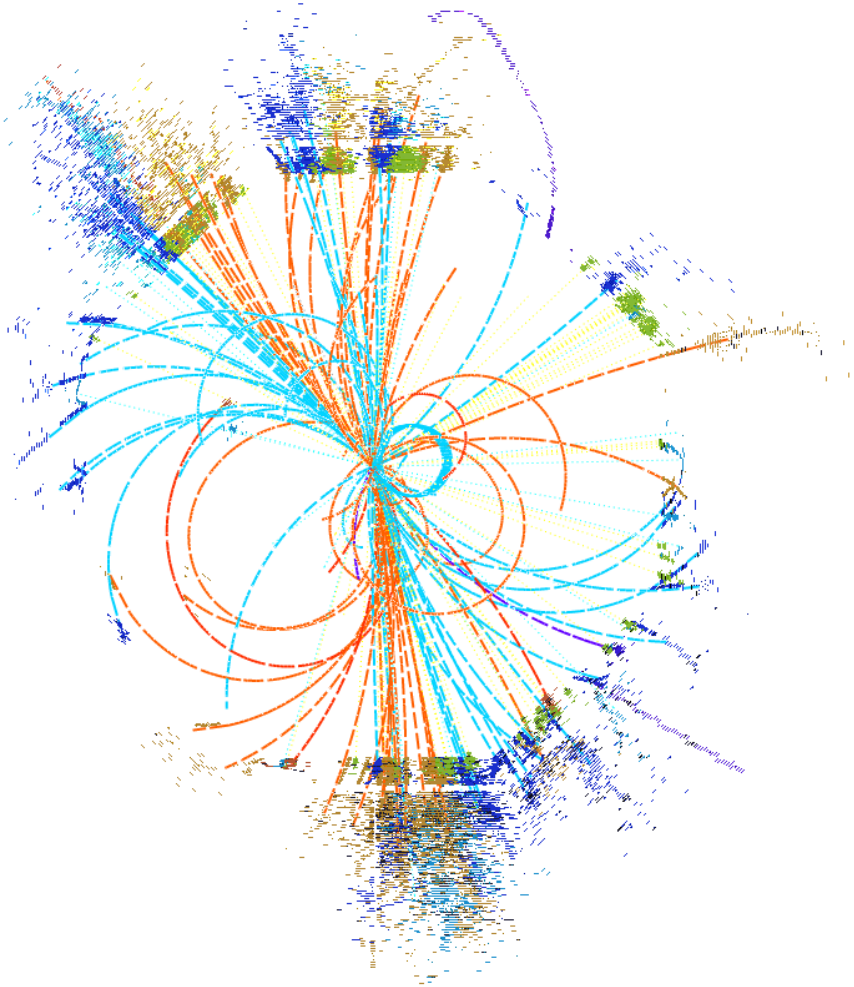
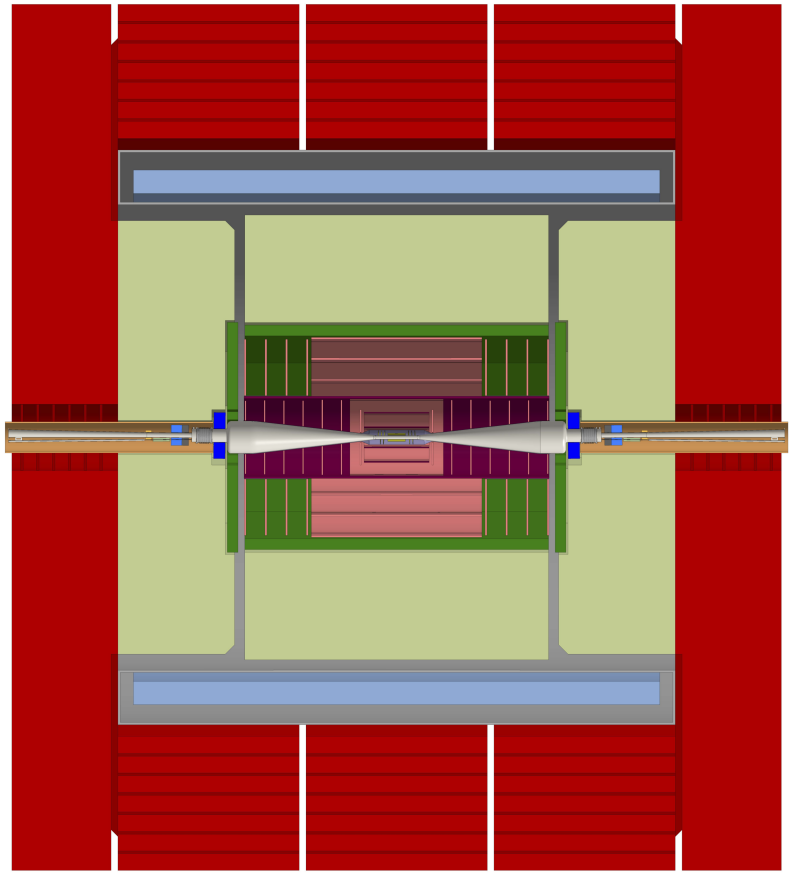
Suggestions for contributions

