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Draft Summary
CLIC Parameter Away-Day held on 28 Mar 06
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The note below is not intended to be a complete summary of all presentations but rather a non-exhaustive collection of the main conclusions and issues.

1. CLIC Reference Configuration (CRC):

A new consistent set of CLIC parameters based on an accelerating field of 150 MV/m in 30 GHz structures as defined last year and describing the CLIC Reference Configuration (CRC) will be published in CLIC note 627.

2. Boundary conditions

The goal of the away day consists in an attempt to converge towards a future set of parameters:

- Optimized as much as possible for a 3 TeV Linear Collider without any constraint about RF frequency and accelerating field (which still comply with a 3 TeV collider)
- Which can be realistically demonstrated before 2010
- Taking into account recent tests results in CTF3 and structure limitations
- Best compromise between performance and cost

Adaptation of the design to different energies like 1 TeV and as recently requested by the CLIC Physics Study Group at 91.2, 161, 344 and 500 GeV, are not considered here.

3. Horizontal beam size at IP

The present CRC performance is limited by the horizontal beam (σ_x) of 60 nm at IP. The optimum value in the range of parameters corresponds to about 30 to 40 nm for which a 30 to 50% luminosity increase could be obtained

4. Beam emittances at Damping Ring

The CRC emittances at exit of the Damping Ring ($\varepsilon_{x=}$550 nm, $\varepsilon_{x=}$3.3 nm $\varepsilon_{z=}$4724 eVm) are supported by a design of a 357 m ring at 2.424 GeV equipped 152 m of short period (10cm) permanent magnet wigglers and are dominated by IBS. These emittances could possibly be further reduced ($\varepsilon_{x=}$375 nm, $\varepsilon_{x=}$1.98 nm $\varepsilon_{z=}$4997eVm) with Nb_3Sn superconducting wigglers. Such a reduction would be welcome as a consolidation of the CBC parameters and to provide some margin for possible errors.

A further reduction of the emittances in the Damping Ring ($\varepsilon_{x=}$315 nm, $\varepsilon_{x=}$3.3 nm $\varepsilon_{z=}$5020 eVm) is not worth the effort as it would imply a larger ring 530m) operating at higher energy (3.746 GeV) equipped with 304 m of wigglers, and would be even more dominated by IBS.

The development of a tracking program correctly taking IBS into account is strongly recommended.

5. Beam delivery

The present beam dimension at IP (before pinch) are 60 nm in horizontal and 0.7 nm vertical, largely dominated by chromatic aberrations.

A further reduction of the horizontal beam dimension to 49 nm looks feasible by stronger focusing and correction of the chromatic aberrations by appropriate multipolar correctors.

A consolidation of a 50 nm horizontal beam size at IP is recommended.

6. High power RF limitations and constraints

Three basic limitations have been assumed up to now:

- Peak surface field: 380 MV/m
- Pulse surface heating: $J*T^{1/2}$ /(540kA/m*70ns$^{1/2}$)
- Power flow-pulse energy: $P*T^{1/2}$ /(Circumference*50MW*70ns$^{1/2}$)

Moreover, breakdown rates lower than 10^{-6} have to be achieved for possible operation in a linear Collider.

But heavy damages and large breakdown rates have been observed during tests in CTF3 of structures equipped with Molybdenum iris with nominal field (150 MV/m) and pulse length (70 ns). About 80 MV/m at 70 ns pulse length have been demonstrated (structure already damaged?) with an increase of breakdown rate by one decade for about 13 MV/m.

Assuming RF conditioning (with high breakdown rate) at field 20% above operational figures, the above criteria have to be reduced by the same amount in order to avoid damages during conditioning.

With the understanding that the power flow-pulse energy limit has been reached during CTF3 tests, it is therefore recommended to:

- review the conditioning strategy
- keep the first two criteria as they are (Peak surface field and Pulse surface heating
- Reduce the Pulse energy criterion by 20% in field (56% in power) to $P*T^{1/2}$ /(Circumference *32MW*$70ns^{1/2}$)

Questions: Validity of tests of CTF3 last run (damaged structure? Vacuum quality? Performance degradation by clamping)?

Origin of damages

Limitation by pulse energy?

Validity of scaling with circumference?

What will be the behavior of HDS structures?

