CLICdp plans

for the next European strategy update and beyond

Lucie Linssen, CERN

CLIC workshop 2016, common plenary, January 22nd 2016

Outline

- CLICdp collaboration
- Ongoing activites
  - Physics
  - Detector optimisation
  - Software development
  - Detector R&D
- Plans for the next European Strategy Update
- Plans from ~2019 onwards

CLIC detector and physics (CLICdp)

Australia	Australian Collaboration for Accelerator Science (ACAS), University of Melbourne
Belarus	National Scientific and Educational Centre of Particle and High Energy Physics (NC-PHEP), Belarusian State University, Minsk
Chile	Pontificia Universidad Católica de Chile, Santiago
Czech Republic	Institute of Physics of the Academy of Sciences of the Czech Republic, Prague
Denmark	Department of Physics and Astronomy, Aarhus University
France	Laboratoire d'Annecy-le-Vieux de Physique des Particules (LAPP), Annecy
Germany	Karlsruher Institut für Technologie (KIT), Institut für Prozessdatenverarbeitung und Elektronik (IPE), Karlsruhe
Germany	Max-Planck-Institut für Physik, Munich
Israel	Department of Physics, Faculty of Exact Sciences, Tel Aviv University
Norway	Department of Physics and Technology, University of Bergen
Poland	The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Cracow
Poland	Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Cracow
Poland	University of Warsaw
Romania	Institute of Space Science, Bucharest-Magurele
Russia	JINR, Dubna
Serbia	Vinca Institute for Nuclear Sciences, Belgrade
Spain	Spanish Network for Future Linear Colliders
Switzerland	CERN
Switzerland	Département de Physics Nucléaire et Corpusculaire (DPNC), Geneva
United Kingdom	The School of Physics and Astronomy, University of Birmingham
United Kingdom	University of Bristol
United Kingdom	University of Cambridge
United Kingdom	University of Glasgow
United Kingdom	The Department of Physics of the University of Liverpool
United Kingdom	Oxford University
USA	Argonne National Laboratory, High Energy Physics Division
USA	University of Michigan, Physics Department

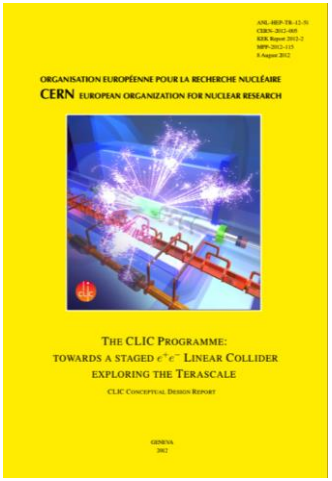
Collaboration hosted by CERN
27 institutes from **17 countries**
(2 new members in 2015)
signed "Memorandum on Cooperation",
on best-effort basis
http://clicdp.web.cern.ch/

Focus of CLIC-specific studies on:

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

work plan up to next European Strategy Update

Work plan for CLIC physics and detector was defined in the CDR (2012) along three main lines:



Exploration of the Physics potential

Detector optimisation

Technology demonstrators

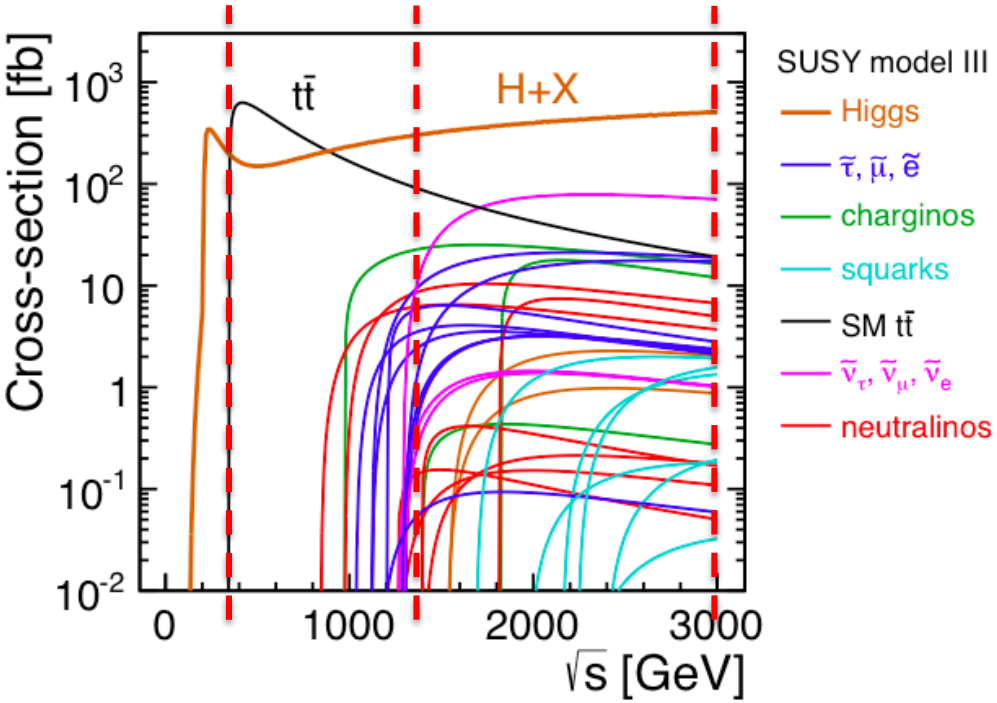
This is our main guideline for the work in 2013-2018.

It includes integration of new LHC physics results in the studies for CLIC (example: Higgs discovery in 2012)

exploration of the physics potential

Following up on 8 TeV and 13 TeV LHC results => CLIC physics potential based on detailed benchmarking studies; all in full detector simulation/reconstruction.

- **Higgs physics**
- **Top physics**
- **Direct searches for new physics**
- **Indirect BSM sensitivity from precision measurements**

