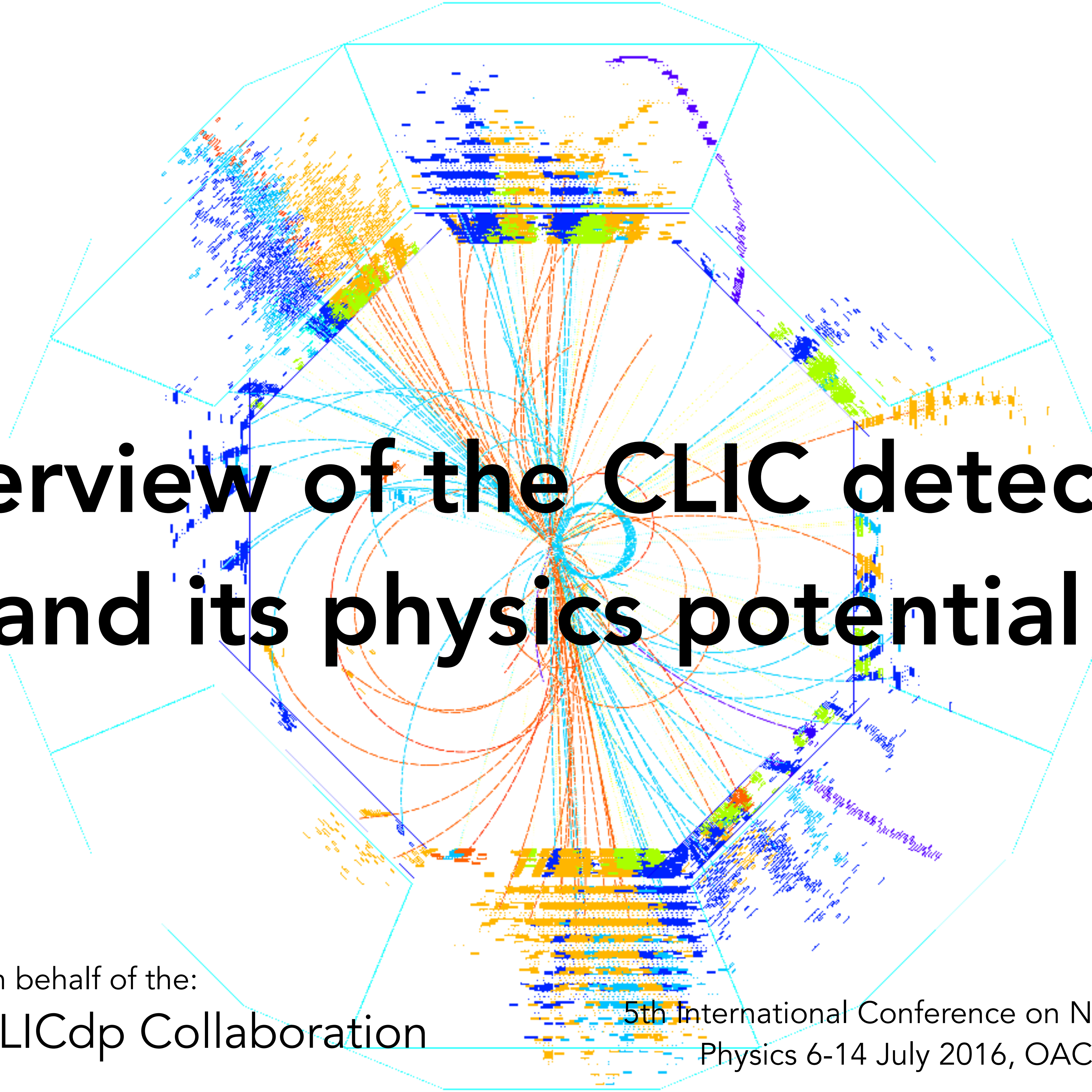


Overview of the CLIC detector and its physics potential

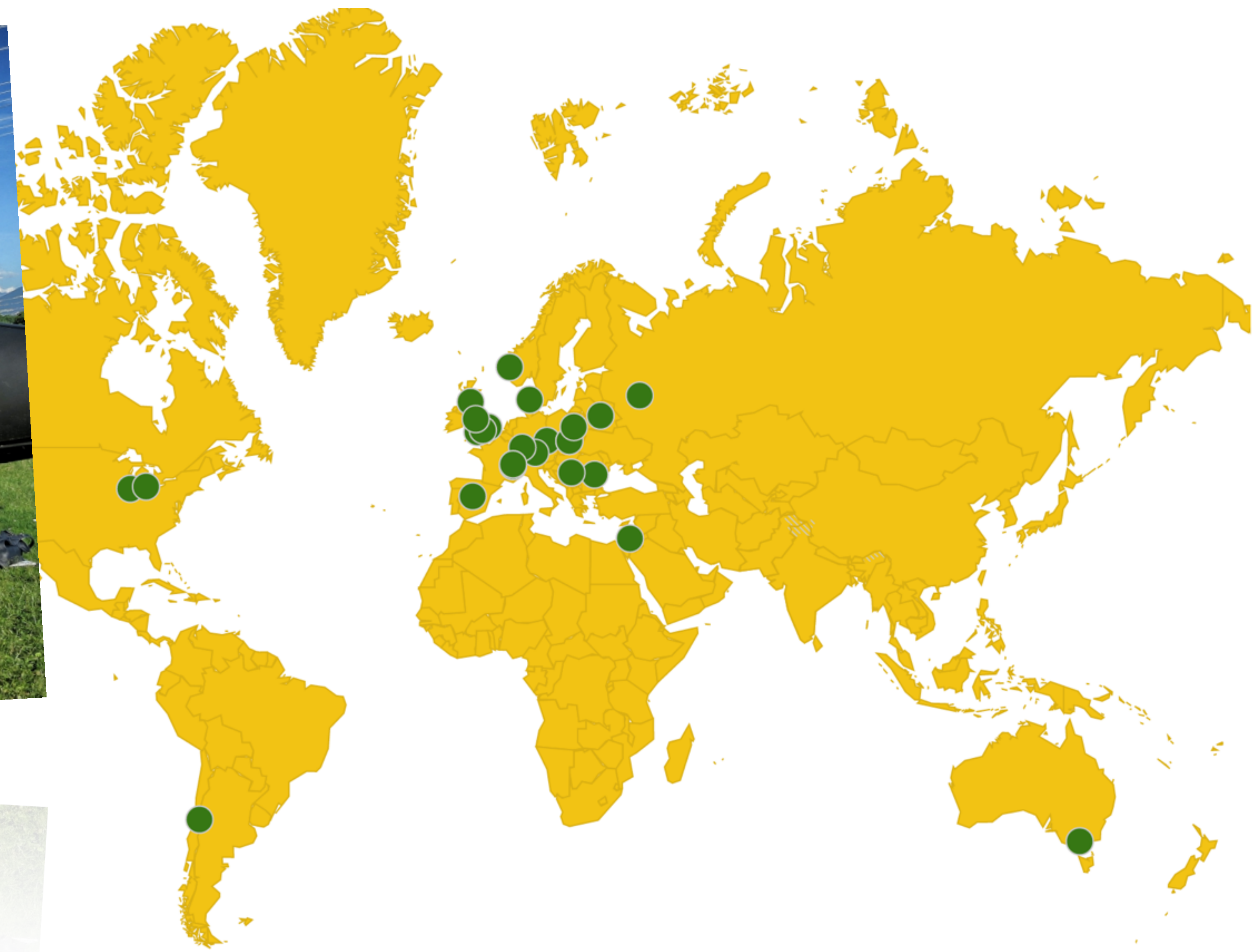
On behalf of the:

CLICdp Collaboration

Rickard Ström

5th International Conference on New Frontiers in Physics 6-14 July 2016, OAC Crete, Greece

CLICdp Collaboration



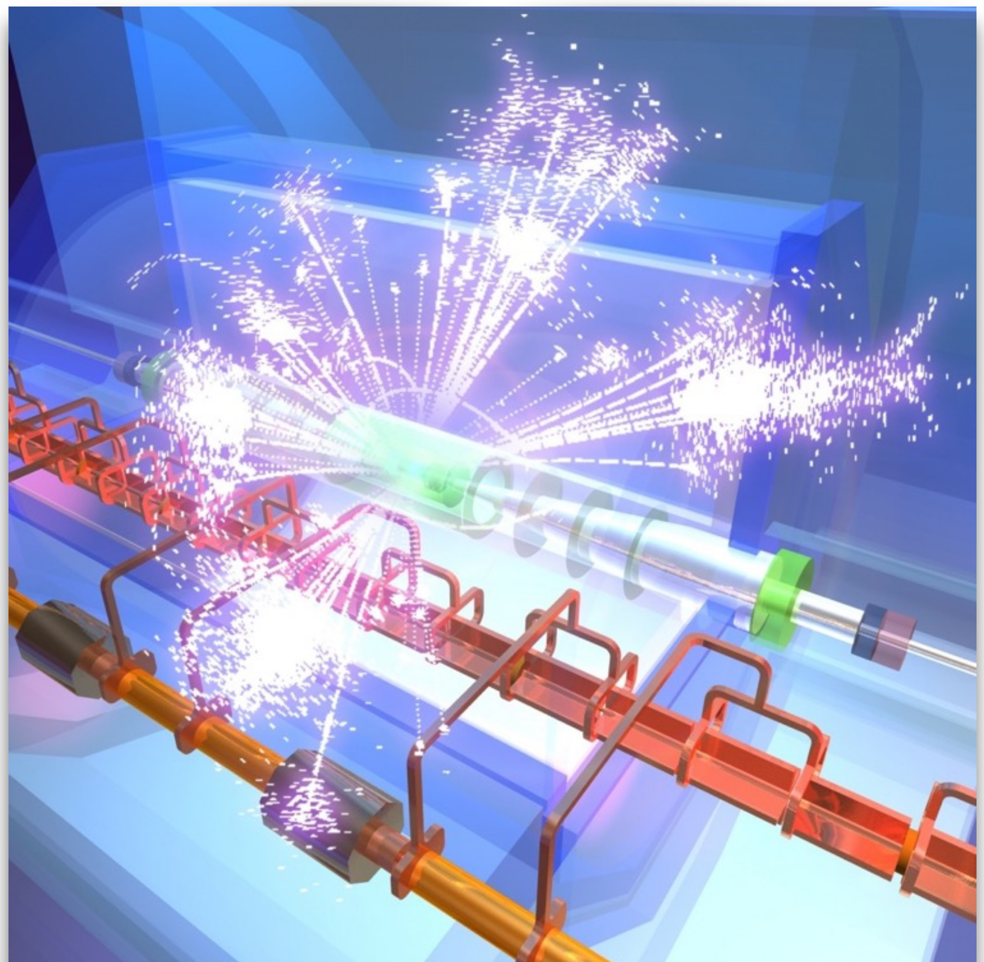
27 institutes from 17 countries!

Focus of CLIC-specific studies:

- Physics prospects and simulation studies
- Detector optimisation + R&D for CLIC detector

http://clicdp.web.cern.ch

Outline



- Introduction to the CLIC accelerator*
- Detector requirements
- CLIC detector overview
- Physics program
  - Higgs, top, BSM
- Conclusions & Summary

***See talk 'Status and plans of the Compact Linear Collider project' by Tobias Persson, Monday 11 July (17:45-18:05)**

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CLIC - Compact Linear Collider - e^+e^-

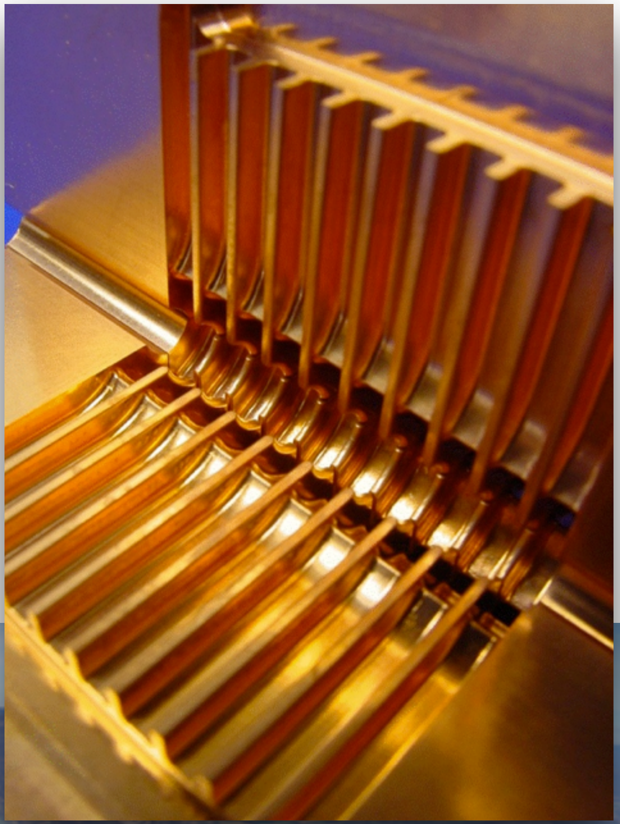
Why do we need an e^+e^- collider after HL-LHC?

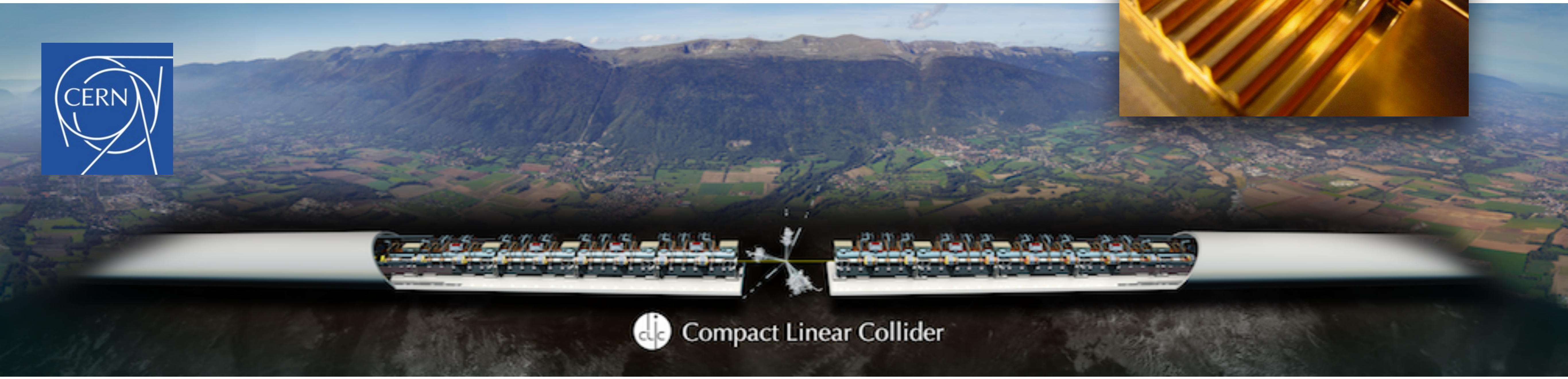
- Precision top and Higgs physics, **deviations from SM**
- Search for new physics, unique sensitivity to electroweak particles

CLIC - Linear e^+e^- Collider @ CERN

- Novel two-beam acceleration scheme
- Provides e^+e^- collision up to 3 TeV
- Rich physics program over ~ 20 years

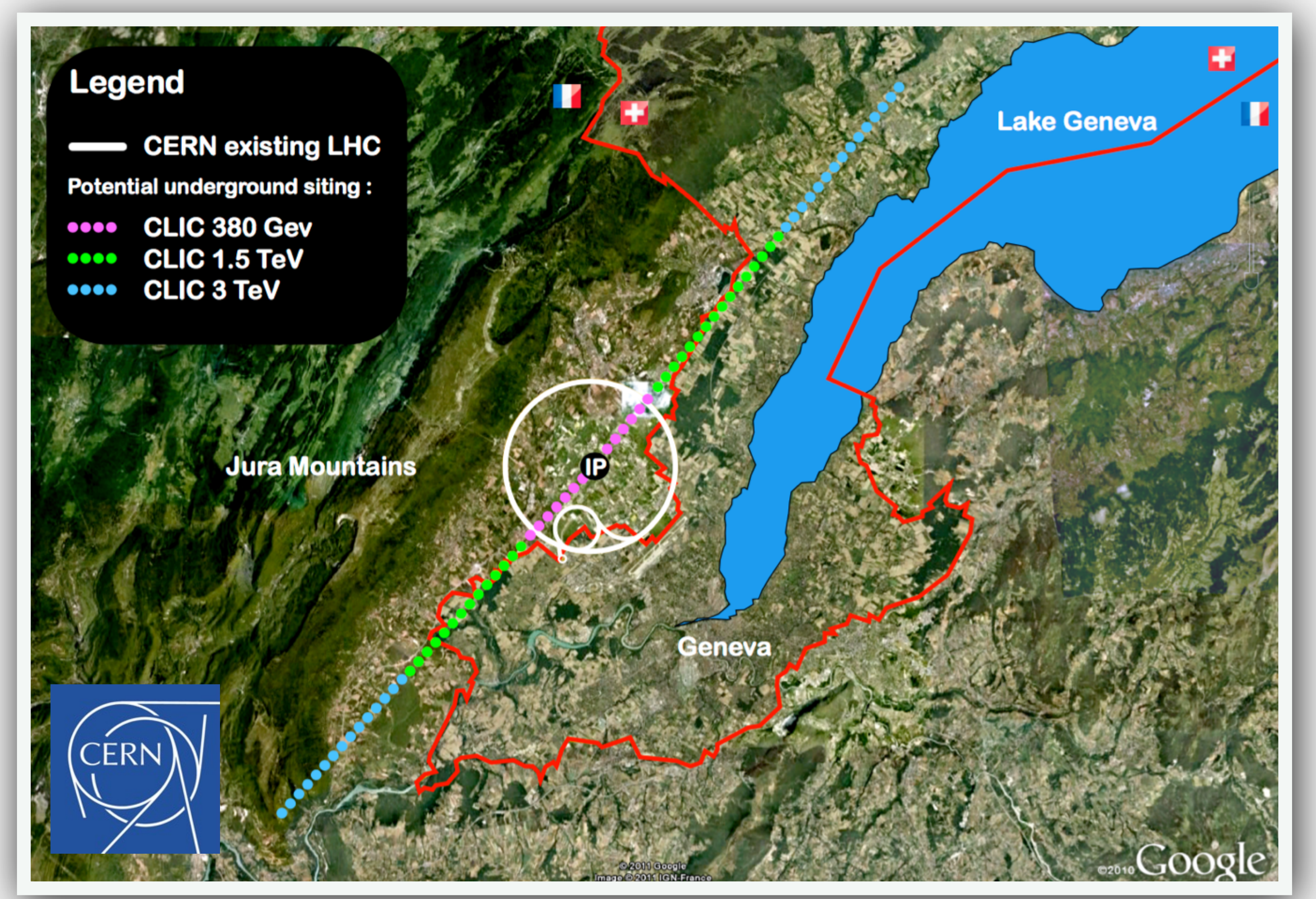
CLIC accelerating structure
L~20 cm





CLIC - Compact Linear Collider - e^+e^-

CLIC footprints near CERN, showing a possible construction scenario



Centre-of-mass energy	Main tunnel length
380 GeV	11.4 km
1.5 TeV	29.0 km
3.0 TeV	50.1 km

