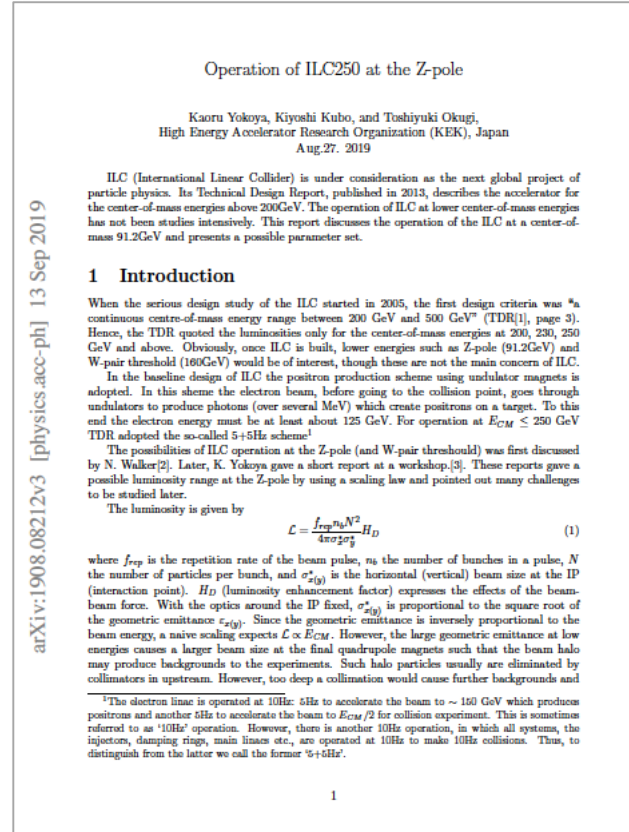LINEAR COLLIDER COLLABORATION

Designing the world's next great particle accelerator

Change Request CR-0021
New estimate of Z pole running power
Benno List, DESY

TCMB Meeting
23.6.2020

Updates since last Meeting

Consider Result from Paper on Z pole running: arXiv:1908.08212

- **Main Linac:**
  - Reduced klystron efficiency: 57% instead of 67% for running at low gradient
  - Fill time: 258 -> 328us
- **Add scenario with 2625 bunches**
- **Add scenario with e driven source**

arXiv:1908.08212v3 [physics.acc-ph] 13 Sep 2019

Operation of ILC250 at the Z-pole

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Aug.27. 2019

ILC (International Linear Collider) is under consideration as the next global project of particle physics. Its Technical Design Report, published in 2013, describes the accelerator for the center-of-mass energies above 200GeV. The operation of ILC at lower center-of-mass energies has not been studies intensively. This report discusses the operation of the ILC at a center-of-mass 91.2GeV and presents a possible parameter set.

1 Introduction

When the serious design study of the ILC started in 2005, the first design criteria was "a continuous centre-of-mass energy range between 200 GeV and 500 GeV" (TDR[1], page 3). Hence, the TDR quoted the luminosities only for the center-of-mass energies at 200, 230, 250 GeV and above. Obviously, once ILC is builts, lower energies such as Z-pole (91.2GeV) and W-pair threshold (160GeV) would be of interest, though these are not the main concern of ILC.

In the baseline design of ILC the positron production scheme using undulator magnets is adopted. In this sheme the electron beam, before going to the collision point, goes through undulators to produce photons (over several MeV) which create positrons on a target. To this end the electron energy must be at least about 125 GeV. For operation at $E_{CM} \leq 250$ GeV TDR adopted the so-called 5+5Hz scheme[1]

The possibilities of ILC operation at the Z-pole (and W-pair threshold) was first discussed by N. Walker[2]. Later, K. Yokoya gave a short report at a workshop.[3]. These reports gave a possible luminosity range at the Z-pole by using a scaling law and pointed out many challenges to be studied later.

The luminosity is given by

$$\mathcal{L} = \frac{f_{rep} n_b N^2}{4\pi \sigma_x^* \sigma_y^*} H_D \qquad (1)$$

where f_{rep} is the repetition rate of the beam pulse, n_b the number of bunches in a pulse, N the number of particles per bunch, and $\sigma_{x(y)}^*$ is the horizontal (vertical) beam size at the IP (interaction point). H_D (luminosity enhancement factor) expresses the effects of the beam-beam force. With the optics around the IP fixed, $\sigma_{x(y)}^*$ is proportional to the square root of the geometric emittance $\varepsilon_{x(y)}$. Since the geometric emittance is inversely proportional to the beam energy, a naive scaling expects $\mathcal{L} \propto E_{CM}$. However, the large geometric emittance at low energies causes a larger beam size at the final quadrupole magnets such that the beam halo may produce backgrounds to the experiments. Such halo particles usually are eliminated by collimators in upstream. However, too deep a collimation would cause further backgrounds and

[1]The electron linac is operated at 10Hz: 5Hz to accelerate the beam to ~ 150 GeV which produces positrons and another 5Hz to accelerate the beam to E_{CM} /2 for collision experiment. This is sometimes referred to as '10Hz' operation. However, there is another 10Hz operation, in which all systems, the injectors, damping rings, main linaes etc., are operated at 10Hz to make 10Hz collisions. Thus, to distinguish from the latter we call the former '5+5Hz'.

