Detector Optimization of the CLIC Tracker

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CLIC - **C**ompact **Li**near **C**ollider

A proposal for CERN's future

Motivation for linear e^-e^+ collider

- Leptons instead of hadrons
  —> Cleaner environment to achieve high precision in CLIC physics studies
- Linear instead of circular
  —> no synchrotron radiation

- **Stage 1** (380 GeV):
  —> high precision studies of Higgs and top properties

- **Stage 2** (1.4 TeV)

- **Stage 3** (3 TeV):
  —> discovery and high precision studies

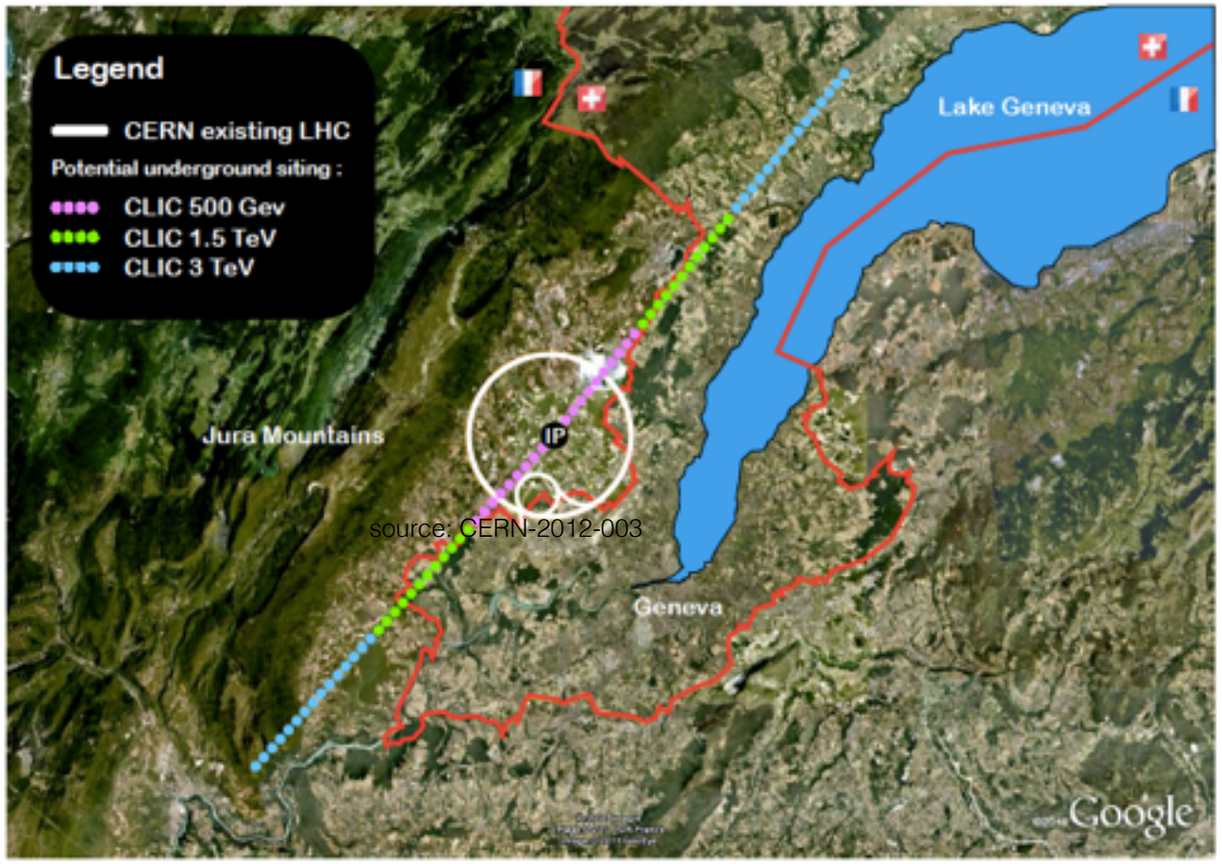
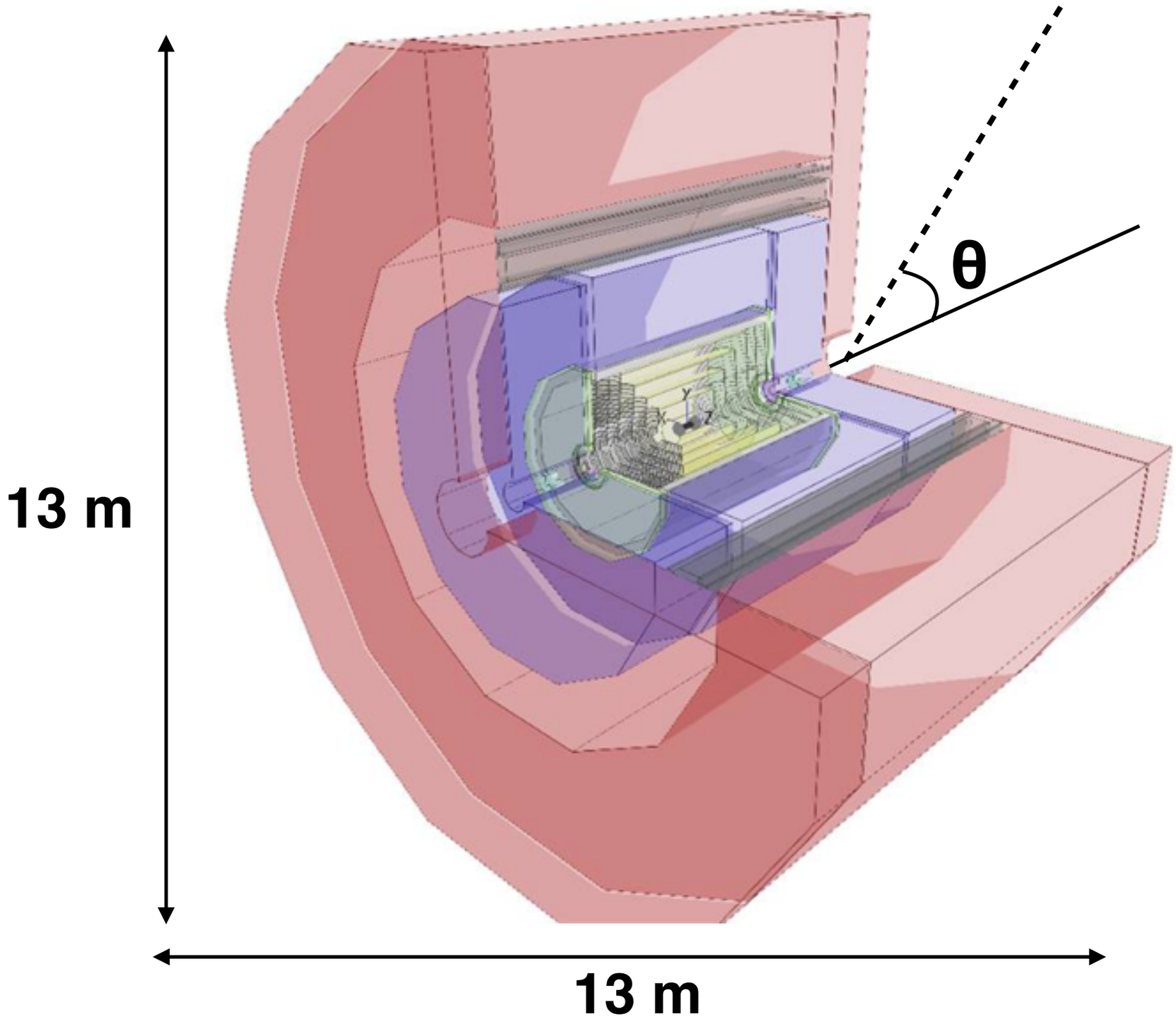


