**JLAB-TN-03-007**
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# JLab polarized electron guns operations in 2002

This report summarizes the performances of the two polarized guns in operation at JLab during the calendar year 2002, such as activations, wafer scans, locations used on the photocathode and polarization measurements. It first presents the results of gun 3, then gun 2 as they were chronologically in use on this order. Lifetime measurements are then detailed.

# Experiment summary

Below are listed all 2002 experiments and major shutdown and work periods on the CEBAF machine or in the halls, along with their approximate running dates.

**Hall A**

E99-114: exclusive Compton scattering on the proton (January-February)
E98-108: electroproduction of kaons (March)
E01-001: new measurement of GE/GM for the proton (May 1-15)
E01-020: deuteron at high Q2 (May 15-June)
E97-110: GDH and spin structure of He3 and neutron (September-October)
E94-107: high resolution hypernuclei 1p shell (November-December)

**Hall B**

e1-6: January-June
g7: September-October
e1: November-December

**Hall C**

E01-006: nucleon spin structure function in nucleon resonance region (January-Februay)
G0 installation: April-September
G0 commissioning: October-January 2003

**Shutdown**

March 19-May 1
July 2-August 20

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## 1. GUN 3

GUN 3 was in operation since May 2001 until the March 2002 shutdown
Since January 2002, beam was originating from on the **one single existing activation for the 3 months of operations**, then

- 1 activation of this wafer was done (July 11)
- 1 new wafer was loaded into the gun (July 24) and activated (July 30)

The new wafer information on July 24 (polog 1109846):

> *The wafer ID is #5 from MO5-5865 from Bandwidth semiconductor, grown 4/5/01, diced 2/12/02, anodized with 5 mm o-ring, wet chemicals 7/22/02, hydrogen cleaned in portable H chamber for 15 minutes 7/23/02.*

Vacuum measurements were done after months of inactivity on December 20 (polog 1130709):

> *I looked at the vacuum on gun3 (it has been idle for months). The rga trace shows only H2 (mass 4 at 3x10^-11Torr) and CO (mass 28 at 4x10^-12 Torr). Maybe a little methane. The extractor gauge reads 0.0x10^-12 Torr. I'm not sure it's working. The vacuum may be really good, lower than this instrument can measure. It's possible.I opened the valve to the beamline. The rga trace shows no change (maybe a slight increase in H2). The extractor gauge flashed at 6x10^-12 Torr and then went bakc to reading 0.0x10^-12 Torr. I'll degas the gauge Jan 3 to see if the 0.0x10^-12 Torr number is an indication of the limitation of the device.*
> NB: the 0e-12 extractor gauge readings are most likely in error.

**Two spots** were used before the July activation and new wafer loading were:
Spot 1: 1260/1160 (starting point)
Spot 2: 1170/1140 (on 2-13)
Since then the gun has not been used for operation.

During the year 2002, wafer scans were made throughout operation of the gun and after, as seen on figures 1 and 2.

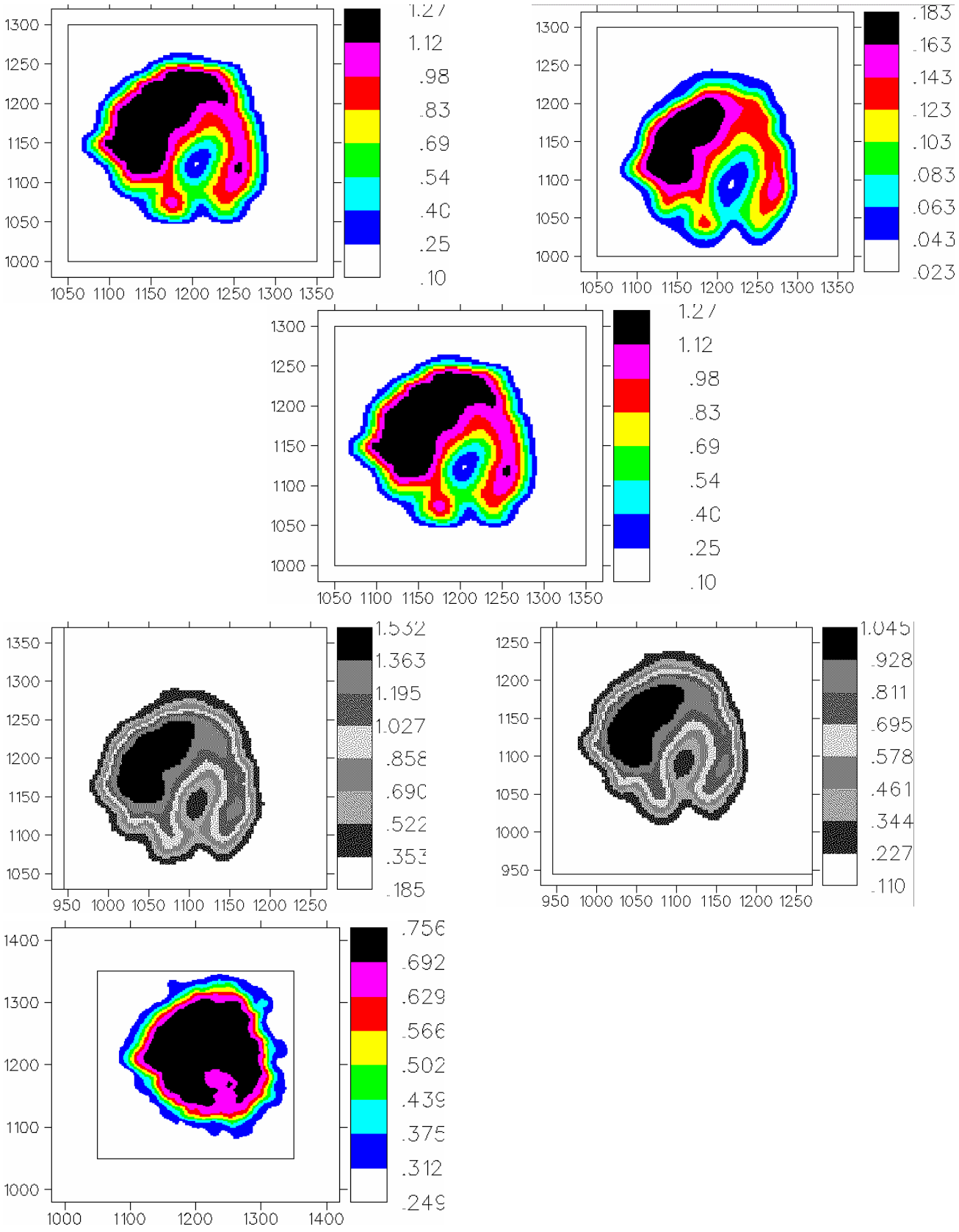


Figure 1: wafer scan, gun 3; row 1: March 19, A (770 nm) & B (840 nm) lasers; row 2: March 19, C (860 nm) laser; row 3: July 9, A & B lasers; row 4: July 11, reactivated (A).