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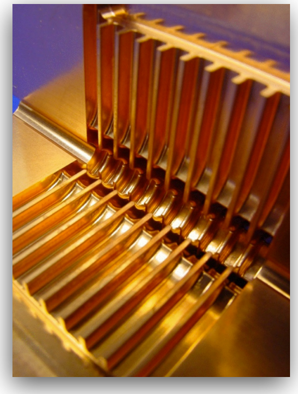
CLIC Two-Beam Acceleration Scheme

CLIC challenges

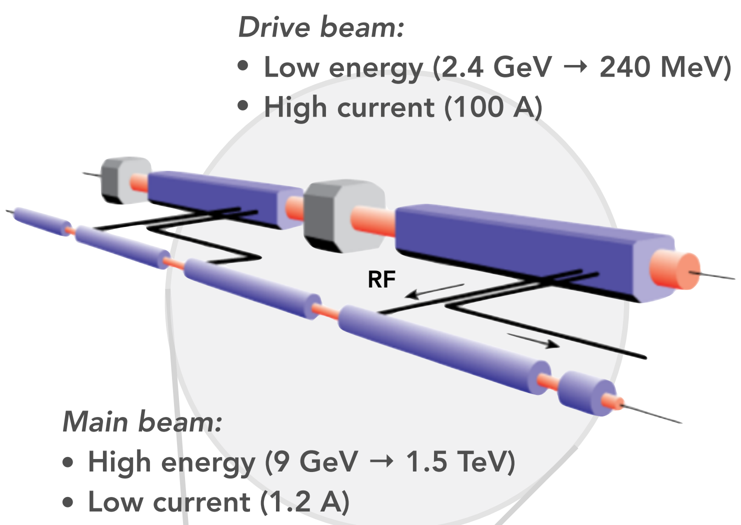
- Beam only passes once - **many accelerating cavities** - control breakdown rate
- High energy → **high accelerating gradient** (100 MV/m), Room temperature RF cavities
- High luminosity → **small beam size** + alignment/stability

CLIC accelerating structure; L~20 cm



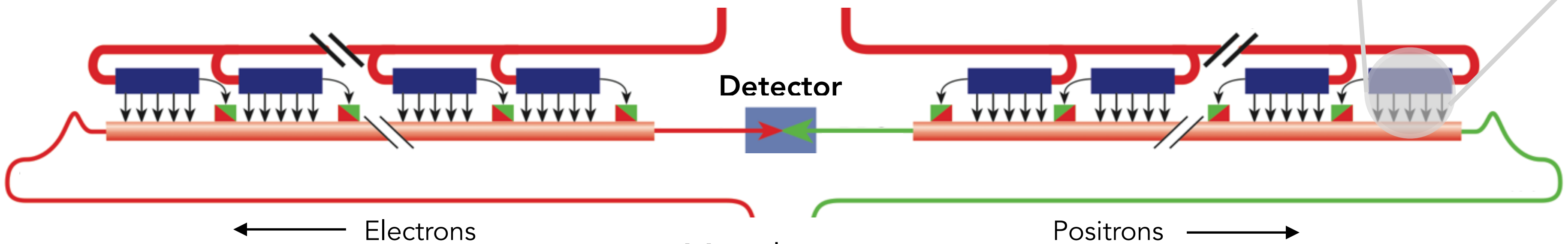
CLIC two-beam approach

- Drive beam accelerated to a few GeV using conventional klystrons
- Frequency increased using a series of delay loops and combiner rings
- Drive beam decelerated through an RF cavity → high frequency RF waves to be used to accelerate main electron/positron beam
- Concept demonstrated at a dedicated test facility at CERN



Drive beams

The electron drive beams supplies RF power



Main beams

The beam of electrons are set to collide with the beam of positrons after acceleration

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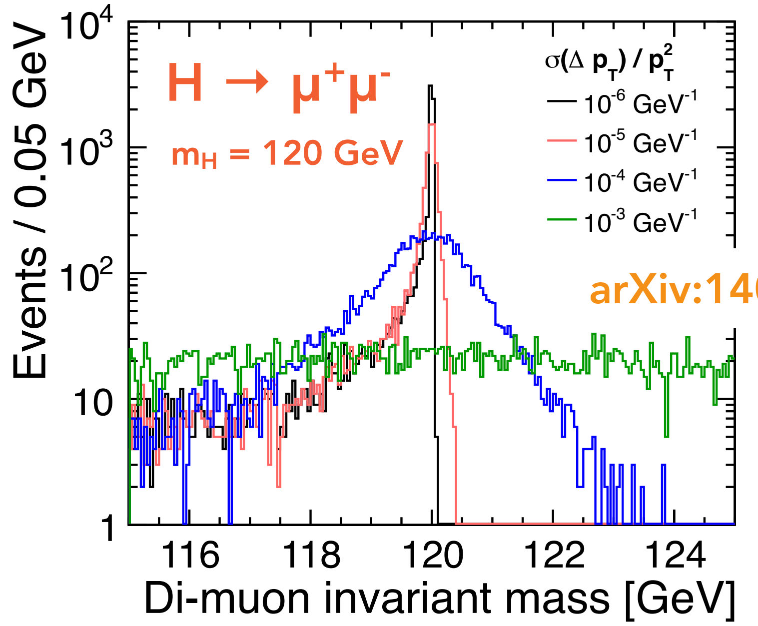
CLIC Detector Requirements

Detector Requirements for performance physics

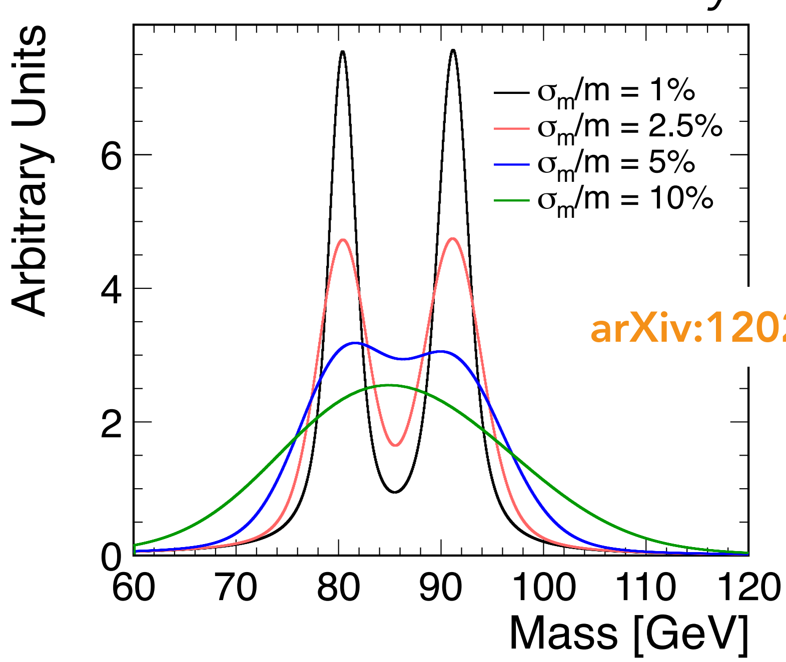
- **Impact parameter resolution** - High-resolution pixel detector for flavour tagging (displaced vertices)
- Small cell sizes needed for pattern recognition/background rejection
- **Track momentum resolution** - $\sigma_{p_T} / p_T^2 \sim 2 \times 10^{-5}$ GeV^{-1}
- Need very good **jet-energy resolution** to distinguish W/Z di-jet decays (to be reached with Particle Flow Algorithm (PFA) - improve energy resolution by using tracking information)
  - $\sigma_E / E \sim 3.5$ % for jet energies in the range 100 GeV - 1 TeV (5 % down to 50 GeV)
- Interactions between colliding bunches constitute large **experimental background** ($\gamma\gamma \rightarrow$ hadrons / e^+e^- pairs)
- Overall need for **precise timing** to suppress background:
  - ~10 ns hit time-stamping in vertex/tracker detector
  - 1 ns accuracy for calorimeter hits
- **Angular coverage** - Lepton identification, missing energy, very forward electron tagging

Higgs mass resolution study



arXiv:1402:2780

Jet mass resolution study



arXiv:1202.5940

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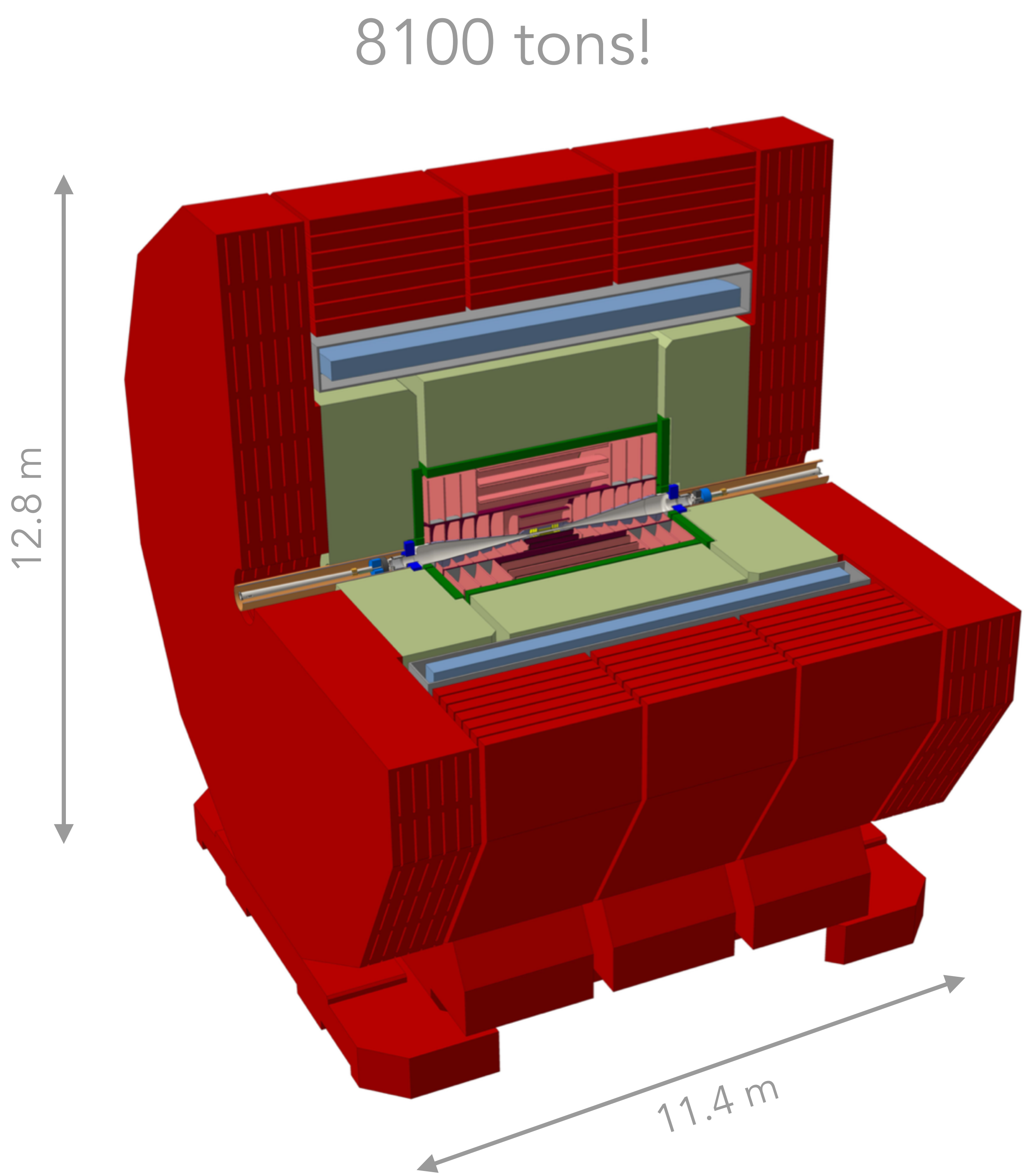
CLIC Detector Overview



Detector model for CLIC

- Optimised through simulation (3 TeV)
- Ultra low-mass vertex detector; 6 x 0.2% X_0 per layer; 25 μm square pixels, ~2 billion pixels
- All-silicon tracker; 1.5 m radius, 4.6 m long
- Fine grained calorimetry (PFA); ECAL/HCAL
- Enclosed in a 4 T superconducting solenoid magnet (R_{in} = 3.4 m, L = 8.3 m)
- Iron return yoke instrumented with muon chambers, for muon identification
- Complex forward region:
  - LumiCal (luminosity monitoring)
  - BeamCal (extended coverage)

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Physics at CLIC - A Staged Program

- Optimal use of physics potential
- Earlier start of physics
- Defined by physics w. considerations for technical constraints

1) $\sqrt{s}$ = 380 GeV (500 fb^{-1})

- Higgs/Top precision physics
- Top mass threshold scan (350 GeV)

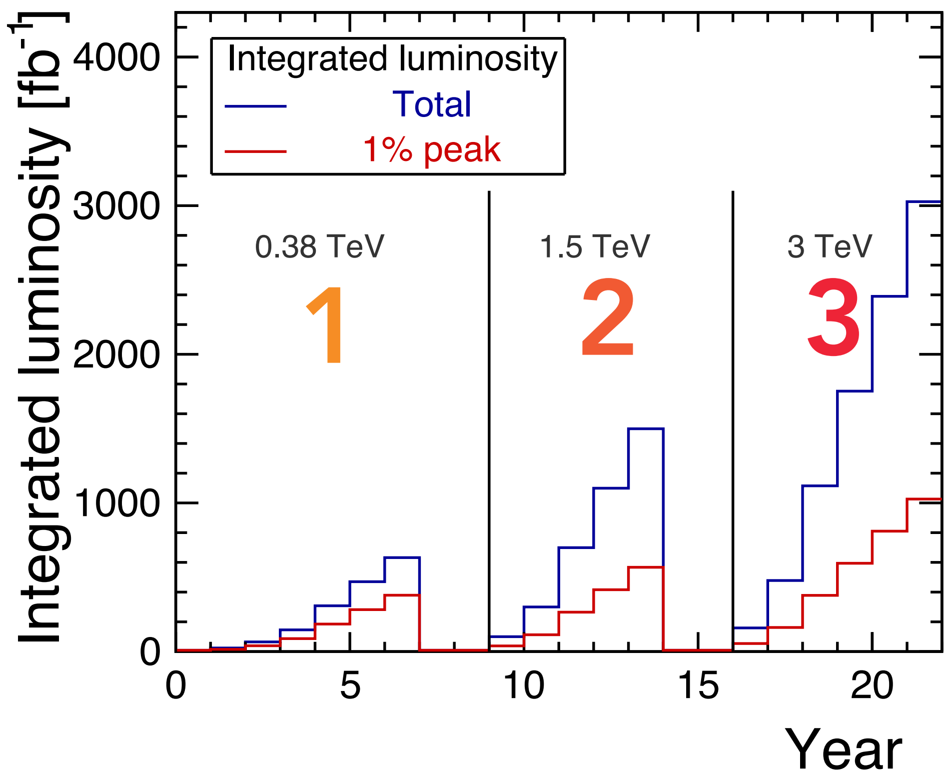
2) $\sqrt{s}$ = 1.5 TeV (1.5 ab^{-1})

- Target: Precision SUSY, BSM reach
- Higgs/Top precision physics
- Rare Higgs decays
- Top Yukawa coupling

3) $\sqrt{s}$ = 3 TeV (3.0 ab^{-1})

