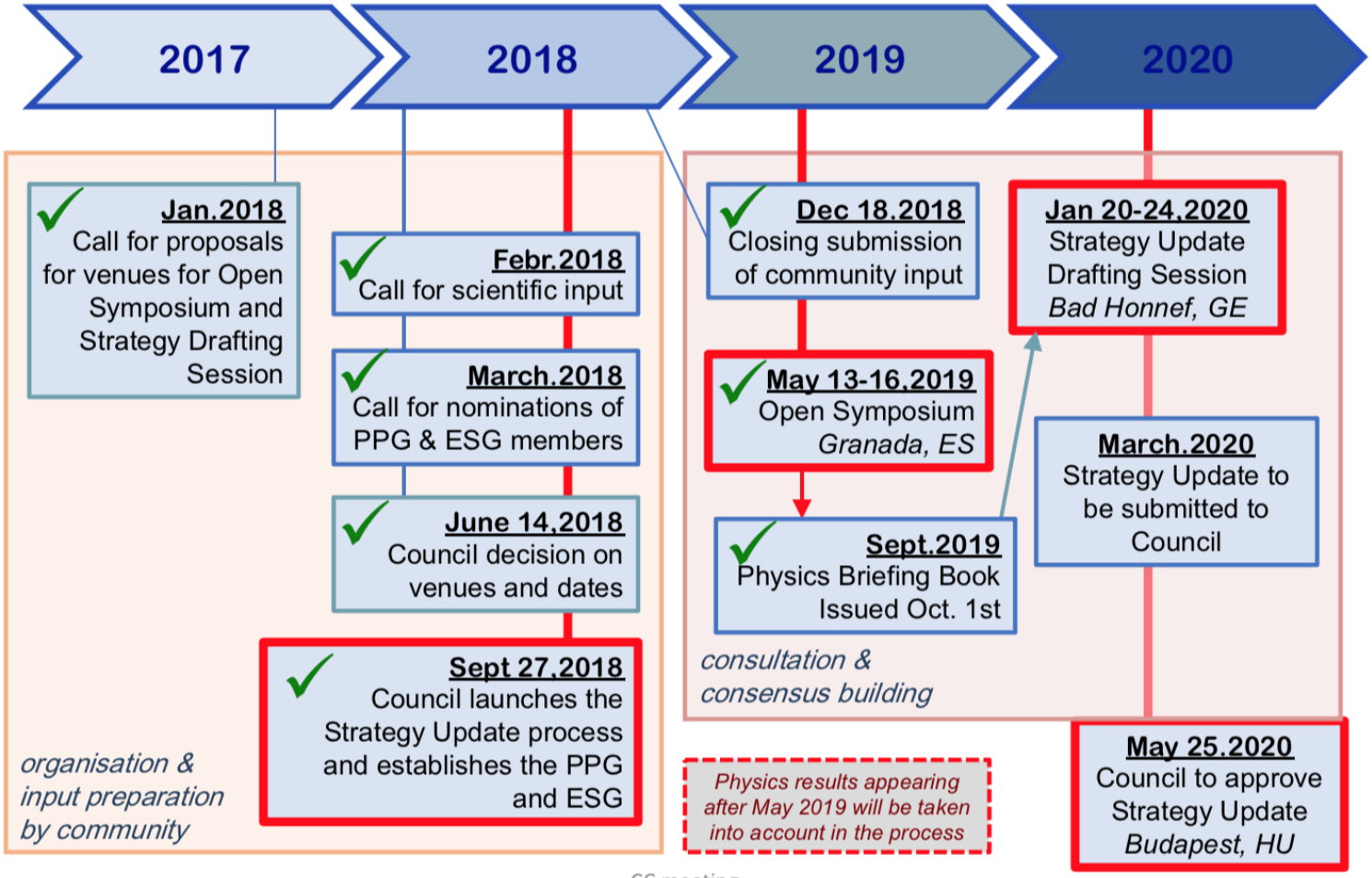
Status of the update of the European Strategy for Particle Physics

