YRHI-98-10

Letter of Intent

June 12, 1998

A Ring Imaging Cherenkov Detector for STAR *

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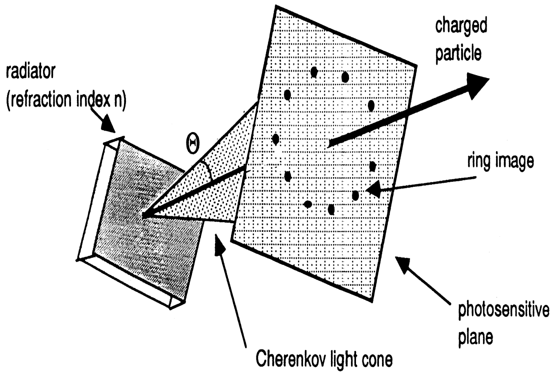

Abstract

We propose to install the RICH module, which was developed and tested for the ALICE/CERN experiment, in the STAR experimental setup at mid-rapidity to provide high transverse momentum particle identification. The RICH detector will allow pion and kaon identification up to ≈ 3.0 GeV/c *and proton identification up to* ≈ 5.0 GeV/c *and therefore extends studies of particle identified spectra to high transverse momenta and enables the study of jet quenching and partonic energy loss in dense matter.*

*In collaboration with the ALICE-HMPID Group at CERN.

This Letter of Intent is being submitted to STAR to solicit interest for the implementation of an existing Ring Imaging Cherenkov Detector that was developed for the ALICE/LHC experiment. It is intended that this detector be installed for the initial operation of RHIC. The physics motivation, description of the detector, its performance, and how it can be utilised in STAR are described in the LOI. This project will be undertaken in collaboration with the ALICE HMPID (High Momentum Particle ID) collaboration, which has developed, constructed and tested the detector at CERN.
We solicit your suggestions, comments and any new ideas regarding implementation of this detector into STAR. We would like to invite groups interested in participating in this project to please contact us, as soon as possible. The present plan is to quickly develop this LOI into a proposal to STAR.

Yale RHI Group

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Letter of Intent

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1 Overview

The STAR experiment at the Relativistic Heavy Ion Collider (RHIC) is designed to perform inclusive and event-by-event measurements of hadrons over the pseudo-rapidity range $|\eta| \leq 2$. In the following, we propose to install the 1 square meter Ring Imaging Cherenkov Detector (RICH) module, which was developed and tested by the HMPID collaboration for the ALICE [ALI95, ALI96] experiment at CERN, into the STAR experiment for the start-up of RHIC. It will be located at mid-rapidity to identify pions and kaons up to 3.0 GeV/c and protons up to 5 GeV/c. The lower bounds for identification will be $\approx$ 0.6 GeV/c for pions, $\approx$ 1.1 GeV/c for kaons and $\approx$ 1.5 GeV/c for protons. The addition of the detector will substantially increase the physics capabilities of STAR, for it will allow the study of high transverse momentum (p_T) observables. High p_T processes dominate the initial conditions of relativistic heavy ion collisions at RHIC and the Large Hadron Collider (LHC) and therefore provide a unique probe of hot dense matter. The high p_T processes are also of broad interest since they belong to a set of questions with overlap between particle and nuclear physics studied in lepton-nucleon, hadron-nucleus and nucleus-nucleus reactions, and they are calculable by perturbative QCD [WAN97]. The unique opportunity for STAR is the high selectivity in measuring event-by-event (EbE) observables which can be used to select subclasses of events, e.g., an unusually high kaon to pion ratio to select high strangeness content, a proposed signature of the Quark Gluon Plasma (QGP). These event ensembles can then be studied to delineate, e.g., whether the slope of the transverse mass distributions differs for events with high and low strangeness content. The combination of exclusive and inclusive measurements for hadrons will be unique among RHIC experiments because it provides a better event discrimination beyond only measuring the charge particle multiplicity to select centrality. The selectivity may furthermore be necessary if the postulated QGP is not produced in every central event but only in subclasses which can, however, be selected by requiring the presence of *several* exclusive signatures in a given event. The RICH detector addition to STAR will add significantly to the overall program of the four major experiments which address relativistic heavy ion collisions at RHIC.

† 'BNL' also supported by Brookhaven National Laboratory,'UF' University of Frankfurt, 'g' graduate student, 'ug' undergraduate student.

2 Physics Motivation

One of the exciting issues the Relativistic Heavy Ion community must address is the effective energy loss [GYU94] of high transverse energy (E_T) partons which are produced via hard or semi-hard processes and subsequently propagate through the dense medium. This jet quenching is calculated in perturbative Quantum Chromo Dynamics (pQCD) and has effects on particle and heavy quark production. It may be addressed by measuring particle ratios as a function of their transverse momentum or in momentum distributions with p_T above approximately 2 GeV/c. An even cleaner signal may be obtained by tagging the high momentum particles with an opposite side direct photon [WAN96, WAN97b].