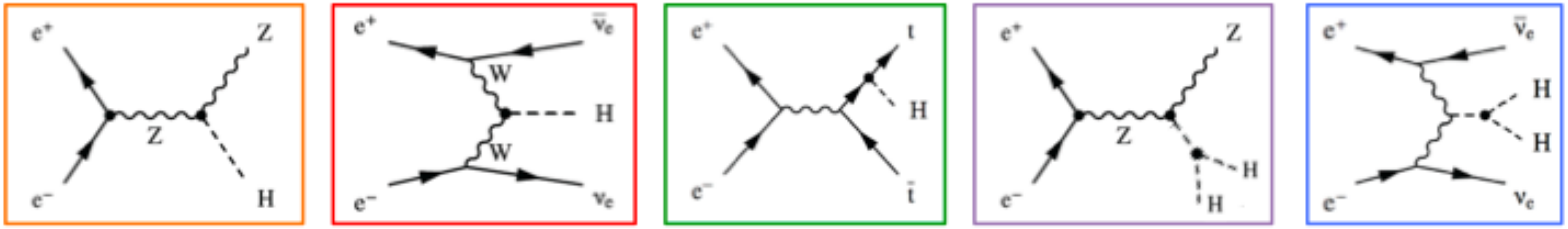


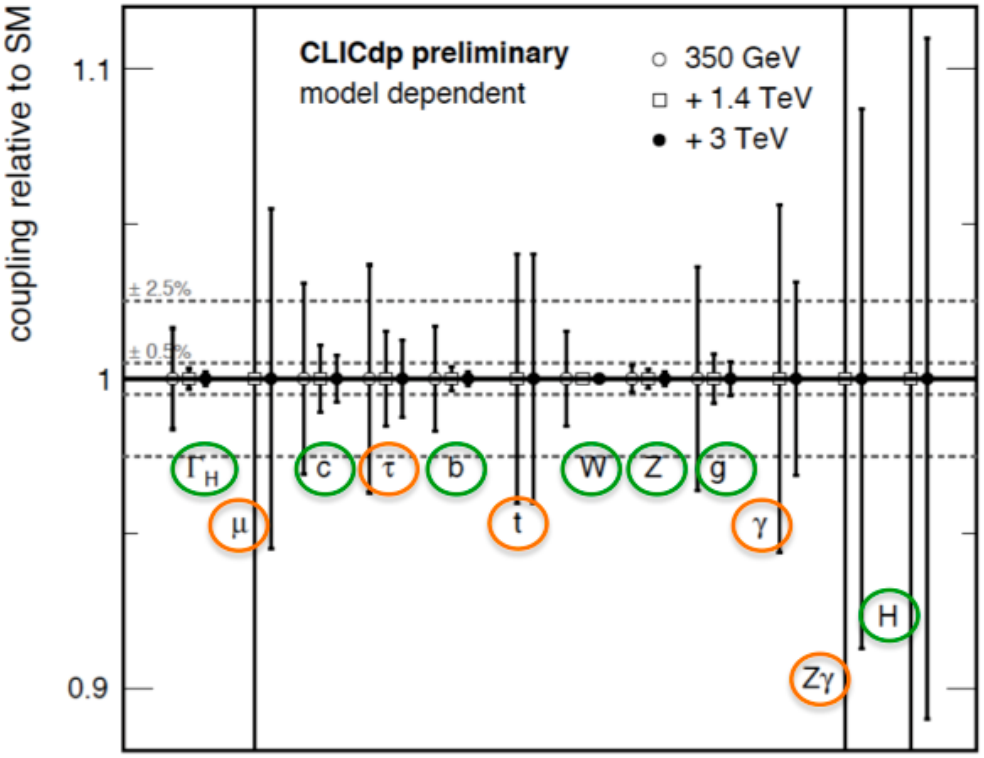
Guaranteed physics cases
-- *Higgs and top physics* --
used to define a staging scenario:
380 GeV, 1.5 TeV, 3 TeV

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

→ *Draft of the new CLIC baseline paper: http://esicking.web.cern.ch/esicking/ClicStagingBaseline/*

physics studies: Higgs





Focus of the CLIC benchmark studies in the past ~3 years

~20 individual physics analyses, covering different CLIC energies

Collaboration-wide effort involving 9 institutes

Accuracy significantly better than HL-LHC

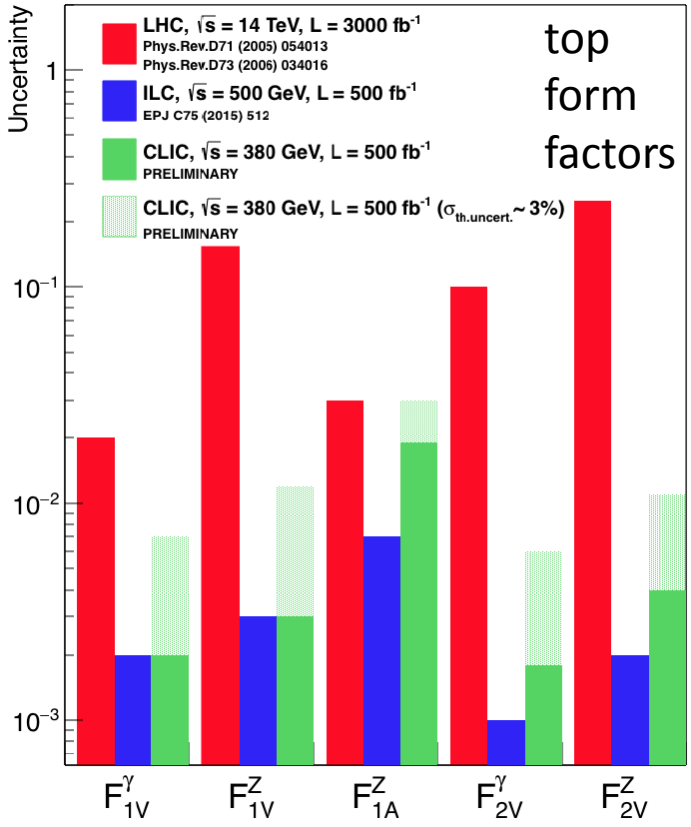
Accuracy comparable to HL-LHC

→ *CLIC Higgs overview publication, draft soon for collab. review: http://proloff.web.cern.ch/proloff/clichiggspaper/*

plans for physics studies

The focus of the work is now moving to:
- top physics
- BSM physics

Top quark physics:
So far studied top mass, now also looking at top as a tool to search for new physics
- Production asymmetries: A^{FB}, A^{LR}
- FCNC top quark decays
- Single top



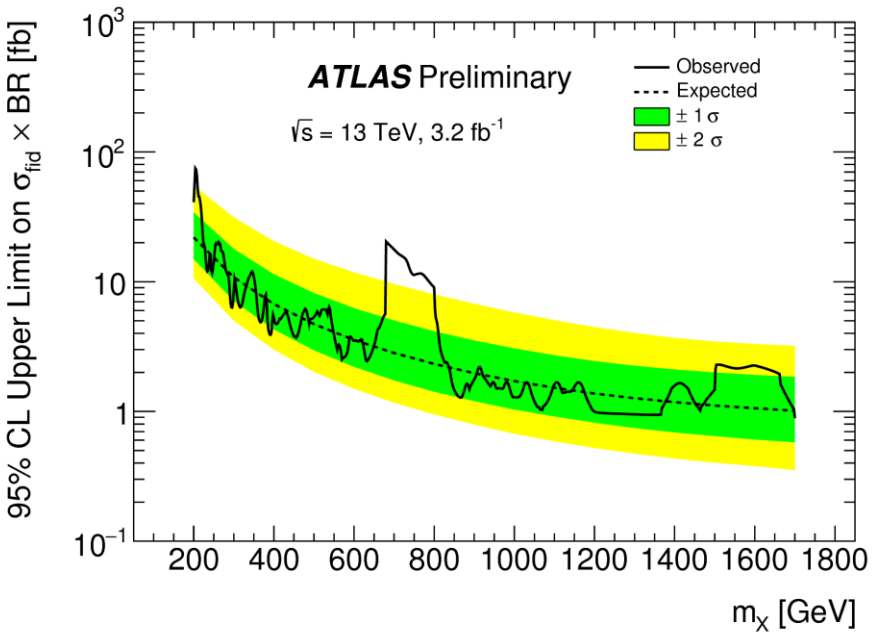
BSM:
Main motivation for high-energy CLIC
- Direct searches for new particles with mass≤√s:
  (Dark matter, electroweak states, compressed spectra, stop, hidden valley models, …)
- Indirect searches through precision observables:
  (Triple and quartic gauge coupling, W mass, effective operators, ...)

