PS-LP Note 89-05 23. 5. 1989

OPERATION OF LIL IN 1989

A proposal

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1. *INTRODUCTION.*

We now have got the experience of running for the LEP Injector Chain in an operational way in Summer 1988 and we did a number of experiments at the end of 88. This was not academic research but it was undertaken to deepen our understanding. All the work [1 ... 7] is now analyzed and has been discussed [8]. Furthermore, we know now very well the LEP requirements [9, 10] which can easily be satisfied with the nominal number of e^+/e^- in a LIL pulse ($N^+ = 6 \times 10^8$, $N^- = 3 \times 10^9$ both in $\pm$ 1%). Hence, a proposal how to run LIL can now be formulated to provide an ordered basis for start-up and running. Since there is no immediate demand for performance exceeding the obtained peak performance, the emphasis is on consolidation at 500 MeV, i. e. reliable, reproducible operation up to say 50% above nominal performance.

Running at 600 MeV is not recommended because it would disrupt the more important 500 MeV consolidation work.

The second point in this note deals with the configuration proposed for the start-up in May 1989. It is recommended to use the settings we had during a good, well-documented e^+ MD run in December 1988[1]), where the nominal e^+ charge was produced with a 50% safety margin and the Q^+/Q^- curve did now show any saturation. The LIL operation procedures being written by H. Kugler (LIL-V) and by A. Riche (LIL-W) propose the same parameter as given under point 2 in order to be consistent. For LIL-V, we propose the same klystron settings as in December 88 with klystron 03 at about 12 MW and klystron 13 with 23 MW. For LIL-W, we do not suggest the settings of December 88 as they were odd and klystron 35 was not working properly. It is proposed to run LIL-W at uniform energy gain per section, namely 43 MeV per section. Although only about 16 MW are needed for that, we have selected experimentally verfied settings of the focal currents for a higher power to have some margin. The actual power is to be adjusted by lowering the high voltage. We hope to have enough input power even with the LAL booster to saturate the klystrons.

The third point lists items requiring special attention during start-up, some of these items are also mentioned in the LIL procedures by Kugler and Riche.

The fourth point gives a list of possible improvements which should be implemented at a later stage.

2. *START-UP CONFIGURATION*

It is identical to the configuration used on 12. 12. 1988 with P(13) = 23.3 MW [1]. This leads to a LIL-V non-load energy of E_0 = 0.26 GeV and an energy spread of $\Delta E = \pm$ 16 MeV for Q^- = 30 nC at VL.UMA15. This configuration showed a constant conversion efficiency as far as we measured. We had $N^+ = 9 \times 10^8$ per pulse in $\pm$ 1% at the maximum. The e^+ energy spread was 1.1% FWHH.

The proposed klystron settings are shown in Table 1. They provide an adequate power reserve; they are either data from Thomson or are tested by J.P. Perrine. It is very likely that the klystrons can be saturated. The required power in LIL-W given in column 6 corresponds to 516 MeV [3,13]. Note that the klystron 03 should provide 14.7 MW in order to give the peak power of 11 MW to buncher V. Since the buncher is at present not conditioned for this high power, we prefer to limit the power to 12 MW at the klystron.

In order to see the difference to the klystron operating conditions in December, Table I must be compared with Table II, which gives an estimate of the klystron input and output powers used in December 88 based on the U (Box C) measurements. The rf powers are derived using the following fit to the box C characteristics

$$P_c(W) = (U(V)/11)^{1/0,572}$$

and by taking into account the attenuation given in the cable list which is based on former measurements. Although the precision of this procedure is not very high, it is the best estimate we can produce. The output power of KLY 35 is very low. An error in the reading of U (PLI 35) is excluded as it is indeed consistently low on both rf logs made independently. Both logs show also as further evidence a very low U (PSI 35 − 1) and a low klystron voltage. Table II gives also the calculated energy gain per section. For the sections connected to LIPS, this value is the maximum obtainable with optimum timing. Adding up all the energy gain in LIL-W would give 570 MeV, if LIPS 27 and 31 had optimum timing. Since we had only 500 MeV, the timing was certainly not optimum and/or we possibly overestimate the klystron power. Since we have no timing measurement,. we cannot disentangle the two effects. Table III gives the focal currents of the klystrons used in December according to P. Pearce. Klystron 35 has been replaced in the meantime. The Thomson booster was used during the relevant tests [1, 11].

Table IV gives the other parameters [11] and the e^+ phases [1] used in December for reference. The table gives for completeness the manual settings of the klystron voltages which are now under computer control. The phases for e^+ operation are given because they might be useful starting points for the new adjustments. New e^+ phases must be found in LIL-W as the operating points of the klystrons are different.

