Accelerator Design – Current Change Requests.

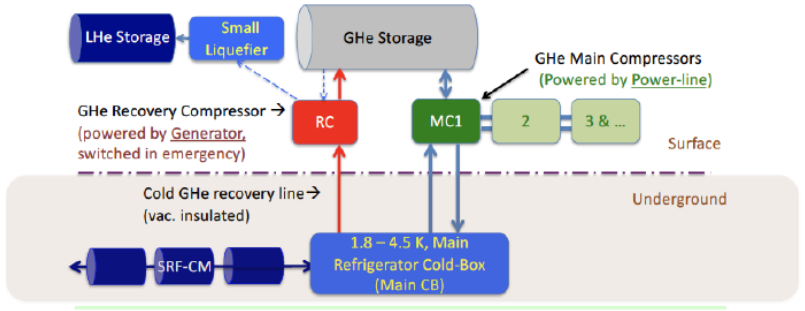
Changes to the accelerator design, under review or recently approved

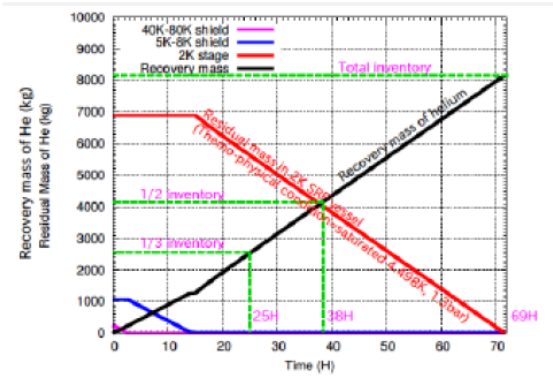
Benno List
ILC@DESY General Project Meeting
21.2.2020

