



# LCUK: Physics and Experiment

18 September 2020

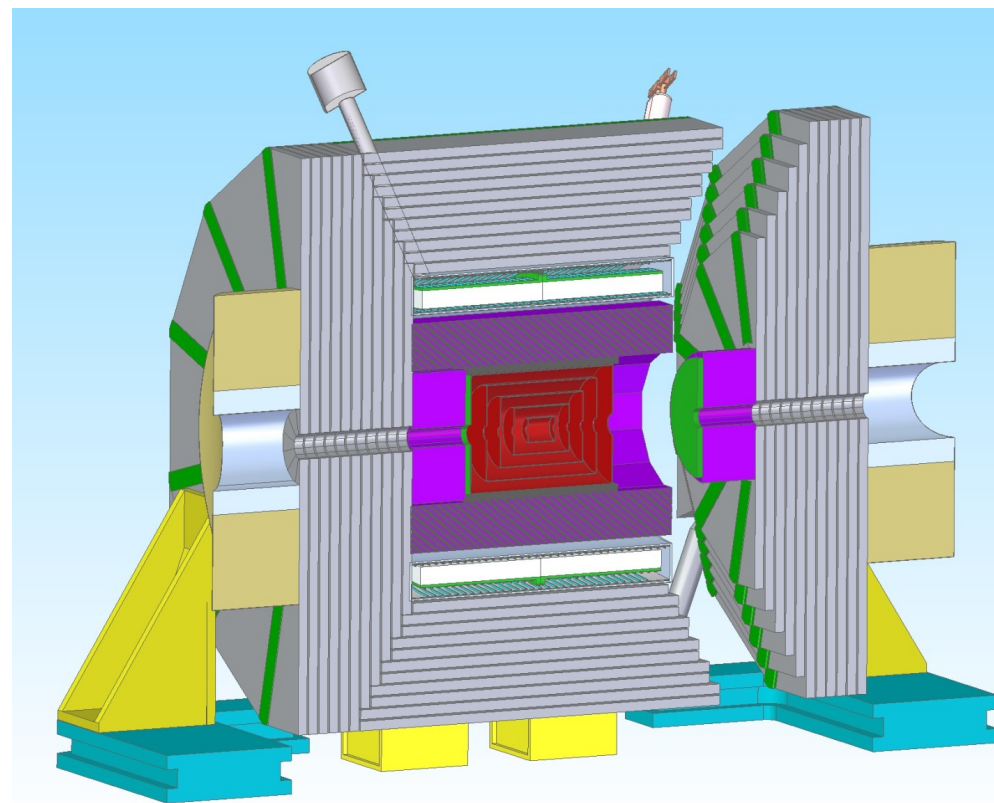
Aidan Robson

Short UK perspective on:

Software and reconstruction

Detector optimisation

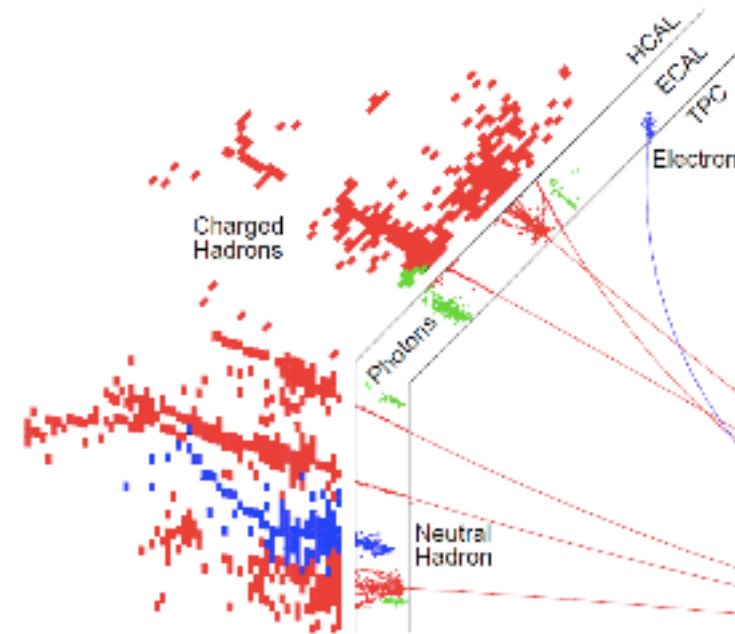
Physics studies



# Some background...



- 🇬🇧 almost all LC studies based on Pandora C++ software development kit (Cambridge/Warwick)
  - flexible particle-flow reconstruction relying on fine-grained calorimetry first developed for LCs (now widened)
- 🇬🇧 almost all LC studies use LCFIVertex flavour-tagging software (written in UK, now maintained in Japan)
- 🇬🇧 physics studies e.g. ZH hadronic recoil
  - > critical staging choices for linear colliders
- 🇬🇧 provided new ECAL simulation model for ILD
- 🇬🇧 provided complete new simulation model for SiD



