The CLIC re-baselining document

Eva Sicking (CERN / LAPP Annecy) on behalf of the CLIC re-baselining editor team

CLIC workshop January 22, 2016

The CLIC re-baselining document



CLIC-Note-201X-XXX 21 January 2016

Updated baseline for a staged Compact Linear Collider

The CLIC and CLICdp collaborations (list incomplete)

P.J. Giansiracusa, T.G. Lucas, R.P. Rassool The University of Melbourne, Australia C. Balazs, T.K. Charles Monash University, Australia

> M. Boland, U. Felzmann Australian Synchrotron, Australia

K. Afanaciev, I. Emeliantchik, A. Ignatenko, V. Makarenko, N. Shumeiko Research Institute for Nuclear Problems of Belazusian State University (INP BSU), Minsk, Belazus

> A.C. Abusleme Hoffman, M.A. Diaz Gutierrez, M. Vogel Gonzalez Pontificia Universidad Católica de Chile, Santiago, Chile

T. Laštovička

T. Laštovička

Institute of Physics, Academy of Sciences of the Czech Republic, Prague, Czech Republic

U. Ungerhoj, T.N. Wistisen

Department of Physics and Astronomy, Aarhus University, Denmark

J.-J. Blaising, M. Chefdeville, Y. Karvotakis

Laboratoire d'Annecy-le-Vieux de Physiques des Particules, Annecy, France

L. Penc Karlsruhe Institute for Technology (KIT), Germany

M. Gabriel, F. Simon, M. Szalay, N. van der Kolk

Max-Planck-Institut für Physik. Föhringer Ring, 6, D-80805 Munich, Germany

H. Abramowicz, Y. Benhammou, O. Borysov, S. Kananov, A. Levy, I. Levy, O. Rosenblat
Raymond & Beverty Sackler School of Physics & Astronomy, Tel Aviv, University, Tel Aviv,

G. Eigen, J. Zalieckas

Department of Physics and Technology, University of Bergen, Bergen, Norway

S. Bugiel, R. Dasgupta, M. Firlej, T.A. Fiutowski, M. Idzik, M. Kuczynska, J. Moron,

K.P. Swientek

Faculty of Physics and Applied Computer Science, AGH University of Science and Technology,

Al. Mickiewicza 30, Kraków, Poland

• Authors:

The CLIC and CLICdp collaborations

- → Please check if your institute is already represented correctly in the author list and in the acknowledgements
- Editors:

Philip Burrows, Philippe Lebrun, Lucie Linssen, Daniel Schulte, ES, Steinar Stapnes, Mark Thomson

- Update of CLIC staging baseline
- Focus on initial energy stage
- Updated official CLIC figures
- Latest version always at this website
 http://esicking.web.cern.ch/esicking/ClicStagingBaseline/

