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# Quantum efficiency measurement system for large area CsI photodetectors

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## Abstract

A proximity focusing freon/CsI RICH detector has been built for kaon physics at Thomas Jefferson National Accelerator Facility (TJNAF or Jefferson Lab), Hall A. The Cherenkov photons are detected by a UV photosensitive CsI film which has been obtained by vacuum evaporation. A dedicated evaporation facility for large area photocathodes has been built for this task. A measuring system has been built to allow the evaluation of the absolute quantum efficiency (QE) just after the evaporation. The evaporation facility is described here, as well as the quantum efficiency measurement device. Results of the QE on-line measurements, for the first time on large area photocathodes, are reported.

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## 1. Introduction

A proximity focusing freon/CsI RICH detector has been built for kaon physics at Jefferson Lab, Hall A [1]. The QE of the CsI film is crucial for the detector performance. A dedicated evaporation facility has been built, in order to monitor the quality of the evaporation and its uniformity on large surfaces. The

evaporation facility and the QE measurement system features, as well as the first results, will be described in the following sections. Measurements to investigate contamination effects and the recovery of consequent degradation will be described too.

## 2. CsI evaporator facility

A dedicated facility has been built for CsI evaporation of large area photocathodes. It

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consists of a cylindrical stainless steel vessel (110 cm height, 120 cm in diameter) equipped with four crucibles containing CsI powder. The pumping system, consisting of three devices (scroll, molecular and cryogenic pumps), allows to easily reach a vacuum of a few  $10^{-7}$  mbar in less than 24 h. The prepolished pad plane (a printed circuit with three layers of metals, nickel, copper, and gold, glued on the vetronite substrate) is housed in the vacuum chamber and heated to  $60^{\circ}\text{C}$ , usually for 12–24 h. The location of the crucibles with respect to the photocathode and their relative distance are optimized to ensure a minimum variation in thickness of  $\sim 10\%$ , using equal amount of CsI in each crucible. The CsI powder evaporates at a temperature of  $\sim 500^{\circ}\text{C}$ . Since  $\text{H}_2\text{O}$  vapor severely affects the performance of the CsI layer, the assembling of the pad planes (Figs. 1 and 2) in the RICH structure is always performed in argon atmosphere.

### 2.1. On-line QE measurement device

In order to monitor the quality of the evaporation and its uniformity, an on-line QE measuring system has been built and successfully employed (Fig. 3). A movement system allows to map out the entire photocathode. A deuterium lamp has been used as UV source light. The UV collimated beam (1 cm in diameter) is split by means of a semitransparent mirror in such a way to allow monitoring the lamp emission by measuring the current from a photodiode. Three narrow band

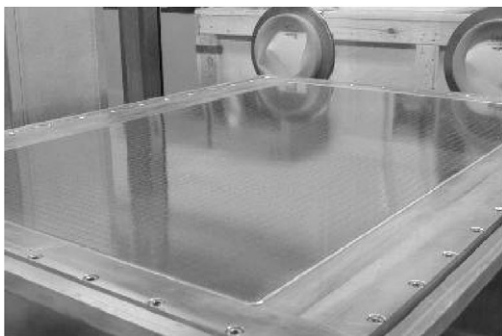


Fig. 1. A photocathode of the Hall A RICH. Single pads are  $8.4 \times 8.0 \text{ mm}^2$ .

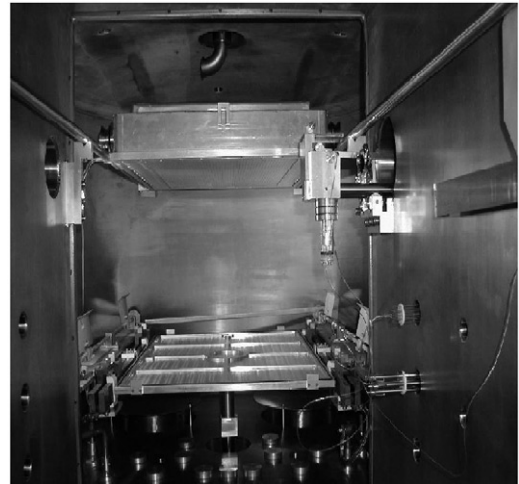


Fig. 2. The Hall A evaporator facility. The plane of CsI sources (bottom), the photocathode (top) and the QE measurement system (right edge of photocathode) are visible inside.

