CHANGE REQUEST NO. ILC-CR-0021	EDMS No: D0000000xxxxxxx	Created: 23-06-2020
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UPDATED POWER ESTIMATE FOR Z-POLE OPERATION OF ILC-250

The estimate of the total power consumption of the ILC in its 250GeV configuration is extended to running at the Z pole.

RATIONALE

Power consumption is a key performance parameter of the accelerator. An up-to-date calculation is needed to assess the performance, also in comparison to other projects.

SCOPE: WHOLE ILC

VALUE/SCHEDULE IMPACT

Operation cost estimates depend on power consumption.

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Attachments:

Number:	modified:	by:
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Change History:

Version:	modified:	by:	what:
1.0	23.6.2020	BL	Initial version
1.1	11.1.2022	BL	Draft for Final version
1.2	11.1.2022	BL	Version for IDT Review

IMPLEMENTATION PLAN

Can be left blank for first submission.

Concerned Parties (Work Packages, Coordinators, Suppliers etc.)

WF/Area	

Affected documents

EDMS ID	Title	Remark
D00000000965055	ILC AC power estimate summary	

ATTACHEMENT 1

1. Introduction

We present here update calculations for the ILC, in its baseline 250GeV configuration with a short tunnel, as proposed in Japan, for operation at the Z pole (91.2GeV centre-of-mass energy).
The configuration assumed is that described in Change Request ILC-CR-0018 [1].

1.1 Accelerator Configuration

1.1.1 ILC-250 baseline configuration for Z pole runnig

We calculate the power consumption of the ILC in the configuration defined in CR-0018 [1], with

The accelerator is built with the minimum main linac tunnel length necessary for 250GeV operation, taking into account the DR timing constraint for an undulator positron source.

- Positrons are produced by an undulator source, with a 231m long helical undulator, from the 125GeV electron beam. The electron accelerator delivers alternating beams at 45.6 GeV for collision and 125GeV for positron production.
- The RF scheme is the "Distributed Klystron System" (DKS) of the TDR.
- One electron and positron damping ring is built.
- The machine operates with 1312 bunches per pulse at 554ns bunch spacing (5.8mA beam current), at 3.7Hz repetition frequency.

This configuration is denoted as ILC91.

1.1.2 Luminosity upgrade: double the number of bunches

The luminosity of the ILC can be doubled by doubling the number of bunches to 2625.

This requires:

- Installation of 50% more modulators and klystrons in the Main Linacs (3 instead of 2 klystrons per short cryo string of 9 cryo-modules)
- The installation of a second positron damping ring to mitigate instabilities from electron clouds (this measure may be unnecessary if electron cloud effects can be controlled well enough)
- Installation of additional RF power in the damping rings, with correspondingly increased cyogenic power.

- An upgrade of the electron and positron sources, with increased power consumption in the 5GeV accelerators (no new klystrons are required).
- Increased RF and cryogenic power in the bunch compressors, but no new klystrons.

1.1.3 Operation with an electron driven source

Two positron source concepts are under investigation for the ILC, the baseline concept with positron production from gammas produced by a helical undulator driven be the electron beam (“undulator scheme”), and an alternative with an independent electron beam impinging on a target (“e driven scheme”).

The undulator scheme requires an electron energy of at least 125GeV for positron production. For operation at electron beam energies below 125GeV, the electron linac has to provide two beam pulses per positron pulse: one 125GeV pulse for positron production, and one pulse for collisions. Thus, at the Z pole, more beam power (125GeV x 5.8mA) is spent on positron production than on collisions (91.2 GeX x 5.8mA).

In the electron driven scheme, a separate 6GeV electron beam is produced in a normal-conducting accelerator that produces positrons off a slowly rotating target. The positrons are accelerated in a second NC accelerator to 5GeV and injected into the Damping Rings.

2. Method

The Power estimate results from a scaling of the power estimate as presented in the TDR; the scaling relations were developed and verified during the TDR preparation.

2.1 Main Linac Power

Main Linac RF power

The main linac RF power is calculated from the RF power transferred to the beam, plus the power needed to fill the cavities, divided by the wall plug to beam efficiency of 43%. This efficiency includes the klystron operating efficiency, losses in the modulators and waveguides and overhead from variations in cavity gradients.
For the TDR, the ML RF power amounts to 52.1MW (32% of the total 163.8MW).

The operation at reduced gradient leads to operation of klystrons at lower than nominal power, which leads to a reduction in efficiency. In Ref. 3, a reduction from 67% to 57% has been determined, therefore the RF efficiency is scaled by 57/67 for the operation at lower gradient resulting in an overall efficiency of 37% instead of 47%.