7. RF structure optimum design

Comparison of the optimization by Alexei of structures (table attached to the summary for completeness) and based on the new criteria with 20% margin field as proposed above. The choice of the structure limitations criteria lead to drastic modifications of the CLIC performances and parameters. New proposed criteria drive towards lower RF Power in the 60 to 100 MWatts at structure entry much easy to provide but also to lower figure of merit, (higher wall plug power), short structures (feasibility and cost issues?) and short RF pulses (Drive beam feasibility?):

- At a field of 150 MV/m:
  - Using a frequency of 30 GHz (Ref. 1 in Alexei table), the parameters do not look feasible:
    - Figure of merit is reduced by a factor of 3 (therefore power needed for same luminosity increased by three) in respect with CRC.
    - Very short structure length of 9.6 cm
    - RF pulse length of 15 nsec

- Using optimum frequency of 20 GHZ (Ref. 4 in Alexei table) provides very small improvements (20% higher figure of merit)

- At a field of 120 MV/m:

  - Using a frequency of 30 GHz (Ref. 2 in Alexei table), the parameters still look out of reach:
    - Power needed increased by two in respect with CRC.
    - Very short structure length of 14.3 cm
    - RF pulse length of 14 nsec
  - Using optimum frequency of 18 GHZ (Ref. 5 in Alexei table) the parameters are envisageable (except for structure length?)
    - Power needed increased by 1.5 in respect with CRC.
    - Very short structure length of 11.8 cm
    - RF pulse length of 41 nsec

- At a field of 100 MV/m:

  - Using a frequency of 30 GHz (Ref. 3 in Alexei table), the RF pulse length still look out of reach for a drive beam scheme:
    - Power needed increased by 1.5 in respect with CRC.
    - Still short structure length of 17.6 cm
    - RF pulse length of 17.4 nsec
  - Using optimum frequency of 18 GHZ (Ref. 6 in Alexei table) the parameters are envisageable
    - Figure of merit and power needed similar to the one in CRC.
    - Still short structure length of 16.7 cm
    - RF pulse length of 43.6 nsec
  - Using even lower frequency of 12 GHz close to NLC (Ref. 7 in Alexei table) makes the RF pulse length (83ns) more feasible by drive beam

scheme, with a loss of figure of merit by 15% and shorter structure lengths

- Reduction of horizontal beam size at IP from 60 to 40 nm improves figure of merit by 30% and optimum frequency towards higher values.

8. Drive beam scheme

The new design of structures envisaged above with reduced RF power criteria and possibly accelerating field reduction of the accelerating field makes design of drive beam less challenging but increases the total beam energy when the overall efficiency is reduced.

The feasibility of the drive beam scheme for RF pulse length lower than the present 70 ns of the CRC is not demonstrated and needs drastic modifications. The most likely scheme is based on a larger number of drive sectors with consequences on

- Smaller delay loop and ring (replacement by delay lines?)
- More turn around and dumps (cost issues?)
- Different combination of energy to beam current

A drive beam scheme adapted to RF pulse lengths of 35 to 40 ns is not totally excluded but needs detailed study. Shorter RF pulse lengths look extremely difficult to achieve.

9. PETS

The new RF constraints impose compete redesign of the CLIC unit. Independently of the field and frequency, optimum layout seems to be based on 4 HDS/PETS and 2 PETS/quad.

Power production can be adapted to a large frequency range.

The continuation of the development of an active switch for pulse compressor is highly recommended.

10.Tests in CTF3

With a primary drive beam of 3.5 Amp at 1.5GHz and using various beam combinations, a large frequency range could be tested in CTF3 with varying drive beam current depending on the number of combinations and the harmonic beam to power:

- 3 GHz (and all harmonics of 3 GHz) with 7 Amp after the delay loop
- 6 GHZ (and all harmonics 12, 18, 24, 30, 36 GHz) with 14 Amp after a combination by a factor 2 in the combiner ring
- 9 GHz (all all harmonics: 18, 27 and 36 GHz) with 21 Amp after a combination by a factor 3 in the combiner ring
- 12 GHz (and all harmonics: 24 and 36 GHz) with 28 Amp after a combination by a factor 4 in the combiner ring
- 15 and 30 GHz with 35 Amp after a combination by a factor 5 in the combiner ring
- The most favorable combination of RF frequency and beam current for tests on CTF3 are therefore:
  - 30 and 15 GHz with 35 Amp
  - 24 GHz with 28 Amp
  - 18 GHz with 21 Amp

Variable pulse lengths can be adjusted in the linac, but pulse length from the combiner ring much less flexible and requires additional phase switches.

Up to 100 MWatts have been obtained in power mode from the PETS line resulting in 70 MWatts@50ns and 52 MW@70 ns for structure tests.

For further increase, various measures to be followed up:

- Reduce losses in RF power transmission line (presently 30%)
- Increase linac current to 6 Amp?
- Development of RF pulse compressors
- New PETS?

11. Costs issues

An overall cost estimation prepared by Hans and Carlo will be available in summer. Preliminary conclusion stands:

- Larger present uncertainty comes from the cost of the two-beam linacs (special working group chaired by Walter).

- Cost estimation of other sub-systems already pretty reliable
- Importance of efficiency and power consumption (emphasized by Figure of merit) as it not only reduces power bill (in fact only small part of overall cost) but also the complexity and sizes of other systems (Conventional facilities, drive beam complex, dumps…).
- Tunnel length important cost driver: 14kms of empty tunnel same cost as 325 MWatts power for 10 years!
- Drive beam power source (Modulators, Klystrons) also important cost driver, with a cost increasing with the energy per pulse thus favoring high repetition rates and high RF frequencies.