Philipp Roloff (CERN)





CLICdp Collaboration Meeting, CLICdp Plenary, 30/08/2016, CERN

Areas covered in this talk

- **Physics benchmark studies:**
Paper on top physics and BSM searches

- **Physics performance validation**
for the new CLIC detector model and software chain

- **Other topics** including high-level reconstruction software and computing

Paper on top physics at CLIC

Paper on top physics

Aim: Comprehensive paper on top physics at CLIC

Timescale: finish within ≈ 1 year

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 1.5 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, 1.5 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?

- Phenomenological interpretations of the results where possible

Current status

1.) Threshold scan around 350 GeV:
Eur.Phys.J. C73 (2013) 2530, to be adapted to new developments (improved theory, systematics, …)
Frank Simon

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, 1.5 TeV (and 3 TeV?):
Testing ground for boosted top quark reconstruction
Nacho Garcia, Martin Perello, Rickard Ström, Marcel Vos
→ see talks by Martin and Rickard tomorrow

3.) FCNC top quark decays: t → cH, t → cγ (and others?) at 380 GeV
Naomi van der Kolk, Filip Zarnecki → see talk by Filip tomorrow

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
Top Yukawa coupling was done: CLICdp-2014-001, CLICdp-2015-001
Victoria Martin is planning to look at Higgs CP properties

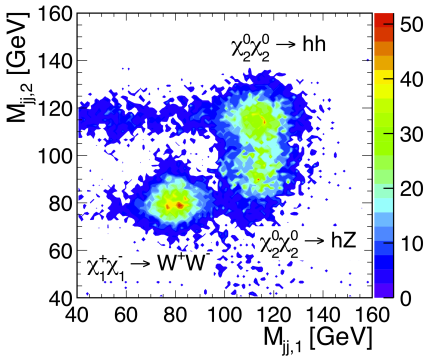
5.) V_{tb} from single top events at 3 TeV?
Not yet covered

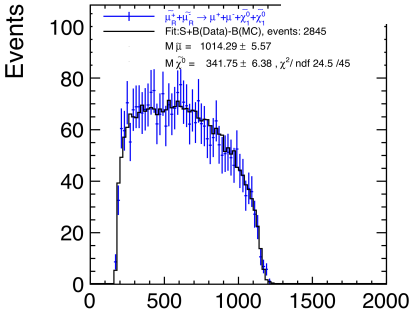
6.) Top squark pair production at 3 TeV?
Previous studies by Edinburgh group using CLIC CDR model 3
→ need to investigate if that is still a good choice
New contributors welcome

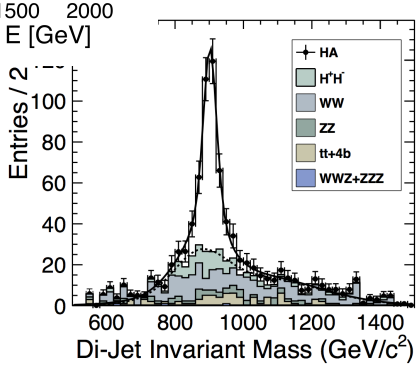
BSM searches including precision measurements

