# Leakage Current Measurements of High Voltage Ceramic Capacitors

**M. Atac[a*], K. Arndt[b], B. Gobbi[c], S. Los[a], N. Parashar[d], G. Sellberg[a], E. Spencer[c]**

**[a]Fermi National Accelerator Lab., Batavia, IL 60510, USA**
**[b]Purdue University, West Lafayette, IN 47907, USA**
**[c]Northwestern University, Evanston, IL 60208, USA**
**[d]Purdue University, Hammond, IN 46323, USA**

## Abstract

**Leakage currents of NOVACAP Company NPO surface mount high voltage multilayer ceramic capacitors were measured before and after irradiation by 200MeV protons at a fluence of $5x10^{14}$. Two banks of 20 capacitors showed that the leakage current was within 2-3 x $10^{-11}$ampere. As we see with the results, the average currents were very close to zero and the fluctuations were mainly due to noise pick up.**

### 1. Introduction

**The Compact Muon Solenoid (CMS) Experiment which is under construction at the Large Hadron Collider (LHC) at CERN, Geneva, Switzerland requires silicon pixel detectors [Refs. 1, 2] as the innermost tracking devices. The Barrel Pixel Tracker is the responsibility of the Paul Scherer Institute (PSI), Zurich, Switzerland and the Forward Pixel Discs (FPix) are being constructed by the U.S.-CMS groups [Ref. 3]. We need to use high voltage (HV) capacitors before the Silicon**

**Sensor Chips to filter out electronic noise. NOVACAP Company has provided us 1nF surface mount NPO multilayer ceramic capacitors with dimensions of 4.6mmx2mmx2mm that were rated at 2 kV. One of the 20 capacitor banks was connected together in parallel for measuring the leakage current at 1 kV, after the irradiation at a fluence of $5x10^{14}$ 200MeV protons at the Indiana University Cyclotron in 8.5 hour duration. The second bank of 20 capacitors was kept at Fermilab and was not irradiated. As we will see, the leakage currents are close to zero before and after the irradiation. The non-irradiated capacitor bank was also soldered in parallel and the leakage current of the bank was measured to have better statistics.**

## 2. Details

**The surface mount multilayer NPO ceramic capacitors were soldered on 0.2 micron thick copper clad on 12 micron thick Kapton (Fig. 1) and glued to a silicon wafer for the measurements, using touch probes semi-automatically (Fig. 2). Equal spacing between the capacitors made the leakage current measurements easier. As seen in Fig. 3, it takes about 50 seconds to fully charge one of the capacitors. After this time, the leakage current at 800V averages to zero. We believe that the fluctuations are due to noise pick up. After this, all 20 capacitors were soldered together measuring the leakage currents. This would give us a good statistical number. One of the capacitor banks was sent to Purdue University to be taken to the Indiana Cyclotron and the second one was kept at Fermilab for measuring the leakage currents.**

**We wanted to keep the capacitor bank at 600 volt while irradiated to find out if any of the capacitors are permanently damaged with 200MeV protons. As seen in Fig. 4, that current went up rapidly due to ionization. The current tripped the HV power supply. About two weeks after the irradiation, the average current went down close to $10^{-11}$amp (Fig. 5) with 1000 volts applied to the bank of 20 capacitors. We are very convinced that the current fluctuations seen in the figures are produced by the noise pick up. The fluctuations found to be about the same magnitude at 600, 800 and 1000 volts. The above observations can be evidenced in Fig. 6, as we see that the average leakage current is about zero for the non-irradiated 20 capacitor bank as well as with the irradiated capacitor bank.**

## 3. Summary

**We are satisfied with the NOVACAP capacitor results. We could even work with $10^{-9}$ amp leakage current. Therefore, we express our appreciation to the manufacturer for their good product.**