The gun parameters are

U (HV)	=	70 kV
U (polar)	=	900 kV
U (pulse)	=	3 kV

The settings for the pulse length is 25 ns yielding a pulse length of 20 ns (FWHH = $Q/\hat{I}$). The prebuncher settings proposed are 56 for the phase and the setting 160 for attenuation. These are the optimum values [5].

Table V gives the currents in the magnetic elements [12] in the form: measured value (value set by control). The currents in bucking coil VL.SNA01 and in the solenoid VL.SNB02 after the anode are set to provide the same number of Ampère x turns in the new solenoids as we had with the old ones. It is suggested to start with all the steering in the quads of LIL-W switched off for e^+ and e^- because the accidental misalignement of the quads will be different after the recent repairs in LIL. A new steering configuration in LIL-W must be established.

Table VI gives the typical LIL-V transmission during e^+ production with an electron charge of 30 nC at the target, which is the value eventually to be reached during start-up. The number of positrons per pulse should then be 6 x 10^8 (resolved in $\Delta E/E = \pm 1\%$) and 8 x 10^8 unresolved.

Since no 500 MeV electrons have been run in this configuration, also new e^- phases must be found and the correct timing of the phase jump of RF 31 to get to 500 MeV with the e^- has to be found. If the difference between the timing of this phase jump for e^+ and e^- becomes uncomfortably big, the timing of the RF 13 phase jump can be made different for e^+ and e^-, a possibility not used until now (hardware and software exist).

3. *ITEMS DESERVING SPECIAL ATTENTION*

- Stable klystrons in saturation (including 03!), Interlock levels correct;
- Iterate a, b, c:

a) UMA tests (watch especially the timing);

b) Make ΔX (UMA) / (ΔI corrector) tests using existing LIL-V TRANSPORT;

c) Correct LIL-V trajectory to eliminate steering by quads.

- Find reason for systematic off-set of Σ (UMA 25) during e^+ production (backscattered e^- from target ?)
- Beam size at target must be around 1 mm (FWHH at WBS 25) at $Q^- = 30$ nC;
- Make ARCHIVES and ALARM really operational by subjecting it to systematic, rigorous tests, e.g. switch off and on repeatedly to find weak points;
- Teach operators how to make complete logs regularly and to analyse them critically. LIL e^+/e^- energies and energy spreads are essential parameters including the number of e^+ in ± 1%. Why not put eventually the log on a VM file of the user LPI?
- Make operators able to "fly alone" by training and by providing them with documentation. Give them clear, written instructions.

4. *INTRODUCTION OF NEW THINGS*

To be done later when time available:

- If not done already during start-up, adjust the klystron power in LIL-W (see Table I) such that all sections have really the same energy gain of 43 MeV, yielding a total gain of 516 MeV. Adding the e^+ input energy of 4 MeV gives 520 MeV which provides an adequate margin of + 4%. The energy is reduced to 500 MeV by changing the LIPS phase-jump timing of 31 as usual. This will do away with the very unusual energy gains in the sections and the spread in the klystron powers which crept in over the years for unknown reasons.

All klystrons must be in saturation. KLY 13 is left at 23 MW. By the way, this is the highest power needed in LIL-W for running it at 600 MeV (51 MeV/ACS) permitting us to gather experience with this power level.

- Optimise the tuning of the LIPS cavities
- Optimise the water temperature of the ACS by taking into account the cross-coupling due to cooling stations (LIPS 27, 31 is cooled by cooling station 25, 27).
- Check whether the currents in the solenoids between gun and prebuncher are optimum [14].
- Introduce and test the LIL-W energy feed-back using the ΔX-signal from HIx.UMA 22 to control the timing of LIPS31 phase jump. Priority e^+ but eventually also e^-.
- Test LIL temperature stability by varying temperature of klystron gallery.
- Test the remote reading of the klystron output power via HP peak power meters. Include the booster.
- Introduce and test software for energy spread measurement. LIL-V: automatic trajectory alignment before spectrometer and adjustment of quadrupoles for focus on MSH15; LIL-W: automatic moving of collimators in HIP to $\pm$ 1% and measurement of resolved intensity; automatic trajectory alignment before BSH00 could be included later.
- Logging and monitoring by ALARM of LIL water temperature (ACS and LIPS); check whether present T are optimum;
- Test off-line TRANSPORT in LIL-W as being prepared by A. Riche;
- Test the new slits installed in LIL-V (water cooling o.k.?);
- Check the steering in LIL-V including the earth-field compensations;
- together with EPA:

  * check the betatron matching to EPA;

  * define software for computer-assisted matching measurement (at present, the measurement is so complicated that we have performed it only *once* in three years)

  * shorten the LIL pulse to Δt = 15 ns or 10 ns to give it a bigger margin in the EPA bucket. Will reduce sensitivity of accumulation in EPA against LIL energy fluctuations. Procedure: keep charge constant and increase current from gun. At present, for 30 nC at UMA 15 gun V delivers I = 3.3 A according to table VI. The gun is built and tested for 12A. The conversion efficiency is independent of the current [2]. The effect of the variation of the gun parameters on the current for e^- operation must also be observed because the proper modulation of current must be maintained.

