Status of the Compact Linear Collider (CLIC) project

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on behalf of the CLICdp Collaboration

Lake Louise Winter Institute 2018

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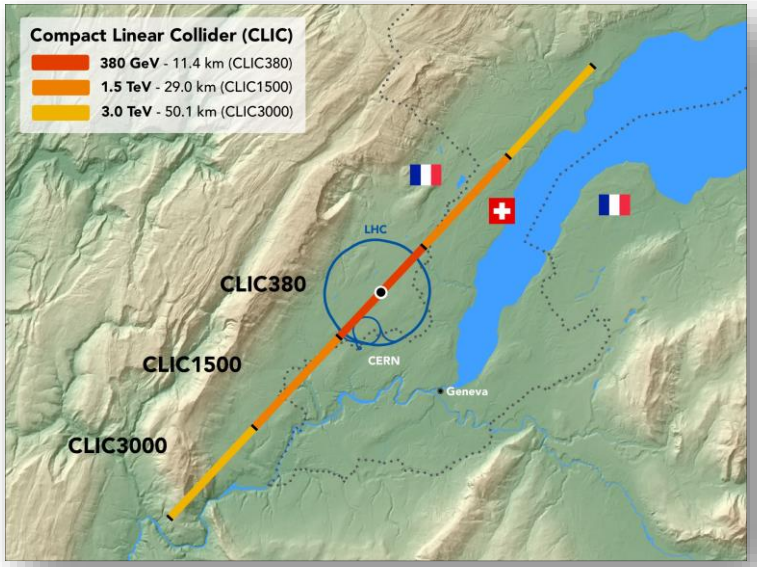
The CLICdp Collaboration

CLIC detector and physics study (CLICdp)

- Physics studies
- Detector technology R&D
- Close connection to ILC detector concepts, CALICE, FCAL, AIDA-2020 project

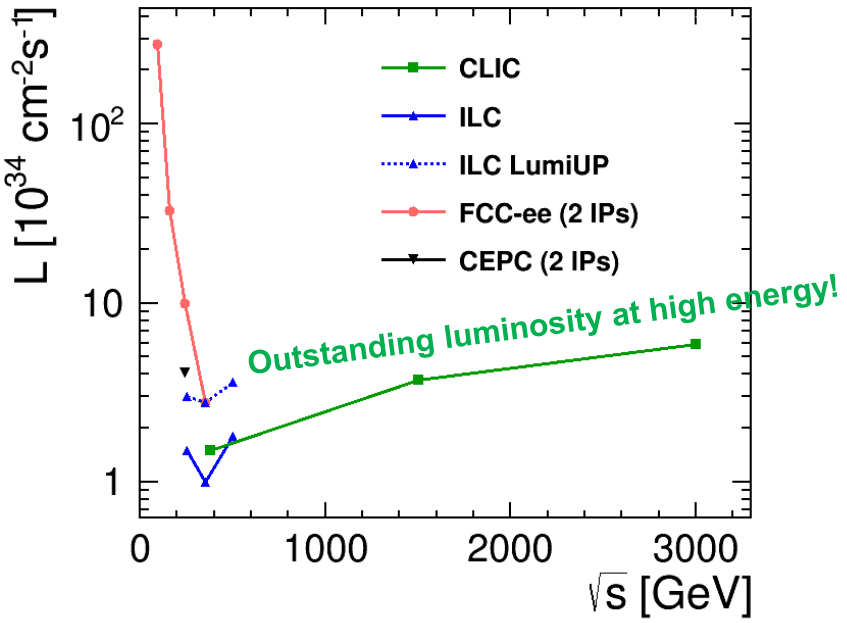
158 members from 30 institutes in 18 countries

