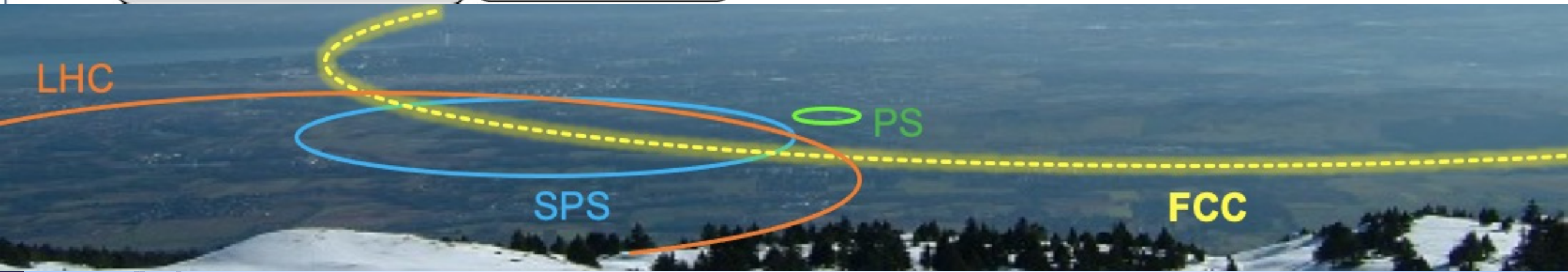


# Future Circular Collider

Monica D'Onofrio

(on behalf of many people at Liv and beyond)