Table 1: Preferred LIL Klystron settings for start-up on May 1989

MDK	Tube	Focal Currents I_A	I_B	I_C	required P_{kl}	measurement P_{kl}	U_{kl}	I_{kl}	P_{in}	Date by
		A	A	A	MW	MW	kV	A	kW	
03	VA05	196	87	85	12	12	188	167	0.25	11.3.88 J.P. Perrine
13	VA06	174	124	91	23	23.3	257 a)	256	0.16	and MD [1]
25	TH04	159	132	156	16.5	20	226	208	0.14	Thomson data
27	TH05	174	157	165	14.6	18.1	225 b)	210	0.25	11.3.88 J.P. Perrine
31	VA04	170	126	83	14.7	18.4	219	211	0.21	9.3.88
35	TH08	175	135	145	16.4	20.1	216	198	0.15	2.3.88 Thomson data

a) reference [1] claims 276 kV (38 kV ref. voltage)

b) TH05 was also run with 233 kV x 216 A at that time but without power measurement.

Table II: Estimated input and output power of klystrons, energy gain per section in December 1988

KLY	03	13	25	27	31	35
U (PPI) (V)	0.84	0.68	?	1.9	1.7	1.5
Attenuation (dB)	43.5	43.4	37.6	37.7	37.9	37.8
P_{in}(kW)	0.25	0.17	0.30 a)	0.27	0.22	0.19
U (PKI) (V)	2.1	0.82 b)	1.95	1.9	1.85	0.7
Attenuation (dB)	83.2	93.4	85.9	87.2	87.3	86.1
P_{kl} (MW)	11.6	23.3 c)	18.9	24.4	23.8	3.3
ΔE/section (MeV)	31	54	46	56	55	19

a) measuurement spring 88 (R. Bossart)

b) calculated from P_{kl} measured

c) measured by peak power meter connected directly to coupler PKI 13.

Table III: Klystron focusing currents in December 1988

KLY	03	13	27	27	31	35
I (focal A) (A)	197.8	173.9	162.8	173.4	170.0	186.8
I (focal B) (A)	87.9	124.0	157.1	157.0	125.9	124.5
I (focal C) (A)	86.7	91.0	141.5	165.5	82.9	157.4
Meas. date in MDK log book	28.9.88	21.9.88	16.11.88	16.11.88	16.11.88	16.11.88

Table IV:

RF parameters (rf log 11. 12. 88 complemented with rf log 10. 12. 88)

MDK/KLY	05	03	13[1]	25	27	31	35
MDK Setting	800	2+64	-	2+8	2+8+	2+8+	2+16+
	-	+ 128	-	+ 32	64+128	32+64	32+64
U_{kl} (kV)	19.5	188	258	239	243	232	172?
RF phase [1]	-	140	340	155	128	72	267
T (°C)	-	31.6	29.9	29.9	30.6	29.9	29.0

Table VI:

Transmission in LIL-V at about nominal e^- charge (P_{13} = 23.3 MW)

Monitor	Particles/pulse x 10^{-11}	Charge/pulse nC	Relative to UMA 15 %
ECM 01	4.13	66	236
WCM 11	2.25	36	129
WCM 12	1.85	30	107
UMA 13	1.81	29	104
WCM 14	1.87	30	107
UMA 15	1.72	28	100
UMA 22	1.82	29	104
UMA 25	1.50	24	86

