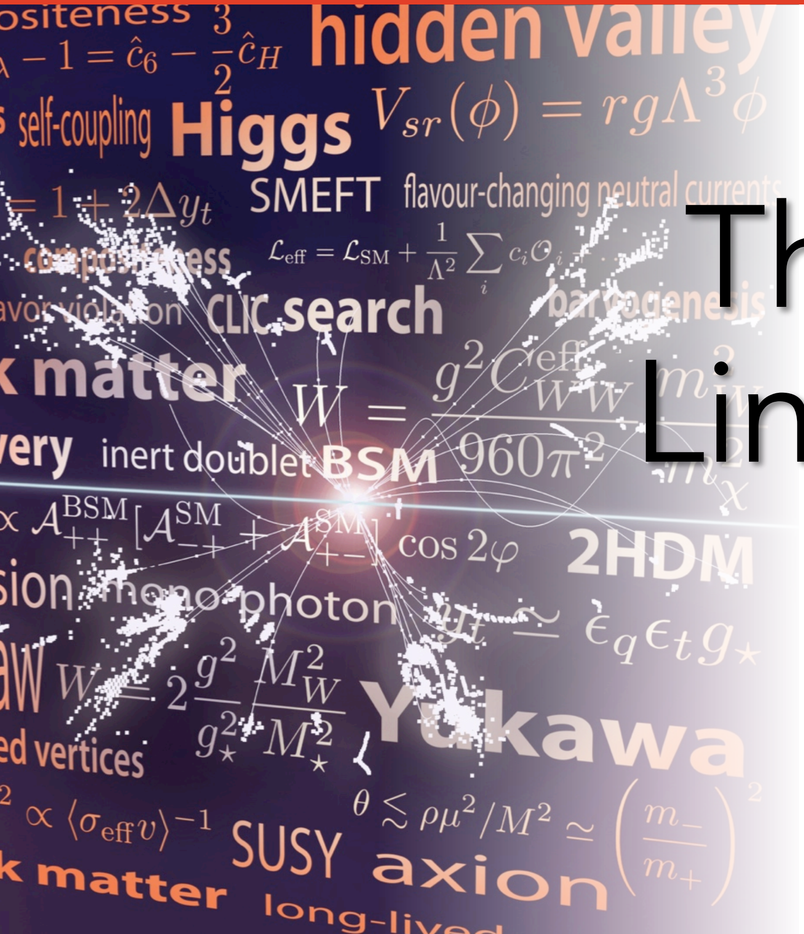
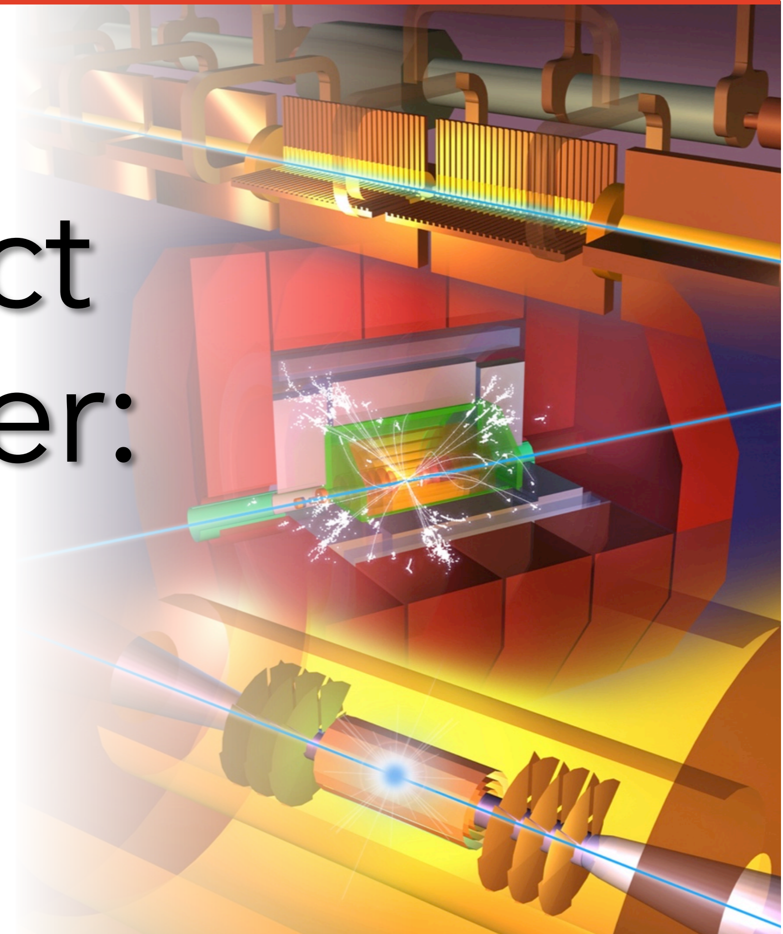


The Compact Linear Collider: CLIC

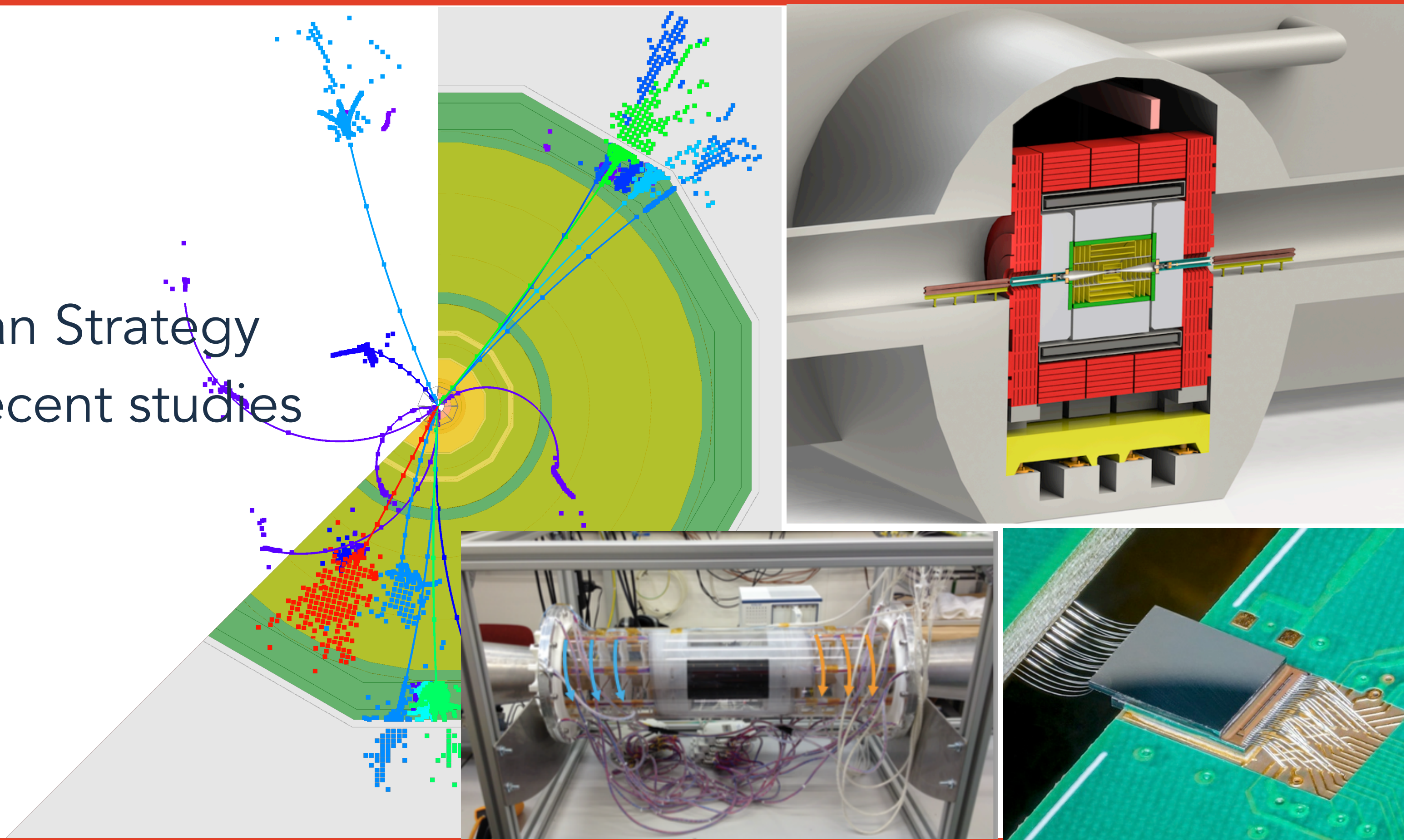


20th Lomonosov Conference, 22 August 2021

Aidan Robson, University of Glasgow

CLIC

- Project overview
- Status after European Strategy
- Physics reach and recent studies
- Outlook



Compact Linear Collider:
e^+e^- collisions up to 3TeV
http://clic.cern/

Collaborations

http://clic.cern/

CLIC accelerator collaboration

~60 institutes from 28 countries

including: JINR, Dubna;
Budker Inst., Novosibirsk;
Inst. of Applied Physics (RAS)

CLIC accelerator studies:

- CLIC accelerator design and development
- (Construction and operation of CLIC Test Facility, CTF3)

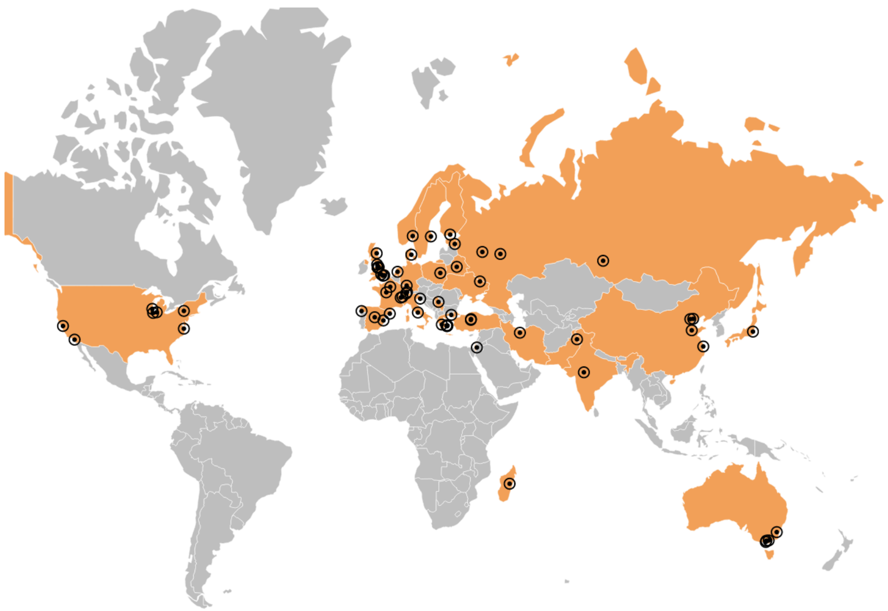
CLIC detector and physics (CLICdp)