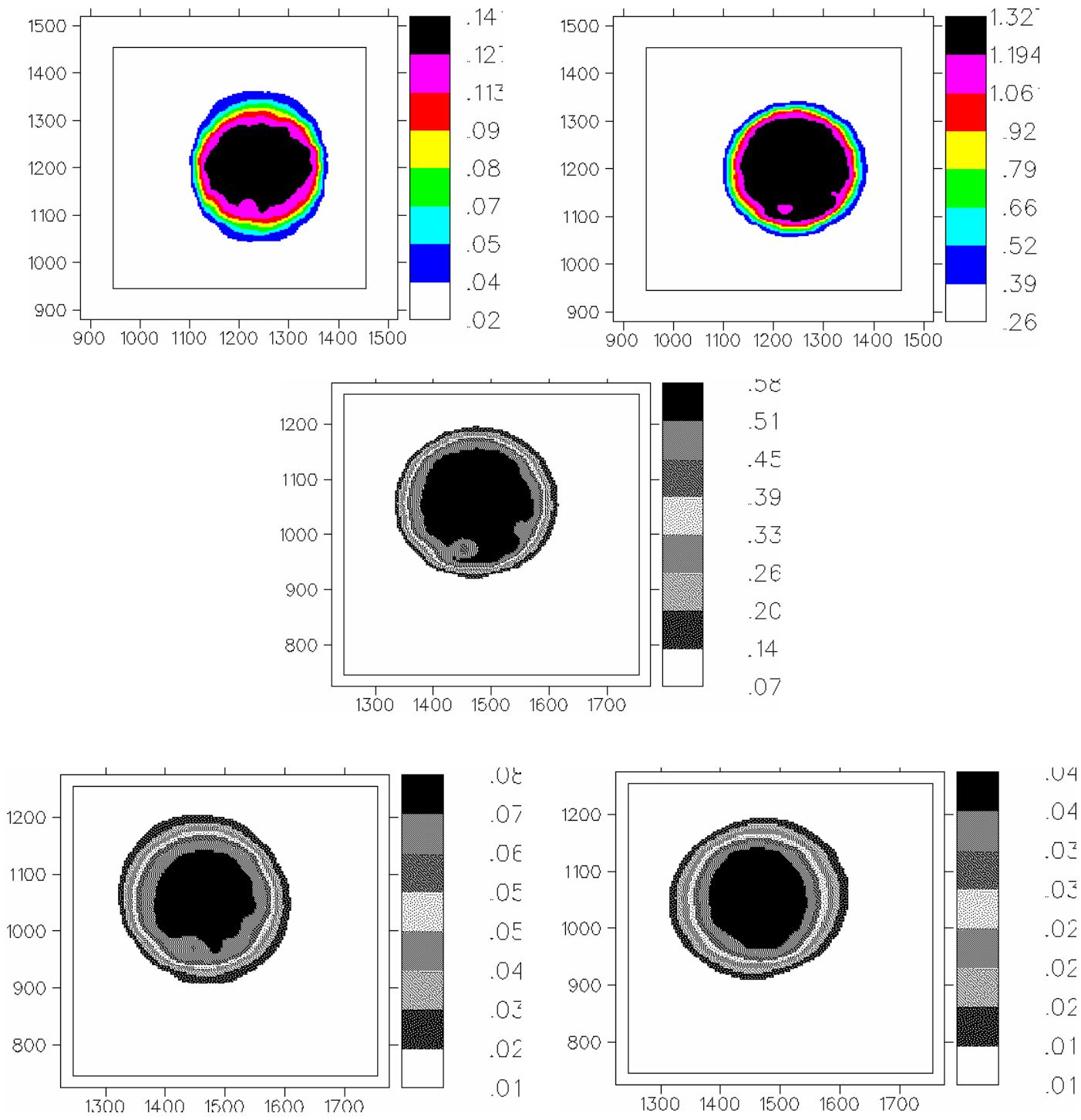


Figure 2: wafer scan, gun 3; row 1: new fresh cathode after activation/hipot (July 30) with B (840 nm) & C (770 nm) laser; row 2: December 20, after months inactive A (770 nm); row 3: December 20, B (840 nm) & C (840 nm);

**Polarization** of the beam in the injector was measured with the 5 MeV Mott on gun 3 on February 20 only (see table 1 and figure 3). An average polarization of 73% was found.

| Beam polarization at cathode | | |
|---|---|---|
| laser | Pe (%) +/- stat | wave-plate |
| A | +73.6 +/- 0.9 | in |
| A | -73.5+/- 1.4 | out |
| A | -73.3 +/- 1.1 | out |
| A | +74.1 +/- 1.1 | in |
| B | +72.5 +/- 1.1 | in |
| B | -72.6 +/- 1.2 | out |
| C | +71.8 +/- 1.0 | in |
| C | -71.2 +/- 1.0 | out |

Table 1: Results of the February 20 Mott measurements with gun 3 for all lasers and wave-plate states.

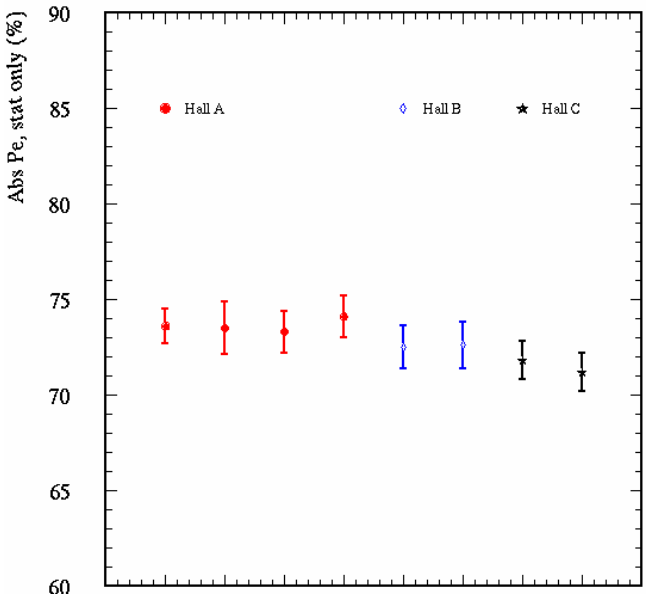


Figure 3: Absolute polarization with all 3 lasers (Feb 20) in Gun 3. Errors are stat. only.

# 2. GUN 2

GUN 2 was in operation from April 2002 (restoration form the March shutdown) until 2003.
Since April, only **2 activations** were used for **9 months** of operation:

- First a bulk wafer was loaded, the gun was baked, HV processed to show that field emission was removed at 120 kV (Mar 24) after the electrode was changed,
- Then the operation strained layer was loaded, and activated on April 5 after the gun bake (**activation 1**)

The new wafer information on March 26 (polog 1091291):

> *Chip #3 (beside the center) of Bandwidth wafer M05-5865 (grown 4-5-01,diced 2-12-02) was anodized with a 5 mm o-ring today for use in gun 2. Cleaned first with TCE/ACE/METH (3 min. ultrasound each), mounted on cover slide to protect back with clear wax (10-20 seconds at 225 on hot plate), o-ring on then into phosphoric acid (3 drops in beaker of DI water), rinse in DI still under vacuum, rinse in meth still under vacuum, then release into methanol. Back onto hotplate ~10 seconds to melt wax and remove from cover slide, then 3 min cycles in ultrasound: 3x ACE in ACE/glue beaker, 3x ACE in fresh ACE beaker, 3x in Methanol. Mounted on long stalk: at 208 C to melt indium, quickly set in place and cooled in about 10 minutes to ~30 C. H cleaned before tunnel.*

- A heat/clean cycle and activation was done on July 31 (**activation 2**)
- A heat/clean cycle and activation was then done at the end of the year after the quoted 9 months of beam (December 20).

Wafer scans were made regularly throughout operation of the gun as seen on figures 5 through 8. We can see QE depletion at the spot in use during high current operation in hall A: see for example the wafer profile shown in figure 5 with the hall A beam (left column) as the spot in use was first 1200/1500 and then 1320/1510, those two regions get depleted with time of high current beam delivery.