12.MAC

The setting-up of a Machine advisory Committee (MAC) has been suggested.

13.Conclusions

- The nominal accelerating field of 150 MV/m will have to be reduced in order to demonstrate its feasibility without damage before 2010. A field of 100 MV/m would greatly improve the chances of feasibility demonstration by 2010 with a better efficiency and less challenging designs of the various CLIC systems. It would still allow a 3 TeV Linear Collider on the 50 kms site envisaged for a possible 1 TeV ILC@CERN. But it would exclude a possible extension to 5 TeV and would substantially increase the cost. J.Ellis confirms that the scheme would still be very attractive for Physics.
- Before deciding on the new nominal field:
  - The structure limitation criteria will be reviewed and updated by Walter taking into account of all measurements already done at various frequencies and of the last CTF3 run.
  - Some HDS results should be available
  - The consequences on cost have to be evaluated.
- Independently of the used criteria, the optimum frequency appears to be always lower than 30 GHz.
- Before deciding on the new frequency:

  - The consequences on cost of drive beam power source through pulse energy and repetition frequency have to be evaluated
  - A strategy about tests in CTF3 have to be defined
  - The availability on possible development of stand alone power source have to be reviewed

- Independently of the new frequency, tests at 30 GHz should be pursued in CTF3 pets line but a TBL line and two beam test stand in CLEX could be envisaged at the new frequency if decision taken in the near future (before the end of the year?).

- The most favorable combination of RF frequency and beam current for tests on CTF3 are therefore:
  - 30 and 15 GHz with 35 Amp
  - 12 and 24 GHz with 28 Amp
  - 9 and 18 GHz with 21 Amp

- RF structure constraints always lead to very short structure length (10 to 18 cm) with heavy consequences on module complexity and cost. Are travelling wave structures still the best design?

- RF structure constraints and figure of merit optimization always lead to short RF pulse. The feasibility of a drive beam scheme for short pulse length (40 ns) has to be demonstrated

- The feasibility of a horizontal dimension of 50 nm at IP constitutes a reasonable assumption.

- A follow-up of the away-day will be organized shortly to define a favored parameters list for study.

- A provocative and preliminary tentative list of boundary conditions for further studies, to be discussed at the forthcoming follow-up meeting is suggested below:
  - RF constraints with margin (a la Walter)
  - Beam emittances as in CRC
  - Horizontal beam dimension at IP not smaller than 50 nm

- RF pulse length not shorter than 40 ns
- 100 MV/m
- Frequencies from 12 to 30 GHz
- …..?

Parameter list of structures:1-7

Structure #	1	2	3	6	7	5	4
$<E_{acc}>$ [MV/m]	150	120	100	100	100	120	150
f [GHz]	30	30	30	18	12	18	20
$\Delta\varphi$ [°]	50	50	50	50	50	50	50
$a_{1,2}$ [mm]	2.14, 1.16	2.47, 1.43	2.63, 1.58	3.03, 1.63	3.41, 1.84	2.71, 1.46	2.21, 1.24
$d_{1,2}$ [mm]	0.25, 0.45	0.25, 0.45	0.25, 0.4	0.25, 0.25	0.25, 0.25	0.25, 0.25	0.25, 0.25
$L_{b\times}/N^{*}\eta$ [a.u.]	5.24	8.03	10.55	13.01	11.63	9.84	6.02
E_{surf}^{max} [MV/m]	379	311	271	282	259	320	380
ΔT^{max} [K]	49.1	49.6	54.1	48.6	49.8	43.2	36.8
$P_{in}\tau_p^{1/2}/C$ [MWns$^{1/2}$/mm]	24	24	24	24	24	24	24
$<a>/\lambda$	0.165	0.195	0.21	0.14	0.105	0.125	0.115
$L_{b\times}$ [m^{-2}]	0.66×10^{34}	0.99×10^{34}	1.00×10^{34}	1.33×10^{34}	1.87×10^{34}	1.15×10^{34}	0.78×10^{34}
N	2.03×10^{9}	2.52×10^{9}	2.55×10^{9}	3.11×10^{9}	4.10×10^{9}	2.80×10^{9}	2.20×10^{9}
N_c, l [mm]	69, 96	103, 143	127, 176	72, 167	37, 128	51, 118	36, 75
N_s	6	6	6	5	5	5	5
N_b	42	39	59	102	132	93	79
τ_p [ns]	14.7	13.6	17.4	43.6	83.2	41.1	31.8
P_{in} [MW]	85	102	96	70	57	64	60
η [%]	16.1	20.5	26.9	30.4	25.6	24.1	17.1