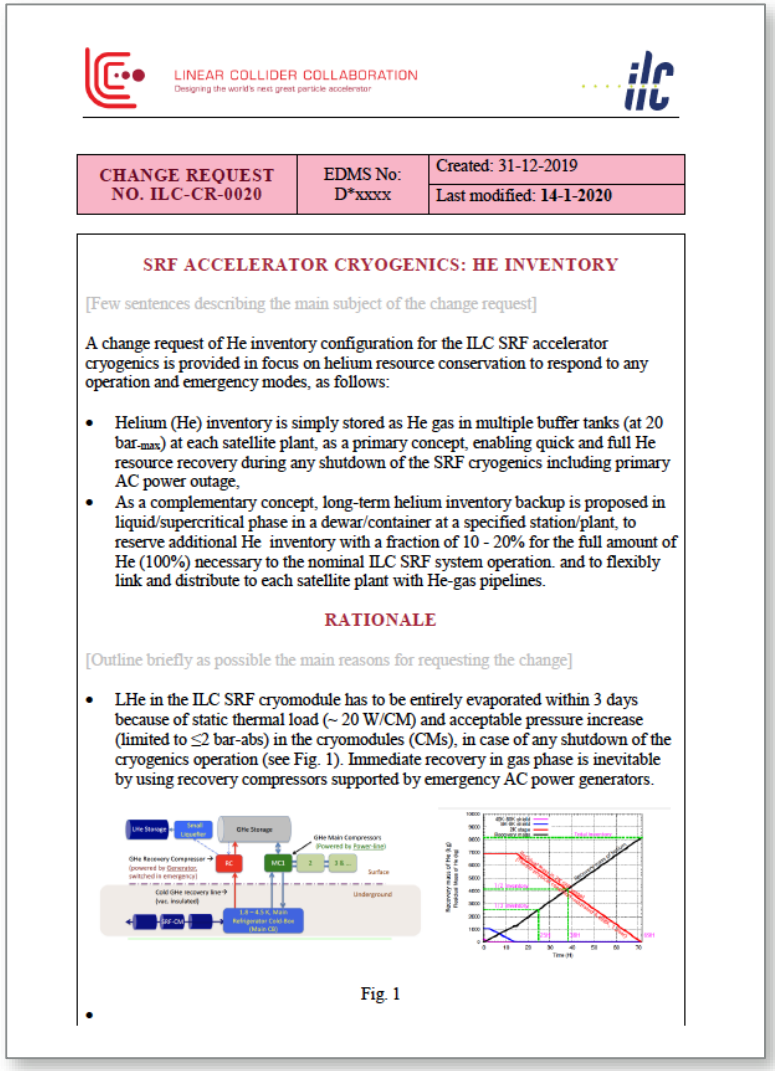
ILC-CR-0020: Helium Storage

Provide gaseous storage for complete helium inventory

- Concern: Long-term (days to weeks) of power failure after storm or earth quake
- Requirement: He inventory must be preserved, limited backup (diesel generator) power available -> no cryo plant operation
- Without operational cryo plant: Helium evaporates within 3 days; max pressure in cryo modules: 2 bar
- CR is now under review







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CHANGE REQUEST NO. ILC-CR-0020	EDMS No: D*xxxx	Created: 31-12-2019
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SRF ACCELERATOR CRYOGENICS: HE INVENTORY

[Few sentences describing the main subject of the change request]

A change request of He inventory configuration for the ILC SRF accelerator cryogenics is provided in focus on helium resource conservation to respond to any operation and emergency modes, as follows:

- Helium (He) inventory is simply stored as He gas in multiple buffer tanks (at 20 bar-$_{max}$) at each satellite plant, as a primary concept, enabling quick and full He resource recovery during any shutdown of the SRF cryogenics including primary AC power outage,
- As a complementary concept, long-term helium inventory backup is proposed in liquid/supercritical phase in a dewar/container at a specified station/plant, to reserve additional He inventory with a fraction of 10 - 20% for the full amount of He (100%) necessary to the nominal ILC SRF system operation. and to flexibly link and distribute to each satellite plant with He-gas pipelines.