**About 10 spots were used during the 9 months operation:**

Spot 1: 1200/1500 (since April, after shutdown)
Spot 2: 1320/1510 (May 28)
Spot 3: 1190/1420 (June 12)
Spot 4: 1220/1480 (June 21)
Spot 5: July 1 then restored previous spot on July 8
Heat/clean, activation on July 31
Spot 6: 1250/1450 (August 1, start up)
Spot 7: 1300/1300 (September 3)
Laser work (September 17), x/y stepper position, spot at cathode slightly moved
Spot 8: 1370/1350 (October 9)
Spot 9: 1350/1300 (October 14)
Spot 10: 1300/1350 (November 7)
Heat/clean, activation on December 20 (45 min at 300 C), same spot

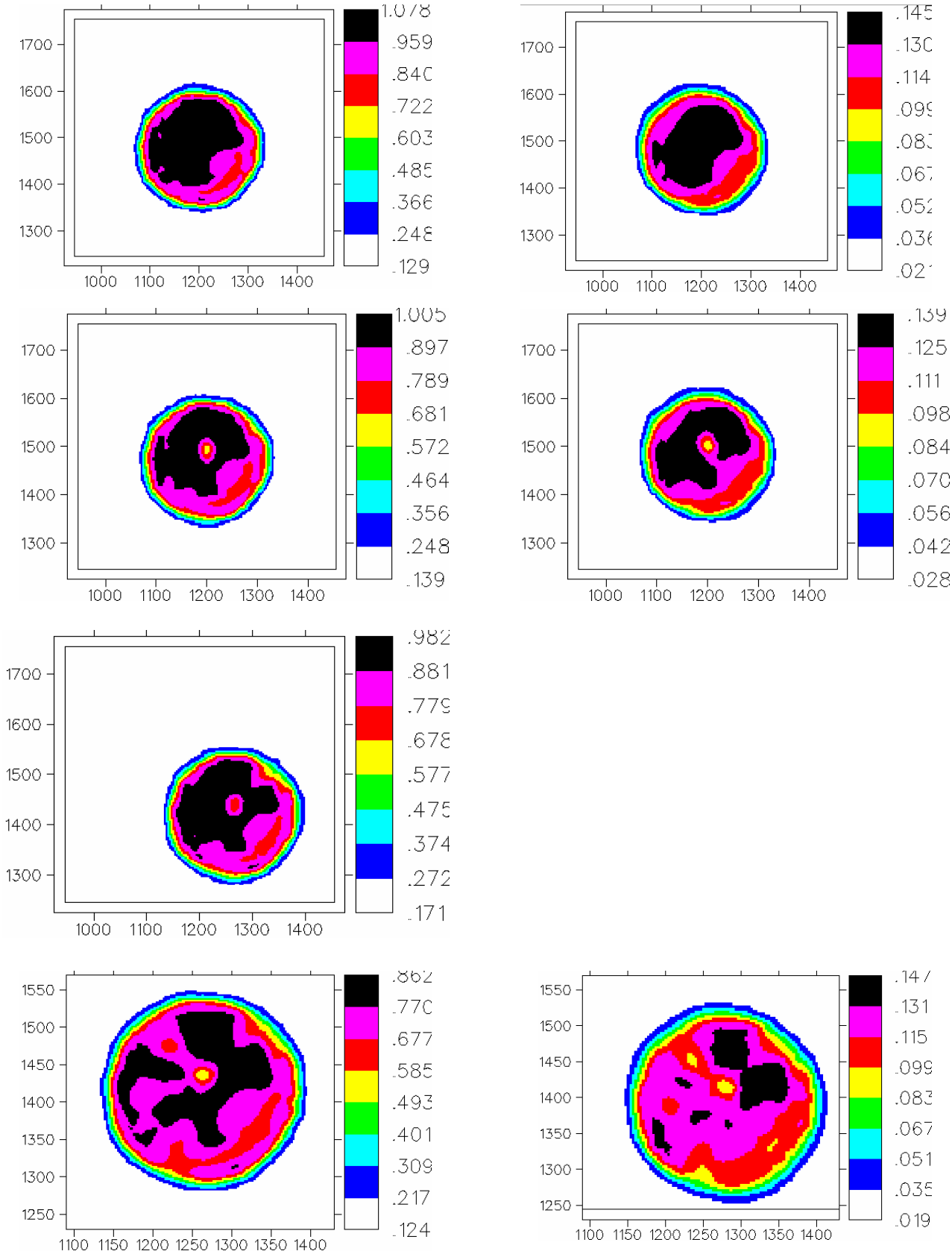


Figure 4: Wafer scan, gun 2 with A (770 nm) & B (840 nm) lasers: row 1: May 3; row 2: May 24; row 3: June 12 (A only); row 4: June 28.

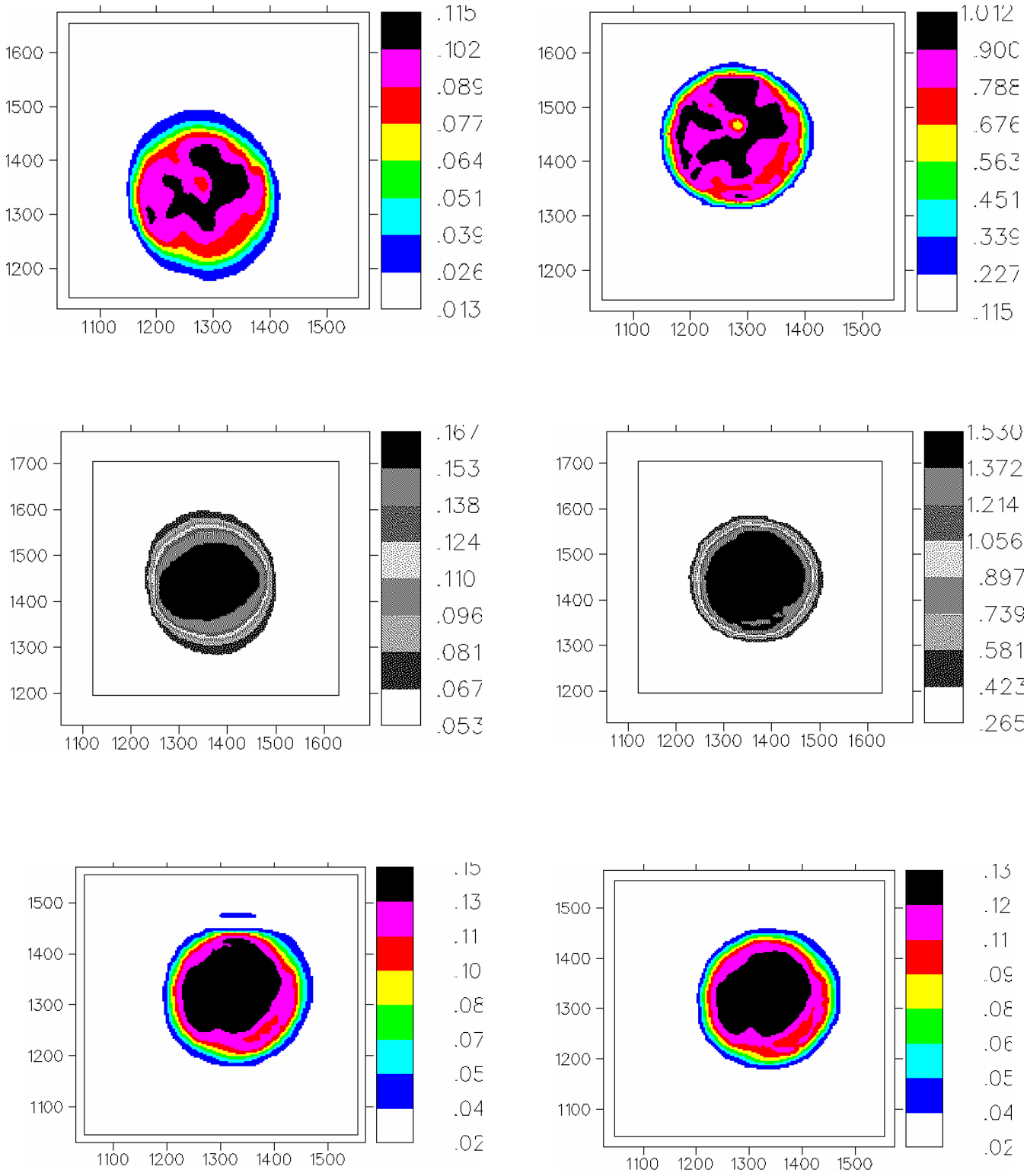


Figure 5: Wafer scans, gun 2. Row 1: July 15, B (840 nm) and C (770 nm); row 2: after activation (July 31), row 3: Sep 17 and Oct 4, A laser (840 nm).

