CLIC Detector & Physics Introduction

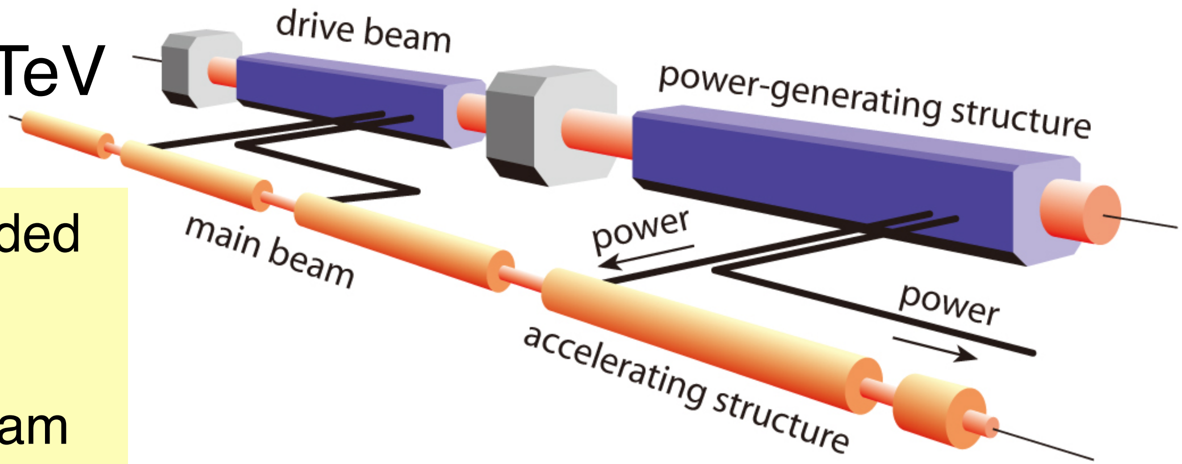
CLICdp BSM direct searches meeting, 21/2/18

Aidan Robson

- Introduction to the CLIC accelerator
- CLIC physics programme highlights
- Timeline and plans
- European Strategy for Particle Physics

Compact Linear Collider: CLIC

e^+e^- collider with $\sqrt{s}$ up to 3 TeV



100 MV/m accelerating gradient needed for compact (~50km) machine
Based on normal-conducting accelerating structures and a two-beam acceleration scheme

Drive beam

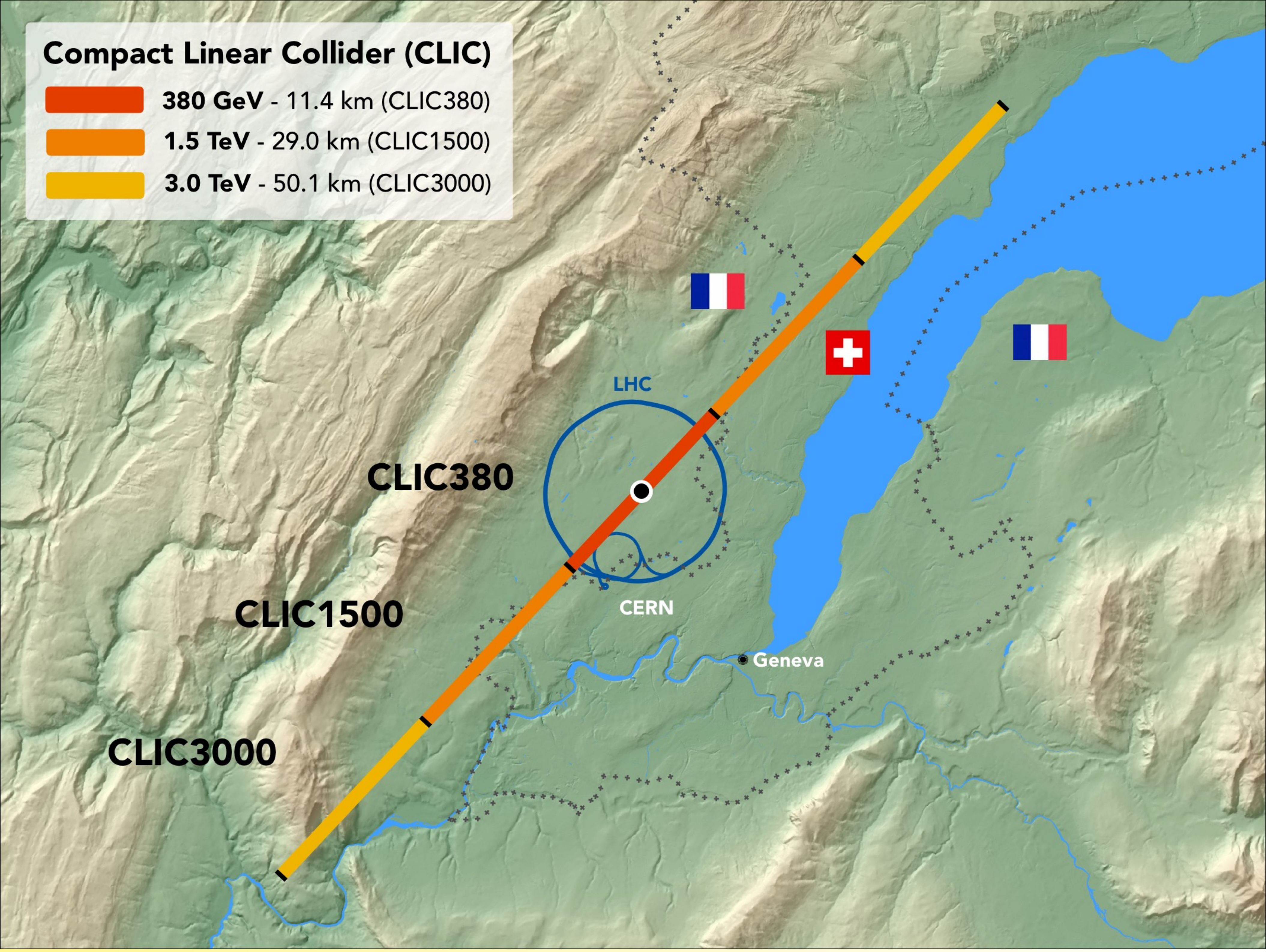
Main beam

CLIC foreseen as a staged machine:

- Stage 1 baseline: $\sqrt{s}$=380GeV: precision SM physics: Higgs and top

Energies of subsequent stages motivated by physics

- Stages 2 & 3 baseline: 1.5 TeV, 3 TeV



Compact Linear Collider (CLIC)
380 GeV - 11.4 km (CLIC380)
1.5 TeV - 29.0 km (CLIC1500)
3.0 TeV - 50.1 km (CLIC3000)
LHC
CLIC380
CLIC1500
CLIC3000
CERN
Geneva

CLIC collaborations

http://clic.cern/

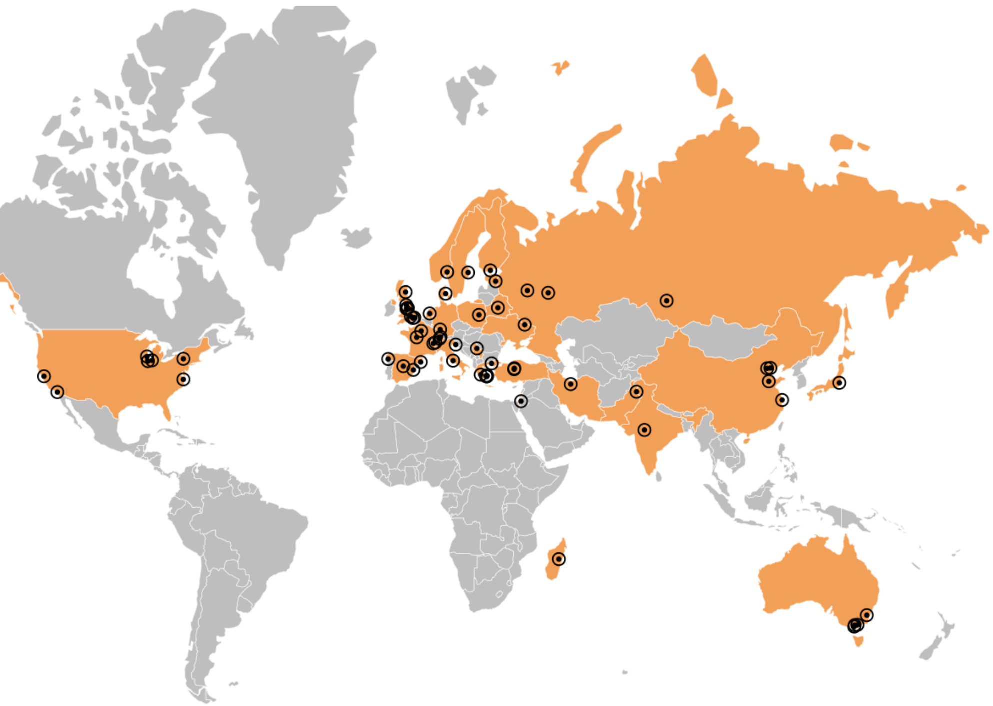
CLIC/CTF3 accelerator collaboration

>70 institutes from **31 countries**

http://clic-study.web.cern.ch/

CLIC accelerator studies:

- CLIC accelerator design & development
- Construction and operation of CTF3



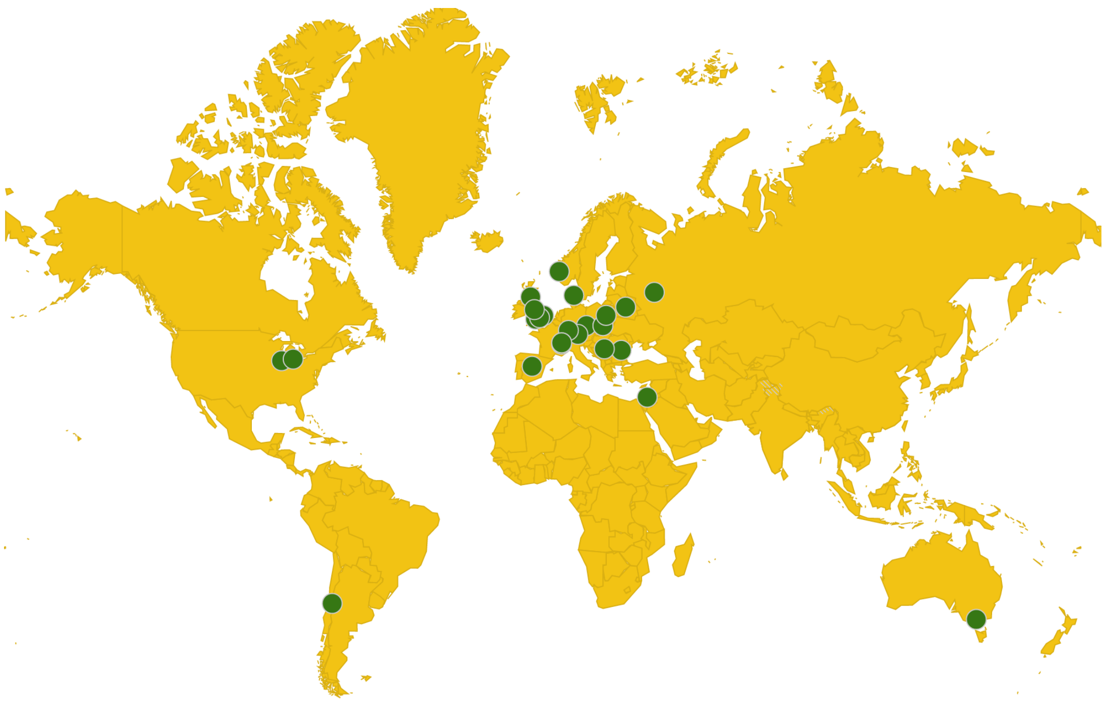
CLIC detector and physics (CLICdp)

30 institutes from **18 countries**

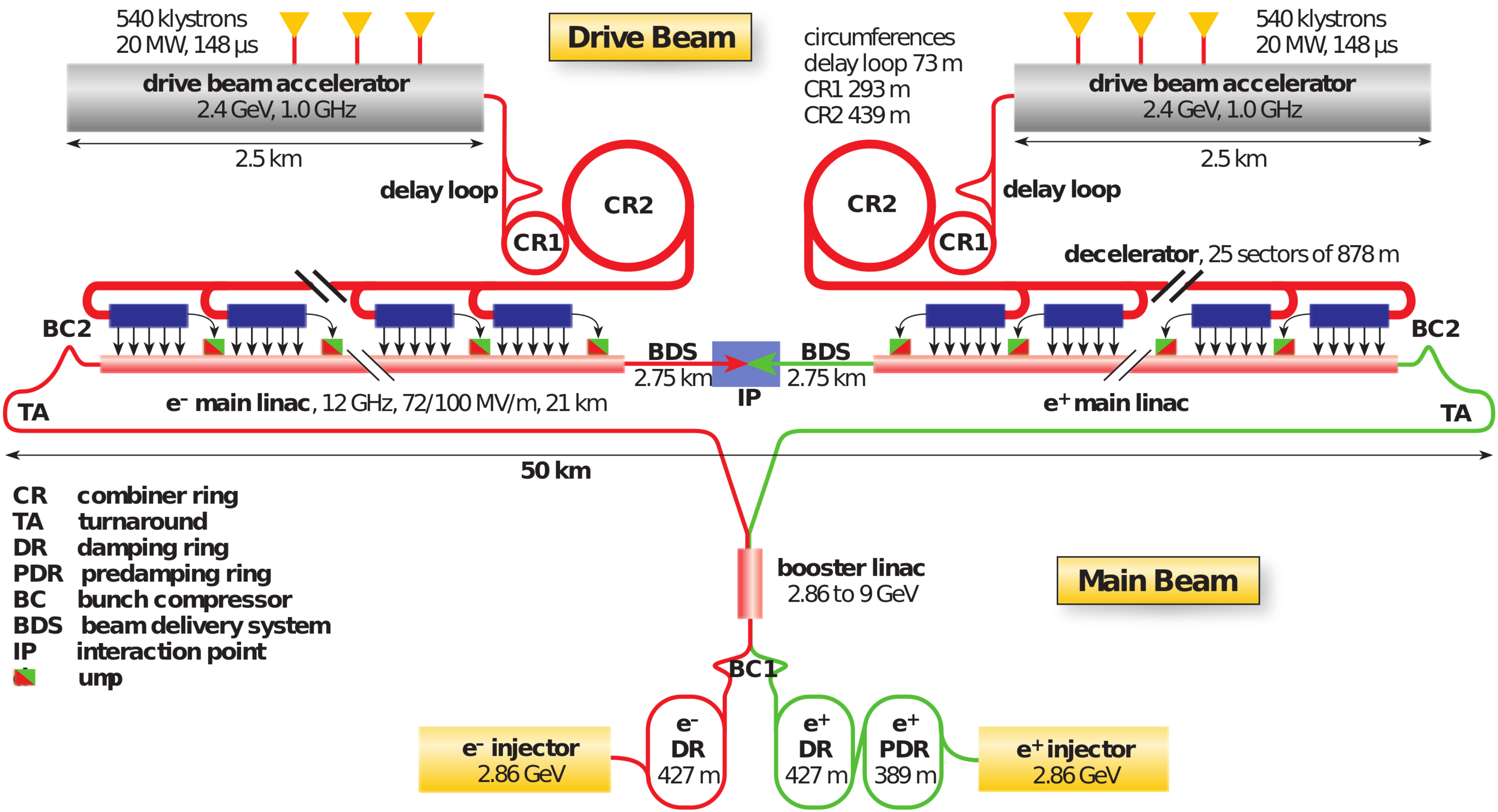
http://clicdp.web.cern.ch/

Focus of CLIC-specific studies on:

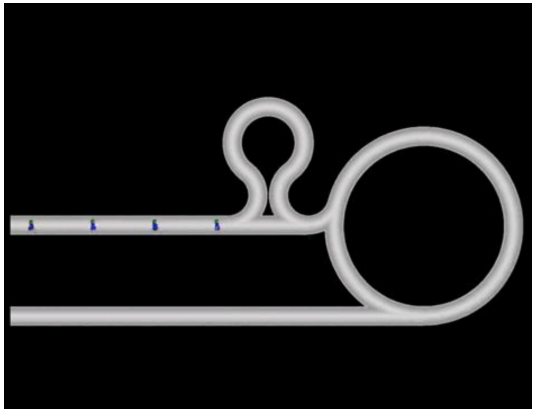
- Physics prospects & simulation studies
- Detector optimization + R&D for CLIC



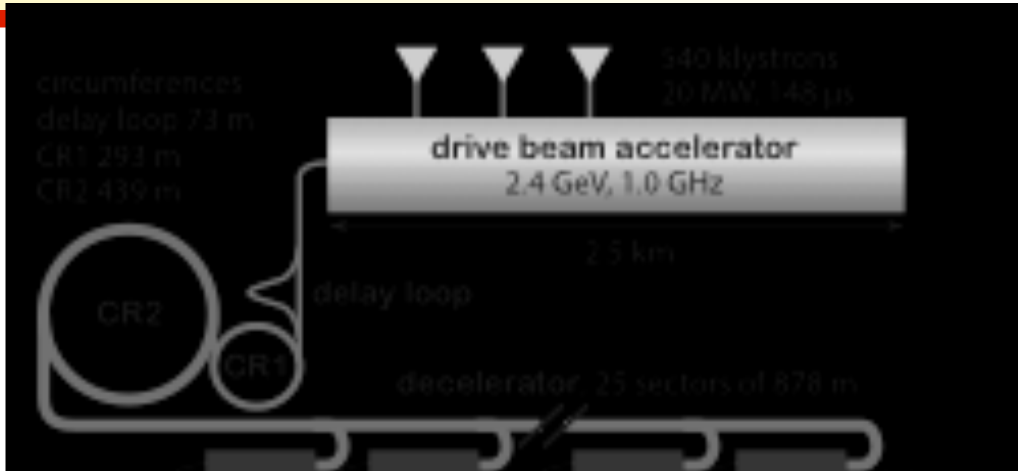
CLIC Layout 3 TeV

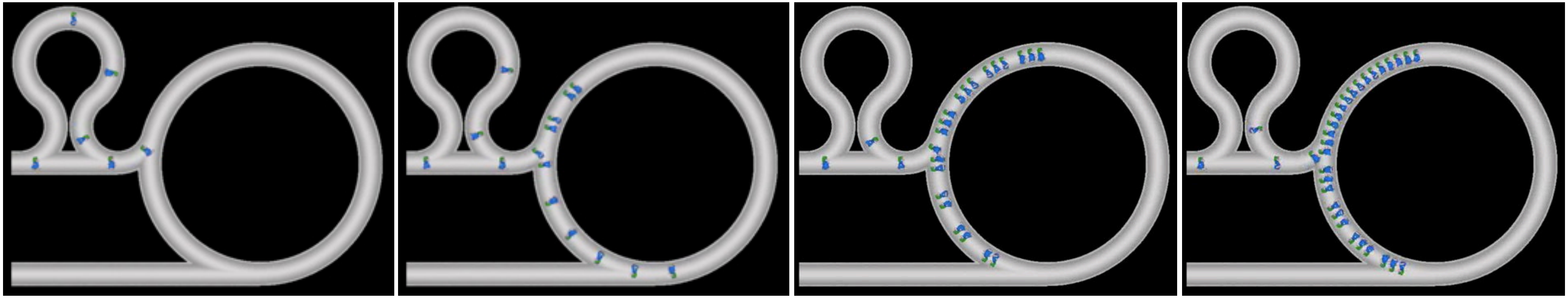


Machine context



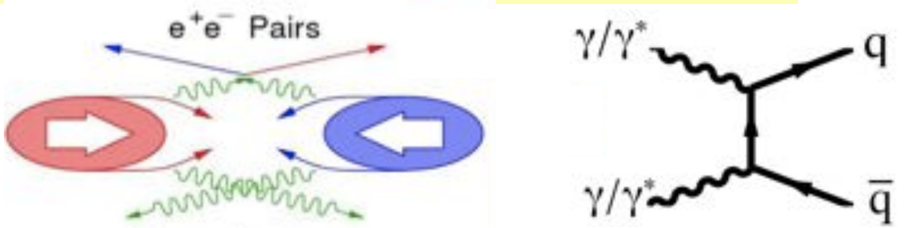
Delay loops create drive beam bunch-structure





