# SECAR Focal Plane Users' Guide

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## I. MCP TIME-OF-FLIGHT SECTION

### A. Introduction

Two metal-foil, microchannel plate (MCP) detector systems are used to measure the position and time of arrival of ions at two different points, nominally separated by 1.4 m. The time difference and positions allow the speeds of ions to be directly determined, providing an important discriminant of beam particles from recoils. The designs of the two MCP detectors are different, with important operational differences, but the mechanical design of the foil-grid is identical for both systems.

### B. Foil-grid system

A foil-grid system for each MCP is inserted into the path of the beam at a 45° angle with respect to the beam axis (parallel to the MCP). The foils currently used are 0.5-$\mu$m-thick mylar with 10-nm thick aluminum coating procured from Lebow company (Part No. 0.01Al-0.5My-C76mm). The foils are mounted on a 4-inch diameter aluminum ring (1/16-inch thick) with a 3-inch diameter hole. The foils are mounted to a supporting plate that contains a grid of gold-plated tungsten wires located 3 mm from the foil. Electrical isolation between the foil and grid (as well as to the mounting arm) is accomplished by insulating (sleeved) couplings. The photographs in Fig. 1 illustrate assembly of the foil-grid system to the linear motion feedthrough.

### C. Position calibration

The MCP detectors have excellent position resolution accomplished by resistive charge division, but an absolute position determination depends on the relative gain of the 4 signals. A mask is mounted on the foil-grid system to allow *in situ* position calibration. A drawing of the mask is shown in the right-hand side of Fig. 1. The center of the mask is in the middle of the 0.40-inch diameter hole, which is located 2.75-inch from the center of large foil. At present

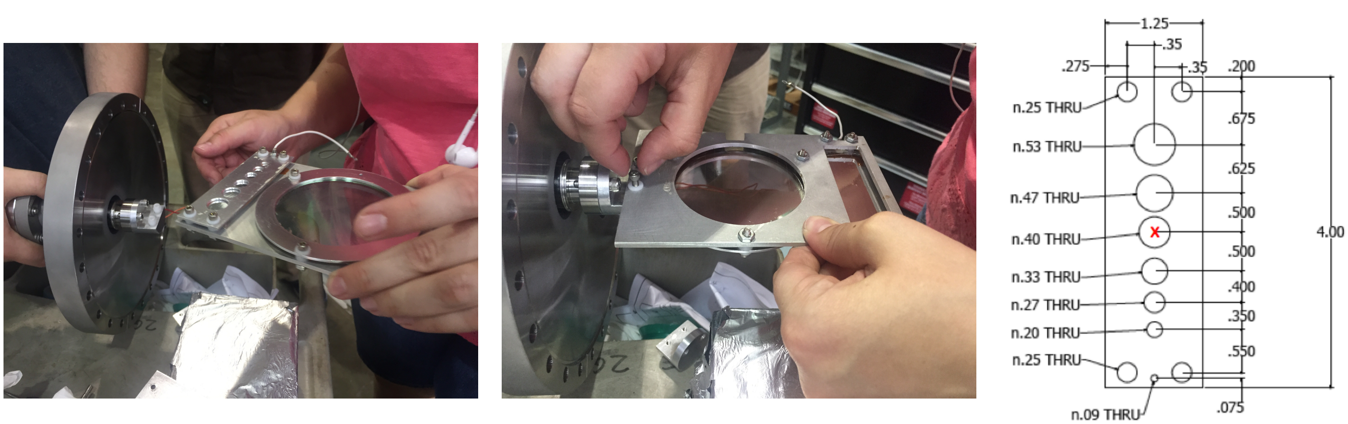


FIG. 1. Mounting the MCP foil-grid system.

