LHeC CDR Update: 2007.14491 (JPhys G ‘in print’)

An ep/h Experiment for the LHC (to appear) AA+eA?

FCCeh: Talk last year (MK) at “Oxford”, 11.9.21
[attached to indico]

ECFA Detector Roadmap – to be published

LDG Accelerator Roadmap – to be published (1/22)

LHeC/FCCeh/PERLE Workshop April 22, 5/6.4. (tbc)

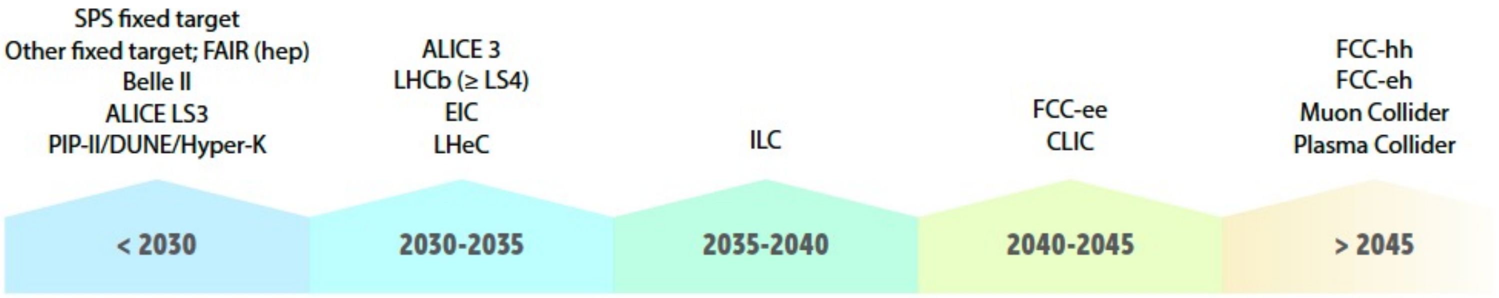
Snowmass

Remarks on FCC-eh

For Introduction, Information and Discussion

UK FCC-eh Meeting, 26 November 2021

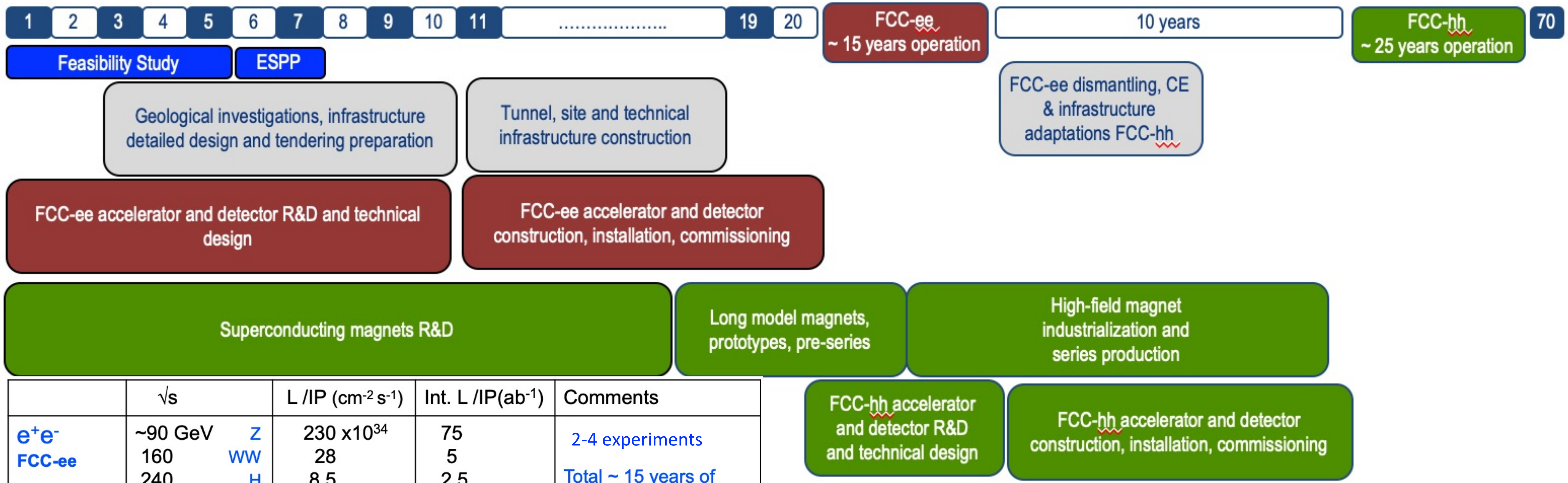
Max Klein (Liverpool University)



The uncertainty of the future.
From Accelerator R&D Roadmap
[tentative]

