

# CLIC DETECTOR STATUS AND PLANS

International Workshop on Future Linear Colliders 2017

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On behalf of the **CLICdp** collaboration

Strasbourg, 23 October 2017

# CLIC Detector and Physics

CLICdp: 29 institutes

[clicdp.cern.ch](http://clicdp.cern.ch)

**Focus of CLIC-specific studies on:**

Physics prospects and simulation studies

Detector optimisation + R&D for CLIC

Strong R&D ties with FCal and CALICE



2012: CLIC Conceptual Design Report published



2012→: Input to European strategy process

2015: Developed new detector concept

2016: Updated

baseline for  
staging

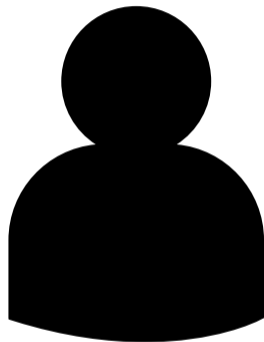


2016: Higgs  
physics at  
CLIC

2019/20: Update of European strategy

# News from CLICdp Management

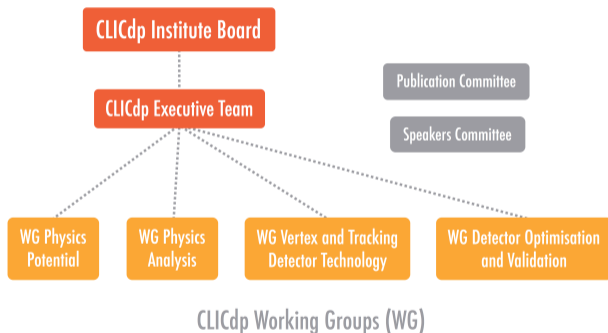
Collaboration board elected  
new Spokesperson



Clc Clickerson

- ▶ Starting 2 year term 2018

## Organizational structure



- ▶ New working group Physics Potential
- ▶ Workshop **Physics at CLIC** in June

# CLIC Energy Stages

- ▶ CLIC staging baseline: CERN yellow report (CERN-2016-004)
- ▶ First stage at 380 GeV, focused on Higgs physics and top quark physics (affordable within CERN budget)

## Current scenario:

Stage 1:  $600 \text{ fb}^{-1}$  @ 350/380 GeV

Precision SM Higgs and top physics

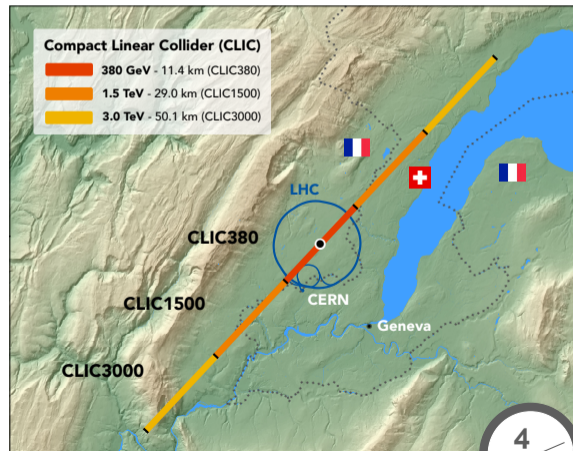
Stage 2:  $1.5 \text{ ab}^{-1}$  @ 1.5 TeV:

BSM, top and rare Higgs processes

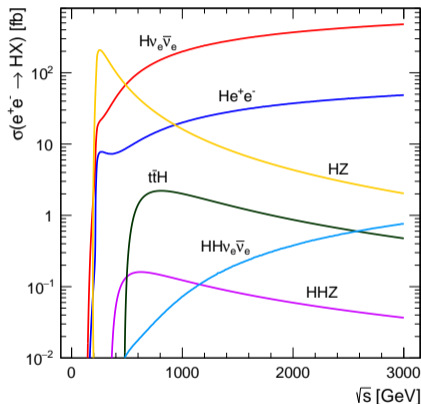
Stage 3:  $3 \text{ ab}^{-1}$  @ 3 TeV :