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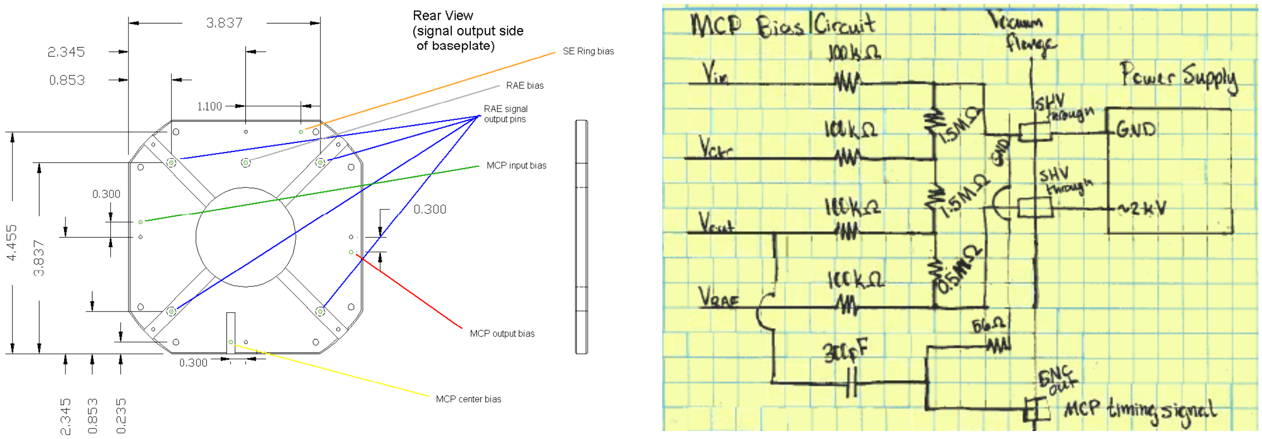


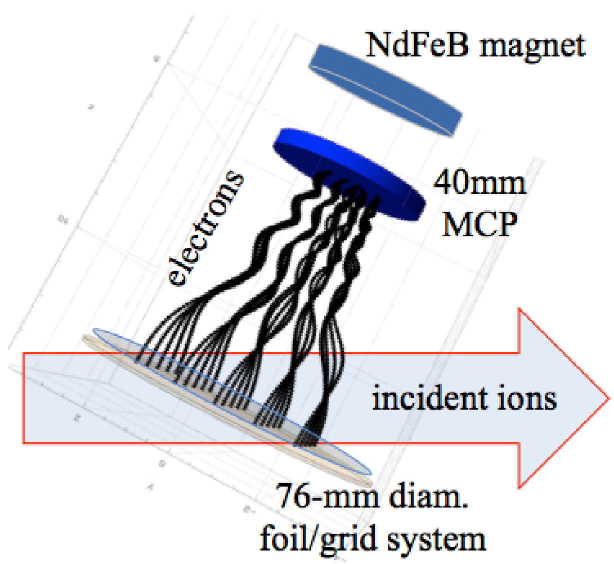

FIG. 2. Electrical connections and voltage divider for the MCPs.

6$\mu$m-thick aluminized mylar is used on the mask, which results in substantially greater energy loss ($\Delta E \approx 1$ MeV for alpha particles) than for the large foil. Thus, particles that pass through the mask can be clearly discriminated from particles that do not by the different energy and time of flight, independent of position.

### D. MCP designs and operations

The two MCP detectors used are Quantar Model 3392A (75mm diameter) and Model 3394A (40 mm diameter). Both are 2 Chevron stacks with resistive anodes and similar operational properties other than the diameter. The electrical and signal connections for the two detectors are the same. Both are operated with the surface facing the foil-grid held at ground potential. High positive voltage is supplied to the resistive-anode encoder (RAE). A voltage divider network was implemented to provide appropriate intermediate voltages, with only one positive HV supply required. Fig. 2 shows an image of the connections on the back of the 75-mm detector with a circuit diagram for the voltage divider. The timing is measured independent of the position by capacitively picking off the HV to the RAE.

A strong NdFeB permanent magnet is mounted behind the 40mm MCP. Electrons are accelerated from the foil towards the grid, but then are focused by the increasingly strong magnetic field to produce a smaller image on the MCP with a magnification of about 0.45. This is illustrated in the ion optics simulation show in Fig. 3 This design



| | 3394A (40 mm) | 3392A (75 mm) |
|---|---|---|
| Type | with magnet | no magnet |
| Foil | $-550V$ | $-2000V$ |
| Grid | $-50V$ | $-500V$ |
| RAE | $+1875V$ | $+1950V$ |