Timeline of the FCC integrated programme

Technical schedule



	√s	L /IP ($cm^{-2} s^{-1}$)	Int. L /IP(ab^{-1})	Comments
e^+e^- FCC-ee	~90 GeV Z 160 WW 240 H ~365 top	230 $\times 10^{34}$ 28 8.5 1.5	75 5 2.5 0.8	2-4 experiments Total ~ 15 years of operation
pp FCC-hh	100 TeV	5 $\times 10^{34}$ 30	20-30	2+2 experiments Total ~ 25 years of operation
PbPb FCC-hh	$\sqrt{s_{NN}}$ = 39TeV	3 x 10^{29}	100 nb^{-1}/run	1 run = 1 month operation
ep Fcc-eh	3.5 TeV	1.5 10^{34}	2 ab^{-1}	60 GeV e- from ERL Concurrent operation with pp for ~ 20 years
e-Pb Fcc-eh	$\sqrt{s_{eN}}$ = 2.2 TeV	0.5 10^{34}	1 fb^{-1}	60 GeV e- from ERL Concurrent operation with PbPb

- ❑ Feasibility Study: 2021-2025
- ❑ If project approved before end of decade → construction can start beginning 2030s
- ❑ FCC-ee operation ~2045-2060
- ❑ FCC-hh operation 2070-2090++

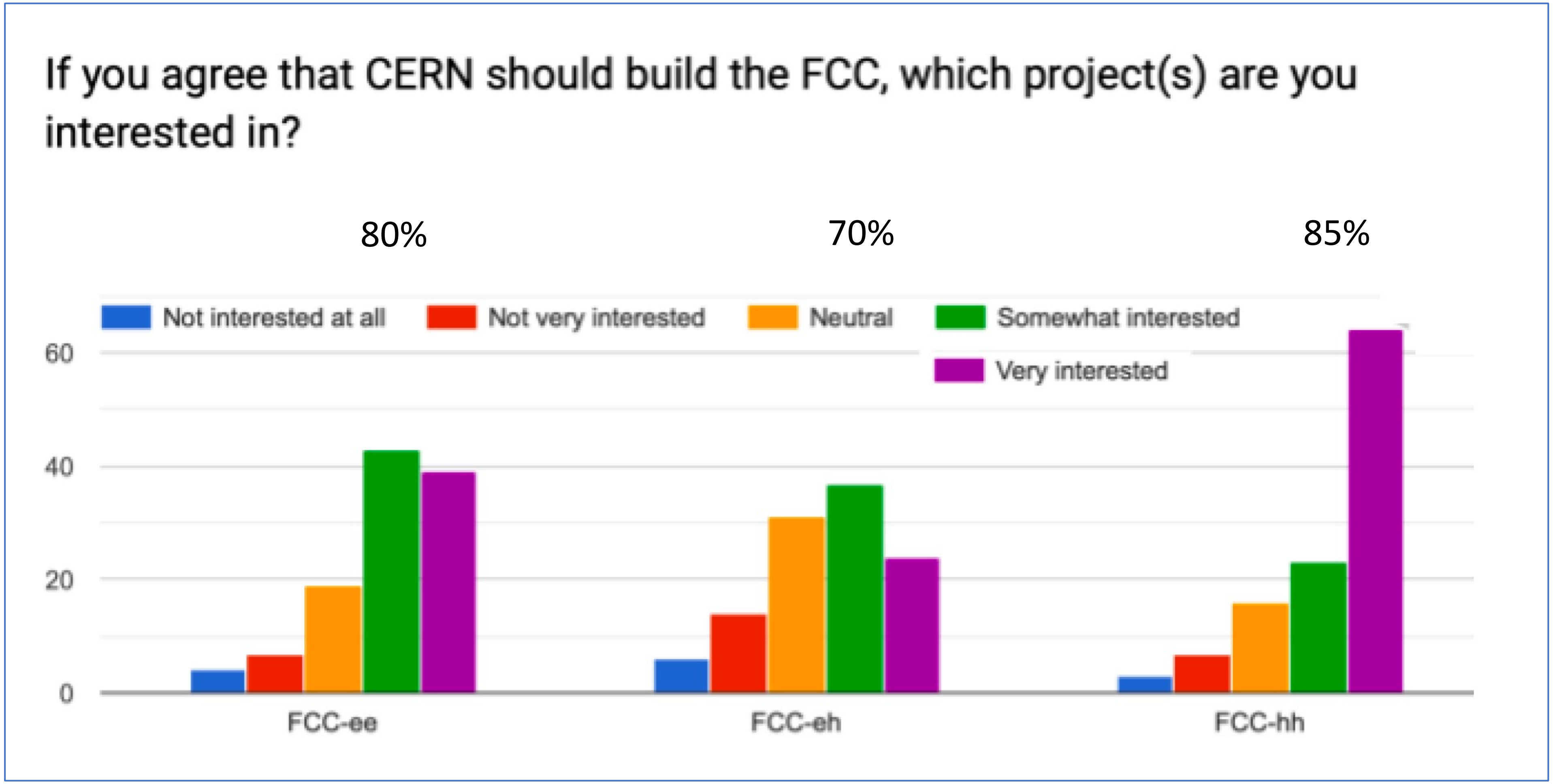
F. Gianotti

Report on the ECFA Early-Career Researchers Debate on the 2020 European Strategy Update for Particle Physics