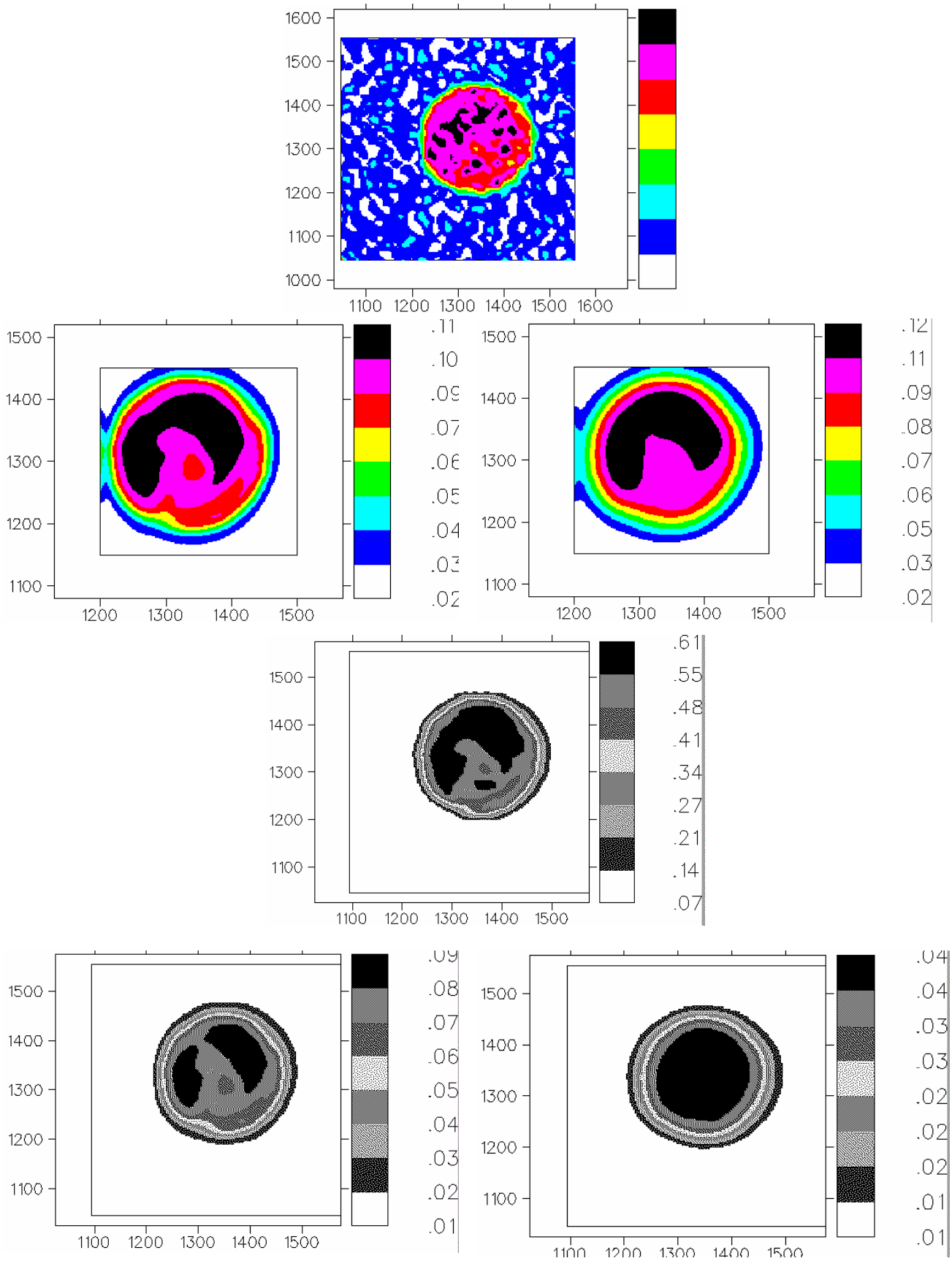


Figure 6: Wafer scans, gun 2. Row 1: November 7, A (no scale); row 2: November 22, B and C; December 20 before activation with A (row 3), B and C (row 4).

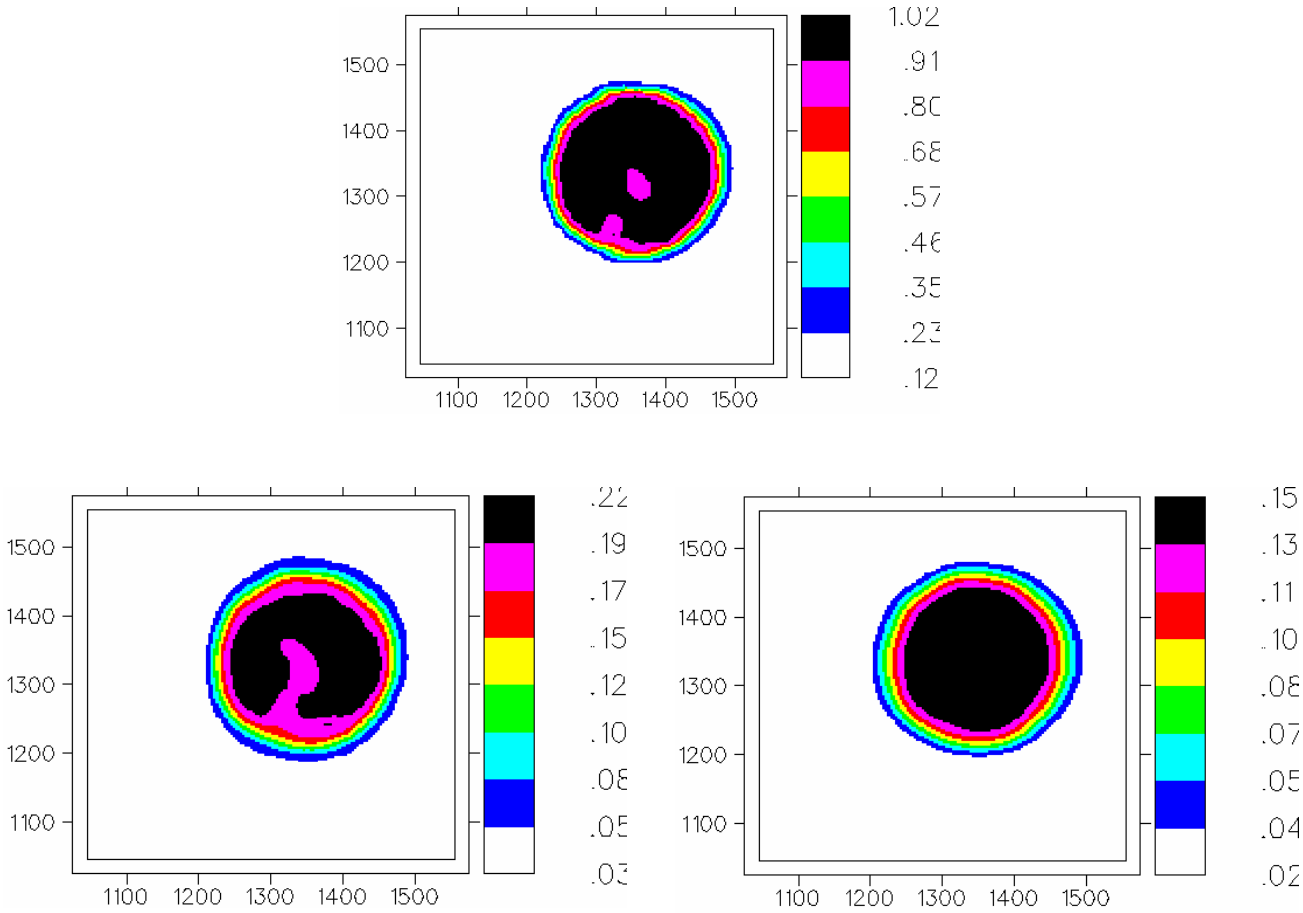


Figure 7: Wafer scans, gun 2, December 20 after reactivation: row 1: A laser (770 nm); row 2: B and C (840 nm) lasers.

**Polarization** of the beam in the injector was measured on gun 2 on April 24 for 3 different spot locations with the B laser at 842 nm (figure 4). An average polarization of 76% was found.