The ratio of anti-protons to protons as a function of transverse momentum has been suggested as a means of determining the energy loss in the dense medium [WAN92, WAN98]. It is known that the gluon to quark density ratio decreases with E_T, therefore the ratio of gluon to quark jet production cross section also decreases with E_T. The ratio of anti-protons to protons should then decrease with transverse momentum since most of the anti-protons come from gluons while the protons come from both valence quark and gluon fragmentation. For Au+Au collisions one expects less proton production per nucleon from valence quark production than in p-p collisions since Au is neutron rich. However, due to the strong coupling in QCD the gluons are expected to lose approximately twice as much energy in the medium as quarks, resulting in an anti-proton to proton ratio which is lower in Au-Au collisions relative to proton-proton collisions. This effect is predicted [WAN98] for proton momenta above 2 GeV/c and is shown in figure 1.

The quenching of jets due to the energy loss in the medium is expected to reflect properties of the medium by modifying the single particle transverse momentum distributions above approximately 2 GeV/c [WAN92]. However, to understand this effect the 'thermal plus flow' contribution to the transverse momentum distributions must be understood. The crossover between the thermal and jet contributions does not only depend on the energy loss of jets in the medium, but also on the thermal distribution for a given hadron type. Therefore, transverse mass spectra of various identified hadrons are required to address this question.

An important aspect of ultra-relativistic heavy-ion collisions is the equation of state of strongly interacting matter. Copious mini-jet production in the central rapidity region is expected to produce a state of high entropy [GEI93, ESK97, DUM97]. Theoretical model studies [XIO94, MUL95, GEI95] suggest that the parton plasma in the central region will thermalise rapidly. The question of whether the increase of the number of degrees of freedom at a critical temperature around 160 MeV could prolong the lifetime of the hydrodynamic fireball significantly [HUN95, RIS96, RIS96b] is of key interest for the understanding of the thermodynamics of QCD matter. These questions can be addressed by determining the collective transverse flow velocity, the average transverse momentum, and the apparent temperature of the transverse momentum spectra of various hadrons [SCH94, DUM98]. For this, the measurement of the transverse momentum spectra of identified hadron species up to transverse momenta of several GeV is required.

Another interesting topic which can be addressed with the information provided by the RICH detector is the phenomenon of hard scattering of diquarks [GEI88]. Diquarks, correlated two-quark objects with large radii, are expected to traverse hadronic matter and a plasma differently if their radii are larger than the Debye screening radius of the medium.

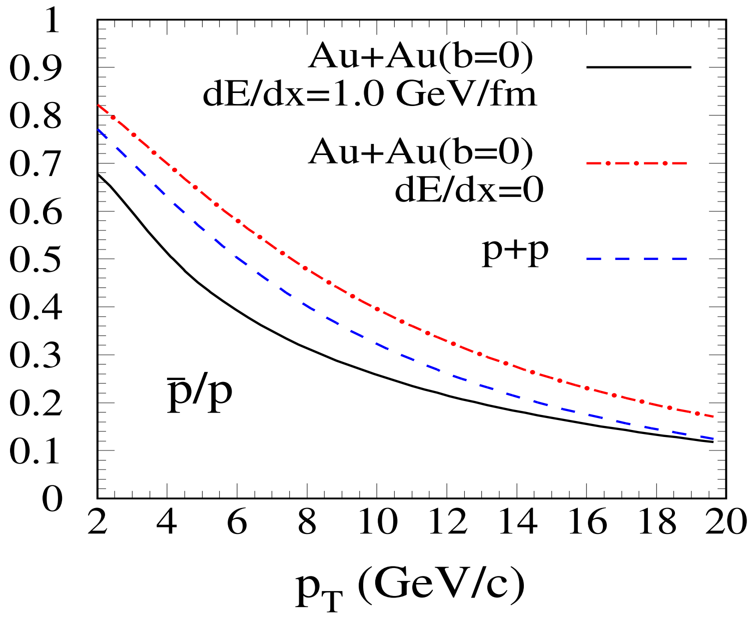

Figure 1: The ratio of anti-proton to proton distributions as a function of the transverse momentum p_T as predicted for proton-proton collisions (dashed) and central Au-Au collisions at a center of mass energy of 200 AGeV. The Au-Au calculations are shown without energy loss (dot-dashed) and with a parton energy loss of dE_q/dx=1 GeV/fm (solid). For details see text.

The amount of suppression depends on the fraction of diquarks traversing the QGP and the time the diquarks stay in the QGP. The suppression of high transverse momentum protons in A-A collisions compared to p-p collisions is predicted to be a signature for the QGP.

Last but not least, the ten-fold increase in the available center of mass energy from the relativistic heavy ion program at CERN to the RHIC program may bring unexpected and unpredicted phenomena. These may only be discovered by having as complete a picture of the collisions as possible. The identified high transverse mass spectra are an important element of this picture.