Low energy high current drive beam -> high energy low current main beam

CTF3 test facility at CERN has demonstrated drive beam generation and two-beam acceleration scheme (up to 135MV/m measured)

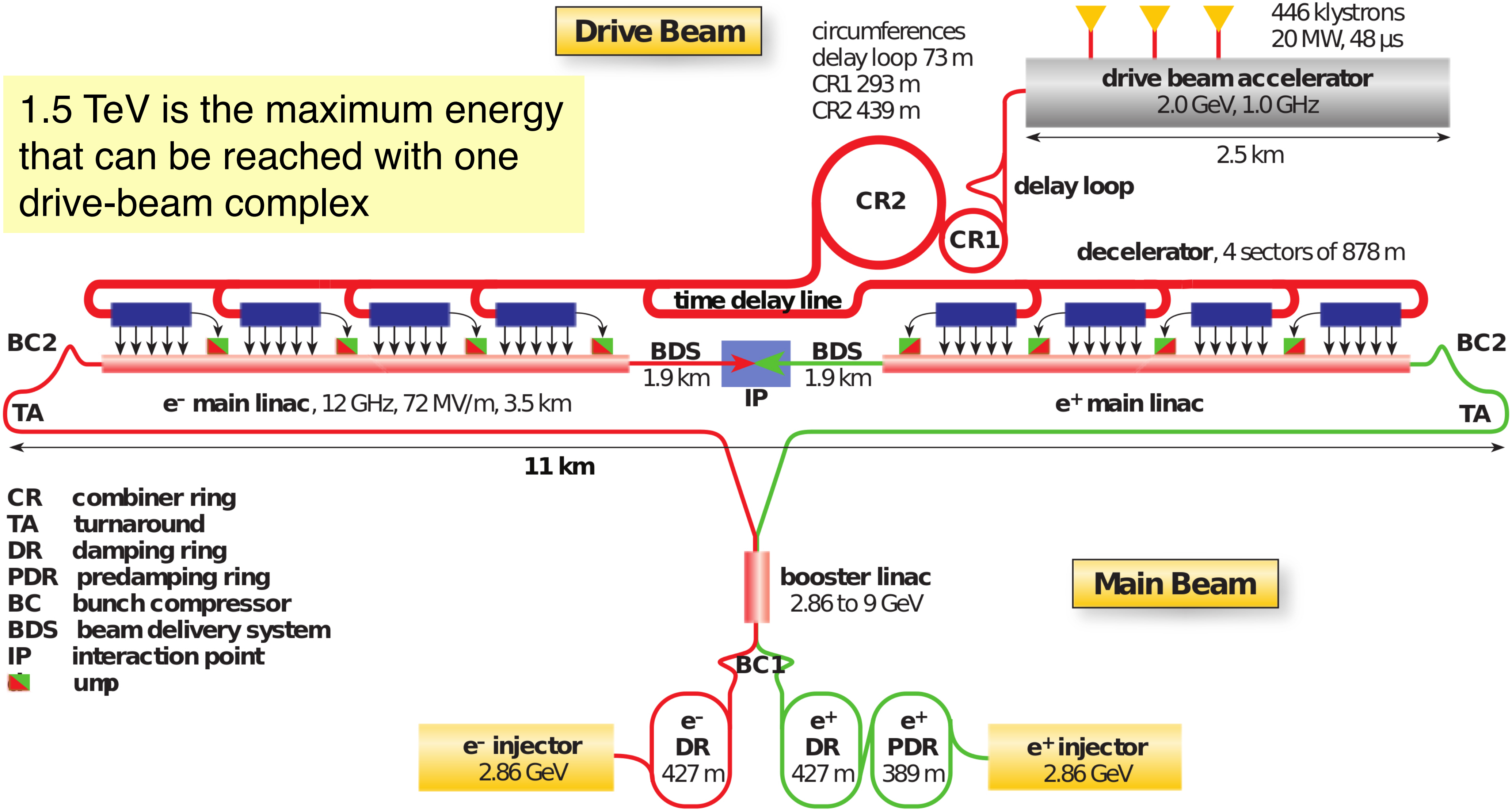


High bunch-charge density –> beamstrahlung

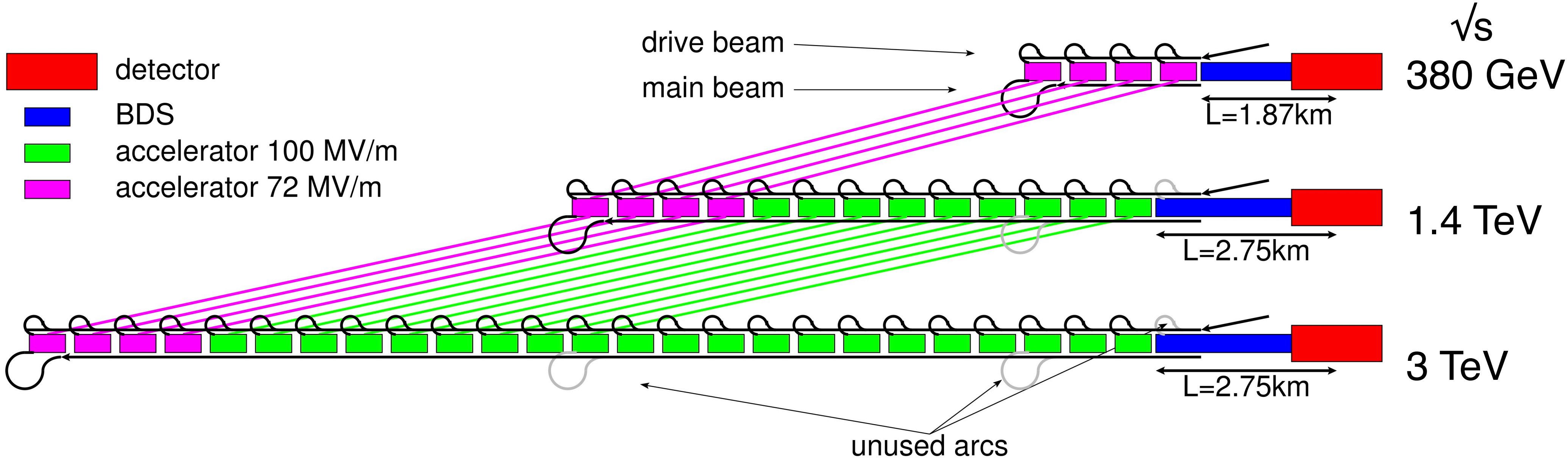
Incoherent e^+e^- pairs and $\gamma\gamma$–>hadrons

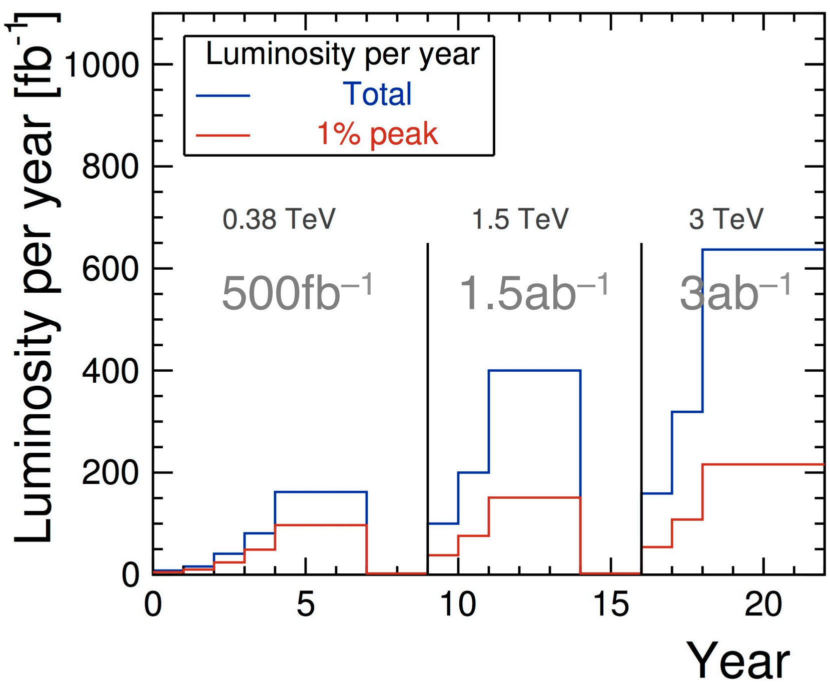
CLIC Layout 380 GeV

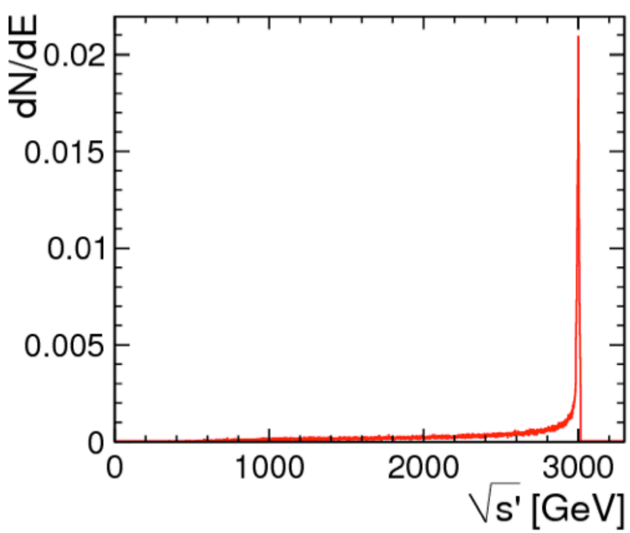
1.5 TeV is the maximum energy that can be reached with one drive-beam complex



