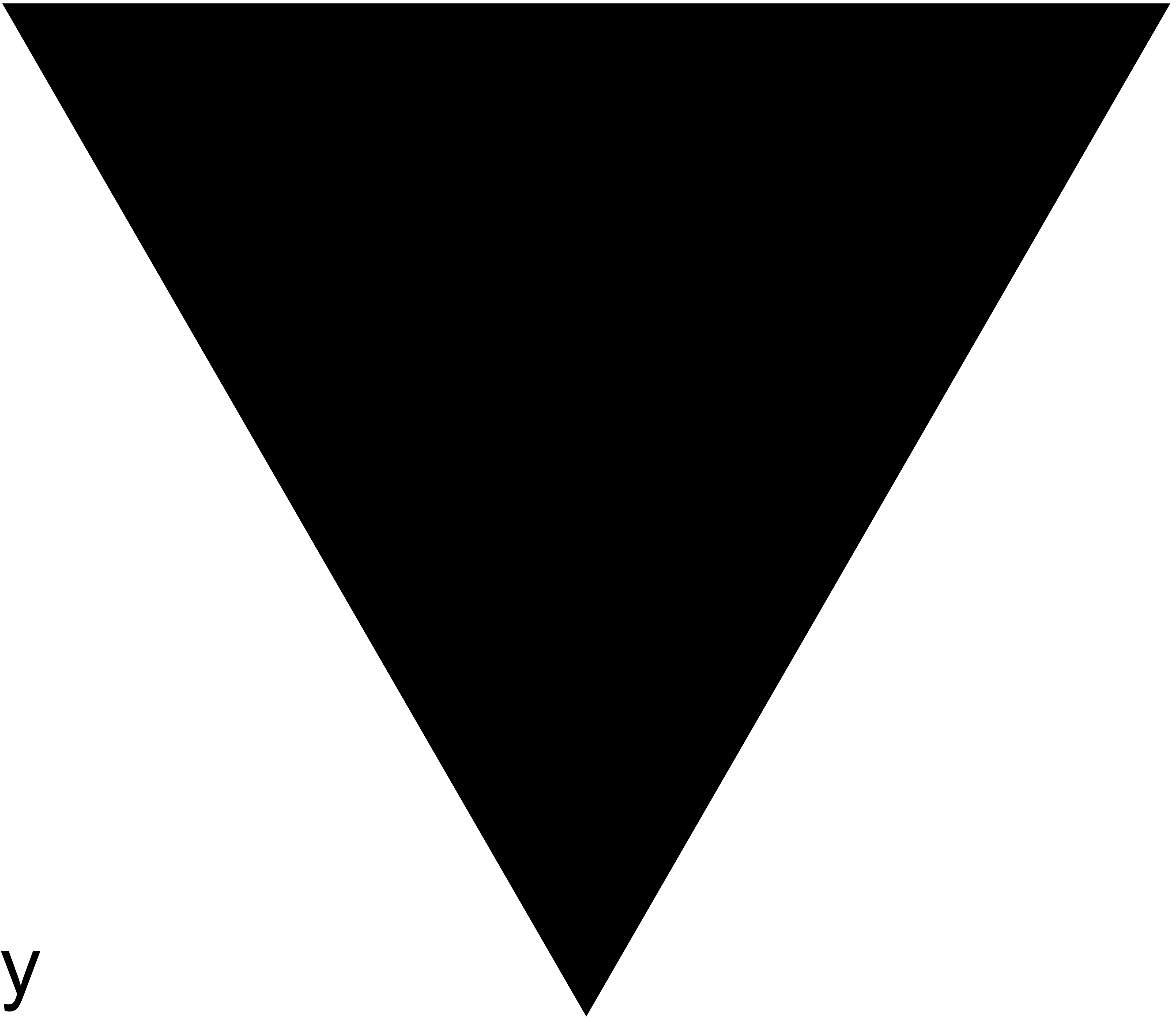
INPUTS TO THE EUROPEAN STRATEGY FOR PARTICLE PHYSICS

Accelerators

Scenarios

Countries

MY PROFESSIONAL LIGHTCONE



2050

<u>Retirement</u>

2030 HL-LHC

2017++ ATLAS

2010-17 PD CMS

2006-10 PhD LHCb

2000-05 MSc Theory

<u>New collider?</u>

2022+ C^3 LC

2022+ Mu Coll

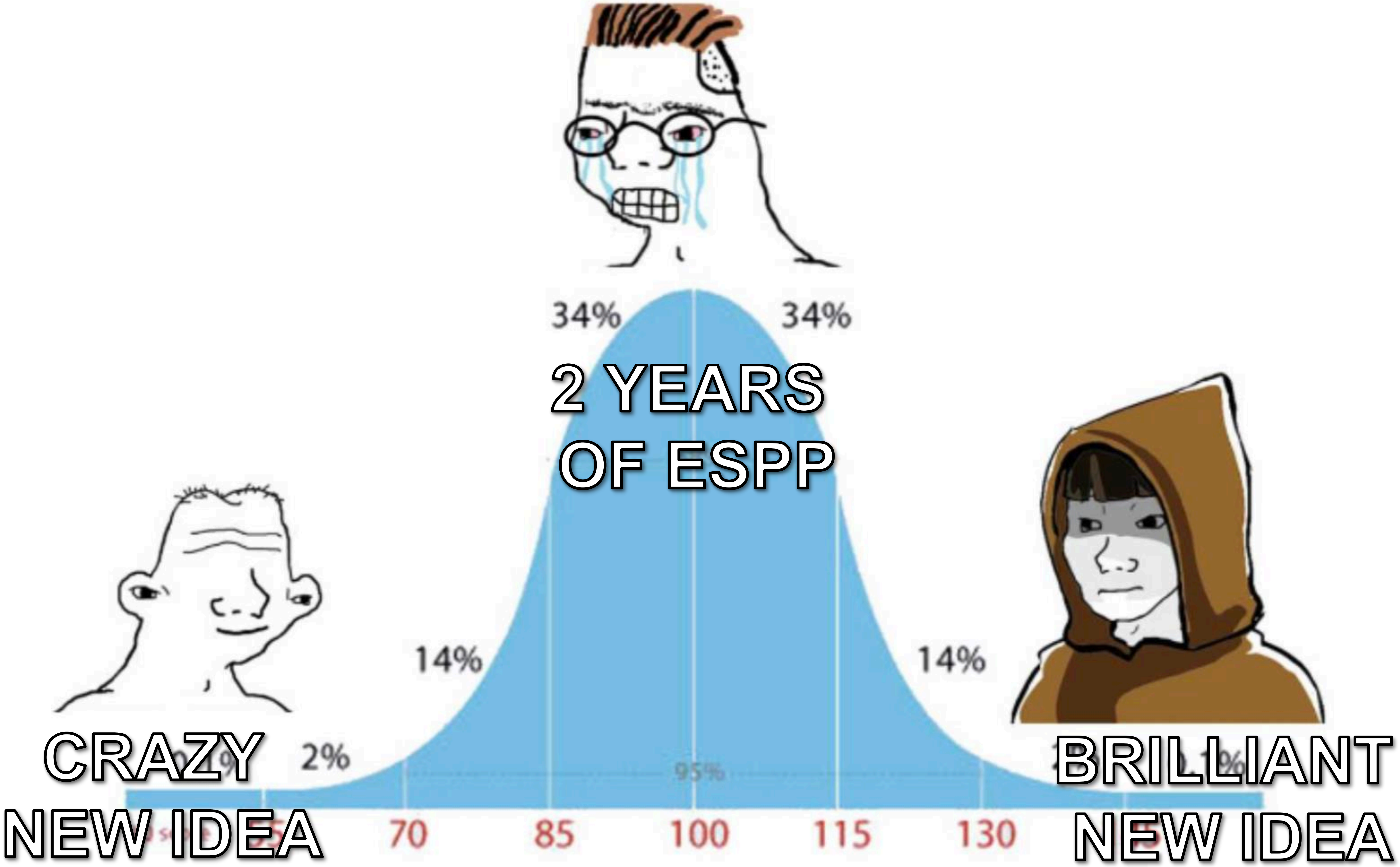
2017 FCC report

2013 ILC site visit

2008 Start of the LHC

2000

TODAY, I AM ASIMOV



INPUTS TO THE ESPP

All 263 contributions
https://europeanstrategyupdate.web.cern.ch/sites/default/files/Submitted_Input_2025.03.04.pdf

Update of European Strategy for Particle Physics

- Deadline 31 March
  - 263 (!) inputs

Accelerators

Detectors

Strategies

Collaborations, Groups and Indidivuals

Theories

Countries

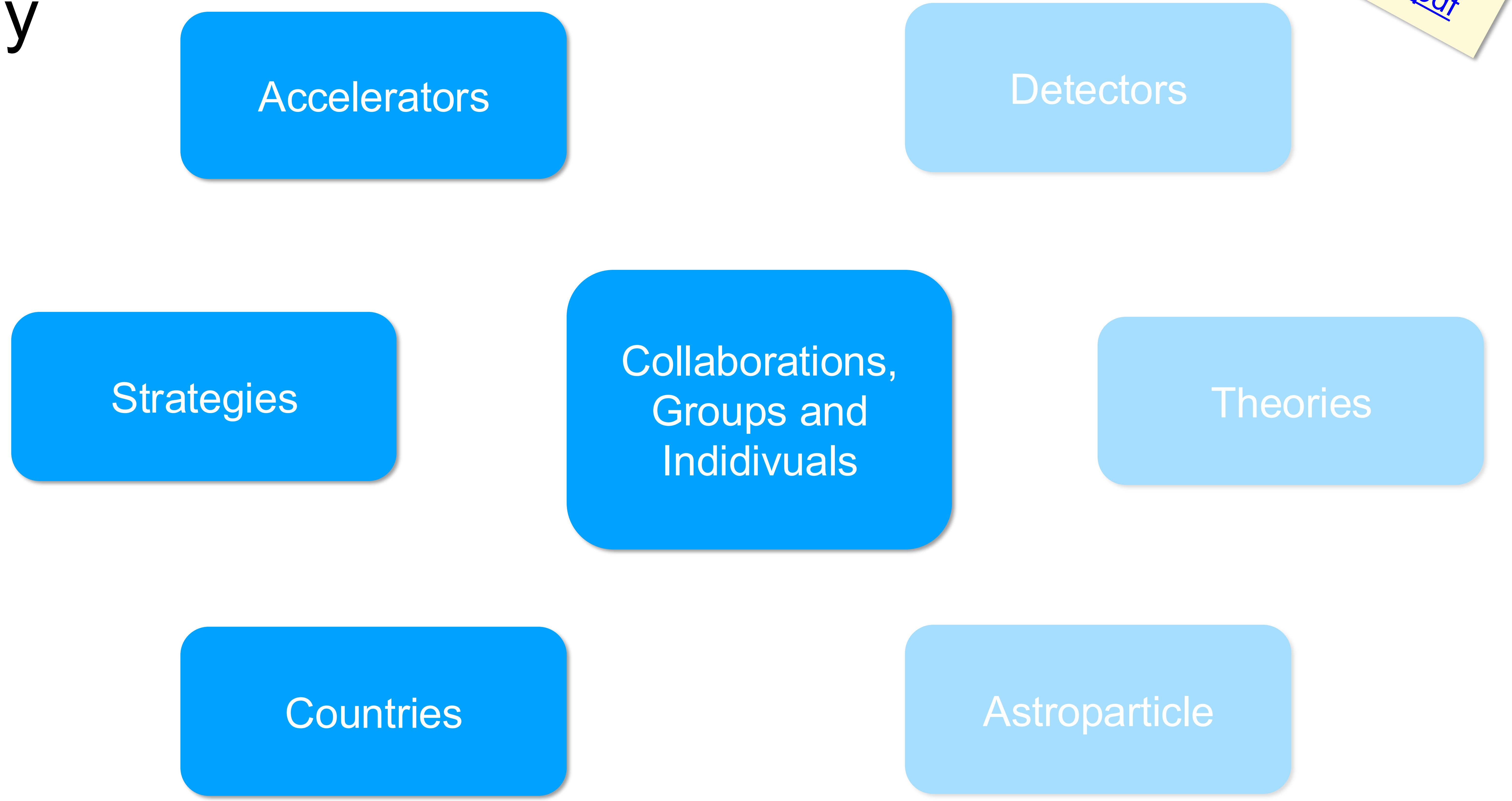
Astroparticle

INPUTS TO THE ESPP

All 263 contributions
https://europeanstrategyupdate.web.cern.ch/sites/default/files/Submitted_Input_2025.03.04.pdf

Update of European Strategy for Particle Physics

- Deadline 31 March
  - Today’s focus:



OUTLINE

I) Accelerator projects

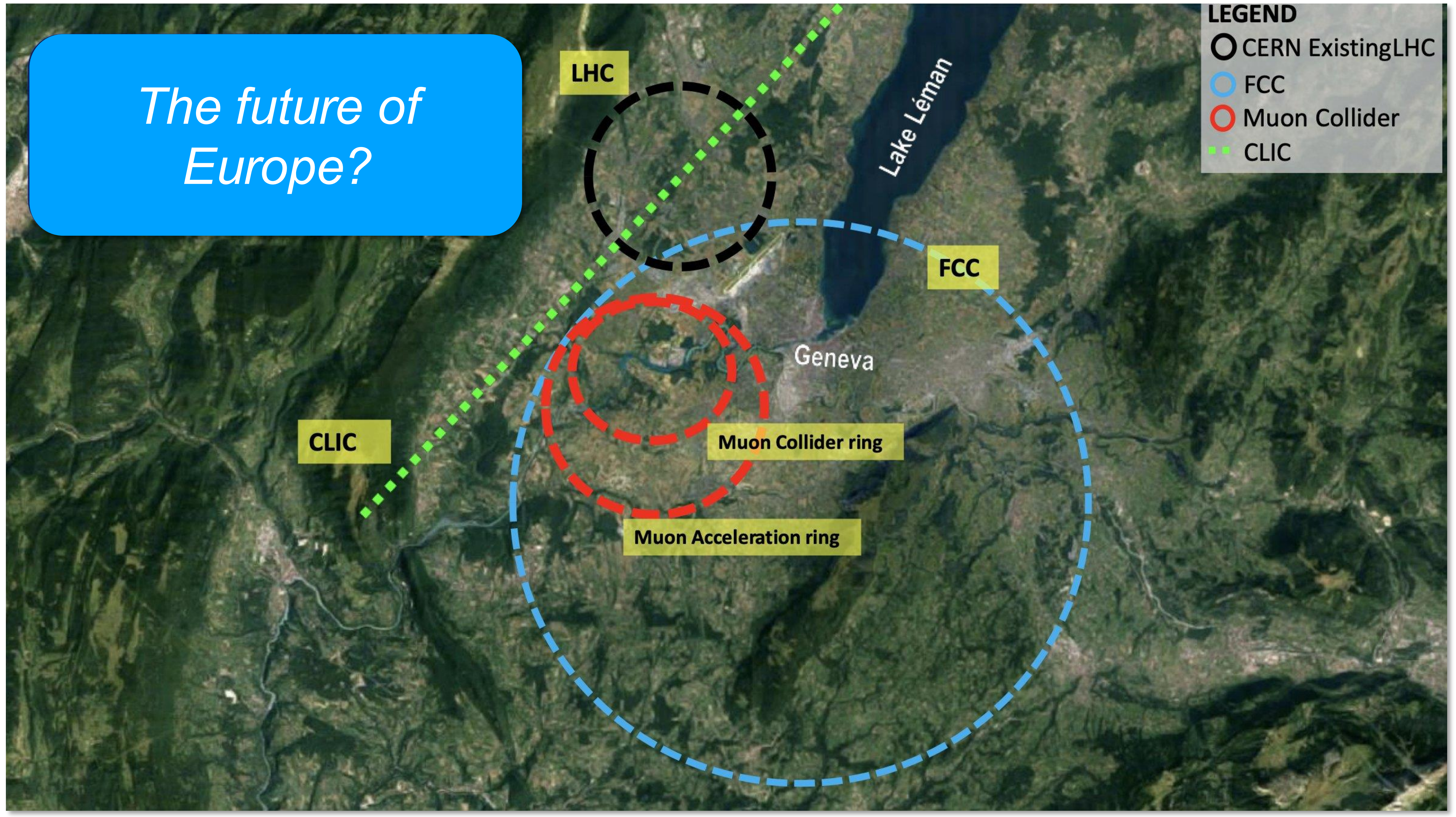
- First 30 minutes

II) Scenarios & visions

- Middle 10 minutes

III) Countries

- Last 10 minutes



➔ I propose we discuss mostly during/after the last section

FUTURE CIRCULAR COLLIDER

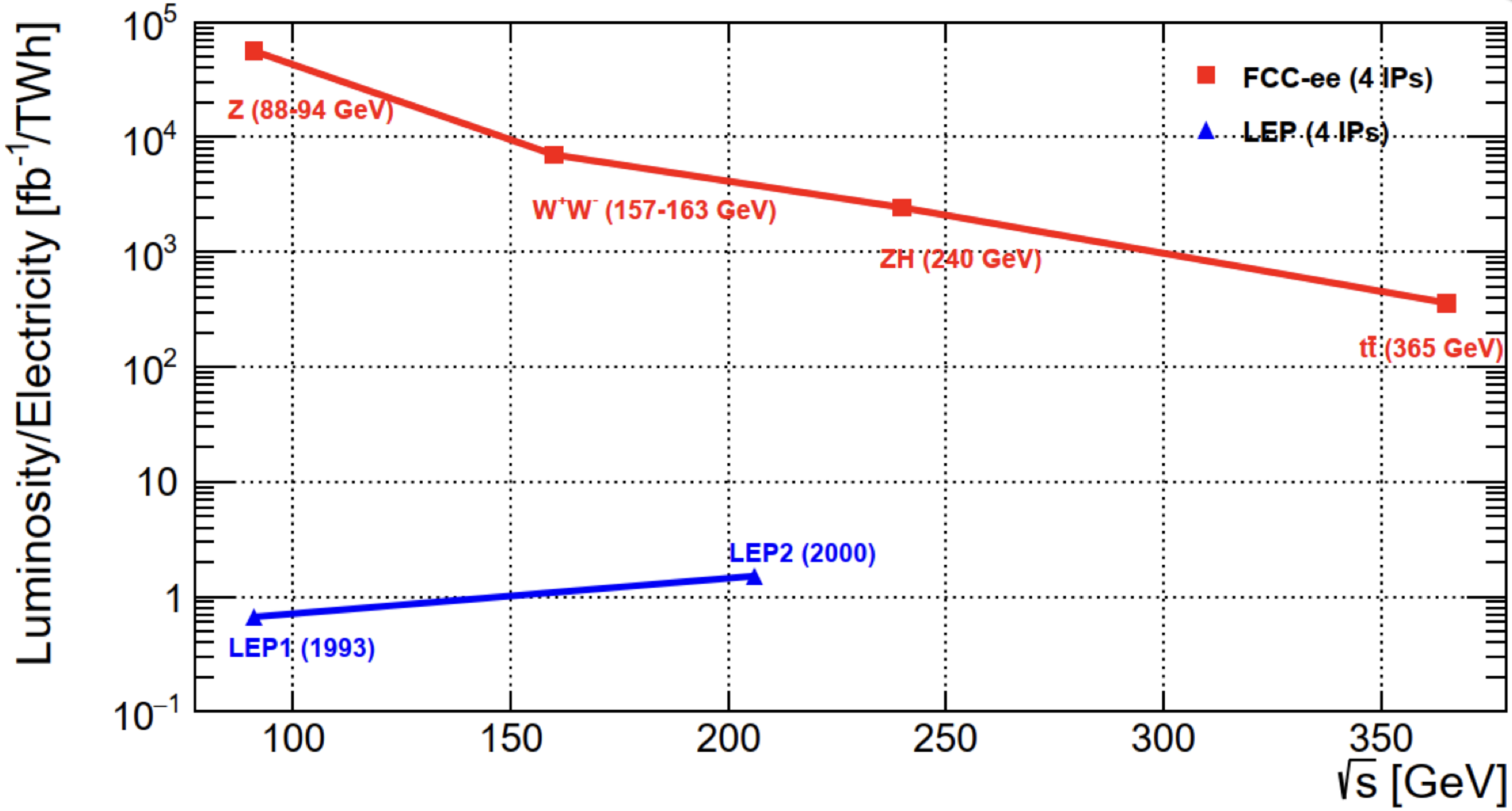
PHOTO: J. WENNINGER

FCC-ee programme
https://indico.cern.ch/event/1439855/contributions/6461636/

FCC-EE: PROJECT

Most famous proposal

- 91 km circle
  - Z+W+H (+t)
- EWK + BPH + top
  - Upgrade to FCC-hh



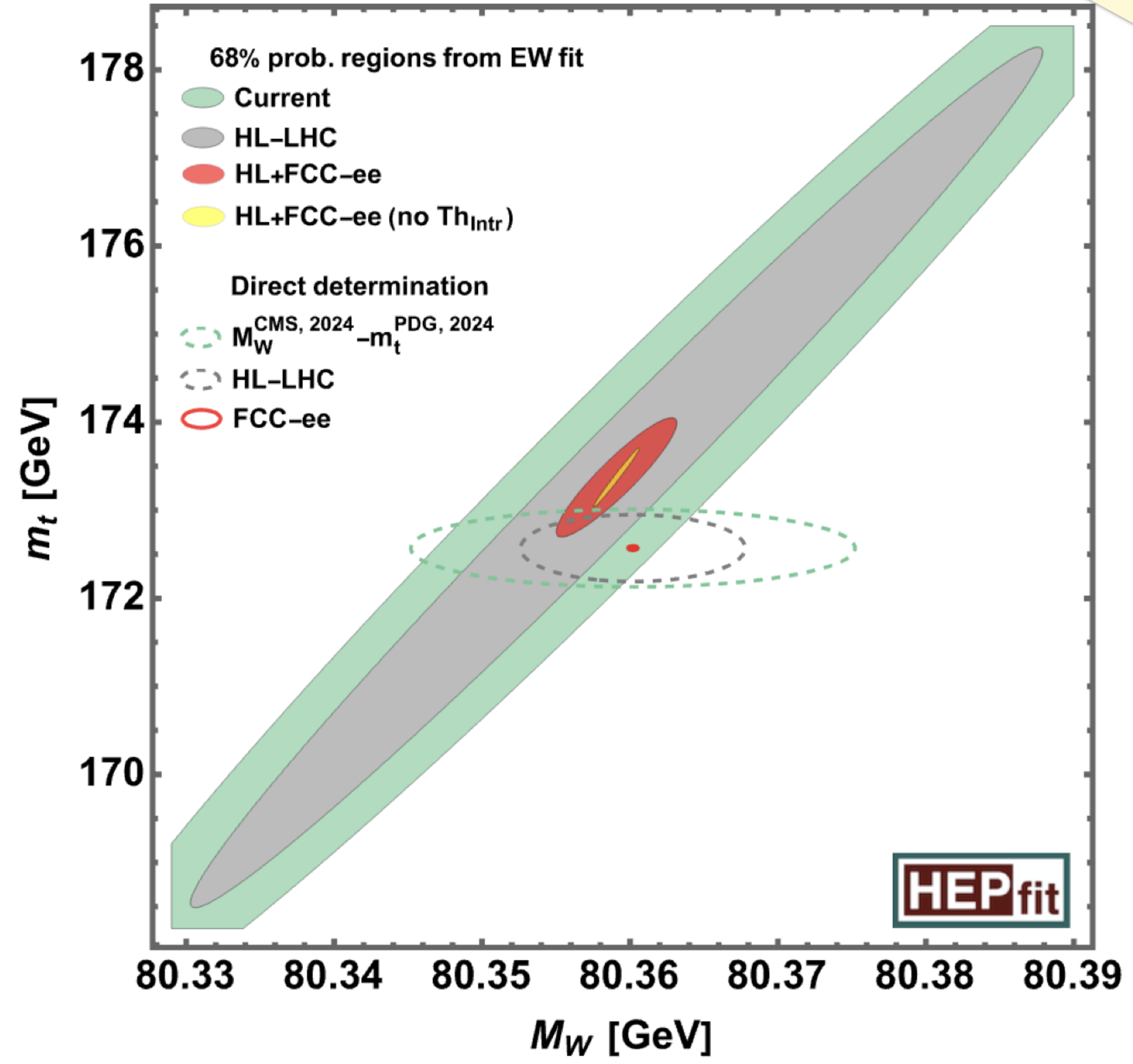
➔ More in colloquium by Frank Zimmermann (16 May)

FCC-EE: PHYSICS

FCC-ee physics
https://indico.cern.ch/event/1439855/contributions/6461657/

EWK

- W + Z + t
  - Precision



FCC-EE: PHYSICS

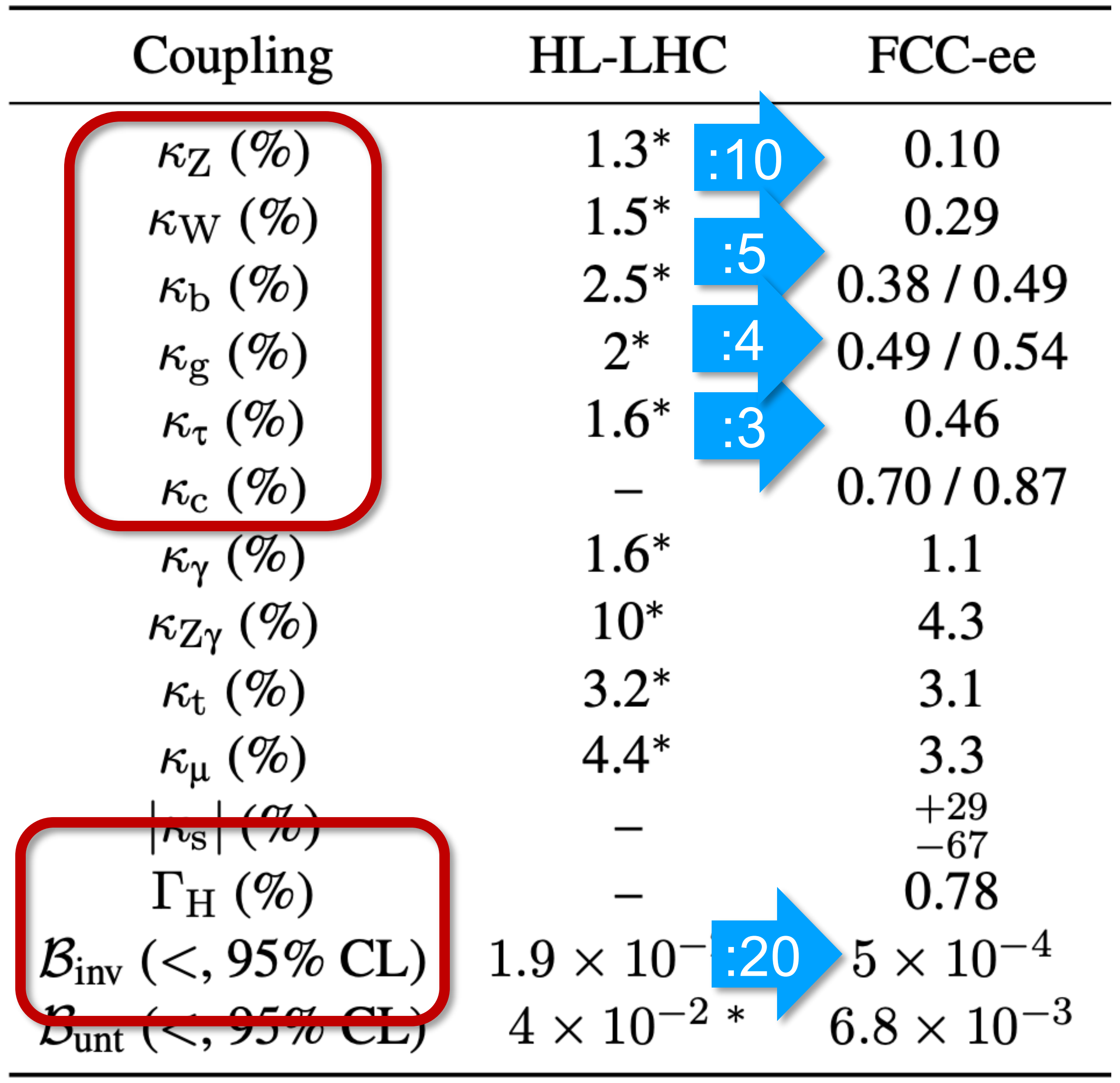
FCC-ee physics
https://indico.cern.ch/event/1439855/contributions/6461657/

EWK

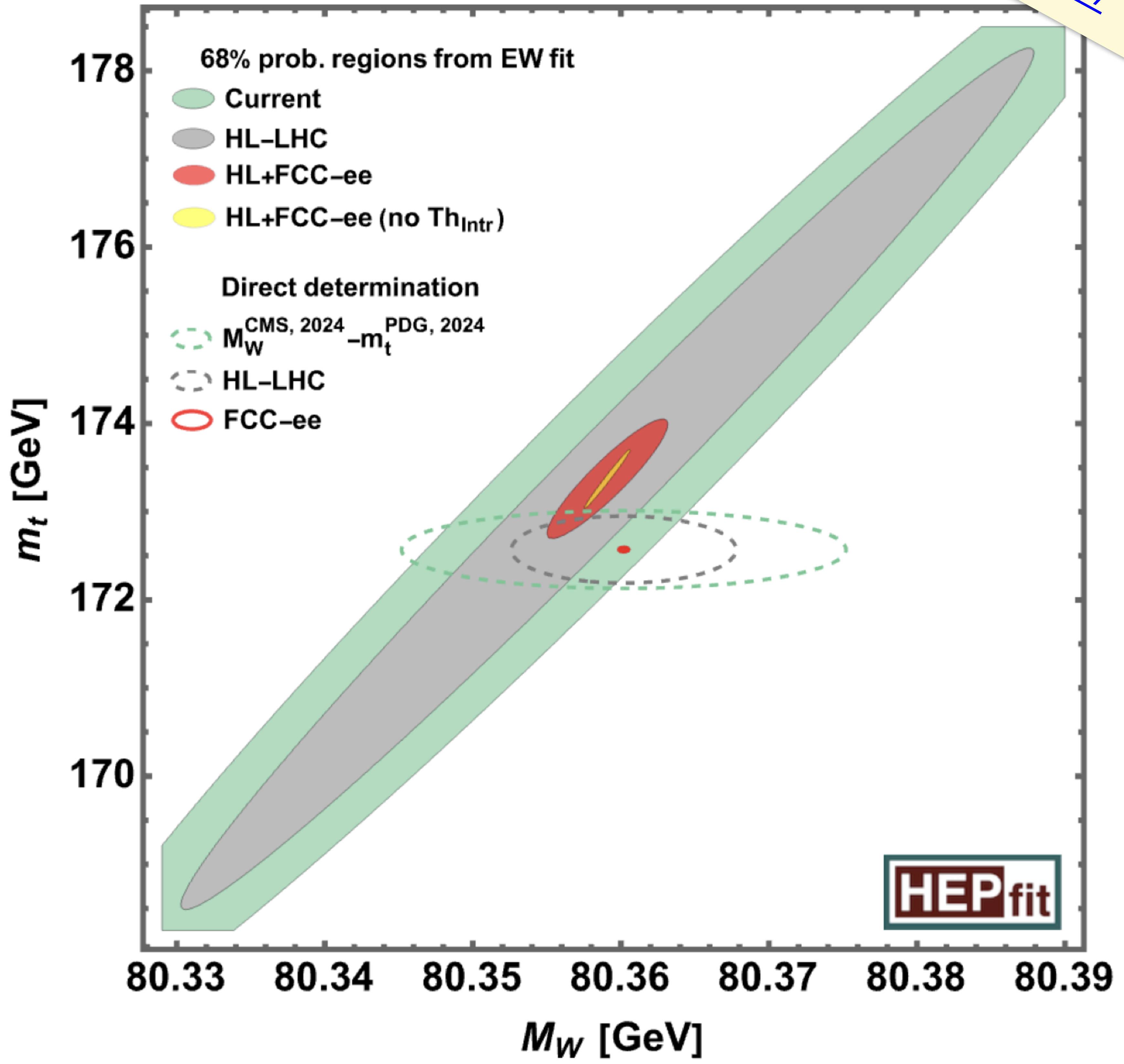
- W + Z + t
  - Precision

Higgs

- Various channels
  - But not all



Coupling	HL-LHC	FCC-ee
κ_Z (%)	1.3*	0.10
κ_W (%)	1.5*	0.29
κ_b (%)	2.5*	0.38 / 0.49
κ_g (%)	2*	0.49 / 0.54
κ_τ (%)	1.6*	0.46
κ_c (%)	–	0.70 / 0.87
κ_γ (%)	1.6*	1.1
$\kappa_{Z\gamma}$ (%)	10*	4.3
κ_t (%)	3.2*	3.1
κ_μ (%)	4.4*	3.3
$\lvert\kappa_s\rvert$ (%)	–	${}^{+29}_{-67}$
Γ_H (%)	–	0.78
$\mathcal{B}_{\text{inv}}$ (<, 95% CL)	$1.9 \times 10^{-}$	5×10^{-4}
$\mathcal{B}_{\text{unt}}$ (<, 95% CL)	4×10^{-2} *	6.8×10^{-3}



FCC-EE: PHYSICS

FCC-ee physics
https://indico.cern.ch/event/1439855/contributions/6461657/

EWK
- W + Z + t
  - Precision

Higgs
- Various channels
  - But not all

Limitations
- BSM & HH
  - LHC & FCC-hh

Coupling	HL-LHC	HL-LHC + FCC-ee
κ_Z (%)	1.3*	0.10
κ_W (%)	1.5*	0.29
κ_b (%)	2.5*	0.38 / 0.49
κ_g (%)	2*	0.49 / 0.54
κ_τ (%)	1.6*	0.46
κ_c (%)	–	0.70 / 0.87
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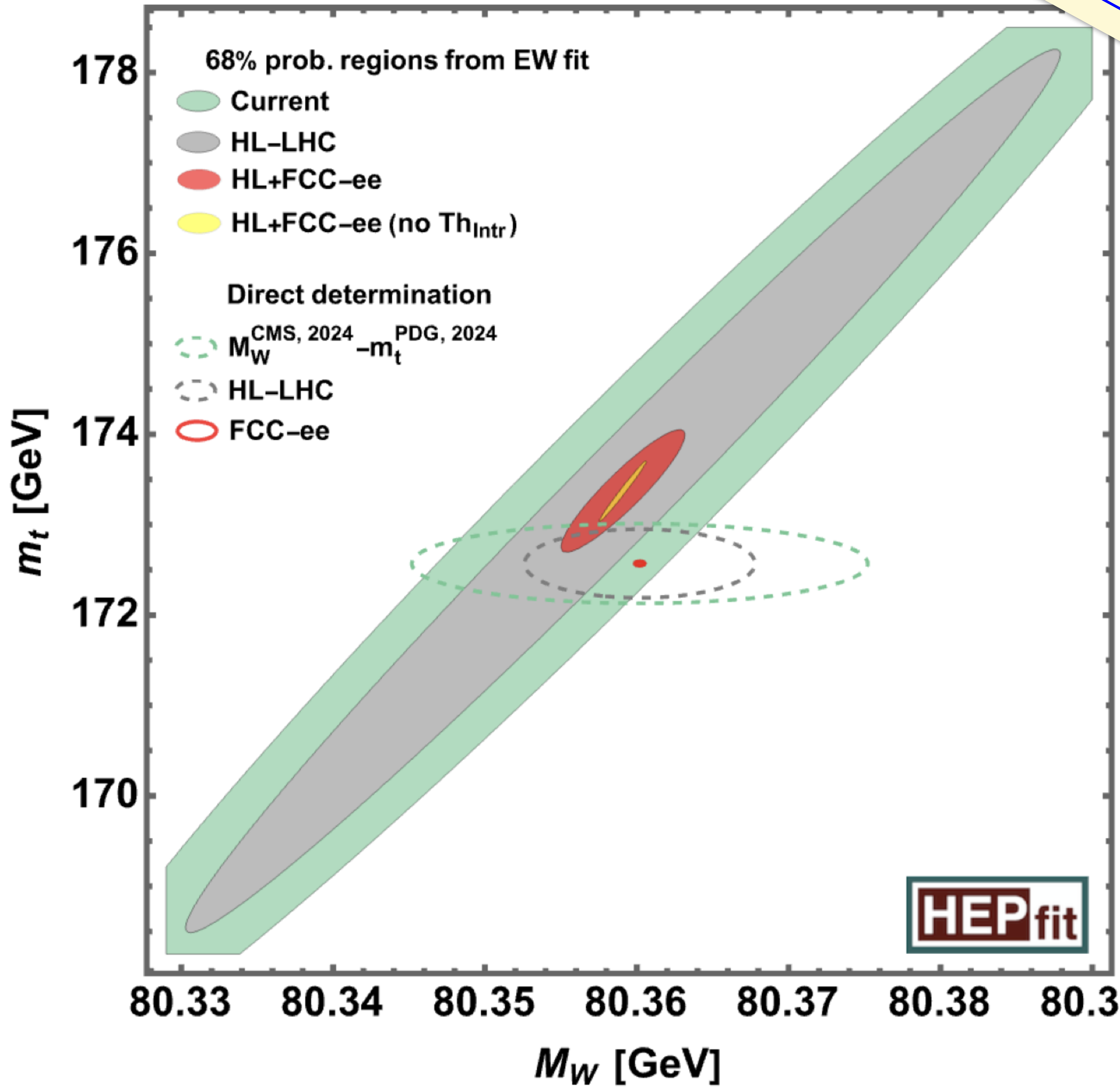


FCC-EE: COSTS

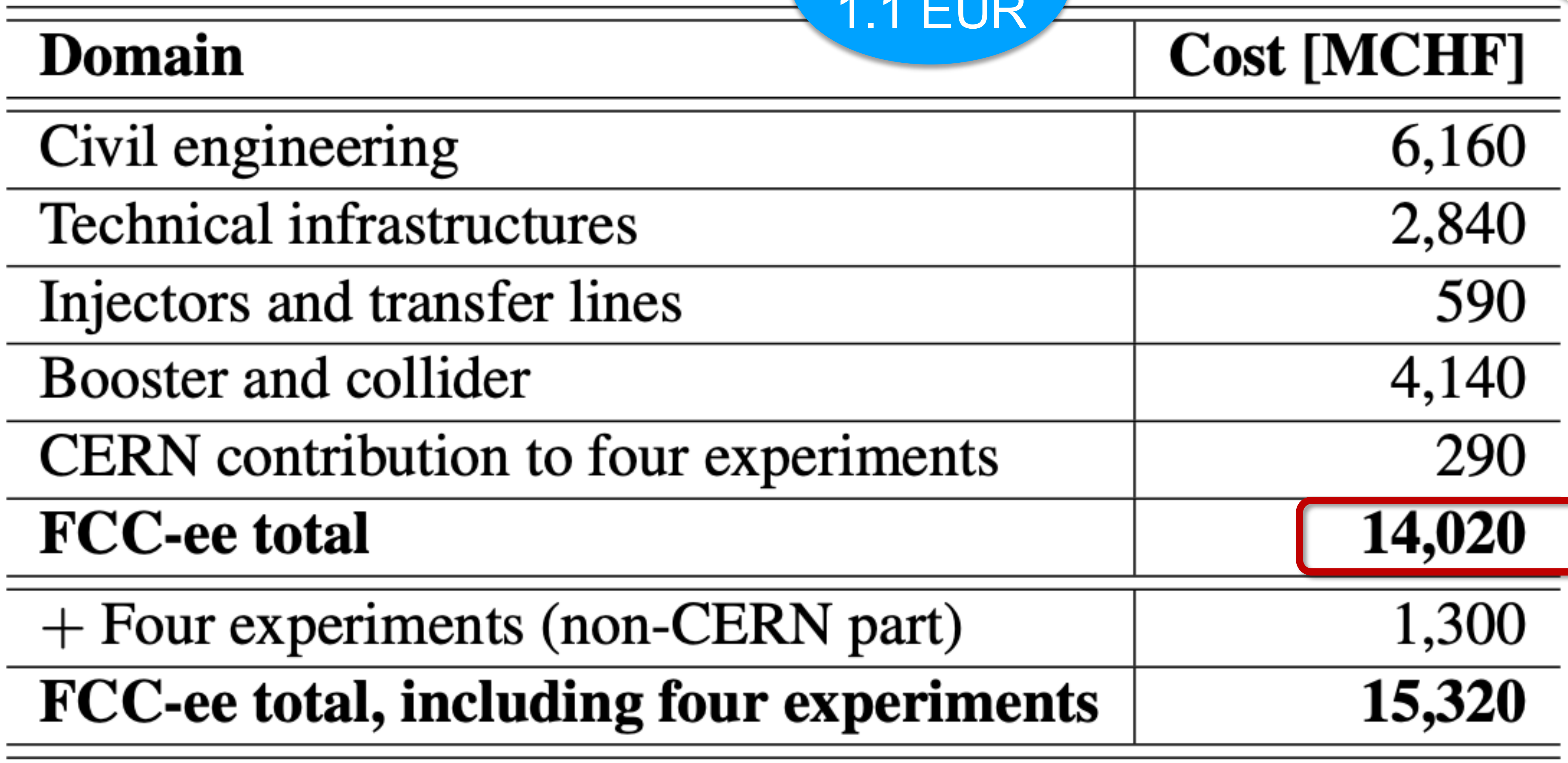
FCC-ee programme
https://indico.cern.ch/event/1439855/contributions/6461636/

Cost: 14 BCHF

- Incl. tunnel
  - 6 BCHF
- Extra: ttbar?
  - 1.3 BCHF

Advantage: up to 4 IPs

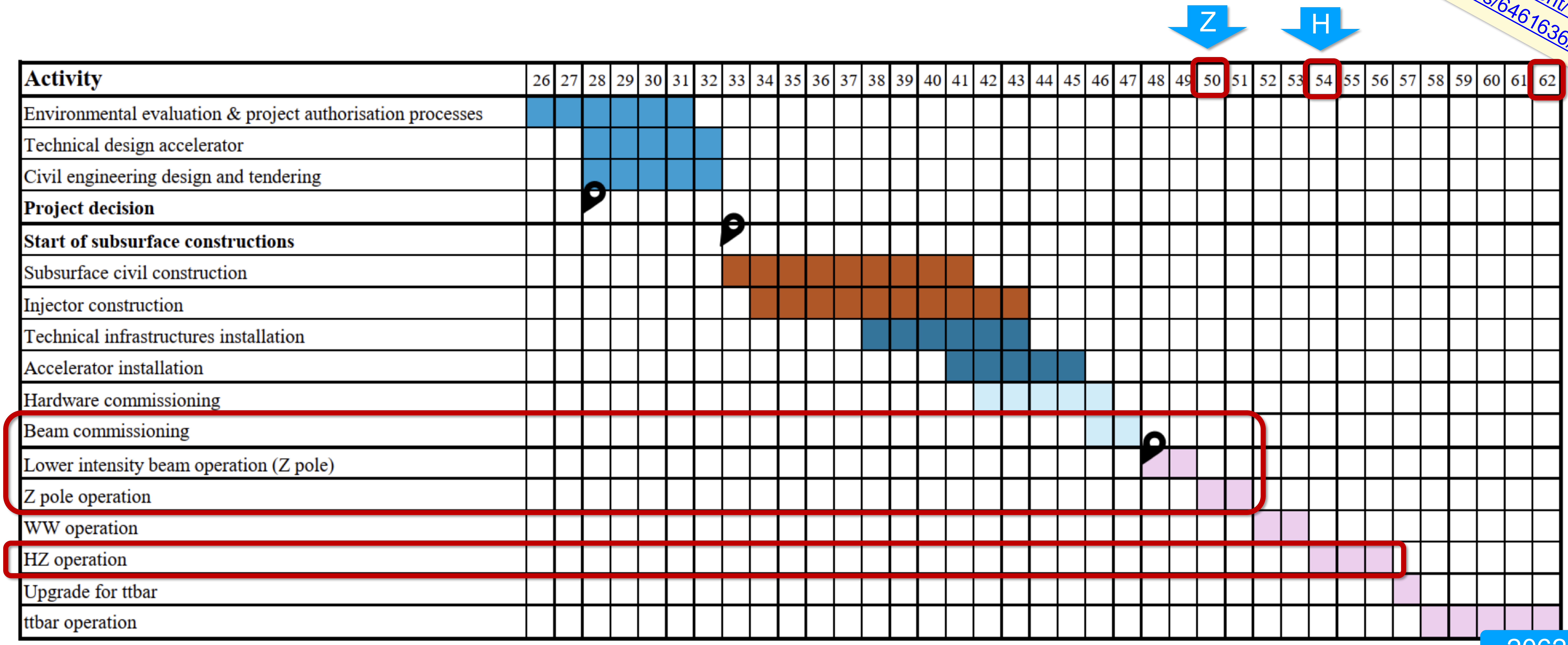
CHF ~ 1.1 EUR



Domain	**Cost [MCHF]**
Civil engineering	6,160
Technical infrastructures	2,840
Injectors and transfer lines	590
Booster and collider	4,140
CERN contribution to four experiments	290
FCC-ee total	**14,020**
+ Four experiments (non-CERN part)	1,300
FCC-ee total, including four experiments	**15,320**

FCC-EE: TIMELINE

FCC-ee programme
https://indico.cern.ch/event/1439855/contributions/6461636/



Activity	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62
Environmental evaluation & project authorisation processes	🟦	🟦	🟦	🟦	🟦	🟦																															
Technical design accelerator			🟦	🟦	🟦	🟦	🟦																														
Civil engineering design and tendering			🟦	🟦	🟦	🟦	🟦																														
Project decision			📍																																		
Start of subsurface constructions								📍																													
Subsurface civil construction								🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫																					
Injector construction									🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫																			
Technical infrastructures installation													🟦	🟦	🟦	🟦	🟦	🟦																			
Accelerator installation																🟦	🟦	🟦	🟦	🟦																	
Hardware commissioning																	▨	▨	▨	▨	▨																
Beam commissioning																					▨	▨															
Lower intensity beam operation (Z pole)																							📍🟪	🟪													
Z pole operation																									🟪	🟪											
WW operation																											🟪	🟪									
HZ operation																													🟪	🟪	🟪						
Upgrade for ttbar																																🟪					
ttbar operation																																	🟪	🟪	🟪	🟪	🟪

2062

	CHF	T_{fin}
FCC	14 B	2060
LCF		
CLIC		

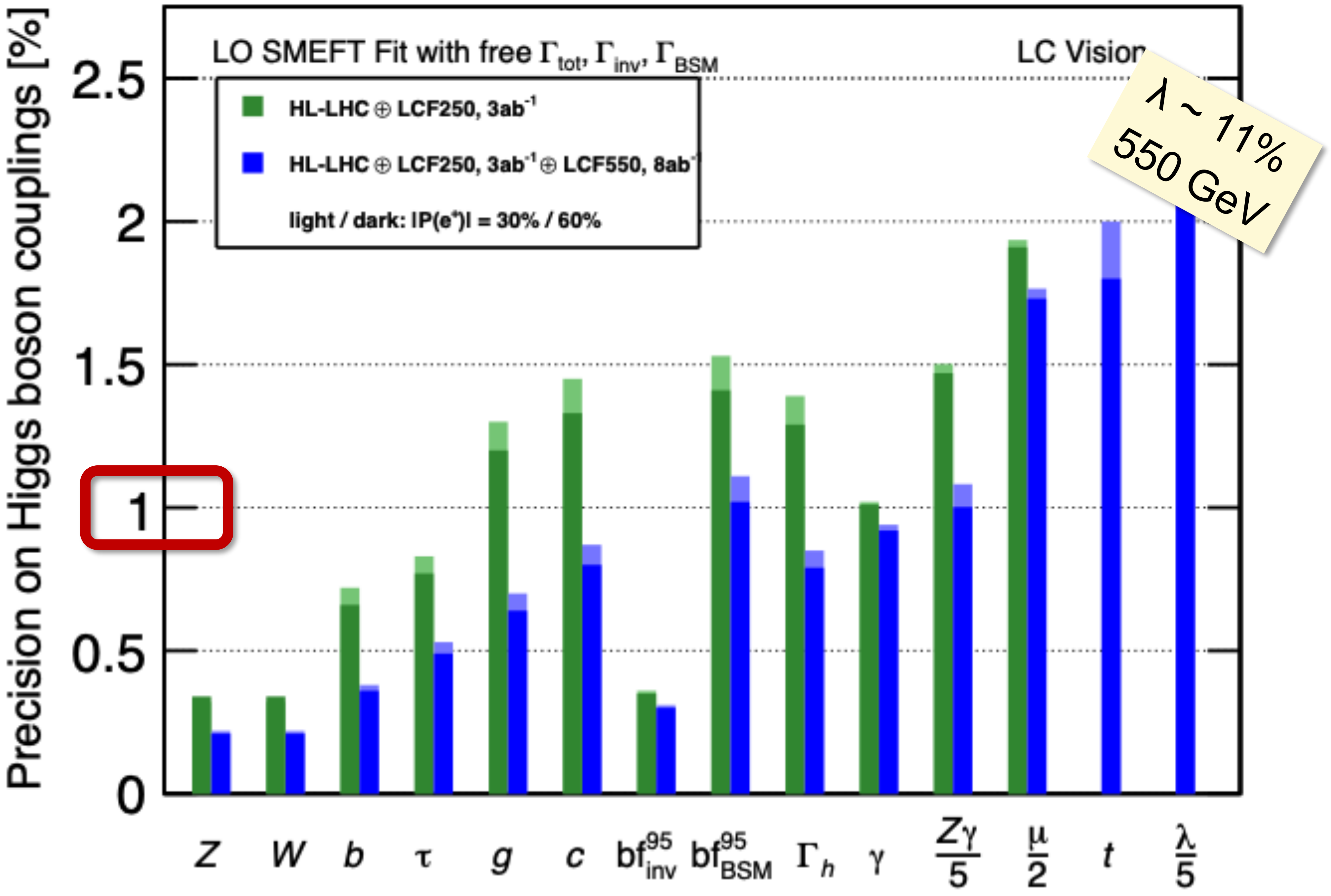
LINEAR COLLIDER AT CERN

LINEAR COLLIDER FACILITY AT CERN

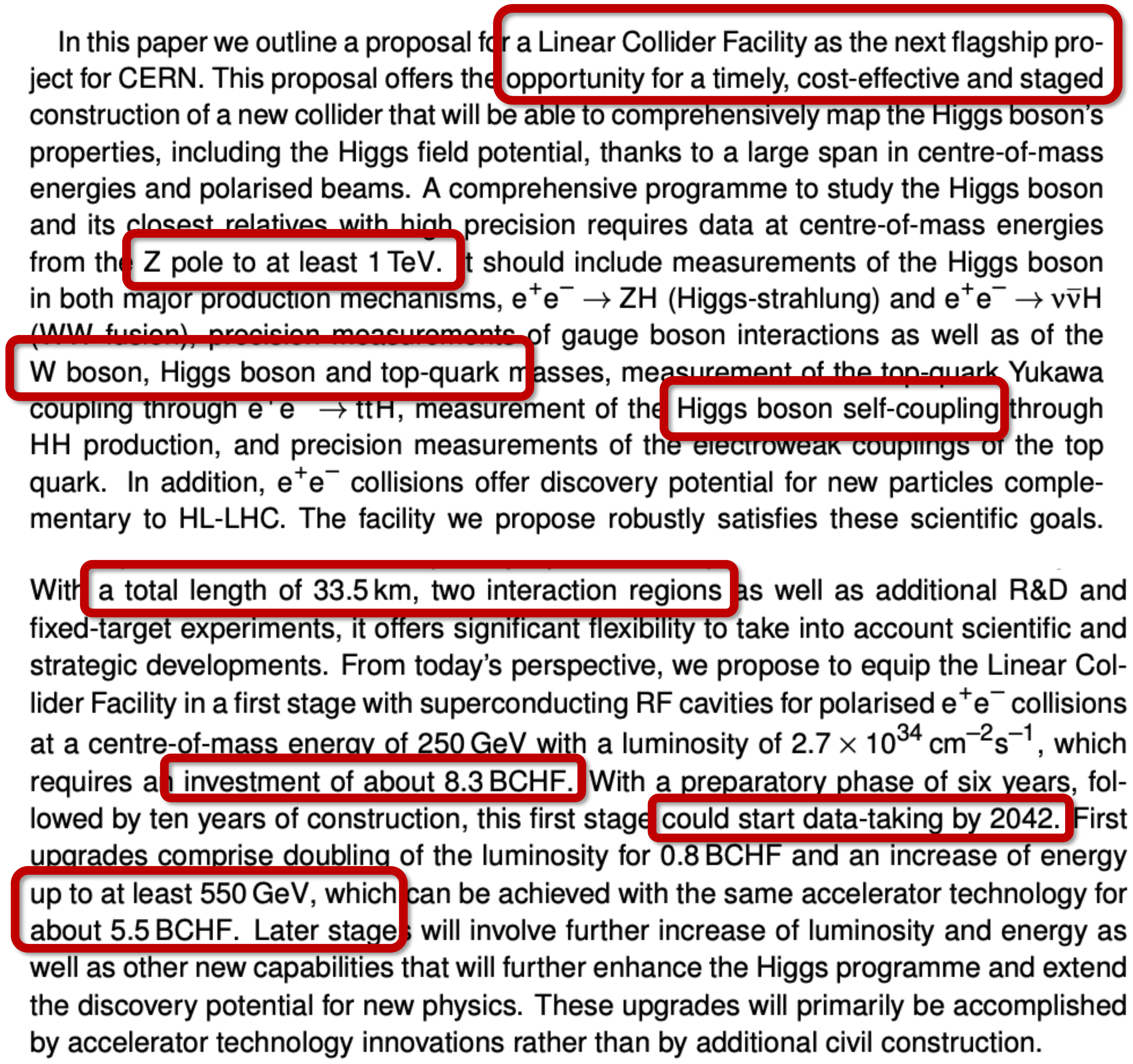
Linear Collider Facility
https://indico.cern.ch/event/1439855/contributions/6461433/

Physics case:

- SM & Higgs factory
  - K<1%, like FCC-ee



λ ~ 11%
550 GeV



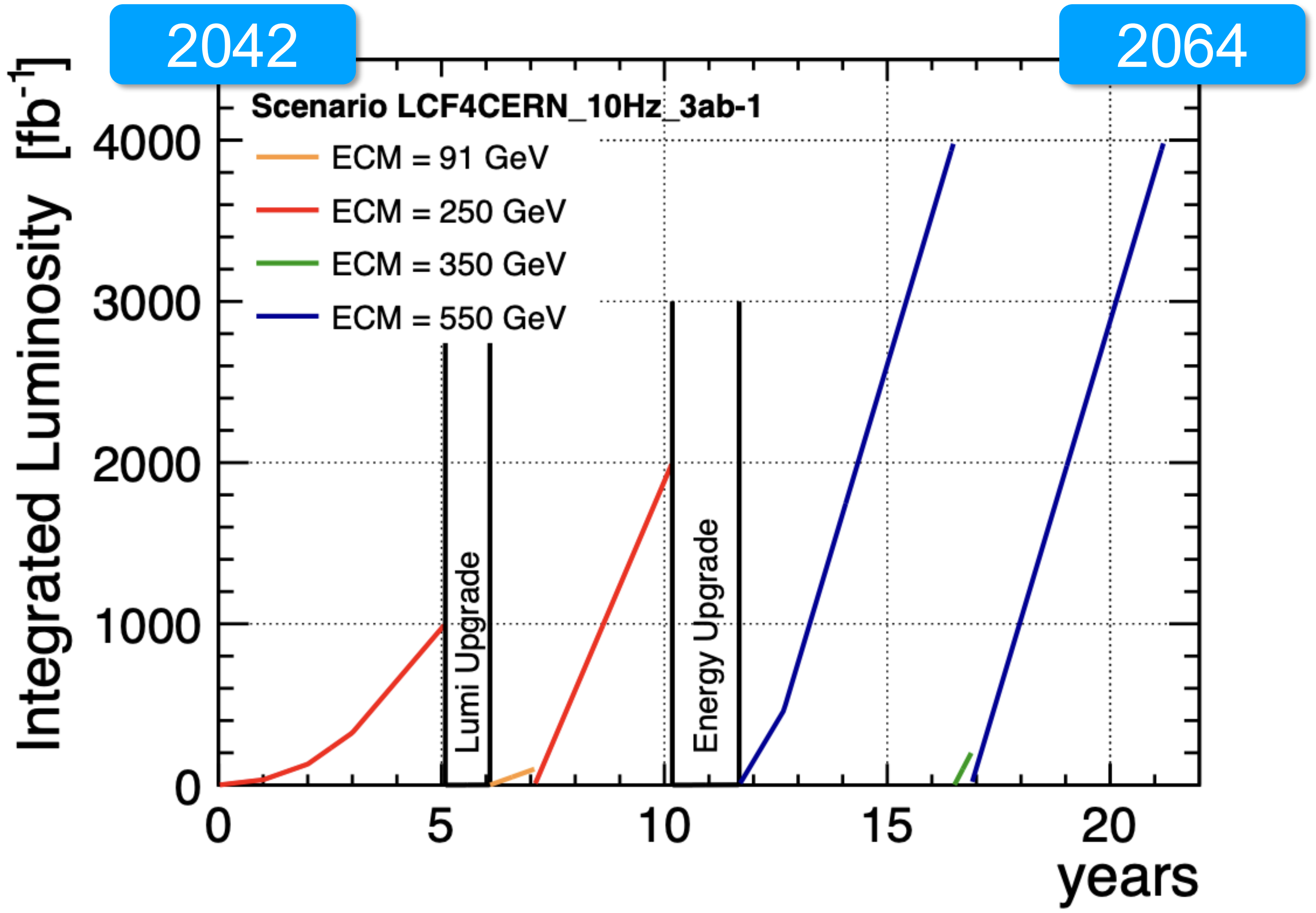
In this paper we outline a proposal for a Linear Collider Facility as the next flagship project for CERN. This proposal offers the opportunity for a timely, cost-effective and staged construction of a new collider that will be able to comprehensively map the Higgs boson's properties, including the Higgs field potential, thanks to a large span in centre-of-mass energies and polarised beams. A comprehensive programme to study the Higgs boson and its closest relatives with high precision requires data at centre-of-mass energies from the Z pole to at least 1 TeV. It should include measurements of the Higgs boson in both major production mechanisms, $e^+e^- \to ZH$ (Higgs-strahlung) and $e^+e^- \to \nu\bar{\nu}H$ (WW fusion), precision measurements of gauge boson interactions as well as of the W boson, Higgs boson and top-quark masses, measurement of the top-quark Yukawa coupling through $e^+e^- \to t\bar{t}H$, measurement of the Higgs boson self-coupling through HH production, and precision measurements of the electroweak couplings of the top quark. In addition, e^+e^- collisions offer discovery potential for new particles complementary to HL-LHC. The facility we propose robustly satisfies these scientific goals.