Typical topology of a simulated 250 GeV jet in ILD

# LC Physics in the UK



UK Physics studies in the last 5 years have been focused on CLIC  
– but much overlap with ILC

Recent PhD theses with LC physics studies:

- ◆ Detectors and Physics at a Future Linear Collider - Boruo Xu, Cambridge (2017)  
– photon, jet, tau reconstruction;  $ZH(\tau)$  and  $HH$
- ◆ Calorimetry at a Future Linear Collider - Steve Green, Cambridge (2017)  
– calorimeter optimisation and anomalous TGCs in vector boson scattering
- ◆ Prospects for Higgs boson & top quark measurements and applications of digital calorimetry at future linear colliders - Alasdair Winter, Birmingham (2018) –  $vvH$ ,  $H \rightarrow WW$  and top  $A_{FB}$
- ◆ Data acquisition software development and physics studies for future lepton colliders - Tom Coates, Sussex (2019) –  $ttH$
- ◆ Higgs CP in  $ttH$  production - Yixuan Zhang, Edinburgh –  $ttH$

→ results included in the comprehensive surveys on Higgs and top physics:

Higgs physics at the CLIC electron-positron linear collider (2017)

<https://link.springer.com/article/10.1140/epjc/s10052-017-4968-5>

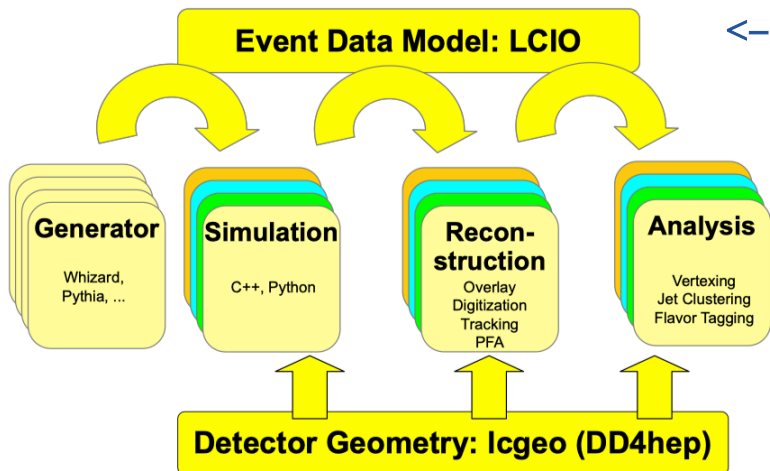
Top-quark physics at the CLIC electron-positron linear collider (2019)

<https://link.springer.com/article/10.1007/JHEP11%282019%29003>

# Software and reconstruction



Coordinated approach across LC community now extended further:



← Generic SW structure for detector optimisation and physics studies

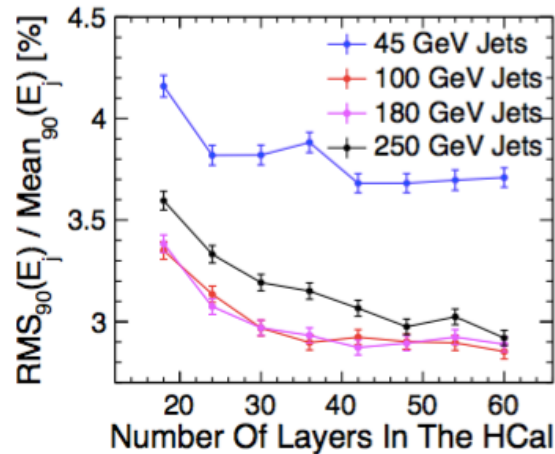
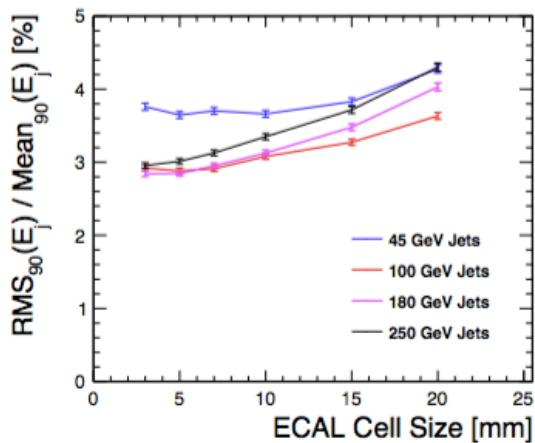
Now	Future
iLCSoft	Key4hep
Marlin framework	GAUDI framework
LCIO event data model	EDM4hep/PODIO event data model