BSM, top and rare Higgs processes

Each stage corresponds to 5-7 years



# Higgs Measurements



- ▶ Geant4 based detector simulation and event reconstruction with bkg. overlay
- ▶ Studies carried out at three stages

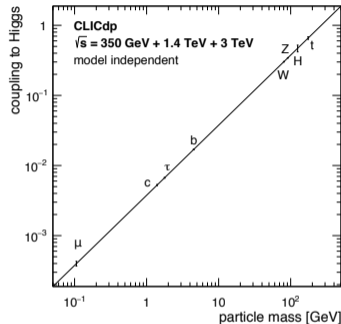
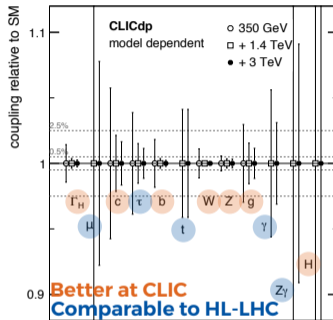
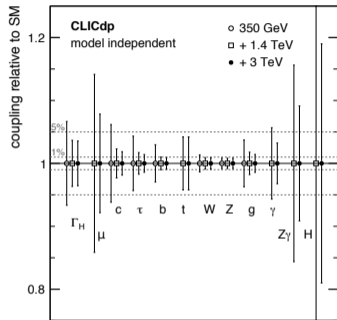
$\sqrt{s}$	350 GeV	1.4 TeV	3 TeV
$\int \frac{d\mathcal{L}}{ds'} ds'$	$500 \text{ fb}^{-1}$	$1.5 \text{ ab}^{-1}$	$2 \text{ ab}^{-1}$
$\sigma(e^+e^- \rightarrow ZH)$	133 fb	8 fb	2 fb
$\sigma(e^+e^- \rightarrow H\nu_e\bar{\nu}_e)$	34 fb	276 fb	477 fb
$\sigma(e^+e^- \rightarrow He^+e^-)$	7 fb	28 fb	48 fb
ZH events	68 000	20 000	11 000
$H\nu_e\bar{\nu}_e$ events	17 000	370 000	830 000
$He^+e^-$ events	3700	37 000	84 000

- ▶  $H\nu_e\bar{\nu}_e$  increases  $\times 1.8$  for 80%  $e^-$  polarisation
- ▶ **High selection efficiencies !**

# Higgs Measurements Summary

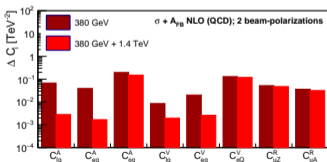
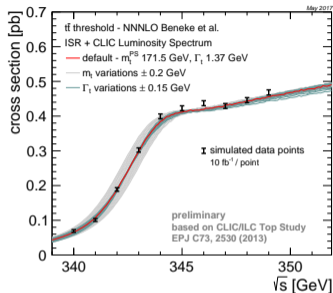
Eur. Phys. J. C 77, 475 (2017)

Lepton collider allows one to measure Higgs properties with high precision



- ▶ Model independent extraction only at lepton colliders due to model independent measurement of  $g_{HZZ}$
- ▶ Many couplings measured with  $\sim 1\%$  precision
- ▶ Higgs width extracted with 5-3.5% precision
- ▶ Model dependent fits can achieve precision below 1%

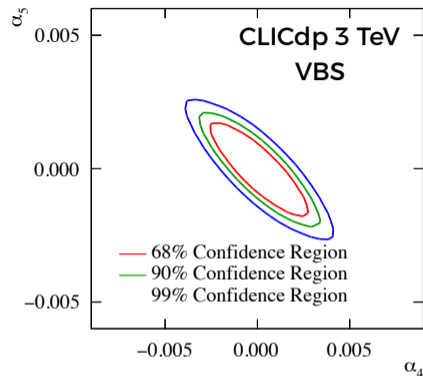
# Top Physics



- ▶ Top physics overview paper in preparation
- ▶ Top threshold scan to extract mass and width
- ▶ Cross section distorted by **ISR** and **lumi. spect.**
- ▶ Precision on 1S mass: **~ 50 MeV** (LHC: 500 MeV)
- ▶ Not limited by theoretical uncertainty (**~ 10 MeV**)
- ▶ EW couplings extracted by measurement of  $\sigma$  and asymmetries (optimal observables)
- ▶ Interpretation; EFT dim. 6 operators and form factors
- ▶ **TeV operation provides better sensitivity to contact-interaction operators.**
- ▶ More info → **talk by M. Perelló (Thur.)**