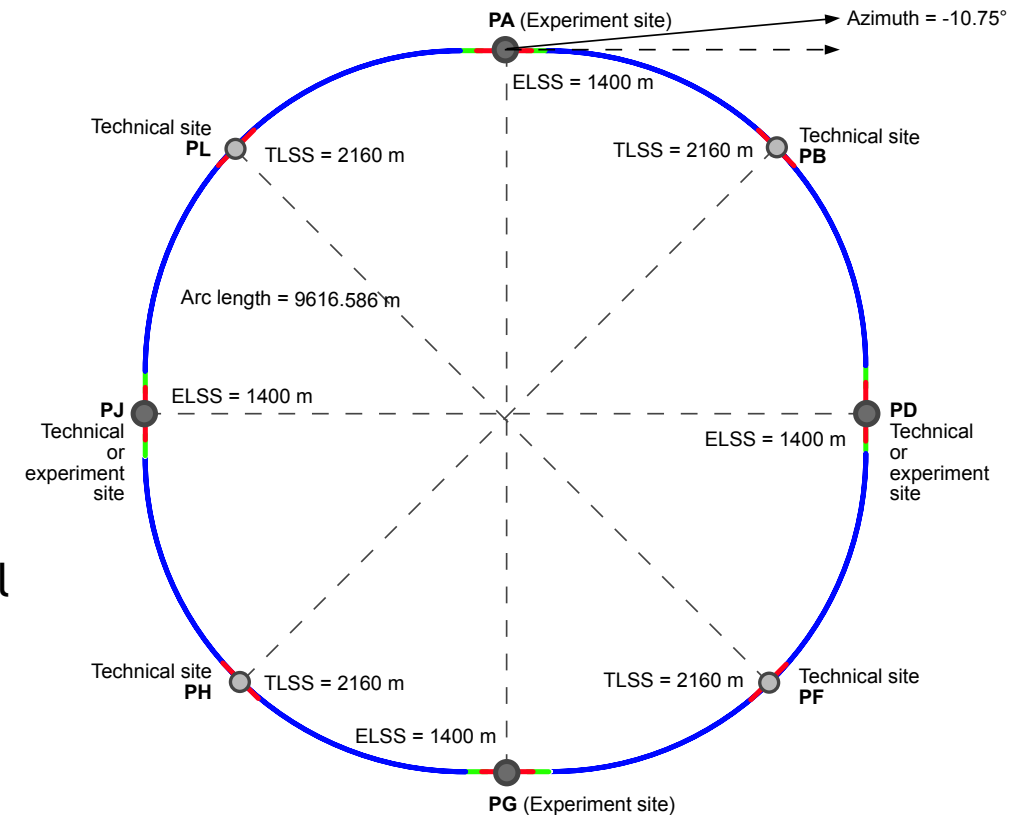


# The European Strategy outcome

- ▶ A huge combined effort of the theory and experimental particle physics communities during the last 5 years led to several proposals for new collider (and non-collider) projects at CERN and elsewhere
  - Beyond HL-LHC, an **electron-positron Higgs and electroweak factory** is certainly considered as the next big priority, followed by a **future high-energy hadron collider** with 100 TeV c.o.m. energy
  - R&D efforts should be focused on **advanced accelerator technologies** (high-field magnets, plasma wakefield acceleration, bright muon beams, energy recovery linacs)
- The **Future Circular Collider (FCC)** is the long-term project CERN is pushing for, comprising of
  - **stage 1:** FCC-ee (Z, W, H,  $t\bar{t}$ ) as Higgs factory, electroweak & top factory at highest luminosities
  - **stage 2:** FCC-hh (~100 TeV) + FCC-eh (through implementation of an Energy Recovery Linac (ERL) for electron beam) as natural continuation at energy frontier, with ion option

Lot of documents already produced, with substantial Liv contributions

[CERN-ESU-015-2020 Update European Strategy.pdf](#)



# FCC in UK

FCC activities towards FCC are getting organised:

- Proformas presented to PPAP and taken into account for preparation of the [PP roadmap](#)

3 national representatives, one for each collider configuration:

- FCC-ee: Guy Wilkinson
- FCC-hh: Andy Pilkington
- FCC-eh: [Uta Klein](#)

ECR forum to get feedback from Early Career Researches:

- [Cristiano Sebastiani](#) as one of the co-organisers
- First meeting last month: <https://indico.cern.ch/event/1145735/>

Although far in time, preparation for a future collider must start now and in a synergic way, starting from consolidation of the physics case to R&D on detector and accelerator technologies



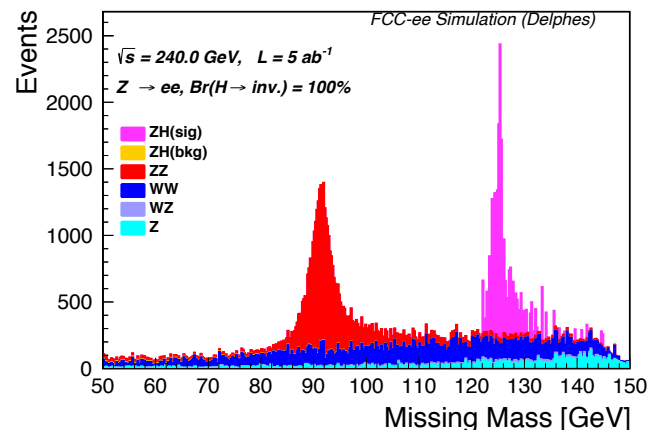
<https://indico.cern.ch/event/1066234/>

Organised by Liverpool although ultimately online

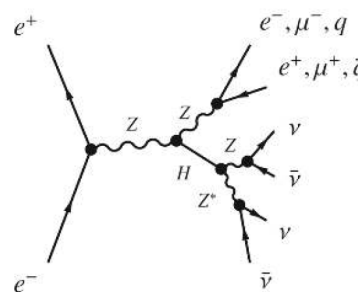
# Physics at the FCC @ Liverpool

All of this and more reported at the FCC Physics Workshop Feb 2022

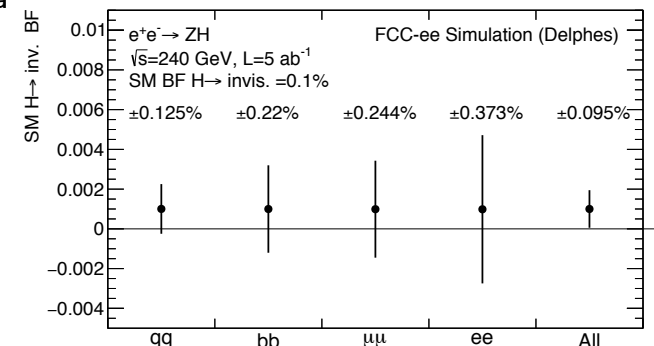
## Higgs invisible @ FCC-ee (Andy, Nikos)



ZH, H->invisible



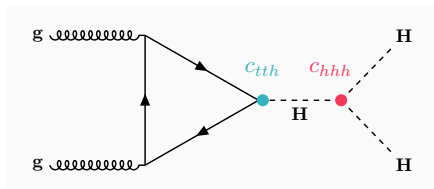
- Aim look at sensitivity using all decays in simulated data
- Only studied  $\sqrt{s} = 240$  GeV events
- Assume  $\int L = 5 \text{ ab}^{-1}$
- Using  $Z \rightarrow ee, \mu\mu, bb$  and  $qq$  channels



