CLIC Physics and Detector Study

Outline:

- CLIC physics potential
- Context
- CLIC detector requirements
- Current activities and R&D plan
- Preparations for the CLIC CDR
- Summary

General Physics Context

- New physics expected in TeV energy range
  - E.g. motivated by particle astrophysics (dark matter)
  - Higgs, Supersymmetry, extra dimensions, …?
- LHC will indicate what physics, and at which energy scale (is 500 GeV enough or need for multi TeV?)
- Even if multi-TeV is final goal, most likely
  CLIC would run over a range of energies (e.g. 0.5 – 3.0 TeV)

CLIC physics up to 3 TeV

What can CLIC provide in the 0.5-3 TeV range?

Higgs physics:

- Complete study of the light standard-model Higgs boson, including rare decay modes (rates factor ~5 higher at 3 TeV than at 500 GeV)
  - Higgs coupling to leptons
  - Study of triple Higgs coupling using double Higgs production
- Study of heavy Higgs bosons (supersymmetry models)

Supersymmetry:

- Complete study of light sparticles
- Discovery of heavy sparticles

See talk Gian Giudice on Tuesday morning

See physics session Wednesday morning

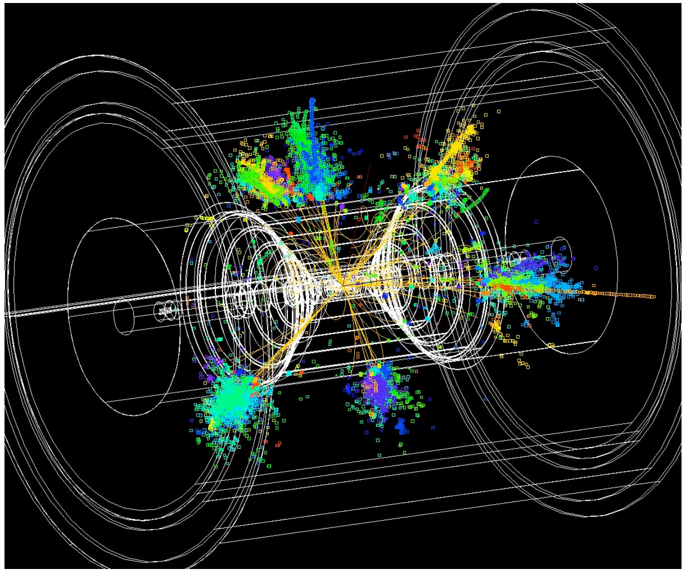
And in addition:

- Probe for theories of extra dimensions
- New heavy gauge bosons (e.g. Z')
- Excited quarks or leptons

How? Context

In several aspects the CLIC detector will be more challenging than ILC case, due to:

- Energy 500 GeV => 3 TeV
- More severe background conditions
  - Due to higher energy
  - Due to smaller beam sizes
- Time structure of the accelerator



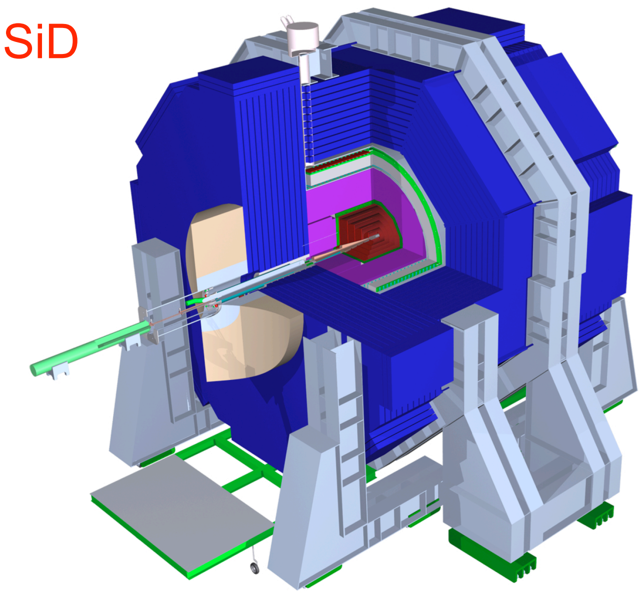
Nevertheless, most of the R&D currently carried out for the ILC is most relevant for CLIC.

Many years of investment in ILC e^+e^- physics/detector simulations, hardware R&D and detector concepts

No need to duplicate work.

ILC experiment concepts

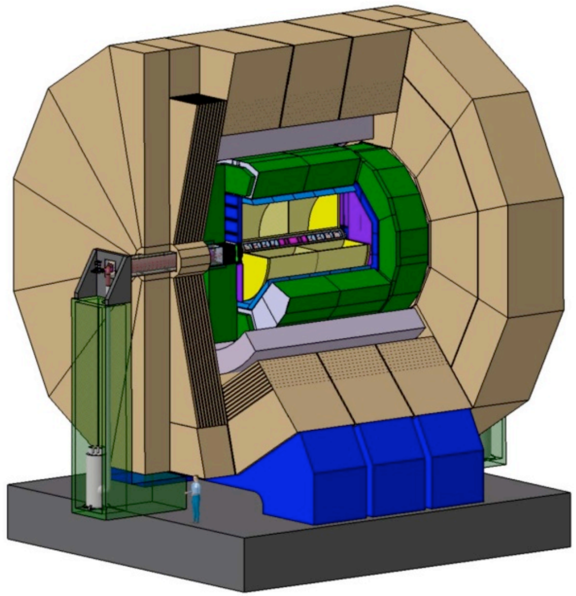
SiD



http://silicondetector.org

"Validated"

