Chapter 1

RICH Detector

The Hall A RICH (F. Garibaldi *et al.*, NIM A **502** (2003) 117) has proximity focusing optics (as shown schematically in fig 1.1). The Cherenkov photons are ‘naturally’ focused on the photo-detection plane due to the small ratio between the radiator thickness (15 mm) and the drift region (>100 mm).

The RICH consists of a gas tight box $\sim 2.2 \times .5 \times .23$ m^3 composed of a sandwich of 6 aluminum frames, a honeycomb cap and 3 pad planes. The honeycomb cap supports the fragile radiator vessel ($1.8 \times .32 \times .025$ m^3) made of neoceram and 0.5 mm thick quartz plates and is filled by recirculating liquid freon (C6F14) The last frame holds the 3×1 photocathode pad planes ($\sim .64 \times .40$ m^2 each) where the Cherenkov photons are photoconverted by a thin layer (300 nm) of CsI evaporated on the pad planes.

The box is filled with a slight overpressure of dry CH_4 gas to permit the proper functioning of the Multi Wire - Multi Pad Proportional Chamber (MW-PPC). Three wire planes are deployed inside the box: the closest to the radiator plane collects the ionized electrons produced along the particle track in the CH_4 atmosphere, while the other two planes are part of the MultiWire Photon detection chamber. At 2 and 4 mm from the pad plane the photoconverted electrons are accelerated toward the anode plane while the corresponding positive avalanche is detected in the pad plane, providing 2D position information for the Cherenkov photons.

Front-end electronics cards based on the Gassiplex chips are attached to the back side of the photocathode pad planes. The collected electronic signals are multiplexed and digitized by CAEN CRAMS VME modules.

This detector, already used in the 2004 and 2205 Hypernuclear experiments, has been designed to identify protons, kaons and pions up to 2 GeV/c with π:K rejection factor better than 1:1000. This figure becomes 1:140 at 2.4 GeV/c (the Transversity experiment central momentum.

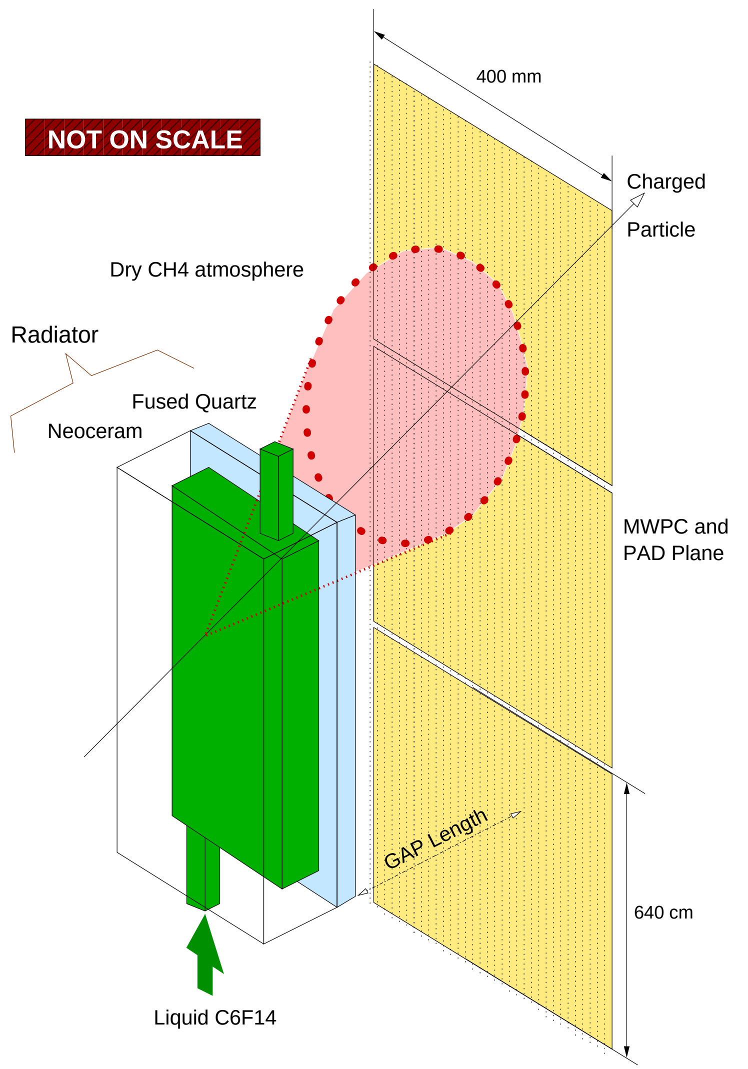

Figure 1.1: Schematic view of the HallA RICH operation.