Content of re-baselining document

2.4 Top physics 2.4.1 Top quark mass 2.4.2 Top quark mass 2.4.2 Top quark as probe for BSM physics. 2.5 Physics beyond the Standard Model 2.5.1 Direct searches for BSM physics. 2.5.2 Sensitivity of precision measurements to BSM physics. 2.5.3 Constitivity of precision measurements to BSM physics. 2.5.3 Summary of physics requirements for the CLIC energy stages 3. CLIC post-CDR accelerator optimisation 3.1 Overview 3.2 State of understanding 3.2.1 Beam Parameters 3.2.2 RF structure design 3.2.2 RF structure design 3.2.3 Cost and power estimates. 3.3.3 Optimisation procedure and results s. 3.3.1 Optimination procedure and results s. 3.3.2 Optimination and SteV 3.3.3 Sanging strategy 4. CLIC staging baseline 4. Description and performance parameters 4. 2 Operation scenario 4. 3 Power and energy consumption.	_		Con	tent
2 CLIC physics at various centre-of-mass energies 2.1 CLIC detector and experimental conditions 2.2 CLIC energy stages and their impact on the physics potential 2.3 Higgs physics 2.3.1 Combined Higgs fits 2.4 Top physics 2.4.1 Top quark mass 2.4.2 Top quark mass 2.4.2 Top quark as probe for BSM physics 2.5.1 Direct searches for BSM physics 2.5.1 Direct searches for BSM physics 2.5.2 Sensitivity of precision measurements to BSM physics 2.5.3 Sensitivity of precision measurements to FSM physics 3.5.3 Sensitivity of precision measurements for the CLIC energy stages 3.1 Overview 3.2 State of understanding 3.2.1 Ream Parameters 3.2.2 RF structure design 3.2.3 Resurrante design 3.3.3 Cost and power estimates 3.3.3 Optimisation procedure and results 3.3 Optimisation procedure and results 3.3 Optimisation and Portornance parameters 4.2 Operation and performance parameters 4.3 Operation and performance parameters 4.4 Cost estimate	С	onte	nts	
2.1 CLIC detector and experimental conditions 2.2 CLIC energy stages and their impact on the physics potential 2.3 Higgs physics 2.3.1 Combined Higgs fits 2.4.1 Top plays mass 2.4.2 Top unark mass 2.4.2 Top unark mass 2.4.2 Top unark mass 2.5.1 Direct searches for BSM physics 2.5.1 Direct searches for BSM physics 2.5.2 Sensitivity of precision measurements to BSM physics 2.5.3 Sensitivity of precision measurements to BSM physics 2.6.5 Summany of physics requirements for the CLIC energy stages 3 CLIC post-CDR accelerator optimisation 3.1 Overview 3.2 State of understanding 3.2.1 Beam Parameters 3.2.2 RF structure design 3.2.3 Cost and power estimates 3.3.3 Optimisation procedure and results 3.3.1 Optimism at 380 GeV 3.3.3 Saging strategy 4 CLIC staging baseline 4.1 Description and performance parameters 4.2 Operation scenario 4.3 Power and energy consumption. 4.4 Cost estimate	1	Intro	duction	,
2.2 CLIC energy stages and their impact on the physics potential 2.3 Higgs physics 2.3 Higgs physics 2.4.1 Combined Higgs fits 2.4.1 Top quark mass 2.4.2 Top physics 2.4.1 Top quark mass 2.4.2 Top quark suppose for BSM physics 2.5.2 Physics beyond the Standard Model 2.5.1 Direct searches for BSM physics 2.5.2 Sensitivity of precision measurements to BSM physics 2.5.2 Sensitivity of precision measurements for the CLIC energy stages 3.5.2 Sensitivity of precision measurements for the CLIC energy stages 3.6.2 New York 3.7.2 New York	2	CLIC	physics at various centre-of-mass energies	
2.3 Higgs physics 2.3 I Combined Higgs fits 2.4 Top physics 2.4.1 Top push mass 2.4.2 Top quark mass 2.4.2 Top quark as probe for BSM physics 2.5.1 Direct searches for BSM physics 2.5.1 Direct searches for BSM physics 2.5.2 Sensitivity of precision measurements to BSM physics 2.5.3 Summary of physics requirements for the CLIC energy stages 3. CLIC post-CDR accelerator optimisation 3.1 Overview 3.2 State of undentanding 3.2.1 Beam Parameters 3.2.2 RF structure design 3.2.3 Cost and power estimates 3.3.3 Optimisation procedure and results 3.3.1 Optimisation procedure and results 3.3.3 Optimisation procedure and results 3.3.3 Optimisation procedure and results 4.3 Staging strategy 4. CLIC staging baseline 4.1 Description and performance parameters 4.2 Operation secaraio 4.3 Fower and energy consumption. 4.4 Cost estimate		2.1	CLIC detector and experimental conditions	