3 Particle Identification

Particle Identification (PID) in STAR can be sub-divided primarily into two main momentum regions, each with different requirements on the identification capabilities. The exclusive coverage for stable hadrons, which enables event-by-event studies and allows a measurement of yields with approximately 5% accuracy, can be restricted to a momentum range which extends up to ≈ 2 times the expected mean transverse momentum. For Au+Au collisions at 200 AGeV (RHIC) this range extends to 0.8 GeV/c, e.g., this represents about 90% of the pion yield for central HIJING [WAN91, WAN94] events. Beyond 0.8 GeV/c,

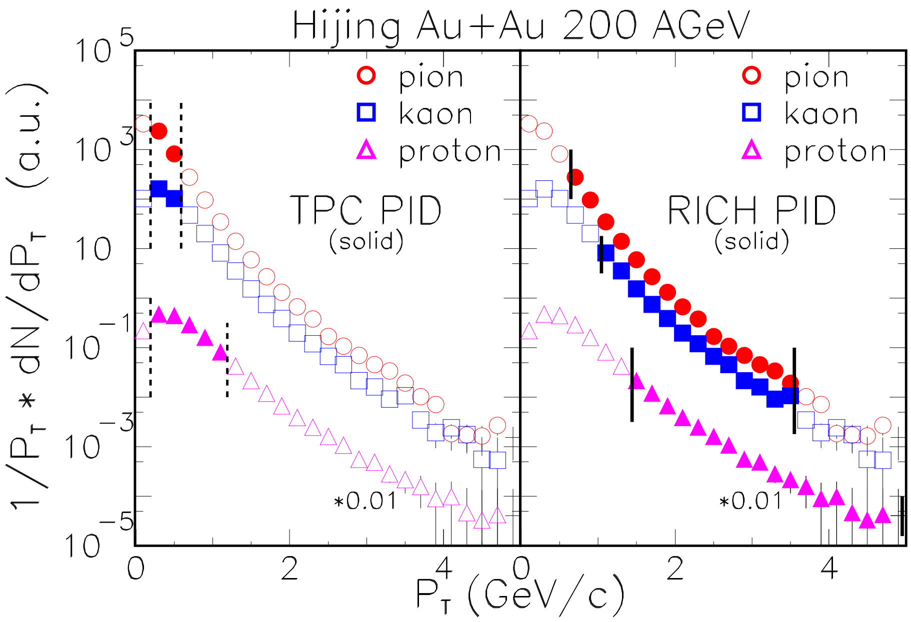

Figure 2: Invariant transverse momentum distributions for Au+Au at 200 AGeV calculated with HIJING. The spectra for pions (circles), kaons (squares) and protons (triangles) are shown. The solid symbols represent regions of the spectra where the various particles can be identified. The range for statistical identification by dE/dx in the TPC is depicted by vertical dashed lines for each particle in the left-hand figure. The ranges for track-by-track identification by the RICH detector are shown by solid lines in the right-hand figure (Note that the proton range extends up to 5 GeV/c).

exclusive coverage is no longer important for event-by-event physics since the yields at high transverse momentum are not statistically significant.

It is, however, important to have inclusive coverage for higher transverse momenta in order to address the physics described above for selected ensembles of events. The measurement of positively-charged or negatively-charged hadron spectra at high momenta without identification is insufficient to thoroughly study these predictions. Perturbative QCD signals require the knowledge of the particle species, and many thermodynamic properties (e.g., flow,temperature) can only be studied if identified transverse mass spectra are available.

3.1 Baseline Particle Identification (Exclusive and Inclusive)

In the baseline configuration of STAR, the specific ionization of tracks measured in the time projection chamber (TPC) is used to perform particle identification for non-minimum ionising pions, kaons, protons and electrons. The TPC alone provides the capability to unambiguously assign a particle identification with 3σ–separation for individual tracks through a momentum and energy loss measurement only over the range of $0.2 - 0.3$ GeV/c particle momentum (track-by-track) [LAS98]. An inclusive spectrum (event integrated yield) for single particle species can be obtained in the range of $0.2 - 0.6$ GeV/c (pion/kaon separation) by deconvoluting the contributions of the various energy losses of the different particles to the integrated dE/dx spectrum (statistical PID) [ELL94, YEP95, YEP95b]. These ranges are shown on the left-hand side of figure 2. The second year addition of the silicon vertex tracker (SVT) will increase the pion/kaon identification range by dE/dx up to approximately 0.8 GeV/c. The range for protons extends up to 1.2 GeV/c for TPC measurements, including the SVT information will increase this range to 1.5 GeV/c (99% C.L., i.e., non overlapping distributions and low track densities). These identification ranges allow for the study of soft hadron physics, e.g., about 70% of the pions have momenta between 0.2 and 0.8 GeV/c, and about 20% have momenta less than 0.2 GeV/c [HIJING].

