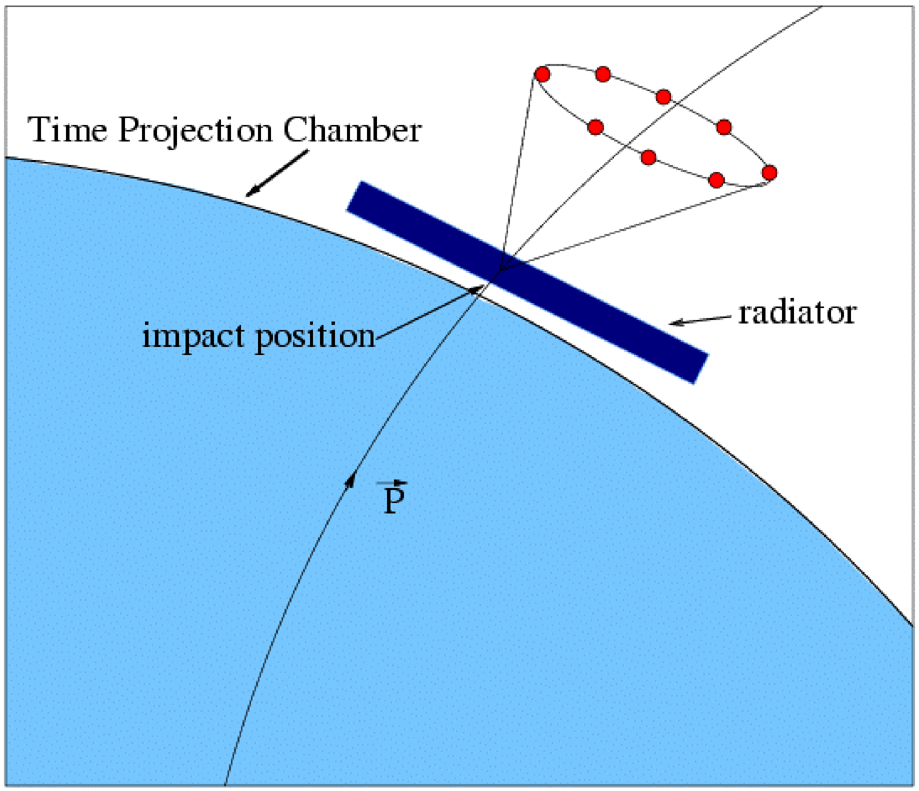
The RICH Detector At STAR

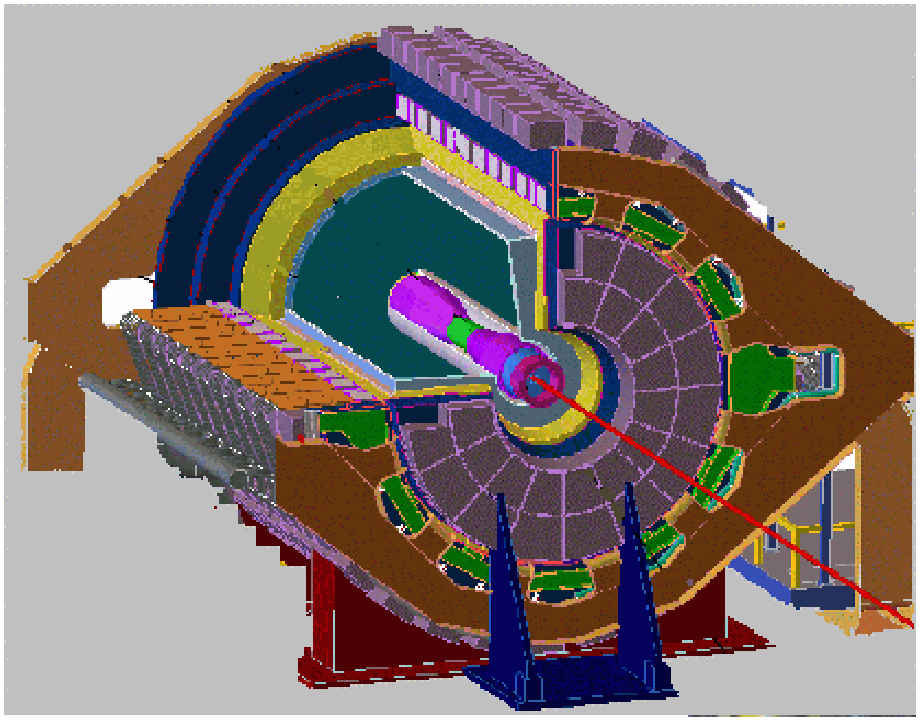
B. Lasiuk (YALE) for the STAR collaboration

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



- Accessible Physics
- Device Characteristics
  - construction
  - components
- Heavy Ion Environment
- Particle Identification