Detector	Collider	SW name	SW status	SW future
ILD	ILC	iLCSoft	Full sim/reco	Key4hep
SiD	ILC	iLCSoft	Full sim/reco	
CLICdet	CLIC	iLCSoft	Full sim/reco	
CLD	FCC-ee	iLCSoft	Full sim/reco	
IDEA	FCC-ee	FCC-SW	Fast sim/reco	
IDEA	CEPC	FCC-SW	Fast sim/reco	
CEPCbaseline	CEPC	iLCSoft branch-off	Full sim/reco	

Recommendation:  
use iLCSoft now  
and  
join Key4hep development

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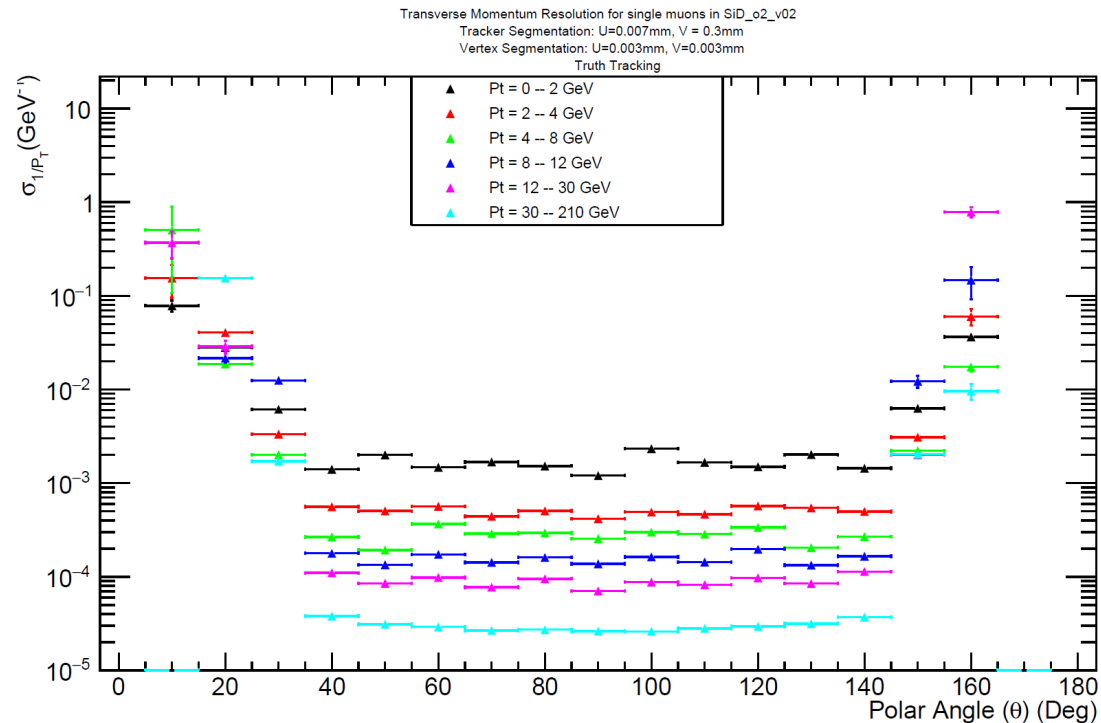
# Optimisation and performance



Calorimeter material and layout optimisation (CLIC/ILD)  
- Cambridge

SiD detector model,  
performance and validation

SiD Optimisation group  
coordinated by Dan  
Protopopescu (Glasgow)

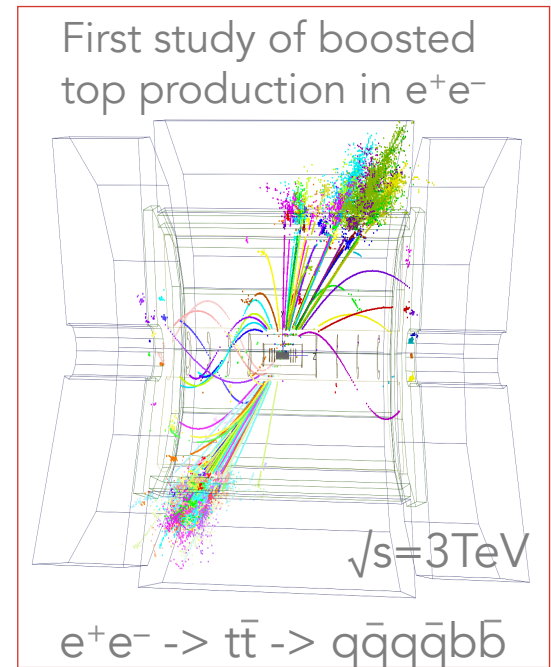


# Novel reconstruction

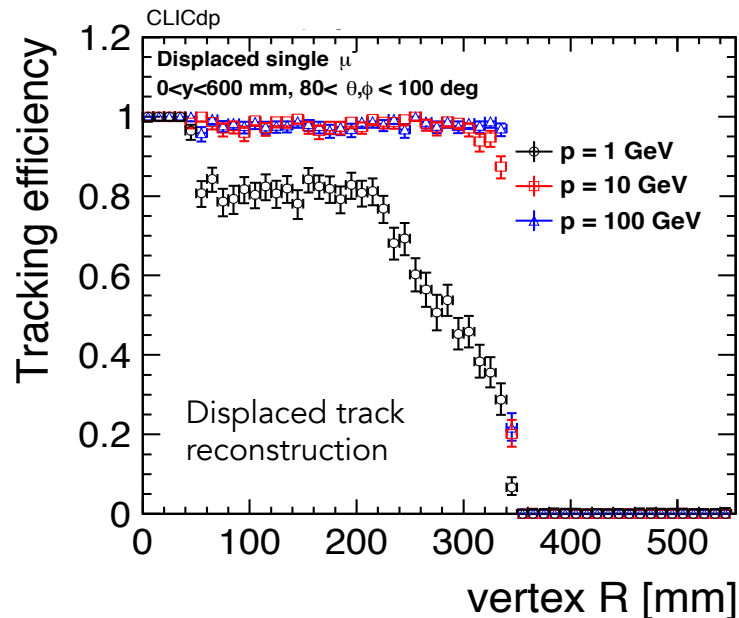


Interesting recent reconstruction developments  
(2018–current)

Use of jet substructure in top and Higgs:  
Stroem and Weber (Glasgow/CERN)



Track stubs: Leogrande  
(Glasgow/CERN)  
for LLP reconstruction



Similarly, recent dedicated developments in jet reconstruction for  $e^+e^-$   
→ VLC algorithm (not UK)

→ *opportunities for LHC reconstruction experts*

# Physics studies for ILC



## ILC Study Questions for Snowmass 2021:

5	Questions about general $e^+e^-$ event analysis	10
6	Questions about Higgs boson physics: $e^+e^- \rightarrow Zh$	13
7	Questions about Higgs boson physics: $WW$ fusion and higher energy reactions	15
8	Questions about top quark physics	16
9	Questions about $e^+e^- \rightarrow f\bar{f}$	18
10	Questions about $W$ boson physics	19
11	Questions about precision electroweak measurements	20
12	Questions about QCD and jets	21
13	Questions about searches for new particles	22
14	Questions about the theory of Higgs boson couplings	25
15	Questions about SM Effective Field Theory interpretation of $e^+e^-$ measurements	26

<https://arxiv.org/abs/2007.03650>

ILC framework tutorial (28 August 2020)

<https://indico.fnal.gov/event/45031/>



ILC will start at 250GeV, but higher energies still a cornerstone of the physics case

My own personal priorities for studies, going beyond Higgs physics and keeping some focus on collisions  $> 250\text{GeV}$  :

- importance of top-quark physics in  $e^+e^-$
- importance of several energy stages in  $e^+e^-$
- direct searches, in particular for elusive signatures
- further and novel ways of constraining NP from precision measurements
- importance of beam polarisation
- BSM scenarios of particular interest in  $e^+e^-$

-> could be interesting collaborations with phenomenologists (see talk from Veronica Sanz)

# The way forward...



- ILC physics case well-developed, but many opportunities; excellent time to enter, during a drive for new participants and when there is support for studies [see talk from Jenny List]
- Detector concepts will soon enter an entirely new phase requiring serious performance/optimisation studies with quick turnaround [see talk from Marcel Stanitzki] – with some extra effort UK would be well-placed. Common tools already developed mean this can be common across detector and accelerator concepts
- UK has deep experience in  $e^+e^-$  physics, and deep expertise in physics, reconstruction, detector optimisation across the particle physics community → don't let this opportunity go past!