The ECFA Early-Career Researchers

February 6, 2020

arXiv:2002.02837



The perception of the DIS potential, Higgs, as an example

Collider	HL-LHC	ILC_{250}	$CLIC_{380}$	FCC-ee			FCC-eh
Luminosity (ab^{-1})	3	2	0.5	5 @ 240 GeV	+1.5 @ 365 GeV	+ HL-LHC	2
Years	25	15	7	3	+4	—	20
$\delta\Gamma_H/\Gamma_H$ (%)	SM	3.8	6.3	2.7	**1.3**	1.1	SM
$\delta g_{HZZ}/g_{HZZ}$ (%)	1.3	0.35	0.80	0.2	**0.17**	0.16	0.43
$\delta g_{HWW}/g_{HWW}$ (%)	1.4	1.7	1.3	1.3	**0.43**	0.40	0.26
$\delta g_{Hbb}/g_{Hbb}$ (%)	2.9	1.8	2.8	1.3	**0.61**	0.55	0.74
$\delta g_{Hcc}/g_{Hcc}$ (%)	SM	2.3	6.8	1.7	**1.21**	1.18	1.35
$\delta g_{Hgg}/g_{Hgg}$ (%)	1.8	2.2	3.8	1.6	**1.01**	0.83	1.17
$\delta g_{H\tau\tau}/g_{H\tau\tau}$ (%)	1.7	1.9	4.2	1.4	**0.74**	0.64	1.10
$\delta g_{H\mu\mu}/g_{H\mu\mu}$ (%)	4.4	13	n.a.	10.1	**9.0**	3.9	n.a.
$\delta g_{H\gamma\gamma}/g_{H\gamma\gamma}$ (%)	1.6	6.4	n.a.	4.8	**3.9**	1.1	2.3
$\delta g_{Htt}/g_{Htt}$ (%)	2.5	–	–	–	–	2.4	1.7
BR_{EXO} (%)	SM	< 1.8	< 3.0	< 1.2	< 1.0	< 1.0	n.a.

FCC CDR Vol 1, *Eur.Phys.J.C* 79 (2019) 6, 474

Physics Potential of eh is often not included or well (re)presented.

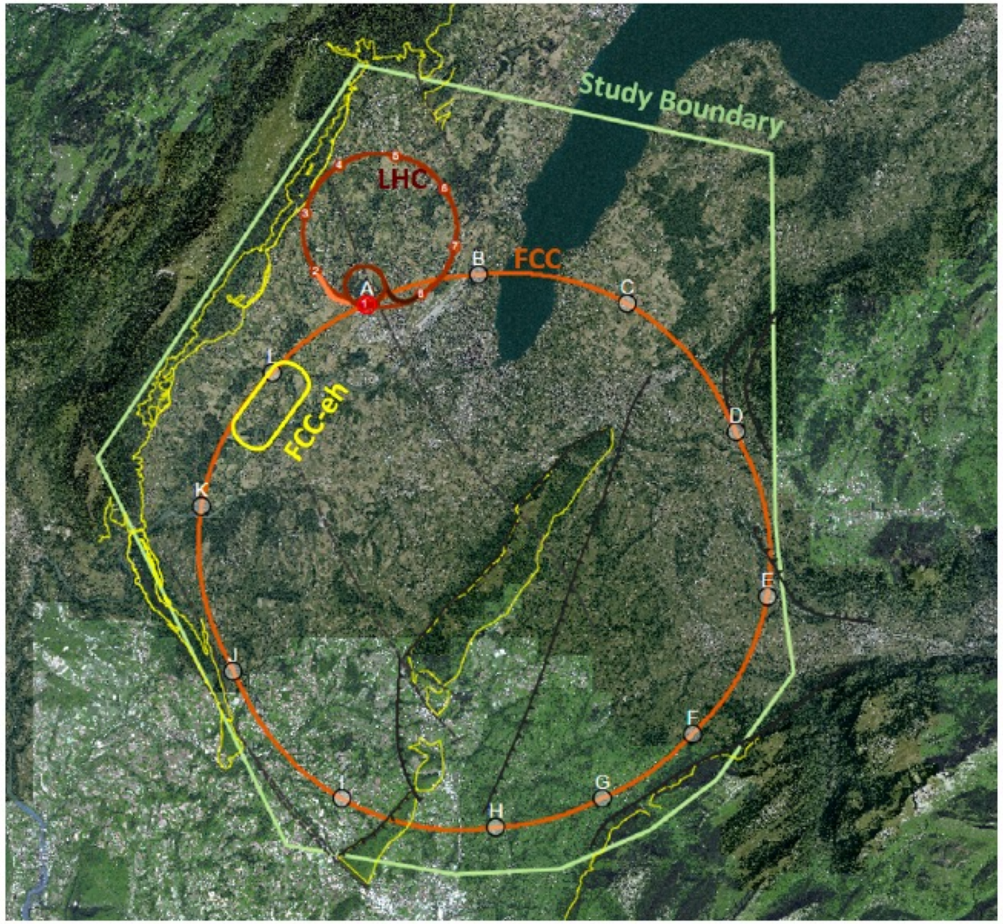
ECFA Higgs Study devoted to e^+e^- but intends to include pp and ep.
Two workshops forthcoming: October 2022 and probably fall 2023