Fig. 7.2: CLIC footprints near CERN, showing various implementation stages [5].

Optimization of CLIC detector is on-going, my work in the tracker optimization

The CLIC Detector

Tracker system
Calorimeter system
Yoke + muon system

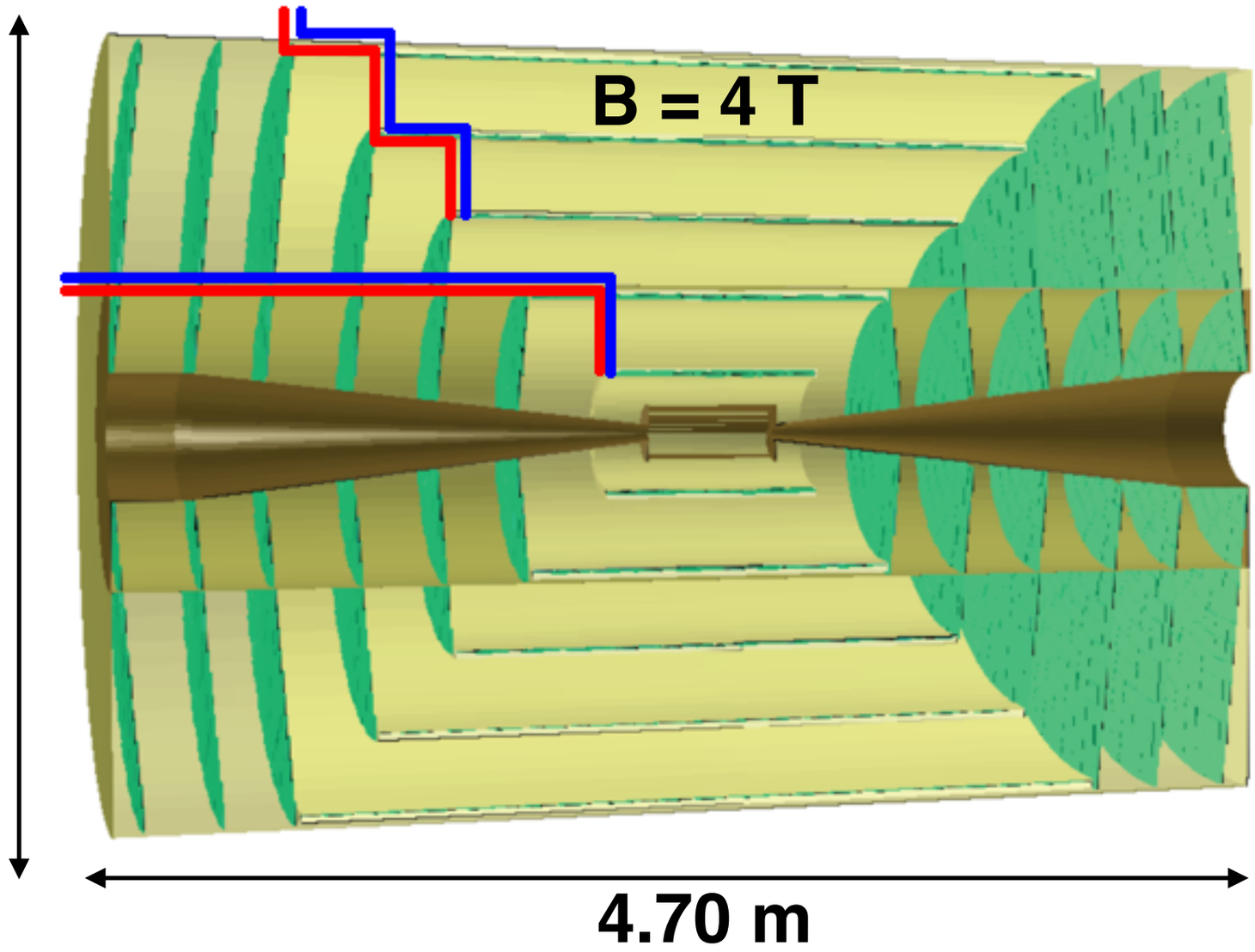


source: Thorben Quast, CERN Summer Student 2015

CLIC tracker simulation model

Elements:

- **sensors**
- **supports**
- **cables**
- **cooling**



My contribution:

- Implemented realistic material composition in simulation model (with input from engineers)
- Studied tracker performance for different scenarios (e.g. adding an extra end-cap disk)

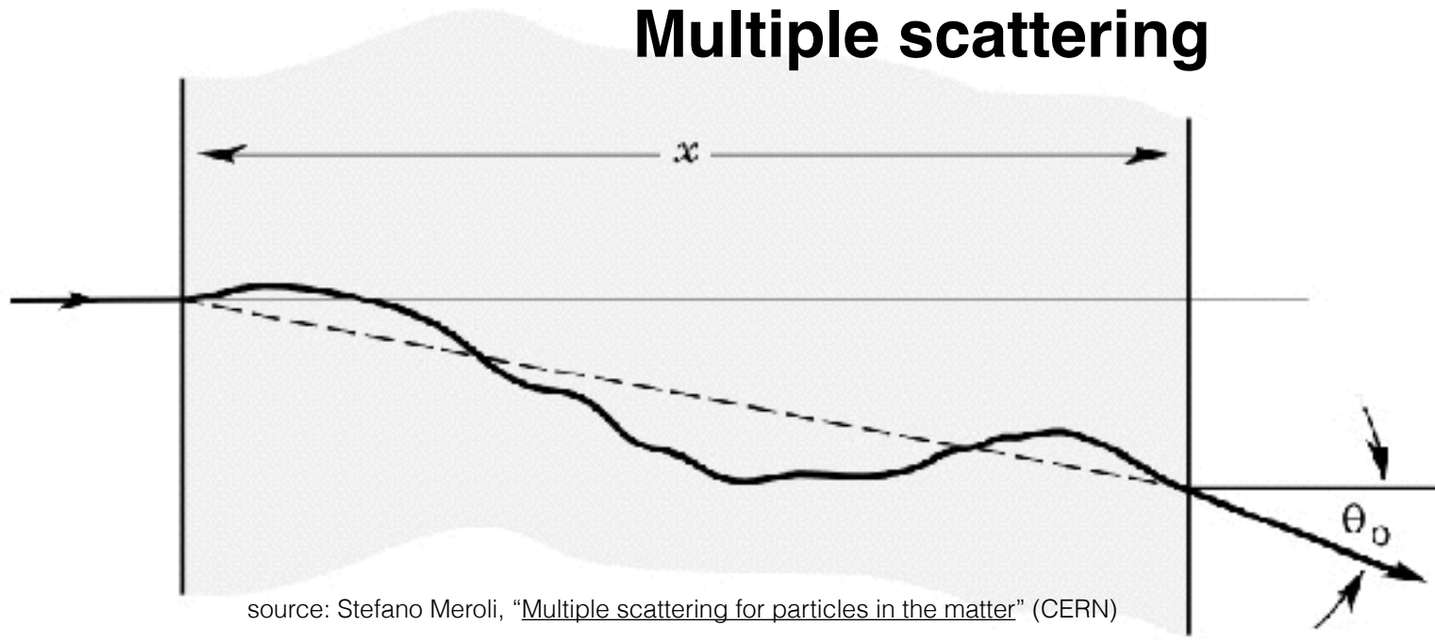
Tracker optimization

Goal of CLIC tracker:

Momentum resolution:

$$\sigma_{p_T}/p_T^2 \approx 2 \times 10^{-5} GeV^{-1}$$

Multiple scattering



source: Stefano Meroli, "Multiple scattering for particles in the matter" (CERN)

It can be achieved with:

1. 7 μm single point resolution
2. Very light —> **Material budget** = 1-2 % X_0 per layer

Challenge: The presence of material affects tracking performances

Effects: Multiple scattering $\begin{cases} \text{Inelastic scattering from atomic electrons} \\ \text{Elastic scattering from nuclei} \end{cases}$

Unit: Radiation length, X_0 = Distance over which an electron loses all but $1/e$ of its energy by bremsstrahlung

—> we specify a **material budget** per layer in terms of X_0

X_0 depends on:

- **Atomic number *Z***
- **Mass number *A***

Material budget results

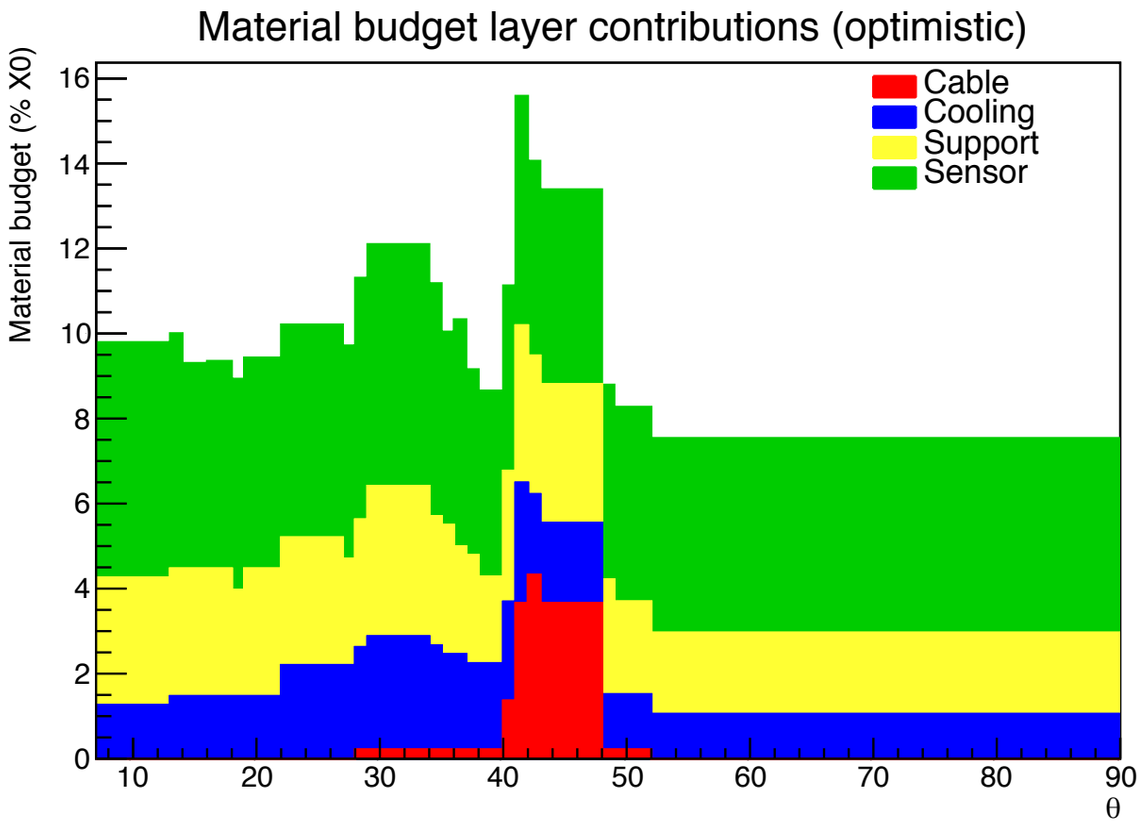
		Barrel (unit: % X_0)					Forward (unit: % X_0)					
	model	1	2	3	4	5	1	2	3	4	5	6
sensors	optimistic	0.49	0.49	0.49	0.49	0.49	0.88	0.88	0.88	0.88	0.88	0.88
	conservative	0.55	0.55	0.55	0.55	0.55	1.00	1.00	1.00	1.00	1.00	1.00
cables	optimistic	0.18	0.30	0.43	0.55	0.67	0.05	0.06	0.10	0.13	0.09	0.06
	conservative	0.36	0.60	0.86	1.10	1.34	0.10	0.11	0.19	0.25	0.17	0.13
cooling	optimistic	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
	conservative	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
supports	optimistic	0.27	1.04	0.52	0.56	0.56	0.50	0.83	1.20	1.50	1.50	1.50
	conservative	0.54	1.04	1.04	1.11	1.11	0.50	0.83	1.20	1.50	1.50	1.50
SUM	optimistic	1.15	2.04	1.65	1.81	1.93	1.64	1.98	1.39	2.72	2.68	2.65
	conserative	1.75	2.49	2.96	3.06	330	1.90	2.24	2.69	3.05	2.97	2.93

