Update on physics benchmark studies

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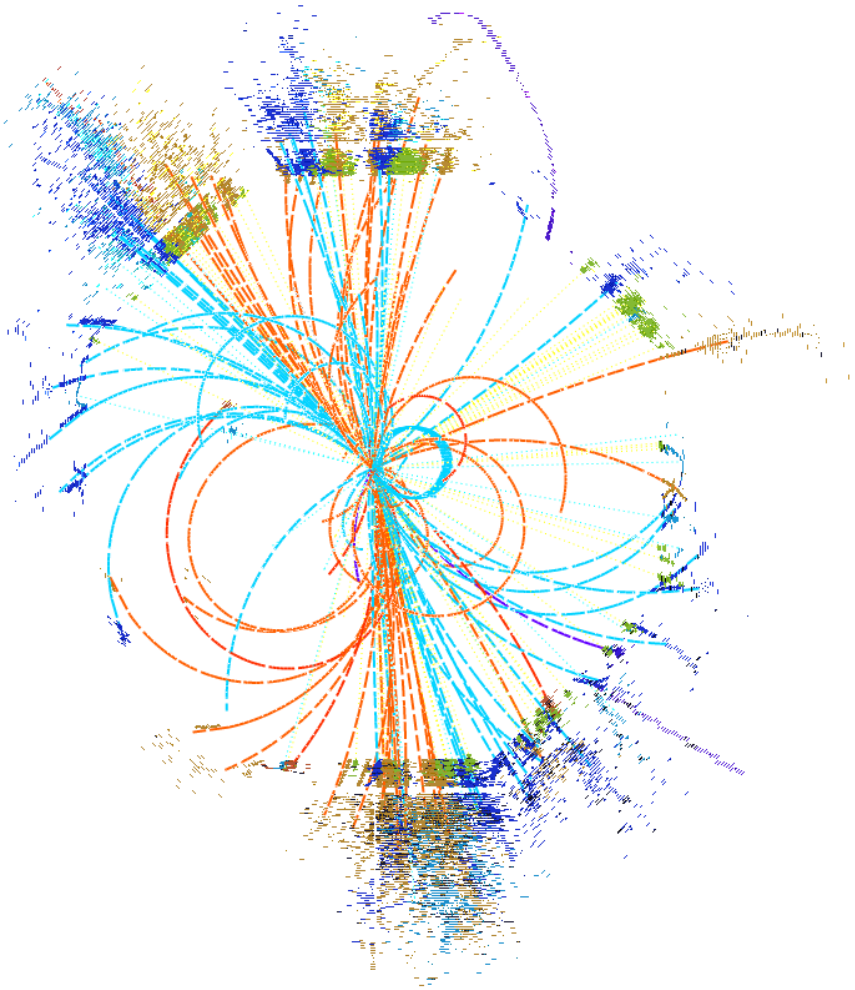

CLIC Workshop 2016, CLICdp Pleanary, 19/01/2016, CERN

Motivation for physics benchmark studies

- Illustrate the CLIC physics potential
- Demonstrate the capabilities of the CLIC detector concepts based on realistic simulations

Physics benchmarks studies lead to:
Hardware requirements, physics-based detector optimisation (not always easy, e.g. reconstruction of multi-jet final states not just driven by detector performance)

Example issues not (sufficiently) addressed so far:
- Reconstruction of jets/resonances in the forward direction
- Boosted top quarks (common issue with hadron colliders)
- Impact of beam polarisation

Current areas of benchmark studies

- **Higgs studies after the paper**
- **Top physics overview paper**
- **Other studies with focus on BSM physics**

Higgs studies after the paper

• **Reanalysis of double Higgs production:**
Simultaneous extraction of the Higgs self-coupling and the HHWW coupling
Rosa Simoniello (HH → $b\bar{b}b\bar{b}$), Bono Xu (HH → WW*$b\bar{b}$), Ph. R.
→ see talk by Bono Xu on Thursday