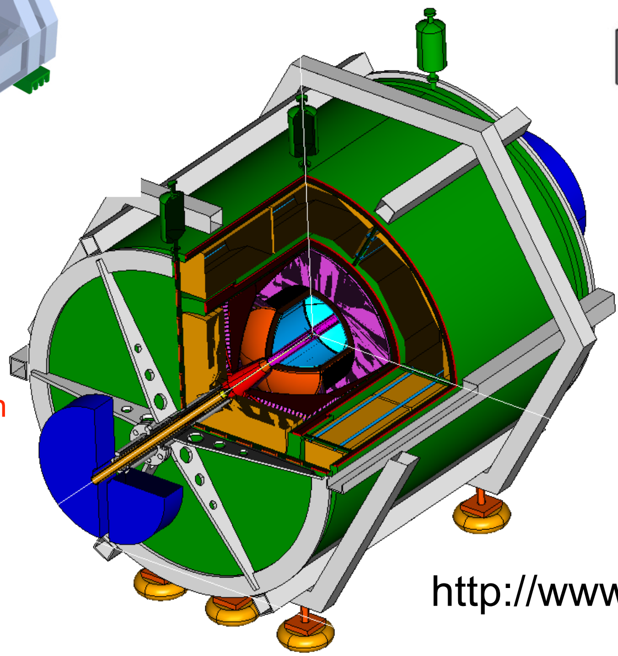
ILD



http://www.ilcild.org/

"Validated"

4th



http://www.4thconcept.org/

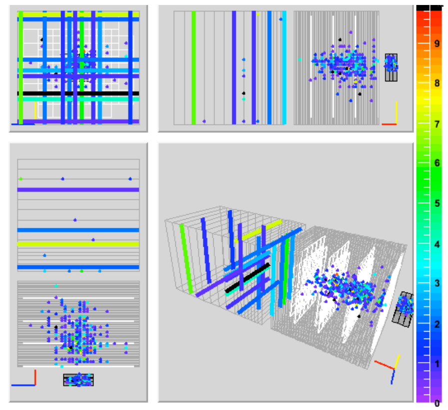
3 LoI documents submitted 31/3/2009

LC technology collaborations

Large international collaborations for Linear Collider detector technology studies:

CALICE

- Fine–grained calorimetry, based on particle flow analysis
- https://twiki.cern.ch/twiki/bin/view/CALICE/WebHome



LC-TPC

- Time projection chmber based on MPGD readout
- http://alephwww.mppmu.mpg.de/~settles/tpc/lp/wpmtg/wpmtg.html

SILC

- Silicon-based tracking technologies
- http://lpnhe-lc.in2p3.fr/

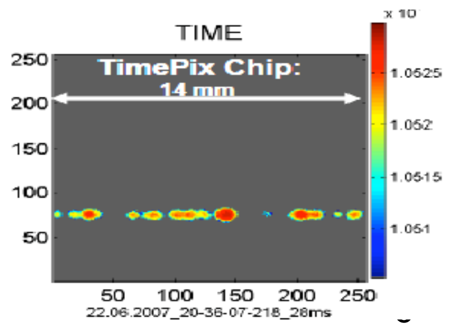
FCAL

- Very forward region: background studies and calorimetry
- http://www-zeuthen.desy.de/ILC/fcal/

EUDET

EU-funded FP6 project on LC detector technologies

http://www.eudet.org/



List not fully complete (e.g. vertex detector groups)

Until recently these technology collaborations concentrated on ILC

LCD collaboration with ILC

CLIC study: Working together with the **ILC detector concepts** and with the linear collider detector **technology collaborations** to study **modifications to the ILC concepts for CLIC energies and beam conditions.**

Newly created Linear Collider (LCD) project at CERN, has formally joined existing linear collider groups:

- ILC validated detector concepts
  - **ILD**
  - **SiD**
- Technology collaborations
  - **LC-TPC** (TPC development)
  - **CALICE** (calorimetry based on Particle Flow Analysis)
  - **FCAL** (very forward region studies)
- European project
  - **EUDET**

More to follow….

CLIC detector requirements

See talk Mark Thomson, Tuesday morning

See special requirements session Wednesday morning

Compared to ILC:

- Energy 500 GeV => 3 TeV
  - Need for deeper calorimetry
  - Possible need for higher granularity, better intrinsic resolution (boosted jets)
  - Forward region tracking/calorimetry becomes more important
  - Possible need for a deeper tracker
  - Changes to flavour tagging, lepton identification

- More severe beam-induced background conditions
- Time structure of the accelerator (0.5 ns bunch separation)
  - Need larger crossing angle (20 mrad)
  - Careful forward region design to avoid back-scattering
  - Larger inner radius of vertex detector
  - Possible need for smaller granularity in vertex/tracker (occupancy issue)
  - Time-stamping of hits in all detectors

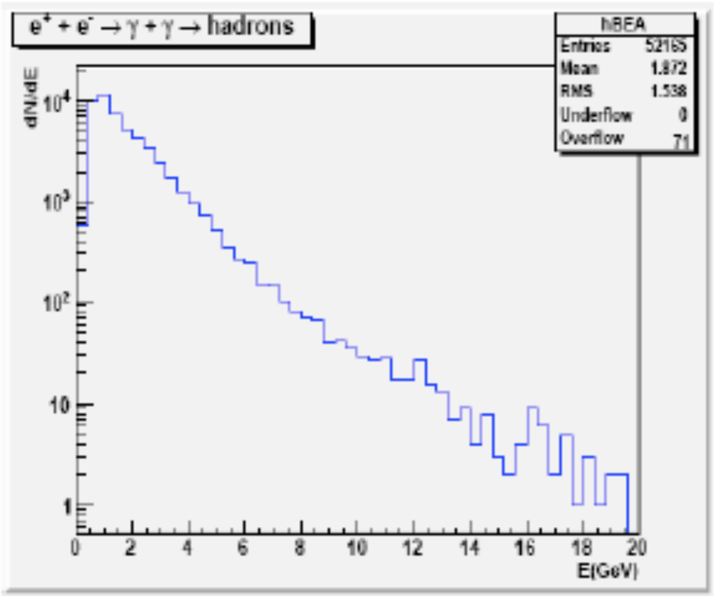
Time-stamping requirements (1)