3.2 Ring Imaging Cherenkov Detector(Inclusive)

The proposed addition to STAR is a Ring Imaging Cherenkov Detector (for a history and the theory of Cherenkov detectors see [SEG94, YPS94]). The module was originally developed by the CERN HMPID collaboration as a prototype for the ALICE experiment at the CERN-LHC. The expected particle multiplicities and transverse momenta in AA-collisions as seen by the detector will be comparable at RHIC and the LHC. This is the case because the distance of the RICH module from the interaction vertex in STAR is half that in ALICE, thus balancing the anticipated four-fold increase in particle densities from RHIC to LHC. The RICH module, schematically depicted in figure 3, employs a liquid radiator and a photo sensitive cathode with a 2-dimensional readout. Its design builds on the efforts of the CERN RD-26 collaboration which pioneered the use of CsI as a solid photon converter [NAP92b, NAP92c, PIU93, RDS94, ALM95b, RDS96]. The introduction [SEG90] of a thin layer of CsI as a photo-converter provides a tremendous advantage over the use of a volume of TMAE, in that it allows direct photo-electron reconstruction in a true plane and very stable operation of the detector. Detectors of the same type described here were used successfully in the NA44 experiment at CERN [BRA97] to identify particles above the Cherenkov threshold and are under construction for the HADES experiment [HAD93] at GSI. In addition, the proposal for the COMPASS experiment [COM96] at CERN contains a CsI RICH detector.

The data obtained with the RICH detector allow position reconstruction and identification of photons and charged particles. The average number of photo-electrons detected in the fiducial area of the Cherenkov ring for a 3 GeV/c pion with normal incidence is approximately 16 [NAP98]. This number is sufficiently high to allow particle identification in the high multiplicity environment expected for Au+Au collision at RHIC. The expected ranges of track-by-track identification with the RICH are $0.6 - 3.0$ GeV/c for pions, $1.1 - 3.0$ GeV/c for kaons and $1.5 - 5.0$ GeV/c for protons (see figure 2). The lower bounds are determined by the number of detected photons, while the upper bounds are determined by the overlapping of the fiducial areas for the various particles as they approach $\beta = 1$.

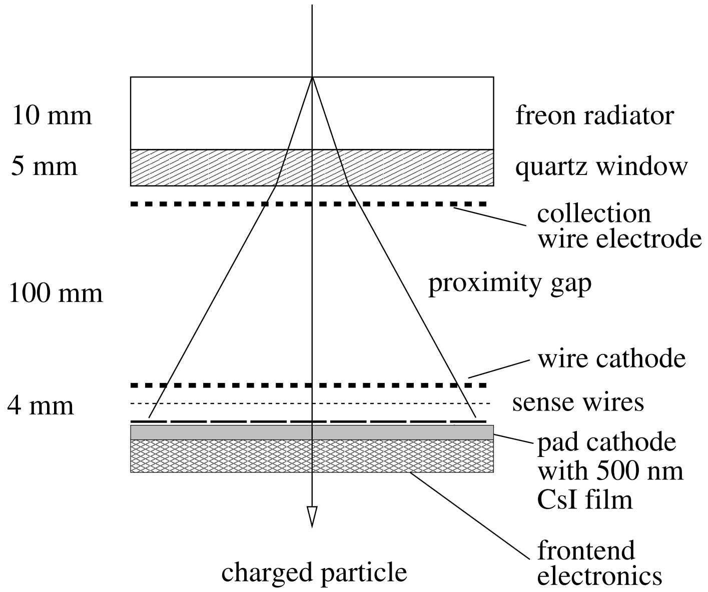

Figure 3: Schematic cross section of the RICH detector module. A charged particle enters the volume from the top. If the particle velocity is above the Cherenkov threshold, light is produced in the radiator C_6F_{14}. The Cherenkov light cone (depicted by lines) is refracted as the light traverses the quartz window (upper hatched area). The proximity gap which is part of the multi-wire proportional chamber (MWPC) yields ring diameters of approximately 35 cm for $\beta \approx 1$ particles. The photo-conversion is performed via a 500 nm CsI layer on the cathode pad plane. The photo-electrons are detected using the MWPC. The 2-dimensional pad readout allows the reconstruction of the photon and charged particle position and the discrimination between photons and charged particles via their amplitudes.

4 Algorithms for Particle Identification employing the RICH

Our general approach for particle identification with the RICH detector has been to test different mass hypotheses for tracks with known momentum and position as reconstructed from the TPC. Thus the pattern recognition will not be a complex quest for finding rings in a high multiplicity environment but rather the simpler task of comparing the photon occupancy in ring areas on the cathode which are reconstructed under the different candidate mass assumptions. The fact that the RICH signals allow the discrimination between photons and charged particles enables the matching of the charged particle hits in the center of the rings with the projected TPC tracks. Momentum and position information are needed for the reconstruction. This implies that the amount of material between the exit of the TPC and the RICH should be minimised to have precise predictors, i.e. the Central Trigger Barrel (CTB) radiation thickness must be minimised. This procedure, comparing hit densities in