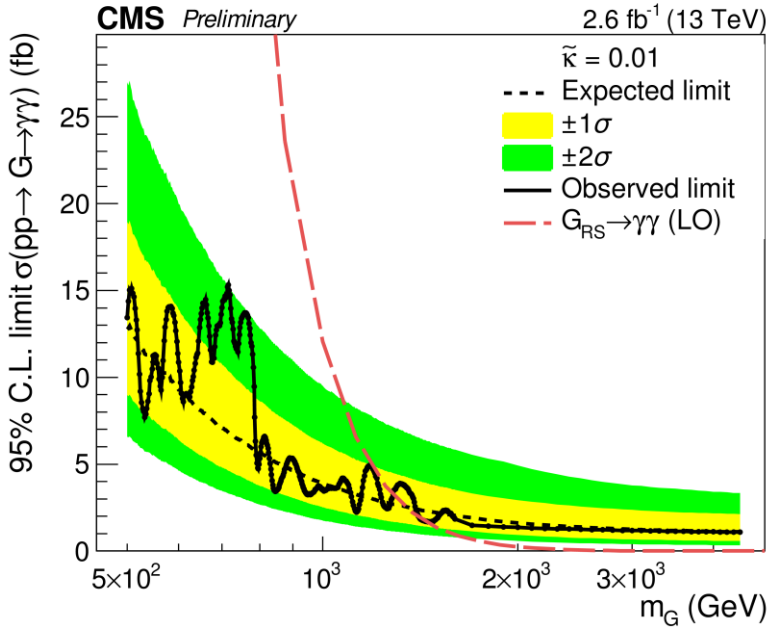
…and react on new LHC discoveries !

→ *For a more detailed physics plan, see: http://indico.cern.ch/event/404368/ and Philipp Roloff's talk on 19/1*

… react on new LHC discoveries

E.g. possible observation of photon-photon enhancement at 750 GeV

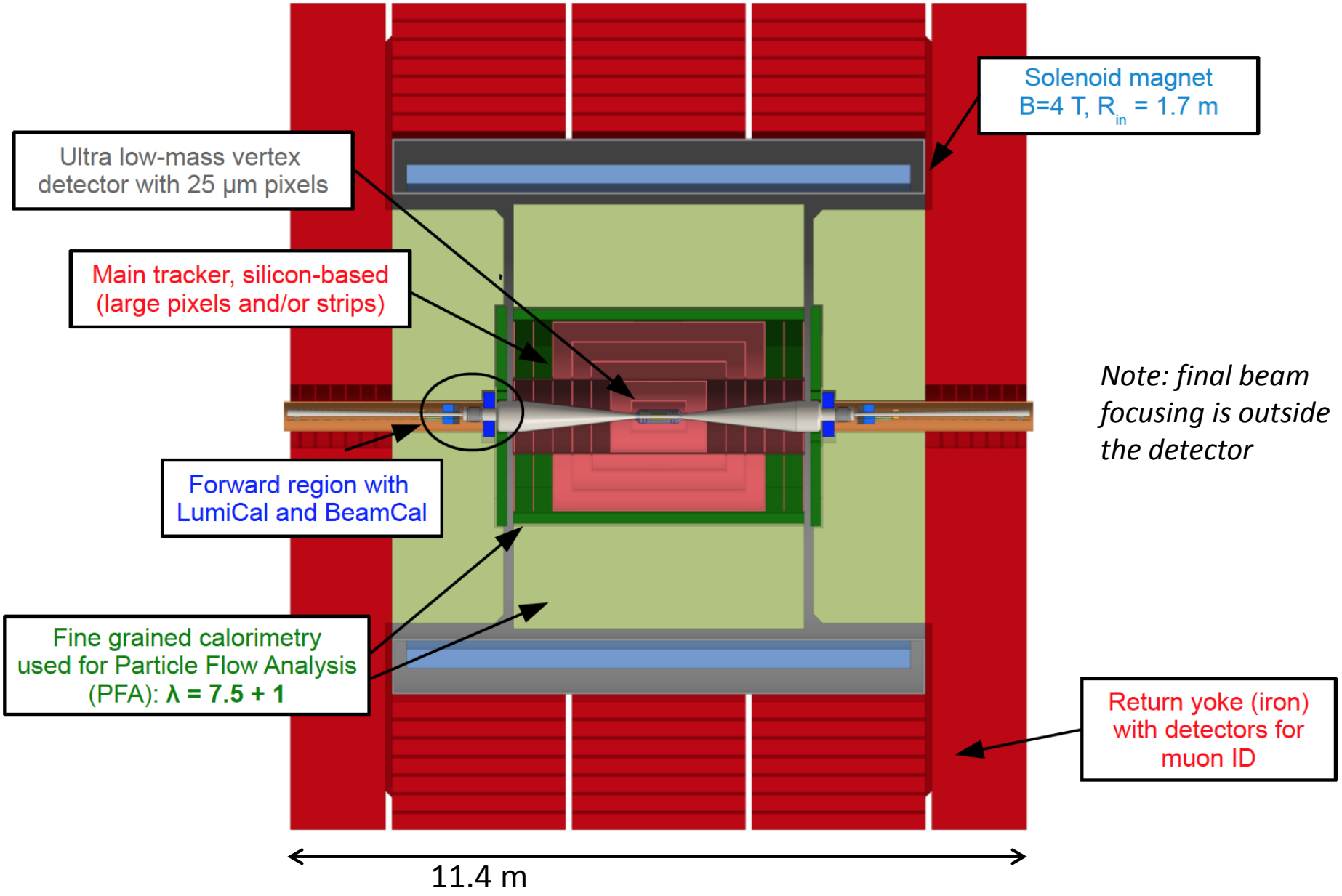




Very many theory papers have appeared about this observation.
E.g.:
Ito/Moroi/Takaesu: http://arxiv.org/abs/1601.01144
Djouadi/Ellis/Godbole/Quevillon: http://arxiv.org/abs/1601.03696

Depending on further clarification from LHC
CLIC could be an excellent facility to study the phenomenon
=> To be followed/studied closely, including machine options