USER POSIT 10-12-1988 16:44:30

TABLE V (1.part) LIL LOG

21.3.89

HORIZONTAL STEERING

```
VL.DHG031                    VL.DHG032                    VL.DHZ11                     VL.DHG1199
    2.45 AMP  (   2.50)          2.50 AMP  (   2.51)          .03 AMP  (    .03)          .05 AMP  (    .05)

VL.DQS121H                   VL.DQS132H                   VL.DQS141H                   VL.DHZ14
    5.88 AMP  (   5.99)          5.72 AMP  (   5.80)        0     AMP  (   0   )          .09 AMP  (    .09)

VL.BSP15        STANDBY      VL.DQL152H                   VL.DHZ25                     WL.DHG251
     .36 AMP  ( 264.36)           .20 AMP  (    .20)         1.69 AMP  (   1.70)       -14.15 AMP  ( -14.28)

WL.DHG252                    WL.DHG261                    WL.DHG262                    WL.DQL272H
  -14.21 AMP  ( -14.40)        -18.78 AMP  ( -18.80)         2.98 AMP  (   2.99)        -3.06 AMP  (  -2.99)

WL.DQNF271H                  WL.DQL28H                    WL.DQNF284H                  WL.DQNF292H
   -3.10 AMP  (  -3.10)          5.03 AMP  (   5.00)        -1.01 AMP  (  -1.00)        0     AMP  (   0   )

WL.DQNF302H                  WL.DQNF313H                  WL.DQNF331H                  WL.DQNF342H
  0     AMP  (   0   )         0     AMP  (   0   )         0     AMP  (   0   )        0     AMP  (   0   )

WL.DQNF362H                  HI.BSHOC                     HI.BHZ
     .06 AMP  (   0   )        173.62 AMP  ( 173.50)       387.04 AMP  ( 388.08)
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VERTICAL STEERING

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VL.DVG031                    VL.DVG032                    VL.DVT11                     VL.DVG1199
    -.03 AMP  (   -.03)          -.03 AMP  (   -.03)         1.47 AMP  (   1.46)          .13 AMP  (    .13)

VL.DQL12V                    VL.DQL13V                    VL.DQL14V                    VL.DVT14
   -2.21 AMP  (  -2.24)          2.01 AMP  (   2.03)        -2.97 AMP  (  -2.99)        0     AMP  (   0   )

VL.DQL153V                   VL.DVT25                     WL.DVG251                    WL.DVG252
   -5.40 AMP  (  -5.50)          1.79 AMP  (   1.79)        11.31 AMP  (  11.40)        11.34 AMP  (  11.40)

WL.DVG261                    WL.DVG262                    WL.DQL271V                   WL.DQNM273V
   12.14 AMP  (  12.19)         11.92 AMP  (  12.00)        -4.72 AMP  (  -4.69)          .84 AMP  (    .81)

WL.DQNF274V                  WL.DQNF283V                  WL.DQNF291V                  WL.DQNF301V
  0     AMP  (   0   )            .01 AMP  (   0   )        0     AMP  (   0   )        0     AMP  (   0   )

WL.DQNF312V                  WL.DQNF323V                  WL.DQNF341V                  WL.DQNF361V
  0     AMP  (   0   )         0     AMP  (   0   )         0     AMP  (   0   )         2.02 AMP  (   2.00)

HI.BVTOO
   63.93 AMP  (  64.29)
```