Kerstin Jon-And, Stockholm University
Swedish discussion meeting 2020-01-14

European Strategy Update

EPPSU 2020 timeline



Physics Briefing Book available
https://arxiv.org/abs/1910.11775

European Strategy Update

EPPSU2020

Main challenge for the European Strategy Group

Recommend the path for the future facility in Europe

Physics case

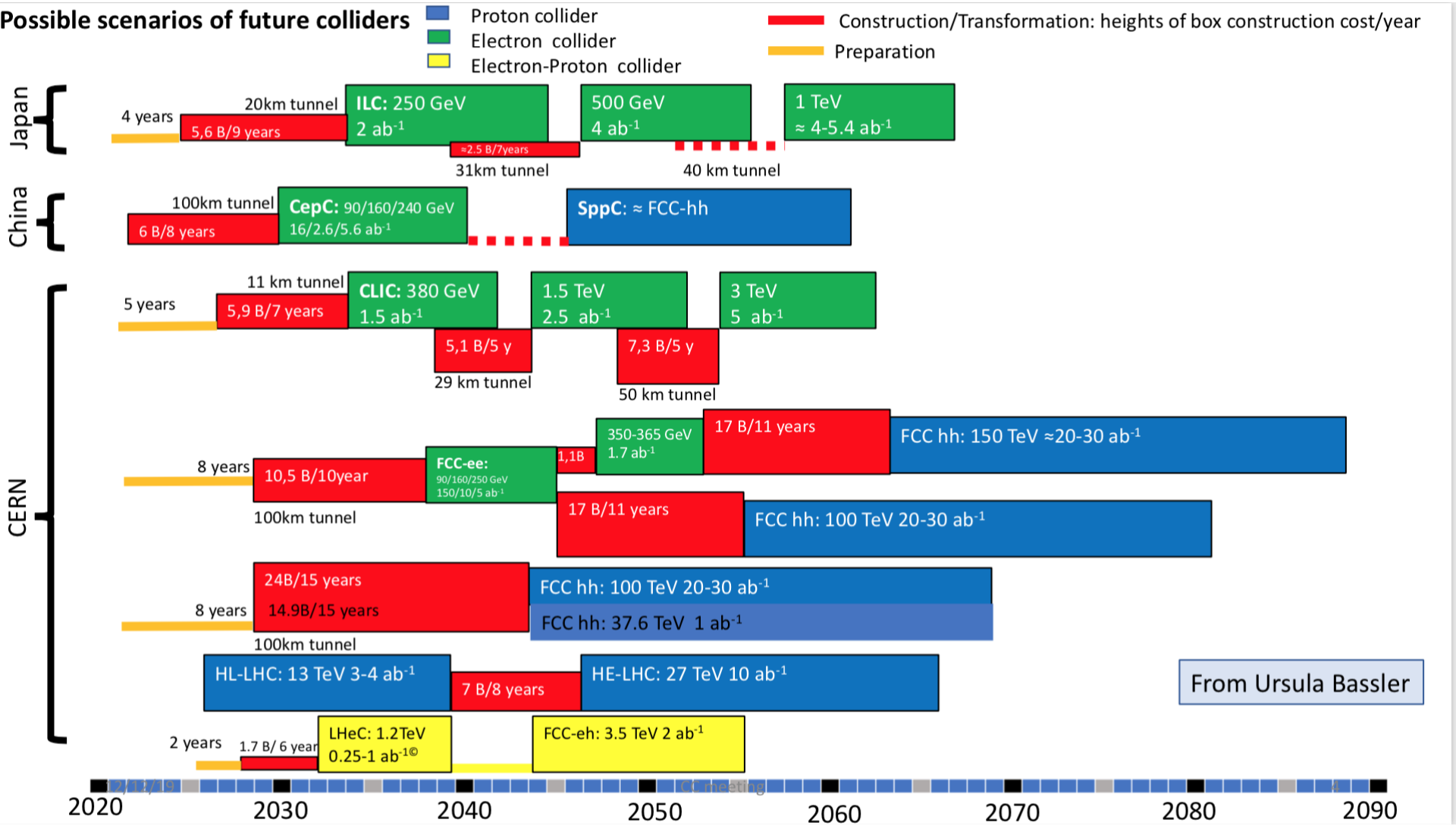
- Explore the unknowns of the Higgs sector
- Explore the boundaries of the Standard Model at the high-energy frontier

To be considered

- Projects assessment of technological readiness, time scales, financial profile, operational costs, innovation, reach, …
- National Inputs

Post-Grenada clarifications on National Inputs

ESG members asked to provide preferences and comments on a list of possible scenarios based on input from Granada to be reported in a dedicated meeting on November 6th, 2019.


