativistic Heavy Ion Collider (RHIC) is being Upgraded
- However, it **lacks** a Particle Identification (PI) System
- PI has been successfully accomplished through **DIRC** detectors
- Never been tested with high-multiplicity collisions

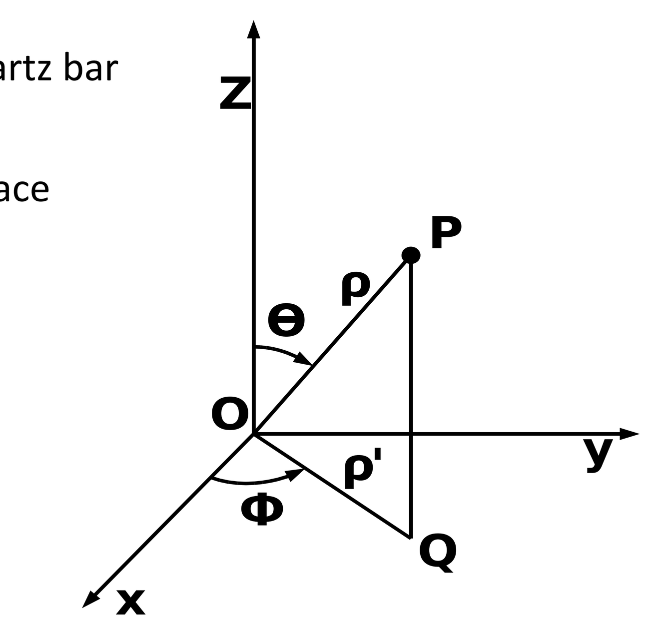
How does a DIRC Detector work?
- **DIRC = D**etection of **I**nternally **R**eflected **C**herenkov Light
- Consists of Quartz slab and Cameras on Detector Surface



- Charged particles emit radiation (photons)
- Photons travel through Quartz Bar to detector surface

Methods

Develop Libraries in C++ to:
- Geometrically model quartz bar
- Simulate particle trajectory to and within quartz bar
- Simulate radiation emission in quartz bar
- Analyze radiation projection on detector surface



What do we know? For each particle:
1. Angle of incidence on bar (θ, φ)
2. Incidence Coordinates (x, y)

Data Analysis
- Over-reconstruct original photon angles
- Study photon distributions in frame of each particle's trajectory
- Correlate photons to particles in order to index photons
- Reconstruct original particle emission angle and radiation intensity

Results

- Successful PI for 1 particle events in 0 : 3 GeV momentum range
- Successful PI for 6 particle events in 0 : 2 GeV momentum range
  - fake-rate > 5% at higher momentum

