The CLIC ESPP update – I

Guidelines:

Preparing "Project Readiness Report" as a step toward a TDR

Assuming ESPP in ~ 2025-6, Project Approval ~ 2028, Project (tunnel) construction can start in ~ 2030.


CERN-2024-nnn-M
31 December 2024

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

THE COMPACT LINEAR COLLIDER (CLIC)
READINESS REPORT

GENEVA
2024

However, several important changes:

- Energy scales: 380 GeV and 1.5 TeV with one drivebeam
- Consider also 100 Hz running at 250 GeV and 380 GeV (i.e. two parallel experiments, two BDSs)
- Several updates on parameters (injectors, damping rings, drive-beam) based on new designs, results and prototyping (e.g. klystrons, magnets) - however no fundamental changes beyond staying at one drivebeam
- Technology results updates, including more on use of them in other projects (e.g. alignment, instrumentation, X-band RF is small linacs)
- Update costing and power – interplay between inflation and CHF
- Life Cycle Assessments
- More detailed prep phase planning (next 5-7 years)

Project summary for Snowmass already include some of these changes, i.e. luminosity improvements, 100 Hz study, power update for 380 GeV: LINK

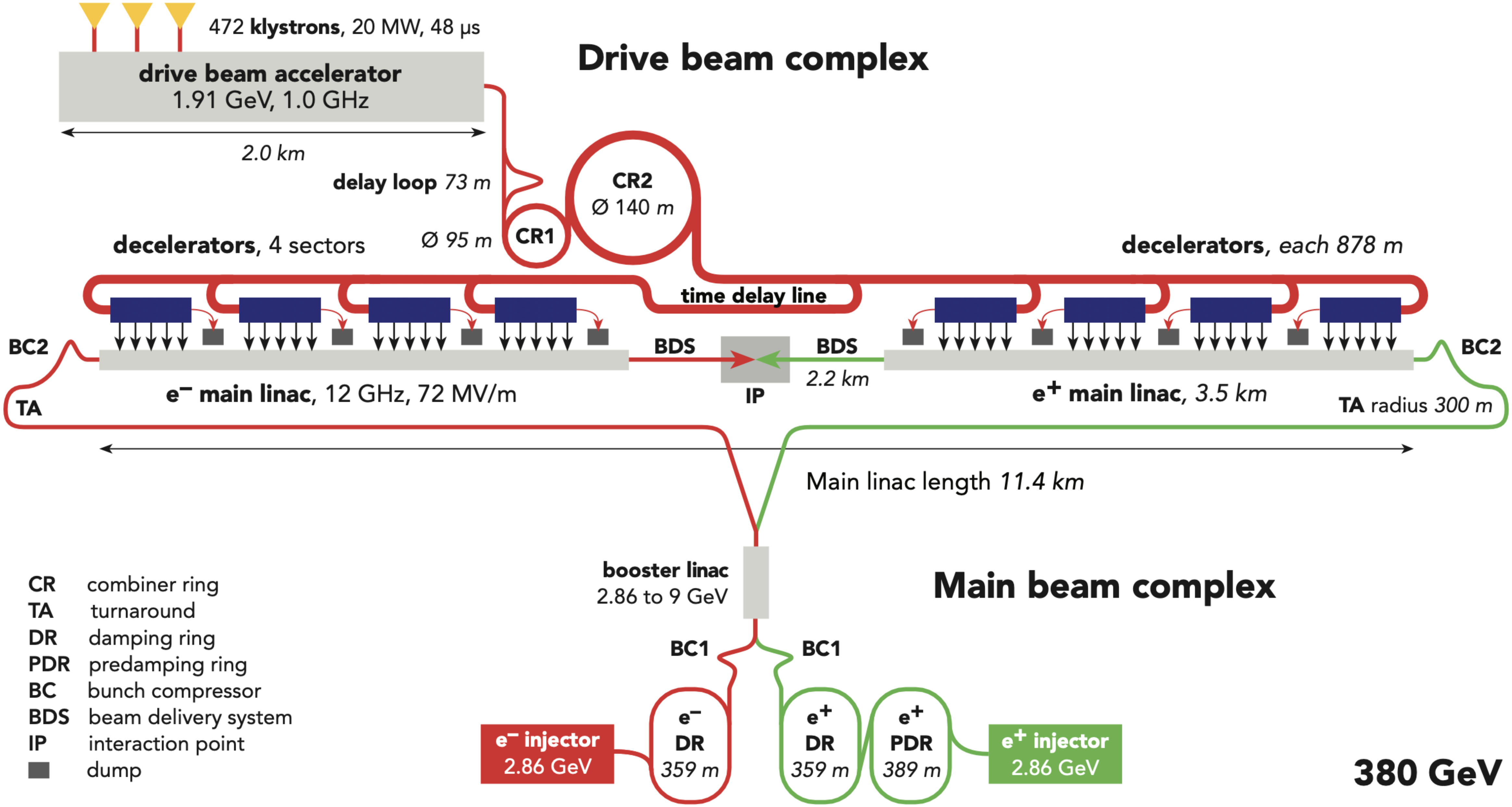


Fig. 1: Schematic layout of the CLIC complex at 380 GeV.

Two BDS/IP

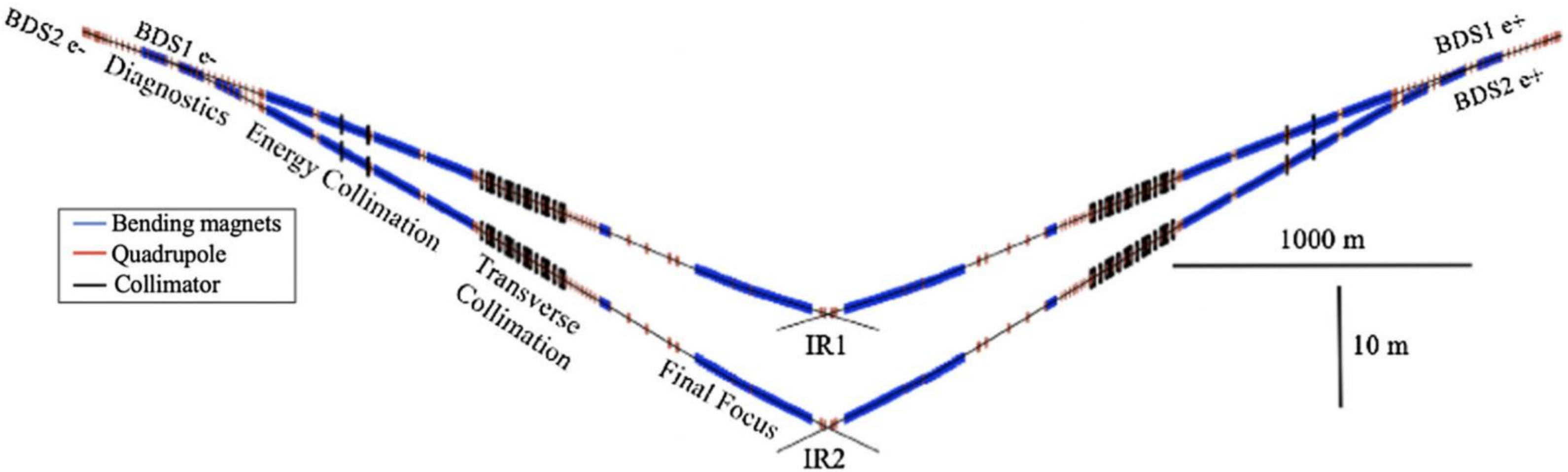
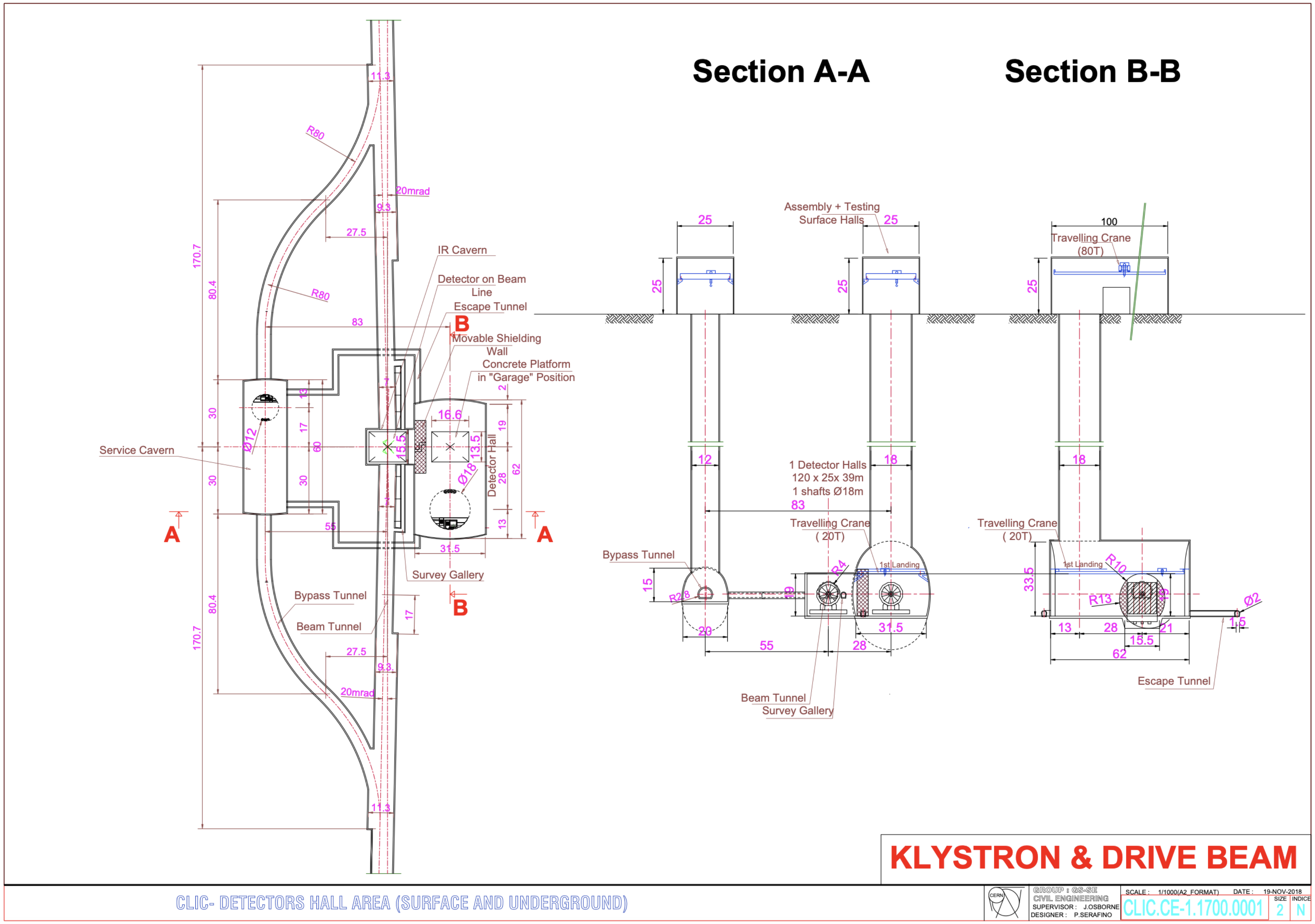