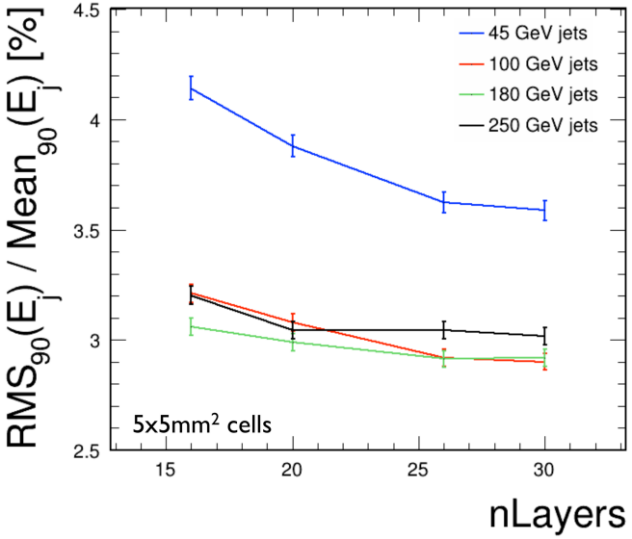
detector optimisation (1)



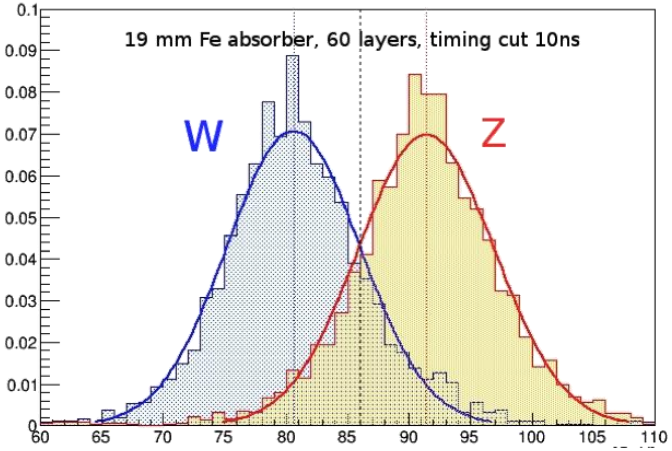
Note: final beam focusing is outside the detector

detector optimisation (2)