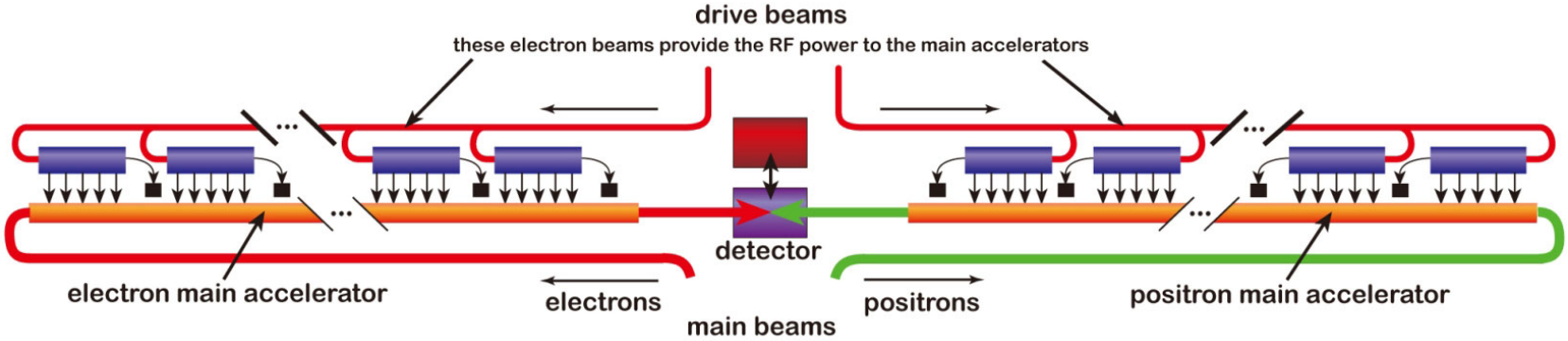


CLICdp and accelerator study: http://clic.cern/

The CLIC accelerator concept

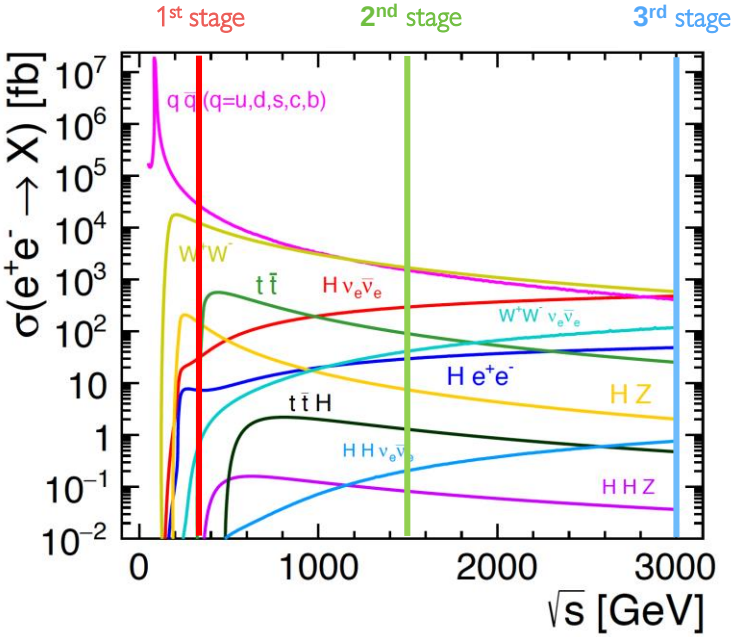
- Two-beam acceleration scheme (drive/main beams)
  - High accelerating gradient of 100 MV/m
  - About 150'000 room temperature RF cavities
  - Allows a 3 TeV collider to be built in only 50 km (compact)
- Electron beam polarization at all energies
- Energy staging from 380 to 3000 GeV

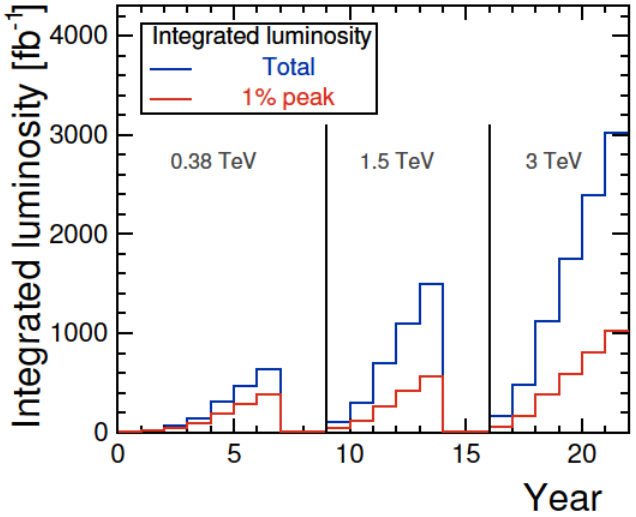




Conceptual Design Report: CERN-2012-007

A Staged Physics Program





1) $\sqrt{s}$ = 380 GeV (500 + 100 fb^{-1})