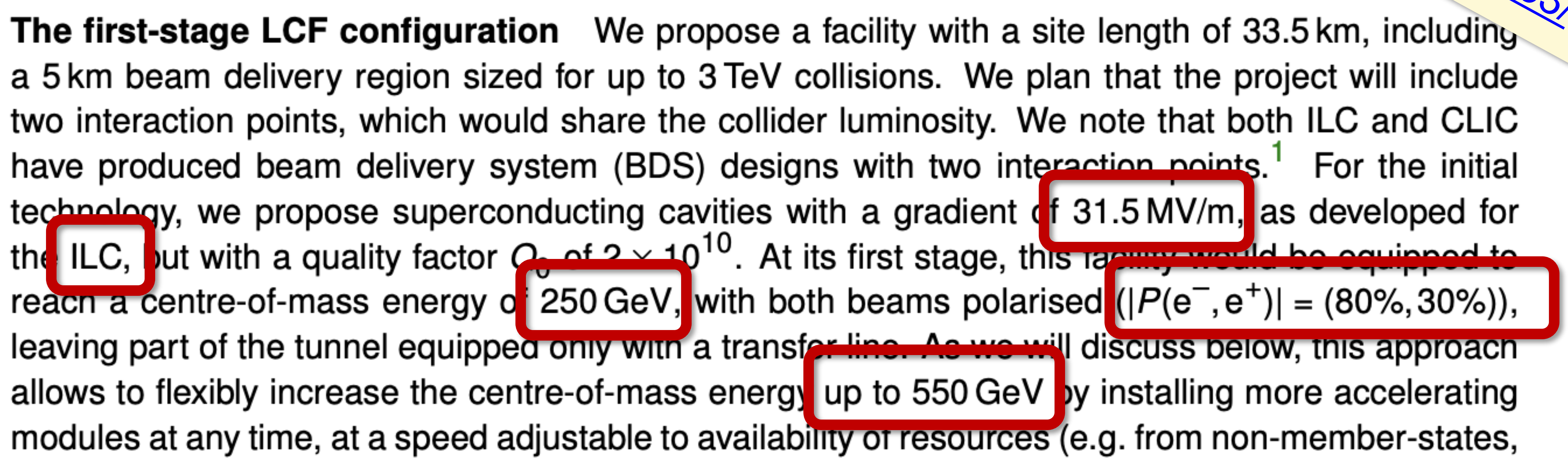
With a total length of 33.5 km, two interaction regions as well as additional R&D and fixed-target experiments, it offers significant flexibility to take into account scientific and strategic developments. From today's perspective, we propose to equip the Linear Collider Facility in a first stage with superconducting RF cavities for polarised e^+e^- collisions at a centre-of-mass energy of 250 GeV with a luminosity of 2.7×10^{34} cm^{-2}s^{-1}, which requires an investment of about 8.3 BCHF. With a preparatory phase of six years, followed by ten years of construction, this first stage could start data-taking by 2042. First upgrades comprise doubling of the luminosity for 0.8 BCHF and an increase of energy up to at least 550 GeV, which can be achieved with the same accelerator technology for about 5.5 BCHF. Later stages will involve further increase of luminosity and energy as well as other new capabilities that will further enhance the Higgs programme and extend the discovery potential for new physics. These upgrades will primarily be accomplished by accelerator technology innovations rather than by additional civil construction.

LCF: PLAN

Linear Collider Facility
https://indico.cern.ch/event/1439855/contributions/6461433/

Start earlier, run longer



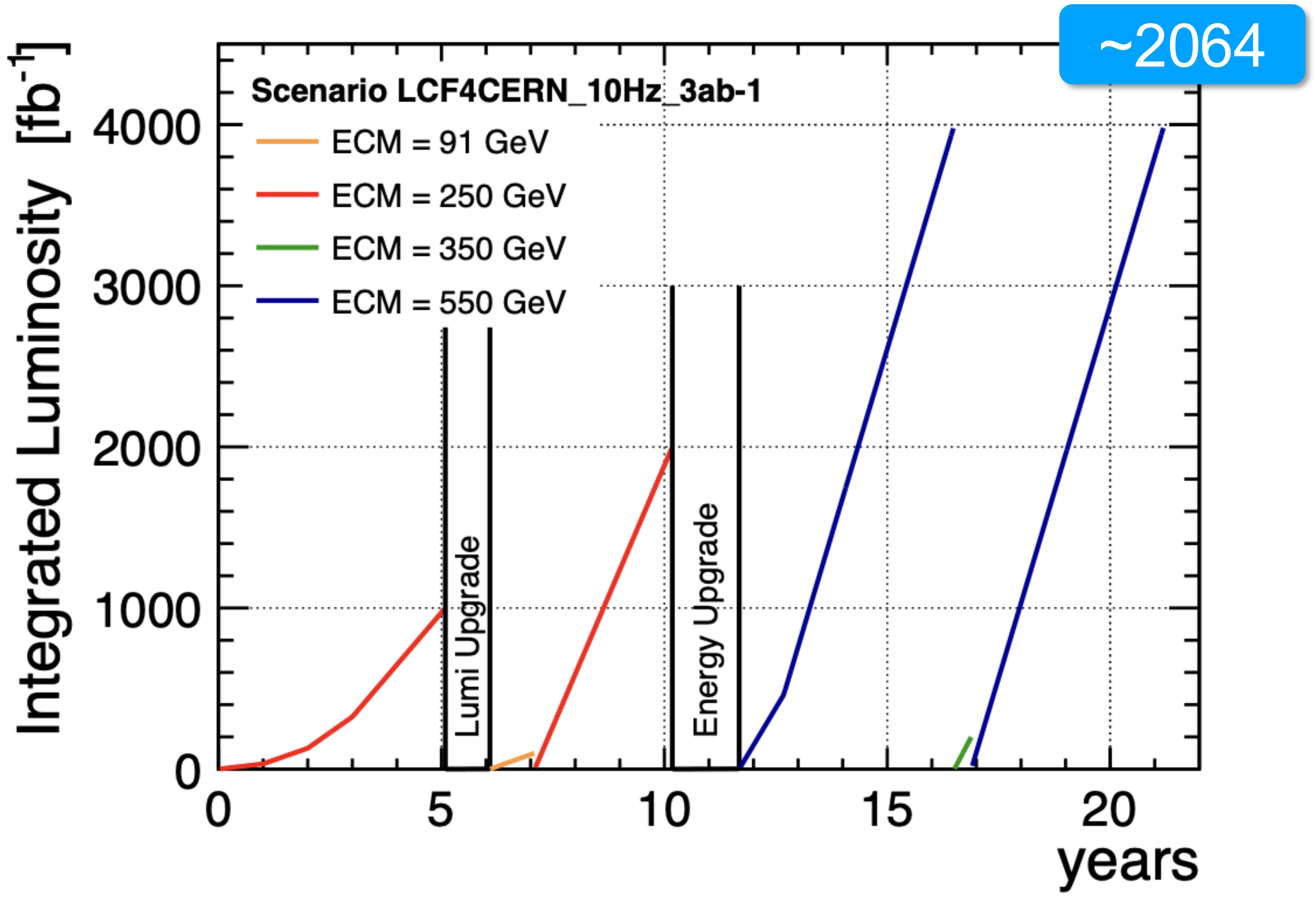


The first-stage LCF configuration We propose a facility with a site length of 33.5 km, including a 5 km beam delivery region sized for up to 3 TeV collisions. We plan that the project will include two interaction points, which would share the collider luminosity. We note that both ILC and CLIC have produced beam delivery system (BDS) designs with two interaction points.[1] For the initial technology, we propose superconducting cavities with a gradient of 31.5 MV/m, as developed for the ILC, but with a quality factor Q_0 of 2×10^{10}. At its first stage, this facility would be equipped to reach a centre-of-mass energy of 250 GeV, with both beams polarised ($|P(e^-, e^+)| = (80\%, 30\%)$), leaving part of the tunnel equipped only with a transfer line. As we will discuss below, this approach allows to flexibly increase the centre-of-mass energy up to 550 GeV by installing more accelerating modules at any time, at a speed adjustable to availability of resources (e.g. from non-member-states,

LCF: PLAN

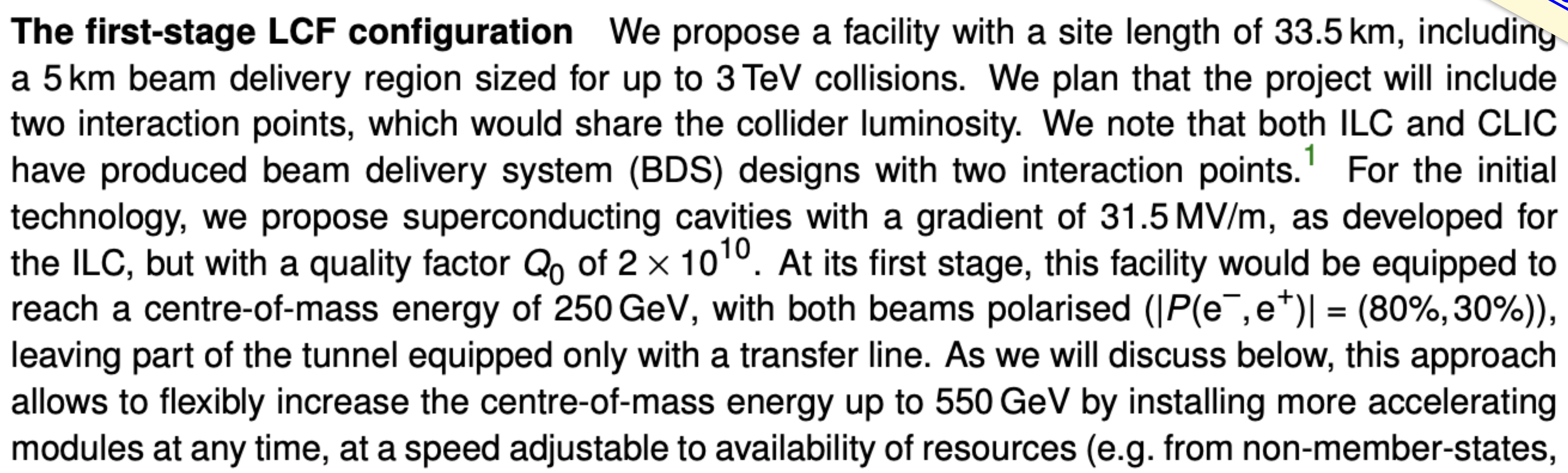
Linear Collider Facility
https://indico.cern.ch/event/14398
55/contributions/6461433/

Start earlier, run longer



Later upgrade to 1-3 TeV

- Same tunnel
  - Subject to available technology



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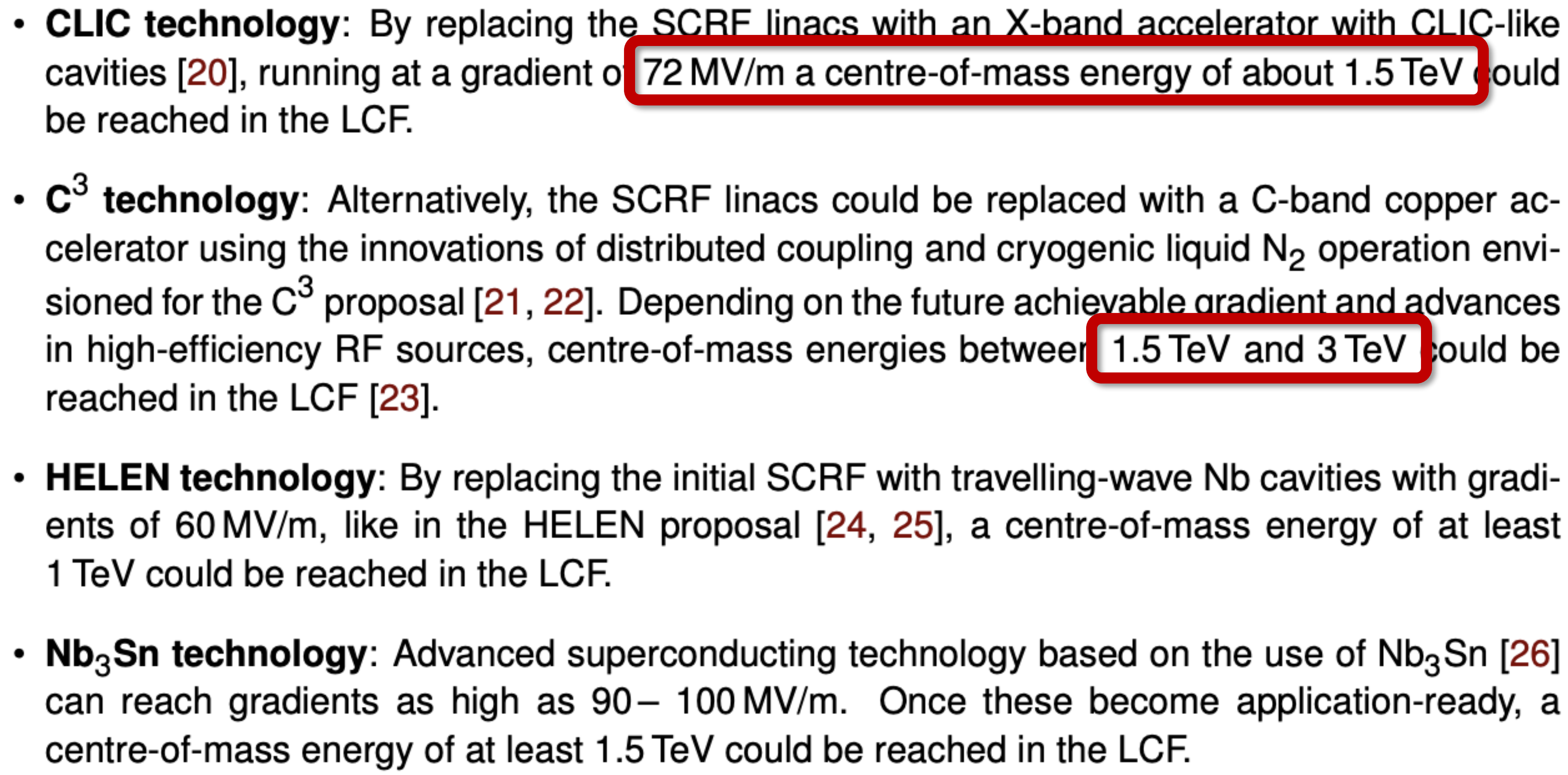


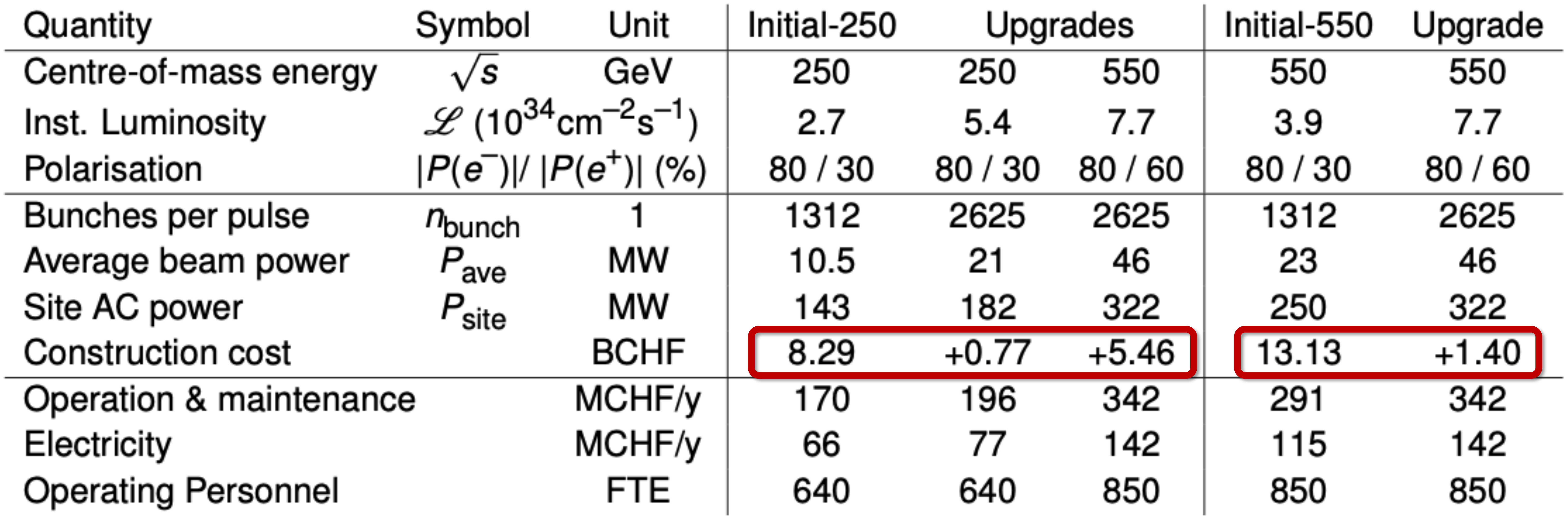
- **CLIC technology**: By replacing the SCRF linacs with an X-band accelerator with CLIC-like cavities [20], running at a gradient of 72 MV/m a centre-of-mass energy of about 1.5 TeV could be reached in the LCF.
- **C^3 technology**: Alternatively, the SCRF linacs could be replaced with a C-band copper accelerator using the innovations of distributed coupling and cryogenic liquid N$_2$ operation envisioned for the C^3 proposal [21, 22]. Depending on the future achievable gradient and advances in high-efficiency RF sources, centre-of-mass energies between 1.5 TeV and 3 TeV could be reached in the LCF [23].
- **HELEN technology**: By replacing the initial SCRF with travelling-wave Nb cavities with gradients of 60 MV/m, like in the HELEN proposal [24, 25], a centre-of-mass energy of at least 1 TeV could be reached in the LCF.
- **Nb$_3$Sn technology**: Advanced superconducting technology based on the use of Nb$_3$Sn [26] can reach gradients as high as 90– 100 MV/m. Once these become application-ready, a centre-of-mass energy of at least 1.5 TeV could be reached in the LCF.

LINEAR COLLIDER FACILITY AT CERN

Linear Collider Facility
https://indico.cern.ch/event/1439855/contributions/6461433/

Costs: initial + upgrade

- 250 – 550 GeV
  - Total ~ 14 BCHF



Quantity	Symbol	Unit	Initial-250	Upgrades		Initial-550	Upgrade
Centre-of-mass energy	$\sqrt{s}$	GeV	250	250	550	550	550
Inst. Luminosity	$\mathscr{L}$ ($10^{34}\text{cm}^{-2}\text{s}^{-1}$)		2.7	5.4	7.7	3.9	7.7
Polarisation	$\lvert P(e^-)\rvert / \lvert P(e^+)\rvert$ (%)		80 / 30	80 / 30	80 / 60	80 / 30	80 / 60
Bunches per pulse	n_{bunch}	1	1312	2625	2625	1312	2625
Average beam power	P_{ave}	MW	10.5	21	46	23	46
Site AC power	P_{site}	MW	143	182	322	250	322
Construction cost		BCHF	8.29	+0.77	+5.46	13.13	+1.40
Operation & maintenance		MCHF/y	170	196	342	291	342
Electricity		MCHF/y	66	77	142	115	142
Operating Personnel		FTE	640	640	850	850	850

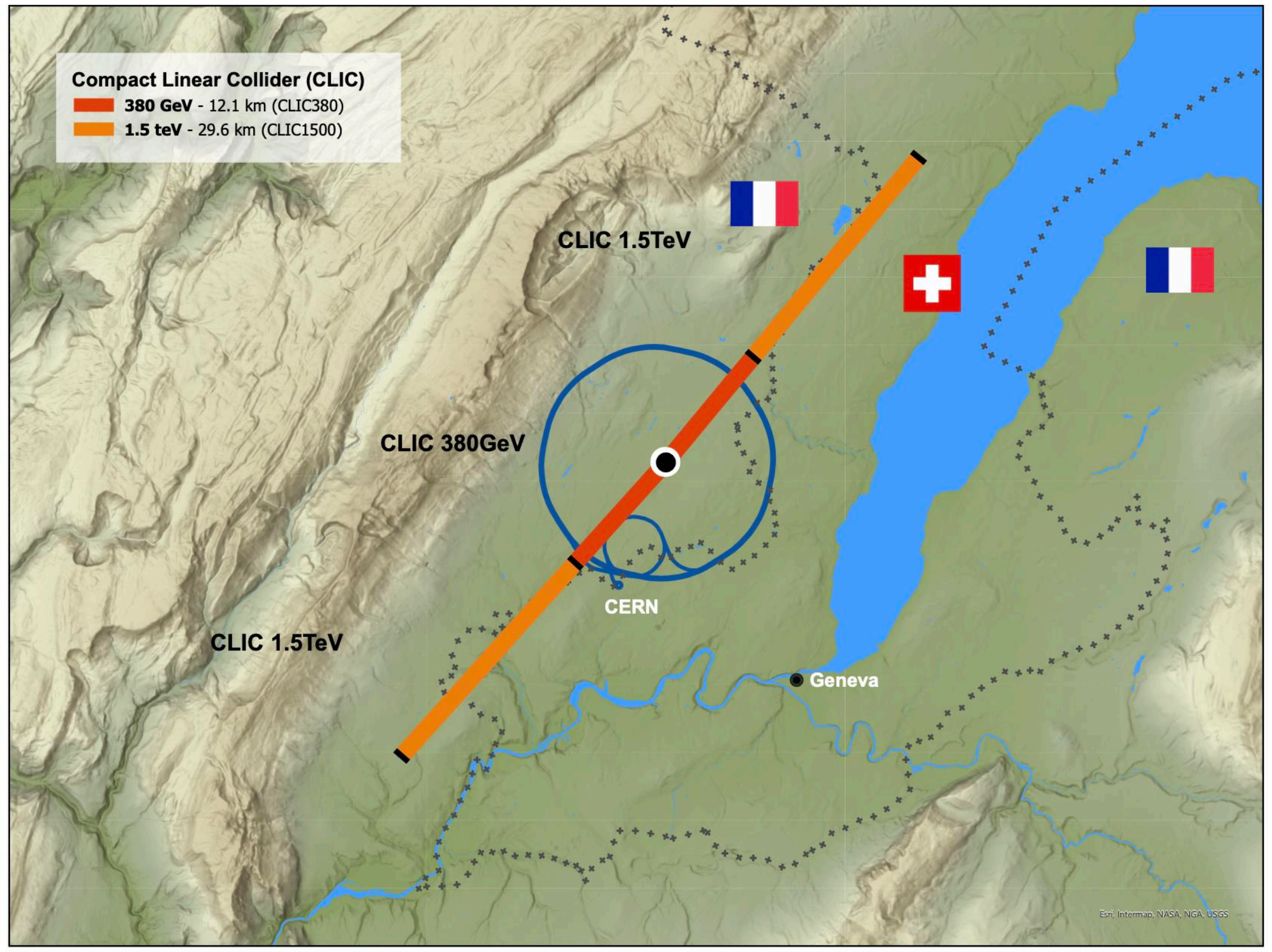
	CHF	T_{fin}
FCC	14 B	2060
LCF	14 B	2060
CLIC		

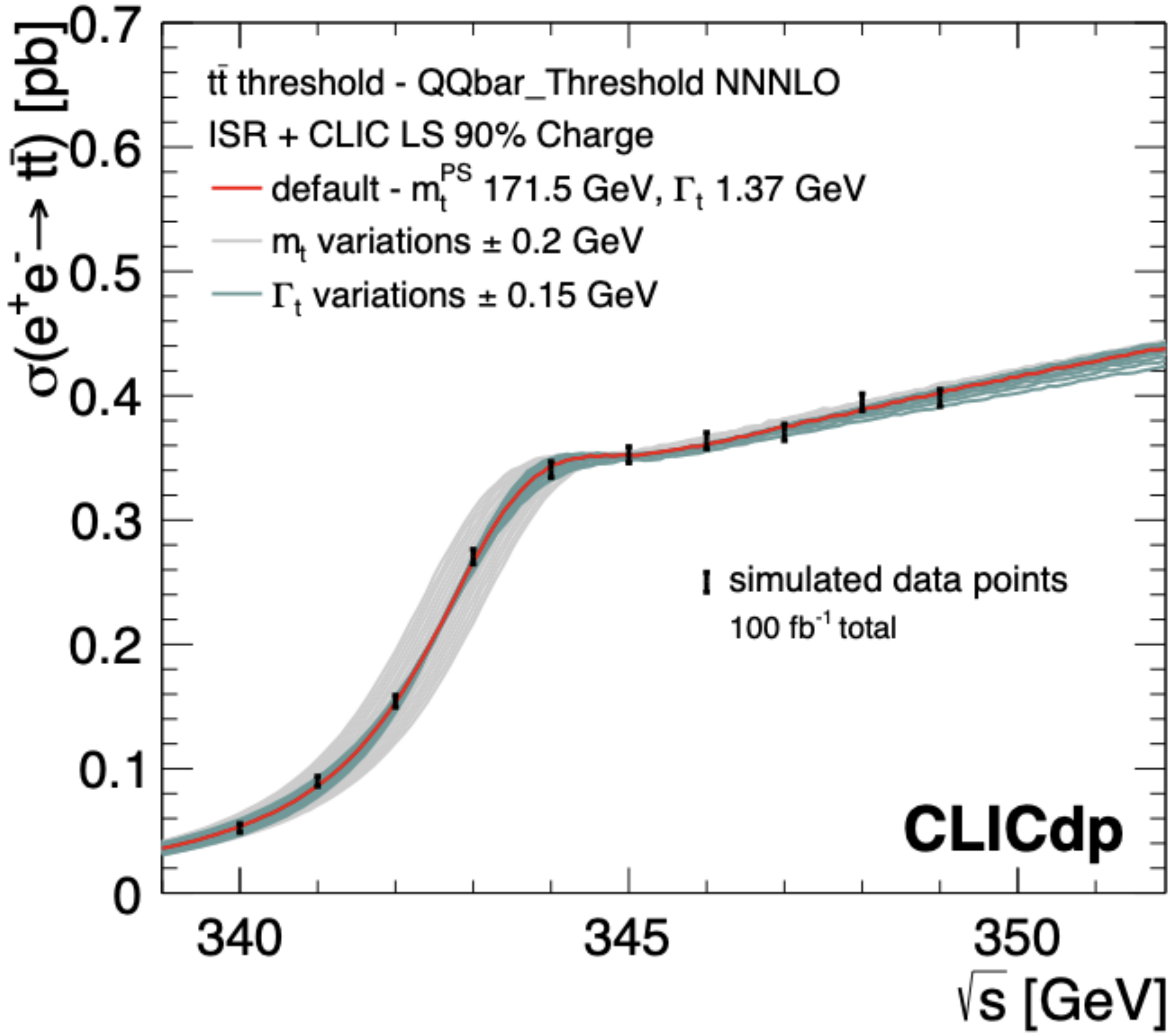
CLIC: PROJECT

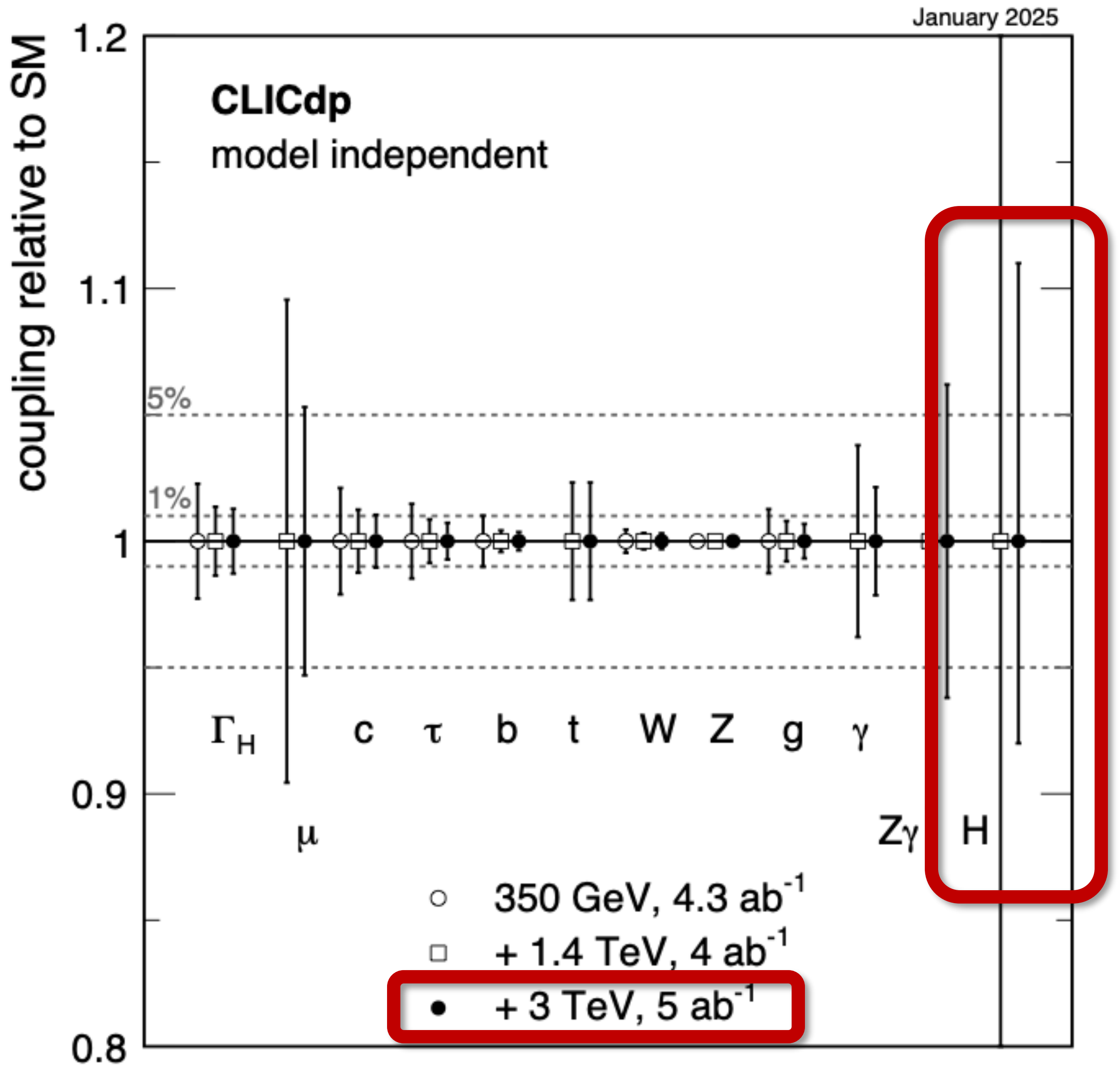
CLIC
https://indico.cern.ch/event/1439855/contributions/6461475/

ESPP input for 380 GeV - 1.5 TeV

- 12 - 30 km
  - Higgs + top + λ~10%





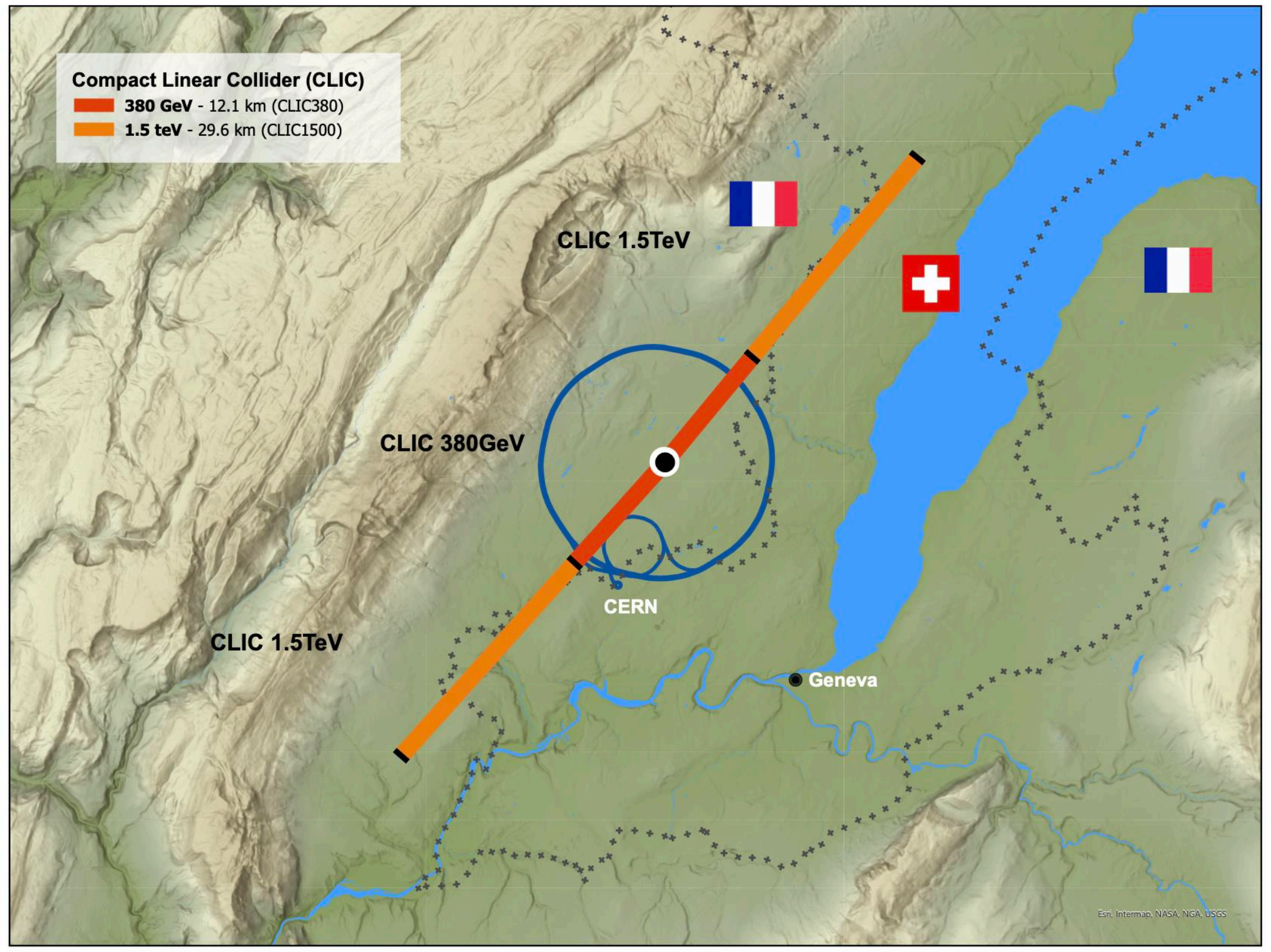


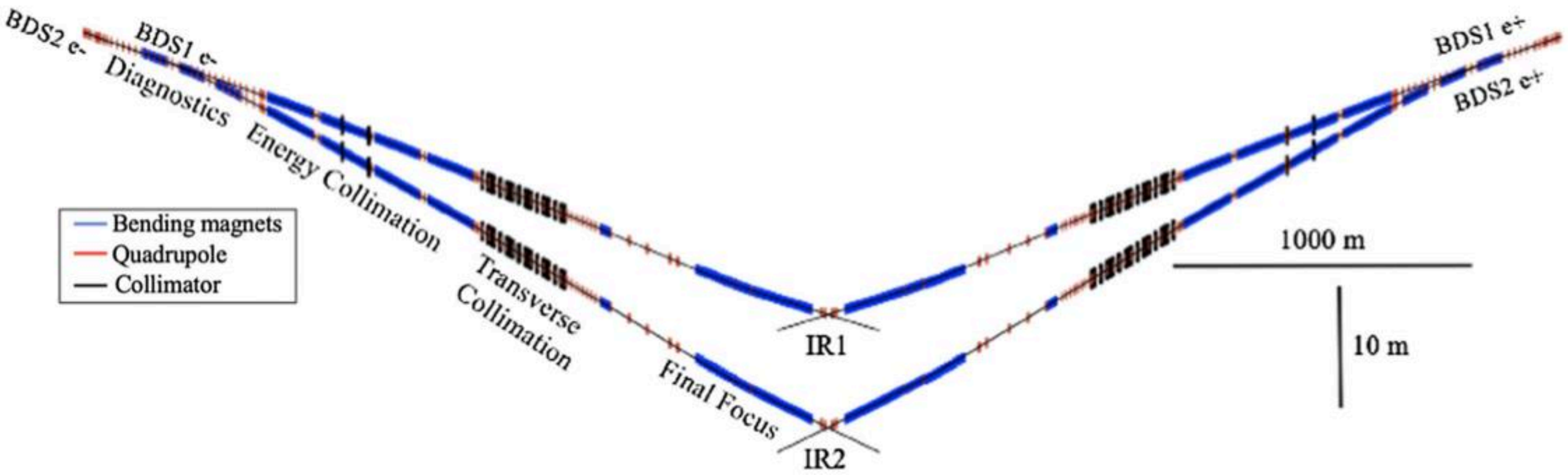
CLIC: DUAL BEAM

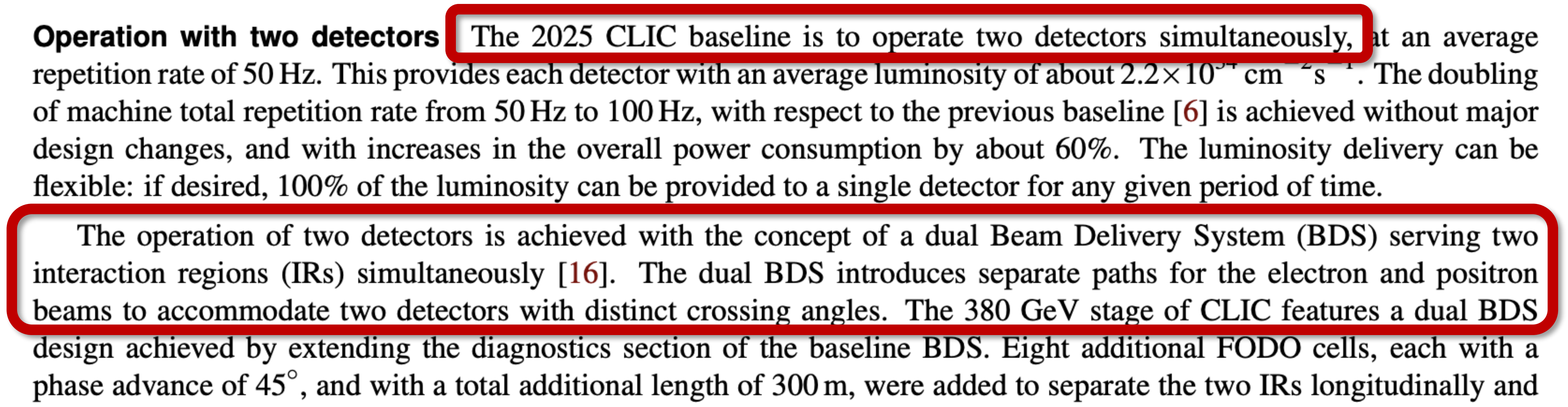
CLIC
https://indico.cern.ch/event/1439855/contributions/6461475/

Two detectors simultaneously

- Dual Beam Delivery







Operation with two detectors The 2025 CLIC baseline is to operate two detectors simultaneously, at an average repetition rate of 50 Hz. This provides each detector with an average luminosity of about $2.2\times10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$. The doubling of machine total repetition rate from 50 Hz to 100 Hz, with respect to the previous baseline [6] is achieved without major design changes, and with increases in the overall power consumption by about 60%. The luminosity delivery can be flexible: if desired, 100% of the luminosity can be provided to a single detector for any given period of time.

The operation of two detectors is achieved with the concept of a dual Beam Delivery System (BDS) serving two interaction regions (IRs) simultaneously [16]. The dual BDS introduces separate paths for the electron and positron beams to accommodate two detectors with distinct crossing angles. The 380 GeV stage of CLIC features a dual BDS design achieved by extending the diagnostics section of the baseline BDS. Eight additional FODO cells, each with a phase advance of 45°, and with a total additional length of 300 m, were added to separate the two IRs longitudinally and

CLIC: COST & TIME

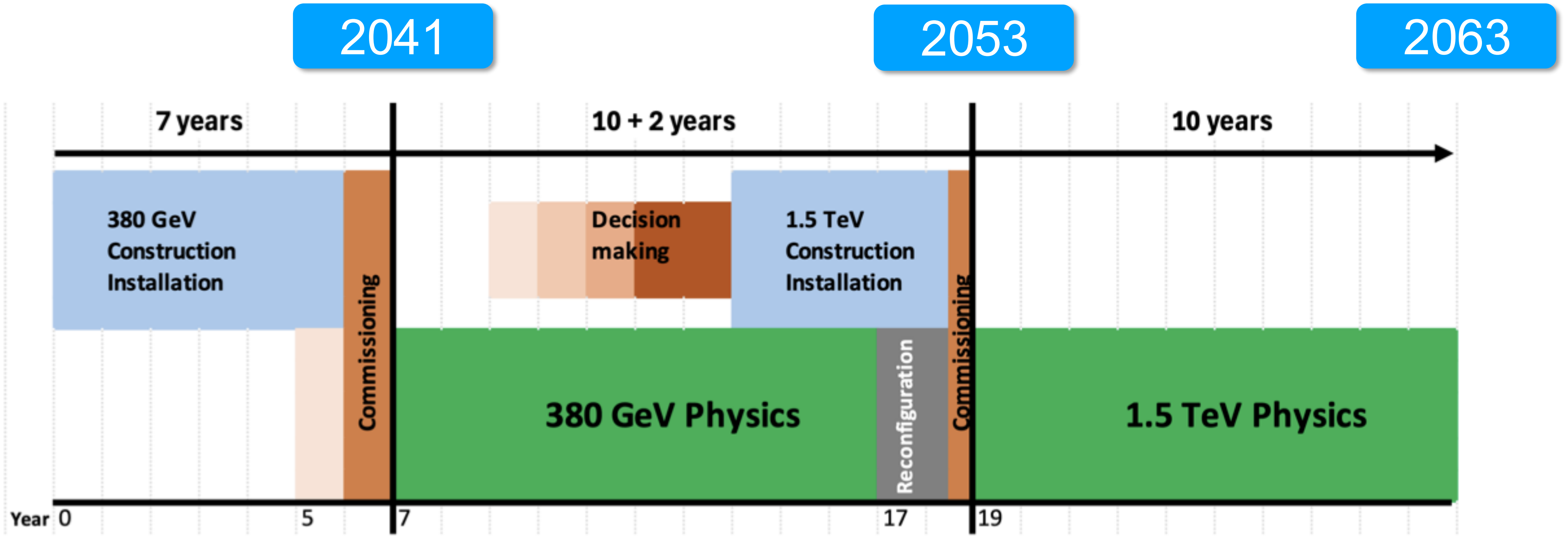
CLIC
https://indico.cern.ch/event/14398
55/contributions/6461475/

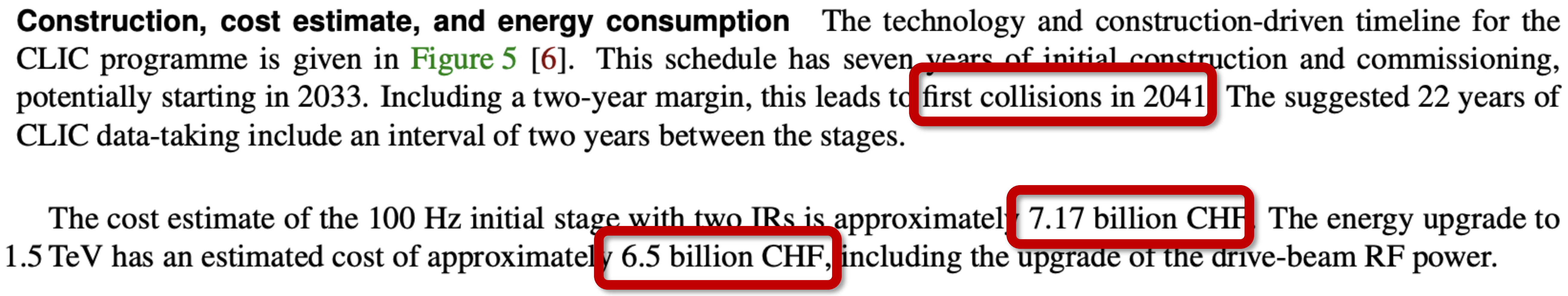
380 GeV
- 7.2 BCHF

1.5 TeV
- 6.5 BCHF

Run 2041 – 2063

➔ Total ~ 14 BCHF (!)





Construction, cost estimate, and energy consumption The technology and construction-driven timeline for the CLIC programme is given in Figure 5 [6]. This schedule has seven years of initial construction and commissioning, potentially starting in 2033. Including a two-year margin, this leads to first collisions in 2041. The suggested 22 years of CLIC data-taking include an interval of two years between the stages.

The cost estimate of the 100 Hz initial stage with two IRs is approximately 7.17 billion CHF. The energy upgrade to 1.5 TeV has an estimated cost of approximately 6.5 billion CHF, including the upgrade of the drive-beam RF power.

	CHF	T_{fin}
FCC	14 B	2060
LCF	14 B	2060
CLIC	14 B	2060

FCC VS LCF

➔ The FCC-ee and LCF proposals have converged 🡐

FCC-ee: W/Z/B	Physics: SM & Higgs	LCF: t & HH
FCC-ee: Faster	End date: ~2060	LCF: Earlier
FCC-ee: Z/W/H program	Cost: 14 BCHF	LCF: ZH + upgrade
FCC-ee: 91 km	Size: > LHC	LCF: 33 km
FCC-ee: 2-4	IPs: 2	LCF: 1-2

The FC erged

FCC-ee:
W/Z/B

LC:
t & HH

FCC-ee:
Faster

LC:
Earlier

FCC-ee:
91 km

FCC-ee:
33 km

FCC-ee:
2-4

LC:
1-2

C3: PARAMETERS

C3 = Cool Copper Collider

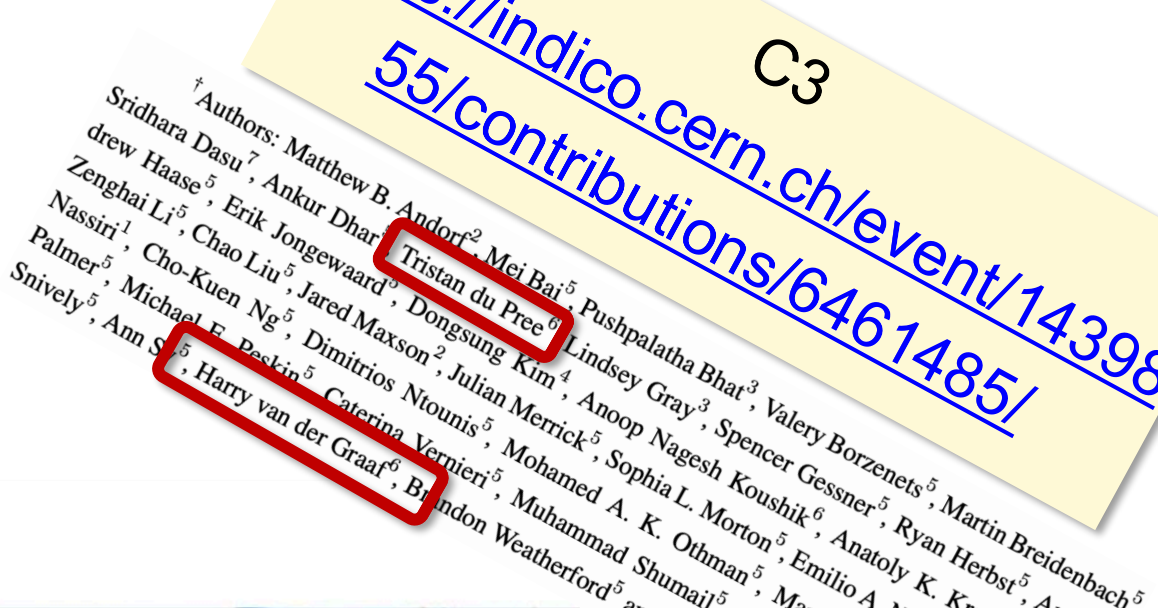
- Upgrade option for LC

Gradient ~100 MV/m

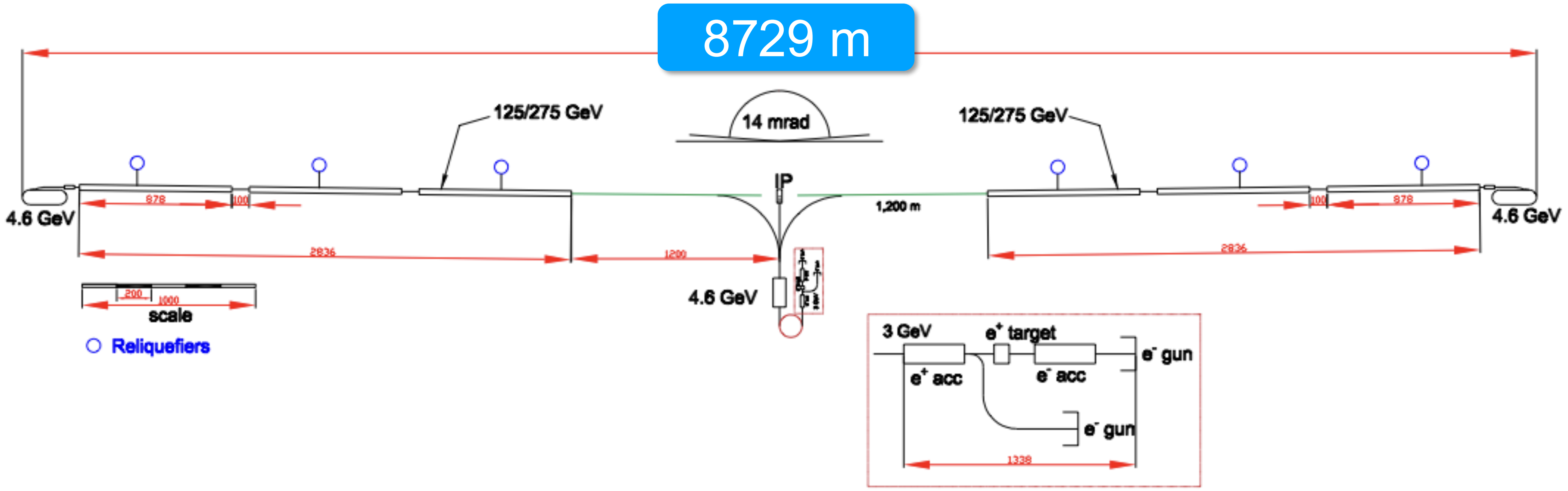
- Compact accelerator
  - 8.7 km: ZH Higgs factory
  - 33 km: 3 TeV (LCVision)

C3

https://indico.cern.ch/event/14398
55/contributions/6461485/



[†]Authors: Matthew B. Andorf[2], Mei Bai[5], Pushpalatha Bhat[3], Valery Borzenets[5], Martin Breidenbach[5], Sridhara Dasu[7], Ankur Dhar, Tristan du Pree[6], Lindsey Gray[3], Spencer Gessner[5], Ryan Herbst[5], Andrew Haase[5], Erik Jongewaard[5], Dongsung Kim[4], Anoop Nagesh Koushik[6], Anatoly K. Krasnykh[5], Zenghai Li[5], Chao Liu[5], Jared Maxson[2], Julian Merrick[5], Sophia L. Morton[5], Emilio A. Nanni[5], Alireza Nassiri[1], Cho-Kuen Ng[5], Dimitrios Ntounis[5], Mohamed A. K. Othman[5], Marco Oriunno[5], Dennis Palmer[5], Michael E. Peskin[5], Caterina Vernieri[5], Muhammad Shumail[5], Evgenya Simakov[4], Emma Snively[5], Ann S[5], Harry van der Graaf[6], Brandon Weatherford[5] and Haoran Xu[4]



C3: TIMELINE

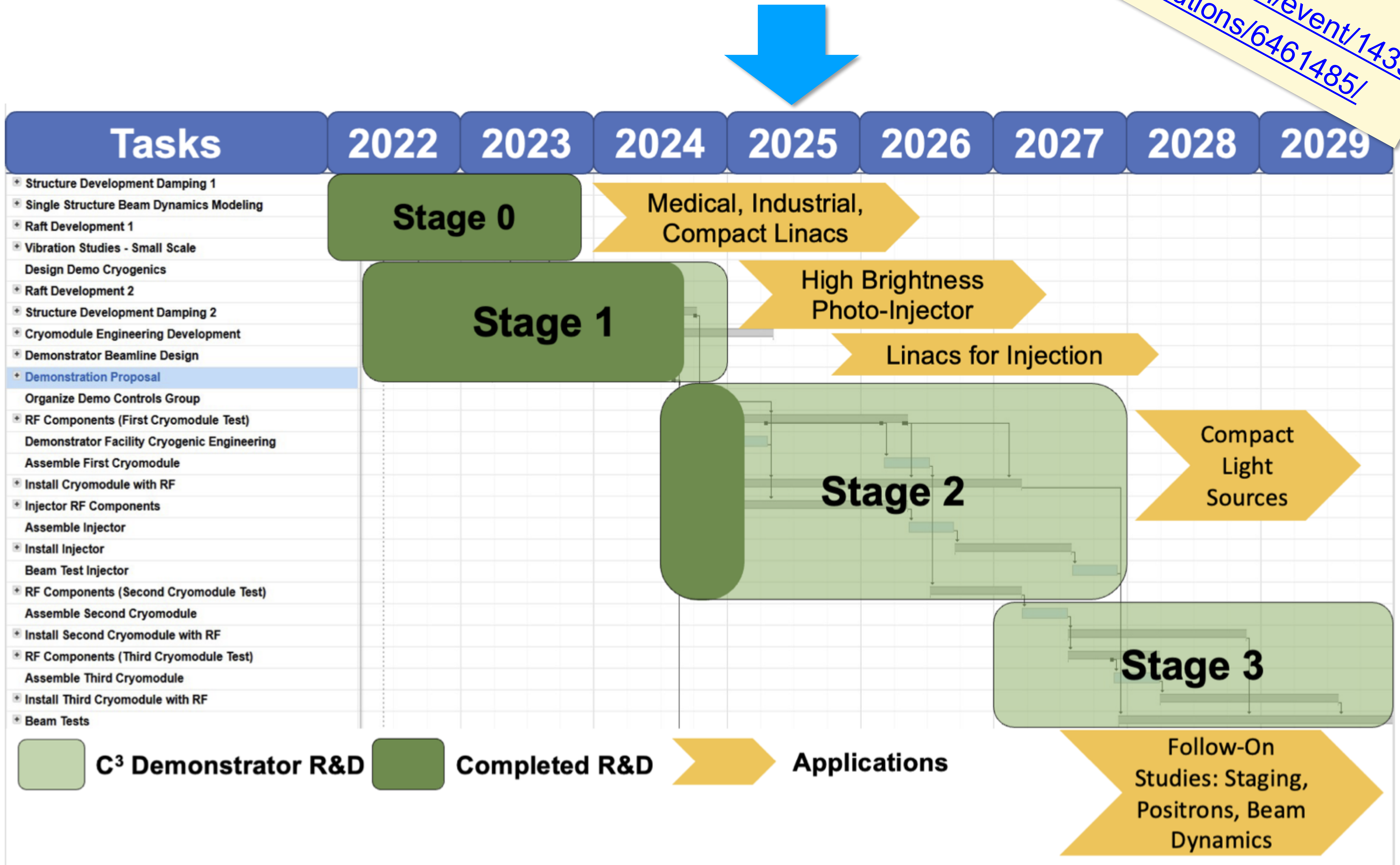
C3
https://indico.cern.ch/event/1439
55/contributions/6461485/

Timeline: R&D

- Development needed
  - Various applications

Nikhef involvement

- RasNik alignment
  - Demonstrator 2025



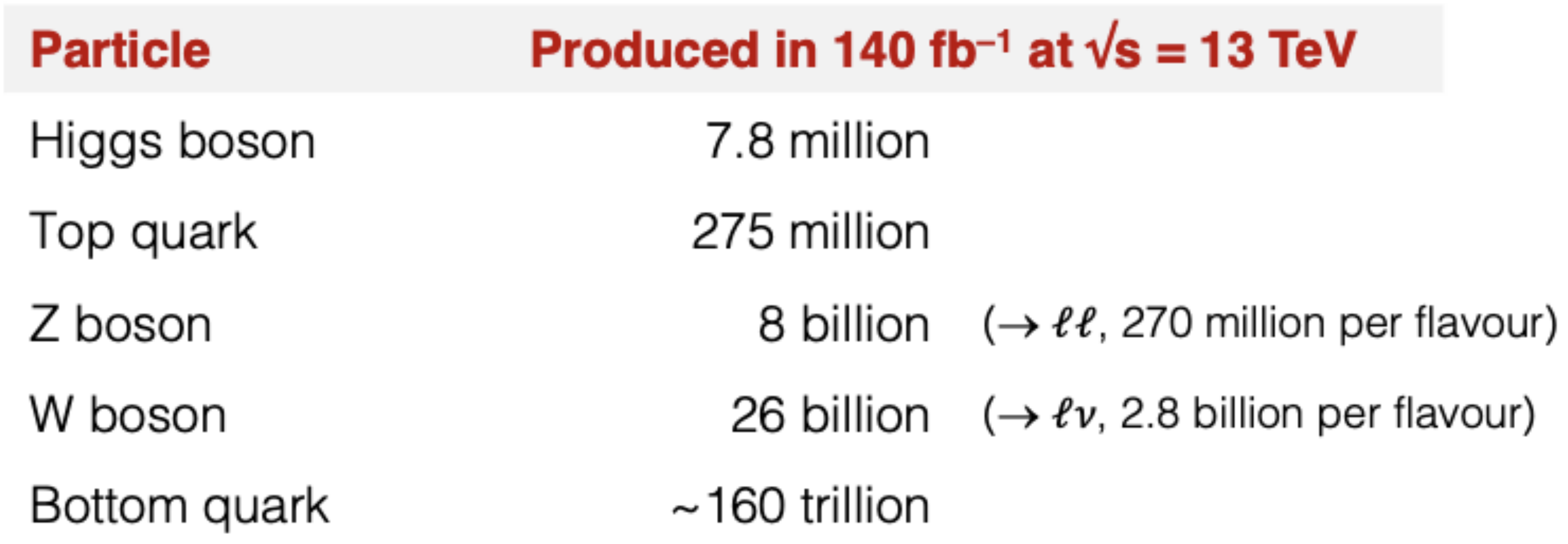
Anyway valuable technology

- Option for smaller Higgs factory

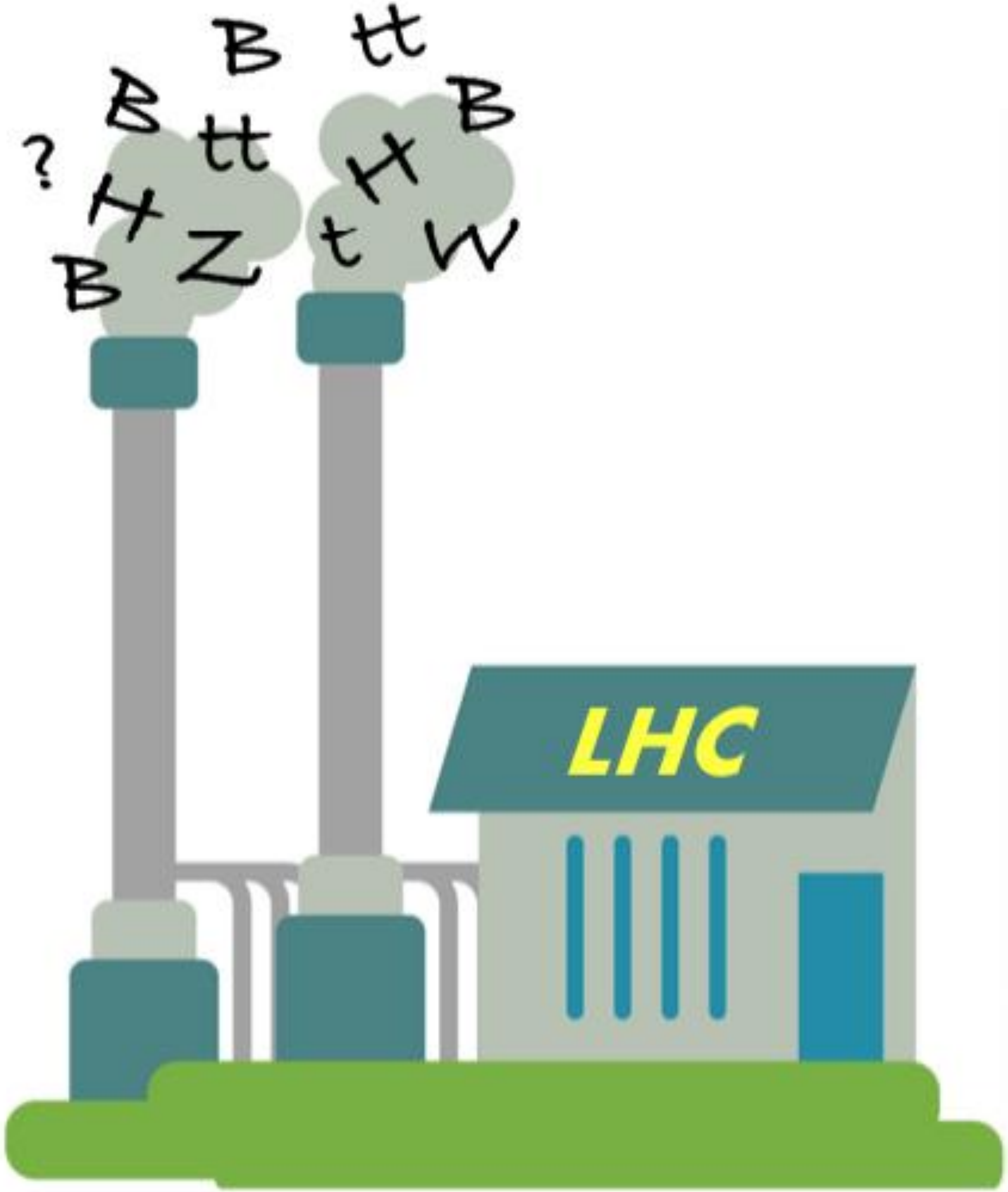
BACK TO THE LHC

“The LHC is an everything factory”

- A.Hoecker – EPS HEP 2019
  - Still true after all those years



Particle	Produced in 140 fb^{-1} at $\sqrt{s}$ = 13 TeV	
Higgs boson	7.8 million	
Top quark	275 million	
Z boson	8 billion	($\rightarrow \ell\ell$, 270 million per flavour)
W boson	26 billion	($\rightarrow \ell\nu$, 2.8 billion per flavour)
Bottom quark	~160 trillion	



(HL-)LHC: TIMELINE

Colloquium P.Ferrari
https://indico.nikhef.nl/event/6494/

Higgs discovery

Nobel Prize

Breakthrough Prize for LHC Experiments

We are here

HL-LHC 2030 – 2041

LHC

HL-LHC

Run 1

Run 2

Run 3

Run 4 - 5...