Reminder: BSM studies for the CDR

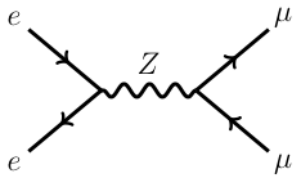
$\sqrt{s}$ (TeV)	Process	Decay mode	SUSY model	Measured quantity	Generator value (GeV)	Stat. uncertainty
3.0	Sleptons	$\tilde{\mu}_R^+\tilde{\mu}_R^- \to \mu^+\mu^-\tilde{\chi}_1^0\tilde{\chi}_1^0$	II	$\tilde{\ell}$ mass $\tilde{\chi}_1^0$ mass	1010.8 340.3	0.6% 1.9%
		$\tilde{e}_R^+\tilde{e}_R^- \to e^+e^-\tilde{\chi}_1^0\tilde{\chi}_1^0$		$\tilde{\ell}$ mass $\tilde{\chi}_1^0$ mass	1010.8 340.3	0.3% 1.0%
		$\tilde{\nu}_e\tilde{\nu}_e \to \tilde{\chi}_1^0\tilde{\chi}_1^0 e^+e^-W^+W^-$		$\tilde{\ell}$ mass $\tilde{\chi}_1^\pm$ mass	1097.2 643.2	0.4% 0.6%
3.0	Chargino Neutralino	$\tilde{\chi}_1^+\tilde{\chi}_1^- \to \tilde{\chi}_1^0\tilde{\chi}_1^0 W^+W^-$ $\tilde{\chi}_2^0\tilde{\chi}_2^0 \to h/Z^0\, h/Z^0\, \tilde{\chi}_1^0\tilde{\chi}_1^0$	II	$\tilde{\chi}_1^\pm$ mass $\tilde{\chi}_2^0$ mass	643.2 643.1	1.1% 1.5%
3.0	Squarks	$\tilde{q}_R\tilde{q}_R \to q\bar{q}\tilde{\chi}_1^0\tilde{\chi}_1^0$	I	$\tilde{q}_R$ mass	1123.7	0.52%
3.0	Heavy Higgs	$H^0A^0 \to b\bar{b}b\bar{b}$ $H^+H^- \to t\bar{b}b\bar{t}$	I	H^0/A^0 mass $H^\pm$ mass	902.4/902.6 906.3	0.3% 0.3%
1.4	Sleptons	$\tilde{\mu}_R^+\tilde{\mu}_R^- \to \mu^+\mu^-\tilde{\chi}_1^0\tilde{\chi}_1^0$	III	$\tilde{\ell}$ mass $\tilde{\chi}_1^0$ mass	560.8 357.8	0.1% 0.1%
		$\tilde{e}_R^+\tilde{e}_R^- \to e^+e^-\tilde{\chi}_1^0\tilde{\chi}_1^0$		$\tilde{\ell}$ mass $\tilde{\chi}_1^0$ mass	558.1 357.1	0.1% 0.1%
		$\tilde{\nu}_e\tilde{\nu}_e \to \tilde{\chi}_1^0\tilde{\chi}_1^0 e^+e^-W^+W^-$		$\tilde{\ell}$ mass $\tilde{\chi}_1^\pm$ mass	644.3 487.6	2.5% 2.7%
1.4	Stau	$\tilde{\tau}_1^+\tilde{\tau}_1^- \to \tau^+\tau^-\tilde{\chi}_1^0\tilde{\chi}_1^0$	III	$\tilde{\tau}_1$ mass	517	2.0%
1.4	Chargino Neutralino	$\tilde{\chi}_1^+\tilde{\chi}_1^- \to \tilde{\chi}_1^0\tilde{\chi}_1^0 W^+W^-$ $\tilde{\chi}_2^0\tilde{\chi}_2^0 \to h/Z^0\, h/Z^0\, \tilde{\chi}_1^0\tilde{\chi}_1^0$	III	$\tilde{\chi}_1^\pm$ mass $\tilde{\chi}_2^0$ mass	487 487	0.2% 0.1%







+ Z' from $e^+e^- \to \mu^+\mu^-$ (arXiv:1208.1148)



Reminder: ongoing studies

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

• **Triple and quartic gauge couplings using $e^+e^- \rightarrow W^+W^- (\nu\bar{\nu}/e^+e^-)$:**
Steven Green → see presentation tomorrow

• **Hidden valley searches using Higgs decays (and other processes?):**
Marcin Kucharczyk, Agnieszka Bialek

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

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

Open topics

Many interesting aspects not investigated for CLIC yet:

- Gauginos / Higgsinos with small mass splittings
- W boson mass determination at high energy
- 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?