Fig. 2: Schematic layout of CLIC operating with two detectors. The longitudinal and transverse separations between the two detectors is about 40 m and about 10 m,



Section A-A
Section B-B
IR Cavern
Detector on Beam Line
Escape Tunnel
Movable Shielding Wall
Concrete Platform in "Garage" Position
Service Cavern
Detector Hall
Survey Gallery
Bypass Tunnel
Beam Tunnel
R80
20mrad
Ø12
Ø18
A
B
Assembly + Testing Surface Halls
Travelling Crane (80T)
1 Detector Halls 120 x 25x 39m
1 shafts Ø18m
Travelling Crane (20T)
1st Landing
Escape Tunnel
Beam Tunnel
Survey Gallery
KLYSTRON & DRIVE BEAM
CLIC- DETECTORS HALL AREA (SURFACE AND UNDERGROUND)
GROUP : GS-SE
CIVIL ENGINEERING
SUPERVISOR : J.OSBORNE
DESIGNER : P.SERAFINO
SCALE : 1/1000(A2_FORMAT)
DATE : 19-NOV-2018
CLIC.CE-1.1700.0001
SIZE 2
INDICE N

Baseline: 380 GeV

- Baseline: 380 GeV drive-beam machine - “low-energy machine”
  - Main parameters, system overview and technology details will primarly refer to 380 GeV
  - Keep details on klystron options
  - $L = 2.25 \times 10^{34}/cm^2/s$
- Option: 100 Hz, with ~65% higher power
  - $L = 4.5 \times 10^{34}/cm^2/s$
- For 100 Hz running, option: two BDS and IPs
  - $L = 2.25 \times 10^{34}/cm^2/s$ per IP