Possible scenarios of future colliders
Proton collider
Electron collider
Electron-Proton collider
Construction/Transformation: heights of box construction cost/year
Preparation
Japan
4 years
20km tunnel
5,6 B/9 years
ILC: 250 GeV
2 ab-1
≈2.5 B/7years
31km tunnel
500 GeV
4 ab-1
40 km tunnel
1 TeV
≈ 4-5.4 ab-1
China
100km tunnel
6 B/8 years
CepC: 90/160/240 GeV
16/2.6/5.6 ab-1
SppC: ≈ FCC-hh
CERN
5 years
11 km tunnel
5,9 B/7 years
CLIC: 380 GeV
1.5 ab-1
5,1 B/5 y
29 km tunnel
1.5 TeV
2.5 ab-1
7,3 B/5 y
50 km tunnel
3 TeV
5 ab-1
8 years
10,5 B/10year
100km tunnel
FCC-ee:
90/160/250 GeV
150/10/5 ab-1
1,1B
350-365 GeV
1.7 ab-1
17 B/11 years
FCC hh: 150 TeV ≈20-30 ab-1
17 B/11 years
FCC hh: 100 TeV 20-30 ab-1
8 years
24B/15 years
14.9B/15 years
100km tunnel
FCC hh: 100 TeV 20-30 ab-1
FCC hh: 37.6 TeV 1 ab-1
HL-LHC: 13 TeV 3-4 ab-1
7 B/8 years
HE-LHC: 27 TeV 10 ab-1
2 years
1.7 B/ 6 year
LHeC: 1.2TeV
0.25-1 ab-1©
FCC-eh: 3.5 TeV 2 ab-1
From Ursula Bassler
2020
2030
2040
2050
2060
2070
2080
2090

European Strategy Update

EPPSU2020

Main challenge for the European Strategy Group

Post-Granada scenarios

	2020-2040	2040-2060	2060-2080
		1st gen technology	2nd gen technology
CLIC-all	HL-LHC	CLIC380-1500	CLIC3000 / other tech
CLIC-FCC	HL-LHC	CLIC380	FCC-h/e/A (Adv HF magnets) / other tech
FCC-all	HL-LHC	FCC-ee (90-365)	FCC-h/e/A (Adv HF magnets) / other tech
LE-to-HE-FCC-h/e/A	HL-LHC	LE-FCC-h/e/A (low-field magnets)	FCC-h/e/A (Adv HF magnets) / other tech
LHeC-FCC-h/e/A	HL-LHC + LHeC	LHeC	FCC-h/e/A (Adv HF magnets) / other tech