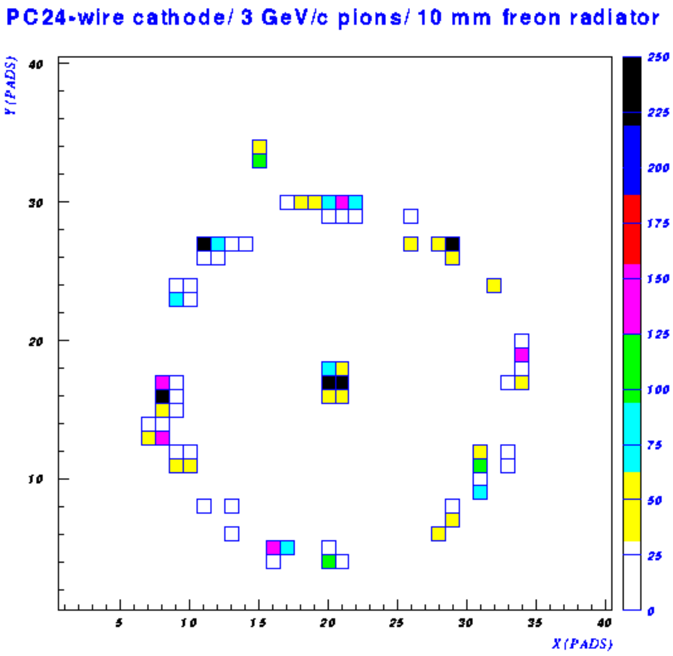

Figure 4: Online display of the pad plane response for a single 3 GeV/c pion at normal incidence, the x versus y coordinates of the pads are plotted, the gray shade indicates the raw amplitudes. The 6–pad cluster in the center of the ring is caused by the charged particle. The average number of observed photon clusters in the Cherenkov ring is approximately 16.

fiducial areas determined via the different mass assumptions for a given momentum, should yield the best resolution since all available information is used in the reconstruction.

The current approach for particle identification used by the HMPID-group [DIM94] is based on the ray-tracing of all detected photons with respect to each individual incident particle. After performing a Hough transform, the Cherenkov angle and therefore the mass are determined, given the particle momentum. The results for the Cherenkov angle resolution displayed in figure 5 and the proton–pion separation shown in figure 6 are obtained with this method [NAP98], they are discussed in the next section.

5 Test Beam and Simulation Results

The RICH detector module has been tested at CERN utilising various test beams [NAP98] and has exhibited very reliable performance with no aging effects over a period of approximately 2 years [PIU96, NAP98]. Figure 4 shows an online display of a pad region responding

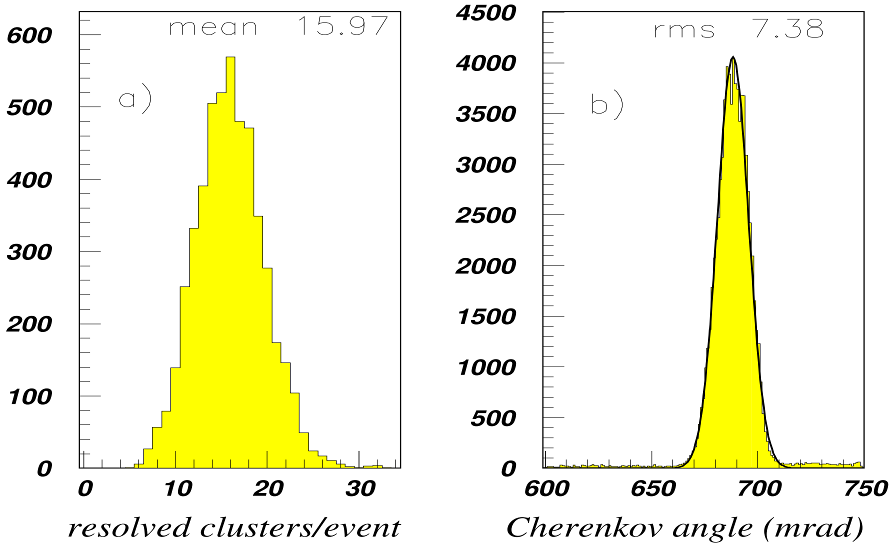

Figure 5: Detector characteristics obtained for pions with a momentum of 3 GeV/c at normal incidence. The figure shows on the left-hand side the number of resolved photo-electrons per event and on the right-hand side the reconstructed Cherenkov angle per photon.

to a single 3 GeV/c pion at normal incidence. The average number of photons detected for a 3 GeV/c pion is 16 if the particle is normally incident (see figure 5). The number of detected feedback photons (a big concern for other Cherenkov detectors) is measured to be approximately 1.5 per track outside the fiducial area of the Cherenkov ring. This small number has no negative effects on the resolution of the detector and is the result of the small ratio of gap size to pad size. Feedback photons produced by an avalanche are predominantly converted at the pad which detects the avalanche. Therefore they do not add to the background. At particle incidence angles above about 13°, Cherenkov light produced in the quartz window is no longer totally reflected and contributes to the background at a level of 1 registered photon per track. The influence of a magnetic field (0.5 Tesla maximum for STAR and ALICE) has been measured and no effect on the CsI quantum-efficiency was observed [PIU98].