30 institutes from 18 countries

including JINR Dubna

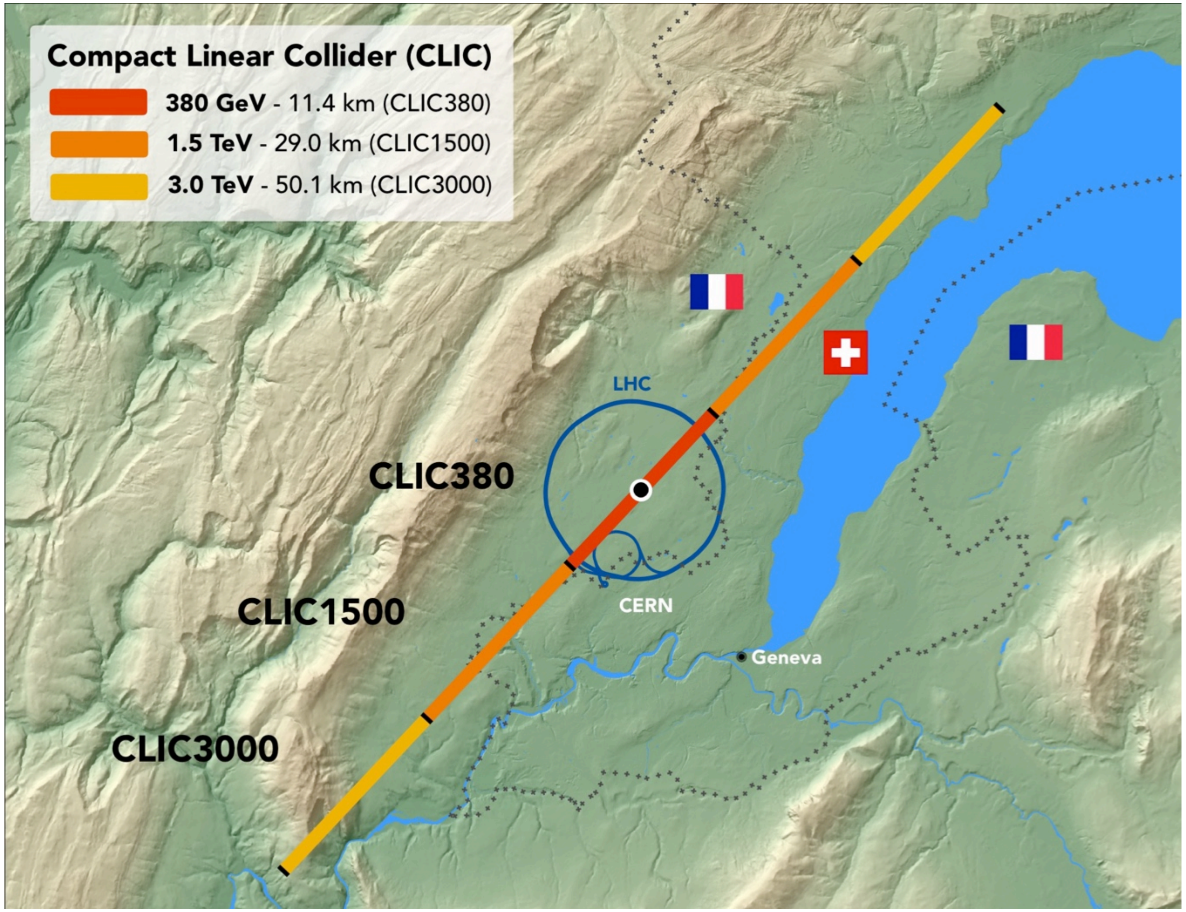
Focus of CLIC-specific studies on:

- Physics prospects & simulation studies
- Detector optimization + R&D for CLIC



The Compact Linear Collider

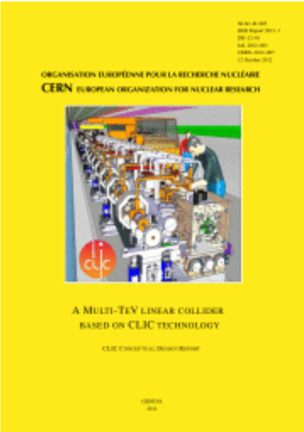
- A high-luminosity, multi-TeV electron–positron collider
- Planned for construction at CERN in three energy stages:



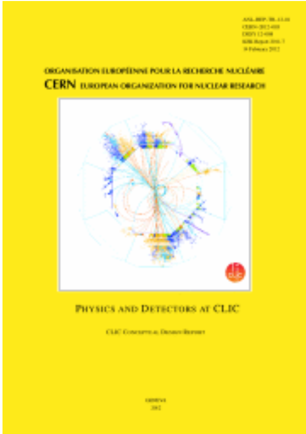
- 380GeV, focusing on precision Higgs boson and top-quark physics
- 1.5 and 3TeV, expanding Higgs and top studies including Higgs self-coupling, and opening higher direct and indirect sensitivity to Beyond Standard Model (BSM)
- Nominal physics programme lasts for 25–30 years; approvable in stages
- Benefit of linear machine: length/energy staging plan can be updated in response to developing physics landscape

CLIC History

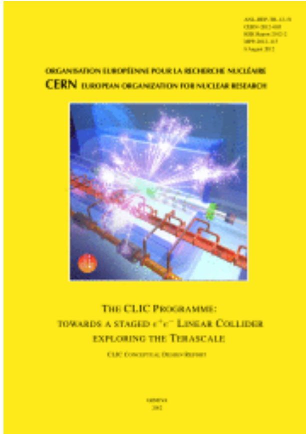
- 3-volume CDR 2012



Accelerator

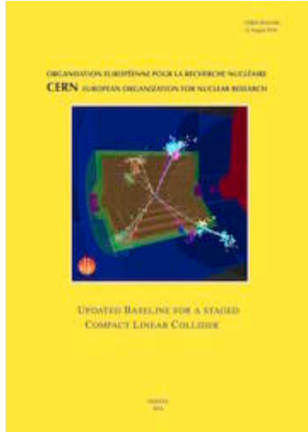


Physics & Detectors



Strategy & Implementation

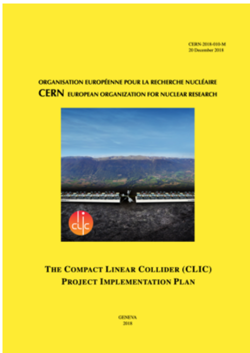
Updated Staging Baseline 2016



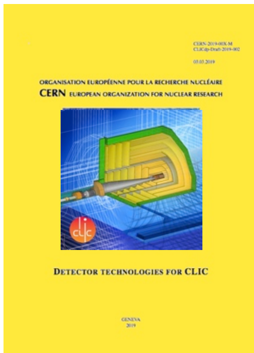
- 4 Yellow Reports 2018

Summary Report

Physics Potential



Project Implementation



Detector Technologies

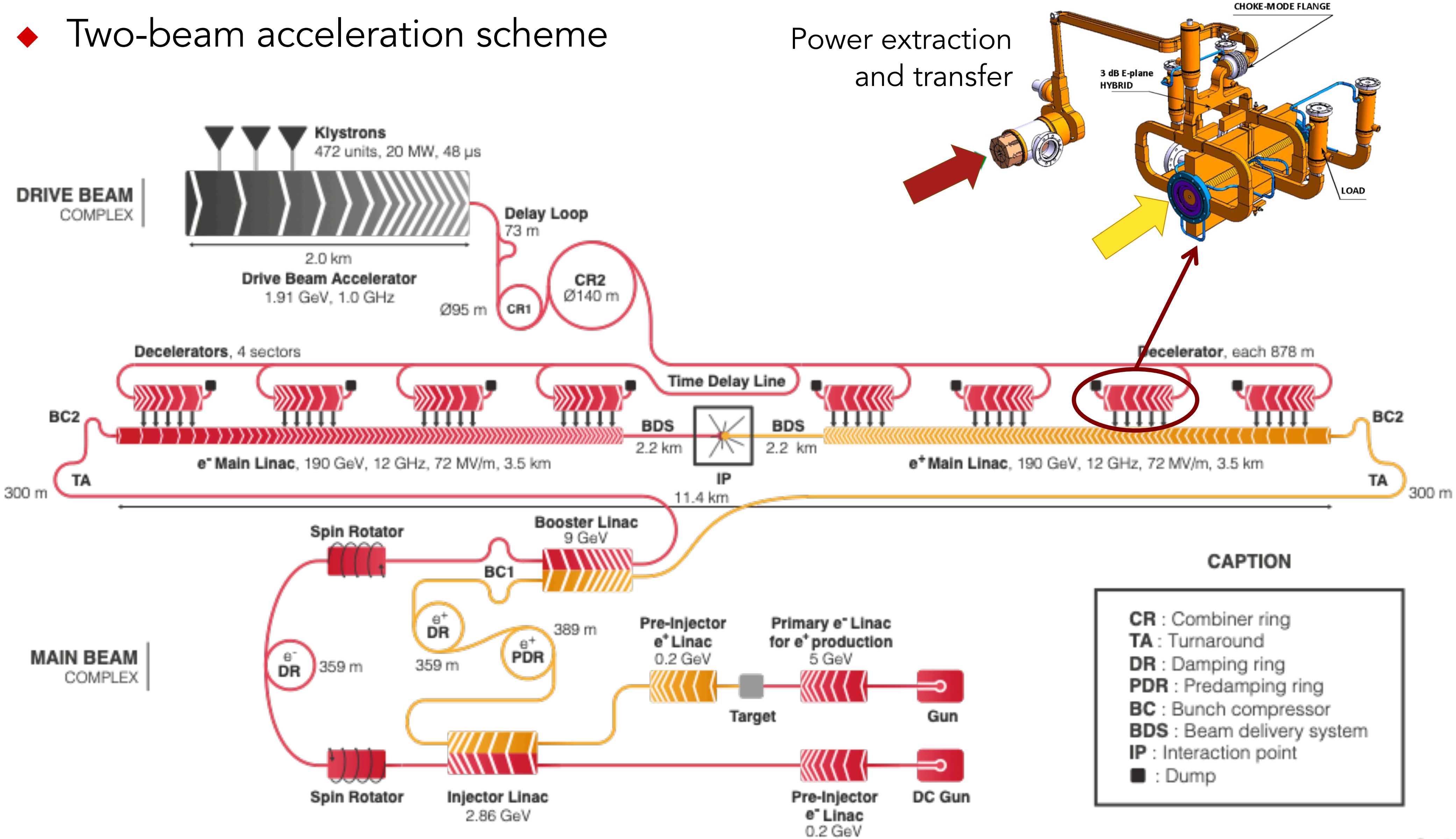
http://clic.cern/european-strategy

- CLIC is now a mature project – technical timeline going into European Strategy gave readiness for construction starting ~2026, with first collisions ~2035

