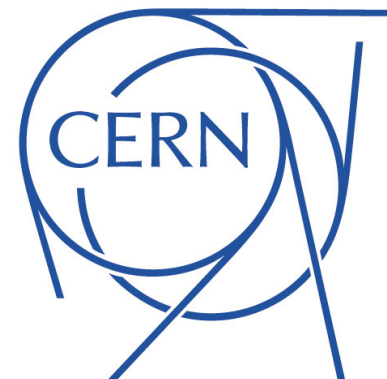


# **CLICdp work plan and foreseen documents in preparation for the next European Strategy Update**



**Philipp Roloff (CERN PH-LCD)**

CLIC Common Project Meeting at the  
International Workshop on Future Linear Colliders (LCWS15)  
03/11/2015, Whistler, Canada

# CLIC detector and physics (CLICdp)

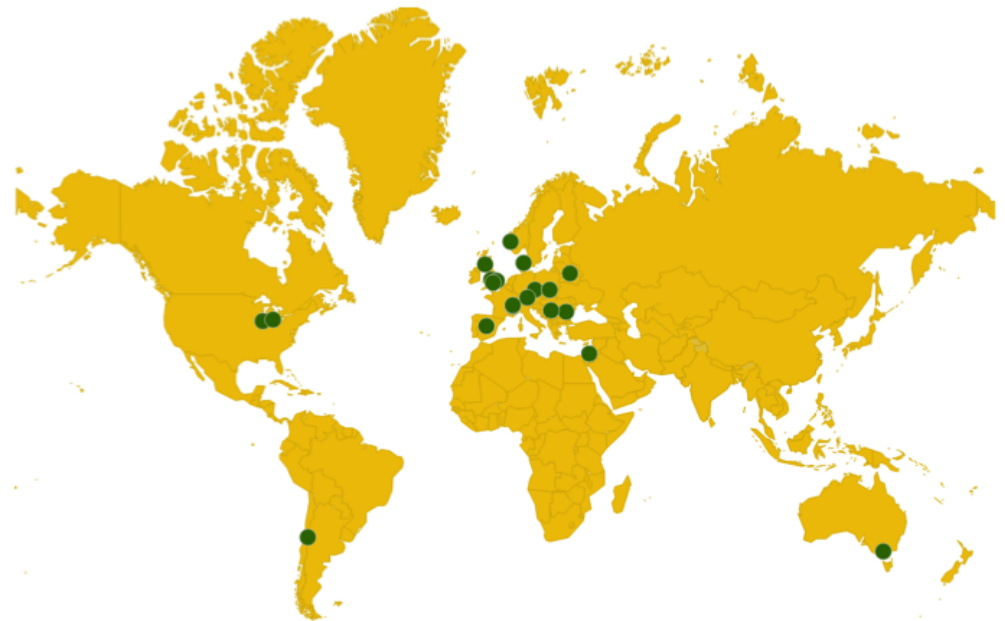
## 26 institutes from 16 countries:

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
Serbia	Vinca Institute for Nuclear Sciences, Belgrade
Spain	Spanish Network for Future Linear Colliders
Switzerland	CERN
Switzerland	Département de Physique 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

- Light-weight collaboration structure
- No engagements, best effort basis
- Strong links to the ILC

### Focus of CLIC-specific studies on:

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



<http://clikdp.web.cern.ch>

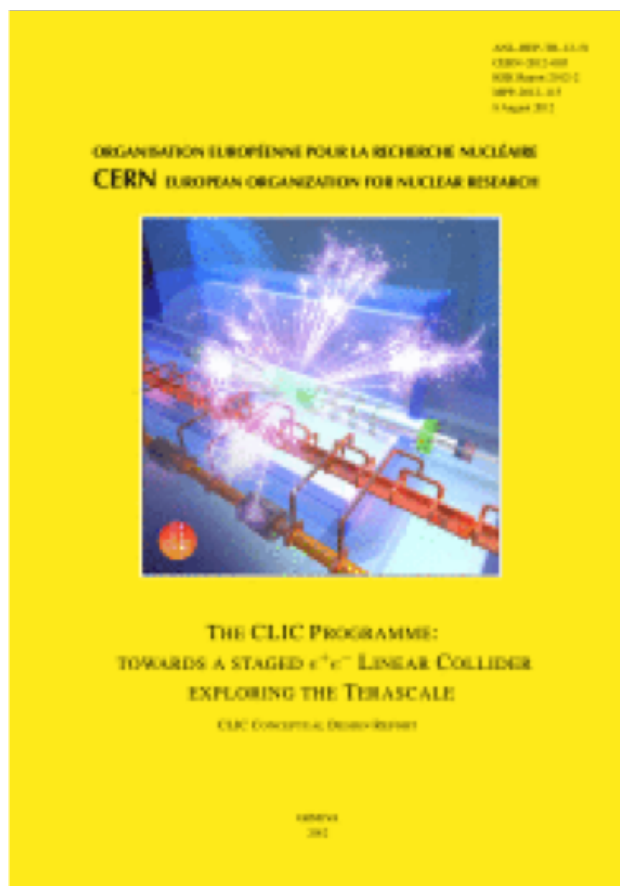
# Work plan for next European Strategy Update

In the CDR (Volume 3) three main activities for CLIC detector and physics were defined:

- Exploration of the **physics potential**
- Detector **optimisation**
- **Technology** demonstrators

This work plan is gradually being followed

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



# Exploration of the physics potential

## Main areas of CLIC physics benchmark studies:

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

Stage	$\sqrt{s}$ (GeV)	$\mathcal{L}_{\text{int}}$ (fb $^{-1}$ )
1	380	500
	350	100
2	1400	1500
3	3000	3000

All studies are performed in the context of a **CLIC staging scenario**

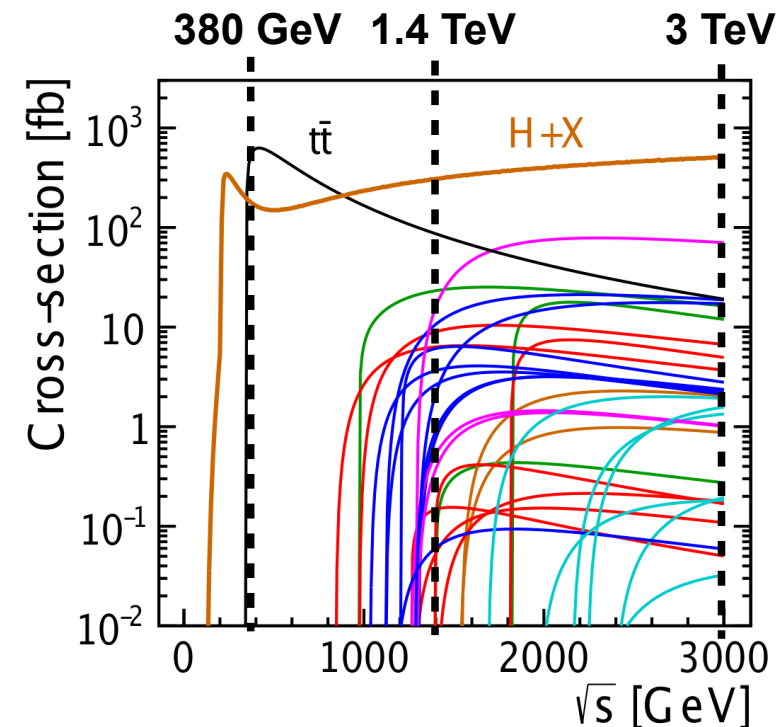
### Guaranteed physics case:

SM Higgs and top used to define a staging scenario:

380 GeV, 1.4 TeV, 3 TeV

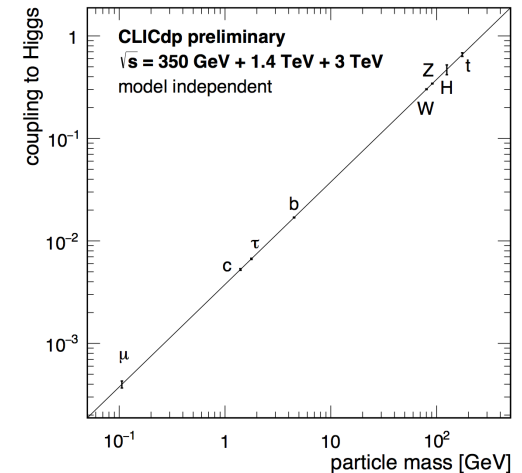
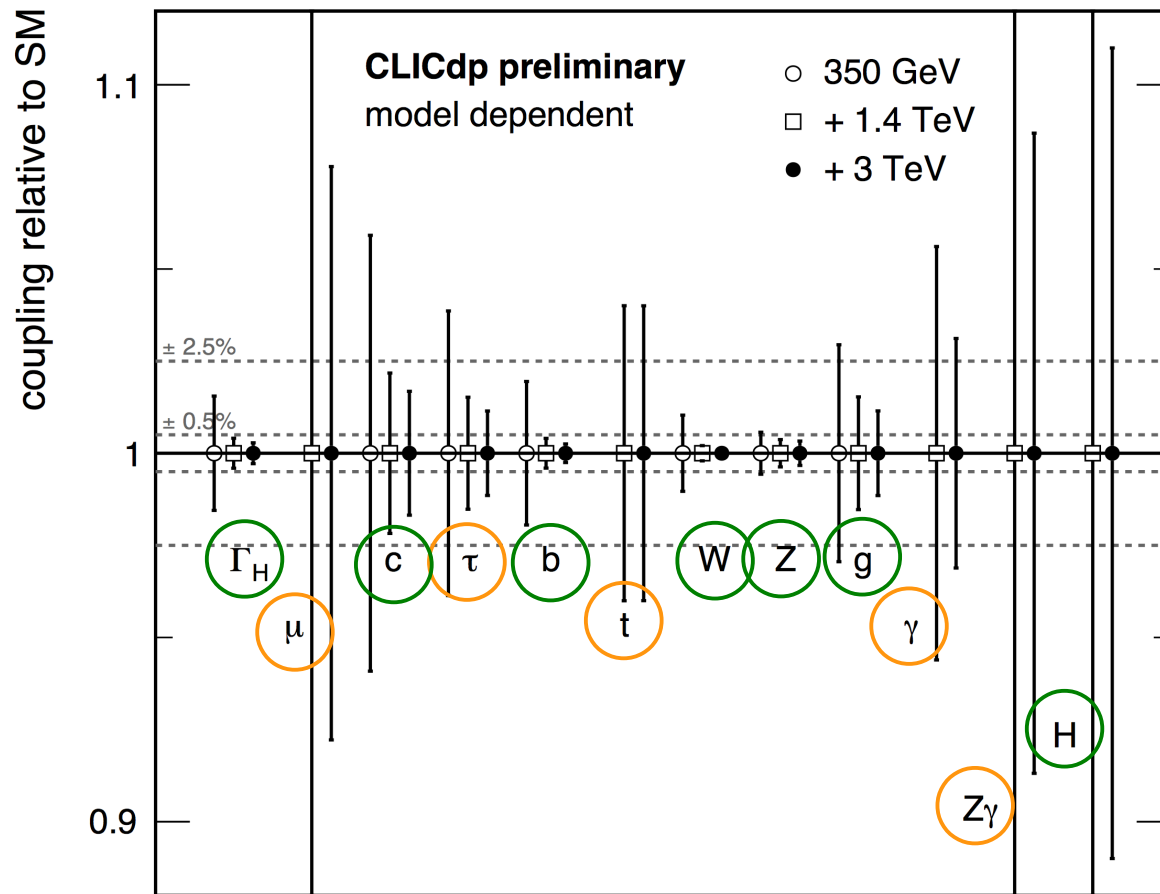
Consistent with current 8 & 13 TeV LHC results, might be refined in case of new input