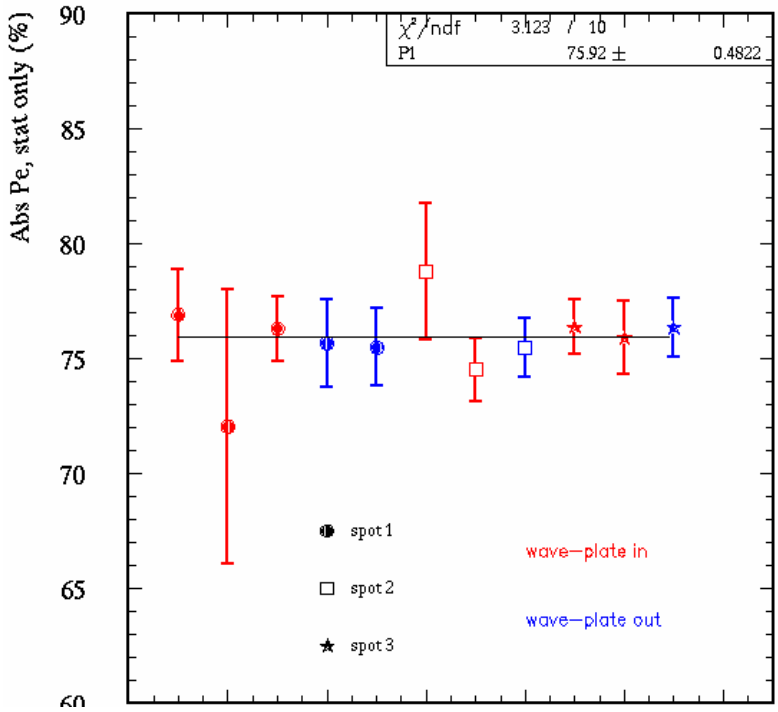


Figure 8: 5 MeV Mott absolute polarization with B laser (842 nm) on April 24 in Gun 2. Errors are stat. only.

During the March shutdown, important rework was performed on gun 2:

- Titanium electrode replaced by stainless steel (March 26)
- Cesiator hat removed
- New apertures A1/A2 installed
- Pcup vs. HV power supply calibration (April 23)

Some miscellaneous informations regarding gun 2 are listed below:

- Hall A laser died (July 2)
- 770 nm Toptica installed (July 9)
- Apertures modified (July 22):
  - A1: becomes 4,6 and 8 mm
  - A2: repair short at 8 mm hole
  - A3: enlarged to 6 mm
- Hall A (770 nm) laser died (October 14)
- Laser room overheat (November 18)

# 3. Guns performance

A total charge exceeding 500 C was extracted from the cathode over the year (figure 9) during beam delivery for the physics program. The quantum efficiency was monitored with each laser approximately every day of operations (figure 10). Figure 10 also indicates the two periods of machine shutdown (spring and summer), and the times when a new cathode location was used (dashed lines). The QE is increased, but not fully restored, after each spot move before being degraded again. Hall A has been running unpolarized beam for almost all of their physics program: the QE with the hall A 770 nm diode laser used in 2002 was ranging between 0.5 and 1%. Hall B has been running highly polarized beam for almost of their run: the QE with the 840 nm hall B diode laser was 0.1 to 0.2 %. Hall C was down after the March shutdown until the G0 commissioning run in September, when highly polarized beam was delivered: the QE measured with the Tiger at 32 MHz, 840 nm, was comparable to the one seen with the hall B beam.

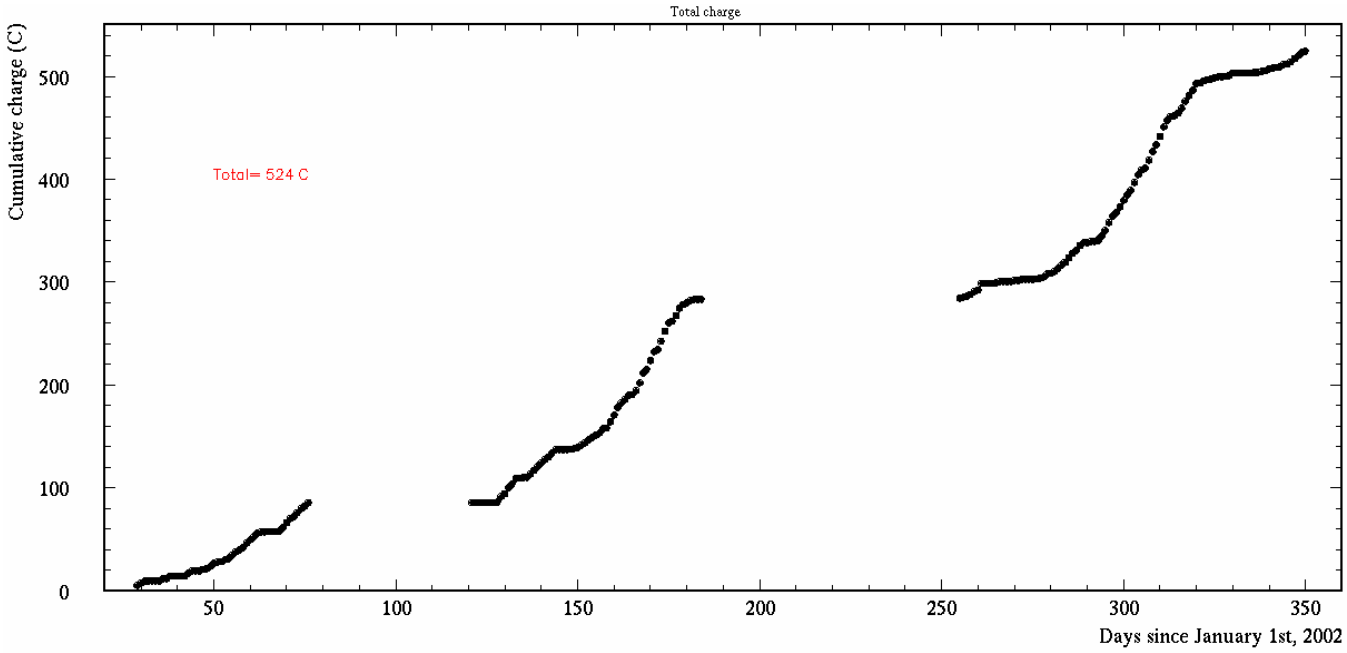


Figure 9: Cumulative charge extracted from the cathode during operations only versus time.