The test beam results give an angular resolution for retraced Cherenkov photons of 7.4 *mrad* [NAP98]. The resolution for the Cherenkov angle of the ring has been measured and improves with the square root of the number of observed photons. A 3 σ pion–kaon separation is observed up to momenta of 3 GeV/c. Figure 6 shows the separation of protons and pions at 3 GeV/c momentum achieved experimentally for the case of single events and for superimposed events to simulate a particle density of 50/m^2 [ALI95]. A Gaussian fit to the pion distribution shows that even for this high density the variance of the distribution changes only slightly.

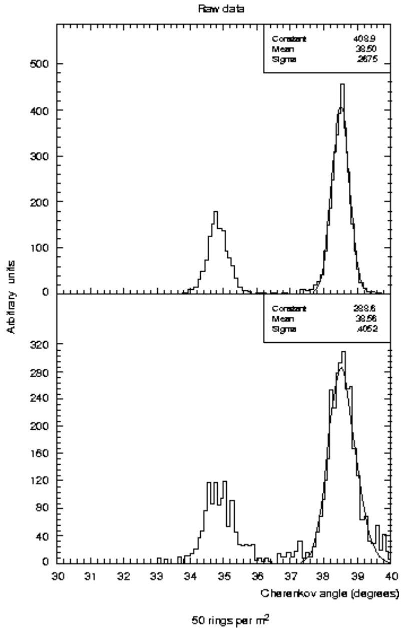

Figure 6: Separation of pions (right peak) and protons (left peak) with a momentum of 3 GeV/c obtained with the RICH module during a CERN test beam. The yields versus the reconstructed Cherenkov angles are plotted. The upper figure shows the separation for events with a particle density of 1 per m^2 and the lower figure shows the separation for a particle density of 50 particles per m^2 obtained by superimposing real events before the analysis to simulate high multiplicity events. The pion distribution is fitted by a Gaussian to measure the resolution.

Two CsI photo-cathodes, read out via MWPC's of the same type described above, have been successfully used in the NA44 heavy-ion experiment, the objective there was the identification of particles above the Cherenkov threshold [BRA97]. The two chambers equipped with CsI photo-cathodes were operated for two heavy ion runs at the CERN SPS without problems or noticeable decrease in response. Even a considerable neutron background which induced currents in the chamber of $\approx$ 300 nA during the beam spill had no effect on the detection capability.

A complete GEANT description of the RICH exists and the test beam results have been reproduced. Several different event generators such as HIJING and VENUS are being used to simulate the high multiplicity environment of RHIC collisions. A comparison of the two approaches is underway and detailed Monte Carlo studies using simulated events and real test beam events are being performed.

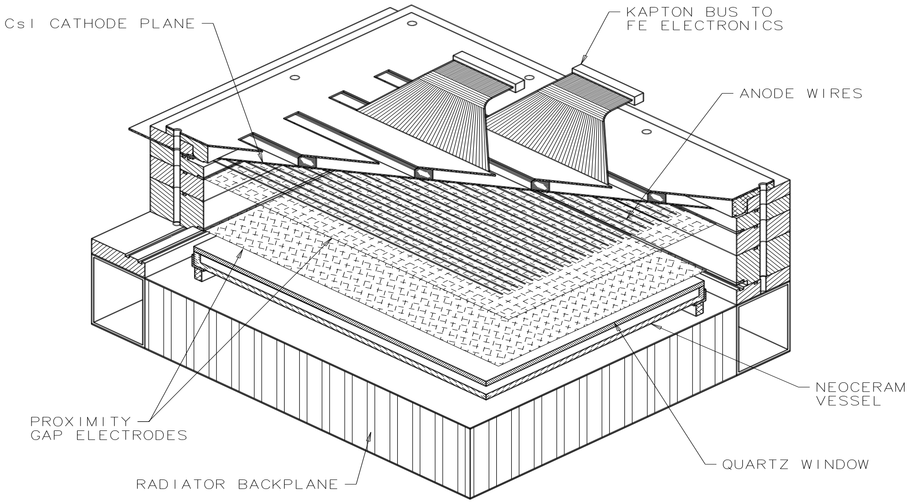

Figure 7: Artist's rendering of the RICH module showing the various detector components including the Kapton bus lines which carry the signals from the pads to the GASSIPLEX amplifiers (not shown).

6 Technical Description

The RICH module (shown in figure 7) contains a 10 mm thick liquid radiator vessel with a 5 mm thick quartz exit window connected to a multi-wire proportional chamber with pad readout. The liquid radiator employed is C_6F_{14} at room temperature and ambient pressure with a threshold momentum of $p_{th}(\mathrm{GeV}/c) = 1.26 \times mc$, where the particle mass m is in GeV/c^2. Proximity focusing is used with a photo-cathode at a distance of 10 cm, this geometry yields radii of approximately 15 cm for asymptotic rings ($\beta \approx 1$). The photon conversion is achieved via a 500 nm CsI coated and conditioned cathode [AND93, RDS94, ALM95, BUZ95, ?] with 8×8 mm^2 Au-Ni coated Cu pads with 1 mm spacing. The photo-electrons cause an avalanche at the anode wires (20 μm diameter), which have a 4 mm wire pitch and a 2 mm anode–cathode gap. The cathode pads are read out via a multiplexed analog VME based readout system. Charge sharing between pads allows the determination of the avalanche location with higher precision by evaluating the cluster centroids. The amplitude information is used to determine the centroids and multi-photon clusters and to discriminate between photons and charged particles. Charged particles have on average a factor 6 higher amplitude. The thin cathode gap minimises the charged particle background and the background due to feedback photons.

The present RICH module (shown in figure 8) has the dimensions 130×87 cm^2, containing two radiator vessels (130×43 cm^2) and four photo-cathode planes (64×43 cm^2). The multi-wire proportional chamber has 130 cm long anode wires with 4 mm spacing, with additional supports in the middle of the RICH module.

The radiator vessels are made from NEOCERAM trays with a UV-grade SUPRASIL plate; 18 cylindrical spacers made from fused silica rods with a diameter of 10 mm are glued to the NEOCERAM plate on one side and to the quartz window on the other side to add to the mechanical stability of the vessel. The two materials have equal thermal dilation coefficients and are designed and measured to be able to cope with the hydrostatic pressure of the 40 cm radiator liquid, which is created by mounting the vessel vertically along the long axis.

The radiator system is based on the technology used for the DELPHI liquid barrel RICH, which has been successfully operated for several years.

The CsI photo-cathode design is the result of the research and development project RD-26 at CERN [NAP92b] which has developed and proven the technique of producing large area CsI photo-cathodes with high and stable quantum efficiency [RDS94, RDS96, PIU93, PIU96, BRE95]. The measured quantum efficiency at 170 nm is approximately 20% and is found to be very stable; the degradation is measured to be less than 5% (relative) over two years if the photo-cathodes are kept in a controlled atmosphere [NAP98]. For normally incident pions at 3 GeV/c a yield of 16 photo-electrons per ring on the average hsa been achieved for several test beams at CERN [NAP98].

The MWPC is operated with pure methane (5 mol). Tests show very stable, discharge-free operation at a gas gain of approximately 10^5 and a single electron detection efficiency of 95% [NAP98]. Methane was chosen since it has a good UV transparency and favourable photo-electron backscattering properties [DIM96], while other gases are also being investigated [ALM95b].

The data acquisition is based on a multiplexed analog readout using the 16 channel VLSI front-end chip GASSIPLEX ($0.7\mu m$ version) [SAN94] with an r.m.s.-noise of 650 electrons at 0 pF input impedance, a noise slope smaller than 11 electrons r.m.s./pF and a selectable peaking time of $300 - 800$ ns. The maximum analog readout speed is 10 MHz. The peaking time requires a level-0 trigger signal to occur less than 1 micro-second after the interaction. The track and hold (T/H) stage which stores the charges in a capacitor has a very low leakage rate, thus a fast clear scheme could be implemented if the level-0 trigger signal arrived later than 1 microsecond after the collision. However, a fast ($\approx$ 600 ns) minimum bias pre-trigger would be required. The pre-trigger acts as pre-hold and then if validated the pre-hold would be maintained and the event processed. If not validated, the falling edge of the pre-hold acts as a fast-clear, allowing acceptance of the next event after $\approx$ 200 ns. The multi-chip module (MCM) version of the chip has the modularity of 3 to 4 daisy chained GASSIPLEX amplifiers, a buffer amplifier and a control signal register. The multiplexed analog signals will be transported via approximately 20 Lemo cables to a VME crate using C-RAM modules in order to perform the analog-to-digital conversion and zero suppression. The maximum event rate is on the order of several KHz, depending on the number of C-RAMs used. The communication between the VME and DAQ will be done in accordance with the fiber standard adopted by the STAR TPC and SVT.

