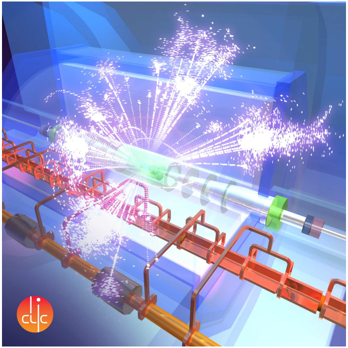
Status of the CLIC Conceptual Design Report
–CLIC energy staging–

Angela Lucaci-Timoce,
on behalf of the CLIC detector and physics study



Outline

Introduction

CLIC Conceptual Design Report (CDR)

Volume 1	*A Multi-TeV Linear Collider based on CLIC Technology: CLIC Conceptual Design Report*	cern edms
Volume 2	*Physics and Detectors at CLIC: CLIC Conceptual Design Report*	arXiv:1202.5940
Volume 3	*The CLIC Programme: towards a staged e^+e^- Linear Collider exploring the Terascale*	arXiv:1209.2543

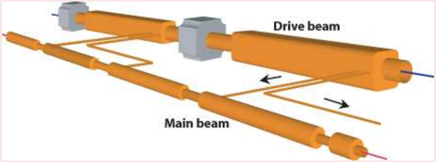
Input to the European strategy for particle physics (September 2012, Krakow, Poland)

From the CLIC group:	*CLIC e^+e^- Linear Collider Studies*	arXiv:1208.1402
From the Linear Collider community (ILC and CLIC):	*The Physics Case for an e^+e^- Linear Collider*	arXiv:1210.0202

CLIC acceleration scheme

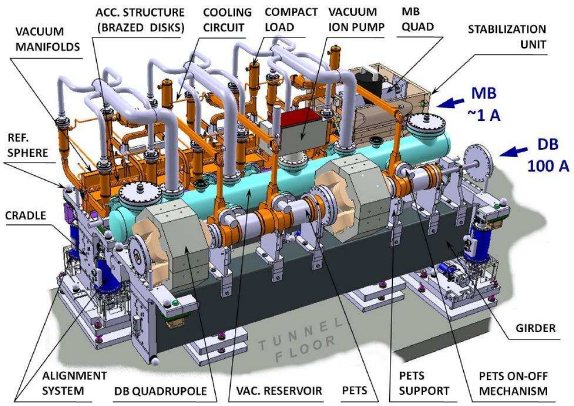
- Novel two-beam acceleration with normal conducting copper cavities at high frequency (12 GHz) and high accelerating fields (100 MV/m)
  $\rightarrow$ **demonstrated in a dedicated test facility**, CTF3, at CERN (details in Volume 1)

- Main beam: consists of the colliding e^+/e^- beams
- Drive beam: runs parallel to the main beam
  - consists of a high intensity electron beam which generates the RF power necessary for acceleration



CLIC module

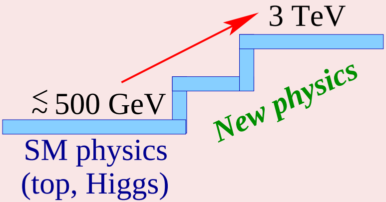
- Basic building block of the main beam: **CLIC module**
- Length: **2 m** (small for reasons of alignment and stability)
- Design might change, but it already has all the necessary ingredients (accelerator structures, supports, quadrupoles, cooling, etc.)



CLIC energy staging (1)

- CLIC ultimate goal: explore physics up to the TeV scale
  - direct searches for production of new particles
  - sensitivity to effects of new physics via precision measurements
- CLIC can be operated in **energy stages**, from a few hundred GeV to the maximum 3 TeV centre-of-mass energy

- Advantages:
  - allows to have first physics results earlier (top quark physics, Higgs sector)
  - discovery potential over a wide range of energies
  - precision measurements of possible new states previously discovered at LHC
  - stretches the budget



⇒ CLIC operation in stages maximises the physics potential

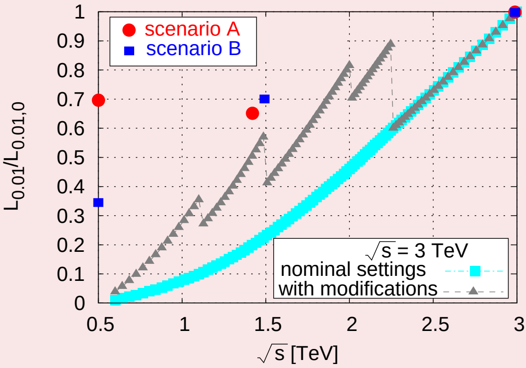
CLIC energy staging (paranthesis)

- Can we start with the 3 TeV design and go to low energies?

- To reduce the collision energy significantly, the drive beam current needs to be reduced

- It is possible, but reduces the luminosity considerably
- Can be partially recovered by an intelligent use of the drive beam generation complex (pulse length, etc.) but not enough

  $\Rightarrow$ a retuning of the machine is necessary to optimise the luminosity



CLIC energy staging (3)

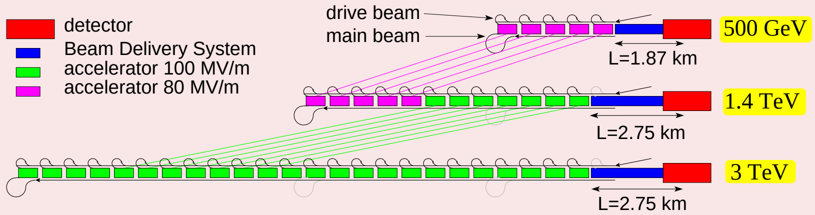
- The optimal choice of the actual energy stages will depend on the physics scenario, driven by 8 TeV + 14 TeV LHC results