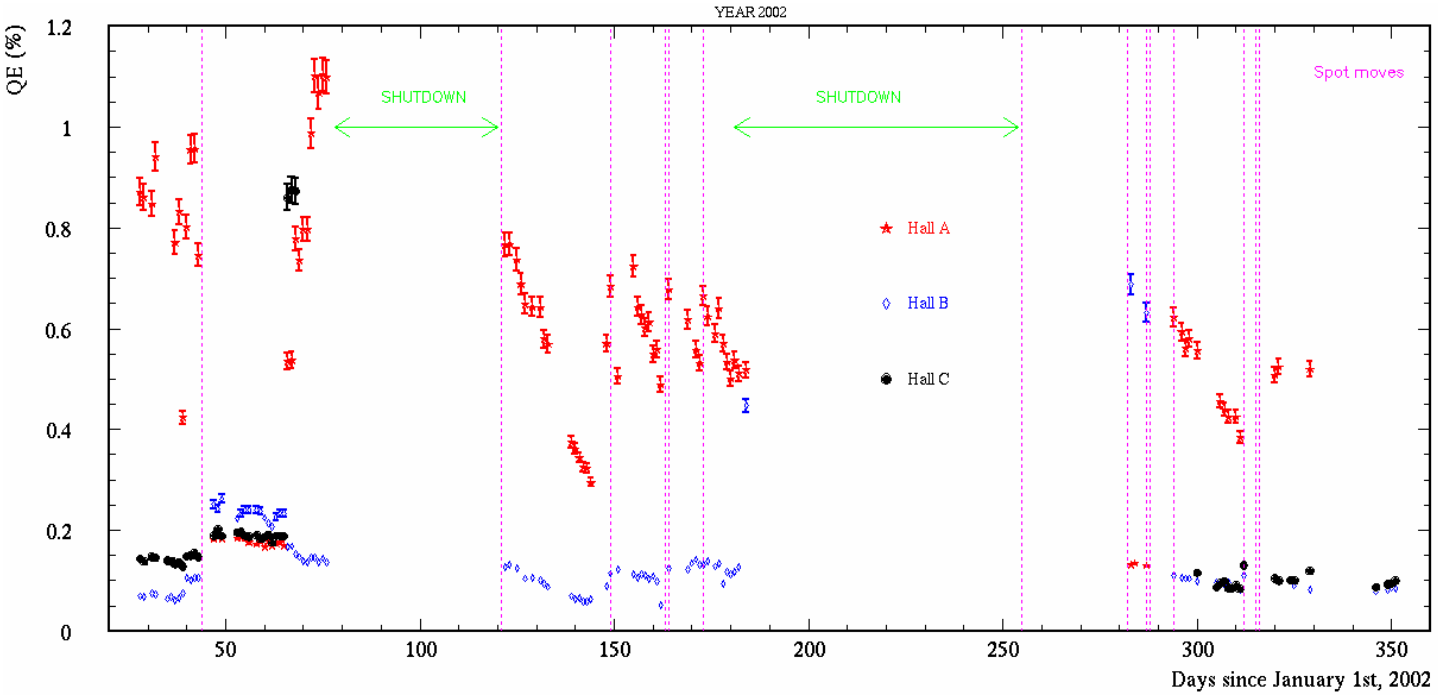


Figure 10: Quantum efficiency for each laser versus time. Dashed lines represent the spot moves. Shutdowns periods include accelerator development and restoration.

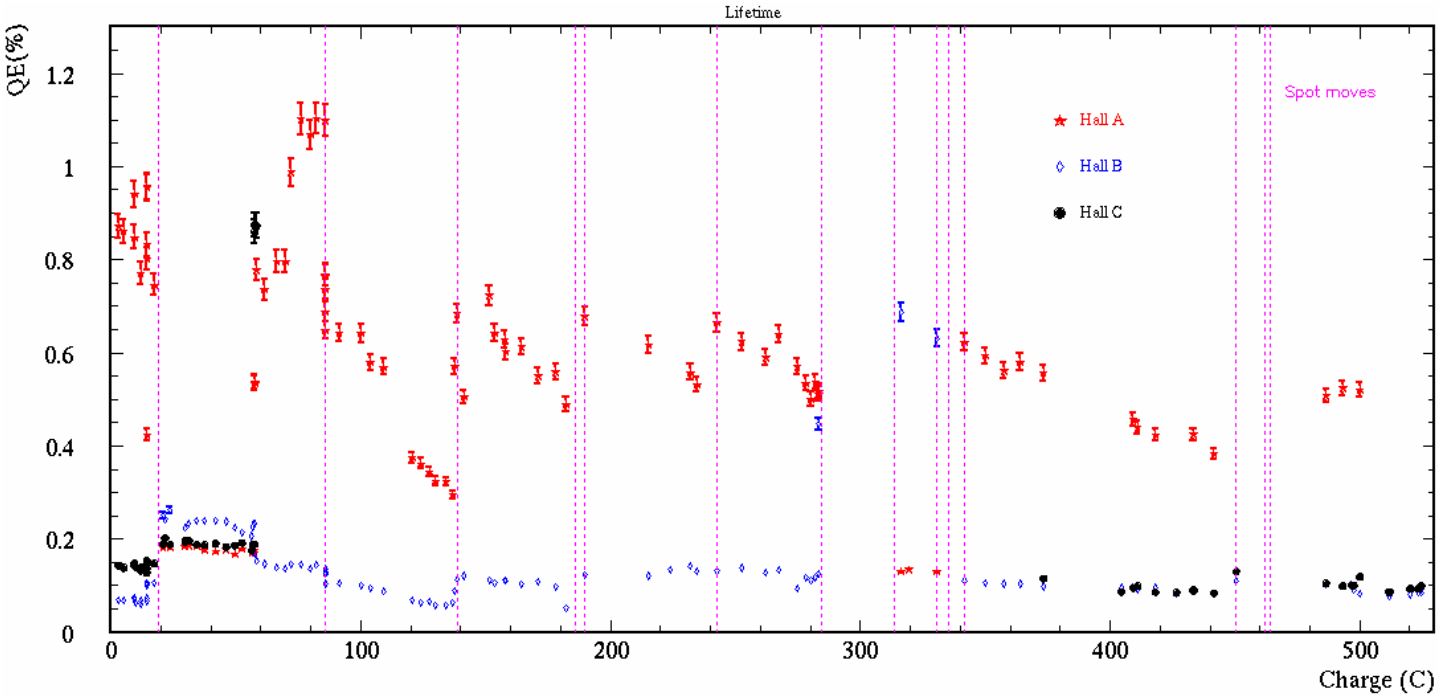


Figure 11: Quantum efficiency for each laser versus charge extracted from the cathode. Dashed lines represent the spot moves.

Figure 11 displays the QE measurements for the 3 beams as a function of the charge extracted from the photocathode. Figures 12 through 14 represent the QE as a function of charge measured with each laser. The decay lifetime of the photocathode is fitted onto the data for each period when beam was originating from one single spot.
Lifetimes on the order of 200 to 300 C are seen at high wavelength (840 nm) in halls B and C (figures 13 and 14).
Lifetimes seen at a lower wavelength, 770 nm (and a higher current, most of the time) are lower in hall A: 100 to 200 C.

The laser beam size was consistent around 400 microns at the wafer whenever diode lasers were used, that is all year long for halls A and B and during the first part of data taking in hall C.
The laser beam size was larger for the G0 experiment starting in September in hall C. The Commercial 32 MHz Ti:Sap Tiger laser was installed on September 3 with the diameter on the order of 550 microns (polog 1114277). The laser spot size was increased to 680 microns (FWHM) at the wafer by adding a lens on November 22 (polog 1126961). The lens was removed on December 16 (polog 1129786). A lens was added again on January 10, 2003 (polog 1132232) to get the beam diameter up to ~950 microns (not shown on figure 14).