CLIC staging



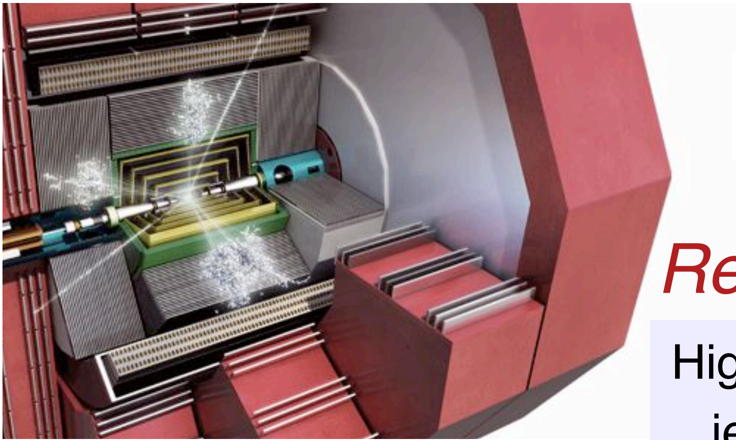


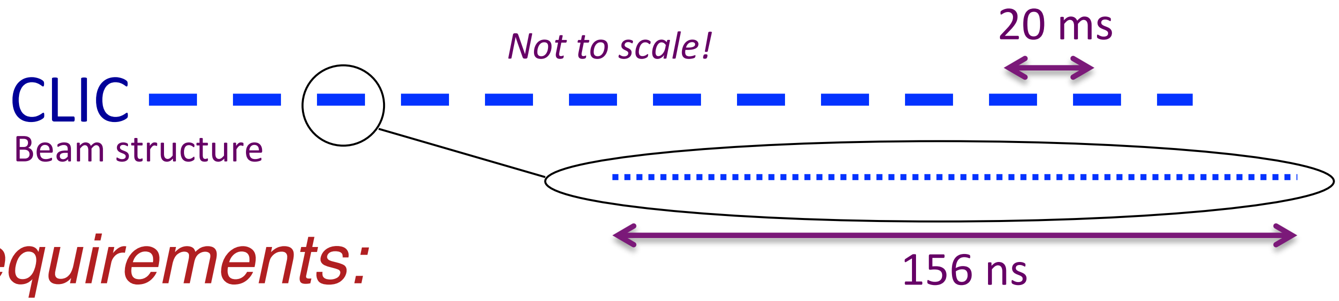


- Luminosity spectrum at $\sqrt{s}$=3TeV

- Polarization: up to ±80% electron polarization; positron polarization a possible upgrade.

CLIC detector and physics



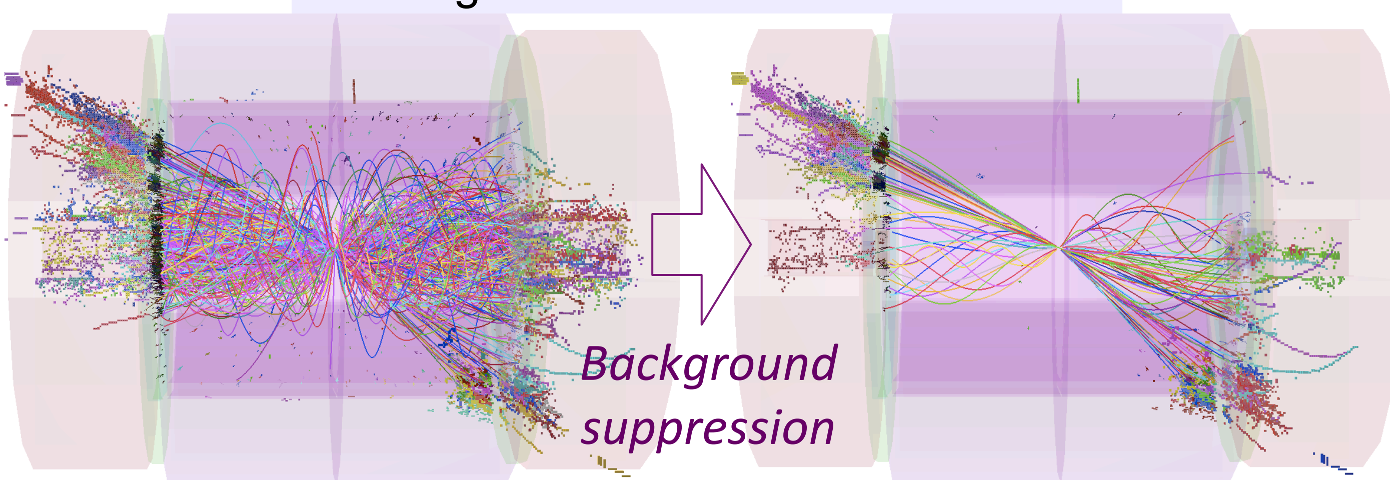


Requirements:

High precision:

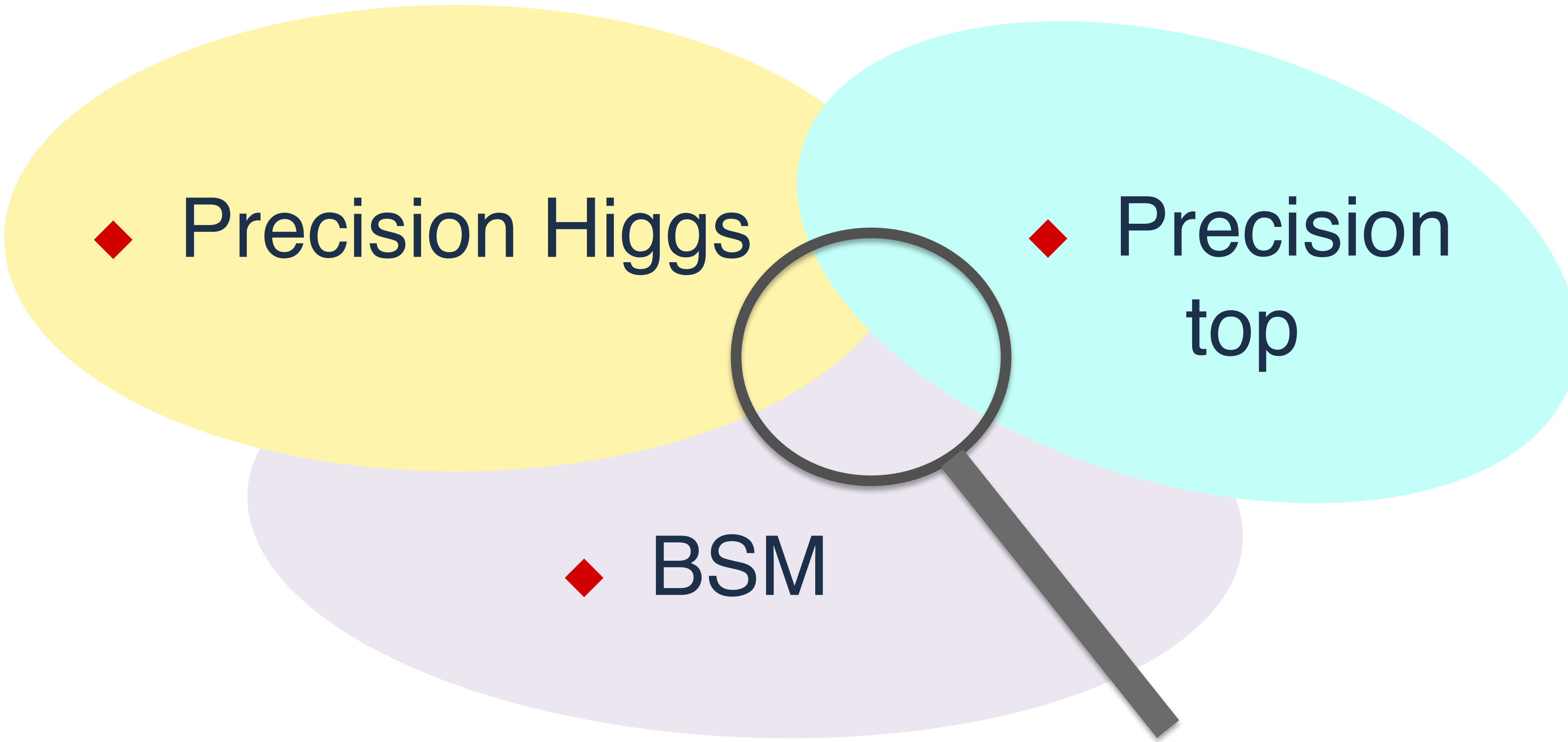
- jet energy resolution
  –> fine-grained calorimetry
- momentum resolution
- impact parameter resolution
- timing resolution