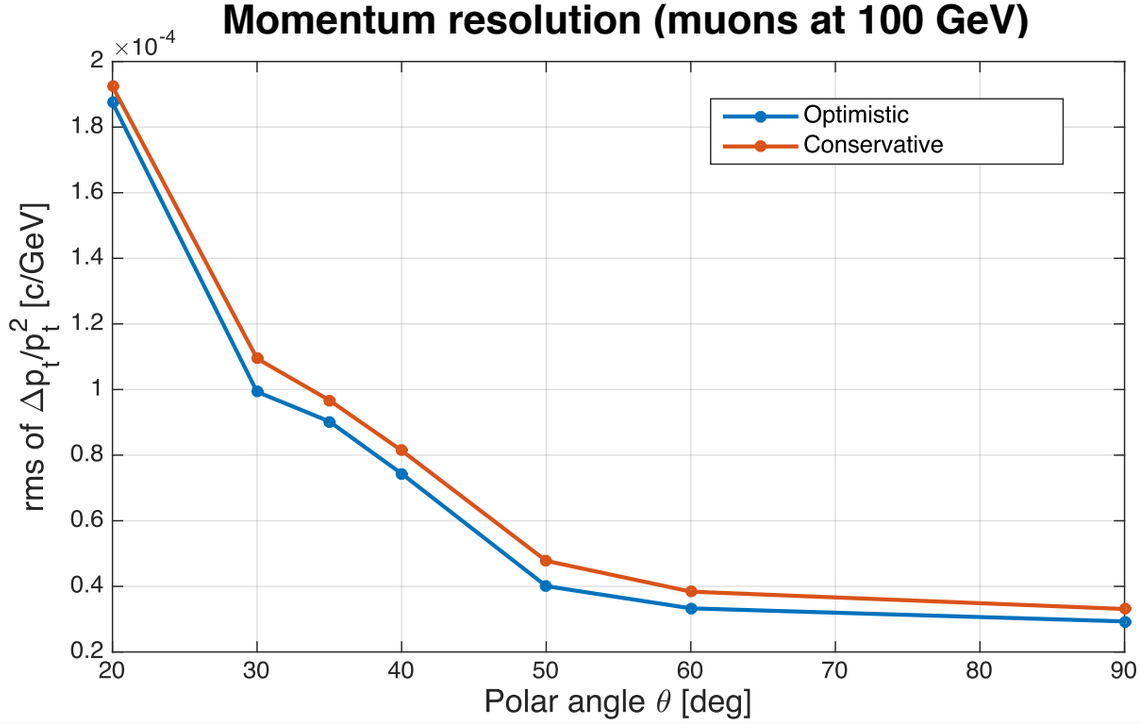
Updated material budget values provided by CLIC engineer Szymon Sroka

Results obtained with LiC Detector Toy program (fast simulation)

More material budget
—> degradation in resolution

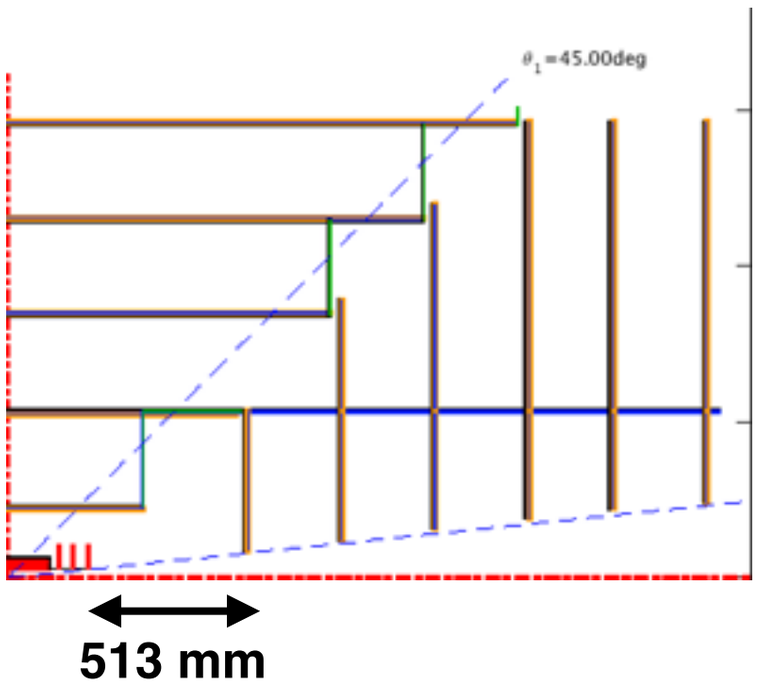
Central region performance close to goal of
$2 \times 10^{-5} GeV^{-1}$