Talk by P Janot at ECFA Meeting 19.11.2021

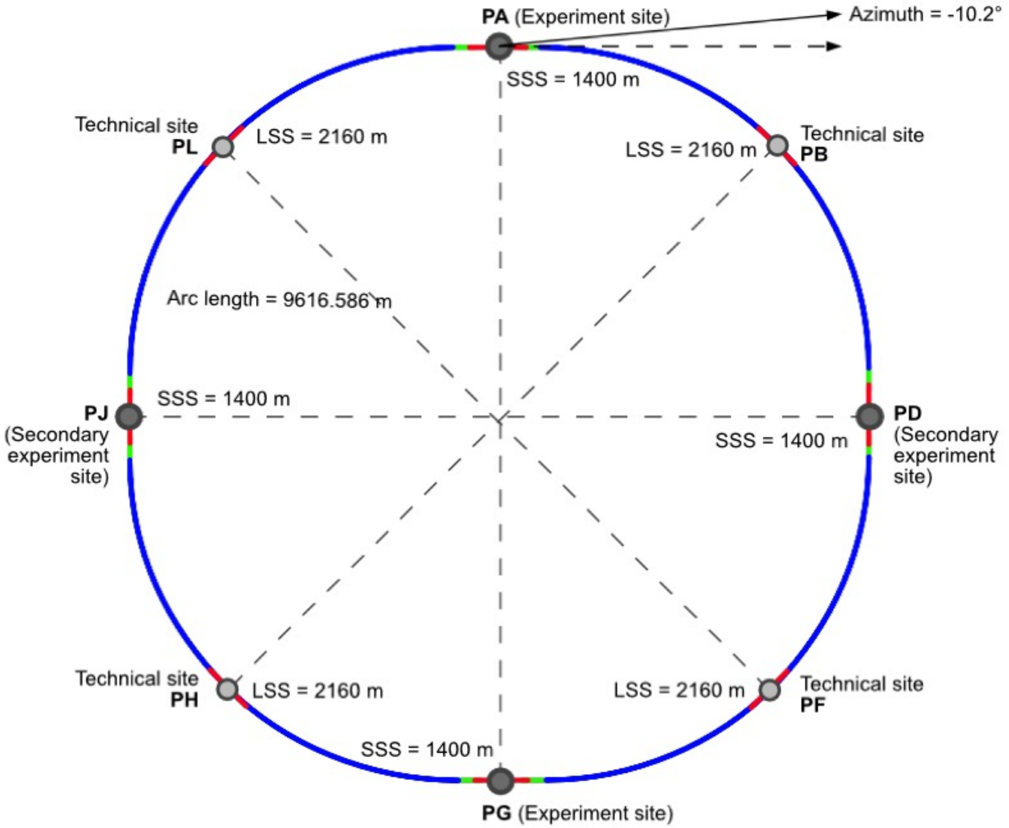
Collider	HL-LHC	$FCC\text{-}ee_{240\rightarrow365}$	FCC-INT	
Lumi (ab^{-1})	3	5 + 0.2 + 1.5	30	
Years	10	3 + 1 + 4	25	
g_{HZZ} (%)	1.5	0.18 / 0.17	0.17/0.16	
g_{HWW} (%)	1.7	0.44 / 0.41	0.20/0.19 *	
g_{Hbb} (%)	5.1	0.69 / 0.64	0.48/0.48	ee
g_{Hcc} (%)	SM	1.3 / 1.3	0.96/0.96	
g_{Hgg} (%)	2.5	1.0 / 0.89	0.52/0.5	
$g_{H\tau\tau}$ (%)	1.9	0.74 / 0.66	0.49/0.46	
$g_{H\mu\mu}$ (%)	4.4	8.9 / 3.9	0.43/0.43	
$g_{H\gamma\gamma}$ (%)	1.8	3.9 / 1.2	0.32/0.32	
$g_{HZ\gamma}$ (%)	11.	– / 10.	0.71/0.7	
g_{Htt} (%)	3.4	10. / 3.1	1.0/0.95	pp
g_{HHH} (%)	50.	44./33. 27./24.	3	
Γ_H (%)	SM	1.1	0.91	ee
BR_{inv} (%)	1.9	0.19	0.024	pp
BR_{EXO} (%)	SM (0.0)	1.1	1	ee