1.1 RICH Upgrade Motivation

Measurement of the neutron single spin asymmetries for π and K (at 2.4 GeV/c) requires an effective pion:kaon rejection ratio of roughly 1:1000 (or equivalently, at least $4.7\sigma_\theta$) for the two hadrons (and proton) in the hadron arm. This can be achieved on-line (with a moderate rejection factor up to 200) by the Cherenkov aerogel counters A1 and off-line (with higher rejection factor) using the RICH detector. In order to safety guarantee sufficient π rejection at the Transversity kinematics it was decided to extend the present RICH detector reach to 2.4 GeV/c. The combined A1 and upgraded RICH responses will provide a pion rejection significantly larger than 1000:1 over the whole momentum range.

1.2 Investigated Upgrade Options

Basically three upgrade options have been investigated in detail: two of them are conceptually identical but require quite different efforts and provide correspondingly different performance.

- replace the liquid radiator Freon C6F14 with the Freon C5F12 which has a lower refractive index. The lower index of refraction results in a smaller Cherenkov angle (and consequently a better photon detector detection), a larger kaon-pion angle separation and therefore an overall better kaon-pion discrimination at the level of $5.1\sigma_\theta$. However, liquid C5F12 has never been used in a RICH detector (or similar detectors) and the pure C5F12 (which would guarantee the best transparency in the useful wavelength range $160-220$ nm) is both extremely expensive and has boiling point is of 29° Celsius. The latter fact requires a careful design (and test) of the freon circulation system (also taking into account the fragile radiator vessel), while the former makes the even the test alone quite expensive. After a detailed analysis and preliminary testing performed at CERN, this hypothesis was abandoned.

- Increase the photon detection plane either by 1.3 times or 2.0 times the original surface. These two factors correspond to two layouts of the existing photocathode planes which avoid the need to rebuilt them:

  - $\times 1.3$: four photocathode planes (rotated 90 degrees with respect to the Hypernuclear configuration) on a 1×4 array; the photodetection plane for this configuration is 15% shorter on the HRS_L dispersion direction and $\sim 50\%$ larger along the transverse direction. The expected pion-kaon separation is at the level of $5\sigma_\theta$, practically equivalent to the previous C5F12 option.
  - $\times 2.0$: 6 photocathode planes on a 2×3 array. With this configuration the overall photodetector planes is doubled relative to the present RICH (same size in the dispersive direction, double in the transverse). In this case, the pion-kaon separation would be at the level of $5.7\sigma_\theta$, largely above the requirements of the Transversity experiment.

Both solutions are mechanical extensions and require the replacement of 4 aluminum frames, the use of additional electronics front-end cards (already available at JLab), and the use of a different readout electronics (already available at JLab, but never used). Moreover, the $\times 2.0$ solution would also require modification to the glove box used for the detector assembly, a larger workspace, and a significantly longer evaporation procedure.

The $\times 2.0$ option would provide the best performance, however the estimated human resources, necessary time, and the collateral work required make it incompatible with the experiment timetable. This leaves the $\times 1.3$ solution as the best choice. It guarantees the performance required for the Transversity experiment and requires human resources and timelines safely compatible with the experiment timetable. This approach will be described in detail below.

1.3 RICH Upgrade Plan

Figure 1.2 presents the FEM of the proposed RICH$\times$1.3 upgrade. The upgrade will extended the photon detection area by a factor of 1.3 over the existing configuration. The higher number of collected photons will reduce the statistical uncertainties in the determination of the Cherenkov angle and will therefore improve the particle identification.

The upgrade design has taken into account:

- fulfill the experiment requirement without degrading current performance
- minimize modifications and costs
- preserve the existing RICH configuration[1]

The upgrade consist of:

- replacing the last 4 frames (slightly more than 1/2 of the RICH box) with new, larger (on the transverse direction) ones used to house 4 rotated photocathode pad planes,
- reuse 3 of the existing pad planes and one spare,
- use new electronics (already available at JLab) together with the existing ones,
- implement additional software for the integration of the new electronics into the DAQ.