Reach SM precision of  $\approx 0.1\%$

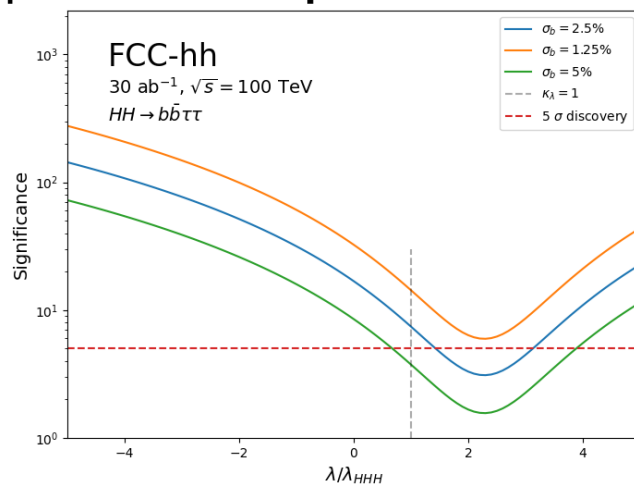
## diHiggs + DM @ FCC-hh (Matt, Carl, Cristiano, Monica)

HH in  $bb+\tau\tau$  using ML techniques  $\rightarrow$  reach precision of 5%



- Discovery significance:

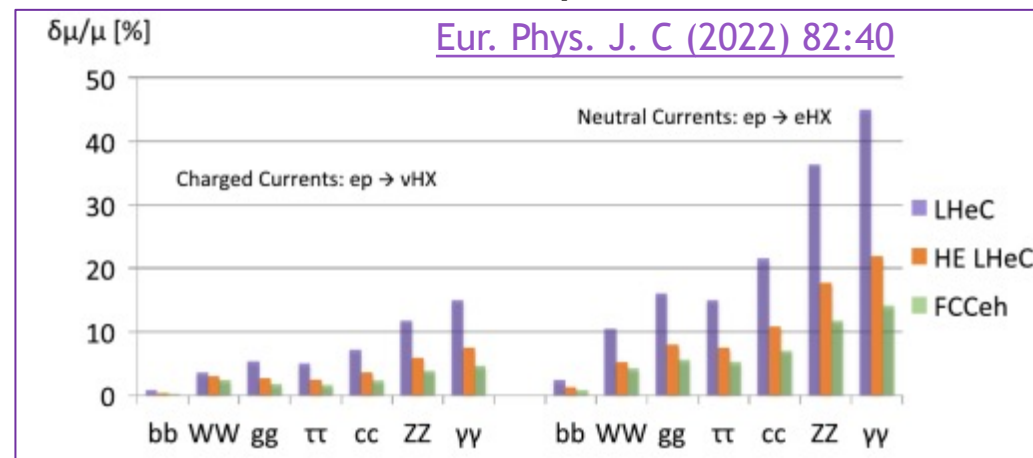
- $b\bar{b}\tau_{\text{lep}}\tau_{\text{had}}$ :  $Z = 5.25$
- $b\bar{b}\tau_{\text{had}}\tau_{\text{had}}$ :  $Z = 1.85$
- $b\bar{b}\tau_{\text{lep}}\tau_{\text{had}}$ :  $Z = 7.42$



Monica D'Onofrio, HEP meeting

## Higgs and BSM @ FCC-ep (Uta, Max, Monica, O.Fischer from Theory department)

HWW and HZZ signal strengths measured at once in DIS, excellent precision on Hcc



Presented at multiple conferences

19/5/22

To be presented at [HiggsPair](#)