# BSM Physics

- ▶ Vector boson scattering gives insight into the mechanism of electroweak symmetry breaking
  - ▶ Has substantially higher sensitivity than at LHC
  - ▶ Easier use of hadronic final states
- ▶  $e^+e^- \rightarrow \gamma\gamma$  unique to lepton colliders
  - ▶ Precise experimental signatures
  - ▶ Very accurate theory interpretations
  - ▶ Sensitivity reach beyond direct production
- ▶ More info → talk by I. Boyko (Tue.)

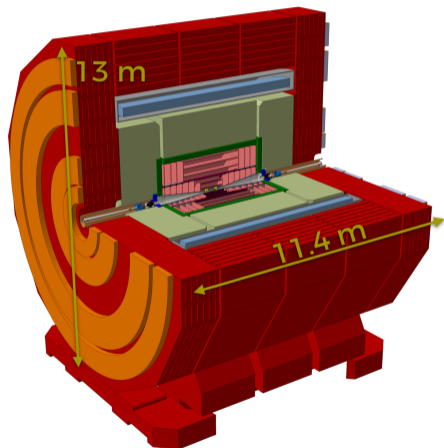


Scenario ( $e^+e^- \rightarrow \gamma\gamma$ )	CLIC (95% CL)
QED cutoff $\Lambda$	6.33 TeV
Contact int. $\Lambda'$	20.1 TeV
Ext. dim.: $M_5\Lambda^{-\frac{1}{4}}$	15.9 TeV
Excited e: $M(e^*)$	4.87 TeV



# CLIC Detector Concept - CLICdet

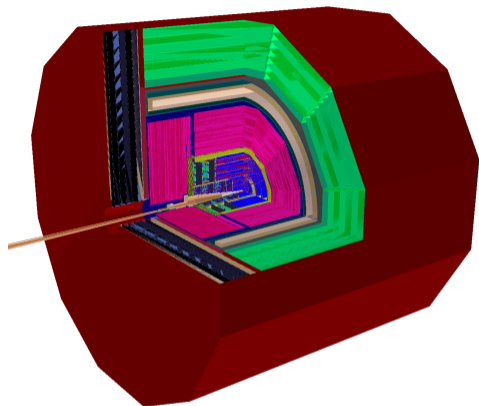
- ▶ R&D + simulation-based optimisation → CLICdet



- ▶ B Field of 4 T
- ▶ Vertex: 3 double layers
  - ▶ Single-hit accuracy  $3 \mu\text{m}$
  - ▶  $0.2\% X_0$  per detection layer
  - ▶ Power pulsing →  $50 \text{ mW cm}^{-2}$
- ▶ Si tracker:  $r_{\text{max}} = 1.5 \text{ m}$
- ▶ ECal (Si + W) with 40 layers ( $22X_0$  &  $1\lambda$ )
- ▶ HCal (scint. + Fe) with 60 layers ( $7.5\lambda$ )
- ▶ Precise timing for background
  - ▶ 10 ns stamping for tracks
  - ▶ 1 ns accuracy for calo. cluster
- ▶  $L^* = 6 \text{ m}$  outside detector

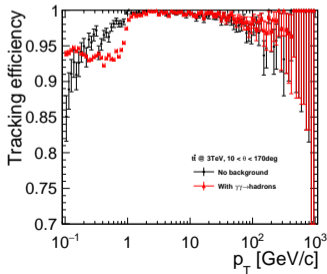
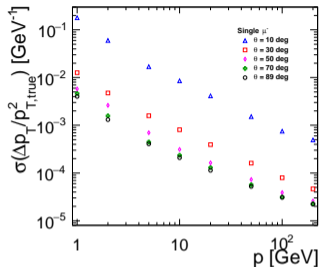
# Simulation Reconstruction Developments

- ▶ Transitioned `iLCSoft` to `DD4hep` based detector description
  - ▶ adopted simulation and reconstruction code
  - ▶ contributed substantially to validation of `DD4hep`
- ▶ `DD4hep` reached stable phase
  - ▶ under investigation by `LHCb` and `CMS` for upgrades and used by `FCC`
- ▶ `DD4hep` integrated into `iLCDirac` and ready to be used for production
- ▶ More on LC software and `iLCDirac`  
→ talk by A. Sailer and M. Petrič (Tue.)