ee collider outside EU

From Halina Abramowicz

”Diversity” programme – smaller scale Europe based projects

			2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
		SPS	LS2						LS3						LS4				
		LHC	LS2		Run 3				LS3			Run 4			LS4				
North Area	NA64-electron	Operational	LS2		Data Taking										LS4				
	NA64-mu	< 1 MCHF	Studies		Test	Pilot	Phase 1												
	NA61/Shine	< 2 MCHF	Detector upgrade		Data Taking					Data Taking									
	MUonE	< 2 MCHF	Preparation		Pilot	Run 1	Data Taking												
	NA62-beamdump	< 1 MCHF	Studies		1e18 PoT in Run 3														
	KLEVER	~40 MCHF	EoI/proposal		R&D/Construction				Installation	Data Taking									
	COMPASS++	~10 MCHF	Studies/proposal		Phase1 Data Taking/Studies/R&D				Installation	Data Taking									
LHC	ALICE fixed target	<5 MCHF			Design/tests				Preparation/Construction			Data Taking							
	LHCb fixed target	<5 MCHF		Design	Construction and testing			Data	LS3			Data Taking							
	LHC Spin	~5 MCHF	Study		R&D				Production/Installation			Data Taking							
	FASER	~5 MCHF	Installation		Data Taking				Upgrade - phase 2			Data Taking							
	MATHUSLA	<100 MCHF		Funding to test design			Construction					Data Taking							
	CODEX-b	<5 MCHF	EoI		Beta		Beta data taking		Production/Installation			Data Taking							
	MilliQan	<5 MCHF	Demonstrator		Funding/Construction				Upgrade			Data Taking							
SPS	LDMX/eSPS	<10 MCHF			Studies		Production/Installation			Data Taking									
	SHiP	~70 MCHF	CDR		TDR/Prototypes			Production/construction			Installation		Data Taking						
	TauFV	tbc	Design		CDR	TDR/Prototypes		Production/construction			Installation		Data Taking						
	BabyIAXO (DE)	<5 MCHF		Production/construction			Commission	Data Taking											
	IAXO	~60 MCHF					Design, prototyping, construction, integration and commissioning (start tbc)												
	AWAKE	~15 MCHF	Prep/construction		AWAKE Run 2				LS3	AWAKE++?									
	eSPS	~80 MCHF	CDR		TDR		Preparation/Construction			Data Taking									
	Beam Dump Facility	~160 MCHF	CDR	TDR			Construction/Installation						Operation						
	Gamma Factory	~2 MCHF		CDR	SPS Proof of Principle/TDR				Preparation			LHC demo							
	nuSTORM	>160 MCHF	Study	CDR		TDR/Prototyping						Approval							
	CPEDM prototype (DE)	~20 MCHF	Study	CDR		TDR		Construction		Data Taking									
	Muon collider			Baseline design				Design optimization							Project Preparation				Approval
	ANA scientific roadmap		Accelerator stages			x10 beam quality at higher energies					Reliable staged acceleration, 10 GeV module				Advanced Linear Collider CDR & TDR				
	ESSvSB (SE)		Design		CDR	Preparatory phase and TDR			Preconstruction		Construction								Data
	PERLE (FR)			TDR	Assembly & installation		Phase 1 OP	2nd cryo ins.	Phase 2 OP										
	HIBEAM/NNBAR (SE)		CDR (HB)		TDR/prototpying (HB)			Construction (HB), CDR (NNBAR)		Data taking (HB), TDR (NNBAR)		Construction and commissioning (NNBAR)			Data Taking (NNBAR)				

Swedish input to the update process

Swedish process organised with help of:
Arnaud Ferrari, Bengt Lund-Jensen, Caterina Doglioni, Christian Ohm, Dave Milstead, Kerstin Jon-And, Richard Brenner, Rikard Enberg and Roman Paseschnik

- Written input submitted in December 2018
  https://indico.cern.ch/event/765096/contributions/3295801/

  In total around 160 inputs received: experiments, national inputs etc

- Oral input to the ESG-meeting 6 November 2019.
  Summarized after local discussions on scenarios for future accelerators

View of the Swedish community

	2020-2040	2040-2060	2060-2080
		1st gen technology	2nd gen technology
CLIC-all	HL-LHC	**CLIC380-1500**	CLIC3000 / other tech
CLIC-FCC	HL-LHC	**CLIC380**	FCC-h/e/A (Adv HF magnets) / other tech
FCC-all	HL-LHC	**FCC-ee (90-365)**	FCC-h/e/A (Adv HF magnets) / other tech
LE-to-HE-FCC-h/e/A	HL-LHC	**LE-FCC-h/e/A (low-field magnets)**	FCC-h/e/A (Adv HF magnets) / other tech
LHeC-FCC-h/e/A	HL-LHC **+ LHeC**	**LHeC**	FCC-h/e/A (Adv HF magnets) / other tech

- Mid-term e+e- and long-term energy frontier hh is a goal
- Particle physics is a large worldwide community and future projects must sustain this in terms of number of running experiments worldwide
- Swedish community favours FCC-hh/energy frontier as a final destination
- CLIC-all scenario not favoured

- Most community support for
  - FCC-all scenario: precision EW/Higgs measurements and high energy frontier
  - LE-to-HE-FCC-h/e/A should e+e- be constructed elsewhere

- Support also expressed for a CLIC-FCC scenario:
  - Start with a minimal upgradable Higgs factory
  - Could possibly be integrated as a segment in a future FCC
  - Potential to serve as eSPS linac and potential to be used for ep-collisions at LHC/FCC
  - Options for the next stage after CLIC380 could be either further measurements of the Higgs potential (requiring at least 500 GeV) or going directly to FCC-hh. It should be guided by physics results, in particular Higgs precision measurements.

- DIS regarded as interesting (LHeC and LE-to-HE-FCC-h/e/A) should e+e- be constructed elsewhere
  - We do not think the LHeC should go ahead if there is no clear path/commitment to a later FCC.