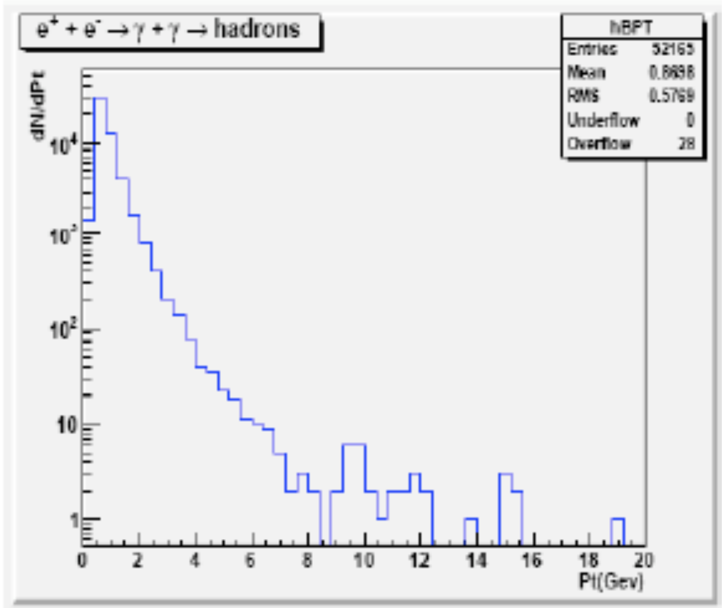
CLIC: bunch crossings separated by 0.5 ns, 312 bunches in the train

High beamstrahlung:

- **Coherent pairs** (3.8×10^{8} per bunch crossing) <= disappear in beam pipe
- **Incoherent pairs** (3.0×10^{5} per bunch crossing) <= inner vertex layers
- γγ interactions => hadrons (**3.3 hadron events per bunch crossing**)

At 3 TeV ~ 3.3 $e^+ + e^- \rightarrow \gamma\,\gamma \rightarrow$ hadrons events / Bx → ~ 13 particles/Bx





<Eh> ~ 1.9 GeV <Pt> ~ 0.9 GeV.

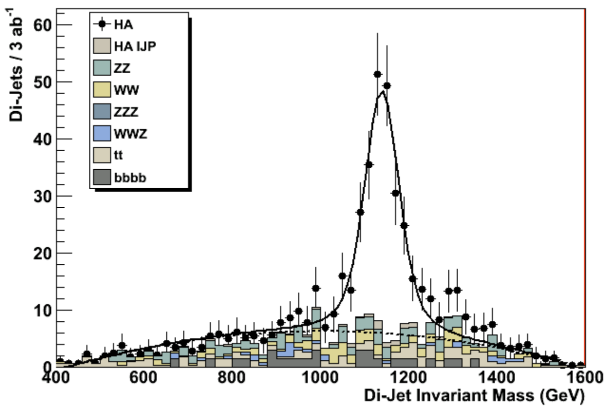
Time stamping requirements (2)

Simulation example of heavy Higgs doublet H^0A^0 at ~1.1 TeV mass (supersymmetry K' point)

e+e- ➔ H^0A^0 ➔ bbbb

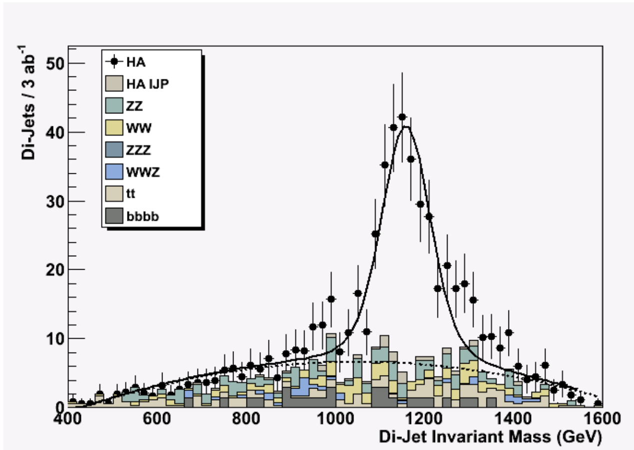
Signal + full standard model background + γγ=>hadron background

CLIC-ILD detector: Mokka+Marlin simulation, reconstruction + kinematic fit.