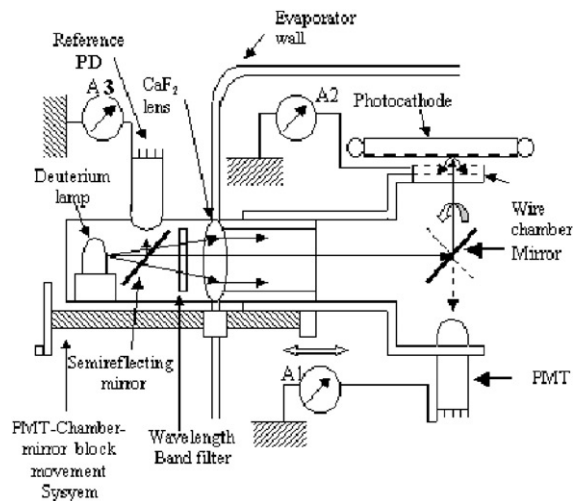


Fig. 3. The QE measurement system.

filters (25 nm FWHM spread) selecting respectively 160, 185 and 220 nm, have been employed, due to the current unavailability of a monochromator. The UV beam is sent, through a rotatable mirror, to the photocathode. The photocurrent, generated by electrons extracted from the CsI film, is detected with a small ( $5 \times 5 \text{ cm}^2$ ) wire chamber (Fig. 4) located at a distance of 2 mm from the photocathode. The wires have a collection voltage

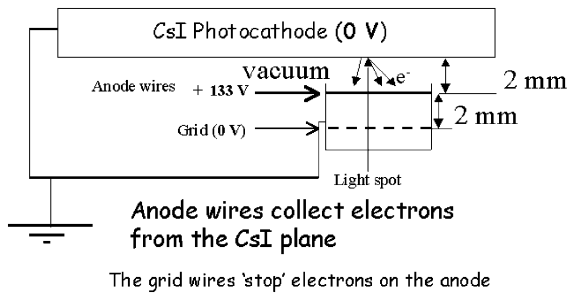


Fig. 4. The wire chamber and the photoelectrons collection principle.

of 133 V. A second wire plane, behind the first and oriented perpendicular to it, is kept at ground potential to obtain good charge collection on the first plane. After measuring the wire chamber photocurrent (A2), by rotating the mirror, the light is sent to a calibrated PMT, used in diode mode (A1). The currents (1–50 nA range) are measured by a picoammeter (KEITHLEY 485). The ratio of the currents  $A2/A1$ , multiplied by the PMT QE, gives the ‘absolute’ QE of the photocathode.

### 3. Measurements

#### 3.1. Evaporation technique

Following the prescription of the ALICE HMPID evaporation system [2], we have operated our system in such a way to deposit a 300 nm CsI film. This thickness should guarantee ‘safe’ operation of photocathode. In fact no difference in QE has been observed in the 150–700 nm range [3]. The thickness of 300 nm has been chosen as a compromise for having a ‘stable’ photocathode, while avoiding charging up problems at high radiation fluxes. An evaporation speed of 2 nm/s has been chosen as a compromise between the need of avoiding CsI dissociation (high crucible temperature, high speed) and the need of avoiding residual gas pollution on the CsI film surface [4].