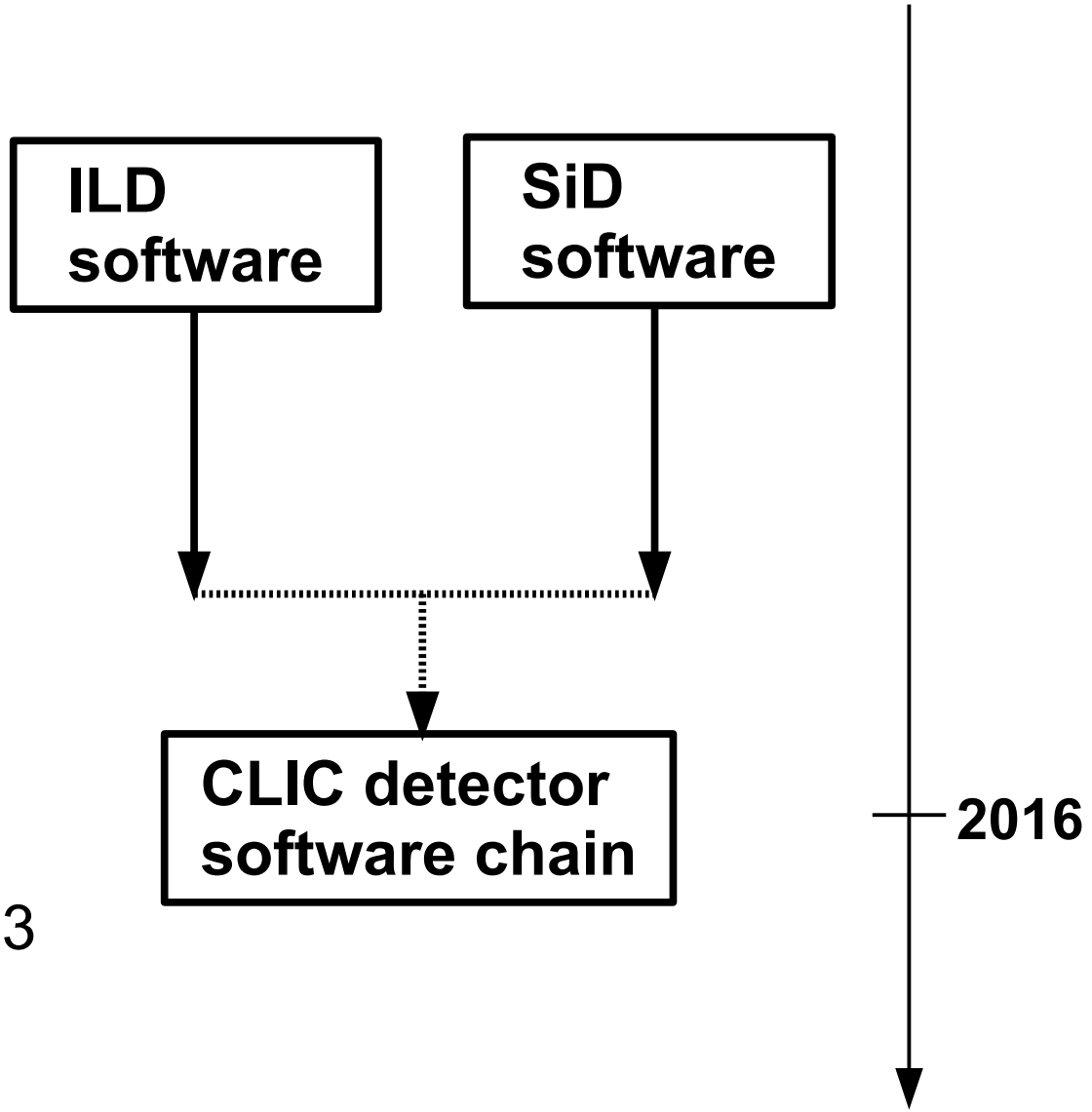
Physics performance validation

Reminder: new detector model and SW 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
→ see talk by André Sailer

• **On the same time scale:**
WHIZARD 1.95 → WHIZARD 2.3
PYTHIA 6.4 → PYTHIA 8?



Physics performance validation

Aim: Check the performance of the new detector model and software chain for the reconstruction of all relevant physics objects

→ Also very useful input to generator level / fast simulation studies

Issues to be investigated:

- Tracking
- Calorimetry
- Particle identification
- Particle flow analysis
- Flavour tagging
- Hadronic tau decay identification

→ help welcome in all areas

Ideally, all studies are performed first without overlay of beam-induced backgrounds and in a second step including the backgrounds

Physics performance validation: tracking

Using single muons:

- Transverse momentum (p_T) resolution as function of p_T and polar angle
- Transverse (R_0) and longitudinal (Z_0) impact parameter resolutions as function of p_T and polar angle

→ Cross check with existing fast simulation studies

Using $e^+e^- \rightarrow t\bar{t}$ events at 3 TeV:

- Tracking efficiency as function of p_T and polar angle
- Track fake rate as function of p_T and polar angle
- Tracking efficiency as function of distance to the closest hit
- p_T resolution as function of p_T and polar angle
- R_0 and Z_0 resolutions as function of p_T and polar angle

Physics performance validation: calorimetry, particle identification

Calorimetry:

Using single electrons, photons and charged pions:
• Energy resolution in calorimeters as function of energy and polar angle
→ see talk by Matthias Weber on photon reconstruction tomorrow
• Angular resolution for photons as function of energy and polar angle

Particle identification:

Using single particles (electrons, muons and photons):
• Identification efficiency as function of energy and polar angle

Using $e^+e^- \rightarrow t\bar{t} \rightarrow$ bqqblv events at 3 TeV:
• Electron and muon identification efficiency as function of transverse momentum and polar angle
• Electron and muon fake rates as function of transverse momentum and polar angle

Physics performance validation: particle flow analysis

Using $e^+e^- \rightarrow Z' \rightarrow q\bar{q}$ (q = u, d and s) events at different values of $\sqrt{s}$:
- "Jet" energy resolution as function of jet energy and polar angle
- Fake missing transverse momentum

Using $e^+e^- \rightarrow W^+W^- \rightarrow q\bar{q}l\nu$ and $e^+e^- \rightarrow Z^0Z^0 \rightarrow q\bar{q}\nu\bar{\nu}$ events at 3 TeV:
- Separation of hadronic W and Z boson decays as function of di-jet energy and polar angle

Using $e^+e^- \rightarrow Z^0Z^0 \rightarrow q\bar{q}\nu\bar{\nu}$ events at 3 TeV:
- Missing transverse momentum resolution

Physics performance validation: flavour tagging, tau identification

Flavour tagging:

Using $e^+e^- \rightarrow q\bar{q}$ (q = u, d, s, c and b) events at different values of $\sqrt{s}$ for fixed values of the jet polar angle:

- Primary vertex position resolution as function of track multiplicity
- Secondary vertex position resolutions in charm and beauty jets
- Fake rates for charm and light quark jets as function of the beauty tagging efficiency
- Fake rates for beauty and light quark jets as functions of the charm tagging efficiency

Hadronic tau decay identification:

Using $e^+e^- \rightarrow \tau^+\tau^-$ and $e^+e^- \rightarrow q\bar{q}$ (q = u, d and s) events at different values of $\sqrt{s}$ for fixed values of the tau/jet polar angle:

- Fake rate for light quark jets as function of the tau tagging efficiency

Other topics

Reconstruction software

Improvements are needed to algorithms for the reconstruction of high-level physics objects:

- Particle ID
- Flavour tagging
- Tau lepton identification
- ...

→ Attractive to combine with a physics benchmark study (e.g. for doctoral students)

Other topics

- **Definition of a new absolute accuracy target for the luminosity measurement:**

In the CDR we requested a precision of 1% which is known to be insufficient.
→ $\sigma(Hv\bar{v})$ x BR($H \rightarrow b\bar{b}$) and the cross sections for several SUSY processes can be measured with a few permille precision.