TABLE I. Recommended voltages for MCPs

| Step | Action | Pseudocode |
|---|---|---|
| 1 | Calibrate | $A = A * C_A, B = B * C_B$, etc. |
| 2 | Sum | $Tp = A + B, Bt = C + D, Lf = A + D, Rt = B + C, Tot = A + B + C + D$ |
| 3 | Threshold | Reject event if $A < Th \vert\vert B < Thr \vert\vert C < Thr \vert\vert D < Thr$ |
| 4 | Raw x/y calc | $X_r = (Rt/Tot - X_{avg}) * 8.0, Y_r = (Tp/Tot - Y_{avg}) * 8.0$<br>$X_{avg} \approx Y_{avg} \approx 0.5$ should produce $X_r$ and $Y_r$ roughly scaled |
| 5 | Rotate by $\theta$ | $X_f = X_r * cos(\theta) - Y_r * sin(\theta)$<br>$Y_f = X_r * sin(\theta) + Y_r * cos(\theta)$ |
| 6 | Stretch/Compress | $X_f = X_f * C_x, Y_f = Y_f * C_y$ |

TABLE II. Pseudocode for MCP position processing

allows for a large foil area to be used with a smaller (cheaper) MCP. Due to the magnetic focusing, the performance of the small MCP is very sensitive to the foil-grid voltages.

Voltage should only be applied to the MCPs (RAE) when a pressure below $10^{-5}$ Torr has been achieved for an extended period (hours). Pressures lower than $10^{-6}$ Torr are safest. The MCP should be biased slowly, looking for anomalous current or uncharacteristic signals.

Both MCPs are operated with the front face held at ground with a high positive voltage applied to the RAE. The range of normal operating voltages for the RAE is from +1700 to +2000 V. Higher voltages result in greater amplification of the signals which generally improves position resolution. However, higher voltages result in greater dark current. It is best to operate the with the RAE at the smallest voltage that produces good performance.

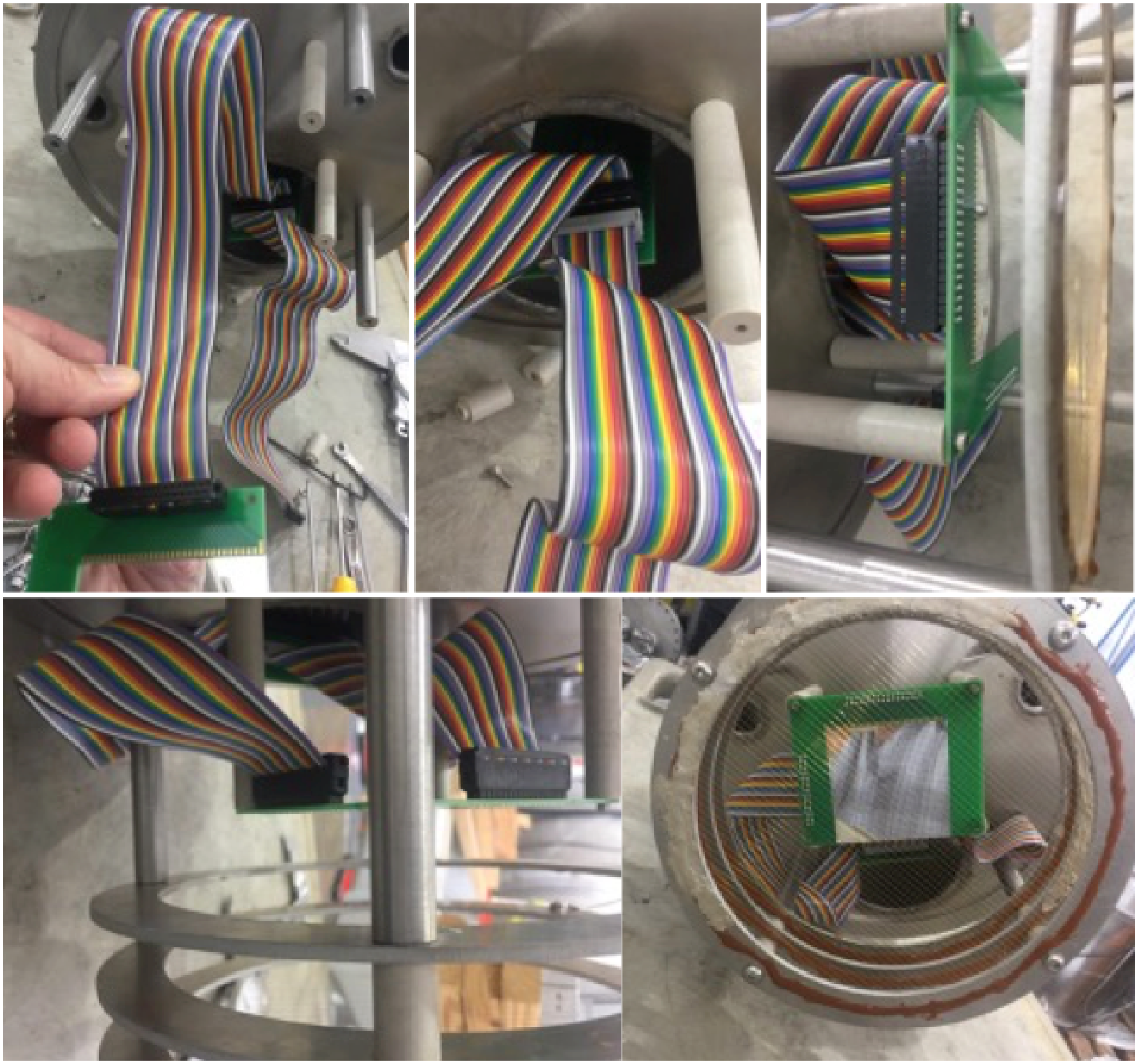
The foil and grid are both operated at negative voltages with the grid held at a lower magnitude voltage than the foil. Electrons are thus accelerated from the foil towards the grid and the front face of the MCP. In the case of the 75 mm MCP, the foil and MCP have the same diameter and the electrons follow a linear trajectory. Higher foil and grid voltages generally produce better time and position resolution, though dark current and risk of sparking is increased at higher voltages. Generally speaking the performance of the 75 mm MCP is not very sensitive to the foil-grid bias above a certain level.