#### 3.2. Results

Three series of measurements on different photocathodes have been performed. The first

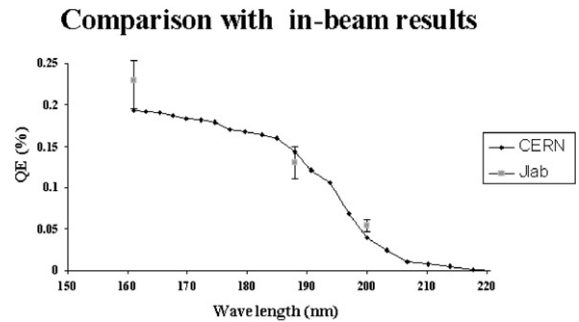


Fig. 5. Average QE value obtained in the last December 2001 evaporation at Jefferson Lab (square symbols), compared to a 1998 CERN curve (circles). The results are typical values for the Jefferson Lab evaporations.

one was performed on one of the photocathodes in Rome (October, 2000). The QE measurement results was  $25.0 \pm 1.4\%$  at 160 nm,  $10.5 \pm 0.6\%$  at 185 nm and  $5.0 \pm 0.3\%$  at 200 nm. The uncertainties ( $\sim 10\%$ ) in the calibration of the reference PMT are not included in the errors. Just after the evaporation the photocathode was transported to CERN for detector tests. Another photocathode was evaporated at CERN, in the HMPID facility. For these tests the wire chamber was operated at 1550 V with Ar/CH<sub>4</sub> (76/24) gas mixture. The results were quite good: the two photocathodes, exposed to 7 GeV pions beam, showed the same results: 12.5 p.e., that can be easily extrapolated to 15 p.e. with CH<sub>4</sub> at 2100 V. The evaporator was transported to JLab. Two other evaporation took place there on photocathodes. The results are consistent with the first evaporation and with the QE values extrapolated from ALICE in-beam measurements (see Fig. 5).

#### 3.3. Thickness dependence

Measurements have been performed to test the QE as function of CsI thickness. We did a non-uniform CsI deposition by asymmetric crucible charging (1.2 g CsI weight on two crucibles, leaving empty the other two crucibles). According to calculation, a thickness variation along the surface from 50 nm (for the part of the photocathode close to the empty crucibles) to 250 nm (close to the charged crucibles) should be obtained.

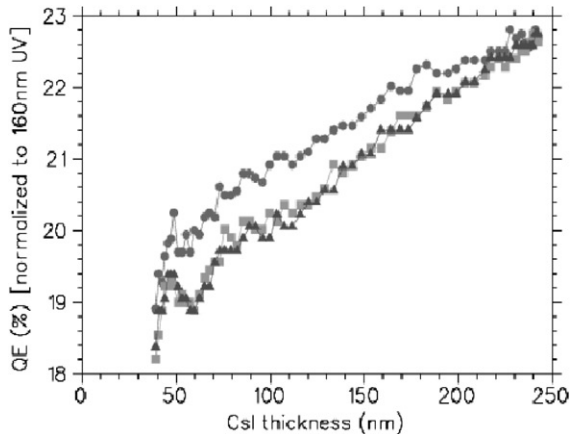


Fig. 6. QE, as function of CsI thickness, for different wavelengths. 160 nm: circles, 185 nm: squares, 200 nm: triangles. The 185 nm and 200 nm data are normalized to 160 nm data to allow easier comparison of the slopes.

Fig. 6 shows the results of QE measurements. It is evident that passing from 50 to 250 nm of CsI the QE constantly increases. This is true for the whole UV spectrum. In addition, it can be noted that the thicker CsI film and longer wavelengths exhibit a stronger thickness dependence. It is not clear if the effect we show actually reflects the CsI thickness dependence. In fact the QE variation could depend on the different deposition speed.

### 3.4. Ageing test

Measurements have been performed to investigate the eventual degradation after contamination and possible recovery of CsI film. One of the photocathodes, just after measuring the QE, was left in the evaporator and the pumping was stopped. After 25 days the vacuum was 0.25 mbar. The pumping was restored reaching (after 2 h)  $10^{-5}$  mbar. A new QE measurement was performed. Further 14 h of pumping allowed to reach  $10^{-6}$  mbar. A second measurement has been performed in this condition. Finally, still continuing pumping, a third measurement has been done after heating the film at  $60^{\circ}\text{C}$  for 12 h. Results are shown in Fig. 7. Some contamination, probably from outgassing of the evaporator walls and from the photocathode itself, caused a