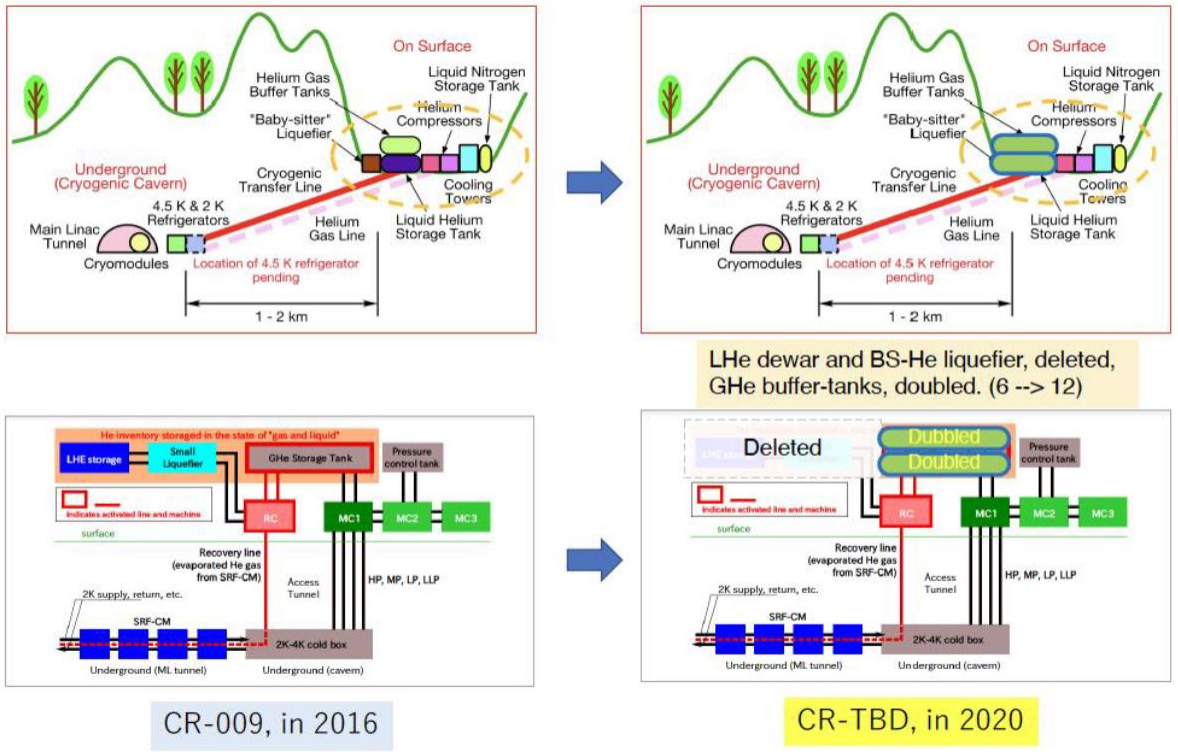
RATIONALE

[Outline briefly as possible the main reasons for requesting the change]

- LHe in the ILC SRF cryomodule has to be entirely evaporated within 3 days because of static thermal load (~ 20 W/CM) and acceptable pressure increase (limited to ≤2 bar-abs) in the cryomodules (CMs), in case of any shutdown of the cryogenics operation (see Fig. 1). Immediate recovery in gas phase is inevitable by using recovery compressors supported by emergency AC power generators.

Fig. 1

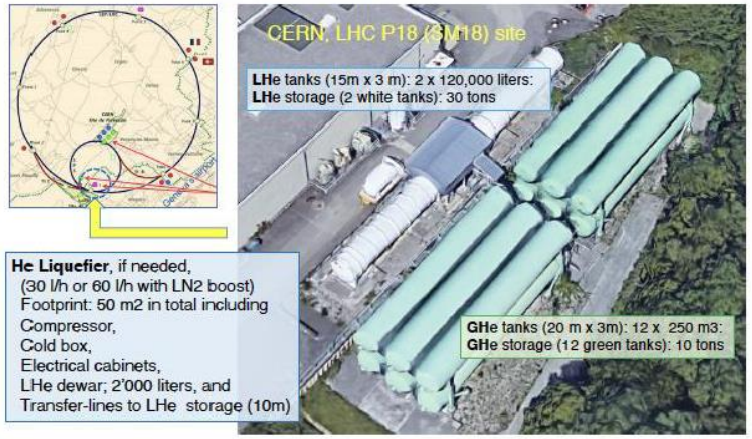
Change of storage concept



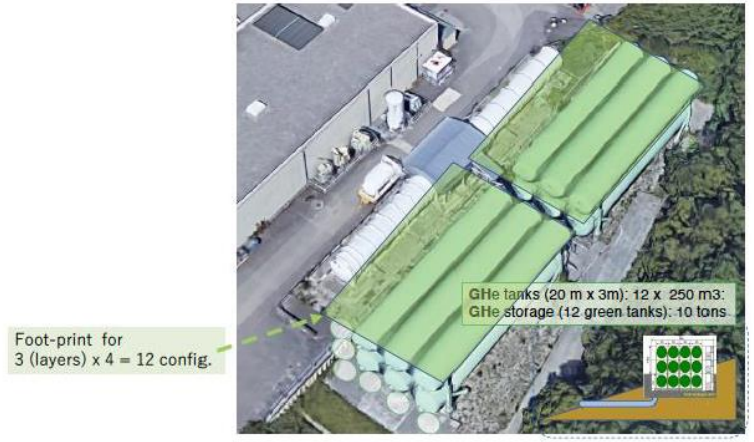
- Original concept:
  - use 50% gaseous storage at 20 bar, 50% liquid storage
  - Requires liquifier at each cryo plant
  - Liquifier must run contunously
- New concept:
  - Provide gaseous storage fo 100% of inventory
  - Only one liquifier at central location
    -> requires (gas) He transfer line in tunnel
  - 20 bar gaseous storage: requires compressor (2 bar -> 20 bar) for 3 days
  - After that: He storage requires no power