- Higgs/top precision physics
- Top mass threshold scan

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

- Focus: BSM searches
- Higgs/top precision physics

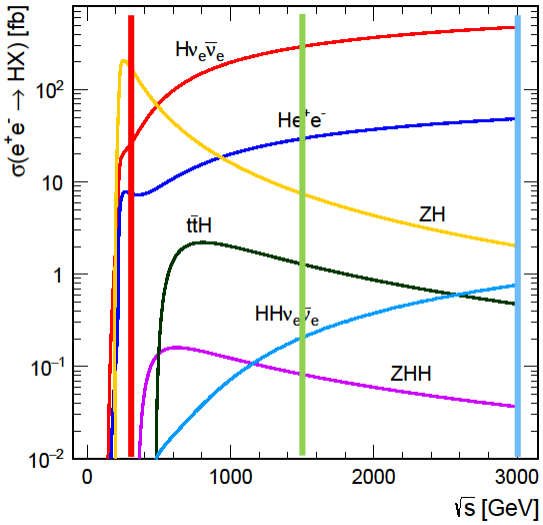
3) $\sqrt{s}$ = 3 TeV (3.0 ab^{-1})

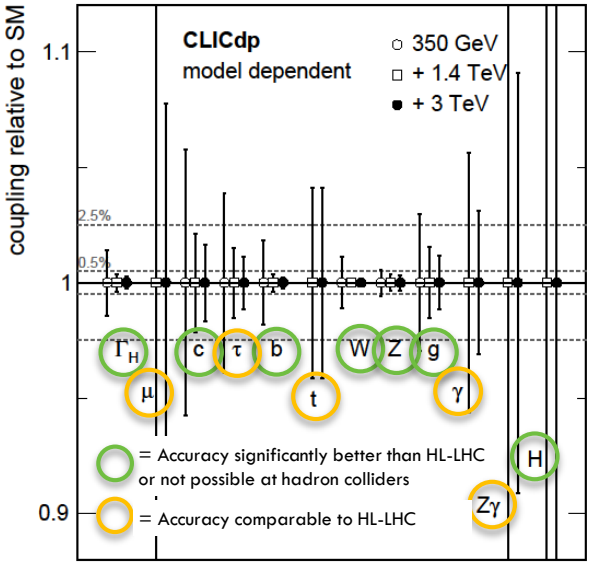
- Focus: BSM searches
- Higgs/top precision physics

Staging can be adapted to possible LHC discoveries: CERN-2016-004

Higgs Physics at CLIC

- CLIC covers several Higgs production processes
- Highlights:
  - **Vector-boson fusion** (dominates at high energies)
  - Higgsstrahlung $e^+e^- \rightarrow ZH$ - **model independent measurement of Higgs properties** using the Z-recoil mass (unique to lepton colliders)
  - Double Higgs production: simultaneous extraction of **model-independent tri-linear self-coupling** (Δλ CLIC: ~10% from differential distributions) and **quartic coupling** (gHHWW: ~3%)
  - Higgs couplings and width can be determined with a **percent-level statistical uncertainty**
    - **in many cases significantly better than or not even possible HL-LHC**