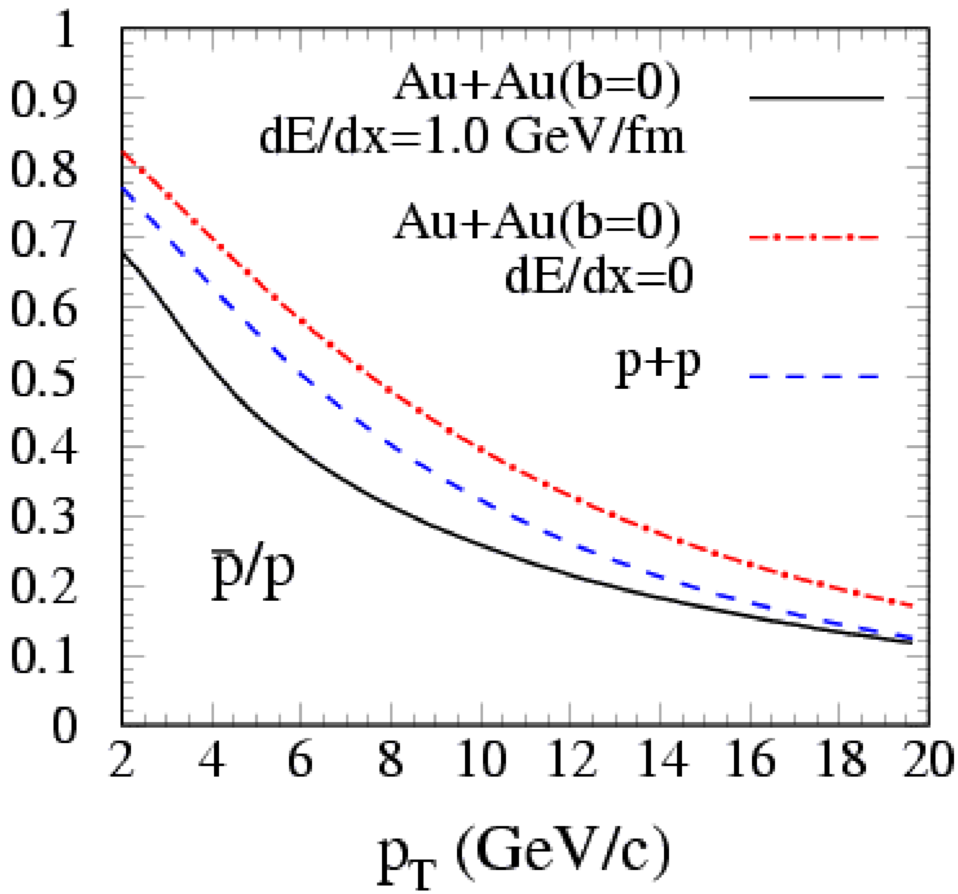
STAR Detector



- 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



X.N.Wang, Phys.Rev.C **58** (1998) 2321

- 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

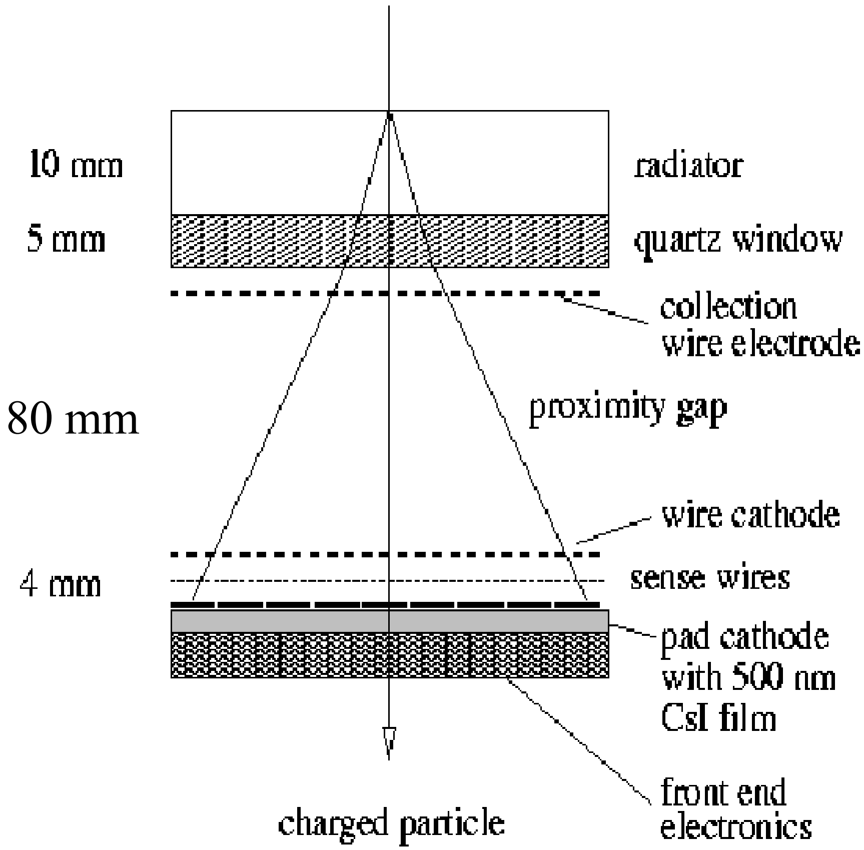
Design Goals and Constraints

- 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**

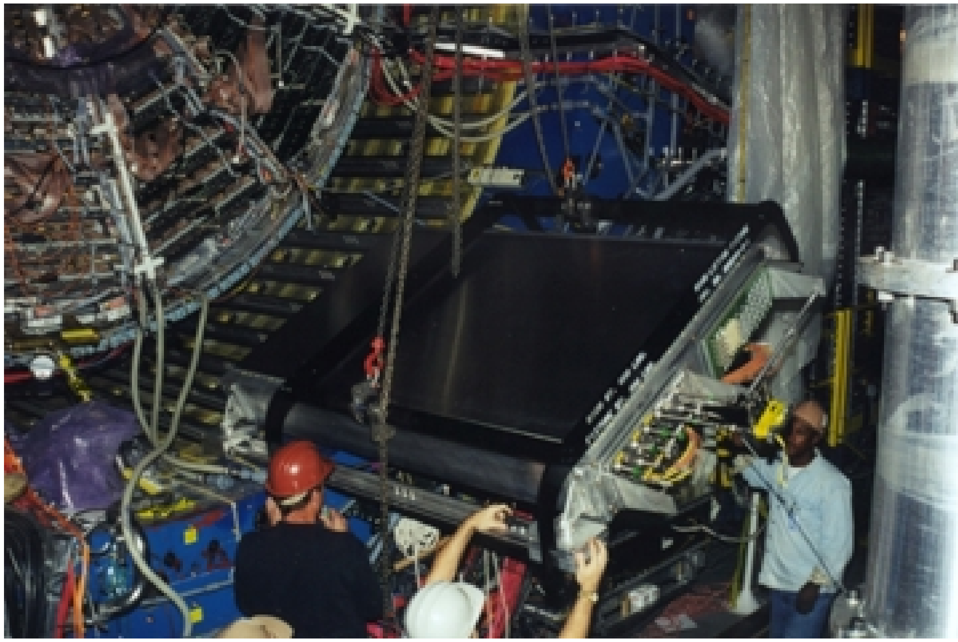
Components

- Developed by CERN RD-26 in ALICE framework headed by F. Piuz, E. Nappi, G. Paic
- ALICE RICH Prototype Module (1 m^2)



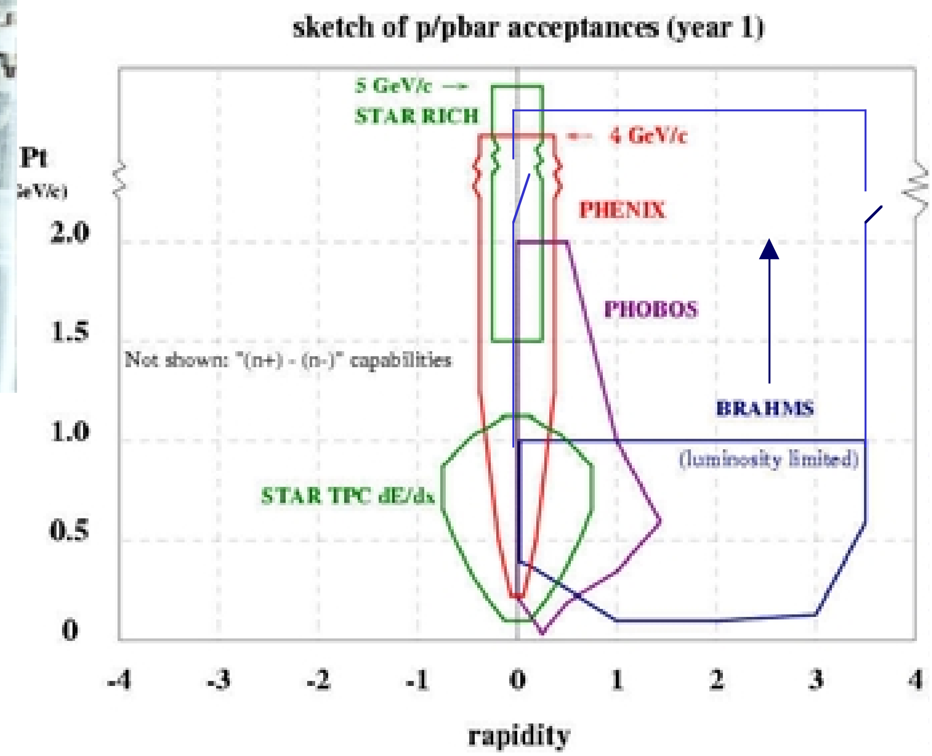
- Radiator
  - **C_6F_{14} Liquid**
- Photo Converter
  - **CsI**
  - **$\lambda < 210$ (nm)**
- Ionization Detector
  - **MWPC pad chamber**
  - **CH_4 Gas**

Device Characteristics



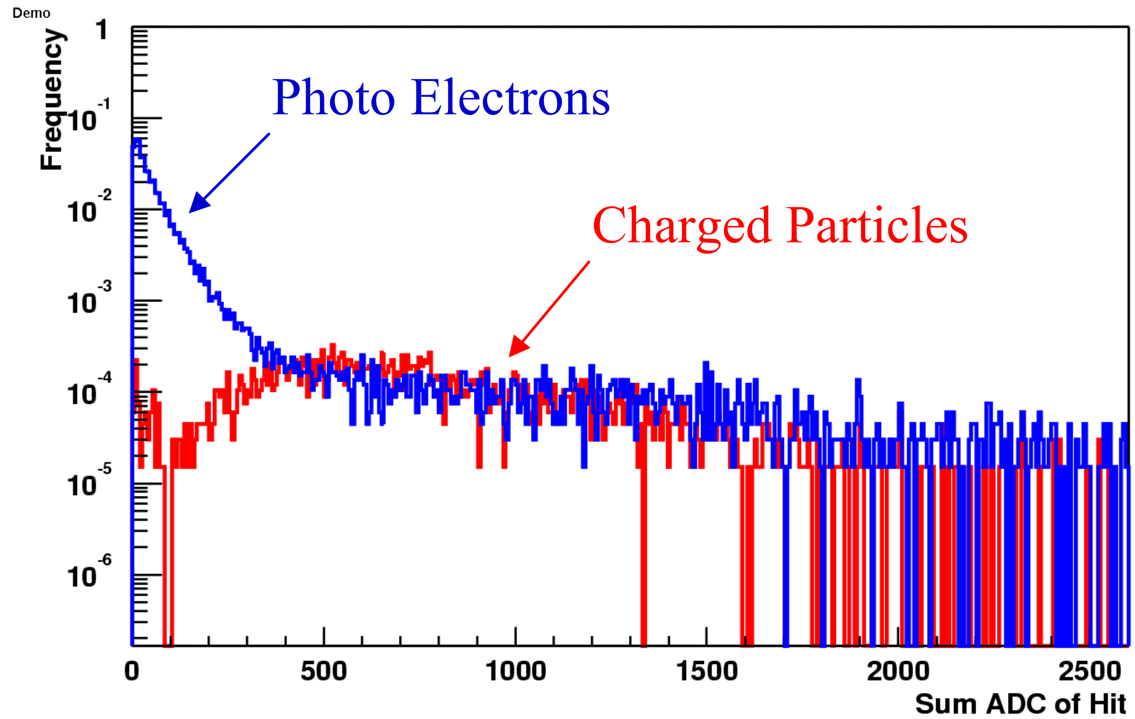
- $160 \times 85\ cm^2 \Rightarrow 1\ m^2$
- Radial Distance of 2.4 m
- $|y| < 0.2$