- Higgs
- $\tilde{\tau}, \tilde{\mu}, \tilde{e}$
- charginos
- squarks
- SM  $t\bar{t}$
- $\tilde{\nu}_{\tau}, \tilde{\nu}_{\mu}, \tilde{\nu}_e$
- neutralinos



# Physics studies: Higgs

- Focus of CLIC physics benchmarking effort in the last  $\approx 3$  years
- $\approx 20$  analyses based on full detector simulations, 9 institutes involved



- significantly better than HL-LHC or not possible at hadron colliders
- similar to HL-LHC

Overview publication complete by end 2015: <http://proloff.web.cern.ch/proloff/clichiggs paper>

# Plans for physics studies

The focus of CLIC physics studies has shifted to:

- Top quark physics
- Beyond the Standard Model

## Top quark physics:

So far focussed on the mass, now also looking at  
top as tool to search for new physics:

- Production asymmetries:  $A^{\text{FB}}$ ,  $A^{\text{LR}}$
- FCNC top quark decays
- Single top

## Beyond the standard model:

Main motivation for high-energy CLIC operation

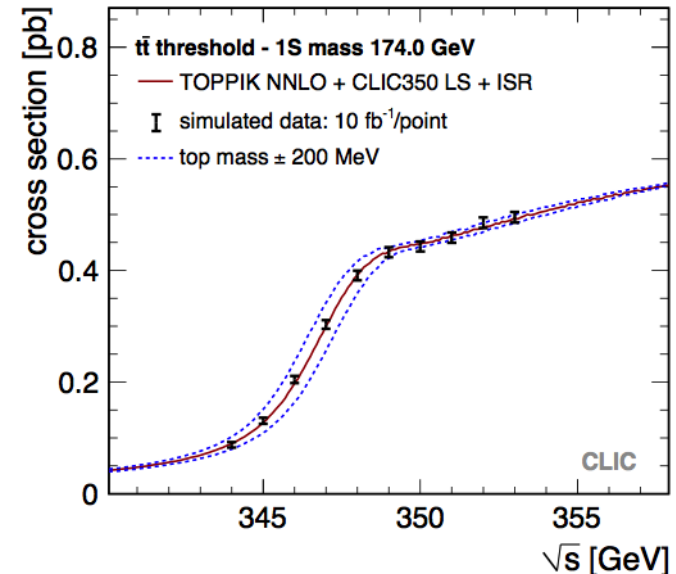
- Direct searches for new particles with  $M \leq \sqrt{s}$ :

Dark Matter, electroweak states, compressed spectra, stop, hidden valley models, ...

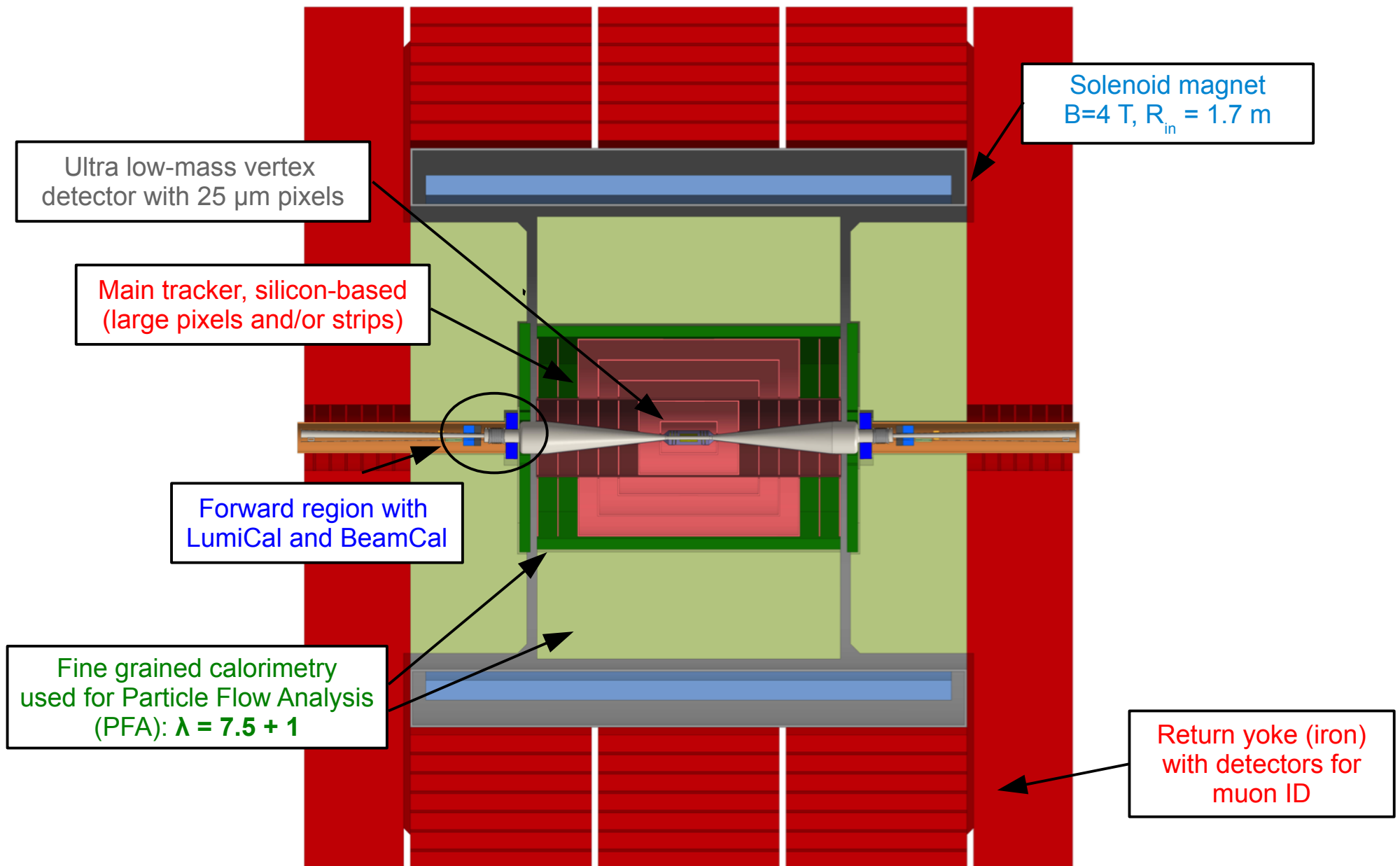
- Indirect searches through precision observables:

Triple and quartic gauge couplings, W mass, effective operators, ...

Detailed plan: [see presentation during CLICdp monthly on 03/08/2015](#)  
(<http://indico.cern.ch/event/404368/>)



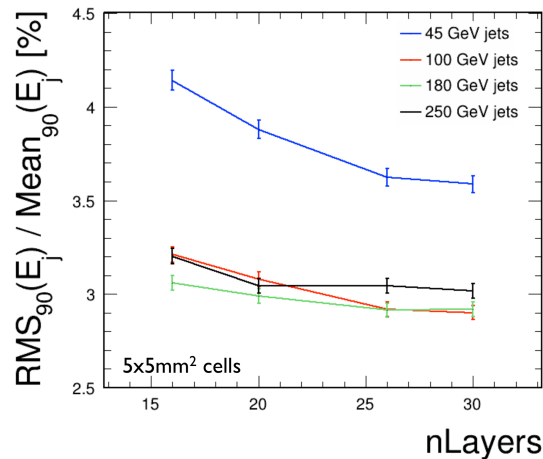
# Detector optimisation



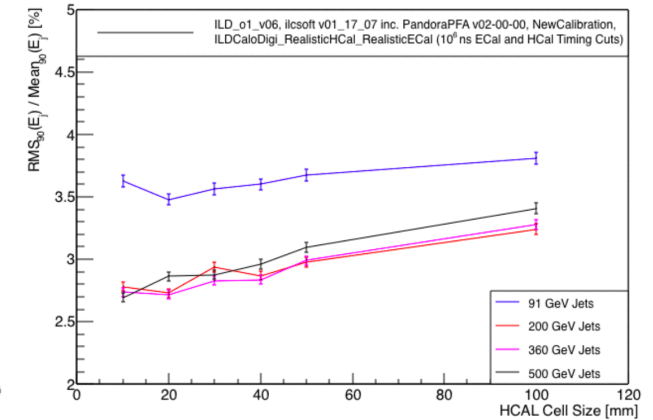
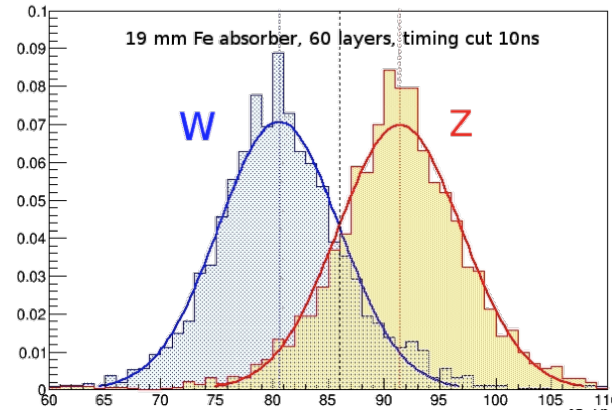


# Detector optimisation (2)

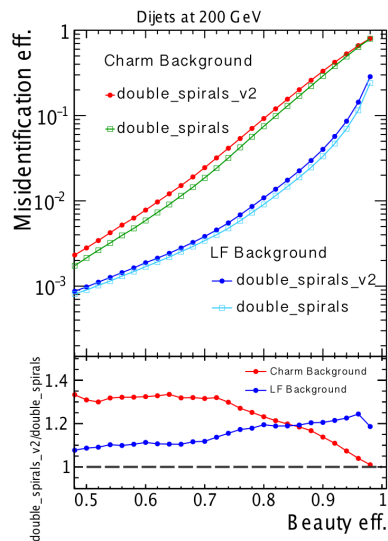
## ECAL



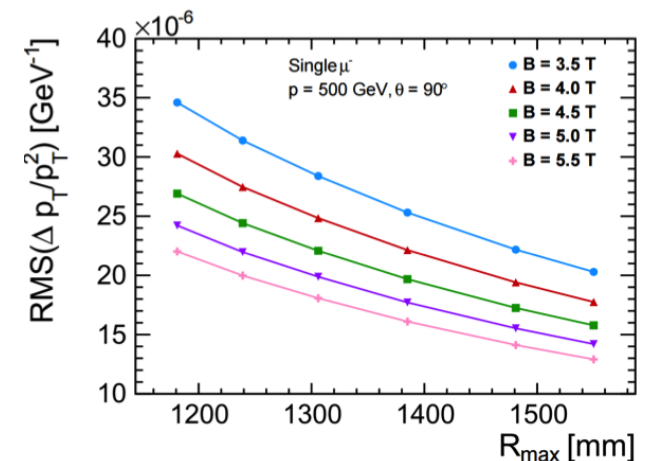
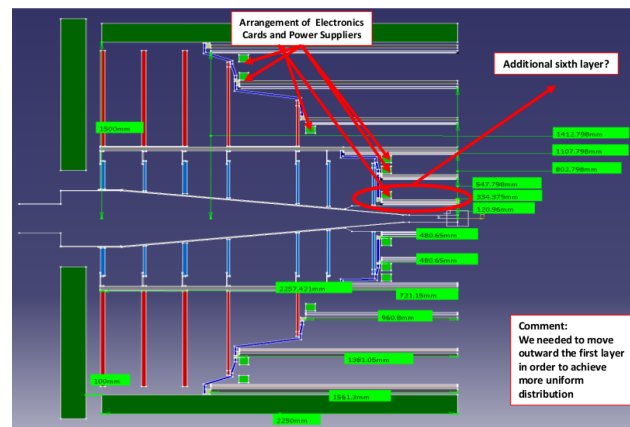
## HCAL



## Vertex detector



## Tracker layout

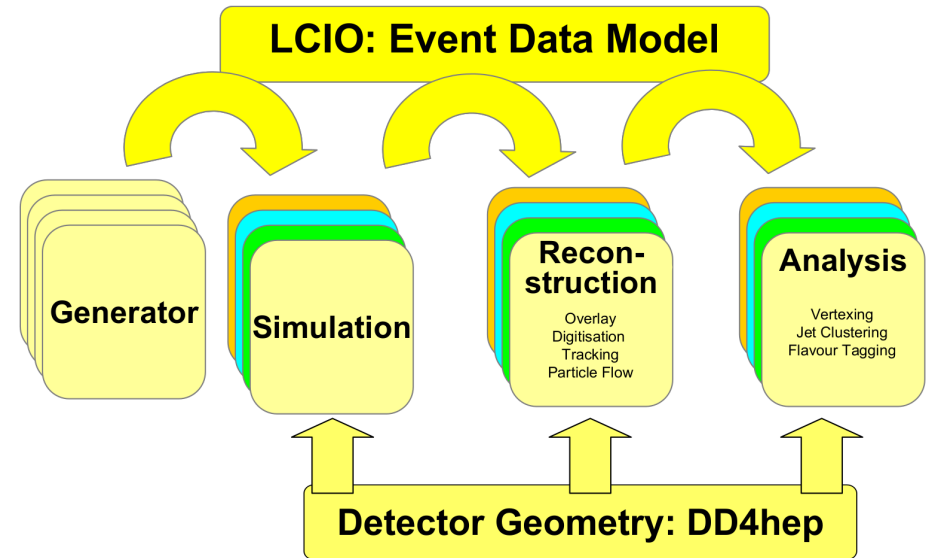




# Software development for the new CLIC detector model

## Development of software chain for detector optimisation and physics simulations:

- Detector geometry description based on **DD4hep**
- Most critical item: **tracking** (intensive work ongoing)
- More work on **improved analysis tools** starting
- Grid production with **ILCDIRAC**



## Overall status on new detector model & software:

- The new **detector model** for the next round of physics simulations is **nearly completed**. A **draft note** describing the model exists.
- The software development is **very advanced**. Currently moving from development to validation phase.
- Hope to start physics simulations with the new detector model **early 2016**.

# Detector technology demonstrators

For the current period, the R&D aims at providing **technology demonstrators**.

**The focus of the R&D is on:**

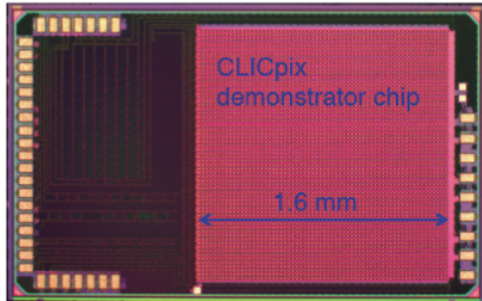
- Vertex detector
- Silicon tracker
- Calorimetry
- Electronics development

→ See illustrations of progress  
on the next few slides

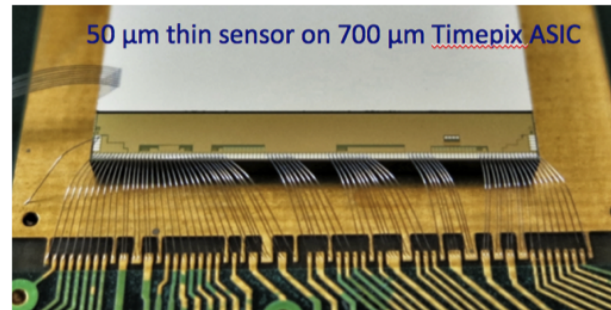
+ Engineering and integration (currently mostly for vertex & tracker system)

# Vertex detector R&D

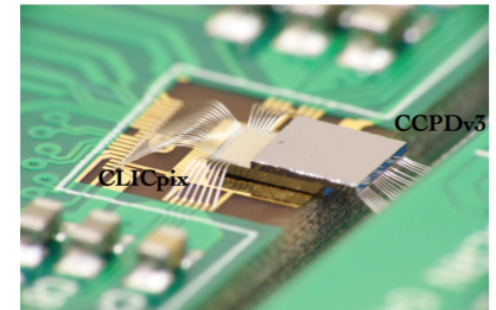
electronics - readout chip



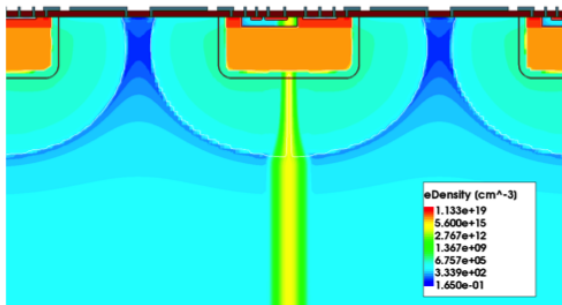
thin readout chip + sensor assembly



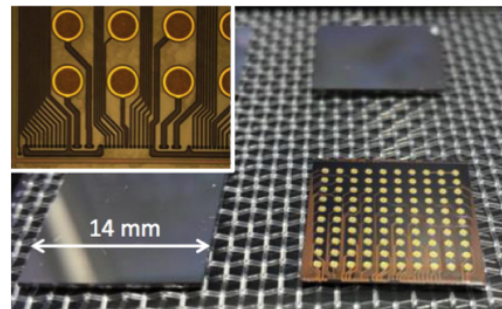
HV-CMOS + CLICpix



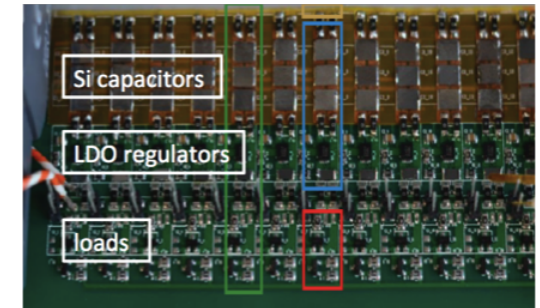
signal simulations (TCAD)



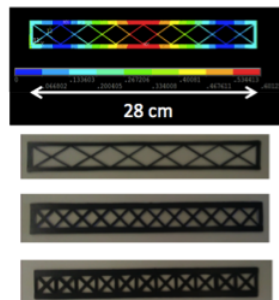
Interconnect technology



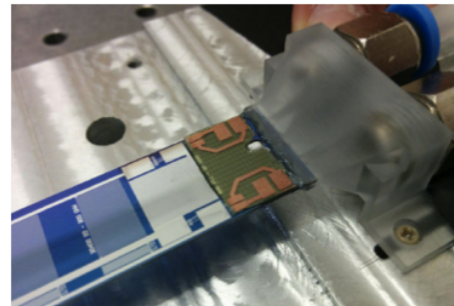
Power delivery + pulsing



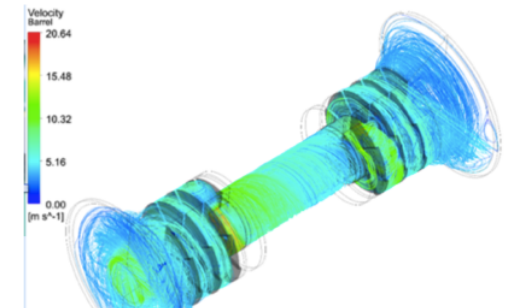
thin supports



micro-channel cooling



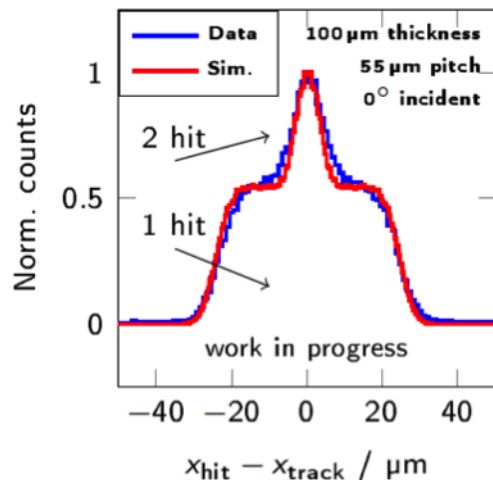
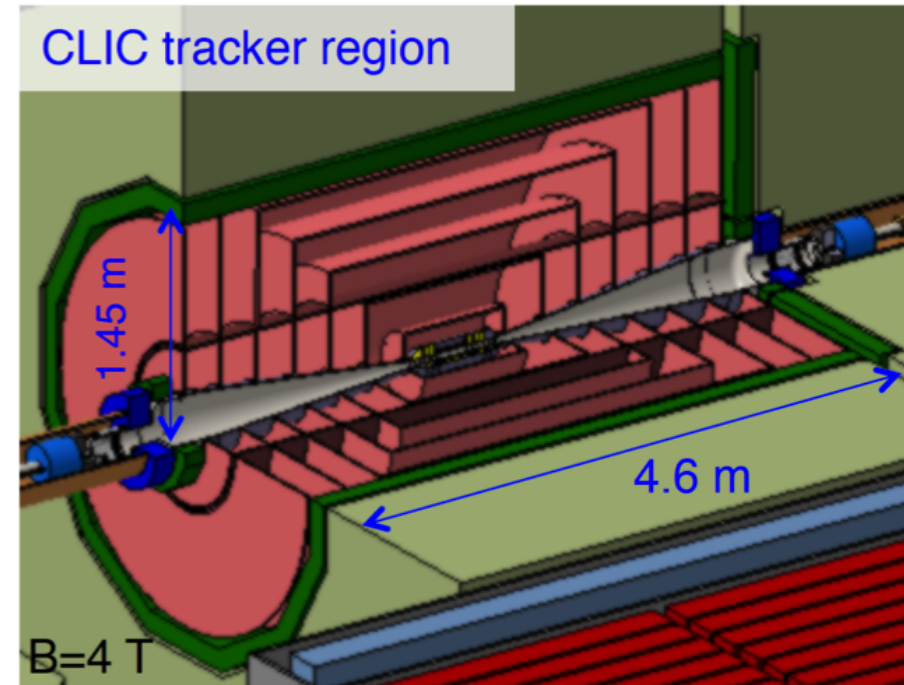
air cooling simulations & tests



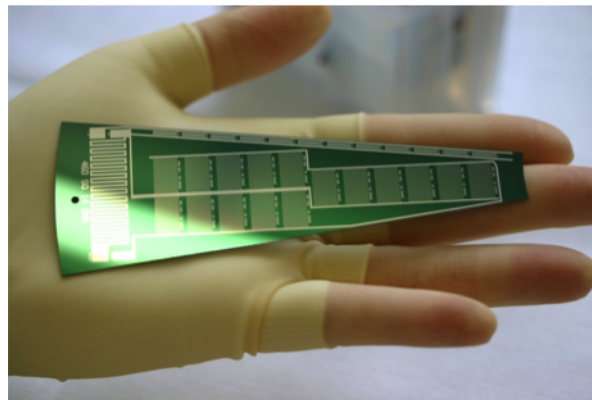
# Silicon tracker R&D

- **7  $\mu\text{m}$**  single point accuracy
- **10 ns** time stamping
- **5-6 tracking layers**, 1.5 m radius, 4.6 m length
- High occupancies in certain regions  
→ require **large pixels and/or short strips**
- Very light →  $\approx 1\text{-}2\%$   $X_0$  per layer

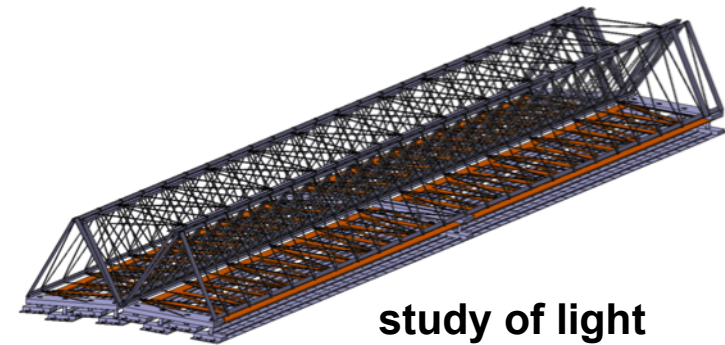
**Tracking working group established in 2015**  
Mostly still simulations + first R&D + engineering



sensor response simulations



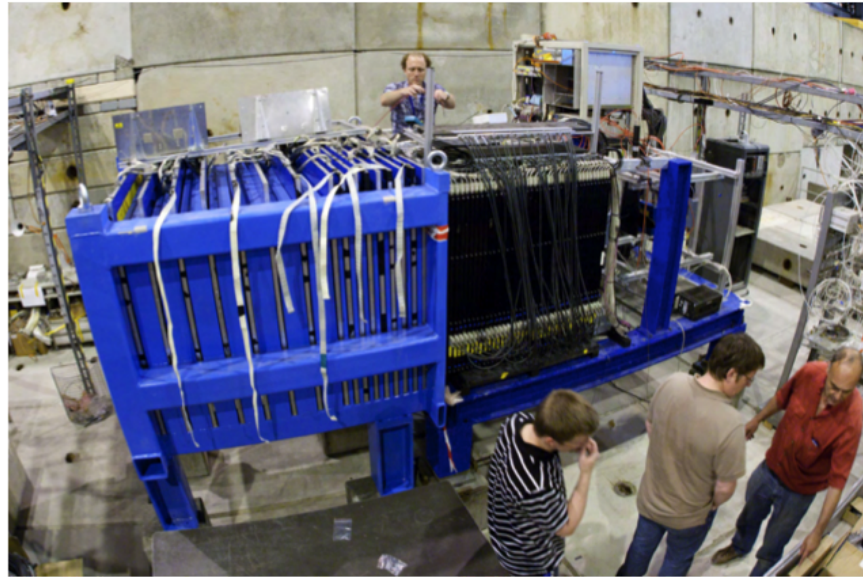
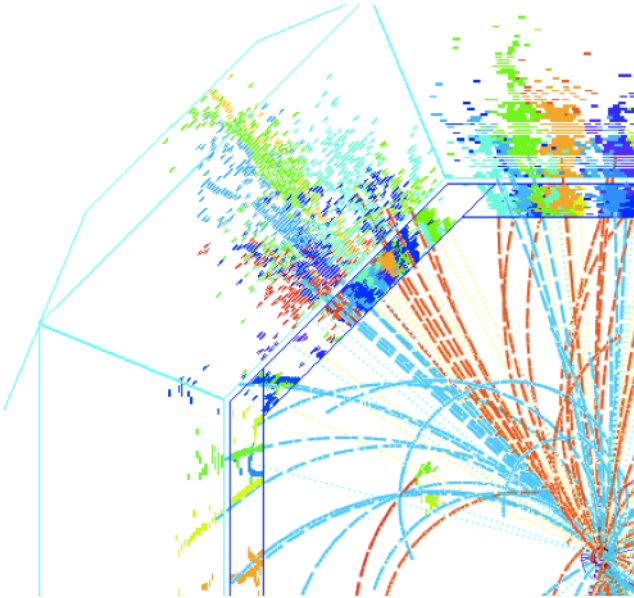
sensor+support in one device  
for forward disk petal



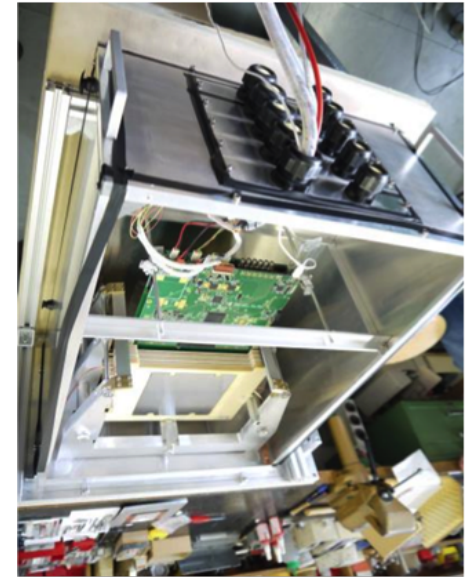
study of light  
supports for the  
tracker barrel



# Fine-grained calorimetry (ECAL/HCAL/FCAL)



CALICE



FCAL

- Strong CLICdp participation in the CALICE and FCAL collaborations  
→ **extensive R&D efforts**
- Beam-tests in 2015:
  - CALICE at CERN
  - FCAL at DESY
- Several publications on results

**Note:** the fine-grained HGC endcap calorimeter for the CMS upgrade is a **spin-off from Linear Collider R&D**. Several CLICdp groups are involved (from “advice” to “participation”).

# CLICdp documents in preparation for the next European Strategy

## CLICdp reports serving as ingredients for a summary report:

- [2015 CLIC re-baselining report](#):  
In preparation, together with accelerator. Draft by by-2015. Publication tbc.
- [The 2015 CLIC detector model](#):  
Nearly complete draft exists. Technical note.
- [The CLIC Higgs physics overview publication of 2015](#):  
Nearly finished. End-2015. Publication.
- [An overview of top physics at CLIC](#):  
Foreseen CLIC top physics publication in 2016/2017?
- [Extended BSM physics studies](#) (hopefully motivated by LHC discoveries):  
Foresee publication in 2017?
- [CLIC R&D report](#) (with main CLIC technology demonstrators):  
Summary report. 2017. Note or publication tbc.
- [Plan for the period  \$\approx\$ 2019-2025](#) (in case CLIC would be supported by the next strategy):  
2017/18. Note to be included in the CLIC input report for the strategy process.