- Next: present 2 examples of possible staging scenarios (from CLIC CDR volume 3)
  - scenario A: **optimised for luminosity at 500 GeV**
  - scenario B: **cost optimised for the total project cost**

- Both scenarios:
  - consist of 3 stages (first at 500 GeV, second at 1.4/1.5 TeV, and the third stage at 3 TeV)
  - first the tunnel for the 500 GeV stage is built and the machine installed
  - while operating at 500 GeV, continue construction to full length

Staging scenario A

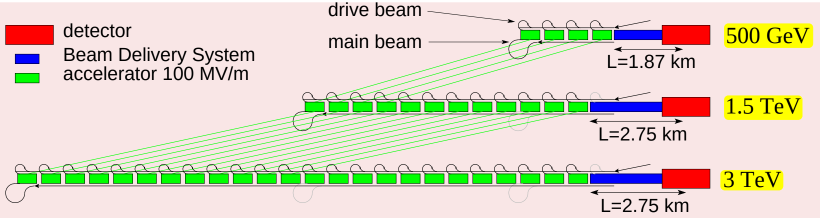
- **Scenario optimised for luminosity at 500 GeV**
- Upgrade sketch: couloured lines indicate the required movement of sectors from one stage to the next



- **Stage 3**: replacing the 80 MV/m structures with 100 MV/m ones allows to reach 3 TeV
  - Alternatively, one could keep the 80 MV/m structures, resulting in 2.9 TeV only

Staging scenario B

- **Cost optimised for the total project cost**
- Upgrade sketch: couloured lines indicate the required movement of sectors from one stage to the next



- **Stage 1**: high gradient structures used (100 MV/m), but only approximately half the luminosity compared to the same stage of scenario A
  - luminosity could be increased by increasing the repetition rate of the whole complex, or by generating a longer drive beam pulse ⇒ needs further investigation
- **Stage 2**: uses a design for the beam delivery system scaled down from 3 TeV
- This scenario can re-use all structures up to 3 TeV

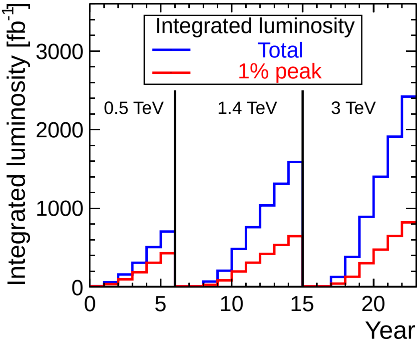
Some parameters of the CLIC staging scenarios

- Red: scenario A (optimised for luminosity at 500 GeV)
- Blue: scenario B (cost optimised for the total project cost)

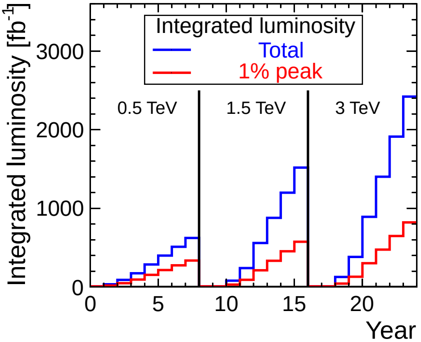
Parameter	Symbol	Unit	Stages 1	Stages 2	Stages 3
Centre-of-mass energy	$\sqrt{s}$	GeV	500	1400/1500	3000
Repetition frequency	f_{rep}	Hz	50	50	50
Number of bunches per train	n_b		354/312	312	312
Bunch separation	Δ_t	ns	0.5	0.5	0.5
Total luminosity	$\mathcal{L}$	$10^{34}\ \mathrm{cm^{-2}s^{-1}}$	2.3/1.3	3.2/3.7	5.9
Luminosity above 99% of $\sqrt{s}$	$\mathcal{L}_{0.01}$	$10^{34}\ \mathrm{cm^{-2}s^{-1}}$	1.4/0.7	1.3/1.4	2

Integrated luminosity

First stage luminosity optimised (scenario A)



Low entry cost (scenario B)



- Based on 200 days/year at 50% efficiency (accelerator + data taking combined)

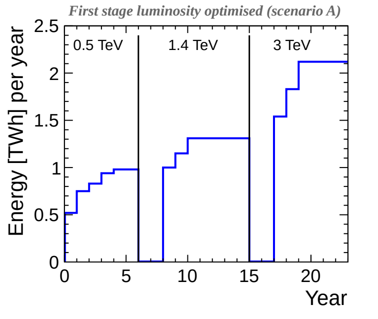
$\sqrt{s}$	Integrated $\mathcal{L}$ (goal)
0.5 TeV	500 fb^{-1}
1.4/1.5 TeV	1500 fb^{-1}
3 TeV	2000 fb^{-1}

- First stage takes 2 years longer in scenario B, but second stage is 1 year shorter ⇒ total difference between scenarios A and B is only 1 year

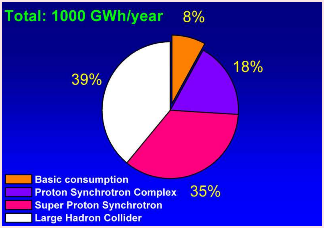
Estimates of energy consumption

- Assume 150 days per year of normal operation at nominal power

- Total energy consumption in the years of running at 500 GeV:
  5 TWh scenario A, 6 TWh scenario B



- Annual electricity consumption at CERN
  source



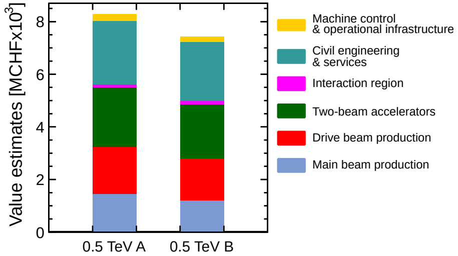
- Several paths for saving power/energy have been identified and are under investigations