2.3.1 Combined Higgs fits 2.4 Top physics 2.4.1 Top quark mass 2.4.2 Top quark as probe for BSM physics 2.5.2 Physics beyond the Standard Model 2.5.1 Direct searches for BSM physics 2.5.2 Sensitivity of precision measurements to BSM physics 2.5.3 Unique properties of the CLIC energy stages 3.5 Life post-CDR accelerator optimisation 3.1 Overview 3.2 State of understanding 3.2.1 Beam Parameters 3.2.2 RF structure design 3.2.3 Root and power estimates 3.3 Optimisation procedure and results 3.3.1 Optimisation procedure and results 3.3.3 Optimisation procedure and results 3.3.3 Optimisation procedure and results 3.3.3 Optimisation procedure and results 4.3 Staging strategy 4. CLC staging baseline 4.1 Description and performance parameters 4.2 Operation scenario 4.3 Power agard energy consumption. 4.4 Cost estimate		2.2	CLIC energy stages and their impact on the physics potential	
2.4 Top physics 2.4.1 Top quark mass 2.4.2 Top quark as probe for BSM physics 2.5.2 Physics beyond the Standard Model 2.5.1 Direct searches for BSM physics 2.5.2 Sensitivity of precision measurements to BSM physics 2.5.3 Sensitivity of precision measurements for the CLIC energy stages 3. CLIC post-CDR accelerator optimisation 3.1 Overview 3.2 State of understanding 3.2.1 Beam Parameters 3.2.2 RF structure design 3.2.3 Root and power estimates 3.3.3 Optimisation procedure and results 3.3.1 Optimisation procedure and results 3.3.3 Optimisation procedure and results 3.3.3 Optimisation procedure and results 4.3 Staging strategy 4. CLIC staging baseline 4.1 Description and performance parameters 4.2 Operation scenario 4.3 Fower and energy consumption. 4.4 Cost estimate		2.3	Higgs physics	
2.4.1 Top quark mass 2.4.2 Top quarks are probe for BSM physics 2.5 Physics beyond the Standard Model 2.5.1 Direct searches for BSM physics 2.5.2 Sensitivity of precision measurements to BSM physics 2.5 Summary of physics requirements for the CLIC energy stages 3. CLIC post-CDR accelerator optimisation 3.1 Operation 3.2 State of understanding 3.2.1 Ream Parameters 3.2.2 RF structure design 3.2.3 Cost and power estimates 3.3 Optimisation procedure and results 3.3.1 Optimisation procedure and results 3.3.2 Optimum at 380 GeV 3.3.3 Saging strategy 4. CLIC staging baseline 4.1 Description and performance parameters 4.2 Operation scenario 4.3 Power and energy consumption 4.4 Cost estimate			2.3.1 Combined Higgs fits	1
2.4.2 Top quark as probe for BSM physics 2.5 Physics beyond the Standard Model 2.5.1 Direct searches for BSM physics 2.5.2 Sensitivity of precision measurements to BSM physics 2.6 Summary of physics requirements for the CLIC energy stages 3 CLIC post-CDR accelerator optimisation 3.1 Overview 3.2 State of understanding 3.2.1 Beam Parameters 3.2.2 RF structure design 3.2.3 Cost and power estimates 3.3 Optimisation procedure and results 3.3.3 Optimisation procedure and results 3.3.3 Optimisation procedure and results 3.3.3 Optimisation procedure and results 4.3 Spating strategy 4. CLIC staging baseline 4.1 Description and performance parameters 4.2 Operation secaraio 4.3 Fower and energy consumption. 4.4 Cost estimate		2.4	Top physics	1
25 Physics beyond the Standard Model 2.5.1 Direct searches for BSM physics 2.5.2 Sensitivity of precision measurements to BSM physics 2.6 Summary of physics requirements for the CLIC energy stages 3 CLIC post-CDR accelerator optimisation 3.1 Overview 3.2 State of understanding 3.2.1 Beam Parameters 3.2.2 RF structure design 3.2.3 Cost and power estimates 3.3.1 Optimum at 3TeV 3.3.2 Optimum at 3TeV 3.3.3 Singing strategy 4 CLIC staging baseline 4.1 Description and performance parameters 4.2 Operation scenario 4.3 Power and energy consumption. 4.4 Cost estimate			2.4.1 Top quark mass	1
2.5.1 Direct searches for BSM physics 2.5.2 Sensitivity of precision measurements to BSM physics 2.6 Summary of physics requirements for the CLIC energy stages 3 CLIC post-CDR accelerator optimisation 3.1 Overview 3.2 State of understanding 3.2.1 Beam Parameters 3.2.2 RF structure design 3.2.3 Root and power estimates 3.3.3 Optimisation procedure and results 3.3.1 Optimisation procedure and results 3.3.3 Optimisation procedure and results 3.3.3 Optimisation procedure and results 4.3 Staging strategy 4. CLIC stagling baseline 4. Description and performance parameters 4.2 Operation scenario 4.3 Power and energy consumption. 4.4 Cost estimate			2.4.2 Top quark as probe for BSM physics	1
2.5.2 Sensitivity of precision neasurements to BSM physics 2.6 Summary of physics requirements for the CLIC energy stages 3 CUIC post-COR accelerator optimisation 3.1 Overview 3.2 State of understanding 3.2.1 Beam Parameters 3.2.2 RF structure design 3.2.3 Cost and power estimates 3.3.0 primusation procedure and results 3.3.1 Optimum at 3TeV 3.3.2 Optimum at 3TeV 3.3.3 Optimum at 3StoGeV 3.3.3 Staging strategy 4 CLIC staging baseline 4 Description and performance parameters 4.2 Operation scenario 4.3 Power and energy consumption. 4.4 Cost estimate		2.5	Physics beyond the Standard Model	1