The recommended operating voltages for the two MCP systems are provided in Table I. It is strongly recommended not to deviate substantially from these values, which were found to provide the best performance. The MCPs are provided with an isolating front ring that allows a voltage to be supplied to an isolated grid just in front of the MCP detectors. There is some evidence in the literature that applying a negative voltage just in front of the mcp system is beneficial for suppressing stray electrons and reducing dark current. We found no significant change in dark current, but did find an increase in baseline noise in the position and timing signals when the grid was connected to high voltage, mostly likely due to grounding issues. For this reason, we currently recommend leaving the front ring floating.

### E. Pseudocode for MCP position

There are 4 MCP position signals, labeled as $A, B, C, D$ which are assumed to be in clockwise order from top left. Each raw signal should be calibrated using scaling coefficients so that uncollimated spectra from the alpha source are the same for all 4 signals. A pseudocode is provided in Table II that outlines the recommended logic for processing of the MCP position signals. A common threshold level, Thr, can typically be defined for all 4 signals. If there is a zero offset (unlikely) then a linear calibration or a custom threshold per channel may need to be defined separately for A, B, C, D. This will likely not be necessary with DDAS. In the final steps, the raw X,Y positions are rotated and scaled to try to produce true X,Y positions, where $\theta$, $C_x$, and $C_y$ are free parameters used to fit to true positions (e.g. determined by data using the mask).

FIG. 3. Photo montage showing Si mounting/cabling with gas $\Delta E$ section.