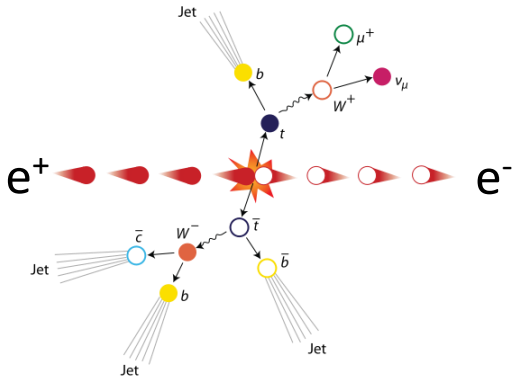




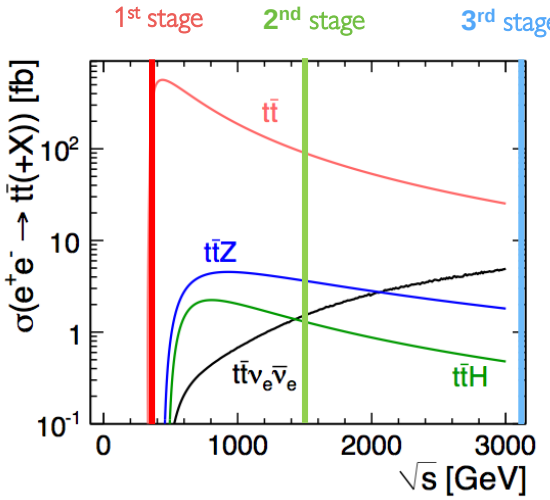
Comprehensive report on our Higgs studies in Eur. Phys. J. C 77 (2017) 475

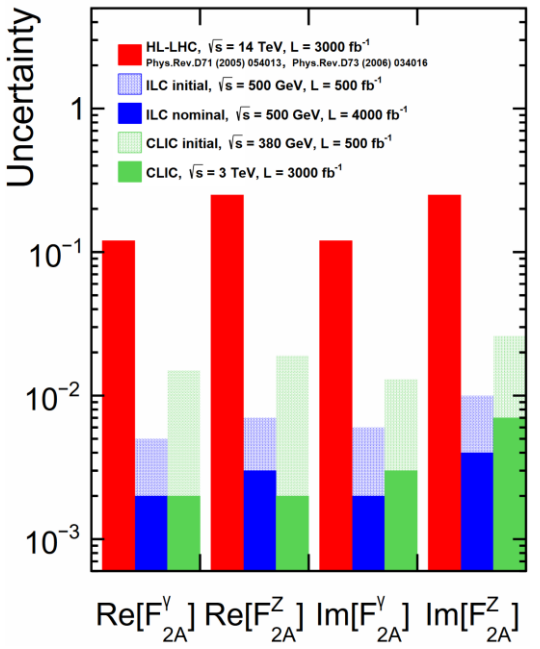
Top Physics at CLIC

- Several hundreds of thousands of top quark pairs are produced at CLIC
- Top quarks have not been studied in e^+e^- collisions yet
- CLICdp is preparing a comprehensive top physics report



- Selected highlights
  - **Complete $t\bar{t}$ study at all three stages**: 380 GeV (resolved), 1.5 TeV (semi-boosted), 3 TeV (boosted)
  - **Threshold scan:** top mass with precision of about 50 MeV
  - **Top couplings** at high precision
    - e.g. **top Yukawa coupling** ($e^+e^- \to t\bar{t}H$)