Option: 250 GeV

- Proposed implementation: missing module scheme, shorter DBA
- Less cost than simply reducing sectors from 4 to 3
- Tunnel same as 380 GeV, for easy upgrade
- L = $1.5 \times 10^{34}/cm^2/s$, $3.0 \times 10^{34}/cm^2/s$ for 50 Hz and 100 Hz

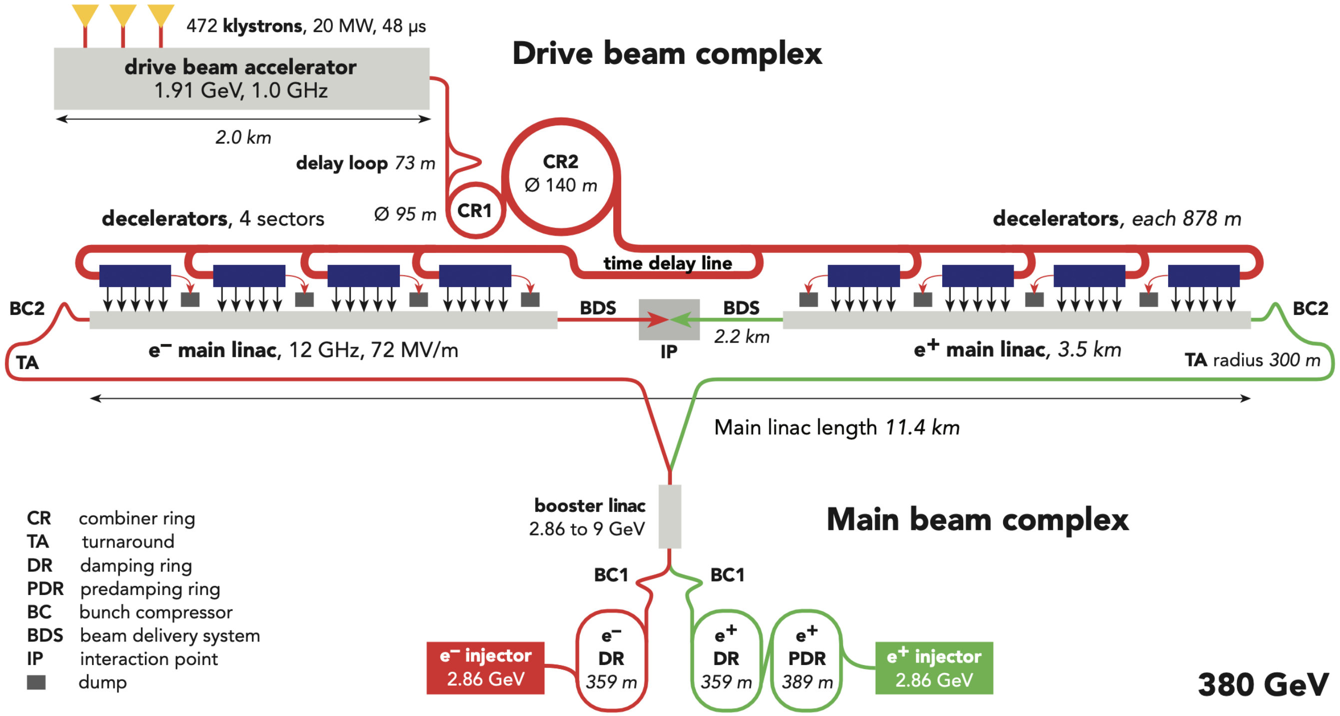


Fig. 1: Schematic layout of the CLIC complex at 380 GeV.

High-energy machine: 1.5 TeV

- L = 3.7 x 10^{34}/cm^2/s. Only 50 Hz, one BDS considered
- Mention that one can reach 2 TeV with a single drive-beam
- No special discussion of 3 TeV machine expect reference to CDR