See dedicated talk by Emilia Leogrande today



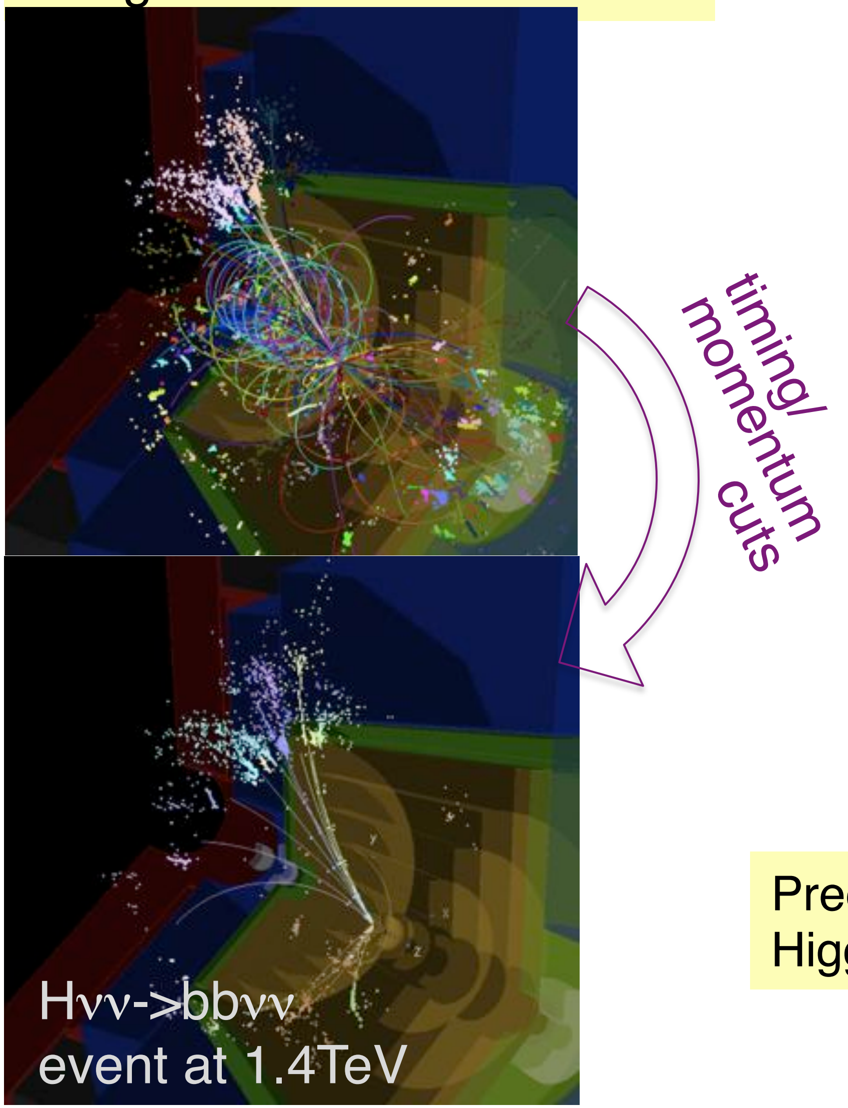
- CLICdp working towards demonstrators for the main technical challenges

Physics motivations

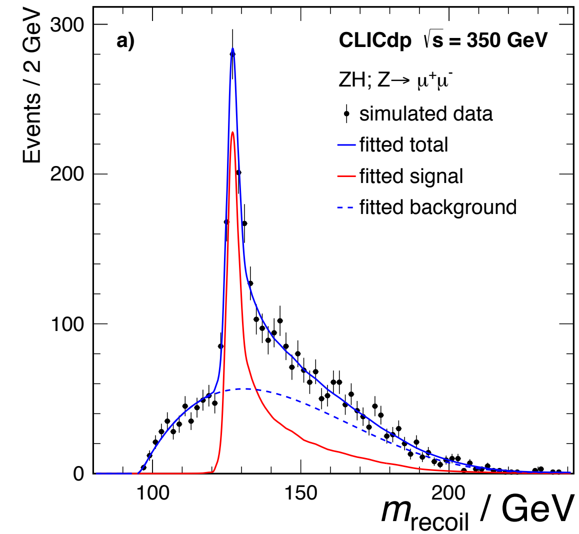


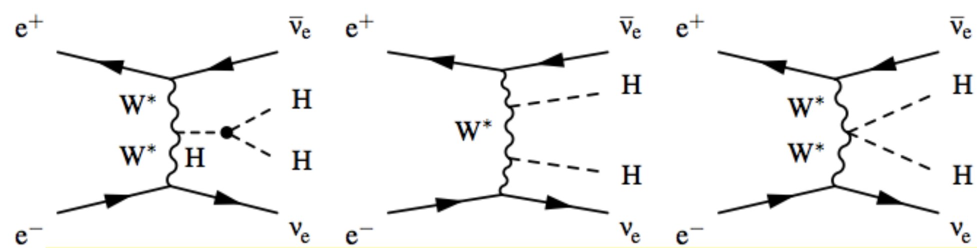
Higgs highlights in e^+e^-

Separation of bb/cc/gg final state possible in e+e–, using excellent detector



Model-independent Higgs coupling measurements from recoil mass





Access to Higgs self-coupling g_{HHH} at 3 TeV; simultaneous extraction with g_{HHWW}

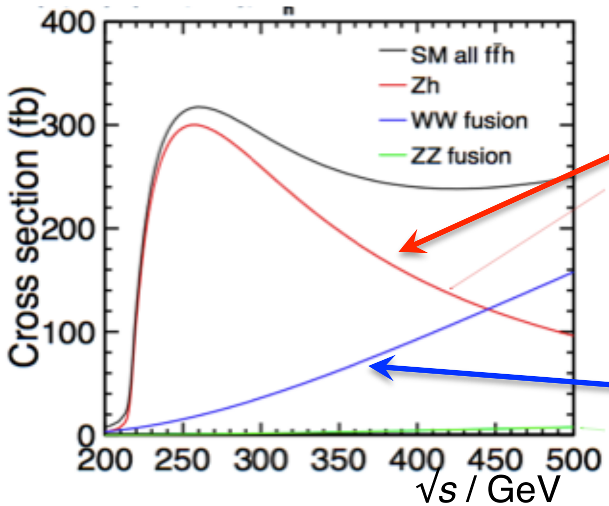
Precision Higgs mass

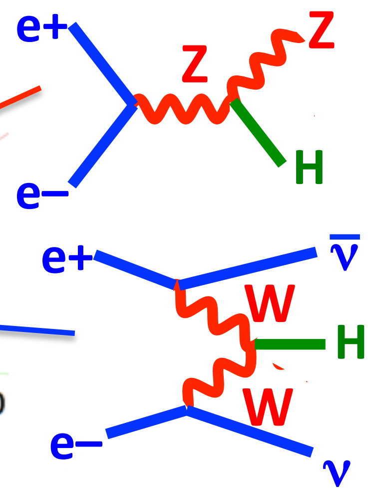
Dataset	Δ*m*H unpolarised	Δ*m*H p(e–)
1.4 TeV	47 MeV	35 MeV
3 TeV	44 MeV	33 MeV
1.4 + 3 TeV	32 MeV	**24 MeV**