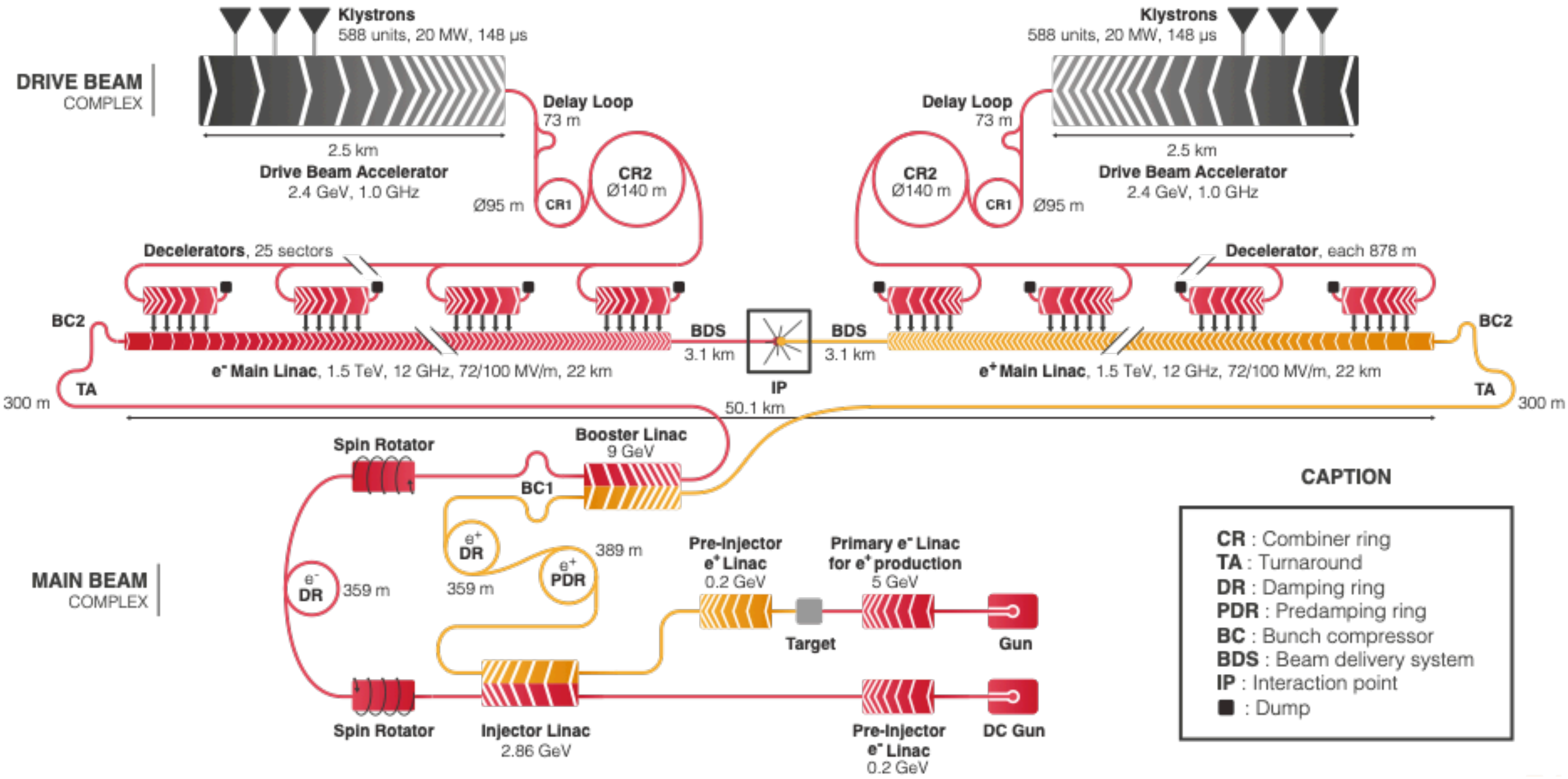
CLIC at 380GeV

- Two-beam acceleration scheme

Power extraction and transfer



CLIC at 3TeV

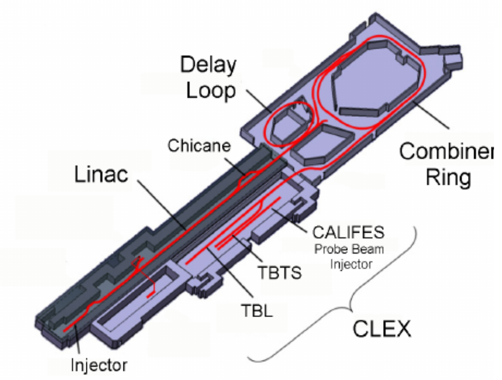


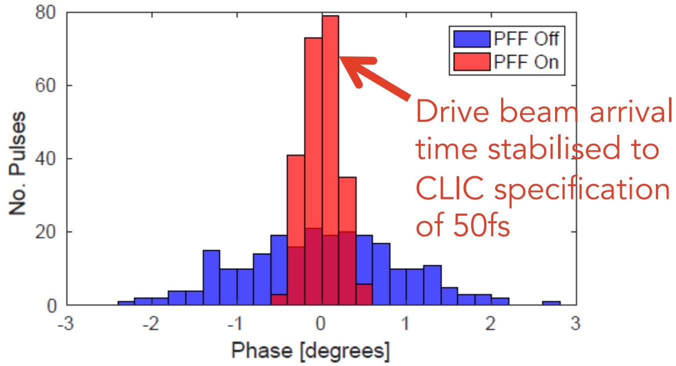
Klystrons
588 units, 20 MW, 148 μs
DRIVE BEAM
COMPLEX
Delay Loop
73 m
2.5 km
Drive Beam Accelerator
2.4 GeV, 1.0 GHz
CR2
Ø140 m
CR1
Ø95 m
Decelerators, 25 sectors
Decelerator, each 878 m
BC2
BDS
3.1 km
IP
e⁻ Main Linac, 1.5 TeV, 12 GHz, 72/100 MV/m, 22 km
e⁺ Main Linac, 1.5 TeV, 12 GHz, 72/100 MV/m, 22 km
TA
300 m
50.1 km
Spin Rotator
Booster Linac
9 GeV
BC1
e⁺ DR
389 m
e⁻ DR
359 m
e⁺ PDR
MAIN BEAM
COMPLEX
Pre-injector
e⁺ Linac
0.2 GeV
Primary e⁻ Linac
for e⁺ production
5 GeV
Target
Gun
Injector Linac
2.86 GeV
Pre-injector
e⁻ Linac
0.2 GeV
DC Gun
CAPTION
CR : Combiner ring
TA : Turnaround
DR : Damping ring
PDR : Predamping ring
BC : Bunch compressor
BDS : Beam delivery system
IP : Interaction point
■ : Dump

Accelerator challenges

High-current drive beam bunched at 12 GHz

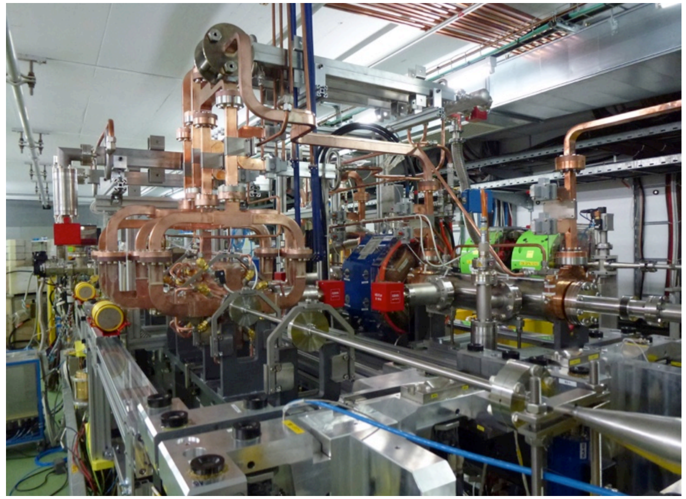
Produced at CLIC Test Facility CTF3, now the 'CERN Linear Electron Accelerator for Research' facility, CLEAR





Power transfer + main-beam acceleration

Demonstrated 2-beam acceleration



~100 MV/m gradient in main-beam cavities

Achieved in structures produced by different sources

Alignment & stability

The CLIC strategy:

- Alignment; vibration damping;
  good beam measurement and feedback
- Tests in small accelerators of equipment and algorithms (FACET at Stanford, ATF2 at KEK, CTF3, Light-sources)

–> Key accelerator technologies have been demonstrated

For more on accelerator, see talk from Steinar Stapnes at June joint Snowmass AF/EF session: https://indico.fnal.gov/event/43871/

CLIC status after European Strategy

- European Strategy for Particle Physics was updated in June 2020 after a several-year process:
– **prioritises an electron–positron Higgs factory as the next collider**
– articulates the ambition to operate a proton–proton collider at the highest achievable energy
– mandates a technical and financial feasibility study for a 100TeV collider
– mandates intensified accelerator R&D, including on high-gradient structures

- **Over the next 5 years CERN will continue the investment in R&D for key technologies related to CLIC**

–> CLIC is maintained, so that if in 2026 the feasibility study is not conclusive for FCC then CLIC could be implemented in an expeditious way:
Project approval ~2028, Tunnel construction starting ~2030

- CLIC is the least-expensive Higgs factory proposed for construction in Europe, and leads to unique physics potential at high energy running

CLIC status after European Strategy

ECFA Newsletter 5 (August 2020)

Initial views on the European Strategy implementation

by Fabiola Gianotti (CERN Director-General)

The 2020 update of the European Strategy for Particle Physics (ESPP) provides a realistic and prudent approach to setting ambitious and visionary scientific objectives. It lays the foundations for a bright future for particle physics in Europe, within the global context of the field.

Implementation of the ESPP has started at CERN, and a few examples are listed below. The full exploitation of the LHC, including the high-luminosity upgrades, remains CERN's highest priority. Accelerator R&D studies are being reinforced, in particular in the domain of superconducting high-field magnets. The feasibility study for the FCC (Future Circular Collider), which should be completed by the next Strategy update, will focus on the tunnel (high-risk zones, environmental aspects, etc.) and on the main technologies for the e^+e^- and pp colliders. To maintain CLIC as an option for a future collider, as recommended by the ESPP, resources will be allocated to continue work on key accelerator technologies. An effort on muon colliders is starting with the goal of addressing the main challenges (neutrino background, muon source and cooling, accelerator and collider rings, etc.) and of developing the design of a demonstrator by the next ESPP update. Physics Beyond Colliders activities will be strengthened. Work at the Neutrino Platform continues, in support of the European community involved in long-baseline projects in the US and Japan. A Quantum Technology Initiative has been launched at CERN, in collaboration with similar efforts in CERN's Member States and beyond, to develop innovative computing technologies for future projects.

The ESPP is the result of two years of intense and successful efforts by our community to prepare and discuss high-quality scientific and other input. Similarly, its implementation will require the work, dedication and enthusiasm of the full community.

https://cds.cern.ch/record/2729018

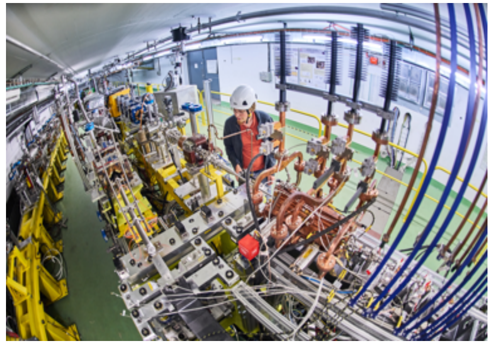
CLIC studies 2021–25

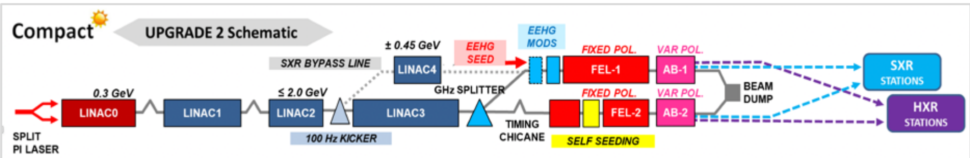
X-band technology:

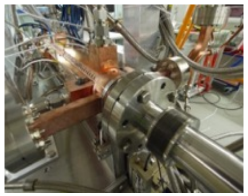
- Design and manufacturing of X-band structures and components
- Study structures breakdown limits and optimization, operation and conditioning
- Baseline verification and explore new ideas
- Assembly and industry qualification
- Structures for applications, FELs, medical, etc

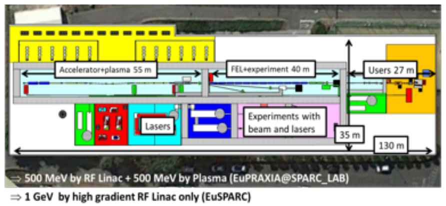
Technical and experimental studies, design and parameters:

- Module studies (see some targets for development below)
- Beamdynamics and parameters: Nanobeams (focus on beam-delivery), pushing multi TeV region (parameters and beam structure vs energy efficiency)
- Tests in CLEAR (wakefields, instrumentation) and other facilities (e.g. ATF2)
- High efficiency klystrons
- Injector studies suitable for X-band linacs (coll. with Frascati)









Application of X-band technology (examples):

- A compact FEL (CompactLight: EU Design Study 2018-21)
- Compact Medical linacs (proton and electrons)
- Inverse Compton Scattering Source (SmartLight)
- Linearizers and deflectors in FELs (PSI, DESY, more)
- 1 GeV X-band linac at LNF
- eSPS for light dark matter searches (within the PBC-project)

CLIC in the news

15 Sept. 2020

https://home.cern/news/news/knowledge-sharing/cern-and-lausanne-university-hospital-collaborate-pioneering-new-cancer

https://physicsworld.com/a/cern-accelerator-technology-to-underpin-flash-radiotherapy-facility/

CERN and Lausanne University Hospital collaborate on a pioneering new cancer radiotherapy facility

CERN and the Lausanne University Hospital (CHUV) are collaborating to develop the conceptual design of an innovative radiotherapy facility, used for cancer treatment