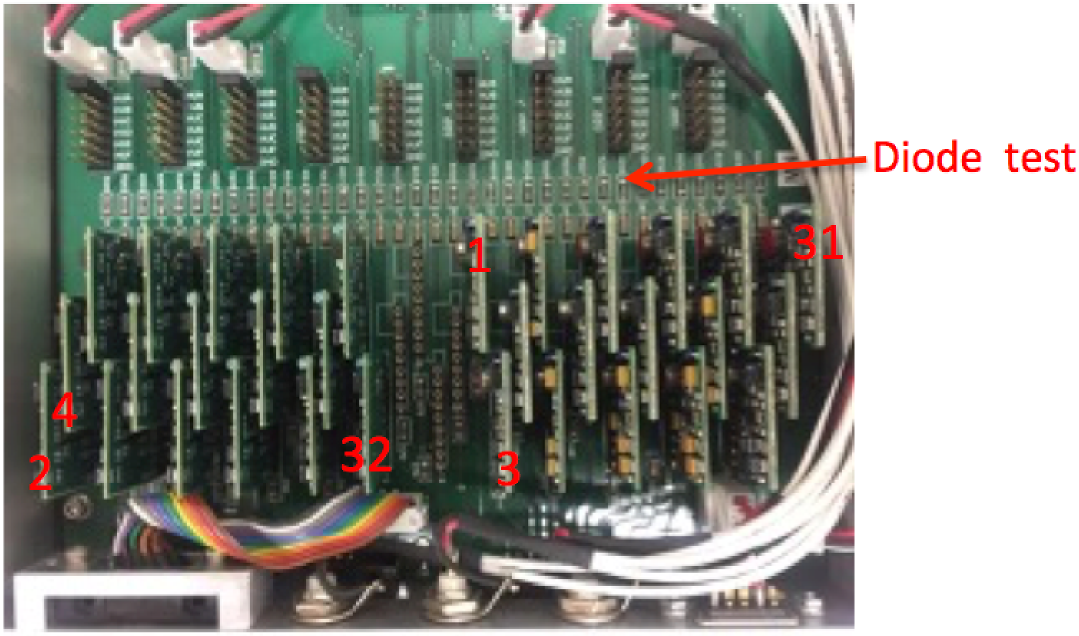
## II. SI-STRIP DETECTOR

The silicon strip detector used in the SECAR focal plane is a Micron Semiconductor Design BB7. The two detectors procured are Serial # 3262-3 (298 $\mu$m thick) and # 3262-4 (292 $\mu$m thick). The detector has an active area of 64 mm X 64 mm divided into 32 strips (x,y) on each face (2 mm pitch per strip). Depletion is indicated at about 30 V, but we typically over bias to +50V on rear ohmic face. Leakage current should be low, $\approx 0.5\mu$A currently.

The detector is cabled to the feedthrough using two short standard 34-pin ribbon cables. Care must be taken in the orientation of the cables so that the two ground pins map to the correct location. If done properly, 32 front (junction) signals will map to one side of the preamp box and 32 back (ohmic) signals will map to the other side of the preamp box. The appropriate orientation of the interior cables using colored ribbon cable is illustrated in Fig. 3.

It is strongly recommended to perform a diode test on the preamp box before installing the detector into the chamber. Electrical contact to the strips is accessible by making contact on the side of the bias resistors closest to the input side as illustrated in Fig. 4. Using a multimeter set on the diode setting, a ground lead touched to the rear

FIG. 4. Photo of preamp box for Si detector. Note that the middle 4 channels are not used for the silicon. The point where the diode test can be performed is indicated. The strip number that each preamp chip corresponds to is indicated for the first/last strips.




| Material | thickness | $P_{\mathrm{fail}}$ (75 mm) | $P_{\mathrm{max}}$ (75 mm) | $P_{\mathrm{max}}$ (100 mm) |
|---|---|---|---|---|
| Mylar | 2 $\mu m$ | 76 Torr | 40 Torr | 22 Torr |
| Mylar | 3 $\mu m$ | 130 Torr | 60 Torr | 34 Torr |
| Kapton | 7.4 $\mu m$ | 410 Torr | 200 Torr | 110 Torr |

TABLE III. Recommended maximum pressure for window materials and diameters.

(ohmic) side and a voltage lead touched to the front (junction) side should produce a voltage reading of about 0.5 V. Each front should act like a diode with any back (and vice versa). In this manner all 32 fronts and backs can be tested. Note that the middle 4 channels are not used for the silicon, but one channel may be used for the gas $\Delta E$ when operated in gas-filled mode. The preamp box bias jumpers should be set to deliver the same bias voltage to all 32 strips, either postive voltage to the rear (ohmic) strips or negative voltgae to the front (junction) strips.

If properly cabled, the odd numbered x strips will map to one of the 34-pin ribbon cables on the preamp box, while the even numbered x strips will map to the other connector. The mapping is similar for the y strips on other side of the box. The numbering layout is also illustrated in Fig. 4. Thus, proper ordering of the singals starts with the first pair of wires on one connector, then goes to the first pair of wires on the other connector, then the 2nd pair of wires on the first connector, etc.

## III. WINDOW MATERIALS, THICKNESSES AND OPERATING PRESSURES

Relative energy loss in isobutane (or $CF_4$ or other gases) provides a powerful discriminant of atomic number for lab energies of $E > 0.5MeV/A$. A thin window with a double o-ring seal is used to separate the gas volume in the stopping detector from the diagnostics box, with a KF 25 bypass line connecting the stopping detector to the diagnostics box for pressure equalization. Separate flanges allow application of a 75 mm diameter or 100 mm diameter window. Note that the silicon active area is 64 mm by 64 mm (square), while the gas IC has an acceptance of 96 mm by 96 mm (square).