Cost estimates of the CLIC accelerator

- Calculated for the **500 GeV stage** of CLIC, in Swiss francs (CHF)
  $\rightarrow$ including all industrial contracts
- Further stages will be the object of separate upgrade projects
  (4 MCHF/GeV to go from stage 1 to stage 2 in scenario B)

Scenario	Accelerator cost
500 GeV A	8300^{+1900}_{-1400} MCHF
500 GeV B	7400^{+1700}_{-1300} MCHF

- Cost of LHC machine:
  4600 MCHF ▸ source



- *There are over 100 billionaires on the* ▸ *Forbes list* *that worth each alone more than 8300 MCHF*
- *Large economic value of basic research* ▸ *source*
  - *devices and techniques to do basic research which find other applications (e.g. crystal detectors in medical imaging)*
  - *www (invented at CERN) generates 5% of the sales of large companies*

Labour estimates for accelerator construction

- Expressed in FTE (*full time equivalent*): number of working hours per year
- Derived from LHC experience: $\sim$1.9 FTE · year/MCHF

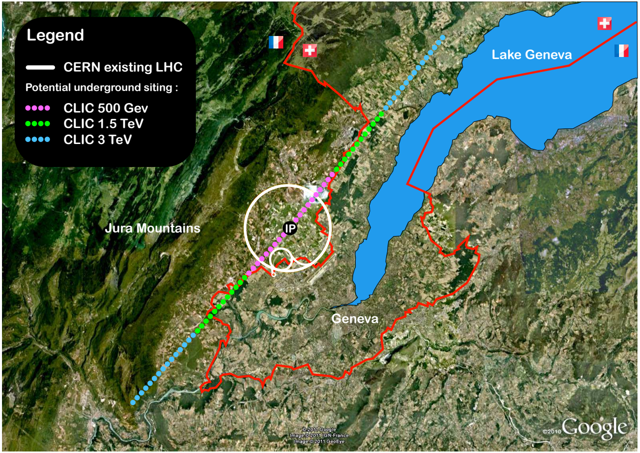
Scenario	Labour estimate
500 GeV A	15700 FTE · year
500 GeV B	14100 FTE · year

- CERN + other scientific universities staff:
  - 40% scientific and engineering personnel
  - 60% technical and execution

- Similar number for the two options, although costs are different

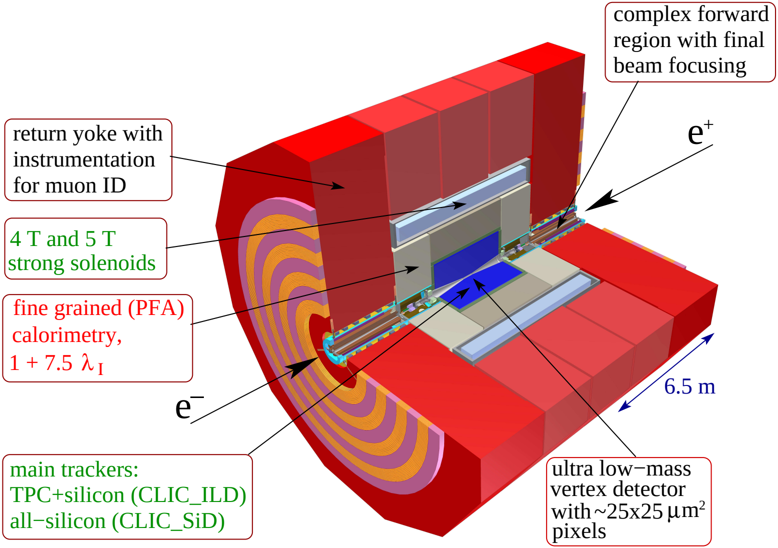
Possible site for CLIC

- Example of CLIC implementation underground near CERN



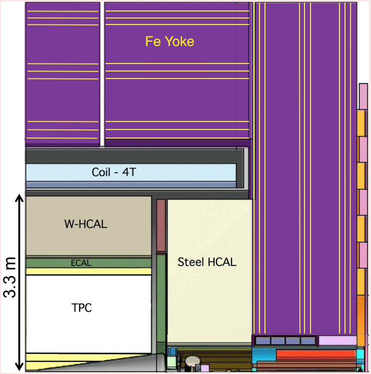
- The site specifications do not constrain the implementation to this location
- Final site authorisations to be established during the Project Preparation Phase (2017–2022)

Overview of a CLIC detector concept

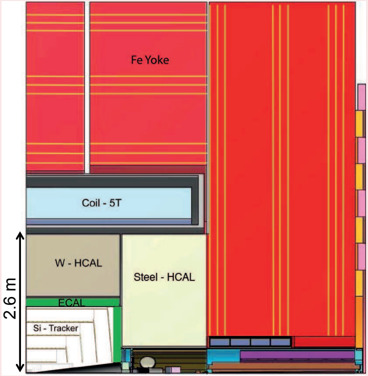


CLIC detector concepts

CLIC_ILD



CLIC_SiD



	CLIC_ILD	CLIC_SiD
Tracker	TPC, silicon	Silicon
HCAL	Scintillator	Glass RPC
Solenoid	4 T	5 T

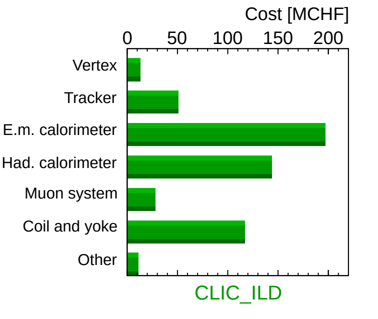
- Calorimeters: other options under consideration