- Extend PID beyond TPC TOF:
  - $1 < p < 3$ GeV/c π K
  - $2 < p < 5$ GeV/c p



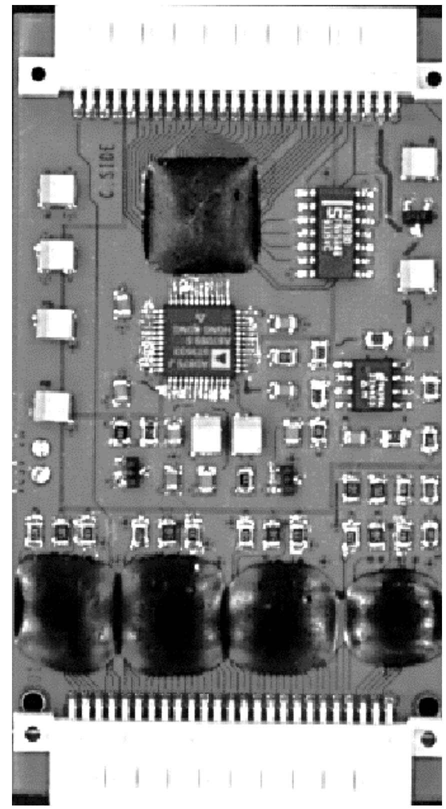
Pad Chamber

- **2-D Cathode Pad Readout**
  - **500 nm CsI** Layer on Pads
    - 8.0 x 8.4 mm^2
    - 15360k pads
- **Dynamic Range**
  - Single Electron
  - MIP detection
  - Chamber Stability
  - Limit Feedback Photons
- **CH_4 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 = 5×10^{-4} $^{o}C^{-1}$

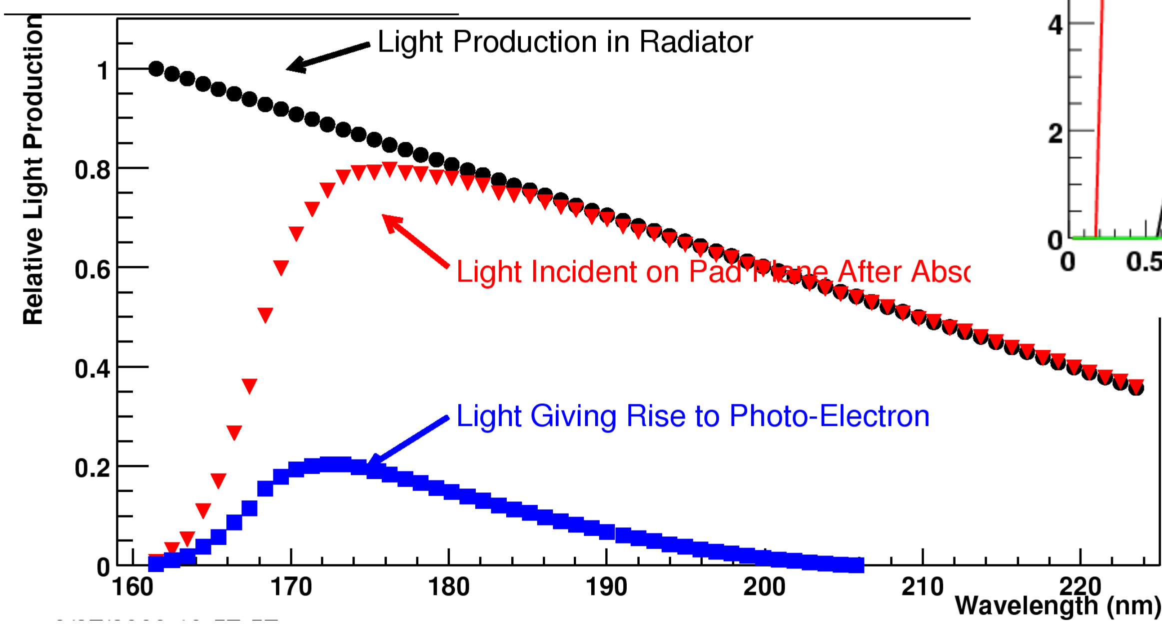


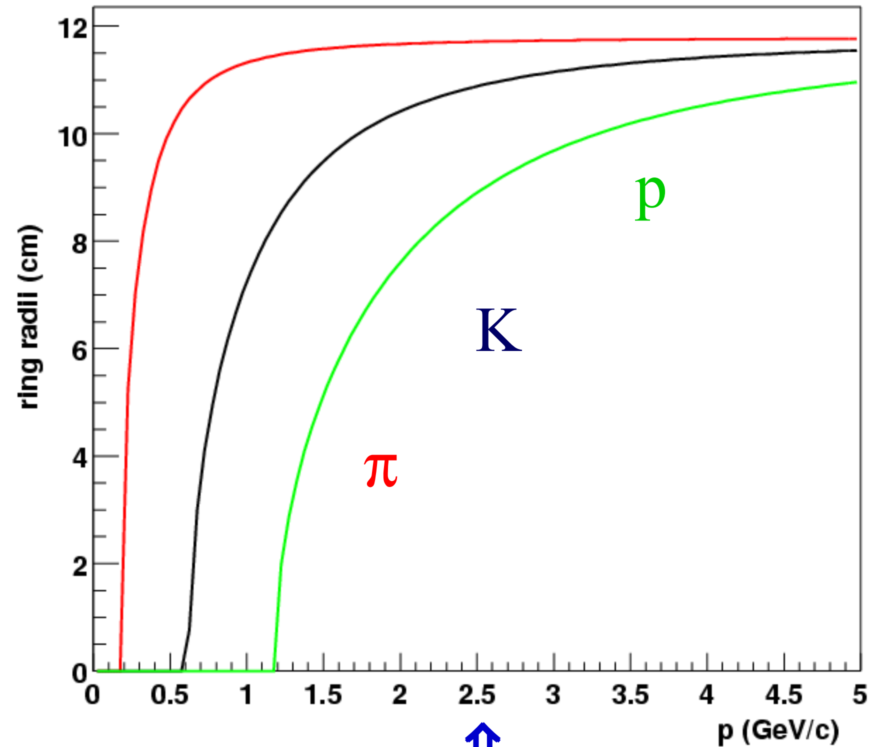
ALICE prototype

Radiator

- **Liquid C_6F_{14}**
  - **Index of Refraction ≈1.29**
  - **p_{th} = 1.26 mc (GeV/c)**
- **Match Spectral Sensitivity of CsI**