New Layout

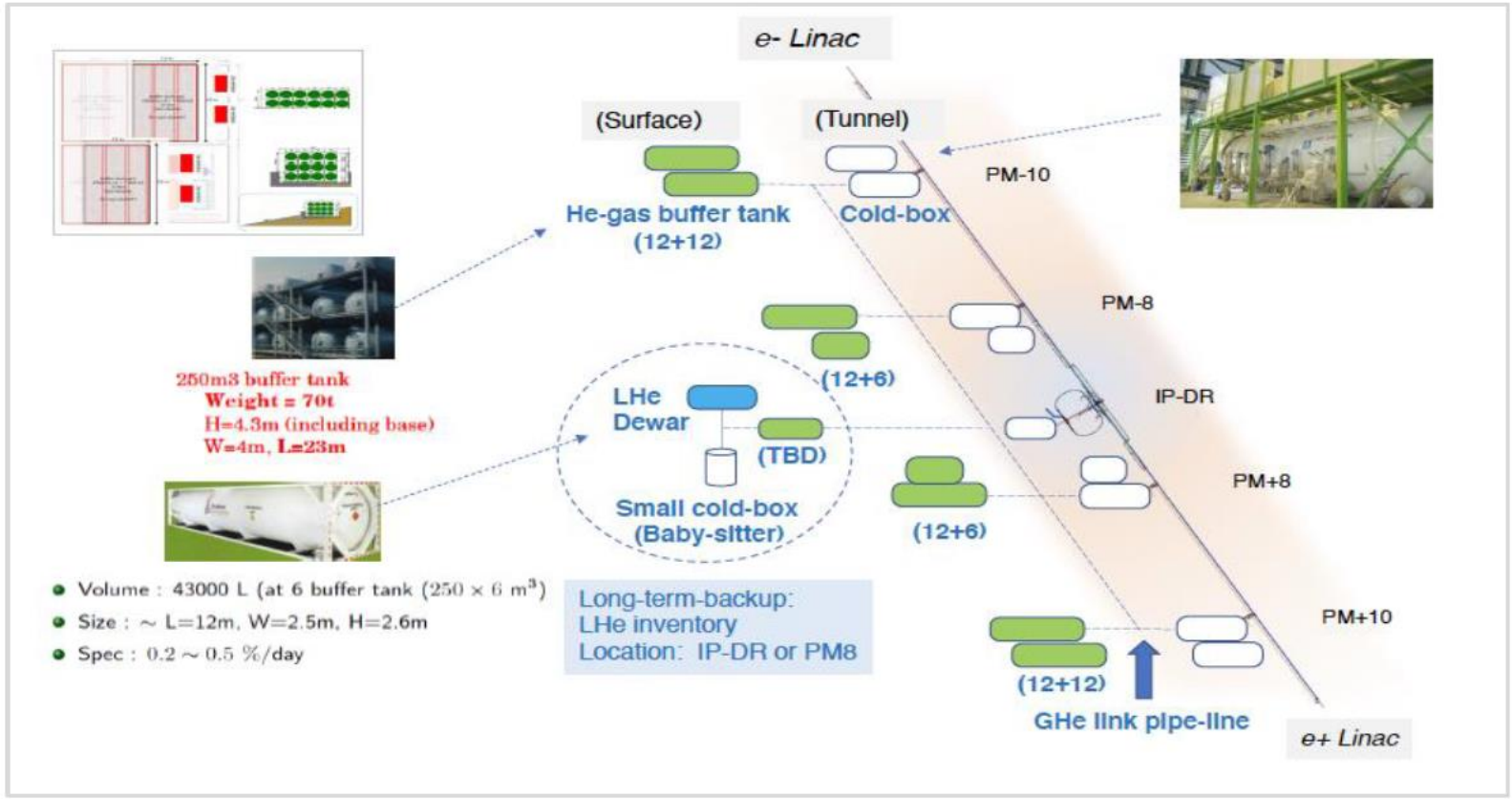
Attachment 5: He Inventory Configuration at CERN LHC P18 (SM18)