Cost estimates of CLIC detectors

CLIC_ILD	CLIC_SiD
560 MCHF	360 MCHF

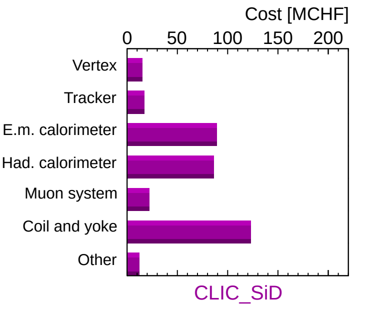
- 30% accuracy

CLIC_ILD



- 35% of the cost driven by ECAL:
  - larger size due to TPC
  - price of Si wafers ⇒ could be optimised with a hybrid ECAL (Si + scintillator)

CLIC_SiD



- 34% of the cost driven by coil and yoke (5 T field + shielding)

Results of benchmark studies

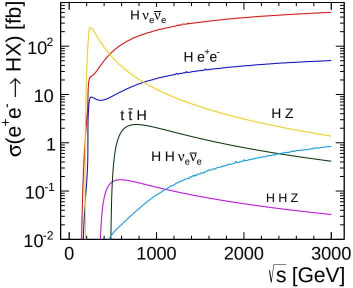
- Benchmark studies:
  detector performance studies using specific physics processes

- Studies performed using detailed GEANT4 simulations
- **Realistic experimental conditions**:
  - luminosity spectrum at the different collision energies
  - overlay of pile-up from $\gamma\gamma \rightarrow$hadrons background events taking into account the time structure of the CLIC beams
- **Full event reconstruction** (tracking, application of particle flow algorithms with timings cuts and flavour tagging)

$\sqrt{s}$	Integrated luminosity
350/500 GeV	500 fb^{-1}
1.4 TeV	1.5 ab^{-1}
3 TeV	2 ab^{-1}

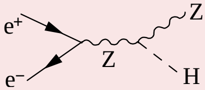
Higgs production at CLIC

- $m_H = 125$ GeV

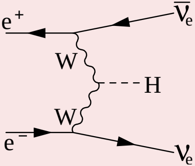


Higgs-strahlung

- Can measure Higgs from the Z recoil mass (**model independent measurement**)

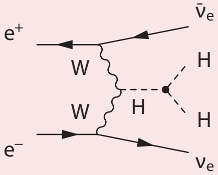


WW fusion



Double Higgs production in *WW* fusion

- Sensitivity to Higgs tri-linear coupling



Higgs production at a linear collider

- Higgs cross-sections for Higgs-strahlung and WW-fusion for $m_H = 125$ GeV
  ▸ arXiv:1209.2543

	250 GeV	350 GeV	500 GeV	1 TeV	1.5 TeV	3 TeV
$\sigma(e^+e^- \rightarrow ZH)$	240 fb	129 fb	57 fb	13 fb	6 fb	1 fb
$\sigma(e^+e^- \rightarrow H\nu_e\bar{\nu}_e)$	8 fb	30 fb	75 fb	210 fb	309 fb	484 fb
Int. $\mathcal{L}$	250 fb^{-1}	350 fb^{-1}	500 fb^{-1}	1000 fb^{-1}	1500 fb^{-1}	2000 fb^{-1}
# ZH events	60000	45500	28500	13000	7500	2000
# $H\nu_e\bar{\nu}_e$	2000	10500	37500	210000	460000	970000

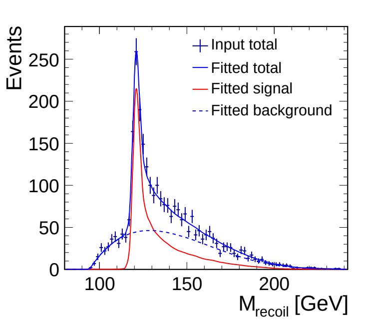
- $\Rightarrow$ Can do complementary Higgs measurements by accessing a wide energy range

- CLIC Higgs studies done for $m_H = 120$ GeV because they started before LHC announcement of the discovery of a Higgs-like particle

Results of Higgs benchmark studies ($m_H = 120$ GeV)

$\sqrt{s}$ =350 GeV

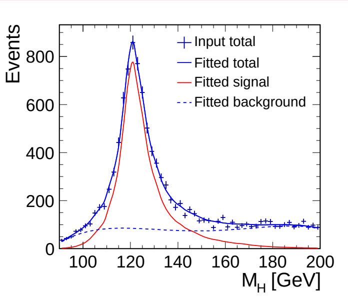
- Recoil mass distribution in $e^+e^- \to ZH \to \mu^+\mu^- X$



- Possible due to clearly defined initial state (not possible at LHC)
- Mass and cross-section extracted from fit of recoil mass

$\sqrt{s}$ =500 GeV

- Recoil mass measurement cannot be done, too large uncertainties (reduced momentum resolution of higher lepton energy, decreasing $\sigma(ZH)$)
  $\Rightarrow$ explicitely reconstruct Higgs from 2 quarks decays: $e^+e^- \to ZH \to \nu\bar{\nu}q\bar{q}$



Results of Higgs benchmark studies ($m_H = 120$ GeV)