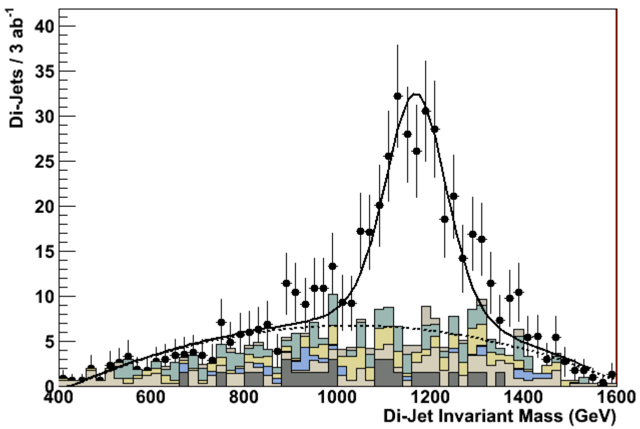
Zero bunch crossings

M_A mass resol. 3.8 GeV



20 bunch crossings

M_A mass resol. 5.6 GeV



40 bunch crossings

M_A mass resol. 8.2 GeV

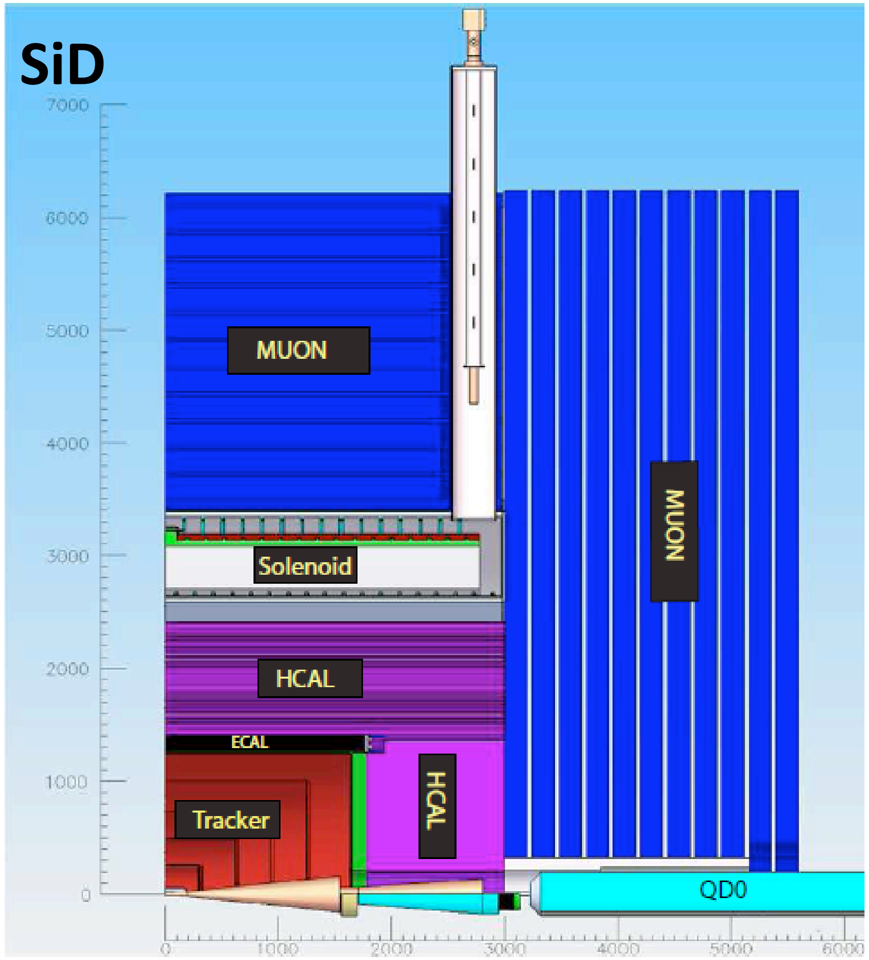
Current activities

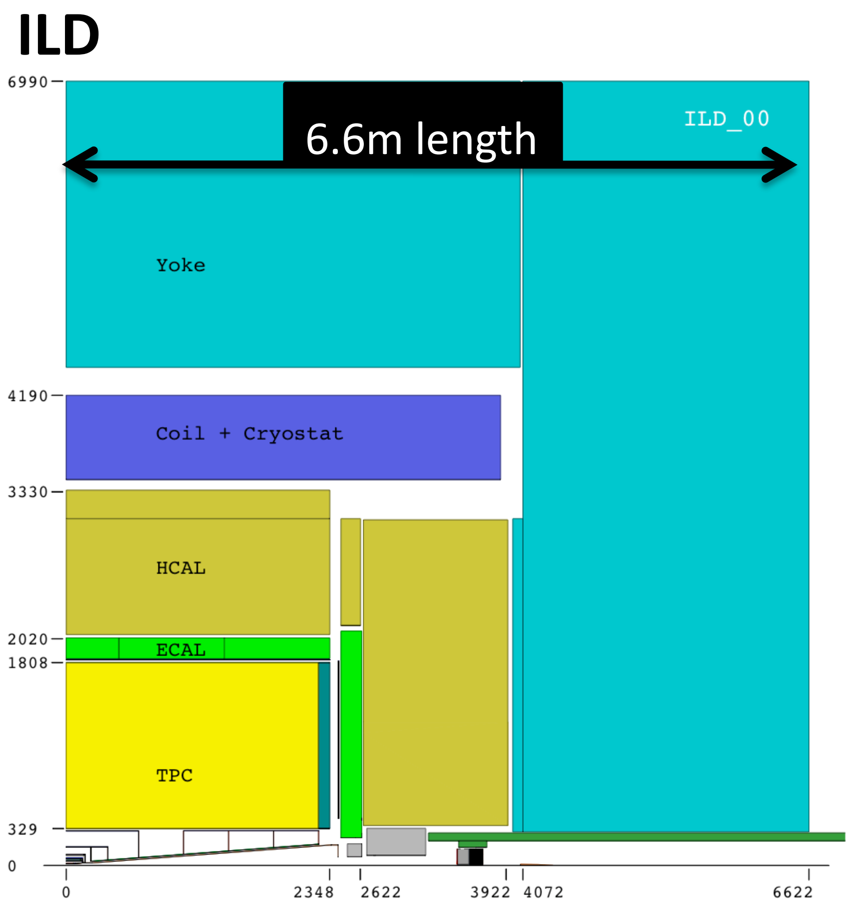
Current activities concentrate on preparation for CDR

