



NOTE ON THE PROPERTIES OF THE LARGE
ION CHAMBER AND SECONDARY EMISSION MONITOR
LOCATED IN NEUHALL

L. N. Hand

Cornell University

August 21, 1972

Information is given about the large ion chamber (LIC) and
SEM now located in Neuhall.

$$\frac{Q_{LIC}}{Q_{BEAM}} = 13.3 \pm .7$$

(up to 10^7 p/burst
on fast spill)

$$\frac{Q_{SEM}}{Q_{BEAM}} = 0.274 \pm .010$$

(any beam intensity)

HV (both) = -800 volts

The purpose of this note is to describe the characteristics of the large ion chamber (LIC) and secondary emission monitor (SEM) which have been placed in the proton beam just upstream of DX1 in Neuhall. These monitors have been loaned to NAL by the Laboratory of Nuclear Studies at Cornell.

Physical Description

LIC: Two HV planes of thin foil surround one foil signal plane. Only the output labeled "thin" works and has been calibrated. The cable ground must be isolated from the ion chamber ground to prevent ground loops. A special connector has been provided for this. HV connections are MHV, signal and ground are BNC.

SEM: 6 HV foils and 5 thin copper signal foils provide 10 gaps for collecting the electrons. Great care must be taken to avoid breaking the Kovar seals for the signal and HV leads. Dirt or fingerprints on the seal for the signal lead will cause leakage current. The outside windows are stainless steel and have been permanently welded on. They would be hard to break but it could be done with a sharp point and would ruin the SEM. Care should be exercised when working near the exposed HV. A 1 meg resistor should be installed in series at the supply, but this has not been done. The signal cable should be a male type C connector at the SEM end.

Gas Filling

LIC: For NAL use the ion chamber was filled to 1.8 psi (using crude meter on chamber) of commercial grade hydrogen gas. The temperature at the time of filling was estimated to be 80°F.

SEM: The SEM has been under vacuum continuously since its initial operation at Cornell in 1967. It is unlikely that the vacuum rose above a few microns in transporting it. A Vacion pump is permanently installed on the SEM and should be left on at all times. If the pump is off for more than 10 minutes, it may be necessary to restart it with a diffusion pump. A typical Vacion current is 200 μ A for a vacuum $<10^{-6}$ mm Hg.

Signal Cables

Two RG 8/u single shielded cables were pulled for the signals. These were previously tested for leakage and found to be mostly satisfactory, although with increased care better results could be obtained. They are about 150 feet long and have rf connectors at the integrator ends. If they are moved or bent, charge leaks out of the dielectric and it is necessary to wait ~ one hour (worst case) before things settle down. These cables should not be run through a patch panel or mistreated or they will become useless.

Calibration Procedure

The calibration of both monitors was done using 100 Mev electrons at the linac located at the U. S. Naval Postgraduate

School in Monterey, California with the help of Professor E. Dally and co-workers. 100 Mev electrons were used because the monitor calibration should depend only on the particle velocity which then is the same as for 200 GeV protons. The primary standard for beam intensity was a Faraday cup, with an absolute precision of $\pm 2\%$. Carey Model 410 vibrating reed electrometers were used along with 1% precision capacitors. The machine gave a nominal 2 μ sec pulse at a rep. rate of 60 cps.

SEM Calibration

$$\frac{Q_{SEM}}{Q_{BEAM}} = 0.274 \pm .010 \quad (HV = -400 \text{ volts})$$

Calibration intensity: 2×10^7 electrons/pulse to 1.4×10^{10} electrons/pulse. 17 ratios were determined. No systematic variation was observed. The lowest ratio was 0.266, the highest 0.292. The calibration took about 2 hours. The beam spot was 1.2 cm in diameter and was not moved during the calibration.

Ion Chamber Calibration (Electrons)

Two gas mixtures were used:

- (a) commercial grade He
- (b) ultra-pure H₂

In both cases the chamber was evacuated to less than 50 microns vacuum and then filled to +2 psi on the meter. We estimate this meter is accurate to $\pm 5\%$ of the absolute pressure (~ 16.7 psi at 70° F.) A range of beam currents was used from 10^6 to over 10^{10} electrons/pulse.