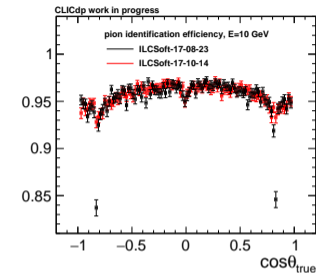
CLICdet visualized with  
`DD4hep`

# Tracking Developments

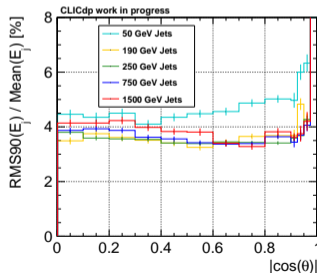


- ▶ Using DDKalTest for track fitting
- ▶ Achieving resolution of  $\sim 2 \times 10^{-5} \text{GeV}^{-1}$  at high energy in central barrel
- ▶ Developed track finding tool based on conformal transformations
- ▶ Perform well down to  $10^\circ$  in CLIC case
- ▶ More than 99% efficiency for above 1 GeV
- ▶ Successfully tackles displaced tracks
- ▶ Better performance compared to CLIC\_SiD
- ▶ More info → talk by E. Leogrando (Thur.)

# Calorimetry Performance and Validation

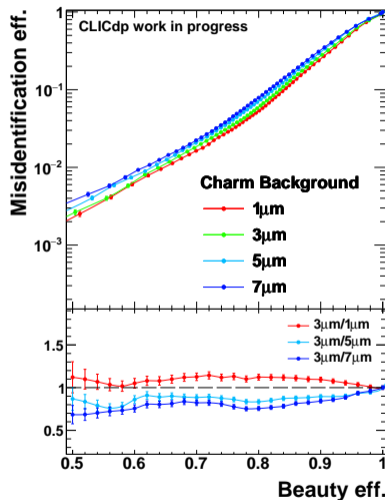


- ▶ Modification in PandoraPFA to address long standing issues of inefficiency of charged particle ID in Calo transition region
  - ▶ Only minor effect of gap remaining
- ▶ Adopted software compensation as default in Pandora settings
- ▶ Work on CLIC specific weights has started
- ▶ Extending reweighing procedure to higher energies and densities
- ▶ Expecting improved JER for higher centre-of-mass energies
- ▶ More info → talk by A. Sailer (Wed.)



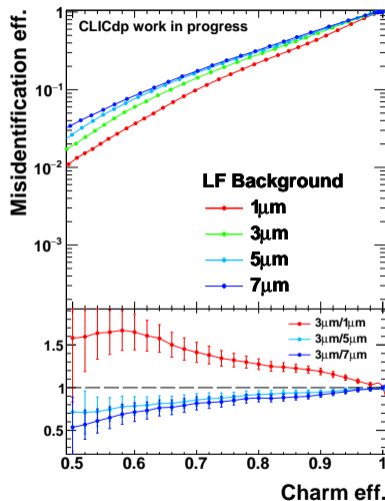
# Flavour Tagging Developments

- ▶ Using LCFIPlus
- ▶ Studying impact of vertex resolution only on flavour tagging
- ▶ Larger impact of single point resolution on c tagging efficiency compared to b tagging efficiency
- ▶ Achieving similar performance to CLIC\_SiD
- ▶ Strides with Conformal tracking and bkg. overlay underway
- ▶ More info → talk by E. Leogrande (Thur.)