* g_{HWW} includes also ep

Evolution of the Design



CDR: 12 access points, eh at point L preferred



91 km circumference, 50 drillings until 24
4-fold symmetry of IPs – change to CDR

FCC-eh Detector Concept Design

Remarks/questions:

- Suitable design for precision DIS

- Muon tagger or spectrometer

- LAr or warm calo

- Beam pipe and Machine-detector Interface

- Final choices not now but later by a collaboration

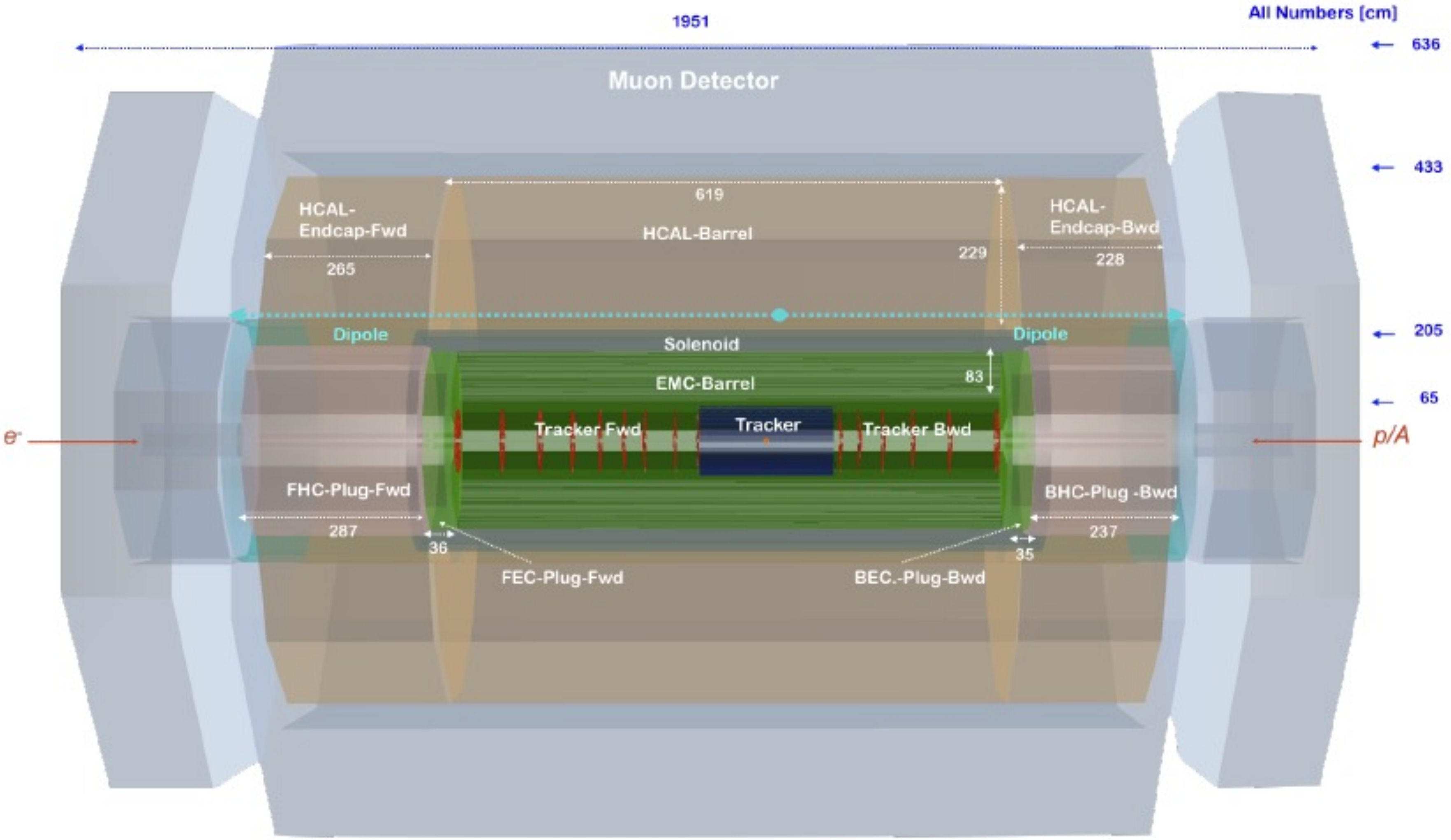


Figure 12.21: Side view of a low energy FCCeh ($E_p = 20\,\text{TeV}$) concept detector, designed using the DD4hep framework [891], showing the essential features. The solenoid is again placed between the ECAL-Barrel and Hadronic-Barrel calorimeters and is housed in a cryostat in common with the