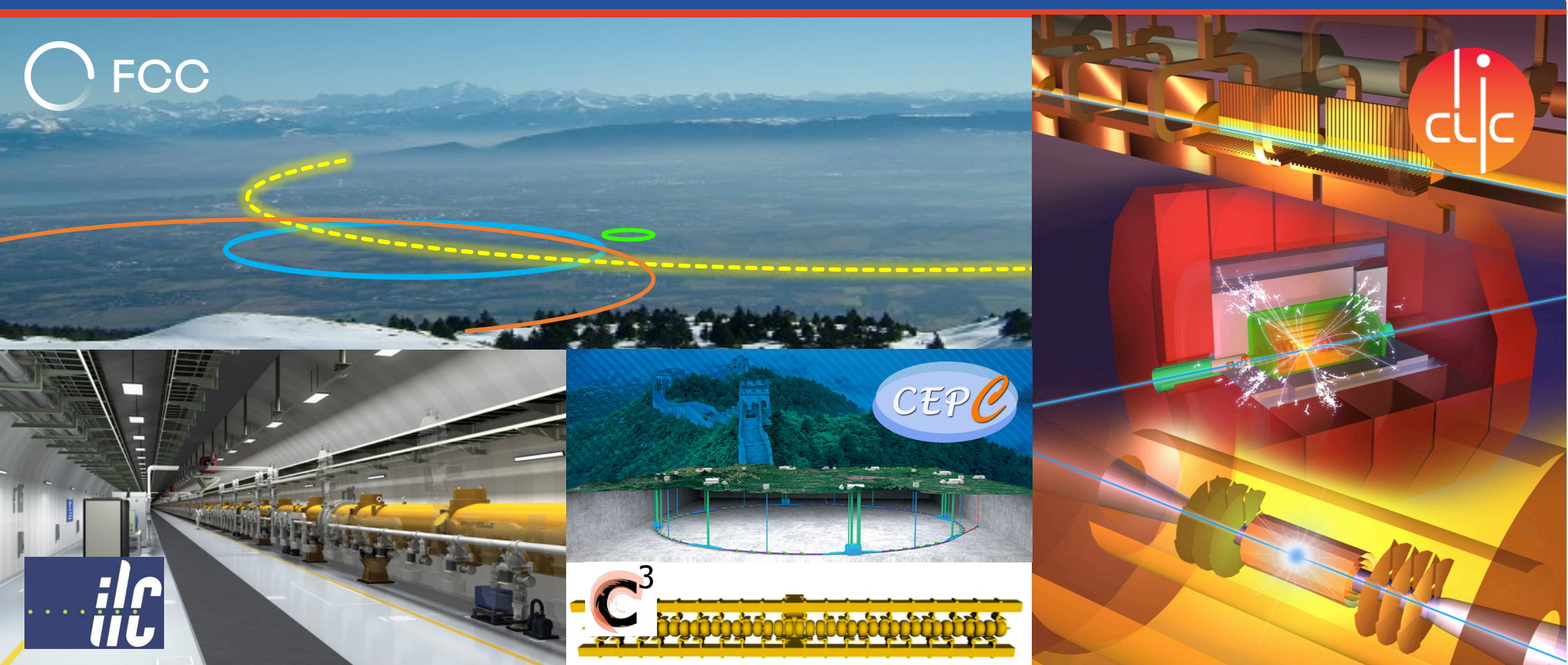


# Opportunities in software/reconstruction

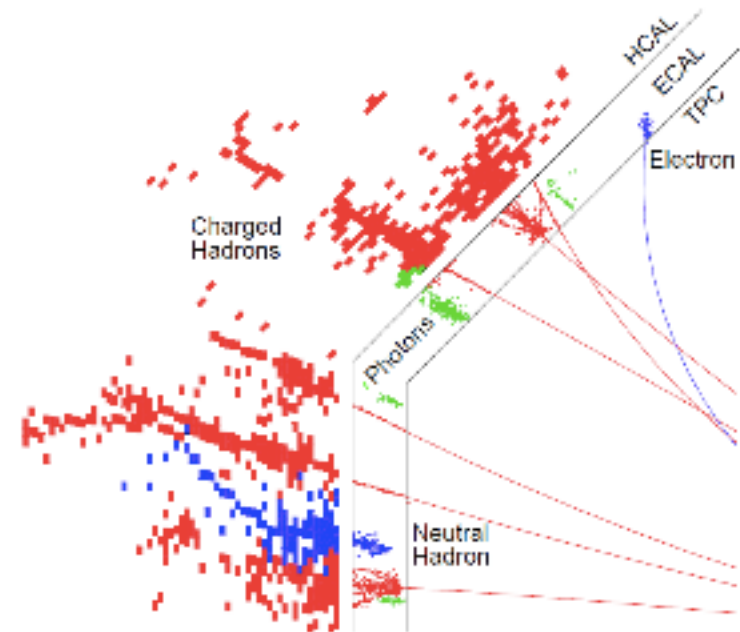


UK meeting on a future  $e^+e^-$  Higgs/EWK/top factory, 5 July 2022, Oxford

Aidan Robson, University of Glasgow