Some comments to the aux questions

- Important to state that LHC/HL-LHC has highest priority for the near-term future
- Strongly in favour of a scientific diversity program - proposals for PBC should not be ranked in the strategy process
- Important to express support for an e+e- machine, upgradeable to at least 500 GeV, regardless of location in the world
- In favour of strengthening the statement on collaboration with neighbouring fields like astroparticle physics, in particular in the area of DM search
- Strong statement that theory support is absolutely critical for the experimental efforts
- In favour of strengthening the statement on instrumentation and computing R&D, e.g. through working with EU; state importance of blue-sky R&D

European Strategy Update

EPPSU2020

Present European perspective on next priorities

- Should not commit to a detailed roadmap beyond 2060
- Next facility after LHC should be an e^+e^- collider (Higgs factory – precision frontier)
  - about 50% would prefer FCC ee; 5 out of 18 would opt for FCC all;
- Europe should lead the energy frontier (pretty much unanimous)
  - Japan and US voiced support
  - If e^+e^- collider in Asia, next facility for Europe FCC hh
  - Some (very few) would even like to see LE-FCC followed by HE-FCC (if magnets not ready); ep and heavy ions programme included
  - HE-LHC has no traction
- Strong support for broad R&D in accelerator technologies (magnets including HTS, plasma wakefield, ERL) and projects (muon collider) by CERN in cooperation with National Labs and Institutes
- High priority for "diversity" programme with no explicit ranking

- Important to approach Bad Honnef in a spirit of compromise.
- "We must, indeed, all hang together or, most assuredly, we shall all hang separately."

SPARES

ESG Working Groups

- **WG1 - Social and career aspects for the next generation**
- **WG2 - Organizational aspects in the implementation of the European Strategy**
- **WG3 - Relations with external bodies and fields of physics**
- **WG4 - Knowledge and technology transfer**
- **WG5 - Outreach, education and communication**
- **WG6 - Sustainability and environmental impact**

Parameters of future colliders, from Briefing Book

Collider	Type	$\sqrt{s}$	$\mathscr{P}$ [%] $[e^-/e^+]$	N_{Det}	$\mathscr{L}_{\text{inst}}$/Det. $[10^{34}\text{cm}^{-2}\text{s}^{-1}]$	$\mathscr{L}$ $[\text{ab}^{-1}]$	Time [years]	Ref.
HL-LHC	pp	14 TeV	–	2	5	6.0	12	[23]
HE-LHC	pp	27 TeV	–	2	16	15.0	20	[23]
FCC-hh	pp	100 TeV	–	2	30	30.0	25	[631]
FCC-ee	ee	M_Z	0/0	2	100/200	150	4	[631]
		$2M_W$	0/0	2	25	10	1-2	
		240 GeV	0/0	2	7	5	3	
		$2m_{top}$	0/0	2	0.8/1.4	1.5	5	
		(1y SD before $2m_{top}$ run)					(+1)	
ILC	ee	250 GeV	±80/±30	1	1.35/2.7	2.0	11.5	[335]
		350 GeV	±80/±30	1	1.6	0.2	1	[339]
		500 GeV	±80/±30	1	1.8/3.6	4.0	8.5	
		(1y SD after 250 GeV run)					(+1)	
CEPC	ee	M_Z	0/0	2	17/32	16	2	[502]
		$2M_W$	0/0	2	10	2.6	1	
		240 GeV	0/0	2	3	5.6	7	
CLIC	ee	380 GeV	±80/0	1	1.5	1.0	8	[632]
		1.5 TeV	±80/0	1	3.7	2.5	7	
		3.0 TeV	±80/0	1	6.0	5.0	8	
		(2y SDs between energy stages)					(+4)	
LHeC	ep	1.3 TeV	–	1	0.8	1.0	15	[630]
HE-LHeC	ep	1.8 TeV	–	1	1.5	2.0	20	[631]
FCC-eh	ep	3.5 TeV	–	1	1.5	2.0	25	[631]

Introduction / Scope

- Is it feasible to combine the CLIC and FCC civil engineering [staging]?
  BUT: This case is neither natural nor obvious: combing a straight tunnel with a circular one!
  Both CLIC and FCC civil engineering have been optimized for their individual requirements
  ➔ 'Enforcing' the above synergy implies compromises that lead to non-ideal layouts that imply in turn performance loss and / or additional costs [e.g. different tunnel depth]

- CLIC380 features two 3.5km long linacs and two 2.2km long Beam Delivery Sections,
  ➔ two 5.7km long straight tunnels that connect at an angle of ca. 20mrad.