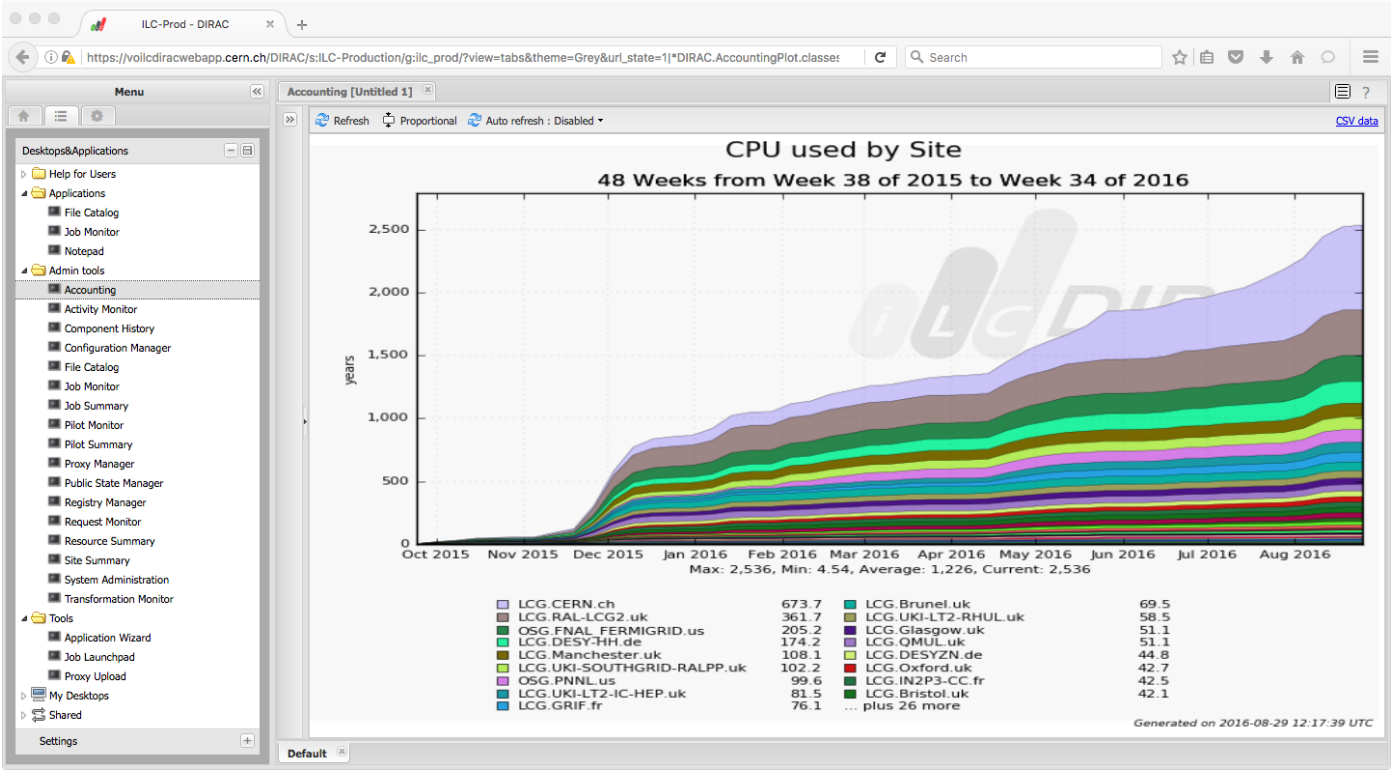
- **Investigate the relevance of dE/dx information**

- **Calibration of the jet energy scale and track momentum scale:**

Identification and study of suitable physics processes for the calibration at different centre-of-mass energies. The jet energy scale also depends on the event topology.

Enlargement of the production system

- Additional computing elements very welcome!
- Please contact André Sailer in case your home institute has a suitable site available



Summary and outlook

- **In the foreseeable future, the CLIC physics benchmark studies will focus on:**

  - Sensitivity to BSM physics, also through precision EW measurements
  - Overview paper on top physics

- **The physics performance validation of the CLICdet detector model and corresponding software chain is staring**

- **Help is also needed for the continuous improvement of the high-level reconstruction tools**

Backup slides