- Target: Precision SUSY, BSM reach
- Higgs self-coupling
- Rare Higgs decays

Each stage corresponds to 5-7 years

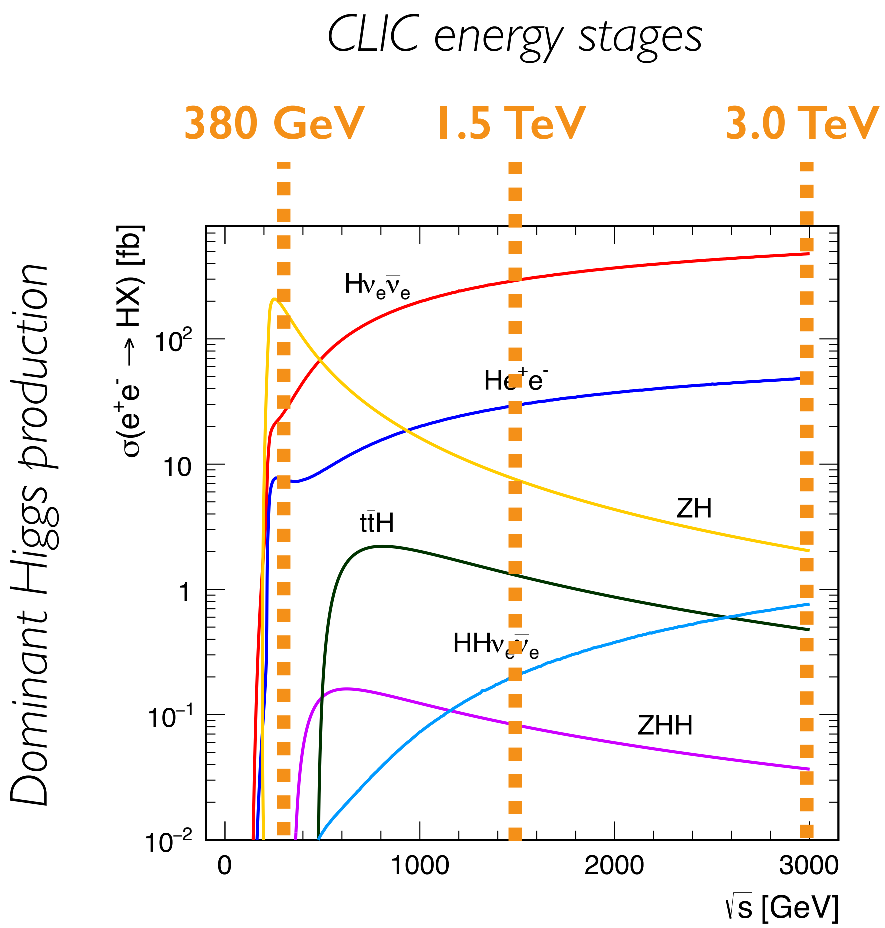


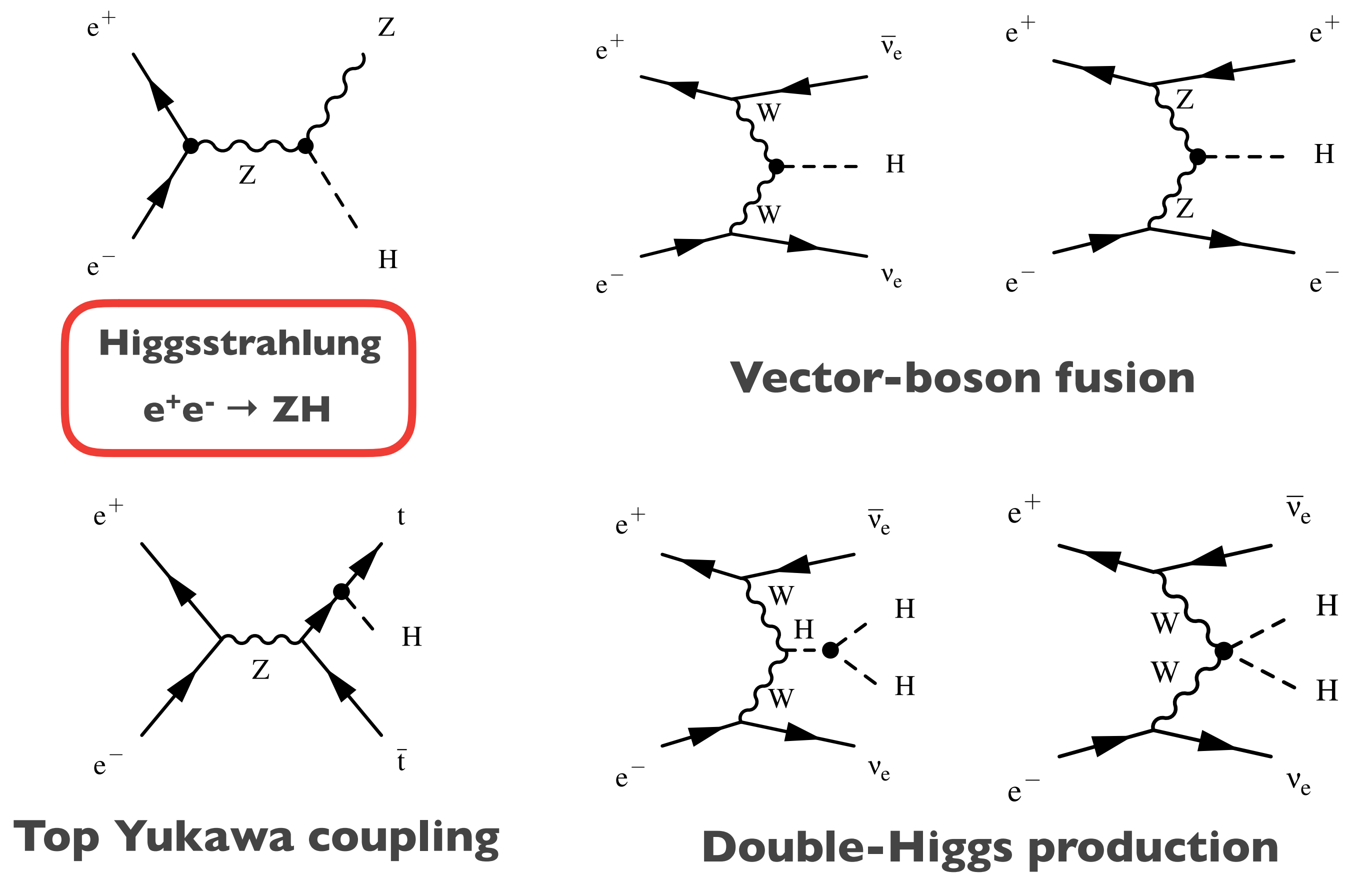
CLIC Integrated luminosity

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

Dedicated time for top mass threshold scan

Higgs Physics at CLIC





- Any deviation from SM Higgs couplings and its properties represents evidence for new physics
- Precision Higgs physics is the main motivation for CLIC operation at 380 GeV
- To fully exploit physics case we need several energy stages going up to multi-TeV energies
- CLIC covers several Higgs production processes, Higgs factory!
- Model-independent Higgsstrahlung process unique to an e^+e^- collider
- Higgs couplings can be determined with a sub-percent statistical uncertainty

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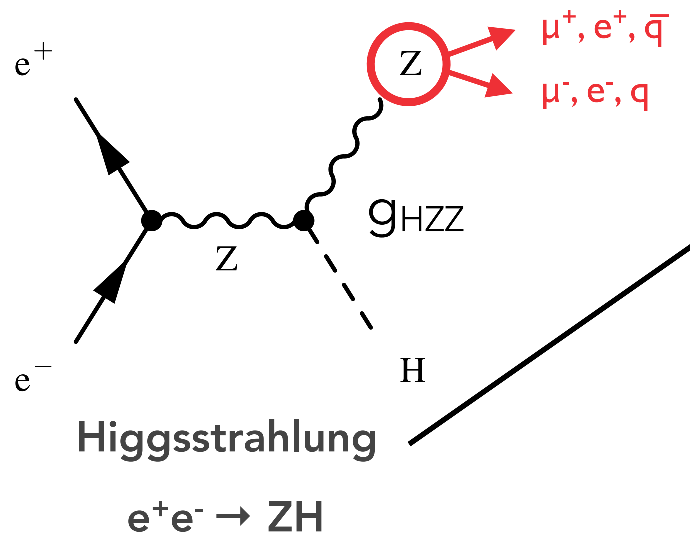
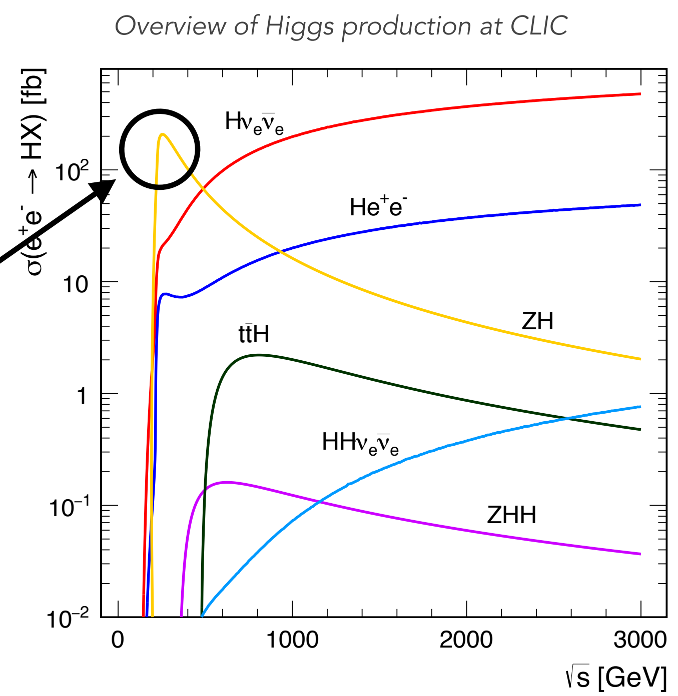
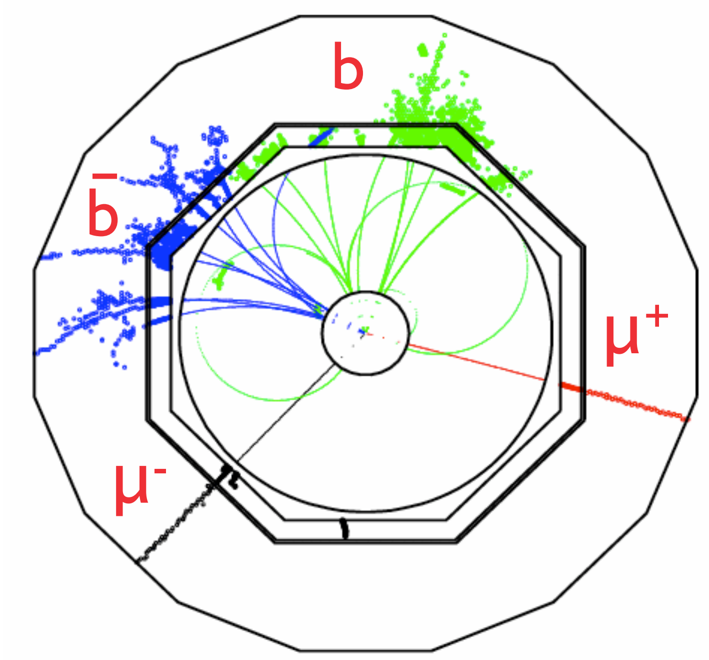
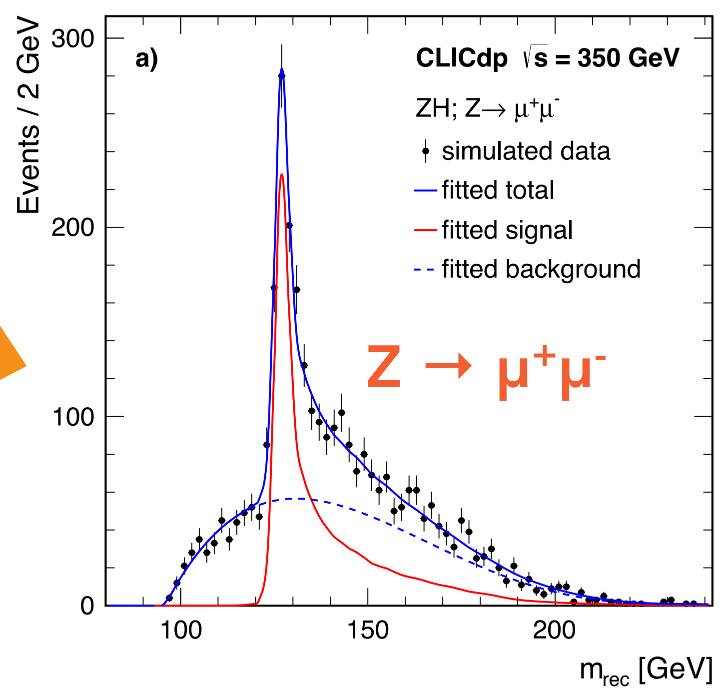
Higgsstrahlung $e^+e^- \rightarrow ZH$







- Why so important? Sets the absolute scale for all model-independent Higgs coupling measurements
- **Model-independent** measurements of Higgs properties from Z-recoil mass
- Independent of the Higgs decay mode
- Combined analysis, $Z\rightarrow e^+e^-$, $Z\rightarrow\mu^+\mu^-$, $Z\rightarrow qq$:
- Absolute coupling of the H boson to the Z boson, $\Delta(g_{HZZ}) = 0.8$ % (stat.)
- Unique sensitivity to invisible decay modes ($\Gamma_{\mathrm{invis}}/\Gamma_{\mathrm{H}} < 0.01$ at 90 % C.L.)
- High flavour-tagging efficiencies → H branching fractions
- 6.3 % (stat.) precision on the **total** Higgs decay width



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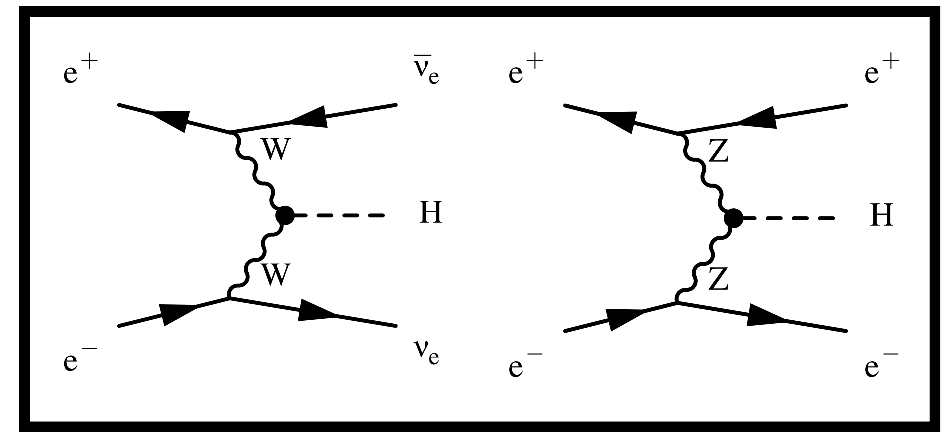
Higgs Physics at Higher Energies

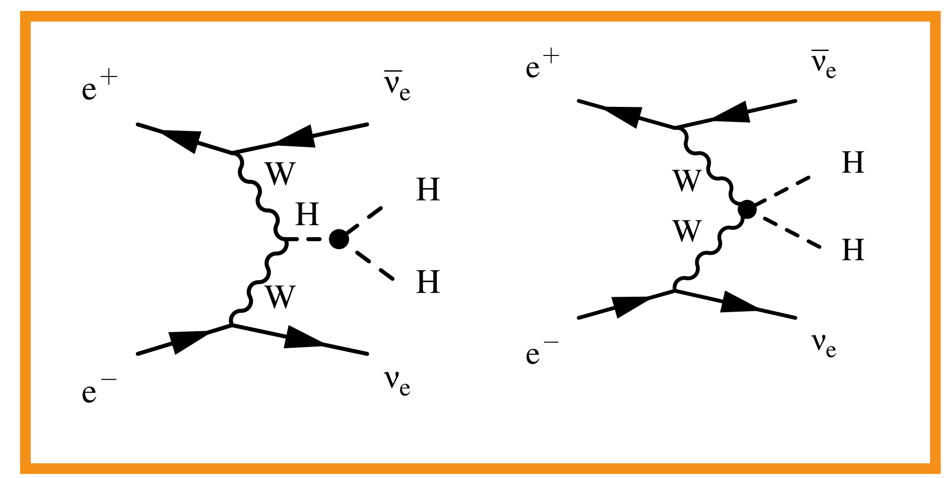
Vector Boson Fusion

- Dominant channel > 450 GeV
- WW-fusion: Constraint on the H coupling to W, g_{HWW}
- Precise coupling measurements
- Rare Higgs decays like $H \rightarrow \mu^+\mu^-$



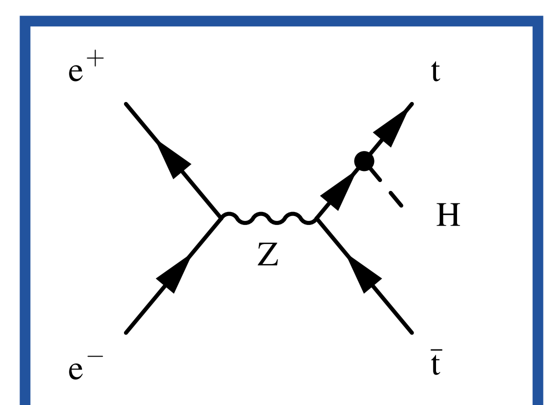
Double Higgs Production - Very high precision for CLIC

- High luminosity and high energy crucial for $e^+e^- \rightarrow HH\nu_e\nu_e$
- Only 225 (1200) $HH\nu_e\nu_e$ events at 1.4 (3) TeV
- Sensitive to Higgs tri-linear self-coupling and the quartic coupling, direct probe of the Higgs potential
- Quartic coupling g_{HHWW}: ~3 %
- Self-coupling λ: about 10 % (HL-LHC 50 %)



Top Yukawa Coupling

- Determined from direct production where a Higgs boson is produced in association with a top quark pair
- CLIC Precision: 4 % (stat.) for 1.5 TeV including electron polarisation (HL-LHC: (7-10) % (stat.) for one experiment)



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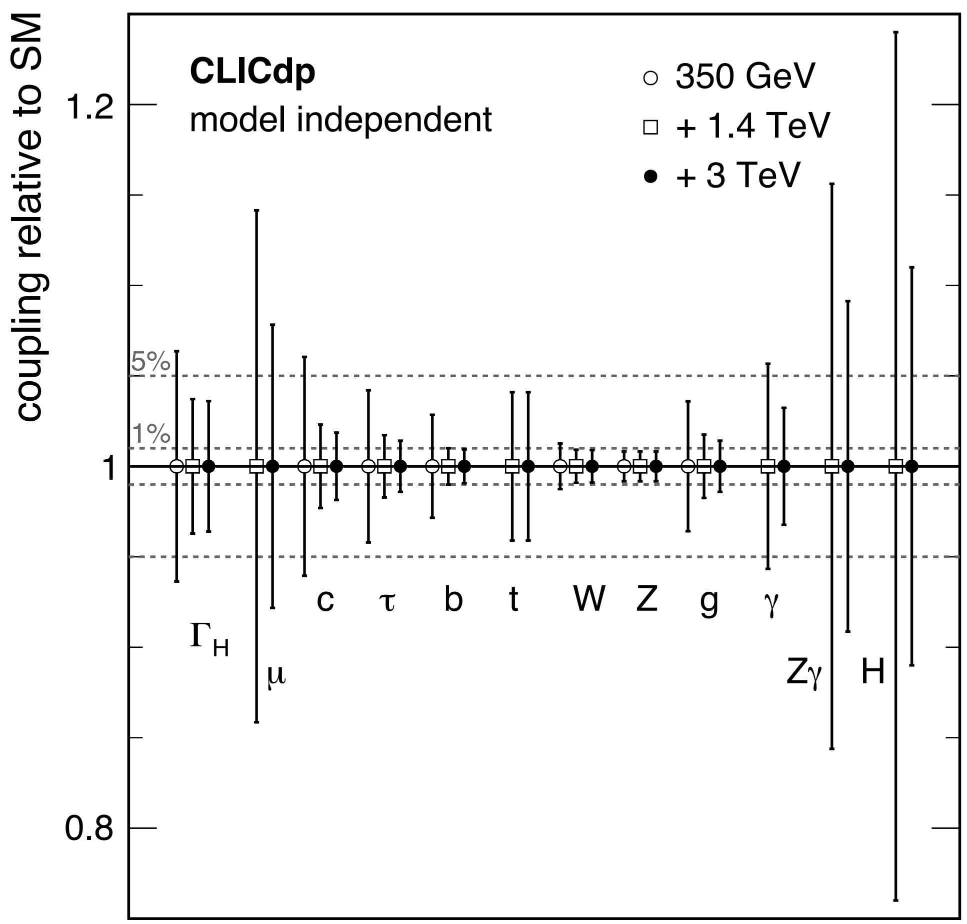
Higgs Physics at CLIC - Global Fits