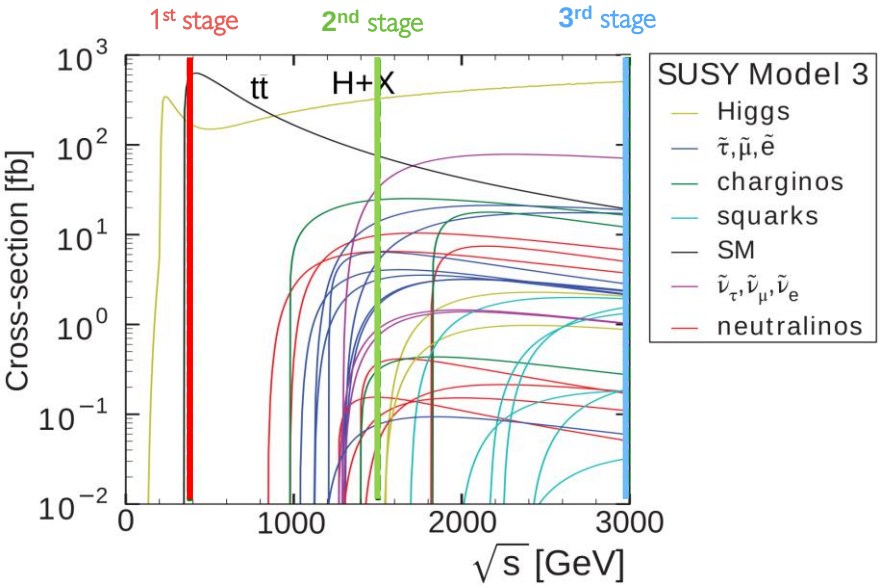




BSM Physics at CLIC

- Indirect searches via precision observables
  - discovery beyond the center-of-mass energy
- Direct Production of new particles
  - Up to the kinematic limit ($\sqrt{s}/2$ for pair production)
  - Precision measurements - measure the mass and production cross-sections to percent-level
  - Complements the HL-LHC program to measure heavy SUSY partners

- Highlights:
  - Lepton colliders offer **superior sensitivity to EW** state
  - Indirect searches give access **new physics scale** O(10) TeV
  - **Tests of EW symmetry breaking** (vector boson scattering)
  - **Test deviations from QED** (Di-photon production at 3 TeV)



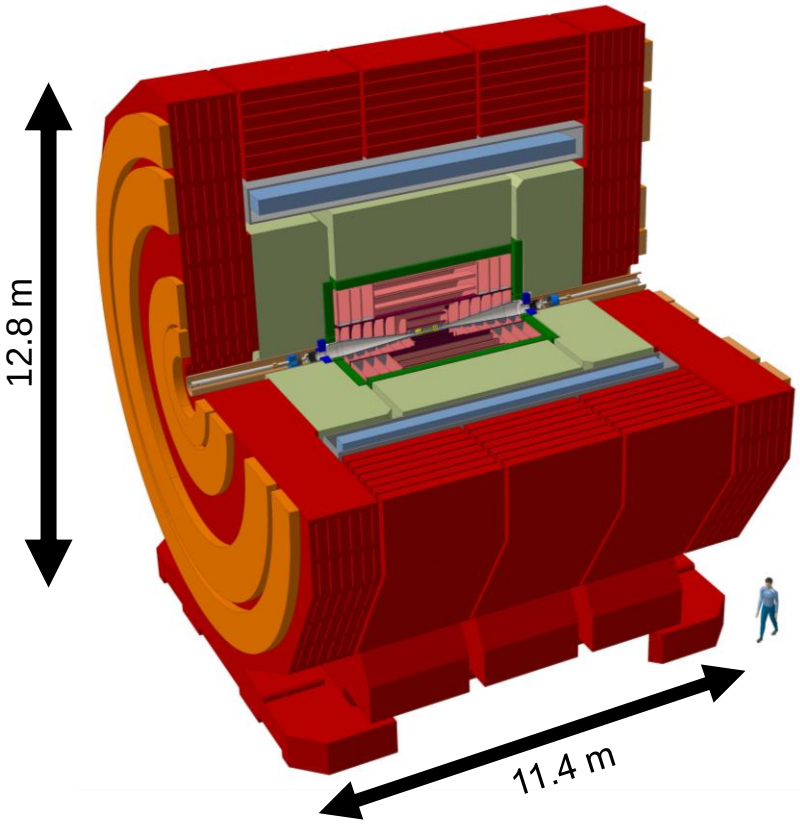
New particle/scenario	CLIC @ 3000 GeV reach
Anomalous gauge couplings	$-0.001 < a_4 < 0.0011$ $-0.00070 < a_5 < 0.00074$
Extra dimensions $M_S/\lambda^{1/4}$ (95% CL)	~16 TeV
Contact interactions (Λ') (95% CL)	~21 TeV
Chargino, neutralinos	≤ 1.5 TeV
Sleptons	≤ 1.5 TeV
Z' (SM couplings)	~20 TeV
Triple gauge coupling (95% CL)	λ_γ: 0.0001
Higgs composite scale	~70 TeV