# 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

# Recent $e^+e^-$ Physics in the UK

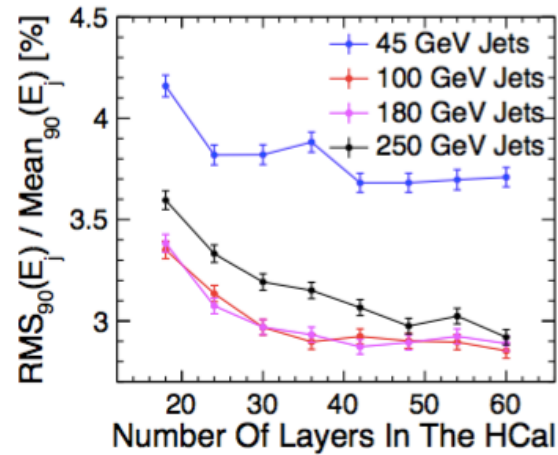
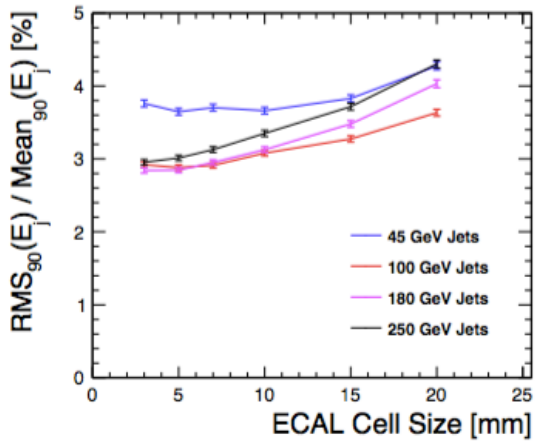
Physics studies often linked with software/reconstruction developments