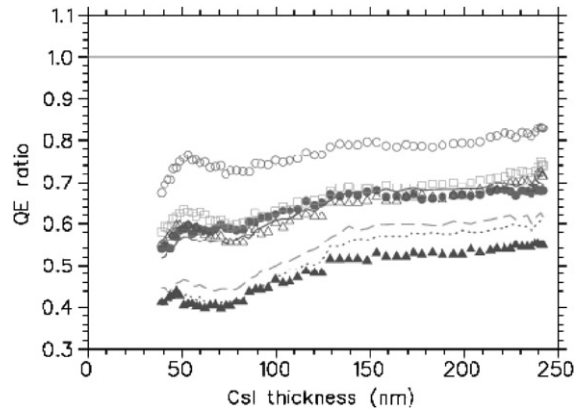


Fig. 7. QE values as function of thickness, in different condition of outgassing contamination (see text), normalized to non-contaminated values. Recovery results after 2 h (solid symbols), 14 h of pumping (lines without symbols) and after subsequent 12 h of heating at  $60^{\circ}\text{C}$  (open symbols). Circles and full line represent 160 nm data, squares and dashed line represent 185 nm data, triangles and dotted line represent 200 nm data.

substantial loss of QE (the photocathode was not baked after having it polished by alcohol before evaporation). The recovery of QE with improvement of vacuum condition is evident. Heating the photocathode for 12 h to  $60^{\circ}\text{C}$  allowed the complete recovery of the QE, for all the three wavelengths. One conclusion might be that a possible contamination by organic outgassing can be completely recovered by heating the detector. Trying to understand the effect of oxygen and moisture contamination, another test has been done. The evaporator chamber has been slowly filled with 8 mbar of Ar and finally slowly filled with ambient air ( $19.5^{\circ}\text{C}$  temperature, 41% relative humidity). Then 24 h later the chamber was pumped out again. Another QE measurement was performed in this condition, with the same procedure described above (2 and 16 h of pumping and further 12 h of heating). The results are shown in Fig. 8. It is evident that contamination by oxygen and moisture cannot be completely recovered. It seems that the QE loss (between 50% and 60%) is more pronounced for thinner CsI layer and for longer wavelengths. It should be noted that for thickness above  $\sim 120$  nm at least 50% of original QE is retained after extensive exposure to

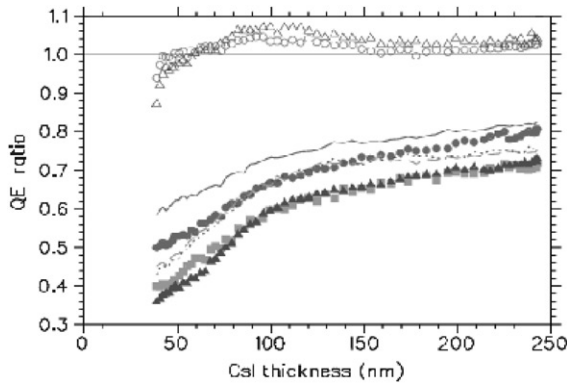


Fig. 8. QE values as function of thickness, in different condition of oxygen and moisture contamination (see text), normalized to non-contaminated value. Recovery results after 2 h (solid symbols), 14 h of pumping (lines without symbols) and after subsequent 12 h of heating at 60°C (open symbols). Circles and full line represent 160 nm data, squares and dashed line represent 185 nm data, triangles and dotted line represent 200 nm data.

the ambient air. Subsequent pumping and heating improved the QE, but only restored  $\frac{1}{3}$  of loss.

#### 4. Conclusion

A facility for CsI film evaporation on large area photocathodes has been built and successfully operated. An ‘on-line’ QE measurement system has been built and successfully used, for the first time, for monitoring the quality of the evaporation and its uniformity on large area photocathodes. A series of three measurements showed that the system is reliable and the QE measurements are compatible with results extrapolated from in-beam

tests. The QE seems to increase up to a certain extent, with the CsI film thickness. It has been shown that contamination from outgassing reduce the QE, but can be completely recovered by short-term heat treatment (60°C). Nevertheless, in our test conditions, the contamination by oxygen and moisture seems to permanently reduce the QE, by 20%–30%.

In both cases the thickest CsI layers are less affected by contamination and recovered better.

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