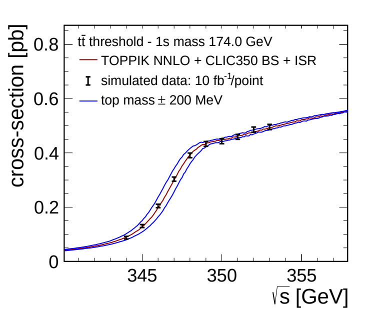
$\sqrt{s}$ (GeV)	Process	Decay mode	Measured quantity	Unit	Generator value	Stat. error	Comment
350	SM Higgs production	$ZH \to \mu^+\mu^- X$	σ	fb	4.9	4.9%	Model independent, using Z-recoil
			Mass	GeV	120	0.131	
500		$ZH \to q\bar{q}q\bar{q}$	$\sigma\times$ BR	fb	34.4	1.6%	$ZH \to q\bar{q}q\bar{q}$ mass reconstruction
			Mass	GeV	120	0.100	
500		$ZH, H\nu\bar{\nu} \to \nu\bar{\nu}q\bar{q}$	$\sigma\times$ BR	fb	80.7	1.0%	Inclusive sample
			Mass	GeV	120	0.100	
1400	WW fusion	$H \to \tau^+\tau^-$	$\sigma\times$ BR	fb	19.8	<3.7%	
3000		$H \to b\bar{b}$			285	0.22%	
		$H \to c\bar{c}$			13	3.2%	
		$H \to \mu^+\mu^-$			0.12	15.7%	
1400 3000	WW fusion		Higgs tri-linear coupling g_{HHH}			~20% ~20%	study still ongoing

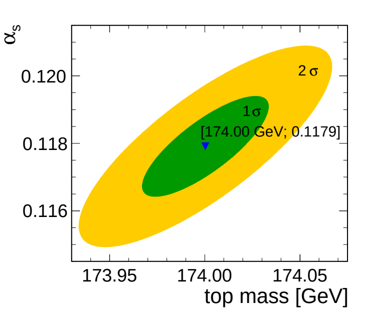
⇒ CLIC enables a detailed exploration of the Higgs sector in various processes over the full energy range of the CLIC programme

Results of top quark studies

- Top quark: interesting because it most strongly couples to the Higgs field, and may provide sensitivity to beyond Standard Model physics
- Measurement of top quark mass:
  - through **direct reconstruction** of top quarks from their products at energies above the production thresholds $\rightarrow$ potentially significant theoretical uncertainties
  - through a **scan** of top-pair production threshold $\rightarrow$ theoretically well defined scheme

Top threshold scan





Results of top quark studies

$\sqrt{s}$ (GeV)	Technique	Measured quantity	Integrated luminosity (fb^{-1})	Unit	Generator value	Stat. error
350	Threshold scan	Mass	6×10	GeV	174	0.021
		Mass α_S	10×10	GeV	174 0.118	0.033 0.0009
500	Invariant mass	Mass	100	GeV	174	0.060

source

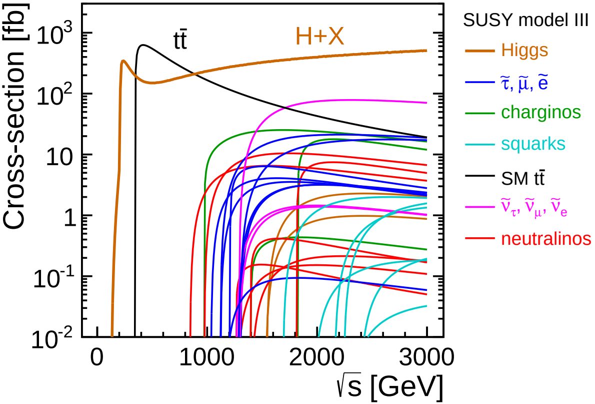
- Combination of ATLAS and CMS results

  source

  $m_{top} = 173.3 \pm 0.5\,(\mathrm{stat}) \pm 1.3\,(\mathrm{syst})$ GeV

⇒ CLIC can do a precise measurement of the top quark mass in a threshold scan, as well as above threshold

Supersymmetry

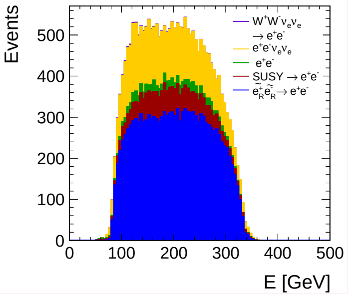


- **SUSY model III**: a specific mSUGRA model with non-universal squark masses (compatible with current LHC data)

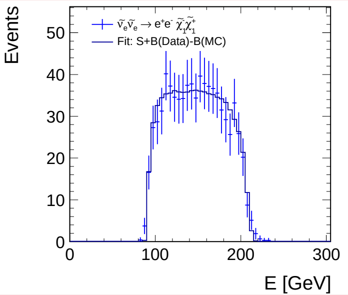
Results of SUSY studies: slepton masses (1.4 TeV)

- Masses determined from the upper and lower edge of the energy distribution of reconstructed final-state leptons
- Signal events identified by high-energy leptons
- SM and SUSY background discrimination using a boosted decision tree based on variables of the di-lepton system

- $e^+e^- \to \widetilde{e}_R^+\widetilde{e}_R^- \to e^+e^-\tilde{\chi}_1^0\tilde{\chi}_1^0$
- Masses of $\widetilde{e}_R$ and $\tilde{\chi}_1^0$



- $e^+e^- \to \widetilde{\nu}_e\widetilde{\nu}_e \to e^+e^-\tilde{\chi}_1^\pm\tilde{\chi}_1^\pm \to e^+e^-W^+W^-\tilde{\chi}_1^0\tilde{\chi}_1^0$
- Masses of $\widetilde{\nu}_e$ and $\tilde{\chi}_1^\pm$



Results of SUSY benchmarks (1.4 TeV)