LS1

EYETS

LS2

LS3

7 TeV

8 TeV

13 TeV

13.6 TeV

13.6 - 14 TeV

energy

splice consolidation
button collimators
R2E project

cryolimit interaction regions

Diodes Consolidation
LIU Installation
Civil Eng. P1-P5

pilot beam

inner triplet radiation limit

HL-LHC installation

2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2041

2010

2041

experiment beam pipes

ATLAS - CMS
upgrade *phase 1*

ALICE - LHCb
upgrade

ATLAS - CMS
HL upgrade

75% nominal Lumi

nominal Lumi

2 x nominal Lumi

2 x nominal Lumi

5 to 7.5 x nominal Lumi

30 fb^{-1}

190 fb^{-1}

500 fb^{-1}

integrated luminosity

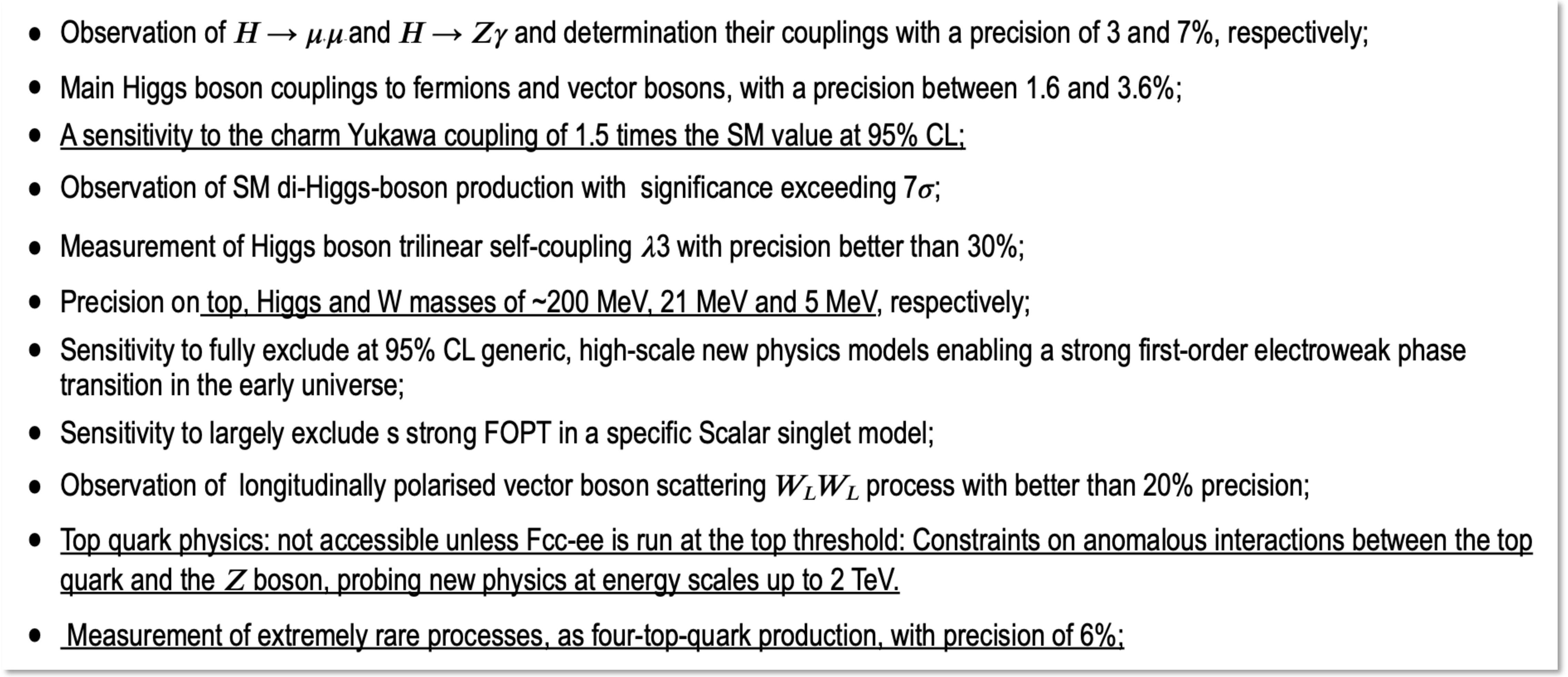
3000 fb^{-1}
4000 fb^{-1}

HL-LHC: PHYSICS

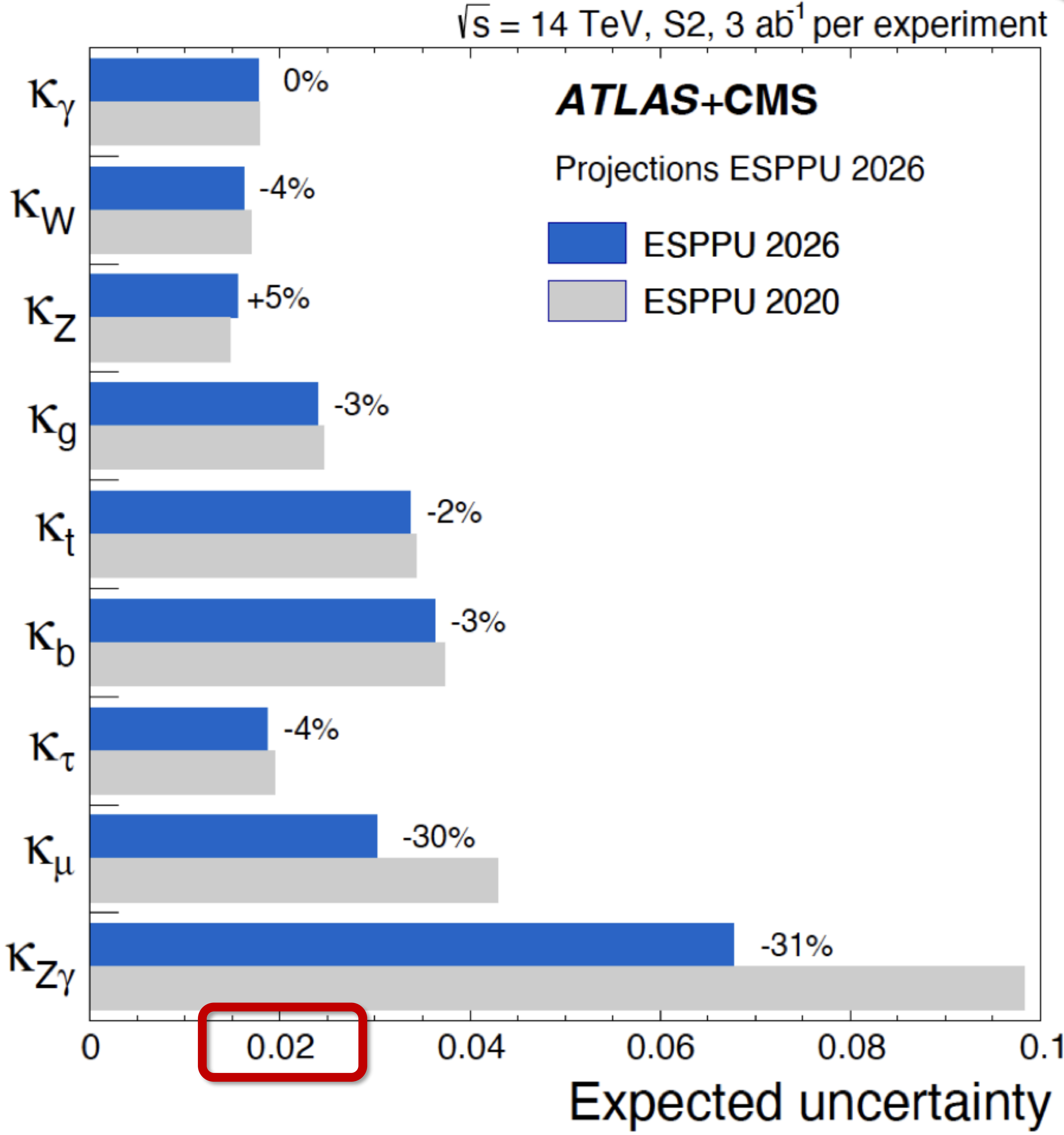
Colloquium P.Ferrari
https://indico.nikhef.nl/event/6494/

Physics prospects

- Higgs: 2-3% uncertainties
  - And much much more for EWK, B-phys, BSM, top, etc…



- Observation of $H \rightarrow \mu\mu$ and $H \rightarrow Z\gamma$ and determination their couplings with a precision of 3 and 7%, respectively;
- Main Higgs boson couplings to fermions and vector bosons, with a precision between 1.6 and 3.6%;
- A sensitivity to the charm Yukawa coupling of 1.5 times the SM value at 95% CL;
- Observation of SM di-Higgs-boson production with significance exceeding 7σ;
- Measurement of Higgs boson trilinear self-coupling $\lambda 3$ with precision better than 30%;
- Precision on top, Higgs and W masses of ~200 MeV, 21 MeV and 5 MeV, respectively;
- Sensitivity to fully exclude at 95% CL generic, high-scale new physics models enabling a strong first-order electroweak phase transition in the early universe;
- Sensitivity to largely exclude s strong FOPT in a specific Scalar singlet model;
- Observation of longitudinally polarised vector boson scattering $W_L W_L$ process with better than 20% precision;
- Top quark physics: not accessible unless Fcc-ee is run at the top threshold: Constraints on anomalous interactions between the top quark and the Z boson, probing new physics at energy scales up to 2 TeV.
- Measurement of extremely rare processes, as four-top-quark production, with precision of 6%;

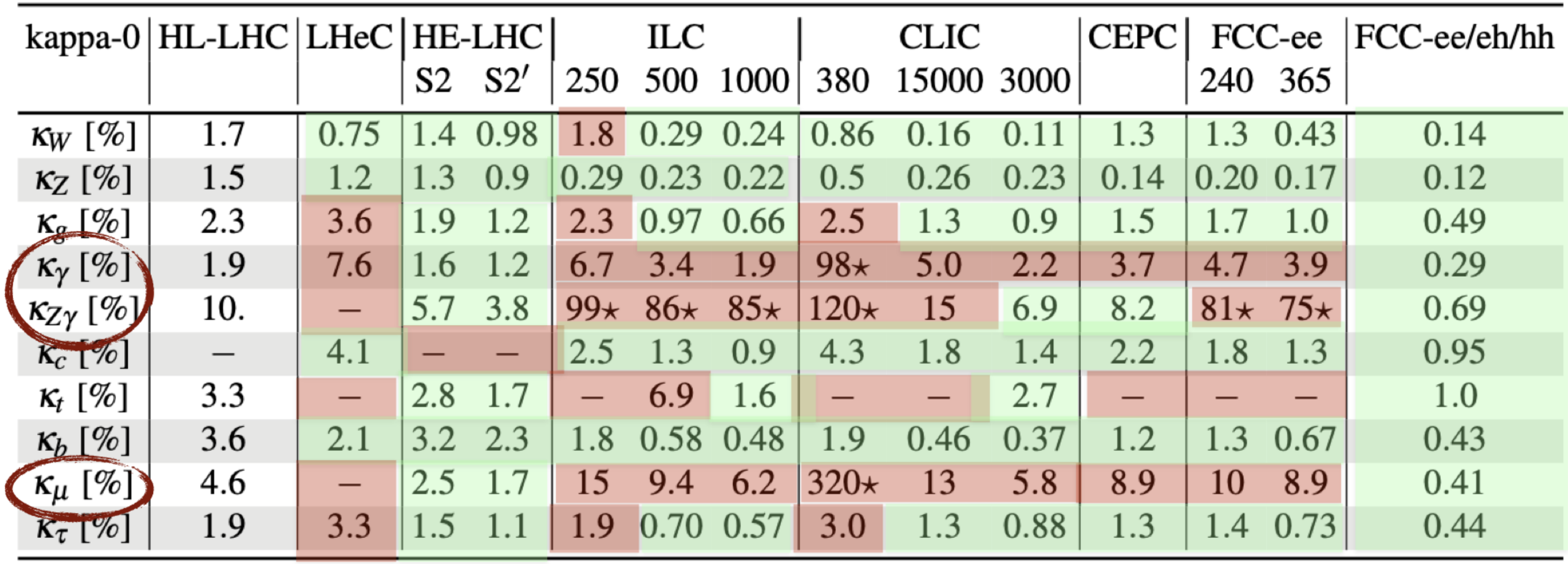


HL-LHC: PHYSICS

Colloquium P.Ferrari
https://indico.nikhef.nl/event/6494/

Physics prospects

- HL-LHC will dominate sensitivity for several processes for decades
  - Not only various Higgs channels, also SM, B-physics, Heavy Ion…



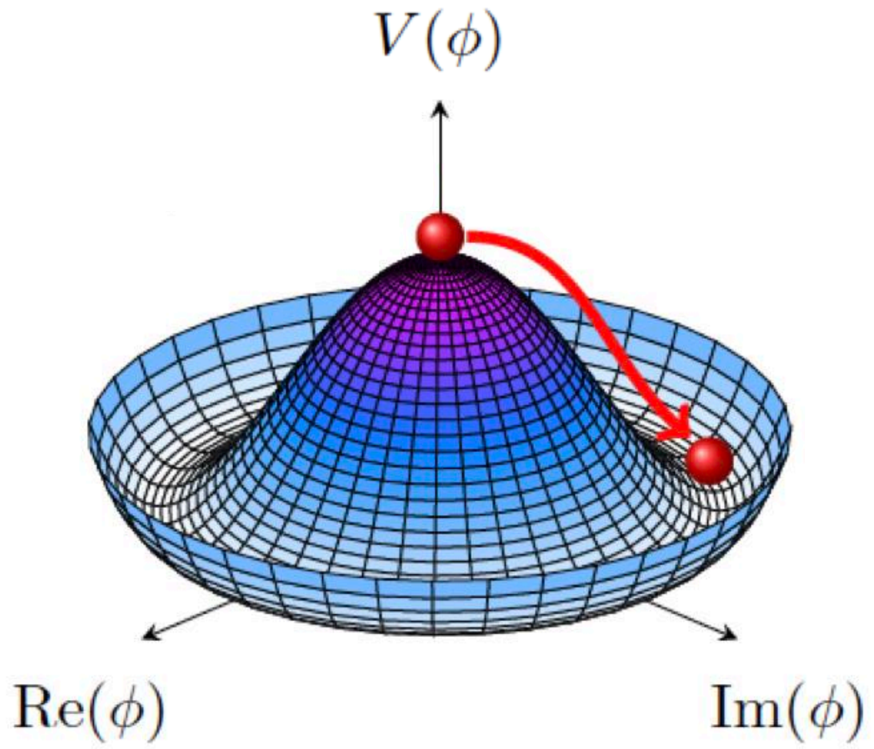
kappa-0	HL-LHC	LHeC	HE-LHC		ILC			CLIC			CEPC	FCC-ee		FCC-ee/eh/hh
			S2	S2′	250	500	1000	380	15000	3000		240	365	
κ_W [%]	1.7	0.75	1.4	0.98	1.8	0.29	0.24	0.86	0.16	0.11	1.3	1.3	0.43	0.14
κ_Z [%]	1.5	1.2	1.3	0.9	0.29	0.23	0.22	0.5	0.26	0.23	0.14	0.20	0.17	0.12
κ_g [%]	2.3	3.6	1.9	1.2	2.3	0.97	0.66	2.5	1.3	0.9	1.5	1.7	1.0	0.49
κ_γ [%]	1.9	7.6	1.6	1.2	6.7	3.4	1.9	98⋆	5.0	2.2	3.7	4.7	3.9	0.29
$\kappa_{Z\gamma}$ [%]	10.	–	5.7	3.8	99⋆	86⋆	85⋆	120⋆	15	6.9	8.2	81⋆	75⋆	0.69
κ_c [%]	–	4.1	–	–	2.5	1.3	0.9	4.3	1.8	1.4	2.2	1.8	1.3	0.95
κ_t [%]	3.3	–	2.8	1.7	–	6.9	1.6	–	–	2.7	–	–	–	1.0
κ_b [%]	3.6	2.1	3.2	2.3	1.8	0.58	0.48	1.9	0.46	0.37	1.2	1.3	0.67	0.43
κ_μ [%]	4.6	–	2.5	1.7	15	9.4	6.2	320⋆	13	5.8	8.9	10	8.9	0.41
κ_τ [%]	1.9	3.3	1.5	1.1	1.9	0.70	0.57	3.0	1.3	0.88	1.3	1.4	0.73	0.44

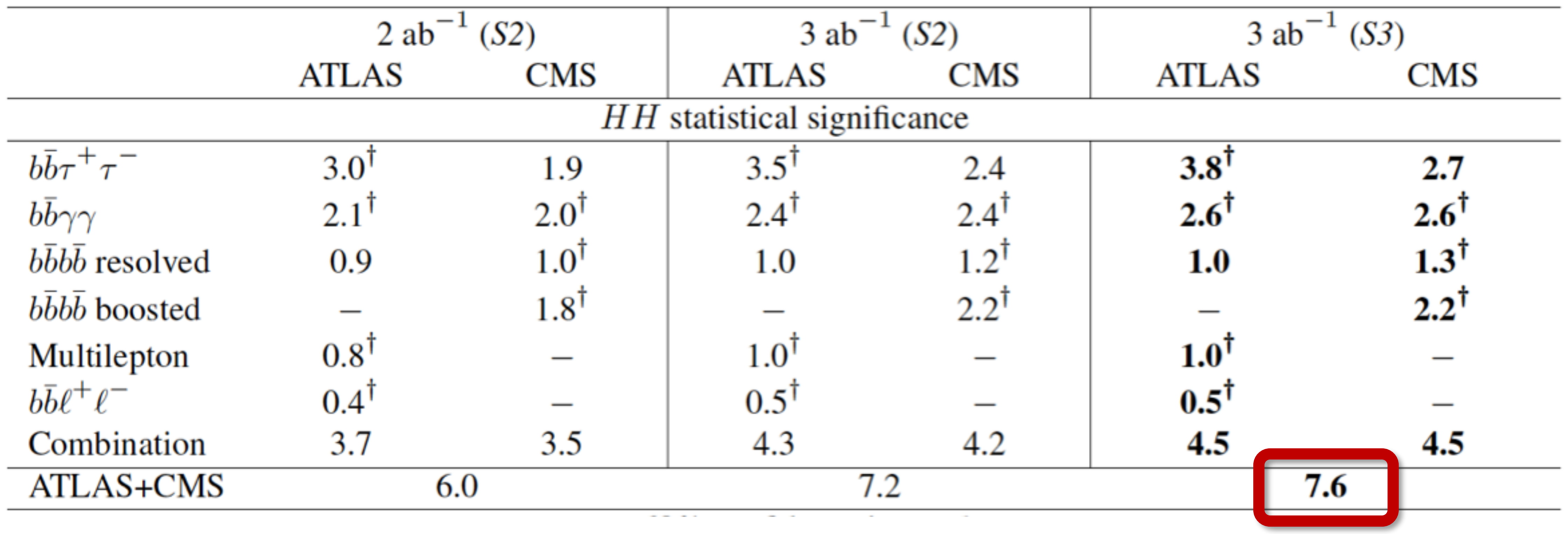
HL-LHC: PHYSICS

Colloquium P.Ferrari
https://indico.nikhef.nl/event/6494/

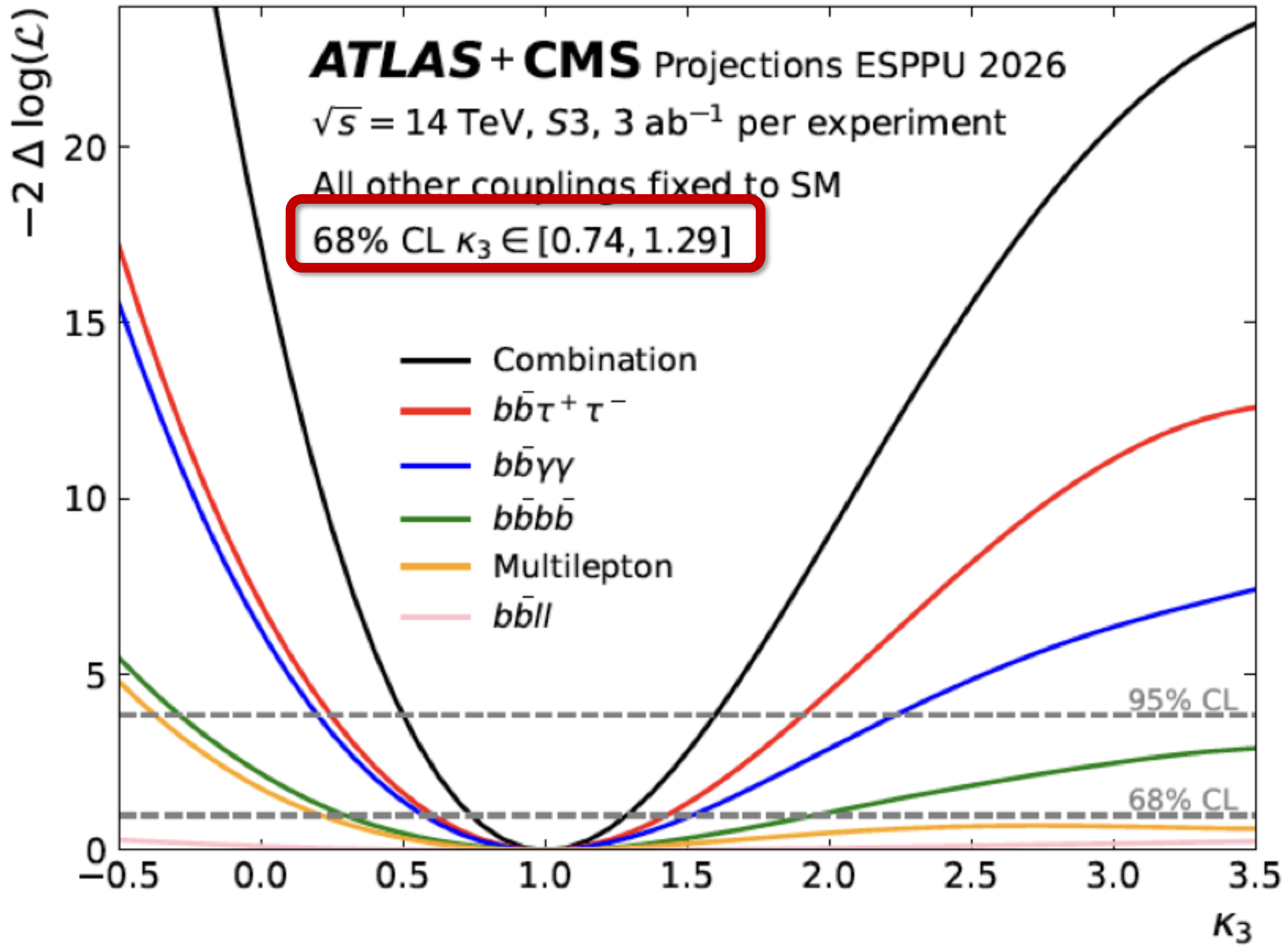
Observation of di-Higgs

- ATLAS+CMS >7σ
  - λ < 30%





	2 ab^{-1} (*S2*)		3 ab^{-1} (*S2*)		3 ab^{-1} (*S3*)	
	ATLAS	CMS	ATLAS	CMS	ATLAS	CMS
	HH statistical significance					
$b\bar{b}\tau^+\tau^-$	$3.0^\dagger$	1.9	$3.5^\dagger$	2.4	**$3.8^\dagger$**	**2.7**
$b\bar{b}\gamma\gamma$	$2.1^\dagger$	$2.0^\dagger$	$2.4^\dagger$	$2.4^\dagger$	**$2.6^\dagger$**	**$2.6^\dagger$**
$b\bar{b}b\bar{b}$ resolved	0.9	$1.0^\dagger$	1.0	$1.2^\dagger$	**1.0**	**$1.3^\dagger$**
$b\bar{b}b\bar{b}$ boosted	–	$1.8^\dagger$	–	$2.2^\dagger$	–	**$2.2^\dagger$**
Multilepton	$0.8^\dagger$	–	$1.0^\dagger$	–	**$1.0^\dagger$**	–
$b\bar{b}\ell^+\ell^-$	$0.4^\dagger$	–	$0.5^\dagger$	–	**$0.5^\dagger$**	–
Combination	3.7	3.5	4.3	4.2	**4.5**	**4.5**
ATLAS+CMS	6.0		7.2		**7.6**	



➔ Major legacy result of the HL-LHC

BACK TO THE FUTURE COLLIDER

PHOTO: J. WENNINGER

FCC-HH: MAGNETS

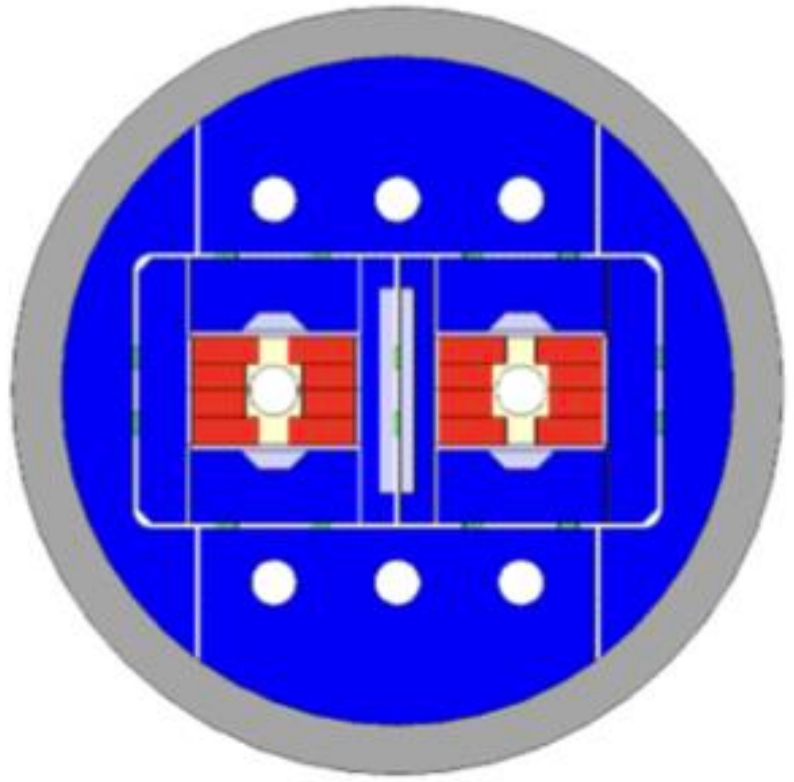
FCC-hh programme
https://indico.cern.ch/event/1439855/contributions/6461658/

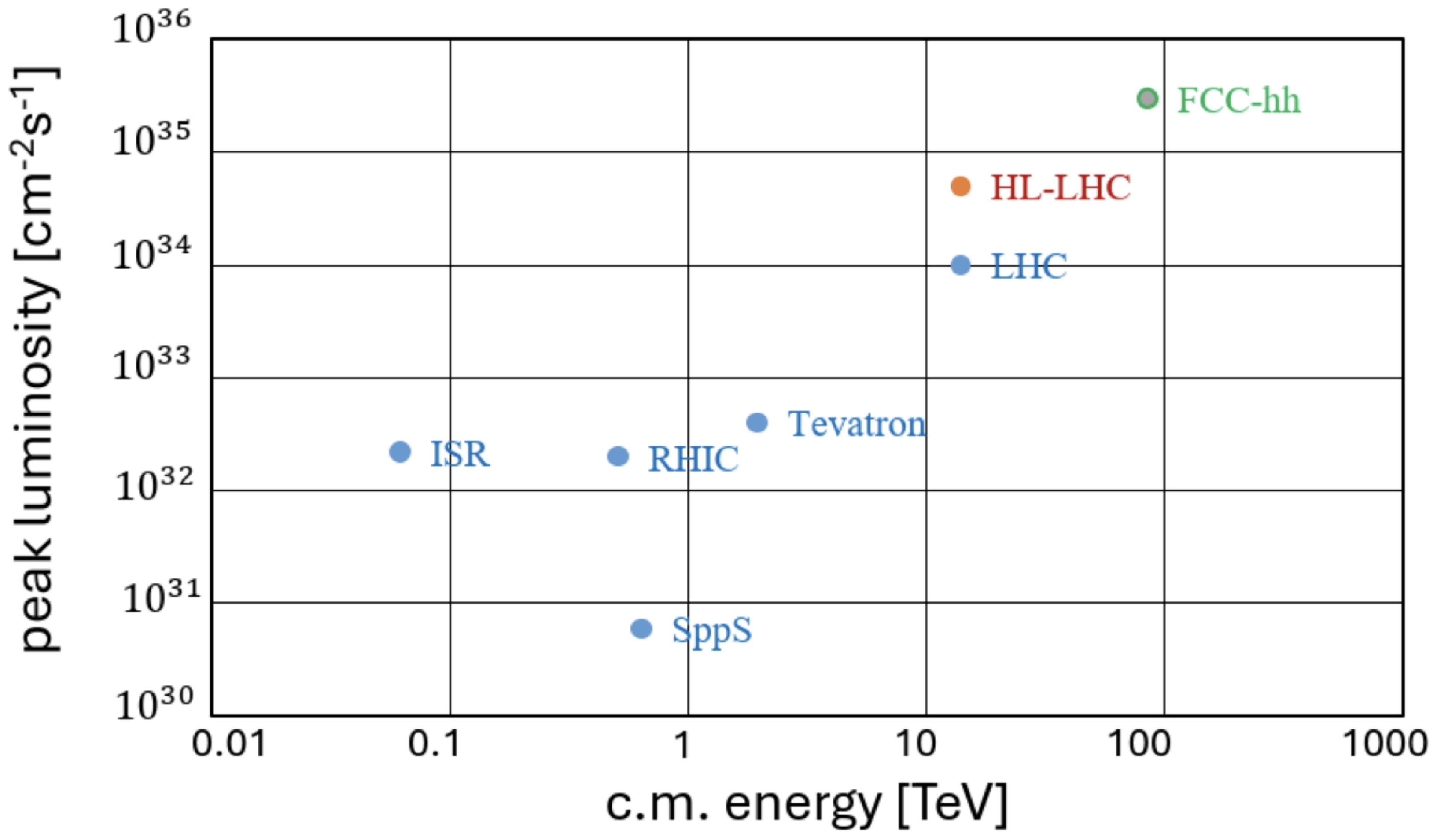
Hadron collider

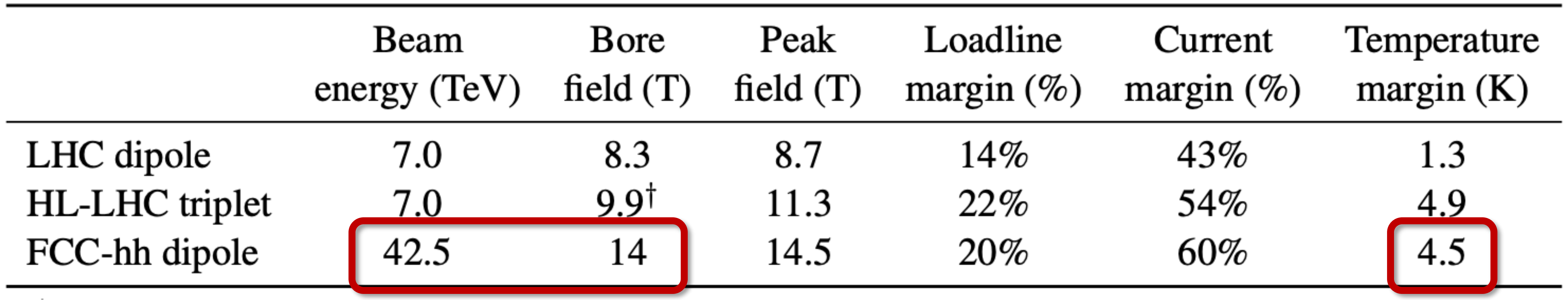
- E_{CoM} = 80-90 TeV
  - 2 IPs

Stronger magnets

- Nb_3Sn tech
  - Current target: 14 T







	Beam energy (TeV)	Bore field (T)	Peak field (T)	Loadline margin (%)	Current margin (%)	Temperature margin (K)
LHC dipole	7.0	8.3	8.7	14%	43%	1.3
HL-LHC triplet	7.0	9.9†	11.3	22%	54%	4.9
FCC-hh dipole	42.5	14	14.5	20%	60%	4.5

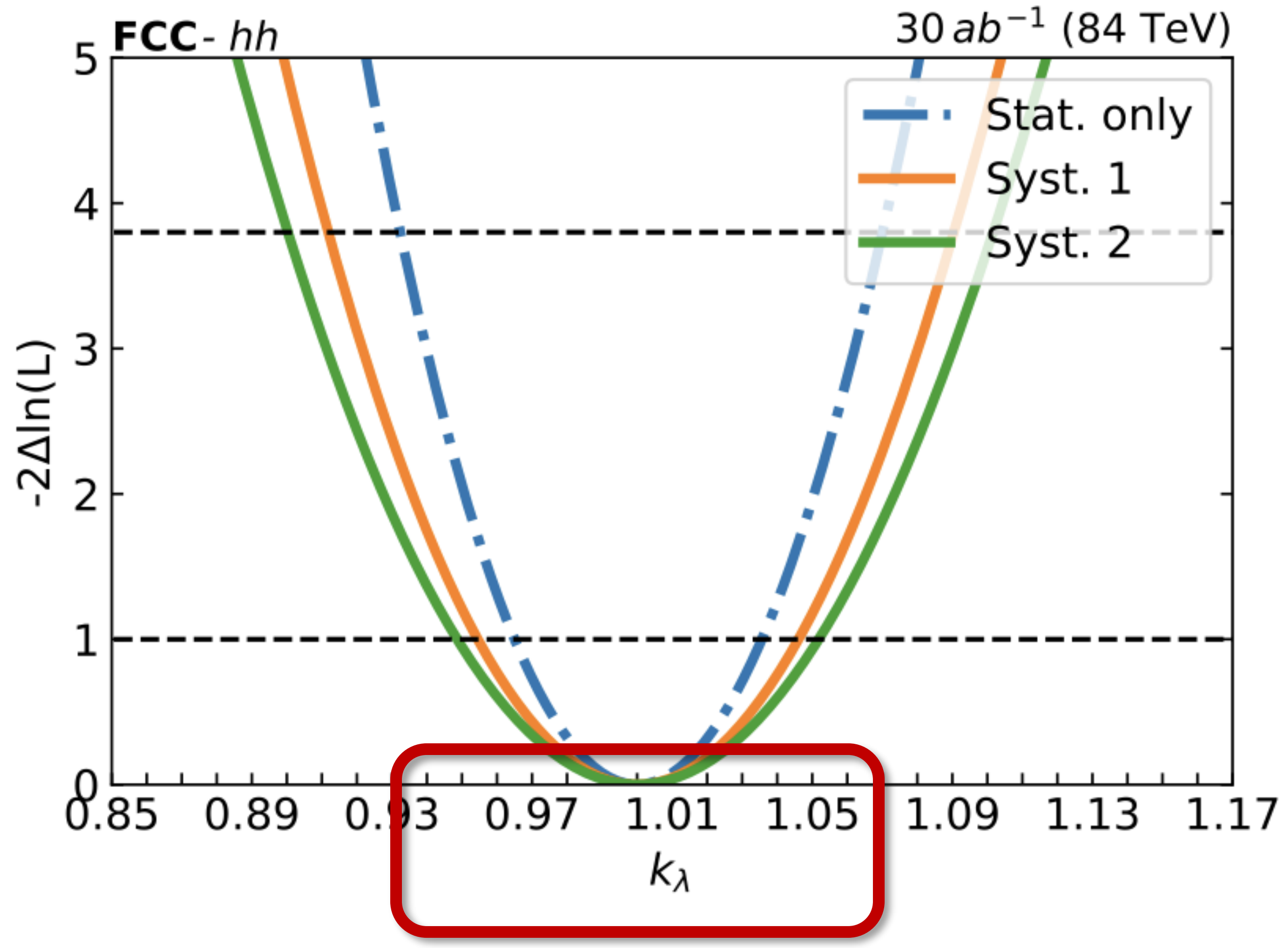
FCC-HH: PHYSICS

FCC-hh physics
https://indico.cern.ch/event/1439855/contributions/6461632/

Physics

- Energy: BSM
    - Tens of TeV
- SM & Higgs
    - λ ~ 5%

BSM object (%)	100 TeV CDR baseline	84 TeV FSR baseline	72 TeV F12LL
$Z'_{SSM} \rightarrow \ell\ell$	43	37	32
$Z'_{SSM} \rightarrow \tau\tau$, tt	18	16	14
$Z'_{TC} \rightarrow$ tt	23	20	18
$G_{RS} \rightarrow$ WW	22	19	17
$Q^* \rightarrow$ jj	40	35	30
$\tilde{W}^0$	4.4	4.0	3.6
$\tilde{h}^0$	1.2	1.1	1.0



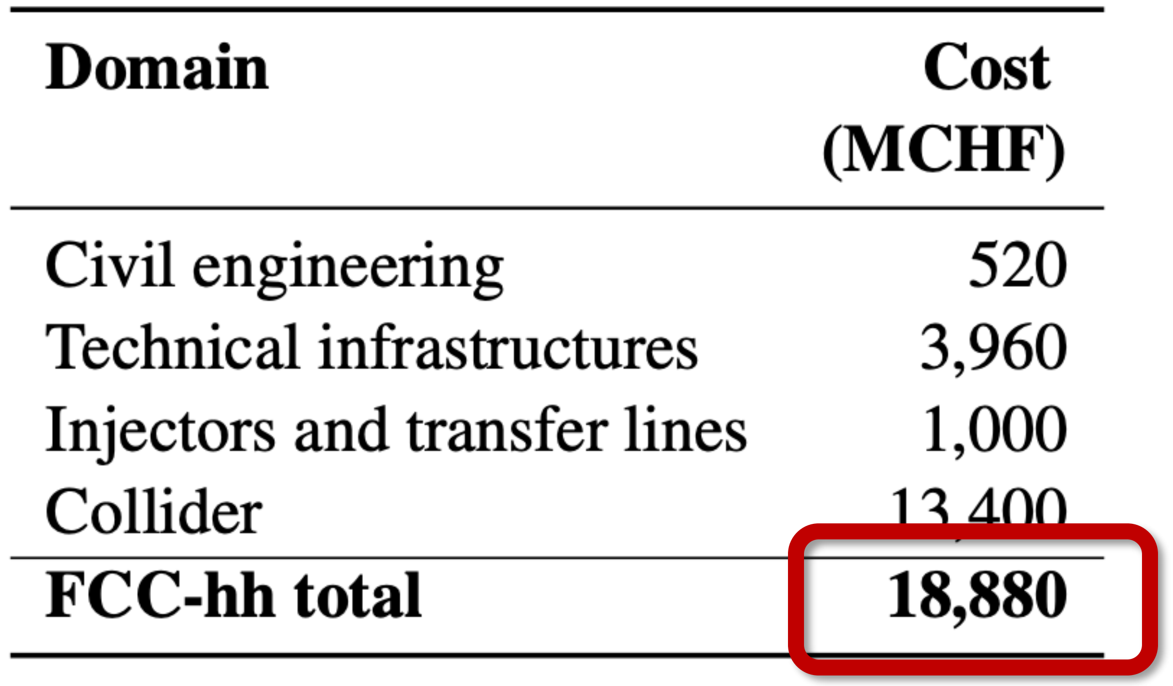
➔ For different collision energy scenarios

FCC-HH: PRACTICALITIES

FCC-hh programme
https://indico.cern.ch/event/1439855/contributions/6461658/

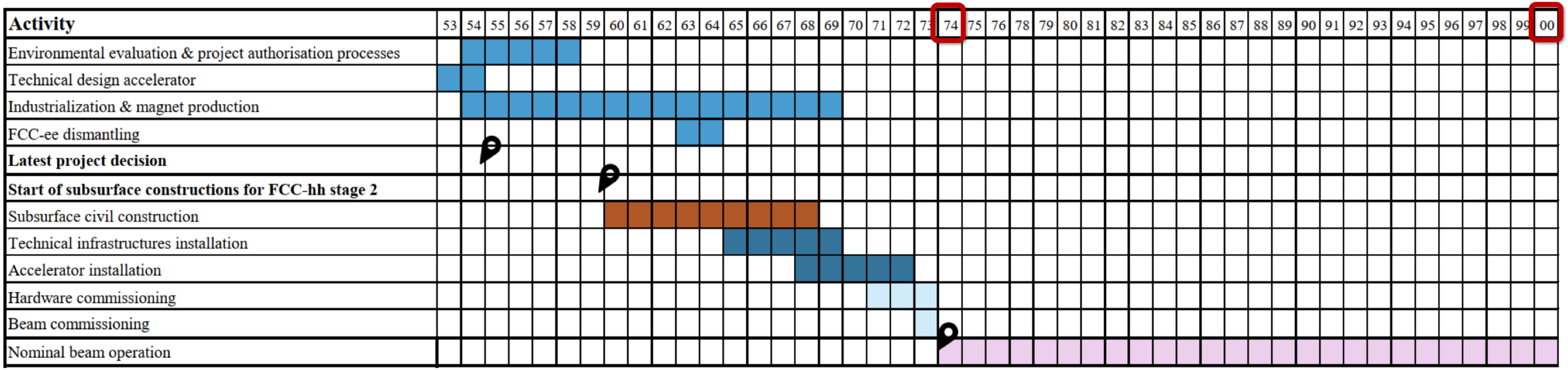
Practicalities:

- Cost: 19 BCHF
  - Run 2074 – 2100



Domain	**Cost (MCHF)**
Civil engineering	520
Technical infrastructures	3,960
Injectors and transfer lines	1,000
Collider	13,400
FCC-hh total	**18,880**

😬



Activity	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00
Environmental evaluation & project authorisation processes		🟦	🟦	🟦	🟦	🟦																																									
Technical design accelerator	🟦	🟦																																													
Industrialization & magnet production		🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦																														
FCC-ee dismantling											🟦	🟦																																			
Latest project decision			📍																																												
Start of subsurface constructions for FCC-hh stage 2								📍																																							
Subsurface civil construction								🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫	🟫																															
Technical infrastructures installation													🟦	🟦	🟦	🟦	🟦																														
Accelerator installation																🟦	🟦	🟦	🟦	🟦																											
Hardware commissioning																			🟦	🟦	🟦																										
Beam commissioning																					🟦	📍																									
Nominal beam operation																						🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪

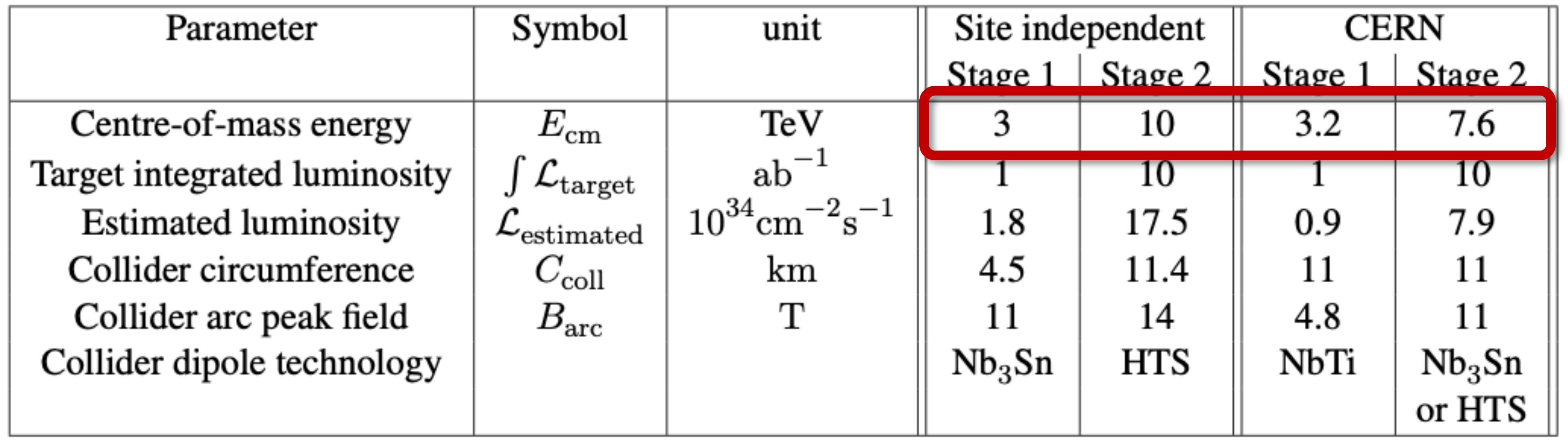
TOWARDS A MUON COLLIDER

MUON COLLIDER: PROJECT

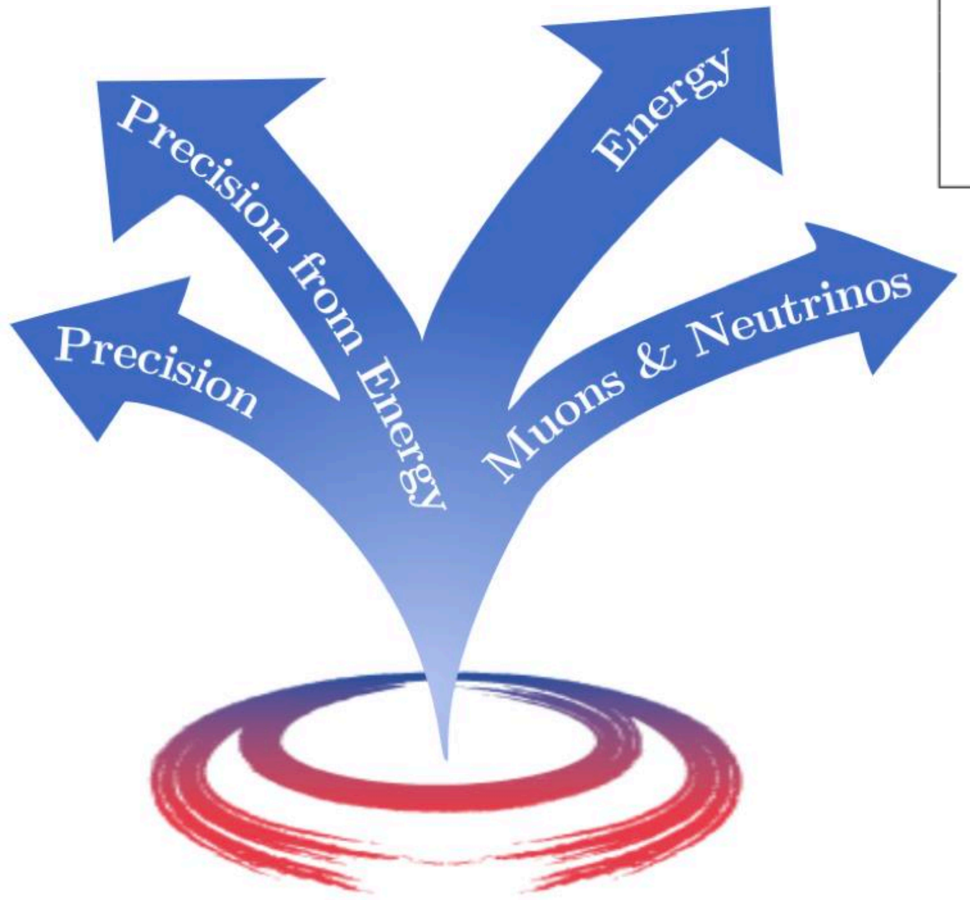
Muon Collider
https://indico.cern.ch/event/1439855/contributions/6461618/

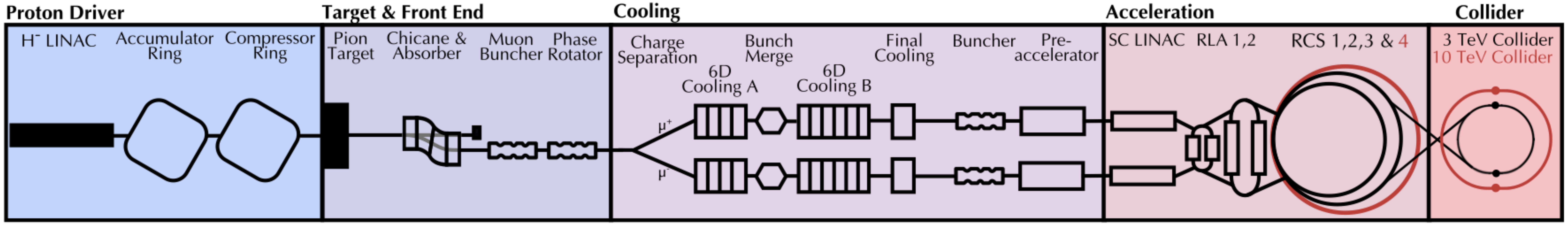
New physics: muon collisions

- Energy and Precision
  - CoM Energy: 3 - 10 TeV
  - At CERN: 3.2 - 7.6 TeV



Parameter	Symbol	unit	Site independent		CERN	
			Stage 1	Stage 2	Stage 1	Stage 2
Centre-of-mass energy	E_{cm}	TeV	3	10	3.2	7.6
Target integrated luminosity	$\int \mathcal{L}_{\mathrm{target}}$	ab^{-1}	1	10	1	10
Estimated luminosity	$\mathcal{L}_{\mathrm{estimated}}$	$10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$	1.8	17.5	0.9	7.9
Collider circumference	C_{coll}	km	4.5	11.4	11	11
Collider arc peak field	B_{arc}	T	11	14	4.8	11
Collider dipole technology			Nb_3Sn	HTS	NbTi	Nb_3Sn or HTS



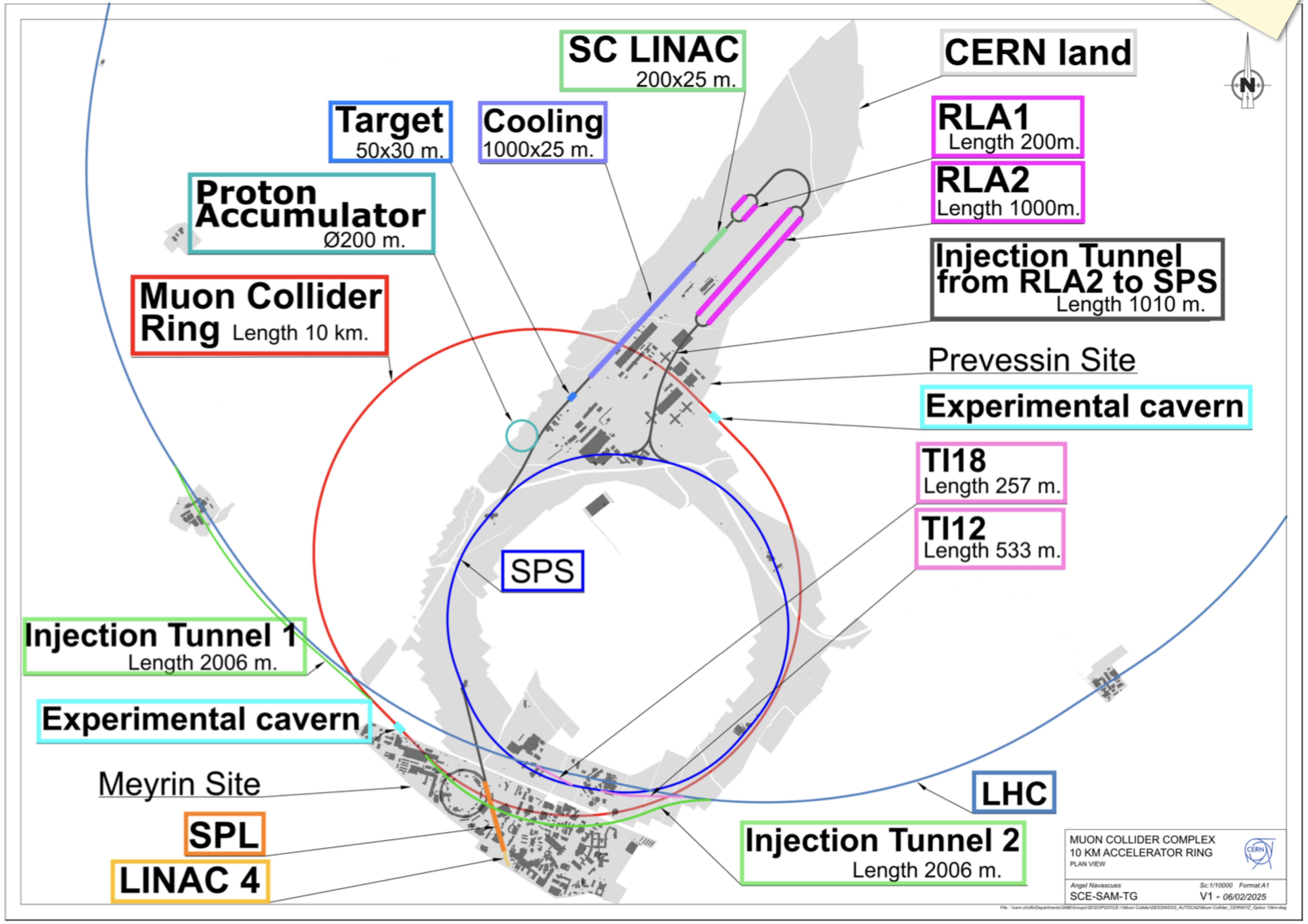


MUCOL: INFRASTRUCTURE

Muon Collider
https://indico.cern.ch/event/1439855/contributions/6461618/

Includes proposal for CERN site

- Reuse infrastructure
  - LHC and SPS!