15 SEPTEMBER, 2020

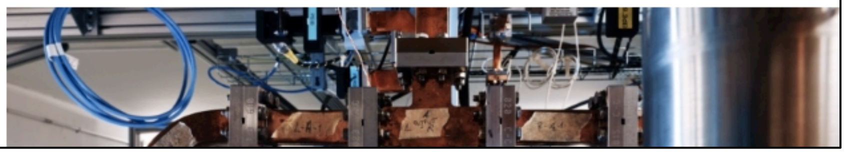
physicsworld

Magazine | Latest

RADIOTHERAPY | RESEARCH UPDATE

CERN accelerator technology to underpin FLASH radiotherapy facility

17 Sep 2020 Tami Freeman



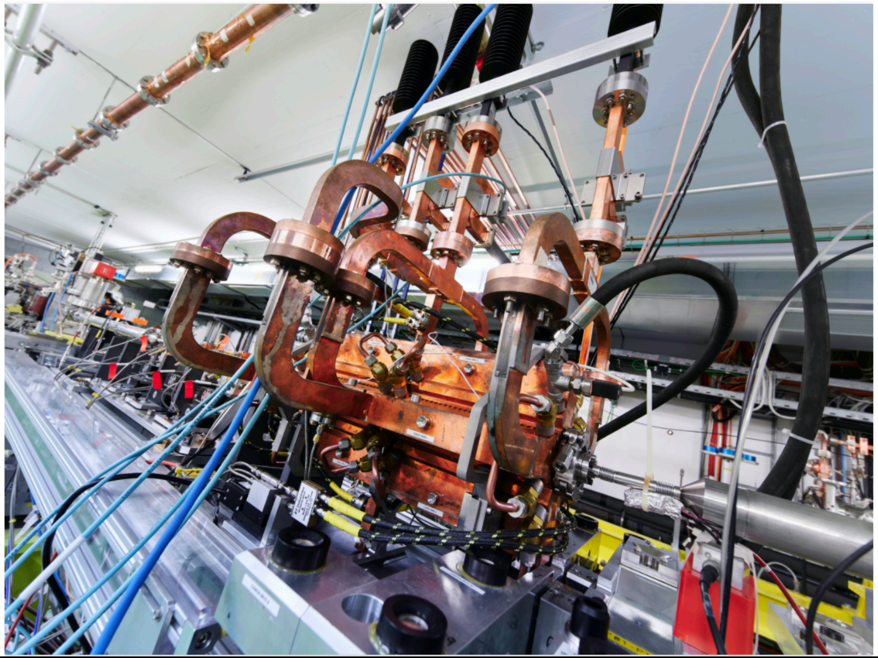
24 June 2021

https://home.cern/news/news/knowledge-sharing/clear-study-paves-way-novel-electron-based-cancer-therapy

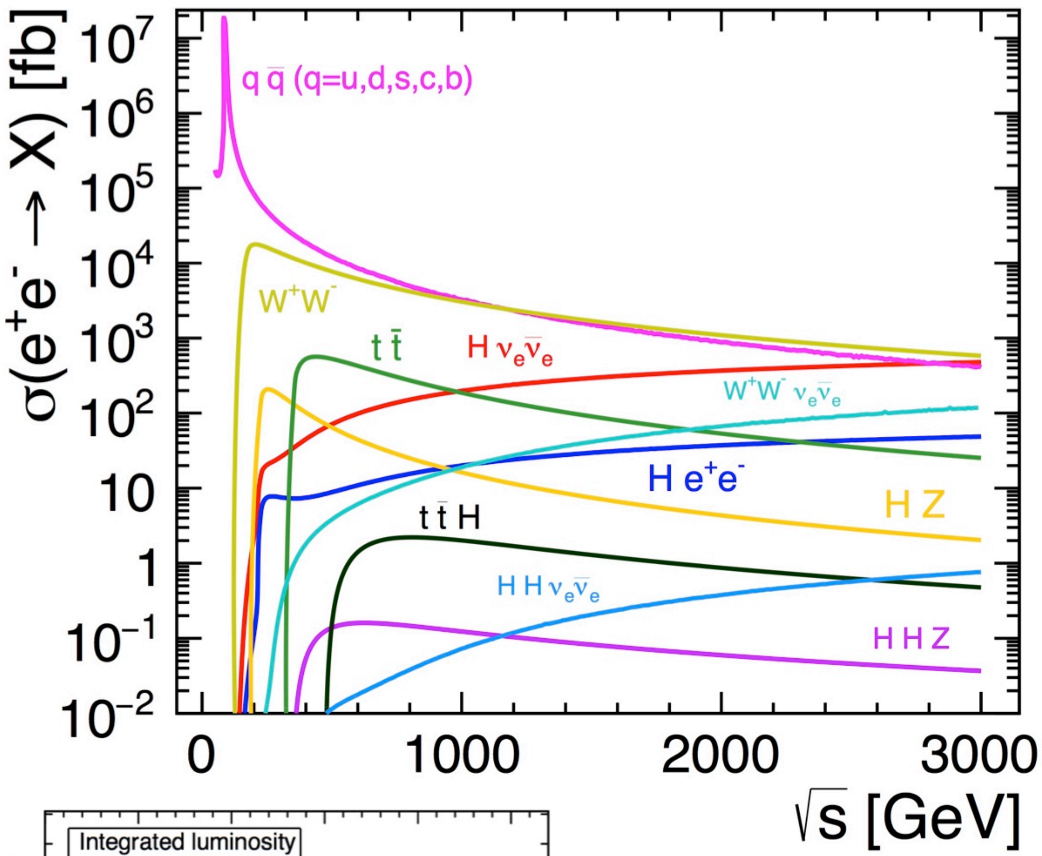
CLEAR study paves the way for novel electron-based cancer therapy

The study, conducted at CERN's CLEAR test facility, demonstrates how very high-energy electron beams can be focused onto deep-seated cancerous tumours

24 JUNE, 2021 | By Thomas Hortala

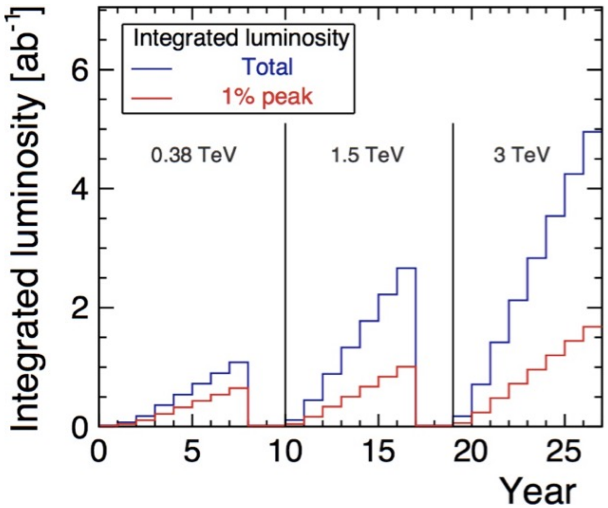


Physics processes and staging



- 2-fermion production e.g. $q\bar{q}$
- WW production
- Higgsstrahlung (HZ):
  - best at 240–380 GeV: "Higgs factory"
- $t\bar{t}$ threshold: 350 GeV
- $t\bar{t}$ continuum: >365 GeV
- Double Higgsstrahlung (HHZ):
  - cross-section maximum ~600 GeV
- Single and double Higgs in WW fusion ($H\nu_e\bar{\nu}_e$ and $HH\nu_e\bar{\nu}_e$):
  - cross-section rises with energy
- Direct searches for new particles:
  highest possible energy

–> Best explored in several energy stages



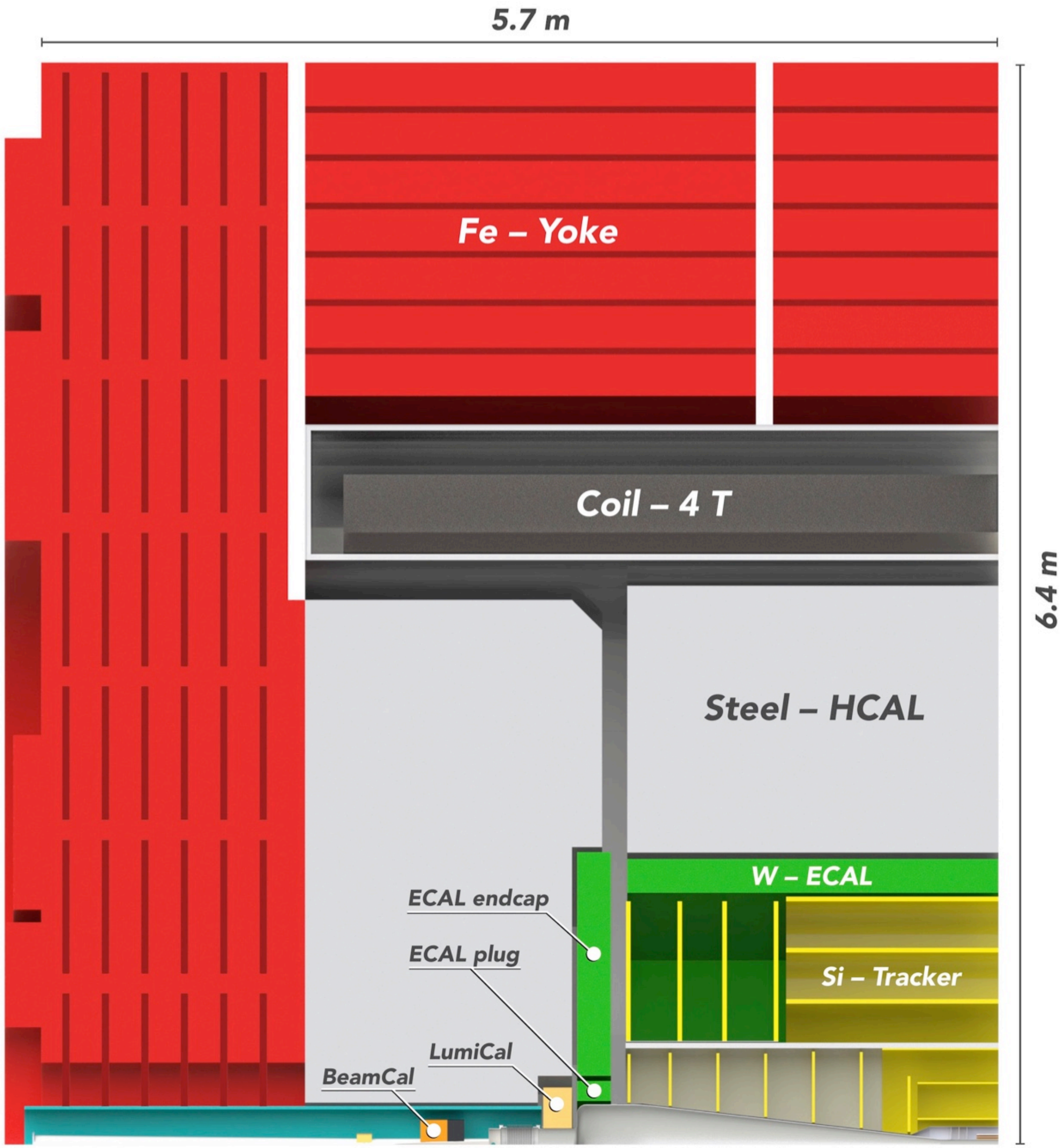
Stage	$\sqrt{s}$ [TeV]	$\mathscr{L}_{int}$ [ab^{-1}]
1	0.38 (and 0.35)	1.0
2	1.5	2.5
3	3.0	5.0

Polarised electron beam (–80%, +80%)

Ratio (50:50) at $\sqrt{s}$=380GeV ; (80:20) at $\sqrt{s}$=1.5 and 3TeV

Baseline staging scenario emphasis is on getting to multi-TeV collisions quickly

CLIC Detector Concept



Essential characteristics:

- B-field: 4T
- Vertex detector with 3 double layers
- Silicon tracking system: 1.5m radius
- ECAL with 40 layers (22 X_0)
- HCAL with 60 layers (7.5 λ)

Precise timing for background suppression (bunch crossings 0.5ns apart)

- ~10ns hit time-stamping in tracking
- 1ns accuracy for calorimeter hits

CLICdp-Note-2017-001
arXiv:1812.07337

+ Dedicated detector R&D programme, particularly on Vertex & Tracking

Vertex and Tracking R&D

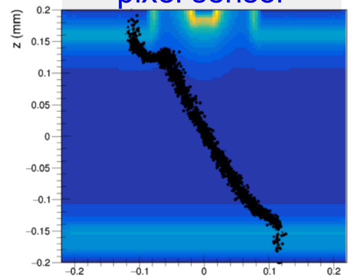
Stringent requirements for CLIC vertex & tracker detectors inspired broad and integrated technology R&D programme

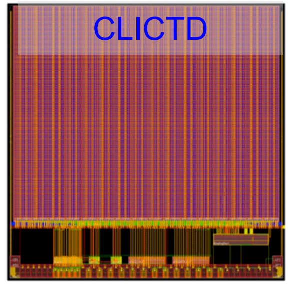
Benefit from rapid progress in Si industry and synergies with HL-LHC

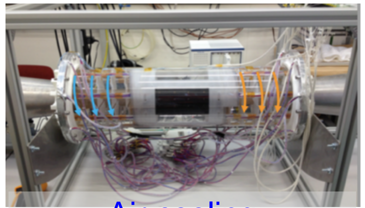
Highlights:

- Full efficiency obtained from hybrid assemblies of 50μm thin sensors that satisfy CLIC time-stamping requirements
- Sensor design with enhanced charge-sharing is underway to reach required spatial resolution with thin sensors
- Good progress towards reducing detector mass with active-edge sensors and through-Si interconnects
- Promising results from fully integrated technologies; CLIC-specific fully integrated designs underway (CLICTD, CLIPS)
- Developed advanced simulation/analysis tools for detector performance optimisation
- Feasibility of power-pulsing demonstrated; power consumption specification met
- Feasibility of air cooling demonstrated in simulation & full vertex detector mockup

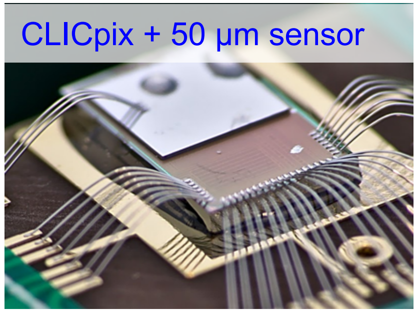
Allpix² simulation of HV-CMOS pixel sensor

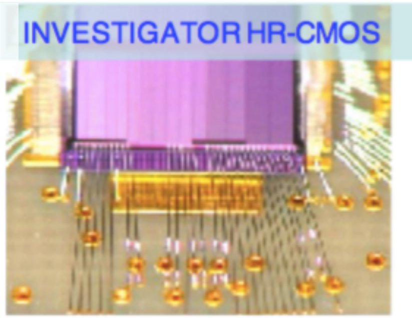






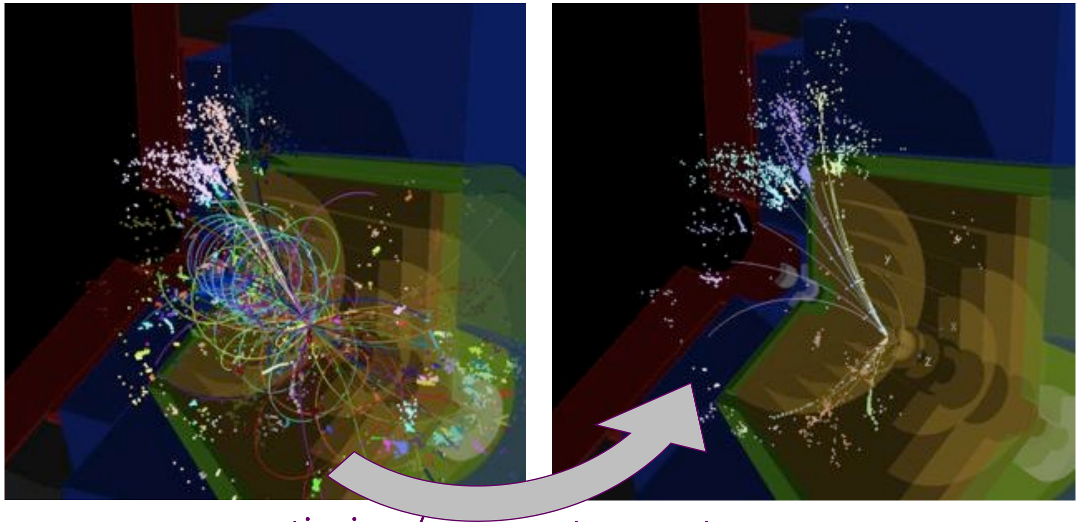
Air cooling



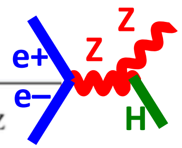


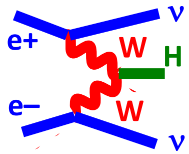
Higgs coupling sensitivity

- Extensive set of full GEANT-based simulation studies including beam backgrounds done for Higgs sector
- Full simulation: imaging calorimetry allows e.g. H->bb/cc/gg separation
- Model-independent coupling extraction
  arXiv:1812.01644
  based on Eur. Phys. J. C 77, 475 (2017)
- Sensitivities used as input for EFT fits



Channel	Measurement	Observable	Statistical precision 350 GeV 1 ab^{-1}
ZH	Recoil mass distribution	m_H	78 MeV
ZH	$\sigma(ZH) \times BR(H \to \text{invisible})$	Γ_{inv}	0.4 %
ZH	$\sigma(ZH) \times BR(Z \to l^+l^-)$	g^2_{HZZ}	2.7 %
ZH	$\sigma(ZH) \times BR(Z \to q\bar{q})$	g^2_{HZZ}	1.3 %
ZH	$\sigma(ZH) \times BR(H \to b\bar{b})$	$g^2_{HZZ} g^2_{Hbb}/\Gamma_H$	0.61 %
ZH	$\sigma(ZH) \times BR(H \to c\bar{c})$	$g^2_{HZZ} g^2_{Hcc}/\Gamma_H$	10 %
ZH	$\sigma(ZH) \times BR(H \to gg)$		4.3 %
ZH	$\sigma(ZH) \times BR(H \to \tau^+\tau^-)$	$g^2_{HZZ} g^2_{H\tau\tau}/\Gamma_H$	4.4 %
ZH	$\sigma(ZH) \times BR(H \to WW^*)$	$g^2_{HZZ} g^2_{HWW}/\Gamma_H$	3.6 %
$H\nu_e\bar{\nu}_e$	$\sigma(H\nu_e\bar{\nu}_e) \times BR(H \to b\bar{b})$	$g^2_{HWW} g^2_{Hbb}/\Gamma_H$	1.3 %
$H\nu_e\bar{\nu}_e$	$\sigma(H\nu_e\bar{\nu}_e) \times BR(H \to c\bar{c})$	$g^2_{HWW} g^2_{Hcc}/\Gamma_H$	18 %
$H\nu_e\bar{\nu}_e$	$\sigma(H\nu_e\bar{\nu}_e) \times BR(H \to gg)$		7.2 %





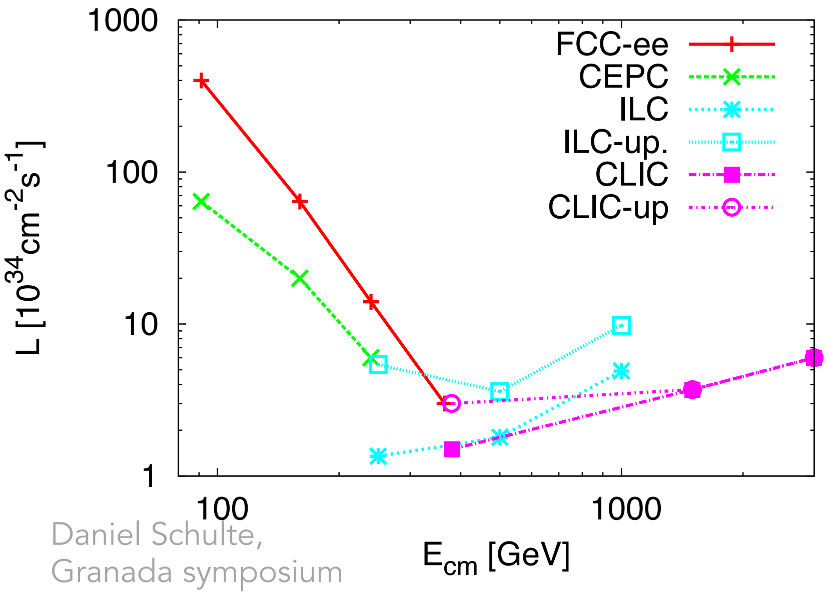
Many channels studied

Channel	Measurement	Observable	Statistical precision 1.4 TeV 2.5 ab^{-1}	3 TeV 5.0 ab^{-1}
$H\nu_e\bar{\nu}_e$	$H \to b\bar{b}$ mass distribution	m_H	36 MeV	28 MeV
ZH	$\sigma(ZH) \times BR(H \to b\bar{b})$	$g^2_{HZZ} g^2_{Hbb}/\Gamma_H$	2.6 %†	4.3 %†
$H\nu_e\bar{\nu}_e$	$\sigma(H\nu_e\bar{\nu}_e) \times BR(H \to b\bar{b})$	$g^2_{HWW} g^2_{Hbb}/\Gamma_H$	0.3 %	0.2 %
$H\nu_e\bar{\nu}_e$	$\sigma(H\nu_e\bar{\nu}_e) \times BR(H \to c\bar{c})$	$g^2_{HWW} g^2_{Hcc}/\Gamma_H$	4.7 %	4.4 %
$H\nu_e\bar{\nu}_e$	$\sigma(H\nu_e\bar{\nu}_e) \times BR(H \to gg)$		3.9 %	2.7 %
$H\nu_e\bar{\nu}_e$	$\sigma(H\nu_e\bar{\nu}_e) \times BR(H \to \tau^+\tau^-)$	$g^2_{HWW} g^2_{H\tau\tau}/\Gamma_H$	3.3 %	2.8 %
$H\nu_e\bar{\nu}_e$	$\sigma(H\nu_e\bar{\nu}_e) \times BR(H \to \mu^+\mu^-)$	$g^2_{HWW} g^2_{H\mu\mu}/\Gamma_H$	29 %	16 %
$H\nu_e\bar{\nu}_e$	$\sigma(H\nu_e\bar{\nu}_e) \times BR(H \to \gamma\gamma)$		12 %	6 %*
$H\nu_e\bar{\nu}_e$	$\sigma(H\nu_e\bar{\nu}_e) \times BR(H \to Z\gamma)$		33 %	19 %*
$H\nu_e\bar{\nu}_e$	$\sigma(H\nu_e\bar{\nu}_e) \times BR(H \to WW^*)$	g^4_{HWW}/Γ_H	0.8 %	0.4 %*
$H\nu_e\bar{\nu}_e$	$\sigma(H\nu_e\bar{\nu}_e) \times BR(H \to ZZ^*)$	$g^2_{HWW} g^2_{HZZ}/\Gamma_H$	4.3 %	2.5 %*
He^+e^-	$\sigma(He^+e^-) \times BR(H \to b\bar{b})$	$g^2_{HZZ} g^2_{Hbb}/\Gamma_H$	1.4 %	1.5 %*
$t\bar{t}H$	$\sigma(t\bar{t}H) \times BR(H \to b\bar{b})$	$g^2_{Htt} g^2_{Hbb}/\Gamma_H$	5.7 %	–

(These precisions are for unpolarised beams; baseline is on slide 13) † : fast simulation *: extrapolated from 1.4TeV

Alternative run scenario

- To illustrate the flexibility of the run-plan: two modifications with respect to the baseline staging:
- **Doubling bunch train repetition rate at initial stage from 50Hz to 100 Hz**
  –> modest increase in cost (~5%) and power (from 170MW to 220MW)
  CERN-ACC-2019-0051
- **Increasing initial stage from 8 to 13 years**
  –> Integrated luminosity at 380GeV increases from 1ab^{-1} to 4ab^{-1}



Daniel Schulte, Granada symposium

	Benchmark	HL-LHC	HL-LHC + CLIC 380 (4 ab^{-1})	HL-LHC + CLIC 380 (1 ab^{-1}) + 1500 (2.5 ab^{-1})	HL-LHC + FCC-ee 240	HL-LHC + FCC-ee 365
$g^{\text{eff}}_{HZZ}[\%]$	SMEFT_{ND}	3.6	0.3	0.2	0.5	0.3
$g^{\text{eff}}_{HWW}[\%]$	SMEFT_{ND}	3.2	0.3	0.2	0.5	0.3
$g^{\text{eff}}_{H\gamma\gamma}[\%]$	SMEFT_{ND}	3.6	1.3	1.3	1.3	1.2
$g^{\text{eff}}_{HZ\gamma}[\%]$	SMEFT_{ND}	11.	9.3	4.6	9.8	9.3
$g^{\text{eff}}_{Hgg}[\%]$	SMEFT_{ND}	2.3	0.9	1.0	1.0	0.8
$g^{\text{eff}}_{Htt}[\%]$	SMEFT_{ND}	3.5	3.1	2.2	3.1	3.1
$g^{\text{eff}}_{Hcc}[\%]$	SMEFT_{ND}	–	2.1	1.8	1.4	1.2
$g^{\text{eff}}_{Hbb}[\%]$	SMEFT_{ND}	5.3	0.6	0.4	0.7	0.6
$g^{\text{eff}}_{H\tau\tau}[\%]$	SMEFT_{ND}	3.4	1.0	0.9	0.7	0.6
$g^{\text{eff}}_{H\mu\mu}[\%]$	SMEFT_{ND}	5.5	4.3	4.1	4.	3.8
$\delta g_{1Z}[\times 10^2]$	SMEFT_{ND}	0.66	0.027	0.013	0.085	0.036
$\delta\kappa_{\gamma}[\times 10^2]$	SMEFT_{ND}	3.2	0.032	0.044	0.086	0.049
$\lambda_Z[\times 10^2]$	SMEFT_{ND}	3.2	0.022	0.005	0.1	0.051