Example models, CLIC 3 TeV, up to 2 ab^{-1}

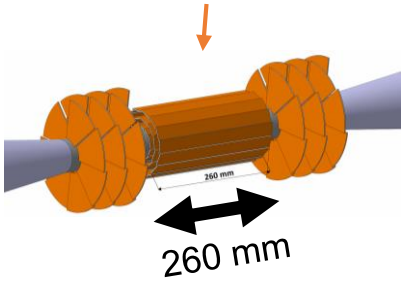
More information on BSM physics at CLIC: CLICdp-Conf-2017-018

CLIC detector model 'CLICdet'

- **Iron return yoke** instrumented with muon detectors, for muon identification
- 4 T superconducting **solenoid magnet** (R_{in} = 3.4 m, L = 8.3 m)
- Fine grained **calorimetry system** (ECAL and HCAL) using particle flow approach
  - Strong contribution to the CALICE and FCAL calorimeter R&D collaborations



- Low-mass all-silicon **tracking system** with separate tracker and **vertex detector**



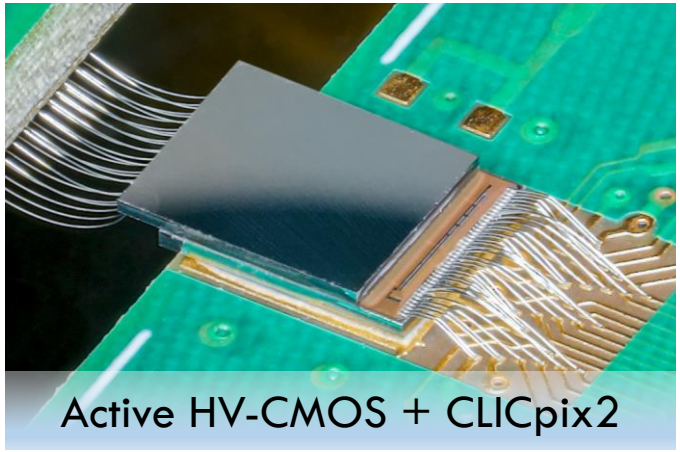
- Enclosed in forward region: LumiCal (luminosity monitoring), BeamCal (extended coverage)

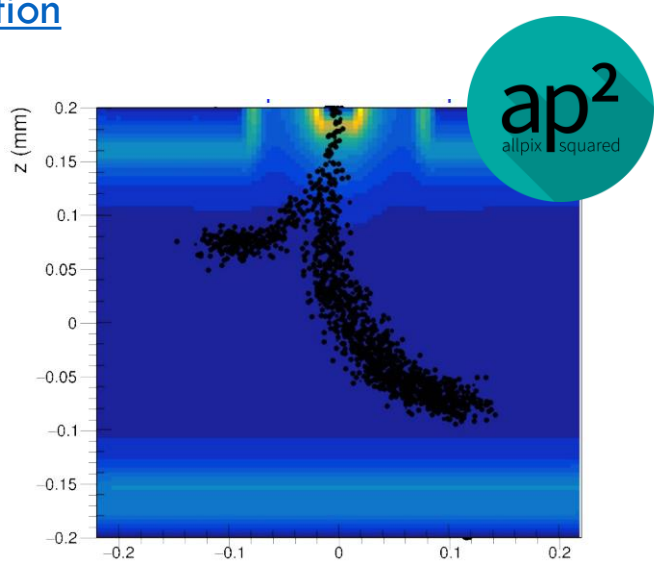
More details: "CLICdet: The post-CDR CLIC detector model", CLICdp-Note-2017-001

Silicon R&D

Pixel technology

- Research areas: sensors, readout, powering, mechanical integration and cooling
- Beam tests: of both hybrid (readout ASICs down to 65 nm) and monolithic assemblies
- Challenging: position-resolution target of ~3 µm for the vertex detector
- Software development:
  - CaRIBOu – detector readout system
  - Allpix^2 - generic pixel detector simulation