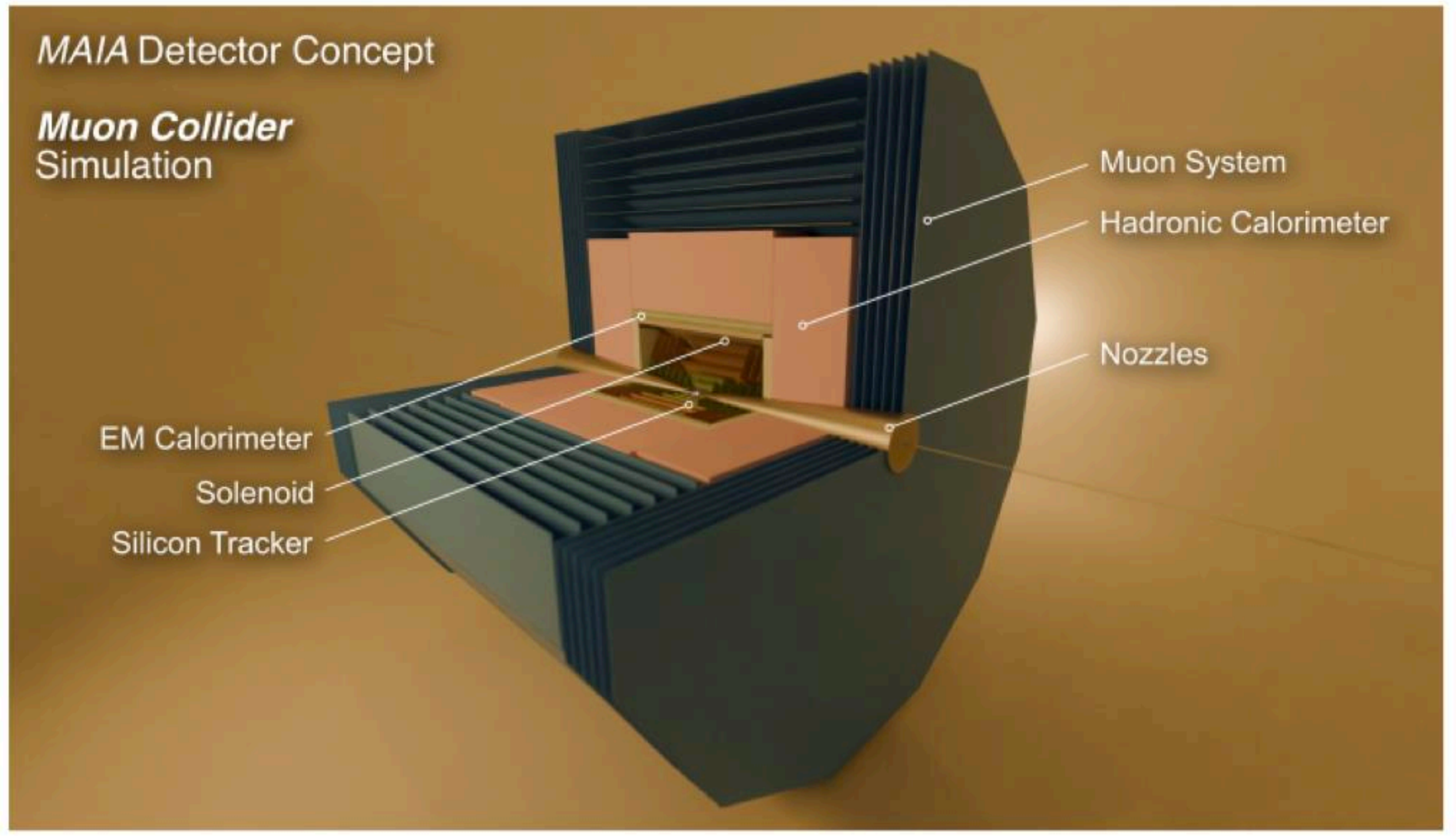


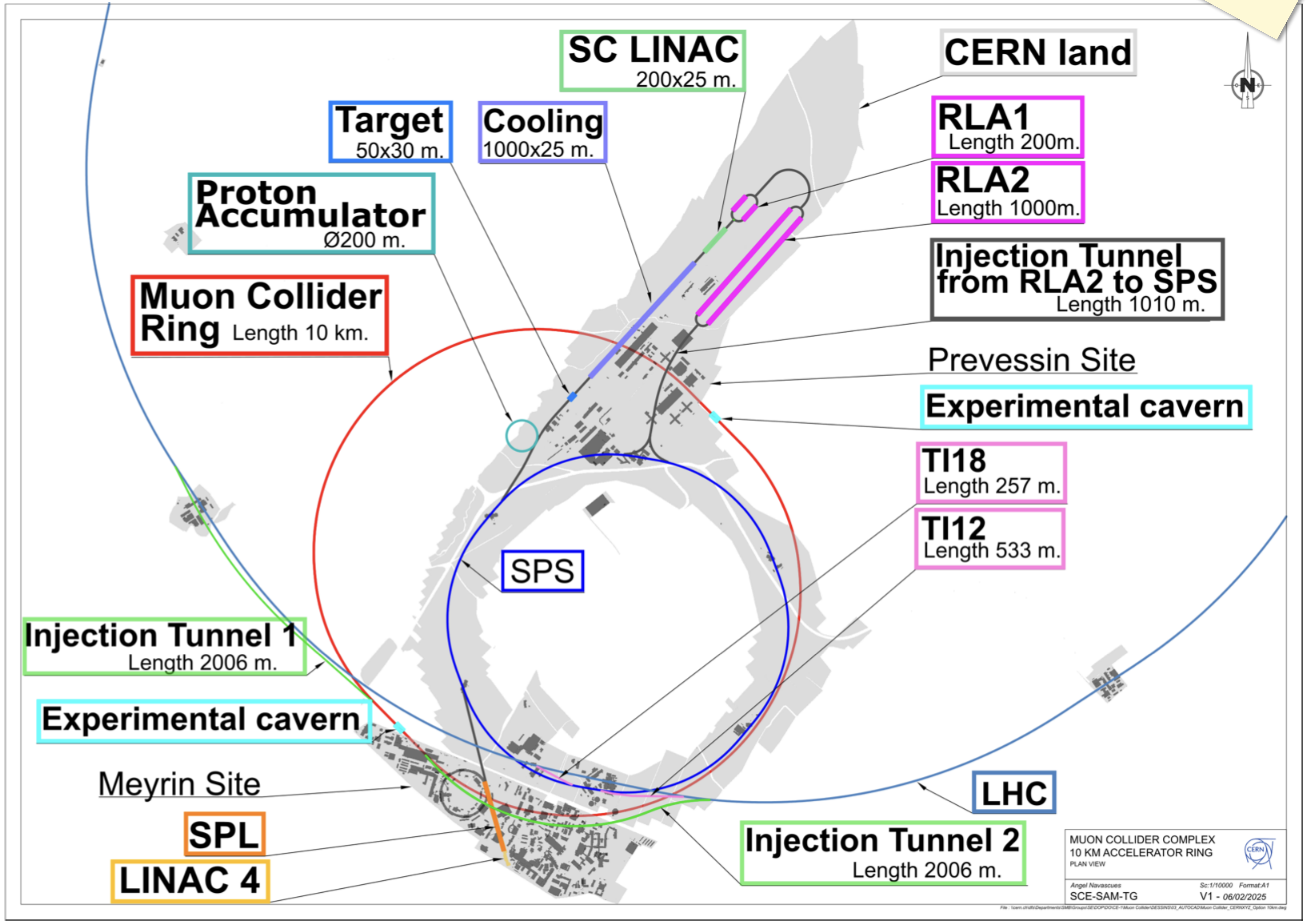
MUCOL: INFRASTRUCTURE

Muon Collider
https://indico.cern.ch/event/1439855/contributions/6461618/

Includes proposal for CERN site

- Reuse LHC & SPS tunnels
  - Detector optimization for both energies



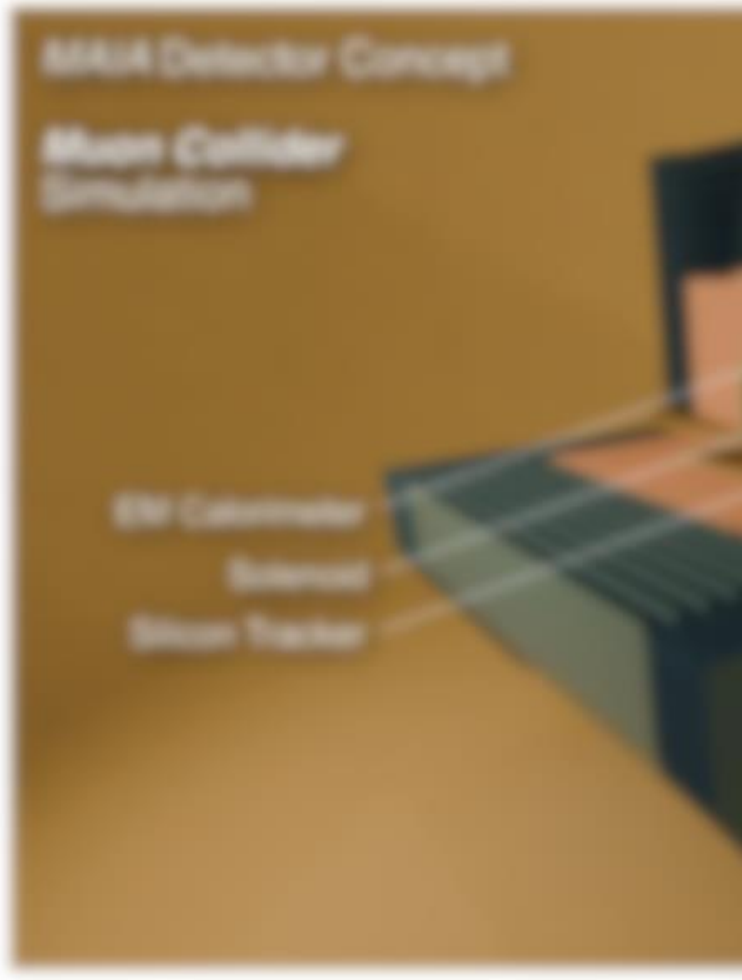


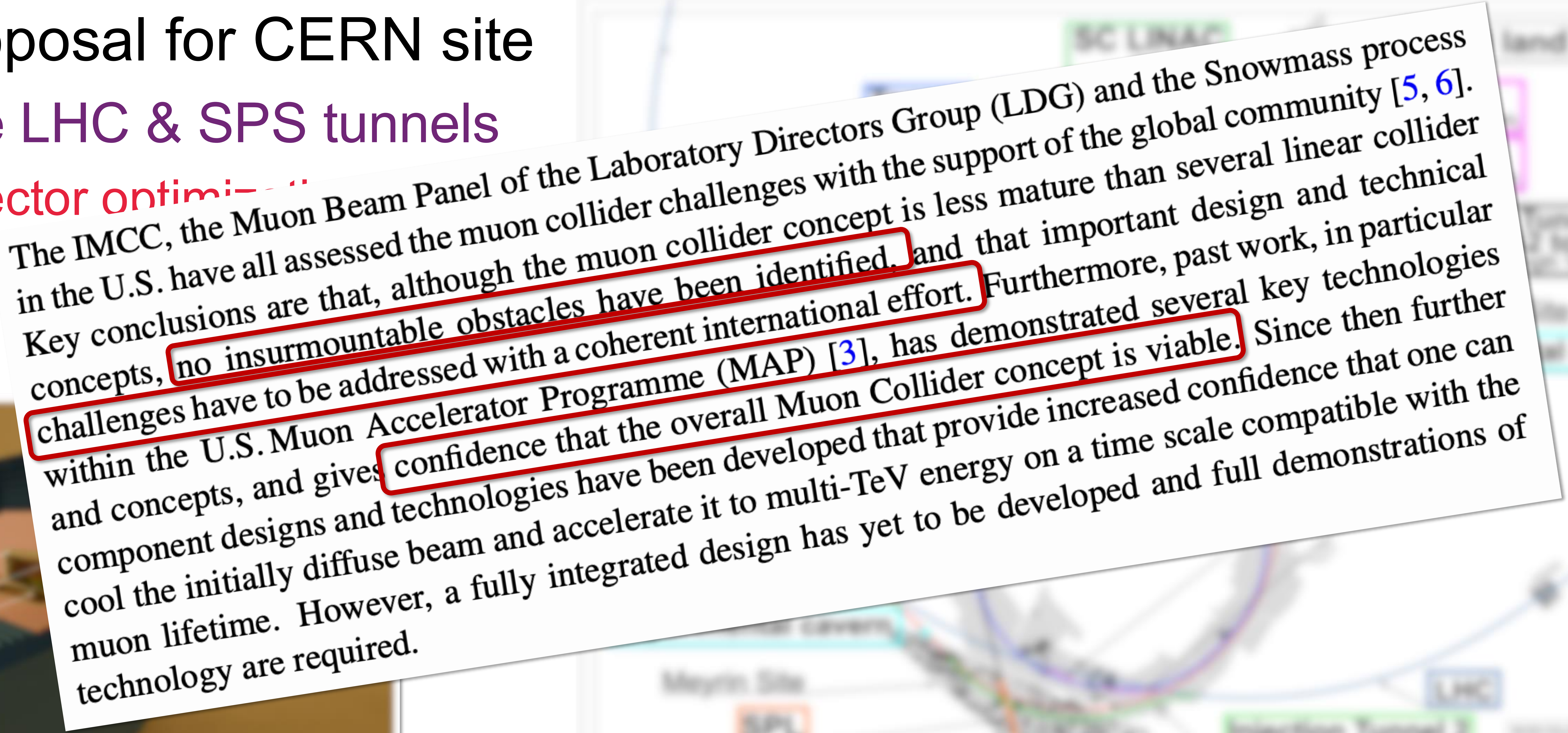
MUCOL: INFRASTRUCTURE

Muon Collider
https://indico.cern.ch/event/1439855/contributions/6461618/

Includes proposal for CERN site

- Reuse LHC & SPS tunnels
  - Detector optimi
    for b





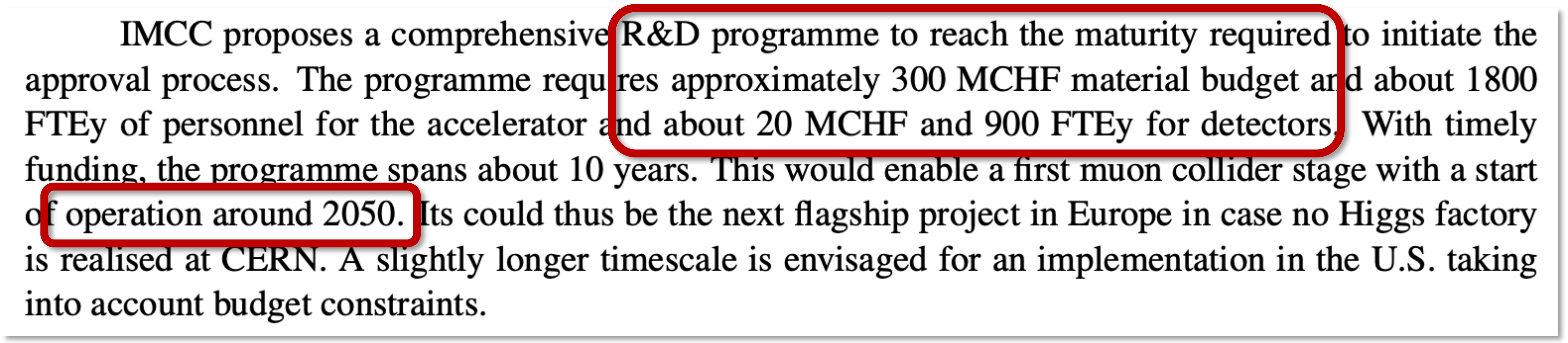
The IMCC, the Muon Beam Panel of the Laboratory Directors Group (LDG) and the Snowmass process in the U.S. have all assessed the muon collider challenges with the support of the global community [5, 6]. Key conclusions are that, although the muon collider concept is less mature than several linear collider concepts, no insurmountable obstacles have been identified, and that important design and technical challenges have to be addressed with a coherent international effort. Furthermore, past work, in particular within the U.S. Muon Accelerator Programme (MAP) [3], has demonstrated several key technologies and concepts, and gives confidence that the overall Muon Collider concept is viable. Since then further component designs and technologies have been developed that provide increased confidence that one can cool the initially diffuse beam and accelerate it to multi-TeV energy on a time scale compatible with the muon lifetime. However, a fully integrated design has yet to be developed and full demonstrations of technology are required.

MUCOL: BUDGET & TIMELINE

Muon Collider
https://indico.cern.ch/event/1439855/contributions/6461618/

R&D programme budget

- Accelerator: 0.3 BCHF
  - + 1800 FTEy
- Detectors: 0.02 BCHF
  - + 900 FTEy



IMCC proposes a comprehensive R&D programme to reach the maturity required to initiate the approval process. The programme requires approximately 300 MCHF material budget and about 1800 FTEy of personnel for the accelerator and about 20 MCHF and 900 FTEy for detectors. With timely funding, the programme spans about 10 years. This would enable a first muon collider stage with a start of operation around 2050. Its could thus be the next flagship project in Europe in case no Higgs factory is realised at CERN. A slightly longer timescale is envisaged for an implementation in the U.S. taking into account budget constraints.

Target first physics

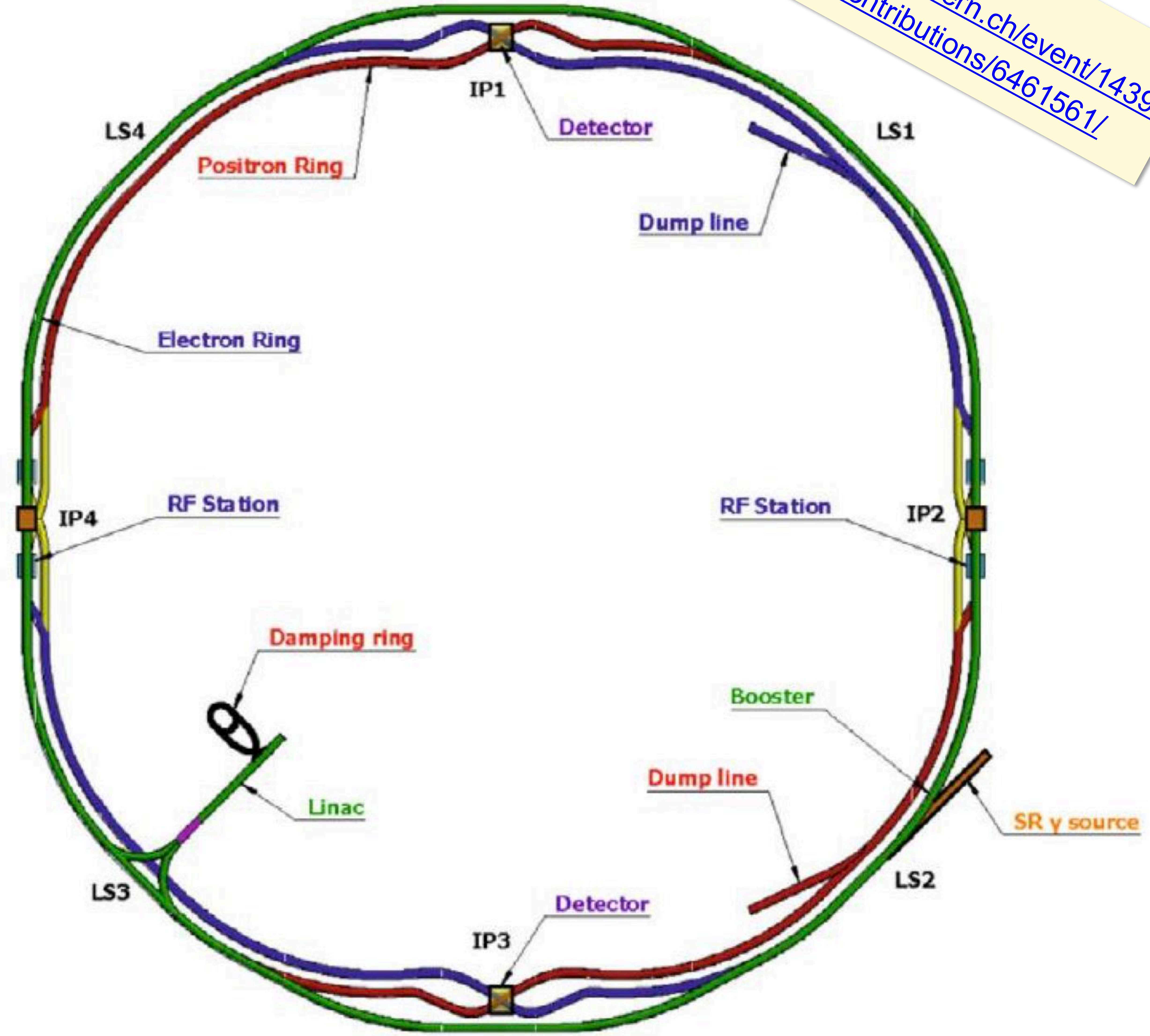
A CHINESE COLLIDER?

PROJECT: CEPC

Very similar to FCC

- Located in China
  - Proposed by IHEP in 2012

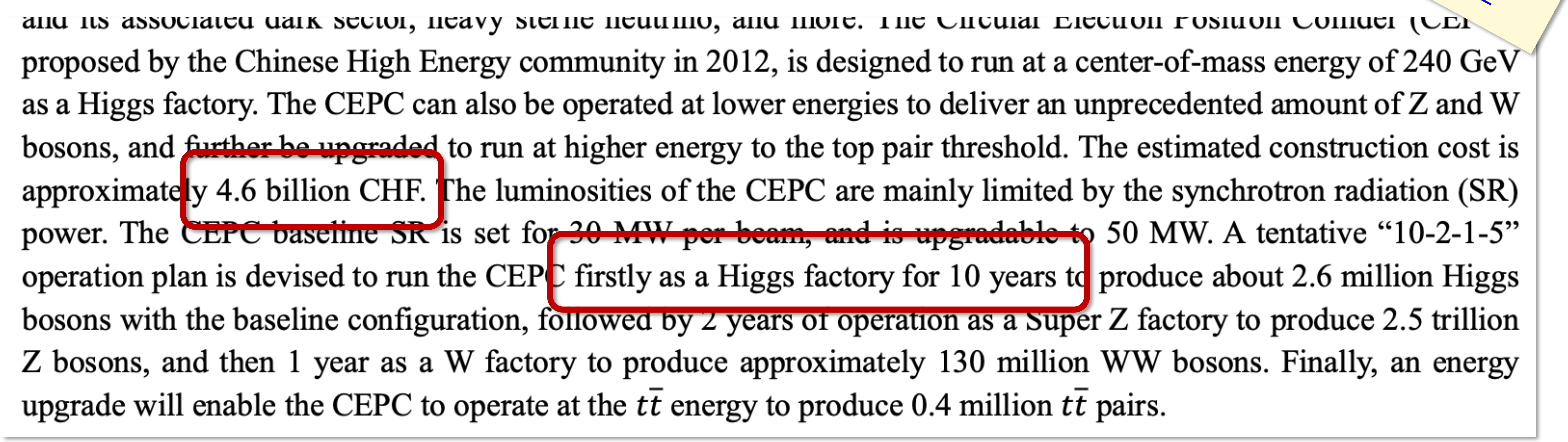
CepC
https://indico.cern.ch/event/1439855/contributions/6461561/



PROJECT: CEPC

Very similar to FCC

- Located in China
  - Cost <5 BCHF
- Start: Higgs (10y)
  - H-Z-W-t = 10-2-1-5


and its associated dark sector, heavy sterile neutrino, and more. The Circular Electron Positron Collider (CEP proposed by the Chinese High Energy community in 2012, is designed to run at a center-of-mass energy of 240 GeV as a Higgs factory. The CEPC can also be operated at lower energies to deliver an unprecedented amount of Z and W bosons, and further be upgraded to run at higher energy to the top pair threshold. The estimated construction cost is approximately 4.6 billion CHF. The luminosities of the CEPC are mainly limited by the synchrotron radiation (SR) power. The CEPC baseline SR is set for 30 MW per beam, and is upgradable to 50 MW. A tentative "10-2-1-5" operation plan is devised to run the CEPC firstly as a Higgs factory for 10 years to produce about 2.6 million Higgs bosons with the baseline configuration, followed by 2 years of operation as a Super Z factory to produce 2.5 trillion Z bosons, and then 1 year as a W factory to produce approximately 130 million WW bosons. Finally, an energy upgrade will enable the CEPC to operate at the $t\bar{t}$ energy to produce 0.4 million $t\bar{t}$ pairs.

CepC
https://indico.cern.ch/event/1439855/contributions/6461561/

PROJECT: CEPC

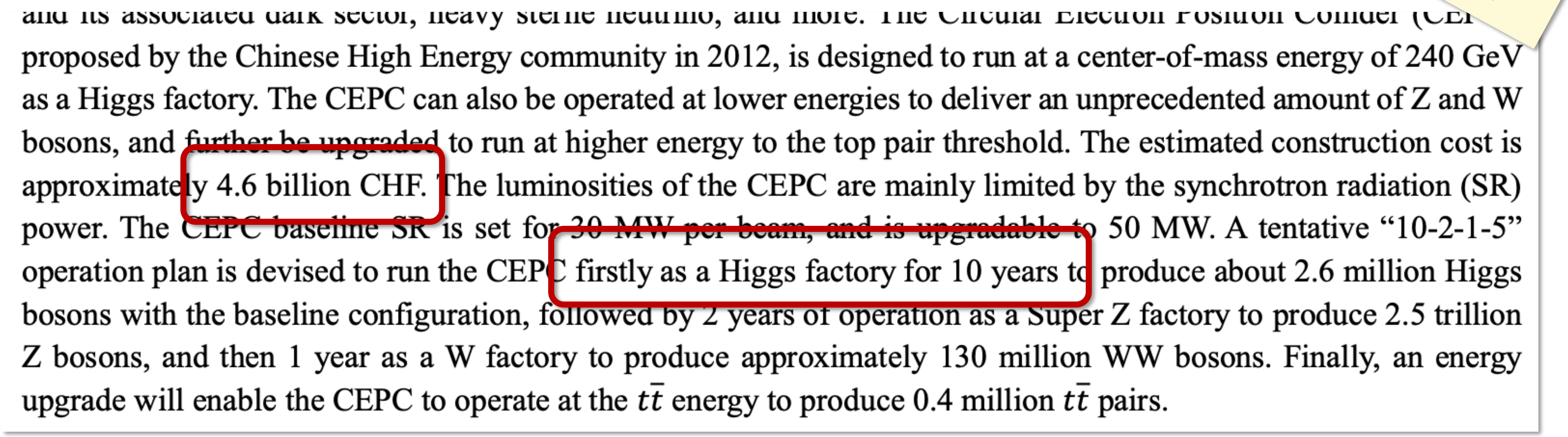
CepC
https://indico.cern.ch/event/1439855/contributions/6461561/

Very similar to FCC

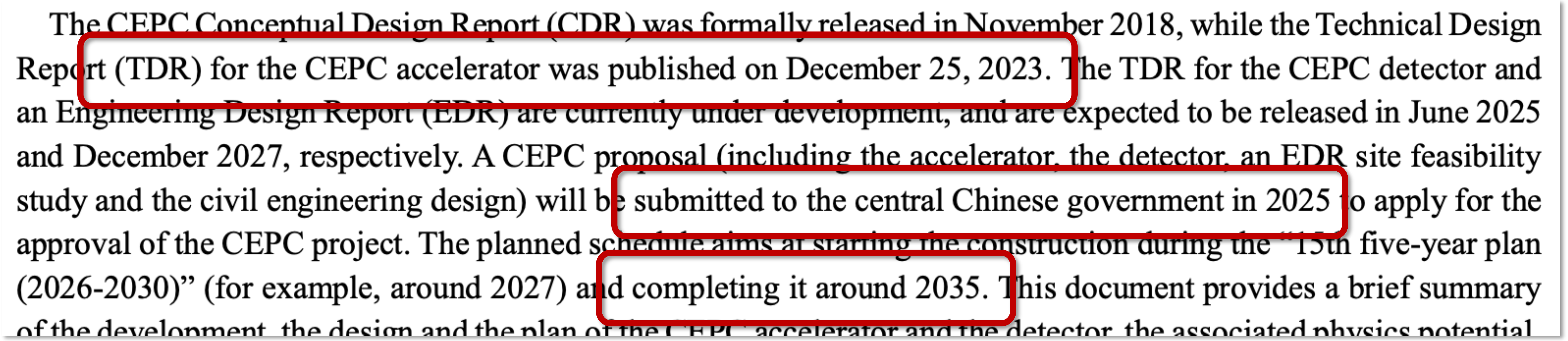
- Located in China
  - Cost <5 BCHF
- Start: Higgs (10y)
  - H-Z-W-t = 10-2-1-5

Advanced status

- TDR in 2023
  - 2025: submission
  - 2026: construction?
  - 2035: ready to go?



and its associated dark sector, heavy sterile neutrino, and more. The Circular Electron Positron Collider (CEP proposed by the Chinese High Energy community in 2012, is designed to run at a center-of-mass energy of 240 GeV as a Higgs factory. The CEPC can also be operated at lower energies to deliver an unprecedented amount of Z and W bosons, and further be upgraded to run at higher energy to the top pair threshold. The estimated construction cost is approximately 4.6 billion CHF. The luminosities of the CEPC are mainly limited by the synchrotron radiation (SR) power. The CEPC baseline SR is set for 30 MW per beam, and is upgradable to 50 MW. A tentative “10-2-1-5” operation plan is devised to run the CEPC firstly as a Higgs factory for 10 years to produce about 2.6 million Higgs bosons with the baseline configuration, followed by 2 years of operation as a Super Z factory to produce 2.5 trillion Z bosons, and then 1 year as a W factory to produce approximately 130 million WW bosons. Finally, an energy upgrade will enable the CEPC to operate at the $t\bar{t}$ energy to produce 0.4 million $t\bar{t}$ pairs.



The CEPC Conceptual Design Report (CDR) was formally released in November 2018, while the Technical Design Report (TDR) for the CEPC accelerator was published on December 25, 2023. The TDR for the CEPC detector and an Engineering Design Report (EDR) are currently under development, and are expected to be released in June 2025 and December 2027, respectively. A CEPC proposal (including the accelerator, the detector, an EDR site feasibility study and the civil engineering design) will be submitted to the central Chinese government in 2025 to apply for the approval of the CEPC project. The planned schedule aims at starting the construction during the “15th five-year plan (2026-2030)” (for example, around 2027) and completing it around 2035. This document provides a brief summary of the development, the design and the plan of the CEPC accelerator and the detector, the associated physics potential

PROJECT: CEPC

CepC
https://indico.cern.ch/event/1439855/contributions/6461561/

Demonstrating readiness

- Forthcoming EDR
  - "Prepare CepC for delivery"

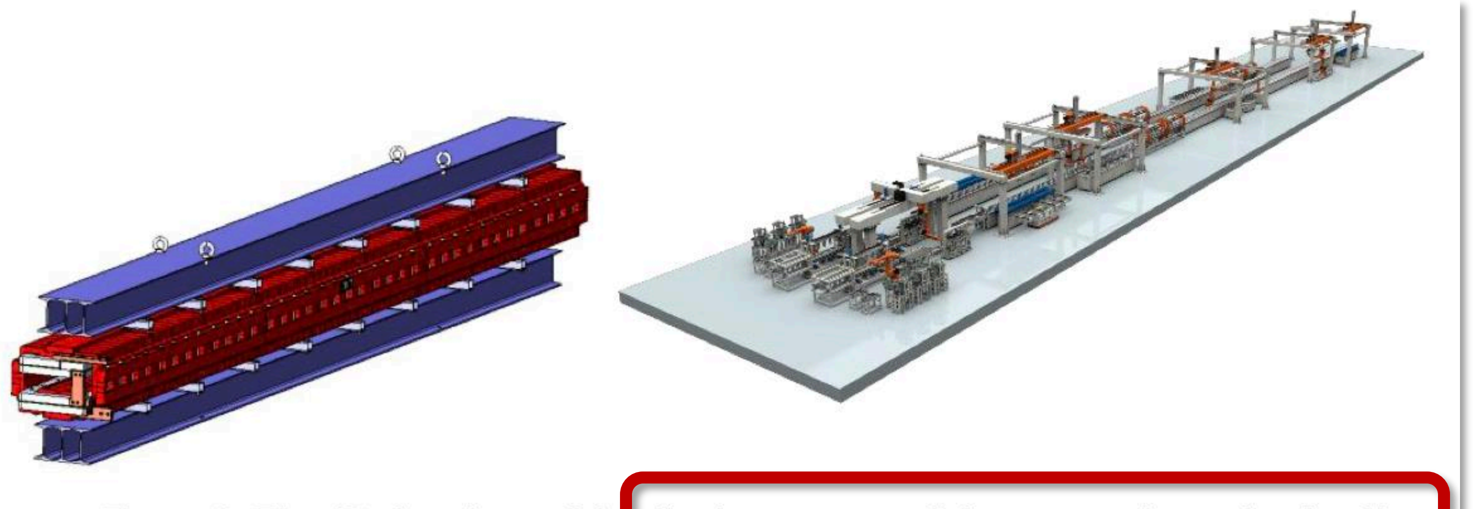


Figure 2. The 3D drawings of th dipole magnet and the automatic production line

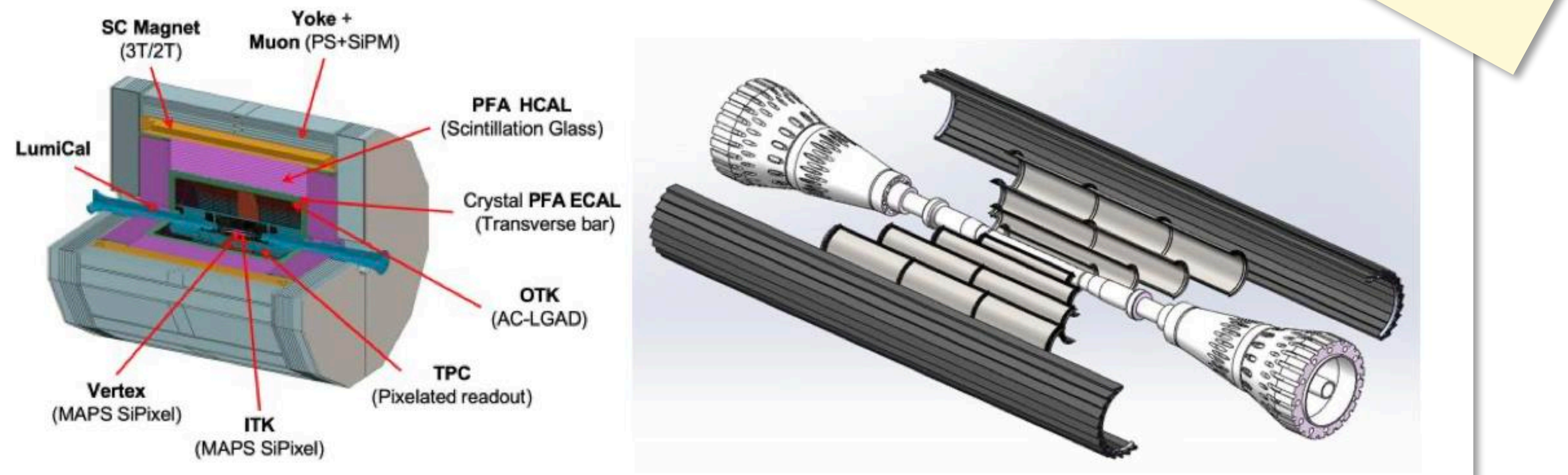


Figure 7 . (a) View of CEPC reference detector; (b) Schematic of the vertex detector.

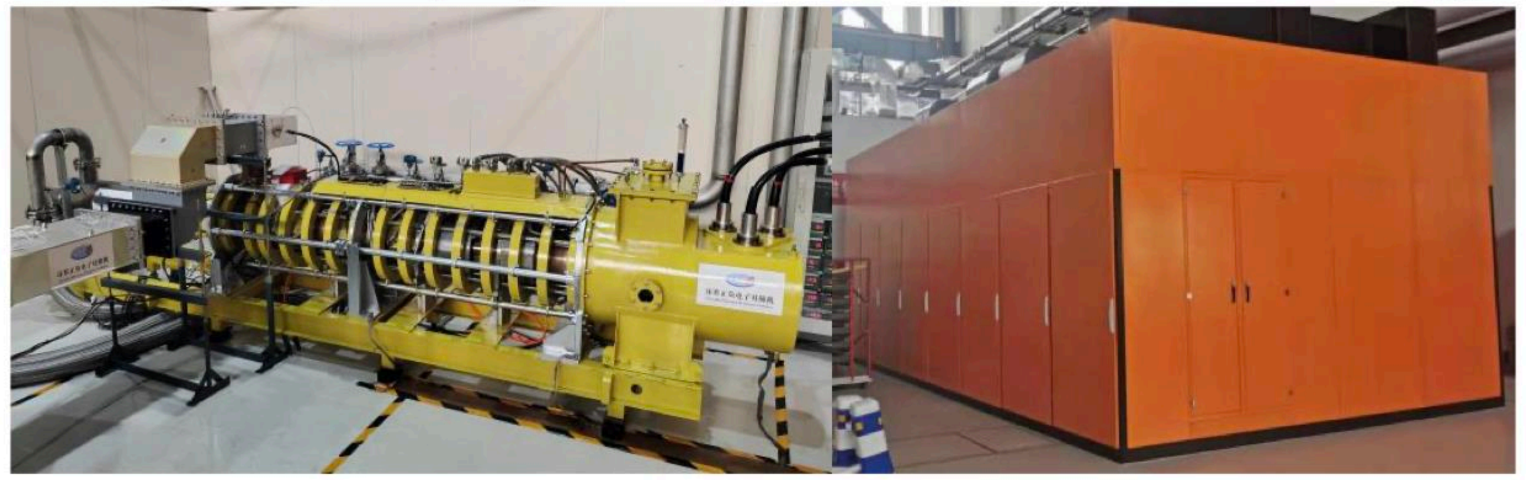


Figure 5. CEPC 650 MHz CW 800 kW klystron and power source.

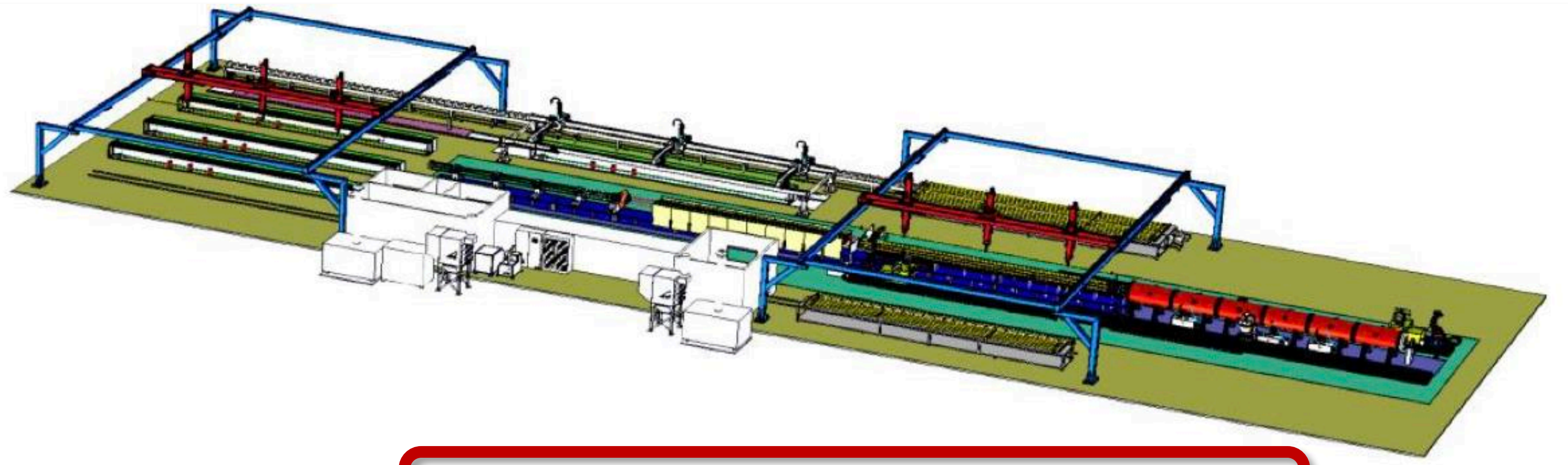


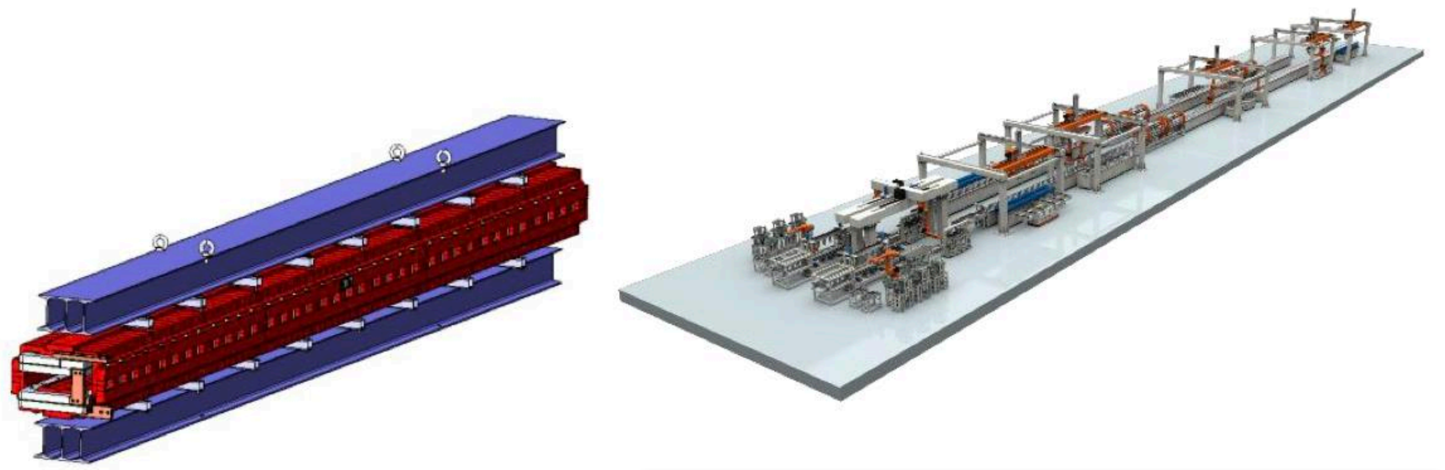
Figure 3. Layout of a automatic fabrication line for the vacuum chamber NEG coating

PROJECT: CEPC

CepC
https://indico.cern.ch/event/1439855/contributions/6461561/

Demonstrating readiness

- Forthcoming EDR
  - "Prepare CepC for delivery"



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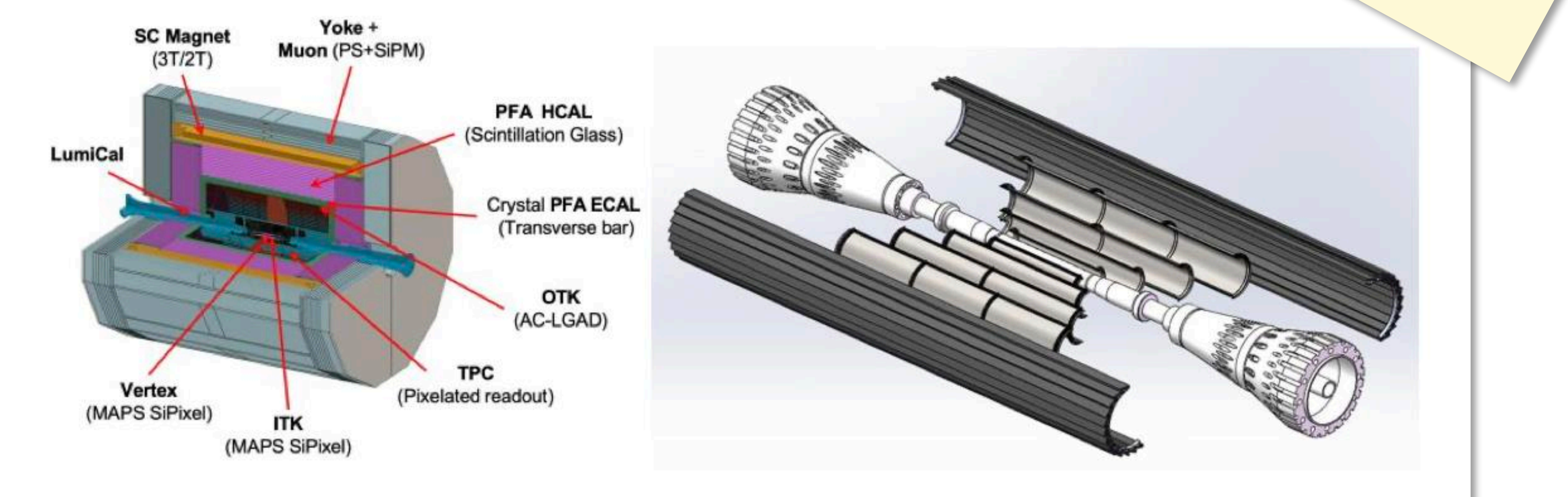

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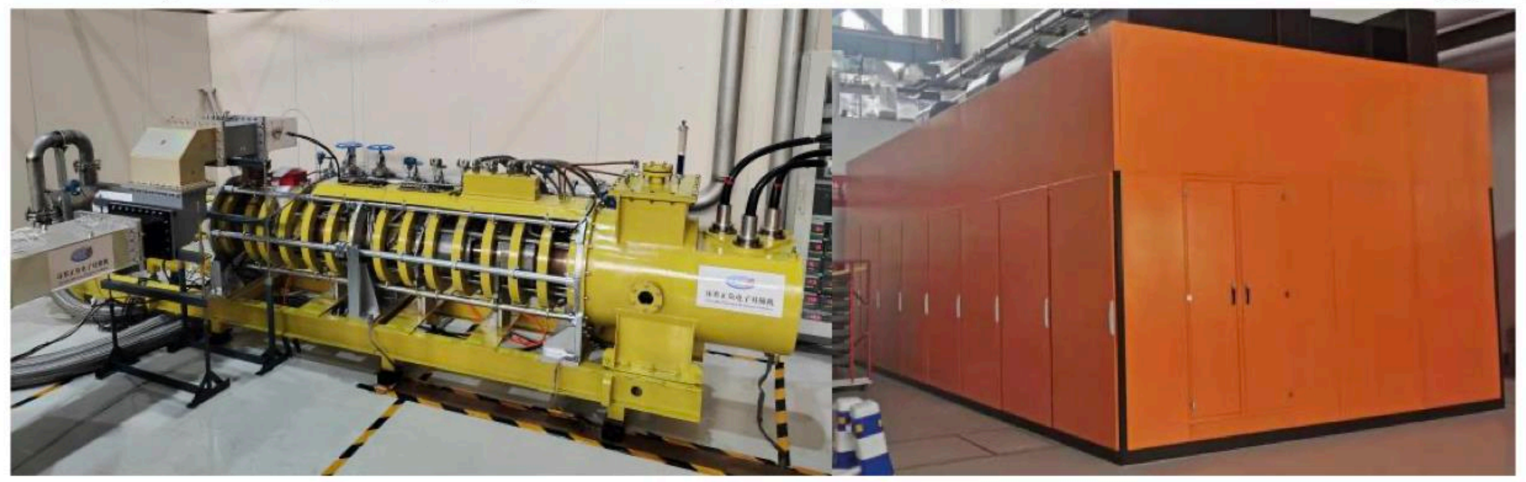

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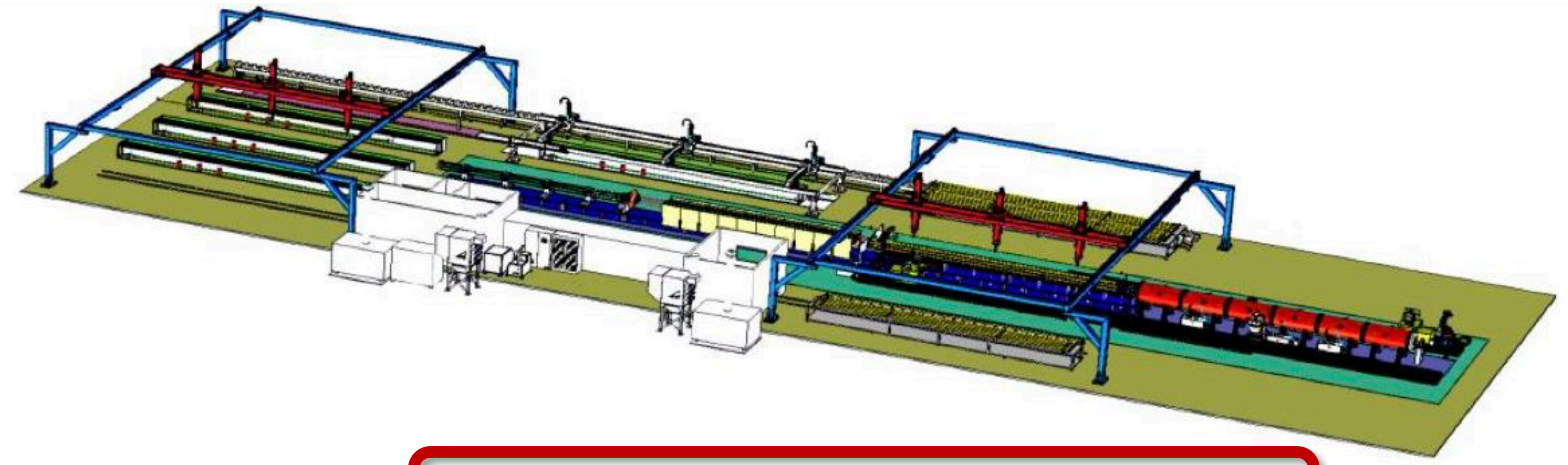
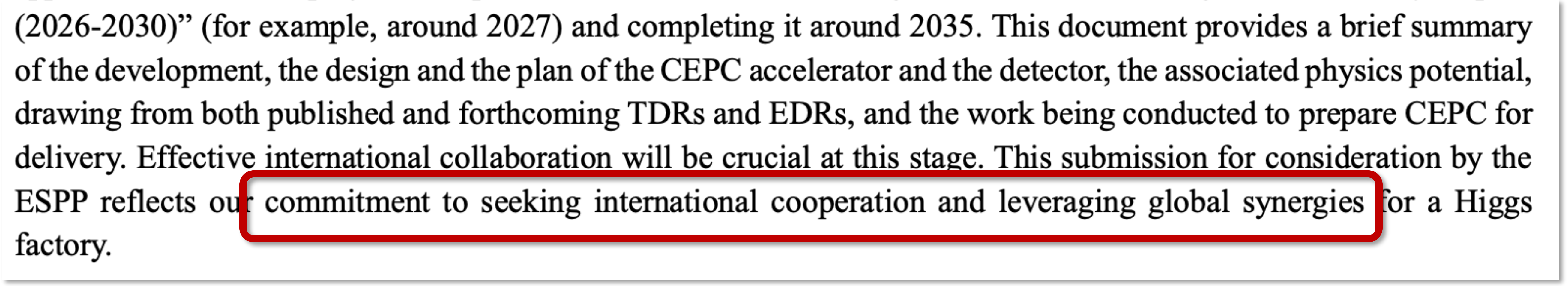


Figure 3. Layout of an automatic fabrication line for the vacuum chamber NEG coating

CepC submission for ESPP:

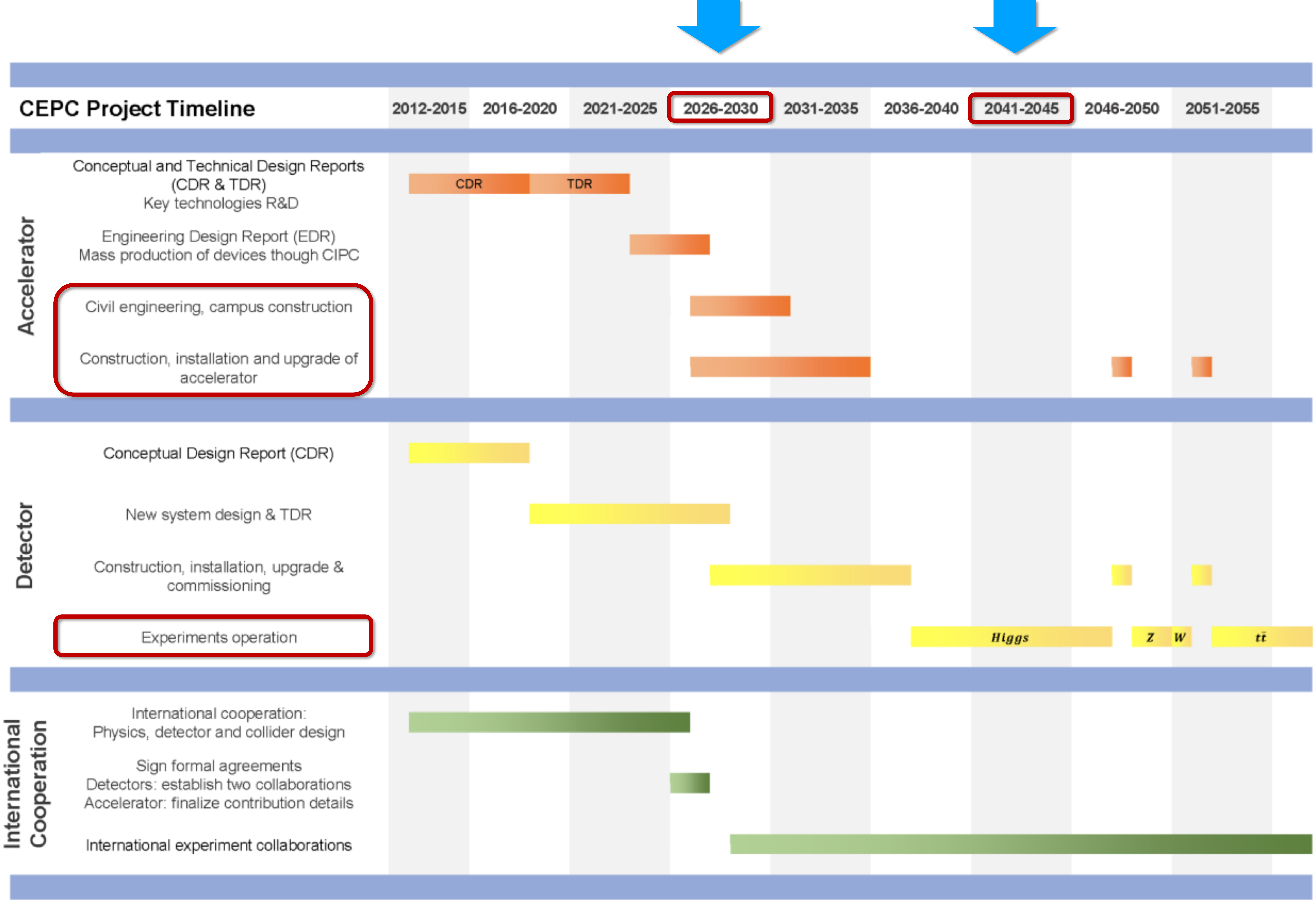
- "Seeking international cooperation"



(2026-2030)" (for example, around 2027) and completing it around 2035. This document provides a brief summary of the development, the design and the plan of the CEPC accelerator and the detector, the associated physics potential, drawing from both published and forthcoming TDRs and EDRs, and the work being conducted to prepare CEPC for delivery. Effective international collaboration will be crucial at this stage. This submission for consideration by the ESPP reflects our commitment to seeking international cooperation and leveraging global synergies for a Higgs factory.

CEPC

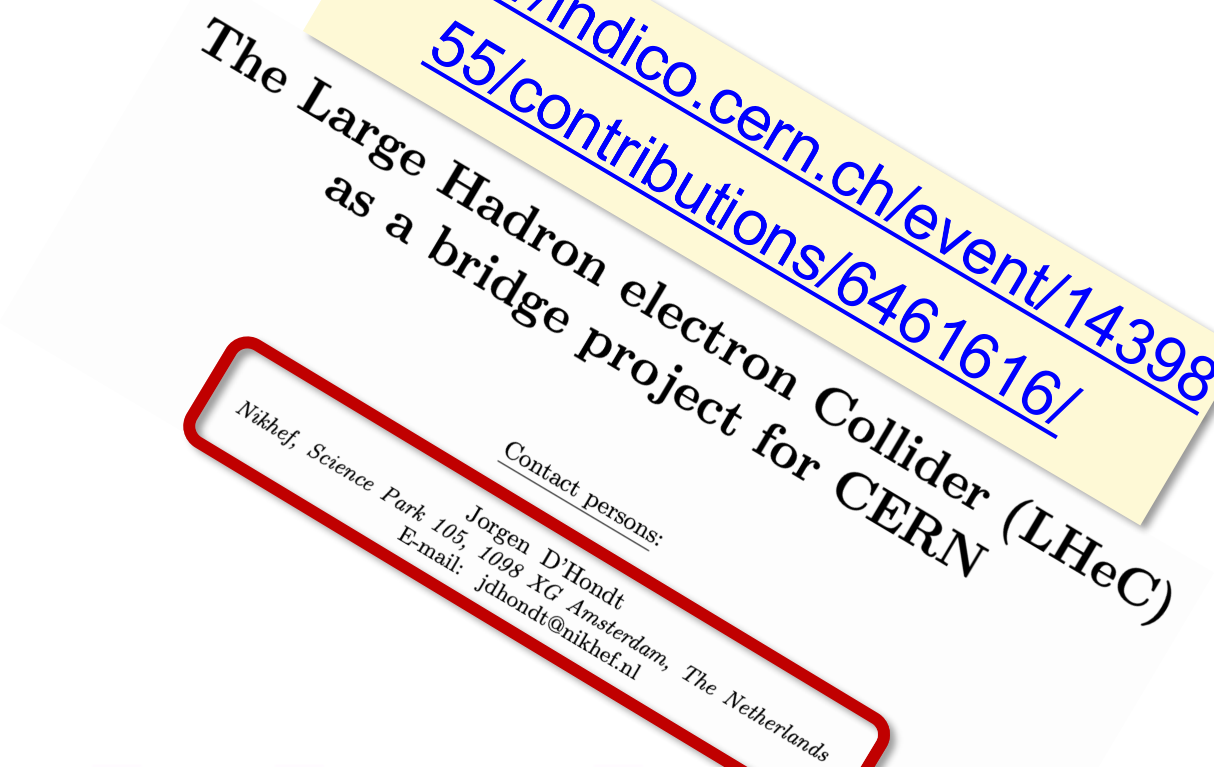
Timeline



LHC → LHeC

LHEC: PHYSICS

https://indico.cern.ch/event/14398
55/contributions/6461616/



**The Large Hadron electron Collider (LHeC)
as a bridge project for CERN**

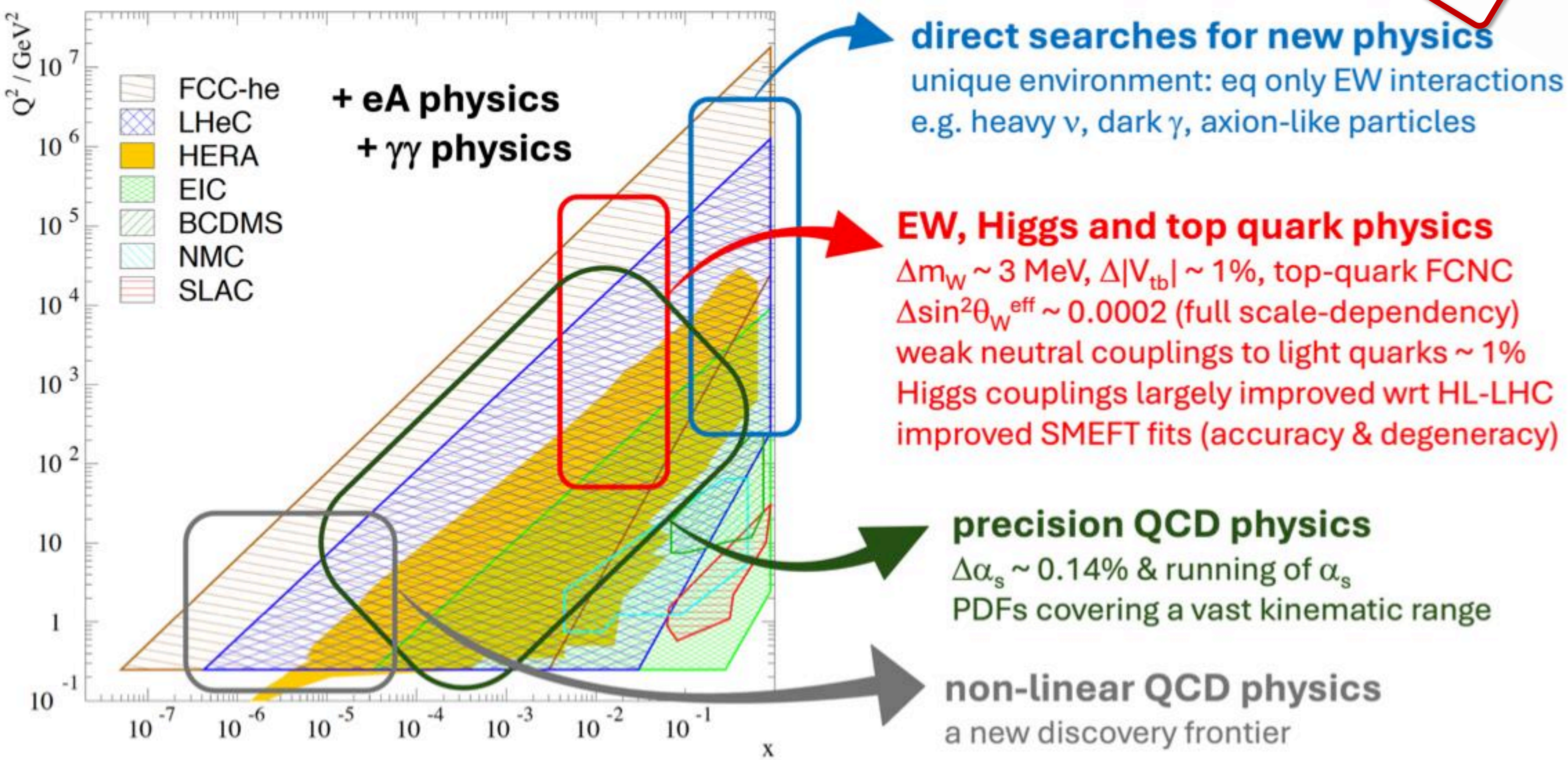
Contact persons:

Jorgen D'Hondt
Nikhef, Science Park 105, 1098 XG Amsterdam, The Netherlands
E-mail: jdhondt@nikhef.nl

LHC + electron beam

- 1.2 TeV e-p
  - 50 GeV e$^-$
- Broad physics
  - QCD, PDFs
  - Some BSM
  - EW+Higgs+t

Develop ERL



direct searches for new physics
unique environment: eq only EW interactions
e.g. heavy ν, dark γ, axion-like particles

EW, Higgs and top quark physics
$\Delta m_W \sim 3$ MeV, $\Delta|V_{tb}| \sim 1\%$, top-quark FCNC
$\Delta \sin^2\theta_W^{eff} \sim 0.0002$ (full scale-dependency)
weak neutral couplings to light quarks ~ 1%
Higgs couplings largely improved wrt HL-LHC
improved SMEFT fits (accuracy & degeneracy)

precision QCD physics
$\Delta\alpha_s \sim 0.14\%$ & running of α_s
PDFs covering a vast kinematic range

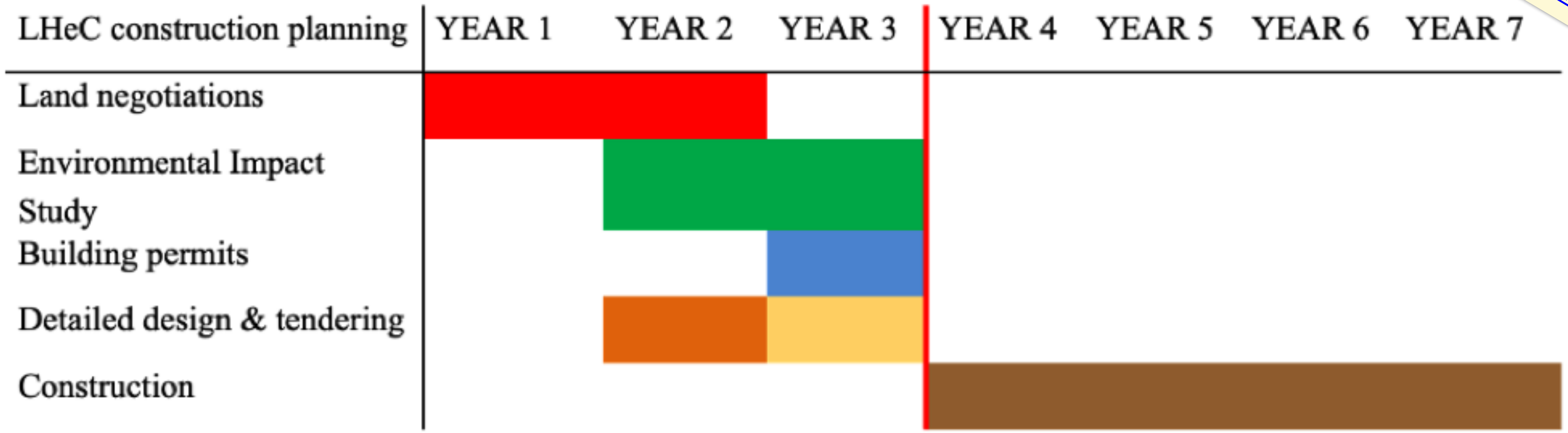
non-linear QCD physics
a new discovery frontier

LHEC: TIMELINE

LHeC
https://indico.cern.ch/event/1439855/contributions/6461616/

Start after HL-LHC

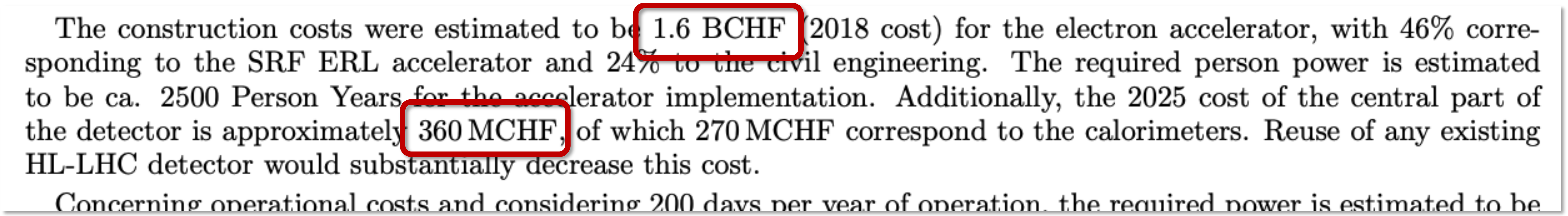
- 2044-2046
- 2048-2050
  - Bridge to future
  - E.g. LHC-FCC



LHeC construction planning	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7
Land negotiations	🟥	🟥					
Environmental Impact Study		🟩	🟩				
Building permits			🟦				
Detailed design & tendering		🟧	🟨				
Construction				🟫	🟫	🟫	🟫

Reasonable cost

- <2 BCHF
  - ERL



The construction costs were estimated to be 1.6 BCHF (2018 cost) for the electron accelerator, with 46% corresponding to the SRF ERL accelerator and 24% to the civil engineering. The required person power is estimated to be ca. 2500 Person Years for the accelerator implementation. Additionally, the 2025 cost of the central part of the detector is approximately 360 MCHF, of which 270 MCHF correspond to the calorimeters. Reuse of any existing HL-LHC detector would substantially decrease this cost.