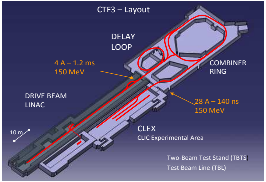
$\sqrt{s}$ (TeV)	Process	Decay mode	SUSY model	Measured quantity	Unit	Generator value	Stat. error
1.4	Sleptons production	$\widetilde{\mu}_R^+\widetilde{\mu}_R^- \rightarrow \mu^+\mu^-\widetilde{\chi}_1^0\widetilde{\chi}_1^0$	III	σ	fb	1.11	2.7%
				$\tilde{\ell}$ mass	GeV	560.8	0.1%
				$\widetilde{\chi}_1^0$ mass	GeV	357.8	0.1%
		$\widetilde{e}_R^+\widetilde{e}_R^- \rightarrow e^+e^-\widetilde{\chi}_1^0\widetilde{\chi}_1^0$		σ	fb	5.7	1.1%
				$\tilde{\ell}$ mass	GeV	558.1	0.1%
				$\widetilde{\chi}_1^0$ mass	GeV	357.1	0.1%
		$\widetilde{\nu}_e\widetilde{\nu}_e \rightarrow \widetilde{\chi}_1^0\widetilde{\chi}_1^0 e^+e^-W^+W^-$		σ	fb	5.6	3.6%
				$\tilde{\ell}$ mass	GeV	644.3	2.5%
				$\widetilde{\chi}_1^\pm$ mass	GeV	487.6	2.7%
1.4	Stau production	$\widetilde{\tau}_1^+\widetilde{\tau}_1^- \rightarrow \tau^+\tau^-\widetilde{\chi}_1^0\widetilde{\chi}_1^0$	III	$\widetilde{\tau}_1$ mass	GeV	517	2.0%
				σ	fb	2.4	7.5%
1.4	Chargino production	$\widetilde{\chi}_1^+\widetilde{\chi}_1^- \rightarrow \widetilde{\chi}_1^0\widetilde{\chi}_1^0 W^+W^-$	III	$\widetilde{\chi}_1^\pm$ mass	GeV	487	0.2%
				σ	fb	15.3	1.3%
	Neutralino production	$\widetilde{\chi}_2^0\widetilde{\chi}_2^0 \rightarrow h/Z^0 h/Z^0 \widetilde{\chi}_1^0\widetilde{\chi}_1^0$		$\widetilde{\chi}_2^0$ mass	GeV	487	0.1%
				σ	fb	5.4	1.2%

$\Rightarrow$ CLIC enables direct measurements of the properties of beyond Standard Model particles

Time line of the CLIC project

2012-16 Development Phase

Develop a Project Plan for a staged implementation in agreement with LHC findings; further technical developments with industry, performance studies for accelerator parts and systems, as well as for detectors.



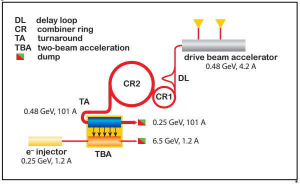
2016-17 Decisions

On the basis of LHC data and Project Plans (for CLIC and other potential projects), take decisions about next project(s) at the Energy Frontier.

2017-22 Preparation Phase

Finalise implementation parameters, Drive Beam Facility and other system verifications, site authorisation and preparation for industrial procurement.

Prepare detailed Technical Proposals for the detector-systems.



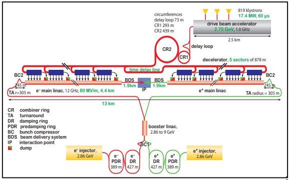
2022-23 Construction Start

Ready for full construction and main tunnel excavation.

2023-2030 Construction Phase

Stage 1 construction of a 500 GeV CLIC, in parallel with detector construction.

Preparation for implementation of further stages.



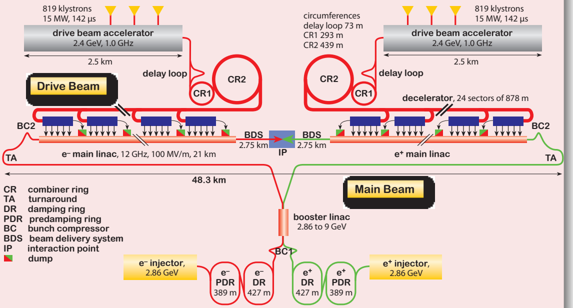
2030 Commissioning

From 2030, becoming ready for data-taking as the LHC programme reaches completion.

Summary

- CLIC conceptual design report finalised
- CLIC accelerator feasibility demonstrated
- Developed detector concepts which can do precision physics at CLIC
- Staged implementation of CLIC ⇒ maximised physics potential

CLIC layout at 3 TeV

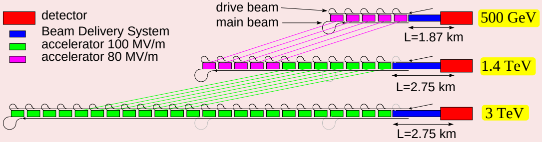


CLIC perspective

- 2016–2017: choice of the next energy frontier machine
- If CLIC: start construction 2022–2023

Backup slides

Staging scenario A: why luminosity optimised?