Current Foot-Print: LHe (2) and GHe (2 x 2 x 3) Configuration



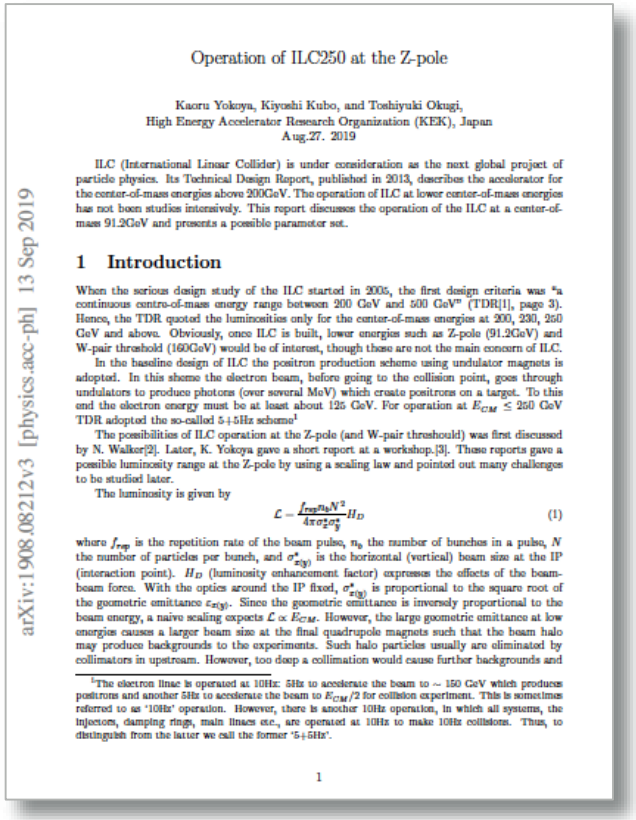
Image, Foot-Print: GHe (2 x 3 x 4) Tanks Configuration.



ILC-CR-0019 Z-Pole luminosity

Performance of the ILC at the Z pole

- Based on arXiv:1908.08212
- Gives performance estimate for running on the Z pole



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

Operation of ILC250 at the Z-pole

Kaoru Yokoya, Kiyoshi Kubo, and Toshiyuki Okugi,
High Energy Accelerator Research Organization (KEK), Japan
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 built, 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 scheme 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.