## References


1. **CMS Tracker Project Technical Design Report, CERN/LHCC 98-6.**
2. **Beam test results of the US-CMS forward pixel detector, Muzaffer Atac, et al., Nuclear Instruments & Methods A488: 271-281, 2002.**
3. **US-CMS-Review, Joel Butler, 2 / 2006.**

**Figure captions**

1. **The surface mount multilayer NPO ceramic capacitors that were soldered on 0.2 micron thick Cu clad on 12 micron Kapton.**

2. **Touch-probe measurement of the leakage current of a surface mount capacitor.**

3. **This demonstrates how long it takes to fully charge a capacitor.**

4. **Ionization current of one of the capacitor banks while being irradiated using 200 MeV protons at the Indiana University Cyclotron.**

5. **Leakage current measurement of the irradiated capacitors two weeks after irradiating them to a fluence of $5x10^{14}$ protons.**

6. **Leakage current measurements of the non-irradiated capacitor bank. The variations are mainly due to noise pick up.**

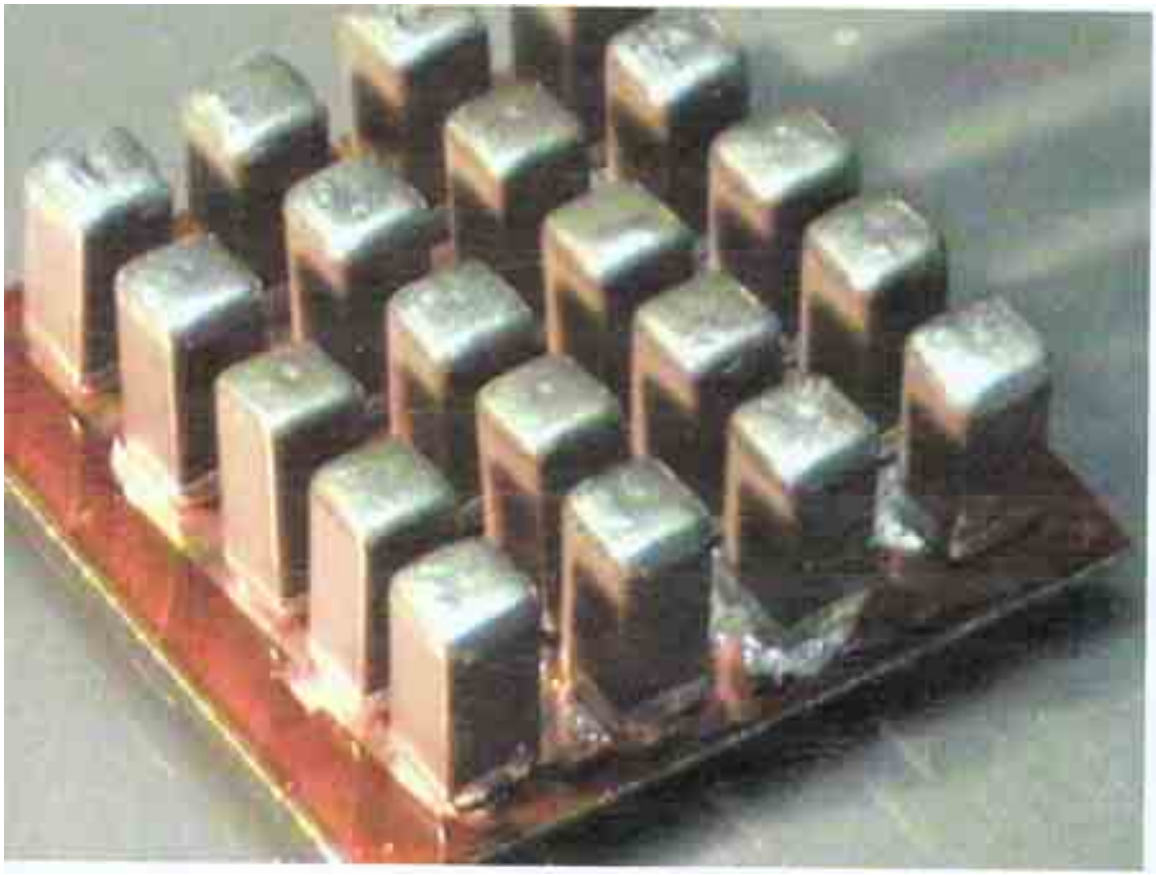

**Figure 1**

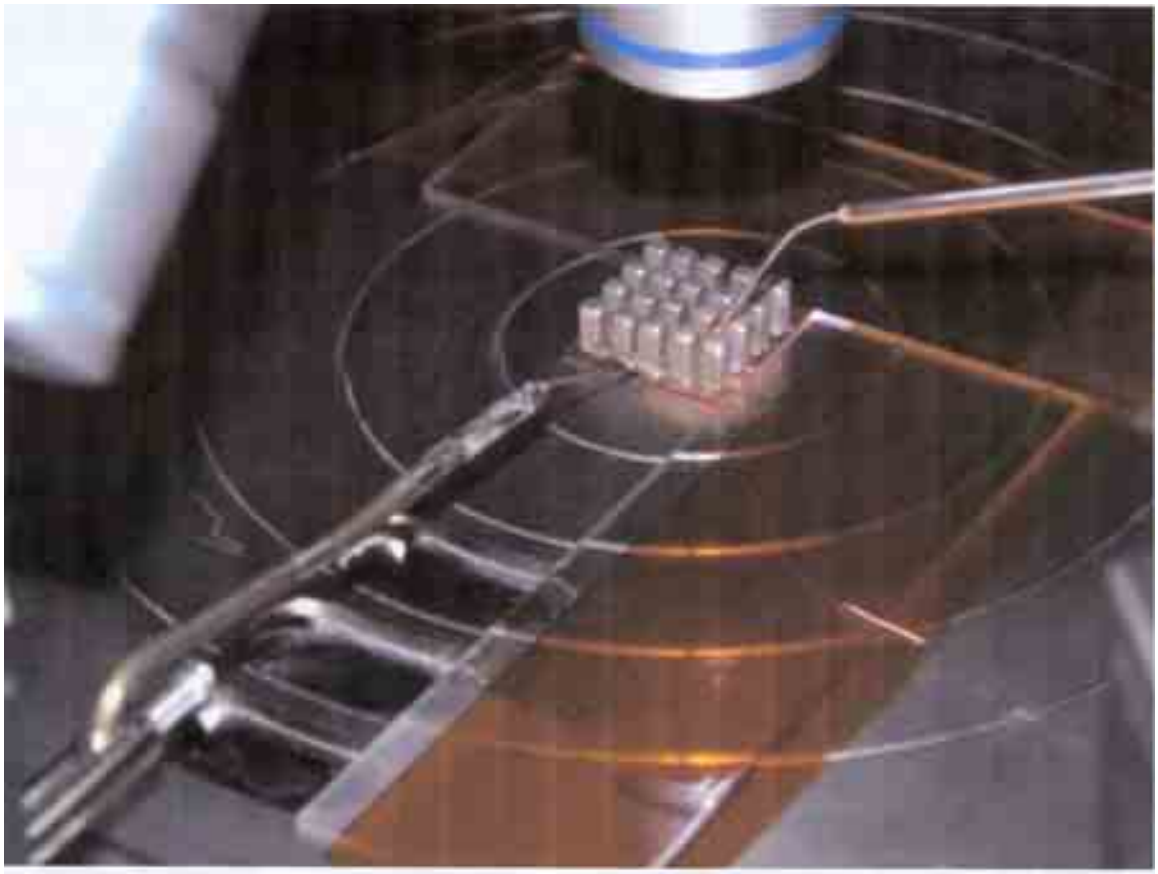

**Figure 2**

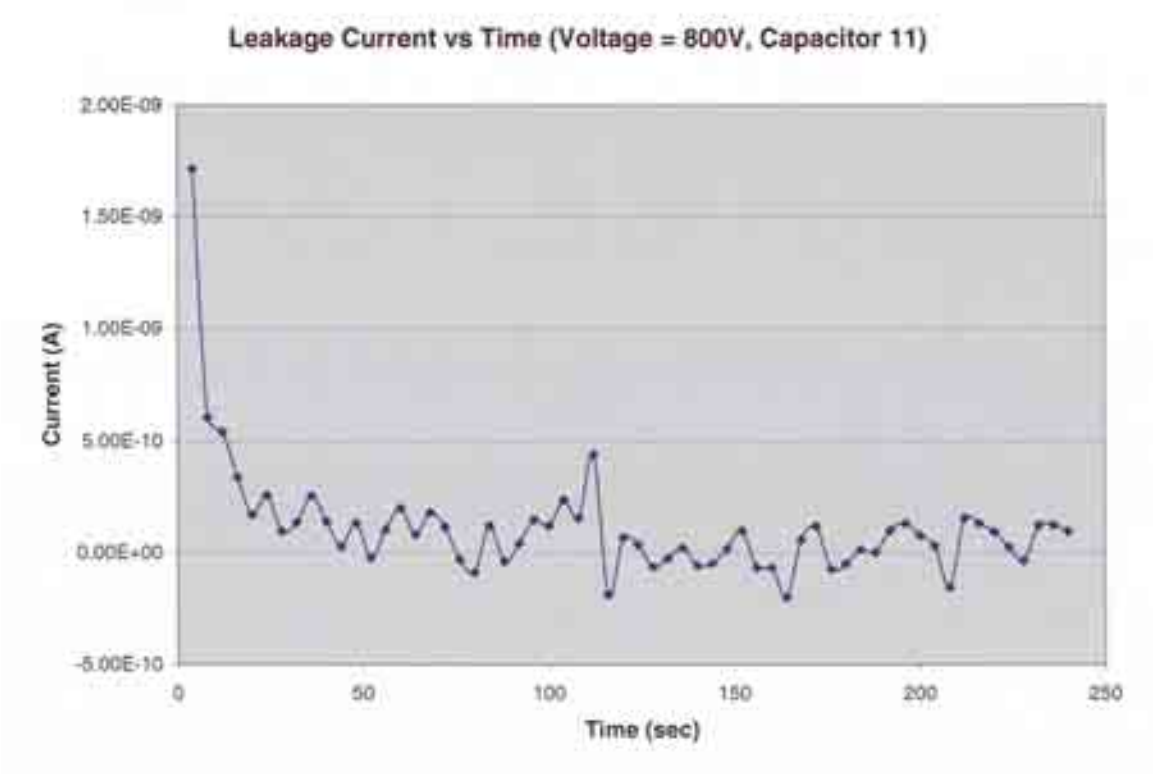
Leakage Current vs Time (Voltage = 800V, Capacitor 11)
2.00E-09
1.50E-09
1.00E-09
5.00E-10
0.00E+00
-5.00E-10
Current (A)
0
50
100
150
200
250
Time (sec)