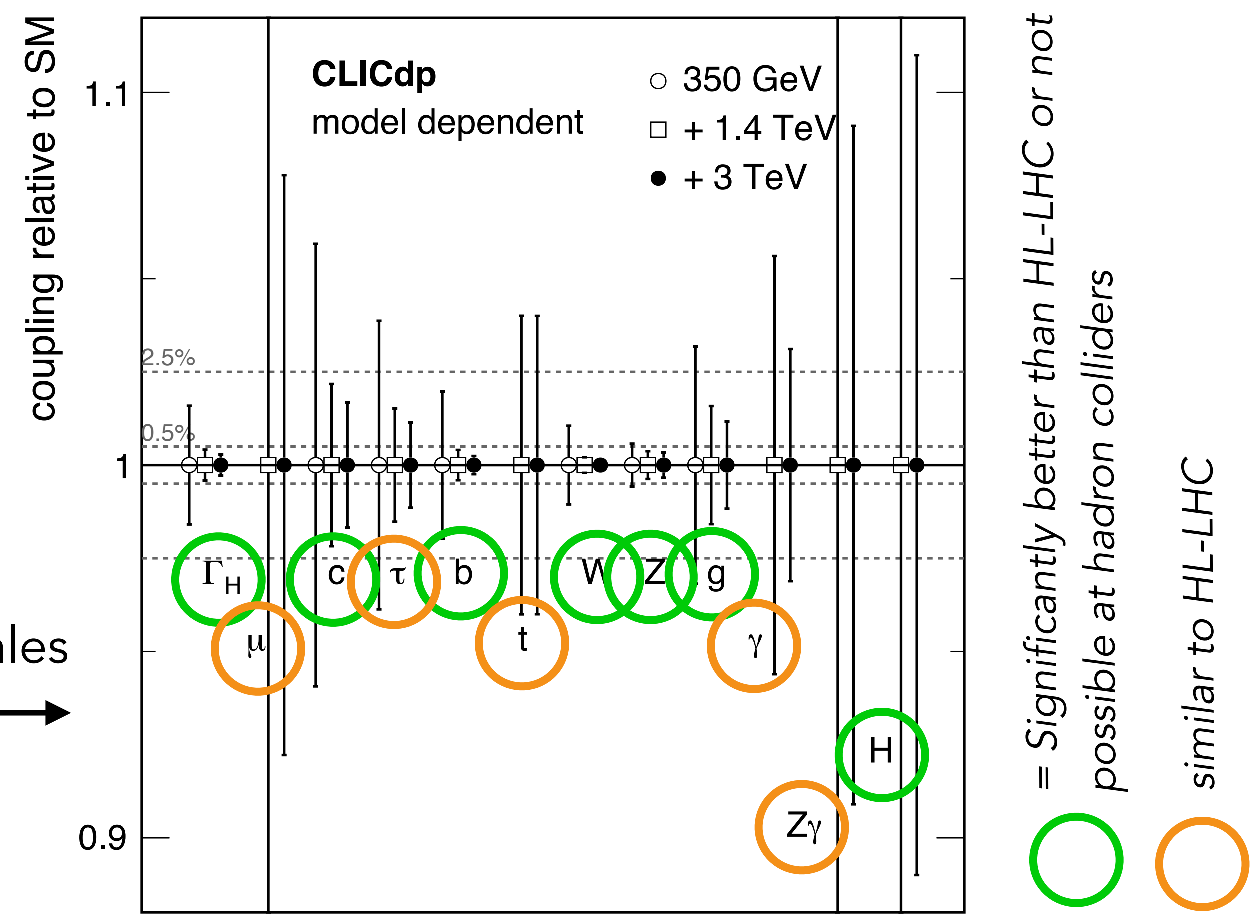
Model-independent global fits



Higgs width is a free parameter allows for additional non-SM decays.

Note the different scales

Model-dependent global fits



Constraining "LHC-style" fits assuming no invisible Higgs decays (model-dep.)

$$\Lambda_{\mathrm{H,md}} = \sum_i \frac{\Gamma_i}{\Gamma_{i|\mathrm{SM}}} \mathrm{BR}_i$$

Global fit results of full CLIC program, ~5-7 years of running at each stage

- Model-independent: down to ~2 % for most couplings (only at lepton colliders)
- Model-dependent: ~0.1-1 % for most couplings
- Accuracy on **Higgs width: ~3.6 % (MI), ~0.3 % (MD, derived)**
- **Higgs mass** with 24 MeV precision (HL-LHC: ~50 MeV)

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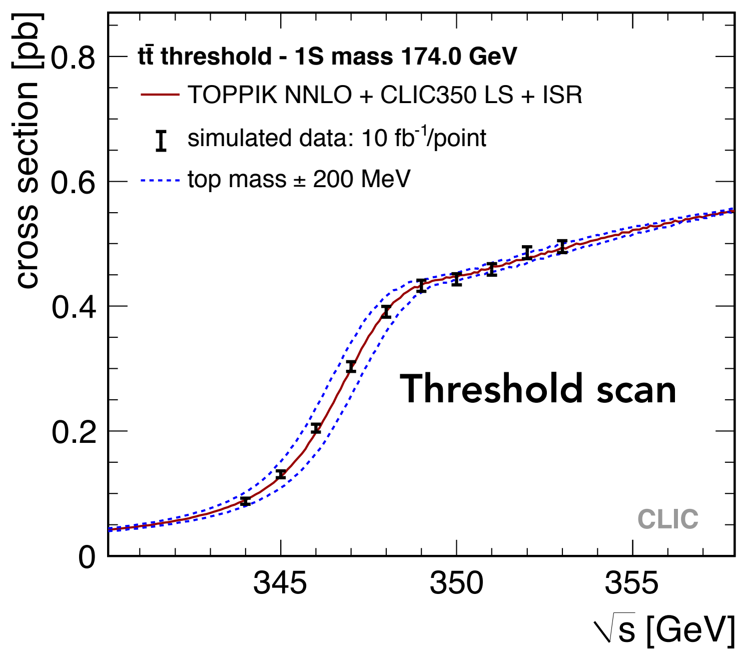
Top Physics at 380 GeV

- The top quark is of particular interest - couples strongly to Higgs field
- May be first place a new particle shows up if strong coupling to mass

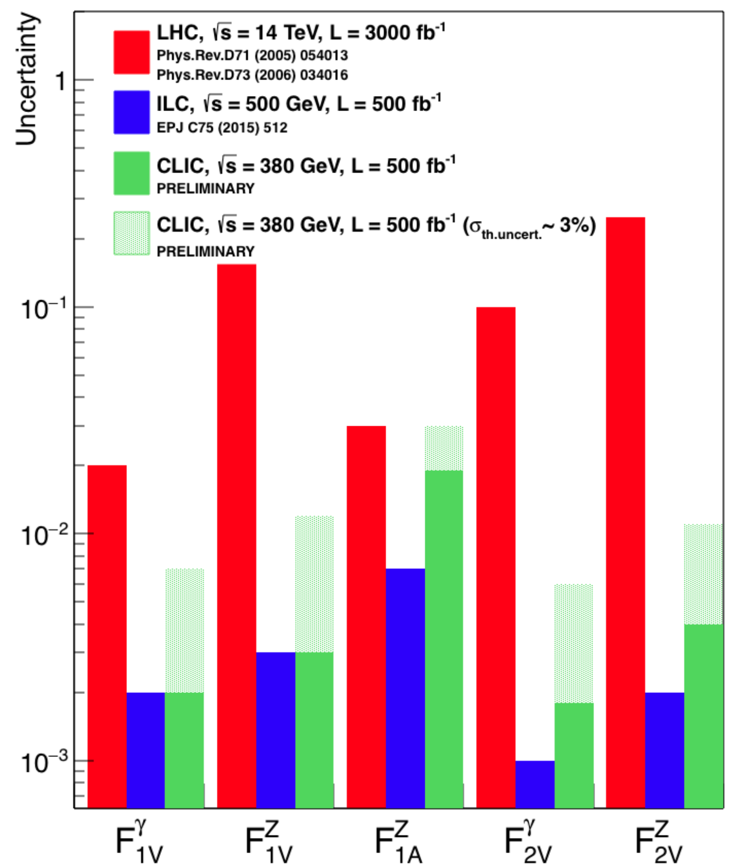
Top mass measurements (run at 350 GeV with 100 fb^{-1}):

- Threshold scan (analogous to the LEP2 WW mass scan)
- Shape depends strongly on mass
- Normalisation sensitive to α_S and top Yukawa coupling
- Extraction of the theoretically well-defined 1S top mass with accuracy ~50 MeV (order of magnitude beyond HL-LHC)



Top quark couplings to Z and γ - high precision:

- Close to maximum of tt production cross section
- Determining top form factors through measurement of cross-sections and forward-backward asymmetries for different polarisations
- In many BSM models top EW couplings substantially modified
- CLIC (solid green) an order of magnitude better than HL-LHC (red)



Exotic top quark decays (competitive limits on e.g. t → cH, t→ cγ)

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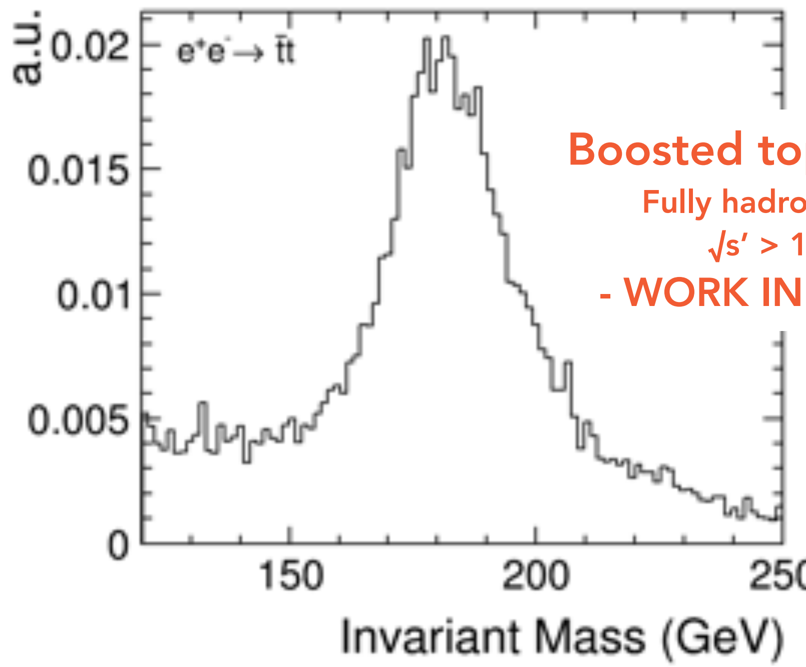
Top Physics at High Energy

Top as a probe for new physics

- Relative contribution from new physics may increase with centre-of-mass energy
- Increased boost → better separation between the decay products of the two top quarks
- Benefit from software development at LHC, top tagger algorithm, etc.
- Further explore top form factors
- The sub-percent precision on anomalous electroweak couplings yields sensitivity to new physics at scales well beyond the direct reach of the machine
- Alternative: Integrate out explicit mediators and describe BSM effect through effective D6 operators
- Significant improvement going to higher energies

Single top production at √s = 3 TeV (2ab^{-1})

- e.g. e+γ → t+b+ν has no background from tt
- Measurement of CKM V_{tb} looks promising



Boosted tops at 1.4 TeV

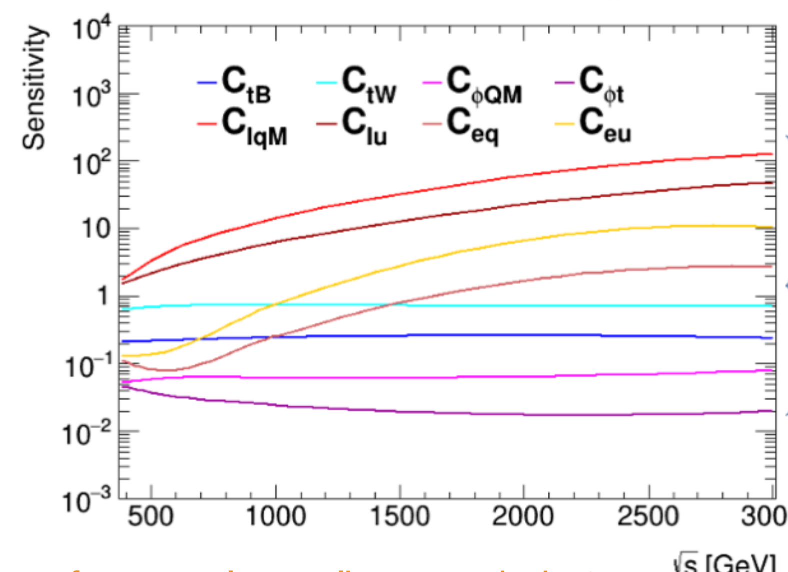
Fully hadronic final state

√s′ > 1350 GeV

- WORK IN PROGRESS -

Effective D6 operators

$$\mathcal{L}_{eff} = \mathcal{L}_{SM} + \frac{1}{\Lambda^2}\sum_i C_i O_i + \mathcal{O}\left(\Lambda^{-4}\right)$$



"4-fermion" operators

"vertex" operators

from Marcel Vos' talk 'Top quark physics' at ECFA LC2016, Santander

BSM Physics at CLIC - Introduction

Direct production of new particles

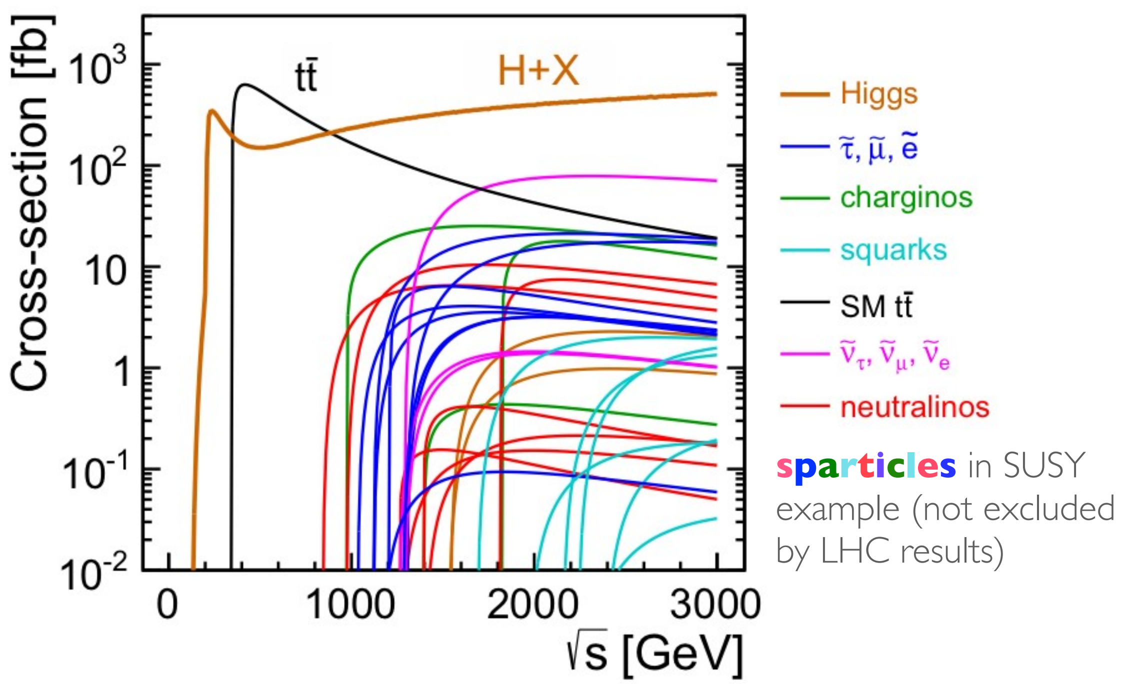
- Possible up to the kinematic limit
- Precision measurements of new particle masses and couplings
- Complements the HL-LHC program to measure heavy SUSY partners

Indirect searches through precision observables

- Compare couplings/cross-sections to SM
- Allows discovery of BSM signals beyond the centre-of-mass energy of the collider

New territory to explore

- SUSY particles with strong electro-weak coupling might be hidden in the LHC due to the large backgrounds



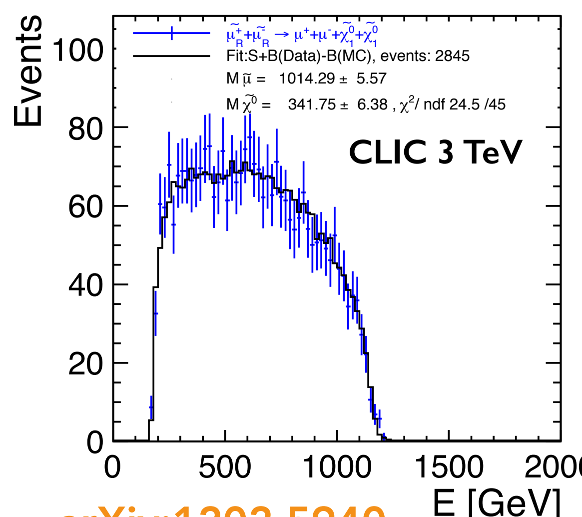
- Examples of benchmark studies shown on the following two slides
- Studies constructed to show the CLIC detector capability (not always optimal channel for each measurement)
- In general always able to measure the mass and other properties