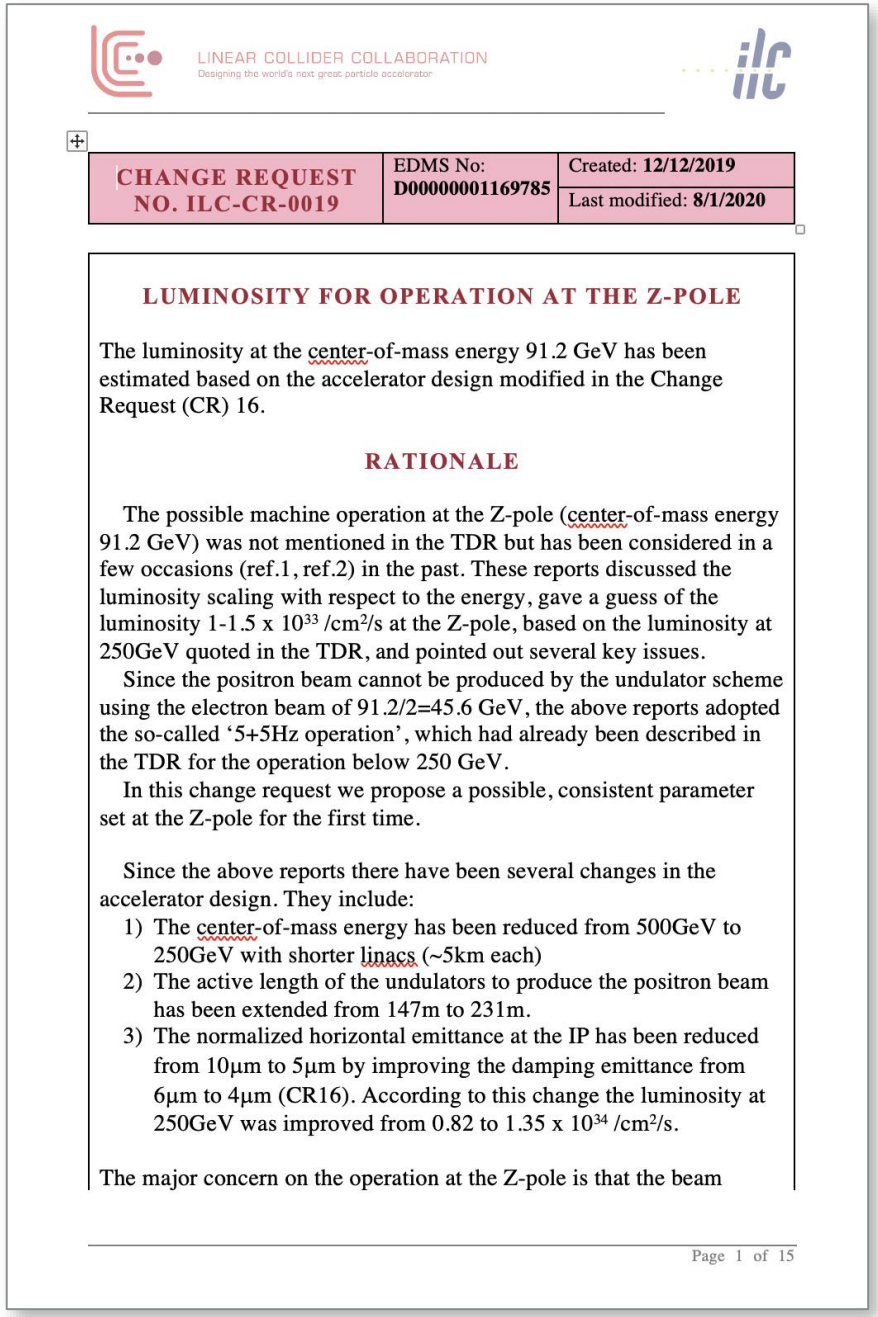
The luminosity is given by

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

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 linacs etc., are operated at 10Hz to make 10Hz collisions. Thus, to distinguish from the latter we call the former '5+5Hz'.

1



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CHANGE REQUEST NO. ILC-CR-0019	EDMS No: D00000001169785	Created: **12/12/2019**
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LUMINOSITY FOR OPERATION AT THE Z-POLE

The luminosity at the center-of-mass energy 91.2 GeV has been estimated based on the accelerator design modified in the Change Request (CR) 16.

RATIONALE

The possible machine operation at the Z-pole (center-of-mass energy 91.2 GeV) was not mentioned in the TDR but has been considered in a few occasions (ref.1, ref.2) in the past. These reports discussed the luminosity scaling with respect to the energy, gave a guess of the luminosity 1-1.5 x 10^{33} /cm^2/s at the Z-pole, based on the luminosity at 250GeV quoted in the TDR, and pointed out several key issues.

Since the positron beam cannot be produced by the undulator scheme using the electron beam of 91.2/2=45.6 GeV, the above reports adopted the so-called '5+5Hz operation', which had already been described in the TDR for the operation below 250 GeV.

In this change request we propose a possible, consistent parameter set at the Z-pole for the first time.