- Mostly simulation studies:
  - Demonstrate that CLIC physics potential can be extracted from detector
  - Propose ILD-type and SiD-type detectors that can do the job
- Concentrate on critical issues
  - Determine required sub-detector performances to see the physics
    - Adapted to CLIC energies
    - In the presence of beam/background conditions
    - With particular emphasis on time-stamping needs
  - Redesign of the very forward region
  - Take engineering aspects, cost etc into account
- Prepare a hardware R&D plan

CLIC’09 program for physics/detector (WG1) has been devised to make progress with the above plan

ILC Detector Concepts





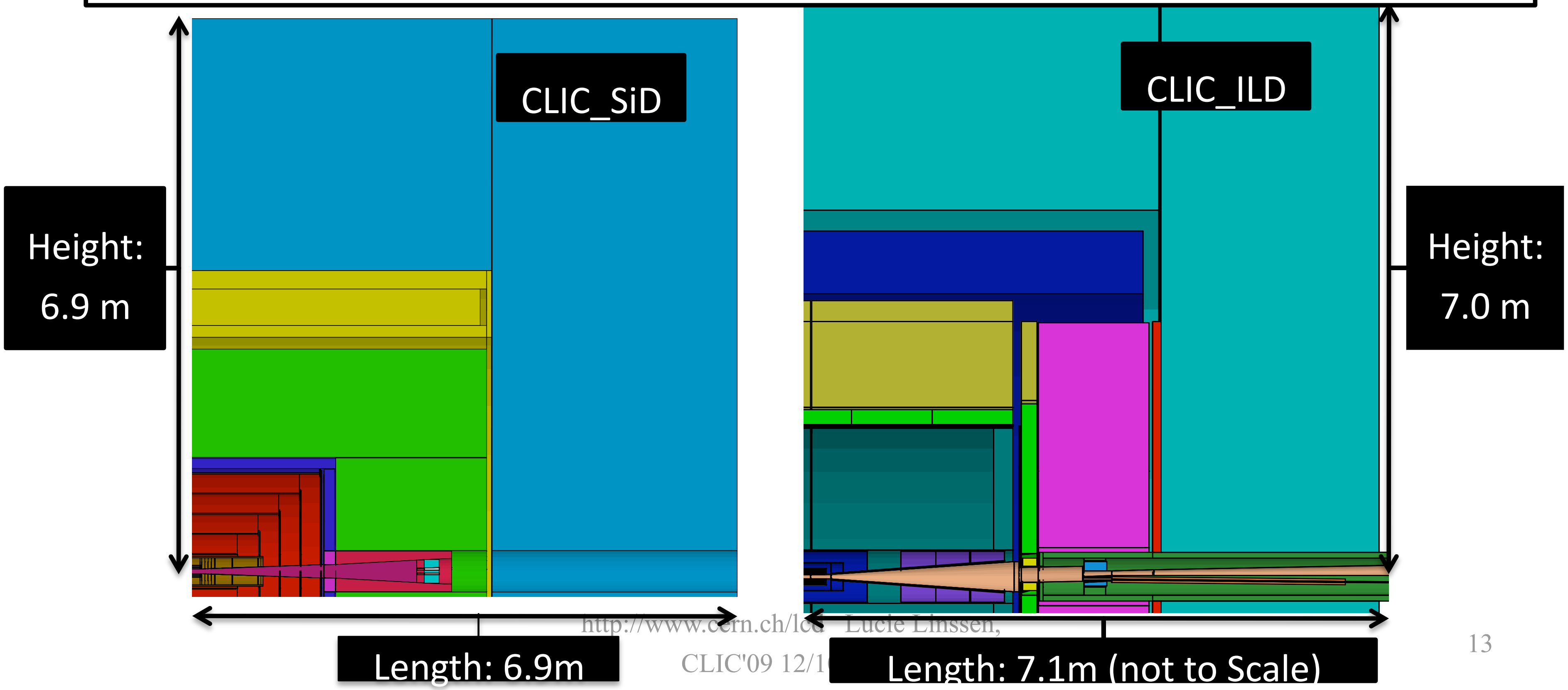
Andre Sailer

From ILC to CLIC Detectors

- Created CLIC 3 TeV detector models using SiD and ILD geometries and software tools