For ML operation for with gradients alternating between positron production mode and collision mode, the external Q of the couplers is set to the matched value at high gradient (Q_{ext} = 5.5E6), leading to a mismatch at lower gradient. This increases the fill time in collision mode for the electron beam from 259 (171) ns for the positron beam to 329 (217) ns for the electron beam at 1312 (2625) bunches.

For an electron driven source, both, electron and positron Main Linacs will operate at matched Q.

Main Linac Cryo power

The main linac cryogenic power is calculated in the same way as in ILC-CR-0018 [Ref. 1].

Main Linac conventional systems power

The power consumption of conventional systems (heating and ventilation etc) is calcaulated in the same way as in the TDR.

Repetition rate

As explained in Ref. 3, for the alternating pulse mode of the Main Linac, the repetition rate is reduced from the nominal 5Hz to 3.7Hz to keep the overall modulator power constant. For a separate, electron driven source, this constraint does not apply, so the repetition rate is 5Hz in this case, with a correspondingly higher luminosity.

2.2 Sources and RTML

The contributions of the sources and the RTML were adjusted for the increased number of bunches per pulse and higher repetition rate by scaling up the power consumption of the RF systems.

The RF power values (4.76MW for the RTML, 1.28/1.39MW for the e-/e+ source) were scaled up by a factor of 1.6 for the case of doubling the bunch number, and doubled again for the case of 10Hz operation.
A small power saving due to the decreased length of the RTML beam transport line has not been considered.

Electron driven positron source

For the electron driven positron source, the power estimate of Ref. 3 has been updated, from 14MW to 19.8MW for the electron driven positron source.

2.3 Damping Rings

The power consumption of the damping rings was evaluated with the same method as in ILC-CR-0018.

A small power saving due to the reduction of the repetition rate from 5Hz to 3.7Hz is not taken into account.

2.4 BDS and Interaction Region

Power estimates for BDS and interaction region are taken from the TDR.

2.5 Main Campus

A 2.7MW estimate for the power consumption of the main campus has been added.

2.6 General Margin

An overall margin of 3% has been added to account for further power demands not included in the other terms, and the general uncertainty arising from the application of relatively simple scaling laws.

3. Results

The complete updated power estimate is detailed in Ref. 5.
The main result is given here for the following configurations:

- 250-A: 250GeV machine, option A (baseline configuration)
- 250-A, Lx2: 250GeV machine, running with twice the number of bunches per pulse (after luminosity upgrade)
- 91: 250GeV machine, option A, running at 91GeV c.o.m. energy, with electron pulses alternating between collision mode and positron production mode.
- 91 Lx2: Same as configuration 91, with twice the number of bunches per pulse (after luminosity upgrade)
- 91 e driven: 250GeV machine, option A, running at 91GeV c.o.m. energy, with a separate electron driven source

	250-A	250-A Lx2	91	91 Lx2	91 e driven
Rep-Rate / Hz	5	5	3.7	3.7	5
Bunches / Pulse	1312	2625	1312	2625	1312
Lumi / 10^{34}	1.35	2.7	0.21	0.41	0.28
Gradient / MV/m	31.5	31.5	8.8	8.8	8.8
Q_0/1E10	1.0	1.0	1.0	1.0	1.0
ML E-gain / GeV	220	220	61.2	61.2	61.2
ML RF / MW	24.4	35.1	13.0	19.3	4.8
ML Cryo / MW	15.4	16.4	10.4	11.5	7.1
ML Power / MW	50.1	63.5	30.9	39.3	17.4
e- Src / MW	4.9	5.6	5.5	6.6	4.5
e+ Src / MW	9.3	10.2	9.0	9.6	19.8
DR / MW	14.2	22.2	15.7	22.2	14.2
RTML / MW	10.4	13.3	10.9	14.1	9.2
BDS / MW	9.3	9.3	9.3	9.3	9.3
Dumps / MW	1.2	1.2	1.2	1.2	1.2
IR / MW	5.8	5.8	5.8	5.8	5.8
Campus / MW	2.7	2.7	2.7	2.7	2.7
Gen. Margin/MW	3.3	4.0	1.8	2.1	2.3
Total	111	138	93	113	87

4. References

1. B. List. A. Yamamoto: Updated power estimate for ILC-250. Change Request ILC-CR-0018, EDMS D00000001169675.
2. K. Yokoya, Luminosity for operation at the Z pole, Change Request ILC-CR-0019, EDMS D00000001169785.
3. K. Yokoya, K. Kubo and T. Okugi, *Operation of ILC250 at the Z pole*, arXiv:1908.08212.
4. Positron Working Group, K. Yokoya et al.: Report on the ILC positron source. EDMS D00000001165115.
5. N.J. Walker et al.: *ILC AC power estimate summary*. EDMS D00000000965055.