Since the above reports there have been several changes in the accelerator design. They include:

1) The center-of-mass energy has been reduced from 500GeV to 250GeV with shorter linacs (~5km each)
2) The active length of the undulators to produce the positron beam has been extended from 147m to 231m.
3) The normalized horizontal emittance at the IP has been reduced from 10μm to 5μm by improving the damping emittance from 6μm to 4μm (CR16). According to this change the luminosity at 250GeV was improved from 0.82 to 1.35 x 10^{34} /cm^2/s.

The major concern on the operation at the Z-pole is that the beam

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Accelerator Parameters

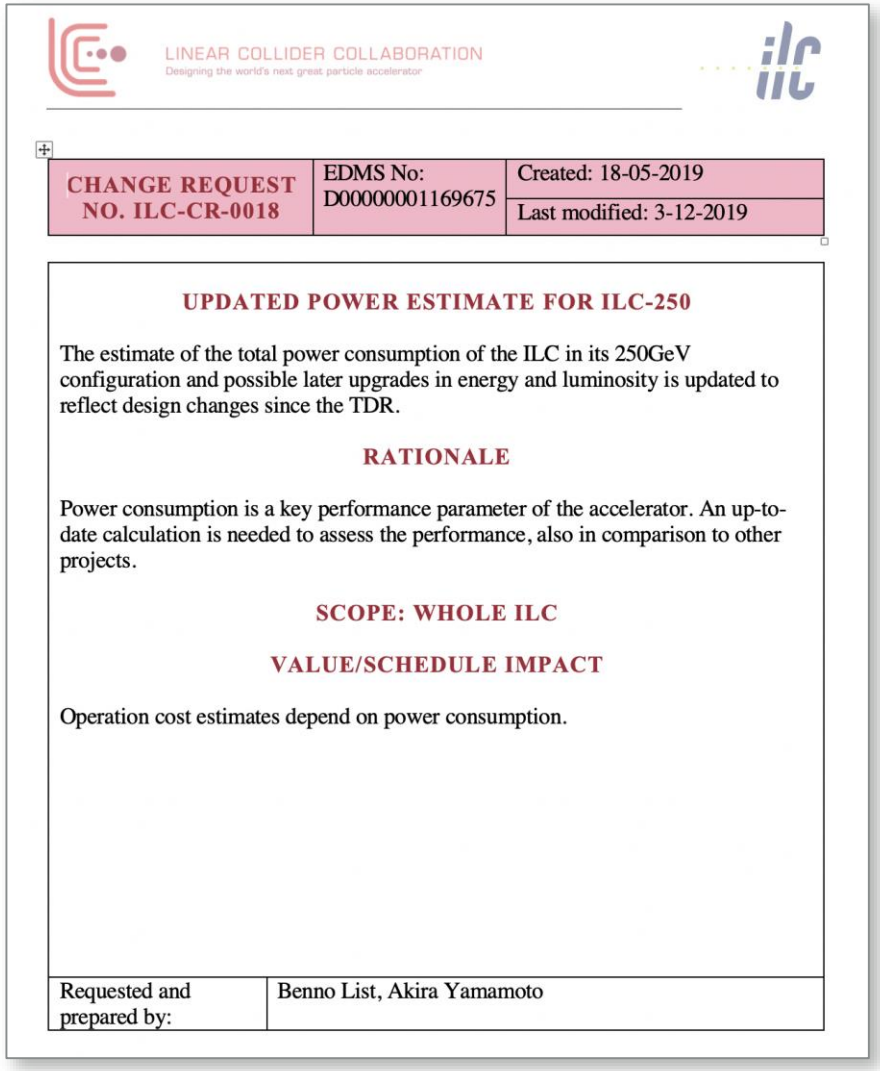
- New baseline numbers for performance at the Z pole
- Change Request has been accepted
- Z pole running is now baseline (for the first time!)
- But: requires additional infrastructure (special line to dump) for helical undulator source
  -> may not be available from day1 on
  -> this is not the performance promised / to be expected for calibration runs