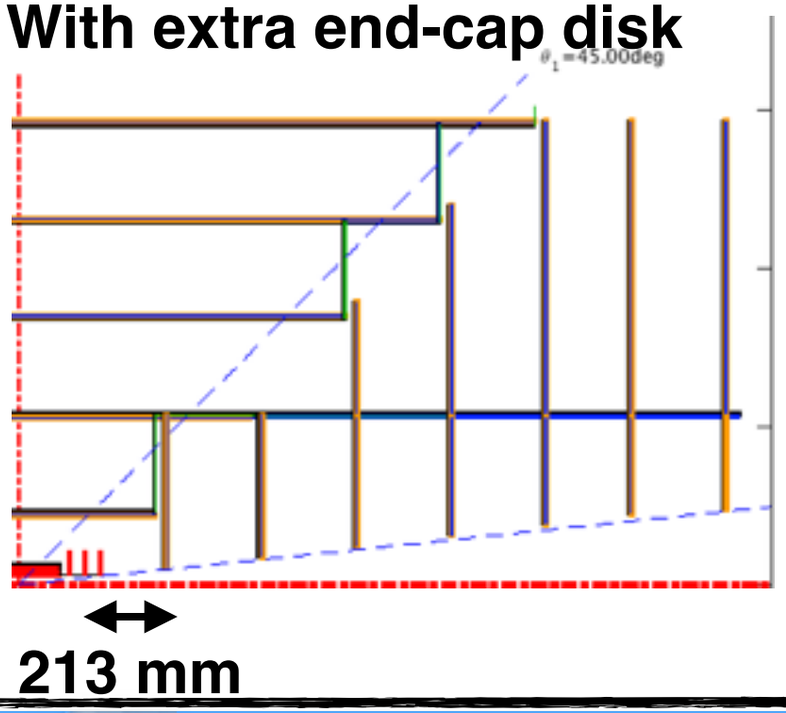


Position of added end-cap

Without extra end-cap disk



With extra end-cap disk



- **Challenge:**
  Large extrapolation can be problematic for track reconstruction in presence of background

  —> pick up the right hits belonging to a track

- **Possible solution:**
  Study the possibility to add an extra disk closer to the vertex detector

Work still ongoing

Conclusion

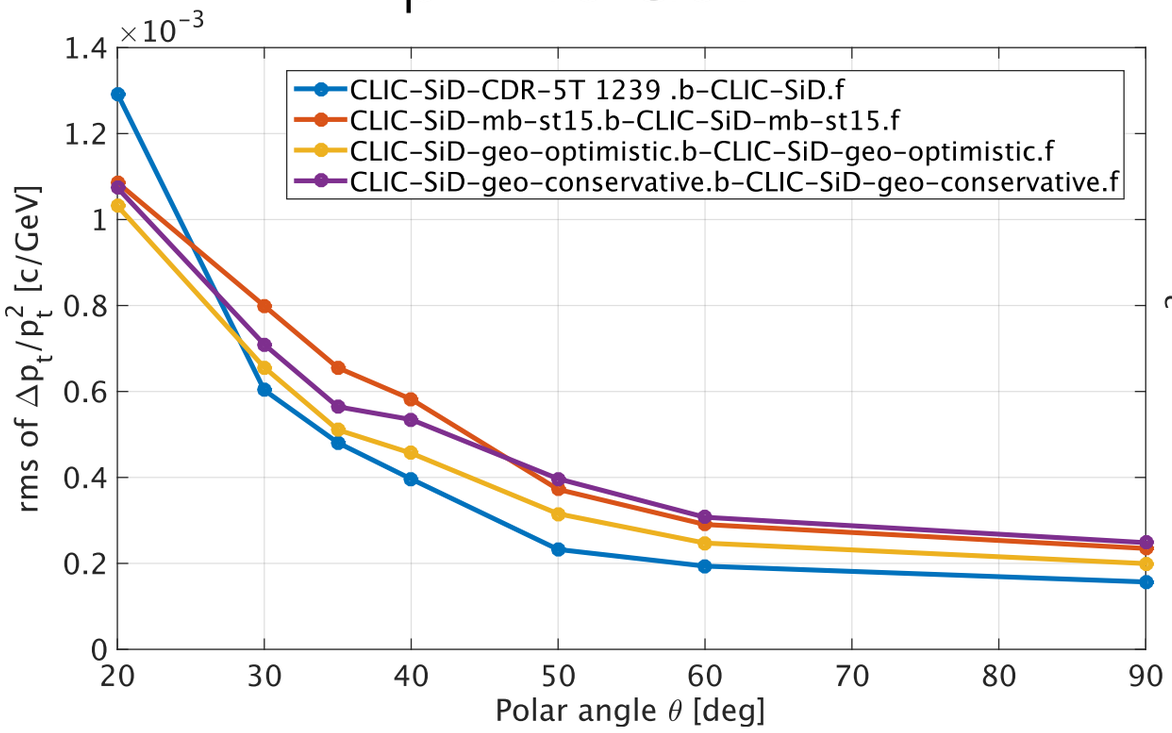
- Optimization of the tracker important to achieve precision physics studies
- Studied the impact of material budget on tracking
- Studies on going for adding an extra disk