BSM Physics at CLIC - Direct Measurements

Masses from endpoints of energy spectra

- The slepton and gauginos masses are extracted from the position of the kinematic edges of the lepton energy distribution
- Slepton mass precision < 1 % for sleptons below 1 TeV

$$e^+e^- \rightarrow \tilde{\mu}_R\tilde{\mu}_R \rightarrow \mu^+\mu^-\tilde{\chi}^0_1\tilde{\chi}^0_1$$



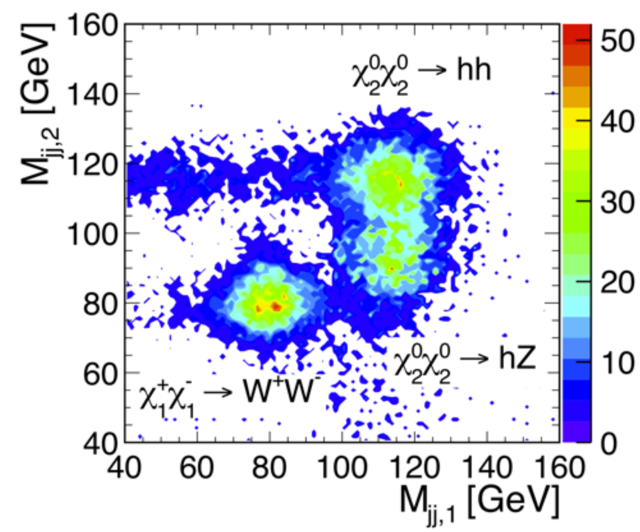
arXiv:1202.5940

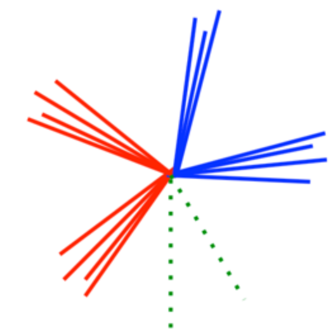
$$m(\tilde{\mu}_R) : \pm 5.6\,\mathrm{GeV}$$
$$m(\tilde{e}_R) : \pm 2.8\,\mathrm{GeV}$$
$$m(\tilde{\nu}_e) : \pm 3.9\,\mathrm{GeV}$$
$$m(\tilde{\chi}^0_1) : \pm 3.0\,\mathrm{GeV}$$
$$m(\tilde{\chi}^\pm_1) : \pm 3.7\,\mathrm{GeV}$$

Slepton masses 1.0-1.1 TeV

Chargino and Neutralino pair-production

- Reconstruct W/Z/H in hadronic decays (4j + missing ET)
- Precision on the measured gaugino masses (few hundred GeV): Δm/m = 1 - 1.5%

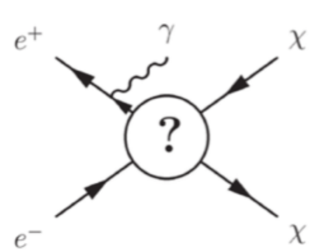




$$e^+e^- \rightarrow \tilde{\chi}^+_1\tilde{\chi}^-_1 \rightarrow \tilde{\chi}^0_1\tilde{\chi}^0_1 W^+W^-$$
$$e^+e^- \rightarrow \tilde{\chi}^0_2\tilde{\chi}^0_2 \rightarrow hh\,\tilde{\chi}^0_1\tilde{\chi}^0_1 \quad (82\ \%)$$
$$e^+e^- \rightarrow \tilde{\chi}^0_2\tilde{\chi}^0_2 \rightarrow Zh\,\tilde{\chi}^0_1\tilde{\chi}^0_1 \quad (17\ \%)$$

Mono-photon events

Single photon + missing E_T allow model-independent searches for dark matter candidates.

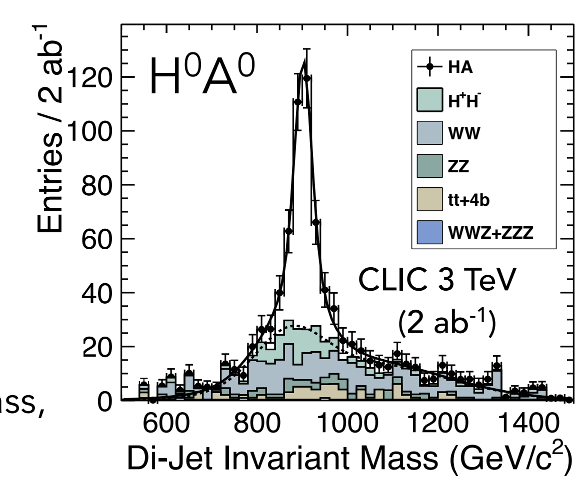


Heavy Higgs bosons

Complex final states!

$$e^+e^- \rightarrow H^0A^0 \rightarrow b\bar{b}b\bar{b}$$
$$e^+e^- \rightarrow H^+H^- \rightarrow t\bar{b}b\bar{t}$$

- Mass precision, Δm/m = 0.3 %
- H^0, A^0, $H^{+/-}$ almost degenerate in mass, separation requires heavy-flavour tagging



arXiv:1202.5940

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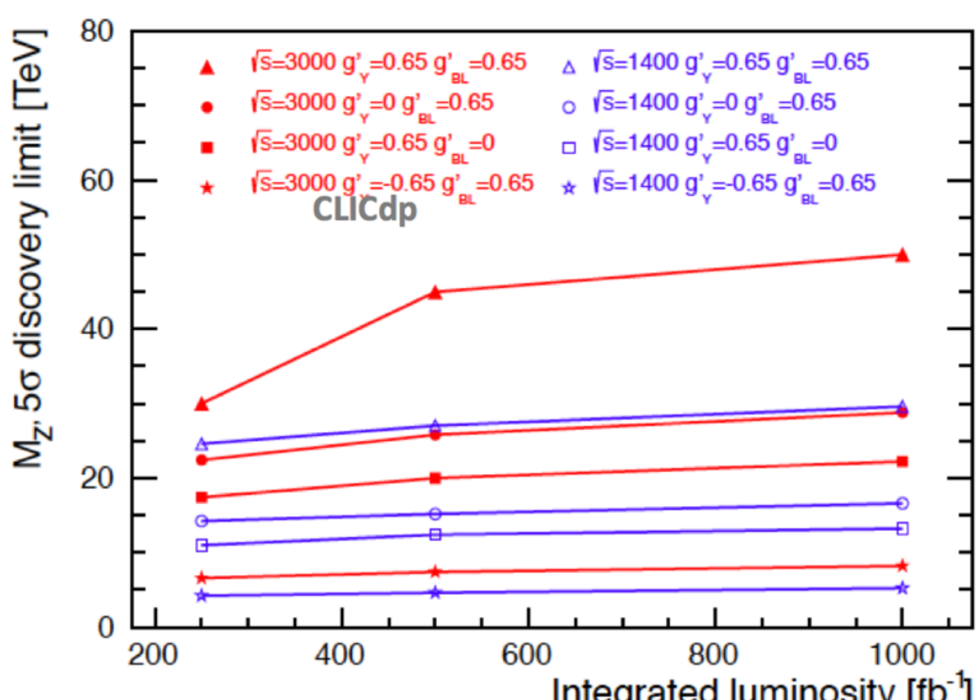
BSM Physics at CLIC - Indirect Measurements

Z′ from fermion pair production

Precision study of $e^+e^- \rightarrow \mu^+\mu^-$

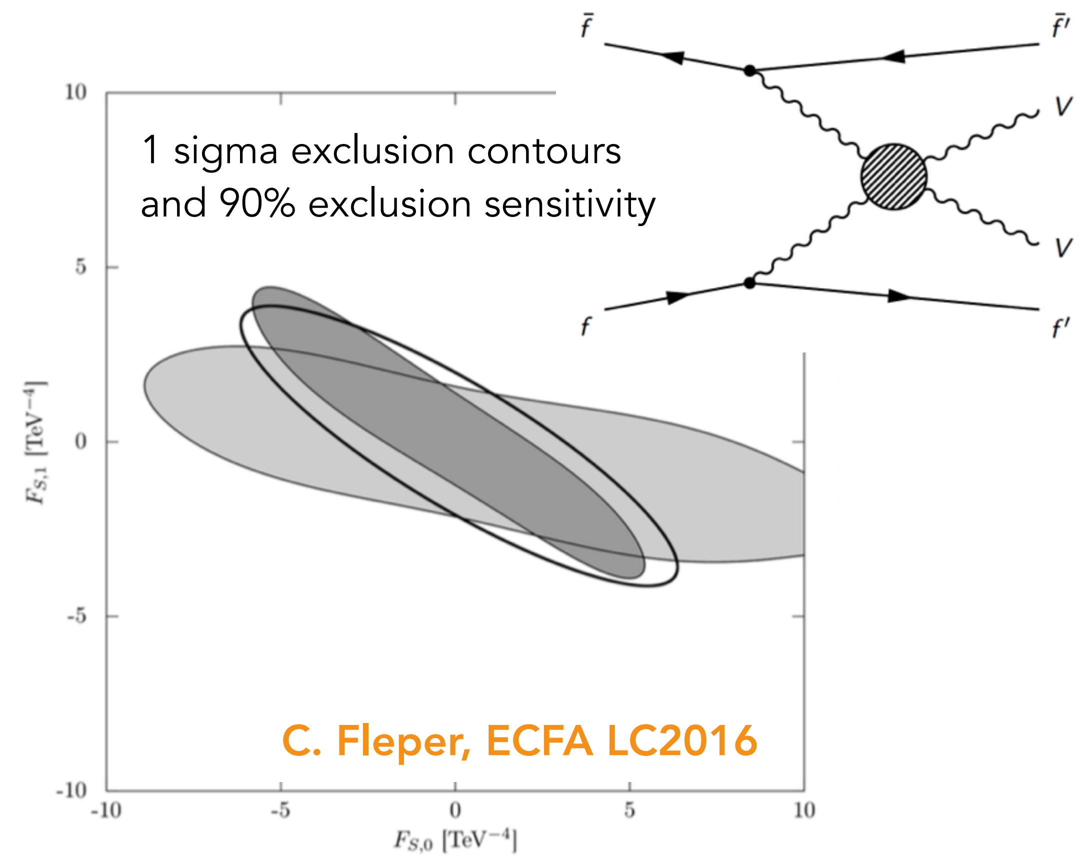
- Hypothetical gauge boson arising from extensions of the electroweak symmetry of the SM
- High-precision measurement of the properties of the SM Z boson → model-dependence through Z′ and Z mixing (cross-section, FB-asymmetry, LR-asymmetry)
- Minimal anomaly-free Z′ (AFZ′) model: Discovery up to tens of TeV (HL-LHC reaches ~8 TeV with 3ab^{-1}) (depending on the couplings)
- Precision measurement of effective couplings, if LHC discovers Z′ (e.g. for $M_{Z'}$ = 5 TeV)



arXiv:1208.1148

Vector boson scattering

Anomalous coupling



C. Fleper, ECFA LC2016

- Sensitive to new physics in the Higgs sector
- Search for additional resonances or anomalous couplings
- At first glance, CLIC at 3 (1.5) TeV roughly two (one) orders of magnitude more precise than LHC at 8 TeV, for anomalous couplings

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Conclusions & Summary

- The CLIC accelerator is an **attractive option for a future e^+e^- collider** at CERN and the only option for an e^+e^- multi-TeV machine
- Feasibility demonstrated through extensive simulation and prototyping, accelerator and detector R&D
- CLICdp has a **well-established physics program**, and can provide an evolving and rich physics case over several decades including a staged implementation
- CLIC opens up the possibility of **e^+e^- collisions with $\sqrt{s}$ >> 1 TeV**, giving improved precision of many observables and access to rare Higgs decays + discovery machine for BSM physics at the energy frontier
- Close eye is being kept on LHC results, strategy can be adapted to potential LHC/HL-LHC discoveries

New documents to be published very soon:

- Staging baseline - 'Updated baseline for a staged Compact Linear Collider'
- Higgs physics paper - 'Higgs Physics at the CLIC Electron-Positron Linear Collider'

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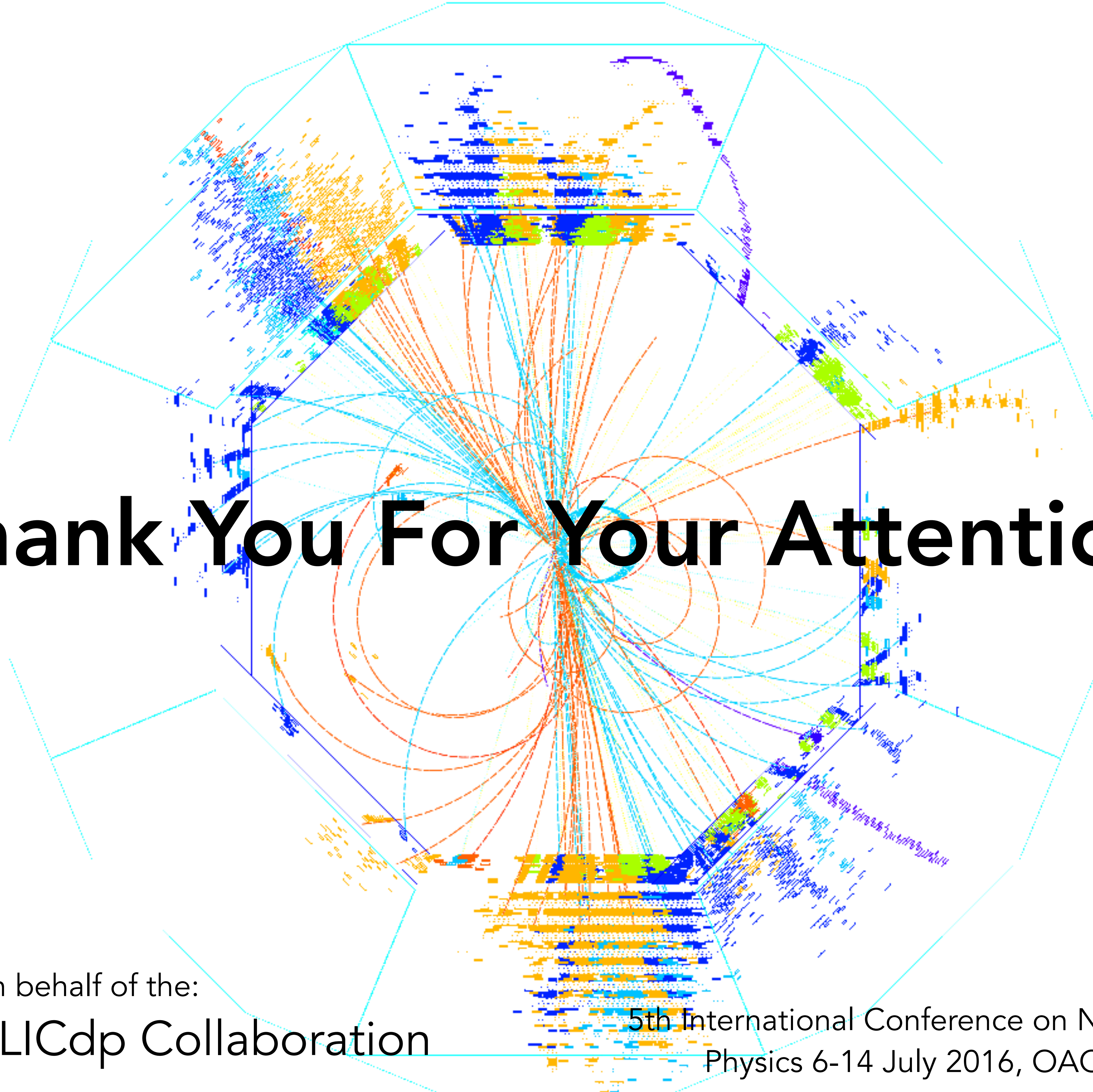
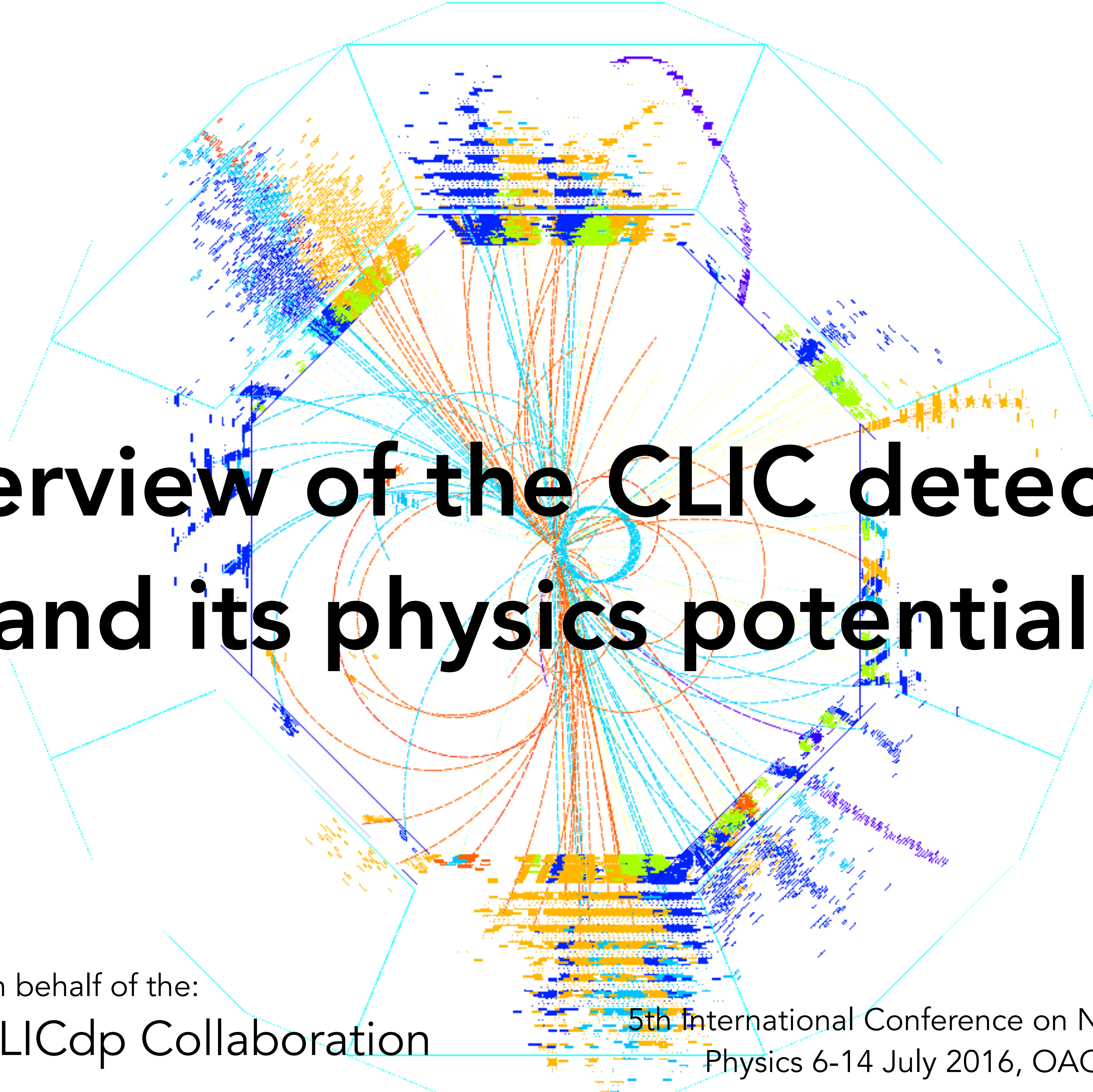


Thank You For Your Attention!