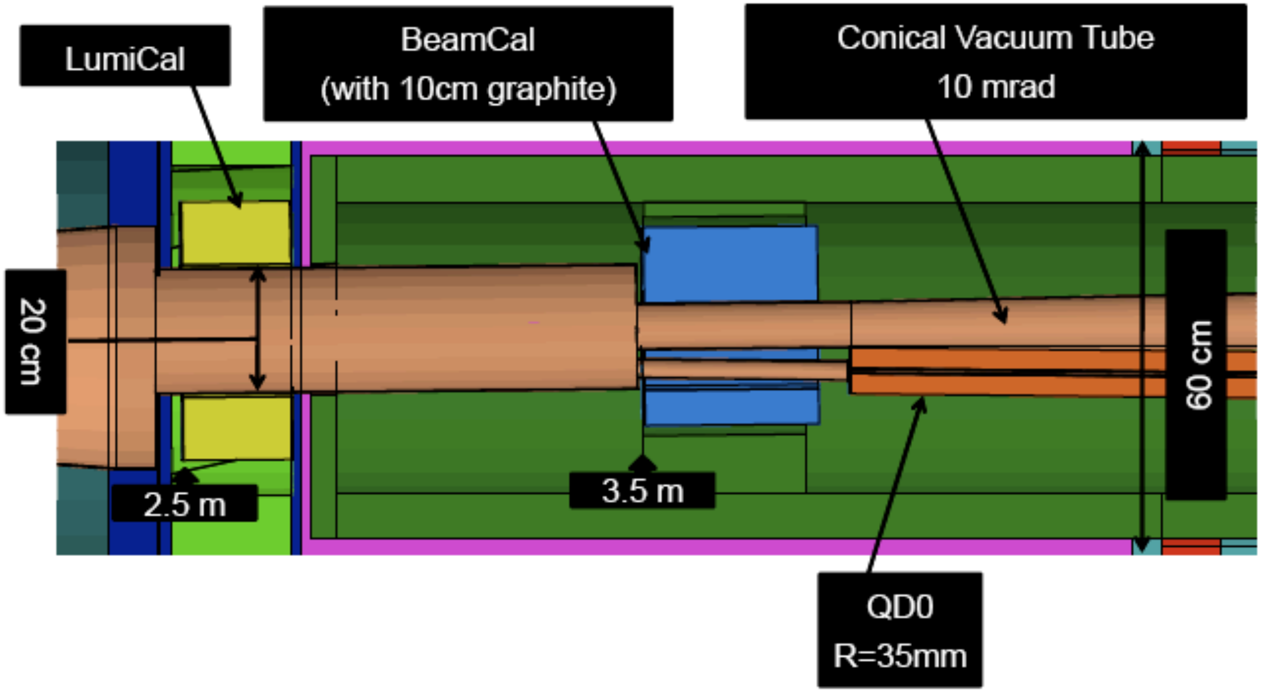
Changes:

- 20 mrad crossing angle (instead of 14 mrad)
- Vertex Detector to ~30 mm inner radius, due to Beam-Beam Background
- Hadron Calorimeter, more dense and deeper ($7.5\ \lambda_i$) due to higher energetic Jets
- For CLIC_SiD: Moved Coil to 2.9m (CMS Like)



Andre Sailer

CLIC01_ILD: LumiCal, BeamCal and QD0



Maintain very forward calorimetry functionalities, adapt to accelerator requirements (stability!), minimise back-scattering of background

See talk Lau Gatignon on Tuesday morning

See common WG1+WG3 and common WG1+WG5 sessions on Wednesday

Hardware/engineering R&D

Hardware/engineering R&D needed beyond present ILC developments:

- Time stamping
  - Needed for all sub-detectors; challenging in inner tracker/vertex region; trade-off between pixel size, amount of material and timing resolution
- Power pulsing and DAQ developments
  - In view of the CLIC time structure
- Hadron calorimetry
  - Dense HCAL absorbers to limit radial size (PFA calo based on tungsten)
- Solenoid coil
  - Reinforced conductor (building on CMS/ATLAS experience)
  - Large high-field solenoid concept
- Overall engineering design and integration studies
  - For heavier calorimeter, larger overall CLIC detector size etc.
  - In view of sub-nm precision required for FF quadrupoles

In addition: Core software development

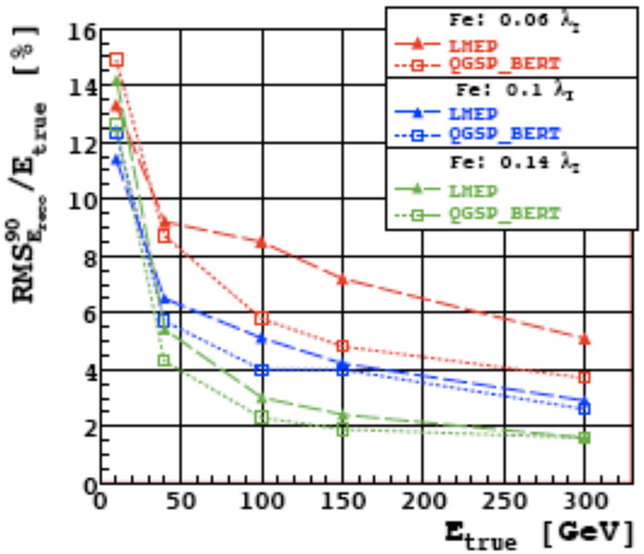
Tungsten HCAL prototype (1)

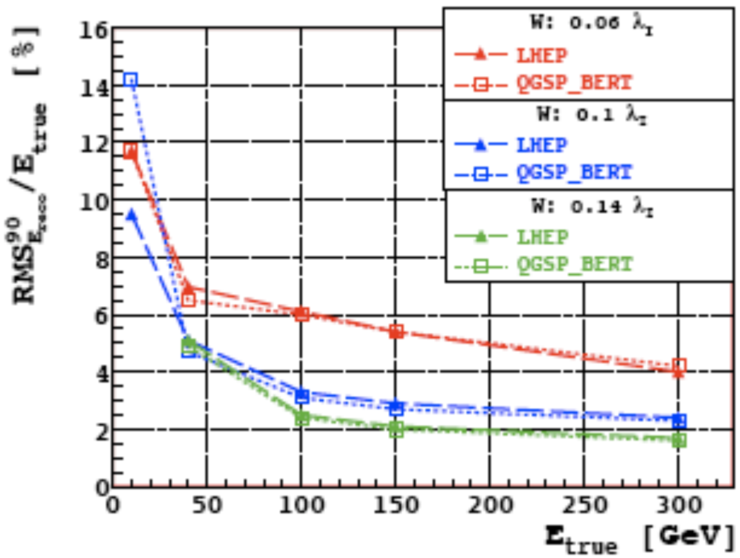
Motivation:

- To limit longitudinal leakage CLIC HCAL needs ~7Λ_i
- A deeper HCAL pushes the coil/yoke to larger radius (would give a significant cost and risk increase and for the coil/yoke)
- A tungsten HCAL is more compact than Fe-based HCAL, while resolutions are similar (increased cost of tungsten barrel HCAL compensates gain in coil cost)

See talks of Peter Speckmayer this Friday

➔Prototype tungsten HCAL: check simulation in test beam





Fe and W based HCAL resolutions

Angela Lucaci-Timoce DESY)

Tungsten HCAL prototype (2)

Main elements (all still under discussion):

- 40 or more layers of Tungsten absorber ~10×800×800 mm^3
- Phase 1: use current CALICE HCAL scintillator planes
- Phase 2:
  a) New integrated AHCAL scintillator planes
  b) New DHCAL micromegas planes

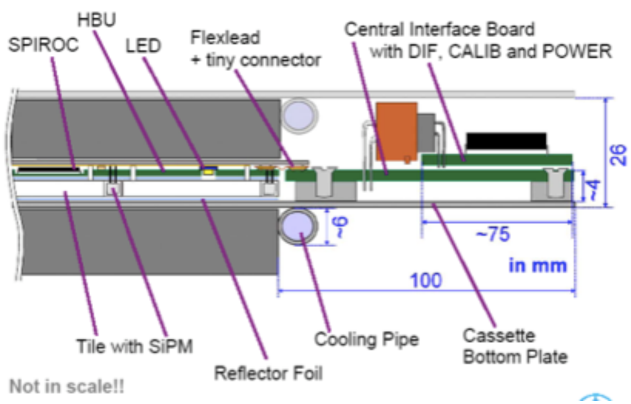
Time scale:

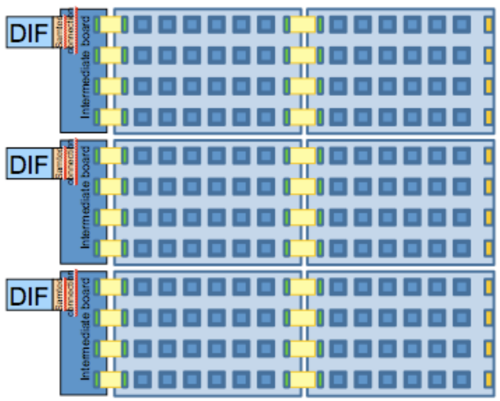
- First (limited) beam tests at CERN in 2010

See talk of Wolfgang Klempt this Friday

Integrated scintillator plane

DESY





Layout 1 m^2 micromegas

LAPP-Annecy

Solenoid R&D

- CLIC/ILC put high demands on solenoid (beyond CMS experience)
- Possible R&D subjects
  - Reinforced conductor (new Al alloys, nano-structured aluminium, cable-in-conduit)
  - Overall solenoid design
  - Ways to reduce yoke mass

First meeting with interested institutes tomorrow

http://indico.cern.ch/conferenceDisplay.py?confId=69626

Second meeting (larger attendance):

- Hefei China, in the margin of MT21 (October 18-23)

See also presentation H. Gerwig on Wednesday

Time-stamping in tracking

Our next hardware R&D priority:

Identify **vertex (tracking) R&D project** suitable for **time-stamping** development

Time-stamping resolution of ~10 ns required (tbc) with very small pixel sizes and very low material budget.

See forum discussion on time-stamping this Thursday

Core software development

Following a common LC software workshop in May 2009
http://indico.cern.ch/conferenceDisplay.py?confId=58717
Common (SiD, ILD, CERN) plans to carry out a number of core LC software improvements:

- Enhanced use of ROOT
- PFA development
  - *See talk of John Marshall on Thursday*
- Generic geometry toolkit
- Data access, data storage database, Grid access

CLIC CDR

The CLIC CDR is due for end (~December) 2010.

There will be 4 volumes:

1. Executive summary document
2. CLIC accelerator and site facilities
3. CLIC Physics and Detectors

The CDR document for physics/detectors will be some 120-150 pages.

CLIC CDR will be based on required changes for CLIC to the validated ILC detector concepts.

This is a conceptual design report. As the study is very recent, feasibility cannot be demonstrated with hardware proof for all issues.

CLIC CDR layout (1)

Chapter 1-4

1. Introduction
2. CLIC physics potential
    2.1. Higgs physics (light Higgs and accompanying new physics)
    2.2. Supersymmetry
    2.3. Extra dimensions and other possible CLIC physics
3. Strategy for design choices
    3.1. Benchmark processes for detector performance assessment
    3.2. Luminosity and background conditions for a CLIC detector at 0.5 TeV and 3 TeV
    3.3. Beyond the ILC detector concepts
4. Detector performance requirements
    4.1. General optimisation (incl. detector aspect ratio, magnetic field vs. radius, flavour tagging)
    4.2. Calorimetry requirements (incl. e.g. general PFA considerations)
    4.3. Vertexing requirements
    4.4. Tracking requirements
        4.4.1. Central tracking
        4.4.2. Forward tracking
    4.5. Very forward calorimeter requirements

CLIC CDR layout (2)

Chapter 5-11

5. Tracking system
   5.1. Vertex detector
   5.2. Tracking detector
      5.2.1. Central tracker
      5.2.2. Forward tracker
6. Calorimeter system
   6.1. Electromagnetic calorimeter
   6.2. Hadron calorimeter
7. Superconducting Solenoid
8. Muon system
9. Very forward calorimeters
   9.1. Luminosity calorimeter
   9.2. Beam calorimeter
10. Readout electronics and data acquisition
11. Detector integration
   11.1. Mechanical concept, assembly and opening
   11.2. Push-pull operation and alignment

CLIC CDR layout (3)

Chapter 12-17

11. Detector integration
    11.1. Mechanical concept, assembly and opening
    11.2. Push-pull operation and alignment
12. Physics performance for benchmark processes
    12.1. Benchmark studies of an XXX-like detector concept
    12.2. Benchmark studies of an YYY-like detector concept
    12.3. …
13. R&D prospects
14. Costs
15. Conclusion
16. Acknowledgment
17. Bibliography

I) Annex: SW packages used

Comments:

Some studies will be done with the SiD concept, others with the ILD concept, so the document will have a mix of both.