• **H → WW* → qqlν using WW fusion at 350 GeV:**
Continuation of the H→WW* analyses using HZ events
Mila Pandurovic

• **H → γγ at 3 TeV:**
Test of photon reconstruction using the new CLIC detector concept
Goran Kacarevic, Strahinja Lukic

• **H → ZZ* at 3 TeV**
Continuation of study done at 1.4 TeV
Gordana Milutinovic-Dumbelovic

• **Higgs production in ZZ fusion at 3 TeV:**
Extension of the analysis at 1.4 TeV
Aidan Robson, more people welcome

• **CP properties of the Higgs in HVV and $t\bar{t}$H couplings:**
→ for more details, see my talk on Thursday, volunteers welcome

Paper on top physics at CLIC

Paper on top physics

Aim: Comprehensive paper on top physics at CLIC

Timescale: finish within 1 – 1.5 years

Assumed running scenario will be the new CLIC staging baseline:

1.) 100 fb^{-1} around 350 GeV + 500 fb^{-1} at 380 GeV
2.) 1.5 ab^{-1} at 1.4 TeV
3.) 3 ab^{-1} at 3 TeV

80% electron beam polarisation assumed at all stages

Possible content of the paper

- Reconstruction strategies for top quarks
(boosted and near threshold)

- **Benchmark analyses:**

1.) Threshold scan around 350 GeV

2.) Measurement of A^{LR}/A^{FB} for different polarisation configurations and extraction of the couplings to the Z boson and photon
at 380 GeV, 1.4 TeV (and 3 TeV?)

3.) FCNC top quark decays: $t \rightarrow cH$, $t \rightarrow c\gamma$ (and others?) at 380 GeV

4.) Analysis of $t\bar{t}H$ events at 1.4 TeV: top Yukawa coupling
and CP properties in the $t\bar{t}H$ coupling

5.) V_{tb} from single top events at 3 TeV?

6.) Top squark pair production at 3 TeV (using CDR Model 3)?

- Phenomenological interpretations of the results where possible

Existing results and ongoing work

- Threshold scan (Eur.Phys.J. C73 (2013) 2530)
→ to be adapted to new developments (improved theory, systematics, …)

- Top Yukawa coupling (CLIDdp-Note-2015-001, CLIDdp-Note-2015-001)
→ add study of Higgs CP properties

- Decay t → cH at 380 GeV
→ generator study by Filip Zarnecki, will be extended to full simulation

- Decay t → cγ at 380 GeV
→ Naomi van der Kolk starting full simulation study

- $t\bar{t}$ production at 380 GeV and Z and γ couping at 380 GeV
→ ongoing study by Nacho Garcia, Martin Perello and Marcel Vos
→ see presentation by Nacho Garcia on Thursday

- $t\bar{t}$ production at 1.4 TeV
→ very first look by Megan Wilson

- Top squark production (CDR model 3)
→ studies by Alan Taylor, Andrew Thornbury and Victoria Martin

→ A lot of open topics / opportunities to contribute

Other topics with focus on BSM physics

Ongoing studies

• **Model-independent searches for Dark Matter using the photon + missing energy final state:**
Jean-Jacques Blaising

• **Triple and quartic gauge couplings using $e^+e^- \to W^+W^- (\nu\bar{\nu}/e^+e^-)$:**
Steve Green

• **Hidden valley searches using Higgs decays (and other processes?):**
Marcin Kucharczyk, Agnieszka Bialek
→ see presentation by Marcin Kucharczyk later today

• **$e^+e^- \to \gamma\gamma$ at 3 TeV:**
Sensitivity to finite electron size (interpretation in other models planned)
Igor Boyko, Yura Nefedov
→ see presentation by Igor Boyko later today

• **$b\bar{b}$ production asymmetry at 1.4 TeV:**
Pawel Sopicki

Open topics

Many interesting aspects not yet investigated for CLIC yet:

- Gauginos / Higgsinos with small mass splittings
- W boson mass determination at high energy
- Higher-dimensional effective operators, weakly interacting exotic particles
- ...

Volunteers for these (and other) studies welcome!

Especially more work on indirect BSM sensitivity of precision measurements is very important!

Aim to extend this table substantially for the next European strategy update:

	CLIC 3 TeV	**HL-LHC**
Z'	50 TeV	7 TeV
Higgs comp. scale	70 TeV	9 - 12 TeV
Finite electron size	3×10^{-18} cm	impossible?

How to get involved

Regular analysis meetings at CERN (every 2-3 weeks):

http://indico.cern.ch/categoryDisplay.py?categId=3222

Remote participation by Vidyo is always possible!

If interested, please contact us:

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philipp.roloff@cern.ch

Summary and outlook

- CLIC physics benchmark studies are a very active area

- **In the foreseeable future, the focus will be on:**

1.) Sensitivity to BSM physics, also through precision EW measurements
→ Be prepared for new input from the LHC at 13 TeV

2.) Overview paper on top physics

3.) Benchmarking of the CLICdet_2015 detector model using the new simulation and reconstruction chain

- Lots of opportunities to contribute
(many examples in this presentation)

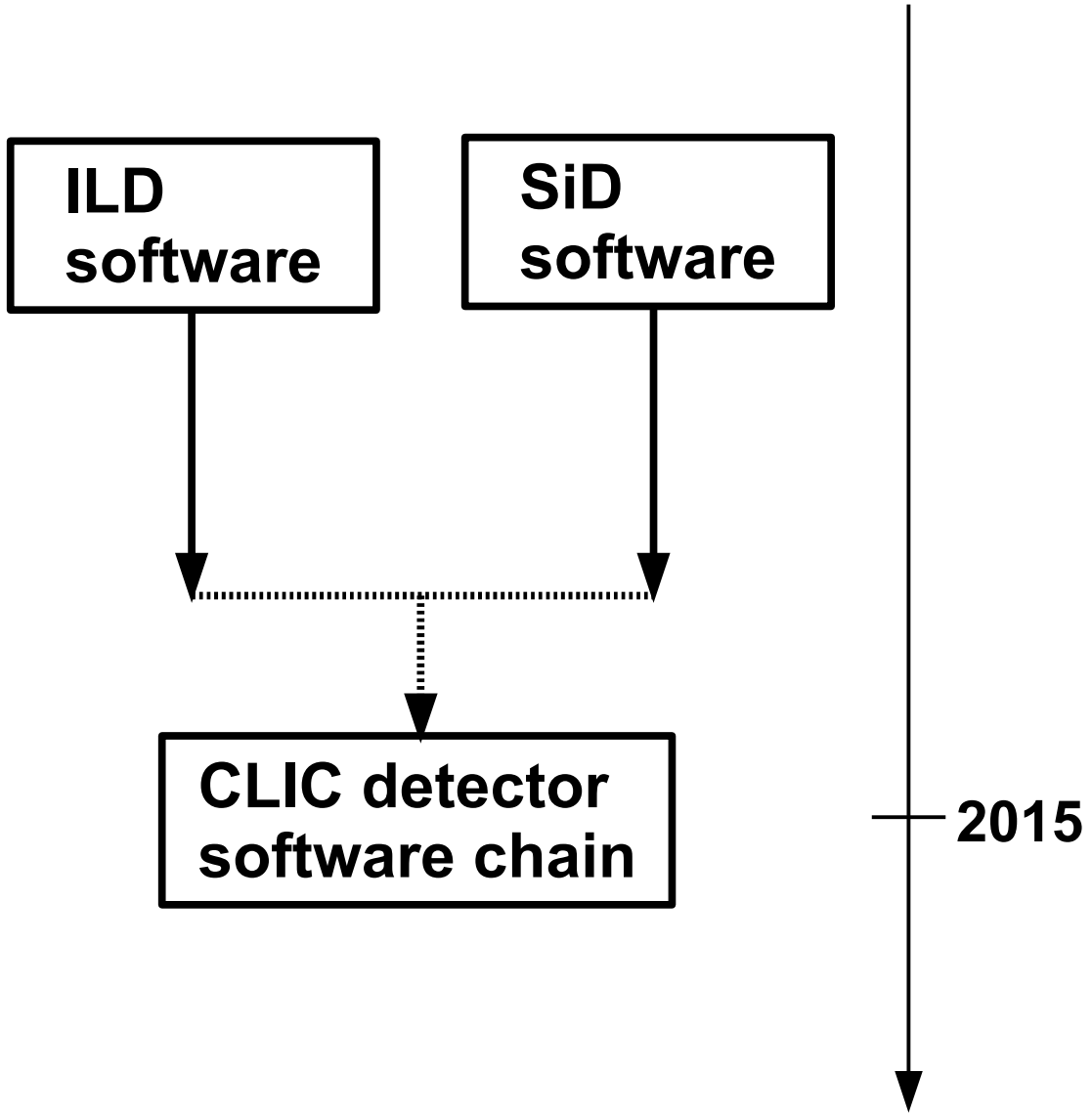
Backup slides

Future detector model and software chain

• All current benchmarks are performed either for the CLIC_ILD or the CLIC_SiD detector model

• **New detector concept optimised for CLIC:** move to single software chain in the future

• **On the same time scale:**
WHIZARD 1.95 → WHIZARD 2
PYTHIA 6.4 → PYTHIA 8?



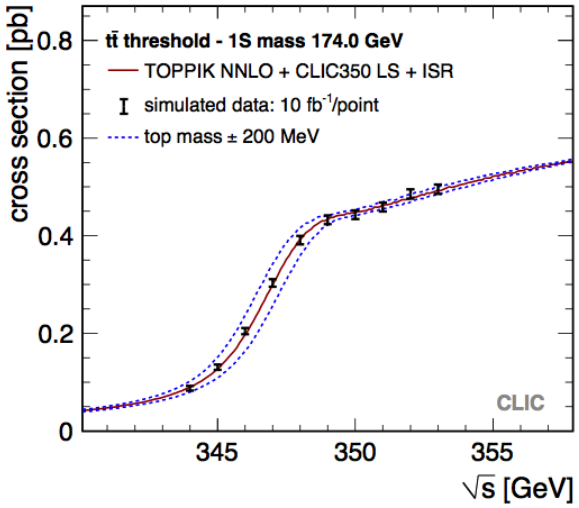
First stage (350 - 380 GeV)

Threshold scan (350 GeV):

• Extract theoretically well-defined top mass

• Currently 50 MeV theoretical uncertainty seem reachable

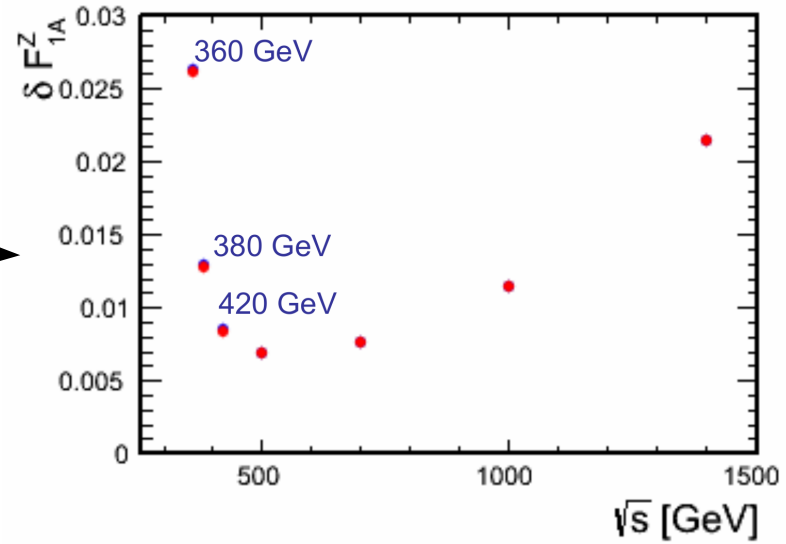
→ Systematic uncertainties need to be controlled on that level



380 GeV:

• Sensitivity to BSM phenomena through precision measurements (A^{LR}, A^{FB}) of $t\bar{t}$ production.

Example: precision measurement of top quark couplings to Z and γ



Marcel Vos at CLIC workshop 2015

• Close to maximum of $t\bar{t}$ production cross section (400000 $t\bar{t}$ pairs in 500 fb^{-1})

→ suitable for rare decays,

e.g. t → cH, t → cγ, ...

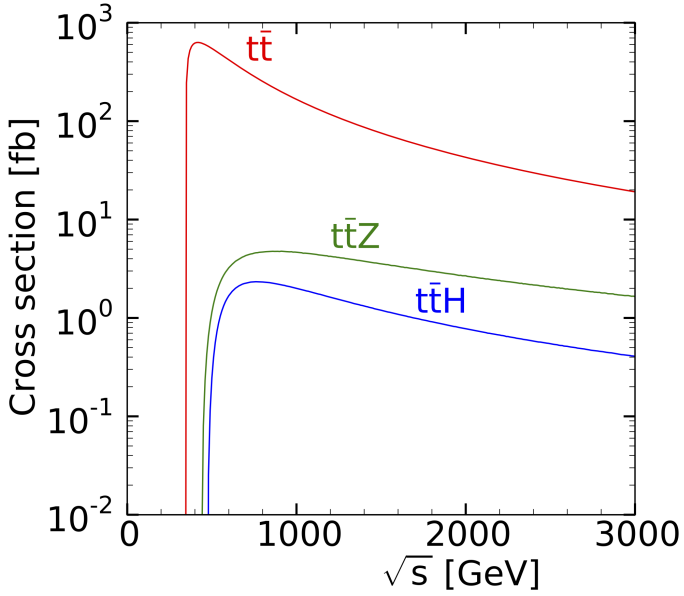
High energy operation

$t\bar{t}H$ production:

• 1.4 TeV not far from maximum of cross section

→ extraction of the top Yukawa coupling

→ Higgs CP properties in ttH coupling



$t\bar{t}$ production:

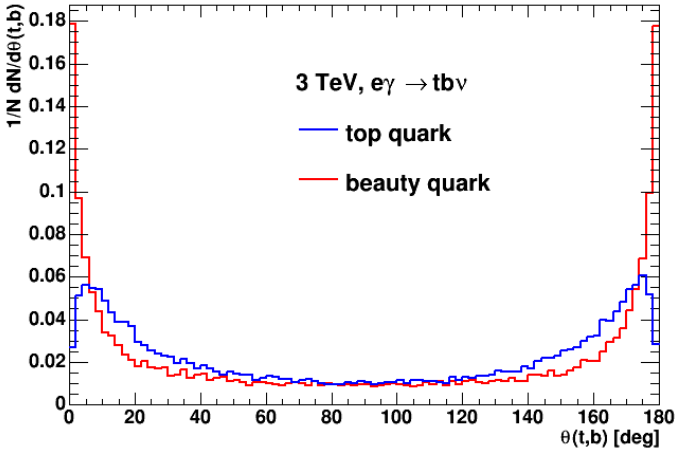
• Often contributions from New Physics rise with the interaction energy as E^2 / Λ^2, where Λ is the scale of New Physics

Single top production:

• $e\gamma \rightarrow tb\nu$ has no background from $t\bar{t}$

• 200000 events expected at 3 TeV for 2 ab^{-1}

→ measurement of V_{tb}



New particle searches using boosted tops:

• Example: light stop quarks