The following important parts will *not* be affected by the upgrade:

- The honeycomb cap and the first 2 frames.
- The liquid freon radiator circulation system.

[1]The existing RICH can be used as a backup solution together with the A1 Cherenkov counter.

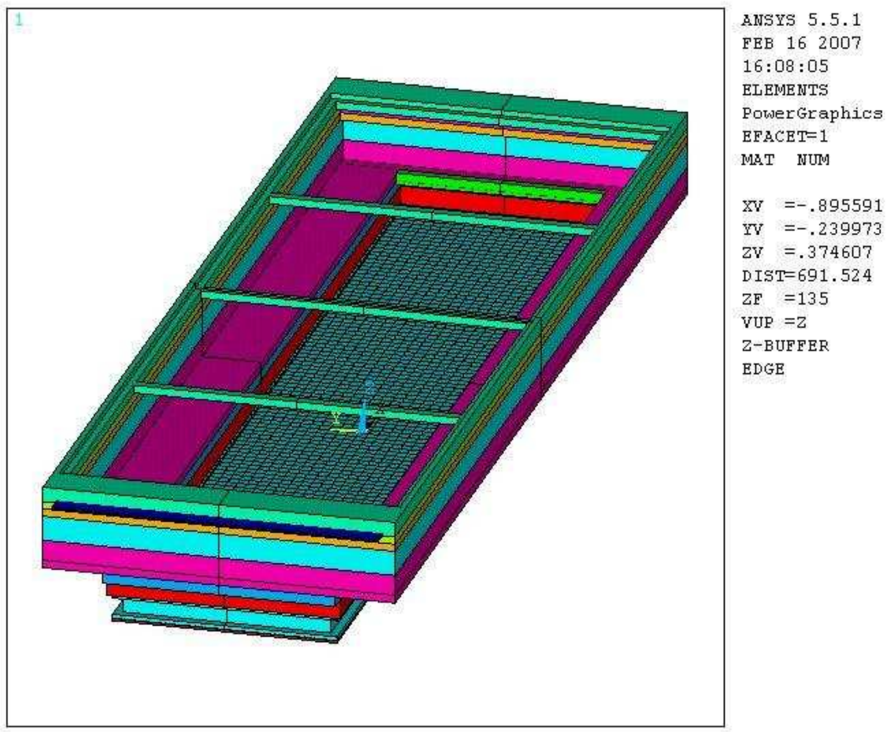

Figure 1.2: FEM of the $\times 1.3$ upgrade; the HRS dispersion direction is along the longer side. The honeycomb cap and the radiator (not shown) is on the bottom side of the detector.

- The evaporation facility.
- The glove box integration facility.
- All slow control and analysis software.

The new electronics consist of a new release of the front-end Gassiplex chips and a new readout logic based on the DILOG chips mounted on FPGA controlled boards connected to the acquisition node via a fast optical link driven by PCI-X cards. All components are available at JLab, and have seen preliminary testing. Only one of the boards needs a hardware upgrade.

It is worth mentioning that this upgrade should be considered as a different RICH configuration since the relevant physics aspects of the RICH (the Cherenkov generation, their focusing and their detection) are unchanged. In fact, the existing RICH can be restored after the upgrade in a couple of days.

1.3.1 Mechanical Analysis

A FEM analysis has been performed on 1/4 of the detector, exploiting both x and y symmetries; the model has been validated with data from the existing RICH. Figure 1.3 shows that deformations are absent in most of the detector and negligible in the middle of the photo detector plane. The maximum distortion of less than 0.03 mm is well below the MW-PPC tolerance of 0.1 mm.

1.3.2 Monte Carlo Performance

The performance has been investigated with a GEANT3 based Monte Carlo simulation. Error in the Monte Carlo estimation is expected to be within $\pm 30\%$ due to the fact that the model has been tuned to the Hypernuclear real data. Figure 1.4 shows the expected separation of the upgrade along the momentum range (RICH at 1.9 m from the HRS Focal Plane, in between the two aerogel counters).