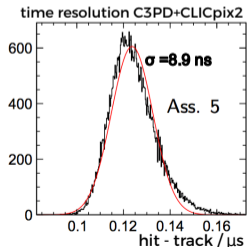
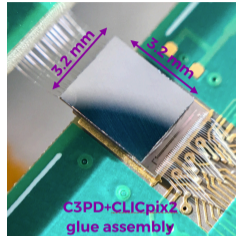
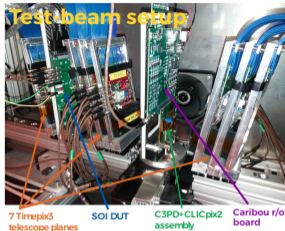
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# Vertex R&D

- ▶ Broad programme targeting CLIC vertex detector requirements:
  - ▶ Thin layers (50  $\mu\text{m}$  active silicon)
  - ▶ High spatial resolution ( $\sim 3 \mu\text{m} \sim 25 \times 25 \mu\text{m}^2$  pitch)
  - ▶ Precise timing ( $\sim 10 \text{ ns}$ )
- ▶ Recent achievements:
  - ▶ First lab + test-beam results for **C3PD+CLICpix2** hybrid HV-CMOS assemblies
  - ▶ **Caribou/Peary** universal DAQ system commissioned for CLICpix2 and C3PD
  - ▶ **Allpix<sup>2</sup>** Si detector sim. released
- ▶ More info  $\rightarrow$  **talk D. Dannheim (Tue.)**



# Tracker R&D

Integrated technologies offer possibility for large surface ( $100 \text{ m}^2$ ) trackers in view of large scale production and low material budget

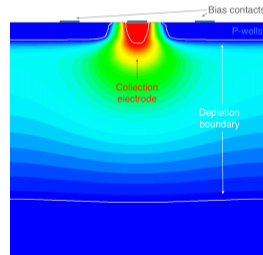
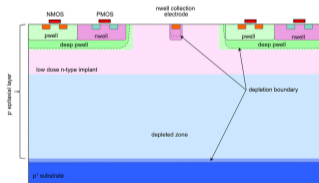
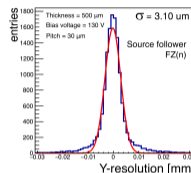
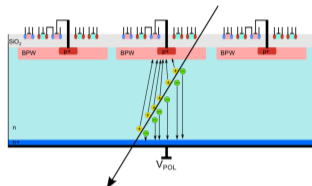
## ► Lapis: Si On Insulator

- CMOS on HR bulk, shielded by insulation
- High bias voltages applicable to bulk

## ► TowerJazz: HR-CMOS

- CMOS on HR epitaxial layer, shielded by deep P-wells
- fast timing, low analogue power consumption

## ► AMS: HV-CMOS



More info → **talk by M. Munker (Tue.)**

TCAD



# Documents for for next European Strategy

## Ingredients for a CLIC summary report

- ✓ Updated baseline for a staged Compact Linear Collider  
CERN yellow report CERN-2016-004
- ✓ Higgs Physics at the CLIC Electron-Positron Linear Collider  
Eur. Phys. J. C 77, 475 (2017)
- ✓ The New Optimised CLIC detector model CLICdet  
CLICdp-Note-2017-001
- 🕒 Performance of CLICdet Detector Model  
CLICdp-Note early 2018
- 🕒 An overview of CLIC Top Physics  
Complete draft before the end of 2017
- 🕒 Extended BSM studies  
Publication planned 2018
- 🕒 CLIC R&D report (main CLIC technology demonstrators)  
Summary publications 2018
- 🕒 Plan for period 2019-2025 if CLIC supported by next strategy

# Summary

- ▶ CLICdet detector model based on optimisation studies finalized
- ▶ Broad software effort to validate and characterise CLICdet and to develop new techniques
- ▶ Physics analyses in full swing; focused on top physics
- ▶ New working group **Physics Potential** targeting BSM
- ▶ Active R&D effort on Vertex and Tracker technologies as well as collaboration with FCal and CALICE
- ▶ Staged operation of CLIC offers an impressive energy frontier physics programme that reaches beyond the LHC. It is an excellent option for a post-LHC facility at CERN.