Recent UK 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 (2020) –  $ttH$

→ sorry if I have missed others

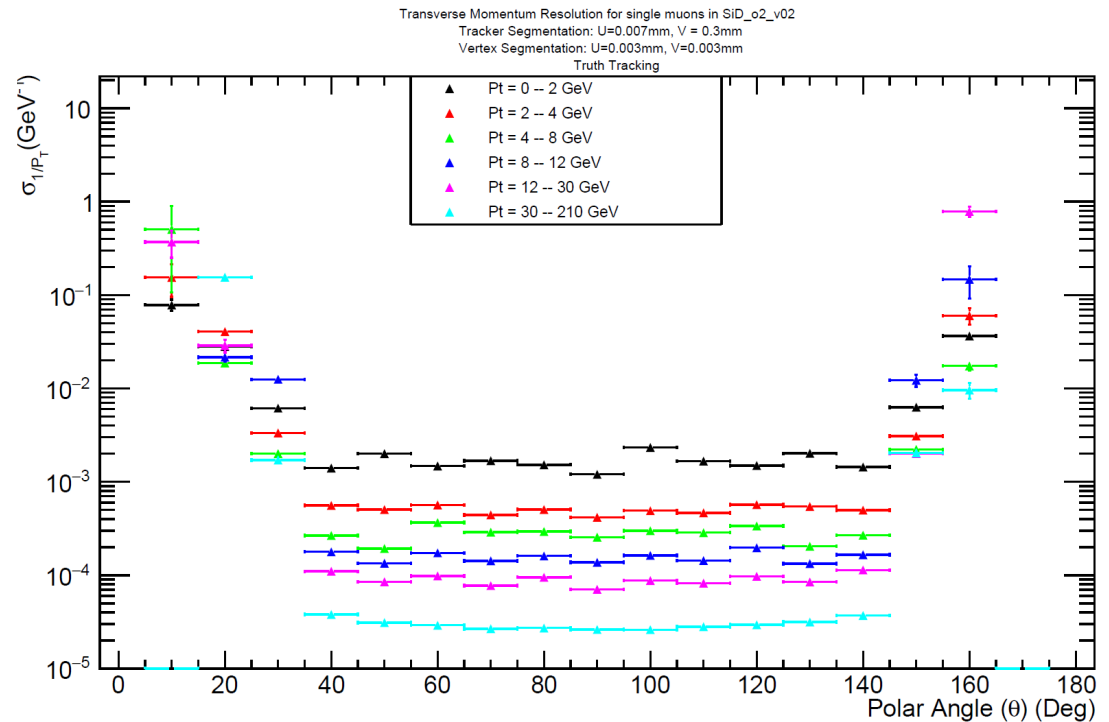
# Optimisation and performance



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

SiD detector model,  
performance and validation

SiD Optimisation group  
coordinated by Dan  
Protopopescu (Glasgow)

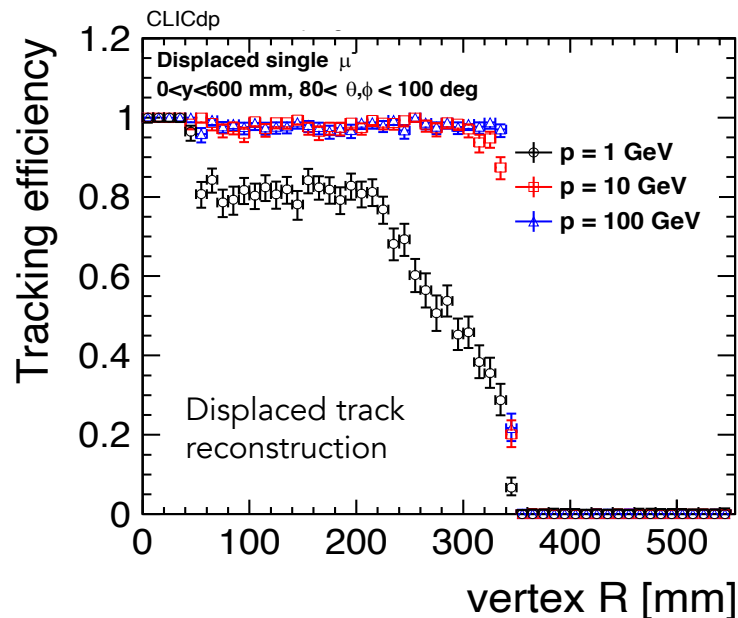




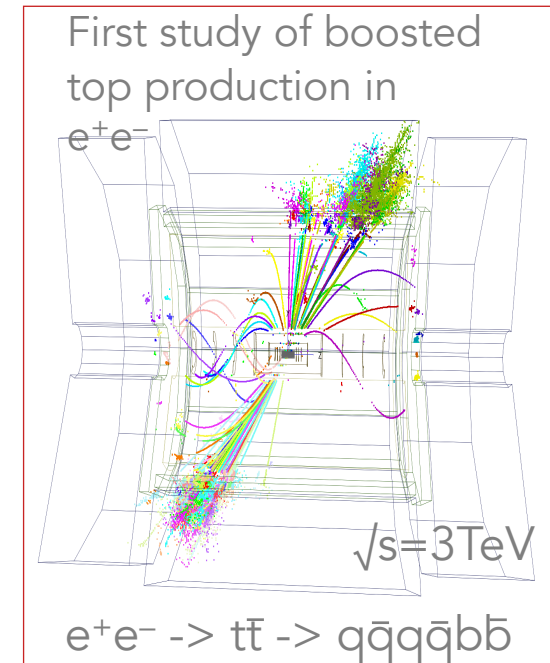
# Novel reconstruction

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*

# Ongoing activities

ECFA Detector R&D Roadmap emphasises importance:

“Making software re-usable beyond a specific experiment or project [...]”

“The trends to exploit additional information [...] will require continuous refinement of the simulation tools [...] The same is true for sophisticated pattern recognition algorithms”

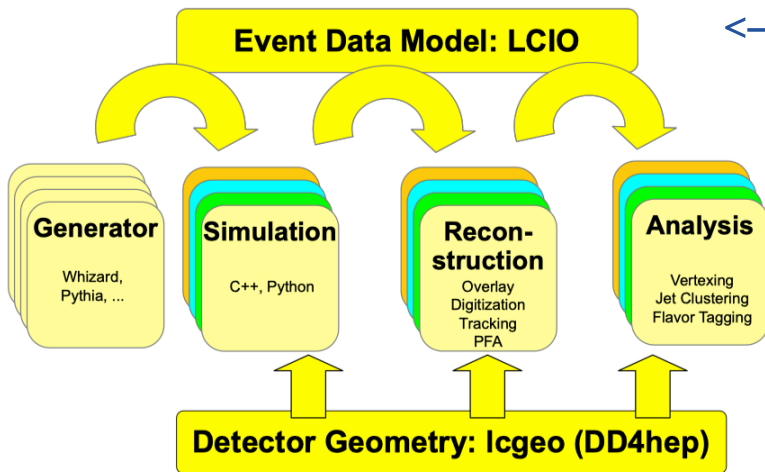
Common issues with LHC and upgrades, & among future projects

Software & reconstruction activities focused

- in CERN SFT group (as part of CERN EP R&D programme),
- in the detector concept collaborations,
- and in the ECFA Higgs/EW/top factory initiative, WG2 (Physics Analysis Methods)

# 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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# Ongoing activities

Overall framework:

Towards 'turnkey software stack' Key4hep:

complete data processing framework, comprising fast and full simulation, reconstruction and analysis

- ◆ Data model: EDM4hep (podio)
- ◆ Common framework: Gaudi
  - Used to schedule and steer simulation, reconstruction, analysis.
  - Adapters (k4MarlinWrapper) provided to interface with CLIC's framework & algorithms
- ◆ Geometry information: DD4hep
- ◆ Common simulation approach
  - Using k4SimGeant + k4SimDelphes
- ◆ Streamlined process for software delivery: Spack, CVMFS
- ◆ Common practices, tools, standards

→ Allows running chains that can contain previous, current and future algorithms  
– interfaces and converters allow integration/transition  
– will gradually rewrite

Validation of physics performance

- Initial validation of CLIC reconstruction
  - comparing original to Key4hep software stack results

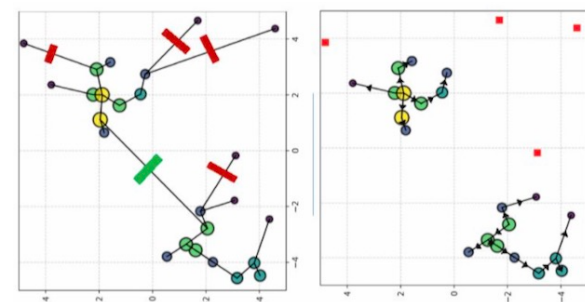
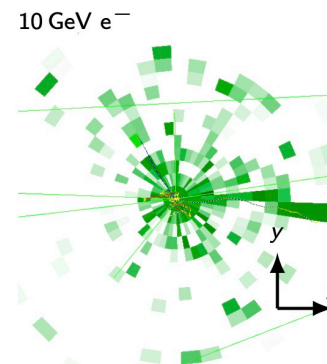


# Ongoing activities

## Common tasks with LHC and HL-LHC

### *some recent/ongoing examples*

- innovations to improve fast simulation,  
–> e.g. MetaHEP idea for retunable parameterisation  
EM showers via neural networks; ‘meta-learning’ to adapt to new geometry with small sample of full sim
- innovations in fine-grained calorimetry reconstruction  
–> CLUE for CMS HGCAL, GPU-friendly energy density clustering approach  
Adapted to run in Key4hep framework and tested in CLIC / CLD reconstruction chains



## Specific tasks for future colliders

- ◆ porting algorithms from Marlin to Gaudi  
–> good introductions to the software
- ◆ further developments at any level of the reconstruction chain

–> **interest and effort welcome!**

# Outlook

- ◆ Software and reconstruction is key to the success of a future project
  - intrinsic to particle flow approach planned for an  $e^+e^-$  Higgs factory
- ◆ Many overlaps with LHC efforts and UK expertise, and closely linked to physics studies
  - > a good 'way in' for people who would like to join
- ◆ Effort very welcome, through detector collaborations or through ECFA WG2

Recent related workshops for further information:

ECFA 1<sup>st</sup> Topical Meeting on Simulation:

<https://indico.cern.ch/event/1097819/>

ECFA 1<sup>st</sup> Topical Meeting on Reconstruction:

<https://indico.cern.ch/event/1124095/>

Kick-off workshop on detector optimisation and benchmarking for FCC-ee

<https://indico.cern.ch/event/1165167/>

CERN EP R&D days

<https://indico.cern.ch/event/1156197/>