The CLIC ESPP update - II

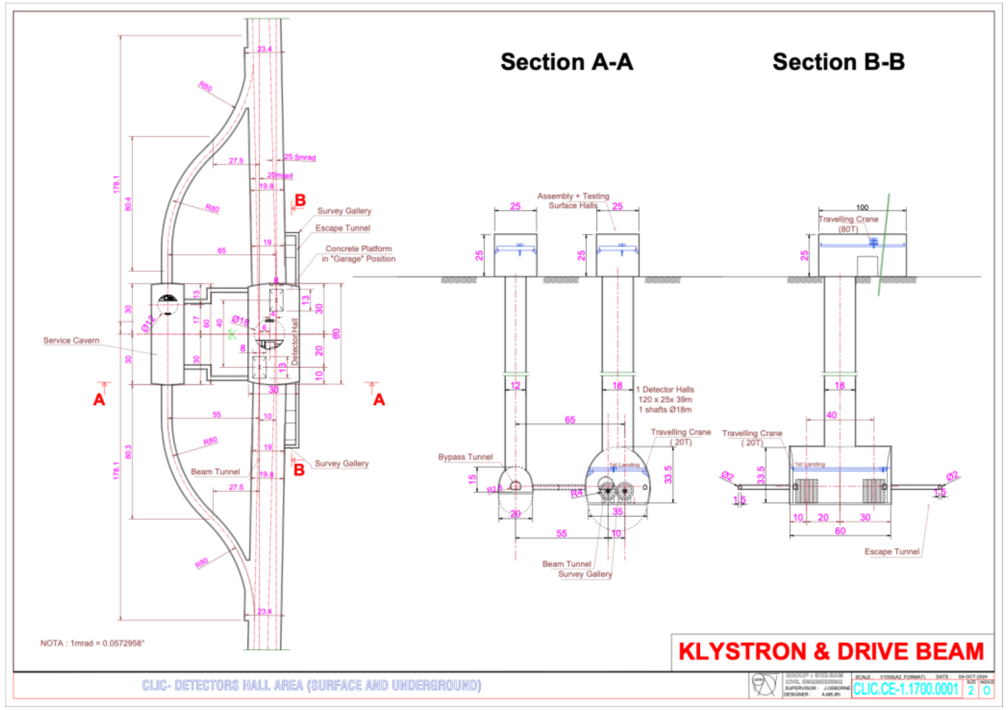
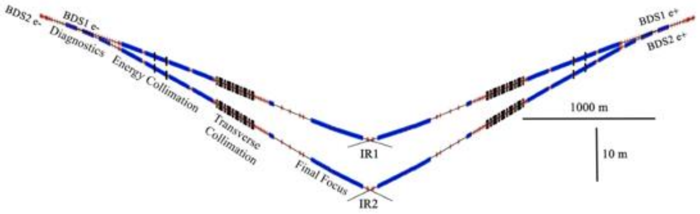


Table 1.1: Key parameters of the CLIC energy stages.

Parameter	Unit	Stage 1	Stage 2	Stage 3
Centre-of-mass energy	GeV	380	1500	3000
Repetition frequency	Hz	50	50	50
Nb. of bunches per train		352	312	312
Bunch separation	ns	0.5	0.5	0.5
Pulse length	ns	244	244	244
Accelerating gradient	MV/m	72	72/100	72/100
Total luminosity	$1\times10^{34}\,\mathrm{cm^{-2}\,s^{-1}}$	2.3	3.7	5.9
Lum. above 99 % of $\sqrt{s}$	$1\times10^{34}\,\mathrm{cm^{-2}\,s^{-1}}$	1.3	1.4	2
Total int. lum. per year	fb^{-1}	276	444	708
Main linac tunnel length	km	11.4	29.0	50.1
Nb. of particles per bunch	1×10^{9}	5.2	3.7	3.7
Bunch length	µm	70	44	44
IP beam size	nm	149/2.0	~60/1.5	~40/1
Final RMS energy spread	%	0.35	0.35	0.35
Crossing angle (at IP)	mrad	16.5	20	20

Plus 250 GeV parameters



Run plan and integrated luminosities

At 380 we are at 2.25 10^34 with 50 Hz, the double at 100 Hz

At 250 it is reduced to 1.5 and 3.0.

At 1.5 we assume only 50 Hz (due to power), 3.7 10^34

We have a ramp up at 10, 30, 60% the first 3 years for 380 (or 250), 25, 75% for second stage