Concerning operational costs and considering 200 days per year of operation, the required power is estimated to be

MANY OTHER PROJECTS AND SUBMISSIONS…

Astroparticle

Accelerators

Computing

Detectors

Magnets

Theory

Etc…

EuCAIF Recommendations for Scaling AI Capabilities in Particle Physics

Higgs Criticality and the Metastability Bound:
a target for future colliders

Magnet R&D for the Muon Collider
European Strategy Input

A Spin-Based Pathway to Testing the Quantum Nature of Gravity

Community input to the European Strategy on particle physics:
Searches for Permanent Electric Dipole Moments

Discovery potential
of LHCb Upgrade II

ATLAS Software and Computing for the Future

XLZD:
The low-background observatory
for astroparticle physics

Einstein Telescope - The future European Gravitational Wave Observatory

Synergies and complementariness with the High Energy Particle Physics

Midterm Review of the European
Accelerator R&D Roadmap

THE FORWARD PHYSICS FACILITY AT THE
LARGE HADRON COLLIDER

ESPP Contribution - Gravitational Field of Proton Bunches

Constraining the real scalar singlet extension of the SM

Light Ion Collisions at the LHC

Input to the European Strategy for Particle Physics- 2026 update.
APPEC, March 2025

High Field Magnet Programme – European Strategy Input

Phase-One LHeC

A Straw Tracker for an FCC-ee experiment

Proton-Driven Plasma Wakefield Acceleration
for Future HEP Colliders

Quantum Sensing for Dark Matter and Gravitational Waves

European Strategy for Particle Physics 2026:
Frontier sensor R&D for the ALICE 3 apparatus

Computer Algebra for Precision Calculations in Particle Physics:
the FORM project

Countering the biodiversity loss using particle physics research sites

KM3NeT contribution to the European Strategy for Particle Physics

PART II: PLANS & VISIONS

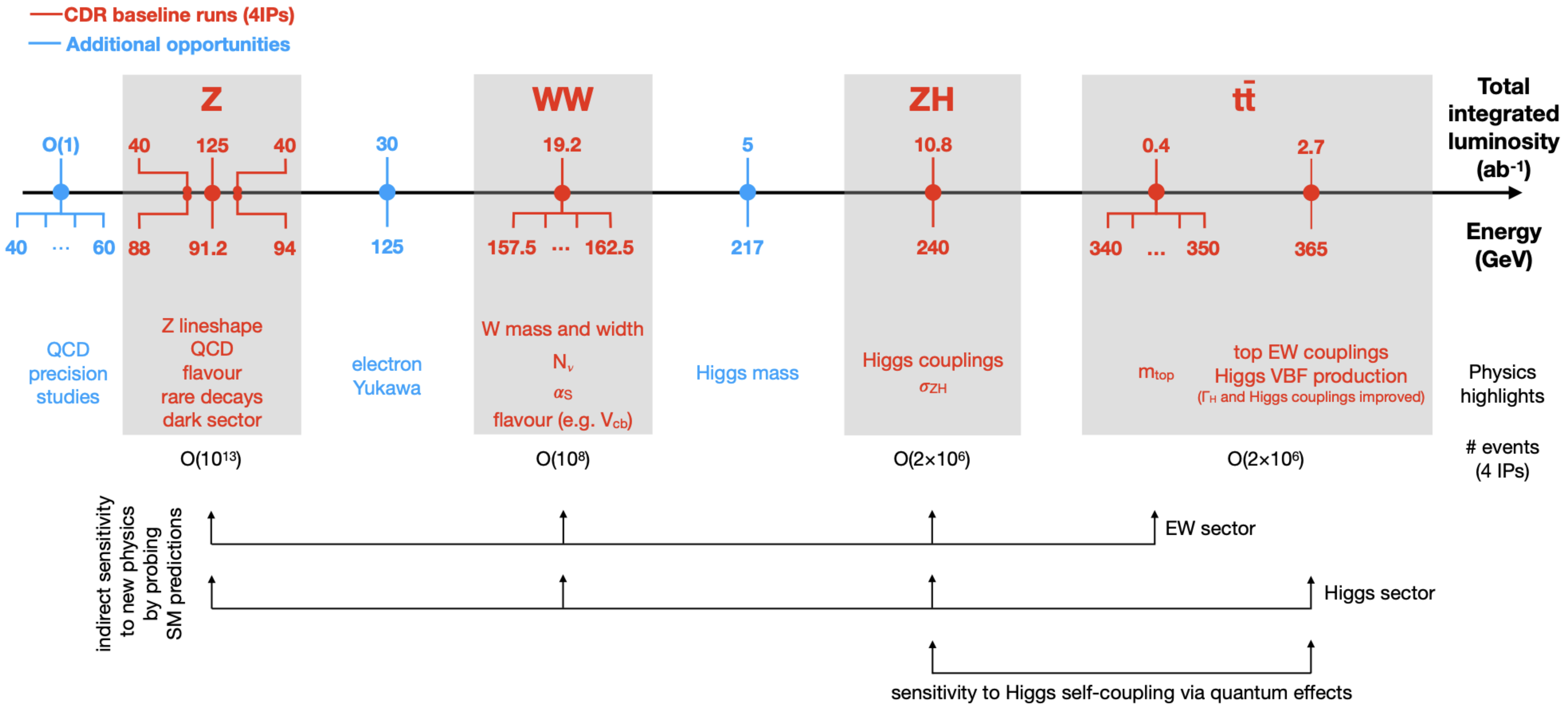
SCENARIO #1: FCC

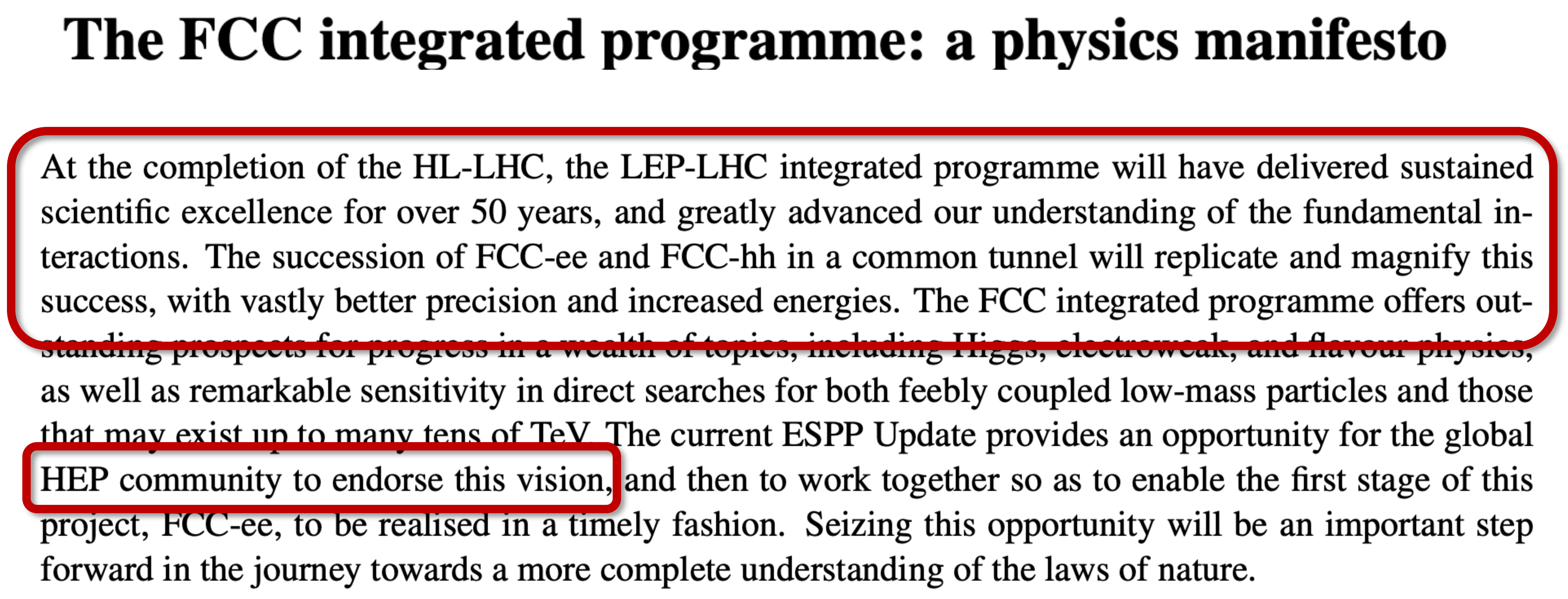
FCC integrated programme
https://indico.cern.ch/event/1439855/contributions/6461657/

FUTURE CIRCULAR COLLIDER

"Vanilla CERN Plan"

- FCC-ee + FCC-hh
  - 2050 – 2100





The FCC integrated programme: a physics manifesto

At the completion of the HL-LHC, the LEP-LHC integrated programme will have delivered sustained scientific excellence for over 50 years, and greatly advanced our understanding of the fundamental interactions. The succession of FCC-ee and FCC-hh in a common tunnel will replicate and magnify this success, with vastly better precision and increased energies. The FCC integrated programme offers outstanding prospects for progress in a wealth of topics, including Higgs, electroweak, and flavour physics, as well as remarkable sensitivity in direct searches for both feebly coupled low-mass particles and those that may exist up to many tens of TeV. The current ESPP Update provides an opportunity for the global HEP community to endorse this vision, and then to work together so as to enable the first stage of this project, FCC-ee, to be realised in a timely fashion. Seizing this opportunity will be an important step forward in the journey towards a more complete understanding of the laws of nature.

PART IIB: PLANS & VISION

SCENARIO #2: “LC VISION”

LC Vision
https://indico.cern.ch/event/14398
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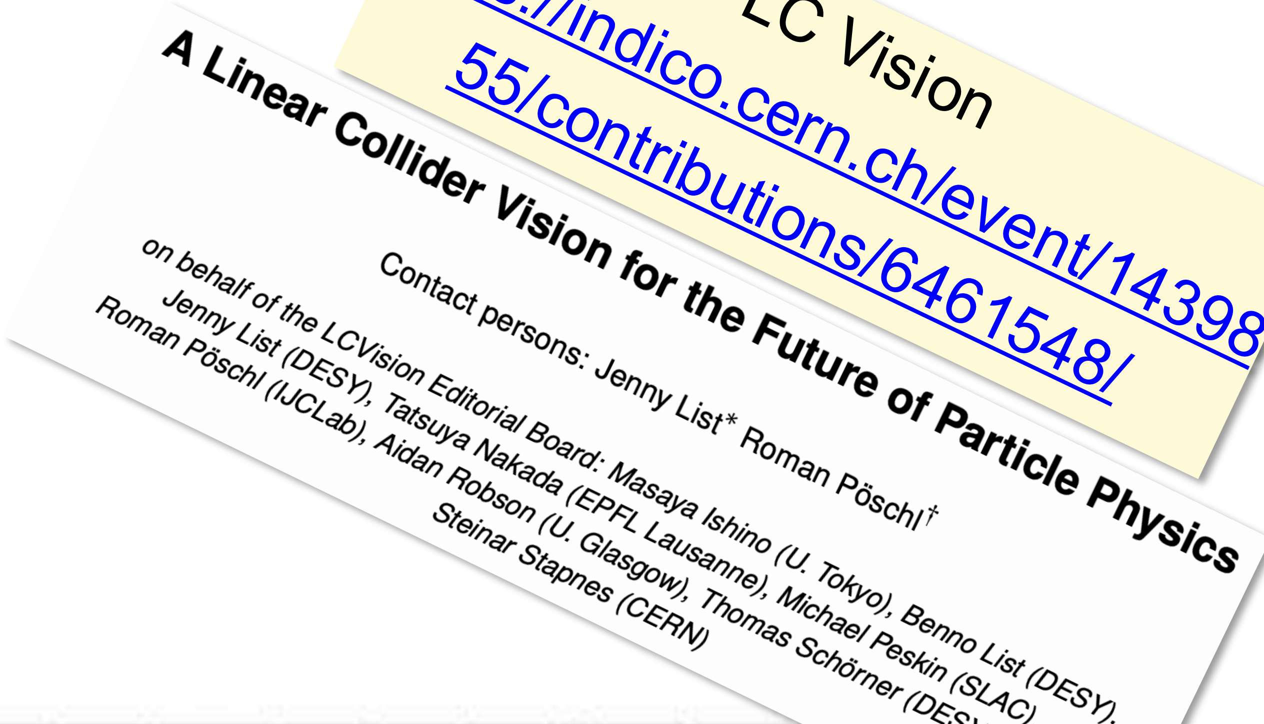


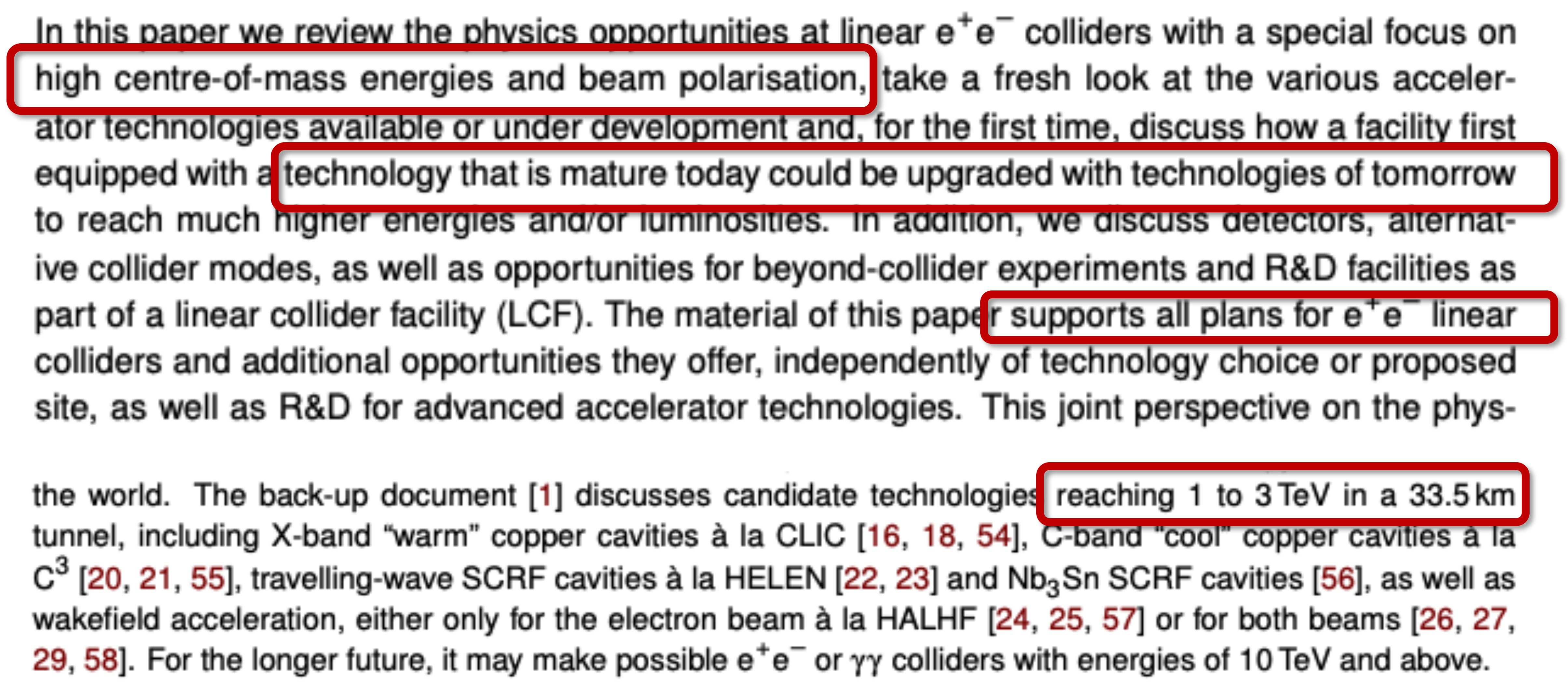
A Linear Collider Vision for the Future of Particle Physics

Contact persons: Jenny List* Roman Pöschl†

on behalf of the LCVision Editorial Board: Masaya Ishino (U. Tokyo), Benno List (DESY),
Jenny List (DESY), Tatsuya Nakada (EPFL Lausanne), Michael Peskin (SLAC),
Roman Pöschl (IJCLab), Aidan Robson (U. Glasgow), Thomas Schörner (DESY/CERN),
Steinar Stapnes (CERN)

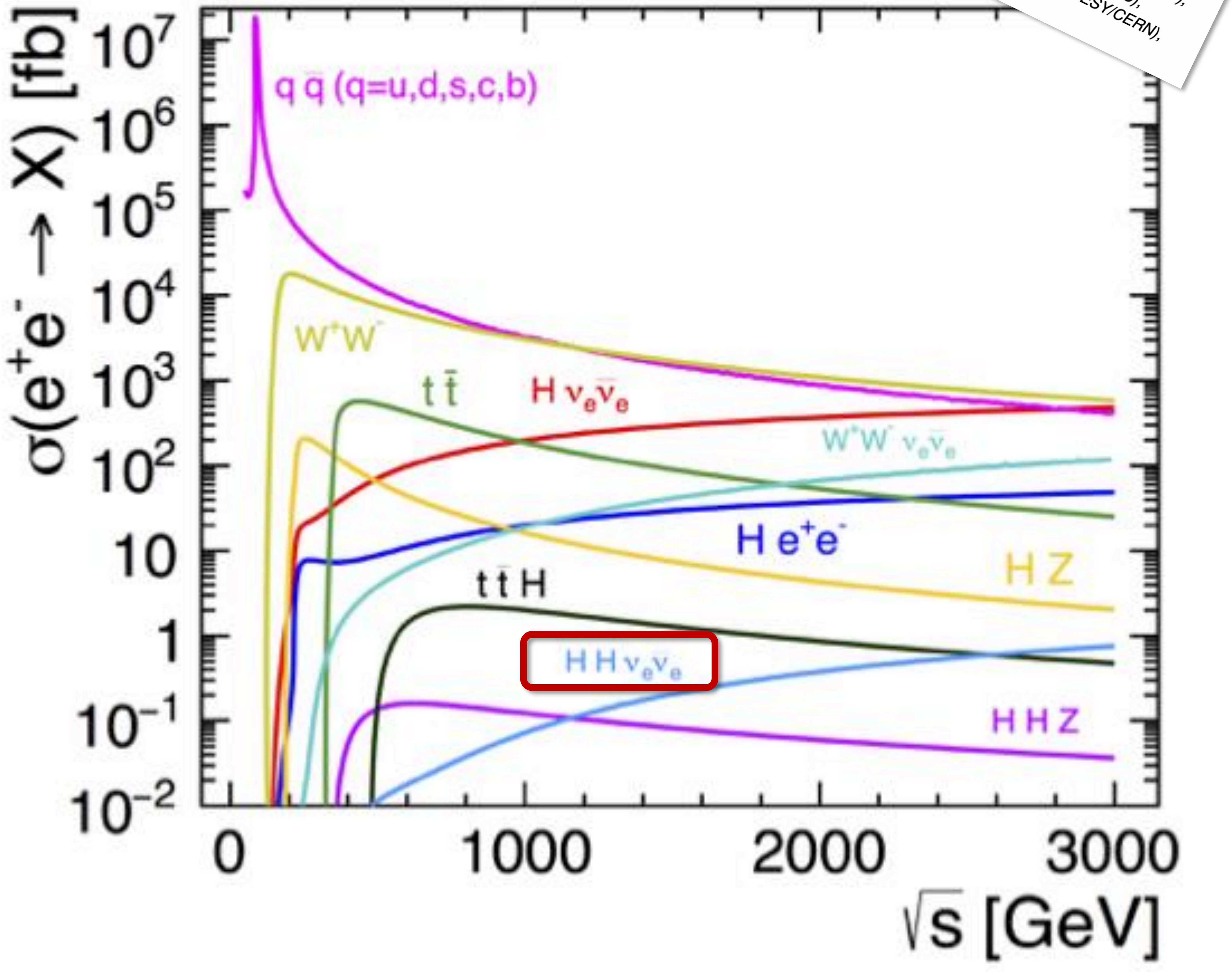
Linear collider vision

- Staged energy increase, λ~10%
  - Unite international LC community

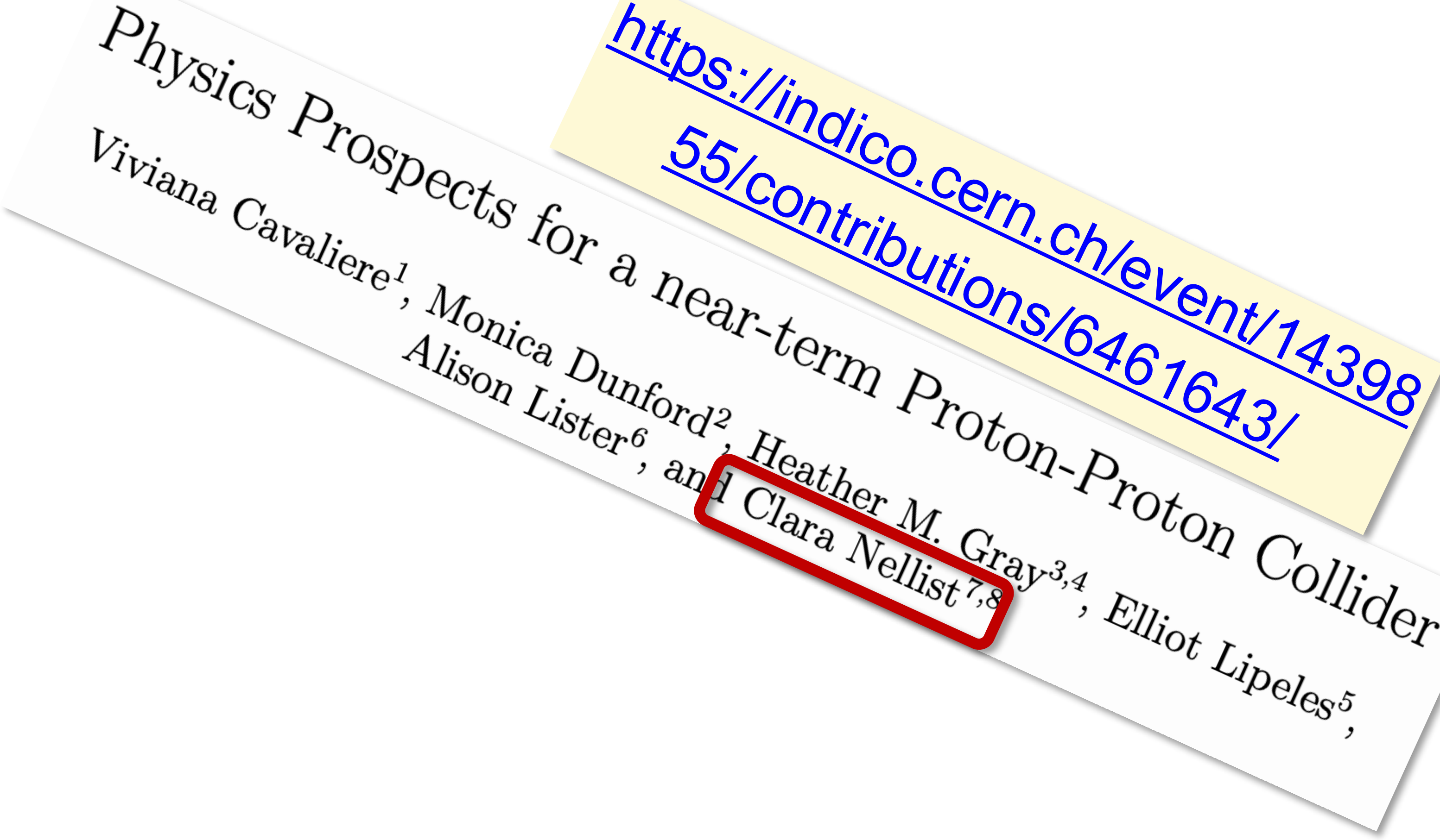


In this paper we review the physics opportunities at linear e^+e^- colliders with a special focus on high centre-of-mass energies and beam polarisation, take a fresh look at the various accelerator technologies available or under development and, for the first time, discuss how a facility first equipped with a technology that is mature today could be upgraded with technologies of tomorrow to reach much higher energies and/or luminosities. In addition, we discuss detectors, alternative collider modes, as well as opportunities for beyond-collider experiments and R&D facilities as part of a linear collider facility (LCF). The material of this paper supports all plans for e^+e^- linear colliders and additional opportunities they offer, independently of technology choice or proposed site, as well as R&D for advanced accelerator technologies. This joint perspective on the phys-

the world. The back-up document [1] discusses candidate technologies reaching 1 to 3 TeV in a 33.5 km tunnel, including X-band “warm” copper cavities à la CLIC [16, 18, 54], C-band “cool” copper cavities à la C^3 [20, 21, 55], travelling-wave SCRF cavities à la HELEN [22, 23] and Nb_3Sn SCRF cavities [56], as well as wakefield acceleration, either only for the electron beam à la HALHF [24, 25, 57] or for both beams [26, 27, 29, 58]. For the longer future, it may make possible e^+e^- or γγ colliders with energies of 10 TeV and above.



SCENARIO #3: EARLY FCC-HH



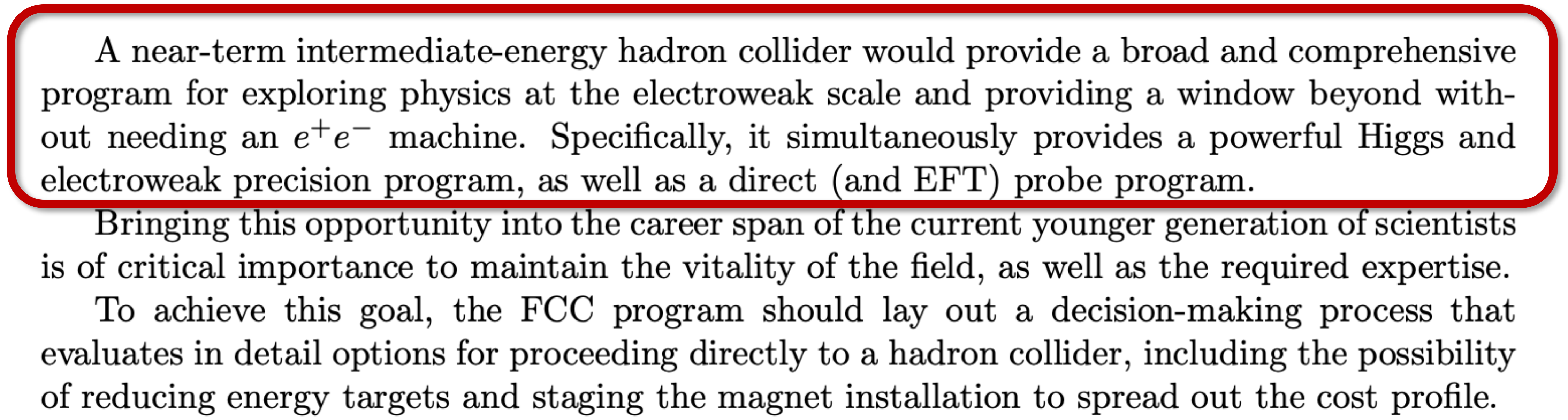
https://indico.cern.ch/event/1439855/contributions/6461643/

Physics Prospects for a near-term Proton-Proton Collider

Viviana Cavaliere[1], Monica Dunford[2], Heather M. Gray[3,4], Elliot Lipeles[5], Alison Lister[6], and Clara Nellist[7,8]

Near-term FCC-hh @ 50-70 TeV

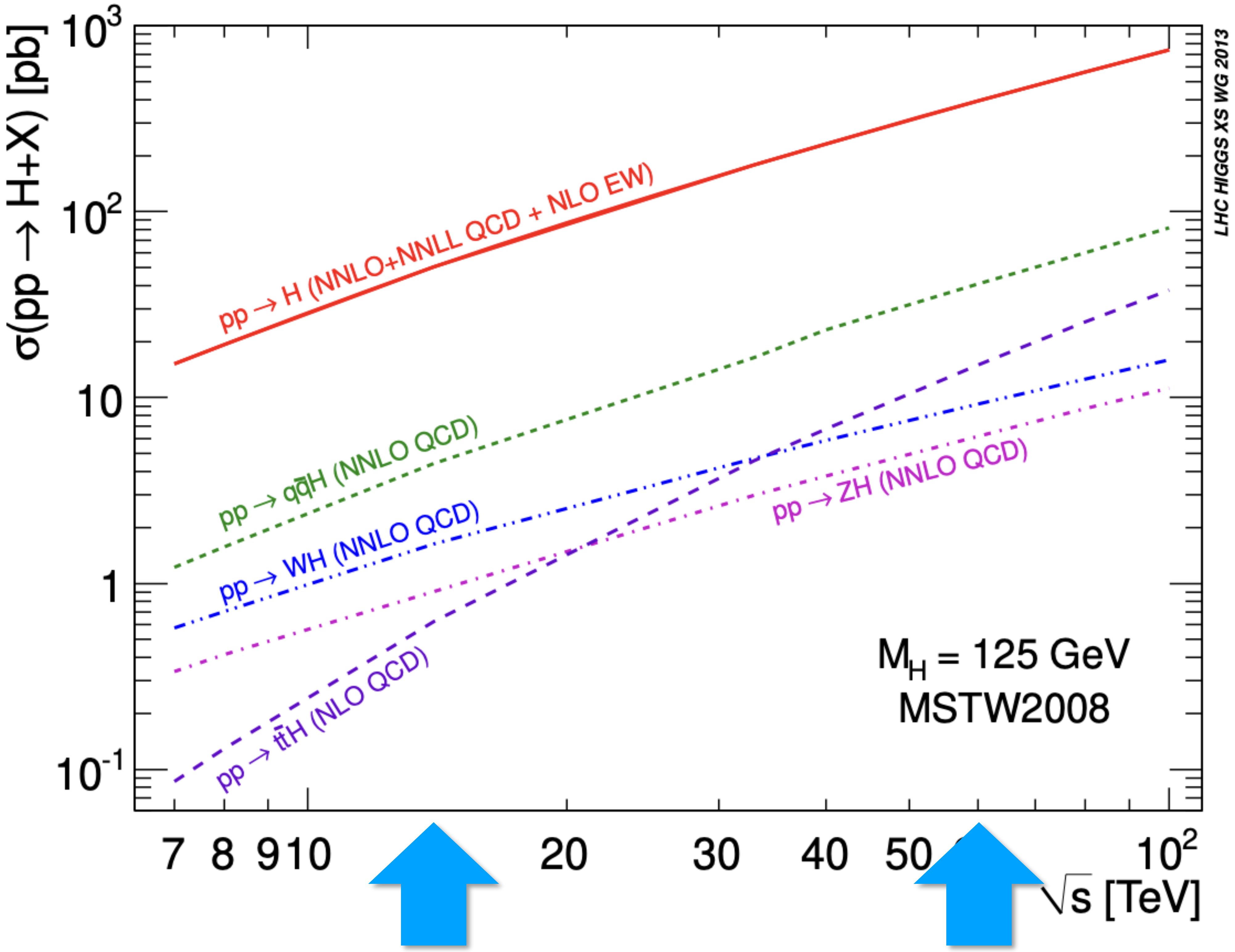
- Physics motivation
  - BSM reach
  - SM production
- Alternative shorter timescale



A near-term intermediate-energy hadron collider would provide a broad and comprehensive program for exploring physics at the electroweak scale and providing a window beyond without needing an e^+e^- machine. Specifically, it simultaneously provides a powerful Higgs and electroweak precision program, as well as a direct (and EFT) probe program.

Bringing this opportunity into the career span of the current younger generation of scientists is of critical importance to maintain the vitality of the field, as well as the required expertise.

To achieve this goal, the FCC program should lay out a decision-making process that evaluates in detail options for proceeding directly to a hadron collider, including the possibility of reducing energy targets and staging the magnet installation to spread out the cost profile.

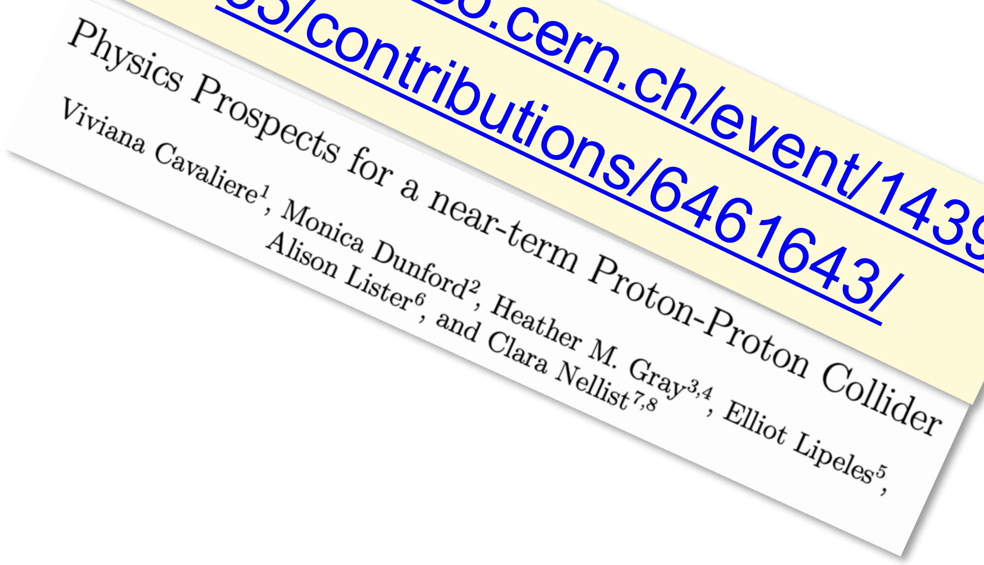


From here…

…to here?

SCENARIO #3: EARLY FCC-HH

https://indico.cern.ch/event/1439855/contributions/6461643/

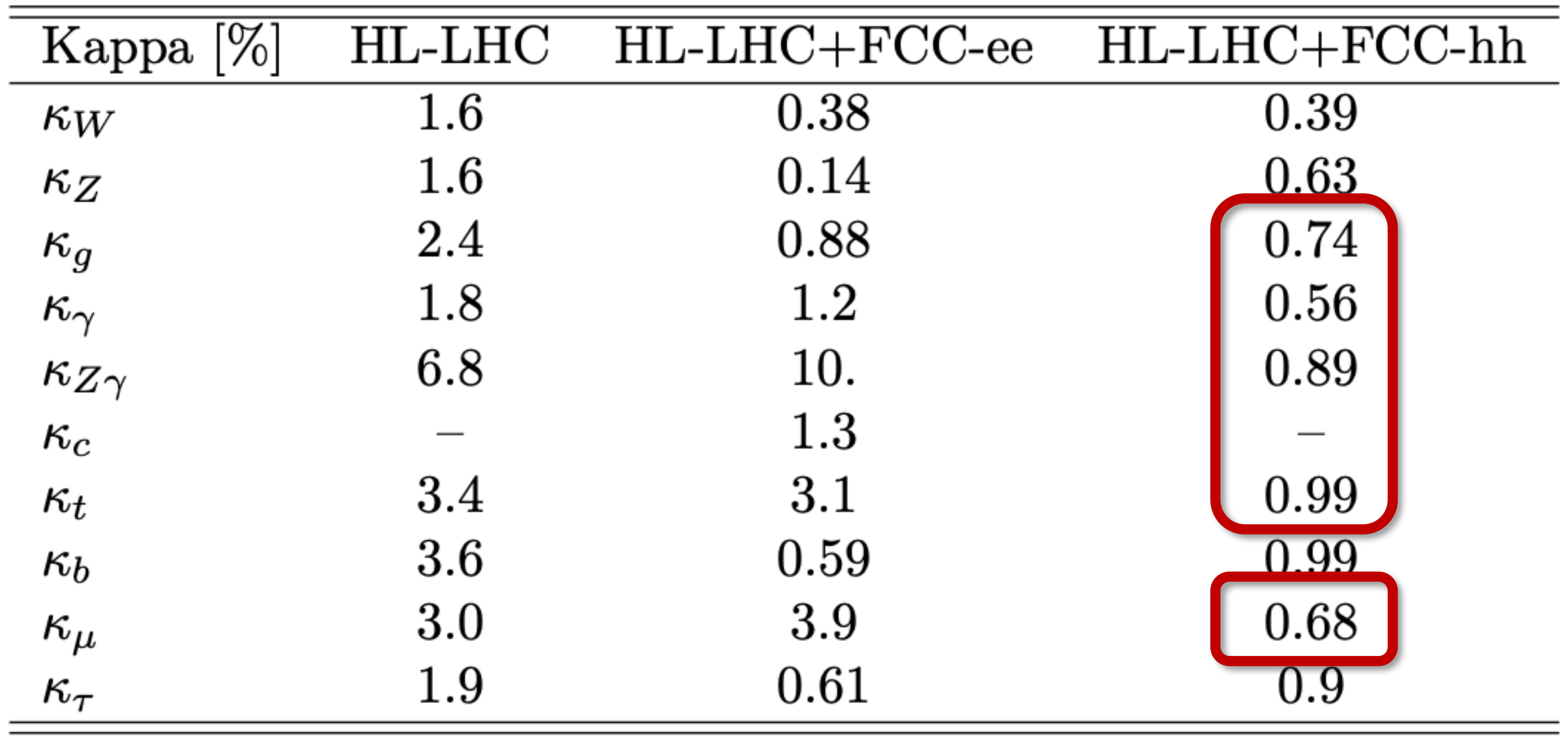


Physics Prospects for a near-term Proton-Proton Collider

Viviana Cavaliere[1], Monica Dunford[2], Heather M. Gray[3,4], Elliot Lipeles[5], Alison Lister[6], and Clara Nellist[7,8]

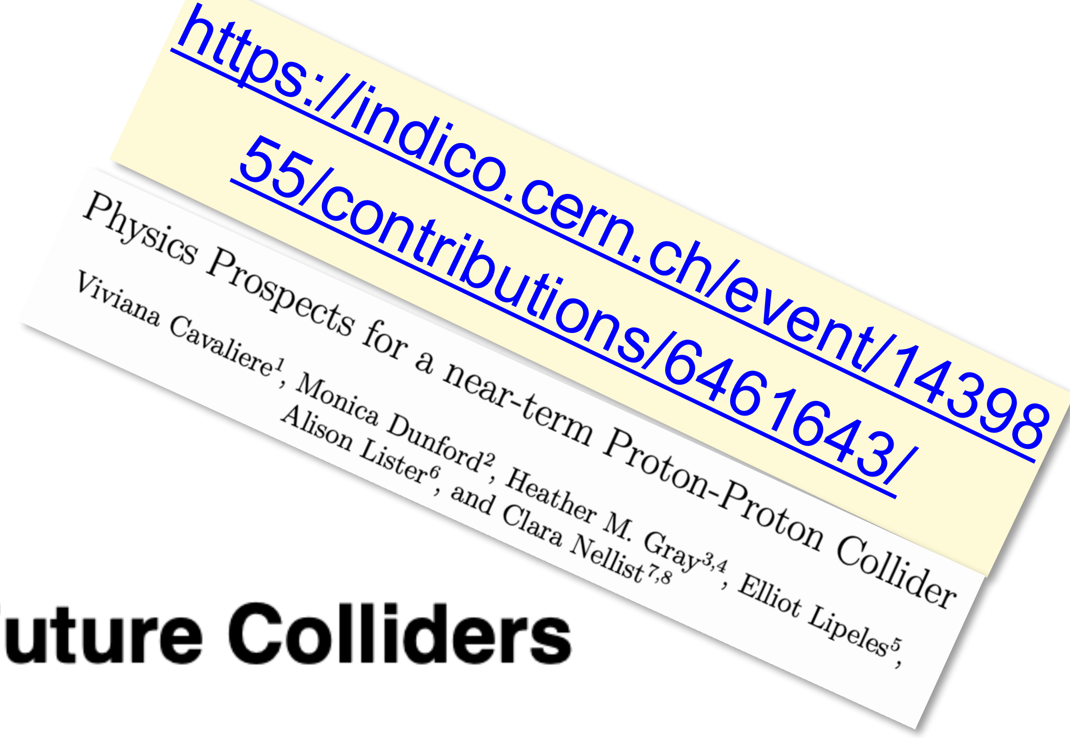
FCC-hh: SM, BSM and HH

- Excellent SM Higgs physics
  - Very competitive with FCC-ee!



Kappa [%]	HL-LHC	HL-LHC+FCC-ee	HL-LHC+FCC-hh
κ_W	1.6	0.38	0.39
κ_Z	1.6	0.14	0.63
κ_g	2.4	0.88	0.74
κ_γ	1.8	1.2	0.56
$\kappa_{Z\gamma}$	6.8	10.	0.89
κ_c	–	1.3	–
κ_t	3.4	3.1	0.99
κ_b	3.6	0.59	0.99
κ_μ	3.0	3.9	0.68
κ_τ	1.9	0.61	0.9

SCENARIO #3: EARLY FCC-HH



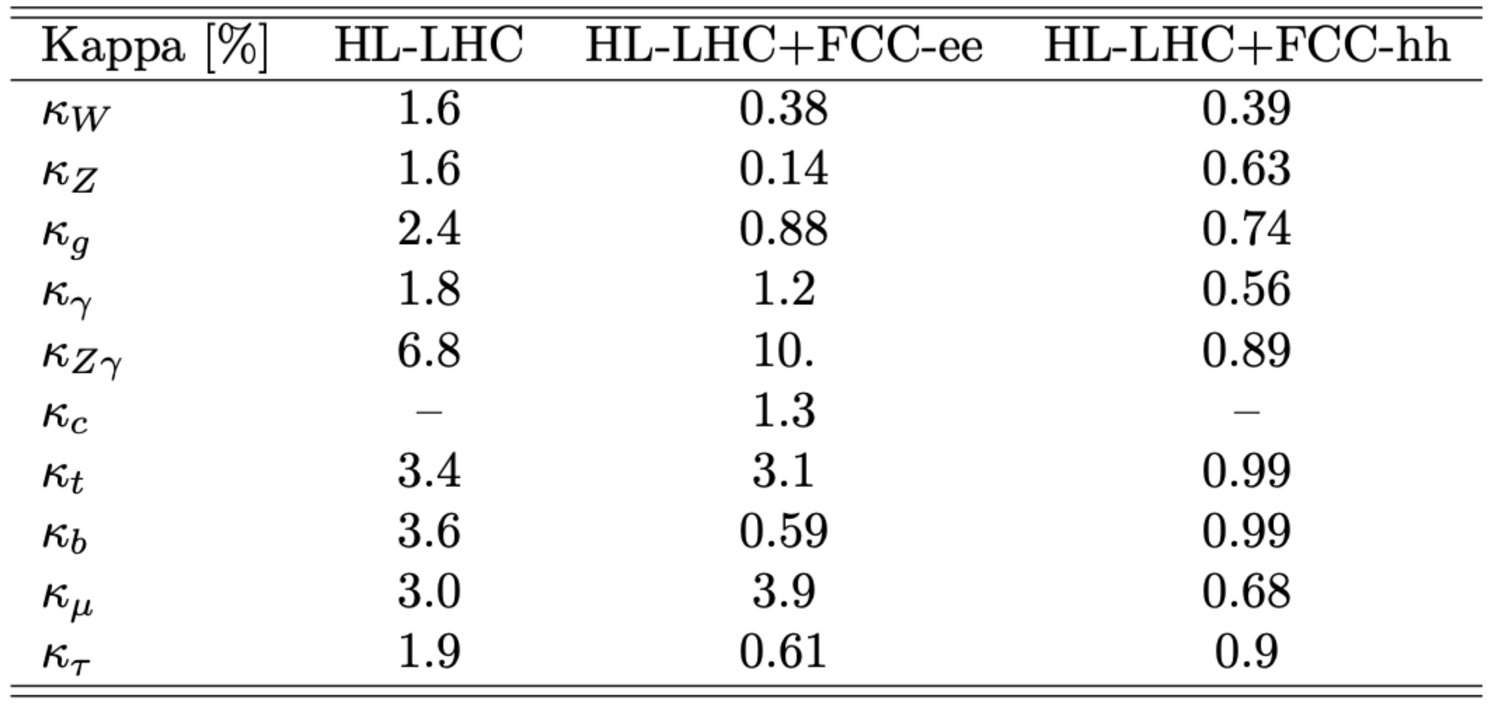
https://indico.cern.ch/event/1439855/contributions/6461643/

Physics Prospects for a near-term Proton-Proton Collider

Viviana Cavaliere[1], Monica Dunford[2], Heather M. Gray[3,4], Elliot Lipeles[5],
Alison Lister[6], and Clara Nellist[7,8]

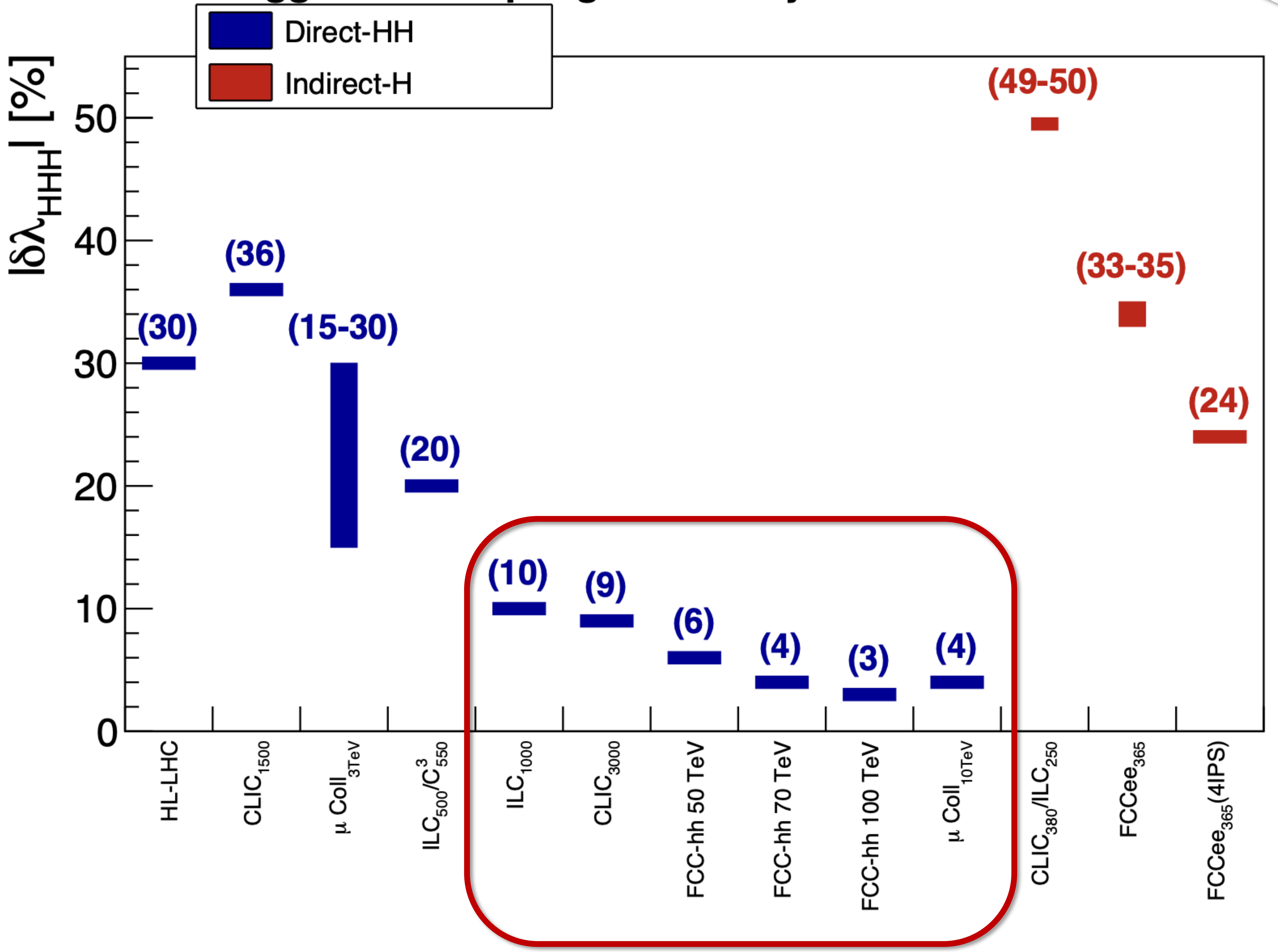
FCC-hh: SM, BSM and HH

- Excellent SM Higgs physics
  - Self-coupling ~5%

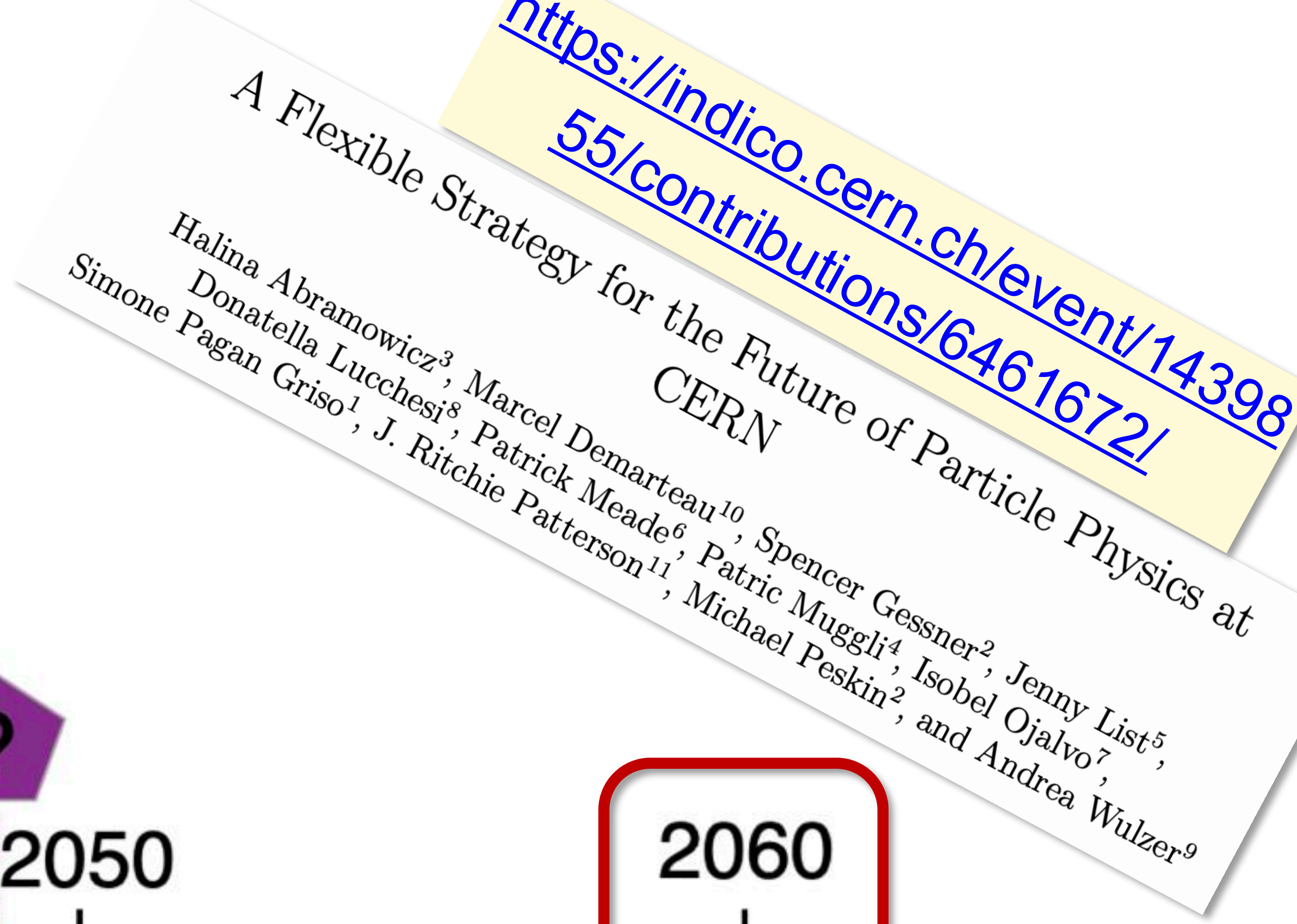


Kappa [%]	HL-LHC	HL-LHC+FCC-ee	HL-LHC+FCC-hh
κ_W	1.6	0.38	0.39
κ_Z	1.6	0.14	0.63
κ_g	2.4	0.88	0.74
κ_γ	1.8	1.2	0.56
$\kappa_{Z\gamma}$	6.8	10.	0.89
κ_c	–	1.3	–
κ_t	3.4	3.1	0.99
κ_b	3.6	0.59	0.99
κ_μ	3.0	3.9	0.68
κ_τ	1.9	0.61	0.9

Higgs Self-Coupling Sensitivity at Future Colliders



SCENARIO #4: LC + MUCOL

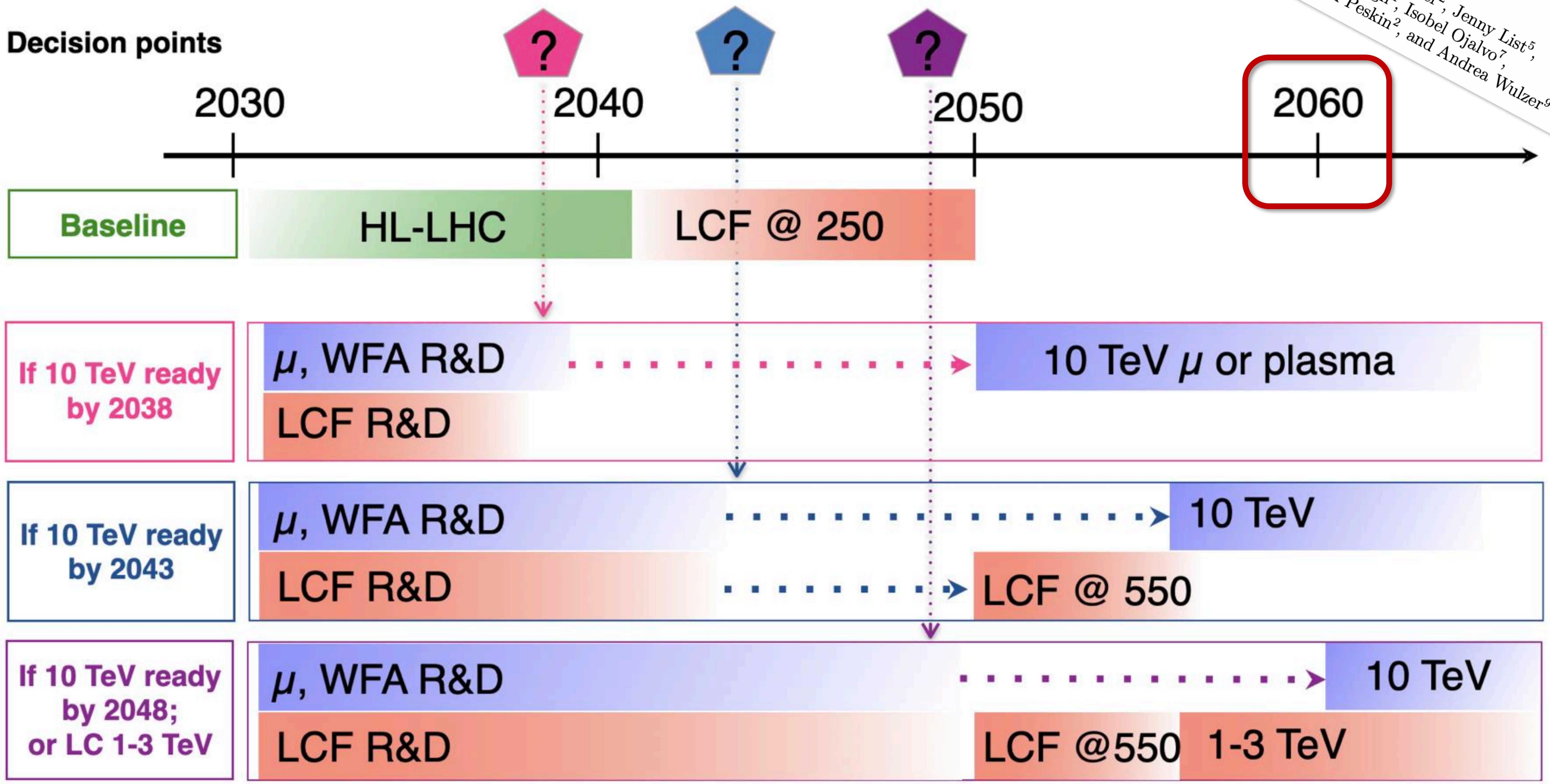

https://indico.cern.ch/event/14398
55/contributions/6461672/

A Flexible Strategy for the Future of Particle Physics at CERN

Halina Abramowicz[3], Marcel Demarteau[10], Spencer Gessner[2], Jenny List[5], Donatella Lucchesi[8], Patrick Meade[6], Patric Muggli[4], Isobel Ojalvo[7], Simone Pagan Griso[1], J. Ritchie Patterson[11], Michael Peskin[2], and Andrea Wulzer[9]

“A Flexible Strategy”

- Linear Collider
  - ZH & SM
- Muon Collider
  - HH & BSM


Decision points

?

?

?