Table 1. Accelerator parameters at 91.2 GeV and 250GeV

Center-of-Mass Energy	E_{CM}	GeV	91.2	250
Beam Energy	E_{beam}	GeV	45.6	125
Beam collision rate	f_{col}	Hz	3.7	5
Electron linac repetition rate		Hz	3.7+3.7	5
Pulse interval in electron main linac		ms	135	200
Electron energy for e+ production		GeV	125	125
Number of bunches per pulse	n_b		1312	1312
Bunch population	N	10^{10}	2	2
Bunch separation	Δt_b	ns	554	554
RMS bunch length at IP	σ_z	mm	0.41	0.30
Electron RMS Beam energy spread at IP	σ_p/p	%	0.30	0.188
Positron RMS Beam energy spread at IP	σ_p/p	%	0.30	0.150
Emittance from DR (x)	$\gamma\varepsilon^{DR}_x$	µm	4	4
Emittance from DR (y)	$\gamma\varepsilon^{DR}_y$	nm	20	20
Emittance at main linac exit (x)	$\gamma\varepsilon^{ML}_x$	µm	5	5
Emittance at main linac exit (y)	$\gamma\varepsilon^{ML}_y$	nm	35	30
Emittance at IP (x)	$\gamma\varepsilon^*_x$	µm	6.2	5
Emittance at IP (y)	$\gamma\varepsilon^*_y$	nm	48.5	35
Electron polarization	P_-	%	80	80
Positron polarization	P_+	%	30	30
Beta_x at IP	β^*_x	mm	18	13
Beta_y at IP	β^*_y	mm	0.39	0.41
Beam size at IP (x)	σ^*_x	µm	1.12	0.515
Beam size at IP (y)	σ^*_y	nm	14.6	7.66
Disruption Parameter (x)	D_x		0.41	0.52
Disruption Parameter (y)	D_y		31.8	35.0
Geometric luminosity	L_{geo}	10^{33}	0.95	5.29
Luminosity	L	10^{33}	2.05	13.5
Luminosity at top 1%		%	99.0	74.0
Luminosity enhancement factor	H_D		2.2	2.55
Number of beamstrahlung	n_γ		0.841	1.91
Beamstrahlung energy loss	δ_{BS}	%	0.157	2.62

ILC-CR-0018 Power Estimate

- Power estimate was updated end of 2019
- Small error in spreadsheet was discovered in calculation of RF power for 10Hz operation
  -> power for sourecs and RTML went up a bit
- Final result is now approved



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CHANGE REQUEST NO. ILC-CR-0018	EDMS No: D00000001169675	Created: 18-05-2019
		Last modified: 3-12-2019

UPDATED POWER ESTIMATE FOR ILC-250

The estimate of the total power consumption of the ILC in its 250GeV configuration and possible later upgrades in energy and luminosity is updated to reflect design changes since the TDR.

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, Akira Yamamoto

The final result

Updated power estimate for the ILC in different configurations

	500 TDR	250-A	250-A' w/R&D	250-A Lx2	500@250	500 Lx2
Rep-Rate / Hz	5	5	5	5	10	5
Bunches / Pulse	1312	1312	1312	2625	2625	2625
Lumi / 10^{34}	1.8	1.35	1.35	2.7	5.4	3.6
Gradient / MV/m	31.5	31.5	35	31.5	14.7	31.5
Q_0/1E10	1.0	1.0	1.6	1.0	1.0	1.0
ML E-gain / GeV	470	220	220	220	220	470
ML Power / MW	107.1	50.1	49.3	53.5	104.3	135.7
e- Src / MW	4.9	4.9	4.9	5.6	7.7	5.6
e+ Src / MW	9.3	9.3	9.3	10.2	12.4	10.2
DR / MW	14.2	14.2	14.2	22.2	31.0	22.2
RTML / MW	10.4	10.4	10.4	13.3	20.9	13.3
BDS / MW	12.4	9.3	9.3	9.3	9.3	12.4
Dumps / MW	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
Campus / MW	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
Total	**173**	**111**	**110**	**138**	**198**	**215**