So 10 years at 250 or 380 is 8 x 1.2 10^7s, 10 years at 1.5 is 9 x 1.2 10^7s

380

50/100 Hz

10 years with ramp up, i.e 8 years

2.25/4.5

Integrated 10 years: 2.2/4.3 at-1

250

50/100 Hz

10 years with ramp, i.e. 8 years

1.5/3.0

1.4/2.9 at-1

1500

50 Hz

3.7 10^34

10 with ramp up, i.e. 9 years

4 at-1

ESPP inputs – I

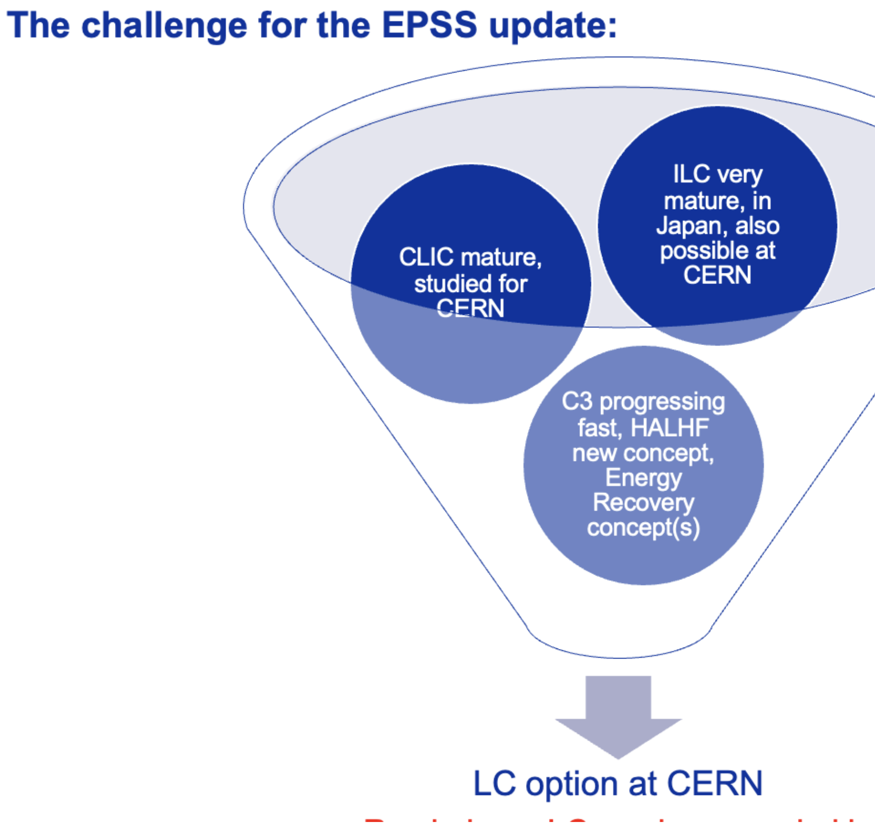
General goals for LCs :

- See physics opportunities on page 5
- Lower cost to get to Higgs and top than a circular machine
- Power similar to LHC, or lower
- Footprint similar to LHC, CE cost risks therefore manageable
- Does not determine footprint of future energy frontier machines (hadrons and muon), and it has its own upgrade opportunities.

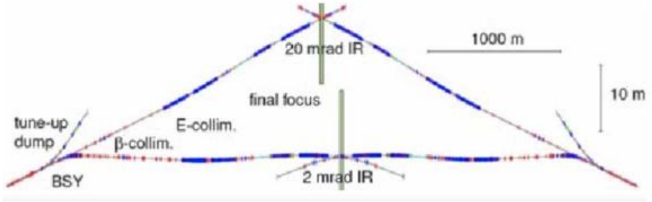
Higgs factory focussed studies	**Project input (the traditional way)** **See earlier slides**
ILC	ILC in Japan (JAHEP/ILC-Japan and IDT)
CLIC	CLIC at CERN
C3	Project study, focus on next phase
HALHF	Project concept, pre-CDR
Energy recovery	Project concepts and plans

ESPP inputs – II

For a LC at CERN, what would be favoured option to start with – keeping in mind technology changes can be envisaged ?



New approach for this ESPP (facility and community approach) – with three key inputs to the ESPP
Common LC physics paper covering from 90 GeV to 1000 GeV or even above. Include also non collider programme (see slide 5). Serves also the projects on previous page.
Starting with ILC technology, look at energy and luminosity extension options with improved SFR, or CLIC, C3, plasma and Energy Recovery technologies
Implementation of the above at CERN in footprint studied for CLIC (and ILC back in the TDR days), with two BDS, and experimental area at Prevessin, and considerations of upgrade options.

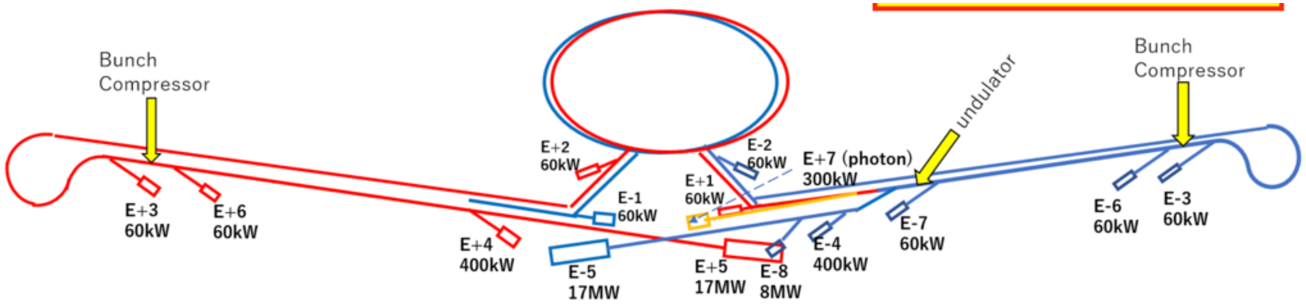


A physics-driven, polarised operating scenario for a Linear Collider

- **250 GeV, ~2ab-1:**
  - precision Higgs mass and total ZH cross-section
  - Higgs -> invisible (Dark Sector portal)
  - basic ffbar and WW program
  - optional: WW threshold scan
- **Z pole, few billion Z's: EWPOs 10-100x better than today**
- **350 GeV, 200 fb-1:**
  - precision top mass from threshold scan
- **500...600 GeV, 4 ab-1:**
  - Higgs self-coupling in ZHH
  - top quark ew couplings
  - top Yukawa coupling incl CP structure
  - improved Higgs, WW and ffbar
  - probe Higgsinos up to ~300 GeV
  - probe Heavy Neutral Leptons up to ~600 GeV
- **800...1000 GeV, 8 ab-1:**
  - Higgs self-coupling in VBF
  - further improvements in tt, ff, WW, ...
  - probe Higgsinos up to ~500 GeV
  - probe Heavy Neutral Leptons up to ~1000 GeV
  - searches, searches, searches, ...

Beyond collider:

- ILCX – e.g. beam-dump experiments, dark sector physics, light dark matter, strong QED (ILCX workshop)
- Test and R&D beams for detector and accelerator studies



From J.List/M.Peskin

CLIC input to the European Strategy for Particle Physics Update 2018-2020

Formal European Strategy submissions

- **The Compact Linear e+e- Collider (CLIC): Accelerator and Detector** (arXiv:1812.07987)
- **The Compact Linear e+e- Collider (CLIC): Physics Potential** (arXiv:1812.07986)

Yellow Reports

- **CLIC 2018 Summary Report** (CERN-2018-005-M , arXiv:1812.06018)
- **CLIC Project Implementation Plan** (CERN-2018-010-M , arXiv:1903.08655)
- **The CLIC potential for new physics** (CERN-2018-009-M , arXiv:1812.02093)
- **Detector technologies for CLIC** (CERN-2019-001 , arXiv:1905.02520)

Journal publications

- **Top-quark physics at the CLIC electron-positron linear collider** (Journal , arXiv:1807.02441)
- **Higgs physics at the CLIC electron-positron linear collider** (Journal , arXiv:1608.07538)
    - Projections based on the analyses from this paper scaled to the latest assumptions on integrated luminosities can be found here: CDS , arXiv .

CLICdp notes

- **Updated CLIC luminosity staging baseline and Higgs coupling prospects** (CERN Document Server ,arXiv:1812.01644)
- **CLICdet: The post-CDR CLIC detector model** (CERN Document Server)
- **A detector for CLIC: main parameters and performance** (CERN Document Server , arXiv:1812.07337)

https://clic.cern/european-strategy

Large-Scale Projects: Guidelines for Input

ESG Secretariat, 3rd December 2024 - v2.1 – final for distribution

Introduction

It is anticipated that a number of proposals for large-scale research projects – including, but not limited to, particle colliders and collider detectors – will be submitted as input to the strategy process. These proposals are likely to vary in scale, anticipated timeline, and technical maturity.

'Large-scale' should be interpreted as meaning 'occupying the resources and efforts of an appreciable fraction of the European particle physics community for a number of years'. In financial terms, this indicates a capital investment of at least 250 MCHF.

In addition to studying the scientific potential of these projects, the ESG wishes to evaluate the sequence of delivery steps and the challenges associated with delivery, and to understand how each project could fit into the wider roadmap for European particle physics.