  FCC features 8 straight sections of 1.4km and 2.8km length. Without modifying severely the FCC layout, FCC can 're-use' at most 2.8km of the CLIC tunnel.
  Perhaps a bit more if including the beam dump lines but that requires significant layout modifications for the FCC [e.g. much longer injection transfer lines]

- Bigger synergies require a race-track configuration for the FCC
  ➔ Significant performance loss, additional CE [e.g. longer transfer lines] and challenges [e.g. combining several experiments and services in one straight section]

Summary and Conclusion:

- Solutions could exist but with a tunnel overlap of only 1.4km and at the price of a deeper CLIC tunnel
- Solutions could exist with a tunnel overlap of 2.8km but without CLIC extendibility to 48km and 3TeV
- FCC with CLIC[illegible] [7km] and 23% [11km] less a[illegible]
  - ➔ 20% lower e[illegible]
  - while still re[illegible]
- The combine[illegible] LHC tunnel and implies r[illegible] C extension
- The FCC rac[illegible] from injection and cleaning
- Integrating the[illegible] ions
  - ➔ re-use of up-to 275MCHF [175MCHF for 7km] CE investment [ca. 25kCHF per meter]
  - ➔ but with 2 kinks in the CLIC tunnel when being extended to full size [impact on performance?]!!
- This 'amortization' is small compared to the total FCC-hh project cost (1% of full FCC-hh cost estimate)

➔ The proposed combination of the projects complicates the layouts of both machines and implies performance loss and additional civil engineering cost for both machines!

➔ Better to decide early on about the physics strategy entirely based on the scientific goals and to pursue either the CLIC or the FCC study – but not a mix of both of them!

Physics Preparatory Group

PPG MEMBERS	
Strategy Secretariat	
Scientific Secretary (Chair)	Prof. Halina Abramowicz (IL)
SPC Chair	Prof. Keith Ellis (UK)
ECFA Chair	Prof. Jorgen D'Hondt (BE)
Chair EU Lab. Directors' Mtg	Prof. Leonid Rivkin (CH)
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ASIA/AMERICAS
Prof. Marcela Carena (USA)
Prof. Brigitte Vachon (Canada)
Prof. Xinchou Lou (China)
Prof. Shoji Asai (Japan)

European Strategy Group (ESG)

Members

- The Strategy Secretary (chair)
- One representative appointed by each CERN MS (23)
- One representative appointed by each of the Labs participating in the European Laboratory Directors Group including its Chairperson (9)
- CERN DG
- SPC chair
- ECFA chair
- Chair EU Lab.Director's Meeting

Invitees

- President of CERN Council
- One representative from each AMS and OS (6+3)
- One representative from the European Commission
- One representative from JINR
- Chairs of ApPEC, NuPECC, FALC, ESFRI
- Members of the PPG (17 - Secretariat)

CERN's Future, Fabiola Gianotti, SPC, 23 Sep 2019

I think it would be good for CERN if the 2020 Strategy update recommended:

- ❑ the direction for a future collider at CERN: linear or circular
  → so that its technical and financial feasibility can be assessed by next Strategy update in ~2026 → pre-requisite for project approval by the Council

- ❑ a compelling scientific diversity programme at the injectors, complementary to high-E colliders for physics reach and size/type of projects (→ attract a diverse community). Based on input from Physics Beyond Colliders (PBC) study group.

- ❑ a vigorous and transformational accelerator R&D programme at CERN and other European laboratories and institutions: high-field magnets (including High-Temperature Superconductors), high-efficiency klystrons, high-gradient accelerating structures, plasma wakefield, feasibility of muon colliders, etc.

Timeline

Several years will be needed to assess the technical and financial feasibility of a future collider before the project can be approved by the Council, in particular to work through the administrative, political, legal and environmental procedures related to the tunnel excavation

→ a clear direction (linear or circular) in 2020 would allow much of this work to be accomplished by the ~ 2026 update of the ESPP

CERN's financial constraints over 2021-2025

do not allow CLIC and FCC to be both supported at the level needed for the next significant step: Technical Design Report by Strategy update in ~2026