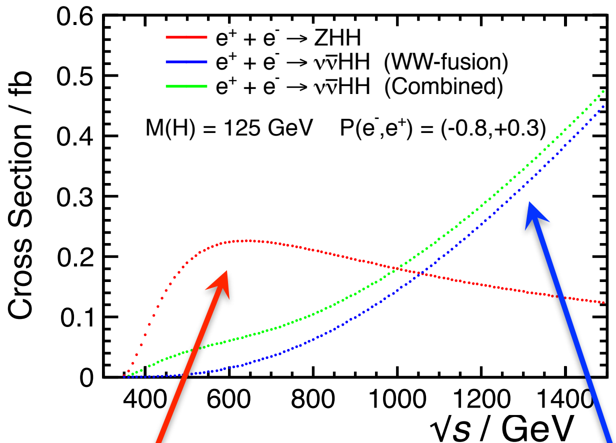
HL-LHC projection: Δm_H = 50 MeV

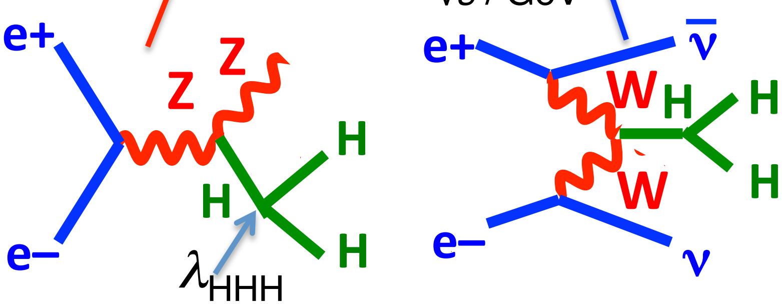
arXiv:1310.8361

Higgs highlights

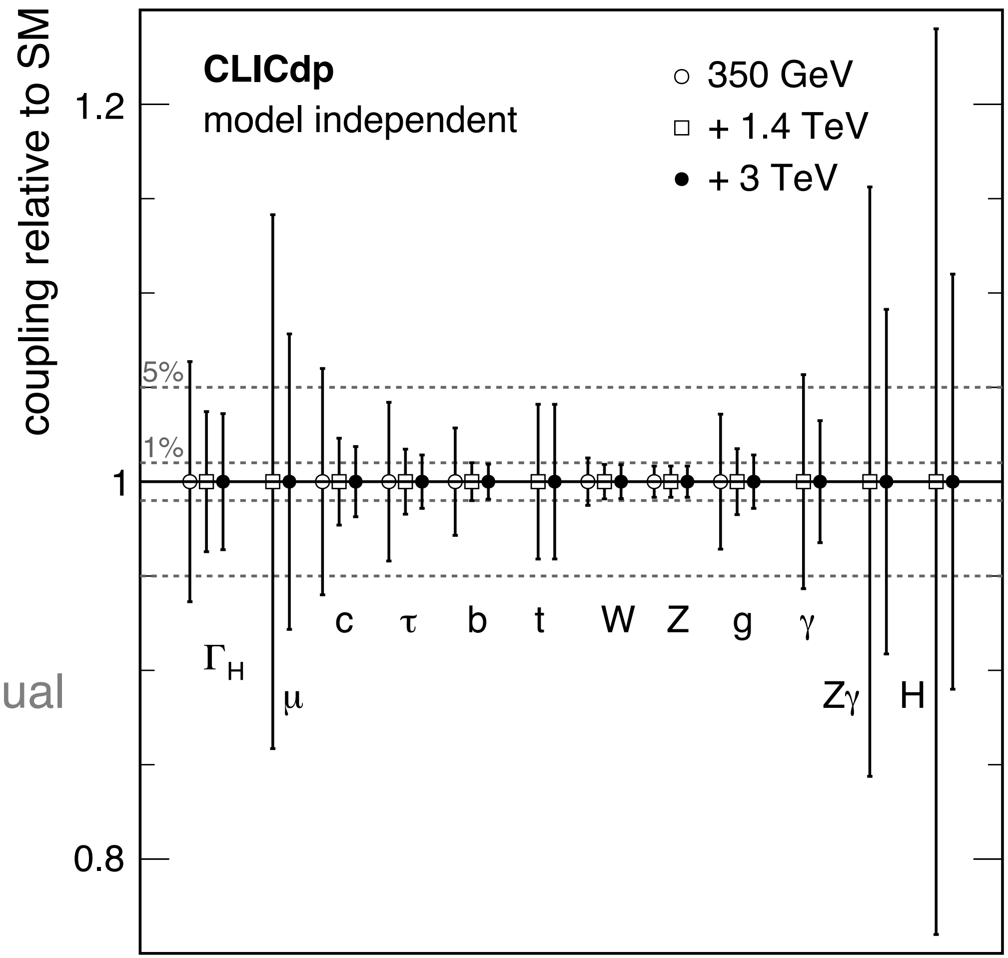






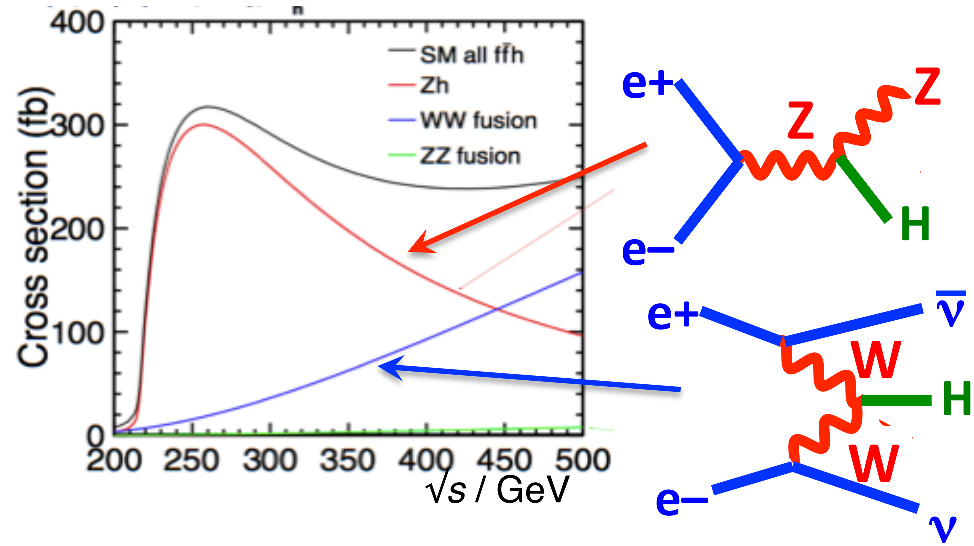


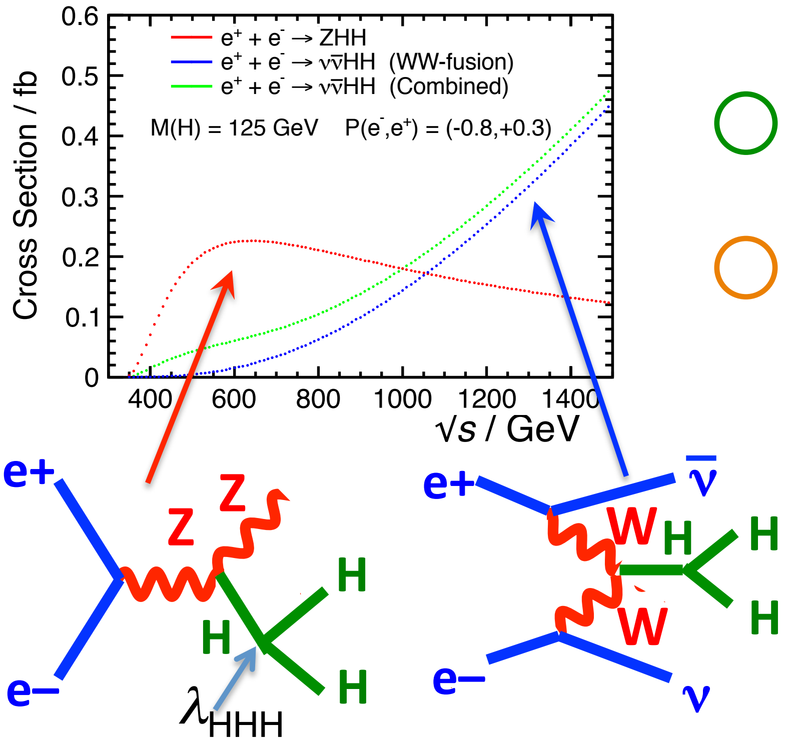
~20 individual analyses

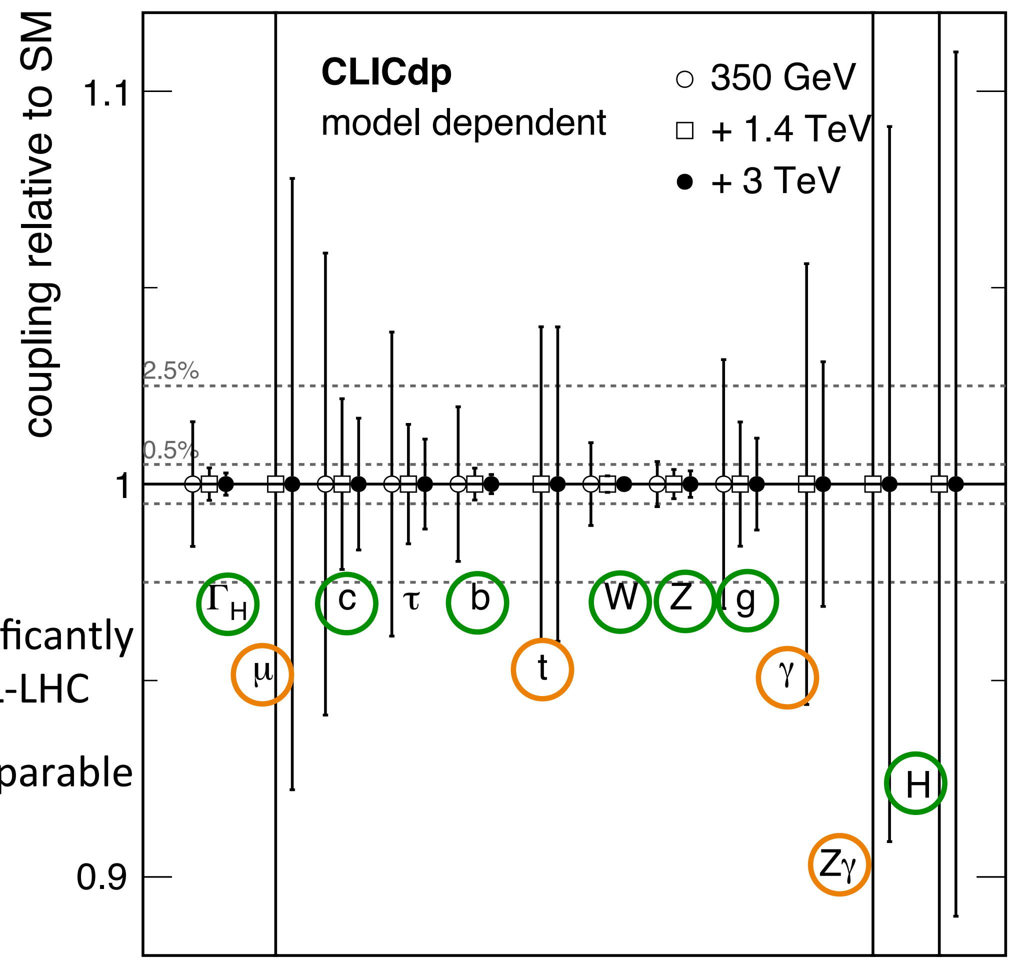


Each stage contributes significantly:
first stage provides crucial model-independent Z coupling measurement, and couplings to most fermions and bosons; higher stages improve them, and add t, μ, γ couplings