On behalf of the:
CLICdp Collaboration

Rickard Ström
5th International Conference on New Frontiers in Physics 6-14 July 2016, OAC Crete, Greece



Overview of the CLIC detector and its physics potential

On behalf of the:

CLICdp Collaboration

Rickard Ström

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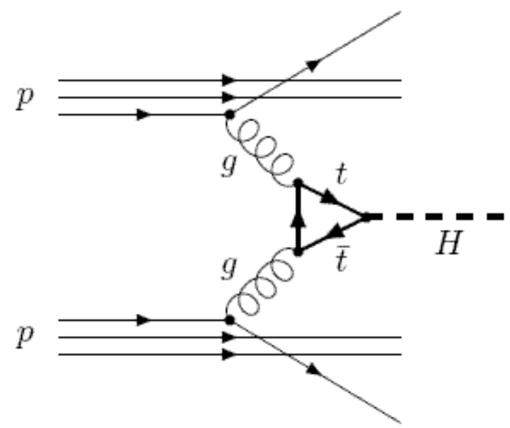
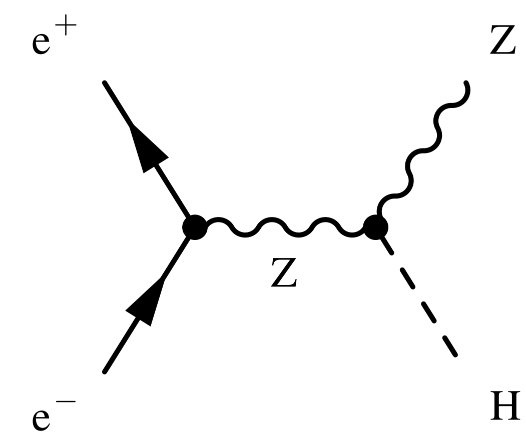
Backup Slides

Hadron vs. Lepton Colliders

from discovery to precision





p-p collisions	e^+e^- collisions
Protons are compound objects: → Initial state not known event-by-event → Limits achievable precision	**e^+e^- are point like:** → Initial state well defined (√s / polarisation) → High-precision measurements
Circular colliders feasible	**Linear colliders** (avoid synchrotron rad.)
High rates of QCD backgrounds → Complex triggering schemes → High levels of radiation	Cleaner experimental environment → Trigger-less readout → Low radiation levels
High cross-sections for **coloured states**	Superior sensitivity for **electroweak states**

Linear e^+e^- Colliders

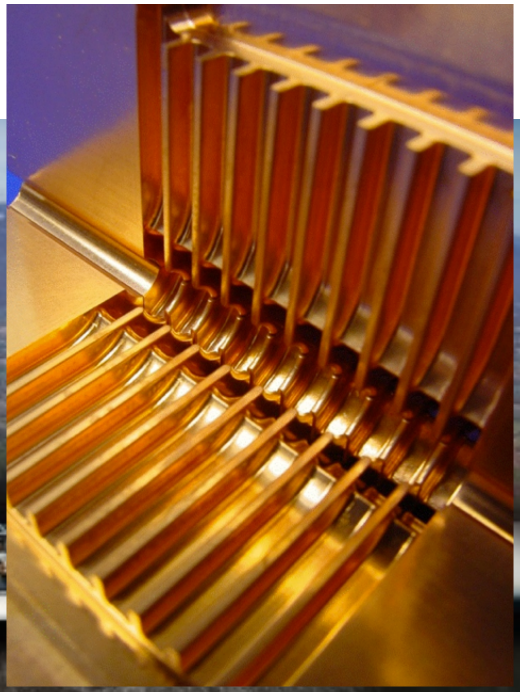
CLIC (Compact Linear Collider) @ CERN

- Novel two-beam acceleration scheme,
- Room temperature RF cavities,
- Accelerating gradient 100 MV/m,
- Provides e^+e^- collision up to 3 TeV
- Staging baseline*: 380 GeV, 1.5 TeV, 3TeV,
- Physics + Detector studies for 350 GeV - 3 TeV,
- CLIC focus is on the energy frontier!
- Rich physics program over ~ 20 years

ILC (International Linear Collider)

- 'Conventional' superconducting RF cavities,
- Accelerating gradient 32 MV/m,
- $\sqrt{s} \leq 500$ GeV (1 TeV upgrade option),
- 30 km length,
- Focus on ≤ 500 GeV, physics studies also for 1TeV.

CLIC accelerating structure



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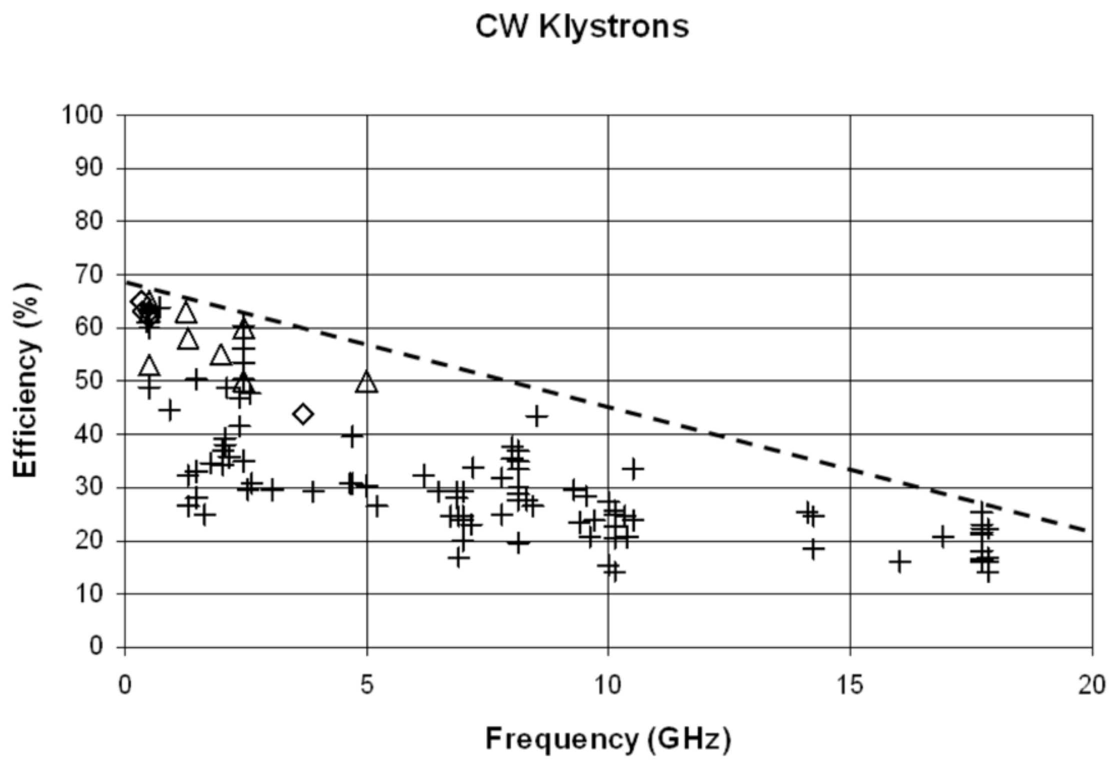
The challenge with high frequency RF

Why do we need two-beam acceleration?

- Compact accelerator (~tens of km) → High acceleration fields → High frequency RF is a challenge → Use drive beam powered by conventional klystrons

- Unfortunately it is not easy/efficient/practical to produce high frequency RF
  - Klystrons generally used for particle acceleration, but drop in efficiency beyond a few GHz
- CLIC approach is to conventionally accelerate a low-frequency particle beam, up the frequency of this beam, then using similar structures to the accelerating cavities extract the RF power (use the beam as an RF generator) and use this to drive the main beam

- **First**: Take a high current beam and use conventional klystrons to accelerate it to a few GeV
- **Second**: Using a series of delay loops and combiner rings, interleave the bunches of the beam in order to increase the frequency
- **Third**: pass this beam (the 'drive' beam) through an RF cavity to generate the high frequency RF waves
- **Fourth**: Use these high frequency RF waves to generate the accelerating gradient for the main beam



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

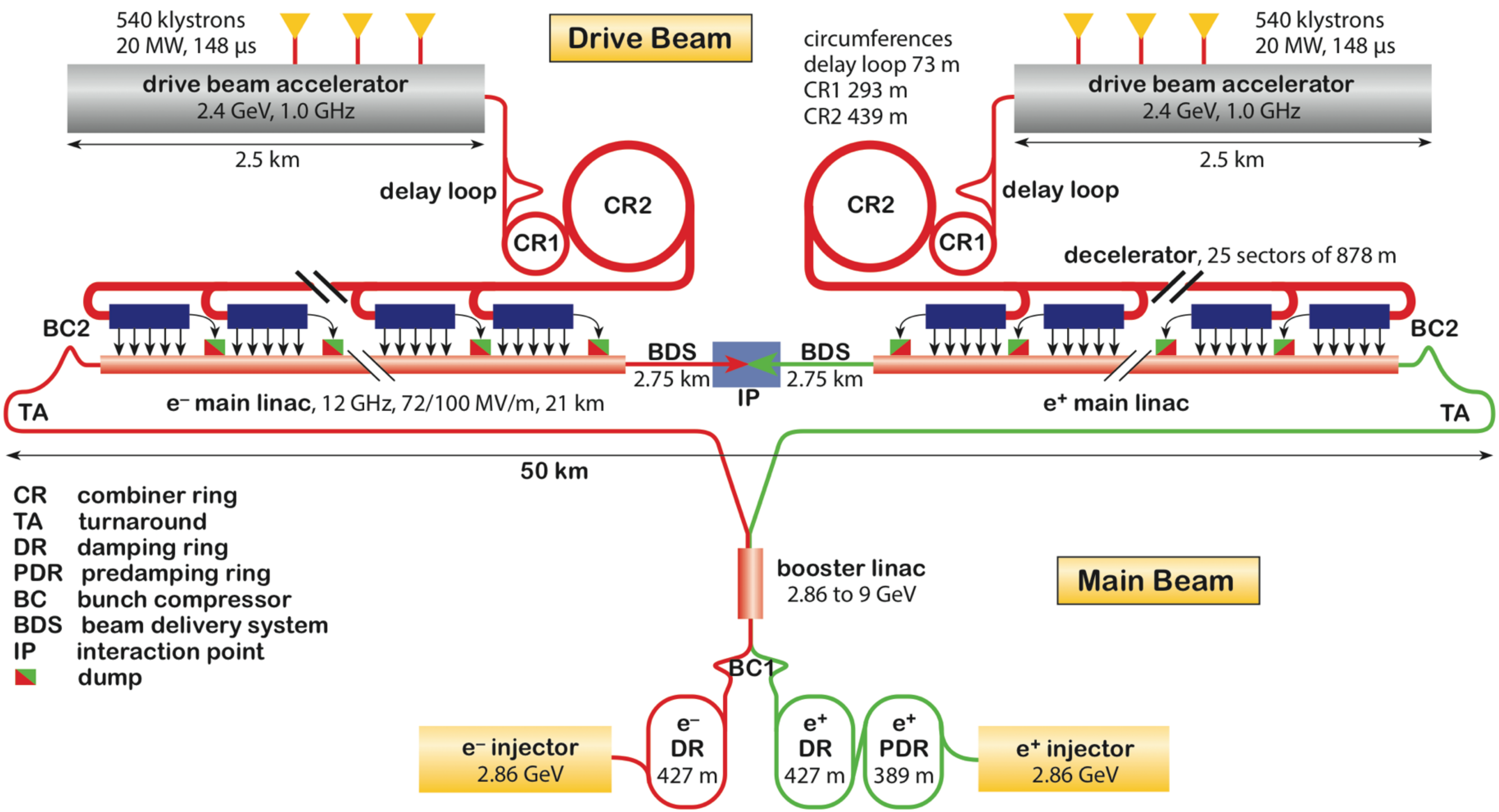
Ready for construction; start of excavations

2035 First Beams

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

CLIC Two-Beam Acceleration Scheme

@ 3TeV



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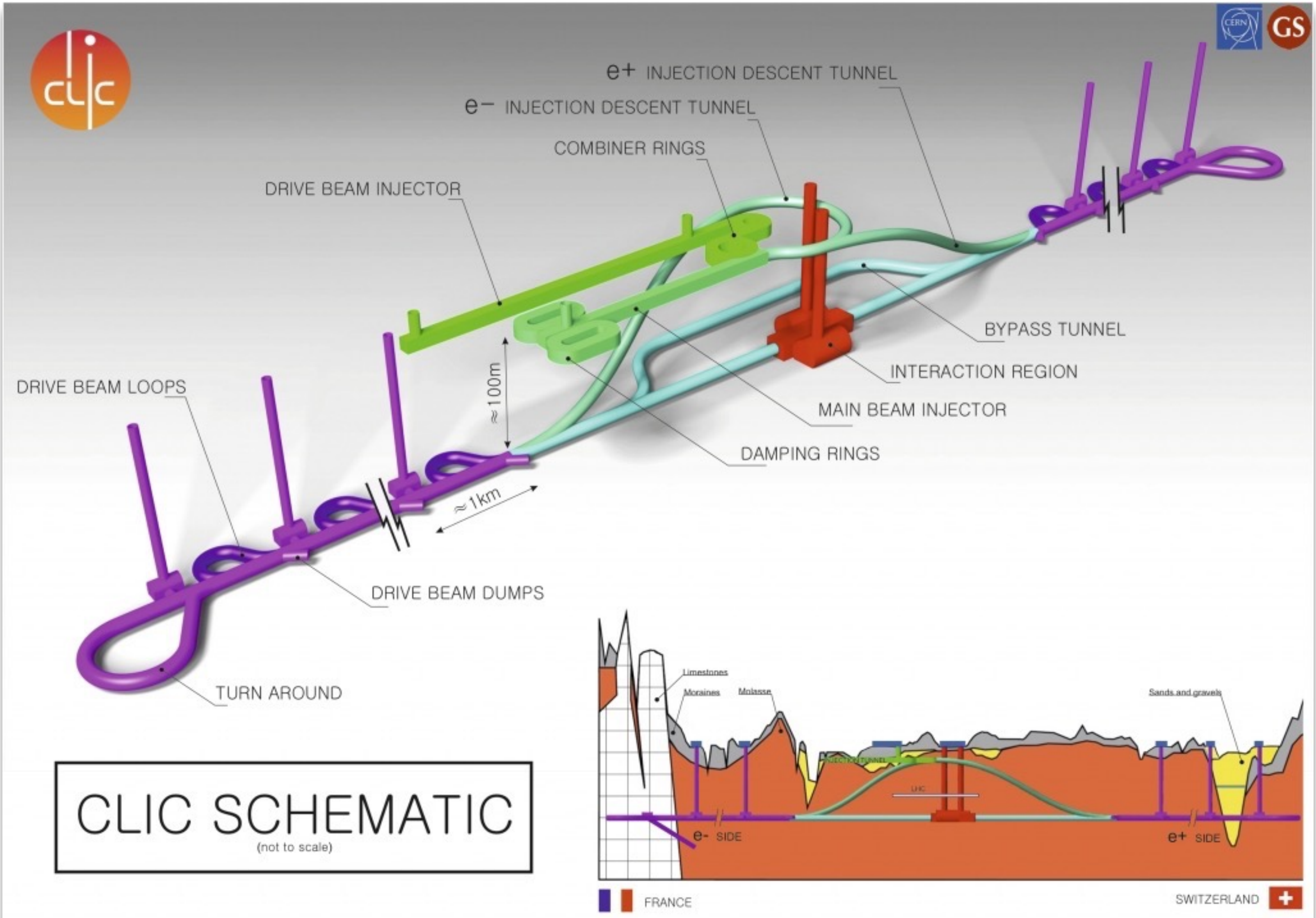
CLIC Tunnel Layout