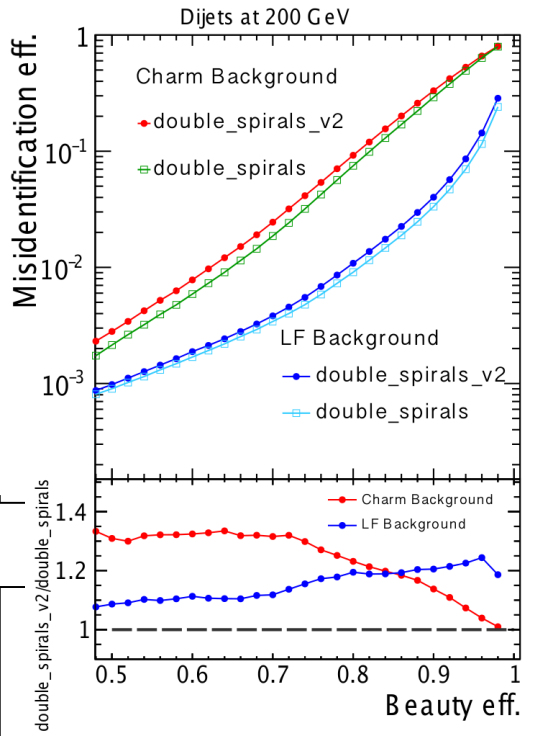
ECAL



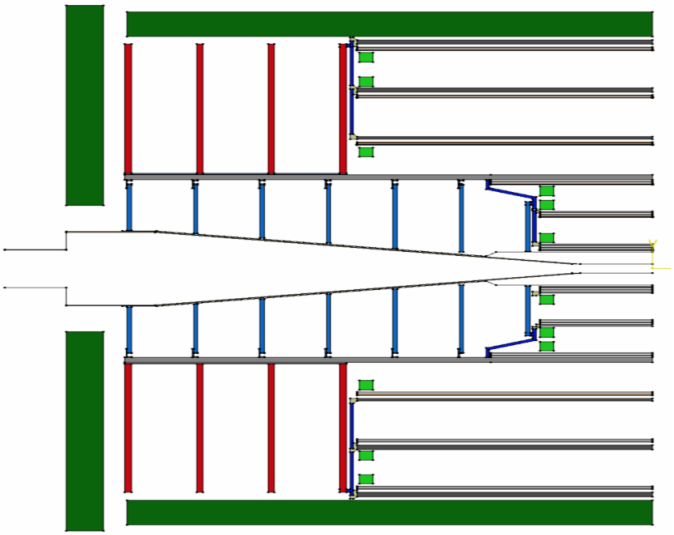
HCAL



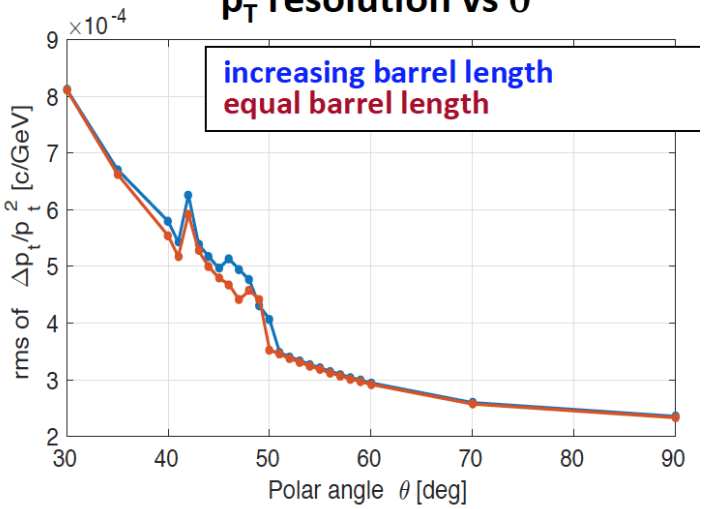
Vertex detector



Tracker layout



p_T resolution vs θ



… etc, with many other optimisation studies

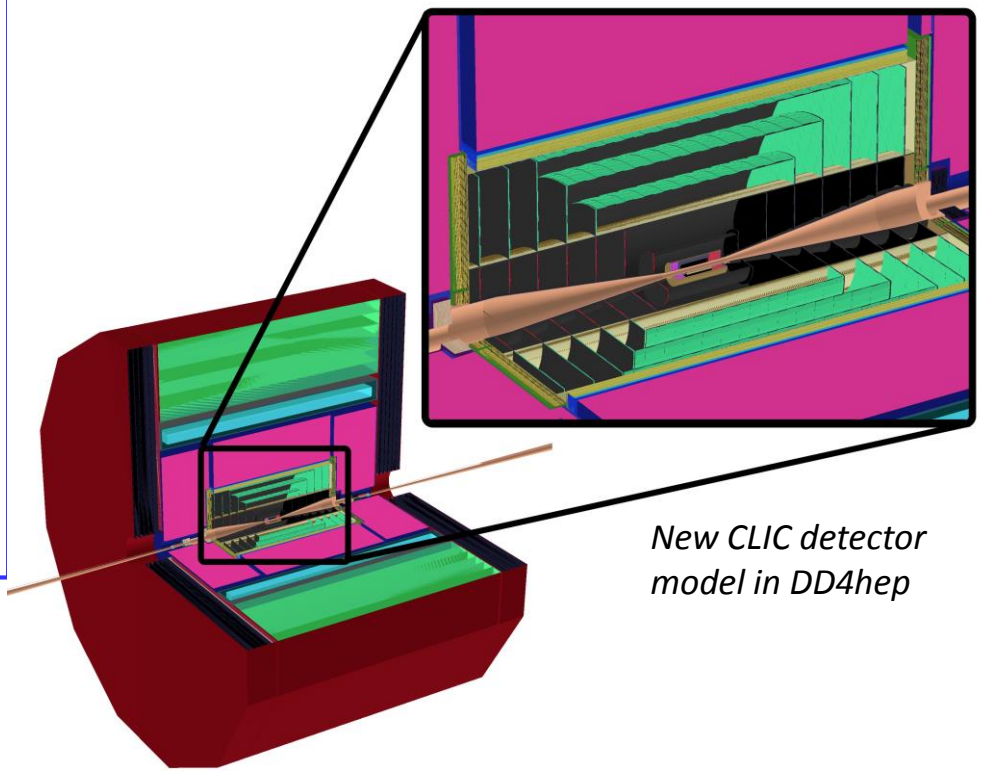
software development for new CLIC detector

Renewal of software chain for detector optimisation and physics simulations

- Detector geometry description based on DD4hep
- Most critical item: track reconstruction (intensive work ongoing)
- Improved high-level analysis tools (e.g. vertex reco, flavour tagging)

Grid production with ILCDIRAC

Software developments serve: CLIC, ILC, FCC



New CLIC detector model in DD4hep

Status:

The new detector model is nearly completed.

Draft note on new model exists: → https://edms.cern.ch/document/1572676/

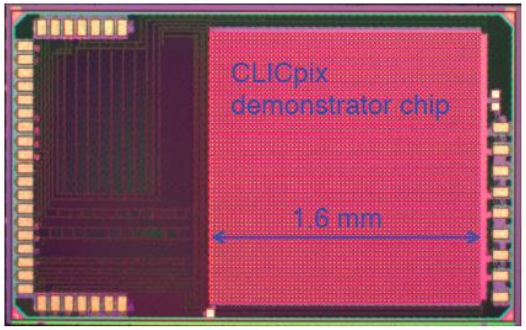
(see Konrad's presentation on the note on 19/1)

The new software is very advanced, mostly "validation" phase.

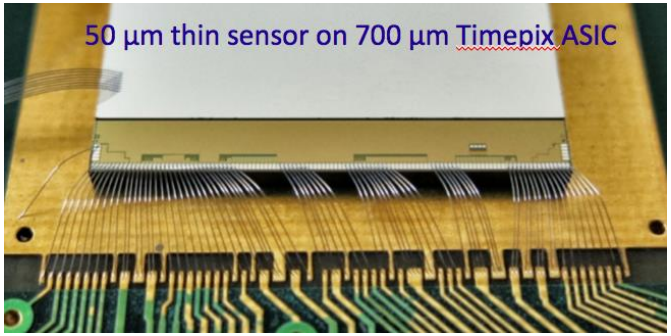
Hope to start physics simulations with the new model early 2016

Si vertex and tracker detector R&D (1)

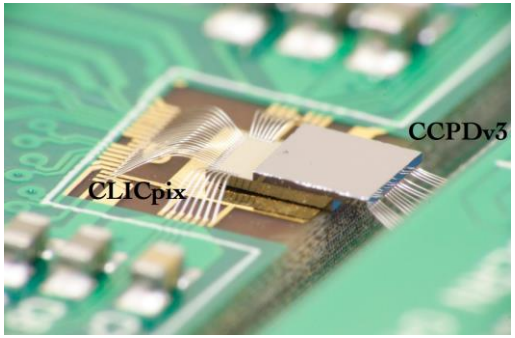
electronics chip (65 nm)