**Figure 3**

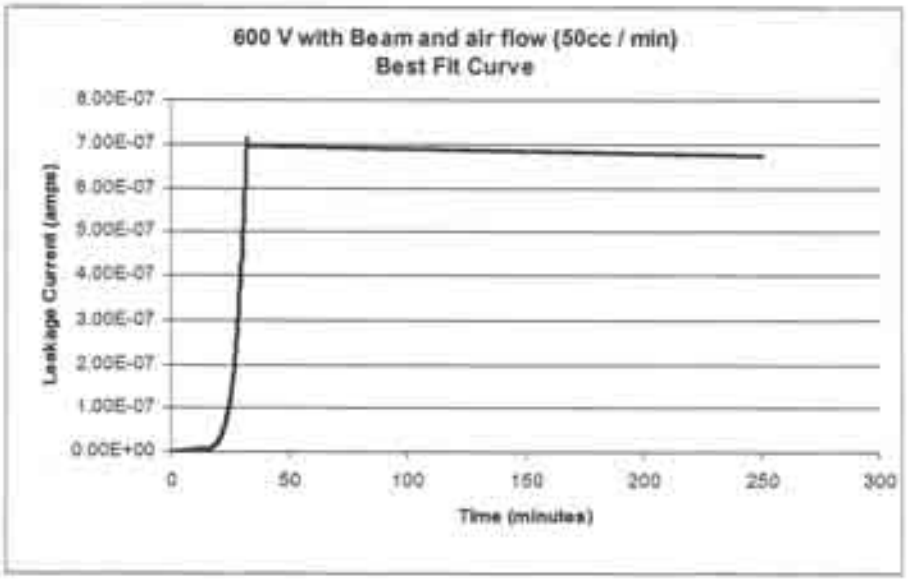
600 V with Beam and air flow (50cc / min)
Best Fit Curve
Leakage Current (amps)
8.00E-07
7.00E-07
6.00E-07
5.00E-07
4.00E-07
3.00E-07
2.00E-07
1.00E-07
0.00E+00
0
50
100
150
200
250
300
Time (minutes)

**Figure 4**

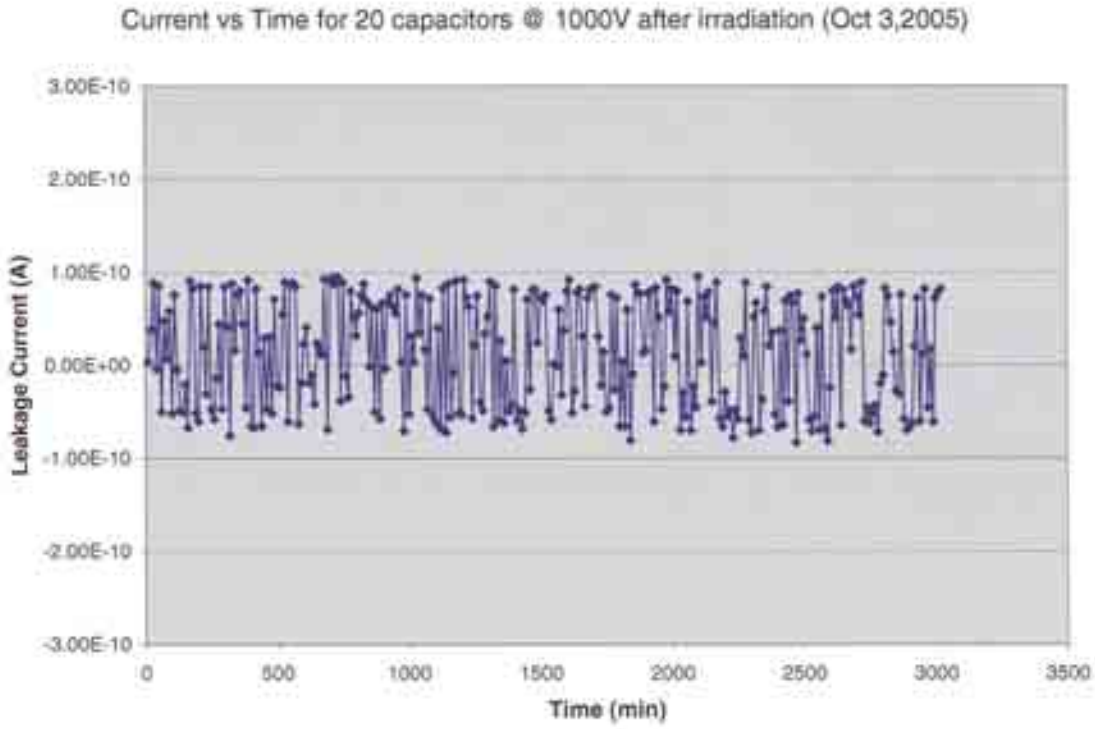
Current vs Time for 20 capacitors @ 1000V after irradiation (Oct 3,2005)
Leakage Current (A)
3.00E-10
2.00E-10
1.00E-10
0.00E+00
-1.00E-10
-2.00E-10
-3.00E-10
0
500
1000
1500
2000
2500
3000
3500
Time (min)