beam steering dipoles extending over the full length of the barrel and plug hadronic calorimeters. The sizes have been chosen such that the solenoid/dipoles and ECAL-Barrel systems as well as the whole tracker are also suitable to operate after an upgrade of the beam energy to $E_p = 50\,\text{TeV}$.

From new paper: 2007:14491

Clean FS

No pile-up

NC-CC-γp clearly separated

Radiation 1000 less than in pp

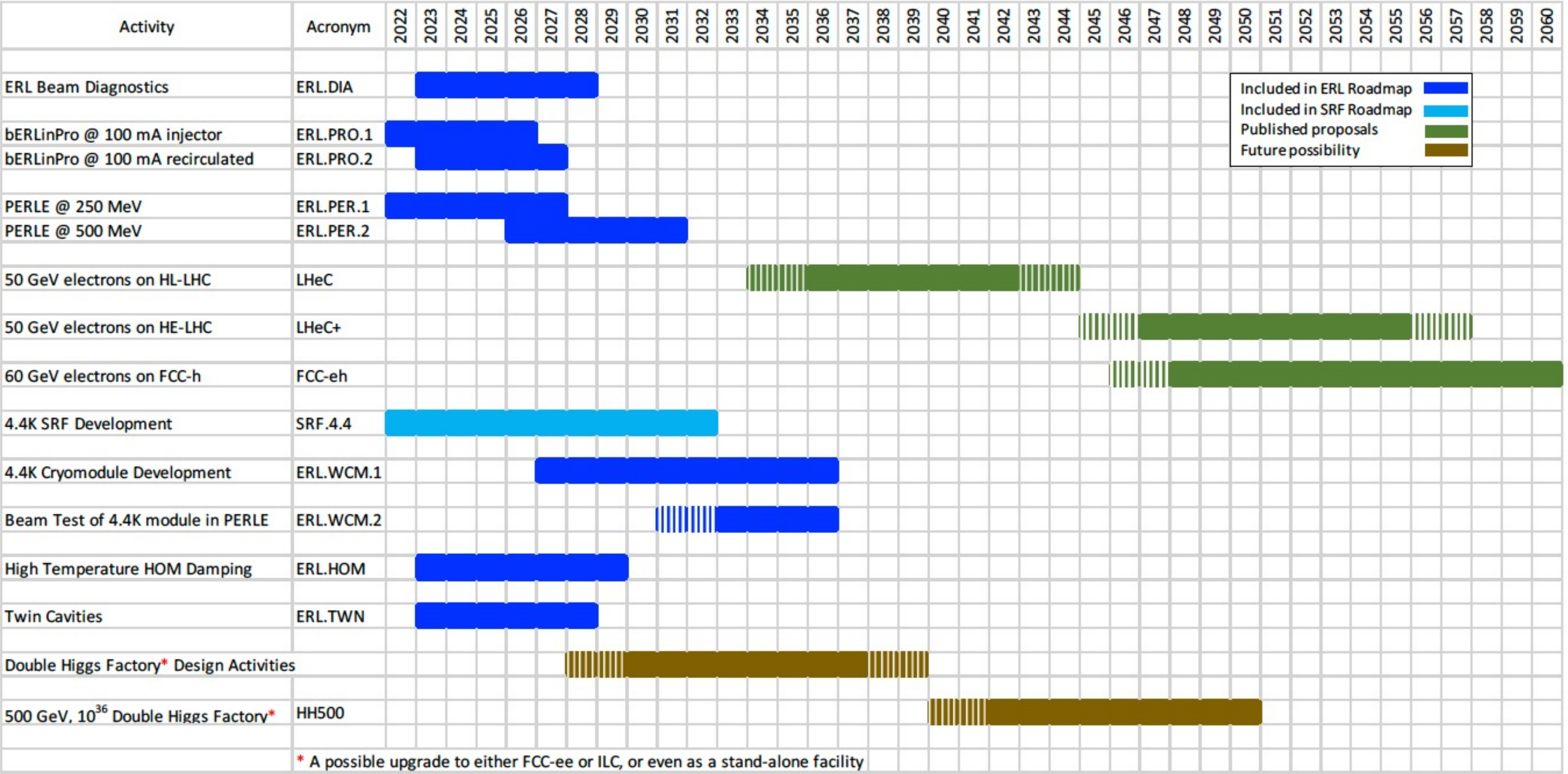
… “easy”

Challenge: IR and e-h

fwd region

ERL Vision of HEP Colliders

PERLE



← eh is more than FCC

From Accelerator R&D Roadmap to be published

Fig. 6.12: Long-term vision for the ERL Roadmap showing how the activities in the next five to ten years lead to multiple options for future HEP Colliders.