CLIC longer first stage | CLIC baseline

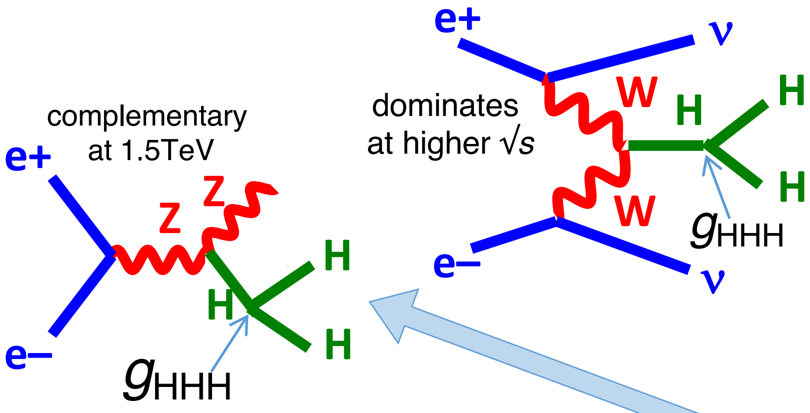
From arXiv: 2001.05278 | From European Strategy Briefing Book

- Either scenario (longer 1st stage, or baseline 1st+2nd stage) very competitive
- Proposed e^+e^- colliders give similar Higgs performance at the initial stage "Higgs Factory"

–> look at what is unique to CLIC

Higgs self-coupling, and ZH at 3TeV

◆ High-energy running gives direct access to Higgs self-coupling



	1.4TeV	3TeV
$\sigma(HH\nu_e\bar{\nu}_e)$	>3σ EVIDENCE $\frac{\Delta\sigma}{\sigma}$ = 28%	>5σ OBSERVATION $\frac{\Delta\sigma}{\sigma}$ = 7.3%
σ(ZHH)	3.3σ EVIDENCE	2.4σ EVIDENCE
g_{HHH}/g_{HHH}^{SM}	1.4TeV: –29%, +67% rate-only analysis	1.4 + 3TeV: **–8%, +11%** differential analysis

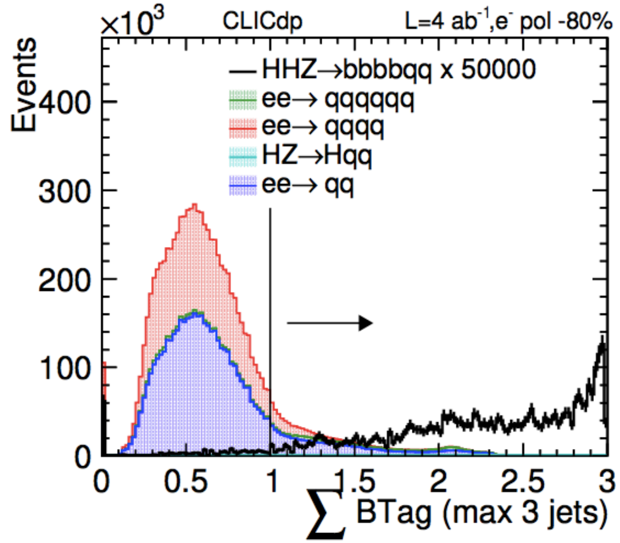
Eur. Phys. J. C 80, 1010 (2020)

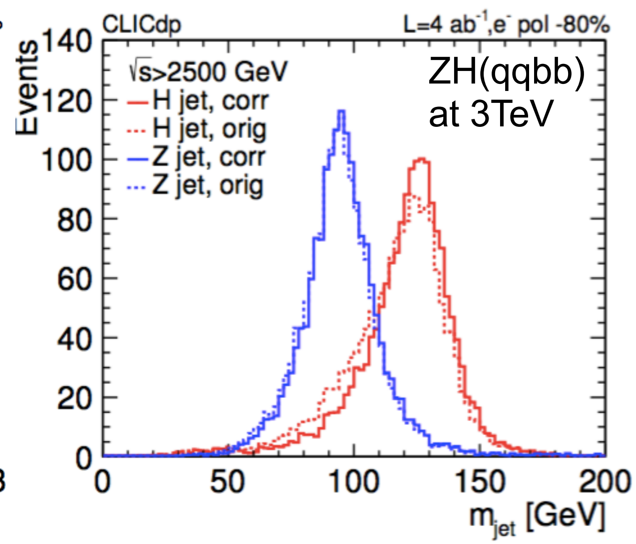
◆ Direct access to two processes that behave differently with non-SM values of self-coupling

◆ Recently-completed high-energy studies

ZHH and ZH(qqbb) at 3 TeV to confirm fast simulation / extrapolation
– use of jet substructure
– first use of b-tagging in boosted Higgs decays at CLIC

all-hadronic ZHH https://arxiv.org/abs/2008.05198

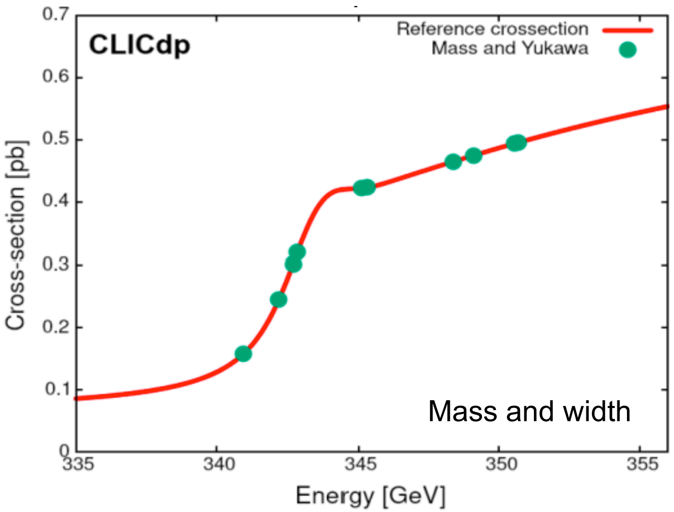




Top-quark physics

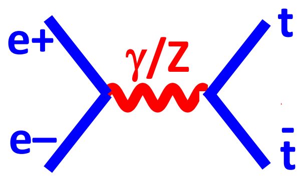
- **CLIC is unique among e+e– colliders by accessing top-quark physics from the initial**

Threshold scan:



- Optimisation of scan points including beam spectrum; here optimising on mass and width.
- Expected top-quark mass precision of 25MeV can be improved by 25% without losing precision on width or Yukawa. https://arxiv.org/abs/2103.00522

new



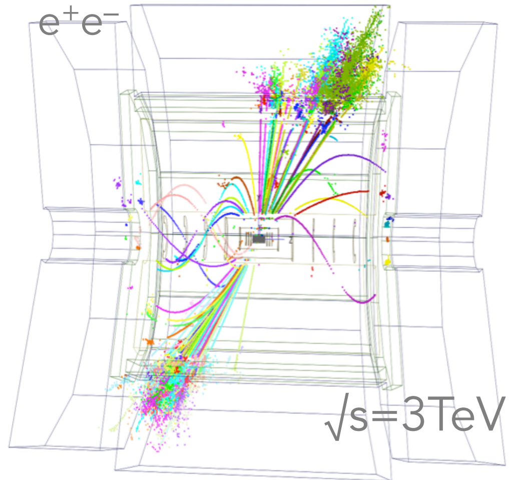
Electron beam polarisation provides new observables

Top-quark physics at CLIC: JHEP11 (2019) 003

Pair production:

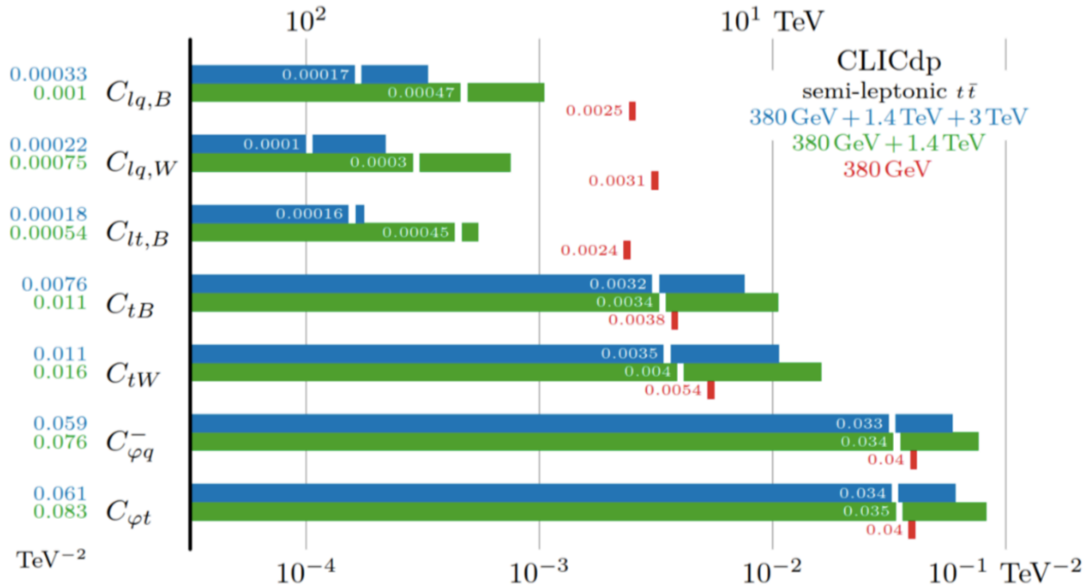
- Top cross-sections, both polarisations ~1%
- Top forward-backward asymmetries ~3–4%
- Statistically optimal observables for top EWK couplings; more than one energy stage allows global fit