2.6 Summary of physics requirements for the CLIC energy stages 3 CLIC post-COR accelerator optimisation 3.1 Overview 3.2 State of understanding 3.2.1 Beam Parameters 3.2.2 RF structure design 3.2.3 Cost and power estimates 3.3 Optimisation procedure and results 3.3.1 Optimisation procedure and results 3.3.2 Optimisation STEV 3.3.3 Optimisation procedure and results 4.3 Optimisation STEV 4.3 Staging strategy 4. CLIC stagling baseline 4.1 Description and performance parameters 4.2 Operation scenario 4.3 Power and energy consumption. 4.4 Cost estimate			2.5.1 Direct searches for BSM physics	2
3 CLIC post-CDR accelerator optimisation 3.1 Overview 3.2 State of understanding 3.2.1 Beam Parameters 3.2.2 RF structure design 3.2.3 Cost and power estimates 3.3 Optimisation procedure and results 3.3.1 Optimum at 3TeV 3.3.2 Optimum at 3TeV 3.3.3 Staging strategy 4 CLIC staging baseline 4.1 Description and performance parameters 4.2 Operation scenario 4.3 Power and energy consumption. 4.4 Cost estimate			2.5.2 Sensitivity of precision measurements to BSM physics	2
3.1 Overview 3.2 State of understanding 3.2.1 Beam Parameters 3.2.2 RF structure design. 3.2.3 Cost and power estimates 3.3.0 primariation procedure and results 3.3.1 Optimum at 3TeV 3.3.2 Optimum at 3StoGeV 3.3.3 Staging strategy 4 CLC staging baseline 4.1 Description and performance parameters 4.2 Operation scenario 4.3 Power and energy consumption. 4.4 Cost estimate		2.6	Summary of physics requirements for the CLIC energy stages $\dots \dots \dots$	2
3.2 State of understanding 3.2.1 Beam Parameters 3.2.2 RF structure design 3.2.3 Cost and power estimates 3.2.3 Optimisation procedure and results 3.3.1 Optimisation procedure and results 3.3.2 Optimism at 380 GeV 3.3.3 Saging strategy 4. CLC staging baseline 4. Description and performance parameters 4.2 Operation scenario 4.3 Power and energy consumption 4.4 Cost estimate 4.5 Cost estimate 4.	3	CLIC	post-CDR accelerator optimisation	2
3.2.1 Beam Parameters 3.2.2 RF structure design 3.2.3 Cost and power estimates 3.3 Optimisation procedure and results 3.3.1 Optimum at 3 TeV 3.3.2 Optimum at 3 TeV 3.3.2 Optimum at 3 TeV 4. CLC staging strategy 4. CLC staging baseline 4. Description and performance parameters 4.2 Operation scenario 4.3 Power and energy consumption. 4.4 Cost estimate		3.1	Overview	2
3.2.2 RF structure design 3.2.3 Cost and power estimates 3.3 Optimization procedure and results 3.3.1 Optimizant a3 TeV 3.3.2 Optimizant a3 TeV 3.3.2 Optimizant a5 TeV 4.3.3.3 Staging strategy 4.1 Description and performance parameters 4.2 Operation scenario 4.3 Power and energy consumption. 4.4 Cost estimate		3.2	State of understanding	2
3.2.3 Cost and power estimates 3.3.0 primisation procedure and results 3.3.1 Optimum at 3 TeV 3.3.2 Optimum at 3 Sto GeV 3.3.3 Staging strategy 4 CLC staging baseline 4 Description and performance parameters 4.2 Operation scenario 4.3 Power and energy consumption. 4.4 Cost estimate			3.2.1 Beam Parameters	2
3.3 Optimisation procedure and results			3.2.2 RF structure design	2
3.3.1 Optimum at 3 TeV 3.3.2 Optimum at 3 StoGeV 3.3.3 Staging strategy 4 CLC staging baseline 4.1 Description and performance parameters 4.2 Operation scenario 4.3 Power and energy consumption. 4.4 Cost estimate			3.2.3 Cost and power estimates	2
3.3.2 Optimum at 380 GeV 3.3.3 Staging strategy 4 CLIC staging baseline 4.1 Description and performance parameters 4.2 Operation scenario 4.3 Power and energy consumption. 4.4 Cost estimate		3.3	Optimisation procedure and results	2
3.3.3 Slaging strategy 4 CLIC staging baseline 4.1 Description and performance parameters 4.2 Operation scenario 4.3 Power and energy consumption. 4.4 Cost estimate			3.3.1 Optimum at 3 TeV	2
4 CLIC staging baseline 4.1 Description and performance parameters 4.2 Operation scenario 4.3 Power and energy consumption 4.4 Cost estimate			3.3.2 Optimum at 380 GeV	2
Description and performance parameters Operation scenario			3.3.3 Staging strategy	2
4.2 Operation scenario 4.3 Power and energy consumption . 4.4 Cost estimate	4	CLIC	Staging baseline	2
4.3 Power and energy consumption		4.1	Description and performance parameters	2
4.4 Cost estimate		4.2	Operation scenario	2
		4.3	Power and energy consumption	2
5 Alternative klystron-based scenario for the first CLIC stage		4.4	Cost estimate	3
	5	Alte	rnative klystron-based scenario for the first CLIC stage	3