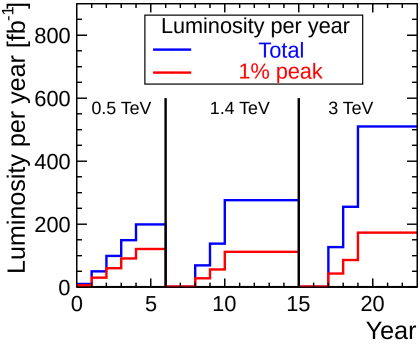


- The main linac components at 500 GeV are the same as at 3 TeV and can be re-used
- The **accelerating structures**: have the same length and almost the same input power as at 3 TeV, but a **larger aperture and lower gradient**
  $\Rightarrow$ a larger bunch charge and slightly more bunches per train
  $\Rightarrow$ **more luminosity** for the 500 GeV machine

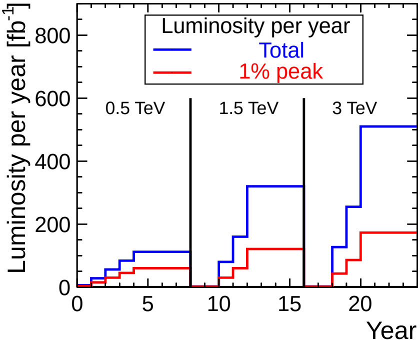
Parameter	Symbol	Unit	Stages 1	2	3
Centre-of-mass energy	$\sqrt{s}$	GeV	500	1400/1500	3000
Repetition frequency	f_{rep}	Hz	50	50	50
Number of bunches per train	n_b		354/312	312	312
Bunch separation	Δ_t	ns	0.5	0.5	0.5
Total luminosity	$\mathcal{L}$	$10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$	2.3/1.3	3.2/3.7	5.9
Luminosity above 99% of $\sqrt{s}$	$\mathcal{L}_{0.01}$	$10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$	1.4/0.7	1.3/1.4	2

Luminosity per year

First stage luminosity optimised (scenario A)



Low entry cost (scenario B)



- Based on 200 days/year at 50% efficiency (accelerator + data taking combined)

- Luminosity ramp-up for scenario A:

Stage	Year 1	Year 2	Year 3	Year 4	Year 5
1	5%	25%	50%	75%	100%
2 and 3	25%	50%	100%	100%	100%

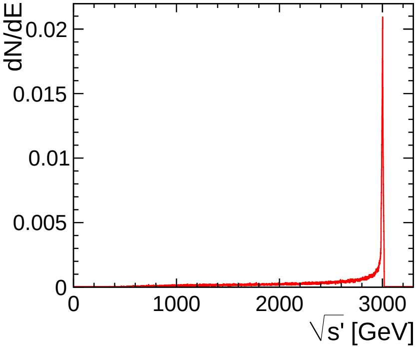
CLIC luminosity spectrum

- Due to intense electromagnetic interactions of the colliding beams, e^+/e^- may radiate a high energy photon before collision (beamstrahlung)

  $\Rightarrow$ the centre-of-mass energy of the e^+/e^- collision ($\sqrt{s'}$) is less than the nominal centre-of-mass energy of the machine ($\sqrt{s}$)

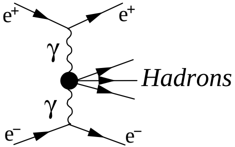
  $\Rightarrow$ luminosity spectrum with a peak at $\sqrt{s}$ (for collisions with no beamstrahlung) and a long tail towards lower energies

- For precision physics at CLIC, need accurate determination of the luminosity spectrum

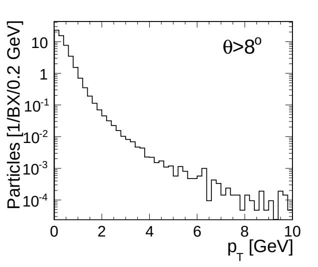


CLIC beam induced background

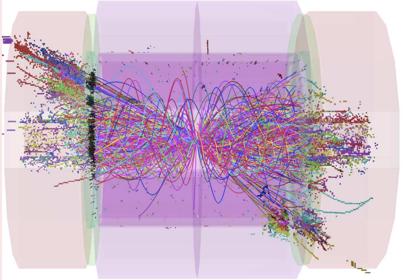
- CLIC: high beam energy, strong beam focusing and high bunch frequency (2 GHz) ⇒ photons are created which can interact to produce hadronic jets
- $e^+e^- \to \gamma\gamma \to hadrons$ is the dominating background at CLIC (due to large angles, mainly affecting the central tracking volumes and the calorimeters)



- p_T spectra of particles from $e^+e^- \to \gamma\gamma \to hadrons$: mostly low p_T particles



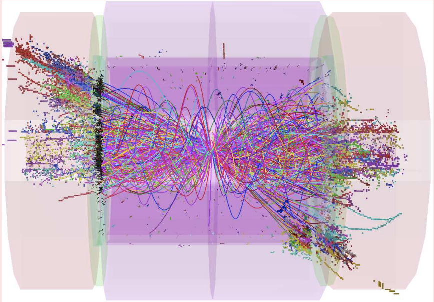
- $e^+e^- \to t\bar{t}$: about 20 TeV per bunch train due to background



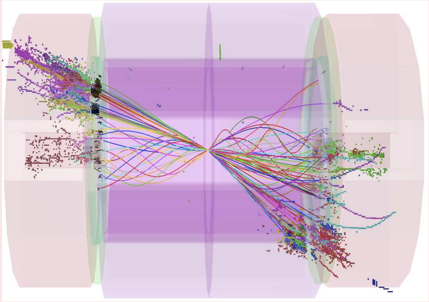
Suppresion of beam-induced background

- Example: $e^+e^- \rightarrow t\bar{t}$
- **Background can be reduced with combined p_T and timing cuts**