1

Damping Ring

- Japanese (DKS) and American (KCS) designs have different numbers for power of conventional facilities
- For Damping Rings, the difference is 0.07MW for „normal" CFS power and 0.56MW for „emergency" power
- Resulting overall power numbers for different configurations
- Assume full 15.7MW for Z pole running

	KCS	DKS
2 Rings, 10Hz (TDR), 1312b	15.1MW	15.7MW
2 Rings, 5 Hz, 1312b	13.6	14.2
2 Rings, 5 Hz, 2625b	21.5	22.2
3 Rings, 10Hz, 2625b	30.3	31.0

Main Linac Power

- Run ML at 3.7 Hz for physics
  - Energy gain per linac: (45.6 – 15)GeV = 30.6GeV
  - Gradient required: 8.8MV/m instead of 31.5MV/m
  - Fill time ~~258us~~ -> 328us pulse length 980us, 170us for 2624 bunches
  - RF beam power 0.96MW (both linacs), ~~3.0MW~~ -> 3.8MW total AC power for RF
- In addition: e- linac runs at 3.7Hz / 31.5MV/m for positron production
  - Adds 9.0MW AC power for RF
- Cryogenics: 3.3MW for e+ linac, 7.0MW for e- linac
  -> compare to 7.7MW per linac for 5Hz 250GeV operation (2.5 static, 4.6 dynamic, 0.7 margin)
- Conventional facilities: 1.9MW for e+, 4.0 for e-
  -> compare to 5.1MW per linac for 5Hz 250GeV
  (assumes that "normal" CF load scales with dumped RF power)
- **Final result: 7.9MW for e+ linac, 22.8MW for e- linac, 30.7MW total
  -> compare to 25.1MW per linac for 5Hz 250GeV**
- **For 2625 bunches: 9.7 + 29.5 = 31.5 MW**
- **For e driven source: 2x7.9 = 15.9MW**

RTML

- TDR has 8.40MW for DKS and 6.59MW for KCS
- On top: 2MW from cryogenics (reassigned from Main Linac)
- Included: 4.76MW RF power
- Scale RF power with puls rate (7.4/5 for e-, 3.7/5 for e+)
  -> 10.9MW for Z running

Power RTML	KCS	DKS
5+5Hz, (TDR), 1312b	8.6 MW	10.4 MW
5 Hz, 1312b		10.4
5 Hz, 2625b		13.3
10Hz, 2625b		20.9
3.7+3.7Hz, 1312b		10.9MW
3.7+3.7Hz, 2625b		14.1MW
3.7Hz, 1312b (e driven)		9.2MW

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Sources

- Sources: include 1.3/1.4 MW RF power
- Assume RF power scales with pulse length and rep rate,
  therefore: add a bit for e- source (5Hz -> 7.4Hz), subtract a bit for e+ source
- Use 14MW power estimate for e driven source from arXiv:1908.08212

Power e-/e+ source	KCS	DKS
5+5Hz, (TDR), 1312b	4.09 / 9.56 MW	4.87 / 9.32 MW
5 Hz, 1312b		4.9 / 9.3
5 Hz, 2625b		5.6 / 10.2
10Hz, 2625b		7.7 / 12.4
3.7+3.7Hz, 1312b		5.5 / 9.0 MW
3.7+3.7Hz, 2625b		6.6 / 9.6 MW
3.7Hz, 1312b (e driven)		4.0 / 14 MW

Others

- For BDS, Dumps, Interaction Region, and Campus:
  Assume same numbers as for 250GeV baseline design
- Margin: 3% of total power
- This is unchanged

The Result

	500 TDR	250-A	250-A' w/R&D	250-A Lx2	500@250	500 Lx2	Z pole	Z pole, Lx2	Z pole, e driven
Rep-Rate / Hz	5	5	5	5	10	5	3.7	3.7	3.7
Bunches / Pulse	1312	1312	1312	2625	2625	2625	1312	2625	1312
Lumi / 10^{34}	1.8	1.35	1.35	2.7	5.4	3.6	0.21	0.41	0.21
Gradient / MV/m	31.5	31.5	35	31.5	14.7	31.5	8.8 (31.5)	8.8 (31.5)	8.8
Q_0/1E10	1.0	1.0	1.6	1.0	1.0	1.0	1.0	1.0	1.0
ML E-gain / GeV	470	220	220	220	220	470	61.2	61.2	61.2
ML Power / MW	107.1	50.1	49.3	53.5	104.3	135.7	30.7	39.1	15.9
e- Src / MW	4.9	4.9	4.9	5.6	7.7	5.6	5.5	6.6	4.5
e+ Src / MW	9.3	9.3	9.3	10.2	12.4	10.2	9.0	9.6	14.0
DR / MW	14.2	14.2	14.2	22.2	31.0	22.2	15.7	22.2	14.2
RTML / MW	10.4	10.4	10.4	13.3	20.9	13.3	10.9	14.1	9.2
BDS / MW	12.4	9.3	9.3	9.3	9.3	12.4	9.3	9.3	9.3
Dumps / MW	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
IR / MW	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Campus / MW	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Gen. Margin/MW	5.1	3.3	3.2	4.0	5.6	6.3	1.8	2.1	2.3
Total	173	111	110	138	198	215	**93**	**113**	**79**

- **Power estimate for Z pole running results in 93MW for running at 91.2GeV CM, 3.7Hz rep rate**
- **This is only 18MW (16%) less than for 250Hz operation**
- **About 22MW (44%) saving in Main Linacs: running e+ linac at 8MV/m takes very little energy**
- **Increased rep-rate of e- arm for positron production requires more power in e- source, damping rings, RTML**

- **Doubling the luminosity adds 20MW (23%)**
- **E driven source saves 14MW (15%)**
- No 125GeV e+ production beam: saves 19MW
- Separate e beam adds 5MW

- **CR-0021 in preparation**

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CHANGE REQUEST NO. ILC-CR-0018	EDMS No: D0000000xxxxxxx	Created: 23-06-2020
		Last modified: 3-12-2019

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.

Requested and prepared by:	Benno List

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