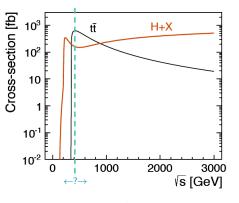
→ Physics considerations

→ Accelerator optimisation methodology

 \rightarrow New staging baseline

Physics motivation of re-baselining

• CLIC is foreseen as staged machine with \sqrt{s} from few-hundred GeV to 3 TeV

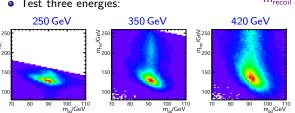


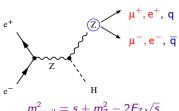
• 1st stage

- Guaranteed physics: Higgs coupings + width and top
- Higgs discovered after CDR
- $m_{\rm H} = 125 \, {\rm GeV}$
- Subsequent (2nd and 3rd) stages
 - Motivated by Higgs physics and new physics
 - ightarrow Potential discoveries at the LHC at 14 TeV
 - → Direct and indirect searches for beyond standard model physics
- Optimal \sqrt{s} for 1st stage is not at peak of HX and $t\bar{t}$ cross sections
 - ightarrow luminosity and backgrounds can scale with centre-of-mass energy
 - \rightarrow theory uncertainties for $t\bar{t}$ can be larger close to on-set of $t\bar{t}$ production

Higgs recoil mass at $\sqrt{s} = 250/350/420 \,\text{GeV}$

- Accuracies of Higgs results governed by accuracy of HZ coupling
- HZ coupling in Z recoil mass measurement in first energy stage
- Hadronic channel (BR_{Z→gq} ≈ 70 %) has largest impact
- Test three energies:





$m_{\text{recoil}}^2 = s + i$	$m_{\rm Z}^2 - 2E_{\rm Z}\sqrt{s}$
-------------------------------	------------------------------------

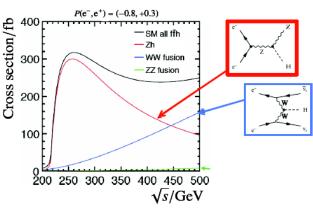
\sqrt{s}	$\sigma(HZ)$	$\Delta \sigma(HZ)$
250 GeV	136 fb	$\pm 3.65\%$
350 GeV	93 fb	$\pm 1.80\%$
420 GeV	68 fb	$\pm 2.63\%$

 \rightarrow arXiv:1509.02853[hep-ex]

- Find optimal energy for first CLIC stage
 - Cross section decreases with \sqrt{s}
 - Absolute detector resolution degrades with \sqrt{s}
 - Background rejection improves with increasing \sqrt{s}
- Optimum close to 350 GeV

Access to Higgsstrahlung and WW fusion

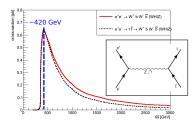
 For a comprehensive Higgs study in the first energy stage only, access to several Higgs production processes is advantageous

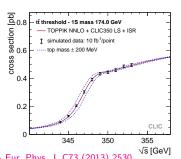


- Below $\sqrt{s} \sim 300 \, \text{GeV}$ Higgsstrahlung dominates
- Above $\sqrt{s} \sim 500 \, {\rm GeV}, \ {\rm WW-fusion} \ {\rm dominates}$

 \rightarrow At $\sqrt{s} = 350-450 \, \text{GeV}$ both processes contribute

Top physics





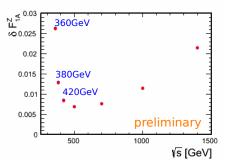
- At $\sqrt{s} > 350 \, \text{GeV}$, top pair production sets on
- Maximum at $\sqrt{s} > 420 \, {\rm GeV}$, then cross section falls steeply (s-channel)

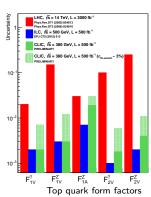
- High precision measurement of top mass from threshold scan with modest luminosity (10 fb⁻¹/point) in addition to first energy stage
- $ightarrow~\delta \emph{m}_{t}=33\, \text{MeV}$ statistical uncertainty

Top form factor measurement

- ightarrow Talk by Ignacio Garcia on Thursday
- Probe top vertex through cross section and forward-backward asymmetry (A_{FB})
 - Derive top form factors (F)
 - Expect deviations from SM expectations in form factors for BSM models

• Form factor uncertainty vs. \sqrt{s} (500 fb⁻¹ each)





- Reconstruction capability and impact of BSM on form factor increases with \sqrt{s}
- Theoretical uncertainty decrease with \sqrt{s}
- \rightarrow Optimum close to 500 GeV (for fixed luminosity per \sqrt{s})

Conclusion on CLIC first energy stage

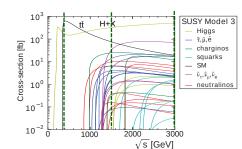
Find compromise for comprehensive physics programme of initial stage

- Higgs recoil mass measurement
 - $ightarrow 250 \, \mathrm{GeV} < \sqrt{s} < 420 \, \mathrm{GeV}$
- Higgs production via Higgsstrahlung and WW-fusion
 - $ightarrow 250\,\mathrm{GeV} < \sqrt{s} < 450\,\mathrm{GeV}$
- Top pair production
 - $\rightarrow \sqrt{s} > 350 \, \text{GeV}$, maximum at $\sqrt{s} \approx 420 \, \text{GeV}$
- Top as probe for BSM
 - $\rightarrow \sqrt{s} > 360 \,\text{GeV}$
- Top not too close to threshold (theory uncertainties, boost)
 - $\rightarrow \sqrt{s} >> 350 \,\mathrm{GeV}$

$$\rightarrow \sqrt{s} = 380 \, \text{GeV}$$

Proposed CLIC staging baseline

- CLIC energy stages defined by physics
- Proposed scenario
 - 1) $\sqrt{s} = 380 \,\text{GeV}$
 - SM Higgs physics including total width measurement
 - Top precision measurements
 - New physics
 - 2) $\sqrt{s} = 1.5 \,\text{TeV}$
 - New physics
 - ttH, Higgs self coupling
 - Rare Higgs decays
 - 3) $\sqrt{s} = 3 \text{ TeV}$
 - New physics
 - Higgs self coupling
 - Rare Higgs decays

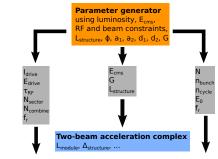


Stage	\sqrt{s} (GeV)	\mathcal{L}_{int} (fb^{-1})
1	380	500
	350	100
2	1500	1500
3	3000	3000

CLIC Accelerator Optimisation for $\sqrt{s} = 380 \, \text{GeV}$

- Accelerator structure design fixed by few parameters (L_{structure}, Φ, ...)
- Find optimal parameter set for 380 GeV CLIC accelerator in parameter scan

- Evaluation tool exists, developed after CDR, based on methods already used in CDR
- Tested ~2 billion possible structures and resulting accelerator complexes based on these parameters



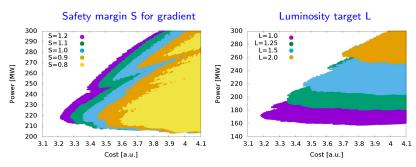
Drive beam generation complex P_{klystron}, N_{klystron}, L_{DBA}, ...

Main beam generation complex P_{klvstron}, ...

- All structures are checked for consistency with beam and RF constraints
- Gauging cost, power and luminosity (not including beam induced backgrounds)

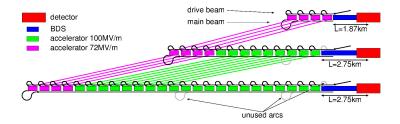
Example: Cost and power for 380 GeV

- Compared cost and power consumption for all resulting structures
 - Choice: fixed pulse length of 244 ns for all stages
 - Note: some accelerator components not included in cost and power, e.g. BDS, main beam injector



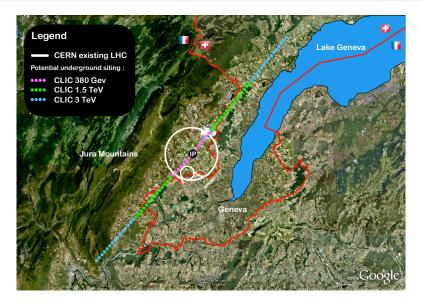
- Choice of safety margin 10% (S=1.1): only small impact on cost and power
- Cost and power increase with luminosity target (choice L=1.5 · 10^{34} cm⁻²s⁻¹: can reach $\mathcal{L}_{int} = 600 \, \text{fb}^{-1}$ in 7 years)
- \rightarrow Most efficient structure: $G = 72 \,\text{MV/m}$, similar to "CLIC_G"

Potential staging concept



 For the structures optimised for 380 GeV, staging scenario towards higher energy stages is available

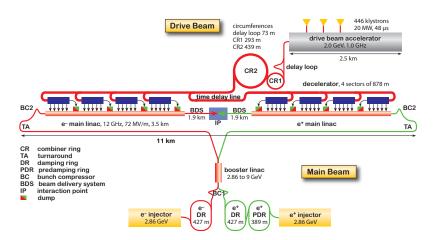
Updated CLIC footprint



Updated CLIC parameter table: Stage 1–3

Parameter	Symbol	Unit	Stage 1	Stage 2	Stage 3
Centre-of-mass energy	\sqrt{s}	GeV	380	1500	3000
Repetition frequency	f_{rep}	Hz	50	50	50
Number of bunches per train	n_b		352	312	312
Bunch separation	Δt	ns	0.5	0.5	0.5
Pulse length	$ au_{pulse}$	ns	244	244	244
Accelerating gradient	G	MV/m	72	72/100	72/100
Total luminosity	\mathcal{L}	$10^{34}~{\rm cm}^{-2}{\rm s}^{-1}$	1.5	3.7	5.9
Luminosity above 99% of \sqrt{s}	$\mathcal{L}_{0.01}$	$10^{34}\ {\rm cm}^{-2}{\rm s}^{-1}$	0.9	1.4	2
Main tunnel length		km	11.4	29.0	50.1
Charge per bunch	Ν	10^{9}	5.2	3.7	3.7
Bunch length	σ_z	μm	70	44	44
IP beam size	σ_x/σ_y	nm	149/2.9	$\sim 60/1.5$	$\sim 40/1$
Normalised emittance (end of linac)	$\epsilon_{\scriptscriptstyle X}/\epsilon_{\scriptscriptstyle Y}$	nm	· —	660/20	660/20
Normalised emittance	$\epsilon_{\scriptscriptstyle X}/\epsilon_{\scriptscriptstyle Y}$	nm	950/30	· —	· —
Estimated power consumption	P_{wall}	MW	252	364	589

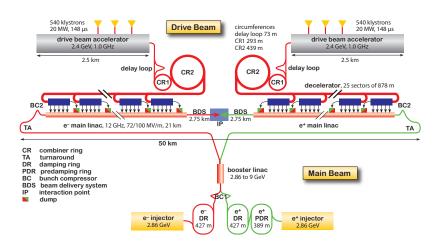
New CLIC layout at 380 GeV



- Removed 1 e-damping ring
- 11 km length (instead of 13 km at 500 GeV)
- 4 sectors (instead of 5 sectors at 500 GeV), ...

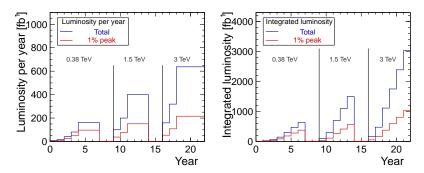
16 / 23

New CLIC layout at 3 TeV



- Removed 1 e⁻-damping ring
- 50 km length instead of 48 km
- 25 sectors instead of 24 sectors, ...

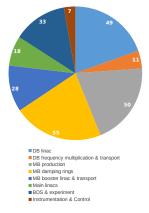
Updated luminosity development



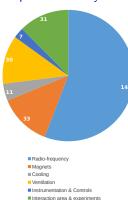
- CLIC programme of 22 years:
 7 years (380 GeV), 5 years (1.5 TeV), 6 years (3 TeV)
 interleaved by 2-years upgrade periods
- Luminosity ramp up of 4 years / 2 years (5%, 10%,) 25%, 50%, 100%

Updated power consumption at 380 GeV





per technical system



CLIC power consumption at 380 GeV: ~ 252 MW_{preliminary} including all accelerator systems, services, experimental area and detector

(Note \rightarrow Numbers scaled from CDR design at 500 GeV

→ To be repeated with detailed tech. description of 380 GeV CLIC)

Updated power consumption at all stages

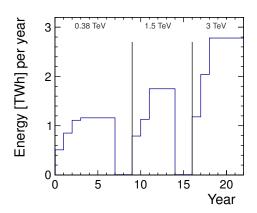
Current estimates of power consumption¹

\sqrt{s} [TeV]	$P_{\text{nominal}}[MW]$	Pwaiting for beam [MW]	$P_{stop}[MW]$
0.38	252	168	30
1.5	364	190	42
3.0	589	268	58

- Potential power savings (not yet included here):
 - Re-design, possibly trading operation expenditure against investment costs
 - Lower current density in normal conducting magnets and cables
 - Use of permanent magnets → Talk by Jim Clarke on Wednesday
 - Reduction of heat loads to ventilation system (enhancement of water cooling)
 - Replacing normal-conducting by "super-ferric" magnets
 - Improving network-to-RF power conversion
 - \rightarrow estimated to be up to 30 MW at 380 GeV

¹Note: 380 GeV numbers scaled from CDR, 1.5 TeV and 3 TeV numbers from CDR

Yearly energy consumption

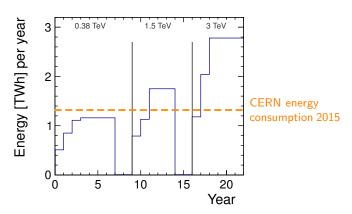


- Including reduced operation in the first years at each energy
- At 380GeV, a single positron target is used for the first three years (-10 MW with respect to nominal)