Before cuts: 20 TeV background



After cuts: 100 GeV background

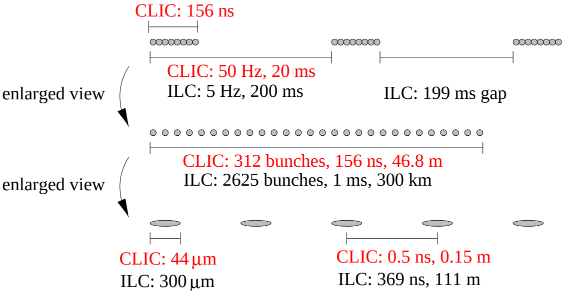


PFO-based tight timing cuts

Region	p_T range	time cut
Photons		
central	$1.0\ \text{GeV} \leq p_T < 4.0\ \text{GeV}$	$t < 2.0$ ns
$\cos\theta \leq 0.95$	$0.2\ \text{GeV} \leq p_T < 1.0\ \text{GeV}$	$t < 1.0$ ns
forward	$1.0\ \text{GeV} \leq p_T < 4.0\ \text{GeV}$	$t < 2.0$ ns
$\cos\theta > 0.95$	$0.2\ \text{GeV} \leq p_T < 1.0\ \text{GeV}$	$t < 1.0$ ns
Neutral hadrons		
central	$1.0\ \text{GeV} \leq p_T < 8.0\ \text{GeV}$	$t < 2.5$ ns
$\cos\theta \leq 0.95$	$0.5\ \text{GeV} \leq p_T < 1.0\ \text{GeV}$	$t < 1.5$ ns
forward	$1.0\ \text{GeV} \leq p_T < 8.0\ \text{GeV}$	$t < 1.5$ ns
$\cos\theta > 0.95$	$0.5\ \text{GeV} \leq p_T < 1.0\ \text{GeV}$	$t < 1.0$ ns
Charged particles		
all	$1.0\ \text{GeV} \leq p_T < 4.0\ \text{GeV}$	$t < 2.0$ ns
	$0\ \text{GeV} \leq p_T < 1.0\ \text{GeV}$	$t < 1.0$ ns

- Track-only minimum p_T: 0.5 GeV
- Track-only maximum time at ECAL: 10 nsec

CLIC bunch structure



- 50 bunch trains per second, occuring at 20 ms interval
- 1 bunch train consists of 312 bunch crossings, separated by 0.5 ns

- Physics events are buried inside an abundance of overlapping background
- ⇒ Need time stamping and sophisticated pattern recognition algorithms to disentangle physics from background

Time window

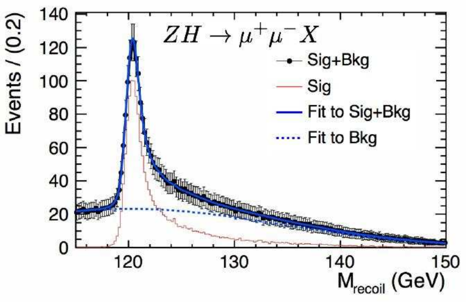
- CLIC detectors readout continuosly (triger-less)
- Assume the entire bunch train of data is available for offline reconstruction
- If an interesting physics event is within a bunch train, assume the corresponding bunch crossing can be identified
- Data within a time window around this time would be passed for event reconstruction

Subdetector	Reconstruction window	hit resolution
ECAL	10 ns	1 ns
HCAL Endcaps	10 ns	1 ns
HCAL Barrel	100 ns	1 ns
Silicon Detectors	10 ns	$10/\sqrt{12}$ ns
TPC	entire bunch train	n/a

- Time window for the reconstruction in the calorimeters drivern by shower development times
- Time resolution of 1 ns for single calorimeter hits allows tighter cuts at the cluster level to further reduce the background

ILC ILD: Higgs studies

- Source: James E. Brau *et al.*, *The Physics Case for an e^+e^- Linear Collider*, input to the European strategy

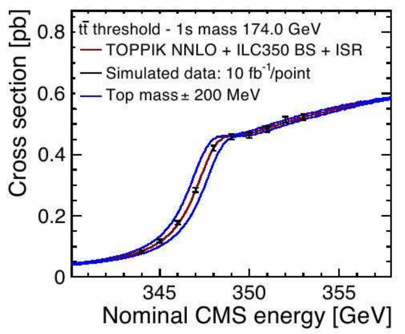


$\sqrt{s}$	250 GeV	350 GeV
Int. $\mathcal{L}$	250 fb^{-1}	350 fb^{-1}
$\Delta(\sigma)/\sigma$	3%	4%
$\Delta(g_{HZZZ})/g_{HZZ}$	1.5%	2%

- CLIC: somewhat larger errors due to spread of luminosity spectrum

ILC ILD: Top threshold

- Source: James E. Brau *et al.*, *The Physics Case for an e^+e^- Linear Collider*, input to the European strategy



Statistical precision with ~ 30 fb^{-1}:

- 20 MeV for the top quark mass
- 30 MeV for the top width

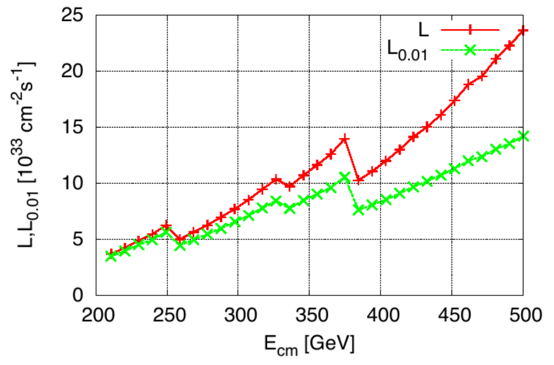
- CLIC: comparable results (analyses not identical)

Luminosity at lower energies

- From D. Schulte, *CLIC Staged Design*, talk given at LCWS 2012

- Use 500 GeV scenario A design
- Energy changed by gradient scaling
- Have to adjust bunch charge
- Can increase pulse length at certain energies
- More luminosity possible using extraction lines

- L: total luminosity
- $L_{0.01}$: luminosity above 99% of $\sqrt{s}$



CLIC and CLIC modules

- From Andreea Jeremie, *Vibration Stabilization – Experimental Results*, talk at ▸ LCWS2012