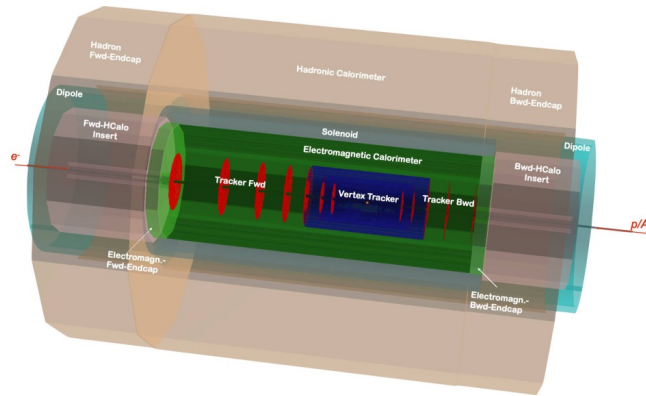
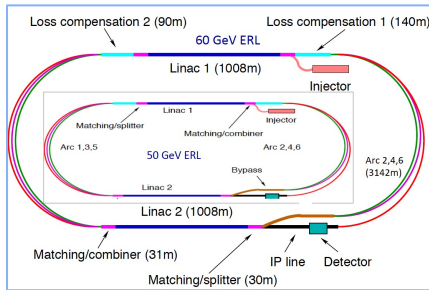
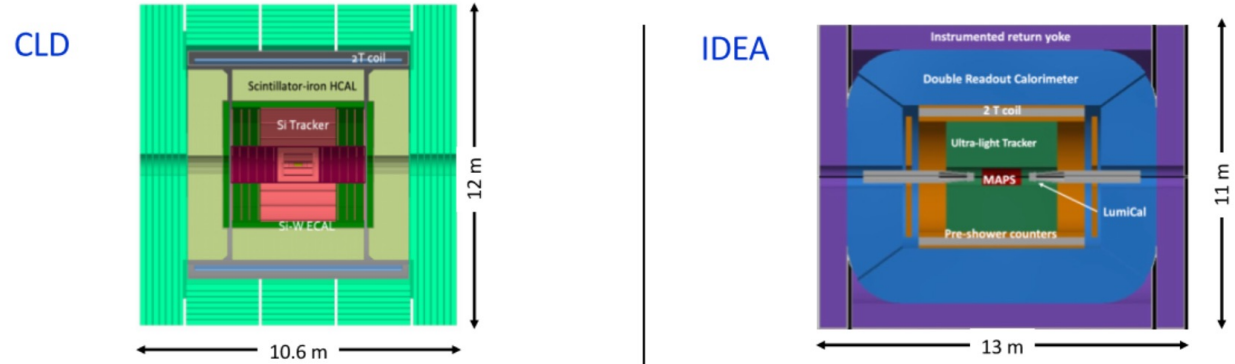
# Detector and accelerator technology developments

Considerable level of R&D specific for FCC detectors is already on-going (also within ECFA)

- FCC-ee/eh/hh detectors: Experiment Concepts documented in CDRs and beyond
- Accelerator challenges: advanced studies on high-field magnets (hh) and Energy Recovery Linac (eh)

**FCC-ee:** Two main detector concepts CLIC-Like Detector (CLD) and Innovative Detector for Electron-positron Accelerator (IDEA):

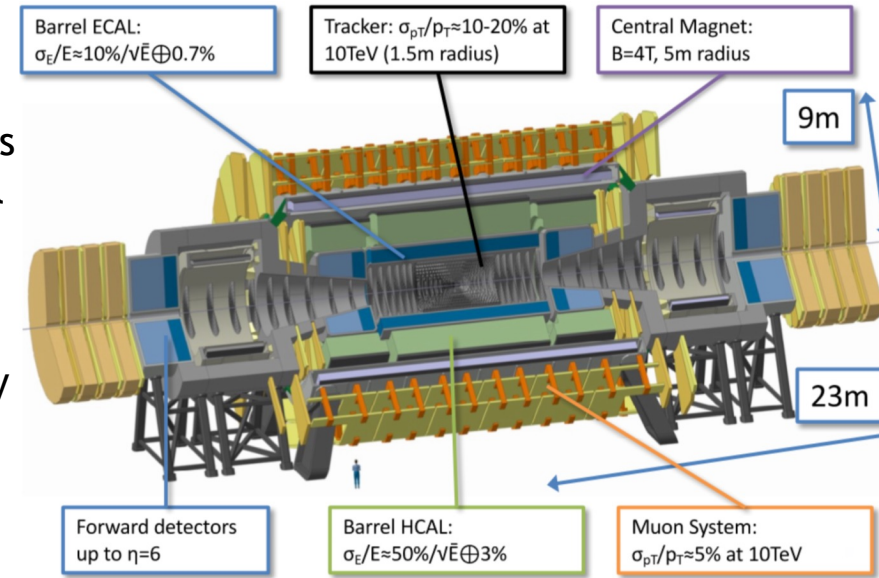
@Liv: HVCMOS studies, gaseous cooling (Joost, Tim..)



**FCC-eh:** scaled up version of proposed LHeC detector, symmetric if hosting pp and ep at the same time

@Liv: studies with ERL (Max, Ben Hounsell PhD Acc.) + dual detector (eh/hh) and layout

**FCC-hh:** Largest challenge is that radiation levels go well beyond what any currently available microelectronics can survive ( $\lesssim$  MGy)  
See also [my talk](#) @ FCC-Italy



# 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.

A lot to exploit!