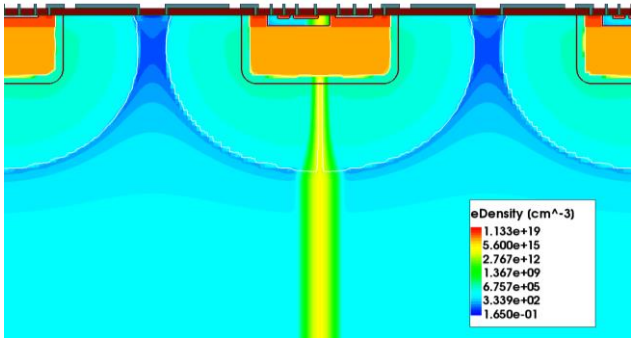


thin sensor+ASIC assemblies

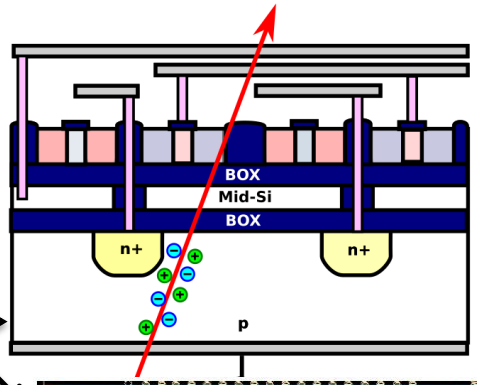


HV-CMOS sensor + CLICpix

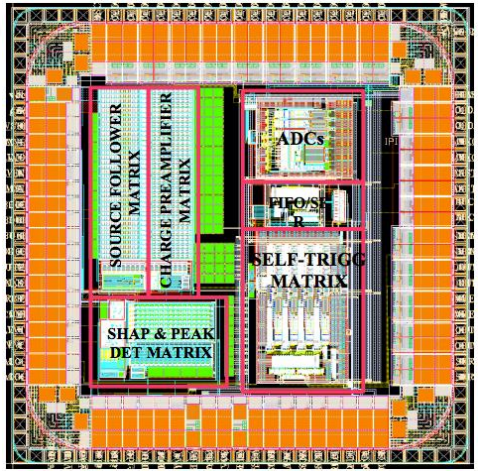


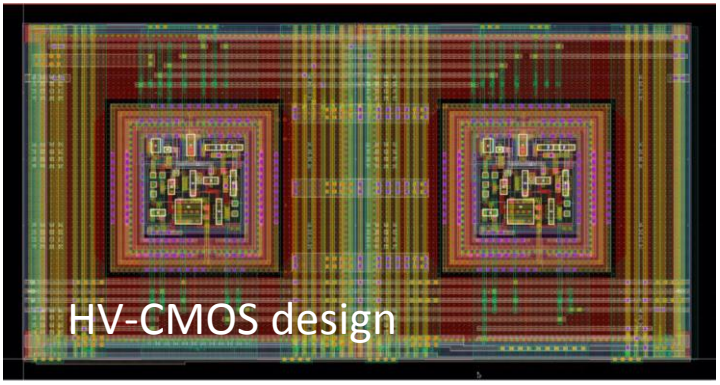


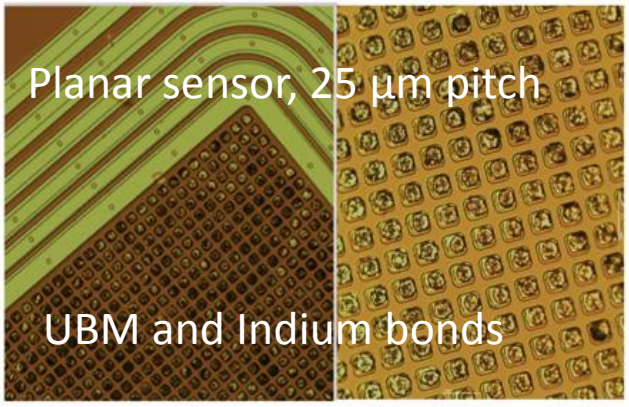
HV-CMOS sensor, signal simulations in TCAD



SoI sensor design

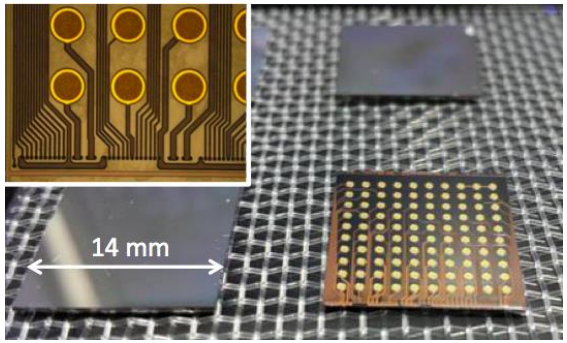




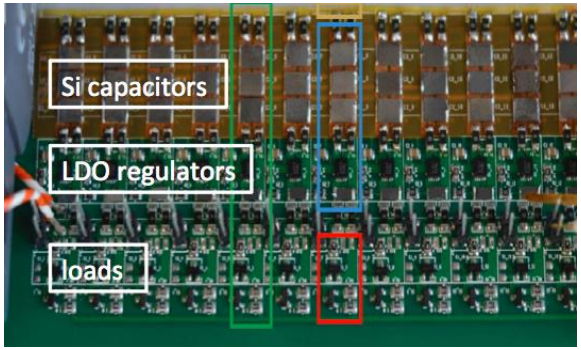


Si vertex and tracker R&D (2)

TSV interconnect technology

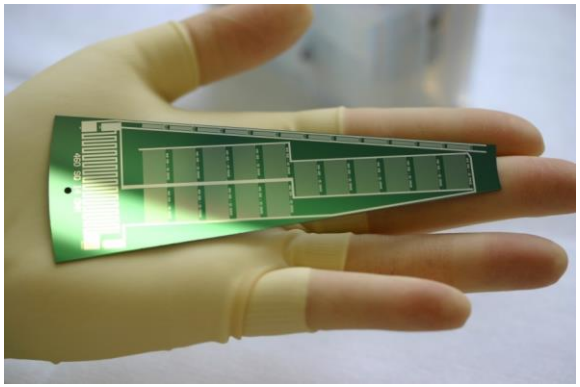


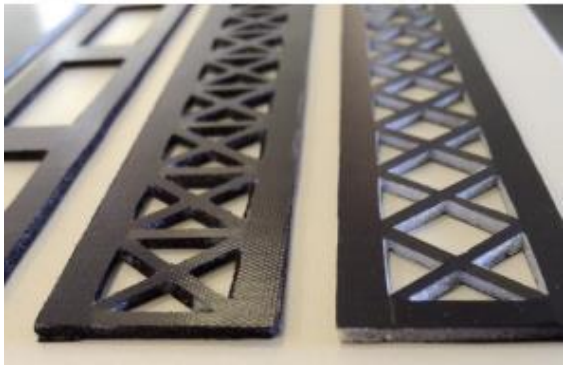
power delivery + pulsing



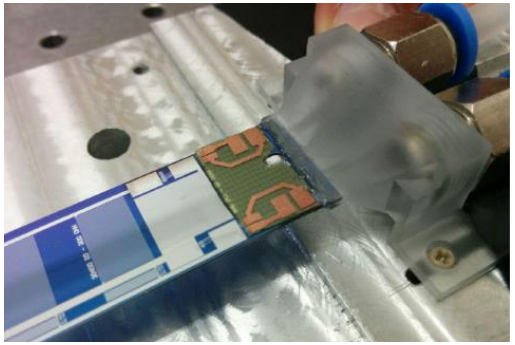
Timepix3 beam telescope

thin supports

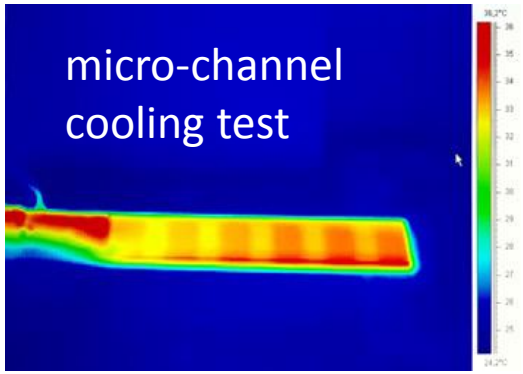


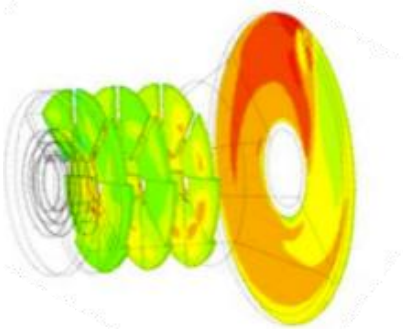


micro-channel cooling



air cooling simulations/tests



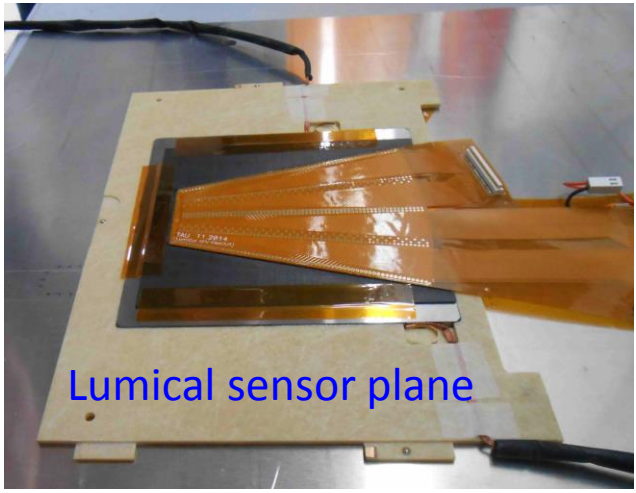


fine-grained calorimetry (CALICE/FCAL)

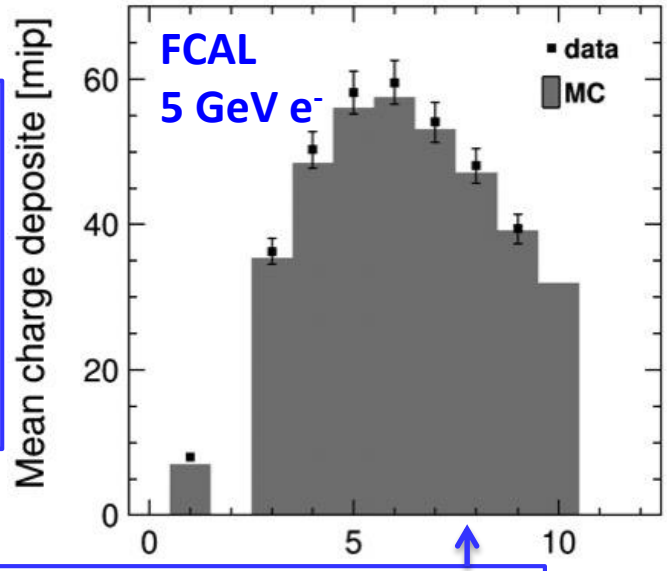
Strong CLICdp participation in CALICE and FCAL collaborations

Beam tests in 2015
- CALICE at CERN
- FCAL at DESY

Several publications in 2015



CALICE AHCAL beam tests with steel and tungsten absorbers



FCAL e- shower depth profile

CLICdp documents in preparation for next European Strategy

CLICdp reports serving as ingredients for a CLIC summary report:

- 2015 CLIC re-baselining report (380 GeV, 1.5 TeV, 3 TeV) ✓
  - Together with CLIC accelerator. Full draft exists, for publication.
- The CLIC Higgs physics overview publication of 2015 ✓
  - Full draft exists, for publication.
- The new optimised CLIC detector model (2015) ✓
  - Nearly complete draft exists, technical note.
- An overview of CLIC top physics
  - CLIC top physics publication in 2016/2017.
- Extended BSM studies (hopefully also motivated by LHC discoveries)
  - CLIC BSM publication by 2017/2018.
- CLIC R&D report => with main CLIC technology demonstrators
  - Summary publication(s) in 2017+2018
- Plan for the period ~2019-2025 in case CLIC would be supported by next strategy
  - 2017/2018, note to be included in CLIC input summary report for the Strategy

After the strategy update => context

From the European strategy document:
"… Europe needs to be in a position to propose an ambitious post-LHC accelerator project at CERN by the time of the next strategy update"

This is reflected in the **CERN financial plan** in which FCC and CLIC fuse into a single budget line from 2020 onwards

Only **one CERN energy frontier project** as of 2020

Next steps

A detailed plan for the next phase (from 2020) to be drafted during the coming years:

- As part of the **input to the European Strategy** (2019-2020)
- To gradually serve as **input** for the **CERN medium-term plan**
- To be included in the **work plans and funding plans of the collaborating institutes**

*assuming CLIC moves to the next phase, as **THE** future project for CERN*

*Need to add observations on our **"generic R&D"** to avoid that very useful activities are stopped in case FCC is chosen*

To make sensible plans for after 2019 => assume **realistic start-of-construction date**

- => requires **input from a higher strategic level**
- => requires **our own technical appreciation** of what is realistic
- => will assume **more groups** will join and **more resources** will be available

Today's presentation serves as initial brain-storming to initiate the process
The above observations show that it needs careful thinking

Transition to next phase

Small scale R&D (technology demonstrators):

- Will continue after 2019 in most challenging areas

Large scale R&D

Work on individual sub-element level => work on **system level**

Requires **more resources**

Requires **broader collaboration involvement** (will come naturally)

Like for the LHC experiments:

- Some detector elements need **early construction**
  - General supporting structure, magnet yoke, etc.
  - SC magnet
  - … then calorimeters
- Other elements shall **profit from continued technology advances**
  - Vertex detector
  - Tracker
  - Electronics, DAQ, data transmission, computing
  - Simulation and reconstruction Software

Enlarging the scope

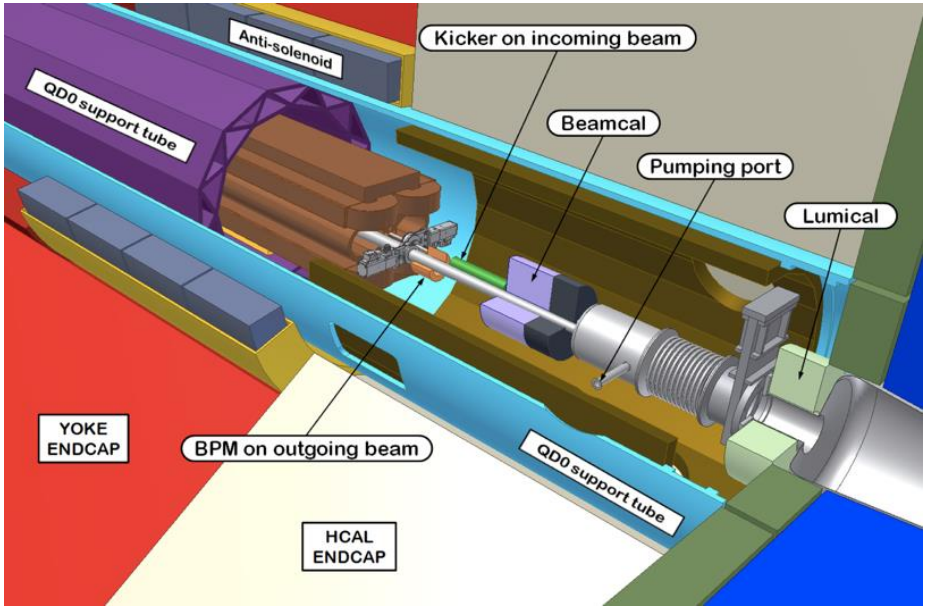
Examples of studies needed in the **engineering + technical coordination** domain (and which are not pursued on a large scale today):

- Full detector **design and integration** studies
- **Cavern** design and related infrastructures
- **Safety** aspects
- **Alignment**
- **Production aspects** with industry involvement
- **Detailed costing** with industry involvement
- **…**

Other examples of studies that need to increase significantly:

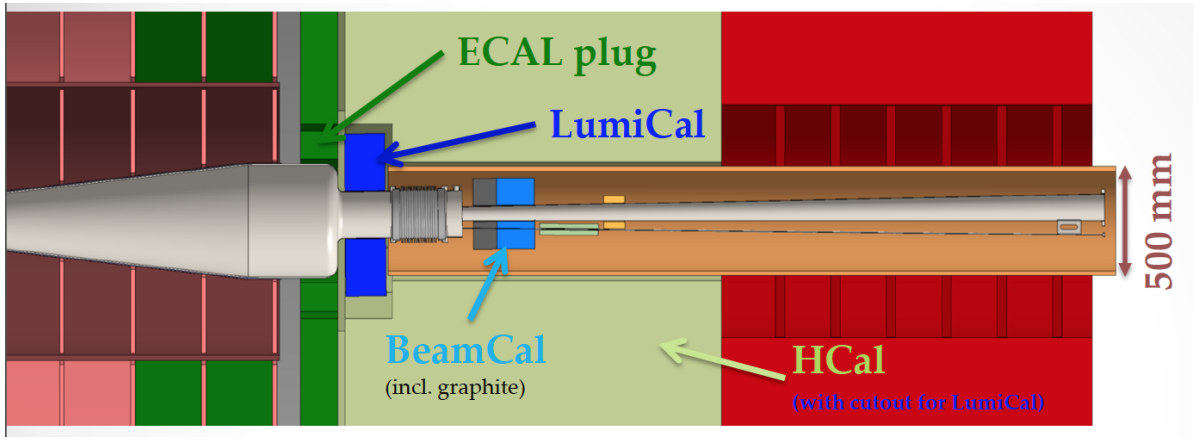
- **Magnet R&D** (too expensive for current funding level)
- Beryllium **beam pipe** connected to heavy steel cones
- **Power pulsing** and power delivery at system level
- **System tests** in a magnetic field
- Design of a **full electronics and readout system**, including timing
- …

Example: QD0 in or out?



In the CDR:

- **QD0 in detector, L* ~3.5m**
- Solution was found for QD0 stability
- Optimal for high luminosity
- Reduced detector acceptance



In CLIC_det2015:

- **QD0 out of detector, L* ~6m**
- Some luminosity loss
- Increased forward acceptance

Studies in the coming years will tell which solution is better
=> large impact on layout and engineering

Summary

In case CLIC would be selected as the preferred option for CERN:

- Detailed sub-system R&D will continue in many areas
- To be complemented with:
  - Significant increase in engineering activities
  - System-level prototypes and tests

Such a next phase will require:

- Significantly more resources
- Significantly increased collaboration involvement
  - => Adaptation in the collaboration structure (less light-weight)

In case CLIC would not be chosen:

- Generic R&D needs to be preserved and resources secured
- Resources may be in danger if we do not prepare for the situation

thank you

…. and keep on going

spare slides

Developments plans, CDR Vol2 dixit

Subject	Progress?	Comment
Simulation studies and detector optimisation	++	New detector model !
Physics at CLIC	++	Strong CLICdp-wide effort
Software development	++	DD4hep, tracking SW, etc. *strong synergy with ILC*
Vertex detector	++	Active R&D
Silicon tracker	+	Early phase study
TPC-based tracking	×	Not chosen for CLIC
Calorimetry	++	CALICE / FCAL
Electronics and power delivery	++	In vertex R&D + power pulsing
Magnet and ancillary system	+	Extrusion tests + studies
Engineering and detector integration	+	CDR work + vertex/tracking work

CLIC strategy and objectives

2013-18 Development Phase

Develop a Project Plan for a staged implementation in agreement with LHC findings; further technical developments with industry, performance studies for accelerator parts and systems, as well as for detectors.

4-5 year Preparation Phase

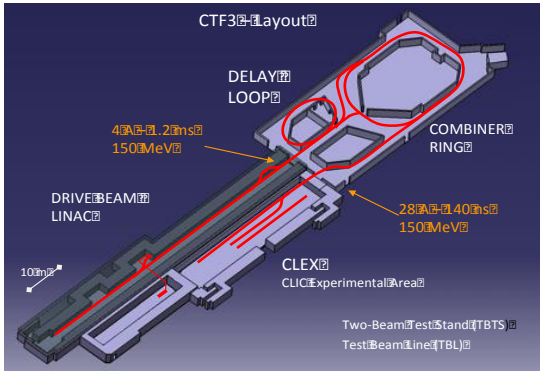
Finalise implementation parameters, Drive Beam Facility and other system verifications, site authorisation and preparation for industrial procurement.

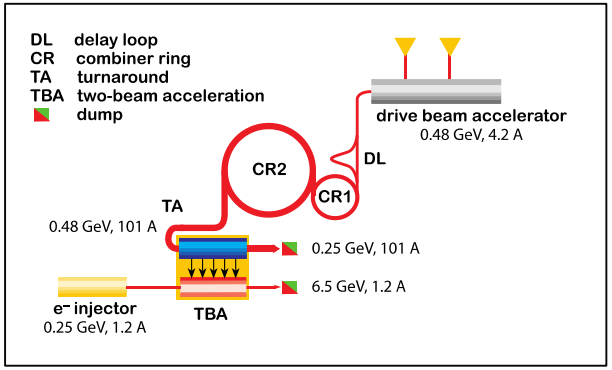
Prepare detailed Technical Proposals for the detector-systems.

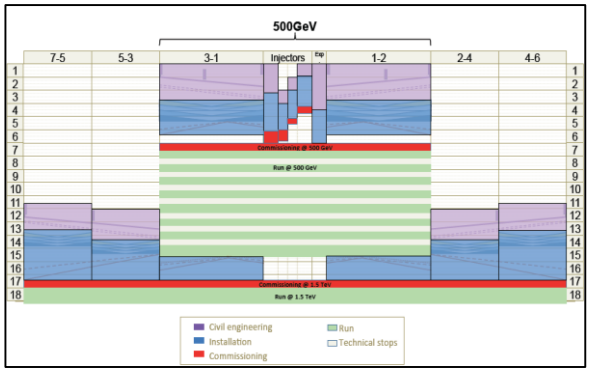
Construction Phase

Stage 1 construction of CLIC, in parallel with detector construction.

Preparation for implementation of further stages.







2018-19 Decisions

On the basis of LHC data and Project Plans (for CLIC and other potential projects), take decisions about next project(s) at the Energy Frontier.

2024-25 Construction Start

Ready for full construction and main tunnel excavation.

Commissioning

Becoming ready for data-taking as the LHC programme reaches completion.