The results are as shown in the table below:

<u>Gas</u>	<u>HV</u>	<u>Q_{IC}/Q_{BEAM}</u>	<u>Saturation Intensity</u>
He	- 500 v	19.1 ± .1 (relative error)	<5x10 ⁸
	-1000 v	19.7 ± .1	<10 ⁹
H ₂	- 800 v	13.7 ± .1	<10 ⁹

Calibration for NAL H₂ Filling

Assuming dE/dx in the NAL commercial grade H₂ is the same as for one pure USN H₂ (the saturation may be somewhat lower due to impurities in the gas), we get (correcting for temperature and pressure differences):

$$\begin{aligned} \frac{Q_{LIC}}{Q_{BEAM}} &= \frac{(293^{\circ}K)}{(298^{\circ}K)} \times \frac{16.5}{16.7 \text{ psi}} \times 13.7 \\ &= 0.97 \times 13.7 \end{aligned}$$

Large ion chamber calibration	$\frac{Q_{LIC}}{Q_{BEAM}} = 13.3 \pm .7$
-------------------------------------	--

The error is largely from uncertainties in the filling of the chamber.

Saturation Characteristics

Figure 1 shows the saturation behavior of the ion chamber filled with He gas at -1000 and -500 volts. The hydrogen data is not shown, but resembles the -500 v curve for He. If we take $I_{SAT} = 5 \times 10^8$ electrons/pulse/1.2 cm diameter beam, we can easily calculate the saturation at NAL with a 2 mm diameter spot.

Fast	$I_{SAT} = \frac{(.2)}{(1.2)} \times 5 \times 10^8$ protons/burst
Spill	$I_{SAT}^{FAST \text{ SPILL}} = 1.4 \times 10^7$ protons/burst

This means that the LIC is not useful on fast spill at normal intensities.

To estimate the behavior with slow spill is difficult since a detailed theory of the recombination and collection of positive ions is necessary. We will make two calculations, one optimistic and one pessimistic. The optimistic calculation assumes that 20 μ sec is sufficient to clear the chamber and the pessimistic that 1 msec is needed. Under the optimistic calculation, a nominal 100 msec spill (5000 main ring traverses, each with 12 booster pulses) will give:

$$I_{SAT}^{SLOW SPILL} < 0.8 \times 10^{12} \text{ p/burst} \quad (\text{optimistic})$$

$$I_{SAT}^{SLOW SPILL} < 1.4 \times 10^9 \text{ p/burst} \quad (\text{pessimistic})$$

There is such a large range here that this number should be empirically determined using the SEM as a primary monitor. Note it will depend on the operating conditions of the main ring and extraction duty factor.

10%

ION CHAMBER
(KROHNE)