More information about the CLIC project:
- http://clicdp.web.cern.ch
- http://arxiv.org/ftp/arxiv/papers/1202/1202.5940.pdf

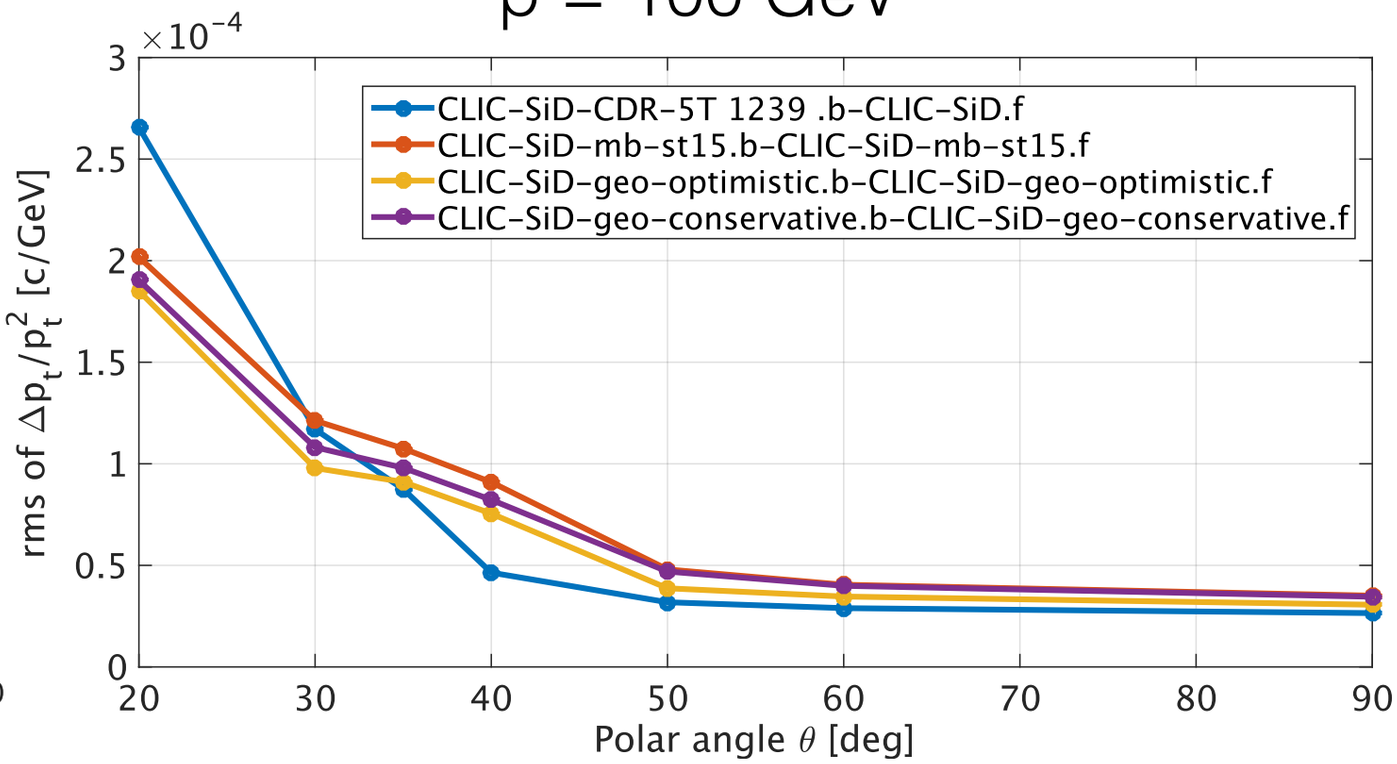
Backup slide 1

$\Delta p_t/p_t^2$ vs. θ

p = 10 GeV



p = 100 GeV

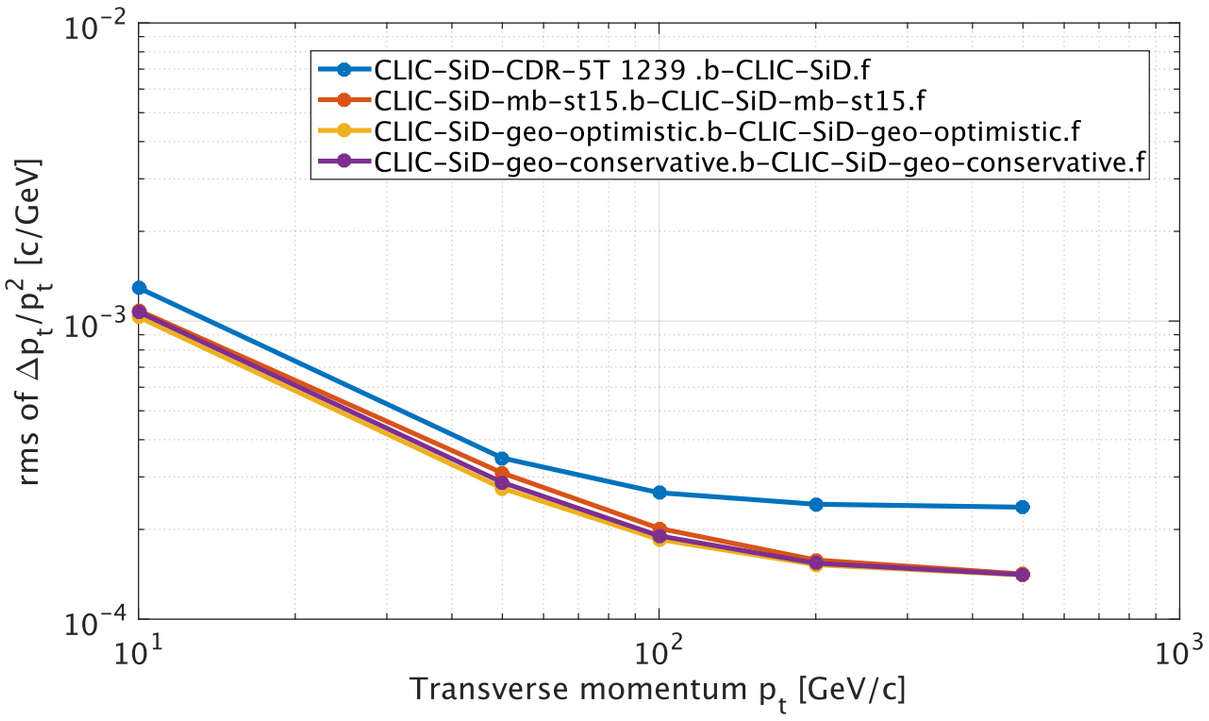