Failure testing of window materials was performed using the 75 mm window. Table III provides the rupture pressure for a 75mm diameter window, and the maximum recommended safe operating pressures for both 75 mm and 100 mm diameter windows.

## IV. SI+GAS

A single anode $\Delta E$ section can be employed with the BB7 silicon detector. The electric field configuration is parallel to the beam axis similar to the high count rate counter developed by LSU and used in Habanero and other experiments at the NSCL. The single $\Delta E$ anode can be connected either to a single BNC feedthrough and separate preamp, or routed through one of the spare center channels on the 72 channel preamp box used or the silicon. As a rule of thumb, anode bias voltages of about 10 V/Torr give good performance up to about 30 Torr of pressure. Above about 300 V, there seems to be little change in performance. Voltages above 400 V are not recommended in the 72 channel box which carries the voltages via ribbon cable! High pressures/voltages have not been thoroughly investigated, but if high voltages are to be used, it is recommended to use a BNC feedthrough and an appropriate single channel preamp (e.g. Canberra 2002).

### Appendix A: Appendixes

FIG. 5. Manufacturer's recommendations for safe MCP handling and storage.

PHOTONIS

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## Storage, Handling and Operation of Microchannel Plates

Microchannel Plates (MCP) and MCP-based devices must be adequately stored to ensure proper performance and longevity. This procedure details proper storage techniques. Any deviation from the recommended storage procedures will void the warranty. If you have any storage questions, please contact our Customer Service Department at 1-800-648-1800 (USA) or 1-508-347-4010.

**STORAGE**

Because of their structure and the nature of the materials used in manufacture, care must be taken when handling or operating MCPs. The following precautions are strongly recommended:

Containers in which microchannel plates are shipped are _not suitable_ for storage periods exceeding the delivery time. Upon delivery to the customer's facility, microchannel plates must be transferred to a suitable long term storage medium.

- **The most effective long-term storage environment for an MCP is an oil free vacuum of at least $10^{-4}$ Torr**. When stored in vacuum, the parts can be removed from their aluminum vacuum storage bags,
- While vacuum storage is strongly recommended, a continuously purged dry box which utilizes a dry inert gas, such as argon or nitrogen, can be used for storage for up to several weeks. In this case it **is critical that the part remain in its sealed aluminum vacuum storage bag while in the purged dry box.**
- Desicator type cabinets which utilize silica gel or other solid dessicants to remove moisture have been proven ***unacceptable.***

**HANDLING**

- Shipping containers should be opened only under class 100 Laminar flow clean-room conditions.
- Personnel should always wear clean, talc-free, class 100 clean-room compatible, vinyl gloves when handling MCPs. No physical object should come in contact with the active area of the wafer. The MCP should be handled by its solid glass border using clean, degreased tools fabricated from stainless steel, Teflon™ or other ultra-high vacuum-compatible materials. Handling MCPs with triceps should be limited to trained, experienced personnel.
- MCPs without solid glass border should be handled *very* carefully with great care taken to contact the outer edges of the plate only.
- MountingPad™ MCP's should be contaced only at the mounting pads.
- All ion barrier MCPs should be placed in their containers with the ion barrier facing down.
- The MCP should be protected from exposure to particle contamination. Particles which become affixed to the plate can be removed by using a single-hair brush and an ionized dry nitrogen gun.
- The MCP should be mounted only in fixtures designed for this purpose. Care should be taken due to electrical potentials involved.
- **CAUTION:** Voltages must not be applied to the device while at atmospheric pressure. Pressure should be $1\times10^{-5}$ or lower _at the microchannel plate_ before applying voltage. Otherwise, _damaging ion feedback or electrical breakdown_ will occur.

**OPERATION**

- A dry-pumped or well-trapped/diffusion-pumped operating environment is desirable.
- A poor vacuum environment will most likely shorten MCP life or change MCP operating characteristics.
- A pressure of $1\times10^{-6}$ Torr or better is preferred. Higher pressure can result in high background noise due to ion feedback.
- MCPs may be vacuum baked to a temperature of 380°C (**no voltage applied**).