First study of boosted top production in e^+e^-

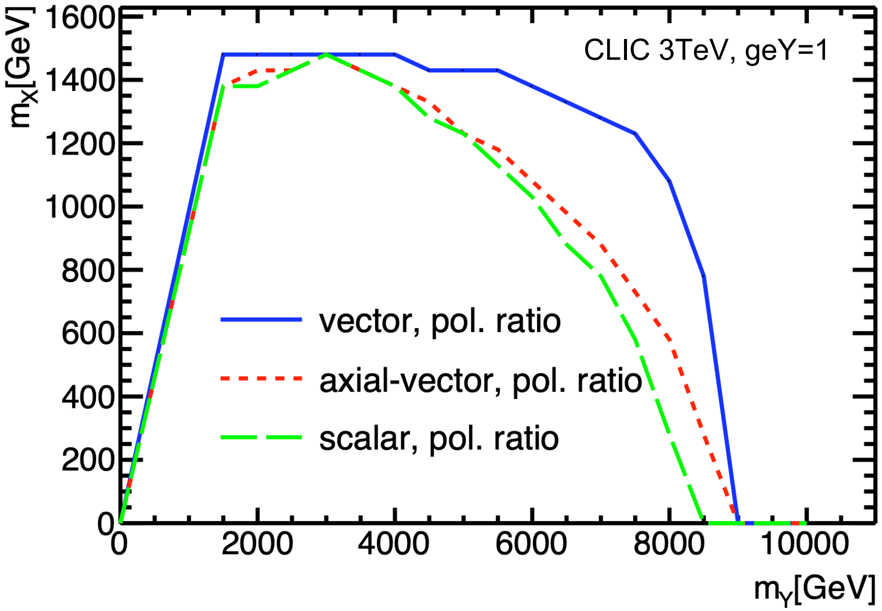


$e^+e^- \to t\bar{t} \to q\bar{q}q\bar{q}b\bar{b}$

https://arxiv.org/abs/2008.05526

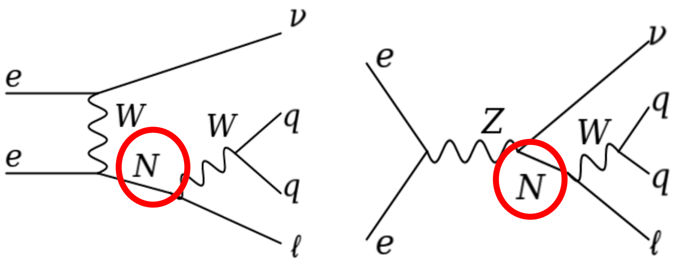


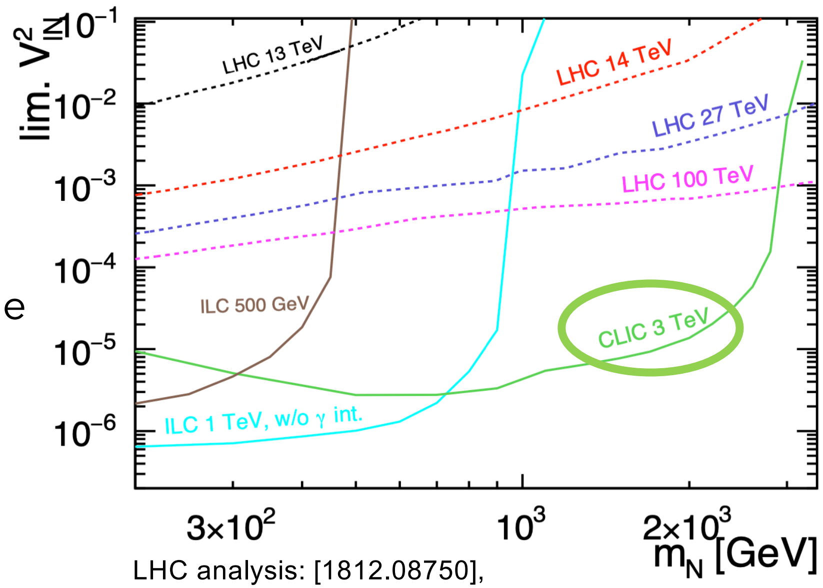
BSM signature searches recent highlights



- **Dark matter using mono-photon signature at 3TeV,** $e^+e^- \to XX\gamma$
- New study using ratio of electron beam polarisations to reduce systematics
- Exclusions for simplified model with mediator Y and DM particle X
- For benchmark mediator of 3.5TeV, photon energy spectrum discriminates different DM mediators & allows 1TeV DM particle mass measurement to ~1% https://arxiv.org/abs/2103.06006

- **Search for heavy neutrinos**
- $e^+e^- \to N\nu \to qql\nu$ signature allows full reconstruction of N
- BDT separates signal from SM; beam backgrounds included
- cross-section limits converted to mass (m_N) coupling (V_{lN}) plane





LHC analysis: [1812.08750], diff. assumption $V_{eN} = V_{mN} \neq V_{\tau N} = 0$

BSM effects through global EFT fits

$$\mathcal{L}_{\rm SMEFT} = \mathcal{L}_{\rm SM} + \sum_i \frac{c_i}{\Lambda^2}\mathcal{O}_i$$

Standard Model

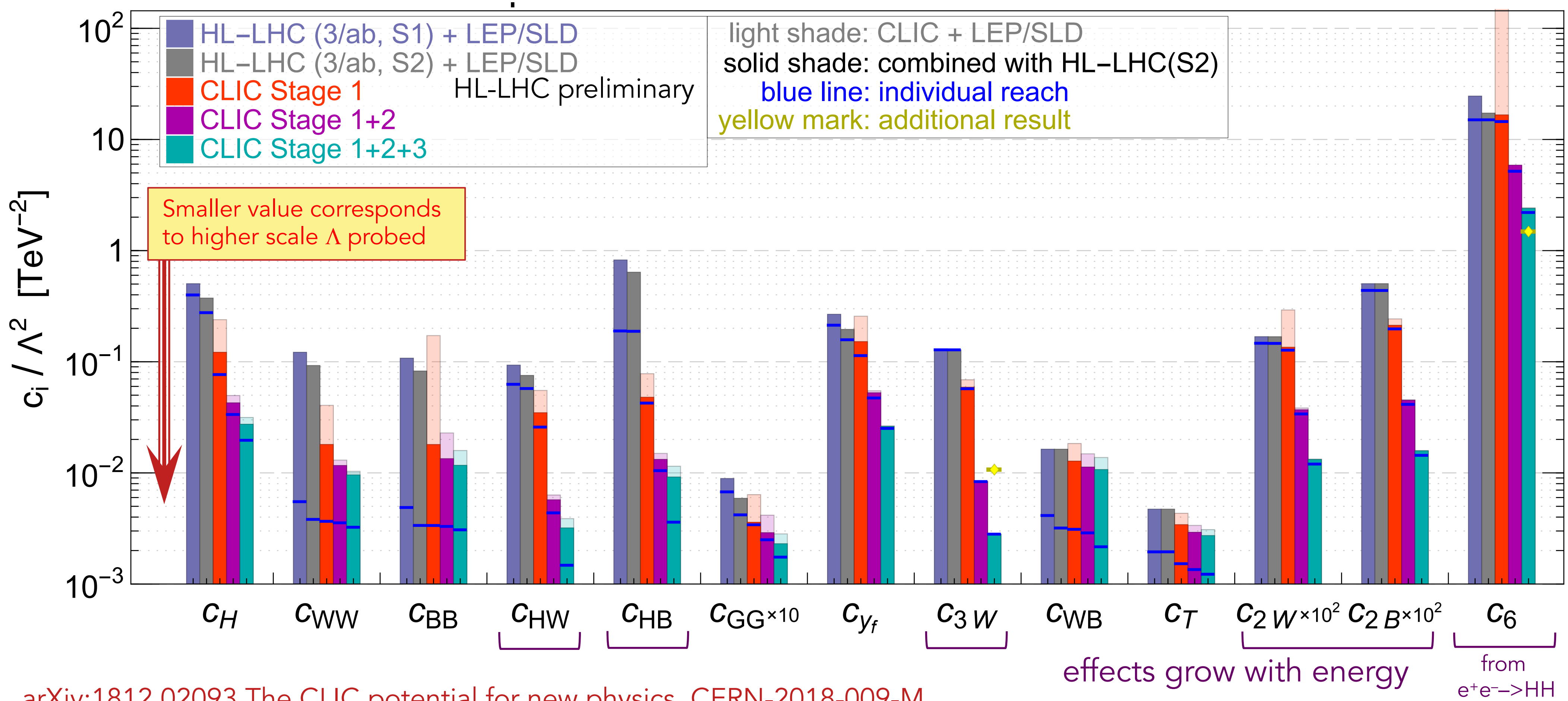
Scale of new decoupled physics

Dimension-6 operators

Includes CLIC measurements of:
- Higgs
- Top
- WW
- $e^+e^- \to f\bar{f}$

Strongly benefits from high-energy running

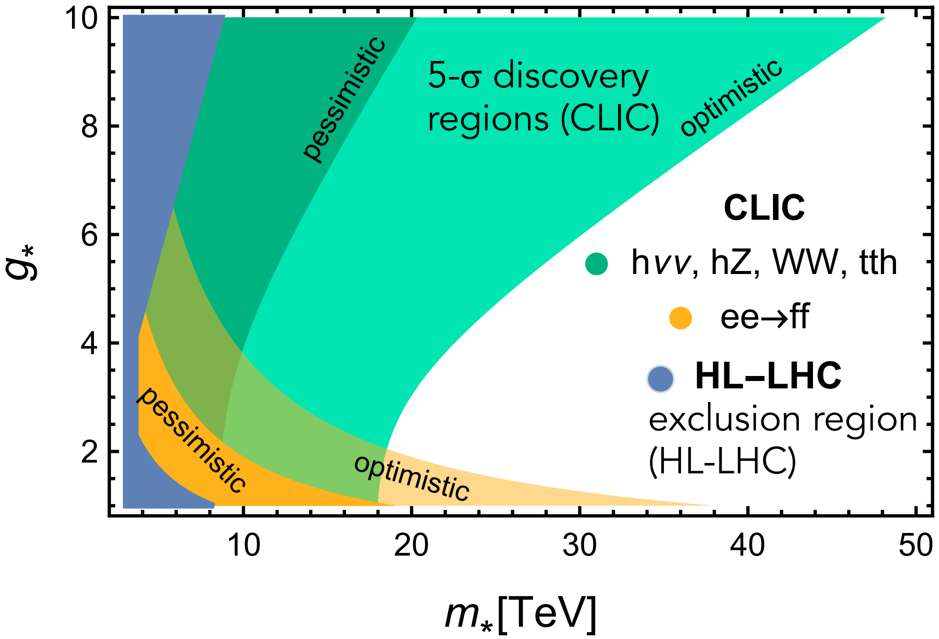
Universal EFT fit



arXiv:1812.02093 The CLIC potential for new physics, CERN-2018-009-M

BSM indirect searches

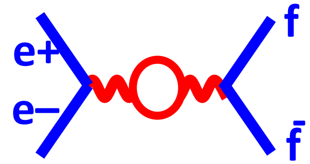
- Composite Higgs (or top) would appear through SM-EFT operators – translate EFT limits into characteristic coupling strength g_* of composite sector and mass m_*



CLIC can ***discover*** compositeness up to ~10TeV compositeness scale
(~30 – ~50TeV in favourable conditions)
– above what HL-LHC can ***exclude***

- Precision measurements e.g.

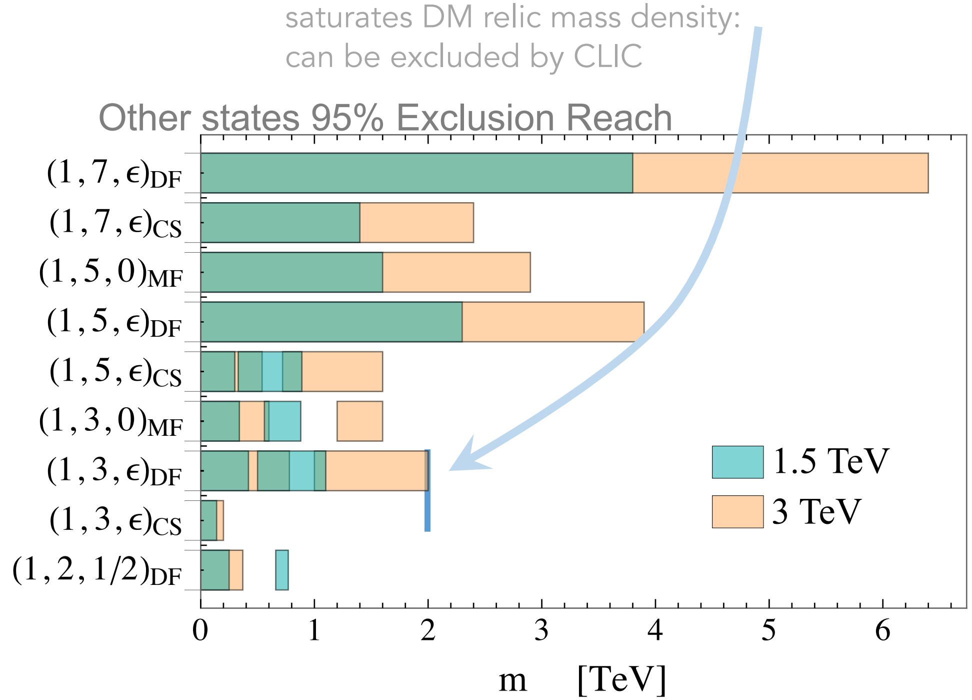
  $d\sigma/d(\cos\theta)$ in $e^+e^- \to f\bar{f}$



can be sensitive to new states
–> excluded mass ranges

arXiv:1810.10993 - Di Luzio, Gröber, Panico

e.g. for *n*=3 Dirac fermion, *m*=2TeV saturates DM relic mass density: can be excluded by CLIC