RECTIFIERS - STATUS ONLY

```
REC27 (sect.27   )  ON     REC28 (sect.28-29)  ON     REC30 (sect.30-32)  ON     REC33 (sect.33-36)  ON
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SLITS

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VL.SLV12AP 49.9  m)                VL.SLV12PO  0    mm.
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Table V.1

8

23.5.

TABLE V.2

23.5.89

FOCUSING

VL.SNA01 5.9 AMP	(5.9)	VL.SNB02 40 AMP	(40)	VL.SNC02 12.23 AMP	(12.20)	VL.SNDE02 112.12 AMP	(112.9)
VL.SNVU03 69.84 AMP	(70.10)	VL.SNF11 114.58 AMP	(114.90)	VL.QSA1212 2.50 AMP	(2.52)	OVL.QLA12 2.68 AMP	(2.78)
VL.QSA1312 2.06 AMP	(2.09)	VL.QLA13 2.84 AMP	(2.89)	VL.QSA1412 4.31 AMP	(4.49)	VL.QLA14 4.82 AMP	(4.79)
VL.QLB1514 53.90 AMP	(53.90)	VL.QLB1523 50.73 AMP	(50.69)	WL.SNP25 3013.92 AMP	(2899.63)	WL.QLA271 5.92 AMP	(6.00)
WL.QLA272 8.80 AMP	(8.99)	WL.QLB2829 54.11 AMP	(55.00)	WL.SNL25 624.85 AMP	(624.97)	WL.SNL26 674.11 AMP	(674.96)
WL.QNM271 96.59 AMP	(96.97)	WL.QNM272 103.34 AMP	(104.08)	WL.QNM273 104.01 AMP	(106.53)	WL.QNFA 135.23 AMP	(135.99)
WL.QNFB 134.85 AMP	(135.00)	WL.QNFC 128.90 AMP	(128.99)	WL.QNM36 82.72 AMP	(84.00)	HI.QFD1 94.96 AMP	(96.99)

LIL TIMING.

VX.SBKLY	29874(FAST RF)	VX.WGUNP	29990(FAST RF)	VX.TAS	19000(FAST RF)	VX.SGUNPC	30000(FAST RF)
VX.SGUND	50000(FAST RF)	VX.SGUNPF	61(1 MHZ)	VX.SKLY03	29911(FAST RF)	VX.SRFP03	29935(FAST RF)
VX.ERFP03	30011(FAST RF)	VX.SKLY13	29885(C/D TR.)	VX.SRFP13	29917(C/D TR.)	VX.ERFP13	30010(C/D TR.)
VX.SRFI13C	29977(C/D TR.)	VX.SRFI13F	49(1 MHZ)	WX.TAS	11000(C/D TR.)	WX.FSNP25	50000(1 MHZ)
WX.ASNP25C	30000(1 MHZ)	WX.WSNP25P	20461(1 MHZ)	WX.WSNP25D	20461(1 MHZ)	WX.SSNP25PC	29852(1 MHZ)
WX.SSNP25DC	29986(1 MHZ)	WX.ASNP25F	4(1 MHZ)	WX.SSNP25PF	4(1 MHZ)	WX.SSNP25DF	4(1 MHZ)
WX.SKLY25	29943(C/D TR.)	WX.SRFP25	29967(C/D TR.)	WX.ERFP25	29900(C/D TR.)	WX.SKLY27	29888(C/D TR.)
WX.SRFP27	29919(C/D TR.)	WX.ERFP27	30011(FAST RF)	WX.SRFI27EC	29985(C/D TR.)	WX.SRFI27PC	29990(C/D TR.)
WX.SRFI27EF	20(C/D TR.)	WX.SRFI27PF	40(C/D TR.)	WX.SKLY31	29885(C/D TR.)	WX.SRFP31	29932(C/D TR.)
WX.ERFP31	30007(FAST RF)	WX.SRFI31EC	29980(C/D TR.)	WX.SRFI31PC	29990(C/D TR.)	WX.SRFI31EF	1(C/D TR.)
WX.SRFI31PF	40(C/D TR.)	WX.SKLY35	29937(C/D TR.)	WX.SRFP35	29978(FAST RF)	WX.ERFP35	30004(C?D TR.)

MODULATOR PHASES

~~MDK03 172.9 (172.9)~~
~~MDK13 11.2 (11.2)~~
~~MDK25 163.1 (163.1)~~

Table V.2

23.5.89

21.3.89

TABLE V.3

*** EPA LOG ***

USER POSIT 11-12-1988 20:29:20

TRANSFER LIL TO EPA.

WL.QNM36 82.72 AMP (84.00)	HI.BSH00 173.56 AMP (173.50)	HI.BVT00 63.90 AMP (64.29)	HI.BVT30 62.56 AMP (64.32)
HI.BHZ 387.04 AMP (388.08)	HI.QFD1 94.94 AMP (96.99)	HI.QFD2 112.87 AMP (113.09)	HIE.DHZ25 -.99 AMP (-.99)
HIP.DHZ25 0 AMP (0)			

SLITS

HIE.SLH20AP 50 mm.	HIE.SLH20P0 0 mm.	HIP.SLH20AP 49.8 mm.	HIP.SLH20P0 0 mm.

GENERAL TIMING

HX.TZC	29987(FAST RF)	HX.AS	1(C/D TR.)	HX.SBURF	2(FAST RF)	HX.WPLS	400(C/D TR.)
HX.RPLS	40(C/D TR.)	HX.FHC	56(C/D TR.)	HX.FHC	56(C/D TR.)	HX.RHC	1500(1 MHZ)
HX.FBP	560(C/D TR.)	HX.WBP	1(C/D TR.)	HX.RBP	1501(1 MHZ)	HX.AEJ	10000(1 MHZ)
HX.FES 0	1(C/D TR.)	HX.FEJ	689(C/D TR.)	HX.REJ	4767(FAST RF)	HX.WEJS	19087(FAST RF)
HX.WEJP	1(FAST RF)	HX.FHS	498(C/D TR.)	HX.RACE	1(C/D TR.)	HX.RACP	1(C/D TR.)
HX.RINT	1(1 MHZ)	HX.RDAMP	476 AQN. ERR	HX.SBURF	2(FAST RF)		

ELECTRON INJECTION. (See Bump Status)

10

23.5.

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