(Note \rightarrow 380 GeV numbers scaled from CDR design at 500 GeV

ightarrow To be repeated with detailed tech. description of 380 GeV CLIC)

Yearly energy consumption



- Including reduced operation in the first years at each energy
- At 380GeV, a single positron target is used for the first three years (-10 MW with respect to nominal)

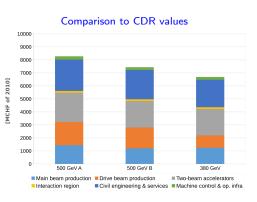
(Note \rightarrow 380 GeV numbers scaled from CDR design at 500 GeV

ightarrow To be repeated with detailed tech. description of 380 GeV CLIC)

Cost estimate for 380 GeV

- Full CLIC cost estimation including all contributions
- Use 2010 CHF for direct comparison to CDR estimates

	Value [MCHF (2010)]
Main beam production Drive beam production Two-beam accelerators Interaction region Civil engineering & services Machine control & operational infrastructure	1245 974 2038 132 2112 216
Total	6690



ullet Full 380 GeV CLIC machine: \sim 6.7 BCHF (2010) $_{preliminary}$ (+ 4 MCHF/GeV up to 1.5 TeV)

(Note \rightarrow Numbers scaled from CDR design at 500 GeV \rightarrow To be repeated with detailed tech. description of 380 GeV CLIC)

Summary

- CLIC re-baselining document close to final
 - Focus on initial energy stage at 380 GeV
 - 380 GeV cost: 6.7 BCHF(2010), power: 252 MW
 - Optimal accelerator structures close to CDR design "CLIC_G"
 - Update of official CLIC figures and tables
- Latest document version can be found at this website
 http://esicking.web.cern.ch/esicking/ClicStagingBaseline/
- Please check if you and your institute are already represented correctly in the author list and the acknowledgements
- Collaboration review will start soon



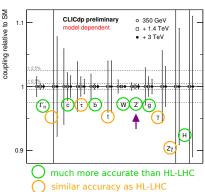
Backup

CLIC Higgs results for example staging scenario

- Studied Higgs physics potential of CLIC in staging scenario including $350 \,\mathrm{GeV} \,(500 \,\mathrm{fb}^{-1}), \, 1.4 \,\mathrm{TeV} \,(1500 \,\mathrm{fb}^{-1}) \,\mathrm{and} \, 3 \,\mathrm{TeV} \,(2000 \,\mathrm{fb}^{-1})$
- Combine results of studied Higgs production and decay channels in global fit → extract couplings and Higgs width

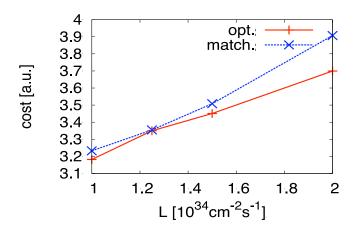
Based on results from full Geant4 detector simulations including $backgrounds \rightarrow$

Assuming 80 % e beam polarisation at 1.4 TeV and 3 TeV



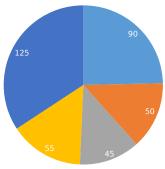
Accuracies governed by H-Z coupling from H recoil mass measurement

Cost of initial stage



• Structures optimised for 380 GeV are similar in cost to those optimised for matching 3 TeV needs (+3% at $L=1.5\cdot 10^{34} {\rm cm}^{-2} {\rm s}^{-1}$)

Assumed operational scenario in "normal" years

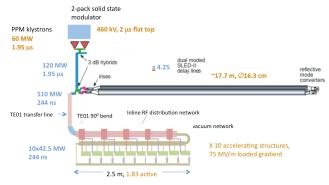


- Annual shutdown
- ■Scheduled short stops
- Fault-induced stops (normal year)
- Operation (MD, beam commissioning)
- ■Operation (data taking)

- 90-day annual shut-down
- 50 days of scheduled maintenance stops (1 day per week and 2 weeks every 2 months)
- Remaining 225 days
 - 45 days (20%) fault-induced stops
 - 180 days (80%) for operation
 - 55 days machine development and tuning runs
 - 125 days for physics data taking

Alternative klystron-based scenario

- At 3 TeV, drive-beam acceleration is more efficient and cost effective than klystrons
- At 380 GeV, X-band klystrons however interesting alternative



- Klystron-based CLIC concept for 380 GeV designed including
 - X-band klystrons
 - Pulse compressor
 - RF distribution system
 - Accelerating structures

Eva Sicking (CERN / LAPP, CNRS)