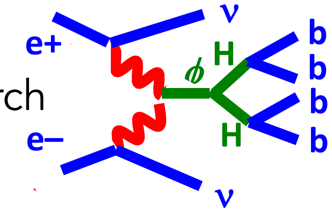


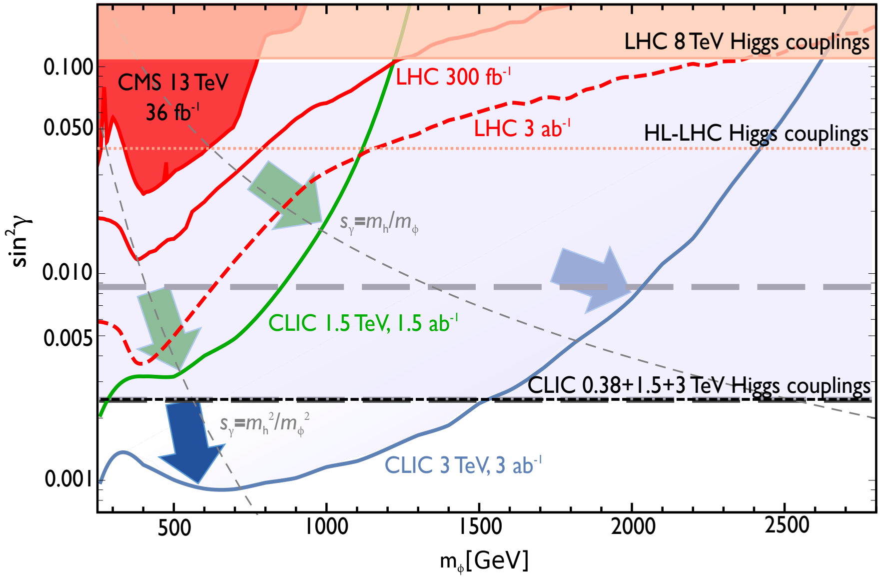
DF=Dirac Fermion, MF=Majorana Fermion, CS=Complex Scalar
SU(3)xSU(2)xU(1) representation; different *n*-tuplet multiplicities

arXiv:1812.02093 The CLIC Potential for New Physics

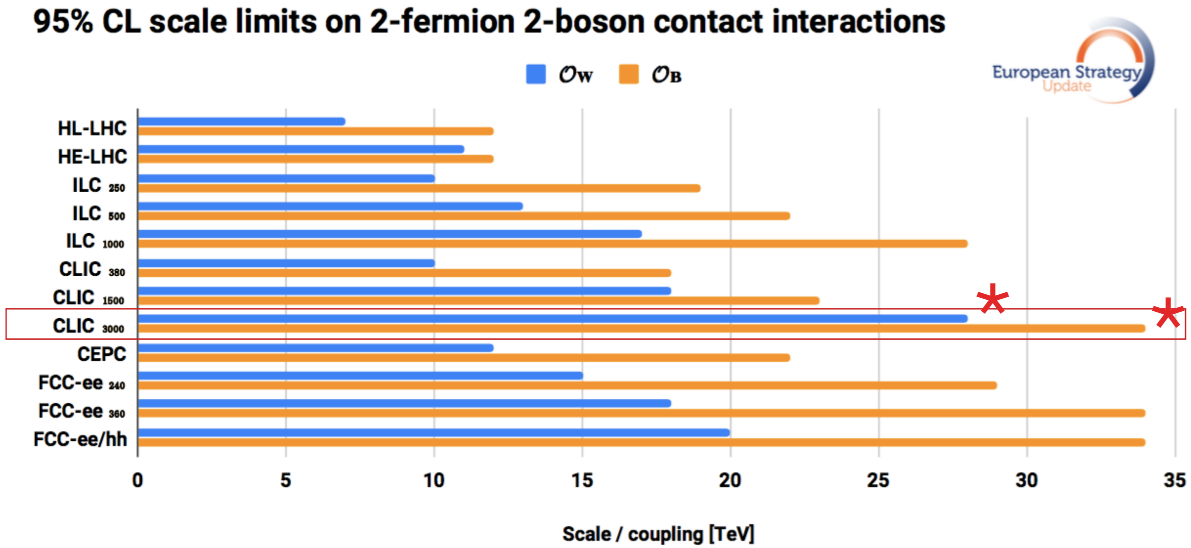
Interpretations and full programme

- Higgs + heavy singlet: Complementarity of direct search and indirect constraints





- Contact interactions interpretations



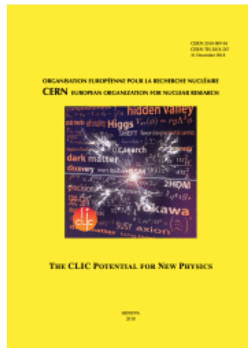
CLIC reaches ~28TeV in O_W, ~34TeV in O_B

Precision Higgs couplings and self-coupling
Precision electroweak and top-quark analysis
Sensitivity to BSM effects in the SMEFT
Higgs and top compositeness
Baryogenesis
Direct discoveries of new particles
Extra Higgs boson searches
Dark matter searches
Lepton and flavour violation
Neutrino properties
Hidden sector searches
Exotic Higgs boson decays

Many more studies in CERN Yellow Report:

The CLIC Potential for New Physics (250 pages)

arXiv:1812.02093 CERN-2018-009-M



Ongoing physics studies

- Accelerator R&D continues –> CLIC physics remains very relevant
- Growing interest in high-energy lepton collisions:

  –> CLIC is by far the most advanced TeV-scale lepton collider considered, and the only one where detailed physics studies have been done.

- Particular areas of focus beyond Higgs physics:
  - importance of top-quark physics in e^+e^-
  - importance of several energy stages in e^+e^-
  - direct searches, in particular for elusive signatures
  - further and novel ways of constraining NP from precision measurements
  - importance of beam polarisation
  - new BSM scenarios of particular relevance to multi-TeV lepton collisions

–> look at your favourite model at CLIC energies
–> if new benchmark models are defined, e.g. during US Snowmass exercise, then please help obtain sensitivities for them!

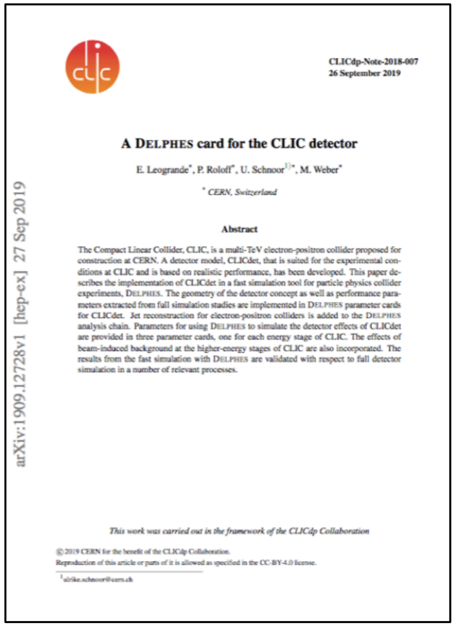
Tools for CLIC sensitivity studies

- A Delphes card for the CLICdet detector model is well-documented and has already been extensively used:

  Whizard settings for CLIC:
  https://gitlab.cern.ch/CLICdp/DetectorSoftware/clic-whizard2-settings

  CLICdet Delphes card description and validation:
  https://arxiv.org/abs/1909.12728

  Further information on the use of the CLICdet Delphes card can be found here:
  https://twiki.cern.ch/twiki/bin/view/CLIC/CLICdetDelphesInstructions



CLICdp-Note-2018-007
26 September 2019

arXiv:1909.12728v1 [hep-ex] 27 Sep 2019

A DELPHES card for the CLIC detector

E. Leogrande*, P. Roloff*, U. Schnoor[1]*, M. Weber*

* *CERN, Switzerland*

Abstract

The Compact Linear Collider, CLIC, is a multi-TeV electron-positron collider proposed for construction at CERN. A detector model, CLICdet, that is suited for the experimental conditions at CLIC and is based on realistic performance, has been developed. This paper describes the implementation of CLICdet in a fast simulation tool for particle physics collider experiments, DELPHES. The geometry of the detector concept as well as performance parameters extracted from full simulation studies are implemented in DELPHES parameter cards for CLICdet. Jet reconstruction for electron-positron colliders is added to the DELPHES analysis chain. Parameters for using DELPHES to simulate the detector effects of CLICdet are provided in three parameter cards, one for each energy stage of CLIC. The effects of beam-induced background at the higher-energy stages of CLIC are also incorporated. The results from the fast simulation with DELPHES are validated with respect to full detector simulation in a number of relevant processes.

This work was carried out in the framework of the CLICdp Collaboration

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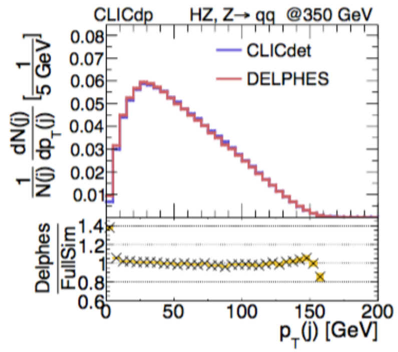
[1] ulrike.schnoor@cern.ch

  - b-tagging working points
  - jet reconstruction choices
  - etc.

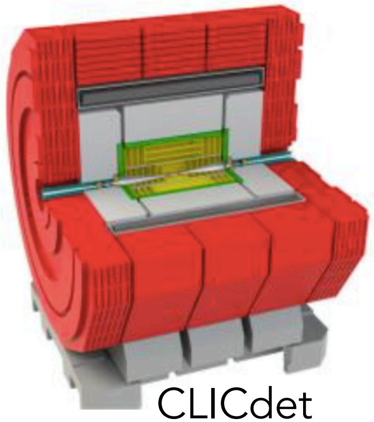


Delphes jet p_T validation in HZ events

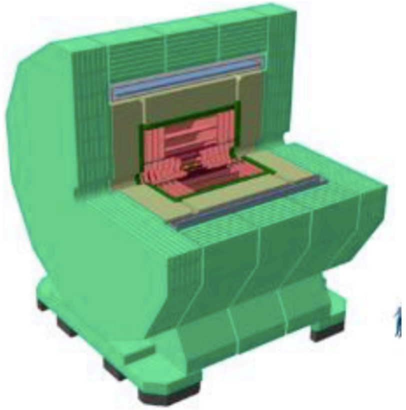
- If you are interested in using the full simulation or have questions on Whizard and Delphes for CLICdet, you are very welcome to contact us:
  clicdp-snowmass-samples-contacts@cern.ch

Exploiting synergies

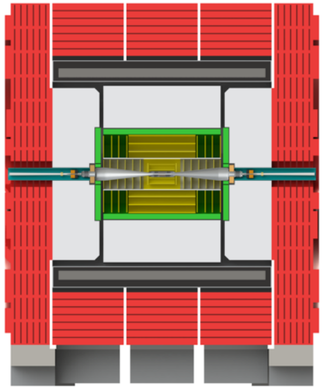
Priority: focusing on project synergies



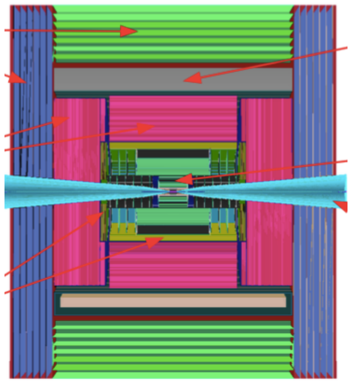
CLICdet



CLICdet adapted for FCC-ee



CLICdet



CLICdet adapted for muon collider

– detector concepts and software tools

Detector	Collider	SW name	SW status	SW future
ILD	ILC	iLCSoft	Full sim/reco	Key4hep
SiD	ILC	iLCSoft	Full sim/reco	
CLICdet	CLIC	iLCSoft	Full sim/reco	
CLD	FCC-ee	iLCSoft	Full sim/reco	
IDEA	FCC-ee	FCC-SW	Fast sim/reco	
IDEA	CEPC	FCC-SW	Fast sim/reco	
CEPCbaseline	CEPC	iLCSoft branch-off	Full sim/reco	

–> all moving to common framework

CLIC perspective

- CLIC is a mature project, ready to provide a Higgs factory and subsequent multi-TeV lepton machine
  - precision measurements
  - sensitivity to elusive signatures
  - extended energy/mass reach
- CERN is continuing investment in CLIC accelerator R&D for the next 5 years
- So far, CLIC has provided the most detailed studies for high-energy lepton collisions, where interest is increasing
- You are strongly encouraged to continue exploring synergies in accelerator technology, detector technologies, and physics studies, among the different collider options and to contribute to CLIC!

Thank you!