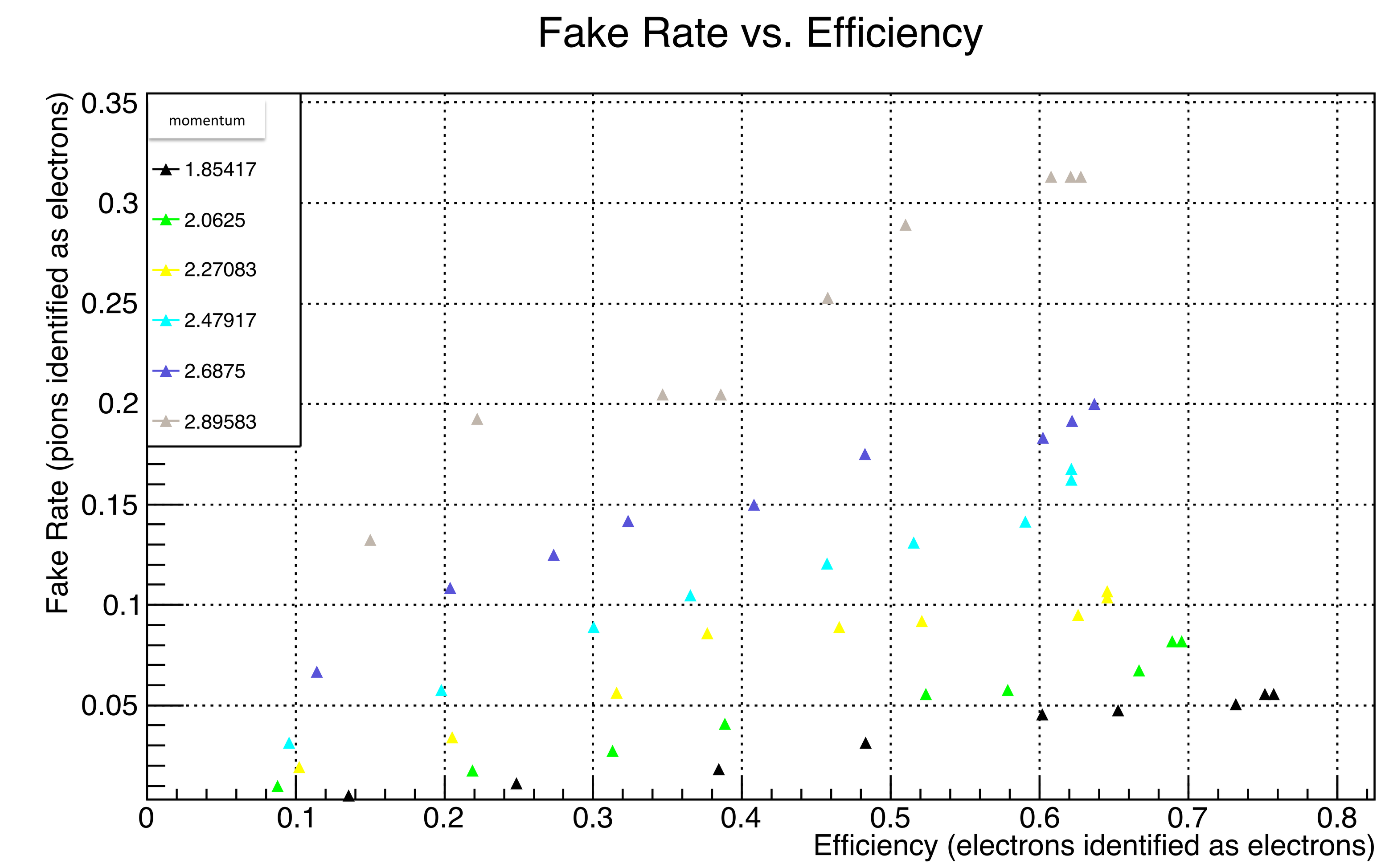


Figure 3: A plot of the percent with which pions are misidentified as electrons (fake-rate) vs. the percent of times with which electrons are correctly identified as electrons (efficiency). This plot focuses on a momentum range of 1.8GeV to 3GeV. One can see that the fake-rate remains low with high efficiency at momentum below 2GeV; however, just above 2GeV, the fake-rate rises above 5% at only 50% efficiency. This rise becomes faster as we look at data points that correspond to higher momentum.

Obstacles:
- Over-reconstruction of photons causes self-interference
  - Causes bias in Gaussian fit
- Photons indexed to multiple particles cause significant signal loss
  - Hinders photon disentanglement

Simulation Details

- 2000 events run
- 6 particles per event
- Possible particles: Kaon, Pion, Muon, Electron, Proton
- 1st 5 particles in momentum range 0 : 3 GeV
- 6th particle always Pion or Electron with momentum ~2GeV

Analysis Details

- Study θ projection of photon angle distribution
- Fit Gaussian to indexed and rebinned θ projection
  - Center corresponds to particle emission angle
  - Area corresponds to particle radiation intensity
  - Compare each quantity to expected values for each particle
- Seek fake-rate < 5%

Successful Particle Reconstruction

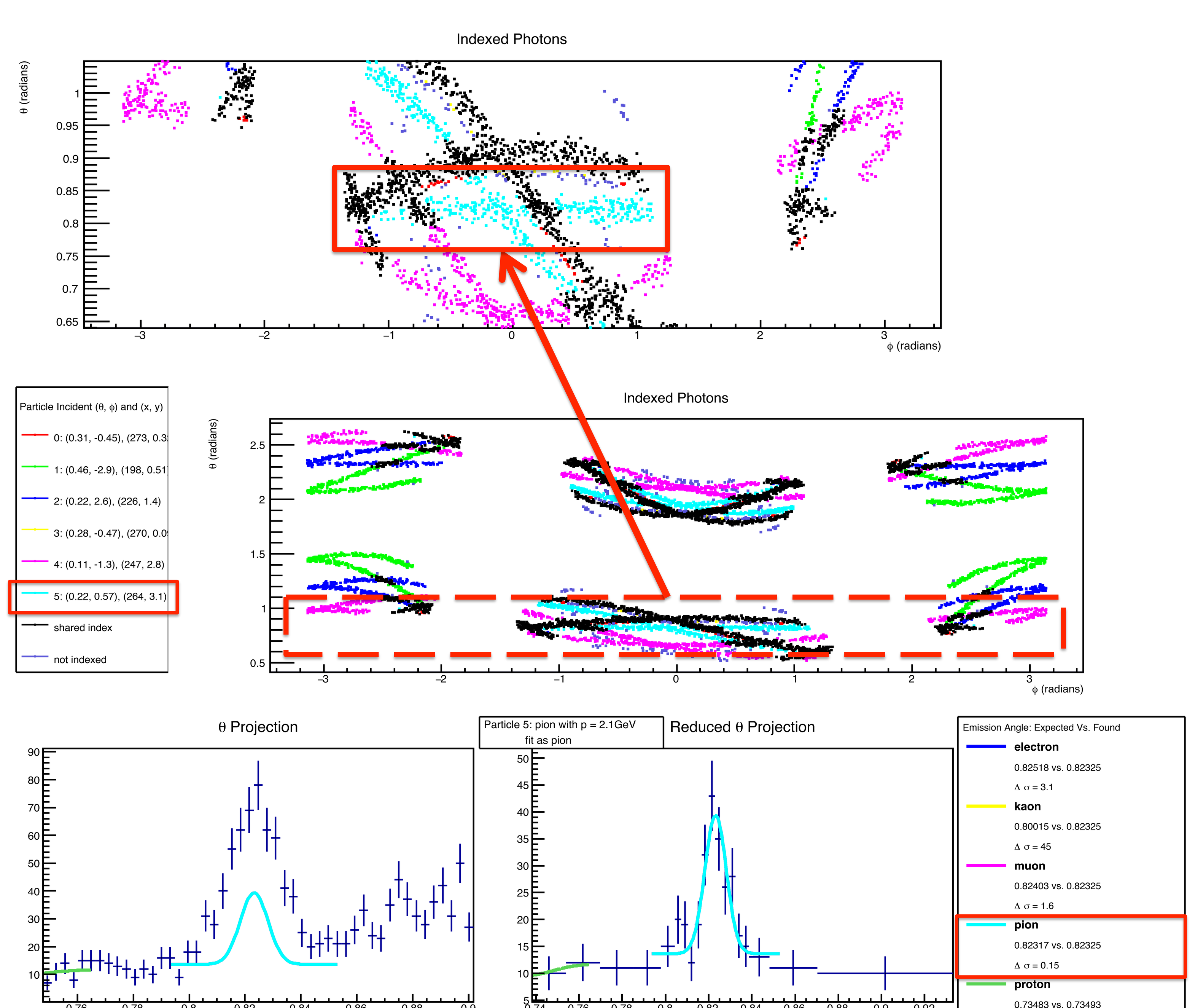


Figure 1. **Top left panel**: Color guide for particles in the event. Includes incidence angle and coordinates on quartz bar. **Top right panel**: Photon angle distribution in frame of 6th particle. Photons are colored according to their hypothesized particle. **Bottom Left panel**: Unaltered θ projection of angle distribution in top right panel. **Bottom Middle Panel**: θ distribution of photons indexed to the 6th particle. The histogram is rebinned to improve Gaussian statistics. **Bottom Right panel**: Gaussian fit information for each particle attempt.

Unsuccessful Particle Reconstruction

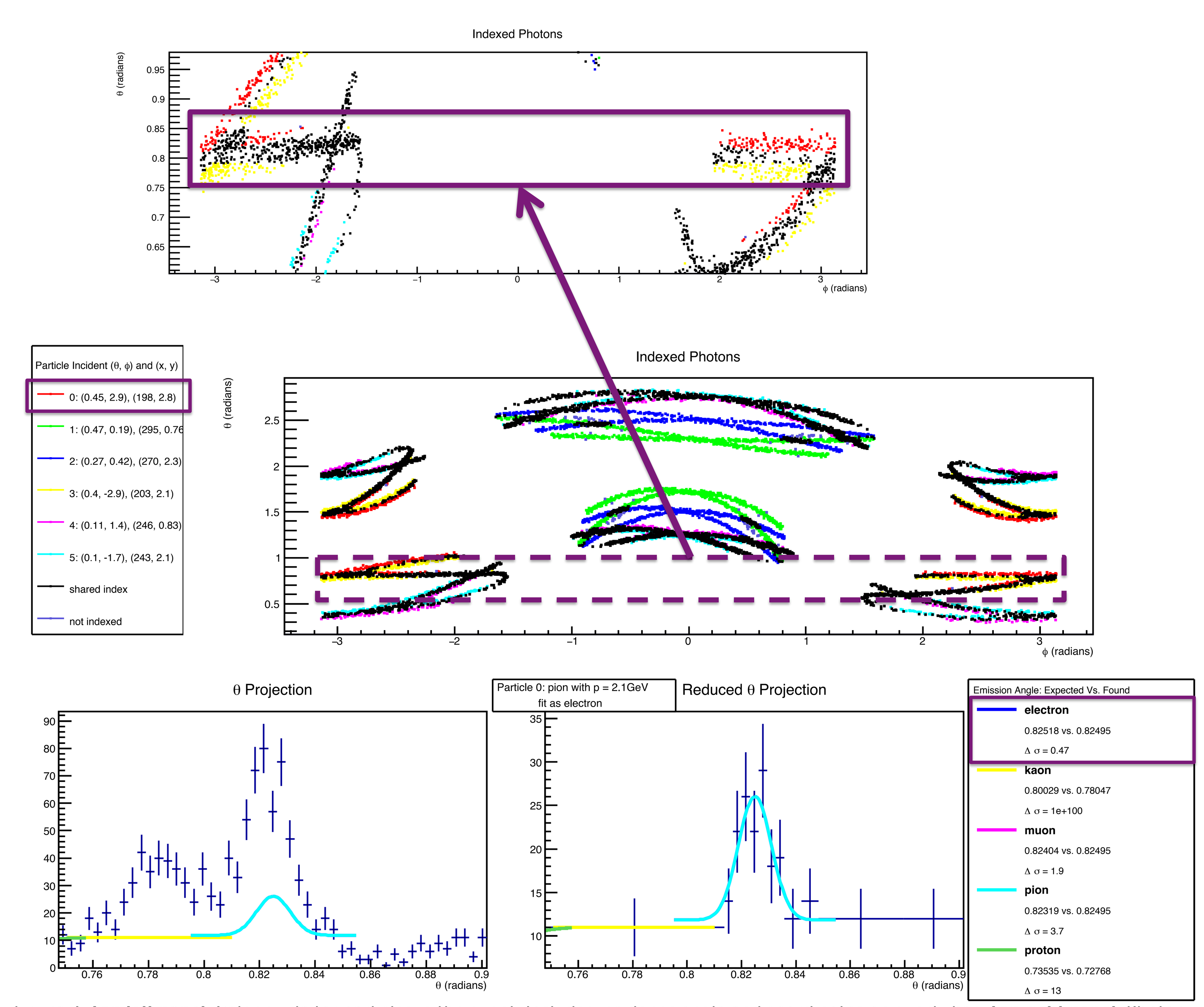


Figure 2. **Top left panel**: Color guide for particles in the event. Includes incidence angle and coordinates on quartz bar. **Top right panel**: Photon angle distribution in frame of 1st particle. Photons are colored according to their hypothesized particle. **Bottom Left panel**: Unaltered θ projection of angle distribution in top right panel. **Bottom Middle Panel**: θ distribution of photons indexed to the 1st particle. The histogram is rebinned to improve Gaussian statistics. **Bottom Right panel**: Gaussian fit information for each particle attempt.

Summary

We have developed a sophisticated algorithm for PI that has shown to be effective to low-medium multiplicity collisions. The potential for further development of our algorithm indicates that a DIRC may be suitable for the high-multiplicity collisions at RHIC.

Future Directions

- More sophisticated photon reconstruction
- Have knowledge of time associated with each photon
  - possible improved discrimination in photon reconstruction
  - improvement in correlating photons to particles
- Perform separate analyses on photons at each side of the quartz bar

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