The pion-kaon separation is expected to be largely satisfactory over more than 80% of the momentum range. In the lower 15% of that range the RICH pion:kaon rejection will be, on average, at the level of 1:100. Taking into account the aerogel counters[2], the expected final rejection should easily reach the desired 1:1000 value. All values have been estimated with 95% of detection efficiency.

1.3.3 Manpower

Most of the manpower for the upgrade will be provided by INFN-ISS which is responsible for the RICH upgrade and its installation (E. Cisbani and F. Garibaldi). JLab support is

[2] In the first aerogel A1 the pions are above threshold while the kaon threshold is at 2.8 GeV/c, quite close to the Transversity momentum range ($2.28 - 2.52$ GeV/c) and therefore the rejection capability is critical at the highest Transversity momenta.

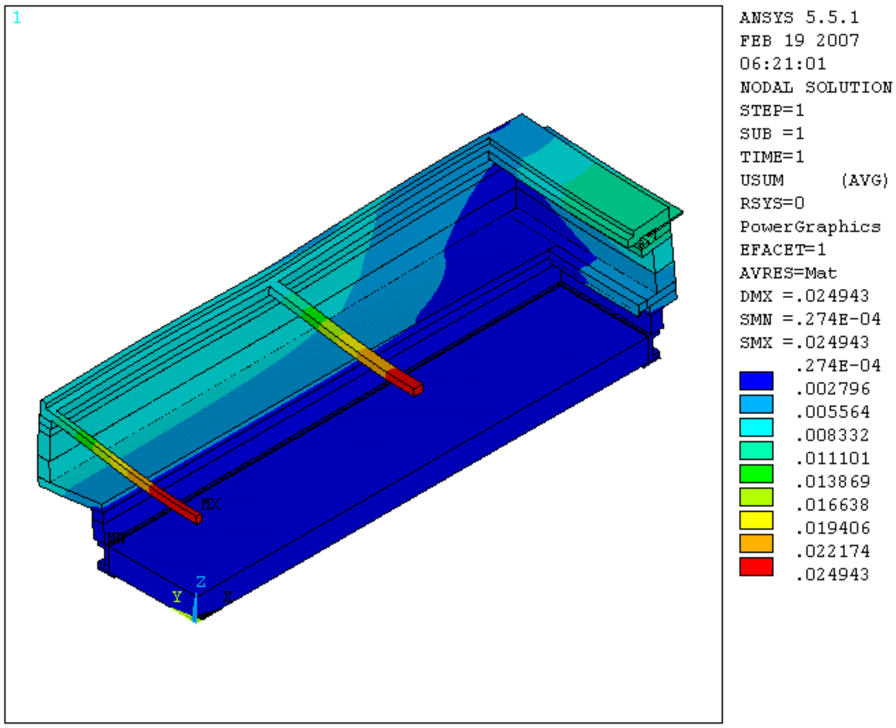

Figure 1.3: FEM analysis: expected distortions in the ×1.3 upgrade.

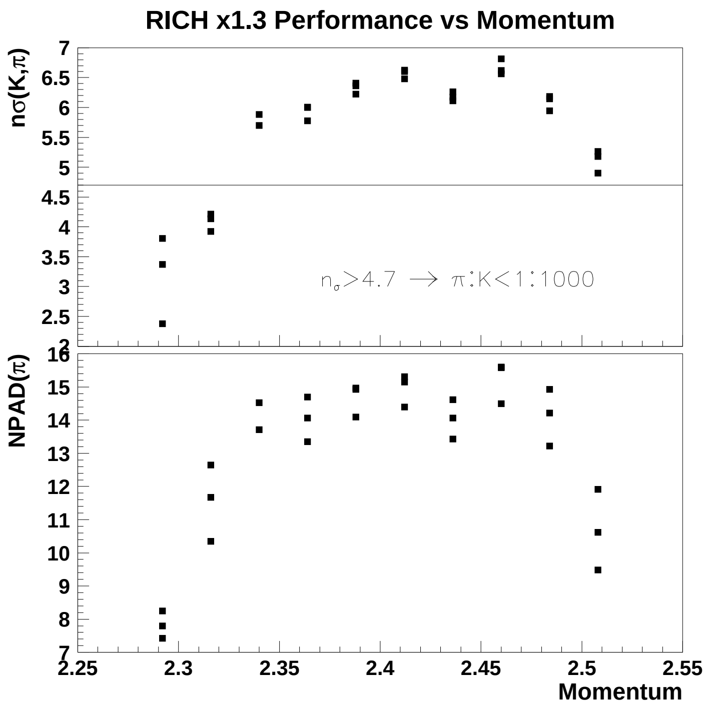

Figure 1.4: Monte Carlo simulation and expected pion kaon separation versus the Transversity hadron momenta.

required for logistics in the USA, technical maintenance, installation in Hall A (Jack Segal), minor mechanical work (one Mechanic of the JLab Mechanical Shop team), and the new electronics testing and integration into the DAQ (A. Camsonne).

The required manpower (see also the next section for details) is summarized in the next table.

	Physicist	Technicians
	Man × Month	
Upgrade		
INFN	4	8
JLab	1.	.5
Installation		
INFN	1.	1.5
JLab	.4	.3

1.3.4 Upgrade and Installation Plans

In figure 1.5, is shown the detailed plan of the upgrade. The relevant milestones are represented in figure and correspond to:

- Upgrade Decision (02 Mar 2007, done): end of the upgrade analysis and start of the upgrade mechanical detailed design.
- RICH frames Ready (25 Sep 2007): availability of the upgraded frames (and accessories).
- RICH Assembled in Rome (16 Nov 2007): RICH frames and wire planes assembled and ready to be shipped to JLab.
- RICH Ready for installation (10 Dec 2007): all parts of the RICH (included the new electronics) have been tested and ready to be integrated for the final installation.

The RICH installation procedure will start as late as possible while remaining compatible with the Transversity schedule. This decision is based on the following facts:

- the RICH installation does not interfere with the other equipment,
- the upgraded RICH is very much like the existing one and therefore does not require new specific and extensive test and commissioning,
- the CsI photoconvertor layer is subjected to aging (degradation) if a dry and inert gas is not properly and continuously flushed.

Based on that, the RICH installation procedure will start a couple of weeks before the beginning of the Transversity installation[3]. As shown in figure 1.6 the first task will be the

[3] According to the current information, Transversity installation will take 6 weeks, starting at the beginning of March.

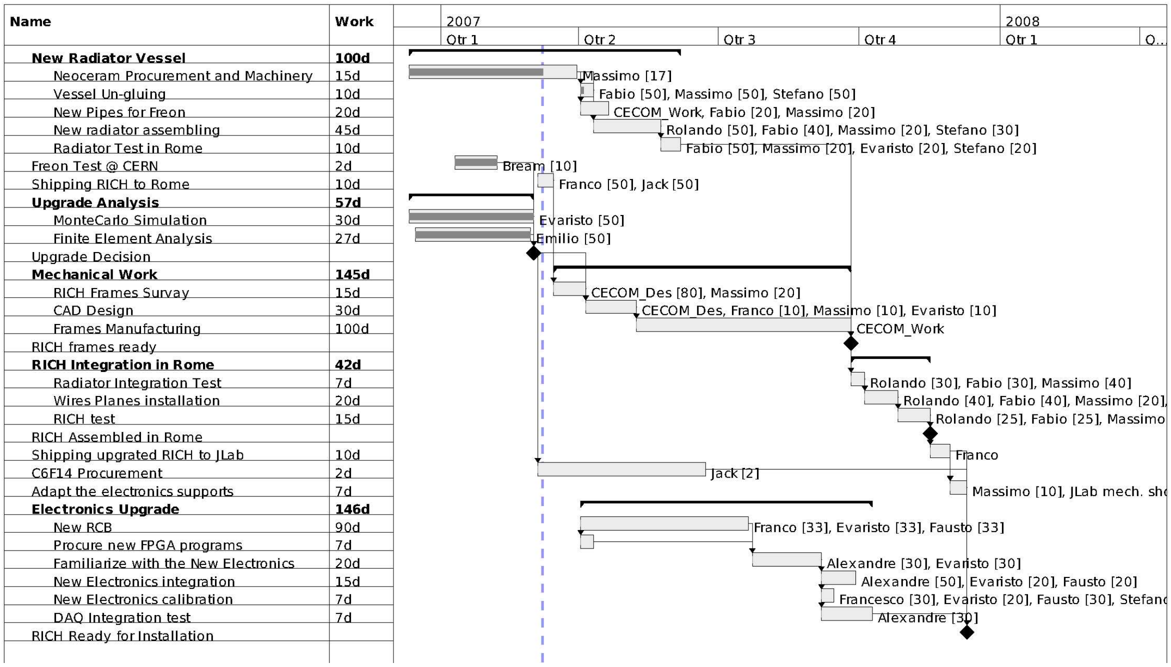

Figure 1.5: RICH upgrade plan.