2030

2040

2050

2060

Baseline

HL-LHC

LCF @ 250

If 10 TeV ready by 2038

μ, WFA R&D

10 TeV μ or plasma

LCF R&D

If 10 TeV ready by 2043

μ, WFA R&D

10 TeV

LCF R&D

LCF @ 550

If 10 TeV ready by 2048; or LC 1-3 TeV

μ, WFA R&D

10 TeV

LCF R&D

LCF @550

1-3 TeV

SCENARIO #N: LEP3

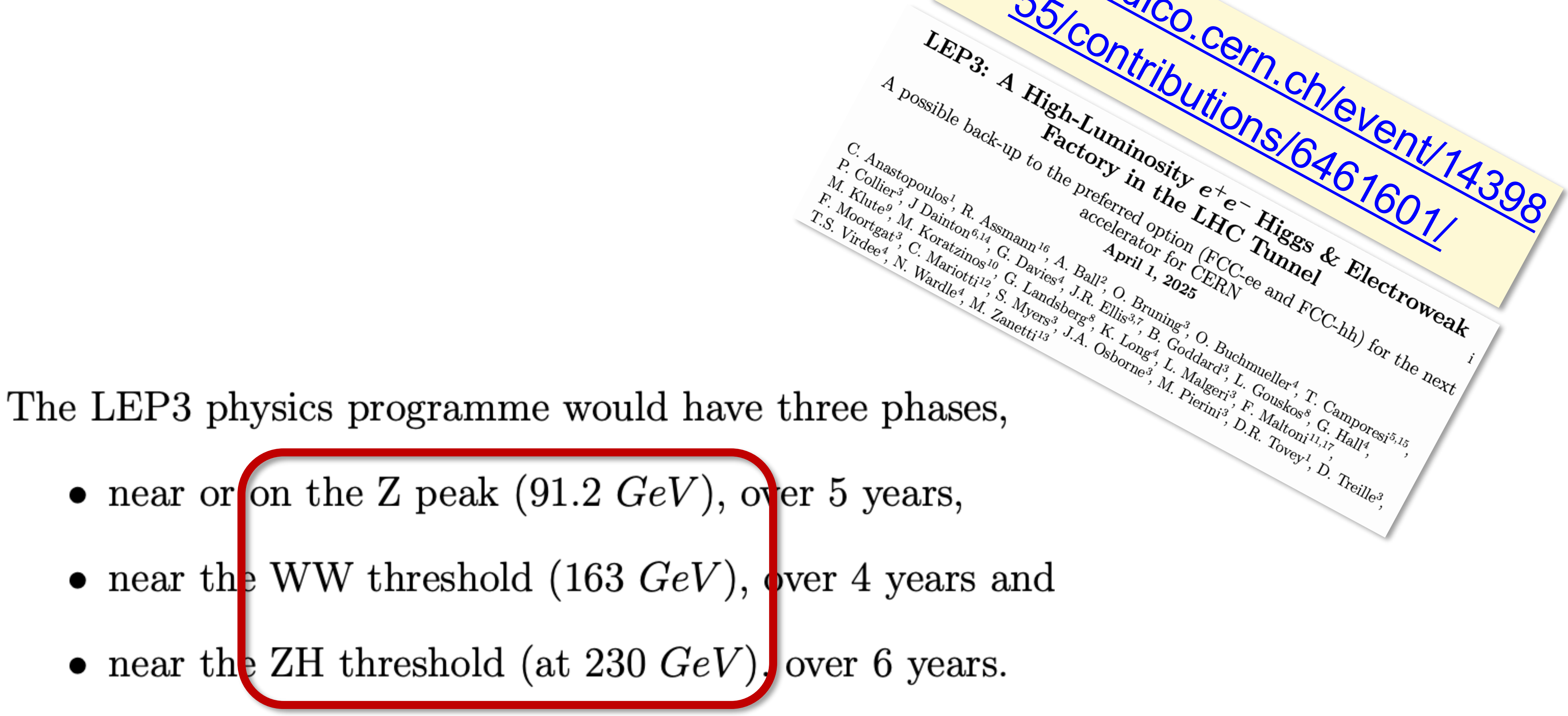
LEP3: e^+e^-

- Reuse tunnel from LEP/LHC
  - Like FCC-ee but Low-E & Low-Lumi

Proposal: 91-230 GeV

- Z / WW / ZH
  - Cost: >3 BCHF

https://indico.cern.ch/event/1439855/contributions/6461601/



LEP3: A High-Luminosity e^+e^- Higgs & Electroweak Factory in the LHC Tunnel

A possible back-up to the preferred option (FCC-ee and FCC-hh) for the next accelerator for CERN

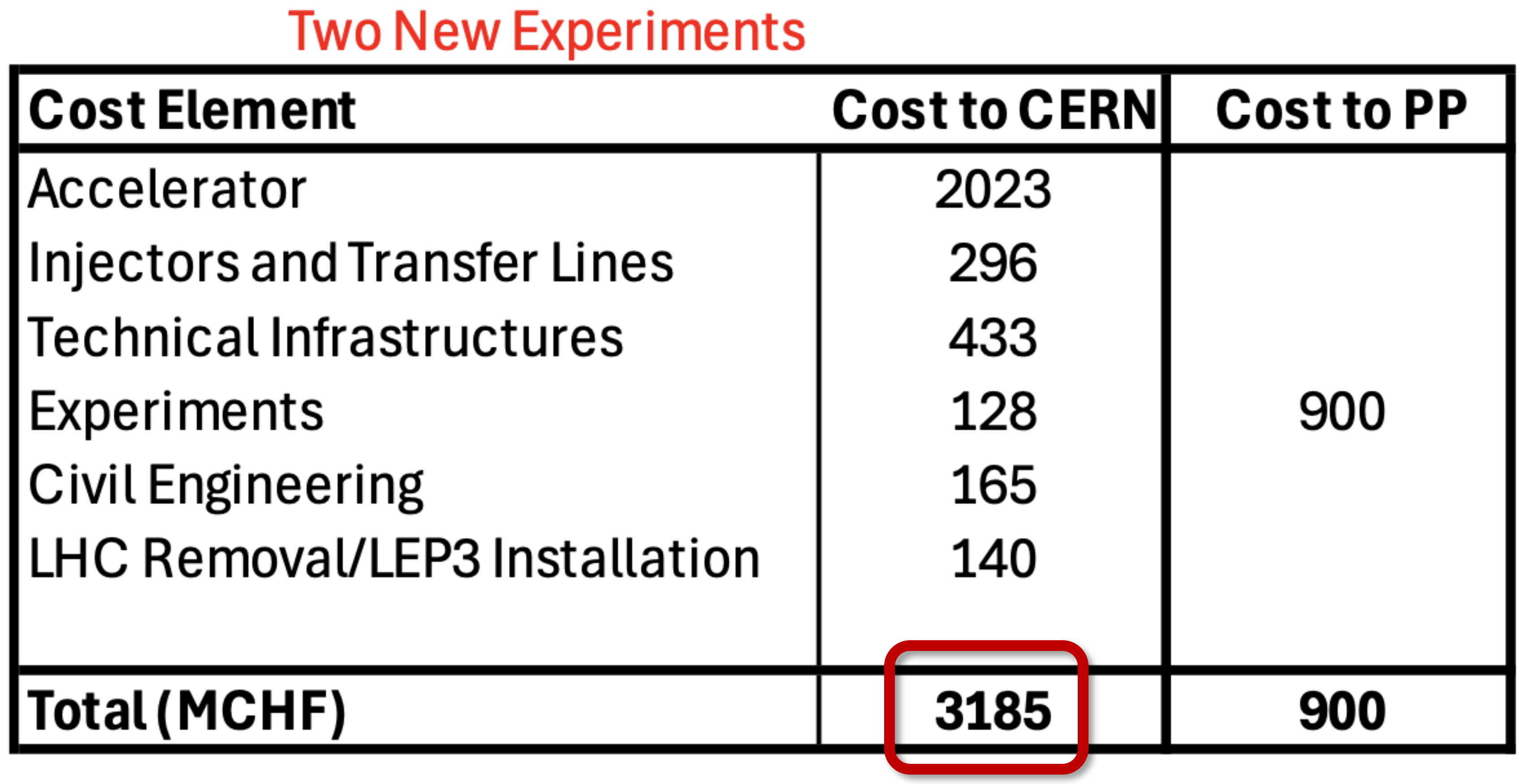
April 1, 2025

C. Anastopoulos[1], R. Assmann[16], A. Ball[2], O. Bruning[3], O. Buchmueller[4], T. Camporesi[5,15], P. Collier[3], J Dainton[6,14], G. Davies[4], J.R. Ellis[3,7], B. Goddard[3], L. Gouskos[8], G. Hall[4], M. Klute[9], M. Koratzinos[10], G. Landsberg[8], K. Long[4], L. Malgeri[3], F. Maltoni[11,17], F. Moortgat[3], C. Mariotti[12], S. Myers[3], J.A. Osborne[3], M. Pierini[3], D.R. Tovey[1], D. Treille[3], T.S. Virdee[4], N. Wardle[4], M. Zanetti[13]

i

The LEP3 physics programme would have three phases,

- near or on the Z peak (91.2 GeV), over 5 years,
- near the WW threshold (163 GeV), over 4 years and
- near the ZH threshold (at 230 GeV), over 6 years.



Two New Experiments

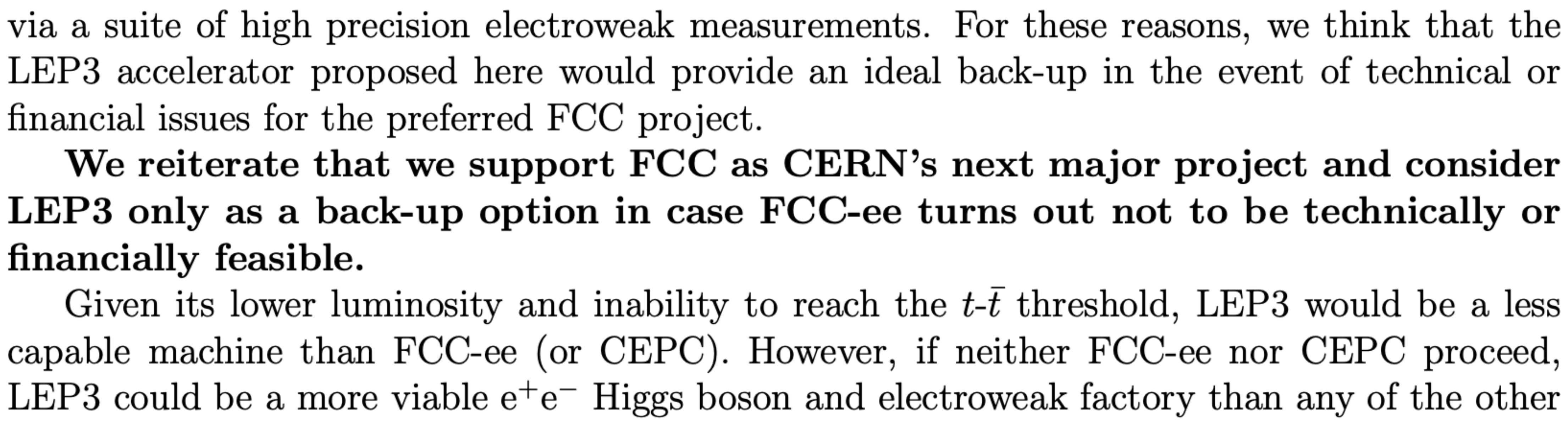
Cost Element	Cost to CERN	Cost to PP
Accelerator	2023	
Injectors and Transfer Lines	296	
Technical Infrastructures	433	
Experiments	128	900
Civil Engineering	165	
LHC Removal/LEP3 Installation	140	
Total (MCHF)	**3185**	**900**

SCENARIO #N: LEP3

LEP3
https://indico.cern.ch/event/1439855/contributions/6461601/

Limited physics case

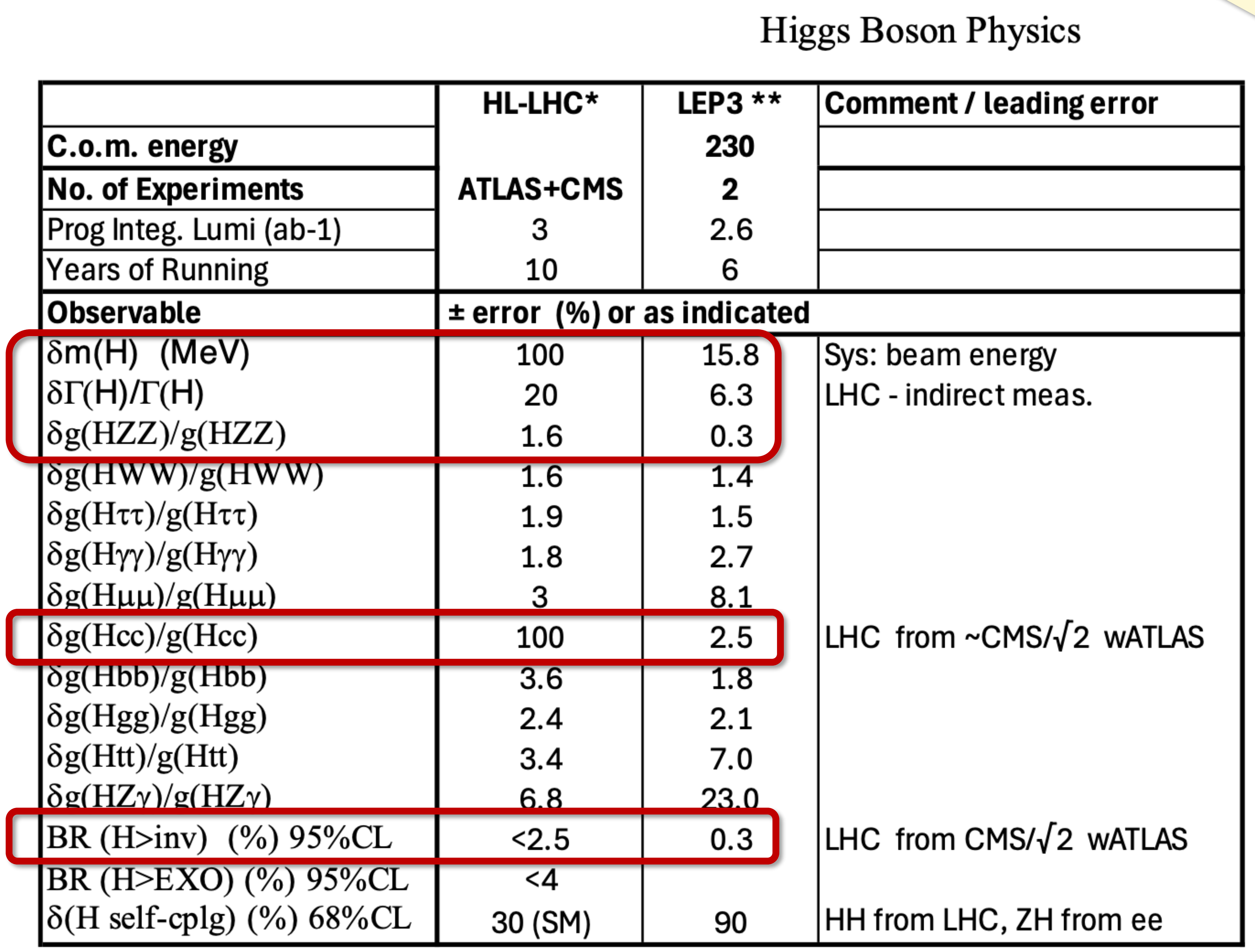
- Disadvantages
  - No ttbar, HH and λ
  - Time after HL-LHC
  - No upgrade to pp



via a suite of high precision electroweak measurements. For these reasons, we think that the LEP3 accelerator proposed here would provide an ideal back-up in the event of technical or financial issues for the preferred FCC project.

We reiterate that we support FCC as CERN's next major project and consider LEP3 only as a back-up option in case FCC-ee turns out not to be technically or financially feasible.

Given its lower luminosity and inability to reach the t-$\bar{t}$ threshold, LEP3 would be a less capable machine than FCC-ee (or CEPC). However, if neither FCC-ee nor CEPC proceed, LEP3 could be a more viable e^+e^- Higgs boson and electroweak factory than any of the other



Higgs Boson Physics

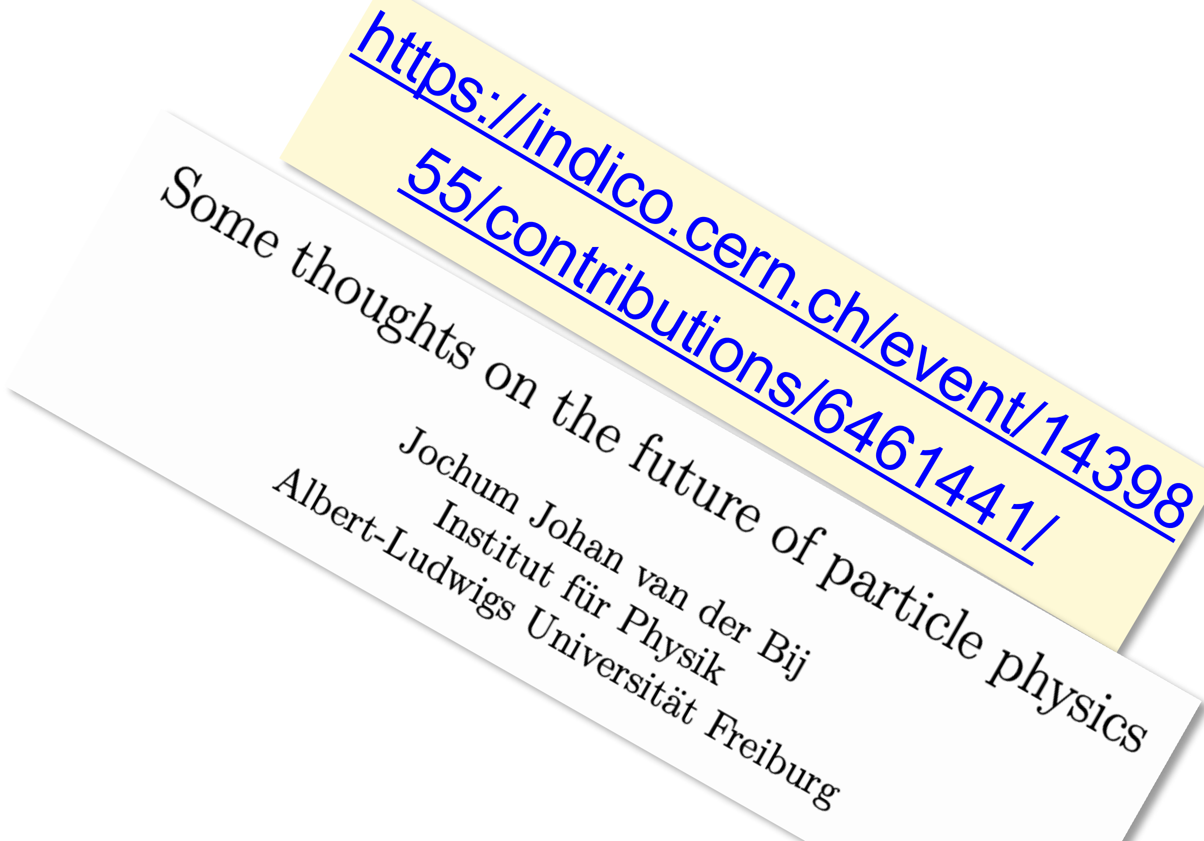
	HL-LHC*	LEP3 **	Comment / leading error
C.o.m. energy		**230**	
No. of Experiments	**ATLAS+CMS**	**2**	
Prog Integ. Lumi (ab-1)	3	2.6	
Years of Running	10	6	
Observable	**± error (%) or as indicated**		
$\delta m(H)$ (MeV)	100	15.8	Sys: beam energy
$\delta\Gamma(H)/\Gamma(H)$	20	6.3	LHC - indirect meas.
$\delta g(HZZ)/g(HZZ)$	1.6	0.3	
$\delta g(HWW)/g(HWW)$	1.6	1.4	
$\delta g(H\tau\tau)/g(H\tau\tau)$	1.9	1.5	
$\delta g(H\gamma\gamma)/g(H\gamma\gamma)$	1.8	2.7	
$\delta g(H\mu\mu)/g(H\mu\mu)$	3	8.1	
$\delta g(Hcc)/g(Hcc)$	100	2.5	LHC from ~CMS/√2 wATLAS
$\delta g(Hbb)/g(Hbb)$	3.6	1.8	
$\delta g(Hgg)/g(Hgg)$	2.4	2.1	
$\delta g(Htt)/g(Htt)$	3.4	7.0	
$\delta g(HZ\gamma)/g(HZ\gamma)$	6.8	23.0	
BR (H>inv) (%) 95%CL	<2.5	0.3	LHC from CMS/√2 wATLAS
BR (H>EXO) (%) 95%CL	<4		
δ(H self-cplg) (%) 68%CL	30 (SM)	90	HH from LHC, ZH from ee

INTERMEZZO

“SOME THOUGHTS”

J. v/d Bij

- Various ideas
  - Bit chaotic



https://indico.cern.ch/event/14398
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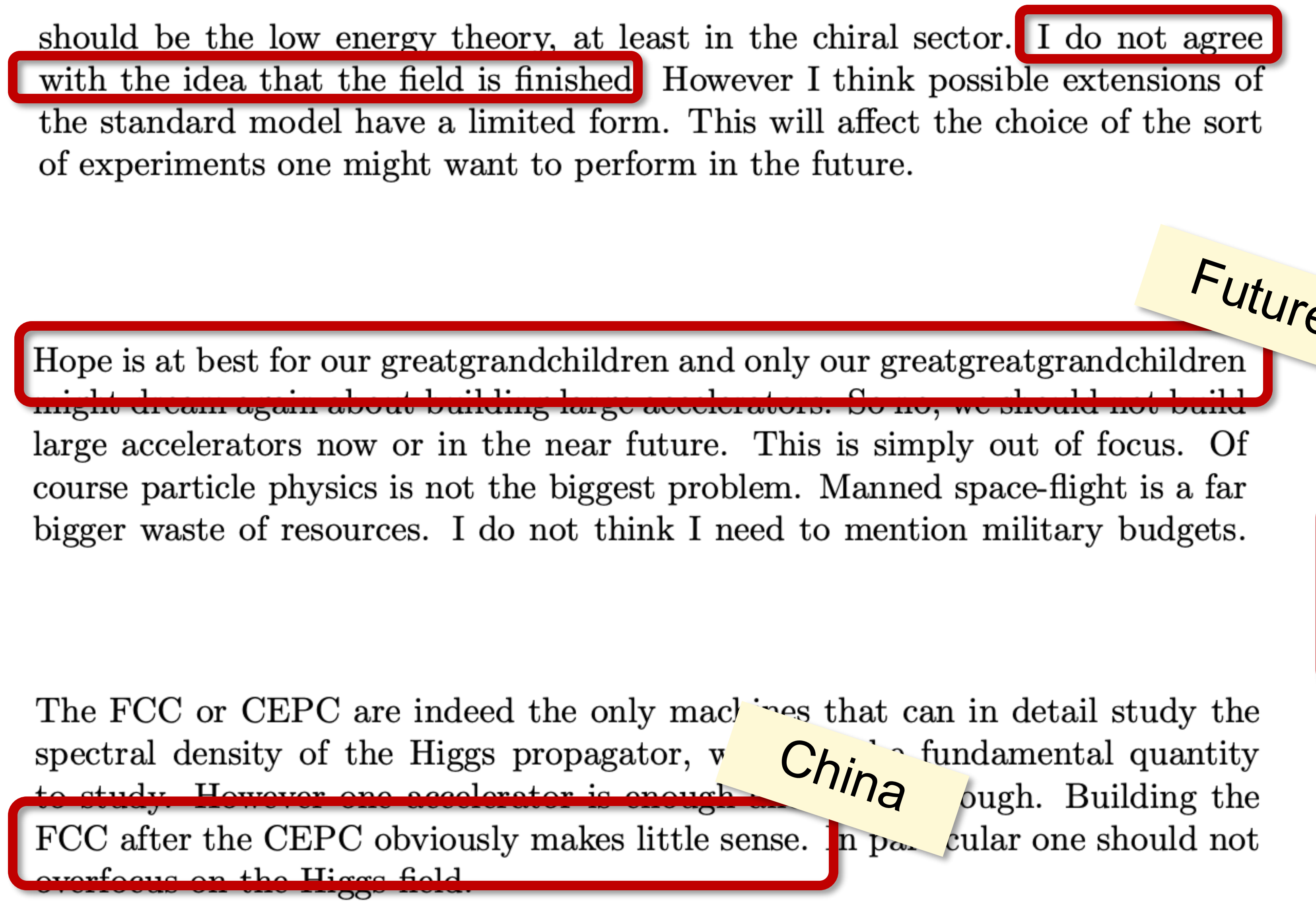
Some thoughts on the future of particle physics

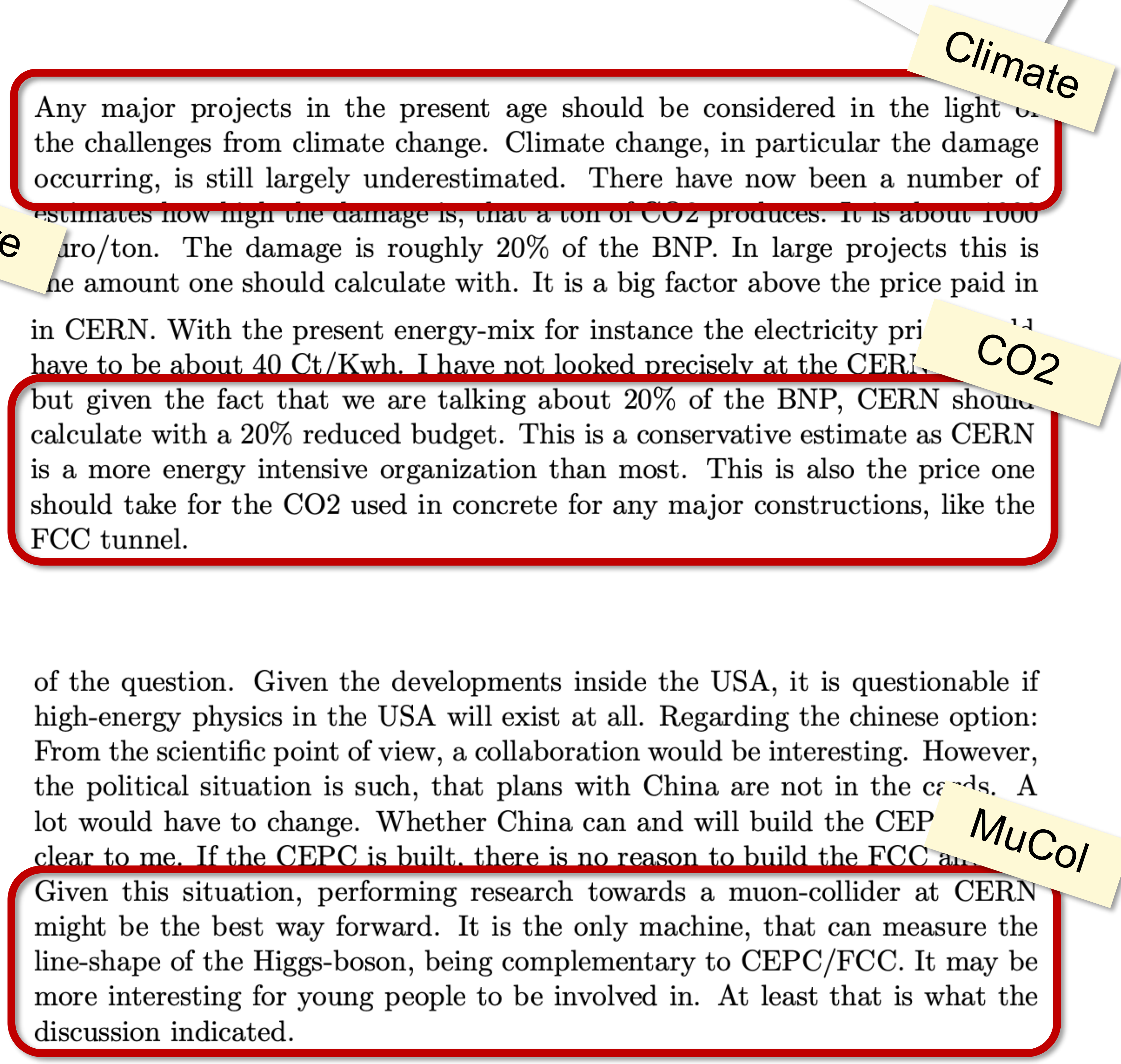
Jochum Johan van der Bij
Institut für Physik
Albert-Ludwigs Universität Freiburg



should be the low energy theory, at least in the chiral sector. I do not agree with the idea that the field is finished. However I think possible extensions of the standard model have a limited form. This will affect the choice of the sort of experiments one might want to perform in the future.

Hope is at best for our greatgrandchildren and only our greatgreatgrandchildren might dream again about building large accelerators. So no, we should not build large accelerators now or in the near future. This is simply out of focus. Of course particle physics is not the biggest problem. Manned space-flight is a far bigger waste of resources. I do not think I need to mention military budgets.

The FCC or CEPC are indeed the only mach nes that can in detail study the spectral density of the Higgs propagator, w fundamental quantity to study. However one accelerator is enough ough. Building the FCC after the CEPC obviously makes little sense. In pa cular one should not overfocus on the Higgs field.



Any major projects in the present age should be considered in the light o the challenges from climate change. Climate change, in particular the damage occurring, is still largely underestimated. There have now been a number of estimates how high the damage is, that a ton of CO2 produces. It is about 1000 uro/ton. The damage is roughly 20% of the BNP. In large projects this is he amount one should calculate with. It is a big factor above the price paid in

in CERN. With the present energy-mix for instance the electricity pri have to be about 40 Ct/Kwh. I have not looked precisely at the CERN but given the fact that we are talking about 20% of the BNP, CERN shoul calculate with a 20% reduced budget. This is a conservative estimate as CERN is a more energy intensive organization than most. This is also the price one should take for the CO2 used in concrete for any major constructions, like the FCC tunnel.

of the question. Given the developments inside the USA, it is questionable if high-energy physics in the USA will exist at all. Regarding the chinese option: From the scientific point of view, a collaboration would be interesting. However, the political situation is such, that plans with China are not in the cards. A lot would have to change. Whether China can and will build the CEP clear to me. If the CEPC is built, there is no reason to build the FCC a Given this situation, performing research towards a muon-collider at CERN might be the best way forward. It is the only machine, that can measure the line-shape of the Higgs-boson, being complementary to CEPC/FCC. It may be more interesting for young people to be involved in. At least that is what the discussion indicated.

“FUTURE OF CERN”

https://indico.cern.ch/event/14398
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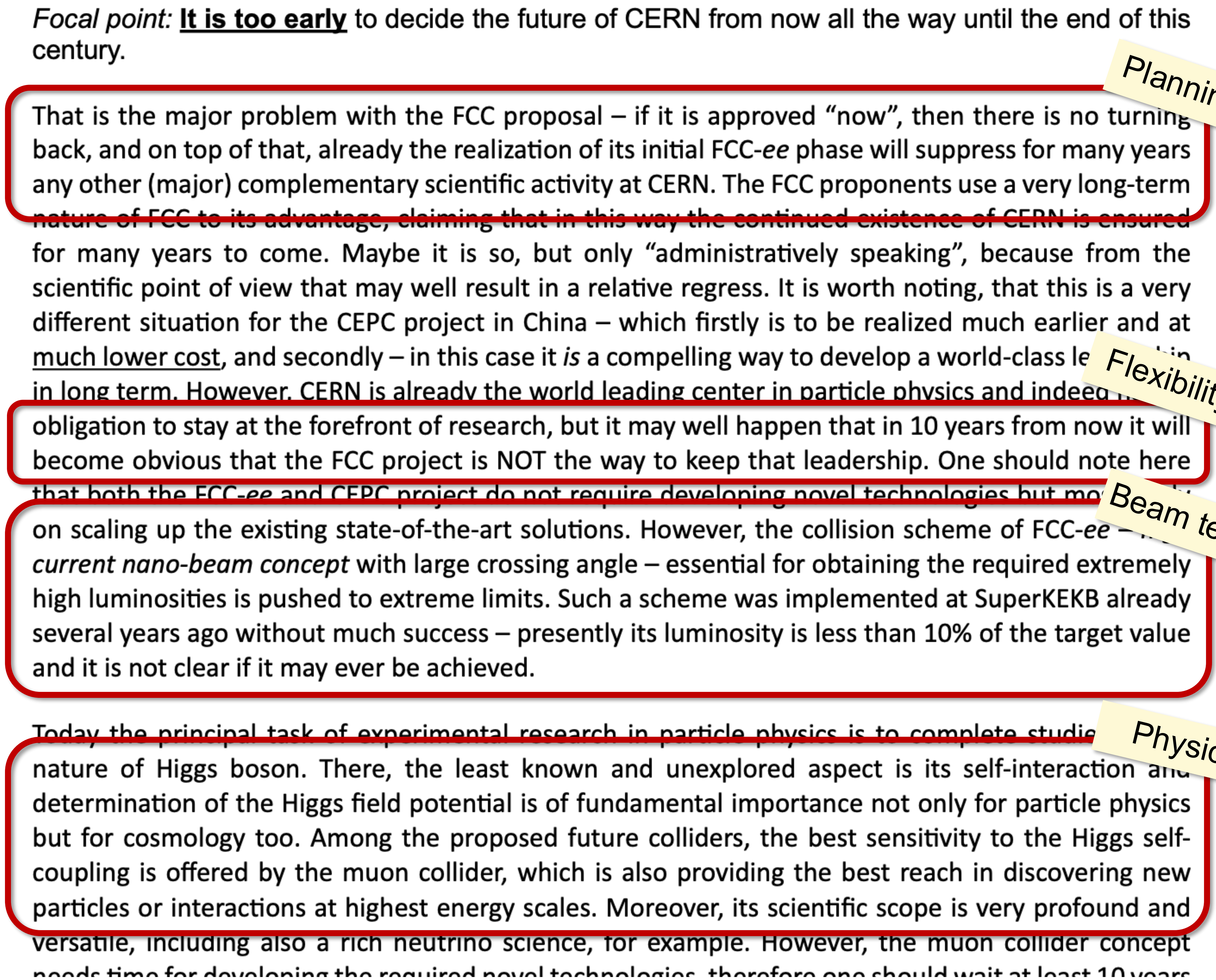
Future of CERN

Krzysztof PIOTRZKOWSKI
(AGH University, Kraków, POLAND)



Focal point: **It is too early** to decide the future of CERN from now all the way until the end of this century.

Planning

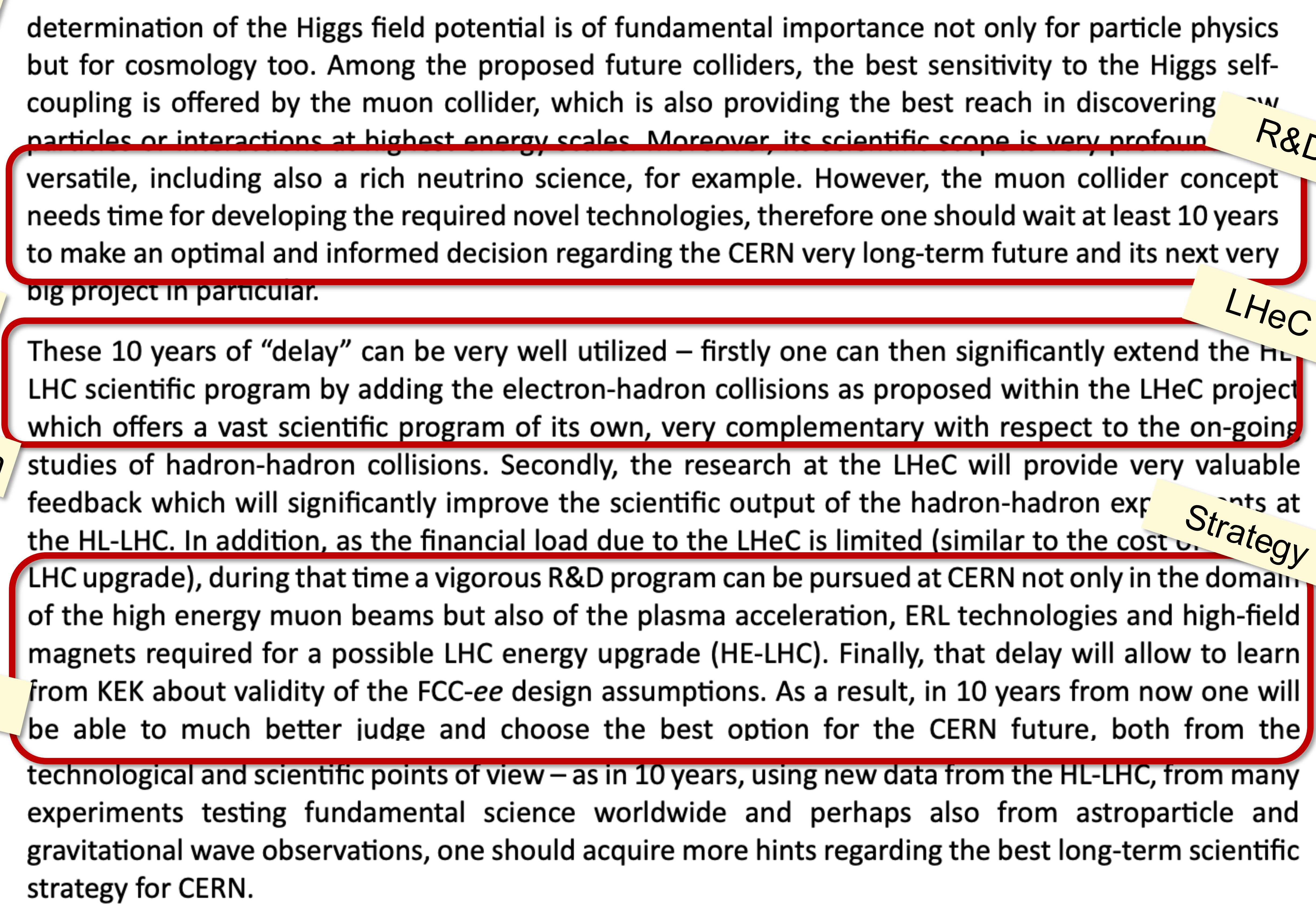
That is the major problem with the FCC proposal – if it is approved “now”, then there is no turning back, and on top of that, already the realization of its initial FCC-*ee* phase will suppress for many years any other (major) complementary scientific activity at CERN. The FCC proponents use a very long-term nature of FCC to its advantage, claiming that in this way the continued existence of CERN is ensured for many years to come. Maybe it is so, but only “administratively speaking”, because from the scientific point of view that may well result in a relative regress. It is worth noting, that this is a very different situation for the CEPC project in China – which firstly is to be realized much earlier and at much lower cost, and secondly – in this case it *is* a compelling way to develop a world-class le in long term. However, CERN is already the world leading center in particle physics and indeed obligation to stay at the forefront of research, but it may well happen that in 10 years from now it will become obvious that the FCC project is NOT the way to keep that leadership. One should note here that both the FCC-*ee* and CEPC project do not require developing novel technologies but mo on scaling up the existing state-of-the-art solutions. However, the collision scheme of FCC-*ee* – *current nano-beam concept* with large crossing angle – essential for obtaining the required extremely high luminosities is pushed to extreme limits. Such a scheme was implemented at SuperKEKB already several years ago without much success – presently its luminosity is less than 10% of the target value and it is not clear if it may ever be achieved.

Flexibility

Beam tech

Today the principal task of experimental research in particle physics is to complete studie nature of Higgs boson. There, the least known and unexplored aspect is its self-interaction and determination of the Higgs field potential is of fundamental importance not only for particle physics but for cosmology too. Among the proposed future colliders, the best sensitivity to the Higgs self-coupling is offered by the muon collider, which is also providing the best reach in discovering new particles or interactions at highest energy scales. Moreover, its scientific scope is very profound and versatile, including also a rich neutrino science, for example. However, the muon collider concept needs time for developing the required novel technologies, therefore one should wait at least 10 years

Physics



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R&D

These 10 years of “delay” can be very well utilized – firstly one can then significantly extend the HL-LHC scientific program by adding the electron-hadron collisions as proposed within the LHeC project which offers a vast scientific program of its own, very complementary with respect to the on-going studies of hadron-hadron collisions. Secondly, the research at the LHeC will provide very valuable feedback which will significantly improve the scientific output of the hadron-hadron exp nts at the HL-LHC. In addition, as the financial load due to the LHeC is limited (similar to the cost o LHC upgrade), during that time a vigorous R&D program can be pursued at CERN not only in the domain of the high energy muon beams but also of the plasma acceleration, ERL technologies and high-field magnets required for a possible LHC energy upgrade (HE-LHC). Finally, that delay will allow to learn from KEK about validity of the FCC-*ee* design assumptions. As a result, in 10 years from now one will be able to much better judge and choose the best option for the CERN future, both from the technological and scientific points of view – as in 10 years, using new data from the HL-LHC, from many experiments testing fundamental science worldwide and perhaps also from astroparticle and gravitational wave observations, one should acquire more hints regarding the best long-term scientific strategy for CERN.

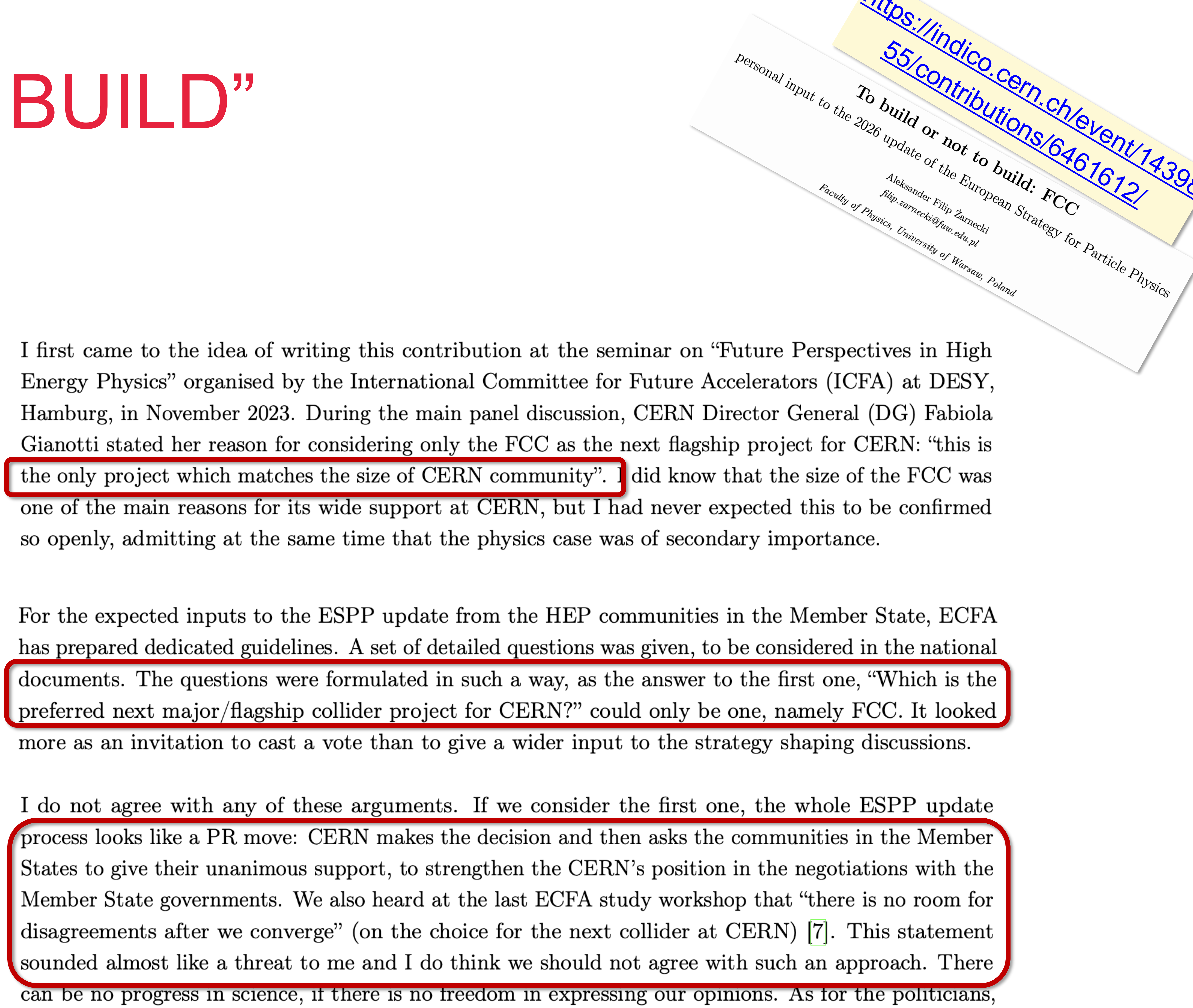
LHeC

Strategy

“TO BUILD OR NOT TO BUILD”

Individual contribution

- A.F. Zarnecki (PL)
  - Comments on the process



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To build or not to build: FCC

personal input to the 2026 update of the European Strategy for Particle Physics

Aleksander Filip Żarnecki
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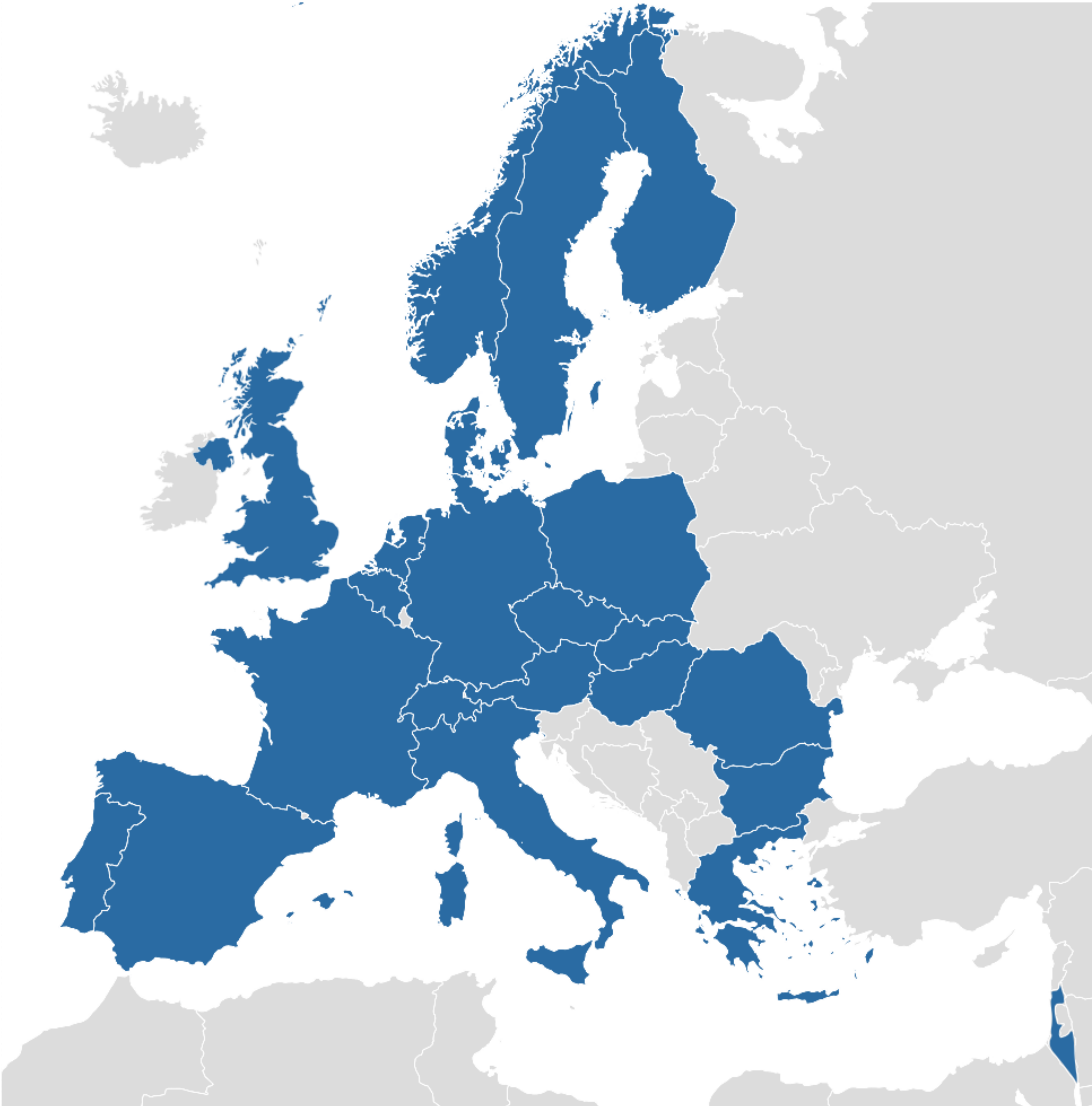
Faculty of Physics, University of Warsaw, Poland

I first came to the idea of writing this contribution at the seminar on “Future Perspectives in High Energy Physics” organised by the International Committee for Future Accelerators (ICFA) at DESY, Hamburg, in November 2023. During the main panel discussion, CERN Director General (DG) Fabiola Gianotti stated her reason for considering only the FCC as the next flagship project for CERN: “this is the only project which matches the size of CERN community”. I did know that the size of the FCC was one of the main reasons for its wide support at CERN, but I had never expected this to be confirmed so openly, admitting at the same time that the physics case was of secondary importance.

For the expected inputs to the ESPP update from the HEP communities in the Member State, ECFA has prepared dedicated guidelines. A set of detailed questions was given, to be considered in the national documents. The questions were formulated in such a way, as the answer to the first one, “Which is the preferred next major/flagship collider project for CERN?” could only be one, namely FCC. It looked more as an invitation to cast a vote than to give a wider input to the strategy shaping discussions.

I do not agree with any of these arguments. If we consider the first one, the whole ESPP update process looks like a PR move: CERN makes the decision and then asks the communities in the Member States to give their unanimous support, to strengthen the CERN’s position in the negotiations with the Member State governments. We also heard at the last ECFA study workshop that “there is no room for disagreements after we converge” (on the choice for the next collider at CERN) [7]. This statement sounded almost like a threat to me and I do think we should not agree with such an approach. There can be no progress in science, if there is no freedom in expressing our opinions. As for the politicians,

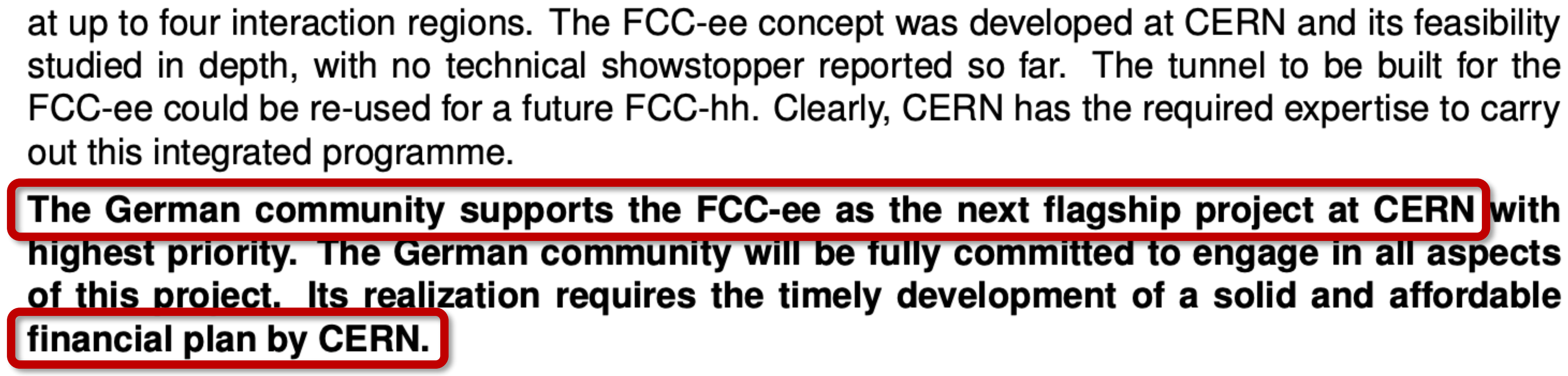
PART III: COUNTRIES



European Strategy Update

BIG COUNTRIES

Germany

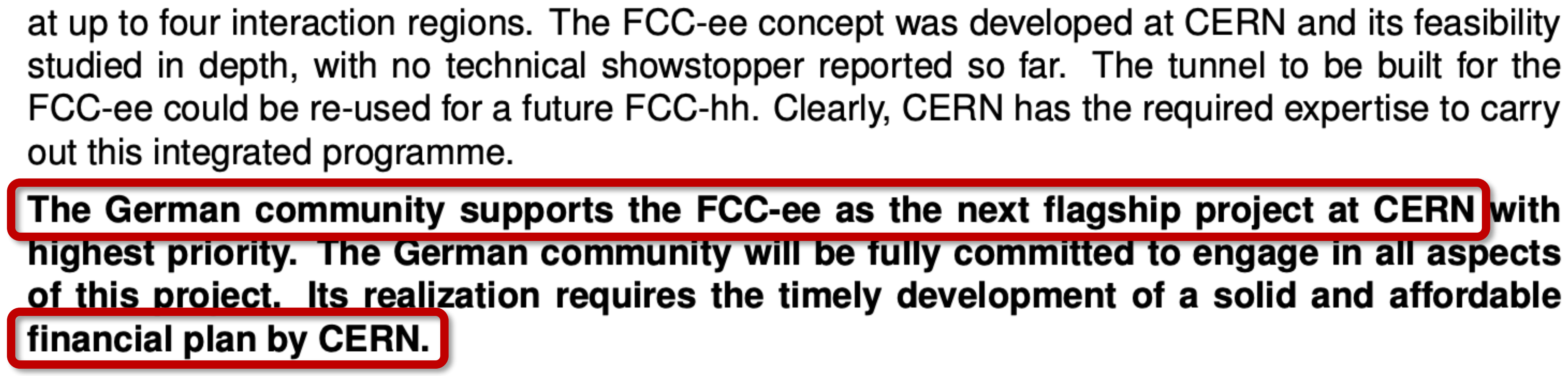


at up to four interaction regions. The FCC-ee concept was developed at CERN and its feasibility studied in depth, with no technical showstopper reported so far. The tunnel to be built for the FCC-ee could be re-used for a future FCC-hh. Clearly, CERN has the required expertise to carry out this integrated programme.

The German community supports the FCC-ee as the next flagship project at CERN with highest priority. The German community will be fully committed to engage in all aspects of this project. Its realization requires the timely development of a solid and affordable financial plan by CERN.

BIG COUNTRIES

Germany



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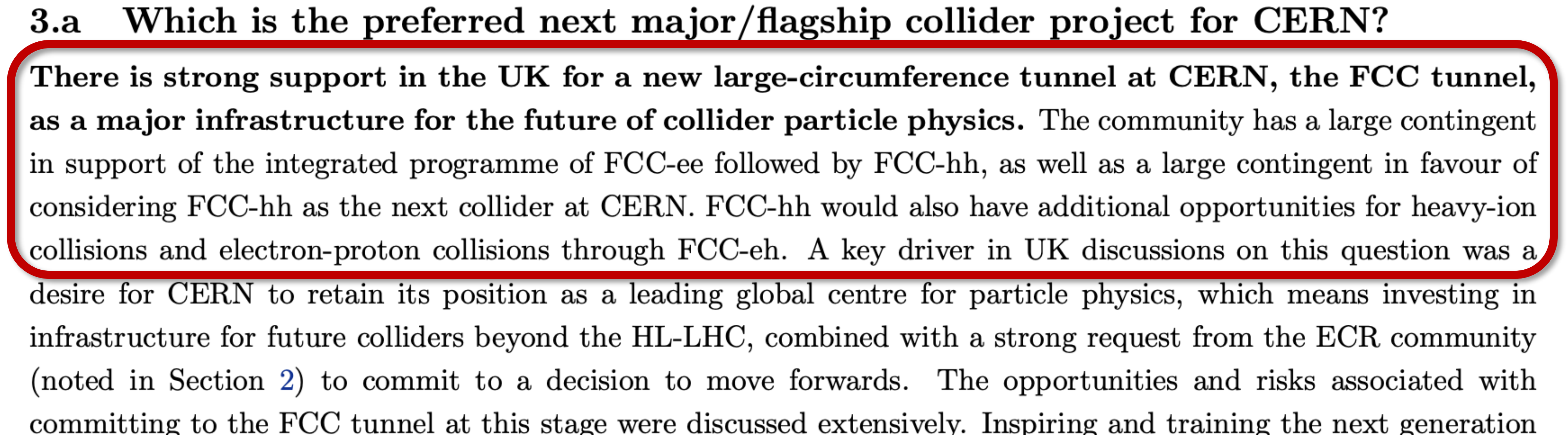
UK



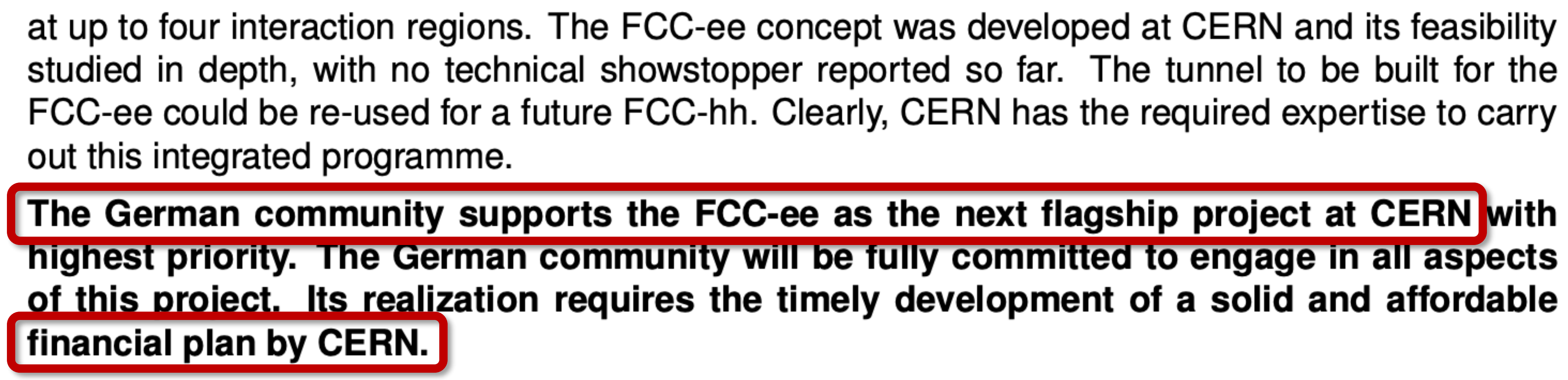
3.a Which is the preferred next major/flagship collider project for CERN?