Observations

By 2025/26 the European community needs to decide upon its energy frontier future as CERN cannot survive without.

The extension of the SM, new physics, hardly can be achieved with one type of experiment for decades, it needs diversity.

The FCC-eh has a cms energy 10 times larger than HERA, i.e Q^2 and 1/x are 100 times extended, and for lA it is 10^4 times.

One may not understand parton dynamics nor pp collisions at 100 TeV without a next generation DIS collider at high energy.

DIS has strong tradition in UK: from BEBC, EMC to H1 and ZEUS, into EIC at lower energies but higher luminosity.

The current position of LHeC and FCC-eh has been reached through/by a motivated, competent community, UK not least.

We have been supported but not funded, besides a few PhD positions by CERN and some other places.

We have much profited from the coherent collaboration and interaction of accelerator, exp and theory colleagues.

…

All good, but how can we proceed, given the uncertainties and the strong constraints on our time. What about:

A 3 years programme (22-24) with the goal of an Energy Frontier DIS Collider Design (FCC-eh, HE-LHeC, with platform LHeC)

and detector developments jointly with ee (thin Si, light solenoid, high resolution calorimetry) and hh (multi-TeV calorimetry)

backup

FCC Feasibility Study – coordination team and contact persons

EU Projects
NN

Collaboration building
Emmanuel Tsesmelis

Communications
Panagiotis Charitos, James Gillies

Study Support and Coordination
Study Leader: Michael Benedikt
Deputy Study Leader: Frank Zimmermann

Study Support Unit
IT: Sylvain Girod
Procurement: Adam Horridge
Quality control: NN
Resources: Sylvie Prodon
Scheduling, quality mangement: NN
Secretariat: Julie Hadre

Physics, Experiments and Detectors
Patrick Janot
Gavin Salam

- **Physics programme** – Matthew McCullough, Frank Simon
- **Detector concept** – Mogens Dam
- **Physics performance** – Patrizia Azzi, Emmanuel Perez
- **Software and computing** – Gerardo Ganis, Clément Helsens

Accelerators
Tor Raubenheimer
Frank Zimmermann

- **FCC-ee collider design** – Katsunobu Oide
- **FCC-hh design** – Massimo Giovannozzi
- **Technology R&D** – Roberto Losito
- **FCC-ee booster design** – Antoine Chancé
- **FCC-ee injector** – Paolo Craievich, Alexej Grudiev
- **FCC-ee energy calibration polarization** – Alain Blondel, Jorg Wenninger
- **FCC-ee MDI** – Manuela Boscolo, Mike Sullivan

Technical Infrastructures
Klaus Hanke

- **Integration** – Jean-Pierre Corso
- **Geodesy & survey** – Hélène Mainaud Durand
- **Electricity and energy management** – Jean-Paul Burnet
- **Cooling and ventilation** – Guillermo Peon
- **Cryogenics systems** – Laurent Delprat
- **Computing and controls infrastructure, communication and network** – Dirk Duellmann
- **Safety** – Thomas Otto
- **Operation, maintenance, availability, reliability** – Jesper Nielsen
- **Transport, installation concepts** – Cristiana Colloca

Host State processes and civil engineering
Timothy Watson

- **Administrative processes** – Friedemann Eder
- **Placement studies** – Johannes Gutleber, Volker Mertens
- **Environmental evaluation** – Johannes Gutleber
- **Tunnel, subsurface design** – John Osborne
- **Surface sites layout, access and building design**

Organisation and financing models
Paul Collier (interim)

- **Project organisation model**
- **Financing model** – Florian Sonnemann
- **Procurement strategy and rules**
- **In-kind contributions**
- **Operation model** – Paul Collier, Jorg Wenninger