The CDR will mostly be based on **simulation studies for the CLIC** case and **existing ILC hardware experience**. As CLIC-specific hardware R&D will only start in 2010, its result will come too late for the CDR.

CDR organisation

We are looking for **editors, taking responsibility for the individual chapters** (typically 2 persons per chapter).

Several editors from CERN are available, but ideally would like to have also many editors from outside CERN (members of the concept and technology groups).

Editors will be appointed on an individual basis, following their involvement and interest.

The editors set up a work plan for the subject of their chapter, and help to identify participants (with our LCD help).

Timeline:

•Appointment of editors ~November 2009 (after CLIC'09 workshop)
•Final detailed work plan for the chapters: ~March 2009 (Beijing)

Summary

CLIC physics/detector studies in close collaboration with ILC
Growing community both inside and outside CERN

Software tools in place for adapted ILD and SiD detector models
(Further adaptations still required for 3 TeV energy)

Progress with CLIC detector requirements

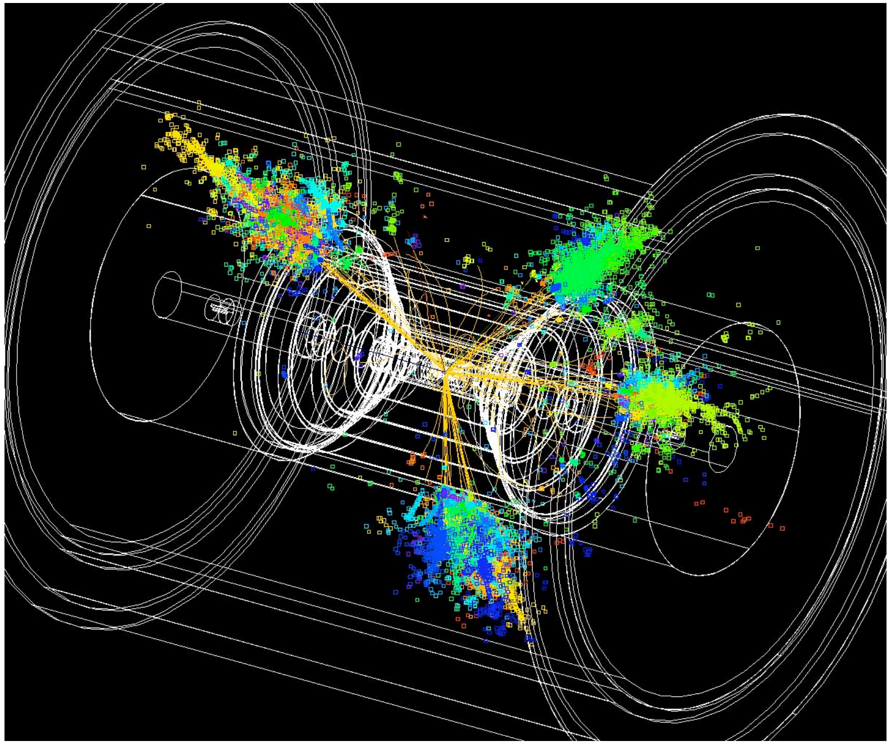
First new results of physics performance studies

R&D plan and collaboration building are coming along

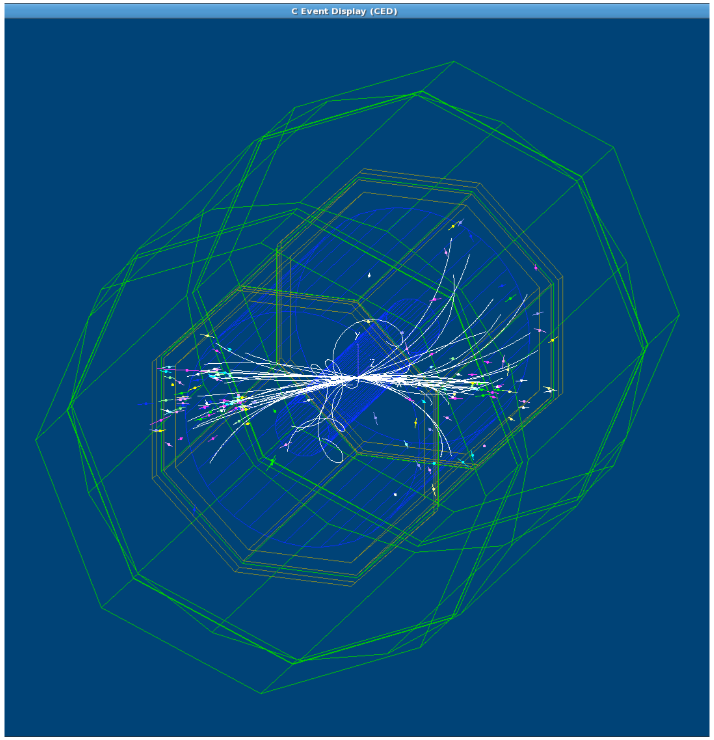
Call for CDR chapter editors

Welcome to join the study and hardware R&D !

With many thanks to all our ILC physics/detector colleagues!



CLIC_SiD detector



CLIC_ILD detector