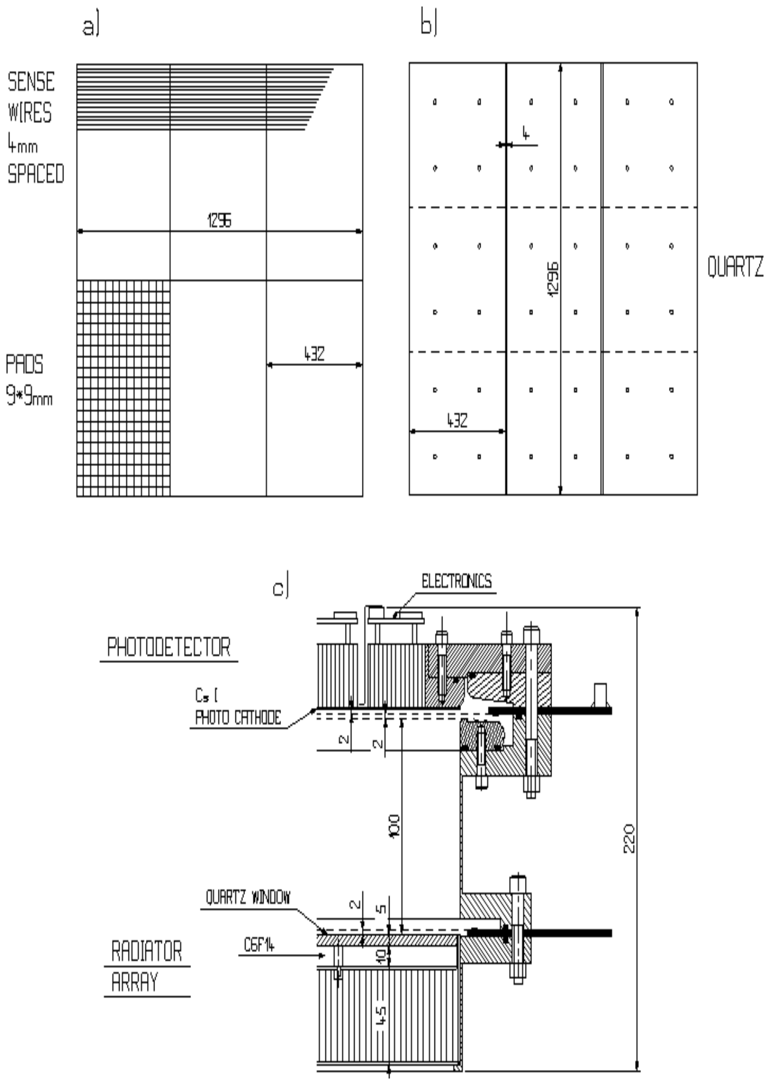

Figure 8: The two top illustrations show a plan view of the configuration and dimensions (mm) of the MWPC (a) and the radiator (b) vessels for the full size ALICE-RICH module. The module for STAR is a 2/3 size module (130 $\times$ 87 cm^2 and contains 2 radiators (of the 3 shown) and 4 cathode planes (of the 6 shown). The lower figure (c) shows a detailed cross section of the edge of the detector module. The structural support utilises honeycomb material which is shown as the striped elements on the top and bottom of the module.

7 Installation/Integration in STAR

We envision the installation of the RICH module at mid-rapidity at a 3 or 9 o'clock position inside the magnet. It is assumed that there will be only a partial EMC patch at day one, so that two tracks of the rail system for the EMC can be used to mount the detector. The weight of the module is on the order of 100 kg. The detector will be positioned so that the center points directly towards the interaction diamond, this will minimise photon losses due to non-normal particle incidence. Further studies are underway to determine whether it will be possible to make measurements at various different rapidities, and whether the rail system can accommodate this. The RICH module can be installed after the TPC is in place for the installation procedure will be similar to that of EMC modules.

The liquid radiator circulation system will be placed outside the magnet and contains approximately 30 litres of C_6F_{14}. A closed circulation system will be used and the gas atmosphere will be nitrogen. The system includes oxygen removal and a condensation system to recover evaporated C_6F_{14}. A UV transparency monitor is planned.

The gas handling and interlock system for the MWPC will be built to the same standards used for the TPC. The RICH detector module will be placed in a mylar bag which is continuously flushed with nitrogen. The TPC gas safety system based on Mattison and Pioneer equipment will be used in order to detect any methane or freon leakage by monitoring the flushed nitrogen.

8 Time of Flight Addition (inclusive)

It was stated in the section on Particle Identification that the track-by-track identification capabilities of the TPC do not extend beyond a transverse momentum of 0.3 GeV/c. It would therefore be desirable, but not necessary, to add a layer of time of flight detectors in front of the RICH to have a continuous track-by-track identification which overlaps both the TPC and the RICH momentum ranges. This would make particle identification cross calibrations possible and efficiency studies easier since redundant information would be available. The geometry and granularity could be optimised for this purpose without compromising the physics capabilities. An array of slats which covers the front of the RICH module read out via mesh-dynode photo-tubes is a favourable solution, simulations to determine the final geometry are underway.

9 Schedule for RICH Installation

The RICH module is scheduled to undergo more beam tests at CERN in 1998. It is anticipated that the module will be shipped to BNL in early 1999. The efforts to build the necessary support infra-structure at Yale and BNL will start in June 1998 and will conclude with the arrival of the module. The simulations have already begun as outlined earlier, they will lead to the integration of the software into the STAR analysis framework (STAF).

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