Higgs highlights







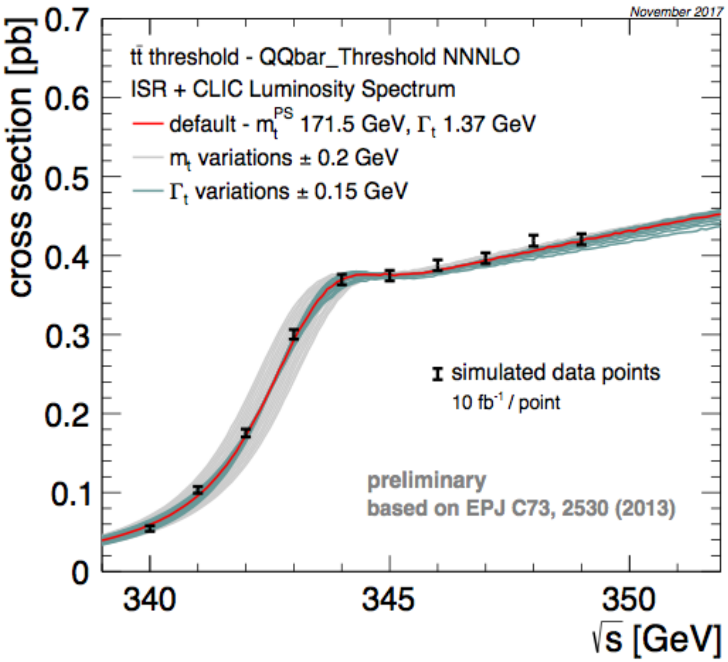
Precision significantly better than HL-LHC

Precision comparable with HL-LHC

'model-dependent' assumes fractional shift in κ is equal for u,c,t ; for d,s,b ; and for e,μ,τ ; and no Higgs decay to invisible/exotic particles

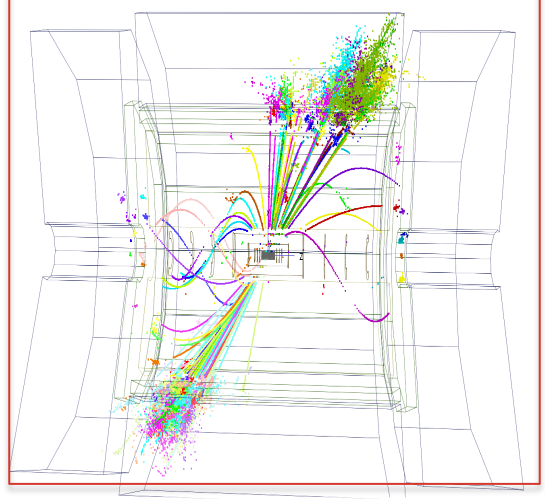
Eur. Phys. J. C **77**, 475 (2017)

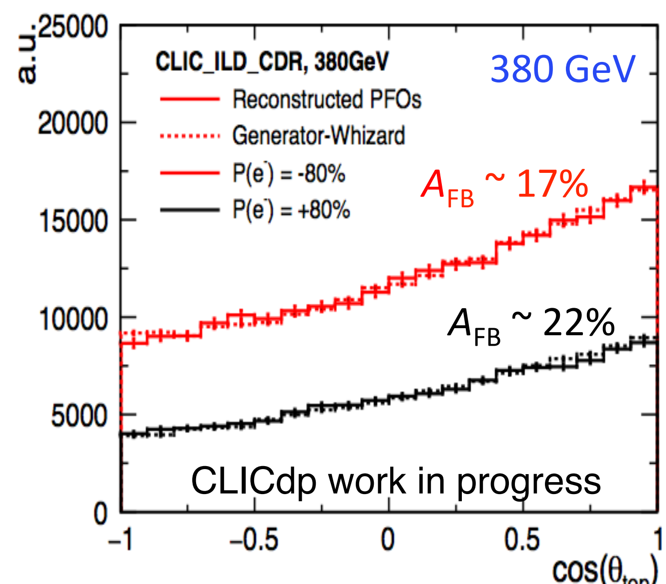
Top physics highlights



- Intending threshold scan around 350 GeV (10 points, ~1 year) as well as main stage 1 baseline √s=380GeV
- sensitive to top mass, width and couplings
- observe 1S 'bound state' $\Delta m_t \sim$ 50–75 MeV

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





- FCNC decays
- couplings to Z and γ
- cross-section and A_{FB}
  -> resolved, semi-resolved, and boosted
- combined EFT interpretation

BSM physics highlights

→ over to you!

Timeline

2013 - 2019 Development Phase

Development of a Project Plan for a staged CLIC implementation in line with LHC results; technical developments with industry, performance studies for accelerator parts and systems, detector technology demonstrators

2020 - 2025 Preparation Phase

Finalisation of implementation parameters, preparation for industrial procurement, Drive Beam Facility and other system verifications, Technical Proposal of the experiment, site authorisation

2026 - 2034 Construction Phase

Construction of the first CLIC accelerator stage compatible with implementation of further stages; construction of the experiment; hardware commissioning

2019 - 2020 Decisions

Update of the European Strategy for Particle Physics; decision towards a next CERN project at the energy frontier (e.g. CLIC, FCC)

2025 Construction Start

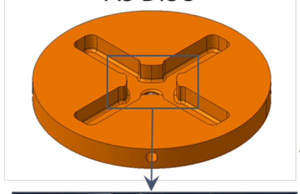
Ready for construction; start of excavations

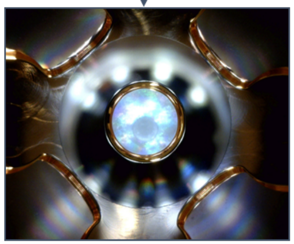
2035 First Beams

Getting ready for data taking by the time the LHC programme reaches completion

Industrialization

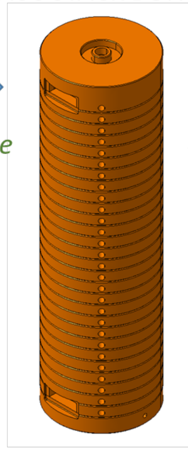
AS DISC





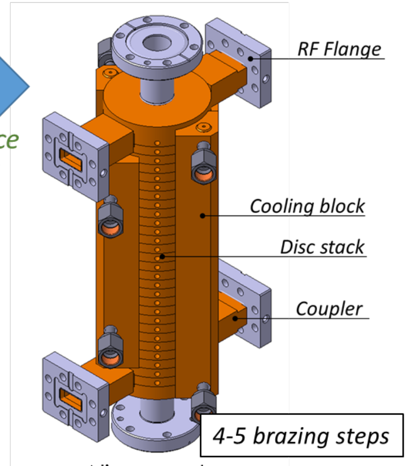
Acceptance at CERN

AS DISC STACK BONDING



Acceptance at CERN

AS ASSEMBLY



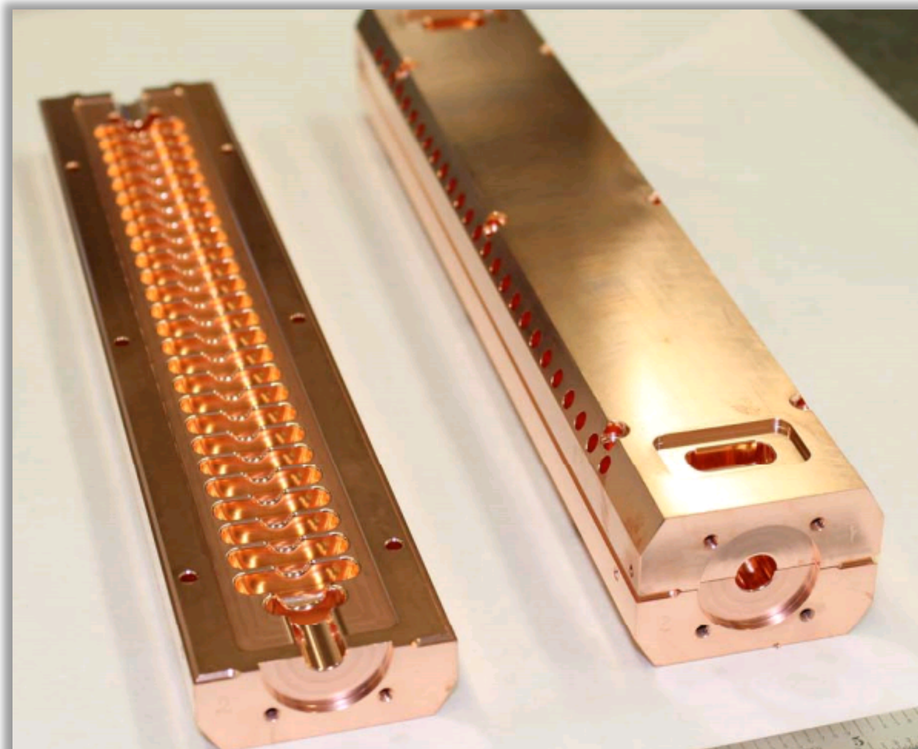
Cell shape accuracy - 0.004 mm
Flatness - 0.001 mm
Surface roughness - Ra 0.025 µm

REQUIREMENTS:
- Alignment
- Special tooling
- Clean environment

Commercial suppliers:
- 4 qualified companies for UP machining;
- Single-crystal diamond tool required.

Suppliers:
- 3 qualified companies for brazing/bonding operations, supervision by CERN;
- Collaborators.