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

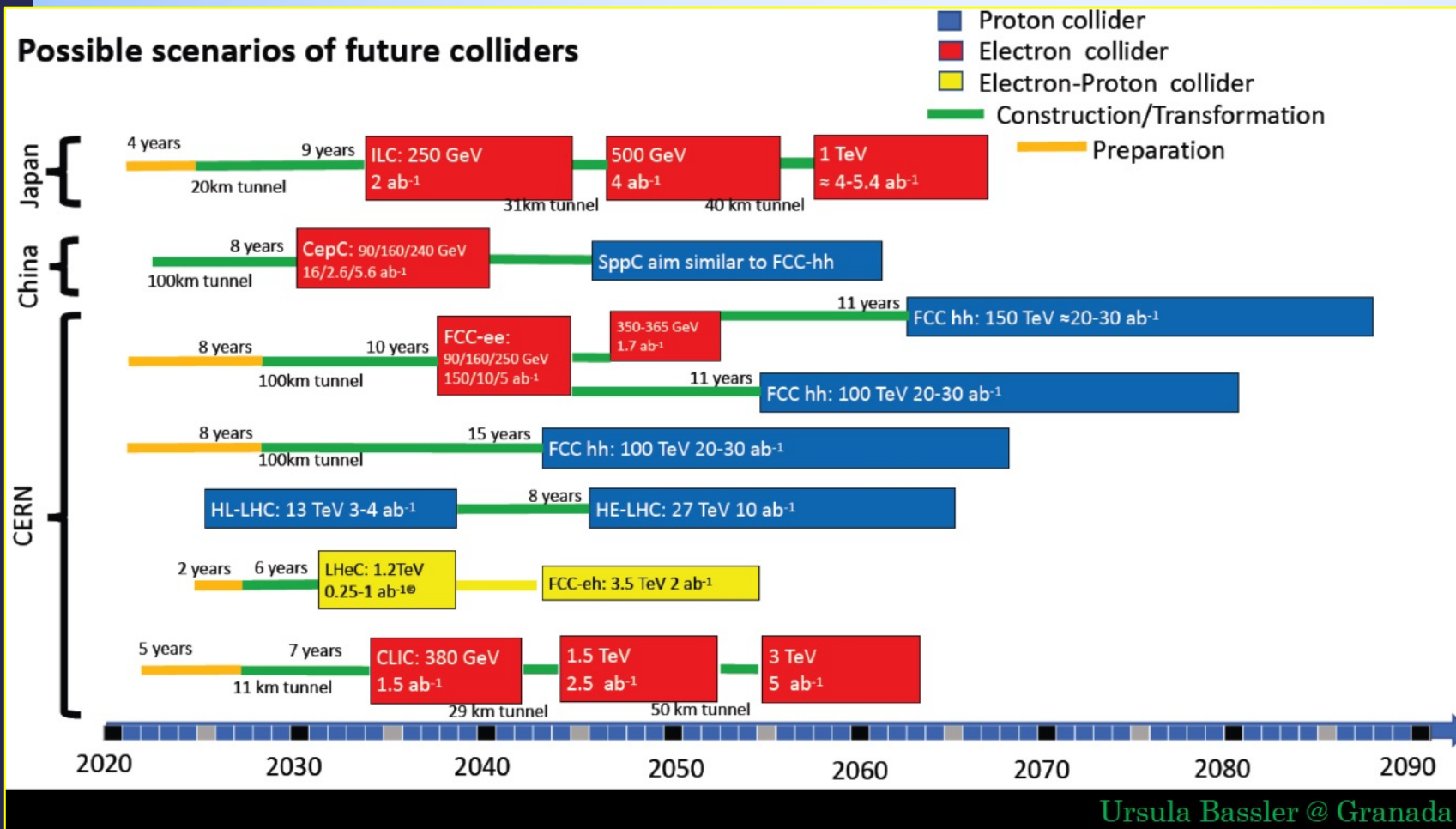
ERL technology potentially relevant for FCC- $ee$  to reach highest energy

# Some final remarks

Since Granada 2019, schedule shifted by few years

Other proposals came out or were corroborated in the mean time, e.g.:  
 e+e- US options (C<sup>3</sup>, HELENA)  
 pp @ 27 TeV (in US)  
 μ+μ- collider

Liverpool already contributing substantially to physics, detector and accelerator developments  
 Open mind but also targeted approach will be needed



Taking this from a *certain* year 1:

