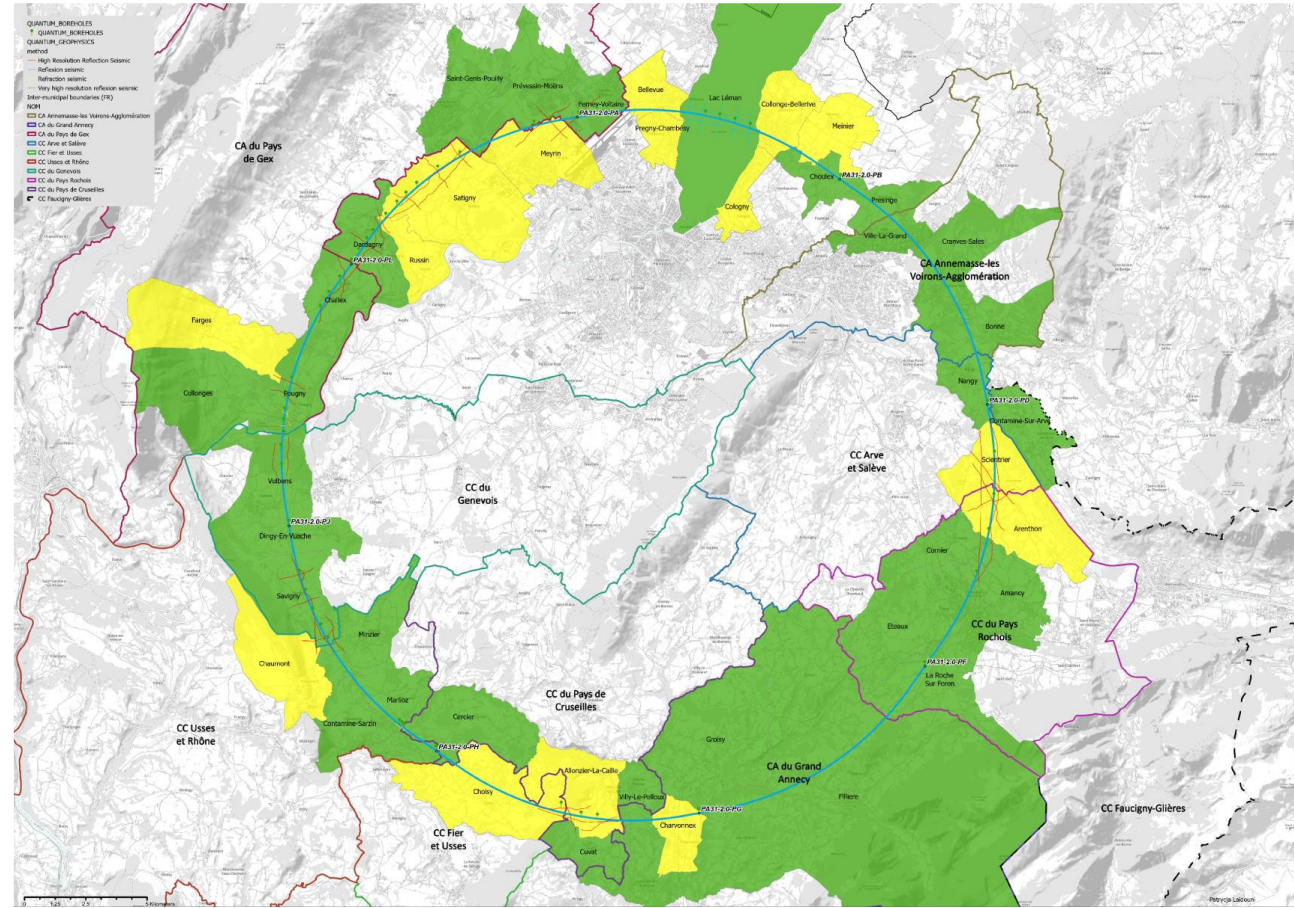


Future Circular collider proposed 100 km successor to LHC Three machines in one:

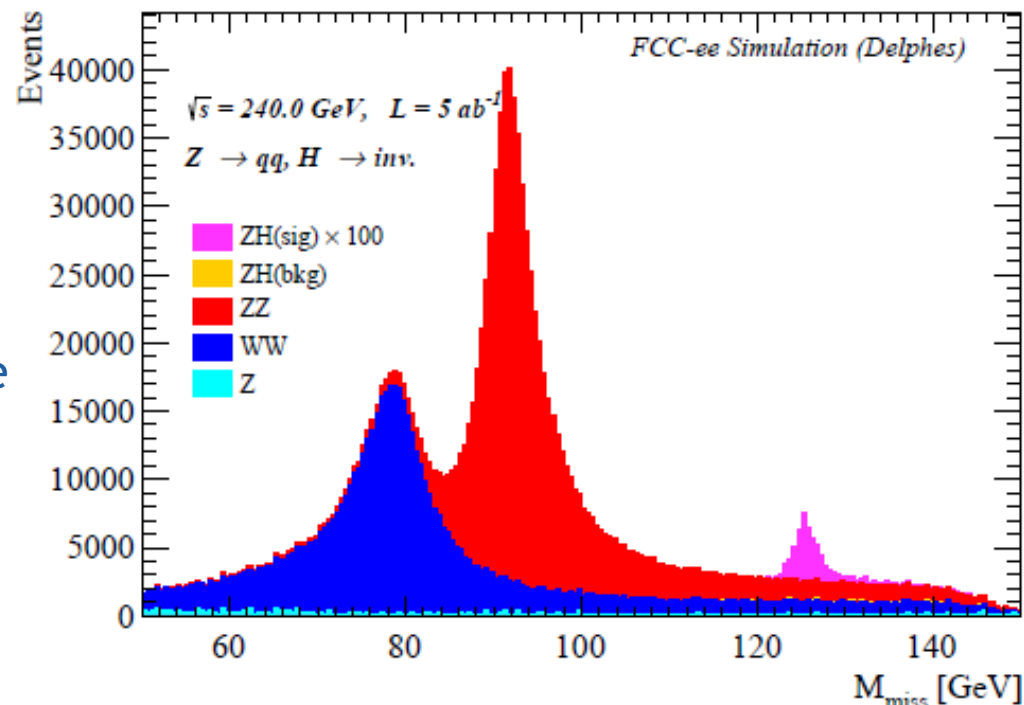
- ee phase $\sqrt{s} \approx 91\text{-}365$ GeV 2030-2045
precision EW, Higgs
- ep phase $\sqrt{s} \approx 3.5$ GeV ??
precision QCD, DIS, Higgs
- pp phase $\sqrt{s} \approx 100$ TeV 2065-2090
searches, Higgs, di-Higgs



FCC ee

$\sqrt{s} \approx 90 \text{ GeV}$ 10^{12} Z - 4 yrs
 $\sqrt{s} \approx 160 \text{ GeV}$ 10^8 W - 2 yrs
 $\sqrt{s} \approx 240 \text{ GeV}$ 10^6 H - 3 yrs
 $\sqrt{s} \approx 365 \text{ GeV}$ 10^{12} t - 5 yrs

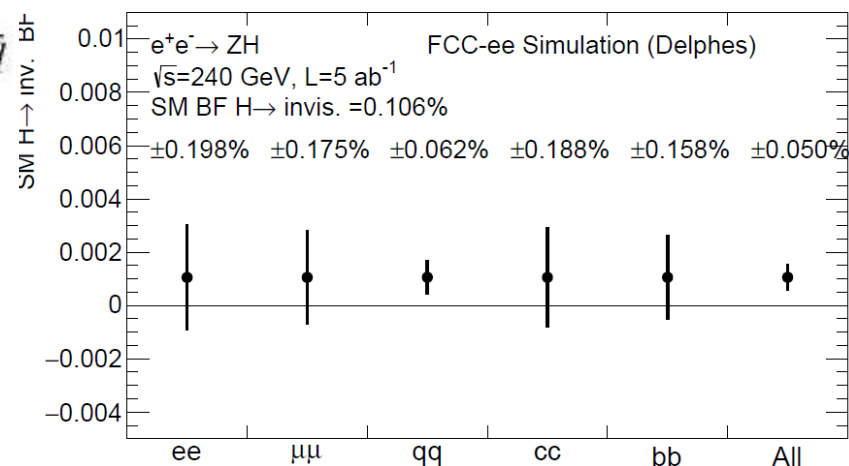
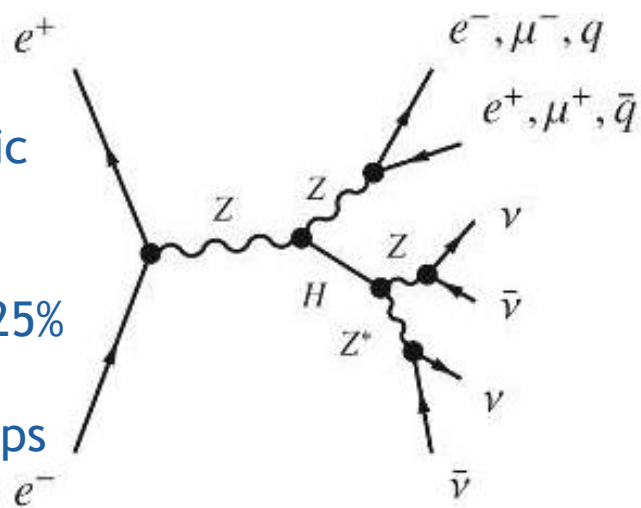
- Precision EW way beyond present levels - best chance to find new physics (imho)
- Much better Higgs precision in most channels
- Searches for hard to find particles
- Chance of finding dark matter if it couples to Higgs



H → invisible (Andy, Nikos)

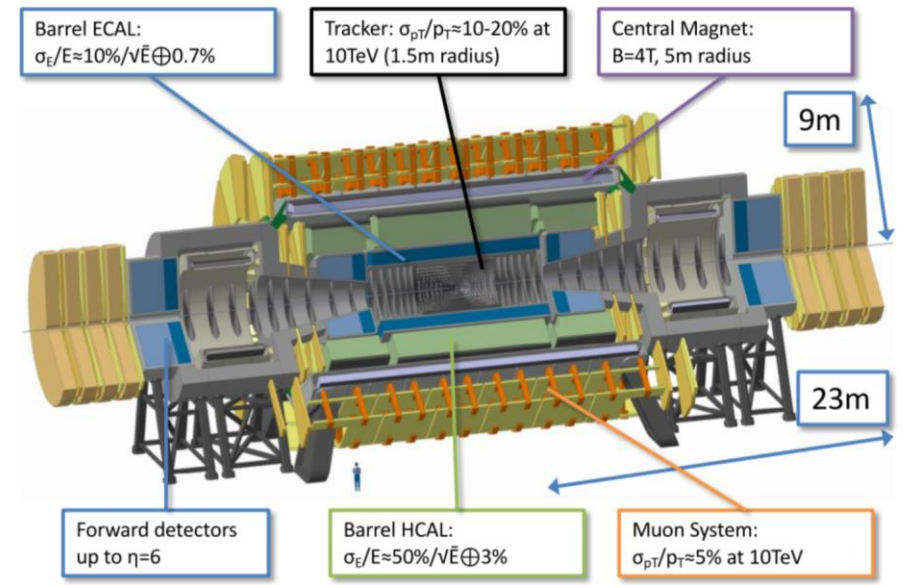
- First FCC analysis to explore leptonic and hadronic Z decays
- Can fully reconstruct Higgs mass
- Discover new physics at 5σ if $\text{BF} > 0.25\%$
- Measure SM with 50% precision

Talks at Liverpool and Krakow workshops



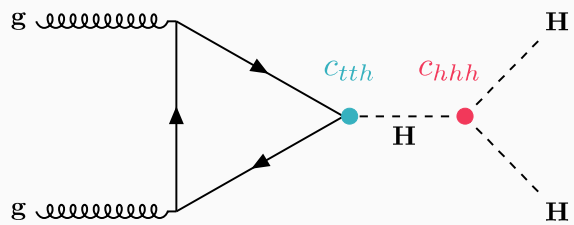
FCC-hh in UK

- ▶ Largest challenge radiation levels well beyond what any current microelectronics can survive (\lesssim MGy) [talk](#) @ FCC-Italy (Monica)
- ▶ Work on R&D carried out in the context of ECFA / DRDs (see Chenfan's talk)
- ▶ UK FCC-hh representative: Andy Pilkington, working in synergy with FCC-eh ([Uta Klein](#))
- ▶ Analysis framework preparation (Matt Sullivan) <https://indico.cern.ch/event/1254077/>



Liverpool contributions so far: diHiggs and DM searches

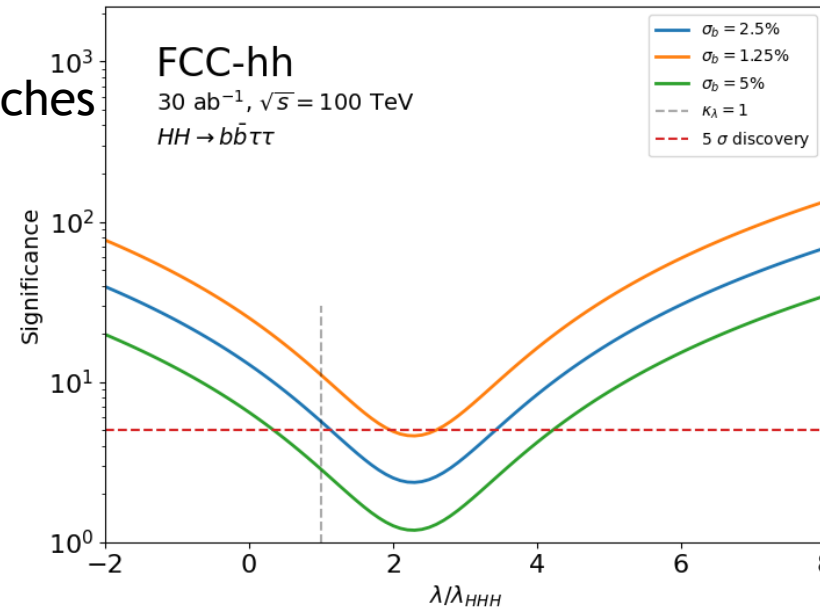
HH in $bb+\tau\tau$ using ML techniques



(Matt, Carl)

Significance $Z = 5.7$ for SM HH:

Presented last summer at [HiggsPair](#)



<https://github.com/HEP-FCC/FCCAnalyses>

Tutorials given on this to improved accessibility

Collaborate with other UK groups to establish benchmark analyses to inform detector work (Monica, Carl, Cristiano + Roy Lemmon)

FCC eh and LHeC @ Liverpool

Book “The Future of the LHC”, World Scientific
To appear 2023

Eds: O Bruening, M Klein, L Rossi, P Spagnolo

Accelerator, Detectors, Physics - ~40 Authors

Introduction (H Schopper)

A The First Decade

B High Luminosity LHC

C Future Prospects (LHeC and HE LHC)

Strong Liverpool Contributions:

Jan Kretzschmar (HL Precision Measurements)
Uta Klein, Oliver Fischer (Higgs and BSM in ep)
Monica D’Onofrio (Physics with HE LHC)

Includes small experiments such as FASER

Novel concept for Detector and IR to serve eh and hh
alternately, concurrent with IR1 and IR5 when in eh mode

An Experiment for electron-hadron scattering at the LHC
[arXiv:2201.02436](https://arxiv.org/abs/2201.02436) **published in EPJ C82(2022)1**

Liverpool co-authors

O Fischer (thy), M Klein, U Klein, P Kostka, E Vilella-Figueras

New Organisation of LHeC/FCC-eh Development (CERN 10/22)

New Coordinator: Jorgen D’Hondt (Brussels)

New Advisory Committee (Chair F Bordry, Member M Klein)

New Convenors: Liverpool Members: Monica D’O and U Klein

Goal: Topical Preparations for next ESSP Update by ~ 2026

More info: see <https://indico.ijclab.in2p3.fr/event/8623/>

FCC-eh developments:

UK founded ee/hh/eh groups - eh Convenor: U Klein

London FCC Conference in June oriented to e+e-

but there will be a session on eh set up by Liverpool

Energy Recovery Roadmap and its Implementation, ERL Facility PERLE

Energy Recovery is at the threshold of becoming a key means for the advancement of accelerators.

Roadmap endorsed by CERN Council in 2022. Three key elements

- Development of Current ERL Facilities [arXiv:2201.07895](https://arxiv.org/abs/2201.07895)
- R&D towards sustainable accelerator technology (eg FRT)
- O(100)mA electron current facilities: bERLinPRO and PERLE

Implementation: mandated by CERN and Lab Directors Group (LDG) (22)

Jorgen D'Hondt (chair), Max Klein (deputy)

*Iens Knobloch (hFRI inPro), Achille Stocchi (PERLE),
Andrew Hutton (R&D oversight)*

- Large ERC grant project (iSAS) submitted in March 23
- Various activities starting (reports to LDG/Council, last 3/23)
- Roadmap explains funding needs of 26 MCHF for 5 years

Other initiative (for whole FCC): [ECR forum to get feedback from Early Career Researchers](#)

[Cristiano Sebastiani](#) as one of the co-organisers

Two events organised so far, also reported at the last PP-UK community meeting, strong participation from ECRs. Most recent:

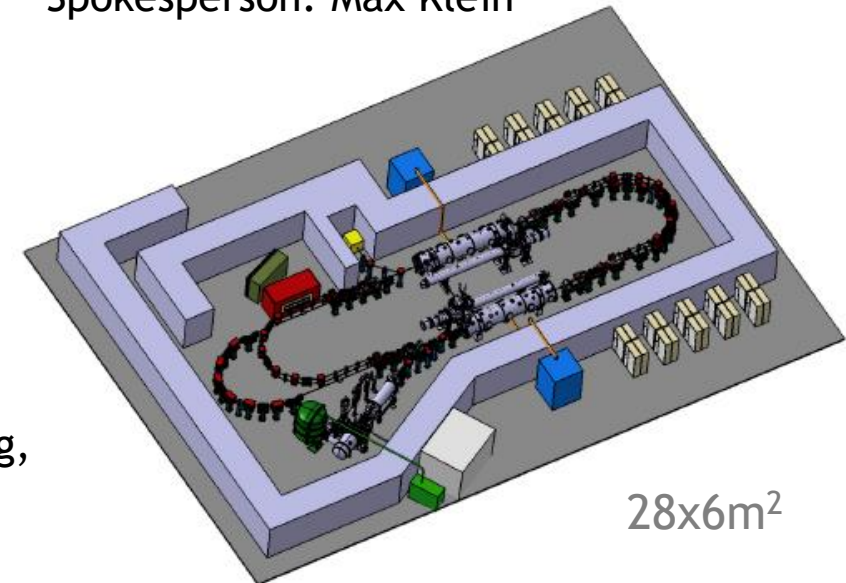
<https://indico.cern.ch/event/1196259/>

PERLE at IJClab Orsay

3-turn ERL, 500 MW, 20 mA, 802 MHz
→ LHeC/FCCeh parameters + technology

Liverpool: PhDs, Injector design,
Diagnostics (Carsten Welsch +3)

Growing Collaboration including
CERN, Jlab, Daresbury, IJCLab +4
Spokesperson: Max Klein



28x6m²

PPAP recommendations on FCC: synergies

Recommendation 4.2 The UK community shares the vision of the European Strategy document to prepare an electron-positron Higgs factory as the highest-priority next collider; and a future hadron collider with sensitivity to energy scales an order of magnitude higher than the LHC. The latter requires development studies to address the associated technological and environmental challenges and opportunities. The UK community should establish a unified future high energy collider programme to be well positioned in a 20+ year plan for future accelerators.

Recommendation 4.3: The UK should engage in the realisation and exploitation of a future high-energy e^+e^- facility. Investment in appropriate R&D on detector and accelerator technologies/systems that capitalises on current UK strengths will position us to take a leading role in e^+e^- collider physics. Where possible, the programme should provide leverage with more than one of the facilities under consideration by the UK.

Recommendation 4.4: The UK community should identify a sub-set of key areas of technology that align with initiatives at CERN and will be informed by appropriate physics studies, that will allow the UK to capitalise on the expertise acquired through the HL-LHC construction and beyond, to carry forward its leading role to the FCC-hh.

Recommendation 4.5: As an adjunct to the FCC-hh studies, feasibility studies to inform accelerator and detector technology options for FCC-eh should be pursued by the UK focusing on common elements of the possible future facilities and their experiments.

Points for discussion

Tracking and calorimeters technologies might serve more than one e^+e^- facility

Common aspects for ee/eh and for pp/eh

Common aspects for ee and EIC

ERL technology potentially relevant for FCC-ee to reach highest energy

Muon collider - should we get involved

Long lived particle detection - optimise detectors to start with

Other physics analyses