There is strong support in the UK for a new large-circumference tunnel at CERN, the FCC tunnel, as a major infrastructure for the future of collider particle physics. The community has a large contingent in support of the integrated programme of FCC-ee followed by FCC-hh, as well as a large contingent in favour of considering FCC-hh as the next collider at CERN. FCC-hh would also have additional opportunities for heavy-ion collisions and electron-proton collisions through FCC-eh. A key driver in UK discussions on this question was a desire for CERN to retain its position as a leading global centre for particle physics, which means investing in infrastructure for future colliders beyond the HL-LHC, combined with a strong request from the ECR community (noted in Section 2) to commit to a decision to move forwards. The opportunities and risks associated with committing to the FCC tunnel at this stage were discussed extensively. Inspiring and training the next generation

- Germany emphasizes finances
- UK mentions FCC-hh option

BIG COUNTRIES

Germany



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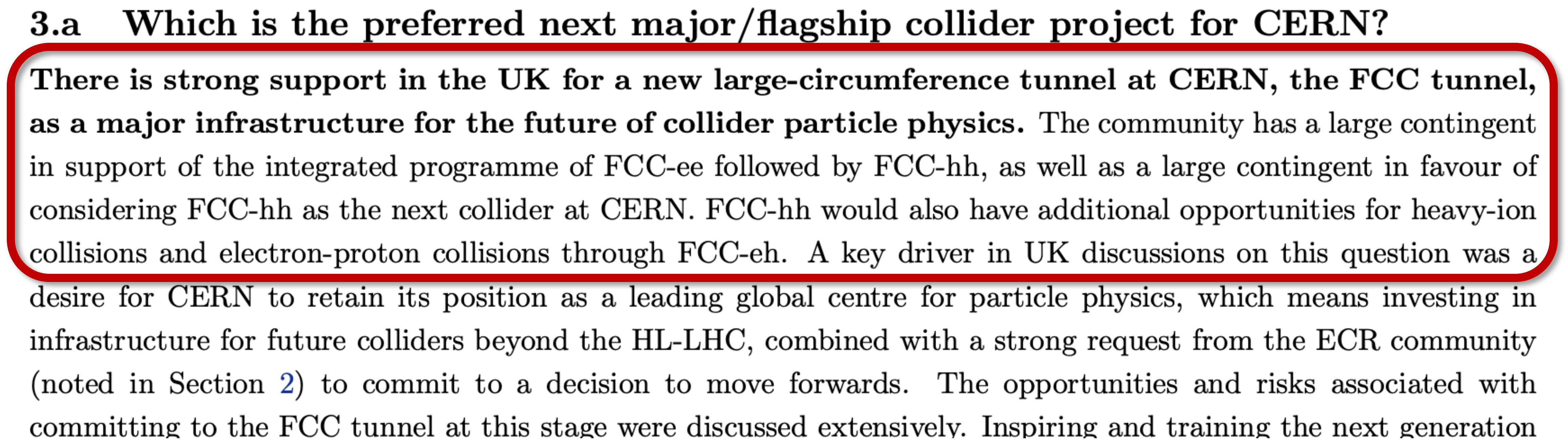

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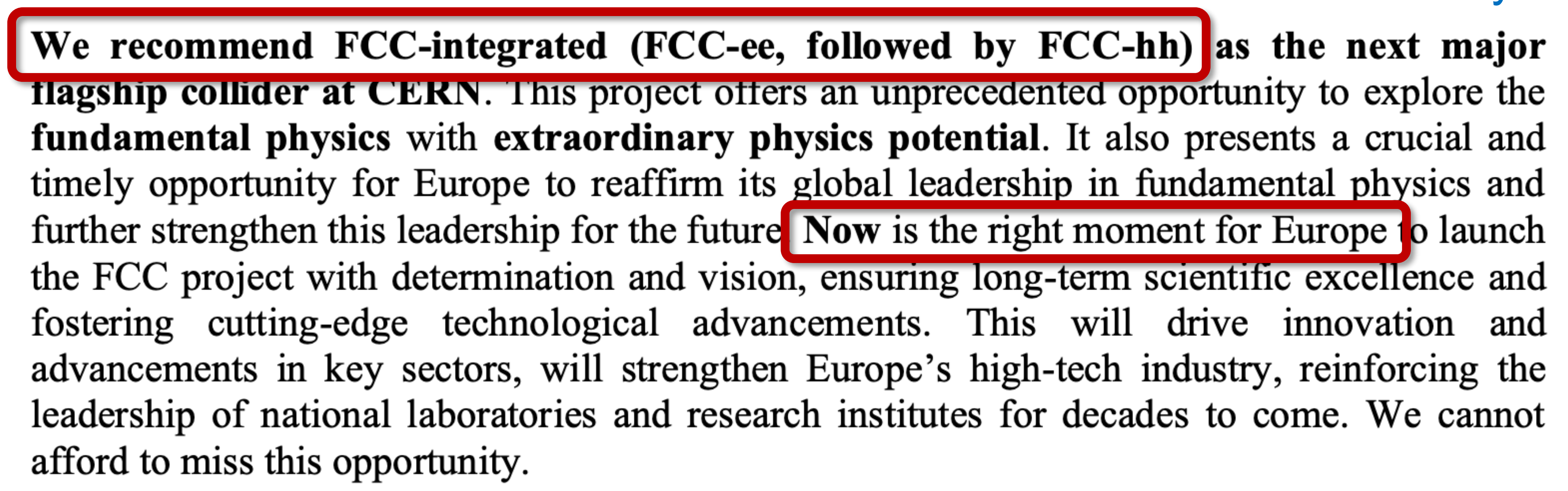
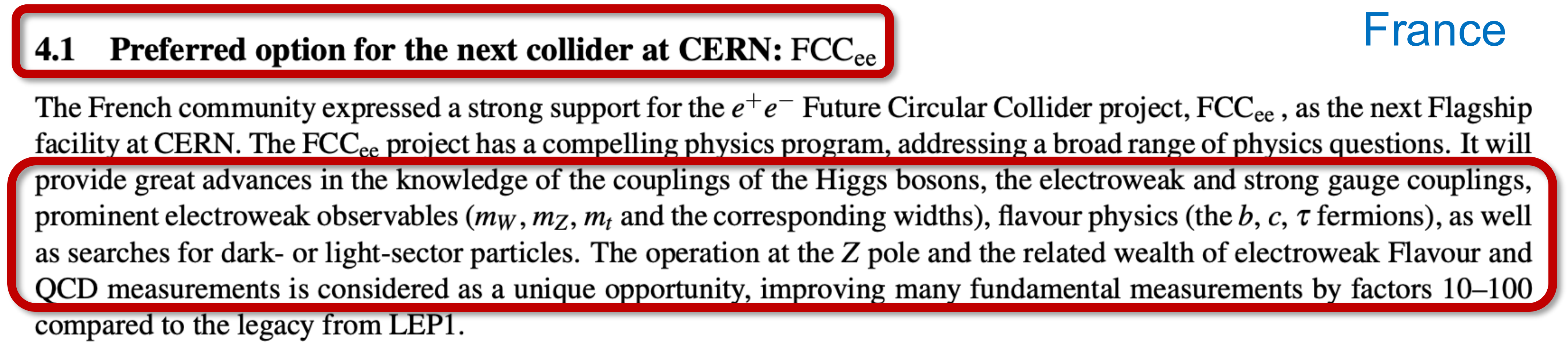
Italy



We recommend FCC-integrated (FCC-ee, followed by FCC-hh) as the next major flagship collider at CERN. This project offers an unprecedented opportunity to explore the **fundamental physics** with **extraordinary physics potential**. It also presents a crucial and timely opportunity for Europe to reaffirm its global leadership in fundamental physics and further strengthen this leadership for the future. **Now** is the right moment for Europe to launch the FCC project with determination and vision, ensuring long-term scientific excellence and fostering cutting-edge technological advancements. This will drive innovation and advancements in key sectors, will strengthen Europe's high-tech industry, reinforcing the leadership of national laboratories and research institutes for decades to come. We cannot afford to miss this opportunity.

France



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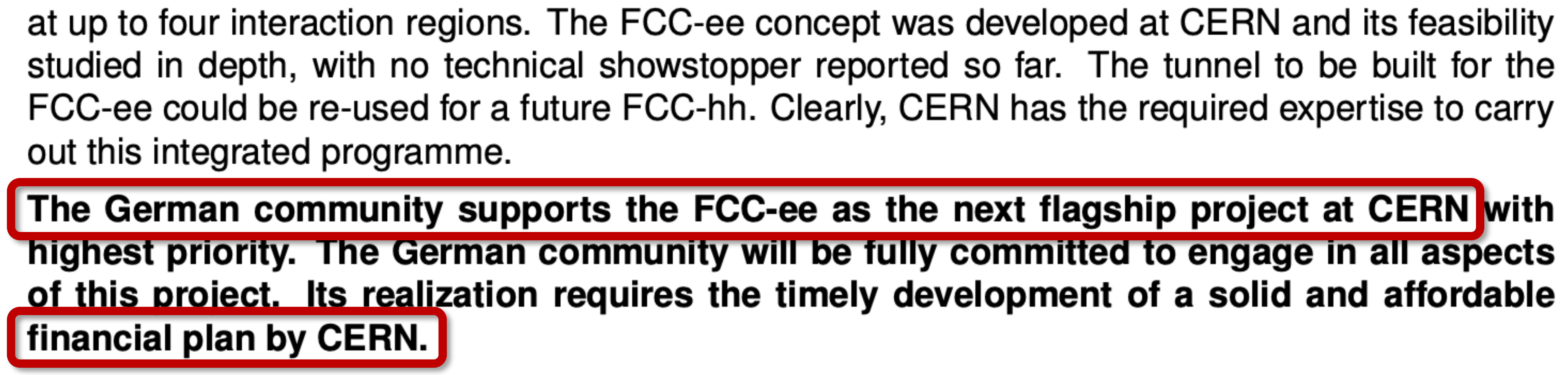
Broad consensus on FCC

- Germany emphasizes finances
- UK mentions FCC-hh option

BIG COUNTRIES

Germany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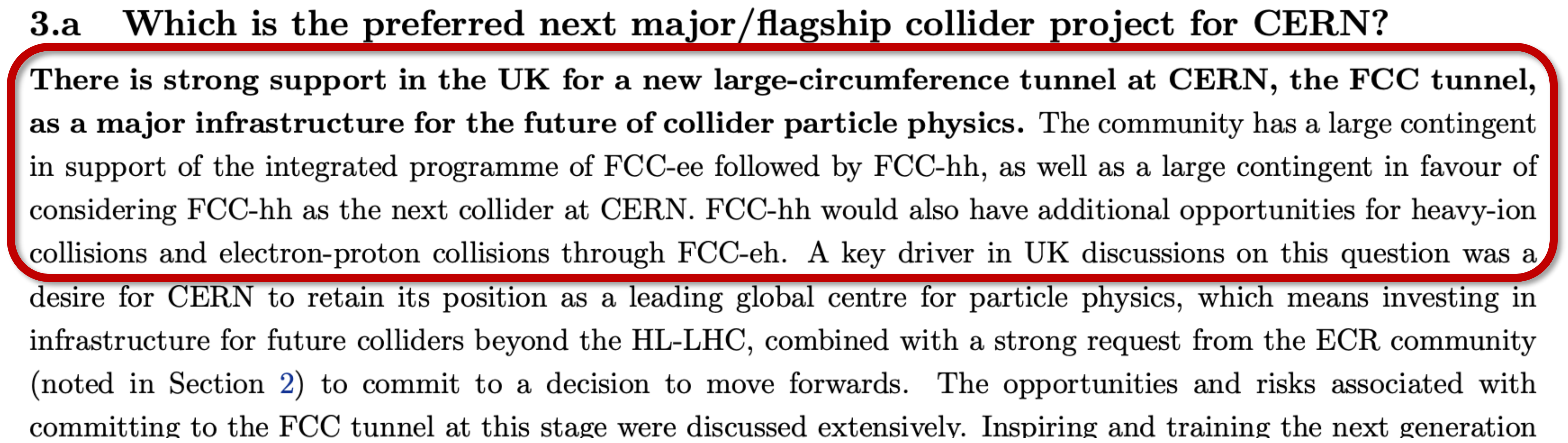
UK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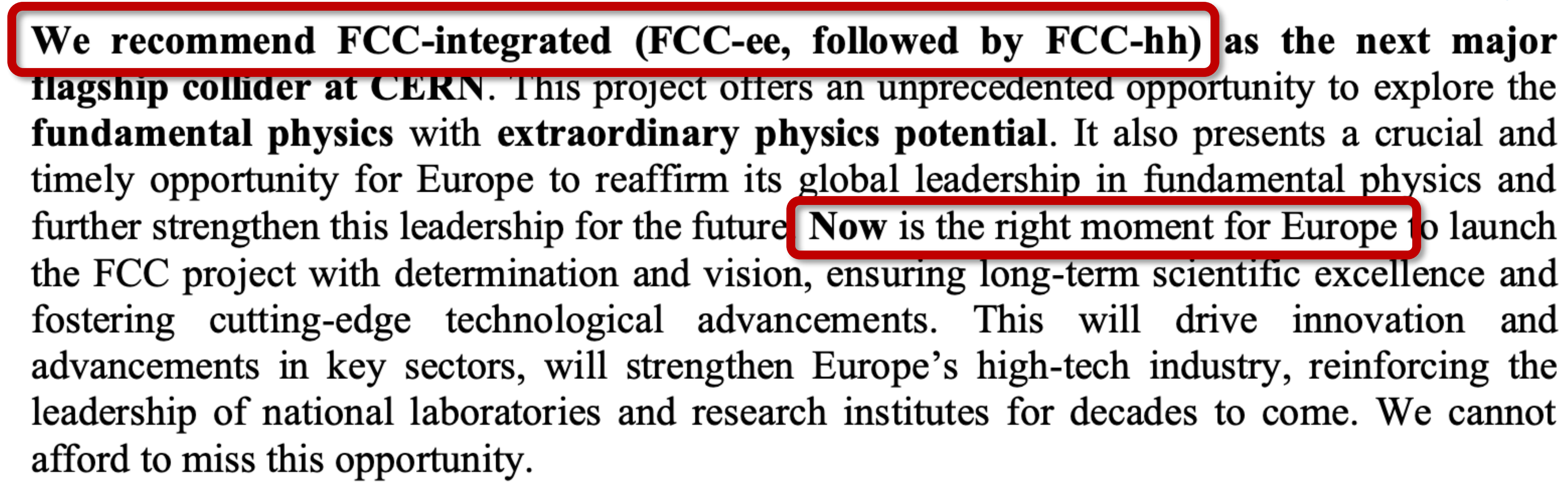
Broad consensus on FCC

- Germany emphasizes finances
- UK mentions FCC-hh option
- CH outrageously enthusiastic

Italy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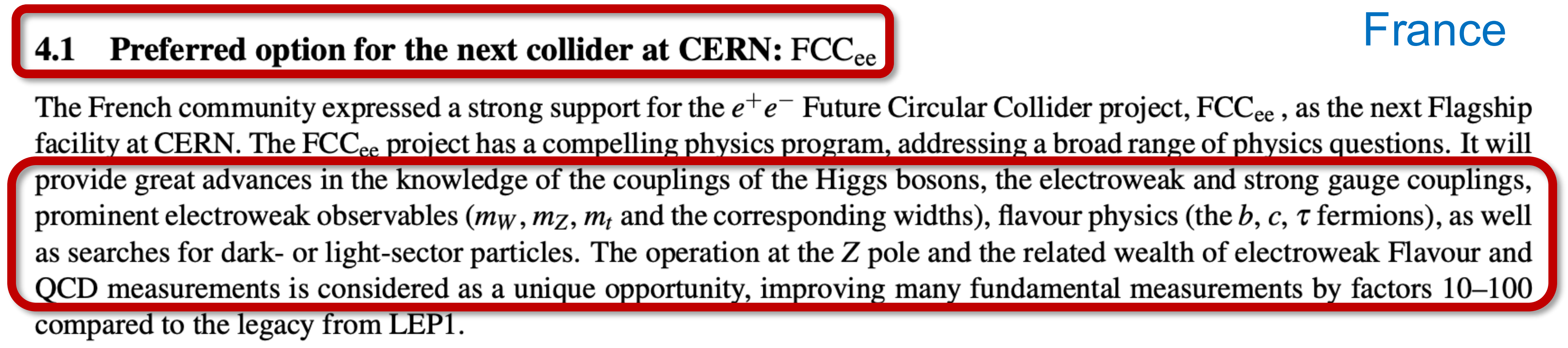
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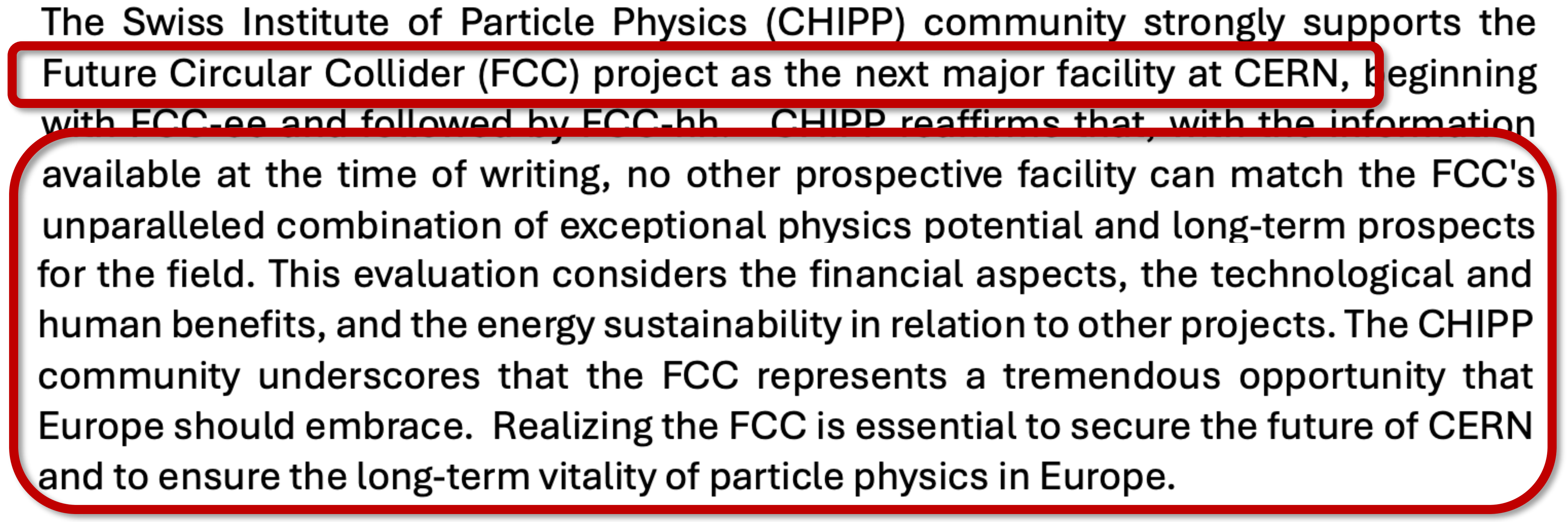
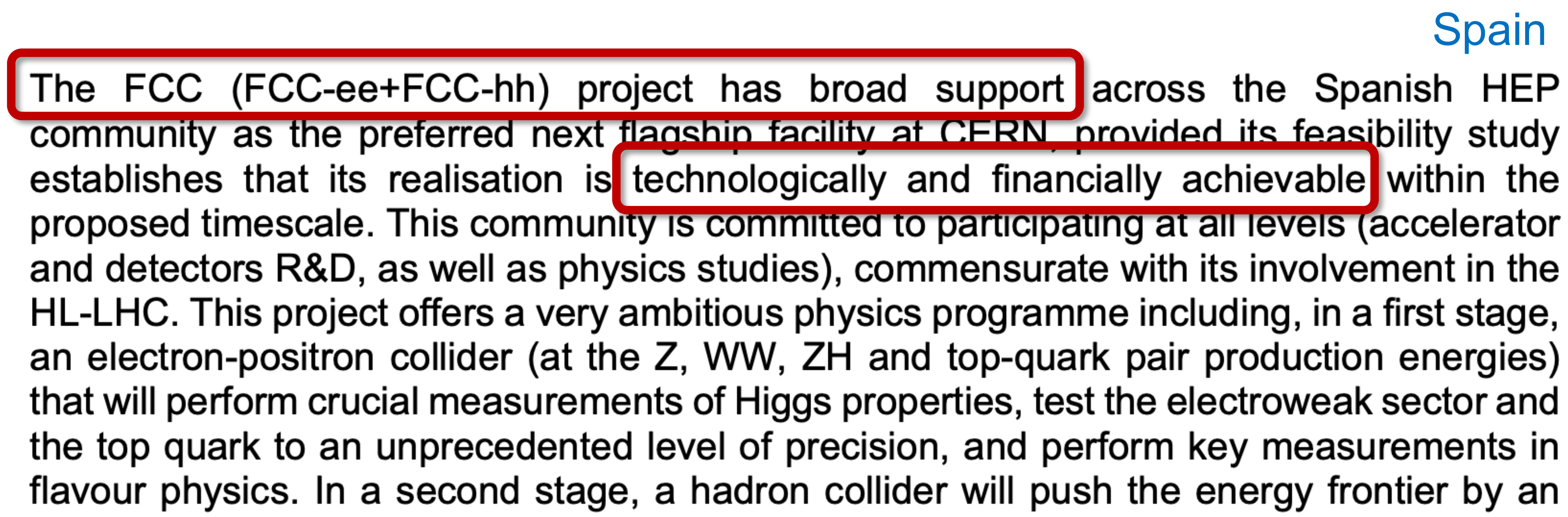
Switzerland


The Swiss Institute of Particle Physics (CHIPP) community strongly supports the Future Circular Collider (FCC) project as the next major facility at CERN, beginning with FCC-ee and followed by FCC-hh. CHIPP reaffirms that, with the information available at the time of writing, no other prospective facility can match the FCC's unparalleled combination of exceptional physics potential and long-term prospects for the field. This evaluation considers the financial aspects, the technological and human benefits, and the energy sustainability in relation to other projects. The CHIPP community underscores that the FCC represents a tremendous opportunity that Europe should embrace. Realizing the FCC is essential to secure the future of CERN and to ensure the long-term vitality of particle physics in Europe.

OTHER COUNTRIES



Spain

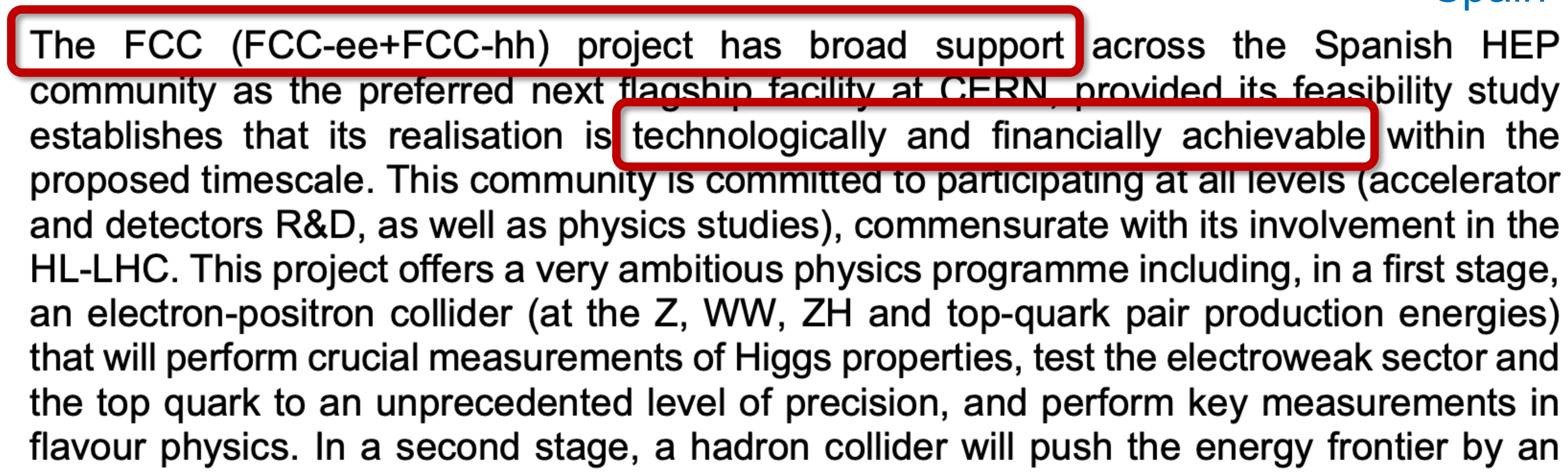
The FCC (FCC-ee+FCC-hh) project has broad support across the Spanish HEP community as the preferred next flagship facility at CERN, provided its feasibility study establishes that its realisation is technologically and financially achievable within the proposed timescale. This community is committed to participating at all levels (accelerator and detectors R&D, as well as physics studies), commensurate with its involvement in the HL-LHC. This project offers a very ambitious physics programme including, in a first stage, an electron-positron collider (at the Z, WW, ZH and top-quark pair production energies) that will perform crucial measurements of Higgs properties, test the electroweak sector and the top quark to an unprecedented level of precision, and perform key measurements in flavour physics. In a second stage, a hadron collider will push the energy frontier by an

Other observations

- Spain emphasizes finances

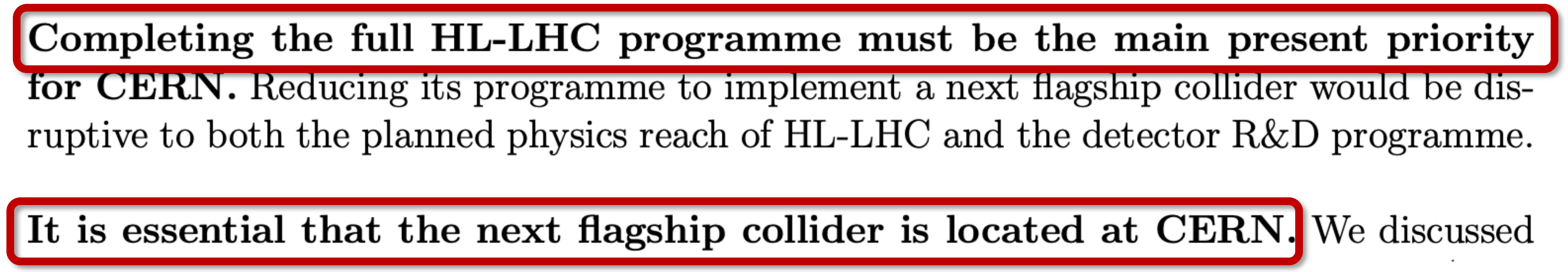
OTHER COUNTRIES

Spain



The FCC (FCC-ee+FCC-hh) project has broad support across the Spanish HEP community as the preferred next flagship facility at CERN, provided its feasibility study establishes that its realisation is technologically and financially achievable within the proposed timescale. This community is committed to participating at all levels (accelerator and detectors R&D, as well as physics studies), commensurate with its involvement in the HL-LHC. This project offers a very ambitious physics programme including, in a first stage, an electron-positron collider (at the Z, WW, ZH and top-quark pair production energies) that will perform crucial measurements of Higgs properties, test the electroweak sector and the top quark to an unprecedented level of precision, and perform key measurements in flavour physics. In a second stage, a hadron collider will push the energy frontier by an

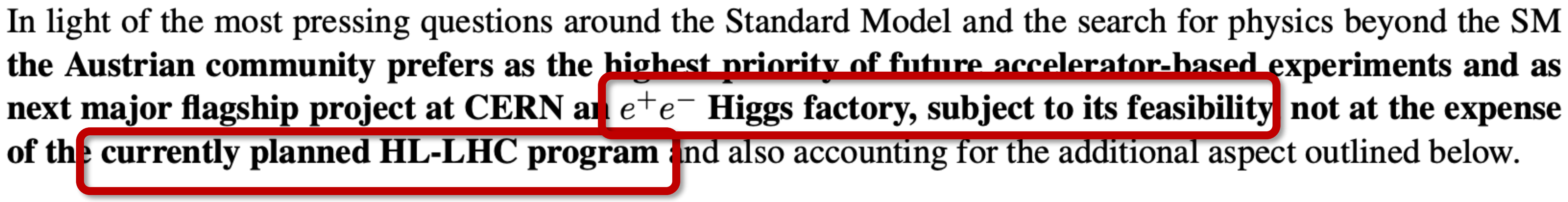
Netherlands



Completing the full HL-LHC programme must be the main present priority for CERN. Reducing its programme to implement a next flagship collider would be disruptive to both the planned physics reach of HL-LHC and the detector R&D programme.

It is essential that the next flagship collider is located at CERN. We discussed

Austria



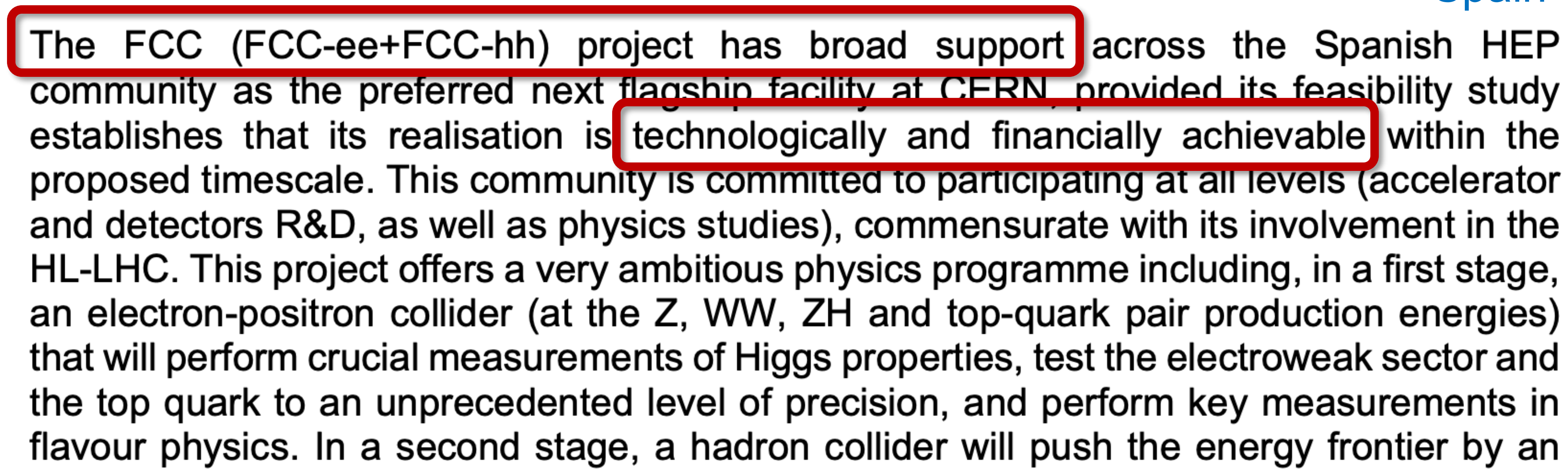
In light of the most pressing questions around the Standard Model and the search for physics beyond the SM **the Austrian community prefers as the highest priority of future accelerator-based experiments and as next major flagship project at CERN an e^+e^- Higgs factory, subject to its feasibility not at the expense of the currently planned HL-LHC program** and also accounting for the additional aspect outlined below.

Other observations

- Spain emphasizes finances
- NL + AU remain quite neutral
- NL + AU mention HL-LHC

OTHER COUNTRIES

Spain



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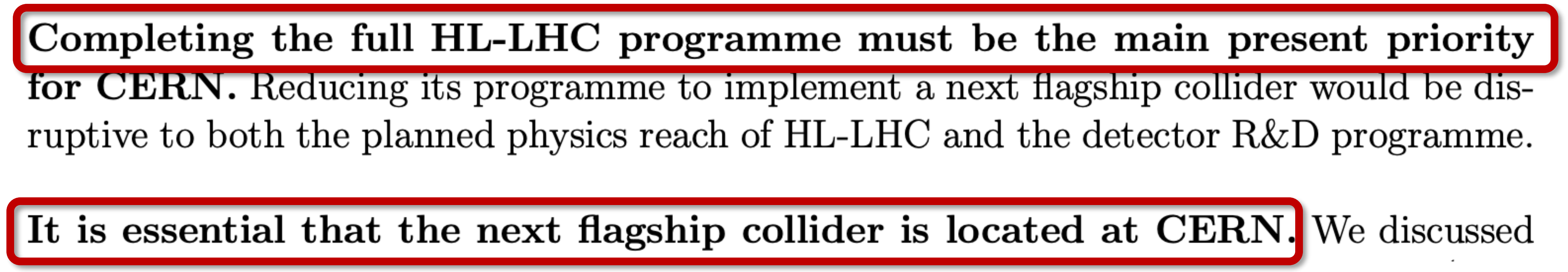
Belgium

The Belgian community strongly supports an ambitious project for the next CERN flagship machine. We believe that CERN should keep its leadership as the largest international center in the world for research in high energy and particle physics, and in related advanced technology development, in a peaceful and worldwide open collaboration organisation. To reach this goal our preferred next long-term project is the FCC-ee/hh.

Other observations

- Spain emphasizes finances
- NL + AU remain quite neutral
- NL + AU mention HL-LHC
- BE: international/global role

Netherlands



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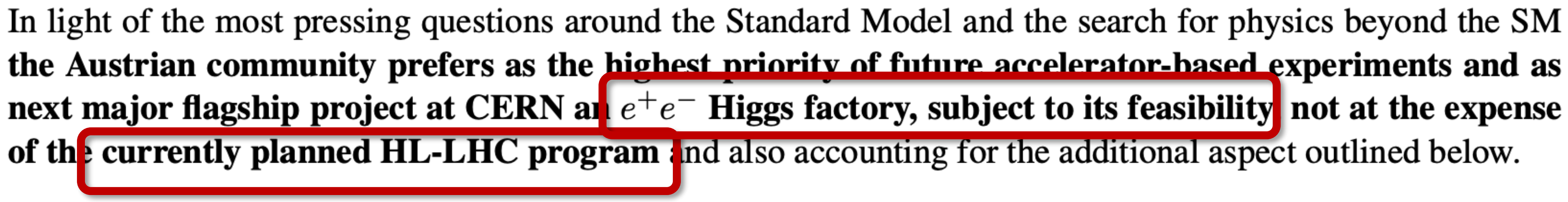

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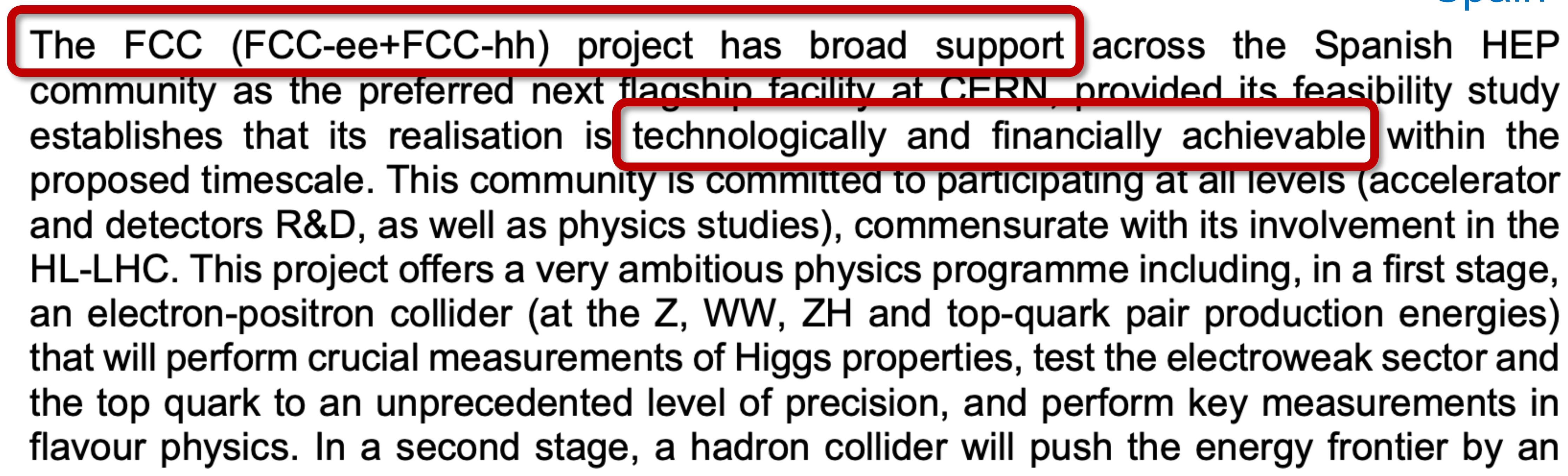

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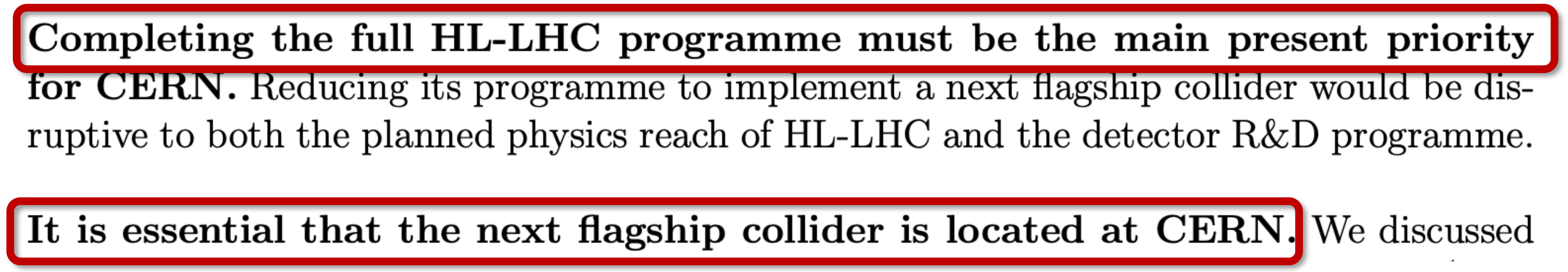
- NL + AU remain quite neutral
- NL + AU mention HL-LHC
- USA strongly supports FCC-ee

Netherlands



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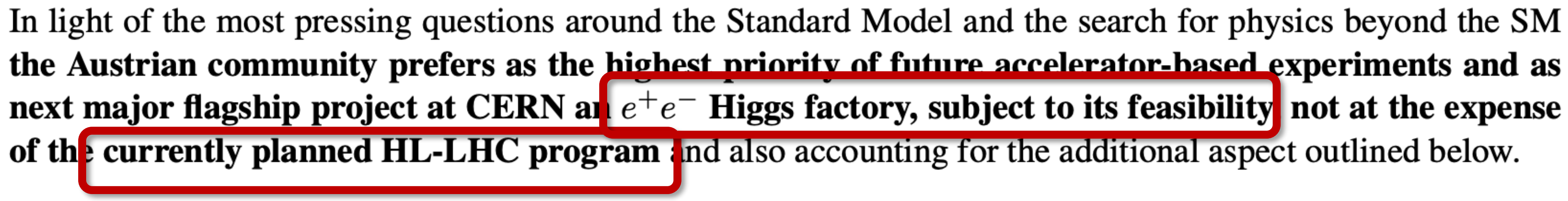

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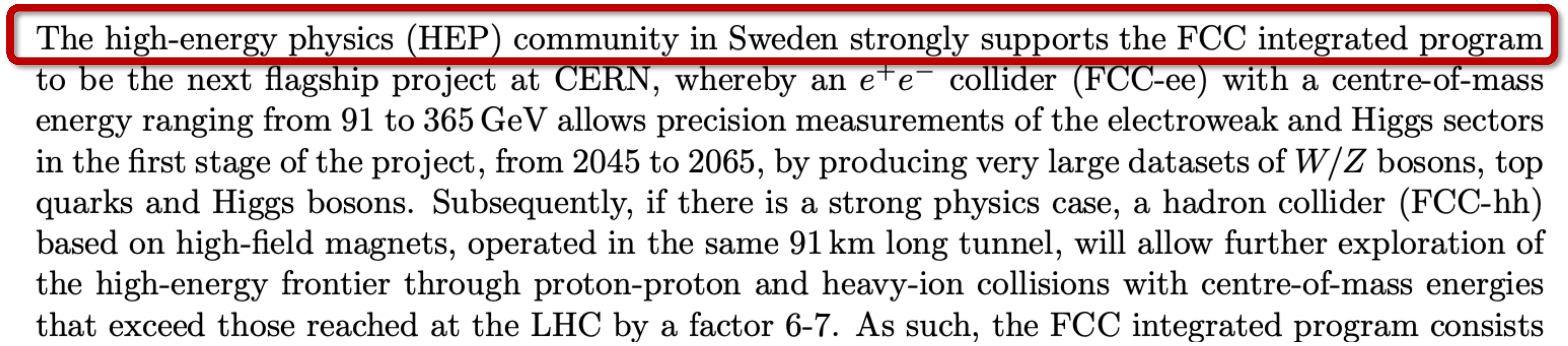
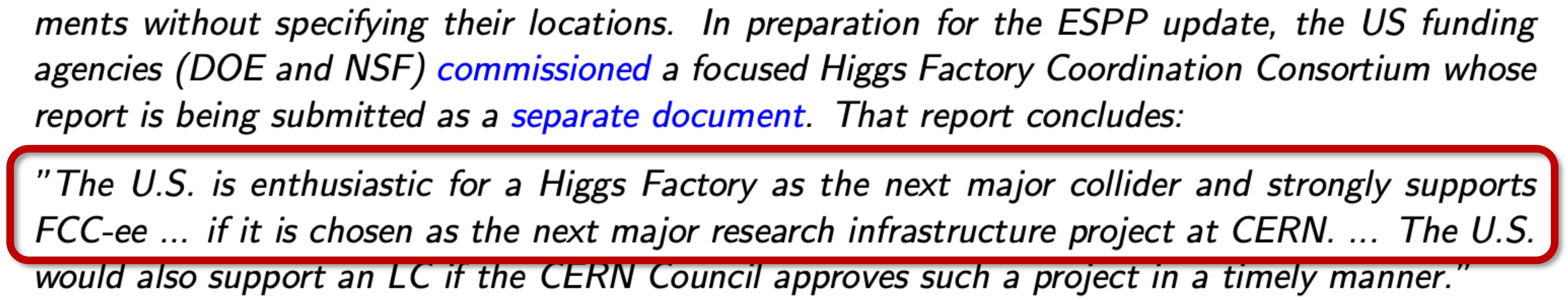
Sweden



The high-energy physics (HEP) community in Sweden strongly supports the FCC integrated program to be the next flagship project at CERN, whereby an e^+e^- collider (FCC-ee) with a centre-of-mass energy ranging from 91 to 365 GeV allows precision measurements of the electroweak and Higgs sectors in the first stage of the project, from 2045 to 2065, by producing very large datasets of W/Z bosons, top quarks and Higgs bosons. Subsequently, if there is a strong physics case, a hadron collider (FCC-hh) based on high-field magnets, operated in the same 91 km long tunnel, will allow further exploration of the high-energy frontier through proton-proton and heavy-ion collisions with centre-of-mass energies that exceed those reached at the LHC by a factor 6-7. As such, the FCC integrated program consists

USA

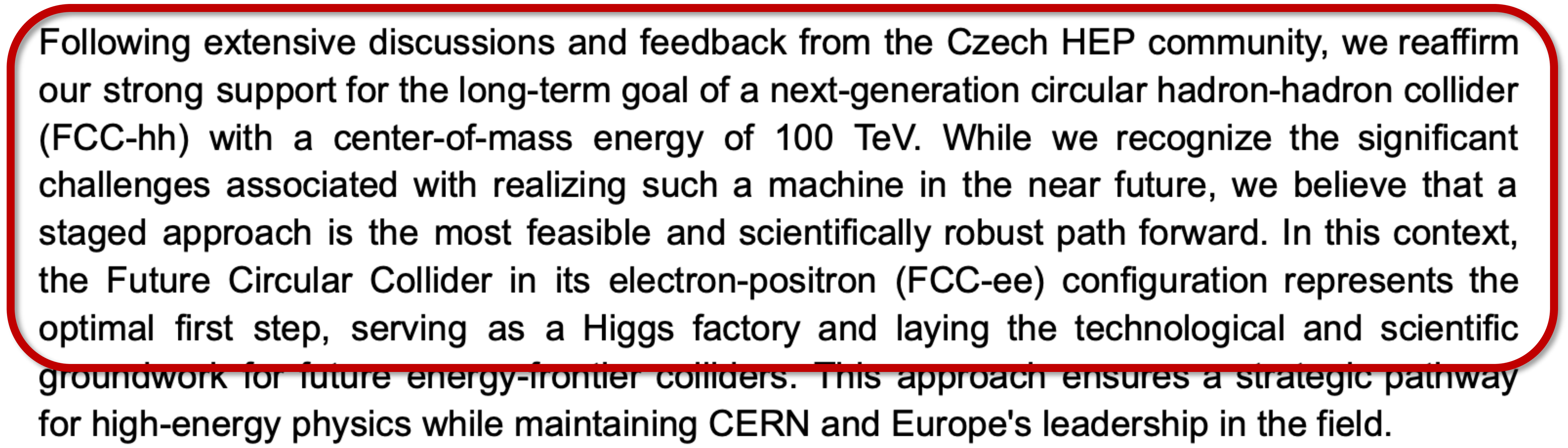


ments without specifying their locations. In preparation for the ESPP update, the US funding agencies (DOE and NSF) commissioned a focused Higgs Factory Coordination Consortium whose report is being submitted as a separate document. That report concludes:

"The U.S. is enthusiastic for a Higgs Factory as the next major collider and strongly supports FCC-ee ... if it is chosen as the next major research infrastructure project at CERN. ... The U.S. would also support an LC if the CERN Council approves such a project in a timely manner."

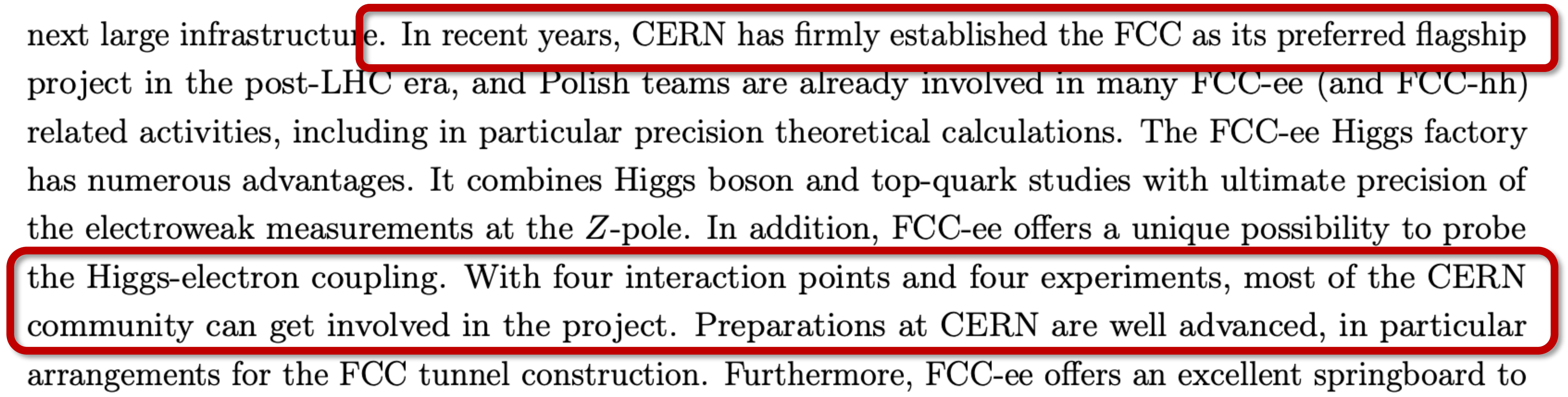
MORE MEMBER STATES

Czechia



Following extensive discussions and feedback from the Czech HEP community, we reaffirm our strong support for the long-term goal of a next-generation circular hadron-hadron collider (FCC-hh) with a center-of-mass energy of 100 TeV. While we recognize the significant challenges associated with realizing such a machine in the near future, we believe that a staged approach is the most feasible and scientifically robust path forward. In this context, the Future Circular Collider in its electron-positron (FCC-ee) configuration represents the optimal first step, serving as a Higgs factory and laying the technological and scientific groundwork for future energy-frontier colliders. This approach ensures a strategic pathway for high-energy physics while maintaining CERN and Europe's leadership in the field.

Poland



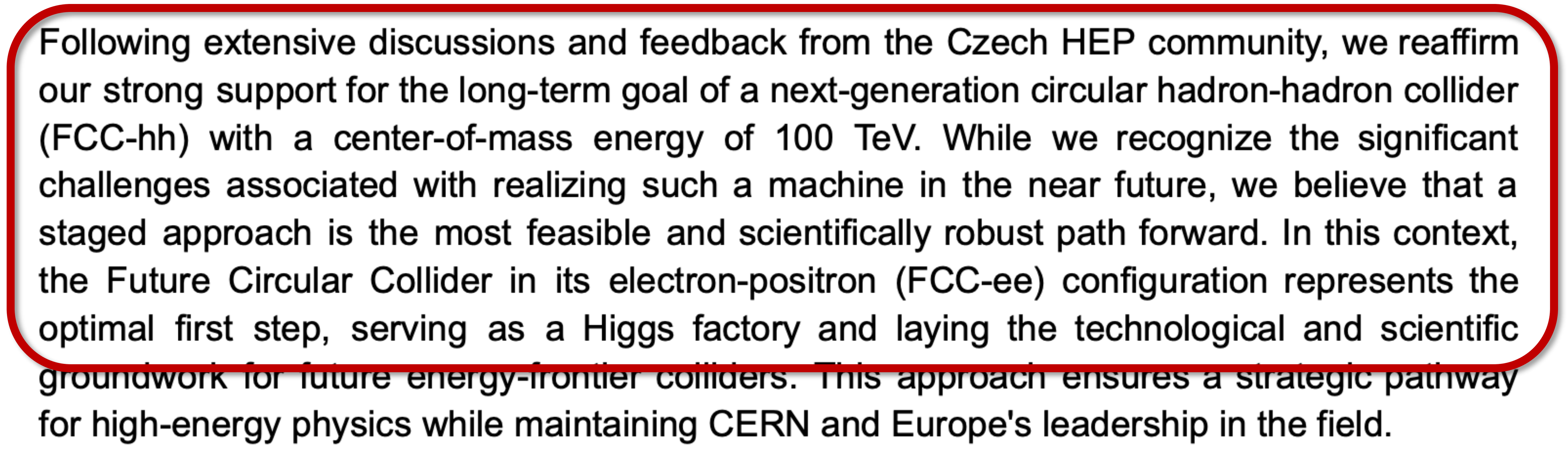
next large infrastructure. In recent years, CERN has firmly established the FCC as its preferred flagship project in the post-LHC era, and Polish teams are already involved in many FCC-ee (and FCC-hh) related activities, including in particular precision theoretical calculations. The FCC-ee Higgs factory has numerous advantages. It combines Higgs boson and top-quark studies with ultimate precision of the electroweak measurements at the Z-pole. In addition, FCC-ee offers a unique possibility to probe the Higgs-electron coupling. With four interaction points and four experiments, most of the CERN community can get involved in the project. Preparations at CERN are well advanced, in particular arrangements for the FCC tunnel construction. Furthermore, FCC-ee offers an excellent springboard to

Some observations

- CZ mentions FCC-hh
- PL mentions CERN preference

MORE MEMBER STATES

Czechia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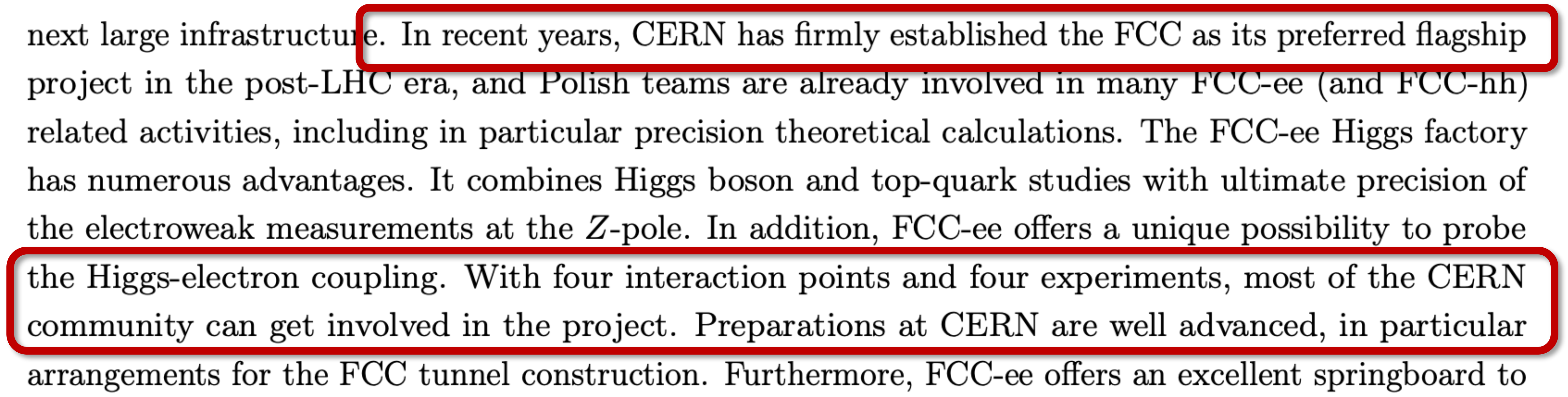
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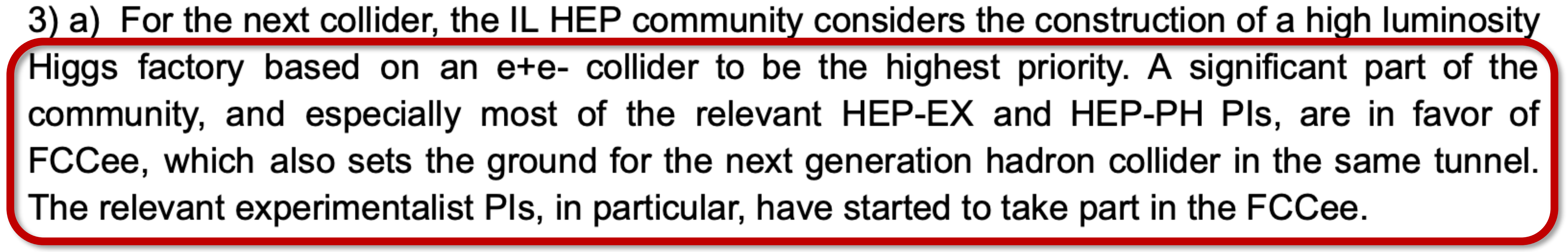
Israel


3) a) For the next collider, the IL HEP community considers the construction of a high luminosity Higgs factory based on an e+e- collider to be the highest priority. A significant part of the community, and especially most of the relevant HEP-EX and HEP-PH PIs, are in favor of FCCee, which also sets the ground for the next generation hadron collider in the same tunnel. The relevant experimentalist PIs, in particular, have started to take part in the FCCee.

Some observations

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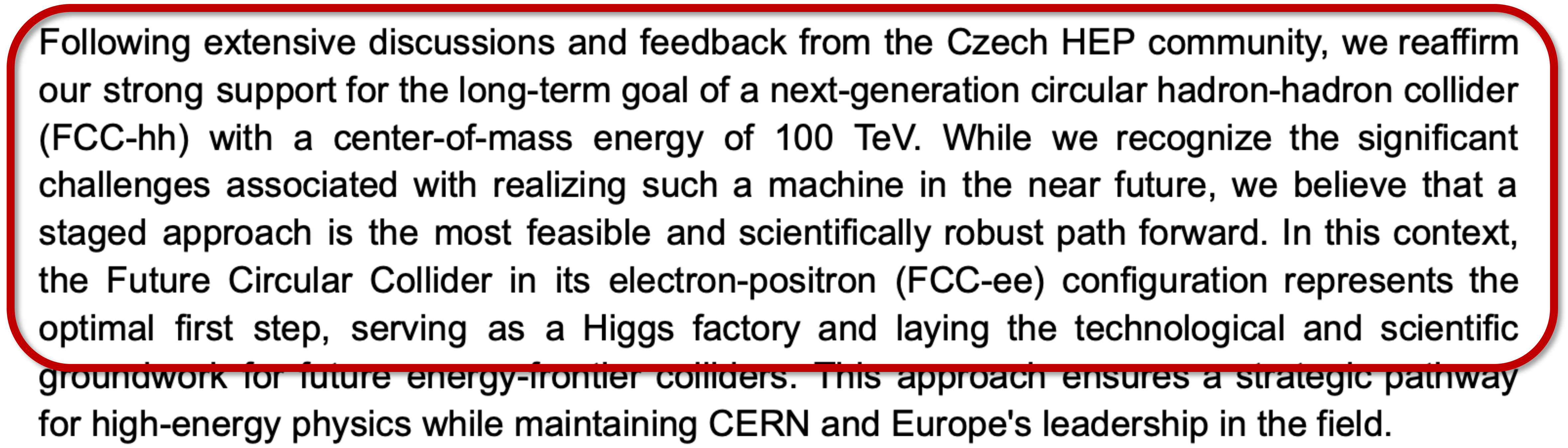
- PL mentions CERN preference

MORE MEMBER STATES

Czechia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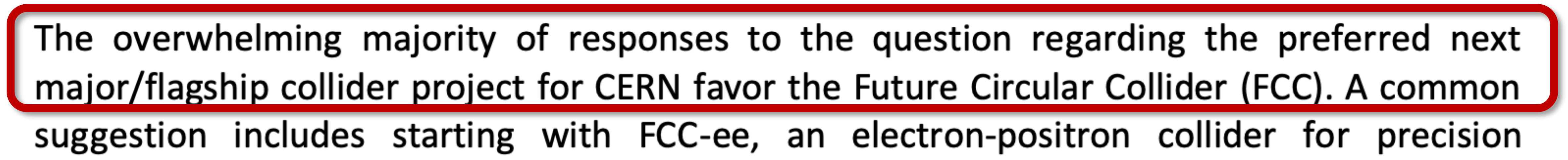
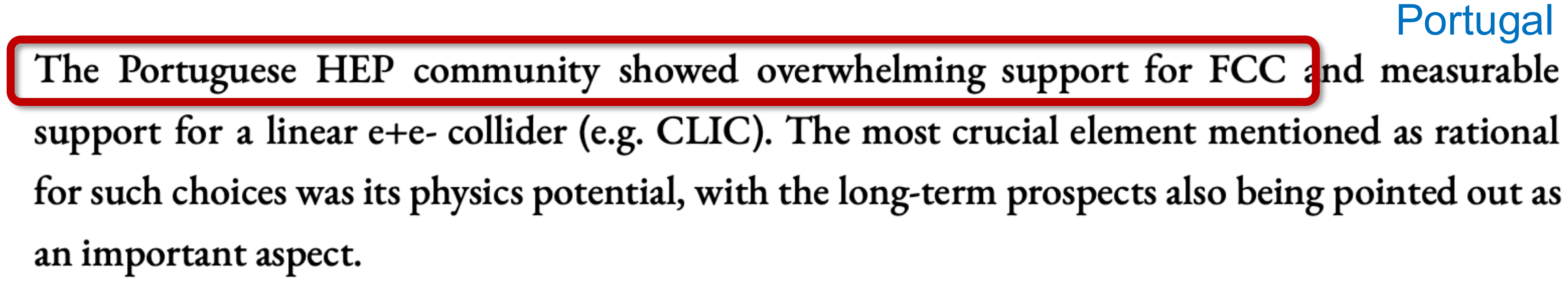
Greece


The overwhelming majority of responses to the question regarding the preferred next major/flagship collider project for CERN favor the Future Circular Collider (FCC). A common suggestion includes starting with FCC-ee, an electron-positron collider for precision

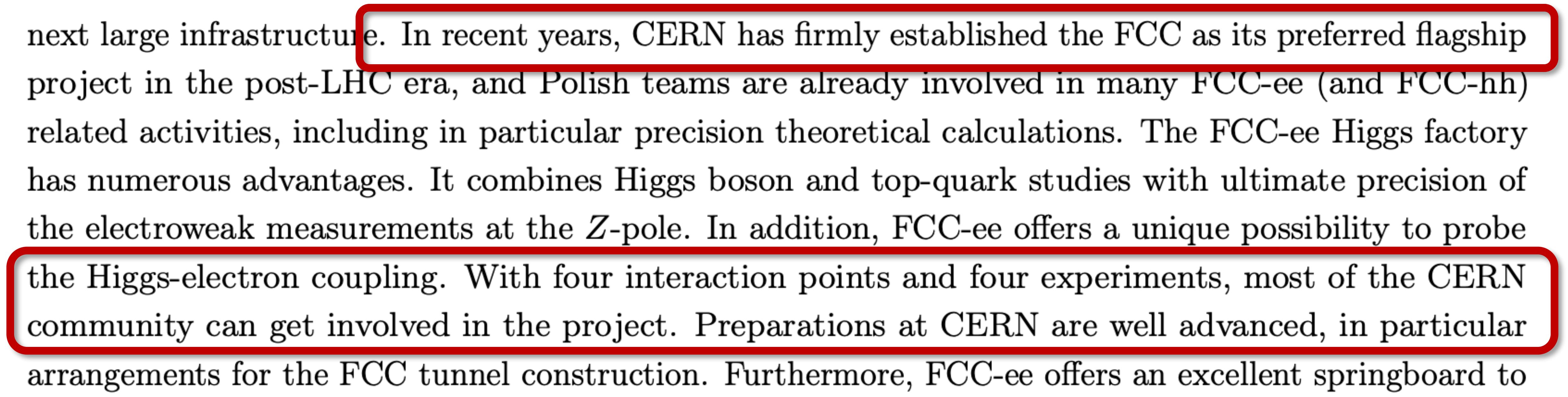
Portugal


The Portuguese HEP community showed overwhelming support for FCC and measurable support for a linear e+e- collider (e.g. CLIC). The most crucial element mentioned as rational for such choices was its physics potential, with the long-term prospects also being pointed out as an important aspect.