**Figure 5**

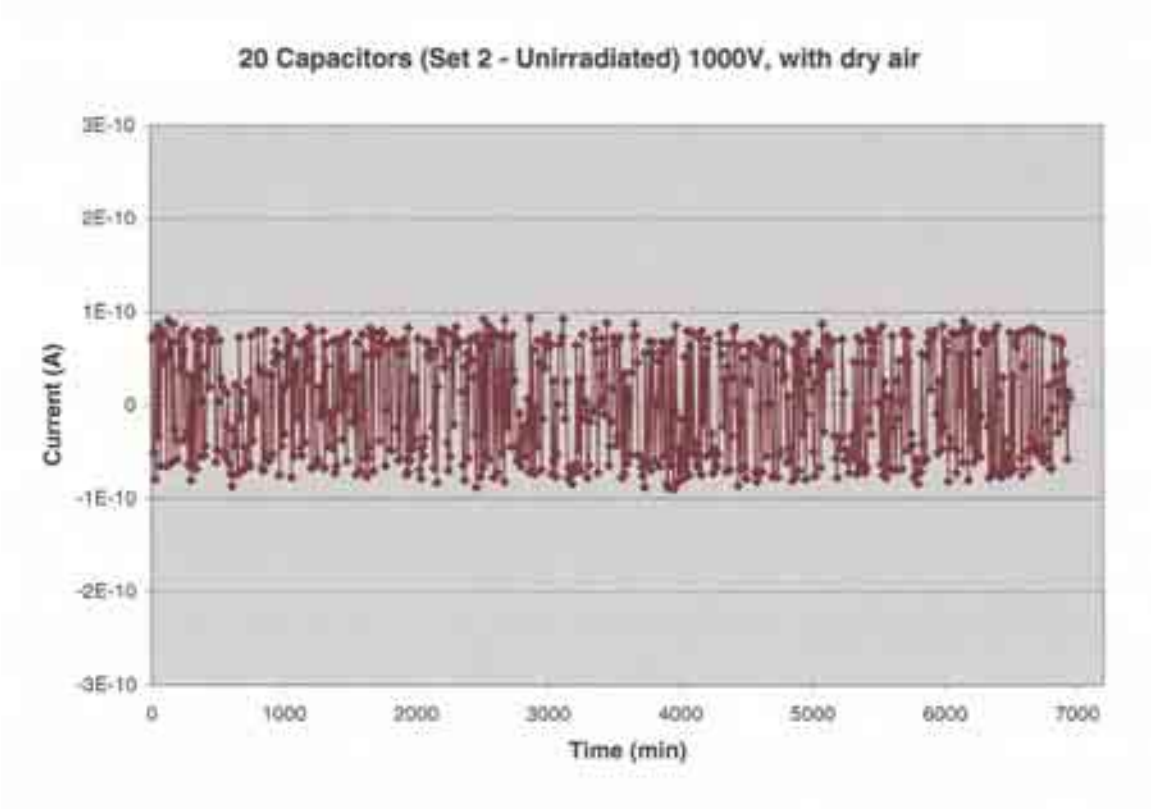
20 Capacitors (Set 2 - Unirradiated) 1000V, with dry air
3E-10
2E-10
1E-10
0
-1E-10
-2E-10
-3E-10
Current (A)
0
1000
2000
3000
4000
5000
6000
7000
Time (min)

**Figure 6**