Towards industrialization of the accelerator components



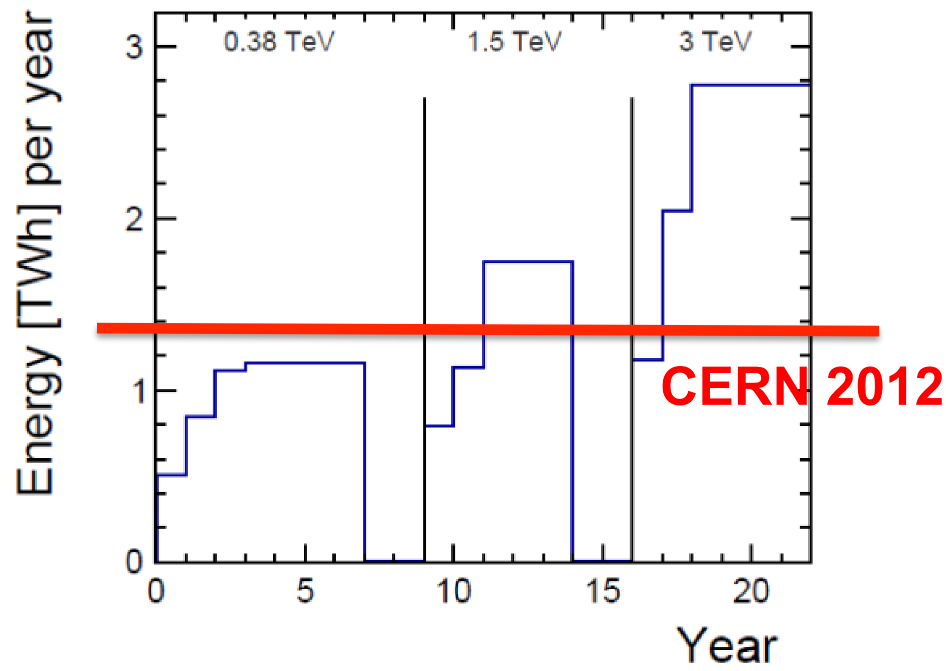
Encouraging other uses of CLIC accelerator technology:
SwissFEL, CompactLight

Cost and power

AC Power

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

-> working on optimization and power reduction

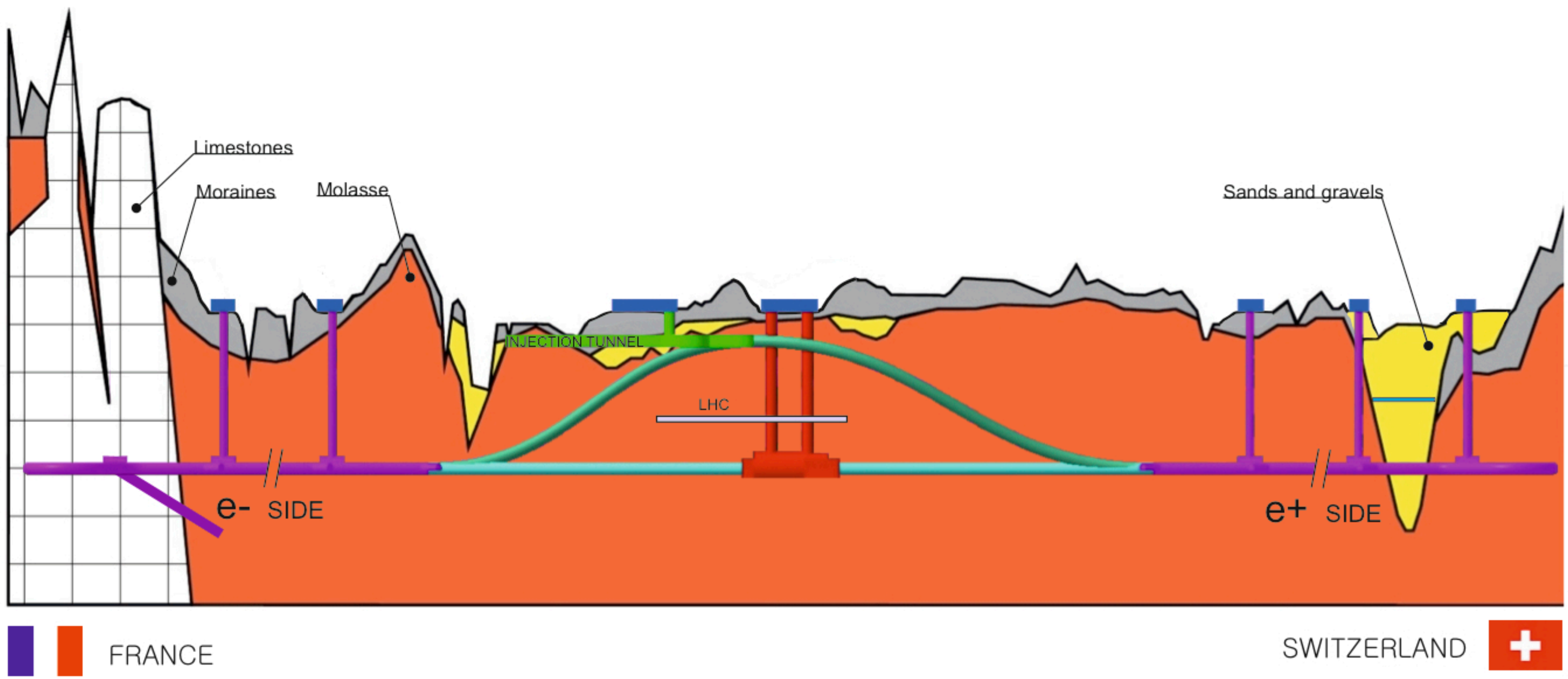


Preliminary cost estimate (380GeV)

Table 11: Value estimate of CLIC at 380 GeV centre-of-mass energy.

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

Civil engineering implementation



European Strategy Update (ESU) planning

The ESU is crucial for determining the future activities of CLIC

The formal submission is due mid-December 2018
-> the input material needs to be in good shape by the summer

CLICdp reports serving as ingredients for a CLIC summary report:

- Updated Baseline for a Staged Compact Linear Collider (380 GeV, 1.5 TeV, 3 TeV) ✔
  - arXiv:1608.07537, CERN-2016-004
- Higgs Physics at the CLIC Electron-Positron Linear Collider ✔
  - arXiv:1608.07538, Eur. Phys. J. C77 (2017) no.7, 475
- The new optimised CLIC detector model CLICdet ✔✔
  - CLICdp note CLICdp-Note-2017-001 Detector description note done
    Detector performance note in progress
- An overview of CLIC top physics
  - CLIC top physics publication => complete draft **is prepared**
- Extended BSM studies (hopefully also motivated by LHC discoveries)
  - CLIC BSM overview publication in 2018
- CLIC R&D report => with main CLIC technology demonstrators
  - Summary publication(s) in 2018
- Plan for the period ~2019-2025 in case CLIC would be supported by next strategy

BSM Report

Aiming for CERN Yellow Report open to (selected) community contributions

2 The Standard Model EFT (Francesco)

2.1 The EFT Framework

2.2 Higgs and Gauge

- Summary of Higgs results (with new H trilinear)
- Drell–Yan (revised analysis from **Andrea&Jorge**)
- Dibosons (improved analysis from **Francesco&Philipp&al**)
- WW>HH? WW>WW? (existing papers)
- BSM interpretation (general Universal, Composite Higgs) (**Oleksii&Gauthier**)

2.3 Top

- ttH (from top report)
- Top Pair Production (existing papers
- WW>tt (**Andrea&Christophe&Tev**
- BSM interpretation (general Top-phi

3 Direct Searches (Michael and Roberto)

3.1 EWSB

- Closing SUSY Holes: Summary of previous studies Compressed spectra
- Extra Scalars (in progress **Sala, Tesi, Redigolo, Buttazzo**)
- SUSY limits from loops
- Extended Higgs Sectors (**Santos**)
- Discovering Naturalness: scenarios that can be truly first seen at CLIC and/or that can be established. (existing literature, plus **Reece, Fan**)

3.2 Dark Matter

- Neutralino DM
- Co-annihilation scenarios (**Plascencia, Sakurai**)
- Minimal (milli-charged) DM
- Non-WIMP scenarios

3.3 New Neutrinos and see-saw mediators

- Gauge-Charged see-saw mediators (**Ghezzi, Prun**
- Singlet see-saw mediators

3.4 EW Baryogenesis (J. M. No)

4 Flavour Phyics

4.1 FCNC

- Direct probes by high-energy q q? (including top), maybe also mu-tau, e-tau
- Exotic top decays and interplay with the above

4.2 BSM impact of Light quark Yukawa determination

4.3 LFUV anomaly

Draft structure from Andrea's summary at CLIC Workshop – superseded by now!

CLICdp Advisory Board

As an extra step in our preparations, CLICdp Advisory Board will meet 17–18 April at CERN

-> a ‘sounding board’ for CLIC ESU preparation

Name	Institute
Dave Charlton (chair)	Univ. Birmingham
Juan ALCARAZ MAESTRE	CIEMAT, Madrid
Freya BLEKMAN	Vrije Univ. Brussels
Keisuke FUJII	KEK
Christophe GROJEAN	DESY
Matthew McCullough	CERN
Sven MENKE	MPI Munich
Roger RUSACK	Univ. Minnesota, Minneapolis
Peter SCHLEPER	Univ. Hamburg
Joao VARELA	LIP and Univ. Lisbon
Vincenzo VAGNONI	Bologna Univ. and INFN
Pippa WELLS	CERN

Give feedback and recommendations on ongoing activities and ESU presentation

Focus on CLIC detector & physics (but will inform on status of CLIC accelerator)

Stronger focus on the physics than on the detectors/technology

We are relying on your studies to show where CLIC could give unique/ best sensitivity, to make the best possible case for the machine!

Thank you!