Some observations

- CZ mentions FCC-hh
- PL mentions CERN preference

Poland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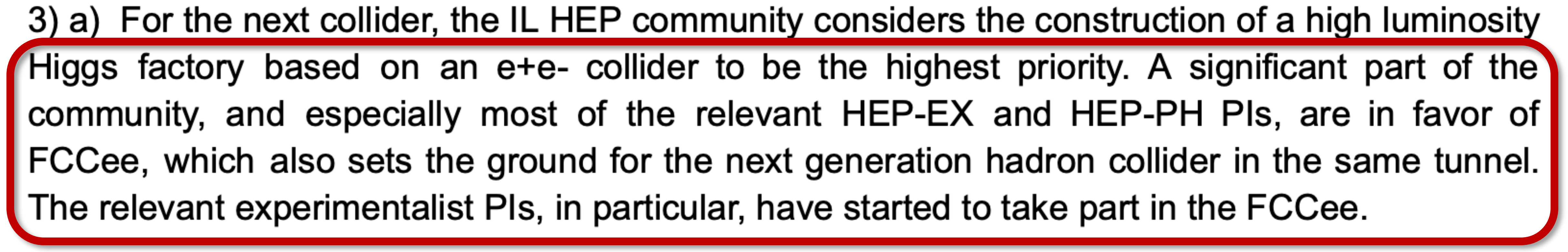
Israel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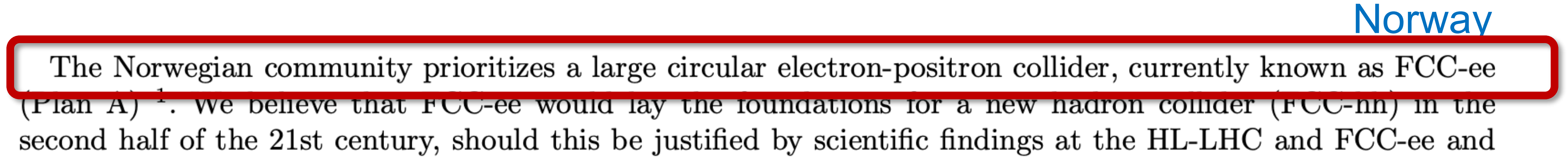
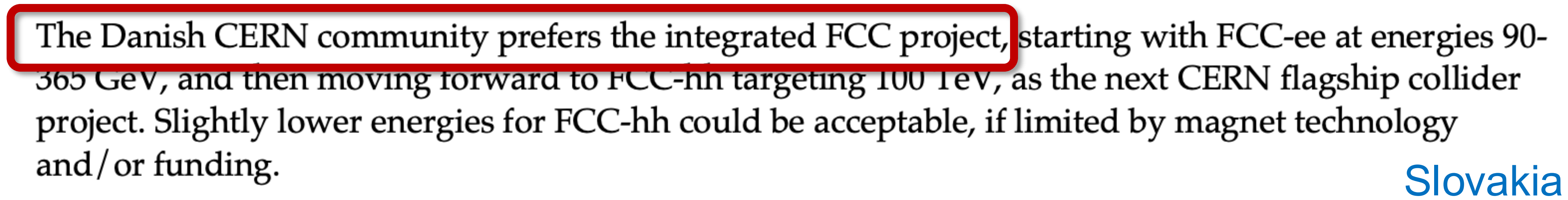
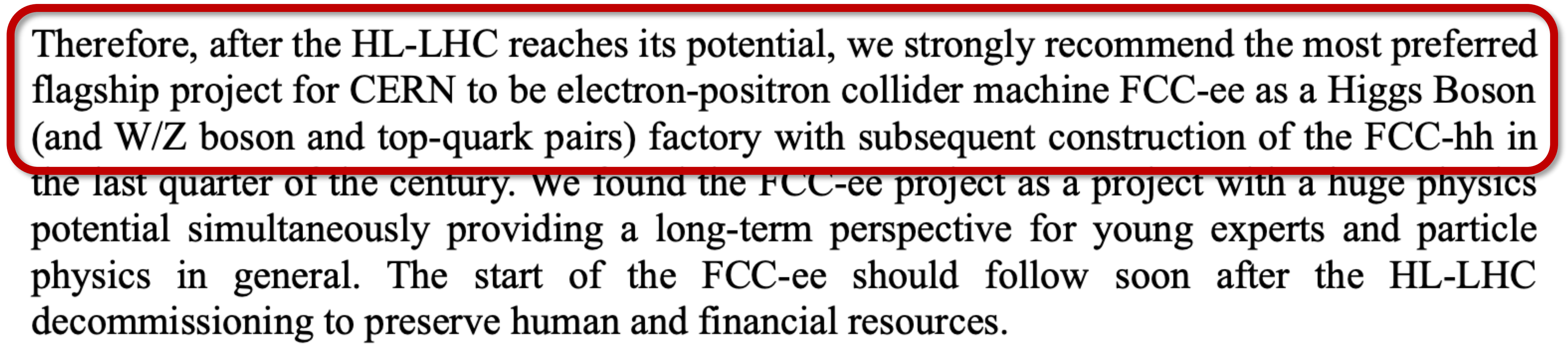
Norway


The Norwegian community prioritizes a large circular electron-positron collider, currently known as FCC-ee (Plan A) [1]. We believe that FCC-ee would lay the foundations for a new hadron collider (FCC-hh) in the second half of the 21st century, should this be justified by scientific findings at the HL-LHC and FCC-ee and

Denmark

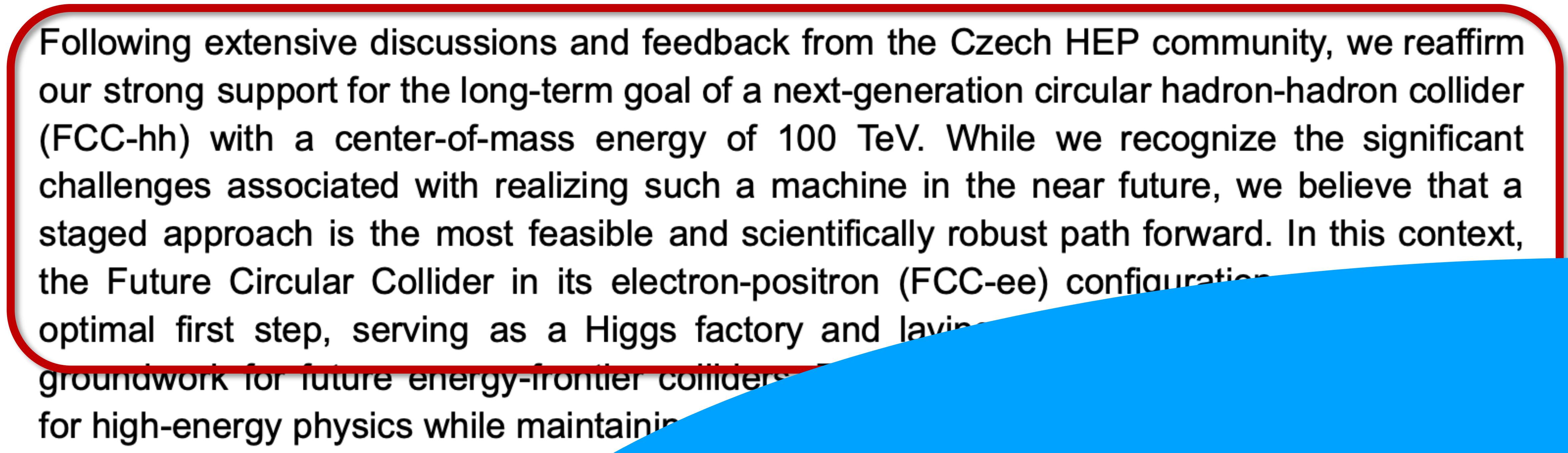

The Danish CERN community prefers the integrated FCC project, starting with FCC-ee at energies 90-365 GeV, and then moving forward to FCC-hh targeting 100 TeV, as the next CERN flagship collider project. Slightly lower energies for FCC-hh could be acceptable, if limited by magnet technology and/or funding.

Slovakia


Therefore, after the HL-LHC reaches its potential, we strongly recommend the most preferred flagship project for CERN to be electron-positron collider machine FCC-ee as a Higgs Boson (and W/Z boson and top-quark pairs) factory with subsequent construction of the FCC-hh in the last quarter of the century. We found the FCC-ee project as a project with a huge physics potential simultaneously providing a long-term perspective for young experts and particle physics in general. The start of the FCC-ee should follow soon after the HL-LHC decommissioning to preserve human and financial resources.

MORE MEMBER STATES

Czechia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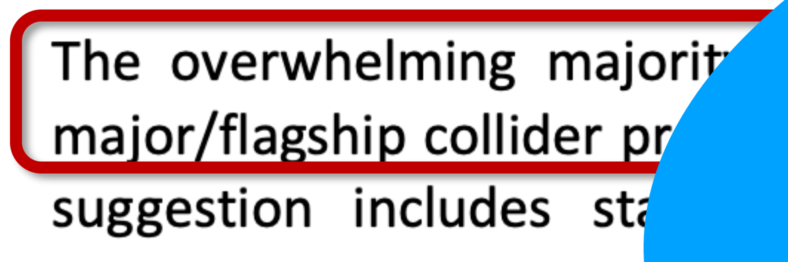
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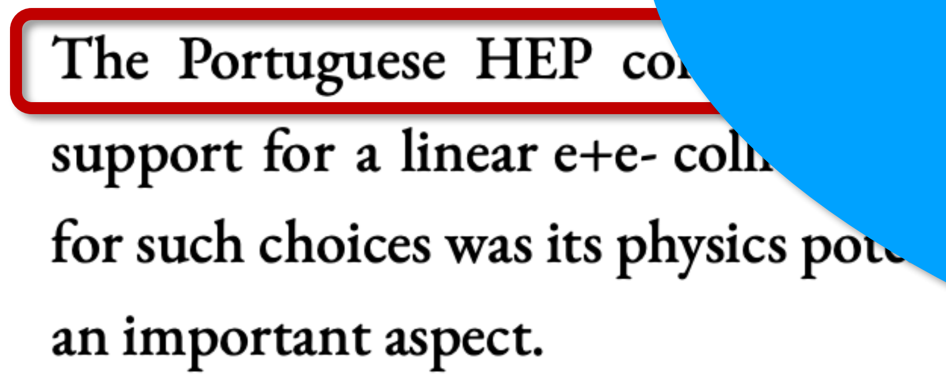
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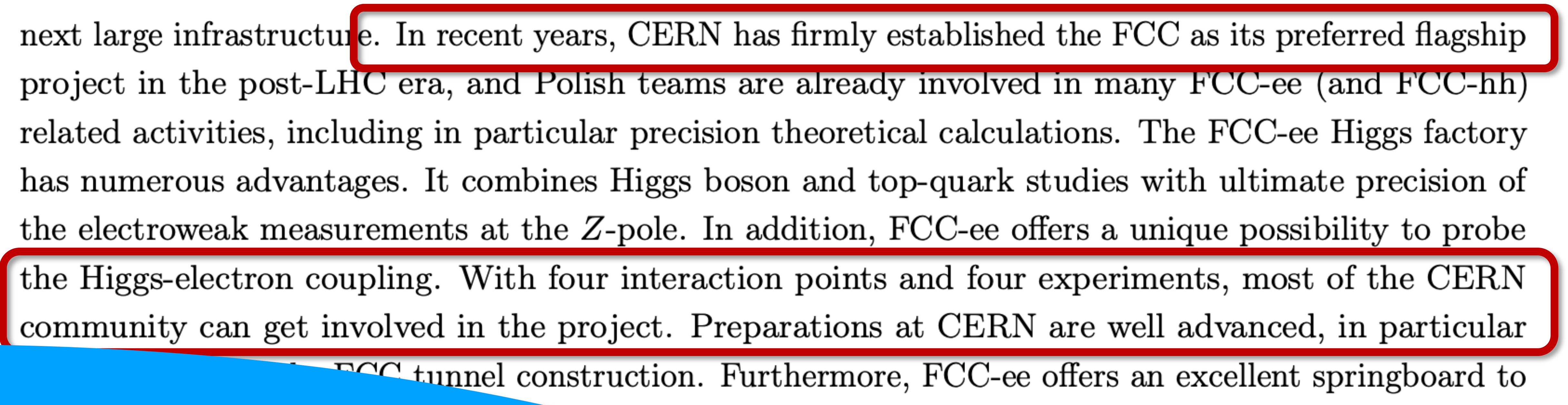
Poland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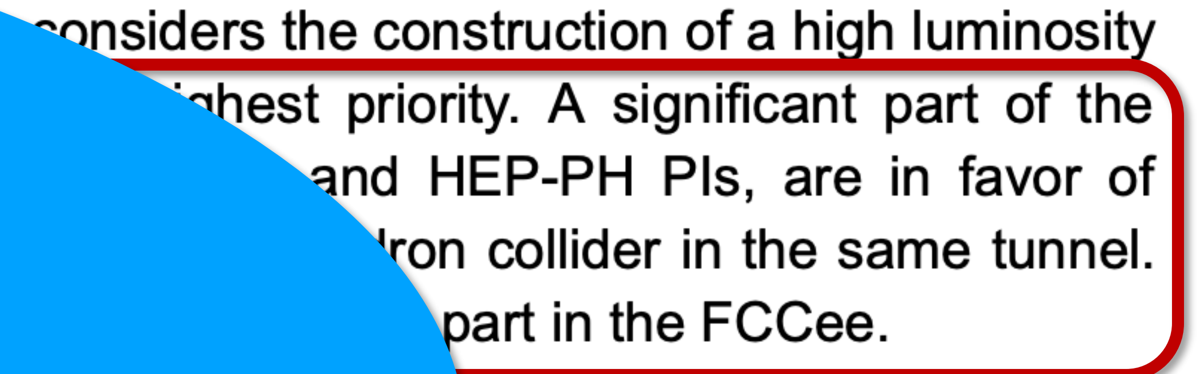
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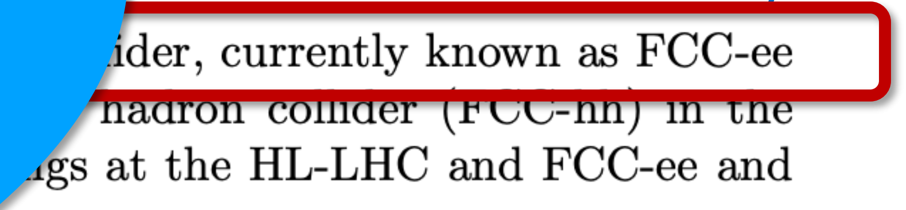
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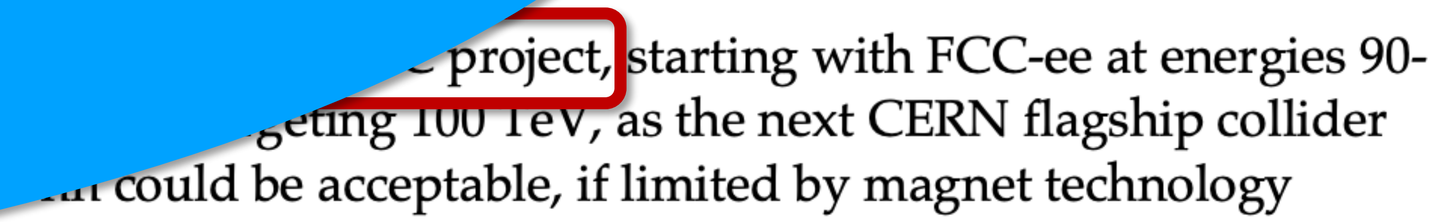
Denmark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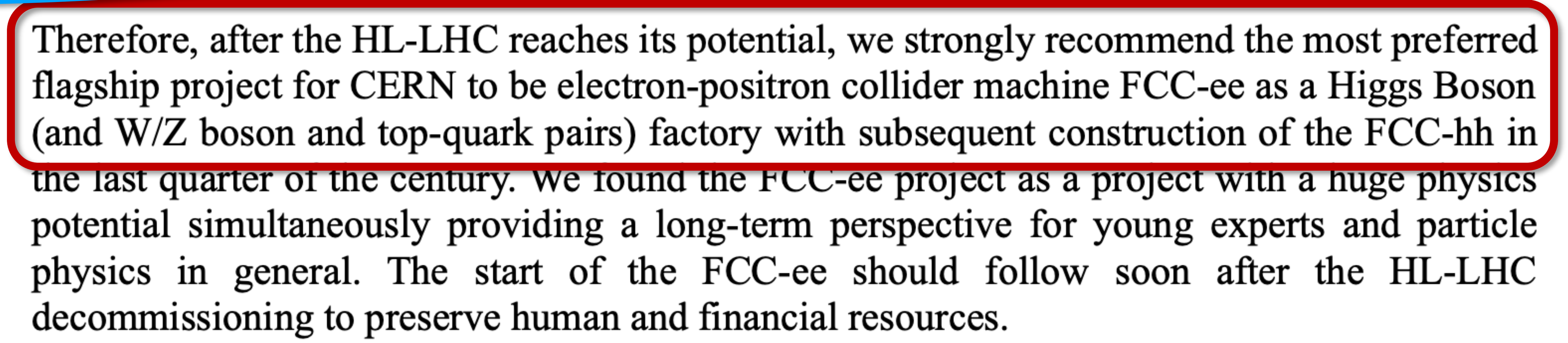
Slovakia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Some observations

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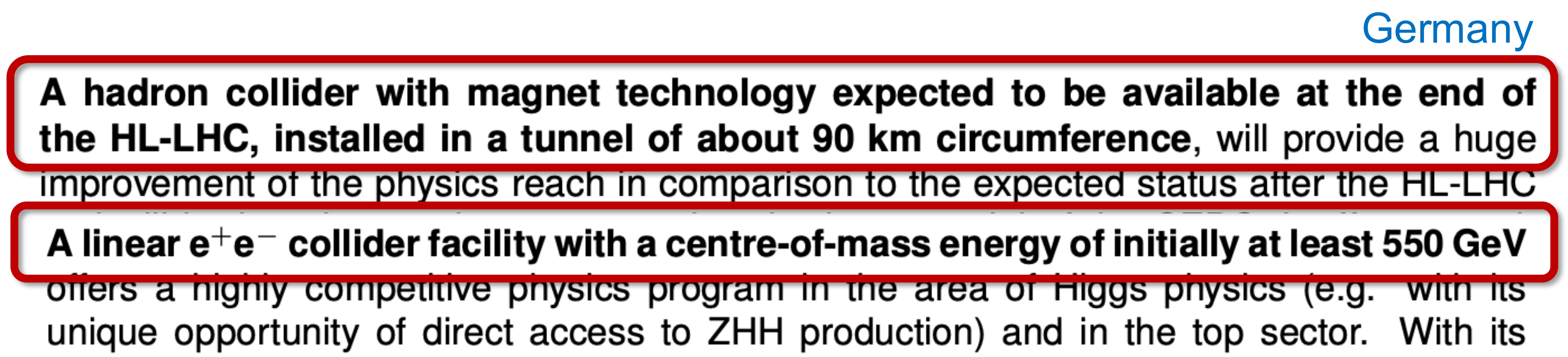
- PL mentions CERN preference

COUNTRIES: ALTERNATIVE SCENARIOS (CEPC)



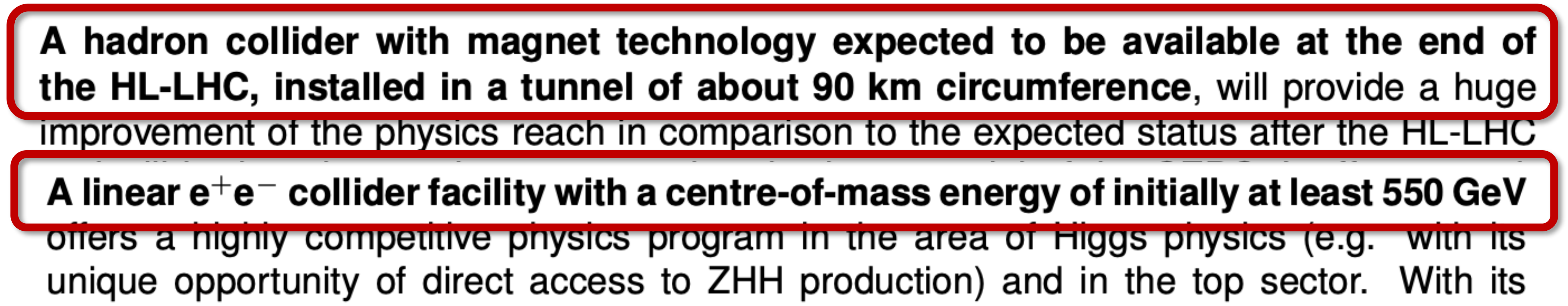
Germany

A hadron collider with magnet technology expected to be available at the end of the HL-LHC, installed in a tunnel of about 90 km circumference, will provide a huge improvement of the physics reach in comparison to the expected status after the HL-LHC

A linear e^+e^- collider facility with a centre-of-mass energy of initially at least 550 GeV offers a highly competitive physics program in the area of Higgs physics (e.g. with its unique opportunity of direct access to ZHH production) and in the top sector. With its

COUNTRIES: ALTERNATIVE SCENARIOS (CEPC)

Germany



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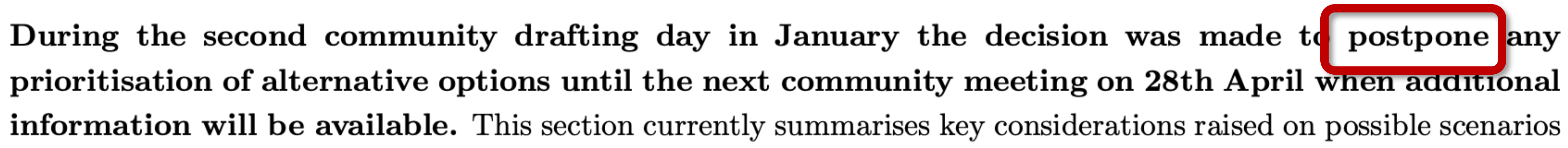
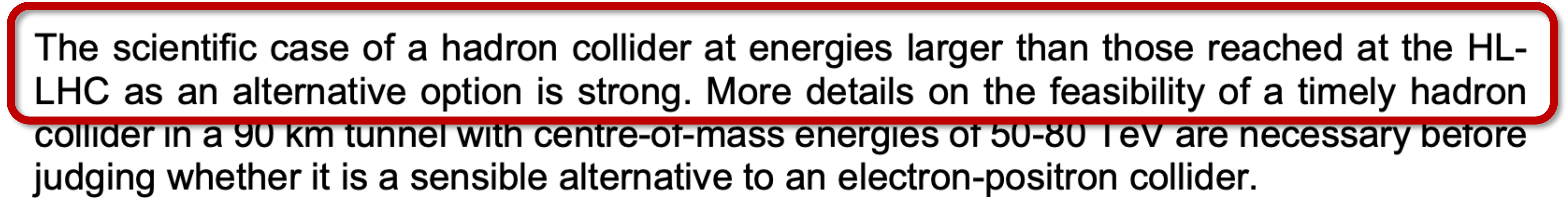
UK



During the second community drafting day in January the decision was made to postpone any prioritisation of alternative options until the next community meeting on 28th April when additional information will be available. This section currently summarises key considerations raised on possible scenarios

Spain

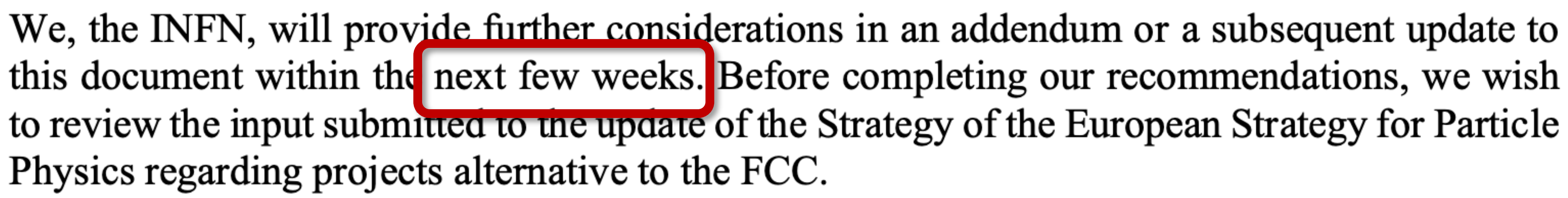


The scientific case of a hadron collider at energies larger than those reached at the HL-LHC as an alternative option is strong. More details on the feasibility of a timely hadron collider in a 90 km tunnel with centre-of-mass energies of 50-80 TeV are necessary before judging whether it is a sensible alternative to an electron-positron collider.

If China builds CepC:

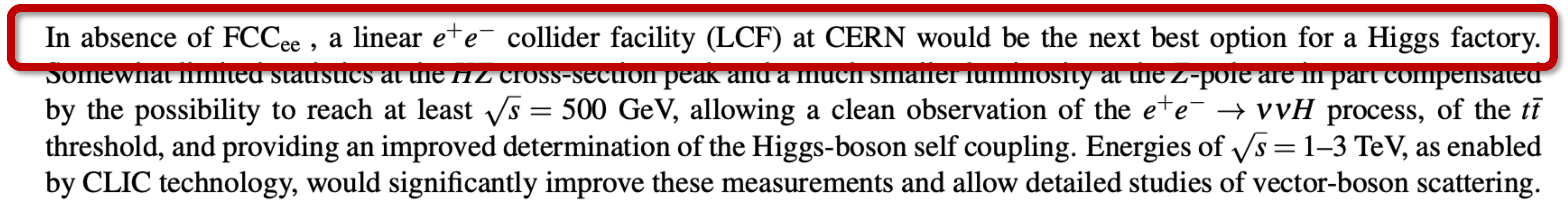
- FCC-hh? Linear Collider?
- FCC-ee? Muon Collider?
  - Quite mixed, some not yet defined

Italy



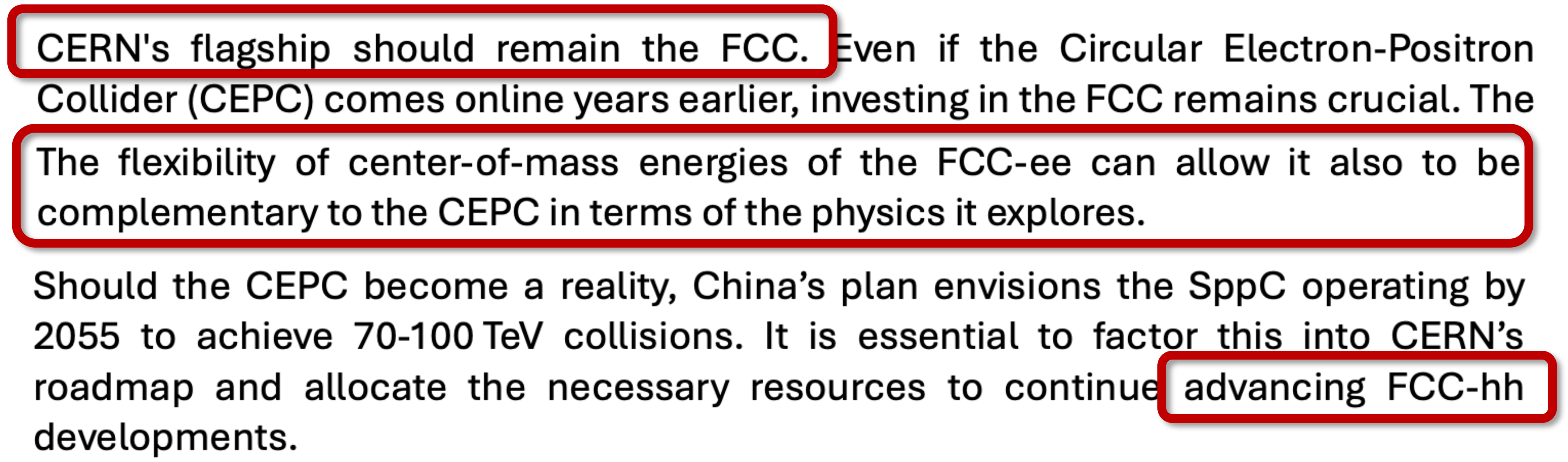
We, the INFN, will provide further considerations in an addendum or a subsequent update to this document within the next few weeks. Before completing our recommendations, we wish to review the input submitted to the update of the Strategy of the European Strategy for Particle Physics regarding projects alternative to the FCC.

France



In absence of FCC_{ee} , a linear e^+e^- collider facility (LCF) at CERN would be the next best option for a Higgs factory. Somewhat limited statistics at the HZ cross-section peak and a much smaller luminosity at the Z-pole are in part compensated by the possibility to reach at least $\sqrt{s} = 500$ GeV, allowing a clean observation of the $e^+e^- \to \nu\nu H$ process, of the $t\bar{t}$ threshold, and providing an improved determination of the Higgs-boson self coupling. Energies of $\sqrt{s} = 1$–3 TeV, as enabled by CLIC technology, would significantly improve these measurements and allow detailed studies of vector-boson scattering.

Switzerland



CERN's flagship should remain the FCC. Even if the Circular Electron-Positron Collider (CEPC) comes online years earlier, investing in the FCC remains crucial. The

The flexibility of center-of-mass energies of the FCC-ee can allow it also to be complementary to the CEPC in terms of the physics it explores.

Should the CEPC become a reality, China's plan envisions the SppC operating by 2055 to achieve 70-100 TeV collisions. It is essential to factor this into CERN's roadmap and allocate the necessary resources to continue advancing FCC-hh developments.

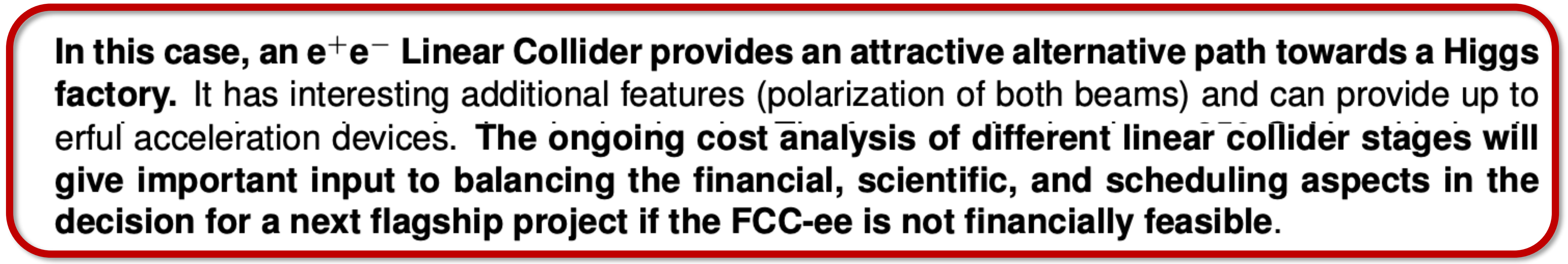
COUNTRIES: ALTERNATIVE SCENARIOS ($$$)

If FCC is not feasible

- Linear Collider?
    - But feasability & cost estimate needed

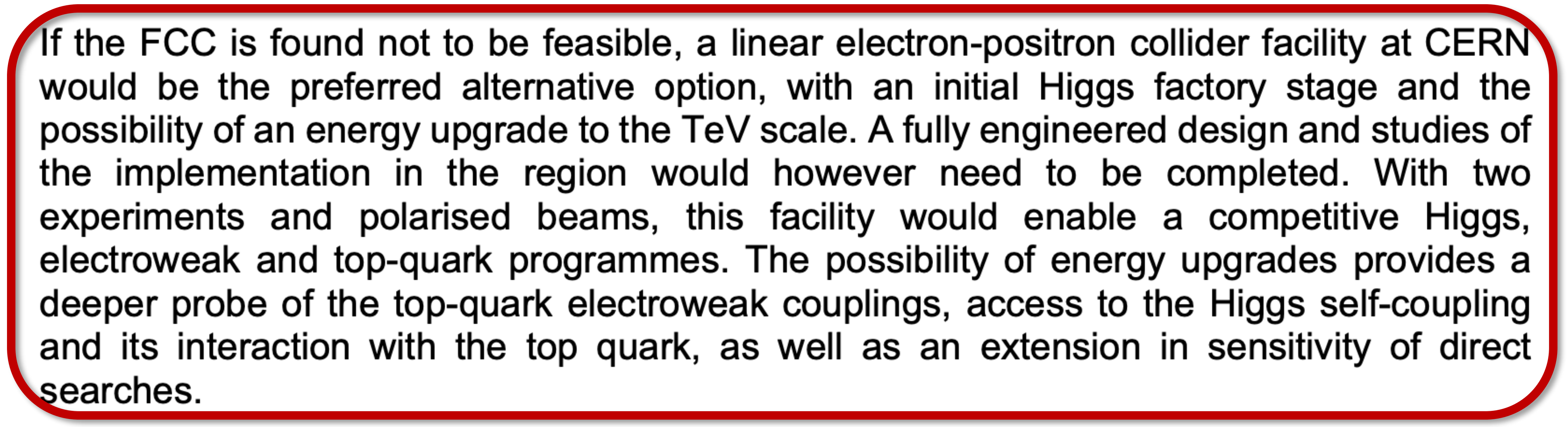
(Switzerland even refuses to consider alternatives)

Germany



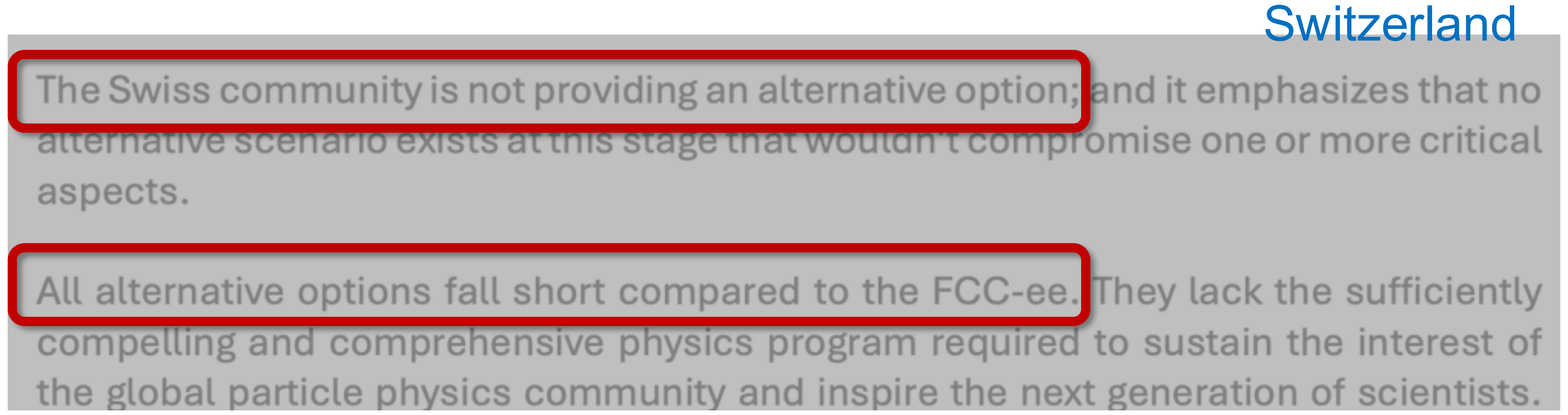
In this case, an e^+e^- Linear Collider provides an attractive alternative path towards a Higgs factory. It has interesting additional features (polarization of both beams) and can provide up to erful acceleration devices. **The ongoing cost analysis of different linear collider stages will give important input to balancing the financial, scientific, and scheduling aspects in the decision for a next flagship project if the FCC-ee is not financially feasible.**

Spain



If the FCC is found not to be feasible, a linear electron-positron collider facility at CERN would be the preferred alternative option, with an initial Higgs factory stage and the possibility of an energy upgrade to the TeV scale. A fully engineered design and studies of the implementation in the region would however need to be completed. With two experiments and polarised beams, this facility would enable a competitive Higgs, electroweak and top-quark programmes. The possibility of energy upgrades provides a deeper probe of the top-quark electroweak couplings, access to the Higgs self-coupling and its interaction with the top quark, as well as an extension in sensitivity of direct searches.

Switzerland



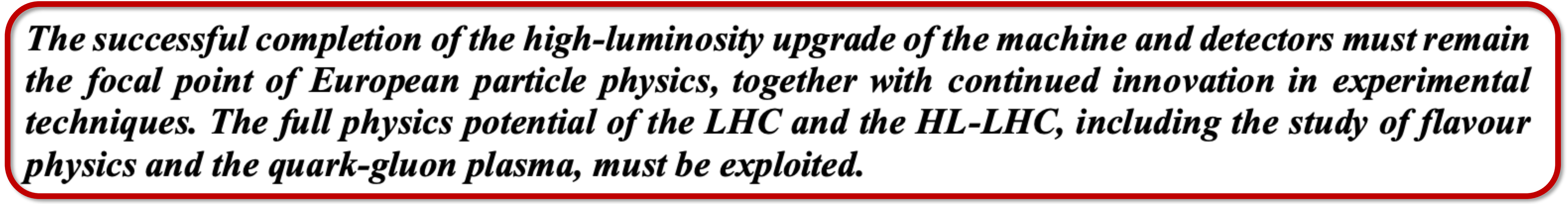
The Swiss community is not providing an alternative option; and it emphasizes that no alternative scenario exists at this stage that wouldn't compromise one or more critical aspects.

All alternative options fall short compared to the FCC-ee. They lack the sufficiently compelling and comprehensive physics program required to sustain the interest of the global particle physics community and inspire the next generation of scientists.

COUNTRIES: AOB

HL-LHC

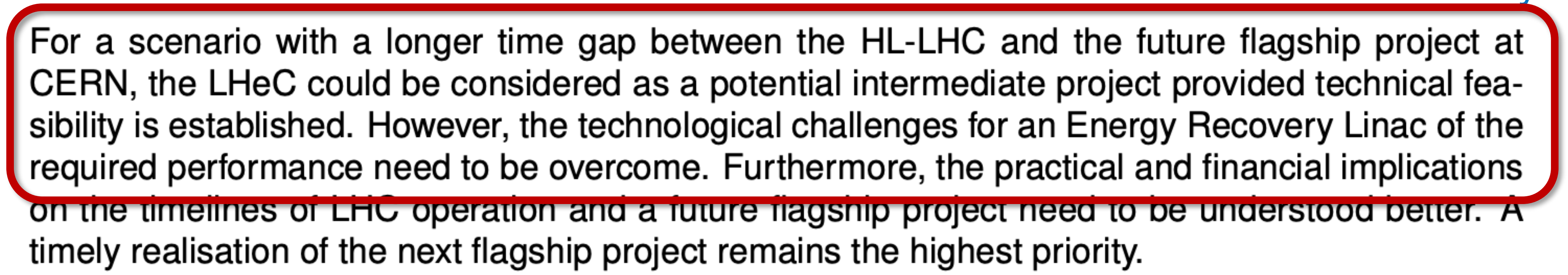
Italy



The successful completion of the high-luminosity upgrade of the machine and detectors must remain the focal point of European particle physics, together with continued innovation in experimental techniques. The full physics potential of the LHC and the HL-LHC, including the study of flavour physics and the quark-gluon plasma, must be exploited.

LHeC

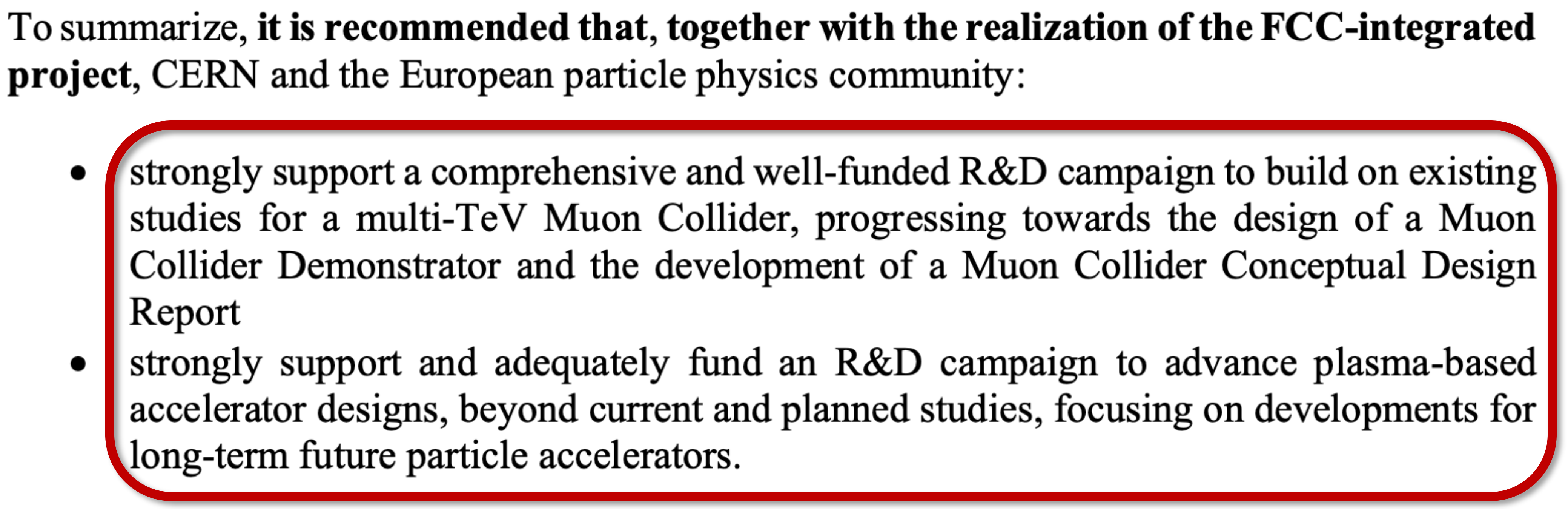
Germany



For a scenario with a longer time gap between the HL-LHC and the future flagship project at CERN, the LHeC could be considered as a potential intermediate project provided technical feasibility is established. However, the technological challenges for an Energy Recovery Linac of the required performance need to be overcome. Furthermore, the practical and financial implications on the timelines of LHC operation and a future flagship project need to be understood better. A timely realisation of the next flagship project remains the highest priority.

R&D

Italy



To summarize, **it is recommended that**, **together with the realization of the FCC-integrated project**, CERN and the European particle physics community:

- strongly support a comprehensive and well-funded R&D campaign to build on existing studies for a multi-TeV Muon Collider, progressing towards the design of a Muon Collider Demonstrator and the development of a Muon Collider Conceptual Design Report
- strongly support and adequately fund an R&D campaign to advance plasma-based accelerator designs, beyond current and planned studies, focusing on developments for long-term future particle accelerators.

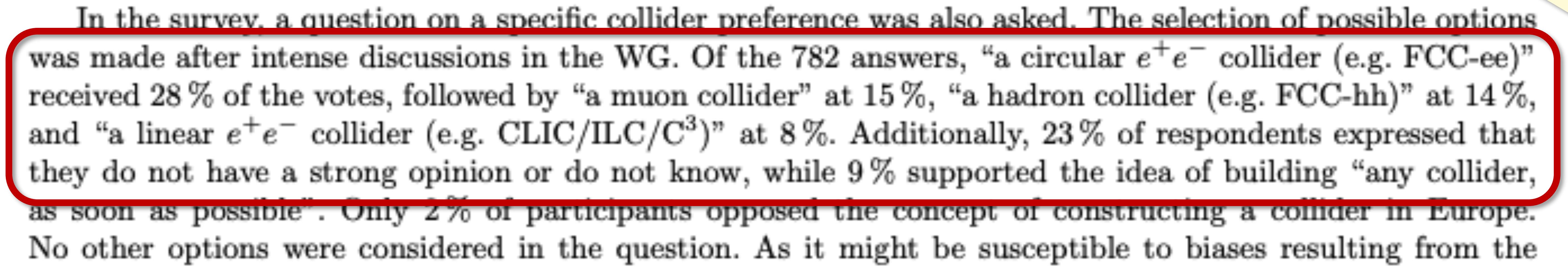
ECRS

ECR Input

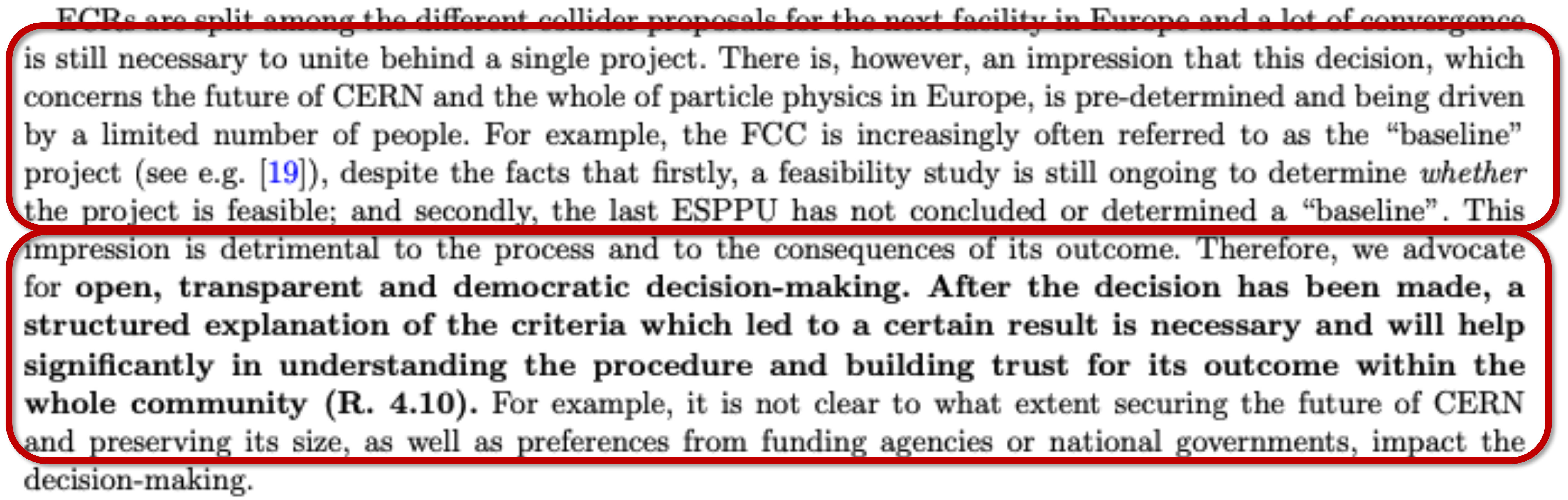
https://indico.cern.ch/event/1439855/contributions/6461451/

Early Career Researchers

- 55 recommendations
  - Some critique on process



In the survey, a question on a specific collider preference was also asked. The selection of possible options was made after intense discussions in the WG. Of the 782 answers, "a circular e^+e^- collider (e.g. FCC-ee)" received 28 % of the votes, followed by "a muon collider" at 15 %, "a hadron collider (e.g. FCC-hh)" at 14 %, and "a linear e^+e^- collider (e.g. CLIC/ILC/C^3)" at 8 %. Additionally, 23 % of respondents expressed that they do not have a strong opinion or do not know, while 9 % supported the idea of building "any collider, as soon as possible". Only 2 % of participants opposed the concept of constructing a collider in Europe. No other options were considered in the question. As it might be susceptible to biases resulting from the



ECRs are split among the different collider proposals for the next facility in Europe and a lot of convergence is still necessary to unite behind a single project. There is, however, an impression that this decision, which concerns the future of CERN and the whole of particle physics in Europe, is pre-determined and being driven by a limited number of people. For example, the FCC is increasingly often referred to as the "baseline" project (see e.g. [19]), despite the facts that firstly, a feasibility study is still ongoing to determine *whether* the project is feasible; and secondly, the last ESPPU has not concluded or determined a "baseline". This impression is detrimental to the process and to the consequences of its outcome. Therefore, we advocate for **open, transparent and democratic decision-making. After the decision has been made, a structured explanation of the criteria which led to a certain result is necessary and will help significantly in understanding the procedure and building trust for its outcome within the whole community (R. 4.10).** For example, it is not clear to what extent securing the future of CERN and preserving its size, as well as preferences from funding agencies or national governments, impact the decision-making.

SOME OTHER OBSERVATIONS

Outreach important
- Mentioned a lot

Sustainability
- Not so much

Nuclear community
- Concern about prospects in case of e^+e^- collider

CERN is much more than just the lab!


CERN openlab: A Flagship Model for Industry-Science Computing R&D

V.Mexner et al

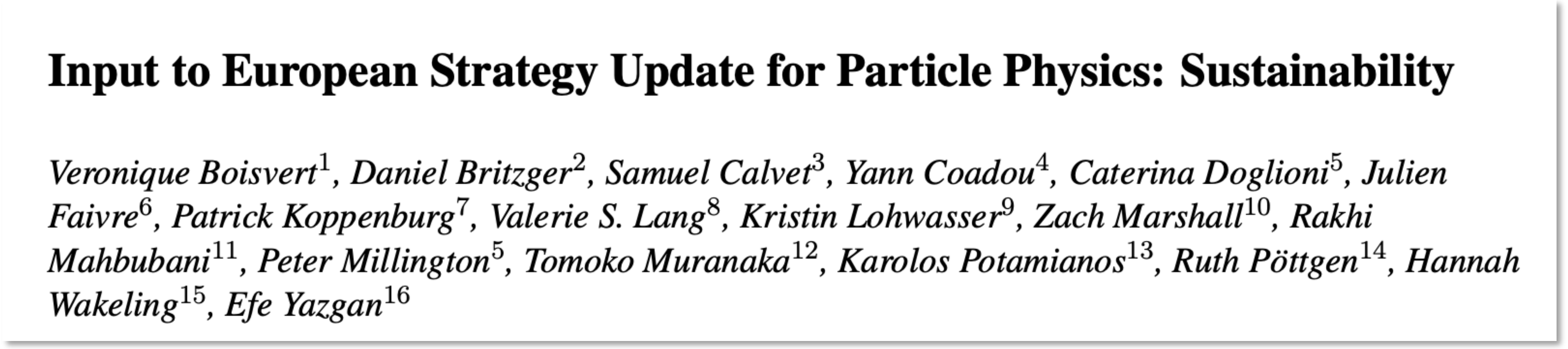

EPPCN
European Particle Physics Communication Network

Communicating for the future of particle physics

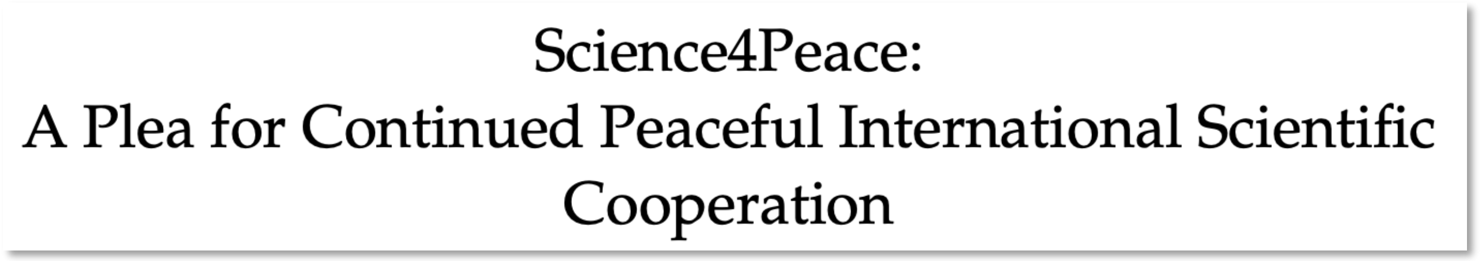
Input to the 2026 update of the European Strategy for Particle Physics by the European Particle Physics Communication Network (EPPCN)

Contact persons:
Arnaud Marsollier (CERN) and Vanessa Mexner (NL), EPPCN co-chairs
Email: Arnaud.Marsollier@cern.ch, Vanessa.Mexner@nikhef.nl

P.Koppenburg et al

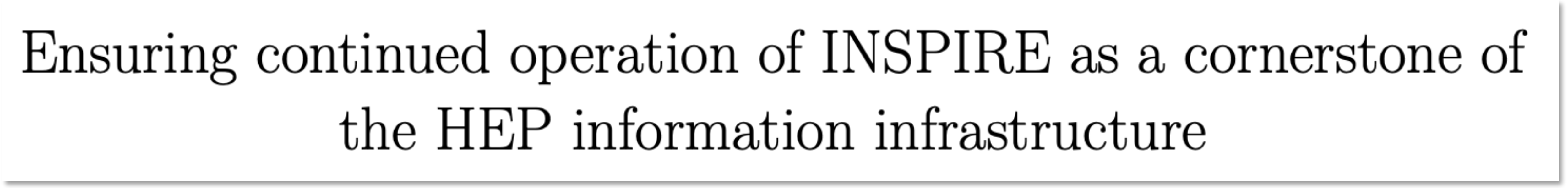

Input to European Strategy Update for Particle Physics: Sustainability

Veronique Boisvert[1], *Daniel Britzger*[2], *Samuel Calvet*[3], *Yann Coadou*[4], *Caterina Doglioni*[5], *Julien Faivre*[6], *Patrick Koppenburg*[7], *Valerie S. Lang*[8], *Kristin Lohwasser*[9], *Zach Marshall*[10], *Rakhi Mahbubani*[11], *Peter Millington*[5], *Tomoko Muranaka*[12], *Karolos Potamianos*[13], *Ruth Pöttgen*[14], *Hannah Wakeling*[15], *Efe Yazgan*[16]


Science4Peace:
A Plea for Continued Peaceful International Scientific Cooperation


Early Career Researcher Input to the
European Strategy for Particle Physics Update
Fifty-five recommendations for the future of our field


Data Preservation in High Energy Physics


Ensuring continued operation of INSPIRE as a cornerstone of the HEP information infrastructure


CERN-MEDICIS

A unique facility for the production of innovative biomedical research radionuclides

THUMBS UP TO THE ESPP PROCESS

Great that everyone could give their input

ESPP IN THE PUBLIC MEDIA

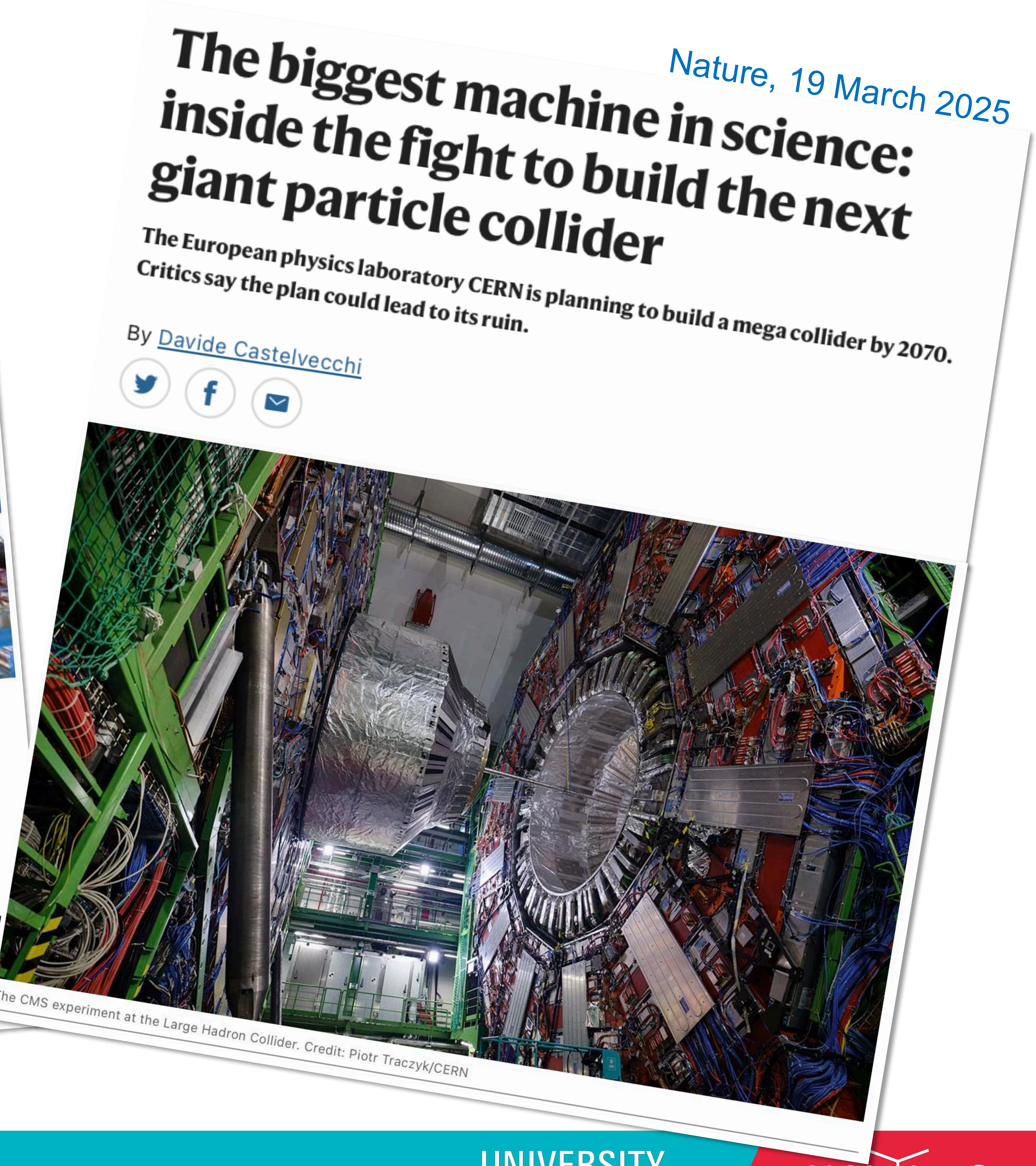
This is not good…

Guardian, 29 March 2025

The Observer

‘The physics community has never split like this’: row erupts over plans for new Large Hadron Collider

Nature, 19 March 2025



The biggest machine in science: inside the fight to build the next giant particle collider

The European physics laboratory CERN is planning to build a mega collider by 2070. Critics say the plan could lead to its ruin.

By Davide Castelvecchi

The CMS experiment at the Large Hadron Collider. Credit: Piotr Traczyk/CERN

CONCLUSIONS

HL-LHC
Our near-future focus
Fully exploit excellent program

FCC-ee
The European community's
preferred future collider project

Plan B ?
What if CepC in China?
What if FCC not feasible?

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FCC-ee? Linear Collider?
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Diversity
A.o. Astroparticle, LHeC

R&D
MuCol, ERL, Wakefield, HTS

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→ Plan A seems already fixed ←

→ The discussion of Plan B and finances is possibly more important ←

THANKS EVERYONE!

To many colleagues for all discussions over the years…

C3

Harrry

ILC
Peter, Gerhard, Patrick

R&D
Niels vB, Kazu, Martin, Joris

FCC
Clara, Eric, Juan, Wouter W

General Strategy
Jorgen, Jos E, Lydia, Frank L, Stan, Marcel M

Astroparticle
Aart, Auke, Paul, Marieke, Patrick

MuCol
Panos, Jacco, Mick, Frank F, Nicolo, Maarten, Alessandro

HL-LHC
Pamela, Flavia, Raimond, Sascha, NielsT, Robert, Melissa, Wouter V&H

…and many students, postdocs and ECRs in the ATLAS group and elsewhere, inside and outside Nikhef

THE FUTURE: FROM GENEVA TO ANNECY?

FROM GENEVA TO ANNECY (VIA VENICE)

Goede reis

Bon voyage

Buon viaggio

旅途愉快