He Gas Filling

500 1000
1000 2000
2000 4000
4000 8000
8000 16000
16000 32000
32000 64000
64000 128000
128000 256000
256000 512000
512000 1024000
1024000 2048000
2048000 4096000
4096000 8192000
8192000 16384000
16384000 32768000
32768000 65536000
65536000 131072000
131072000 262144000
262144000 524288000
524288000 1048576000
1048576000 2097152000
2097152000 4194304000
4194304000 8388608000
8388608000 16777216000
16777216000 33554432000
33554432000 67108864000
67108864000 134217728000
134217728000 268435456000
268435456000 536870912000
536870912000 1073741824000
1073741824000 2147483648000
2147483648000 4294967296000
4294967296000 8589934592000
8589934592000 17179869184000
17179869184000 34359738368000
34359738368000 68719476736000
68719476736000 137438953472000
137438953472000 274877906944000
274877906944000 549755813888000
549755813888000 1099511627776000
1099511627776000 2199023255552000
2199023255552000 4398046511104000
4398046511104000 8796093022208000
8796093022208000 17592186044416000
17592186044416000 35184372088832000
35184372088832000 70368744177664000
70368744177664000 140737488355328000
140737488355328000 281474976710656000
281474976710656000 562949953421312000
562949953421312000 1125899906842624000
1125899906842624000 2251799813685248000
2251799813685248000 4503599627370496000
4503599627370496000 9007199254740992000
9007199254740992000 18014398509481984000
18014398509481984000 36028797018963968000
36028797018963968000 72057594037927936000
72057594037927936000 144115188075855872000
144115188075855872000 288230376151711744000
288230376151711744000 576460752303423488000
576460752303423488000 1152921504606846976000
1152921504606846976000 2305843009213693952000
2305843009213693952000 4611686018427387904000
4611686018427387904000 9223372036854775808000
9223372036854775808000 18446744073709551616000
18446744073709551616000 36893488147419103232000
36893488147419103232000 73786976294838206464000
73786976294838206464000 147573952589676412928000
147573952589676412928000 295147905179352825856000
295147905179352825856000 590295810358705651712000
590295810358705651712000 1180591620717411303424000
1180591620717411303424000 2361183241434822606848000
2361183241434822606848000 4722366482869645213696000
4722366482869645213696000 9444732965739290427392000
9444732965739290427392000 18889465931478580854784000
18889465931478580854784000 37778931862957161709568000
37778931862957161709568000 75557863725914323419136000
75557863725914323419136000 151115727451828646838272000
151115727451828646838272000 302231454903657293676544000
302231454903657293676544000 604462909807314587353088000
604462909807314587353088000 1208925819614629174706176000
1208925819614629174706176000 2417851639229258349412352000
2417851639229258349412352000 4835703278458516698824704000
4835703278458516698824704000 9671406556917033397649408000
9671406556917033397649408000 19342813113834066795298816000
19342813113834066795298816000 38685626227668133590597632000
38685626227668133590597632000 77371252455336267181195264000
77371252455336267181195264000 154742504910672534362390528000
154742504910672534362390528000 309485009821345068724781056000
309485009821345068724781056000 618970019642690137449562112000
618970019642690137449562112000 1237940039285380274899124224000
1237940039285380274899124224000 2475880078570760549798248448000
2475880078570760549798248448000 4951760157141521099596496896000
4951760157141521099596496896000 9903520314283042199192993792000
9903520314283042199192993792000 19807040628566084398385987584000
19807040628566084398385987584000 39614081257132168796771975168000
39614081257132168796771975168000 79228162514264337593543950336000
79228162514264337593543950336000 158456325028528675187087900672000
158456325028528675187087900672000 316912650057057350374175801344000
316912650057057350374175801344000 633825300114114700748351602688000
633825300114114700748351602688000 1267650600228229401496703205376000
1267650600228229401496703205376000 2535301200456458802993406410752000
2535301200456458802993406410752000 5070602400912917605986812821504000
5070602400912917605986812821504000 10141204801825835211973625643008000
10141204801825835211973625643008000 20282409603651670423947251286016000
20282409603651670423947251286016000 40564819207303340847894502572032000
40564819207303340847894502572032000 81129638414606681695789005144064000
81129638414606681695789005144064000 162259276829213363391578010288128000
162259276829213363391578010288128000 324518553658426726783156020576256000
324518553658426726783156020576256000 649037107316853453566312041152512000
649037107316853453566312041152512000 1298074214633706907132624082305024000
1298074214633706907132624082305024000 2596148429267413814265248164610048000
2596148429267413814265248164610048000 5192296858534827628530496329220096000
5192296858534827628530496329220096000 10384593717069655257060992658440192000
10384593717069655257060992658440192000 20769187434139310514121985316880384000
20769187434139310514121985316880384000 41538374868278621028243970633760768000
41538374868278621028243970633760768000 83076749736557242056487941267521536000
83076749736557242056487941267521536000 166153499473114484112975882535043072000
166153499473114484112975882535043072000 332306998946228968225951761070086144000
332306998946228968225951761070086144000 664613997892457936451903522140172288000
664613997892457936451903522140172288000 1329227995784915872903807044280344576000
1329227995784915872903807044280344576000 2658455991569831745807614088560689152000
2658455991569831745807614088560689152000 5316911983139663491615228177121378304000
5316911983139663491615228177121378304000 10633823966279326983230456354242756608000
10633823966279326983230456354242756608000 21267647932558653966460912708485513216000
21267647932558653966460912708485513216000 42535295865117307932921825416971026432000
42535295865117307932921825416971026432000 85070591730234615865843650833942052864000
85070591730234615865843650833942052864000 170141183460469231731687301667884105728000