In order to allow a straightforward comparison of projects, we therefore request that all large-scale projects submit – in addition to their physics case and technical description – a standardised set of technical data. This will allow comparison and presentation of projects on a like-for-like basis without the need for re-interpretation of inputs. It is recognised that careful consideration of the entire scope of the strategy inputs, beyond summary data, will be needed when coming to conclusions. It is also understood that depending on the current level of technical planning, projects may be able to provide greater or lesser detail or certainty of estimates in response to each question.

The additional information may be contained in an addendum to the main submission.

Definitions

Since most major infrastructures will proceed through several stages of construction, upgrade, and potential re-use, we define a 'project' as 'the pursuit of a clearly-defined scientific programme using a major research infrastructure'. A given infrastructure (e.g. the LEP/LHC tunnel) may support multiple projects in its lifetime. Moreover, we assume that each project may have multiple stages with varying scientific goals. An example would be the use of the LHC machine and its detectors in their original form and then as the upgraded HL-LHC complex.

The choice of how to divide the lifetime scientific programme of an infrastructure into projects and stages is left open, though we suggest this is done in such a way that successive stages of construction / operation with different parameters are made distinct.

Questions for projects

1. Stages and parameters
    a. The main stages of the project and the key scientific goals of each
    b. Whether the ordering of stages is fixed or whether there is flexibility
    c. For each stage, the main technical parameters
    d. The number of independent experimental activities and the number of scientists expected to be engaged in each.
2. Timeline
    a. The technically-limited timeline for construction of each stage
    b. The anticipated operational (running) time at each stage, and the expected operational duty cycle
3. Resource requirements
    a. The capital cost of each stage in 2024 CHF
    b. The annual cost of operations of each stage
    c. The human resources (in FTE) needed to deliver or operate each stage over its lifetime, expressed as an annual profile
    d. Commentary on the basis-of-estimate of the resource requirements
4. Environmental impact
    a. The peak (MW) and integrated (TWh) energy consumption during operation of each stage
    b. The integrated carbon-equivalent energy cost of construction
    c. Any other significant expected environmental impacts
5. Technology and delivery
    a. The key technologies needed for delivery that are still under development in 2024, and the targeted performance parameters of each development
    b. The critical path for technology development or design
    c. A concise assessment of the key technical risks to the delivery of the project
6. Dependencies
    a. Whether a specific host site is foreseen, or whether options are available
    b. The dependencies on existing or required infrastructure
    c. The technical effects of project execution on the operations of existing infrastructures at the host site
7. Commentary on current project status
    a. A concise description of the current design / R&D / simulation activities leading to the project, and the community pursuing these
    b. A statement of any major in-kind deliverables already negotiated
    c. Any other key technical information points in addition to those captured above, including references to additional public documents addressing the points above.

Notes

1c: For particle colliders, this should at least indicate the centre-of-mass collision energy, integrated luminosity, peak luminosity, and number of collision points/experiments.

1d: ‘Experimental activities’ means ‘the activities of a formal collaboration of scientists working towards a well-defined set of scientific goals’.

2a(i): ‘Technically-limited’ means ‘with consideration for a realistic sequence of approval, territorial negotiation, R&D, design, prototyping, industrialization, production, and installation given the capacity of the field’ but not limited by capital funding or external political delays.

2a(ii): The timeline should include the intermediate steps/goals of the R&D program.

2b: Duty cycle means the fraction of each year spent in physics operations. For guidance, a past report documenting anticipated operational parameters of future colliders is available.

3a(i): ‘Capital cost’ here corresponds to the usual ‘core cost’ model of CERN, including purchases, materials, equipment, but not human resources.

3a(ii): Costs should be broken down at top level where possible, e.g. into R&D, civil engineering, infrastructure, contracts, and support costs.

3a(iii): The costs of infrastructures (e.g. colliders) and associated scientific equipment (i.e. number of detectors and their estimated CORE costs) should be stated separately.

3a(iv): Costs should be expressed as a time profile over the project duration where possible.

3b: Include maintenance, power, and other support costs.

3c: This should include ‘direct’ costs associated with staffing and running the project. ‘Indirect’ costs including those of data-handling and computing should not be included, but further information may be given under item 7.

3d: Projects should provide an assessment of the maturity of estimates, and a concise explanation of how the estimates were arrived at. Where possible, please use AACE standards for classification of uncertainties.

4c: Include use of land area and consumption of other natural resources, e.g. significant consumption of water, helium or significant use of rare earth materials.

5b: Include any critical decision points on technology choices yet to be made.

6c: For example, the sequencing of construction with existing scientific programmes.