ERL Facilities

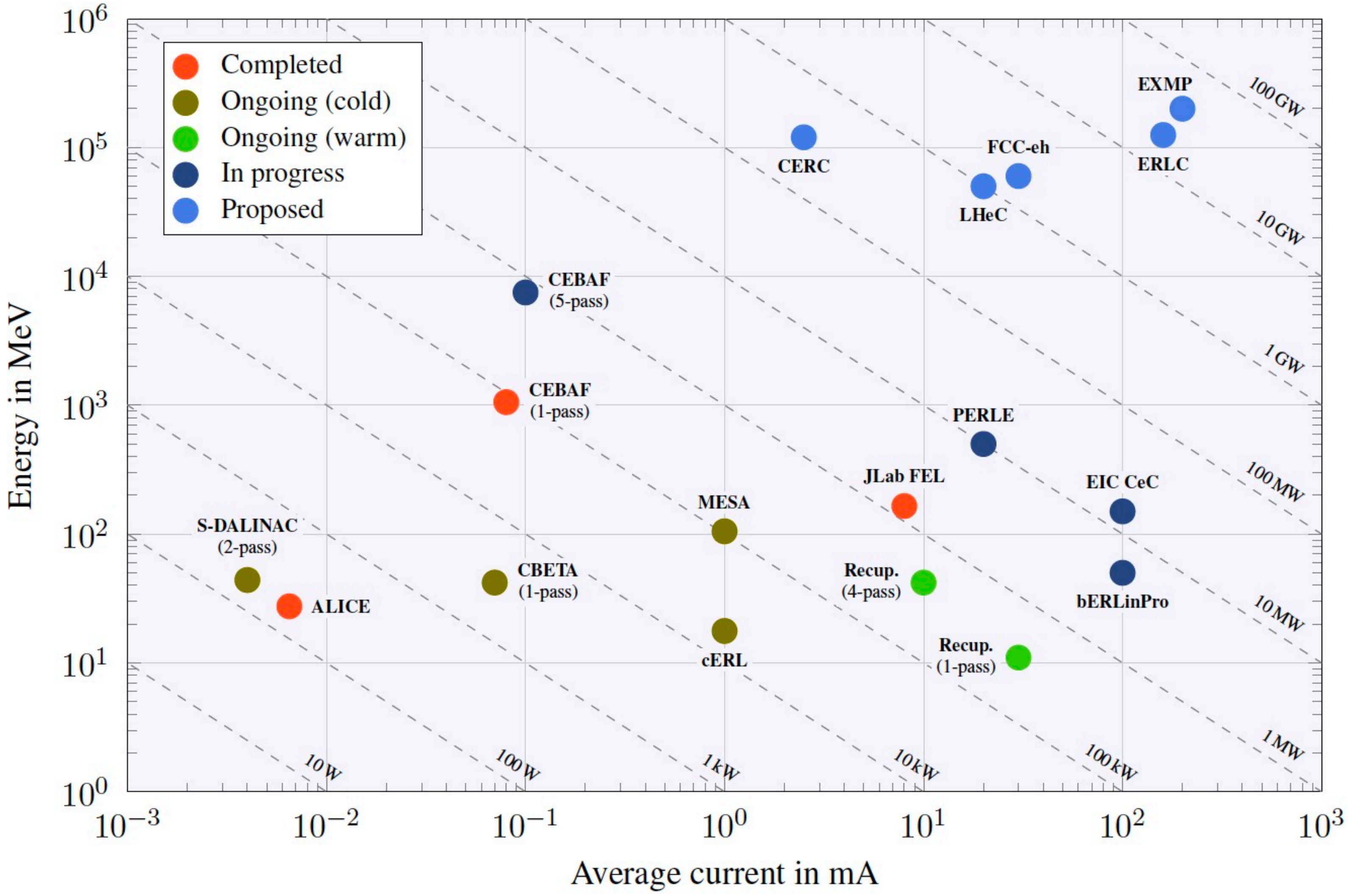


Fig. 6.1: Electron energy E vs. electron source current I for classes of past, present and possible future ERL facilities as are introduced in the text. Dashed diagonal lines represent constant power, $P[\text{kW}] = E[\text{MeV}] \cdot I[\text{mA}]$.

From Accelerator R&D Roadmap
To be published

Beyond the LHC/LHeC: FCC

Far Future

The far future is least defined
There big questions will remain
and new ones shall be posed
Crucial:
LHC and 1 TeV exploration
Developments of
Accelerator Technology
Experiments
Theoretical Physics
Peace for world collaboration

pp

FCC - hh

Higgs Potential
Rare H Decays
SUSY
GUT
??

ep

FCC - eh

High Precision Higgs
BSM in multi TeV range
DIS of top, g saturation
Leptoquarks and GUT

l^+l^-

CLIC, FCC - ee

High Precision Higgs
Top and BSM
Rh Neutrinos

Muon Collider ?

Neutrino Physics
Factory, Proton Decay

Particle Physics has a long term future,
many of its quests are unresolved,
Nr of families, GUT, substructure, DM..

It has been and will be science at a global scale, with many question marks for USA, China and Japan at present.

Former times:

CDHS,BCDMS../SppS/PETRA,PEP

HERA/Tevatron/LEP,SLC

Nearer future, perhaps

LHeC/LHC/ILC,CepC