- Forward region, better than CDR for all models, due to the 2 extra discs
- Transition region, material budget added for taking out cable and cooling (all models, but CDR)
- Barrel region, added cables and cooling along all sensors,

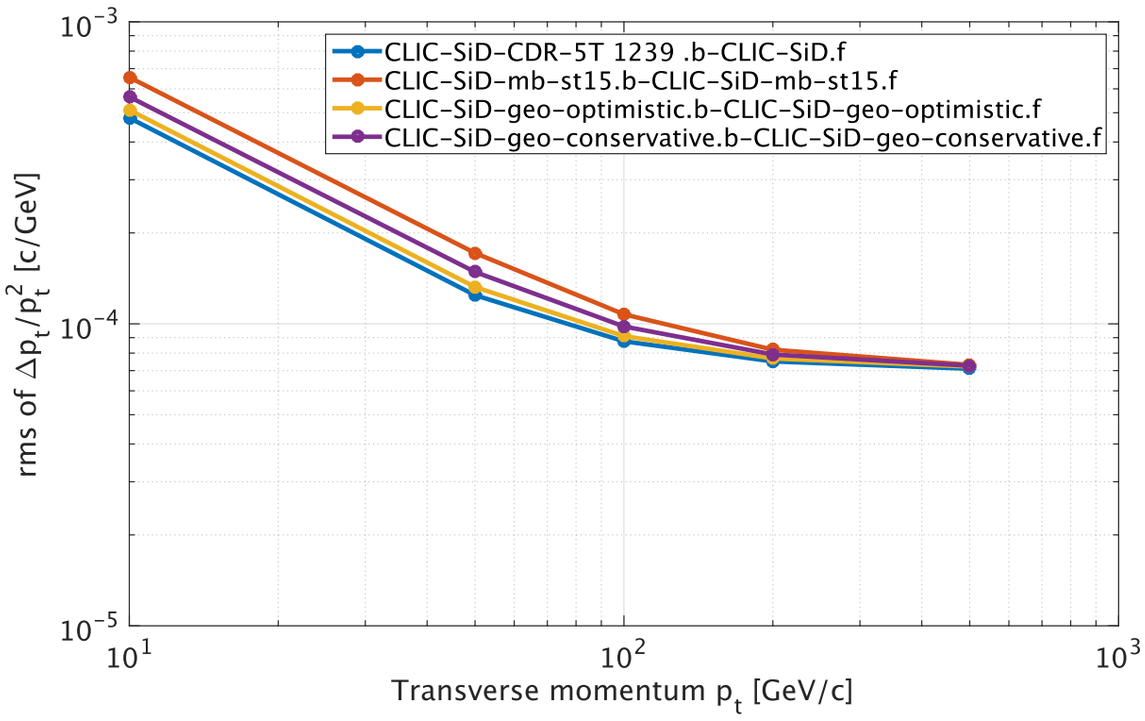
Backup slide 2

$\Delta p_t / p_t^2$ vs. p

θ = 20°



θ = 35°



θ = 90°