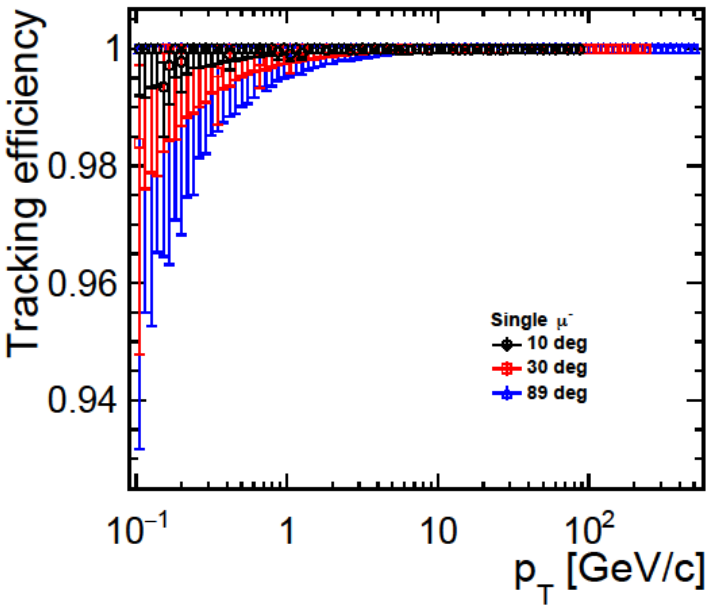


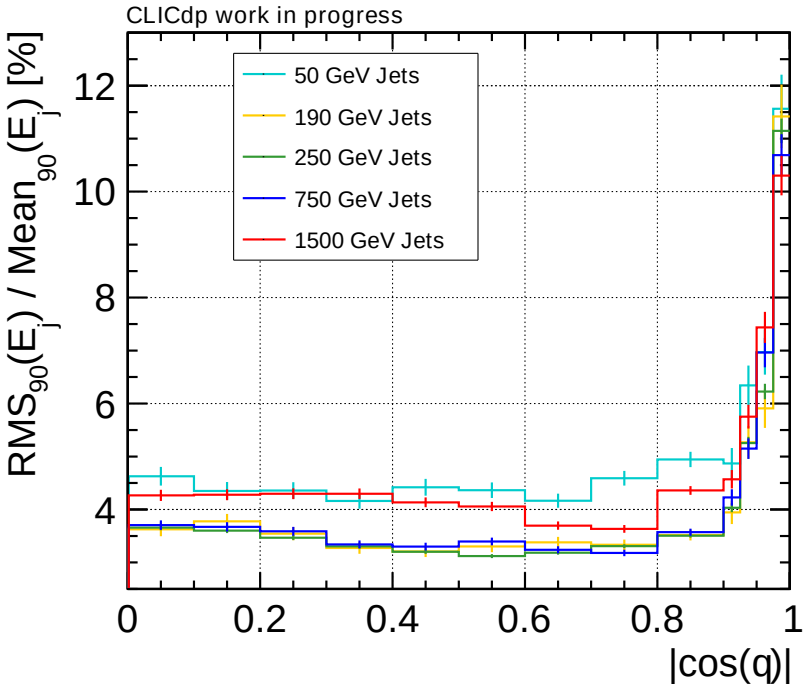


Reconstruction and Simulation

Validation of CLICdet

- Tracking – target muon momentum resolution of $\sigma_{p_T}/p_T^2 < 2 \cdot 10^{-5}$ GeV^{-1}
- Particle Flow Algorithm (PFA) – target jet energy resolution of $\frac{\sigma_E}{E} < 3.5{-}5\ \%$
- Flavor tagging





Summary and conclusions

Status

- CLIC is a future multi-TeV e^+e^- collider at CERN
  - **Powerful** tool to address the open questions in particle physics
  - **Mature** project with energies between 380 GeV and 3 TeV
  - **Optimized** for a broad precision physics program
  - Well-established and **flexible** physics program (adapt to potential discoveries)
  - Feasibility **demonstrated** through extensive prototyping, accelerator and detector R&D

Outlook

- The CLICdp Collaboration is currently preparing a series of reports and summary documents for the European Strategy Update

Thank you for your attention!

Time plan

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