⇓





⇑

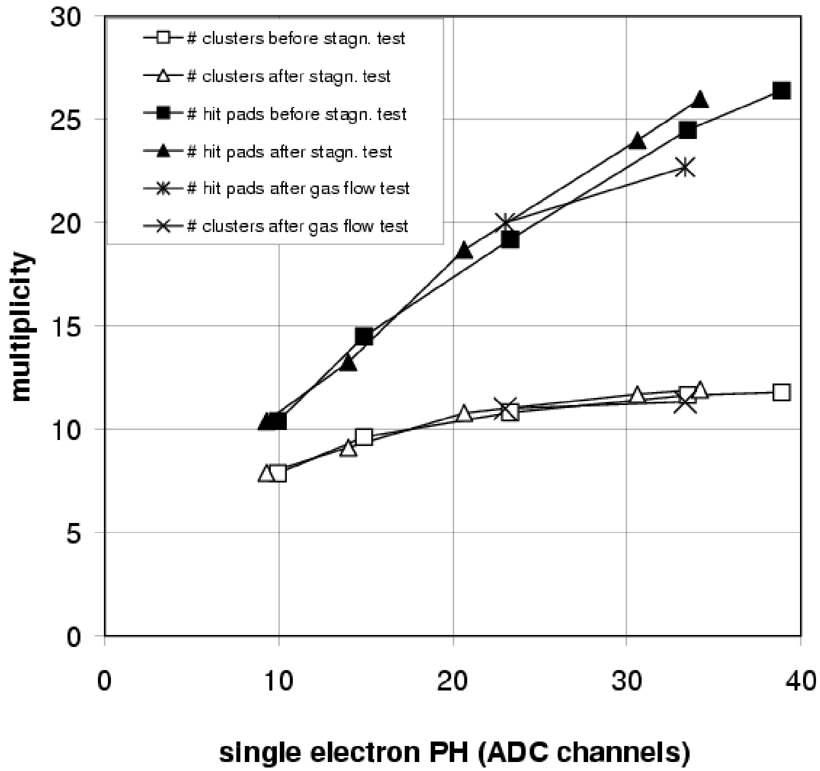
Expected Ring Radius

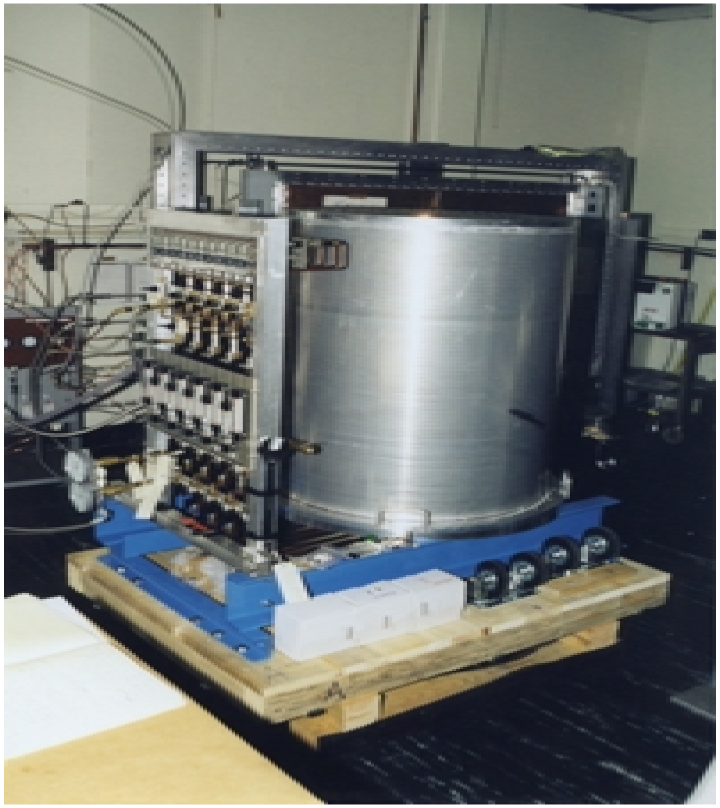
*** Proximity Focussing**

*** Normally Incident Tracks**

Gas Requirements

- **O_2 & H_2O hazardous to CsI**
- **Must Deliver Clean Anhydrous Gas**
  - **CH_4 Flow Rate of ≤ 30 l hr^{-1}**
  - **Ar Purge/Buffer Flow at 60 l hr^{-1}**



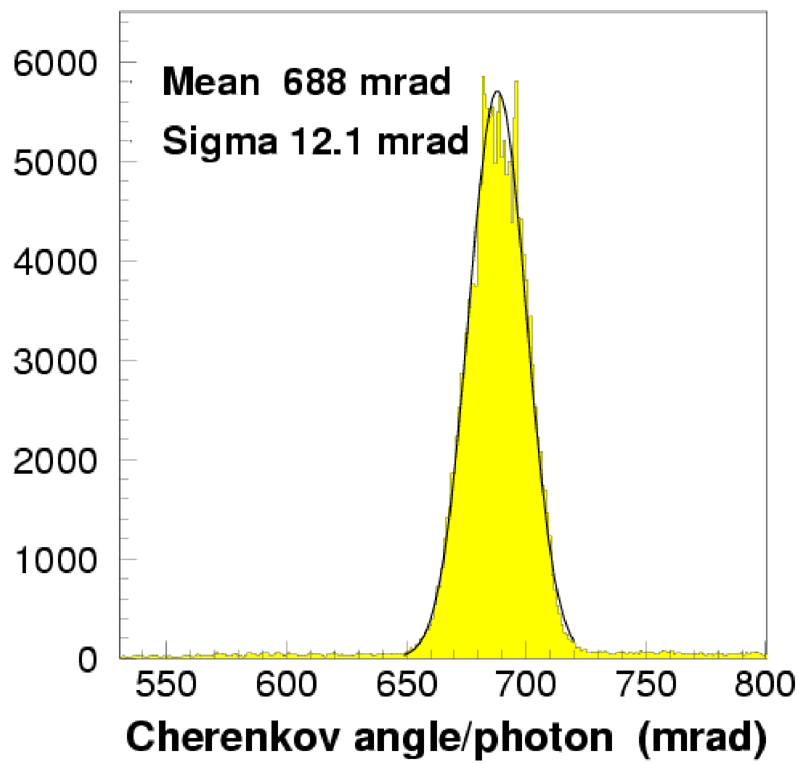


Exposure Limits Test Allow Shipment

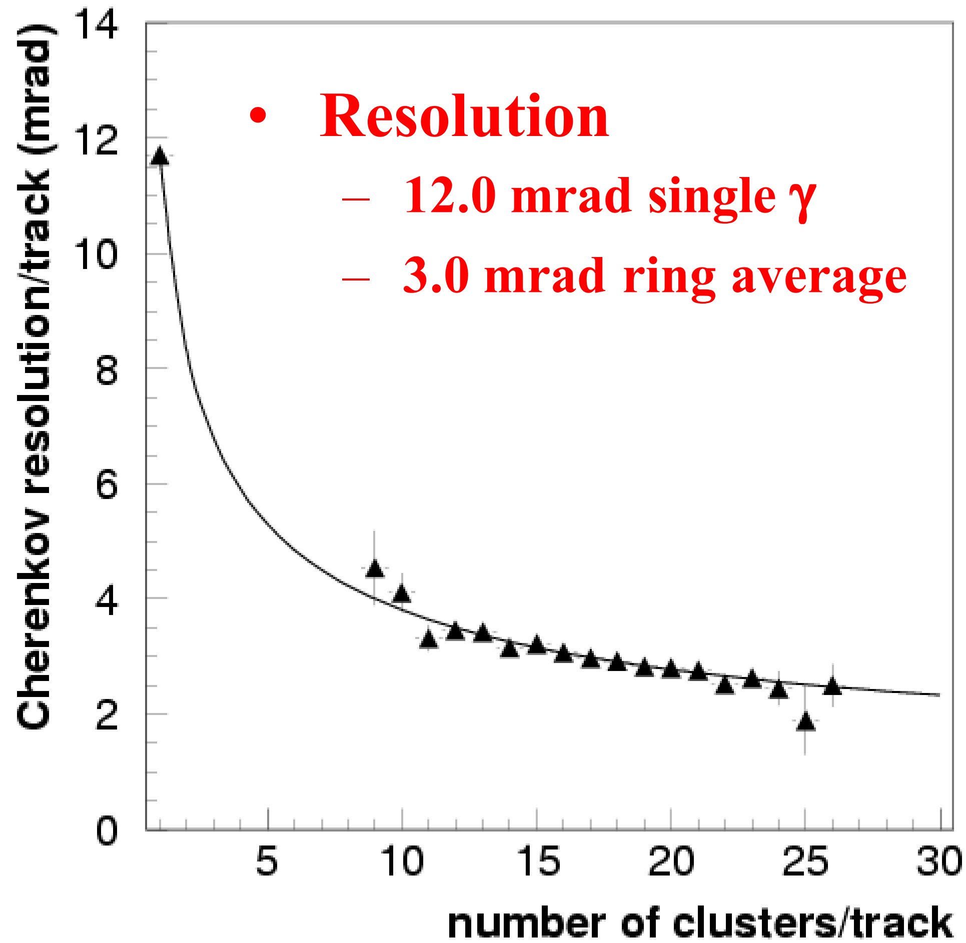
24 hours	**18 hours**
10000 ppm O_2	18000 ppm O_2
40 ppm H_2O	

Determination of Cerenkov Angle

- **Test Beam Determination**
  - **350 GeV/c π^-**
  - **Normal Incidence**



- **Resolution**
  - **12.0 mrad single γ**
  - **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

photon Cerenkov angle

$$(x,y) \rightarrow ((x_p,y_p,\theta_p,\varphi_p),\ \eta_c)$$

cluster coordinate

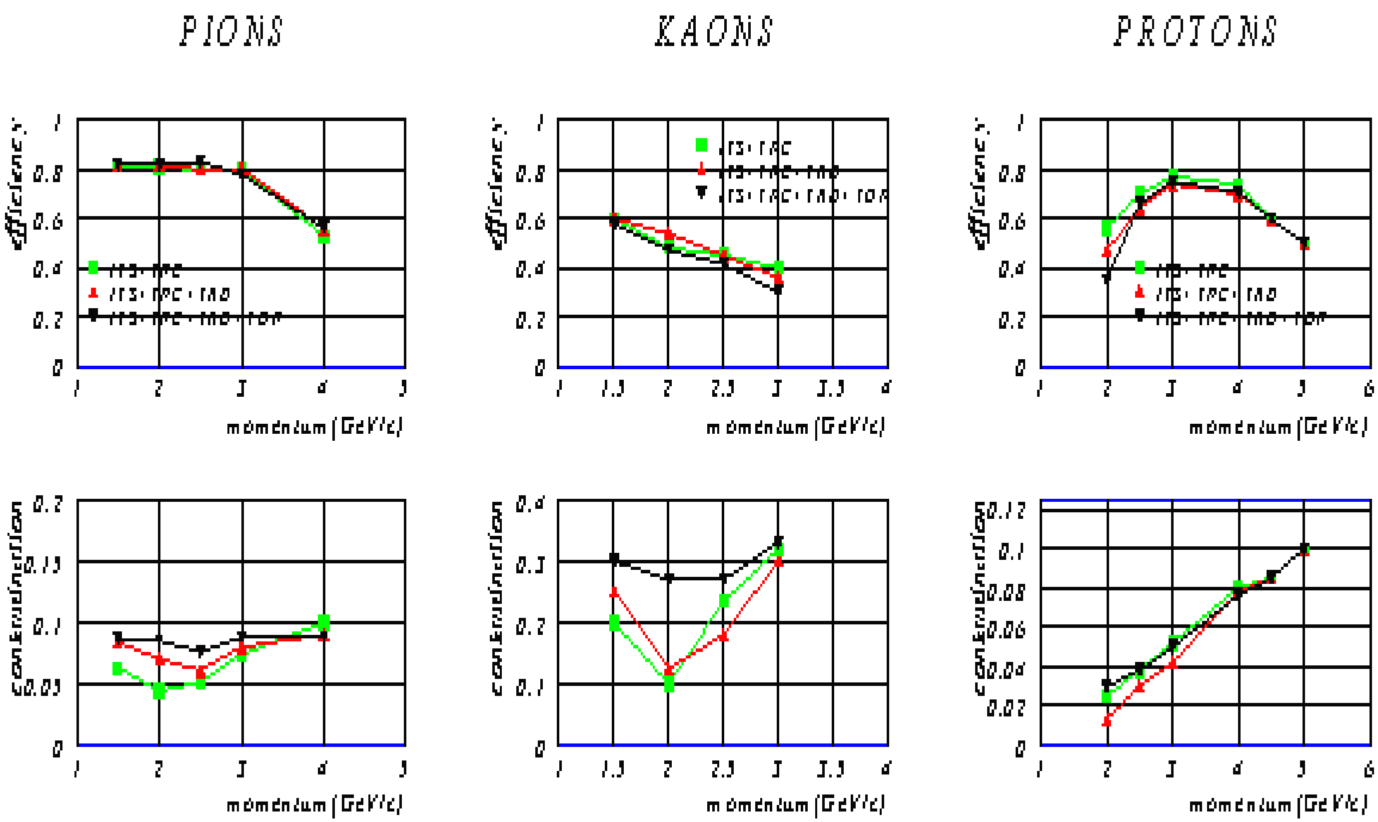
impact track parameter known

solution in one dimensional mapping space η_c

N. DiBari

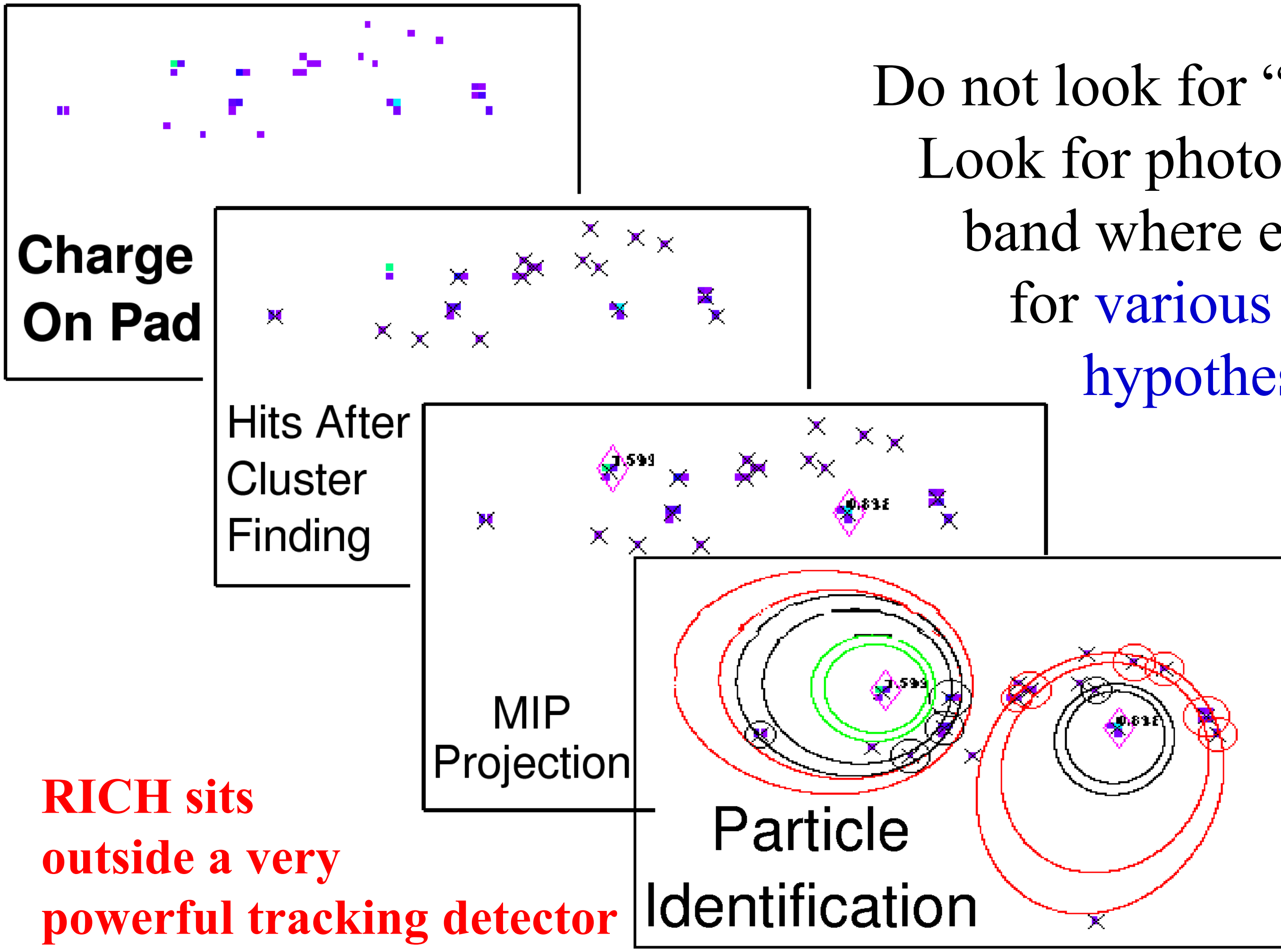
Pattern recognition with Hough Transform

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

RICH sits outside a very powerful tracking detector

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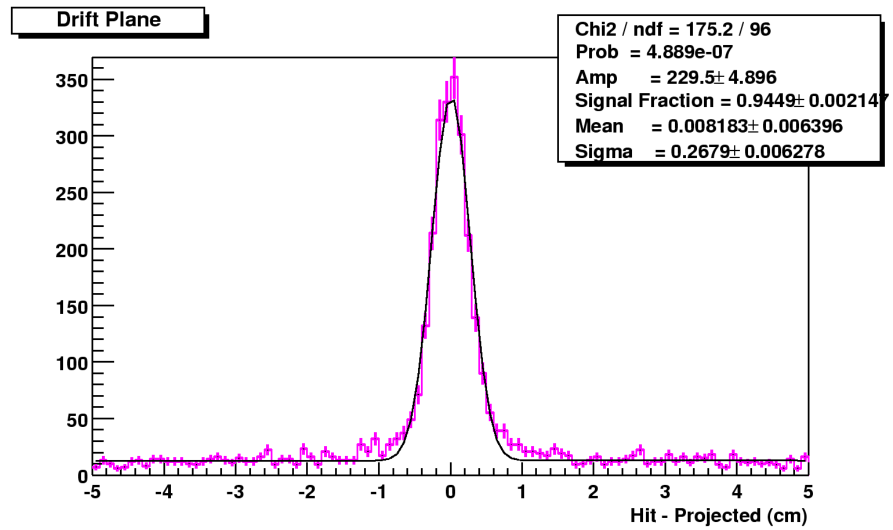
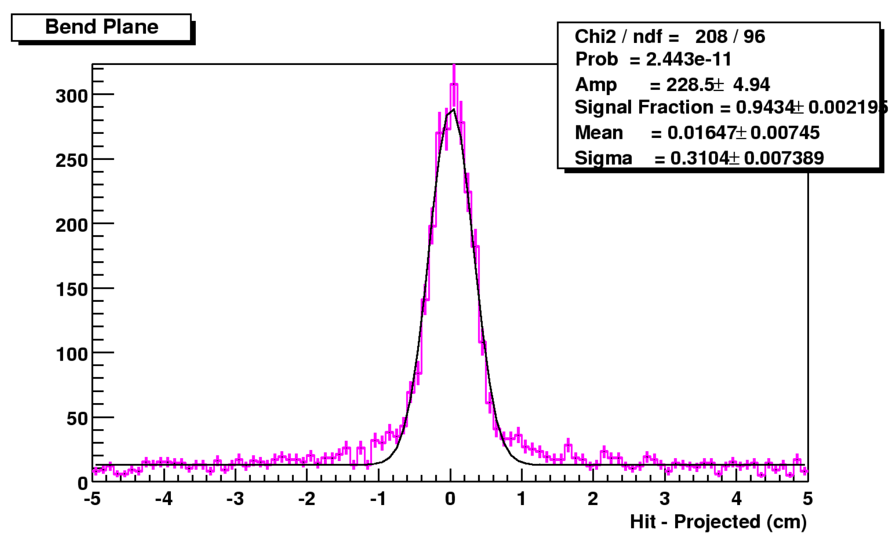
Chamber Alignment

- Track Extrapolation
  - $\sigma_{\text{drift}} = 2.7$ mm
  - $\sigma_{\text{bend}} = 3.1$ mm



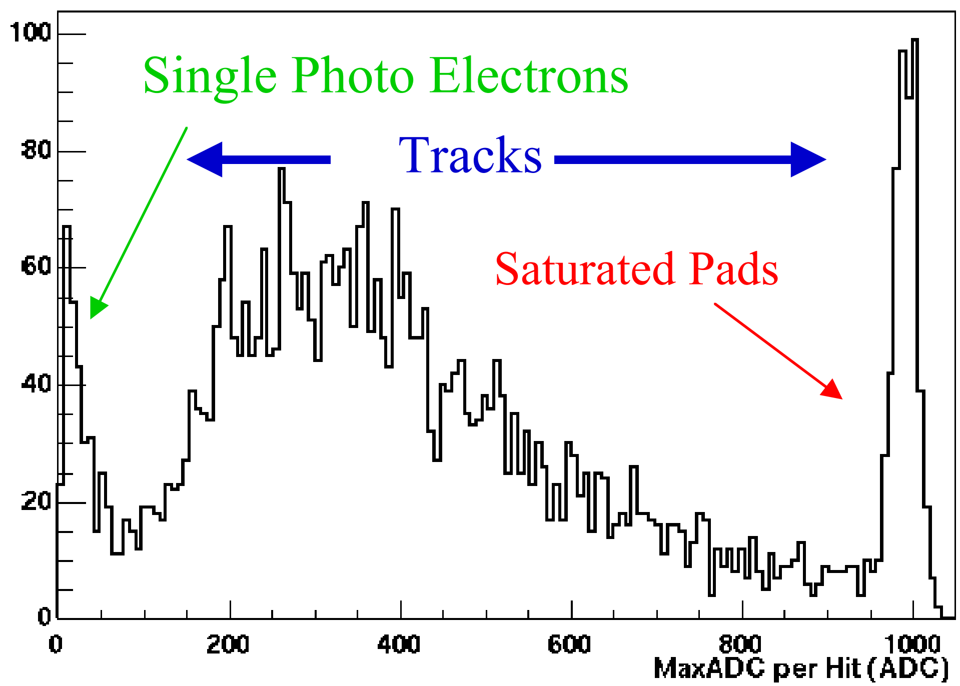
- Near Expected Resolution
  - 8.0 x 8.4 mm^2 pads
    - center of gravity method
  - 4 mm anode wire pitch
  - 2 mm anode-cathode spacing

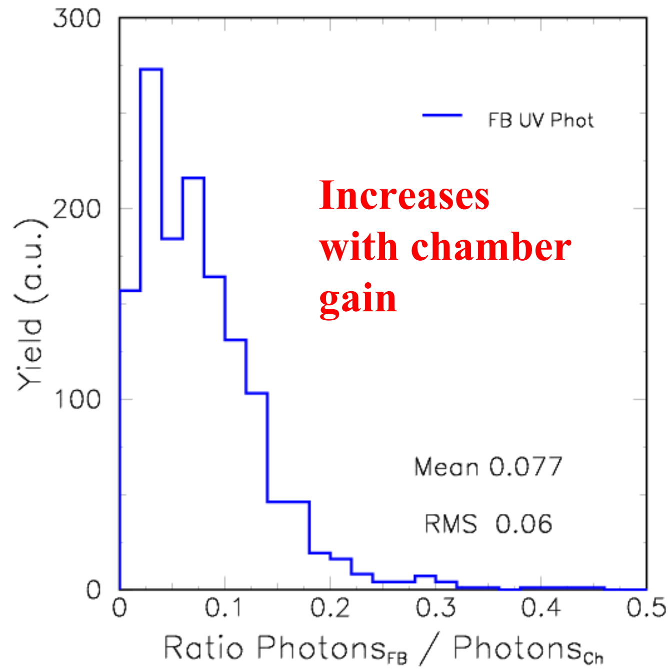


Cluster Characteristics

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

Characteristics of "Associated MIPS"

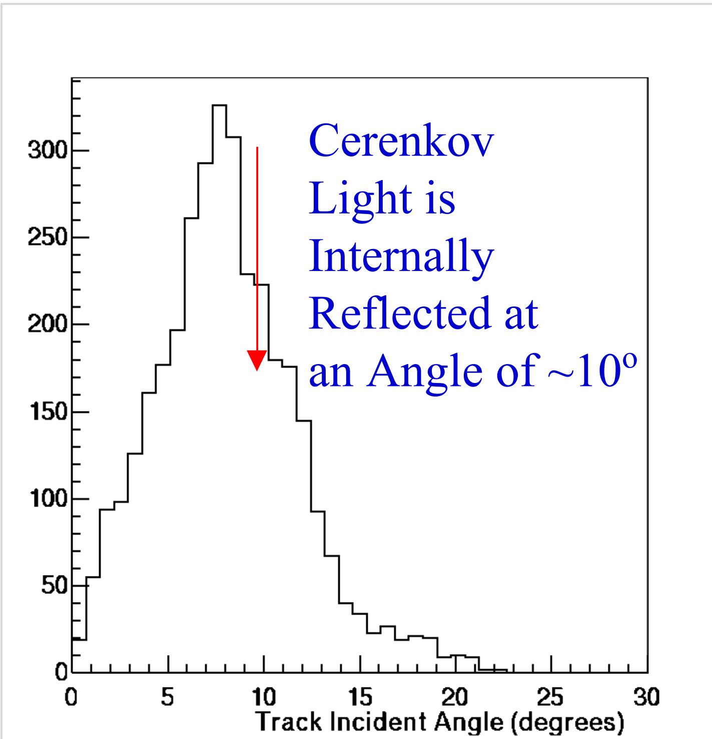




High Chamber Gain Introduces Photon Background From Avalanche:

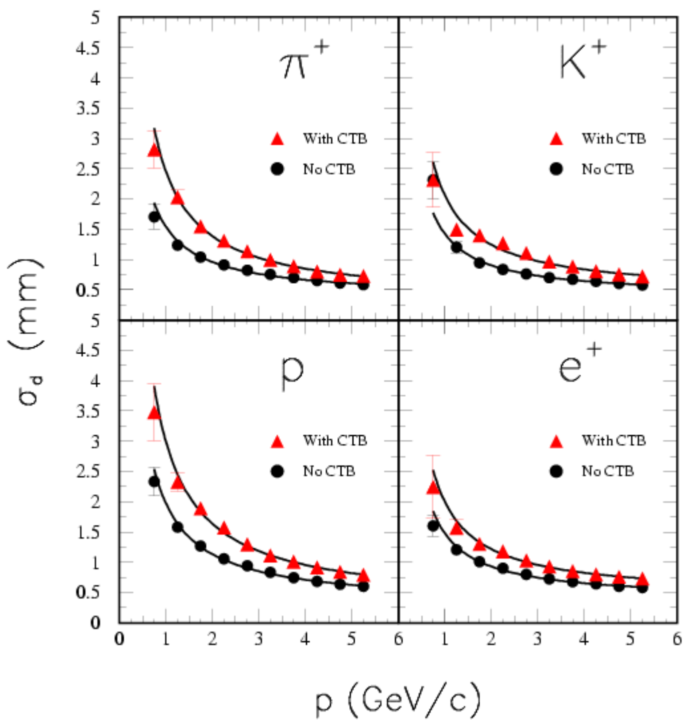
FeedBack Photons

The STAR Environment



The Large Range of Track Incident Angle on Radiator Affects the Ring Shape and Character

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

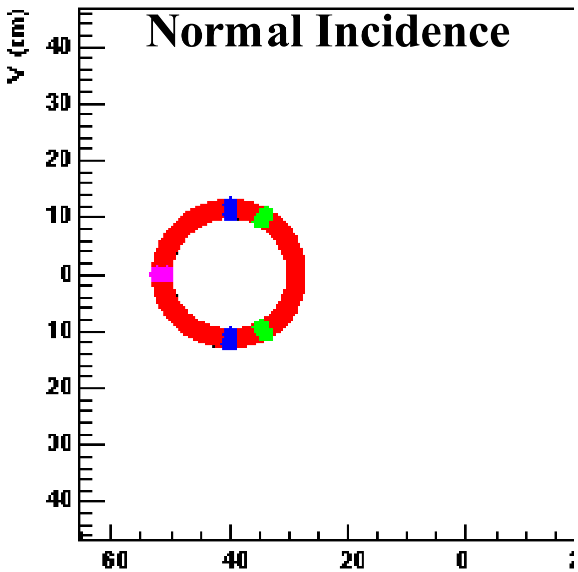


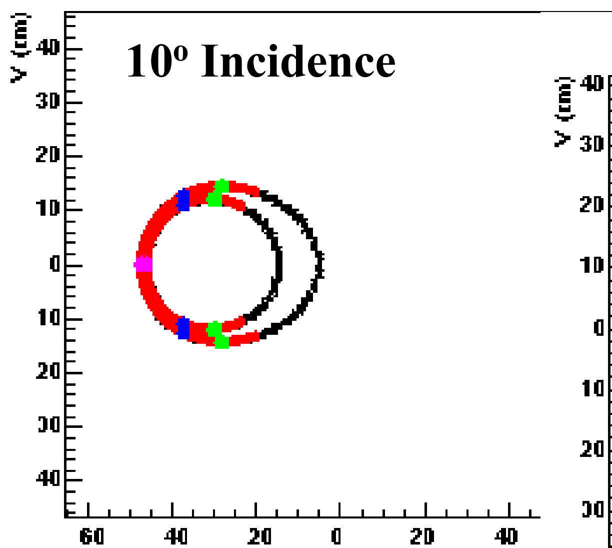
Cerenkov “Ellipses”

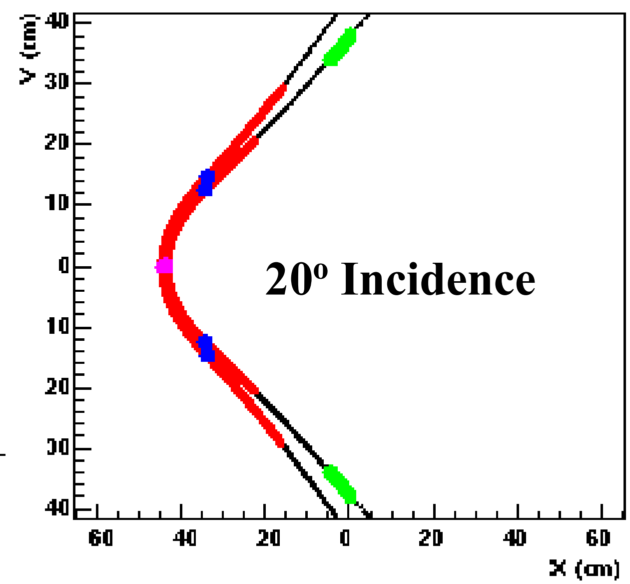
- **Effect of:**
  - **Track Incidence Angle**
  - **Proximity Focussing**