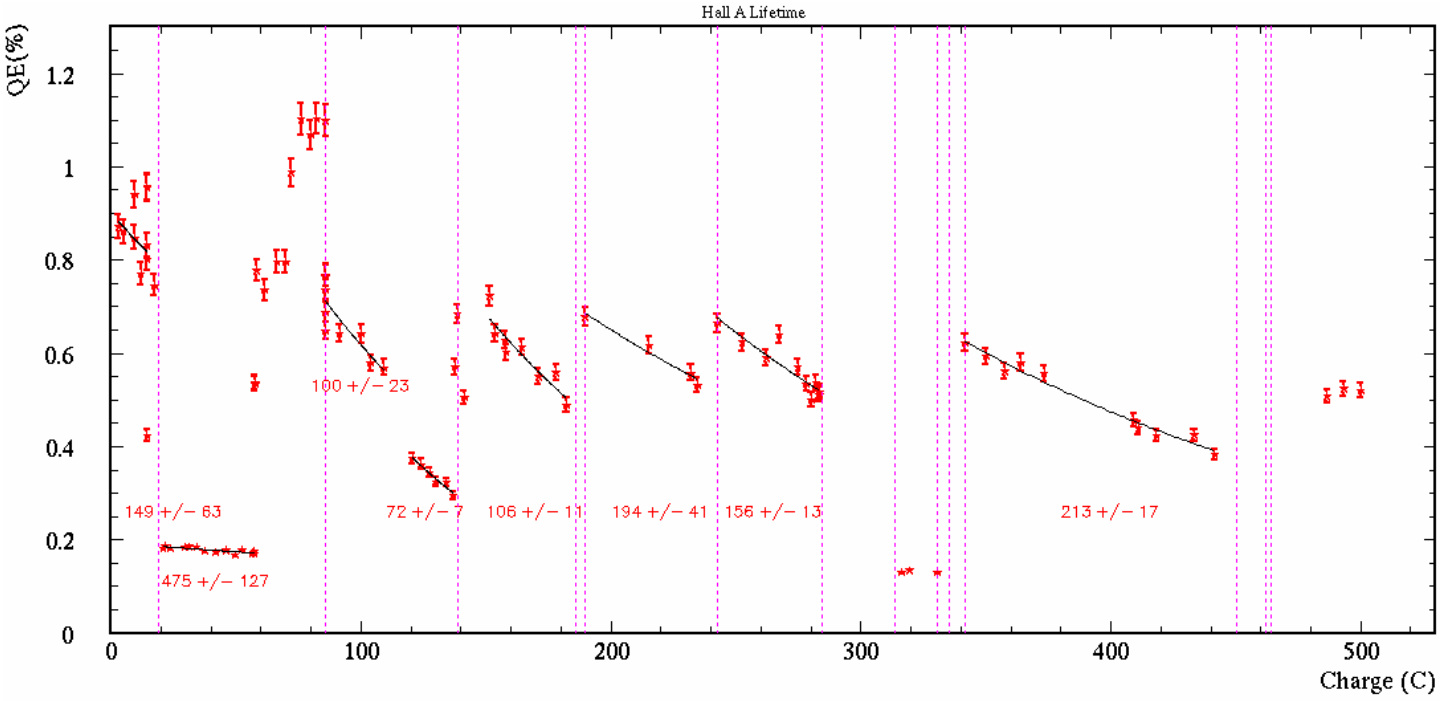


Figure 12: Lifetime for hall A beam: quantum efficiency versus extracted charge, fit of relevant data (results are expressed in coulombs for each period). Dashed lines represent the spot moves.

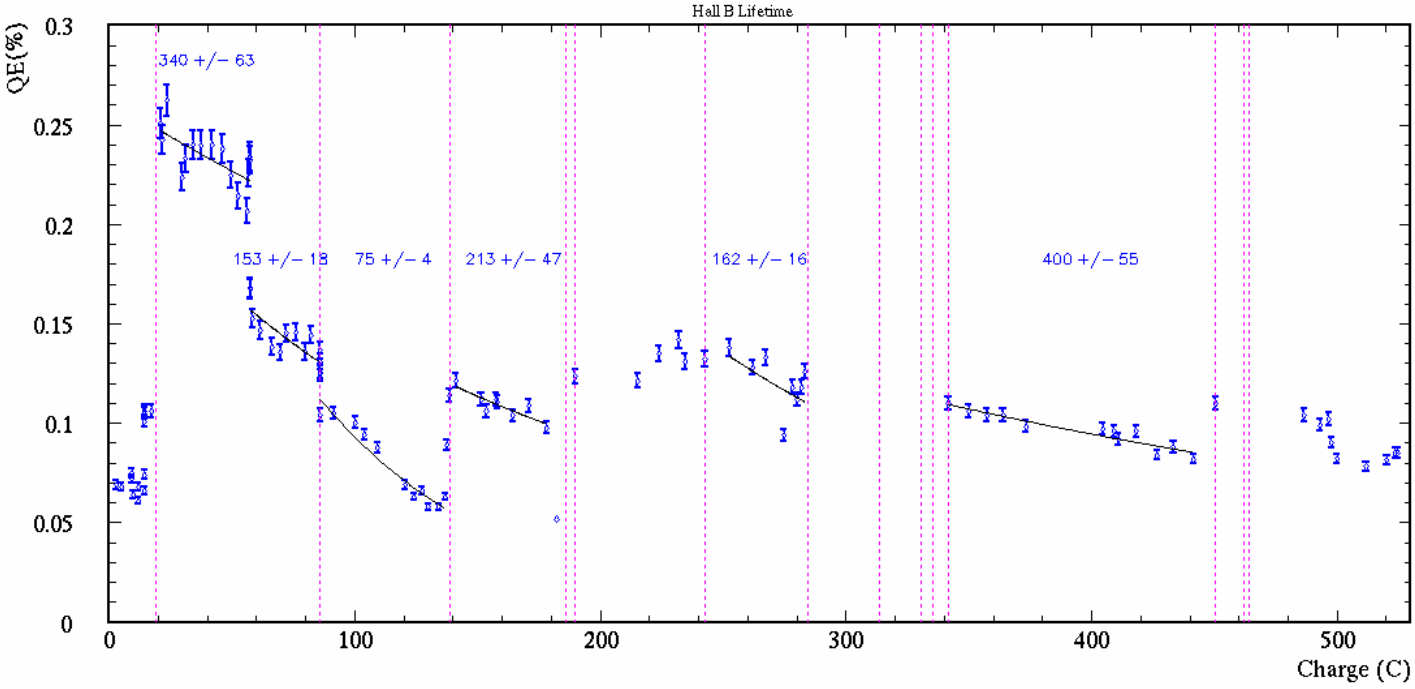


Figure 13: Lifetime for hall B beam: quantum efficiency versus extracted charge, fit of relevant data (results are expressed in coulombs for each period). Dashed lines represent the spot moves.

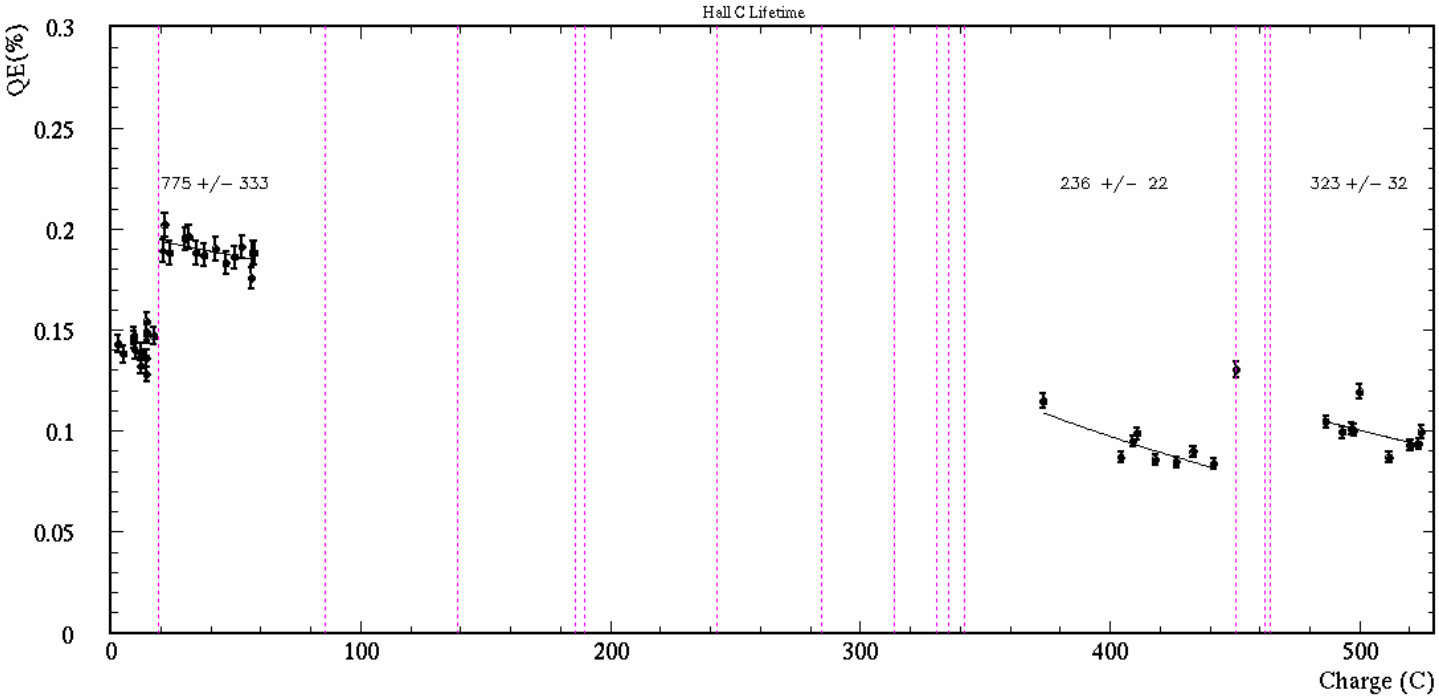


Figure 14: Lifetime for hall C beam: quantum efficiency versus extracted charge, fit of relevant data (results are expressed in coulombs for each period). Dashed lines represent the spot moves.