170141183460469231731687301667884105728000 340282366920938463463374603335768211456000
340282366920938463463374603335768211456000 680564733841876926926749206671536422912000
680564733841876926926749206671536422912000 1361129467683753853853498413343072845824000
1361129467683753853853498413343072845824000 2722258935367507707706996826686145691648000
2722258935367507707706996826686145691648000 5444517870735015415413993653372291383296000
5444517870735015415413993653372291383296000 10889035741470030830827987306744582766592000
10889035741470030830827987306744582766592000 21778071482940061661655974613489165533184000
21778071482940061661655974613489165533184000 43556142965880123323311949226978331066368000
43556142965880123323311949226978331066368000 87112285931760246646623898453956662132736000
87112285931760246646623898453956662132736000 174224571863520493293247796907913264465472000
174224571863520493293247796907913264465472000 348449143727040986586495593815826528930944000
348449143727040986586495593815826528930944000 696898287454081973172991187631653057811888000
696898287454081973172991187631653057811888000 1393796574908163946345982375263306115623776000
1393796574908163946345982375263306115623776000 278759314981632789269196475052661223247552000
278759314981632789269196475052661223247552000 557518629963265578538392950105322446495104000
557518629963265578538392950105322446495104000 1115037259926531157076785900210644892990208000
1115037259926531157076785900210644892990208000 2230074519853062314153571800421289785980416000
2230074519853062314153571800421289785980416000 4460149039706124628307143600842579571960832000
4460149039706124628307143600842579571960832000 8920298079412249256614287201685159143921664000
8920298079412249256614287201685159143921664000 17840596158824498513228574403370318287843328000
17840596158824498513228574403370318287843328000 35681192317648997026457148806740636575686656000
35681192317648997026457148806740636575686656000 71362384635297994052914297613481273151373312000
71362384635297994052914297613481273151373312000 142724769270595988105828595226962546302746624000
142724769270595988105828595226962546302746624000 285449538541191976211657190453925092605493248000
285449538541191976211657190453925092605493248000 570899077082383952423314380907850185210986496000
570899077082383952423314380907850185210986496000 1141798154164767904846628761815700370421972992000
1141798154164767904846628761815700370421972992000 2283596308329535809693257523631400740843945984000
2283596308329535809693257523631400740843945984000 4567192616659071619386515047262801481687891968000
4567192616659071619386515047262801481687891968000 9134385233318143238773030094525602963375783936000
9134385233318143238773030094525602963375783936000 18268770466636286477546060189051205926751567872000
18268770466636286477546060189051205926751567872000 36537540933272572955092120378102411853503135744000
36537540933272572955092120378102411853503135744000 73075081866545145910184240756204823707006271488000
73075081866545145910184240756204823707006271488000 146150163733090291820368481512409647414012542976000
146150163733090291820368481512409647414012542976000 292300327466180583640736963024818828828025089536000
292300327466180583640736963024818828828025089536000 584600654932361167281473926049637657656050179072000
584600654932361167281473926049637657656050179072000 1169201309864722334562947852099275315312100358144000
1169201309864722334562947852099275315312100358144000 2338402619729444669125895704198550630624200716288000
2338402619729444669125895704198550630624200716288000 4676805239458889338251791408397101261248401432576000
4676805239458889338251791408397101261248401432576000 9353610478917778676503582816794202522496802865152000
9353610478917778676503582816794202522496802865152000 18707220957835557353007165633588405044993605730304000
18707220957835557353007165633588405044993605730304000 37414441915671114706014331267176810089987211460608000
37414441915671114706014331267176810089987211460608000 74828883831342229412028662534353620179974423121216000
74828883831342229412028662534353620179974423121216000 149657767662684458824057325068707240359948846242432000
149657767662684458824057325068707240359948846242432000 299315535325368917648114650137414480719897721484864000
299315535325368917648114650137414480719897721484864000 598631070650737835296229300274828961517915442969728000
598631070650737835296229300274828961517915442969728000 1197262141301475670592458600549657923135829885939552000
1197262141301475670592458600549657923135829885939552000 2394524282602951341184917201099315846671657711879104000
2394524282602951341184917201099315846671657711879104000 4789048565205902682369834402198631693343315423758208000
4789048565205902682369834402198631693343315423758208000 9578097130411805364739668804397263386686630847516416000
9578097130411805364739668804397263386686630847516416000 19156194260823610729479337608794526773373261695032832000
19156194260823610729479337608794526773373261695032832000 38312388521647221458958675217589053546746523390065664000
38312388521647221458958675217589053546746523390065664000 76624777043294442917917350435178107093493046780131328000
76624777043294442917917350435178107093493046780131328000 153249554086588885835834700870356214186986093560262656000
153249554086588885835834700870356214186986093560262656000 306499108173177771671669401740712423739171787120525312000
306499108173177771671669401740712423739171787120525312000 6129982163463555433433388034814248474783435742410506048000
6129982163463555433433388034814248474783435742410506048000 12259964326927110866866776069628496949566871484821101216000
12259964326927110866866776069628496949566871484821101216000 24519928653854221733733552139256993899133742969642202224000
24519928653854221733733552139256993899133742969642202224000 49039857307708443467467104278513987798266745939284404448000
49039857307708443467467104278513987798266745939284404448000 98079714615416886934934208557027975596533491878568808896000