- **Ring Azimuth Angles**
  - **180^o**
  - **90^o**
  - **60^o**

“Constant Angle” Characterization
Allows Uniform Treatment

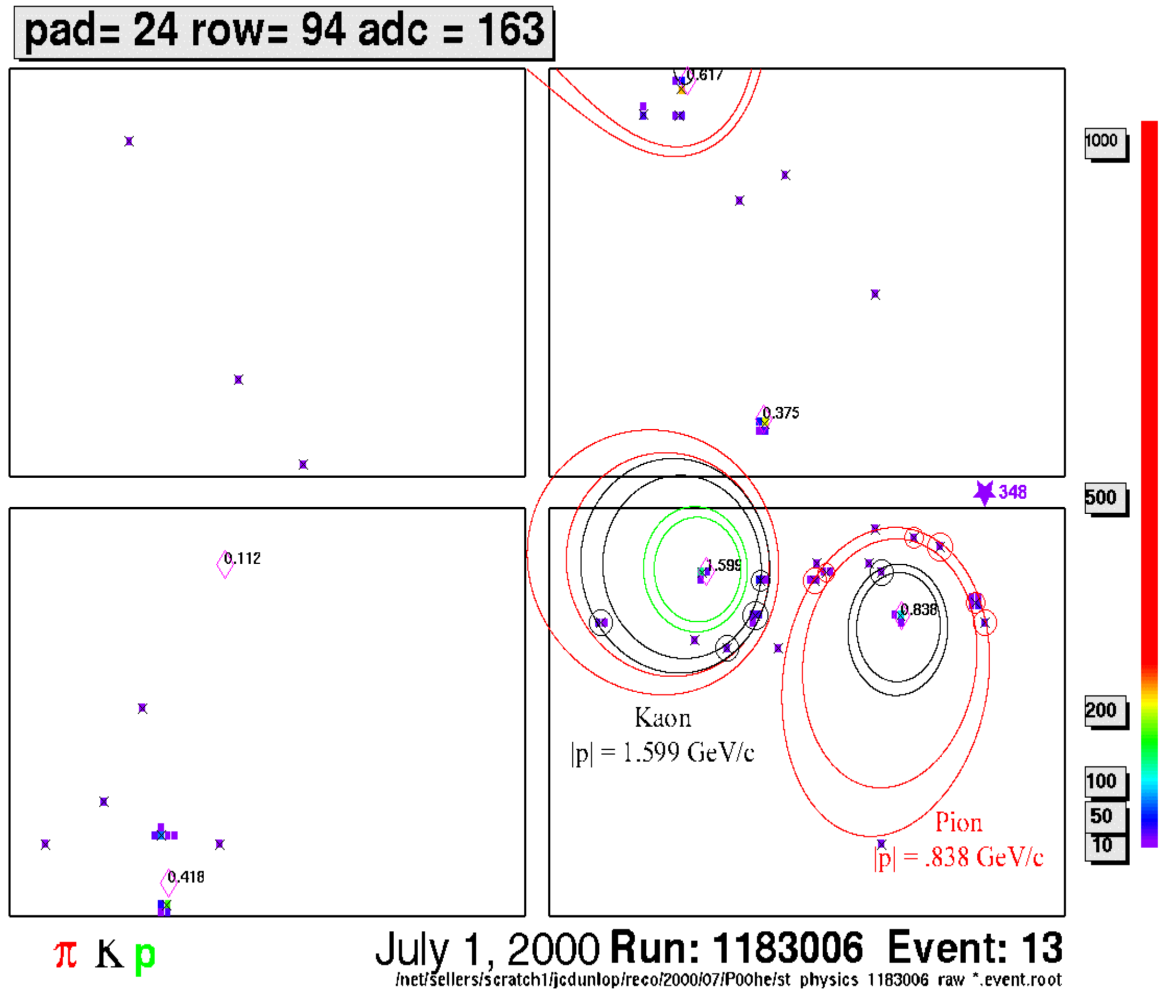




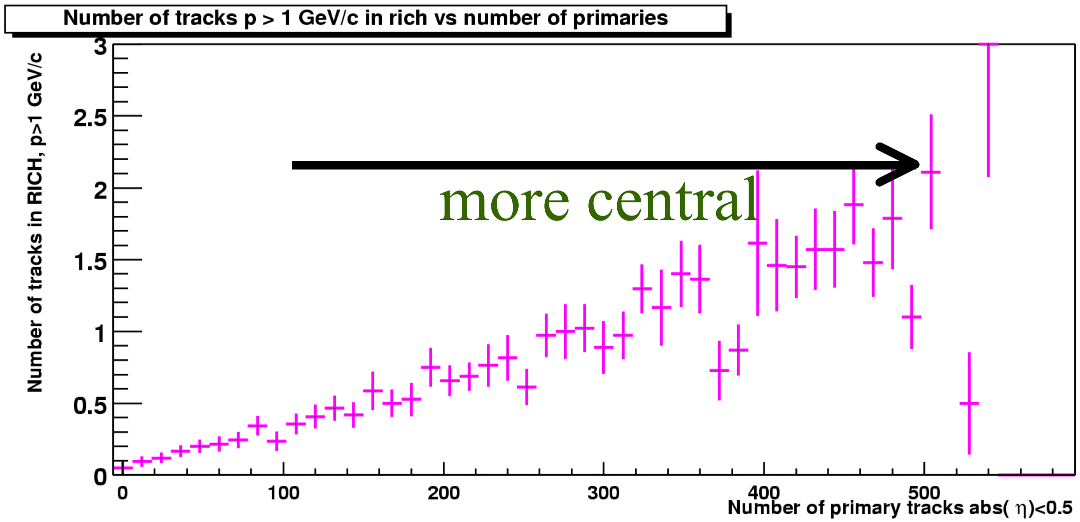


Golden Event

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



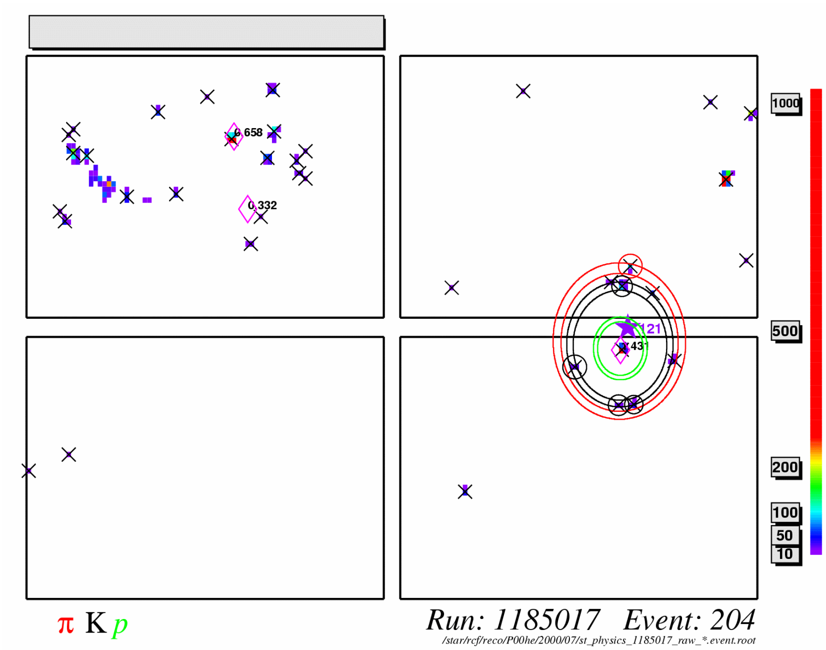
Event Characteristics

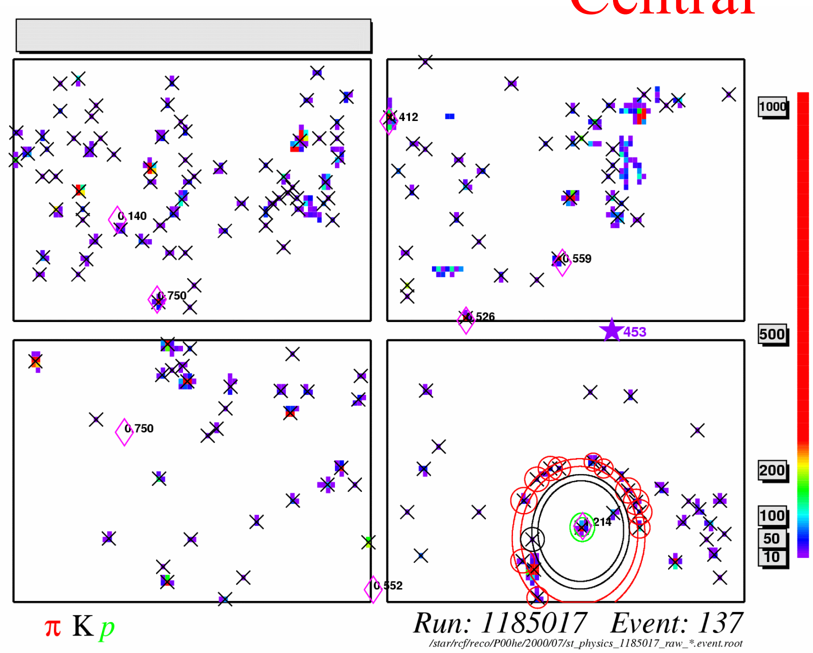


Occupancy <5%

Peripheral

Central



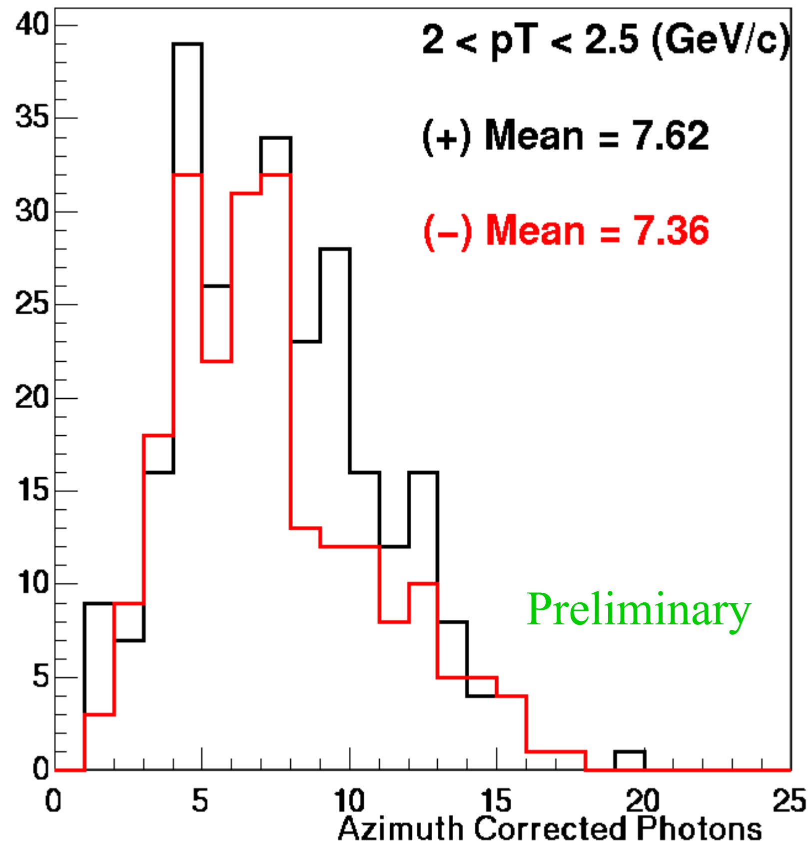


Method For PID I

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

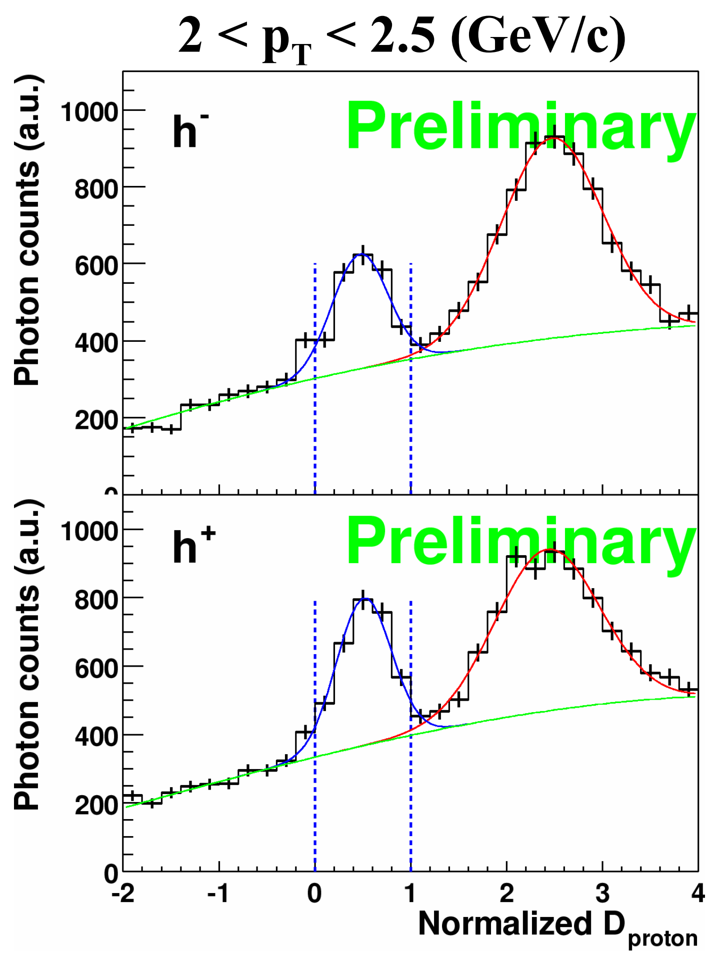
- **Track-by-Track** Observables
  - Number of Hits
  - Area on Pad Plane
  - Density of Hits in Fiducial
  - Evolution of Number of Hits
    - d distribution

Proton “Candidates”



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



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

- Y.Andres[1], A.Braem[1], M.Calderon[2], N.Colonna[3], D. Cozza[3] , M.Davenport[1], L. Dell'Olio[3], D. DiBari[3], A. DiMauro[1], J.C.Dunlop[2], D.Elia[3], E.Finch[4], R.Fini[3], D. Fraissard[1], J. Gans[2], B.Ghidini[3], B. Goret[1], R.Gregory[1], J.W.Harris[2], M.Horsley[2], G.J.Kunde[2], B.Lasiuk[2], Y. Lescenechal[1], R.D.Majka[4], P.Martinengo[1], A.Morsch[1], E.Nappi[3], G.Paic[1], F.Piuz[1], F.Posa[3], J.Raynaud[1], S.Salur[2], J.Sandweiss[4], J.C.Santiard[1], J.Satinover[2], E.Schyns[1], N.Smirnov[2], S.Stucchi[3], G.Tomasicchio[3], J. Van Beelen[1], T.D. Williams[1], Z. Xu[4]

1 CERN HMPID Group

2 Yale Relativistic Heavy Ion Group

3 Bari HMPID Group

4 Yale High Energy Group