Polarization was measured throughout the year by the halls polarimeters. Figure 15 displays all measurements provided by the halls polarimeter groups [1] [2] [3]. The average of the Mott data presented in sections 1 and 2 are displayed for comparison. The polarization measurements in the halls are not corrected by the Wien angle. Polarization at the cathode between 65 and 80% were reported. The reported polarization in hall B includes any polarization dilution, such as bleedthrough coming from other halls (for example, as hall A was running highly polarized beam, 45 to 65 days after January first, hall B polarization drops). Very few measurements were reported by the hall A Moller since the hall has been running low polarization beam most of time.

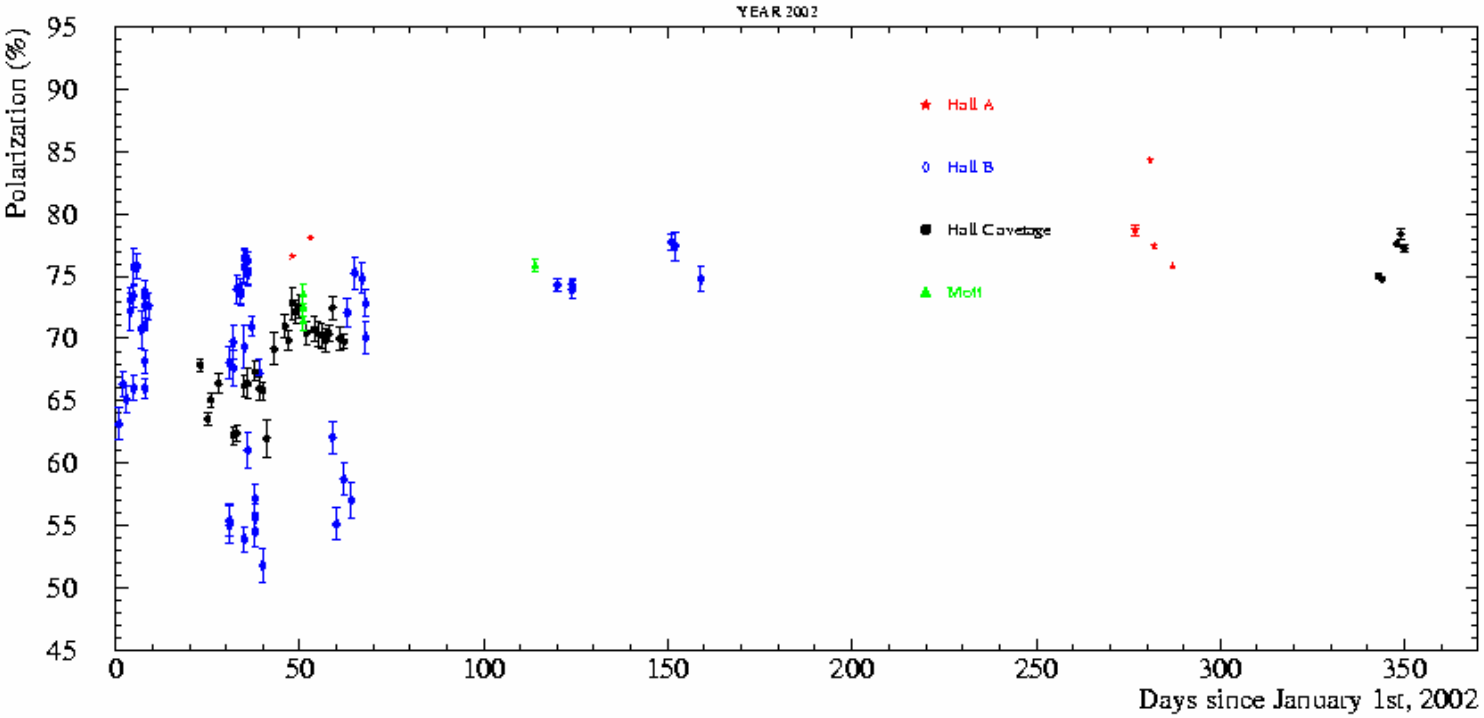


Figure 15: Beam polarization measurements versus time with the three hall Moller polarimeters and the Mott polarimeter.

Figure 16 illustrates the QE and beam polarization measurements in hall C before the spring shutdown (January-March). A quantity proportional to QE and a quantity proportional to absolute beam polarization are displayed versus time (for the convenience of seeing both QE and Pe on the same graph). No real evidence of a polarization increase can be seen over the time range.

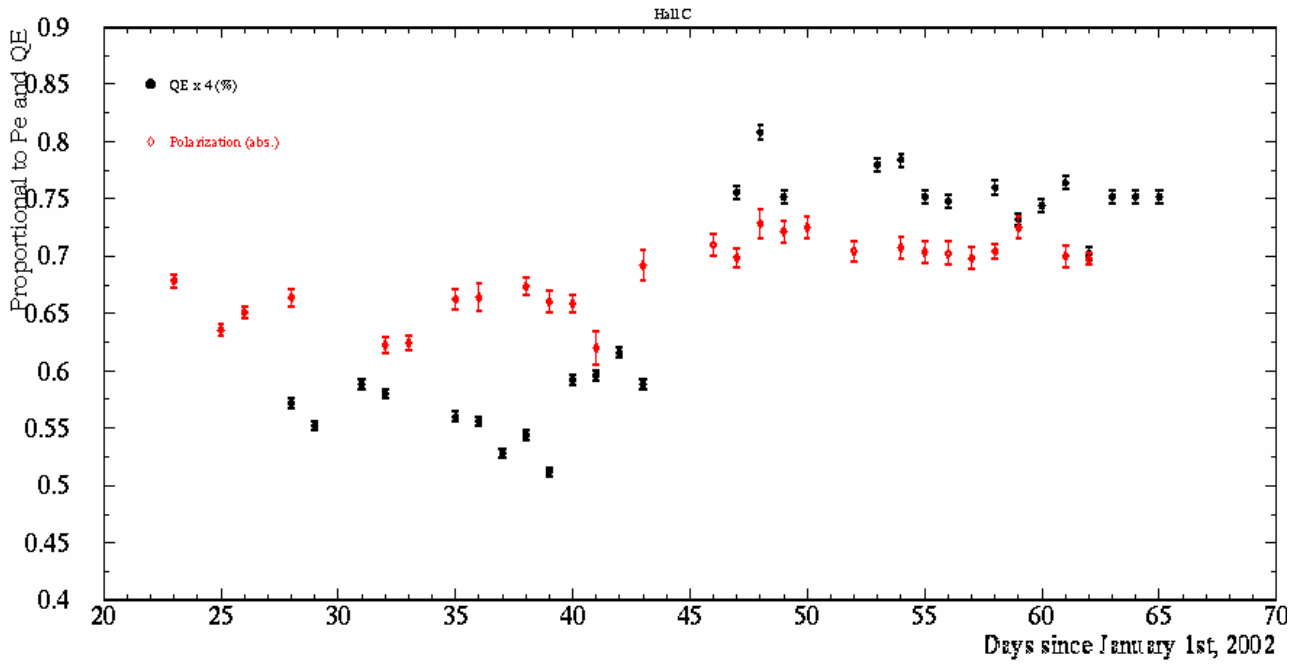


Figure 16: Beam polarization and quantum efficiency in Hall C versus time.

# References


1. http://www.jlab.org/~moller/2002_raw_results_archive.html.
2. D. Gaskell, private communication.
3. A. Freyberger, private communication.