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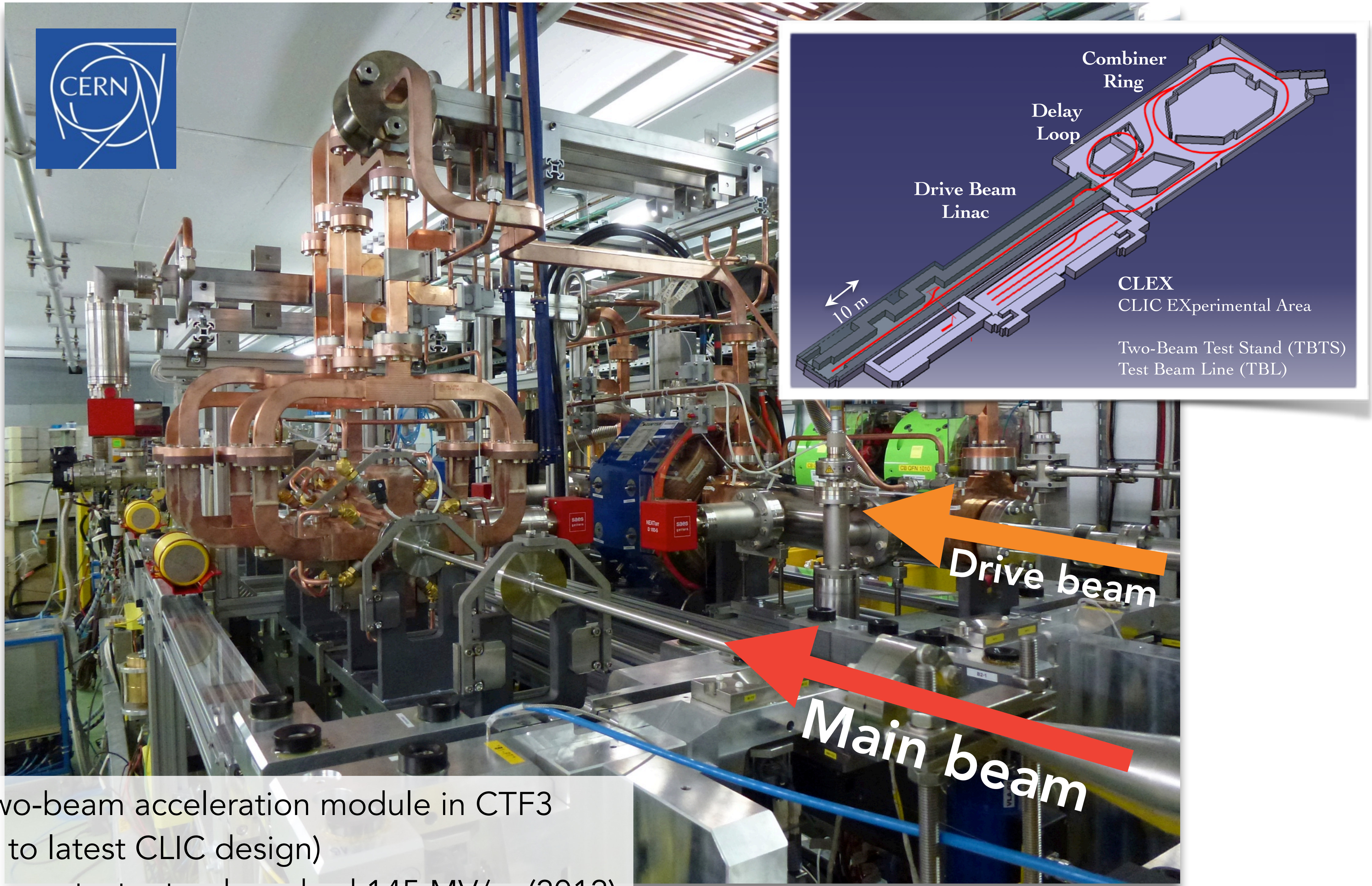
CTF3 - two-beam acceleration module

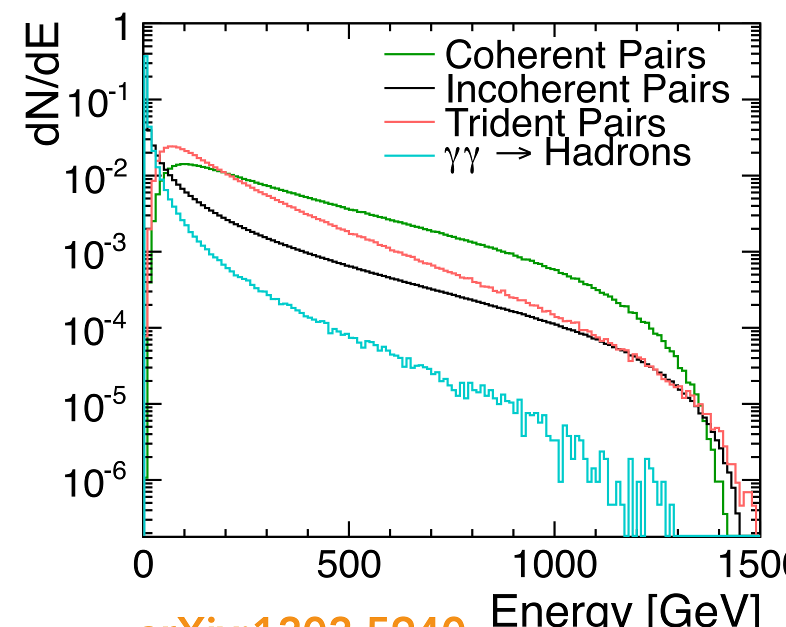


Installed two-beam acceleration module in CTF3
(according to latest CLIC design)
First two-beam tests stand reached 145 MV/m (2012)

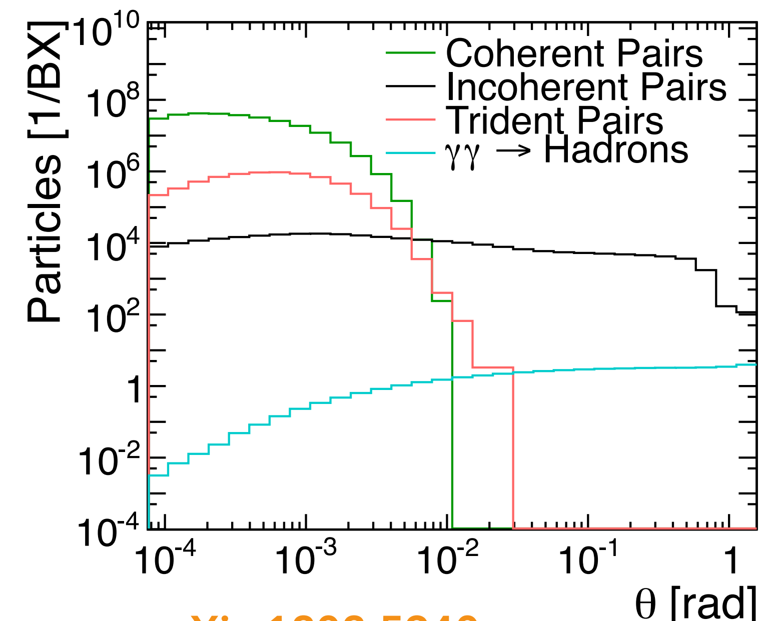
The CLIC beam structure

What is the impact of the two-beam acceleration scheme?

- The beam (and bunch) structure is rather distinct
- Very small beam size at IP leads to very high E-field
- Interactions between colliding bunches, even in the absence of a ‘hard’ interaction (~1 interesting event per bunch train), constitute large experimental background ($\gamma\gamma \rightarrow$ hadrons / e^+e^- pairs),
- Reduced to manageable level by combined p_T and timing cuts in the subdetectors
- Energy losses right at the interaction point leads to luminosity spectrum (compare ISR), but most physics processes are studied well above production threshold and profit from full luminosity



arXiv:1202.5940



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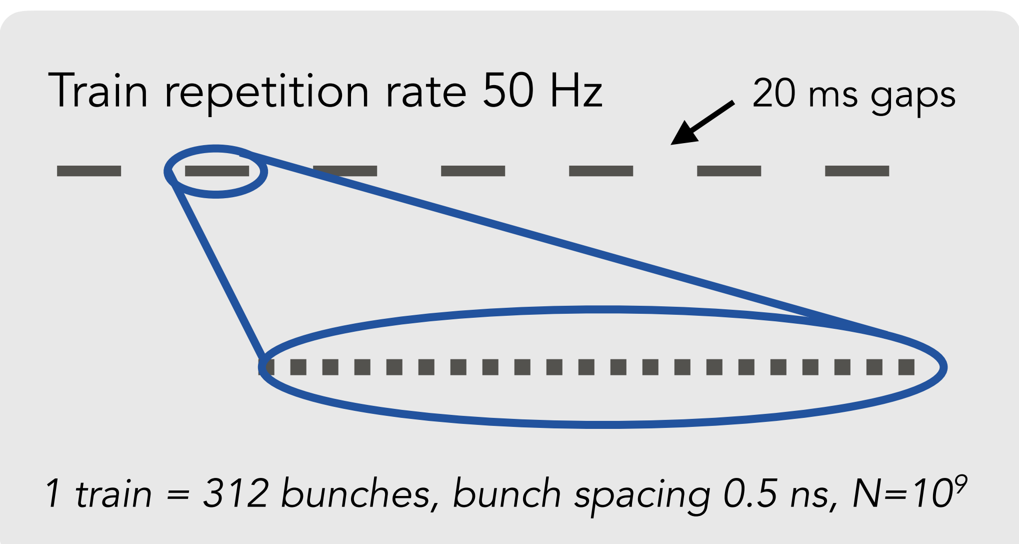

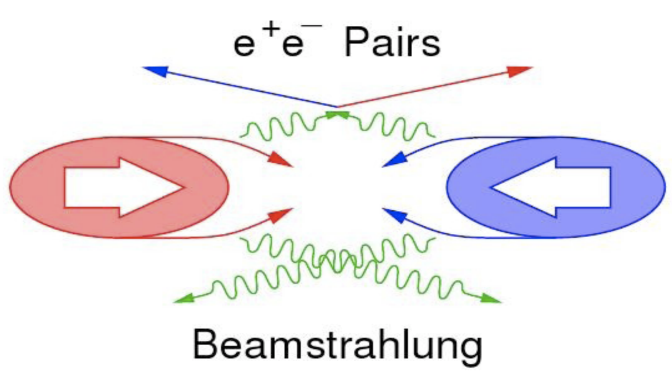

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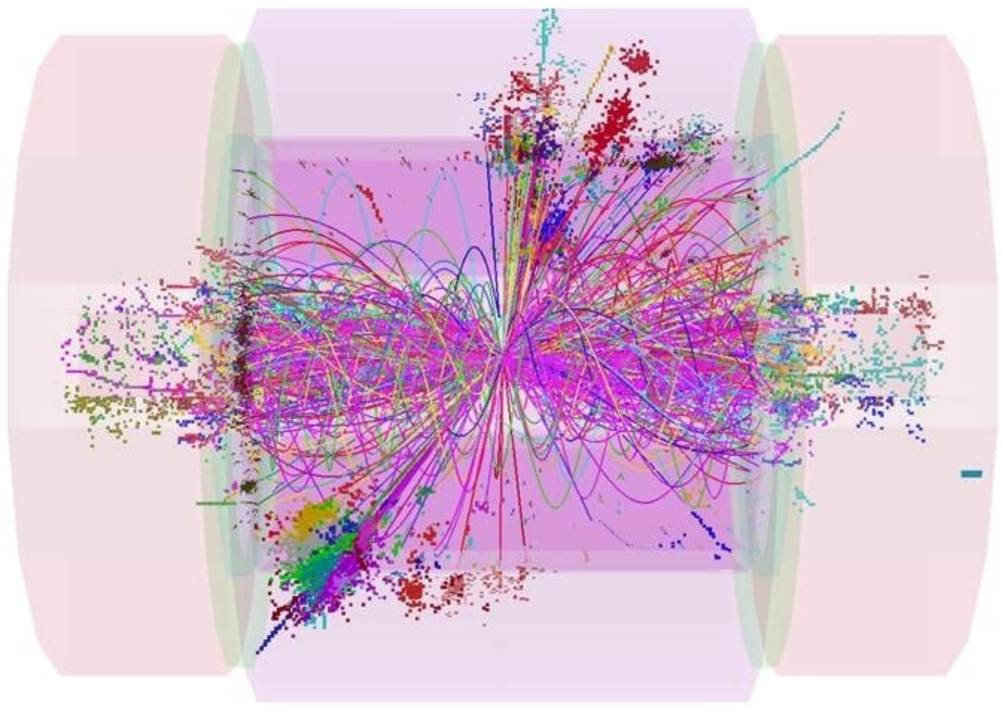
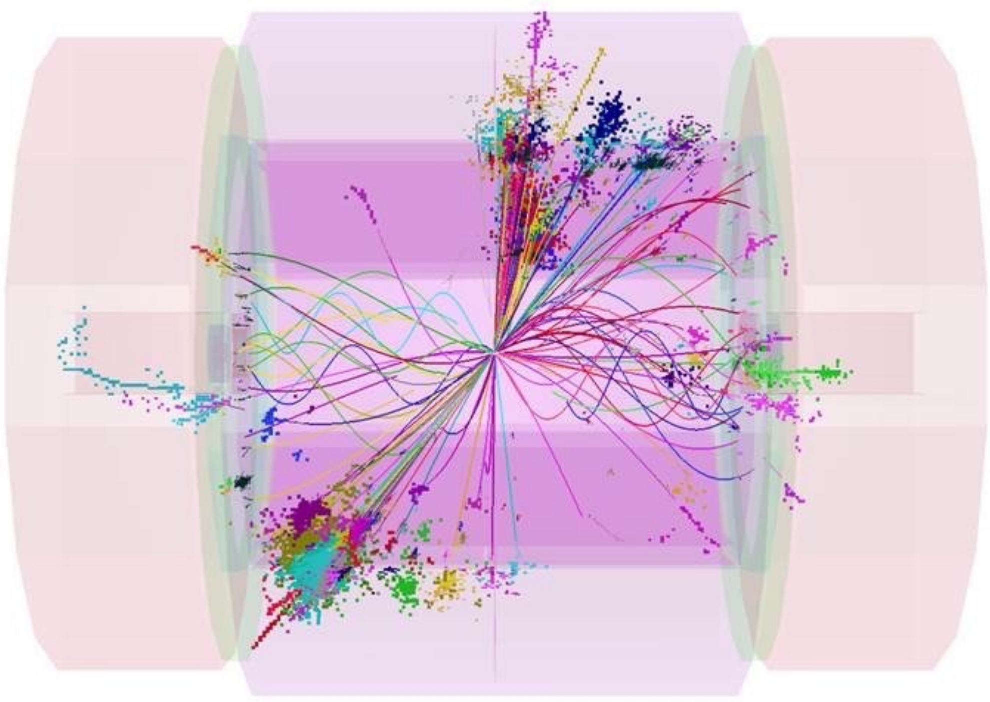
Combined p_T and timing cuts

$e^+e^- \rightarrow H^+H^- \rightarrow t\bar{b}b\bar{t} \rightarrow$ 8 jets

1.2 TeV background in reconstruction time window



85 GeV background after tight cuts



Apply cluster-based timing cuts:
- Cuts depend on particle-type, p_T and detector region,
- Allows to protect high-p_T physics objects.

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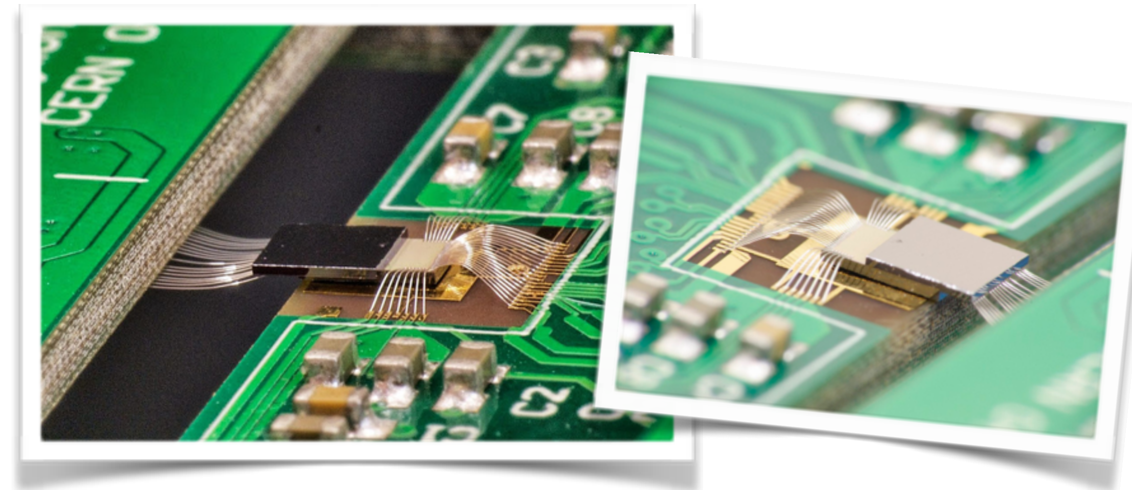
Vertex Detector

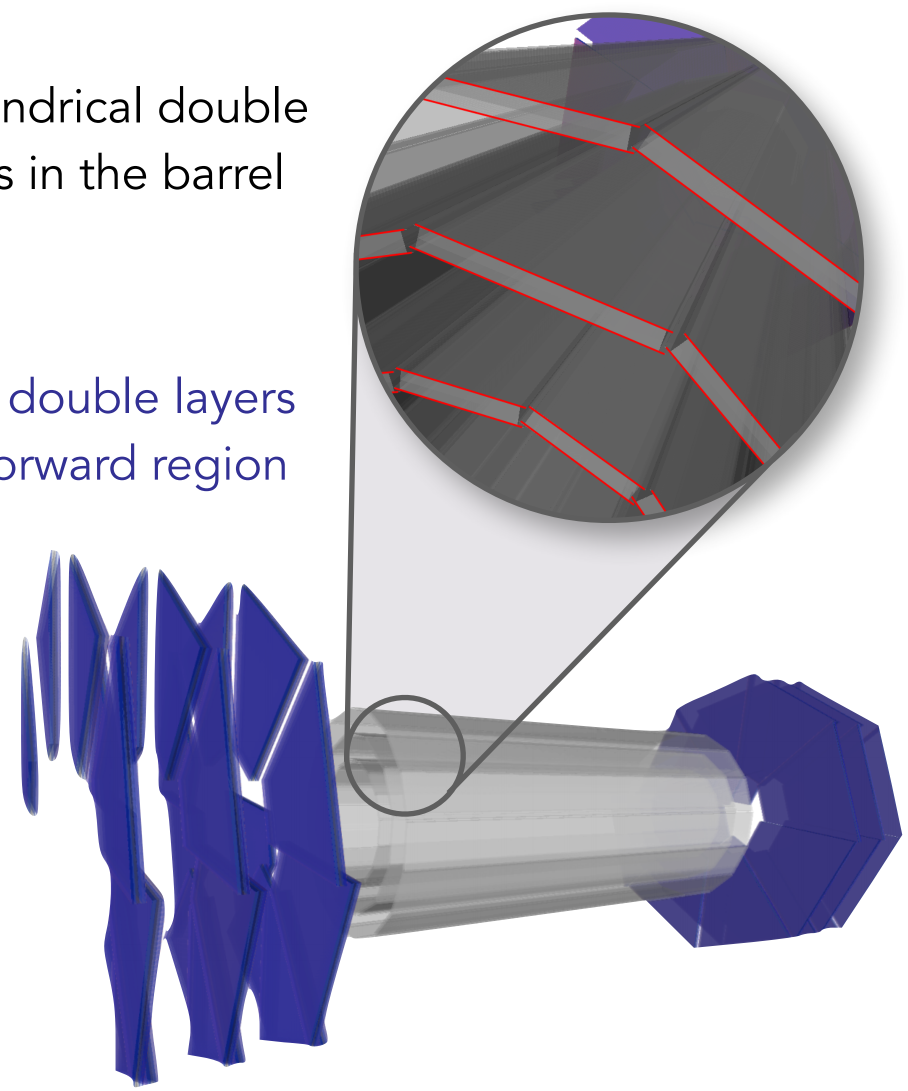
Ultra low-mass vertex detector:

- Very thin materials/sensors: 0.2% X_0 material per layer (equivalent to 200 μm of Si),
- Low-power design (no material budget for cooling components):
  - power pulsing at 50 Hz,
  - air cooling strategy (spiral airflow),
- ~2 billion pixels,
- 25 μm square pixels (charge + time).
- Single point resolution of ~3 μm (needed for flavour tagging),
- Coverage θ>7°,
- Radiation level <10^{11} $n_{eq}cm^{-2}year^{-1}$ (10^4 lower than LHC!).