evaporation of the CsI photoconvertor on the pad planes. That will be performed at Stony Brook University (Long Island) where the Evaporator Chamber is presently located.

The RICH is expected to be installed in Hall A at the end of March, ready for the final integration tests (mainly DAQ and readout) which will take 2 weeks maximum.

1.3.5 Funding

The major cost of the upgrade is the frame fabrication which will be supported by the INFN-ISS. Large fractions of the other costs are related to the 'standard' RICH maintenance and will be shared by INFN-ISS and JLab as done in the past. The company that will do the mechanical work is the same one that built parts of the existing RICH and a formal quote has been already provided.

Cost details and funding allocation are reported in Fig. 1.7.

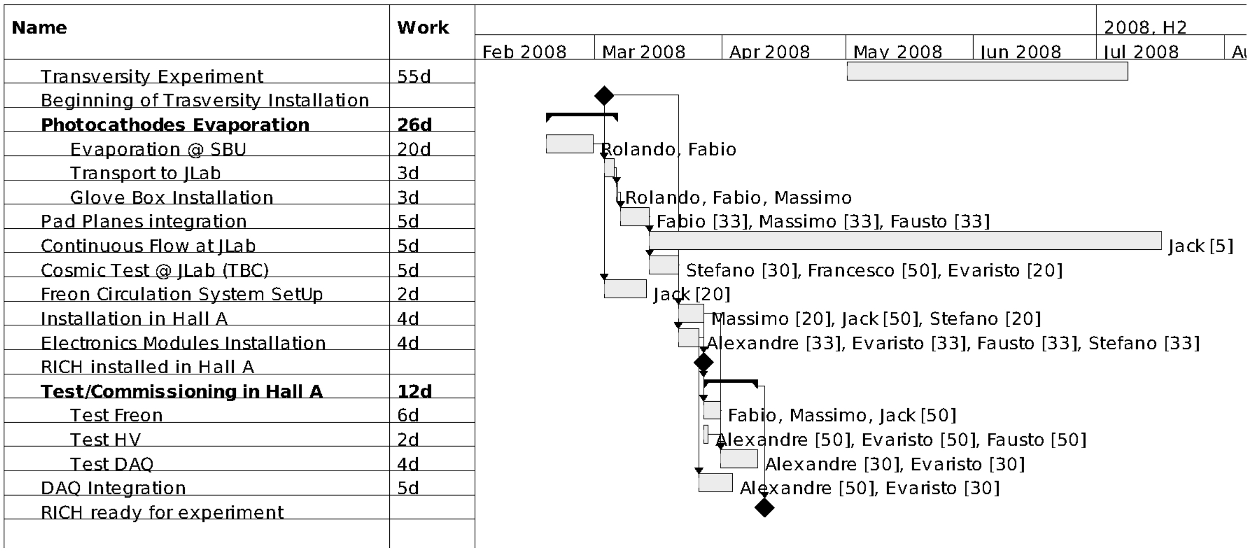

Figure 1.6: RICH installation plan.

	Jlab	INFN
Freon	5	0
Test Set Up (Rome)	0	0
Circulation System	0	0
Gap Extender Frame	0	0
Frame Manufacturing	0	59
Mechanical Support	2	0
HV plane	0	5
LV FE electronics	3	0
New RCB board	0	5
Glove Box Upgrade	0	0
Transport Jlab<->Rome	0	5
Transport SBU->Jlab	5	0
Pad Plane Shells	3	0
Spare Radiator Repairi	0	7
	0	0
Hotel at SBU	3	0
Car Rent at SBU (?)	1.5	0
	0	0
Total	**22.5**	**81**
Values are in kUSD		
1 euro = 1.3 USD		

Figure 1.7: RICH funding scheme.