3 cylindrical double layers in the barrel

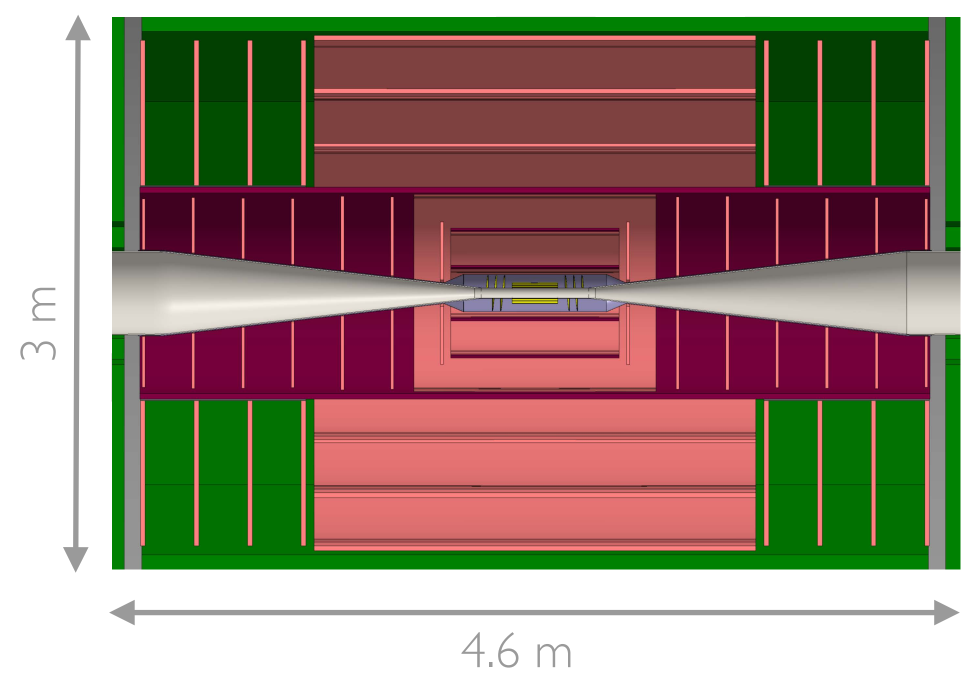
3 spiral double layers in the forward region



Trackers and Calorimetry

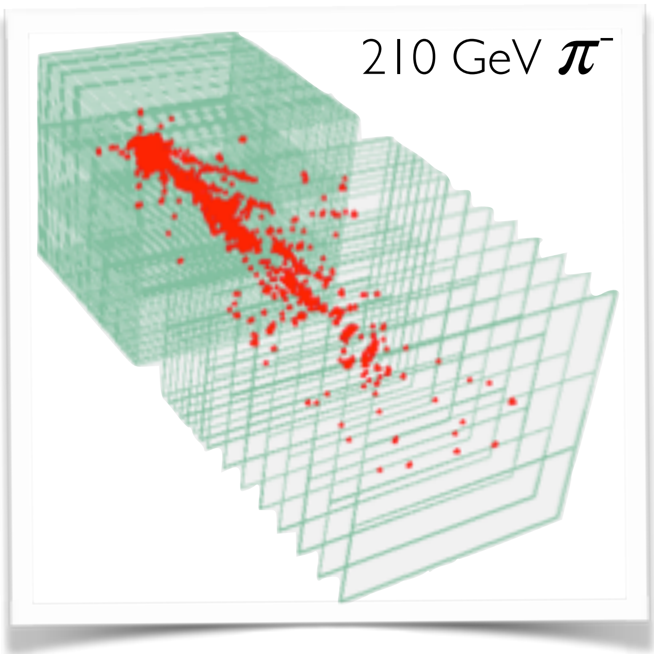
All-silicon tracker in 4T field:

- Low material budget 1-2%X_0 per layer,
- Single point resolution of ~7 μm,
- Large occupancy for pattern recognition (at least 8 hits for θ>8°),
- Ongoing optimisation of the track layout, number of layers, material budget, etc.
- Inner tracker: 3 barrel layers and 7 forward disks.
- Outer tracker: 3 barrel layers and 4 forward disks



Fine-grained calorimeters

- ECAL - 40 layers of tungsten absorbers interleaved with silicon sensors of 5x5 mm^2 (corresponding to 23 X_0),
- Configuration re-optimised to ensure good resolution of high energetic photons,
- HCAL - 60 layers of steel absorbers interleaved with scintillator tiles of 30x30 mm^2
- The CLICdp collaboration contributes to the CALICE and FCAL R&D collaborations, which have constructed and tested fine-grained SiW ECALs, a 1m^3 prototype ScW HCAL and forward calorimeter prototypes.



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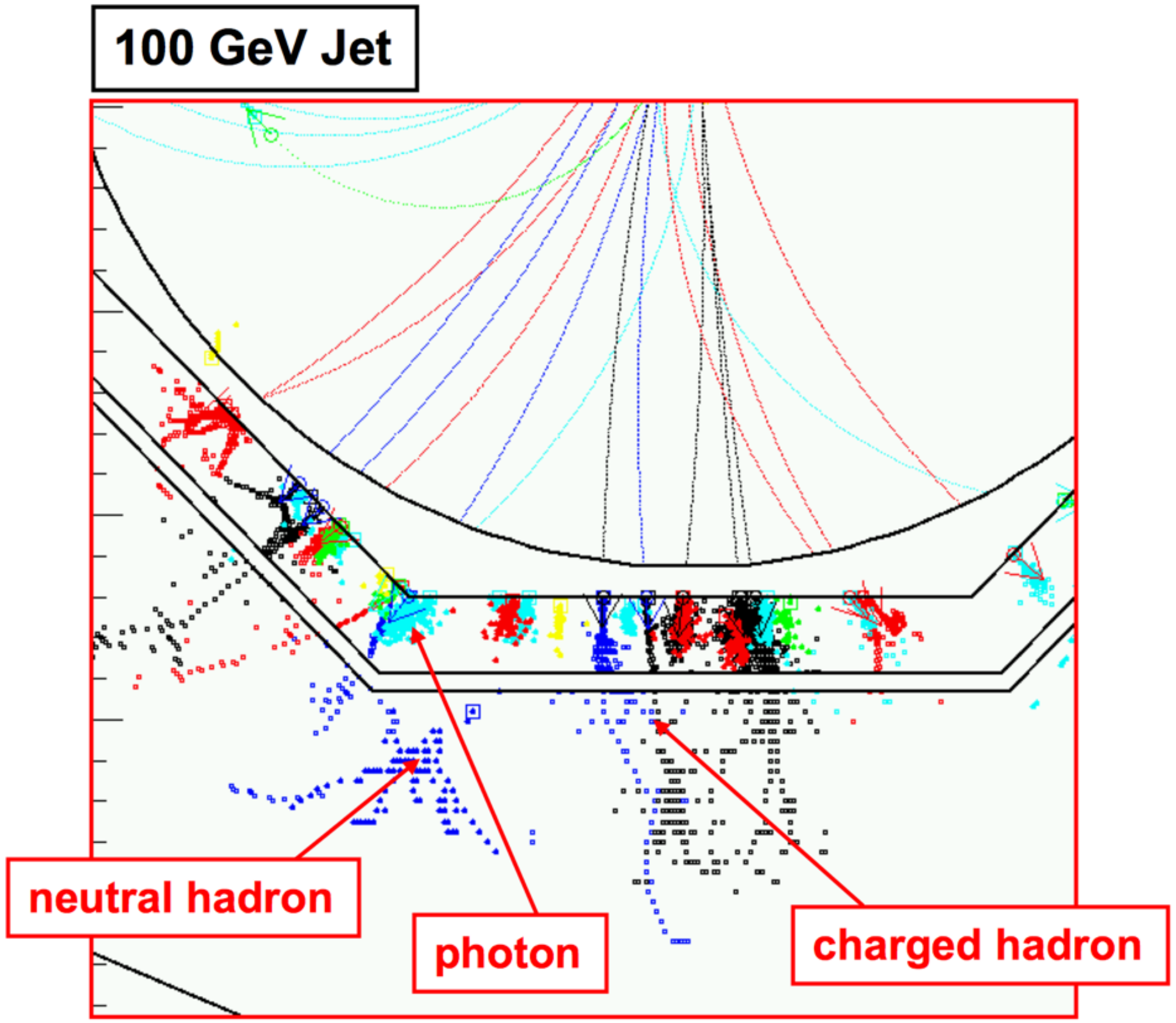
Particle Flow Calorimetry

- Typical jet contains 60 % charged hadrons, 30 % photons and 10 % neutral hadrons
  - Intrinsically "poor" HCAL energy resolution typically limits jet energy resolution
  - Identify contributions which come from charged hadrons and use information from the tracking system instead
  - Apply corrections for different identified deposits



- Particle flow algorithms (PFA) not a new concept → first used by ALEPH
- Currently planned for the CMS end-cap calorimeter upgrade
- New application to high grain calorimeters
  - Most popular algorithm 'PandoraPFA' developed at Cambridge, initially for use at linear collider
  - Complicated multi-variate analysis using information from full detector

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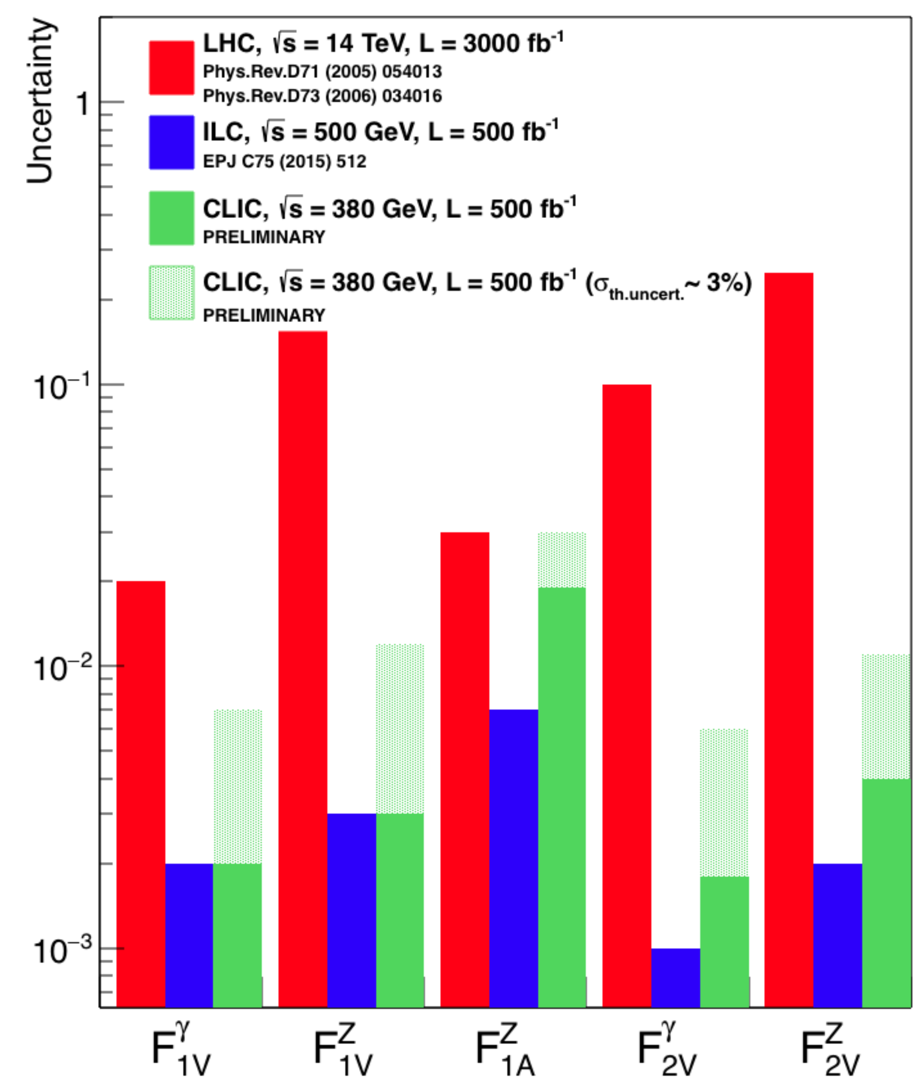
Top Physics at 380 GeV

Determination of top quark couplings to Z and γ with high precision

- Close to maximum of tt production cross section
- Determining top form factors through measurement of cross-sections and forward-backward asymmetries for different polarisations
- In many BSM models the top couplings to the electroweak interaction are substantially modified
- CLIC (green) prospects an order of magnitude better than HL-LHC (red) at $\sqrt{s}$ = 380 GeV

Uncertainties of the top quark form factors



Rare decays at $\sqrt{s}$ = 380 GeV

- e.g. t → cH, t→ cγ (competitive)

Assume production is dominated by SM and NP scale is beyond direct reach, express in terms of form factors in general Lagrangian:

$$\Gamma_{\mu}^{t\bar{t}X}(k^2,q,\bar{q}) = ie\left\{\gamma_\mu\left(\underline{F_{1V}^X}(k^2)+\gamma_5 \underline{F_{1A}^X}(k^2)\right) - \frac{\sigma_{\mu\nu}}{2m_t}(q+\bar{q})^\nu\left(i\underline{F_{2V}^X}(k^2)+\gamma_5 F_{2A}^X(k^2)\right)\right\}$$

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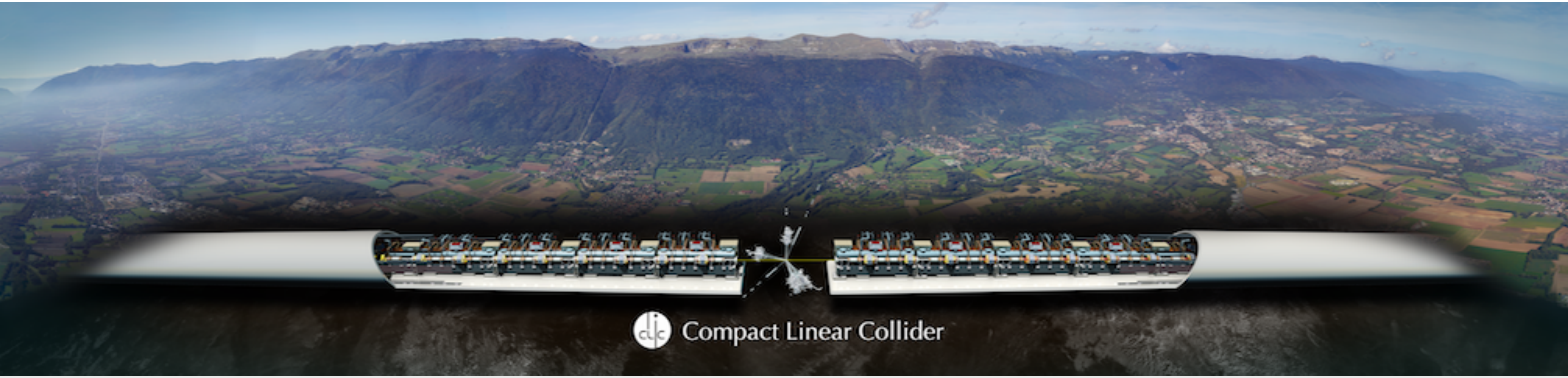
CLIC Cost and Power

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

How much will CLIC cost?
To build the first stage of the accelerator is estimated to cost about 50% more than the cost for the LHC, **~6690 MCHF**. Most of this cost is in excavating the tunnels and caverns, and in the two-beam modules. The LHC construction cost was comparatively cheap because it used, to a large extent, the pre-existing LEP tunnels and infrastructure. To build a detector for CLIC is estimated to cost approximately the same as each of the LHC experiments ATLAS or CMS, **~500 MCHF**. Most of the detector cost is in the calorimeters, the superconducting coil and the yoke.

arXiv:1202.5940	CLIC_ILD (MCHF)	CLIC_SiD (MCHF)
Vertex	13	15
Tracker	51	17
Electromagnetic calorimeter	197	89
Hadronic calorimeter	144	86
Muon system	28	22
Coil and yoke	117	123
Other	11	12
Total (rounded)	560	360

How much power will CLIC use?
Designed to be a high luminosity, high energy linear collider, CLIC will inevitably need high power. Compared to an accelerator using superconducting technology, CLIC nevertheless has very low power consumption in stand-by or "waiting-for-beam" mode. A preliminary analysis of t**he overall CLIC energy consumption per year for the various stages shows that the first stage of CLIC would be similar to LHC**, and the second stage similar to the total CERN energy consumption. However, work is on-going in several domains (overall re-baselining, permanent magnets, air-handling etc.) to further reduce the anticipated power consumption of CLIC.



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